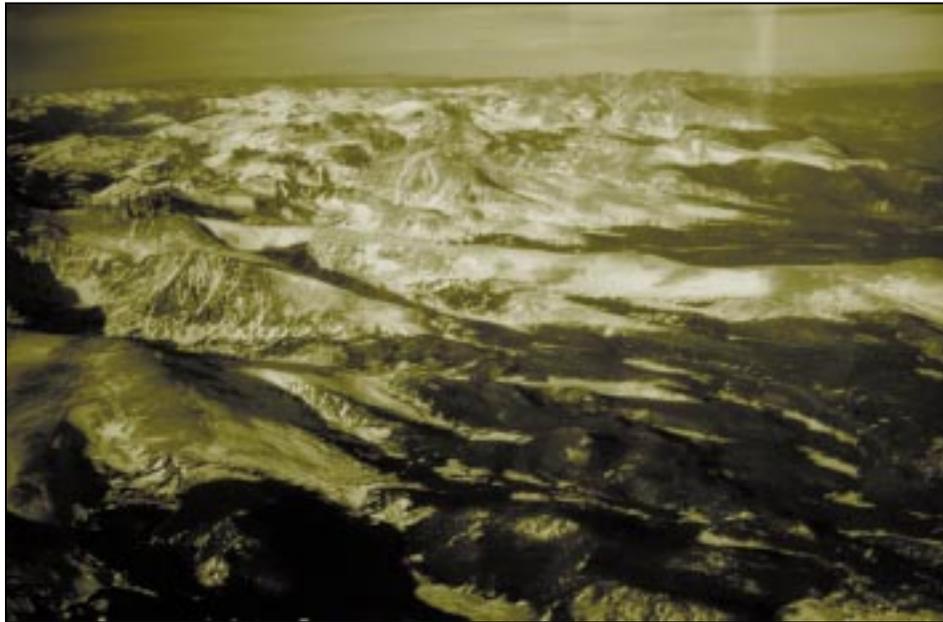


# Institute of --- Arctic and --- Alpine Research ---



**1998** Annual Report  

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### **Cover Picture**

*East slope of the Colorado Front Range looking north. Niwot Ridge, site of INSTAAR's research activities and the NSF-funded Niwot Long-Term Ecological Research site (LTER) is the long treeless ridge in the middle of the picture. Photo: A. W. Johnson, 3 January 1956.*



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# Annual

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# Report

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# 1998

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Institute of Arctic and Alpine Research  
University of Colorado at Boulder

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# Institute of Arctic and Alpine Research

## University of Colorado at Boulder

The Institute of Arctic and Alpine Research strives for excellence in research, education, and societal outreach. The Institute facilitates and accomplishes interdisciplinary studies offering special expertise in high-altitude and high-latitude regions of the world. INSTAAR's research mission also includes non-cold-region Quaternary studies and geochronology, as well as global issues such as earth-system science, landscape evolution, and climate dynamics. INSTAAR aims to understand how the varied regions of the world are affected by natural and human-induced physical and biogeochemical processes on the local, regional, and global scales. Research initiatives are interlinked with our educational and societal outreach missions. By encouraging the use of our facilities, and the expertise of our personnel, INSTAAR provides excellent educational opportunities to graduate and undergraduate students. Our outreach to the wider community, both locally and farther afield, includes aspects of research and education. INSTAARs provide leadership in setting regional, national, and international science priorities and agendas, with particular emphasis on societal-relevant issues.

## Research

INSTAAR's research activities integrate field studies, state-of-the-art laboratory experiments, field and laboratory data analysis, and modeling. INSTAAR emphasizes four themes of research:

**Ecosystems Group** focuses on the biological components of polar and alpine systems. Important topics include the dynamics of tundra ecosystems, biogeochemical cycling, biodiversity, and ecosystem disturbance and recovery. Long-term studies in polar and alpine regions are emphasized, involving populations and communities, biogeochemistry, and ecophysiology. Modern tools include geographic information systems (GIS), remote sensing, and ecosystem modeling.

**Geophysics Group** applies quantitative field and numerical methods to recover the properties and dynamics of snow, ice, water, and sediments in the world oceans, glaciers, and land areas. Methods of analysis include theoretical and numerical development, remote sensing, and land and ship-borne field experiments; all these are applied to problems in hydrology, glaciology, frozen ground studies, paleoclimate, physical oceanography, and marine geology.

**Past Global Change Group** focuses on the reconstruction of the dynamics of paleoenvironments and past climate variability, to enhance our understanding of the interactions between all components of the earth system, including atmosphere, ocean, land, ice, and the biosphere. Integration of a variety of records from a global network of sites, from the polar ice caps to continental alpine regions and to the world's oceans, provides the capability to test conceptual and predictive global change models, and to facilitate the differentiation between natural and human-induced change.

**Center for Geochronological Research**, an integral part of INSTAAR, provides scientists and state-of-the-art analytical facilities to address the cause, timing, and rates of environmental change in recent Earth history. The Center's goal is to foster synergistic relationships across traditional disciplinary boundaries in order to understand the global circulation system.

## Education

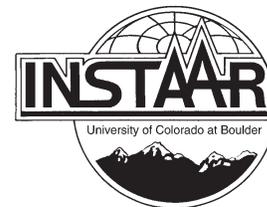
The Mountain Research Station, located 25 miles west of Boulder, is an interdisciplinary research facility administered by INSTAAR. Its mission is to facilitate research and education to understand better the unique patterns and processes of biotic and physical systems in mountains and how environmental changes may affect these processes.

INSTAAR's teaching mission is directed towards fostering an appreciation and understanding of the biological, chemical, and physical processes operating in continental and ocean environments. Education efforts are aided by the Mountain Research Station and other study sites in the mountains of Colorado. INSTAAR supports the University of Colorado's educational mission and provides interdisciplinary graduate and undergraduate classes and research opportunities. Our teaching mission includes international educational experiences for University of Colorado students, training of foreign students, and volunteer outreach to community schools and various other external constituencies.

## Societal Outreach

INSTAAR's societal mission consists of activities in research, education, and science leadership. These activities address critical concerns involving issues such as ecosystem stability, biodiversity, water resources, agriculture, national security, and resources in sites ranging from the alpine areas of the Rocky Mountains to the remote regions of the world. Our expertise is applied to predictive understanding of environmental processes including the maintenance of water quality, and anticipating and responding to long-term environmental alterations. Changes and disturbance in high-latitude regions not only affect the lives of the indigenous residents, but have a bearing on the lives of people everywhere, through global teleconnections.

The purpose of this report is to inform the University administration, granting agencies, researchers, students, and the general public of INSTAAR's goals and activities during 1998.



Information regarding the Institute of Arctic and Alpine Research, Niwot Ridge Long-Term Ecological Research (LTER) Program, the Mountain Research Station, and the journal *Arctic, Antarctic, and Alpine Research* is available on the World Wide Web respectively at:

[instaar.colorado.edu](http://instaar.colorado.edu)  
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[www.colorado.edu/INSTAAR/arcticalpine/](http://www.colorado.edu/INSTAAR/arcticalpine/)

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# The State of the Institute

## A Message from the Director

INSTAAR facilitates interdisciplinary research in high-altitude and high-latitude regions of the world, to define and understand linkages within the coupled earth-system. We investigate how sensitive or high-energy environments affect, and are affected by, natural and human-induced processes on the local, regional, and global scales. Our research activities result in significant impacts at the state, national, and international levels. Our interdisciplinary scientists integrate this understanding into the educational fabric of the University of Colorado.

In 1998 the governing body of INSTAAR, the Directorate, was comprised of 34 Fellows and Research Scientists, led by a Director, an Associate Director and an Executive Committee. The Directorate consisted of 12 teaching faculty (EPO Biology, Geography, Geological Sciences, Chemical Engineering, Civil Engineering), 2 Fellow-Emeriti, 3 Research Professors, 1 Fellow-Adjoint, 16 Research Scientists, and the Managing Editor of the journal *Arctic, Antarctic, and Alpine Research*. The Directorate received representation from the 58 graduate students and 39 professional research assistants. Institute members are loosely associated with one of four research groups: Ecosystems, Geophysics, Past Global Change, and the Center for Geochronological Research. In addition to the 34 Directorate Scientists, other Ph.D.-level Institute scientists included 20 Research Affiliates, 13 Visiting Scientists, and 17 Postdoctoral Scientists. The 1998 INSTAAR family also included 80 undergraduate students, a Mountain Research Station (MRS) staff of 7, and 7 MRS instructors. Together these 276 members of INSTAAR were supported by a Front Office Administrative Staff of 7.

Researchers at INSTAAR collaborate with investigators from 27 countries and 94 U.S. institutions, attesting to the international prominence of INSTAAR. In 1998, INSTAAR Fellows, and Scientists convened or chaired 10 sessions/symposia at the national level and 13 at the international level, presented 27 keynote talks to scientific and government assemblies, sat on 17 editorial boards, and edited 5 different journals.

1998 saw INSTAARs chair or contribute to 30 science boards, panels, and steering committees. For example, Professor John Andrews chaired the National Academy Committee to evaluate NSF's Arctic Natural Science program, Professor Vera Markgraf chaired IGBP-PAGES Pole-Equator-Pole Paleoclimate of the Americas, Professor Gifford Miller co-chaired the IGBP-PAGES PaleoEnvironments program, and Dr. Robin Webb co-chaired the IGBP-PAGES Paleoenvironmental MultiProxy Analysis program. INSTAARs continue to receive prominent national and international awards. Professor John Andrews received the AMQUA Distinguished Career Award. Dr. David Anderson received the Sustained Superior Performance Award (NOAA). Professor Julie Cole was speaker at the First Chinese-America Frontiers of Science Conference (National Academy of Science). Professor William Krantz received an Outstanding Teaching Award from the American Society for Engineering Education. Professor Mark Meier was the 1998 Walter B. Langbein Memorial Lecturer (AGU). Professor Tad Pfeffer received the AGU Editor's Citation for Excellence in Refereeing. Professor Mark Williams won the EPA-Region VIII Outstanding Environmental Achievement Award. Professor James Syvitski and Ph.D. student Mark Morehead were awarded the 1998 Outstanding Paper Award by the International Association of Mathematical Geologists.

In 1998 INSTAAR had over 120 grants in force providing, with CU general funds and gifts, a total operating budget in excess of \$9 million.

Professor Bill Bowman, Director of INSTAAR's Mountain Research Station, oversaw the development of a MRS Master Plan that outlines the space requirements for future MRS activities. These include:

- A new academic building, containing a new classroom, computer laboratory, and a few support offices;
- A new building containing four separate laboratories to upgrade the existing wet chemistry, soils, and plant laboratories;
- Four new winterized family cabins with indoor plumbing;
- A greenhouse facility.

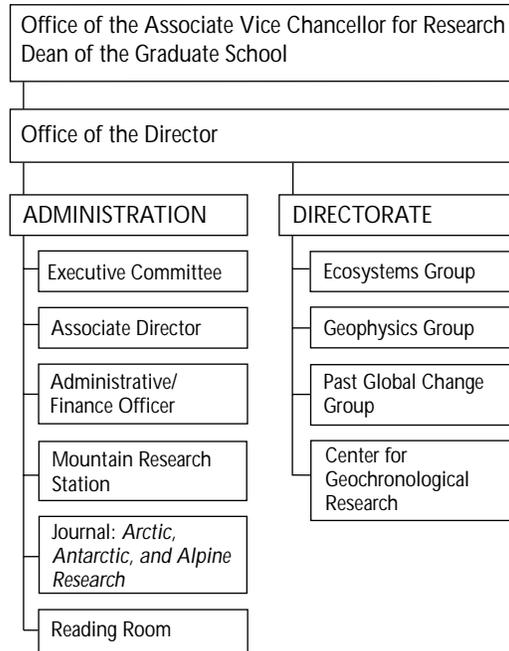


Don Costello surveys borehole locations from bedrock above Worthington Glacier, southeast Alaska.

INSTAAR increased its main campus space by acquiring 3000 sq. ft. of new lab space in East Campus building RL1 and 10,000 sq. ft. of office and computer lab space in RL3 (possession by year 2000). New space assignments are well underway. INSTAAR ran its second Summer Undergraduate Research Fellowship program, and its second SMART STARS program (Summer Minority Access to Research Training at INSTAAR), the latter sponsored by MOBIL Oil. Both programs contribute to INSTAAR's commitment to bringing research to undergraduates at the University of Colorado.

A few of the interesting 1998 research findings discussed in this report include:

- Droughts of the Great Plains, as witnessed in the 1930s and 1950s, have occurred with some regularity over the past 400 years. Is another drought coming?
- Prehistoric insects show Great Plains cooler and wetter during the late Wisconsin than today, elsewhere southwest Alaska was substantively drier (by 60%).
- Early humans in Australia apparently disrupted the natural fire cycle and greatly changed the ecosystem, including the desertification of the continental interior.
- Norse colonizers of Greenland (~AD 985) experienced 6 to 12 years of mild weather, unfortunately the longest period for centuries to come.
- Prehistoric North Atlantic ocean-climate events extend into and alter the Antarctic coastal climate.
- During deglaciation, ice-dammed lakes emptied into the North Atlantic engineering a regional Holocene cold event.
- A 15,000-year continuous record of El Niño climate of the Andes shows the modern El Niño climate became established 5,000 years ago.
- Microbial activity and the nitrogen-cycling of individual plant species appear key agents in the control of alpine ecosystem dynamics, and the acidification of alpine streams.
- Root productivity in deep soil horizons of the tundra greatly enhance carbon storage. In other findings, terrestrial sedimentation may account for much of the "missing carbon" in global flux studies.
- A regional pH-substrate boundary in the Arctic dominates the role in gas flux and other ecosystem properties, rather than soil moisture as previously believed.



Krummhoiz tree island on Niwot Ridge

# Research Highlight

The following article describes one of the research areas of INSTAAR glaciologists. Other areas of glaciological research are mentioned in the Geophysical Group report in this annual report. This Research Highlight was prepared by Mark F. Meier and was taken, in part, from the Walter B. Langbein Memorial Lecture he delivered at the 1998 Spring Meeting of the American Geophysical Union, and recent articles by colleagues.

## Glaciers Shrinking, Runoff Peaking, Sea-Level Rising

### Glaciers and Global Change

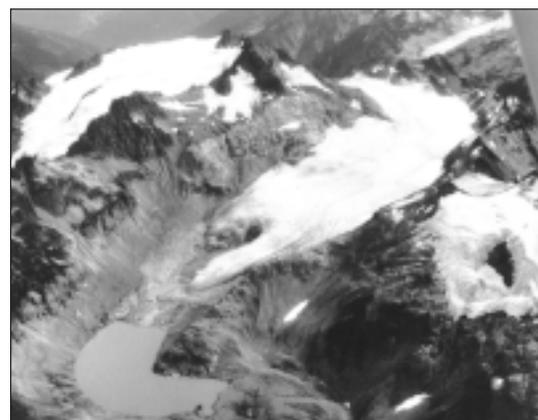
One of the most serious consequences of global warming is rising sea level. With so much human activity concentrated along coastlines and areas only a few meters above sea level, modest flooding will likely cause many societal and economic impacts. Global sea-level rise is due to thermal expansion of ocean water and runoff from the melting of glaciers, ice caps, and ice sheets; other causes may be important locally but are not significant on a global (eustatic) basis. The contributions to sea-level rise due to changes in the Antarctic and Greenland ice sheets are imperfectly understood, may be less important than the contributions due to smaller glaciers and ice caps, and are not discussed here. Because of the economic and societal implications, it is important to understand all causes of sea-level rise during the present so that projections into the future can be based on the best possible information.

Glaciers are sensitive indicators of climate change. Because they often exist in remote regions and high altitudes far from any weather stations, measurement of their mass and energy balance also extends our knowledge of the global climate system and its changes, and an understanding of their interactions with climate is useful for confident application of glacier variations as proxy indicators of paleoclimate variations.

Glaciers exist on all continents save Australia and at virtually all latitudes from the tropics nearly to the poles, and they affect the liquid water balance in many regions. As glaciers shrink due to climatic warming, their runoff first increases, then falls due to the loss of ice area. Thus the hydrologic regime of glacier-fed rivers must be treated differently from that of nonglaciated watersheds. A relatively small fraction of glaciers in a drainage basin significantly lowers the annual variability of runoff. A similar phenomenon happens at longer time scales: glacier shrinkage results in a transfer of water mass to river runoff, augmenting the river discharge for years or decades. This cannot continue, of course: either the climate will change to cause glacier growth (reducing runoff) or the glaciers will disappear (reducing runoff to that normally supplied by precipitation).

### Observed Changes in the Glaciers

Most glaciers in the world are currently retreating and becoming thinner, after some centuries or longer of relative stability. One example is South Cascade Glacier, Washington (Fig. 1). Fresh-appearing tree trunks were exposed in 1958 because of glacier recession. They were buried under ice for 5500 years; the glacier was 3.6 km long when it sheared off these trees. The glacier's maximum length since the early Holocene, when it formed a moraine dated at about the year 1600, was 4.6 km. Thus for a period of 4 millennia it fluctuated in length between 3.6 and 4.6 km. Now, however, in 1995 it was only 2.9 km long and retreating rapidly. Clearly the current climate is more conducive to glacier wastage, at



**Fig. 1.** South Cascade Glacier, in the North Cascades of Washington State. These photographs were taken in 1958 by Austin Post (above) and in 1993 by Robert Krimmel (below). Note the extensive loss of ice mass during this period. This is the most extensively studied glacier in the western hemisphere and many mass balance observational programs were developed here.

this site, than at any time during the last 5500 years. Another interesting example is Grinnell Glacier in Glacier National Park, which diminished in area from 2.2 km<sup>2</sup> in 1900, to 1.0 km<sup>2</sup> in 1981. Our calculations suggest that it and all of the existing glaciers in Glacier National Park will disappear during the next century.

These are only two examples, but such retreat and wastage have prevailed, on the average, for the past several decades to a century, over much of the Earth's glacier regions. The loss of glacier ice in many regions at temperate latitudes has been striking (Table 1a.); this is especially true for small continental glaciers at lower latitudes and many of these small glaciers are disappearing (Table 1b.). Glaciers and ice caps in the high Arctic have been shrinking only slightly in spite of increased warming at these high latitudes (Table 1d). The reasons for this include the refreezing of the increased surface melt within the ice, serving to warm the glacier without causing appreciable loss of mass, together with some increased snow accumulation above the equilibrium line.

## Climate, Mass Balance, and Runoff in Central Asia

Dr. Vladimir Konovalov, a senior scientist from Tashkent, Uzbekistan, is working at INSTAAR under a Fulbright grant studying the relation of glacier changes to runoff in Central Asia. This area is one of the most important sources of runoff causing sea-level rise. By processing topographical maps, applying GIS techniques, and adding some new glacier



**Fig. 2.** Abramov Glacier, Pamir Mountains. This is a glacier with a more than 30-year history of mass balance and climate observations. Note the research station, which is operated by the Central Asia Research Hydrometeorological Institute in Tashkent, Uzbekistan. INSTAAR is developing cooperative programs with scientists of this institute.

**Table 1.** Changes ( $\Delta$ ) in glacier ice in large areas, compiled by Drs. Meier, Dyurgerov, Konovalov, and many colleagues.

### a. Mid-latitude glaciers

	time period	$\Delta$ area	$\Delta$ vol.
Switzerland	1850-1973	-27%	-31%
Alps-total	≈1850-1994	-35%	-50%
New Zealand	≈1890-1996	-26%	—
Caucasus	≈1894-1970	-29%	-50%

### b. Small, lower-latitude glaciers

	time period	$\Delta$ area	$\Delta$ vol.
Kilimanjaro	1912-1989	73%	—
Mt. Kenya (Lewis Gl.)	1899-1990	-62%	-92%
number of glaciers in Spain:	in 1980: 27		
	in 1994: 13		

### c. Glaciers in Central Asia

	time period	$\Delta$ area	$\Delta$ vol.
Tien Shan	1955-1995	-15%	-22%
Gissaro-Alai	1957-1980	-16%	-15%
Pamir-Alai	1957-1980	-10%	-11%

### d. Arctic glaciers

	time period	$\Delta$ area	$\Delta$ vol.
Svalbard	≈1880-1980	-6 %	-13%
Franz Josef Land	"	-5 %	-14%
Novaya Zemlya	"	-4 %	- 4.5%
Severnaya Zemlya	"	0 %	- 1.5%

inventory data, he obtained for the first time a data set of accurate information about size and other parameters of contemporary glaciers within the huge Tarim River basin (including the Tien Shan-Karakorum-Kunlun mountain areas: the total glacier area is 25,290 km<sup>2</sup> [17,938 km<sup>2</sup> by the first estimate], and its volume is 2903 km<sup>3</sup> [computed by scaling, see below]).

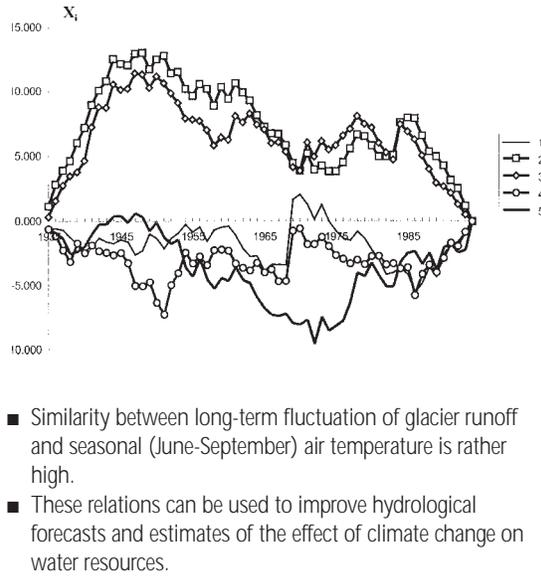
The Pamir-Alai has the most extensive glacierized area among other mountainous regions in the former USSR (Fig. 2). Konovalov and colleagues revised and updated for the older inventory of glaciers in this territory; examples of the recent changes in ice mass of the Gissaro-Alai and Pamir-Alai regions are listed in Table 1c. It is interesting that in 1957-1980, the decrease of ice mass was 56.1 km<sup>3</sup> of water which nearly equals the average annual runoff of Amudarya River, one of the main feeders of the shrinking Aral Sea.

Long-term series of river and glacier runoff and their climatological factors (seasonal sums of precipitation and air temperature) in the basins of Pamirs and Gissaro-Alai showed increased ice melting from the end of the 1930s until the second half of the 1940s (Fig. 3). Low water yield (runoff) then lasted till the beginning of the 1970s. After this, higher runoff in Central Asian basins is now due to increased volumes of glacier water yields.

These studies of Central Asian glaciers indicate that

- During 1960-1980, significant reductions of volumes and areas of Pamir-Alai glaciers has taken place. However, this did not decrease the total runoff of the Amudarya River; in addition to water taken out of ice storage, the seasonal snow accumulation has increased.
- Long-term variation of glaciers runoff in the Pamirs is mostly synchronous during 1935-1994 and provides natural regulation of Amudarya River runoff.
- The relation of seasonal air temperatures sums to normal, low, and high water yield years shows its role in producing ablation and runoff formation.

