Annual Report for Period: 09/2011 - 08/2012
Submitted on: 09/25/2012
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.

Name: Rajaram, Harihar

Worked for more than 160 Hours: No

Contribution to Project:

Dr. Rajaram, Civil, Environmental and Architectural Engineering at CU, joined the project for the renewal proposal. He has been quite active in planning, participating in meetings in the last 6 months of the project and will continue in the renewal.

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.

Name: Mills, Taylor

Worked for more than 160 Hours: Yes

Contribution to Project:
PhD student with S.P. Anderson, working on hydrology and water chemistry.

Name: Wickert, Andrew

Worked for more than 160 Hours: No

Contribution to Project:
Andy Wickert designed and built arduino-based data loggers for several instrumentation packages for us in 2011. He has helped the electrical engineer at Christina River CZO with some of their datalogger designs.

Name: Shea, Neil

Worked for more than 160 Hours: No

Contribution to Project:
Univ. Connecticut MS student, working with Will Ouimet on meteoric 10Be in Gordon Gulch. Supported elsewhere.

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.

Name: Torrens-Bonano, Angel

Worked for more than 160 Hours: No

Contribution to Project:

RESESS summer intern, 2012, from Geology Dept, University of Puerto Rico at Mayaguez. Worked with Anne Sheehan on electrical conductivity survey of Betasso.

Name: Skeets, Breanna

Worked for more than 160 Hours: Yes

Contribution to Project:

RESESS summer intern, 2011 and 2012, from Geology Dept. Lawrence University. Worked with Holly Barnard on ecohydrology.

Name: Epple, Kara

Worked for more than 160 Hours: No

Contribution to Project:

Summer 2012: Worked with Anne Sheehan on electrical conductivity survey of sites in BcCZO. Supported with CU Geology Dept. mentorships and CZO funds.

Name: Larson, Michael

Worked for more than 160 Hours: No

Contribution to Project:

Summer 2012: Worked with Anne Sheehan on electrical conductivity survey of sites in BcCZO. Supported with CU Geology Dept. mentorships and CZO funds.

Name: Campbell, Scott

Worked for more than 160 Hours: No

Contribution to Project:

Summer 2012: Worked with Anne Sheehan on electrical conductivity survey of sites in BcCZO. Supported with CU Geology

Dept. mentorships and CZO funds.

Name: Lewis, Gabriel

Worked for more than 160 Hours: No

Contribution to Project:

2012 Keck Program undergraduate student, from Williams College. Working on electrical resistivity tomography to study permafrost.

Name: Boateng, Timothy

Worked for more than 160 Hours: No

Contribution to Project:

2012 Keck Program undergraduate student, from Amherst College. Working on rock strength, using the Donath press.

Name: Mondrach, Hannah

Worked for more than 160 Hours: No

Contribution to Project:

2012 Keck Program undergraduate student, from University of Connecticut. Working on short term isotopes (137Cs and 210Pb) to study slope transport.

Name: Patton, Annette

Worked for more than 160 Hours: No

Contribution to Project:

2012 Keck Program undergraduate student, from Whitman College. Working on Mn in soils and vegetation.

Name: Nesbitt, Ian

Worked for more than 160 Hours: No

Contribution to Project:

2012 Keck Program undergraduate student, from Williams College. Working on snowmelt hydrology in alpine.

Name: Corona, Claudia

Worked for more than 160 Hours: No

Contribution to Project:

2012 Keck Program undergraduate student, from Williams College. Working on geochemistry of snowmelt runoff in alpine.

Name: Halcsik, Christopher

Worked for more than 160 Hours: No

Contribution to Project:

2012 Keck Program undergraduate student, from Beloit College. Working on flood deposits from late Pleistocene Lake Devlin.

Name: Purinton, Ben

Worked for more than 160 Hours: No

Contribution to Project:

2012 Keck Program undergraduate student, from Wesleyan University. Working on post-fire sediment deposits in Fourmile Canyon.

Name: Jensen, Clayton

Worked for more than 160 Hours: Yes

Contribution to Project:

Undergraduate field assistant, supported by Work-study program and CZO.

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. Left CU for Alaska in 2010.

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. Worked 2 years with us, found job at 2x pay rate in August 2012.

Name: Millar, Colin

Worked for more than 160 Hours: No

Contribution to Project:

Lab manager, replaced Christina Pruett August 2012. Continued on renewal project.

Name: Carpenter, Eric

Worked for more than 160 Hours: Yes

Contribution to Project:

Eric Carpenter is a teacher and teaching program developer for K-12 curriculum with Science Discovery. He guided and led the outreach activity we did with middle schoolers and their teachers in 2011-12.

Name: Lestak, Leanne

Worked for more than 160 Hours: No

Contribution to Project:

Leanne Lestak, a member of the INSTAAR GIS lab, reduces automated snow sensor data each year. She also worked with Open Topography to make sure the BcCZO LiDAR data was appropriately transferred, and with full metadata.

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

Tim and Theresa Brown, provided access to their property for digging a soil pit on a Slocum level terrace, and used their backhoe to dig the pit for us.

Dr. Shannon Mahan, USGS Lakewood, is working with graduate student Melissa Foster to provide optically-stimulated luminscence (OSL) dates at a reduced (student) rate.

