
Principal Investigator: Williams, Mark W.
Organization: U of Colorado Boulder

Submitted By:
Williams, Mark - Principal Investigator

Title:
Long Term Ecological Research: The Landscape Continuum Model: A Biogeochemical Paradigm for High Elevation Ecosystems

Project Participants

Senior Personnel

Name: Williams, Mark
Worked for more than 160 Hours: Yes
Contribution to Project:
Dr. Mark Williams is the current PI of the NWT LTER project and is project director. Provides overall project guidance and leadership. His research areas are in snow hydrology, surface-groundwater interactions, terrestrial-aquatic interactions, and biogeochemistry.

Name: McKnight, Diane
Worked for more than 160 Hours: Yes
Contribution to Project:
Dr. McKnight is a Co-I on the NWT LTER program. Her research focuses on limnology, aquatic ecology, reactive transport of metals and organic material in mountain streams and rivers. She is the NWT LTER lead on K-12 outreach activities.

Name: Seastedt, Timothy
Worked for more than 160 Hours: Yes
Contribution to Project:
Dr. Tim Seastedt is a Co-I on the NWT LTER program. He is the former lead PI of the NWT LTER program. He provides continuity in leadership as well as mentoring as M. Williams transitions to the lead PI position. His research interests focus on terrestrial ecosystem studies, including factors influencing primary productivity, soil carbon dynamics, decomposition and mineralization processes, and how these processes affect short- and long-term ecosystem-atmosphere interactions. Ongoing research collaborations involve cross-site comparisons of mechanisms controlling nutrient availability, carbon storage, and biotic productivity, invasive species, and ecosystem processes-biodiversity relationships.

Name: Bowman, William
Worked for more than 160 Hours: Yes
Contribution to Project:
Dr. William Bowman is a Co-I on the NWT LTER project. He is also director of the Mountain Research Station. His research has focused on the interaction between plants and their resources, broadly defined from plant adaptations to low resource availability to how plants influence soils and subsequently ecosystem function. Over the past decade his work has concentrated on the interaction between alpine plants and nutrients, examining the response of plants to low nutrient supply, as well as the influence that plants have on their nutrient environment.

Name: Townsend, Alan
Worked for more than 160 Hours: Yes
Contribution to Project:
Dr. Alan Townsend is a Co-I on the NWT LTER project. His research is largely within the fields of terrestrial ecosystem ecology and biogeochemistry, with a focus on tropical and alpine ecosystems which include: controls over nutrient limitation and carbon storage in moist tropical and alpine tundra ecosystems; the effects of human activity on regional to global scale carbon and nitrogen cycling, and the effects of changing biogeochemical cycles on human health.

Name: Blanken, Peter
Worked for more than 160 Hours: Yes
Contribution to Project:
Dr. Peter Blanken is new to the NWT LTER project. He is an associate professor in Geography and an expert in boundary layer
climatology. He is the lead on installing and operating two eddy covariance towers at NWT LTER, beginning summer 2006.

Name: Bourgeron, Patrick

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
Dr. Bourgeron is a research scientist at INSTAAR and continues his involvement with the NWT LTER program. He co-chairs the US portion of ILTER activities. His research focuses on ecotone/Treeline studies.

Name: Caine, Nel

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
Nel Caine is a former lead PI on the NWT LTER project. His involvement provides continuity in leadership as well as a historical perspective for the NWT LTER program. He is a hydrologist, glaciologist, and geomorphologist who is now looking at responses of these systems to changes in climate over the last several decades.

Name: Helmig, Detlev

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
Detlev Helmig investigated the transfer and uptake of atmospheric ozone in seasonal, mid-latitude snowpack at a subalpine forest site at Niwot Ridge, Colorado. He is a research scientist based at CU-INSTAAR.

Name: Mast, M

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
Dr. M. Alisa Mast is a senior scientist on the NWT LTER project. She is a hydrochemist with the USGS-WRD based out of Lakewood, CO, specializing in atmosphere-aquatic interactions. Alisa is a cooperating scientist with the USGS WEBB project at nearby Loch Vale watershed, the other major high-elevation research program in the US. Alisa's new involvement with the NWT LTER provides the opportunity for closer links with the USGS, while also facilitating the expansion of the NWT LTER research focus to the Rocky Mountain region.

Name: Losleben, Mark

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
Mark Losleben continues as climatologist at the NWT LTER, a position he has held continuously since 1982. This year his position was changed from 50% LTER and 50% MRS to 100% LTER, with the 50% that was previously supported by the MRS now supported by INSTAAR. Mark now reports directly to the NWT LTER PI.

Name: Monson, Russel

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
Russ Monson is a professor of EEB at CU-Boulder and continues his involvement with the NWT LTER. He is PI of the Niwot Ridge Ameriflux Site, located at the subalpine forest on Niwot Ridge. His involvement assures good cooperation between alpine and subalpine systems at NWT ridge.

Name: Neff, Jason

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
Dr. Neff is an assistant professor in Geosciences at CU-Boulder. His involvement brings new energy, enthusiasm, and direction to the NWT LTER program. His research focuses on fundamental studies of terrestrial biogeochemistry, working toward an understanding of how ecosystems work and how human activities can influence the service and function ecosystems provide humanity.

Name: Sanford, Robert (Buck)

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
Dr. Sanford is a professor in Biology at the University of Denver and continues his involvement with the NWT LTER program. His research focuses on nutrient cycling in terrestrial soils. He is also director of the Mt Evans Research Program and provides
complementary high-altitude research areas.

Name: Schmidt, Steven

Worked for more than 160 Hours: Yes

Contribution to Project:
Steve Schmidt is a professor of EEB and continues his involvement with the NWT LTER program. He is PI on the recently-funded Alpine Microbial Observatory and studies microbial activity at Niwot Ridge.

Name: Sievering, Herman

Worked for more than 160 Hours: Yes

Contribution to Project:
Dr. Sievering is a Professor in Atmospheric Chemistry at CU-Denver and continues his involvement with the NWT LTER program. He is investigating the influence of canopy N uptake on chlorophyll fluorescence and gas exchange.

Name: Suding, Katharine

Worked for more than 160 Hours: Yes

Contribution to Project:
Dr. Suding is a new assistant professor at the University of California at Irvine. She conducted her Post-Doc work at Niwot Ridge. We are happy to welcome Katie as a new senior personnel on the NWT LTER program. Katie is working on feedbacks between plant species and ecosystem processes which may enhance community diversity and stability.

Name: Tonnessen, Kathy

Worked for more than 160 Hours: Yes

Contribution to Project:
Dr. Kathy Tonnessen is the lead scientist for the Rocky Mountain Cooperative Ecosystem Study Unit, and is based at the University of Montana, Missoula, Montana. She directs and funds much of the National Park Service research in the Rocky Mountain region. Her involvement helps expand the NWT LTER to a regional focus in the Rocky Mountains.

Post-doc

Graduate Student

Name: Anderson, Sheena

Worked for more than 160 Hours: Yes

Contribution to Project:
Buck Sanford's Graduate Student

Name: Abood, Paul

Worked for more than 160 Hours: Yes

Contribution to Project:
Mark Williams's Graduate Student

Name: Bocquet, Florence

Worked for more than 160 Hours: Yes

Contribution to Project:
Detlev Helmig's Graduate Student

Name: Cohen, Lana

Worked for more than 160 Hours: Yes

Contribution to Project:
Detlev Helmig's Graduate Student

Name: Costello, Elizabeth

Worked for more than 160 Hours: Yes

Contribution to Project:
William Bowman's Graduate Student
Name: Flanagan, Colleen  
Worked for more than 160 Hours: Yes  
Contribution to Project: Diane McKnight's Graduate Student

Name: Freeman, Kristen  
Worked for more than 160 Hours: Yes  
Contribution to Project: Steven Schmidt's Graduate Student

Name: Hill, Ken  
Worked for more than 160 Hours: Yes  
Contribution to Project: Mark Williams's Graduate Student

Name: King, Andrew  
Worked for more than 160 Hours: Yes  
Contribution to Project: Steven Schmidt's Graduate Student

Name: Lawton, Charles  
Worked for more than 160 Hours: Yes  
Contribution to Project: Steven Schmidt's Graduate Student

Name: Liptzin, Dan  
Worked for more than 160 Hours: Yes  
Contribution to Project: Tim Seastedt's Graduate Student

Name: Meier, Courtney  
Worked for more than 160 Hours: Yes  
Contribution to Project: William Bowman's Graduate Student

Name: Miller, Matt  
Worked for more than 160 Hours: Yes  
Contribution to Project: Diane McKnight's Graduate Student

Name: Tomaszewski, Tim  
Worked for more than 160 Hours: Yes  
Contribution to Project: Herman Seivering's Graduate Student

Undergraduate Student
Name: Gurung, Anobha  
Worked for more than 160 Hours: Yes  
Contribution to Project: Anobha is an undergraduate student worker assisting Dr. Sievering and Todd Ackerman.

Technician, Programmer
Name: Ackerman, Todd  
Worked for more than 160 Hours: Yes
Contribution to Project:
Todd Ackerman is the NWT LTER Information Manager and GIS Coordinator.

Name: Chowanski, Kurt
Worked for more than 160 Hours: Yes
Contribution to Project:
Kurt is the Field Technician for the NWT LTER project.

Name: Seibold, Christine
Worked for more than 160 Hours: Yes
Contribution to Project:
Christine Seibold supervises the Kiowa Wet Chemistry Laboratory of the NWT LTER program.

Name: Matheson, Kelly
Worked for more than 160 Hours: Yes
Contribution to Project:
Kiowa Lab PRA

Other Participant
Name: Clippenger, Norman
Worked for more than 160 Hours: Yes
Contribution to Project:
Dr. Clippenger is a research associate for the EEB Department at CU-Boulder. He is conducting research on small mammals at the NWT LTER program and is supported in part with NWT LTER funds.

Name: Rosenbaum, Barry
Worked for more than 160 Hours: Yes
Contribution to Project:
Dr. Barry Rosenbaum is a research associate with the EEB Department at CU-Boulder. He is conducting research on small mammals at NWT LTER, along with Dr. Norm Clippenger. He is supported in part by NWT LTER.

Research Experience for Undergraduates
Name: Abbey, Rebecca
Worked for more than 160 Hours: Yes
Contribution to Project:
From Pomona College. Advised by McKnight.

Years of schooling completed: Junior
Home Institution: Other than Research Site
Home Institution if Other: Pomona College
Home Institution Highest Degree Granted(in fields supported by NSF): Bachelor's Degree
Fiscal year(s) REU Participant supported: 2005
REU Funding: REU supplement

Name: Burns, Mercedes
Worked for more than 160 Hours: Yes
Contribution to Project:
From Macalaster College. Advised by Breed.

Years of schooling completed: Junior
Home Institution: Other than Research Site
Home Institution if Other: Macalaster College
Home Institution Highest Degree Granted(in fields supported by NSF): Bachelor's Degree
Fiscal year(s) REU Participant supported: 2005
REU Funding: REU supplement
Name: Fulkerson, Justin
Worked for more than 160 Hours: Yes
Contribution to Project:
From Humboldt State University. Advised by Bowers.

Years of schooling completed: Sophomore
Home Institution: Other than Research Site
Home Institution if Other: Humboldt State University
Home Institution Highest Degree Granted (in fields supported by NSF): Doctoral Degree
Fiscal year(s) REU Participant supported: 2005
REU Funding: REU supplement

Name: Grisby, Hershel
Worked for more than 160 Hours: Yes
Contribution to Project:

Years of schooling completed: Junior
Home Institution: Other than Research Site
Home Institution if Other: Westminster College
Home Institution Highest Degree Granted (in fields supported by NSF): Bachelor's Degree
Fiscal year(s) REU Participant supported: 2005
REU Funding: REU supplement

Name: Merrell, Andrew
Worked for more than 160 Hours: Yes
Contribution to Project:
From Lewis and Clark College. Advised by Breed/Sanchez.

Years of schooling completed: Sophomore
Home Institution: Other than Research Site
Home Institution if Other: Lewis and Clark College
Home Institution Highest Degree Granted (in fields supported by NSF): Doctoral Degree
Fiscal year(s) REU Participant supported: 2005
REU Funding: REU supplement

Name: Meriwether, Rachel
Worked for more than 160 Hours: Yes
Contribution to Project:
From University of Louisiana, Lafayette. Advised by Diggle/Lay.

Years of schooling completed: Freshman
Home Institution: Other than Research Site
Home Institution if Other: Univ. of Louisiana, Lafayette
Home Institution Highest Degree Granted (in fields supported by NSF): Doctoral Degree
Fiscal year(s) REU Participant supported: 2005
REU Funding: REU supplement

Name: Miller, Brian
Worked for more than 160 Hours: Yes
Contribution to Project:
From University of Colorado. Advised by Cruz.

Years of schooling completed: Junior
Home Institution: Same as Research Site
Home Institution if Other:
Home Institution Highest Degree Granted (in fields supported by NSF): Doctoral Degree
Fiscal year(s) REU Participant supported: 2005
REU Funding: REU supplement

Name: Plume, Fronny
Worked for more than 160 Hours: Yes
Contribution to Project:
From University of Colorado. Advised by Bowman.

Years of schooling completed: Sophomore
Home Institution: Same as Research Site
Home Institution if Other:
Home Institution Highest Degree Granted (in fields supported by NSF): Doctoral Degree
Fiscal year(s) REU Participant supported: 2005
REU Funding: REU supplement

Name: Rodgers, Althea
Worked for more than 160 Hours: Yes
Contribution to Project:
From Colorado College. Advised by Monson/Hu.

Years of schooling completed: Sophomore
Home Institution: Other than Research Site
Home Institution if Other: Colorado College
Home Institution Highest Degree Granted (in fields supported by NSF): Bachelor's Degree
Fiscal year(s) REU Participant supported: 2005
REU Funding: REU supplement

Name: Smith, Jane
Worked for more than 160 Hours: Yes
Contribution to Project:
From University of Colorado. Advised by Seastedt.

Years of schooling completed: Sophomore
Home Institution: Same as Research Site
Home Institution if Other:
Home Institution Highest Degree Granted (in fields supported by NSF): Doctoral Degree
Fiscal year(s) REU Participant supported: 2005
REU Funding: REU supplement

Name: Woltz, Megan
Worked for more than 160 Hours: Yes
Contribution to Project:
From NC State. Advised by McKnight.

Years of schooling completed: Sophomore
Home Institution: Other than Research Site
Home Institution if Other: NC State
Home Institution Highest Degree Granted (in fields supported by NSF): Doctoral Degree
Fiscal year(s) REU Participant supported: 2005
REU Funding: REU supplement

Name: Blevins, Kali
Worked for more than 160 Hours: Yes
Contribution to Project:
2007 Summer REU under the mentorship of Katie Suding.

- **Years of schooling completed:** Junior
- **Home Institution:** Other than Research Site
- **Home Institution if Other:** University of Texas
- **Home Institution Highest Degree Granted (in fields supported by NSF):** Doctoral Degree
- **Fiscal year(s) REU Participant supported:** 2007
- **REU Funding:** REU supplement

**Name:** Howison, Jon
**Worked for more than 160 Hours:** Yes

Contribution to Project:
2007 Summer REU under the mentorship of Tim Seastedt.

- **Years of schooling completed:** Junior
- **Home Institution:** Same as Research Site
- **Home Institution if Other:**
- **Home Institution Highest Degree Granted (in fields supported by NSF):** Doctoral Degree
- **Fiscal year(s) REU Participant supported:** 2007
- **REU Funding:** REU supplement

**Name:** Bornis, Evyan
**Worked for more than 160 Hours:** Yes

Contribution to Project:
REU - Diane McKnight

- **Years of schooling completed:** Sophomore
- **Home Institution:** Other than Research Site
- **Home Institution if Other:** University of San Francisco
- **Home Institution Highest Degree Granted (in fields supported by NSF):** Doctoral Degree
- **Fiscal year(s) REU Participant supported:** 2007
- **REU Funding:** REU supplement

**Name:** Chow, Kaela
**Worked for more than 160 Hours:** Yes

Contribution to Project:
REU - Mike Breed

- **Years of schooling completed:** Freshman
- **Home Institution:** Other than Research Site
- **Home Institution if Other:** Colgate University
- **Home Institution Highest Degree Granted (in fields supported by NSF):** Doctoral Degree
- **Fiscal year(s) REU Participant supported:** 2007
- **REU Funding:** REU supplement

**Name:** Davis, Kyle
**Worked for more than 160 Hours:** Yes

Contribution to Project:
REU - Tom Veblen

- **Years of schooling completed:** Junior
- **Home Institution:** Other than Research Site
- **Home Institution if Other:** University of California Davis
- **Home Institution Highest Degree Granted (in fields supported by NSF):** Doctoral Degree
- **Fiscal year(s) REU Participant supported:** 2007
REU Funding: REU supplement
Name: Eilers, Katie
Worked for more than 160 Hours: Yes
Contribution to Project: REU - Noah Fierer
  Years of schooling completed: Junior
  Home Institution: Other than Research Site
  Home Institution if Other: Northern Arizona University
  Home Institution Highest Degree Granted (in fields supported by NSF): Doctoral Degree
  Fiscal year(s) REU Participant supported: 2007
  REU Funding: REU supplement

Name: Gerber, Katie
Worked for more than 160 Hours: Yes
Contribution to Project: REU - Tom Juenger
  Years of schooling completed: Junior
  Home Institution: Other than Research Site
  Home Institution if Other: Ohio State University
  Home Institution Highest Degree Granted (in fields supported by NSF): Doctoral Degree
  Fiscal year(s) REU Participant supported: 2007
  REU Funding: REU supplement

Name: Hovel, Rachel
Worked for more than 160 Hours: Yes
Contribution to Project: REU - Piet Johnson
  Years of schooling completed: Junior
  Home Institution: Other than Research Site
  Home Institution if Other: Northern Michigan University
  Home Institution Highest Degree Granted (in fields supported by NSF): Doctoral Degree
  Fiscal year(s) REU Participant supported: 2007
  REU Funding: REU supplement

Name: Kain, Katie
Worked for more than 160 Hours: Yes
Contribution to Project: REU - Tom Juenger
  Years of schooling completed: Junior
  Home Institution: Other than Research Site
  Home Institution if Other: University of Vermont
  Home Institution Highest Degree Granted (in fields supported by NSF): Doctoral Degree
  Fiscal year(s) REU Participant supported: 2007
  REU Funding: REU supplement

Name: Martinez, Ciera
Worked for more than 160 Hours: Yes
Contribution to Project: REU - Pam Diggle
  Years of schooling completed: Junior
  Home Institution: Other than Research Site
Home Institution if Other: Northeastern Illinois University
Home Institution Highest Degree Granted (in fields supported by NSF): Doctoral Degree
Fiscal year(s) REU Participant supported: 2007
REU Funding: REU supplement

Name: Sconiers, Warren
Worked for more than 160 Hours: Yes
Contribution to Project: REU - Katie Suding

Years of schooling completed: Junior
Home Institution: Other than Research Site
Home Institution if Other: University of California, Irvine
Home Institution Highest Degree Granted (in fields supported by NSF): Doctoral Degree
Fiscal year(s) REU Participant supported: 2007
REU Funding: REU supplement

Name: Sekor, Michael
Worked for more than 160 Hours: Yes
Contribution to Project: REU - Bill Bowman

Years of schooling completed: Sophomore
Home Institution: Other than Research Site
Home Institution if Other: Vassar College
Home Institution Highest Degree Granted (in fields supported by NSF): Doctoral Degree
Fiscal year(s) REU Participant supported: 2007
REU Funding: REU supplement

Organizational Partners

State of Colorado
- Matching equipment funds for the NWT LTER ($25K/yr).
- Operating funds for the Mountain Research Station.

University of California, Irvine
- Katies's stuff

National Park Service
- Kathy Tonnessen (Co-I)

USGS Water Resources Division

National Oceanic and Atmospheric Administration (NOAA)
- U.S. Climate Reference Network (USCRN) is a network of climate stations developed as part of a National Oceanic and Atmospheric Administration (NOAA) initiative. Its primary goal is to provide future long-term homogeneous observations of temperature and precipitation that can be coupled to long-term historical observations for the detection and attribution of present and future climate change. Data from the USCRN will be used in operational climate monitoring activities and for placing current climate anomalies into an historical perspective. The USCRN will also provide the United States with a reference network that meets the requirements of the Global Climate Observing System (GCOS).

USDA Forest Service
U of Colorado Mountain Research Station

NRCS - Snotel

Mountain Studies Institute
The Mountain Studies Institute (MSI) is a non-profit organization based out of Silverton, CO, dedicated to serving the educational and research needs of mountain communities and environments. NWT LTER provides guidance, facilities, personnel exchanges and other help to MSI.

National Atmospheric Deposition Program

City of Boulder Watershed

Rocky Mtn Coop. Ecosystems Study Unit

NOAA - CMDL
NOAA Climate Monitoring and Diagnostics Laboratory (CMDL) air monitoring for carbon cycle greenhouse gases, halocarbons, and surface ozone at T van and C1.

NOAA - National Weather Service
NOAA National Weather Service - coop precipitation network gage at C1

Other Collaborators or Contacts

Italian Alps. In October, 2006, we hosted a visiting delegation of 4 research scientists from the University of Turino, Italy. They represent the Laboratory Research on Snow and Alpine Soils (www.lnsa.unito.it), a new research team focused on studying snow and soil in the Italian Alps. The main centre is located in Torino, and includes a high elevation laboratory (3000 m asl) accessed from the MonteRosa ski area. In April 2007 Williams returned the site visit with funding from the Italian team, giving a plenary address to a conference sponsored by the Italian team. We have initiated a student exchange with their program. Gianluca Filippa, a PhD student from that program, will be in residence at Niwot Ridge from about June through October 2007. Gianluca will study carbon and nitrogen cycling in high-elevation soils.

Matt Oden: masters student in the Yale school of forestry and environmental studies. Conducted a series of altitudinal transects to measure organochlorine pesticide concentrations.

Norm Pace's laboratory. The goal of the project is to sample air from Niwot Ridge and the San Juans during different weather regimes (upslopes, westerlies, dust events, etc.) and to quantify the bioaerosol community diversity using PCR techniques.

