The Mountain Research Initiative

Workshop on Global Change Research in Mountainous Regions

Sunday, 14 December 2008
University of California Berkeley, California

Catalog of Research Summaries



Report:
The Mountain Research Initiative

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RESEARCH SUMMARIES

Vladimir Aizen (Eisen)

Central Asia Climate Water resources Variability International Project (CACWVIP)

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What are your central research objectives?

Objective 1: modeling and predicting environmental, social, and economic consequences of changes in moisture exchange and water resources redistribution between natural stores of waters (seasonal snow, glaciers, permafrost, lakes, rivers and ground aquifers) on land degradation and agricultural resources in central Asia mountains (Altai-Sayan, Tien Shan, Pamir, Karakorum and Kunlun) during the last 40 to 60 years by integrating NASA Remote Sensing products and in situ long-term terrestrial data.

The in-situ long-term glacio-hydro-meteorological observational data collected in the national archives digitized and expanded by high-resolution gridded maps of climatic, hydrological, glaciological, and topographic properties of the studied region. Due to the central Asia large area, different scales used to moderate high resolution satellite-based imagery and derived products from different instruments for large scale modeling, along with high resolution imagery from airborne sensors and GPS survey data for studies requiring small scales. The satellite products and the basin area aerial photographs integrated with glacio-hydro-meteorological data to characterize present and last 40 years regime and dynamics of snow/glacier/lake covered areas in alpine basins.

The proposed research will help to answer the questions:

- How well we can predict when and where the thresholds will be crossed?
- How well we can predict their ecological consequences? How will the local and regional changes in glacier/snow cover degradation feed back to the hydrology?

Objective 2: reconstruction of past hundreds to thousands of years Asian climate and water resources variability based on ice-cores from Altai, Tien Shan, Pamir, Karakorum, Kunlun, Tibet and Himalayas physical and chemical analysis. Specific objectives and examples of the databases we propose to develop are as follows:

- How does the strength of major circulation features such as the Asian monsoon, westerlies, and polar air masses vary on annual to decadal-centennial scales?
- How does the monsoon influence climate in the more northerly regions of the Tibetan Plateau?
- What factors control changes in the major circulation features impacting Asia?
- What are the associations between Asian climate and global (e.g., ENSO, cross-equatorial flow) circulation features?
- How have extreme environmental events (dust storms, droughts) varied in time and space over Asia?
- Is there evidence of climate events such as the little Ice Age and Medieval Warm Period over Asia?
- Are changes in Asian climate related (timing, magnitude) to climate events in other regions?
- How are changes in climate over Asia related to forcing (e.g., solar variability, volcanic activity?)

The result of this research will provide in-depth understanding of physical and chemical climate variability; a baseline for assessing modern climate variability in the context of human activity; and a contribution to the prediction of future climate variability for Asia.

Objective 3: examine the spatial/temporal extent of Asian dust outbreaks and their potential impacts on climate by integrating snow and ice-core geochemical records, routine ground-based observations, and satellite data.

This research will deliver in situ meteorological and lidar data on the dynamics of atmospheric aerosols, optical characteristics of atmospheric aerosols, solar radiation, and synoptic patterns data over central Asia. The lidar monitoring on atmospheric aerosols combined with a description of the regional climatology and synoptic regime will be used to document and identify the causes of temporal spatial and temperate variations in atmospheric chemistry and in the physical climate system.

Collection of historical data will greatly aid efforts to understand the effects of central Asian dust outbreaks on the Earth's radiation balance and regional climate. Development of reliable databases and climatology are required for driving aerosol distributed models, for calibration of remote sensing data/products, isotope/geochemistry ice core records and for validation of model outputs.

The result of this research will provide new insight on the traces and regime of aerosol spatial transformation during the 20th centuries and relate its variability to climatic parameters such as solar radiation/air temperatures, precipitation amount and synoptic patterns frequency.

All three scientific objectives and results will contribute to academic environmental science programs in the national universities and schools and build a foundation for dozen of field and laboratory based graduate theses and undergraduate student projects in US, Germany, Japan, Kyrgyzstan, Tajikistan, Russia, China, and Switzerland.

The research results will be translated into publicly accessible information through public lectures, media appearances and an extensive on-going outreach activity.

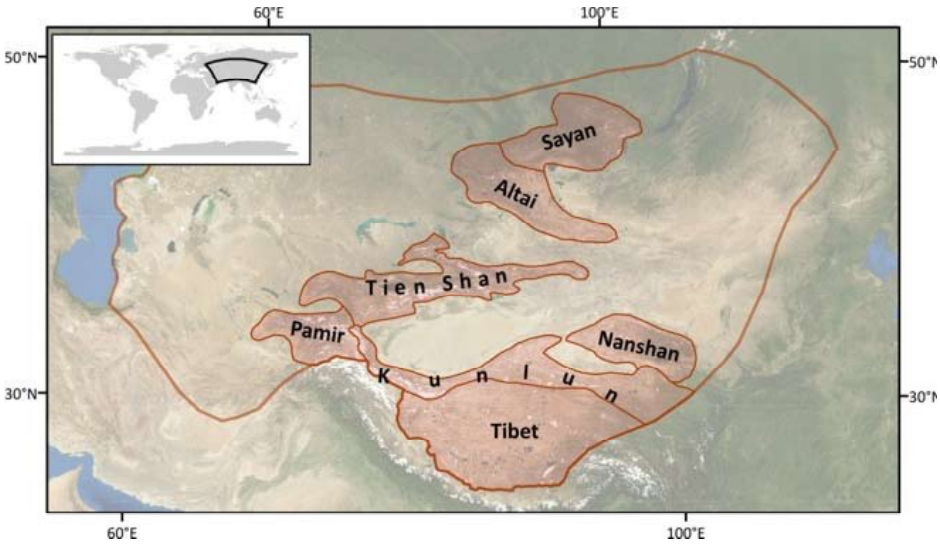
The research findings will be reported to local governments and the policy makers as recommendations. The results of this research have particular significance to climatologists, hydrologists, paleo-climatologists, atmospheric chemists, geochemists, climate modelers, solar-terrestrial physicists, economists, and environmental statisticians.

Funding agencies: US NSF, NASA, German Ministry of Foreign Affairs, Japan Ministry of Science and Educations and JSPS, Russian Academy of Sciences, Chinese Academy of Sciences.

Coordinated programs: NEESPI, CADIP, CEOP-HE

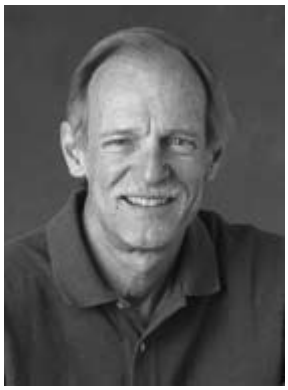
Next 5-10 years of the program: Most projects funded for 3-5 years and will be continued upon the national funds availability and scientific results.

Geographic scope:



Richard Armstrong

Global Land Ice Measurements from Space (GLIMS) project at NSIDC



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Current Objectives

The Global Land Ice Measurements from Space (GLIMS) project represents a baseline study with the goal of systematically quantifying the areal extent of past and present glaciers in order to accurately assess the magnitude of glacier change that is occurring worldwide. The GLIMS project at the National Snow and Ice Data Center (NSIDC), University of Colorado, Boulder, (funded by NASA, Dr. Richard L. Armstrong PI) is creating an inventory of the majority of the world's estimated 160 000 glaciers and mapping their extent and rate of change. GLIMS is an international project, coordinated by NSIDC, with participation from more than 60 institutions in 28 nations worldwide. Each institution (called a Regional Center, or RC) oversees the creation and analysis of data for a particular region appropriate to their expertise. These data are submitted to the GLIMS database at NSIDC, accessible at http://nsidc.org/glims This work is being undertaken in direct collaboration with the World Glacier Monitoring Service (WGMS), Zurich, Switzerland and is a logical extension of the WGMS World Glacier Inventory (WGI). In addition, we have established, and maintain, close coordination with the newly formed European Space Agency (ESA) GlobGlacier Project.

Database

The NSIDC GLIMS project has created a geospatial and temporal database composed of glacier outlines and various scalar attributes. These data are derived from high resolution optical satellite imagery, primarily the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) instrument aboard the NASA EOS Terra satellite and the LandSat Enhanced Thematic Mapper Plus (ETM+), while historic data (maps and photographs) are used to document changes from earlier periods. The database currently contains outlines for approximately 83 000 glaciers. The database also includes metadata for approximately 200 000 ASTER images (2000-2008) acquired over glacierized terrain. The ASTER footprints can be spatially viewed, temporally constrained, and queried to help researchers quickly find suitable cloud-free ASTER imagery. We have also implemented a Google Earth interface to our database.

MapServer

The GLIMS MapServer web site (http://glims.colorado.edu/glacierdata/) allows users to view and query several thematic layers, including glacier outlines, ASTER footprints, selected high resolution source imagery, MODIS Blue Marble imagery, GLIMS Regional Center locations, the World Glacier Inventory, the WGMS Fluctuations of Glaciers (FoG), and glaciers from the Digital Chart of the World. Query results for glacier outlines can be downloaded into a number of GIS-compatible formats, including KML (for viewing in Google Earth), ESRI Shapefiles, MapInfo tables, Generic Mapping Tools (GMT), and Geographic Mark-up Language (GML). Glacier outlines can be selected visually using the interactive map, or by using the text search interface to specify values (e.g. glacier name, area, etc.). The data are stored in a spatially enabled database (PostGIS), which has sophisticated functions for spatial data analysis and query.

