INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

WMO UNEP

IPCC Expert Meeting on The Science to Address UNFCCC Article 2 including Key Vulnerabilities

Buenos Aires, Argentina
18 – 20 May 2004

EXPERT MEETING - SHORT REPORT

(This report contains the same written material as the main report, but none of the presentations)

This expert meeting was agreed in advance as part of the IPCC work plan, but this does not imply working group or panel endorsement or approval of the proceedings or any recommendations or conclusions contained herein.

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WMO **INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE** UNEP

IPCC Expert Meeting on The Science to Address UNFCCC Article 2 including Key Vulnerabilities

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1 Introduction

The Intergovernmental Panel on Climate Change (IPCC) is preparing a Fourth Assessment Report (AR4) which will assess the scientific, technical, and socio-economic information relevant to understanding human-induced climate change, its potential impacts, vulnerability to it, and options for adaptation and mitigation. Consistent with the principles of the IPCC, this assessment will be carried out in a comprehensive, objective, open, and transparent manner.

Planning for the AR4 has considered the need for treatment of knowledge relating to key objectives of the UN Framework Convention on Climate Change (UNFCC) which includes Article 2. This states that:

"The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system". The Framework Convention on Climate Change further suggests that such a level should be achieved within a time frame sufficient

- to allow ecosystems to adapt naturally to climate change,
- to ensure that food production is not threatened and
- to enable economic development to proceed in a sustainable manner.

Following an IPCC Expert Meeting on the levels of greenhouse gases in the atmosphere preventing dangerous anthropogenic interference with climate system (Geneva, January 2003) which concluded, amongst other things, that this is a significant issue which must continue to be addressed by the IPCC in its future work programme, the IPCC at its 20th Session (February 2003, Paris) agreed that consideration of Article 2, including key vulnerabilities, should be one of seven cross-cutting themes in AR4. Furthermore there was agreement that it should fully involve all three IPCC Working Groups. A concept paper on this theme identified some of the key issues (see Annex 1) to be addressed under this theme such as:

- focus on assessing scientific, technical and socio-economic aspects related to the three UNFCCC criteria mentioned above
- identification of indicators or parameters on the basis of which these criteria could be evaluated
- consideration of various types of thresholds and of critical levels and outcomes
- consideration of the overall consequences for human well-being (HWB), and in particular, the negative effects on the components of HWB, such as health, prosperity, social development and ecosystem services and for the WEHAB (Water, Energy, Health, Agriculture and Biodiversity) framework and its components (plus coastal regions)
- evaluation of the societal costs of climate change, including market as well as non-market goods and services, and aspects of intergenerational and distributional equity.

Following from these initial steps, the expert Meeting reviewed present knowledge that relates to the issue of Article 2 and key vulnerabilities and considered how best this can be incorporated in AR4, particularly for a more integrated treatment of the subject across the three Working Groups.

1.1 Introduction to the meeting

The opening ceremony was chaired by Osvaldo Canziani, Co-chair of IPCC Working Group Two. Talks were then given by:

Ambassador Raúl Estrada Oyuela, Argentine Ministry of Foreign Relations, Argentina
Professor Martin Parry, Co-chair of IPCC Working Group II, United Kingdom

1.2 Purpose and scope of meeting

Background

The Intergovernmental Panel on Climate Change (IPCC) is preparing a Fourth Assessment Report (AR4) which will assess the scientific, technical, and socio-economic information relevant to understanding human-induced climate change, its potential impacts, vulnerability to it, and options for adaptation and mitigation. Consistent with the principles of the IPCC, this assessment will be carried out in a comprehensive, objective, open, and transparent manner.

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- *to allow ecosystems to adapt naturally to climate change,*
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- *to enable economic development to proceed in a sustainable manner."*

Following an IPCC Expert Meeting on the levels of greenhouse gases in the atmosphere preventing dangerous anthropogenic interference with climate system (Geneva, January 2003) which concluded, amongst other things, that this is a significant issue which must continue to be addressed by the IPCC in its future work programme, the IPCC at its 20th Session (February 2003, Paris) agreed that consideration of Article 2, including key vulnerabilities, should be one of 7 cross-cutting themes in AR4. Furthermore there was agreement that it should fully involve all three IPCC Working Groups. A concept paper on this theme identified some of the key issues (see Annex C) to be addressed under this theme such as:

- Focus on assessing scientific, technical, and socio-economic aspects related to the three UNFCCC criteria mentioned above

- Identification of indicators or parameters on the basis of which these criteria could be evaluated, consideration of various types of thresholds and of critical levels and outcomes
- Consideration of the overall consequences for human well-being (HWB), and in particular, the negative effects on the components of HWB, such as health, prosperity, social development and ecosystem services and for the WEHAB framework and its components (plus coastal regions)

- Evaluation of the societal costs of climate change, including market as well as non-market goods and services, and aspects of intergenerational and distributional equity.

Some scientific and technical aspects of relevance to Article 2 were covered in the IPCC Third Assessment Report (TAR). "What can scientific, technical, and socio-economic analyses contribute to the determination of what constitutes dangerous anthropogenic interference with the climate system as referred to in Article 2 of the Framework Convention on Climate Change?" was addressed in Question 1 of the TAR Synthesis Report. The TAR concluded that "Natural, technical, and social sciences can provide essential information and evidence needed for decisions on what constitutes "dangerous anthropogenic interference with the climate system". At the same time, such decisions are value judgments determined through socio-political processes, taking into account considerations such as development, equity, and sustainability, as well as uncertainties and risk." It also stated that "the basis for determining what constitutes "dangerous anthropogenic interference" will vary among regions - depending both on the local nature and consequences of climate change impacts, and also on the adaptive capacity available to cope with climate change — and depends upon mitigative capacity, since the magnitude and the rate of change are both important". The TAR explored the parameters of the impacts relating to Article, which it terms 'reasons for concern', namely:

- risk to unique and threatened systems,
- risk from extreme climate events,
- distribution of impacts, aggregate impacts,
- different development and technological pathways that might achieve stabilisation,
- and risk from future large-scale discontinuities / irreversibilities

The TAR also explored the array of different metrics for evaluating 'levels' as mentioned in Article 2, such as: market impacts, human lives, biodiversity loss, distributional effects, quality of life and it provided an assessment of the potential for achieving a broad range of levels of greenhouse gas concentrations in the atmosphere through mitigation, as well as information about how adaptation can reduce vulnerability.

The concept of critical thresholds (i.e. exceeding of certain levels determined on scientific grounds) had already been proposed at the IPCC Special Workshop on Article 2 of the UNFCCC (at Fortaleza, Brazil, October 1994) and has been addressed briefly in the TAR. The cross cutting theme concept paper further developed this concept, distinguishing different types of thresholds such as incremental changes that exceed tolerances, as against significant non-linear processes in physical systems that might affect major system stability (e.g. of the West Antarctic Ice Sheet). These and more complex distinctions need further consideration.

Purpose and Scope of the Meeting

Following from these initial steps, the expert Meeting reviewed present knowledge that relates to the issue of Article 2 and key vulnerabilities, and considered how best this can be incorporated in AR4, particularly in a more integrated treatment of the subject across the three Working Groups.

The Expert Meeting focused primarily on scientific issues, with the first two days devoted to these, and a third discussed how best to incorporate this knowledge in the AR4. The prime questions were:

- what new developments in scientific knowledge — including explicit and quantitative treatment of uncertainties — can help address Article 2 and key vulnerabilities;
- what are the key gaps in knowledge;
- what developments in science are likely in the next 2 to 5 years;

- what is the range of scientific knowledge and disciplinary insights relevant for addressing issues related to Article 2 and key vulnerabilities
- how can this inform the AR4 and subsequent assessments?

Participation was by experts from Working Group I, II and III field of interest, approximately in equal quantity, together with a small number of those familiar with formal treatments of uncertainties via decision analytic methods and some who were able to advise on key policy requirements for scientific and technical information (and one IPCC Bureau member).

The Expert meeting was held from May 18-20, 2004 in Buenos Aires at the invitation of the Government of Argentina.

The output of the Meeting is: a) a report of the meeting which summarises new knowledge; key gaps in knowledge; methodological issues regarding Article 2 (including uncertainties); research priorities for the future ; b) an improved understanding between Working Group Co-Chairs, TSUs and lead authors of chapters in the AR4 assessment of how different aspects of the issue will be considered in AR4; and c) brief guidance notes for AR4 authors suggesting how best to embed the breadth and depth of the topic into the AR4.

Key questions that were addressed include:

- the relation between science and Article 2, including issues such as uncertainty, risk, levels and the exceedance, rates/timing/magnitude issues;

- knowledge of the sensitivities of the areas covered by Article 2 (e.g. food, ecosystems, development), as well as others that are contingent to them or related to them (e.g. water, health) and to climate change; how these would vary under different development pathways;

- knowledge of the costs of, barriers to and opportunities for adaptation, in the context of Article 2.

- knowledge of key levels (of rates, timings, amounts and types) of climate change that would be relevant for examining the sensitivities of the sectors specified in Article 2 at appropriate scales: local, regional and global;

- knowledge of the nature of climate changes (their rate, timing, magnitude, type, etc) that might lead to exceeding key levels of effect;

- knowledge about critical thresholds and irreversibilities, and slow versus abrupt changes, including high risk - low probability events;

- knowledge of the emissions pathways that would lead to concentrations consistent with reducing the probabilities of such climate changes;

- costs/methods of emissions reduction and stabilization and what constitutes “dangerous” for sustainable development when costs for mitigation are incurred.

It is anticipated that recent developments in knowledge will allow experts to examine a wide range of possible outcomes in the future array of emissions/concentrations/climate changes/impacts; and the intent will not be to prescribe specific ones, but rather to evaluate risks and distribution of effects across a spectrum of scenarios available in the literature.

1.3 Context within IPCC AR4

The following abstract was prepared by Dr. R. Pachauri, IPCC Chair, for the meeting and distributed to participants in advance.

Extract from speech by Dr. Rajendra K. Pachauri
Chairman of the IPCC at the Twenty First Session of the IPCC
Vienna, Austria, 3 – 7 November 2003
For circulation at the Expert Meeting on the science related to UNFCCC Article 2 including key vulnerabilities

Buenos Aires, Argentina
18 - 20 May, 2004

While ensuring the greatest possible attention to policy relevance in the contents of the AR4, we would also have to be duly cautious in ensuring that at no stage must any part of the AR4 cross the storm front that would inappropriately take us into policy prescriptive territory. This would be a difficult but critically important requirement, and one that is at the core of the scientific credibility and effectiveness of the IPCC. Various demands may be placed on us, perhaps by those who would like the IPCC to take certain positions that could deviate from scientific assessment. Purely as an example I would like to refer to the need for treading carefully on the issue of Article 2 of the Framework Convention on Climate Change, which refers to the level of stabilization of greenhouse gas concentrations at a level that would prevent dangerous anthropogenic interference with the climate system. The Third Assessment Report very rightly stated that decisions on what constitutes dangerous anthropogenic interference “are value judgments determined through socio-political processes, taking into account considerations such as development, equity, and sustainability, as well as uncertainties and risk”. In its most unimpeachable form a scientific assessment can, however, provide essential information that is needed for such decisions and highlight (1) key vulnerabilities, (2) the specific nature and extent of impacts of climate change including damage to ecosystems, and the socio-economic implications of these impacts; and 3) the risk of occurrence of such impacts across a wide range of possible development futures and climate scenarios (ranging from unmitigated to stabilized). Scientists must faithfully and as accurately as possible confine their efforts to these three subjects. It is for others to determine what constitutes dangerous levels of interference with the world’s climate system and what actions should be taken. For instance, it is for others to decide whether we have already crossed the danger threshold with the damage that has taken place to coral reefs, the widespread effects of sea level rise, the melting of glaciers, the changes in precipitation levels, and last but not least, higher temperatures. Some may feel that we already have. On the other hand others may perhaps conclude that even the disappearance of small island states is not dangerous, because entire populations could be moved from these states and from coastal areas to other locations as part of what could be termed as adaptation measures. Such value judgements do not reflect scientific assessment, and can at best be facilitated by an objective assessment of risks, impacts and key vulnerabilities of the systems thus affected and their relationship with specific mitigation options. Of course, these key vulnerabilities of different systems need to be defined not only in a biophysical sense but also in terms of socioeconomic implications which would also have relevance to mitigation options. I am highlighting these examples only as a word of caution, because at no stage of our work must we deviate from the scientific objectivity of what we are charged with doing.

1.4 Results from preceding IPCC expert meetings on Article 2 issues

The following abstract was prepared by Yuri Izrael, IPCC Vice-chair, for the meeting and distributed to participants in advance.

RESULTS/ACTIONS FROM PRECEDING EXPERT MEETINGS RELATING TO ART2 ISSUES:
THE HISTORY OF THE ISSUE AND THE CONCEPT OF DANGEROUS ANTROPOGENIC INTERFERENCE WITH THE CLIMATE SYSTEM IN THE VIEW OF UNFCCC ARTICLE 2

Yu. A. Izrael, Vice-Chairman of the IPCC

When arising the problem of a necessity to control negative consequences of the climate change (particularly those caused by anthropogenic impact), the basic question is whether a dangerous limit of the impact does exist (and what is it) which can result in destruction of now existing climate system or in rather serious consequences for both the human-beings and the biosphere.

The UN Framework Convention on the Climate Change (Article 2) declares:
"The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system".

The issue of safe limits for greenhouse gas content in the atmosphere is of high importance with respect to practical implementation of the Convention. However, there is essentially a lack of knowledge on what is a "dangerous anthropogenic interference with the climate system".

The problem of dangerous impact on the climate system was considered as a political one for a long time by international organizations dealing with the climate problems (the IPCC, for instance). For several years the author of this paper insisted that essential part of the problem is the Convention itself, i.e. understanding of approaches to definition of the danger and, finally, admissible limit of impact on the climate system. This is an evident problem for scientists.

But, only in 2001 the following statement has been included into the final version of Third Assessment Report of the IPCC: "Natural, technical, and social sciences can provide a comprehensive information and evidence needed for definition on what constitutes "dangerous anthropogenic interference with the climate system".

At the final stage of preparing the TAR (particularly in addressing Questions 1, 6 and 9 of the Synthesis Report) it was admitted by the Panel that this question requires comprehensive and integrated investigations since the issue has substantial scientific component in addition to political one.

As a part of the way toward addressing this issue, the author of this report chaired a group that prepared a scoping paper entitled: “Levels Of Greenhouse Gases in the Atmosphere Preventing Dangerous Anthropogenic Interference with the Climate System”. This scoping paper was submitted to the 19th Session of the Panel.

This issue was finally reconsidered at the 27th Session of the IPCC Bureau (Geneva, August 2002). During the Session Chairman of the IPCC Dr. R. Pachauri said that the problem must be properly addressed in the preparation of the IPCC Fourth Assessment Report (AR4). Dr. Pachauri has also noted that the issue of the levels of greenhouse gases in the atmosphere preventing dangerous anthropogenic interference with climate system should be considered as a "cross-cutting" issue for all three Working Groups of the IPCC, and requires effective coordination. It was suggested that the author is to coordinate this work within the IPCC.

Speaking about "dangerous" we assume critically dangerous, because we are most worrying about such conditions. This is obvious that dangerous for the climate system are those changes that do not allow climate system to come back to its initial state.

As early as in 1979, the author has formulated in [5] the concept of critical limits of a state of the biosphere (and, respectively, critical impacts on it). This concept is completely appropriate (with proper additions and enhancing of the interpretation) for a similar concept regarding limiting dangerous anthropogenic impacts on the climate system.

Recently, many books and papers are published (for example, [1-4]) in which problems of the risk as well problems of its control are discussed.

The author believes that a hazard is a field of certain threats or impacts, which exists regardless the availability of object or element (i.e. recipient) exposed to the impact (compare with gravitational, electromagnetic, or radiation fields). And, a risk is a probabilistic indicator of a possibility for any object to be exposed to particular danger. Exactly such danger is mentioned in the Framework Convention on climate change.

Thus, we have fields of critical danger for the set of elements of existing systems and for people as well as respective fields of danger varying in time. All of them are characterized by a certain criteria which identification is necessary for the estimations of real critical danger.

The scientific basis of a concept of admissible and limiting (dangerous) impacts on the biosphere (developed by the author in 1979 and later) together with possible ways to apply it to the climate system [5] are shortly presented below.

Admissible load on an individual organism of any population (or on an element of the climate system) is a value, at which the deviation from average (normal) state of a given organism or population (or an element of the system) does not exceed on average the natural fluctuations (without a breakdown of the system as a whole). To determine admissible (critical) loads on elements of the system for a future time, one need a detailed prediction of influence of different impacts on a wide set of elements of the biosphere or the climate system which do not lead to a partial or entire destruction of the system considered (with consideration for the above proposed approaches).

In a case of identification of the critical level of the impact on the climate system (despite the wider scope of the planetary system elements) the problem seems to be more simple.

Initial impact can be reduced to the an influence of temperature change when we deal with the climate warming or cooling at global or regional scales.

Further still, considering as such basic element of the impact at the first stage we can limit ourselves only by the climate system itself because exactly its change can result in further change of climate which we should to investigate.

Nevertheless, the problem is still immense, and a selection of criteria of critical impacts on individual elements of the systems, a totality of elements or on subsystems and the system as the whole is still uncertain. Although, this way is a real one and we should use this if we wish to get to a desirable result.

When considering the issue, we understand that the critical state of the climate system can be determined from the most weak component or this can be done on the basis of some new criterion.

The critical state of the climate system (or its change) could be considered in different sense with account for one of the following:

- first observed response of the climate system to the impact;
- destruction of an element of the climate system;
- destruction of links between elements;
- destruction of the system as a whole.

Critical state and dangerous levels of impact are determined with consideration for vulnerability of elements or systems and a degree of their tolerance. For those who investigate critical impacts it should be noted that majority of the elements or subsystems have two levels of critical states, which are upper and lower. Thus, the climate system as a whole has the lower critical level, and this is so called "White Earth" (it corresponds to approximately 200 ppm of CO_2). It has also the upper level, which coincides with the "super-heating" of the system. If the lower level is known from the geological past of the planet, the upper level of the system state is still unknown. With regard to the impacts, and particularly to CO_2 concentration, it should be noted that during the Carboniferous CO_2 concentration was ten times greater than the current level, and, hence, it was admissible for the biosphere that time. But, it is unknown whether this concentration is admissible or not for normal life of the mankind nowadays. This can be determined only when the impact on the climate system is properly investigated and critical limits are found..

Conclusions:

1. Determination and quantification of dangerous anthropogenic impact on biological-climatic system are the most important tasks for future scientific activity and making decisions on necessity and measures on prevention of negative consequences of the climate change.
2. When estimating a danger of anthropogenic impact it is necessary to conduct thorough scientific studies in the area of natural, technical and social sciences.
3. Solving the problem of dangerous impact presented in the report is necessary for scientific justification of decisions following from the UN Convention on the Climate Change.

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1.5 Outline of the meeting and its purpose

A presentation on this topic was prepared for the meeting by Martin Parry

2 Background to the issue

2.1 Article 2 and key vulnerabilities: terms, concepts and issues

The following abstract was prepared by Stephen Schneider for the meeting and distributed to participants in advance.

UNFCCC Article 2 including key vulnerabilities
Stephen H. Schneider, Stanford University, USA

The potential range of climate change impacts, or "reasons for concern", has been represented graphically by the IPCC Working Group 2 TAR: shown here as Figure 1. This figure, also known as the "burning embers diagram", shows that the most potentially dangerous climate change impacts (the red colors on the figure) typically occur after only a few degrees Celsius of warming. What it does not fully depict (except in the third "reason for concern"), however, is how those impacts will be distributed across specific countries and societies. Mastrandrea and Schneider (2004), who drew the black line on the figure to represent percentile estimates of "dangerous" levels of warming that accumulate as more aspects or red-colored impacts occur on the figure, note that some who focus on equity and justice will consider the third reason for concern, distribution of impacts, to be most important and want to weigh it most heavily, whereas those focusing on market-tradable commodities will put the largest weight on the fourth reason, aggregate impacts, whereas conservationists worried about species extinctions and ecosystems disruptions might weigh the first "burning ember", risks to unique and threatened systems (e.g., including mountain top ecosystems or low-lying coastal areas) , most heavily. These value judgments will permeate analyses for some time to come.

The scientific role is to estimate the impacts in each category, their distribution across sectors and regions and income groups, their relative likelihood, and the confidence that can be assessed in each category as well as a "traceable account" in any aggregation metrics. This will be a prime purpose of Chapter 19: to examine the literature of a broad range of climatic changes that could imply impacts, to assess the potential for significant impacts from such climate changes in light of various scenarios of human development that would affect adaptive capacity, to consider which groups are most affected by such potential consequences and their possible probabilities, and to, following Article 2, assess the literature on stabilization scenarios and their differential implications for impacts assessments such as those described above in this sentence.

There are alternative sets of metrics in the literature for impact assessment — the "five numeraires", (Chapter 2, IPCC Working Group 2 TAR). Of course, they have not been as well analyzed as the IPCC "reasons for concern", which were formulated by dozens of authors and hundreds of reviewers, which is why Matrandrea and Schneider used the "burning embers" diagram for their preliminary probabilistic assessment of what might be considered "dangerous" climate warming levels. Schneider, Kuntz-Duriseti, and Azar (2000) labelled "the five numeraires": market system costs in dollars per ton Carbon (C); human lives lost in persons per ton C; species lost per ton C; distributional effects in changes in income differentials between rich and poor per ton C; and quality of life changes, such as heritage sites lost per ton C or refugees created per ton C. It is the belief of those authors that all of these factors must be considered to arrive at a fair and accurate assessment of climate change damages. However, it is difficult to assign a monetary value to non-market categories of damages. Can we, for example, place a dollar value on a human life and the quality of that life? How do we value ecosystem goods and services (see Daily, 1997)? That is the normative component that must be settled by political negotiations among decision makers. (For yet another approach to impact assessment, see Parry et al.'s (2001) "millions at risk" work, which measures the additional millions of people who could be placed at risk as a result of different amounts of global warming. The risks Parry et al. focus on are hunger, malaria, flooding and water shortage.) All of this literature and more will inform the Chapter 19 analyses, and this Chapter will also tap into relevant assessments from Working Groups 1 and 3 as well, the former for examples of climatic changes with particular potential impacts and the latter for information on stabilization scenarios and their implications for impacts assessment.

Who Will Be Affected?

Developed "versus" developing worlds

Although the world's developed nations are responsible for most of the greenhouse gases emitted into the atmosphere thus far, it is thought that the poorer, warmer nations of the world will experience more and severer climate change impacts than their rich counterparts, most of which sit at higher latitudes. Some of the industrialized nations may even incur *benefits* from climate change (i.e., more land conducive to farming and longer growing seasons), whereas the developing nations will most likely experience predominantly detrimental effects (IPCC WG 2 TAR). Situations like these, in which the countries inflicting the bulk of the damage (through greenhouse gas emissions) are not harmed to the same extent as those countries who contribute minimally to the problem are clearly rife with the perception, if not the reality, of injustice and have the potential to increase the tension between the political "north" and "south"—itself a potential impact.

In addition to the inequity in impacts issue, there is an imbalance between rich and poor nations' ability to cope with these impacts. The socioeconomic conditions driving emissions also help to form the adaptive and mitigative capacities of various countries (Yohe, 2003), meaning that the countries that have contributed the most to global emissions are often richer and thus have more resources and are likely to be better able to cope with the effects of climate change. Conversely, less developed countries and disadvantaged groups within countries will tend to have lower adaptive capacities, as they are oftentimes limited by financial, technological, and governmental constraints (IPCC, WG 2 TAR, p. 84). Many have been impoverished by coups, wars, and other destabilizing events and have very few resources to devote to any preventive or adaptive measures concerning climate change. The uneven distribution of consequences that climate change promises to bring leaves the hotter, poorer nations – the same countries that have less adaptive capacity – more vulnerable and more in need of successful adaptation. As evidenced by the high tolls (in lives, fraction of GDP, quality of life, etc.) paid by developing countries when other disasters such as widespread flooding occur, these countries are not well-equipped to deal with *any* catastrophe, much less a sudden, unforeseen one. It will be difficult enough for them to cope with gradually-occurring, moderate climate change; "surprises" could be devastating in both an absolute and relative (to developing nations) sense.

Within poor nations, the most marginalized groups, especially those that rely on subsistence activities, will tend to be most vulnerable. This will be especially true if/when thresholds are exceeded and surprise events are triggered.

Intergenerational equity

If mitigation measures are postponed and income gaps between populations increase, climate change is likely to increase world- and country-scale inequity, both within the present generation and between present and future generations, particularly in the developing countries (IPCC, WG 2 TAR, p. 85). This is a situation Article 2 dictates to be addressed. Moreover, abrupt or irreversible events could be triggered in the long-term from policies and behaviours practiced in the near term (the 5th "ember" in Figure 1 below). The extent to which short-term activities that carry the potential to damage future generations of humans or other species are ethical, is a basic value question concerning intergenerational equity and the debate of appropriate discounting. Again, as there is a significant normative component to selecting any discounting process. Chapter 19 cannot "answer" the discounting question from a strictly scientific point of view, but certainly can survey the literature on the consequences of various discounting proposals on the scale and distribution of potential impacts.

Inter-species equity

Thus far, the discussion of climate change effects has been anthropocentrically-focused. However, species other than humans are affected by global warming. In to some groups, this is more concerning, as natural systems have limited adaptive capacity and are expected to be less resilient than human systems – particularly for rapid changes for which all but micro-species with short generational times generally have no evolutionary mechanisms to adapt quickly. In addition, natural systems will likely be the most "undeserving victims" of future climate change, as they obviously have no influence on the policymaking process, except to the extent that humans value their services and survival.

Scientists have already detected that the approximate 0.7ºC of warming that has occurred on Earth since the mid-1800s is having a discernible impact on various ecosystems (IPCC WG 2, TAR). Root and Schneider (2001) reported that the ranges of the species they studied were moving poleward, up mountain slopes, or both. They also found a strong pattern of consistent shifting towards earlier spring activities occurring in many of the species investigated. Their early findings were supported by further work by that team (Root et al., 2003) and by Parmesan and Yohe (2003), who, after analyzing more than 1,700 species, detected habitat shifts towards the poles (or vertically upward) averaging about 6.1 km per decade, as well as the advancement of typical spring activities by 2.3 days per decade.

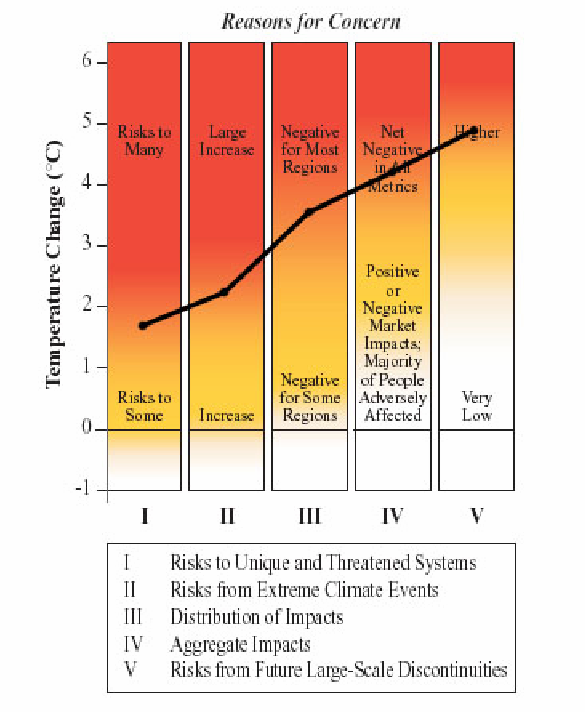
Furthermore, it is ecological systems that are likely to be more affected than human ones if/when thresholds are exceeded. Scientists have identified various “geo-boundaries,” locations such as coastlines and mountaintops that are more prone than other areas to irreversible losses. If these areas become unsuitable for their present occupants or disappear altogether, many of the plant and animal species that dwell there will be unable to find suitable alternative habitats, making extinction much more probable (e.g., Thomas, et al., 2003).

The severity of the effects of climate change will vary among species, implying a dismantling of some existing plant and animal communities as individual species’ responses to climate unfold, which could create disruptions in what Daily (1997) terms ecosystem goods (seafood, fodder, fuel wood, timber, pharmaceutical products) and services (purification of air and water, detoxification and decomposition of wastes, climate moderation, and soil fertility regeneration). Additionally, the more rapidly climate changes, the more likely there will be “no-analog” communities (e.g., see Overpeck, Webb and Webb, 1992; Root and Schneider, 2001), a scenario that will likely lead to increases in endangerment and extinction.

Chapter 19 tasks

There is a rich and growing literature on the components of what constitutes “dangerous” climate changes, and Chapter 19 must tap into this literature and coordinate it across all three Working Groups. Great care will be needed *to separate out the normative from positive components of the assessment*, as well as to present results to the extent possible as probabilistic at a given level of confidence, not as fixed point value “answers”, so as not to convey a false precision concerning this difficult and controversial topic.

Figure 1 (IPCC WG 2, TAR, as modified by Mastrandrea and Schneider, 2004):



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2.2 Natural science aspects including levels and thresholds

The following abstract was prepared by Serguei Semenov for the meeting and distributed to participants in advance.

Natural science aspects including levels and thresholds: Article 2 and key vulnerabilities
Serguei Semenov

Global CO_2 concentration ranged from 180 to 300 ppmv over past 400,000 years (Barnola et al., 2003), see Fig. 1. It varied roughly within 270-290 ppm interval over last 1000 years, thus was practically stable (Climate Change 2001,2001a, p. 185). Since the middle of 19th century (Ibid, p. 201) CO_2 concentration has begun to increase rapidly and exceeded 370 ppmv at present, see Fig. 2.

Fig. 2. Increase in CO_2 concentration since 1850s (below).

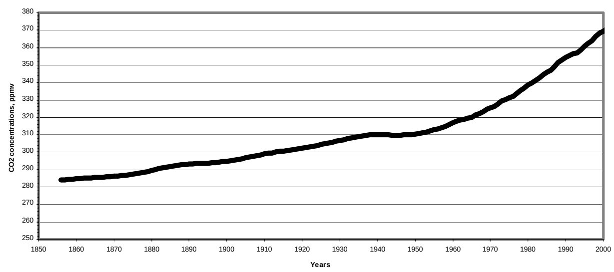
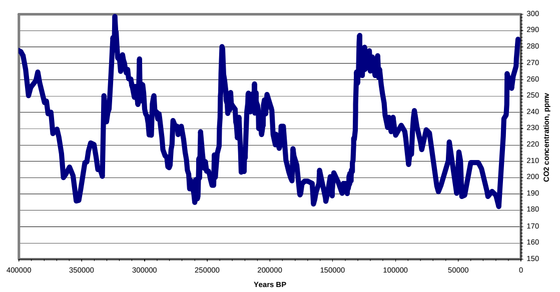


Fig.1. Historical records of CO_2 concentration, Vostok station, Antarctic (below)



Unprecedented (for last 400,000 years) rise of CO_2 level in the atmosphere since 1850s and discernable increase in global surface temperature (0.6 ± 0.2 °C) in 20th century, usually associated with anthropogenic enhancement of the greenhouse effect, were the major reasons for development and adoption of the United Nations Framework Convention on Climate Change (UNFCCC) in 1992. As it is stated in its Article 2: ***“The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic***

interference with the climate system". Thus, until the ultimate objective of the UNFCCC is amended, the main aim is STABILIZATION, i.e. keeping CO_2 concentration below certain threshold value - certain constant level. However, up to now no decisions on PARTICULAR LEVEL were taken, and the nature of the threshold remained unclear.

