

**Annual Report for Period:**09/2009 - 08/2010

**Submitted on:** 06/16/2010

**Principal Investigator:** Anderson, Suzanne P.

**Award ID:** 0724960

**Organization:** U of Colorado Boulder

**Submitted By:**

Anderson, Suzanne - Principal Investigator

**Title:**

CZO: Boulder Creek Critical Zone Observatory--Weathered Profile Development in a Rocky Environment and Its Influence on Watershed Hydrology and Biogeochemistry

### Project Participants

#### Senior Personnel

**Name:** Anderson, Suzanne

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

**Contribution to Project:**

Suzanne has been working with landowners to establish permission for our field project; working with team members to site stream gages, met towers and other instrumentation; organizing regular meetings of project members during the academic year; coordinating logistics for non-local project members; giving talks about the CZO objectives; recruiting students and staff members.

**Name:** Anderson, Robert

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

**Contribution to Project:**

Bob has worked with post-doc Miriam Duhnforth on CRN analysis, glacier modeling, and landscape incision history. Bob is beginning to think about weathering front propagation and interactions between fracture networks, hydrology and chemical weathering.

**Name:** Sheehan, Anne

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

**Contribution to Project:**

Anne is coordinating the geophysical surveying component of the project. She has supervised a grad student through a Masters on the project, and has several summer interns involved in project.

**Name:** Tucker, Gregory

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

**Contribution to Project:**

Greg has started working on developing landscape models relevant to the CZO landscapes. He is supervising a grad student working on weathering/hydrology models, and is involved in ground-truthing LiDAR.

**Name:** Fierer, Noah

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

**Contribution to Project:**

Noah is developing microbial community assessment tools for application in the project. He is supervising a PhD student working on microbial ecology and microbial activity in Gordon Gulch watershed.

**Name:** McKnight, Diane

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Diane is supervising several students in the CZO, one working on organic matter on hillslopes, and one working on the diatom *Didymosphenia geminata* in Boulder Creek. She has run several DOM workshops, and is actively involved in cross-CZO DOM work.

**Name:** Williams, Mark

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Mark has supervised a student working on isotope hydrology, and another working on N fluxes across elevation gradients. He is

the chair of the National CZO integrated data management committee.

**Name:** Caine, Nel

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

**Contribution to Project:**

Nel is an invaluable resource for planning field work; designing and locating stream gauges; supplying insight from decades of work in Green Lakes Valley; aiding graduate student recruitment

**Name:** Wobus, Cam

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

**Contribution to Project:**

Cam's involvement has tapered in year 3, since he took a job in consulting.

**Name:** Dethier, David

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

**Contribution to Project:**

David has successfully obtained Keck project funding for undergraduate research for 3 years. His summer field work with these students has resulted in 7 undergraduate theses to date. The program is increasing in size in 2010, with a total of 11 students coming (both CZO supported and Keck supported), and another faculty advisor joining in. David and the Keck students participate in our annual Boulder CZO science meeting.

**Name:** Voelkel, Joerg

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

**Contribution to Project:**

Joerg coordinates the TUM geophysical surveying efforts each summer, and has undertaken XRF analysis of soils and thermoluminescence dating.

**Name:** Leopold, Matthias

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

**Contribution to Project:**

Matthias conducts geophysical surveys, using primarily GPR and electrical resistivity, in coordination with Anne Sheehan's shallow seismic refraction. Matthias also works with Keck project undergraduate researchers supervised by David Dethier each summer.

**Name:** Murphy, Sheila

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

**Contribution to Project:**

Sheila has participated in Science Discovery outreach programs, and is involved in planning water sampling work.

**Name:** Blum, Alex

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Alex is responsible for mineralogical and elemental analysis of rocks and soils we collect, and interacts with others in the project on weathering.

**Name:** Loague, Keith

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Will begin working on hydrologic simulations of Green Lakes Valley summer 2008.

**Name:** Molotch, Noah

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

**Contribution to Project:**

Noah joined the faculty at CU in 2009. He has helped with snow depth sensing, overseeing LiDAR analysis of snow, and contributed to CZO meetings.

**Name:** Ouimet, William

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

**Contribution to Project:**

Dr. Ouimet is at Amherst College. He will join David Dethier in Colorado to oversee a group of 11 undergraduate students, who will do research projects in July-August 2010.

**Post-doc**

**Name:** Duhnforth, Miriam

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

**Contribution to Project:**

Working with Bob Anderson on CRN sampling and analysis.

**Name:** Miller, Matthew

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

**Contribution to Project:**

Matthew completed his PhD in 2008 on nutrient fluxes in Green Lakes Valley and their relationship to hydrology and impact on diatom *Didymosphenia geminata*. He worked as a post-doc for the CZO and Niwot LTER from August-December 2008, before moving to a post-doc with Beth Boyer at the Penn State CZO.

**Name:** Hinckley, Eve-Lyn

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

**Contribution to Project:**

NSF Earth Sciences Post-doctoral fellow, arrived September 2009. Eve has conducted snowmelt N15 tracer experiments on 5 plots, and will conduct rainfall experiments on 5 more plots this summer. She is mentoring all CZO graduate students, and is teaching a week-long summer camp on water to a dozen 10-14 year olds.

**Name:** Barnes, Becca

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

**Contribution to Project:**

Dr. Barnes has an NSF Earth Sciences post-doctoral fellowship, and is based at the USGS in Boulder. Her original project on in-stream processing of nitrogen in coal bed methane discharge became unnecessary because of changes in regulations on water discharge in these extraction operations. She has revised her project to study in-stream processing of nitrogen and its relationship to dissolved organic matter in Boulder Creek and the tributaries that are foci in the Boulder CZO.

**Name:** Bates, Scott

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Worked with undergraduate Garrett Cropsey on lichen weathering at Gordon Gulch.

**Graduate Student**

**Name:** Kandel, Cary

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

**Contribution to Project:**

New (2008) student work with Suzanne Anderson (Geography), who decided to leave graduate school in her first term.

**Name:** Huber, Juliane

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Graduate student (PhD) at Technical Univ. Munich who will spend >1 month in field this summer.

**Name:** Eilers, Kathryn

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

**Contribution to Project:**

Graduate student working with Noah Fierer (EBio) on soil microbiology in the CZO.

**Name:** Gray, Chris

**Worked for more than 160 Hours:** No

**Contribution to Project:**

New graduate student will work with Noah Fierer (Ebio) on CZO soil microbiology, funded from other sources.

**Name:** Cowry, Rory

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

**Contribution to Project:**

Graduate student with Mark Williams (Geography) working on isotope hydrology.

**Name:** Befus, Kevin

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

**Contribution to Project:**

Graduate student with Anne Sheehan (Geology), finished M.S. thesis on shallow seismic refraction surveying of CZO sites in 2010.

**Name:** Gabor, Rachel

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

**Contribution to Project:**

Graduate student with Diane McKnight (Civil Eng), working on hydrology and dissolved organic matter, and overseeing 3 undergraduate assistants.

**Name:** Daferner, Johannes

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Diplom student from Technical Univ. Munich; finished degree.

**Name:** Doetterl, Sebastian

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Diploma student from Technical Univ. Munich, worked in field in 2008.

**Name:** Riggins, Susan

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Worked on understanding regolith formation. Finished PhD in 2010.

**Name:** McLaughlin, Aimee

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Completed Master's thesis in 2009 under Diane McKnight on *Didymosphenia geminata*.

**Name:** Hill, Ken

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Completed MA thesis in 2008 on Green Lakes Valley hydrology, analyzing 26 years of observations.

**Name:** Nielson, Ashley

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Completed MA thesis in 2008 on hydrochemistry of a wetland in Green Lakes Valley.

**Name:** Lee, Jeana

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

**Contribution to Project:**

New graduate student with Suzanne Anderson (Geography), who will work on weathering and water chemistry across the Boulder CZO sites.

**Name:** Culp, David

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Graduate student with Anne Sheehan (Geology), helped with seismic surveying in summer 2009.

**Name:** Cullis, James

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

**Contribution to Project:**

Graduate student in Civil, Environmental and Architectural Engineering with Diane McKnight, working on *Didymosphenia geminata* in Boulder Creek, and hydraulic controls. Supported by CU Chancellor's Fellowship in 2008-9, partial project support in 2009.

**Name:** McLoughlin, Rachel

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Graduate student in Environmental Sciences with Diane McKnight. Completed MA thesis on *Didymosphenia geminata* in spring 2009.

**Name:** Cooper, Leigh

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Graduate student in Ecology & Evolutionary Biology working with Bill Lewis on effects of spruce beetle on aquatic ecology; partially supported by CZO.

**Name:** Langston, Abigail

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

**Contribution to Project:**

Abby is a PhD student working with Greg Tucker in Geological Sciences on weathering and water models. She is overseeing LiDAR ground-truth work in summer 2010.

**Name:** Littrell, BobbiJo

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

**Contribution to Project:**

MS student in Environmental Engineering & Science at Colorado School of Mines, working as assistant to Becca Barnes for summer 2010. Funded through Edna Bailey Sussman Foundation Environmental Internship Program

## Undergraduate Student

**Name:** Buraas, Eirik

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Keck Geology Consortium 2008 participant from Williams College. Completed senior thesis on infiltration in Gordon Gulch. Working in field with Keck students in 2009.

**Name:** Gannaway, Evey

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Keck Geology Consortium 2008 participant from Sewanee. Complete senior thesis on fractures in Green Lakes Valley bedrock.

**Name:** Nelson, Ken

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Keck Geology Consortium 2008 participant from Macalester College. Completed senior thesis on soils of Betasso catchment.