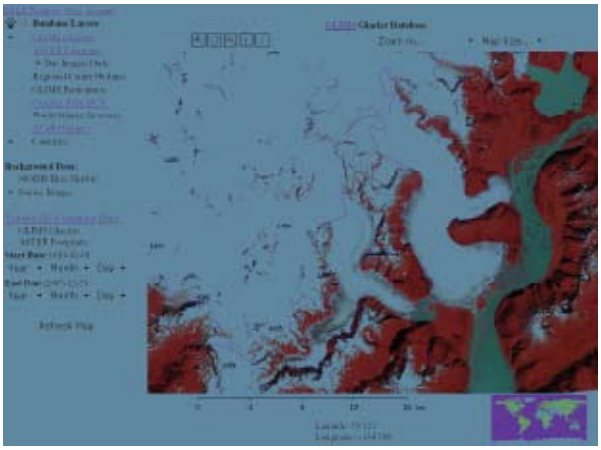
Funding and Other Activities

Our current funding is provided by NASA and has provided support for two graduate students, working both in the area of GIS enhancements to the GLIMS database and mapserver as well as field work to validate glacier mapping from satellite imagery. Our current PhD student, Adina Racoviteanu, is working in India and Nepal using precision GPS to accurately geolocate glacier outline shapefiles derived from ASTER satellite imagery.

Future Research Plans

Future plans include the continuation of the collaborative process of populating the baseline collection of global glacier outlines. However, primary focus in

future work will be to generate and archive glacier outlines which represent later time periods than the initial baseline entries such that change detection analysis can begin over key geographic regions. In addition, work continues on evaluating optimal methods and software packages to generate DEMs for application in the GLIMS project. DEMs are used by glaciologists in the derivation parameters such as length (using flow direction functions), terminus elevation, median elevation, hypsometric information and glacier flow patterns. When combined with glacier outlines, DEMs are also useful for deriving ice divides from flow direction grids, for watershed analysis, and, in a semi-automated fashion, for orthorectifying satellite imagery. DEMs from different time steps may be used to determine changes in glacier surface elevation at decadal scales. While DEM accuracy is a key issue for all these applications, there is no consensus within the glaciology community regarding the best software package and methodology for generating DEMs from satellite imagery. We are currently evaluating four individual software packages.



Screenshot of NSIDC GLIMS MapServer showing database layers and options for temporally constraining data.

Dominique Bachelet

How is climate change affecting mountainous areas?

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What are your central research objectives?

How is climate change affecting mountainous areas (among others)

a. On what phenomena do you take data?
I don't take data, I simulate climate change impacts so I gather as many datasets as I can to test the models. I use climate data as fine scale as I can depending on the science question asked and the area of interest.

b. What are you attempting to predict or characterize using those data?
Changes in vegetation and associated biogeochemical cycles and fire, eventually translating these into habitat characteristics or vulnerability indices to help land managers plan for a sustainable future

What is the geographic scope of your research?

Currently I am finishing a project at Yosemite National Park. My PhD student is testing our model run at 800m resolution against data collected by Park scientists and from the Grinnell survey and resurvey. I am very interested in continuing this type of work in the Olympics (my backyard) and Yellowstone (good fire information). I am also collaborating on a NICR proposal looking at the Central Appalachians.

a. Where do you gather data?
From the literature, from colleagues.

b. Over what geographic domain do your conclusions hold?
Depending at what resolution we run the model: for Yosemite at 800m, it's a regional/local analysis but we have run the model globally at 50km, the central Appalachian project would be for the Appalachian trail, so a narrow corridor.

What agencies and foundations fund your research?

USFS has funded the work of the MAPSS team I have belonged to until 2006. The Park Service has funded my PhD student for the Yosemite project.

a. What are the time horizons for your funding?
Yosemite project is finished. I am looking for funding and grant writing opportunities in collaboration with colleagues.

b. What kinds of resources does your funding provide for you? (graduate students, post-doc, lab facilities)
The funding I had paid my PhD student.

How you would like to see your research program evolve over the next 5-10 years?

Well established collaborative work with easy exchange of data/observations or model output between colleagues with multi-author publications

Synthesizing findings, creation of a central database with climate data easily accessible and formatted, creation of a modeler's platform with various modeling tools, user friendly, easily accessible with interchangeable parts.

a. New methodologies for data acquisition?
Working with climatologists like Daly who have strong reservations about the relevance of GCM projections in complex terrain: new climate dataset creation.

b. New methodologies for data analysis?
Better handle on uncertainties associated with climate inputs and hydrological features such as riparian corridors. Incorporating hydro features.

c. Incorporation of new disciplines into your program?
Close contacts with hydrologists, climatologists

d. Expansion to new geographic areas?
Yosemite and Olympics, maybe the central Appalachians

e. Other?
I have colleagues working in China who would really like to learn how to manage high elevation areas under climate change. I have colleagues in France working in European mountains who would welcome collaborative projects..

Franco Biondi

How ecoclimatic factors control landscape patterns and processes in present, past, and future environments

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What are your central research objectives?

My long-term scientific goal is to understand how ecoclimatic factors control landscape patterns and processes in present, past, and possibly future environments. I pursue this goal using natural archives, especially tree rings.

I would say that my work links earth systems to ecological systems, a link that the GLP highlights with the green arrow T1.3 (see Global Land Project Science Plan, p.8, http://www.globallandproject.org/documents.shtml).

a. On what phenomena do you take data?
Tree-ring data are used to quantify climatic change, wildfire regime, woodland species dynamics (including treeline ones), and biogeographic/ecoclimatic regions.

b. What are you attempting to predict or characterize using those data?
Data are used to define a baseline record of natural variability, to be used for the determination of ecological reference conditions, which in turn guide conservation and restoration of natural landscapes and ecosystems by providing a baseline for measuring the effects of past and present activities. Emphasis is placed on responses to regional climatic modes, such as the North American monsoon, and on the application of research results to watershed and natural resource management, particularly in terms of drought planning, fire use, and old growth conservation.

What is the geographic scope of your research?

a. Where do you gather data?
Great Basin, USA (see http://dendrolab.org/gb_climate.htm)
Central Mexico (see http://dendrolab.org/mexico.htm)

b. Over what geographic domain do your conclusions hold?
Western North America, Tropical North America (NAMS region)

What agencies and foundations fund your research?

Mostly NSF

a. What are the time horizons for your funding?
Currently the next 2 years or so are covered

b. What kinds of resources does your funding provide for you? (graduate students, post-doc, lab facilities)
Grad students, equipment, travel, technician, professional (either post-doc or computer programmer)

4. How you would like to see your research program evolve over the next 5-10 years?

More analysis of actual climate-tree growth relationships at multiple time and spatial scales. For example, the Mexico site risks being abandoned after having provided excellent, continuous data on atmospheric, soil, and tree parameters from 2001 to the present.

a. New methodologies for data acquisition?
Remote download of sensor data.

b. New methodologies for data analysis?
Expanded eco-physiological measurements.

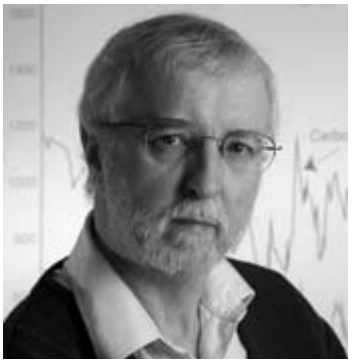
c. Incorporation of new disciplines into your program?
Linking models of landscape change with actual observations of landscape-level climate, disturbance, and vegetation dynamics.

d. Expansion to new geographic areas?
Not at this time.

e. Other?
More integration with existing large-scale efforts.

Ray Bradley

Changes in climate at high elevations in the Northern Andes and in Central America



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What are your central research objectives?

To characterize contemporary changes in climate at high elevations in the northern Andes (above 5000m) & in Central America (>3000m), and to assess potential anthropogenic changes and their impacts on hydrology (glaciers, runoff) & ecosystems in the future.

On what phenomena do you take data?

Meteorological conditions using a multiparameter array of instruments, relayed by satellite to our base in Massachusetts

b. What are you attempting to predict or characterize using those data?
To better understand the conditions on high elevation ice caps and adjacent regions, and provide data that can be used in glacier mass balance and hydrological (runoff) models. These models will be interfaced with regional climate model simulations for present and future conditions, under different scenarios of greenhouse gas changes.

What is the geographic scope of your research?

a. Where do you gather data?
Bolivia & Peru, with plans in hand to expand into Ecuador & Colombia. We would like to expand this nascent network of high elevation observing stations to sites in Central America, and to link to high elevation sites in the western U.S. and southern South America so as to establish a Pan- Cordilleran network of high elevation meteorological stations.

b. Over what geographic domain do your conclusions hold?
Currently we are focused on the northern Andes and central America, through field-based studies and regional climate modeling (using the Hadley Center PRECIS RCM)

What agencies and foundations fund your research?

a. What are the time horizons for your funding?
We have had funding from NOAA & NSF; currently the World Bank & NOAA support the research and an NSF proposal is in review.

b. What kinds of resources does your funding provide for you? (graduate students, post-doc, lab facilities)
Equipment, field operations, technical support only. No funding (yet) for graduate students.

How you would like to see your research program evolve over the next 5-10 years?

a. New methodologies for data acquisition?
We plan to broaden the observational network to other high elevation sites in the western U.S. and southern South America so as to establish a Pan- Cordilleran network of high elevation meteorological stations.

b. New methodologies for data analysis?
We will continue to run regional climate model simulations to broaden the ensemble averages and to examine different scenarios of future change. We may expand the analysis to other RCMs as resources permit.

c. Incorporation of new disciplines into your program?
We would welcome interactions with ecologists, conservation planners and managers working at high elevations in these regions.

d. Expansion to new geographic areas?
As noted earlier…

e. Other?
I have focused here on our work in the Americas. We also have on-going interests in East Africa, focused on Kilimanjaro. All of the above points also apply to that region.

