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A Concept Paper for the AR4 Cross Cutting Theme: Uncertainties and Risk

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Overview

An assessment of climate change science requires careful consideration of the level of scientific understanding that applies to all of the key issues covered. Uncertainties affecting currently available scientific results need to be explained clearly and in ways that avoid confusion and assist policymakers and non-specialists when considering decisions and risk management.

The AR4 should build on previous treatments of uncertainty in IPCC reports and assess relevant new literature in this respect. It will be important to further enhance the development of a consistent but unrestrictive style of describing the source and character of uncertainties during the assessment process. Authors should be encouraged to: explain the nature of underlying hypotheses and simplifying assumptions; identify scarcity or quality issues with data; and recognise the limitations of models which do not simulate all processes perfectly.

Wherever possible uncertainties should be quantified using well defined procedures based on relevant literature. Projections into the future should show ranges in which the effects of lack of predictability (chaos), uncertainty in modelling, and scenario assumptions are separately identified. The treatment of uncertainties in the AR4 should improve the value of key findings by providing a more precise context for decision making and for structured approaches to risk management.

1. Introduction

This concept paper is intended to elaborate ways in which uncertainty might be dealt with in the preparation of the IPCC Fourth Assessment Report (AR4). A basic premise adopted here is that a useful focus for treating uncertainty will be to consider how it affects risk assessment and risk analysis, hence the title of the theme deliberately links the two concepts. However, the scope of this theme is not intended to extend into the area of risk analysis itself. Rather the focus is on dealing with uncertainty, itself a highly complex topic, and how that may be treated in ways that are useful for risk analysis.

One purpose of linking uncertainty to risk is to improve communication between climate scientists and potential users of the information they can provide. Several initiatives to improve the use of climate change science and deal with uncertainty in the policy process over recent years have identified risk analysis as a useful focal point (e.g. Willows and Connell, 2003). Such developments deserve attention from the authors of the AR4 as they are likely to provide useful guidance on how uncertainty can be characterized in a constructive manner. Recognition of existing attempts to develop a dialogue between science and policy over issues of uncertainty could make the AR4 part of that development.

This paper is not intended to directly influence the structure of any of the Working Group reports. We believe that the issues raised here will inevitably permeate those reports quite broadly. In addition there have been significant advances since the TAR in specific areas of uncertainty analysis which will require coverage in the AR4. Such advances should be covered naturally in relation to the underlying material being assessed.

In the remainder of this concept paper we provide a summary of:

- the relationship between uncertainty and risk assessment;
- the treatment of uncertainty in the IPCC Third Assessment Report (TAR);
- some general issues that arise when describing uncertainty;
- some suggested areas in which uncertainty and risk may need specific consideration;
- a suggested process for reviewing the treatment of uncertainty during the AR4 drafting process.

This paper is not intended to provide a comprehensive review of all the topics covered but should identify a representative cross-section of them so as to guide further decisions on how the theme might be implemented in the AR4.

2. The nature of uncertainties and their relation to risk assessment

IPCC Assessment Reports play a key role in the dialogue between scientists and non-specialists (decision makers, citizens, consumers) regarding the risks of anthropogenic climate change. The role of scientists is to understand the meaning of available observations and to develop rational projections of the future. On the other hand, a wide range of people have to make their own decisions, irrespective of their scientific background. A fundamental premise of the IPCC's existence is that they can benefit from scientific and technical information on the possible consequences of their decisions. This requires that the IPCC process be used to translate scientific understanding into terms which can help every one in making up their own minds.

The goal of making scientific understanding of climate change widely accessible raises particular challenges when it comes to dealing with uncertainty. Uncertainties are usually more difficult to quantify than the factors to which they apply; their treatment is more complex both conceptually and operationally; and the normal use of language to describe uncertainty is often ambiguous. In order to deal with uncertainty in a way that is coherent across the AR4 and useful for decision making it is recommended that descriptions of uncertainty be designed in ways that will improve risk assessment. This approach recognizes that climate change will modify existing risks and in doing so introduce additional sources of uncertainty into risk assessment (e.g. Willows and Connell, 2003).

