IPCC SREX Summary for Policymakers

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A. CLIMATE, EXTREMES, AND DISASTERS: CONTEXT AND HISTORY

Weather and climate events impact human society and natural ecosystems. The character and severity of impacts, as well as the risk of disasters, result from the exposure and vulnerability of human systems and the sensitivity of natural systems, and from the type, magnitude, and extent of weather and climate events. This report assesses the influences of climate change on exposure and vulnerability and on weather and climate events, with a focus on extreme events, extreme impacts, and disaster risk. It also examines the potential for adaptation and disaster risk management to reduce risks and impacts and the wider implications for sustainable development.

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Box SPM.1: Extreme Events, Exposure, and Vulnerability

Extreme events are defined in this report as the occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) end of the range of observed values of the variable.[1] What is called an extreme event will vary from place to place in an absolute sense (e.g., a hot day in the tropics will be a different temperature than a hot day in mid-latitudes) and possibly in time, given some adaptation. Extremes in some climate variables (e.g., drought) may not necessarily be induced by extremes in meteorological variables (precipitation, temperature) but may be the result of an accumulation of moderate weather or climate events.

[INSERT FOOTNOTE 1: Definitions of thresholds vary, but values with less than a 5% or 1% or even lower chance of occurrence during a specified reference period (generally 1961-1990) are often used. Absolute thresholds (rather than these relative thresholds defined probabilistically relative to the range of possible values of a variable) can also be used to identify extreme events (e.g., specific critical temperatures for health impacts).]

Exposure is defined in this report as the presence of people, livelihoods, environmental services and resources, infrastructure, and economic, social, and cultural assets in areas or places that are subject to the occurrence of physical events and that thereby are subject to potential future loss and damage.

Vulnerability is defined in this report as the susceptibility or predisposition for loss and damage to human beings and their livelihoods, as well as their physical, social, and economic support systems when affected by hazardous physical events. Vulnerability includes the characteristics of a person or group and its situation that influences its capacity to anticipate, cope with, resist, respond to, and recover from the impact of a physical event.

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A changing climate can affect the frequency, intensity, or duration of extreme events and may result in unprecedented, previously unobserved extremes. Many extreme events are the result of natural climate variability (including phenomena such as El Niño Southern Oscillation – ENSO), and natural decadal or multi-decadal variations in the climate provide the backdrop for anthropogenic changes. Irrespective of the magnitude of any anthropogenic changes in climate over the next century, the occurrence of a wide variety of natural weather and climate extremes can be expected. [3.1]

Extreme impacts and disaster risk are strongly dependent on patterns and trends in extreme weather and climate events, exposure, and vulnerability. Extreme impacts can arise when extreme events intersect with people and their natural, social, and economic support systems; the severity of impacts depends on the vulnerability and exposure of the affected people and systems. Extreme impacts result in climate-related disasters when they produce widespread human, material, economic, or environmental damage and cause severe alterations in the normal functioning of communities or societies. Given variations in exposure and vulnerability, disasters and extreme impacts can arise from weather or climate events that are not extreme in a statistical sense. This can occur when a critical threshold in a social, ecological or physical system is crossed, or when two or more non-extreme events occur simultaneously or sequentially. Additionally, some extreme events may not lead to disasters and extreme impacts when exposure or vulnerability is low. In some cases, extreme events can have positive impacts on some ecosystems and economic sectors. [1.2; 2.1; 2.2; 2.5; 2.7; 3.1; 4.1; 4.3]

Disasters cause significant socioeconomic impacts in all countries, but low- and middle-income countries experience higher fatalities and direct economic losses relative to annual GDP (*high confidence*). Disasters create barriers for continued socioeconomic development (*medium confidence*). Disasters can cause important adverse macroeconomic and developmental effects, such as increased poverty, reduced direct and indirect tax revenue, dampened investment, and reduced long-term economic growth. [4.6.3.1; 6.1]

Because most estimates of disaster losses are based on direct losses, often recorded only as monetized direct damages to infrastructure, productive capital stock, and buildings, they substantially underestimate the extent of losses. These estimates exclude indirect losses, including primarily the economic flows constituting livelihoods and economies and intangible losses including ecosystem services, human lives, quality of life, and cultural impacts. [4.6.1.1; 6.1]

There is *high confidence* that climate change will affect disaster risk not only through changes in the frequency, intensity, and duration of extreme events, but also through indirect effects on exposure and vulnerability. These indirect effects include impacts on the number of people who are in poverty or who suffer from food and water insecurity, on changing disease patterns and general health levels, and on settlement patterns. In some cases, indirect effects of climate change may reduce vulnerability and/or exposure, but in many cases, they will increase exposure and/or vulnerability, especially for groups and areas already among the most vulnerable. [2.7]

B. OBSERVATIONS OF VULNERABILITY, EXPOSURE, EXTREME EVENTS, IMPACTS, AND DISASTER LOSSES

Exposure and vulnerability are highly context specific and dynamic, varying widely across different locales and populations and shifting in response to physical, environmental, economic, social, cultural, institutional, and governance changes. Exposure of people and economic assets to extreme weather and climate events is increasing, but trends in vulnerability are increasing for some areas and groups and decreasing for others. People are differently exposed and vulnerable according to characteristics such as wealth, gender, age, race/ethnicity/religion, disability and health status, and class/caste. Lack of resilience and the capacity to anticipate, cope with, and adapt to change are important causal factors of vulnerability. [2.2; 2.4; 2.5; 2.7; 4.3.2]

There is evidence of changes in extreme events occurring over recent decades.
Since 1950, it is *very likely* that there has been an overall decrease in the number of unusually cold days and nights and an overall increase in the number of unusually warm days and nights on a global scale for land areas for which data are available. It is *likely* that this statement also applies at the continental scale in North America and Europe and *very likely* that it applies in Australia. There is *medium confidence* of a warming trend in temperature extremes in Asia. There is *low confidence* in observed trends in temperature extremes in Africa and South America. It is *likely* that the number of warm spells, including heatwaves, increased since the middle of the 20th century in many (but not all) regions. [3.3.1; Table 3.2]

It is *likely* that there have been statistically significant increases in the number of heavy precipitation events (e.g., 95th percentile) in more regions than there have been statistically significant decreases, but there are strong regional and subregional variations in the trends. [3.3.2]

There is *low confidence* that any reported long-term increases in tropical cyclone activity are robust, after accounting for past changes in observing capabilities. [3.4.4]

There is *medium confidence* that, since the 1950s, some regions have experienced more intense and longer droughts, in particular in southern Europe and West Africa, but also opposite trends exist. [3.5.1]

There is no clear and widespread evidence of observed changes in the magnitude/frequency of floods at the global level based on instrumental records, and there is thus *low confidence* regarding the magnitude and even the sign of these trends. [3.5.2]

There is evidence of widespread impacts of extreme events on biodiversity and ecosystems, based on observations of physiology, development, phenology, and carbon balance. Ecosystem services can be impaired by extreme events. Even though some ecosystems are adapted to or depend on particular extremes, ecosystem susceptibility to negative impacts of extremes is generally increased when ecosystems are already stressed by fragmentation, deforestation, urbanization, road and infrastructure corridors, environmental contamination, and residual damage from earlier events. [4.2.3.3; 4.3.5; 4.4.3]