Jeffrey Bury

Relationships between climate change and human vulnerability and adaptation in the Peruvian Andes

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What are your central research objectives?

a. On what phenomena do you take data?
b. What are you attempting to predict or characterize using those data?

My central research objectives are to examine the relationships between climate change and human vulnerability and adaptation in the Peruvian Andes. As a social scientist, I am examining the impacts of recent climate change induced glacier recession on household livelihoods and activities in communities surrounding the Cordillera Blanca, Peru. My research largely falls within T3.1, T3.2, T3.3 in terms of integrating modelling and analysis and within T1.2 in terms of analyzing what human beings are doing in response to current changes (see Global Land Project Science Plan, p.8, http://www.globallandproject.org/documents.shtml).
I am attempting to understand how climate change will affect high Andean livelihoods over the next several decades.

What is the geographic scope of your research?

a. Where do you gather data?
b. Over what geographic domain do your conclusions hold?

The scope of my research is currently focused on the Peruvian Andes. Over the course of the past several years we have been developing interdisciplinary research efforts, models and a set of extensive field based observations that link both social and ecological systems. My conclusions hold generally over the tropical Andean region, but have implications for many high altitude natural resource based livelihood systems.

What agencies and foundations fund your research?

a. What are the time horizons for your funding?
b. What kinds of resources does your funding provide for you? (graduate students, post-doc, lab facilities)

My research is currently funded by the National Science Foundation. We have 2 years of funding and this allows for field research and graduate student training monies.

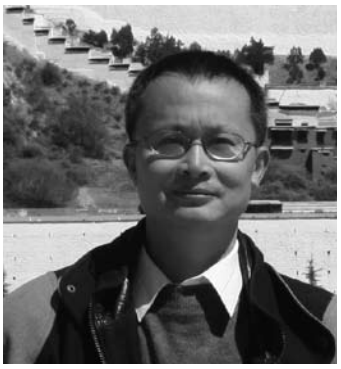
How you would like your research program to evolve over the next 5-10 years?

a. New methodologies for data acquisition?
b. New methodologies for data analysis?
c. Incorporation of new disciplines into your program?
d. Expansion to new geographic areas?

Over the next few years I would like to develop a multi-year project that allows for more complex and comparative analyses of the impacts of climate change in mountain environments. I would like to have access to high resolution geographic imagery, develop new models for understanding human vulnerability and adaptation and perhaps extend the research to other mountainous areas.

Song Cheng

Responses of ecosystems in Mt. Hengduan areas of China to global change



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The great project will start in 2009, and be conducted by our research team of more than 10 researchers over next 5 years. Our field station (Mt. Gongga Alpine Forest Ecosystem Research and Observation Station, Institute of Mountain Hazards and Environment, Chinese Academy of Sciences) is one of the most important mountain research bases for the study in China. The project will be briefly described as follows:

Research objectives

The objectives are

1) to reveal the altitudinal heterogeneity of various vegetation zones as well as relationships between the heterogeneity and altitudinal gradient of mountain environment, and effects of global change on multi abiotic factors associated with vegetation structures and change in the altitudinal distribution of the vegetation zones;

2) to expose effects of global change on dominant tree species and ecological functioning of various altitude-distributed vegetation communities in typical mountainous regions through simulating the growth and succession of the species in natural and artificial environments;

3) to examine hypothesis that is the balances of between carbon source and sink, and between soluble sugar and starch in alpine trees interactively determine the upper limit of timberline by investigating spatial-temporal changes in ecophysiological traits in the leaves. The hypothesis may likely explain the distribution pattern of the timberlines in the present and future;

4) to understand ecohydrological changes in various altitude-distributed vegetation zones and the effects of various stream scales on hydrology with global change through investigating the water-energy circulation processes in soil-plant-atmosphere system of the typical ecosystems in the zones. The knowledge would better evaluate water conservation and predict the changing trend of the hydrological process in some mountainous areas;

5) to disclose the resilience and adaptation of mountainous ecosystem to climate change and environmental stresses by determining the thresholds of multi environmental factors for typical vegetation zones in some regions of Mt. Hengduan. The information would be helpful for a better estimation of the frangibility of the mountain ecosystems in Mt. Hengduan areas and protect from the ecosystems by making policies and taking countermeasures.

Geographic scope of research

The study is for the Mt. Hengduan areas in southwest of China. The Mt. Gongga Alpine Forest Ecosystem Research and Observation Station is located in the area. The peak of Mt. Gongga with 7556 m is the highest in the Mt. Hengduan area. Its elevational range is 6400 m within an horizontal range of 29 km, and is the highest in the world. Consequently, altitudinal changes in climate and vegetation zones are obvious in the Mt. Gongga. In the region, broadleaf forests, mixed broadleaf and coniferous forests, conifers, dark coniferous forests, alpine shrubs and meadow are distributed from 1,900 to 2,200 m, 2,200 to 2,800 m, 2,800 to 3,600 m, 3,600 to 3,800 m, 3,800 to 4,000 m, and above 4,000 m high, respectively. Additionally, other typical mountains, including Mt. Zheduo and Mt. Miyaluo above 5,300 m high in the Mt. Hengduan areas will be also important experimental sites for the study.

Foundations

The Mt. Gongga station has been established since 1987. Five meteorological stations are set up at the altitudes of 1,600 m, 2,100 m, 2,700 m, 3,000 m and 4,200 m to monitor weather in the different zones. Many research projects have been completed and supported by Science Foundations of Chinese Academy of Sciences, National Natural Science Foundation of China, and China Ministry of Science and Technology.

We are trying to obtain some grants from the above organizations and would like to obtain some internationally financial resources to sponsor this project.

Outcomes

(1) Models will be developed for vegetation community succession with altitudinal and horizontal gradients, especially for the areas disturbed by glacier retreat and debris flow. The patterns of vegetation distribution will be completed for the mountainous regions.

(2) Models will be developed to simulate the responses of plant species diversity, vegetation community structures and productivities, vegetation distribution and ecosystem functioning to climate change.

(3) Hydro-thermal coupled models will be developed to simulate the hydrological process in the atmosphere-soil-plant system in the different zones for the better understanding of the water-energy balances and the influences of climate and ecosystem on the hydrological processes in the mountainous regions.

(4) New knowledge may be developed to explain the formation and distribution of alpine timberline in some typical areas, and the influences of global change on the alpine timberline in Mt. Hengduan areas.

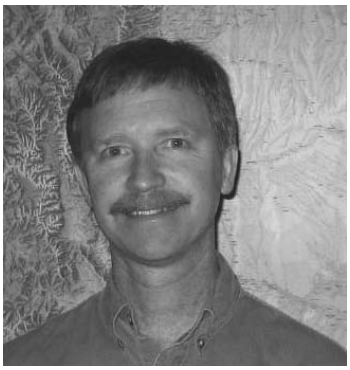
(5) The thresholds of abiotic and biotic factors in the dominant tree species of the different vegetation zones will be determined to assess the frangibility of natural ecosystems in the zones as climate change. The information is useful to make policies on protecting the ecosystems in Mt. Hengduan areas in the future.

Evolution over the next 5-10 years

The station will be developed to be an advanced experimental center for alpine ecosystem and hydrological researches in China, and one of international research stations for mountain sciences in next 5-10 years. The above project is a huge, complicated and the most important project in our station during the period. The project needs to cooperate with international institutions in many different ways by enhancing the academic exchange of scientists around the world, and being financially supported by international organizations if possible.

David Clow

Effects of climate change and climate variability on hydrologic and biogeochemical processes in alpine and subalpine ecozones



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What are your central research objectives?

Our research focuses on the effects of climate change and climate variability on hydrologic and biogeochemical processes in alpine and subalpine ecozones. We investigate how climate variability affects water, energy, and biogeochemical budgets in the Rocky Mountains.

a. On what phenomena do you take data?
We collect chemical, isotopic, and physical data on surface water and groundwater, and climate data at several locations within our study area.

b. What are you attempting to predict or characterize using those data?
We seek to characterize the response of hydrologic and biogeochemical processes to climate variability.

What is the geographic scope of your research?

The scope of our research covers high-elevation areas throughout the mainland of the western United States.

a. Where do you gather data?
Our primary study area is in the Loch Vale watershed, in the southern Rocky Mountains of Colorado. We also collect somewhat less intensive data within a 50-100 km zone around Loch Vale, which allows us to "scale-up" and regionalize our results.

b. Over what geographic domain do your conclusions hold?
Our results are most pertinent to the southern Rocky Mountains, but should have some utility to most other high-elevation areas in North America and around the globe.

What agencies and foundations fund your research?

Our research is funded primarily by the United States federal government. Ancillary funding for focused research topics is provided through grants from state agencies (Colorado).

a. What are the time horizons for your funding?
Our research program began in 1992, and is designed to be long term, but can be affected by changes in funding priorities by the US Congress.

b. What kinds of resources does your funding provide for you? (graduate students, post-doc, lab facilities)
The funding we receive pays for our salaries as well as those of field technicians and maintenance and operation of our monitoring network.

How you would like to see your research program evolve over the next 5-10 years?

We would like to contribute to data integration, synthesis, and modeling efforts at regional, national, and international scales. We also would like to contribute to more interdisciplinary studies focusing on alpine/subalpine landscapes.

