Toward Integrative Science at NCAR: Building Links Between the Climate and Ecosystem Impact Research Communities

A proposal to the 2006 NCAR Opportunity Fund

James W. Hurrell and Dave Schimel (CGD/ESSL); Zach Powell (UC Berkley);
Kathleen Miller and Linda Mearns (ISSE/SERE); and Maura Hagen (ASP/SERE)

1. Introduction

Ecosystems significantly affect societies and nations by providing essential renewable resources and other benefits, including food, fiber, shelter, energy, biodiversity, clean air and water, recycling of elements, and cultural, spiritual, and aesthetic returns, while human activities, in turn, affect ecosystem processes and dynamics. Ecosystems also affect the climate system by exchanging large amounts of energy, momentum, and greenhouse gases with the atmosphere. Global climate change is altering the structure and functioning of ecosystems, which in turn affects availability of ecological resources and benefits, changes the magnitude of some feedbacks between ecosystems and the climate system, and could affect economic systems that depend on ecosystems. A grand challenge problem is to understand and be able to project the potential effects of global climate variability and change on ecosystems, the goods and services ecosystems provide, the drivers and consequences of human responses to ecosystem variability and change, and ecosystem links to the climate system.

Changes in natural patterns or "modes" of the atmospheric and oceanic, such as the El Niño/Southern Oscillation (ENSO) and the North Atlantic Oscillation (NAO), orchestrate large variations in weather and climate over much of the globe on interannual and longer time scales. For instance, much of the global warming in recent decades has been attributed to decadal changes in the phase and amplitude of these two dominant patterns of variability. Moreover, it has been argued that the spatial pattern of the response to anthropogenic forcing may project principally onto such modes of natural climate variability (e.g., Corti et al. 1999).

At the same time, there is a growing appreciation that changes in the frequency and amplitude of modes of climate variability profoundly influence a variety of ecological processes and, consequently, temporal and spatial patterns of population and species abundance (e.g., Stenseth et al. 2003; Wang and Schimel 2003). These changing spatial patterns can have significant societal impacts — for example, by benefiting or harming different nations or groups of resource users, and by disrupting international agreements regarding the division of fishery benefits (Miller and Munro, 2004). Early studies of the influence of climate on ecological systems typically focused on local weather parameters such as temperature, precipitation and snow depth, and this approach is still common in ecology (Stenseth et al. 2005). Indices of large-scale climate modes, in contrast, provide an integrated measure of weather, and therefore can be linked more to the overall physical variability of the system than any individual, local variable. For instance, the NAO infers information about temperature, storms and precipitation, cloudiness, hydrographic characteristics, mixed layer depths, and circulation patterns in the ocean that likely explain more of the observed variability of a species than just, for example, water temperature. Moreover, since mode

variations produce coherent variations in climate over large regions, they produce impacts on ecosystems at spatial scales that have major effects on society in many ways, including substantial control over Atlantic and Pacific fisheries, wildfire and other disturbances.

Modal variability thus forms a natural subject in which investigators of climate, ecosystem and climate impact science can collaborate. This collaboration is also required to determine the most societally relevant effects of global change on ecosystems. Unfortunately, work in these disciplines remains too disparate. We are asking for seed money to initiate the development of a new NCAR-community activity to integrate modeling of climate variability, coupled climate-ecosystem modeling and climate impact studies. The scope of this activity is potentially very broad; here we propose an initial, more focused project to serve as a pathfinder for a new type of end-to-end analysis. It centers on positioning NCAR as a major resource for the marine ecological and fishery management communities, using and linking tools such as the Community Climate System Model (CCSM), high-resolution ocean models embedded within CCSM, and marine ecosystem and foodweb models. The goal is to trace the linkages from variations in modes of climate variability to changes in the physical ocean and changes in marine nutrients, primary producers, and the higher trophic levels that support human fisheries, and ultimately to assess possible impacts on the characteristics and dynamics of those fisheries. The initial focus on the marine community is also in part because NCAR's links to the terrestrial impacts community are more mature.

2. Linkages

NCAR has a base of expertise across the disciplines to frame this study: climate and ecosystem modeling in CGD and ISSE, and fisheries and marine impacts and policy studies in ISSE. But this study is beyond the scope of NCAR scientists alone. A key feature of the project will be a systematic collaboration with the US and international GLOBEC (Global Ocean Ecosystem Dynamics) programs. U.S. GLOBEC has long been part of the U.S. Global Change Research Program, and the multi-national international program is the core project of the International Geosphere-Biosphere Programme (IGBP) responsible for understanding how global change will affect the abundance, diversity and productivity of marine populations. For more information on GLOBEC, please see (http://www.pml.ac.uk/globec/).

