General Background on the Weather and Climate Impacts Assessment Initiative

Climate and weather create hazards and opportunities for society at multiple scales. However, most of society does not have scientific expertise, and most scientists are unfamiliar with how societal decision-making processes work. In the climate context, this process of bridging between scientific knowledge and societal need is known as "*assessment*," while the weather community might more familiarly call it "developing usable forecast information." Assessment can be broadly defined as "the entire social process by which expert knowledge related to a policy problem is organized, evaluated, integrated and presented in documents to inform policy or decision-making" (GEA 1997). Assessments such as the U.S. National Assessment of the Potential Consequences of Climate Variability and Change (USNA) and the international Intergovernmental Panel on Climate Change (IPCC) assessment reports focus on synthesizing, evaluating and reporting on what is known about climate variability and change and its impacts

Not all processes and products that fall under the rubric of assessment are the same however. The NCAR Assessment Initiative focuses on impact assessments, a more narrow focus that aims to assess the severity, likelihood, and effects of a given phenomenon, such as climate change and extreme weather events, on a system of concern to society, such as agriculture, health or energy supply. Within this area of research lie a number of critical scientific gaps that currently limit our ability to effectively assess future impacts and provide quality information to decision-makers. These difficulties include differing perceptions of uncertainty and extremes between climate scientists, social scientists, and decision-makers; lack of tools for quantifying current and future frequency of extremes; and so on (e.g., Moss and Schneider 2000, Webster et al. 2003, Parson et al. 2003). This initiative concerns both filling these critical gaps and integrating the different scientific disciplinary research necessary for informing decision makers regarding current and future weather and climate hazards.

The Weather and Climate Impacts Assessment Initiative is organized around three themes: characterizing uncertainty in all phases of impacts assessment, extreme weather and climate events, and climate and health. It is mapped onto the following specific scientific objectives.

- To quantify uncertainties related to multiple forcings (i.e., greenhouse gases plus land cover change, and natural forcings--solar variability, aerosols from volcanic eruptions) in climate models;

- To characterize uncertainty on regional scales in climate projections that support decision-making;

- To determine new robust measures of changes in weather and climate extreme events and their uncertainties (using extreme value theory), for extremes relevant to societal impacts;

- To nurture an interdisciplinary research community to address the interactions between climate and human health; and

- To work towards end-to-end integrated projects in extreme events and uncertainty that encompass physical science, impacts, and decision-making.

These objectives are fulfilled by a number of individual tasks (described below) that have been selected because they address identified weaknesses of existing national and international assessment processes such as lack of uncertainty estimates for climate projections, missing elements of scenarios, or differences in the perceptions of the most appropriate way to consider extremes (e.g., Moss and Schneider 2000, Webster et al. 2003, Parson et al. 2003).

NCAR is uniquely poised to study these topics, as it has a mission firmly grounded in the atmospheric sciences, including climate and weather, as well as the responsibility as a national center to provide science in service to society. NCAR also is staffed by renowned scientists in these areas and has a multidisciplinary structure--the capability to mobilize scientists from different disciplines around a central topic. This initiative is also of critical relevance for NCAR because it provides timely, needed input to ongoing processes of national and international importance—for example the IPCC, and future national and regional assessments.

Renewal Proposal for the

NCAR Weather and Climate

Impact Assessment Science Initiative

Linda O. Mearns and Warren Washington

September 6, 2002

National Center for Atmospheric Research

Introduction

The WCIAS Initiative is built on three major themes:

- Characterizing Uncertainty in Impact Assessment Science
- Extreme Weather and Climate Events
- Climate/Health Interactions

We organize this document around these three themes, which are described in full in the Assessment Initiative Foundation Document (Mearns and Washington, June 2001). A number of the projects are continuing tasks from FY01-02. These projects take priority over the new projects. A separate attached sheet lists the priorities of all tasks in descending order. What can be accomplished with level funding is indicated in the body of the document under the continuing projects. Essentially, given the small amount of funding provided in FY01-02, very little could be accomplished at that very low level. For several of the larger projects, efforts will be made to seek complementary outside funding for some of their tasks.

I. Characterizing Uncertainty in Impact Assessment Science

The projects described in this Initiative element are highly diverse and cover many different aspects of uncertainty analysis: uncertainty in climate model simulations with different emissions forcings, uncertainty in future climate due to changes in land cover, exploration of the uncertainty of past climates in climate models, incorporating uncertainty measures into climate scenarios for impacts use, and uncertainty and decision making. Five projects covering these topics are described below.

1. Uncertainty in Climate Model Simulations

Goals

The major goals of this project are to develop new techniques for quantifying uncertainty in climate model projections and to apply theses techniques to recent transient runs of atmosphere-ocean general circulation models (AOGCMs). Particular emphasis will be given to quantifying regional uncertainty.

Progress to Date

In the first year of this project, transient Business as Usual (BAU) runs from the Parallel Climate Model (PCM) were used to investigate aspects of the control run and climate change run in reproducing some extreme events. Also, using a mixed model approach, progress was made in elaborating on the uncertainty approach of Giorgi and Mearns (2002) in combining criteria of validation and convergence in evaluating future climate changes using regionalized output from 9 different atmosphere-ocean general circulation models (AOGCMs) run with two different emissions scenarios.

Research Plans

The research on uncertainty in climate model simulations will continue to be developed in three main tasks.

The first one is aimed at the analysis of single model ensemble runs, using model output already available to us (PCM all forcings runs for present day climate; BAU runs for end of the 21st century climate; and Special Report on Emissions Scenarios [SRES] scenarios). Within this context, the analysis of uncertainty will focus on issues of downscaling model output to the observations' domain - and conversely "upscaling" station records to the model gridbox domain - in order to correctly compare present-day climate simulations to available records and to sensibly infer local impacts of simulated future changes. Aspects of climate change analyzed will be indices of extreme events' intensity and frequency, influence of ENSO-like signals on them, their trends and spatial patterns, and, for all of these quantities, a characterization of uncertainty under precise statistical assumptions will be the central part of the analysis.