**Name:** Rodriguez, Miguel

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Keck Geology Consortium 2008 participant from Colgate College. Completed senior thesis on apatite.

**Name:** Pettit, Mollie

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Undergraduate intern from Virginia Tech, working with the geophysics team under guidance of Anne Sheehan.

**Name:** Rock, Nate

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

**Contribution to Project:**

Field assistant, working on water sampling, snow surveying, sample processing. Completed senior honor's thesis in 2010 on hydrology of Gordon Gulch. Upon graduation, moved to full time CZO field assistant employment.

**Name:** Mass, Sarah

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

**Contribution to Project:**

Field and lab assistant: water sampling, soil sampling, lab processing of soil, rock and water samples.

**Name:** Kelsay, Travis

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Undergrad assistant to geophysics team, supported by Geology department mentorship and this project.

**Name:** McClave, Graham

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Undergrad assistant to geophysics team, supported by Geology department mentorship and this project.

**Name:** Austin, Andrus

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Michigan Tech undergraduate student, supported as an IRIS intern, helping geophysics team.

**Name:** Anarde, Katherine

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Undergrad assistant to the geophysics team and working with Alex Blum, USGS, on XRD analyses.

**Name:** Bonilla, Emanuelle

**Worked for more than 160 Hours:** No

**Contribution to Project:**

RESESS undergraduate intern.

**Name:** Byrd, Steve

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

**Contribution to Project:**

Ecology and Evolutionary Biology undergraduate working with Diane McKnight.

**Name:** Ianniello, Rick

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

**Contribution to Project:**

Environmental Studies undergraduate student working with Diane McKnight.

**Name:** Crisp, Steven

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

**Contribution to Project:**

Environmental engineering undergraduate student working with Diane McKnight.

**Name:** Dengler, Liz

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Bates College undergraduate student in the Keck Geology Consortium program to learn about the Front Range and the Boulder CZO, conduct field work, and over the course of 2009-10 produce a senior thesis based on summer field research.

**Name:** Riddle, Evan

**Worked for more than 160 Hours:** No

**Contribution to Project:**

North Carolina State University undergraduate student in the Keck Geology Consortium program to learn about the Front Range and the Boulder CZO, conduct field work, and over the course of 2009-10 produce a senior thesis based on summer field research.

**Name:** Trotta, James

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Williams College undergraduate student in the Keck Geology Consortium program to learn about the Front Range and the Boulder CZO, conduct field work, and over the course of 2009-10 produce a senior thesis based on summer field research.

**Name:** Gilbert, Rebecca

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Williams College undergraduate student in the Keck Geology Consortium program to learn about the Front Range and the Boulder CZO, conduct field work, and over the course of 2009-10 produce a senior thesis based on summer field research.

**Name:** Krall, Lindsey

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

**Contribution to Project:**

University of Michigan undergraduate student working with Diane McKnight

**Name:** Rosenbaum, Sarah

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Undergraduate student (CU) working with Diane McKnight and James Cullis on Didymo.

**Name:** Russell, Nina

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Nina completed a senior thesis in Environmental Studies in 2010 under the supervision of Diane McKnight on dissolved organic matter in Gordon Gulch soil extracts.

**Name:** Tarshall, Jeffrey

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

**Contribution to Project:**

Jeff is a field assistant working for Suzanne Anderson in summer 2010.

**Name:** Coate, Jacob

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

**Contribution to Project:**

Jake is an undergraduate student working as a field assistant for Suzanne Anderson in summer 2010.

**Name:** Fancher, Hana

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

**Contribution to Project:**

Hana is working with Eve Hinckley on hydrology and N-cycling.

**Name:** Czastkiewicz, Alexandra

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

**Contribution to Project:**

Ola is working with Eve Hinckley on hydrology and N-cycling.

**Name:** O'Grady, Sean

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

**Contribution to Project:**

Sean is working with Abby Langston on LiDAR ground truth in summer 2010.

**Name:** Grigsby, Shane

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

**Contribution to Project:**

Shane is working with Abby Langston on LiDAR ground truth in summer 2010.

**Name:** Kemper, Cayla

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

**Contribution to Project:**

Working as summer assistant for Rachel Gabor in 2010.

**Name:** Elg, Jordan

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

**Contribution to Project:**

Working as summer assistant for Rachel Gabor in 2010.

**Name:** Lee, Robert

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

**Contribution to Project:**

Working as summer assistant for Rachel Gabor in 2010.

**Name:** Corson-Rikert, Hayley

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

**Contribution to Project:**

Wesleyan undergraduate student in the Keck Geology Consortium program to learn about the Front Range and the Boulder CZO, conduct field work, and over the course of 2010-11 produce a senior thesis based on summer field research.

**Name:** Dethier, Evan

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

**Contribution to Project:**

Williams undergraduate student in the Keck Geology Consortium program to learn about the Front Range and the Boulder CZO, conduct field work, and over the course of 2010-11 produce a senior thesis based on summer field research.

**Name:** Kantack, Keith

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

**Contribution to Project:**

Williams undergraduate student in the Keck Geology Consortium program to learn about the Front Range and the Boulder CZO, conduct field work, and over the course of 2010-11 produce a senior thesis based on summer field research.

**Name:** Lyerly, Reece

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

**Contribution to Project:**

Fuhrman undergraduate student in the Keck Geology Consortium program to learn about the Front Range and the Boulder CZO, conduct field work, and over the course of 2010-11 produce a senior thesis based on summer field research.

**Name:** Mayley, Ellen

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



**Contribution to Project:**

Smith undergraduate student in the Keck Geology Consortium program to learn about the Front Range and the Boulder CZO, conduct field work, and over the course of 2010-11 produce a senior thesis based on summer field research.

**Name:** McCarthy, James

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

**Contribution to Project:**

Williams undergraduate student in the Keck Geology Consortium program to learn about the Front Range and the Boulder CZO, conduct field work, and over the course of 2010-11 produce a senior thesis based on summer field research.

**Name:** Shircliff, Corey

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

**Contribution to Project:**

Beloit undergraduate student in the Keck Geology Consortium program to learn about the Front Range and the Boulder CZO, conduct field work, and over the course of 2010-11 produce a senior thesis based on summer field research.

**Name:** Warrell, Kathleen

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

**Contribution to Project:**

Georgia Tech undergraduate student in the Keck Geology Consortium program to learn about the Front Range and the Boulder CZO, conduct field work, and over the course of 2010-11 produce a senior thesis based on summer field research.

**Name:** Wyshnytzky, Cianna

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

**Contribution to Project:**

Amherst undergraduate student in the Keck Geology Consortium program to learn about the Front Range and the Boulder CZO, conduct field work, and over the course of 2010-11 produce a senior thesis based on summer field research.

**Name:** Camp, Erin

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

**Contribution to Project:**

Amherst undergraduate student in the Keck Geology Consortium program to learn about the Front Range and the Boulder CZO, conduct field work, and over the course of 2010-11 produce a senior thesis based on summer field research.

**Name:** Yzeiraaj, Dhokela

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

**Contribution to Project:**

Colby undergraduate student in the Keck Geology Consortium program to learn about the Front Range and the Boulder CZO, conduct field work, and over the course of 2010-11 produce a senior thesis based on summer field research.

**Name:** Crawford, John

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

**Contribution to Project:**

Undergraduate field assistant with Becca Barnes in 2009; completed senior honors thesis on dissolved organic matter and denitrification; graduated summa cum laude.

**Name:** Cropsey, Garrett

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Did senior honor's thesis in 2010 on lichens on rock outcrops at Gordon Gulch and their potential role in mineral weathering

**Technician, Programmer**

**Name:** Parrish, Eric

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

**Contribution to Project:**

Assists with web development, graphics.

**Name:** Frederick, Zan

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

**Contribution to Project:**

Oversees field operations for CZO.

**Name:** Waterman, Jim

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Jim is the developer of the BASIN website, and will sustain it and grow it to include the Boulder Creek CZO.

**Name:** Yang, Chi

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

**Contribution to Project:**

Data manager.

**Name:** Lubinski, David

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

**Contribution to Project:**

David is supported by a supplement to develop the National CZO website.

**Name:** Bergmann, Gaddy

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Technician in Noah Fierer's lab. Studied microbial carbon dynamics in soils from different vegetation types within Gordon Gulch

## Other Participant

### Research Experience for Undergraduates

**Name:** Debenport, Spencer

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

**Contribution to Project:**

Undergraduate from St. Olaf's college, in REU run by Ecology & Evolutionary Biology department at the Mountain Research Station. Worked with Katie Eilers in summer 2009 on microbial distributions in the surface soils of Gordon Gulch

**Years of schooling completed:** Junior

**Home Institution:** Other than Research Site

**Home Institution if Other:** St Olaf's College

**Home Institution Highest Degree Granted(in fields supported by NSF):** Bachelor's Degree

**Fiscal year(s) REU Participant supported:** 2009

**REU Funding:** No Info

## Organizational Partners

### United States Geological Survey

Alex Blum and Sheila Murphy, both USGS, are integral members of the project team. Their contributions are in soil/rock/water geochemical analysis, lab support, and outreach.

### Technical University of Munich

Two researchers (Joerg Voelkel and Matthias Leopold) of TUM are a major part of the geophysics team for the project. They conduct geophysical survey field work this summer, and are bringing several students with them. They work closely with several members of the team, including Nel Caine, Anne Sheehan, and David Dethier.

**Williams College**

David Dethier from Williams College is bringing a group of undergraduate students for summer research in the CZO this summer, and his work ties in with efforts of the geophysics, geochemical and geomorphology teams.

