Climate Change Research: Evaluation and Policy Implications
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ASSESSMENT REPORT ON NRP SUBTHEME "RISK ANALYSIS"

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Contents

ABSTRACT

This report presents an overview and assessment of the three research projects carried out under NRP funding that concern risk-related topics: (1) The risks of nonlinear climate changes, (2) Socio-economic and policy aspects of changes in incidence and intensity of extreme (weather) events, and (3) Characterizing the risks: a comparative analysis of the risks of global warming and of relevant policy strategies.

1. INTRODUCTION

The great degree of uncertainty in the dynamics of the climate system, in the (quality and quantity of the) effects that may be expected, and the long time delays between causes and effects imply that the greenhouse problem can be regarded as a risk problem. The consequences of climate change may be great, and the probability of its occurrence is hardly known. Risk analysis is therefore regarded under the NRP program to be an important means for the evaluation and assessment of the possible (positive and negative) consequences of climate change. This not only implies the necessity of research into the risks attached to global change itself and the relationships with the presently existing natural and man-made risks, but also research into to risks attached to the social and policy response. This is pertinent to the Dutch situation, where Dutch climate policy is based upon the precautionary principle, proceeding from a risk approach to the formulation of environmental quality objectives. These are provisionally based on the indicators and environmental quality objectives formulated by the RIVM and the Stockholm Environmental Institute. The continued development of such indicators and risk limits requires regionalisation, attention to extreme values and non-linear effects, and analysis of multi-stress situations. Such a line of research should be related to the limited analyzing power of current climate models and thus to the relevance of additional information and to the propagation (and accumulation) of uncertainties of various kinds.

The programming memorandum "Integration" of the Dutch NRP on Global Air Pollution and Climate Change thus concludes that research is needed in the analysis of risks associated with the various effects of climate change, and also in the comparative analysis of the risks of different policy strategies on national, European and global levels. This should result in a comparison of the risks and costs associated with strategies directed at adaptation or prevention or directed at temporisation (too early or too late) in the adoption of measures.
Specifically, the memorandum proposed the following studies:

1. Research (in close collaboration with others NRP bodies) into regional indicators of global change.
2. A systematic inventory of extreme climatic conditions and of non-linear events that have been neglected thus far.
3. A systematic inventory and an assessment of the risks and costs associated with various abatement/adaptation/temporisation options.
4. A coordinating study into the development of an integrated risk approach which should enable the support and evaluation of the setting of standards.

The selection process that followed the publication of the memorandum has resulted in the funding of the three projects described in this assessment report. They cover only a part of the requirements formulated above, due to a limited supply of project proposals and to limitations in the NRP funding.

Table 1.1
List of Projects in the NRP subtheme "Risk Analysis"

Title	Project leader	Number
The risks of non-linear climate changes	J. van Ham	853118
Socio-economic and policy aspects of changes in incidence and intensity of extreme (weather) events	P. Vellinga	853137
Characterizing the risks: a comparative analysis of the risks of global warming and of relevant policy strategies	L. Hendrickx	853114

A common characteristic of the projects described here is a relatively late start in the first phase of the NRP-program, namely only in the summer and fall of 1993. Not surprisingly, none of the projects has been completed at the time of writing of

the assessment report. Two of the projects (number 2 and 3) are scheduled to continue into mid 1995.
Assessment of such studies is not an easy job, especially because the issues involved are complex and because the studies under focus are in general first-of-a-kind projects. Developing a suitable research methodology tends thus to be an iterative process. Producing interim documents for the NRP evaluation process may very well not be the first priority of the teams involved, nor apt to generate the most useful ingredients for an assessment.
Special procedural attention should be given to the second project as it has been financed in two steps: after a preliminary study the results have been evaluated by the NRP programming committee in order to judge the wisdom of continuation with the other phases. This evaluation is not laid down in written documents, but has resulted in modifications of the original research plan, putting more emphasis on the description of the possible socio-economic aspects than on scenario development.

2. THE RISKS OF NON-LINEAR CLIMATE CHANGES

2.1 Summary of findings

This project aims to provide a survey of non-linear mechanisms of global change that operate in addition to those already incorporated in the usual GCMs. In this survey special attention is paid to the relevance for the climate in North-west Europe. The project is conducted within the TNO-organization (project leader: dr. J. van Ham, SCMO-TNO), and covers less than one man year research in a period of about 20 months in 1993 and 1994 (Van Ham, 1994).