The goal of GLOBEC is to understand how physical processes influence marine ecosystem dynamics in order to predict the response of the ecosystem and the stability of its food web to climate change. Some GLOBEC Regional Programs also incorporate the goal of evaluating societal impacts and response strategies. A combination of field studies, model and technology development and retrospective data analysis has been mounted to address this ambitious goal. U.S. GLOBEC has undertaken a series of field programs over the last ten years to: (1) assess basic ecosystem characteristics including the natural variability of populations and their environments; (2) measure the rates of biological and physical processes; and, 3) characterize ecosystem sensitivity to climate forcing at regional to planetary scales. U.S. GLOBEC is now in a synthesis phase that has as its goal the integration of the above comparative studies. Ultimately, GLOBEC aims to determine critical global change variables and produce an ecosystem description that couples observations and modeling, including the development of coupled biological/physical models. Clearly, the

interests and emphases of the GLOBEC community resonate with interests and emphases found at NCAR, including the development of Earth System Models. Several potential linkages thus exist, including:

- A connection between the GLOBEC and CCSM modeling efforts. The most recent versions of the CCSM are sufficiently flexible that the GLOBEC ocean modeling efforts could appear as alternative modules to existing CCSM ocean models. This will demand continued progress on embedding regional scale models within the CCSM, but such efforts have been identified as a high priority within ESSL and our university PI (Z. Powell) has recently successfully embedded a high resolution coastal ocean/ecosystem model into CCSM.
- Analyses of observational data to further document and understand variations in modes of climate variability and their linkage to ecological responses. In addition, improved simulation of modes of natural variability has been a major emphasis for the CCSM (Alexander et al. 2005), and improvements in the simulation of ENSO and its associated extratropical teleconnections are notable (Deser et al. 2005). Thus, studies of modal variations in the ensembles of CCSM 20th Century and future simulations produced for the Fourth Assessment Report of the Intergovernmental Panel on Climate Change will be of interest to both the climate and marine ecosystem communities.
- Analyses of the long records from fisheries (usually involving fish catch) have provided insight to researchers interested in multi-decadal phenomena in the ocean. It would prove useful to re-analyze a number of the most reliable, and longest, fisheries records in light of recent knowledge gained on modes of climate variability and their role in climate change. Synergism should emerge, for instance, between investigators looking retrospectively at "GLOBEC" data and climate analysis researchers at NCAR, several of who have pioneered recent advances in climate mode research.
- Analyses of the practicality and usefulness of GLOBEC and CCSM model results for managers, policy makers, and economists working with commercial firms and government agencies focused on the marine environment. For example, can the assessment of fisheries stocks be improved with information provided by such models? If so, how? Can fishery management organizations design their decision-making, monitoring and enforcement processes to promote socially beneficial use of such information? Another application might involve attempts to improve effective location of marine protected areas. Links between appropriate ISSE scientists at NCAR and GLOBEC investigators in government labs with responsibility for such marine resources would be very constructive.

3. Proposed activities

a. Initial planning meeting

We seek funds for a small planning meeting to initiate this endeavor. The participants will number no more than 20-25, and we aim to hold the meeting at NCAR in the early autumn of 2005. The participants will be asked to prepare an informal meeting report upon which further workshops and/or colloquia and pilot studies will be based.

The charge to the attendees will be to produce a list of challenges that can be best and perhaps only be addressed through the collaborative efforts of ecologists (including fisheries experts), climate scientists, and policy professionals. Further, the participants will be asked to make a preliminary prioritization of the suggested challenges, stating how they arrived at their ranking.

The planning meeting organizers will include representatives from NCAR and from GLOBEC - with the PIs of this opportunity fund proposal acting as an informal oversight committee. NCAR scientists and GLOBEC investigators will dominate the list of attendees, including representatives from the CCSM effort and ISSE. But approximately one-third of the group will include external researchers from academic institutions and government laboratories, whose primary affiliation is not with NCAR or GLOBEC.

b. Potential pilot projects

The attendees at the initial planning meeting will be asked to identify a small number of experiments and data products to be carried out in the current CCSM framework. It might be worthwhile, for instance, to create a web site that tailors existing and new CCSM output specifically for the marine ecosystem community. In addition, the attendees will be asked to suggest pilot projects of modest size that could present compelling evidence why the endeavor we propose here should be encouraged and expanded, possibly to full "initiative" status.