**LELAND JUNIOR STANFORD UNIVERSITY**

Keith Loague of Stanford is producing hydrologic simulations using the Integrated Hydrologic Model (InHM). He is currently working on a hydrologic simulation of Green Lakes Valley.

**Keck Geology Consortium**

A Keck Geology Consortium project involving 3 undergraduate students will take place at the Boulder Creek CZO this summer.

**Niwot Long Term Ecological Res. (LTER)**

Boulder Creek CZO shares one field site- Green Lakes Valley- with the Niwot LTER. LTER personnel assist CZO personnel, and we are sharing some lab work. The CZO will augment instrumentation in the Niwot LTER- notably the met station in Green Lakes Valley.

**Other Collaborators or Contacts**

U.S. Forest Service- one of our field sites is on National Forest.

Boulder County Open Space- one of our field sites is on Boulder County Open Space land.

City of Boulder- one of our field sites is on City of Boulder land.

Dr. Iggy Litaor, Tel-Hai Academic College, Israel, in 2008 re-sampled soil pit sites he originally sampled in the 1980s in Green Lakes Valley with CZO and Niwot LTER personnel.

Prof. Dennis Harry, Colorado State University, associate of HMF-Geophysics, collaborated with our geophysics team in 2008.

Dr. Andy Manning, USGS, is working with us on mountain hydrology and coring rock.

William J. (Bill) Stephenson at the USGS in Golden has provided us with advice and loaned us equipment for the shallow seismic work

IRIS Pascal has provided seismic equipment for the passive source tree seismology project as well as the active seismic work (reflection and refraction, surface waves). They are also providing some analysis software.

NEON is moving forward on establishing a test bed site at Gordon Gulch, one of our focus catchments.

Dr. William Manley, INSTAAR GIS laboratory, is working with us to develop a database of historical orthorectified high resolution imagery of our focus subcatchments.

Dr Christy McCain, CU Natural History Museum and Dept. of Ecology & Evolutionary Biology, PI of NSF grant 'Diversity and Climate Change: using elevational gradients to uncover processes underlying mammalian species distributions' will use some of our field sites.

**Activities and Findings**

**Research and Education Activities: (See PDF version submitted by PI at the end of the report)**

**Findings: (See PDF version submitted by PI at the end of the report)**

**Training and Development:**

Year 3: 1 Sept 2009-31 August 2010

Graduate students

Graduate students recruited in year 1 (2008)

Kevin Befus defended his Geological Sciences M.S. thesis titled "Applied geophysical characterization of the shallow subsurface: Towards quantifying recent landscape evolution and current processes in the Boulder Creek watershed, CO" in May 2010. He is starting a PhD program at Rutgers in Fall 2010.

Rachel Gabor passed her preliminary exam in the PhD program in Environmental Studies in Feb 2010. She is attending the 2010 Hydrologic Synthesis Summer Institute, run by the Hydrologic Synthesis Institute at the University of Illinois and hosted at the University of British Columbia. It is a 7 week intensive institute to explore the open questions in freshwater science and develop a conceptual framework for how to use an interdisciplinary approach to the problem. The three themes of this summer's institute are solute transport and nutrient dynamics, links between sediment transport and nutrient cycling, and harmful algal blooms.

Katie Eilers passed her 3rd semester exam in the PhD program in Ecology & Evolutionary Biology in Feb 2010. In summer 2010, she will be attending the 2010 International Geobiology Course through the University of Southern California during June and July to learn geobiology methods.

Rory Cowie is working to complete his M.A. thesis in Geography in summer 2010, and has been accepted into the PhD program in the department. He won two presentation awards in 2010: the J. E. Church Award for best student paper at the Western Snow Conference, and the Dr. Robert Farvolden Scholarship for best student presentation at the National Ground Water Associations Ground Water Summit.

Graduate students recruited in year 2 (2009)

Jeana Lee, Geography M.A. student, is working on water and weathering in Gordon Gulch and Betasso.

Abby Langston, Geological Sciences Ph.D. student, has extended our snow depth and soil moisture sensors into Betasso, is coordinating our LiDAR ground truth data collection, and is working on a weathering model.

Associated graduate students (largely supported elsewhere)

Leigh Cooper, Ecology & Evolutionary Biology PhD student is in year 3 of her aquatic ecology survey of Front Range streams impacted by pine beetle infestation.

James Cullis, Civil, Environmental and Architectural Engineering PhD candidate is working on hydrologic control of nuisance diatom *Didymosphenia geminata* in Boulder Creek and elsewhere. (See report published in Colorado Water).

Caitlin Crouch, Environmental Studies student, is working for Rachel Gabor in the lab in summer 2010.

Jordan Parman, Geography MA student, is working on nitrogen and organic matter across an elevation gradient from lower montane to subalpine catchments. He is funded through the Geography Dept. and the Niwot LTER, but his work uses Boulder Creek CZO sites and infrastructure.

Post-docs:

Becca Barnes is an NSF Earth Sciences post-doctoral Fellow. She regularly attended weekly CZO meetings, and participated in outreach activities with the Science Discovery program. In this setting, she helped current graduate students develop classroom and field activities for 5th grade students.

Eve-Lyn Hinckley is an NSF Earth Sciences post-doctoral Fellow. She regularly attended weekly CZO meetings, and participated in outreach activities with the Science Discovery program. She ran a 1-week summer camp for 10-14 year old kids, with assistance from graduate student Rachel Gabor, and input from Sheila Murphy (USGS).

Miriam Duhnforth is a post-doctoral researcher, working closely with Bob Anderson. She has received partial support from CZO (a few months total), yet nonetheless came to a number of CZO meetings.

Keck Undergraduate researchers

Four undergraduate researchers in the Keck Geology Consortium program run by David Dethier completed senior theses in 2010, based on their 2009 summer field work. These are described in the "Activities" section of this report.

In summer 2010, this program will expand. Six Keck Geology Consortium undergraduate students will join 3 students from Williams College,

one from Colby and one from Amherst. The group of 11 students will be supervised by Dethier, Will Ouimet (Amherst College), and Robert Nelson (Colby College), assisted by Matthias Leopold (Tech. Univ Munich). The students learn about the Front Range and the Boulder CZO and conduct field work in July and August 2010. Each of these students will produce a senior thesis or extended independent project over the course of the 2010-11 academic year based on their summer field research and laboratory studies at their home institutions. The students selected for this year's program come from eight institutions, and will involve six additional faculty members, shown below:

Name First name School Support Advisor

Corson-Rikert Hayley Wesleyan Keck/NSF Tim Ku  
 Dethier Evan Williams NSF David Dethier  
 Kantack Keith Williams NSF David Dethier  
 Lyerly Reece Fuhrman Keck/NSF Brannon Andersen  
 Maley Ellen Smith Keck/NSF Amy Rhodes  
 McCarthy James Williams NSF David Dethier  
 Shircliff Corey Beloit Keck/NSF Carl Mendelson  
 Warrell Kathleen Georgia Tech Keck/NSF Josef Dufek  
 Wyshnytzky Cianna Amherst Keck/NSF Will Ouimet  
 Camp Erin Amherst Amherst Anna Martini  
 Yzeiraaj Dhokela Colby Colby Robert Nelson

University of Colorado undergraduates

Four undergraduates completed senior theses on CZO research in 2010:

Nathan Rock, completed B.A. cum laude in Geography and honors thesis on snow in Gordon Gulch, supervised by Suzanne Anderson

Nina Russell, completed B.A. magna cum laude in Environmental Studies and honors thesis on dissolved organic matter in Boulder Creek and Gordon Gulch, supervised by Diane McKnight

John Crawford, completed B.A. summa cum laude in Environmental Studies and honors thesis on dissolved organic matter and denitrification, supervised by Becca Barnes

Garret Cropsey, completed B.A. in Ecology & Evolutionary Biology and honors thesis on lichens on rock outcrops at Gordon Gulch and their potential role in mineral weathering, supervised by Noah Fierer

The following undergraduate students are working as field or lab assistants in summer 2010:

Jeffrey Tarshall (working for Suzanne Anderson)  
 Jacob Coate (working for Suzanne Anderson)  
 Hana Fancher (working for Eve Hinckley)  
 Alexandra Czastkiewicz (working for Eve Hinckley)  
 Sean O'Grady (working for Abby Langston)  
 Shane Grigsby (working for Abby Langston)  
 Cayla Jasmine Kemper (working for Rachel Gabor)  
 Jordan Bradley Elg (working for Rachel Gabor)  
 Robert Hunter Lee (working for Rachel Gabor)

### **Outreach Activities:**

We developed a new national CZO flier for the AGU meeting. An initial run of 500 copies has been exhausted, and a second printing of 1500 copies was ordered in June 2010.

Kevin Befus gave 2 class lectures on his CZO geophysics research at Wheaton College and also taught five middle school science classes using a similar presentation (Harvest Bible Christian Academy, Elgin, IL [where his father teaches these classes]).

Bob and Suzanne Anderson ran a field trip to Betasso for a group of 35 fourth and fifth grade students to study soils, trees, and outcrops. The field trip was part of the students study unit on erosion.

Science Discovery:

CZO grad students and post-doc Becca Barnes teamed with CU's Science Discovery program's Outdoor Classroom for fifth grade students from disadvantaged schools. The team brought classroom activities to three classes at Spangler Elementary in Longmont Colorado on two

occasions (a total of 6 hours in the classroom- 3 classes x 1 hour x 2 visits). The team then led each class on an overnight field trip that encompassed a visit to University of Colorado classrooms, labs, and museum, followed by a trip to the Mountain Research Station and field sites around the station. Students learned about water, streams, soils, stream ecology, bark beetles, and snow. The project reached three classrooms of ~25 students each. Graduate students who worked with the program were: Katie Eilers, Rachel Gabor, Leigh Cooper, Rory Cowie, Kevin Befus, and Jeana Lee.