Derrick Lampkin, Penn State: Site visit as part of the NASA AIST project to scope out the Martinelli Ice Field for potential deployment of a robotic system in the third year of their project.

Tim Davie, Nematode Evolution Lab at Brigham Young University in Provo, UT: Sampled tardigrades (microscopic invertebrates, related to arthropods).

Dr. Iggy Litaor of Tel-Hai University, Israel, rejoined the NWT LTER group through the summer of 2004. Dr. Litaor was one of NWT LTER's most prolific scientists during the late 1980s, with expertise in soils, especially soil phosphorus, and geostatistics. He's recently written several papers using Niwot data that are in review. He worked with Drs. Townsend, Bowman, Williams and Seastedt on landscape patterns of herbaceous vegetation in response to climate drivers.

Dr. Barry Rosenbaum, Univ. of Colorado, conducted small mammal surveys at NWT in 2003-2005. In 2006 he was assisted by Dr. Norman Clippinger and two undergraduate students supported by supplemental LTER funding. These results will be evaluated with respect to a substantive historical database to evaluate what, if any changes in species composition or abundances have occurred during this interval.
Jessica Lundquist, NOAA CDC. Distribution of temperature sensors along an elevational transect on Niwot Ridge for the dual purpose of evaluating the equipment (iButtons) and characterising air and soil temperatures in this complex terrain with respect to topography and elevation.

Douglas Hardy, Univ of Mass, Amhusrt. Elevational profile of temperature and relative humidity from the base to the summit of Mt Kilimajaro, Tanzania.

Nicholas Pepin, University of Portsmouth, Geography Dept. Comparison of surface and free air temperatures at equivalent elevations in the western US. Micro-site air temperatures in complex terrain on Niwot Ridge. Historical comparison of high and low elevation snowpacks on east and west slopes of selected mountain ranges in the western US.

Britton Stevens, NCAR. Three elevation vertical profile of CO2 at T van.

John Miller, NOAA CMDL Carbon Cycle Group. Automated CO2/13CO2 sampling at T van (T van is a good mid-tropospheric air proxy for all downwind locations in the US (to the east coast).

University of Regensburg (Thomas Raabe, Matthias Leopold, and Jorg Volkel), Williams College (David Dethier). Ground Penetrating Radar (GPR): Measurements of ground ice on Niwot Ridge, Martinelli catchment, and GL5 Rock Glacier.

TingJun Zhang (NSIDC). Development of permafrost model for western US based on Niwot Ridge ground-truthing. Installation of borehole temperature measurement system for measuring subsurface temperatures.

Tad Pfeffer-Arapahoe Glacier. Conducted annual mass balance surveys of the Arapahoe glacier.

Bob Anderson and Suzanne Anderson: The interaction of mechanical and chemical processes that produce and transport regolith are explored in a simple landscape: the alpine high surfaces in the Front Range of Colorado. These high surfaces are an ideal laboratory because their parabolic shape implies that they are steady state landforms, the regolith is thin and accessible and is generated from granitoid rock, and easily characterized frost processes are expected to dominate the mechanical processes.

Tim Kittel: Research Affiliate with INSTAAR and Research Scientist at Colorado State University. His research interests are on the interactions between ecosystems and climate at global to landscape scales. He is currently studying multidecadal changes in the tundra plant community on Niwot Ridge.

Dale Toetz, University of Oklahoma. Continues to conduct research on aquatic biological processes in the Green Lakes Valley.

Niwot Ridge Ameriflux Program. Continue to work with the Russ Monson, PI, on various components of the carbon balance. The NWT LTER contributes weekly measurements of snow properties, etc.

Katie Suding has collaborated with a number of scientists, including: C. DeMazancourt, B. Clark, S. Pennings, L. Gough, K. Gross, S. Collins, D. Milchunas, C. Clark, J. Fargione, A. Miller, J. Grace, E. Cleland.

INTERNATIONAL

Bowman: Completion of field work in Western Tatra Mountains. Preliminary indications are that 1) soils have been acidified extensively (pH from 3.5-3.3), with aluminum the primary cation; 2) primary production is limited by P, with slight decreases in production when N is added, and 3) pools of soil inorganic N are higher than at Niwot Ridge. Collaborators include Lubos Halada (Slovak Academy of Sciences), R?diger Kaufmann (University of Innsbruck).

Patrick Bourgeron has spent the last several years working with US-LTER colleagues and NSF officers on the reorganization of the International Long Term Ecological Research Network (ILTER, http://www.ilternet.edu/), the implementation of the US-LTER International Committee (http://intranet.ilternet.edu/committees/), and the redeployment of the US-LTER contribution to it. This work is conducted as co-Chair of the US-LTER IC under NSF funding and with direct involvement from NSF officers. He was awarded the French International Visiting research Blaise Pascal Chair (http://www.chaires-blaise-pascal.org/uk/index.html) to work with the French LTER program and develop several French-US projects, among other tasks. Duties included advising the leadership of the emerging French LTER program (zones ateliers), including developing further ties with the US-LTER and sponsoring joint research with NWT.
Activities and Findings

Research and Education Activities: (See PDF version submitted by PI at the end of the report)
See attached activities/findings file.

Findings: (See PDF version submitted by PI at the end of the report)
See attached activities/findings file.

Training and Development:

Outreach Activities:
The NWTLTER K-12 outreach program emphasizes collaboration with existing programs for children in the Denver/Boulder area. The conceptual theme is the connection between the alpine ecosystems in the mountains and the communities of the Rocky Mountain Front Range. Local school children experience the mountains as familiar landmarks and are particularly receptive to environmental education that emphasizes discovery, exploration and empathy with their local environment. Our program includes direct interaction with children and distribution of educational materials, including children's science books and supporting curricular materials.

Field trips for children and teacher training. One important aspect of our outreach program involves direct interaction, and a hike to the Tundra lab, for students through several local summer programs (Science Discovery and Bixby School in Boulder and Wild Bear Center for Nature Discovery in Nederland. Each field trip includes 12-18 children, with 4-6 scientists and student teachers. The program with Science Discovery offers one all-day field class for elementary students and one for middle school students. Wild Bear has two- and one-week sessions for students on ecological themes. These field trips are coordinated with a MRS summer course- 'Alpine Ecology and Experiential Learning'. Five to fifteen students have taken this course each year, with about half being in-service teachers. The course is taught by NWTLTER scientists and Dr. Jane Larson, an expert in science education. As the service learning aspect of the summer course, the undergraduates and teachers, along with the course instructors, lead the field trips.

During the school year, we have conducted an additional outreach activity for middle school students. Since 1999, INSTAAR has brought 200-middle school students to INSTAAR for a half-day of lab tours. For this event, NWTLTER scientists have conducted activities at Boulder Creek (located two blocks from INSTAAR) in which we demonstrate methods for stream flow measurement, water quality sampling and measurement, and collection of aquatic biota, and discuss the connections between Boulder Creek in the city and its origins in Green Lakes Valley. During the 45-minute activity student groups work at 3 stations along the creek. This activity is further supported by a virtual field trip to Niwot Ridge (web address) which provides background information, and then 3 field trips that emphasize the mammals, plants and the effect of nitrogen on biodiversity. The trip is structured with pictures of the animals and plants that can be enlarged. The virtual field trip complements the hands-on field trips in many ways: providing a back up should inclement weather limit the trip and virtual access for physically handicapped children.

The LTER Schoolyard Children's Book Series. Our program has been in active in developing the opportunities associated with the successful publication of the children's book My Water Comes from the Mountains by Tiffany Fourment, which was distributed as classroom sets to all elementary school in Boulder Valley and St. Vrain Valley school districts in 2004. An important activity has been to promote the establishment of an educationally vibrant book series by communicating with other LTER educators and scientists in workshops and supplemental materials. In the summer of 2005, we held a workshop for the LTER community in which experts gave presentations on all the different steps involved in a successful children's science book. From the recordings of these presentations, NWTLTER scientists, along with Monica Elser from CAPLTER, have produced an edited DVD that has already served as a resource for potential authors and scientists at other sites who are interested in pursuing a future book for their site. This DVD was distributed at the ASM and the plans for the series were further developed at an ASM workshop organized by NWTLTER and CAPLTER.

We have continued to build on the positive response to the first book by local educators. This book takes readers on a journey from snowpack sources of the Continental Divide to the plains and water in their faucets. A NWTLTER graduate student, Colleen Flanagan, has developed a curriculum guide and resource kit to promote watershed understanding for 4th and 5th grade students in the two local districts and these materials were distributed in April 2006. The guide ü 'MY H2O' ü blends Colorado state educational standards in science, language arts, geography and math into activities, educational games, story plots and community action tasks. The curriculum is organized under 4 themes: The Water Cycle, Our Watersheds, Boulder County's Flora, Fauna and Life Zones, and Human Impact on Water. The hands-on projects are enhanced by a resource kit containing supplies to implement each activity, such as a 3-D relief map to advance understanding of Boulder County watersheds; hand lenses, nets, and taxonomic keys to explore stream macroinvertebrates; and laminated illustrations of local plants and
animals. The guide was interwoven into preexisting district science curriculum distribution centers (i.e., FOSS Center and the Science-To-Go Center). Other organizations receiving MY H2O include Wild Bear Center for Nature Discovery, Thorne Ecological, CU Science Discovery, Bixby School, Friends’ School, CU Earth Education, Boulder County Parks and Open Space, The Watershed School, Running River School, and the Girl Scout Council of Denver. The curriculum can be used as a stand-alone unit or to augment currently used units on water, ecosystems, outdoor education, or the 5th grade Children’s Water Festival. In addition to NWTLTER, support was provided by the U.S. EPA, the CU-Boulder Outreach Committee, the City of Boulder and the Watershed Approach to Stream Health, or WASH, a partnership of communities in Boulder County formed to protect water quality.

Average scores from teacher feedback on the North American Alliance for Environmental Education (NAAEE)-based 6-month evaluations indicate MY H2O averaged 4.65 of 5.0 possible points, an overall merit rating of 93%. Evaluations indicate that teachers marked great improvements in understanding place-based themes 'Our Watersheds' and 'Human Impact on Water'. Comments from teachers and administrators included the following:

'The activities are age appropriate, standards are met, and perhaps most importantly, the kids are engaged and learning!' - SVVSD schoolteacher

'The curriculum and kit go perfectly with the material that I teach in preparation for the 5th grade Water Festival.' û BVSD schoolteacher

'This kit is a wonderful tool to fill our Earth science standards in grades 3 - 5.' û SVVSD Science Coordinator

'I would definitely use 'MY H2O' again, it has many fun and engaging activities that can induce higher level thinking in students. It also has the aspect of being extremely relevant by discussing issues that are happening right here in Colorado.' - Wild Bear Center for Nature Discovery educator

Development of regional edition. My Water Comes from the Rocky Mountains describes the concepts put forth in our first book and applies them to the whole Front Range. The development of this new regional edition is currently being coordinated with the Colorado State Parks in conjunction with their extensive outreach program to the elementary schools in the Denver-Front Range region. The text of the first book has been updated, expanded, and critically edited by a NWTLTER graduate student (Lindsay Weber) and Kenneth Nova, a 5th grade teacher. The text has been reviewed for accuracy, well-roundedness, and applicability towards the entire Front Range by several individuals at the Cherry Creek Stewardship Partners, Boulder County Water Department, Aurora Water Department, and the Sevilleta LTER site. The revisions are mainly comprised of adding text about groundwater, snowpacks, diversions, and storm drains and generalizing the specific text describing the glaciers, snowfields, tributary streams and reservoirs in the Boulder watershed in order to be applicable to the wide-range of watersheds. Further, the student artwork and comments in the page margins of the book are being replaced. Weber has been working with 15 educators throughout the region in developing the new student artwork. Over 300 artwork pieces and associated comments have already been collected from several elementary schools in New Mexico, Colorado, Wyoming, and Montana, and further artwork and comments are expected from schools in Idaho, Utah, and Kansas. These pictures and comments are being placed on a website for the book at http://culter.colorado.edu/MyWater/.

Development of Spanish language edition. Mi Agua Viene de las Montañas Rocosas is a Spanish language children's book based on the text and concepts put forth in the regional edition. The overarching goal in the development of Mi Agua is to integrate children's earth science literature within 'English as a Second Language' (ESL) educational programs. Also, Mi Agua Viene de las Montañas Rocosas is an outreach activity that responds to the positive feedback My Water Comes from the Mountains received and to several calls for such a Spanish language edition from regional educators. Specifically, Dr. Paul Flack, lead hydrologist of the Colorado State Parks, and Karen Hunter, St. Vrain Valley educational coordinator, have both emphasized the need to develop Spanish-language materials to address bilingual students in Colorado communities. The text of the Spanish edition has been translated by Weber and edited for accuracy by Boris Illade, a bilingual 4th grade teacher at University Hill Bilingual Elementary School in Boulder.

For this edition, unique attributes of the Spanish-language culture will be addressed by using artwork and comments developed by ESL students in local bilingual elementary schools. Weber has been working with 3 educators in the Boulder/Longmont area. We expect between 100-150 artwork pieces and comments to be finished by early June. These pictures and comments will also be placed on a website specific to the book, linked to the NWT LTER site, and developed in coordination with the NWT information manager.

**Journal Publications**


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Books or Other One-time Publications

Collection: Paper presented at the annual meeting of the National Association for Research in Science Teaching. Dallas, TX.
Bibliography: National Association for Research in Science Teaching. Dallas, TX.

Editor(s): U. M. Huber, H. K. M. Bugmann, and M. A. Reasoner
Collection: Global Change and Mountain Regions (A State of Knowledge Overview)
Bibliography: Springer, Dordrecht

Editor(s): Karsten Zengler
Collection: Accessing Uncultivated Microorganisms
Bibliography: ASM Press, Washington DC

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**Web/Internet Site**

**Other Specific Products**

**Product Type:**
Web Server

**Product Description:**
The Website for the Niwot Ridge LTER Site was updated and redesigned.

**Sharing Information:**
http://culter.colorado.edu

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**Contributions**

**Contributions within Discipline:**

**Contributions to Other Disciplines:**

**Contributions to Human Resource Development:**

**Contributions to Resources for Research and Education:**

**Contributions Beyond Science and Engineering:**

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**Conference Proceedings**

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**Special Requirements**

**Special reporting requirements:** None

**Change in Objectives or Scope:** None
Animal, Human Subjects, Biohazards: None

Categories for which nothing is reported:

Activities and Findings: Any Training and Development
Any Web/Internet Site
Contributions: To Any within Discipline
Contributions: To Any Other Disciplines
Contributions: To Any Human Resource Development
Contributions: To Any Resources for Research and Education
Contributions: To Any Beyond Science and Engineering
Any Conference
I. RESEARCH HIGHLIGHTS

TWO NWT LTER's SHARE NOBEL PEACE PRIZE WITH AL GORE: Diane McKnight and Tim Seastedt. We are particularly proud and happy to brag about our two NWT LTER's who shared in the 2007 Nobel Peace Prize for their efforts on behalf of the Intergovernmental Panel on Climate Change, Tim Seastedt and Diane McKnight. The Nobel Peace Prize cites in part "for their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change".

NWT RIDGE LTER SITE SELECTED AS THE NEON CORE SITE FOR THE SOUTHERN ROCKIES CLIMATE DOMAIN.
NEON has selected the Niwot Ridge LTER site as the candidate core site for NEON climate domain 13, the Southern Rockies and Colorado Plateau. M. Williams, PI of the NWT LTER program, is the lead for the NEON core site at Niwot Ridge. NEON conducted a thorough and extensive site review from 17 to 20 August, 2008. The site review went reasonably well, and was attended by Liz Blood, the NSF program officer for NEON, and Henry Gholz, the NSF program officer for the LTER program. Climate domain 13 extends westward from the eastern boundary near Boulder, CO, west to Las Vegas NV. The Niwot Ridge core site is thus located on the very northeastern corner of climate domain 13. The core site for climate domain 10 to the east is located at the SGS LTER site, on the western edge of that climate domain. Thus, the two core sites, both LTER sites, are only 100 km's or so apart. As part of the site review, three relocatable sites were located: (1) Moab Utah in partnership with the USGS; (2) Fraser Experimental Forest about 25 kms west of Niwot Ridge, in partnership with the USFS; and (3) the eastern edge of Rocky Mountain National Park, in partnership with the NPS and also Jill Baron's USGS group. Essentially, we borrowed one of the relocatable sites designated for climate domain 10. Williams facilitated the selection of these sites and federal partners. The hope is that these sites serve as the core of a regional mountain network that connects to the plains to the east.

BOULDER CREEK CRITICAL ZONE OBSERVATORY ESTABLISHED
A University of Colorado team led by INSTAAR Suzanne Anderson was awarded funding by the National Science Foundation for a five-year project to establish a Critical Zone Observatory (CZO) in the Boulder Creek Watershed. The project is one of three new CZO awards designed to build the first systems-based observatories dedicated to Earth surface processes. The critical zone is the region from the base of groundwater to the outer limit of the vegetation canopy, essentially the zone that supports terrestrial life. The CU group, which includes NWT LTERs Nel Caine, Diane McKnight, and Mark Williams, and 10 other scientists at CU and elsewhere, plans to focus on the rocky mountainous portion of Boulder Creek watershed, including the NWT LTER site. The project will study how weathering and erosion processes control the architecture of the weathered profile within the critical zone in this eroding landscape. They will then explore how different architectures influence the hydrologic, biogeochemical and ecological functioning of catchments. Boulder Creek watershed encompasses over 2500 m in elevation, and spans a range of vegetation and climate zones. Erosional regimes vary significantly as well, from the glacial scoured headwaters, to the late-Cenozoic fluvial incision of Boulder Canyon, to a band of relatively quiescent topography in between. The Boulder Creek CZO team plans to use these environmental gradients as a set of natural experiments to delve into the processes that shape the Earth’s surface and affect its function.
NSF SGER: HUMAN AND ECOSYSTEM RESPONSES TO MOUNTAIN PINE BEETLE OUTBREAKS IN THE COLORADO FRONT

We received a SGER award in June 2008 to study the mountain pine beetle outbreak in the subalpine portion of Niwot Ridge. This proposal builds on the strengths of our current LTER team, including PI Alan Townsend and Co-I's Mark Williams, Tim Seastedt, and Russ Monson. Bill Travis was added as a Co-I to bring in a human dimensions component to the proposal. Alan Townsend is the designated PI on the NWT LTER renewal for 2010. This project provides a nice transition for Alan to start learning the management end of the NWT LTER program, as well as begin new initiatives that will be incorporated into the 2010 renewal.

Summary: Pests and pathogens pose an increasing threat to forests throughout North America. In Western conifer forests, massive outbreaks of endemic insects are transforming forests on a grand scale, in ways that are likely to have important consequences for both ecological and human systems. The mountain pine beetle (MPB; Dendroctonus ponderosae) provides one clear example. In recent years, MPB outbreaks throughout the western U.S. and Canada have been startling in both their speed and areal extent; in Colorado alone, more than 600,000 hectares have been infected since the late 1990’s. Yet, our understanding of how both ecosystems and humans react to such outbreaks – and how such responses alter critical ecosystem services – remains poor. This SGER proposal will take advantage of a unique opportunity to collect pre-infection data at the Niwot Ridge LTER and AmeriFlux site, just prior to a pine beetle invasion that is virtually certain to occur. So far, the core study areas of the LTER remain largely MPB-free, but the first signs of infection appeared in 2007, and watersheds on all sides of the LTER have seen heavy outbreaks with areas of 100% tree mortality. Thus, the opportunity to monitor an outbreak in real time, as it proceeds through a well documented study area, is now. This proposal also responds directly to central goals of the recent Integrative Science for Society and Environment (ISSE) report, and brings together a consortium of investigators and programs to begin a long-term investigation of the ecological, biogeochemical, hydrological, and social impacts of the MPB epidemic in and near the Como Creek drainage and the Colorado Front Range. Partners in this effort include: the NWT LTER (led by co-PIs Williams, Seastedt and Townsend), NWT AmeriFlux (directed by co-PI Monson), Alpine Microbial Observatory (led by S. Schmidt), USGS-Biological Resources Discipline’s Western Mountain Initiative (led by T. Veblen), and noted social scientist and co-PI W. Travis. Data to be collected in this effort include not only those on ecosystem responses (biogeochemical, hydrological and ecological), but also on public and policy responses to the outbreak in the Colorado Front Range region.

The broader impacts of an integrated study on human and ecosystem responses to MPB outbreaks are considerable. Not only will the work contribute to established education and outreach programs that are part of the LTER and other partner programs in this effort, it will directly address a phenomenon that has the attention of the highest levels of government in the western U.S. and Canada. Senator Ken Salazar (D-CO) called the current MPB epidemic “the Katrina of the West”, and states and provinces from New Mexico to British Columbia are scrambling to enact new management policies in the wake of large-scale beetle kills. Yet, scientific understanding of both the short- and long-term consequences of MPB infestation is far from complete, creating a worrisome situation in which policies with far-reaching consequences
for the region’s forested ecosystems are being invoked largely without thorough scientific understanding.

REVIEW PUBLISHED ON HUMAN TRANSFORMATION OF THE NITROGEN CYCLE

Alan Townsend is incoming PI on the NWT LTER program and director of the International Nitrogen Initiative's (INI) North American Nitrogen Center, housed at INSTAAR. He and other members of the INI are co-authors of a review on human influence on the nitrogen cycle published in Science Magazine. They show that humans continue to transform the global nitrogen cycle at a record pace, reflecting increased combustion of fossil fuels, growing demand for nitrogen in agriculture and industry, and pervasive inefficiencies in its use. Much anthropogenic nitrogen is lost to air, water, and land to cause a cascade of environmental and human health problems. Simultaneously, food production in some parts of the world is nitrogen-deficient, highlighting inequities in the distribution of nitrogen-containing fertilizers. Optimizing the need for a key human resource while minimizing its negative consequences is a central goal of the INI, and requires an integrated interdisciplinary approach and the development of strategies to decrease nitrogen-containing waste. Science 16 May 2008: Vol. 320, no. 5878, pp. 889 – 892 DOI: 10.1126/science.1136674. Transformation of the Nitrogen Cycle: Recent Trends, Questions, and Potential Solutions James N. Galloway Alan R. Townsend, Jan Willem Erisman, Mateete Bekunda, Zucong Cai, John R. Freney, Luiz A. Martinelli, Sybil P. Seitzinger, Mark A. Sutton.