New methodologies for data acquisition?
There is an urgent need for establishing long-term collection of hydrometeorological data in the alpine zone in western North America. Because much of this area is in wilderness, technologies with minimal impact (visual and otherwise) are needed.

Christopher Daly

Spatial and temporal variations in the climatic environment - translation of that understanding into spatial climate products for the public good

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Introduction

The PRISM Group is a research team dedicated to producing spatio-temporal climate research, analyses, and modeled data sets. My group is developing an emerging sub-discipline of climatology called "geospatial climatology," which is a powerful combination of climatology and geo-spatial analysis. I am the author of the PRISM spatial climate modeling system, which produces state-of-the-science spatial climate products currently used in thousands of applications worldwide. Spatial data sets include official USDA temperature and precipitation climatologies for the United States and possessions, a US climate atlas, climate maps for China/Mongolia and the European Alps, and a 113-year monthly time series of digital maps of temperature, precipitation, and dew point for the US spanning 1895-present. I am responsible for securing 100% external funding for my group, which currently consists of five permanent FTEs (including myself).

What are your central research objectives?

Advance understanding of the spatial and temporal variations in the climatic environment, especially in complex physiography, and translate that understanding into spatial climate products for the public good.

a. On what phenomena do you take data?
We use observed station data from a variety of external sources, but collect our own data on a limited basis for research purposes. We work with most of the major climate variables.

b. What are you attempting to predict or characterize using those data?
To advance understanding of the spatial and temporal variations in the climatic environment, especially in complex physiography (i.e., terrain and coastal environments), and apply that understanding to accurately estimate climatic conditions where no observations exist.

What is the geographic scope of your research?

Global, continental, regional, landscape, at multiple scales, but our main interest is in climatic variations at scales of 10 km or less.

a. Where do you gather data?
We gather field data at the HJ Andrews Experimental Forest (through the NSF Long-Term Ecological Research program) in the Oregon Cascades (44.23 Lat, -122.18 Lon), but mainly use climate data gathered by others world-wide. Most of our work is in the United States.

b. Over what geographic domain do your conclusions hold?
We would like to think our conclusions (i.e., PRISM modeling assumptions) hold world-wide, but we learn something new with every application of the model. Most of our applications have been in the northern hemisphere, ranging from tropical islands to Alaska.

What agencies and foundations fund your research?

Our research has been funded largely by Federal agencies in the United States. They include several agencies within the USDA (particularly NRCS and USFS) and NOAA; and NPS, USAF, and USEPA. The Nature Conservancy has recently funded two projects. A very small part of our funding comes from NSF.

a. What are the time horizons for your funding?
It is rare for a given project to last for more than three years; most last for 1-2 years. Unfortunately, this is at odds with the kind of work we do, which requires stable appropriations over long periods to allow the regular updating of climate data sets required by users. During times of Federal budget cuts, when many agencies simultaneously choose not to fund our program from their discretionary budgets, the life of the program is threatened (as is happening now). Funding of the PRISM Group is at a crossroads. With the prospects for discretionary funding appearing grim, and given

the operational nature of our products, we must attract operational funding sources that are not so volatile.

b. What kinds of resources does your funding provide for you? (graduate students, post-doc, lab facilities)
The PRISM Group is composed of one professor and four permanent research assistants with several to many years of experience. It is rare for us to be able to support graduate students and post-docs. Overhead from our external grants and contracts help support our facilities and computing infrastructure. Research, development, and dissemination of PRISM spatial climate data sets require sophisticated computing capabilities.

How you would like to see your research program evolve over the next 5-10 years?

We would like to evolve into a stable, multi-faceted research/applications organization that has base funding to provide needed spatial climate products, analyses, and quality-controlled data, and is able to attract research funding on the complex spatial-temporal aspects of climate variability. Our ultimate goal is to be able to have such good estimates as to significantly reduce the need to establish and maintain monitoring stations. We also want to continue to expand our working relationships with user groups in ecology, agriculture, hydrology, natural resources management, and many others.

a. New methodologies for data acquisition?
We anticipate that much of the interest in spatial climate analysis and data sets will be at very fine resolutions, i.e., 100 m or less. As we move our analysis and downscaling methods to these fine scales, we need fine scale spatial data sets to support them. These include terrain, vegetation, hydrography, and very precise locations and environmental characteristics for climate stations.

b. New methodologies for data analysis?
We would like to explore whether mesoscale modeling and satellite analyses can be used to inform the PRISM climate mapping process. We see using PRISM as an effective downscaling tool for fine resolution analyses and climate change scenarios. We would like to explore ways to recast PRISM in a more sophisticated statistical framework. Much of our work involves climate data quality; we hope to continue to develop increasingly intelligent quality control systems. The best spatial data sets are developed with strong user interaction; we would like to have increased communication with user projects and have the funding to be able to improve our products based on that feedback.

c. Incorporation of new disciplines into your program?
Mesoscale modeling, satellite analysis, statistics, ecology, hydrology.

d. Expansion to new geographic areas?
We would like to model more areas of the world so we can further enrich the PRISM knowledge base. That said, exploring the "known" world as much finer scales will also be a major focus.

Alvaro J. Duque M.

Forest diversity and functioning in natural protected areas in Andean mountains in Colombia, South America

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What are your central research objectives?

We focus our aims on understanding spatial and temporal changes of biodiversity, structure, and functioning of natural ecosystems in the northern Andes, in relation to global change. Forest functioning will mainly focus on carbon and water storage and regulation.

a. On what phenomena do you take data?
We basically are sampling plant species in order to assess species dynamics (mortality and recruitment), growth, and biomass (Net Primary Productivity).

b. What are you attempting to predict or characterize using those data?
We want to gain insights on species extinction rates; switching in species geographic ranges; changes in carbon fluxes and forest dynamics; all of them related to climate and global change.

What is the geographic scope of your research?

The three ranges of the Andean cordillera in the northern part of South America, Colombia

a. Where do you gather data?
In natural reserves areas ranging from locally protected to National Natural Parks.

b. Over what geographic domain do your conclusions hold?
The domain of the conclusions will cover geographical scales from regional to global, and from landscapes to ecosystems.

What agencies and foundations fund your research?

The National Environmental Bureau through the regional agency (CORANTIOUIA); the research division of the National University of Colombia; the regional government of Antioquia through Expedición Antioquia. The National Natural Parks System of Colombia gives support through accommodation, facilities, local transportation, fieldwork assistance, etc.

a. What are the time horizons for your funding?
Two years with certainty

b. What kinds of resources does your funding provide for you? (graduate students, post-doc, lab facilities)
Undergraduate, master, and graduate students; lab and equipment facilities; supplies, field trips, and fieldwork assistance.

How you would like to see your research program evolve over the next 5-10 years?

a. New methodologies for data acquisition?
Very much. In special those related to carbon fluxes and hydrological monitoring.

b. New methodologies for data analysis?
Yes. Mainly through graduate and post-doc positions

c. Incorporation of new disciplines into your program?
Yes. Mainly in social issues

d. Expansion to new geographic areas?
Instead of expanding to other areas we will focus on covering as well as possible the current whole geographic area in the Colombian Andean mountains

e. Other?
We also aim to identify potential uses of plants based on biological assessments on chemical and resource compounds in order to find new strategies for forest conservation based on non-timber products.

Hilde Eggermont

Paleoclimate, paleolimnology, and glacier history of the Rwenzori Mountains, Uganda/Congo

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Central research objectives

Recent observations of glacial termini in the Rwenzori Mountains (the so-called *Mountains of the Moon*; Uganda-DR Congo) confirm rapid glacial recession over the past 100 years. The rates of this recession suggest that the permanent ice will disappear entirely within the next two decades. In order to understand the climatic controls of glacier recession, the relative impacts of human-induced global warming versus natural climate variability, and the long-term tropical mountain ecosystem and glacier stability in the Rwenzori, there is an urgent need for sound knowledge of past climate and ecosystem variability and glacier dynamics in this high mountain environment. Sediments accumulating on the bottom of alpine glacial lakes chronicle the history of central African climate and environmental dynamics, and can thus provide the historical perspective needed for resource conservation.

The main goal of our research program (2005-present) is to investigate century-scale variability in rainfall and temperature and its impact on alpine glaciation and ecosystems in central equatorial Africa during the mid- to late Holocene through multi-proxy analysis of sediment records from Rwenzori lakes. To this end, we maintain an active field and laboratory research programme to:

- Explore the physical and chemical limnology of virtually all lakes on the Ugandan side of the range (*status: completed*).
- Collect temperature, humidity, and rainfall data using automated in-situ loggers from multiple sites at 1,500-5,000 m asl (*status: ongoing since 2005*).
- Calibrate sedimentological, geochemical and biological climate-proxy indicators through analysis of their variation in the surface sediments of lakes and pools both above 4000 m (with some direct input of glacial meltwater) and below 4000 m (remote from current glacial melt) (*status: ongoing since 2005*).
- Develop chironomid- and diatom-based transfer functions for quantitative reconstruction of air and lake temperature and nutrient regime (status: ongoing since 2005).
- Quantify the effects of temperature and rainfall amount on the isotopic composition of Rwenzori meteoric waters using field data and isotope-enabled climate models for quantitative reconstruction of precipitation amount (*status: ongoing since 2005*).
- Identify the lakes most suitable for high-resolution paleoclimate reconstruction; and recovery long sediment cores from the most promising sites to construct a regional picture of African paleoclimate history over the past 5000 years (*status core recovery: completed; status core analysis: ongoing since 2008*).