The second task will be the continuation of the analysis of multi-model ensembles following Giorgi and Mearns (2002), with particular focus on determining regional measures of climate change and their confidence levels. In this context, statistical models will be aimed at separating within from between model variability through mixed effects models; assessing different factors' relative importance (region/season/scenario/model and their interactions, for example) through ANOVA-type analysis; accounting for outliers through robust statistics; investigating the sensitivity of the summary measures of climate change to the scales of regional aggregation, by use of spatial statistical models; and modeling the temporal evolution of processes through multivariate time series analysis.

The third task concerns designing of experiments (model runs). A proof-of-concept will take place using the idea of "daughters ensemble members." These will be short runs generated by randomly selecting as initial conditions states at the end of ensemble members' long runs in order to explore the "weather patterns" space under the same climate scenario. Underlying this experiment is the more general issue of studying the relation between ensemble size and variance of the estimates. A more complete approach will then be pursued, in which the theory of experimental design will be applied, in particular ideas of latin hypercube-type design, in which factors are varied optimally and efficiently in order to analyze their relative importance. We will consider factors including changes to the emission scenarios.

(Note: Under level funding, only the second task could be accomplished).

Timeline of Accomplishments

YEAR 1
Results from tasks 1 and 2 will be available for specific study regions, together with a toolbox of R software programs able to be easily adapted for similar analyses of different regions.

YEAR 2
Results of global analyses and full development of R software plug-in modules will be complete, ready to be made available for the larger research community.

YEAR 3
Inter-model and inter-scenario comparisons will be performed. The results of task three will have been analyzed with particular attention to the issue of modeling the propagation of uncertainty stemming from emission scenario uncertainty.

NCAR Team
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External Collaborators
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2. Land Cover Forcing From the SRES Scenarios in Climate Models

Goal

To extend future climate change scenarios by including human impacts on land cover and soils. This work has been initiated with LSM/PCM and will be expanded to use CLM/CCSM. Simulated changes are land cover, human impacts on soil, and urbanization. These experiments will address how human land use and land cover change are altering climate, water and carbon cycles, and biogeochemistry. In particular it will address: (1) How have changes in land use and land cover altered present-day climate, and how are they likely to alter future climates? (2) How important is the land use and land cover change forcing relative to other IPCC SRES forcings (e.g., greenhouse gases)? Parts of this work will be accomplished in collaboration with the Biogeosciences Initiative.

Research Plan

A. LSM/PCM simulations

To assess the first-order impacts of land cover change, we propose a series of simulations using PCM with the LSM land surface model. These simulations will complement existing climate simulations of PCM using pre-industrial atmospheric forcings for 1870, transient historical forcings from 1870 to present-day, and transient simulations to 2100 using the SRES A2 atmospheric forcing.

Proposed runs include: a pre-industrial atmospheric forcing equilibrium run to evaluate the impact of present-day land use (existing control) against a natural vegetation land surface representation; and transient simulations using the A2 SRES atmospheric forcings from 1980 to 2100 to evaluate the impacts of SRES-derived changes in land cover. By comparing runs using natural vegetation, present land cover, and the A2 2100 land cover scenario (for the period 2065 to 2100 only), we can evaluate the impacts of land cover change and the need for accurate land cover information in assessing SRES scenarios.

B. CLM/CCSM development

While the LSM/PCM model provides a good first order estimate of land cover influence on climate, there are a number of shortcomings to these simulations, especially the representation of sub-grid scale land heterogeneity. We propose several new databases and model improvements for the Community Land Model (CLM) used with CCSM to simulate different aspects of human land cover change in more detail. These include:

a. *Land cover change*

Goal: Create transient CLM land surface datasets to match those used in the IPCC SRES scenarios.

Needs: Develop translation algorithms to convert SRES scenario land cover classes (biome classification) to CLM-compatible plant functional types (PFTs), which allow for sub-grid land cover.

Expected outcome: We expect significant impacts to both the hydrologic cycle and energy balance on regional scales. We propose to develop a temperature fingerprint associated with historic land cover change to compare to the observed surface temperature record.

b. *Agriculture*

Goal: Include multiple crop types and implement aspects of the CERES crop models and the CENTURY soil biogeochemistry and crop management to improve agriculture productivity estimates and their impacts on climate. This will be in collaboration with the Biogeosciences Initiative.

Needs: This work will proceed in several phases. (a) Develop additional agricultural classes matching those used in the IPCC assessments. (b) Implement existing models of crop growth and development (i.e., CERES crop models). (c) Develop and implement an irrigation parameterization and a global irrigation dataset. (d) Develop and implement a full carbon cycle for agroecosystems.

Expected outcome: Simulations of natural vegetation, and historical, present-day, and future land-cover change will assess, in a consistent manner, the impact of agroecosystems on climate, water resources, and the carbon cycle.

c. *Soil degradation*

Goal: Assess the effect of human-induced erosion and soil compaction on regional climates.

Needs: Use the GLASOD database and historical population trends to simulate past and future soil degradation. CLM soil properties will be modified on the basis of these simulations.

Expected outcome: We propose to evaluate this impact on a global scale, and to identify a temperature fingerprint.

d. *Urbanization*

Goal: Evaluate the effects of urban heat islands on regional and global climate and hydrology.

Needs: Develop an urban canyon model as part of CLM. Develop an urban land cover database linked to population density. Collaborative work in the Biogeosciences initiative will develop anthropogenic biogeochemical emissions datasets in relation to population.

Expected outcome: Simulations will help understand the scale and nature of urban impacts on regional and global climate. We will evaluate potential mitigation measures such as urban planning policies that limit urban sprawl.

e. *Regional models*

Goal: Much of land use and land cover change occurs at a fine spatial scale not explicitly resolved by global models. This landscape heterogeneity is better resolved by regional climate models, which are an important scientific tool for downscaling and impacts research.

Needs: Develop a common modeling framework and databases for global and regional climate models.

Expected outcome: Reduction in redundancy and a common modeling framework for global and regional models.

