CLIMAS Update

News from the Climate Assessment for the Southwest Project

Integrating science, policy, and community

THE UNIVERSITY OF ARIZONA.

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Researchers Improve Snowpack Prediction

Snow is a distant thought for many Arizonans, even as fall brings cooler days and nights to our desert home. Yet snow has a huge impact on our everyday lives, all year round. In Arizona, 54 percent of our water supply comes directly from spring streamflow and other surface waters. Across the West, 50 to 80 percent of annual water supply is derived from alpine snowmelt.

Predicting spring water availability depends on accurate measurements of snowpack the preceding winter. Snow in the West falls across thousands of miles of inaccessible alpine terrain, and the network of stations used to monitor snow is quite sparse, which makes accurate measurement difficult. In addition, variables such as soil moisture, slope, and snow composition affect the amount of water that snow in a particular area will yield (i.e., snow water equivalent, SWE). In the Southwest, decreased annual precipitation and soil moisture combined with increased water demands in recent years have made accurate water availability estimates an acute necessity.

Water resource managers and management operations have expressed dissatisfaction with the geographically sparse, ground-based, SWE data presently available for input into their hydrologic models. CLIMAS researchers Roger Bales and Noah Molotch, along with researchers from the Southwest Regional Earth Science Application Center (RESAC), are improving methods to estimate SWE across the western United States and to increase the accuracy with which they and others can estimate water availability for the rest of the year. This will provide decision makers with improved SWE data and allow them proactively address water issues in the Southwest.

Improvements on past methodology

In the past, Snowpack Telemetry (SNOTEL) sites provided the sole measurements of snow and estimations of SWE, based on the water content of fallen snow. In the semiarid Southwest, SNOTEL has provided a regular but limited historical record of SWE, since sites represent only a few points relative to the entire Colorado and Rio Grande River Basins for which they provide data. Moreover, current forecast methods convert all fallen SWE to runoff, when in fact the amount of snow that will melt to replenish surface streams depends on many factors. In New Mexico, for example, drought conditions can cause up to 25 percent of snowmelt to be absorbed directly into dry soils.

To address the problems inherent in traditional water forecasting, Bales and other CLIMAS researchers have developed a new process in which they: (1) determine snow-covered area (SCA) on the land surface, (2) integrate the SCA information with ground-based estimates of SWE, (3) estimate SWE over an entire river basin or larger land surface, and (4) assimilate the SWE estimates into hydrologic models. They use a process-based methodology that takes into account basin-wide snowfall patterns, elevation, terrain, local hydrology, solar radiation, air temperature, soil composition, and other physical factors that affect total SWE.

In order to determine SCA, researchers can compare the unique spectral properties of snow as portrayed in satellite imagery (e.g., its reflection and absorption of light) with calculated spectral properties of water

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Announcements

- Chicago will be the scene of the American Anthropological Association's 102nd Annual Meeting, November 19–23, 2003. Visit http://www.aaanet.org/mtgs/mtgs.htm for details.
- The Land Open Science Conference will be held in Morelia, Mexico, Dec. 2–5. For more info, visit http://www.oikos.unam.mx/landOSC.
- The American Geophysical Union will hold its 2003 Fall Meeting Dec. 8–12 in San Francisco. See http://www.agu.org/meetings/fm03/.
- The 84th American Meteorological Society Annual Meeting will be held January 11–15, 2004 in Seattle, Washington. For more info, see http://www.ametsoc.org/.
- The Association of American Geographers 100th Annual Meeting will be held in Philadelphia, March 14–19, 2004. For info, see http://www.aag.org/.

CLIMAS Mission

CLIMAS was established to assess the impacts of climate variability and longer-term climate change on human and natural systems in the Southwest. Our mission is to improve the ability of the region to respond sufficiently and appropriately to climatic events and climate changes.

What We've Been Up To…

Climate and Water

Transboundary Challenges in the Americas (Kluwer 2003), co-edited by Henry Diaz and Barbara Morehouse, has just been published. The book gives insight into climate-water interactions on the U.S.-Canada and U.S.-Mexico border areas, as well as in Colombia, Costa Rica, and Chile. Included are chapters by CLIMAS researchers Andrew Comrie and Barbara Morehouse, as well by researchers associated with the Western Water Assessment, the California Applications Project, and the Climate Impacts Group-Pacific Northwest.