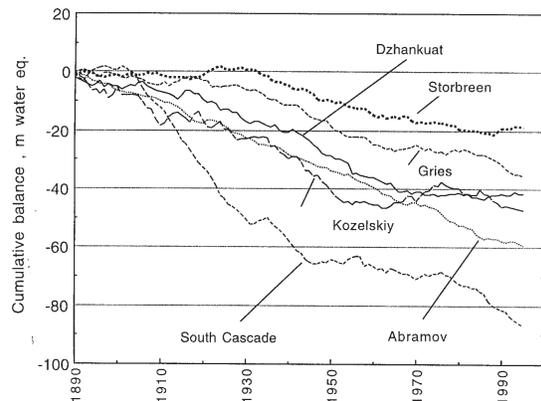
**Fig. 3.** Long-term fluctuations of river and glacier runoff and their climatological factors for two basins in the Pamir, provided by Dr. Konovalov. Values plotted are normalized, detrended, divided by the coefficient of variation, and then integrated through the 1935-1994 period. (1): total runoff of Pyandzhe river for May-October; (2): glacier runoff of Pyandzhe river for May-October, (3): glacier runoff of Vakhsh river for May-October; (4): seasonal sum of precipitation for October-April, (5): seasonal sum of air temperature for June-September.



- Similarity between long-term fluctuation of glacier runoff and seasonal (June-September) air temperature is rather high.
- These relations can be used to improve hydrological forecasts and estimates of the effect of climate change on water resources.

### Global Mass Balance Synthesis

The net mass balance is the critical link between climate change and glacier fluctuations and runoff. The mass balance is the difference between mass and energy inputs and outputs from the general meteorological environment. This can be averaged over a year, or recorded during the winter accumulation season as an approximate measure of the input (winter balance), or over the summer melt season as a measure of the output (summer balance). A nonzero net balance causes a change in the thickness of the glacier, changing the driving stress, and as result the glacier flows faster or slower, changing the position of the terminus and thus the area, which then feeds back to the net balance. All of these processes, including the nonlinear dynamic response, are involved in the long-term glaciers–climate relation.



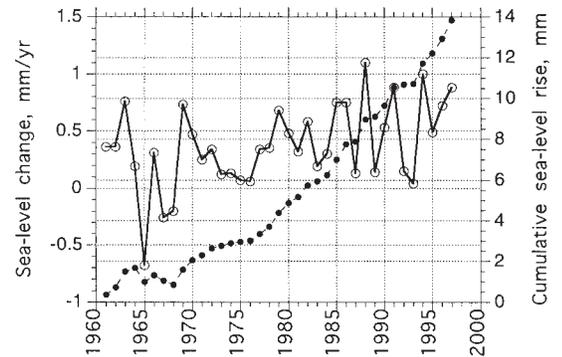
**Fig. 4.** Cumulative mass balances for six typical glaciers. These are all glaciers with long periods of mass balance observations used to calibrate models to extend the results back to the 19th century. The Dzhankuat Glacier is in the Caucasus, Storbreen in Norway, Gries in Switzerland, Kozelskiy in Kamchatka, Abramov in Central Asia, and South Cascade in Washington State. As is obvious, all have been losing mass, and this has augmented river runoff and contributed to sea-level rise.

The mass balances of most glaciers have been negative, most of the time, during the last century (Fig. 4). This behavior is typical of mid-latitude glaciers around the world, although in some areas there are exceptions.

Figure 5 is a global compilation of glacier mass balances, reported in sea-level equivalent, prepared by Dr. Mark Dyurgerov. The mass balance values are a straight average weighted by regional glacier area. It is interesting to note the positive mass balances in 1992 and 1993, which appear to be related to the observed decrease in air temperature following the eruption of Mount Pinatubo. Dr Dyurgerov has calculated that about 360 km<sup>3</sup> of water-equivalent was stored in glaciers due to the eruption of this volcano, equivalent to 1 mm of sea-level fall. This compilation has not yet been subjected to a stochastic scaling analysis, so the absolute values may need some adjustment, but the trend is robust.

A global compilation of seasonal balances is shown in Figure 6. Note that the summer balance has been increasing significantly, and its variance (standard deviation) may have been increasing slightly. The winter balance, on the other hand, shows that snow accumulation may have increased very slightly but its year-to-year variation has increased significantly. All of these results are consistent with global warming. The increased variability in mass balances may be related to an increased variability in climate, but this is difficult to verify.

Data compilations such as these, which probably are the best available, is somewhat limited because glacier observations are poorly distributed in space and in time. Few observations extend back before the mid-1960s, the time of the International Hydrological Decade. Far more important, however, is the fact that most of the observations have been made near populated areas in the Northern Hemisphere. The Arctic, the Western Hemisphere, Asia, the Southern Hemisphere, and some other regions with appreciable glacier cover are seriously under-represented. This makes regional



**Fig. 5.** Sea-level rise due the wastage of mountain and subpolar glaciers. Annual fluctuations (open circles) in glacier mass balances are averaged for all measurements, 70-80 glaciers per year. The cumulative sum of these (solid circles) results in a sea-level rise component of 14 mm (about 20% of the total observed rise) for this period, but the rate of increase has accelerated in recent years.

and global compilations difficult, which is unfortunate because of the current interest in global effects such as sea-level rise. A complete synthesis should incorporate information on each glacier's sensitivity to climate (temperature and precipitation), its history of change in area and volume, and its dynamic response characteristics, and this calculation would then need to be summed over several hundred thousand existing glaciers. Alternatively, one could develop distribution functions to link these variables for many glaciers in an aggregate. Scaling has the potential to accomplish this.

## Use of Scaling to Develop a Global Synthesis

Dr. David Bahr has applied stochastic scaling to glaciology, providing the critical link to a global synthesis. This method includes all of the appropriate physics—it is not a simple statistical game. One must first determine the distribution of values of some easily measured variable such as area; this can be obtained from glacier inventory data, or possibly from a theoretical view using percolation theory. The procedure then is:

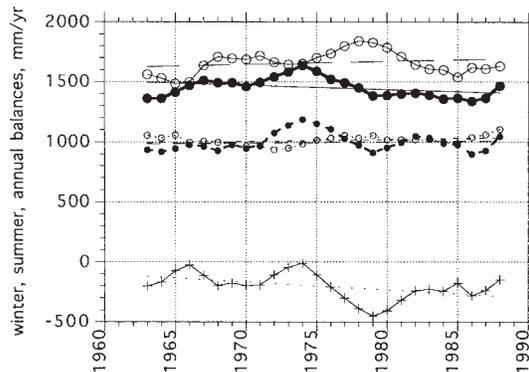
- (1) Express the pertinent physics (e.g., conservation of mass and momentum and constitutive law for ice flow).
- (2) Define characteristic values for each variable.
- (3) Relate these in a power-law sense.
- (4) Develop closure conditions for each variable.
- (5) This then allows one to relate the distribution of any one variable (e.g. volume) to the distribution of any other variable (e.g. area).

The importance of the method can be seen in the fact that, at least in principle, data on any variable (e.g., area, length, mass balance, response time) can be used to infer the distribution of any other variable. The beauty of the method is that it allows one to use plentiful measurements or estimates of "easy" variables to estimate the distribution of difficult variables.

The scaling algorithm suggests a rethinking of the "brute-force" strategy of measuring everything possible, which is doomed to failure due to money and man-power limitations; or the view promulgated in many official publications, to select "the representative glacier" and concentrate resources on it. The real world contains a distribution of glacier sizes, shapes, etc., and Bahr has shown that it is necessary to sample the whole distribution.

## Summary of Recent Glacier Changes

- Glaciers contributed about 20% of the global sea-level rise in the last century.
- This contribution is currently increasing, mainly due to increasing summer ablation.
- Year-to-year variability of glacier mass balances also seems to be increasing.
- Glacier changes show strong regional differences:
  - Arctic ice caps and glaciers show little change.
  - Mid-latitude glaciers are shrinking markedly.
  - Many small continental glaciers are disappearing.
- Glacier reservoir depletion is causing significant but temporary increases in river flow in many regions.



**Fig. 6.** Seasonal mass balance information, compiled by Dr. Dyurgerov. Included are the global trends in the winter balance, a measure of snow accumulation (heavy line with large solid circles), and the standard deviation of these observations (small solid circles); the straight lines are linear regressions; the trend in summer balance (large open circles), a measure of melting and runoff, together with its standard deviation (small open circles); and net balance (crosses). All data have been smoothed slightly. Note that snow accumulation has been increasing very slightly and its variance has also been increasing. The summer balance shows an increasingly negative trend accompanied by a slight increase in its variance. The resulting net balance, the difference between these two curves, is becoming more negative.

- Glacier studies are a useful adjunct to other proxy and instrumental climatic studies, because they reveal changes in precipitation and temperature in parts of the world not covered by other observations. The ability to infer climate change as it varies with altitude is especially interesting.
- Pervasive glacier wastage indicates long-term (decades to centuries) climate warming. The glacier record clearly indicates major thinning and retreat in the 20th century, accelerating in recent years. The rate of retreat in the last few decades is unprecedented in the observation record which extends over several centuries or longer. This is another firm indication that the Earth is warming.

## Implications for the Future

It is clear that the rate of sea-level rise due to glacier wastage has been increasing during the last few years, and, with increased global warming in the future, this component of sea-level rise will certainly increase. There are many uncertainties in the several projections for this rise, depending in part on greenhouse gas and aerosol scenarios, but the conclusions that sea level will rise, and that the rate of rise will increase, are robust. Sea-level rise will have deleterious effects on low-lying coastal areas, where much of the world's most expensive real estate exists. The Small Island Nations are especially vulnerable, and may lose large fractions of their total area. Other problems exist: destruction of wetlands, saltwater incursion into estuaries and coastal aquifers, and increasing probability of flooding due to storm surges. Land-use planning can help minimize social and economic problems, but effective planning requires accurate sea-level rise scenarios. Refined glaciologic data, analysis, and numerical models are needed to provide the information needed for planning.

Water resources development will be affected in those areas near high mountains where glaciers provide much of the runoff. Glacier wastage will provide additional increments of water for downstream uses for a time, but this source will peak and then disappear, on a time scale of decades or more. Water resource planners in these areas will have to understand and predict the effect of glacier changes.

Other effects are certain to occur. One that is rather intangible but important to many is the degradation of alpine scenery—in the Alps, Glacier National Park, and other areas—as the glaciers and semipermanent snowpatches disappear leaving barren terrain.

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# INSTAAR Directorate Members

## New Member

### Robert F. Stallard

Research Scientist of INSTAAR, Research Hydrologist of the U.S. Geological Survey, Research Associate of the Smithsonian Tropical Research Institute. PhD: 1980, Massachusetts Institute of Technology - Woods Hole Oceanographic Institution Joint Program in Oceanography

**Specialty:** Biogeochemistry, hydrology, and geomorphology

**Research Interests:** Biogeochemistry of weathering and erosion, sediment and solute transport in rivers, geochemistry of clastic sedimentation, the impact of land-use change on environmental quality and biodiversity. Principal interest is the Earth-surface environment and how it changes on human and geologic time scales. Current research focuses on the study of recent land-use changes and Pleistocene time-scale geomorphic processes and how these affect the composition and dispersal of dissolved and solid phases in rivers and trace gases in the atmosphere. Some of the questions asked are (1) can we develop general physically and biologically based models of the processes that generate the dissolved and particulate load in rivers and trace substances in the atmosphere? (2) how do various phases chemically partition and disperse during transport through rivers and estuaries? (3) how do human activities, particularly land-use change, affect environments being examined? (4) how do we use rivers to integrate phenomena described at local research sites up to continental scales? (5) can we formulate provenance models to reconstruct the biogeochemistry of past geologic environments? A theme that repeats itself in all these questions is that of the interaction of vegetation, soil formation, and physical erosion, in the context of basic differences between flat and steep terrain.

For his Ph.D., Robert Stallard started at the largest scale, doing an oceanographic-style study of the geochemistry of the Amazon River system, which supplies about 20 percent of the river discharge to the ocean. Investigations continued with a post doc at the USGS Office of Marine Geology in Woods Hole, a faculty appointment at the Department of Geological and Geophysical Sciences at Princeton University, and eventually a research position at the National Research Program of the US Geological Survey- Water Resources Division. His subsequent work has included smaller big-river systems such as the Orinoco, Mississippi, and Mackenzie, as well as tiny research watersheds in the Panama Canal Basin, eastern Puerto Rico, the Colorado Front Range, and the South Cascade Lake Basin.

Bob focuses his current research on the biogeochemical and geomorphic effects of land-use change. In this context, he has pioneered the study of the effects of land-use change on a regional scale, and has led the USGS in initiating programs in this arena. Since 1990, he has organized and led two large, inter-linked, multidisciplinary studies with this theme. The first project is part of the USGS Water, Energy, and Biogeochemical Budgets (WEBB) Project in eastern Puerto Rico and is officially linked to parallel work in central Panama at the facilities of the Smithsonian Tropical Research Institute. The second program took several years to develop, starting in early 1993, and is now an Inter-Divisional research program called the Mississippi Basin Carbon Project (MBCP). In addition to the design and implementation of these projects, he has prepared new theoretical infrastructures needed to interpret data. Each study seeks to reconstruct biogeochemical cycles from today back into the last Ice Age with the objective of not only examination of human effects but also identification of feedback that affect atmospheric trace gases through the Pleistocene, and earlier.

At the global scale, Bob is modeling terrestrial sedimentation and biogeochemical cycles. This involves integration of data from his and other field studies with information from innumerable standard and grey-literature sources. Recent developments in database design - especially Geographic Information Systems (GIS) - and hillslope hydrologic models have increased the sophistication of this endeavor. Presently, he is exploring the possibilities of linking satellite data and digital topography into geochemical models using GIS.



## Directorate Members



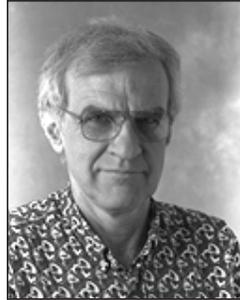
### David Anderson

Research Associate of INSTAAR, Physical Scientist, Paleoclimatology Program, United States Department of Commerce, National Oceanographic and Atmospheric Administration. PhD: 1991, Brown University.

#### Research Interests:

Research on the marine

geologic record of climate change, with emphasis on quantitative estimates of past ocean temperature and ocean upwelling/productivity. Projects include sediment trap studies in the California Current, investigations of modern hydrography and late Quaternary climate in southern Chile, and investigations of the sediment record of the SW Asian monsoon using cores from the Ocean Drilling Project.



### John C. Behrendt

Fellow, Senior Research Associate of INSTAAR. PhD: 1961, University of Wisconsin, Madison.

#### Outstanding Awards:

Department of Interior Meritorious Service Award, Department of Defense Antarctic Service Medal with Winter Over Bar.

**Research Interests:** Antarctic and marine geophysics, glaciology. Presently studying lithospheric controls on the behavior of the West Antarctic Ice Sheet. Also investigating the tectonics of the West Antarctic rift system including the continental margin. Deep crustal seismic investigations of continental rifts and rifted continental margins. Charleston, S.C. earthquake studies. Atlantic continental margins of U.S. and West Africa. Use of gravity and aeromagnetic surveys to investigate continental tectonics.



### John T. Andrews

Professor, Geological Sciences, Fellow of INSTAAR. PhD: 1965, DSc 1978, University of Nottingham, UK.

#### Outstanding Awards:

Kirk Bryan Award, Fellow Norwegian Academy of Science and Letters, 1997; DSc. *honoris causa*, University of Nottingham,

1998; Distinguished Career Award, American Quaternary Association, 1998.

**Specialty:** Ice sheet/ocean interactions, Quaternary paleoenvironments.

**Research Interests:** Main interests are in ice sheet/ocean interactions and their influence and effects on the adjacent oceans. Research is undertaken off the Canadian Arctic, NW Iceland, East Greenland and Antarctica.



### William B. Bowman

Director of Mountain Research Station and Associate Professor, EPO Biology, Fellow of INSTAAR. PhD: 1987, Duke University.

#### Specialty:

Plant ecology. **Research Interests:** Biotic control over community and ecosystem properties, resource use by plants, alpine ecology.



### Martha Andrews

Librarian, Fellow of INSTAAR. MA: 1964, McGill University; MA, 1973, University of Denver.

#### Outstanding Award:

Alaska Historical Society Pathfinder Award, 1994.

**Specialty:** Organization and dissemination of polar regions information.

**Research Interests:** Networking polar regions information; conversion of print information to electronic format; development of electronic databases.



### T. Nelson Caine

Professor, Geography, Fellow of INSTAAR. PhD: 1966, Australian National University.

#### Outstanding Awards:

1989 Fellow AAAS, 1993 Frost Lecturer BGRG, 1994 G. K. Gilbert Award AAG.

**Specialty:** Geomorphology and hydrology.

**Research Interests:** Present-day processes of erosion and sedimentation in mountain environments. This includes studies of snow hydrology, streamflow generation, and sediment transport. It incorporates work on periglacial processes, mountain permafrost, and hillslope processes.



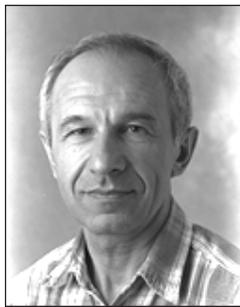
**Julia E. Cole**

Assistant Professor, Geological Sciences, Associate of INSTAAR. PhD: 1992, Columbia University.

**Specialty:** Paleoclimate dynamics

**Research Interests:** Recent research focuses on Holocene climate variability in the tropics, particularly on the

behavior and global influence of large-scale ocean-atmosphere systems. Approaches include the development of quantitative climate reconstructions from geochemical measurements and the application of general circulation model simulations to questions of recent climate variability.



**Mark Dyurgerov**

Research Associate of INSTAAR. PhD: 1974, Moscow State University, Russia.

**Outstanding Award:** State Grant of Russian Federation.

**Specialty:** Glaciology, Terrestrial Hydrology.

**Research Interests:** Current research focuses on: (1)

gathering glacier global mass-balance data and analysis for estimation of glacier contribution to sea-level changes as a part of global water balance; (2) studying climate variability as it is shown by glacier mass balance data; (3) developing new methodology of global glacier mass-balance and runoff monitoring; (4) Central Asia water resources, particularly change in amount of glacier runoff since the Last Glacial Maximum.



**Scott A. Elias**

Senior Research Associate, Fellow of INSTAAR. PhD: 1980, University of Colorado at Boulder.

**Specialty:** Quaternary insect fossils, paleoecology, paleoclimatology.

**Research Interests:** The paleoecological, paleoclimatic, zoogeographic, and evolutionary implications of

insect fossil assemblages from the Quaternary period. Studies of insect fossil assemblages from more than 150 sites in North America and Europe, deriving data for use in paleoecological and paleoclimatic reconstructions. Presently investigating late Pleistocene environments of Beringia (unglaciated regions of eastern Siberia, Alaska, the Yukon, and the Bering Land Bridge), the Colorado Front Range, and the Great Basin.



**Ute C. Herzfeld**

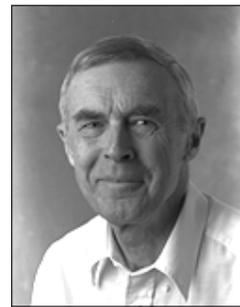
Fellow Adjoint of INSTAAR, Affiliate Professor of Applied Mathematics. PhD: 1986, Johannes Gutenberg-Universität, Mainz, Germany.

**Outstanding Award:**

Heisenberg Fellow, German Science Foundation.

**Specialty:** Geomathematics, glaciology, marine geophysics, remote sensing.

**Research Interests:** Geomathematics, satellite geophysics, glaciology (Antarctic ice streams, Arctic calving glaciers, surging glaciers), marine geology and geophysics (mid-ocean ridge systems, Antarctic continental margin), oceanography (global primary productivity and global changes), geostatistics, nonlinear processes in geophysics, automated surface classification.



**John T. Hollin**

Fellow Emeritus of INSTAAR. PhD: 1972, Princeton University.

**Specialty:** Glaciology, Quaternary especially last interglacial history.

**Research Interests:** Glacier and ice-sheet profiles, empirical and theoretical. Sea-level evidence for Antarctic

melting and/or surging. Gondwana ice surges and Carboniferous coal cyclothem.



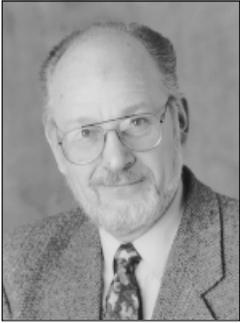
**Anne E. Jennings**

Assistant Professor Attendant Rank of Geological Sciences, Research Associate of INSTAAR. PhD: 1989, University of Colorado at Boulder.

**Specialty:** Paleoceanography, glacial history, foraminifera.

**Research Interests:**

Paleoceanography, glacial history, and climate change in high latitude regions, specifically Greenland, Baffin Island, Iceland, and Antarctica. Specializes in using foraminifera for interpreting paleoenvironments and chronology on high latitude continental shelves.

**William B. Krantz**

Professor of Chemical Engineering, Fellow of INSTAAR. PhD: 1968, University of California-Berkeley.

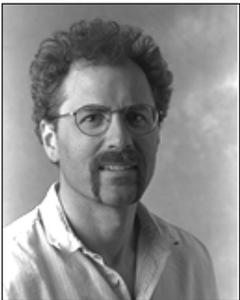
**Outstanding Awards:**

President's Teaching Scholar, Fellow of American Association for the Advancement of Science, Guggenheim Fellowship, Fulbright

Fellowship (3), NSF NATO Senior Research Fellowship NSF Outstanding Achievement and Outstanding Performance Awards, George Westinghouse Award of American Society for Engineering Education, Sigma XI National Research Lecturer, Teaching Recognition Award of CU-Boulder Faculty Assembly, Teaching Recognition Award of CU-Boulder Student Development Association, Hutchinson Teaching Award of CU-Boulder College of Engineering, Outstanding Research Award of CU Boulder College of Engineering, Innovation in Coal Conversion Award given by University of Pittsburgh, AAAS John Wesley Powell Lecturer, Excellence in Research, Scholarly and Creative Work Award of CU-Boulder Faculty Assembly.

**Specialty:** Geomorphology, chemical engineering.

**Research Interests:** Patterned-ground formation in recurrently frozen soils, differential frost heave and membrane science.

**Scott Lehman**

Fellow of INSTAAR, Associate Research Professor of Geological Sciences: PhD: 1989, University of Colorado at Boulder.

**Outstanding Award:**

Appointed to National Academy of Sciences "Frontiers of Science" Steering Committee, 1994, 1995, 1996.

**Research Interests:** Paleoclimatology, paleoceanography, paleochemistry, past global change. The role of the oceans in climate change, cycling of heat and carbon by the oceans, ocean-icesheet interactions, paleotemperature applications of marine biomarkers and amino acids, radiocarbon calibration, exposure age dating, Quaternary stratigraphy, and glacial geology.

Currently director of INSTAAR's Laboratory for Radiocarbon Preparation and Research, which serves the AMS radiocarbon dating needs of the US-NSF's Earth System History Program. Other current research programs focus on temperature reconstructions of the subtropical North Atlantic, calibration of the radiocarbon time-scale, and glaciation history of Scandinavia.

**Vera Markgraf**

Research Professor of Geography, Fellow of INSTAAR. PhD: 1968, Bern, Switzerland.