Although the concept of "risk" is used in several different ways (e.g. German Advisory Council on Global Change, 2000) it is defined quantitatively in a broad range of formal risk analysis techniques as the product of two factors: the likelihood that some event will occur or its expected frequency of occurrence, and the magnitude of the consequences of that event. This usage of the term "risk" has been adopted in previous IPCC activities (e.g. IPCC, 1998), however, given the potential for ambiguous usage or interpretation of the term, it will need prominent definition in the AR4.

There is strong evidence that people treat consequences in a highly non-linear fashion, discounting small effects and emphasising large effects (e.g. Patt and Schrag, 2003). Systems normally survive because they are well adapted to the more frequent forms of low consequence events, whereas high consequence events can overwhelm the ability of any system to recover. This non-linear perception of consequences applies to the risk value, with low risk events normally being discounted and high risk events emphasised.

Probabilistic approaches can be applied to risk analysis when strict numeric probabilities can be defined, e.g. when long term statistics are available for stationary phenomena. Because of this, risk analysis is most easily linked to probabilistic approaches to uncertainty. However, risk analysis techniques are frequently adapted to deal with circumstances in which strict numeric probabilities can not be defined. In either case, uncertainty analysis plays a key role in risk assessment.

In order to assist risk assessment, descriptions of uncertainty should be focussed on aspects that are relevant to the strategies that might be applied to the issue being considered. For example, a tolerable pathways strategy, that aims to avoid impacts above some threshold, requires a focus on uncertainties in relevant critical thresholds and in the amount of climate change that would lead to crossing those. Risk assessment strategies that aim to identify unpredictable regimes[1] require information on how the reliability of estimates for likelihood and consequence decrease as a function of the magnitude or rate of change.

The above very brief summary of how an understanding of uncertainty may interact with risk assessment is intended to demonstrate that the best choices for describing uncertainty will depend both on the level of understanding of the relevant science, the nature of associated risk factors, and on the types of decisions that a corresponding risk assessment might influence.

3. The treatment of uncertainty in the TAR

Uncertainty was recognized as a cross-cutting issue early in the process of preparing the TAR. Moss and Schneider (2000) prepared a guidance document which was subject to two rounds of review. A series of recommendations was made regarding: careful characterization of the sources of uncertainty, coverage of ranges given in the literature, and consistent use of confidence descriptors. The latter recommendation introduced five levels of confidence to characterize collective expert judgements in terms of probabilistic ranges. In addition, an alternative means of quantifying confidence, was proposed in which authors would refer to a level of understanding based on both the amount of evidence available and the degree of consensus among experts.

The Moss and Schneider approach recognizes the need to obtain semi-quantitative assessments of uncertainties based on subjective judgments of confidence and that these can be more robust when pooled across several experts (e.g. Morgan and Keith, 1995). It also required that such judgments be mapped into a five-level confidence scale using the terms:

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[1] This is a common risk management strategy in the face of uncertainty, e.g. many insurance companies recently withdrew from the event insurance market in response to the outbreak of SARS because they felt unable to assess the risks being covered.

very high (95% or greater), *high* (67-95%), *medium* (33-67%), *low* (5-33%), and *very low* (5% or less). The WG II TAR used these terms as defined in the guidance document and in many cases followed an informal process within expert teams for deciding which term should apply to the collective judgment.

The WG I TAR adopted a different seven-level scale to characterize confidence as follows: *virtually certain* was used to describe a greater than 99% chance that the result was true, *very likely* a 90 – 99% chance, *likely* a 66 – 90% chance, *unlikely* a 10 – 33% chance, *very unlikely* a 1 – 10% chance, and *exceptionally unlikely* less than a 1% chance. The mid-range option, 33 – 66%, was not used.