Extreme events have impacts on sectors sensitive to climate conditions, such as water, food systems and food security, tourism, and public health. Settlements combine and concentrate the exposure of many sectors and their infrastructure, including energy, water, and transport, as well as most components of manufacturing and trade. Because of the connected nature of sectors, vulnerabilities in one sector can negatively impact others. [4.4]

There is *high confidence* that absolute losses from weather- and climate-related disasters are increasing. For weather- and climate-related disasters, recorded global annual accumulated losses have ranged (in USD 2009 values) from a few billion to as much as 250 billion (for 2005, the year of Hurricane Katrina). Over the period of 2000-2008, the Americas suffered the most direct economic damage in absolute terms from weather- and climate-related disasters, accounting for 55% of the total losses, followed by Asia (28%) and Europe (16%), while Africa accounted for only 0.6%. When expressed as a proportion of gross domestic product (GDP), estimated losses of natural disasters in developing regions are generally higher than those in developed regions. Disasters can cause even larger losses in small economies such as small island states. For example, average direct losses due to disasters to infrastructure, public buildings, and productive capital stock in Samoa have been reported to amount to 6.7% when measured against gross domestic product and averaged over all (disaster and non-disaster) years. [4.2.4; 4.6.3.1; Table 4-16; 6.1]

There is *high agreement*, but *medium evidence* that increasing losses cannot yet be formally attributed to anthropogenic climate change. There is *high confidence* that changes in exposure of people and economic assets, and in some cases changes in vulnerability, have been the major drivers of observed increases in disaster losses. The ability to attribute changes in disaster losses to anthropogenic climate change is limited by data availability; type of weather and climate events studied (e.g., many studies providing evidence of increasing losses focus on cyclones, for which there is *low confidence* in anthropogenic changes [3.4.4; Table 3.1]); confounding factors; and the methods used to normalize loss data over time. [2.7.1; 4.2.4]

C. PROJECTIONS OF VULNERABILITY, EXPOSURE, EXTREME EVENTS, IMPACTS, AND DISASTER LOSSES

Climate change, in addition to natural climate variability, can affect vulnerability, exposure, and the type and magnitude of extreme weather and climate events, thereby altering the potential for extreme impacts and the risk from disasters. Unprecedented, previously unobserved extreme events and impacts may result, and the possible occurrence of low-probability high-impact events, associated with the crossing of poorly understood thresholds, cannot be excluded. Non-linear feedbacks play an important role in either damping or enhancing extremes in several climate variables and related impacts. [3.1.4; 3.1.7; 4.2.1]

There is *high confidence* that trends in vulnerability and particularly in exposure will continue to be drivers of changes in risk patterns over the coming decades. Key factors determining these trends include population growth, changing demographics and health status, changing settlement patterns including urbanization, economic growth, environmental degradation, evolving science and technology, institutional and governance issues, and gradual shifts in climate and its variability. Important complexities arise from feedbacks among these drivers, accumulation and social amplification of risk, dynamic changes in vulnerabilities, and interactions among crises and disasters. [2.7; 2.9; 4.3.4; 4.4]

Confidence in projecting changes in the direction and magnitude of extreme events depends on many factors, including the type of extreme, as well as the region and season, the amount and quality of observational data, the level of understanding of the underlying processes, and the reliability of their simulation in models. Assigning "low confidence" for projections of a specific extreme neither implies nor excludes the possibility of changes in this extreme. The following assessments of the likelihood and/or confidence of projected changes in weather or climate events are generally for the end of the 21st century, with a reference climate period of 1961-1990. Climate projections for differing emission scenarios[2] generally do not strongly diverge in the coming two to three decades, but uncertainty is large over this time frame due to natural climate variability. For projected changes by the end of the 21st century, either model uncertainty or uncertainty associated with the emission scenario used becomes dominant, depending on the extreme. [3.1.5; 3.2.3]

[INSERT FOOTNOTE 2: Emission scenarios for radiatively important gases result from pathways of socioeconomic and technological development. This report uses a subset of the 40 scenarios extending to year 2100 that are described in the IPCC Special Report on Emission Scenarios (SRES). None of the scenarios includes initiatives explicitly addressing climate change.]

It is *virtually certain*, on the global scale and in most regions, that the frequency of hot temperature extremes will increase, and that the frequency of cold temperature extremes will decrease. A one-in-twenty year annual hottest day is *likely* to become a one-in-two year annual extreme by the end of the 21st century in most regions, except in the high latitudes of the northern hemisphere where it is *likely* to become a one-in-five year annual extreme. It is *very likely* that the length, frequency and/or intensity of heatwaves will continue to increase on the global scale. Moderate (cold and warm) temperature extremes on land are projected to warm faster than global annual mean temperature in many regions and seasons. See Figure SPM.1a. [3.3.1]

[INSERT FIGURE SPM.1A HERE:
Figure SPM.1a: Left (yellow) plot -- Projected changes (in degrees C) in 20-year return values of annual maximum of the daily maximum temperature. Right (blue) plot – Projected return period (in years) for late-twentieth-century 20-year return values of annual maximum of the daily maximum temperature. The bar plots (see legend for more info) show results for regionally averaged projections for two time horizons, 2045 to 2065 and 2081 to 2100, as compared to the late-twentieth-century, and for three different SRES emission scenarios. Results are based on 14 GCMs contributing to the CMIP3 (adapted from Kharin et al., 2007). [3.3.1] See Figure 3.2 for defined extent of regions.]

The frequency of heavy precipitation (or proportion of total rainfall from heavy falls) is *likely* to increase over many areas of the globe in the 21st century, in particular in the high latitudes and tropical regions, and in winter in the northern mid latitudes. For a range of emission scenarios (SRES B1, A1B, A2), a one-in-twenty year annual maximum 24-hour precipitation rate is *likely* to become a one-in-five to one-in-fifteen year event by the end of 21st century in many regions. See Figure SPM.1b. [3.3.2]

[INSERT FIGURE SPM.1B HERE:
Figure SPM.1B: Figure SPM.1b: Left (yellow) plot – Projected changes (relative %) in 20-year return values of annual maximum 24-hour precipitation rates. Right (blue) plot – Projected return period (in years) for late-twentieth-century 20-year return values of annual maximum 24-hour precipitation rates. The bar plots (see legend for more

info) show results for regionally averaged projections for two time horizons, 2045 to 2065 and 2081 to 2100, as compared to the late-twentieth-century, and for three different SRES emission scenarios. Results are based on 14 GCMs contributing to the CMIP3 (adapted from Kharin et al., 2007). [3.3.2] See Figure 3.2 for defined extent of regions.]

