Progress Report to NOAA 2011

NA10OAR4310210

July 2010 - March 2011

The International Research Institute for Climate and Society

Columbia University in the City of New York

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NA10OAR4310210
July 1, 2010 - March 31, 2011

Contents

From the Director-General

This year is the fourteenth year of activity for which the International Research Institute for Climate and Society (IRI) is reporting to its principal funder and co-founding partner, the National Oceanographic and Atmospheric Administration (NOAA). It has continued to be a very productive and successful effort to address the challenge of climate issues at the interface with the needs of societies, especially in developing nations. I am pleased to report IRI's progress and activities in research, application demonstrations, outreach, capacity building and education.

Research

Within the research and innovation area considerable efforts have been devoted to aspects of forecast calibration and verification. For example, IRI has developed tools to verify tercile-based predictions, new methods of seasonal forecast calibration, a decadal prediction verification framework and evaluation of IRI's multi-model ENSO prediction plume. Ensemble systems based on coupled Global Climate Models are now being evaluated alongside IRI's continuing 2-tier forecast system. In the realm of impact modeling and prediction, new results are reported regarding drought prediction, analysis of extreme flooding events, predictability and predictions of crop production, as well as modeling of dust and its relation to meningitis in West Africa. And a serious comparison of dynamical versus statistical seasonal forecasts has been undertaken for applications in Philippines.

Outreach

Several developments in the IRI Data Library are notable, including innovations allowing more powerful search and manipulation of multisectoral data, a stand-alone Data Library that can easily be ported to sites lacking in broadband internet access, and new Map Room facilities for specific user communities, including tools to analyze jointly climate variability and change.

Demonstrations

Climate risk management demonstrations remain a core element of IRI work. For this reporting period there were important advancements in each of our regional programs (Africa, Latin America/Caribbean and Asia-Pacific) with particular attention to the IRI Focus Areas that were introduced in our current NOAA award. To cite one example:

- In Ethiopia efforts with the health and climate communities are building capacities both to produce and incorporate climate information products in operational health practices.

- A major pan-African workshop on climate and Health has just recently concluded with major policy and program recommendations building significantly on the work in Ethiopia.
- Work with the Ethiopian Meteorological Service is advancing new technologies to merge satellite and in situ data to create extended rainfall time series.
- And work continues to develop and deploy new tools around index insurance, in a "scaled-up" program with Oxfam and Swiss Re, addressing agricultural livelihoods.

Capacity Building and Education

More generally on the capacity building and education front, IRI's activity continues to grow with ongoing formal training courses, and contribution to education courses at Columbia University. We have revised the curriculum for regular training activities with the NOAA CPC Africa Desk. We have also collaborated with the World Meteorological Organization in training activities associate with Hydrological Outlooks, building on the well-established Climate Outlooks.

Partnership Expansion

IRI's work depends crucially on partnerships – in research, practice and outreach. This year there were several important developments with global scale partners:

- We initiated a partnership with the Consultative Group in International Agricultural Research to participate in the new Challenge Program on Climate Change, Agriculture and Food Security, with IRI's Dr. Jim Hansen designated as a Theme Leader. This enables an entirely new scale of engagement for IRI in agricultural climate risk management.
- IRI continues to build on an active collaboration with the International Federation of Red Cross/Red Crescent Societies, with further tailoring of information to inform global disaster risk assessment, and with regional interactions and capacity building, including opportunities for student internships at Red Cross sites throughout the world.
- And we were delighted to begin collaboration with the World Food Programme this year, focusing on climate information to inform food security risk assessment and response.

In the pages that follow there is additional detail about the work I have mentioned and much more. I am grateful to our dedicated and talented IRI staff who make this possible, along with you, our partner, NOAA.

Should you desire additional information, please see http://iri.columbia.edu, or please be in touch with me.

Stephen E. Zebiak

Communications is a vital part of IRI's strategy to raise its profile, forge new partnerships and entice new donors. As a mission-oriented institution, we recognize the importance of narrative and storytelling: of showing how our scientists and staff foster change in the regions in which we work. In the last two years, we have placed greater emphasis on audio slideshows and videos because we've found them to be quite effective in generating interest in our activities. Our use of social media such as Twitter (@climatesociety) and blogging are helping us reach new audiences. As always, we place high value in our collaboration with the communications staff at both the Earth Institute and at the NOAA Climate Program Office. Most recently, we've undertaken the mentorship of a new communications coordinator position, sponsored by the CPO to promote the innovations and research produced by the IRI, the RISAs and other programs funded by the Climate and Societal Interactions Division.

Media Roundup

During this reporting period, the IRI and its staff appeared 74 times among the online and print publications listed here.

Major/International

ABC News
The Atlantic
BBC
Climate-change TV
CNN
The Economist
NewsWeek
The New York Times
Int'l News Service
IRIN News
ReliefWeb
Reuters

Non-U.S. National

El País
The Hindu Business Line
La República
Semanario Tiempo
The Times of India
The Times of Swaziland
El Universal
UrduVOA News

U.S. Local

The Herald Tribune
The Journal News
News12 TV
The Roanoke Times
The Star Tribune
YubaNet

Blogs

Climate Central
Climate Matters
The Daily Crawler
Dying In Haiti
News Around the World
Watts Up With That

Newsletters/Institutional

CLIMAS
Columbia University Record
FrameWeb
Insurance ERM
MicroRisk
Red Cross/Red Crescent Climate Centre
Taiwan Health in the Globe
Universidad de la República Uruguay
U.S. Department of State
U.S. NOAA Climate Services Portal
World Meteorological Organization

Improving Climate Prediction in Africa *3.23.2011*

With climate data from Kenya's Kericho Tea Estates, IRI's Judy Omumbo (right) confirmed that the region has been warming.
Credit: David Gottlieb

by Kim Martineau
Earth Institute's State of the Planet blog

Africa lags the developed world in weather stations but still produces a surprising amount of data. Too bad few people are using it.

Scientists at Columbia University and a growing number of others—among them Bill Gates and the charity arm of Google—are pushing to open Africa's climate archive to the world by making it free. If Africa's climate information becomes more accessible, scientists can make more accurate short and long-term weather forecasts, allowing farmers, relief workers and public health experts to plan for and manage catastrophic events.

Like their European counterparts, most African countries charge for their climate data to offset the cost of running their weather services. In a newly published paper in Nature, Madeleine Thomson, a malaria expert at Columbia's International Research Institute for Climate and Society (IRI), argues that an alternative funding mechanism to allow the free-sharing of data would help Africans better fight disease. Climate data is a "resource for development," she writes, "a classic public good that increases in valued the more times the data are used."

Researchers will share ideas for unlocking Africa's climate data at an upcoming conference in Ethiopia, "Climate and Health in Africa: Ten Years On" organized by IRI, April 4-6.

In Kenya, some 1,500 weather stations gather detailed climate data but the data from only a few dozen of those stations are publicly available. Airlines that serve the country are willing to pay for some of that extra information, but most researchers are not. As a result, scientists rely heavily on global satellite data, producing less accurate climate models.

For the last decade, researchers have debated whether Kenya's highlands are getting hotter—a question that might begin to explain why new cases of malaria rose dramatically in the 1980s and 1990s. In a paper published in Malaria Journal earlier this year, IRI epidemiologist, Judy Omumbo and colleagues, showed conclusively that the region had warmed by 0.6 degrees C since 1979. In short order, Omumbo was able to resolve a question her colleagues had wrestled with for years by gaining access to climate data from a regional tea plantation that had never been analyzed before.

Getting a hold of that data was not easy. At first, the Kenya Meteorological Department wanted $52,000 for it. But Omumbo, a native of Kenya, convinced the department to share it for free by collaborating with one of its meteorologists and citing him in her paper. Another researcher at the IRI, Ethiopian Tufa Dinku, has established similar collaborations in his home country.

If those breakthroughs are to continue, policy makers need to rethink how Africa's national weather services are funded, the researchers at the IRI say. Ideas include a mix of public and private funding arrangements.

Permalink for this story:

http://blogs.ei.columbia.edu/2011/03/23/improving-climate-prediction-in-africa/

Homecoming *3.23.2011*

Ousmane Ndiaye wants to provide farmers with reliable and useful forecasts

by Ken Kostel
IRI web feature

It would be easy for any graduate student to turn inward during his or her time at Columbia University, to focus solely on the long, rigorous task of publishing journal articles and completing the thesis. It would be easier still for a newly minted scientist to look anywhere other than his or her impoverished home country to launch a promising career. But Ousmane Ndiaye, a native of Senegal, isn't a typical graduate student.

As a student, and now scientist, Ndiaye has focused on developing better methods of forecasting short-term and seasonal climate variability in the African Sahel. Throughout his time at Columbia, he has been an active member of the Senegalese community in Central Harlem, where he and others in this tightly knit group help newcomers adapt to life in the United States, providing an informal safety net for those who fall on hard times. In many ways, these two parts of his life are inseparable.

Ndiaye's scientific work at the International Research Institute for Climate and Society (IRI) under the supervision of Neil Ward has centered around developing accurate ways to predict both the character of the rainy season in the Sahel and the onset of the rainy season over his native Senegal. For small farmers who make up the bulk of the region's rural agricultural population, knowing when and what to plant often make the difference between a successful growing season and famine. It can also help countries and relief organizations anticipate and plan for an outbreak of climate related diseases such as malaria—a need that Ndiaye knows only too well. "Everyone in the Sahel is affected by malaria in some way," he said. "I got it. Climate has a huge impact on our society."

“Everyone in the Sahel is affected by malaria in some way. Climate has a huge impact on our society”

Now Ndiaye’s research stands to impact people all across the Sahel as well. His work revealed that the onset of the monsoon in the region is tightly linked to global sea surface temperatures, while the onset in southern Senegal is tied most closely to the southern Atlantic dipole-a pattern of temperature differences involving the northern and southern tropical Atlantic. It is work that could easily catapult Ndiaye to a tenure-track position in the United StatUndecided about his future plans after graduation, Ndiaye sought out the advice of Mamadou Diouf, the head of Columbia’s Institute for African Studies. Even though the two men had never met before, it was natural for Ndiaye to approach the elder Diouf, because in the Senegalese tradition, age and experience garner real respect. Even in an emigrant community, social mores resonate. “Wherever we go, we recognize ourselves,” said Diouf. “It’s a way of rebuilding familiar ties.”

Diouf didn’t steer Ndiaye toward any one path, but, in conversation, it soon became clear that Ndiaye was intent on reconnecting with both his native Senegal and with the people who live in the Sahel. Ndiaye is now the head of climate and society at Senegal’s National Meteorological Agency.

“It’s rare to see someone like him go back,” said Diouf, sounding like a true elder brother. “But he knows the misery of the Sahel and he wants to contribute to the development of his country. I am very proud of him.” ■

Ken Kostel was previously senior science writer at the Earth Institute and is currently web editor and science writer at the Woods Hole Oceanographic Institute. He graduated in 2003 from Columbia with masters degrees in journalism and Earth & Environmental Science.

Permalink for this story:

http://iri.columbia.edu/features/2011/homecoming.html

La Niña Subsiding, Atlantic Climate Phenomenon Forming

3.21.2011

by Brian Kahn
Earth Institute's State of the Planet blog

A unique climate phenomenon is forming as a more familiar one weakens. At this month's climate briefing, forecasters from the International Research Institute for Climate and Society (IRI) discussed each of these in detail.

First the one you likely know a little about. Tony Barnston, IRI's lead forecaster, said this year's strong La Niña is in the process of subsiding for now. Ocean temperatures in the eastern equatorial Pacific continue to warm, though they are still roughly a degree Celsius cooler than normal. By the end of April, temperatures are expected to return to near normal.

Barnston noted that though the sea surface temperature (SST) anomalies continue to weaken, the atmospheric conditions associated with La Niña are still quite strong. They'll likely remain that way for at least the next month or two, increasing the likelihood of wet weather in Australia, cooler than normal temperatures in the Pacific Northwest and other impacts associated with La Niña during that time.

This map, updated weekly, shows the warmer-than-normal sea-surface temperatures (red) off the coast of Angola and Namibia over the last three months that define a Benguela Niño. Click on the chart to go to an interactive, updated version in the IRI Data Library.

Brad Lyon, a research scientist at IRI, also highlighted a lesser-known climate phenomenon occurring in the southeastern Atlantic. The phenomenon is known as a Benguela Niño. A slackening of alongshore winds possibly accompanied by the southward movement of waves called Kelvin waves leads to the southward migration of warm water from the equator to off the coast of Namibia and Angola. Lyon noted, "the relative roles of Kelvin waves versus local wind anomalies [is] still an open area of investigation."

This map, updated weekly, shows the above normal precipitation in Angola and Namibia for the last three months caused in part by the Benguela Niño. Click on the chart to go to an updated version in the IRI Data Library.

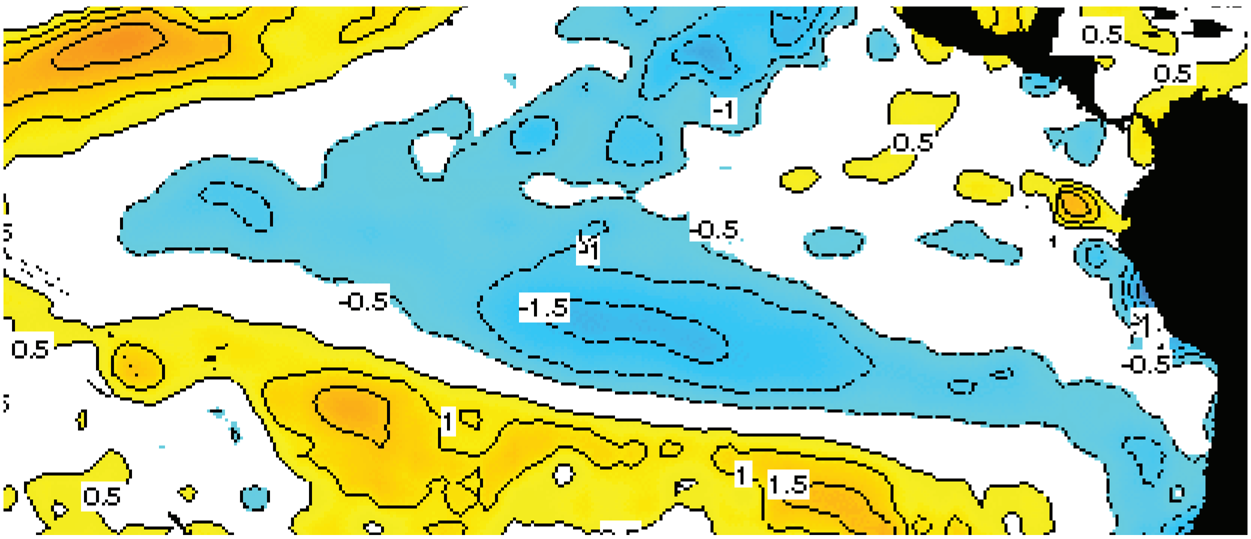
On average the phenomenon occurs about once a decade. The last strong Benguela Niño occurred in 1995. Just as El Niño can lead to increased rainfall in Peru, so a Benguela Niño can lead to increased rainfall in Namibia and Angola. Precipitation in the region from December through February shows just such a pattern.

For a more in-depth look at IRI's La Niña forecast, visit IRI's ENSO resources page. More on the causes of the Benguela Niño can be found in this October 2010 paper from Geophysical Research Letters.

Permalink for this story:

http://blogs.ei.columbia.edu/2011/03/21/la-nina-subsiding-atlantic-climate-phenomenon-forming/

La Niña Begins to Weaken *2.18.2011*



This map, updated weekly, shows the cooler-than-normal sea-surface temperatures (blue) in the equatorial Pacific that define La Niña. Click on the chart to go to an interactive version in the IRI Data Library.

by Ashley Curtis
Earth Institute's State of the Planet blog

The current moderate-strength La Niña is now weakening and is expected to dissipate by late spring, said Tony Barnston, the lead forecaster at the International Research Institute for Climate and Society, which holds a monthly climate briefing.

Early February showed the first easing in strength of the cool sea-surface temperatures in the central and eastern tropical Pacific. The warmer sub-surface waters of the western Pacific are also gradually nosing eastward. Both these indicators led IRI forecasters to predict only a 49% chance that this La Niña will continue through the April-May-June season and a 34% chance it will continue through the May-June-July season.

This chart shows historical sea-surface temperature anomaly averages for part of the equatorial Pacific. Red signifies the warmer-than-normal temperatures of El Niño, while blue signifies the cooler-than-normal temperatures of La Niña. Click on the chart to go to an interactive version in the IRI Data Library.

Because of this current La Niña's extended duration, its strong rainfall impacts will likely also continue farther into the spring than is typical for La Niña events. This La Niña has already been linked to flooding in Pakistan, West Africa, South Africa and eastern Australia, according to climate scientists.

If you want to learn more about El Niño, La Niña and everything in between, visit the IRI's ENSO resources page.

Permalink for this story:

http://blogs.ei.columbia.edu/2011/02/18/la-nina-begins-to-weaken/

Multimedia: Summer Institute *2.14.2011*

Screengrab of title screen from the *Summer Institute on Climate Information for Public Health* video. J. Rodriguez/IRI

IRI web feature

Since 2008, public-health professionals and climate scientists from around the world have come to Columbia University to take part in the Summer Institute on Climate Information for Public Health. Participants spend two weeks learning how to use climate information to make better decisions for health-care planning and disease prevention. The event is organized by the International Research Institute for Climate and Society in partnership with the Center for International Earth Science Information Network (CIESIN) and The Mailman School of Public Health.

We produced a short video featuring interviews from the Summer Institute's organizers and its participants explaining the necessity of such training. Enjoy and feel free to share! ■

If you would like to learn even more about the Summer Institute, please visit this page: **http://iri.columbia.edu/education/ciph11**

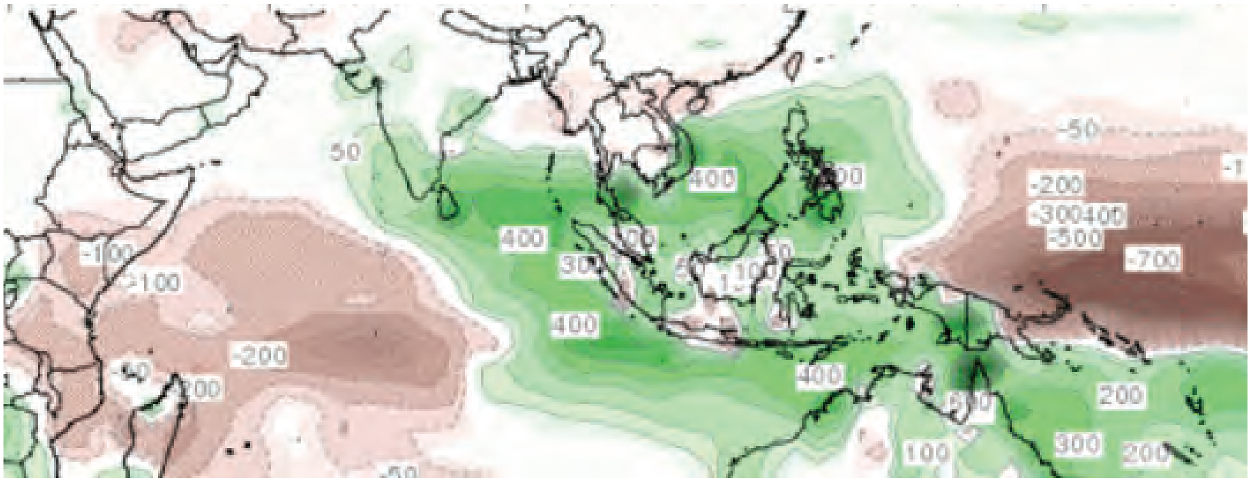
Permalink for this story:

http://iri.columbia.edu/features/2011/climate_information_for_public_health.html

Link to video:

http://vimeo.com/19037641

Floods in Eastern Sri Lanka and North-Eastern Australia: Contrasts in Disaster Risk Management *2.10.2011*



Rainfall Anomalies for November 2010 to January 2011 from what is normal in the region. The signature pattern of La Nina which includes reduced rainfall over the Central Pacific Ocean and Eastern Indian Ocean and increased rainfall over a swathe from Australia to South Asia is seen – although the pattern this year is displaced to the East when compared to the average over past La Nina events.

by Lareef Zubair
Earth Institute's State of the Planet blog

Flooding across Sri Lanka and Northern Australia

The rain falling over Queensland, Australia and Sri Lanka during the last two months has been extraordinary. There have been systematic and timely warning and risk mitigation and emergency management steps in Queensland but the response in Sri Lanka was inadequate. More than a million people were affected, 185,000 were displaced and 16 had died by February 5, 2011 according to the Sri Lanka Guardian and Nation Newspaper in Sri Lanka. There are also crop losses and untold harm to animals during January and the first week of February. The second week of February brought fresh flooding particularly in the Central and Eastern region piling on to the problems. The purpose of this post is to point to information that can help target relief efforts, and to point out the need to enhance local risk management capacity in the medium term.

Rainfall Anomalies for November 2010 to January 2011 from what is normal in the region. The signature pattern of La Nina which includes reduced rainfall over the Central Pacific Ocean and Eastern Indian Ocean and increased rainfall over a swathe from Australia to South Asia is seen – although the pattern this year is displaced to the East when compared to the average over past La Nina events.

Information Resources for Disaster Risk Management in Sri Lanka

1. The Foundation for Environment, Climate and Technology (www.climate.lk) and a group of scientists/engineers provides a customized weekly hydrometeorological report .

2. See rainfall maps at:
http://fectsl.wordpress.com/

3. A case study in disaster hazard assessment for Sri Lanka is available See the project brief.

Eastern Sri Lanka – A Hazard and Vulnerability Hotspot

After every major disaster, affecting eastern Sri Lanka whether it be the 1978 Cyclone and Floods, the 2001-2 drought, the 2003 Floods and Landslides and the 2004 Tsunami, lessons were drawn up but not really acted upon. Eastern Sri Lanka bore the brunt of the Tsunami and the 30-year civil war Sri Lanka. Both the Tsunami and the civil war led to the break down of community disaster resilience - informal relief networks are weakened and regional scientific capacity has not improved. The people here are among the most vulnerable and poor in Sri Lanka. To add to this, the Eastern Coast is a flood/cyclone/storm risk "hotspot" even in a normal year and what is needed is the reduction of vulnerability of the population.

Rainfall over Sri Lanka during January 2011. The rainfall ranges up to a total of 800 mm with the heaviest rainfall over the East.

Improving Disaster Risk Management

After the Tsunami, the role of disaster risk management – focusing on reducing risks and enhancing resilience rather than focusing on relief alone- was acknowledged including by a parliamentary commission, and through the setting up of a dedicated Ministry. There were plans to manage risk by better zoning, identifying vulnerabilities in communities, providing meaningful and useable warnings in a timely manner and coordinated action from the local to national scale. The least of the bottlenecks is the lack of scientific knowledge. For example, our own work in collaboration with colleagues Sri Lanka contributed to mapping disaster risk based on climate information. Our partners in Sri Lanka, The Foundation for Environment, Climate and Technology and the Mahaweli Authority of Sri Lanka continue to generate and use information on hydro-meteorological variability. Yet, the response to this disaster has been not much better than in the past. While the priority remains disaster relief in the short-term, it is important to highlight the need to build regional capacity in disaster risk management and to enable community resiliency particularly in the peripheral areas in the medium term. And the biggest lesson is that lessons from major disasters are identified but not acted upoun.

References for Further Information:

Zubair, L., Ralapanawe V., Tennakone, U., Yahiya, Z., and Perera, R., Natural Disaster Risks in Sri Lanka: Mapping Hazards and Risk Hotspots, in Eds: Margaret Arnold et al., , Natural Disaster Hotspots Case Studies, Washington, DC: World Bank 2006.amazon

Zubair, L., Empowering the Vulnerable , TIEMPO, 52:3-6, pdf version , Also see SciDev.net Communities facing climate change need local science, 2004.

Zubair, L., U. Tennakone, Z. Yahiya, J. Chandimala & M.R.A. Siraj, What led to the May 2003 Floods?, Journal of the Institute of Engineers, Sri Lanka, XXXVI (3): 51 – 56, 2003 (see lay version at What led to the May Flooding)

Permalink for this story:

http://blogs.ei.columbia.edu/2011/02/10/floods-in-eastern-sri-lanka-and-north-eastern-australia-contrasts-in-disaster-risk-management/

Columbia University's Master of Arts program in Climate & Society *2.9.2011*

by Ben Orlove
Earth Institute's State of the Planet blog

There is still time to apply to Columbia University's Master of Arts program in Climate and Society (C&S). The need for professionals who understand the links between climate and society is acute, and grows ever more so as human activity alters the global atmosphere. The 12-month Columbia M.A. in Climate and Society will give you the knowledge and skills to meet this need.

Housed in the Department of Earth and Environmental Sciences within Columbia's Graduate School of Arts and Sciences (GSAS), the Climate and Society program shares its name and as well as its mission with the International Research Institute for Climate and Society (IRI), a research unit of the Lamont-Doherty Earth Observatory and the Earth Institute.

The core coursework is a set of tailor-made courses providing a scientific basis for inquiry that stresses interdisciplinary problem solving. The core consists of dynamics of climate variability and change, regional climate and climate impacts, quantitative models of climate-sensitive natural and human systems, and the integrative policy course titled managing and adapting to climate variability and change. A professional development seminar and a choice between a summer internship and research thesis complete the required core. Five electives across the fall and spring allow students to tailor the program across disciplines including economics, energy, sustainable development, atmospheric science and more.

Scholarships are available. If you would like more information about the program, or the application process, please contact us at climatesociety@ei.columbia.edu or 212-854-9896.

Application Deadline: April 1

To learn more about the program, visit:

http://www.columbia.edu/cu/climatesociety/

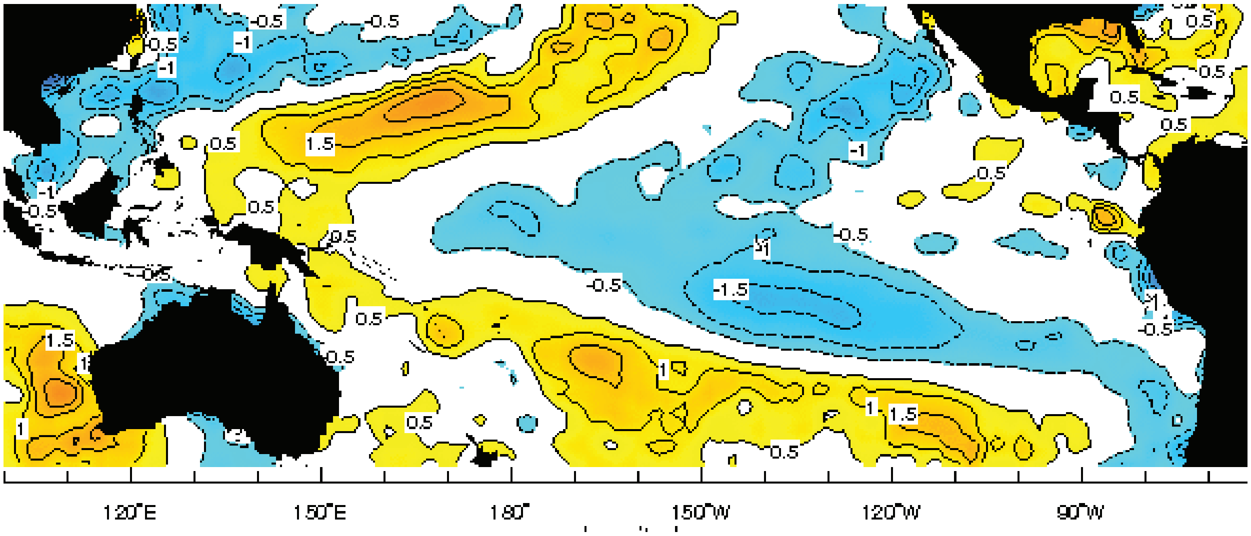
Link to IRI:

http://portal.iri.columbia.edu/portal/server.pt

Permalink for this story:

http://blogs.ei.columbia.edu/2011/02/09/columbia-universitys-master-of-arts-program-in-climate-and-society/

La Niña Rolls On *1.21.2011*



This map, updated weekly, shows the cooler-than-normal sea-surface temperatures (blue) in the equatorial Pacific that define La Niña. Click on the chart to go to an interactive version in the IRI Data Library.

by Ashley Curtis
Earth Institute's State of the Planet blog

The current moderate-to-strong La Niña is expected to continue through at least the middle of spring, said forecasters at the International Research Institute for Climate and Society's monthly climate briefing.

La Niña events typically die out quickly this time of year, but the sustained presence of very cool sea-surface and sub-surface temperatures in the eastern tropical Pacific led IRI forecasters to predict a 67% chance this La Niña will continue through the March-April-May season. But its days are limited because warmer sub-surface waters in the western Pacific are beginning to nose eastward.

While this La Niña's peak sea-surface temperature anomaly did not quite reach the strength of the one in 2008, its extended duration and strong rainfall impacts may make this one more memorable. Climate scientists have already linked it to widespread flooding that has occurred in Pakistan, West Africa, eastern Australia and other areas. Rainfall patterns around the world have shifted more dramatically than is typical of a La Niña of this strength, although the reasons why aren't yet fully understood, says IRI's lead forecaster, Tony Barnston.

In the video embedded here, IRI's Brad Lyon gives a rundown of the current situation, with maps showing how La Niña has affected precipitation and temperature. ■

Permalink for this story:

http://blogs.ei.columbia.edu/2011/01/21/la-nina-rolls-on/

La Niña Related Impacts Likely to Continue *1.14.2011*

Flooding in Brisbane, Australia in January 2011. Flickr/ Erik K. Veland

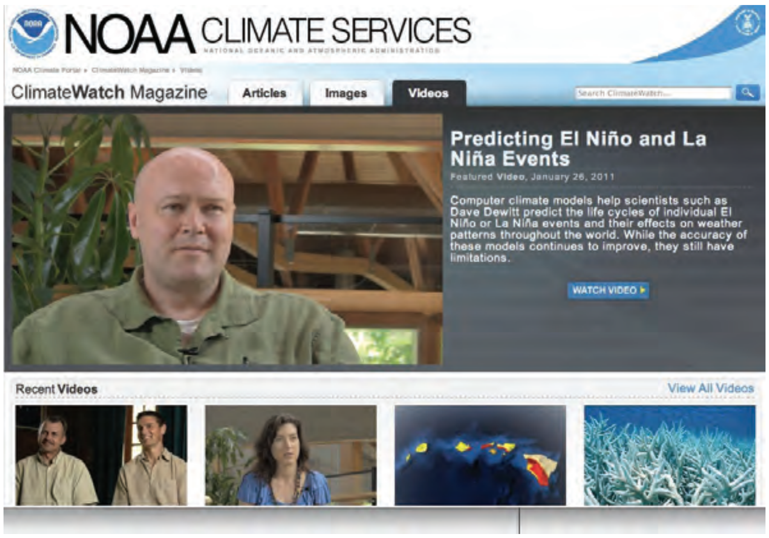
IRI Web Feature

As of mid-January, moderate-to-strong La Niña conditions continue to exist in the tropical Pacific. Scientists at the International Research Institute for Climate and Society expect these to linger, potentially causing additional shifts in rainfall patterns across many parts of the world in months to come. These shifts, combined with socioeconomic conditions and other factors, can make some parts of the world more vulnerable to impacts. However, La Niña conditions do allow the IRI and other institutions to produce more accurate seasonal forecasts and help better predict extreme drought or rainfall in some parts of the world. This enhanced predictability could help societies improve preparedness, issue early warnings and reduce any potentially negative impacts from La Niña.

"Based on current observations and on predictions from models, we see at least a 90% chance that La Niña conditions will continue through March 2011," says IRI's chief forecaster, Tony Barnston.

IRI scientists discuss the challenges of modeling and predicting ENSO, as well as its impacts, in a series of videos below.

The term La Niña refers to a period of cooler-than-average sea-surface temperatures in the eastern and central equatorial Pacific Ocean that occurs as part of natural climate variability. This situation is roughly the opposite of what happens during El Niño events, when waters in this region are warmer-than-normal (see our past story on El Niño). Both are part of a larger climate cycle known as the El Niño-Southern Oscillation, or ENSO. Because the Pacific is the largest ocean on the planet, any significant changes in average conditions there, such as those that occur during La Niña or El Niño, can have consequences for temperature, rainfall and vegetation in faraway places.



Climate scientists have found La Niña's signature in the widespread flooding that occurred in Pakistan last year, as well as flooding in West Africa, South Africa, and most recently in Queensland, Australia, where an area estimated to be the size of France and Germany combined was left underwater. Places such as Indonesia and northern South America have also been receiving above-normal rainfall. But La Niña probably isn't to blame for the recent flooding in southeastern Brazil, says Barnston. The more likely culprit there was a pocket of above-average sea-surface temperatures in the southwest Atlantic that promoted low atmospheric pressure and an increased tendency for heavy rainfall.

La Niña can be associated with droughts as well. It's keeping east Africa drier-than-usual, sparking food-security concerns in areas lacking irrigation, including parts of Somalia, Kenya, Ethiopia and

Tanzania. Areas in southeastern South America, central southwest Asia, and the southern U.S. may also see lower-than-normal rainfall for the first quarter of 2011.

Since 1950, the world experienced six major La Niña events, which were linked to widespread flooding in some areas. For example, in Bangladesh, La Niña was implicated in four out of six devastating flood events documented since 1954 (read more here). In 2000, floods associated with La Niña affected 400,000 people in southern Africa, caused at least 96 deaths and left 32,000 homeless. Of course, such events can also occur during non-La Niña years. What La Niña does is increase the likelihood that certain areas will get above-normal or below-normal rainfall (see map on this page for more details).

Once developed, La Niña conditions typically persist for 9-12 months, peaking sometime during November, December, or January. But 2010 was an interesting and lively year for climate scientists. For the first four months of this year, El Niño conditions prevailed in the tropical Pacific, but that quickly changed, and by June, a La Niña pattern had emerged.

“Last year’s transition from El Niño to La Niña was about the most sudden we’ve ever had,” Barnston says. “When we had rapid flips like this in the past, we sometimes ended up having a two-year La Niña, such as right after the El Niño episodes of 1972/73 and 1997/98.” Barnston cautions that the likelihood of this happening with the current La Niña is unknown. “Even if we do have a second year of La Niña developing in northern summer 2011, we expect at least a brief return to neutral conditions from May to July of 2011.” ■

Permalink for this story:

http://iri.columbia.edu/features/2011/la_nina_related_impacts_likely_to_continue.html

Important Gains Made in Global Effort to Control Malaria

12.19.2010

Malaria control workers distributing free insecticidal bed nets to families with children under five in Benin. WHO

IRI web feature

A massive scale-up in the distribution of insecticide-treated mosquito nets and other control programs are helping to protect more than half a billion people in sub-Saharan Africa against malaria, according to the World Health Organization. In its latest World Malaria Report, the organization cited these efforts as contributing to significant but fragile decreases in malaria cases and deaths in the region.

Worldwide, the WHO estimates deaths from malaria in 2009 were 781,000, about 200,000 fewer than they were in 2000. The most significant gains were made in Africa, where the disease extracts the heaviest burden on society. There, eleven countries saw cases and deaths drop by at least half between 2008 and 2010. Additionally, in 32 countries outside of Africa where malaria is considered to be endemic--occurring year-round--the number of confirmed cases also dropped by more than half. However, some countries, such as Rwanda, São Tomé and Príncipe, and Zambia showed a worrying reversal to this trend in malaria cases in 2009, highlighting the need for constant vigilance and careful assessment of the roles that socioeconomic and environmental factors, including climate, play in driving these changes.

"The news coming out of the WHO report is overall very encouraging, but we still need to know if any of the changes in malaria trends are really a result of the interventions and not due to other factors, such as a drought," says Madeleine Thomson, a senior research scientist at the International

Research Institute for Climate and Society, which is also a PAHO/WHO Collaborating Centre for Climate Sensitive Diseases. "Knowing this would improve the quality of our impact assessment," she says.

> *"Climate information is another tool in the malaria control toolbox."*
>
> *- Madeleine Thomson, IRI*

Climate is an especially important factor in malaria control programs. Seasonal changes in rainfall and temperature may hinder, or aid, the effectiveness of intervention programs. Then there's longer term climate change, which could work to alter the distribution of malaria in ways that are not yet fully understood.

At the behest of the WHO, Thomson, along with colleagues Pietro Ceccato and Michael Bell, analyzed the relationship between climate and disease trends in a number of African countries for the malaria report. For that rapid fire analysis, the group accessed globally available climate data derived from satellite information and ground-based rainfall and temperature measurements and correlated these results with malaria data at the regional level. They found that for the most part, it is unlikely climate played a major role in the observed changes in malaria trends. However, using the global data sets limited the strength of conclusions that could be drawn at the regional level.

"These data sets tend to be incomplete in regions where ground measurements are sparse and have coarse resolution," says Pietro Ceccato. "To really get a deep understanding of the relationship between climate and malaria trends, scientists need access to higher resolution, local data sources, which means working closely with national institutions."

IRI scientist Judy Omumbo at a malaria training workshop held recently in Addis Ababa, Ethiopia.

But often the data are not easily available due to logistic, resource and policy constraints.

The IRI has made progress toward this end in Ethiopia, where it collaborates with the Ministry of Health and the National Meteorological Agency to improve decision making on public-health and disease-control issues. In November, the three organizations led a malaria training workshop organized by the Climate and Health Working Group of Ethiopia and funded by Google.

org. The public-health and climate professionals who attended the workshop explored how climate conditions affect malaria distribution. They used local data sets provided by the health ministry and meteorological agency to conduct their analyses. They learned how climate information such as seasonal forecasts and environmental monitoring could help improve predictions of year-to-year variations of epidemics and could be used to more accurately evaluate the role of interventions.

“Taking climate out of the equation is important for malaria impact evaluation,” Thomson says. “Doing this using the national data sets is not only likely to get the best results, but also helps control programs understand the extent to which their outcomes are climate-sensitive. Climate information is another tool in the malaria control toolbox.” ■

Permalink for this story:

http://iri.columbia.edu/features/2010/important_gains_made_in_global_effort_to_control_malaria.html

Strengthening US India Agricultural Research *11.15.2010*

President Obama speaks to the Indian Parliament. Sneha TV

IRI web feature

Earlier this month, U.S. President Barack Obama and Indian Prime Minister Manmohan Singh announced a new era of collaboration on agricultural research in the face of climate change. In fact, efforts have been underway since 2009: the Earth Institute's International Research Institute for Climate and Society (IRI) has been working for the past two years with India's Ministry of Agriculture and other institutions to improve forecasts of the seasonal monsoon rains that water much of the nation's farms, and to help farmers manage drought.

"Cooperation between Indian and American researchers and scientists sparked the Green Revolution," said Obama during a Nov. 8 joint session of India's Parliament in New Delhi. "Now, as farmers and rural areas face the effects of climate change and drought, we'll work together to spark a second, more sustainable Evergreen Revolution." He and Singh later issued a joint pledge to pursue initiatives on clean energy, health and jobs, as well as agriculture and climate.

Shiv Someshwar, director of the IRI's Asia and Pacific regional program, said that the two leaders "sent a clear signal that scientific and technological advancements in managing weather and climate risks are critical for making rural communities more resilient. The dual emphasis on better climate prediction and its uptake by farmers and policy makers is exactly right. The IRI's work with Indian partners over the past two years has been built on this very premise."

More than 60 percent of farmland in India lacks irrigation, and thus depends on monsoonal rains, which come roughly from late May to early October. A failed monsoon often means complete loss of a crop, and even below-average rainfall often results in increased food prices and hurts economic growth. The government spends massive sums on drought relief--according to the agriculture ministry, about $5 billion during the last major drought, in 2002. A lesser, but still damaging, drought took place in 2009.

These costs have sparked interest in identifying ways to plan ahead, particularly as concern grows over the potential for climate change to affect monsoon cycles. IRI's effort is funded by the U.S. National Oceanic and Atmospheric Administration and India's Ministry of Agriculture, which together plan to issue detailed forecasts to farmers starting in the 2011 rainy monsoon season. The IRI project, known as the Extended Range Forecast System for Climate Risk Management in Agriculture, is aimed not only improving the forecasts, but helping farmers and policy makers prepare early for adverse conditions. In addition to conducting field-based research, IRI has co-hosted training events in India and sponsored Indian scientists for research visits to the United States to improve their forecasting and risk-management abilities. Partners include the Indian Institute of Technology, Delhi; India Meteorological Department; National Center for Medium-Range Forecasting; Indian Council of Agricultural Research, and a number of state agricultural universities. For full details, visit the project home page or download this flyer.

> "*Together, we're improving Indian weather forecasting systems before the next monsoon season. We aim to help millions of Indian farmers...and enhance climate and crop forecasting to avoid losses that cripple communities and drive up food prices.*"
>
> *Barrack Obama*

Below are Obama's remarks about agriculture. (The entire transcript of his speech is here):

Together, we can strengthen agriculture. Cooperation between Indian and American researchers and scientists sparked the Green Revolution. Today, India is a leader in using technology to empower farmers, like those I met yesterday who get free updates on market and weather conditions on their cell phones. And the United States is a leader in agricultural productivity and research. Now, as farmers and rural areas face the effects of climate change and drought, we'll work together to spark a second, more sustainable Evergreen Revolution.

Together, we're improving Indian weather forecasting systems before the next monsoon season. We aim to help millions of Indian farmers -- farming households save water and increase productivity, improve food processing so crops don't spoil on the way to market, and enhance climate and crop forecasting to avoid losses that cripple communities and drive up food prices.

And as part of our food security initiative, we're going to share India's expertise with farmers in Africa. And this is an indication of India's rise -- that we can now export hard-earned expertise to countries that see India as a model for agricultural development. It's another powerful example of how American and Indian partnership can address an urgent global challenge. ■

Permalink for this story:

http://iri.columbia.edu/features/2010/strengthening_us_india_agricultural_research.html

'Democratizing' Seasonal Forecasts in Latin America *11.3.2010*

Workshop participants (clockwise from back) Marilia Shimizu, Guilherme Martins and Fabricio Silva.
Photo courtesy of Guilherme Martins

by Cathy Vaughan
IRI web feature

A central tenet of the International Research Institute for Climate and Society's is that providing people and institutions with climate information is just one step in a larger effort. There's also a clear need to build the capacity of scientists to generate tailored information -- and to help users ask for information relevant to them.

This is particularly true in the case of seasonal climate forecasts. Despite advances that have been made in seasonal forecasts, many people still find them difficult to use. Perhaps it's because forecasts sometimes seem too complicated, says Simon Mason, IRI's chief climate scientist. "Plus, scientists frequently make forecasts about things that users are not directly interested in."

Walter Baethgen, director of IRI's program in Latin America and the Caribbean, points out another impediment to the use of seasonal forecast: "In Latin America, the development of forecasts has often been restricted to groups that have access to powerful computing resources."

As part of ongoing efforts to improve the use of seasonal forecasts, Baethgen helped lead a two-week training workshop in Buenos Aires, Argentina. The course was co-organized by the School of Exact and Natural Sciences at the University of Buenos Aires in Argentina and the Inter-American Institute for Global Change Research; it was funded by the National Science Foundation and co-sponsored by the World Climate Research Program.

Thirty-eight participants from 12 Latin American countries attended the workshop, which explored issues surrounding seasonal prediction in Latin America, including the downscaling of global models, the use of probabilistic approaches and verification techniques. In addition to Baethgen and Mason, IRI scientists Lisa Goddard and Gilma Mantilla also presented at the workshop.

The participants were drawn from the climate community and from different sector communities in order to encourage interdisciplinary work, says IAI's assistant director for capacity building, Marcella Ohira. "Getting people involved in these kinds of interdisciplinary conversations will help and, hopefully, have a lasting effect."

Juan Jose Nieto, an oceanographer at the International Center for Research on El Niño (CIIFEN) who led some of the workshop sessions, saw the experience as a "big opportunity to work together and to see things from the point of view of the user -- not just from climate scientists perspective, but also from the perspective of people working in agriculture, health, and risk."

> *"In Latin America, the development of forecasts has often been restricted to groups that have access to powerful computing resources."*
>
> *Walter Baethgen*

This includes Gustavo Almeria, a specialist working to develop a climate-based early-warning system for respiratory diseases in Buenos Aires. "Having information as soon as possible about the range of temperatures expected in Buenos Aires will allow us to put into action different measures and to warn the population about health risks, including influenza and bronchitis," he explains.

A key part of the training focused on the use of the IRI's Climate Predictability Tool, a freely downloadable program that lets users make customized seasonal forecasts quickly, easily, and without the benefit of powerful computers.

"The CPT is a very democratic tool", says Carolina Vera, an adjunct professor at the University of Buenos Aires and a co-organizer of the workshop. "It doesn't require a lot of resources, and it's so easy anyone can use it."

With the right training, tools like the CPT put the power of forecasting into the hands of potentially many more users. "With the CPT and a personal computer, any scientist who has an adequate background in statistics and reasonable knowledge of the climate in her or his region can produce useful seasonal forecasts for climate, streamflow, crop yields, malaria incidence and more," says Baethgen. ■

Permalink for this story:

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Cathy Vaughan is a project coordinator at the International Research Institute for Climate and Society. She is a member of the secretariat of the Climate and Society Publication and works frequently in Latin America.

IRI Scientist wins NSF CAREER award *10.15.2010*

Alessandra Giannini wins the NSF CAREER award.

IRI web feature

Alessandra Giannini, a research scientist at the International Research Institute for Climate and Society, has been awarded a National Science Foundation CAREER award to advance our understanding of climate model projections in the African Sahel, a semi-arid region south of the Sahara Desert that stretches from the Atlantic Ocean to the Red Sea.

The Faculty Early Career Development Program, known as CAREER, is the National Science Foundation's most prestigious award for junior professors that are exemplary "teacher-scholars" who can integrate education and research within the context of the mission of their organizations.

At the heart of Giannini's research is a quest to understand why 21st century climate-change projections diverge in the Sahel and other parts of the developing world.

"Anthropogenic climate change is expected to affect less-developed societies with greater severity, yet it's in the tropics, where these societies are located, that projections of change, especially of changes in regional rainfall, have the greatest uncertainty," says Giannini.

The global models that the Intergovernmental Panel on Climate Change uses in its assessments are inconsistent for the Sahel. Some of the models project the region to become wetter than it is currently, while others project it to be dryer, she says. "Having a better grasp of the situation is critical, because this region is highly vulnerable to rainfall variability and change."

In the 1970s and 80s, the Sahel suffered from devastating droughts and famines that killed hundreds of thousands of people and forced hundreds of thousands to migrate elsewhere. Giannini and her colleagues at the National Center for Atmospheric Research and at Texas A&M University conclusively demonstrated that those droughts could have been caused not by deforestation and land-use change, but by changes in global ocean temperatures. They published their results in the journal Science in 2003.

The CAREER award will fund Giannini's work for five years, and includes support for a doctoral student in climate science. In their research, Giannini and the student will analyze output from global models that diverge in order to try to identify any mechanisms attributable to natural variability, land use change or global warming. They will then look for the 'fingerprints' of such mechanisms in actual observations of the Earth's atmosphere collected by the U.S. Department of Energy's Atmospheric Radiation Measurement Mobile Facility (AMF) in Niamey, Niger - in the heart of the Sahel. The AMF is a portable laboratory equipped with a suite of instruments designed to collect data on clouds and other components of the atmosphere. Finally, they will test sensitivity in the models' behavior to such mechanisms with carefully crafted simulations.

Reaching out to the Columbia Community

Giannini's CAREER award also funds a particularly interesting educational component. She will be working with Columbia's Institute of African Studies to develop lessons and materials that benefit community organizations and public schools in Harlem, a historically African-American neighborhood near Columbia University with a sizable immigrant population from West African

"Anthropogenic climate change is expected to affect less-developed societies with greater severity, yet it's in the tropics, where these societies are located, that projections of change, especially of changes in regional rainfall, have the greatest uncertainty."

countries such as Senegal and Mali. Her aim is to teach climate-change science to high-school students from an environmental justice perspective, using air pollution as a way to connect local and global issues.

"I applaud Dr. Giannini's willingness to share knowledge, broaden connections between people and ideas and create opportunities for participatory growth," says Mamadou Diouf, the director of the Institute of African Studies.

Giannini wants to open up dialogue with immigrant community organizations in Harlem to share perspectives on climate change and its impacts. "Of great interest to me is to understand how they understand and explain drought, which may have ultimately led them to leave their countries. It's a mutual education - reaching a common understanding can help the IRI build projects in the region so it and its partners can act in the best informed way possible, with local support, to help avert the worst consequences of future change."

Immigrants routinely contribute to the survival of their communities of origin through remittances. Ultimately, Giannini hopes that scientific knowledge will empower them to learn from the past in order to shape a different future - a future that confronts head-on the same problems of poverty eradication and sustainable development that form the core of the mission of the IRI. ■

Permalink for this story:

http://iri.columbia.edu/features/2010/iri_scientist_wins_nsf_career_award.html

New Report: The State of Climate Prediction *9.22.2010*

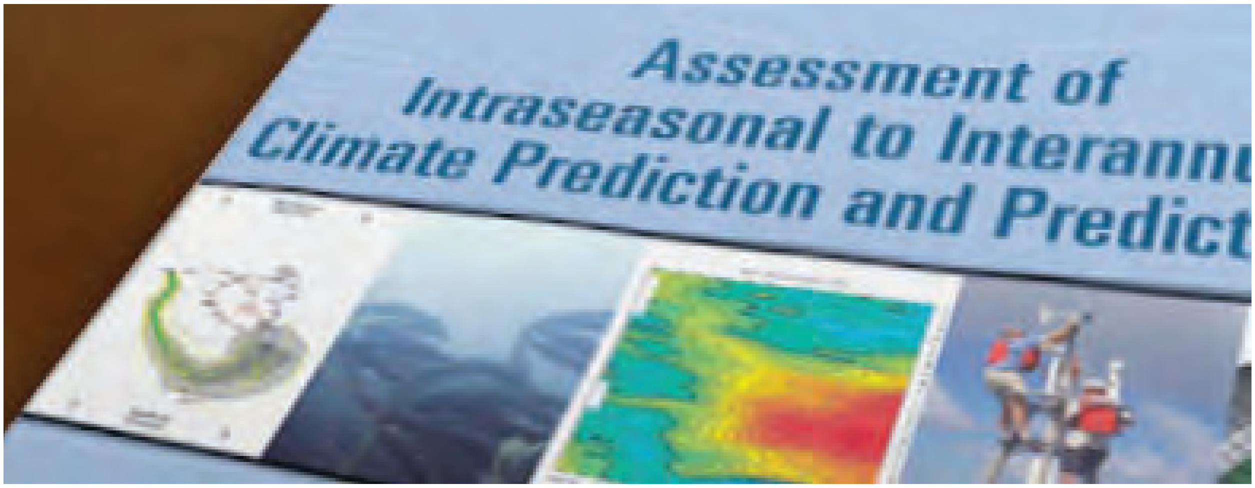

Image: The National Academies Press

IRI web feature

A report recently released by the National Research Council called "Assessment of Intraseasonal to Interannual Climate Prediction and Predictability" examines the current state of medium-term climate forecasting--over time periods of a few weeks to a few years. It makes suggestions on how these forecasts might be improved.

The International Research Institute for Climate and Society is among a number of institutions that regularly produce climate predictions, such as seasonal or longer-term rainfall and temperature forecasts. These institutions, the report states, could increase the value of such products to decision makers by improving the procedures for archiving and disseminating the information. In addition, the report concludes that making advances in observational capabilities, statistical and dynamical models and data assimilation systems could improve our understanding of key climate processes, as well as improve the forecasts themselves.

IRI research scientist Lisa Goddard was on the committee that wrote the report. In a brief Q&A below, she discusses the publication and some of its key recommendations.

Q: First, why is such a report necessary?

LG: The report was primarily commissioned by the National Oceanic and Atmospheric Administration, which wanted an assessment of the current capabilities in seasonal prediction and what additional efforts might improve the quality of forecast information. We know we have some skill in predicting the climate on intraseasonal-to-interannual time scales. For the United States, much of this skill is realized during El Niño or La Niña events. In order to improve our skill, we would not only need better models, but more complete observing systems, as well as better techniques for inserting those observations into the models' initial conditions for prediction. There are other aspects of the climate system that may influence the climate on these time scales, such as the stratosphere or land-atmosphere interactions. These will require much more research, observations, and modeling before the operational community can quantify their impact on intraseasonal-to-interannual predictions.

However, we wrote the report with a broader audience in mind. We included sections on the history of prediction, on how forecasts are made, plus the extensive observations, scientific research and operational efforts required to develop, improve and communicate these forecasts.

> *"Many important decisions regarding water management, agriculture, and energy are made on weekly, monthly, seasonal, and annual timescales. These decisions can benefit from high quality, reliable predictions. Yet making useful predictions about the climate system on these timescales is a challenge."*
>
> *Assessment of Intraseasonal to Interannual Climate Prediction and Predictability*

Q: The report recommends some "best practices" for improving the utility and accessibility of forecasts to researchers and decision makers. What are the major impediments that prevent the uptake of this information by these groups currently? Is there one best practice that stands out from the rest in your opinion?

LG: In my opinion, creating publicly-available archives of information associated with forecasts is paramount. IRI's experience is that the needs of researchers, decision makers and others who would use climate forecasts, or the model predictions on which they are based, are too diverse and difficult for any operational center to address thoroughly. So making available the data from the models and the observations, as well as what considerations went into the issued forecasts is very important. It allows different communities to tailor or assess the information in ways that are more consistent with their decision processes or risk thresholds.

Q: The report also lays out some key research questions that need addressing if we are to improve our forecasts. Which of these intersect directly with your work and why are they important to answer?

LG: The focus of my research is on how to make the best use of available prediction information, especially to those who might be able to act on that information. This is related to the report's recommendations on improving the development and understanding of multi-model ensemble prediction and merging statistical and dynamical techniques

I think this is an important issue because models are still deficient when it comes to representing some of the characteristics of the climate and its variability. These deficiencies aren't necessarily the same from one model to the next. The better the models and their use of observations become, the more robust the data I have to plug into my own research. So the key research questions that others throughout the climate community are addressing to improve forecasts also intersect directly with my work. ■

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http://iri.columbia.edu/features/2010/new_report_state_of_climate_prediction.html

The Pearl of Africa *9.1.2010*

by Michelle Cordray
Earth Institute's State of the Planet blog

My cell phone rang in the middle of the night. "Are you in Kampala?" On the other line was my husband informing me that two bombs went off in Uganda's capital city just several hours before, killing scores of people gathered at public spots to watch the final game of the World Cup. I was safe in a rural town a good 300 kilometer trek from Kampala and a world away from the violence that had erupted in the capital. But the next morning would bring sad news: the brother-in-law of a colleague was killed in one of the blasts.

As a graduate student in the Climate and Society Masters program at Columbia University, I was entering my sixth week in Uganda at the time of the bombings, completing an internship for the Uganda Red Cross, the Red Cross/Red Crescent Climate Centre and Columbia's International Research Institute. The goal of the internship: to produce short videos about the Uganda Red Cross Society's work in proactively reducing the impact of environmental hazards on the country's rural communities. Increasingly, such hazards include events associated with climate change (erratic rainfall patterns, floods and droughts), which in turn interact with other types of environmental degradation–primarily deforestation and wetlands encroachment–to increase the vulnerability of Ugandan communities reliant on natural resources for their livelihoods.

Uganda, often referred to as the "pearl of Africa," is a lushly verdant country, with dramatically convective skies, temperate climate, abundant water (in most regions) and fertile land. For the first two weeks, I was based in Katakwi, a sleepy town with no electricity in the central eastern region of the country. Residents have motorbikes, small businesses, cell phones, email addresses in some cases and at times dress as smartly as New Yorkers – but no power. Firewood and charcoal are the chief fuels used for cooking and paraffin and kerosene are used for lighting.

Upon arrival in Katakwi, we went to work right away: I joined former Climate and Society alumna Julie Arrighi and a team of Red Cross volunteers in the field as they conducted vulnerability and capacity assessments of various parishes in the area. My task was to film the process and capture one method by which the Red Cross works with communities to assess environmental risk. One portion of the assessment is something called the transect walk, whereby a handful of villagers walk with one or two volunteers through their parishes and describe the different areas (fields, tree plantings, wetlands, etc.) and the hazards they're experiencing. This year, floods pose the biggest threat and water logging has already caused many of their cassava plants to rot: one woman pointed to her crops and appealed to me for help with a hint of desperation. The transect walks, while challenging under the intense equatorial sky, are a unique opportunity to see how farming families live. On two occasions, I was invited into their homes: mud-packed cylindrical huts covered by grass roofs. Every family has several huts that encircle a cleared plaza where millet, sorghum, groundnuts and other staple crops are often laid in the sun to dry.

After our stay in Katakwi, we visited the region near the town of Pallisa where I interviewed local leaders about steps they have taken to protect their water sources (natural springs) and reduce the risk of malaria by using tools provided by the Red Cross to clear grass around their homesteads. Downstream from Mount Elgon, this region is prone to flooding; additionally, residents report that more erratic rainfall patterns are complicating their planting schedules. Farmers are beginning to adapt by planting at the first sign of rains, harvesting as early as possible and then storing crops in granaries elevated above ground.

Almost everyone I interviewed talked of changes in the seasons and the increased unpredictability of the rains. Uganda has a limited and broken historical climate record, so it is difficult to say with certainty that these shifts are due to climate change. Nevertheless, reports around the country were similar: farmers could no longer count on seasonal patterns to plan their planting schedules. Furthermore, people of all societal levels seem to demonstrate an awareness of seasonal shifts but may have differed in attribution: some were aware of global warming, others may attribute the changes to divine intervention.

Looking through hours of footage back in the States, I feel so grateful for the remarkable experience I had in Uganda. Ultimately, it was the friendships I formed that made the trip so rewarding; in putting together the Red Cross videos, I hope I accurately portray the struggles they face.

Disclaimer: the opinions I express in this post are my own and not of the Uganda Red Cross, the Red Cross/Red Crescent Climate Centre, the IFRC and the IRI. ■

Permalink for this story:

http://blogs.ei.columbia.edu/2010/09/01/the-pearl-of-africa/

Managing Risk in a Changing Climate: Obstacles *8.27.2010*

Farmers in Srirangapur Village, India, discuss climate risk management. (Haresh Bhojwani/IRI)

by Steve Zebiak
IRI web feature

As I wrote in the previous installment, climate risk management is a process that informs decision-making through the application of climate knowledge and information. IRI's approach to climate risk management consists of four components. The first is identifying vulnerabilities and potential opportunities posed by climate variability or change in a given part of the world and in a given sector. For example, an extended drought or a delayed rainy season could have serious impacts on farmers who grow rain-fed crops. On the other hand, there might be periods of above-normal rainfall they could take advantage of, if they had access to information on the likelihood of when and where those rains would occur.

The second component is assessing the relevant climate risks. Relevance here is determined by the problem at hand. For example, are wheat farmers in Ethiopia more concerned about the predicted timing of the rainy season--how early or late it starts--or how much total rain is predicted to fall? Perhaps instead they are most interested in the predicted total number of dry days or dry spells. Using the best science and available data, we endeavor to assess the range of possible future conditions for whatever climate parameters are targeted. This typically involves gleaning information from historical records; assessing the skill of climate forecast products; estimating the uncertainties in monitored information. It also requires us to understand the nature of climate variability at the different time scales defined by stakeholders. Farmers and health workers might need information at seasonal to interannual scales-three months to a year ahead of time. Development banks, foresters and dam builders may need decade-level outlooks; national authorities negotiating in the United Nations Framework Convention on Climate Change may require climate scenarios for the next 50-100 years. Each satisfies a set group of stakeholders, and each comes with its own set of uncertainties and limitations.

The third component is identifying technologies and practices that optimize results in normal or favorable years as well as those that can reduce vulnerabilities during unfavorable years or during extreme events such as droughts and floods. Farmers could decide whether to invest in fertilizers and improved seeds or switch crops altogether, if they had access to seasonal forecasts and understood how to interpret them. Forecasts could also help food-security agencies determine if, when, and where to preposition food aid in anticipation of a crisis. Some crop failures may not be avoidable, but every famine is. In the water sector, engineers using good quality decade-scale climate information can optimize the design of dams. For existing reservoirs, they can use the information to make better decisions on how to allocate the water, or better quantify the chances that extremely low or extremely high reservoir levels will occur.

> *"Communities are left exposed to a great deal of climate-related risk. This happens despite the increased interest in climate, evidenced by the resources invested in climate-related science, unprecedented discussions on climate policy and increasing support for disaster-risk reduction and climate-smart development"*

Once we've identified the best technologies and practices, the fourth and final step is finding the "real world" arrangements that enable their implementation. Using the example of an early-warning system for food crises, we can ask: What are the actual mechanisms to have in place for hunger relief? Who are the key decision makers to identify? What specific types of climate information do they need in order to take action and who will supply it? How do we make this sustainable?

The fact that climate risk management can be effective doesn't make it easy. Because the process is inherently interdisciplinary, it requires a detailed understanding of complex, context-specific interactions between physical, natural and social systems. It also involves collaboration among experts who must work together on cross-disciplinary problems. Although developing the proper strategies is a complicated task, climate risk management can be applied to agricultural, water, health or any other sector, on spatial scales that range from local to global, and on time scales from near- to long-term.

While the science of climate risk management is still in its infancy, strategies already exist for every sector. For instance, an effort to address deepening drought in Western Australia created a constructive engagement between water managers and climate scientists that improved practice in both fields and contributed to better policy (see relevant links below). In the realm of public health, a group of partners developed an integrated malaria epidemic early warning and response system that is being implemented in conjunction with the Roll Back Malaria campaign. The system includes seasonal forecasts, climate monitoring, vulnerability assessments, case surveillance and response planning.

“Communities are left exposed to a great deal of climate-related risk. This happens despite the increased interest in climate, evidenced by the resources invested in climate-related science, unprecedented discussions on climate policy and increasing support for disaster-risk reduction and climate-smart development. ”

Similarly, an IRI project in the Southern Cone of South America manages agriculture related climate risk through a series of technological and policy interventions. It also works to reduce the uncertainty associated with the impacts of climate variability on agriculture. Our project partners are currently developing information and decision support systems that include long-term climate and agricultural impact information, continuous monitoring of climate and vegetation, and seasonal climate forecasts.