Dr. Arnaud Temme, Wageningen University, Netherlands, visiting scientist July-Oct 2012. Two MA students working with him on soils and hydrology in alpine and montane forest regions of BcCZO.

Dr. Fran?ois Chabaux, University of Strasbourg, France. Measuring U-series isotopes in rock samples for weathering rate; collaborating with S.P. Anderson.

Dr. William Ouimet, University of Connecticut. Will has brought his grad student to BcCZO for two summers, and 1 or 2 undergrads. They work with the Keck Project students, and Will helps supervise Keck students. Will has brought funding from U. Conn. to help support his

activities, and is an important collaborator.

Dr. Peter van der Beek, University of Grenoble, France, was a visiting scientist to CU in 2011. He worked with Greg Tucker on mountain range-basin evolution, using the Colorado Front Range as a type case.

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 has provided access to a soil pit site on Table Mountain, which we have used for cosmogenic radionuclide dating.

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 5: 1 Sept 2011-31August 2012

Fall-Spring: PI level meetings held periodically to plan our research program for the next five years; these discussions were the basis of our accomplishments-based renewal proposal submitted in March 2012.

Spring 2012: Graduate geomorphology seminar focused on how to connect weather and hydrology, with time scales of minutes to seasons, with landscape evolution on timescales of centuries to epochs.

Graduate students
Recruited in 2008:

Rachel Gabor (Environmental Sciences PhD student) continued her dissertation research on dissolved organic matter in soil extracts and streams. She has two papers in press (Perdrial et al., Soil Science Society of America Journal; Gabor et al., Aquatic Organic Matter Fluorescence, Cambridge University Press). She plans to defend her PhD in early 2013.

Katie Eilers (Ecology & Evol. Biol. MA student) completed her MA thesis in November 2011. Her work on microbial ecology from soil pits in Gordon Gulch has been published: Eilers et al. (2012): Soil Biology & Biochemistry 50: 58-65.

Rory Cowie (Geography PhD student) was supported in spring 2012 to work on publications stemming from his MA thesis.

Recruited in 2009:
Abby Langston (Geological Sciences Ph.D. student) continued her modeling work. She presented some results at GES9 meeting, and at Goldschmidt 2011. She attended SoilTrEC modeling workshop in Crete, July 2012. Manuscript on observations of soil moisture and VS2DI models of vadose zone in soil-fractured rock system will be submitted this fall (2012).

Recruited in 2010:
Patrick Kelly (Geography M.A. student) completed his thesis on rock strength and weathering in August 2012. His results will be used in a manuscript in prep on slope aspect and weathering.

Melissa Foster (Geological Sciences PhD student) passed her comprehensive exam in April 2012. She has 10Be data from soil pits in Gordon Gulch, and is collecting OSL data from terraces on the plains. The data are being used to analyze soil transport and mobile regolith production rates in Gordon Gulch, and to constrain evolution of the watershed through fluvial incision.

Recruited in 2011:
T. Joe Mills (Geography PhD student) is working on hydrology and water chemistry in Gordon Gulch and elsewhere in the CZO. He has assisted Rory Cowie with end-member mixing models. He attended the SoilTrEC modeling workshop in Crete, July 2012.

Associated graduate students (largely supported elsewhere)
James Cullis (Civil Eng. PhD student) completed his dissertation on hydraulic controls of Didymosphenia geminata in Fall 2011. He has one publication (Cullis et al. (2012): JGR-Biogeosciences 117, G00N03, 11 pp, doi:10.1029/2011JG001891), and two additional manuscripts in review.

Mariela Perignon (Geological Sci. PhD student) modeled rainfall-runoff for the Fourmile catchment (tributary to Boulder Creek) under Thompson-Flood style events; this work will form a chapter in her dissertation.

Anya Byers (Geography MA student) is working on ecohydrology on Niwot Ridge.

Recruited in 2012:
Eric Winchell (Geological Sci. PhD student) arrived in August 2012 to work on hydrology in CZO. He has assembled snow data from the first 5 years of project in his first month.

Maggie Burns (Geography MA student) arrived in August 2012 to work on sapflow and carbon in Gordon Gulch.

Post-docs:
Eve-Lyn Hinckley completed her NSF post-doctoral fellowship in October 2011. One manuscript from her experiments is now in press: (Hinckley et al., (in press) Hydrological Processes), and another manuscript is in preparation.

Adrian Harpold, started an NSF Earth Sciences post-doctoral fellowship in July 2012, working with mentor Noah Molotch, and also affiliated with NCAR. He will work on parameterizations for snow-vegetation interactions in land surface models, including detailed snow modeling for Gordon Gulch and Como Creek.