Stabilization is not free for the world community. IPCC has developed several stabilization scenarios using, in particular 1000, 750, 650, 550 and 450 ppmv of CO_2 as a stabilization level; this would cost up to 18 trillions US$ (Climate Change 2001, 2001c, p. 544-545). Of course peoples have the right to be aware of potential efficiency of such non-negligible "investment". What will be potential benefits measured as a damage prevented at various scales? A reasonable stabilization level could be then determined as ensuring equilibrium between overall cost and benefit, namely, (*BENEFIT - COST*) should be maximal. Of course, a discounting coefficients should be applied as needed.

However, the latter is just a theoretical statement that perhaps cannot have any practical immediate implications. Yes, with respect to emission reductions the costing methodologies have been developed to a certain extent and successfully applied by the IPCC in evaluation of stabilization scenarios. But with respect to benefit, i.e. damage prevented, accounting methodologies have not yet been properly developed. One of the first steps in their development is to build up our capacity to assess actual and potential climate-driven changes in nature, and health and life supporting systems of humans, and to identify key vulnerabilities, partial thresholds and risks. This appears feasible in the IPCC Forth Assessment, at least with respect to natural science aspects. Respective scientific literature exists.

First publications on this topic appeared about 20 years ago (Izrael, 1983). The IPCC Third Assessment Report (TAR) gives certain guidance on priority areas of such assessments. Namely, five "reasons for concern" have been identified in the TAR: risk to unique and threatened systems, risk from extreme climate events, distribution of impacts, aggregate impacts, and risk from future large-scale discontinuities (Climate Change 2001, 2001b, p. 958). A Concept paper (CP) on key vulnerabilities and Article 2 issues, which is a part of the IPCC Forth Assessment scoping process (Patwardhan, Schneider, Semenov, 2003, p. 4 - 5), suggested to employ the WEHAB (Water, Energy, Health, Agriculture and Biodiversity) framework for searching and assessing the most vulnerable elements to climate change among perhaps the most essential for human well being. The CP stated that: "The climate system (*that is climate itself plus all biogeochemical and physical processes responsible for the Earth's climate)* may play different roles with regard to the WEHAB – in some cases determining the availability, quality and variability of respective resources (water, food, hydro-energy, etc.), and in other cases influencing our ability to use these resources. Examples of climate system elements might include the oceans, terrestrial permafrost, forests, fluxes of heat and moisture, global cycle of water, thermohaline circulation, ENSO, Asian summer monsoon, etc. Having identified the climate system elements and the linkages with WEHAB components, it might be possible to determine key elements of the climate system changes of which (?) may significantly affect the WEHAB components."

Although a linear approach to characterizing climate sensitivity is often employed, relationships describing response of particular WEHAB elements to climate change have essential non-linearities. For instance, availability of water resources is a non-linear function of temperature and precipitation regimen. Depth and dynamics of permafrost active layer, phenological dates of plants, suitability of given climate for development of certain pathogens (e.g., malaria) in vector organism are controlled by annual course of daily mean temperature, and the relationships are strongly non-linear. Scientific literature abounds of such relationships with respect to water availability, human and animal diseases, boundaries of cropping systems, tree ranges and rate of growth. In addition to the non-linearity, these relationships often are of threshold character, i.e. they imply some limits beyond which respective objects cannot sustain. This could be used in setting partial thresholds for climate change (Izrael, Semenov, 2003).

Some positive feedbacks within the climate system as well as between climate system and WEHAB elements are presented in literature. For instance, an increase in GHG concentration in the atmosphere causes warming that leads to decline in albedo which, in turn, amplifies the greenhouse effect and thus further warming. Another example: an increase in GHG concentration in the atmosphere causes warming that leads to additional release CO_2 from ocean to the atmosphere, thus, amplification of CO_2 enrichment of the atmosphere and further enhancement of the greenhouse effect. Irreversibilities are poorly investigated.

It should be mentioned that our knowledge on relationships controlling interactions within the climate system and between the climate system and the WEHAB elements is incomplete. This inevitably leads to uncertainties in cause-response models and thresholds. Thus, ultimately the damage functions will be more of stochastic nature, rather of deterministic one (Mastrandrea, Schneider 2003). However, the AR4 process should reflect a natural logical way of thinking: mean values go first, then variances (i.e. uncertainties) are to be analyzed. Otherwise we concentrate our attention on what we do not know rather than on what we know.

In addition to papers published in scientific periodicals it would be important to use reports of relevant international organizations and programs, e.g. World Meteorological Organization (WMO), World Health Organization (WHO), Food and Agriculture Organization (FAO), Global Climate Observing System (GCOS), Global Ocean Observing System (GOOS), International Geosphere-Biosphere Programme (IGBP), United Nations Environment Programme (UNEP). Specialized reports of some regional organizations and national academies of sciences also could be important.

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Patwardhan A., Schneider S. H., Semenov S. M. 2003. Assessing the science to address UNFCCC Article 2 (IPCC Concept Paper, available at www.ipcc.ch/activity/cct3.pdf), 13 pp.

2.3 Socio-economic aspects including criteria and trade offs

A presentation on this topic was given at the meeting by Anand Patwardhan.

2.4 Risk, decision-making and legal aspects of Article 2

The following is a summary of the presentation given at the meeting by Farhana Yamin.

1 IPCC should draw upon national communications (NC) and NAPAs (National Adaptation Programmes of Action (prepared by UNFCCC Parties as a source of approaches to defining key vulnerabilities and insight into 'adaptation capacity'. IPCC could request UNFCCC secretarial synthesis information from NC/NAPA relevant to Article 2.

2 Socio-economic impacts should be disaggregated by region, country, sectoral household and gender as different groups are impacted differently and their vulnerability is differentiated too and this makes for sharper equity analysis.

3 Much expert knowledge on key vulnerabilities/adaptation capacity resides within local communities who are best placed to know their vulnerabilities and their range of feasible adaptation. But this knowledge is unlikely to feature within IPCC as its not formally written down and/or peer reviewed. IPCC must have a more inclusive approach to sources of expertise and e.g. get results of specific case studies on a way of learning from community level expertise. Recent literature suggests the IPCC should distinguish between them.

Societal ignorance	and	institutional ignorance
↓		↓
refers to lack of knowledge in in whole society		knowledge exists but not within a particular institution

4 The IPCC can learn from other MEAs and non-environmental regimes (ozone, LRTAP, asbestosis, growth hormones (about how these regimes organized complex scientific/technical issues and how science/policy linkages were handled). This will illuminate how IPCC can better organize its own work, organizational structure and working methods for AR4 and beyond.

5 The IPCC reports serve a broad range of policy-makers and act to (e.g. COP, national research bodies, global media, research communities, NAOs and civil society and law/legal groups and courts/tribunals). Their other non-formal actions can take actions and make decisions that will inform Article2 discussions. IPCC should be bold in the way it deals with Article 2 to serve the needs of all these communities. Instead of focusing on the dangers to the IPCC's reputation of crossing the policy-prescriptive threshold, the IPCC should also consider the damage to the reputation of not providing a conceptual framework and information the scientific community considers relevant for formal policy processes to determine Article 2 implication for comments for Partners.

2.5 Top-down approaches

The following abstract was prepared for the meeting by Ferenc Toth and distributed to participants in advance.

Top-down Approaches to Article 2: Methods and Models
Ferenc L. Toth (IAEA/Austria, BUES/Hungary)

Article 2 of the UNFCCC frames the requirement for long-term climate policy in terms of an environmental objective 'to prevent dangerous anthropogenic interference with the climate system'. This calls for "inverse approaches" that provide information about possible emission strategies with respect to environmental targets. Early attempts by the Intergovernmental Panel on Climate Change (IPCC) Working Group I (IPCC, 1996) and Wigley et al. (1996) depict emission paths with respect to given concentration targets. Subsequent work takes climate change attributes (magnitude and rate of change in global mean temperature) or geophysical consequences (magnitude and rate of sea-level rise) as environmental targets (Alcamo and Kreileman, 1996; Swart et al., 1998; Toth et al., 1997, 1999) to guide long-term climate policies. While these analyses provide useful insights into the issue of concentration/climate stabilization, they are only remotely related to the ultimate concerns about climate change: its possible adverse effects on ecosystems, food production, and sustainable development. The ICLIPS Integrated Assessment Model (IAM) (Toth, 2003) combines impact analysis and cost estimates and requires two types of normative inputs: social actors' willingness to accept a certain amount of climate change impacts and their willingness to pay for climate change mitigation for determining whether there exists a corresponding corridor of permitted emission paths. There are efforts to establish impact-driven concentration pathways by using arbitrary intermediate signposts (O'Neill and Oppenheimer, 2004). Other approaches adopt advanced modelling techniques to identify robust policies that perform well under a wide range of plausible futures (Lempert and Schlesinger, 2000) or use a cost-benefit framework to estimate probabilities of crossing "dangerous climate change" thresholds under deep uncertainties (Mastandrea and Schneider, 2004). See Table 1 for an overview.

Methods diverge widely in how close they get to the "ultimate" climate change concerns in defining "dangerous anthropogenic interference": some stop at cumulative emissions, most are concerned with concentrations (CO2, CO2-equivalent, GHG basket), others define climate change limits (magnitude, and in some cases, rates of temperature change, typically global mean annual temperature), and only few start from (un)acceptable impacts based on inferred or explicitly modelled links between impacts and climate change (ecosystems, agricultural yields). Accordingly, most methods and the models behind them seek and analyze "dangerous interferences" at the global level and only a few provide clues about what might be dangerous regional impacts and establish links back to global climate change. The level of model sophistication varies from patches of carbon cycle and simple climate models to highly aggregated integrated assessment models to comprehensive integrated assessment frameworks incorporating emissions, technologies, mitigation, climate change, and impacts. Some integrated assessment frameworks incorporate approximations of vulnerability but none contains a proper representation of adaptation processes in the global context. Finally, the disclosure of where scientific analysis ends and where normative social choices begin remains limited in many publications reporting results about avoiding "dangerous anthropogenic interference with the climate system."

Table 1. Methods to identify climate policies to avoid "dangerous" climate change

Method	Summary	Reference
Smooth stabilization paths	Create emission paths to stabilize CO2 concentrations at different levels	IPCC 1996, WGI
Safe landing analysis	Derive ranges of emissions to keep climate change within predefined ranges (temperature change and sea-level rise and their rates)	Alcamo and Kreileman (1996): RIVM Report Swart et al. (1998): in Alcamo et al. van Vuuren and de Vries (2000): RIVM Rep. van Vuuren et al. (2003) RIVM report
Cost-effectiveness	Identify emission pathways minimizing the total costs of achieving alternative concentration stabilization targets	Wigley et al. (1996): Nature 379:240. Models and results reviewed in IPCC 2001, WGIII Chapter 10
Exploratory modelling	Find robust strategies (including mitigation pathways) under conditions of deep uncertainty	Lempert et al. (2000): Climatic Change 45:129 Lempert and Schlesinger (2000): Climatic Change 45:387
Tolerable Windows/Inverse/Guardrails approach	Derive emission corridors including all pathways that satisfy normative constraints on tolerable climate change impacts and mitigation costs	Toth et al. (1997): in Cameron et al. Toth et al. (2002): Environment 44:No 5 Toth (2003): Climatic Change 56:Nos 1-2
Concentration stabilization pathways	Obtain CO2-equivalent stabilization paths by using standardized specification rules for emissions and approaching the target	O'Neill and Oppenheimer (2002): Science 296:1971 O'Neill and Oppenheimer (2004): PNAS
Probabilistic Integrated Assessment	Establish probabilities of "dangerous anthropogenic interference" from probability distributions of future climate change in a global cost-benefit framework	Mastandrea and Schneider (2004): Science 304:571

The following is a summary of the presentation given at the meeting by Ferenc Toth.

1 Top-down approaches to Article 2 include arbitrary stabilization paths, the Safe Landing Analysis/Safe Emission Corridors, cost-effectiveness frameworks, Exploratory Modelling, Tolerable Windows/Inverse Approach, Probabilistic Integrated Assessment, and ‘guided’ stabilization pathways.

2 Methods diverge widely in how close they get to the ‘ultimate’ climate change concerns in defining ‘dangerous anthropogenic interference’: some stop at cumulative emissions, most are concerned with concentrations (CO2, CO2-equivalent, GHG basket), others define climate change limits (magnitude, and in some cases, rates of temperature change, typically global mean annual temperature), and only few start from (un)acceptable impacts based on inferred or explicitly modelled links between impacts and climate change (ecosystems, agricultural yields). Most methods and the models behind them seek and analyze ‘dangerous interferences’ at the global level and only a few provide clues about what might be dangerous regional impacts and establish links back to global climate change.

3 The level of model sophistication varies from patches of carbon cycle and simple climate models to highly aggregated integrated assessment models to comprehensive integrated assessment frameworks incorporating emissions, technologies, mitigation, climate change, and impacts. Some integrated assessment frameworks incorporate approximations of vulnerability but none contains a proper representation of adaptation processes in the global context.

4 The disclosure of where scientific analysis ends and where normative social choices begin remains limited in many publications reporting results about avoiding “dangerous anthropogenic interference with the climate system.”

2.6 Article 2’s context in UNFCCC, and the need for scientific information

The following slides were presented at the meeting by Dennis Tirpak.

2.7 Bottom-up approaches

The following abstract was prepared for the meeting by Jan Corfee-Morlot and distributed to participants in advance.

Article 2 and key vulnerabilities: towards a sectoral view of the benefits of mitigation (or the costs of inaction)
Jan Corfee Morlot and Shardul Agrawala

Any analysis of the key vulnerabilities to climate change must also consider how and what types of policies might reduce such vulnerabilities over time. Mitigation is the key pillar of international climate policy negotiations and of national climate policies and, more recently, interest has grown in adaptation to projected climatic changes as a complementary policy response. Much of the policy and analytical discourse to date has been characterized by asymmetric attention to the *costs* of mitigation commitments on the one hand, and, more recently, to the potential *benefits* of adaptation on the other. By contrast, there is also only limited analysis of the costs of adaptation and of the benefits of mitigation. The latter has been dominated by attention to near-term secondary or ancillary benefits of greenhouse gas abatement measures in related domains such as air pollution and public health, leaving us with an incomplete picture about the full range of mitigation policy benefits.

What has received too little attention in climate policy debates is estimation of the *direct benefits* of greenhouse gas mitigation through avoided climatic change and the reduced likelihood of any ensuing net adverse impacts. Drawing on the OECD project entitled Benefits of Climate Change Policies, the presentation will cover 5 points: 1) climate change impacts as a function of time scales – today, mid-century, late century or beyond – and the implications for policy; 2) framing the analytical discourse to address Article 2, including key vulnerabilities – shifting emphasis away from costs to include benefits; 3) elements of a sectoral/regional assessment framework; 4) insights from the global impacts literature; 5) sectoral/regional risk and threshold assessment as a means to guide mitigation decisions.

The following is a summary of the presentation given at the meeting by Jan Corfee-Morlot.

1 Framing the discourse to address Article 2, KV issue. Compared to costs of mitigation, benefits of mitigation in the form of avoided impacts has received much less attention from the policy and research communities. Yet avoided impacts from mitigation is the central issue in the search for methods and tools to operationalise the language of Article 2 of the Convention.

2 Understanding regional-sectoral climate change impacts in different time frames/ today versus mid/to late centuries and beyond – is a means to identify key vulnerabilities, thresholds, and their relevance to different policy responses. Very near term impacts are relevant to adaptation only, whereas long term impacts may be avoided through a combination of mitigation and adaptation. Better organizing imparts information by time frames will assist policy assessment and decision-making.

3 A sectoral/regional assessment framework for mitigation benefits may help to improve the understanding of global impacts and advantage of mitigation decisions. Standardising metrics, for each sector is key to understanding the risks of climate change and how they fit with other risk factors over time. Sector-level thresholds at the regional-level can be used to organize risk assessments; but must be connected to global climate change problems (e.g. GMT4) to be useful to policy-makers with respect to global mitigation goal-setting. Can this be done with today's knowledge and tools?

4 The global impacts literature provides some insight into sector or system damages at different levels of climate change. Patterns of damages vary by sector with two general patterns (parabolic and increasing adverse) emerging for some systems, with whereas for a large number of other systems these damage relationships are either unclear or there are no studies from which to draw. While this literature provides some insights into key vulnerabilities, these damage relationships (as a function of GMT increase) need to be tested and improved through more careful regional/sectoral assessments.

5 Concluding thoughts: emphasise the need to narrow in and 'frame' information on climate change impacts so as to inform the global mitigation policy debate. Global trends are key but they must be built from the bottom up. Risk assessment frameworks need to be advanced, alongside the better valuation and economic assessments. In particular more attention to ecosystems is urgently needed to better quantify and characterize the risks of climate change in 'wider' socio-economic context. Overall there is a need for more accessible information and standard tools and methods to highlight impact risks of climate change and their trade offs with mitigation decisions.

2.8 Rapporteur's summary

Session 1: Background to the issue (Tuesday 18 May), Tim Carter

S. Schneider: Terms, concepts and issues
Introduced the questions to be addressed in tackling the scientific questions raised by Article 2. He referred to the conclusions of the TAR encapsulated in the 'burning embers' diagram and how the interpretation of these conclusions is case, region, sector-specific. Moreover, there are uncertainties in all estimates of change, impacts and responses, and these needs to be treated in a risk framework.

S. Semenov: Natural science aspects
Suggested that WEHAB offers a framework for addressing the scientific aspects of vulnerability to climate change. Systematic literature review could allow thresholds of climate that can be tolerated in each sector. Cannot base damage functions on mean climate alone. Must account for climate variability and non-linearities in relationships.

A. Patwardhan: Socio-economic aspects
Emphasised that vulnerability has to consider more than climate questions alone. Responses need to be analysed in terms of their basis (adaptation or mitigation); prioritization and action. There is a range of approaches to determining key vulnerabilities; frameworks come from different perspectives, and the process is one that the IPCC can contribute information to, but ultimately it is a socio-economic process. It is important to capture adaptation, differential regional impacts and the importance of scenarios. The roles of individual Working Groups: WG II Ch 19 – synthesis from impacts/vulnerability perspective; WG I – thresholds, irreversibilities, non-linearities; WG III – socio-economic scenarios and baselines; interaction between adaptation and mitigation.

Discussion points
- Question of policy-prescriptiveness. IPCC should offer information on consequences of certain decisions.
- Definitions of different types of threshold
- Could one put grids onto the embers diagram to indicate who is affected and where?
- Use of SRES scenarios in the AR4
- Issue of valuation in IA modelling.

F. Yamin: Risk, decision making and legal aspects
Focused on the legal issues underlying Article II. IPCC's role is different from governments' role in the UNFCCC Convention. Similar objectives are embedded in other environmental treaties (e.g. biodiversity, wetlands, desertification, acid range, ozone). Many have similar normative components. It is debatable if countries can relate to top-down approaches pursued in the literature. Local participation and knowledge are critical for defining key vulnerabilities. Regardless of UNFCCC, Principle 21 of the Stockholm Declaration states that all regions of the world should refrain from inflicting environmental damage on neighbouring states. Some legal cases relating to climate change liability may be filed which could open up the issue to scrutiny from lawyers, etc.

Discussion points

- Distinguishing between Conventions and Protocols. For example, the Framework Convention is an initial step. It is in fact a treaty. The Kyoto Protocol is only a surgical incision in the treaty.
- Separation of IPCC from the UNFCCC prevents procedural, political antics.
- There is a social dimension to differential vulnerability
- Trend of legal empowerment and increasing litigation.

F. Toth: Top-down methods
Summarised alternative top-down methods for identifying critical impacts (see abstract). Most methods deal with concentrations. Some deal with temperature or SLR. Few actually look at impacts. Most are global impacts. A few include regional impacts and climate change windows. Defining what is dangerous is a social decision. The task for science is to present the biophysical implications of incremental climate change, present socio-economic vulnerability-adaptation aspects, and present the mitigation requirements

Discussion points
- Could models be built on more realistic assumptions?
- Some top-down methods can be linked to bottom-up methods.
- Value of damages

D. Tirpak: Article 2's context in UNFCCC (the bold and the beautiful)
Provided a brief history of targets related to climate change and impacts. Noted that Article 2 is not on the agenda of the COP or SBSTA, though vulnerability and risk is now being addressed in SBSTA. All countries are assessing impacts and vulnerabilities and the Secretariat is attempting to improve access to Parties as they prepare their National Communications and National Adaptation Plans of Action (NAPAs).

Posed some questions:
- Should there be a long-term concentration targets?
- What scientific basis?
- What would be lost/protected at different levels?
- Economic damages and costs?
- What are the trade offs between mitigation and adaptation?

Concluded that IPCC should be bold. Can help to set the agenda.

J. Corfee-Morlot: Bottom-up approaches
Contended that the policy community has been over-focused on the cost of mitigation. IPCC WG II has focused on adaptation, but conclusions about aggregate impacts are built on a handful of studies. Most of the non-market impacts are left out. There is a lack of transparency in damage-cost literature and this is nowhere near comprehensive. Three sets of policy-relevant questions were identified:

- Article 2 – tools/categories for identifying thresholds
- Interactions between adaptation and mitigation
- Policy capacities

Suggested the following points meriting further attention:

- Organise impact information to inform mitigation policy assessment as well as adaptation
- Regional understanding of impacts
- Strengthen sector/regional assessment to improve understanding of global impacts
- Ground truth model-driven impact assessments against observed impacts
- Improve empirical and theoretical basis for understanding risks
- Quantify and account for non-market risks.

3 Key sensitivities and levels of impact in selected areas and regions

3.1 Food

The following abstract was prepared for the meeting by Prabhu Pingali and distributed to participants in advance.

Climate Change and Food Systems
Prabhu Pingali, FAO, UN, Rome, Italy

There is wide scientific evidence that global climate is changing in part as a result of human activities, and that the social and economic costs of slowing down global warming and of responding to its impacts will be large. However, there are large uncertainties as to when and where and how climate change will impact on agricultural production and food security.

The projected climate change will result in mixed and geographically varying impacts on crop production. The Food and Agricultural Organization of the United Nations (FAO), in collaboration with the International Institute of Applied Systems Analysis (IIASA) has developed the Agro-ecological Zones (AEZ) methodology, a worldwide spatial soil suitability database. The AEZ approach has been used to quantify the regional impact and geographical shifts in agricultural land and productivity potentials, and the implications for food security resulting from climate change and variability. The analysis indicates that on average, many Industrialized countries stand to substantially gain in production potential, while many developing countries are expected to lose.

In the developing world, climate change would lead to an increase in lands that are arid and lands with moisture stress. In Africa for instance, there are 1,080 million hectares of land with a length of growing period of less than 120 days. Climate change would by 2080 result in an expansion of such land by 5-8%, equivalent to 58 million hectares and 92 million hectares respectively (IIASA, 2002).

The FAO/IIASA study indicates that the developing world would experience an 11% decrease in cultivable rain fed land with consequent declines in cereal production. Sixty-five developing countries, representing more than half the developing world's total population in 1995, will lose about 280 million tons of potential cereal production as a result of climate change. This loss, valued at an average of US$ 200 per ton totals US$ 56 billion, equivalent to some 16% of the agricultural gross domestic product of these countries in 1995. Some 29 African countries face an aggregate loss of around 35 million tons in potential cereal production (FAO/IIASA, 2001). In the case of Asia, the impact of climate change is mixed: India loses 125 million tons, equivalent to 18% of its rain fed cereal production. China's rain fed cereal production potential of 360 million tons, on the other hand, increases by 15%. Among the cereals, wheat production potential in the sub-tropics is expected to be affected the most, with significant declines anticipated in Africa, South Asia, and Latin America (IIASA, 2002). Of course, the above-mentioned estimates refer to potential cereal production. Changes in actual cereal production are more difficult, if not impossible, to assess, but the changes in production potential indicate an increasing stress on resources induced by climate change in many developing countries already hard-pressed.

The industrialized nations will see a considerable potential for expansion of suitable land extents and increased production potential for cereals only when considering the use of "new land" at high latitudes. These potential increases are mainly located in North America, Northern Europe, the Russian Federation, and in East Asia (IIASA, 2002). The positive growth in cereal production potential in the Northern Hemisphere tends to buffer the impact of anticipated production shortfalls in the South, hence the impact of climate change on global cereal prices is expected to be moderate. But the distributional effects will be overall negative for the developing world.

Alterations in the patterns of extreme events, such as the increased frequency and intensity of droughts, will have much more serious consequences for chronic and transitory food insecurity than shifts in the patterns of average temperature and precipitation. These rainfall deficits can dramatically reduce crop yields and livestock numbers in rain fed production systems that are common in the semi-arid tropics. Localized increases in food prices could be frequently observed. Subsistence producers growing orphan crops, such as sorghum, millets, etc, could be at the greatest risk, both from a potential drop in productivity as well as from the danger of losing crop genetic diversity that has been preserved over generations. Humid areas are also vulnerable to climate variability. They can suffer from changes in the length of the growing season and from extreme events, such as tropical cyclones. Food insecurity and loss of livelihood is further exacerbated by the loss of cultivated land and nursery areas for fisheries by inundation and coastal erosion in low-lying areas of the tropics.

Climate change impacts on agriculture could increase the number of people at risk of hunger. The impact of climate change on food security will be higher in countries with low economic growth potential that currently have high malnourishment levels. In some 40 poor developing countries with a combined population of 2 billion, including 450 million undernourished people, production losses due to climate change may drastically increase the number of undernourished, severely hindering progress against poverty and food insecurity (IIASA and FAO, 2001). These low-income food-deficit countries often do not have the resources to finance food imports in order to fill the gap in requirements. Some of the severest impacts seem likely to be in the currently food insecure areas of sub-Saharan Africa with the least ability to adapt to climate change or to compensate for it through greater food imports (FAO, 2003).

Land-use changes and the development of improved bioenergy systems that have already been identified as important means of achieving sustainable rural development among small and poor land users also have a significant potential to contribute to climate change mitigation through sequestration and carbon substitution. Results from the empirical studies of carbon sequestration and bioenergy efficiency indicate that there is considerable heterogeneity in the opportunity costs and sequestration/substitution productivity over varying land uses and agro-ecological zones. Thus, there is considerable variation in the returns to carbon offsets for poor producers. Carbon emission offset payments, also known as "payments for environmental services", may serve either as a means of overcoming financial barriers for reducing the lag time between expenditures and returns in the adoption of perennial cropping systems, or for other measures to reduce vulnerability to climate change and ways of promoting adaptation of production systems and society to climate change impacts. In other cases, carbon offset payments offer a means of diversifying incomes, allowing producers who are operating traditional pastures to obtain a higher source of income by refraining from deforesting to expand pasture area, or moving into the production of bioenergy crops.

FAO in close cooperation with others will continue to monitor the relationships between climate change and food systems. As more data becomes available and policies and research lead to further action at the local level, mitigation and adaptation to climate change measures will hopefully reduce vulnerability of the rural poor and open new opportunities for development and food security.

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3.2 Water

The following abstract was prepared for the meeting by Luis Mata and distributed to participants in advance.

Luis Jose Mata
Center for Development Research (ZEF), University of Bonn, Germany

The presentation aims to offer information on what is the current knowledge of key vulnerabilities in the water sector, where is the knowledge in the literature and how can this be integrated into the fourth assessment report, what development in science is likely in a 2- to 5-year period, and where are the gaps.

The nature of the water issue and our current state of knowledge are directly related to two items (i) explanation of key *vulnerabilities*, i.e., what are the most significant impacts, and where they are likely be most serious, and (ii) stabilization of concentrations and the interpretation of *dangerous climate change*.

Without doubt, both items are related, but they are not the same. Perhaps the two questions could address the most central question in climate change management *how can we avoid a dangerous climate change?* Certainly, the water sector has to be included into any analysis of key vulnerabilities and into Article 2 despite the fact that it is not directly mentioned in the article. This is because water and water resources are extremely related to the level that would prevent dangerous anthropogenic interference with the climate system within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened, and to facilitate economic development in sustainable way. Changes in availability (quantity and quality aspects) and use of water resources associated with climate change could have significant impacts across many sectors of the economy, society and environment (IPCC, 2001a).

Unfortunately, there are conceptual inconveniences concerning the two items mentioned before, and they turn around on the understanding of what is the definition of significant impacts and vulnerabilities. An important issue, perhaps, would be to come to a consensus on the definition of vulnerability and to elucidate the roles of climate changes and system characteristics with respect to vulnerability. The importance of thresholds at specific scales should be defined in order to characterise water vulnerability in a reliable way.

However, it is convenient to mention that few studies have attempted to explicitly address the above-mentioned questions, since almost all impact assessments are localized and apply only to a small range of scenarios, that there have only been very few spatially distributed global scale impact assessments explicitly examining different emissions scenarios, and that integrated assessment models continue to be very top down, which means that there is no identification of vulnerable hotspots (Arnell, 2003). Furthermore, more accurate modeling of the land surface schemes and more reliable GCM and RCM outputs for local precipitation are necessary.

Due to the importance of water as an element that is indispensable to sustain biological life and, in large amounts, to virtually all human activities, adverse changes in availability and demand for water that may have a significant impact on the society are of considerable concern. Climate change is commonly understood as change in temperature and precipitation (among other processes), both of which play essential roles in the hydrological cycle, with consequences for the water resources. Conditions and trends will be mentioned in the presentation related to water quality, water and food production, water availability, water demand, freshwater and biodiversity, and human modification of freshwater systems.

The interplay between climate and water has been extensively tackled in the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2001, 2001a). In particular, volume two of the TAR (IPCC, 2001a), devoted to impacts, adaptation and vulnerability, contains ample material on water not only in its fourth chapter on hydrology and water resources (Arnell *et al.*, 2001), but also in several other sectoral and regional chapters of the volume. Water is indeed an essential issue, cutting across the science of climate change, impacts, adaptation, and vulnerability, and economic and social perspectives. The material related to climate and water resources should be treated consistently and coherently through all IPCC groups.

After TAR, many articles have been published in the scientific literature, e.g., a special issue in Nature magazine was devoted to climate and water and includes papers directly related to climate change, a well-documented report “Climate changes the water rules: How water managers can cope with today’s climate variability and tomorrow’s climate change”, and articles on extreme events (Palmer et al., 2002, Schnur, 2002, Kundzewicz and Schellnhuber, 2004).

Very recently, a special issue of Global Environmental Change was released with one chapter directly related to climate change and global water resources: SRES emissions and socio-economic scenarios by Arnell (2004).

Several chapters related to freshwater will be published soon in Millennium Ecosystem Assessment.

Water-related vulnerability issues and key regional concerns, associated with climate change, have been identified in all regions of the world. Hazards related to extreme hydrological events are likely to increase in the future. Plausible climate change scenarios indicate the possibility of increases in both amplitude and frequency of flooding events, while intensification in drying in continental interiors in the vegetation season is a robust result from models. Yet, the degree of uncertainty, particularly in water-related projections, is still high. There has been no conclusive and general proof as to how climate change affects flood behaviour in the light of data observed so far. Results of some studies indicate that high floods are becoming more frequent while others studies indicate the opposite.

