Annual Report for Period: 09/2010 - 08/2011
Submitted on: 07/07/2011
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:

New Assistant Professor who has been involved in CZO research on snow, in Boulder, Southern Sierra and Jemez River.

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.

Name: Barnard, Holly

Worked for more than 160 Hours: No

Contribution to Project:

New Assistant Professor involved in ecohydrology research at Boulder CZO.

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 processsing 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.

Name: Portillo, Carmen

Worked for more than 160 Hours: No

Contribution to Project:

Dr. Portillo is a post-doc in Noah Fierer's lab. She has worked on pyrosequencing DNA extracted from stream water samples. Her work began in 2011.

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 Technische Universit?t M?nchen who will spend severa; weeks 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 Technische Universit?t M?nchen; finished degree.

Name: Doetterl, Sebastian

Worked for more than 160 Hours: No

Contribution to Project:

Diploma student from Technische Universit?t M?nchen, worked in field in 2008; finished degree.

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 (2009) with Suzanne Anderson (Geography), who will work on weathering and water chemistry across the Boulder CZO sites. On time-out, 2010.

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

Name: Kelly, Patrick

Worked for more than 160 Hours: Yes

Contribution to Project:
Graudate student with Suzanne Anderson (2010), working on rock weathering.

Name: Foster, Melissa

Worked for more than 160 Hours: No

Contribution to Project:
Graduate student with Bob Anderson (2010), working on cosmogenic radionuclides and landscape evolution. Department fellowship in 2010-11; CZO RA in 2011-12.

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: 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 interm, 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 worked with Eve Hinckley on hydrology and N-cycling over summer 2010; she now provides 10 hours per week field/lab support as a work-study student for us.

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. Thesis title: Extractable P in soils of the Boulder Creek catchment, Colorado

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. Thesis title: Knickpoints?a study of channels in the Boulder Creek catchment

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. Thesis title: Reconstructing Pinedale ice in the Green Lakes valley, Colorado

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. Thesis title; Characterizing trace-metal distribution in Boulder Creek CZO soils

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. Thesis title: Assessing eolian contributions to soils in the Boulder Creek catchment

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. Thesis title: Using pollen to understand paleoenvironments in Gordon Gulch and Betasso Gulch, Colorado

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. Thesis title: Stream terrace mapping in lower Gordon Gulch, Colorado

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. Thesis title: Erosion, particle paths and deposition?Meteoric 10 Be in Gordon Gulch

Name: Camp, Erin

Worked for more than 160 Hours: Yes

Contribution to Project:
Amherst undergraduate student in the Keck Geology Consortium group 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. Funding for her involvement from Amherst College. Thesis title: Coring a 12 kyr sphagnum bog in the N. Boulder Creek valley ?a search for mercury and its implication

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

Name: Tweeten, Jon

Worked for more than 160 Hours: No

Contribution to Project:
Field assistant about 10 hours per week; helps with water, snow sampling and processing.

Name: O'Halloran, Theresa

Worked for more than 160 Hours: Yes

Contribution to Project:
Theresa is a summer field assistant. She also worked with Eve Hinckley and Sheila Murphy on Fourmile fire sampling in early spring.

Name: Safulko, Andrew

Worked for more than 160 Hours: Yes

Contribution to Project:
Andy is a summer field assistant.

Name: Jones, Joel

Worked for more than 160 Hours: No

Contribution to Project:
Joel is a summer field assistant.

Name: Hoffman, Benjamin

Worked for more than 160 Hours: No

Contribution to Project:
Ben is working part-time as summer field assistant (Lewis & Clark college student)

Name: Heckman, Chris

Worked for more than 160 Hours: No

Contribution to Project:

Chris is taking samples when he is in town this summer to use in a senior honor's thesis on water chemistry and spring flow in Gordon Gulch.

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: Yang, Chi

Worked for more than 160 Hours: Yes

Contribution to Project:

Data manager.

Name: Rock, Nathan

Worked for more than 160 Hours: Yes

Contribution to Project:

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

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

Name: Pruett, Christina

Worked for more than 160 Hours: Yes

Contribution to Project:

Lab and field technical support staff. Supported in part by funds from university Associate Vice Chancellor for Research.

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 Passcal 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 4: 1 Sept 2010-31 August 2011

Fall 2010: All CZO scientists and students were invited to participate in a graduate seminar on weathering and geomorphology.
Spring 2011: Weekly CZO meetings are being held to discuss science questions, research goals, and gaps in our understanding. Attendance is strong at these group meetings, and includes graduate students, technical staff, and faculty.

Graduate students recruited in 2008
Kevin Befus completed his M.S. in spring 2010, and is working on a PhD at UT Austin. His thesis work is in press in Vadose Zone Journal.

Rachel Gabor passed her comprehensive exam in the PhD program in Environmental Studies in December 2010.

Katie Eilers has a manuscript nearing completion on spatial distribution of microbial communities in Gordon Gulch, and has microcosm experiments running. She went on time-out in Jan 2011, and as of June had decided to stop at a Master?s degree, which she will complete in Fall.

Rory Cowie defended his M.A. thesis in Geography in October, and has started the PhD program in the department. Rory attended the PiHM workshop at Penn State in August. He spent a month in Europe spring 2011 working with Italian and ETH snow scientists and isotope hydrologists, and presenting at EGU.

Graduate students recruited in 2009
Jeana Lee, Geography M.A. student, went on time-out due to health issues, Aug 2010, and dropped out of the program (and graduate school) in May 2011.

Abby Langston, Geological Sciences Ph.D. student, attended the PiHM workshop at Penn State in August. She passed her comprehensive exam in May 2011.

Graduate students recruited in year 2010
Patrick Kelly, Geography M.A. student is working on rock material properties and weathering, particularly paying attention to rock strength. He is doing field sampling in soil pits and with a portable rock-coring device in summer 2011.

Melissa Foster, Geological Sciences, PhD student, is working on cosmogenic radionuclides and application to landscape evolution. She has taken a lead in using the LiDAR data.

Associated graduate students (largely supported elsewhere)
Leigh Cooper, Ecology & Evolutionary Biology PhD student is in year 4 of her aquatic ecology survey of Front Range streams impacted by pine beetle infestation.

James Cullis, Civil, Environmental and Architectural Engineering PhD candidate is supported by CZO this year, as he completes his work on hydrologic control of nuisance diatom Didymosphenia geminata in Boulder Creek and elsewhere.

Jordan Parman, Geography MA student, completed his MA in Geography in August.

Post-docs:
Becca Barnes, NSF Earth Sciences post-doctoral Fellow, has completed her fellowship. She is now at Rice University in a post-doctoral position.

Eve-Lyn Hinckley, NSF Earth Sciences post-doctoral Fellow. She regularly attends weekly CZO meetings, and has regular meetings with Suzanne Anderson and Mark Williams (mentors). She is taking a leading role in outreach activities with the Science Discovery program. She will finish papers on her field experiments over the summer and fall of 2011.

Miriam Duhnforth is a post-doctoral researcher, working closely with Bob Anderson. She has frequent meetings with mentor Bob Anderson, and attends weekly CZO meetings, and has several manuscripts in review on Boulder Creek chronology. Miriam has taken a position in Germany, and will leave Boulder in August.

Keck Undergraduate researchers
Eleven undergraduate researchers in the Keck Geology Consortium program run by David Dethier and Will Ouimet are working on senior theses or projects, based on their 2010 summer field work. These are described in the ?Activities? section of this report.

