MEETINGS

The Impact of Climate Change in the American Cordillera

The mountain regions comprising the western American Cordillera (from Alaska to southern Argentina and Chile) are especially vulnerable to changes in climate and to the ensuing changes in snowpack, streamflow, ecosystem functioning, and a host of other impacts on human and nonhuman systems. The effect of elevation on temperature and precipitation induces a compression of the typical meridional climatic gradients, causing changes in life zones—geographic regions or areas defined by their characteristic life forms, e.g., alpine, subalpine, coniferous forests, and so forth—over relatively short distances.

In mountain regions, relatively small perturbations in global processes can operate through the system to produce large local changes. Because mountains provide life-sustaining water for people living there as well as in adjacent lowland regions, climatic and other environmental changes in the American Cordillera will have a large impact on the future well-being of an area far larger than the mountain region itself.

More than 160 researchers, government officials, and representatives from donor institutions met recently in Mendoza, Argentina to discuss the current state of climate change science and the next steps needed to promote successful adaptation to climate change in the western American Cordillera. Anticipating future changes requires a better understanding of the climate system, biophysical and ecological systems, and the role of resource management institutions. Such information is vital in order to better manage mountain ecosystems, maintain their biodiversity, sustain the use of mountain resources and ecosystems, and preserve the social and economic well-being of mountain communities in this region of the Americas.

The Symposium on Climate Sciences of the North and South American Cordillera (CONCORD) built on past efforts to develop a continent-wide focus for climate and global change science, monitoring, and application activities in the mountains of the American Cordillera [see *Diaz and Millar*, 2004].

CONCORD focused on:

1) Highlighting the current understanding of climate and the adequacy of climate observation systems (current and planned) in the American Cordillera;

2) Summarizing current research on the likely impacts of climate variability and change on key environmental features (e.g., the alpine cryosphere: snow- and ice-covered areas, and regions with permanently frozen ground) and coupled human-environment systems (e.g., the land and its hydrologic systems as manifested in agriculture, energy, and transportation sectors);

3) Assessing the key scientific gaps in the understanding of climate and its impacts on key systems, and assessing the research needed to support adaptation to global change in the Andes; and

4) Evaluating and identifying possible long-term institutional arrangements for integrated climate and Earth system science in the American Cordillera.

Climate Monitoring

Climate monitoring was broadly defined to include the climate system components for model simulations of atmospheric, geomorphic, hydrologic, and biospheric processes. The approach was to consider as many elements as needed in order to develop integrated models of climate change to improve predictions and to quantify and reduce uncertainties. An effort was made to include meeting participants with the expertise necessary to establish effective frameworks for evaluating integrated model performance, and for establishing mechanisms for the diffusion of effective information to decision makers.

Many of the speakers stressed that effective climate monitoring requires a long-term commitment to data quality and network stability. Climate-related signals can be subtle and are sometimes obscured by short-timescale variability; hence, changes in variability arising from changes in the observing system can obstruct efforts at detection of climate change. The integration of measurement programs at mountain research sites with operational and research activities in the region will ensure that the data are state-of-the-art, and that they continue to meet research requirements for studies of climate variability and change [*Bradley et al.*, 2004].

Results from paleoclimate studies have shown that during the past 2000 years, climate variation has resulted in warming as well as cooling events; these events have been accompanied by significant elevation shifts in lake levels and alpine tree lines, as well as by temperature and precipitation shifts. Several speakers (Ricardo Villalba, Instituto Argentino de Nivología, Glaciología y Ciencias Ambientales, Mendoza, Argentina; Connie Woodhouse, U.S. National Oceanic and Atmospheric Administration's (NOAA) National Climatic Data Center, Boulder, Colo.; Brian Luckman, University of Western Ontario, London, Ontario, Canada; Mathias Vuille, University of Massachusetts, Amherst; among others) noted that regional studies with high-resolution paleorecords are useful in determining the spatial pattern of past climate variability in the American Cordillera, and are helpful in interpreting possible mechanisms of climate forcing.