The dynamic of science will necessarily improve current knowledge and will fill many of the gaps that exist at present on the water and climate issue: level of impacts, global and regional forces, thresholds in hydrology and in water resources, vulnerable hotspots and stabilization of concentration. These aspects will then be better defined and understood in such a way that conflicting interpretation of vulnerabilities and what is a *dangerous climate change* can be avoided.

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The following is a summary of the presentation given at the meeting by Luis Mata.

1 Risk from extreme climate events (e.g., floods and droughts) is considered a reason of concern that may help policy makers to identify what is 'dangerous' climate change. A small increase of approximately 2°C of global mean temperature would cause important impacts. However, this temperature should only be taken as an approximate indicator of impacts, not as an absolute critical threshold.

2 Climate Change will contribute to increase the already existing water crisis. Thus, it is important to explore the character of critical thresholds in the natural (physical hydrological system) and in the managed water environment (water resources system) in order to identify thresholds of change in terms of magnitude or rates of change.

3 The frequency and magnitude of (hydrological) extreme events increase even with a small increase in temperature and will become greater at higher temperature. The impacts of those events often are large locally and could strongly affect specific sectors and regions. Increase in extreme events can cause critical design values or natural thresholds to be exceeded, beyond which the magnitude of the impacts increases rapidly. It is convenient to explore the different likelihood of crossing dangerous warming thresholds for storylines scenarios such as B1 and B2 which represent different view of the world and for the water sector.

4 Since 2001 many peer review publications related to the theme 'climate and water' have appeared. They should all be included for assessment for the next IPCC process. The following gaps among others have been identified regarding the water sector: (1) insufficient knowledge of impacts in different parts of the world (especially in developing countries), (2) almost complete lack of information on impacts under different development pathways and under different amount of mitigation, (3) no clear relationship between climate change and impacts on water resources, (4) little analysis of the capacity and cost of adaptation and (5) how do changes in variability affects the water environment?

3.3 Ecosystems

The following abstract was prepared for the meeting by Sandra Díaz and distributed to participants in advance.

Incorporating biodiversity in IPPC Assessments – Global biodiversity change can affect the vulnerability of ecosystem processes and services

Sandra Díaz, Marcelo Zak and Marcelo Cabido

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How to incorporate biodiversity in the assessment of vulnerabilities in the face of climate change? Biodiversity in the broad sense refers to the number, abundance and composition of the genotypes, populations, species, functional types and landscape units in a given system. Biodiversity can be seen as a response variable that is affected by changes in climate, resource availability, and disturbance), but can also be interpreted as a factor with the potential to influence the rate, magnitude and direction of ecosystem processes. Because of this, biodiversity can be seen both as vulnerable in the face of global environmental change, and as an active factor affecting the vulnerability of ecosystem processes and services. The two largest knowledge gaps with respect to biodiversity in previous IPCC Assessment Reports arguably are: (1) the consideration of the combined, non-linear effects of different global change drivers; and (2) the consideration of biodiversity as an intervening factor altering the vulnerability of ecosystems.

According to several large-scale scientific assessments, the projected effects of climate, land use, and biological invasions on biodiversity are both profound and widespread. It has been suggested that the most important of these drivers in the 21st century will land use change. However, recent reports suggest that climate change may be playing a more important role than initially suspected, and there is consensus on the fact that the synergistic combination of land use and climatic factors produce the most dramatic projected changes in biodiversity and ecosystem processes.

The importance given to biodiversity in IPCC Assessment Reports has increased over time. The issue was hardly taken into account in the first reports, but TAR has thoroughly covered the effects of climate and land use on biodiversity. However, a growing body of evidence suggests that biodiversity, significantly influences the provision of ecosystem services and therefore human well-being. The most updated global assessment that has considered the indirect effects of climate change on ecosystem processes mediated by altered biodiversity is the Millennium Ecosystem Assessment (MEA). According to MEA, biodiversity regulates, and thus can potentially influence the vulnerability of, many ecosystem services, such as pollination, seed dispersal, climate regulation, carbon sequestration, agricultural pest and disease control, and human health regulation. Also, by affecting processes such as primary production, nutrient and water cycling, and soil formation and retention, biodiversity indirectly supports the production of food, fibre, potable water, shelter and medicines. The following are the main conclusions of MEA on how biodiversity can affect ecosystem services:

- *The preservation of a rich regional pool of species enhances the provision of biodiversity-derived ecosystem services.*

- *Changes in species composition can alter the dominant functional traits, with important effects on ecosystem processes, even if the number of species present remains unchanged or even increases.*

- *The reduction of the number of species, especially if the species lost are locally rare, often has only subtle effects in ecosystem services in the short term, but may compromise their capacity for long-term adjustment in the face of a changing environment.*

- *The integrity of the interactions between species is critical for the long-term preservation of human food production on land and in the sea. These include pollination, seed dispersal, regulation of natural populations through predators, parasites and pathogens, and symbiosis.*

- *The capacity of terrestrial ecosystems to sequester carbon and regulate climate at the local, regional and global scales can change according to the characteristics of the plant species present, and their relative abundances. These effects are directly relevant to the future trade of carbon credits and Clean Development Mechanisms.*

- Habitat fragmentation not only reduces biodiversity per se, but also triggers non-linear feedback effects, such as accelerated carbon release mediated by plant compositional changes at the edges of fragments.

- *In terms of the agricultural production of food and fibre, the preservation of a large number of species, crop varieties, and their wild relatives, and a high degree of spatial heterogeneity are considered crucial for the long-term viability of many agricultural systems, including those used by subsistence farmers. High diversity of genotypes, populations, species, functional types and spatial patches decreases the negative effects of pests and pathogens on crop, and keep open our possibilities to develop crops suited to future environmental challenges.*

- A major threat to the regulating and supporting ecosystem services provided by biodiversity is large-scale land use change, especially the intensification and extensification associated with large-scale industrial agriculture. In other words, functional shifts of vegetation and biotic homogenisation can pose a threat at least as important as that of global species extinctions. The most vulnerable human groups appear to be those whose livelihoods rely strongly on the use of natural and semi-natural ecosystems, such as of subsistence farmers, the rural pool, and traditional societies.

The following is a summary of the presentation given at the meeting by Sandra Diaz.

- Consider biodiversity not only as a **response variable vulnerable to global change**, but also as **an intervening factor that affects ecosystem processes and services**, and therefore **can influence ecosystem vulnerability** to global change.
- Consider the **combined, non-linear effects of more than one global change driver** (e.g. climate plus land-use changes). these are likely to have the most dramatic and immediate effects on biodiversity and ecosystem processes. How to consider them? By increasing study cases and modelling them more explicitly.
- Consider that there is more to biodiversity than species numbers. Preserving the integrity of communities in terms of species number, composition, and interactions, rather than simply maximizing species numbers, is more likely to maintain ecosystem services and to decrease ecosystem vulnerability.
- Large-scale homogenisation of vegetation are likely to have impacts on ecosystem services and processes at least as important as (and likely more important than) the impacts of global extinctions.

3.4 Health

The following abstract was prepared for the meeting by Ulisses Confalonieri and distributed to participants in advance.

CLIMATE CHANGE AND HEALTH VULNERABILITIES

Ulisses Confalonieri, Brazil

Physical processes resulting from global climate change can generate different types of hazards, which affect human population health in several ways. Some of these hazards operate directly but most are produced via complex social-environmental pathways. The projected health effects of climate change can be roughly classified into three main groups, namely:

1. Direct effects of weather extremes.

2. Effects of climate on the cycle of infections diseases.

3. Indirect effects mediated by complex social-ecological systems.

Social vulnerability to the health effects of climate change can be defined as "the characteristics of a group of people in terms of their capacity to anticipate, cope with, resist and recover from the impacts caused by climate."

A few conceptual models for the analysis of human vulnerability to the health impacts of climate variability and change have been developed. In general terms, they are of the **exposure-response** type, where two types of drivers are considered: <u>immediate</u> drivers and <u>ultimate</u> drivers. The immediate drivers are linked to both the exposure and the responses. These are: geographical situation; infrastructure; individual factors (age, gender etc.); risk perception; demography; access to information and medical care. These factors can be modified trough short-term interventions. The ultimate drivers are income; culture; education and political power, which shape the immediate drivers and can be modified only trough long-term policies.

Most of the existing knowledge on key vulnerabilities to the health effects of climate is found in the analyses made by geographers of the social impacts caused by disasters, especially droughts. It would be better incorporated into AR4 if weather extremes can be accurately predicted, on a regional basis, in general climate models

In regard to the major gaps in the knowledge of the health impacts of climate these range from the scarcity of empirical studies of correlation between climate parameters and human health conditions, to the modeling of disease distributions under different climate change scenarios.

Three major areas are identified as research priorities for studies on climate-health linkages:

A. The mapping of specific social-environmental factors which determine the vulnerability of human populations on a local, regional or national scale

B. Analysis of the effects of global climate change on the distributions of human pathogens, vectors and animal reservoirs of focal infections from natural systems

C. Integrated assessments of climate, social and environmental aspects as a subsidy to scenarios modeling.

The recent development in biogeography that may become an important tool for the analysis of the geographical distribution of zoonotic infections in natural ecosystems, under different scenarios of climate change, is the modeling of ecological niches of infections using genetic algorithms.

The following is a summary of the presentation given at the meeting by Ulisses Confalonieri.

1 There is good knowledge on types and mechanisms of health impacts; on vulnerability factors and on the interventions needed for adaptation but not on the spatial distribution of health risks associated to climate change.

2 Few health conditions have been addressed so far and more comprehensive indicators should be added in the assessment of health impacts of climate change (e.g. Disability-adjusted life years)

3 Health vulnerability maps are needed for climate policy issues (global level) and for targeting public health interventions (regional/national/local levels).

4 There is the need for an integration of the health assessment with other impacts areas in AR4, especially for the use of information on the spatial distribution of health hazards such as food scarcity; ecosystem changes; water shortage and the occurrence of weather extremes.

3.5 Development

The following abstract was prepared for the meeting by Youba Sokona and distributed to participants in advance.

Key sensitivities and levels of impact in selected areas and region : Development

Youba SOKONA

Limiting global climate change to a safe levels in the long-term and sustainable development are two faces of the same coin. Industrialized countries in order to re-orient their development path to a sustainable one need to implement GHG mitigation policies while Least Developed Countries with limited mitigation potentials should explore adaptation strategies in order to mainstream climate change in their development path. A range of countries in between those two extremes need to explore right balance between mitigation options and adaptation strategies in their ongoing and future development path.

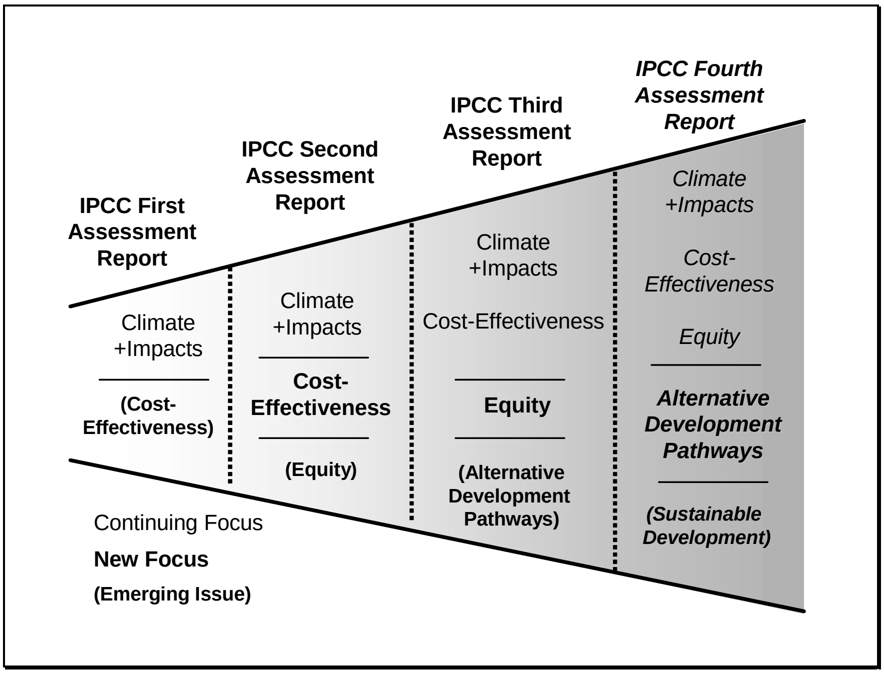
The scientific community of the United Nations Framework Convention on Climate Change (UNFCCC) process has gradually inched towards acknowledging and exploring the inter-linkages between climate change and sustainable development. Indeed, during the past ten years an abundant literature more or less highlighted the deep, multiple and varied links between sustainable development and climate change. The policy mandate to deal with climate change within the context of sustainable development – as a right and as an obligation –

was articulated as early as 1992 in the UNFCCC and then re-affirmed in the 1997 Kyoto Protocol. However, the larger literature has only recently begun exploring these issues in earnest. Arguably, this belated recognition is itself an indirect output of the IPCC process. It is an emerging literature that has been propelled by, on the one hand, developing country policymakers and scholars persistently demanding that the sustainable development context of climate change policy be explored within IPCC reports and, on the other hand, finding that the broader scholarship has been mostly negligent of such concerns. The literature that has now begun to emerge as a result of this felt need and recognized void is largely driven by IPCC experts, particularly by developing country scholars who have been making the case for such linkage most strongly.

Over the last decade and a half, the IPCC has stumbled towards progressively greater inclusion of sustainable development concerns. Although this evolution has been in step with the evolution of the greater literature it has continued to lag behind the policy mandate articulated in the UNFCCC. The Third Assessment Report (TAR) went the furthest by first acknowledging that “the attention accorded in the UNFCCC to sustainable development… [had not] been matched by its treatment in previous IPCC assessment reports” and then seeking to “address this mismatch by placing policy evaluation in the broader context of development, equity, and sustainability as outlined in the Convention”. While it can be argued that sustainable development concerns are still peripheral to the central thrust of the TAR and were unevenly integrated into it, the fact remains that the TAR was an important step forward in the IPCC’s ongoing quest to catch up to sustainable development.

Figure below, based on the TAR, highlights how the range and scope of the policy analysis tools used by the IPCC have expanded over its three assessment reports and how each expansion has brought it closer to a relatively deeper treatment of sustainable development. The central questions motivating the First Assessment Report (FAR) were those related to climate and climatic impacts: what is the extent of anthropogenic interference in global climate systems and what are the likely impacts of such interference? These have remained, and will remain, a central preoccupation of IPCC enquiries. At the same time, FAR also began raising a set of emerging questions related to what might be done about global climate change and the cost-effectiveness of potential policies. These questions gained more prominence as a new focus area in the Second Assessment Report (SAR). However, the SAR further broadened the IPCC policy discourse by introducing the issue of equity into the IPCC mix. By the Third Assessment Report (TAR), climate impacts as well as cost-effectiveness were both firmly established as continuing focus areas of the IPCC while questions about equity, which had only begun to be raised in SAR, began gaining a little more prominence as a new focus of the assessment process. In addition, TAR contributed to the evolutionary broadening of the IPCC process by introducing discussions about alternative development pathways and global sustainability (especially through its emphasis on scenarios) into the IPCC mix.

Evolution of the IPCC Assessment Process (based on Banuri et al)



Projecting forward the trends exhibited in the evolution of the first three IPCC assessments suggests that the upcoming Fourth Assessment Report (AR4) could present an important opportunity to meaningfully integrate sustainable development into the IPCC assessment process.

3.6 Disasters and insurance

The following abstract was prepared for the meeting by Robert Muir-Wood and distributed to participants in advance.

Climate Change, Disasters and the Role of Insurance

Robert Muir-Wood, Chief Research Officer, Risk Management Solutions, London: robertm@rms.com

Increases in the severity of 'weather catastrophes' are one of the key outcomes predicted for Climate Change. Such a rising number of disasters will impact societies: economically, socially and politically. Insurance is in many ways the most adaptive and versatile part of this societal response, and arguably the least likely to be critically impacted.

This is because insurers can reset premiums every year, in response to perceived changes in risk. In the aftermath of a major catastrophe, premiums typically rise significantly. Where the occurrence of an event, or improved risk modelling, reveals that risk in some location or class of business was much higher than anticipated and where, for regulatory or political reasons, it is not possible to demand compensatory increases in premiums, insurers may withdraw coverage, pushing the risk back onto individuals and governments. In all cases insurance premiums will only be paid if what is insured is economically sustainable. Once insurance is withdrawn, or becomes too expensive, it is left to government to provide subsidies (or build flood-defences etc.) or for individuals to be left holding the risk.

Wherever there is sufficient personal and commercial wealth to be worth protecting, insurance is an important part of the solution for disaster management. Increasing insurance participation in post-disaster financing has many benefits, relieving states of the need to fund reconstruction (accompanying the other economic consequences of a catastrophe), imposing market discipline on disaster economics and incentivising risk mitigation through the use of premium differentials.

As an industry dealing in risk, when the best insurance organizations look ahead they find climate-change dominating their horizon. In this they see considerable uncertainty, and therefore tend to fall into patterns of response according to their own more immediate commercial imperatives. This is why the largest reinsurers are the ones to have been most vocal in warning about the potential impacts of climate change, a message that they use to argue for higher premiums from insurers today. The insurers, as purchasers of the reinsurance, have been far less ready to promote an argument supporting an underlying increase in risk.

Up to now (!) insurers' economic participation in catastrophe risk has been almost inverse to the climate-change related susceptibilities. There is only a very modest insurance component of the consequences of heat-waves and the large majority of river and storm-surge flood risk is uninsured (or covered by government schemes). Yet while there is more widespread insurance coverage of windstorms – since 1980 the most catastrophic tropical cyclones have (so far) shown few signs of increased impacts.

The use of Historic data

Extremes form in the tail of all climate states. (The 50 year return period windstorm that lasts for a few hours represents the 0.001% climatology). The question of 'attribution' to climate change for any catastrophe is therefore the degree to which the probability of a particular event's occurrence has been modified. This is not at all an easy question to answer - but the starting point has to be an understanding of what was the 'baseline probability'.

In order to see how catastrophe occurrence has changed over time, the effects of dramatic increases in exposure and values need to be removed, and the 'hazard footprints' of historical windstorms, floods etc reconstructed with a consistent set of values and exposures. In performing this exposure/values normalization for the principal peril regions there is, so far, no evidence for a late 20th Century increase in tropical cyclone impacts. (In many regions the most active decades for normalized losses were in the middle of the 20th

Century.) There is, however, some indication that hurricanes have become more intense around the Caribbean and 2004 saw the first evidence for hurricane initiation in the marginal south Atlantic basin.

In contrast, Catastrophic European Windstorms have shown increases in activity since 1980. Other perils that have also shown increases in activity, include flooding resulting from persistent winter rainfall as well as intense summer rainfalls (although changes in river management often make it difficult to compare long-baseline extreme-flow behaviour). There is also some suggestion that severe thunderstorms, and their accompanying hail and tornado effects, are becoming more intense and more frequent.

Looking forward

In projecting climate change impacts across the next few decades, it is important to explore overall disaster response mechanisms and disaster economics, rather than to focus primarily on the most adaptive element of this process: insurance. A principal battle is likely to be fought over expanded flood insurance, as the move by governments to shift the costs of catastrophe risk off their balance sheets, together with the arrival of high-resolution flood pricing and portfolio management models are encouraging an expansion of private (river and storm surge) flood insurance. However an increase in the risk of flooding will lead insurers to resist picking up all the risk, or to price the risk prohibitively. This will return responsibilities to Governments to determine whether the costs of additional flood protection are merited relative to the value and economic activity preserved. As insurance becomes smarter at high-resolution risk-pricing: so increasingly properties, and even whole towns, may be identified as being too risky to insure - and hence could simply be abandoned.

The following is a summary of the presentation given at the meeting by Robert Muir-Wood.

1 The private insurance system is highly versatile and adaptive to changes in risk having the ability to vary risk prices annually and also to choose what business to write. The insurance industry will thrive as long as the economy thrives and if risk rises, more insurance will be purchased. The issue under Climate Change therefore concerns the occurrence of disasters – and where the costs of disasters will be born - rather than simply the impact on the insurance industry. After major catastrophes in developed countries, insurance coverages tend to be reduced and/or insurance withdrawn from those at highest risk, leading to more risk being borne by governments and individuals.

2 The techniques that have been developed for quantifying catastrophe risk for the insurance industry (including the use of Loss Exceedance Probability – LEP – relationships and high resolution risk costs maps) are very suitable for identifying the costs of changes in disaster occurrence under Climate Change.

3 Figure TS-5 in the Climate Change 2001 Synthesis Report gives a misleading impression of accelerating disaster occurrence. This figure principally shows volatile catastrophe occurrence superimposed on rapid increases in the exposure at risk. In order to explore changes in the occurrence of rapid onset disasters over time it is important to separate out the changes in exposure, vulnerability and values. Once normalized in this way, tropical cyclone windstorm losses in the US and Japan catastrophe are significantly below those found around the middle of the 20th Century. In Europe windstorm activity since 1980, has however shown an increase.

4 Increases in flood risk (both river and storm surge) are likely to be at the intersection of policy issues around disaster management (and the allocation of disaster costs) under climate change.

3.7 Integrated assessments of key impacts – millions at risk

The following abstract was prepared for the meeting by Prof. Martin Parry and distributed to participants in advance. Prof. Parry also gave a presentation at the meeting.

Millions at risk: defining critical climate change threats and targets

Martin Parry

ABSTRACT

Agreements to mitigate climate change have been hampered by several things, not least their cost. But the cost might well be more acceptable if we had a clear picture of what damages would be avoided by different levels of emissions reductions, in other words, a clear idea of the pay off. The problem is that we do not. The Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) published this year (IPCC, 2001a, b) lists a wide range of potential impacts but has difficulty in discriminating between those that are critical in their nature and magnitude from those that are less important. Yet, the identification of critical impacts (e.g. ones that should be avoided at any reasonable cost) is obviously a key to addressing targets for mitigating climate change. Indeed, a central objective of the UN Framework Objective on Climate Change (UNFCCC) is to avoid ''dangerous levels'' of climate change that could threaten food security, ecosystems and sustainable development (areas of risk that are specifically mentioned in UNFCCC Article 2).

For several years, we have been researching impacts in key areas of risk: hunger, water shortage, exposure to malaria transmission, and coastal flooding, as part of a global fast-track assessment (Parry and Livermore, 1999). The results of our work have been reported widely and form a significant part of the IPCC's assessment of likely impacts (IPCC, 2001a, b). But they are scattered through different parts of the IPCC report and other literature and, before now, we have not brought them together. For this review, we have graphed our estimates of effects as a single measure: the additional millions of people who could be placed at risk as a result of different amounts of global warming (Fig. 1).

The figure shows the increase in millions at risk due to higher temperatures for two time periodsF2050s and 2080s. The analysis takes into account likely non-climate developments such as growth in population, and income and developments of technology, and these become important assumptions behind future trends in, for example, increases in crop yield and the building of coastal defences. These developments themselves have very great effects on the numbers at risk and represent a

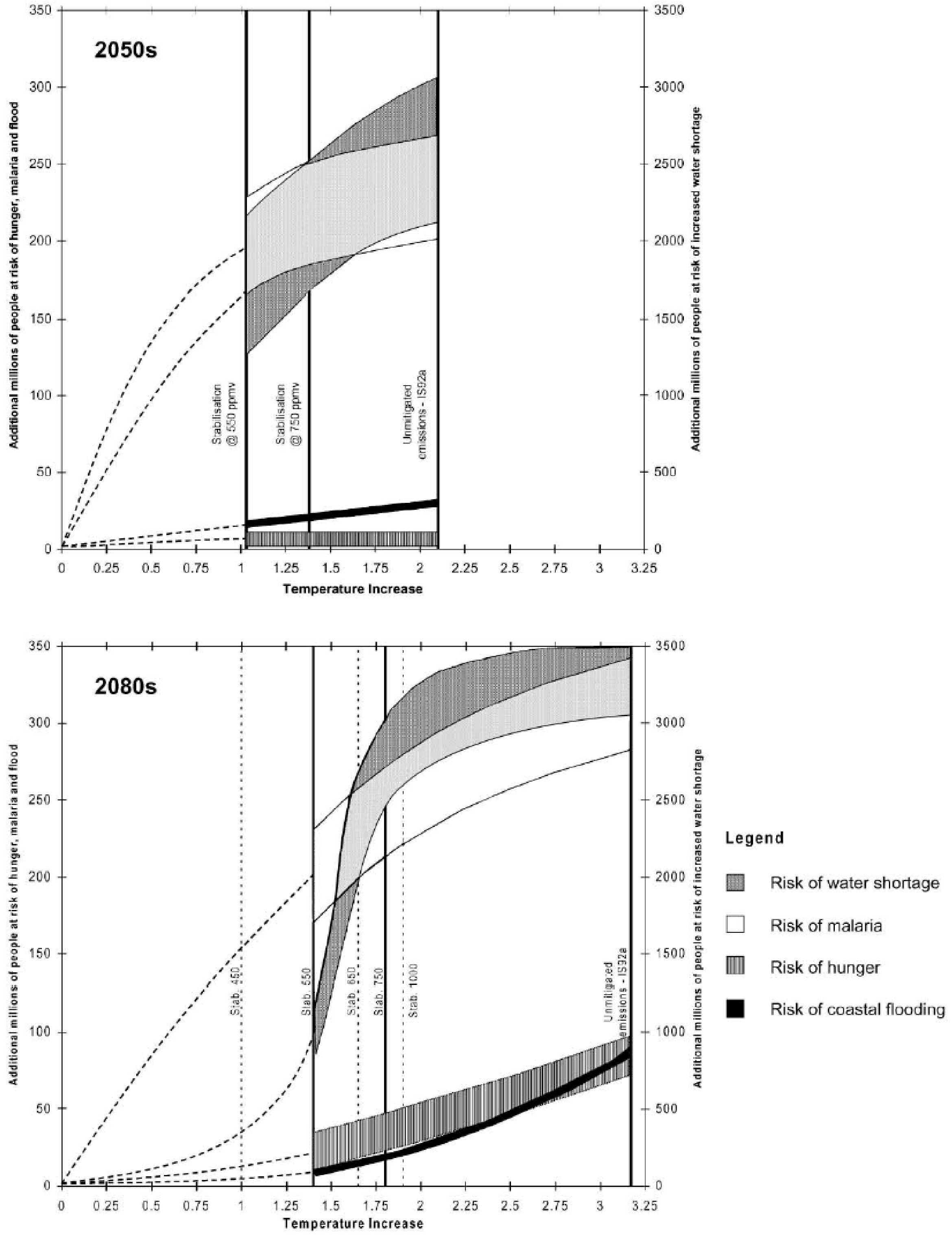


Fig. 1. Additional millions at risk due to climate change in 2050s and 2080s for hunger, coastal flooding, water shortage and malaria. The width of the curve indicates one standard deviation of variance around the mean, based on results from four HadCM2 experiments (Parry and Livermore, 1999; IPCC, 2000). Solid lines indicate model-based estimates. Dotted lines are inferred (IPCC, 2001a, b) and intended as schematic. Stab. 450 (etc.) = stabilisation@450 ppmv (etc.).

(non-climate change) reference case. The graph thus shows the additional millions at risk due specifically to estimated future changes in climate.

But now for the caveats: the reference case is only for one future world (what the IPCC used to call a best estimate or "business-as-usual" future, now referred to as IS92a). More recently, the IPCC has explored a set of six different developmental pathways that the world may follow (IPCC, 2000), and the millions at risk in these alternative futures will certainly differ. Our work on these is in hand but will probably take a year to complete. We need also to emphasise that the graph is a global estimate which hides important regional variations and, so far, it is based on one model of future climate patterns (the UK's Hadley Centre second generation global climate model) (Johns et al., 1997). While these are the only global impact estimates currently available, we need urgently to complete similar ones for different climate models and for a variety of development pathways.

Five important points emerge from this figure. First, the curves of additional millions at risk generally become steeper over time. Less obviously, this results as much from a larger and more vulnerable exposed population in 2080 than in 2050, as from increases in temperature or inferred changes in precipitation and sea-level rise. For example, the remarkable steepness of the water shortage curve in 2080 is the outcome of very large city populations in China and India becoming newly at risk. In the case of hunger, however, the rising curve in 2080 stems from widespread heat stress of crops, while up to about 2050 lesser amounts of warming lead to yield gains in temperate regions that balance losses elsewhere and lead to only small net increases in hunger (Parry and Livermore, 1999). These complex interactions between exposure and climate change tell a clear story: there will be more millions at risk as time progresses.

Secondly, the figure indicates how much we need to reduce emissions in order to draw-down significantly the numbers at risk. We have estimated effects assuming that atmospheric concentrations of CO_2 are stabilised at 750 parts per million (ppmv) by 2250 and at 550 ppmv by 2150 (Arnell, in press). These are approximately equivalent, respectively, to 10 times and 20 times the reduction in emissions assumed in the Kyoto Protocol. The 750 ppmv target delays the damage but does not avoid it. By 2080, it would halve the number at risk from hunger and flooding, reduce the population at risk of malaria by perhaps a third and water shortage by about a quarter. But to bring risk levels down from hundreds to tens of millions would require a stabilisation target of about 550 ppmv.

We have also indicated on the graph, but only in a schematic form, the approximate locations of 450, 650 and 1000 ppmv stabilisation pathways and their effect on millions at risk (IPCC, 2001a, b). Although impact analyses have not yet been conducted for these stabilisation levels, it appears that the 450 ppmv pathway would achieve very great reductions in millions at risk, although very high costs of mitigation would be incurred. It is precisely this kind of pay-off that needs to be analysed properly.

A third conclusion is that information is now available that can help inform the selection of climate change targets. Thus far these targets, such as Kyoto, have been chosen in broadly a top–down manner, without clear knowledge of the impacts that would be avoided, and that has been partly their weakness. Now we may argue, for example, that in order to keep damages below an agreed tolerable level (for example, a given number of additional people at risk) global temperature increases would need to be kept below a given amount; and emissions targets could then be developed to achieve that objective.

Fourthly, it is clear that mitigation alone will not solve the problem of climate change. Adaptation will be necessary to avoid, or at least reduce, much of the possible damage, and since we need many of the benefits of adaptation today, regardless of climate change in the future (e.g. increased drought protection of agriculture, improved flood defences, more efficient use of water, better malaria control), many of the adaptive strategies for climate change can be "win–win".

We need to find a blend of mitigation and adaptation to meet the challenge of climate change. Mitigation can buy time for adaptation (for example, delaying impacts until improved technology and management can handle them), and adaptation can raise thresholds of tolerance that need to be avoided by mitigation (for example, by increasing drought tolerance of crops). Considered separately, they appear inadequate to meet such a challenge, but combined they would make a powerful response.

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3.8 Integrated assessment of key impacts - methods

The following abstract was prepared for the meeting by Hadi Dowlatabati and distributed to participants in advance.