University of Colorado undergraduates
The following undergraduate students are working as field or lab assistants :
Jeffrey Tarshall May 2010-January 2011.
Jacob Coate May 2010-present (doing an internship in San Francisco over summer, but will return in Fall)
Alexandra Czastkiewicz May-Aug 2010, January-April 2011.
Jon Tweeten February-May 2011.
Chris Heckman March 2011-present (working on senior thesis based on sampling springs in Gordon Gulch)
Theresa O?Halloran May 2011-present.
Andy Safalko May 2011-present
Joel Jones May 2011-present
Ben Hoffman (Lewis and Clark College undergrad, working with us for summer)

Outreach Activities:

Outreach activities

Science Discovery:
Post-doc Eve Hinckley coordinated our second year of work with Science Discovery, a science education program based at the University of Colorado. We are offering outreach through three programs with Science Discovery: a schoolyear project for 5th graders called Outdoor Classroom, a summer day camp, and a workshop based program for middle schoolers called Science Explorers.

The CZO team is offering an Outdoor Classroom for three classrooms of fifth grade students (about 75 kids) from a disadvantaged school, Spangler Elementary in Longmont Colorado. The team brings classroom activities to on two occasions (a total of 6 hours in the classroom- 3 classes x 1 hour x 2 visits). The team will lead each classroom on a field trip that includes 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 learn about water, streams, soils, stream ecology, bark beetles, and snow. Dr. Hinckley has enlisted an enthusiastic group of about 12 graduate students to develop classroom activities and run the program for spring 2011. Many of these graduate students are not directly in the CZO program!

A summer day-camp called ?Go with the flow- a field class? was developed by Post-doc Eve-Lyn Hinckley and Sheila Murphy in 2010. The week long camp for is for 10-14 year old kids in the Science Discovery summer program. About half the spots are reserved for kids sponsored by the ?I have a dream? Foundation in Denver. The course will be offered three times in 2011. One of the camps will be taught by CZO grad students Rachel Gabor and Abby Langston, and two will be taught by a Science Discovery teacher, thus reaching about 36 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 is supported by the National Science Foundation 0724960.

Science Explorers runs professional development and science enrichment workshops for 5th-8th grade teachers and students in the state of Colorado. Each year, the workshops deliver hands-on, inquiry based curriculum built around a theme to about 1500 participants (groups of teacher and students); these participants return to their schools with curriculum, an activity kit, and knowledge. The workshops are offered throughout the state over the school year. During summer 2011, two CZO graduate students (Rachel Gabor and Melissa Foster) are working with Science Discovery staff to develop curriculum for a yet-to-be named Critical Zone theme for the 2011-12 Science Explorers.

Water Festival
CZO hosted a booth at the annual Boulder Water Festival in May 2011, held on the University of Colorado campus. The Water Festival is attended by hundreds of fifth graders from elementary schools in Boulder each spring. Sheila Murphy is

Journal Publications

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Web/Internet Site

URL(s):

http://czo.colorado.edu/, http://criticalzone.org

Description:

The czo.colorado.edu website describes our project, lists people involved, provides information on our field sites, is a source for data, and lists our publications. We continue to develop content on the website. In late 2010 we added a 3-D Google Earth tour of the watershed. In 2011, we have added clickable maps of sensor locations in the data catalog pages, and now have data from one met tower (at Betasso) streaming onto the web.

The criticalzone.org website is the National CZO program website. Developer David Lubinski at CU Boulder is working on a new, upgraded national website to be released in May 2011 that will enhance the readability and searchability of the site, as well as enhance linkages between individual CZO websites. He is working with CZO PIs on the message to convey, the audience to direct the content to, and ways to make maintenance simple

Other Specific Products

Product Type:

Data or databases

Product Description:

Boulder Creek CZO data is housed in an Oracle database, maintained by a dedicated Data Manager, Chi Yang. Data can be accessed through a data catalog on our website, and either viewed as html tables or downloaded as ascii files. Time series data are harvested by the San Diego Super Computer for a National CZO database: http://central.criticalzone.org/

Data currently available in Boulder's database (available on our website, czo.colorado.edu) includes:
Data from meteorological towers
Snow surveys
Snow pit data
Soil moisture and temperature
Time lapse photos of snow cover
Stream water chemistry

Sharing Information:

Data is available from our website (czo.colorado.edu). Some data is also available from the National CZO database (central.criticalzone.org) using hydrodesktop.

Product Type:

Interactive Google map fly-through

Product Description:

A Google Earth tour of the Boulder Creek watershed is available for visitors to the Boulder CZO website. Users may either watch the fly-through, or they may jump in and take the controls along the
way.

Sharing Information:

The 3-D tour is a highlight on the Boulder CZO website, or directly available at:
http://czo.colorado.edu/geGIS/czoGISpublic.shtml

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:
Stephanie Kampf, Colorado State University, CAREER proposal 'A wetness state approach for scaling soil moisture from points to catchments: application along a gradient of seasonal snow persistence in the Colorado Front Range. (This is a letter of collaboration). July 2011.

Grit Steinhoefel, GFZ German Research Centre for Geosciences, Potsdam, proposal to DFG (German Research Foundation) to study granite weathering using novel stable isotopes (Li, Mg, Si). Field sites will be in Boulder Creek CZO and Grimselpass in the Swiss Alps. July 2011.

Rolf Aalto, Exeter University, proposal to NERC for a Macronutrient Observatory. Proposal title: ?Timescales of transfer and transformation of particulate nitrogen, phosphorous and carbon: Quantifying source, process and pathway?. July 2011.

Noah Molotch, University of Colorado, proposal to NSF entitled: 'Climatic Controls on Snow-Vegetation Interactions Across an Elevational Gradient'. June 2011.

Martyn Clark, NCAR, proposal titled ?Process-based evaluation of climate change impacts on sublimation and transpiration in the transient snow zone? submitted to the NSF Hydrological Sciences. May 2011.
-share data collected at Betasso and Gordon Gulch
-archive data and merged data-model products

Henry Lin, Penn State University, proposal titled ?Is soil formation and evolution similar to a life process? Testing a thermodynamic principle and developing a DTS protocol for X-CZO science?, March 2011. (Signed by all 6 CZO PIs)

Anthony K. Aufdenkampe, Stroud Water Research Center, Frontiers in Earth System

Dynamics (FESD) proposal entitled ?Globally Significant Carbon Sequestration by Anthropogenic Erosion: A Soils to Sea Integration of Carbon and Mineral fluxes?. March, 2011. (Signed by all 6 CZO PIs).

Dr. Dave Williams, U Wyoming, for the INEWS (Isotope Network of Ecological Warning Signals) Research Coordination Network (RCN, January 2011. Offered to help coordinate a joint workshop on stable isotope system, and to establish student or post-doc exchanges with stable isotope laboratories. The CZOs would supply people with questions, samples, and field sites, while INEWS would supply labs with cutting edge stable isotope tools.

Dr. Michael Ellis, British Geological Survey, for a NERC proposal in Dec. 2010 to develop a collaboration between BGS, Exeter Univ and Boulder CZO. The proposal would bring scientists from BGS and Exeter to Boulder to work on nutrients, organic matter and geochronology (with fallout nuclides), allowing great synergy between the researchers. This proposal is a first step toward developing next-generation environmental observatories for the European Commission.

Dr. Holly Barnard, CU, Soil water connectivity across hydrologic regimes: a test and application of the ?two water worlds? hypothesis, NSF Hydrological Sciences proposal, Nov 2010.