**Specialty:** South America and southern hemisphere paleoclimates and interhemispheric paleoclimate correlations.

**Research Interests:**

High resolution, multi-proxy paleoclimate analysis, using pollen, charcoal (fire history), and stable isotopes from late-Quaternary sediment records in southern South America, in collaboration with J. W. C. White (INSTAAR) and INSTAAR graduate students. International cooperative research: Patagonian Lake Drilling Project (PATO), focusing on recovery of long sediment cores from large, extra-Andean lakes, thought to contain several glacial/interglacial cycles. Chair of "Pole-Equator-Pole Paleoclimates of the Americas" (PEP 1) IGBP-PAGES research initiative, culminating in the first scientific inter-American meeting in Merida, Venezuela, in March 1998. Coordinator of the Latin American Pollen Database (NOAA-NGDC), resulting in over 100 records now available on the public domain.

**Diane McKnight**

Associate Professor, Department of Civil, Environmental and Architectural Engineering, Associate Director of Mountain Research Station and Fellow of INSTAAR. PhD: 1979, Massachusetts Institute of Technology.

**Outstanding Award:**

Meritorious Service Award, USGS, 1995.

**Research Interests:** Limnology, biogeochemistry of lakes and streams. Research focuses on interactions between hydrologic, chemical and biological processes in controlling the dynamics in aquatic ecosystems. This research is carried out through field-scale experiments, modeling, and laboratory characterization of natural substrates. Main field sites are located in the Rocky Mountains and in the Transantarctic Mountains, and include pristine and stressed ecosystems, such as acid mine drainage influences mountain streams. Conducts research focusing on interactions between freshwater biota, trace metals, and natural organic material in diverse freshwater environments, including lakes and streams in the Colorado Rocky Mountains, and in the McMurdo Dry Valleys in Antarctica. Develops interactions with state and local groups involved in mine drainage and watershed issues in the Rocky Mountains. A co-principal investigator in the McMurdo Dry Valley LTER and in the Niwot Ridge LTER.

**Mark F. Meier**

Professor Emeritus of Geological Sciences, Fellow of INSTAAR. PhD: 1957, California Institute of Technology.

**Outstanding Awards:**

Robert E. Horton Medal, American Geophysical Union; Seligman Crystal, International Glaciological Society;

Distinguished Service Award (Gold Medal), U.S. Department of the Interior; other medals and honors.

**Specialty:** Glaciology, Global Change

**Research Interests:** Glaciers in the Earth system, glacier dynamics, snow and glacier hydrology, causes and projections of sea-level change, mechanics of iceberg calving, flow of fast surging and calving glaciers, climate change, and global change in general.

**Gifford H. Miller**

Chair and Professor of Geological Sciences, Fellow of INSTAAR. PhD: 1975, University of Colorado at Boulder.

**Specialty:** Quaternary stratigraphy and geochronology.

**Research Interests:** My primary scholarly interests focus on gaining an improved

understanding of how the physical earth system operates. Toward this end, I am specifically interested in recent Earth history as a tool to reconstruct the coupled ocean/atmospheric/ice climate system. By reconstructing past environmental changes it is possible to get a better understanding of the rates and magnitude of natural climate variability, and the various feedback mechanisms in the global climate system.

**Astrid E. J. Ogilvie**

Associate Director (1995 through May 1998) and Fellow of INSTAAR. PhD: 1982, University of East Anglia, Norwich, UK.

**Research Interests:**

Historical climatology and environmental history. Main areas of interest are the use of historical records to

reconstruct past climate, in particular, the past climate and sea-ice record of Iceland, and the human dimensions of climatic and environmental changes, and the comparison and integration of different proxy climate records. Interests include the general environmental and human history of countries bordering the North Atlantic regions, in particular Iceland, Greenland, Norway, and the United Kingdom, and North

Atlantic fisheries history. Working closely with colleagues in the fields of archaeology and anthropology, in particular through NABO (the North Atlantic Biocultural Organization) and also in the general field of climate history, especially in connection with EACH (European and Atlantic Climate Historians).

**Jonathan T. Overpeck**

Adjunct Associate Professor of Geological Sciences, Fellow of INSTAAR. NOAA Scientist. PhD: 1985, Brown University.

**Outstanding Awards:** U.S. Department of Commerce Bronze Medal; 1995 National Geophysical Data Center Director Award.

**Specialty:** Global change, paleoclimatology, paleoecology, paleoceanography.

**Research Interests:** Understanding the Earth's climate system from the perspective of the past. Particular emphasis on Late Quaternary patterns and causes of decadal to millennial-scale climate/ocean dynamics, and on the interdependence between climate and vegetation (land-cover)—past, present, and future. Active research in the Arctic to tropics, in North America, South America, Africa, Asia, Indian and Atlantic Oceans.

**W. Tad Pfeffer**

Associate Director, May 1998-present and Fellow of INSTAAR, Assistant Research Professor of Geological Sciences. PhD: 1987, University of Washington.

**Outstanding Award:** 1997 American Geophysical Union Editor's Citation for Excellence in Refereeing for JGR-Solid Earth.

**Specialty:** Glaciology, continuum mechanics, heat transfer.

**Research Interests:** Dynamics of present and past glaciers and ice sheets, through field observational methods and numerical modeling, with emphasis on analysis of stress, deformation and defrature, and iceberg calving and ice/ocean interaction. Also, heat and mass transfer in seasonal and perennial snowpacks and atmospheric and snowpack temperature measurement methods.



**Lincoln F. Pratson**  
 Research Associate of INSTAAR; Instructor, Geological Sciences; Adjunct Research Associate of Lamont-Doherty Earth Observatory of Columbia University. PhD: 1993, Columbia University.  
**Specialty:** Marine geology and geophysics.

**Research Interests:** Surface processes, sedimentology, continental margin evolution, geomorphology, process modeling, geoacoustics and its integration with borehole data, potential fields and remote sensing data



**Kathleen A. Salzberg**  
 Managing Editor, *Arctic and Alpine Research*, Associate of INSTAAR. MA: 1964, University of Edinburgh.  
**Specialty:** Publication and dissemination of scientific research.



**Tim Seastedt**  
 Professor of Environmental, Population and Organismic Biology, Fellow of INSTAAR. PhD: 1979, University of Georgia.  
**Specialty:** Terrestrial ecosystem and biogeochemistry.  
**Research Interests:** Interested in how biota

interact with physical and chemical properties of the environment to control patterns of energy flow and material cycling. These interests center on soil phenomena, particularly those of grassland and tundra ecosystems.



**Eric J. Steig**  
 Research Associate of INSTAAR. PhD: 1996, University of Washington.  
**Outstanding Awards:** Department of Energy Fellowship in Global Change, 1992-96  
**Specialty:** Glaciology, cosmogenic and stable isotope geochemistry

**Research Interests:** Main interests are in the analysis and interpretation of ice cores as archives of past climate

variability. Current research projects in Wyoming, Greenland, Antarctica, and British Columbia.



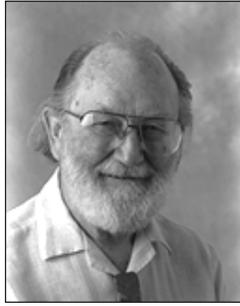
**James P. M. Syvitski**  
 Director and Fellow of INSTAAR, Professor of Geological Sciences. PhD: 1978. University of British Columbia (1) Geological Sciences, 1st class, (2) Oceanography, 1st Class.  
**Research interests:** Sedimentology, palaeoceanography,

oceanography, numerical modeling (climate-ice-water-sediment interactions), Quaternary geology, marine geophysics, slope instabilities. Presently investigating (1) the discharge dynamics of arctic rivers and the sediment load they carry, (2) the morphology and deposits of continental margins, (3) the impact of high-energy weather events on our coastline; and (4) the impact of ice sheets on high-latitude shelves and slopes.



**Alan R. Townsend**  
 Assistant Professor of Environmental, Population and Organismic Biology. Research Associate of INSTAAR, PhD: 1994, Stanford University.  
**Outstanding Awards:** NOAA Climate and Global Change Postdoctoral Fellow, SCOPE-Nitrogen Postdoctoral

Fellow, NASA Global Change Graduate Fellowship.  
**Research Interests:** Terrestrial biogeochemistry/ecosystem ecology. Carbon and nitrogen dynamics at regional to global scales; phosphorus controls over C and N in moist tropical systems; effects of N deposition in the Colorado alpine. Currently working on a NASA-funded project to look at carbon, nitrogen, and phosphorus cycling in primary forests, successively older pastures, and secondary forests in the Tapajos region of the Amazon. Part of this work involves a collaboration with J. W. C. White to assess the effects of land-use changes in the use of  $^{13}\text{CO}_2$  as a tracer of sources and sinks in the global C cycle. Other work includes collaboration with other INSTAAR members on work in the Niwot LTER region, continued involvement with the SCOPE-N project, which charts extent and effects of human-induced N cycling in large regions, and the development of research along a N- deposition gradient in the Mt. Zirkel Wilderness Area.



**Mort Turner**

Fellow Emeritus of INSTAAR. PhD: 1972, University of Kansas.

**Outstanding Award:**

H. Marie Wormington Award in recognition of outstanding contribution to the understanding and preservation of America's earliest cultural heritage, from the Center for

the Study of the First Americans, Oregon State University 1995.

**Specialty:** Glacial and archaeological geology.

**Research Interests:** Active research interests are (1) glacial geology and archaeological geology of southwestern Montana, (2) environment and archaeological geology of late Pleistocene ice-sheet margins in the United States, (3) geology and mineral resources of Antarctica, (4) tectonic development of the Caribbean region, and (5) archaeological geology of early man in the Americas, China, and Russia.



**Marilyn D. Walker**

Associate Professor Attendant Rank of Environmental, Population and Organismic Biology, Co-Director of Tundra Ecosystem Analysis and Mapping Laboratory, Fellow of INSTAAR. PhD: 1987, University of Colorado at Boulder.

**Specialty:** Community and population dynamics of arctic and alpine tundra; quantitative vegetation analysis; plant/soil/hydrologic interactions. Major field areas are arctic Alaska and Colorado alpine.

**Research Interests:** Use of geographic information systems to model and monitor community and population dynamics; interactions between spatial and temporal scales of variability; floristic classification of circumpolar arctic tundra; analysis of spatial patterns in tundra at multiple spatial scales; and linking hydrology, soil-water, and plant community models to spatial databases.



**Donald A. Walker**

Associate Professor Attendant Rank of Environmental, Population and Organismic Biology, Co-Director of Tundra Ecosystem Analysis and Mapping Laboratory, Fellow of INSTAAR. PhD: 1981, University of Colorado at Boulder.

**Specialty:** Tundra ecology,

vegetation mapping, quantitative ecology methods, vegetation of Northern Alaska, geographic information systems and remote sensing, snow ecology.

**Research Interests:** Particularly interested in the evolution of arctic landscapes and how this relates to current ecosystem processes such as trace-gas fluxes, energy budgets, biodiversity, and patterns of wildlife use. This also has major implications for historical use of these landscapes by man and sensitivity of these landscapes to present-day patterns of development. Three other areas of current interest are snow-ecosystem relationships in arctic and alpine systems, the role of arctic riparian systems during the Pleistocene-Holocene, and development of a circumpolar arctic vegetation map.



**Robert S. Webb**

Associate of INSTAAR. NOAA Scientist. PhD: 1981, Brown University

**Research Interests:**

Paleoclimate research, past and future global change. Reconstructing Late Quaternary climate change from geologic record and using numerical models to

investigate the mechanisms of the past climate and environmental change. This work includes (1) generating quantitative estimates of past climate from fossil pollen data and paleolake level records, (2) modeling of past changes in vegetation distributions, (3) developing hydrologic models for evaluation the dynamics of past changes in regional moisture balances, (4) assessment and improvement of the hydrologic cycle in general circulation models (GCMs), and (5) the design and implementation of GCM paleoclimate simulations to test hypotheses of past climate change.



**James W.C. White**  
Associate Professor of Geological Sciences, Fellow of INSTAAR. PhD: 1983, Columbia University.  
**Specialty:** Global change, paleoclimate dynamics, biogeochemistry.  
**Research Interests:** Stable isotope laboratory: global scale climate and environmental

dynamics, carbon dioxide concentrations and climate from stable hydrogen isotopes peats and other organics, climate from deuterium excess and hydrogen isotopes in ice cores; isotopes in general circulation models; modern carbon cycle dynamics via isotopes of carbon dioxide and methane.



**Mark Williams**  
Associate Professor of Geography, Associate of INSTAAR. PhD: 1991, University of California-Santa Barbara.  
**Outstanding Award:** NSF Predoctoral Fellowship, DOE Distinguished Post-Doc.  
**Specialty:** Alpine biogeochemistry, hydrology, and snow hydrology.

**Research Interests:** The processes that determine the hydrochemistry and biogeochemistry of high-elevation basins including the storage and release of solutes from the snowpack, biogeochemical modifications of snowpack runoff, nutrient cycling, and hydrologic pathways and residence time. The majority of this research has been conducted in the Rocky Mountains, Sierra Nevada of California, and the Tien Shan, China.

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## INSTAAR Affiliates & Visitors

### Affiliates

#### Ecosystems

##### Jane H. Bock

Professor, Environmental, Population and Organismic Biology, University of Colorado at Boulder. PhD: 1966, University of California-Berkeley.

Biogeography of alpine flowering plants.

##### Stephen Jackson

Assistant Professor, Botany, University of Wyoming. PhD: 1983, Indiana University.

Verification of the range of vegetation responses to environmental changes, and delineation of the relationships between modes of response and the magnitudes and rates of environmental forcing.

##### Michael Hunt Jones

Department of Evolution, Ecology, and Organismal Biology, The Ohio State University. PhD: 1995, University of Alberta, Edmonton, Alberta, Canada.

Plant ecology: population and physiological ecology.

##### Herman Sievering

Professor, Environmental Science Program and Physics Department, University of Colorado at Denver. PhD: 1971, University of Illinois.

Atmospheric physics and chemistry.

##### Cathy Tate

Research Biologist, Water Resources Division, United States Geological Survey, United States Department of Interior, Denver Federal Center. PhD: 1985, Kansas State University.

Ecology and biogeochemistry of temperate and Antarctic streams.

#### Geophysics

##### Edmund Andrews

Chief River Mechanics Project, National Research Program, United States Geological Survey, United States Department of Interior, Denver Federal Center. PhD: 1977, University of California-Berkeley.

Sedimentation in alluvial rivers.

##### Andrew G. Fountain

Professor, Department of Geology, Portland State University. PhD: 1992, University of Washington.

Glacier hydrology.

##### Pierre Julien

Professor, Department of Civil Engineering, Colorado State University. PhD: 1983, Laval University.

Hydrology and sediment transport modeling.

##### John Pitlick

Assistant Professor, Department of Geography, University of Colorado at Boulder. PhD: 1988, Colorado State University.

Geomorphology and sediment transport modeling.

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## Past Global Change

### Larry Benson

United States Geological Survey, United States Department of Interior, Denver Federal Center. PhD: 1974, Brown University.  
Quaternary fluctuations of closed basin lakes.

### William Briggs

PhD: 1974, Victoria University of Wellington New Zealand.  
High-latitude Marine Ostracodes.

### Parker Calkin

Professor of Geology, State University of New York at Buffalo.  
PhD: 1963, The Ohio State University.  
Glacial geology, geomorphology, Quaternary geology.

### P. Thompson Davis

Associate Professor, Natural Sciences Department, Bentley College. PhD: 1980, University of Colorado at Boulder.  
Paleoclimatology, sedimentology, tephrochronology, palynology.

### James Dixon

Curator of Archeology, Denver Museum of Natural History.  
PhD: 1979, Brown University.  
Archeology and paleoecology.

### John F. Hoffecker

Environmental Scientist, Argonne National Laboratory. PhD: 1986, University of Chicago.  
Archaeology and human paleoecology.

### Joan A. Kleypas

Marine Geologist, Marine Biologist, National Center for Atmospheric Research, Climate Change Research Section.  
PhD: 1992, James Cook University.  
Coral reefs and climate change.

### Richard F. Madole

United States Geological Survey, United States Department of Interior, Denver Federal Center. PhD: 1963, Ohio State University.  
Quaternary geology and geomorphology.

### Daniel R. Muhs

United States Geological Survey, United States Department of Interior, Denver Federal Center. PhD: 1980, University of Colorado at Boulder.  
Uranium-series dating methods of Quaternary problems.

### Alan R. Nelson

United States Geological Survey, United States Department of Interior, Denver Federal Center. PhD: 1978, University of Colorado at Boulder.  
History of late Holocene.

### Richard Reynolds

United States Geological Survey, United States Department of Interior, Denver Federal Center. PhD: 1975, University of Colorado at Boulder.  
Geologic records of climate change; environmental magnetic studies.

## Visitors

### Mr. Tim Barrows

Australian National University, Australia. Host: Nel Caine

### Dr. Maria Martha Bianchi

PROGEB, Briloché, Argentina. Host: Vera Markgraf

### Mr. Gary Bolton

University of Arizona. Host: Vera Markgraf

### Prof. Dr. Harald Bugmann

Swiss Federal Institute of Technology, Zurich. Host: Tim Seastedt

### Dr. Robert Courtney

Bedford Institute of Oceanography, Nova Scotia. Host: James Syvitski

### Dr. Sveinung Hagen

University of Tromsø, Norway. Hosts: John Andrews and Anne Jennings

### Dr. Morten Hald

University of Tromsø, Norway. Host: Anne Jennings

### Dr. Gudrun Helgadóttir

Marine Research Institute, Iceland. Host: Anne Jennings

### Dr. Vladimir G. Konovalov

Tashkent, Uzbekistan. Fulbright Scholar. Hosts: Mark Meier and Mark Dyurgerov

### Dr. Patrick Lajeunesse

Université Laval, Canada. Host: James Syvitski

### Dr. Han Lindeboom

LOCIZ Office, Netherlands. Host: James Syvitski

### Dr. Robert Marchant

University of Amsterdam, Netherlands. Host: Vera Markgraf

### Dr. Nick Pepin

University of Portsmouth, U.K. Host: Nel Caine

### Dr. Patrick Quilty

Australian Antarctic Division, Australia. Host: Charles Hart

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# Postdoctoral Research Scientists

**Dr. Anna Maria Arft**

1995, University of Colorado at Boulder. Plant ecology, genetics, and conservation biology.

**Dr. David Bahr**

1993, University of Colorado at Boulder. Glaciology and sediment transport.

**Dr. Lisa Barlow**

1994, University of Colorado at Boulder. High resolution paleoclimatology, climate/societal interactions.

**Dr. Carol Bilbrough**

1996, Utah State University. Rangeland ecology.

**Dr. Paul Brooks**

1995, University of Colorado at Boulder. Biogeochemistry, watershed elemental cycling.

**Dr. William Gould**

1998, University of Colorado at Boulder. Landscape and vegetation ecology, Arctic ecosystems, field education.

**Dr. Konrad Hughen**

1991, University of Colorado at Boulder. Paleoclimatology.

**Dr. Hope Humphries**

1993, Colorado State University. Landscape ecology, ecological modeling, conservation planning.

**Dr. Beverly Johnson**

1995, University of Colorado at Boulder. Use of stable isotopes in organic compounds for reconstructing paleovegetation and paleoenvironment.

**Dr. William F. Manley**

1995, University of Colorado at Boulder. Quaternary geology, geochronology, and GIS.

**Dr. David Lubinski**

1998, University of Colorado at Boulder. Late-Quaternary reconstruction of arctic glacial and marine paleoenvironments.

**Dr. Scott Peckham**

1995, University of Colorado at Boulder. Mathematical modeling, fluid dynamics, hydrology and geomorphology.

**Dr. Elise Pendall**

1997, University of Arizona. Paleoclimate and carbon cycle biogeochemistry.

**Dr. Mel A. Reasoner**

1996, University of Alberta. Quaternary geology, palynology.

**Dr. Julian P. Sachs**

1997, Massachusetts Institute of Technology/Woods Hole Oceanographic Institution. Oceanography.

**Dr. Udo Schickhoff**

1993, University of Münster, Germany. Vegetation ecology, landscape ecology, arctic and high mountain regions.

**Dr. Alexander P. Wolfe**

1994, Queen's University. Freshwater diatom ecology and taxonomy, paleolimnology of Arctic and Alpine regions.

**Dr. Connie Woodhouse**

1996, University of Arizona. Dendrochronology.