CONSERVATION, RESTORATION STRATEGIES MUST SHIFT WITH GLOBAL ENVIRONMENTAL CHANGE

Tim Seastedt, along with colleagues Richard Hobbs (Murdoch Univ, Australia) and Katherine Suding (UC Irvine, former INSTAAR and current NWT LTERer), investigated ecosystem management studies from the past 12 years in an effort to begin determining best practices for the future. They propose that biologists and managers focus on making existing ecosystems resilient to further environmental change rather than on attempting to restore them to their original state. In their view, enormous global environmental changes are rapidly and irreversibly modifying nearly all ecosystems on Earth into so-called "novel ecosystems" -- thriving combinations of plants, animals and habitat that have never occurred together before. It is these new ecosystems that should be accepted, preserved and enhanced in order to shield them from further modifications linked with global environmental change (i.e., atmospheric pollution, climate change, exotic species invasions, extinctions and land fragmentation).

Current management practices often involve trying to fix only one aspect of an ecosystem, like eradicating an invasive species. But in many cases, such action does little to improve the ecosystem's overall health. Invasive plant species that have been removed, for example, are frequently replaced by other invasive species that quickly colonize the ecological "vacuum." Instead, biologists and managers need to work with new approaches that focus on desired outcomes, emphasizing genetic and species diversity. Such projects could include "reassembling" forest ecosystems in the West devastated by bark beetles, replanting them with bug-resistant trees and introducing vegetation that absorbs large amounts of carbon dioxide and filters nutrient-enriched water. Seastedt. R.J. Hobbs and K.N. Suding. 6, doi:10.1890/070046,

FIREPROOFING HOMES DRAMATICALLY REDUCES FOREST FIRE SIZE
Patrick Bourgeron of the NWT LTER worked with Michael Ghil (UCLA) and Vassilis Spyratos (Ecole Normale Superieure) to model the spread of fires in forest ecosystems in Colorado, Montana Utah, New Mexico, Washington and Wisconsin. Their study is the first to systematically look at both houses and trees in forest fire scenarios. They found that the size of fires is directly linked with the density and flammability of houses built in the so-called "wildland-urban interface." Since houses are much more flammable per square yard than forests, homes that erupt in flames can propel forest fires to a critical intensity threshold much more quickly. Thus, fireproofing homes not only preserves structures, but limits the size of forest fires. The study was published in the Sept. 4 print edition of the Proceedings of the National Academy of Sciences: Development at the wildland–urban interface and the mitigation of forest-fire risk, Vassilis Spyratos, Patrick S. Bourgeron, and Michael Ghil.

GLOBAL WARMING TO CHANGE SKI INDUSTRY IN WESTERN USA
Mark Williams and Brian Lazar (former INSTAAR student, now at Stratus Consulting) presented a study of the potential affects of global warming on Park City to more than 1,000 of the town's 8,500 residents, who crowded into the local auditorium to hear that temperatures are projected to rise 6 to 15 degrees Fahrenheit and that the snowpack will likely be substantially reduced by the end of the century. Williams and Lazar modeled seven different scenarios, built upon prior work by United Nations teams of experts and Williams research at the NWT LTER site. All scenarios predict dire consequences for the winter sports industry. If the world continues to accelerate its use of carbon-based fuels that create greenhouse emissions, then Park City's mountains will likely become virtually snow free. Even with dramatic cuts in greenhouse emissions, the ski season at the turn of the century could extend only from Christmas to President's Day, eliminating the profitable shoulder season in the ski and snowboard industry. The study was funded by the POWDR Corporation, which operates Park City Mountain Resort. Lazar, B., and M. W. Williams, Climate change in western ski areas: Potential changes in the timing of wet avalanches and snow quality for the Aspen ski area in the years 2030 and 2100, Cold Regions Science and Technology, V 51, pp 219-228, 2008.

EFFECTS OF NUTRIENT ENRICHMENT ON PHYTOPLANKTON IN AN ALPINE LAKE, COLORADO, U.S.A. Deposition of atmospheric nitrogen from urban and agricultural sources has caused surface water nitrate concentrations to increase in the Front Range of the Colorado Rocky Mountains. To investigate the effects of sustained increases in nitrate concentrations on phytoplankton dynamics in an alpine lake, we conducted nutrient enrichment experiments in mesocosms amended with nitrate, phosphate, and phosphate plus nitrate on four dates in July and August 2002. During this period, phytoplankton species composition shifted as diatoms decreased in abundance. Phytoplankton chlorophyll a increased in the phosphate and phosphate plus nitrate enrichments, but did not increase in the nitrate only enrichments. Analysis of the phytoplankton community using Principal Component Analysis showed that 34% of the variance was accounted for by the primary axis, which was associated with different time
periods, and 21% of the variance was explained by the secondary axis, which was associated with treatments. The response to phosphorus enrichment was taxon-specific, and the two chlorophyte species which became more abundant, Chlamydomonas sp. and Scenedesmus sp., were strongly weighted on the secondary axis. These results indicate that the productivity of this phytoplankton community is phosphorus-limited throughout the summer. Therefore, additional inputs of nitrogen are not expected to directly alter the productivity of the phytoplankton community.

MICROBIAL CONTROL OF BIOGEOCHEMICAL CYCLING IN COLD REGIONS
15 years of microbial research at Niwot Ridge has shown that microbial turnover of soil nutrients is about 10 times faster than by plants. Thus, for every unit of N cycling by plants, microbes work ten times as fast. Soil microbial communities have the metabolic and genetic capability to adapt to changing environmental conditions on very short time scales. In this paper we combine biogeochemical and molecular approaches to reveal this potential, showing that microbial biomass can turn over on time scales of days to months in soil, resulting in a succession of microbial communities over the course of a year. This new understanding of the year-round turnover and succession of microbial communities allows us for the first time to propose a temporally explicit N cycle that provides mechanistic hypotheses to explain both the loss and retention of dissolved organic N (DON) and inorganic N (DIN) throughout the year in terrestrial ecosystems. In addition, our results strongly support the hypothesis that turnover of the microbial community is the largest source of DON and DIN for plant uptake during the plant growing season. While this model of microbial biogeochemistry is derived from observed dynamics in the alpine, we present several examples from other ecosystems to indicate that the general ideas of biogeochemical fluxes being linked to turnover and succession of microbial communities are applicable to a wide range of terrestrial ecosystems. SK Schmidt, EK Costello, CC Cleveland, AP Martin, AE Miller, A. Seimon, Biogeochemical consequences of rapid microbial turnover and seasonal succession in soil, ECOLOGY, V88 N6, pp 1379-1385, 2007.

DAYCENT_CHEM MODELING ACTIVITIES.
We participated in biogeochemical modeling at the watershed scale using the DayCent-Chem model. The project is lead by Jill Baron with funding from EPA and NPS. The objective is to conduct simulations of hydrochemical responses to atmospheric N deposition for mountain sites around the US. There are seven sites participating (four of which are LTER sites): Coweeta, Great Smoky Mountains, Hubbard Brook, Acadia, Niwot Ridge, HJ Andrews, and Mt Rainier. Initial results are being published as a USGS Open File Report. There is one chapter for each site. This first data paper is a way to collect all the initial site descriptions, model parameter estimation and initial conditions, and model output from the seven sites. DayCent-Chem simulations of ecological and biogeochemical processes of eight mountain ecosystems in the United States. Melannie D. Hartman, Jill S. Baron, David W. Clow, Irena F. Creed, Charles T. Driscoll, Holly A. Ewing, Bruce D. Haines, Kate LaJtaha, Jennifer Knoepp, Dennis S. Ojima, William J. Parton, Jim Renfro, R. Bruce Robinson, Helga Van Miegroet, Kathleen C. Weathers, and Mark W. Williams. USGS Open File report xxxx.

II. RESEARCH ACTIVITIES
Here we focus on new activities for 2008.

ROA RESEARCH REPORT, Dr GARY GIANNY, FORT LEWIS COLLEGE, CO
Field work during May, June, July and August of 2008 in Western Archuleta County, Colorado, has identified mapped and characterized 15 wetlands and associated springs that occur on or near the Fruitland Formation along 20 miles of outcrop. In addition, 21 measured stratigraphic sections in the Fruitland formation were measured and or complied in an effort to better understand the potential role of stratigraphic heterogeneity in controlling near surface hydrology. The stratigraphic data are also being used to facilitate "line mapping" of individual coal beds by the Colorado Geological Survey. These line maps will be useful for identifying not only hydrologic dynamics but also potential methane seepage to the surface from the coal beds. All of the data above are currently being compiled to guide the sampling design for the next phase of this project that includes a synoptic water chemistry survey of the region. Together, the stratigraphic, hydrologic and geochemical characteristics combined in this study should provide insights into this and other basins experiencing Coal Bed Methane development. This project embodies the spirit of stakeholder-driven science while refining our understanding of this type of hydrologic system.

Three Fort Lewis College undergraduate students worked on this project over the course of the summer. NSF ROA funding was leveraged with significant support from the Colorado Geological Survey (funded by the Colorado Oil and Gas conservation Commission), and the San Juan Public Lands Center (Joint BLM and USFS). During the project these students had the opportunity to work with three faculty from Fort Lewis College, geologists from the Colorado Geological Survey, and hydrologists, plant ecologists and land managers from the U. S. Forest Service. Two of three students funded in this study are very interested in graduate school opportunities at CU Boulder, and all three are interested in meeting CU faculty involved in similar research.

Results of this research will be published in a number of locations: The Colorado Geological Survey is publishing the stratigraphic data in a special report expected in late 2008 or early 2009. The undergraduate students may present their work at regional or national meeting of the Geological Society of America as well as the Ecological Society of America in 2009. Pending funding for the synoptic portion of the study, publication by the PI s (Williams, Gianniny, and Knydick) in a peer reviewed journal is expected in 2009 as well.

CHRISTOPHE RANDIN, SWISS POSTDOC
We hosted Chris Randin, a visiting Post-Doc from the University of Lausanne, Switzerland, who was in residence from Sept 2007 to Sept 2008. Funding for Chris is from the Swiss NSF. The title of his research is: "Towards mechanistic models to predict the distribution of alpine plant species under climate change". Chris addressed three goals during his stay at the Institute of Arctic and Alpine Research (INSTAAR, University of Colorado at Boulder): (1) develop a dynamic model of snow coverage for Niwot Ridge with the PREVAH model; (2) extend this models to include process-based spatially-explicit predictions of alpine plant species distribution; and (3) integrate the effects of plant species interactions into predictions of distribution change under future climate change scenarios. Results to date include: (1) standardized field
observations for 88 gridded vegetation plots for 81 alpine plant species have been coded and are ready for analysis for six years (1989, 1990, 1995, 1997, 2006 and 2008), (2) environmental GIS data have been developed for the study area (snow coverage, air temperature and solar radiation at a daily time step from 1987 to 2008), (3) the blowing snow model developed by Glen Liston has been successfully validated against field data, and (4) climate change scenarios derived from 17 General Circulation Models (GCMs) are available for simulations in the future. Three articles based on this work are in preparation. Chris felt his time at the NWT LTER site was productive and has written a proposal to the Swiss NSF to return to Boulder from January to June 2009 to finish his model simulations and manuscripts.

UNAVCO PROJECT HIGHLIGHTS-NIWOT RIDGE LTER, SEPTEMBER 2007

* Principal Investigators (PI): Mark Williams, University of Colorado-Boulder
* UNAVCO Engineers: Marianne Okal, Seth White, Bjorn Johns, Thomas Nylen
* Dates: September 2007
* Location: Niwot Ridge, Colorado

The Niwot Ridge Long Term Ecological Research (LTER) area, located approximately 35km west of Boulder, is one of 26 field sites devoted to ecosystem studies in the larger LTER Network. Numerous studies in the area are currently underway, and in September UNAVCO provided researchers at the University of Colorado-Boulder one GPS unit with which to conduct hydrological surveys of the area's wells. The group's main interest is to determine the subterranean water elevations of the wells, and it will then use this data to establish subsurface flow, subsurface storage, and seasonal fluctuations in hydrologic source waters. This data can then in turn be combined with water chemistry and water stable isotope data to further climate, hydrology, and water quality knowledge. The surveys were conducted using PPK techniques.

The UNAVCO Polar engineering group took advantage of the field opportunity to visit its test bed receiver and power system, which was originally installed at NWT in 2005. The unit's power system was checked and tested, and a new Iridium communications system was installed, mimicking the PoleNET set-up that is being deployed in Greenland (GNET) and Antarctica over the next several years. As the test site lies in alpine tundra at 11,600 ft. in elevation, the environmental conditions resemble those found in Polar regions, and hence provide a natural, local setting to test and maintain a PoleNET-style GPS site.
Figure 1 - Graduate student Ashley Nielsen and GIS specialist Todd Ackerman survey one of the many wells in Ashley's study area. By measuring the water level relative to the top of the PVC pipe with a plumb line, and then using the GPS data, they will be able to determine the true elevation of the water level.

Figure 2 - Polar engineers Bjorn Johns, Marianne Okal, and Thomas Nylen relax after installing the Iridium communications at the GPS site at Niwot Ridge. The Iridium antenna is visible on the far right of the photo.

**LONG-TERM CHANGES IN ALPINE TUNDRA.** We re-inventoried 88 long-term vegetation plots in 2008, and in conjunction with experimental plots, are using these data sets to evaluate the role of climate and N-deposition on alpine tundra. The major research area at the
Niwot LTER is the Saddle, an Alpine Tundra site, located 5.6 km from the Continental Divide. During the early 1970s, Pat Webber and Diane May used ordination techniques to broadly define six vegetation communities, or noda, on the Saddle: fellfield, dry meadow, moist meadow, shrub tundra, wet meadow, and snowbed. We hypothesize that this site is exhibiting changes in species composition and diversity of vegetation as a result of a) increased precipitation and b) increased atmospheric deposition of inorganic nitrogen in rain and snow. These 88 plots act as reference plots and range from low precipitation, wind-scoured fellfield areas through dry meadows, through moist and wet meadows, into late snowpack communities. Experimental plots are used to develop relationships between these variables and plant response. Relationships between plant species and soil moisture were obtained by using preexisting data sets on vegetation cover and TDR soil moisture measurements. Litaor et al. (2008) have conducted the initial analyses on these data sets. Post-doc Chris Randin has spent the last year organizing the data sets in such a way that models can now be developed to test the hypotheses above.

GLEON
Diane McKnight and graduate student Matt Miller are participants in The Global Lake Ecological Observatory Network (GLEON, a grassroots network of limnologists, information technology experts, and engineers who have a common goal of building a scalable, persistent network of lake ecology observatories. Data from these observatories will allow us to better understand key processes such as the effects of climate and landuse change on lake function, the role of episodic events such as typhoons in resetting lake dynamics, and carbon cycling within lakes.

COMPARATIVE SURVIVAL AND PHYSIOLOGY OF THE AMERICAN PIKA
Supplemental funding in 2008 was used to support new research on the American Pika. Investigator: Chris Ray, Research Associate, EE Biology, CU-Boulder, cray@colorado.edu
Objectives: Estimate and model physiological stress and survival in the American pika (Ochotona princeps) across a climatic gradient

Study System and Background: The American pika is in decline in the western US, and recent research implicates climate change in the extirpation of pika populations. Hypothesized links between climate change and pika morbidity include reduced survival due to 1) heat stress during warmer summers, and 2) cold stress during winters with lower snow cover (reduced thermal insulation). However, currently there is no direct evidence that the microclimates experienced naturally by pikas cause physiological stress or affect survival. We hypothesize that pikas experience higher physiological stress at lower elevations, lower latitudes, and on south-facing slopes. Summer temperatures should be higher in these locations, and winter temperatures may be lower within pika habitats in these locations due to reduced snow accumulation. Pikas in these locations may be stressed directly by climate, or may be stressed indirectly by, for example, climate-induced changes in the water content of forage plants. To test these hypotheses, sampling and tagged pikas at sites differing in latitude, altitude and slope aspect in order to estimate physiological parameters and survival rates. During July and August of 2008, pikas were sampled from two study sites: 1) the Niwot Ridge LTER site (Niwot) and surrounding pika habitats in north-central Colorado, and 2) a long-term pika research site in the Gallatin Range of south-central Montana (Gallatin). Samples of blood, urine, feces, saliva and hair will be used in a comparative study to characterize relative levels of stress hormones (e.g.,
cortisol and TNFa) and other metrics of metabolic stress in pikas at each site. We will also characterize microclimatic variables and patterns of activity in pikas at each site, in order to compare behavioral responses that may mitigate climatic influences.

Methods and results to date (8/15/08):

1) Sampling is complete at Niwot. Of 41 pikas sampled at this site, 23 were captured on the ridge and 18 were captured in an adjacent valley, 21 on north-facing slopes and 20 on south-facing slopes. Sampling will begin at the Gallatin site on 8/18/08.

2) Samples will be analyzed for metabolic substrates (glucose and fatty acids) and hormones, as well as hemoglobin levels (which may contribute to individual fitness at higher elevations) and thiobarbituric reactive substances (to determine the overall oxidative stress levels). Laboratory analyses will begin in September.

3) Tagged individuals will be re-sighted for survival analyses. Re-sights will be made in 2009, allowing estimates of annual survival. Annual survival will also be estimated from data individuals tagged in previous years at these long-term study sites.

4) Microclimatic data sensors will be positioned within the territory of each tagged individual to record data hourly throughout the year of study. All sensors will be in place by early September.

5) Activity budgets have been estimated from observations of pikas at each elevation and slope aspect within the Niwot study site. Activity budgets will be estimated from observations of pikas at the Gallatin site by early September.

6) Physiological variables, behavior and survival will be modeled as responses to habitat variables including latitude, elevation, slope aspect, and microclimate.
Fig. 1. Pikas on slopes at higher elevation (on the West Knoll of Niwot Ridge) exhibited similar patterns of activity, regardless of slope aspect. Patterns of activity were also strikingly similar between pikas at these higher elevations and pikas at lower elevations (in a valley approximately 300 m below), as is evident by comparing Figs. 1 and 2.
Fig. 2. At lower elevations, pikas on slopes with a southern aspect spent more time moving and haying (caching forage) than their counterparts on slopes with a northern aspect. However, differences in activity patterns were slight, suggesting little behavioral response to climate within the range of study sites available in the vicinity of Niwot Ridge.
Projected Results and Broader Significance: This study will determine whether local habitat variables related to climate can explain levels of physiological stress and rates of survival in the American pika. If local variables related to climate can explain stress and survival, then climate change may have relatively direct effects that are contributing to local extinctions of this species. Otherwise, local extinctions may be related to climate change only indirectly (e.g., through the redistribution of disease agents) or to other changing factors (e.g., human land use patterns). These questions are of immediate importance because this species is being petitioned for listing under the Endangered Species Act.

This study is part of a large and collaborative research project designed to determine the factors affecting local extinctions of pikas throughout the western US, and takes advantage of several pre-existing studies to broaden the scope and depth of proposed analyses. Long-term demographic studies undertaken at the Gallatin site, in conjunction with microclimatic measurements there, are providing data on how climate relates to individual survival and population density. Pre-existing data from Niwot Ridge (LTER climate data and data from previous pika studies) will also be used to address this question.

Two REU students were involved in the collection and analysis of data from the Niwot site during June-August 2008. Both students will continue to be involved in analyses of data from both sites, and will co-author manuscripts to be submitted for publication.

EDDY FLUX MEASUREMENTS OF CO₂ TUNDRA-ATMOSPHERE EXCHANGES.
Operation of the first site to make direct measurements of the surface energy balance and CO₂ flux using the eddy covariance technique above alpine tundra at Niwot Ridge, Colorado, began on 1 June 2007. Measurements are compared to simultaneous measurements made over an adjacent subalpine forest, the Ameriflux site at C1 on Niwot Ridge. Energy balance closure averaged 91% due to the high wind speeds, short turbulent flux footprint, and relatively flat ridge-top location of the measurement site. Air temperature and relative humidity at the two sites were highly correlated, with lower air temperatures and higher relative humidities at the alpine site. The horizontal wind speed was poorly correlated between sites, with higher wind speeds and persistent downslope (westerly) flows at the alpine site. Net radiation was higher at the forest site, yet the evaporative fraction was similar. Except for the soil heat flux, the sensible and latent heat fluxes were larger above the forest than the alpine tundra. Both sites were a net sink of CO₂ during the observation period, but the alpine site changed to a source much earlier than the forest site. Greater CO₂ uptake during the daytime by the forest was offset by greater CO₂ losses at night, making the net CO₂ exchange of both sites more similar than that suggested by parameters such as above-ground leaf area index.
NADP HIGH-ELEVATION REPORTING CHANGE
We continue to work with NADP to change how they collect and report atmospheric deposition in mountain environments. NADP has agreed to include atmospheric deposition of mountain sites on their national isopleth maps as points. Secondly, they will publish a separate set of national isopleth maps that include atmospheric deposition from all mountain sites with high amounts of snowfall. These maps differ from how the normal isopleth maps are calculated, using precipitation amount generated at approximately 1-km pixels by the PRISM algorithm. A trial set of these maps was included in the recent Frontiers article on NEON. Third, NADP has designed a new wet chemistry collector designed for high snowfall environments that we have installed and are donating time for collection and maintenance.

INFORMATION MANAGEMENT
Todd Ackerman continues to serve as a member of the LTER Information Management Executive Committee (IMExec), and is currently the Chairman of the Unit Dictionary Committee for the LTER. Over the past year he has served on the program committee for the first Environmental Information Management Conference being held in Albuquerque September 2008.