C. Proposed modeling runs

In addition to the previously described LSM/PCM simulations, the following CLM/CCSM simulations will address the climatic impacts of the new land cover specifications (bold script indicates the difference from control):

Run	**Type of Run**	**Objective**	**Sensitivity test**	**Status**
CEC	***22 years Equilibrium***	***Present day atmosphere Present CLM land cover***	***Control Run***	***Exists***
CE1	22 years Equilibrium	Present day atmosphere **Urbanization**	a) Optimal number of urban classes b) Sprawl vs no sprawl scenarios	Year 1
CE2	22 years Equilibrium	Present day atmosphere **Irrigation**	a) Impact of irrigation	Year 1
CE3	22 years Equilibrium	Present day atmosphere **Land Cover**	a) IPCC scenario comparison (e.g. A2 vs B2 etc.) b) Within scenario land cover uncertainty	Year 2
CE4	22 years Equilibrium	Present day atmosphere **Agriculture**	a) Optimal number of crop types b) Prescribed vs interactive crop simulations	Year 2
CE5	22 years Equilibrium	Present day atmosphere **Soil Degradation**	a) Impact of degradation	Year 2
CT1	1870-2100 Transient	IPCC Scenario **Integrated land cover**	Evaluate multiple IPCC scenarios (e.g. A2 vs B2 etc.)	Year 3

D. Convergence of impact models and earth system models – Workshop

With agriculture and urbanization as climate feedbacks, our model becomes more of an earth systems model and overlaps greatly with the climate change impacts community, who are greatly interested in the impacts of climate change on vegetation, agriculture, and urban climate. We propose a workshop in the second year to address the convergence of impacts and earth system models in the context of interactive vegetation (both natural ecosystems and agroecosystems) and also possibly hydrology. We expect a workshop of 40 people, of whom about 10 would be international.

Other Funding Opportunities

We will seek outside funding to partially support activities in the second and third years through the NASA Land Cover Land Use Change Program.

Timeline of Accomplishments

YEAR 1
First-order sensitivity of IPCC simulations to land cover. Transient human population datasets. Urban land cover parameterization and transient datasets. Irrigation sub-model and datasets.

YEAR 2
Soil degradation parameterization and transient datasets. Transient SRES land cover change. Interactive crop parameterization using CERES crop models. Workshop on Impacts and Earth System Model Convergence.

YEAR 3
Simulated climate with cities, soil degradation, and land cover change. Transient SRES simulations. Merging crop model with Biogeosciences initiative.

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Internal Collaborator
Biogeosciences Initiative (Bonan on Project # 4)

External Collaborators
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3. Climate Scenario Development and Distribution

Goal

To continue and expand upon NCAR's role as developer and provider of climate scenarios for impacts research in the United States and internationally.

Progress to Date

The U.S. Workshop on Climate Projections, Uncertainty, and Climate Scenario Development for Impacts Assessments was held in July 2002 at NCAR. An action plan on developing a Unified U.S. Program on Scenario Development is being developed as the main output of the Workshop.

Research Plans

We will develop a data system to collect the most recent outputs from AOGCMS, minimally all the climate model simulations from the SRES scenarios, develop appropriate baseline data sets needed for combining with the climate model output, and incorporate measures of uncertainty into the scenarios (perhaps even regional probabilities of the different scenarios). We will also create a web-based tool that will allow for easy data acquisition of the scenarios, provide guidance material on the use of scenarios, and provide links to other data distribution centers. Particular attention will be given to providing scenarios based on projections from the three U.S. Climate modeling Centers, NCAR, GFDL, and GISS. Also, collaboration with the Canadian Climate Center is planned to include their modeling efforts. Regional climate model outputs for domains covering all or parts of North America will also be collected and made available for scenario use. The baseline climate data needed by impacts researchers will be developed in collaboration with NOAA NCDC (T. Karl). Soils databases will be examined and produced on the same grid as the climate data. The soils databases of VEMAP will be the point of departure for this activity.

(Note: under level funding, little could be accomplished on this project, beyond continued development of the action plan and some minor work on gathering outputs.)

Timeline of Accomplishments

YEAR 1
Work will begin in mid-FY03. Collect outputs of existing AOGCM simulations using SRES scenarios A2 and B2, from North American Climate Centers. Start Development of Web-tool. Coordinate with NOAA NCDC the development of gridded climate database.

YEAR 2
Incorporate newer climate simulations from the other SRES scenarios, including North American regional model runs, into the data distribution. Start developing guidance material for scenario use. Complete development of Web-tool.

YEAR 3
Develop measures of uncertainty and incorporate into the scenarios. Provide guidance on the measures of uncertainty and how they can be used in impacts assessment.

NCAR Team
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External Collaborators
R. Stouffer, GFDL. J. Hansen, GISS, T. Karl, NOAA NCDC, G. Boer, F. Zwiers, CCCma, R. Street, E. Barrow, Environment Canada, L. Gates, B. Santer, LLNL

4. Climate Variability of Past Centuries – Regional and Climate Mode Response

Goal

This component of the strategic initiative is an extension to the CSENT project of the CGD-Paleogroup, which focuses on natural climate variability during pre-industrial times. Previously, Climate System Model (CSM) and Parallel Climate Model (PCM) simulations have been very successful in reproducing climate variability and trends verified by the instrumental record, a period strongly affected by the anthropogenic forcing. Extending the time frame several hundred years prior to the appearance of this trend is crucial to verifying overall climate sensitivity. CSENT performs experiments employing the fully coupled Community Climate System Model (CCSM vers. 2.0) by sequentially adding important forcings including volcanic aerosol, solar irradiance changes, land use and greenhouse gases. Because the period after A.D. 1600 is now well covered by high-resolution proxy data of exceptional quality, comparing the best currently available proxy records with coupled climate model results acts as an important test of the model’s ability to represent both past and future climatic changes. This is the first-order goal of this project. Three general focus areas are pursued.