Post-doc Eve-Lyn Hinckley developed a one-week summer day camp for 10-14 year old kids in the Science Discovery summer program. She was assisted by grad student Rachel Gabor and a counselor who works for Science Discovery. Sheila Murphy helped with curriculum development. The course was titled "Go with the flow", and was offered free to local residents, with about half the 12 spots reserved for kids sponsored by the "I have a dream" Foundation in Denver. The course will be offered a second time in the summer, led by a Science Discovery teacher, thus reaching about 24 kids.

Description: Ever wonder what path water takes from the headwaters of Boulder Creek through the City of Boulder and beyond? How soils, plants, animals, and people change the chemistry of water? Or how scientists study water in the landscape and laboratory? If so, this class is for you! We will spend a week tracking water through our watershed and community, exploring how it changes along the way, and learning some of the tools and techniques that scientists use to quantify water flow, measure chemical and biological processes, and understand challenges to sustaining this important natural resource. This class is a collaboration between the Institute of Arctic and Alpine Research and Science Discovery. It supported by the National Science Foundation.

### Journal Publications

Anderson, S.P., Blum, A.E., Dethier, D.P., Murphy, S.F., Williams, M.W., McKnight, D., Fierer, N., Tucker, G., Wobus, C., Anderson, R.S., Caine, N., Loague, K., Leopold, M., Voelkel, J., and Sheehan, A., "Developing Methods to Test the Influence of Critical Zone Development on Watershed Hydrology and Biogeochemistry", *Eos Trans. AGU, Fall Meeting Supplement*, p. Abstract, vol. 88, (2007). Published,

Riggins, SG, Anderson, SP, and Blum, AE, "Transformations across the bedrock/saprolite-regolith boundary", *Geochim. Cosmochim. Acta Suppl.*, p. A798, vol. 72, (2008). Published,

Anderson, SP, Anderson, RS, and Riggins, SG, "Fractures and the weathering front", *Geochim. Cosmochim. Acta Suppl.*, p. A25, vol. 72, (2008). Published,

Anderson, S.P., Bales, R.C., and Duffy, C.J., "Building a network to advance interdisciplinary study of Earth surface processes", *Mineralogical Magazine*, p. 7, vol. 72, (2008). Published, 10.1180/minmag.2008.072.1.7

Ward, D. J., Anderson, R. S., Guido, Z.S and Briner, J. P., "Numerical modeling of cosmogenic deglaciation records, Front Range and San Juan mountains, Colorado", *Journal of Geophysical Research- Earth Surface*, p. , vol. 114, (2009). Published, 10.1029/2008JF001057

Wobus, C., G. E. Tucker and R. S. Anderson, "Cenozoic incision of the North American High Plains: Topographic re-analysis and the possible role of climate change", *Geological Society of America Abstracts with Program*, p. , vol. , (2008). Submitted,

Dethier, David P., and Bove, Dana J, "Slow weathering of granitic rocks and the low-relief landscape of the Boulder Creek catchment, Colorado", *Geological Society of America Abstracts with Programs*, p. 108, vol. 39, (2007). Published,

Leopold, Matthias, Dethier, David, Voelkel, Joerg and Raab, Thomas, "Combining sediment analysis and seismic refraction to describe the structure, thickness and distribution of periglacial slope deposits at Niwot Ridge, Rocky Mountains Front Range, Colorado, USA", *Annals of Geomorphology*, p. 77, vol. 52, Sup, (2008). Published, 10.1127/0372-8854/2008/0052S2-0077

Leopold, Matthias, Dethier, David, Voelkel, Joerg, Raab, Thomas, Corson-Rickert, Tyler and Caine, Nel, "Using geophysical methods to study the shallow subsurface of a sensitive alpine environment, Niwot Ridge, Colorado Front Range, USA", *Arctic, Antarctic, and Alpine Research*, p. 519, vol. 40, (2008). Published, 10.1657/1523-0430(06-124)[LEOPOLD]2.0.CO;2

R.T. Jones, M.S. Robeson, N. Fierer, "Moving beyond 'species' richness: phylogenetic comparisons of fungal and bacterial communities in soil", *ISME Journal*, p. , vol. , (2008). Submitted,

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### **Books or Other One-time Publications**

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Bibliography: M.A. Thesis, University of Colorado at Boulder
- Nielson, Ashley, "The hydrology and hydrochemistry of an alpine wetland, Green Lakes Valley, Colorado", (2008). Thesis, Published  
Bibliography: M.A. Thesis, University of Colorado at Boulder
- Miller, Matthew, "Interactions between hydrology, dissolved organic matter, and algal populations in the headwaters of Boulder Creek", (2008). Thesis, Published  
Bibliography: Ph.D. dissertation, University of Colorado at Boulder.



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Bibliography: MA thesis in Environmental Science, University of Colorado.
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- DM McKnight, MP Miller, SC Chapra, and MW Williams, "A model of degradation and production of three pools of dissolved organic matter in an alpine lake", (2009). Abstract, Published  
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- M. Williams, K Hill, N Caine, and J Janke, "Climate impacts on the hydrology of high elevation catchments, Colorado Front Range", (2009). abstract, Published  
Bibliography: Geophysical Research Abstracts, Vol. 11, EGU2009-6387
- M. Williams and D. McKnight, "Scientific Outreach for K-6 Students: The LTER Schoolyard Children's Book Series", (2009). Abstract, Published  
Bibliography: Geophysical Research Abstracts, Vol. 11, EGU2009-14047
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Bibliography: Senior thesis, Williams College
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Bibliography: Eos Trans. AGU 90 (52), Fall Meeting Suppl., Abstract EP51E-06.

Williams MW, "Hydrochemical responses to climate change in high-elevation catchments of the Colorado Front Range", (2009). abstract, Published  
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### Web/Internet Site

#### **URL(s):**

<http://czo.colorado.edu/>

[http://czo.colorado.edu/html/ge\\_bcczo\\_map.shtml](http://czo.colorado.edu/html/ge_bcczo_map.shtml)

<http://www.criticalzone.org/>

#### **Description:**

The second url is currently only available to members of Boulder Creek CZO. It offers a 3-D Google API with toggle-able layers showing different aspects of the Boulder CZO landscape including topography and the locations of some sensors and ongoing research stations. We probably will release this to the public, with sensor locations remaining obscured.

The third url is the National CZO website, currently being developed by David Lubinski at Boulder.

### Other Specific Products

### Contributions

#### **Contributions within Discipline:**

The Boulder Creek Critical Zone Observatory takes an interdisciplinary approach to understanding the structure and function of the region at the Earth's surface (known as the critical zone) where air, water, rock, and life interact. Our observatory spans three distinctive erosion regimes in which the rate and history of removal of material from the 'reactor' of the critical zone varies. We posit that these differences in erosion will be manifested in differences in the depth and development of the weathered rock profile. Simply posing the conceptual model of weathered profile development in terms of interplay between erosion and weathering front advance constitutes an advance of the science. The project has brought together team scientists from geomorphology, geophysics, biology, geography, and engineering to think in a unified way about the critical zone.

### **Contributions to Other Disciplines:**

Wrote letters of support for the following proposals:

Dr. Martyn Clark, NCAR, 'Process-based evaluation of climate change impacts on sublimation and transpiration in the transient snow zone' submitted to the NSF Hydrological Sciences program, May 2010

Dr. Holly Barnard, University of Colorado, proposal 'Carbon-water cycling in the critical zone: understanding ecosystem process variability across complex terrain' to the DOE program in Terrestrial Carbon Cycle Research, April 2010.

Dr. Ty Ferr?, University of Arizona, 'MRI: Development of Next Generation Distributed Electrical Resistivity Technology with Real Multi-Tier Adaptive Capacity' to the NSF Major Research Instrumentation Development program, April, 2010.

Dr. Christina Tague, University of California, Santa Barbara, 'Climate change impacts on the fate of precipitation: A strategy for cross-site modeling and synthesis using the Critical Zone Observatories' to the NSF Water, Sustainability, and Climate program, April 2010.

Dr. Sergio Morales, University of Montana, 'Testing the Core-Satellite Species Hypothesis in Bacterial Communities: Identifying microbial community structure and functional roles across ecosystems?', to NSF, July 2009.

Dr. Noah Molotch, University of Colorado, CAREER proposal entitled: 'Ecohydrological Feedbacks of Snow-Dominated Sub-Alpine Forests', July 2009.

### **Contributions to Human Resource Development:**

We are providing the research context for a group of undergraduate students in the Keck Geology Consortium each summer and from University of Colorado. A total of 10 undergraduates from across the country have learned about the critical zone and completed senior research projects rooted in the Boulder Creek CZO thus far.

PI Suzanne Anderson teaches about the critical zone in her large, freshman level physical geography class titled Landscapes and Water. The majority of these students are non-science majors for whom this course may be their sole training in college level science.

The critical zone is discussed in a new textbook, authored by R.S. Anderson and S.P. Anderson (Geomorphology: The Mechanics and Chemistry of Landscapes, Cambridge Univ. Press, 2010).

Lab assistant Daniel Eldridge worked for the CZO for a year after completing a BA in Geological Sciences at CU. He is now heading to graduate school at UMB to study sulfur isotope systems. His experience working in the field and lab for us, and interacting with our students and post-doc have expanded his understanding of science.