III. OUTREACH ACTIVITIES.

SAN JUAN COLLABORATORY INTERN PROGRAM
The NWT LTER project help fund and direct the San Juan Collaboratory Intern Program, conducted in southwestern Colorado. Eleven interns participated in an 11-week program from June 2 to August 15, 2008. The program was coordinated by Koren Nydick of the Mountain Studies Institute and funded mainly by the San Juan Public Lands Center (USFS/BLM) and University of Colorado at Boulder. The internships were based in Durango, Silverton, and Dolores, Colorado. Interns were either current undergraduates or recent graduates. Most were from Colorado and had attended a Colorado college or university. A few students from other states added diversity to the group.
The interns worked with researchers and land managers addressing issues such as climate change, land development, air and water pollution, ecosystem restoration, and community revitalization. They worked on lakes and in forests, wetlands, alpine tundra, high desert, and human communities. Interns and their projects are listed below.

<table>
<thead>
<tr>
<th>Intern Name</th>
<th>Intern’s Institution</th>
<th>Intern Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Justin Anderson</td>
<td>University of Kansas</td>
<td>High-Elevation Ecology</td>
</tr>
<tr>
<td>Anya Angst</td>
<td>Fort Lewis College</td>
<td>Environmental Mercury Monitoring</td>
</tr>
<tr>
<td>Camila Fierro</td>
<td>Smith College</td>
<td>Fen Wetland Restoration</td>
</tr>
<tr>
<td>Hannah Grossman</td>
<td>Colorado State University</td>
<td>Hydrologic Inventory, Restoration, and Monitoring</td>
</tr>
<tr>
<td>Safiya Jetha</td>
<td>Emory University</td>
<td>Invasive Plant Mapping</td>
</tr>
<tr>
<td>Clayton Kampf</td>
<td>Fort Lewis College</td>
<td>Hydrologic Inventory, Restoration, and Monitoring</td>
</tr>
<tr>
<td>Jacob William Maggart</td>
<td>University of Colorado at Boulder</td>
<td>Sudden Aspen Decline</td>
</tr>
<tr>
<td>Mary Beth Miles</td>
<td>University of Colorado at Boulder</td>
<td>Abandoned Mine Lands</td>
</tr>
<tr>
<td>Andrew Straub-Heidke</td>
<td>University of Colorado at Boulder</td>
<td>Hydrologic Inventory, Restoration, and Monitoring</td>
</tr>
<tr>
<td>Andrew Verbonitz</td>
<td>Fort Lewis College</td>
<td>Post-Wildfire Aspen Regeneration</td>
</tr>
<tr>
<td>Jeremy Yanko</td>
<td>Fort Lewis College</td>
<td>Animas River Corridor Revitalization</td>
</tr>
</tbody>
</table>

The interns and many of the mentors participated in three program events. Orientation was held at Fort Lewis College in Durango and included “get-to-know-you” activities, a regional environmental and socio-economic overview, a tour of local ecosystems, and a raft trip down the Animas River. During a field trip in Silverton half-way through the program, interns visited...
high-elevation forests and an abandoned mine site to learn about a few of the projects. Interns gave informal project updates and cooked dinner over a campfire. The final morning of the program, interns and a few mentors took a boat trip on Vallecito Reservoir to discuss mercury and wildfire and learn lake monitoring skills. The group then had lunch at the San Juan Public Lands Center and each intern gave a presentation about their project.

**ROCKY MOUNTAIN NATIONAL PARK**
Bill Bowman (February 2008) provided a training seminar to NPS naturalists at RMNP on climate change effects in the alpine. He stressed: (1) treeline and its response, past, present, and future; (2) diversity of alpine plants (as mediated by warming and biogeochemical feedbacks); (3) pikas, with some cautionary remarks.

Mark Williams was a Lyceum Program speaker at the Beaver Meadows Visitor Center, East Entrance, Rocky Mountain National Park, 9 February 2008, Estes Park, CO. His talk was entitled "Save our Snow: Climate change in the Rocky Mountains". The talk was well-attended and well-received. He was asked and gave the same talk at the Kawuneeche Visitor Center on the west entrance several weeks later.
NWT LTER SUPPORTS ECOARTS
NWT LTER helped support and personnel participated in a unique outreach activity that combined performing art with science. EcoArts is a collaboration of 22 science, environmental, arts, indigenous, and other organizations in 3 cities to increase awareness of climate change and sustainable living. Jason Neff, a senior scientist with the NWT LTER, was a performer in “Balancing Acts: Visions for a Sustainable Future”, which is a series of performance pieces informed and/or “co-created” by artists and scientists that include the arts disciplines of dance, theatre, music, and poetry, and the science areas of biogeochemistry, evolutionary biology, and science education and communication. The performances were held September 12-14 at the Dairy Center for the Arts in Boulder, Colorado. Collaborating organizations and institutions include NOAA, NCAR, CIRES, Denver Museum of Nature & Science, University of Colorado Museum of Natural History, Niwot Ridge LTER program, Center for ReSource Conservation, Blair-Caldwell African American Research Library, Newman Center for the Performing Arts, Denver Botanic Gardens, Curious Theatre, and the Fort Collins Museum of Contemporary Art, among others.

Each of the performers brings his/her own unique artistic sensibilities to “Balancing Acts” – and all of them are not what one might expect. For example, Michelle Ellsworth describes her collaboration with biogeochemist Jason Neff, visual artist Priscilla Cohan, and composer Michael Theodore as “a dense and efficient performance piece about ‘the situation’ that employs choreography, chatting, and lubricated ball bearings to explore the complexities and interconnectedness/co-dependence of sex, blame, and science.”

FLUORESCENCE/PARAFAC WORKSHOP
Diane McKnight and Matt Miller hosted a fluorescence and PARAFAC workshop on Monday and Tuesday March 10-11. The workshop was primarily intended as training for students and
scientists working on projects involving DOM analyses at INSTAAR, CEAE and the USGS-Boulder lab. This training opportunity was offered to others at a charge of $250 per person. There were a total of 12 participants who are listed below.

On Monday morning there were presentations related to background information on fluorescence spectroscopy, the usefulness/limitations of fluorescence in characterizing DOM in natural waters, and how to collect reliable fluorescence scans. On Monday afternoon participants spent time in the Limnology and DOM labs at INSTAAR learning the laboratory techniques associated with collecting 3-dimensional fluorescence scans. There were then presentations on Tuesday morning that described the theoretical and statistical approaches used to develop the PARAFAC model. Finally, the rest of the day was spent teaching the participants how to use Matlab to correct fluorescence scans and subsequently fit the corrected scans to the PARAFAC model.

List of Participants:
- Kevin Rose - Miami University
- Brian Lutz – Duke University
- Murage Ngatia – California Department of Water Resources
- Christine Seibold – Kiowa Lab Manager, University of Colorado
- Alisa – Kiowa Lab Assistant
- Ariann Blankenship – Center for Limnology, University of Colorado
- 6 graduate Students from Diane McKnight’s Advance Aquatic Chemistry Class

LTER SCHOOLYARD CHILDREN'S BOOK FUND.
Diane McKnight was instrumental in developing this program. From Monica Elser, 1 Feb 2008:
Dear LTER Community: We are pleased to announce the establishment of an LTER Schoolyard Childrens Book Fund which is designed to help defray some of the costs associated with publishing books to be included in the LTER Schoolyard Childrens Book Series. This current fund is a result of support by the LTER network for the Childrens Book Series and is being administered by the non-profit Hubbard Brook Research Foundation. A Childrens Book Fund Committee made up of people associated with LTER sites oversees this fund. We have put together a request for proposals so you can access these funds for book projects. We have established two dates this year for proposals (Feb 29 and Oct 15) and will probably have one date in subsequent years. Our hope is that we will continue to receive money for this fund through a variety of sources, including private donations. These donations are tax-deductable. We have attempted to create documents outlining the publishing process as best as we understand it. Since this is a series, we only expect one to two books to be published in any one year. For more information, please view the Request for Proposals and associated documents at: http://schoolyard.lternet.edu

NWT LTER FEATURED IN CAPITOL HILL LOBBYING BY CU-BOULDER
NWT LTER program was featured by the University of Colorado's Office of State and Federal Government Relations in their Annual Federal Priorities book that President Brown and the Chancellor's take to Capitol Hill each year to highlight CU's FY07 research projects.

TREE-ISLAND PROPOSAL
Cooperated with Ayers and Seltzer at Colorado State University on an NSF proposal (DEB-0816720) *Does home-field advantage cause faster decomposition rates in temperate forest ecosystems?* They proposed to study this topic in the tree islands on Niwot by conducting a reciprocal litter transplant experiment and a facilitated migration experiment (i.e. moving the soil cores containing the forest soil community) within tree island chronosequences (i.e. with time a function of the rate that the tree islands move). NWT LTER wrote a letter of cooperation and is providing logistical support and archived data.

**EPA STAR PROPOSAL**
Charles Driscoll of the Hubbard Brook LTER site submitted a proposal to the U.S. Environmental Protection Agency to conduct hydrochemical modeling of the response of high elevation watersheds to climate change and atmospheric deposition. In this study, they proposed to apply the model PnET-BGC to Niwot Ridge LTER. We are cooperators with this proposed study. The research would involve using existing climate deposition, discharge and water chemistry data to calibrate/test the model and making long term discharge and soil and water chemistry projections under future scenarios of climate change and atmospheric deposition. Their main goal would be to compare model calculations across a range of sites with a range of climate conditions to better understand how water quality of high elevation watersheds might respond to changing climate.

**THE THIRD INTERAGENCY CONFERENCE ON RESEARCH IN THE WATERSHEDS (ICRW):**
Planning for an Uncertain Future: Monitoring, Integration, and Adaptation, was organized by the U.S. Geological Survey and held 8-11 September 2008 in Estes Park, Colorado. M. Williams was on the steering committee. He hosted a field trip for attendees to Niwot Ridge LTER on 10 September 2008, with 10 participants.
I. RESEARCH HIGHLIGHTS

TWO NWT LTER's SHARE NOBEL PEACE PRIZE WITH AL GORE: Diane McKnight and Tim Seastedt. We are particularly proud and happy to brag about our two NWT LTER's who shared in the 2007 Nobel Peace Prize for their efforts on behalf of the Intergovernmental Panel on Climate Change, Tim Seastedt and Diane McKnight. The Nobel Peace Prize cites in part "for their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change".

NWT RIDGE LTER SITE SELECTED AS THE NEON CORE SITE FOR THE SOUTHERN ROCKIES CLIMATE DOMAIN.
NEON has selected the Niwot Ridge LTER site as the candidate core site for NEON climate domain 13, the Southern Rockies and Colorado Plateau. M. Williams, PI of the NWT LTER program, is the lead for the NEON core site at Niwot Ridge. NEON conducted a thorough and extensive site review from 17 to 20 August, 2008. The site review went reasonably well, and was attended by Liz Blood, the NSF program officer for NEON, and Henry Gholz, the NSF program officer for the LTER program. Climate domain 13 extends westward from the eastern boundary near Boulder, CO, west to Las Vegas NV. The Niwot Ridge core site is thus located on the very northeastern corner of climate domain 13. The core site for climate domain 10 to the east is located at the SGS LTER site, on the western edge of that climate domain. Thus, the two core sites, both LTER sites, are only 100 km's or so apart. As part of the site review, three relocatable sites were located: (1) Moab Utah in partnership with the USGS; (2) Fraser Experimental Forest about 25 kms west of Niwot Ridge, in partnership with the USFS; and (3) the eastern edge of Rocky Mountain National Park, in partnership with the NPS and also Jill Baron's USGS group. Essentially, we borrowed one of the relocatable sites designated for climate domain 10. Williams facilitated the selection of these sites and federal partners. The hope is that these sites serve as the core of a regional mountain network that connects to the plains to the east.

BOULDER CREEK CRITICAL ZONE OBSERVATORY ESTABLISHED
A University of Colorado team led by INSTAAR Suzanne Anderson was awarded funding by the National Science Foundation for a five-year project to establish a Critical Zone Observatory (CZO) in the Boulder Creek Watershed. The project is one of three new CZO awards designed to build the first systems-based observatories dedicated to Earth surface processes. The critical zone is the region from the base of groundwater to the outer limit of the vegetation canopy, essentially the zone that supports terrestrial life. The CU group, which includes NWT LTERs Nel Caine, Diane McKnight, and Mark Williams, and 10 other scientists at CU and elsewhere, plans to focus on the rocky mountainous portion of Boulder Creek watershed, including the NWT LTER site. The project will study how weathering and erosion processes control the architecture of the weathered profile within the critical zone in this eroding landscape. They will then explore how different architectures influence the hydrologic, biogeochemical and ecological functioning of catchments. Boulder Creek watershed encompasses over 2500 m in elevation, and spans a range of vegetation and climate zones. Erosional regimes vary significantly as well, from the glacial scoured headwaters, to the late-Cenozoic fluvial incision of Boulder Canyon, to a band of relatively quiescent topography in between. The Boulder Creek CZO team plans to use these environmental gradients as a set of natural experiments to delve into the processes that shape the Earth’s surface and affect its function.
NSF SGER: HUMAN AND ECOSYSTEM RESPONSES TO MOUNTAIN PINE BEETLE OUTBREAKS IN THE COLORADO FRONT

We received a SGER award in June 2008 to study the mountain pine beetle outbreak in the subalpine portion of Niwot Ridge. This proposal builds on the strengths of our current LTER team, including PI Alan Townsend and Co-I's Mark Williams, Tim Seastedt, and Russ Monson. Bill Travis was added as a Co-I to bring in a human dimensions component to the proposal. Alan Townsend is the designated PI on the NWT LTER renewal for 2010. This project provides a nice transition for Alan to start learning the management end of the NWT LTER program, as well as begin new initiatives that will be incorporated into the 2010 renewal.

Summary: Pests and pathogens pose an increasing threat to forests throughout North America. In Western conifer forests, massive outbreaks of endemic insects are transforming forests on a grand scale, in ways that are likely to have important consequences for both ecological and human systems. The mountain pine beetle (MPB; Dendroctonus ponderosae) provides one clear example. In recent years, MPB outbreaks throughout the western U.S. and Canada have been startling in both their speed and areal extent; in Colorado alone, more than 600,000 hectares have been infected since the late 1990’s. Yet, our understanding of how both ecosystems and humans react to such outbreaks – and how such responses alter critical ecosystem services – remains poor. This SGER proposal will take advantage of a unique opportunity to collect pre-infection data at the Niwot Ridge LTER and AmeriFlux site, just prior to a pine beetle invasion that is virtually certain to occur. So far, the core study areas of the LTER remain largely MPB-free, but the first signs of infection appeared in 2007, and watersheds on all sides of the LTER have seen heavy outbreaks with areas of 100% tree mortality. Thus, the opportunity to monitor an outbreak in real time, as it proceeds through a well documented study area, is now. This proposal also responds directly to central goals of the recent Integrative Science for Society and Environment (ISSE) report, and brings together a consortium of investigators and programs to begin a long-term investigation of the ecological, biogeochemical, hydrological, and social impacts of the MPB epidemic in and near the Como Creek drainage and the Colorado Front Range. Partners in this effort include: the NWT LTER (led by co-PIs Williams, Seastedt and Townsend), NWT AmeriFlux (directed by co-PI Monson), Alpine Microbial Observatory (led by S. Schmidt), USGS-Biological Resources Discipline’s Western Mountain Initiative (led by T. Veblen), and noted social scientist and co-PI W. Travis. Data to be collected in this effort include not only those on ecosystem responses (biogeochemical, hydrological and ecological), but also on public and policy responses to the outbreak in the Colorado Front Range region.

The broader impacts of an integrated study on human and ecosystem responses to MPB outbreaks are considerable. Not only will the work contribute to established education and outreach programs that are part of the LTER and other partner programs in this effort, it will directly address a phenomenon that has the attention of the highest levels of government in the western U.S. and Canada. Senator Ken Salazar (D-CO) called the current MPB epidemic “the Katrina of the West”, and states and provinces from New Mexico to British Columbia are scrambling to enact new management policies in the wake of large-scale beetle kills. Yet, scientific understanding of both the short- and long-term consequences of MPB infestation is far from complete, creating a worrisome situation in which policies with far-reaching consequences
for the region’s forested ecosystems are being invoked largely without thorough scientific understanding.

**REVIEW PUBLISHED ON HUMAN TRANSFORMATION OF THE NITROGEN CYCLE**

Alan Townsend is incoming PI on the NWT LTER program and director of the International Nitrogen Initiative's (INI) North American Nitrogen Center, housed at INSTAAR. He and other members of the INI are co-authors of a review on human influence on the nitrogen cycle published in Science Magazine. They show that humans continue to transform the global nitrogen cycle at a record pace, reflecting increased combustion of fossil fuels, growing demand for nitrogen in agriculture and industry, and pervasive inefficiencies in its use. Much anthropogenic nitrogen is lost to air, water, and land to cause a cascade of environmental and human health problems. Simultaneously, food production in some parts of the world is nitrogen-deficient, highlighting inequities in the distribution of nitrogen-containing fertilizers. Optimizing the need for a key human resource while minimizing its negative consequences is a central goal of the INI, and requires an integrated interdisciplinary approach and the development of strategies to decrease nitrogen-containing waste. *Science* 16 May 2008: Vol. 320. no. 5878, pp. 889 – 892 DOI: 10.1126/science.1136674. Transformation of the Nitrogen Cycle: Recent Trends, Questions, and Potential Solutions James N. Galloway Alan R. Townsend, Jan Willem Erisman, Mateete Bekunda, Zucong Cai, John R. Freney, Luiz A. Martinelli, Sybil P. Seitzinger, Mark A. Sutton.

**CONSERVATION, RESTORATION STRATEGIES MUST SHIFT WITH GLOBAL ENVIRONMENTAL CHANGE**

Tim Seastedt, along with colleagues Richard Hobbs (Murdoch Univ, Australia) and Katherine Suding (UC Irvine, former INSTAAR and current NWT LTERer), investigated ecosystem management studies from the past 12 years in an effort to begin determining best practices for the future. They propose that biologists and managers focus on making existing ecosystems resilient to further environmental change rather than on attempting to restore them to their original state. In their view, enormous global environmental changes are rapidly and irreversibly modifying nearly all ecosystems on Earth into so-called "novel ecosystems" -- thriving combinations of plants, animals and habitat that have never occurred together before. It is these new ecosystems that should be accepted, preserved and enhanced in order to shield them from further modifications linked with global environmental change (i.e., atmospheric pollution, climate change, exotic species invasions, extinctions and land fragmentation).

Current management practices often involve trying to fix only one aspect of an ecosystem, like eradicating an invasive species. But in many cases, such action does little to improve the ecosystem's overall health. Invasive plant species that have been removed, for example, are frequently replaced by other invasive species that quickly colonize the ecological "vacuum." Instead, biologists and managers need to work with new approaches that focus on desired outcomes, emphasizing genetic and species diversity. Such projects could include "reassembling" forest ecosystems in the West devastated by bark beetles, replanting them with bug-resistant trees and introducing vegetation that absorbs large amounts of carbon dioxide and filters nutrient-enriched water. *Seastedt. R.J. Hobbs and K.N. Suding. 6, doi:10.1890/070046,*

**FIREPROOFING HOMES DRAMATICALLY REDUCES FOREST FIRE SIZE**

Patrick Bourgeron of the NWT LTER worked with Michael Ghil (UCLA) and Vassilis Spyratos (Ecole Normale Superieure) to model the spread of fires in forest ecosystems in Colorado, Montana, Utah, New Mexico, Washington and Wisconsin. Their study is the first to systematically look at both houses and trees in forest fire scenarios. They found that the size of fires is directly linked with the density and flammability of houses built in the so-called "wildland-urban interface." Since houses are much more flammable per square yard than forests, homes that erupt in flames can propel forest fires to a critical intensity threshold much more quickly. Thus, fireproofing homes not only preserves structures, but limits the size of forest fires. The study was published in the Sept. 4 print edition of the Proceedings of the National Academy of Sciences: Development at the wildland-urban interface and the mitigation of forest-fire risk, Vassilis Spyratos, Patrick S. Bourgeron, and Michael Ghil.

**GLOBAL WARMING TO CHANGE SKI INDUSTRY IN WESTERN USA**

Mark Williams and Brian Lazar (former INSTAAR student, now at Stratus Consulting) presented a study of the potential affects of global warming on Park City to more than 1,000 of the town's 8,500 residents, who crowded into the local auditorium to hear that temperatures are projected to rise 6 to 15 degrees Fahrenheit and that the snowpack will likely be substantially reduced by the end of the century. Williams and Lazar modeled seven different scenarios, built upon prior work by United Nations teams of experts and Williams research at the NWT LTER site. All scenarios predict dire consequences for the winter sports industry. If the world continues to accelerate its use of carbon-based fuels that create greenhouse emissions, then Park City's mountains will likely become virtually snow free. Even with dramatic cuts in greenhouse emissions, the ski season at the turn of the century could extend only from Christmas to President's Day, eliminating the profitable shoulder season in the ski and snowboard industry. The study was funded by the POWDR Corporation, which operates Park City Mountain Resort.

Lazar, B., and M. W. Williams, Climate change in western ski areas: Potential changes in the timing of wet avalanches and snow quality for the Aspen ski area in the years 2030 and 2100, Cold Regions Science and Technology, V 51, pp 219-228, 2008.

**EFFECTS OF NUTRIENT ENRICHMENT ON PHYTOPLANKTON IN AN ALPINE LAKE, COLORADO, U.S.A.** Deposition of atmospheric nitrogen from urban and agricultural sources has caused surface water nitrate concentrations to increase in the Front Range of the Colorado Rocky Mountains. To investigate the effects of sustained increases in nitrate concentrations on phytoplankton dynamics in an alpine lake, we conducted nutrient enrichment experiments in mesocosms amended with nitrate, phosphate, and phosphate plus nitrate on four dates in July and August 2002. During this period, phytoplankton species composition shifted as diatoms decreased in abundance. Phytoplankton chlorophyll a increased in the phosphate and phosphate plus nitrate enrichments, but did not increase in the nitrate only enrichments. Analysis of the phytoplankton community using Principal Component Analysis showed that 34% of the variance was accounted for by the primary axis, which was associated with different time
periods, and 21% of the variance was explained by the secondary axis, which was associated with treatments. The response to phosphorus enrichment was taxon-specific, and the two chlorophyte species which became more abundant, Chlamydomonas sp. and Scenedesmus sp., were strongly weighted on the secondary axis. These results indicate that the productivity of this phytoplankton community is phosphorus-limited throughout the summer. Therefore, additional inputs of nitrogen are not expected to directly alter the productivity of the phytoplankton community.