UNFCCC Article 2: Integrated Assessment and Uncertainty

The UNFCCC objectives have been stated in terms of climate stabilization in order to prevent dangerous interference with the climate system. Unless the climate system has intrinsic value, the objective is actually about dangerous impacts. Dangerous impacts need not arise from a dramatic change (or rate of change) in the climate system. Extinctions occur on a daily basis. The question is therefore about an accounting algorithm that defines some threshold on the aggregate level of impacts.

Anthropogenic activities generate multiple simultaneous stresses on ecologic and social systems. The attribution of "dangerous impacts" to climate change alone is a theology not science.

The vast majority of Integrated Assessment (IA) efforts have been solely focussed on climate as the stressor. As such, they can only serve to propagate an incomplete framework of attribution and response. Horizontal and vertical integration of concurrent stressors and their interactions can be incorporated into the models. However, the basic science to achieve this goal is far from complete.

Impacts can be due to anomalies in first (or higher order) statistics of one or more stressors (climate, land cover, etc.). Adaptations are often designed to address sensitivity to a particular pattern of anomalies in a specific stress. However, the adaptive measure may introduce new sensitivities to stressors or their aspects that have not been considered or not been considered serious enough to worry about. IA methods can be used to address this complex of interacting stressors as well as the barriers and bridges to implementation of effective adaptations. However, only a handful of studies have attempted this.

In summary, we are uncertain about: attribution, distribution, interactions, and amelioration of stressors and their impacts.

Hadi Dowlatabati also prepared a presentation for the meeting which was given by Jean Palutikof. Ferenc Toth and Jan Corfee-Morlot also gave presentations on this topic.

3.9 Issues of generational equity and justice

A presentation on this topic was given by Rajendra Pachauri, the Chair of IPCC.

3.10 Rapporteur's summary

Session 2 : Key sensitivities and levels of impact in selected areas and regions (Wednesday 18 May), Luis Jose Mata

1- Climate Change and Food Systems (Prabhu Pingali, FAO)

- A global assessment undertaken by IIASA and FAO was presented. The assessment claims to provide high degree of spatial specificity. It assesses the impact of climate change on agricultural potential of 28 crops at three levels of farming technology. The results are presented graphically.
- Floods and droughts are the main causes of food emergencies. Tabulated results for the years 2000, 2001 and 2002 were presented for several drivers of food emergencies such as conflict, refugees, economic problems and others.
- The food security issue was analysed in terms of the impact of climate change on food production using several GCMs models and for the 2080s.

2 - Key vulnerabilities and the Water Sector (Luis Jose Mata, Venezuela)

- Risk from extreme climate events (e.g., floods and droughts) was considered a reason of concern that may help policy makers to identify what is 'dangerous' climate change.
- Climate Change will contribute to increase the already existing water crisis. Thus, it is important to explore the character of critical thresholds in the natural (physical hydrological system) and in the managed water environment (water resources system) in order to identify thresholds of change in terms of magnitude or rates of change.
- The frequency and magnitude of (hydrological) extreme events increase even with a small increase in temperature and will become greater at higher temperature. It is convenient to explore the different likelihood of crossing dangerous warming thresholds for storylines scenarios such as B1 and B2 which represent different view of the world and for the water sector.
- Since 2001 many peer review publications related to the theme 'climate and water' have appeared. They should all be included for assessment for the next IPCC process. The following gaps among others have been identified regarding the water sector: (1) insufficient knowledge of impacts in different parts of the world (especially in developing countries), (2) almost complete lack of information on impacts under different development pathways and under different amount of mitigation, (3) no clear relationship between climate change and impacts on water resources, (4) little analysis of the capacity and cost of adaptation and (5) how do changes in variability affects the water environment?

3 - Incorporating biodiversity in IPCC assessment (Sandra Diaz, Argentina)

- Global biodiversity change can affect vulnerability of ecosystems processes and services: Biodiversity was considered not only as a response variable that is vulnerable to global change, but also as an intervening factor that affects ecosystem processes and services, and therefore can influence ecosystem vulnerability to global change.
- It was considered that there is more to biodiversity than species number: Large-scale homogenization of vegetation is likely to have impacts on ecosystem service and processes at least as important as (or perhaps more important than) the impacts of global extinctions.
- It was suggested to establish a coordination mechanism between the Millennium Ecosystem Assessment and IPCC in order to increase the efficiency of the process.
- There is no information on how many species are needed to keep the integrity of ecosystem process and services. However, some evidence suggests that a rich regional species pool is necessary to maintain ecosystem stability in the face of a changing environment.

4 - Vulnerability and the Health Sector (Ulisses Confalonieri, Brazil)

- The following issues were recognized: (1) mortality as an indicator to measure impact is not enough, (2) it is necessary to agree on which is the level of tolerance for health impacts, (3) to define the scale of the assessment and (4) how to get public health institution involved.
- Three different effects (on the impact of climate change on health) were presented: (1) direct effects caused by hazards from extreme events, (2) direct and indirect effects of climate on cycles of infectious diseases and (3) indirect effect mediated by social-ecological pathways (includes sea level rise).
- Information on which are the main gaps in knowledge and how can they best be filled was presented as follow: (1) Factors of vulnerability are not considered in empirical studies, (2) there is a poor quality health information in several developing countries, (3) only a few health conditions have addressed so far and (4) there has not been sufficient integration with others sectors such as food, ecosystem and disasters.

5 - Key Vulnerability and Development (Youba Sokona, Senegal)

- Climate Change can offer to developing countries opportunity to revisit development strategies from a new perspective, improve integration of environment and development issues and address issues such as income distribution.
- Some key structural characteristics of least development countries (LDCs) were mentioned: (1) very low GHG emissions, (2) countries are particularly vulnerable to adverse impacts of climate change, (3) there is absence or weak basic infrastructure and (4) there are few heavy investments to protect or to absorb new strategies.
- Specific concerns of developing countries are for example: (1) clarification and better understanding of concepts of additionally, complementary and cost effectiveness and to ensure that their socio-economic development priorities are served and safeguarded.

6 - Climate Change Disaster and the role of Insurance (Robert Muir-Wood, UK)

- This presentation was based in the following ideas: (1) how is the price for risk transfer determined, (2) a probabilistic methodologies for quantifying catastrophe risk with direct application for investigating climate change and (3) quantifying catastrophe risk by mean of the exceedance probability (EP) curve.
- Illustrations of what happens to insurance after major catastrophe were presented for two examples (1) 15.5 billion pounds 1992 Hurricane Andrew and (2) the 1.0 billion pound UK flood in 2000.
- The idea that the link between sudden onset disaster and climate change has become sensationalized and exaggerated was suggested (including in the TAR WGII Chapter 8)
- Questions were posed such as what insurance would be like if there was higher hazard due to climate change and which are the appropriate methodologies for quantifying climate change ‘catastrophe’ impacts.

4 Reducing the risks of key impacts by adaptation

4.1 Opportunities, limits and barriers

The following abstract was prepared for the meeting by Nobuo Mimura and distributed to participants in advance.

Past Findings and Future Discussions on Adaptation
Nobuo Mimura, Ibaraki University, Japan

[1] What is the extent and nature of current information? -TAR Findings
A basis for AR4 is obviously the Third Assessment Report(TAR). In TAR, there are already many discussions and comments on the role, nature, measures, cost, and relationship with policy of adaptation. The following are some of the major points presented in the WGII Technical Summary.

6. Adaptation, Sustainable Development, and Equity
1) Adaptation to climate change has the potential to substantially reduce many of the adverse impacts of climate change and enhance beneficial impacts, though neither without cost nor without leaving residual damage.
2) Planned anticipatory adaptation has the potential to reduce vulnerability and realize opportunities associated with climate change.
3) Adaptations to current climate and climate-related risks (e.g., recurring droughts, storms, floods, and other extremes) generally are consistent with adaptation to changing and changed climatic conditions.
4) The costs of adaptation often are marginal to other management or development costs.
5) To be effective, climate change adaptation must consider non-climatic stresses and be consistent with existing policy criteria, development objectives, and management structures.

6.1 Adaptive Capacity
6) The capacity to adapt varies considerably among regions, countries, and socioeconomic groups and will vary over time.
7) The ability to adapt and cope with climate change impacts is a function of wealth, scientific and technical knowledge, information, skills, infrastructure, institutions, and equity.

6.2 Development, Sustainability, and Equity
8) Activities required for enhancement of adaptive capacity are essentially equivalent to those promoting sustainable development. Climate adaptation and sustainability goals can be jointly advanced by changes in policies that lessen pressure on resources, improve management of environmental risks, and enhance adaptive capacity.
9) Development decisions, activities, and programs play important roles in modifying the adaptive capacity of communities and regions.

7. Global Issues and Synthesis

7.2.1. Unique and Threatened Systems
10) Small increases in global average temperature may cause significant and irreversible damage to some systems and species, including possible loss. Some plant and animal species, natural systems, and human settlements are highly sensitive to climate change.

7.2.2. Aggregate Impacts
11) With a small temperature increase, aggregate market-sector impacts could amount to plus or minus a few percent of world GDP; aggregate non-market impacts could be negative.

7.2.3. Distribution of Impacts

12) Developing countries tend to be more vulnerable to climate change than developed countries. The different results are attributable partly to differences in exposures and sensitivities, and partly to lesser adaptive capacity in developing countries.

13) Particularly vulnerable regions include deltaic regions, low-lying small island states, and many arid regions. Within regions or countries, impacts are expected to fall most heavily on impoverished persons.

14) Impacts on unmanaged systems are likely to increase in severity with time, but impacts on managed systems could increase or decrease through the 21st century. The benefits of increased adaptive capacity are likely to be greater for intensively managed systems than for systems that presently are unmanaged or lightly managed.

15) Future development paths will shape future vulnerability to climate change, and climate change impacts may affect prospects for sustainable development. Development can influence future vulnerability by enhancing adaptive capacity through accumulation of wealth, technology, information, skills, and appropriate infrastructure; development of effective institutions; and advancement of equity.

7.2.4. Extreme Weather Events

16) Many climatic impacts are related to extreme weather events. Their severity, suddenness, and unpredictability make them difficult to adapt to.

7.2.5. Large-Scale Singular Events

17) Climate change has the potential to trigger large-scale changes in Earth systems, which include complete or partial shutdown of the North Atlantic and Antarctic Deep Water formation, disintegration of the West Antarctic and Greenland Ice Sheets, and major perturbations of biosphere-regulated carbon dynamics.

18) These may be very difficult to adapt to.

8. Information Needs

19) Sensitivity: Sensitivity to climate stimuli is still poorly quantified for many natural and human systems. Quantification of the curvature, thresholds, and interactions of system responses is poorly developed for many systems.

20) Adaptability: Work is needed to better understand the applicability of adaptation experiences with climate variability to climate change, to use this information to develop empirically based estimates of the effectiveness and costs of adaptation, and to develop predictive models of adaptive behaviour that take into account decision making under uncertainty.

21) Work also is needed to better understand the determinants of adaptive capacity and to use this information to advance understanding of differences in adaptive capacity across regions, nations, and socioeconomic groups, as well as how capacity may change through time.

[2] Where are the main gaps in knowledge, and how best can the AR4 assess this information?

The above list indicates that TAR has already analyzed and summarized major points on adaptation.

The AR4 should be given clear answers to the following key questions.

- What is the total amount of impacts of climate change (global, regional, and national levels)?
- Where are the hot spots, i.e. the sectors and places which would receive the most serious impacts?
- What is the threshold of climate change (dangerous level) in terms of impacts? Dangerous level of climate change can be determined in several categories; i.e., atmospheric concentration of GHGs, global warming (increased temperature), sea-level rise and climate change, and level of impacts.
- When will the climate change exceed the dangerous level, if we do not take appropriate countermeasures?

- As adaptation is one of the two frameworks of response to global warming, it should be discussed in the context of effectiveness of the overall responses. The major indices for the effectiveness are;
  - Changes in threshold: How can we change the threshold of adverse impacts by adaptation? Adaptation will enhance the ability of human society and natural systems to stand still against the impacts, which means the increase of the threshold.
  - Cost of responses: The cost of global warming consists of damages costs and costs for mitigation and adaptation. Theoretically, there should be an optimal point where the total costs is minimized. If we combine

the mitigation and adaptation in an appropriate way, we can reduce the cost of mitigation in parallel with keeping the impacts less than the threshold level.

- The present studies are mainly still qualitative. However, the quantitative results of the above indices (changes in threshold and costs of responses, both in many systems, and regions and countries) are necessary to give a clear indication toward development of the future response policies.

- Another point which is still unclear in the discussions on adaptation is how we can distinguish between ordinary development and adaptation policy/measures. As indicated in TAR, "The ability to adapt and cope with climate change impacts is a function of wealth, scientific and technical knowledge, information, skills, infrastructure, institutions, and equity." And, countries with well developed systems for disaster prevention have higher tolerance level (threshold) against climate change and extreme events.
  However, as the factors listed above are the common targets of development of countries, how we can differ between ordinary development and adaptation policy/measures. We may not necessarily distinguish them, for adaptation to climate change is a component of sustainable development. Therefore, adaptation should be mainstreaming in national and international policies. If the relation between development and adaptation policy/measure is so close, what is the peculiar nature of adaptation to climate change which we should specially paid attention to in the AR4?

The following is a summary of the presentation given at the meeting by Nobuo Mimura.

Key Messages of the presentation in the Buenos Aires meeting.

1. TAR has already summarized major points on adaptation including roles and nature of adaptation, adaptive capacities, and adaptation policies. Though more concrete and quantitative studies are needed for further development of adaptation strategies, new information is rather limited.

2. As adaptation is one of the two responses to global warming, i.e. mitigation and adaptation, it should be discussed in the context of effectiveness of the overall responses. The major indices for the effectiveness are: 1) Changes in threshold: How can we change the threshold of adverse impacts by adaptation? Adaptation will enhance the ability of human society and natural systems to stand still against the impacts, which means the increase of the threshold; 2) Cost of responses: The cost of global warming consists of damages costs, and costs for mitigation and adaptation. Theoretically, there should be an optimal point where the total costs is minimized. If we combine the mitigation and adaptation in an appropriate way, we can reduce the cost of mitigation in parallel with keeping the impacts less than the threshold level.

3. Quantitative results of the above indices (changes in threshold and costs of responses, in both many systems, and regions and countries) are necessary to give a clear indication for the development of future response policies.

4. The TAR indicated "The ability to adapt and cope with climate change impacts is a function of wealth, scientific and technical knowledge, information, skills, infrastructure, institutions, and equity." Countries with well developed systems for disaster prevention have a higher tolerance level (threshold) against climate change and extreme events. As these factors are the common targets of development, how we can differ between development and adaptation? Adaptation to climate change is an important component of sustainable development, therefore, adaptation should be mainstreamed in national and international policies. If the relation between development and adaptation is so close, what is the peculiar nature of adaptation to climate change which should be specially paid attention to in the AR4.

4.2 Experience from modelling impacts under different SRES futures

The following abstract was prepared for the meeting by Prof. Martin Parry and distributed to participants in advance. Prof. Parry also gave a presentation on this topic at the meeting.

DIFFERENCES IN IMPACT UNDER DIFFERENT SRES FUTURES

ABSTRACT Martin Parry

This presentation summarises the results of a collected set of projects (published as a theme issue in **Global Environmental Change, Vol 14, No. 1, April 2004)** on **water shortage, food supply, flooding** and **malaria** under different SRES scenarios**.**

The results indicate how far key levels of vulnerability may vary for different development pathways.

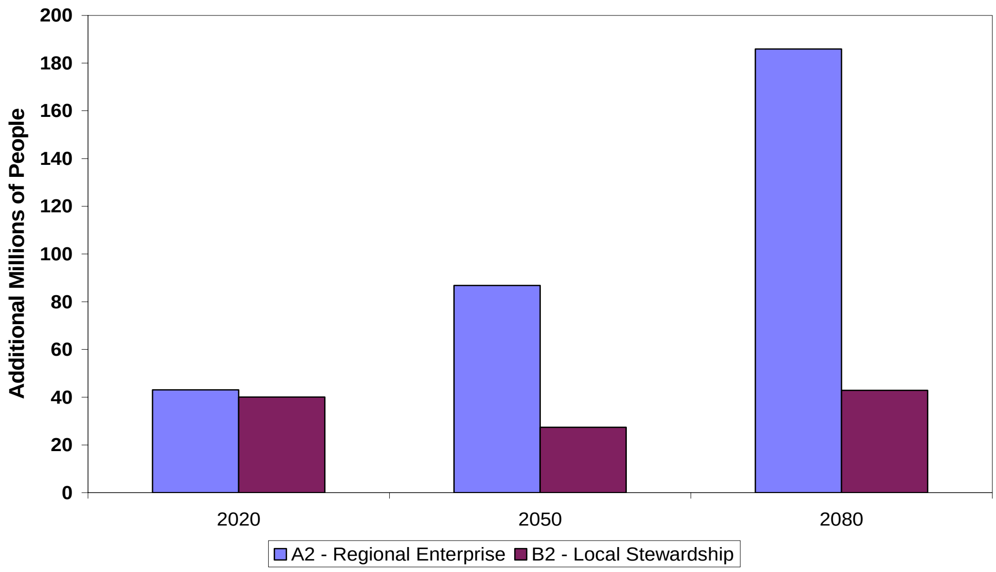
Water shortage (Arnell in GEC, 2004)

In 1995, nearly 1400 million people lived in water-stressed watersheds (runoff less than 1000 m^3/capita/year), mostly in south west Asia, the Middle East and around the Mediterranean.

By the 2020s there is little clear difference in the magnitude of impact between population or emissions scenarios, but a large difference between different climate models: between 374 and 1661 million people are projected to experience an increase in water stress. By the 2050s there is still little difference between the emissions scenarios, but the different population assumptions have a clear effect. Under the A2 population between 1092 and 2761 million people have an increase in stress; under the B2 population the range is 670-1538 million respectively. The range in estimates is due to the slightly different patterns of change projected by the different climate models. Sensitivity analysis showed that a 10% variation in the population totals under a storyline could lead to variations in the numbers of people with an increase or decrease in stress of between 15 and 20%. The impact of these changes on actual water stresses will depend on how water resources are managed in the future.

Food Supply (Parry, et al., in GEC 2004)

MILLIONS AT RISK FROM HUNGER, WORLDWIDE:



Flood impacts (Nicholls in GEC, 2004)

Assuming that defence standards improve with growth in GDP/capita (lagged by 30 years), flood incidence increases in all four cases to the 2020s due to the growing exposed population. Then to the 2080s, the incidence of flooding declined significantly to ≤ 5 million people/ year in the B2 world, ≤ 2 million people/ year in the B1 world and ≤ 1 million people/year in the A1FI world due to improving defence standards. In contrast, flood incidence continues to increase in the A2 world to the 2050s, and in the 2080s it is still 18 to 30 million people/year. This reflects the greater exposure and more limited adaptive capacity of the A2 world, compared to the other SRES storylines.

Sea-level rise increases the flood impacts in all cases although significant impacts are not apparent until the 2080s when the *additional* people flooded are 7 to 10 million, 29 to 50 million, 2 to 3 million and 16 to 27 million people/year under the A1FI, A2, B1 and B2 worlds, respectively. Hence, the A2 world also experiences the highest increase in the incidence of flooding. This is true under all the realistic scenario combinations that were considered demonstrating that socio-economic factors can greatly influence vulnerability to sea-level rise. The trends of the results also suggest that flood impacts due to sea-level rise could become much more severe through the 22nd Century in all cases, especially in the A1FI world.

Coastal wetlands will be lost due to sea-level rise in all world futures with to 5% to 20% losses by the 2080s in the A1FI world. However, these losses are relatively small compared to the potential for direct and indirect human destruction. Thus the difference in environmental attitudes between the A1/A2 worlds and the B1/B2 worlds would seem to have more important implications for the future of coastal wetlands, than the magnitude of the sea-level rise scenarios during the 21st Century.

Risk of malaria (Van Lieshout, et al., in GEC 2004)

Table 2 Additional population at risk of malaria by WHO Region by 2080s (millions)

	A1FI		A2		B1		B2	
	>3	>1	>3	>1	>3	>1	>3	>1
West Africa AFR_D	-46	-13	-35	-11	-25	-1	-8	-2
Sub-Saharan Africa AFR_E	49	44	53	56	21	38	51	67
North America AMR_A	-15	9	-46	33	-9	15	11	13
Latin America AMR_B	-92	-21	-169	-40	-29	16	-49	14
W South America AMR_D	-19	-5	-42	-7	-12	2	-17	1
West Asia EMR_B	0	39	0	62	0	34	0	20
West Asia EMR_D	23	140	16	237	-2	100	62	139
Western Europe EUR_A	-1	7	-1	22	-1	4	0	33
Central Europe EUR_B	-1	19	-1	33	-1	25	-1	15
Eastern Europe and CIS EUR_C	1	-12	1	-13	1	-2	1	-14
South East Asia SEAR_B	0	0	-1	0	0	0	0	0
South Asia SEAR_D	102	7	-77	13	-104	6	-35	9
Australasia WPR_A	17	1	17	1	13	1	9	1
East Asia WPR_B	82	12	143	29	-6	11	7	12
world	100	227	-141	416	-153	250	31	307

4.3 Policy and equity issues

The following abstract was prepared for the meeting by Patricia Romero Lankao and distributed to participants in advance. A presentation on this topic was also given at the meeting by Dr. Romero Lankao.

“One Earth, Diverse Pathways of Development
(Equity and Policy Implications)”

Patricia Romero Lankao
Metropolitan Autonomous University, Xochimilco, Mexico

The construction of global scenarios is a powerful and simple tool to explore tendencies in both carbon emissions and evolution of their underlying driving forces (e.g. affluence, population and technology). But scenarios do not capture key regional differences. In my presentation I will introduce a historical lens and use a “world economy” approach to explore the relations among three development pathways (core, rim, peripheral) and the carbon cycle.

I will state that some carbon-relevant characteristics of development, such as demographic concentration in urban areas, are common to all regions; can be thus managed through similar policy strategies, which of course should consider the socioeconomic and politic context of each region. Other features though are diverse in historical and regional terms. Cores are by far the main carbon releasers not withstanding have become less intensive in recent years, while most peripheries are expected to be more vulnerable to multiple stressors, such as climate variability and change, international markets, and neoliberal reform of the state. I will also show that differences in development patterns demand a range of diverse carbon related policies. Actions to reduce CO_2 emissions are for instance, more adequate for cores. Policies aimed at reducing social disparities, increasing local capacities, and strengthening institutional settings are essential for enhancing the adaptation capacities of many rims and peripheries.

4.4 Rapporteur’s summary

Session 3 : Reducing the risk of key impacts by adaptation (Wednesday 18 May), Ferenc Toth

The rapporteur’s summary was given by Ferenc Toth in the form of a presentation.

5 Climate changes associated with key levels of impacts and vulnerability

5.1 Nature, timings, rates, magnitudes (global level analysis)

The following abstract was prepared for the meeting by Tom Wigley and distributed to participants in advance. Prof. Wigley also gave a presentation on this topic.

Timing, Rates and Magnitudes of Global-mean Temperature Change

Tom. M.L. Wigley, National Center for Atmospheric Research, Boulder, CO 80307, USA

The objective of Article 2 of the UNFCCC is "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system". Concentration stabilization is usually interpreted as the objective. However, from a more careful reading it is clear that the primary objective is stabilization of the climate system – at some level below that which is deemed to represent the 'dangerous interference' threshold. Stabilization of greenhouse gas concentrations is merely the mechanism by which climate stabilization is to be achieved. No metric for defining 'dangerous interference' is specified in Article 2, but a number of authors have used global-mean temperature for this purpose.

The primary controls on future global-mean temperature changes are:

(1) the emissions of greenhouse gases, gases that affect the build up of greenhouse gases, and aerosol precursors
(2) the sensitivity of the climate system to external forcing (often characterized by the equilibrium (or eventual) global-mean warming that would occur if CO_2 levels were doubled – ΔT2x), and
(3) the rate of mixing of heat into the ocean.

In the context of climate stabilization (i.e., the stabilization level), it is really only the first two of these that are important. To avoid dangerous interference, however, there may well be thresholds for the rate of climate change – this is clear, for example, from the Article 2 directive that we should "allow ecosystems to adapt naturally". Too rapid a rate of change might preclude this. All three of the items above are important controlling factors for the rate of change.

For emissions, we must distinguish between no-climate-policy emissions scenarios and policy (i.e., climate stabilization) scenarios. In this presentation I will begin by considering no-policy scenarios, as defined by the Special Report on Emissions Scenarios (SRES). I will use a probabilistic approach to illustrate the range of uncertainty in global-mean warming accounting for uncertainties in emissions, the climate sensitivity, ocean mixing, the carbon cycle and aerosol forcing. Both magnitudes and rates of change will be considered.

I will then consider stabilization scenarios concentrating on the effects of CO_2. The primary CO_2 stabilization pathways in the literature are the WRE pathways, which follow smooth concentration trajectories to stabilization at different levels. Concentration stabilization raises two issues, how do we choose a stabilization level and what pathway should we take to stabilization.

I will use a probabilistic approach to determine the range of CO_2 concentration stabilization levels that would avoid dangerous interference. I define a dangerous threshold for global-mean temperature in terms of a probability density function. This is necessary because there is no single value for this threshold. What is deemed dangerous in one economic sector or geographical region may be far less consequential in another; and what is a dangerous change in one climate variable (such as precipitation) may occur in conjunction with an innocuous or even beneficial change in another (such as temperature). Furthermore, what is dangerous now may not be dangerous in the future, given that economic development generally reduces a society's vulnerability to climate change.

Next I will show how different stabilization pathways affect the magnitudes and rates of warming relative to each other and relative to the no-policy case. This analysis will consider both 'monotonic' pathways (where the eventual stabilization level is never exceeded) and 'overshoot' pathways. The latter may occur when an initial choice of stabilization level is found, at some future date, to be too high, requiring a mid-course correction to bring concentrations back down to a lower target.

5.2 Abrupt events, surprises: e.g. ENSO, THC, WAI

Stefan Rahmstorf gave a presentation on this topic at the meeting.

5.3 Regional-level climate changes

The following abstract was prepared for the meeting by Tim Carter and distributed to participants in advance.

Regional climate changes associated with key levels of impacts and vulnerability

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National policy-makers face a dilemma of scales in addressing the climate issue. They need to weigh the costs of reducing greenhouse gas emissions to limit global climate change against the costs of the impacts incurred by such changes. While the effectiveness of emissions policies can be judged globally using measures such as atmospheric greenhouse gas concentrations or global mean annual temperature change, policies designed to cope with the impacts of climate change are primarily regional in focus, requiring information both on projected regional climate changes and their likely impacts.

Until recently, climate policy has been dominated by discussion of mitigation targets to prevent or limit global climate change. With emerging recognition that climate change is already occurring, and continued change is inevitable, attention has shifted towards defining tolerable limits to climate change, within which unacceptable impacts can be avoided. At the time of the IPCC Third Assessment Report (TAR), efforts to define such limits focused on evaluating aggregate measures of climate change impact at the global scale. IPCC authors identified "five reasons for concern" about projected climate change impacts: (i) risks to unique and threatened systems, (ii) risks from extreme climate events, (iii) distribution of impacts, (iv) aggregate impacts, and (v) risks from future large-scale discontinuities. For each of these, the risks of adverse impacts from climate change at different levels of projected global mean annual temperature change from 1990 to 2100 were illustrated as coloured bars using a classification that ranged from white (little or no risk) through yellow and orange to red (high risk). However, while offering a useful device for illustrating potential global risks, the figure is highly generalised and offers little information for policy-makers operating at a regional scale. A similar observation can be made of several follow-up studies to assess aggregate global impacts of global mean annual temperature change.

This raises important questions for the IPCC Fourth Assessment Report (AR4) regarding the most effective methods of assessing scientific information on regional impacts and vulnerability to guide the policy community on what might constitute dangerous anthropogenic interference with the climate system. Five questions are posed below, along with a brief discussion of how they have been or might be treated.

1. *What is the most effective scale at which to undertake regional assessments?*

This issue has been a bone of contention throughout the IPCC process and regional integration is a separate cross-cutting theme in the AR4. Climate scientists tend to favour regional scales that equate with major climatic zones or circulation patterns, while socio-economic assessments and policy requests are for information more aligned with political boundaries. A compromise for carrying out systematic regional assessments is the continental scale, but with each continent sub-divided into major climatic zones. This was a model favoured in the TAR and in preparatory discussions for the AR4. Other regional options for identifying critical levels of climate change include specific localities or "hot spots" containing key indicators of climate change (e.g. mountain regions, coral reefs, Arctic) or delimiting systems that may be susceptible to abrupt change (e.g. N. Atlantic, W. Antarctic, Asian monsoon).

2. *What types of regional information can scientists provide to allow policy makers to judge which levels of climate change might be dangerous?*

Since the TAR here have been a number of efforts to identify critical levels of climate change with respect to regional impacts on natural systems and human activities. Three main approaches can be distinguished. One approach makes use of spatially explicit, global or regional impact models (e.g. for natural vegetation, runoff, crop production) to simulate potential impacts of climate change across a range of scenarios.

Response surfaces showing the sensitivity of an indicator to changes in climate variables can be constructed for different regions, and this information might assist policy makers in deciding at what level and/or rate of climate change the impacts become unacceptable, and hence what limits on climate change are desirable. Models are sometimes linked to energy/emissions models (e.g. in integrated assessment models), which are used to compute alternative emissions trajectories that would succeed in avoiding exceedance of the climate change limits – the tolerable windows approach. This approach is instructive for calculating emissions to achieve given targets, but is constrained in its ability to cover a wide range of indicators needed to judge the level of climate change producing unacceptable impacts..

A second approach is for alternative impact models to be run in parallel over the same region and time period for a consistent set of scenarios, with attention also paid to defining and projecting indicators of adaptive capacity. Results can then be summarised and/or combined using a standardised vulnerability index, which in turn might allow a judgement to be made on the tolerable limits of climate change. This approach is somewhat more flexible than the first approach, potentially embracing many different modelling methods and disciplines and not bound to a single model framework. However, it is still limited in its representation of the many potential dimensions of regional impacts.

A third approach is to make use of all available regional information on the potential impacts of climate change, to compile this in as consistent a manner as possible (e.g. by region, by sector and by indicator) and then to construct pseudo-response surfaces for a given indicator *versus* one or more measures of climate change. This work is laborious, but ultimately it could yield very valuable and comprehensive sets of alternative indicators of potential impacts for different regions. Such an exercise, if co-ordinated within and between regional chapters, seems eminently suited to the IPCC assessment process. Examples of efforts of this kind are already emerging in the literature, but an IPCC evaluation would have the advantage of being policy-neutral.

3. *How can we relate regional-scale climate changes, impacts and vulnerability systematically to measures of global climate change?*

The most widely adopted measure of global climate change is the global mean annual temperature (GMAT) change. It is the measure most commonly adopted to detect past and ongoing changes. It is also used extensively in global cost-benefit studies of climate change, commonly in association with different concentrations of atmospheric greenhouse gases. More recent attention has focused on the relationship between GMAT change and critical levels of global impact. If this idea is extended to regional impacts, the relationship between GMAT change and regional climate change needs to be established. Climate change at a regional scale can differ markedly from the global mean, as results from global climate models (GCMs) reveal. Moreover, the climate variables that have a dominant role in determining impacts may differ between regions and between indicators. Tools exist to relate the regional pattern of climate change from climate models to GMAT change through a technique known as pattern-scaling.