It is *likely* that the global frequency of tropical cyclones will either decrease or remain essentially unchanged, but there is *medium confidence* that the frequency of the most intense cyclones will increase in some ocean basins. Based on consistency among models and physical reasoning, it is *likely* that tropical-cyclone-related rainfall rates will increase. It is *likely* that mean tropical cyclone maximum wind speed will increase, although increases may not occur in all tropical regions. [3.4.4]

A reduction in the number of mid-latitude storms averaged over each hemisphere due to future anthropogenic climate change is *about as likely as not* and models show large regional changes in cyclone activity, but there is *low confidence* in the detailed geographical projections. Confidence in a projected poleward shift of mid-latitude storm tracks due to future anthropogenic climate change is *medium*. [3.4.5]

There is *medium confidence* that droughts will intensify in the 21st century in some seasons and areas, due either to an enhanced precipitation deficit or to evapotranspiration excess. Confidence is limited because of inconsistent projections of the sign of changes of drought indicators in several regions and between models. There is *medium confidence* that regions that will be affected by an intensification of drought at the end of the 21st century include the Mediterranean, Central Europe, Central North America, and southern Africa. See Figure SPM.2. [3.5.1]

[INSERT FIGURE SPM.2 HERE:
Figure SPM.2: Projected seasonal changes (December, January, February DJF, upper row; and June, July, August, JJA, lower row) of two dryness indices. Left column: Number of consecutive dry days (CDD, days with precipitation < 1mm) expressed in standard deviation from the climatology. Right column: Average soil moisture expressed in kg/m^2. Results are based on multi-model means from CMIP3 projections and expressed as changes of the decadal means, i.e., 2080-2100 mean minus 1980-2000 mean under emission scenario A2 relative to "20th Century Climate in Coupled Model" (20C3M) simulations. Shading is only applied for areas where at least 66% of the models agree in the sign of the change; stippling is applied for regions where at least 90% of all models agree in the sign of the change [from Orlowsky and Seneviratne, 2011, after Tebaldi et al., 2006].]

The magnitude and even the sign of any anthropogenic influence on global patterns of floods are uncertain, and thus there is *low confidence* in projected changes. Nevertheless, an increase in the magnitude and/or frequency of rain-generated floods is anticipated in some catchments and regions where short-term (e.g., daily) rainfall extremes and/or long-term (e.g., monthly, wet-season total) rainfall extremes are projected to increase. Earlier spring peak flows in snowmelt and glacier-fed rivers are *very likely*. [3.5.2]

There is *low confidence* in projections of changes in monsoons (rainfall and circulation), and ENSO (variability and frequency), which are changes in climate phenomena that may affect the frequency and intensity of extremes in several regions simultaneously. Land use changes and aerosols from biomass burning appear to influence monsoons, but these effects are associated with large uncertainties. Models project a wide variety of changes in ENSO variability and the frequency of El Niño episodes as a consequence of increased greenhouse gas concentrations, and so there is *low confidence* in projections of changes in the characteristics of this phenomenon. [3.4.1; 3.4.2]

Mean sea level rise will *very likely* contribute to upward trends in extreme sea levels in the future. Future changes to significant wave height are *likely* to be caused by future changes in storminess and associated patterns of wind change. [3.5.3; 3.5.4]

In most regions, the severity of impacts of heatwaves, wildfires, droughts, and floods (fluvial and coastal) is projected to increase, while changes in cyclone impacts are uncertain. There will be considerable regional variation in the severity of impacts due to differences in exposure, vulnerability, and adaptive capacity. [4.3.4; 4.4; 4.5]

Projections based on unchanging exposure and vulnerability suggest that impacts of weather- and climate-related disasters will increase with climate change. However, confidence in these projections is *low* because they infrequently include changes in non-climatic factors, exposure, and vulnerability. Projected future weather- and climate-related loss studies mostly focus on tropical cyclones in the US and floods in Europe and the US, although some studies have addressed flash floods and hail damage. For the studies that do consider socioeconomic change as well as climate change, there is *medium agreement* but *limited evidence* that the expected changes in exposure are at least as large as the effects of climate change. Indirect and intangible losses are rarely addressed. [4.6.3]

D. CURRENT KNOWLEDGE OF MANAGING THE RISKS OF EXTREME EVENTS AND DISASTERS

Current disaster risk management and climate change adaptation policies and measures have not been sufficient to avoid and fully prepare for and respond to extreme weather and climate events. Improvements in disaster risk management have not kept pace with non-climatic trends that increase vulnerability and exposure, including more people and infrastructure in harm's way. Gaps in national and local public policies and suboptimal risk management at multiple scales have increased disaster risk. [5.2; 6.2.1; 6.3.1; 6.3.2; 6.3.3]

Advances in disaster risk management offer lessons for adapting to climate change. Managing disaster risk involves a continuum of complimentary actions and policy options, including measures to manage uncertainty, reduce risk, transfer and share residual risk, and prepare for and respond to disaster impacts. The relative emphasis placed on different actors and actions depends on the scale of potential impacts, the capacities of governments or agencies to act, the comparative advantage of community based organizations, the level of certainty about the future, the timeframes associated with predictions, and the costs and political consequences of decisions. Lessons learned include [1.1; 1.3; 5.1; 5.3; 5.5; 6.2; 6.3, 6.4]:

- Systematically managing risk is enhanced when policies and measures are coordinated across sectors and scales from local to global, led by organizations at the highest political level, and integrated into economic development and environmental management efforts.
- Legislation supporting managing disaster risks is more effective when regulations are clear and effectively enforced and are complemented by sectoral development and management legislation that explicitly integrates risk considerations.
- Making informed decisions about which policy options to pursue strongly depends on comprehensive databases of observations, losses, and forecasts, on inventories of assets and socioeconomic information, and on the capacity for risk assessment and management.
- Ecosystem-based investments, including conservation measures associated with forestry, land use, coastal wetlands, and biodiversity, help reduce disaster risk across multiple sectors, as well as providing livelihood benefits.
- Effectiveness of early warning systems depends on four interacting components: generation and management of risk knowledge such as monitoring and forecasting, surveillance and warning services, dissemination and communication, and response capability.

Whether or not disaster risk management specifically incorporates climate change, disaster risk management is an important component of adaptation. Successfully managing the risks of existing extreme events, while at the same time not exacerbating future vulnerability, involves anticipating and reducing exposure and vulnerabilities, evaluating the consequences of potential management responses, incorporating uncertainty into planning and implementation, and emphasizing opportunities for learning, flexibility, and innovation. However, institutional separation between disaster risk management and adaptation policy and practice impedes synergy and cooperation. [1.1; 1.3; 1.4; 6.3; 6.4]

Effective disaster risk management and climate change adaptation incorporate a portfolio of strategies, policies, and measures that address exposure and vulnerability within the context of multiple stressors. Managing extreme weather and climate events without considering other stresses and processes may lead to suboptimal strategies and trade-offs. In the absence of comprehensive, multi-stressor analyses, measures implemented to reduce one risk can amplify other stresses (e.g., demographic change and urbanization, pressure on land availability, socio-economic trends, and resource constraints). [5.2; 5.3; 5.4; 5.5.3; 6.2]

Climate change adaptation cannot be effectively pursued without understanding the diverse ways that social processes contribute to the creation and/or reduction of disaster risk. In many cases, disaster risk is causally related to ongoing, chronic, or persistent environmental, economic, and/or social risk factors. Policies and measures affecting quality of life, livelihoods, infrastructure, and natural resource management benefit from integrating disaster risk management and climate change adaptation. [1.1; 2.8; 2.9; 5.3, 6.4]