Research Plan

a) Fingerprinting of Forcings

Results from the CSENT simulations will be compared to recent climate reconstructions on a number of spatial and temporal scales. This work will be done as a data-model intercomparison with Prof. M.E. Mann (U. of Virginia) and Prof. R.S. Bradley (U. of Massachusetts). We employ new fingerprinting techniques, developed over the last year, which distinguish imprints of climate forcings from internal natural climate variability. Results of such analyses using model output with known specified forcings are compared to the relations from proxy climate networks. Collaborators include Prof. P. Naveau (U. of Colorado), Prof. H.-S. Oh (U. of Edmonton, Canada) and a PostDoc from the NCAR-GSP group led by Dr. D. Nychka. Short sensitivity experiments with varying forcing series aim to increase the signal-to-noise ratio for periods such as the Maunder Minimum and early 19th century.

b) Regional and Climate Mode Responses

North Atlantic Basin: The North Atlantic Oscillation (NAO), the dominant mode of winter climate variability in the North Atlantic sector, is a natural mode well captured in atmospheric GCMs. The NAO is one of the few large-scale modes that exhibit a clear dynamic response to external forcing factors (solar, volcanic and greenhouse gases). Its low-frequency variability component could suggest that the Little Ice Age episodes (LIA; ~A.D. 1300-1850) are an expression of a positive NAO phase. However, there is debate within the paleoclimate community as to whether there is indeed a clear fingerprint of the NAO present in land and ocean proxies. Nevertheless, both sides claim a link to solar irradiance changes as a source of variability in their reconstructions. Using CSENT experiments, we will investigate the role of the NAO with and without external forcing, placing a particular emphasis on comparisons between empirical paleo data and modeled patterns of forced temperature variation.

American Southwest (SW): Environmental conditions in the US-SW have always been strongly controlled by climate, in particular, the availability of water. The richness of good high-resolution proxy data (derived from tree rings) allows reconstruction of important environmental parameters such as precipitation, summer temperature, drought, and fire occurrence. As a regional application, we will compare the climate variability represented in the global coupled experiments with the range observed in the historical and proxy climate record over the US-SW. We particularly focus on drought conditions, which can directly be related to regional wild fire danger. We will investigate controlling mechanisms for low-frequency changes responsible for wet and severe drought conditions. To complement these investigations, a regional modeling effort using the MM5/OSU nested into CCSM covering the conterminous U.S. and Northern Mexico will be led by E. Small (U. of Colorado), building on his previous work to investigate climatic patterns in higher spatial resolution. Forced with CSENT runs as boundary conditions for a selected multi-decadal window, the regional model can better resolve local contributions from, for example, topography and soil moisture, to the regional climate variability. Of particular interest will be the influence from land use and external forcing effects on the North American Monsoon system.

c) Uncertainty Propagation

The overarching problem of uncertainty propagation in paleo applications (from the forcings to the impacts) has not been seriously addressed in the literature. We will evaluate the robustness of climate signals in both modeling and proxy data. On the one hand, we revisit fundamental assumptions often applied in proxy reconstructions through comparison with globally available, physically consistent climate model output. On the other hand, a number of "unusual" events of past climates well captured by climate proxy information are simulated, using varying forcing combinations and internal mode states with the GCM to evaluate uncertainty forcings and model.

d) *Education and Outreach Component*

We are collaborating and cost-sharing with the NCAR Education and Outreach Office (EO) to develop K-12 educational activities on natural climate changes of the LIA that directly integrate into the new Climate and Global Change exhibit (in preparation for FY03) for the Mesa Laboratories. Inquiry-based exhibit components and worksheets for classroom use (K-12 levels), as well as instructional support materials for teachers following National Science Education Standards are developed, tested, and disseminated by EO and the PIs together with an education consultant.

Requested Computer Time:

To produce the special runs required for this project (dedicated runs of the AOGCM for regional model resting, regional model runs, etc.), a total of approximately 10,000 GAUs would be required. While some of these GAUs can be accommodated through the CGD allocations, approximately 5,000 GAUs will be needed from other sources. We are requesting approximately 5,000 GAUs from the Director's Reserve to cover primarily the regional modeling runs over the three-year period. Most of the GAUs will be needed in the second year (see timeline below).

Additional funding opportunities:

We have identified a number of programs and special calls that we will pursue for complementary funding of this project. These include: NOAA OGP, NSF-GEO-MATH for aspects of the uncertainty analysis, and NASA RAs for the Earth System Enterprise Program.

Timeline of Accomplishments

YEAR 1
Completion of CCSM forcing runs and general analysis; temporal fingerprinting of Forcings, estimate uncertainty; assemble database of North Atlantic reconstructions, characterize patterns and their evolution; study of temporal ENSO/drought teleconnections in US-SW; drought-fire link in SW from proxy data and control runs; Setup of MM5/OSU nested in CCSM.

YEAR 2
Spatial fingerprinting of external forcing and internal modes (NAO); sensitivity experiments using varying forcings; specified SST runs with North Atlantic basin cooling; 30-year runs of MM5/OSU using control conditions; analysis of drought and fire in US-SW.

YEAR 3
Focus on uncertainty: test of robustness of global reconstruction techniques; investigate mechanism for low frequency variability in North Atlantic (thermohaline circulation); 30-year nested runs of MM5/OSU forced with landuse and external forcing; comparison of model and proxy climate reconstructions for SW; depending on previous results, extension of analyses using projection runs to AD 2100 with statistically prescribed external forcing; Winter: workshop on integrated Little Ice Age research at intersection of models and proxy data.

NCAR Team
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External Collaborators
E. Small (regional modeling): U. of Colorado; G. Bond, E. Cook and R. D'Arrigo (Lamont-Doherty Earth Observatory, Columbia U.), H. Wanner (Swiss National Competence Center of Research in Climate, Director), J. Luterbacher and C. Casty (Dept. of Geography, U. of Bern), T.W. Swetnam (U. of Arizona, Laboratory of Tree-Ring Research), M.E. Mann (U. of Virginia), and R.S. Bradley (U. of Massachusetts), P. Naveau (U. of Colorado), H.-S. Oh (U. of Edmonton, Canada) .

5. Decision Making and Uncertainty: Managing Wildland Fire Risks: Climate and Weather Information and Uncertainty

Goals

This program element will contribute to the development of a methodology for examining the effects of uncertainty and the value of weather and climate information for the effective management of wildland fire risks. The focus of the research will be on analyzing the roles of uncertainty and information in situations where autonomous, but mutually interdependent, decisions are being made by a number of individuals whose interests and objectives may conflict. The goal of the proposed research is to contribute to the development of policy alternatives, decision support tools and risk communication methods that could improve societal management of these risks. This project entails major collaboration with the Wildland Fire Initiative and some with the Water Cycle Initiative.