A group of Postdoctoral Research Scientists

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# Research and Support Personnel

## **Jim Anderson**

Primary duties: Assisting with GIS work. Supervisor: Skip Walker

## **Kathy Anderson**

Primary duties: Paleoclimatological studies on a continental scale in North America, using pollen, plant macrofossils, and modern vegetation to look at past and future climate and vegetation changes. Supervisor: Jonathan Overpeck

## **Nancy Auerbach**

Primary duties: Landscape-scale vegetation ecology statistical analysis for the Columbia River Basin. Research interests: Vegetation ecology analysis using GIS and remote sensing, Arctic ecology. Supervisor: Patrick Bourgeron

## **Jim Barber**

Primary duties: Geographic Information System (GIS) Analyst. Research interests: Prediction and modeling of ecosystem patterns using biophysical criteria. Supervisor: Patrick Bourgeron

## **Tim Bardsley**

Primary duties: Field technician, collection of field data, maintenance of field equipment. Research interests: Long-term ecological research. Supervisor: Tim Seastedt

## **Peter Brown**

Primary duties: Drought reconstructions from the Central Plains region using tree-ring data. Research interests: Use of tree-ring data to reconstruct climate and forest dynamics. Supervisor: Connie Woodhouse

## **Wendy Cunningham**

Primary duties: Diatomist working on Ross Sea paleoceanography. Research interests: Antarctic paleoceanography. Supervisor: John Andrews

## **Mark Dreier**

Primary duties: Assistant laboratory manager in Isotope Laboratory, providing technical expertise with the hardware; develop new systems, maintain old systems, and rebuild mass spectrometers and vacuum pumps. Research interests: Climate research in Patagonia. Supervisor: Bruce Vaughn

## **Matt Duvall**

Primary duties: Develop a "living" electronic atlas of environmental change for the Berginian region of the Arctic, synthesizing as many lines of evidence as possible under the PALE program within NSF. Supervisor: Gifford Miller

## **Nanette Elias**

Primary duties: Assistant to the Managing Editor of *Arctic, Antarctic, and Alpine Research* and Assistant Librarian to the INSTAAR Reading Room. Supervisors: Kathleen Salzberg and Martha Andrews

## **Karen Erbe**

Primary duties: Iceland Project, core splitting and sediment analysis. Research interests: Sedimentology. Supervisor: John Andrews

## **Charles Hart**

Primary duties: Oversee the operation of the Amino Acid Geochronology Laboratory, including sample preparation, analysis, data reduction, and database management. Supervisor: Gifford Miller

## **Michael Hartman**

Primary duties: Data and information management Niwot LTER project. Research interests: Data management and information technology. Supervisor: Tim Seastedt

## **Chanda Herring**

Primary duties: Prepare samples for carbon-14 dating from a Cariaco core. Research interests: Generate high-resolution carbon-14 plot to correlate with tree ring and coral plots. Supervisor: Scott Lehman

## **Eric Hutton**

Primary duties: Develop process-based sediment transport models. Supervisor: Scott Peckham

## **Katie Hyland**

Primary duties: Field technician on Niwot LTER project, maintaining the automatic weather stations and collecting stream and soil solution samples for chemical analysis. Supervisor: Mark Williams

## **Trudy Kernan**

Primary duties: Oversee operation of paleoclimatology laboratory, sample preparation and analysis, and data reduction. Research interests: Paleoclimate reconstruction. Supervisor: Julian Sachs

## **Andrew Lillie**

Primary duties: Graphic design, editing, and web design, and field assistance. Supervisor: Skip Walker



A group of Research and Support Personnel

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**Mark Losleben**

Primary duties: Long-term climatic database, atmospheric and precipitation measurements. Research interests: Long-term climatic trends and related processes affecting Niwot Ridge. Supervisor: William Bowman

**Kim Marsella**

Primary duties: Science Management Office head for the NSF-PALE program, and oversees the compilation of a pan-Arctic database of paleoenvironmental data collected with PALE support. Supervisor: Gifford Miller

**Helmut Mayer**

Primary duties: Geomathematics and structural glaciology, snow and ice research; geostatistical analysis of ice surfaces. Supervisor: John Behrendt

**Steve Muller**

Primary duties: GIS and remote-sensing analyst. Research interests: Mapping and spatial analysis of tundra ecosystems. Supervisor: Skip Walker

**Christine Seibold**

Primary duties: Manager of Environmental Chemistry Laboratory. Research interests: Long-term ecological research chemistries. Supervisor: Tim Seastedt

**Steve Seibold**

Primary duties: Manager Mountain Research Station. Supervisor: William Bowman

**Denise Steigerwald**

Primary duties: Data manager for long-term ecological research conducted in McMurdo Dry Valleys, Antarctica. Research interests: Ecology, human impact on global conditions. Supervisor: Diane McKnight

**Jocelyn Turnbull**

Primary duties: Manager of AMS radiocarbon dating laboratory. Research interests: Radiocarbon dating techniques and methods. Supervisor: Scott Lehman

**Joanne Turner**

Primary duties: Geoarchaeological assistant. Research interests: Earliest peopling of the Americas and sources of raw materials for stone tools. Supervisor: James Syvitski

**Candice Urban Evans**

Primary duties: Operates mass spectrometers for analysis of greenhouse gases and carbonates, prepared samples and manages data storage and quality assurance. Supervisors: James White and Julia Cole

**Bruce Vaughn**

Primary duties: Manager of Stable Isotope laboratory which houses six mass spectrometers. Research interests: Collaborates in isotopic studies in ice cores, glaciers, atmospheric gases, and global change. Supervisor: James White

**Nancy Weiner**

Primary duties: Micropaleontology laboratory technician, supervises students and conducts foraminiferal analysis. Research Interests: Micropaleontology. Supervisor: Anne Jennings

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## Administrative Staff

Margaret Ahlbrandt	Accounting Technician III
Ashley Holladay	Assistant to Director
Julie Hughes	Chief Financial Officer/ General Professional III
Donivan Miller	Accounting Technician III
Sean Prescott	Accounting Technician II
Vesper Tanaka	Administrative Assistant I
Susan Tatum	Accounting Technician III



INSTAAR Administrative Staff

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# Education

Undergraduate and graduate students are an integral part of INSTAAR and they play important roles in the research conducted by the institute and its members. INSTAAR students are registered for degree programs in an appropriate department and college. Financial support is available for INSTAAR graduate students as research assistants employed on research grants. Undergraduate support is available through special programs. These programs are sponsored by INSTAAR, the university, industry (e.g. MOBIL), and agencies such as the National Science Foundation and are designed to encourage undergraduate participation in research. They include SURE (Summer Undergraduate Research Program), SURF (Summer Undergraduate Research Fellowships), SMART (Summer Minority Access Research Training), UROP (Undergraduate Research Opportunities), UMP (University Mentoring Program), and REU (Research Experience for Undergraduates). Undergradu-

ate research opportunities may lead to Honors Theses and internships. These programs have contributed greatly to the feasibility of including undergraduates in INSTAAR research and to encouraging undergraduate students to continue to graduate degrees.

Prospective graduate students should contact the department that they wish to enter and apply for admission to the University of Colorado. Applications forms are available from Graduate School, Campus Box 30, University of Colorado, Boulder, Colorado 80309-0030.

The following list of most undergraduate students gives the student name, program, department affiliation, and supervisor/mentor name. The list of graduate students gives student name, degree program, department, advisor, and thesis topic. Other undergraduate students are employed at INSTAAR as student assistants.

## Undergraduate Students 1998

Elyse Ackerman, UROP, Geological Sciences, Scott Elias  
Heather Bechtoldt, URAP, EPOB, William Bowman  
Meredith Berlin, Student Assistant, Williams Village, Anne Jennings  
Alicia Berry, Student Trainee, INSTAAR  
Anita Bhuyan, Student Assistant, INSTAAR  
Alisa Bieber, Student Assistant, INSTAAR  
Sarah Blakesley, EPOB, Mark Williams  
Gabriela Buamscha, Mellon Training Grant, Argentina, William Bowman  
Sarah Carsey, Student Assistant, Environmental Studies, John Andrews  
Andrew Cassady, Student Assistant, INSTAAR  
Lisa Chism, REU, EPO Biology, Anne Jennings

Chris Clark, Student Assistant, INSTAAR  
Megan Clute, REU, Geological Sciences, William Manley  
Julie Czywczynski, REU, ENVS and EPOB, William Manley  
Jill Dahlke, UROP  
Christy Davis, Student Assistant, INSTAAR  
Joshua Dick, Student Assistant, Tim Seastedt  
Micah Dunthorn, Student Assistant, Tim Seastedt  
Stephanie Dvall, Student Assistant, INSTAAR  
Kim Eastman, Student Assistant, Geological Sciences, John Andrews  
Patrick Ernst, Student Assistant, INSTAAR  
Juliet Fabbri, Lab Assistant, EPOB, Alan Townsend  
Daniel Fenyvesi, Student Assistant, INSTAAR  
Susanna French, Student Trainee, INSTAAR  
Alex Gallego, Biosphere/Atmosphere Research Training Program, William Bowman  
Elizabeth Ganser, Student Assistant, INSTAAR  
Linda Gerson, Honors Thesis, Environmental Studies, Anne Jennings  
Shira Gordon, EPO Biology, MCMLTER, Diane McKnight  
Emily Gorton, Student Assistant, INSTAAR  
Brian Graham, UROP/SURF, Geological Sciences, William Manley  
Stephen Halsey, Student Assistant, INSTAAR  
Gabriela Hess, Student Assistant, INSTAAR  
Kristi Heuer, Student Assistant, Mark Williams

Grizelle González, assistant with the Arctic Field Ecology class, prepares soil invertebrate extraction along the remote Hiukitak River, Nunavut.



Rachael Hilberman, REU, Mathematics Program, Anne Jennings

Christopher Hill, Student Assistant, EPOB

Jordan Holtz, Student Assistant, INSTAAR

David A. Huber, SURF & REU, Chemical Engineering, William Krantz

Kate Hyland, Geography, Mark Williams

Travers Ichinose, Student Assistant, William Briggs

Laura Ireland, Student Assistant, INSTAAR

Eric James, Honors Thesis, Geological Sciences, John Andrews

Jennifer Johnson, Student Assistant, INSTAAR

Jessica Kelleher, Mentoring Program & Honors Thesis, Geological Sciences, Julie Cole and Frank Urban

Matthew Kohn, Student Assistant, INSTAAR

Kelly Krieger, Student Assistant, INSTAAR

Michael Kunz, Student Assistant, INSTAAR

Julia Larson, Carleton College, NSF REU Program, William Bowman

Jennifer Limbird, EPO Biology, MCMLTER, Diane McKnight

Lucille Lupfer, Student Assistant, INSTAAR

Christina Lynch, Student Assistant, INSTAAR

Ajay Madiah, Student Assistant, INSTAAR

Gavin Malia, Mentor Program, Geological Sciences, William Manley

Sam Massman, Geography, Mark Williams

Scott McCauley, Student hourly, Biology, Dev Niyogi

Deborah Moffett, Student Assistant, INSTAAR

Timber Moreland, Student Assistant, INSTAAR

Derek Mortisen, Student Assistant, INSTAAR

Lisa Munger, Student Assistant, INSTAAR

Alessandra Nisco, Student Assistant, INSTAAR

Andy Orahoske, Lab assistant, EPOB, Alan Townsend

Andrew O'Reilly, Student Assistant, INSTAAR

Daniel Olsen, Student Assistant, INSTAAR

Laurie Oneill, Student Assistant, INSTAAR

Allie Osborne, Humboldt State, NSF REU Program, William Bowman

Phalla Ouch, Student Assistant, INSTAAR

Zarife Pipkin, EPO Biology, NSF REU Program, William Bowman

Joel Pletcher, Student Assistant, INSTAAR

Rebecca Preston, Undergraduate Assistant, Geological Sciences

Sharon Quach, Student Assistant, Educational Development

Adina Racoviteanu, Student Trainee, INSTAAR

Michael Rafoul, Student Assistant, INSTAAR

Morghan Reeve, Student Assistant, INSTAAR

David Remucal, Student Assistant, INSTAAR

Rodney Richardson, Student Assistant, INSTAAR

Victoria Rystrom, Student Assistant, INSTAAR

William Safford, Student Assistant, INSTAAR

Benjamin Scheich, Student Assistant, INSTAAR

Michael Scott, Student Assistant, INSTAAR

Nina Seevers, Student Assistant, INSTAAR

Winston Seiler, Student Assistant, Geological Sciences

Kerry Shea, Student Assistant, UROP

Derek Shrou, Student Assistant, INSTAAR

Penelope Sinton, Student Assistant, INSTAAR

Brian Smith, Student Assistant, INSTAAR

Laura Smith, Student Trainee, INSTAAR

Winston Wheeler, Lab Assistant, EPOB, Alan Townsend

Amy Whitledge, Student Assistant, INSTAAR

Peter Wilson, Student Assistant, INSTAAR

John Yerton, Student Assistant, INSTAAR

Theresa Zawistowski, Student Assistant, INSTAAR

Lee Turner, assistant with the Arctic Field Ecology class, pressing plants with undergraduates along the Hiukitak River, Nunavut.



## Graduate Students 1998

\* Lysanna Anderson, PhD, Geography, Vera Markgraf, "Quantitative Paleoclimatic Reconstructions for the Late Quaternary of Southern South America Based on Calibration of Modern Pollen and Climate Relationships"

Donald Barber, PhD, Geological Sciences, John Andrews, "Temporal and Spatial Patterns of Ice Sheet/Ocean Interactions: The Northeast Laurentide Ice Sheet and Labrador Sea during the Last 40,000 Years"

Arne Bomblied, MS, Civil, Environmental, and Architectural Engineering, Diane McKnight, "Climatic Controls on Streamflow Generation from Antarctic Glaciers"

Alex Brown, MS, Civil Environmental, and Architectural Engineering, Diane McKnight, "Characteristics and Reactivity of Microbially-Derived Humic Substances in a Coastal Pond on Cape Royds, Antarctica"

Christina Clark, PhD, Atmospheric and Ocean Sciences, Julia Cole and Peter Webster, "The Relationship of Indian Ocean Variability to Monsoon Strength on Subannual-Multidecadal Time Scales"

Cory Cleveland, PhD EPO Biology, Alan Townsend, "Microbial Regulation of Nutrient Losses following Land-Use Change in Terrestrial Ecosystems"

Josh Cohn, MS, Geological Sciences, Tad Pfeffer, "Columbia Glacier Dynamics"

Daniel Costello, MS, Geological Sciences, Tad Pfeffer, "Seismic Profiles of Galena Creek Rock Glacier, Wyoming"

Noah Daniels, MA, Geological Sciences, Giff Miller, "Holocene Paleoclimatology of the High Plains"

Thomas Davinroy, PhD, Geography, Mark Williams, "Hydrologic and Biogeochemical Characteristics of Alpine Talus: Colorado Front Range"

Lisa Doner, PhD Geological Sciences, John Andrews, "Late Holocene Climatic Changes in the North Atlantic Region"

Andrew Fox, MA, Geography, Nel Caine, "Equivalent Permeability of a Continental Alpine Snowpack"

Wendy Freeman, MS, Geological Sciences, John Andrews, "Use of Lake Ice Records for Studying Climate Variability in the Eastern Canadian Arctic"

Grizelle Gonzalez, PhD, EPO Biology, Tim Seastedt, "Soil Fauna and Plant Litter Decomposition in Tropical and Subalpine Forests"

Michael Gooseff, PhD, Civil, Environmental, and Architectural Engineering, Diane McKnight, "Hyporheic and In-Stream Nutrient Dynamics Modeling"

\* William Gould, PhD. EPO Biology, Marilyn Walker. "A multiple-scale analysis of plant species richness, vegetation, landscape heterogeneity, and spectral diversity along an Arctic river"

Hillary Hamann, PhD, Geography, Nel Caine, "Snowmelt Flowpaths and Stream Chemistry in the Alpine"

Jorunn Hardardottir, PhD, Geological Sciences, John Andrews, "Late Weichselian and Holocene Environmental History of South and West Iceland as Interpreted From Studies of Lake and Terrestrial Sediments"

Jennifer Hazen, MA, Geography, Mark Williams, "Hydrologic Flowpaths and Zinc in Neutral pH Mine Drainage"

Eran Hood, PhD, Geography, Mark Williams, "The Role of Dissolved Organic Nitrogen in the Alpine Nitrogen Cycle"

Anna Adele Hopkins-Arnold, PhD, EPO Biology, Tim Seastedt, "Response of Colorado Tallgrass Prairie to Fire, Winter Grazing, and Nitrogen Manipulation"

Uli Huber, PhD, Geography, Vera Markgraf, "Linkages Between Past Climate, Vegetation, and Fire Regimes in Patagonia"

Barbara Inyan, PhD Geography, Mark Williams, "High Elevation Watershed Characterization and Sensitivity Analysis: A Methodology for Watershed Protection From Future Degradation"

Ernest Joynt, MS, Geology, Gifford Miller. "Calibration and application of lake diatoms as proxies for climate change on Baffin Island, Nunavut, Canada"

Michael Kaplan, PhD, Geological Sciences, Gifford Miller, "Glacial History of Middle to Outer Cumberland Sound Area and Numerical Modeling of the Northeastern Laurentide Ice Sheet, Eastern Canadian Arctic"

A group of Graduate Students



\*Degree completed in 1998.

Michael Kerwin, PhD, Geological Sciences, Jonathan Overpeck, "Pollen/Climate Calibration for the Eastern Canadian Arctic"

Greta Bjork Kristjansdottir, MS, University of Iceland, Aslaug Geirsdottir, Arny E. Sveinbjornsdottir, John Andrews, Anne Jennings, "Environmental and Climatic Changes in Eyjafjarðaráll, N-Iceland Shelf"

Kate LeJeune, PhD, EPO Biology, Tim Seastedt.

Karen Lewis, PhD, Geological Sciences, Tad Pfeffer, "The Effect of Dust and Surface Roughness on Glacier Melt and Runoff in the Antarctic Dry Valleys"

Kathy Licht, PhD, Geological Sciences, John Andrews, "Glacial History of the Ross Sea, Antarctica"

\* David Lubinski, PhD, Geology, Gifford Miller. "Latest Pleistocene and Holocene paleoenvironments of the Franz Josef Land region, Northern Barents Sea, Arctic Russia"

Ken Mack, MA, Geological Sciences, James White Jennifer Mangan, PhD, Atmospheric and Oceanic Sciences, Jonathan Overpeck

Amy Miller, PhD, EPO Biology, Bill Bowman, "Differential Utilization of Organic and Inorganic Nitrogen by Co-existing Dry Meadow Tundra Species: Implications for Plant Partitioning of Soil N Pools"

Mark Morehead, PhD, Geological Sciences, James Syvitski, "Sediment Supply to the Ocean: The Temporal and Spatial Variability of Rivers and Plumes"

Carrie Morrill, PhD, Geological Sciences, Julie Cole and Jonathan Overpeck, "Lake Level Records of Variability in the Asian Monsoon During the Holocene"

Randy Mrugala, M.S., Geological Sciences, Tad Pfeffer, "Effects of Original Snow Density and Magnitude of Temperature Gradient on Grain Growth and Sintering Processes in Snow"

Dev Niyogi, PhD, Civil, Environmental, and Architectural Engineering, William Lewis and Diane McKnight, "Response of Ecosystem Functions to Stress in Streams Affected by Acid Mine Drainage"

Damian O'Grady, PhD, Geological Sciences, James Syvitski, "Continental Margin Sedimentation"

Sean Pack, MA, Geological Sciences, Giff Miller, "Drought in the Australian Outback"

Heather Reed, MA, EPO Biology, Tim Seastedt, "Soil Biodiversity and Ecosystem Processes"

Alex Robertson, MS, Geological Sciences, Jonathan Overpeck, "Hypothesized Climate Forcing Time Series for the Last 500 Years"

Stephanie Schoolfield, MS, Geological Sciences, John Andrews, "Late Pleistocene Sedimentation in the Denmark Strait Region"



Eric Steig drives through Sunlight Creek, the only way to Galena Creek Rock Glacier, Absaroka Range, Wyoming. Photo courtesy Don Costello.

Durelle Scott, PhD, Civil, Environmental, and Architectural Engineering, Diane McKnight, "Manganese Photochemistry"

Susan Sherrod, PhD, EPO Biology, Tim Seastedt, "A Multiscale Analysis of the Northern Pocket Gopher (*Thomomys talpoides*) in the Alpine, Niwot Ridge, Colorado"

\* Valerie Sloan, PhD, Geography, John Andrews and Nel Caine, "The Rheology, Distribution, and Origins of Rock Glaciers in the Selwyn Mountains, Yukon and Northwest Territories, Canada"

Laryn (Mikie) Smith, PhD, Geological Sciences, John Andrews and Anne Jennings, "Holocene Paleooceanography of the Continental Shelves Adjacent to the Denmark Strait"

Heidi Steltzer, PhD, EPO Biology, Bill Bowman, "Plant Control Over Nitrogen Cycling in Moist Meadow Alpine Tundra"

Lee Turner, MA, EPO Biology, Bill Bowman and Marilyn Walker, "Influence of Warming and Snow Augmentation on Plant Phenology and Reproduction in Alpine Tundra"

Frank Urban, MS, Geological Sciences, Julie Cole and Jonathan Overpeck, "A New Index of ENSO Based on Multiple Central Pacific Corals"

Summer Waters, MS, Civil, Environmental, and Architectural Engineering, Diane McKnight, "Phytoplankton Ecology and Paleolimnology of an Alpine Lake in Green Lakes Valley"

Jake Wegmann, MS, Geological Sciences, Tad Pfeffer, "Finite Element Modeling of Temperate Glaciers"

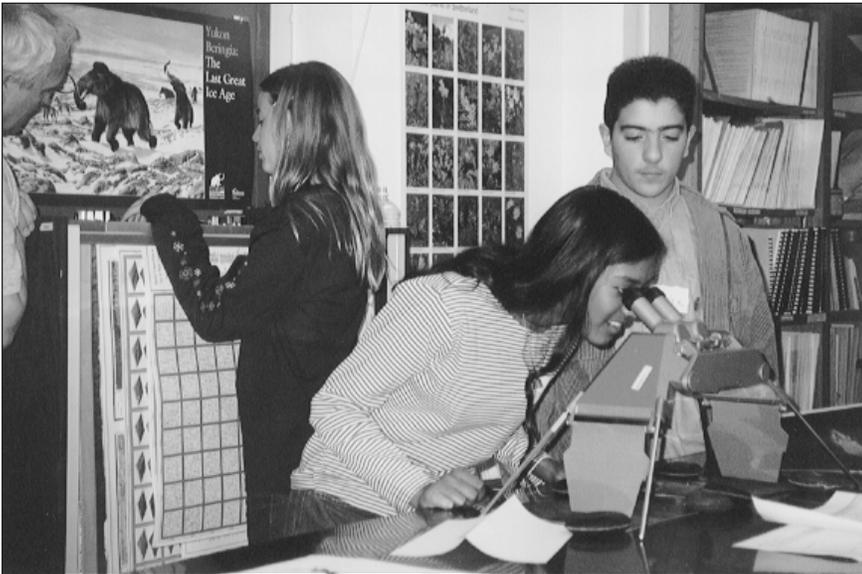
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# Societal Outreach

Public outreach is an important activity of the Institute, and it involves the communication of our goals, mission, and research activities to the general public of the State of Colorado. During 1998, INSTAAR members have participated in numerous public outreach activities. The most common activities were lectures, field trips, and other presentations to school classes and civic groups. For example, Diane McKnight, Tim Seastedt, and Mark Williams participated for a second year in the Boulder Creek Watershed Forum. Field trips have focused on avalanche awareness for elementary school students (Tad Pfeffer) and Ice Age environments of Rocky Mountain National Park (Scott Elias). INSTAAR members have served as judges for science fairs at the school, district, and state levels. They have also responded to telephone call from the press and the public requesting information on scientific matters within INSTAAR's areas of expertise. The Mountain Research Station actively reaches the public through a variety of educational activities. For example, during the summer of 1998, Diane McKnight (INSTAAR) and Ken Emo (CU College of Education) taught a course

involving three undergraduate students and 60 children who participated in five field trips to the Tundra Laboratory on Niwot Ridge. Several INSTAAR members have been interviewed for popular science articles, and have appeared on television.

INSTAAR held a broadly successful two-day Open House last November, attracting the interest and enthusiasm of nearly 550 middle-school students and 75 members of the public. At the Open House, participants were able to attend presentations on ice-age environments, the Antarctic Dry Valleys, glaciers, and crossing into the Americas via the Bering Land Bridge. Laboratory tours emphasized hands-on and visual experiences, including, among others, the popular ice-cream making from liquid nitrogen in the Stable Isotope Lab, cold-weather field clothing, computer simulations of the ocean floor, and a field experience at nearby Boulder Creek. Feedback from teachers and students was very enthusiastic. Many INSTAAR faculty, staff, students, and researchers were involved in making the Open House a success.



Left: A middle-school student examines air photographs through a stereoscope at INSTAAR's Open House.

Below: A middle-school student tries on cold-weather clothing at the Open House.



# Mountain Research Station

The Mountain Research Station (MRS), located near Nederland, 25 miles from Boulder, is an interdisciplinary research facility of the University of Colorado devoted to advancement of study of mountain ecosystems. Our mission is to facilitate research and education to understand better the unique patterns and processes of biotic and physical systems in mountains, and how environmental changes may affect these processes.

The MRS was established in 1921 and since then has served as an outstanding facility in field education and research. Work on nearby Niwot Ridge is internationally known for its excellent research on the biology, geology, and atmospheric environment of mountain ecosystems. Approximately 40 researchers per year use the MRS as a base of operations, including CU faculty and students and many from other universities in the US and around the world.

The station's teaching mission includes formal undergraduate and graduate field courses, which have been offered at the MRS for over seven decades and have become an integral part of the academic experience of many college students. During the past several years enrollment in MRS courses has been near capacity, with approximately 110 students per summer. Several K-12 courses also use the MRS as a site to introduce students to field environmental science.

The MRS participated in educational experiences for the general public aimed at policy decisions that affect our environment. Through formal interactions with U.S. federal agencies such as the Forest Service, the Environmental Protection Agency, and the National Park Service, the MRS has provided expertise to help regulatory agencies make informed decisions about minimizing human impacts on mountain ecosystems. The MRS also provides summer seminars open to all on subjects of interest to both scientists and nonscientists. The MRS is a popular site for symposia and workshops aimed at decision making and information sharing, CU departmental retreats, and national scientific meetings.