Many factors determine the penetration of new technologies into disaster risk management and climate change adaptation, particularly in developing countries, including the presence of appropriate and effective institutions, the skill base in the recipient countries, appropriate market conditions, appreciation and implementation of quality control, the availability of spare parts, and an assured supply of basic services such as electricity and water. Often interconnected socioeconomic, institutional, and governance issues determine the degree of success of technology transfer, rather than the technologies themselves. [7.4.3]

Pre-disaster financial mechanisms (including remittances, novel forms of insurance such as index-based micro-insurance, and catastrophe bonds) are important components of disaster risk management and climate change adaptation in regions with little formal insurance or post-event government compensation. The international community, including international financial institutions, non-government organizations, the private sector, and development organizations, is working towards making these mechanisms feasible, affordable, and effective in developing countries, often in the form of public-private partnerships. Adaptation funding could play an additional role in supporting these mechanisms and linking them with pre-disaster risk reduction measures. [5.5.2; 6.3.1; 6.3.3.3; 7.4.4]

E. AVOIDING, PREPARING FOR, AND RESPONDING TO CHANGING DISASTER RISKS AND EXTREMES

Integrated approaches to the assessment and understanding of risk provide the foundation for actions to avoid, prepare for, and respond to extreme weather and climate events and disasters. Risk assessment methods and tools depend on management context, access to data and technology, and stakeholder involvement; these methods vary from formalized probabilistic risk assessment to more qualitative, community-based, participatory assessment schemes. Important elements for risk assessments include recognition of the likelihood and magnitude of extreme events and their impacts, of uncertainties associated with projections, of asymmetric reactions to gains and losses, of differences in coping capacity, and of the influence of cultural worldviews and preconceptions. Because values and beliefs drive perceptions of risk and may be influenced by motivational factors, effective risk communication exchanges, integrates, and shares knowledge about climate-related risks with all stakeholder groups. [1.3; 5.1.5; 5.3.2; 5.4.1; 5.5.1; 6.3.3]

Effective risk management is iterative; accounts for climate change and dynamic trends in exposure and vulnerability; includes regular assessment of the effectiveness of risk prevention, reduction, and response policies and measures; and makes adjustments to maintain and increase effectiveness under changing conditions. Iterative risk management is not a finite set of actions, but is instead an ongoing process of reducing exposure and vulnerability to extreme events, evolving in the context of sustainable development. Management approaches affect current and future exposure and vulnerability, from fostering resilience and sustainable development to inadvertently increasing maladaptation. Principles include mainstreaming disaster risk management into policies and practices; addressing social welfare, quality of life, infrastructure, and livelihoods; and incorporating a multi-hazards approach into planning and action. Iteratively managing risks involves overcoming a multitude of barriers and emphasizing opportunities for learning, flexibility, and innovation. [5.2; 5.4; 5.6; 5.5.3; 6.3.1; 6.3.3; 6.4.2; 8.3.2; 8.3.3; 8.6.3.2; 8.7]

Strategies for improving local disaster risk reduction and climate change adaptation increase resilience when they integrate national and sub-national planning and coordination with knowledge of local conditions and

experiences, supporting local empowerment and collective action. Action at one level of governance can affect other levels, and the resulting interactions among national and sub-national governments, private sectors, and communities can either enhance or constrain risk management. Because there is a strong and complex link between local livelihood security and extreme events, building sustainable livelihoods is an important adaptation to climate change at the local level. [5.1; 5.3; 6.2; 6.3; 6.4]

Integration of disaster risk reduction and climate change adaptation into national development provides the foundation for strategic shifts in managing changing vulnerability and climate risks. An important component is aligning the different roles of national and sub-national governments, private sectors, and communities. National-scale approaches for reducing vulnerability include a range of policy instruments: actions to promote human development, secure livelihoods, and reduce poverty; investments in natural capital and ecosystem-based adaptation; integrated land and water use and development planning, along with appropriate technological and infrastructure approaches; early warning systems; improved engagement with bi-lateral and multi-lateral agencies; and, in the case of developing countries, improved aid effectiveness. [6.3; 6.4]

International policy frameworks and coordination mechanisms have begun incorporating and integrating disaster risk management and climate change adaptation. However, there is less effective integration in operational support for national or local level action. The decisions and the coordination mechanisms of the Hyogo Framework for Action and the UNFCCC explicitly recognize the inter-linkages of disaster risk management and climate change adaptation. However, independent evaluations highlight weaknesses in sustained and effective international support to local level implementation. [7.3]

Synergies in international financing support for disaster risk management and climate change adaptation have yet to be achieved. International funding for disaster risk management remains low compared with spending on post-disaster humanitarian response. Governments have committed to establish much larger funding streams for climate change adaptation, which also could support the longer-term investments necessary for disaster risk management. Achieving this goal relies on donors meeting their funding commitments, improvements in current disbursement procedures, and careful management to ensure responsiveness to the overall goals of disaster risk management and climate change adaptation. Such international efforts, combined with national-level integration of disaster risk reduction and climate change adaptation, have the potential to produce synergistic outcomes in resilience [6.4.4; 7.4.2]

Observed and projected trends in exposure, vulnerability, and extreme events can provide guidance in designing risk management and adaptation strategies, policies, and measures. The importance of these trends for decision making depends on their magnitude and degree of certainty at the temporal and spatial scale of the risk being managed and on the available capacity to implement risk management options. Table SPM.1 provides illustrative examples of how adaptation and risk management decisions can be informed by trends in vulnerability, exposure, and extreme events. Trends are provided at the scale relevant to decision making in each example. Trends in extreme events are also provided at global and regional scales to illustrate that the direction, magnitude, and/or degree of certainty for trends may differ at these scales.

When there is a high degree of certainty about trends in extreme events at a scale relevant to adaptation and risk management decisions, projections of extreme events can inform adjustments in strategies, policies, and measures, such as adjustments in infrastructure design. A high degree of certainty about trends in extreme events may not exist at local and national scales of decision making; at these scales, there may be a higher degree of certainty about trends in exposure and vulnerability. The certainty about trends in extreme events at different scales depends on the type of extreme event, its spatial extent, and its dependence on non-climatic factors such as land use patterns. Although regional and global trends in extreme events imply some probability of events occurring at smaller scales, confidence in projected trends at smaller scales is often more limited. Using global and regional trends in extreme events to inform risk management when there is a low degree of certainty in trends at the scale of risk management may lead to strategies, policies, and measures that do not effectively manage risk. A more robust approach is to focus on low-regrets risk management options that reduce exposure and vulnerability across a range of outcomes, including measures to manage residual risk such as early warning and risk transfer. [2.5.4.2; 2.7.2; 2.7.4.1; 3.2.3; 4.2.5; 4.3.1; 4.4.5.1; 4.5.4; 6.3.1.3; 6.3.2.2; 6.4.2; 9.2.2; 9.2.13]

[INSERT TABLE SPM.1 HERE
Table SPM.1 provides illustrative examples of how adaptation and risk management decisions can be informed by information on trends in exposure, vulnerability, and extreme weather and climate events. Trends are provided at the scale relevant to decision making in each example. Trends in extreme events are also provided at global and regional scales to illustrate that the direction, magnitude, and/or degree of certainty for trends may differ at these scales.]

