Climate Impacts on Natural Resources
A CLIVAR Working Group Prospectus

Background

To manage the nation's natural resources, including marine and terrestrial ecosystems as well as water resources, there is a pressing need for predictions of how they might be impacted by climate variability. This is a challenge for climate prediction systems, whether they be seasonal forecasts or climate change simulations, because unresolved and underanalyzed processes with spatial scales of tens of kilometers or less often control the distribution of natural resources and habitats. For example, upwelling, which determines nutrient distributions upon which marine life at all trophic levels depends, is usually confined to a narrow strip 10-20 km wide along the coast, and arises from complex interactions between the regional atmospheric circulation and local coastal topography and geometry. At the same time, the preferred habitats of terrestrial species, shaped by local circulation patterns in areas of complex topography and coastlines, often exhibit a comparable degree of spatial structure. Finally, orographic effects on precipitation and the inherently small scales of cloud and precipitation processes together create spatial heterogeneity in water resources that is sometimes even visible to a ground-based observer. Quantifying impacts of climate variations on natural resources therefore requires a prediction system that takes into account these landscape-scale atmosphere, ocean, and land processes.

The emerging solution to this challenge has been the development of what might be called regional earth system analysis. This is comprised of a high-resolution regional modeling and prediction system, forced at its lateral boundaries by a more conventional climate prediction, usually a global solution much coarser in resolution. Ideally, the model is validated by *in situ* measurement networks as well as remote sensing data, and its parameterizations are adjusted accordingly. The observations are also often examined independently to assess current fine-scale variability and trends in the current climate. Because the modeling system is designed for applications such as climate impacts on natural resources, it often involves multiple sub-models of the earth system, including atmosphere, ocean, and land components, each with embedded chemical and biological processes. The sub-models are sometimes coupled to one another, but in general they pass information only in an offline sense. The sub-models are often, though not always, adapted from community-developed software infrastructure. For example, the Weather Research and Forecasting model (WRF) is a particularly common choice for a regional atmospheric model.

The regional analysis approach has arisen spontaneously and in uncoordinated fashion at centers throughout the U.S. Some prominent examples (among many) are the North American Regional Climate Change Assessment Program (NARCCAP), based at NCAR (http://www.narccap.ucar.edu/), the Pacific Northwest Climate Impacts Group, coordinated at the University of Washington (http://www.cses.washington.edu/cig/), the Chesapeake Bay Forecast System, based at the University of Maryland (http://www.climateneeds.umd.edu/index.html), and a loose confederation of efforts focused on climate change forecasts in California, based at Scripps (http://meteora.ucsd.edu/cap/), Lawrence Livermore National Laboratory (http://universitygateway.llnl.gov/strategic/irccsi/), and UCLA/JPL (http://www.jifresse.ucla.edu/).

Purpose of the Working Group

These efforts each show promise in their own way in tackling the problem of high-resolution climate prediction; however, because of their regional focus, communication, coordination, and resource sharing is rare among the groups, in spite of the fact that they share similar tools and have similar potential user constituencies. The purpose of this working group is to overcome the isolation of these groups, and address three critical challenges they face in common:

(1) The first is the lack of information flow between the scientists doing regional earth system analysis and the users the predictions systems are designed eventually to serve. For this reason we propose to include in the working group representatives from the three constituencies noted above, namely people whose main expertise is marine ecosystem, terrestrial ecosystem, and water resource management. Their participation would serve to educate both user communities about the capabilities and limitations of the regional prediction systems, and scientists about the climate information needs of natural resource managers. Though there are conspicuous exceptions, the current practice is effectively to dump the output of the regional simulations on the users. The model output becomes a "black box" and little attention is paid to its quality or the credibility of the mechanisms driving changes in natural resources.

(2) The second challenge is to identify and prioritize the common model development needs of the prediction systems. This is related to the first challenge in that some model developments are more likely than others to improve the quality and usefulness of the climate information, and the dialogue between users and producers will clarify which development efforts to place first. Mechanisms can also be implemented to facilitate software sharing across regional models with widely varying strengths and weaknesses. Currently no such mechanisms exist, greatly hampering regional model development. To address this challenge we propose to include scientists whose primary responsibility is the development and execution of regional climate models. These would be drawn from atmospheric, oceanic, and land modeling communities.

(3) The final challenge is to identify and prioritize the observational tools necessary for independent analysis and model validation, particularly of the quantities to be predicted. The need for input from the user communities is clear here too. For example, currently remote sensing data is processed to produce quantities such as ocean chlorophyll, leaf area index, and snow extent. However, it is possible to imagine many other quantities of interest for natural resource applications, such as ocean nutrients, plant species distribution, and snow depth. The extent to which these could be derived from currently available products or whether new satellite missions must be proposed is unclear. To address this challenge we propose to include scientists from the regional observational communities, with an emphasis on those familiar with remote sensing techniques.

The entire climate community will have to face these challenges eventually as well, as the resolution of the global models increases to the point where the information they produce becomes more meaningful for natural resource applications. In this way, the working group proposed here would pave the way for more productive future interactions between climate scientists and user communities. This would be an important legacy of the working group.

We will seek nine panel members. The table below summarizes the panel membership and the communities each member would be drawn from. Each will be a leader and an expert in either applications, modeling, or observations, of either marine ecosystems, terrestrial ecosystems, or water resources. The full complement of the panel will be well-equipped to address the challenges listed above. Note that this way of balancing the panel mirrors the three-fold division of CLIVAR itself. We will also balance the panel among the various leading regional prediction efforts, so that it is truly a national effort to systematically improve predictions of climate impacts on natural resources.

Applications	Models	Observations
Marine Ecosystem Management	Oceanic Modeling	Marine Ecology
Terrestrial Ecosystem Management	Land Modeling	Terrestrial Ecology
Water Resource Management	Atmospheric Modeling	Hydrology

Potential Panel Members

Here are some potential panel members, with their expertise and affiliations (more suggestions are welcome):

Louis Botsford (marine ecologist, UC Davis)
Lisa Crozier (ecologist, NOAA fisheries)
Lisa Curran (terrestrial ecosystem mgmt, Yale)
Mike Dettinger (Hydrologist, Scripps)
Curtis Deutsch (Oceanic Biogeochemical Modeling, UCLA)
Chris Field (Terrestrial Ecology, Stanford University)
Jon Foley (terrestrial obs/remote sensing, UW Madison)
Inez Fung (Land Modeling, UC Berkeley)
Alex Hall (Atmospheric Modeling, UCLA)

Lee Hannah (Terrestrial Ecosystem Management, Senior Research Fellow, Conservation International)
John Harte (terrestrial ecosystems, UC-Berkeley)
Peter Kareiva (Marine Ecosystem Management, Chief Scientist for the Nature Conservancy)
Joanie Kleypas (marine ecosystems, NCAR)
Dennis Lettenmaier (Hydrology, University of Washington)
Ruby Leung (Atmospheric Modeling, Pacific Northwest Laboratory)
Nate Mantua (Marine Ecosystems, University of Washington)
Harold Mooney, (Terrestrial Ecosystem Management, Stanford)
Raghu Murtuggude (Oceanic Modeling, University of Maryland)
Ranga Myneni (Terrestrial Ecology, Boston University)
E. Shevliakova (terrestrial modeling, NOAA/GFDL)

Timeline and Deliverables
TBD pending input on the overall prospectus from CLIVAR membership.