MICROBIAL CONTROL OF BIOGEOCHEMICAL CYCLING IN COLD REGIONS
15 years of microbial research at Niwot Ridge has shown that microbial turnover of soil nutrients is about 10 times faster than by plants. Thus, for every unit of N cycling by plants, microbes work ten times as fast. Soil microbial communities have the metabolic and genetic capability to adapt to changing environmental conditions on very short time scales. In this paper we combine biogeochemical and molecular approaches to reveal this potential, showing that microbial biomass can turn over on time scales of days to months in soil, resulting in a succession of microbial communities over the course of a year. This new understanding of the year-round turnover and succession of microbial communities allows us for the first time to propose a temporally explicit N cycle that provides mechanistic hypotheses to explain both the loss and retention of dissolved organic N (DON) and inorganic N (DIN) throughout the year in terrestrial ecosystems. In addition, our results strongly support the hypothesis that turnover of the microbial community is the largest source of DON and DIN for plant uptake during the plant growing season. While this model of microbial biogeochemistry is derived from observed dynamics in the alpine, we present several examples from other ecosystems to indicate that the general ideas of biogeochemical fluxes being linked to turnover and succession of microbial communities are applicable to a wide range of terrestrial ecosystems. SK Schmidt, EK Costello, CC Cleveland CC Cleveland, AP Martin, AE Miller, A. Seimon, Biogeochemical consequences of rapid microbial turnover and seasonal succession in soil, ECOLOGY, V88 N6, pp 1379-1385, 2007.

DAYCENT_CHEM MODELING ACTIVITIES.
We participated in biogeochemical modeling at the watershed scale using the DayCent-Chem model. The project is lead by Jill Baron with funding from EPA and NPS. The objective is to conduct simulations of hydrochemical responses to atmospheric N deposition for mountain sites around the US. There are seven sites participating (four of which are LTER sites): Coweeta, Great Smoky Mountains, Hubbard Brook, Acadia, Niwot Ridge, HJ Andrews, and Mt Rainier. Initial results are being published as a USGS Open File Report. There is one chapter for each site. This first data paper is a way to collect all the initial site descriptions, model parameter estimation and initial conditions, and model output from the seven sites. DayCent-Chem simulations of ecological and biogeochemical processes of eight mountain ecosystems in the United States. Melannie D. Hartman, Jill S. Baron, David W. Clow, Irena F. Creed, Charles T. Driscoll, Holly A. Ewing, Bruce D. Haines, Kate Lajtha, Jennifer Knoepp, Dennis S. Ojima, William J. Parton, Jim Renfro, R. Bruce Robinson, Helga Van Miegroet, Kathleen C. Weathers, and Mark W. Williams. USGS Open File report xxxx.

II. RESEARCH ACTIVITIES
Here we focus on new activities for 2008.

ROA RESEARCH REPORT, Dr GARY GIANNY, FORT LEWIS COLLEGE, CO
Field work during May, June, July and August of 2008 in Western Archuleta County, Colorado, has identified mapped and characterized 15 wetlands and associated springs that occur on or near the Fruitland Formation along 20 miles of outcrop. In addition, 21 measured stratigraphic sections in the Fruitland formation were measured and or complied in an effort to better understand the potential role of stratigraphic heterogeneity in controlling near surface hydrology. The stratigraphic data are also being used to facilitate "line mapping" of individual coal beds by the Colorado Geological Survey. These line maps will be useful for identifying not only hydrologic dynamics but also potential methane seepage to the surface from the coal beds. All of the data above are currently being compiled to guide the sampling design for the next phase of this project that includes a synoptic water chemistry survey of the region. Together, the stratigraphic, hydrologic and geochemical characteristics combined in this study should provide insights into this and other basins experiencing Coal Bed Methane development. This project embodies the spirit of stakeholder-driven science while refining our understanding of this type of hydrologic system.

Three Fort Lewis College undergraduate students worked on this project over the course of the summer. NSF ROA funding was leveraged with significant support from the Colorado Geological Survey (funded by the Colorado Oil and Gas conservation Commission), and the San Juan Public Lands Center (Joint BLM and USFS). During the project these students had the opportunity to work with three faculty from Fort Lewis College, geologists from the Colorado Geological Survey, and hydrologists, plant ecologists and land managers from the U. S. Forest Service. Two of three students funded in this study are very interested in graduate school opportunities at CU Boulder, and all three are interested in meeting CU faculty involved in similar research.

Results of this research will be published in a number of locations: The Colorado Geological Survey is publishing the stratigraphic data in a special report expected in late 2008 or early 2009. The undergraduate students may present their work at regional or national meeting of the Geological Society of America as well as the Ecological Society of America in 2009. Pending funding for the synoptic portion of the study, publication by the PI s (Williams, Gianniny, and Knydick) in a peer reviewed journal is expected in 2009 as well.

CHRISTOPHE RANDIN, SWISS POSTDOC
We hosted Chris Randin, a visiting Post-Doc from the University of Lausanne, Switzerland, who was in residence from Sept 2007 to Sept 2008. Funding for Chris is from the Swiss NSF. The title of his research is: "Towards mechanistic models to predict the distribution of alpine plant species under climate change". Chris addressed three goals during his stay at the Institute of Arctic and Alpine Research (INSTAAR, University of Colorado at Boulder): (1) develop a dynamic model of snow coverage for Niwot Ridge with the PREVAH model; (2) extend this models to include process-based spatially-explicit predictions of alpine plant species distribution; and (3) integrate the effects of plant species interactions into predictions of distribution change under future climate change scenarios. Results to date include: (1) standardized field
observations for 88 gridded vegetation plots for 81 alpine plant species have been coded and are ready for analysis for six years (1989, 1990, 1995, 1997, 2006 and 2008), (2) environmental GIS data have been developed for the study area (snow coverage, air temperature and solar radiation at a daily time step from 1987 to 2008), (3) the blowing snow model developed by Glen Liston has been successfully validated against field data, and (4) climate change scenarios derived from 17 General Circulation Models (GCMs) are available for simulations in the future. Three articles based on this work are in preparation. Chris felt his time at the NWT LTER site was productive and has written a proposal to the Swiss NSF to return to Boulder from January to June 2009 to finish his model simulations and manuscripts.

UNAVCO PROJECT HIGHLIGHTS-NIWOT RIDGE LTER, SEPTEMBER 2007

* Principal Investigators (PI): Mark Williams, University of Colorado-Boulder
* UNAVCO Engineers: Marianne Okal, Seth White, Bjorn Johns, Thomas Nylen
* Dates: September 2007
* Location: Niwot Ridge, Colorado

The Niwot Ridge Long Term Ecological Research (LTER) area, located approximately 35km west of Boulder, is one of 26 field sites devoted to ecosystem studies in the larger LTER Network. Numerous studies in the area are currently underway, and in September UNAVCO provided researchers at the University of Colorado-Boulder one GPS unit with which to conduct hydrological surveys of the area's wells. The group's main interest is to determine the subterranean water elevations of the wells, and it will then use this data to establish subsurface flow, subsurface storage, and seasonal fluctuations in hydrologic source waters. This data can then in turn be combined with water chemistry and water stable isotope data to further climate, hydrology, and water quality knowledge. The surveys were conducted using PPK techniques.

The UNAVCO Polar engineering group took advantage of the field opportunity to visit its test bed receiver and power system, which was originally installed at NWT in 2005. The unit's power system was checked and tested, and a new Iridium communications system was installed, mimicking the PoleNET set-up that is being deployed in Greenland (GNET) and Antarctica over the next several years. As the test site lies in alpine tundra at 11,600 ft. in elevation, the environmental conditions resemble those found in Polar regions, and hence provide a natural, local setting to test and maintain a PoleNET-style GPS site.
Figure 1 - Graduate student Ashley Nielsen and GIS specialist Todd Ackerman survey one of the many wells in Ashley's study area. By measuring the water level relative to the top of the PVC pipe with a plumb line, and then using the GPS data, they will be able to determine the true elevation of the water level.
LONG-TERM CHANGES IN ALPINE TUNDRA. We re-inventoried 88 long-term vegetation plots in 2008, and in conjunction with experimental plots, are using these data sets to evaluate the role of climate and N-deposition on alpine tundra. The major research area at the Niwot LTER is the Saddle, an Alpine Tundra site, located 5.6 km from the Continental Divide. During the early 1970s, Pat Webber and Diane May used ordination techniques to broadly define six vegetation communities, or noda, on the Saddle: fellfield, dry meadow, moist meadow, shrub tundra, wet meadow, and snowbed. We hypothesize that this site is exhibiting changes in species composition and diversity of vegetation as a result of a) increased precipitation and b) increased atmospheric deposition of inorganic nitrogen in rain and snow. These 88 plots act as reference plots and range from low precipitation, wind-scoured fellfield areas through dry meadows, through moist and wet meadows, into late snowpack communities. Experimental plots are used to develop relationships between these variables and plant response. Relationships between plant species and soil moisture were obtained by using preexisting data sets on vegetation cover and TDR soil moisture measurements. Litaor et al. (2008) have conducted the initial analyses on these data sets. Post-doc Chris Randin has spent the last year organizing the data sets in such a way that models can now be developed to test the hypotheses above.

GLEON
Diane McKnight and graduate student Matt Miller are participants in The Global Lake Ecological Observatory Network (GLEON, a grassroots network of limnologists, information
technology experts, and engineers who have a common goal of building a scalable, persistent
network of lake ecology observatories. Data from these observatories will allow us to better
understand key processes such as the effects of climate and landuse change on lake function, the
role of episodic events such as typhoons in resetting lake dynamics, and carbon cycling within
lakes.

**COMPARATIVE SURVIVAL AND PHYSIOLOGY OF THE AMERICAN PIKA**

Supplemental funding in 2008 was used to support new research on the American Pika.

Investigator: Chris Ray, Research Associate, EE Biology, CU-Boulder, cray@colorado.edu

Objectives: Estimate and model physiological stress and survival in the American pika
(Ochotona princeps) across a climatic gradient

Study System and Background: The American pika is in decline in the western US, and recent
research implicates climate change in the extirpation of pika populations. Hypothesized links
between climate change and pika morbidity include reduced survival due to 1) heat stress during
warmer summers, and 2) cold stress during winters with lower snow cover (reduced thermal
insulation). However, currently there is no direct evidence that the microclimates experienced
naturally by pikas cause physiological stress or affect survival. We hypothesize that pikas
experience higher physiological stress at lower elevations, lower latitudes, and on south-facing
slopes. Summer temperatures should be higher in these locations, and winter temperatures may
be lower within pika habitats in these locations due to reduced snow accumulation. Pikas in
these locations may be stressed directly by climate, or may be stressed indirectly by, for
example, climate-induced changes in the water content of forage plants. To test these
hypotheses, sampling and tagged pikas at sites differing in latitude, altitude and slope aspect in
order to estimate physiological parameters and survival rates. During July and August of 2008,
pikas were sampled from two study sites: 1) the Niwot Ridge LTER site (Niwot) and
surrounding pika habitats in north-central Colorado, and 2) a long-term pika research site in the
Gallatin Range of south-central Montana (Gallatin). Samples of blood, urine, feces, saliva and
hair will be used in a comparative study to characterize relative levels of stress hormones (e.g.,
cortisol and TNFa) and other metrics of metabolic stress in pikas at each site. We will also
characterize microclimatic variables and patterns of activity in pikas at each site, in order to
compare behavioral responses that may mitigate climatic influences.

Methods and results to date (8/15/08):

1) Sampling is complete at Niwot. Of 41 pikas sampled at this site, 23 were captured on the
ridge and 18 were captured in an adjacent valley, 21 on north-facing slopes and 20 on south-
face facing slopes. Sampling will begin at the Gallatin site on 8/18/08.

2) Samples will be analyzed for metabolic substrates (glucose and fatty acids) and hormones, as
well as hemoglobin levels (which may contribute to individual fitness at higher elevations) and
thiobarbituric reactive substances (to determine the overall oxidative stress levels). Laboratory
analyses will begin in September.
3) Tagged individuals will be re-sighted for survival analyses. Re-sights will be made in 2009, allowing estimates of annual survival. Annual survival will also be estimated from data individuals tagged in previous years at these long-term study sites.

4) Microclimatic data sensors will be positioned within the territory of each tagged individual to record data hourly throughout the year of study. All sensors will be in place by early September.

5) Activity budgets have been estimated from observations of pikas at each elevation and slope aspect within the Niwot study site. Activity budgets will be estimated from observations of pikas at the Gallatin site by early September.

6) Physiological variables, behavior and survival will be modeled as responses to habitat variables including latitude, elevation, slope aspect, and microclimate.

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![Northern Aspect, High Elevation](image-url)

*Figure: Activity budgets for pikas in a northern aspect, high elevation environment.*

- **SCAN**
- **MOVE**
- **REST IN VIEW**
- **PREEN**
- **FEED**
- **HAY**
- **SHORT CALL**
- **LONG CALL**
- **CHASE**
- **VISIT**
- **TOUCH**
- **OUT OF VIEW**

*Graph showing the percentage of time spent in different activities.*
Fig. 1. Pikas on slopes at higher elevation (on the West Knoll of Niwot Ridge) exhibited similar patterns of activity, regardless of slope aspect. Patterns of activity were also strikingly similar between pikas at these higher elevations and pikas at lower elevations (in a valley approximately 300 m below), as is evident by comparing Figs. 1 and 2.
Fig. 2. At lower elevations, pikas on slopes with a southern aspect spent more time moving and haying (caching forage) than their counterparts on slopes with a northern aspect. However, differences in activity patterns were slight, suggesting little behavioral response to climate within the range of study sites available in the vicinity of Niwot Ridge.

Projected Results and Broader Significance: This study will determine whether local habitat variables related to climate can explain levels of physiological stress and rates of survival in the American pika. If local variables related to climate can explain stress and survival, then climate change may have relatively direct effects that are contributing to local extinctions of this species. Otherwise, local extinctions may be related to climate change only indirectly (e.g., through the redistribution of disease agents) or to other changing factors (e.g., human land use patterns). These questions are of immediate importance because this species is being petitioned for listing under the Endangered Species Act.

This study is part of a large and collaborative research project designed to determine the factors affecting local extinctions of pikas throughout the western US, and takes advantage of several pre-existing studies to broaden the scope and depth of proposed analyses. Long-term demographic studies undertaken at the Gallatin site, in conjunction with microclimatic measurements there, are providing data on how climate relates to individual survival and population density. Pre-existing data from Niwot Ridge (LTER climate data and data from previous pika studies) will also be used to address this question.

Two REU students were involved in the collection and analysis of data from the Niwot site during June-August 2008. Both students will continue to be involved in analyses of data from both sites, and will co-author manuscripts to be submitted for publication.
EDDY FLUX MEASUREMENTS OF CO₂ TUNDRA-ATMOSPHERE EXCHANGES.
Operation of the first site to make direct measurements of the surface energy balance and CO₂ flux using the eddy covariance technique above alpine tundra at Niwot Ridge, Colorado, began on 1 June 2007. Measurements are compared to simultaneous measurements made over an adjacent subalpine forest, the Ameriflux site at C1 on Niwot Ridge. Energy balance closure averaged 91% due to the high wind speeds, short turbulent flux footprint, and relatively flat ridge-top location of the measurement site. Air temperature and relative humidity at the two sites were highly correlated, with lower air temperatures and higher relative humidities at the alpine site. The horizontal wind speed was poorly correlated between sites, with higher wind speeds and persistent downslope (westerly) flows at the alpine site. Net radiation was higher at the forest site, yet the evaporative fraction was similar. Except for the soil heat flux, the sensible and latent heat fluxes were larger above the forest than the alpine tundra. Both sites were a net sink of CO₂ during the observation period, but the alpine site changed to a source much earlier than the forest site. Greater CO₂ uptake during the daytime by the forest was offset by greater CO₂ losses at night, making the net CO₂ exchange of both sites more similar than that suggested by parameters such as above-ground leaf area index.

Figure 1. Eddy correlation instrumentation near the Saddle site on Niwot Ridge.

NADP HIGH-ELEVATION REPORTING CHANGE
We continue to work with NADP to change how they collect and report atmospheric deposition in mountain environments. NADP has agreed to include atmospheric deposition of mountain sites on their national isopleth maps as points. Secondly, they will publish a separate set of national isopleth maps that include atmospheric deposition from all mountain sites with high amounts of snowfall. These maps differ from how the normal isopleth maps are calculated, using precipitation amount generated at approximately 1-km pixels by the PRISM algorithm. A trial set of these maps was included in the recent Frontiers article on NEON. Third, NADP has designed a new wet chemistry collector designed for high snowfall environments that we have installed and are donating time for collection and maintenance.
INFORMATION MANAGEMENT
Todd Ackerman continues to serve as a member of the LTER Information Management Executive Committee (IMExec), and is currently the Chairman of the Unit Dictionary Committee for the LTER. Over the past year he has served on the program committee for the first Environmental Information Management Conference being held in Albuquerque September 2008.

III. OUTREACH ACTIVITIES.

SAN JUAN COLLABORATORY INTERN PROGRAM
The NWT LTER project help fund and direct the San Juan Collaboratory Intern Program, conducted in southwestern Colorado. Eleven interns participated in an 11-week program from June 2 to August 15, 2008. The program was coordinated by Koren Nydick of the Mountain Studies Institute and funded mainly by the San Juan Public Lands Center (USFS/BLM) and University of Colorado at Boulder. The internships were based in Durango, Silverton, and Dolores, Colorado. Interns were either current undergraduates or recent graduates. Most were from Colorado and had attended a Colorado college or university. A few students from other states added diversity to the group.

The interns worked with researchers and land managers addressing issues such as climate change, land development, air and water pollution, ecosystem restoration, and community revitalization. They worked on lakes and in forests, wetlands, alpine tundra, high desert, and human communities. Interns and their projects are listed below.

<table>
<thead>
<tr>
<th>Intern Name</th>
<th>Intern’s Institution</th>
<th>Intern Position</th>
</tr>
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<tbody>
<tr>
<td>Justin Anderson</td>
<td>University of Kansas</td>
<td>High-Elevation Ecology</td>
</tr>
<tr>
<td>Anya Angst</td>
<td>Fort Lewis College</td>
<td>Environmental Mercury Monitoring</td>
</tr>
<tr>
<td>Camila Fierro</td>
<td>Smith College</td>
<td>Fen Wetland Restoration</td>
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</tbody>
</table>
The interns and many of the mentors participated in three program events. Orientation was held at Fort Lewis College in Durango and included “get-to-know-you” activities, a regional environmental and socio-economic overview, a tour of local ecosystems, and a raft trip down the Animas River. During a field trip in Silverton half-way through the program, interns visited high-elevation forests and an abandoned mine site to learn about a few of the projects. Interns gave informal project updates and cooked dinner over a campfire. The final morning of the program, interns and a few mentors took a boat trip on Vallecito Reservoir to discuss mercury and wildfire and learn lake monitoring skills. The group then had lunch at the San Juan Public Lands Center and each intern gave a presentation about their project.

**ROCKY MOUNTAIN NATIONAL PARK**

Bill Bowman (February 2008) provided a training seminar to NPS naturalists at RMNP on climate change effects in the alpine. He stressed: (1) treeline and its response, past, present, and future; (2) diversity of alpine plants (as mediated by warming and biogeochemical feedbacks); (3) pikas, with some cautionary remarks.

Mark Williams was a Lyceum Program speaker at the Beaver Meadows Visitor Center, East Entrance, Rocky Mountain National Park, 9 February 2008, Estes Park, CO. His talk was entitled "Save our Snow: Climate change in the Rocky Mountains". The talk was well-attended and well-received. He was asked and gave the same talk at the Kawuneeche Visitor Center on the west entrance several weeks later.
NWT LTER SUPPORTS ECOARTS
NWT LTER helped support and personnel participated in a unique outreach activity that combined performing art with science. EcoArts is a collaboration of 22 science, environmental, arts, indigenous, and other organizations in 3 cities to increase awareness of climate change and sustainable living. Jason Neff, a senior scientist with the NWT LTER, was a performer in “Balancing Acts: Visions for a Sustainable Future”, which is a series of performance pieces informed and/or “co-created” by artists and scientists that include the arts disciplines of dance, theatre, music, and poetry, and the science areas of biogeochemistry, evolutionary biology, and science education and communication. The performances were held September 12-14 at the Dairy Center for the Arts in Boulder, Colorado. Collaborating organizations and institutions include NOAA, NCAR, CIRES, Denver Museum of Nature & Science, University of Colorado Museum of Natural History, Niwot Ridge LTER program, Center for ReSource Conservation, Blair-Caldwell African American Research Library, Newman Center for the Performing Arts, Denver Botanic Gardens, Curious Theatre, and the Fort Collins Museum of Contemporary Art, among others.

Each of the performers brings his/her own unique artistic sensibilities to “Balancing Acts” – and all of them are not what one might expect. For example, Michelle Ellsworth describes her collaboration with biogeochemist Jason Neff, visual artist Priscilla Cohan, and composer Michael Theodore as “a dense and efficient performance piece about ‘the situation’ that employs choreography, chatting, and lubricated ball bearings to explore the complexities and interconnectedness/co-dependence of sex, blame, and science.”

FLUORESCENCE/PARAFAC WORKSHOP
Diane McKnight and Matt Miller hosted a fluorescence and PARAFAC workshop on Monday and Tuesday March 10-11. The workshop was primarily intended as training for students and
scientists working on projects involving DOM analyses at INSTAAR, CEAE and the USGS-Boulder lab. This training opportunity was offered to others at a charge of $250 per person. There were a total of 12 participants who are listed below.

On Monday morning there were presentations related to background information on fluorescence spectroscopy, the usefulness/limitations of fluorescence in characterizing DOM in natural waters, and how to collect reliable fluorescence scans. On Monday afternoon participants spent time in the Limnology and DOM labs at INSTAAR learning the laboratory techniques associated with collecting 3-dimensional fluorescence scans. There were then presentations on Tuesday morning that described the theoretical and statistical approaches used to develop the PARAFAC model. Finally, the rest of the day was spent teaching the participants how to use Matlab to correct fluorescence scans and subsequently fit the corrected scans to the PARAFAC model.