Dr. Jerome Gaillardet, Inst. de Physique du Globe, Paris, CRITEX (Critical Zone Excellence) proposal to CNRS in Sept. 2010. Proposal is to build collaborations with French Critical Zone researchers, sharing labs, field sites, and complementing expertise.

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 19 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.

PI Suzanne Anderson and post-doc Eve-Lyn Hinckley developed and taught an upper division undergraduate class on Earth's Critical Zone in the Geography department (Spring 2011). The class had an enrollment of 23 students, each of whom completed a critical zone case study, in which ecology, hydrology, geomorphology, and geochemistry components must be discussed. The course is a hybrid lecture-seminar format.

Bob Anderson uses cosmogenic results from the Table Mountain and Pioneer sites in his graduate-level Advanced Geomorphology course as a homework exercise to develop skills at interpretation of surface ages from 10Be profiles. In the same class, students used detailed LiDAR profiles of hillslopes across Gordon Gulch.

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.

We hire undergraduate students to assist in field work each summer. We usually have a group of 3 or 4 undergraduate students involved in the project at any time.

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, Christine Pruett.

We are in the process of establishing a data management system for the CZO community, an effort spearheaded by Mark Williams. A report on the data management system is attached.

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:

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. A fourth focus site straddles the Pleistocene glacial moraine in the subalpine zone. CZO activities aim 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:
- One of our scientific questions concerns the origins of the unique topography of the Colorado Front Range, in which Boulder Creek sits, and its relation to the stratigraphy and geologic history of the adjacent Denver basin. Cameron Wobus, together with Greg Tucker and Bob Anderson, completed and published a preliminary modeling study that explores alternative hypotheses for Plio-Pleistocene incision of the range-front piedmont. The study, which is reported by Wobus et al. (2010), concludes that the incision and relief patterns are consistent with either a reduction in volume and/or size of sediment delivered from the Front Range, or an increase in the effective water discharge delivered by Front Range streams.

- Tucker and colleagues have developed a mathematical "box" model to describe the coupled evolution of a crystalline range and adjacent flexural sedimentary basin, from its active phase to its post-orogenic decay phase. The model provides a simple, low-dimensional framework for understanding what conditions are both necessary and sufficient to drive aggradation in the basin (represented by the Miocene Ogallala Group sediments) and subsequent incision (represented by incision along the South Platte and Arkansas river basins and the resulting knickpoints along the Front Range streams such as Boulder Creek). This study is intended as a precursor to an investigation of the long-term evolution of the Boulder Creek basin (and its near neighbors) using a landscape evolution model.

- Understanding the potential links between climate change and landscape evolution requires, among other things, knowledge of hydrology and weathering dynamics at the hillslope scale. To this end, grad student Abby Langston (Geol) and Greg Tucker have begun investigating the vadose zone hydrology in the Betasso and Gordon sites. They continue to monitor moisture and tension head within saprolite and soil at two sites in

the Betasso watershed. In addition, Langston has begun using a two-dimensional vadose zone model to investigate how subsurface moisture varies as a function of hillslope aspect, snowmelt timing, and rock-fracture characteristics.

-R.S. Anderson and post-doc Miriam Dühnforth completed a manuscript on the timing of deglaciation of Green Lakes valley, and the climate change (equilibrium elevation rise) required to fit this chronology. This work sets the chronology for critical zone development in glaciated terrain at the headwaters of Boulder Creek, and constrains the glacial climate under which critical zone evolved over the region. The manuscript is in press with *Arctic, Antarctic, and Alpine Research*.

-Duhnforth and R.S. Anderson completed CRN analysis (in situ and meteoric 10Be) on boulders and sediment samples on abandoned pediment surfaces on the High Plains. Both dating approaches, meteoric and in situ, reveal ages of ~90ka for Table Mountain, whereas a similar *in situ* profile from the Pioneer surface suggests deposition of terrace gravels at ~170 ka. Two amalgamated surface samples from Gunbarrel Hill, further from the mountain front, yield ages of 270 ka and 330 ka. 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. The young ages based upon in situ ^{10}Be results are strongly supported by low meteoric ^{10}Be inventories at each site. These ages all document the occupation of these broad surfaces by streams during glacial times, although not necessarily at glacial maxima. These new results suggest that the exhumation of the Denver Basin around Boulder occurred at highly non-steady rates, and contradict the hypothesis that the incision of this area was slow and steady since the latest Pliocene. Furthermore, the Table Mountain site sits adjacent to a channel that does not access alpine glacial terrain, suggesting that variations in water or sediment flux that may have driven abandonment of the terrace surface is not directly due to glacier dynamics. This implicates the changes in critical zone function in a broad sense, and suggests that during glacial periods the CZ in the crystalline headwaters of these catchments releases more sediment to the streams. The data and incision history implications are described in a manuscript submitted in March 2011 to *JGR-Earth Surface,* currently in revision.

-S.P. Anderson has worked with Alex Blum and Kevin Befus (and a host of soil pit diggers) to show that rock weathering differs with slope aspect in Gordon Gulch watershed on the slowly evolving Rocky Mountain surface. New graduate student Patrick Kelly has begun a program of measuring rock weathering, with a focus on mechanical properties (tension strength and bulk density), as well as chemical analysis (XRD, XRF. Kelly is sampling soil, saprolite and rock in pits and cores collected in Gordon Gulch, and will extend his collections into Betasso in Fall 2011.

-S.P. Anderson and R.S. Anderson have begun constructing a model that can be used to explore the relative roles of weathering rates and transport rates on the depth of mobile regolith (soil), degree of rock weathering, and depth to the weathering front.

The aspect differences described in Gordon Gulch are a modeling target, in a sense providing an interesting natural experiment on weathering and erosion. In the model, weathering is considered damage to the rock, and it is the accumulated damage that ultimately sets the physical architecture of the critical zone beneath the mobile regolith. This damage profile may govern the susceptibility of rock to be entrained in the mobile regolith (regolith production), and will certainly play a role on the hydrologic properties of the saprolite. The preliminary model acknowledged the role of frost cracking as a damage process. The depth of the process, and the degree of damage of the rock upon emergence at the base of the regolith indeed differs from north to south in the model, potentially explaining the asymmetry of the CZ architecture in Gordon Gulch. As cracking of the subsurface alters its hydrologic properties, and as access to water is crucial in allowing frost cracking to proceed, we are developing models of the subsurface hydrology that honor the role of cracks as conduits, and that acknowledges the chemical weathering of rock adjacent to the cracks (work of graduate student Abby Langston). The model has been described in abstracts, most fully in an extended (4 page) abstract published in Applied Geochemistry in 2011.

-The rate at which bedrock is incorporated into the mobile soil layer is an important constraint on landscape evolution. Recent PhD Susan Riggins published her work on how a hillslope lowering at a steady rate over time can yield a wide range of regolith production rates and mobile regolith (soil) depths if rock detaches in large blocks from the bedrock. Riggins et al. was published in 2011 in *Geomorphology*. Although the field site used in the work is in Cornwall, England, the model and concepts are applicable to any system in which bedrock cleaves off large blocks. Graduate student Pat Kelly (Geog) will measure rock fragment grain size and distribution in soil pits in Gordon Gulch to test the rate of block release versus block decay by weathering, a logical extension of Riggins' modeling work.