Former post-docs Miriam Duhnforth and Becca Barnes published in the year (D?hnforth and Anderson, 2011, Arctic, Antarctic and Alpine Research 43 (4): 527-542.; D?hnforth et al., 2012, J Geophysical Res.; Barnes et al., 2012, Journal of Geophysical Research- Biogeosciences 117, G01014, doi:10.1029/2011JG001749). Post-doc Carmen Portillo worked with Noah Fierer to produce a publication on microbes in streams based on samples collected and frozen in 2008-2009: Portillo et al., 2012, Environmental Microbiology, doi:10.1111/j.1462-2920.2012.02785.x

Keck Undergraduate researchers

Three undergraduates were in the Keck program in 2011, and eight students participated in 2012. They conduct field research for one month in the summer under the supervision of David Dethier and Will Ouimet, and produce senior theses or senior projects with materials from the summer during the schoolyear. 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 :
Jacob Coate May 2010-June 2012
Chris Heckman March 2011-present (working on senior thesis based on sampling springs in Gordon Gulch)
Theresa O?Halloran May 2011-April-2012.
Andy Safalko May 2011-present
Joel Jones May 2011-present
Clayton Jensen May 2012-present
Kara Epple Summer 2012 intern
Michael Larson Summer 2012 intern
Scott Campbell Summer 2012 intern

Other Undergraduate students
Ben Hoffman (Lewis and Clark College undergrad, summer 2011, 2012; left data and draft of manuscript on trees and sediment transport)
Angel Torrens-Bonano, RESESS intern from University of Puerto Rico, worked with Anne Sheehan.
Breanna Skeets, RESESS intern from Lawrence University, summer 2011, 2012, worked with Holly Barnard. Currently working as Research Assistant with Barnard.

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
Year 5: 1 Sept 2011-31 August 2012

This year saw significant efforts to augment and to modify our outreach program. Activities included significant enhancement of our partnership with Science Discovery under its new leadership, and production of an instructional video to serve as an introduction to critical zone science in the Boulder Creek CZO.

Science Discovery:
In 2011-12, we developed ?Earth System Science: Exploring Change in the Critical Zone?, a middle school experiential science workshop for the long-running Science Explorers program. It featured 3 new modules on fires and erosion, on watersheds and snow, and on landscape evolution. Each module was built around hands-on activities (eroding landscapes with rain and shaved ice in a stream table, measuring infiltration and erosion on burned and unburned soils, deciphering layers in snow tubes, playing a water balance game on a giant watershed map). Science Discovery?s Eric Carpenter developed the curriculum, with help from CZO graduate students Rachel Gabor and Melissa Foster.
See http://sciencediscovery.colorado.edu/class/czo_workshop/.
The lesson plans and curriculum developed for this workshop are available online, along with short videos that demonstrate setting up materials for the modules (such as building snow tubes).

See http://sciencediscovery.colorado.edu/resources/lesson-plans/czo-workshop/.
We ran 9 day-long workshops, 2 professional development programs, 3 summer and day camp programs for K-12 students, and 5 outreach events over the year. All told, these reached more than 3300 people, of which >2000 were K-12 students, with estimated 50% from underrepresented groups.

Armed with this experience, Science Discovery?s Eric Carpenter represented Boulder Creek CZO at the Critical Zone Observatories booth in the USA Science and Engineering Festival, held in Washington, DC in April 2012. Eric brought the stream table exercise we created for Science Explorers to this outreach event, and drew throngs of kids into the booth all day with his infectious enthusiasm and the chance to experiment with mud and water.

Videos:
We worked with Vantage Point Media to produce several video segments that introduce the Boulder Creek CZO. These videos on now available on our website: http://czo.colorado.edu/mm/boulderCZO/vIntro.shtml.

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

Product Type:

Audio or video products

Product Description:

Short videos on the Boulder Creek Critical Zone Observatory

Sharing Information:

Served on our website: http://czo.colorado.edu/mm/boulderCZO/vIntro.shtml

Product Type:

Software (or netware)

Product Description:

Google Earth interface for data discovery: Find instrument locations and sample collection points via Google Earth, and connect to the data available from that location.

Sharing Information:

Find the interface on our website data page as "data by location": http://czo.colorado.edu/geGIS/ge_data_v120127.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:

Our infrastructure has drawn the attention of DOE scientists interested in developing models that work from genome to watershed scale. We have discussed ways to collaborate with them as we move forward.

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 32 undergraduates from across the country have participated in the Keck Project during the five years of this project. Of these, 14 are in graduate school, in broadly defined geoscience disciplines, 7 are in consulting firms, 1 is teaching Earth science at the secondary level, and 9 are still undergraduate students. One did not complete the program.

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. One student changed her trajectory from policy to field research as a result of this class. Another is now working on a senior honors thesis on

hydrology and planning to apply to graduate programs in engineering or hydrology.

Our on-line videos, Google earth maps, and other resources are being used in at least one university class. Dr. Arjun Heimsath at Arizona State University wrote the following: Your videos (and site materials) are truly terrific! What a great community resource and my [Earth?s critical zone] class is getting special enjoyment from watching bits and pieces of these to supplement our course material.

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).

We have hosted 3 RESESS interns (Fernando MartinezTorres, Breanna Skeets, Angel Torrens-Bonano).

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 in charge of our field operations, and oversees a group of undergraduate assistants, maintains instrumentation, and is a resource to other research teams on GPS data reduction, snow surveys, Campbell Scientific data loggers, and other aspects of field research.

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. We are beginning to amass a collection of photographs from exotic locations of these students with signs reading ?CZO 4 Life?.