We’ve also been involved on innovative weather-risk transfer solutions such as index insurance, which provides a way to minimize the livelihood impacts of ‘bad years’ associated with extreme events. This has the benefit of setting people free to invest in production during good years. In the future, it may be possible to combine index insurance with climate forecast information, providing insurance against the uncertainty of the forecast. At the same time, drought index insurance allows relief agencies to respond quickly as droughts unfold, thus avoiding catastrophes that may otherwise destroy livelihoods and force farmers into poverty traps.

Obstacles to effective climate risk management

The practice of climate risk management as described above is rare throughout the world today. Communities are therefore left exposed to a great deal of climate-related risk. This happens despite the increased interest in climate, evidenced by the resources invested in climate-related science, unprecedented discussions on climate policy and increasing support for disaster-risk reduction and climate-smart development.

Very few development organizations use climate knowledge, information products, or related management strategies as part of their overall toolkit. Practitioner communities in health, water, agriculture, finance and other key sectors have not yet begun to incorporate climate risk management into their day-to-day programs. Many climate service providers do not provide information on scales that are relevant to policy and management decisions, or that can be easily incorporated into their decision-making process.

A recent study by the IRI characterized the current situation as one of market atrophy - negligible demand coupled with inadequate supply of climate services for development decisions. In this sense, the main obstacle to the widespread implementation of climate risk management is the lack of engagement and communication between communities, and the lack of investment to foster these critical interactions. Climate researcher and service communities develop knowledge and related information products from a disciplinary research perspective - often uninformed about stakeholder needs. Meanwhile stakeholders in development, policy and planning are not capable of assimilating relevant climate information that is available. As a result, research is not being taken up, while stakeholders increasingly worry about climate but remain largely at a loss about what to do in practice.

The solution to this dilemma requires a focus at the nexus of these communities. It also requires the cooperation of relevant communities on global and local scales. The extent to which we can meet this challenge will, in large measure, determine the benefit that can be realized from major ongoing investments in research, observations, assessments, international policy and climate-sensitive development programs in years to come.

In the next and final installment, I'll provide a path forward for the improvement and uptake of climate risk management practices.

A version of this essay appeared in "Climate Sense". ■

Permalink for this story:

http://iri.columbia.edu/features/2010/what_is_climate_risk_management.html

Permalink for the first part:

http://iri.columbia.edu/features/2010/managing_risk_in_a_changing_climate_making_the_case.html

Stephen Zebiak is director-general of the International Research Institute for Climate and Society at Columbia University, which uses a science-based approach to enhance society's ability to understand, anticipate and manage climate risk to improve human welfare. He leads an interdisciplinary team of more than 40 scientists specializing in climate prediction, agriculture, health, water, economics and development policy. Dr. Zebiak has worked in the area of ocean-atmosphere interaction and climate variability since completing his Ph.D. at the Massachusetts Institute of Technology. He and Mark Cane authored the first dynamical model used to predict El Niño successfully.

Managing Risk in a Changing Climate: Making the Case

7.9.2010

Pétionville camp for displaced Haitians. Eric Holthaus/IRI

by Steve Zebiak
IRI web feature

We live in a time of rapidly escalating concern about climate change. Although scientific evidence on climate change has been steadily building over many years, only recently has the consensus concerning observed impacts and future scenarios reached a level to capture the world's attention. Increasingly, the question of whether or not climate change is happening is being replaced with the question of what we can and should do about the problem. The response will require concerted efforts not only to control atmospheric greenhouse gas emissions, but to adapt to and manage the effects of climate change as well.

Climate shocks in the form of droughts, floods, cyclones, and related problems such as epidemics, food insecurity and infrastructure loss have been playing out throughout recorded history, but with increasing severity as populations become increasingly vulnerable. A growing body of evidence, much of it captured in the 2007-2008 Human Development Report by the United Nations, points to the direct effects of climate on economic and human development, particularly in low-income countries. Scan the headlines of recent weeks, and you'll undoubtedly come across stories about the ongoing food crisis in Niger caused by irregular rainfall, which threatens the lives and well being of at least seven million people. You'll see pictures from the extremely harsh winter in Mongolia, which wiped out nearly 20% of the country's livestock, leading to food shortages and loss of livelihood for tens of thousands of families. You'll read about how hundreds of thousands of earthquake survivors in Haiti are still living in relief camps and other temporary structures, under threat of a hurricane season forecasted to be unusually active. The ability to cope better with climate is thus a paramount issue of the present, and a potentially even greater issue in the foreseeable future. We need 'win-win' approaches to better manage current climate risks and to build capability to cope with the climate of the future.

Many of the world's leading development institutions -- including the United Nations Development Programme, the World Bank and major foundations -- recognize that efforts to meet development goals, in particular the Millennium Development Goals, are threatened by climate risk. As a result, they have begun reviewing their programs from the perspective of climate-related risk assessment and risk management. Similarly, national governments and decision makers at the local and regional levels are now asking how they can better manage climate-related risk.

There is a great deal of relevant information now available to assist these efforts. Under the United Nations Framework Convention on Climate Change, and particularly through the work on the Intergovernmental Panel on Climate Change (IPCC), authoritative assessments of the current climate and possible future climate scenarios are readily accessible. In addition, routine monitoring information and seasonal-to-interannual climate forecasts are available in several centers, including the IRI. In practice, however, it is difficult to cast this information in terms that can inform decisions and policies in key socioeconomic sectors. As a result, little uptake has been achieved and livelihoods and economies remain vulnerable to climate risk.

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The work needed to provide problem-specific information and to advance innovations in the use of such information is the science of climate risk management practice. Put simply, climate risk management is the process of climate-informed decision-making. It involves the use of strategies that reduce uncertainty through the systematic use of climate information. This work is especially challenging because it involves a complex interplay between physical, natural, and social systems and requires that practitioners engage with good science, good policy, and good practice. At present there are some organizations working to connect these disparate disciplines -- but while their work has provided examples of practical ways to manage climate risk, the demand for useable knowledge and information far outstrips what can be provided.

If the global community is to become serious about managing climate risks, it must close the gap between knowledge and practice. In addition to major programs in climate assessment, international policy, and development assistance, the global community must also provide a mechanism to advance climate risk management practice.

In the next installment, I'll discuss in detail what we mean by climate risk management and what the current challenges are to
its implementation. ■

A version of this essay appeared in "Climate Sense". Stephen Zebiak is director-general of the International Research Institute for Climate and Society at Columbia University, which uses a science-based approach to enhance society's ability to understand, anticipate and manage climate risk to improve human welfare. He leads an interdisciplinary team of more than 40 scientists specializing in climate prediction, agriculture, health, water, economics and development policy. Dr. Zebiak has worked in the area of ocean-atmosphere interaction and climate variability since completing his Ph.D. at the Massachusetts Institute of Technology. He and Mark Cane authored the first dynamical model used to predict El Niño successfully.

Permalink for this story:
http://iri.columbia.edu/features/2010/managing_risk_in_a_changing_climate_making_the_case.html

Selected Abstracts

The following pages present selected abstracts of work for the period of this report. Research abstracts are organized as follows:

- Climate and forecasting topics, including methodology and tool development
- Climate analyses that pertain to specific impacts in regions
- Climate and environment studies that integrate with sectors and practice
- Tailoring information for knowledge sharing through outreach and training

Abstracts are also keyed to the below icons.

TOPIC AND REGION ICONS

Agriculture and Food Security	Environmental Monitoring and Remote Sensing	Water Management
Climate	Fire Management	
Data Library and Map Rooms	Forecasting	Africa
Economics and Livelihoods	Hazards	Asia and the Pacific
Education and Training	Public Health	Latin America and the Caribbean

IRI Products that feed into NOAA/CPC's and NOAA/PEAC's climate forecasts

Each month, the Climate Prediction Center (CPC) conducts two teleconferences that are two business days apart. The first teleconference is a discussion about the latest climate conditions relevant to developing a new set of seasonal forecasts for the U.S. to be issued by CPC the following week. Topics include verification of the most recent seasonal forecast, the latest El Niño – Southern Oscillation (ENSO) developments, and updated input tools supporting the new set of climate forecasts. One of the tools is the IRI's multi-model forecasts for temperature and precipitation for the first four of their 13 lead times. The ultimate topic concerns the revisions to the forecasts to be issued, with respect to those issued the previous month for the same 3-month periods. During the call, meteorologists in the field express their thoughts about forecasts for their region, based on their local climate history.

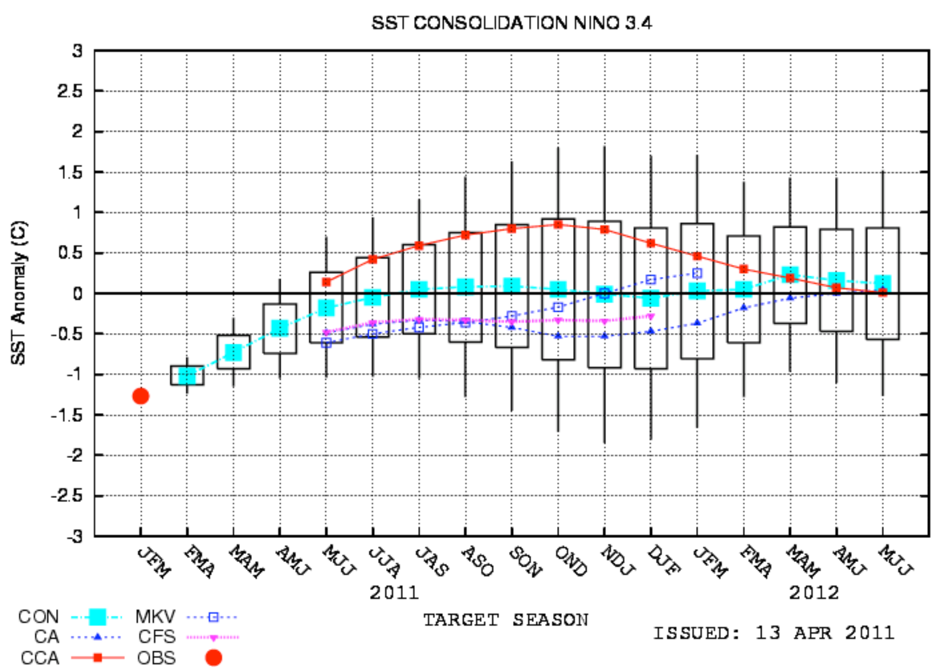


Figure 1. The Climate Prediction Center's consolidated Nino 3.4 SST anomaly forecasts, showing four model forecast inputs and a resultant probabilistic confidence interval.

To help define the ENSO situation as one important determinant of the new climate forecasts, the latest model predictions for the NINO3.4 SST region are examined. At the time of the first teleconference, the IRI's ENSO forecast plume is usually not yet available, but the ENSO forecasts produced by NCEP's own four models has been established and a multiple regression is used to develop an SST consolidation forecast (e.g., see Figure 1). Comments from the IRI teleconference participant about those additional ENSO forecasts that have been received for the IRI plume adds additional information to the discussion. Following the teleconference (held on a Friday), CPC forecasters develop their set of seasonal forecasts for the U.S., to be viewed and discussed during the second teleconference to come on the following Tuesday.

During the second seasonal forecast teleconference, called the "Sanity Check", the draft forecasts made by CPC are examined and discussed. By this time, the IRI has delivered its ENSO forecast plume (e.g., see Figure 2) to CPC, including up to 23 model forecasts, to complement the ENSO forecasts produced by NCEP's own models. Because NCEP's models are included on the plume, it is possible to assess their representativeness of the larger set of forecasts, and possibly re-evaluate the thinking about the most likely ENSO development.

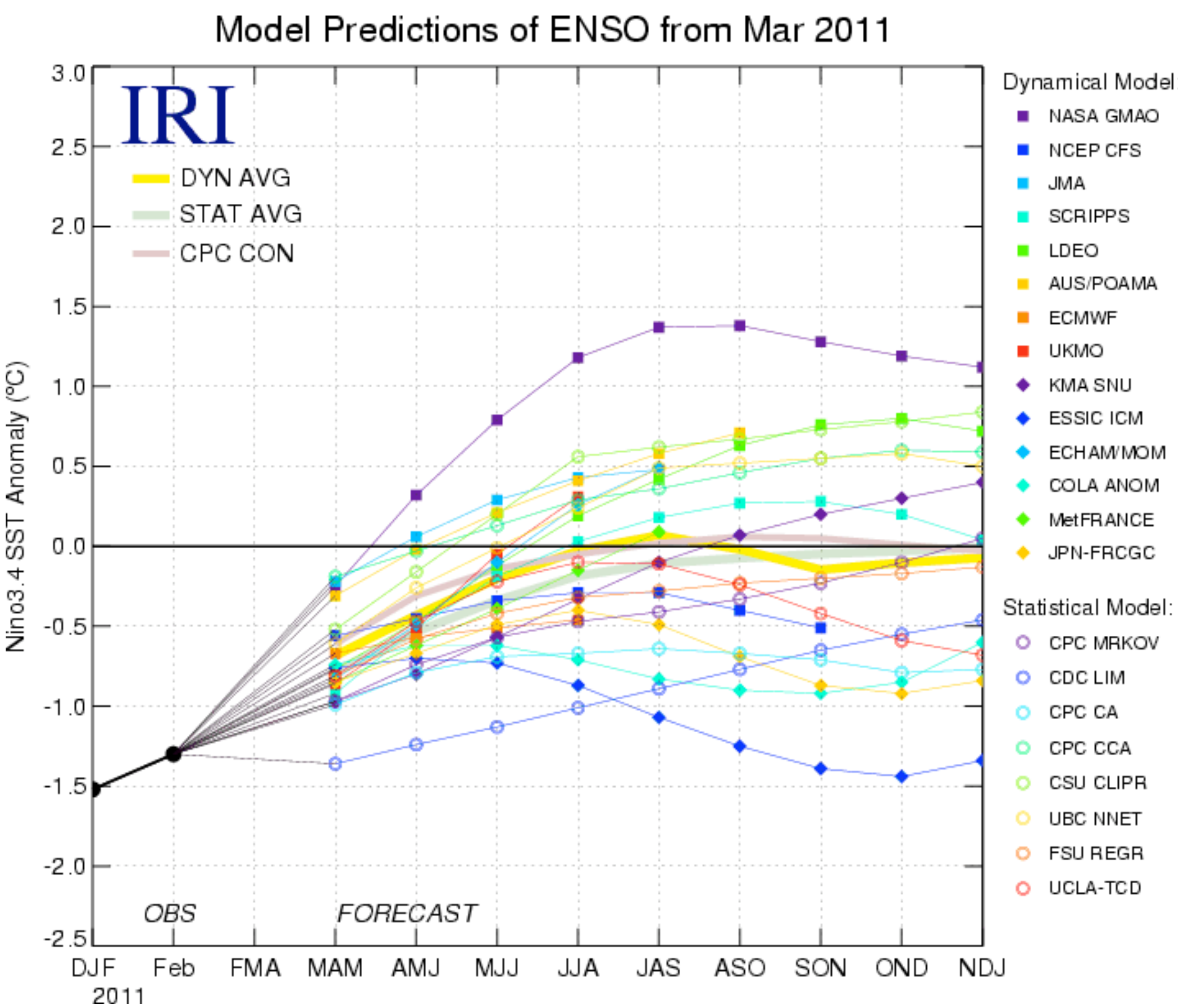


Figure 2. An example of the IRI's ENSO prediction plume, containing predictions of up to 23 models.

The part of the discussion requiring the most time is that concerning the newly drafted seasonal forecasts, and their differences from the forecasts made one month earlier for the same target periods. To enable a careful consideration of the role of each of the input tools toward the new forecasts, the forecasts from those tools are shown individually (e.g., see Figure 3).

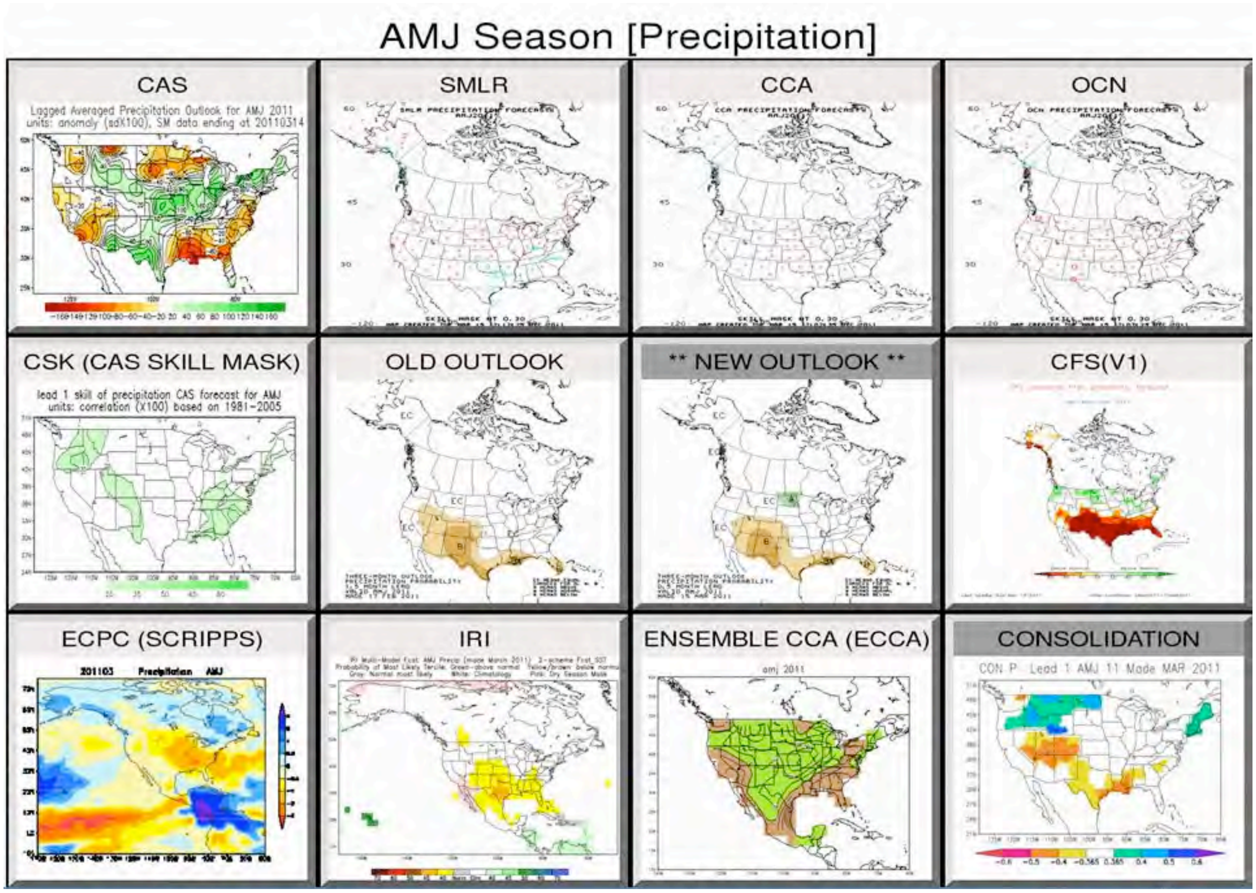


Figure 3. The Climate Prediction Center's set of individual forecast tool inputs (all panels on top row, first three panels on bottom row, and rightmost panel in middle row). The consolidated forecast is shown in the lower right panel, and the final probabilistic forecast from the previous month is shown in the second panel in the second row, with a tentative version of this current month's forecast shown to its right.

The panel in the lower right of Figure 3 is an objective consolidation of a subset of the tools shown in the other panels, using multiple regression. The six tools included are the four across the top row, the CFS (at far right in second row), and the ECCA (toward right in bottom row). The tools not included are the ECPC and the IRI predictions, due to their lack of multi-decadal hindcasts using an identical model configuration, as required to develop weights for the multiple regression. Long-period hindcasts are impractical for those two tools for various reasons; for the IRI forecasts they would require forcing some of the participating partner models (e.g. NASA, COLA, Scripps) with predicted SSTs, which has not been able to be arranged. Despite not being included in the objective consolidation, the IRI and ECPC inputs are taken into account informally in the formulation of the "New Outlook" (Figure 3), which is allowed to deviate from the guidance provided by the consolidation. The CPC forecasters are aware of the large number of dynamical models feeding into the IRI's multi-model forecast, as opposed to a single model going into their consolidation, and thus give the IRI's forecast ample consideration.

Each month, besides participating in the formulation of the CPC's seasonal climate outlooks, the IRI also participates in a teleconference with the Pacific ENSO Applications Center (PEAC). PEAC issues probabilistic precipitation forecasts for the U.S.-affiliated Pacific islands, most of which are shown as black dots in Figure 4. The IRI's forecast for the U.S.-affiliated islands is

combined with similar forecasts from the models from UKMO, ECMWF, NASA, NCEP (CSF model), CPC (constructed analogue model), and University of Hawaii (PRIDE model).
In summary, IRI is proud to support NOAA's seasonal climate forecasting efforts for the U.S. in

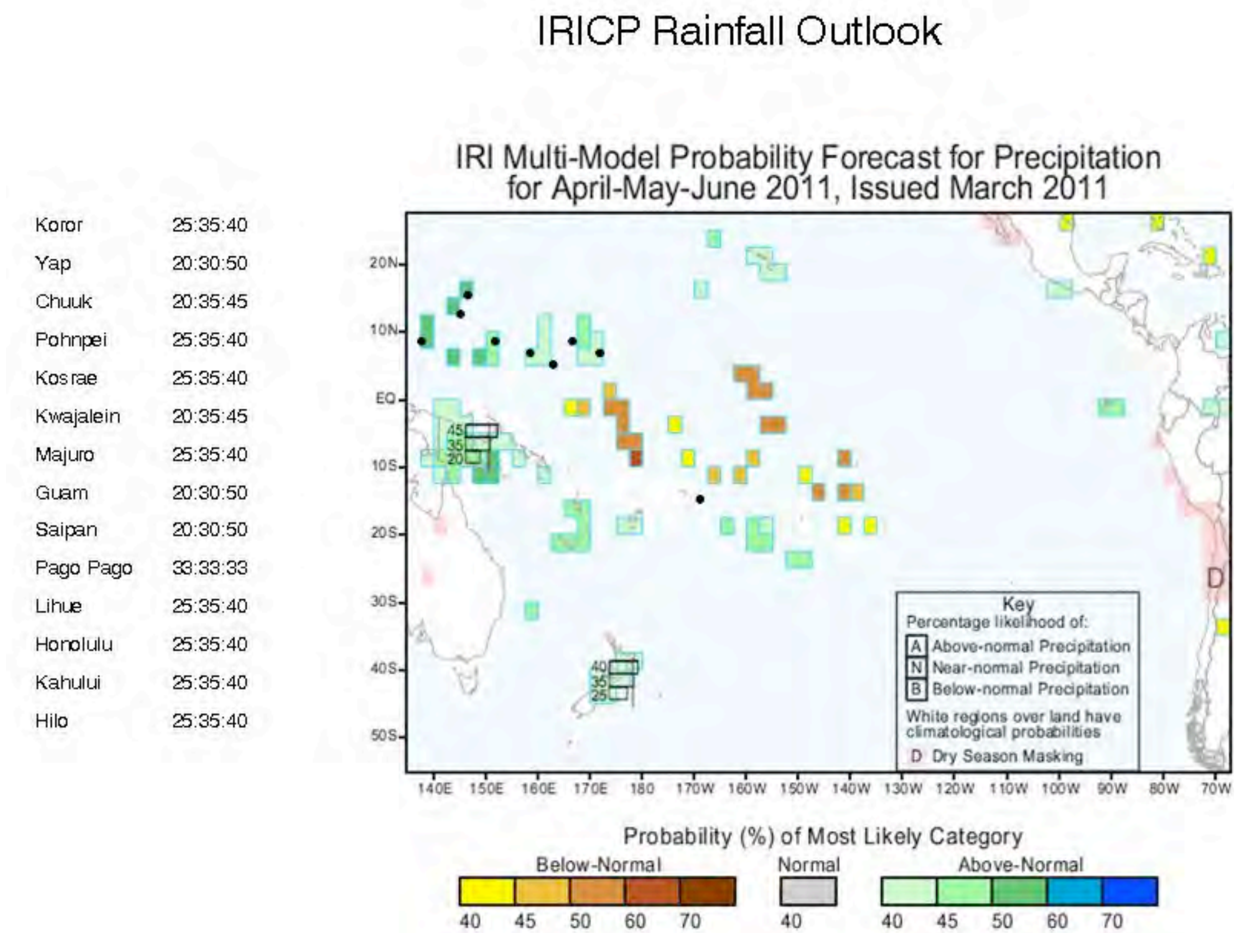


Figure 4. The IRI's probabilistic precipitation forecast for most of the U.S.-affiliated islands, used as one of several inputs to PEAC's final precipitation outlook (see http://iri.columbia.edu/climate/forecast/net_asmt/).

whatever ways possible. After years of equivocating, IRI is now developing a second version of the ENSO prediction plume that includes only models able and willing to furnish a 25+ year hindcast record using the same model as used in the real-time forecasts, so that an objective weighting system would be possible for developing a multi-model ensemble ENSO prediction. In similar fashion, IRI could generate a specific version of its 2-tiered multi-model climate forecast that uses only models for which 25+ year hindcasts using predicted SST are available, enabling the forecast to qualify as an input to CPC's consolidated climate forecast.

Contributed by ***A.G. Barnston****,* ***S. Li*** *and* ***B. Li****.*

Evaluation of IRI's seasonal climate forecasts for the extreme 15% Tails

In addition to IRI's tercile-based probabilistic seasonal forecasts of near-global precipitation and temperature beginning in October 1997 (Mason et al. 1999), forecasts for events falling into the lower or upper 15 percentiles of the climatological distribution began being issued in 1998. Based on the same model output as the standard forecasts, forecasts for the 15% tails are issued only for the season having the shortest lead-time. These forecasts are provided for users particularly sensitive to climate events farther away from the climatic average than can be specifically represented by the tercile-based categories.

Three gradations of probability enhancement above the 15% climatological level are defined for the 15% tail forecasts: "slightly enhanced" (defined by probabilities of 25-40%), "enhanced" (40-50%), and "greatly enhanced" (≥50%). Together with the climatological neutral default, this forecast format was chosen to make the forecasts more easily understood by users, and because of the greater uncertainty associated with forecast probabilities in the outer portions of the climatological distribution.

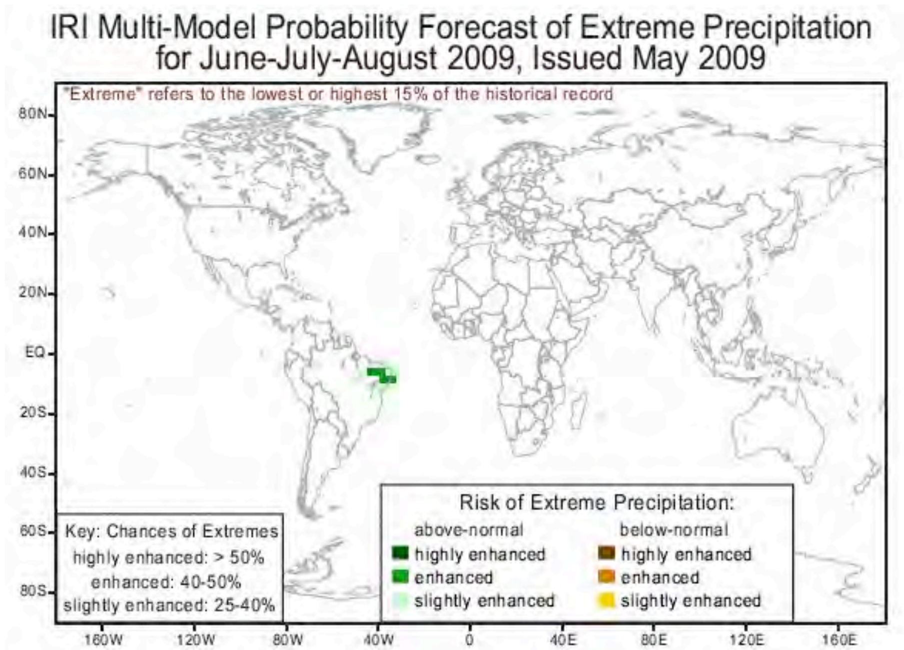


Figure 5. Example of a forecast for the 15% precipitation extremes, issued in May 2009 for June-July-August 2009. An area of enhanced (40-50%) probability for above-normal rainfall is indicated in part of northeast Brazil, surrounded by some area of slightly enhanced (25-40%) probability.

An example of a forecast map for the extreme 15% tails for precipitation is shown in Figure 5. Forecasts for the 15% extremes were issued conservatively, resulting in spatial coverage averaging less than 5% for both precipitation and temperature, with largest coverage in the tropics. Hence, many occurrences of upper and lower 15% of precipitation and temperature were not forecast. However, within the set of extremes forecasts that *were* issued, largely satisfactory resolution and favorable calibration are shown by a reliability analysis (see Figure 6, below). Nonetheless, two notable weaknesses are that forecasts for extreme above-normal precipitation were somewhat overconfident, and that 15% above normal temperature extremes were substantially underforecast. This second finding has been noted also in IRI's standard tercile probability forecasts (Goddard et al. 2003; Barnston et al. 2010), and can be attributed in part to the use of fixed (and outdated) CO_2 concentrations in the atmospheric general circulation models.

Improvements currently being implemented in IRI’s forecast system are expected to benefit the forecasts for the 15% extremes. The new system performs multivariate rather than only local calibration of individual model forecast outputs prior to multi-model combination. Additionally, single-tiered (coupled) models are being introduced. Expected increases in forecast sharpness are resulting in larger coverage of areas of enhanced probabilities for the 15% tails.

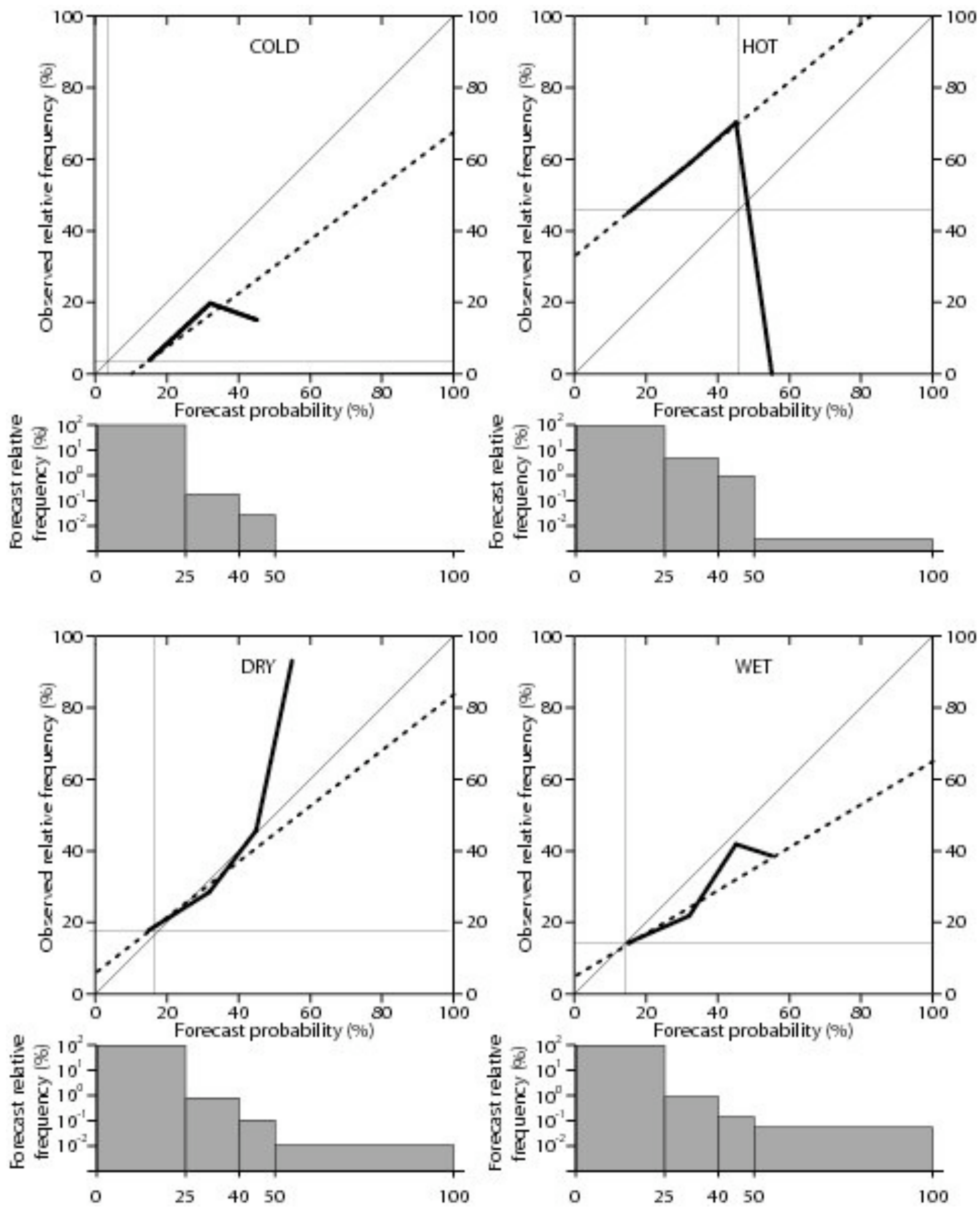


Figure 6. Reliability plots for forecasts of temperature (top) and precipitation (bottom) extremes in the tropics (25ºN–25ºS). The straight 45º line represents ideal reliability. The dashed line is the least-squares linear regression fit to the points forming the reliability curve, weighted by the sample sizes represented by each point. Horizontal and vertical lines are drawn at the observed relative frequency for the study period. Forecast probabilities are plotted at the midpoints of their respective probability intervals, except “neutral default” is plotted at 15% and “extremely enhanced” at 55% because values greater than 60% were never indicated. Sub-panels below each chart show the percentage frequencies with which the four forecast probability categories were forecast, with a logarithmic scale.

Contributed by ***A.G. Barnston*** *and* ***S.J. Mason***

A verification package for tercile-based probabilistic climate forecasts

The IRI has developed a verification package that can be used for a continuing suite of probabilistic climate forecasts for defined categorical events, such as defined by the terciles of the climatological distribution. A number of skill scores are developed. These can be shown as spatial maps of the time-averaged skill, or by time series graphs of spatially averaged skills. Reliability diagrams are also included. The scores are updated whenever another month of observations is obtained and new forecasts can be verified. The calculations and their graphical illustrations require very little computer resources. IRI would be pleased to give the Climate Prediction Center the FORTRAN software and help set up a verification system for the U.S. forecasts. The scores currently available in the package are shown in Table 1.

Table 1: IRI verification package

Main Score	Related Scores	What Is Measured
Heidke skill score	Additional variations	Proportion of "hits"
Brier Skill Score (specific to a single category)	Ranked probability skill score (RPSS) (for all categories collectively)	Squared probability error (for RPSS, cumulative over the 3 ordered categories)
Relative Operating Charac-teristics (ROC) (specific to a single category)	Generalized ROC (GROC) (for all categories collectively)	Discrimination (rank-based, and therefore insensitive to biases)
Likelihood Score, and Likelihood Skill Score	Rate of return, and Ignorance score	Assesses probabilities given only to the category that verifies
Correlation	Uncentered correlation: credit (penalty) given for reproducing (contradicting) mean climate shift, such as a warming trend	Discrimination for the deterministic equivalent of the probability forecasts (the center of the probab-ility distribution is defined)
Unconditional Bias		For each category, the difference between the average forecast probability and the corresponding observed relative frequency
Reliability diagram		Unconditional bias, conditional bias, resolution, reliability, underconfidence, overconfidence, sharpness

A few of the verification measures have been applied to IRI's seasonal forecasts for the 0.5 month lead time, issued from late 1990's to the present, and are illustrated in the figures that follow. First, we illustrate a time series of the likelihood score for temperature for the globe and the tropics, along with the ENSO state (see Figure 7). Because this score is the geometric average of the probabilities given to the later verifying category, scores of more than 0.333 indicate positive skill. The skill is related to the ENSO state, especially in the tropics, with

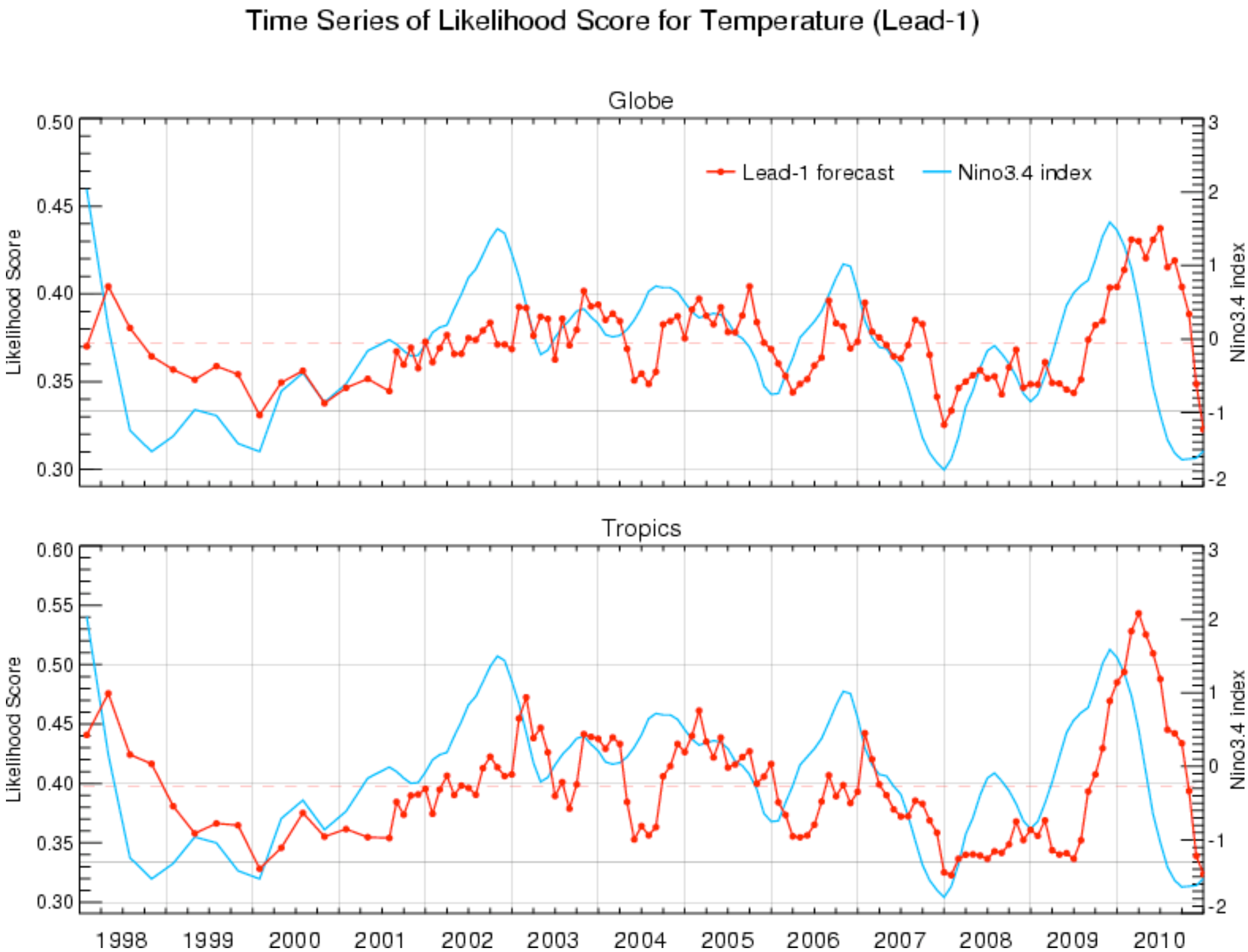


Figure 7. Time series of likelihood score for temperature forecasts made at 0.5 month lead, which is the geometric average of the probabilities given to the verifying category; the blue line shows the ENSO state

highest skill occurring during the second half of El Niño events and for several months following the event. On the other hand, relatively low skills occur with and just after La Niña events. A likely explanation for the relationship is that the two main sources of predictive skill for temperature are ENSO and the warming trend associated with global climate change. During El Niño these two signals compound one another, particularly in the tropics, while during La Niña they tend to cancel one another, leading to greater net uncertainty and lower skill.

Figure 8 shows the geographical distribution of the likelihood score for the Jan-Feb-Mar season. Skill is positive throughout most of the globe, but is greatest in the tropics. Because ENSO episodes have typically just matured by this late northern winter season, a

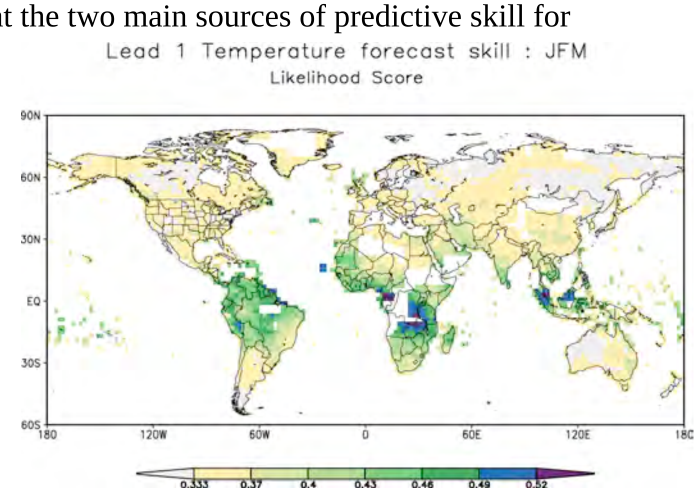


Figure 8. Spatial distribution of average likelihood score over all temperature forecasts made for the Jan-Feb-Mar season at 0.5 month lead.

considerable portion of the skill is related to teleconnections during ENSO extremes. By contrast, during northern summer (not shown) a greater proportion of the skill is related to the general warming trend rather than to ENSO.

Figures 9 and 10 show similar graphics for the same set of 0.5-month lead forecasts, except for precipitation, and for the RPSS rather than the likelihood score. In the case of IRI's forecasts, the likelihood score and RPSS usually show similar results, because IRI's forecast probability distributions are quasi-Gaussian—i.e., they rarely have highly irregular or bimodal probability distributions. The likelihood score is based only on the probability given to the verifying category, while RPSS is additionally sensitive to the distance involved in poor forecasts, and penalizes more severely when the highest probability is two categories away from the verifying category. For quasi-Gaussian probabilities, the probability given to the verifying category is closely related to the distance to the category receiving the highest probability, so that the two scores are usually proportional to one another, differing only in their scaling. The skills of precipitation are usually lower than those for temperature, both because precipitation is a "noisier" field less related to the large-scale circulation anomaly structure and because it generally has a smaller climate change signal. It is also far more seasonally dependent than temperature over most of the globe, being relatively more predictable in different regions as a function of season. Jan-Feb-Mar is a season benefitting from predictable ENSO teleconnections, and consequently skill is noted over portions of the tropics and the southern U.S.

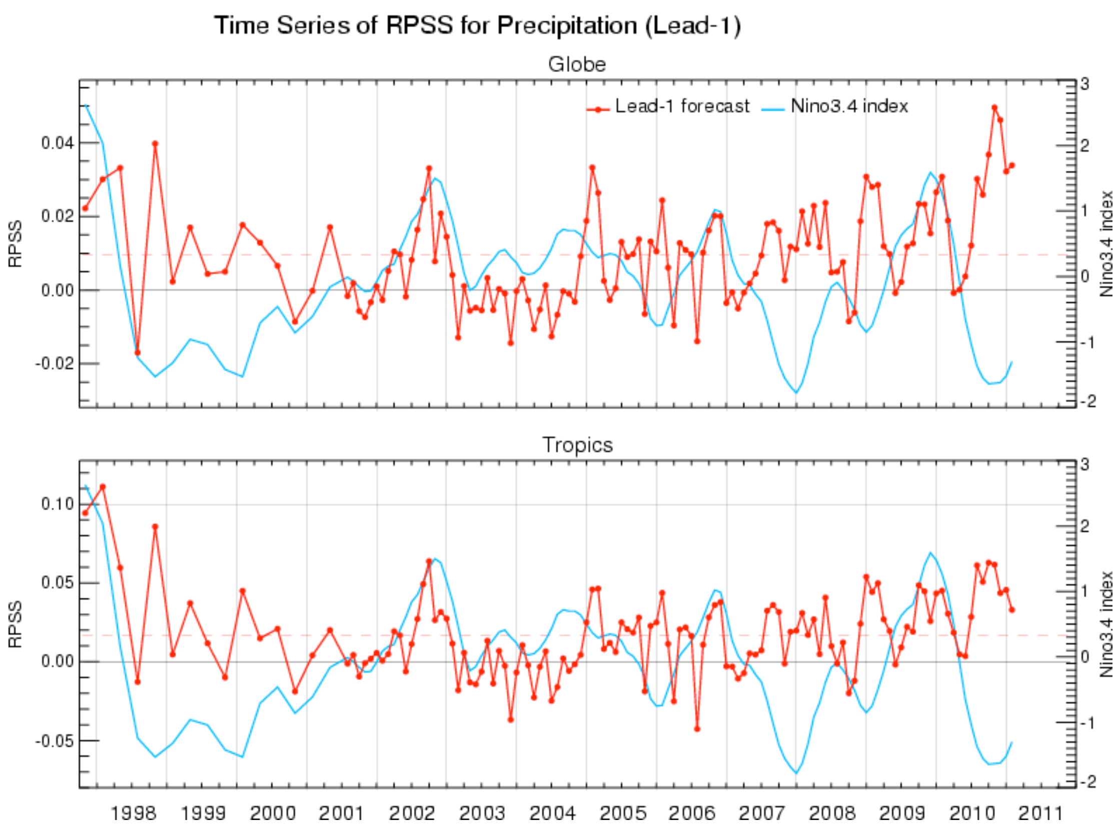


Figure 9. Time series of ranked probability skill score (RPSS) for precipitation forecasts made at 0.5 month lead, based on the cumulative squared probability error over the three categories in rank order; the blue line shows the ENSO state (NINO3.4 index).

Reliability diagrams show the correspondence between specific intervals of forecast probability and their associated relative frequency of observed occurrence, spanning the full range of issued forecast probabilities. Figures 11 and 12 show reliability diagrams for IRI's global temperature and precipitation forecasts, respectively, at 0.5 month lead. Ideally, the forecast probabilities should closely match their corresponding observed relative frequencies of occurrence, so that the curves would hover near the 45° line having a slope of 1. The diagram for temperature (Figure 11) reveals a fairly dramatic underforecasting of above normal and underforecasting of below normal, despite that the average forecast probability for above and below normal temperature were 0.41 and 0.26, respectively. But the observed relative frequencies of observing those categories were 0.63 and 0.18, respectively, indicating a more than three-to-one odds of observing above to below normal—an odds that was only partially met in the forecasts. Aside from this large overall bias, the inter-forecast changes in probability appear appropriate for the above normal category but somewhat overdone for below normal (i.e. overconfident), with a slope of somewhat less than 1. The reliability diagram for precipitation (Figure 12) indicates good reliability with only small overall biases. However, the inset diagram shows that the forecast sharpness is lower than seen for temperature (deviations from climatology are smaller), indicating lower predictive potential and skill despite better probabilistic reliability.

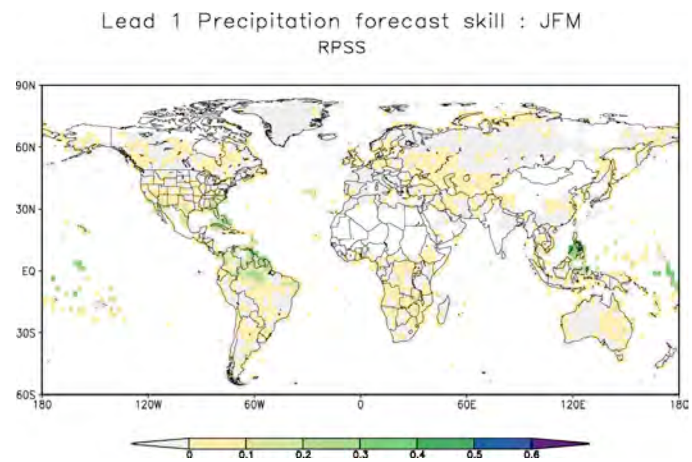


Figure 10. Spatial distribution of average RPSS over all precipitation forecasts made for the Jan-Feb-Mar season at 0.5 month lead.

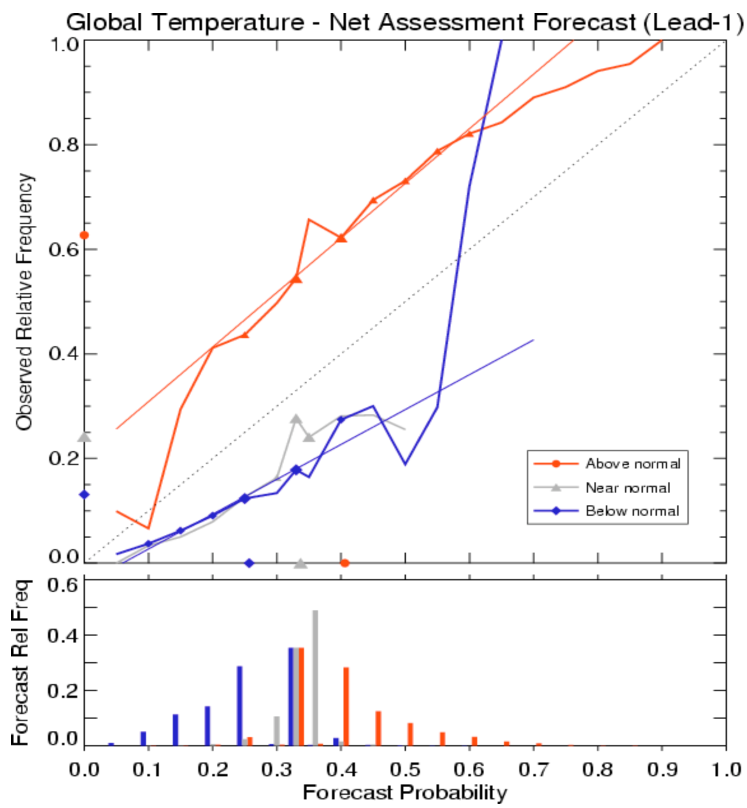


Figure 11. Reliability diagram for temperature for 0.5 month lead IRI forecasts for all seasons. Each line pertains to a single category being forecast. For above and below normal categories, least squares regression lines are shown, weighted by the sample sizes represented by each point. The diagonal y – x line represents perfect reliability. The dot size indicates the frequency with which the probability interval was forecast, shown more explicitly in the inset below the main plot. The colored marks on the axes show the overall means of the forecast probabilities or observed relative frequencies. The forecast interval widths are 0.05, except that the climatological (0.333) probability is also explicitly shown.

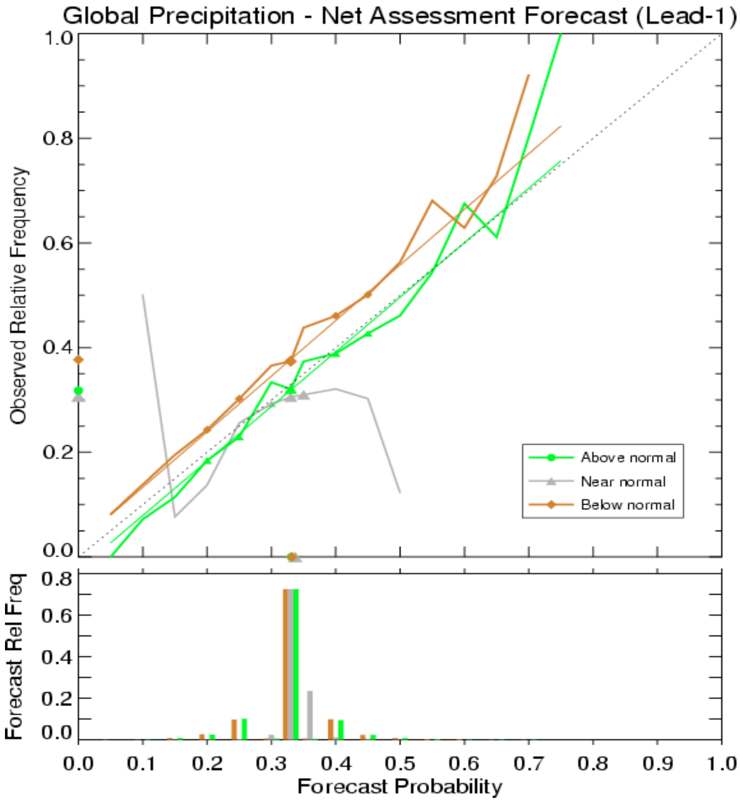


Figure 12. Reliability diagram for precipitation for 0.5 month lead IRI forecasts for all seasons. Details are as described in the caption for Figure 11.

In summary, a set of probability forecast verification measures has been coded and applied to IRI's issued forecast history. The measures aim to assess a number of attributes of the forecasts, enabling users to better interpret and apply the forecasts to their particular needs. A subset of these scores have been illustrated here as an introduction to what could be extended to any season or selected region. All of these measures and graphics are accessible on the IRI's web site.

Contributed by ***A.G. Barnston****,* ***A. Curtis****,* ***J. Turmelle, S. Li*** *and* ***S.J. Mason****.*

Performance of the IRI multi-model ENSO prediction plume

Since February of 2002, a number of groups have provided their ENSO forecasts to the IRI. Those forecasts are the basis for a probabilistic ENSO category forecast as well as an "ENSO prediction plume" like the one shown in Figure 13 from February 2009. The ENSO plume shows forecasts of seasonal (three-month average) NINO 3.4 anomalies for the upcoming 9 overlapping three-month seasons; the number of models represented in the plume ranges from 15 at its inception in February 2002 to 23 at present. Here we document the performance of the ENSO prediction plume product over the period 2002-2011. The most common questions

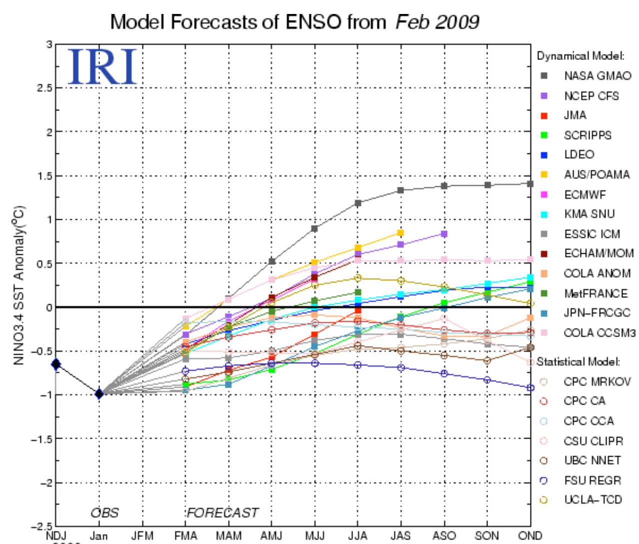
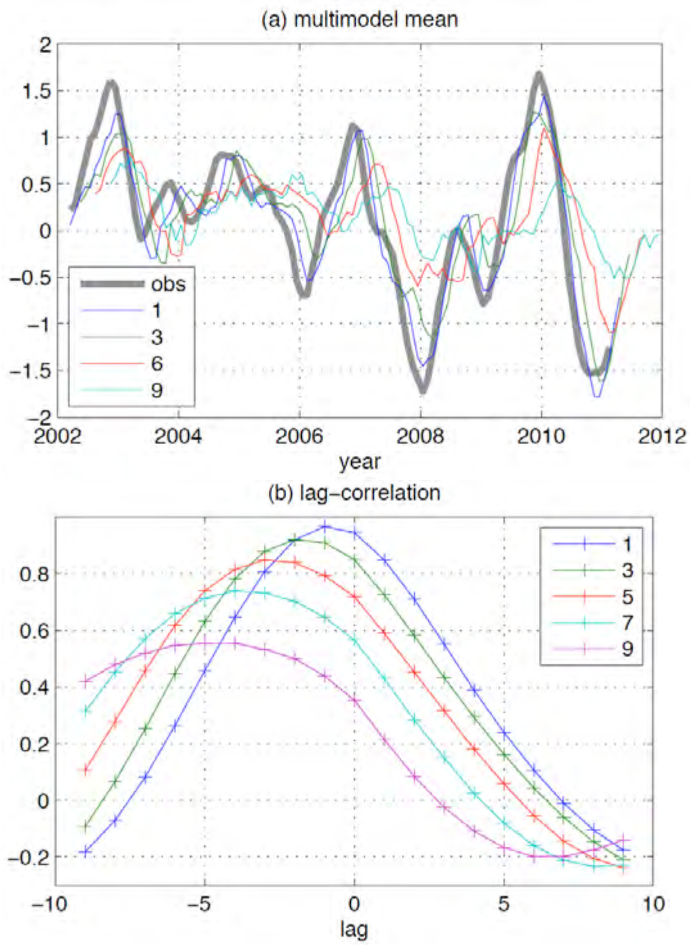


Figure 13. Example of a forecast plume.

asked by users of this product are ones regarding skill: What is the skill of the multimodel mean and how does it vary according to lead and season? How is the spread of the prediction plume related to forecast error? Such questions are difficult to answer unequivocally on the basis of hindcasts alone for at least two reasons. First, not all the models included in the prediction plume have extensive hindcasts. Second, hindcast skill may not be representative of real-time skill. The difference between hindcast and real-time skill difference may be due to difficulties that occur in real-time (e.g., human error, data availability), as well as to model development choices that enhance skill only during the hindcast period. Since real-time forecasts are the ones that users must use, it is valuable to evaluate their performance directly.

Phasing and Bias - the observed NINO 3.4 SST index anomaly (NCEP OI version 2; Reynolds et al. 2002)) and the multi-model mean anomaly forecast at lead times of 1, 3, and 9 months are shown in Figure 14 (a). The first lead is defined as the first 3-month period following the latest observations. For example, the first lead of a forecast using data through December is January to March (JFM). The observations indicate moderate El Niños in 2002-03 and 2009-10, weaker El Niños in 2004-05 and 2006-07, moderate La Niñas in 2007-08 and 2010-11, and weak La Niñas in 2005-06 and 2008-09. The multi-model mean forecasts do capture the observed anomalies, but with lower amplitude and at a time lag with respect to the observations, both effects increasing with increasing lead time. In particular, the longest lead forecasts are "slow" to capture the transition into and out of ENSO events. This point is made more precise in Figure 14 (b), which shows lagged correlations of forecasts and observations. Maximum correlations occur for negative values of lag somewhat less than the lead, i.e., for the lead 3 and 5 forecasts the maximum correlation occurs with a lag of -2 and -3 months, respectively. This phasing problem also manifests itself as a conditional bias where forecasts starting during warm events have a warm bias and forecasts starting before warm events have a cold bias. The systematic nature of this discrepancy between forecasts and observations suggests the utility of applying a statistical correction to the model output, a procedure we have tested and found beneficial.



Figures 14: (a) The observed NINO 3.4 SST index (thick line) anomaly and the multi-model mean anomaly forecast (thin lines) at lead times of 1, 3, and 9 months for the multi-model mean. (b) Lag correlations between observations and multi-model forecasts.

To measure the level of association between forecasts and observations we use the mean squared error skill score (MSESS) given by

$$\mathrm{MSESS} = 1 - \frac{\langle (f-o)^2 \rangle}{\langle o^2 \rangle}$$

where f and o are the forecast and observation anomalies, respectively and $\langle \cdot \rangle$ denotes average. In the absence of biases, MSESS is the fraction of explained variance. MSESS averaged over the study period is shown in Figure 15 as a function of verification and lead. The prominent feature is the northern spring predictability barrier. Skills are greatest for target seasons near the beginning and end of the calendar year and lowest during transition times when episodes often dissipate or begin. SST conditions during the MJJ and JJA seasons are the most difficult to predict with antecedence, with forecasts of MJJ having no significant MSESS skill at any lead. The performance of the dynamical multi-model mean (not shown) is superior to that of the full multi-model mean and the statistical multi-model mean during these two seasons, though the difference is not statistically significant.

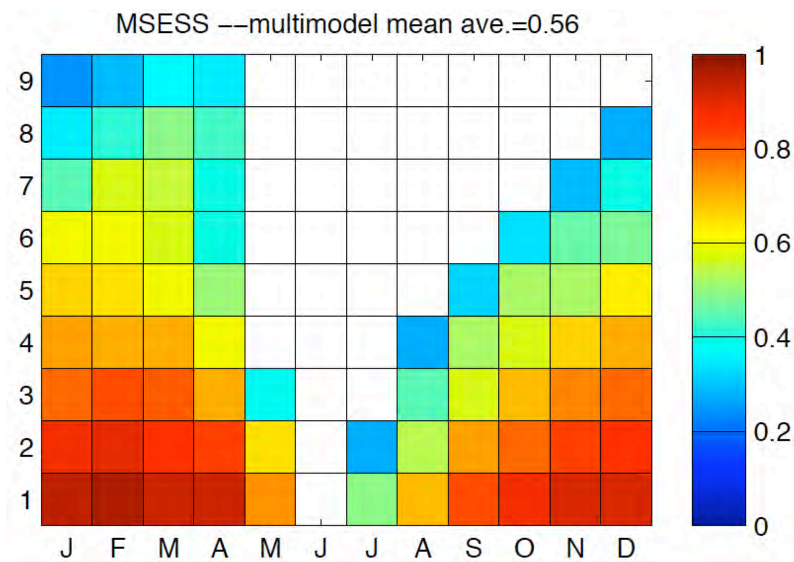


Figure 15. Mean square error skill score (MSESS) as a function of verification season and lead. The horizontal month label indicates the middle month of the 3-month season. Only significant (95%) values are shown.