In June, Bonnie Colby (Agricultural and Resource Economics) presented a paper on "Managing Risks and Costs of Water Supply Variability" at the Natural Resources Law Center Conference in Boulder, Colorado. She also organized and moderated a session at the Western Economic Association International Meetings in Denver on assessing the challenges of voluntary environmental restoration and acquisition in the western United States given climate-related water supply variability.

Climate Variability

CLIMAS co-investigators Barbara Morehouse and Margaret Wilder presented papers at the open meeting of the Human Dimensions of Global Environmental Change Research Community in Montreal, Canada, October 16–18.

David Brown, Ph.D. candidate in Geography, presented dissertation research on decadal-scale growing season variability in the western United States at the recent NOAA Climate Diagnostics and Prediction Workshop in Reno, Nevada. Brown also co-authored a paper on summer season precipitation enhancement in the Phoenix area that appeared in the June 2003 issue of the *Annals of the Association of American Geographers.*

Forecast Evaluation

Holly Hartmann presented her work on customized on-line climate forecast evaluations at the Water, Climate, and Uncertainty: Implications for Western Water Law, Policy, and Management conference, June 11–13. She demonstrated the dynamic forecast evaluation webtool through the CLIMAS partnership with NOAA's GAPP program, the joint NASA and Raytheon Synergy program, and the NASA-University of Arizona HyDIS project.

At the invitation of the NWS Climate Services Division, Hartmann participated in a workshop on CPC climate forecasts at the 32nd AMS Conference on Broadcast Meteorology. Hartmann presented on helping broadcast meteorologists understand and communicate probabilistic forecasts.

Hartmann participated in a policy forum on improving responses to climate predictions, organized by the American Meteorological Society and Columbia University April 23–24. Discussions covered many topics addressed by CLIMAS researchers, including the usability and accessibility of climate information.

Climate & Community Stakeholders

Bonnie Colby presented on "Innovative Responses to Water Supply Variability" at the Aspen Global Climate Change Institute. Attendees included federal water managers from around the West, environmental NGOs, and scientists from government agencies and universities.

Marcela Vásquez-León, of the Bureau of Applied Research in Anthropology co-authored a paper with CLIMAS associates Colin West and Tim Finan entitled "A Comparative Assessment of Climate Vulnerability: Agriculture and Ranching on Both Sides of the U.S.-Mexico Border." It was published in the journal *Global Environmental Change* [13(3):159–173.]

Vásquez-León and West also published "Testing Farmers' Perceptions of Climate Variability: A Case Study from the Sulphur Springs Valley, Arizona," in the book *Weather, Climate, Culture: Building Anthropological Bridges from Past to Future*, edited by B. Orlove and S. Strauss, Berg Publishing, New York.

Pima County resource managers have invited Bonnie Colby and Rosalind Bark to help design effective riparian habitat acquisition and restoration strategies for the county. Such habitat is valuable for many species, Colby explains, but is also highly vulnerable to climate-related water supply fluctuations, since riparian-area vegetation often is "last in line" to receive water during high demand.

Colby has been working with Colorado, New Mexico, and Arizona conservation groups to identify practical and cost-effective ways to maintain riverine habitat. Meetings over the past four months focused on the upper Rio Grande, San Pedro, and Upper Colorado Rivers, which are vulnerable to surface water flow variation resulting from regional climate variability.

In September, Colby participated in a small workshop sponsored by the Hewlett Foundation on "Assessing Environmental Outcomes of Community-Based Collaboratives." The group assessed results of mediation to resolve scarce natural resource conflicts.

Gregg Garfin and Rebecca Carter presented "END InSight: Expanding the Use and Usability of Climate Information" at the 2003 Arizona Association of Environmental Educators conference.

Drought

This summer, CLIMAS project manager Gregg Garfin gave a class entitled "Understanding Drought in the Southwest" at the Arizona Game & Fish Annual Department School in Flagstaff, Arizona.

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Submissions and Subscription Information

CLIMAS Update is published quarterly and welcomes the submission of items of interest. The editorial staff reserves the right to select and edit copy submitted for publication. All material in the newsletter may be reproduced, provided CLIMAS is acknowledged as the source. The newsletter is provided through the support of the National Oceanic and Atmospheric Administration (NOAA).

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Snow Prediction *(continued from page 1)*

and land features that might be confused with snow in the images. Clouds are also easily confused with snow, since they share spectral characteristics, and researchers need to develop an image analysis procedure (masking) to distinguish the two. Finally, they have developed a classification system that recognizes the percent of snow cover for each satellite data pixel, rather than using the simple snow cover/no snow cover identification system that other investigators have used. Thus by a combination of painstaking manual work and efficient computer-programming methods, CLIMAS researchers can recognize pixels that contain "snow" as unique from "land," "cloud," or "water."