Finally, we also aim to document the poorly known biodiversity of aquatic algae, insects and micro-crustacea in the unique setting of tropical high-elevation lakes. Apart from throwing light on the auto-ecology and biogeography of the different groups of Afroalpine aquatic biota, the data will also provide a baseline against which to compare future ecological changes (*status: ongoing since 2005*).

Geographic scope

a. Study region
Rwenzori Mountains (with plans to extend research to Mt Kenya and the Bale Mts, see 4.)

b. Geographic extent
East African region

Funding

a. Funding agencies

- The National Geographic Society (US), 2006-2007
- Fund for Scientific Research of Flanders (Belgium), 2007-2010
- Leopold III-funds (Belgium), yearly grant applications
- Richard B. Salomon Fund (US), yearly grant applications
- Fonds ter Bevordering van het Wetenschappelijk Onderzoek in Afrika (Belgium), yearly grant applications
- Ghent University (Belgium), 2008-2014 (PhD student)

b. Funded facilities
Funding provides 2 PhD students, lab facilities, lab analyses, and fieldwork.

Prospects

Although the automated in-situ loggers provide good service, we hope to find even more adequate means to collect temperature, humidity, and rainfall data (in the form of sound meteorological stations). Such data are invaluable to our calibration work, and will also allow better integration/interpretation of purely climatological aspects in our research.

In January, 2008, we recovered new piston cores from 7 lakes in the Rwenzori. Cores vary in length from 1.3 to 4.5 meters long, with basal age estimates ranging from a few thousand to perhaps ~10,000 yr BP. The lakes include 3 lakes that currently receive glacial melt-water and 4 lakes that do not. Multi-proxy comparative analyses of these glacial vs. non-glacial lakes will allow to reconstruct not only the climate history of this alpine zone (i.e. a reference against which to compare future change) but also will provide independent assessments of fluctuations in its glaciers. We plan similar research on Mt. Kenya (starting date: summer 2009)

Early 2009, H. Eggermont will start up fieldwork in the Bale Mountains of Ethiopia. The new project (entitled Bale Mountain lakes: Ecosystems under pressure of Global Change?) aims at evaluating the sensitivity of Bale Mountains lakes and pools to effects of global change. More specifically, it aims to (1) gain information on the physical, chemical and biological properties of the lakes and pools as a baseline against which to compare future changes; (2) reconstruct the response of the Bale Mountains' aquatic biota to environmental change of the past 100-200 years to evaluate the sensitivity/resilience of the Afroalpine aquatic ecosystems to global change impacts. Additionally, we also aim to assess feasibility to put up a long term monitoring program for aquatic ecosystems in the Bale Mountains. As such, this study will help to formulate management strategies for aquatic ecosystem conservation in the face of future climate change and increasing human impact.

Rwenzori project personnel

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Leen Audenaert, Ghent University, Belgium

Shannon Loomis, Brown University, USA

Immaculate Ssemmanda, Makerere University, Uganda

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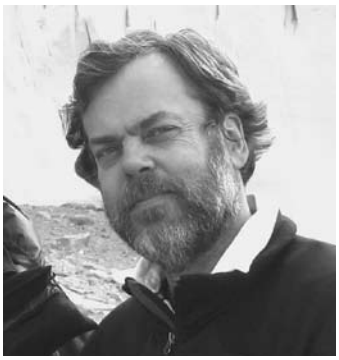
Andrew Fountain

Mass change of glaciers and glacier area and volume in the American West and in Antarctica



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What are your central research objectives?

a. On what phenomena do you take data?
Glacier change. This includes the mass change of glaciers and glacier area and volume in Antarctica. I am also collecting current and historic data via photographs and maps of area changes for the past century for the glaciers in the American West, exclusive of Alaska.

b. What are you attempting to predict or characterize using those data?
We are trying to do four things: (1) estimate the rate and magnitude of area change of glaciers in the American West; (2) define the spatial and temporal variations across the West; (3) correlate the observed glacier response to changes in the high alpine climate to infer the controls on the rate and magnitude of glacier change; (4) calculate the effect on high alpine runoff.

What is the geographic scope of your research?

The alpine region of the American West, inclusive of the states of Washington, Oregon, California, Idaho, Nevada, Utah, Montana, Wyoming, and Colorado.

a. Where do you gather data?
We gather the historic data from libraries of the national parks, hiking clubs, private holdings, and federal, state, municipal libraries. We also search the scientific literatures. We acquire new or recent aerial photographic data from which we create new data.

b. Over what geographic domain do your conclusions hold?
While the observations are exclusive to the American West general principles should hold for all temperate alpine regions.

What agencies and foundations fund your research?

National Science Foundation, NASA, US Geological Survey, hiking clubs.

a. What are the time horizons for your funding?
Two grants are ending and I have ~5 years of continued funding.

b. What kinds of resources does your funding provide for you?
Graduate and undergraduate students, some of which use this topic for thesis work. Travel expenses to collect the data including funding some new aerial photography, and attend meetings. To support computer software and hardware.

How you would like to see your research program evolve over the next 5-10 years?

We plan on soon ending the search for historic data and continuing to collect new glacier data on different regions. These data are being synthesized and importance to runoff examined. In the near future, we will become more involved in climate-glacier modeling to calculate the glacier changes in the past and to infer future possibilities.

a. New methodologies for data acquisition?
With new funding we may collect new data to better estimate glacier volume. Also aerial photography is revolutionizing such that new, better, more efficient data acquisition is continually being improved.

b. New methodologies for data analysis?
New software for aerial analysis is coming on line and improved climatic data sets are being improved.

c. Incorporation of new disciplines into your program?
I am currently collaborating with ecologists and hydrologists. I expect that to continue.

d. Expansion to new geographic areas?
Yes, perhaps. I would like to collaborate with investigators in other countries including Canada, Scandinavia, and around Antarctica.

Umesh K. Haritashya

Satellite and field based glaciological studies in the Himalaya, Hindu Kush and Karakoram region

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What are your central research objectives?

My research revolves around the fact that due to climate change and global warming, temperature changes now seem inevitable and are changing the landscape of snow, ice and glaciers, or even existence thereof. This changing environment requires interdisciplinary research of the complex phenomena that control the dynamics of earth's and atmospheric processes. To do that, I utilize both field collected data as well as satellite borne data.

a. On what phenomena do you take data?

- Hydro-meteorological data to characterize hydrological flux, estimate various components of streamflow, and utilize them in calibrating melt runoff model.
- Suspended sediment yield and their quantification and variability with hydrometeorological records.
- Spatio-temporal fluctuation of glacier using variety of camera model and remote sensing satellite imagery (ASTER, LANDSAT, IRS, SPOT, CORONA, Keyhole)
- Development of melt-runoff model using field oriented and remote sensing data.

b. What are you attempting to predict or characterize using those data?
To characterize climate change impact on the cryosphere including spatio-temporal fluctuations of the glacier; practical application of the hydrology of glacierized basins on runoff prediction, reservoir management, hydroelectric production, irrigation, and flood control; as well as better understanding of the weather systems in the high altitude region, and the hydrological and sediment transport behavior including hydrological processes and storage characteristics of the glaciers.

What is the geographic scope of your research?

a. Where do you gather data?
Himalaya, Hindu Kush and Karakoram

b. Over what geographic domain do your conclusions hold?
India, Nepal, Pakistan, Afghanistan

What agencies and foundations fund your research?

Recently, I have started new position and received World Bank fund through private Danish company to provide input in decision support hydrological modeling. I also have had some success with other private agencies in the past. Before joining this position I have worked in the NASA and the USAID funded projects, and wish to submit my future grant applications to those agencies along with NSF.

a. What are the time horizons for your funding?
Maximum of three years

b. What kinds of resources does your funding provide for you? (graduate students, post-doc, lab facilities)
Support towards data purchase, field instruments, travel, and other analyses.

How you would like to see your research program evolve over the next 5-10 years?

- Improve model and test it in other glacierized basins
- Assess glacier fluctuations in other region
- Interdisciplinary collaborations (including geophysicist, climate modeler, ecologists, and social scientists)

Syed Iqbal Hasnain

Study of glacier mass-balance in the Indian Himalaya by a network of benchmark glaciers

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What are the central research objectives ?

The glacier-climate-hydrology interactions in the Hindu Kush-Himalaya are of great interest for both global and regional purposes. Our primary objectives are to select one benchmark glacier for intensive studies from each well defined climate settings from the Indian Himalaya. The goals for long-term monitoring is to quantify the magnitude of glacier mass change and its effect on stream flow; define the relation between mass change in glacier cover and climate variations; and use satellite imageries for developing regional mass balance of glaciers in the vicinity of benchmark glacier and predict changes in the ice cover.

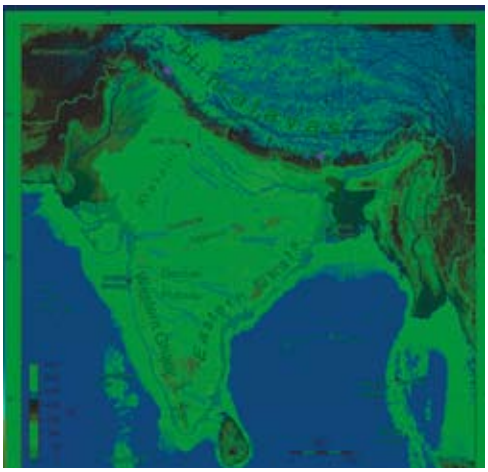
a. On what phenomena do you take data ?