4. *How should we account for extreme climate events and singularities?*

The pattern-scaling method is most commonly applied to relate changes in mean regional climate (temperature and precipitation) to GMAT change. Less well understood are the relationships between GMAT change and changes in climatic variability and extreme climate events. Many important impacts of climate can be attributed to these phenomena, but results from climate models are sometimes contradictory or ambiguous about future trends in climatic variability. This is an area meriting greater attention by the IPCC, and new results from regional climate model inter-comparison studies, statistical downscaling exercises and associated regional impact studies may offer some guidance on how to account for variability and extremes in relation to GMAT change.

Singularities refer to large, rapid changes in components of the climate system that could have potentially major regional impacts but are currently thought to be of low probability (e.g. abrupt changes such as those described under question 1). The possibility of such events was highlighted in the TAR, but few results were available from studies seeking to assess the potential impacts of such events, in part due to a lack of credible scenarios to describe them. Some recent work that directly address such events may offer new insights for the AR4.

5. *How should we account for uncertainties in regional projections?*

All regional estimates of climate change and its impacts are subject to a range of uncertainties. Some of these uncertainties are inherent features of complex systems, while others hold promise of being narrowed with improved scientific understanding. New research is focusing on probabilistic methods of projecting future climate and risk assessment frameworks for assessing regional impacts.

The following is a summary of the presentation given at the meeting by Tim Carter.

Four key points

1. A systematic and comprehensive regional approach is essential for assessing key levels of impacts and vulnerability. An assessment by IPCC would be the most ‘policy-neutral’ environment in which to achieve this.

2. This issue is treated at a range of spatial scales in the literature, and there are interactions between scale, but as an organising principle for summarising this literature in AR4 there may be some sense in working at sub-continental scale.

3. It would be useful to be able to relate regional changes in climate, impacts and vulnerability to a global metric such as global mean annual temperature (GMAT) change. On the climate side, it would be useful to see to what extent trends in GMAT can be related both to changes in mean climate and in climate variability at a regional scale.

4. It is important that uncertainties in projections of impacts and any levels of key vulnerability that are identified, be accompanied by appropriate measures of uncertainty, either expressed as ranges or, if possible, in terms of risk.

5.4 Changes in South Asian monsoon

The following abstract was prepared for the meeting by Anil Gupta and distributed to participants in advance. Dr. Gupta also gave a presentation on this topic.

Abrupt changes in the Indian summer monsoon and their impact on climate and human societies in South Asia during the last 10,000 years

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The Indian summer monsoon affects climate and societies over a large part of Asia between 35°N and 10°S. Monsoon plays an important role in global hydrological and carbon cycles. Across the region, the effects of the monsoon are preserved in different proxies that include tree rings, soils, ice, lake deposits, peat deposits, cave deposits and marine sediments. Paleo proxies provide evidence of slow changes in the monsoon related to orbitally-driven changes in summer radiation, and also evidence of abrupt, millennial-scale events throughout the last 10,000 years.

Abrupt changes in the monsoon are documented in several papers recently published or are in preparation. Proxies include marine sediment records of the summer monsoon winds (Anderson et. al. 2002; Gupta et al., 2003), cave deposits that record precipitation in Oman (Fleitmann et al., 2003), peat deposits that indicate humidity and temperature (Hong et al., 2003), runoff in the Bay of Bengal (Kudrass, et al., 2001), sedimentation in the Northern Arabian Sea, and the N15/N14 ratio in Arabian Sea organic matter (related to the upwelling and the monsoon winds (Altabet, et al., 2002). Strong monsoon events had a potentially dramatic effect on the fluvial systems (Goodbred and Kuehl, 2000) and thus human populations in South Asia during the Holocene (past 10,000 cal years) (Gupta et al., 2004). Periods of weaker monsoon winds correlate with intervals of cold spells, called the Bond Cycles, in the circum-north Atlantic during the Holocene, providing evidence of a century-millennial scale link between low and high-latitude climate. The changes in the monsoon winds were accompanied by changes in rainfall over South Asia affecting the fluvial systems and thus fauna and flora of the region.

The origin of agriculture and domestication of animals in South Asia were linked to changes in the monsoon precipitation, which in turn would have driven the beginning of human civilizations in the region. As the monsoon weakened since ~5,000 cal yrs BP, the societies in India migrated to more productive areas and some may have developed mechanisms of adaptation to climate change (Pandey et al., 2003; Gupta et al., 2004). For instance, widespread evidence exists for the development of ponds, tanks, and artificial reservoirs during the late Holocene across India when the monsoon reached its Holocene minimum, and we find correlation between heightened historical human efforts for adaptation and the most recent minima in the monsoon winds that occurred during the Maunder Minimum (1600 AD). The monsoon record supports an emerging paradigm that at least in the tropics, the largest climate changes and societal responses were driven by changes in precipitation rather than surface temperature.

The evidence published so far provides important information on hydrologic change in the tropics. Current research is aimed at developing new proxies of changes in climate, vegetation, and land surface characteristics, and improving the initial time series with additional data to reduce uncertainty. Eventually, the paleo proxy time series need to be converted to quantitative measures of wind (or pressure) and rainfall in order to be most useful in the context of the AR4. It would also be valuable to integrate the paleo record with the instrumental record of all India rainfall, or other monsoon records, to extend the instrumental records farther back in time. These topics are currently being investigated by individual research groups as opposed to a coordinated research effort.

Testing hypotheses regarding the monsoon variability seen in the paleo record is an active research area that is rapidly growing. Indian Ocean Dipole and El Nino-Southern Oscillation (ENSO) have been implicated for interannual-decadal scale variability in the summer monsoon. However, the relation between ENSO and monsoon is not that strong as it has weakened over the last one century and a half (Kumar et al., 1999). Whether the weakening relation between ENSO and summer monsoon is linked to increased surface temperature over the past century (Mann et al., 1999) remains debatable. Variations in solar output have been suggested as the driver for century-millennial scale variations in Oman precipitation (Neff et al., 2001). Solar variations could influence the monsoon regime indirectly, perhaps amplified by the North Atlantic teleconnection, based on numerical simulations of North Atlantic cooling (Rind and Overpeck, 1993; Gupta et al., 2003). Alternately, solar variations could directly affect the land-sea contrast that drives the monsoon,

based on numerical simulations with reduced solar output during the Maunder Minimum (Shindell et al., 2001; Anderson et al., 2002). These papers indicate that the monsoon could be sensitive to relatively small changes in forcing (0.25% change in solar output, or a 2°C change in SST). Internal forcing caused by oscillations in North Atlantic northward heat transport/deep water production are an alternate explanation that excludes the role of insolation. A summary view of the current hypotheses attributes some of the variation in the monsoon during the past 10,000 years to small variations in solar forcing, and some variation to changes in the circum-North Atlantic region that have a down-stream effect on the monsoon. In this view, abrupt changes forecast for the North Atlantic region would translate to abrupt changes in the monsoon. Whatever are the reasons for these repeated changes, the increasing surface temperature could be a cause of worry for climate modellers as well as policy planners because as the global temperature will rise due to increase in greenhouse gases the summer monsoon may undergo sever and dramatic changes thus influencing the population and economy of the South Asian region that houses about 30% of the global population.

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5.5 Commentators summaries for days 1 and 2

The following comments were prepared at the meeting.

Henry David Venema, International Institute for Sustainable Development
Commentary for Buenos Aires Meeting, May 19, 2004

Very pleased to provide these comments in this forum, my comments largely reflect the linkage between climate change and sustainable development.

The global sustainable development agenda moved from the MEA focus of the Rio era (of which the UNFCCC is a prominent example) – to the poverty alleviation focus of the World Summit on Sustainable Development.

Indeed, one of the major insights from the WSSD Plan of Implementation (which we have referred to here as the WEHAB agenda) is that is that the world's poor are most heavily dependent on ecosystem services, and most vulnerable to deteriorating environmental conditions, worsened but not necessarily created by climate change.

With respect to the Integrated Assessment Modelling issues that comprises a large a chunk of our discussion, again I'm really pleased to note the support for the concept that of Human Well-Being interpreted as the Water-Energy-Health-Agriculture-Biodiversity should be a component of these comprehensive modelling approaches. The concept of critical thresholds on the WEHAB components, described by Schneider is useful:

- Type 1 – target values of smooth transitions in climate variables
- Type II - stability of intrinsic process, i.e. WAIS/THC stability

The key omission from a sustainable development perspective is that the primary vulnerability of the world's poor is not neither Type I or II, but rather exposure to high frequency extreme events, like droughts, floods and heat stress – which at some point exceeds their coping capacity.

The poverty alleviation agenda is then to buffer the most vulnerable from shocks and stresses, among which climate change is prominent. With respect to the primary focus of this gathering, Article 2, and KV, and particularly in light of Pingali's report from the FAO on the State of Food Insecurity in the World, the IPCC should review the literature regarding the possibility that DAI has already occurred for the most vulnerable members of the human community. Essentially the possibility emerges that DAI is a region-specific function with thresholds, and we may beyond the threshold for the most vulnerable.

I am nonetheless heartened by the modelling community belief that essentially key HWB elements can be practically modelled as disaggregated impact and threshold studies for the various WEHAB components. The papers on water resources and food security suggest that these thresholds may be knowable in the case of Water and Agriculture dimensions of WEHAB. For the Health and Biodiversity components of WEHAB, the prospects are for a clear identification of key vulnerabilities and associated thresholding is decidedly less clear. In fact the papers reveal that although conceptual frameworks are sound and some strong empirical research is available, we are only starting to unpack the web of impact pathways and vulnerabilities.

We did have the excellent suggestion emphasized, by Drs. Romero and Yamin that vulnerabilities be explored from a bottom-up perspective; essentially having the vulnerable assist in the identification of their vulnerabilities, including through the outputs of the NAPA process. Including the narratives of the vulnerable more consistently should reveal the social determinants of vulnerability more clearly. A curious omission in the larger discussion of the WEHAB agenda is the "E" Energy (although it was mentioned briefly by Youba Sokona, and this morning by Ogunlade Davidson) – I believe the issue of rural energy deprivation is a key vulnerability and a huge and largely unexplored territory for adaptation/mitigation synergies – unlike most of the integrated discussion of M&A, occurs at the same scale.

More generally, it appears that the WEHAB components of HWB will be addressed individually, primarily because most, though not all of the literature is organized as such, and for the time being this is practical. I must note however that this does deviate somewhat from the spirit of the WSSD plan of implementation, which conceived of these elements not as sectors but as a landscape mosaic of assets that exists locally (a concern which foreshadows the gap of IAM – the lack of highly resolved landuse and landscape ecology models

Steve Schneider observes that the WEHAB elements have monetary and non-monetary dimensions and we will therefore need some kind of weighted, multi-attribute accounting system for numeraire aggregation – that ensures transparency in this ultimately normative valuation exercise. Unfortunately, his very lucid stochastic IAM approach for DAI analysis is based on an ad-hoc assembly of key concern metrics in the burning embers diagram, which may foreshadow the inherent difficulty of ensuring this transparency.

Ultimately though, I'm keeping the faith with the IAM community. It acknowledges its large shortcomings, which prominently include a valuation methodology (that somehow must account for the inability of the world's most vulnerability to express their WTP to avoid impacts). The IAM enterprise will, however, continue to reveal insights, if not answers, and I agree strongly with Dennis Tirpak's call for the IPCC to be bold (but not reckless) in calling for the required database products and tools consistent with the required level of IAM sophistication.

Enthusiastic about the prospect for IAMs, noting the following concerns:

1. Unresolved issues regarding valuation
2. No representation of extreme/discontinuities – probably not possible unless IAMs are actually embedded in GCMs
3. Although we have Martin Parry's illustration of alternative metrics, we don't have an unambiguous cross-sectoral or spatial aggregation strategy yet.

4. We have Hadi Dowlatabadi's concerns about the fundamental and irresolvable uncertainties; we may in fact have a fractal problem, the more resolution that you attempt, the more complexity emerges – revealed by the lack of specific thresholds.
5. Jan Corfee-Morlot's discussion of outstanding M benefits, and A costs is extremely important as is the still mostly unacknowledged issue of deep A+M co-benefits in the Energy component of the WEHAB agenda. Also her comments on the need for standardized design or post-processing of IAM is important for risk-based decision-making.

[What has only been mentioned in passing, is a deeper integration of modelling foundations with the MEA; what will differentiate the climate analysis community will be the more analysis of appropriate driver scenarios, and what will distinguish the MEA community is more emphasis on ecosystem-level adaptation dynamics.]

IPCC should also recognize the possibility that DAI will remain weakly defined and locally/regionally determined, which means that when local decision maker's reach their enough is enough point, the IPCC should have a large palette of demonstrated adaptation (or as Nobuo Mimura might say synonymously SD) options to chose from, which speaks to (and I believe that this is consistent with Dr. Pachauri's message) a stronger linkage with the development literature that reflects capacities for resilience to CC (among other stresses). I think that a stronger linkage with the development literature is inevitable, particularly given Martin Parry and colleagues work that illustrates that the development trajectory has at least as much influence on impacts than the actual climate drivers.

Commentators notes by Hans von Storch were given in the form of a presentation.

5.6 Rapporteur's summary

Session 4: Climate change associated with key levels of impacts and vulnerabilities (Tuesday 18 May), Chris Sear

This session enabled us to consider the causes, effects and uncertainties of global and regional climate change, with four informative and erudite presentations and interesting and stimulating discussions.

Tom Wigley explained how we might go about choosing stabilisation targets, some pathways to get there and some of the issues surrounding these policy choices; whilst Stefan Rahmstorf helped us think about the nature of some possible abrupt changes and possible thresholds, leading us to think about the concept of 'lowest acceptable risk', not just globally but regionally. Then, Tim Carter raised the thorny issue of uncertain regional futures in a warmer world and encouraged us to consider how we might undertake better regional assessments. Finally, Anil Gupta provided a very comprehensive exposition of the nature and history of the South Asian Summer Monsoon, a supra-regional phenomenon with a reach that includes perhaps 30% of global population. This led us to consider again the human dimension in respect of climate history, variability and 21st century change.

This was an extremely rich session and I have noted some of the points made by the speakers, interspersed with some discussion highlights (indicated by use of italics).

While we learned that a no-policy route might give us between two and eight times 20th century warming during this century, we also learned that there may be a residual probability of approximately 3% that global temperature will stabilise without any intervention. Sea level rise can't be stabilised through CO_2 stabilisation, however; it will continue for hundreds of years. *In response to a discussion question, Tom suggested that TAR sea level rise projections are now seen as underestimates and further discussion centred on the validity of setting especially low temperature or sea level targets when some may already be impossible to achieve.* Tom then posed the question: "what might be appropriate CO_2 stabilisation pathways?" It seems though from recent work that there is perhaps a 17% probability that the CO_2

stabilisation threshold is ***lower*** than the current atmospheric concentration. A second key question addressed was: "Can the target CO_2 concentration be relaxed (and mitigation delayed and / or mitigation costs reduced through adaptation and by reducing emissions of other gases) and yet still allow us to reach acceptable futures?" Tom showed us some pathway analysis, including overshoot pathways and mid-course corrections using analysis of PDFs. An example of a possible overshoot pathway is to go for 550ppm until 2030 and then correct in mid-course and go for 440ppm after that. A general conclusion from this type of analysis is that overshooting would give us more time but we'd need to consider now what (if any) key thresholds might be overtopped in the interim. *It seems that PDFs are useful as they can express both the complexity of concept of dangerous interference and also the uncertainty in determining thresholds for dangerous interference. Considering priority ways to reduce uncertainty during discussion, Tom suggested that uncertainties concerned with climate sensitivity are still dominant and that while the level has decreased somewhat since the FAR, there is little prospect of up-coming rapid reductions in uncertainty – we are going to have to live with uncertainty for some time to come but we might be able to reduce uncertainty for some specific issues*. Another concern Tom's work highlighted was that pathway control through policy might significantly increase rates of temperature change in coming decades. Tom's conclusion was that we need to make an early decision on what global targets should be.

Stefan Rahmstorf eloquently reminded us that abrupt climate change (significant change on decadal time scales) is part of the Earth's recent history and by way of 'entertainment', possibly also part of our near future! He reviewed some TAR conclusions and asked whether abrupt changes may come within this century that may exceed some 4 or 5^{o}. He outlined some examples of plausible causes of such abrupt 21^{st} century change and concentrated on two: reduction in the strength of the North Atlantic Thermohaline Circulation (THC); and breaking-off and melting of major Antarctic ice shelves and increased ice stream flow rates, leading to destabilisation of the West Antarctic Ice Sheet (WAI). Stefan stressed the process and modelling uncertainty that currently reduce our confidence in forecasts of the likelihood of these and other plausible abrupt changes, as well as our understanding of the global effects if such changes occur. *In response to questions, he suggested that understanding WAI-relevant Antarctic science and modelling improvements would be slow and steady over the next decade and not likely to show any imminent dramatic improvement. A similar logic would apply to THC and other similar issues of abrupt change*. Stefan concluded by posing the key policy questions: "What is an unacceptable risk?" (or alternatively: "What level of risk of abrupt change are we willing to accept?") He reiterated that non-linear responses of the climate system make it very difficult to predict whether one of more of these abrupt changes will occur and thus make current best-guess scenarios inadequate to address this issue; adding greatly to policy uncertainty. *From the floor it was stressed that our incomplete understanding of Antarctic science evinces the continuing need for observations as the key to understanding processes relevant to climate change. A suggestion was made that WGII might generate some 'indicators for significant thresholds'. However, it was seen as debatable whether this last suggestion is do-able. Finally, a suggestion was made that (in view of the large uncertainties associated with plausible extreme events and abrupt changes) couldn't the Precautionary Principle be employed to set bounds for 'lowest acceptable risk'*.

Tim Carter was tasked with considering for us some regional climate changes and he asked how we might move from global to regional assessment with respect to key vulnerabilities. He looked at five research questions concerning: scales and divisions; information available; scaling down from global to regional; singularities; and uncertainties. For the first of these, Tim listed some possible ways of splitting up the world: by continents; by WMO regions; by watersheds; by nation; by climate zones; etc.; or perhaps pointing to 'hot spots' with particular sensitivities; and he suggested some of these possible hot spots. He stressed that 'Burning Embers' type diagrams do not give us regional scale impact sensitivities and he queried how we can provide traceable accounts of essentially qualitative methods and how we might best quantify vulnerability.

Tim provided some suggestions for how we might work regionally, including using integrated assessment modelling, mixed modelling (running sectoral models in parallel), and bottom-up (multi-source) analyses with expert assessment; but he stressed how much time and effort the last of these takes. *The question of* *appropriate scales for integrated assessment was taken up from the floor and it was thought that IA work might be undertaken through nesting so as to capture as much information as possible and thus to tease out as much up-scale and down-scale coherence as possible. An example of an attempt at this was the Millennium Ecosystem Assessment. Further discussion suggested, however, that such cross-scaling might be very difficult to achieve, as scale and impact severity are intertwined and yet apparently pre-determined by individual studies. A strong comment was made that the* ***right*** *scale is* ***that which fits the data, research aims and required outputs****. It is important that assessment is not constrained or forced by climate modelling priorities.* Tim suggested that for AR4, WGII may be able to generate policy-neutral integrated assessments, leading to normative targets. He also asked whether we might be able to provide TAR-type confidence and likelihood estimates at a regional level whilst being able to account for uncertainties at this scale and yet remain policy-neutral?

Finally, Anil Gupta expounded on the scope and history of the South Asia Monsoon system. He suggested that the system may be as old as 8 to 10 million years and brought us up to date by noting that there were large changes in its amplitude throughout the Holocene and probably before, that there were century scale variations during the past millennium, and finally that there is considerable evidence that the strength of the monsoon system has increased over the past two centuries. The complexity of the monsoon system, our incomplete understanding of its drivers, its wide reach and importance to billions of people, all ask AR4 authors a lot of questions and this sparked a lively discussion. Anil stressed that it is most difficult to forecast the strength of the monsoon, year by year *and this led to questions and comments from the floor as to whether monsoon strength changes are associated with changes in the frequency or severity of extreme events. It was noted that forecasting changes in variability is very difficult and also that past history and the human condition are not always good analogues for possible geophysical or human futures. This generated a lively concluding debate.*

6 Emissions and concentrations leading to reduced climate change

6.1 The literature on 'plausible targets'

The following abstract was prepared by Brian O'Neill for the meeting and distributed to participants in advance.

The literature on "plausible targets"

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Extended abstract prepared for IPCC Expert Meeting on the science related to Article 2, session on "Emissions and concentrations leading to reduced climate change",

Beginning before the signing of the UN Framework Convention on Climate Change, a variety of targets serving as long-term climate change goals have been proposed. While there have been relatively few studies explicitly arguing whether achieving particular targets is plausible or not, there is a substantial body of literature that explores, in more generic terms, the conditions under which various targets might be met. After briefly reviewing the types of targets that have been proposed, I review assessments of emissions/concentration pathways required to meet such targets, and mitigation scenarios aimed at achieving them. I propose a set of principal characteristics that could be used to judge plausibility of scenarios meeting various targets, which include technical feasibility, several dimensions of costs, burden sharing assumptions, political and institutional implications, and the degree of certainty with which the target is to be met. Plausibility is a subjective judgment, but mitigation analyses that clearly articulate characteristics along these dimensions can provide valuable input to any such assessment. A particularly important case involves assessing which climate targets may be implausible already, and which may become so over the next decade or two. Progress on targets and their plausibility would be facilitated by additional analyses of long term, multi-gas (rather than CO_2-only) mitigation scenarios, closer attention to equity considerations, and wider accounting for uncertainties that can strongly affect the feasibility of reaching a target.

What types of targets have been considered?

While Article 2 itself includes a target specifically in terms of "stabilization of greenhouse gas concentrations", a variety of types of targets have been proposed, both before and after the Framework Convention, aimed directly or indirectly at avoiding dangerous interference with the climate system (see Oppenheimer and Petsonk, 2003, for a review, including many additional references to examples). These include: sea level rise (e.g., Barnett and Adger, 2003); levels of temperature change (e.g., Rijsberman and Swart, 1990); rates of temperature change (e.g., WMO, 1988); atmospheric concentration levels (e.g., Azar and Rodhe, 1997); medium-term emissions targets (e.g., Corfee-Morlot and Höhne, 2003); and activity based targets (Pershing and Tudela, 2003). In addition, I describe a new proposal (O'Neill and Oppenheimer, in preparation) for an interim concentration target, in terms of equivalent CO_2 concentration, that could be designed to constrain the rate of climate change while also keeping open the option of achieving a relatively low ultimate stabilization level.

What concentration and emissions pathways are associated with these targets?

One body of literature has focused on exploring the range of concentration and emissions pathways that might meet various targets. The CO_2 stabilization pathways from IPCC (1995; "S" pathways) and from Wigley et al. (1996; "WRE" pathways) are well known cornerstones. The WRE pathways demonstrate that achieving stabilization does not necessarily require immediate emissions reductions relative to a reference scenario, at least from the carbon cycle point of view, and especially for stabilization levels of 550 ppm or above (Wigley, 2004). The Tolerable Windows Approach (TWA; Toth, 2003) is a broader framework for deriving corridors of emissions or concentration pathways that would achieve a given target (or a number of targets considered simultaneously). Since the approach allows constraints on factors such as mitigation costs that are important aspects of plausibility, it can be a particularly useful approach for investigating feasible mitigation pathways. More recently, analysis has expanded the range of stabilization scenarios to include pathways that follow a wider range of reference scenarios before emissions reductions begin, reach given stabilization levels at a wider range of dates, include non-CO_2 gases, and overshoot long term targets before ultimately returning to them (Wigley, 2004; O'Neill and Oppenheimer, 2004). The consequences of delay have been analyzed in additional detail and coupled with uncertainty in the strength of terrestrial carbon sinks. For example, O'Neill and Oppenheimer (2002) argue that stabilizing at 450 ppm may become implausible if emissions reductions are delayed until 2020 or later, particularly if reference emissions increase substantially before 2020 and carbon cycle sink strength turns out to be weak. Wigley (2004) argues that overshoot pathways may make some stabilization targets more plausible by easing mitigation costs, although the benefits of avoided climate change would also be reduced (an issue explored in more detail by O'Neill and Oppenheimer, 2004). Finally, the fact that stabilization scenarios for 350 CO_2 were included in the IPCC Second Assessment Report but excluded from the Fourth Assessment Report may be seen by some as a judgment on the plausibility of this target.[1]

How can plausibility be judged?
The plausibility[2] of meeting any particular target is, except in extreme cases, a subjective judgment. However, scenarios exploring what it would take to meet any particular target can be useful input to such judgments. There are a number of characteristics of such scenarios that are especially relevant to plausibility.

Technical feasibility. Whether mitigation scenarios involve plausible assumptions (implicit or explicit) about the availability of advanced technologies has been a key point of contention. For example, Hoffert et al. (2002) argue that the post-SRES mitigation scenarios published in the TAR (Morita et al., 2001) suffer from "misperceptions of technological readiness", and that stabilization of CO_2 at levels of 550 ppm or below is not possible with existing, operational energy sources. In contrast, authors of the chapter argue that current technologies, combined with energy efficiency improvements and non-energy measures, can be developed and deployed fast enough to stabilize CO_2 levels (Swart et al., 2003). In particular, feasible scenarios for stabilization at relatively low levels require significant mitigation over the next several decades, before radically new energy technologies are likely to be widely available (O'Neill et al., 2003; Swart et al., 2003). Other studies test the technical feasibility of relatively low stabilization levels by developing model-based scenarios exploring in detail how stabilization at such levels might be achieved. Several early analyses supported the technical feasibility of limiting CO_2 to less than 550 ppm or below (Ishitani et al. 1996; Nakicenovic, 1995; Lazarus, 1993). More recently, Nakicenovic and Riahi (2003) analyze stabilization at 400-450 ppm CO_2, in some cases including constraints on some sources of zero-carbon energy sources such as nuclear, biomass, and carbon sequestration. Azar et al. (2003) develop a scenario that relies heavily on biomass energy with CO_2 capture and storage (BECS) to achieve stabilization at 350 or 450 ppm, finding that BECS technologies create the option of removing carbon from the atmosphere, making stabilization even at the level of 350 ppm feasible (see also Obersteiner et al. 2001, 2002).

Costs. Achieving particular goals might be technically feasible but prohibitively expensive. A number of dimensions of costs are relevant: aggregate costs over time and regions, costs to particular regions or countries, costs at particular times (e.g. peak costs), costs to particular sectors. The TAR (Synthesis Report; see also Swart et al., 2002) concluded that costs rise substantially for CO_2 stabilization levels below 550 ppm. Constraining the rate of climate change also typically implies higher costs (e.g., Manne and Richels, 2001; see also EMF-21 in progress). The question of what constitutes an implausibly "high" cost is contested. Azar and Schneider (2002) argue that costs typically cited as implausibly high can also be seen as minor adjustments relative to projected income growth over the next century. Costs are also conditional not only on the climate change goal, but also on the socio-economic and technological development pathway. High emissions baseline scenarios (particularly the SRES A2 and A1FI storylines) are associated with higher mitigation costs for achieving a given stabilization level. Technical feasibility associated with different

[1] For example, Swart et al. (2002) assert that for stabilizing at 350 ppm CO_2, "the socio-economic and political feasibility of such a scenario is generally considered to be extremely low".
[2] The term "plausible" has two shades of meaning: (1) apparently reasonable, or capable of being believed, as in a "plausible story"; and (2) likely but not certain. I use the first definition, which suggests dividing scenarios for meeting particular targets into two categories: plausible and implausible. The second definition can be seen as making a finer distinction between degrees of likelihood.

scenarios is particularly important to cost outcomes. For example, Roehrl and Riahi (2000) show how costs of meeting various CO_2 thresholds depend critically on assumptions about the availability of mitigation technologies across variants of the SRES A1 storyline.

Equity. Mitigation scenarios may have implications for the distribution of impacts or of mitigation costs across countries, socio-economic groups, or other sub-populations that would affect plausibility. For example, a scenario may require mitigation burdens in some regions that are too large or too early to be politically plausible. Many studies do not address this issue, instead assuming perfect markets in emissions reductions that encompass all regions of the world at all times (i.e., complete where and when flexibility), and that reductions are made (and paid for) by region according only to economic efficiency criteria (e.g., Nordhaus and Boyer, 2000). However, perfect markets may be implausible given institutional barriers and, even if they were plausible, allocation schemes for emissions rights may imply financial flows that are unlikely to be acceptable to particular regions. There is an extensive literature on the evaluation of alternative allocation rules; while much of it focuses on allocation of emissions rights in the short term, many also explore consequences in longer term scenarios (e.g., Leimbach, 2003; Klepper and Springer, 2003; Shukla, 1999; Rose et al., 1998), including an ongoing assessment of the Brazilian proposal on using historical responsibility for climate change as an allocation rule (Höhne et al., 2003).

Political/Institutional. Scenarios may require substantial political will to sustain large investments in mitigation technologies, research and development, etc., in different regions of the world. This political will may be challenged by high costs, but other factors such as public acceptance of the target, and of the perceived equity of any mitigation strategy, may be important as well. Dowlatabadi (2000) emphasizes that political will may be susceptible to failure on a regional basis, threatening the success of global agreements, and analyzes quantitatively the likelihood of successfully achieving a target of 2 C warming given this risk of unacceptability. In addition, scenarios in which little policy action is taken in the near term, but then policymakers are assumed to respond quickly to new information, may be implausible due to institutional inertia and the time required for institutional learning (Nordhaus, 2001).

Uncertainty. Incorporating uncertainty into the question of the plausibility of meeting particular targets is essential. Meeting targets with certainty may be implausibly expensive (Dowlatabadi, 2000), whereas if some risk of exceeding a target is acceptable, the task may become substantially less difficult. A few studies have proposed a framework for decision in making that explicitly include assessing the probability of crossing impact thresholds (Jones, 2001; Mastrandrea and Schneider, 2004). In addition, costs themselves are uncertain, so plausibility assessments based on anticipated costs must take this into account.

What broad conclusions emerge from this literature?

1. Analyses of alternative atmospheric pathways to stabilization suggest that decisions about when to reach stabilization, and whether to overshoot the ultimate stabilization level, have implications for climate change outcomes that may be significant in terms of the risk of dangerous interference.
2. Characterizing scenarios aimed at achieving particular long-term goals along several dimensions, rather than costs alone, can aid in assessing plausibility.
3. Recent analyses indicate that the question of which stabilization levels are plausible, and under what conditions, is an area of active debate. In particular, there is no clear consensus in the literature that stabilizing CO_2 levels below a doubling of pre-industrial levels is implausible.
4. While attention is beginning to shift toward analyses of multi-gas targets and emissions reduction strategies (e.g., Manne and Richels, 2001; EMF-21), the preponderance of literature is on CO_2 targets, or on CO_2-only mitigation strategies. Conclusions regarding plausibility of various targets may change when multiple gases are considered, particularly for rate of temperature change constraints. The recent EMF model comparison analyzing multi-gas stabilization at 4.5 W/m^2 should be an important input into this topic.
5. More work is needed on developing plausible scenarios of burden sharing for meeting various long-term targets.
6. Judgments of the plausibility of meeting various targets must account for the uncertainty inherent in whether a given mitigation strategy will achieve the desired environmental outcome, as well as the uncertainty in the various characteristics of the mitigation strategy discussed above, including costs.
7. A useful contribution of AR4 would be to systematically assess the conditions under which various stabilization levels might be met. Such an assessment could be used as input to judgments about plausibility, but perhaps more importantly would inform discussions of appropriate climate policies that also take into account benefits of avoided damages associated with various stabilization levels.