State-of-the-art Coupled General Circulation Models (CGCMs) describe the behaviour of the atmosphere and the oceans as well as the interaction between both. The results represent several aspects of present and past climate reasonably well, although systematic deviations from observations exist. Consequently errors occur in predicted distribution patterns of e.g. temperature, wind and precipitation. The spatial resolution is relatively low, so the performance in the prediction of regional climatic features is rather low too.
The addition of extra feed-back mechanisms to such models makes only sense as far as significant changes will occur within the context of CGCM outcomes that exhibit various degrees of accuracy and resolution.
The project has produced a list of mechanisms that may provide feedbacks with a risk for non-monotonous or discontinuous behaviour of the climate system. Included are the following:

* Snow-ice albedo feedback, which may lead to a positive feedback on a timescale of a few centuries,
* Cloud feedback is an issue not well covered in GCMs due to the complex role of clouds in the radiative balance. Nevertheless the sensitivity of GCMs for cloud feedback is known to be relatively high. Satellite measurements have revealed that at present the globally averaged net cloud forcing is negative. The interactions between aerosol and cloud feedbacks and their coupling with other feedback mechanisms is only partially known and will require an integrated approach that is needed before these mechanisms can be incorporated into or coupled with GCMs.

* Biogeochemical feedbacks form an important but complex issue. With regard to phosphorous compounds it turns out that the increased availability of phosphate in surface and coastal waters may promote the primary production. In the carbon budget opposing trends are present, although most of them tend to provide a positive feedback to the CO_2 accumulation in the atmosphere. The overall nitrogen budget seems to be neutral, although major uncertainties concerning e.g. nitrous and nitric oxide have been identified. The net result of changes in the sulphur budget are uncertain. The dominant trends here will be determined by the developments in the anthropogenic sources of carbon and nitrogen.
* Interaction between greenhouse and ozone effects can occur due to the fact that an enhanced greenhouse effect results in cooling of the lower stratosphere, thereby favouring conditions under which the ozone hole is formed in spring. Also, loss of ozone reinforces stratospheric cooling, so here a positive feedback loop is available.
* Combined effects of global change processes on forests constitute an additional stress factor for forests and natural vegetations of a yet unknown magnitude.
* Glaciological mechanisms could result in effects that become pronounced only at timescales of centuries. On a shorter timescale the formation of melting ponds in the Greenland ice-sheet may result in a positive feedback through albedo loss. An enhanced run-off could in principle affect the salinity in the North Atlantic ocean (see also next point).
* Modifications of ocean circulation patterns are a major concern as e.g. future climate changes in North Western Europe may be caused by a collapse of the Warm Gulf Stream. The so-called thermohaline circulation patterns turn out to be strongly influenced by changes in the influx of freshwater. The overall effect on the climate in North Western Europe may be moderate: a global warming of about 3°C could be compensated by a lowering of on the average 4°C in The Netherlands during winter days with advection from sea. Of course also other effects on weather conditions will occur (rainfall, wind patterns). The overall changes could occur on a timescale of centuries.

2.2 Discussion of results

The final reports of this project are not yet available. This hinders the final assessment. This is especially true for a major step in the project proposal: the confrontation of the project results with the opinion of experts via a dedicated workshop, to be held in 1994.

The uncertainties associated with the various non-linear feedback mechanisms are high. A full assessment of the risks (timing, magnitude, consequences) is impossible at the present state of knowledge. Following the results of this project, the most important issue concerns the interaction of greenhouse and ozone effects. In the following decades a gradual decline in ozone depleting substances is foreseen, while at the same time the concentration of greenhouse gases may reach levels that are critical for the process of stratospheric cooling with its associated negative consequences.