We use stake and pit method to collect annual mass balance and installed two meteorological station on each glacier; one in the ablation region and second outside the glacier snout in the valley. This way we will be computing annual mass balance and energy balance. Within ten kilometers from the glacier snout we have set up discharge site to monitor diurnal and seasonal variations of flows emerging from the glacier basin.

b. What are you attempting to predict and characterize using those data ?

We are attempting to quantify the magnitude of glacier mass change and its effect on stream flow and also attempt to define the relation between mass change in ice cover and climate variations. By using satellite imageries of IRS, Spot and Aster we will study ice cover area, mass and dynamics on a regional scale to quantify changes by the global warming. By coupling mass balance, ice flow and energy models we will run for IPCC scenarios for future changes.

What is the geographic scope of your research ?



We have selected three benchmark glaciers for intensive studies located in the west Himalaya (Kolahoi glacier, (N 340 07'-340 12': E 750 16'-750 23' Lidar valley, Jammu and Kashmir. This glacier receives its nourishment by the westerly jet streams during winter and ablation takes place during the summer. It is north facing glacier without debris cover. The glacier selected in the east Himalaya is known as East Rathong Glacier (270 33', 48' 36'' N: 880 06', 51 95 E), located in the west Sikkim, a south facing debris free glacier having total ice covered area around 8.49 square kilometers. Sikkim Himalaya receives more accumulation in summer than winter (each half year) are called the "summer accumulation type glaciers".

a. Where do you gather data ?

We conduct two field campaigns for E. Rathong glacier, east Himalaya; one in March/ April and second in October/ November 2009 to study precipitation input from June to September which probably is around 80 % of annual amount, because it is wet in summer due to monsoon. Winter is dry but it does receive precipitation between December and February which is probably

less than 25 %.The accumulation and ablation takes place simultaneously. Therefore, air temperature at the ground can be related whether precipitation occurs in the form of snow or rain. One field campaign (September/ October) will be conducted on Kolahoi glacier, Liddar valley, Jammu & Kashmir (N 340 07'-340 12': E 750 16'-750 23'), a north flowing debris free glacier having total ice covered area around 15 square kilometers. The glacier receives all its accumulation between November and February by westerly winds and ablation takes place during summer time.The Chhota Shigri glacier is a North flowing glacier .The Snout of this glacier at an elevation of 4050 m, located in the Lahul valley, Himachal Pradesh has been selected as it receives nourishment by both westerly jet stream during winter and by summer monsoon during summer. The field campaign on this glacier will be conducted during September and October and early in summer by June/ July to measure both winter and summer accumulation.

b. Over what geographic domain do your conclusions hold ?

The data generated by three benchmark glaciers practically covers three important zones of climate in the Himalayan arc. The conclusions drawn will be comprehensive as the impact of climate change on Himalayan glaciers would be viewed under all geographic domain.

What agencies and foundations fund your research ?

The government of Norway is providing funds under bilateral agreement with The energy and Resources Institute (TERI). The Carnegie Corporation, USA will also be funding to promote research activities in the Indian Himalaya and funds will be routed through Global centre, Iceland and other stakeholder in the program will be Ohio state university, USA.

a. What is the time horizon of your funding ?
All funding is for a period of five years.

b. What kind of resources does your funding provide for you ?
The funds are being utilized for purchasing field equipment like Differential GPS, automatic weather stations and water level recorders besides high altitude equipment. Part of funds will be used for conducting annual field campaigns. Provision is also there to fund graduate students and post-doctoral fellows.

How do you like your research program to evolve over the next 5-10 years.

After five years we will have enough field data sets to develop models which can be tested on real time series on benchmark glaciers and would provide accurate prediction on the glacier ice cover in the Indian Himalaya. We would be able to identify the human, economic, social and environmental vulnerability factors of melting glaciers on the livelihood of communities.

a. New methodologies for data acquisition.

Differential GPS will be used to delineate boundaries of glaciers and digital elevation models will be made by using satellite data and conventional contour maps of the glacierized basins. We have installed automatic weather stations at high elevations to acquire data sets for energy balance. Also run geo-radars to determine the geometry of the glacier. Instruments will also be installed to monitor black carbon soot on the glacier to determine the impact of atmospheric brown clouds on the accelerated melting of glaciers. Vertical towers will also be erected to measure microclimate of the valley and to record compositions above the glacier.

b. New methodologies for data analysis ?

Coupled models will be run for different climate change scenarios. Ice cores record from glaciers in the west, centre and east Himalaya will help to model glacier responses in the past and future.

c. Incorporation of new disciplines in your program ?

Social scientists and ecologist will help us in quantifying the impact of glacier melting on the vulnerable communities. Ecologist will help in interpretation data sets on the impact on biodiversity of the Himalayan ecosystems.

d. Expansion to new areas

We have planned to choose more benchmark glaciers from the Gnaga river basin, Indus basin and Brahamputra basins from western, central and eastern Himalaya. This way network of benchmark glaciers will be more representative and will also study the glacier lakes and the risk posed by them to the downstream communities and high value investments like power projects and school buildings.

Ansgar Kahmen

The influence of plant species composition and diversity on biogeochemical cycles in mountain ecosystems

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Central research objectives

I am generally interested in the interaction of plants with their biotic and abiotic environment. My current research largely addresses the influence of plant species composition and diversity on biogeochemical cycles in mountain ecosystems with particular emphasis on a changing climate. Stable isotope analyses are a critical tool in my work. I use stable isotopes as tracers to understand how nitrogen, carbon and water cycle in ecosystems. In addition, I have used stable isotope ratios in plant materials, soil and water at their natural abundances as spatial and temporal integrators of biogeochemical processes such as N mineralization and de-nitrification ($\delta^{15}N$) and evapotranspiration ($\delta^{18}O$). In my most recent work, I am investigating the variability of oxygen and deuterium isotopes in precipitation, ground water and various organic plant materials along steep elevation gradients along Mauna Loa, Hawaii. The goal of this recent work is to calibrate the δD and $\delta^{18}O$ signal that can be determined in plant material as an integrative signal of the water cycle in these mountain ecosystems.

Geographic scope

My work does not focus on a specific geographic region right now. The main areas of research are mountain systems in Germany, Switzerland and Hawaii. Given that I will relocate to Switzerland in 2010, there will be an increased focus on European mountain ecosystems.

Funding

Funding for my work comes from the Austrian Science Fund (Erwin Schroedinger Postdoctoral Fellowship) and the European Union (Marie-Curie Outgoing International Fellowship).

Perspectives

I would like to keep a strong focus on plant-mediated biogeochemical cycling in my future work. The effects of plant species composition and diversity on ecosystem carbon, nitrogen and water relations will therefore remain in the focus of my research with particular emphasis on the link between above- and below-ground processes. Stable isotopes both as tracers and at their natural abundances will remain a critical tool for my work. Recent analytical developments now allow determining stable isotope ratios of specific plant and soil compounds. I will incorporate this technique into my research, which will provide new and critical information on biogeochemical cycles. In particular alpine ecosystems with their large gradients in precipitation and temperature are ideal systems to applying compound specific isotope analyses to investigate the effects of a changing climate on biogeochemical cycling in terrestrial ecosystems.

Bryan Mark
Changes in tropical mountain glacier environments over time

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What are your central research objectives?

I research changes in tropical mountain glacier environments over time, with the objectives of understanding the nature, extent, and impact of these changes over different scales of space and time.

a. On what phenomena do you take data?

We evaluate glacier volume changes and quantify hydrological fluxes using observations and models. My research group incorporates field and computer-based methods from different disciplines, including glacial geology and geomorphology, hydrology, hydrogeology, climatology, and geodetic science. Specific recent data acquisition efforts include: airborne laser swath mapping (ALSM) over glaciers and proglacial valleys; photogrammetry (aerial and terrestrial) of glacier changes; ground (ice) penetrating radar of glacier depth; hydrochemistry to analyze hydrological sources and contributions to surface and groundwater; stream discharge logging; groundwater monitoring with piezometers and temperature loggers; hydrometeorological observations with vertically distributed instrument arrays; satellite image and altimetry analysis (ASTER, LandSAT, SPOT, SRTM); moraine mapping with GPS; lake and wetland coring; and computer modeling, including GIS-based coupled glacier mass balance and ice flow, catchment scale hydrologic balance, and hydrochemical basin characterization (HBCM).

b. What are you attempting to predict or characterize using those data?

Tropical glaciers exist at the interface between atmosphere and lithosphere in a region known as the planetary heat engine, and tracing changes in their mass over time holds clues about global climate dynamics. We aspire to better constrain the extent, rate and climatic forcing of glacier-hydrological changes (modern and late-glacial to Holocene). In this context, the role of local topography in modifying regional to global climate signals is an important dimension. [Fig. 1 Earth System; links T2.1, T1.3, see Global Land Project Science Plan, p.8, http://www.globallandproject.org/documents.shtml] Tropical glaciers also literally crown a diverse ecosystem, and changes in ice volume impact both physical phenomena (erosion, sedimentation, hydrology) and human society (availability and quality of water) down slope. Thus we also desire to quantify these processes, better predict their future changes, and inform societal impacts. [Fig. 1 Land Systems; links T1.1 in support of T3.1, 3.2]

What is the geographic scope of your research?

While my research focuses primarily is on glaciers and mountain environments in the tropical Andes and Africa, I also work in mid-latitude sites once occupied by glaciers, including Great Basin National Park and Central Ohio.

a. Where do you gather data?

We gather field data in a number of specific tropical highland regions: in the Peruvian Andes, including Cordilleras Blanca and Huayhuash (8-12°S) and Vilcanota/Quelccaya Ice Cap (12-14°S); and Kilimanjaro, Tanzania (3°S). I have also compiled glacial geological data from sites throughout the global tropics. In addition I conduct annual research in the Great Basin National Park, Nevada, USA.

b. Over what geographic domain do your conclusions hold?