-Bob Anderson, Suzanne Anderson, and Greg Tucker are working on a manuscript that outlines the role of geomorphic history in defining critical zone architecture and function. We have developed models of solar radiation on the landscape that operate on an hourly basis to calculate the radiative forcing of the thermal state of the landscape. These can be driven with modern orbital parameters, or with those at any time in the last million years, allowing us to assess the direct role of Milankovitch forcing on specific thermally-modulated processes. For example, we may now calculate the annual and daily cycles of freezing and thawing (with attention to the roles of degree of saturation of the various components of the critical zone, and with presently simple algorithms to deal with the role of snow). These in turn can modulate the efficiency of frost cracking as a subsurface damage process, and frost creep as a regolith transport process. The strong asymmetry of the Gordon Gulch catchment provides a target for such models, as the N-facing and S-facing slopes should accept very different solar radiation. This is the subject of a GES-9 extended abstract presented in June 2011 (Anderson et al., *Applied Geochemistry*).

-Keck Program undergraduate students, supervised by David Dethier, studied ice contact extent in Green Lakes valley, riparian terrace features in Gordon Gulch, soil depth, character and residence time (meteoric 10Be) in Gordon Gulch, and channel knickpoints throughout the Boulder Creek watershed.

Hydrology:
-Mark Williams, grad student Rory Cowie (Geog), Noah Molotch, post-doc Eve-Lyn Hinckley and grad student Abby Langston (Geol) have established an array of sonic snow sensors from Betasso to Niwot Ridge. These were operational starting in early 2010 through the 2010 snowmelt, and are operating again in 2011. The automated data from these sensors are augmented by manually read (weekly) snow poles in two transects, and by time lapse cameras taking images every 4 hours in Green Lakes valley and in Gordon Gulch (see Boulder CZO data page http://czo.colorado.edu/flexApp/tl/swf/tl.shtml). The automated snow sensors are co-located with soil moisture sensors.

-Graduate student Rory Cowie completed his MA thesis (Geog), supervised by Mark Williams, on "The Hydrology of Headwater Catchments from the Plains to the Continental Divide, Boulder Creek Watershed, Colorado". Cowie has begun working on a PhD. In spring 2011, he used CZO International Student funding to visit ETH and Italy to work with snow and stable isotope hydrologists there.

-NSF Earth Sciences Post-doc Fellow Eve-Lyn Hinckley completed experiments in Gordon Gulch on hillslope water flow paths and nitrogen processing in soils. She used 10 instrumented plots in Gordon Gulch on N-facing slopes, valley floor, and S-facing slopes. Each plot contained soil moisture sensors, temperature sensors, snow depth sensors, and soil lysimeters (tension and zero-tension). She applied N15 tracer under snowmelt conditions, and in mid-summer under simulated rain conditions. Most of the data is now analyzed (still awaiting 15N results), and manuscripts are in preparation.

-Eve Hinckley and Suzanne Anderson submitted a proposal to NSF (Geobiology and low-temperature geochemistry) to support Hinckley beyond her post-doc (which ends 9/2011) to model hydrologic flowpaths through soil to the weathering front using Hydrus-1D, and to analyze soil, spring, and stream water chemistry. Preliminary analysis of spring and stream water chemistry shows distinctive chemical signatures can be seen in stream waters during melt events from S-facing versus N-facing slopes in Gordon Gulch at different times during winter and spring seasons. The proposal was not funded. NSF will provide a supplement to bridge Eve for two months between the end of her post-doc in September, and the beginning of her new position at NEON in November. She is working on two manuscripts based on her tracer experiments.

-Six wells were drilled to the water table in Gordon Gulch in October 2010. One well is located on a N-facing slope, one on a S-facing slope, and four are in a small area

adjacent to the channel in the valley bottom. These wells have been instrumented with pressure sensors, and regular water sampling has begun.

Biogeochemistry:

-Becca Barnes completed her NSF Earth Sciences Post-doc Fellowship and moved to Rice University in September 2010. She has a manuscript in review in *JGR-Biogeosciences* on connections between denitrification and dissolved organic matter quality in stream sediments from multiple sites in BcCZO. She also has a manuscript in prep (with MA graduate Jordan Parman) on biogeochemical cycling and climate change in Green Lakes valley.

-NSF Earth Sciences post-doc Eve-Lyn Hinckley's plot experiments with N15 tracer applied to plots in Gordon Gulch has shown strong differences in water movement under snowmelt vs. summer rain conditions, and on N-facing versus S-facing slopes. Nitrate applied at the surface did not move as deeply as water applied (as measured with LiBr tracer), and instead appeared to be taken up by vegetation or lost through microbial processing. Full analysis of the fate of N awaits the analysis of 15N in samples (currently in a queue at UC Davis; data expected in early August 2011). Two manuscripts are in preparation on differences in water movement on opposing aspect slopes during snowmelt and during summer rain.

-Hinckley teamed with Geoff Writer (USGS) and Sheila Murphy (USGS and CZO senior personnel) to work on changes in nitrogen and organic carbon cycling in a catchment impacted by wildfire. The project is based on a hillslope severely burned in the Fourmile Fire, which burned parts of the Boulder Creek watershed in September 2010. The work builds on Hinckley's observations from Gordon Gulch, located nearby but not burned, and also complements hydrologic studies being conducted by a USGS team lead by John Moody. Their Rapid proposal, submitted in October, was declined after 8 months of review by NSF, but they are have forged ahead with the work. They installed soil water lysimeters and other equipment, and collected samples during winter and spring.

-Postdoc Eve-Lyn Hinckley received NSF funds to support international collaboration with CZEN scientists. She traveled to ETH, Zurich, Switzerland, in August and September 2010 to work with Professor Stefano Bernasconi. During that time, she analyzed soil and vegetation samples from her plot studies for 15N in Prof. Bernasconi's laboratory and investigated future collaborations with ETH scientists working at the BigLink project.

-Jordan Parman completed his MA thesis (Geog), supervised by Mark Williams: "Climatological and Elevational Controls on Organic and Inorganic Nutrients in Stream Waters, Boulder Creek Watershed, Colorado Front Range". Jordan was funded primarily through Niwot LTER, but his research analyzed trends across the CZO and LTER catchments. Parman has a manuscript in press at Vadose Zone Journal (special issue on the Critical Zone) titled "Stream water chemistry along an elevation gradient from the Plains to the Continental Divide".

- Grad student Rachel Gabor (Environmental Studies), supervised by Diane McKnight, is studying the annual cycling of dissolved organic matter in Boulder Creek, through analysis of stream water samples and leachate from soil samples. Repeated sampling of surface soils and stream water in Gordon Gulch allow analysis of temporal variability of the quality of organic matter on slopes and in streams. To date, there is little temporal variability in the water soluble organic matter in soils, but there is a spatial signal. Gabor is developing a Boulder Creek soil PARAFAC model (the standard Cory-McKnight PARAFAC is based on stream waters) to better quantify soil organic matter. Gabor is working with people at the Santa Catalina-Jemez CZO, where similar soil organic matter results are found. Gabor will attend the watershed Gordon Conference in summer 2011.

- Grad student James Cullis (Civil Eng), supervised by Diane McKnight, is studying nuisance diatom *Didymosphenia geminata* in Boulder Creek. Cullis has been analyzing data on *D. geminata* persistence through varying annual flow conditions and water quality. He is modeling the shear on the bed, and its role in removing mats from the bed, and also analyzing the role of water quality (nutrients) on mat growth. Cullis is attended the Hydrologic Synthesis Summer Institute at UBC in Vancouver during summer 2010 to learn more the role of hydrology in the control of nuisance algal species such as *D. geminata* in the streams.