Participants recognized the importance of various paleoclimate activities in the region; they, including the authors of this report, encourage funding agencies and institutions to continue to support capacity building (scientific education and training) and research focused on climate change and its impact throughout the Americas.

Land Cover Changes

Changes in the alpine cryosphere may represent some of the earliest signs of large-scale climate change. A reduction in the area covered by snow and ice not only serves as an indicator of change but also provides powerful feedbacks through changes in albedo. In addition, melting of permafrost destabilizes slopes in areas of high relief, leading to landslides and rockfalls.

In discussions among the participants, it was agreed that development agencies (such as the World Bank), networks of networks (such as the Inter-American Institute for Global Change Research), and others need timely and detailed knowledge of ongoing changes in mountain regions of the Western Hemisphere [see *Bradley et al.*, 2006]. Decision support tools that could be used to better understand what is happening in the region include so-called integrated assessment models that consider an ensemble of physical, socioeconomic, and other inputs relevant to mountain environments.

Satellite images and airborne repeat photography of the margins of glaciers in the Cordillera region presented at the symposium demonstrate the significant changes in the extents of glaciers that have occurred in the past century. These changes are having, and will have, profound consequences for societies in the region that have depended on water from these previously glaciated catchments for their livelihood and culture.

The characterization of land surface changes on regional to continental scales is becoming increasingly important in assessing the impacts of climate change in relation to direct human modification. Changes in biogeochemical cycles are linked to changes in climate, the water cycle, land use patterns, and changing vegetation types. Such changes could have adverse impacts on agricultural production, unmanaged systems, and aquatic systems receiving runoff.

Several presentations showed that anticipating or avoiding these adverse impacts requires a fundamental understanding of linkages within terrestrial and aquatic systems, and an ability to predict the consequences of climate variability and the adoption of adaptive management practices. This suggests that appropriate downscaling tools (i.e., regional climate models) must be developed in order to improve the utility of the scientific research. To that end, long-term regional-scale models operating at various spatial and temporal scales should be supported, participants noted. The integrated use of these regional models for multidisciplinary research should be a high priority of systems modeling activities, participants indicated.

Recent studies have documented a number of phenological changes in many parts of the world. For example, since 1950, the beginning of spring in the western United States has advanced by one to two weeks, and about 20% of the late spring-summer snowmelt runoff from middle-elevation watersheds has been occurring in earlier months. Global change projections indicate that western snowpacks will diminish markedly over the next century and that this crucial spring-summer portion of the runoff will be sharply reduced.

Research Gaps and Future Work

In addition to having direct economic impact, such changes in mountain hydroclimate presumably would affect ecosystems, upstream as well as downstream. Large areas of the American Cordillera currently are poorly monitored by conventional or remote-sensing systems, several speakers noted. Large changes in climatic and environmental conditions can occur over small distances in the highly complex topography of the Cordillera, and this points to the need for a multifaceted observational system to monitor and better understand future changes.

The goals of the symposium are consistent with national and international efforts dealing with global change in mountain regions, such as the Mountain Research Initiative, supported by the International Geosphere-Biosphere Programme [*Decker and Bugmann*, 1999], and are relevant to climate change and biodiversity initiatives, such as the Global Mountain Biodiversity Assessment Program and the European Union's Global Change and Mountain Regions.

The symposium received support from the Inter-American Institute for Global Change Research, NOAA's Climate Program Office; the Mountain Research Initiative; the Argentinean Institute for Snow, Ice and Environmental Science; Forecos; the World Bank; the International Hydrologic Program (United Nations Educational, Scientific, and Cultural Organization); and the International Human Dimensions Program (International Geosphere-Biosphere Programme).

The Symposium on Climate Sciences of the North and South American Cordillera was held 4–6 April 2006 in Mendoza, Argentina. Conference materials, including the abstract volume and Webcasts of the presentations, are available at http://mri.scnatweb.ch/content/category/7/44/66/

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