Contributions to Resources for Research and Education:

We augmented the meteorological instrumentation of the Niwot LTER Green Lakes Valley site, and added soil instrumentation (moisture, temperature, hydraulic head, and soil water samplers) to this heavily studied valley. We installed a time-lapse camera in Green Lakes Valley for documenting changes in snow conditions on a daily basis.

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, Colin Millar.

The LiDAR data and its documentation is a resource that is now available for all to use to analyze topography, snow distribution, ecosystem structure and the like.

Our web resources and data distribution system for the Boulder Creek CZO are easy to use and informative.

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

New Findings Year 5- Sept 2011-Aug 2012
Boulder Creek Critical Zone Observatory

Geomorphology

-The Tucker and van der Beek (2012) model of post-orogenic landscape evolution suggests that alteration between basin sedimentation and basin erosion require asymmetric changes in erosional efficiency between range and foreland, which may be of climatic or lithologic origin. Broad wavelength foreland-downward tilting does not appear to be a viable mechanism for sedimentation, though it would be consistent with erosion, as has been proposed in the literature. The simple mathematical framework sets the stage for developing more detailed landscape evolution models and using these to test the viability of different hypotheses.

-The Anderson et al. (in press) model of landscape evolution driven by frost processes produced striking aspect differences in weathering depth and sediment transport efficiency. The model is novel in that it attempts to capture for the first time a self-consistent set of processes involved in hillslope evolution. These include damage to the underlying rock as it is exhumed, entrainment of weathered rock into mobile regolithm that depends upon the state of damage, and the subsequent transport of mobile regolith. The model was run for conditions meant to mimic those to which landscapes like Gordon Gulch have been subjected. For the temperature cycles run, and slope aspects given, the model produced deeper weathering and greater transport efficiency on N-facing slopes. This result mirrors the deeper weathering we have measured on N-facing slopes in Gordon Gulch. It is intriguing that frost processes alone can produce the critical zone architecture we have observed.

- Modeling and measurements of water dynamics in the vadose zone characterized by mobile regolith carpet overlying a fractured bedrock shows significant variation with slope aspect (Langston et al., in review.). Saprolite on north-facing slopes stays significantly wetter for a larger fraction of the year than on south-facing counterparts, demonstrating the importance of the contrasting snow dynamics on opposing slopes in this setting.

-Langston's CHILD model runs start with a landscape with lithology contrast (resistant rock, e.g. crystalline, in a domain adjacent to erodible rock, e.g. soft sediments) under 1.5 Ma steady forcing, which produces a range/basin topography similar to the Front Range. She then varies the hillslope diffusivity in the range, and finds that when hillslope diffusivity in the range is low, rivers flowing from the range begin incising in the adjacent basin. When hillslope diffusivity in the range is high, rivers switch to deposition in the basin.

-Table Mountain, a fluvial terrace previously thought to be a Rocky Flats (>1.5 Ma) correlative on the Plains, dates around 90 ka from ^{10}Be (both in situ and meteoric) (Duhnforth et al., 2012). This is one of the first times that both in situ and meteoric ^{10}Be have been employed to date a single surface. Verdos surface on the High Plains, previously thought to be ~640 ka, yields ^{10}Be dates of ~170 ka. Together, these

cosmogenic radionuclide dates on abandoned alluvial surfaces on the High Plains adjacent to the mountain front point to non-steady incision or downcutting by Boulder Creek and its tributaries. 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. The tie to the variation in the rates of critical zone processes in the crystalline Front Range bears directly upon the long-term climate-modulated variations in these processes, and demonstrates their relevance to the basic topography of the western edge of the High Plains. These results are now published in detail in Duhnforth et al. (2012). This finding informs both the process models of Anderson et al. (Earth Surface Processes and Landforms, in press), and the CHILD landscape modeling efforts of Langston, both of which explore how climate change may alter the sediment production and sediment flux from a mountain range to its adjacent basin.

-Rock strength varies significantly between rock cores extracted from outcrops and from weathered rock beneath mobile regolith. The weathered rock beneath mobile regolith is weaker in tension than is rock from outcrops. Rock from north-facing slopes is significantly weaker than rock from south-facing slopes. No correlation was found between rock strength variations and rock chemistry. These results suggest that conditions that control water and temperature, both of which vary significantly with slope aspect and soil cover, control the mechanical degradation of the rock. The work is published in the MA thesis of Patrick Kelly.

-Trees can play important roles as geomorphic agents in the landscape. The root mounds around ponderosa trees demonstrate that growth of roots within the mobile regolith can serve to transport soil downslope at rates that are significant. Trees do not have to fall over to perform geomorphic work.

Hydrology

-Vadose Zone Dynamics: Evidence for Aspect Control on Water Recharge and Saprolite Weathering. Soil moisture and matric potential data from Gordon Gulch and Betasso show a surprisingly large difference in the timing of snow-melt water input, and in the resulting moisture content and pattern between pole-facing and equator-facing slopes. In Gordon Gulch, which sits near the rain-snow transition, snow-melt on north-facing slopes tends to occur in a single, prolonged spring melt. By contrast, melt on south-facing slopes is intermittent throughout winter and early spring. Soil moisture data, together with calculations with a numerical vadose-dynamics model, show that this difference in timing leads to substantial differences in total moisture. Sustained melt on north-facing slopes allows water to be driven relatively deeply. Intermittent melt in south-facing slopes tends to reside at higher levels in soil, where it is prone to evapotranspiration. Model calculations suggest roughly a factor of two difference in evapotranspiration between north- and south-facing slopes. These findings suggest the hypothesis that the observed

thicker soils and more intensely weathered rock on north-facing slopes results from greater water delivery and enhanced weathering rates on these slopes.