Evidence of the economic efficiency of specific adaptation approaches remains limited and fragmented. Although cost-benefit analyses are often used to estimate economic efficiency, their applicability for evaluations of adaptation appears limited. In some cases, a cost-effectiveness evaluation is preferable, involving the selection of options with the lowest cost for reaching a given objective. In other cases, risk-based approaches assessing whether policies achieve an acceptable level of risk are more useful. [4.6.2; 4.6.4; 5.4.2; 6.3.3; 6.4.1]

The costs of enhancing disaster risk management and climate change adaptation to address changing risks are difficult to assess, with most studies focusing on sea level rise and slower onset impacts on agriculture. Assessments of the costs of adaptation infrequently distinguish extreme events from gradual change, or they treat extreme events as similar to gradual onset phenomena with deterministic impact metrics**.** Estimates of the costs of adaptation globally range from 4 to 100 billion USD per year, with a bias towards the higher end of costs, but *confidence* remains *low*. These estimates significantly underestimate costs because sectors such as ecosystem services, energy, manufacturing, retailing, and tourism are excluded and because the adaptation cost estimates assume low levels of investment. These estimates also do not consider remaining, unavoidable residual damages. [4.6.2; 4.6.4; 6.4.1]

F. IMPLICATIONS FOR SUSTAINABLE DEVELOPMENT

Transformational changes in socio-ecological systems can influence the capacity of societies to adapt to changes in extreme weather and climate events (*medium agreement, limited evidence*). In some cases and in some locations, changes in extreme events will complicate the prospects for adaptation unless anticipatory action is taken. Transformations, defined as fundamental qualitative changes or changes in composition or structure (see Box SPM.2), can be planned and anticipated, or reactive and forced. Deliberate transformations frequently involve adaptive management, learning, innovation, and leadership (*medium evidence*). [8.3.2; 8.5.2; 8.6.3]

_____ START BOX SPM.2 HERE _____

Box SPM.2: Transformations

Disaster risk management and climate adaptation strategies can contribute to sustainable development, but the success of such strategies in the context of climate extremes and a changing risk landscape will be, in some cases, dependent upon transformational changes, as contrasted with incremental change or business as usual. Transformation often involves a change in mindsets, mental models, assumptions, beliefs, priorities, and loyalties, which can be prerequisites to changes in systems and structures. Adaptive management, learning, innovation, and leadership can facilitate transformation through trust building among stakeholders and a willingness to experiment and move beyond rigid agendas and practices to take on new information, new challenges, and new ways of operating. The transformation of socio-technical systems can potentially facilitate transitions from established systems to sustainable systems. [8.6.2]

_____ END BOX SPM.2 HERE _____

Addressing the underlying causes of vulnerability, as well as the structural inequalities that create and sustain poverty and constrain access to resources, is an important prerequisite for sustainability (*high agreement, robust evidence*). This involves integrating disaster risk reduction with other social and economic policy areas, as well as a long-term commitment to managing risk (*medium evidence*). [8.7]

Resilience-based approaches provide insights and tools for dealing with disturbances and surprises. These approaches include, for example, building institutional capacity and adaptive organizations, such as in hospitals or in the humanitarian sector, and enhancing the range and diversity of ecosystems responses to extreme events by reducing non-climatic stresses on coral reefs and rainforests (to increase their ability to buffer impacts of climate change). [6.4.2; 8.3.3; Box 8.2].

Short-term and long-term perspectives on both disaster risk reduction and climate change adaptation are often difficult to reconcile (*high agreement, robust evidence*). There are recognized tensions, trade-offs, and potential conflicts between different values, interests, objectives, and visions for the future. Resilience thinking offers some tools for reconciling short-term and long-term responses, including integration of different types of knowledge, an emphasis on inclusive governance, and principles of adaptive management. However, there is no single approach or development pathway for managing the risks of extreme events. [8.3.1; 8.3.3; 8.7]

Climate-related disasters generate both losers and winners, with long-term implications for human security (*medium agreement, robust evidence*). The outcomes are closely linked to existing capacities and resources that reflect patterns of development. Social thresholds and tipping points may pose limits to a sustainable and resilient future (*low agreement, limited evidence*). [8.4.3; 8.5.1; 8.5.3; 8.5.4]

Progress toward sustainable development benefits from leadership that questions mindsets, assumptions, and paradigms and that encourages innovation and the generation of new patterns of response (*medium agreement, medium evidence*). Responding successfully to multiple stressors, including disaster risk, often involves broad participation in strategy development, the capacity to combine multiple perspectives and differing worldviews, and contrasting ways of organizing social relations [8.2.5; 8.6.3; 8.7].

A wide range of technological innovations is being explored to facilitate risk reduction and risk enhancement (*high agreement, robust evidence*). The transformation of society towards sustainability and resilience involves both social innovations and technological innovations, incremental as well as radical. Although there is much uncertainty about the future, there is *medium evidence* that adding an anticipatory dimension to planning and decision making can build resilience. [8.2.2; 8.2.3]

There is *high confidence* that integrated disaster risk management and climate change adaptation, through reduction of exposure and vulnerability, significantly reduce impacts from extreme events, including economic losses, morbidity, and mortality. [1.1; 1.3; 5.2; 5.4; 5.5.3; 6.3]

_____ START BOX SPM.3 HERE _____

Box SPM.3: Treatment of Uncertainty

Based on the Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties,[3] this Summary for Policymakers relies on two metrics for communicating the degree of certainty in key findings:

- Confidence in the validity of a finding, based on the type, amount, quality, and consistency of evidence (e.g., mechanistic understanding, theory, data, models, expert judgment) and the degree of agreement. Confidence is expressed qualitatively.
- Quantified measures of uncertainty in a finding expressed probabilistically (based on statistical analysis of observations or model results, or expert judgment).

[INSERT FOOTNOTE 3: Mastrandrea, M.D., C.B. Field, T.F. Stocker, O. Edenhofer, K.L. Ebi, D.J. Frame, H. Held, E. Kriegler, K.J. Mach, P.R. Matschoss, G.-K. Plattner, G.W. Yohe, and F.W. Zwiers, 2010: *Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties*. Intergovernmental Panel on Climate Change (IPCC). Available at <http://www.ipcc.ch>.]

Key findings are based on the evaluation of associated evidence and agreement. Depending on the nature of the evidence evaluated, uncertainty may be quantified probabilistically. In most cases, either a quantified measure of uncertainty or an assigned level of confidence is presented.

The following summary terms are used to describe the available evidence: “limited,” “medium,” or “robust”; and for the degree of agreement: “low,” “medium,” or “high.” A level of *confidence* is expressed using five qualifiers “very low,” “low,” “medium,” “high,” and “very high.” It synthesizes the author teams’ judgments about the validity of findings as determined through evaluation of evidence and agreement (Box SPM.3 Figure 1).