One pilot study the NCAR and university PIs have already agreed on is the link between North Atlantic and North Pacific marine variability and fisheries. The NAO is well known as a significant control over recruitment of cod and Norwegian Spring Spawning Herring via temperatures in critical regions. Pacific variability also affects fisheries, with documented effects of ENSO on tuna, salmon, and small pelagic fisheries, and highly suggestive correlations between North Pacific fisheries (salmon and other species) and the PDO. The initial pilot study will analyze existing CCSM 20^{th} and 21^{st} Century experiments for temperature and dynamic features (currents and vertical exchange controlling nutrients) in areas known to be critical to North Atlantic and Pacific fisheries. These analyses will assess the skill of the simulation in the key areas, as well as identifying the potential for changes with climate change. Results will be provided to the GLOBEC and climate impacts groups in forms compatible with their analysis procedures. A subsequent set of experiments will repeat a late 20^{th} Century simulation and a modest number of future scenarios using the coupled CCSM-ocean mesoscale regional model capability currently under development (Z. Powell and W. Large, CGD/ESSL) to repeat these analyses taking advantage of the improved resolution and dynamics in coastal areas the two-way nesting provides. At this early stage it would be a mistake to be too proscriptive in limiting the scope of desirable pilot investigations much beyond the aforementioned study, other than we anticipate developing a group of projects addressing the highest priority challenges identified at the planning meeting. Outside support (e.g., NSF SGER) for these pilot projects will be sought.

c. International workshop

The initial meeting will also serve as early planning for a larger, international meeting tentatively targeted for NCAR in the summer of 2006. Resources from both IGBP and the Climate Variability and Predictability (CLIVAR) initiative of the World Climate Research Programme, as well as from national funding agencies, will be sought to support this workshop.

This meeting should serve to: (1) build bridges from physical climate through to marine resource policy; (2) identify the role of coupled modeling and coupled climate-ecosystem models in building those bridges; (3) identify goals for improved coupled (climate-marine ecosystem) models; and (4) provide a focused activity linking the physical, biological and social science communities together with building a science focus that links CGD/ESSL and ISSE. Results from the pilot studies, including the one described above, will be presented at this meeting to provide a concrete example of what can be done, and to illustrate what cannot, and what model development and diagnostic activities might be required. Although an exciting meeting could be held without this type of preparatory science, our goal of promoting greatly enhanced research in this area depends on building and maintaining scientific momentum both within NCAR and between NCAR and GLOBEC.

In addition, we anticipate that the international conference would set the stage for an ASP colloquium on the topic the following summer.

4. Budget Justification

We are seeking funds to support the costs of the initial planning meeting: roughly $2,000 per external participant plus incidental costs ($35,000). In addition, we seek funds for three months support for an associate scientist to complete work related to our identified pilot study.

References

Alexander, M., and co-authors, 2005: Extratropical atmosphere-ocean variability in CCSM3. *J. Climate*, submitted.

Corti, S., F. Molteni, and T. N. Palmer, 1999: Signature of recent climate change in frequencies of natural atmospheric circulation regimes. *Nature*, **398**, 799-802.

Deser, C., A. Capotondi, R. Saravanan, and A. Phillips, 2005: Tropical Pacific and Atlantic climate variability in CCSM3. *J. Climate*, submitted.

Miller, K.A., and G. R. Munro, 2004: Climate and cooperation: A new perspective on the management of shared fish stocks. *Marine Resource Economics,* **19**(3), 367-393.

Stenseth, N.C., A. Mysterud, G. Ottersen, J. W. Hurrell, K.-S. Chan, and M. Lima, 2002: Ecological effects of large-scale climate fluctuations. *Science,* **297**, 1292-1296.

Stenseth, N.C., G. Ottersen, J. W. Hurrell, and A. Belgrano, 2005: *Marine Ecosystems and Climate Variation.* Oxford University Press, 252 pp.

Wang, G., and D. Schimel, 2003: Climate change, climate modes, and climate impacts. *Annu. Rev. Environ. Resour.*, **28**, 1-28.