The following is a summary of the presentation given at the meeting by Brian O'Neill.

Key summary points from the literature on "plausible targets"
Brian O'Neill, May 20, 2004

1. Analyses of alternative atmospheric pathways to stabilization suggest that decisions about when to reach stabilization, and whether to overshoot the ultimate stabilization level, have implications for climate change outcomes that may be significant in terms of the risk of dangerous interference. Thus attention should not focus solely on the stabilization level, but also on the path to any given stabilization level.
2. Characterizing mitigation scenarios aimed at achieving particular long-term goals along several dimensions, rather than costs alone, can aid in assessing plausibility. In particular, useful dimensions include technical feasibility, various dimensions of costs beyond aggregate global costs, equity considerations, political/institutional factors, and the degree of certainty with which a target should be achieved.
3. While attention is beginning to shift toward analyses of multi-gas targets and emissions reduction strategies, additional work in this area would be highly desirable. Conclusions regarding plausibility of various targets may change substantially when multiple gases are considered, particularly for rate of temperature change constraints.
4. A useful contribution of AR4 would be to systematically assess the conditions under which various stabilization levels might be met. Such an assessment could be used as input to judgments about plausibility, but perhaps more importantly would inform discussions of appropriate climate policies that also take into account benefits of avoided damages associated with various stabilization levels.

6.2 The literature on the array of stabilization pathways

The following abstract was prepared for the meeting by Mikiko Kainuma and distributed to participants in advance. Dr. Kainuma also gave a presentation on this topic at the meeting.

The Literature on the Array of Stabilization Pathways
Mikiko Kainuma, National Institute for Environmental Studies
Abstract

The major efforts that consolidate the current knowledge about stabilization pathways are the Post-SRES and EMF21 studies involving several international modelling teams. These studies analyze policy and technology options for achieving certain stabilization targets, corresponding impact on economy, energy and other indicators, and their region-wise characteristics.

Nine Integrated Assessment modelling teams engaged in analyzing Post-SRES options for stabilizing atmospheric CO_2 concentrations at 450-750 ppmv by 2150 under six different developmental paths. These developmental paths represent different attitudes of the world toward globalization vs. regionalism and economic growth vs. environmental protection, and capture these differences in their assumptions about future trends in socio-economic drivers like population, economic growth, technological progress, energy supply, and agricultural land-use. Major findings of this stabilization study can be summarized as follows:

(i) Different developmental paths (baselines) require different technology and policy measures for achieving same levels of stabilization of CO_2 concentration, and show different costs of mitigation due to difference in the amount of required reduction (Fig.1). Thus CO_2 emission trajectories for stabilization are influenced by baseline scenarios.
(ii) A portfolio of multiple measures is necessary for timely development, adoption and diffusion of desired mitigation options. Policy integration across different technologies, sectors and regions is the key.

(iii) The robust technology and policy options across different carbon mitigation scenarios include (a) continuous energy efficiency improvements, (b) afforestation, (c) introduction of low-carbon energy especially natural gas in early 21st century and biomass over next hundred years, (d) technology innovations like gas combined cycle with carbon removal and storage; hydrogen fuel cells; solar photovoltaics; solar thermal power; advanced nuclear technologies; biomass integrated gasification power plants; high temperature fuel cells; and scrubbing technologies.

(iv) Known technological options can potentially stabilize CO2 concentrations in the range of 450-500 ppmv over the next 100-150 years; However, associated socio-economic and institutional changes are necessary to realize this potential in practice.

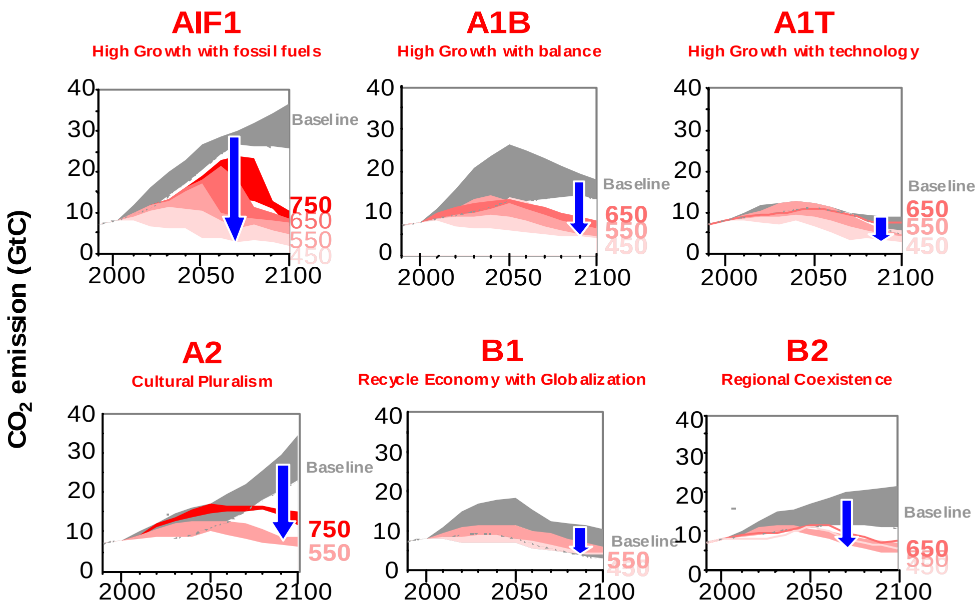


Fig.1 CO_2 stabilization under different baseline scenarios

EMF21 Working Group, organized by John Weyant and Francesco de la Chesnaye, conducted a comprehensive multi-gas policy assessment for long-term GHG mitigation using eighteen models. Two policy scenarios – one focusing on CO_2 mitigation only and the other covering multi-gas mitigation – to stabilize radiative forcing at 4.5 W/m^2 by 2150 relative to pre-industrial times were analyzed. Under reference scenario, different models indicate an increase in average global surface temperature of 2.8-3.8 ^oC by 2100 relative to pre-industrial times. This reduces to 1.8-3.0 ^oC in case of policy scenarios.

While the policy scenario results for atmospheric CO_2 concentration from different models show stabilization within 450-550 ppmv range by 2100, those for atmospheric methane concentration show a wide variation (1190-3350 ppmv by 2100). However, all models show that the amount of CO_2 reduction required in case of 'CO_2-Only Abatement' is more than that in case of 'Multi-gas Abatement' policies to achieve same stabilization target. Thus the carbon permit price in case of 'Multi-gas Abatement' is less than that in case of 'CO_2-Only Abatement' policies (Fig.2).

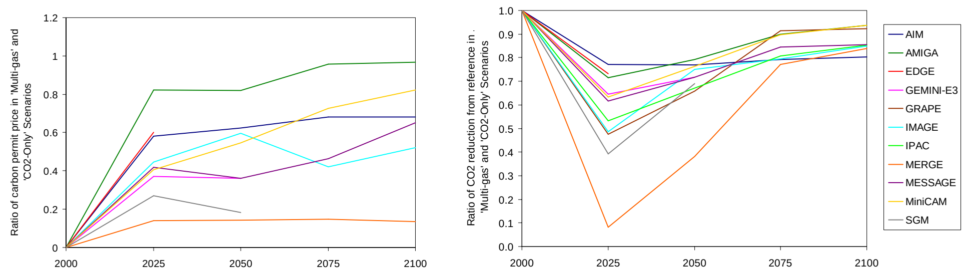


Fig.2 Comparison of 'Multi-gas' and 'CO_2-Only' abatement policies

Current knowledge on mitigation scenarios and technological options for mitigation in various energy supply and demand sectors is contained in chapters 2 and 3 respectively of Contribution of WG III to Third Assessment Report of IPCC, Climate Change 2001: Mitigation. Mitigation options relating to land-use and C sequestration are outlined in chapter 4 of the report.

Key gaps in the knowledge on stabilization can be summarized as follows:

(i) Design and efficacy of policy instruments leading to CO_2 mitigation has not been analyzed comprehensively. Though adequate literature on CO_2 emission scenarios and mitigation potential of specific options is available, a systemic analysis of policy measures needed to materialize the options is still a challenge.

(ii) The results of different models for Non-CO_2 GHGs vary widely because of inadequate coverage of Non-CO_2 sources, especially agriculture, and less reliable estimation of abatement options and technical change of those options in the long run.

(iii) Estimates of C sink and emissions from deforestation are uncertain and show high regional variability. This is because magnitude of forest regeneration and degradation processes is not well documented, and understanding of the phenomena of changes in land-use, land management, and the environment is inadequate. Understanding the future C stocks; C sequestration options and their costs and benefits; causes of the complex phenomenon of land-use change; and effects on deforestation and C emissions are key research gaps.

In the coming years GHG mitigation research is likely to witness greater exploration of policy instruments for realizing CO_2 mitigation options; uncertainty in scenarios; country level scenarios and mitigation options especially for developing countries; stabilization of CO_2 at levels other than 550 ppmv; scenarios and mitigation options for Non-CO_2 GHGs and particulates; and linkages between sustainable development and climate change objectives.

Land-use change and C sequestration are likely to be among the other thrust areas of future developments. Greater multi-disciplinary research, covering statistical, ecological and socio-economic modelling approaches, would enhance the knowledge of dynamics of land-use change and C sinks, their relation to human activities and natural disturbance, and costs and benefits of mitigation options.

Moreover, increased collaboration between emissions and impacts researchers is expected. This would enable more integrated assessment of mitigation and adaptation strategies and trade-offs.

6.3 Information on related development, demographic and governance futures

The following abstract was prepared for the meeting by Wolfgang Lutz and distributed to participants in advance.

Uncertain Demographic Futures, Human Capital Formation and Their Possible Effects on Vulnerability

Wolfgang Lutz, International Institute for Applied Systems Analysis, Laxenburg, Austria

While the 20th century was the century of population growth – with the world's population increasing from 1.6 to 6.1 billion – the 21st century is likely to see the end of world population growth and become the century of population aging. At the global level the proportion above age 60 is likely to increase from currently 10 percent to between 24 and 44 percent (95 percent interval) by the end of the century. Unlike 10-20 years ago, rapid global population growth no longer seems to be in our future; we are likely to see the end of world population growth during the course of this century. These massive changes in demographic structure will have far reaching consequences for health, social and economic development and even for the environment. With respect to climate change this changing demographic outlook has implications for both the drivers of emissions as well as for the vulnerability of populations to the consequences of climate change.

1) New population outlook

In 2001 IIASA published a new set of probabilistic world population projections for 13 world regions.[3] The methods and the substantive reasoning for the various assumptions are extensively described in Lutz et al. (2004).[4] The medium variant of the most recent UN long range projections[5] is very close to the IIASA median, but the UN does not consider mortality and migration uncertainty and therefore does not provide a quantitative assessment of uncertainty. The table below summarizes the current assessments about the uncertainty of future demographic trends.

2) The future of human capital formation, vulnerability and governance

Recently demographic methods have been developed that allow the projection of the educational composition of the adult population. While changes in school enrolment typically affect only the young population, it will take decades to significantly change the structure of the labour force by level of education (see illustration in figure below). Also, since women with different levels of education tend to have different average family sizes, the changing educational composition has direct implications for demographic change. **More importantly, improvement in the human capital base of a society tends to be an important (necessary but not always sufficient) prerequisite for economic growth, reduced vulnerability and improving governance.** While there are straightforward quantitative tools for projecting human capital by age and sex, the effects of these improvements on vulnerability and governance are more complex and have been less well studied (except for the literature on the effects of human capital formation on economic growth rates). Given the weakness of other indicators of society's adaptive capacities, particularly when it comes to forecasting such capacities, the rather easily projectable educational structure may represent a most useful quantitative indicator.

Recently the IIASA/IUSSP/UNU Global Science Panel on Population and Environment conducted a major survey of work in this field and stressed in its concluding policy statement:

"Policy must account for differential vulnerability within populations. Deteriorating environmental conditions and extreme events do not affect all countries, populations, or households in the same way. Even within a household, the effects may differ by age and gender. Consideration of vulnerability must therefore focus not only on countries but also on the most vulnerable segments of the population within countries.
Many factors contribute to vulnerability, including poverty, poor health, low levels of education, gender inequality, lack of access to resources and services, and unfavourable geographic location. Populations that are socially disadvantaged or lack political voice are also at greater risk. Particularly vulnerable populations include the poorest, least empowered segments, especially women and children. Vulnerable populations have limited capacity to protect themselves from current and future environmental hazards, such as polluted air and water and catastrophes, and the adverse consequences of large-scale environmental change, such as land degradation, biodiversity loss, and climate change.

Vulnerability can be reduced by promoting empowerment, investing in human resources, and fostering participation in public affairs and decision-making."

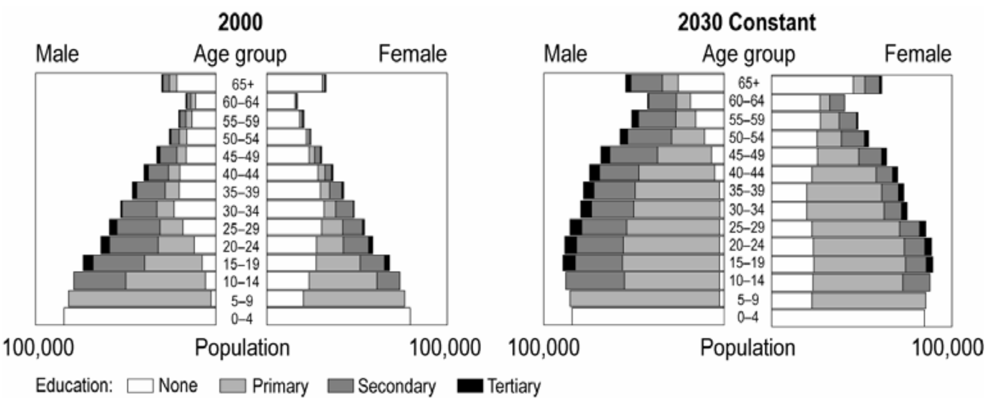
[3] Lutz, W., W. Sanderson, and S. Scherbov. 2001. The end of world population growth. *Nature* 412: 543–545.
[4] Lutz, W., W.C. Sanderson, and S. Scherbov, Eds. 2004. *The End of World Population Growth in the 21st Century: New Challenges for Human Capital Formation and Sustainable Development*. London: Earthscan.
[5] United Nations. 2003. *World Population in 2300. Highlights*. ESA/P/WP.187. Draft. New York: UN.

Table 1. Forecasted population sizes and proportions over age 60

	Median world & regional population sizes (millions)					Share of population over 60		
Region	2000	2025	2050	2075	2100	2000	2050	2100
World total	6,055	7,827 (7,219–8,459)	8,797 (7,347–10,443)	8,951 (6,636–11,652)	8,414 (5,577–12,123)	0.10	0.22 (0.18–0.27)	0.34 (0.25–0.44)
North Africa	173	257 (228–285)	311 (249–378)	336 (238–443)	333 (215–484)	0.06	0.19 (0.15–0.25)	0.32 (0.23–0.44)
Sub-Saharan Africa	611	976 (856–1,100)	1,319 (1,010–1,701)	1,522 (1,021–2,194)	1,500 (878–2,450)	0.05	0.07 (0.05–0.09)	0.20 (0.14–0.27)
North America	314	379 (351–410)	422 (358–498)	441 (343–565)	454 (313–631)	0.16	0.30 (0.23–0.37)	0.40 (0.28–0.52)
Latin America	515	709 (643–775)	840 (679–1,005)	904 (647–1,202)	934 (585–1,383)	0.08	0.22 (0.17–0.28)	0.33 (0.23–0.45)
Central Asia	56	81 (73–90)	100 (80–121)	107 (76–145)	106 (66–159)	0.08	0.20 (0.15–0.25)	0.34 (0.24–0.46)
Middle East	172	285 (252–318)	368 (301–445)	413 (296–544)	413 (259–597)	0.06	0.18 (0.14–0.23)	0.35 (0.24–0.47)
South Asia	1,367	1,940 (1,735–2,154)	2,249 (1,795–2,776)	2,242 (1,528–3,085)	1,958 (1,186–3,035)	0.07	0.18 (0.14–0.24)	0.35 (0.25–0.48)
China region	1,408	1,608 (1,494–1,714)	1,580 (1,305–1,849)	1,422 (1,003–1,884)	1,250 (765–1,870)	0.10	0.30 (0.24–0.37)	0.39 (0.27–0.53)
Pacific Asia	476	625 (569–682)	702 (575–842)	702 (509–937)	654 (410–949)	0.08	0.23 (0.18–0.29)	0.36 (0.26–0.49)
Pacific OECD	150	155 (144–165)	148 (125–174)	135 (100–175)	123 (79–173)	0.22	0.39 (0.32–0.47)	0.49 (0.35–0.61)
Western Europe	456	478 (445–508)	470 (399–549)	433 (321–562)	392 (257–568)	0.20	0.35 (0.29–0.43)	0.45 (0.32–0.58)
Eastern Europe	121	117 (109–125)	104 (86–124)	87 (61–118)	74 (44–115)	0.18	0.38 (0.30–0.46)	0.42 (0.28–0.57)
European part of the former USSR	236	218 (203–234)	187 (154–225)	159 (110–216)	141 (85–218)	0.19	0.35 (0.27–0.44)	0.36 (0.23–0.50)

Note: 80 percent prediction intervals are shown in parentheses.

Figure 1. Age and education pyramids for South Asia in 2000 and 2030 assuming constant enrolment rates.



The following is a summary of the presentation given at the meeting by Wolfgang Lutz.

- Population and Human Capital trends are important drivers of climate change but also key to adaptation : → 'millions at risk'
  → adaptive capacity

- We can with rather high confidence produce population projections and human capital projections to 2030-50, and may be able to extend them (with less confidence) to 2100

- Such projections may be some of the few 'hard data' we have on the complex issue on future vulnerability and future adaptive capacity

- Future governance and the quality of institutions are very hard to anticipate. It is meaningful to assume that better educated populations have high probability of having efficient governance and institutions because there are more checks and balances by more empowered people.

6.4 Literature and current research on costs

The following abstract was prepared for the meeting by Richard Richels and distributed to participants in advance.

The Costs of Stabilization
Richard Richels, EPRI

Initial studies on the costs of stabilization focused on atmospheric CO_2 concentrations primarily from the combustion of fossil fuels. (For purposes of the current discussion, the term "cost" applies exclusively to abatement or mitigation costs. It does not include the damages associated with global climate change.) More recently, the analyses have been expanded to include non-CO_2 greenhouse gases and terrestrial sequestration. The addition of other trace gases has highlighted problems associated with Global Warming Potentials (GWPs) and has led to the exploration of alternative approaches for making tradeoffs among gases. Most recently, the discussion has been expanded to include what constitutes an appropriate stabilization metric (e.g., concentrations, radiative forcing, temperature change, or impacts). In this note, each of these issues is discussed in turn.

Studies of the costs of stabilizing CO_2 concentrations suggest that mitigation costs are sensitive to a variety of socioeconomic, scientific, technological, and geopolitical factors. Key determinants include:

1) Future emissions in the absence of policy intervention;
2) The behaviour of the natural carbon cycle;
3) The cost differential between carbon venting technologies and carbon free alternatives;
4) Technological progress and the rate of adoption of technologies which emit less carbon per unit of energy produced;
5) Transitional costs associated with capital stock turnover which increase if carried out prematurely;
6) The concentration target and route to stabilization;
7) The degree of international cooperation;
8) The extent to which market mechanisms are employed both internationally and domestically.

Cost-effectiveness studies suggest that the costs of stabilizing CO_2 concentrations in the atmosphere increase as the stabilization level declines. Whereas there appears to be a moderate increase in costs when passing from a 750 to a 550ppmv stabilization level, there is a larger increase when passing from 550 to 450ppmv. The nonlinearity in the abatement cost curve appears to be due to increasing pressure to prematurely retire existing plant and equipment as the ceiling approaches 450ppmv. Different assumptions about the key determinants of costs (as summarized above) can have a strong influence on absolute costs.

Until the TAR, climate policy analyses had focused almost exclusively on CO_2 emissions abatement. This is not surprising, given the importance of CO_2 relative to other greenhouse gases, and both the capabilities of existing models and the paucity of data related to the non-CO_2 greenhouse gases at that time. Nevertheless, it was recognized that a CO_2 emissions only approach can lead to significant biases in the estimation of compliance costs.

Since the TAR, there have been a number of efforts to incorporate multiple greenhouse gases into stabilization analyses. Most notable is the current study organized by the Stanford Energy Modelling Forum (EMF 21) (Contact John P. Weyant: weyant@stanford.edu), which involved 18 modelling teams from around the world, including participants from Asia, Australia, Europe, and the US. In addition, extensive data gathering efforts were conducted by the USEPA and the IEA Greenhouse Gas R&D Program. The modellers worked closely with those responsible for data gathering to identify data requirements and to ensure that the analyses were based on the best available information.

For its long-term stabilization target, the EMF 21 study chose radiative forcing rather than atmospheric concentrations for a ceiling. Using the latter is problematic since it requires an *arbitrary* way to make trade-offs among gases. By choosing a ceiling to which each gas contributes (i.e., radiative forcing), the trade-offs among gases can be based on the relative prices of each gas as determined by its contribution to the ceiling. This approach, which includes both physical and economic considerations, avoids the methodological problems associated with the use of GWPs.

The results of the EMF 21 study showed that total abatement costs were reduced (in some cases substantially) when multiple greenhouse gases were included in the abatement strategy. Although the focus was on limiting radiative forcing, the models also showed the concentration levels associated with each gas in order to meet a particular target. Differences in results among models were due not only to different assumptions regarding those factors influencing CO_2 emissions abatement costs, but also different assumptions regarding the costs of non-CO_2 greenhouse gas abatement. The results of this effort will be published in a special edition of the *Energy Journal* in early 2005.

More recently, there has been an effort to extend the analysis further along the causal chain connecting human activities and impacts. Given the current uncertainties in our understanding of the climate system, it is impossible to project with any degree of confidence the effect of a given concentration ceiling on temperature. Or conversely, for a particular temperature cap, the required concentration ceiling is highly uncertain. This calls into question the current focus on atmospheric concentrations.
From a benefit-cost perspective, it would be desirable to minimize the sum of mitigation costs and damages. Unfortunately, our ability to quantify and value impacts is limited. For the time being, we must rely on a surrogate. Some argue that focusing on temperature rather than on concentrations provides much more information on what constitutes an ample margin of safety. Concentrations mask too many uncertainties that are crucial for policy making. This issue is likely to be a major focus of the new EMF 22 study, which will consider alternative long-term climate stabilization scenarios and is scheduled to begin this fall.

The following is a summary of the presentation given at the meeting by Richard Richels.

- The literature is rich with studies on the costs of stabilizing atmospheric CO2 concentrations. These studies focus on both the costs of reducing industrial emissions and enhancing terrestrial sinks.

- More recently the focus has shifted towards including other greenhouse gases. To avoid the problems associated with GWPs (Global Warming Potentials), energy modellers have begun focusing on targets to which all greenhouse gases contribute. The first comprehensive study of this type was conducted by the Energy Modelling Forum (EMF21). The analysis focused on stabilizing radiative forcing. The results are scheduled to be published early next year.

- Energy modellers are just beginning to focus on the issue of limiting temperature change. The motivation is to factor in such key uncertainties as climate sensitivity, which is ignored in studies that focus exclusively on stabilizing CO2 concentrations or even radiative forcing.

- As we move down the causal chain connecting human activities to impacts, energy modellers are currently using the stabilization of concentrations, radiative forcing or temperature as surrogates for impacts. A major challenge will be to incorporate impacts directly into such analyses.

6.5 The HOT Project and other stabilization research projects in progress

The following abstract was prepared for the meeting by Joyeeta Gupta and Youba Sokona and distributed to participants in advance. Dr. Sokona gave a presentation on this topic at the meeting.

Helping Operationalise article Two: the HOT Project
Joyeeta Gupta and Youba Sokona

Climate change presents the global community with what has been called an “unstructured” problem, that is, a large scale, highly complex problem containing many uncertainties and cross-cutting issues. Science can only make educated guesses as to what the effects of the problem will be and there is little agreement among and within countries as to how, and to what extent, climate change should be addressed. It is especially difficult to reach negotiated solutions to such problems, partly because of the shear range of issues and unknowns involved, but also because difficult to assess and little discussed value questions are prominent. Thus, while science may be able to offer its “best guess” scenarios as to what the effects of climate change will be, this in itself is insufficient because it does not answer questions such as: To what extent are people willing to accept a changed environment? What are the sacrifices and trade-offs that are acceptable in dealing with the climate change problem? Yet it is these types of questions that form the basis of any negotiation in the area of climate change. Furthermore, while science *cannot* answer these questions, the formal negotiation process simply *does not* discuss broad value issues. The pressures and structure of the formal negotiation setting tends to focus negotiators on problems that are readily solvable or easy to debate. The result is that only short-term issues and details are discussed while the wider context and consequences of climate change are forgotten This is evident in the fact that negotiations have largely avoided Article 2 of the Framework Convention on Climate Change (FCCC) which states the long-term objectives of the climate change regime.

The central assumption of the project, Helping Operationalise article Two, is that without a clearly defined long-term objective, it will be impossible to check if the climate change regime is on track to achieve the goals of the community. Article 2 of the Climate Change Convention provides the framework for a discussion on the long-term objective, but does not articulate the long-term objective in terms of clear targets within a specified time-frame. It specifies that:

The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, the stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.

The scientific community has thus far argued that defining what is dangerous is outside the ambit of science and is a political question. Against this background, the HOT Project uses a science-policy stakeholder discussion to define what the key elements of Article 2 should be.

The HOT project is an incrementally developing project. The first phase of HOT was the regional stakeholder dialogues in different parts of the world, financed by the Dutch Ministry of Housing, Spatial Planning and the Environment. The first phase of the project was implemented by the Environmental Studies (IVM), Vrije Universiteit in Amsterdam, the National Institute for Public Health and the Environment (RIVM) in the Netherlands, The Energy and Resources Institute (TERI) in Delhi, ENDA-Tiers Monde in Dakar, the Tyndall Centre for Climate Research in the UK, and COPPE/Climate Centre in Brazil. The second short phase of HOT examined the theoretical foundations of such a project more closely and was financed by some MISTRA money. The third phase of the project has been financed by the Dutch government to help frame the contours of the Dutch discussion on Article Two. The (Dutch) partners in this project include RIVM, Royal Meteorological Institute (KNMI), UNESCO-IHE Institute for Water Education, Environmental System Analysis Group of Wageningen University, National Institute for Coastal and Marine Management (RIKZ), National Institute for Inland Water Management and Waste Water Treatment (RIZA), International Centre for Integrative Studies (ICIS) Maastricht University and the IVM.

The project methodology has been to aim to hold national and regional meetings in all parts of the world to encourage a discussion of Article 2, to identify the information needs of policymakers in order to be able to come up with an evaluation of Article 2, and to provide opportunities for a science policy dialogue. The project is still in the stages of undertaking regional and national dialogues. The international dialogue is planned but is dependent on funding.

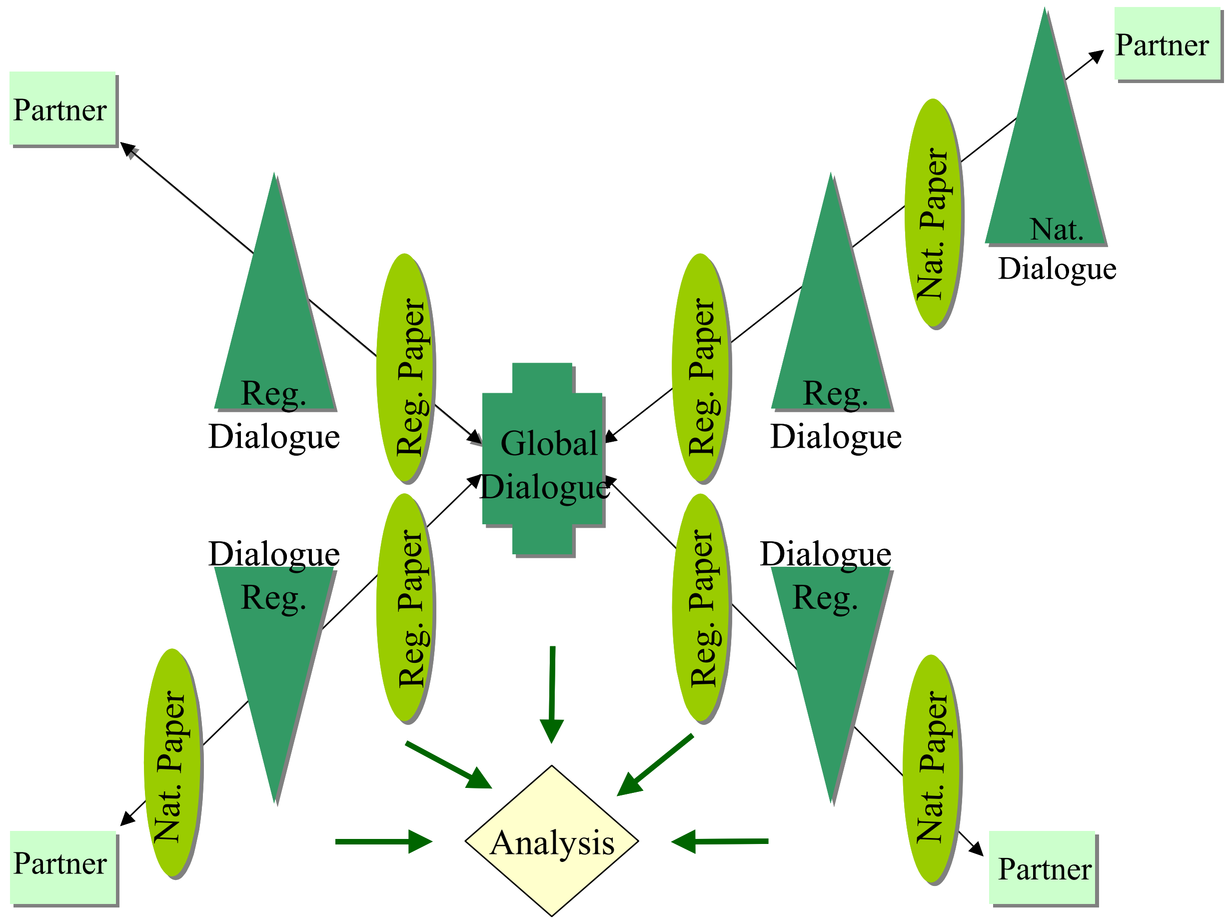


Figure 1. The regional and global workshops in the HOT Project

In total five national and / or regional dialogues were carried out in Asia, Africa, Latin America and Annex I countries and one is being presently executed in the Netherlands. The purpose of the dialogues was not to change the participants' negotiating positions however. Dialogue success rather, was defined as a situation in which participants from different groups listened openly to each other, felt that they were truly listened to, were fully involved in the discussion, and were given a chance to reflect on their own position without compromising their core values. The point is that the dialogues are not related to political negotiations. The overall aim of the exercise was to increase understanding and explore new areas of agreement by providing a neutral and open environment – not to directly impact the ongoing climate negotiations. The project in the Netherlands is however more ambitious than the other national/ regional dialogues because it aims to support the Dutch preparations for the Dutch Presidency of the European Union in the second half of 2004. Prior to the dialogues, questionnaires were distributed in different parts of the world to gauge the responses of the stakeholders and to prepare for the initial workshops.