Undergraduate Nathan Rock worked for the CZO as a work-study student for over a year. In that time, he completed a senior thesis. He now is working for the CZO full-time as a field and lab assistant.

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

We are augmenting the meteorological instrumentation of the Niwot LTER Green Lakes Valley site, and adding soil instrumentation (moisture, temperature, hydraulic head, and soil water samplers) to this heavily studied valley.

We are developing two entirely new watershed field sites in Gordon Gulch and Betasso. This entails first developing an understanding with the landowners (USFS, County and City of Boulder). Each watershed is being instrumented with stream gauges, soil instrumentation, and meteorological instrumentation.

PI Anderson is expanding her water analysis lab to handle the regular field sampling and parts of the analyses for CZO samples. The lab now occupies more space at INSTAAR, and is being reorganized to act as a hub of field activity for the project. The lab is run by the CZO field and

lab technician, Zan Frederick.

We are in the process of establishing a data management system for the CZO community. Mark Williams hosted two workshops on data management:

Critical Zone Observatory workshop on developing an integrated data management system, 26-27 February, Boulder CO.

National workshop on developing an integrated data management system for the Critical Zone Observatories program, Boulder CO, May 19-20.

### **Contributions Beyond Science and Engineering:**

#### **Conference Proceedings**

#### **Special Requirements**

#### **Special reporting requirements:**

Data Access and Standardization:

We are in the process of searching for a data manager for the Boulder Creek CZO. Our data collection systems are just becoming established in summer of 2008. For the present, our data is stored and available through the Niwot Ridge LTER.

Discussions have been ongoing with the Sierran CZO and the Susquehanna CZO about how they will establish their data management systems. Significant progress will come when we all have data managers on-board.

Annual Meetings:

The first annual CZO science meeting will be held in September 2008 at the Sierran CZO. We have requested supplemental funding that includes support for non-hosting CZO members to attend this meeting.

Steering Committee (SC):

A national Steering Committee has been established. Five distinguished scientists have accepted membership on the committee, and the first meeting of the group will take place at the first annual CZO science meeting in September 2008.

**Change in Objectives or Scope:** None

**Animal, Human Subjects, Biohazards:** None

#### **Categories for which nothing is reported:**

Any Product

Contributions: To Any Beyond Science and Engineering

Any Conference

## **Project Activities**

### *Boulder Creek Critical Zone Observatory*

#### *Goals and objectives*

The Boulder Creek CZO is designed to study how weathering and erosion processes together form the critical zone and affect its structure. Three focus field sites are situated in crystalline bedrock regions within the Boulder Creek watershed, each representing different erosional rates and histories. The CZO will undertake activities to understand the differences across these sites in CZ architecture, erosion rates, and in hydrologic-geochemical-ecological function. This understanding will be built into models of landscape evolution, hydrology and geochemical processes. We also seek to build cross-disciplinary bridges in Critical Zone study, and to engage a broad community participation in working and thinking about the CZ in this way.

Major **research and education activities** (experiments, observations, simulations, presentations, etc.)

Geomorphology: In 2009, R.S. Anderson and post-doc M. Duhnforth obtained the results from the cosmogenic  $^{10}\text{Be}$  measurements of glacial polish and moraine boulder samples from Green Lakes Valley. The five dated boulders give ages ranging between 18.3 and 23.7 ka. These ages are clearly older than the eight glacial polish samples showing ages between 12.0 and 16.1 ka; five of these samples cluster around 14 ka suggesting that the glacier retreat likely occurred very rapidly.

R.S. Anderson and M. Duhnforth also worked on deciphering the incision history of Boulder Creek by determining ages of abandoned pediment surfaces lining Boulder Creek on the High Plains. They received the results from meteoric and in situ-produced  $^{10}\text{Be}$  samples that they took in early summer 2009 in a soil pit on Table Mountain north of Boulder. Both dating approaches, meteoric and in situ, reveal ages between 130 and 150 ka that coincide with the last stage of the penultimate glaciation (regional Bull Lake glaciation) and predate the onset of interglacial climate conditions during marine isotope stage 5e. The measured ages are one order of magnitude younger than expected, as the Table Mountain site is mapped as a Rocky Flats pediment surface with an age of >1.5 Ma.

In spring 2010 R.S. Anderson and M. Duhnforth sampled a vertical wall exposure on a Verdos (expected age ~640 ka) pediment surface south of Boulder to measure meteoric  $^{10}\text{Be}$ . The profile was previously dated using in situ-produced  $^{10}\text{Be}$  by R.S. Anderson, which showed an age of ~140 ka, significantly younger than the mapped Verdos age. Preliminary results from the meteoric  $^{10}\text{Be}$  dating confirm the younger age of 140 ka. Four more samples from the profile are currently being processed at the CU Boulder cosmogenic isotope laboratory.

The cosmogenic ages place an absolute constraint on the incision history of the high plains adjacent to the mountain front of the Boulder Creek watershed. These new results suggest that the exhumation of the Denver Basin around Boulder occurred at highly non-steady rates. These results contradict the hypothesis that the incision of this area was slow and steady since the latest Pliocene.

Greg Tucker and graduate student Abby Langston continued to develop a simple weathering model to incorporate into 2-d landscape evolution models. The model predicts production of regolith based on depth below the surface, distance from fractures, and degree of attachment of a model cell to its neighbors. Tucker has produced some fascinating movies of soil depth and outcrop evolution based on this model for differing erosion rate and fracture density scenarios, which provide insight into how differing landscapes may develop over time. Langston plans to develop these preliminary models further for her dissertation, incorporating aspects of reality such as realistic, observation-based moisture delivery patterns, and the effect of hydrothermal alteration on landscape development. Tucker and Langston have initiated some new soil moisture and snow depth sensors in the Betasso catchment as part of this effort.

PhD student Susan Riggins finished her dissertation on regolith production. Although her field work was based in Wyoming and Cornwall (U.K.), she has received some CZO support for her activities studying the general problem of regolith production. With R.S. Anderson and S.P. Anderson she developed a model of steady state landscape evolution (steady lowering rate, parabolic hillslopes) being possible even with regolith production occurring by cleaving of variably sized blocks from bedrock. The model is applicable to settings like the Front Range, the Sierras, and Luquillo forest.

Preparation underway of a manuscript with a working title of “Co-evolution of a Laramide Range - basin pair: The large scale landscape setting of the Boulder Creek critical zone observatory”

Hydrology: Mark Williams, grad student Rory Cowie, and undergrad student Nate Rock, have worked on snow cover variability and composition, especially in Gordon Gulch catchment, but also in sites up to Niwot Ridge, and down to Betasso. Cowie continued to maintain snow poles over the winter, but added a number of snow depth sensors with assistance from Noah Molotch. Snow poles were visited and snow pits dug weekly over the winter. In addition, Cowie installed snowmelt lysimeters and snow samplers. Cowie has measured stable isotopes from sites from Niwot Ridge to Betasso (a large elevation gradient), in both open and under canopy sites, weekly over the past year. The data on isotopic composition of water inputs to the CZ (snow and snowmelt) are being used to assess water residence times across sites with differing total annual precipitation, fraction of precipitation as snow, and vegetation, and to look at groundwater-surface water interactions. Cowie should complete his Master's thesis in summer or fall of 2010, and will continue at CU to work on a PhD.

NSF post-doc Eve-Lyn Hinckley is conducting experiments in Gordon Gulch with the goal of understanding hillslope water flow paths and nitrogen processing in soils. She has instrumented 10 plots in Gordon Gulch in a transect from N-facing slopes to valley floor to S-facing slopes. Each plot contains soil moisture sensors, temperature sensors, snow depth sensors, and soil lysimeters (tension and zero-tension). She conducted a snowmelt experiment in which N15 tracer was applied to the soil underneath the snow pack as it began to melt, followed up with daily water samples for the next month. A rain

experiment is planned for July 2010, in which tracer will be applied and plots will be irrigated with artificial rain.

Biogeochemistry: Experiments are underway to examine nitrogen processing on hillslopes and in streams, and connections between nitrogen and dissolved organic matter. NSF Earth Sciences post-doc Becca Barnes continued experiments examining linkages between nitrogen and carbon cycling within stream environments. After completing the denitrification experiments (results to be submitted to ES&T in the next month), Barnes worked on watershed scale models in an effort to compare the laboratory results with what is observed in the field (from a mass balance perspective, see presentation for ASLO/NABS meeting). In addition Barnes has been working with Mark Williams and Jordan Parman to examine both the historical and spatial patterns of nutrient and weathering product fluxes within the Boulder Creek watershed. Barnes has assisted Parman with his Master's thesis work and they currently working up a historical dataset for Niwot LTER sites. This summer Barnes has started a new set of experiments in conjunction with daily (during snow melt) to weekly (currently) sampling of Gordon Gulch. This set of experiments is investigating the linkages between the photo-oxidation products of organic matter and in-stream nitrogen processing (i.e. nitrification and mineralization).

NSF Earth Sciences post-doc Eve-Lyn Hinckley is conducting experiments to understand nitrogen dynamics on hillslopes. She applied N15 tracer to plots in Gordon Gulch, and is examining nitrogen species in soil, foliar tissues and soil water. She will take some samples to ETH in September to analyze in the labs of Stefano Bernasconi.

Diane McKnight and grad student Rachel Gabor are studying the annual cycling of dissolved organic matter in Boulder Creek. In 2009-2010 they also began looking at the soluble organic matter in the soil at Gordon Gulch to see if fluorescence could be used to understand chemically the role the organic matter is playing in weathering processes and how the organic matter travels to the stream. It appears that microbes may use organic matter as an electronic acceptor in areas near bedrock, the same way they have been shown to do so in anoxic areas of streams. Additionally, the surface appears to be contributing a greater amount of organic matter to the stream than areas closer to bedrock, corresponding with hydrologic findings of the water mostly flowing overland and as shallow interflow toward the creek.