3. SOCIO-ECONOMIC ASPECTS OF EXTREME EVENTS

3.1 Summary of findings

The enhanced greenhouse effect is not only expected to raise average global temperatures, it may also affect the frequency and intensity of extreme weather events, such as windstorms, tropical cyclones, heat or cold waves, and periods of extreme rainfall or drought. These events may have profound consequences, in terms of loss of life, material damages, and/or social-economic disruption. It has been suggested that in many parts of the world the negative consequences of global warming associated to increases in extreme weather events will be more serious that those resulting from a change in average temperatures. Thus, the following questions need to be answered: (1) Will the accumulation of greenhouse gasses result in changes in the incidence and severity of extreme weather events? (2) If so, what will be the (direct and indirect) impacts of an increase in weather related natural disasters? (3) Which strategies can be developed by relevant actors (e.g., governments, insurance companies) to avoid climate change or to ameliorate its consequences? The aim of the project is to generate information required to answer such questions. The project is conducted at the Institute for Environmental Studies (IES) of the Free University in Amsterdam (NL) with prof.dr. P. Vellinga as the project leader. Parts of the project are carried out by the Environmental Change Unit (ECU) of the University of Oxford (UK). The total number of man years spend in this project amounts to Section 3.2.

The project consists of four main research activities: (1) organization of an introductory workshop; (2) development of weather scenarios; (3) assessment of socio-economic impacts; and (4) assessment of possible response options.

1. In june 1993, a two-day *workshop* was organized, the main aim of which was to identify and demarcate the specific research questions and issues to be addressed in the remainder of project. A comprehensive list of research issues was composed, centring around five key topics: (1) weather scenarios, (2) vulnerable areas, (3) exposure scenarios, (4) risk scenarios, and (5) policy scenarios (for details, see Olsthoorn and Tol, 1994). It was decided to focus on two combinations of weather events and target regions: "storms in NW-europe' and "cyclones in the SW-Pacific".
2. A *weather scenario* is: "a plausible future for weather patterns with reference to extreme weather events". Methodologies for developing weather scenarios are discussed in Downing et al. (1993). Weather scenarios may be based on General Circulation Models (GCM's) or they may be extrapolated from observed weather statistics. In the latter case, so-called stochastic weather generators (SWG's) are used. Basically, SWG's are models that generate weather patterns with the same statistical features as the observed weather; in the case of climate *change* studies, SWG-models with "perturbed parameters" may be used. Because of their expertise in SWG's, ECU Oxford was asked to develop the weather scenarios.

   The work on weather scenario development still continues. It is clear, however, that for both the events studied (storms and cyclones) scenario development turned out to be more difficult than expected. One reason for this is that the resolution of current climate models is insufficient for predicting (regional) changes in extreme weather events. For instance, a review of recent GCM-studies (in Tol et al. 1994) reveals that the evidence with regard to the effect of CO_2-doubling on the frequency and intensity of tropical cyclones is highly conflicting. While some models predict an increase in the destructive potential of cyclones of up to 50%, others predict a decrease of cyclones under 2 x CO_2; yet other investigators conclude that outcomes strongly depend on the model parameters chosen. Analysis of historical data on cyclone prevalence in the SW-Pacific also failed to result in clear conclusions about existing trends, due to limitations in the available data sets. Tol et al. (1994) conclude that: "neither theory nor observations are conclusive on how the incidence and intensity of tropical cyclones will change under a doubling of CO_2". Consequently, scenario construction is to a large extent based on "educated guesswork". With respect to "windstorms in europe", a similar conclusion applies (Olsthoorn and Tol, 1994).

3. Assessment of *socio-economic impacts* and assessment of relevant *response options* both belong to the second phase of the project. Since the reports available to date all refer to the first phase, information on the nature and content of these activities is limited. With regard to point (4), the results of a preliminary analysis of response options, available to (re)insurance companies, is presented in Olsthoorn and Tol (1994). Most of the response options available to insurance companies merely aim to restrict the potential financial consequences for the company (e.g. raise premiums or deductibles, hedge risks through reinsurance, or exclude certain risks or areas). Some response options, however, are more fundamental in the sense that they aim to decrease the amount of damage resulting from climate change (by promoting reduced exposure through, e.g., education, premium incentives or contract conditions), or to prevent climate change itself (e.g. by investing in energy saving measures or by lobbying for climate change prevention).