Our conclusions hold for different spatial regions, from tropical highlands globally (glacial-Holocene paleoclimate), to local mountain regions (as listed above). Tropical climate conditions of thermal homogeneity and highly seasonal precipitation provide unique situations for tropical glaciers, with implications for water availability. Given the uniform recession of mountain glaciers globally, our research tracing this phase change of ice to water applies to other glacierized mountain regions.

What agencies and foundations fund your research?

We have been funded by NASA, NSF National Geographic, Western National Parks Association, as well as the Climate, Water & Carbon initiative, Geography Department and Office of International Affairs at the Ohio State University. Funding has been in 1-3 year grants, and resources are used for supporting students, postdocs, field equipment, laboratory analyses, travel, and computing software and support.

How you would like to see your research program evolve over the next 5-10 years?

Ongoing and future developments over the next 5-10 year include new technologies and methods, new integrations with social scientists on human dimensions of global climate change, and expansion into new regions of the Andes and Asia. Specifically, we have begun to acquire light distance and range (LiDAR) data over glaciers to quantify volume changes, and are expanding the use of hydrogeologic-hydrochemical models to quantify end-member contributions to stream flow. I plan to build on integrated geographic efforts currently underway with NSF Geography funding, where our physical hydrological work to quantify glacier volume changes and meltwater contributions are being coupled with human geographic assessment of indigenous livelihood level impacts, adaptation schemes, and resilience to environmental change.

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Consortium for Integrated Climate Research in Western Mountains (CIRMOUNT)

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The Consortium for Integrated Climate Research in Western Mountains (CIRMOUNT) is a collaborative, interdisciplinary consortium dedicated to understanding climates and ecosystems of western North American mountains. CIRMOUNT's overall goal is to bring together researchers from diverse disciplines and in-stitutions to measure and understand climate-driven changes in the unique landscapes that define western North American mountains, and to respond to the needs and challenges of western society for mountain resources imposed by climate change. CIRMOUNT is sponsored by a diverse group of agencies, universities, and institutions.

CIRMOUNT addresses four urgent challenges facing western North American climate science and policy communities:

- Mountain regions are vastly under-instrumented to measure climate and longterm changes - we do not even know how mountain climates are related to lowland conditions;
- Research on western North American mountain climates & ecosystems is intensive, but scattered and poorly integrated;
- Societal demands on western mountain ecosystems are exponentially escalating, imposing new and cumulative stresses on natural resources and rural community capacities;
- Climate change is widely ignored in mountain land-use planning and natural-resource policy to the detriment of ecosystem conservation and natural resource management. In confronting these demands, CIRMOUNT provides a forum that is responsive to the needs and challenges of western society imposed by climate changes on mountain ecosystems.

CIRMOUNT's specific goals for the mountains of western North America are to:

- Promote installation and analysis of coordinated high-elevation climate, hydrologic, and ecosystem monitoring (observation);
- Catalyze integrated research on mountain climates and their effects on ecosystems (research);
- Communicate science among diverse disciplines and provide sound science for effective land-use planning and management (communication and decision-support);
- Promote development of longterm, policy-relevant mountain climate and ecosystem databases (research, observation, communication, and decision-support);
- Develop CIRMOUNT as a pilot regional model for integrating climate-related sciences at the international scale; encourage participation of the CIRMOUNT community in global mountain-climate programs and assessments (international collaboration).

CIRMOUNT aligns with the goals of the U.S. federal Climate Change Science Program, coordinates with the USGS Western Mountain Initiative, and is endorsed as a pilot regional project of the international Mountain Research Initiative.

CIRMOUNT's six Working Groups address specific consortium goals and proceed with varying success. These include:

1. Alpine Plant Monitoring (the Global Observation Initiative in Alpine Environments, GLORIA):
   http://www.fs.fed.us/psw/cirmount/wkgrps/gloria/
2. Mountain Climate Network (MONET):
   http://www.fs.fed.us/psw/cirmount/wkgrps/monet/
3. Hydrologic Observatories:
   http://www.fs.fed.us/psw/cirmount/wkgrps/hydro/
4. Ecosystem Responses:
   http://www.fs.fed.us/psw/cirmount/wkgrps/ecosys_resp/
5. Paleoclimatic Archives:
   http://www.fs.fed.us/psw/cirmount/wkgrps/paleo/
6. International Relations:
   http://www.fs.fed.us/psw/cirmount/wkgrps/int_rel/

Background information on CIRMOUNT can be found in the Consortium's Framework booklet, "Mapping New Terrain; Climate Change and America's West":
http://www.fs.fed.us/psw/cirmount/publications/pdf/new_terrain.pdf

CIRMOUNT publishes a biannual newsletter, "Mountain Views":
http://www.fs.fed.us/psw/cirmount/publications/mtnviews.shtml

CIRMOUNT hosts a biennial science workshop, "MtnClim" as well as an annual session at the Fall Meet-ing of the American Geophysical Union:
http://www.fs.fed.us/psw/cirmount/meetings/

Future

In that CIRMOUNT has both disciplinary (monitoring; databases) and integrative (integrated research, decision-support) goals, future projects are desirable that have depth as well as projects with breadth. All activities need not be integrated with each other, but all should address one or more of CIRMOUNT goals. In some cases, the goal of a project or activity may best be met with integration, while in other cases, it may not. Ideally CIRMOUNT will have a balance of both breadth and depth activities. To achieve this, CIRMOUNT must engage in collaborative partnerships with universities; federal, state, and local agencies; NGOs; and private sector interest groups.

Specific opportunities for CIRMOUNT future projects are outlined in the consortium's Strategic Plan (2007):
http://www.fs.fed.us/psw/cirmount/publications/pdf/strat_plan_0407.pdf

Anne Nolin

The integrated effects of climate variability and change on snow and glaciers from a water resources perspective

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What are your central research objectives?

Exploring the integrated effects of climate variability and change on snow and glaciers from a water resources perspective.

a. On what phenomena do you take data?
Spatial distributions of snow water equivalence and snow covered area, near-surface air temperature, streamflow, glacier melt rates and meltwater runoff.

b. What are you attempting to predict or characterize using those data?
Watershed-scale distributions of snow water equivalence and streamflow.

What is the geographic scope of your research?

a. Where do you gather data?
McKenzie River watershed, H.J. Andrews Experimental Forest (LTER site), Mt. Hood and Mt. Rainier

b. Over what geographic domain do your conclusions hold?
Pacific Northwest, United States

What agencies and foundations fund your research?

NSF, NASA, USGS

a. What are the time horizons for your funding?
1-3 years

b. What kinds of resources does your funding provide for you?
Graduate students, fieldwork costs.

How you would like to see your research program evolve over the next 5-10 years?

a. New methodologies for data acquisition?
More use of isotope tracers.

b. New methodologies for data analysis?
Greater integration of models and observations (including remote sensing)

c. Incorporation of new disciplines into your program?
Geomorphology

d. Expansion to new geographic areas?
Andes, New Zealand

Benjamin S. Orlove

Human perceptions of and responses to glacial retreat

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What are your central research objectives?

To characterize the perceptions of the human communities that live in close proximity to retreating glaciers, to describe their responses to this retreat, and to study the networks that link these communities with development organizations and research scientists

a. On what phenomena do you take data?
Human perceptions and actions, as reflected in the interactions of members of mountain communities with each other, with social science researchers, with development organizations and with governments. I integrate quantitative and qualitative methods, such as interviews, focus groups and examination of community archives.

b. What are you attempting to predict or characterize using those data?
To understand the variability, within and between communities and regions, of levels of perception and response to glacial retreat. I am particularly interested in three dimensions of the perceptions: the social/spatial scale (who are the "we" that are being affected?), the temporal dimension (how far into the past and into the future do people look?) and the specific impacts about which they are concerned (e.g. livelihoods, hazards, culturally significant landscapes).

What is the geographic scope of your research?

a. Where do you gather data?
The three field sites are in the Cordillera Blanca of Peru, the South Tirol of the Italian Alps, and the North Cascades in the state of Washington, US.

b. Over what geographic domain do your conclusions hold?
In addition to these three cases, I would like to add other regions, such as Norway and the Karakoram. I would also like to add one additional site for the Andes, the Alps and the North American Cordillera.

What agencies and foundations fund your research?

The US National Science Foundation

a. What are the time horizons for your funding?
Funding extends into 2010.

b. What kinds of resources does your funding provide for you?
Field research and equipment for grad students and a post-doc.

How you would like to see your research program evolve over the next 5-10 years?

a. New methodologies for data acquisition?
I might add participatory mapping to the range of techniques that I use. I would also like to engage in "action research" by involving residents of mountain communities in the design of websites to build publish awareness about glacier retreat.

b. New methodologies for data analysis?
I would like to draw on new mapping technologies that could promote the participation of residents of mountain communities. For example, local residents could use products related to Google Earth to trace the history of their local environments and to communicate this history broadly.