The key methodological approach was to analyse at a parallel level the national positions, the arguments and the values underlying these positions. Simultaneously we focused on identifying indicators and threshold values about when an indicator had reached a dangerous point and finally work out what concentrations of greenhouse gas emissions were compatible with the different threshold levels.

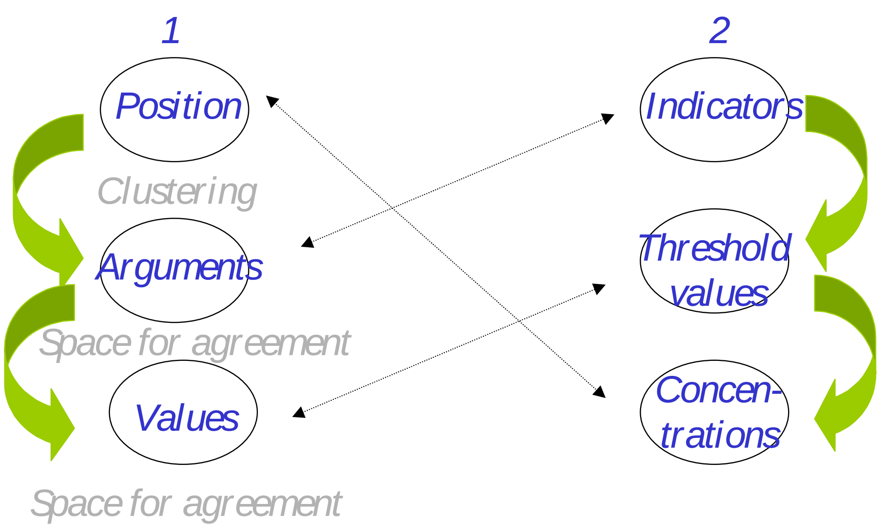


Figure 2. The key methodological approaches

The key conclusions of the research thus far is that first, many of the stakeholders felt that the true significance of understanding the relationship of the long-term goal with the daily pressures of negotiation was something most had hardly spent any time thinking about; and that they felt that the information provided helped them understand the importance of Article 2, and also the need to think more deeply about the information needs they had in order to reach an articulation of dangerous. Second, there was in general consensus that climate change would be a serious problem especially for the South, although within the South, some stakeholders were not sure how climate change compared to other more pressing problems. Third, there was some support for the argument that climate change and development should not be dichotomised and instead climate change measures should somehow become mainstreamed. Fourth, there was in general consensus that the key controversies around Article 2 would be how monetization of the impacts would influence people's views on what is dangerous. Fifth, there was some consensus that certain outcomes of defining adverse outcomes re unacceptable, including adverse environmental outcomes such as increase in famines, natural disasters, disturbances to global/regional climate patterns, depopulation of small islands and the rise of environmental refugees and the relegation of adaptation as a secondary issue; adverse policy outcomes for developing countries such as binding commitments that compromise the right to development, economically unfeasible implementation time frames, inequitable distribution of costs, inappropriate technology transfer, and other negative impacts on the domestic economy, etc. and adverse policy outcomes for all countries which would allow unsustainable energy use, unplanned industrialization and fuel-wood consumption, excessively high per capita emissions, high carbon intensity of GDP.

Fifth, participants in all the workshops emphasised the need to identify the close issue-links with local health, air pollution, desertification and water problems as a means to give priority to addressing the climate change problem. Sixth, stakeholders asked for more information regarding information about how to communicate to the public on climate change; More specific information on the costs and benefits of taking policy at the level of the local, regional and international level; Information about how specific ecosystems will be harmed; Information to develop the indicators further; and Information on how to develop the issue linkages with local pollution better. Sixth, some of the workshops were able to identify the key indicators that would indicate if climate change was becoming dangerous or not. A total of twenty indicators have been suggested and these indicators are presently being analysed in terms of their robustness as scientific criteria, their communicability to the public, and whether they are indeed important from the perspective of the public. Seventh, as an undercurrent in all the projects was the realisation that possibly countries will commit themselves only to the extent that they feel that they will suffer individually from climate change, there are no globally established norms about how to deal with issues that are not perceived as uniformly dangerous to all countries. Finally, most stakeholders argued that the questionnaires and workshops had provided a relaxed sphere to understand some of the fundamental problems in the climate change regime.

6.6 UK Stabilisation project

The following abstract was prepared for the meeting by Jean Palutikof and distributed to participants in advance. Dr. Palutikof also gave a presentation on this topic.

The UK Climate Stabilization Project: Development of a Research Agenda

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[2] IPCC WGII TSU, Hadley Centre, UK Met Office, Exeter, UK

The explicit aim of the UN Framework Convention on Climate Change, as stated in Article 2, is to achieve 'stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system', allowing ecosystems to adapt naturally, ensuring security in food production, and permitting sustainable economic development. Negotiations are likely to focus on finding an acceptable target for the stabilization of atmospheric greenhouse gas concentrations. Such targets are likely to be specified in terms of a concentration or concentration range, and a range of emissions pathways to reach the target by a stated date.

The UK government through Defra (Department for Environment, Food and Rural Affairs) is funding a project to develop a research agenda which will explore a range of stabilization strategies in terms of:

- their associated emissions trajectories,
- the developmental pathways associated with these emissions trajectories,
- the technological implications of following these trajectories,
- the potential climatic, physical, ecological, social, political and economic impacts of the associated climate changes and
- the adaptation strategies required to address these impacts.

This project is held by the Tyndall Centre for Climate Change Research, is led by Mike Hulme, the Executive Director of the Tyndall Centre, and runs through the first half of 2004.

The research agenda is divided into three domains, reflecting the process described above. These are:

i. **Climate system responses** to greenhouse gas forcing, and the implications of different greenhouse gas emissions profiles for rates and magnitudes of climate change and the crossing of critical thresholds.
ii. **Technology pathways**, assessing the implications of different emissions profiles for economic and technology policy, and the nature of technological and economic innovations required in order to adhere to the various emissions pathways.
iii. **Impacts, damages and adaptation**, investigating the impacts of climate change consistent with a particular emissions profile, together with the potential socio-economic impacts of developmental pathways consistent with that emissions profile. The implications of different adaptation pathways for these impacts is also considered.

7 Integrating current knowledge

7.1 considering the mix of mitigation and adaptation approaches to avoid key impacts

The following abstract was prepared for the meeting by Tom Wilbanks and distributed to participants in advance.

CONSIDERING THE MIX OF MITIGATION AND ADAPTATION APPROACHES TO AVOID KEY IMPACTS

Thomas J. Wilbanks, Oak Ridge National Laboratory, USA

We now understand that both mitigation and adaptation are needed in responding to risks of impacts from climate change. Mitigation is essential in order to keep climate change impacts as low as possible; but impacts can no longer be avoided and progress has been slow with actions to implement mitigation potentials. Adaptation is essential because impacts cannot be avoided; but costs will be a constraint for some areas, adaptation is more difficult to envision for natural ecosystems, and adaptation is limited in its ability to cope with abrupt events. Both are necessary, recognizing that each has limits.

Clearly, it is difficult to evaluate alternative stabilization levels without understanding impact costs of different levels. What, for example, would be the net impact costs to the world's physical, ecological, and human systems at a level of 550 ppm vs. a level of 750 ppm of CO2 equivalent? Such impact costs (and conceivably benefits) depend not only on an area's exposure to such primary climate change impacts as temperature increase, changes in precipitation patterns, and sea level rise but also on the capacity to adapt to these changes so that secondary impacts are moderated or minimized. This suggests that mitigation targets and adaptation potentials are related: if the fundamental objective of climate change policy is to limit impact costs rather than to limit atmospheric concentrations, then a highly adaptive world can live with a higher stabilization level if necessary.

Several references illustrate this relationship, including an evocative figure from the Summary for Policymakers of IPCC Working Group II's Third Assessment Report (Fig. SPM-2, p. 5) and results of recent research at the Oak Ridge National Laboratory (ORNL). Simply stated, these sources indicate that adaptation can cope, at least to a considerable degree, with many impact costs at a moderate rate and level of climate change but not at a more massive rate and level. In other words, if mitigation can be successful in keeping impacts at a lower level, adaptation can be successful in coping with more of the resulting impacts. Mitigation and adaptation are therefore partners in climate change response, not alternatives.

Mitigation and adaptation are also related in more action-specific ways. For instance, individual mitigation and adaptation actions often have the potential to interact with each other. In some cases, they offer alternatives; e.g., mitigation to reduce changes in precipitation patterns that would affect agriculture vs. adaptive development of crop varieties resilient to a wider range of precipitation. Progress with either reduces payoffs from investment in the other. In some cases, they reinforce each other: e.g., more efficient space cooling both reduces electricity consumption for space cooling (mitigation) and makes cooling more affordable for lower income groups (adaptation). In either case, the actions are also related to other aspects of sustainable development pathways as well.

Considering mitigation and adaptation as parts of an integrated portfolio of strategies, policies, and actions is complicated by the fact that adaptation is in many ways more complex than mitigation -- e.g., it can be both anticipatory and reactive and it often depends on a mosaic of local circumstances -- but it has received less research attention, especially where costs are concerned.

More fundamentally, mitigation and adaptation actions often differ in their nature, their co-benefits, their limits, who decides, and who pays the price vs. who benefits. For example, mitigation and adaptation measures tend to differ in the timing of the efforts (mitigation benefits are lagged in time, unlike some adaptation benefits), the geographical pattern of their effects (mitigation benefits are more global; adaptation benefits are more localized), and the sectoral focus of their responses (mitigation focuses on greenhouse gas emitters and sinks; adaptation focuses on sectors and activities sensitive to climate impacts).

At least in part because of these complications, the integrative knowledge base is still formative. A number of conference sessions and workshops since early 2002 have been organized to stimulate research attention and discussion, and several initiatives are under way to accelerate peer-reviewed publication of relevant research, including special issues of two journals aimed at publication by the end of 2004. Together, these publications and workshops are likely to point AR4 toward most of the current topics and centres of research concerned with considering mitigation and adaptation together as aspects of climate change responses.

As a starting point for discussion, it can be suggested at this early stage in mitigation-adaptation research that top-down analyses are severely limited by inadequacies in available building-block information: e.g., reliable climate change forecasts at detailed scales, reliable characterizations of costs, benefits, and performance over time of a host of individual mitigation and adaptation actions, and reliable information about coping capacities. Bottom-up analyses can in some cases deal with these issues more satisfactorily, and they have the potential to explore linkages with other stresses on sustainable development besides climate change alone; but they raise questions about generalizing from small and perhaps unrepresentative samples.

Some questions seem especially important to pursue, such as whether in many cases adaptive capacities may have nonlinear (threshold-related) relationships with a spectrum of stabilization levels.

In the meantime, however, it is important to emphasize that neither mitigation nor adaptation should be delayed while the research community works to reduce uncertainties about specific pathways and relationships. In many cases, win-win actions can be identified, co-benefits are high, and agreement can be attained now, especially at scales other than international or national. Action and learning can move ahead in parallel and in partnership, each learning from the other, while we find our way toward the most appropriate relationships between mitigation and adaptation.

CONSIDERING THE MIX OF MITIGATION AND ADAPTATION APPROACHES TO AVOID KEY IMPACTS.

FOUR MAIN MESSAGES :

- Responding to risks of impacts from climate changes calls for a portfolio of strategies and actions that includes both integration and adaptation.
- But it is difficult at the present time to carry out integrated analyses of mitigation and adaptation pathways, representing the variety of cost/benefits, tradeoffs, and interactions, because the options are fundamentally different and because essential information is severely limited.
- A literature on this subject is emerging but is likely to support rather broad statements in AR4 and how to think about an appropriate mix of approaches : e.g., that because so many adaptation actions are related to local contexts, integration will include considerable attention to regional and local scales.
- These limitations on the available science should not be used as an excuse for inaction with either mitigation or adaptation. It seems clear that many mitigation and adaptation actions make sense now because of possibilities and or often abundant co-benefits. Action should proceed on both fronts while we learn more about how to determine appropriate mixes.

RELATED CHALLENGES TO IPCC AR4 WORKING GROUPS:

I. Climate forecasting at relatively detailed scales that can serve as a basis for estimating damages to be reduced: e.g. pay offs from mitigation and/or adaptation instruments.
II. Characterizations of adaptation pathways: cost, benefits, performance over time, limits.
Characterization of sectoral sensitivities.
Characterization of coping capacities and their determinants.
III. Characterizations of mitigation pathways: same as above.

Loose end: Characterization of impacts and adaptation challenges relative to mitigation efforts: mitigation polities associated with different stabilization levels would have impacts requiring adaptation.

Where is this considered on the IPCC structure?

7.2 Summary by IPCC Chair

Rajendra Pachauri, the IPCC Chair, gave a summary presentation.

7.3 Commentators Summaries for day 3

Comments by Jaihua Pan were given as a presentation

Comments by Bill Hare:

O'Neill – Plausibility of scenarios

The criteria presented are quite comprehensive and could form a good basis for assessment of the plausibility. Two other factors appear relevant.

Convergence and synergies with Sustainable development objectives (Beg *et al.* 2002): this goes beyond political and institutional feasibility.

Conditionality on development path (Roehrl *et al.* 2000): The infeasibility referred to in relation to the WBGU 400 ppmv CO2 stabilization scenario related to one of the reference scenarios only - the B2 scenario. The other reference scenarios were feasible. The B2 scenario was feasible without the WBGU constraints, which amongst other things limited Biomass to 100 EJ in 2100.

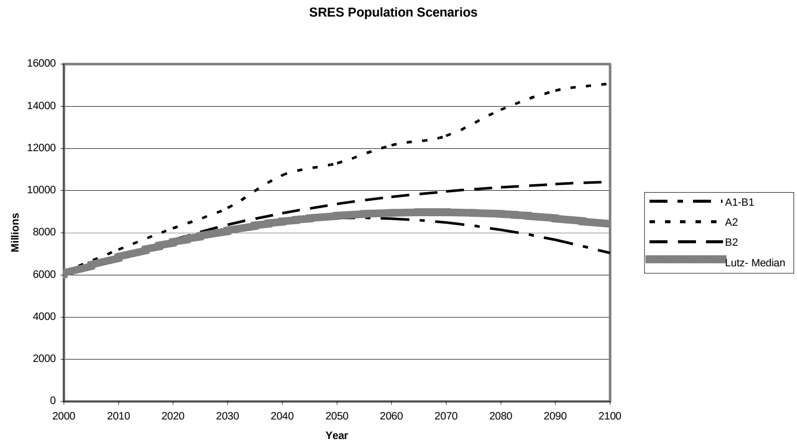
Kainuma – Stabilization scenarios

Multi-gas scenarios with consideration of other radiative forcing agents (black carbon, sulphur) are very relevant to the connection between climate policy and sustainable development in relation to the ancillary benefits of mitigation. The literature is growing and showing large co-benefits of mitigation at regional levels around the world (Alcamo *et al.* 2002; Barker 2003; Burtraw *et al.* 2003; Dessus and O'Connor 2003; Dudek *et al.* 2003; Kan *et al.* 2004; Yang *et al.* 2004).

The EMF21 BAU case is based on the SRES B2 scenario which is very pessimistic and will have highest costs than other reference cases (Roehrl *et al.* 2000). The choice of a radiative forcing stabilization level 4.5W/m^2 is close to 650 ppmv CO_2 equivalent and corresponds for a climate sensitivity of 2.5^{o}C to an equilibrium warming of 3.7^{o}C above 1990 (4.3^{o}C above 1860), far above the EU target of 2^{o}C (above pre-industrial).

Lutz - Population

Lower population projections have large implications for mitigation costs, vulnerability and adaptation assessment. The SRES scenarios diverge significantly from the new assessments of Lutz. For example the A2 population in 2100 is well above the 90% decile, the B2 is close to the 70% decile and B1 and A1 is close to the 30% decile.



In relation to stabilization scenarios population appears to be a main determinant of non CO_2 gases from agriculture and land use change based on current literature, particularly in the long term. This is particularly so for climate targets such as the EU 2^{o}C target, where the level of non CO_2 emissions from agriculture and land use is quite important.

One of the key message is that of the differential vulnerability within countries and key question is how this is to be dealt with in the Article 2 context. The UNFCCC is an agreement between Parties, not regions and households. Water assessments for example can show country level aggregate risk indicators which are much different than watershed based analyses: How is this to be relevant to measures of risk and vulnerability?

Richels – Costs of stabilization

Several issues:

Need to include role of technology learning and its implications for costs: There is a substantial literature on this (Gritsevskyi and Nakicenovic 2000; Janssen M.A and de Vries B 2000; Gerlagh and van der Zwaan 2001; Grubb *et al.* 2002; Grubb and Ulph 2002; Loschel 2002; van der Zwaan *et al.* 2002).

Timing of action issues are not as clear cut as presented and several recent studies find that early action is better than delay (Bretteville and Aaheim 2003), reinforcing findings of Grubb *et al.* (1995) and HaDuong *et al.* (1997) as opposed to non dynamic findings Wigley *et al.* (1996).

Issues of policy-lock are significant as this can increase costs (Edenhofer and Jaeger 1998; Unruh 2000; Mulder and Van den Bergh 2001; Unruh 2002; Soderholm and Stromberg 2003).

Temperature as a metric is quite a good approach for target setting. There are complexities with observed changes and monitoring progress towards the target. However these are not dominant issues. A range of similar problems and uncertainties characterise any metric chosen (concentration, radiative forcing).

Integrating thresholds

There is a need to choose regional case studies in order to explore the issue of socio-economic thresholds in relation to vulnerability and adaptation. For example some water studies show moderate risks at the country scale and large risks at the watershed scale for large number of peoples where there is presently little capacity to move water around (Arnell 2004). To understand whether reported thresholds for water risk (Parry *et al.* 2001) actually exist, it is necessary, (for example, in the case of China) to fully understand the water supply system in detail and how this might change in relation to socioeconomic, environmental and climate change (e.g., shift in the East Asian monsoon).

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Summary of commentators remarks on day 3 by Jean Palutikof:

COMMENTATORS

Bill Hare

Plausible targets. Good basis for assessment. There are problems associated with them:

1. Convergent pathways. Synergies of stabilization target scenarios with sustainability targets. Need to understand these. Otherwise risk that one will act negatively with respect to the other.
2. Conditionality of cost on development targets.

There is a question mark over the B2 scenario. Is it a plausible target? There are technical constraints.

Ancillary points which should be considered:

1. Air pollution reduction – black carbon. Inter-relationship of these.
2. Wide range of regions to explore – importance of regional studies.

MM21 and MM22 scenarios – very helpful. Time scales are important. Is it likely that these scenarios will be ready for incorporation in AR4?

Relationship between projections and stabilization scenarios. Population determines emissions from land use, agriculture - thus assumptions in the projections determine whether targets can be met. The relevance of population projections is very high.

Vulnerability. Different levels of vulnerability exist within regions/countries. This poses problems for Article 2. For example, high levels of scarcity in regions where water can't be transported – how should this be dealt with?

Paper on costs of stabilization. Four points to make:

1. Role of technology learning and its relation to costs. Large literature has developed since TAR – large benefits accrue from technology learning – the literature on this should be emphasised by AR4.
2. Timing of action – again, a large literature has emerged on the importance of this since the TAR
3. Policy lock-in/technology lock-in. Carbon trading schemes are relevant to the overall cost.
4. Temperature as a metric of the long-term target – good idea. It's hard to find a good metric. Need to consider the uncertainties surrounding any chosen metric. Temperature is good in part because it is understandable by policymakers.

Thresholds & case studies

Vulnerability of regions to problems. Generic/broad brush studies are of little use in understanding this – need to look in detail. Are Arnell's thresholds real? This can only be tested by looking in detail.

Regional case studies are needed.

Dr Pan

Vulnerability – Richels talked about solutions. Not clear how he can rely on modelling at global scale. Need to get down to the local/regional scale, otherwise results may be imaginary. Baseline very imp. for assessment of vulnerability.

Indigenous knowledge important in adaptation. Discrepancies between OECD countries and others, in projection of SRES trends. China – very tricky – very enthusiastic for technology – high demand for services, products of technologies. Huge increases (10-15% per year) when compared to the projections in energy/steel demand. Projections very poor.

What is vulnerability? What is its relationship to adaptive capacity?

Stages of industrialization – OECD are de-industrializing. Then industrialized, newly industrialized, industrializing. Where is China? Shift from rural to urban, construction of physical/institutional infrastructure; transition from labour intensive to knowledge economy.

Kamal Puri

Modeller (AGCMs). Need expert from WGI to give review of GCMs. Especially role of ensemble runs.

Uncertainty – important topic. Ensemble runs could assist in this. Little account taken of uncertainties in the presentations. Could use ensemble runs to assist.

Integrated assessment – both bottom up and top down. These contain many assumptions. How sensitive are they to internal assumptions – this evaluation is required. This is an additional source of uncertainty in IAMs.

Where we talk about probabilities in scenarios, need to consider uncertainty.

It appears to be a common problem throughout the work of WGII that uncertainty is not properly considered.

Regional information. How to go from model grid to a point? Discussion by Carter interesting. How will WGII handle this in impacts assessments? Can it use results from regional climate models? Modelling community have believers and non-believers re RCMs. Puri is a non-believer. If parent GCM is rubbish, RCM cannot do better.

Abrupt events (Rahmstorf). No adequate discussion of extreme events here, yet have high societal impacts. Only Carter made an attempt to look properly at these. Tropical cyclones. GCMs can't model these. Yet these are important, high-impact, phenomena. Other important extremes include - heavy rainfall, high winds etc. They will have to be addressed by WGII.

Dangerous levels climate change, tolerable thresholds. How to address these? How to define them? Not made clear here. Wigley, Carter mentioned them. But otherwise the treatment was inadequate. Methods exist to define these levels in Europe – could they be used elsewhere?

7.4 Panel Discussion

A panel discussion between Klaus Radunsky, Jean-Pascal van Ypersele, Osvaldo Canziani, Martin Parry and Ogunlade Davidson was conducted with some of the members giving short presentations.

Klaus Radunsky gave a presentation at this point.

Jean-Pascal van Ypersele gave a presentation at this point.

Ogunlade Davidson gave a presentation at this point.

7.5 Summary and Conclusions

Stephen Schneider, Serguei Semenov and Anand Patwardhan each gave a presentation in which they summarised how the material presented and discussion generated at the meeting would input into the AR4.

Stephen Schneider gave a presentation at this point.

The following slides were presented by Serguei Semenov.

0-order draft outlines

The following items related to UNFCCC Art2 might be considered in the IPCC Fourth Assessment**, in particular, in chapter 19 "Assessing key vulnerabilities and the risk from climate change" of contribution of WGII to the AR4.** The annotations present issues to be highlighted.

Introduction

The section outlines specific goals of the theme, distinguishes scientific issues from political ones and emphasizes the inter-WGs nature of the task.

Past IPCC findings

The section describes past IPCC activity (meetings, publications, papers) on the theme, and the Plenary and Bureau decisions, interactions with UNFCCC bodies, *earlier publications.*

Concepts and methods

Responses of elements of the climate system and WEHAB (Water, Energy, Health, Agriculture, Biodiversity) components to climate change are to be employed in assessing key vulnerabilities and risk from climate change. The section characterizes relationships "equilibrium GHG level - eq. climate" (WGI to contribute), "eq. climate - potential (large-scale) key vulnerabilities" (WGI to contribute), "eq. climate - accessibility & quality of WEHAB resources", as well as relationships between their changes.

Methods to assess response and damage functions for natural and social systems, as well as to establish thresholds for particular elements by regions and sectors are to be considered. Various metrics for measuring responses will be presented and existing costing methodologies applicable for converting response functions into damage functions (monetary equivalents) are to be described. Methods to quantify uncertainties will be presented

Relevant WGI chapters: 2, 9, 10, 11
Relevant WGII chapters: 2, 3-8, 19
Relevant WGIII chapters: 2

Stabilization scenarios for GHG concentrations and respective climate
The section describes a set of plausible time series of global GHG concentrations leading to stabilization of GHG content in the atmosphere at various levels (WGI to contribute, WGIII to contribute). Dynamics in climate associated with the series using large-scale terms (WGI to contribute, information from WGII scenarios chapter is to be employed) will be characterized.

Relevant WGI chapters: 8, 10
Relevant WGII chapters: 19
Relevant WGIII chapters: 3, 11

Threat to the global climate system: assessing key large-scale vulnerabilities
The section considers key large-scale vulnerabilities, assesses their sensitivity to climate change and adaptation capacity, as well as describes climate change driven consequences of and possible thresholds for climatic impacts.

Relevant WGI chapters: 6, 7, 8
Relevant WGII chapters: 19
Relevant WGIII chapters:

Regional and sectoral effects: assessing responses
The section selects by regions and sectors the major WEHAB resources affected by climatic change, assesses sensitivities, response functions, adaptation options, key vulnerabilities and possible thresholds.

Relevant WGI chapters: 6, 11
Relevant WGII chapters: 3-8, 9-16
Relevant WGIII chapters:

Assessing damage using costing methodologies
The section converts response functions into damage functions (adaptations are taken into account) for some WEHAB resources, in between, agricultural production, water, hydro-energy. The assessment will be made predominantly at regional scale, but global scale assessment also will be attempted.

Relevant WGI chapters:
Relevant WGII chapters:
Relevant WGIII chapters: 4-10

Uncertainties and a way to reduce them
Residual uncertainties and ways to reduce them will be described. What is needed for reducing uncertainties (including further progress in modelling and improvements in observation methodologies and monitoring systems) will be considered in the light of risk of acting at existing level of uncertainty.

Relevant WGI chapters: 9-11
Relevant WGII chapters: 19
Relevant WGIII chapters: 2

Anand Patwardhan gave a presentation at this point.

8 Acknowledgements

The IPCC Expert Meeting on 'the Science to Address UNFCCC Article 2 including Key Vulnerabilities' was held at the kind invitation of the Argentine Government with the generosity of the Ministry of Foreign Affairs in the Palacio San Martin in Buenos Aires. Thanks are also due to the Fundación Ecológica Universal who acted as hosts and organised the local arrangements.

The report was prepared by the presenters, commentators, rapporteurs, co-anchors and co-chairs together with the IPCC WGII Technical Support Unit.

The meeting was organised by the IPCC Working Group II Technical Support Unit. The staff of the Technical Support Unit would like to thank all of the following:

- the staff of the Ministray of Foreign Affairs of the Argentine Government
- the staff of the Fundación Ecológica Universal
- the members of the steering committee, who provided advice on the scope, structure and planning of the meeting
- the Chairs and Secretary of IPCC who contributed their expertise at the meeting
- the speakers, who set the scene for the subsequent discussions
- the commentators and rapporteurs who provided useful insight and worthwhile summaries of the sessions

and all others who generously contributed their time and effort to the planning and implementation of the meeting.

Annex A: Programme

IPCC Expert Meeting on the science related to UNFCCC Article 2 including key vulnerabilities, Buenos Aires, Argentina, 18 - 20 May, 2004.

DAY ONE

08.30 Registration

09.00 Introductions

- Welcome: *O. Canziani (Argentina)*
- Context within IPCC AR4 *R. Pachauri (India)*
- Results/actions from preceding expert meetings relating to Art2 issues *Y. Izrael (Russia)*
- Outline of the meeting and its purpose *M. Parry (UK)*

09.30

1. Background to the issue

- Article 2 and key vulnerabilities: terms, concepts and issues *S. Schneider (USA)*
- Natural science aspects including levels and thresholds *S. Semenov (Russia)*
- Socio-economic aspects, including criteria and trade-offs *A. Patwardhan (India)*

Papers 15 minutes each followed by 30 minutes discussion

11.00 Coffee

11.30 Background, continued.

- Risk, decision-making and legal aspects of Art2 *F. Yamin (UK)*
- Top-down approaches: e.g. tolerable windows, safe corridors, guardrails, ICLIPS etc *F. Toth (IAEA)*

Papers 15 minutes each followed by 30 minutes discussion

13.00 Lunch

14.00 Background, continued

- Article 2's context in UNFCCC, and the need for scientific information *D. Tirpak (UNFCCC)*
- Bottom-up approaches: key vulnerabilities: *J. Corfee-Morlot (OECD)*

Papers 15 minutes each followed by 15 minutes discussion

2. Key sensitivities and levels of impact in selected areas and regions

- Food: *P. Pingali (FAO);*
- Water: *L. Mata (Venezuela)*

Presentations 15 minutes each followed by 15 minutes discussion

15.30 Coffee

- Ecosystems: *S. Diaz (Argentina)*
- Health: *U. Confalonieri (Brazil)*
- Development: *Y. Sokona (Mali)*
- Disasters and insurance: *R. Muir-Wood (UK)*

Presentations 15 minutes each followed by 30 minutes discussion

17.30 Session ends

DAY TWO

09.00
Key sensitivities, continued:

- Integrated assessment of key impacts: a) Millions at Risk *M. Parry (UK)*; b) Methods: *H. Dowlatabati (Canada)*
- Issues of generational equity and justice, *R. Pachauri (India)*

Presentations 15 minutes each followed by 30 minutes discussion

10.30 coffee

11.00
3. Reducing the risk of key impacts by adaptation

- Reducing vulnerability a) opportunities, limits and barriers *N. Mimura (Japan);* b) experience from modeling impacts under different SRES futures: *M. Parry (UK); c)* Policy and equity issues *P. Romero Lankao (Mexico)*

Presentations 15 minutes each followed by 30 minutes discussion

Commentators on progress: [3 experts, 5 minutes each] followed by 15 minutes discussion

13.00 lunch

14.00
4. Climate changes associated with key levels of impacts and vulnerability

- Nature, timings, rates, magnitudes (global level analysis) *T. Wigley (USA)*
- Abrupt events, surprises: e.g. ENSO, THC, WAI*: S. Rahmstorf (Germany)*

Presentations 15 minutes each followed by 30 minutes discussion

15.30 coffee

16.00 Climate changes continued
- Regional-level climate changes *T. Carter (Finland)*
- Changes in S. Asian monsoon *A. Gupta (India)*

Presentations 15 minutes each followed by 30 minutes discussion

17.30 session ends

DAY THREE

08.30
5. <u>Emissions and concentrations leading to reduced climate change</u>
- The literature on 'plausible targets' *B. O'Neill (USA)*
- The literature on the array of stabilization pathways *M. Kainuma (Japan)*
- Information on related development, demographic and governance futures *W. Lutz (IIASA)*

Presentations 15 minutes each followed by 30 minutes discussion

10.00 coffee

10.30
<u>Emissions and concentrations, contd.</u>
- Literature and current research on costs *R. Richels (USA)*
- The HOT Project and other stabilization research projects in progress. *Y. Sokona (Mali);* UK stabilization project *J. Palutikof (UK)*

Presentations 15 minutes each followed by 30 minutes discussion

Commentators on progress: [3 experts, 5 minutes each] followed by 15 minutes discussion]

12.30 Lunch

13.30
6. <u>Integrating current knowledge</u>
- Summary by rapporteurs: *5 sessions, 5 minutes each*
- Considering the mix of mitigation and adaptation approaches to avoid key impacts: *T. Wilbanks (USA)*
30 minutes followed by 15 minutes discussion
- Panel discussion on overall conclusions. Handling new knowledge on Art2 issues in AR4*:Chair Pachauri, Co-chairs Parry/Canziani; Davidson. J-P. van Ypersele (Belgium), K. Radunsky (Austria) 30 minutes panelists + 30 minutes discussion*

15.45 coffee

16.15
- Summary of conclusions and outline of the meeting report to IPCC: S. *Schneider (USA), S. Semenov (Russia) and A. Patwardhan (India)*
- Closing comments: *M. Parry (UK)* and *O. Canziani (Argentina)*

17.30 Close of meeting

NOTES:
Apart from speakers:
5 session chairs
5 or 6 commentators

WG Co-chairs as sessions chairs; commentators drawn from the 10 non-presenters

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Annex C: Cross cutting theme paper 4: Assessing the science to address UNFCCC Article 2

A concept paper relating to cross cutting theme number four

Co-anchors:
Anand Patwardhan (India), Stephen H. Schneider (USA), and Serguei M. Semenov (Russia)

Introduction and Background

Article 2 of the UN Framework Convention on Climate Change (UNFCCC) states that: "The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system". The Framework Convention on Climate Change further suggests that "Such a level should be achieved within a time frame sufficient

- to allow ecosystems to adapt naturally to climate change,
- to ensure that food production is not threatened and
- to enable economic development to proceed in a sustainable manner."