Progress to Date

Alison Cullen has spent time at NCAR assisting in the development of the Uncertainty and Decision– Making part of this initiative. Kathleen Miller attended a conference on decision-making and uncertainty to gather information on the state of research in this area world-wide.

Through these activities, Miller and Cullen developed the idea of starting the task on wildland fires and decision-making.

Research Plan

The incidence and significance of wildland fire risks as well as the costs and damages arising during and after individual fire events are the result of decisions made by a large number of public agencies and private individuals on many different time scales. Long-term decisions regarding road construction, timber harvesting, vegetation management and investment in homes and other built infrastructure affect the likelihood, intensity, and costliness of fire events. Near-term fire-suppression decisions determine the net social costs and environmental impacts, as well as the distribution of costs and benefits arising from current fire events. Post-fire land treatment has further ecological and hydrological impacts, for example on aquatic ecosystems. Fire suppression also affects future fire risks. (We will be working in collaboration with the Wildland Fire and Water Cycle Initiatives regarding post-fire hydrologic impacts and land management decisions.)

A systematic analysis of the interconnections among decision problems faced by all of these many players would help to illuminate the nature of current controversies surrounding implementation of the National Fire Plan, and could be useful in tailoring policies to best fit local circumstances. Such an analysis also could help to identify the types of climate/weather and other scientific information likely to be most valuable at various points in the decision process and the most effective modes for transmitting that information to the appropriate decision-makers.

Our proposed analytical approach will be to characterize decision environments as composed of a set of interconnected decision trees. This will allow us to map out important nodes of interaction among otherwise independent decision problems. This mapping technique can be extended over any appropriate time-scale. Our working hypothesis is that conflicts, as well as opportunities for productive negotiations and policy interventions, will tend to be clustered around those points of intersection.

(Note, under level funding, this project will essentially not exist-- some continued project idea development could be pursued through visits from A. Cullen).

Timeline of Accomplishments

YEAR 1

1) Survey existing work in this area. Identify linkages to other research efforts. Convene small workshop to help map out research strategy and to develop a template or framework of elements to be considered in looking at the role of climate/weather or other atmospheric science information in the various decisions relevant to wildfire risks and impacts.

2) Create a mock-up model of the interconnected decision framework. Identify relevant software for displaying and quantifying the decision problems, and examine the flexibility of the modeling framework and the potential sensitivity of the overall social optimum to model specification

(e.g., number of independent actors, number and magnitude of spillover effects among their decisions).

YEAR 2
3) Conduct case studies focused on two regions with contrasting characteristics (e.g., with respect to: climatic fire regime/seasonality; level of development; susceptibility to post-fire erosion damage; land ownership characteristics). This element will entail conducting on-site interviews with relevant decision-makers in each area to identify variables affecting their individual decisions, and their perceptions regarding the impacts of decisions made by others on the costs and risks pertaining to their own decision problems.

4) Identify the critical policy issues facing each of these regions.

5) To the extent possible, quantify the range of uncertainty surrounding the important variables in a set of policy-relevant decision problems for each of the two geographical areas.

YEAR 3:
5) Model the interconnected decision processes, using linked decision trees, in sufficient detail to identify options for (a) improving coordination among decision makers and (b) optimizing the flow of forecasts and other information to them.

NCAR Team
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Internal Collaborators
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External Collaborators
A. Cullen, U. of Washington; S. Kane, NOAA

II. Weather and Climate Extremes

Research in climate and weather extremes is fundamentally motivated by their impacts on society, which are considerable. The IPCC reports highlighted extreme events from both the physical science and impacts point of view and strongly recommended more research in all aspects of extremes. The initiative element on extremes consists of five projects, several of which are continuing. The projects concern research in weather and climate modeling of extreme events, downscaling of extreme weather phenomena, spatial scaling of extremes, application of extreme value theory to atmospheric problems, and research on reducing societal vulnerability to extremes. A particular effort is made through these different projects to integrate across both atmospheric science aspects of extremes and societal concerns. Collaboration with both the Wildfire and Water Cycle Initiatives is involved in several of the projects.

1. Extremes Toolkit

Goal

The goal is to develop software and a web-based tutorial for the fitting of meteorological extremes in a form accessible to the broader atmospheric community.

Accomplishments to Date

In FY02, work was begun on the toolkit in RAP. Preliminary programming of appropriate algorithms and preliminary development of a graphical user interface was completed.

Research Plan

A website will be developed that will make the software available and provide a tutorial on its use, along with ample weather, climate, and impacts examples. The essential software in S-plus or R will be developed, as well as the basics of the tutorial.

(Note: under level funding, this project would still be completed as described).

Expected Accomplishments

YEAR 1
Toolkit and guidance material and web interface will be completed (1-year project).

NCAR Team
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External Collaborators
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2. Extremes in Aviation-Related Weather

Goal

Extreme events, though of great societal importance, often are difficult to forecast using standard objective forecasting approaches. Extreme value theory seems to provide a potentially useful alternative approach for these prediction problems, which will be investigated in this study. In particular, we propose to apply extreme value theory to four forecasting problems that are currently under investigation in the Research Applications Program (RAP). Although research and development in three of the four forecasting areas is supported through the Federal Aviation Administration's Aviation Weather Research Program, this funding is for directed research, and not intended for exploratory research such as that proposed here.

Progress to date

During the first year, the main focus of the extremes work was on initial development of the extremes toolkit. In addition, in-flight icing was identified as the first area of focus for applications of extreme value theory. Specifically, the problem of predicting or diagnosing icing severity was selected as an area that could benefit greatly from this work. Initial datasets to be used in this application were identified, and a general approach was developed.