In retrospect it appears that use of specific language (words such as *likely* or *low confidence*) to describe probability ranges can be misleading or confusing and this aspect of describing uncertainty needs to be reviewed. For example, writing that the judgmental estimates of confidence expressed by *low* is 5-33%, suggests that experts are able to agree that an estimate of 32 % is better than an estimate of 34 %. Actually, they don't agree on a probability value, but on a range of probability which can be defined at best on a 5 five points scale (as sometimes used in weather forecasts), anything significantly more precise being unjustified. If the AR4 is to use similar 5 or 7 point scales of confidence then at least the definitions used need to recognize fuzzy boundaries as done in the US National Assessment (USGCRP, 2000).

Similar choices occur between use of numeric ranges or semi-quantitative language to describe results. For example, in the SPM of the WG II TAR the expression "2 to 3 degrees" was replaced with "a few degrees". Such a change has implications for the degree of certainty being expressed in the underlying message and also raises potential problems with differing interpretations when translated to other languages. In general, numeric estimates of ranges and of probabilities provide more accurate ways of communicating results.

A more qualitative characterization of "level of scientific understanding" was used for cases where the authors were unable to express uncertainties in probabilistic terms. The TAR WG II SPM followed the Moss and Schneider (2000) recommendation using four categories: *well established, established-but-incomplete, competing explanations*, and *speculative*. The WG I TAR also used the concept of level of scientific understanding to qualify estimated ranges for some key parameters. However, that usage did not employ the two-dimensional separation into extent of information and degree of consensus suggested by Moss and Schneider.

The use of similar words in different contexts may lead to confusion. For example the TAR WGII SPM states:

> *Economic modeling assessments indicate that impacts of climate change on agricultural production and price are estimated to result in small percentage changes in global income (low confidence) with larger increases in most developed regions and smaller increase or declines in developing regions*.

The intent here is to say that, although analyses generally indicate small changes in agricultural income at a global scale, we have low confidence in the tools available. That implies a significant probability that actual changes might be large, but such an interpretation of the statement is not immediately obvious. Thus describing uncertainty well requires careful use of language and it would be useful to review the TAR, particularly the SPMs, in order to provide guidance to authors of the AR4.

Authors of the WG III SPM felt it necessary to describe uncertainties in estimating costs and benefits of mitigation measures in explicit terms depending on the context. E.g.

> *These two approaches (bottom-up and top-down) lead to differences in the estimates of costs and benefits, which have been narrowed since the SAR. Even if these differences were resolved, other uncertainties would remain. The potential impact of these uncertainties can be usefully assessed by examining the effect of a change in any given assumption on the aggregate cost results, provided any correlation between variables is adequately dealt with*.

Such a statement might be judged as disappointing for a policy maker who would like to use those cost estimates, but it conveys precisely what are the present scientific uncertainties. In such situations, where sensitivity analyses are used to describe the limits of our understanding, graphical presentations of results are often the most effective form of communication.

While the language used to describe uncertainty was not strictly uniform across the TAR, the approaches adopted by different groups of authors were similar in many cases and some advances were achieved over the Second Assessment. The focus on careful treatment of uncertainty alerted authors to some forms of ambiguity that had appeared in earlier reports. For example, the use doubly caveated statements of the form “we have *medium confidence* that phenomenon X *might* occur” was largely avoided. By highlighting the subjective nature of confidence levels, the guidance document stimulated greater discussion of confidence within the author teams. Also the use of an arbitrary collection of words such as “possible”, “doubtful”, etc was avoided, improving comparability of confidence assessments from one part of the report to another.

It should be noted that IPCC assessments incorporate a conservative treatment of uncertainty at a structural level. The general approach of identifying consensus among a group of climate scientists means that areas where there remains considerable uncertainty tend to be automatically de-emphasized or simply omitted. Comparison with the peer reviewed literature shows that in many cases individual experts tend to use more definitive language than that agreed as the consensus among a team of authors. The role of the author teams can thus be to drive towards the lowest common denominator view which may offset an apparent tendency for individuals to be overconfident in their own assessments (e.g. Kahneman and Lovallo, 1993).