-Grad student James Cullis awarded an Outstanding Student Paper award by the Hydrology Section of the American Geophysical Union for his invited presentation on "A conceptual model for the growth, persistence, and blooming behaviour of the benthic mat-forming diatom *Didymosphenia geminata"*. Abstract H44C-08 presented at 2010 Fall Meeting, AGU, San Francisco, Calif., 13- 17 Dec

<u>Microbial Ecology</u>:
-Grad student Katie Eilers (EBio) and Noah Fierer have focused on determining how microbial communities in soil and in streams vary across the CZO watershed and the implications for ecosystem processes at these sites. Data was collected on soil properties (C, N, texture, and ammonium/nitrate) for surface samples and soil profiles. Microbial communities were pyrosequenced with barcoded primers (with assistance of Donna Berg-Lyons, a lab technician) and processed using QIIME. A manuscript describing variations in microbial populations in >200 surface soil samples and 9 vertical soil profiles Gordon Gulch is in preparation.

-Eilers and Fierer are also conducting a lab-based microcosm study of microbial weathering in soils collected from the Gordon Gulch and on mineral think sections and chips in order to determine the microbial taxa that promote mineral weathering and how microbial activities alter weathering rates.

-Post-doc Maria del Carmen Portillo and Noah Fierer have begun looking at microbial populations in free-flowing stream and spring samples from 2009-2010. As with the soil samples analyzed by Eilers, DNA extracted from the water is pyrosequenced with barcoded primers and processed using QIIME. This is the first time temporal variations in stream water microbial populations have been analyzed. The data show differences in communities from Boulder Creek to tributaries (Gordon Gulch, Betasso, springs), and temporal variability in some of these sites as well. They are now looking at correlations between the microbial community variations and environmental variables, including temperature, season, DOC, nutrients, and chl-a.

-Bates, Fierer and others published a study in *Applied and Environmental Microbiology* of the bacterial symbionts that live within lichens found on rock outcrops (from Gordon Gulch) and their potential to fix atmospheric N2 and generate acidity (possibly to promote rock weathering).

Geophysics:

- The team from the Technische Universität München (Völkel and Leopold) completed data processing from the summer campaign (August 2010). Geophysical data (ERT, electric resistivity tomography and GPR ground penetrating radar) were collected in Gordon Gulch and Green Lakes watersheds. In Gordon Gulch profile lines were surveyed in advance of combination with soil-geomorphological studies. Sediments on the slope don't follow simple in situ weathering but complex layering probably due to old periglacial solifluction activities. An early summer campaign in 2011 focused on Gordon Gulch profiles aligned with wells drilled in October 2010, and with soil pits excavated in summer 2010, using GPR and electrical resistivity.

-Several ERT lines were surveyed in high alpine areas in the Green Lakes (> 3400 m asl) watershed to detect wet permafrost. Two new sites have been detected however permafrost distribution seems not to be as wide as previously modelled by Janke (2005). They seem to be restricted in the northern parts of the valley whereas many south facing slopes are free of permafrost. Sites formerly described as permafrost sites in the 1970's did not show indications of permafrost.

-Together with David Dethier, Williams College, and Robert Nelson, Colby College, GPR studies on a peat bog were conducted in order to find best drilling locations. The bog was detected by Leopold, Völkel and Dethier in 2007 and provides palynological data back to 12 ka. It is an important and high resolution geoarchive to reconstruct climatic parameters relevant for the CZ-development in the Holocene.

-Leopold published two manuscripts on ice in Green Lakes valley- one on permafrost in the alpine setting (Leopold et al., 2010), and the second on internal ice within Green Lakes 5 rock glacier, deduced from ground penetrating radar and electrical resistivity (Leopold et al., 2011).

-Recent grad Kevin Befus (Geol) and supervisor Anne Sheehan have a manuscript in press in Vadose Zone Journal from his MS thesis on shallow seismic refraction

characterization of the Critical Zone in Boulder Creek watershed. His data showing slow seismic velocities on N-facing slopes to depths >10 m in Gordon Gulch is the most comprehensive to date on differences in rock weathering with slope aspect.

-Grad student Patrick Kelly (Geog) and Suzanne Anderson are exploring variations in rock strength across Gordon Gulch and elsewhere in Boulder Creek watershed. Kelly has begun rock tensile strength testing on small cores obtained with a portable coring device. He is also testing properties of rock clasts in from dated deposits (moraines, alluvial terraces on the plains) to explore how these properties vary with exposure age.

Weathering and geochemistry:

-S.P. Anderson, Alex Blum, David Dethier, and Joerg Voelkel have analyzed soil and rock samples from soil pits and rock exposures in sites in Betasso, Gordon Gulch, Green Lakes valley, and scattered locations elsewhere. To date, the most interesting observation is that the weathered profile in Gordon Gulch shows differences depending on slope aspect. 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.

- Joerg Völkel and Matthias Leopold analyzed soil chemical studies together with optical stimulated luminescence data from the sediments were conducted at a gully section in the Betasso watershed. Sediment chronology proves continuous sedimentation since late glacial times interrupted by a phase of intense soil development. For the first time within BCCZO 13C-Nuclear Magnetic Resonance (NMR) techniques were applied to characterize the organic matter of a buried A-horizon. Numerous field inspections by various people identified this horizon as an in situ A-horizon but NMR clearly documents that large amounts of the organic matter is diffuse black carbon from fires. The NMR studies are ongoing and will provide important information of the Holocene soil history within the Critical Zone of the Betasso watershed. We plan to apply state of the art analysis techniques to further characterize the soil archives within the BC-CZO study sites. Soil samples form a planned field campaign in the summer 2011 will be screened with 13C-NMR techniques and also with Nano-Sims techniques. TU Munich offers the only Nano-SIMS hardware within a soil laboratory world wide, which we will be able to use for the CZO program.

-S.P. Anderson has begun interpretation of stream water chemistry as a record of soil and rock weathering. The first signal to unravel is one of water source variations to the stream, and then we can analyze weathering processes. The first groundwater samples

from wells have been partially analyzed, and will be important contributions to this analysis.

Spatial analysis:
-LiDAR data was acquired from 600km2 of Boulder Creek watershed in August 2010. Over the summer of 2010, a team led by grad student Abby Langston collected ground truth data on snow cover and vegetation for analysis of these parameters from the LiDAR data.

-Technician Eric Parrish assembled GIS layers for use by CZO researchers interested in Boulder Creek. These are available (more to come) on the Boulder CZO data web page (http://czo.colorado.edu/geGIS/czoGISpublic.shtml). Eric has also tiled ortho-rectified airphotos of our study catchments for easy access. Our LiDAR data can be accessed as shaded relief images of our study catchments, and as point clouds (original data) via web links on our GIS page.