[INSERT BOX SPM.3 FIGURE 1 HERE:
Box SPM.3 Figure 1: A depiction of evidence and agreement statements and their relationship to confidence. Confidence increases towards the top-right corner as suggested by the increasing strength of shading. Generally, evidence is most robust when there are multiple, consistent independent lines of high-quality evidence.

The following terms have been used to indicate the assessed likelihood:

Term*	**Likelihood of the outcome**
Virtually certain	99-100% probability
Very likely	90-100% probability
Likely	66-100% probability
About as likely as not	33 to 66% probability
Unlikely	0-33% probability
Very unlikely	0-10% probability
Exceptionally unlikely	0-1% probability

* Additional terms that were used in limited circumstances in the AR4 (*extremely likely* – 95-100% probability, *more likely than not* – >50-100% probability, and *extremely unlikely* – 0-5% probability) may also be used in the AR5 when appropriate.

Table SPM.1. Table SPM.1 provides illustrative examples of how adaptation and risk management decisions can be informed by information on trends in exposure, vulnerability, and extreme weather and climate events. Trends are provided at the scale relevant to decision making in each example. Trends in extreme events are also provided at global and regional scales to illustrate that the direction, magnitude, and/or degree of certainty for trends may differ at these scales.

		Observed and Projected Trends in Extreme Events Type Across Spatial Scales			
Issue of concern	**Trend in aggregate vulnerability and exposure at scale of risk management in example region**	**Global observed (since 1950) and projected (to 2100) trend in extreme event type**	**Observed (since 1950) and projected (to 2100) trend in extreme event type in example region**	**Observed and projected trend in extreme event type at scale of risk management in example region**	**Risk management/adaptation options**
Public health concerns about increasing mortality and morbidity due to **heatwaves in an urban area** in Western Europe	Factors affecting vulnerability and exposure include age (old and young); pre-existing health conditions including certain chronic diseases; body-mass index; outdoor work; clothing choices; access to and use of cooling (partly related to the risk of power failures during heatwaves, which also depends on electricity generation and transmission systems); urban infrastructure; and socioeconomic factors including poverty, crime levels, and social isolation. Trends in these factors may increase vulnerability and/or exposure, including an aging population, the loss of urban green space, and the increase of urban heat island effects due to planned and unplanned urbanization. [2.5.4.2; 2.7.2; 2.7.4.1; 4.3.1; 4.4.5.1; 4.5.4; 9.2.2]	Observed: *Likely* increase in warm spells, including heatwaves, in most regions. Projected: *Very likely* increase in length, frequency, and/or intensity of warm spells, including heatwaves over most land areas. [Table 3.1; 3.3.1]	Observed: *Medium confidence* in increase in heatwaves in Europe. Projected: *High confidence* in *likely* increase in heatwave duration in Europe [Table 3.2; Table 3.3; 3.3.1]	Observations and projections can provide information about observed trends and projections of hot days and heatwaves in specific urban areas (because most urban areas in the region can expect increased heatwaves due to both regional trends and additional urban heat island effects).	Low-regrets options that reduce vulnerability and exposure across a range of trends in heatwaves: • early warning systems • public information on what to do during heatwaves; emergency hotlines • community sensitization, warning systems, and home caretaking • installation of air conditioning, for instance in elderly homes and schools • use of social networks to reach vulnerable elderly Specific adjustments in strategies, policies, and measures informed by trends in heatwaves: • awareness raising (for general public and relevant authorities and organizations) of rising risk that people may not be aware of, particularly in cities where in the past heatwaves occurred at very low frequency • changes in building design and urban land use planning • changes in standards for cooling capacity, particularly of public facilities and critical infrastructure • adjustments in energy generation and transmission infrastructure Increasing disaster risk due to climate change suggests higher prioritization of heatwaves as a public health concern, particularly in cities not considered at risk in the past. [6.3.1.3; 9.2.2]
Increasing **losses from hurricanes** in the USA and the Caribbean	*High confidence* that exposure of people and economic assets is increasing, and *very likely* that this is the major cause of the long-term changes in disaster losses.	Observed: *Low confidence* of any robust long-term increases in tropical cyclone activity, after accounting for changes in observing capabilities. Projected: *Unlikely* increase in global frequency of tropical	Observed: Observational evidence for an increase in intense tropical cyclone activity in the North Atlantic since about 1970, but *low confidence* that any long-	Limited model capability to project changes with resolution relevant to specific settlements or other locations.	Low-regrets options that reduce vulnerability and exposure across a range of trends in hurricanes: • Early warning systems • Integration of seasonal forecasts with projections of the upcoming hurricane season's possible activity • Regional risk pooling reducing financial exposure

Table SPM.1 continued

		Observed and Projected Trends in Extreme Events Type Across Spatial Scales			
[4.2.5]	[4.2.5]	cyclones (*likely* decrease or no change). *Likely* increase in mean maximum wind speed, but possibly not in all basins. *Likely* increase in tropical cyclone-related rainfall rates. Projected sea level rise *likely* to further compound tropical cyclone surge impacts. [Table 3.1; 3.4.4]	term observed increases in tropical cyclone activity are robust, after accounting for past changes in observing capabilities. Projected: *Medium confidence* that the frequency of the most intense cyclones will increase in some ocean basins [3.4.4]		For hurricane risk, climate information is too uncertain and imprecise to justify large-scale adjustments in strategies, policies, and measures (except for adjustments to long-term coastal infrastructure given possible changes in storm surge levels primarily driven by sea level rise). Instead, in this context of high underlying variability, adaptive management involving learning becomes even more important, such as: • Improving localized climate and risk information • Emphasizing adaptive management for authorities managing risk in terms of flexibility, learning, and responsive governance The Cayman Islands National Hurricane Committee provides an example of a learning-based organization. [6.4.2] [6.3.1.3; 9.2.13]
Flash floods in Nairobi's informal settlements	*High confidence* of increases as Nairobi experienced high impact flooding in last decade. Rapid expansion of poor people living in informal settlements around Nairobi has led to houses of weak building materials being constructed immediately adjacent to rivers and to a lack of natural drainage areas, increasing rapid run-off and exposing more people. [6.3.2.2]	*Observed:* *Low confidence* in changes in the magnitude and frequency of floods at the global level. AND *Likely* statistically significant increases in the number of heavy precipitation events in more regions than there have been statistically significant decreases, but with strong regional and subregional variations in the trends. *Projected* *Low confidence* in global projections of changes in flood magnitude and frequency because of insufficient literature and poor agreement between models. BUT Increase in magnitude and/or frequency anticipated in regions where rainfall extremes are projected to increase. AND *Likely* increase in frequency of heavy precipitation events (or increase in proportion of total rainfall from heavy falls) over many areas of the globe, in particular in the high latitudes and tropical regions, and in winter in the northern mid latitudes. [Table 3.1; 3.3.2; 3.5.2]	Observed: Inconsistent patterns in existing studies of heavy precipitation across Africa. In East Africa, *medium confidence* of an observed decrease in heavy precipitation. Projected: *Very likely* increase in heavy precipitation in East Africa. *High confidence* in *likely* increase in heavy precipitation days and contribution to annual totals. [Table 3.2; Table 3.3; 3.3.2]	Limited ability to provide quantified local flood projections, partly due to lack of fine-scale climate projections, but also due to lack of knowledge of changes in local hydrology.	While it is difficult to directly link increased heavy precipitation to more severe flooding, the upward trend of aggregate exposure and vulnerability increases the need to reduce exposure and vulnerability even without a strong climate signal. Examples of such "no or low regrets" measures include strengthening building control regulation, focused poverty reduction schemes and city-wide drainage and sewerage improvements. More specific climate-related disaster risk reduction measures include the involvement of poor people in decision-making processes with the potential of developing "cash-for-work" programs to install riparian buffers, canals, drainage channels, and trenches between structures. Climate change is specifically mentioned in the African Development Bank sponsored Nairobi Rivers Rehabilitation and Sewerage Improvement project, and addressed through investments in: • tree planting in riparian areas • attention to climate variability and change in the choice of location and design of wastewater infrastructure • environmental monitoring plan that includes river flow monitoring to enable early predictions of floods and drought [6.3.1.3; 6.3.2.2]