Another structural way in which uncertainty is embedded in the IPCC assessments is through the use of scenarios for future change in underlying factors such as socio-economic change. The IPCC Special Report on Emission Scenarios (SRES) had a strong influence on the projections and timescales used in the TAR which may have obscured some longer term issues but did create a focus on a wide range of emission scenarios. Scenario analysis is widely used as a way of characterizing uncertainty for less predictable aspects of future projections.

This leads to the question as to whether some form of likelihood can be ascribed to individual scenarios – e.g. in the form of a time varying cumulative probability distribution for specific parameters such as CO_2 emissions. This issue has been strongly debated among experts and there is as yet no consensus on the issue (e.g. Wigley and Raper, 2001; Reilly et al, 2001; Allen et al, 2001; Schneider, 2001; Lempert and Schlesinger, 2001; Pittock *et al*, 2001)

4. General issues that arise in describing uncertainty

The probabilistic approach to uncertainty in relation to climate change raises some important conceptual issues. Frequency of occurrence can be defined for repeating weather related events, and changes in such frequencies can be derived from model projections. However, global scale climate change in the real world will occur only once and a frequentist definition of probability can only be considered in an academic sense using a sample space of climate outcomes constructed using models. Development of a consistent approach to the probabilistic description of uncertainty as applied to climate projections, and to frequencies of weather related events implied by such projections, appears to require further discussion.

Experience with the TAR has shown that confusion arises when insufficient attention is paid to the definition of what is being assigned a probability or confidence level. This is particularly so when probability or confidence is low but the issue sufficiently important to require discussion. A general issue of language arises in differentiating clearly between the estimated probability of a particular outcome and the confidence level of such an estimate. It is possible to have high confidence in a finding indicating that climate change would lead to a low probability of some outcome and conversely to have low confidence in a finding that climate change would lead to a high probability of another outcome.

There is some evidence that use of specific language to describe probabilities alone may not be interpreted accurately as people link probability descriptors to event magnitude. For example, a study involving 150 undergraduate science students by Patt and Schrag (2003) confirmed the existence of a behavioral tendency for people in general to interpret probability language describing weather events in a way that responds to event magnitude. Thus people are more likely to choose more certain sounding probability descriptors (e.g., *likely* instead of *unlikely*) to discuss more serious consequence events. But people are also sensitive to this practice in others, expecting a certain amount of exaggeration about the likelihood of high magnitude events. A related consequence is that if the language used is based solely on probability of occurrence the reader may have a tendency to over-estimate the likelihood of low-magnitude events, and to under-estimate the likelihood of high-magnitude events.

Characterization of uncertainties should clearly reflect their origin and the ways in which corresponding probabilities or ranges are derived. The origins of different components of uncertainties can be classified into five broad areas as follows:

1. *Incomplete or imperfect observations*. This type of uncertainty is a joint property of the system being studied and and our ability to measure it. Particularly in the natural and physical sciences the implications of observational uncertainty tends to be the best developed of the five sources of uncertainty considered here. It is well recognized that accurate treatment of obervational uncertainties must go beyond simplistic assumptions of normally distributed random errors. The effects of data sparsity, systematic and calibration errors need to be considered as does the sometimes subtle difference between the quantity of interest and the proxy that is generally measured. Comparison of independent observing systems and analyses provide key approaches to this type of uncertainty. Many important findings depend on a combination of observations of different factors having very different uncertainty characteristics, e.g. the use of multiple proxies to draw inferences about past climate change. However, techniques are available to deal with such issues and are generally used in the climate

science community. For the AR4 the challenge here will be to provide clear explanations of the sources of uncertainty and how they have been dealt with.