In summer 2010 Gabor is attending the 2010 Hydrologic Synthesis Summer Institute, run by the Hydrologic Synthesis Institute at the University of Illinois and hosted at the University of British Columbia. It is a 7-week intensive institute to explore the open questions in freshwater science and develop a conceptual framework for how to use an interdisciplinary approach to the problem. The three themes of this summer's institute are solute transport and nutrient dynamics, links between sediment transport and nutrient cycling, and harmful algal blooms.

*Didymosphenia geminata*: Diane McKnight and grad student James Cullis continue to monitor growth of nuisance diatom *D. geminata* in Boulder Creek. Cullis will conduct



laboratory experiments to determine the shear resistance of *D. geminata* as part of his dissertation work on hydraulic controls on the spread of the diatom. Grad student Aimee McLaughlin completed her Environmental Studies Master's thesis on the impact of *D. geminata* on stream macroinvertebrates. Cullis is attending Hydrologic Synthesis Summer Institute at UBC in Vancouver to investigate the role of hydrology in the control of nuisance algal species such as *D. geminata* in the streams.

Microbial Ecology: Noah Fierer and graduate student Katie Eilers' work has focused on the microbial ecology of the CZO sites - the spatial distributions of microorganisms and the role of these organisms in biogeochemical processes. In summer of 2009 they completed a comprehensive sampling of soils at Gordon Gulch, sampling surface soils across a wide range of landscape positions (200 soils collected). The results show that the spatial distribution of soil microbial communities across this watershed is predictable based on basic landscape properties with slope aspect, slope angle, and vegetation type explaining a large portion of the variability in community composition. They also analyzed microbial communities in 9 soil profiles from Gordon Gulch and found that the deeper soils harbor unique bacterial communities that have novel metabolic capabilities, results which suggest that these understudied communities may have important influences on subsurface biogeochemistry. Other CZO-related projects include: a study of the bacterial symbionts that live within lichens found on rock outcrops and their potential to fix atmospheric N<sub>2</sub> and generate acidity (possibly to promote rock weathering) and a study of microbial carbon cycling under different vegetation types within the Gordon Gulch watershed. They are currently preparing the results from these studies for publication and continuing with ongoing experiments to examine more specifically how soil microorganisms may influence mineral weathering rates.

In fall 2009 and into spring 2010 we finished collecting data on soil properties (C, N, texture, and ammonium/nitrate) for the pit and transect studies. Microbial communities were pyrosequenced in the spring with barcoded primers (with assistance of Donna Berg-Lyons, a lab technician) and processed using QIIME. With the assistance of Paul Boni (geology), we prepared thin-section slides and mineral chips for the microbial mineral weathering experiment that was set up in December. Microcosms were monitored for CO<sub>2</sub> production through July. DNA extraction methods are currently being developed and DNA will be extracted from the mineral chips in July. SEM-EDS will be conducted on the slides beginning in August.

Geophysics: In summer 2009 M. Leopold and J. Voelkel finished the geophysical survey of the Betasso research site. Their electric resistivity results have been fully integrated into the 2010 master thesis of CU graduate student Kevin Befus, who compared electric resistivity with seismic refraction data and provided first pseudo 3D-models of the critical zone in Gordon Gulch and Betasso. There were intense collaborations in summer 2009 between the geophysics teams. Starting in summer 2010, they now concentrate on the upper alpine areas of Green Lakes Valley, where they try to get more information on permafrost distribution and its possible degradation due to temperature variations. As part of this, Leopold had a winter field campaign in December 2009 to geophysically image the refreezing of the active layer, working in some of the coldest weather of a cold

winter. In summer 2010 Leopold and Voelkel will have another field campaign to continue data acquisition in the high alpine.

Kevin Befus processed and analyzed seismic refraction data collected during summer 2009. This included manually picking over 50,000 P wave arrival times and inverting over 200 velocity profiles within the CZO catchments. These results were used in writing his M.S. thesis. Befus also created a graphical user interface in MATLAB for viewing seismic refraction results. Through the summer of 2010 Befus will prepare a publication for the journal *Vadose Zone*. He will also assist in drilling cores and obtaining other ground truthing data within the three catchments and link those to the geophysical results.

Weathering and geochemistry: S.P. Anderson, Alex Blum, and David Dethier have analyzed soil and rock samples from a series of 9 pits dug in Gordon Gulch in summer 2009, and from scattered locations in Betasso. To date, the most interesting observation is that the weathered profile in Gordon Gulch shows differences depending on slope aspect. North-facing slopes are more weathered, as assessed by depth that saprolite can be excavated with shovels and other hand implements, and mobile regolith or soil is deeper on these slopes. These soil pit observations are consistent with slower seismic velocities observed with shallow seismic refraction (Sheehan and Befus) on N-facing slopes, although the geophysics view is to a depth of about 20 m, while soil pits were all less than 2 m deep. The qualitative assessment of greater weathering on N-facing slopes was not apparent in mineralogy of the soil and saprolite samples. Heterogeneity in the gneissic bedrock was as great as or greater than differences from one pit to another. Mobile regolith samples were much more homogeneous than saprolite samples, probably reflecting mixing during transport.

S.P. Anderson and R.S. Anderson have begun simple weathering and sediment transport model development to explore hypotheses that the difference between N and S-facing slopes is due to rate of rock weathering (by both physical and mechanical processes) or due to differences in sediment transport on the two slopes. Preliminary results suggest that rock weathering rates have greater impact on soil thickness and degree of rock weathering than do differences in erosion (sediment transport) rates.

S.P. Anderson and grad student Jeana Lee are analyzing stream chemistry and the chemistry of springs in Gordon Gulch to relate these signals to the style and rate of weathering taking place in the soil and rock profiles.

Undergraduate researchers supervised by David Dethier, Williams College

Four students spent a month from July-August 2009 at the Boulder Creek CZO under the tutelage of Dr. David Dethier. Three were supported by the Keck Geology Consortium, and one supported by this project. All completed senior theses during the 2009-2010 school year. They gave presentations in Colorado at the Boulder Creek CZO annual meeting in August 2009, and the Keck students also attended the Keck Research Symposium in spring 2010 to present their findings.

**Elizabeth Dengler: Fracture Distribution and Characterization in Betasso Gulch, CO. (Keck Geology Consortium)**

Liz Dengler measured fracture orientation and mapped bedrock geology at 284 sites in the Betasso catchment and nearby Bumpers Rock, which are underlain by rocks of the Boulder Creek batholith (Gable, 1980). Granodiorite and quartz monzonite are cut by two predominant

conjugate fracture sets (N-NW; E-NE) that likely record Laramide reactivation of Precambrian structures. Field evidence suggests that faults and zones of hydrothermal alteration are present parallel to the fractures. Most fractures dip steeply to the east or northeast at a spacing that has a mean value between 0.5 and 1.0 m (n= 143); local spacing ranges from less than 10 cm to ~7 m. Bedrock appears to be more densely fractured near major faults and fracture spacing is wider in local areas near Bummars Rock, perhaps accounting for its persistence in an erosional landscape.

**Evan Riddle: Talus Structure and Evolution: A Comparison between Talus near Green Lake 3 and at Bummer's Rock, Colorado (Keck Geology Consortium)**

Evan Riddle studied the morphology and accumulation rate of talus north of Green Lake 3, an alpine zone that was deglaciated at about 12 ka, and below Bummars Rock, in the low-elevation Betasso catchment. Working with Matthias Leopold, Evan used GPR to estimate the thickness and volume of the alpine talus. Talus blocks at that site are subangular and relatively unweathered and their size distribution mirrors fracture spacing in their source area. Preliminary estimates suggest that talus accumulation rates integrated over the past 12,000 yrs are equivalent to < 0.1 mm of cliff retreat per year, consistent with values reported by Caine (1986) from the upper Green Lakes Basin. Talus below Bummars Rock consists of more rounded, partially weathered blocks that only partially cover the slope below their source area. Release of talus blocks apparently requires weathering and rounding of blocks bounded by joint surfaces, followed by eventual sliding or toppling. When surface exposure ages at Bummars Rock become available, local rates of cliff retreat can be calculated.

**J. R. Trotta: The distribution of tors in Gordon Gulch, Front Range, Colorado, (Keck Geology Consortium)**

JT Trotta mapped the distribution of isolated bedrock outcrops (tors) in Gordon Gulch, which is developed on a rolling surface of low relief developed on what has been mapped as thick saprolite and well-developed soils (Birkeland *et al.*, 2003). Work by Keck students and investigators from the University of Colorado, however, suggests that the weathered zone may be thin in many areas and the soils young. Bedrock exposures form the surface in ~ 4.5% of the 2.7 km<sup>2</sup> catchment and tors locally stand as high as 15 m above surrounding slopes. Tors are unevenly distributed and are more common on steep, south-facing slopes than in adjacent areas with northern aspects. Slow-weathering bedrock, which consists of sillimanite and garnet-bearing gneisses and granitic rocks, does not appear to control directly the size, shape or location of tors. However, foliation, which strikes NW and dips NE, is mainly slope-parallel on north-facing slopes, where there are fewer bedrock exposures. Tors are thought to be remnant features typical of deeply weathered landscapes (Street, 1971). The association of tors with steep areas in Gordon Gulch suggests that these features may record geologically recent erosion that stripped regolith and saprolite.