Undergraduate researchers supervised by David Dethier, Williams College
Eleven students spent a month from July-August 2010 at the Boulder Creek CZO under the tutelage of Dr. David Dethier (Williams College) and Dr. Will Ouimet (Amherst College). Six were supported by the Keck Geology Consortium, and three supported by this project, one supported by Colby College, and one supported by Amherst College. All are working on senior theses or senior projects during the 2010-11 school year. They gave presentations in Colorado at the Boulder Creek CZO annual meeting in August 2010. Keck students will attend the Keck Research Symposium in spring 2011 to present their findings, and their reports are published in the annual Keck Symposium volume (see Dethier, in prep, in Publications).
Undergraduate student research activities—titles
Extractable P in soils of the Boulder Creek catchment, Colorado (Hayley Corson-Rikert, Wesleyan College, Keck Geology Consortium)
Coring a 12 kyr sphagnum bog in the N. Boulder Creek valley—a search for mercury and its implication (Erin Camp, Amherst College,—Amherst College funding)
Knickpoints—a study of channels in the Boulder Creek catchment (Evan Dethier, Williams College, CZO funding)
Reconstructing Pinedale ice in the Green Lakes valley, Colorado (Keith Kantack, Williams College, CZO funding)
Characterizing trace-metal distribution in Boulder Creek CZO soils (Ellen Maley, Smith College, Keck Geology Consortium)
Assessing eolian contributions to soils in the Boulder Creek catchment (James McCarthy, Williams College, CZO funding)
Using pollen to understand paleoenvironments in Gordon Gulch and Betasso Gulch, Colorado (Corey Shircliff**,** Beloit College, Keck Geology Consortium)
Stream terrace mapping in lower Gordon Gulch, Colorado (Kathleen Warrell, Georgia Tech, Keck Geology Consortium)

Erosion, particle paths and deposition—Meteoric 10 Be in Gordon Gulch (Cianna Wyshnytzky, Amherst College, Keck Geology Consortium)

Findings

Green Lakes Valley. Detailed field mapping and analysis of lidar imagery shows that the LGM extent of glacial ice is similar to that mapped by Madole and others. Ice-contact landforms are extensive downvalley from Silver Lake and provide a minimum estimate for the amount of sediment removed from GLV in late Pinedale time.

Gordon Gulch. Soil pits, reconnaissance sampling and detailed analysis of lidar imagery in lower Gordon Gulch show that regolith is generally thinner than 0.6 m on the south facing slope, but thicknesses exceed 1.9 m locally on north-facing slopes. Soil morphology and chemistry suggest that regolith weathering has taken place in the past 25,000 yrs. Low terraces along the axial drainage extend as high as 3 m above the drainage, but most deposits are within ~1 m and are 1000 to 1500 years old. The knickpoint that separates the upper and lower basin appears to be controlled by rock strength and fracture spacing, but little bedrock is exposed in the channel.

Betasso Gulch. The thick colluvium and saprolite of the upper basin and the bare rock and thin regolith of the lower basin are separated by bedrock knickpoints in the channel that are as high as 3 m. The thick colluvium has been accumulating for at least 20,000 years and is unusually rich in smectite clays.

-David Dethier and Will Ouimet will bring a team of four undergraduates to do research in July-Aug 2011.

<u>Presentations (Sept 2010-Mar 2011)- published abstract</u>

<u>ASLO</u>

Barnes, R.T., R.L. Smith, and G.R. Aiken. 2010. Denitrification and DOM reactivity: A comparison between experimental and modeling results, *ASLO – NABS Meeting,* June 2010.

Cooper, L. A., J. H. McCutchan, T. M. Detmer, and W. M. Lewis. 2011, February 15. Effects of lodgepole pine mortality due to mountain pine beetle infestation on stream chemistry. Poster session presented at the Aquatic Science Meeting of the American Society of Limnology and Oceanography, San Juan, Puerto Rico.

<u>SDGG (Schriftenreihe der Deutschen Gesellschaft für Geowissenschaften)</u>

Huber, J., Voelkel, J. Birkeland, P.W. & Leopold, M. (2010): Soils and slope deposits of different genesis and ages in the Colorado Front Range (Rocky Mountains) and their environmental implications. – SDGG Heft 68: 258. Meeting of the Hydrogeology section of the DGG, October 2010, Darmstadt.

Leopold, M., Befus, K., Voelkel, J., Dethier, D., & Sheehan, A. (2010): Imaging the Critical Zone – Results from the boulder creek Critical Zone Obvervatory, USA, SDGG, Heft 68: 360. Meeting of the Hydrogeology section of the DGG, October 2010, Darmstadt.

Geological Society of America

Voelkel, Joerg, Huber, Juliane, Leopold, Matthias, and Dethier, David P. (2010): Young Quaternary slope sediments and paleosols in the Colorado Front Range—process and age: Geological Society of America *Abstracts with Programs*, Vol. 42, No. 5, p. 469.

Dethier, David P., and Birkeland, Peter, 2010, Using the accumulation of CBD-extractable iron and clay to estimate soil and landform age, Front Range, Colorado: Geological Society of America *Abstracts with Programs*, Vol. 42, No. 5, p. 364.

Buraas, Eirik M., and Dethier, David P., 2010, Assessing the hydrologic impact of land-use change in upper Gordon Gulch, a small upland catchment in the Arapaho National Forest, Colorado: Geological Society of America *Abstracts with Programs*, Vol. 42, No. 5, p. 351.

American Geophysical Union

Barnes, R.T., J. Parman, and M. W. Williams (2010): Climate Change and Biogeochemical Cycling in Green Lakes Valley, Colorado Front Range, USA, Abstract B13C-0494 presented at 2010 Fall Meeting, AGU, San Francisco, Calif., 13- 17 Dec.

Cowie, R. M., and M. W. Williams (2010): Use of isotopic and geochemical tracers to identify source waters, flow paths, and residence times of headwater catchments in Boulder Creek watershed, Colorado, Abstract H31D-1036 presented at 2010 Fall Meeting, AGU, San Francisco, Calif., 13- 17 Dec.

Duehnforth, M., R. S. Anderson, and D. Ward (2010): Placing absolute timing on basin incision adjacent to the Colorado Front Range: results from meteoric and in situ ^{10}Be dating, Abstract EP52A-05 presented at 2010 Fall Meeting, AGU, San Francisco, Calif., 13- 17 Dec.

Gabor, R. S., N. Russell, and D. M. McKnight (2010): An analysis of the chemical character of dissolved organic matter and soluble soil organic matter within the same catchment Abstract B23E-0422 presented at 2010 Fall Meeting, AGU, San Francisco, Calif., 13- 17 Dec.

Hinckley, E. S., R. T. Barnes, M. W. Williams, and S. P. Anderson (2010): Mobilization and Metabolism of Deposited N in High Montane Forests of the Colorado Front Range, U.S., Abstract B42E-02 presented at 2010 Fall Meeting, AGU, San Francisco, Calif., 13- 17 Dec.

Jepsen, S. M., N. P. Molotch, M. W. Williams, K. E. Rittger, and J. O. Sickman (2010): 1996-2007 Interannual Spatio-Temporal Variability in Snowmelt in two Montane Watersheds, Abstract C33C-0551 presented at 2010 Fall Meeting, AGU, San Francisco, Calif., 13- 17 Dec.

Khan, A.L., and D. M. McKnight (2010): Evaluation of the relationship between dissolved organic material, chlorophyll-a and algal species in lakes and drinking water reservoirs throughout the state of Colorado, Abstract B11I-05 presented at 2010 Fall Meeting, AGU, San Francisco, Calif., 13- 17 Dec.

Langston, A. L., G. E. Tucker, S. P. Anderson, and R. S. Anderson (2010): Exploring subsurface flow paths as a precursor to understanding the spatial pattern of

weathering in a rocky landscape, Abstract EP41D-0738 presented at 2010 Fall Meeting, AGU, San Francisco, Calif., 13- 17 Dec.