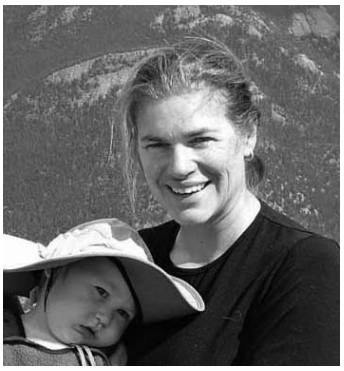
c. Incorporation of new disciplines into your program?
My work draws primarily on my own field of anthropology and the closely allied discipline of geography, with contributions from history, economics and psychology. I seek to develop these ties with other fields.

d. Expansion to new geographic areas?
As mentioned above, I would like to add other sites in areas with mountain glaciers.

e. Other?
When people seek information about climate change from the media, they see many sources that emphasize the impacts of climate change on the Arctic and on low-lying islands. I would like to bring the communities near retreating mountain glaciers into public awareness, and to bring the residents in those communities into the global dialogue about climate change.

Chris Ray

Response of alpine mammal populations to past, present and future climates



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A model system: climate explains montane mammal extinctions across the Great Basin

The American pika (Ochotona princeps) has been disappearing rapidly from alpine habitats across western North America over the past few decades. My most recent research, in collaboration with ecologists Erik Beever (USGS) and Jennifer Wilkening (University of Colorado) as well as climatologist Phil Mote (University of Washington), has focused on modeling these extinctions as a function of climate or climate change. We have been able to accurately predict recent extinctions of this species within the Great Basin as a combined function of four metrics of climate-induced stress, including two metrics of acute cold stress as well as chronic and acute heat stress. Three of the predictive metrics of stress were derived from the prevailing climate over the past 60 years: number of days below -5 °C (acute cold stress), average summer temperature (chronic heat stress), and number of days above 28 °C (acute heat stress). One predictive metric was based on climate change over the past 60 years: change in number of days below -5 °C. These results suggest that climate can explain recent "local" extinctions of pikas—extinctions at the subpopulation level.

Proposed research: a collaborative test of ecological forecasting

But whole metapopulations of the American pika have been disappearing from alpine habitats across western North America ever since the last thermal maximum several thousand years ago. My original goal in studying this species was to explain why prehistoric extinctions occurred in some alpine habitats but not others. I expect that these extinctions can be explained by a combination of habitat spatial structure and climate; in short, I expect that only spatially robust metapopulations can survive periods of climate-induced stress.

If we can accurately predict which habitats should have supported pikas through periods of past climatic stress, then there is hope that we can predict which habitats will continue to support this species under future climate scenarios. This system presents perhaps the best known opportunity to test predictive modeling of changing species distributions: There are prehistoric and historical data on pika presences, as well as recent data on absences within apparently suitable habitats throughout the Great Basin. Recent extinctions can be explained using climatic models based on pika physiology. The most important climatic variable in these models, the frequency of extremely low temperatures at ground level, is influenced by both temperature and precipitation (lack of insulating snow cover)—a combination of variables that can be inferred for past climates using tree-ring data.

Finally, there is a tremendous potential for a detailed spatial analysis of tree-ring data within the Great Basin, which could support the development of spatially explicit models of climate-induced metapopulation dynamics. I propose a collaboration spanning population biology, paleoecology, physiology, climatology, microclimatology, geology and dendrochronology, to test our ability to predict past extinctions of the American pika within the Great Basin. Our models would be based on first principles, derived from data on past habitat structure and climate, on the behavioral and physiological response of pikas to microclimate, and on the metapopulation dynamics of pikas. Most of these data are currently available, awaiting only analysis at the appropriate spatial and temporal scales.

Broader implications

The goal of this research program is not limited to predicting the future distribution of a single species. Rather, the data analyses and expected results from this focused project should immediately facilitate similar work aimed at other western species, especially alpine mammals but including alpine birds, herps and invertebrates, as well as any species (including lowland species) that respond to the climatic variables modeled within this project. Long-term impacts of this project would extend to many applications of ecological niche

modeling, as the lessons learned from analysis of this system are applied elsewhere.

Funding

I am currently working with a large network of collaborators to implement the ideas described here, but this effort—and the funding for it—is piecemeal and is unlikely to produce timely results without a more coordinated framework. Current funding for specific aspects of this project is provided by the US National Science Foundation, WWF, the National Geographic Foundation and other private entities, including the Charlotte Martin Foundation.

Thomas Reichler

Predictability from cryosphere-atmosphere interaction over high terrain

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Central research objectives

Implement, calibrate, and validate a regional numerical model of the coupled atmosphere/land-surface system over high terrain and use the model system to explore the mutual links between Earth System and ecological system.

a. Data taken
In-situ and remotely sensed meteorological (precipitation, temperature) and land-surface data (snow, skin temperature, vegetation index, vegetation cover).

b. Goals
Role of cryosphere-atmosphere interaction and topography for short-term climate predictability; impact of interannual (ENSO) and long-term (climate change) climate variability on surface hydrology.

Geographic scope of research

Bolivian Altiplano

a. Geographic region where data are taken
We use already existing meteorological data and remotely sensed data over our study area.

b. Geographic domain where conclusions holdT
Tropical high-altitude and eventually other mountain area.

Funding agencies

NOAA/NSF (planned)

a. Time horizons for funding
3 year

b. Resources provided by funding agency
graduate students, post-docs, limited computer hardware

Future plans

- Implement the model over other mountainous regions like the western part of the United States.
- Model improvements (resolution, parameterizations).
- Couple regional model to global climate models to make climate change simulations.
- Couple regional model to a glacier model and examine impact of climate change on future water supplies.

John (Jack) Shroder
Himalayan Geomorphology

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Research Program Past Progress

1. GLIMS (Global Land Ice Measurements from Space) Regional Center for Southwest Asia (Afghanistan & Pakistan). For the past 3 years we have been mapping glacier changes in the Hindu Kush (decreasing) and western Himalaya (minimal change or increasing).

2. Afghanistan natural resources. This has been a project of ours for much of the past 30 years and focuses in large part upon ice and water in an area with a devastating drought sequence for most of the past 8 years.

3. Science for peace. Bringing together geoscientists from Asia with their Western counterparts has been an objective of ours for a long time, and most recently resulted in a nice collaboration with ICIMOD in Kathmandu in a workshop on the Cryosphere and Hazards that we funded.

4. MAIRS (Monsoon Asia Integrated Regional Studies). An invitation from the Government of China enabled us 2 years ago to help write a research design for the Himalaya and Tibetan Plateau.

5. Himalayan geomorphology & landscape evolution. Permafrost degradation & deglaciation debuttressing produce valley-wall-collapse landslides.

Research Program Future Possibilities

1. GLIMS progress for the whole Himalayan & Tibetan Plateau. Variable glacier changes in different places need explanation.

2. Science in Afghanistan must be brought (back?) into the mainstream to save the country from more of the Talibanistanization of this wretchedly poor place.

3. Science for peace in South Asia is in need of being addressed by other scientists too, perhaps through the good offices of enhanced collaborations with ICIMOD.

4. MAIRS enhancement. We produced a useful document that was meant to lead to further collaborative research but it seemed to disappear into a black hole of detachment on the part of the Government of China, perhaps as the Olympics transcended most thought in Beijing.

5. Continued assessment of Himalayan geomorphology.

Christina L. Tague
Coupled hydrologic-ecosystem biogeochemical cycling models

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My research group focuses on the design and application of coupled hydrologic-ecosystem biogeochemical cycling models to improve our understanding of climate change impacts in mountain regions.

By representing key processes and interactions over space and time, spatially distributed process-based models offer a tool for predicting responses to changes in forcing conditions and for improving theoretical understanding of complex watershed behavior. A core part of our research agenda is the development of models as tools to scale the results of field research in space and time and to estimate watershed responses to land use and climate change scenarios. Most of our model development work has been done through RHESSys (Regional Hydrologic Ecosystem Simulation System). We maintain RHESSys code and documentation through our website at (http://fiesta.bren.ucsb.edu/~rhessys/).

We focus on three main areas to improve the model:
a) model parameterization and representation of uncertainty,
b) model functionality and usability, and
c) science based evaluation and refinement of process representation in the model.

Previous applications of RHESSys have shown that it can successfully model both hydrologic and carbon cycling behavior in mountains of western North America [e.g. *Mackay et al.*, 2003; *Tague et al*., 2004]. A recent study by *Zierl et al*. [2007] compared RHESSys estimates of streamflow and carbon flux with measured data for 15 EUROFLUX sites in mountain catchments across Europe. RHESSys captured significant cross-site differences in water and carbon fluxes as well as distinctions between managed and undisturbed forests and tree species.

Recent applications include examining how geology mediates streamflow response to warming in the Western US mountains (*Tague et al.*, 2008, *Jefferson et al*., 2008). Results show that spatial differences in geologic-based drainage efficiency are a first order control on the sensitivity of summer streamflow to changes in snow accumulation and melt. We have also used RHESSYs to develop hypotheses about spatial patterns of vegetation response to changes in the timing and magnitude of snow accumulation and melt (e.g. Christensen et al., 2008, Tague et al., in review) and to guide strategic field-based monitoring. In more semi-arid regions, model estimates show that potential changes in vegetation biomass are likely to have a significant effect on summer streamflow availability. These structural changes in vegetation are often not considered in hydrologic models of climate change impacts on streamflow.

Current projects include involvement in the National Science Foundation Critical Zone Observatory in the Sierra Nevada (http://www.czen.org/node/286/about). Our group is also participating in the Western Mountain Initiative WMI (Western Mountain Research Initiative http://www.cfr.washington.edu/research.fme/wmi/, Baron et al., 2006). Here we seek to integrate field-based analysis of vegetation drought stress and mortality and fire into our coupled eco-hydrologic model. We will use field-based estimates of tree water stress using carbon isotope, sap flow and tree ring width to improve model parameterization and representation of local vegetation processes, and then link these with watershed hydrology and streamflow and stream chemistry data to scale local processes to watershed scales.