Research Plan

The four research areas to be considered are (1) In-flight icing, (2) Turbulence, (3) Convection, and (4) Public Weather forecasts. Each of the first three phenomena occurs quite infrequently (e.g., over less than 5% of the continental U.S. at any one time) and can be directly thought of as an extreme event. With respect to the fourth topic, it is difficult for statistical/objective forecasts to correctly anticipate extreme values of variables such as temperature, winds, and precipitation. Each of these areas has particular attributes that make them difficult to forecast, as well as particular features of interest for forecasting. For example, one of the important aspects of icing and turbulence events is the severity of the conditions; this aspect is especially difficult to forecast due to the very limited observations of the phenomena that are available.

The four forecasting areas will be considered in the order presented above, through three stages: (1) isolate the problem; (2) apply analysis techniques to appropriate data sets; and (3) incorporate results into an improved forecasting algorithm. Stage one for each product will begin as the previous topic enters the second stage. All stages will involve collaboration with a RAP scientist. The extremes toolkit that is being developed as another aspect of this initiative will be applied to the analysis of the data for these topics.

(Note, under level funding, only two of the four research areas would be considered, and the project start would be delayed until FY04, after the completion of the extremes toolkit).

Expected Accomplishments

YEAR 1
Extreme value method for icing severity in an experimental version of the Integrated Icing. Diagnosis/Forecast Algorithm. Methodology and data sets for analysis of turbulence data and severity algorithm development.

YEAR 2
Extreme value method for turbulence severity in an experimental version of the Integrated Turbulence Forecast Algorithm. Methodology and data sets determined for analysis of convection data and forecast algorithm development. Analysis of convection data completed.

YEAR 3
Extreme value method for convection forecasting completed, insertion either into Autonowcaster or other system. Methodology and data sets determined for analysis of public weather forecast techniques. Analysis of forecasting data completed. Extreme value method for public weather forecasts of extreme events in an experimental version of the Intelligent Forecast System.

NCAR Team
B. Brown, M. Politovich

External Collaborators
P. Naveau, U. of Colorado

3. Downscaling of Extreme Weather/Climate Phenomena

Goal

We will downscale severe thunderstorms (those containing large hail, strong wind gusts, or tornadoes), using upper air variables from reanalysis, regional models, and global models. Using the developed methodology, we will estimate changes in extreme climate phenomena under various climate change conditions.

Research Plan

Severe thunderstorms pose significant threats to life and property around the world. Understanding their geographic distribution and the potential for changes in that distribution are important in helping people prepare for threats. The IPCC noted that we know little about the future changes in these phenomena, which are not resolved in global or regional climate models. Since they are rare events at any particular location, and the most extreme severe thunderstorm events (e.g., violent tornadoes, 5 cm diameter hail, 120 km/hr wind gusts) occur infrequently even in the locations where they are most common, the direct observational record of their occurrence is of questionable value in estimating their true distribution. The best observational record of severe weather events extends only back to the early 1990s for all severe weather and back to the mid-1970s for the most extreme events that, due to their impacts, tend to be observed more reliably.

Over the past several years, databases of observed radiosonde ascents taken in the vicinity of severe thunderstorms in the U.S. have been developed. These contain thousands of so-called “proximity soundings,” with approximately 1,000 associated with tornadoes rated F2 and higher on the Fujita scale of damage (the 10% most damaging tornadoes), 2,000 associated with 120-km and stronger winds, and 3,000 associated with 5-cm larger diameter hail. These soundings have made it possible to develop relationships for environmental conditions (moisture, instability, and shear) that are favorable for severe thunderstorms, and to discriminate between the environments associated with different severe weather types. A recent study at the U. of Oklahoma, wherein proximity soundings were derived, demonstrated that NCAR/NCEP reanalysis data are sufficiently accurate to provide discrimination between weather types that is almost as good as the observed data, but with more complete coverage than the radiosonde network provides. A combination of four parameters identifies conditions that are more than 100 times as likely to be associated with strong tornadoes than other conditions.

We propose to go beyond the observed and reanalysis project studies to look at the ability of models to capture realistic environmental conditions associated with severe thunderstorms. In the first stage, we will examine if soundings derived from the analysis cycle and forecasts out to 24 hours from a state-of-the-art mesoscale model, MM5, can discriminate between environments. This will allow us to evaluate how well models that are well designed to handle convective environments evolve in threatening environmental conditions. In the second stage, we will extend the work to regional climate model simulations, in which the basic model formulation is not tailored to convection. Finally, we plan to use recent results from AOGCMS to look at the climatological distribution of severe convective environments in current conditions and under climate change scenarios. The results of the previous studies, focusing on severe convection in the U.S. will be applied on a worldwide basis, to see where and how often favorable environments occur in other regions and how that frequency changes in climate change scenarios.

Timeline of Accomplishments

YEAR 1
Develop and analyze 3-year climatology of proximity gridpoint soundings from 0-24 MM5 forecasts for continental U.S.

YEAR 2
Analyze 10-year archived regional climate model simulations from Iowa State U. for climatology of favorable conditions for severe thunderstorms in and develop relationships between model parameters and severe weather occurrence.

YEAR 3
Analyze global climate simulations of current and future climate conditions in order to study changes, if any, in frequency and geographical distribution of conditions favorable to severe thunderstorms around the globe.

NCAR Team
J. Bresch

Internal Collaborators
R. Katz

External Collaborators
H. Brooks, NOAA/NSSL (Project Leader); C. Anderson, Iowa State U.

4. Extreme Events In Climate Models And Spatial Scaling

Goal

We will analyze the frequency and intensity of various extreme events particularly relevant to climate impacts in regional and global climate models. Extreme value theory will be used in these analyses. In addition, we will undertake a detailed robust examination of the spatial scaling characteristics of extremes in climate models.

Research Plan

The statistics of extremes have only rarely been applied to evaluate the ability of numerical models of climate to represent extreme events or their projections of changes in the frequency and intensity of extremes. Comparisons of control run output with observations have been hindered by a mismatch of scale between grid point averages and point measurements, an issue that is particularly problematic for extremes and especially for precipitation.

We will work on relating extremes for point measurements to the corresponding ones for grid cell averages, making use of bivariate extreme value theory. We will make a more systematic study of the scaling properties of climate extremes, ultimately developing a fully spatio-temporal statistical model. As a part of this activity simulations with the Convection Resolving Model (CRM) as part of the Water Cycle Initiative (subtask 2e) will be used. Simulations will be performed at a 3 km resolution for ten Julys for the U.S. Great Plains. The spatial scaling of the extremes of precipitation from these runs will be examined and compared with those from observations. It is assumed that the convective resolving simulations should scale similarly to observations.