The team also created an advanced mathematical interpolation scheme in order to generalize the ground-based SNOTEL SWE data to create area-wide estimates of SWE. The researchers applied linear regression analysis to SNOTEL point SWE data and fine-scale digital elevation models in order to extrapolate SWE estimates across entire river basins.

Results of improved methodology

The methods Bales and his fellow CLIMAS researchers developed have increased levels of accuracy in satellite imagery and SWE estimates. RESAC researchers hope to combine similar tree-cover and cloud-induced error elimination schemes into future satellite-based SCA mapping. Their past merging of physically-based SCA and SWE estimates resulted in fine-scale (1-km^2), basin-wide total daily snowpack water content maps and data for the Colorado and Rio Grande River Basins from 1995–2002.

In addition to more accurate estimates of SWE based on a combination of traditional SNOTEL data, satellite imagery, physical parameters, and mathematical extrapolation, CLIMAS researchers have been able to model the impact of spatially and temporally variable SWE on basin hydrology. For example, they have been able to develop a better understanding of the relationship between persistence in SCA and maximum basin-wide SWE in the upper Rio Grande watershed. Research on incorporating these SWE products into hydrologic modeling is ongoing (Figure 1). Early results indicate that updating the state of the snowpack with these data products will improve model results.

Future models may combine physical data, cloud and ground-cover sensitive satellite imagery, GIS-based elevation models, and SNOTEL data for even more accurate estimates of snow water equivalence and basin-wide hydrological impacts. For more information, visit http://hydis.hwr.arizona.edu/snow/index/html and http://hydis2.hwr.arizona.edu.

Forecast Evaluation Tool Goes International

Holly Hartmann has been selected by the American Association for the Advancement of Science (AAAS) to receive a National Science Foundation international travel grant to work with Claudia Natenzon and other colleagues in Argentina on the use of Internet technology to deliver advanced hydroclimatic information and forecasts for the La Plata River Basin. This work builds on the forecast evaluation tool developed for CLIMAS and Hartmann's participation earlier this year at the Multi-national Workshop on Soil Moisture Variability in the Río de la Plata Basin: Assessments of the Impact of its Variability and Forecast Applications for End Users, hosted by CPTEC-INPE (Brazil's climate research institute) in Cachoeira Paulista, Brazil, March 17–20, 2003.