The first phase of construction was completed on the New Fireweed Hostel during 1998. The external shell, the floor for the second story, and the heating system were included in this initial effort. The high-efficiency radiant floor heating in combination with advanced passive solar energy collection, using a trombe wall, will result in a comfortable winterized building when completed. Fund raising by the CU Foundation is ongoing to provide the support to complete this building.

A fiber optic cable between the MRS and the Tundra Laboratory at 3400 m was established this past year, thanks to a lot of manual labor by various individuals. This connection will allow downloading of data remotely from the alpine, and real-time viewing of climate data at the Saddle Research Site (<http://culter.colorado.edu:1030/exec/sdlmetpage.pl>). This will greatly complement the newly established line-power at the Tundra Lab, and enhance the capabilities of tundra researchers.

Two 30-m-tall towers were constructed near the C1 climate station in the fall of 1998 to measure the flux of gases between the subalpine forest and the atmosphere. The

project was spearheaded by Dr. Russ Monson in the EPO Biology Department as part of a Department of Energy and NSF funded program, and the US Geological Survey. The principal species being measured include CO<sub>2</sub>, ozone, oxidized compounds of nitrogen, and terpenes. The tower projects are part of the nationwide AmeriFlux Tower Network.

Several of the small student cabins received renovations, including new porches, new roofs, and new wood stoves, in 1998. The Megaron Building has new blinds and projection screen, which were installed in time for the annual Guild of Rocky Mountain Population Biologists meeting in September. CU Facilities Management continues to work with the Colorado Division of Wildlife to engineer a "green" sewage treatment facility which will not endanger one of the last remaining populations of Greenback Cutthroat Trout in nearby Como Creek. Completion is planned for the fall of 1999.

## MRS Staff

Director: William D. Bowman  
Associate Director: Diane McKnight  
Station Manager: Steven Seibold  
Facilities Management: Karla Adami  
Course Coordinator: Kristen Laubach  
Climatologist: Mark Losleben  
LTER technician: Tim Bardsley  
Kiowa Laboratory Manager: Christine Seibold



### 1998 Mountain Research Station Staff

(left to right) Kurt Chowanski, Chris Seibold, Steve Seibold, Karla Adami, Mark Losleben  
(not pictured) Kristen Laubach, Tim Bardsley

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# Center for Geochronological Research

## Aim

The Center for Geochronological Research promotes fundamental research in the development and application of geochronological methods and geochemical tracers that will lead to an improved understanding of processes controlling environmental change, and the rates at which those processes act. These techniques allow a quantitative reconstruction of past environmental changes, from which temporal linkages between components of the global climate system, particularly biosphere/atmosphere/ocean/ice-sheet interactions, can be identified. The active participation of graduate and undergraduate students is ensured through formal course offerings, access to specialized research facilities, and employment opportunities.

## Research Highlights

### 2000 Years of Drought Variability in the Central United States

Droughts are one of the most devastating natural hazards faced by the United States today. Severe droughts of the 20th century have had significant impacts on economies, society, and the environment, especially in the central U.S. However, the instrumental record of drought for this region is only about 100 years long and contains only a limited subset of droughts. How representative is the 20th century record over time scales of hundreds to thousands of years? In a 1998 paper in the *Bulletin of the American Meteorological Society*, Connie Woodhouse and Jonathan Overpeck use paleoclimatic data to evaluate the characteristics of 20th century droughts in the context of longer time scales. In this study, a variety of proxy data, including historical documents,

tree rings, archaeological remains, lake sediments, and geomorphic data, are used to evaluate the representativeness of 20th century droughts compared to droughts which have occurred under the naturally-varying climate conditions of the past two thousand years.

The results of this review of paleoclimatic data suggest that 20th century droughts are not representative of the full range of drought variability that has occurred over the last several thousand years. Proxy data for the Great Plains region indicate that the severe droughts of the 20th century, although certainly major droughts, are by no means unprecedented and it is likely that droughts of a magnitude at least equal to those of the 1930s and 1950s have occurred with some regularity over the past 400 years. A look further back in time reveals evidence that multidecadal drought events occurred in the late 13th and 16th centuries that were of a greater duration and severity than 20th century droughts. Other proxy records, including the few annually resolved paleoclimatic records, provide some evidence for longer periods of drought or periods of more frequent drought prior to the 13th century, and support the idea of a drought regime shift roughly around the 13th–15th centuries.

This assessment of the paleoclimatic record suggests that droughts of the 20th century are not unusual in the context of the past 2,000 years, and that future droughts could be of a much greater severity and duration than what we have yet experienced. Assessments of future drought variability should consider the range of natural drought variability of the past several thousand years as documented by the paleoclimatic record, over which possible anthropogenically-induced climate changes will be superimposed.

### A Long History of Human-Caused Extinctions: Human Impact on Australian Megafauna 50,000 Years Ago

Australia suffered a major loss of its large- and medium-sized land mammals in the Late Pleistocene. All marsupials larger than a human (19 species) and 75% of all marsupials weighing more than 10 kg became extinct, along with three large reptiles and the ostrich-sized *Genyornis newtoni*; two other large flightless birds, the emu and the cassowary, survived. Collectively, the lost species are often referred to as the Australian megafauna, although most are of modest body mass.

For more than a century the cause of this exceptional extinction has been debated without a clear consensus, largely because of the difficulty in dating faunal remains close to the limit of radiocarbon dating. The cause of megafauna extinction initially focused on climate change or human predation, but more recently has included indirect consequences of human activity, particularly ecosystem change



Effects of drought and wind erosion in a Kansas cornfield. Photo courtesy of the Wind Erosion Unit, USDA Agriculture Research Unit and Kansas State University.

resulting from burning practices. Resolving the debate requires secure dates on the extinction events, on the arrival of humans in Australia, and on major climate and environmental changes. Gifford Miller, Beverly Johnson, and colleagues have established new dates that constrain the ages of these key events based on amino acid racemization (AAR), AMS  $^{14}\text{C}$  and thermal ionization mass spectrometry (TIMS) U-series analyses on eggshells, and luminescence dates on associated sediment. These new dates allow us for the first time to rigorously evaluate the cause of this major extinction event.

At INSTAAR's Amino Acid Geochronology Laboratory the authors determined more than 700 AAR dates on *Genyornis* eggshells from three different climate regions that document the continuous presence of *Genyornis* from more than 100,000 years ago until their sudden disappearance about 50,000 years ago. This is about the same time that humans arrived in Australia. The extinction of *Genyornis* 50,000 ago is corroborated by more than 100 AMS  $^{14}\text{C}$  dates, 8 luminescence dates between 40 and 120 thousand years ago on eolian sand from which eggshell has been collected, and 5 TIMS U-series dates on *Genyornis* eggshell.

By evaluating paleoenvironmental reconstructions for the past 150,000 it was demonstrated that *Genyornis* was able to survive the range of natural environmental changes caused by Pleistocene climate oscillations. During the period of *Genyornis* extinction climate was moderate. Consequently, climate change as an explanation for *Genyornis* extinction is unlikely.

Humans colonized Australia about 55,000 years ago, shortly before the extinction event. The authors hypothesize that burning practices of the earliest human immigrants differed enough from that of the natural fire cycle to disrupt ecosystems across the semi-arid zone. The vegetation may have been particularly susceptible due to the continent's geological quiescence; soils in this low-relief landscape were depleted of most nutrients, resulting in a lack of ecosystem resiliency. The authors go on to postulate that human burning at times of the year and at frequencies to which the vegetation was not pre-adapted, resulted in a dramatic decrease in tree and shrub vegetation across the continental interior, which in turn placed unprecedented stress on the dependent fauna.

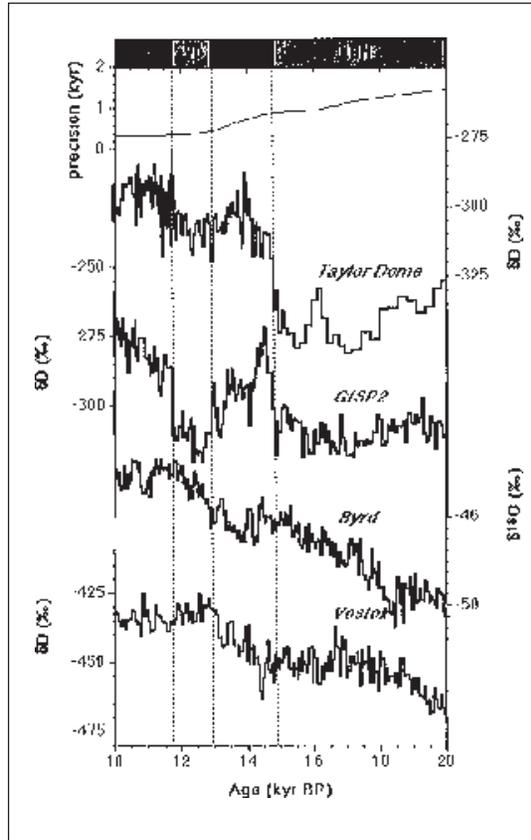


50,000-year-old eggshells in Australia. Dates from INSTAAR labs on these shells support the theory that humans were the cause of the extinction of many large animals in Australia at that time.

### **Synchronous Climate Changes in Antarctica and the North Atlantic**

Central Greenland ice cores provide evidence of abrupt changes in climate over the past 100,000 years. These large temperature shifts of  $5^{\circ}$  to  $10^{\circ}\text{C}$  or more are very fast, occurring in few decades. Many of these changes have also been identified in sedimentary and geochemical signatures in deep-sea sediment cores from the North Atlantic, confirming the link between millennial scale climate variability and ocean thermohaline circulation. In a 1998 paper in *Science*, Eric Steig, James White and Scott Lehman, with a number of colleagues, showed that two of the most prominent North Atlantic events—the rapid warming that marks the end of the last glacial period and the Bølling/Allerød—Younger Dryas oscillation—are also recorded in an ice core from Taylor Dome, in the western Ross Sea sector of Antarctica. The study is based on stable isotope measurements on ice made in INSTAAR's Stable Isotope Laboratory. This result contrasts with evidence from ice cores in other regions of Antarctica,

Temperature records (from stable isotopes) in ice cores from Greenland (GISP2) and Antarctica (Taylor Dome, Byrd and Vostok) covering the time of the end of the last glaciation, 10,000 to 20,000 years ago. The similarities between the temperature records at GISP2, a Greenland site, and Taylor Dome, an Antarctic site, indicate that large, rapid climate changes did occur synchronously at the poles, a conclusion in striking contrast to earlier studies using the other two Antarctic sites, Vostok and Byrd.



which show an asynchronous response between the Northern and Southern Hemispheres. For example, the Antarctic Cold Reversal (ACR), a period of cooling that appears in the Vostok and Byrd Station Antarctic stable isotope records, has in the past been compared with the Younger Dryas (YD), a prominent feature in Northern Hemisphere records (see graph).

Based on new measurements of atmospheric trace gas concentrations in trapped air bubbles by the French, we now know that the ACR occurred at least 1000 years before the YD. Just as we were mulling how to account for this asynchrony of polar climate, the Taylor Dome results show that for some parts of Antarctica, these major climate events are actually synchronous.

The study concludes that the differences between the isotope temperature history from Taylor Dome and those from other Antarctic sites are too large to be attributed to dating errors. Rather, the results indicate that the circum-Antarctic climate response to changes in major ocean circulation patterns, specifically the formation and export of deeper ocean water from the North Atlantic region. Given the current substantial difficulty of realistically simulating ocean atmosphere interactions in general and the dynamics of the Southern Ocean in particular, it may be some time before the role of North Atlantic Ocean circulation in shaping Antarctic climate can be rigorously evaluated. In the meantime, the authors are pushing forward with plans to test this observation by collection and analysis of additional Antarctic ice cores, especially from near coastal sites.

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# Geophysics Group

## Aim

The application of modern mathematical, physical, and chemical knowledge to increase understanding of Earth-system processes is the general objective of the Geophysical Group. Members bring skills in solid and fluid mechanics and dynamics, heat transfer, chemistry, applied mathematics, solid earth geophysical methods, and remote sensing to address questions of how these processes act to create the environment we live in today. The group also seeks to understand how past environments were produced, how predicted future climatic forcing will affect future environments, and how deep-earth processes have been involved in the development of the modern earth environment. The Geophysics Group applies theoretical analysis as well as quantitative field, laboratory, and remote sensing studies, and numerical modeling, to snow, ice, water, and sediments in the world's oceans, glaciers, and land areas.

Public concerns ranging from sea-level rise to deforestation to degradation of ecosystems indicate that global change has become a pressing and controversial topic throughout the world. Disagreement persists about how the global environment may change in the future, and whether human activities are involved in climate change. Work in the INSTAAR Geophysics Group is broadly focused on understanding the physical processes and objects (such as ocean, rivers, sediment, permafrost, glaciers, and snow cover) underlying the changing Earth system. Our research seeks this understanding on a global scale and for site-specific processes which have large-scale or global applications.

## Current Research by the Geophysics Group

### Hydrology, Sedimentation, and the Carbon Cycle

Dr. Robert Stallard's current research focuses on the coupled biogeochemical and geomorphic effects of modern land-use change and Pleistocene climate change. Two hypotheses were tested: (1) that significant amounts of carbon are buried during the deposition of sediments in terrestrial environments, and (2) that human modification of hydrologic systems enhances long-term storage of sediments and carbon. This storage is not significant unless the eroded carbon is replaced by means of photosynthetic processes. Results indicate that terrestrial sedimentation may account for much of the so-called "missing carbon." Field testing of this model is done under the auspices of two projects run by the US Geological Survey: Water, Energy, and Biogeochemical Budgets (WEBB) Project, which has sponsored work in Puerto Rico, Panama, and the South Cascade Glacier; and the Mississippi Basin Carbon Project (MBCP), which focuses on

land-use change in the Mississippi River Basin, with fieldwork in the Nishnabotna, Yazoo, and South Platte subbasins. As part of this work, the role of event-type processes, such as land-slides and fire-flood events, is a major focus, at the hillslope to small-watershed scale.

### Glacier Changes and Sea-level Rise

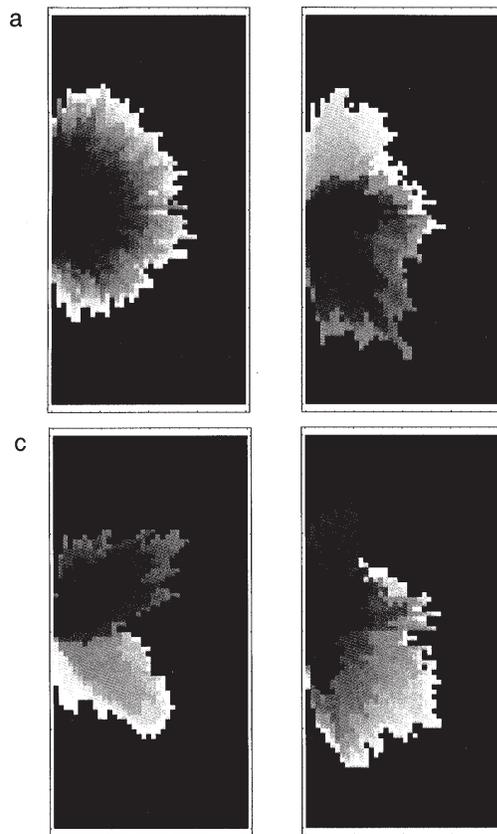
Professor Mark Meier, Dr. Mark Dyurgerov, Dr. David Bahr, and visiting Scientist Dr. Vladimir Konovalov continued regional and global syntheses of glacier mass balance data relevant to the problem of detecting current and predicting future sea-level change (see Research Highlight on p. 6–9). The Glaciology Group welcomed the arrival of Dr. Konovalov, a Senior Scientist from the Central Asia Research Hydrometeorological Institute in Tashkent, Uzbekistan.

### Coastal Sediment Dynamics and Structure

Oceanic continental shelf margins contain a wealth of information relevant to mineral resources, geologic history and oceanographic and climate change. Much of this information is contained in sedimentary shelf deposits, and a wide variety of observational tools exist for the investigation of marine sedimentation. However, the complications of sediment delivery, and seafloor erosion and deposition have been traditionally regarded as being too complex for highly detailed deterministic modeling. By combining individual event models of continental margin processes into one interactive model, INSTAAR has produced a numerical simulator of seascape evolution and its resultant acoustic character. The model is uniquely suited to make predictions of the seafloor characteristics of margins having limited seafloor data. The acoustic nature of buried geological structures can be evaluated in terms of their size and coherency. A component of the model is well suited to predict the discharge characteristics of many ungauged river basins. This modeling technique provides a new approach leading to insights on how local factors compete with global forcing in controlling the fine-scale structure seen in shelf and slope seismic stratigraphy.

Work by members of INSTAAR's Oceans Laboratory ("the Delta Force"), led by Professor James Syvitski, has developed theory and code for predicting the sediment dispersal by river plumes flowing into the coastal ocean. Stratigraphic simulation models (SSMs) are useful for predicting the time-varying impact of sedimentary processes,

Numerical simulations of delta formation by Dr. David B. Bahr are shown in this figure. A delta is formed at the mouth of a river as it enters the ocean (from left to right). Gray levels indicate the time of deposition (white is recent, black is older). The river has channels that switch positions as a random walk. More lobe-like behavior (e.g. figure c) occurs when the random walk is governed by a random distribution with a narrow standard deviation. More rounded deltas (e.g., figure a) are formed by larger standard deviations.



b The INSTAAR Delta Force 1998 saw the recent departure of Dr. Lincoln Pratson to accept a tenure track teaching position at Duke University, and the arrival of Dr. Scott Peckham from the Water Resources Division of the USGS. Dr. Peckham arrived to work on the analysis of environment data records in the visible and infrared wavelength from satellite acquisition on a contract from Raytheon Systems Company. Dr. Bahr, Ph.D. candidate Damian O'Grady and numerical analyst Eric Hutton continued to work on numerical model development related to the reservoir characterization of marine deposits with gift support from MOBIL Technology Corp. Professor Syvitski, Dr. Pratson, and Ph.D. Candidate Mark Morehead continued to work on numerical predictors of sediment transport by rivers, ocean currents, and gravity flows.

### Antarctic Subice Structure

Dr. John C. Behrendt has accomplished an interpretation of a 1995-96 aeromagnetic survey combined with radar ice sounding over the divide of the West Antarctic Ice Sheet and the underlying 3-km relief Sinuous Ridge (which bisects the Byrd Subglacial Basin). The result shows a circular pattern of magnetic-anomaly distribution interpreted as evidence of a 70-km diameter caldera (?) complex (one of the largest on earth) beneath the ice. Models show that sources of the caldera (?) anomalies are at the base of <1-2-km thick ice, and limited examination of radar profiles shows that all but one volcanic edifice have been glacially removed. The exception is a 700-m high, 15-km wide "volcano" producing an 800-nT anomaly marking the south rim of the caldera(?). "Intrusion" of this "volcano" beneath 3 km of ice probably resulted in pillow basalt rather than easily removed hyaloclastite erupted beneath thinner ice.

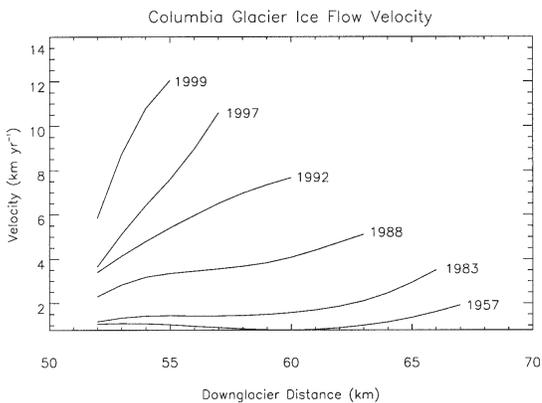
### Iceberg Calving

Dr. Tad Pfeffer has continued an extensive research program to study retreat of Columbia Glacier, the largest tidewater glacier draining the Chugach Mountains of south-central Alaska. This program was initiated by Prof. Mark Meier in the late 1970s and is now being continued in an NSF-funded program involving Prof. Meier, Prof. Bernard Amadei, Robert Krimmel (USGS Water Resources Division office in Tacoma, Washington), and students. Retreat of the terminus has progressed fairly steadily at about 1 km per year, because the increasing iceberg calving rate has been offset by steadily increasing ice flow velocity—a result that was not expected at the outset of the research program. The pattern of calving rate balanced by ice flow velocity may be challenged in the next few years, however, as the Columbia Glacier terminus retreats beyond a narrow constriction in its channel and enters deeper water.

Ice flow velocities are already increasing dramatically. The latest set of velocities on Columbia Glacier, derived by Mr. Krimmel from aerial photography are higher than ever observed before. While the 1997 and 1998 velocity profiles occurred in the spring—when the seasonal variation in

and the distribution of lithostratigraphic properties away from points of control. SSMs allow earth scientists to better understand the behavior of the earth system when the earth was a different planet (i.e. abiotic, hotter or colder atmosphere or ocean, closer moon, more saline oceans). SSMs also prove valuable to those working on modern environmental applications, global warming scenarios, natural disaster mitigation efforts, reservoir characterization, oil exploration, and national security. The difficulty of modeling sedimentary architecture dynamically relates to the numerical task of duplicating inherently complex natural systems and the computational power required. The INSTAAR Delta force has successfully developed both 2D and 3D versions of a fully integrated process-based model that evolve sedimentary sequences over short geologic time scales. The models are being deployed both in federal agencies and petroleum companies

Dr. David B. Bahr, using numerical simulations, has shown that rivers with high sediment outputs form deltas by a process akin to random walks, Brownian motion, and diffusion; channels in this simulation switch positions as a random walk. Lobe-like behavior occurs when the random walk is governed by a random distribution with a narrow standard deviation; rounded deltas form with larger standard deviations. The standard deviation is related to the diffusion coefficient, which can be easily measured in the field.



The along-flow profile of velocity in the lowest 15 kilometers of Columbia Glacier's channel is shown here, as it has varied through time. The ice flow direction in the figure is from left to right, and annual profiles extend progressively shorter distances below kilometer 50 as the glacier has become progressively shorter. Note the major increases of speed from 1957 to the present. These results were obtained by Robert M. Krimmel (USGS), Dr. Mark F. Meier, and Dr. Tad Pfeffer.

velocity is at its peak—the 12.5 kilometer per year maximum velocity at the terminus in March 1998 exceeds the previous maximum velocity (10.6 kilometers per year in April 1997) by 18%, and the typical maximum springtime velocity seen in 1992–1996 (about 8.75 kilometers per year) by 43%. This is now the fastest-moving glacier in the world, except for transient surges, exceeding the speed of the famous Jakobshavn Ice Stream in Greenland. Anomalously high autumn velocities were measured in 1998 – the season when velocities are typically at their low point. Velocities for the interval 2 October–22 December 1998 were 60% greater than those for the interval 12 August–2 October 1998. Thus, the very high velocities observed now are a continuation of a trend of acceleration during a normally quiescent time of year.

Of all the changes in geometry currently being experienced by Columbia Glacier, probably the most important will be the retreat of the terminus into a 500-meter-deep basin only 4 km upstream from the present location of the terminus. Retreat into this basin will in all likelihood result in even larger increases in flow velocity and calving rate. The present rate of change of conditions at Columbia Glacier is the result of a slight imbalance between very large (and increasing) values of ice speed and calving speed. The sensitivity of this slight imbalance to changes in ice and calving speed is very great, and rapid and dramatic changes in the state of Columbia Glacier are almost inevitable at this stage in the glacier's history.