List of Participants:
- Kevin Rose - Miami University
- Brian Lutz – Duke University
- Murage Ngatia – California Department of Water Resources
- Christine Seibold – Kiowa Lab Manager, University of Colorado
- Alisa – Kiowa Lab Assistant
- Ariann Blankenship – Center for Limnology, University of Colorado
- 6 graduate Students from Diane McKnight’s Advance Aquatic Chemistry Class

LTER SCHOOLYARD CHILDREN'S BOOK FUND.
Diane McKnight was instrumental in developing this program. From Monica Elser, 1 Feb 2008:

Dear LTER Community: We are pleased to announce the establishment of an LTER Schoolyard Childrens Book Fund which is designed to help defray some of the costs associated with publishing books to be included in the LTER Schoolyard Childrens Book Series. This current fund is a result of support by the LTER network for the Childrens Book Series and is being administered by the non-profit Hubbard Brook Research Foundation. A Childrens Book Fund Committee made up of people associated with LTER sites oversees this fund. We have put together a request for proposals so you can access these funds for book projects. We have established two dates this year for proposals (Feb 29 and Oct 15) and will probably have one date in subsequent years. Our hope is that we will continue to receive money for this fund through a variety of sources, including private donations. These donations are tax-deductable. We have attempted to create documents outlining the publishing process as best as we understand it. Since this is a series, we only expect one to two books to be published in any one year. For more information, please view the Request for Proposals and associated documents at: http://schoolyard.lternet.edu

NWT LTER FEATURED IN CAPITOL HILL LOBBYING BY CU-BOULDER
NWT LTER program was featured by the University of Colorado's Office of State and Federal Government Relations in their Annual Federal Priorities book that President Brown and the Chancellor's take to Capitol Hill each year to highlight CU's FY07 research projects.

TREE-ISLAND PROPOSAL
Cooperated with Ayers and Seltzer at Colorado State University on an NSF proposal (DEB-0816720) *Does home-field advantage cause faster decomposition rates in temperate forest ecosystems?* They proposed to study this topic in the tree islands on Niwot by conducting a reciprocal litter transplant experiment and a facilitated migration experiment (i.e. moving the soil cores containing the forest soil community) within tree island chronosequences (i.e. with time a function of the rate that the tree islands move). NWT LTER wrote a letter of cooperation and is providing logistical support and archived data.

**EPA STAR PROPOSAL**
Charles Driscoll of the Hubbard Brook LTER site submitted a proposal to the U.S. Environmental Protection Agency to conduct hydrochemical modeling of the response of high elevation watersheds to climate change and atmospheric deposition. In this study, they proposed to apply the model PnET-BGC to Niwot Ridge LTER. We are cooperators with this proposed study. The research would involve using existing climate deposition, discharge and water chemistry data to calibrate/test the model and making long term discharge and soil and water chemistry projections under future scenarios of climate change and atmospheric deposition. Their main goal would be to compare model calculations across a range of sites with a range of climate conditions to better understand how water quality of high elevation watersheds might respond to changing climate.

**THE THIRD INTERAGENCY CONFERENCE ON RESEARCH IN THE WATERSHEDS (ICRW):**
Planning for an Uncertain Future: Monitoring, Integration, and Adaptation, was organized by the U.S. Geological Survey and held 8-11 September 2008 in Estes Park, Colorado. M. Williams was on the steering committee. He hosted a field trip for attendees to Niwot Ridge LTER on 10 September 2008, with 10 participants.

**IV. EDUCATIONAL ACTIVITIES**

Below we highlight educational activities conducted at the Niwot Ridge LTER site.

**REU PROGRAM AT THE MOUNTAIN RESEARCH STATION.** _Pl Bill Bowman._
For the summer of 2008 we received 346 applications for 9 funded positions. We made offers to 4 students from groups underrepresented in field biology. Two of these students accepted our offers, while 2 went to other REU programs (one after accepting, and then declining our offer). Six of the 9 students were from schools that do not offer advanced degrees in biology. Six of the 9 students were women. Two additional students participated in the program through supplemental REU funding for the Niwot Ridge LTER program. Most of the projects conducted by the REU students were conducted at least in part at the NWT LTER site and with NWT LTER mentors.

The students, their mentors, and their projects are listed below:
• Lisette Arellano, University of California, Santa Barbara, Piet Johnson, Distribution of trematode parasites along an elevational gradient in the Colorado Front Range
• Max Breckbill, Earlham College, Noah Fierer, Volatile Organic Compounds in Soil
• Christine Chee, University of New Mexico, Mike Breed, The role of aggression in interspecific competition in subalpine ants
• Erica Goad, Whitman College, Tom Veblen, The Effects of Stress in Lodgepole and Limber Pine on Mountain Pine Beetle Target
• Moira Hough, Carleton College, Diane McKnight, Impacts of DOM on Aquatic Macroinvertebrate Communities
• Kaleb Keyerling, Kenyon College, Bill Bowman, Root extracts stimulate microbial activity, but do not affect plant growth
• Beth McGarry, University of St. Thomas, Katie Suding, Patterns of increasing woody encroachment on Niwot Ridge
• Eden Steele, Colorado College, Pam Diggle, Does Solanum pennellii Exhibit Functional Andromonoecy as Form of Phenotypic Plasticity

The 2008 REU students at Niwot Ridge.
Chris Ray mentored 2 REU students who conducted field research on mountain pikas on Niwot Ridge. The report for that project is presented in section II of this report.

**REU VEGETATION STUDIES. RECYCLED LTER SUPPORT.**

Two REU students worked with Seastedt during summer, 2008 on 1) reinventoring the Marr vegetation plots for invasive plant species, and 2) setting up new plots to be used with the ongoing lodgepole pine die-off. In addition, one of the REU students measured abundance of a native thistle, *Cirsium centaureae*, its seed production, and the abundance of native and non-native seed predators.

The Marr vegetation plots were first inventoried in the 1950s and have been re-inventoried twice since, once in the 1980s and 1990s (Korb and Ranker 2000). Preliminary results of this summer inventory have not been analyzed fully, but 1) invasions onto these sites have been relatively slow and 2) at one site forest succession has largely inhibited invasion by non-native species. The thistle study has produced a novel finding. Upper elevations of the thistle (found at treeline) are apparently above the zone that can be colonized by the non-native seed predators. In contrast, thistles in the subalpine meadows around the field station have been attacked by a non-native seed predator, in spite of the fact that its native hosts are not found at this elevation. Thistles in the subalpine meadows are less than half the densities first measured in 2004. Overall, the lower elevation populations experience about twice the seed mortality of higher-elevation populations due to the presence of the introduced predators.


**UNDERGRADUATES: SNOW HYDROLOGY INTERNS**

6 undergraduate students worked with Mark Williams to collect information on snow properties during the winter of 2008. The students dug weekly snowpits at two sites on Niwot Ridge each Friday. At each snowpit the students collected information on snow depth, snow density, snow temperature, grain size, grain type, and snowpack stratigraphy.

**GRADUATE STUDENT: Andrew King; Advisor: Steven K. Schmidt**

*Mapping the Invisible, Characterizing Heterotrophic Microbial Activity in Alpine Rock Slope Soils*

Barren high-altitude soils are among the most extreme terrestrial environments on Earth. The goal of my research is to quantify broad-scale spatial patterns of total microbial biomass, activity, and community composition in alpine rock slopes. I have conducted the bulk of my research in the subnival zone of Niwot ridge, which is the region from the end of the zone of continuous tundra vegetation to the continental divide. Over the past two years, I have measured a suite of soil properties including microbial biomass CNP, microbial extracellular enzyme activity, bacterial community diversity, and plant community diversity for 160 locations in the Niwot subnival zone. My work builds on previous studies by Niwot LTER members and covers the most extensive continuous area of rock slope of any microbial study to date. This summer I presented my preliminary results at the American Society for Microbiology Annual Meeting. In addition, through the LTER program, I was fortunate enough to have the opportunity to travel to Lausanne, Switzerland to attend a workshop on modeling shifts in
species distributions with climate change. As a result I will be able to model changes in both bacterial and plant species occurrences in various climate change scenarios. Working with the Niwot LTER has improved both the quantity and quality of my research and I look forward to working with the LTER program in the future.

**GRADUATE STUDENT: Anthony Darrouzet-Nardi; Advisor: William D. Bowman**

*Vegetation Effects on Nitrogen Cycling Hotspots in an Alpine-Subalpine Ecosystem*

By burning fossil fuels and using nitrogen fertilizers, humans have doubled the global rate of nitrogen inputs to natural ecosystems. These higher nitrogen inputs contribute to a cascade of environmental problems including air pollution, invasive species, biodiversity loss, acid rain, eutrophication, and global climate change. To aid in understanding and managing these environmental problems, researchers have developed a detailed understanding of the nitrogen cycle based on small-scale plot-based measurements. While forming an important foundation, these small-scale measurements may not be representative of whole landscapes, especially in complex mountainous terrain. This summer I have been working toward a landscape-scale understanding of nitrogen cycling in an alpine-subalpine ecosystem. I seek to locate hotspots (unusually active areas) of nitrogen cycling activity within a heterogeneous 0.89 km² alpine-subalpine ecosystem within the Niwot Ridge Long Term Ecological Research site in the Rocky Mountains of Colorado. I am also investigating the relative roles of biotic and abiotic factors in controlling nitrogen cycling rates. To accomplish these goals, I have made measurements of nitrogen cycling rates across a landscape and will evaluate the measurements using field-collected and remotely sensed data that describe physical, chemical, and biotic conditions.

This work will contribute to: (1) our basic knowledge by improving our understanding of landscape-level nitrogen cycling; (2) our policy goals by improving our understanding of the effects of anthropogenic nitrogen deposition on mountain landscapes; and (3) our methodological capabilities by developing methods for ecological measurement at larger scales.

**GRADUATE STUDENT: Courtney Meier; Advisor: William D. Bowman**

Plant species impose critical controls on the cycling of carbon (C) and nitrogen (N) in soils, and plant-soil feedbacks may influence neighboring plant growth, competition between plants, and ecosystem responses to environmental change. The first research goal was to improve our understanding of which plant functional traits mediate species effects on soil nutrient cycling, and how plant species effects on soil processes influence neighboring plant growth. Alpine moist meadows were used as a model system. These plant communities are co-dominated by Acomastylis rossii and Deschampsia caespitosa, and these two species are associated with strong plant-soil feedbacks. Moist meadow communities are also relatively species-rich. The second research goal was to improve our ability to predict effects of plant species diversity on soil C and N cycling.

I tested whether concentrations of phenolics in C fractions from fresh A. rossii leaves and leaf litter are important functional traits that regulate soil microbial activity and influence neighboring plant growth. Fraction effects fell into two categories: 1) some fractions were recalcitrant, and killed D. caespitosa plants; and 2) some fractions stimulated soil respiration, and reduced plant growth and plant %N while simultaneously inhibiting root growth. LMW phenolic-rich fractions had more profound effects on soil respiration and reductions in plant growth than tannins. These results are consistent with phenolic-rich fractions reducing neighbor
performance by inhibiting root growth via a phytotoxic mechanism, and by indirectly reducing pools of plant available N by stimulating soil microbes. Furthermore, labile phenolic inputs from roots are likely a more important influence on soil nutrient dynamics during the alpine growing season than phenolic inputs from leaf litter. These results suggest roots may provide the dominant input of labile phenolics to soil during the growing season in alpine ecosystems, as well as other ecosystems with seasonal patterns of plant growth and senescence. Finally, litter from four abundant moist meadow species was used to determine how well species richness, chemical diversity, and specific litter chemical traits predicted litter mixture effects on soil respiration, net N mineralization, and microbial biomass N. Species richness was a poor predictor of variation in these variables, but specific litter chemical traits and chemical diversity explained considerable variation in soil respiration, N mineralization, and microbial biomass N. These results contribute to a new mechanistic framework for understanding the effects of plant litter diversity on key components of ecosystem function.


**GRADUATE STUDENT:** Marko Spasojevic; **Advisor:** Katie Suding

*Species and trait associations: Insights into the processes that affect community composition*

While trait-based ecology is beginning to be incorporated into understanding the processes of community assembly, there has been a recent interest into incorporating broader scale patterns into community assembly. My research objective is to integrate trait-based ecology and biogeography by examining the patterns of species and trait associations in areas with different local species pools and to relate these results to the different processes suggested to affect species coexistence within plant communities. This summer I sampled species and trait composition in 12 areas of alpine tundra around the Colorado Rockies (including Niwot Ridge) that vary in both habitat heterogeneity and geographic isolation. With this data I will explore how both biotic and abiotic factors interact to affect species coexistence within plant communities. Additionally I set up a competition experiment at Niwot Ridge to test the assumption of trait based approaches that functionally similar species should compete more that functionally dissimilar species.

**GRADUATE STUDENT:** Ken Hill; **Advisor:** Mark Williams

*Potential climate impacts in alpine hydrochemistry*

I recently completed my master's thesis focusing on long term trends of water chemistry and climate at Niwot Ridge LTER. My research evaluates the role of potential climate drivers causing changes in water chemistry and flowpaths. A comparison watershed study was implemented to assess potential landscape heterogeneity in climate/atmospheric deposition
response. Elevations range from over 4,000 meters (13,100 feet) at the continental divide to 3,250 meters (10,660 feet) at the valley outlet. Climate, snow, groundwater, and surface water methods are all employed to collect and analyze data. Robust statistical analyses for trend testing, principle components analysis (PCA), and redundancy analysis (RDA) are completed using R-project software. Modeling techniques include End Member Mixing Analysis (EMMA), the coupled hydrobiogeochemical watershed model DAYCENT, and permafrost distribution models using GIS under simulated climate change scenarios.

**GRADUATE STUDENT: Ty Atkins; Advisor: Mark Williams**

*Surface-groundwater interactions and nutrient transport in alpine and subalpine catchments, Front Range, CO*

Nutrient fluxes from two high elevation catchments in the Colorado Front Range, Como Creek and the Green Lakes Valley, are compared across differing landscapes. These watersheds share similar climate, aspect, and geography. Como Creek primarily drains subalpine forest with little alpine area, while in contrast the adjacent Green Lakes Valley drains alpine tundra and talus slopes, before reaching the subalpine forest. Comparing NH4+, NO3-, DON, and DOC yields from Como Creek and the Green Lakes Valley from the last 30 years, show that alpine areas subsidize transport of inorganic nitrogen down gradient into forested areas. In contrast, at Como Creek there is little export of inorganic N, higher export of organic N, and much greater export of DOC compared to Green Lakes Valley. Three-component hydrologic mixing models using O18 and Na as tracers from groundwater and surface water sources show that discharge at Como Creek is characterized by a well-mixed deep groundwater reservoir with a residence time of years to decades, whereas the Green Lakes Valley discharge shows more recent water characterized by shallow subsurface flow. These distinct flow paths confirm that changes in nutrient processing in shallow soil across the alpine – subalpine ecotone control nitrogen loss in these ecosystems.
Our LTER program is now over 20 years old. Our major science and research objectives have evolved during the interval. As a site where substantial, long-term research has been conducted, we now feel our paradigm for understanding the structure and functioning of the alpine system has been substantially altered from the model used in earlier proposals. Our 2004 proposal resulted in a new direction for NWT that might be best described as "Biogeochemical and Ecological Linkages Among High Elevation Systems and the Regional Environment".

Over the last several years we’ve focused on updating and analyzing our long-term data sets and experiments. This activity has enhanced cooperation and synthesis among subteams within the NWT LTER that cut across disciplinary boundaries. During this process, there has been a strong emphasis on improving the linkage between the alpine and subalpine forest ecosystems. We’ve also made a concerted effort to regionalize our research, and to develop stronger international ties. Our research activities are now mature enough to inform land-use managers with ecological knowledge, resulting in innovative and anticipatory research activities directed at the sustainability of high-elevation—alpine and subalpine—ecosystems.

NWT LTER activities are leveraged with NWT Ameriflux (Monson PI) and Alpine Microbial Observatory (Schmidt PI) long-term programs.

THE LANDSCAPE CONTINUUM MODEL: A BIOGEOCHEMICAL PARADIGM FOR HIGH ELEVATION ECOSYSTEMS

The panoramic splendor and complexity of high-elevation ecosystems have inspired and challenged humans for centuries. In our time, the perception that the mountains 'are forever' may provide solace to those seeking stability in a rapidly changing world. However, changes in the abundance and species composition of the native flora and fauna of these mountain ecosystems are potential bellwethers of global change. The flora and fauna of high-elevation ecosystems are on the edge of their environmental tolerance (Williams et al., 1998), and hence may be more sensitive to directional change in climate than downstream ecosystems (Williams et al., 2002). This sensitivity to small changes in climate is due to the propensity of these systems to amplify environmental changes within specific portions of this landscape. Here, we examine the potential of high elevation ecosystems to accumulate and redistribute exogenous materials from the atmosphere and endogenous materials from the mountains. This analysis led us to a conceptual model of the coupled relationships among high-elevation ecosystems that emphasizes the importance of transport processes, the Landscape Continuum Model (LCM) (Seastedt et al., 2004).

The LCM serves as the over-arching paradigm that guides research and monitoring activities at the NWT LTER. The LCM is the conceptual framework that provides the unifying ecological theme for our site.

The LCM explicitly links terrestrial ecosystems to each other and to aquatic ecosystems. The heart of the model is that strong linkages are generated among landscape components as a result of transport processes caused by the extreme topography. These transport agents cause biogeochemical amplification and attenuation of processes not observed in most landscapes. Overall, the model links Billings’ (1973) mesotopographic alpine model with ideas developed in
the Vannote et al. (1980) river continuum concept (RCC). The major difference between the RCC and our model is that the RCC is one-dimensional, containing just one transport agent (water), whereas we explicitly consider wind, water, and landslides as transport agents in a spatially complex system.

Our model generates numerous, testable hypotheses that form the core of our current research activities. We hypothesize that small changes in climate and/or nutrient loading will lead to large changes in terrestrial and aquatic biota. Thus, we hypothesize phytoplankton communities will respond quickly to changes in climate and nutrient deposition. Similarly, we hypothesize that the species composition and richness of alpine tundra will change in response to increases in N deposition that are modest when compared to grassland or forest ecosystems. We hypothesize that increases in air temperature will lead to shrub encroachment in alpine tundra ecosystems. The LCM suggests that the maximum, landscape-scale impact of biota on materials occurs at treeline, where trees function as windbreaks, collecting snow, particulates, and nutrients. Treeline areas may receive substantial subsidies of water, nutrients, and organic material from upwind and uphill sources. Thus we hypothesize higher amounts of C, N, and P in treeline soils compared to alpine and forested areas, with resultant increases in NPP and litter decomposition rates.

Niwot Ridge is the only multidisciplinary, long-term study site for high-elevation areas on the North American continent (Figure 1). As such, our site is an essential benchmark for regional, national, and global networks that measure biological changes and feedbacks, and experimentally determine mechanisms for these relationships. Both high-elevation and high-latitude areas have been identified as being at risk from a variety of anthropogenic materials added to the atmosphere. The LCM suggests that high-elevation lakes and treeline may be the first locations to experience the impacts of these materials because of the amplification effects of transport processes.
Climate Drivers. Mid-latitude mountain systems are critically sensitive to recent and projected climate change under an elevated greenhouse-gas world. This sensitivity is in terms of both local physical and biological processes (IPCC-WG1 2007, IPCC-WG2 2007). It is often taken that climatic change at high elevation sites will reflect those at lower sites – regional warming is assumed to be consistently played out in mountains, or even amplified by the snow-albedo feedback. The anticipated outcome is that the alpine will eventually be “pushed off the top of mountains.” There are several reasons why this might not be the case, or at least considerably
delayed – one is whether high elevation climates reasonably reflect regional lowland trends or if they are decoupled from them as a result of mountain climatic processes.

We evaluated climate change by cleaning and updating climate station records from subalpine (C1, 3048m) and high alpine (D1, 3749m) sites under the supervision of Tim Kittel. These records have full years for a 54-year period from 1953-2006. A daily spatial correlation process was used to fill data gaps based on observations from the other NWT station and neighboring montane stations (Ackerman 2006; this dataset is available in the NWT LTER database: http://culter.colorado.edu/). This process created continuous records with more reliable monthly and yearly values than did previous infilling routines. We used standard climatological variables (minimum & maximum temperature, precipitation) and derived variables [diurnal temperature range, growing season length (using both 0º & –3ºC thresholds), and growing degree days (0ºC base)]. Trend analysis had two components. First, we used Kendall’s rank correlation to evaluate the statistical significance of record trends. Second, we used linear regression analysis to determine linear slopes for significant trends.

Key findings – (Figure 2).

- Over the last 54 years, Niwot Ridge has experienced strong trends in temperature and precipitation in the alpine and subalpine. Many of these trends are significant at the p<0.01 level, some at p<0.001.
• Trends also differ by site (alpine vs. subalpine) – at times illustrating a decoupling of their climate signals.

• Mean maximum temperature (Tmax) increased through much of the year in the subalpine (trend in annual Tmax=+0.4°C/decade), but in the alpine decreased in early winter (–0.4 to –0.6°C/decade; see Figure, left panel). These patterns resulted in altered seasonal cycles for the two sites, but in different ways: a positive offset in the subalpine (C1) and amplification in the alpine (D1; Figure, right panels).

• Precipitation (ppt) increased at the alpine site from October through April (trend in annual ppt=+100mm/decade), but not during any season in the subalpine.

• Growing degree-days have gone up at the subalpine site; this due to the positive trend in maximum temperatures. The alpine showed no corresponding trend.

An integrated view of these trends infer synoptic dynamics and surface energy processes that act differently in the high alpine near the Continental Divide vs. in the subalpine dominated by closed conifer forest. At the same time, these climates are affected by multidecadal hemispheric circulation changes. Nearly all temperature-related time series for both sites show a period of cooling until around 1980, followed by warming. Precipitation series show corresponding periods of increasing then decreasing precipitation. On the face of it, this pattern resembles that of the Pacific Decadal Oscillation (PDO) understood to influence climate variability in the Rockies (Kittel et al. 2000) and which switched phases in the late 1970’s and again in the late 1990’s. Major differences between sites and seasons arise from whether the first trend (cooling, increasing precipitation) or the second (warming, declining precipitation) dominates the overall record. This suggests that alpine and subalpine climate signals are not as decoupled as they appear, but rather that across a relatively short elevational gradient (Δ700m) synoptic and landscape-scale processes react differently to and differentially modify a prevailing hemispheric signal.