2. *Incomplete conceptual frameworks* (models that do not include all relevant processes, etc). This type of uncertainty arises where there are shortcomings in our understanding that essentially require a “breakthrough” to rectify and is the most difficult aspect of uncertainty to characterize accurately. A major issue here is the extent to which comparison of models with observations can serve to constrain uncertainties (e.g. Allen et al, 2000). The limitations of model validation need to be recognized, particularly where models are used to simulate circumstances that extend beyond ranges over which observations are available. A related issue is the ability of models to identify thresholds for ‘state change’ in the climate system.

3. *Inaccurate prescriptions of known processes* (poor parameterisations, etc). This type of uncertainty arises where defects in our understanding are subject to incremental improvement. Approaches to constraining uncertainty estimates in these cases tend to rely on comparison of models with observations and on model intercomparisons. It should be noted that the adequacy of observations for testing simulations may limit confidence in some aspects of models. To some extent this component of uncertainty might be treated as a subset of the one above, however, it is important to differentiate between the range of projections produced by a set of models and the broader uncertainty in projections that might arise because all models share a common defect.

4. *Chaos*. This type of uncertainty is a property of the system being studied. Chaos as defined classically arises where future states of a system are highly sensitive to small changes in initial conditions. Meteorology is well recognized as having a chaotic component and this concept is increasingly used in treatments of climate change. We expect recent progress in this area to provide a much clearer picture of projected climatic change in the presence of meteorological chaos.

5. *Lack of predictability*. Lack of predictability applies more broadly and can be extended to socio-economic studies where some aspects of societal behaviour are much less amenable to prediction than others. For example, in considering the rate at which new technology may affect energy systems, attempts are being made to separate uncertainty in the rates of market penetration of new technologies from the less predictable rate of invention of new technologies (Nakicenovic, private communication 2003). A widely used approach to characterize uncertainty in systems where lack of predictability dominates is to explore outcomes implied by a representative range of scenarios. This approach was the basis for treating uncertainty in future greenhouse gas emissions in previous IPCC reports and should be used again in the AR4. However, scenario analysis might be used in other areas of the assessment where predictability is poor.

Most key findings in the AR4 are expected to have component uncertainties corresponding to more than one of the classes identified above. It will be important to present results in such a way as to reflect these different sources of uncertainty. For example, projected ranges of future global mean warming should identify clearly the parts of that range that arise from: lack of predictability (chaos) in the climate system, uncertainty in climate models, and assumptions about emission scenarios.

5. Some specific issues for consideration in the AR4

5.1 Working Group I

Working Group I relies on a strong observational basis for its assessment and extends this using highly sophisticated computer models. This creates a dichotomy in the way uncertainties are treated. Concerning the existence of a global warming trend, recent data are quite reliable and statistical methods allow estimates of the degree of confidence for different components of apparent trends, e.g. global mean temperature, mean temperature over large geographical areas, night and day time increases, etc. Paleoclimatic data typically involve a wider range of more diverse sources of information, are sparse spatially, and involve varying degrees of temporal smoothing. Uncertainties in paleodata should deal with those issues.

Uncertainties regarding model projections are generally more difficult to deal with. It is accepted that many physical processes take place on much smaller spatial scales than the model grid and therefore cannot be modelled or resolved explicitly. Their average effects are approximately included through parameterizations which may take advantage of physically based relationships between the large-sale variables. Evaluating the errors associated with processes that are not explicitly resolved in the model and tracing the effect of these through to major conclusions drawn from model outputs is difficult.

One of the more critical parameters inferred from process based climate models is climate sensitivity, often defined as the equilibrium temperature change resulting from a forcing equivalent to a doubling of CO_2 concentration. Estimates of climate sensitivity in previous assessments by the IPCC and other groups have cited the range 1.5°C to 4.5°C for over 20 years. This factor of 3 uncertainty directly impacts any consideration of scientific and technical information that might guide policy decisions on dangerous levels of greenhouse gas concentrations. However, the TAR, like preceding reports, does not indicate clearly what probability should be assigned to the 1.5°C to 4.5°C range, nor whether the central part of that range should be considered more likely than extremes. Is this factor 3 truly representative of the uncertainty? Does our present understanding merit presentation of the uncertainty as a probability distribution function? Can we indicate what is required to significantly reduce the range and if so can we set a time frame on when that might occur? Each of these questions has very important implications for objective decision making processes.