## Achievements

- A major new result was the theory and code for predicting the sediment dispersal by river plumes flowing into the coastal ocean. A paper on this result, by Syvitski, Nicholson, Skene, and Morehead, received the outstanding paper award for those published in *Computers and Geoscience* for 1998.
- Dr. Robert Stallard published a global model for the interaction among pedogenesis, erosion, terrestrial sedimentation, and the carbon cycle. His research suggests that terrestrial sedimentation may account for much of the so-called "missing carbon."
- The INSTAAR Delta Force produced an integrated, process-based stratigraphic simulation model (SSM) for sedimentation in the coastal zone. This model is being used by federal agencies and petroleum companies.
- The cause of the transition between lobe-like and rounded structures of river deltas has been shown by Dr. David B. Bahr to relate to the statistical variance of the river flow.
- Dr. John C. Behrendt found evidence of a huge caldera structure under the West Antarctic Ice Sheet, using airborne geophysical data.
- Dr. Tad Pfeffer and collaborator Robert M. Krimmel of the USGS observed a major acceleration of the iceberg-calving Columbia Glacier in which speeds exceeded any measured by nonsurging glaciers elsewhere, and predict that the acceleration will continue as the glacier enters a new and interesting phase in its retreat.



Dr. Tad Pfeffer measuring the orientation of load cells for a borehole stress measurement unit used at Worthington Glacier, Alaska, as part of a collaborative project with Professor Neal Humphrey, University of Wyoming, Professor Bernard Amadei (CU's Department of Civil, Architectural, and Environmental Engineering), Dr. Pfeffer of INSTAAR, and their students. This device has enabled the first direct, *in situ* measurement of the full stress tensor in glacier ice, a result that will have a number of applications in the active field of glacier dynamics. The Worthington Glacier program has produced a number of new techniques and tools for glacier geophysics since its inception in 1993 as a joint CU-INSTAAR/University of Wyoming project.

- Dr. Mark F. Meier compiled data from many observations that show a remarkable loss of glacier ice in the last 100 years. Reductions in ice volume of 50% were observed in some areas, and many small glaciers are disappearing. This trend will continue and probably accelerate due to global warming.
- Drs. Mark Dyurgerov and Vladimir Konovalov produced new results on the impact of glacier wastage on sea level and on runoff variability. Glaciers currently produce more than 20% of the observed sea-level rise, and the glaciers of Central Asia can now be recognized as having a major role in this effect. Streamflow variability in Central Asia has been naturally regulated by glacier mass exchanges, and in some cases runoff has temporarily increased due to glacier wastage.
- Dr. David B. Bahr has developed additional stochastic scaling functions which assist large-scale syntheses of glacier behavior, and which may set the stage for fully-integrated projections of the impact of glaciers on sea-level change, of interest to the IPCC and society as a whole.
- A glacier borehole stress measurement instrument has been developed, as part of a collaborative project with Professor Neal Humphrey, (University of Wyoming), Professor Bernard Amadei (CU's Department of Civil, Architectural, and Environmental Engineering), Dr. Pfeffer of INSTAAR, and their students. This device has enabled the first direct, *in situ* measurement of the full stress tensor in glacier ice, a result that will have a number of applications in the active field of glacier dynamics.
- Dr. John C. Behrendt recounted his experience on the initial scientific exploration of the Filchner-Ronne Ice Shelf system during the International Geophysical Year in the book, *Innocents on the Ice; a Memoir of Antarctic Exploration, 1957*. He compared and contrasted the U.S. Antarctic Program of that era with the changes to the present.
- Dr. Mark F. Meier presented the Walter B. Langbein Memorial Lecture at the Spring Annual Meeting of the American Geophysical Union, and a special seminar on Capitol Hill organized by the US Global Change Research Program. Both presentations discussed changes in climate, glaciers, water resources, and sea level.

## Facilities

Facilities maintained by the INSTAAR Geophysics Group include extensive work station-based numerical modeling platforms and graphics facilities, oceanographic apparatus, complete glaciological field supplies, and various laboratory facilities, including refrigerated apparatus for frozen ground studies and a 400 square-foot walk-in cold laboratory. INSTAAR Geophysics Computing Facilities include 7 Unix servers (HP-725, HP-715, DEC-433au, SGI-O2, Sparc 10, Sparc 20, Ultra 30), 6 Unix clients, and numerous networked PC and Mac computers. The Oceans Laboratory has a state-of-the-art Floc Camera Assembly, including digital, video, and conventional photographic components, SBE 19 SEACAT (CTD) Profiler, Sea Tech transmissometer, LISST 100 laser Particle Sizer, settling and profiling frames. The INSTAAR Delta Force operates 12 workstations, X-terms and PCs with a combined power of 2GB of RAM and 65GB of hard drive, including printing and scanning peripherals. The Snow and Ice Laboratory is built around a 400-square-foot cold room, with facilities presently configured for experimental work in heat and mass transfer in snow, as well as general electronics and mechanical design and fabrication. INSTAAR has a fully equipped Sediment Laboratory, which is used by geophysics members and other research groups.

# Ecosystems Group

## Aim

The primary aim of the Ecosystems Group is to study the ecological components of arctic and alpine systems and their interactions with climatic and biophysical variables. In addition, the Ecosystems Group has recently expanded its research efforts to other areas from montane and submontane systems to the tropics and also to several aspects of the human dimension. Basic research topics include ecosystem dynamics, biogeochemical processes, biodiversity, ecosystem disturbance and recovery, modeling of biotic pattern distribution, ecological assessments, and conservation planning. We address general questions of how the climatic and biophysical factors and biotic components interact to control the distribution and maintenance of ecosystems; how the hierarchical organization of current ecosystems was produced in response to past and present environments; how predicted climatic changes and current and future changes in land-use patterns will affect ecosystems; and how conservation planning can contribute to sustainable desirable future conditions of ecosystems at multiple geographic scales.

## Background

Changes in ecosystem structure, function, and distribution, whether induced by global climatic shifts or by land-use practices, have become a pressing and controversial topic worldwide. Public awareness and concern have increased in response to climatic events (e.g., droughts and blizzards) which have led to dramatic large-scale floods and fires. Indeed, such recent events as the Yellowstone fires and floods in the Midwest have led to the rapid implementation of regional ecological assessments in order to mitigate the effects of potential changes and sustain managed and natural ecosystems. The general public and politicians have increasingly sought answers from scientists about how much pressure ecosystems can withstand, what probable changes will occur, and how to sustain ecosystems within desirable bounds. As both public perception and need for scientific advice have increased, disagreements and lack of understanding have persisted concerning how the potential changes may affect ecosystems, whether and how human activities interact with other changes to alter ecosystems, and what the appropriate geographic and temporal scales are at which these changes may be expected.

To answer these questions, work in the Ecosystems Group is organized along six general scientific objectives: (1) effects of global changes on ecosystem composition and structure; (2) degree to which various biogeochemical processes (e.g., C, N, and P cycles) constrain ecosystem response; (3) relationships between biophysical and biotic components of ecosystems; (4) determination of the appropriate ecological units for analysis at various geographic scales and definition of the types of ecological issues and functions that must be addressed at each scale; (5) linkage of terrestrial and aquatic systems; (6) prototyping new methods for conservation planning. Meeting these objectives and integrating results will provide the basis for answering basic

scientific questions and societal demands for understanding and predictions of ecosystem response to global changes and human activities. Most projects of the Ecosystems Group are interdisciplinary and each includes two or more of these objectives.

## Summaries of Activities in 1998

Dr. Patrick Bourgeron continued his work on large-scale ecosystem characterization and modeling of biotic patterns. Dr. Bourgeron studies the climatic and biophysical controls on the distribution of biotic patterns (species and communities), the hierarchical organization of ecosystems, and the applications of new techniques to conservation planning. Under grants from the US-EPA the USDA Forest Service, Dr. Bourgeron and his group have quantified the performance of several hierarchical classifications used by state and federal agencies for land management and land use planning (see achievements). They also have analyzed the regional-scale patterns of vegetation structure and the controlling factors for the vegetation of the interior Columbia River basin. This is the first study of the multiscaled controls on vegetation structure over such a large area using a very large data set (ca. 18,000 plots and 2500 species). Another project of the group consisted in developing a knowledge base integrated within a GIS framework to assess the suitability of land areas for conservation. This approach marks the first time that fuzzy logic network is used for conservation planning.

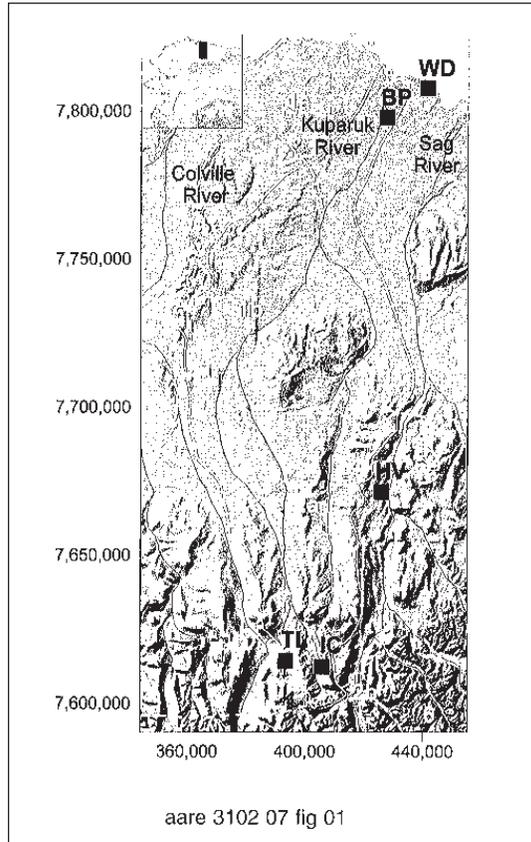
Dr. William Bowman has continued work on the biotic control of alpine ecosystem processes and on partitioning of N species as a mechanism of coexistence in alpine tundra with funding from Environmental Protection Agency and the



Tundra Laboratory on Niwot Ridge. Photo courtesy Tim Seastedt

Shaded relief map of the Kuparuk River basin in north-central Alaska (outlined in white). Arctic System Science (ARCSS) grids are shown with squares.

Physiographic provinces: 1a/b–Arctic Coastal Plain; 2a/b–Arctic Foothills; and 6–Central and Eastern Brooks Range are shown (from Nelson *et al.*, 1999, in *Arctic, Antarctic, and Alpine Research*, p. 180).



Mellon Foundation. Dr. Diane McKnight's recently established limnology laboratory is now being used for all of her projects. Dr. McKnight's work includes studies on biogeochemical processes in mountain watersheds in Colorado in the Snake River-Deer Creek catchment in Summit County, Colorado; laboratory experiments focusing on microbial interactions with humic substances; research on hydrology and stream ecology at the McMurdo Dry Valleys Long-Term Ecological Research (LTER) project in Antarctica and maintenance of that LTER database.

The Niwot Ridge, INSTAAR-based LTER, coordinated by Dr. Tim Seastedt, has continued interdisciplinary research on alpine ecosystems. The LTER includes all the ecosystem group members in various research activities. A major milestone has been achieved with the fourth renewal of the project. The next six years of the Niwot Ridge LTER includes work on the subalpine forests neighboring the alpine ecosystem. Studies will be initiated to analyze and model the linkages between the alpine tundra and the high elevation forests. Work proceeds on alpine sensitivity to climate changes, in particular on the switch from nitrogen (N) limited to N-saturated ecosystems due to atmospheric deposition following the results of Dr. Mark Williams *et al.* (1996). Process-level control on N-cycling is still a major area of research. Microbial activity and the role of individual plant species on N-cycling have been further identified as key

agents in alpine ecosystem dynamics. Niwot Ridge LTER-funded projects undertaken in 1998 include effects of tree islands on soil characteristics; the role of pocket gophers; fauna-substrate quality interactions in decomposition processes; effects of snowpack on decomposition processes; impact of anthropogenic N deposition; a long-term snow-fence experiment; and analyzing long-term vegetation response to climate change.

Dr. Alan Townsend has continued his work on terrestrial biogeochemistry, with emphasis on regional to global scale C and N cycling, and on the response of tropical ecosystems to changes in climate, land-use, and nitrogen inputs. Dr. Townsend studies biogeochemical dynamics along gradients of land-use and soil type in the central Amazon. The focus is on how changes in P and base cation cycling affect C balance. Dr. Townsend is also involved in the SCOPE international nitrogen project. The objectives of this international, multi-investigator project are to hold a series of workshops, perform data synthesis, and develop models to answer questions about the extent and effects of a changing global N cycle.

Work by members of INSTAAR's Tundra Ecosystem Analysis and Mapping Laboratory (TEAML) directed by Drs. Marilyn and Skip Walker continues on many aspects of arctic ecosystems. Dr. M. Walker is pursuing a modeling effort as part of a multi-institution project examining sustainability of arctic human communities in the face of both environmental and cultural/sociopolitical/economic changes. Dr. M. Walker is also part of a larger international effort of linked sites that conduct field experiments investigating the responses of arctic and alpine plant species and communities to changes in summer temperature and winter snow regime. Dr. S. Walker continued work on the Arctic System Science Flux Study, where he is investigating the interactions between climate, substrate, and vegetation. A circumpolar pH boundary separating acidic Low Arctic ecosystems from nonacidic High Arctic systems was found that has major implications for energy and trace-gas fluxes, and for wildlife distribution patterns (see achievements below). Additionally, Dr. S. Walker is directing the Circumpolar Arctic Vegetation Map (CAVM) effort. The electronic geobotanical atlas developed for the Kuparuk River Basin and the Arctic Long-Term Ecological Research Site by Dr. S. Walker and his group has been widely distributed. Finally, Dr. S. Walker obtained funding for a 5-year, \$2.045 million project entitled "Arctic Climate Change, Substrate, and Vegetation" as part of the NSF Arctic Transitions in the Land-Atmosphere System (ATLAS) project.

Dr. Mark Williams continues to research and publish on watershed dynamics and sensitivity. His work in San Miguel County, Colorado, documents the sensitivity of alpine ecosystems to development (e.g., ski resorts). By collecting and analyzing water quality samples from 18 headwater basins, Dr. Williams has established a scientific basis for zoning laws. Dr. Williams conducts additional research on aquatic terrestrial linkages under 12 grants with funding from NSF, Army Research Office, National Park Service and the China NSF.

## Achievements

In 1998, while conducting their research activities, the members of the ecosystem groups found intriguing, remarkable results in their area of expertise that resulted in advances of their scientific field and either will benefit or have the potential to benefit society. Some of these achievements are outlined below.

Hierarchical ecological classifications (HECs) are increasingly used in ecological assessments for management and conservation purposes at continental, regional and landscape scales. Decisions are made using these HECs that impact the economy and the human communities of entire regions. Competing HECs have been proposed. While considerable controversy has risen and still is rising over which of those is the most appropriate for specific purposes, and even if they are useful at all for any purpose, very little work has been done to formally compare these HECs and assess their relative performance. Dr. Bourgeron and his team have designed and implemented a series of the studies to test the ability of terrestrial and aquatic ecological classifications to represent the regional variation in specific patterns and processes in the ICRB. Results indicate that a strong relationship exists among all HECs tested and that the higher levels of the terrestrial classifications explain a significant portion of the variance of finer scale aquatic patterns. However, the strength of the relationships among ecological classifications varies depending upon scales, pattern, and process of interest. The results will allow governmental agencies and nongovernmental organizations (NGOs) to test whether the stratification of an area in ecological regions results in increased confidence in the management decisions and whether existing systems can be used with no new R&D cost, or at the opposite new research and development (R&D) should take place before decisions are made.

Dr. William Bowman and Heidi Steltzer investigated an important potential biotic response to N deposition in the alpine (Bowman and Steltzer, 1998). Two questions were addressed: 1) is there a positive feedback to N cycling as a result of increased N deposition?; 2) if yes, will this feedback result in a nonlinear response of the tundra to increasing N inputs? Results indicate that increasing N inputs will result in changes in plant species composition which, will have a positive effect on N cycling. Replacement of slow-growing dominant species, which have high production of phenolics, by fast growing species with high root turnover, would lead to a 10-fold increase in net N mineralization rates, higher soil  $\text{NO}_3^-$  levels, and potentially greater leaching of N into surface waters. This work pieced together some puzzling aspects of the impact of environmental change in the alpine by explicitly linking anthropogenic changes and biotic response in a pristine ecosystem. These results show that human induced N deposition could have a very important influence on water quality and the rate of acidification of surface water on alpine streams of the Front Range.



Field work on Niwot Ridge.  
Photo courtesy Tim Seastedt

Dr. Diane McKnight and colleagues have made an advance in understanding the biogeochemical role of humic substances, a large fraction of natural organic material in soil, sediment and natural waters. Rather than being recalcitrant organic material removed from energy and carbon cycling, humic substances can act as terminal electron acceptors in the microbial degradation of organic compounds under anoxic conditions. Using electron spin resonance spectroscopy, quinones were shown to be the chemical groups in the humic material responsible for accepting electrons (Scott et al., 1998). Humics may be particularly important electron acceptors in the degradation of organic contaminants found in marine and freshwater sediments. The amount of quinones in humics varies significantly among different environments. In the research for the McMurdo Dry Valleys LTER project, progress was made on understanding nitrogen cycling in the glacial meltwater streams which flow during the austral summer. Analysis of an experimental addition of nitrogen and phosphorus showed that the cyanobacterial mats have a large capacity to assimilate nutrients, controlling the nutrient flux to the receiving lakes, and that dissimilatory nitrate reduction occurs in the sediments underlying the stream. Further, analysis of the record for lake level rise over the past century showed that the climate has been much warmer in the past 30 (1968-1998) years than in the previous 65 years (1903-1968). These results can be used with other data sets to understand the changing climate in the Antarctic.

Dr. Tim Seastedt worked on several projects that related life history phenomena of autotrophic and heterotrophic organisms to patterns of carbon and nitrogen sequestration in soils. Current knowledge and models assumed that the vegetation functions as a block with respect to C and N sequestration. Dr. Seastedt specifically compared soils of tree islands to those of adjacent tundra. Results indicated that root productivity in deeper soil horizons of the tundra was largely responsible for enhanced carbon storage at those sites.

Enhanced nitrogen enrichment of more recalcitrant, decomposing substrates in graminoid-dominated ecosystems is correlated with reduced decay rates of these substrates and is consistent with global patterns of carbon sequestration in grasslands and forests. These identified differences among biomes change the conceptual framework used to build models. Results have implications for policy dealing with carbon sequestration (e.g., several aspects of land use) and mitigation (e.g., power plants).

Dr. Skip Walker and colleagues published ground-breaking results in *Nature* (Walker et al., 1998). Studies and models of trace-gas flux in the Arctic usually consider temperature and moisture to be the dominant controls over land-atmosphere exchange with little attention paid to the effects of different lithologic substrates. Dr. Walker et al. studied the ecosystem properties on either side of a prominent pH boundary with the Kuparuk River basin in Alaska. Results show that rapid changes in ecosystem processes (e.g., photosynthesis and respiration) that are related to changes in climate and land usage will be superimposed upon and modulated by differences in substrate pH. Therefore, substrate is probably as important as climate in controlling gas flux and other ecosystem properties. These results change our view of the arctic ecosystems and our conceptualization of vegetation dynamics in that region, as well as the possible response of the arctic vegetation to global change.

Dr. Alan Townsend addressed the question the biogeochemical consequences of conversion of tropical forests to cattle pasture in the central Amazon, Brazil. Results indicate that sites degrade over time as expected. However, the very large amount of loss in cations and phosphorus was unexpected. The amount of cation and P loss was correlated with soil types and management practices. Some sites lost all of their P. Implications of these losses are potentially severe. To replace P, it would take up to thousands of years in some soils. Results indicate the potentially significant effect of tropical land use, adding a new aspect to our current knowledge.

Dr. Mark Williams and his group continued their research to understand local area change in the context of the global-local continuum so as to translate science into public policy. Their research aims at preventing future degradation of high-elevation ecosystems in the San Miguel drainage from future degradation. Water quality parameters were used to evaluate basin sensitivity to perturbations such as ski-area expansion, construction of trophy homes, and new roads. This scientific information was the foundation for developing land use codes to protect 18 headwater catchments in and near the Telluride area. This work has two significant implications: 1) scientific approach and land-use codes developed for the Telluride area are transferrable to other sites and set a precedent for doing so; 2) this research project serves as a model for how county, state, federal, and university researchers can work together to understand and protect natural resources.

## Facilities

Facilities maintained by the Ecosystems Group include extensive work-station-based statistical and numerical modeling platforms, GIS, remote sensing and graphics facilities, ecology and hydrology field supplies and analytical apparatus, and biogeochemistry laboratory equipment.

The LTER operates an analytical laboratory at MRS, the Kiowa Environmental Chemistry Laboratory directed by Dr. Williams, which performed about 20,000 separate analyses on water and soil samples during the year. The LTER also maintains an extensive on-line database on its web site (<http://culter.colorado.edu:1030/>) which experienced almost 50,000 visits in 1998. Additionally, two subnivial laboratories on Niwot Ridge managed by Dr. Williams include two fully-equipped meteorological towers with fast-response eddy correlation equipment for measuring turbulent fluxes, 100 snowmelt lysimeters, 16 zero-tension lysimeters, and other field equipment.

Dr. McKnight's laboratory is equipped for analysis of water samples for major cations and trace metals using a Perkin Elmer Atomic Absorption spectrophotometer, and for dissolved organic material using a Dohrmann carbon analyzer. Other capabilities include isolation and purification of humic substances from waters and sediments using preparative-scale column chromatography, and incubation and analysis of microbial and algal cultures and samples from the field. Incubations are done in a large environmental chamber.

Dr. Townsend's laboratory is equipped for wet chemistry with an emphasis on analyses of C, N, and P in plant tissues and soils. In addition to the basic set of wet lab needs, current equipment includes multiple full size incubators, an Alpkem autoanalyzer for N and P, drying ovens, microbalances, autoclave, and a temperature controlled centrifuge. A Carlo-Erba CHN analyzer set up both as a stand alone instrument and equipped to be linked to a continuous flow mass spectrometer will be added in the summer of 1999.

TEAML supports a large array of computing equipment: two DEC Alpha workstations, two DEC station computers and 10 Macintosh computer systems, and a full complement of peripheral devices for GIS and remote sensing including a large format digitizer and an inkjet plotter. Software packages include: ARC/INFO (GIS), ENVI (remote sensing software), IMAGEZ (graphic software), Adobe PhotoShop 4.0.1, and Macromedia Freehand 7.02. TEAML's equipment for vegetation analysis include: a plant-canopy analyzer, an LAI meter, a line-quantum sensor, spectrometers, and complete laboratory for equipment including dryers and freezers.

The Ecosystem Characterization Laboratory led by Dr. Bourgeron supports two Sun workstations, a Dell workstation, five PCs, and an inkjet plotter. Numerous analytical and modeling software packages include ARC/INFO, ArcView, S-PLUS, S+SPATIALSTATS, EMDS, NetWeaver, GLIM, CANOCO, and others.

# Past Global Change Group

## Aim

The Past Global Change Group aims to reconstruct the dynamics of past environmental and climatic variability in order to enhance our understanding of the interactions between all components of the global system, including atmosphere, ocean, land, ice, and the biosphere. Integration of a variety of records from a global network of sites, from the polar ice caps to alpine regions in all continents, and from all of the world's oceans, provides the capability to test conceptual and predictive global change models, and to facilitate the differentiation between natural and human-induced change.