**Driver, Inorganic Nitrogen (N) in Wetfall.** The NWT LTER program continues its participation in the National Atmospheric Deposition Program (NADP), which began in the early 1980s, maintaining the highest-elevation site in the US at 3,520 m on Niwot Ridge, and also the subalpine Sugarloaf site at 2,524 m. Annual deposition of inorganic N in wetfall at the Niwot Ridge site has shown a significant increase of 0.3 kg N ha⁻¹ yr⁻¹ for the (Figure 3) (Williams and Tonnessen, 2000). A sophisticated analysis of atmospheric deposition of pollutants throughout the entire Rocky Mountain Region from Canada to Mexico shows that nitrate and sulfate deposition increase from north to south, with hot spots of deposition in the Colorado Front Range (Nanus et al., 2003). Burns (2003a) shows that the increase of inorganic N in wetfall in the Front Range is partly driven by increases in the metropolitan population east of the Front Range. We added a third NADP site at C1 (elevation 3,000 meters) that complements our two existing sites at Sugarloaf and also the Niwot Saddle. The new NADP site provides three sites along an elevational transect, the only such elevational transect of NADP sites in the US. The new NADP site at C1 also provides a direct link to Monson’s Ameriflux program at C1. We are also working directly with NADP to test precipitation collectors that might improve measurements in snow-dominated regions. As part of this program, we installed an NADP Ott Pluvio precipitation
collector at the new site at C1 in November 2005. We are one of three sites testing larger buckets for improved snow collection.

**Nitrogen Inputs In Wetfall (NADP)**

\[ y = 0.4235x - 838.3 \]
\[ r^2 = 0.6057 \]

![Graph of Nitrogen Inputs In Wetfall (NADP) with equation and coefficient of determination](image)

Figure 3.

**Long-Term Research Activities and Experimental Results**

Shifts in the thickness of lake ice and the dates of ice out are consistent with this apparent decoupling of alpine and subalpine climate (Figure 4). The date at which the Green Lakes clear of the winter ice cover has shifted forward over the period of LTER records. At the subalpine Silver Lake, the lowest in the system, the shift has amounted to about 1 day/year, whereas at the alpine Green Lake 4 and Green Lake 5 it has been only 0.2 day/year.
The sensitivity of alpine areas to changes in climate, and the potential for non-linear responses, is illustrated by the response of the mass balance of the Arikaree Glacier to a severe drought at the turn of the century (Figure 5). The mass balance (Bn) of Arikaree Glacier at the head of Green Lakes Valley has been estimated for the 1965 – 2006 period by Caine. Until the late 1990s, Bn was approximately zero (+6.0 ± 74 cm W.E./yr). After 1997, it has been consistently negative (-132 ± 88 cm W.E./yr), most markedly in the drought years of 2001 and 2002 when the glacier lost about 5.2 m W.E. Over the last decade, the total loss of mass has amounted to almost 10 m. These results are corroborated by repeated surveys across the glacier since 1968 and by mapping which suggests a loss of 12% of the glacier area since 1963. This pattern is consistent with data from other mountain glaciers (Dyurgerov & Meier 2005) and, if continued, suggests that Arikaree Glacier is unlikely to survive more than a few more decades.
Phytoplankton Response to Climate Change. Because the hydrologic regime of alpine catchments is dominated by snowmelt, alpine aquatic ecosystems are hypothesized to be sensitive to interannual fluctuations in depth of snowpack, chemical nature of snow, and timing of snowmelt. McKnight’s group examined how the phytoplankton community response to an extreme drought year (2002) was superimposed upon the responses to the observed gradual environmental changes. Phytoplankton community composition was quantified and water column chemistry was characterized throughout the summers of 2000–2005. A redundancy analysis highlighted 2002 as an extreme year, indicating a relationship between increased water temperature, abundant populations of the diatom Synedra sp., and depletion of silica (Figure 6). Increased phosphate concentrations in the post-drought period were associated with an increase in algal biovolume and greater abundance of chlorophyte and chrysophyte taxa. These results indicate that changes in climate variability, leading to more frequent extreme droughts or warmer water temperatures, may be associated with greater variability in phytoplankton communities and lake ecosystem processes.
Hyporheic Zone. At the Navajo site in Green Lakes Valley, the influence of hyporheic zone interaction on the redox state of humic substances and other redox active species was investigated in an alpine stream and adjacent wetland, which is a more reducing environment (Miller et al., 2006). A tracer injection experiment using bromide (Br⁻) was conducted in the stream system. Simulations with a transport model (OTIS) showed that rates of exchange between the stream and hyporheic zone were rapid ($\alpha = 10^{-3}$ s⁻¹). Parallel Factor Analysis (PARAFAC) of fluorescence spectra was used to quantify the redox state of dissolved humic substances. The rate coefficient for oxidation of reduced humic substances ($\lambda = 6.5 \times 10^{-3}$ s⁻¹) in
the stream is consistent with electron transfer reactions occurring over short time scales. The rate coefficients for decay of ammonium ($\lambda = 1.2 \times 10^{-3} \text{ s}^{-1}$) and production of nitrate ($\lambda = -1.0 \times 10^{-3} \text{ s}^{-1}$) were opposite in sign but equal in magnitude. These results suggest that humic substances may be involved in rapid electron transfer processes in and near the stream channel. This study indicates that the oxidation and reduction of humic substances occurs over short temporal and spatial scales and may be important in determining energy flow at the catchment scale.

Species Compositional Change, 1988-2006. At the saddle of Niwot Ridge, species abundance has been sampled across a grid of 88 1m$^2$ permanent plots in 1989, 1990, 1995, 1997, and 2006, spanning fell field to wet meadow tundra communities. Over this sampling period, diversity ($H'$) was significantly lower in 2006 than in 1995/1997 (but not 1989/1990) and evenness was significantly lower during the 2006 survey than all other census dates. The strongest declines in diversity appear to be in the fellfield and barren plots. The relative cover of Carex rupestris, Lloydia serotina, and Trifolium dasyphyllum have significantly increased over time, and the covers of the grasses Deschampsia caespitosa and Trisetum spicatum have marginally significant increases. Gentianodes algida, a wet meadow gentian species, was the only species that showed a significant decline in its cover since 1989; another forb, Acomastylis rossii, has also significantly declined but only in the wetter communities. The changes in community structure do not follow predicted changes based on warming or nitrogen manipulations, although we did find some species-specific trends: for instance, C. rupestris and T. spicatum marginally increase and G. algida marginally declines due to nitrogen fertilization.

Shrub Encroachment. Alpine ecosystems are highly sensitive to warming air temperatures and snowpack decline. Alpine plant species could be particularly threatened by local and regional extinction if they are replaced by species from lower elevations. Concurrent with warming, there has been an increase in the abundance and distribution of woody shrubs in alpine zones. These dynamics may be analogous to those in arctic tundra where feedbacks among temperature, snowpack, and nutrient availability have been shown to accelerate shrub encroachment. In 2006, Suding and others initiated fully-factorial experiment to manipulate summer air temperature (via open-top chambers), snowpack (replicate snowfences), and nitrogen availability (N addition) to test the causal link between climate changes, the increasing distribution of a woody shrub, Salix glauca, and the subsequent decline in the alpine tundra community. Salix is common to arctic and alpine regions throughout the Northern Hemisphere and is rapidly increasing in abundance in the Rocky Mountains. The experiment will enable us to determine 1) if increasing temperatures and feedbacks between temperature and snow pack or nutrient availability favor the growth and establishment of Salix over the existing herbaceous alpine community and if these changes can drive rapid conversion, including the loss of alpine species and increase Salix distribution.

Critical Loads for N Deposition to Alpine Plants. Recognizing the need to identify sensitive indicators of biotic response to N deposition, the Bowman group has empirically estimated the N critical load for changes in alpine plant community composition and compared this with the estimated critical load for soil indicators of ecological change (Bowman et al., 2006). They have conducted a multi-factorial N fertilization experiment to a species-rich alpine dry meadow for an eight-year period. Change in plant species composition associated with the treatments occurred within three years of the initiation of the experiment and were significant at all levels of N
addition. Using individual species abundance changes and ordination scores, they estimated the N critical loads (total deposition) for (1) change in individual species to be 4 kg N ha\(^{-1}\) yr\(^{-1}\) and (2) for overall community change to be 10 kg N ha\(^{-1}\) yr\(^{-1}\). Note that current N deposition levels in wetfall as measured by NADP are about 8 kg N ha\(^{-1}\) yr\(^{-1}\).

Species Loss at Different N availabilities: Biotic Resilience and Environmental Change. To understand the role biota play in a system’s resilience or vulnerability to environmental change, Suding and others conducted an experiment to understand the interactive nature of the relationships between plant-soil feedbacks and limiting factors. They investigated soil, plant, and microbial responses to a widespread environmental change, increased nitrogen (N) supply, and how its effects are mediated by changes in biotic structure. For six years, we removed one of two co-dominant species, *Acomastylis rossi* and *Deschampsia caespitosa*, in moist meadow alpine tundra at NWT. In a factorial design, they also manipulated nutrient availability by adding carbon to reduce N and adding N to increase N. Results to date indicate that both co-dominants compete at reduced and ambient nitrogen levels: each species increased in relative abundance with the removal of the other. This competitive balance, however, was broken at increased N levels. *Acomastylis* responded directly to changes in N availability by decreasing in relative abundance. This change in plant abundance was correlated with changes in soil extracellular enzyme activities and microbial biomass. In contrast, *Deschampsia* did not respond to external changes in N supply; regardless of nutrient level; it only responded to the removal of *Acomastylis*. Thus, with continued N deposition forecast at Niwot Ridge, our results suggest that the soil feedbacks conferring initial resilience of *Acomastylis* to increased N availability will be overwhelmed through elimination of beneficial microbial effects. Eventually, continued N increase will directly inhibit *Acomastylis*. Once *Acomastylis* declines, the loss will indirectly facilitate *Deschampsia* via competitive release. Because *Deschampsia* exerts stronger competitive effects on subordinate species compared to *Acomastylis*, the increase in *Deschampsia* abundance may be subsequently accompanied by diminished abundance of many subordinate species and a dramatic decline in diversity (particularly evenness). Initial results published by Suding et al. 2006 in Oecologia; a manuscript detailing 6-year results will be submitted to Ecology in June.

Resource Partitioning depends on Neighbor Identity. Plant resource partitioning of chemical forms of nitrogen (N) may promote species coexistence across a variety of N-limited ecosystems. Suding, Bowman and others have conducted a series of \(^{15}\)N tracer addition experiments to test if uptake patterns vary in the presence of interspecific neighbors and if N acquisition patterns were consistent with plant-soil feedbacks. While the importance of interspecific competition as a cause of resource partitioning among species is widely-assumed, they have been the first to demonstrate that the identity of neighbors influence the degree of N-partitioning in the dry meadow (Miller, Bowman, Suding, in press, Ecology) and moist meadow (Ashton, Miller, Bowman & Suding, in review, Oecologia). In addition, in the moist meadow, it appears that interspecific interactions may stimulate plants to more effectively acquire N. N uptake, foliar N concentrations and rhizosphere extracellular enzyme activity increased in the presence of other species, indicating facilitation rather than competition for nitrogen. They are currently exploring the roles of rhizosphere signaling through signal manipulation (hsl addition) in driving this increased N uptake.
Schmidt’s group investigated the year-round microenvironment of an alpine tundra wet meadow soil on Niwot Ridge, focusing on the biogeochemistry and microbial diversity of spring snowmelt – a dynamic time for alpine ecosystems. Cold, water-saturated soils play important biogeochemical roles, yet almost nothing is known about the identity and habitat of microbes active under such conditions. Analyses of bioavailable redox species showed a shift from Mn reduction to net Fe reduction at 2–3 cm soil depth, elevated sulfate and decreased soluble Zn at spring snowmelt. Terminal restriction fragment length polymorphism profiles detected a correlated shift in bacterial community composition at the surface to subsurface transition. Bacterial and archaeal small-subunit rRNA genes were amplified from saturated spring soil DNA pooled along a depth profile. The most remarkable feature of these subsurface-biased libraries was the high relative abundance of novel, uncultivated Chloroflexirelated sequences comprising the third largest bacterial division sampled, and representing seven new Chloroflexi subdivisions, thereby dramatically expanding the known diversity of this bacterial division. We suggest that these novel Chloroflexi are active at near 0°C temperatures, under likely anoxic conditions, and utilize geochemical inputs such as sulphide from upslope weathering. Their research and Niwot Ridge was featured on the cover of Applied Microbiology (Costello and Schmidt, 2006).

Williams’ group followed on this theme of life in extreme environments by evaluating a possible microbial signature in the outflow of a little-studied system, rock glaciers (Williams et al., 2006; 2007 (in press). Collaborating with Nel Caine and McKnight’s student Rose Cory, they report average nitrate concentrations of 69 μmoles L⁻¹ in the outflow of the rock glacier, compared to 7 μmoles L⁻¹ in snow and 25 μmoles L⁻¹ in rain. Nitrate concentrations from the rock glacier generally increased with time, with maximum concentrations of 135 μmoles L⁻¹ in October, among the highest nitrate concentrations reported for high--elevation surface waters. These high nitrate concentrations appear to be characteristic of rock glacier outflow in the Rocky Mountains, as a paired-difference t-test shows that nitrate concentrations from the outflow of 7 additional rock glaciers were significantly greater compared to their reference streams (p = 0.003). End-member mixing analysis suggest that snow was the dominant source of nitrate in June, ``soil'' solution was the dominant nitrate source in July, and base flow was the dominant source in September. Fluoresence index values and PARAFAC analyses of dissolved organic matter (DOM) are also consistent with a switch from terrestrial DOM in the summer time period to an increasing aquatic-like microbial source during the autumn months. Schmidt’s students are following up by characterizing the microbial populations in the outflow of the rock glacier.

Niwot Ridge LTER has supported since 2004 a Small Mammal Monitoring Program, conducted by Dr. Norman Clippinger and Dr. Barry Rosenbaum. NWT LTER supported Dr. Clippinger’s appointment as an RAI at INSTAAR in 2007. The small mammal monitoring program consists of 600 small mammal live-traps at four monitoring locations: a subalpine web, two “saddle” webs, and a krummholz web. Each web consists of 150 traps checked for four straight nights in June and again in August. They have been assisted by at least two undergraduate field assistants each year for the past four years, supported by a combination of the NSF REU program and the Undergraduate Research Opportunity Program (UROP) of CU Boulder. With their help, we have captured mice, voles, and the occasional weasel in our webs. We are particularly interested in observing the fluctuation of vole
populations (very low the past two years!), as they tend to show a more direct influence of vegetation mass and nutritive content on their populations. We have also started a study investigating alpine small mammals as a reservoir for Giardia. In the near future, we will be sharing our data on small mammal populations and capture locations with our colleagues observing snow deposition patterns and plant communities on the ridge to explore possible connections with these abiotic and biotic ecosystem factors. Our monitoring of pika populations on the western side of the saddle will generate data that we can correlate to possible climate change. In addition, we are studying the pattern of pocket gopher soil disturbance in the alpine over time.

**Alpine—Subalpine Connections.**

We have made explicit linkages between alpine and subalpine ecosystems on Niwot Ridge a high priority. Some examples:

*The Forest-Alpine Tundra Ecotone (FATE).* FATE in the Front Range of Colorado typically occurs as a gradual transition from the treeless tundra to the closed canopy coniferous subalpine forest. Lipzten, Seastedt and Sanford evaluated the patterns of snow and dust inputs and soil properties and processes of this ecotone at three spatial scales: across the entire FATE, with distance from tree limit in the transitional krummholz zone, and around individual trees. Both Total P and Available P were highest in the Upper Krumholz, consistent with the LCM (Figure 7). Plant community and litter decomposition were related to maximum snow depth in the FATE, similar to the alpine tundra. Patterns observed over the entire length of the transect were often replicated on the scale of individual trees with downwind of trees similar to the forest and upwind of trees similar to the tundra.
Figure 7.

Trace Gas Flux Through Snow at Treeline. Helmig’s group working with Liptzin has developed new state-of-the-art techniques to measure trace gas fluxes through snow. Air samples are collected at four heights throughout the snowpack and analyzed for nitrous oxide on a gas chromatograph at the Soddie underground laboratory (Figure 8). The sample collection was automated such that the concentration gradient through the snowpack was assessed every eighty minutes. In addition to nitrous oxide, the concentrations of nitric oxide, carbon dioxide and ozone were also measured. Fluxes of these gases were then calculated based on the concentration gradient using Fick’s law. This sampling design allows us to examine the patterns of gas fluxes throughout the snowpack and at multiple temporal scales. In addition, we can compare the fluxes of multiple gases produced by microbial processes in soils. The winter fluxes can also be contrasted to growing season fluxes to estimate the contribution of winter fluxes to the annual total. This research endeavors complements the Ameriflux group at CI.
**Figure 8.**

*Treeline and Climate Change.* The spatial variability of species richness patterns across the FATE may obscure responses to global warming. Bourgeron is working with Seastedt and others on a study of patterns of plant species richness to determine the relationships among plant species richness patterns, environmental factors, and canopy structure within and among FATE types along transects from patch forest to subalpine forest. Overall, high richness was associated with heterogeneous topography, disturbance, and patchy tree distributions, and decreased along a landscape gradient. Richness was generally higher in patch forest than subalpine forest plots, but between-transect variability in richness was high. The results indicated that variability among FATE types should be taken into account in predicting species diversity responses to environmental changes.

*Climate Change, Snow, And Carbon Dioxide In A Sub-Alpine Forest.* A five-year record of net ecosystem CO2 exchange at C1 shows that years with extreme reductions in the early-spring snowpack are accompanied by lower soil temperatures and concomitantly higher rates of ecosystem carbon sequestration (Monson et al., 2006a). Furthermore, they showed that the winter soil exhibits sensitivity to snowpack depth and soil temperature that is several orders of magnitude higher than more temperate soils. This high sensitivity is due to a unique winter soil microbial community that is capable of exponential growth and high rates of substrate utilization.
at the cold winter temperatures that exist beneath the winter snowpack. These research findings are important because at mid-latitudes in the northern hemisphere, most terrestrial carbon sequestration occurs in montane forest ecosystems. The winter and early spring respiratory CO2 losses in these ecosystems are susceptible to changes in soil temperature that are coupled to changes in the depth of the winter snowpack. Winter and spring respiration can cause over half of the carbon assimilated by photosynthesis the previous summer to be lost the following winter.

This Monson et al. report stands as an example of the benefits of cooperation from several large programs that bring together very different programmatic goals and investigator skills: Monson, Ameriflux program (DOE) and land-atmosphere carbon exchange; Schmidt, microbial observatory program (NSF) and environmental microbiology; and Williams, LTER (NSF) and snow research. Collaboration and synthesis among the various disciplines resulted in unique discoveries.

Total Vs Soil Wintertime Respiration in a Subalpine Forest. We have shown that respiratory loss of CO2 from soil microbes beneath winter snow in forests from cold climates can significantly influence the annual carbon budget. How important, then, is beneath-snow respiration in the winter? We explored the magnitude of winter soil respiration using continuous measurements of beneath-snow CO2 concentration within the footprint of a flux tower at the C1. We used eddy covariance measurements from the tower to obtain estimates of total wintertime ecosystem respiration and compared them to the calculated beneath-snow CO2 flux. Soil respiration in the winter was estimated to contribute 35 - 48% of the total wintertime ecosystem respiration, and 7 - 10% of the total annual ecosystem respiration (Monson et al., 2006b).

Regionalization

A major goal of our 2004 renewal was increasing the footprint of our NWT LTER activities. Here we provide some examples of current regionalization activities.

San Juan Mountains. The Neff lab is investigating how different geologies in the San Juan Mountains of southern Colorado affect ecosystem structure and processes. Secondly, they are investigating the biogeochemical implications of eolian deposition, by collecting dust from distinct layers deposited into the seasonal snowpack. Corey Lawrence, a PhD student in Neff’s lab, is supported by NWT LTER with base funding from the Mellon Foundation and NSF to Neff to conduct this research. NWT LTER provides support to two non-profit NGO’s in the Silverton area which conduct and facilitate research in the San Juan Mountains, the Mountain Studies Institute (MSI) and the Center for Snow and Avalanche Studies (CSAS). Williams is on the advisory board of MSI and has laundered several grants through MSI. NWT LTER supports CSAS in several ways, including $1,000 in annual funding to support data collection in high-elevation catchments, letters of cooperation and support for philanthropic organizations, and directing potential researchers to the CSAS field site.

Rocky Mountain National Park. NWT LTER research scientists cooperate with several research organizations active in ROMO, including the NPS, Jill Baron’s USGS program, and the USGS WEBB program. Bowman currently has a fertilization project at ROMO to investigate how increasing amounts of inorganic N in atmospheric deposition may be changing species
composition and richness of alpine vegetation. Seastedt and Bowman wrote chapters of Baron’s book “Rocky Mountain Futures”. Williams works extensively with the USGS Webb program based in the Loch Vale catchment.

**Grand Teton National Park.** Jennifer Corbin, a PhD student at the University of Montana, is transferring our knowledge and procedures developed at Niwot Ridge for understanding the fate and transport of inorganic nitrogen in wetfall to high-elevation areas to high-elevation lakes located in the Teton Mountain Range of Wyoming. Corbin’s mentor is NWT LTER senior scientist Kathy Tonnessen of the National Park Service. Funding is primarily through the NPS, supplemented by NWT LTER funds. Corbin is conducting a paired watershed study looking at multiple inputs or stressors – specifically, Mica Lake and Lake Solitude in Grand Teton National Park (GRTE). Soil, surface water, atmospheric deposition and nitrogen-fixing plant material are being collected on a seasonal basis to determine the rate of nutrient flux. In addition, water samples will be collected to observe daily and seasonal trends and to correlate soil and water chemistry samples. These data will form the basis for an estimate of water and nutrient flux in high elevation headwater systems with varying times since deglaciation.