**Rebecca Gilbert: Regolith stirring by biological processes, Gordon Gulch, Colorado, (NSF)**

Rebecca Gilbert surveyed soil stirring by biologic processes in Gordon Gulch, focusing on treethrow and on sediment moved by ants and by prospectors looking for gold, silver and tungsten. To help calibrate root and pit measurements made at some 150 uprooted trees, Gilbert and Keck students pulled apart 15 recent rootballs and weighed the rocks and soil that had been disrupted by the treefalls. Gilbert's results show that over a period of a century prospectors disrupted the greatest area and volume. Treethrow lifts and mixes an average of ~ 2 m<sup>3</sup> km<sup>-2</sup> of

regolith from depths of 20 to 50 cm each year. Ants (*Formica* sp.) may be the most effective mixers of shallow regolith in Gordon Gulch, but additional work is needed to quantify how frequently anthills are constructed. In areas like Gordon Gulch, the upper 50 cm of regolith creeps downslope under the influence of a suite of processes, but biological activity may be the most important.

Presentations- published abstract

- Anderson, R.S., Wobus, C., Berlin, M., Duhnforth, M., Tucker, G., and Anderson, S.P. (2009): History matters: The Large Scale Landscape Setting of the Boulder Creek Critical Zone Observatory. *Eos Trans. AGU* 90 (52), Fall Meeting Suppl., Abstract EP51E-01.
- Anderson, SP, Blum, A, Lee, J., Cowie, R., Williams, M., and Frederick, Z. (2009): Weathering, water, and slope aspect. *Eos Trans. AGU* 90 (52), Fall Meeting Suppl., Abstract EP53D-0639.
- Anderson, SP, Duhnforth, M., Anderson, R.S., Berlin, M., Dethier, D., Tucker, G., Wobus, C., Blum, A., Leopold, M., Williams, M., Befus, K., and Sheehan, A. (2009): Transient Events and Landscape Response in Boulder Creek, Colorado Front Range. *Eos Trans. AGU* 90 (52), Fall Meeting Suppl., Abstract EP44A-02 (*Invited*)
- Anderson, S.P., Blum, A.E., Hinckley, E.S., Lee, J., Gilbert, R., Trotta, J. and Dethier, D. (2010): Slope aspect and weathering in the Colorado Front Range, Goldschmidt Conference Abstracts (*Geochemica et Cosmochimica Acta Suppl.*).
- Andrus, A.B., Befus, K.M. and Sheehan, A.F. (2009): Surface and Shear Wave Analysis of the Critical Zone in Betasso Catchment, Colorado, *Eos Trans. AGU* 90 (52), Fall Meeting Suppl., Abstract EP53D-0646.
- Barnes, R.T. and Smith, R.L. (2009): Linking Carbon Quality to In-stream Nitrogen Processing, Boulder Creek, Colorado, *Eos Trans. AGU* 90 (52), Fall Meeting Suppl., Abstract B33E-06.
- Barnes, R.T., R.L. Smith, G.R. Aiken. 2010. Denitrification and DOM Reactivity: A Comparison Between Experimental and Modeling Results, *ASLO/NABS Aquatic Sciences Meeting*, Santa Fe, June.
- Befus, KM, Kelsay, T, Sheehan, AF, Leopold M. (2009): Shallow Geophysical Exploration of the Boulder Creek Critical Zone Observatory, *Eos Trans. AGU* 90 (52), Fall Meeting Suppl., Abstract EP53D-0645.
- Cowie, R. (2010) Estimated residence time of two snowmelt dominated catchments, Boulder Creek Watershed, Colorado, *Proceedings of the Western Snow Conference*, in press.

- Cowie, R. M., Williams, M.W., and Atkins, P.T. (2009): Use of isotopic and geochemical tracers to identify source waters, flow paths, and residence times of headwater catchments in Boulder Creek Watershed, Colorado, *Eos Trans. AGU* 90 (52), Fall Meeting Suppl., Abstract H33H-0978
- Cullis J and McKnight D (2010) “Determining a removal threshold for *Didymosphenia geminata*” Paper presented at the North American Benthological Society (NABS) conference in Sante Fe, USA. 6<sup>th</sup> - 10<sup>th</sup> June 2010
- Dengler, Elizabeth, 2010, Fracture distribution and characterization among rock types in Betasso Gulch, Colorado: Geological Society of America Abstracts with Programs, Vol. 42, No. 1, p. 87.
- Dethier, David P., and Blum, Alex E., 2009, Evolution of soils derived from weathering of saprolitic bedrock and colluvium, Betasso catchment, Front Range, Colorado: Geological Society of America Abstracts with Programs, Vol. 41, No. 7, p. 336.
- Dethier, David P. et al., 2010, Interdisciplinary studies in the critical zone, Boulder Creek catchment, Front Range, Colorado: in deWet, A. P. (ed.), 2010, Proceedings of the 23rd Annual Keck Research Symposium in Geology: Keck Geology Consortium, Lancaster, PA., ISSN#1528-7491, p. xxx to xx.
- Gabor, R., McLouglin, R., McKnight, D. (2009): Annual cycling of dissolved organic matter in an alpine stream. *Eos Trans. AGU* 90 (52), Fall Meeting Suppl., Abstract EP53C-0631.
- Huber, J. & J. Völkel (2009): Slope sediments as crucial part of the critical zone – examples from the Bavarian Forest (Germany) and the Colorado Front Range (U.S.A.). Book of Abstract – GeoTag Vienna, 2009.
- Leopold, M., Voelkel, J., Dethier, D., Williams, M. & Caine, N. (2010): Mountain Permafrost - a valid archive to study climate change? - Examples from the Rocky Mountains Front Range of Colorado, USA. Geophysical Research Abstracts, EGU2010-5036
- Leopold, M., Williams, M., Caine, N., Völkel, J. & Dethier, D. (2009): Interne Struktur und hydrologische Fließwege am Green-Lake-5-Blockgletscher, Colorado USA. Book of abstracts, annual meeting German Geomorphological Workgroup, Vienna
- Leopold, M., Völkel, J. & Dethier, D. (2009): Imaging the Critical Zone Using Ground Penetrating Radar and Electric Resistivity. Initial Results from the Boulder Creek Critical Zone Observatory. Geophysical Research Abstracts, Vol. 11, EGU2009-9450.
- Parman, J., and Williams, M.W. (2009): Are All Headwater Catchments the Same? Elevational Controls on Organic and Inorganic Nutrients in Headwater Catchments in the Boulder Creek Watershed, Colorado Front Range, *Eos Trans. AGU* 90 (52), Fall Meeting Suppl., Abstract B33A-0381.

Riggins, SG, Anderson, SP, and Anderson, RS (2009): Predicting Soil Production in Diverse Landscapes, *Eos Trans. AGU* 90 (52), Fall Meeting Suppl., Abstract EP51E-06.

Williams MW (2009): Hydrochemical responses to climate change in high-elevation catchments of the Colorado Front Range, *Eos Trans. AGU* 90 (52), Fall Meeting Suppl., Abstract B32A-07. *Invited*.

Presentations- no abstract

Suzanne Anderson “Weathering, erosion and the Critical Zone”, Oregon State University, Water Resources Graduate Program seminar series, May 5, 2010.

Suzanne Anderson pop-up on critical zone at Bretz Club (Oregon geomorphologists) meeting, H.J. Andrews Experimental Forest, May 7, 2010.

Suzanne Anderson, invited presentation on Boulder Creek CZO at an NSF-NERC workshop, Arlington, VA, March 1, 2010.

Suzanne Anderson, “Transient events and landscape response in Boulder Creek, Colorado Front Range”, University of Colorado Hydrologic Sciences Symposium, April 2, 2010

Barnes, R.T. and R.L. Smith. 2009. “Linking Carbon Quality to In-stream Nitrogen Processing, Boulder Creek, Colorado”, *LTERR All Scientist Meeting*, September.

Barnes, R.T. and R.L. Smith, 2009. “Linking Carbon Quality to In-stream Nitrogen Processing Across an Ecosystem Gradient”, *Gordon Research Conference: Catchment Science: Interactions of Hydrology, Biology & Geochemistry*, July (*invited*)

Caine, TN, 2010. Recent hydrologic change in a Colorado alpine basin: an indicator of permafrost thaw? Oral presentation at *Global change and mountain resources (GLOCHAMOR)* conference in Perth, Scotland, September, 2010.

Cowie, R., 2009. Poster at *LTERR All Scientists meeting*, Estes Park, CO (September 5, 2009).