## Background

The instrumental record that spans the last 100 years is simply too short to capture the full range of climate variability needed to understand the natural variability of climate. Longer climatic records are needed. For these we must rely on proxy data from tree-rings, ice cores, lake, bog, and ocean sediments, corals, and other natural recorders of past environments. In addition to providing a window on the past, these records can be used to identify and understand processes that may affect climate on earth in the coming decades, for example the response of the climate system to changes in the amount of carbon dioxide in the atmosphere. Human activities are not the only source of greenhouse gases, and paleoenvironmental research done at INSTAAR and elsewhere has shown that the greenhouse blanket has varied in the distant past as well as in this century. Understanding how this system works requires models as well as observations, and INSTAAR is actively engaged in testing and improving numerical models of the components of the global climate system, and how climate interacts with other aspects of the environment. At INSTAAR, the Past Global Change Group conducts field and laboratory research to produce needed records of past environment, in Colorado and in other parts of North America and the world. Our funding from the National Science Foundation and other sources provides many opportunities for students to participate in research in both the field and the laboratory. Recognizing that climate operates as a system on a global scale, the group's research is not confined to a single discipline or region. One example of interdisciplinary/inter-regional work is the Pole-Equator-Pole (PEP) transect, which was one of the first international initiatives of the Past Global Changes Program (PAGES). It is well on its way to accomplishing the PAGES (and INSTAAR) objective of producing the panhemispheric array of paleodata needed to understand past climate changes.

## Achievements

- 15,000-year continuous record of El Niño climate in the Andes  
Dr. David Anderson published the results of a lake-sediment study from a high-altitude lake in southern Ecuador. This is the longest continuous record ever published for this region. It documents flood events in the lake that are triggered by storms in El Niño years, and the record shows that the modern El Niño climate pattern did not become established until about 5000 years ago.
- First marine record of deglaciation on the coast of Chile  
Dr. David Anderson and a team of researchers from INSTAAR and the National Oceanic and Atmospheric Administration (NOAA) Paleoclimate group took sediment cores from the Chilean Channels region. The sedimentary record joins a body of evidence showing the differential timing of deglaciation events between the Northern and Southern Hemispheres; deglaciation took place along the Chilean coast about 2000 years before the retreat of continental ice sheets in the Northern Hemisphere.
- East Greenland shelf: glaciated during the last glacial maximum (LGM)  
Dr. Anne Jennings, Dr. John Andrews, and INSTAAR graduate student Laryn Smith studied sediment cores from the East Greenland shelf region, and discovered that this shelf was covered by glacial ice during the LGM. This work followed up on seismic studies led by James Syvitski. The discovery is important because it shows that the East Greenland shelf was a major source of icebergs during the deglaciation, which began by 14,500 yr B.P. These icebergs moved out into the Denmark Strait between Greenland and Iceland, and may have played an important role in Heinrich events (see below) seen in North Atlantic sediment records.

Rough seas in Hudson Bay during research cruise on CCGS Hudson. Photo courtesy Don Barber



- Ice core work links Norse history to paleoclimates of Greenland

Dr. Lisa Barlow has been working with the NABO team and Dr. Anne Jennings to link paleoclimate data from Greenland ice cores and marine cores with the historical and archaeological records of the western Norse settlement in Greenland. In this collaboration, the team has discovered that the initial Norse colonization (ca. AD 985) took place at the end of a century of relatively mild climate in which sea ice posed no risk to travelers. Ice core isotopic records suggest that the settlers experienced above average temperatures for the first 6 to 12 years after landing; the longest period of "mild" weather for centuries to come.

- Multiproxy records link human history and climate in North Atlantic region

Dr. Astrid Ogilvie has led an interdisciplinary study linking instrumental, historical, ice-core, and marine and lake sediment records in Greenland and Iceland. Among their recent accomplishments, the research group has discovered that there is good correlation between marine sediments in southern Iceland (developed by Dr. Anne Jennings) and the historical sea-ice record for the coasts of Iceland. The marine record complements the historical climate record and in some cases may be used to fill in gaps in the historical record.

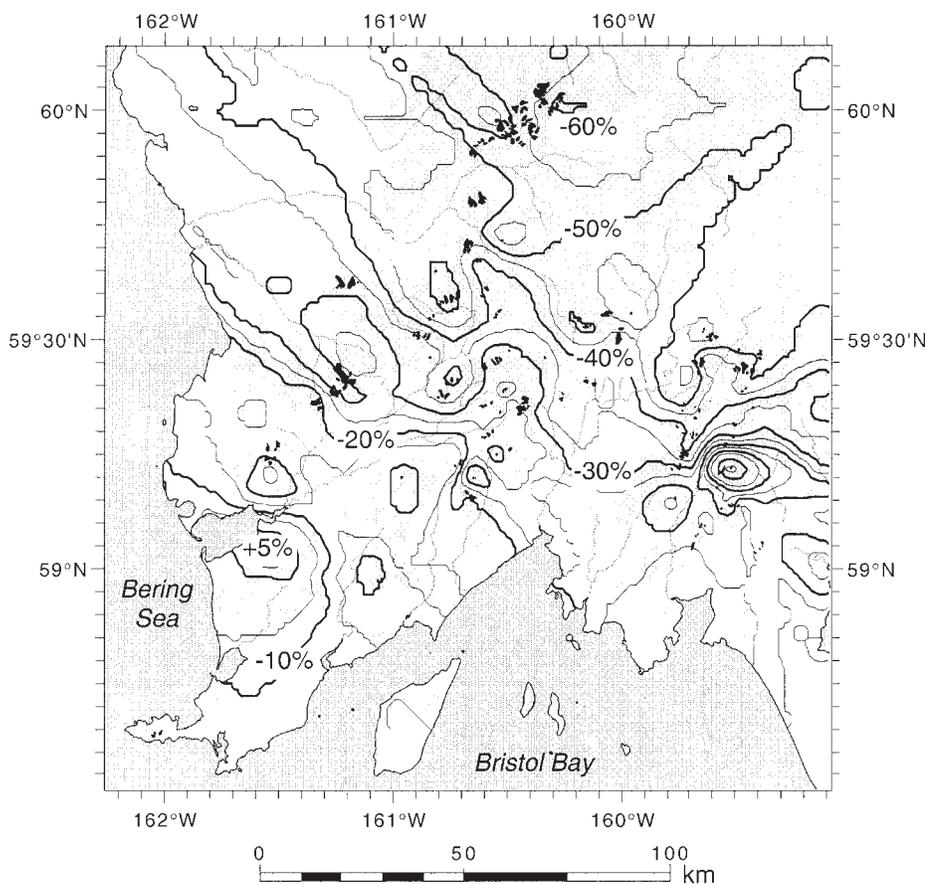
- Early Holocene cold event the result of glacial lake drainage

INSTAAR graduate student Donny Barber, working with Dr. John Andrews, Dr. Anne Jennings, and others, has discovered that a cold event that is registered in deep sea core sediments throughout the North Atlantic was brought on by the rapid, large-scale influx of cold meltwater from huge glacial lakes that existed south of Hudson Bay toward the end of the last glaciation. As the Laurentide Ice Sheet melted, these ice-dammed lakes emptied into the North Atlantic via the Hudson Strait. This paper has been submitted to *Nature*.

- Heinrich events: research in eastern Canadian Arctic led the way

Dr. John Andrews has recently reviewed the literature concerning Heinrich events, pulses of ice bergs that calved from the edges of the Laurentide and other ice sheets that drifted across the North Atlantic in the late Pleistocene and earliest Holocene. The groundwork for Heinrich's description of this phenomenon was laid by researchers studying the sediments in the Labrador Sea and Baffin Bay in the 1970s and early 1980s, but these earlier studies did not have access to reliable chronologies of these events. Moreover, the prevailing paradigm at this time was focused on Milankovitch variations and the evidence for abrupt changes in ice sheet/ocean interactions had not been well documented nor accepted.

Winter precipitation anomalies about 20,000 years ago for southwestern Alaska, estimated from glacier equilibrium-line altitudes. The study area, 450 km southwest of Anchorage, was on average about 35% drier than it is today. Anomalies range from ca. 50% drier than present in the northeastern portion, to ca. 5% wetter than present in the southwestern portion of the study area. Small, former glaciers are shown in black. Using the glacier data to reconstruct precipitation patterns clarifies past climate dynamics, and helps to test model simulations of future climate change.



- Great Basin Pleistocene insect fauna shows links with Pacific Northwest-style climate

Dr. Scott Elias worked with Drs. David Rhode and Peter Wigand from the Desert Research Institute, Reno, to develop a fossil insect record from Great Basin packrat middens in Nevada. The late Pleistocene beetle faunas are composed of species mainly found today in the Pacific Northwest region, from the Alaskan Panhandle to northern California. This research shows that late Wisconsin climate in the Great Basin was substantially cooler and wetter than it is today.

- Beetle evidence for a Younger Dryas oscillation in Beringia  
Dr. Scott Elias has developed the Mutual Climatic Range (MCR) method of paleoclimate analysis for use with fossil beetle assemblages from Beringia (regions of northeastern Siberia, Alaska, the Yukon, and the Bering Land Bridge that were unglaciated in the late Pleistocene). His results show a dramatic rise in summer temperatures just prior to 11,000 <sup>14</sup>C yr BP, followed by a rapid cooling (on the order of 7°C mean July temperature). This phenomenon has been documented in Beringian pollen profiles, but the temperature changes have never before been quantified.

- Digital mapping reveals relationships between Pleistocene glaciers and precipitation in Alaska

Dr. William Manley is using a Geographic Information System (GIS) to map variations in the extent of late Pleistocene valley glaciers in southwestern Alaska. Bill is using this new method to quantify glacial responses to changing precipitation patterns (see figure). He has found that southwest Alaska was substantially drier (up to 60%) during the Last Glacial Maximum (LGM) (ca. 20,000 yr BP) than it is today, in part because the Bering Land Bridge that connected Siberia to Alaska blocked the flow of moisture to many interior regions. Because sea level was relatively high at the beginning of the Wisconsin glaciation (ca. 80,000 yr BP), Alaskan glaciers were larger at that time than they were during the LGM. This is an important difference between Eastern Beringia (Alaska and the Yukon Territory) and most high-latitude regions of the world, where the ice volume during the LGM was greater than it had been in the early Wisconsin interval.

- Patagonian lakes yield sediment records spanning late Pleistocene

As part of the IGBP-PAGES effort to retrieve long paleoclimate records that cover several glacial/interglacial cycles, Dr. Vera Markgraf has been leading an international team of paleolimnologists to reconnoiter three closed, extra-Andean lake basins in Argentina at latitudes 33°, 41° and 49°S, Salinas del Bebedero, Lagos Cari-Laufquen Grande, and Lago Cardiel, respectively. The initial site survey included modern sampling (chemistry and isotopic signature of all water bodies in the basins and of fossil content of surface samples), seismic analysis of the three basins, retrieval of short



Field work using a Linvingtone corer. Lago Cardiel, Argentina. Photo courtesy Vera Markgraf.

sediment cores for dating by <sup>210</sup>Pb and <sup>14</sup>C and study of these sediments for pollen, diatom, and ostracode stratigraphy. Preliminary results were presented at the 1998 American Geophysical Union Fall meeting. The team has documented a series of low- and high-stands of Lago Cardiel over the past 30,000 years. The second portion of this project will focus on the recovery of longer sediment cores, expected to yield records dating back beyond the last full glacial interval.

## Facilities

The Micropaleontology Laboratory includes equipment for preparation of samples for micropaleontological and carbon dating and computers for data analysis. It has a wet lab for marine sample analysis using x-radiography, photography, and magnetic susceptibility. The Palynology Laboratory includes two separate chemical pretreatment labs and one combined microscope and computer lab. The processing lab contains state-of-the-art equipment of chemical pretreatment of samples. The microscope lab is fully equipped with several high-powered microscopes (anox, Olympus, Leitz Ortholux, and Zeiss), a binocular microscope (Wild), and three computers with software for statistical analysis of data and plotting programs. Pollen reference collections emphasize arctic, alpine, and southern hemisphere collections. The Quaternary Entomology Laboratory includes wet lab for fossil extraction and microscopy lab for specimen identifications. The fossil collection contains more than 10,000 identified specimens; modern collection contains more than 5000 identified specimens. The Sedimentology Laboratory serves several research groups. It is equipped with a settling tower, SediGraph, Malvern Analyzer, carbon, sediment color, reflectivity, and susceptibility analyzers, in addition to standard sediment analysis equipment.

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# Library Collection and Publications

The INSTAAR Reading Room continues to grow and to provide increasingly wide access to information around the globe. The Reading Room web site <<http://www.colorado.edu/INSTAAR/ReadingRoom/>> has added several pages this year, notable of which is "Electronic Journals." Links on this page provide full text access to over 500 journals, through the University of Colorado Libraries subscriptions. In addition, several "electronic only" journals are available through these links. Numerous other web site links connect the user with such databases as GeoRef, Geobase, and Biosis.

The Reading Room branch at the Mountain Research Station has access to these same resources in addition to a complete list of the 50 theses held at their library.

Internal electronic indexes to the Reading Room collections continue to be updated and upgraded both in terms of software and content. The book collection, hitherto

electronically searchable only on CD-ROM, is now searchable as an Inmagic file, as is the case with several other Reading Room files. The Inmagic software allows broad search capabilities, and now allows the user to access our collection with knowledge of only one software program. One CD-ROM, Arctic and Antarctic Regions, is still vital for access to periodical literature on the polar region.

## Publications

INSTAAR publishes two series: *Arctic and Alpine Research*, a quarterly journal, and *Occasional Papers*, an irregular monograph series.

*Arctic and Alpine Research* is a refereed quarterly, interdisciplinary journal devoted to publishing original research papers, shorter contributions, resulting correspondence, and book reviews. This internationally authored and circulated journal reports on any scientific or cultural aspect of arctic/subarctic and alpine/subalpine environments and related paleoenvironments. The content of the journal reflects areas of research performed at INSTAAR. The journal will expand its coverage and readership in 1999 and continue as *Arctic, Antarctic, and Alpine Research*.

James Syvitski is Editor of the journal and Kathleen Salzberg is Managing Editor. The Editorial Board is composed of INSTAAR and University of Colorado faculty; members review papers and advise on policy. An international Interdisciplinary Board reviews papers and promotes the interests of the journal in their respective countries. Most of the peer reviewers are selected by the Editor and Managing Editor from outside the boards.

During 1998, 96 papers were submitted for review, an increase of 16 over 1997. Volume 30, 1998 contained 436 pages and included 45 research papers. First authors represented 17 countries. Overall rejection rate is about 30%. The journal web site was launched in 1998, in order to give the journal wider exposure to potential authors, subscribers, and other readers. It contains contents and abstracts of recent issues, instructions for manuscript submission, and subscription information. The address is [www.colorado.edu/INSTAAR/arcticalpine/](http://www.colorado.edu/INSTAAR/arcticalpine/).

The *Occasional Paper* series is a miscellaneous collection of reports and papers on work performed by INSTAAR personnel and their associates which are generally too long and data intensive for publication in research journals. No new titles were published in 1998. *Occasional Paper* No. 53, "Streamflow and Water Quality Characteristics for the Upper Snake River and Deer Creek Catchments in Summit County, Colorado: Water Years 1980 to 1990" by Elizabeth W. Boyer, Diane M. McKnight, et al. is in press for publication in 1999.



Middle-school students attending INSTAAR's Open House learn about the Reading Room collection.

# INSTAAR Courses

CHEN	3320	Chemical Engineering Thermodynamics	W. Krantz
CHEN	5210	Transport Phenomena	W. Krantz
CVEN	4834	Elementary Education in Alpine Biology*	D. McKnight
CVEN	5894	Surface Water Quality Modeling	D. McKnight
CVEN	XXX	Alpine Ecology and Elementary Education	D. McKnight
CVEN	5834	Stream Ecology	D. McKnight
ENVS	3930	Internship in ENVS	J. White
EPOB	3020	Principles of Ecology	B. Bowman & A. Townsend
EPOB	4500	Global Biogeochemical Cycles	J. Cole & A. Townsend
EPOB	4040	Conservation Biology*	M. Dybdahl (Indiana Univ.)
EPOB	4520	Plants of Colorado*	J. Gellhorn (Independent)
EPOB	4100	Field Ecology*	M. Grant (EPOB)
EPOB	4120	Mammology*	B. Rosenbaum (EPOB)
EPOB	4/5170	Ecosystem Ecology	T. Seastedt
EPOB	4100	Lake & Stream Ecology*	L. Smith & R. DiDomenico (EPOB)
EPOB	6000	Biosphere-Atmosphere Interactions	A. Townsend
GEOG	3511	Introduction to Hydrology	N. Caine
GEOG	6241	Geomorphology/Hydrology	N. Caine
GEOG	5241	Periglacial Geomorphology	N. Caine
GEOG	4241	Principles of Geomorphology	N. Caine
GEOG	5133	Data Processing for Earth Science	N. Caine
GEOG	4291	Mountain Geomorphology*	J. McCalpine (Utah State)
GEOL	3023	Statistics for Earth Sciences	J. Andrews
GEOL	1060	Global Change I	J. Cole & L. Barlow
GEOL	4/5700	Global Environmental Modeling	J. Cole
GEOL	4/5800	Global Biogeochemical Cycles	J. Cole & A. Townsend
GEOL	5710	High-Latitude Glacimarine Processes/Products	J. Syvitski
GEOL	1070	Global Change	J. White & L. Barlow
GEOL	3520	Environmental Issues	J. White
GEOL	1110	Global Change Lab	J. White
GEOL	5770	Stable Isotope Geochemistry	J. White

\*courses offered through the Mountain Research Station



Mountain Research Station—  
John W. Marr Laboratory

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# INSTAAR Noon Seminars

John Aber (University of New Hampshire), "Nitrogen Reservoirs in Carbon-Limited Soils"

Jill Baron (USGS/Colo. State Univ.), "Biogeochemistry of Alpine Catchments in the Colorado Front Range"

Larry Benson (USGS), "High Resolution Studies of Great Basin Lakes"

Harald Bugmann (INSTAAR/NCAR Visitor), "What Can Succession Models Tell Us about Past and Future Vegetation Structure?"

Parker Calkin (INSTAAR), "Tree-Ring Based Holocene Glacial Chronologies in the Gulf of Alaska"

Andy Dugmore (University of Edinburgh), "Tephrochronology in Iceland"

Michael Grant (EPOB), "What's in a Hole? Stomate Stories"

Morten Hald (University of Tromso, Norway), "Paleoceanography of High Latitude Eurasian Seas"

Charles Hart (INSTAAR), "Aminostratigraphy of Antarctic Cenozoic Mollusks from Glacimarine Deposits"

Vera Markgraf (INSTAAR), "Comparison of Full-Glacial Early Holocene Paleoclimates of the Temperate Forest

Ecosystems of Western North and South America"

Diane McKnight (INSTAAR), "Global Transport of Soluble Organic Carbon From Firestorms of the K/T Boundary: Was the Strangelove Ocean a Blackwater Ocean?"

Elise Pendall (INSTAAR), "Soil Carbon Cycling Under CO<sub>2</sub>-Enriched Winter Wheat"

Patrick Quilty (ANARE, Australian Antarctic Division), "The Global Significance of Antarctica. Antarctic Research: An Australian Perspective"

Melton Reasoner (INSTAAR), "Radiocarbon Dating Lateglacial Climatic Reversals in the North American Cordillera"

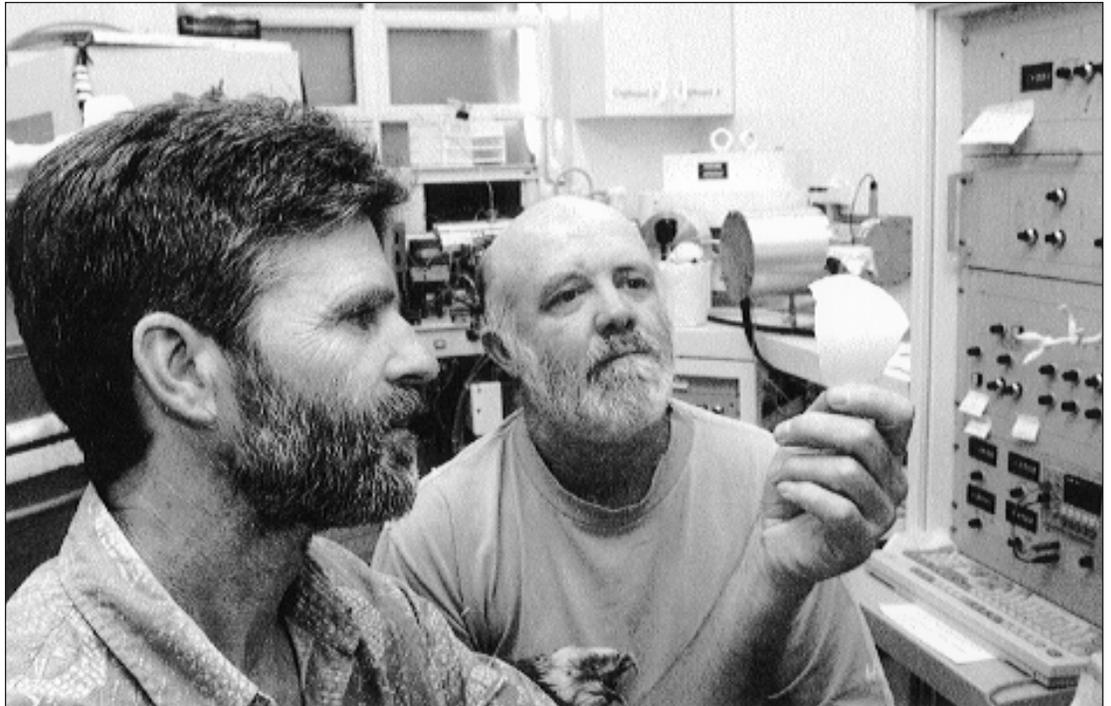
Richard Reynolds (USGS), "Eolian dust on the Colorado Plateau: Ecological and Biogeochemical Implications"

Herman Sievering (INSTAAR), "The Role of Ammonium in Nitrogen Transport and Deposition to Alpine and Subalpine Ecosystems"

Koni Steffen (CIRES), "Climatology of the Greenland Ice Sheet"

Bob Thompson (USGS), "Paleoclimate and Paleovegetation: Date-Model Comparisons"

Gifford Miller and his colleague John Magee at the Australian National University are studying an eggshell fragment from the flightless Pleistocene bird, *Genyornis*. The shell dates to the time just before this species became extinct.