The introduction of probability distribution functions (pdfs) for key results, such as climate sensitivity or the change in global mean temperature by 2100, into IPCC assessments would raise some significant new issues. Recent literature has produced rather different estimates of the pdf for climate sensitivity based on different models and approaches, but little attention has been given to methods for, or the validity of, pooling such estimates. Decisions would also need to be made as to whether (and how) a range of emission scenarios should be folded into a pdf for global mean temperature change. However, there could be several advantages to presenting some key results in terms of probability distributions. For example, presenting the range of warming in 2100 as a probability distribution would provide more useful information for impact analyses and risk assessment, and could also reduce misunderstanding. The 1.4 to 5.8°C range given in the TAR has been criticized for its opaqueness and the implication that all temperatures in this range are equally plausible in the absence of clear statements to the contrary.

There have been many new studies characterizing uncertainty in climate change since the TAR. The use of statistical approaches in analysing model results is leading to further clarification of the origins and ranges of uncertainty (e.g. Stott and Kettleborough, 2002; Weaver and Zwiers, 2000). The role of observational constraints on near term model projections has been investigated (e.g. Allen et al, 2000). Probability distribution functions for climate sensitivity have been considered by various authors (e.g. Andronova and Schlesinger, 2001; Wigley and Raper, 2001) and the interactions between uncertainty in radiative forcing, particularly of aerosols, and climate sensitivity have been discussed from various perspectives (e.g. Forest et al, 2002; Knutti et al, 2002; Anderson et al, 2003). A further important development is the use of multi-ensemble projections to consider and quantify changes in extreme events (e.g. Palmer and Räisänen, 2002).

Given the importance of regional scale climate change from a policy perspective a careful uncertainty analysis of methods for deriving regional climate projections is necessary. This should include consideration of statistical downscaling techniques as well as regional climate models. The roles of resolved and parameterised scales and processes are likely to be different between regional and global models suggesting that careful treatment of these issues will be necessary.

The issue of assessing the likelihood of a major state change in the climate system as a possible response to increased forcing remains a difficult area. However, some specific attempts to address uncertainty in such areas have been undertaken – e.g. Vaughan and Spouge (2002) have carried out an assessment of the risk of significant collapse of the Western Antarctic ice sheet using an approach similar to a decision tree analysis.

5.2 Working Group II

The impacts associated with a greenhouse gas emissions pathway are estimated in two steps: first an evaluation of the resultant climate change, then an evaluation of the effects of this climate change on the ecological and socio-economic systems. This causes a cascade in the overall uncertainties which come from combination of the uncertainties affecting the two steps. Based on experience in the SAR and the TAR it appears that greater clarity in describing our understanding of the effects of climate change is achieved if Working Group II focuses on the conditional uncertainty in effects for a given climate change scenario and that overall uncertainties are best treated at the synthesis report level.

Note that the conditional premise used in Working Group II is a climate change scenario which should be distinguished from an emission scenario. This distinction is assisted by the work of the Task Group on Climate Scenarios for Impact Assessment (TGCIA) which makes relevant climate scenarios widely available to impacts researchers (e.g. Carter et al, 1999).

However, the interaction between WGs I and II in terms of uncertainty raises other issues. Risk assessment generally requires a focus on lower probability high consequence events, whereas assessment of physical climate changes is most reliable for medium to high probability characteristics where there are better statistics. For example, flood control decisions might plan for a one in a 100 year event while most climate model runs extend for 200 years or less and so could only be expected to capture the background conditions for two such events. In the TAR, WG II naturally tended to use a risk (i.e. probability times consequence) based weighting for different aspects of climate change while WG I tended to use a probability based weighting. This has implications for how information on uncertainties is transferred between the two groups and requires more detailed consideration during the AR4. In particular, high consequence low probability aspects of climate change should be treated in a compatible manner.