Comparisons of control run regional and global climate model extremes with observations will be performed by the postdoctoral fellow, making use of the statistics of extremes and including the scaling research to take into account the scale mismatch. Comparisons will also be made with these coarser-resolution climate models and the CRM results decribed above. Changes in extremes simulated by a transient response climate model experiment would be estimated using the statistics of extremes with time varying parameters. Specifically, climate model output being used in the Water Cycle Initiative Task 1, Diagnostics Study of the Diurnal Cycle and Precipitation, will also be used in our investigations.All these analyses would include explicit statistical modeling of the annual cycle of extremes.

Timeline of Accomplishments

YEAR 1
Archiving and preliminary processing of extremes output from climate model control runs and change experiments. Preliminary processing of extremes from daily precipitation and temperature observations, as well as reanalysis data. In latter part of year, analyze output from CRM simulations. Identify inadequacies in existing spatial scaling theory as applied to climate extremes.

YEAR 2
Development of an application of bivariate extreme value theory to point and areal climate extremes. Analysis of transient response of extremes in climate change experiments (regional and global models). Development of spatio-temporal statistical model of extremes.

YEAR 3
Comparison of control run and observed climate extremes. Application of spatio-temporal statistical model to climate extremes. Development of extremes toolkit module tailored to analysis of extremes from climate models.

NCAR Team
R. Katz, D. Nychka, C. Tebaldi, M. Moncrieff (Water Cycle Inititiative)

Internal Collaborators
R. Wagoner, J. Coen (Fire Initiative), K. Trenberth, A. Dai (Water Cycle Inititiative)

External Collaborators
R. Smith, University of North Carolina, P. Naveau, University of Colorado

5. Influence Of Climate Variability And Uncertainty On Flood Hazard Planning In Colorado

Goal

This project is intended to enhance the understanding and use of flood-related climate information by the many groups involved in floodplain management along the Colorado Front Range (CFR), including local officials and floodplain administrators, private consultants, state and regional flood control authorities, and federal agencies. It has four research components: (1) policy and decision-making, (2) weather and climate, (3) hydrology, and (4) impacts on flood hazard planning; therefore, a multidisciplinary approach is needed.

Progress to Date

In FY02, funding was provided to develop a detailed project plan and a proposal for submission to NOAA/OGP Human Dimensions Program. The proposal has been submitted ,but results will not be known until early winter.

Research Plan

(1) Policy and decision-making. The primary objective of this component is to understand the decision-making processes in floodplain management at local, state, and federal levels; the methods of using weather and climate information and dealing with uncertainty in that information; and the problems perceived by users and stakeholders. An additional objective is to aid providers of weather and climate information by explaining how new information is diffused and new methods are adopted within the flood management structure. Key flood risk variables used in flood hazard planning and mapping (such as discharge, depth, and velocity) will be identified in discussions with floodplain managers and used in the other study components.

(2) Weather and climate diagnostics. Rainfall attributes over the CFR are affected by large-scale climate forcings, especially during summer. The overall objective of this component is to investigate whether estimates of flood risk variables can be improved through better understanding of relationships between climate/weather regimes and summer precipitation on a variety of temporal and spatial scales. Past flood events in the region will be associated with meteorological scenarios that can be explored using hydrologic models. Meteorological scenarios will also be related to larger-scale climate signals to evaluate the potential usefulness of summer season precipitation forecasts for flood hazard planning.

(3) Hydrological modeling. The objective of this component is to develop a framework that simulates plausible hydrologic scenarios consistent with the large-scale climate. A stochastic weather generator, in combination with hydrologic models, will be used to generate realistic scenarios of streamflow associated with the meteorological scenarios developed in (2). This framework will be tested against data from past years and compared with flood conditions and decisions made in those years. The resulting probability density functions will be used to demonstrate how uncertainty in precipitation data propagates through hydrologic models, increasing the uncertainty in estimates of flood risk variables.

(4) Impacts on flood hazard planning. Geographic Information System (GIS) technology will be used to demonstrate potential effects of variability and uncertainty in climate information on floodplain maps and risk assessments. Effective communication of the findings of this project to stakeholders in flood hazard management and to providers of weather and climate information is a primary objective. Results will be shared with stakeholders and researchers through presentations and discussions at professional meetings, a website, and publications.

(Note: under level funding, the project probably will not be feasible. Reliance on the external funding possibilities would be complete. Funding for M. Downton to further formulate research plan would be maintained.)

Timeline of Accomplishments

YEAR 1
Interview officials and technical experts in floodplain management. Prepare report on decision processes and information use in flood hazard planning. Obtain hydromet data for case study areas; develop meteorological scenarios; develop stochastic weather generator and generate weather realizations. Calibrate hydrologic and hydraulic models. Develop database of land-use and land surface characteristics.

YEAR 2
Evaluate impact of uncertainty by comparing simulations of flood risk variables associated with different design rainfall estimates. Verify simulated streamflow against observational data; refine meteorological scenarios. Enter weather realizations into hydrologic model to generate simulated streamflow realizations. Incorporate socioeconomic data and hydrologic information.

YEAR 3
Discuss project results with flood management professionals; obtain feedback; present findings at professional meetings. Develop scenarios to evaluate impacts of land-use change and large-scale climate impacts. Test skill of model results through hindcasting; compare with actual decision-making process. Develop demonstration of flood potential under varied conditions.of model results through hindcasting; compare with actual decision-making processes. Combine output of communications, diagnostics, and modeling to provide seasonal updates of flood hazard in case study areas.

NCAR Team
M. Downton, H. Cullen, R. Morss, O. Wilhelmi

External Collaborators
B. Rajagopalan, U. of Colorado

III. Climate/Health

1. Development of a Climate/Health Program

Goal

NCAR plans to develop a unique interdisciplinary research and education program via a health-climate collaboratory. It will bring together leading institutions in health and climate science.