The ENSO plume, by its very format, emphasizes the uncertainty of ENSO predictions, and we now consider the skill of categorical probabilistic forecasts based on the plume. We emphasize that the plume-based probabilistic forecasts shown here do not correspond to the probabilistic IRI ENSO forecast product, which is informed by expert opinion as well as model outputs. We consider categorical probabilistic forecasts for the occurrence of La Niña, neutral or El Niño conditions, defined using IRI thresholds. The simplest way of computing ENSO probabilities from the prediction plume is to use the fraction of models in each category. Figure 16(a) shows the dominant forecast probabilities for La Niña and El Niño conditions when the dominant forecast probabilities are nonneutral. The ENSO events of the period are forecast for the most part with increasing probability as lead-time decreases. Longer lead forecasts fail to capture the initiation and termination of events and show the same phase problem noted with the deterministic forecasts. The dependence of ranked probability skill score (RPSS) on verification season and lead (not shown) is similar to that seen for MSESS. However, RPSS is more affected by sampling error. For instance, RPSS harshly penalizes cases like the winters of 2005 and 2007 when the forecast probabilities pointed towards warm conditions, which did occur, but failed to meet the El Niño threshold. Reliability is shown in Figure 16(b) for leads 1-3 using bins with a probability width of 0.2; error bars are calculated using a binomial approximation. Reliability is acceptable given the sampling uncertainty. The forecast issuance frequency shows considerable forecasts of zero probability. Forecast probabilities constructed from a Gaussian distribution whose mean is the plume average and whose variance depends only on verification season and lead has much the same skill and slightly higher average RPSS, suggesting that most of the skill is due to shifts in the plume mean and a variance annual cycle.

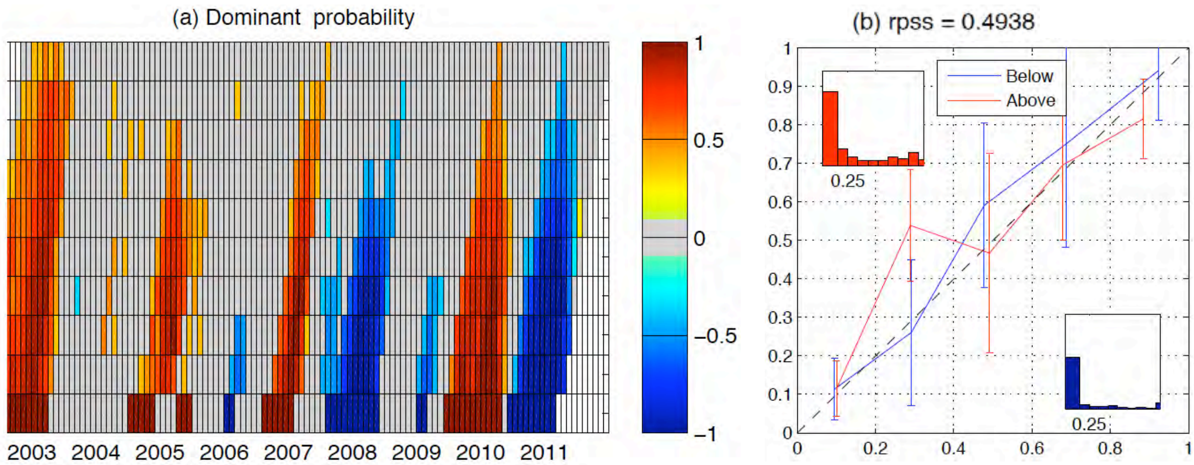


Figure 16: (a) Observed categories and forecast category probabilities. The horizontal axis is verification time and the vertical axis is lead time with the observed category shown in the bottom row with 1,0 and -1 indicating El Niño, neutral and La Niña conditions respectively. Positive (negative) values show the forecast probability of El Niño (La Niña) when the probability of that category is largest. Values of zero indicate that the enhanced probability of the neutral category is greater than that of the other two categories. (b) Reliability diagram for leads 1-3.

An important question is the extent to which spread in the forecast plume reflects actual forecast uncertainty. Strictly speaking, the forecast plume is not designed to represent forecast uncertainty in the same manner as a single model ensemble forecast; individual dynamical model forecasts are already ensemble averages and as such contain minimal initial condition uncertainty. We find a good relationship (not shown) between the climatological (averaged over years) values of the plume variance and the squared error as function of verification season and lead. However, the magnitude of the plume variance is generally too small relative to the squared error, especially at the longest leads. This underestimate is more severe for the statistical models whose inter-model variance is about half that of the dynamical models.

In summary, the performance of the IRI "ENSO forecast plume" during the 2002-2011 period has been evaluated both for skill of the multi-model mean and for its probabilistic aspects. We note a phasing problem, not seen in hindcasts, with forecasts being "slow" to capture the transition into and out of ENSO events. The consistency of this problem, at least in this period, permits the application of seasonally dependent statistical corrections. Consistent with previous results, skills decline with increasing lead time, and are highest for forecasts made after the northern spring predictability barrier. Probabilistic aspects of the plume show similar skill characteristic in regard to seasonal and lead dependence, although categorical probabilities suffer more from sampling, as do continuous probabilities. Examination of the plume spread versus forecast error relationship shows a good seasonal correlation but an underestimate of the uncertainty, a problem that is worse for the collection of statistical models than for the dynamical models. Skillful changes in probabilities are mainly due to changes in plume mean and climatological changes in variance.

*Contributed by **M.K. Tippett** and **A.G. Barnston**.*

Diagnosing conditional biases in a forecast ensemble

The motivation behind producing an ensemble of forecasts at all forecast timescales is to estimate the uncertainty in the prediction, and so an important component of forecast verification is to determine whether the ensemble does represent the uncertainty reliably. The rank histogram (Anderson *et al.* 1996) is a widely used procedure for evaluating the reliability of an ensemble forecast system (Jolliffe and Stephenson 2003). It indicates the probability that the observed value exceeds the k^{th} of K ordered ensemble member, and is less than the $k+1^{\text{th}}$ ordered ensemble member, with additional bins to indicate the probabilities that the observed value is less than the smallest, and greater than the largest ensemble member values, respectively. If the forecasts are reliable, then a graph of these probabilities will show equal values for all bins. The ranked histogram can be presented equivalently in terms of exceedance probabilities: the probability that an observation exceeds the k^{th} of K ordered ensemble members. In a reliable forecast system the observed values should exceed the k^{th} of K ordered ensemble members

$$\left(1-{}^{k}\!/_{K+1}\right)\times 100\%$$

of the time. A graph of these exceedance probabilities will step downwards evenly to the right.

It is generally recognized that, a uniform rank histogram provides no guarantee that the ensemble system being tested indicates a conditionally unbiased forecasting system (Hamill 2001; Gneiting *et al.* 2007). For example, a forecast system whose ensemble mean is negatively correlated with a normally distributed random variable is conditionally biased, but if the ensemble has variance of $a+b-2c$, where a is the variance of the observed values, b is the ensemble mean variance, and c the covariance between the observations and the ensemble mean is c, then the ranked histogram will be approximately uniform. For example, consider a forecast system where a and b are 1.0, and c therefore represents the correlation. Ranked histograms for forecasts of positive anomalies compared to those for negative anomalies indicate clear conditional unreliability for all but perfectly correlated forecasts (Figure 17).

Conditional exceedance probabilities (CEPs) were suggested by Mason et al. (2007) as a procedure for identifying those cases when a uniform ranked histogram was obtained from a conditionally biased forecast system. Bröcker et al. (2011) explain that a positive sampling error in estimating a quantile of the forecast distribution will decrease the exceedance probability, while any negative sampling error will increase the exceedance probability. Because the exceedance probability is a function of the sampling error, the curves are therefore not flat even in a completely calibrated forecast system. However, if the CEPs could be calculated so that they are independent of the sampling errors in the quantiles then the curves can become flat. Mason *et al.* (2007) define the CEP for the k^{th} quantile as:

$$P\left(Y>\xi_k \mid \xi_k\right)=\frac{\exp\left(\beta_{0,k}+\beta_{1,k}\xi_k\right)}{1+\exp\left(\beta_{0,k}+\beta_{1,k}\xi_k\right)} \quad ,$$

where $\beta_{0,k}$ and $\beta_{1,k}$ are parameters to be estimated, and ξ_k is the kth quantile estimate (whether obtained from the values of the ranked ensemble members or from a fitted distribution). If the ensemble is divided randomly into two halves, *A* and *B*, and then independent quantile estimates are obtained from these two halves, the CEP can then be calculated as

$$P\left(Y > \xi_{k/2,A} \mid \xi_{k/2,B}\right) = \frac{\exp\left(\beta_{0,k/2} + \beta_{1,k/2}\xi_{k/2,B}\right)}{1 + \exp\left(\beta_{0,k/2} + \beta_{1,k/2}\xi_{k/2,B}\right)} \quad ,$$

where $\xi_{k/2,A}$ is the quantile estimate from the first division, while $\xi_{k/2,\mathrm{B}}$ is the corresponding estimate from the second division. Since it is arbitrary which of the two divisions is *A* and which is *B*, separate parameter estimates of the CEP curves could be made. Repeated random divisions of the ensemble could also be conducted to obtain additional estimates as a check for sampling

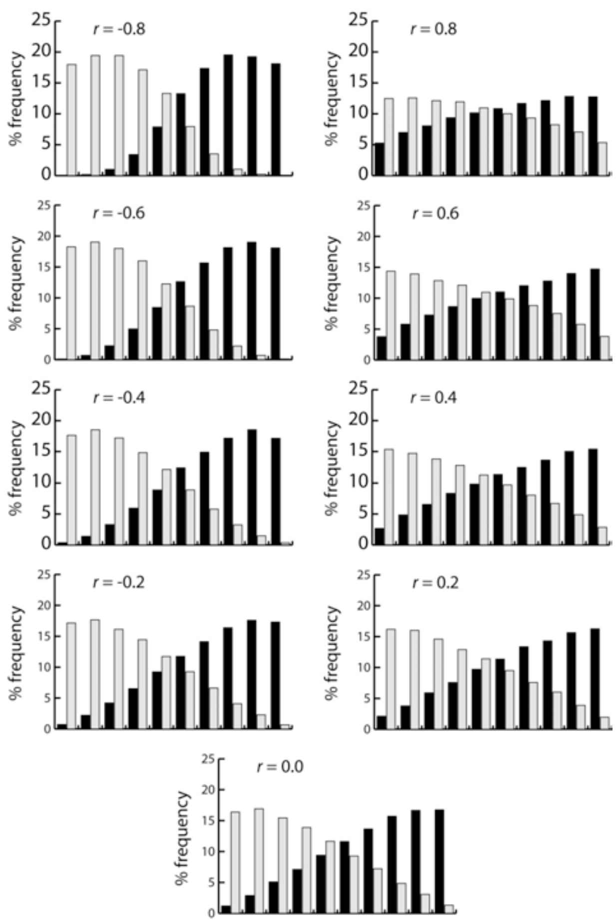


Figure 17: Conditional rank histograms for a nine-member ensemble forecast of a normally distributed variable, with the ensemble-mean variance equal to the observed variance, and the ensemble variance set to the mean-squared error. The binned frequencies were calculated using a random sample of 100,000. The black bars are for forecasts with positive anomalies, while the grey bars are for negative anomalies.

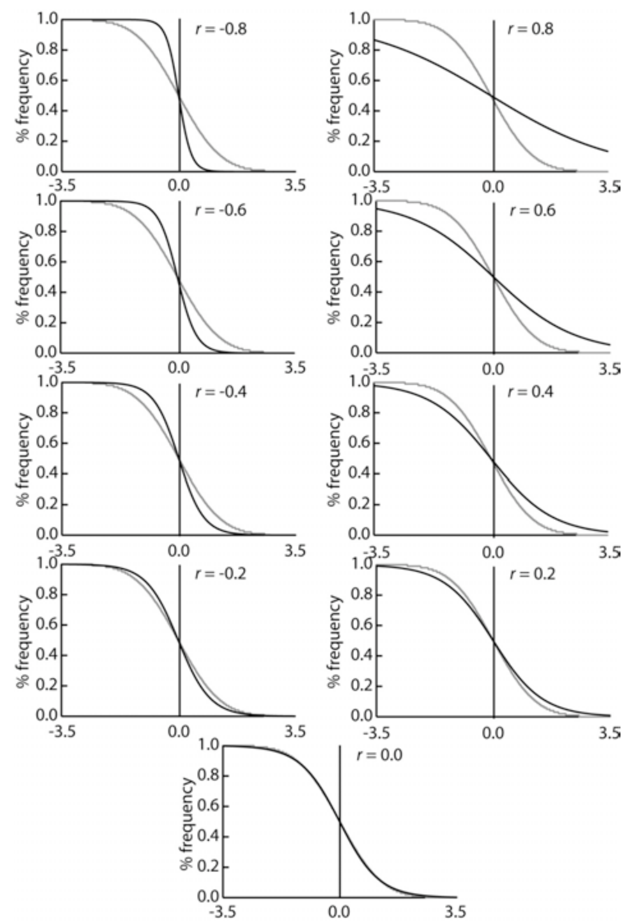


Figure 18: Conditional exceedance probability curves for a forecast of a normally distributed variable, with the forecast variance equal to the observed variance. The grey curve indicates the climatological probability of exceedance. The exceedance probability curves were calculated using a sample of 100,000.

uncertainty. The conclusion is that since it is possible to obtain independent estimates of the quantiles and the exceedance events, the CEP test for conditional unreliability can be applied. To illustrate, CEP curves for the ensemble mean of the conditionally unreliable forecasts shown in Figure 17 are illustrated in Figure 18. The curves indicate clear negative slopes indicating that the probability of exceeding the ensemble mean decreases as a stronger positive anomaly is forecast.

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L. Goddard*,* ***P. Gonzalez****, and B. Rajaratnam.*

Design of a verification framework for decadal predictions

Interest in the understanding and prediction of decadal variability and how it may contribute to our realization of climate change over the coming 10-20 years has increased on both the demand and supply side. Those who use climate information for long-term decisions indicate that the 50-100 year time horizon of climate change projections are too distant to be useful. In the climate community, recent research suggests that initial conditions of the ocean may offer some predictability on the order of 10 years into the future, particularly during certain phases of the variability (e.g. Collins et al. 2006) that would be in addition to the predictability imparted by changing greenhouse gasses. The decadal-scale oceanic variability has been linked to decadal-scale temperature and precipitation variability over some terrestrial regions (Knight et al. 2005), and even changes in the character of weather (Kenyon and Hegerl 2008).

A coordinated set of decadal hindcast experiments will be part of the suite of model runs available for the Fifth Assessment of the IPCC. Several of these experiments are done, and will soon appear on the database for model experiments. The added complexity of using ocean initial conditions based on observational data, particularly in the past when salinity measurements (important to density variations) are extremely limited, means that the community has yet to agree on the optimal way to initialize these hindcasts. Therefore, it is not clear that the potential predictability demonstrated in models will be realized in real forecasts/hindcasts. However, many outside the climate community are eager to use the hindcasts and forecasts for impacts studies and sectoral forecasts that use climate data as an input. It is therefore crucial that there be a coordinated assessment of the prediction skill of these experiments that can guide their use.

This is one of the two main objectives of the US CLIVAR Working Group on Decadal Predictability. Several scientists from IRI have been actively participating in this effort. Goddard serves as co-chair of the group together with Arun Kumar (NCEP/CPC) and Amy Solomon (U. Colorado). Greene is a contributing panel member, and Gonzalez is a post-doc who has been instrumental in developing code and the verification website (Figure 19). Mason has been contributing also to the selection of metrics and estimation of forecast uncertainty.

Figure 19. Prototype webpage for verification graphics, code, and links to data.

The approach adopted for much of the work builds on the experience and methods used in the seasonal-to-interannual (SI) forecast community. Even the push to provide verification ahead of the release of the hindcasts (if possible), is motivated by our experience in the provision of SI forecast information, where assessment of past performance of the forecasts leads to more appropriate use.

The purpose for coordinated verification is twofold. The primary reason is to make the skill assessments across forecast systems comparable, in terms of which observations are used for verification, what period(s) are used, and how that information is displayed. This will certainly not be the only forecast verification work done by the centers, or the scientific community, but it serves as a minimum set of metrics. The second reason is to provide this information through a common location (i.e. webpage) to make it easier for those interested in using the hindcasts to view their past performance, and to serve as a repository for the forecast centers that can be updated over time. The IRI is home to this page now, but the intention is to transfer the page and code to WCRP or an IPCC institution once the prototype has been completed.

The metrics have been determined in response to basic questions regarding the quality of the forecasts, particularly relative to the climate change projections, and their use in probabilistic risk assessment.
Q1: Do the initial conditions in the hindcasts lead to more accurate predictions of the climate, as compared to the un-initialized climate change projections?
Q2: Is the model's ensemble spread an appropriate representation of forecast uncertainty on average?

Q3: In the case that the forecast ensemble does offer information on overall forecast uncertainty, does the forecast-to-forecast variability of the ensemble spread carry meaningful information?

For the first question, the deterministic metrics of correlation and a variant of the mean squared skill score (MSSS) are used on both the initialized and un-initialized (i.e. climate change projections), and the difference between the two presented. Significance is also assessed. This shows where the hindcast has skill in terms of its association with the observed variability, and where the skill exceeds that available from the un-initialized hindcasts. The second and third questions address the validity of using the models' ensemble spread as an indication of uncertainty, which is important for risk assessments.

Model hindcasts are being supplied to the working group by members of institutions that are contributing them to the IPCC Fifth Assessment report. To date the data from the Hadley Centre DePreSys system (Smith et al. 2007), and from the Canadian Climate Centre (Merryfield et al. 2011) have been transferred and placed on IRI's Data Library. The observational data agreed upon by the working group is the HadCRUT3v data for temperature and the Global Precipitation Climatology Centre (GPCC) data for precipitation, both of which are also available through the IRI Data Library.

The verification results provided by this effort are specific to the models involved. These results are therefore not the final word in the possible ability to provide interannual-to-decadal climate outlooks that could, like SI forecasts, employ conditional bias correction techniques and multi-model ensembling. The only bias correction used here is correction of the mean bias, as described by WCRP (ICPO 2011), and commonly employed for SI predictions.

The preliminary results obtained so far do indicate additional skill, as measured by correlation, provided by the initial conditions. For example, decadal scale precipitation anomalies over the western United States show significant correlations in the initialized hindcasts. The improvement over the uninitialized hindcasts is also deemed significant in some parts of the region (Figure 20). However, this result from the Hadley Centre model is not seen in the Canadian Climate Centre model hindcasts. Also, even though there is a predictable signal in the western United States in the Hadley Centre model, the ensemble spread provides no additional information on a reliable range of outcomes about that signal.

A verification framework is being developed by the US CLIVAR Working Group on Decadal Predictability as guidance for those who would use this experimental prediction data and as feedback to the modeling and forecasting community as it investigates the feasibility of interannual-to-decadal predictions. Scientists at the IRI have taken a leading role in realizing this framework, which has been informed by a diverse group of scientists, many with substantial experience in the production and verification of seasonal-to-interannual forecasts. As has been established for seasonal forecasts, preliminary results on decadal hindcasts show that prediction skill varies with model, region, and season, and it also appears to be conditional on the state of the variability. The goal of the working group, and specifically with reference to this activity, is to facilitate progress and understanding of decadal predictability and to inform the use of the hindcasts/forecasts through the assessment of past performance of the forecast systems.

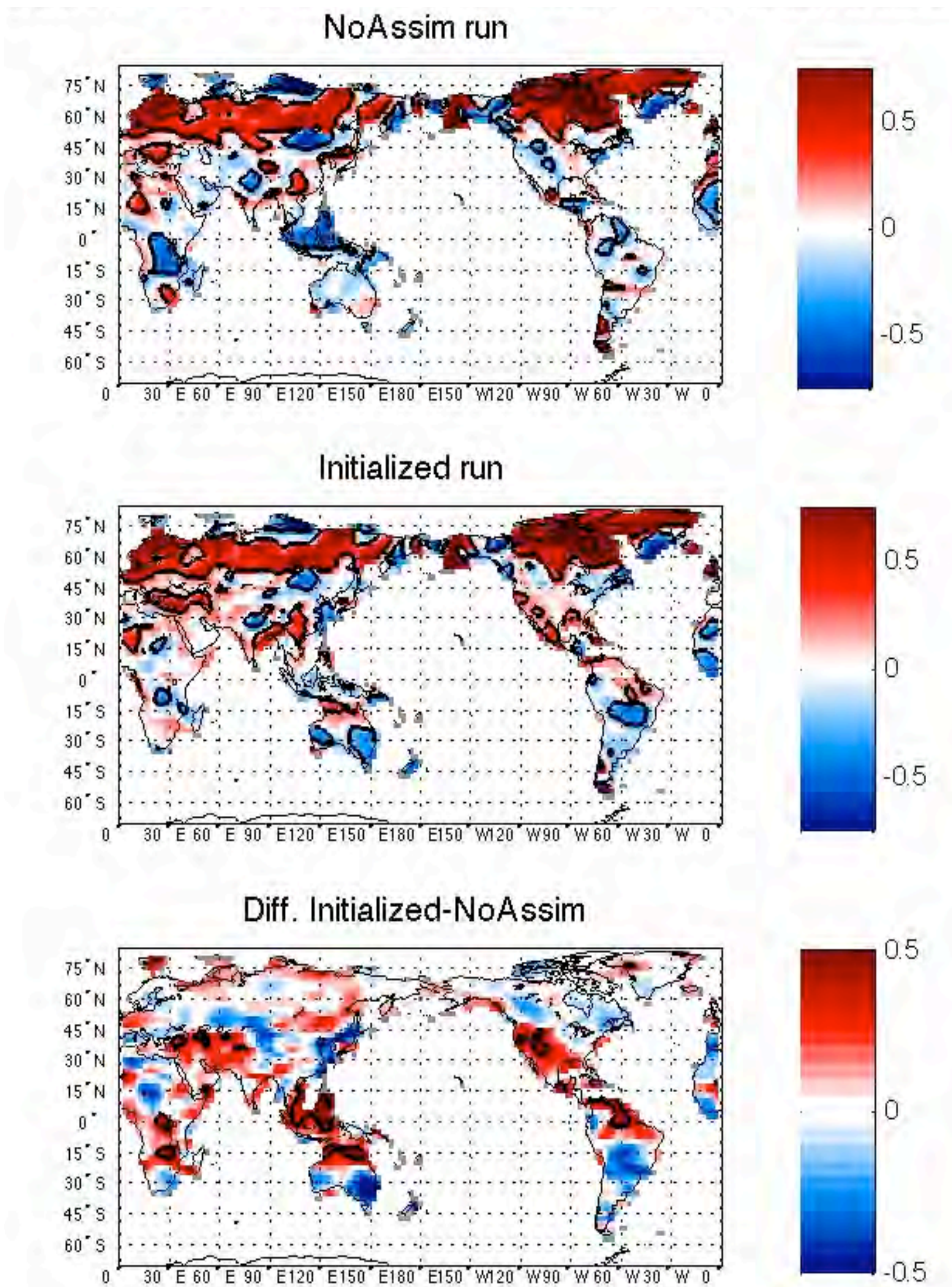


Figure 20. Anomaly correlation coefficients between annual mean precipitation anomalies averaged over forecasts 2-9 years out for forecasts initialized each year over the period 1960-2005 from the Hadley Centre DePreSys system and GPCC observations. Top: un-initialized; Center: initialized, Bottom: Difference between initialized and un-initialized. Contours delimit regions of statistical significance (90% confidence level).

Contributed by ***L. Goddard****,* ***P. Gonzalez****,* ***A.W. Greene****, and* ***S.J. Mason****.*

Calibration of seasonal forecasts by penalized regression

The "model output statistics" (MOS) approach has long been used in forecasting to correct systematic errors of numerical models and to predict quantities not included in the model (Glahn and Lowry 1972). The MOS procedure is based on capturing the statistical relation between model outputs and observations and, in its simplest form, consists of a linear regression between these quantities. In theory, this procedure optimally calibrates the model forecast and provides reliable forecasts. In practice, the regression parameters must be estimated from data. In seasonal forecasting, forecast histories are short, and skill is modest. Both factors lead to substantial sampling errors in the estimates. This work examines two problems where sampling error effects the reliability of regression-calibrated forecasts and provides solutions based on two "penalized" methods: ridge regression and lasso regression (Hoerl and Kennard 1988; Tibshirani 1996). The first problem comes from the observation that, even in a univariate setting, ordinary least squares estimates lead to unreliable forecasts. The second problem arises in the context of multivariate MOS and is that common methods of predictor selection lead to negative skill and unreliable forecasts.

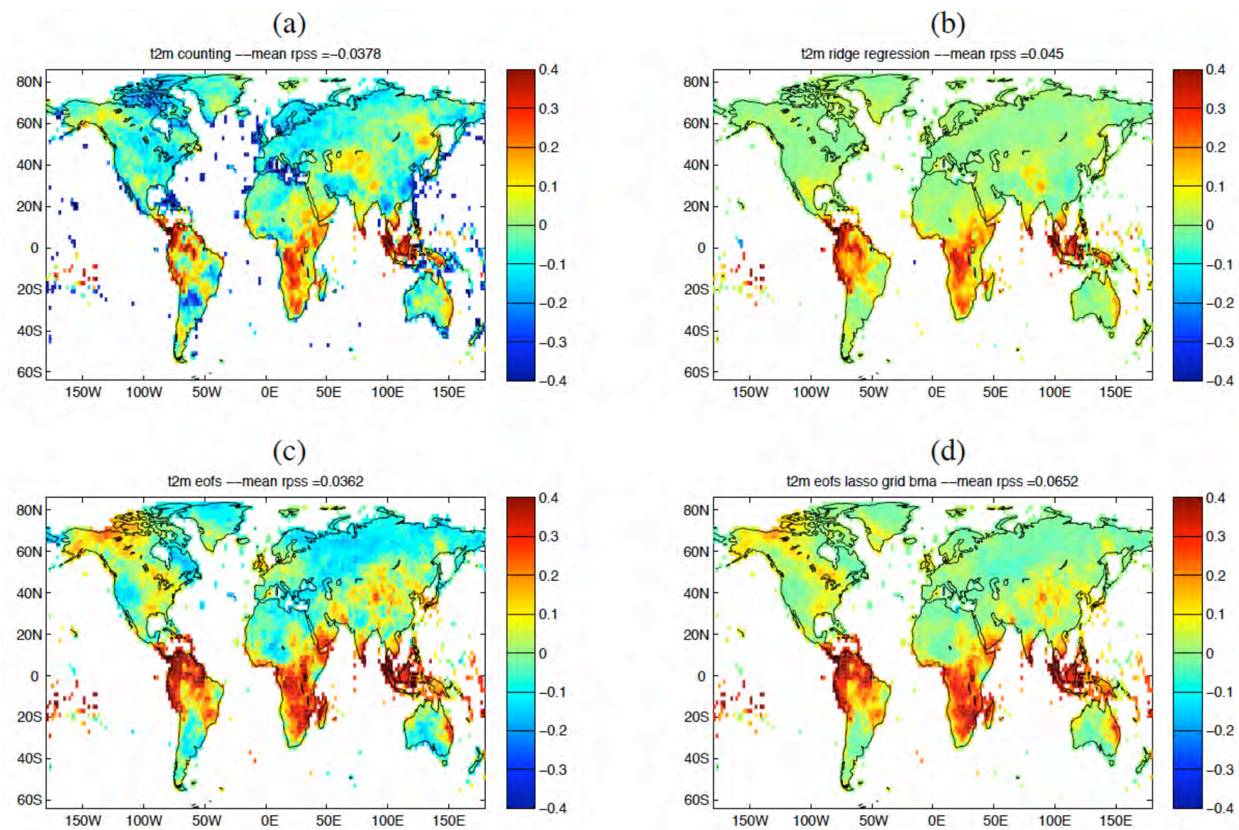


Figure 21. Ranked probability skill score (RPSS) for forecasts of DJF 2m-temperature from (a) ensemble frequency, (b) gridpoint ridge regression, (c) EOF regression and (d) lasso regression.

To illustrate our findings we use two-tier hindcasts of Dec-February (DJF) 2-meter temperature using the ECHAM4.5 atmospheric GCM with 24 ensemble members forced by Constructed Analogue (CA) forecast SST. The CA SST forecasts use data through the end of October. We use the period 1958-2001 and University of East Anglia observation data sets.

Generating tercile category probability forecasts from ensemble frequencies results in forecasts that have positive RPSS in many areas of the tropics but also negative RPSS in many regions, especially in the extratropics as seen in Figure 21(a). This results in overall poor reliability due to overconfidence (see Figure 22(a)). The gridpoint averaged RPSS is negative. Estimating tercile probabilities from a cross-validated linear regression model on a gridpoint basis reduces the area with negative skill and improves reliability (not shown); the average RPSS is 0.041. However, estimate of the regression coefficients using ordinary least squares leads to a positive bias in the signal variance which manifests itself as a slight overconfidence in the reliability diagram. Estimating regression coefficients using ridge regression removes this overconfidence and improves the average RPSS to 0.045 as seen in Figures 21(b) and 22(b). Importantly, the specification of the ridge parameter must be included in the cross-validation procedure. A simple multivariate extension of the gridpoint regression is one which uses spatial patterns as predictors. Here we use correlation-based EOFs of model output as predictors. Figure 21(c) shows that this results in an increase in RPSS in many regions, especially in the tropics, but is also accompanied by negative RPSS areas, especially regions which in Figure 21(b) showed no skill. The average RPSS is 0.36, and the reliability diagram in Figure 22(c) shows overconfidence. Again this is due to excessive forecast signal, especially in areas where a climatological forecast of equal odds is more appropriate. One way to proceed is to cast the problem as a model selection one, where one must chose between a pattern based regression forecast or a climatological forecast. Methods like cross-validation and AIC can be used to select the model. This model selection approach offers some improvement, but does not entirely eliminate areas of negative skill and forecast overconfidence. Lasso

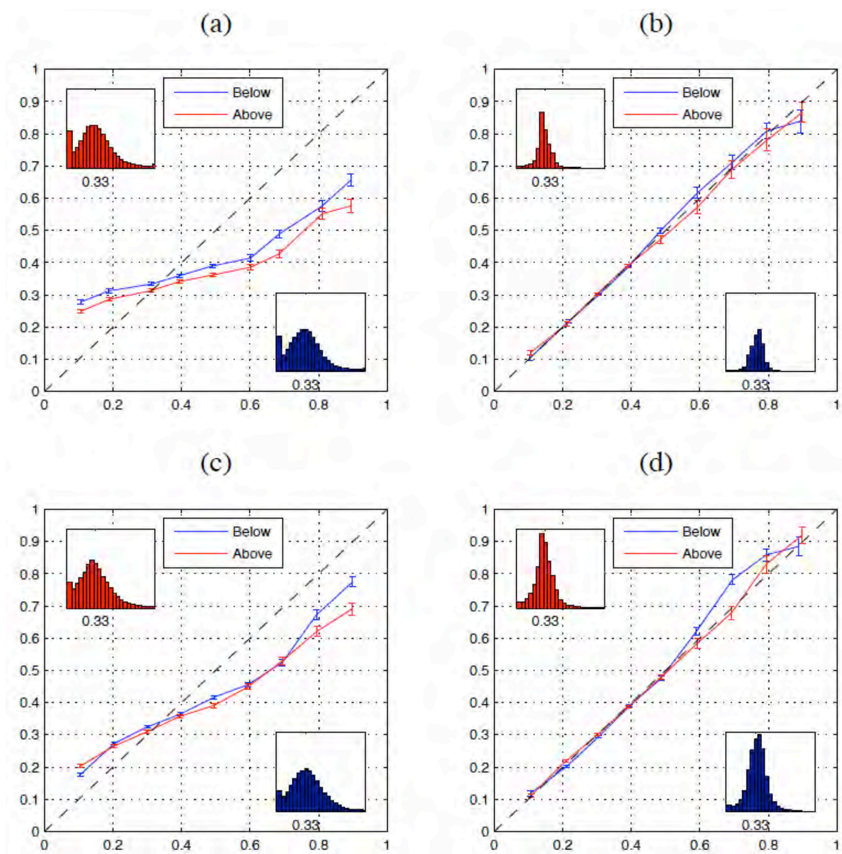


Figure 22. Reliability diagrams for forecasts of DJF 2m-temperature from (a) ensemble frequency, (b) gridpoint ridge regression, (c) EOF regression and (d) lasso regression.

regression is similar to ridge regression but more aggressively eliminates poor predictors. Figure 21(d) shows that lasso regression retains much of the skill improvements of EOF regression while not introducing negative skill and improving reliability (Figure 22(d)); average RPSS is 0.65.

Linear regression based probability forecasts provide reliable, calibrated forecasts in theory. However, sampling error tends to cause a positive bias in signal variance and leads to overconfidence. This problem is severe when the training data is limited and skill is marginal. Penalized regression methods shrink regression coefficients, reduce signal variance and, in the case of lasso regression, eliminate predictors with questionable skill. Here, we have demonstrated that these methods result in less negative skill and more reliable seasonal climate forecasts.

Contributed by ***M.K. Tippett****,* ***L. Goddard*** *and* ***A.G. Barnston****.*

Are regression forecasts reliable?

The motivation for this study was the observation that linear regression on a gridpoint basis between observations and seasonal climate forecasts results in probabilistic tercile category forecasts that are not reliable. One explanation for the failure of regression to produce reliable forecasts is that some aspect of the observations or forecasts does not fit into the framework of linear regression, e.g., the assumption of Gaussian distributions. Another explanation is that some previously unexamined aspect of the regression procedure degrades the forecast quality. To investigate the latter issue, we examine the reliability of regression forecasts in the ideal situation where the data satisfy the assumptions associated with linear regression.

Linear regression has long played an important role in model-based forecasting (Glahn and Lowry 1972). Often, the task of a forecaster is to make the best estimate of a future observation given available model output. In the case of probabilistic forecasts, the uncertainty of the estimate is also needed. Modeling the forecast f and its verifying observation o as random variables, the goal of the forecaster is to obtain the *conditional distribution* $p(o|f)$ which is defined to be the probability distribution of the verifying observation o given that the forecast f is known to have a particular value (DelSole 2005). The mean of the conditional distribution is the "best" estimate in the sense that it minimizes the expected squared error. Uncertainty information such as the forecast variance can be computed from the conditional distribution and used to make probabilistic forecasts.

The challenge is to obtain the conditional distribution which, in general, requires a complete description of the statistical relation between the forecast f and the verifying observations o. However, when forecast and observations have a joint Gaussian distribution, this only requires knowing the means and variances of o and f, and the correlation between o and f. In this case, the conditional distribution $p(o|f)$ is itself Gaussian, and moreover, the conditional mean is simply given by linear regression, and its variance is the error variance of the regression. Such regression forecasts are known to be reliable when the regression parameters are known (Johnson and Bowler 2009). In practice, regression parameters must be estimated from data, and in the case of seasonal climate forecasts, fairly short records. Therefore, a reasonable issue is the impact of sampling error on the quality of forecasts, and in particular, on their reliability.

We suppose that the model output *f* and verifying observations *o* have a joint Gaussian distribution with mean zero:

$$o = bf + \epsilon , \quad \epsilon \sim N(0, \sigma^2) \, ,$$

where the notation $\sim N(0, \sigma^2)$ means Gaussian distributed with mean 0 and variance σ^2. Estimates for the regression coefficient *b* and the error variance σ^2 must be computed from data. The estimate *b* depends on the data and is itself a random variable. For ordinary least squares,

$$\hat{b} \sim N(b, \sigma^2/n) \qquad ,$$

where *n* is the sample size. In other words, $\hat{b}$ is an unbiased estimate of the true value and has variance that depends on the sample size and the underlying skill level.

The estimate of the conditional mean and “best” forecast, sometimes called the signal, is then

$$E[o|f] = \hat{b}f \, ,$$

Where $E[\cdot]$ denotes expectation. A necessary condition for reliability is that the average squared error of this forecast be equal to the forecast distribution variance (Johnson and Bowler 2009). The expected prediction error variance is

$$\begin{aligned} E[(o - \hat{b}f)^2] &= E[(b - \hat{b})^2]E[f^2] + \sigma^2 \\ &= \left(1 + \frac{1}{n}\right)\sigma^2 \, . \end{aligned}$$

The squared error of the regression coefficient estimate contributes to the prediction error. While the ordinary least squares estimate is the unbiased estimate with the smallest variance, biased methods like ridge regression may estimate the regression coefficient with smaller mean squared error and reduce prediction error. The question now is whether the conditional distribution with estimated parameters,

$$N\left(\hat{b}f, \left(1 + \frac{1}{n}\right)\sigma^2\right) \, .$$

is reliable. Another necessary condition for reliability is that forecasts and observations be statistically identical in a climatological sense (Johnson and Bowler 2009). For the regression model with known parameters, this requirement is indeed satisfied. More generally, the climatological forecast variance is the sum of the signal and error variances. The error variance of the regression model with estimate parameters is $(1+1/n)\sigma^2$. The signal variance of the regression model with estimated parameters is

$$\begin{aligned}\hat{b}^2\sigma_f^2 &= b^2\sigma_f^2 + E[(\hat{b}-b)^2]\sigma_f^2\\ &= b^2\sigma_f^2 + \frac{\sigma^2}{n}\\ &= \sigma_o^2\left(r^2 + \frac{1}{n}(1-r^2)\right)\,.\end{aligned}$$

where *r* is the correlation between forecast and observations. This value compares with the signal variance of the regression model with known parameters, which is $r^2\sigma_o^2$. The signal variance of the regression model with estimated parameters has a positive bias. This bias is largest when *n* and *r* are small. The 95% significance level for correlation is approximately $2/\sqrt{n}$, and at this correlation level the overestimate of signal variance is about 25%.

These calculations show that the regression forecast with estimated parameters is not reliable because its climatological variance is greater than the observed climatological variance. We expect this to lead to overconfident forecasts. The contribution of the error variance to this overestimate depends only on sample size and is on the order of a few percent for $n = 30$. The signal variance overestimate depends on both sample size and skill level, and is large in marginal skill situations. The precise impact on reliability is more difficult to quantify analytically, and for that, we use numerical simulations.

We design a numerical simulation that mimics the application of linear regression to seasonal climate forecasts on a gridpoint basis and the construction of tercile category probabilities. We take the number of gridpoints to be 5000 and the training period to be 30 years, that is $n = 30$, a typical value for coupled model seasonal forecasts. All gridpoints are assumed to have the same correlation with observations, an unrealistic assumption that allows us to isolate the role of underlying skill level. Linear regression parameters are estimated on the 30-year period and then used to estimate and verify tercile probabilities on an independent 500-year period. Figure 23 shows the resulting reliability diagrams for two cases: one when the correlation is 0.3 and the other when the correlation is 0.5, corresponding to skill levels associated with precipitation and temperature forecasts, respectively. While the probabilities are reliable during the training period (blue lines), they are not reliable during the verification period (red lines) and display overconfidence. This behavior is consistent with our analysis showing the positive bias in signal variance. Additional diagnosis shows that the overconfidence is almost entirely to the overestimate of signal variance.

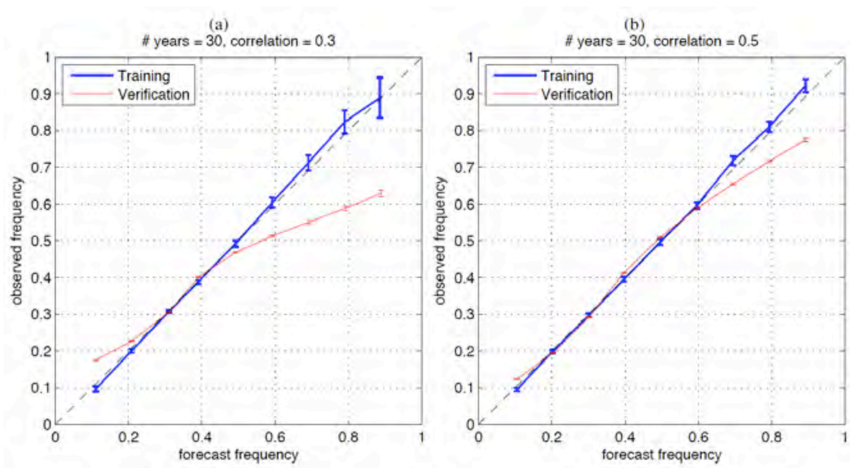


Figure 23. Reliability diagrams for regression forecasts in the case that the correlation between observations and forecasts is (a) 0.5 and (b) 0.3.

Contributed by ***M.K. Tippett*** *and* ***A.G. Barnston****.*

Development of a seasonal forecast system based on the GFDL CM2.1p1 CGCM

IRI is developing a coupled-atmosphere-ocean general circulation model (CGCM) seasonal forecast system based on the Geophysical Fluid Dynamics Laboratory (GFDL) generalized vertical coordinate Coupled Model Version 2.1 (CM2.1p1; Delworth et al., 2006; Griffies, 2009). Work so far has concentrated on examination of different initialization strategies and testing of physical parameterizations. The goal of this work is to optimize the forecast skill for the global Tropics, both in terms of sea surface temperature (SST) and near-surface air temperature and precipitation. Initialization strategies explored so far include coupled initialization (as done for example by Keenlyside et al., 2005; and Luo et al., 2005), nudging of sub-surface temperature and salinity from the GFDL Ensemble Kalman Filter Assimilation System (Zhang et al., 2007), and ocean initialization using surface fluxes from the NCEP Re-analysis2 (Kanamitsu et al., 2002) data sets. Currently, nudging of sub-surface temperature and salinity from the NCEP ocean re-analyses products (Behringer et al., 1998; Saha et al., 2010) is being tested. Ocean physical parameterizations tested include the ocean vertical mixing, horizontal viscosity and horizontal neutral mixing. The parameter spaces being used for these parameterizations have been obtained from other researchers currently using MOM4 (including from GFDL and NCEP).

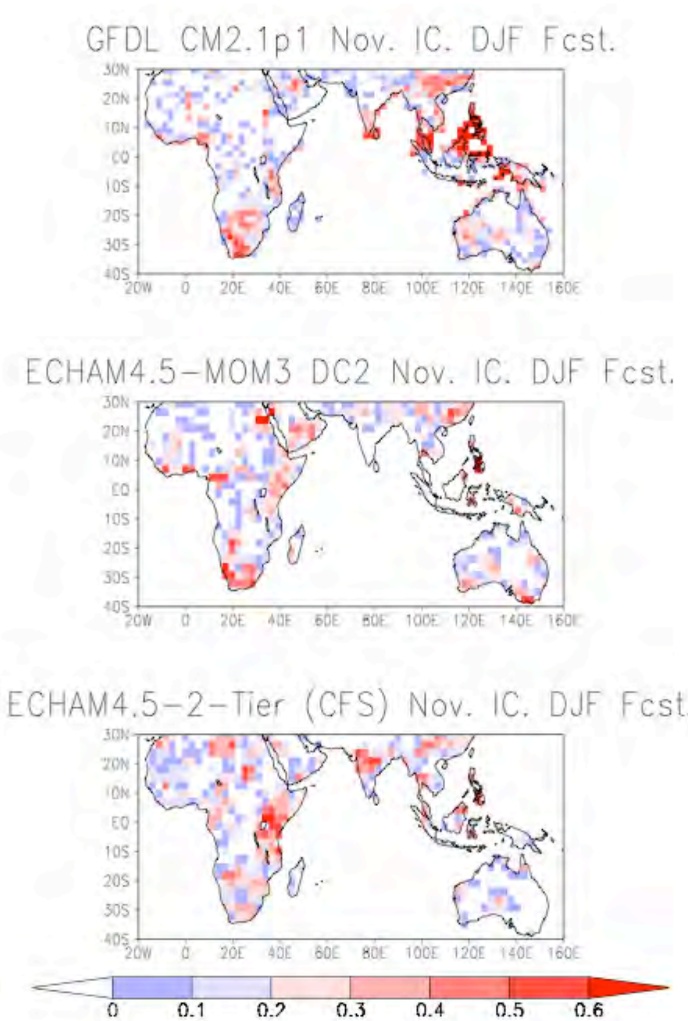


Figure 24. Anomaly correlation coefficients (ACC) for December-January-February (DJF) forecasts starting from November initial conditions for years 1982-2007. Top panel: GFDLCM2.1p1. Middle panel: ECHAM4.5-MOM3 DC2. Bottom Panel: ECHAM4.5-2-Tier (CFS). Shading values are given in the color bar.

The IRI employs a multi-model ensemble (MME) seasonal forecast system which benefits from models having non-homogeneous skill among models. Currently, IRI runs a 2-tier (uncoupled) and a 1-tier (coupled) MME forecast systems. Work is currently being performed to merge these 2 forecast systems into a combined MME forecast system. The seasonal forecasts from the final configuration chosen for the CM2.1p1 will first be included in the 1-tier MME and then in the combined MME forecast systems. Forecast skill for 2 models currently being used for real-time forecasts at IRI are compared with those from the CM2.1p1 utilizing the simple coupled initialization strategy in the figure at right. The other models are: 1. An updated version of the directly coupled CGCM described in DeWitt (2005) which couples the Max-Planck Institute for Meteorologie (MPI) ECHAM4.5 (Roeckner et al., 1996) atmospheric general circulation model (AGCM) and the GFDL Modular Ocean Model Version 3 (MOM3; Pacanowski and Griffies, 1998) ocean model, denoted ECHAM-MOM3 DC2; 2. A 2-tiered forecast system based on the ECHAM4.5 AGCM forced with SST forecasts from the NCEP CFS (Saha et al., 2006), denoted ECHAM4.5-2-Tier (CFS). Shown in Figure 24 is the anomaly correlation coefficient (ACC) for December-January-February (DJF) precipitation forecasts initialized from November 1 initial conditions (IC). It is clear from the figure that each of the models possesses a region of useful skill (here defined as an ACC > 0.3) not found for the other models. For example, the CM2.1p1 has skillful forecasts over the Maritime Continent and southern India which are unique. The ECHAM-MOM3 DC2 has a skillful region in Southern Africa including the coastal regions, while the ECHAM4.5-2-Tier (CFS) has skillful regions over central and northern India and eastern Africa.

*Contributed by **D.G. DeWitt**.*

The atmospheric circulation over the North Atlantic as induced by the SST field

Spectral analyses of the SST in the Simple Ocean Data Analysis (SODA) reanalysis for the past half-century identify prominent and statistically significant interannual oscillations in two regions along the Gulf Stream front over the North Atlantic. A model of the atmospheric marine boundary layer coupled to a baroclinic quasi-geostrophic model of the free atmosphere is then forced with the SST history from the SODA reanalysis. Two extreme states are found in the atmospheric simulations: they consist of (1) an eastward extension of the westerly jet associated with the front, which occurs mainly during boreal winter; and (2) a quiescent state of very weak flow found predominantly in the summer. This vacillation of the oceanic-front–induced jet in the model is found to exhibit periodicities similar to those identified in the observed Gulf Stream SST front itself. In addition, a close correspondence is found between interannual spectral peaks in the observed NAO index, and the SODA-induced oscillations in the atmospheric model.

In particular, significant oscillatory modes with periods of 8.5, 4.2 and 2.8 years are found in both the observed and simulated indices, and shown to be highly synchronized and of similar energy in both time series. These oscillatory modes in the simulations are shown to be suppressed when either (a) the Gulf Stream front or (b) its interannual oscillations are omitted from the SST field (see also (Feliks et al., 2010b). Moreover, these modes also disappear when (c) the SST front is spatially smoothed, thus confirming that they are indeed induced by the oceanic front.

*Contributed by Y. Feliks, M. Ghil and **A.W. Robertson**.*

New tools for the seasonal prediction of meteorological drought in North America

Drought lacks a universal definition, as it is a site- and sector-specific phenomenon that operates on multiple time scales. However, a common attribute of drought across the regions where it occurs and the time scales at which it operates is a persistent period of deficient precipitation relative to the expected climate of a given location. Compared with other hydrometeorological extremes, such meteorological drought events are frequently characterized by a slow onset (and often, termination). As such, meteorological drought (hereafter, simply ‘drought’) typically displays appreciable persistence from one month to the next, a valuable property from drought monitoring, early warning, and prediction perspectives alike (Redmond 2002). The inherent persistence of drought conditions is reflected in the design of the numerous precipitation-based drought indices where precipitation variations are assessed over different time periods (e.g., 3, 6, 12 months, etc.) in an attempt to mimic the characteristic timescales of their influence on variations in other attributes of land surface hydrology (soil moisture, streamflow, etc.) (Heim 2002).

Efforts to generate seasonal predictions of drought (i.e., where drought indices are the predictants) benefit from its persistence characteristics either explicitly or implicitly. For example, various auto-regressive models have been developed which explicitly incorporate the autocorrelation (and other statistical properties) of a given drought index in their design (e.g. Sen and Boken 2005). Drought predictions based on dynamical climate model forecasts can implicitly benefit from the initial drought condition given the recursive design of drought indices. For instance, if the drought index being predicted is based on a 6-month accumulation of precipitation, then a 3-month lead forecast of the index (e.g., based on a seasonal precipitation forecast from a dynamical model) will still contain 3 months of memory of the initial condition.

Advances in the understanding of drought from a climate perspective have shown the importance of sea surface temperatures (SSTs) and the land surface conditions as important sources of forcing. In this work, we take a hierarchical approach to the prediction of drought on seasonal time scales. We first consider the role of *unconditional* persistence of multiple meteorological drought indicators then predictions *conditioned* on the state of global SSTs and coupled climate models that include initialized atmospheric and land surface conditions. Web-based tools that exploit these various sources of predictability are also being developed to make probabilistic drought index forecasts.

The observationally-based precipitation data sets used include the Global Precipitation Climatology Center (GPCC; Schneider et al. 2010) monthly gridded analyses for the globe at 0.5° lat/lon. spatial resolution (1901-2007) and the US climate division data obtained from archives at the National Climatic Data Center (1895-2009; Guttman and Quayle 1996). Monthly, gridded precipitation analyses for the US and Mexico are also used, being obtained from the US Climate Prediction Center (Chen et al. 2008). Multiple atmospheric climate models (AGCMs) were used, here results are shown for the National Center for Atmospheric Research

(NCAR) Community Climate Model version 3 and version 3.6 (CCM3; Kiehl et al., 1996) and the Max-Planck Institute for Meteorologie (MPI-M) ECHAM5 (Roeckner et al., 2003; Roeckner et al., 2006). The coupled model results shown here are for the National Centers for Environmental Prediction (NCEP) Climate Forecast System model (CFS) versions 1 and 2. Emphasis is placed on the predictability of the standardized precipitation index (SPI; McKee et al. 1993). The SPI was computed following the methodology described in Guttman (1999).

The inherent (unconditional) persistence of various drought indicators was evaluated in order to a) examine the associated predictive skill at various lead times, and b) establish baseline correlations that model-based drought indicator forecasts need to exceed to show additional utility in their use. This “structural” persistence was evaluated for the SPI by first generating 100 synthetic time series each 100 years in length by concatenating randomly sampled, monthly precipitation values taken from the US climate division data that retains seasonality. The autocorrelation (AC) at various lags was then computed for each of the 100 time series. Results for the 9-month SPI for the western US climate zone (i.e., CA and NV) are shown in Figure 25.

These results indicate the importance of the seasonality of monthly precipitation when determining the persistence of the 9-month SPI. Depending on the starting month considered, such seasonality can be seen to either increase or decrease the persistence. It can be shown (Lyon et al. 2011) that for the case of no seasonality in precipitation the AC of the SPI drops off in a linear fashion with increasing lag. In addition to examining the influence of seasonality on persistence characteristics, the above results can be used to provide baseline probabilities when making predictions of the SPI at various lead times. Such information can be used, for example, as the baseline prediction of the SPI for locations and seasons where there is no demonstrable skill in seasonal precipitation forecasts. This is similar to the ensemble streamflow prediction methodology (ESP; Day 1985). An example of a prediction of the 3-month SPI at 2-month lead-time from a starting time of March 2011 is shown in Figure 26. Plotted in the figure is the probability that the 3-month SPI will be below -1.0 at the end of May 2011 using the unified US/Mexico precipitation data from the CPC (Chen et al. 2008). Output is from a web-based tool developed at the IRI for the seasonal prediction of drought indicators.

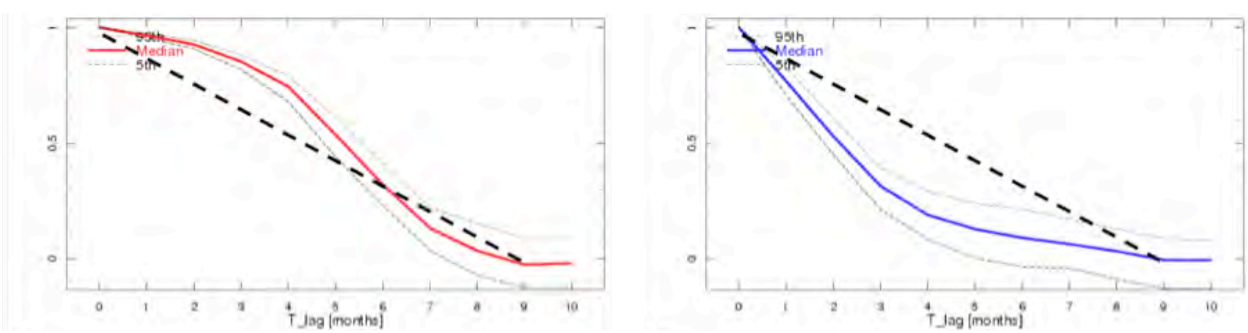


Figure 25. Autocorrelation (AC) of the 9-month SPI at different lag times averaged across the western US climate region for (left) a starting time of May and (right) starting time of September. Solid lines denote the median value of the AC obtained from the 100 synthetic time series used; the thin dashed lines show the 95% confidence limits. The thick dashed lines indicate the AC structure for the case of no seasonality in precipitation.

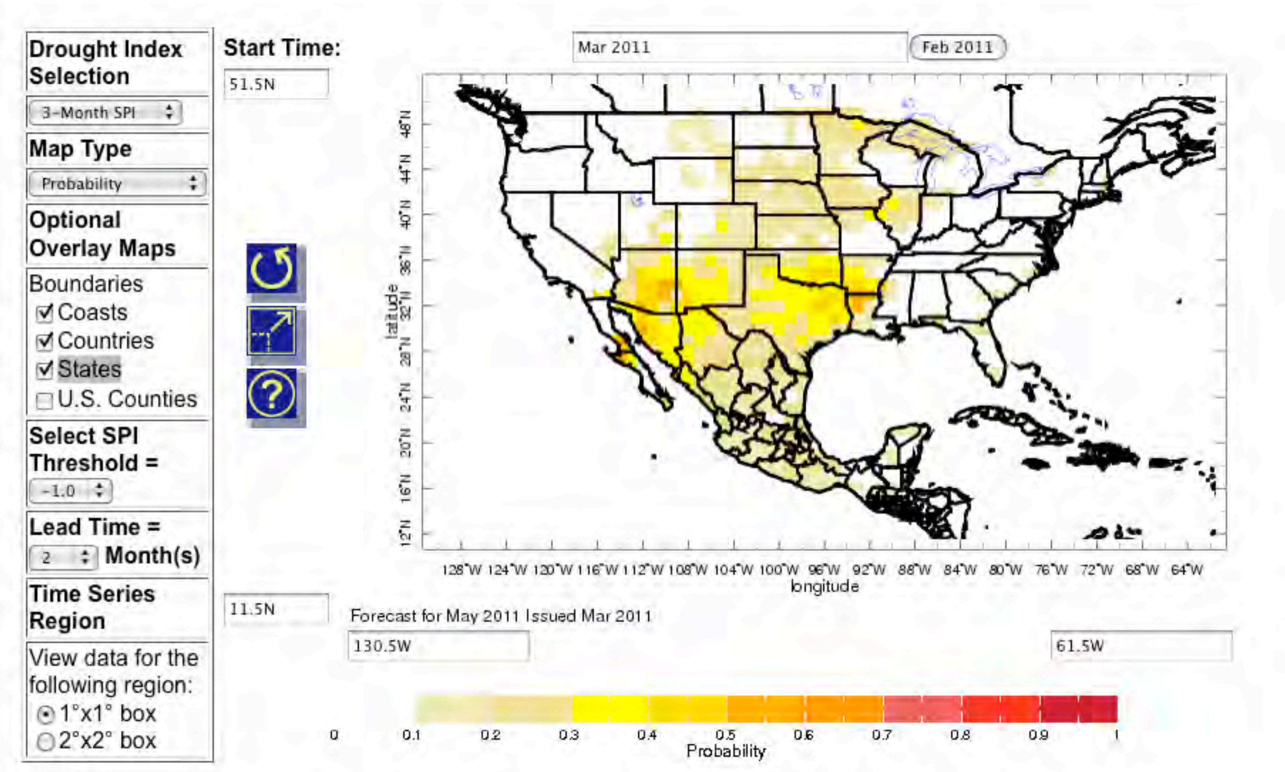


Figure 26. Unconditional probability of the SPI-3 being < -1.0 at the end of May 2011 given initial conditions in March 2011. Result shown above is from a web-based tool that allows the user to select different drought indicators, lead-time and either the probability of exceedance, the best estimate value, or the marginal distribution of the SPI for a selected probability level.

To examine the role of SSTs and initialized atmospheric and land surface conditions on the seasonal prediction of various drought indicators, multiple climate models were examined over a common analysis period of 1982-2008. Since the unconditional (structural) persistence of the drought indictors can clearly contribute to the predictive skill, the example below (Figure 27) shows the difference of the temporal correlation between the predicted and observed values of the 6-month SPI that incorporate model precipitation forecasts and that which arises solely from the structural persistence of the 6-month SPI. Thus, the difference needs to be positive to show enhanced skill in using the model. For the CFS, the additional contribution of the initialized atmospheric and land surface conditions can similarly be evaluated. Figure 27 indicates that, at least when evaluated over all seasons, there is little additional predictive skill obtained when using dynamical climate models for the prediction of the 6-month SPI. The regions where the skill is improved using the models is typically in those areas most influenced by ENSO. There may be a tendency for enhanced skill using the dynamic model during strong ENSO years, however. That is, the results in this figure group all years together, even those with weak SST forcing.

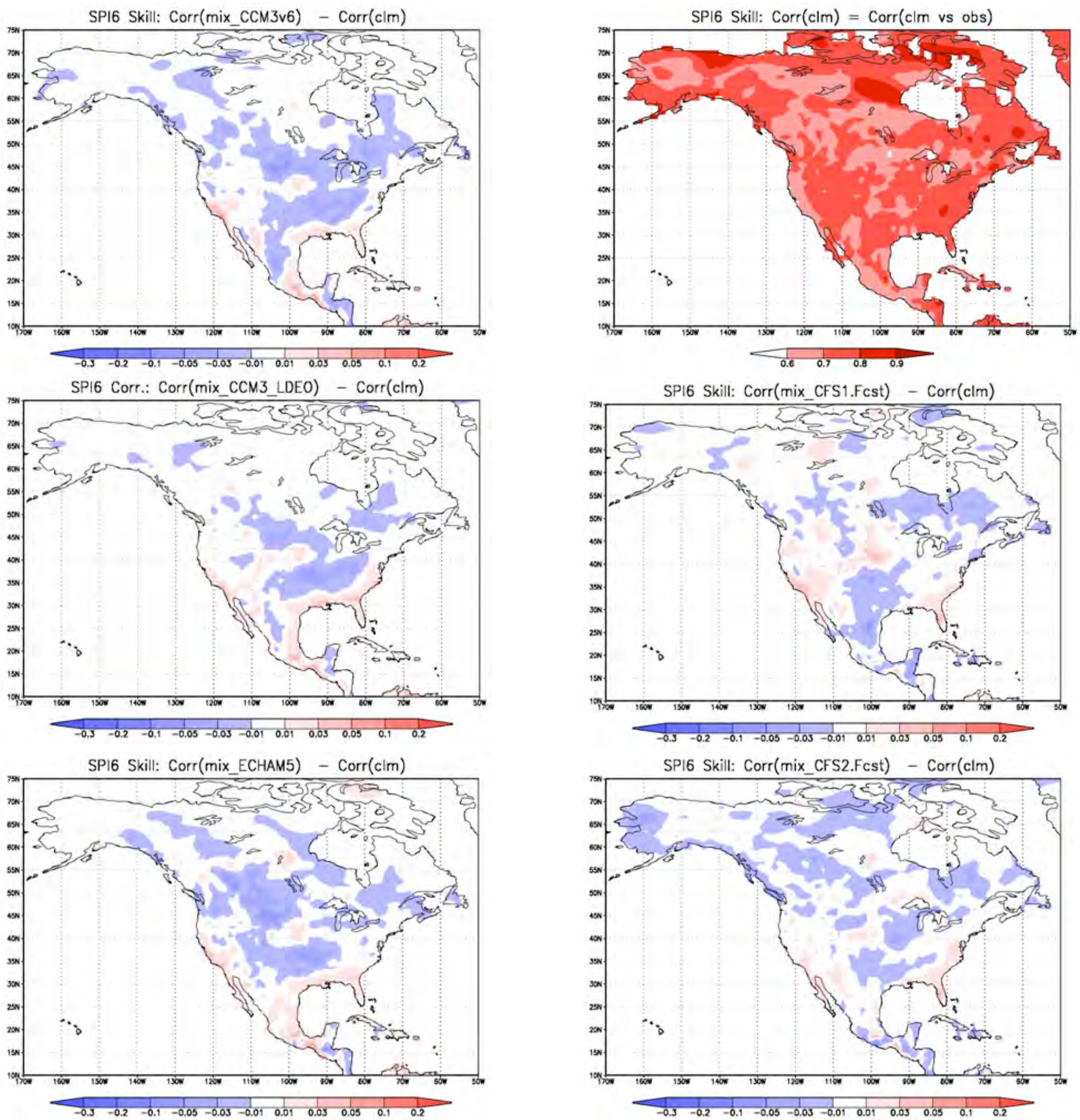


Figure 27. Correlation between the observed 6-month SPI and the value obtained using the initial condition and climatological precipitation (unconditional persistence) at a lead-time of three months (for all seasons; top-right). Difference of the correlation between predicted 6-month SPI and observed values at one season lead and the correlation obtained from the unconditional persistence for (left-column) three climate models forced only with SSTs and (right column, lower two panels) two versions of the CFS which include initialized atmospheric and land surface conditions. Positive values suggest some measure of enhanced skill using the climate model forecasts. Notice that differences from the unconditional persistence are typically small, with only modest positive values which indicates only slightly enhanced skill when using climate model precipitation forecasts.

A web-based tool that includes climate model precipitation forecasts from multiple models in the probabilistic prediction of different flavors of the SPI is also being developed. An example of a display from that tool is shown in Figure 28 below. As with the unconditional forecast tool, the user can display the best estimate prediction of SPI at different lead times, the marginal distribution, or the probability of exceedance.