3.2 Discussion of results

The list of research issues, which resulted from the introductory workshop, makes clear that answering the three questions indicated in the introduction will require a vast research effort. In view of this, the project team's decision to focus on methodological aspects and two case studies (storms in Europe, cyclones in SW/Asia) appears to be a wise one.

The currently available project output addresses the first part of the project and, as a consequence, mainly pertains to meteorological issues (i.c. weather scenarios). This is a somewhat unfortunate situation, for two reasons. The first is that, although the work on weather scenarios has not been completed, it is clear that the outcome will not be entirely satisfying. The current state-of-the-art in climate (change) modelling does not allow unambiguous conclusions with respect to regional changes in extreme weather events. And at least for one of the events studied (cyclones), scenarios can neither be reliably extrapolated from existing data sets (which, in our view, would be tricky anyhow since global warming may change existing trends or may have non-linear effects, see section 2). As a consequence, the weather scenarios to be used in the remainder of the project are chosen rather arbitrarily; they are not firmly rooted in meteorological theory or analyses. In view of the lack of relevant knowledge and data, this seems to be the only viable course of action, but it may cause difficulties later on in the course of the project; for instance, choosing between the response options (to be) identified in step 4 will probably require information on the conditional likelihoods of weather scenarios (conditional on emission scenarios). Whether such estimates can be generated in a reliable way seems doubtful.

That the existing project output mainly deals with meteorological issues "tends to conceal the mainly socio-economic nature of the study" (Olsthoorn and Tol, 1994). We agree with these authors that the quintessence of the project is to develop a methodology for assessing and quantifying the social and economical impacts of extreme weather events. The emphasis on meteorological issues is probably temporary and due to the premature timing of the assessment (see section 1). Nevertheless, the fact that the current output hardly addresses the impact assessment methodology precludes an evaluation of the project as a whole. Despite the difficulties encountered with regard to weather scenario development, the project may yield a valuable contribution to NRP-program in general and to decision-oriented approaches in particular (see e.g. section 4), if the project team succeeds in developing an appropriate methodology for impact assessment and quantification. Whether this will be the case cannot be decided on the basis of the currently available material.

4. CHARACTERIZING THE RISKS

4.1 Summary of findings

The purpose of this project is to examine whether or not a decision-analytic approach yields an effective and integrated assessment methodology for ordering and combining the research results about global warming. The focus of the project is on representing the global warming as a decision problem for the Dutch (public) policy makers. The research is conducted at the Center for Energy and Environmental Studies of the University of Groningen, with dr. L. Hendrickx acting as the project leader. The projects has started in September 1993, will continue until mid 1995 and entails 3 man years of research.

Research presently conducted under the NRP program is primarily problem-centred (or 'diagnostic'), i.e., it is aiming at identifying and quantifying the risks associated to the (anthropogenic) greenhouse effect itself. Some therapeutic). i.e., they aim at the identification of possible and relevant policy measures and at the assessment of their societal impacts. The present project aims at the development of a methodology that relates and combines conclusions from 'diagnostic' oriented research with those from 'therapeutic' oriented research. In other words, this project is directed at the development of a methodology for *ordering* the various (geophysical, ecological, technical, socio-economical and political) elements of the global warming problem in a coherent and meaningful decision analysis.
Integrated assessment has to do with surveying and ordering a particular state of knowledge about a particular issue. However, it is a misconception to consider integrated assessment to be simply a matter of collecting and ordering all available knowledge in all its details. The challenge of integrated assessment is primarily one of information management and the development of representations at an adequate high level of aggregation. The issue is to *make the analysis as simple as possible but no simpler* (Morgan and Henrion, 1990). It is useful to distinguish integrated assessment in a pure scientific context from that in a policy context. In the latter case the additional - and possibly even more important - challenge exists in casting the problem from the perspective of policy makers. Decision-analytical approaches might fit the purpose of such integrated assessment as they explicitly incorporate an analysis of the uncertainties involved. Uncertainties are attached

to almost every step in the global warming causal chain (driving forces - human activities - greenhouse gases and aerosols - enhanced greenhouse effect - temperature increase - secondary climate changes - socio-economic impacts). Much global climate research is aimed at the reduction or even elimination of these uncertainties, although the relevance for public policy is not always clear.
Insights from decision theory might facilitate the assessment problem at hand as a policy oriented decision-analytic tool could (a) result in a transparent and intelligible synoptic view which spans all significant aspects of the global warming problem, (b) assist policy making by representing the problem such that it links up with the decision perspective of policy makers, and (c) explicitly include uncertainty in the analysis for, amongst other things, identifying critical knowledge gaps or performing sensitivity analyses.