Figure SPM.1a (Modified from Figures 3.6 and 3.8).

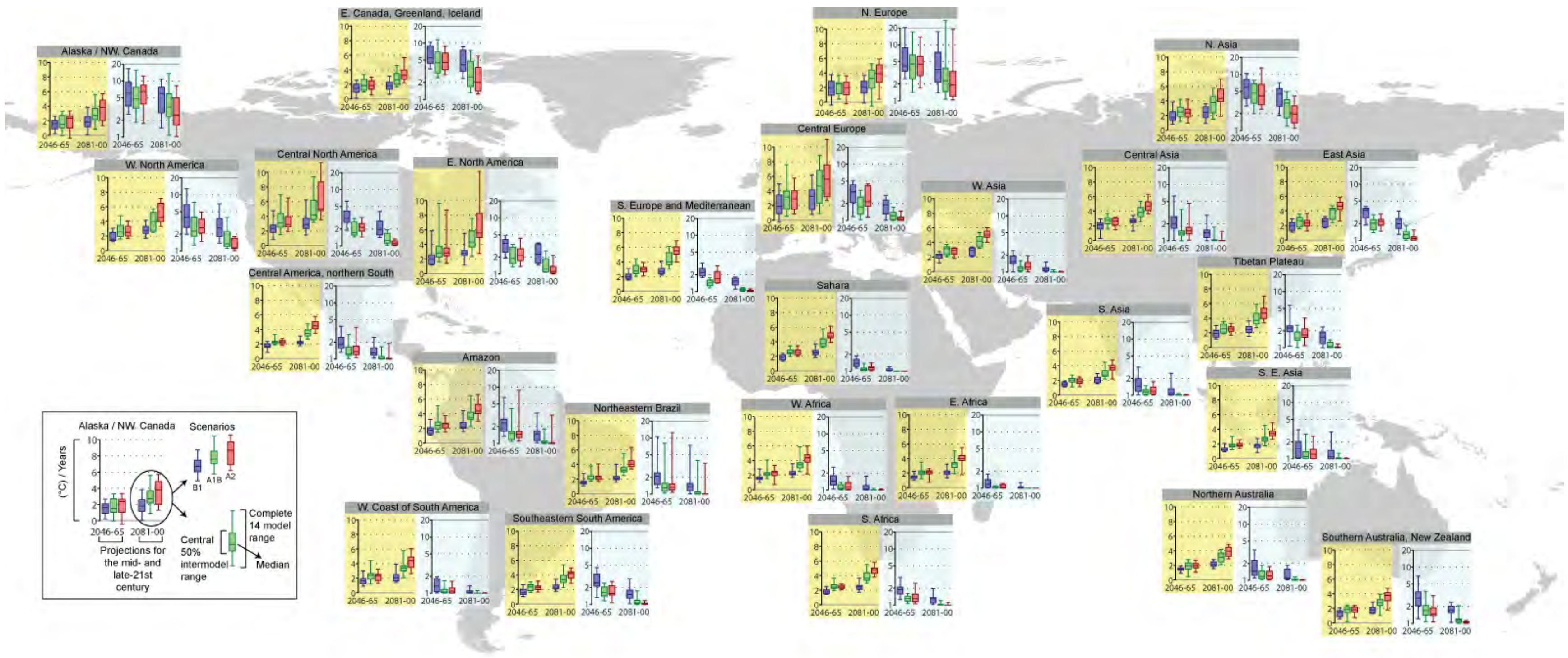


Figure SPM.1a: Left (yellow) plot -- Projected changes (in degrees C) in 20-year return values of annual maximum of the daily maximum temperature. Right (blue) plot – Projected return period (in years) for late-twentieth-century 20-year return values of annual maximum of the daily maximum temperature. The bar plots (see legend for more info) show results for regionally averaged projections for two time horizons, 2045 to 2065 and 2081 to 2100, as compared to the late-twentieth-century, and for three different SRES emission scenarios. Results are based on 14 GCMs contributing to the CMIP3 (adapted from Kharin et al., 2007). [3.3.1] See Figure 3.2 for defined extent of regions.

Figure SPM.1b (Modified from Figures 3.6 and 3.8).