Cowie, R., “Use of isotopic and geochemical tracers to identify source waters and residence times at different elevations in Boulder Creek watershed, Colorado”, INSTAAR grad student talk, February 18, 2010

Cowie, R., and Williams, M., “Water Resources in a Changing Climate—Hydrological Sciences Annual Student Research Symposium”, Invited talk at *CU Hydrological sciences symposium* (April 1,2 2010)

- Cowie, R., Oral presentation at *National Ground Water Association Ground Water Summit Conference* in Denver, CO on April 14, 2010
- Fierer, N. 2010. The biogeography of soil microorganisms. Univ. of California - Davis, Department of Plant Sciences. (invited speaker, special lecture for the Kearney Foundation of Soil Science).
- Fierer, N. 2010. The biogeography of microorganisms: exploring 'terra incognita'. Univ. of California - Riverside, Soil and Water Sciences Program (invited speaker).
- Fierer, N. 2009. Predicting microbial processes from microbial community phylogenetics. Workshop at the Lorentz Center ("Microbes in ecosystems: weaving intracellular processes into ecological networks"). Leiden, The Netherlands. (invited speaker and workshop participant)
- Fierer, N. 2009. Comparing the biogeography of soil bacteria, archaea, and fungi. Annual meeting of the Soil Ecology Society. Burlington, VT (invited symposium speaker)
- Gabor, R. 2010. The use of Fluorescence Spectroscopy to Compare the Chemical Character of Soil and Dissolved Organic Matter within a Section of the Boulder Creek Watershed, *Humic Science & Technology Conference XIII*, Boston, MA, March, 2010.
- Gabor, R., 2010. Using fluorescence spectroscopy to analyze the organic matter of soil extracts. *American Chemical Society National Meeting*, San Francisco, CA, March 2010.
- Gabor, R., 2010. The use of Fluorescence Spectroscopy to Compare the Chemical Character of Soil and Dissolved Organic Matter within a Section of the Boulder Creek Watershed, *CU Hydrologic Sciences Symposium*, Boulder, CO, April 2010.
- Gabor, R., 2010. The Use of Fluorescence Spectroscopy to Analyze the Soluble Organic Matter of Soil Extracts and Compare it to Dissolved Organic Matter from the same Watershed, *International Training Workshop on Organic Matter Characterization Using Spectroscopic Techniques*, May 2010, Granada, Spain
- M. Leopold, Mountain Permafrost, a valid archive to study mountain permafrost? *Continents under Climate Change*, Berlin, 4/2010. [http://www.huberlin.de/climatechange2010/Presentations/America%20\\_Leopold.pdf](http://www.huberlin.de/climatechange2010/Presentations/America%20_Leopold.pdf)
- M. Leopold, *Interne Struktur und hydrologische Fließwege am Green-Lake-5-Blockgletscher, Colorado USA*. Annual Meeting of the German Geomorphological Workgroup, Vienna, 10/2009.
- Williams MW, Plenary address, NSF - NERC Workshop: Critical Zone Science, Arlington VA, 1 March 2010

Williams MW, Colloquia, CSU water resources seminar series, 16 February 2010, Fort Collins CO.

Williams MW, Keynote speaker, NSF-sponsored Cyber-observatories workshop, Boulder Colorado, May 18 2010.

Williams MW, Plenary speaker, NCALM national steering committee, Boulder CO, 30 May 2010.

### *Proposals*

NSF-EAR 0922307 Acquiring Airborne Lidar data to study hydrologic, geomorphologic, and geochemical processes at three Critical Zone Observatories (CZO). PI: Qinghua Guo, UC Merced. Co-PIs: SP Anderson, Roger Bales (UC Merced), Chris Duffy (Penn State). \$935,457 (budget for UC Merced). 9/15/09-8/31/12.

NSF-EAR 0930048 Acquisition and upgrade of instrumentation for research on transport and reactivity of dissolved and particulate organic materials in soils, sediments and the atmosphere. PI: Diane McKnight. Co-PIs: Mark Williams, Suzanne Anderson, Natalie Mladenov. \$80,069. 12/15/09-11/30/10.

NSF-0949398 Acquisition of Liquid Chromatography and Sample Preparation Instrumentation for Enhanced Reconstruction of Quaternary Environmental Change. PI: Giff Miller. Co-PIs: Diane McKnight, Suzanne Anderson, Jason Neff, Sarah Spaulding. \$203444. 6/1/10-5/31/11.

NSF-1036598 RAPID: Collecting field data in support of LiDAR acquisition during maximum snow conditions and maximum leaf out in the Boulder Creek Critical Zone Observatory. PI: Suzanne Anderson. Co-PIs: Noah Molotch, Greg Tucker. \$33150. 6/1/10-5/31/11.

Williams MW (Co-I), NSF CMG: "Multiscale nonlinear domain decomposition method for modeling the impact of climate change on groundwater resources"; \$564,704; 9/1/09-8/31/12.

Becca Barnes: NSF Long Term Ecological Research Cross-Site Synthesis Workshop Grant, *Predicting the influence of inland climate change on continental-scale carbon and nutrient processing in river networks*, J. Kominoski, W. Wollheim, R. Barnes, J. Blair, E. Hotchkiss, A. Ulseth (\$11,300)

*Wrote letters of support for the following proposals:*

Dr. Martyn Clark, NCAR, "Process-based evaluation of climate change impacts on sublimation and transpiration in the transient snow zone" submitted to the NSF Hydrological Sciences program, May 2010



Dr. Holly Barnard, University of Colorado, proposal “Carbon-water cycling in the critical zone: understanding ecosystem process variability across complex terrain” to the DOE program in Terrestrial Carbon Cycle Research, April 2010.

Dr. Ty Ferré, University of Arizona, “MRI: Development of Next Generation Distributed Electrical Resistivity Technology with Real Multi-Tier Adaptive Capacity” to the NSF Major Research Instrumentation Development program, April, 2010.

Dr. Christina Tague, University of California, Santa Barbara, “Climate change impacts on the fate of precipitation: A strategy for cross-site modeling and synthesis using the Critical Zone Observatories” to the NSF Water, Sustainability, and Climate program, April 2010.

Dr. Sergio Morales, University of Montana, “Testing the Core-Satellite Species Hypothesis in Bacterial Communities: Identifying microbial community structure and functional roles across ecosystems”, to NSF, July 2009.

Dr. Noah Molotch, University of Colorado, CAREER proposal entitled: "Ecohydrological Feedbacks of Snow-Dominated Sub-Alpine Forests", July 2009.

## Findings

### Geomorphology:

- Glacial retreat in Green Lakes Valley began between 18.3 and 23.7 ka. Glacial polish samples in the valley show ages between 12.0 and 16.1 ka; five of these samples cluster around 14 ka suggesting that the glacier retreat likely occurred very rapidly.
- Table Mountain, previously thought to be a Rocky Flats (>1.5Ma) correlative surface on the plains, dates between 130 and 150ka from  $^{10}\text{Be}$  (both in situ and meteoric).
- Verdos surface on the plains, previously thought to be ~640ka, yields preliminary  $^{10}\text{Be}$  dates of ~140ka.
- Together, these cosmogenic radionuclide dates on abandoned alluvial surfaces on the plains point to non-steady incision or downcutting by Boulder Creek, with surface abandonment late in glacial times.
- Fracture spacing and density appear in models to set the stage for evolution of the critical zone by erosion and weathering processes.
- Steady landscape morphologies can form when mobile regolith production occurs in a discontinuous (non-steady on short timescales) steps, by release of blocks from rock to soil.

### Hydrology

- Water in Green Lake 4 in the alpine headwaters of Boulder Creek has tritium levels similar to incoming precipitation, indicating short residence times.
- Water in Como Creek, in the subalpine, shows tritium levels during snowmelt similar to incoming precipitation, indicating short residence times. During baseflow, however, some bomb spike tritium is detected, indicating deeper flowpaths and longer residence times.
- Tracer applied on S-facing slope plots in Gordon Gulch broke through to lysimeters at depths up to 30 cm in a few days during snowmelt season, while tracer applied on N-facing slope plots was delayed and came through in lower concentration.

### Biogeochemistry

- Microbes may be using organic matter as an electronic acceptor at depth (near bedrock) in soil profiles.
- Surface flowpaths appear to contribute more organic matter to the stream than deeper flowpaths (near bedrock).

### *Didymosphenia geminata*

-High flow events appear to be important in controlling the spread of *Didymosphenia geminata*. In Boulder Creek, a flow of ~10 m<sup>3</sup>/s (the mean annual maximum flood), keeps didymo growth in check.

### Microbial ecology

-Spatial distribution of soil microbial communities across Gordon Gulch is predictable based on basic landscape properties such as slope aspect, slope angle, and vegetation type.

-Deeper soils in Gordon Gulch harbor unique bacterial communities that have novel metabolic capabilities.

-Microbial communities were most variable at the surface in Gordon Gulch, and converged to a roughly uniform community structure at moderate depths across the landscape.

-The relative abundance of individual taxa varied with depth though the same taxa (Acidobacteria, Actinobacteria, Proteobacteria, and Verrucomicrobia) remained dominant throughout the profile.

-Although Archaea were rare, their abundance increased with depth. Sequencing results from the surface transects indicate that there is a correlation between Archaeal distributions and C:N ratio and only a slight difference in community structure between north-facing and south-facing slopes.

### Geophysics

-In Betasso, the weathering front (weathered bedrock to fresh bedrock) determined from seismic refraction is on average approximately 9-13 m depth but reaches the surface where bedrock outcrops.

-Multiple seismic refraction transects across the Betasso catchment reveal a change in the thickness of unconsolidated material with more overburden further up the catchment.

-In Gordon Gulch, seismic refraction shows subsurface weathering fronts on the densely forested north-facing slopes extending to depths of > 15 m. On the south-facing slope, this boundary is only 6 m deep. This relationship between north- and south-facing slopes describes a majority of Gordon Gulch.

-In the upper Green Lakes Valley, this weathering front is harder to describe. "Fresh" bedrock resides generally 5-7 m deep with block fields on the steep northern slope (Niwt Ridge) extending 15 m into the subsurface near its base. No permafrost was imaged using the seismic refraction method in the upper Green Lakes Valley.

### Weathering and geochemistry

-In Gordon Gulch, North-facing slopes are more weathered, as assessed by depth that saprolite can be excavated with shovels and other hand implements, and mobile regolith or soil is deeper on these slopes.

-More smectite than kaolinite is found in soils in Betasso and Gordon Gulch.

-Simple models suggest that rates of soil transport do not affect the weathered profile, while rates of rock breakdown (broadly defined) do affect the weathered profile (thickness of soil, degree of weathering of saprolite).