-Runoff production in Gordon Gulch watershed, located in the marginal snow pack, can be out of synchrony with the seasonal snow pack at higher altitudes. Annual discharge peak and total annual discharge in Gordon Gulch (marginal snow pack) were high in 2010, an average snow pack year in the alpine, but were low in 2011, an exceptionally high snow pack year in the alpine. (Presented by S.P. Anderson at Goldschmidt, 2012).

-Runoff production in 2012 was exceptionally low during snowmelt season in all watersheds in the Front Range, but turned around during rainstorms in July. The annual peak discharge occurred in response to rain, rather than snowmelt, in all streams.

Geophysics

Shallow Subsurface Electrical Conductivity Survey of Betasso Watershed: Surveys of the shallow subsurface in Betasso were conducted using an EM-31 conductivity meter that has high horizontal resolution (~3.5m), and vertical resolution of ~6 m. In this study, we examine whether subsurface conductivity is higher in areas of steeper slopes or varies with slope aspect. Conductivity in subsurface sediments could be expected to be greater in gently sloping areas versus steeply sloping areas because water and clay sediments tend to accumulate in topographic lows and to be washed away from steeper slopes. We might also expect conductivity to be greater on north-facing slopes, where vegetation tends to be more abundant. We created a map of the electrical conductivity of part of Betasso watershed by contouring ~2,900 EM-31 data points. We created slope steepness and aspect maps using a 1m resolution DEM obtained from LiDAR that was collected as a part of the Boulder Critical Zone Observatory project, using GIS. We correlated the conductivity map with the slope and aspect using data from areas were both kinds of data were available. Results shows that subsurface conductivity values were not correlated with slope or aspect. It may be that the EM-31 measurements average conductivity at a depth that is much greater than the depth to which clays and water accumulate in the soil, and that only conductivity values closer to the surface actually vary with slope or aspect. Variations in the EM-31 data may therefore be more strongly controlled by depth to bedrock. Combining the EM-31 data with DC resistivity measurements shows promise for creating a map of depth to bedrock, which will have significance for geomorphic studies on bedrock weathering and for environmental hydrogeology studies.

Wildfire

In the first year after a wildfire, differences in discharge, turbidity, and dissolved organic carbon at sites upstream and downstream from a burned area during spring snowmelt and low-intensity storms were minimal. However, high-intensity convective storms resulted in dramatic increases in these parameters at sites downstream from the burned area.

Elevated nutrient export from the burned area was observed during both spring snowmelt and summer convective storms, which increased the primary productivity of stream biofilms.

During and after high-intensity thunderstorms, turbidity, dissolved organic carbon, nitrate, and some metals increased by 1 to 4 orders of magnitude, which could pose problems for water-supply reservoirs, drinking-water treatment plants, and downstream aquatic ecosystems.

New Publications

Anderson, S.P., Anderson, R.S., **Hinckley, E.S., *Kelly, P., and **Blum, A.E**. (2011): Exploring weathering and regolith transport controls on critical zone development with models and natural experiments. *Applied Geochemistry* 26(S1): S3-S5.

*Befus, K.M., **Sheehan, A.F., Leopold, M., Anderson, S.P**., and **Anderson, R.S.** (2011): Seismic constraints on critical zone architecture, Boulder Creek Watershed, Colorado. *Vadose Zone Journal* 10: 915-927.

Brantley, S.L., Megonigal, J.P., Scatena, F.N., Balogh-Brunstad, Z., **Barnes, R.T., Bruns, M.A., Van Cappellen, P., Dontsova, K., Hartnett, H.E., Hartshorn, A.S., Heimsath, A., Herndon, E., Jin, L., Keller, C.K., Leake, J.R., McDowell, W.H., Meinzer, F.C., Mozdzer, T.J., Petsch, S, Pett-Ridge, J., Pregitzer, K.S., Raymond, P.A., Riebe, C.S., Shumaker, K., Sutton-Grier, A., Walter, R., and Yoo, K. (2011): Twelve testable hypotheses on the geobiology of weathering. *Geobiology* 9(2): 140-165, doi: 10.1111/j.1472-466902010.00264.x.

*Cullis JDS (2011): Shear resistance of the nuisance diatom *Didymosphenia geminate*. *Colorado Water* 28(2): 5-8.

Dethier, D.P. and Bove, D.J. (2011): Mineralogic and Geochemical Changes from Alteration of Granitic Rocks, Boulder Creek Catchment, Colorado. *Vadose Zone Journal* 10: 858-866.

*Dühnforth, M., and **Anderson, R.S.** (2011): Reconstructing the glacial history of Green Lakes Valley, North Boulder Creek, Colorado Front Range. *Arctic, Antarctic, and Alpine Research* 43 (4): 527-542.