In the first three IPCC assessment reports, effects have tended to be evaluated qualitatively rather than quantitatively and through sensitivity to change, rather than in terms of scenario based analyses. More quantitative projections would be appreciated by decision makers. However, if uncertainties in the results are too large then such projections become meaningless. Improving the treatment of uncertainty in cost estimates of climate change requires that the sensitivity of impacts to assumptions made in the models are critically assessed. Even if it turns out that some assumptions have a crucial effect these may be included in an assessment in order to show what might happen, even if the probabilities are unknown. But selection of such cases requires careful judgment, should avoid normative decisions by scientists as to what is policy-relevant, and the larger uncertainty and its more qualitative character need to be made clear.

Treatment of uncertainty in costing impacts should take into account that many factors other than climate change will impact the future and it is necessary to identify clearly the domains and regions which are likely to be mainly affected by climate change. Uncertainty in cost estimates for adaptation measures and their comparison with avoided damages raises specific issues of costing methodologies. This is an area of high policy relevance and should be considered carefully by WGs II and III in connection with the cross cutting theme of integrating Adaptation and Mitigation.

The development of integrated assessment models is leading to a broader understanding of how sensitivity and uncertainty analysis can be carried through an analysis of multi-faceted issues (e.g. Toth et al, 2003) but it must be recognized that results are still systematically dependent on model assumptions.

WG II also appears to face significant challenge in assessing uncertainties surrounding future adaptive capacity and the limits to adaptive responses. This may be a key factor in uncertainty when considering vulnerability.

5.3 Working Group III

Working Group III deals with mitigating future emissions of greenhouse gases and the feasibility and cost (in the broadest meaning of that term) of stabilizing their atmospheric concentration. A large number of factors will play a role: demography, economic and social development, scientific and technical progress, and international frameworks for shared decision making. Outcomes are much less predictable because societal behaviour is not controlled by immutable laws and the corresponding uncertainties become necessarily much broader. For these reasons short term economic predictions are treated with caution and longer term ones are considered more as scenarios of what could happen rather than having some identifiable probability of occurrence.

Some progress may be made in separating the more and less predictable aspects of technical and societal change. To the extent that this may be achieved it would be valuable to identify their separate contributions to uncertainty. However, assessment of our understanding of mitigation options will inevitably rely heavily on scenario based analyses. Treatment of uncertainties in this case can be done through careful identification of how the assumptions made in different scenarios affect results.

5.4 Synthesis Report

If it is decided to prepare a Synthesis Report for the AR4 then it will be necessary to integrate aspects of uncertainty arising from the different WG reports. For example, the uncertainty cascade effect mentioned above would require a reasonable degree of consistency between Working Groups I and II if overall uncertainties are to be assessed in a systematic way. This would apply in particular to attribution of observed effects to anthropogenic climate change or of projected effects to future anthropogenic climate change. Whether this linkage between Working Groups I and II strictly requires a probabilistic approach to uncertainty on both sides is an issue that should be discussed further within the appropriate expert communities.

There are clearly issues in common between the assessment of key vulnerabilities and issues relating to Article 2 of the UNFCCC and the general approach to uncertainties in the AR4. Some harmonization of approach between these two themes would appear to be necessary. In addition at the synthesis level degrees of uncertainty can be affected by choices of aggregation across regions and timescales. Thus there may be interactions between the regional climate and uncertainty themes.

6. A process for reviewing the treatment of uncertainty during preparation of the AR4

The various facets of uncertainties associated with climate change are sufficiently different that specific treatments may need to be applied in each case. Thus from an editorial standpoint, for each chapter, the Lead Authors should feel free to express their uncertainties in their own way, but be asked to provide all available information on the limits to every statement in ways that can be understood by non-specialists.

Editorial management of the report should also call for an emphasis on clarity and transparency in language relating to uncertainty. Use of specific language constructs and standard uncertainty scales remains an issue to be considered further. It appears these can be restricting for authors and can be misleading for the readers. On the other hand the uniformity they provide may be important when considering syntheses of findings at the level of a Technical Summary, a Summary for Policymakers, or in a Synthesis Report.