Research Plan

The area of human health impacts of climate is an extremely complex one, which requires the interdisciplinary efforts of health professionals, climatologists, biologists, and social scientists to successfully analyze the myriad relationships among physical, biological, ecological, and social systems relevant to health impacts. This area is an endeavor where an integrated assessment framework is obviously most needed. It is particularly important that as complete and rigorous knowledge as possible regarding health/climate interactions be obtained in the context of all appropriate technological and social considerations. The flurry of commentary over the past few years on health/climate connections and the dangers of oversimplifying relationships, as well as the recent NRC panel report that addresses issues in human health and climatic variability, reflects this importance.

Much progress towards enhancing institutional coordination and collaboration to enrich climate/health research has been and will continue to be brought about through development of specific multidisciplinary projects. However, to effect more complete progress, an ongoing multi-year program in health/climate issues would be particularly desirable, since problems in appropriately developing, needed health/climate linkages often transcend the specifics of any one study. In essence, specific studies in the context of a broader climate/health program may be the most effective context for rapid development of this complex impacts area. The NRC Report explicitly recommends the establishment of interdisciplinary climate/health programs to foster research, training, and appropriate communication to policy-makers on issues concerning climate and health.

Research Program Plan

NCAR plans to develop a unique interdisciplinary research program via a health-climate collaboratory. It will bring together leading institutions in health and climate science. Such a program is necessary to properly train individuals in performing the kind of complex interdisciplinary research necessary to successfully tackle research questions in climate/health/society interactions. Thus, the program will include a postdoctoral training program that will produce the first generation of scholars dedicated to an integration of the health and climate sciences. We envision a multi-year program that would be dedicated primarily to establishing interactions between climate scientists and health scientists. Interaction among these groups, social scientists, and ecologists is an additional goal. Three main institutions will initially form the center of the Program: the National Center for Atmospheric Research, Johns Hopkins University, and the Center for Disease Control and Prevention.

Program Elements

We will consider studying a wide range of issues in climate and health, ranging from heat-related mortality and morbidity to complex models of vector-borne disease (e.g., malaria and dengue fever). Consideration of interactions between climate variability (interannual fluctuations in climate) as well as longer-term climate change and human health effects will be included in the program plan. One focus of the program will include careful research regarding dangers of extrapolating research results across different temporal scales. In conjunction with the research interests within NCAR/ACD, health effects of increased UV-B radiation and air pollution will also be considered as initial research topics. In addition to fostering in general greater interaction between the two main communities, the following specific goals will be sought:

1) Evaluation of vector-borne disease and other health-climate models, with particular attention to their completeness in how climate effects are represented and their adequacy for use in a climatic change context; this will also entail the determination of the completeness of the models in representing the linkages between climate, disease incidence, and the complex societal and environmental contexts of the interactions of all factors (societal, environmental, medical);

2) Examination of and inclusion of the modeling of other resource systems (particularly agriculture and water resources) in conjunction with the disease models;

3) Examination of the adequacy of climatological databases for use in human health models and development of recommendations for extending the climatological and epidemiological data bases necessary for performing effective research in climate/health interactions;

4) Examination of adequacy of field data collection and measurement techniques for model development and evaluation;

5) Formal scholarly exchanges between NCAR and other institutions, such as Johns Hopkins, and the Center for Disease Control (e.g., summer visits at NCAR);

6) Establishment of a formal postdoctoral program at NCAR for health researchers and climatologists interested in health problems;

7) Visitor program for policy-makers and public health workers to become more informed regarding climate and human health interactions.

Initial Development Plan and Timeline

The most essential starting point for this project is seeking out and hiring a climate-health expert to direct the project. Through consultation with some of those experts interested in participating in such a program, it was determined that having such an expert in place at NCAR was essential, and that such a person should be supported on NCAR funds. Seeking out and hiring such a person would be the main activity of FY03. Then, toward the end of FY03 or beginning of FY04, a meeting of the interested collaborators would be held at NCAR and a detailed program plan would be developed. The program plan would be submitted within the existing RFP cycles of interested funding agencies or presented directly to interested program managers. It is thus assumed that the program would be funded from outside funding but that the project leader would be funded from the Assessment Initiative for the full three years. Other details of FY04 and 05 activities will be developed through the project leader and external collaborators.

NCAR Team

R. Harriss, M. Glantz, L. Mearns, S. Madronich

External Collaborators

The following individuals have already been contacted and have expressed and interest in participating in such a program: Dr. Duane Gubler, Director, Division of Vector-Borne Infectious Diseases, Center for Disease Control and Prevention; Dr. Dana Focks, USDA, Gainesville, Florida; Dr. Joan Rose, Department of Marine Sciences, U. of S. Florida; Dr. Jonathan Mayer, U. of Washington; Dr. Jonathan Patz, Johns Hopkins U.; Dr. Peter Webster, Georgia Tech; Dr. Elizabeth Whitcolmbe, Royal Hospital for Neuro-disabilities, London, U.K.; Dr. Mark Wilson, U. of Michigan, Michael Sharpe, Health Canada. The collaborators include experts in epidemiology, disease-society interactions, microbiology and water-borne diseases, environmental health sciences, and climatology.

Attachment A

Project (and Budget) Priorities: FY03

The priorities are organized by project and then also by the different level of funding. The levels include 1) Level funding, the same level as FY02; 2) Low, which is the a level generally higher than the FY02 level, but one in which the projects have been reduced from their high levels to something close to "bare bones"; and 3) High, which is the desired amount to fully complete the projects as they are described.

The effects of level funding are presented in parentheses in the main narrative at the end of each research plan. The research plans described in the narratives assume the high level of funding. The low-level funding usually involves reducing some tasks in the various projects, but we do not go into those details here. It is assumed that such details will be relevant in discussions of the Initiative.

The key final numbers to be considered are the sums of priorities 2-6, which essentially provide the total needed to fund all projects at the low level except for the climate health program ($994,388). Including the health climate program raises the amount to $1,091.588. The amount for funding all projects at the high level (for which detailed figures are provided in the budget) is $1,544,786. Low-level amounts for FY04 and FY05 are also being calculated and are available upon request. On average across budget reductions for those fiscal years would amount to about 25% from the high funding level.