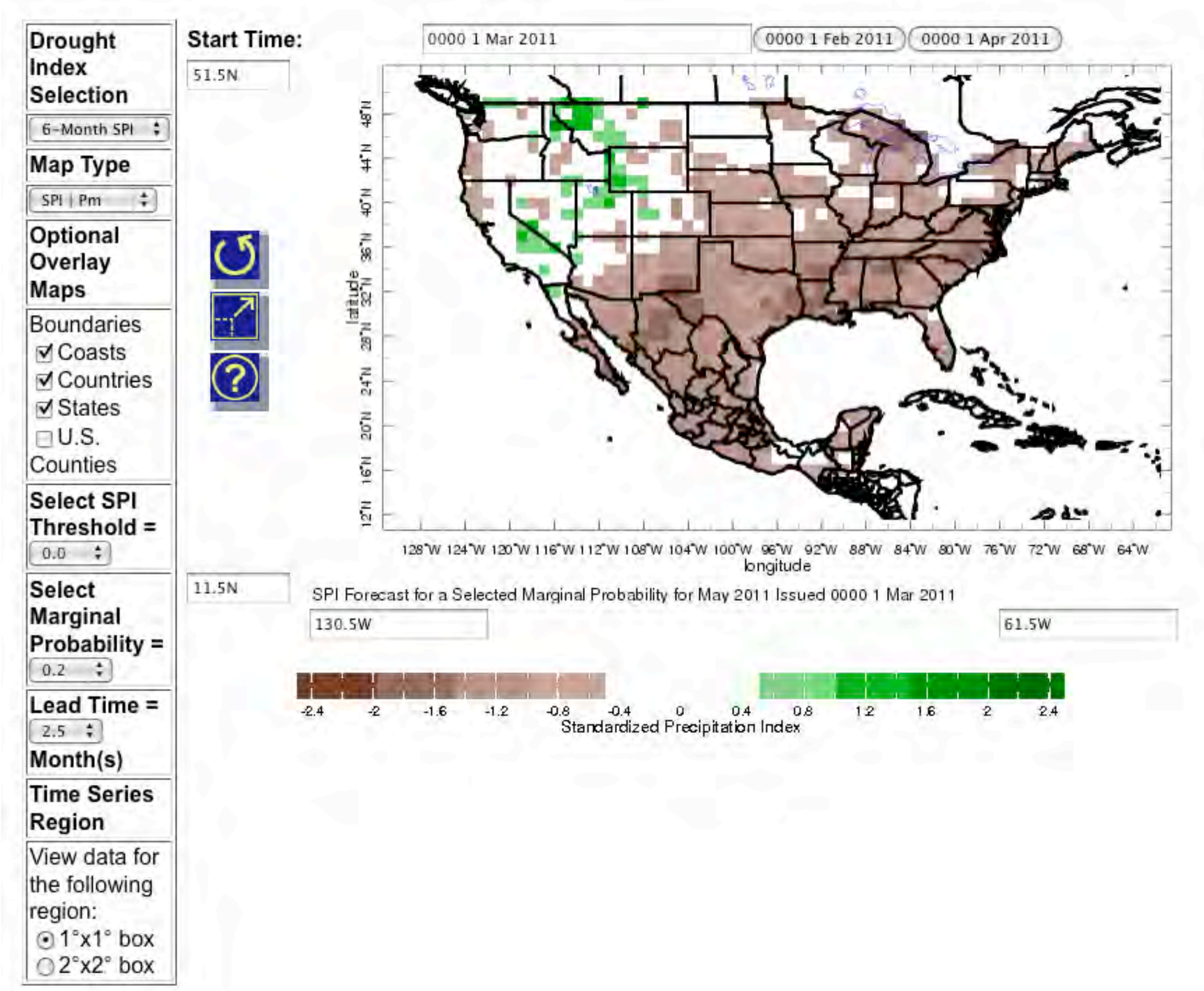


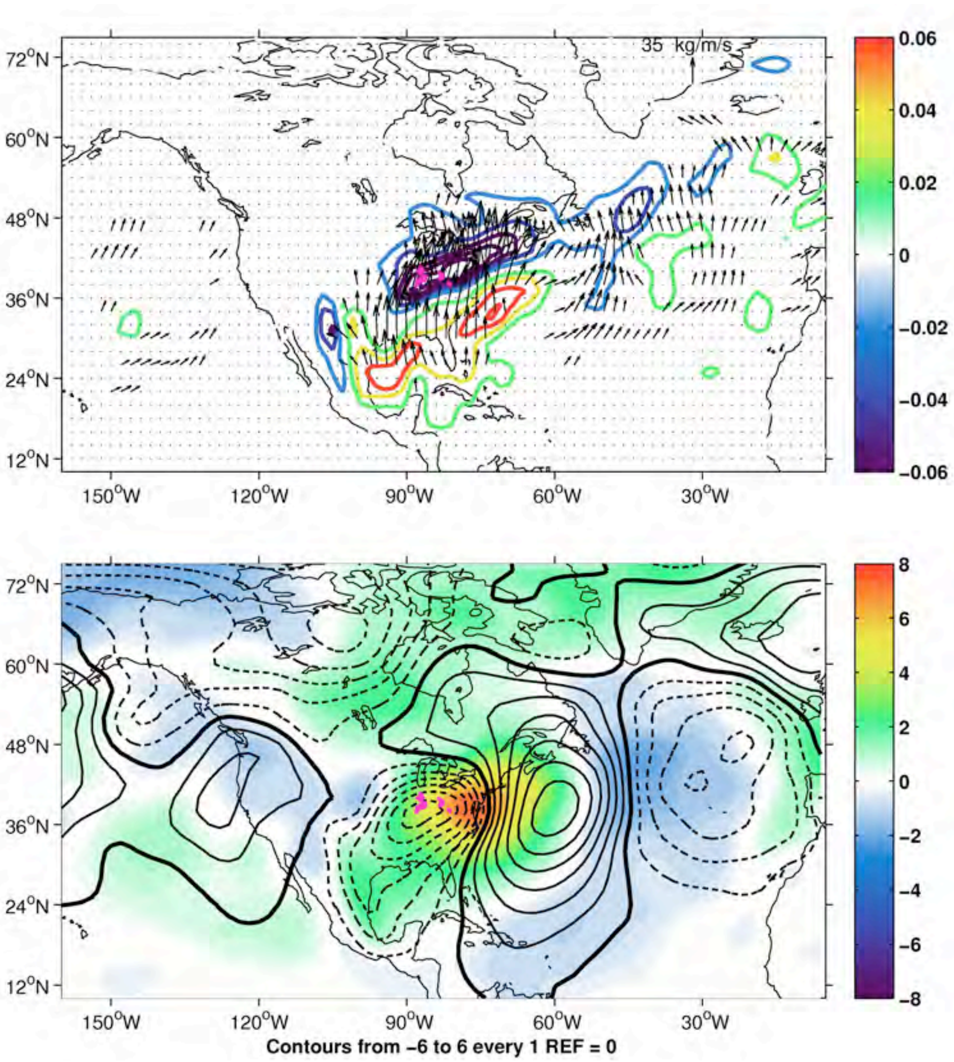
Figure 28. The 20% marginal distribution of the 6-month SPI for the end of May 2011 based on an initial condition of the 6-month SPI in March 2011 and the multi-model average forecast of precipitation for April and May 2011. In the case where the combined climate models do not exhibit any predictive skill, the above forecast relies on the unconditional persistence of the SPI.

New tools for the seasonal prediction of meteorological drought are being developed as a collaborative effort between the IRI, ESRL and CPC. These tools utilize predictive skill associated with the persistence inherent in the design of drought indicators (such as the SPI) as well as dynamical model precipitation forecasts. The methodologies used in this approach are currently being documented in two manuscripts that will shortly be submitted to peer-reviewed journals. The web-based tools will be made available to users later this year.

Contributed by ***B. Lyon***, ***M.A. Bell***, *M. Hoerling, and A. Kumar.*

Moisture transports and extreme floods during spring over the Ohio Valley

For extreme floods, it is hypothesized that large-scale climate dynamics associated with oceanic moisture sources and organized transport are key factors, and that a better understanding of these mechanisms may lead to improved prediction of flood risk on climate time scales. Here, we analyze daily river discharge data from the Hydro-Climatic Data Network over the Ohio valley, extended with U.S. Geological Survey (USGS) streamflow data, to identify "extreme" floods with annual exceedance probability of less than 0.1 during the March–May season. Composites of synoptic fields for 20 flood events (see Figure 29) show sustained movement of low-level moisture and warmth around semi-stationary strong pressure systems from sources over the Gulf of Mexico and eastern Atlantic Ocean, together with widespread upward motion in the region.



Lead times on those features begin as early as nine days before a 10-yr flooding event, with stronger features emerging five days before. The persistence and large-scale organization of these circulation features raises the possibility for an improved understanding of extreme floods as a function of large-scale modes of climate variability and change.

Figure 29. Composite anomalies 1 day prior to flood peak of (a) 1000–700hPa moisture flux (arrows) and divergence (contours), and (b) 850hPa temperature (colors) and mean sea level pressure (contours).

Contributed by J. Nakamura, Y. Kushnir, ***U. Lall****, and* ***A.W. Robertson****.*

Mechanisms for the East-West dipole of rainfall variability associated with ENSO in the boreal winter season over Borneo Island

Using the Global Precipitation Climatology Centre (GPCC) gridded rain gauge observation, Climate Predictability Center Morphing technique (CMORPH) satellite estimates of precipitation, the NASA Quick Scatterometer (QuikSCAT) sea winds, and the National Centers for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) reanalysis data, we studied the opposite sign of interannual variability of precipitation between West and East Kalimantan over Borneo Island in Southeast Asia. Besides the well-known anomalous dry conditions that characterize the boreal fall season (September to November) during an El Niño year, analysis of rain gauge data show a dipolar structure of wet west versus dry east in precipitation anomalies associated with El Niño over Borneo Island during the boreal winter season (December to February).

Composite analyses of the 108-year GPCC data confirm the ENSO-related dipole pattern of anomalous rainfall over Borneo. By using the high-resolution (0.25 degree of longitude and latitude) and high-frequency (3-hourly) CMORPH satellite estimates of precipitation, it is found that rainfall over Borneo is strongly affected by the diurnal cycle of land-sea breezes. The spatial distribution of rainfall over Borneo also depends on the horizontal propagation of the diurnal rainfall maxima following the direction of synoptic winds. Weather typing analysis results indicate that this dipolar structure of rainfall anomalies associated with ENSO is caused by the variability in the frequency of occurrence of different weather types. Multi-scale processes of ENSO, large-scale monsoonal winds and local diurnal cycle of land-sea breezes are analyzed to understand the mechanisms for this heterogeneity of rainfall variability. Rainfall reaches diurnal maxima in late afternoon and then propagates downstream in the direction of synoptic-scale low-level winds.

In the December-February of El Niño years, the northwesterly Austral summer monsoon is weaker than normal in the Maritime Continent and easterly winds are more frequent than normal over Borneo, enhancing westward propagation of daily maximum rainfall over the island. On the other hand, the strong westerly monsoon weather types are less frequent than normal in El Niño years, which means that there are fewer days for the maximum daily rainfall to propagate from the central region toward east Borneo. This parity of rainfall propagation by different weather types explains why there is a wet west versus dry east in the rainfall anomaly pattern over Borneo Island in El Niño years.

*Contributed **by J.-H. Qian**, **A.W. Robertson** and **V. Moron.***

Interactions between ENSO, monsoon and diurnal cycle in rainfall variability over Java, Indonesia

Using a high-resolution regional climate model RegCM3, station and satellite observations, we have studied the spatial heterogeneity of climate variability over Java Island, Indonesia. Besides the well-known anomalous dry conditions that characterize the dry and transition seasons during an El Niño year, analysis of regional model output reveals a wet mountainous south versus dry northern plains in precipitation anomalies associated with El Niño over Java during the peak rainy season. Modeling experiments indicate that this mountains-plains contrast is caused by the interaction of the El Niño-induced monsoonal wind anomalies and the island/mountain-induced local diurnal cycle of winds and precipitation. During the wet season of El Niño years, anomalous southeasterly winds over the Indonesian region oppose the climatological northwesterly monsoon, thus reducing the strength of the monsoon winds over Java. This weakening is found to amplify the local diurnal cycle of land-sea breezes and mountain-valley winds, producing more rainfall over the mountains, which are located closer to the south coast than to the north coast. Therefore, the variability of the diurnal cycle associated with this local spatial asymmetry of topography is the underlying cause for the heterogeneous pattern of wet south/dry north rainfall anomalies in El Niño years. It is further shown that the mean southeasterly wind anomalies in December to February of El Niño years result from more frequent occurrence of a quiescent monsoon weather type, during which the strengthened sea-breeze and valley-breeze convergence leads to above normal rainfall over the mountains.

Contributed by ***J.-H. Qian****,* ***A.W. Robertson*** *and* ***V. Moron****.*

Modulated seasonal and intraseasonal cycles of Indian summer monsoon and their connections with rainfall variability

Variability of the Indian summer monsoon is decomposed in terms on an interannually-modulated annual cycle (MAC), together with a northward-propagating intraseasonal (30–60-day) oscillation (ISO), by means of multichannel Singular Spectrum Analysis (MSSA) applied to daily fields of outgoing long-wave radiation (OLR) and low-level winds over the Indian domain. An example of this decomposition is shown in Figure 30 for the year of 1987. The impact of these components on rainfall is then analyzed using a 1-degree gridded daily dataset.

Active and break phases of monsoon rainfall variability are found to be well characterized by the linear superposition of the MAC and ISO components, while the relatively weak ISO component alone cannot account for them. Monsoon onset is shown to be sensitive to the phase of the ISO, except when the latter is delayed in which case the phase of the ISO is found to be much less relevant. The phase of MAC onset is shown to be highly correlated with a large-scale pattern of SST over the Pacific that resembles the Pacific Decadal Oscillation (PDO).

This study departs from previous work on the relationships between seasonal-mean rainfall anomalies and intraseasonal variability by expressing the former in terms of a seasonal cycle that is modulated from year to year; this framework clarifies their relative roles in accounting for intraseasonal rainfall variability.

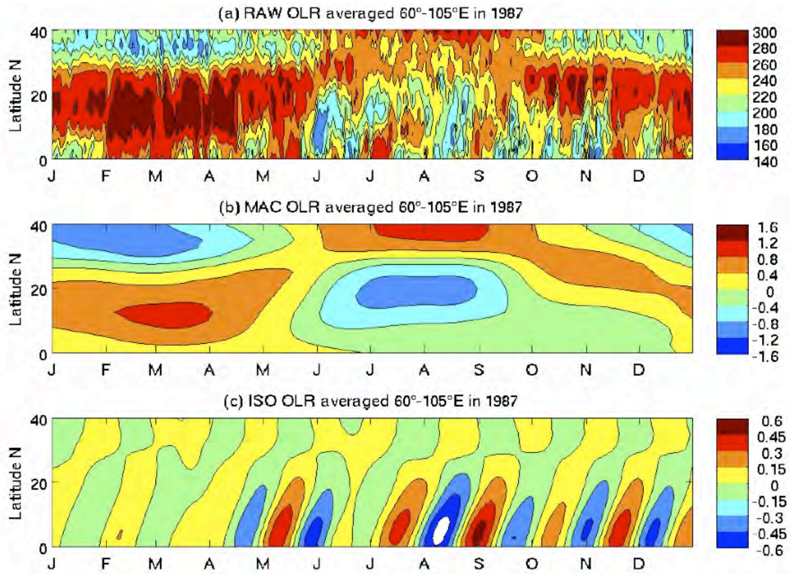


Figure 30. Decomposition of OLR daily variability over India during 1987, in terms of its leading spectral components. Shown are time evolutions in the meridional plane of zonally averaged [60E–105E] OLR anomalies (panel a: W/m^2), with the modulated annual cycle component (MAC, panel b, in standard deviations), and intraseasonal oscillation component (ISO, panel c, in standard deviations).

*Contributed by **V. Moron** and **A.W. Robertson**.*

Analysis of intraseasonal and interannual variability of the Asian summer monsoon using a hidden Markov model

Intraseasonal and interannual variability of Asian summer monsoon rainfall in pentad precipitation data is examined using a Hidden Markov Model (HMM). The spatial patterns of discrete rainfall states derived with the HMM and the associated transition probabilities between the states are shown to represent well the principal Asian summer monsoon ISO, propagating eastward and northward with a period of 40–50 days. Stochastic simulations made with the HMM reasonably reproduce the canonical ISO propagation and its observed statistics such as the frequency of ISO events.

The interannual modulation of the ISO associated with El Niño-Southern Oscillation (ENSO) is assessed by employing a nonhomogeneous HMM (NHMM) with summer-mean NINO3.4 index prescribed as an input variable. ENSO influence on the ISO is found to manifest as preferences toward particular ISO phases depending on the ENSO condition, thus adding an asymmetry to the ISO. In the presence of seasonal mean anomalies, the El Niño seasonal mean rainfall anomaly pattern is identified by the HMM as a distinct state, in addition to the ISO states, whereas the La Niña seasonal mean rainfall anomaly pattern does not appear distinct from the ISO states (see also Yoo et al., 2010).

*Contributed by J.H. Yoo, **A.W. Robertson**, and I.-S. Kang.*

Downscaling projections of Indian monsoon rainfall using a nonhomogeneous hidden Markov model

Precipitation fields in general circulation models (GCMs) do not capture detail at the fine spatial scales of interest in many climate risk management applications. GCM parametrizations also tend to produce biased rainfall distributions. These factors preclude the direct imputation of localized, temporally disaggregated precipitation changes from GCM simulations. On the other hand, GCMs are the most comprehensive tools yet devised for the quantitative characterization of climate change. Observational data, by contrast, *do* represent the fine spatial detail lacking in GCM simulations, and are less likely to be biased with respect to spatial patterns or rainfall distributions. However, they are records of past climate, fundamentally mute with respect to the future.

In this work (Greene et al., 2011), these contrasting data types are fused – large spatial scales are informed by the GCMs, fine-scale properties by the observations. The focus is on the summer monsoon season, June through September (JJAS). A statistical model – the hidden Markov model – is trained on 54 years of daily JJAS observational data (1951-2004), along with a GCM-derived index of monsoon circulation strength. It is then used to simulate both 20th- and 21st-century rainfall, using in each case the GCM index from the appropriate time period (1951-2000 and 2070-2099). Large-scale, regional precipitation change is constrained by an ensemble of GCMs, but disaggregated to the fine spatial scale using observed patterns of variability. Statistics can then be computed on the simulations (which have daily time resolution) to estimate changes in rainfall occurrence frequency, wet-day amounts, dry spell lengths, shifts in extreme precipitation, growing-season length and any other quantities that may be of interest. Out simulations indicated small but significant shifts for most of these quantities, including reduced rainfall frequency but greater wet-day amounts, increases in the number of dry days and, to a lesser extent, in dry-spell lengths. Growing-season length changed very little, with somewhat later onset compensated, in the agronomic sense, by increased rainfall. The regional mean increase in JJAS rainfall (estimated from the GCM ensemble) is about 6%. This is reflected in small increases in nearly all rainfall percentiles, as illustrated in Figure 31.

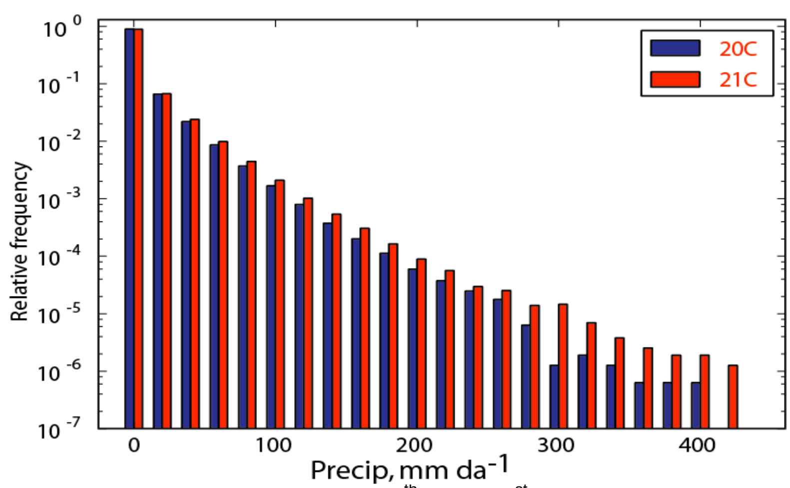


Figure 31. Daily distributions for 20th- and 21st-century rainfall, pooled over the 24-location network that was the subject of this study. Almost all precipitation percentiles occur with increased frequency during 2070-2099. The principal exception occurs in the lowest bin, which include dry days.

The nonhomogeneous hidden Markov model (NHMM) used in this study is of interest in and of itself. In essence, the NHMM sifts through the thousands of days of rainfall data in the observational records, grouping together those with similar spatial rainfall patterns. The order in which these patterns tend to follow one another is also modeled. One of the patterns is "dry," meaning that little rainfall occurs over the network of locations on days when this pattern is observed. Others are "wet" to different degrees. The overall precipitation climatology, for each period, is governed by the relative frequency of occurrence of dry and wet patterns, as well as the rainfall amounts associated with each. Four patterns are modeled in the present study.

Figure 32 illustrates an intermediate step in the modeling process, and shows how the relative prevalence of the four patterns shifts as the GCM-based circulation index (x-axis in left panel) increases. Here, the yellow and green curves represent dry and wettest states, respectively. As the index increases the dominance the dry state decreases and the wet state comes to predominate. Panel (b) shows the 20th-century climatology of the four patterns, which are labeled with corresponding colors as "states" in panel (a). At the beginning of the season the dry state (yellow) occupies most of the vertical space on the plot; by 1 August, however, it has become quite infrequent and the wettest of the states (green) plays a dominant role. The circulation index weakens in the 21st century, shifting the balance away from the wetter states and toward the dry. However wet-day amounts associated with all of the states increase as the planet warms. These effects together result in a general tendency toward more dry days but more rainfall on wet days, for the monsoon of the future.

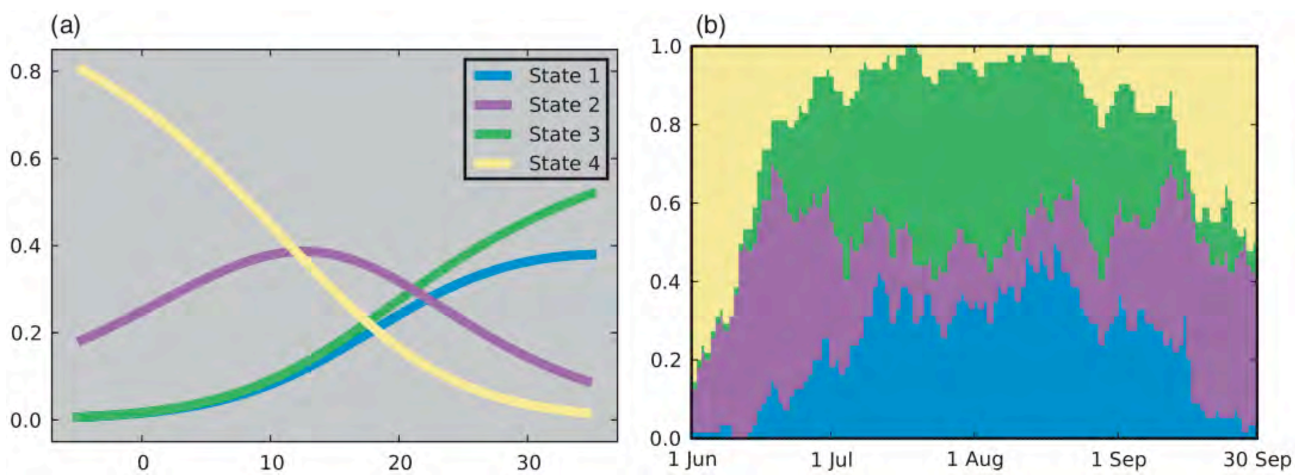


Figure 32. Panel (a) shows the relative occurrence frequencies of the four rainfall patterns (states) modeled by the NHMM. Yellow represents the "dry" state, green (and to a lesser extent, blue) wetter conditions. As the circulation strengthens during the course of the monsoon, the dry state becomes infrequent and wetter states come to the foreground. This is reflected in the seasonal climatology of the four states, as shown in panel (b).

*Contributed by **A.M. Greene**, **A.W. Robertson**, P. Smyth and S. Triglia.*

The effect of grid spacing and domain size on the quality of ensemble regional climate downscaling over South Asia during the northeasterly monsoon

We evaluated the performance of an ensemble-based dynamical regional climate downscaling over Southern Asia in a northeast monsoon season for choices in grid resolution and domain extent. We used a seven-member ensemble of the ECHAM4.5 global atmospheric general circulation model at a resolution of about 300 km (2.8125 degree) and the International Center for Theoretical Physics (ICTP) Regional Climate Model 3 (RegCM3) with grid resolutions of 100km, 50km, 25km and 20km, respectively. Unlike the rest of South Asia that garners most of its annual rainfall in the boreal summer, the southern most Indian states and Sri Lanka obtain a large fraction of its annual rainfall during the October to December season. We report in detail on the performance in Sri Lanka.

The size of Sri Lanka (about 432x224 km) is slightly larger than a gridbox of ECHAM and has mountain ranges that reach up to 2532 meters in altitude. Two sets of regional model runs were undertaken to assess the effect of grid resolution and model domain size on the downscaling performance. We evaluated the skill in simulating the spatial distribution of precipitation and seasonal evolution. Our simulations show that the RegCM3 with 100km grid (‘large-domain’), which estimates the peak of the mountains at less than 200m, is too coarse to capture orographic influences on the monsoon rainfall. The RegCM3 simulation with grid size from 20km to 50km (‘small-domain’) captures fine scale details resulting from the topographic effect on monsoon rainfall associated with the uplift condensation on the windward side. While the small-domain runs (where only the forcings for the region immediately around Sri Lanka - 4N-11N and 76E to 85E - were used) are computationally more efficient, the results are overly controlled by the lateral boundary driving of the ECHAM4.5 due to insufficient space for spinning up fine scales. As a result, the topographic precipitation is displaced compared to the observed precipitation.

The large-domain simulation used a domain comprising both land and ocean (approximately 4S-22N and 65E-96E). The large-domain group of simulations produced reasonable spatial distribution of precipitation over both land and ocean regions. Moreover, the uncertainties, represented by the ensemble spread among the seven realizations, are reduced in the large-domain high-resolution runs. Therefore, fine enough grid resolution (25 km or less) and sufficiently large domain size are both needed to simulate the essential features of precipitation in this tropical and monsoonal region.

Contributed by ***J.-H. Qian*** *and* ***L. Zubair****.*

Downscaling of seasonal rainfall over the Philippines: dynamical vs. statistical approaches

A longstanding yet very important question concerns the additional value derived from labor intensive regional climate models (RCMs) nested within GCM seasonal forecast models, over and above simple statistical methods of downscaling. In a collaborative study with the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) and the European Center for Research and Education in Environmental Geoscience (CEREGE), we compare the two types of downscaling of precipitation ‘hindcasts’ over the data-rich region of the Philippines, using observed data from 77 raingauges for the April-June monsoon onset season. Spatial interpolation of RCM and GCM grid box values to station locations is compared with cross-validated regression-based techniques such as canonical correlation analysis. The GCM hindcasts are formed from an ensemble of simulations from the ECHAM4.5 model at T42 resolution made with observed SSTs prescribed, over the 1977 – 2004 period. The RegCM3 with 25km resolution is nested within each of a 10-member GCM ensemble over the Philippines. To first order, we find that anomaly correlation skill at the station scale for simulations of seasonal total rainfall and monsoon onset date is quite similar using all the techniques considered, including simple spatial interpolation of the GCM values. The RCM has significantly smaller RMS error than the ‘raw’ interpolated GCM, although statistical correction can greatly improve the latter.

*Contributed by **A.W. Robertson**, **J.-H. Qian**, **V. Moron**, **M. Tippett** and A. Lucero.*

Enhancing forecast skill of the Indonesian rainfall onset using MJO updates

The onset dates of the rainy season in Indonesia are crucial for the local farmers, for the first planting dictates their annual rice production (Naylor et al, 2001). ENSO is the major driver for the rainfall variability in the region, and a successful method to forecast the onset dates using the SST anomalies in the Tropical Pacific has been introduced (Moron et al., 2009).

As the influence of Madden-Julian Oscillation (MJO) is also substantial in this region, the expectation for improving the prediction emerges here. A successful attempt may be of great use to users, since spatial and temporal details on top of the ENSO dependence may add value to the prediction. MJO is represented by two major modes of a combined empirical orthogonal function (EOF) of the high pass filtered upper and lower level zonal winds as well as outgoing long-wavelength radiation (OLR) (Wheeler and Hendon, 2004). Its status is updated to public on a daily bases via website (http://www.bom.gov.au/climate/mjo).

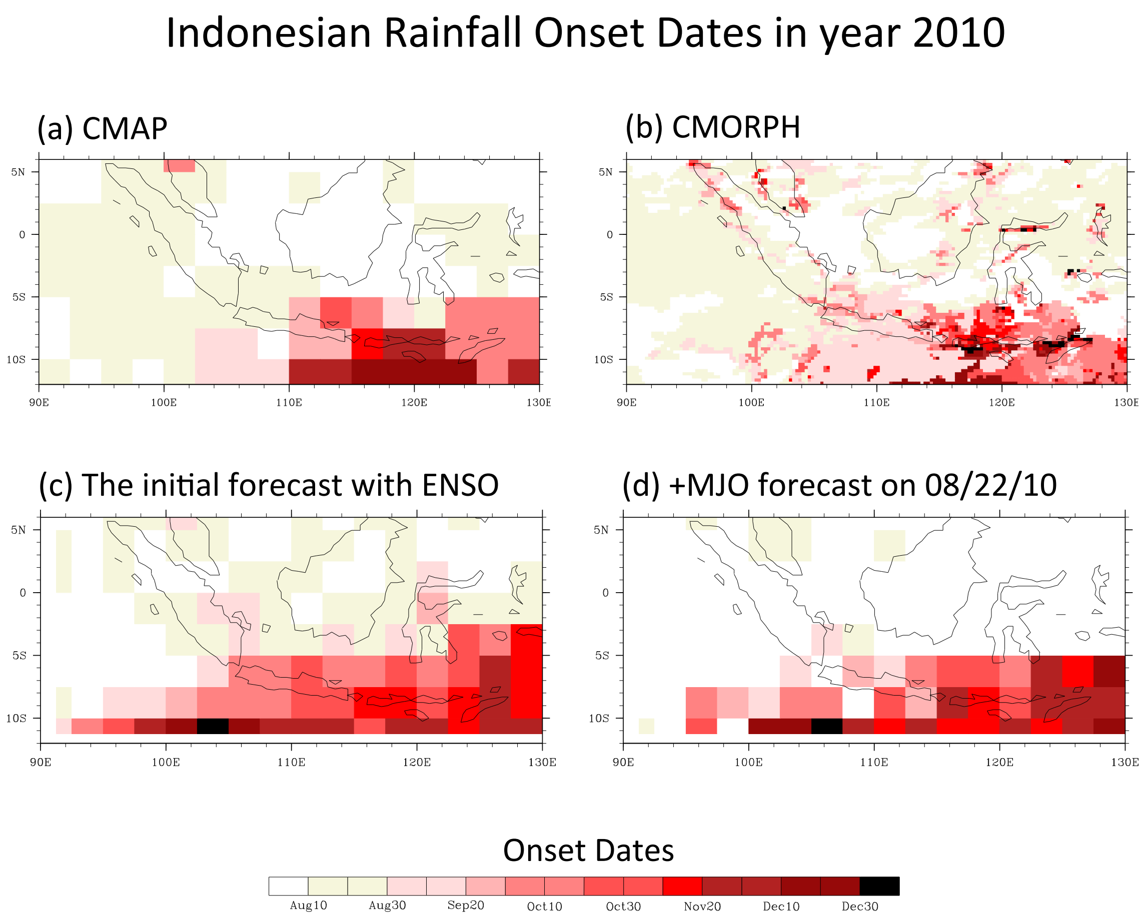


Figure 33. Forecasts of onset date from (a) CMAP, (b) CMORPH, (c) initial forecast with ENSO, (d) new forecast with MJO predictors.

In this preliminary study, we test a statistical model to provide timely alert of the onset, moving forward in time. The first guess is obtained based on SST anomalies following the approach of Moron et al (2009), using principal components regression. A multiple linear regression model for the first guess error is then constructed for every grid point, using standard MJO indices (RMM1 and RMM2) as predictors. The MJO predictors are chosen only when they become available, within 3 pentads before the first guess onset dates. This 3-pentad window is chosen because the MJO is known to be predictable for up to 14-18 days in advance, depending on the method of prediction. By using three consecutive pentads, higher frequency noise can be reduced as well. The model is trained using the CMAP (Xie and Arkin, 1997) pentad data. Substantial increases in anomaly correlation coefficients with respect to those for the first guess are found in northern Sumatra and southern Indochina, as well as east of Indonesia (not shown).

Figure 33 shows an example forecast of onset date for the year 2010, in which a somewhat earlier onset was expected due to the strong La Niña event. As shown by two different observation data sets, CMAP and CMORPH (Joyce et al, 2004), the actual onset in the western Java was even earlier than the first guess prediction by at least 20 days, for the wet condition developed near Java Island. The forecast made on August 22nd with the new model with MJO predictors successfully predicted the earlier onset in western Java.

*Contributed by **D.E. Lee** and **A.W. Robertson**.*

A framework for the simulation of regional decadal variability for agricultural and other applications

Decadal climate variability, sometimes referred to as “near-term climate change,” has received increasing attention in recent years, and the potential for numerical models to forecast climate variations on time scales out to a few decades is currently an active area of research. At present, however, well-verified, reliable near-term climate forecasts for terrestrial regions, particularly at local to regional scales, have not been demonstrated. Alternative methods for assessing near-term climate-related risks may thus have considerable value.

One technique that can useful in this regard involves stochastic simulation, the creation of synthetic climate sequences having statistical properties representative of a region or locality of interest. Such sequences, while not forecasts *per se*, can nonetheless help to quantify ranges of uncertainty associated with near-term climate variability. Simulations may be structured so as to incorporate the long-term climate change trends associated with anthropogenic greenhouse forcing. These trends then provide a slowly-changing background state on which decadal, and by extension, higher-frequency fluctuations are superimposed. Acting in concert, these influences can provide a better description of the expected range of near-term climate variations, and their potential impacts on the statistics of interest for agriculture or other applications, than either considered alone.

An example is shown in Figure 34, which shows an individual simulation created for the Berg and Breede water management areas in the Western Cape Province of South Africa (the “study area”). Three variables, precipitation (pr) and maximum and minimum temperatures (Tmax and Tmin, respectively), are simulated jointly. This is necessary because these variables are not *independent:* Wetter days tend to have lower values of Tmax, while days with higher Tmax tend to also have higher values of Tmin. This important covariability was simulated using a vector autoregressive (VAR) model, applied to annualized data representative of the study area.

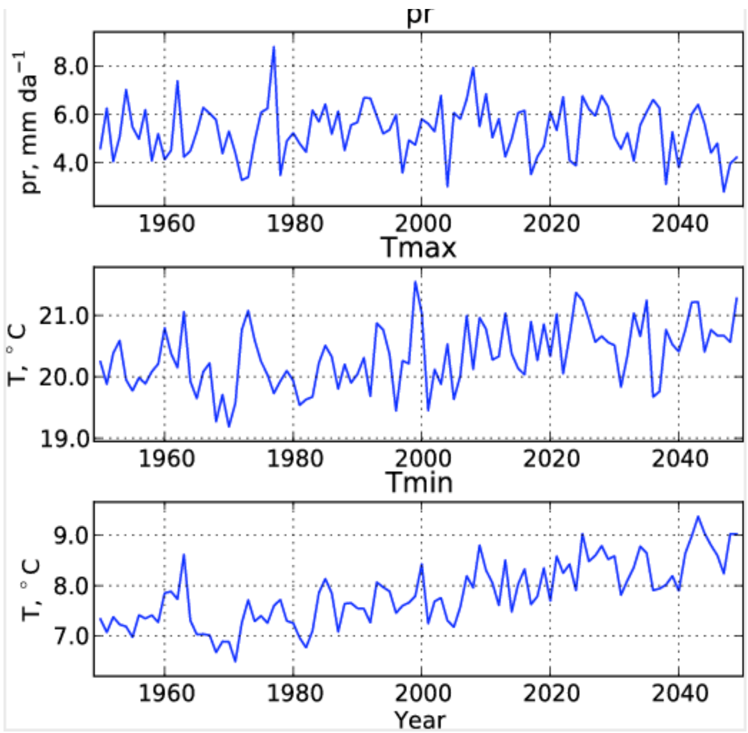


Figure 34. Stochastic simulations for precipitation and maximum and minimum daily temperatures for the region of the Berg and Breede water management areas, Western Cap, South Africa. Prior to year 2000 the traces show the observational record, which is well-matched in statistical terms by the simulated values, which extend from 2000 through 2049. The negative trend in precipitation may eventually pose a challenge for resource managers.

The simulation runs from 1950-2049, inclusive. The first 50 years shown consists of the observational record; the segment from 2000-2049 is synthetic. Climatic trends are observed prior to year 2000, imposed thereafter. For precipitation, the 21st-century trend, which has no analog during the 20th century, is derived from the IPCC multimodel ensemble; for the temperature records the trends are inferred from 20th-century behavior.

Of interest is the greater trend in Tmin than in Tmax, implying a reduction in the diurnal temperature range. Of greater concern is the pronounced drying trend. For wet-season rainfall the IPCC multimodel change, by the end of the 21st century, amounts to a reduction of 23%, which could pose a serious challenge for resource managers. The variability encoded in such simulations, superimposed on the secular trends expected during coming decades, is expected to provide a valuable tool for the characterization of climate-related risks in a warming world.

Contributed by ***A.M. Greene****,* ***L. Goddard*** *and* ***J.W. Hansen****.*

Scenario development for estimating potential climate change impacts on crop production in the North China plain

Climate change is expected to have major impacts on agriculture and water resources, although regional climate projections are uncertain. It is important to quantify the potential impacts of projected changes in temperature, precipitation and solar radiation changes on agricultural productivity for specific regions, and to estimate the role of different sources of uncertainty. In this study, climate change scenarios of precipitation, temperature and solar radiation for the North China Plain (NCP), the largest agricultural area in China, are constructed in terms of stochastic daily weather sequences. A nonhomogeneous hidden Markov model (NHMM) is used to downscale daily precipitation projections at 32 stations during winter wheat and summer maize seasons for a baseline (1966-2005) and 21st century (2081-2099) A1B scenario, using selected general circulation models (GCMs). A climatological seasonal cycle of regional-averaged daily reanalysis precipitation defines the input to the downscaling for the baseline simulation; this input was then scaled by the precipitation changes from GCMs projections to construct downscaled stochastic simulations of daily precipitation in the 21st century. Temperature is generated using a multivariable normal distribution, conditional on precipitation occurrence, with 21st century additive changes taken from the GCMs at the regional scale. Three hypotheses about the changes in solar radiation (-20%, 0% and 20%) were made considering the large uncertainty in its change in the future.

A summary of the projected downscaled precipitation changes is shown in Figure 35 for three different scenarios driven by: (1) the GCM with the largest projected precipitation increase (left column); (2) the GCM multi-model mean (middle); and (3) the GCM with the largest projected precipitation *decrease* (right column). For the winter wheat season (top row), the downscaled simulations exhibit station increases in the mean daily rainfall of 13.3–30.0% in case (1) and 1.9–11.5% in case (2), with changes of 1.2–34.1% and 0.9–13.2%, respectively, for the summer maize season (bottom row). In case (3), the simulated station rainfall decreases at all stations, indicating substantial uncertainty even in the sign of the climate-change response, with changes ranging from -14.1 to -6.3% for the wheat season and from -9.6 to -2.7% for the maize season. Maximum and minimum temperatures would increase 3.68°C and 3.69 °C for the wheat season, and 3.47°C and 3.61°C for the maize season, respectively.

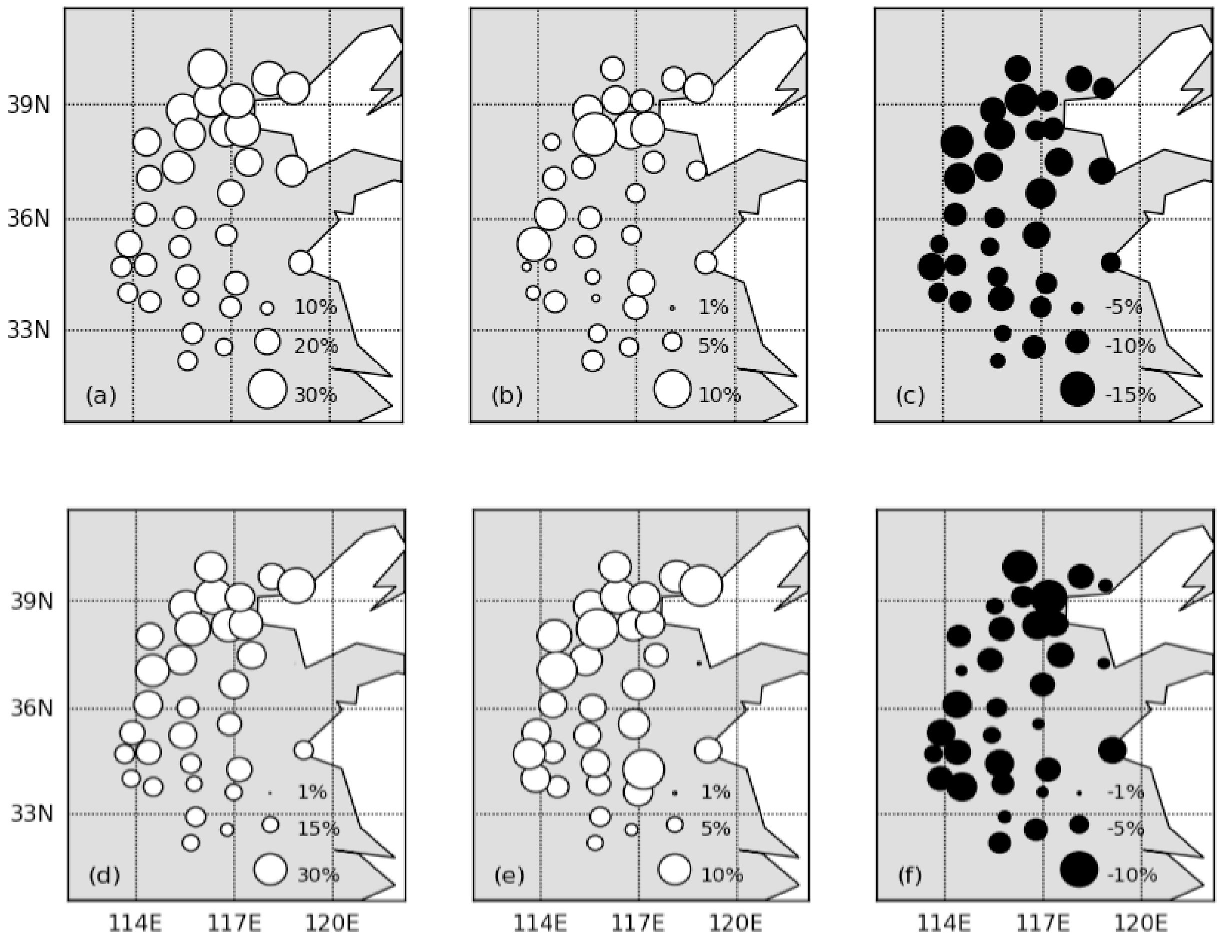


Figure 35. Percentage changes of the simulated mean precipitation for the 21st century, using the highest simulated change by an individual GCM (a,d), multimodel ensemble mean (b, e) and the lowest simulated change by an individual GCM. The upper and lower panels represent the wheat and maize seasons respectively.

*Contributed by **C. Chen**, **W. Baethgen**, **A. M. Greene**, and **A.W. Robertson**.*

Predictability and teleconnections of western Himalayan river flow

The spring melt flow in Himalayan Rivers is important for hydropower generation and irrigation during the dry pre-monsoon season. In addition, winter snow over Himalayas helps in maintaining the glaciers, which serve as a storehouse of freshwater throughout the year. With the help of the hydro-climatological data provided by the Bhakra Beas Management Board in India, we have analyzed relationships between winter (DJF) climate variability and spring flow (MAMJ) of the Satluj River, upstream of Bhakra dam, which is a major source of water for irrigation and electricity generation (1325MW) for north India. Spring seasonal inflow anomalies are found to be strongly correlated with large-scale precipitation and diurnal temperature range in the preceding winter over the Western Himalayas and adjoining north and central Indian plains (Figure 36),

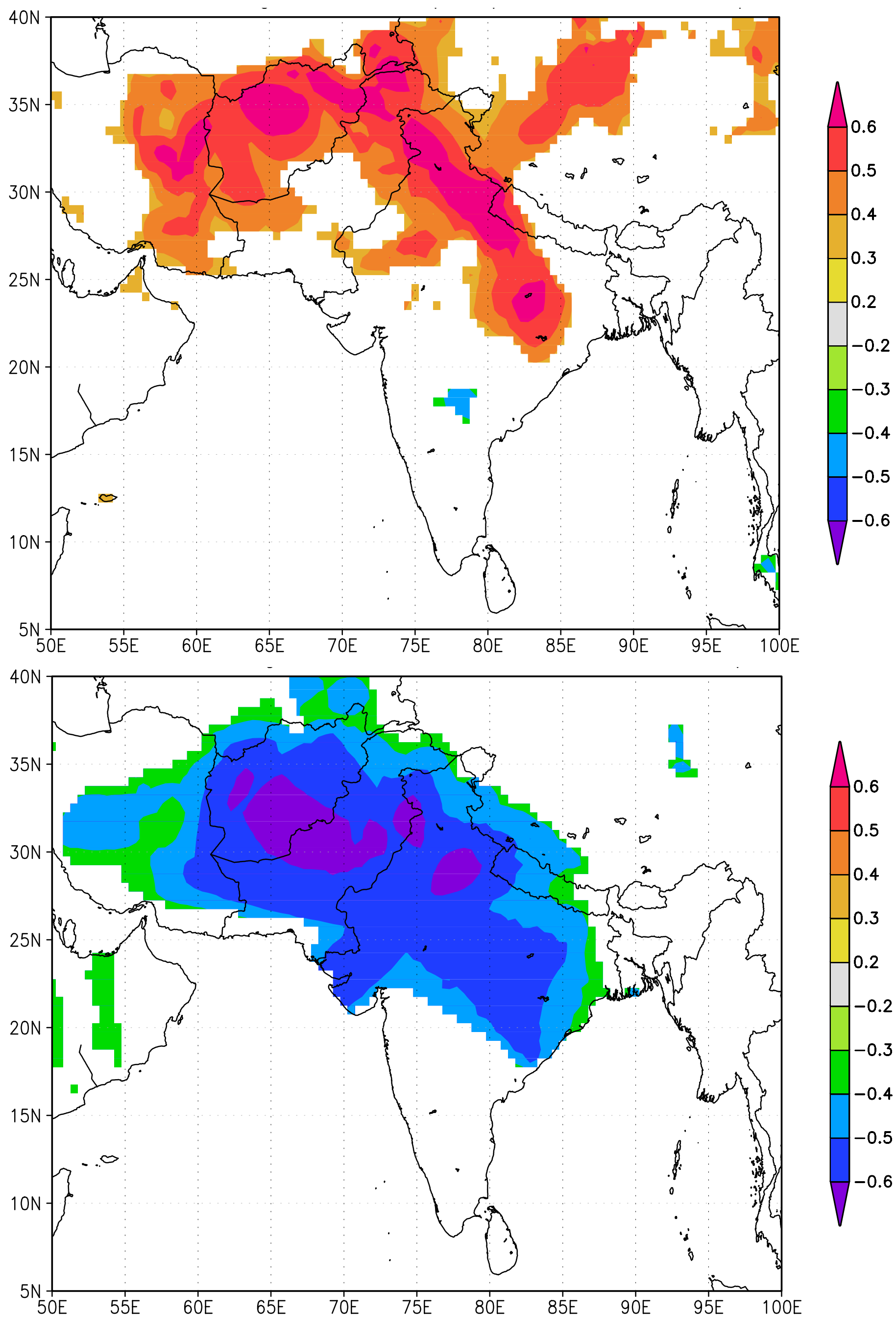


Figure 36. Pearson's Correlation Fields of spring (MAMJ) seasonal total Bhakra inflow with preceding winter (DJF/DJFM) precipitation (upper) and daily temperature range (lower) over the Western Himalayas and adjoining north and central Indian plains (also includes part of Pakistan and Afghanistan) for 1978-2004. Shading indicates local statistical significance level at 90% confidence.

suggesting a potentially usable predictability for reservoir managers. Winter precipitation in the Western Himalayas is mainly brought about by the mid-latitude jet stream leading to the formation of low-pressure synoptic systems known as Western Disturbances (WD). WDs originate over the North Atlantic Ocean or Mediterranean Sea, with secondaries developing over the Persian Gulf and Caspian Sea either directly or as a result of the arrival of low-pressure systems from southwest Arabia, and travel eastward over Iran, Afghanistan, Pakistan, and northwest India. Winter WDs (and therefore the average volume of winter precipitation over Western Himalayas) are also modulated by the large-scale interaction between ocean and atmosphere led by the variation of the SSTs of the Indian Ocean and Pacific. As a result, average spring inflow volume, which is a function of the average volume of precipitation in winter, was also found to be positively correlated with the SSTs over the western and equatorial Indian Ocean, and with below-normal sea-level pressures centered over the Azores, both during the preceding winter. These relationships suggesting additional potential seasonal predictability are under current investigation.

Contributed by ***I. Pal****,* ***U. Lall****,* ***A.W. Robertson*** *and M. Cane.*

The extended range forecast system for climate risk management in agriculture

The Extended Range Forecast System for climate risk management in agriculture (ERFS) project was launched by the Government of India in 2009, with IRI serving as the lead international agency, with funds from Government of India's Ministry of Agriculture. The Indian Institute of Technology Delhi (IITD) serves as the project secretariat and the primary partners are the India Meteorological Department (IMD), the National Center for Medium-Range Forecasting (NCMRWF), the Indian Council of Agricultural Research (IARI), and state agriculture universities in the project's nine demonstration states: Andhra Pradesh, Gujarat, Maharashtra, Madhya Pradesh, Orissa, Himachal Pradesh, Rajasthan, Tamil Nadu, and Uttarkhand. The project's primary objective is to enhance climate resiliency of agriculture in India at the farm, village and district levels. The effort involves the generation and use of quality climate forecasts for weather/climate risk-resilient decision-making and to develop and test risk management tools for farmers and district level decision makers in anticipating and responding to weather and climate-related agricultural risks. This abstract provides an overview of the activities and accomplishments achieved in the second year of the project's implementation, during the period of this report.

Enhanced forecast methodologies in India - Research to improve forecasting of the summer monsoon continued into the second year of activities with the six month visit (July-December 2009) of four Indian scientists from IITD to the IRI campus in New York. During this period, IRI and IITD scientists collaborated on signal-to-noise maximizing techniques to enhance forecast skill, developed stochastic rainfall downscaling models to link the forecast with crop-simulation models, and integrated station data into an India-based Data Library and online maproom. The IRI Data Library is a powerful tool for decision makers because it allows for the analysis of wet and dry spell patterns using historical rainfall data and enhances access to information to provide better-informed risk management. Maprooms were created for 0.5-degree daily IMD rainfall, 1-degree daily IMD temperature data, as well as Global Daily Climatology Network daily station rainfall data.

Agriculture risk management and decision-making research - IRI has coordinated with the national stakeholders in developing a methodology for analyzing climate risks and identifying risk management options at the plot and farm levels for specific crops. The research in partnership with Dr. D. R. Reddy's group at the Acharya Ranga Reddy Agricultural University focused on maize in the Mahabubnagar district. Here for low and high clay content soil, working with farmers, we have identified the key weather and climate risks and potential management options across the pre-sowing, vegetative growth, reproductive, and harvest stages. Findings of this research have been consolidated into a decision support matrix that identifies biotic and abiotic climate risks as they are expressed in soils with both low and high clay content.

In developing this matrix, IRI has also worked with agricultural stakeholders in the Srirangapura and Ippallapally villages of Mahabubnagar district to identify opportunities in existing institutional and decision-making contexts to enhance the use of climate information in managing agricultural risks. Decisions related to climate risks are influenced by factors such as credit and water availability, farm gate price, and the role of the government agencies at district and state levels in specific government programs that support agricultural production. While initial research has focused on Mahabubnagar district, the next phase of activities will scale-up these activities in the other demonstration sites in partnership with the other demonstration site partners.

Quantitative analysis of climate risk in agriculture using crop models - Using the information from the risk matrix above, we set up a crop model to simulate maize responses to climate in light soil conditions in Mahabubnagar. This enabled estimation of the optimal planting window for maize (across the nominally three sowing periods), and to develop a risk-index for guiding decisions on the best time for sowing and implementing risk interventions (e.g. supplementary irrigation to minimize crop loss due to water stress under a given weather/climate condition). Using 30 years of weather data, the crop model was run for multiple sowing dates and documented the responses of the crop under rainfed condition. Figure 37 shows a sample risk profile (water stress) for maize crop planted in the sowing window between June 20 – July 2. For this sowing period, most of the stress occurs at the later silking stage, and for the sowing windows investigated, promises maximum crop yield.

We also developed a model-based index for estimating thresholds of accumulated rainfall for estimating the need for applying supplementary irrigation at a particular crop stage. In addition, several stand-alone tools were developed to calculate dry spell lengths, probabilities of having dry spells in a standard week, etc.

Capacity building - IRI scientists and Indian climate and agriculture experts met for a five-day workshop in Bhubaneshwar, India from April 12-17, 2010. The workshop was hosted by the Orissa University for Agriculture and Technology and brought together project scientists from the state agriculture universities in the demonstration sites, in addition to experts from IIT-Delhi

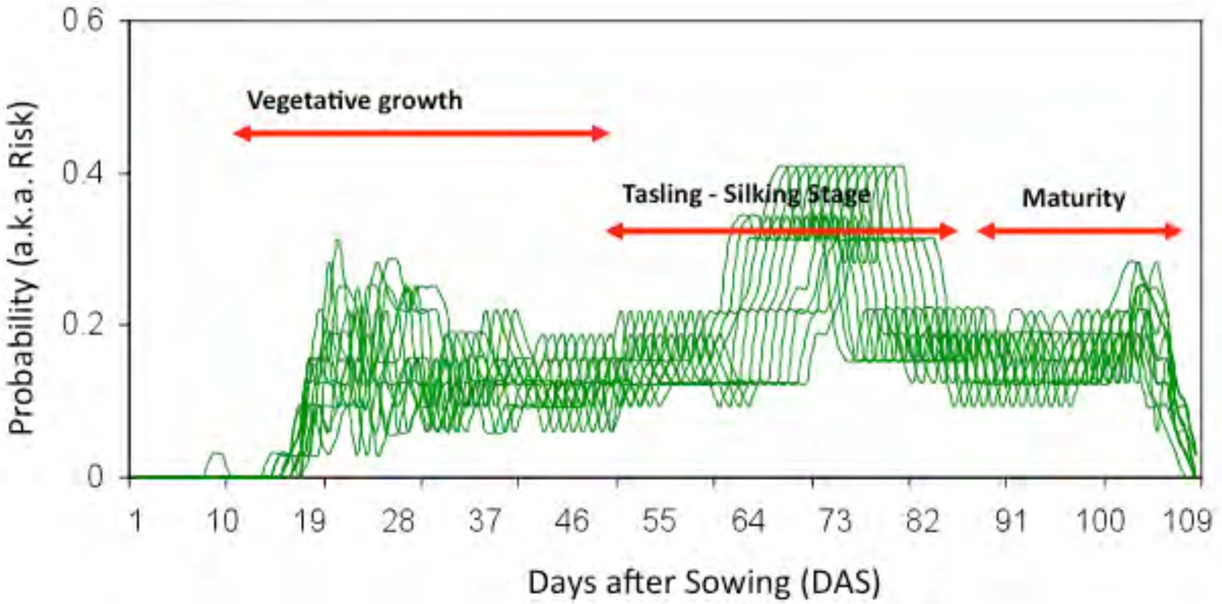


Figure 37. Sample risk profile for maize planted between June 20 – July 2, Mahabubnagar district.

and the IMD. During this event, climate and agricultural scientists worked together on practical approaches to systematically assess climate risks to specific crops in the context of each demonstration site. Participants engaged in practical exercises for analyzing specific crop risks throughout the growing season, promising interventions to manage these risks, and costs and benefits associated with each. IRI scientists also led sessions on statistical methods for crop and rainfall data analysis. Finally, workshop participants presented and discussed the use of climate forecasts for crop planning in the nine demonstration sites across India. This improved understanding of climate-related agricultural risks and potential risk management strategies will help guide climate analysis and forecasting components of the ERFS project. The Bhubaneshwar workshop built upon the previous workshop, held in Hyderabad in April 2009, at which a workplan was developed to guide efforts in the nine district-level demonstration sites. Outcomes of the Bhubaneshwar workshop include a call for all demonstration efforts to undertake the approach to analyzing risks to selected crops in each demonstration district, and recommendations for organizing and disseminating climate research and forecasting outputs at the demonstration level.

Further to the significant accomplishments achieved to date on the ERFS project and the overwhelmingly positive response of stakeholders, USG (State Department) has expressed interest in scaling up ERFS project efforts. Potential work includes the development of a suite of tools for transitioning climate forecast methodologies into a software platform for use by IMD, building additional data management and virtual maproom tools for agricultural and food security risk management decision support at district and farm levels, and additional technical capacity building efforts in India on agricultural risk forecasting and risk management.

Contributed by ***S. Someshwar****,* ***E. Allis****,* ***A. Ines****, and* ***A. Robertson****.*

IRI participation in CCRUN (Consortium for Climate Risk in the Urban Northeast) NOAA RISA project

Three scientists from the IRI are playing leading roles in the Consortium for Climate Risk in the Urban Northeast (CCRUN), a RISA that is working with stakeholders in the urban corridor stretching from Boston to Philadelphia to improve the management of climate risks and adaptation to climate change. The project, which began in October 2010, is working to develop locally-specific climate information and apply that science to support decision-making at stakeholder institutions, such as city government agencies, and non-profit, and for-profit private organizations that influence adaptation. CCRUN addresses the complex challenges associated with climate risks in densely populated, highly interconnected urban areas, including: urban heat islands, poor air quality, intense coastal development, multifunctional settlement along inland waterways, integrated infrastructure systems, and highly diverse socio-economic communities. In order to address the risks of future climate impacts at a local scale, climate science will be advanced in probabilistic predictions and projections with a special emphasis on high-impact climate and extreme events. The research accomplishments and stakeholder engagement will yield important lessons for managing climate risks in other urban areas in the United States.

CCRUN focuses on three broad thematic areas: water, coastal zones, and health (Figure 38). In each area, the research team will conduct climate analyses and develop climate information in response to stakeholder needs at scales of interest to decision-makers, including historical and remotely sensed data fields, weather prediction, and seasonal-to-multi-decadal climate projections. In addition, climate scientists within the RISA will be working to raise the understanding of the climate information among the stakeholders. We believe this capacity building combined with the collaborative development of information will increase trust in the climate information as well as help guide its use. As starting point to the collaborative development of climate information, we will analyze the impacts of current climate and the projected range of future climate on outcomes relevant to stakeholders in the three sectors. The team will work with stakeholders to put the research results to use in planning and decision-making.

Dr. Shiv Someshwar and Dr. Malgosia Madajewicz are analyzing the vulnerability to climate risks in the three sectors in the northeast urban population. The objective of the research is to inform the selection of issues and the interaction with stakeholders to ensure that the applications of climate science address climate vulnerabilities manifested in the population. Building adaptive capacity to current and future climate extremes among disadvantaged socio-economic groups is a priority for the project. We will analyze what methods we should use to assess vulnerability to climate risks, how vulnerability to different risks is distributed within the northeast urban population, and how effectively existing institutions address the vulnerability of different groups.

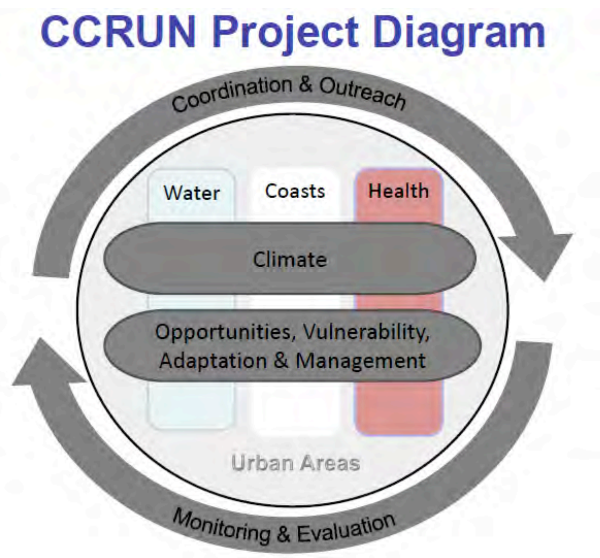


Figure 38. Schematic overview of CCRUN project.

An extremely important and novel element to this RISA is the impacts evaluation, which is being designed now – at the beginning of the project. This allows us to define a baseline of climate-related decision making against which the CCRUN effort can be measured. Dr. Madajewicz is leading the impact evaluation research. The objective is to understand and communicate what are effective approaches to reducing vulnerability to climate risks in the water, health, and coastal zone sectors under different climatic, environmental, and socio-economic conditions. We want to understand which approaches undertaken by CCRUN teams work, which do not work, for which groups within the population they work and which groups need a different approach, under what conditions the approaches work, and why. We will evaluate the impacts of the approaches that CCRUN develops on decision-making and on vulnerability to climate risks in order to produce evidence that can guide the design of effective strategies in other urban settings.

We will evaluate the climate risk management strategies developed by CCRUN at two different levels, using integrated quantitative and qualitative approaches. First, we will examine effects on decision making processes and intermediate outcomes. For example, the initial work of the health team will focus on reducing the effects that heat waves have on health. We will document how stakeholders make decisions that affect mortality and morbidity from heat waves: who makes which decisions, what information they use, how decisions translate into intermediate outcomes that ultimately affect mortality and morbidity such as availability of cooling centers, and how the outcomes differ across neighborhoods with different vulnerability profiles. In order to understand causal relationships between approaches and outcomes, we will work with stakeholders to implement the strategies informed by CCRUN in some randomly chosen neighborhoods and not in others, and/or we will identify changes in outcomes that would not be possible without CCRUN. The decision making processes and intermediate outcomes will be the first to change, enabling us to assess which approaches are working and which are not while approaches can still be redesigned. We will also use the analysis to understand why changes are taking place and under what conditions, how the changes are likely to affect livelihoods, and how effective approaches may be implemented in other contexts.