Mladenov, N., M. W. Williams, and S. K. Schmidt (2010): Organic carbon input from atmospheric deposition: a potential driver of nitrogen export from barren alpine ecosystems (Invited), Abstract B32C-08 presented at 2010 Fall Meeting, AGU, San Francisco, Calif., 13- 17 Dec.

Molotch, N. P., K. N. Musselman, E. Trujillo, P. D. Brooks, J. R. McConnell, and M. W. Williams (2010): Ecohydrological response to snowmelt dynamics from plot to regional scales, Abstract C14B-02 presented at 2010 Fall Meeting, AGU, San Francisco, Calif., 13- 17 Dec.

Whitenack, T., M. W. Williams, D. G. Tarboton, I. Zaslavsky, M. Durcik, R. G. Lucas, C. Dow, X. Meng, B. Bills, M. Leon, C. Yang, M. Arnold, A. K. Aufdenkampe, K. Schreuders, and O. Alvarez (2010): Development of an integrated information system for Critical Zone Observatory data, Abstract IN31B-1289 presented at 2010 Fall Meeting, AGU, San Francisco, Calif., 13- 17 Dec.

Williams, M. W., and R. M. Cowie (2010): Evaluating the utility of stable isotopes within environmental observatories in the Colorado Front Range to quantitatively estimate the age of water and determine the time and spatial dynamics of hydrologic processes, Abstract H54B-08 presented at 2010 Fall Meeting, AGU, San Francisco, Calif., 13- 17 Dec.

Cullis JD, Gillis, C-A,Bothwell Max, Kilroy C, Packman A, and Hassan M (2010): A conceptual model for the growth, persistence, and blooming behaviour of the benthic mat-forming diatom *Didymosphenia geminate*. Abstract H44C-08 presented at 2010 Fall Meeting, AGU, San Francisco, Calif., 13- 17 Dec.
(Hydrology section Outstanding Student Paper Award winner!)

Cullis JD, Gillis C-A, Drummond J, Garcia T, Bothwell M, Kilroy C, Larned S,Hassan M, and Packman A (2010): Factors affecting the growth of *Didymosphenia geminata* in New Zealand rivers: Flow, bed disturbance, nutrients, light, and seasonal dynamics. Abstract H41G-1168 presented at 2010 Fall Meeting, AGU, San Francisco, Calif., 13- 17 Dec.

<u>Ecological Society of America</u>

Hinckley, E.S., Barnes, R.T., Williams, M.W., and Anderson, S.P. (2011) The fate of reactive nitrogen differs by hillslope aspect in montane forests of the Colorado Front Range, U.S.A.. Ecological Society of America abstract.

<u>European Geophysical Union</u>

Leopold, M. & Voelkel, J. (2011): Imaging the architecture of the Critical Zone along an altitudinal gradient in the Rocky Mountains Front Range of Colorado, USA. EGU abstracts EGU2011-10955

Voelkel, J., Leopold, M., Huber, J. & Dethier, D. (2011): Parameters and genetic interpretation of a palaeosol from the Colorado Front Range, USA. EGU abstracts EGU2011-11019

Ninth International Symposium on Geochemistry of the Earth's Surface
See listings under "abstracts", published in Applied Geochemistry.

Chapman Conference on The Galápagos as a Laboratory for Earth Science (July 2011)
Anderson, S.P., Tucker, G.E., Anderson, R.S., Langston, A., and Kelly, P. (2011): Rock into Regolith: Earth's Critical Zone on Volcanic Ocean Islands.

Presentations (Sept 2010-Mar 2011)- - no published abstract
Suzanne Anderson "Highlights from the Boulder Creek CZO", University of Colorado, INSTAAR noon seminar, August 30, 2010.

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.

Suzanne Anderson "Highlights from the Boulder Creek Critical Zone Observatory", National CZO meeting, September, 2010.

Suzanne Anderson "Weathering, erosion and the Critical Zone", University of Wyoming, Geology and Geophysics Distinguished Lecturer Series, October 25, 2010.

Suzanne Anderson "Weathering, erosion and the Critical Zone", University of Michigan, Dept. of Geological Sciences Smith Lecture Series, Nov 5, 2010.

Suzanne Anderson "Boulder Creek Critical Zone Observatory", NSF CZO Program Review, March 2011.

Anderson, R. S., S. P. Anderson, G. Tucker, Of damage zones, reactors and conveyor belts: A geomorphologist's view of the long term evolution of the critical zone, CZO annual meeting, Biosphere2, Arizona, May 2011.

Tucker, G. E., P. van der Beek, A. Langston, R. S. Anderson, S. P. Anderson, Critical Zones and Decaying Mountains: A Simple Model for Post-Orogenic Landscape Evolution of a Range and its Adjacent Basin, CZO annual meeting, Biosphere2, Arizona, May 2011.

Cullis, James, and McKnight, Diane (2011): Hydrologic controls on the growth and distribution of the nuisance mat-forming diatom *Didymosphenia geminata* in Boulder Creek, Colorado. Gordon Conference (watershed Science, July 2011)

Conference Sessions
International Conference ***Fragile Earth***, Munich 4-9 July 2011
Leopold, M. & Völkel, J., organizers, The Earth surface in the Anthropocene

Ninth International Symposium on **Geochemistry of the Earth's Surface** (GES-9), Boulder 3-7 June 2011.

Suzanne Anderson and Steven Banwart, organizers, Earth's Critical Zone theme, 44 abstracts (largest session of the meeting)

Boulder Creek CZO field trip, held during meeting on 6 June. 25 participants (full capacity)

International Critical Zone Student Symposium, 1-2 June 2011, for students and post-docs from SoilTrEC and from US Universities. 26 participants did a tour of Boulder Creek CZO, and spent a day giving presentations to each other. Participants then attended GES-9.

Proposals funded

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. 6/15/10-5/31/11.

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.

Proposals submitted

NSF EAR-1051483 Instrumentation & Facilities: Upgrade of Laboratory Facilities for Sediment Characterization in the INSTAAR Sedimentology Laboratory. PI: Suzanne Anderson, Co-PIs: Mark Williams, Anne Jennings, Holly Barnard. $192157. 12/1/10-11/30/11. Submitted July 2010. (Recommended for funding; on hold since January 2011)

EAR-1102551: RAPID: Evaluation of Changes to Biogeochemical Fluxes and the Corresponding Impact on Stream Ecology and Water Quality Following a Wildfire in the Colorado Front Range, USA. PI: Eve-Lyn Hinckley, co-PI Geoff Writer, co-I Mark Williams. $93687. 3/1/11-2/28/12. Submitted October, 2011. Declined June, 2011.

NSF-1111947 Supplement to CZO: Boulder Creek Critical Zone Observatory--Weathered Profile Development in a Rocky Environment and Its Influence on Watershed Hydrology and Biogeochemistry. This supplement supports Work on Ecohydrology, Snow Distribution, Soil Residence Times, and Precipitation Quantity and Quality. $278371. 1/1/11-08/31/12. Submitted November, 2010. Declined, June 2011 (verbal).

NSF-1123936 Feeding the Deep Critical Zone: Water Flow Paths and Chemical Evolution from the Soil Surface to the Weathering Front. PI: Suzanne Anderson, Co-PI Eve-Lyn Hinckley. $301847. 8/1/11-7/31/13. Submitted January, 2011. Declined.