The DEMOS model (DEcision MOdeling System) is the product of over a decade of research on uncertainty analysis and on tools for integrated assessment at the Department of Engineering and Public Policy of Carnegie Mellon University, USA. This model is currently in use for their Global Changes Integrated Assessment Program which aims at integrating the many disparate pieces of science relevant to the global warming problem. DEMOS is a software environment for creating, analyzing and communicating complex models involving uncertainties for risk and policy analysis. These models are described through graphical influence diagrams, much like the tools used in system dynamics. Large models can conveniently be organized into a hierarchy of more manageable submodels, each with its own influence diagram. DEMOS contains built-in sensitivity and uncertainty tools for the explicit treatment and propagation of uncertainty. It is flexible enough to include traditional approaches like subjective expected utility (SEU) analyses and multi-attribute utility (MAUT) analyses.
This model has been made available for use in the current IVEM project, and functions as the primary tool for the characterization of the global warming risks.

The present state of affairs in this project is that an initial conceptualization of the global warming problem has been constructed and is being filled with quantitative information (data, values, relationships). The current representation involves a first and provisional conceptualization that should be adjusted in a subsequent iterative process of modification and refinement in the research period until mid 1995. The results of the first phase of the NRP program can thus be used in this process.
The IPCC scenarios are used for the representation of possible different economic, social and environmental developments. For the formulation of Dutch policy options the results of the NRP project "Development of policy options for dealing with the greenhouse effect on sustainable development" have been used. Greenhouse damage appears to be one out of five socio-economic impact categories. The other categories are: abatement costs, adaptation costs, international relations and first mover. The greenhouse damage category could be subdivided using the Cline categorization as a point of departure. The end result will be a (multi-attribute) tree of impacts with the five impact categories mentioned before as the main branches. The impacts at the end of branches should provide operational measures for evaluating and comparing Dutch policy options. Within this context it is an option to relate the set of expected Dutch socio-

economic impacts to the OECD list of socio-economic indicators as proxies for welfare indicators.

4.2 Discussion of results

A comparative analysis of the risks of global warming and of relevant policy strategies concerning that problem is central to the current NRP program. One of the approaches chosen concerns decision analysis. This could provide a hierarchical representation of the policy problem at a high level of aggregation, thereby avoiding irrelevant reliance on complex models and massive handling of information by actors not fit for that purpose.
The present project capitalizes on the insights gained in this field of research by the cooperation with Carnegie Mellon University. The use of the DEMOS model greatly facilitates the development of the required methodology.
At present a first representation of the global warming problem in terms of hierarchical influence diagrams is being finalized. Results of the first phase of the NRP program should be made available in order to refine and detail that version. Tuning with the current research on the (meta) IMAGE model and with projects that generate policy options in cooperation with public policy officials seems necessary for the next phase in this research project.

5. GENERAL DISCUSSION

None of the projects discussed in this assessment report has entered their last stage - hat of producing the final documents. That hinders a full assessment.
The overview of extreme weather events project concerns a study of only moderate manpower, and has produced a list of possible categories of extreme weather events that may pose serious and non-linear risks to society and nature. The final assessment of these results will be produced after a workshop with various experts that will be conducted in 1994.
The assessment of the socio-economic aspects of extreme weather events project has thus far mainly addressed meteorological issues. The results cast doubts upon the feasibility of generating reliable extreme weather scenarios. This requires the rest of the project to focus and concentrate on the development of a methodology for the assessment and quantification of the social and economical impacts of extreme weather events.
The project concerning the characterization of the risks of global warming and of relevant policy strategies has thus far resulted in the selection of an appropriate programming environment, and in the preliminary formulation of a set of hierarchical influence diagrams describing the global problem from a Dutch policy perspective. This implies that the first steps are made in the formulation of a suitable methodology, that may be of great importance for other lines of research (to be) pursued under the NRP programme.

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