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# Research Grants

- Andrews, J.T.: NSF OPP-9614129. Support for Graduate Attendance at the Arctic Workshops, 1997-1999. 1996-1999. \$73,381.
- Andrews, J.T., Jennings, A., and Syvitski, P.M.: NSF ATM-9531397. Paleoclimate (0 to > 14 KA) of W and NW Iceland, A Comparison of Lake and Near-Shore Marine Proxy Records: A USA/Iceland Contribution to P.A.L.E. 1996-2000. \$340,167.
- Andrews, J.T., and Miller, G.: NSF OPP-9614667. Lake Ice Modelling and the Paleoenvironment of the Eastern Canadian Arctic Over the Last 21 KA: A P.A.L.E./LAI S.I.M.S. 1996-1999. \$130,398.
- Andrews, J.T., and Jennings, A.: NSF OPP-9614287. Late Quaternary History of the Western and East-Central Ross Sea, Antarctica: A contribution to the West Antarctic Ice Sheet Initiative. 1997-2000. \$305,000.
- Behrendt, J.: INT USGS 1434-CR-AG-A00776. Cooperative Geophysical Research with the U.S. Geological Survey. 1996-1999. \$71,000.
- Bourgeron, P.: NSF DEB-9810218. The Niwot Ridge Long Term Ecological Research Program 1998-2004: Controls on the Structure, Functions and Interactions of Alpine and Subalpine Ecosystems of the Colorado Front Range. 1998-1999. \$23,697.
- Bourgeron, P.: EPA R825465-01. Multi-Scaled Assessment Methods: Prototype Development Within the Interior Columbia Basin. 1997-2000. \$1,516,180.
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- Bowman, W. D. and Miller, A.: Mellon Foundation. Partitioning of nitrogen by alpine tundra plants: implications for species coexistence. 1997-1998. \$240,000.
- Cole, J.: NSF OCE-9809319. Multicentury ENSO Reconstruction from the South Central Pacific (Marquesas). 1998-1999. \$54,635.
- Cole, J.: NSF OCE-9510062. Recent Variability in the Intertropical Convergence Zone of the Western Atlantic: Seasonal, Multicentury Reconstructions from Venezuela Corals. 1995-1999. \$193,830.
- Cole, J.: NSF OCE-9614137. Deciphering the Ocean's Influence on East African Climate Using Multicentury Multivariate Coral Records. 1996-1999. \$141,700.
- Cole, J.: NSF EAR-9628080. Acquisition of a Stable Isotope Mass Spectrometer for Automated Carbonate Analysis: Analytical Instrumentation for Earth Science/Global Change Research. 1996-1999. \$113,487.
- Dyurgerov, M., Meier, M., and Dwyer, J.: NSF OPP-9634289. A New Methodology for Assessing Glacier Mass Balances and Runoff for Global Studies of Climate Change and Sea-Level Rise. 1996-1999. \$399,953.
- Elias, S., and Anderson, K.: NSF ATM-9612641. Mutual Climatic Range Reconstructions of Late Quaternary Climates in Beringia. 1996-1999. \$166,297.
- Herzfeld, U.: NASA NAG5-6114. Geostatistical Methods for Determination of Roughness, Topography, and Changes on Antarctic Ice Streams from Sar and Rada Altimeter Data. 1997-1999. \$70,000.
- Hoffecker, J.: INT NPS CA 1268-2-9005/UCO-26. Cultural Resources Management: Technical Support to the Remediation Venture Office, Rocky Mountain Arsenal. 1998-1999. \$50,025.
- Hughen, K., Overpeck, J., and Lehman, S.: NSF ATM-9709563. Radiocarbon, Ocean and Climate Change Over the Last Deglaciation. 1997-1999. \$210,000.
- Jennings, A., and Andrews, J.: NSF OPP-9707161. Late Quaternary Ice Sheet Extent, Chronology, and Paleooceanography, West Greenland Margin/Denmark Strait: Implications for the Arctic and North Atlantic Oceans. 1997-1999. \$194,024.
- Jennings, A., and Andrews, J.: NSF OPP-9707161. Late Quaternary Ice Sheet Extent, Chronology, and Paleooceanography, East Greenland Margin/Denmark Strait: Implications for the Arctic and North Atlantic Oceans. 1997-1999. \$10,000.
- Krantz, W., and Caine, N.: NSF OPP-9321405. Development of a Differential Frost Heave Model: Application to Patterned Ground Formation. 1994-1999. \$183,239.
- Lehman, S.: NSF ATM-9809285. Preparation and AMS 14C Dating of Terrestrial Materials for the ESH Program: Making Good Chronology a Priority. 1998-1999. \$228,300.
- Lehman, S.: NSF EAR-9726185. Cosmogenic Nuclide Chronology of Bedrock Weathering Zones in Fennoscandia and Implications for the History of the Fennoscandian Ice Sheets. 1998-2000. \$50,057.
- Lehman, S.: NSF ATM-9610128. High Resolution UK 37 Alkenone Paleothermometry at Bermud Rise: The Last Interglacial to the Little Ice Age. 1997-2000. \$542,208.
- Losleben, M.: COMM 43RANR800071. Halocarbon Sampling on Niwot Ridge. 1998-1999. \$12,682.
- Losleben, M.: COMM 43RANR800071. Carbon Cycle Atmospheric Gas Collection. 1998-1999. \$13,729.
- Losleben, M.: QSTENVIR S68D98112-SITEOP-701. Site Operator Agreement, Castnet II Site 701 (CO94). 1998-1999. \$4,830.
- Markgraf, V.: NSF EAR-9709145. Patagonia Lake Drilling Project (PATO): Phase I. 1997-2000. \$596,368.
- Markgraf, V.: NSF ATM-9526139. Coordination of PEP I Research Activities. 1995-2000. \$184,342.
- Markgraf, V.: NSF ATM-9729145. Merida PEP I Meeting Support, March 16-20, 1998. 1997-1999. \$89,072.
- McKnight, D.: UALABAMA CDFR #47.049. McMurdo Dry Valley Long Term Ecological Research. 1998-1999. \$125,043.
- McKnight, D.: EPA R826649-01. Photochemical Processes Controlling Manganese Chemistry in Pristine and Contaminated Mountain Streams. 1998-2001. \$17,654.
- McKnight, D.: DRI 97-B36. McMurdo Dry Valley Long Term Ecological Research: A Cold Desert Ecosystem. 1997-1999. \$53,991.
- Meier, M., Dyurgerov, M., and Armstrong, R.: NSF OPP-9530782. Global Glacier Mass Balance Synthesis. 1996-1999. \$233,076.
- Miller, G., Sauer, P., and Wolfe, A.: NSF ATM-9809795. Holocene and Last Glacial Maximum Paleoclimates of the Eastern Canadian Arctic Reconstructed from Biotic and Geochemical Proxies in Lake Sediments. 1998-1999. \$50,222.

- Miller, G., Wolf, A., and Steig, E.: NSF ATM-9708418. Paleoenvironmental Reconstructions and Paleoclimate Implications for the Last Interglacial and the 40 to 10 KA Time Windows in the Eastern Canadian Arctic. 1997-1999. \$100,000.
- Miller, G., and Pfeffer, T.: NSF EAR-9510063. Late Quarternary Dynamics of the Labrador/Foxe Sectors of the Laurentide Ice Sheet, Eastern Canadian Arctic. 1995-1999. \$277,865.
- Miller, G., and Johnson, B.: NSF ATM-9709806. Drought in the Australian Outback: Milankovitch and Anthropogenic Forcing of the Australian Monsoon. 1997-1999. \$360,000.
- Miller, G.: NSF ATM-9526384. Pale Steering Committee, Data Coordination, and Community Radiocarbon Dating. 1995-1999. \$535,270.
- Miller, G., and Manley, W.: NSF OPP-9529350. Collaborative Research: Late Quaternary Glaciation of Northern Novaya Zemlya, Russia. 1996-1999. \$165,727.
- Miller, G., and Manley, W.: NSF OPP-9529350. Improved Age Resolution of Arctic Molluscs Through Measurement of Free Aspartic Acid Racemization Ratios. 1997-1999. \$5,000.
- Ogilvie, A., Jennings, A., Barlow, L., and Andrews, J.: NSF OPP-9726510. Environmental Changes and Human Responses in the North Atlantic (Iceland and Greenland Sectors) During the Last 2,000 Years. 1998-2000. \$257,816.
- Overpeck, J.: NSF ATM-9810254. Lake Bosumtwi, Ghana: High-Resolution Paleoclimatology and Seismic Reflection Site Survey. 1998-1999. \$64,834.
- Overpeck, J., and Miller, G.: NSF ATM-9709918. Labrador Sea Variability Over Decade to Millennial Time Scales. 1997-1999. \$403,191.
- Overpeck, J., Miller, G., Goetz, A., and Webb, R.: NASA NAG5-6051. Assessing Future Stability of U.S. High Plains Landcover: Integration of Process Modeling with Landsat, In Situ Modern and Paleoclimate Data. 1997-2000. \$362,013.
- Overpeck, J.: NSF ATM-9631282. Climate Change of the Last 500 Years: Simulations Versus Data. 1996-1999. \$270,000.
- Pfeffer, T., Amadei, B., and Meier, M.: NSF OPP-96154493. REU Supplement to Collaborative Research: Observation and Modeling of Flow and Fracture Processes Leading to Iceberg Calving. 1998-2000. \$1,303.
- Pfeffer, T., and Amadei, B.: NSF OPP-9531450. Direct Measurement of the In-Situ Stress Tensor at Depth in Glacier Ice: A Collaborative Study. 1996-1999. \$335,034.
- Pfeffer, T., Meier, M., and Amadei, B.: NSF OPP-9614493. Observations and Modeling of Flow and Fracture Processes Leading to Iceberg Calving. 1997-2000. \$344,795.
- Seastedt, T.: NSF DEB-9806438. Collaborative Research: Identifying Ecosystem Controls on Biodiversity: A US/UK Project. 1998-2000. \$134,754.
- Seastedt, T.: NSF DEB-9211776. Biotic Controls on Terrestrial C and N Flux: Comparisons Between Species and Between Ecosystems a Supplement to the NWT LTER. 1996-1999. \$40,000.
- Seastedt, T., Bowman, W.D., Bittenfield, B., Caine, N.T., Elias, S., McKnight, D., Seivering, H., Townsend, A., Townsend, S., Veblen, T., Walker, D., Wessman, C., and Williams, M.: NSF DEB-9810218. The Niwot Ridge Long Term Ecological Research Program 1998-2004: Controls on the Structure, Function and Interactions of Alpine and Subalpine Ecosystems of the Colorado Front Range. 1998-1999. \$842,977.
- Seastedt, T., Wessman, C., Caine, N.T., and Townsend, A.: NSF DEB-9211776. Effects of Climate Change in the Colorado Alpine: Ecosystem Response to Altered Snowpack and Rainfall Regimes. 1992-1998. \$3,620,600.
- Steig, E.: NSF OPP-9807066. Testing Alternative Models of Laurentide Ice Sheet Dynamics Using Cosmogenic Nuclide Exposure Dating. 1998-1999. \$43,520.
- Steig, E., and White, J.: NSF ATM-9809463. Continued Support of an International Ice Core Data Cooperative. 1998-1999. \$74,983.
- Steig, E., and Pfeffer, T.: NSF EAR-9614424. Ice-Core Analysis and Physical Glaciology of the Galena Rock Glacier, Wyoming. 1997-1999. \$204,881.
- Syvitski, J.: RAYTHEON LC315776. Littoral Sediment Delivery and Stratigraphy on Marginal Slopes and Shelf Basins. 1995-2000. \$105,000.
- Syvitski, J.: DOD ONR N00014-95-1-1281. Predicting Sediment Delivery and Stratigraphy on Marginal Slopes and Shelf Basins. 1995-2000. \$366,566.
- Syvitski, J.: DOD ONR N00014-96-1-0994. Numerical Coupling of River Discharge to Shelf/Slope Sedimentation Models. 1996-1999. \$110,000.
- Syvitski, J.: Mobil Oil. Numerical simulation of continental margin deposits for enhancement of reservoir characterization. \$140,000.
- Townsend, S., and Asner, G.: NASA NAGW-5253. An Integrated use of Experimental, Modeling, and Remote Sensing Techniques to Investigate Carbon Isotope and Phosphorus Dynamics in the Humid Tropics. 1996-1999. \$201,537.
- Walker, D., and Walker, M.: NSF OPP-9318530. A Workshop to Develop a Legend for a New Vegetation Map of the Circumpolar Arctic: Arendal, Norway, January 15-20, 1996. 1995-1999. \$39,500.
- Walker, D., and Walker, M.: NSF OPP-9318530. A Hierarchic GIS for Studies of Process, Pattern and Scale in Arctic Ecosystems. 1994-1999. \$726,293.
- Walker, D.: NSF OPP-9732076. Climate, Substrate, and Vegetation: Distribution and Causes of Moist Nonacidic Tundra. 1998-1999. \$726,293.
- Walker, D.: NSF OPP-9732076. REU Supplement: An AVHRR-Derived Landcover. 1998-1999. \$5,000.
- Walker, D.: MBL 98221646. A Hierarchical Geographic Information System and Electronic Geobotanical Atlas for the Kuparuk River Basin, Alaska. 1998-1999. \$15,000.
- Walker, M.: UAlaska VAF96-0033. Sustainability of Arctic Communities: Interactions between Global Change, Public Policies, and Ecological Processes. 1995-1999. \$172,860.
- Walker, M., Walker, D., and Seastedt, T.: NSF OPP-9400083. Comparative Response of Moist and Dry Arctic Tundra to Altered Snow and Temperature Regimes. 1994-1999. \$567,020.
- Walker, M.: NSF OPP-9400083. REU Supplement: Comparative Responses to Moist and Dry Arctic Tundra to Altered Snow and Temperature Regimes. 1996-1999. \$10,432.
- White, J.: NSF OPP-9615232. Isotopic Analyses on the Ngrip Deep Ice Core. 1997-2000. \$300,515.
- White, J., and Steig, E.: NSF OPP-9526979. Isotopic Measurements on the WAIS/SIPLE Dome Ice Cores. 1996-1999. \$288,000.

Williams, M., and Pfeffer, T.: DOD ARO DAAH04-96-1-0033. Meltwater Flow Through Snow From Plot to Basin Scales. 1996-1998. \$100,000.

Williams, M., and Pfeffer, T.: DOD ARO G5598 I 0505. Meltwater Flow Through Snow From Plot to Basin Scales. 1996-1998. \$12,500.

Williams, M.: SMIGUELC OCG4101B. Watershed Characterization for Purposes of Alpine Basin Sensitivity Analysis: San Miguel. 1998-1999. \$28,000.

Williams, M., and Schmidt, S.: INT NPS CA-1268-2-9005. Nitrogen Dynamics: Interactions Between Snowmelt and Runoff. 1993-2000. \$172,556.

Williams, M.: NATO ENVIR.LG 974676. Glaciers of Central Asia and Their Relation to Global Hydrological Cycle. 1999-2001. \$12,703.44.

Williams, M., and Schmidt, S.: NSF EAR-9523886. Biogeochemical and Hydrologic Controls on Solutes and Flowpaths in Alpine Watersheds: Collaborative Proposal to the NSF from CU, CSU, UA, and USGS. 1995-1999. \$223,000.

Williams, M., Caine, N., Pfeffer, T., and Illangasekare, T.: NSF EAR-9526875. Meltwater Flow Through Snow From Plot to Basin Scales. 1996-2000. \$120,000.

Williams, M., and Davinroy, T.: NSF SBR-9628375. Doctoral Dissertation Research: Biogeochemical Processes and Hydrologic Characteristics of Alpine Talus. 1996-1999. \$10,000.

Williams, M., Steffen, K., Illangasekare, T., and Stone, D.: DOD ARO DAAH04-1-0289. Instrumentation for Snow Hydrology Research. 1996-1999. \$136,248.

Wolfe, A.: NSF ATM-9808943. Lacustrine Records of Late Quaternary Water Balance Fluctuations in the Venezuelan Andes: Assessing the Interplay of Insolation and Ocean Circulation. 1999-2001. \$64,054.

Woodhouse, C.: NSF ATM-9815439. A Well Documented Set of Annual Tree-Ring Chronologies From the International Tree-Ring Data Bank for Dendroclimatic Studies. 1998-2000. \$26,540.

Woodhouse, C.: UARIZONA U501756. Temperature Variability Since AD 1000 in the Western US from Tree Rings. 1998-1999. \$12,791.

Woodhouse, C., and Brown, P.: NSF ATM-9729571. Expanded and Lengthened Dendroclimatic Reconstructions of Great Plains Drought. 1998-2000. \$207,048.

## Support at INSTAAR, 1994-1999

Source of Funds	1994-95		1995-96		1996-97		1997-98		1998-99	
	Awards	Amount								
<b>Federal Agencies</b>										
National Science Foundation	40	\$4,182K	31	\$3,005K	39	\$4,295K	37	\$4,549K	42	\$4,170K
NASA	2	111K	3	559K	3	216K	5	656K	0	-
Department of Commerce	7	176K	4	101K	4	59K	5	101K	2	26K
Department of Energy	1	167K	1	163K	0	-	0	-	0	-
Department of Defense	3	135K	6	445K	5	337K	5	275K	4	220K
Department of the Interior	1	38K	1	149K	1	48K	3	47K	2	132K
Department of Agriculture	1	32K	0	-	2	353K	0	-	0	-
Environ. Protection Agency	0	-	1	137K	1	1,516K	1	11K	2	234K
<b>Non-Federal Agencies</b>	9	236K	4	145K	8	181K	9	271K	13	567K
<b>Gift Funds</b>	1	32K	1	74K	3	118K	3	242K	1	143K
<b>Total Awards Received</b>	<b>66</b>	<b>\$5,110K</b>	<b>52</b>	<b>\$4,780K</b>	<b>66</b>	<b>\$6,086K</b>	<b>67</b>	<b>\$6,159K</b>	<b>65</b>	<b>\$5,492K</b>
<b>CU General Funds</b>		671K		947K		875K		867K		1,045K
<b>CU Auxillary Funds</b>		635K		657K		873K		730K		888K
<b>Total Revenue</b>		<b>\$6,416K</b>		<b>\$6,384K</b>		<b>\$8,851K</b>		<b>\$7,756K</b>		<b>\$7,425K</b>
<b>Budget Expenditures</b>										
Contract and Grant Funds		\$3,766K		\$3,919K		\$4,675K		\$6,020K		\$5,671K
General Funds		668K		905K		842K		851K		900K
Plant Funds		98K		148K		272K		287K		80K
Auxillary Funds		633K		673K		796K		618K		712K
Gift Funds		1K		47K		72K		100K		223K
<b>Total Expenditures</b>		<b>\$5,167K</b>		<b>\$5,692K</b>		<b>\$6,652K</b>		<b>\$7,876K</b>		<b>\$7,586K</b>

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# 1998 Publications

- Andrews, J.T.** 1998: Abrupt changes (Heinrich events) in late Quaternary North Atlantic marine environments: a history and review of data and concepts. Invited Review. *Journal of Quaternary Science* 13(1):3-16.
- Andrews, J.T.** 1998: Dating glacial events and correlation to climate change. In: Sowers, J.M., Noller, J.S., and Lettis, W.R. (eds.), *Dating and Earthquakes: Review of Quaternary Geochronology and Its Application to Paleoseismology*. Washington, DC, pp. 703-716.
- Andrews, J.T.;** Kirby, M.E.; Aksu, A.; **Barber, D.C.;** Meese, D. 1998: Late Quaternary detrital carbonate (DC-) layers in Baffin Bay marine sediments (67 deg. - 74 deg.N): Correlation with Heinrich events in the North Atlantic. *Quaternary Science Reviews* 17:1125-1137.
- Andrews, J.T.;** Cooper, T.A.; **Jennings, A.E.;** Stein, A.B.; Erlenkeuser, H. 1998: Late Quaternary iceberg-rafted detritus events on the Denmark Strait-Southeast Greenland continental slope (~65 deg. N): related to North Atlantic Heinrich events. *Marine Geology* 149:211-228.
- Andrews, J.T.;** Kirby, M.E.; **Jennings, A.E.;** **Barber, D.C.** 1998: Late Quaternary stratigraphy, chronology, and depositional processes on the slope of S.E. Baffin Island, detrital carbonate and Heinrich events: implications for onshore glacial history. *Geographie physique et Quaternaire* 52(1):91-105.
- Bahr, D.B.;** **Syvitski, J.P.** 1998: Predicting compacted sediment porosity profiles. *Proceedings of IAMG '98, A. Buccianti, G. Nardi and R. Potenza (Eds.) Isola d'Ischia, Naples, 1998*. pp. 627-632.
- Bahr, D.B.;** **Pfeffer, W.T.;** Sassolas, C.; **Meier, M.F.** 1998: Response time of glaciers as a function of size and mass balance: I. Theory. *Journal of Geophysical Research* 103(B5):9777-9782.
- Bahr, D.B.;** Passerini, E. 1998: Statistical mechanics of collective behavior: Macro-Sociology. *Journal of Mathematical Sociology* 23(1):29-49.
- Bahr, D.B.;** Passerini, E. 1998: Statistical mechanics of opinion formation and collective behavior. *Journal of Mathematical Sociology* 23(1):1-27.
- Bartlein, P.J.; **Anderson, K.H.;** Anderson, P.M.; Edwards, M.E.; Mock, C.J.; Thompson, R.S.; **Webb, R.S.;** Webb, T., III; Whitlock, C. 1998: Paleoclimate simulations for North America over the past 21,000 years: features of the simulated climate and comparisons with paleoenvironmental data. *Quaternary Science Reviews* 17:549-585.
- Behrendt, J.C.;** Finn, C.A.; Blankenship, D.; Bell, R.E. 1998: Aeromagnetic evidence for a volcanic caldera(?) complex beneath the divide of the West Antarctic Ice Sheet. *Geophysical Research Letters* 25(23):4385-4388.
- Behrendt, J.C.** 1998: Innocents on the ice. Niwot, Colorado, University of Colorado Press, 428 pp.
- Benson, L.V.;** May, H.M.; Antweiler, R.C.; Brinton, T.I.; Kashgarian, M.; Smoot, J.P.; Lund, S.P. 1998: Continuous lake-sediment records of glaciation in the Sierra Nevada between 52,600 and 12,500 14C yr B.P. *Quaternary Research* 50:113-127.
- Bieber, A.; **Williams, M.W.;** Johnsson, M.; **Davinroy, T.** 1998: Mineralization in alpine talus fields, Green Lakes Valley, Colorado elevation ecosystem in the Rocky Mountains, USA. *Arctic and Alpine Research* 30(3):266-271.
- Blair, J.M.; **Seastedt, T.R.;** Rice, C.W.; Ramundo, R.A. 1998: Terrestrial nutrient cycling in tallgrass prairie. In: Knapp, A.K., Briggs, J.M., Hartnett, D.C. and S.C. Collins (eds.). *Grassland dynamics: Long-Term Ecological Research in Tallgrass Prairie*. New York, Oxford Univ. Press, pp. 222-243.
- Bowman, W.D.;** Steltzer, H. 1998: Positive feedbacks to anthropogenic nitrogen deposition in Rocky Mountain alpine tundra. *Ambio* 27:514-517.
- Brooks, P.D.; **Williams, M.W.;** Schmidt, S.K. 1998: Inorganic nitrogen and microbial biomass dynamics before and during spring snowmelt. *Biogeochemistry* 43:1-15.
- Calkin, P.E.;** Kaufman, D.J.; Przybyl, B.I.; Whitford, W.B.; Peck, B.J. 1998: Glacier regimes, periglacial landforms and Holocene climate change in the Kigluaik Mountains, Seward Peninsula, Alaska. *Arctic and Alpine Research* 30:154-165.
- Caseldine, C.J.; Hatton, J.M.; **Huber, U.M.;** Chiverrell, R.; Woolley, N. 1998: Assessing the impact of volcanic activity on mid-Holocene climate in Ireland: the need for replicate data. *Holocene* 8:105-111.
- Clark, R.; **Huber, U.M.;** Wilson, P. 1998: Late Pleistocene sediments and environmental change at Plaza Creek, Falkland Islands, South Atlantic. *Journal of Quaternary Science* 13:95-105.
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