Toward the end of the project, we will analyze the final impacts that CCRUN aimed to achieve. For example, we will analyze what impacts the approaches implemented by the health team have had on the relationship between heat waves and mortality and morbidity. We will design the analysis to enable us to make causal inferences whenever possible.

*Contributed by **M. Madajewicz**, **L. Goddard** and **S. Someshwar**.*

Incorporating climate variability and change into fire potential assessments in the Ucayali region

In Amazonia, fire is the least expensive tool used for clearing agriculture fields, pastures and industrial scale plantations. Although fire has been traditionally used for centuries, escaped fires from burning fields have become increasingly common in the Ucayali region of western Amazonia, ravaging forests, farms, and settlements. While the pattern of land uses and circular rural-urban migration patterns may affect fire use and spread, our focus is to determine the most relevant climate variables to fire occurrence and whether climate variability and trends can explain the increased fire severity in Western Amazonia. The World Fire Atlas from the European Space Agency fire data and Peru's Servicio Nacional de Meteorologia y Hydrologia (SENAMHI) meteorological stations data are used in our analysis. Positive trends in hotspots count are found in western Amazon for July, August and September (JAS) 1996-2009 as seen in Figure 39.

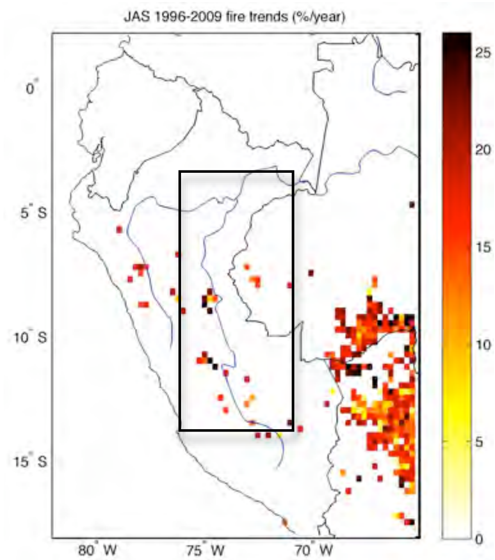


Figure 39. Seasonal (JAS) hotspots trends in western Amazon in percentage of increase per year for the period 1996-2009. Inset box depicts approximate domain over which fire and climate variables were

In a domain defined by coordinates 76.5W-71W and 13S-4S (see box inset in Figure 39) and altitude below 800m, 3 months Standardized Precipitation Index (SPI) drought index and saturation vapor pressure (e_s) show 99% statistically significant correlation with fire anomalies in western Amazon (see Figures 39). An anomalously active fire season responds to both a persistent deficit in precipitation (negative SPI; Figure 40, left plot) and higher potential for evapotranspiration (positive e_s; Figure 40, right plot).

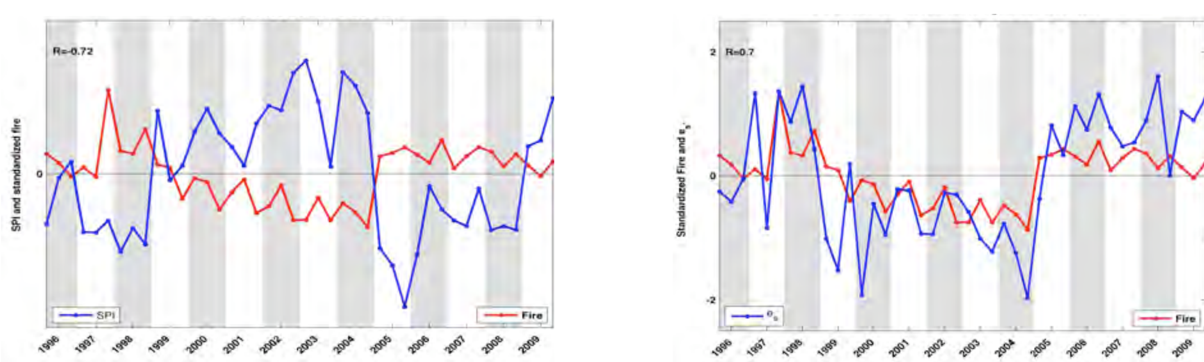


Figure 40. A linear regression model using SPI (left) and e_s (right) as predictors can explain 65% of hotspots count variance in JAS in the domain of study, indicating encouraging potential for fire season predictability in

Contributed by ***K. Fernandes, W.E. Baethgen*** *and* ***L. Goddard.***

Simulating malaria transmission dynamics in the pilot sites of the Colombian integrated national adaptation plan: steps toward an integrated surveillance and control system

Changes in climatic conditions are likely to alter malaria incidence and spatial distribution in Colombia. As part of the Integrated National Adaptation Plan, the Colombian Institute of Health is working on the implementation of a proactive, collaborative, multidisciplinary, integrated surveillance and control system (ISCS). The aim of this initiative is to improve risk assessments of malaria transmission in order to facilitate effective allocation of health resources and more cost-effective preventive responses.

One of its key components is an Early Warning System Framework, in which we are proposing several dynamical and statistical models. Dynamical models, in particular, are being used to integrate climatic variables with non-climatic factors in order to simulate malaria transmission dynamics. Twelve process-based models were studied and included in a single multi-model ensemble. Five tools were initially applied in the pilot sites where the ISCS is being implemented. Activities included the characterization of local eco-epidemiological settings and numerical simulations. Characteristics such as general profile (population at risk, natural resources, economic activities), climatic conditions (climatology, long-term trends), entomology (primary and secondary vectors, breeding sites, feeding frequencies, preferences), malaria situation (annual cycles of malaria incidence, stability conditions), and non-climatic factors (including control campaigns) were analyzed to assess local conditions. Simulations included retrospective experiments (base scenarios, changes in initial conditions, local settings, sensitivity analyses, and uncertainties) of at least 8-year simulation periods, as well as short-, medium- and long-term future changing scenarios. Complementary activities included the study of local spatial patterns of vectorial capacity, descriptions of the vulnerability of populations at risk, and a conceptual framework for the analysis of non-climatic drivers. Outreach activities included the design of interactive and online platforms as well as the documentation of our experiences.

Dynamical models have improved our understanding of malaria complexity, allowed us to estimate previous malaria outbreaks in the selected pilot sites, and helped us to investigate decision-making processes. All these activities constitute steps forward in the implementation of the Colombian ISCS.

*Contributed by **D. Ruiz Carrascal**, A.M. Molina, V. Cerón, P. Gutiérrez, M.L. Quiñónes, M.M. Jiménez, **M. Thomson**, **S. Connor**, M.E. Gutiérrez, P.A. Zapata, C. López, **R. Cousin**, S. Osorio and **G.C. Mantilla.***

The contribution of NCEP's CFS predictions to guide water resources in Ethiopia

Ethiopia's population is booming and its economy is growing, demanding energy that has yet to be developed. As a result, 83% of the population lacks access to electricity. Ethiopia possesses abundant hydropower potential, yet less than 10% has been harnessed due to financial, political, socio-economic, and climate challenges. To alleviate this pressure, the Ethiopian government has embarked on an aggressive energy development strategy, doubling installed hydropower capacity within the last few years, with no indication of decelerating (e.g., Figure 41). While other natural sources of electrical generation exist and will likely be exploited, their expected potential is dwarfed by the 30,000MW of economically and technically feasible hydropower generation.

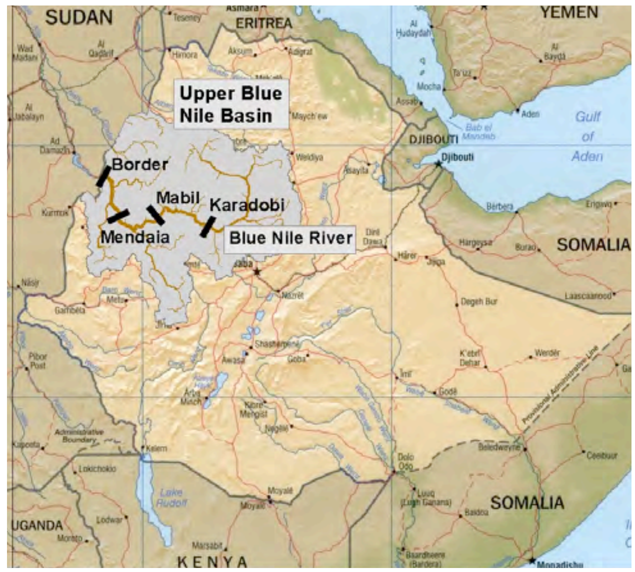


Figure 41. The upper Blue Nile basin, Ethiopia, including proposed hydropower dams. Base map courtesy of the Perry-Castañeda Library map collection, University of Texas.

The Ethiopian highlands, characterized by mountaineous terrain and a major rainy season, is well-suited for hydropower deveopment. This *Kiremt* season (June – September) is an element of the larger east African monsoon season incited by a shift in the Intertropical Convergence Zone (ITCZ) northward. Near the border with Sudan, rains during this season account for nearly 90% of total annual precipitation, while in the Ethiopian highlands, approximately 75% of the annual precipitation falls during the monsoon season (Conway 2000). Dominant factors influencing interannual variability over the upper Blue Nile basin include periods of anomalous warming and tropical depressions over the Indian Ocean, often prompted by the El Niño Southern Oscillation (ENSO) phenomenon, and El Niño events generally are associated with drier than normal conditions.

Understanding and prediction of local precipitation and streamflow variability can improve system operation through informed decision-making and offers advanced warning of droughts and floods. Increased hydropower benefits and the dependability of energy delivery for this region has been demonstrated using a statistical precipitation forecast model, in comparison to a no-forecast approach in which decision-making is based solely on the average precipitation climatology (Block 2011). Accounting for forecast uncertainty has also been demonstrated to improve reservoir release decisions (e.g. Georgakakos and Graham 2008). Multi-model streamflow forecasts for reservoir management have been developed previously (e.g.

Golembeskey et al. 2009), but there had been no demonstration of combined statistical and dynamical precipitation forecast models for application to hydropower management.

The modeling framework consists of probabilistic multi-model seasonal precipitation forecasts, disaggregated into monthly rainfall, which is then fed to hydrology and hydropower models.

Statistical rainfall prediction – The statistical model (Block and Rajagopalan 2007) predicts total June-September seasonal precipitation over the upper Blue Nile basin. One-season lead (March–May) predictors, and their correlation with seasonal precipitation in parenthesis, include sea level pressure (+0.60), sea surface temperature (+0.56), geopotential height (-0.48), air temperature (+0.45), and the Palmer Drought Severity Index (PDSI, +0.33). The predictor patterns of sea surface temperature and sea level pressure resemble ENSO features, yet offer more skill than common ENSO indices. The remaining three predictors capture regional characteristics, with PDSI acting as a surrogate for soil moisture (Block 2011).

The model consists of a nonparametric approach based on local polynomial regression (Loader 1999). Given a set of current predictors, precipitation forecasts are based on neighbors of predictors jointly exhibiting similar conditions to the current ones. The distinct advantage over linear regression lies in the ability to capture features (i.e. nonlinearities) that might be present locally, without granting outliers any undue influence in the overall fit. Optimal model parameters and predictors are selected via the generalized cross validation score function, and the final seasonal forecasts are also cross-validated.

Forecast ensembles are generated by adding to the predicted precipitation value normal random deviates with zero mean and a standard deviation of the cross-validated global predictive error. The seasonal ensemble members are disaggregated into four monthly forecasts through a proportion technique utilizing cross-validated historical averages.

Dynamical rainfall prediction – The dynamical model chosen for this study is the Climate Forecast System (CFS) model of the NOAA's National Centers for Environmental Prediction, Environmental Monitoring Center (NCEP/EMC) (Saha et al. 2006). The CFS was judged superior to other models (atmospheric and coupled GCMs) available through the IRI Data Library for this region and season. The model is a fully coupled ocean-atmosphere model, with no-flux correction. The prediction of land surface hydrology in the CFS uses a two-layer model described in Mahrt and Pan (1984). The hindcasts used to assess model performance and prediction quality, provide 15-member predictions starting each month over the period 1981-2004 and run 9 months into the future. This study uses the one-month lead predictions for June-September (i.e. those available in May).

Combined model rainfall prediction – The combination of dynamical and statistical model is accomplished by assessing each model's forecast performance at each observed time-step, then maximizing the total likelihood through optimally selected model weights. Each month is evaluated independently. A relative balance in contribution between techniques is apparent in July, but more skewed in June, August and September, with each technique dominating in turn. Even so, both techniques clearly contribute information in each month, signifying merit in retaining both statistical and dynamical approaches.

Hydrology & Hydropower Models – The Investment Model for Planning Ethiopian Nile Development (IMPEND, Block and Strzepek 2010) models hydropower potential along the Blue Nile River from its inception at Lake Tana to the existing Roseires dam, downstream of the Sudan-Ethiopian border. IMPEND is deterministic, requiring monthly streamflow and net evaporation at proposed Ethiopian dam locations and at Roseires dam, but may be looped over many climate simulations seamlessly. The four proposed dams are an integral part of the Ethiopian development plan; the version adopted here assumes only Karadobi dam is online (see Figure 41.) IMPEND is classified as a planning tool with operational-level detail to help define feasibility and expectations of project choice. Reservoir head represents the decision variable and net present hydropower benefits constitute the objective value (Block 2011). Hydropower benefits assume that all the hydropower generated is sold at eight-cents per kilowatt-hour. Outputs include net and monthly hydropower benefits, which are discounted back to the simulation start year, energy production, and monthly reservoir levels.

Linked model structure – A time sequence of hydroclimatic variables is required to drive the linked climate – hydrology – hydropower modeling structure. One approach is to choose the 1981-2000 sequence in chronological order. However, since the order in which hydroclimatic variables occur influences the ensuing streamflow, given lags in the system, and since we wish to test the robustness to the climate information, randomly generated sequences are evaluated to understand the envelope of total hydropower benefits based on 1981-2000 climate.
Equally important is a water manager's level of acceptable risk and operational nature. A strategic balance must be made between dependably meeting or exceeding a predefined minimum energy threshold and optimizing overall energy benefits, contingent on priorities and demands. To reflect this, probability of exceedance curves are constructed from each model's precipitation prediction ensemble. Two thresholds of probability exceedance are explored: 95% and 80%, the former being a more conservative prediction. A set of "No forecast" exceedance curves are also presented based on historical climatology, but constructed in a cross-validated mode based on the entire 1981-2000 record.

All prediction techniques yield greater skill than climatology, with the multi-model forecast outperforming the statistical and dynamical approaches by improving correlations with observations and reducing model prediction errors.

A comparison of hydropower outcomes, including economic benefits from the sale of all hydropower generated and the dependability of energy delivery, clearly favor the multi-model forced approach (Table 2). Transitioning to a less conservative probability of exceedance (i.e. from 95% to 80% probability of exceedance) gives an increase in benefits and reduction in losses, without decreasing the dependability of energy delivery. Thus a water manager has a high incentive to adopt the less stringent probability of exceedance without forfeiting benefits or dependability. For reference of the upper limit obtainable in this decision system, the benefits based on a perfect precipitation forecast are also presented in Table 2.

Table 2: Hydropower benefits by forecast technique using various probabilities of exceedance and a threshold of 200 GW_hrs/month.

Forecast Technique	Mean Benefits [$M/dec]	Mean Losses [$M/dec (*f*)]	Dependability [%]	Superior Benefit Cases Decadal [%]	Superior Benefit Cases Annual [%]
Perfect Forecast	3350	-	100%		
prob = 80%					
Statistical	2740	25 (10%)	100%	18	23
Dynamical	2610	100 (66%)	100%	0	15
Multi-model	2780	5 (2%)	100%	82	35
No Forecast	2610	-	>99%	0	27
prob = 95%					
Statistical	2500	35 (23%)	100%	8	20
Dynamical	2200	237 (100%)	100%	0	0
Multi-model	2550	48 (5%)	100%	88	44
No Forecast	2440	-	100%	4	36

Notes: prob = precipitation probability of exceedance, $M/dec = million US dollars per decadal simulation, *f* = frequency of occurrence in %, dependability = percent of months above threshold.
Mean Losses represents the average of simulations for which a loss occurred, defined as years when **No Forecast** benefits are greater than the given Forecast Technique benefits.
For **Superior Benefit** Cases, quantities reflect the percent of simulations for which that technique produced benefits greater than the other techniques.
Perfect forecast uses observed precipitation; **no forecast** uses climatological precipitation

Noteworthy is the fact that the climatological approach (effectively no forecast) appears to outperform the dynamical approach on average (Figure 42 and Table 2). The poor performance of the dynamical approach may be partially attributable to under-dispersion of its ensemble members (Goddard and Hoerling 2006). However its retention is worthwhile, as it provides valuable information in forming the multi-model. Statistical correction of the dynamical model, beyond simple mean bias removal, may also prove beneficial, and is an on-going piece of research. Additionally, although climatological mean benefits are not drastically inferior to benefits

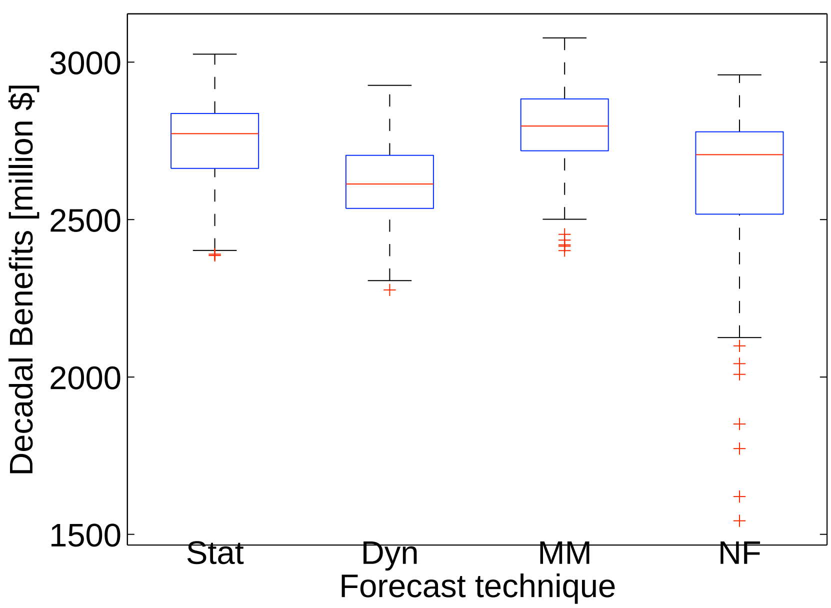


Figure 42. Box plot of decadal benefits from 100 simulations using the statistical (Stat), dynamical (Dyn), multi-model (MM), and no forecast (NF, e.g. climatology) approaches. Precipitation exceedance probability is 80%; target threshold for minimum energy production is 200 GW_hrs/mo.

derived from the statistical or multi-model approaches, a number of simulations are notably low (Figure 42). Elimination of these with the prediction – hydropower forecast system is promising, and may begin to entice managers to incorporate such methodologies into their practices.

Climate predictions with lead times of one season or more often provide prospects for exploiting climate-related risks and opportunities. Past work with statistical rainfall predictions have demonstrated improved information for decision making over long-standing use of simple climatological averages. This study demonstrates that a good quality dynamical model – in this case the NCEP CFS – can improve upon that of tailored statistical prediction as part of a multi-model prediction system. This is true even with straightforward use of the dynamical model (i.e. no sophisticated conditional bias correction, and even though the other approaches may be marginally more skillful when viewed independently.

The linked probabilistic multi-model climate forecast – hydropower system leads to an expected increase in annual benefits by $4-5 million dollars on average. The climate forecast – hydropower system is sufficiently flexible to allow water managers to attain an optimal balance between benefits and the dependability of energy delivery, by varying exceedance probability and target energy thresholds, with the added benefit of forecast guidance. Ideally this provides decision-makers with incentives to integrate improved prediction techniques into sectoral management models, and further justifies expanding efforts into climate forecast improvement.

*Contributed by **P. Block** and **L. Goddard**.*

Blending satellite rainfall estimates and national raingauge observations to produce long -term rainfall time series over Ethiopia

Long-term, temporally homogeneous time series of rainfall data with good spatial coverage are of great importance in a number of applications. The conventional source of climate data is weather stations. However, reliable climate information, particularly throughout rural Ethiopia, is very limited. The available stations are unevenly distributed. The density of stations is relatively good over the central highlands, while there are very few stations over the lowland areas (see Figure 43). Almost all stations are located in cities and towns along main roads. The number of stations with longer time series is even much less. This imposes severe limitations to availability of climate data on the farms and rangelands, where the data are

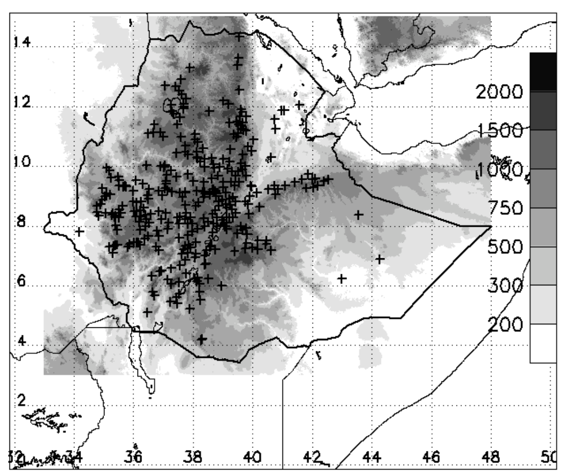


Figure 43. Distribution of raingauge stations with 20 or more years of data between 1981 and 2005. Shading is elevation in meters. Station locations from NMA.

needed most. Data available in the cities and towns also suffer from short time series and severe data gaps. The alternative has been satellite rainfall estimates. The main advantage of the satellite products is the excellent spatial covearge. However, satellite rainfall estimates also suffer from a number of critical shortcomings that include heterogeneous time series, short time period, and poor accuracy particularly at higher temporal and spatial resolutions. Thus, it makes a lot of sense to combine the point accuracy of the raingauge measurements with the better spatial coverage of the satellite estimates. A project underway at the National Meteorological Agency (NMA) in Ethiopia, in collaboration with the IRI, is an implementation of this appraoch. It involves rigorous quality check, gridding the station data to regular grids and blending station data with satellite estimates. The outputs would be 30-year time series of high-resolution (10 km and ten-daily) gridded data sets that can be used to characterize observed recent climate variability and trends and that could be routinely updated to provide real-time monitoring and verification. The gridded products (see Figure 44 for examples) will be in a format that is easier to import into GIS software and could easily be combined with other data of interest.

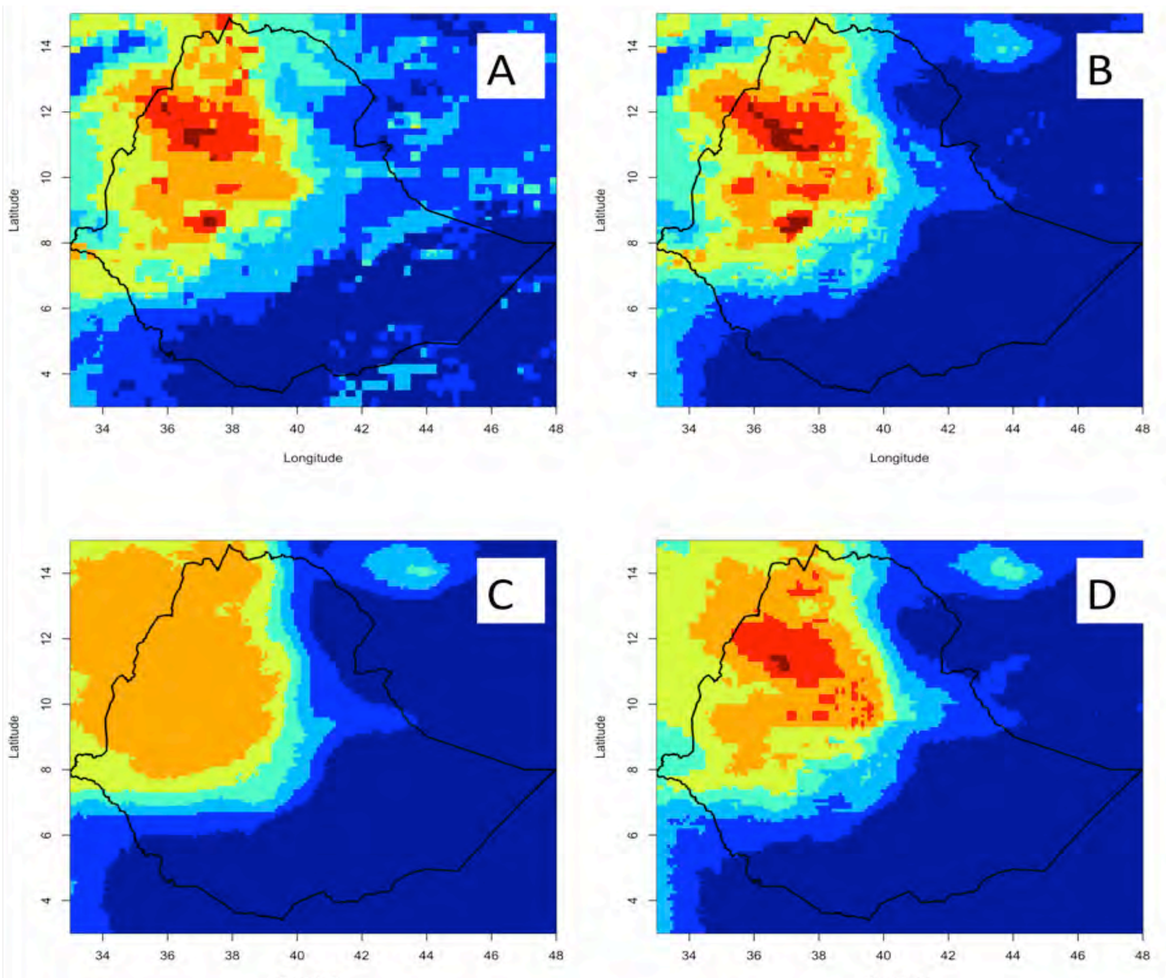


Figure 44. Sample outputs from the collaborative study: (A) Interpolated decadal raingauge data; (B) Same as (A) but satellite estimate used as background filed; (C) Satellite rainfall estimate for the same dekad; and (D) Bias-adjusted satellite estimates using raingauge data.

*Contributed by **T. Dinku**, **S.J. Connor**, D. Grimes, K. Hailemariam, R. Maidement and E. Tarnavsky.*

Statistical and dynamical climate predictions to guide water resources in Ethiopia

Climate predictions with lead times of one season or more often provide prospects for exploiting climate-related risks and opportunities for sectoral application. This motivates the evaluation of precipitation prediction techniques to potentially augment current prediction skill over the Blue Nile basin in Ethiopia. Previous work demonstrated skill using a statistical precipitation prediction model over the basin; here, precipitation predictions from a dynamical model, specifically the Climate Forecast System from NOAA, are also evaluated – both independently and in combination with the statistical approach (forming a multi-model.) Further, this work considers to what degree greater skill or reliability in a particular prediction technique translates through hydropower management models given their nonlinear response.

One hundred precipitation series from the period 1981-2000 are generated to compare prediction techniques. The linked multi-model ensemble climate forecast – hydropower system proves superior to the statistical and dynamical prediction technique linked systems across a range of metrics; an increase in annual benefits by $2-5 million dollars on average, while surpassing a predefined minimum energy threshold with equivalent or greater frequency, is also evident. The climate forecast – hydropower system (e.g., see Figure 45) is sufficiently flexible to allow water managers to attain an optimal balance between benefits and the dependability of energy delivery, by varying exceedance probability and target energy thresholds, with the added benefit of forecast guidance. Ideally this provides decision-makers with incentives to integrate improved prediction techniques into sectoral management models, and further justifies expanding efforts into climate forecast improvement.

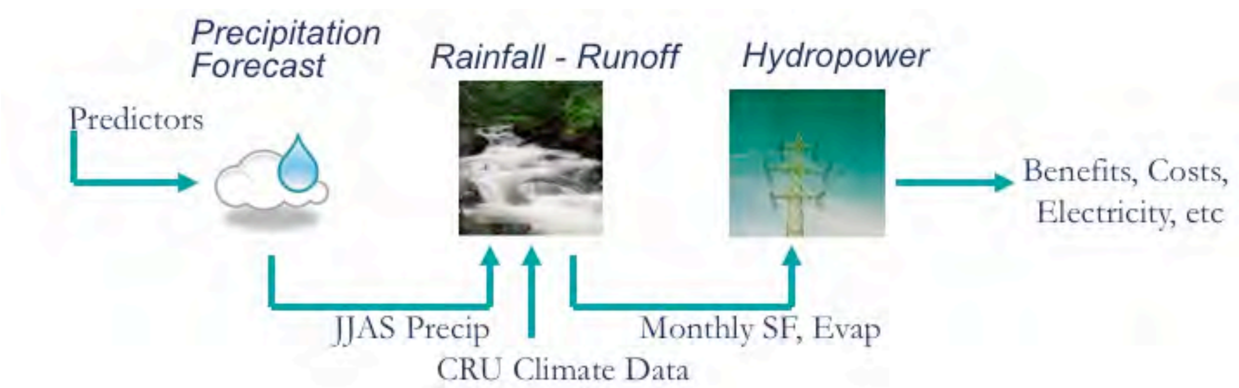


Figure 45. Linked model system components, inputs, and outputs for the upper Blue Nile Basin, Ethiopia. Precipitation forecast component includes statistical, dynamical, and combination approaches.

*Contributed by **P. Block** and **L. Goddard**.*

The impacts of thresholds on risk behavior: what's wrong with index insurance?

Index insurance is a relatively new tool being explored for implementation in developing countries. Since it remains to be established if index insurance is scalable or effective in helping to address development problems, it is important that critiques and evaluations of index insurance interventions appropriately identify and address the basic features of the index insurance and low-income households. An index insurance contract is one that provides its holder with a payout based on the measurement of an index that is correlated with the holder's income. For example, a farmer, whose annual income varies according to his crop's yield, may wish to buy an index insurance contract that pays its holder some amount of money in the event of low rainfall - which is typically associated with lower than average crop yields. A well-designed contract of this type can significantly reduce the variance of the farmer's annual income, which, in turn, can induce a desirable change in the distribution of his long-term wealth and his chance of avoiding a poverty trap (Barnett, Barrett, and Skees, 2008).

One of the most common types of index insurance currently in use is weather-based index insurance for farmers (Hellmuth et al 2009). These contracts are sometimes referred to in the literature as weather derivatives, area-yield insurance contracts, catastrophe bonds or catastrophe options, or index-based risk transfer products (Miranda, 1991; Skees, Black, and Barnett, 1997; Barnett, Barrett, and Skees, 2008). Almost universally, implementers of index insurance for low-income households recommend that index insurance be embedded with other interventions to improve productivity. The insurance is used almost entirely to make the other interventions possible instead of being risk reducing per se (Hellmuth et al, 2009). A common example is to use the insurance to allow farmers to have access to loans by reducing the probability of weather related defaults. Because of the threat of large-scale defaults due to droughts, microfinance institutions are unable to manage the risk of massive simultaneous defaults, leaving farmers without access to credit. By providing index insurance to the lender or the farmer, the risk of drought-driven defaults is lowered, enabling access to credit for productive inputs. In the projects with relatively high-income farmers for which banks can easily enforce repayment, insurance is purchased directly by the banks, and loans are forgiven during drought years. For very low-income farmers, limited liability problems make repayment enforcement problematic (Banerjee and Newman, 2003). For these projects, loans are insured through contracts sold directly to the farmer, and the farmer is required to repay in full in all years, using the insurance as payment when necessary.

An example of such a program exists for groundnuts in Malawi. The goal of the insurance package was to increase productivity (as opposed to reducing the variance of income). The index insurance was bundled as part of a package to provide farmers with high yielding ground- nuts, using drought insurance contracts purchased directly by smallholder farmers to enable access to loans (Hellmuth et al., 2007). Instead of designing the insurance as a tool to reduce variance in income, the contracts were designed solely to target the drought related loan repayment risks that alternate risk management strategies could not effectively address (Osgood et al., 2007).

Implementation partners included the National Association of Smallholder Farmers (NASFAM), the Malawi Rural Finance Corporation (MRFC), Opportunity Inter- national Banking Malawi (OIBM), the Insurance Association of Malawi (IAM), the Malawi Meteorological Agency, and the World Bank Commodity Risk Management Group (CRMG). Technical assistance for contract design was provided by the International Research Institute for Climate and Society at Columbia University (IRI). The key challenge to this program was that the overwhelming farmer take-up rate outpaced the growth capacity of the groundnut supply chain, leading to a shift to other crops with stronger supply chains in the third year of the project (Hellmuth et al., 2009).

Testing the assumptions behind the bundled design of the pilot, in the second year of the project's implementation, Gine and Yang (2009) offered two versions of the contract in a randomized experiment. It is important to note that this study was an analysis of the insurance bundling issue, not an evaluation of the impacts of the insurance-driven development project. The first product was the combined insurance/loan bundle offered outside the experiment. In the other version, the researchers offered the loan without requiring the farmer to purchase insurance. They found that take-up rates of the package that required insurance were substantially lower than those of the package that did not require insurance. These perhaps surprising findings were that the farmers were more interested in the purely production-improving package than the one that included insurance-based risk reduction. The authors attribute the lack of interest in the insurance to the implicit insurance due to the limited liability of the low-income farmers. These findings support the assumptions of the implementation project, that index insurance for low income farmers should be used not as risk reduction per se, but instead to enable productivity-increasing activities. From this experience it appears that these farmers whose livelihoods are severely threatened by weather variability place relatively little value on reduction of variance as compared to increases in productivity. If low-income farmers are highly risk averse, why do they place so little value on risk reducing insurance once their access to productive inputs is secured? In general, what could justify the assumption of index insurance implementers targeting the lowest income households that insurance should be used as a tool to increase productivity instead of using it to reduce variance? In the project reports of implementers, poverty traps are mentioned, however a model explaining how poverty traps lead to a preference for productivity over variance reduction is missing.

We explore the optimal design of an insurance contract for farmers who are living in great poverty, and find another reason for farmers to be less risk averse than they would be in a mean-variance utility framework. This reason is that less risk aversion results in a greater probability of avoiding a poverty trap. In fact, the closer a farmer is to a poverty trap threshold, the less willing he is to give up some of his expected income in exchange for a reduction in income variance. The focus of our work is the optimal design of index insurance contracts, with applications to weather-based index insurance for farmers. We consider contract design as it relates to two goals: (1) reducing the variance of a farmer's annual income, and (2) helping a farmer avoid a poverty trap. We set-up the problem by introducing a simple form for the payout function, using a known joint probability distribution to describe the relationship between the index and the yield. We then design optimal contracts in a mean-variance utility maximization framework. That is, we create a framework for a poverty trap and design contracts that are optimal in the sense that they minimize a farmer's probability of falling into a poverty trap.

*Contributed by **D.E. Osgood** and K.E. Shirley.*

Rising temperatures over the Kericho tea estates: revisiting the facts in the East African highlands malaria debate

The distribution of malaria in sub-Saharan Africa is determined largely by climatic influences and so malaria is considered a climate-sensitive disease. The development of both the parasite *Plasmodium falciparum* that causes malaria and the Anopheline mosquito that transmits it, are particularly sensitive to temperature. The availability of suitable climatic conditions for the development of Anopheles mosquitoes and *Plasmodium falciparum* is largely responsible for the geographical distribution of malaria today.

A study in 1998 by Lindsay and Martens suggested that increasing global warming could result in the geographic spread of malaria transmission into previously malaria–free highland areas. Since then the research community has been divided over the validity of this statement resulting in a highly polarized debate reported in multiple peer-reviewed publications; more than 10 years later, researchers are unable to concur. Studies on temperature impacts on malaria have centered on analyses conducted in the East African highlands in Kericho, a district that lies at 1600 to 3000 meters above sea level in the western highlands of Kenya. Laboratory-confirmed malaria incidence data are available from the Brooke Bond tea estate health facilities from a period where confounding effects such as those brought about by demographic influences, interventions against malaria and marked environmental changes are constrained (Malakooti et al. 1998).

The malaria data from Kericho are a significant resource for modeling climatic and other drivers of malaria epidemics given the paucity of long time series of high quality data. Researchers have generally paid inadequate attention to the quality and relevance of the climate data used in the analysis of temperature and malaria. The result of this is that the findings from many studies are largely confounded by the poor quality and inappropriate use of climate data. Research to date has focused on answering four key questions: (1) Is malaria increasing or re-emerging in the East African highlands; (2) Are temperatures increasing in the East African highlands; (3) If there is a warming trend in the highlands, is it related to global climate change; and, (4) If there is a warming trend, is there a causal relationship between this trend and trends in malaria incidence?

This study uses 31 years (Jan.1979 to Dec. 2009) of quality controlled (97% complete) daily observations of maximum and minimum temperature from Kericho meteorological stations sited in a tea-growing area (e.g., Figure 46) of Kenya's western highlands. These 'Gold Standard'

Figure 46. Partial view of a large tea estate in Kericho, Kenya

meteorological observations are compared with gridded temperature datasets that have been used extensively to investigate climate trends in Kericho. The relationship of local climate processes (at Kericho) with larger climate variations (SST, ENSO), is also assessed.

An upward trend of 0.2^{O}C/decade was observed in both temperature variables ($P<0.01$) after adjusting the time series for temporal inconsistencies. Temperature variations in Kericho were associated with large-scale climate variations including tropical Sea Surface Temperatures ($r= 0.61$; $p<0.05$). A comparison with two versions of a gridded temperature data set showed markedly different trends when compared with each other and with the Kericho station observations.

This study presents conclusive evidence of a warming trend of ~ 0.2^{o}C per decade in observed minimum (Figure 47) and maximum (Figure 48) temperatures at Kericho during the period 1979 to 2009. The findings also show strong connections to global climate processes including El Niño and La Niña, as well as longer-term trends.

Global climate services, relevant to the achievement of the Millennium Development Goals and the analysis of infectious disease in the context of climate change are being developed and the malaria community could avail themselves of this new opportunity through partnership with national meteorological agencies and climate scientists.

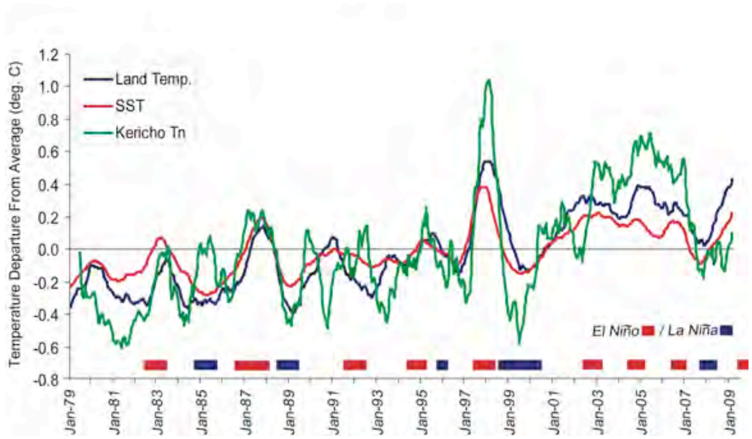


Figure 47. Monthly departures from 1980-2009 mean values (in degrees C with 11 month moving average applied) for Kericho Tmin (green), global tropical SST (red), and tropical land area temperature (blue). Bars at base show occurrence of ENSO events.

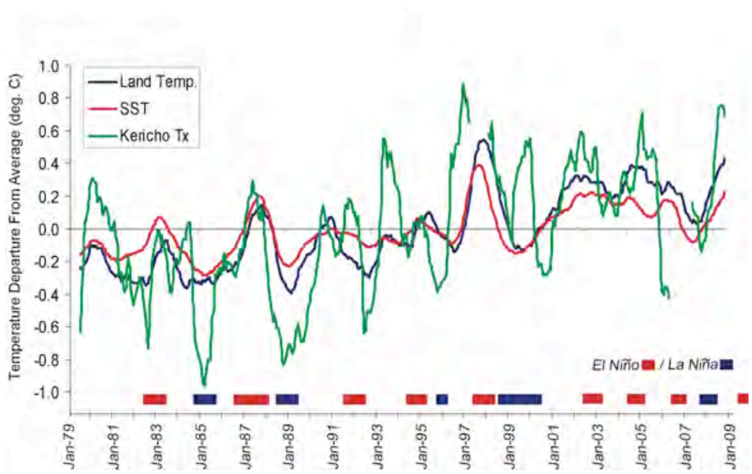


Figure 48. Monthly departures from 1980-2009 mean values (in degrees C with 11 month moving average applied) for Kericho Tmax (green), global tropical SST (red), and tropical land area temperature (blue). Bars at base show occurrence of ENSO events.

*Contributed by **J. Omumbo** and **B. Lyon**.*

Assessing the impact of mineral dust on human health: dust monitoring campaign in the Sahel

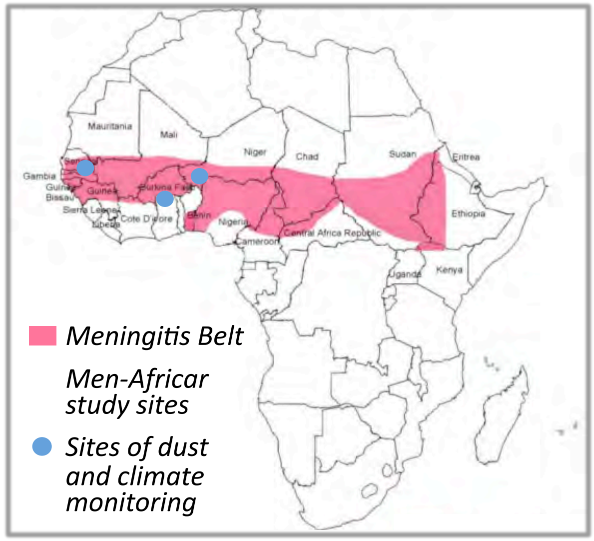


Figure 49: Map of dust and meteorological conditions monitoring sites in the context of Meningitis Belt and Men-Africar study site.

It is well known that mineral dust aerosols have a strong impact on climate and environment by, for example, altering the global energy balance, affecting ozone chemistry and impacting oceanic and terrestrial biochemical cycles. Close to sources, they also directly affect a number of human activities by reducing visibility, thus disturbing ground and air transportation, or directly threatening human health, causing acute respiratory and eye infections, pneumonia, bronchitis, cardiovascular disease and potentially meningococcal meningitis. The latter occur especially in the so-called 'Meningitis Belt' (Figure 49) where the attack rates are many times higher than elsewhere in the world. The region lies within the Sahara–Sahel 'Dust Corridor', extending from Chad to Mauritania, along which winter Harmattan winds (November to March) blow huge amounts of mineral dust mainly from northeast to southwest. To the south of this region intensive burning of agricultural waste occurs in the dry season and aerosol particles—mainly black carbon (BC) and organic carbon (OC) —are advected to the region by the warm and moist southerly winds. The determination of surface aerosol concentrations and their detailed chemical and mineralogical characterization are needed to establish a detailed assessment of human exposure levels. However, the information on atmospheric aerosol is sparse in the Sahel and severely limited by the availability of data – existing data consist of in situ horizontal visibility or column-integrated measurements from sun-photometers in a handful of locations, which clearly do not have appropriate spatial and/or temporal coverage. The remote-sensed observations, while providing a better spatial coverage, suffer from short time span and do not directly provide information about surface conditions – the latter could be potentially retrieved using calibration techniques that require in-situ measurements. None of those sources is able to provide information about dust composition and its potential toxicity. Thus, there is a need to obtain in situ measurements of mineral aerosol characteristics to examine human exposure levels and assess the potential of proxy historical data and remote-sensed information to perform such assessments on larger scales.

To complement the on-going 'Men-Africar' (http://www.menafricar.org/) effort, aimed at the assessment of meningitis bacteria carriage levels and their relationships to meningitis infection across 7 countries in the Sahel, we implemented pilot observing systems for dust and meteorological variables in 3 of the Men-Africar sites (Figure 49), in collaboration with local institutions.

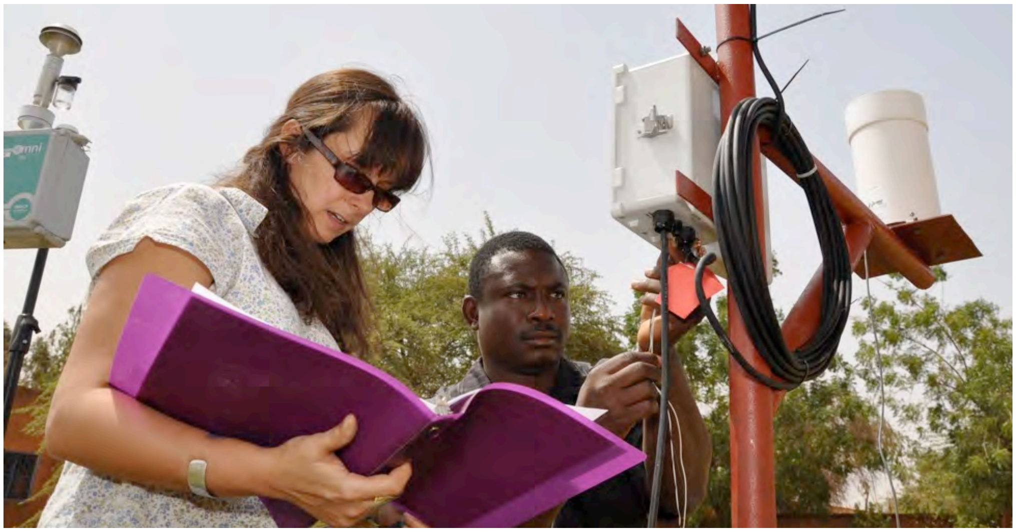


Figure 50: IRI Associate Research Scientist S. Trzaska and CERMES Laboratory Technician Ibrahim Arzika testing equipment at CERMES, Niamey, Niger.

Our objectives are:

1. To quantify atmospheric aerosol levels in order to better understand and quantify related health impacts in sub-Saharan Africa: investigate near surface atmospheric aerosol (mainly dust) characteristics specific to the Sahel, including mass concentration and elemental composition and their variability during the dry season in three sites in sub-Saharan Africa; explore the potential for exposure inference from proxy sources (visibility and satellite proxies); validate a dust forecast model and analyze the predictability of dust storms; and,

2. Perform a preliminary analysis of the relationship between aerosol concentrations and compositions and weekly MM incidence in each locale: are the concentration and composition of mineral dust (and/or biomass burning smoke) in the meningitis belt likely factors in the transition from asymptomatic carriage to meningitis? Are the concentrations exceptionally high or is there any toxicity specific to the region? Can the weekly evolution of concentration/composition be related to the evolution of weekly MM cases? Are there extreme events or cumulative effects? Is there a best fitted time lag between events and meningitis? Can changes of concentration and/or composition be traced back to specific sources and/or specific meteorological events? Can those be predicted and at which lead-time?

The equipment was deployed between February and March 2011 (Figure 50) and the current campaign will last till the end of 2012 dry season. We hope to extend the monitoring period as well as to add sites in the near future.

This project is partly supported by the NIEHS Center for Environmental Health in Northern Manhattan grant ‘The role of dust in meningococcal meningitis in the Sahel: are dust characteristics conducive to higher incidence rate?’ and Columbia University Cross Cutting Initiative ‘Atmospheric aerosol impacts on health in sub-Saharan Africa’.

Contributed by ***S. Trzaska***, ***C. Perez***, ***M.C. Thomson***, *P. Kinney, and S. Chillrud.*

Modeled and observed atmospheric mineral dust aerosol in sub-Saharan Africa and meningococcal meningitis: preliminary results

In addition to impacting the climate and environment, mineral dust aerosols have a direct effect on human health, often causing acute respiratory symptoms and potentially contributing to Meningococcal Meningitis outbreaks. In order to understand the relationship between Meningitis epidemic outbreaks and dust events it is important to monitor mineral dust variability occurring in the ‘Meningitis Belt’ where the attack rates are many times higher than elsewhere in the world. This area roughly coincides with the Sahel, and Meningitis disease adds to the already strained economy of the region. The scientific and user communities have expressed the need for high spatial resolution and real-time information on mineral dust aerosols in order to develop methods to mitigate their impact. The objective of this study is to validate recent mineral dust products that have been developed to estimate and monitor the evolution of mineral dust at high spatial and temporal resolutions.

The new mineral dust aerosol products have been derived from: i) Satellite aerosol products; In particular, we used Aerosol optical depth (AOD) and nonspherical (dust) aerosol fraction products provided by the Multi-angle Imaging SpectroRadiometer (MISR) sensor on-board the TERRA satellite (*Diner et al., 2005; Kalashnikova et al., 2005; Kalashnikova and Kahn, 2006* - referred to hereafter as MISR*);* ii) two recently developed dust models: one embedded in a regional model – NMMB/BSC-Dust (Perez *et al.*, 2011 - referred to as RCM) and one embedded in a global model - GISS ModelE-Dust (Miller *et al.*, 2006 - referred to as GCM). For comparison purposes data derived from TOMS OMI (referred to as OMI) have also been used. These data have been compared to data from AERONET stations that record aerosol optical depth in 16 stations across the Sahara and the Sahel (Figure 51).

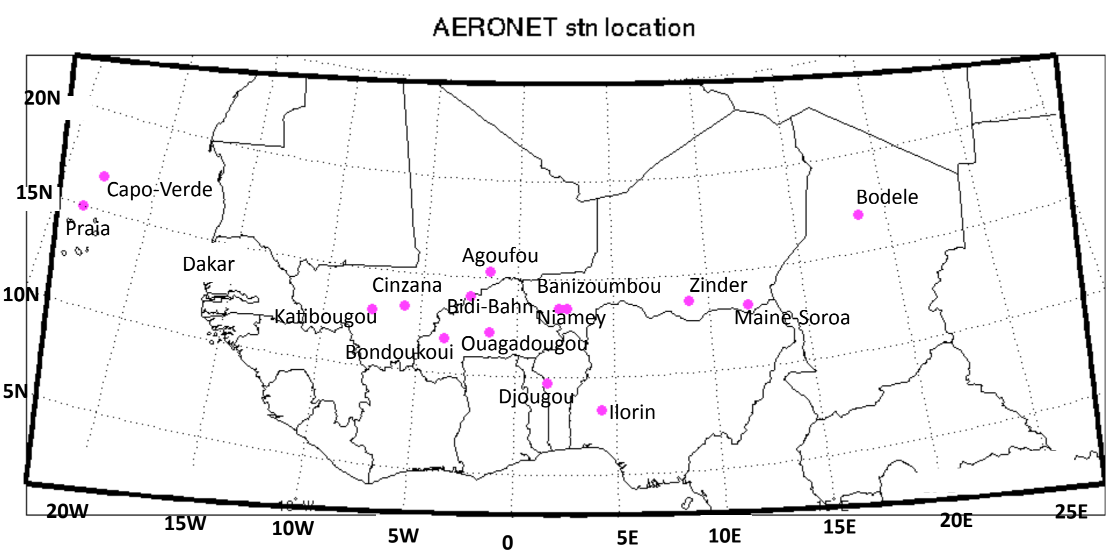


Figure 51. Locations of AERONET stations in the Sahara and the Sahel.

The initial validation included linear correlation analysis between pairs of daily, weekly and monthly values from different sources at the 16 locations. The results presented in Figure 52 show correlation coefficients obtained between the daily data from each of the new products and the AERONET data and between different products.

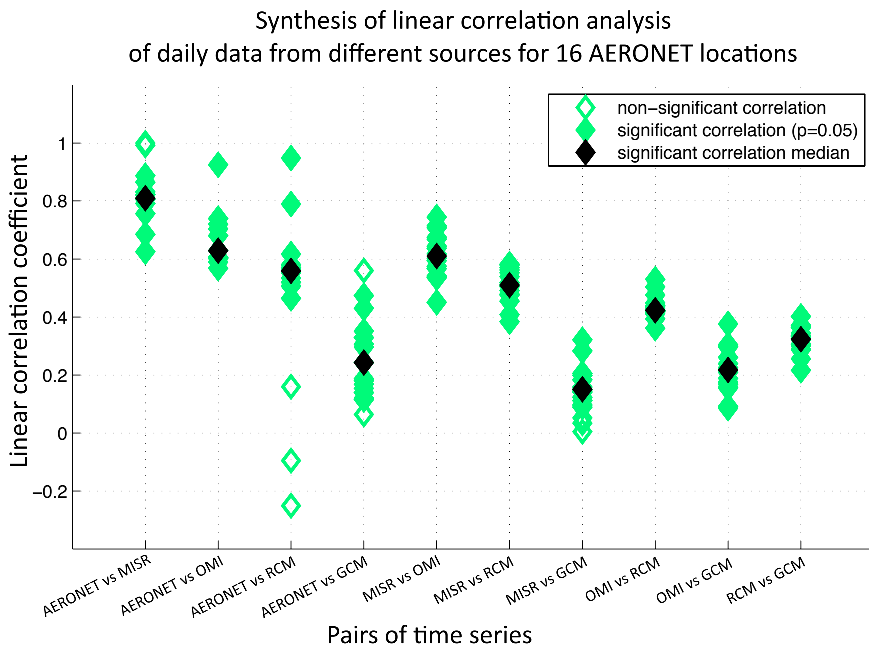


Figure 52. Linear correlation coefficients between time series of daily data from different products at the 16 AERONET locations

Preliminary results show that the highest correlation values are obtained when comparing the AERONET and MISR data. Correlations are also high between AERONET and OMI and between MISR and OMI. This highlights the consistency between satellite-derived products. Correlations between observations or satellite data and RCM are also good while the GCM performs less well at this spatial scale. However, although the MISR products seem to provide a better point estimation of mineral dust aerosols than the models, they do not provide the high temporal and spatial coverage (daily values covering the entire region for an extended period) of dust events that is required to understand the risk of meningitis outbreak. Good performance of the RCM gives us hope that the combination of RCM and MISR data will give us a good representation of mineral dust in the region. While the GCM may not perform as well in this 'point' validation it is expected that it will capture well other aspects such as interannual variability and larger scale events, not investigated in this study. Further investigations will assess how well MISR and the two models capture the seasonal cycle and inter-annual variability. These findings and additional analyses will soon be submitted for publication in a peer-reviewed journal.

This work has been partly supported by the NASA grant NNX09At49G "Environmental Factors and Population Dynamics as Determinants of Meningococcal Meningitis Epidemics in the Sahel: An Investigation of NASA and NOAA Products"

*Contributed by **P. Ceccato**, **J. del Corral**, O. Kalashnikova, R. Miller, **C. Perez**, J. P. Perlwitz and **S. Trzaska**,*

Quantifying the influence of climate on meningococcal meningitis epidemics in sub-Saharan Africa in the context of reactive control

An area of sub-Saharan Africa termed 'the Meningitis Belt' is frequently affected by large-scale meningitis epidemics with heavy consequences for the populations. Because currently available vaccines do not confer long-lasting immunity, meningitis epidemics in this region are controlled via a reactive vaccination: once the meningitis incidence has exceeded a particular threshold the population at-risk is vaccinated. This strategy operates at the district-level. There is a strong demand from WHO in charge of control operations to predict the risk of meningitis outbreaks before the operational threshold is crossed to increase preparedness and save more lives in resource scarce environments via actions such as improving the surveillance or prepositioning the vaccines.

Climate conditions have long been recognized as potential meningitis determinants: epidemics only occur during the dry season, in locations where humidity is low and conditions are dusty, and end abruptly with the beginning of the rains. However, as yet, little has been done to determine if these relationships can assist in improving epidemic control. Under the remit of the Meningitis Environmental Risk Information Technologies (MERIT) project, meningitis incidence data from Niger, a country which one of those most affected by meningitis epidemics, has been used to explore the relationship between incidence and a number of climate variables, with a particular emphasis on whether a particular variable, or combination of variables, can be used to predict future epidemics. Meningitis incidence data were available on a weekly temporal scale and district-level spatial scale for the period 1986-2007. Climate variables for the same period were obtained from the daily NCEP Reanalysis, and were extracted and aggregated to the appropriate spatial and temporal scale via the IRI data library.

Two temporal and two spatial scales have been explored - the seasonal and the weekly time scales and the national and district spatial scales. The analysis at the seasonal scale is aimed at determining if climate conditions could provide information about the epidemic risk before the start of the season (and at which spatial scale). The weekly scale analysis was conducted in order to determine whether climate information could help predict which districts would cross the epidemic threshold next (thus increasing the lead-time for the decision to vaccinate).

At the national scale, the variables most strongly related to the dry season incidence were monthly values of specific humidity at 10m in November, and specific humidity at both 2m and 925hPa in December, explaining respectively 28%, 42% and 35% of the log transformed incidence at the national level. The best multivariate linear model, determined through a backward selection, retained 4 climate variables, and explained 67% of the variability in the incidence data. The 'leave-one-out' cross-validation predictions captured 59% of observed variations. At the district scale, the best correlations between average seasonal incidence and climate variables were obtained for February averaged temperature at the surface, and December and February specific humidity at the surface and at 925hPa with strongest relationships observed in the south and the west of the country (Figure 53). In general, the relationships

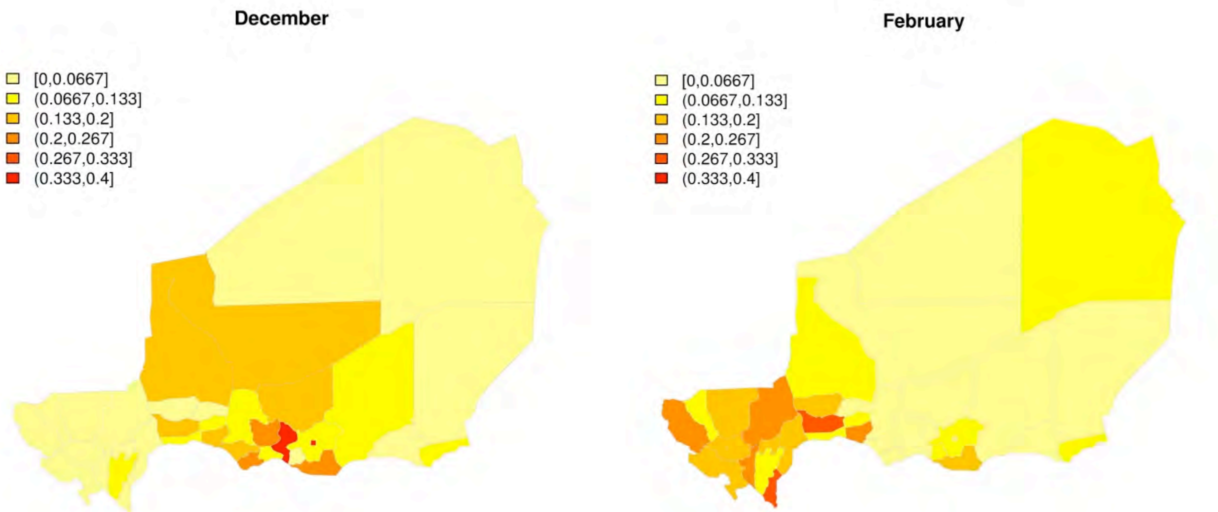


Figure 53. Coefficient of variation between dry season incidence at district level and December atmospheric humidity (left), and February minimum surface temperature (right)

between climate and dry season incidence in the north and east of the country were weak.

At the weekly temporal scale, three types of models were fitted to the data: (a) a univariate model, (b) a model with a fixed seasonal cycle, (c) a dynamic linear model, with a varying season cycle. Several forms of the climate variables considered, including single lagged climate anomalies, and lagged climate anomalies averaged over the previous four weeks (to account for the cumulative affects of climate on the disease). Additionally, the information about incidence levels in previous weeks was considered. Models were evaluated through standard scores such as root mean square error as well as criteria more relevant to the meningitis control strategy such as True Positive/Negative rates.

At the national level, a statistically significant relationship was observed with several weekly climate indicators; however, no variable stood out as a particularly good predictor. The largest improvement in the performance of the model was made through incorporating previous incidence in both models of type (a) and type (b) – as shown in Figure 54. Further incorporating

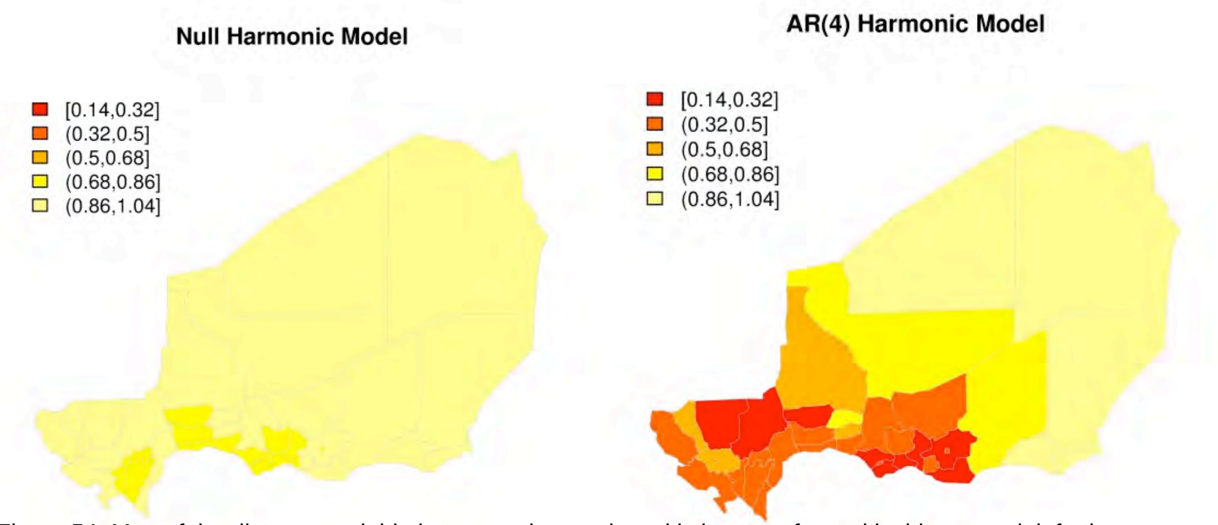


Figure 54. Map of the distance variable between observed weekly log transformed incidence and: left -the regression model including only the seasonal cycle of incidence; right- the model with 4 autoregressive components.

climate variables into these models made a small, but noticeable improvement to the control-driven criteria, with the weekly meridional wind leading to the largest improvement. The dynamic linear model results were similar to those obtained from fitting the fixed seasonal cycle model with a dependence on previous incidence. The analysis at the district level yielded similar conclusions.