University of Michigan Biological Station (UMBS). Brian Seok, a graduate student at the University of Colorado under the mentorship of Detlev Helmig, has received an IGERT fellowship from the UMBS BART program to investigate: “Oxidized carbon and nitrogen exchanges through the seasonal snowpack at the University of Michigan Biological Station and their contribution to the annual ecosystem gas exchange budget”. Brian has been conducting research on trace gas flux through snow at the Soddie site on Niwot Ridge with equipment and stipend support from NWT LTER. He will expand his study area to address how future changes in snowpack thickness, in snow cover season, and in winter and springtime soil temperature and moisture will alter soil biogeochemical processes and feedbacks on atmospheric composition and chemistry at the UMBS forest ecosystem. While a selected number of related studies have been done in alpine environments; this study will be the first to investigate gas fluxes through the snowpack at a low-elevation, deciduous forest environment.

**Modeling and Synthesis Activities.**

Modeling has always been a weak link at NWT. We have made strides towards improving our modeling activities. These modeling approaches explicitly incorporate synthesis activities.

Tom Meixner of the University of Arizona is conducting hydrochemical modeling of the Green Lakes Valley that explicitly links terrestrial and aquatic systems. Tom was brought on board as a Senior Personnel for years 3 and 4 of the project to add modeling expertise to our program. Tom’s current modeling efforts build on his previous modeling activities conducted in Green Lakes Valley and the Loch Vale catchment of Rocky Mountain National Park as part of his PhD research, funded with a Cannon Fellowship (Meixner et al., 2000).

Williams group has developed a spatially explicit model of snow distribution in the Green Lakes Valley that builds on long-term measurements of snow depth (Erickson et al., 2005). Snow depth was modeled as a random function that can be decomposed into a deterministic trend and a stochastic residual, based on terrain parameters. The terrain parameters considered were
Of the five terrain parameters considered, the index of wind sheltering was found to have the greatest effect on predicted snow depth. The methodology presented in this paper allows for the characterization of the spatial correlation of model residuals for a variable mean model, incorporates the spatial correlation into the optimization of the deterministic trend, and produces smooth estimate maps that may extrapolate above and below measured values.

We know that the composition and production of the alpine tundra is greatly affected by snow cover and redistribution that in turn affect the soil moisture and govern its thermal regime. Litaor and others combined the approach of Erickson et al. with decision tree techniques to model the relations between snow depths, snow water equivalent (SWE), snow disappearance rate, soil moisture, alpine plants attributes and selected terrain-based parameters measured at NWT, using the 20+ years snow depth record at the Saddle (Litaor et al., in review). The model was sufficiently robust to predict the spatial snow distribution in 12 other years that exhibited average snowfall ($r^2 = 0.8, P<0.001$) but yielded low correlation ($r^2 = 0.2, P<0.001$) in drought years and moderate correlation ($r^2 = 0.67, P<0.001$) in years of above average snowfall. Plant biomass did not correlate well with snow attributes, soil moisture or any of the terrain-related variables. On the other hand, the species richness index was correlated with snow depths and soil moisture ($r^2 = 0.7, P<0.001$) demonstrating the importance of snow on plant community structure.

Chris Randin of ETH Zurich will be in residence at NWT LTER from September 2007 through August 2008 to develop spatially explicit models of alpine tundra species composition in response to climate change for his post-doctoral research, funded by the Swiss equivalent of NSF. He has three goals during his stay in Boulder: 1) improve the models of snow cover developed at Niwot Ridge with the PREVAH model to better explain the distribution patterns of plant diversity and biomass; 2) extend these models to include a process-based spatially-explicit prediction of species distribution driven by snow distribution and soil moisture; and 3) integrate the effects of species interactions into predictions of distribution change. For number 2), he proposes to build a cellular automaton coupling a local model of species growth and a spatial model of biomass expansion for individual plant species, based on his PhD work. The local model will describe the temporal evolution of a given species’ biomass according to soil moisture and nutrient availability.

**The Future of the NWT LTER Program**

Here we emphasize some important new programs at NWT. Alan Townsend will give a vision talk to the site review team that addresses long-term strategic thinking.

NEON. Niwot Ridge has been selected as a NEON core site for the Southern Rocky Mountains and Colorado Plateau domain. NWT will be the only high-elevation NEON core site. Gradient sites for this domain are anchored at NWT Ridge and are based on a grasslands to glaciers gradient that extends from Boulder to the Continental Divide at Niwot Ridge. Williams is the lead on both activities, with Monson and Jill Baron of NREL-CSU as co-leads. Many of the NEON national activities will be based in Boulder. NEON is negotiating with INSTAAR to host
several of their national cyber-infrastructure and analytical laboratories. Integration of NEON activities with NWT LTER, NWT Ameriflux, and Schmidts Alpine Microbial Observatory present interesting challenges and exciting possibilities. The collaboration among Monson, Schmidt, and Williams on the Monson et al. (2006) paper in Nature provides a model for collaborative activities in this high-elevation environment.

Lower elevation climate record. We are cooperating with CU-Boulder professors Nufio and Guralnick on a recently funded NSF grant to utilize the recently curated and databased Alexander grasshopper collection coupled with a new resurvey program to measure the effects of climate change on regional insects. Alexander processed over 65,000 grasshoppers from repeatedly sampled sites along an elevational gradient from Boulder (1530 m elev.) to Niwot Ridge (3,660 m) in the Colorado Front Range. Because of the quality and type of data available, this project will be able to determine the effects of a changing climate on the 1) phenology (timing of life history events), 2) elevational ranges and 3) morphological characteristics (namely body size) of a well studied and economically important group of organisms. They will use our methodology and help to produce high quality daily temperature and precipitation data for the lower elevation sites at A1 and B1 (NWT LTER still operates those sites), producing a long-term (50+ years) climate record along an elevational gradient from Boulder to the Continental Divide.

Eddy flux measurements. We have begun the first attempts to make direct measurements of the surface energy balance and CO2 flux using the eddy covariance technique above alpine tundra. Due to the special considerations caused by the complex terrain characteristic of alpine areas, a pair of identical eddy covariance systems were installed in the winter and spring of 2007. One site is approximately 150 m in the prevailing downwind direction of the other. This arrangement allows estimates of the downslope advection component of the carbon dioxide flux to be made. The alpine eddy flux system complements the eddy flux measurements made by the Ameriflux program at C1 and future NEON activities.

Adding NWT LTER to the Nutrient Network. We received supplemental funding in 07 to install a set of plots that allows us to participate in the LTER cross-site experiment “Nutrient Network (NutNet)”. The goal of NutNet is to conduct coordinated, long-term experimental research that will enable us to gain a general understanding of the extent to which multiple resource limitation and bottom-up controls influence community dynamics and ecosystem functioning. We hypothesize that enhanced N deposition in the alpine herbaceous communities will enhance herbivory and select for a vegetation community dominated by less-preferred browse species. The research design follows that proposed by Smith et al., with our exclosure plots designed to evaluate the effects of elk and vole grazing. Collection of baseline plant and soils information would occur during the 2007 growing season. We will experiment with exclosures designed to exclude both small mammals and larger grazers. Our proposed research site is a dry-moist meadow with low evidence of gopher activity. Once plot selection is made, both voles and gophers will be trapped out of the herbivore exclosures. Exclosures will be constructed in 2007 using a design that minimizes microclimate (snowfence) effects. Nutrient additions would initiate at the end of the 2007 growing season so as to be in place during snowmelt 2008. A field technician and REU student will conduct these activities under the supervision of T. Seastedt and K. Suding. This research activity builds on our current small mammal program run by Clippinger and Rosenblum.
**Participation in the National Phenology Network (NPN).** We are working with the NPN to develop a phenology program for (1) subalpine forests and (2) alpine tundra. The subalpine forest program was initiated in April 2007, in cooperation with Monsons’ Ameriflux site. Initial images and protocol can be found at: [http://urquell.colorado.edu/photos/photos_pheno.html](http://urquell.colorado.edu/photos/photos_pheno.html). We have received 2007 supplemental funding for the alpine tundra component. Carol Wessman has agreed to be the lead on this program. Our experimental design will follow that developed by the Sevilleta LTER site for grassland communities. The goal of this experiment is to create a better link between community level phenology and satellite-derived remote sensing products. Field measurements will be conducted about every 2 weeks along transects nested to capture spatial variability within ASTER and MODIS 250-m pixels. All of the transects will be within a single MODIS 1 km pixel. A total of 12 transects will be collected, 4 each within 3 plots corresponding to MODIS 250 m pixels. Field measurements consist of: (1) percent substrate cover; (2) digital photographs; and (3) hand-held spectrophotometer measurements. Aster imagery has been requested and granted for 20-May, 05-Jun, 21-Jun, 07-Jul, and 23-Jul, 2007.

**Colorado Front Range Socio-Ecological System.** Bourgeron is the lead on developing a plan for integrating human dimensions into the NWT LTER program. NWT LTER represents a challenge and a unique contribution to the LTER network because of the seemingly isolated location of its high elevation alpine terrestrial and aquatic ecosystems. NWT provides a relatively pristine end-member for LTER network activities. It is located in a subregion and region that have experienced dramatic changes since the mid 19th century, especially in the last decades due to rapid demographic changes. NWT is already experiencing the ecological effects caused by increased N deposition from the regional airshed. We have identified three nested levels (Figure 9) for developing feedback loops. These three levels comprise NWT LTER, the alpine-subalpine area, and the Colorado Front Range forested area. The feedback loops developed for each level serve as a framework for integrating social and natural sciences at NWT and surrounding areas, as a basis for collaboration with other LTER sites at the appropriate levels of the questions, and as a basis for linking LTER research and the NEON data stream. The feedback loop for the Colorado Front Range Socio-Ecological System (Figure 10) illustrates how human systems interact with two key structural drivers of COFR mountain ecosystems.
Figure 9.
II. Recent Synthesis, Cross-site, LTER Network Activities and International Activities

*International Programs.* We have begun to increase the research excellence of the NWT LTER through international collaboration of our scientists, post-docs and graduate students with the leading scientists working on high-elevation research topics in Europe and other areas of the world. As the only high-elevation (alpine tundra and subalpine forest) LTER program in the US, we have no natural partners to collaborate with in the US LTER program. In contrast, Europe has well-developed, long-term and extensive research programs focused on high-elevation areas of the Alps and other mountain ranges. Highlights include:
Bourgeron has spent the last several years working with US-LTER colleagues and NSF officers on the reorganization of the International Long Term Ecological Research Network (ILTER, http://www.ilternet.edu/), the implementation of the US-LTER International Committee (http://intranet.lternet.edu/committees/), and the redeployment of the US-LTER contribution to it. This work is conducted as co-Chair of the US-LTER IC under NSF funding and with direct involvement from NSF officers. He was awarded the French International Visiting research Blaise Pascal Chair (http://www.chaires-blaise-pascal.org/uk/index.html) to work with the French LTER program and develop several French-US projects, among other tasks. Duties included advising the leadership of the emerging French LTER program (zones ateliers), including developing further ties with the US-LTER and sponsoring joint research with NWT.

Bowman has an NSF-funded project with L’uboš Halada and Juraj Hreško of Slovakia to investigate soil acidification studies in the Western Tatra Mountains, an area with long legacies of acid deposition and elevated rates of N deposition. Results from experimental manipulations of nutrient additions suggest that this site, and possibly others in central Europe, have reached a transition stage to Fe dominated buffering of soils, and N inhibition of plant growth due to loss of base cations and a combination of Al and Fe toxicity.

Sievering is using his January-August 2007 sabbatical for a collaborative fluorometry venture jointly with the Swiss Federal Research Inst. (WSL in Zurich) and with Nina Buchmann’s BGC Cycling group (Inst. of Plant Sciences) of the ETH, also in Zurich. WSL manages the Swiss ILTER network. The BGC Cycling group of ETH, which performs or directs research at network sites, is providing a strong intellectual center for receipt of his sabbatical results (along with WSL). The Swiss ILTER network provides an excellent field setting to further develop N-deposition fluorometry relationships and, of course, foster fluorometry as an important part of the Swiss ILTER measurement program. Supplemental LTER funding supported his post-doc Tim Tomaszewski to spend the month of April 2007 conducting fluorometry research in Switzerland.

Italian Alps. In October, 2006, we hosted a visiting delegation of 4 research scientists from the University of Turino, Italy. They represent the Laboratory Research on Snow and Alpine Soils (www.lnsa.unito.it), a new research team focused on studying snow and soil in the Italian Alps. The main centre is located in Torino, and includes a high elevation laboratory (3000 m asl) accessed from the MonteRosa ski area. In April 2007 Williams returned the site visit with funding from the Italian team, giving a plenary address to a conference sponsored by the Italian team. We have initiated a student exchange with their program. Gianluca Filippa, a PhD student from that program, will be in residence at Niwot Ridge from about June through October 2007. Gianluca will study carbon and nitrogen cycling in high-elevation soils.

Suding is the lead on “Cross-site Synthesis on Species Response to Nitrogen Fertilization”, with E. Clelend (NCEAS), S. Collins (SEV), C. Clark (CDR), L. Gough (ARC), K. Gross (KBS), and S. Pennings (GCE). The aim of this synthesis is to understand effects of enhanced N fertilization at the species level. They have compiled a dataset encompassing 9 sites, over 32 N fertilization experiments, the responses of over 1,000 species to N fertilization, and their traits. The major results are:
• N enrichment reduces diversity while it increases productivity, and that rare species and those with particular functional traits are particularly susceptible to loss. (Suding et al. 2005, PNAS)

• In addition to the above, species responses to N enrichment depend on environmental context (Pennings et al. 2005, Oikos)

• There is also a great deal of variation across sites in the degree of diversity loss with N enrichment, again attributable to environmental context. The communities most susceptible to species losses are in cold places, have soils with low cation exchange capacities, and a large productivity response to N enrichment. (Clark et al. in press, Ecology Letters).

The synthesis effort is ongoing. This month, they will submit the complete dataset to Ecology as an Ecological Archives dataset. Several LTER sites have budgeted monies for standardized data collection (across sites) for collection of environmental predictor variables (C:N:P soils, more plant traits). Next winter, they will run a distributed graduate seminar at NCEAS with this dataset as its focus (Suding, Collins, Cleland PIs).

Suding is a core participant in the NSF-funded Research Collaboration Network “TraitNet” 2007-2012 and in the NSF-ITR (Information technology research) project “SEEK: Science Environment for Ecological Knowledge”. The aim of TraitNet Research Collaboration Network is to coordinate trait-based evolutionary and ecological research by synthesizing and integrating trait-based approaches (such as the LTER network-funded fertilization synthesis) across disciplines. The aim of the SEEK project is to create cyberinfrastructure for ecological, environmental, and biodiversity research and to educate the ecological community about ecoinformatics and their application to data synthesis.

Gloria Project. Bowman’s group began establishment of a Global Observation Research Initiative in Alpine Environments (GLORIA) site at the Niwot LTER site in 2006, funded with NWT LTER supplemental funding. The goals of GLORIA are to establish a global network of monitoring sites using uniform procedures to evaluate global climate change effects on mountain biodiversity, and to contribute this information in an international effort to help mitigate loss of diversity and habitat in mountain ecosystems. His group have established GLORIA monitoring plots on the summits of Albion, Kiowa, and Arikaree Peaks. These summits are ideal for this work, because they are in the City of Boulder Watershed, and recreational use of is forbidden. He plans to follow species presence and abundance at annual intervals for the first 5 years of the monitoring program. Following this, plots will be recensused every 5 years.

Regional Treeline Change. NWT representatives Patrick Bourgeron and graduate student Dan Lipson attended a regional meeting on treeline change in the Western US. The meeting was held in West Glacier, Montana. Thirteen scientists representing nine universities, one institute (Woods Hole) and two agencies (USFS and USGS) attended the meeting. The workshop is part of the western mountain initiative (http://www.cfr.washington.edu/research.fme/wmi/) sponsored by USFS, USGS and NPS. A state—of—the science manuscript from the workshop submitted to Frontiers of Ecology is under revision.
Climate Change and Alpine Tundra. Niwot Ridge LTER participated with 10 other tundra sites to evaluate whether recent observations of changes in some tundra ecosystems appear to be responses to a warming climate. The experimental protocol consisted of metaanalysis on plant community measurements from standardized warming experiments at 11 locations across the tundra biome involved in the International Tundra Experiment. The passive warming treatment increased plant-level air temperature by 1-3°C, which is in the range of predicted and observed warming for tundra regions. Responses were rapid and detected in whole plant communities after only two growing seasons. Overall, warming increased height and cover of deciduous shrubs and graminoids, decreased cover of mosses and lichens, and decreased species diversity and evenness. These results predict that warming will cause a decline in biodiversity across a wide variety of tundra, at least in the short term. They also provide rigorous experimental evidence that recently observed increases in shrub cover in many tundra regions are in response to climate warming. These changes have important implications for processes and interactions within tundra ecosystems and between tundra and the atmosphere (Walker et al., 2006).

A New Technique For Quantifying The Components Of Dissolved Organic Matter In Cold Regions. Diane McKnight and her student Rose Cory presented an exciting breakthrough in a method to quantify the components of dissolved organic matter in cold regions (Cory and McKnight, 2005). Excitation-emission matrixes (EEMs) of 379 dissolved organic matter (DOM) samples from diverse aquatic environments were modeled by parallel factor analysis (PARAFAC). These data sets were primarily from the Niwot Ridge LTER, Toolik Lake LTER, and McMurdo Dry Valley LTER. Thirteen components likely representing groups of similarly fluorescing moieties were found to explain the variation in this data set. Seven of the thirteen components were identified as quinone-like based on comparison of their excitation and emission spectra to spectra of model quinones. These quinone-like fluorophores were found to vary in redox state and degree of conjugation. Two components were identified as amino acidlike based on comparison to tyrosine and tryptophan fluorescence spectra. Further, the distribution of the quinone-like fluorophores was evaluated as a function of environmental and laboratory redox gradients. Under reducing conditions, the contribution of the reduced quinone-like fluorophores increased concurrent with a decrease in the oxidized quinone-like fluorophores, indicating that DOM fluorescence is a function of redox state of quinone-like moieties. Lastly, a ratio of two quinone-like fluorophores was found to explain the variation in the fluorescence index. These results provide new insight into the redox reactivity of DOM and have implications for the application of fluorescence spectroscopy as a tool to characterize DOM.

LTER Planning Grant. NWT has worked closely with the proposed expansion of the LTER program. Williams chaired the working group on climate change, one of the four initial working groups. He is on the writing team for the proposal/plan due 30 September 2007 and has attended all but one of the planning meetings. Suding was a participant in the LTER Conference Committee related to the LTER network planning grant. Bourgeron attended the April 2007 meeting in Athens.

DAYCENT_CHEM Modeling Activities. We are participating in biogeochemical modeling at the watershed scale using the DayCent-Chem model. The project is lead by Jill Baron with funding from EPA and NPS. There are four LTER sites participating in this modeling activity: NWT
LTER, Hubbard-Brook, HJ Andrews, Coweeta. All four sites attended a February 2006 workshop and were co-sponsors of an ASM workshop on the modeling efforts.

*Translating Science for Society Brochure.* NWT LTER contributed 4 of the published pictures and one of the case studies "Basic science guides acid mine drainage remediation" to the NSF brochure.

*LTR Workshop on Ecophylogenetics, 2007.* Bowman was a participant.

*First LTER Graduate Student Collective Research Symposium.* Held on April 13th through the 17th, 2005, at H. J. Andrews LTER, in Blue River, Oregon. Attended by Dan Liptzin and Courtney Meier of NWT LTER. They chaired two of the 5 workshops at the meeting.

*National Science Board Presentation.* The University of Colorado, Boulder, had the honor of hosting the meeting of the NSF National Science Board on February 10, 2006. NWT LTER lead graduate student Corey Meiers presented a poster on NWT LTER to the board, emphasizing the role of graduate and undergraduate education at NWT LTER.

*Bio-Math Program.* NWT-LTER received a special LTER supplement in 2003 to facilitate collaboration between undergraduate ecology and mathematics majors. We call our supplement the BioMath program. While the LTER supplement was to NWT LTER, several undergraduates worked on diatom data sets from the McMurdo LTER under the tutelage of D. McKnight, because those data sets were very mature. Students Shannon Horn and Amber Roche, along with their mentor R Esposito, analyzed data and also conducted field research in Antarctica, which lead to a peer-reviewed publication (Esposito et al., 2006).

*ASM 2006.* Tim Seastedt served on the planning committee and was co-chair for the 2006 ASM, held at Estes Park in Colorado. NWT had a large presence at the ASM, co-sponsoring five workshops and presenting 20+ posters. NWT sponsored a field trip to NWT LTER, with 22 participants, four from NSF. Most importantly, NWT handled logistics for procuring beer and wine.

*Alpine Monitoring Workshop.* The workshop was held September 20-23, 2005, at the Mountain Research Station and sponsored and hosted by NWT LTER. This 2.5 day workshop facilitated the process of discussion and integration of alpine monitoring among NPS I&M networks (Williams and Seastedt are on Science Advisory Teams). Common goals included identification of core commonalities among NPS alpine systems and development of specific questions/objectives, a set(s) of recommended measurements and associated analyses. The purpose of this compilation is to inform protocol development and implementation across the region. If multiple networks implement consistent Vital Signs (measures, sample designs, etc.) we all gain analytical and interpretive power, giving our Parks better monitoring results and providing a broad perspective on the health of alpine communities across the west. Monitoring of these important, but isolated and often small areas is a challenge for NPS I&M Networks. Challenges include site accessibility, frequently hostile weather conditions, relatively poorly understood drivers (e.g., atmospheric chemical deposition and climate change) and response indicators, and potentially complicated interactions between vegetation, fauna, weather,

*NPS Award.* M. Williams received the National Park Service, Intermountain West Annual Award for Research to Support Park Service Resource Management by a non-federal scientist (quite a mouthful). Presented here becomes it emphasizes our trajectory to provide scientific results that can be used by land managers and other decision makers to maintain the environmental sustainability of high-elevation ecosystems.