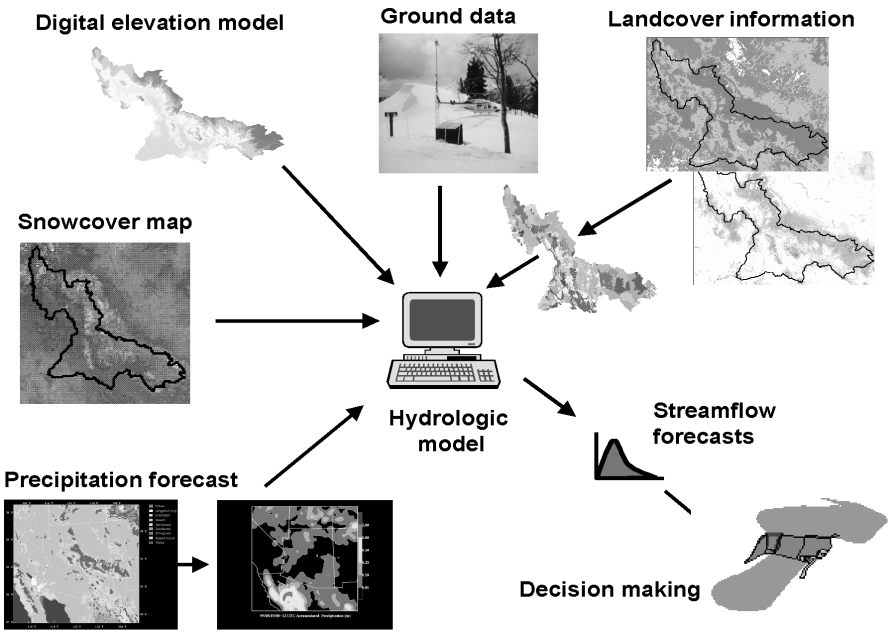

Figure 1. The role of snow cover information in hydrologic modeling and water resource decision making. Researchers use the hydrologic modeling framework shown above to produce spatially-distributed snow covered area data as well as SWE. The model inputs include, clockwise from bottom left: precipitation forecasts and observations, which are used to calculate future inputs into the watershed water balance; satellite-based snow covered area, which is used to estimate the amount of water stored in the snowpack; GIS and satellite topographic information, which is used to determine the distribution of meteorological variables across the watershed; ground observations of air temperature and snow water equivalent (distributed across the watershed based on the topographic information), which are used to estimate the amount of water stored in the snowpack and the rate of snowmelt; and finally satellite and remotely-sensed land cover information such as vegetation type, vegetation density and soil type, which are used to estimate the evapotranspiration rate and the infiltration rate. All of these inputs are used to model streamflow. Scientists can then issue model forecasts to stakeholders, who in turn can incorporate forecasted water availability into their management decisions.

What We've Been Up To (cont. from page 2)

At the North American Drought Monitor Workshop and the U.S. Drought Monitor Workshop, Garfin and Joe Abraham gave presentations on stakeholder insights into the effective presentation of climate information. Their presentations were a synthesis of results from the END InSight project, based in part on manuscripts prepared by former CLIMAS postdoc Rebecca Carter and ISPE postdoc Nan Schmidt. Garfin, Abraham, and CLIMAS investigator Barbara Morehouse are in the process of completing these manuscripts.

An October 6, 2003 *USA Today* article quoted National Interagency Coordination Center meteorologist Heath Hockenberry as saying that the relatively low impact of the 2003 fire season may have been due to preseason fire danger outlooks (prepared at a workshop coordinated and facilitated by CLIMAS) and accompanying resource allocation decisions. "[The] new seasonal outlook, issued last spring by federal climate and wildfire experts, predicted above-average danger in several regions. That led wildfire managers to position firefighting resources ahead of time at potential hot spots… But pre-placing firefighters and equipment may have helped keep some fire 'starts' from growing into major blazes."

The Northern Arizona University 2003 Southwest Drought Summit report is now available at the following URL: http://www.mpcer.nau.edu/megadrought/drought_summit_report/index.htm. Garfin is a contributor to the report.

Welcome

CLIMAS is pleased to welcome Thomas W. Swetnam, director of the Laboratory of Tree-Ring Research, and graduate student Erica Bigio to the team. Swetnam's work focuses on climate and human disturbances of forest and woodland ecosystems. This year he is continuing research on forest fire, insect outbreak, and climate studies in the western United States. With his input, CLIMAS will be able to strengthen ongoing fire research and expand the scope of ecological research. His outreach efforts include serving on the Arizona Governor's Forest Health Advisory Council and lecturing at continuing education and training courses for fire and forest managers.

CLIMAS Wishes Farewell…

Diana Liverman, CLIMAS PI and founding member, has accepted a professorship and chair in the School of Geography and Environment at the University of Oxford in the UK and a fellowship at Linacre College. Liverman is a leading figure in global change research and in Latin American environmental research, and a strong advocate of the need for a strong social science research presence within integrated assessment research programs. Though she will continue to maintain contact with CLIMAS researchers, Liverman's close participation in CLIMAS will be greatly missed.

We also express a regretful farewell to co-investigator Maria Carmen Lemos, who played an important role in CLIMAS through conducting research on co-production of science and policy. Lemos accepted a position as Assistant Professor in the School of Natural Resources and Environment at the University of Michigan in Ann Arbor.

CLIMAS also extends its sincere thanks to Soroosh Sorooshian, who will be joining the faculty at the University of California-Irvine. Sorooshian served as a co-investigator for CLIMAS from its beginning in 1998 to the end of the 2002–2003 funding year. His contributions to the project include the development of forecast evaluations and an innovative Web-based tool for delivering interactive forecast evaluation information. His success in attracting NSF funding to establish the SAHRA Science and Technology Center at UA and funding to initiate the HyDIS Web-based decision support system provided opportunities for linkages and leverage that significantly enhanced CLIMAS work.

Congratulations and a fond farewell to CLIMAS postdoc Rebecca Carter, who accepted a position as project manager for the Sonoran Institute SocioEconomics Program. Carter will work with Bureau of Land Management field managers and planners to use a collaborative, community-based approach to planning and land stewardship, and increasing their understanding the economic role of these lands. Carter's contributions during five years with CLIMAS include publications on urban water use, editorship of *CLIMAS Update*, and major contributions to the success of the END InSight project.

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