The seasonal analysis confirmed previous results obtained at the national scale with different data and allowed us to estimate climate influence at the district level. The strongest links occur between seasonal incidence and temperature or specific humidity present coherent spatial structures, consistent with the scales of climate variability and need to be further investigated. At the weekly scale, the best predictor is past incidence itself, with observed climate conditions improving predictions only marginally.

Contributed by M. Stanton, ***S. Trzaska****,* ***C. Perez*** *and* ***M.C. Thomson****.*

Integration of demographic, climate and epidemiological factors in the modeling of meningococcal meningitis epidemic occurrence in Niger

Meningococcal meningitis (MM) presents its highest activity and toll on populations in Sub-Saharan Africa, in an area determined by its environmental conditions and designated as the ‘meningitis belt’ stretching from Senegal in the west to Ethiopia in the east. Outbreaks of Meningococcal epidemics have been related to natural conditions such as dry and dusty environment (Lapeyssonie 1963) with epidemics usually concentrated in the core of the dry season (January to April). The spatial risk distribution based on environmental suitability factors (absolute humidity, absorbing aerosols, rainfall and land-cover) has been previously modeled based on large scale information (Molesworth et al. 2003; Savory et al. 2006). However, other factors need to be incorporated in the modeling of meningitis such as demography (population size, density, age structure) and immunological state of the population. In particular the spatial distribution and concentration of large-size epidemics suggests that “demographic risk factors are important in the development of larger disease outbreaks” (Pollard and Maiden 2003).

The availability of high quality epidemiological data (weekly incidence at district level between 1986 and 2007) allow us to further explore the role of those factors: the overall climate conditions in Niger are adequate for meningitis outbreaks everywhere but the incidence of meningitis varies during the year, from year to year, and across districts. As a starting point we explored the role of population distribution (size, density, urban vs. rural fraction) on the spatial distribution of the frequency of epidemic outbreaks as defined by WHO operational threshold of 10cases/100,000 per week. District population data were obtained from the same WHO source as the epidemiological data while the urban/rural distribution was estimated within the GRUMP project (CIESIN *et al.* 2004). Population density (Figure 55) is likely related to the spread of the disease, while a rural or urban residence generally marks differences in terms of access to health care, information and resources (Balk et al. 2003).

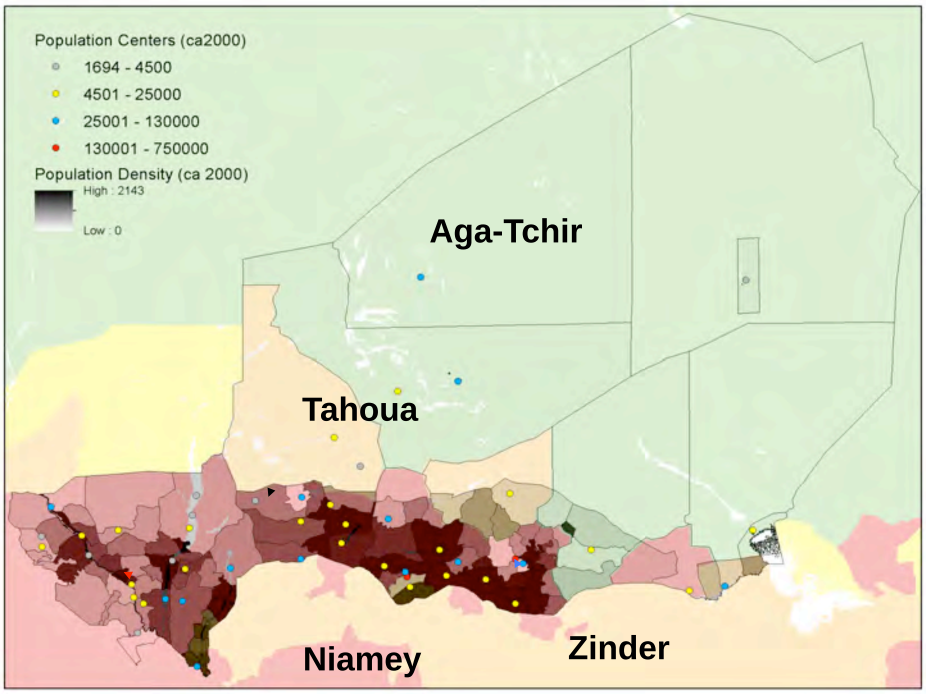


Figure 55. Meningitis risk zones, population density and population centers in Niger's districts, ca 2000. A darker shadow indicates higher population density. Sources: own elaboration based on Molesworth et al. 2003;and CIESIN et al. 2004.

Results from a stepwise linear regression drawing from 11 independent variables at district level that capture: demographic characteristics such as log10(Total Population), log10(Population density), percentage urban population, and percentage urban area; geographic factors such as district area ad latitude and longitude of district centroids; and, climatic characteristics - the January to March averages for zonal and meridional wind components, temperature and specific humidity at 925 hPa level from NCEP Reanalysis indicate that the spatial distribution of epidemic frequency in Niger is modeled reasonably well using log10(pop density), and only modest improvement in the skill is obtained by adding meridional wind at 925hPa and log10(total population) as predictors (Figure 56). Those results highlight the fact that, in areas where climate is not a limiting factor, spatial differences in average climatic conditions may not

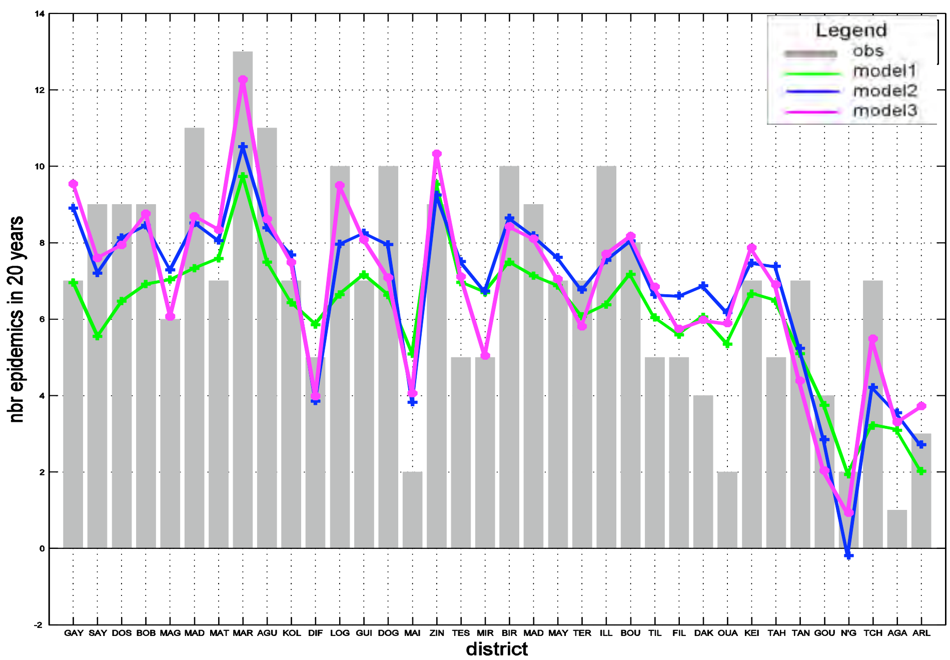


Figure 56. Observed (grey bars) and modeled (solid lines) number of epidemic years in each district in Niger during 1986-2007. Model 1, 2 and 3 refer respectively to linear regression models using 1,2 or 3 predictors. Linear correlation coefficients between observed and modeled number of epidemic year are: 0.69, 0.76 and 0.8 respectively and the RMSE=2.1, 1.93 and 1.79. Districts are ranged according to the latitude of their centroid.

be a discriminating factor in spatial distribution of epidemic and that, at this scale, variations in population density play the key role. Future work will focus on exploring the role of population mobility.

This study was partly supported by a NASA-ROSES grant NNX09AT49G - ' Environmental factors and population dynamics as determinants of meningococcal meningitis epidemics in the Sahel: an investigation of NASA and NOAA products' - and by a Cross Cutting Initiative grant from the Earth Institute, Columbia University -'Towards improved control of meningitis outbreaks in sub-Saharan Africa'.

Contributed by ***S. Trzaska****, S. Adamo, G. Yetman,*
J. del Corral*,* ***M. Thomson*** *and* ***C. Perez.***

Enhancing the utility of daily GCM rainfall for crop yield prediction in Kenya

Global climate models (GCMs) are promising for crop yield predictions because of their ability to simulate seasonal climate in advance of the growing season. However, their utility is limited by unrealistic time structure of daily rainfall and biases in rainfall frequency and intensity distributions. Crop growth is very sensitive to daily variations of rainfall; thus any mismatch in daily rainfall statistics could impact crop yield simulations. Here, we present an improved methodology to correct GCM rainfall biases and time structure mismatches for maize yield prediction in Katumani, Kenya. This includes GCM bias correction (BC), to correct over- or under-predictions of rainfall frequency and intensity, and nesting corrected GCM information with a stochastic weather generator, to generate daily rainfall realizations conditioned on a given monthly target.

Bias-corrected daily GCM rainfall and generated rainfall realizations were used to evaluate crop response. Results showed that corrections of GCM rainfall frequency and intensity could improve crop yield prediction but yields remain under-predicted (see also Ines et al., 2010). This is strongly attributed to the time structure mismatch in daily GCM rainfall leading to excessively long dry spells. To address this, we tested several ways of improving daily structure of GCM rainfall. First, we tested calibrating thresholds in BC but these were found not very effective for improving dry spell lengths. Second, we tested BC-stochastic disaggregation (BC-DisAg) and appeared to simulate more realistic dry spell lengths using bias-corrected GCM rainfall information (e.g., frequency, totals) as monthly targets. Using rainfall frequency alone to condition the weather generator removed biases in dry spell lengths, improved predicted yields, but under-predicted yield variability.

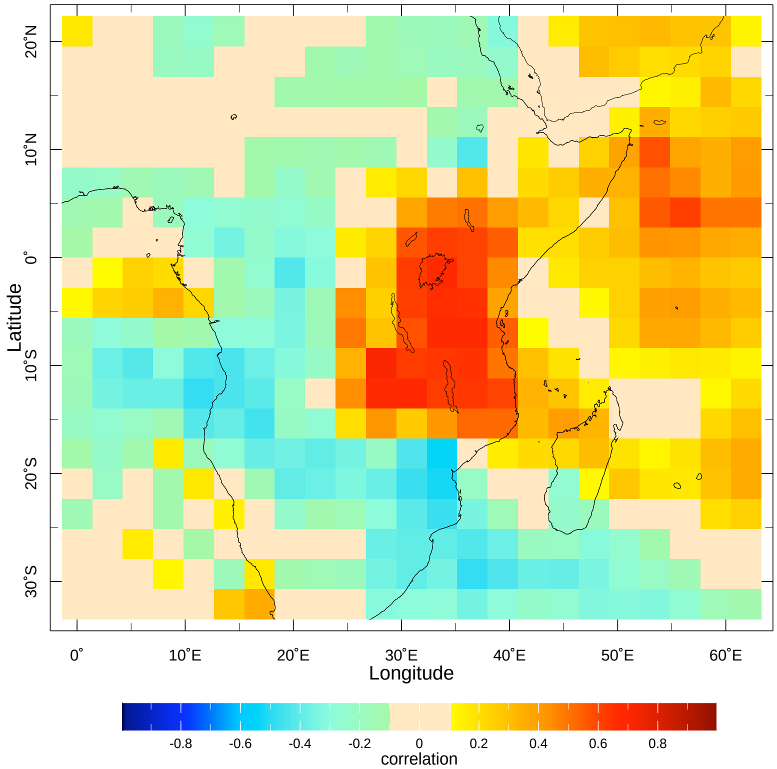


Figure 57. Correlation map of raw October-December ECHAM v4.5 rainfall and maize yield simulated by observed weather at Katumani Dryland Research Center.

Combining rainfall frequency and totals, however, not only produced more realistic yield variability but also corrected under-prediction of yields. The skill of the GCM (e.g., see Figure 57) is still the final determinant for the overall success of the approach. We envisaged that the presented method would enhance the utility of daily GCM rainfall in crop yield prediction.

*Contributed by **A.V.M. Ines**, **J.W. Hansen** and **A.W. Robertson**.*

Predictability of rice production in the Philippines with seasonal climate forecasts

The El Niño Southern Oscillation (ENSO) is the most influential factor on interannual variability of the Philippines climate, and the impacts of ENSO on the Philippine rice production have been previously documented. In this study, predictive empirical models for rice production and yield are constructed and tested based on coupled and uncoupled general circulation models (GCMs) currently used for seasonal climate forecasts, as well statistical predictors comprising Niño 3.4 SSTAs and warm water volume (WWV) in the equatorial Pacific Ocean, using multiple linear regression (MLR), principal component regression (PCR), and canonical correlation analysis (CCA).

A summary of results for nationally-aggregated crop data is shown in Figure 58. The two coupled GCMs are shown to have high predictive skills (r~0.8) for dry-season national rice production (both irrigation and rainfed systems) with lead time of half a year (six months before the beginning of the harvest). It is found that purely empirical models based on WWV and zonal wind anomalies over the equatorial west Pacific attain similar predictive skills to those of the coupled GCMs, whereas the skill of the uncoupled GCM is somewhat lower. Predictive skills at regional levels are generally lower than those for the Philippines as a whole, with higher

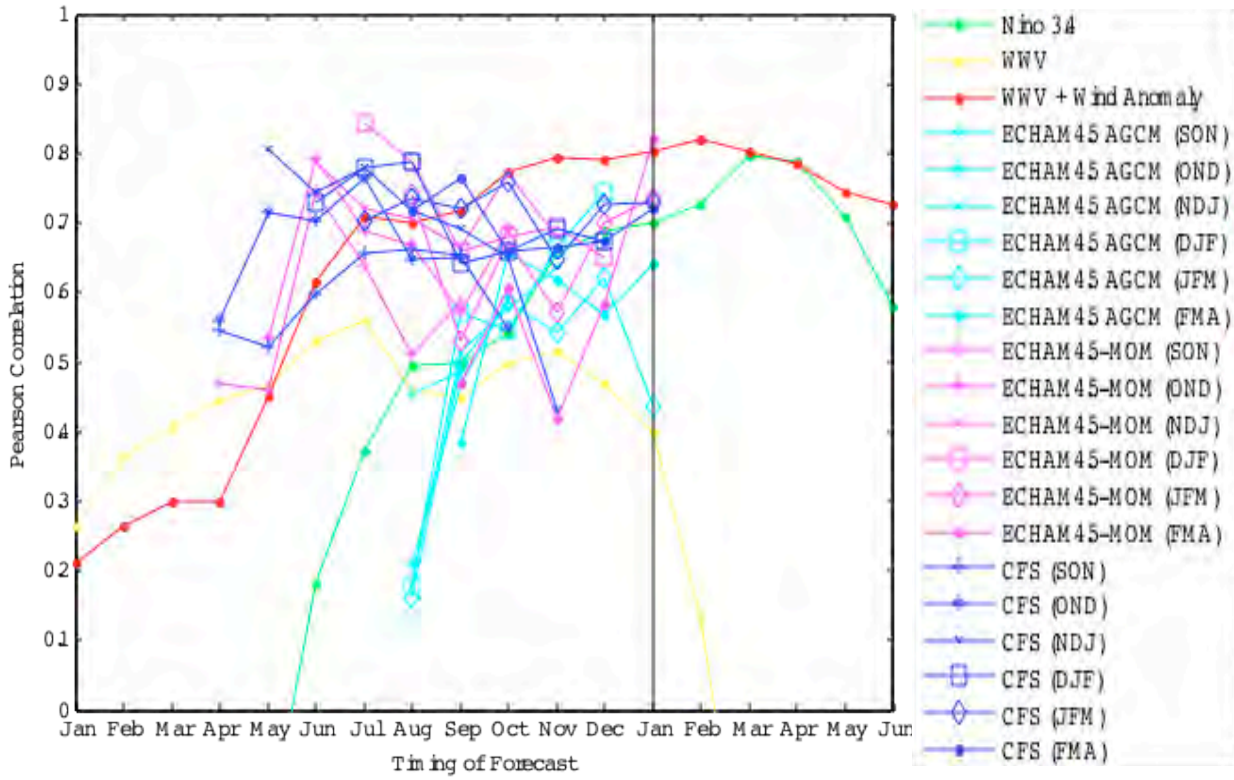


Figure 58. Cross validation correlation skills of dry-season rice production of all ecosystems of the Philippines. Nino 3.4, WWV, and WWV plus zonal wind anomalies over the west equatorial Pacific (1980-2007) were used as predictors of multiple liner regression (MLR). Seasonal precipitation anomalies over 0N-25N, 110E-130E forecasted with ECHAM 4.5(1980-2006), ECHAM4.5-MOM (1982-2007), and NOAA CFS(1981-2007) were used as predictors of principle component regression (PCR).

predictive skills located in southwest of Mindanao and the central Philippines.

Rainy season rice national production is found to be correlated with rainfall in a more complex manner. The national area harvested in the Philippines correlates positively with rainfall during the preceding dry season, while national-level yield in the rainy season exhibits positive and negative correlations with rainfall in JAS and in OND respectively. We found that WWV plus zonal wind anomalies over the equatorial west Pacific have high predictive skills (r~0.7) with a few months lead time from the beginning of the harvest. Only regions in Luzon showed high predictability while the other regions do not. Such a spatial difference in predictability of rainy season rice production might be due to difference in impacts of climate such as flood and tropical cyclones on the yield.

The results show high potential of climate information for prediction of rice production in the Philippines, and encourage efforts to evaluate the potential value of this climate information for prediction of rice production.

*Contributed by N. Koide, **A.W. Robertson**, **A.V.M. Ines** and **J.-H. Qian**.*

Seasonal and longer - range forecasts: a new chapter

A second edition of the standard and widely cited text book *Forecast Verification: A Practitioner's Guide in Atmospheric Science* (Wiley& Chichester, 2nd edition) is planned for publication in 2011. The new edition will include a new chapter on the verification of seasonal and longer-range forecasts. This chapter begins with the premise that there is no inherent reason why forecasts of different timescales (seasonal, decadal, and longer-term climate change projections) should be verified in different ways, except to the extent to which the forecasts are presented in different ways. Verification procedures should be defined according to what one wants to know about the quality of forecasts, and it is only the extent to which the nature and availability of forecasts at different timescales limit the extent to which one can meaningfully address these questions of forecast quality that verification procedures should be timescale specific. That said, there are a few criteria that do impose restrictions on the choice of verification procedures when analyzing the quality of seasonal and longer-range forecasts, which necessarily shape how these forecasts are best verified. These criteria are: the limited availability of historical predictions, which severely limits sample size; and the often-weak levels of skill largely because of inherently low predictability.

The sample size issue is often addressed by generating a set of back-forecasts, but the chapter demonstrates that it can be very difficult to generate these in a way that does not result in biased estimates of forecast skill, especially in the context of statistical models (the problem is less severe, but not completely unavoidable, for dynamical model predictions). This problem has important implications for the design of cross-validation experiments, for example, that are rarely adhered to in practice. A related issue to that of the limited sample size is that there is often interest in verifying individual forecasts, most notably for seasonal forecasts where there is a desire to know how "good" the forecast was for the last season. At shorter timescales similar questions may be asked, but will usually focus on only those occasions in which some kind of extreme event occurred, and the question then relates to how well the event was pre-visioned. The subsequent analysis will then generally include an evaluation of the deterministic forecasts available, and a detailed diagnostic analysis. For seasonal forecasts, the question is asked regardless of the outcome, usually every season, and there is a fixation on obtaining a single score. The problem would be reasonably simple if seasonal forecasts were deterministic, but given that they are almost invariably probabilistic the appropriate way to verify a forecast is not so obvious. Mason argues that to verify a single probabilistic interpretation one must acknowledge that there is a different set of attributes that define how good that forecast is compared to the attributes of a good set of probabilistic forecasts. Specifically, the attribute of reliability is appropriate only to the set of forecasts, but not to the individual forecast because of the spatial dependence of forecasts and verifications in a single forecast. Once one is able to focus on the attributes of interest, it is possible to identify meaningful verification procedures.

The second criterion - the often-weak levels of skill - means that there is a heavy focus on demonstrating whether forecasts are potentially useful. In practice this objective translates into the calculation of a suite of skill scores against a reference strategy such as climatology. Mason demonstrates that this practice often results in overly pessimistic estimates of forecast quality since the most commonly used skill scores for probabilistic forecasts are both biased, and have an arbitrary weighting of different attributes. He argues that the preferred solution is to focus on measuring individual attributes for more easily interpretable results. Specifically, calculating the resolution or discrimination skill of the forecasts is recommended if the interest is to identify whether the forecasts have any potentially usable information.

Contributed by ***S.J. Mason***.

Updates to the IRI Climate Data Library and map rooms

With increasing demand for the IRI climate data library both within the activities of collaborating operational partners and in research environments, the IRI continues to invest in upgrades to climate and remote sensing data, map rooms, portable/stand alone Data Libraries, and semantic technology. Below is an overview of highlights for the period.

Climate Data - New datasets are routinely added to the IRI Climate Data Library to support the work of IRI and its partners and to provide convenient access to publicly-available datasets to the research community in general. New datasets recently added to the Data Library include outputs from a variety of experimental model runs to support IRI climate research, and aggregated versions of a number of datasets produced by NOAA, including the Climate Forecast System, Version 2 (CFSv2), the World Ocean Atlas 2009 (WOA), and the North American Regional Reanalysis (NARR). Model output to support the production of the IRI Net Assessment forecasts is routinely updated within the IRI Data Library each month, as are the resulting Net Assessment forecasts themselves, and numerous observational datasets of interest to the climate research community.

Remote Sensing Data - The use of remotely-sensed data from sensors such as MODIS on-board of TERRA and AQUA satellites, SEVIRI on-board of METEOSAT SECOND GENERATION (MSG) have been developed further at IRI to estimate i) presence of sparse vegetation in the Desert Locust area and water bodies based on a new multi-temporal colorimetric transformation approach (Pekel *et al.*, 2010) and ii) minimum and maximum air temperatures derived from Land Surface Temperature (LST) (Vancutsem *et al.*, 2010. Ceccato *et al.*, 2010). The products developed have been made accessible to the user community e.g. Ministries of Agriculture and UN FAO for the sparse vegetation and water bodies; Ministries of Health and NASA to produce a Vectorial Capacity Model using estimation of air temperature for malaria transmission. The SEVIRI (MSG) data are currently being investigated to monitor land surface moisture and evapotranspiration in Africa based on visible, near infrared and thermal infrared data collected every 15 minutes. The research on land surface moisture characteristics and evapotranspiration is part of an IRI-University of Copenhagen collaborative project: Earth Observation of long term changes in land surface moisture conditions (CaLM).

Maprooms - Maproom work this period included the Time Scale maprooms for Climate and the International Federation of Red Cross and Red Crescent (IFRC). Tailored Forecast maproom prototypes were developed for the Center International for the Investigation of the Phenomena of El Niño (CIIFEN) countries to assess climate risk for hydrologic applications. A tailored Historical maproom for Mali and Food Security maproom for Mali were also developed.

The Time Scale maprooms are part of an effort to better disseminate near term climate change information (i.e. at decadal time scales) as interest in this information within the impacts and adaptation communities has been increasing. The maprooms make information available on the relative contributions of the long term trend, decadal time scale and inter-annual time scale to the historical climate record. The Climate maproom targets the broad scientific community whereas the IFRC one targets more specific users. An important part of the Time Scale maprooms was implementing a new variation of the Butterworth filter appropriate for the problem at hand.

A new Tailored Forecast maproom based on the Climate Prediciton Tool (CPT) outputs has been developed for CIIFEN countries in a hydrological context. This is an adaptation to that region of the previously existing Tailored Forecast maprooms. Collaboration with the World Food Programme (WFP) consisted of studying the relationship between climate and food security in Mali, in light of the integration of climate information and socio-economical datasets from WFP. Two prototype maprooms came out of this activity. One is a tailored Historical maproom for Mali enabling one to explore historical precipitation variability in Mali. The other informs on the statistical relationship between seasonal rainfall and crops production and how population economically relies on said crops, in an attempt to provide insight of the possible impact of rainfall variability on food security.

Portable/Standalone Data Library - The IRI Climate Data Library developed a new standalone and mirror configuration with a bootable USB disk. This has been delivered to partners in India and Indonesia. A tailored configuration is ready to deliver to the National Meteorological Agency in Ethiopia. This disk is attached to a host computer and is used to boot the computer with the Data Library and database services running. The disk can be preloaded with partner-specified data or the partner’s data can be added to it in country. The software can be configured to run off the internet (in a standalone mode), or on the internet as a mirror site for the Data Library. With the mirror configuration, it is possible to view the partner’s data from the central Data Library in New York. The bootable USB disk is easily cloned to another disk thereby making multiple deployments easy. The process of getting a mirror site up and running in other countries has been greatly streamlined.

Semantic Technology - Developed Java based persistence/inferencing framework for OPeNDAP. This framework is based on innovative development, the use of ontologies, and leading Semantic Web technologies, such as, Sesame and OWLIM. Because this framework was developed on Java technology, the system is highly portable between various platforms and can be adopted easily. The OWLIM Sesame repository has the capability of organizing triples into groups to which a URI is assigned as its context. We organize the triples by context to efficiently update the repository. An update operates on triples within a context instead of the whole repository which has about 8M triples describing the Data Library.

We also developed an XML element extraction system based on Java, which allows the extraction of information from the framework into an XML format that is based on data description and deliver standards (WMS, SERF, etc.). With this tool we can further develop technologies of delivering climate data and analysis to other partners' systems.

Contributed by ***M.B. Blumenthal****,* ***J. del Corral****,* ***M.A. Bell****,* ***R. Cousin****,* ***H. Liu****,* ***P. Ceccato*** *and* ***S.J. Connor****.*

Interactive map room provides perspective on 20th century climate variability and change

The International Research Institute for Climate and Society (IRI) has developed an interactive "map room," providing a decomposition by time scale of observed 20th-century temperature and precipitation variations at: http://iridl.ldeo.columbia.edu/maproom/.Global/.Time_Scales/. This web-based tool permits users to assess the relative contributions of long-term trend, decadal and interannual variability to the historical climate record, at a point, averaged over an area or in map form. Although not designed for the formal attribution of climate variability, the map room offers a simple means of de-constructing regional or local climate variations in a way that is intuitively comprehensible. It clearly indicates, for example, the dominant role played by interannual variability in most locations, information that should be useful in managing climate-related risks.

Within the impacts and adaptation communities interest has been increasing in the potential for near-term enhancement (or possibly attenuation) of the secular trends that are generally associated with anthropogenic climate forcing. The existence of absolute environmental or health-related thresholds implies that short-term risks will be modulated by low-frequency variability, impacting decision-making or planning that is typically carried out year by year. The map room can shed light on this sort of scale interaction, and in the process clarify the potential utility of different types of climate information (predictions, projections, uncertainty estimates) in the context of anticipated risks.

The web interface initially presents a map showing the percentage of Jun-Aug precipitation variance that is associated with decadal-scale variations (Figure 59). The user can zoom, choose between temperature and precipitation, define a season one to twelve months in length, choose the timescale for which information is displayed and either select a region for averaging or click at a point. A decomposition by time scale is then displayed (Figure 59, inset). Fractions of variance attributable to trend, and, for the detrended series, to decadal and high-frequency components are provided.

The decomposition is accomplished in several steps. First, the selected data is screened; the default requirement being that no more than half the yearly values can be missing. For precipitation it is also required that climatological seasonal rainfall must exceed 30 mm, since very dry basic conditions render estimation uncertain, and interest is more likely to center on the wet season, or seasons.

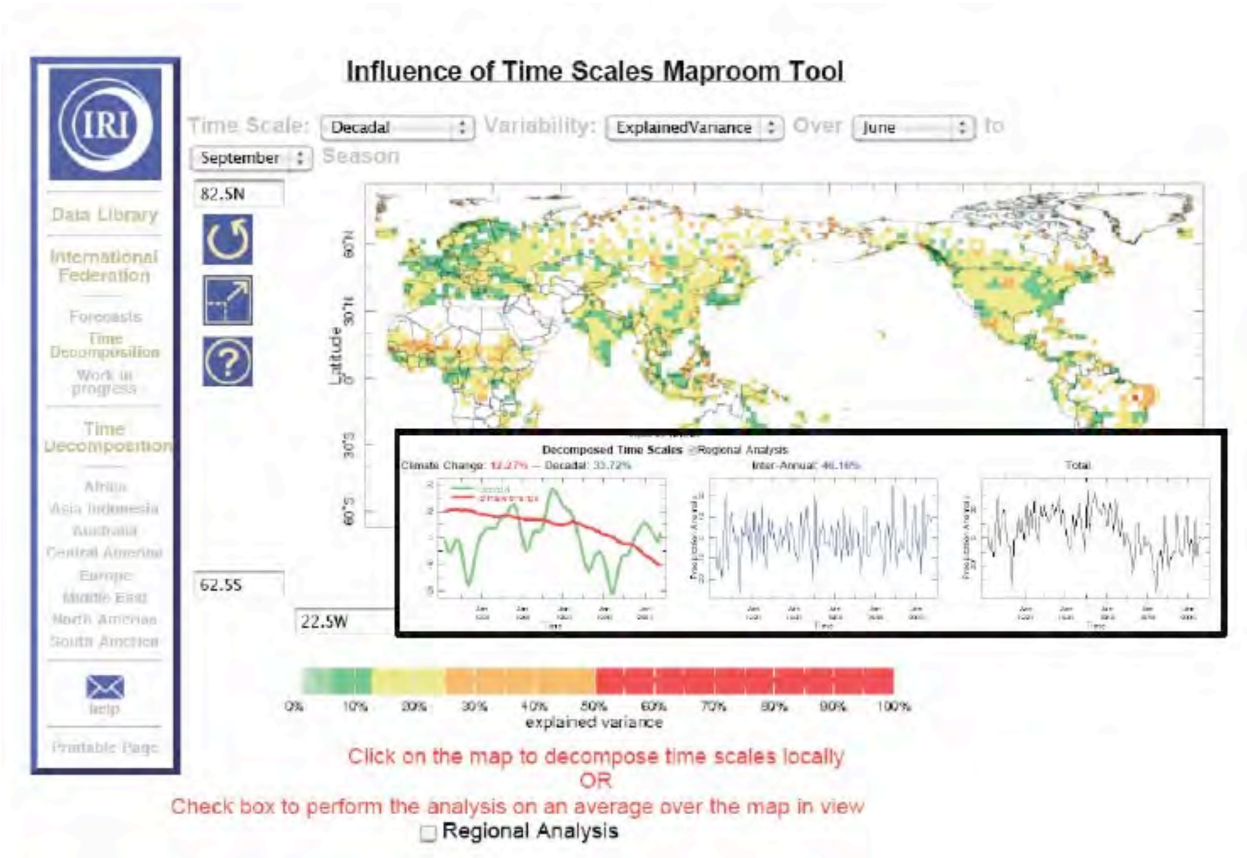


Figure 59. Snapshot of the IRI Time Scales Map Room prototype (some revisions may be implemented before release on the IRI website). The global map shows the percent of total variance in the decadal band for Jun-Sep precipitation for 1900-2007. The inset shows (a) long-term trend and decadal components of the signal, (b) the interannual component and (c) the original series.

The trend component is then extracted, by regressing the series on a smoothed global-mean, multimodel-mean temperature record derived from an ensemble of 23 of the general circulation models (GCMs) from the fourth assessment report of the Intergovernmental Panel on Climate Change. These models are forced by realistic 20th-century boundary conditions, including greenhouse gases and aerosols; their outputs include both the response to these forcings and intrinsic, unforced variability. Since the latter is essentially incoherent across models it is attenuated by averaging, while the common climate change signal is enhanced. Fitted values from the regression represent that part of local variability that is linearly dependent on the GCM-estimated forced response, and are taken as the trend, or “climate change” component. The residuals represent natural, unforced variability. The latter are low-passed using a Butterworth filter having half-power at a period of 10 yr, which produces a reasonably clean separation between decadal and interannual time scales: covariation between the two components generally amounts to no more than a few percent of the variance of the detrended series.

The 10-yr filter cut-off effectively classifies variability owing to El Niño-Southern Oscillation, which exhibits a broad spectral peak in the 2-8 yr band, as “high-frequency.” Phenomena responsible for variability on longer time scales belong to a class of processes that are less well-understood, and whose predictability is currently the subject of active research. This “low-frequency” class includes large-scale modes such as the Pacific Decadal Oscillation (PDO) and

Atlantic Multidecadal Oscillation (AMO), as well as low-frequency stochastic variations. Thus the filtering effectively partitions variability by process class, not simply by nominal time scale.

The map room's apparent simplicity poses interpretive risks. Appropriate guidance is therefore provided, including the following points:

- Detrending via regression on the multimodel temperature record represents only an approximate separation of forced and natural variability; rigorously performed, such separation is not a simple exercise. Depending on timing and period, natural fluctuations could project onto the global mean temperature signal and be incorrectly identified with the forced response. The potential for such entanglement becomes lower as length-of-record increases.
- About 20% of the variance of annually-resolved white noise would be expected to accrue to the "decadal" band, as here defined. This should not be mistaken for the signature of a mechanistic process.
- The map room is a means of deconstructing past variations, not a predictive tool. In particular, it cannot tell us how the character of variability may change in response to global warming and thus, how the decomposition of variance by time scale might evolve in the future.

Caveats notwithstanding, it is hoped that this product will further the dissemination of climate information in a format that is intuitively understandable, and that the decomposition presented can serve as a useful vehicle for consideration and discussion of the contributions of variability on differing time scales to the climate histories actually experienced, in the diverse settings of users around the world.

Contributed by ***A.M. Greene, L. Goddard*** *and* ***R. Cousin.***

Expanding the reach of data portals with a portable IRI Climate Data Library

For the last 10 years, the IRI Climate Data Library has been delivering climate data and analyses to the greater scientific community via the internet. In the past year, new efforts have been made to expand the use of the Climate Data Library in areas where there is little or no internet and to sectors where use of climate information has become a priority. The Climate Data Library can be used as a teaching tool for explaining how to analyze climate data and to correlate it with sectoral data such as health data, agricultural data, and water resource data. This technology has been encapsulated in two forms to extend its application to far corners of the world. One encapsulated form is the pure standalone Climate Data Library, which runs on a laptop, or bootable hard drive. This has been used in Africa for training courses in climate data analysis techniques for local professionals where internet access to the IRI Climate Data

Library is slow or non-existent (e.g., see Figure 60). The second encapsulated form is a Climate Data Library mirror portal built on a local computer using the IRI Climate Data Library software. This form is being set up in India (ERFS) and Indonesia (CCROM) to give local professionals full access to the IRI Climate Data over the internet, and the ability to add their own local data to the mirror portal. If they chose to share their data with the IRI, that data will appear as a catalog entry on the central IRI Climate Data Library. We have delivered bootable hard drives to India and Indonesia with updated software to speed up the establishment of these mirror sites. There has recently been interest in establishing a mirror site in South America (CIIFEN). With this interest, there is a desire and willingness on the part of CIIFEN to translate relevant web pages of the Climate Data Library into Spanish. This will extend the effective reach of the Climate Data Library to those that speak Spanish, but not English.

Figure 60. Training participants study the relationship between land surface temperature derived from satellite imagery and minimum/maximum air temperatures.

*Contributed by **J. del Corral** and **M.B. Blumenthal***

Development of tailored and climate information for the disaster management community

Climate extremes have major impacts on society, and are a primary concern in many climate risk management settings, whether through humanitarian preparedness for and response to disasters, or through development efforts to build resiliency, or through more direct commercial interests. Through its Partnership to Save Lives with the IFRC, the IRI has made important contributions to the use of weather and climate information for disaster risk management through tools such as the IFRC Map Room and the Help Desk. The Map Room (Fig. 61) has served a valuable function in serving forecasts at a range of timescales in user-friendly formats and directly into the IFRC's Disaster Management Information System. Most of the information products are based either on the Earth System Research Laboratory (ESRL) Physical Sciences Division (PSD) 6-day precipitation forecasts (Caplan *et al.*1997), or on the IRI's seasonal forecasts.

The Map Room has recently been translated into Spanish, and a number of improvements to the presentation of the information have been implemented in consultation with representatives from the humanitarian community. The primary interest is in the risk of exceptionally heavy rainfall resulting in flooding, although there is also some interest in heat waves. While the 6-day forecasts provide a fairly direct indication of exceptionally heavy rainfall, the seasonal forecasts

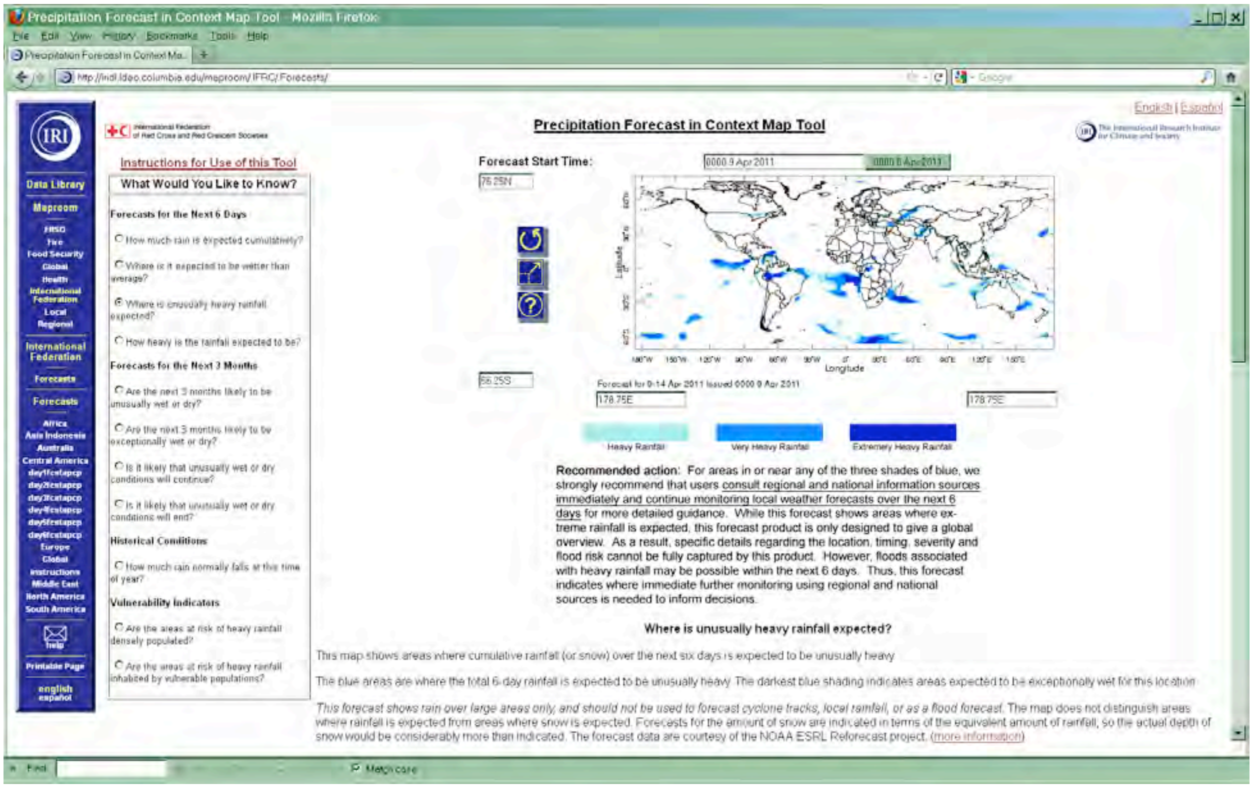


Figure 61. The IRI's IFRC Map Room page, showing interpreted 6-day precipitation forecasts from the Earth System Research Laboratory (ESRL) Physical Sciences Division (PSD). For more examples, go to: http://iridl.ldeo.columbia.edu/maproom/.IFRC/.Forecasts/

are less obviously indications of flooding risk. In many parts of the globe seasonal rainfall totals are strongly correlated with the frequency of heavy rainfall events within the season, and so it seems quite reasonable to assume that a forecast that indicates a high risk of "above-normal" rainfall also implies a high risk of heavy rainfall events and thus increased flooding risk. However, without direct quantification it is unclear how reasonable this assumption is. Research has been conducted to assess the extent to which standard seasonal forecasts, which indicate probabilities of 3-month accumulated precipitation, incidentally provide indications of the risk of individual heavy rainfall events during the target season, and also the extent to which the risk of heavy rainfall events themselves can be predicted directly.

Using high-resolution gridded daily rainfall data for South Africa for 1971 – 2009, frequencies of locally-defined heavy rainfall over the whole of the summer rainfall region (which is most of the country excluding the south and west coasts) were calculated for each 3-month period. Heavy rainfall was defined using a range of return periods from 0.2 to 5 years. Although the definitions of heavy rainfall are gridbox specific, the frequencies were calculated regardless of location. Hence, the numbers of heavy rainfall events somewhere within the summer rainfall region, and somewhen within the 3-month period, without specifying precisely where or when, were calculated. This counting procedure means that widespread heavy rainfall is counted at numerous locations and so no distinction can be made between frequent localized storms and infrequent large-scale storms. Although the resulting information loses geographical specificity, given the lead-time of weeks to months, and the possibility to plan at regional and national levels (Braman *et al.* 2011), it can still be highly useful. The frequencies of the heavy rainfall events were counted separately for forecasts of different probabilities of "above-normal" rainfall as indicated on the IRI's seasonal forecast products. The results provide an indication of whether seasonal forecasts of 3-month precipitation accumulations provide an indication of changes in the risk of individual heavy rainfall events.

Through an RCCC/WMOworkshop held in Dar es Salaam in September 2010, participants from 6 countries in east and southern Africa investigated the predictability of the frequencies of heavy rainfall events directly. It has been demonstrated before that the frequency of rainfall events can be forecasted at seasonal timescales, often with greater skill than the seasonal total (Moron *et al.*, 2006). However, when trying to predict the frequency of heavy rainfall events, the numbers of events rapidly become too small as the threshold for defining "heavy" is raised, and so the skill drops off rapidly. This problem was addressed by counting the number of heavy rainfall events over an area rather than at specific locations, just as in the analysis for events over South Africa. Using the Climate Predictability Tool (http://iri.columbia.edu/climate/tools/cpt/) the predictability of the frequencies of the heavy rainfall events was investigated using the NOAA NCDC Extended Reconstructed Sea-Surface Temperature version 3b dataset (Smith 2008) as predictors.

Seasonal forecasts as indications of heavy rainfall frequencies in South Africa - The IRI November – January rainfall forecasts had probabilities for above-normal rainfall varying between 20% and 40%. This range is fairly limited, indicating that there were no forecasts which indicated very strong probabilities of above-normal rainfall. However, the forecasts for this period were skillful, indicating that above-normal rainfall increased in frequency as the probability for above-normal rainfall increased (Figure 62). However, more importantly,

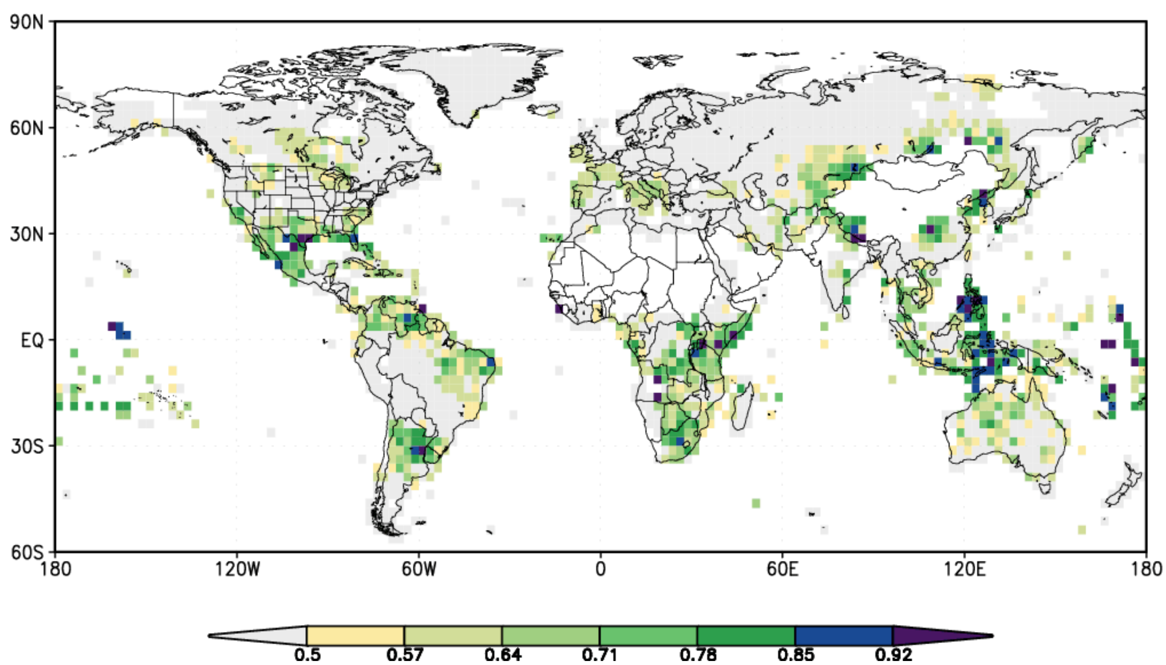


Figure 62. Skill of the IRI's seasonal forecasts for November – January, as measured by the generalized discrimination score (Mason and Weigel, 2009).

Figure 63 provides evidence that the frequency of heavy rainfall events, regardless of how "heavy" is defined, generally increased as the forecast probability for above-normal rainfall increased. Although there are some minor decreases in frequency of heavy rainfall as the forecast probability for the seasonal total to be above-normal increases from 20% to 25%, in general the increases in frequency are marked. For a doubling in the forecast probability from 20% to 40%, heavy rainfall events increase in frequency at least threefold for the one-day totals, and at least six-fold for the five-day totals. The increases in heavy rainfall frequencies are much stronger for the heaviest rainfall events. These results demonstrate that the standard IRI seasonal rainfall forecasts provide a very strong indication of changes in the risk of heavy rainfall events in South Africa for this time of year. It therefore seems reasonable to use seasonal forecasts as forecasts of the changing risk of flooding.

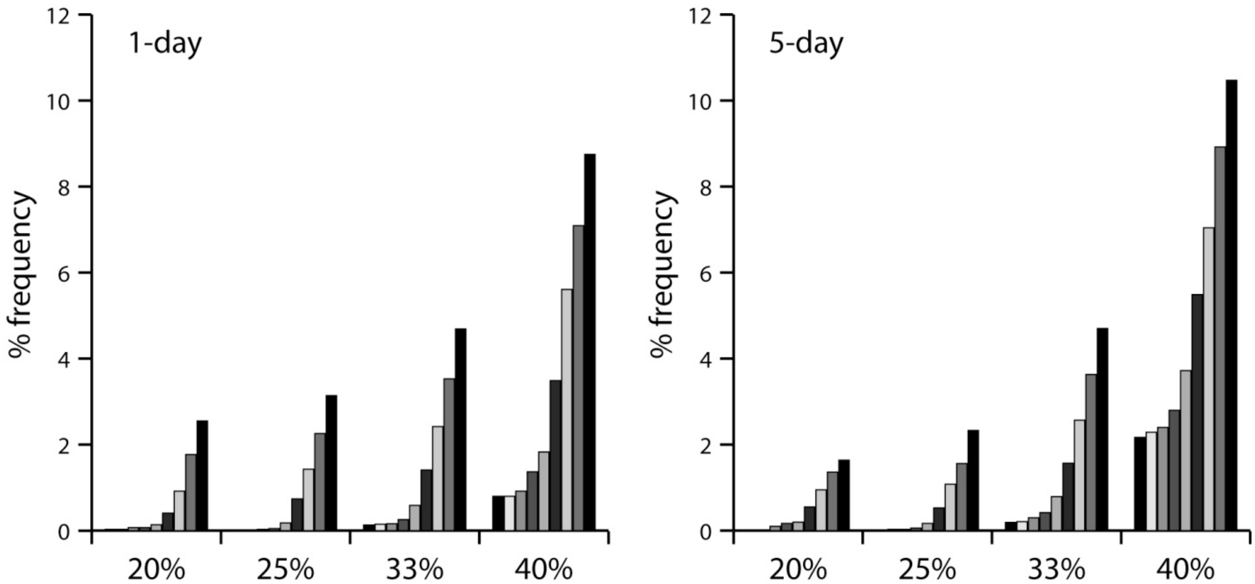


Figure 63. Relative frequencies of the occurrences of 1-day and 5-day "heavy" rainfall events given different forecast probabilities for "above-normal" November – January rainfall over South Africa. The different bars in each bin represent different definitions of "heavy": from left to right "heavy" is defined as the amount of rainfall that is exceeded, on average, once every 5 years, once every 4 years, once every 3 years, once every 2 years, once per year, twice per year, three times per year, four times per year, five times per year.

Predicting heavy rainfall frequencies in Tanzania - Historical records from four stations in the Tanga district of Tanzania were used to compute the number of days during the October – December rainfall season when the daily rainfall exceeded various thresholds. To reduce the sampling "noise" in this approach, the values obtained were then summed over the four stations resulting in a single time series of the number of rainy days above various thresholds for each year, 1971-2000. The cross-validated skill of predicting frequencies of events exceeding 20 mm per day was higher than for lower thresholds, and with a correlation exceeding 0.5 indicates a high degree of predictability (Figure 64). Forecasts for above-normal frequencies of heavy rainfall appear to be more skilful than forecasts for below-normal frequencies (Figure 60). An experimental forecast made by representatives of the Tanzanian Meteorological Agency for the 2010 rainfall season, indicated low probabilities of above-normal frequencies of heavy rainfall, consistent with the occurrence of La Niña conditions.

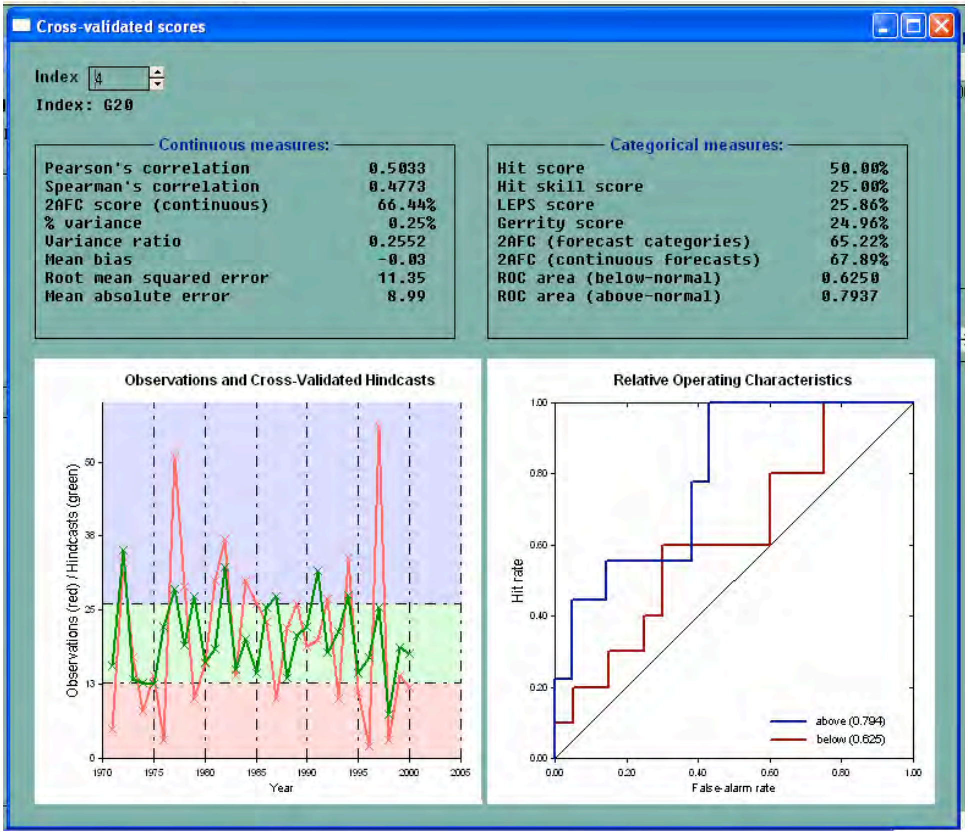


Figure 64. The lower-left plot shows the cross-validated forecasts (green line) and observations (red line) of the number of days with rainfall >20 mm during the October – December rainfall season over the Tanga district in Tanzania. Various skill scores are also shown at the top. The lower right hand plot shows ROC curves for above- (blue) and below-normal frequencies of heavy rainfall.

Forecasts of 3-month seasonal rainfall totals may provide skillful indications of changes in the risk of heavy rainfall events when considered over sub-national spatial scales. There is also some ability to predict frequencies of heavy rainfall events directly when the rainfall events are counted over similarly large areas. Although the lack of temporal and spatial precision in such forecasts limits their usefulness to some extent, when combined with shorter range forecast with greater precision, these seasonal forecasts could prove valuable for disaster risk management purposes.

Conributed by ***S.J. Mason****,* ***A. Curtis****,* ***L. Braman****, and* ***M.A. Bell***

Climate and health in Africa: Overview of executive summary and recommendations from the '10 Years On' workshop

One of the defining challenges of the 21st century is increasingly recognized to be the world's changing climate. The health consequences of climate variability and change are linked inextricably to poverty, equity and development choices. Protecting health from climate impacts is now a priority for the public health community. The need for this is greatest in developing countries, where vulnerable people do not have the basic economic choices and infrastructure to cope with the varying climate. These communities bear a disproportionately large burden of infectious diseases and climate related disasters while having the poorest access to effective public health services. Climate change will exacerbate this inequity.

Over the past decade, the public health community has committed itself to scaling up awareness, action and responses to the challenges posed by a varying climate. In 2008, several high-level policy recommendations were made on the importance of climate and environmental change and their potential impacts on health. Among these was a special resolution on climate and health passed at the 61st World Health Assembly (World Health Assembly, 2008). The public health sector's ability to adapt will rely on the generation of accurate and reliable data and capacity building among research and disease control communities to build resilience and support of observation and monitoring systems.

New opportunities exist for better management of climate related health risks and a body of knowledge has been built over the past decade on the shared experiences of the public health and climate communities. These opportunities are made available through advances in climate science, improvements in communication technology (that impact on data and knowledge sharing), changes in policies on sharing of climate data and a new global focus on effective management and even elimination of certain infectious diseases. Critical in this process are collaborations between health sector users of climate products with climate sector producers. While it is clear to both sectors that this would be beneficial, experience has shown that such collaborations are hampered by gaps in policies, practices, data and services and research that is not prioritized to meet the needs of African adaptation programs.

In 1999, the IRI led a collaborative training course in Bamako, Mali on *Climate Prediction and Diseases/Health in Africa.* Convened by the Faculté de Médecine, de Pharmacie et d' Odonto-Stomatologie and by the Direction Nationale de la Météorologie du Mali, it was one of the first interdisciplinary workshops of its kind to address the challenges of and opportunities around climate and health in Africa. This multi-disciplinary initiative was co-sponsored by the African Center of Meteorological Applications for Development (ACMAD), the World Meteorological Organization (WMO), the Institut de Recherche pour le Développement (IRD) and the National Institutes of Health (NIH), USA.

Since the Bamako workshop, awareness around the risks of climate has risen considerably and significant lessons have been learned through multiple initiatives and partnerships. The 'Climate and Health in Africa: 10 Years On' workshop was planned as a forum to present, debate and evaluate lessons learned and to elaborate on newly emerging perspectives and opportunities for managing climate and health risks in Africa. Over 100 stakeholders representing critical thinkers from multiple disciplines participated in the 3-day meeting (Figure 65). Participants examined examples of best practice in climate change adaptation in health and deliberated on how to bring key African partners in adaptation together to focus on common demand-driven objectives around an African led agenda. With this as a first step, it was underscored that *Africa will be taking the lead in Climate and Health in the future.* Key outcomes for the workshop include the following consensus recommendations for *policies, practice, services and data, and research and education* for the integration of Climate Risk Management into Africa's health sector.

Figure 65. Participants in the ‘Climate and Health In Africa – 10 Years On’ workshop.

Theme 1: Policy - support effective implementation of the Joint Statement on Climate Change and Health in Africa adopted by African Ministers of Health and Environment in Luanda, 2010, as an overarching platform for addressing climate and health issues to:

- **Bridge the gap between policies and practices** through legislation and guidelines, appropriate planning, including relevant vulnerability assessments, programmatic support and multi-sectoral and participatory processes that are gender sensitive.
- **Support countries to establish** integrated health surveillance and climate observation and processing systems.
- **Strengthen health systems** using climate information tailored to decision needs at all relevant levels and time scales.
- **Make evidence-based, sound climate-informed decisions** to implement a set of preventive actions to reduce population vulnerability and lessen the additional burden imposed by climate-sensitive diseases and health issues according to their respective epidemiological circumstances.
- **Anticipate, prepare for and respond** to the health consequences of extreme weather events, particularly by strengthening the functioning of health systems and other relevant sectors.
- **Encourage multilateral partners** to consider the significant co-benefits of environment integrity, population health and consequent economic development that can result from mitigation and adaptation policies in the climate and health sectors and to support African countries in gaining access to resources under the various climate-related funds.

Theme 2: Practice

- **Integrate climate health risk management** into cross-sector planning and practice for adaptation to climate variability and change by developing climate services and products that address disease prevention at end-user level.
- **Create a human resource center/virtual hub** where expertise is shared in order to develop the capacity of African health and climate communities, institutions, practitioners and negotiators to understand/integrate climate change challenges into policy, socio-economics, planning and programming by identifying institutions and organisations in Africa that can deliver training courses and conduct research on "Climate, Health and Prevention".
- **Strengthen community-based organisations** by liaising, in a gender-sensitive fashion, with their leaders to develop locally owned sustainable strategies for adaptation to climate change and/or variability in their communities taking account of local knowledge rooted in social history and disseminated by appropriate channels, including the mass media.
- **Define the different levels and needs** (including learning outcomes) of health practitioners and stakeholders across different geographic scales, specifically researchers and teachers, graduate and undergraduate students, practitioners in the public health system, community opinion leaders, traditional healers, impacted communities and other special interest groups and develop appropriate curricula for adaptation to climate change and/or variability in the health sector.
- **Promote a gender-sensitive approach to interventions** on climate and health in cross-sectoral disaster risk reduction and preventive health strategies.

Theme 3: Services and Data

- **Develop tailored services** in partnerships with weather/climate and health organisations. These should recognise that health forecasts, which are different from weather forecasts, should be well designed and understood by all. They should act as early warnings to users of differing types, that assist in the prediction of future health outcomes.
- **Improve existing data**, for example through: the digitisation of historical health and climatic data; the increased use of metadata analyses and validation tools; the inclusion of aggregated health data at appropriate spatial and temporal scales; and the enhanced awareness of, and use of, observational and processed data, appropriate satellite, and climate model data sources.
- **Access and use data in a systematic manner** in order to identify vulnerable groups and areas. This needs to involve: employing data strategically within and across sectors; considering trend and seasonality issues; using data to evaluate the success of interventions; and, importantly, understanding how communities cope.
- **Incorporate other data into these health forecast services**, for example population, rural *vs*. urban residence, migration, nutritional status, environmental and poverty data.
- **Promote collaboration +:** encourage new, multi-disciplinary initiatives that involve communities beyond health and climate/weather; build upon existing initiatives and progress; aim to meet emerging challenges; and communicate with end-users in appropriate ways.

- **Enable commitment at all levels** that brings climate and health communities together, clarifies responsibilities, builds capacity in the climate and health sectors to achieve these services, facilitates joint initiatives and ensures resources such as data are shared in a suitable way.

Theme 4: Research and Education

- **Understand the relationships between climate and climate-sensitive diseases and health issues** under different environmental conditions through interdisciplinary, multi-sectoral and multi-center research.
- **Ensure that climate change mitigation and adaptation** strategies are informed by multi-disciplinary research.
- **Develop capacity within Africa** for the generation, interpretation and use of climate, health and other interdisciplinary data enabling informed, evidence-based decision making.
- **Standardize and quality control** data collection and storage, ensuring data are available on relevant temporal and spatial scales.
- **Enhance knowledge transfer and communication** of information across disciplines and communities through existing networks, encouraging the introduction of climate and health into the curriculum at all levels of education.
- **Strengthen existing partnerships and collaborations** while developing new groups and building links across disciplines.

Additionally, contributions were agreed towards a ‘Road Map’ during a steering committee and partnership meeting on April 7, 2011 including next steps leading to COP17 in South Africa and beyond. An Expert Group (EG) or consortium chaired by the ACPC and a secretariat based in Addis Ababa would be set up to facilitate immediate activities of the workshop recommendations. Judy Omumbo (IRI) would serve as secretary for the EG. This consortium provides the framework for the ownership of the recommendations and also facilitates the continued participation of WHO AFRO. Membership includes partners from UNDP AAP, ACPC, WHO AFRO, WMO, University of Exeter and IRI (Omumbo et al., 2011).

The Ethiopian Climate and Health Working Group (CHWG), along with a steering committee comprised of the African Climate Policy Center (ACPC), the World Health Organization-Africa Regional Office (WHO-AFRO), the United Nations Development Programme’s Africa Adaptation Programme (UNDP-AAP), the UK Met Office, University of Exeter, UK and the IRI, convened the “Climate and Health in Africa: 10 Years On” workshop at UNECA in Addis Ababa, Ethiopia from April 4-6, 2011. Additional sponsorship for the meeting was provided by: Columbia University, Google.org, Health and Climate Foundation (HCF), National Oceanic and Atmospheric Administration (NOAA), National Institute of Environmental Health Sciences (NIEHS) and the Government of Japan.

*Contributed by **J.A. Omumbo**, **B. Platzer**, A. Girma and **S.J. Connor**.*

Africa needs climate data to fight disease

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change predicts increased rainfall in eastern Africa over the coming century. Yet there has been a region-wide drought over the past ten years. Policy-makers want to know whether to prepare, short-term, for floods or droughts. They also need to know if the recent drying has aided malaria-control interventions in the region. But answering such questions is tricky.

Figure 66. IRI Associate Research Scientists T. Dinku (climate and environmental scientist, left) and J. Omumbo (epidemiologist, right) review climate and health data and model outputs for the Kenyan highlands.