*Langston, A.L., **Tucker, G.E., Anderson, R.S.,** and **Anderson, S.P**. (2011): Exploring Links between Vadose Zone Hydrology and Chemical Weathering in the Boulder Creek Critical Zone Observatory. *Applied Geochemistry* 26(S1): S70-S71.

LeDee, O., R.T **Barnes, R.E. Emanuel, P.B. Fisher, S.K. Henkel, and J.R. Marlon (2011): Training a "New Scientist" to Meet the Challenges of a Changing Environment. *EOS, Trans. AGU* 92 (16): doi:10.1029/2011EO160002.

Leopold, M., Voelkel, J., Dethier, D., Huber, J. & Steffems, M. (2011): Characteristics of a palaeosol and its implications for the Critical Zone development, Rocky Mountain Front Range of Colorado, USA. *Applied Geochemistry* 26(S1): S72-S75.

Murphy, S.F., and Writer, J.H. (2011): Evaluating the effects of wildfire on stream processes in a Colorado front range watershed, USA. *Applied Geochemistry* 26 (S1): S363-S364.

Voelkel, J., Huber, J. & **Leopold, M.,** (2011): Significance of slope sediments layering on physical characteristics and interflow within the Critical Zone – Examples from the Colorado Front Range, USA. *Applied Geochemistry* 26(S1): S143-S145.

Williams, M.W., **Barnes, R.T., *Parman, J.N., Freppez, M., and Hood, E.W. (2011): Stream water chemistry along an elevation gradient from the Continental Divide to the Foothills of the Rocky Mountains. *Vadose Zone Journal* 10: 900-919.

Bates, S.T., W.A. Walters, R. Knight, **N. Fierer**. 2012. A preliminary survey of lichen associated eukaryotes using pyrosequencing. *The Lichenologist*. 44(1): 137-146.

**Barnes, R.T., R.L. Smith, & G.R. Aiken (2012): Linkages between denitrification and organic matter quality, Boulder Creek Watershed, CO. *Journal of Geophysical Research- Biogeosciences* 117, G01014, doi:10.1029/2011JG001749.

Jepsen, S.M., **N. P. Molotch**, **M.W. Williams**, K.E. Rittger, J.O. Sickman (2012): Interannual variability of snowmelt in the Sierra Nevada and Rocky Mountains, USA: Examples from two alpine watersheds, *Water Resources Research* 48, W02529, doi:10.1029/2011WR011006.

*Dühnforth, M., **Anderson, R.S.,** Ward, D.J., and **Blum, A.E.** (2012) Unsteady late Pleistocene incision of streams bounding the Colorado Front Range from measurements of meteoric and in situ ^{10}Be. *JGR- Earth Surface*.

*Eilers, K.G., S. Debenport**, S.P. Anderson, N. Fierer** (2012): Digging deeper to find unique microbial communities: the strong effect of depth on the structure of bacterial and archaeal communities. *Soil Biology & Biochemistry* 50: 58-65.

*Cullis J.D.S., Gillis C-A, Bothwell M.L, Kilroy C, Packman A. and Hassan M. (2012): A conceptual model for the blooming behavior and persistence of the benthic mat-forming diatom *Didymosphenia geminata* in oligotrophic streams, *JGR-Biogeosciences* 117, G00N03, 11 pp, doi:10.1029/2011JG001891.

Portillo, MC, **Anderson, SP**, and **Fierer, N** (2012): Temporal variability in the diversity and composition of stream bacterioplankton communities. *Environmental Microbiology*, doi:10.1111/j.1462-2920.2012.02785.x.

Murphy, S.F., McCleskey, R.B., and Writer J.W., 2012, Effects of flow regime on stream turbidity and suspended solids after wildfire, Colorado Front Range. In *Wildfire and Water Quality: Processes, Impacts and Challenges*, Proceedings of a conference held in Banff, Canada, 11-14 June 2012, International Association of Hydrological Sciences Publ. 354.

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McCleskey, R.B., Writer, J.H., and **Murphy, S.F**., 2012, Water chemistry of surface waters affected by the Fourmile Canyon wildfire, Colorado, 2010-2011: *U.S. Geological Survey Open-File Report 2012-1104*, 11 p.

Writer, J.H. and **Murphy, S.F**., 2012, Wildfire Effects on Source-Water Quality—Lessons from Fourmile Canyon Fire, Colorado, and Implications for Drinking-Water Treatment*: U.S. Geological Survey Fact Sheet* 2012–3095, 4 p.

Dethier, David P., Birkeland, Peter W., and †McCarthy, James A. (2012) Using the accumulation of CBD-extractable iron and clay content to estimate soil age on stable surfaces and nearby slopes, Front Range, Colorado. *Geomorphology 173-174*: 17-29.

Tucker, GE, and van der Beek, P (2012) A simple model for post-orogenic decay of a range and its basin. *Basin Research*, 12: 1-19, doi:10.1111/j.1365-2117.2012.00559.x.

Anderson, S.P. (2012): How deep and how steady is the Earth's surface? *Geology*, 40 (9): 863-864, doi:10.1130/focus092012.1.