Thus, the term "dangerous anthropogenic interference" may be defined or characterized in terms of the consequences (or impacts) of climate change outcomes, which can be related to the levels and rates of change of climate parameters. These parameters will, in turn, be determined by the evolution of emissions and consequent atmospheric greenhouse gas concentrations. Evaluating the consequences of climate change outcomes to determine those that may be considered "dangerous" is a complex undertaking, involving substantial uncertainties as well as value judgments. In this context, the IPCC's role should be to assess the literature with a view to providing information that is policy-relevant, without being prescriptive.

While the notion of "dangerous" does involve value judgments, the IPCC could certainly provide inputs to help policymakers consider this judgment. The three criteria mentioned in Article 2 may be evaluated as purely scientific questions to varying degrees. At the same time, it is important to recognize that these three criteria are normative in nature, that is, they may considered as objectives of policy, and not only as indicators or markers, per se. . For example, while evaluating the questions of whether ecosystems can adapt naturally, and whether food production is threatened it will be necessary to examine not only the range of climate outcomes, but also the adaptive capacity of the systems at risk, which is, in turn, determined by human perception, evaluation and response. The criterion of sustainable economic development is even more complex, , inasmuch as there are various definitions of sustainability, and it is not entirely independent from the first two criteria. There has long been debate about whether "things"—e.g., specific species or resources—are what is to be sustained, or rather productivity capacity, given optimistic expectations for substitutability . We will defer to the CCT "Climate change and sustainable development"for guidance on definitions.

The Fourth Assessment Report (AR4) should thus focus assessment predominantly on these three UNFCCC criteria, assessing their scientific, technical, and socio-economic aspects, although it could summarize various views expressed in the literature about the elements of more normative analysis. In particular, it will be important to identify the basic indicators or parameters on the basis of which these criteria could be evaluated. That is, the IPCC assessment could evaluate the range of possible climate change outcomes and the uncertainty associated with these outcomes corresponding to different adaptation and mitigation policies, without attempting to evaluate acceptability of such outcomes. This process has already been represented by IPCC WG 2 TAR as five "reasons for concern": see Figure 1. Assessment of risk--probability of the occurrence of events—is a scientific function, whereas choice of which risks are acceptable or how mitigation or adaptation should be deployed are political value judgments.

The necessity for strengthening the scientific efforts related to Article 2 has been noted by the IPCC XVIII Session (Wembley, UK, 24-29 September, 2001). The IPCC Synthesis Report, adopted by the session, had noted essential lack of knowledge on what is a "dangerous anthropogenic interference with the climate system", and that this question requires comprehensive and integrated investigations (see Question 9 of the IPCC Synthesis Report - SYR). Plenary XVIII considered this question as one of the priorities of its future work (see Document IPCC-XVIII/INF. 6 of the IPCC XVIII Session). As was stated in the SYR, "Natural, technical, and social sciences can provide essential information and evidence needed for decisions on what constitutes dangerous anthropogenic interference with the climate system" (SYR, Question 1). However, it should be re-emphasized that developing and taking such value-laden decisions are not within the IPCC mandate and in practice will happen through socio-political processes that go beyond the IPCC. At the same time, it is likely that better understanding of the socio-political and institutional processes that underlie responses and policies at different scales will itself lead to an improvement in the response to climate change.

The IPCC XX Session (Paris, France, 19-21 February, 2003) has decided to treat this issue as a crosscutting theme (CCT). The plenary requested, following the recommendations of the IPCC expert meeting on "Levels of greenhouse gases in the atmosphere preventing dangerous anthropogenic interference with climate system" (Geneva, Switzerland, 21 – 22 January, 2003), that this theme should include attention to the scientific, technical and socio-economic issues associated with Article 2 of the UNFCCC (*see above*).

The First Scoping Meeting (FSM, Marrakech, Morocco, 14-16 April, 2003) following the decision of Plenary XX developed a list of the CCT's to be addressed in the AR4 process. The current theme "Key vulnerabilities including issues related to UNFCCC Article 2" (KV&Art2) is amongst them. Although its co-ordination is housed in Working Group II (WGII) of the IPCC at present, we believe that to really address the issues in this theme close co-operation and interaction between all the three Working Groups will be essential. Interaction with three other CCTs will be essential as well: "integrated approach to adaptation and mitigation", " risk and uncertainty" and "climate change and sustainable development".

Prior to the FSM WGII Co-Chair Dr. Martin Parry in consultations with WGII Co-Chair Dr. Osvaldo Canziani and Vice-Chair of the IPCC Dr. Yuri Izrael prepared and distributed a note on KV&Art2. This note stated: "It is likely that the theme (i.e. KV&Art2) will give attention to exposure fields additional to food, ecosystems and development and include, for example, health, water and settlement; and it may address relevant sensitivities and vulnerabilities in subject areas across all three Working Groups. Local, regional and global scales will need to be considered, as well as the multiple stresses due to climate and non-climate factors". Subsequently, the FSM requested a Concept Paper (CP) on KV&Art2 outlining how these issues should be incorporated and reflected in the AR4 outputs of the IPCC Working groups.

Scientific understanding of the issue to date

The term "dangerous" is used in UNFCCC Article 2 with regard to "anthropogenic interference with the climate system". Thus, this term is related on the one hand to the consequences or impacts of climate change, and on the other, to the levels of greenhouse gas concentrations that are responsible for the climate change. The evaluation of dangerous anthropogenic interference requires therefore an understanding of the consequences of climate change together with an assessment of their undesirability, as well as the sustainability implications of both climate impacts and climate stabilization levels and their timing (see three UNFCCC criteria above).

Different attributes of climate parameters closely related to these consequences could be employed in characterizing climate change. Such attributes might include mean values, variances, and trends (rates of change) , and the concentrations of greenhouse gases and rates of their changes that are likely to be associated with these attributes.

While examining the consequences of climate change, and whether they may be considered as "dangerous", it is useful to look at the overall consequences for human well-being (HWB), and in particular, the negative effects on the components of HWB, such as health, prosperity, social development and ecosystem services. Such an approach is absolutely consistent with the basic UNFCCC criteria concerning GHGs levels and rates of their change, namely,

- to allow ecosystems to adapt naturally to climate change,
- to ensure that food production is not threatened and
- to enable economic development to proceed in a sustainable manner."

The umbrella term "human well-being" is now well-recognized, and is being used in assessments of global change, including, for example, the Millennium Ecosystem Assessment (REF). It is important to note that this umbrella term encompasses a range of trade-offs not only within the different components of HWB, but also including intergenerational and distributional issues.

The consequences of climate change for HWB are not amenable to high confidence quantification for all important sectors or regions. Moreover, the socio-natural system is a coupled set of interacting processes, so examinations of impacts on sectors one at a time—while a classical scientific approach—will not in the end describe the systemic nature of the coupled components that determine overall impacts. However, certain "reasons for concern" have been already identified (Figure 1) in the TAR, namely: risk to unique and threatened systems, risk from extreme climate events, distribution of impacts, aggregate impacts, and risk from future large-scale discontinuities (IPCC 2001; IPCC2001b, Chapter 19; van Ypersele and Schneider, 2003). IPCC scientists have considered some aspects of KV&Art2 problem in previous assessment reports, other publications or in working and discussant papers (see Section "Literature" below). Some ideas presented in these publications have been incorporated into this Concept paper. One of the important practical examples in this regard is the "tolerable windows" approach developed by Schellnhuber and Held (2002) and Toth et al (2002) others at Potsdam, and used to identify emission pathways that would be consistent with constraints imposed to avoid "dangerous" levels of climate change.

"Dangerous" climate change and the WEHAB framework

While HWB is appealing as an umbrella concept, in practice it may be useful to focus on some well-defined, important and more easily measurable aspects that also have policy significance. One such subset is the components that went into the WEHAB framework introduced during the 2002 World Summit on Sustainable Development (WSSD). The WEHAB framework identified a number of areas that would be considered as essential for human well-being and development: Water, Energy, Health, Agriculture and Biodiversity, which map well into the umbrella HWB concept. Thus it may be useful to focus on the WEHAB framework and its components, due to the widespread recognition of these components as being key for short- and long-term development goals. In addition to the five WEHAB components, Working Group II has added coastal regions, The WEHAB (plus coastal regions) framework also encompasses the original three criteria identified in Article 2 of the UNFCCC (see page 1 of this paper), and can also serve as a point of interface with a CCT on "Climate change and sustainable development". For this reason, this concept paper uses the WEHAB framework as the operational representation of human well-being.

The climate system (*that is climate itself plus all biogeochemical and physical processes responsible for the Earth's climate)* may play different roles with regard to the WEHAB – in some cases determining the availability, quality and variability of respective resources (water, food, hydro-energy, etc.), and in other cases influencing our ability to use these resources.. Examples of climate system elements might include the oceans, terrestrial permafrost, forests, fluxes of heat and moisture, global cycle of water, thermohaline circulation, ENSO, Asian summer monsoon, etc. Having identified the climate system elements and the linkages with WEHAB components, it might be possible to determine key elements of the climate system changes of which may significantly affect the WEHAB components.

Parameters (quantitative or qualitative characteristics) of such key elements of the climate system have different attributes characterizing climatic impacts on the WEHAB components. These attributes might include the levels of climate parameters, for example, surface temperature or percentage of ice cover or sea level, extent of mountain glaciers or amount of total monsoon precipitation. At the same time, these attributes might include the rates of change of the climate parameters. Long-term levels of the climate parameters, when approaching certain limits, could lead to critical impacts on the WEHAB components. The same is correct also with regard to the rates, since in some cases impacts may be critical because the rate of change of the climate parameter is too high for effective adaptation. Such limits of the climate parameters associated with critical impacts on the WEHAB components are labeled as critical limits of climate (CL-Climate).

The concept of critical impacts on the WEHAB components may be examined using notions of thresholds (or boundaries). For example, at the simplest case one could think of two types of thresholds. Thresholds of type I are simply target values of linear or other "smooth" changes that after some point would lead to damages that might be considered "unacceptable" by particular policy-makers. It is likely that such thresholds would be determined as the outcome of a socio-political process that weighs the relative risks to different sectors and regions. For example, a certain amount of sea level rise might be considered "unacceptable" for particular small island states, although the same amount of sea level rise falls within a coping range for another country. For this discussion, the help of decision analysis framework specialists will be needed, and the existing experiences involving multi-stakeholder dialogues and multi-criteria decision-making will need to be assessed. At the same time, it will be important to assess the potential and scope for adaptation strategies, together with the limits to adaptation (may be a link with CCT on integrated analysis of mitigation and adaptation).

Thresholds of type II might be those that are linked directly to the key intrinsic processes of the climate system itself (often non-linear) and might be related to maintaining stability of those processes or some of the elements of the climate system discussed earlier. Some thresholds that all would consider dangerous have no support in the literature as having a non-negligible chance of occurring. For instance, a "runaway greenhouse effect"—analogous to Venus--appears to have virtually no chance of being induced by anthropogenic activities. So our focus will be on those events that the literature suggests have a non-negligible chance of being induced by anthropogenic activities. For example, stability of thermohaline circulation or the West Antarctic Ice Sheet (WAIS) or the Greenland ice sheet, the mobilization of biospheric CO_2 stocks, changes in the Asian summer monsoons, loss of mountain glaciers, coral reefs and ENSO all appear to be of global or regional significance, respectively, and thus these are some of the natural bounds, which if exceeded, would lead to major potentially irreversible impacts. It is very likely that the irreversibility and scale of such changes would be considered "unacceptable" by virtually all policy-makers and would thus qualify as "dangerous" change. It would be important for the IPCC to perform a comprehensive identification of such potential thresholds or irreversibilities at various spatial and temporal scales, which would help in setting the boundaries for high-impact change in the climate system. More examples of different key elements of the climate system and critical thresholds can be found in (Dessai et al., 2003; Mimura, 2003).

In the process of determining criteria or defining critical thresholds (both target values–Type I--and intrinsic thresholds—Type II), uncertainty is an important factor to be considered. Scientific knowledge is always limited, and capability of policymakers to adequately assimilate scientific information for making decisions is also limited. Therefore, selection of key elements and establishing critical thresholds implies differing levels of confidence (see the concept paper on Risk and Uncertainties CCT).

It should be emphasized, that decisions on what level of WEHAB-related impacts is "acceptable" and which key elements of the climate system should remain stable are to be made by policymakers with use of scientific information provided by the IPCC. Acceptability is negotiated through socio-political processes at country, regional or global level, "taking into account development, equity and sustainability considerations, as well as uncertainties and risk" (IPCC 2001, 2001, Question 1, p. 2]

What metrics are involved in describing impacts on WEHAB?

In describing the impacts and consequences for the WEHAB elements, it is important to construct appropriate metrics or "numeraires" of damage / change, which go beyond a simple, binary market and non-market characterization (see Table 1). A good example of a diverse set of numeraires is provided by Schneider, Kuntz-Duriseti and Azar (2000), who summarize the effects of climate change in terms of the "Five Numeraires": Monetary loss; loss of human life; degraded quality of life (including coercion to migrate, conflict over resources, cultural diversity, loss of cultural heritage sites, etc.); species or biodiversity loss, and mal-distribution/equity (e.g., the common scenario in the literature in which the cooler rich countries in the political "North" get improved crop yields while hotter, poorer countries in the political "South" get reduced crop yields with warming).

The WEHAB elements include market as well as non-market dimensions. While economic theory provides a number of approaches for valuing changes in market goods and services, there is little agreement on how to value and monetize changes in the non-market goods and services that form a part of HWB. It is clear that any comprehensive attempt to evaluate the societal value of climate change should include market as well as non-market goods and services, as well as aspects of intergenerational and distributional equity. Some of the end-points could include, for example, loss of species diversity, loss of coastline from increasing sea level, environmentally-induced displacement of persons, change in income distributions and regional differences in agricultural losses. It is well recognized that the environment has a variety of sources of value, including, existence value (a priority is placed on preserving the environment, even if one doesn't intend to personally experience it), or option value.

The relevance of this discussion for KV & AR 2 is that it is essential for analysis of costs of climate change impacts or mitigation or adaptation strategies to consider explicitly alternative numeraires and to be as clear as possible which are being used and what is omitted. Moreover, before any aggregation is attempted — e.g., cost-benefit optimization strategies — authors should first disaggregate costs and benefits into several numeraires and then provide a "traceable account" (see Moss and Schneider, 2000) of how they were re-aggregated. Such transparency is essential given the normative nature of the valuation of various consequences characterized by the different metrics, and the fact that different decision makers at different levels are likely to perceive (see Dessai, 2003) “dangerous anthropogenic interference” very differently and thus the socio-political process requires assessments that make the scientific dimensions of the risk-management tradeoffs as transparent as possible.

Critical limits of climate parameters (CL-Climate): deterministic and stochastic approaches

Main sequential steps in analysis of "dangerous" climate change are a) to identify key elements of the climate system, b) map linkages between these elements and numeraires for HWB, c) establish, where feasible, critical outcomes affecting HWB, and d) calculate for such outcomes associated critical limits of parameters of the climate system (temperature, percentage ice-cover, sea level rise, water balance etc.) and/or rates of their changes. Since some degree of uncertainty will always remain in our knowledge, data, calculations and judgments, instead of assessing precise critical limits, ranges and probabilities are all that can be produced in most cases. Moreover, in many cases these will be subjective probabilistic (i.e., Bayesian) estimations. Of course, such limits/range(s) will be regionally specific in the many cases, in particular, depending on other non-climatic factors.

Three categories of outcomes. While steps a), b) and d), as well as uncertainty analysis are scientific assessments, value judgments often play essential roles in establishing critical thresholds for the consequences for HWB (step c). The following categorization of outcomes encompasses the earlier classification of thresholds (type I and type II), with type I mapping into Categories 2 and 3 and type II mapping into Category I.

Category 1. In the first instance, assessors can look at those climate outcomes that would lead to widespread negative consequences for each of the WEHAB categories. That is, in these types of outcomes, in socio-economic sectors there are no “winners”, only “losers”-- viewed at virtually any scale of decision-making – temporally or spatially. These would include, for instance, WAIS or thermohaline collapse, or perhaps large-scale or rapid changes in the monsoon. For ecosystems these outcomes could include loss or near total loss of an ecosystem and a large fraction of its endemic species.

Category 2. These limits are associated with consequences that are unambiguously negative for specific regions, sectors, populations or ecosystems (e.g., Parry et al. 2001), and with high degree of confidence. In this category, “dangerous” interference could be evaluated in light of rights-based or other ethical or cultural considerations. Here a “reverse Pareto” criterion could apply – at least some sector or region will be substantially worse-off, and others are not likely to be benefited by that outcome. For ecosystems this would imply that there are substantial negative effects on specific ecosystems and substantial increase in vulnerability or risk of extinction over reasonable time frames for some taxa.

Category 3. These kinds of outcomes are those where gains and losses are widely distributed . The determination of “unacceptability” may be partly informed by examining costs and benefits. Scientific assessment can help delineate components that would aid in making such judgments.

We recommend that the IPCC consider a systematic approach of synthesizing the appropriate literature for each of these species of thresholds, and identify from the literature particular measures and indicators that could be tracked.

It should be emphasized that the problem of uncertainty requires very serious attention in calculating CL-Climate. The following can illustrate this with an example. Assume that one estimated a value ΔT_0 that is an upper limit for increase of long-term mean temperature for a region. Maintenance of actual rise in long-term mean temperature below this limit implies a high confidence in the stability of some key element of the climate system, for instance, the Greenland ice sheet. In this case ΔT_0 equals approximately to 3ºC according to the TAR (IPCC 2001, 2001a, p. 17). A "stair" curve in figure 2 illustrates a deterministic case with no uncertainty. In this case, if a long-term increase in mean temperature is more than ΔT_0, the chosen key element looses stability with probability 1 (see figure 2). However, any models employed in such assessments cannot be absolutely precise. This inevitably results in uncertainty in magnitude of ΔT_0. Therefore, the "stair" curve on figure 2 is replaced with a "smooth" curve quantifying probability *P* of the event: - if a long-term increase of mean temperature exceeds ΔT, the chosen key element implies losing stability with a probability more than $P(\Delta T)$ (stochastic case). If one decided to adopt a level of confidence, for instance, 90%, two different critical limits would emerge, for instance, $\Delta T_1 \approx 1$ºC and $\Delta T_2 \approx 5$ºC (see figure 2). If $\Delta T < \Delta T_1$, the critical threshold would not be exceeded with probability > 90%. If $\Delta T > \Delta T_2$, the critical threshold would be exceeded with probability > 90%. In this example, the range from 1 to 5 ºC is a zone of uncertainty. A size of any zone of uncertainty can be reduced through obtaining new knowledge, data and modeling results. This requires more assessment, research, monitoring and modeling activity.

Thus, in reality we usually must formulate a probabilistic distribution, and thus define a certain level of risk for quantifying any critical limits. Moreover, there will be uncertainty in the very probability distribution assessed. Thus, which value to use - lower or upper - is still problematic. This example of estimating a range or distribution of critical limits is one-dimensional just for simplicity. In reality the task will be multidimensional, and will involve a number of different trade-offs.

In practice, the determination of "acceptable" levels of risk is a complex mixture of positive and normative processes. Particularly in situations where there is an enormous diversity in the set of stakeholders and actors, reaching consensus for such quantities might be extremely difficult (e.g., Functowitz and Ravetz, 1993). In such situations, the IPCC role could be to assess the literature to derive estimates of the probability (WGs 1, 2, and 3) and consequences of outcomes (WGs 2 & 3).

Critical levels for GHG concentrations (CL-GHG)

The UNFCCC, Article 2, does not refer directly to dangerous climate, but to stabilization of GHG concentrations at a level that would prevent "dangerous" interference with the climate system. Therefore, the next scientific task is to determine the constraints on the evolution and stabilization of GHG concentrations, to maintain climate parameters and rates of their changes within some set of defined critical limits. This task could be subdivided into two subtasks: A) to calculate critical levels for GHG concentrations and rates of their changes (CL-GHG) associated with defined critical limits for climate parameters (CL-Climate), and B) to fashion pathways and scenarios for global emissions of greenhouse gases likely not to exceed CL-GHG.

The concept of critical levels has been successfully used in applied environmental science, where they have been employed in setting of ceilings for environmental pollution (Radunsky, 2003). They have also been applied in the health sector, and some lessons could be drawn from the WHO methodology (WHO, 1999). At this stage once again a problem of uncertainty and associated risks has emerged, since "GHG concentrations – climate" models (even very advanced) cannot be precise. Therefore, uncertainty in CL-Climate plus inaccuracy of models will inevitably lead to a range and/or distribution of CL-GHG rather than to particular values.

Risk is classically defined as probability times consequence, and that framework needs to be considered in all calculations of critical levels for GHG concentrations in the atmosphere from critical limits for climatic parameters. This has not been done in the case of Figure 1, although many aspects of the TAR in WG 1 and WG 2 did assess confidence levels or likelihood with respect to a quantitative scale of subjective probability (see Moss and Schneider, 2000). Since Figure 1 suggests that larger warming is more likely to imply more damage (and not necessarily linearly—suggesting the possibility of threshold phenomena), the question of what is the probability of a given level of greenhouse gas concentration (and thus eventual warming) must be addressed. IPCC WG 1 TAR did combine 6 SRES scenarios with several climate models of differing climate sensitivities (the climate sensitivity is typically defined as by how much the atmosphere at the Earth's surface warms in equilibrium for a doubling of CO_2 from pre-industrial levels). In the TAR, the models used had climate sensitivities in the range of typically 1.5 to about 4 ^oC warming for a doubling of CO_2. However, probabilities were neither assigned to the 6 SRES scenarios nor the climate model sensitivities, thus the joint probability of warming in 2100—the left hand side of figure 1) is not given; only a range is shown—the gray shaded part.

Upon estimating critical levels for GHGs concentrations in the atmosphere, further questions logically emerge:

- How far contemporary concentrations are from the critical levels?
- At which rate they are approaching those limits?
- Have we any realistic opportunities to reduce the levels and rates?
- How to fashion pathways and scenarios for global emissions of greenhouse gases likely not to exceed CL-GHG.

How should the KV&Art2 CCT be reflected in the WGs contributions to AR4?
Some findings on the KV&Art2 problem are presented in previous IPCC assessment reports as well as in other IPCC publications (see section "Literature"). As the issue will likely be one of the major *foci* of the AR4, even more results are expected in the next 4 years on the basis of assessing recent scientific literature. According to their traditional scope, the following KV&Art2 related issues could potentially be considered by the IPCC WGs:

WG2
- key elements of the climate system at different scale (local/country, regional, global) determining availability and quality of WEHAB-related resources;
- critical outcomes in terms of consequences for HWB;
- critical limits of climate parameters associated with these outcomes (CL-Climate);
- timing aspects, including temporary exceedance of the critical limits and effects of various rates of change.
- adaptation options;
- adaptation costs.
-benefits of various mitigation pathways
-distribution of costs and benefits

WG1
- critical levels for stabilization of GHG concentrations in the atmosphere associated with the critical limits for climate parameters (the latter jointly assessed by WG1 and WG2); these scenarios should include the full range of GHGs and aerosols (and land use change, as new literature is emerging on this potential forcing factor—e.g., Pielke, et al, 2002);
- current and future GHG content in the atmosphere;
- stabilization scenarios (considered jointly by WGI and WGIII, based on "SRES-like" coherence with socio-economic driving forces);
- timing aspects, including temporary exceedance of the critical levels of climate parameters, and effects of various rates of change;
- effects of uncertainty in the climate sensitivity for the determination of critical levels of GHGs and the timepath by which they are achieved.

WG3
- evaluation of stabilization scenarios including the significance of climate sensitivity uncertainty (considered jointly by WGI and WGIII);
- timing aspects (pathways of emissions);
- mitigation options;
- costs of various mitigation pathways;
-distribution of costs and benefits
-decisionmaking frameworks

Special sections for CCTs. Since IPCC WGs have a very broad scope, their assessments on the issues listed above will be inevitably spread throughout their contributions to AR4. Therefore, to facilitate the use of the assessments relevant to KV&AR2, especially for policymakers who would find it difficult to dig these issues out of hundreds of pages, it is expedient to place a summary on KV&Art2 issues—including a guide to sections of the WG reports where these topics are discussed in detail - somewhere in each of the IPCC AR4 publications. We suggest the following two options be considered by WG Co-Chairs and discussed by interested IPCC scientists at the Second Scoping Meeting (SSM):

a) Each WG has a special chapter or section (i.e. sub-chapter) devoting to KV&Art2 CCT, and a list of sections of the WG report where key related issues are discussed.
b) Major findings on CCTs, in particular, on KV&Art2 will be reflected in the AR4 Synthesis Report.

A Workshop is needed

An IPCC workshop would be extremely useful to discuss ideas and approaches to the critical limits/levels setting presented in the world scientific literature. This could be a good starting point and form of guidance for the authors that will work on respective chapters of the WGs contributions to the AR4. It is expedient to take into account the results of the IPCC Special Workshop organized in Fortaleza in 1994 (IPCC, 1994).

Of particular importance is a frank and open discussion of the subjective probabilities that might be attached both to SRES storylines and the climate sensitivity results of models and semi-empirical studies that have emerged in the past few years—many since the TAR. Moreover, illumination of the joint probability of scenarios and sensitivities needs to be explicitly considered, again in the light of recent debates in the literature.

Broad representation of experts involved with the relevant aspects of all three working groups need to be in attendance, as well as some experts with special skills appropriate for this CCT (e.g., decision analysis).

This workshop should take place at the end of 2003/beginning of 2004.

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TABLES AND FIGURES

Table 1. The Five Numeraires. Multiple metrics for the valuation of climatic impacts are suggested (from Schneider, Kuntz-Duriseti and Azar, 2000). Typically in economic cost-benefit calculations, only the first numeraire—market sector elements—is included. Different individuals, cultures and governments might have very different weights on these five—or other—numeraires, and thus it is suggested that analysis of climatic impacts be first disaggregated into such dimensions and that any re-aggregation provide a traceable account of the aggregation process so that decision makers can apply their own valuations to various methods of analysis.

The Five Numeraires*

{Vulnerabilities to Climate Changes}

- Market Impacts {$ per ton C}
- Human Lives Lost {persons per ton C}
- Biodiversity Loss {species per ton C}
- Distributional Impacts {Income redistribution per ton C}
- Quality of Life {loss of heritage sites; forced migration; disturbed cultural amenities; etc. per ton C}

*Disaggregate by value differences—provide traceable account of re-aggregations to make value differences transparent

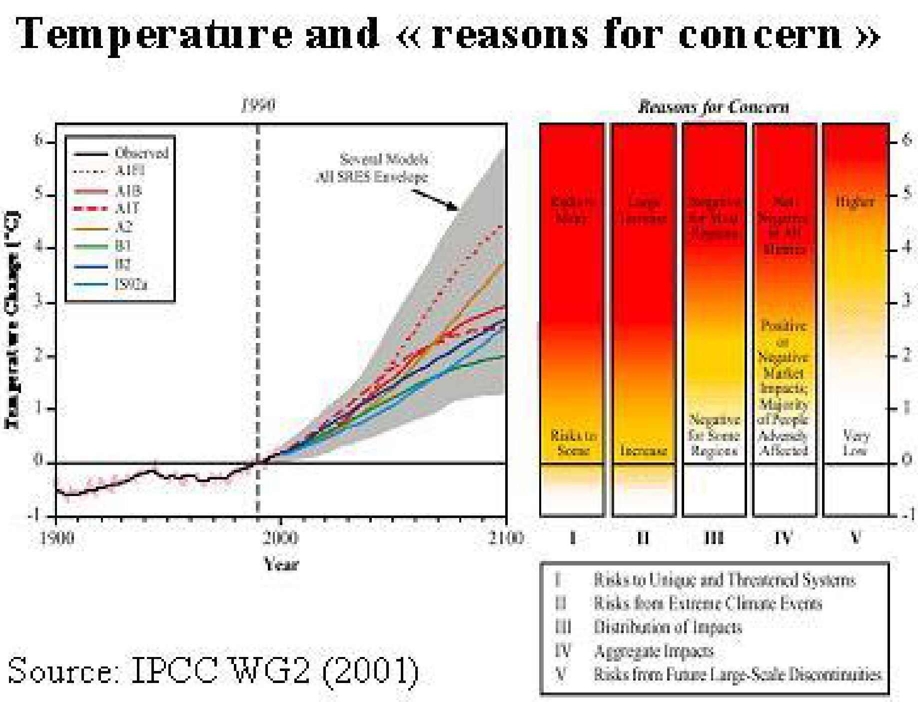

Figure 1. Reasons for concern if temperatures are to continue to rise as projected by applying various SRES scenarios linked to several climate models (left hand side of the figure—from IPCC WG 1 TAR). Note that the darker shades of red—implying intensified impacts more likely to be defined as "dangerous" than lesser impacts represented by the lighter shading—occur for the most part above "a few degrees" warming, as noted in IPCC WG 2 TAR. These are mapped onto the five reasons for concern. Note that for some unique and valuable systems significant damages that some might label as "dangerous" are already occurring or are about to occur, whereas for other dimensions—e.g., risks of large scale discontinuities—warming of several more degrees is suggested before large and thus potentially "dangerous" changes become highly probable. The AR4 could further explore such a representation, stressing the many specific examples of significant impacts and spelling out explicitly as possible the subjective confidences in assessments of such impacts in the literature and among lead authors for each example. Such scientific assessments can help to put socio-political judgments as to what is "dangerous" on a firmer scientific foundation.

Fig. 2. Probability of damage vs. temperature increase: deterministic (stair) and stochastic (smooth curve) cases