Climate information is not readily available, so is rarely incorporated into development decisions. At the same time, few public-health institutions or practitioners are equipped to understand or manage the effects of a changing climate, despite major advances in recent years in alerting the health community to its risks. A dramatic improvement is needed in the availability of relevant and reliable climate data and services, particularly in Africa, where vulnerability to climate is so high. Information — such as historical observations of temperature, ten-day satellite estimates of rainfall, the predicted start date of the rainy season or the likelihood of extreme temperatures in the coming season — should inform the management of all diseases sensitive to climate. These include: malaria, leishmaniasis, acute respiratory infections, intestinal helminths and diarrhoeal diseases. This information could also contribute to food security by providing, for example, early warning for agricultural and livestock pests and diseases.

The following must be put in place within the next decade: new partnerships between the public-health community and national meteorological agencies, space agencies and researchers; a governance structure that ensures data sharing between public and private agencies; a funding model that builds open-access climate databases; climate scientists focused on the delivery of quality products, tailored to user needs; health professionals trained to demand and use climate information; and evidence of the value of all this, relative to alternative investments in health.

Good climate information, if freely available, could transform the way in which the health community does business (e.g., Figure 66). For example, it could improve health calendars for seasonal diseases. It could lead to better timing of the distribution of bed nets, local public awareness campaigns, and drugs with a short shelf life. Health professionals could be better prepared for the diseases that follow floods and storms, such as leptospirosis and cholera. It would also enable better mapping of regions and populations vulnerable to emerging health problems such as meningococcal meningitis epidemics, which favor the hot, dry and dusty Sahel, a region that may be expanding owing to climate and environmental change. On longer time scales, researchers could probe the drivers and potential recurrence of major climatic events, such as the devastating Ethiopian drought of 1984–85 (immortalized in the Western psyche by Bob Geldof's Band Aid). The value of the data held by national meteorological and hydrological services was made evident through a recent analysis of 30 years (1979–2009) of daily temperature and rainfall data from the Kericho meteorological station managed by the Kenya Meteorological Department (Omumbo et al., 2011); the data conform to World Meteorological Organization standards.

Contributed by ***M.C. Thomson****,* ***S.J. Connor****,* ***S.E. Zebiak****, M. Jaclos, and A. Mihretie*

Climate risk knowledge for water resource management

The International Research Institute for Climate and Society has completed a new training resource for water managers that it will invite the community to explore and use. Designed specifically for professionals, IRI's Climate Risk Knowledge for Water web site (http://crk.iri.columbia.edu/water) describes methodologies for addressing risks and opportunities associated with climate variability and change. Users can work through specific exercises, watch video tutorials and download a comprehensive 155-page manual (Figure 67) for offline use.

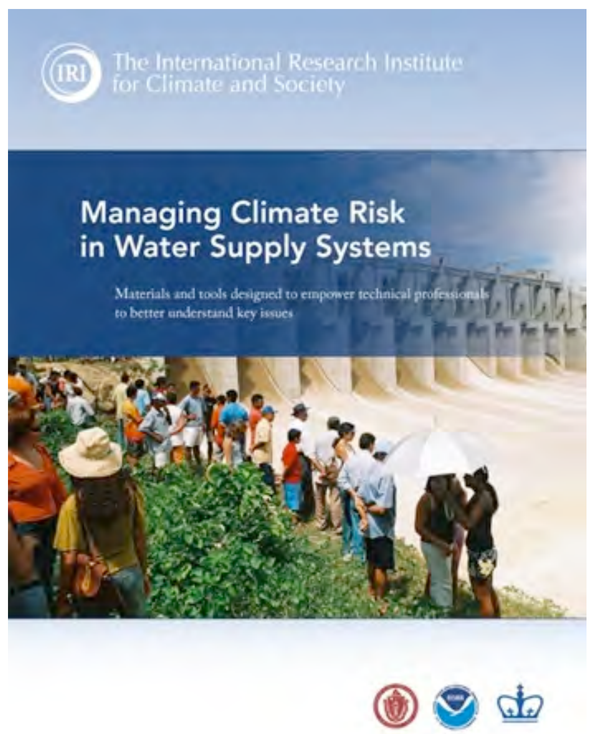


Figure 67. Downloadable manual on climate risk knowledge for water resource management.

In many regions, the supply of fresh water is extremely sensitive to climate variability. Population growth, changing lifestyles, and shifting land-use patterns also place heavy demands on water systems. The combination of climatic uncertainty with increased demand makes it essential that water managers use the best climate information available. Advances in hydroclimatic science provide rich new opportunities for "climate-smart" water management. These advances -- including better data sets, more accurate models, and improved forecasts -- provide opportunities to facilitate policies and operations that can support urban planning, resolve multi-user conflicts, and improve resiliency to droughts and floods.

Climate information is but one input to the decision-making processes water managers engage - but it can have a significant effect on outcomes for a water system. The goals of the Climate Risk Knowledge for Water web site are to provide knowledge and tools on the use of improved climate information and forecasts in water resource management, and to give users access to a network for sharing this information through subscription to a watercrk@iri.columbia.edu list serve community. The website, web resources, and manual are possible owing to the generous support of NOAA. Approaches, examples and practical exercises also benefited from collaborations with universities, technical advisory groups, governmental agencies, and water and power service providers in the Philippines, as well as project engagement with USAID/OFDA (see website and/or manual for details).

*Contributed by C. Brown, C., K. M. Baroang, E. Conrad, **B. Lyon**, D. Watkins, **F. Fiondella**, Y.Kaheil, **A.W. Robertson**, **J. Rodriguez**, M. Sheremata, **J. Turmelle**, **B. Baiden**, **C.Z. Mutter** and M. N. Ward.*

IRI training course in support of CPC Africa Desk

In March of 2011, the IRI hosted Maher Ben Mansour (National Institute of Meteorology in Tunisia) and Peter Omeny (Kenya Meteorological Department) from the National Centers for Environmental Prediction (NCEP) Climate Prediction Center (CPC) Africa Desk. The purpose of the visit was to expose the Africa Desk visitors to IRI methodology for seasonal forecasting in the African region and use of seasonal climate forecasts in various sectors including water management, health, and agriculture. This activity is envisioned to be ongoing with a new set of Africa Desk visitors coming to IRI periodically for the same baseline activities. These visits will support the Africa Desk in helping to build capacity in climate monitoring and prediction in developing countries. Below we provide a brief description of the curriculum covered during the visit, followed by a brief summary of training motivation and outcomes.

Introduction to the basis for climate predictability and use of the climate predictability tool - The training began with a discussion of the scientific basis for seasonal climate prediction, emphasizing in particular the mechanisms through which anomalies in SST can tilt the odds for specific climate anomalies in known seasons and regions. This discussion then led toward the practical applications of making climate forecasts using large data sets of observations and/or model output. In learning to use the Climate Predictability Tool (CPT), hands-on examples of developing prediction models and making specific individual forecasts were illustrated, so that the trainees could replicate these and carry out similar exercises using data that were more relevant to the climate prediction problems in their own countries. Important aspects of the exercises included downloading data from IRI's Data Library, selecting the intended spatial and temporal domains, setting the desired analysis parameters on the CPT menus, and finally running CPT. The next focus was on using the information provided by the tool. In particular, an understanding of the model verification statistics was necessary to learn the strengths and weaknesses of the model and its individual forecasts. Finally, interpretation of the diagnostics produced by the tool was emphasized, with the aim of understanding the likely physical sources of the predictive skill, and using this information for possible redesign of the model to capture still greater skill. By the end of the day the trainees became more knowledgeable about using CPT either as a purely statistical prediction tool (e.g. using observed SST as the predictor) or as a statistical correction to the predictive output from a dynamical model to reduce systematic biases.

Statistical downscaling/tailoring of seasonal forecasts for hydrologic seasonal outlooks - The beginning lecture provided background on hydrologic topics relevant to climate risk management, including presentation of the different types of hydrologic models available for daily versus monthly or seasonal simulation, and spatially “lumped” versus distributed models. The second lecture covered the topics of regression models (e.g. CPT) for seasonal or monthly streamflow prediction, choice of predictors including antecedent flow, precipitation or sea surface temperature (SST) and general circulation model (GCM) seasonal forecasts, as well as methods for stochastic disaggregation of seasonal climate forecasts (bootstrap resampling based on tercile category forecasts, K-nearest neighbors, and nonlinear hidden Markov models (NHMM)). In the practical session, CPT was used to explore the seasonal predictability of the Blue Nile (Ethiopia) summer streamflow historical records, as a function of antecedent flow conditions, concurrent tropical SST anomalies, and the NCEP Climate Forecast System (CFS) and the Max-Planck Institute for Meteorology (MPI-M) ECHAM-based retrospective seasonal forecasts.

Climate and health - Epidemiologists are concerned with the analysis of disease risk within population groups. Disease risk waxes and wanes between populations, geographical areas and in time. This variation is driven by environmental and social change. In the case of climate sensitive diseases, variations in disease risk are also driven by climate variability on a seasonal, annual, inter-annual or even decadal time scale. The course material describes how time and space are used as an epidemiological framework to measure and monitor variability in disease risk. Trainees will learn how to capture and store spatial and temporal information and what aspects of space and time need to be measured and monitored for disease risk management. The rationale for organizing information, within a time and space framework and identifying patterns and associations, with the aim of providing insight to epidemiological processes, including climatic factors, is discussed.

Remote sensing as a tool to manage environmental data - The session on remote sensing introduced the concepts of remote sensing and provided information on how to retrieve environmental factors such as rainfall, air temperature, vegetation and water bodies using remotely-sensed data in the visible, near-infrared, thermal infrared and passive microwave spectra. The session also provided the basis to both visualize remotely-sensed products for rainfall, temperature, vegetation, and water bodies, extract time series, download images and integrate them into Geographical Information Systems (GIS), Google Earth, and NAS Worldwind (SERVIR). Applications on how to use remote sensing were shown for monitoring and forecasting fire risk in Kalimantan, monitoring risk of Desert Locust outbreaks, and malaria epidemics.

Using climate information for crop forecasting and food security applications - The aim of the lecture was to introduce some methodologies for integrating advanced climate information for crop forecasting and food security applications. To frame the discussion, we started with the scale mismatch problem (spatial and temporal) between climate forecasts and crop model data requirements and how this can be solved. Several pathways for tailoring seasonal climate forecasts for crop yield predictions were introduced, from deterministic regression models, to more complex stochastic modeling especially designed for temporal downscaling. Case studies were presented using three specific methods: i) stochastic disaggregation (DisAg), ii) bias correction of GCM daily rainfall (BC) and iii) combination of BC-DisAg. After the lecture, the participants were given a practicum to familiarize themselves with the selected methods.

Practical session/Q&A - Participants are encouraged to apply their training to specific problems during the visit (Figure 68). The concluding session provides an opportunity to explore outcomes of those analyses, to engage in a question and answer session about methodologies and findings, and to participate in a survey on course content, design, and delivery.

Summary - The African Desk was established at the CPC in 1994 as part of the US contributions to the WMO voluntary cooperation program to help build capacity in climate predictions, monitoring, and assessments at African meteorological institutions. It was expanded in 2006 to include weather in support of the WMO severe weather forecasting demonstration project for Africa. IRI looks forward to working with the leadership of CPC and the African Desk to make this experience of maximum benefit to the participants and CPC. Many thanks to the lecturers for the course, which included: Tony Barnston, Andy Robertson, Tara Troy, Judy Omumbo, Michael Bell, Pietro Ceccato, Amor Ines, and Simon Mason.

Figure 68. Simon Mason fields questions on the final day of IRI training.

*Contributed by **D.G. DeWitt**, **C.Z. Mutter** and **A. Curtis**.*

WMO-IRI hydrological outlooks: The training of trainers at IRI

Figure 69. Paul Block assists a workshop participant in the exploration of seasonal hydrologic outlook products.

In September of 2010 the IRI and the World Meteorological Organization (WMO) co-sponsored a workshop to train scientists to develop and undertake hydrologic outlook trainings appropriate to their region (Figure 69). A specific aim was to enable the establishment of hydrological seasonal outlooks for the hydrological services of six countries in western South America (Chile, Peru, Bolivia, Colombia, Ecuador, Venezuela). The workshop explored different techniques for constructing probabilistic seasonal hydrologic outlooks, including the direct statistical downscaling of precipitation to streamflow and the disaggregation of seasonal precipitation forecasts into daily time series for input into hydrological models. The workshop broadly followed the approach of Verbist et al. (2010), in which predictive downscaling models were built with the Climate Predictability Tool and conditioned on Global Climate Models with the Non-Homogeneous Hidden Markov Model. K-nearest neighbor sampling was also implemented as a complimentary approach for disaggregation to daily data. The workshop was proposed at an international workshop held at the International Center for the Investigation of El Nino (CIIFEN), in Ecuador, in early 2010. Participants included representatives from CIIFEN and from Colombia's Institute for the Study of Hydrology, Meteorology, and the Environment (IDEAM), Peru's National Meteorological and Hydrological Service (SENAMHI), and India's National Water Academy (NWA).

Contributed by ***A.W. Robertson*** *and* ***P. Block****.*

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FOCUS ON India and Indonesia

Agricultural production, food security and the economic livelihoods of hundreds of millions of people are threatened by climate variability and change, across the Asia Pacific region. Despite rapid economic growth over the last decade, an estimated 30 percent of the population in Asia Pacific live on less than $2 per day. The livelihoods of the region’s poor, dependent on the natural resource base, is often directly impacted by climate anomalies. Persistent poverty coupled with the fact that more than 60 percent of the economically active population rely on agriculture for their livelihoods, has made this region highly vulnerable to climate shocks. There is both a need and an opportunity to enhance the resilience of vulnerable populations in the Asia and Pacific region to climate change and vulnerability. The IRI has met this challenges through its collaborative regional work, working with national and local partners from the meteorological, disaster, agriculture, health and water resource sectors. Work on the ground enables the uptake of the latest climate and risk management science and practice, enhanced by intensive capacity building efforts.

In the Asia Pacific Region, a failed or delayed monsoon can damage rural livelihoods and threaten urban and rural food securities. Farmers can face a complete loss of crops, threatening years of development and productivity, and pushing already stressed areas into further poverty. Decreased agriculture production has resulted in higher food prices and lower food consumption, especially among the poor. In this context, the IRI has developed a stakeholder-focused approach to providing meaningful climate information to decision makers at farm, district and higher spatial scales, developed context-specific tools to help transfer climate risks, and enhanced capacities of relevant stakeholders in the effective development and use of climate information and science-based tools to guide decision making.

As outlined in the IRI/NOAA Bridge Proposal, the IRI has focused its efforts in the Asia and Pacific Region in two focal countries: India and Indonesia. In India, implementation efforts have continued on the Extended Range Forecast System for Climate Risk Management in Agriculture (ERFS) project. The ERFS project financed partly by the Government of India, includes in-kind IRI staff contributions that is enabled by NOAA funding. The primary objective of this project is to enhance climate resiliency of India’s agriculture sector at the farm, village and district levels. The ERFS project activities include the generation and use of quality climate forecasts for weather/climate risk-resilient decision-making and the development and testing of risk management tools for farmers and district level decision makers in anticipating and responding to weather and climate-related agricultural risks. Through this project, the IRI is working in collaboration with the Indian Institute of Technology Delhi (IITD), India Meteorological Department (IMD), National Center for Medium-Range Forecasting (NCMRWF), Indian Council of Agricultural Research (IARI), and state agriculture universities in nine summer monsoon dependant demonstration states: Andhra Pradesh, Gujarat, Maharashtra, Madhya Pradesh, Orissa, Himachal Pradesh, Rajasthan, Tamil Nadu, and Uttarkhand.

During President Barack Obama's November 2010 diplomatic mission to India a communique of the US State Department highlighted IRI's ERFS project. President Obama highlighted joint US/India scientific efforts to better manage climate risks in agriculture in his 8 November 2010 speech to India's Parliament. President Obama and Indian Prime Minister Manmohan Singh announced a new era of collaboration on agricultural research in the face of climate change. This position was further supported by the Secretary of India's Ministry of Agriculture, whom during a March 2011 meeting with Shiv Someshwar, director of the IRI's Asia and Pacific Regional Program, agreed to the costed extension of the ERFS project.

In Indonesia the IRI has continued its partnership with the Center for Climate Risk and Opportunity Management for Southeast Asia and the Pacific (CCROM-SEAP), the provincial level department of environment and district level governments in Central Kalimantan on the scaling up of early warning systems for peatland fires. During his March mission to Central Kalimantan, Shiv Someshwar continued collaborative work on institutional mapping and research on incentive system and its architecture, to enhance uptake of the peatlands fire early warning system. IRI and CCROM staff met with farmers and local decision makers at village, Kabupaten and province levels in Central Kalimantan and identified practical alternatives to fire use and the economic incentives that may be needed for their uptake. The findings of this research would be of critical importance in the implementation of the recently launched pilot demonstration in Central Kalimantan of the Norway-Indonesia REDD+ program (with Norway pledging $1 Billion for the effort to Indonesia),

Though these efforts are still underway, the IRI will expand its work in Indonesia this summer by sending a student from the Climate and Society Masters Program at Columbia University to the CCROM-SEAP at Institut Pertanian Bogor. The student will support collaborative efforts between the IRI, CCROM-SEAP, the Indonesia Red Cross Society, the Red Cross/Red Crescent Climate Centre and its Partners for Resilience, to improve the production, flow and understanding of climate and weather information for improved humanitarian decision-making, preparedness, and response. This will involve organizing and collecting data so as to make it more easily accessible to the partners and local decision makers. At the same time, the IRI will work with IFRC to improve monitoring and seasonal forecasts and the integration of this information into place-based maprooms to improve disaster management and decision-making.

The IRI has worked in the Asia and Pacific Region for more than 10 years. Our engagement with local stakeholders has included improving the quality and use of climate information in agricultural decision-making, the provision of climate services to aid disaster risk reduction, and the implementation of demonstrations in climate risk management in a number of development sectors. The IRI's regional efforts are receiving recognition at the highest levels of government and our local level project partners and donors have expressed continued interest in scaling up activities to improve regional capacities to anticipate and manage climate-related risks.

PROPOSALS

To further support activities in Indonesia, the IRI and CCROM-SEAP partnered to submit a proposal to the U.S. Agency for International Development's APS 09-014 initiative 'Supporting Universities to Partner Across the Pacific'. The proposal, entitled 'Columbia University and

Institut Pertanian Bogor Partnership to Build Capacity for Adaptation to Climate Risks in Indonesia' has the goal to increase the scientific and technological capacities of Institut Pertanian Bogor in order to strengthen Indonesia's capacity for climate change adaptation. The proposal outlines activities in priority areas of agriculture and peatland fires, including the necessary climate modeling and analysis. The proposal was submitted in January 2011, total requested funds $650,000 over three years.

Furthermore, the IRI and CCROM-SEAP have collaborated in the development of proposals to support the creation of a weather index insurance product in Indonesia. Proposals have been developed for the Korea International Cooperation Agency (KOICA) and the Climate and Development Knowledge Network and outline activities required to develop an implementable weather index in the Indramayu and Pacitan districts.

PROJECTS *(Ongoing)*

Extended Range Forecast System for Climate Risk Management in Agriculture (2009-present)

Development of a Fire Early Warning and Response Systems in Central Kalimantan, Indonesia (2009-present)

OTHER ACTIVITIES

Shiv Someshwar attended USG and Government of India meetings to discuss collaboration on agriculture initiatives and the Climate Bilateral Program. August 2010, Washington, DC.

Stephen Connor presented "Climate Risk Management for Disease Prevention and Control" at the Taiwan Health Forum. October 2010, Taipei, Taiwan.

Shiv Someshwar visited ERFS demonstration sites to advance climate risk management work. October 2010.

Shiv Someshwar presented the "Fire Early Warning and Response" project in Central Kalimantan, Indonesia at COP-16 on Cancun Climate Change TV. December 2010.

Shiv Someshwar and Erica Allis traveled to Indonesia to conduct a scoping mission for upscaling climate risk management projects in Indonesia and advance collaborative efforts with CCROM. December 2010.

Andrew Robertson presented at the International Meeting on Climate Risks in Agriculture, an event co-organized by IIT Delhi and IMD. December 2010, Jaipur, India.

Joshua Qian presented "The Effect of Grid Spacing and Domain Size on the Quality of Ensemble Regional Climate Downscaling over South Asia during the Northeasterly Monsoon" at the *Indian Northeast Monsoon: Recent Advances and Evolving Concepts* Seminar. February 2011, Chennai, India.

Shiv Someshwar traveled to Asia and met with local stakeholders in Central Kalimantan to continue collaborative work on the institutional mapping and policy context to enhance uptake of the peatlands fire early warning system. He also traveled to Japan for discussions with Asian Development Bank Institute on their Asia regional low-carbon study and in India met with ERFS stakeholders and the Agriculture Ministry of India. March 2011.

FOCUS ON The Southern Cone

The Southern Cone comprises Argentina, Bolivia, Chile, Paraguay, Uruguay and parts of southern Brazil. While recent decades have brought incredible growth to these countries, persistent inequality still threatens to undermine their ability to achieve a prosperous and sustainable future. The successful management of climate risk may help these countries reduce the threats faced by vulnerable populations and contribute to the creation of more egalitarian societies.

Over the last 20 years, dramatic increases in international food prices have encouraged farmers of the Southern Cone to concentrate on the production of basic commodities such as soybeans, corn, and wheat. While these efforts have transformed the Southern Cone into a major food supplier for both South America and the world, they have also prompted the widespread expansion of intensive agriculture onto marginal land. According to the Food and Agriculture Organization reports, more than 25 million hectares of marginal land were converted to agriculture in the Southern Cone between 1965 and 2005.

Against this backdrop, scientists at the IRI began to explore the relationship between agriculture, water management, and climate risk in the Southern Cone in 1999. Faced with one of the worst droughts its country's history, the government of Uruguay appealed to the IRI for help using climate forecast and monitoring tools to identify the regions in which aid was most needed most. In the years that followed this event, the IRI also supported Uruguay's Ministry of Agriculture as it helped develop similar Decision Support Systems in Paraguay and Chile as well.

Based on this initial experience, the IRI has expanded its efforts to explore the threats and vulnerabilities associated with agricultural water management in the region. In collaboration with the National Agricultural Research Institutes of the Southern Cone, the Inter-American Institute for Cooperation in Agriculture (IICA), and the International Maize and Wheat Improvement Center (CIMMYT), the IRI has analyzed the region's climatic history as a means to shed light on future. It has also worked with the National Agricultural Research Institutes of the Southern Cone, and the International Center for Agricultural Research in Dry Areas (ICARDA) to identify the threats associated with increasing the water demand in the Southern Cone. A third project, undertaken with the Center for Research on Environmental Decisions, explores the utility of near-term climate scenarios to water managers in Chile.

As part of these efforts, the IRI has helped countries of the Southern Cone to improve seasonal climate forecasts and to establish plausible climate change scenarios. In addition to assessing needs and opportunities, this work has also involved linking climate information to decision support systems that assess the technologies, management practices, and production systems most suited to the region's variable climate.

Though these efforts are still underway, the IRI has recently expanded its work in the Southern Cone to include two new projects. In the first of these, the IRI will work with Brazil's National

Institute of Meteorology to improve the capacity of the Ministry of Agriculture to make climate-related decisions. This will involve improving agro-meteorological monitoring, seasonal climate forecasts, and the accessibility of information to the Ministry and to national and international research institutions. By translating PDF forecasts to the station scale, the IRI has also developed methodologies that may be transferable to other parts of the world.

The IRI has recently been engaged by Uruguay's Ministry of Agriculture as well. This project will also begin by improving the Ministry's ability to manage and access data. The IRI will also help Uruguayan scientists improve seasonal forecasts and develop near-term climate change predictions, establishing methodologies that can eventually be transferred to other locations. The IRI will also contribute to the project by developing crop and pasture simulations that use climate information to generate probabilistic production forecasts based on a range of climatic outlooks and by developing appropriate insurance tools for the nation's dairy industry.

The IRI has worked in the Southern Cone for more than 10 years. While these efforts have focused almost exclusively on improving the quality and use of climate information in agricultural decision-making, the character of the work has fundamentally changed. Indeed, while the IRI's first foray in Uruguay responded to the Ministry of Agriculture's immediate need for drought-monitoring information, current efforts involve the implementation of a comprehensive climate risk management system. The IRI's work in Brazil will also require the IRI to draw on intellectual resources from across the region to help the Ministry of Agriculture improve its ability to manage climate-related risk. Both projects build on experience in the Southern Cone gained over the course of the last decade. Both will produce tools and methodologies that facilitate the use of climate information and that can be transferred to other regions as well.

RECENT ACTIVITIES IN THE SOUTHERN CONE (July 1, 2010 – March 31, 2011)

PROJECTS (*Recently Completed)*

Assessment of the Changes in Water Productivity under Different Climate Scenarios in the Southern Cone (2008-2010) - Final report submitted.

Climate Change and Variability in the Expansion of Agricultural Frontier in the Southern Cone: Technological and Policy Strategies to Reduce Vulnerabilities (2008-2010) - Final report submitted.

PROJECTS (*Ongoing)*

Diagnosing Decadal-Scale Climate Variability in Current Generation Coupled Models for Informing Near-Term Climate Change Impacts (2009-2012)

As part of this project, Paula Gonzalez, Lisa Goddard (PI), and Arthur Greene explored the relative significance of interannual to multidecadal variability in temperature and precipitation in South Eastern South America.

Preliminary results suggest that the relevance of different time scales is strongly season dependent; work will be completed with the analysis of observational data from long-record weather stations through collaborations with regional institutions. This team also presented:

Paula Gonzalez (with Lisa Goddard, and Arthur M Greene) presented the poster, "A Framework for the Development of Multi-scale Regional Climate Information" for AGU's 2010 Fall Meeting. December 2010, San Francisco, CA.

As part of Lisa Goddard and Arthur Greene's involvement with the U.S. CLIVAR Decadal Predictability Working Group, the team explored the influence of ocean initialization of coupled models in the quality of decadal predictions over South Eastern South America. Basic verification metrics indicate that ocean initialization does not significantly improve the quality of decadal hindcasts over this region, but deeper analysis will be needed to take into account the seasonality of the variability.

Elucidating Near-Term Climate Change Information to Guide Water Resources Decisions and Foster Sustainability (2010-2011)

Paul Block and Cathy Vaughan traveled with representatives of Columbia University's Center for Research on Environmental Decisions to Chile's Elqui River Basin in January, 2011 in order to meet with partners and gather information regarding utility of seasonal and decadal climate forecasts to water managers.

In February, it was agreed that Koen Verbist of CEAZA would visit the IRI to evaluate forecast skill in the region.

In March 2011, Luc Bonnafus of the Ecole Nationale Superieure des Mines de Nancy was brought on to develop a forecast communication tool for reservoir management and planning in the Elqui river basin.

Development of a Monitoring and Forecasting System of Crop and Pasture Production for Managing Climate Risks (2010-2013)

Amor Ines and Haibo Liu, together with Columbia undergraduate, Harry Liu, processed remote sensing data for surface energy flux estimation, to be used eventually in soil hydrologic characterization of the integrated modeling framework. The integrated framework was designed, tested and evaluated.

Multi-scale climate information for Agricultural Planning in Southeastern South America for Coming Decades (2011-2014)

The scientific objectives of this proposal led by Lisa Goddard are:

1. To design prototype climate information appropriate to agriculture on the 10-20 year time horizon.
2. To assess agricultural vulnerabilities to climate variability and change and develop adaptive management strategies to increase resiliency.

Development of a National Information System for Agriculture for Uruguay's Ministry of Agriculture (2012-2017)

In July of 2010, Uruguay's Minister of Agriculture Tabaré Aguerre traveled to IRI to discuss an upcoming project. In March of 2011, a proposal was submitted for this project. Initial work planning activities have taken place both within IRI and with partners in Uruguay.

OTHER ACTIVITIES

Walter Baethgen served on a delegation from Uruguay's Ministry of Agriculture to discuss funding of climate change adaptation project in the agricultural sector. July 2010, Washington, DC.

James Hansen presented "Seasonal to Inter-Annual Climate Forecasts and their Applications in Agriculture," at the WMO International Workshop on Addressing the Livelihood Crisis of Farmers: Weather and Climate Services. July 2010, Belo Horizonte, Brazil.

Lisa Goddard presented "Outreach and Capacity Building in VAMOS," to the 13th Session of Variability and Predictability of the American Monsoon System (VAMOS) Panel. July 2010, Buenos Aires, Argentina.

Walter Baethgen, Lisa Goddard, Gilma Mantilla and Simon Mason participated in the IAI Training Institute on the Use of Seasonal Climate Predictions for Applications in Latin America. August, 2010, Buenos Aires, Argentina.

Gilma Mantilla met with Carmen Ciganda, head of Environmental Health Department at Uruguay's Ministry of Public Health. August 2010, Montevideo, Uruguay

Walter Baethgen, Haresh Bhojwani, and Cathy Vaughan attended the 2nd International Conference: Climate, Sustainability and Development in Semi-arid Regions. August 2010, Fortaleza, Brazil.

Katia Fernandes presented "Incorporating Climate Variability and Change into Fire Potential Assessments in the Ucayali Region" (with W. Baethgen, R. S. DeFries, L. M. Goddard, M. Uriarte, C. Padoch, M. Pinedo-Vasquez) at AGU's Meeting of the Americas. August 2010, Foz do Iguacu, Brazil.

Pietro Ceccato presented "Human Health Infectious Diseases Early Warning Systems" at EMBC 2010 Workshop on Global Health Information. August 2010, Buenos Aires, Argentina.

Walter Baethgen and Lisa Goddard discussed with regional scientists, including INIA, projects related to the assessment of the changes in water productivity under different climate scenarios in the Southern Cone. They also discussed climate change and variability in the expansion of agricultural frontier in the Southern Cone, and technological and policy strategies to reduce vulnerabilities. November 2010, Montevideo, Uruguay.

Madeleine Thomson presented “Spatial methods for tropical disease epidemiology” at the International Biometric Conference. December 2010, Florianopolis, *Brazil*.

Madeleine Thomson met with Carmen Ciganda, head of Environmental Health Department of Uruguay’s Ministry of Health, to discuss possible climate and health training in Southern Cone. December 2010, Montevideo, Uruguay.

Luis de la Plaza and Julie Dana of the Treasury of the World Bank, along with Michael Carroll of the World Bank, traveled to IRI to discuss potential work on index insurance in Uruguay. December 2010, Palisades, NY.

Antonio Divino Moura, director of the Brazilian National Meteorological Institute, traveled to IRI to discuss potential work with the Ministry of Agriculture. December 2010, Palisades, NY.

IRI submitted a proposal to UNDP for *Index Insurance for Climate Risk Management for Dairy Farmers in the Metropolitan Region of Montevideo, Uruguay (2011-2012)*. January 2011.

Work planning activities were conducted for the proposal *Improving Capacity for Climate-Informed Agricultural Decision-Making in Brazil (2012-2014).* January – March 2011.

Walter Baethgen and Dan Osgood arranged for Laura Gastaldi, a researcher at Argentina’s National Institute for Agrobusiness Technology (INTA), to spend 3 months at IRI to develop capacity on the analysis of climate and index insurance on the management of dairy herds (arrival April 18, 2011). January, 2011.

Daniel Ruiz Carrascal and Cathy Vaughan engaged in planning meetings for the IAI-funded *Climate Change Impacts on Biodiversity in the Tropical Andes*, which will include both climate and biodiversity research in Bolivia. February, 2011.

FOCUS ON Colombia

Colombia is now one of the most promising emerging economies in the world. In the last five years, the country has made dramatic gains in security, trade, human rights, and the rule of law. Unfortunately, Colombia still suffers from high levels of social inequality and environmental degradation. These factors combine to make the country extremely vulnerable to climate risk – particularly with respect to water management, natural disasters, and climate-sensitive diseases. Protecting against these climate risks will help Colombia to further unlock its development potential.

The IRI's first engagement in Colombia came through the Integrated National Adaptation Pilot Project, which began in 2006. As part of this project, the IRI collaborated with Colombia's National Institute of Health (INS) on the development of a malaria early warning system for its National Integrated Surveillance and Control System. Over the course of five years, scientists at the IRI helped incorporate climatic variables into predictive models that facilitate the early detection and timely response to emerging epidemics. As a result of these ongoing efforts, the INS may be better able to manage and respond to malaria epidemics.

The IRI's next engagement in Colombia came by way of a long-term collaboration with the School of Engineering of Antioquia (EIA). In a project funded by the World Bank, the IRI has worked with researchers at the EIA to assess the impact of climate variability and change on high-altitude ecosystems in the Andes. Because many Andean cities depend on water from high-altitude ecosystems for drinking, irrigation, hydropower, and manufacturing, climate change threatens not just the survival of endemic species but also the economic framework on which Colombia is built.

In recent years, Colombia has actively taken on the challenge of incorporating climate risk management into national policy as a means of promoting sustainable development. For instance, Colombia National Development Plan was officially revised in 2011 in order to specifically address climate-related risk. In addition, the Department of National Planning (DNP) – the executive agency responsible for defining, recommending, and promoting public policy – has recently consulted with the IRI regarding the incorporation of climate into policy development. To date, this collaboration has involved Policy Dialogs between IRI scientists and DNP officials. IRI has also arranged a climate-information session for high-level members of Colombia's cabinet.

Moving forward, the IRI will continue its collaboration with the DNP in order to help implement the climate-risk management initiatives articulated in the National Development Plan. An important endeavor already under way involves improving the ability of the country's economic-forecasting models to account for climate variability and change. By linking the models the DNP is already using to plausible scenarios of future climate, the IRI will help Colombia's planning department to understand the impact that variability and change will have on individual sectors and the economy as a whole.

In the coming months, the IRI will also begin a new initiative with IDEAM, Colombia's national meteorological service. As part of this project, the IRI will consult with scientists at IDEAM in order to improve forecasts at both short- and long-term temporal scales. The collaboration will also improve the quality of forecast inputs to the National Institute of Health's surveillance system. The goal is to improve IDEAM's ability to produce and distribute the information needed by the national government to make climate-informed decisions.

The IRI began working in Colombia on issues related to health and ecosystems. In the 5 years since these collaborations began, the IRI has translated its sector-specific experience into broad-based efforts to inform national policy. These new efforts involve direct consultation with the Department of National Planning and high-level cabinet members. They will also include building the capacity of the national meteorological service to provide the climate information necessary for climate-informed decision-making and the incorporation of plausible climate scenarios into economic forecasting models. By helping the country to successfully manage climate-related risk, the IRI hopes to contribute to the enormous progress Colombia has made in recent years.

RECENT ACTIVITIES IN COLOMBIA (July 1, 2010 – March 31, 2011)

PROJECTS (*Recently Completed*)

Supporting Colombia's National Integrated Dengue and Malaria Surveillance and Control System (2009 – 2010)

Gilma Mantilla was an invited lecturer at the National University's International School on Environment and Health, presenting three talks on climate and public health to a group of 25 graduate students. July 2010, Bogotá, Colombia.

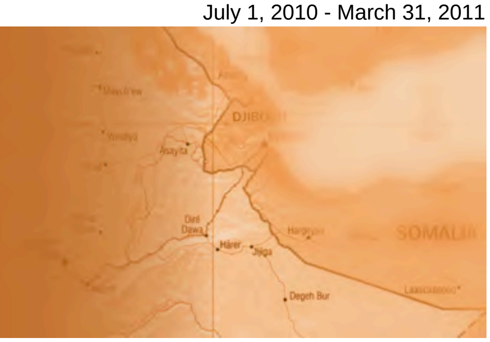
Gilma Mantilla, Hugo Oliveros, and Walter Baethgen were invited participants at the INS-sponsored International Conference on Health, Environment, and Climate. Together, the three scientists presented four talks on topics related to climate and public health. July 2010, Bogota, Colombia.

Simon Mason was invited to speak at the First National Climate Congress. His talk was entitled "Climate Variability and Human Health." He was also invited to speak at Banco de la Republica, Colombia's central bank, at its Economic Research Seminar. His talk was entitled "Climate Forecast and Uncertainties." July 2010, Bogotá, Colombia.

Gilma Mantilla visited Bogota to explore new opportunities in climate and health with the INS. (A result of that visit is a formally signed agreement between the INS and IRI during 2011) August 2010, Bogotá, Colombia.

The final report has been submitted. January 2011.

FOCUS ON Ethiopia



Managing climate risks is essential for the achievement of sustainable development in Ethiopia. As the second most populated country in Sub-Saharan Africa and with more than 70% of its people dependent on rain-fed agriculture, Ethiopia's extremely variable climate has had a profound impact on agricultural production and economic development. Sustainable development is now further threatened by climate change. The IRI has been working with Ethiopian partners to facilitate the implementation of climate risk management practices in key socioeconomic sectors. This includes work with the National Meteorological Agency (NMA) to improve climate data and services while building capacity for sectoral engagement. The use of climate information in health, agriculture, water, index insurance and other areas is being demonstrated by the Ethiopian Climate and Health Working Group (CHWG), the Ethiopian Institute of Agricultural Research, the Climate Change Forum- Ethiopia (CCF-E), Oxfam America and other local private and public partners.

Improving the Provision of Climate Data and Services

IRI has been working with the NMA to improve its management of climate data and provision of seasonal climate forecasts. Weather stations across Ethiopia and many parts of Africa are unevenly distributed. Most of the stations are located along main roads and few stations serve rural communities. Because of their excellent spatial coverage, satellite rainfall estimates are being used to supplement station measurements. An optimal combination of station measurements and better spatial coverage of satellite products will improve climate observations across many parts of Africa. The IRI is working with the NMA and the University of Reading to generate a 30-year time series of such a product at a ten-daily time scale and spatial resolution of ten kilometers under the IRI-Google.org project, *Building Capacity to Produce and Use Climate and Environmental Information for Improving Health in East Africa*. Additionally, a project funded by the CGIAR Climate Change, Agriculture & Food Security (CCAFS) program aims to produce a 30-year time series of daily high-resolution rainfall and temperature data. IRI is also working with the NMA to develop an online Digital Climate Atlas of Ethiopia that will provide sector-relevant climate information. IRI has also provided support to improve the agency's web page for better presentation of current products, as well as to make the 30-year climatology described above available online.

Integrating Climate into Practices

Climate services will have little value unless potential user communities are capable of using the available climate information and are able to request products that better suit their particular needs. The IRI works with a number of institutions in Ethiopia to build climate-risk-management capacity in user communities for health, agriculture, water, disaster response and financial services. A good example is the multi-agency Climate and Health Working Group supported under the IRI-Google.org project mentioned above. Other efforts include the development of a similar community of practice for the water sector, a collaborative assessment of recent trends in surface/air temperature in highland areas and training for climate-risk-management research in agriculture in collaboration with the Institute for Agricultural Research and the NMA. Risk transfer tools such as weather index insurance for rural farmers have been tested and are being scaled up in collaboration with Oxfam America, Swiss Re, NMA and other government and local partners. Further tools and products such as yield forecasting and disease prediction models, risk maps and climate atlases will be developed with relevant institutions.

Integrating Climate into Policy

IRI is exploring how it could be helpful to Ethiopia in integrating climate into regional and national policy. It has participated in the Climate Change Forum-Ethiopia (CCF-E) since the forum's founding in 2008 and supported the development of its terms of reference and its strategic plan. IRI climate scientist, Dr. Tufa Dinku, was also a panelist in CCF-E's first conference, which was opened by Prime Minister Meles Zenawi. Currently, IRI is working with CCF-E to develop a conceptual framework for climate risk management in agriculture, while exploring similar ideas for the water sector.

RECENT ACTIVITIES IN ETHIOPIA (July 1, 2010 – March 31, 2011)

PROJECTS (*Recently Completed)*

Oxfam HARITA: IRI MIEL (Monitoring, Impact Evaluation and Learning) Planning and Technical Support for HARITA Micro-Insurance Pilot (2009 - 2010)

Papers on index insurance were presented at:

- The 2010 Agriculture and Applied Economics Conference, July 2010, Denver, CO:
  - Daniel Osgood (with K. E. Shirley): The impacts of thresholds on risk behavior: What's the matter with index insurance?
  - Michael Norton: Weather index insurance and the pricing of spatial basis risk
- The 2nd International Remote Sensing Index-Based Crop Insurance Working Group, August 2010, San Francisco, CA
  - Daniel Osgood: The IRI experience with remote sensing in index insurance in Africa

Eric Holthaus, Daniel Osgood and Jessica Sharoff conducted HARITA stakeholder meetings and field training. September 2010, Mekele and Addis Ababa, Ethiopia.

The project team conducted field work for three weeks in September 2010 in Addis Ababa and Mekele, Ethiopia:

- Conducted game exercises with CU-CRED; supported Tigray Regional Index Insurance Stakeholder Workshop in Mekele. Michael Norton.
- One-day workshop at the Ethiopia National Index Insurance Stakeholder Workshop (Addis Ababa) conducted for interested insurance parties and NGOs on the technical aspects of index insurance; and a Tigray Regional Index Insurance Stakeholder Workshop working session (Mekele) to set the stage for the 2011 scale-up of the HARITA project. Priority regions for scale-up were selected, building block indices were created, and training materials were reviewed and distributed. Eric Holthaus, Jessica Sharoff.

IRI hosted Rahel Legesse, Micro Insurance Project Officer at Oxfam-America Horn of Africa Regional Office in Addis Ababa, Ethiopia. October 2010, Palisades, NY.

Eric Holthaus conducted capacity building training for insurance companies and other project partners. January 2011, Mekele, Ethiopia.

In December 2010, the World Bank Agricultural Risk Management Team led training on index insurance. Daniel Osgood, Michael Norton and Jessica Sharoff participated to present the IRI web tool, WIIET, commissioned by World Bank.

Malgosia Madajewicz conducted a site visit to supervise the beginning of the follow up survey for the HARITA project impact evaluation. January - February 2011, Mekele, Ethiopia.

Project team field work in March and April 2011:

• Project capacity building training for NGOs and insurance sector. Eric Holthaus. Addis Ababa, Ethiopia.
• Experimental economic games. Michael Norton. Tigray, Ethiopia.
• Project workshop training for index design teams. Eric Holthaus. Mekele, Ethiopia.

PROJECTS (*Ongoing*)

Google.org: Building Capacity to Produce and Use Climate and Environmental Information for Improving Health in East Africa

In July and August 2010, Tufa Dinku was in Addis Ababa, Ethiopia to meet with partners and work with Ethiopia's National Meteorological Agency (NMA):

- Presented on IRI, the CRM approach, and work in Ethiopia at the FAO-sponsored Climate Change Forum Ethiopia (CCF-E) workshop *Strengthening Capacity for Climate Change Adaptation in the Agriculture Sector*; and met with Mr. Gebru Jember, CCF-E scientific officer (and NMA).
- Ethiopian Institute of Agricultural Research. Meeting.
- UN-SPIDER Workshop on *Building upon Regional Space-based Solutions for Disaster Management and Emergency Response for Africa* (a workshop for the mapping and remote sensing community); presented: on the IRI-DL, the relevant Map Rooms, and the IRI-NMA project during a session on "Information Management Including Spatial Data Infrastructure."
- Meeting with OXFAM America on areas for collaboration.
- Meeting with Abere Mihrete (Anti Malaria Association), Adugna Woyessa (Ethiopian Health and Nutrition Research Institute), and Abenet Girma (Climate and Health Working Group [CHWG] coordinator) to discuss the implementation of the baseline survey for the Google project.
- Planning meeting for the Seventh African Development Forum, with J. Williams and M. Boulahya.
- Meetings at Addis Ababa University with Dr. Semu Moges, Civil Engineering Department and Dr. Gizaw Mengistu, Physics Department.

Stephen Connor visited the Universities of Reading, Norwich, Liverpool, UK for collaborative discussions. July-August 2010.

John del Corral collaborated with Ethiopia NMA on their current and future website and climate atlas. August 2010, Addis Ababa, Ethiopia.

Bradfield Lyon and Ousmane Ndiaye conducted a forecast methodology and verification workshop for the NMA. August 2010, Addis Ababa, Ethiopia.

Stephen Connor and Barbara Platzer met with Google project partners, including the Ethiopian Ministry of Health, the NMA and the CHWG Secretariat. They visited the CDC Ethiopia office-EFELTP, WHO country office, Addis Ababa University's School of Public Health; and met with M. Boulahya to discuss ADF-VII. August 2010, Addis Ababa, Ethiopia.

At the 2010 EUMETSAT Meteorological Satellite Conference, Tufa Dinku presented: Blending METEOSAT Rainfall Estimates and National Raingauge Observations to Produce High-resolution 30-year Time Series over Ethiopia. September 2010, Cordoba, Spain.

IRI hosted Amy Luers, google.org project manager, to discuss IRI-Google project; opportunities and to build on Google's investments in climate data and services in Africa. September 2010, Palisades, NY.

Tufa Dinku presented "Historical Time Series of Merged Raingauge-Satellite Rainfall Data for Climate Risk Management Applications in Ethiopia" (with K. Hailemariam, D.F. Grimes) at the Fifth Workshop of the International

Precipitation Working Group. October 2010, Hamburg, Germany.

Simon Mason and Ashley Curtis met with Google to discuss CPT software development and scale up. November 2010, New York, NY.

Stephen Connor was an invited speaker and panelist on "Climate Services and Global Health" at the CDC/CARE-USA/Emory Conference on Innovations in Global Health, Development, and Climate Change Adaptation. November 2010, Atlanta, GA.

John del Corral, Judy Omumbo and Madeleine Thomson co-organized, with the CHWG, the Climate and Malaria Workshop 2010. Participants included: regional health bureaus, schools of public health, public health emergency management, Anti-Malaria Association, Aklilu Lemma Institute of Pathobiology, Carter Center, Ethiopian Field Epidemiology and Laboratory Training Program (FELTP), NMA. November 2010, Addis Ababa, Ethiopia.

John del Corral met with K. Hailemariam (NMA) to review progress on NMA website redesign project. November 2010, Addis Ababa, Ethiopia.

Tufa Dinku and Bradfield Lyon conducted Google and CCAFS partner discussions, and visited the NMA and the African Climate Policy Center (ACPC). December 2010, Addis Ababa, Ethiopia.

CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) - Theme 2: Adaptation Through Managing Climate Risk

Kevin Coffey and James W. Hansen participated in the CCAFS Management Team Meeting. August 2010, Aberdeen, UK.

Kevin Coffey attended the CCAFS Scenarios Workshop. August 2010, Nairobi, Kenya.

Tufa Dinku and Bradfield Lyon conducted the Data Quality and Analysis Workshop for Ethiopia's NMA. August-September 2010, Addis Ababa, Ethiopia.

Jessica Sharoff was in region to:
- Participate in the 26th Climate Outlook Forum for the Greater Horn of Africa and Food Security Outlook. September 2010, Kisumu, Kenya.
- Conduct Climate and Society Publication (CSP) case study research and CCAFS scoping. September-October 2010, Nairobi, Kenya.
- Scope CCAFS. September 2010, Addis Ababa, Ethiopia

James W. Hansen participated in COP-16 activities in December, 2010, in Cancun, Mexico.
- CCAFS Climate Change Adaptation and Mitigation in Agriculture Research Workshop, Playacar Palace
- Agriculture and Rural Development Day, Gran Melia Cancun Hotel

James W. Hansen participated in the CCAFS Management Team Meeting. February 2011, Copenhagen, Denmark.

IRI hosted Seydou Traore, agrometeorologist and head of the Scientific Coordination Unit, AGRHYMET. He met with Tufa Dinku on CCAFS-supported activities to develop a methodology for a daily-time step rainfall and temperature climatology for the 9 CILSS countries building on the Ethiopian climatology work completed under Google. March 2011, Palisades, NY.

Tufa Dinku visited the International Potato Center (CIP). March 2011, Lima, Peru. He participated in:
- CIP-CCAFS sponsored workshop, *Methodological approaches in climate downscaling and weather data reconstruction*
- Meeting to discuss areas of collaboration in generating historical time series of daily rainfall

Collaboration: Meningitis Environmental Risk Information Technologies (MERIT)

Madeleine Thomson visited and met with the WHO Tropical Disease Research Unit to establish climate research agenda. August 2010, Geneva, Switzerland.

Sylwia Trzaska participated in the Meningitis Weather Project Team Meeting. October 2010, Boulder, CO.

Madeleine Thomson, Sylwia Trzaska and Carlos Perez Garcia-Pando were in Lancaster University to attend meetings. November 2010, Lancashire, UK:

- Medical Research Council Methodology Grant: Statistical modeling for real-time spatial surveillance and forecasting
- Launch meeting for Meningitis Research Foundation project with P. Diggle

Madeleine Thomson, Sylwia Trzaska and Carlos Perez Garcia-Pando participated in *Health Climate Risk Management in Health: Lessons Learned*, a half-day seminar on climate and health organized by Ethiopia's Climate and Health Working Group in collaboration with the Addis Ababa University's School of Public Health, IRI and MERIT. November 2010, Addis Ababa, Ethiopia. Presentations:

- M. Thomson: IRI Climate Risk Management in Health: Lessons Learned
- Woyessa Ethiopian Health and Nutrition Research Institute: Malaria and Climate: Ethiopia in case
- K. Hailemariam National Meteorological Agency of Ethiopia: Building capacity at the NMA
- E. Firth, WHO: Building sustainable partnerships to improve meningitis surveillance and response: The MERIT initiative

John del Corral, Carlos Perez Garcia-Pando, Madeleine Thomson, and Sylwia Trzaska participated in the 4th International MERIT Technical Meeting. November 2010, Addis Ababa, Ethiopia. Posters and presentations included:

- John del Corral: IRI Data Library meningitis maproom
- John del Corral: OpenHealth/SERVIR/IRI Data Library
- Carlos Perez Garcia-Pando, Madeleine Thomson, Sylwia Trzaska: A 30-year high resolution model reanalysis of dust and climate for the Meningitis Belt
- Madeleine Thomson: New opportunities in the context of climate and health in Africa
- Sylwia Trzaska, (with S. Adamo, G. Yetman), John del Corral, Carlos Perez Garcia-Pando, Madeleine Thomson: Demographic and Environmental Factors in Meningococcal Meningitis Outbreak Frequency in Niger
- Sylwia Trzaska, C. Perez Garcia-Pando, Madeleine Thomson (with S. Hugonnet, E. Bertherat, E. Firth, K. Fernandez, T. Seydou, M. Kadi, M.-Ch. Dufresne, M. Bell): 2010 Meningitis Epidemic Season in West Africa: Experimental Real-time Monitoring of the Environmental conditions.

At Addis Ababa University's Department of Physics, Sylwia Trzaska made presentations on:

- End-to-end and interdisciplinary approach to climate research at the International Research Institute or Climate and Society: Investigating the role of climate in epidemic outbreaks of Meningococcal Meningitis in the Sahel
- Introduction to IRI Data Library, 3-hour hands-on introduction/training session with graduate students

Sylwia also met with Dr. Gizaw Mengistu, Chair, Department of Physics, on potential for collaboration on dust and aerosols. November 2010, Addis Ababa, Ethiopia.

Madeleine Thomson participated in the MERIT Steering Committee Meeting at WHO Headquarters. January 2011, Geneva Switzerland.

IRI is hosting Michelle Stanton, visiting scientist from Lancaster University's Division of Medicine. She conducted an IRI Seminar: Towards Real-Time Spatio-Temporal Monitoring and Forecasting of Meningitis

Incidence in Sub-Saharan Africa. January 2011, Palisades, NY.

OTHER RELATED ACTIVITIES

IRI hosted Belay Begashaw, Director of the MDG Centre in Nairobi, Kenya. Discussions focused on potential IRI contributions to the MDG Centre's Drylands Initiative. September 2010, Palisades, NY.

Stephen Zebiak, Walter Baethgen, Haresh Bhojwani and Madeleine Thomson participated in the NOAA International Climate Services Workshop and Review Activity: Understanding and Responding to the Needs of Decision Makers. September 2010, Washington, DC.

Stephen Zebiak, Haresh Bhojwani and Ousmane Ndiaye participated in the African Development Forum VII and pre-forum. October 2010, Addis Ababa, Ethiopia. Presentations included:

- Ousmane Ndiaye: Pre-forum, Getting it Right: Reporting climate change for sustainable development in Africa" (Africa Media Training Workshop); presented "Climate Risk Management" and "Uncertainties in Climate Change Models" to 25 participants from the African region
- Stephen Zebiak delivered keynote presentation for the ADF-VII session *Climate risk management: Monitoring, Assessment, Early Warning and Disaster Risk Reduction*

Madeleine Thomson attended the Institute on Science for Global Policy conference on *Emerging and Persistent Infectious Diseases: Focus on Surveillance*. She presented: Thomson, and Mantilla, 2010: Integrating climate information into surveillance systems for infectious diseases: new opportunities for improved public health outcomes in a changing climate. October 2010, Warrenton, VA.

Jeremy Webb, statistician at the African Climate Policy Center (ACPC) in Addis Ababa, Ethiopia visited the IRI, November 2010, Palisades, NY. Activities included:

- Meeting to discuss ACPC activities including collaboration with African Centre for Statistics (ACS) to populate the ACS database with climate and related information, and the potential for applications using IRI's data library and other products.
- Seminar: ClimDev-Africa and the African Climate Policy Centre: Going forward

Stephen Zebiak, Haresh Bhojwani, Lisette Braman, James W. Hansen, Molly Hellmuth and Shiv Someshwar attended the COP16/CMP6 United Nations Climate Change Conference. December 2010, Cancun, Mexico.

Bradfield Lyon, Judy Omumbo and Madeleine Thomson attended a President's Malaria Initiative/USAID meeting to discuss technical support needed to evaluate the impact of PMI's malaria control program interventions in sub-Saharan countries, and the avenues to move forward on a formal collaboration. In response to a USAID invitation, the following presentations were made on February 2011, in Washington, DC:

- B. Lyon: Some thoughts on connecting health outcomes to climate
- J. Omumbo: Climate information for decision support in malaria control

Madeleine Thomson participated in February 2011 activities in Washington, DC:

- Centres for Disease Control and Prevention; presented: Climate Information for Public Health Action
- 2011 Malaria Program Review

Paul Block and Bradfield Lyon were invited to make a joint presentation, "Linking Africa's Climate and Water-related Infrastructure," at the Earth Institute meeting, *Investing in infrastructure in Africa*. March 2011, New York, NY.

Arne Bomblies, Assistant Professor at University of Vermont's School of Engineering visited the IRI. March 2011, Palisades, NY:

- IRI Seminar: Hydrological controls of malaria transmission
- Meeting with staff on Africa Regional Program, Climate and Health activities

SELECTED PROJECTS 2010-2011

TOPIC AND REGION ICONS

Agriculture and Food Security
Climate
Data Library and Map Rooms
Economics and Livelihoods
Education and Training
Environmental Monitoring and Remote Sensing
Fire Management
Forecasting
Hazards
Public Health
Water Management
Africa
Asia and the Pacific
Latin America and the Caribbean

Topics/ Region	Project Title	Description	Partners	Project / IRI Lead
	Assessment of the Changes in Water Productivity under Different Climate Scenarios in the Southern Cone	Define plausible scenarios of climate variability and near-term climate change and integrating these into information and decision support systems for improving water management in South America's Southern Cone.	▪ Instituto Nacional de Tecnología Agropecuaria (INIA) (Argentina) ▪ Empresa Brasileira de Pesquisa Agropecuária ▪ Fondo Regional de Tecnologia Agropecuaria ▪ Universidad Mayor de San Andres (Bolivia) ▪ Programa Cooperativo para el Desarrollo Tecnologico Agroalimentario y Agroindustrial del Cono Sur ▪ Inter-American Institute for Cooperation in Agriculture ▪ Instituto Nacional de Investigaciones Agropecuarias (INIA) (Chile) ▪ Instituto Nacional de Investigacion Agropecuaria (INIA) (Uruguay) ▪ International Center for Agricultural Research in the Dry Areas	Baethgen, W. E.
	Atmospheric Aerosol Impacts on Health in Sub-Saharan Africa	Towards increased understanding of related health impacts in sub-Saharan Africa through the investigation of near-surface dust characteristics specific to the Sahel during the dry season.	▪ Columbia University: NASA Goddard Institute for Space Studies; Department of Ecology, Evolution and Environmental Biology; Mailman School of Public Health; Lamont-Doherty Earth Observatory; Tropical Agriculture Program of the Earth Institute	Perez Garcia-Pando, C. Trzaska, S.

Topics/ Region	Project Title	Description	Partners	Project / IRI Lead
	Building Capacity to Produce and Use Climate and Environmental Information for Improving Health in East Africa	Building capacity in the climate and health community (both individuals and institutions) to produce and use climate knowledge and information in routine health decision-making.	▪ Ethiopia Ministry of Health ▪ Liverpool School of Tropical Medicine ▪ National Meteorological Agency of Ethiopia ▪ IGAD Climate Prediction Centre ▪ Anti-Malaria Association (Ethiopia) ▪ University of Reading, Department of Meteorology (UK) ▪ World Health Organization Eastern and Southern African Malaria Control ▪ Climate and Health Working Group (CHWG) of Ethiopia ▪ CHWG of Kenya ▪ CHWG of Madagascar ▪ Meningitis Environmental Risk Information Technologies ▪ Health and Climate Foundation	Connor, S.
	CAREER: Characterizing the Uncertainty in Projections of Climate Change in the Semi-Arid Tropics Based on the Moist Static Energy Framework	Advancing climate change research through increased understanding of the physical processes that cause uncertainty in climate model projections, and improving communication of its results to the broader community.	▪ Columbia University: School of International and Public Affairs; Department of Earth and Environmental Sciences; Institute of African Studies	Giannini, A.
	CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) - Theme 2: Adaptation Through Managing Climate Risk	Conducting and leading strategic and theme research activities that bring promising innovations in climate risk management to bear on the challenge of protecting and enhancing food security and rural livelihoods in the face of a variable and changing climate.		Hansen, J.
	Climate Change and Variability in the Expansion of Agricultural Frontier in the Southern Cone: Technological and Policy Strategies to Reduce Vulnerabilities	Identifying the vulnerabilities of the expansion of agriculture to climate change and variability in the Southern Cone and exploring technological alternatives and policy interventions to improve adaptability.	▪ Inter-American Development Bank ▪ INIA (Argentina) ▪ Programa Cooperativo para el Desarrollo Tecnologico Agroalimentario y Agroindustrial del Cono Sur ▪ Centro Internacional de Mejoramiento de Maiz y Trigo ▪ Inter-American Institute for Cooperation in Agriculture ▪ INIA (Chile) ▪ INIA (Uruguay) ▪ Ministerio de Ganaderia y Agricultura (Paraguay Ministry of Livestock and Agriculture)	Baethgen, W. E.

Topics/ Region	Project Title	Description	Partners	Project / IRI Lead
	Climate Information for Public Health Action	Providing public health professionals with knowledge, methodologies, tools, and data to better manage climate sensitive diseases toward improving health outcomes	▪ Columbia University: Center for International Earth Science Information Network; Mailman School of Public Health	Thomson, M.
	Climate Predictability Tool Development	This project will deliver a platform independent version of a Climate Predictability Tool with dynamic link libraries (DLLs). DLLs facilitate user access by breaking the program into smaller, separately downloadable components.	▪ World Meteorological Organization	Mason, S
	Climate Predictability Tool Training	Foster a network of expertise for improved understanding of climate predictability.	▪ World Meteorological Organization	Mason, S.
	Climate Predictability of Extreme Floods in the United States	Developing a statistically-based inference and modeling system for the conditional simulation of floods given climate attributes		Lall, U.
	Climate-Related Risk Assessment and Risk Management in the Agricultural and Forestry Sectors of Uruguay *Completed*	Assessed the impact of climate variability at different temporal scales (from seasonal/interannual, through decadal, to climate change) on food crops, livestock and forest production.	▪ INIA (Uruguay) ▪ Universidad de la Republica	Baethgen, W. E.
	Collaborative Research: Regional Climate-Change Projections Through Next-Generation Empirical And Dynamical Models	The development of a twin approach of non-homogeneous hidden Markov models and coupled ocean-atmosphere, intermediate-complexity models to identify the potentially predictable modes of climate variability and to investigate their impacts on the regional scale.	▪ University of California, Irvine ▪ National Oceanic and Atmospheric Administration ▪ University of California, Los Angeles ▪ University of Wisconsin Milwaukee	Robertson, A.
	Collaborative Research: Separating Forced and Unforced Decadal Predictability in Models and Observations	We propose a methodology to identify unforced predictable components on decadal time scales in models and observations, distinguish these components from forced predictable components, and assess the reliability of model predictions of these components. The methodology will be applied to the decadal hindcasts generated by the CMIP5 project to assess the reliability of model projections. The question of whether anthropogenic forcing changes decadal predictability, or gives rise to new forms of decadal predictability will also be investigated.	▪ George Mason University	Tippett, M. K.

Topics/ Region	Project Title	Description	Partners	Project / IRI Lead
	Consortium for Climate Risk in the Urban Northeast	Working with stakeholders in the urban corridor stretching from Boston to Philadelphia to improve the management of climate risks and adaptation to climate variability and change. IRI involvement is in impacts evaluation (Madajewicz), vulnerability of urban populations (Someshwar), and development of climate information (Goddard).	▪ Columbia University: NASA Goddard Institute for Space Studies, Center for International Earth Science Information Network, Mailman School of Public Health, Cooperative Institute for Climate Applications and Research, Department of Earth and Environmental Engineering ▪ Drexel University ▪ City College of the City University of New York ▪ Stevens Institute of Technology ▪ University of Massachusetts	Goddard, L. Madajewicz, M. Someshwar, S.
	Contributing to an OPeNDAP/OCG Gateway to Support Regional IOOS Interoperability *Completed*	Contributed to overall design of OPeNDAP/OCG Gateway to Support Regional IOOS Interoperability, with particular focus on semantic mapping necessary to translate data through different interfaces, and the designing of a framework that allows semantic mapping without interfering with or changing the data transport.	▪ Open-source Project for a Network Data Access Protocol	Blumenthal, M. B.
	Data Library Operations	Facilitate data exchange by providing an online data library that provides multi-disciplinary access to data needed to study short-term climate change and its impact.	▪ Thematic Realtime Environmental Distributed Data Services ▪ OPeNDAP Distributed Ocean Data Sets	Blumenthal, M. B.
	Decentralization and Local Public Goods: How Does Allocation Of Decision-Making Authority Affect Provision?	Determine under what conditions community participation in projects designed to raise living standards in the community improves project outcomes.	▪ NGO Forum for Drinking Water Supply & Sanitation	Madajewicz, M.
	Decision Support System for Irrigated and Rainfed Conditions in the Coquimbo Region of Chile	Improving preparedness and response to droughts in rainfed areas of Chile's Coquimbo region by collaborating with local partners to establish a drought early warning system and to improve water use efficiency.	▪ Centro del Agua para Zonas Aridas y Semi Aridas de America Latina y El Caribe ▪ Centro de Estudios Avanzados en Zonas Aridas (Chile) ▪ Junta de Vigilancia del Rio Elqui ▪ Gobierno Regional de Coquimbo, Chile ▪ Direccion General de Aquas (Chile) ▪ University of Gent (Belgium)	Baethgen, W. E.