Hinckley, E.-L., Ebel, B.A., **Barnes, R.T., **Anderson, R.S., Williams, M.W., and **Anderson, S.P**.: Aspect control of water movement on hillslopes near the rain-snow

transition of the Colorado Front Range, U.S.A.. *Hydrological Processes*. DOI: 10.1002/hyp.9549 In press.

Anderson, R.S., Anderson, S.P., and **Tucker, G.E**.: Rock damage and regolith transport by frost: An example of climate modulation of critical zone geomorphology. *Earth Surface Processes and Landforms*, special issue on the deep critical zone. In press.

Anderson, R. S., *Dühnforth, M., Colgan, W. and Anderson, L. (in press) Far-flung moraines: Exploring the feedback of glacial erosion on the evolution of glacier length, *Geomorphology*

Perdrial, J.N., N. Perdrial, A. Harpold, X. Gao, *R.S. Gabor, K. LaShaar and J. Chorover (2012): Sampling soil organic matter with passive capillary wicks and aqueous soil extraction. *Soil Science Society of America Journal* (in press)

*Gabor, RS., A Baker, **DM McKnight**, *MP Miller. Fluorescence Indices and their Interpretation. *Aquatic Organic Matter Fluorescence*, Cambridge University Press (In Press).

In review

Anderson, S.P., Anderson, R.S., and Tucker, G.E.: Landscape scale linkages in critcal zone evolution, *Comptes Rendus Geosciences de l'Académie des Sciences*

*Cullis J.D.S., **McKnight D.M.** and Pitlick J. (in review): The role of spatial variation in bed disturbance in maintaining patch dynamics at the reach scale in streams impacted by *Didymosphenia geminata*, *JGR-Earth Surface*

*Cullis J.D.S., Crimaldi J.P. and **McKnight D.M.** (in review): Shear removal function for the nuisance stalk forming diatom *Didymosphenia geminate*. *L&O: Environments and Fluids*.

Leopold, M., Völkel, J., Dethier, DP, & Williams, MW. (in revision): Changing mountain permafrost 1970s and today – comparing two examples from the Niwot Ridge, Colorado Front Range, USA. *Annals of Geomorphology*.

Leopold, M., Völkel, J., Huber, J., and Dethier, DP (in revision): Subsurface Architecture of the Boulder Creek Critical Zone Observatory from Electrical Resistivity Tomography. *Earth Surface Processes and Landforms*, special issue on the deep critical zone.

Langston, A.L., Tucker, G.E., Anderson, R.S., and Anderson, S.P. (in review): Evidence for climatic and hillslope-aspect controls on vadose zone moisture and saprolite weathering. *Water Resources Research.*

Theses Completed

Eilers, Kathryn (2011): *Landscape-scale variation in soil microbial communities across a forested watershed*. MA Thesis, Ecology and Evolutionary Biology, University of Colorado, Boulder.

Cullis, James (2011): *Removal of benthic algae in swift flowing streams: The significance of spatial and temporal variation in shear stress and the potential for bed disturbance*. PhD dissertation, CAE Engineering, University of Colorado, Boulder.

Kelly, Patrick (2012): *Subsurface evolution: Characterizing physical and geochemical weathering in bedrock of Gordon Gulch, Boulder Creek Critical Zone Observatory*, M.A thesis, Dept. of Geography, University of Colorado.

Project Activities, Year 5 Sept 2011-August 2012
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.

Geomorphology
Deep Time History of the BCCZO One of our interests has been in understanding more clearly the geomorphic evolution of the Colorado Front Range, because that evolution is strongly reflected in the topography and environmental conditions of the Boulder Creek CZO. The Front Range's history reaches back to the early Cenozoic, when it was an actively growing structure. Since approximately 40 million years ago, the range --- like the other Laramide ranges --- appears to have been inactive as a compressional, fault-bounded structure. Nonetheless, the Front Range has had a rich history even in its "post orogenic" state, with a widespread episode of fluvial sedimentation during the Miocene period (the famous Ogallala gravels, which extend from South Dakota to Texas), and a switch to exhumation, relief growth, and canyon cutting (including the incision of Boulder Canyon) in the Plio-Pleistocene. To help frame and quantify the general problem of post-orogenic landscape evolution, we developed a simple mathematical model and used it to identify the necessary and sufficient conditions for alternation between basin sedimentation and basin erosion in the post-orogenic phase (Tucker and van der Beek, 2012).

Climate change and landscape evolution Understanding the impact of climate change on landscape evolution has been addressed through two different modeling efforts. Bob Anderson, Suzanne Anderson, and Greg Tucker explored climate-driven landscape evolution on glacial-interglacial timescales. They focused on two explicit frost-driven processes, frost cracking that fractures rock and frost creep that transports sediment downslope. First, they developed a new model of frost cracking of rock that uses constraints based on temperature, presence of unfrozen parts of the critical zone (to supply water), and distance from potential water supply sources to site of frost cracking. The result is a more realistic parameterization of frost cracking rate profiles, driven by surface temperature fluctuations. This rock-damage model was then coupled to a temperature controlled frost creep model, and run on two different slope aspects for a climate cycling between glacial and interglacial temperature conditions. These climate-driven geomorphic models (as opposed to the more prevalent topography driven models) are presented in Anderson et al. (in press) Earth Surface Processes and Landforms. The

second modeling effort was undertaken by graduate student Abby Langston (with Greg Tucker). She used the CHILD model to explore the impact of changing hillslope diffusivity values on glacial-interglacial timescales on erosion and deposition in a range-basin pair. The diffusivity is a measure of the efficiency of sediment production and transport, and is therefore a general measure of process switches with climate change. In this approach, the impacts of climate change are implicit in the choice of the value of the diffusivity parameter, rather than explicitly determined. Langston was trying to explore the conditions that lead to switching from fluvial incision to fluvial deposition (and terrace planation) that marks the evolution of the Plains.