It is proposed that, following the second scoping meeting for the AR4, the co-anchors work with selected experts to develop a more substantive background paper on the uncertainty and risk theme. Such a background paper would include discussion of options and suggestions for dealing with different types of uncertainty with references to the recent literature. The aim would be to build on work done for the TAR and, to the extent possible, address issues that arose there using input from some LAs of the TAR.

The background paper would need to be reviewed broadly and a reasonable amount of time would need to be allowed for that. In order to advance this process rapidly it is proposed to hold an expert meeting on “Uncertainty and Risk” early in 2004. Given the need to make the characterization of uncertainty in the AR4 relevant to policymakers, it would be appropriate to include a carefully focused policy perspective in this meeting.

It would clearly be most valuable if the background paper could be completed in advance of the first LA meetings for the AR4. This paper should be placed on a closed IPCC web site reserved for LAs and include an index addressing the reader directly to the issue for which she or he is seeking advice.

As a second step we propose that in the review process specific reviewers be identified to consider the treatment of uncertainty in the WG reports. Some of these reviewers might be drawn from outside the normal pool of climate experts. Their role would be fully consistent with the normal open review process used by the IPCC, although their focus would be specific to the uncertainty issue. This complementary type of review would not displace the IPCC's standard rules governing the roles of LAs and REs. In particular, the LAs and REs would remain pre-eminent in the drafting process.

We suggest that the co-anchors would continue to have a monitoring role during the review process. This would involve maintaining contact with the "uncertainty reviewers" during the review periods and considering any difficulties that arose in dealing with uncertainty issues. However, the co-anchors would not play any role in drafting the reports beyond the normal review process. They might be consulted during the plenaries devoted to the reports acceptance.

If substantive issues regarding treatment of uncertainties arose during the preparation of the AR4, and appeared to merit further consideration, we suggest that these be summarized in a report for the benefit of the next IPCC Bureau and their preparations for the AR5.

7. Conclusions[2]

The way in which uncertainty is treated in the AR4 will have a significant bearing on the overall utility of the assessment for decisionmakers. In this respect a focus on providing assessments of uncertainty that can improve risk analysis appears to be a constructive approach and is consistent with recent studies and literature particularly in the Working Group I and II areas.

The treatment of uncertainty in the TAR was an improvement on that used in previous assessments, and aspects of that approach have been used subsequently in national assessments. Based on this experience and on new approaches appearing in the literature it should now be possible to improve on the approaches to uncertainty used in the TAR.

The best approach to assessment of uncertainty will vary depending on the issue being addressed and the nature of the available research results. This suggests that some flexibility in approach is necessary.

However, some degree of compatibility in the treatment of uncertainty is also necessary if systematic approaches to uncertainty are to be used for issues that require a synthesis of findings from different disciplines or Working Groups. Thus a careful balance between flexibility and compatibility will need to be developed.

[2] This conclusion section was added in the final revision to this paper because several review comments appeared to indicate a need for some general summary points and because the general tone of the comments received have suggested a consensus on several aspects.

Clarity in describing uncertainty requires very careful attention to choices of the ideas being expressed and the language used to do so. Distinctions between the probability of events and the confidence in such probability estimates, between subjective and objective assessments of uncertainty, and between uncertainty applying to more observationally based and more model based results, all require careful and consistent use of language.

Description of uncertainty where outcomes are expected to have very high consequence, but where probability is expected to be low or where predictive ability or confidence in present understanding is low, present particular challenges.

While there may be merit in examining how uncertainty issues are dealt with in other disciplines (e.g. financial, chemical and nuclear industries), it appears that climate change presents some unique circumstances that will need to be addressed in an inter-disciplinary way within the climate science community. This should be done in consultation with the future users of the AR4, to avoid any misunderstanding and to ease the adoption of the reports during the relevant plenary.

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