Topics/ Region	Project Title	Description	Partners	Project / IRI Lead
	Development of Coupled Model Products	This project explores improvements to real-time coupled model forecasts, including provision of diagnostics of coupled models provided by collaborating partners, that will aid implementation of operational coupled seasonal forecasting in Africa.	▪ Center for Ocean-Land-Atmosphere Studies ▪ European Centre for Medium-Range Weather Forecasts ▪ National Centers for Environmental Prediction	DeWitt, D.
	Development of Global Climate Maps and Data Layers for Climate Change *Completed*	Developed tools that enhance project support decision-making by helping to answer questions about the relative importance of historical climate variations on different time scales.		Baethgen, W. E.
	Development of a Monitoring and Forecasting System of Crop and Pasture Production for Managing Climate Risks	Incorporating climate-related information into decision support tools to enhance monitoring and forecasting of crop and pasture production in Uruguay.	▪ INIA (Uruguay)	Baethgen, W. E.
	Diagnosing Decadal-Scale Climate Variability in Current Generation Coupled Models for Informing Near-Term Climate Change Impacts	Examining and documenting characteristics of decadal-scale variability in current generation coupled models, particularly in the context of initialized predictions, to prepare for the work in experimental decadal predictions emerging from modeling centers.	▪ Geophysical Fluid Dynamics Laboratory ▪ The National Center for Atmospheric Research ▪ Hadley Centre	Goddard, L.
	Elucidating Near-Term Climate Change Information to Guide Water Resources Decisions and Foster Sustainability	Identifying the linkages and feedbacks between near-term climate change projections and decadal decisions to lay the groundwork for a water management decision system in Chile's Elqui River Basin	▪ Junta de Vigilancia del Rio Elqui ▪ Columbia University: Center for Research on Environmental Decisions; Tree Ring Lab; Columbia Water Center ▪ Universidad de la Serena	Block, P.
	Environmental Factors And Population Dynamics As Determinants Of Meningococcal Meningitis Epidemics In The Sahel: An Investigation Of Nasa And Noaa Products	Exploring the potential of satellite observations and model outputs combined with available epidemiological and demographic information for meningitis risk mapping with a focus on Niger.	▪ NASA Jet Propulsion Laboratory ▪ Columbia University Center for International Earth Science Information Network	Trzaska, S.
	Evaluating Impacts of Sustainable Development Projects	Designing innovative methods to evaluate impacts of the projects we undertake towards sustainable development	▪ Columbia University: Tropical Agriculture Program of the Earth Institute; Applied Statistics Center; Department of Mechanical Engineering; Center for International Earth Science Information Network	Madajewicz, M.

Topics/ Region	Project Title	Description	Partners	Project / IRI Lead
	Experimental Crop Disease Outlooks for SE South America	Testing the ability of ENSO and seasonal climate forecasts to establish outlooks of the incidence of two important crop diseases (fusarium in wheat and rust in soybeans) in southern Brazil.	▪ Centro de Previsão de Tempo e Estudos Climáticos ▪ Empresa Brasileira de Pesquisa Agropecuária ▪ Instituto Agronomico do Parana(Brazil)	Baethgen, W. E.
	Extended Range Forecasting and Agriculture Risk Management, India (ERFS)	Integrating risk management and climate science research to improve forecasting capacity and the understanding of climate risks in the context of rural livelihoods.	▪ Indian Institute of Technology Delhi ▪ Government of India Ministry of Agriculture ▪ India Meteorological Department ▪ National Centre for Medium Range Weather Forecasting ▪ Indian Council of Agriculture Research	Someshwar, S. Robertson, A.
	Fires in Western Amazonia: Understanding and Modeling the Roles of Climatic, Social, Demographic, and Land Use Change	Columbia University's Center for Environmental Research Conservation takes the lead in this collaboration with IRI, and the Department of Ecology, Evolution, and Environmental Biology (E3B) to investigate the relevant processes of change in land use, migration, urbanization, and climate in Western Amazonia, and links to the probability of changes in the incidence, size and severity of escaped fires.	▪ Columbia University: Center for Environmental Research and Conservation; Department of Ecology, Evolution and Environmental Biology	Baethgen, W. E.
	Forecasting Tropical Cyclone Activity Using Atmospheric General Circulation Models *(Completed)*	Developed and improved operational tropical cyclone forecasts products, increasing coastal societies' preparedness for tropical cyclone impacts.	▪ Max Planck Institute for Meteorology ▪ South African Weather Service	Camargo, S.
	Global Model Outputs	Coupled and Atmospheric Model Runs		DeWitt, D.
	IRI CSL Computing Project: Development & Application of Seasonal Climate Predictions	We utilize CSL computational resources to investigate the potential to predict extreme seasonal and sub-seasonal climate variability. The results of this work contribute to better estimates of the skill realizable by real-time forecasts of climate, and in improvements to sector forecasts that incorporate climate factors.	▪ Max Planck Institute for Meteorology ▪ The National Center for Atmospheric Research	DeWitt, D.

Topics/ Region	Project Title	Description	Partners	Project / IRI Lead
	IRI MIEL (Monitoring, Impact Evaluation and Learning) Planning and Technical Support for HARITA Micro-Insurance Pilot *Completed*	Planning and technical support in the expansion of Oxfam America's climate change resiliency pilot in Adi Ha, Tigray, Ethiopia, providing a holistic package that combines risk reduction, drought insurance and credit for food insecure households.		Osgood, D.
	IRI-IFRC Partnership to Save Lives	A partnership with IFRC in the use of climate information to enhance IFRC's national and regional offices' capacity in effective early warning-early action to minimize the effects of weather- and climate-related natural disasters.	▪ International Federation of Red Cross and Red Crescent Societies	Mason, S.
	IRI-SCG Developing User Requirements Registry, Concepts and Approaches for Cross-Cutting Analyses Between Nine Societal Benefits Areas for Identifying User Needs in Terms of Earth Observation Priorities from the 2009 US-09-01A Primary Reports *Completed*	Provided analyses and consultation on cross-cutting issues to set the observational priorities for the health components of the Group on Earth Observations (GEO) System of Systems (GEOSS)		Ceccato, P.
	IRI-WFP Collaboration on Climate Change	IRI and the UN World Food Programme collaborate to identify practice areas in food security risk to which climate information, tailored for policy and planning can benefically be incorporated.	▪ World Food Programme	Zebiak, S. E.
	Implementation of New or Improved Systems, Tools, Software and Products	Implementation of new or improved components into the forecast operations for the production of the global "net assessment" forecasts is considered an essential step in the completion of a successful research activity on forecast combination and / or recalibration. The transition into "real-time" forecasting products and tools is an integral component of predictability research at the IRI.	▪ Max Planck Institute for Meteorology ▪ NASA/Goddard Space Flight Center ▪ Center for Ocean-Land-Atmosphere Studies ▪ Geophysical Fluid Dynamics Laboratory ▪ Climate Prediction Center ▪ Environmental Modeling Center ▪ National Centers for Environmental Prediction ▪ Experimental Climate Prediction Center ▪ Queensland Climate Change Centre of Excellence	Barnston, A.
	Improved SST Prediction	Provide the most accurate and reliable predictions possible of global SSTs and of ENSO probabilities	▪ European Centre for Medium-Range Weather Forecasts ▪ National Centers for Environmental Prediction	Tippett, M. K.

Topics/ Region	Project Title	Description	Partners	Project / IRI Lead
	Incorporating Scale and Predictability Information in Multi-model Ensemble Climate Predictions	Developing a state-of-the-art multi-model ensemble prediction system informed by the best available prior information using a mathematically rigorous procedure.	▪ National Centers for Environmental Prediction ▪ George Mason University	Tippett, M. K.
	International Internships for Climate and Society	Working with IFRC to provide opportunities for students in the Climate & Society MA Program to work on climate risk management in Asia, Africa and Latin America.	▪ NOAA Climate Program Office ▪ International Federation of Red Cross and Red Crescent Societies ▪ Red Cross/Red Crescent Climate Centre	Zebiak, S. E.
	LDEO: The American Midsummer Drought: Casual Mechanisms and Seasonal-to-Interannual Predictability	We seek to understand more fully the "mid-summer drought" (MSD), which is unique to Central America and southern Mexico. We propose to focus on analysis of observations, using approaches that will allow us to identify what features of the atmospheric circulation are critical to predicting inter-American hydro-climate.	▪ Columbia University Lamont-Doherty Earth Observatory ▪ Woods Hole Oceanographic Institution	Giannini, A.
	Large Ensemble Impact on Predictive Skill in Tier-2 Integrations Using Prescribed Sea Surface Temperature	Assess the impact of ensemble size on seasonal forecast skill, and assess parameterization of the forecast probability distribution function as a function of ensemble size.	▪ Max Planck Institute for Meteorology ▪ The National Center for Atmospheric Research	Goddard, L.
	Linking Seasonal Forecasts into RiskView to Enhance Food Security Contingency Planning *Completed*	Equipped a water requirement satisfaction index tool for crops with climate forecast information to generate probabilistic estimates of emerging or current food production risks across Africa		Hansen, J.

Topics/ Region	Project Title	Description	Partners	Project / IRI Lead
	Managing Climate Risk for Agriculture And Water Resources Development in South-Western South Africa: Quantifying the Costs, Benefits and Risks Associated with Planning and Management Alternatives	Managing climate risk for agriculture and water resources development in South Africa, a collaboration with three South African universities led by the University of the Free State	▪ Climate Systems Analysis Group ▪ University of the Free State ▪ UNEP Risoe Centre on Energy, Climate and Sustainable Development ▪ University of KwaZulu Natal, School of Bioresources Engineering and Environmental Hydrology	Hellmuth, M.
	Map Rooms - Capability Enhancements	Enhance society's ability to understand climate variability and its synergistic relationships with other environmental factors for applications in various sectors and decision systems.	▪ World Meteorological Organization ▪ United States Geological Survey ▪ Columbia University Center for International Earth Science Information Network	Blumenthal, M. B.
	Mapping Institutions and Policy Responses	Develop and pilot methodologies to map institutions and policy processes to manage climate-related problems, initially in the context of diverse demonstration sites in Southeast Asia.	▪ Institute of Strategic Planning and Policy Studies ▪ Center of Agricultural and Rural Development Studies ▪ Udayana University	Someshwar, S.
	Monitoring Air and Land Surface Temperature Using Satellite Derived Products *Completed*	An analysis of the air and surface temperature derived from satellite images to monitor temperature conditions favorable to vector-borne disease transmissions.		Ceccato, P.
	Monitoring Air and Land Surface Temperatures from Remotely-Sensed Data for Climate-Human Health-Agriculture Applications *Completed*	The objective of this project was to provide minimum and maximum air temperature maps to researchers studying the relationships between changes in air temperature and certain diseases affected by climate.	▪ National Oceanic and Atmospheric Administration ▪ Columbia University Mailman School of Public Health	Ceccato, P.

Topics/ Region	Project Title	Description	Partners	Project / IRI Lead
	Multi-scale Climate Information for Agricultural Planning in Southeastern South America for Coming Decades	We investigate the climate changes acting across a range of time scales in a region traditionally considered semi-arid, but which is undergoing drastic agricultural expansion due partly to increased annual precipitation since 1990. Through collaborations with ministerial partners in the region, the work of the project team will contribute to improved decision-making and vulnerability reduction through better understanding of decadal-scale climate variability and change and improved informational products on the climate and its agricultural impacts.	▪ Columbia University Lamont-Doherty Earth Observatory	Goddard, L.
	Near Term Climate Change (NTCC)	This project aims to develop methods and products for guidance on near term climate change (NTCC)	▪ Geophysical Fluid Dynamics Laboratory ▪ Centro de Previsão de Tempo e Estudos Climáticos ▪ Columbia University Lamont-Doherty Earth Observatory ▪ Bureau of Meteorology and Geophysics, Indonesia	Goddard, L.
	New Tools for North American Drought Prediction	The work will develop and test best new tools for drought prediction based on empirical-dynamical forecasting approaches. The goal is to enhance real-time, seasonal drought assessment and prediction capabilities for the U.S. and Mexico.	▪ Universidad Nacional Autonoma de Mexico	Lyon, B.
	A Prototype Earth-Gauging System Integrating Weather and Health Data to Manage Meningitis	Identifying global partnerships and related research opportunities to link understanding of the meningitis-related environmental risks with action for the improved management of meningitis.	▪ University Corporation for Atmospheric Research (The) ▪ North Carolina State University	Thomson, M.
	Real-Time Dynamically Based Climate Diagnostics of Observations and Forecasts	Improve understanding and attribution of real-time observed and forecasted climate anomalies via use of dynamical techniques.	▪ Center for Ocean-Land-Atmosphere Studies ▪ Columbia University Lamont-Doherty Earth Observatory	DeWitt, D.
	Recalibrating and Combining Ensemble Predictions	Developing and evaluating a seasonal forecasting system that takes advantage of the latest innovations in multi-model combination, pattern correction and recalibration of forecast distributions.	▪ Climate Prediction Center ▪ National Centers for Environmental Prediction	Tippett, M. K.

Topics/ Region	Project Title	Description	Partners	Project / IRI Lead
	Regional Climate Outlook Forums (SE S Am, Western S Am, NE Brazil, Central Am)	Provide climate information (model runs, data library, IRI forecasts); train researchers on the use of the Climate Predictability Tool; and present educational material to stakeholders on probabilistic climate forecasts and their applications in decision making.	▪ World Meteorological Organization ▪ Centro de Previsão de Tempo e Estudos Climáticos ▪ Centro Internacional de Investigaciones para el Fenomeno El Niño, Ecuador	Baethgen, W. E.
	Research and Capacity Building Partnership between IRI and the Earth Observation, Department of Geography & Geology, University of Copenhagen, Denmark	This project aims to develop a long-term research and capacity building partnership between IRI and the Earth Observation, Department of Geography & Geology, University of Copenhagen, Denmark.	▪ University of Copenhagen	Ceccato, P.
	Retrospective Forecasts Made Using Using Retrospectively Forecast SST	Estimate real-time forecast skill from two of the operational IRI forecast models using hindcasted SST	▪ Max Planck Institute for Meteorology ▪ The National Center for Atmospheric Research	Goddard, L.
	The Role of Airborne Dust and Climate in Meningococcal Meningitis Outbreaks in the Sahel	A pilot study on the influence of seasonal and spatial climate variability on dust concentrations and composition specific to the "meningitis belt" of sub-Saharan Africa, to further the understanding on the quantitative relationships between these climatic and environmental factors and high transmission and incidence rates and epidemic outbreaks of meningococcal meningitis.	▪ Columbia University: Lamont-Doherty Earth Observatory; Mailman School of Public Health	Trzaska, S.
	Routine Forecasts	Routine monthly production of climate and SST forecast products	▪ Max Planck Institute for Meteorology ▪ NASA/Goddard Space Flight Center ▪ Center for Ocean-Land-Atmosphere Studies ▪ Geophysical Fluid Dynamics Laboratory ▪ Climate Prediction Center ▪ Environmental Modeling Center ▪ Experimental Climate Prediction Center ▪ Queensland Climate Change Centre of Excellence	Barnston, A.

Topics/ Region	Project Title	Description	Partners	Project / IRI Lead
	Supporting Colombia's National Integrated Dengue and Malaria Surveillance and Control System *Completed*	Supported Colombia's national integrated dengue and malaria surveillance and control system by providing the evidence of the role of climate in disease dynamics, the use of climate information and development of tools for disease prevention and control	▪ Instituto Nacional de Salud de Colombia ▪ Instituto de Hidrología, Meteorología y Estudios Ambientales ▪ Conservacion Internacional Colombia	Baethgen, W.
	Sustainable Development in the Sahel - Learning from the Recent Greening	Laying the groundwork for quantifying the relative roles of physical and societal factors in the recent "re-greening" of the Sahel, and for assessing the potential for sustainable practices to combat land degradation in adapting to climate change.	▪ University of California, Irvine ▪ Columbia University: Lamont-Doherty Earth Observatory; Center for International Earth Science Information Network	Giannini, A.
	Swiss Proposal for an Insurance Pillar under the UNFCCC *Completed*	Provided the climate framework to inform the analysis of the needs and capabilities of various stakeholders, such as private sector, individuals, public institutions on the national and sub-national level, and the role of index insurance providers and users in developing countries.	▪ Swiss Reinsurance Company ▪ INFRAS Forschung und Beratung	Osgood, D.
	Tailored Forecast and Monitoring Products	This project focuses on the provision of real-time forecasts tailored to specific climate risk management approaches.	▪ Climate Prediction Center ▪ Centro de Previsão de Tempo e Estudos Climáticos ▪ European Centre for Medium-Range Weather Forecasts ▪ Centre Europeen de Recherche et d'Enseignement des Geosciences de l'Environnement	Robertson, A.
	Towards Improved Control of Meningitis Outbreaks in Sub-Saharan Africa	Fostering research on epidemiological, environmental, demographic and socio-economic determinants of Meningococcal Meningitis outbreaks in sub-Saharan Africa.	▪ NASA Goddard Institute for Space Studies ▪ Columbia University: Center for International Earth Science Information Network; Mailman School of Public Health	Trzaska, S.
	Validation of Satellite and Other Climate Data Sets	This project compares the performance of various satellite-derived and other climate data sets over different parts of the world, with more of a focus on Africa.		Dinku, T.

Topics/ Region	Project Title	Description	Partners	Project / IRI Lead
	Verification of Seasonal Climate Predictions	This project aims to set and implement standards for the verification of real-time seasonal climate forecasts.	▪ African Center of Meteorological Applications for Development ▪ Intergovernmental Authority on Development Climate Prediction and Applications Centre ▪ Drought Monitoring Centre ▪ MeteoSwiss - Federal Office of Meteorology and Climatology	Mason, S.
	The World Food Programme in Egypt and the IRI *Completed*	Collaborated with the World Food Programme in Egypt and its partners, to provide the technical support and focus on vulnerability and food security mapping in light of climate change.		Hellmuth, M.

Technical Training Overview:
A summary of activities and contributions by IRI Staff

Date / Place Contributors	**Event** Description of efforts, participants, collaborators
13 - 16 July 2010 *Bogota, Colombia* G. Mantilla	**Invited lectures at the National University's International School on Environment and Health** Delivered to 25 graduate students: • Basic Concepts: Climate and Public Health • Impacts of Climate Change on Public Health • Use of Climate Information in Public Health
27 July - 4 Aug 2010 *Alanya, Turkey* L. Sun	**International Training Workshop on Climate Variability and Predictions for the Mediterranean Basin** Training leader for climate downscaling and prediction Sponsors: WMO, NOAA, USAID, and Turkish State Meteorological Service (held at the WMO Regional Training Center)
2 - 13 Aug 2010 *Buenos Aires, Argentina* W. Baethgen L. Goddard G. Mantilla S. Mason	**IAI Training Institute on the Use of Seasonal Climate Predictions for Applications in Latin America** For 25 participants from the IAI member countries (Argentina, Brazil, Bolivia, Canada, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, Guatemala, Jamaica, Mexico, Panama, Paraguay, Peru, Uruguay, USA, and Venezuela) To build local and regional capacity on the use of seasonal prediction tailored to needs of various Latin American socio-economic sectors such as agriculture, health, and water resources • W. Baethgen: organizing committee member; presented "Climate Information to Aid in Decision-Making" • L. Goddard presented "Verification Issues in Seasonal Prediction" • G. Mantilla presented "Climate Change Impacts on Public Health" and "The Use of Climate Information in Public Health" • S. Mason demonstrated a verification game, "Weather Roulette" (with L. Goddard) and conducted climate predictability tool training Hosts: School of Exact and Natural Sciences, University of Buenos Aires (FCEN/UBA); in collaboration with the IAI and the International Research Institute for Climate and Society (IRI). Funding: US National Science Foundation (NSF) through the University Corporation for Atmospheric Research (UCAR); and co-sponsors: the World Climate Research Program (WCRP), UNESCO´s International Hydrological Programme (PHI). Web link: https://iaibr3.iai.int/twiki/bin/view/TIClimatePredictions2010

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2 - 13 Aug 2010 *Trieste, Italy* A. Barnston M. Tippett	**ICTP Targeted Training Activity: Statistical Methods in Seasonal Prediction** For 49 participants from 23 countries. Contributed lectures to: provide better understanding of statistical properties of climate system and state-of-the-art knowledge in statistical methods; highlight limitations/cautions in the use of statistical methods in short-term climate prediction; and review current seasonal forecast methods of participating countries: • Tippett: Predictor Selection; PCR, CCA, and other Pattern Based Regression Techniques; Pitfalls of Linear Regression; Constructing Probability Forecasts • A. Barnston: Lessons in Statistical Prediction; Verification Measures; Interpretation of Canonical Correlation Analysis Results; Seasonal Prediction at IRI Web Link: http://cdsagenda5.ictp.trieste.it/full_display.php?ida=a09161
9 - 13 Aug 2010 *Hokkaido University, Sapporo, Japan* S. Barone L. Sun	**10th International Regional Spectral Modeling (RSM) Workshop** Delivered to 42 participants from 12 countries To understand the current status of RSM and RSM research in progress, encourage model development and improvement as a community effort, promote greater interaction among its users, provide training, and set future targets L. Sun delivered: • Talks: Verification of downscaling forecasts" and "Rainfall trends over Northeastern Brazil • Lecture: "Introduction to climate change downscaling" • Lead trainer for two-day course S. Barone provided analyst support for participants. Hosted by Hokkaido University's IFES-GCOE Program, Japan's Ministry of the Environment, Japan's Meteorological Research Institute, IRI, NOAA, and the Experimental Climate Prediction Center (ECPC) (G-RSM) Web link: http://ecpc.ucsd.edu/projects/RSM/RSM2010/

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22 - 29 Aug 2010 *Addis Ababa, Ethiopia* B. Lyon O. Ndiaye	**Forecast methodology and verification workshop for the National Meteorological Agency (NMA) of Ethiopia** Delivered to 15 regional NMA representatives with the goal of enhancing knowledge of CPT acquired from previous year's training and to verify the seasonal forecast from 1999 to 2009. Workshop activities included: • discussions on the current forecast for JJAS 2010, • introduction to GCMs outputs as predictors (CFS, ECHAM and ECHAM using CFS_SST), • identifying the best GCM predictor fields using the MOS approach (i.e., CPT), • introduction to the verification of probabilistic forecasts (excel spreadsheet exercises), • examining the different possible outcomes of a probabilistic forecast with respect to observation, • calculating and interpreting the bias and the hit rate, and • presentation of results at the NMA headquarter to an audience which included national experts. Hosted by NMA, with support from google.org
30 Aug - 2 Sept 2010 *Addis Ababa, Ethiopia* T. Dinku B. Lyon	**Data quality and analysis workshop for Ethiopia's NMA** Delivered to 7 NMA staff members to enhance NMA capacity to conduct quality control of surface station data across the country. Activities included: • introducing approaches to enhance data quality of surface observations, primarily maximum and minimum temperature and precipitation (obtaining metadata for stations, use of reference stations, identifying and adjusting for breakpoints in a time series, and • introducing several statistical tests to evaluate statistical significance of changes in mean and variance in time series. Funding from the project, Challenge Program on Climate Change, Agriculture and Food Security (CCAFS) - Theme 4: Adaptation pathways based on managing current climate risk
13 Sept 2010 *Mekele, Ethiopia* E. Holthaus D. Osgood J. Sharoff	**Regional Workshop on the Weather Index Insurance** Delivered to 57 participants–representing local insurance companies, government offices, researchers, academic experts–to share knowledge and experience acquired from the weather index insurance pilot project. This is the first of a series of workshop/training activities involving core partners of the HARITA project who will be led through the development, implementation and review of actual product implementation. A collaboration of Oxfam America, the Relief Society of Tigray and IRI

Date / Place Contributors	**Event** Description of efforts, participants, collaborators
14 - 22 Sept 2010 *Dar es Salaam, Tanzania* B. Lyon	**Training Workshop on Seasonal Weather Forecasting Tailored to Disaster Risk Management** Delivered to 8 participants from the national meteorological services of Botswana, Malawi, Mozambique, Tanzania, Zambia and Zimbabwe: CPT training on seasonal forecasting of within-season rainfall extremes. Topics/activities included: • Review of statistical downscaling, model output statistics and the Climate Predictability Tool (CPT) software • Generating probabilistic, seasonal forecasts of rainfall for stations in the countries of the trainees • Tailoring seasonal forecasts (changing forecast categories, using absolute thresholds, probability of exceedance) • Developing station-based, daily rainfall indices that measure the frequency of occurrence of rainfall intensity above various thresholds • Generating probabilistic forecast of the daily rainfall indices described above • Comparing forecast skill when using sea surface temperatures (SST) versus general circulation model (GCM) fields as predictors Hosted by the Tanzania Meteorological Agency, with funding from through the IRI-IFRC Partnership to Save Lives Project, and additional funding from WMO
20 Sept - 1 Oct 2010 *Palisades, NY* W. Baethgen P. Block M. Bell O. Ndiaye A. Robertson	**WMO-IRI Hydrological Outlooks Training for Trainers Workshop** Delivered to: Claudia Contreras (Sistema de Información Ambiental de Colombia - IDEAM), Dr. Waldo Lavado (Peruvian National Service of Meteorology and Hydrology - SENAMHI), Juan José Nieto (Centro Internacional para la Investigación del Fenómeno de El Niño - CIIFEN, Ecuador), and Dr. R. N. Sankhua (India, National Water Academy - NWA) The focus was on methodologies for developing hydrologic seasonal outlooks primarily targeted on western South America, with the goal of training scientists to train others in regional workshops on these methodologies for the meteorological and hydrological services of Chile, Peru, Colombia, Ecuador and Venezuela. • Week 1 focus: Streamflow downscaling using seasonal averages via CPT • Week 2 focus: Streamflow downscaling using stochastic daily rainfall sequences via NHMM IRI workshop wiki link: http://wiki.iri.columbia.edu/index.php?n=Climate.Downscaling-HydrologicalOutlooks

Date / Place Contributors	**Event** Description of efforts, participants, collaborators
5 - 6 Oct 2010 *Brazzaville, Republic of Congo* O. Ndiaye	**4th Climate Outlook Forum in Central Africa** *Training in CPT and topics to enhance knowledge on statistical forecasting approaches* Delivered to participants from Congo, Cameroon, Democratic Republic of the Congo, Gabon and Sao Tome and Principe (COF results were presented at the Ministry of Finance in front of national experts and users). Topics: • Issues related to building seasonal forecasting model : fishing, over fitting • Introducing GCMs outputs as predictors (ECHAM and ECHAM using CFS_SST) • Identifying the best GCM predictor fields using the MOS approach (i.e., CPT) • Discussion: “why are we doing what we are doing” and the added value of the seasonal product and outreach to users
8 - 10 Oct 2010 *Addis Ababa, Ethiopia* O. Ndiaye	**Pre-forum / African Development Forum-VII: "Getting it Right: Reporting Climate Change for Sustainable Development in Africa" (Africa Media Training Workshop)** Delivered to 25 participants from the African region; presentations: • Climate Risk Management • Uncertainties in Climate Change Models
10 - 11 Nov 2010 *Quito, Ecuador* A. Robertson	**Regional Workshop on Hydrology Seasonal Forecast in Western South America** Delivered to 15 participants from the national meteorological and hydrological services of Bolivia, Chile, Ecuador, Peru and Venezuela; presentations and activities: • Introduction to climate forecasts • Using daily data: Introduction to HMM and KNN • Hands on demonstration of the Climate Predictability tool (with Juan Jose Nieto/*CIIFEN* and Dr. Waldo Lavado/*SENAMHI Peru*) Jointly developed by WMO, IRI and CIIFEN Web link to WMO final report: http://www.wmo.int/pages/prog/hwrp/documents/Western_SouthAmerica_Final_Report.pdf

<table>
<tr><td>Date / Place
Contributors</td><td>Event
Description of efforts, participants, collaborators</td></tr>
<tr><td>22 - 23 Nov 2010
Addis Ababa, Ethiopia
J. del Corral
J. Omumbo
M. Thomson</td><td>Climate and Malaria Workshop 2010
Participation from regional health bureaus, schools of public health, public health emergency management, Anti-Malaria Association, Aklilu Lemma Institute of Pathobiology, Carter Center, Ethiopian Field Epidemiology and Laboratory Training Program (FELTP), National Meteorological Agency
Agenda:
22 Nov
• J. Omumbo: Welcome and Introductions
• P. Graves, M. Wondabeku, J. Omumbo: Overview of Malaria Data from Carter Center
• J. del Corral: Overview of IRI Climate Data Library, and Uploading Tool
• J. Omumbo: Demonstration of Climate Suitability for Malaria Transmission (CSMT) Tool in the Data Library and Corresponding Map in the NMA Monthly Health Bulletin
• Practical Exercise with Representative time series of Malaria and Climate Variables for selected Zones in each of Six Regions
• Presentation and Discussion of Results of Exercise
23 Nov
• M. Lemma, NMA: Overview of NMA and Rainfall and Temperature Data
• G. Tsegaye, NMA: ENSO Effects on Ethiopia’s Climate
• Group Exercise to Prepare a Time Series Analysis of Malaria and Climate Data for Representative Zones in Six Regions in Ethiopia
• Presentation and Discussion of the Six Regional Analyses on seasonality of malaria incidence, rainfall and temperature for selected zones and temporal correlations between malaria and climate variables.
• J. Omumbo: Principles of Cluster Analysis – using K-means
• J. del Corral: Presentation of Cluster Analysis of Ethiopia Rainfall, Temperature, and Malaria Data —Produced by the IRI Climate Data Library
Funded by the Google project</td></tr>
<tr><td>22 - 23 Nov 2010
Belgrade, Serbia
S. Mason</td><td>Fourth Session of Southeastern Europe Climate Outlook Forum (SEECOF-4), Pre-COF Capacity Building and Consensus Outlook
Introduction to CPT and Practical Training, (conducted with Emily Hamilton, UK Met Office)</td></tr>
</table>

Date / Place Contributors	**Event** Description of efforts, participants, collaborators
23 Nov 2010 *Addis Ababa, Ethiopia* S. Trzaska	**Addis Ababa University, Department of Physics presentations** • End-to-end and interdisciplinary approach to climate research at the International Research Institute or Climate and Society: Investigating the role of climate in epidemic outbreaks of Meningococcal Meningitis in the Sahel • Introduction to IRI Data Library, 3-hour hands-on introduction/training session with graduate students Hosted by Dr. Gizaw Mengistu, Chair, Department of Physics
28 Jan - 3 April 2011 *Mekele, Addis Ababa, and Tigray, Ethiopia* E. Holthaus M. Norton	**HARITA Project Capacity Building activities** 28 - 31 Jan 2011 *Mekele, Ethiopia* E. Holthaus: Capacity building training for insurance companies and other project partners 26 - 29 March 2011 *Addis Ababa, Ethiopia* E. Holthaus: Capacity building training for NGOs and insurance sector 26 March - 3 April *Tigray, Ethiopia* M. Norton: Experimental economic games 30 March - 3 April *Mekele, Ethiopia* E. Holthaus: Project workshop training for index design teams
7 - 11 March 2011 *Palisades, NY* A Barnston M. Bell P. Ceccato A. Ines S. Mason J. Omumbo A. Robertson T. Troy	**IRI - NOAA CPC African Desk Training Activity** Delivered for Maher Ben Mansour *(National Institute of Meteorology, Tunisia)* and Peter Omeny *(Kenya Meteorological Department) NOAA CPC African Desk* Topics: • Seasonal and inter-annual forecasting as practiced in IRI sectors • Statistical downscaling/tailoring especially as applied to the water sector • Climate risk management in health and agriculture sectors, environmental monitoring
14 - 18 March 2011 *Copenhagen, Denmark* P. Ceccato	**IRI-University of Copenhagen international PhD course: Remote Sensing and Environmental Change** Delivered to 14 participants. Lectures provided the practical and theoretical foundation for applying remote sensing techniques to identify and monitor environmental change. This activity is the capacity-building component of an IRI-University of Copenhagen collaborative effort to improve the understanding of land surface processes, particularly those related to surface and soil moisture. The potential benefit of the research conducted is in improved methods feeding into assessments of agricultural and environmental stress and risk.

Date / Place Contributors	**Event** Description of efforts, participants, collaborators
30 March - 1 April 2011 *Pucallpa, Peru* K. Fernandes	**Universidad Nacional de Ucayali - 6-hour course** Delivered to 12 professors and other local regional government staff: concepts of climate variability and change, including an introduction to the IRI Data Library

Academic Courses designed and taught by IRI staff (F2010 – S2011)

Earth and Environmental Engineering 4010 - Remote Sensing and Environmental Change **Instructors: Pietro Ceccato and Michael Bell** (S2011) This is a practically oriented course designed to teach students how to apply remote sensing techniques to identify and monitor environmental changes. Students will experience hands-on the capabilities of remote sensing data for analyzing environmental problems. This includes designing and applying spectral indices for assessment and monitoring of environmental changes, time series analysis of remote sensing data, and a range of classification procedures. This course is designed for students having research interests that include the analysis of remote sensing data supported by the IRI data library.
Earth and Environmental Science 4400 - Dynamics of Climate Variability and Change **Instructor: Lisa Goddard** (F2010) This is the comprehensive climate science course in the Climate and Society program. Students learn how the climate system works, primarily on large scales of time and space. It is these large-scale features and processes that dominate variability of the regional and local climate immediately relevant to social and individual decision making.
Earth and Environmental Science 4401 - Quantitative Models of Climate-Sensitive Natural and Human Systems **Instructor: Tony Barnston** (F2010) Quantitative models are used routinely to evaluate impacts of climate variability and climate change. In their subsequent careers, students will be called upon to interpret and evaluate the results of both statistical and dynamical models. This course is intended to equip students with an understanding of how climate-societal and intra-societal relationships can be evaluated and quantified using relevant data sets, statistical tools, and decision models. In addition to experimenting with statistical techniques, students have an opportunity to do some simple decision model experiments and evaluate the results.
Earth and Environmental Science 4403 - Managing Climate Variability and Adapting to Climate Change **Instructor: Ben Orlove** (F2010) This spring semester course deals with climate and environment-development issues, and helps investigate ideas and methods for analyzing problems to reduce societal vulnerability and build resilience to climate variability and climate change. In order to integrate learning, the course is structured around modules that bridge several "divides": the social and natural sciences, temporal scales of variability and change impacting various sectors, the developing and industrialized regions, across local, national and international spatial levels, as well as socio-political, economic and ecological dimensions of development. The lectures and discussions move back and forth between theory and practice, required for the effective management of risks from a changing climate. Practicum sessions, in addition, are designed to help integrate learning.
Earth and Environmental Science 4404 - Regional Dynamics, Climate, and Climate Impacts **Instructor: Andrew Robertson and Alessandra Giannini** (S2011) The dynamics of environment and society interact with climate and can be modified through use of modern climate information. To arrive at the best use of climate information, there is a need to see climate in a balanced way, amongst the myriad of factors at play. Equally, there is a need to appreciate the range of climate information available and to grasp its underlying basis and the reasons for varying levels of certainty. Many decisions in society are at more local scales, and regional climate information considered at appropriate scales and in appropriate forms (e.g., transformed into vegetation stress) is key. Building a sufficient understanding of the science behind the information, and providing examples of how the information can and is being used, mean this course seeks to contribute toward the holistic understanding needed for wise use of climate information.
Earth and Environmental Policy U6260 - Climate change in Africa **Instructor: Alessandra Giannini** This course enables students in their appreciation for the complexity of the climate system, and provides a basic understanding of baseline observational features and physical arguments related to climate change in Africa. Students learn how to discern which questions it is reasonable to expect that science can answer, and which it is not. Students become familiar with an interdisciplinary approach to climate change adaptation that encourages the investigation of complementary perspectives in the search for solutions to real-world problems. This includes local, regional and global scales; consideration of perspectives derived from theory or practice; the synthesis of knowledge from different fields of inquiry; and contributions from the physical sciences as well as from the humanities.

Students engaged in Internships or other project work, July 1, 2010 - March 31, 2011			
Student Name	IRI Supervisor	Project Name/Description	Time Period
Akhavan, Tala, Columbia College, Columbia University	Sylwia Trzaska	Migration Patterns in Sub-Saharan Africa and its potential contribution to meningococcal meningitis outbreaks.	October - December 2010
Basche, Andrea, DEES C&S MA 2010, Columbia University	Esther Conrad & Rizaldi Boer	IRI & The Center for Climate Risk and Opportunity Management (CCROM) - Completing the preliminary research to help establish a weather insurance program for the farmers in the Indramayu and Pacitan Districts of Central Java.	June - August 2010
Bhattacharjee, Arindam, DEES C&S MA 2011, Columbia University	Shiv Someshwar & Andrew Robertson	Developing web-based tools to harness and downscale seasonal climate forecasts for use in climate risk management in agriculture in India.	October 2010 - May 2011
Chatikavanij, Vansa, DEES C&S MA 2011, Columbia University	Shiv Someshwar	IRI & the Global Network for Climate Solutions (GNCS) - Researching and developing knowledge modules for adaptation-related sectors and themes and Utilizing the IRI Data Library and other resources to produce comprehensive climate profiles for countries and regions, in support of the GNCS adaptation program.	October 2010 - May 2011
Cordray, Michelle, DEES C&S MA 2010, Columbia University	Paul Blick & Molly Hellmuth	Coverage of Uganda Red Cross Society's disaster risk reduction projects; impacts of climate change, deforestation, and wetlands encroachment in Uganda; what farmers are doing to adapt to climate change.	June - August 2010
Coughlan,Erin, DEES C&S MA 2011, Columbia University	Shiv Someshwar	IRI & GNCS - Researching and developing knowledge modules for adaptation-related sectors and themes and Utilizing the IRI Data Library and other resources to produce comprehensive climate profiles for countries and region, in support of the GNS adaptation program.	October 2010 - May 2011
Flemming, Megan, DEES C&S MA 2011, Columbia University	Paul Block	IRI & The Center for Research on Environmental Decision (CRED) - Elucidating near-term climate change information to guide water resources decisions and foster sustainability in Chile.	October 2010 - May 2011
Huber, Daniel, DEES C&S MA 2010, Columbia University	Esther Conrad & Rizaldi Boer	IRI & CCROM - Conducted background research, field visits, and data collection and analysis to lay the groundwork for developing pilot index insurance efforts in Indramayu or Pacitan district.	June - August 2010
Jankowski, Krista, DEES C&S MA 2010, Columbia University	Ashley Curtis and Francesco Fiondella	IRI & IFRC - worked with the disaster management unit of the Southeast Asia Regional Delegation office in Bangkok, Thailand to develop a two-week field session on disaster risk reduction, climate risk reduction, and the Vulnerability and Capacity Assessment (VCA) process.	June - August 2010
Jensen, Sean, DEES C&S MA 2011, Columbia University	Amor Ines	Estimating effective soil hydraulic properties from remote sensing.	October 2010 - May 2011
Kinfe, Yosef, DEES C&S MA 2011, Columbia University	Dan Osgood	Contribute to the Index Insurance initiative underway in Ethiopia, in support of an IRI project supported by Oxfam.	October 2010 - May 2011
Kirk,Jeanie, DEES C&S MA 2010, Columbia University	Esther Conrad	IRI & The Energy and Resources Institute (TERI) - Assessing climate change vulnerability and adaptation strategies for Maharashtra State and Coastal vulnerability assessment and strategies for better preparedness towards impacts of climate change and sea level rise along the West Bengal coast.	June - August 2010
Koide, Naohisa, ISERP QMSS, Columbia University	Andrew Robertson	Masters Thesis: Assessment of Predictability of Rice Production in the Philippines with Seasonal Climate Forecast	January - September 2010
Lafferty, Amy, Hertford College, Oxford University	Simon Mason	Assist in developing and testing Excel spreadsheets for use in verification training workshops; will also conduct comparative studies of Africa Regional Climate Outlook Forum forecasts with objetively generated re-forcasts made using CPT.	July - August, 2010
Liu, Harry, SEAS, Columbia University	Amor Inez, Walter Baethgen & James Hansen	IRI & The Tropical Agriculture Program - Estimating effective soil hydraulic properties from remote sensing.	October - December 2010
Moy, Bryan, MPH Epidemiology, Mailman School, Columbia University	Madeleine Thomson, Steve Connor & Gilma Mantilla	Evaluation of malaria interventions in Botswana.	October 2010 - February 2011

Student Name	IRI Supervisor	Project Name/Description	Time Period
Omiyale, Abimbola, DEES C&S MA 2011, Columbia University	Shiv Someshwar	IRI & GNCS - Researching and developing knowledge modules for adaptation-related sectors and themes and Utilizing the IRI Data Library and other resources to produce comprehensive climate profiles for countries and regions, in support of the GNCS adaptation program.	October 2010 - May 2011
Podgorska, Anna, DEES C&S MA 2010, Columbia University	Shiv Someshwar	IRI & GNCS - In support of the development of the GNCS adaptation program, engage with participating research centers in developing countries, and contribute to development of outreach materials.	June - August 2010
Robbins ,Patrick, DEES C&S MA 2011, Columbia University	Madeleine Thomson	Assist in the compilation of material for, and writing of, a synthesis and integration chapter for a book on natural disasters and adaptation to climate change	October 2010 - May 2011
Rosen, Jessica, DEES C&S MA 2010, Columbia University	Esther Conrad & Rizaldi Boer	IRI & CCROM - Gather information on approaches and technologies currently used by farmers to manage climate risks. Literature review and data analysis to summarize current approaches of farmers and advance climate modeling and risk management research agendas relating to food security in Indonesia.	June - August 2010
Sousa, Frank, DEES C&S MA 2010, Columbia University	Ashley Curtis and Simon Mason	IRI & IFRC - assisted in the writing of background documents for the Preparedness for Climate Change Programme of the Middle East North Africa Zone in Amman and developed a Powerpoint presentation on climate change for the region. Delivered this and two other presentations for 12 National Societies at the Disaster Risk Reduction and Climate Change Adaptation workshop held in Amman this August.	June - August 2010
Stiffle, Sarah, Edinburgh University	Dan Osgood	Participate in work to understand the role that insurance plays in climate risk management for smallholder farmers, with a focus on Ethiopia.	June - July 2010
Stypa, Amy, DEES C&S MA 2010, Columbia University	Liqiang Sun	In Mongolia, assisted with completion of the National Society's PfCC2 background document, developed a climate change project proposal, gave input on development of climate change communications materials, and delivered a workshop presentation on climate change. In China, worked in the Fujian province helping with preparations for a workshop designed to build partnerships and shared visions for collaborative efforts on climate change adaptation and disaster risk reduction.	June - August 2010
Talati, Shuchi, DEES C&S MA 2010, Columbia University	Shiv Someshwar	Support the development of the Adaptation component of the Network, engage with participating research centers in developing countries, and contribute to development of outreach materials.	June - August 2010
Verjee,Neelam, SIPA, Columbia Univeristy	Shiv Someshwar	Support the development of the Adaptation component of the Network, engage with participating research centers in developing countries, and contribute to development of outreach materials.	June - August 2010
Wong, Anjela, Barnard College, Columbia University	Paul Block	Senior Thesis: Understanding the interactions of climate extremes, food security, and available water; mapping policy and economic aspects.	September 2009 - August 2010
Wood, Scott, DEES C&S MA 2010, Columbia University	Simon Mason	Worked with both the Tanzania Red Cross Society (TRCS) and the Tanzania Meteorological Authority (TMA) facilitated processes to help the TRCS identify and articulate their needs for climate and weather information so that the TMA could improve and tailor their products and support to user needs. The TRCS now receives 12 hour forecast updates from the TMA daily, and advances have been made to develop an MoU together.	June - August 2010
Wu, Gavin, DEES C&S MA 2011, Columbia University	Gilma Mantilla	Provide research and logistical support for all -related activities on the development of the Climate Information for Public Health Action Network (CIPHAN).	October 2010 - May 2011
Zhou, Yufang, DEES C&S MA 2011, Columbia University	Amor Ines	Estimating effective soil hydraulic properties from remote sensing.	October 2010 - May 2011

Governance at a glance

Board of Overseers

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Dr. Stephen E. Zebiak	Director-General, IRI

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Prof. Sulochana Gadgil	Professor, Center for Atmospheric and Oceanic Sciences, Indian Institute of Science
Prof. Graeme Hammer	Professorial Research Fellow, University of Queensland
Professor James W. Jones	Distinguished Professor, University of Florida
Dr. Francisco de Assis de Souza Filho	Former President, FUNCEME; Adjunct Research Scientist, IRI
Dr. R. Wayne Higgins	Director, NOAA Climate Prediction Center

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Maria Salgado	Executive Assistant to the Director-General

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Stephen Connor	Program Leader, Environmental Monitoring Research; Director, PAHO/WHO Collaborating Centre on early warning systems for malaria and other climate sensitive diseases; Senior Research Scientist
David DeWitt	Program Leader, Climate; Research Scientist
Bradfield Lyon	Interim Chair, Africa Regional Program Committee (2010 -); Research Scientist
Simon Mason	Climate Program Chief Scientist; Research Scientist
Shiv Someshwar	Director, Asia and Pacific Regional Program; Director, Institution and Policy Systems Research; Research Scientist
Madeleine Thomson	Chair, Africa Regional Program Committee (-2010); Senior Research Scientist

Senior Research, Information Technology, and Data Library Staff

Anthony Barnston	Lead Forecaster
M. Benno Blumenthal	Data Library Manager
Remi Cousin	Staff Associate
Lisa Goddard	Research Scientist, Adjunct Professor, DEES
James Hansen	Research Scientist
Upmanu Lall	Senior Research Scientist, Professor, DEEE
Bin Li	Senior Analyst/Programmer
Ben Orlove	Senior Research Scientist, Professor, SIPA
Leo Ostwald	Manager, IRI Computing
Andrew Robertson	Research Scientist
Adam Sobel	Professor, DEES/APAM
Liqiang Sun	Research Scientist
Michael Tippett	Research Scientist
Jeff Turmelle	Senior Systems and Network Analyst/Program Manager
Jian-Hua (Joshua) Qian	Research Scientist

Research Staff

Erica Allis	Staff Associate
Julie Arrighi	Staff Associate
Michael Bell	Senior Staff Associate
Paul Block	Associate Research Scientist
Daniel Ruiz Carrascal	Graduate Research Student
Pietro Ceccato	Associate Research Scientist
Chao Chen	Postdoctoral Research Fellow, EI
Laurence Cibrelus	Staff Associate
Kevin Coffey	Senior Staff Associate
Esther Conrad	Senior Staff Associate
Ashley Curtis	Staff Associate
John del Corral	Senior Staff Associate
Tufa Dinku	Associate Research Scientist
Katia Fernandes	Postdoctoral Research Scientist
Alessandra Giannini	Research Scientist
Paula Gonzalez	Postdoctoral Research Scientist
Arthur Greene	Associate Research Scientist
Eric Holthaus	Staff Associate
Amor Ines	Associate Research Scientist
Dong Eun (Donna) Lee	Staff Associate
Shuhua Li	Senior Staff Associate
Haibo Liu	Staff Associate
Malgosia Madajewicz	Associate Research Scientist
Gilma Mantilla	Senior Staff Associate
Ousmane Ndiaye	Postdoctoral Research Scientist
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Daniel Osgood	Associate Research Scientist
Indrani Pal	Postdoctoral Research Scientist, EI
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Christelle Vancutsem	Senior Staff Associate
Tara Troy	Postdoctoral Research Fellow, EI
Sylwia Trzaska	Associate Research Scientist
Catherine Vaughan	Staff Associate
Derek Willis	Postdoctoral Research Fellow, EI
Lareef Zubair	Associate Research Scientist

Adjunct Research Staff

Sankar Arumugam	Adjunct Associate Research Scientist, North Carolina University
Rizaldi Boer	Adjunct Research Scientist, Department of Geophysics and Meteorology, Bogor Agricultural University, Indonesia
Kenneth Broad	Adjunct Research Scientist, University of Miami
Casey Brown	Adjunct Associate Research Scientist, University of Massachusetts
Delcon Conway	Adjunct Research Scientist, University of East Anglia, United Kingdom
Francisco de Assis de Souza Filho	Adjunct Senior Research Scientist, Universidade Federal do Caerá, Fortaleza Brazil
Peter Diggle	Adjunct Senior Research Scientist, University of Lancaster, United Kingdom
Patricia Graves	Adjunct Research Scientist, Carter Center, Centers for Disease Control and Prevention, Atlanta, GA
Hugo Oliveros	Adjunct Research Scientist, Banco Republica, Colombian Central Bank (Retired)
Vincent Moron	Adjunct Senior Research Scientist, CEREGE, UMR 6635 CNRS and Université d'Aix-Marseille, France
Maartin van Aalst	Adjunct Research Scientist, International Federation of Red Cross and Red Crescent Societies

Affiliates

Kye Mesa Baroang	Coordinator, Adaptation Board, Earth Institute
Mohammed Boulahya	Senior Advisor (Africa)
Lisette Braman	Staff Associate, International Federation of Red Cross and Red Crescent Societies
Suzana Camargo	Associate Research Scientist, Lamont Doherty Earth Observatory
Roberto Lenton	World Bank, Washington DC
Sabine Marx	Associate Research Scholar, Columbia University, Center for Research on Environmental Decisions (CRED)
Cheryl Palm	Senior Research Scientist, Tropical Agriculture Program, Columbia University
Pedro Sanchez	Director, Tropical Agriculture Program, Columbia University
Jim Williams	Consultant, European partnerships and mobilization

Visiting Research Scientists

Kinfer Hailemariam Beyene	National Meteorological Agency, Addis Ababa, Ethiopia
Kripan Ghosh	Indian Meteorological Department, Pune, India
Lars Hansen	Department of Gegraphy and Geology, University of Copenhagen
Marakand Kulkarni	Centre for Atmospheric Sciences, Indian Institute of Technology, Delhi, India
Haiqin Li	School of Geography, Beijing National University, Beijing, China
Vincent Moron	CEREGE, UMR 6635 CNRS & Université d'Aix-Marseille
Jean-François Pekel	Researcher, Environmetry and geomatic unit, Université Catholique de Louvain, Belgium
Palash Sinha	Centre for Atmospheric Sciences, Indian Institute of Technology, Delhi, India
O.P. Sreejith	Indian Meteorological Department, Pune, India

Institutional Support

Office of the Director General

Francesco Fiondella	Communications Officer
Maria Risë Fullon	Project Coordinator
Althea Murillo	Administrative Assistant
Barbara Platzer	Africa Program Coordinator
Jason Rodriguez	Draftsman 1
Lori Scally	Project Finance Manager
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Sandra Vitelli	Administrative Assistant

Computer Systems

Baaba Baiden	Web Manager
Sara Barone	Analyst/Programmer
Mike Dervin	Analyst/Programmer
Chi-Huei Liu	Junior Web Developer
Lulin Song	Analyst/Programmer

Part-Time Research Assistants

Timothy Murphy
Mary Mildred Stith
Cynthia Thomson

Selected Publications

Peer-Reviewed

Adhikari, S., S. Liyanarachchi, J. Chandimala, B. K. Nawaratne, R. Bandara, Z. Yahiya, and **L. Zubair**, 2010: Rainfall prediction based on the relationship between rainfall and El Niño Southern Oscillation (ENSO). *Journal of the National Science Foundation*, **38**, 249 - 255.

Aggarwal, P. K., **W. E. Baethgen**, P. Cooper, R. Gommes, B. Lee, H. Meinke, L. S. Rathore, and M. V. K. Sivakumar, 2010: Managing Climatic Risks to Combat Land Degradation and Enhance Food Security: Key Information Needs. *Procedia Environmental Sciences*, **1**, 305-312, doi: 10.1016/j.proenv.2010.09.019.

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VISITORS TO THE IRI

2010

26 - 27 July Agr. Tabare Aguerre *Uruguay Minister of Agriculture, Montevideo, Uruguay*
Meeting to discuss IRI-Uruguay Ministry of Agriculture collaborations

12 Aug Andreas Schaffer and Prof. Kerry Sieh *Earth Observatory of Singapore*
Discuss tropical climate science and sustainability issues

15 - 28 Aug • John Mac Callaway *UNEP Risoe Centre on Energy, Climate and Sustainable Development Denmark* • Trevor Lumsden *University of KwaZulu-Natal, South Africa* • Daan Luow *University of the Free State, South Africa*
Climate Change in Africa project discussions

15 - 19 Aug Roland Schulze *Professor Emeritus and Senior Research Associate at the University of KwaZulu-Natal, South Africa*
Climate Change in Africa project discussions; and 15 Aug - IRI Seminar: On climate, climate change and adaptation: A South African water practitioner's perspective

9 - 10 Sept John Furlow, Jennifer Frankel-Reed, John Garrison *USAID Climate Change Team*
Discuss possible collaborative efforts on the Data Library, index insurance and West Africa climate services

15 Sept Herve Bisseleua *MDG Centre West and Central Africa*
Discuss concept for a workshop on "Adaptation/coping strategies for climatic vulnerability and change in the Sahel" (with H. Bhojwani, B. Platzer, M. Thomson, S. Trzaska)

16 Sept Belay Begashaw *Director, MDG Centre, Nairobi, Kenya*
Discuss potential IRI contributions to the MDG Centre's Drylands Initiative

21 - 23 Sept Yves Tourre *METEO-France, Direction de la Climatologie, Toulouse, France (former IRI Director of Training)*
Participate in the GEO User Requirements Registry workshop coordinated by P. Ceccato for the SCG-EPA project; and discuss preparation for the "Climate and Health 10 Years On" workshop

22 Sept Amy Luers *Project Manager, Google.org*
Discuss: IRI-Google project; opportunities to build on Google's investments in climate data and services in Africa

30 Sept Steve Charles *CSIRO Land and Water, Perth, Australia*
IRI Seminar: Downscaling for hydrological applications using a non-homogeneous hidden Markov model

30 Sept - 1 Oct Sergey Kirshner *Department of Statistics, Purdue University, West Lafayette, IN*
Department of Energy project meeting

4 Oct Norman Barth *Regional Environmental Officer, U.S. Embassy, Suva, Fiji Islands*
Discussions to enhance IRI collaboration in initiatives in the Pacific Islands; and IRI Seminar: A Pacific Climate Change Primer; Organizations, Players and Opportunities in the Region

7 Oct Naresh Devineni *PDRS, Columbia Water Center, Columbia University*
IRI Seminar: Improved Prediction of Winter Precipitation and Temperature over the continental United States: Role of ENSO State in Developing Multimodel Combinations

18 - 20 Oct Rahel Legesse *Micro Insurance Project Officer, Oxfam-America Horn of Africa Regional Office, Addis Ababa, Ethiopia*
HARITA project meetings

18 - 22 Oct Professor Sulochana Gadgil *Indian Institute of Science, Bangalore, India; IRI ISTAC member*
ISTAC member visit and (19 Oct) IRI Seminar: Challenge of predicting the Indian summer monsoon rainfall

25 Oct Andres Baeza *Ann Arbor, MI*
Meeting with P. Ceccato on new vegetation products derived from remotely-sensed data, analysis to understand the relationship between environmental factors and malaria in Gujarat and Rajasthan, India

3 Nov Claire Monteleoni *Center for Computational Learning Systems Fu Foundation School of Engineering and Applied Science, Columbia University*
IRI Seminar: Tracking Climate Models: Advances in Climate Informatics

4 Nov Dr. B. Venkateswarlu *Director, Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad, India*
Meeting to discuss potential collaboration on CRIDA's project on climate-resilient agriculture—involving research, field testing of best practices, and capacity building.

5 Nov Guy P. Brasseur *Director*, *Climate Service Center-Germany*, *GKSS*, *Hamburg, Germany*
Meeting; and seminar: From Climate Change to Earth System Management: The German Climate Service Center

12 Nov Jeremy Webb *Statistician, African Climate Policy Center (ACPC), UNECA, Addis Ababa, Ethiopia*
• Meeting to discuss ACPC activities including collaboration with African Centre for Statistics (ACS) to populate the ACS database with climate and related information, and the potential for applications using IRI's data library and other products.
• Seminar: ClimDev-Africa and the African Climate Policy Centre: Going forward

16 - 20 Nov Giampiero Renzoni, Ana Maria Loboguerrero *(respectively) Environmental Sustainable Deputy Director and Leader of the Economic Impacts of Climate Change, Colombia's Department of National Planning, Bogota, Colombia*
Visit to discuss MoUs with IRI and SIPA

17 Nov In-Sik Kang *School of Earth Environment Sciences, Seoul National University, Republic of Korea*
IRI Seminar: MJO Modelling

19 Nov Dr. Daniel Maxwell *Department of Food and Nutrition Policy, Tufts University*
Discussion with J. Hansen and K. Coffee on CCAFS food security scoping project

19 Nov Lauren Sorkin *Asian Development Bank, Manila, Philippines*
Presentation on the Asian Development Bank's Climate Change Program, including examples of their experience in using climate modeling in projects and analytical studies

28 Nov - 7 Dec Willem Landman *CSIR (Council for Scientific and Industrial Research) of South Africa*
Statistical modeling and downscaling over South Africa work

10 Dec Dr. Jagadish Shukla *President, Institute of Global Environment and Society*
Visit with S. Zebiak

13 Dec Col. David Carstens *US Army, working with the Center on Climate Change and National Security*
Interviews with S. Zebiak and S. Mason

13 Dec Luis de la Plaza, Julie Dana *respectively, Lead Financial Officer, and Senior Financial Officer, Banking and Debt Management, Treasury of the World Bank*, and Michael Carroll *Lead Natural Resources Specialist, World Bank's Europe and Central Asia Region*
Meeting with S. Zebiak, W. Baethgen, H. Bhojwani, D. Osgood, and C. Vaughan

13 - 14 Dec Antonio Divino Moura *Director, INMET (Brazilian National Meteorological Institute), Brazil's permanent representative to the WMO, IRI Founding Director-General*
Meetings with S. Zebiak and staff

2011

13 Jan Takashi Otsuka *Senior Coordinator and Principal Researcher, Japan's Institute for Global Environmental Strategies (IGES)*
Meeting to discuss IRI activities in the Asia and Pacific Region and learn more about the activities of IGES, an international research institute which conducts sustainable development research in the Asia-Pacific region

31 Jan Michelle Stanton *Visiting Scientist from Lancaster University's Division of Medicine*
IRI Seminar: Towards Real-Time Spatio-Temporal Monitoring and Forecasting of Meningitis Incidence in Sub-Saharan Africa

2 Feb Dr. John Gray *Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES), Canberra, Australia*
Meeting with J. Hansen, A. Ines, K. Coffey, P. Block, D. Osgood

4 - 11 Feb Dr. Ed Sarachik *Chair, IRI International Science and Technical Advisory Committee (ISTAC)*
(Hosted by S. Zebiak)

10 Feb Audrey Dorelien *PhD Candidate, Demography and Public Affairs, Princeton University*
IRI Seminar: Birth Seasonality in Sub-Saharan Africa: Is it Present? What are the Drivers? What are the implications for Infectious Disease Dynamics?

15 Feb Dr. Edward Allison *The WorldFish Center, Penang, Malaysia*
Discussions with J. Hansen and K. Coffee about CCAFS collaboration

17 - 18 Feb Chet Ropelewski *NOAA, IRI Program Manager*
(Hosted by S. Zebiak)

27 Feb - 5 March Dr. Narendra Das *Research Scientist, Water and Carbon Cycle Group, NASA Jet Propulsion Laboratory, Pasadena, CA*
Work with A. Ines on CCAFS-funded project, developing a data assimilation framework for improved crop yield forecasting

2 March Dr. Dileni Gunawardhana *Coordinator, Masters in Development Practice Program, University of Peradeniya, Sri Lanka* and Dr. Samanmala Dorabawila *University of Peradeniya, Sri Lanka*
Meetings with D. Osgood, M. Madajewicz, K. Coffey and E. Allis to discuss the University of Peradeniya's Masters in Development Practice Program, a program recently awarded by the McArthur Foundation

3 March Chungli Tsai *Microfinance Program Director, NetHope, McLean, VA*
Presentation and discussions about Weather INformation for Development (WIND) project

7 - 11 March Seydou Traore *Agrometeorologist/Head, AGRYHMET Scientific Coordination Unit*
Meeting on CCAFS supported activities to develop a methodology for a daily-time step rainfall and temperature climatology for the 9 CILSS countries building on the Ethiopian climatology work completed under Google (with T. Dinku)

7 - 11 March Maher Ben Mansour *(National Institute of Meteorology, Tunisia)* and Peter Omeny *(Kenya Meteorological Department) NOAA CPC Africa Desk*
IRI training on: seasonal and inter-annual forecasting as practiced in IRI sectors, statistical downscaling/tailoring especially as applied to the water sector, climate risk management in health and agriculture sectors, environmental monitoring (hosted by the Climate Program and Africa Regional Program)

10 March Arne Bomblies *Assistant Professor, School of Engineering, University of Vermont*
IRI Seminar: Hydrological controls of malaria transmission
Meeting with staff on Africa Regional Program, Climate and Health activities (hosted by M. Hellmuth)

23 March Victor Magana *Universidad Nacional Autonoma de Mexico (UNAM); and lead author, IPCC Fourth Assessment Report* - *chapter on regional climate projections*
Visit and exchange on research topics of common interest, and meeting on project, New Tools for North American Drought Prediction (PI, B. Lyon)

31 March Richard Kleeman *Center for Atmosphere Ocean Science, Courant Institute of Mathematical Sciences, New York University*
IRI Seminar: The spectra of stochastic geophysical models with an application to ENSO decadal variability

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Credits:

Cover graphics, by J. Rodriguez & F. Fiondella, depict a few of the diverse work environments of the IRI.
Upper panel: With climate data from Kenya's Kericho Tea estates, IRI's Judy Omumbo (right) confirmed that the region had been warming. Photo kindly provided by David Gottlieb.
Lower panel: IRI's Sylwia Trzaska (left) and CERMES' Ibrahim Arzika (right) test meteorological and dust monitoring equipment in Niamey, Niger.

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