Wrote letters of support for the following proposals (Sept 2010-July 2011)*:*
Grit Steinhoefel, GFZ German Research Centre for Geosciences, Potsdam, proposal to DFG (German Research Foundation) to study granite weathering using novel stable isotopes (Li, Mg, Si). Field sites will be in Boulder Creek CZO and Grimselpass in the Swiss Alps. July 2011.

Rolf Aalto, Exeter University, proposal to NERC for a Macronutrient Observatory. Proposal title: "Timescales of transfer and transformation of particulate nitrogen, phosphorous and carbon: Quantifying source, process and pathway". July 2011.

Noah Molotch, University of Colorado, proposal to NSF entitled: "Climatic Controls on Snow-Vegetation Interactions Across an Elevational Gradient". June 2011.

Martyn Clark, NCAR, proposal titled "Process-based evaluation of climate change impacts on sublimation and transpiration in the transient snow zone" submitted to the NSF Hydrological Sciences. May 2011.
-share data collected at Betasso and Gordon Gulch
-archive data and merged data-model products

Henry Lin, Penn State University, proposal titled "Is soil formation and evolution similar to a life process? Testing a thermodynamic principle and developing a DTS protocol for X-CZO science", March 2011. (Signed by all 6 CZO PIs)

Anthony K. Aufdenkampe, Stroud Water Research Center, Frontiers in Earth System Dynamics (FESD) proposal entitled "Globally Significant Carbon Sequestration by Anthropogenic Erosion: A Soils to Sea Integration of Carbon and Mineral fluxes". March, 2011. (Signed by all 6 CZO PIs).

Dave Williams, University of Wyoming, INEWS (Isotope Network of Ecological Warning Signals) Research Coordination Network (RCN), January 2011.
-develop a joint workshop on an aspect of stable isotope systems of interest to both communities
-student and post-doc exchanges with stable isotope laboratories

Sue McGeary, University of Delaware, Critical Zone STEP center proposal to NSF, January 2011.
-consortium for undergraduate education
-signed by all 6 CZO PIs.

Michael A. Ellis, British Geological Survey, NERC proposal to establish pilot-scale collaboration between researchers at BGS, Exeter, and Boulder Creek CZO. December 2010.
-share expertise in nutrient processing, chronometry, geomorphology.
-develop proposals for European Commission-NERC-CZO collaboration.

Holly Barnard, University of Colorado, NSF Hydrological Sciences program proposal: Soil water connectivity across hydrologic regimes: a test and application of the "two water worlds" hypothesis, November 2010.

Jérôme Gaillardet, Laboratoire de géochimie cosmochimie, IPGP, proposal to the French government for CRITEX (Critical Zone Excellence) infrastructure development. September 2010.

- student exchanges, cross-site comparisons of weathering rates and landscape evolution models, and standardization of methods

Publications

Haugen, B.D., Scambos, T.A., Pfeffer, W.T., and Anderson, R.S. (2010): Twentieth-century changes in the thickness and extent of Arapaho Glacier, Front Range, Colorado. *Arctic, Antarctic, and Alpine Research* 42 (2): 198-209.

Wobus, C.W., Tucker, G.E., and Anderson, R.S. (2010): Does climate change create distinctive patterns of landscape incision? *Journal of Geophysical Research* 115, F04008, doi:10.1029/2009JF01562 (12 pages).

Riggins, S.G., Anderson, R.S., Anderson, S.P., and Tye, A.M. (2011): Solving a conundrum of a steady-state hillslope with variable soil depths and production rates, Bodmin Moor, UK. *Geomorphology,* 128: 73-84.

Leopold, M., Voelkel, J., Dethier, D., Williams, M., and Caine, N., (2010): Mountain Permafrost – a valid archive to study climate change? Examples from the Rocky Mountains Front Range of Colorado, USA: *Nova acta Leopoldina*, v. 112: 281–289.

Leopold, M, Williams, M., Caine, N., Voelkel, J., and Dethier D. (2011): Internal Structure of the Green Lake 5 Rock Glacier, Colorado Front Range, USA: *Permafrost and Periglac. Process*. 21: 1–13, published online DOI: 10.1002/ppp.706.

Caine, N. (2010): Recent Hydrologic Change in a Colorado Alpine Basin: an indicator of permafrost thaw. *Annals of Glaciology* v. 51, issue 56; p. 130-134.

Bates, S.T., G.W.G. Cropsey, J.G. Caporaso, R. Knight, and N. Fierer. 2011. Bacterial communities associated with the lichen symbiosis. *Applied and Environmental Microbiology* 77: 1309–1314.

Bates, S., D. Berg-Lyons, J.G. Caporaso, W. A. Walters, R. Knight, N. Fierer. 2010. Examining the global distribution of dominant archaeal populations in soil. *ISME Journal*. doi:10.1038/ismej.2010.171

Anderson, RS, and Anderson, SP (2010): *Geomorphology: The Mechanics and Chemistry of Landscapes*. Cambridge University Press, 340 pp. (Textbook; weathering chapter presents the critical zone description of the earth surface.)

Bergmann, G.T., S.T. Bates, K.G. Eilers, C.L. Lauber, J.G. Caporaso, W.A. Walters, R. Knight, N. Fierer (2011): The under-recognized dominance of Verrucomicrobia in soil bacterial communities. *Soil Biology & Biochemistry* 43: 1450-1455.

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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 around 90ka from ^{10}Be (both in situ and meteoric).

-Verdos surface on the plains, previously thought to be ~640ka, yields ^{10}Be dates of ~170ka.

-Together, these cosmogenic radionuclide dates on abandoned alluvial surfaces on the plains point to non-steady incision or downcutting by Boulder Creek. During protracted times of even moderate glacial climate, these surfaces were broadened by lateral beveling of the rivers into the highly erodible Cretaceous shales of the High Plains by sediment-choked streams. The surfaces are abandoned by rapid downward incision into the soft bedrock during relatively short, rare periods of deep interglacial climate conditions that correspond with low sediment supply from the headwaters. Implied vertical incision rates into the shale bedrock of the High Plains in these rare events must be of the order of several mm/yr.

-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 discontinuous (non-steady on short timescales) steps, by release of blocks from rock to soil.

-Differences in weathering rate exert greater control on depth to weathering front than does rate of removal of weathered products by sediment transport (model result).

-Climate change (hydrology and sediment flux) can trigger incision of large-scale landscapes. This must now serve as a viable alternative to the traditional inference that incision reflects rejuvenation by tectonic processes. These different drivers may have different spatial signatures of incision that could be diagnostic (model results).

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 in 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.

-Snowmelt on S-facing slopes in Gordon Gulch produce shifts in stream runoff chemistry, suggesting that hydrologic sources do not just switch between shallow and deep paths over time, but also switch between sources on one slope to another.

-Fraction of precipitation derived from snow increases with elevation over the Boulder Creek watershed, from 30% at Betasso (2000 m) to 90% at Green Lakes valley (3500 m).

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).

-High flow events appear to be important in controlling the spread of *Didymosphenia geminata*. In Boulder Creek, a flow of ~10 m3/s (the mean annual maximum flood), keeps didymo growth in check.

- Unlike traditional algal blooms the growth of *didymo* biomass (primary due to thicker mats) appears to be inversely related to the nutrient concentrations in the stream.

-Soluble organic matter leached from soils does not vary significantly over time, but does vary spatially from N-facing to S-facing to riparian locations.

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.

-Microbial communities in headwater stream samples vary over time. The most significant correlation found so far is between changes in dissolved organic carbon concentration and the microbial community shifts.

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 (Niwot 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).