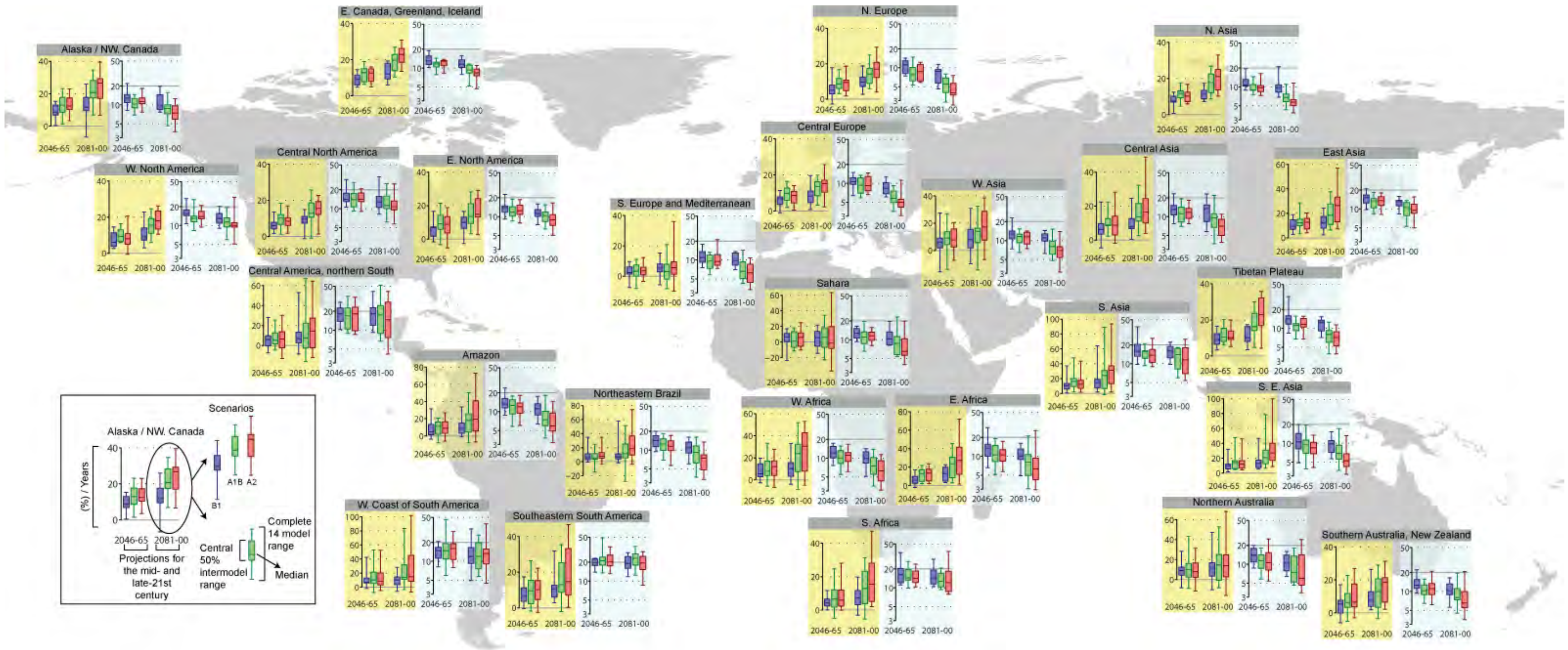


Figure SPM.1b: Left (yellow) plot – Projected changes (relative %) in 20-year return values of annual maximum 24-hour precipitation rates. Right (blue) plot – Projected return period (in years) for late-twentieth-century 20-year return values of annual maximum 24-hour precipitation rates. The bar plots (see legend for more info) show results for regionally averaged projections for two time horizons, 2045 to 2065 and 2081 to 2100, as compared to the late-twentieth-century, and for three different SRES emission scenarios. Results are based on 14 GCMs contributing to the CMIP3 (adapted from Kharin et al., 2007). [3.3.2] See Figure 3.2 for defined extent of regions.

Figure SPM.2 (Modified from Figure 3.10).

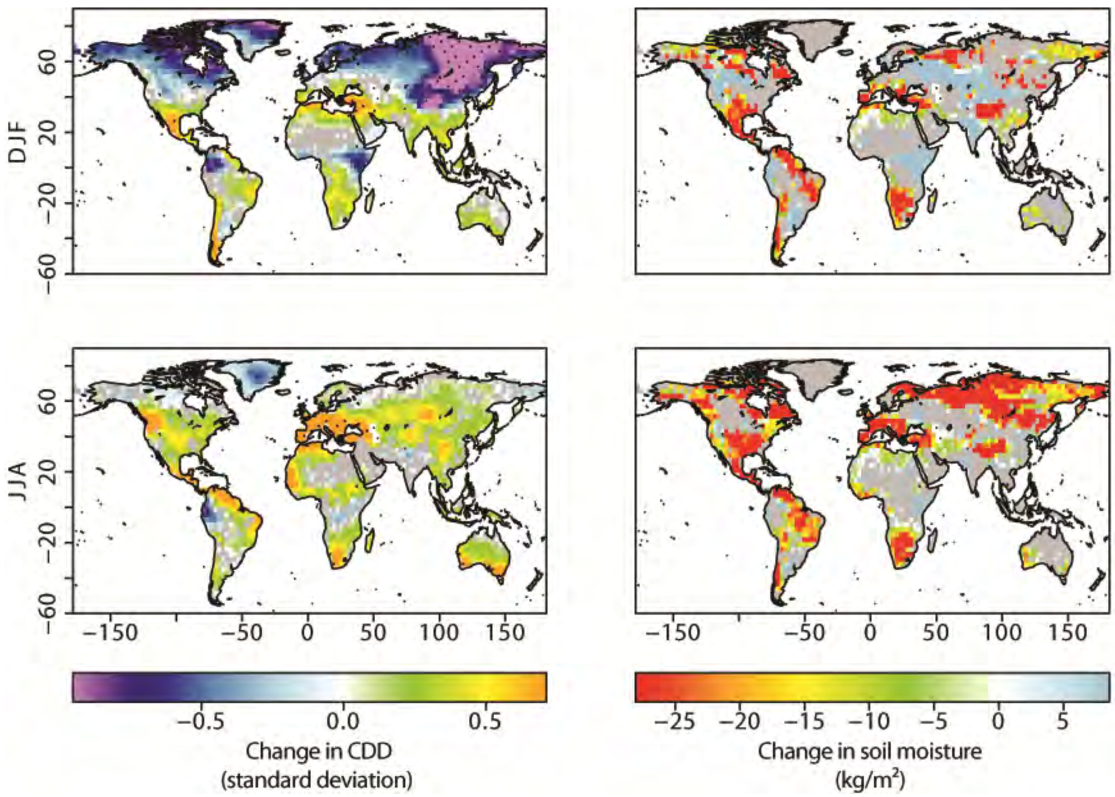
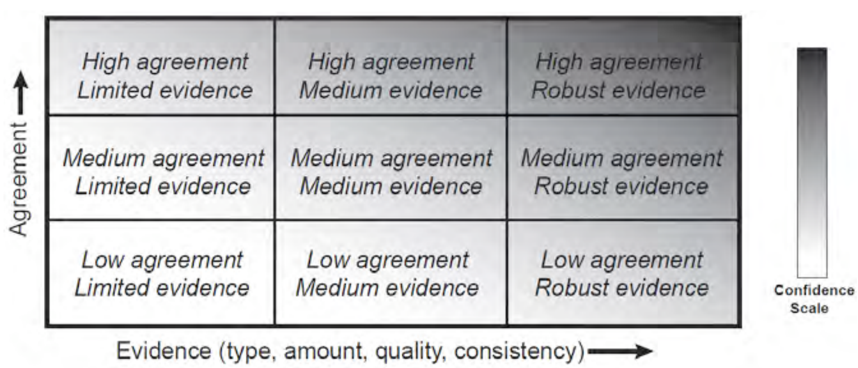


Figure SPM.2: Projected seasonal changes (December, January, February DJF, upper row; and June, July, August, JJA, lower row) of two dryness indices. Left column: Number of consecutive dry days (CDD, days with precipitation < 1mm) expressed in standard deviation from the climatology. Right column: Average soil moisture expressed in kg/m^2. Results are based on multi-model means from CMIP3 projections and expressed as changes of the decadal means, i.e., 2080-2100 mean minus 1980-2000 mean under emission scenario A2 relative to “20th Century Climate in Coupled Model” (20C3M) simulations. Shading is only applied for areas where at least 66% of the models agree in the sign of the change; stippling is applied for regions where at least 90% of all models agree in the sign of the change [from Orlowsky and Seneviratne, 2011, after Tebaldi et al., 2006].



Box SPM.3 Figure 1: A depiction of evidence and agreement statements and their relationship to confidence. Confidence increases towards the top-right corner as suggested by the increasing strength of shading. Generally, evidence is most robust when there are multiple, consistent independent lines of high-quality evidence.