Mobile regolith production and transport: Rock strength was measured by graduate student Patrick Kelly (with Suzanne Anderson) to characterize rock weathering prior to its incorporation in the mobile regolith. Samples came from 10 bedrock cores collected with a portable coring device, and the results formed the basis of Pat's MA thesis. Rock strength and core recovery data were supplemented with geochemical analyses of the cores as well. A small study on the influence of trees on mobile regolith transport was conducted by Lewis and Clarke undergraduate student Ben Hoffman. He measured and modeled topographic disturbance (mounds) around trees on different slope aspects and for two different species (lodgepole—*Pinus contorta*, and ponderosa—*Pinus ponderosa*). This is now being worked up for publication.

Chronology: CRN analysis (in situ and meteoric ^{10}Be) of samples from Gordon Gulch has been completed by graduate student Melissa Foster (with R.S. Anderson). Their sampling program is complementary to that of Will Ouimet and David Dethier in Gordon Gulch.

-Fluvial terraces on the Plains have been sampled by graduate student Melissa Foster (with R.S. Anderson and USGS colleague Shannon Mahan) for optically stimulated luminescence (OSL) dates to fill in chronology of terrace abandonment and fluvial incision. Foster has focused on terraces she expects to be less than 100 ka. Where exposures warranted it, she generated full soil descriptions.

Geomorphic Instrumentation: Graduate student Andrew Wickert built Arduino-based dataloggers for four new installations in Gordon Gulch. Although the Arduino-based dataloggers are inexpensive to build, and simple in theory, the reality is that they have been plagued with challenges ranging from programming to power consumption to wiring problems. In this case, the work was a side-project for a student interested and talented in electronics and programming. We may have success with version 2 of these dataloggers, but it is unclear whether that will happen before Andy graduates. We are evaluating whether to replace the Arduino-based data loggers with commercial dataloggers or trying to find another electrical engineer. The instrumentation packages associated with these data loggers includes temperature sensors that extend up to 1.2 m below the surface, heave sensors, volumetric water content, soil matric potential sensors. These packages were intended to measure parameters relevant to frost creep and frost cracking.

Hydrology

Vadose Zone Dynamics: Creation of the saprolite that composes much of the critical zone requires delivery of water to the subsurface. Graduate student Abby Langston (with Greg Tucker) investigated the timing and magnitude of water delivery in the BCCZO by collecting data on soil moisture, saprolite moisture, water potential, and snow depth in the Gordon Gulch and Betasso catchments. She also ran 2D vadose zone models to test different scenarios of water input rates on water delivery to the weathering front.

Snow: A snow sensor array from Niwot Ridge to Betasso consisting of 56 automated sensors (35 owned by LTER, and 21 owned by CZO) was operational starting in early 2010, winter 2011, and will be emplaced for winter 2012 in October. CZO augments data from these sensors by manually read (weekly) snow poles in two transects (20 poles), and by 4 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 photo record in Green Lakes Valley and the manual snow pole both started in 2008. Automated snow sensors are co-located with soil moisture sensors. The data from automated sensors is processed by Leanne Lestak each year. Post-doc Adrian Harpold (working with Noah Molotch) is now assembling the full data sets to use in his project.

Subsurface Instrumentation: At Gordon Gulch, we installed two new profiles with Decagon matric potential, volumetric water content, and electrical conductivity sensors, with the deepest sensors inserted into saprolite. These two sites are logged with Decagon dataloggers (rather than the Arduino-based dataloggers described above). These are intended to provide data to constrain hydrologic models of water flow through mobile regolith into saprolite.

-We now have data over two snowmelt and summer seasons on water table height in six wells in Gordon Gulch (January 2011-present). The wells were sampled approximately weekly in 2011; on the basis of that data the sampling program was reduced to monthly in 2012.

-Undergraduate Chris Heckman initiated a campaign to sample water from springs in Gordon Gulch, with first collections in spring 2011, and much more widespread collections in spring 2012. He will use data from these for a senior honors thesis.

-Suzanne Anderson conducted a campaign to collect soil water samples from lysimeters in Gordon Gulch in fall 2011 following early season snow events. Graduate student Joe Mills plans to continue the campaign in winter 2012. Collecting samples from the array of samplers takes a full day in the field.

-Two met towers were installed in Gordon Gulch in early summer 2012. These 2 m towers measure air temperature, relative humidity, precipitation, radiation, and wind speed. One tower is on a S-facing slope, in the open between large ponderosa pines, and the other is under canopy of lodgepole pines on a N-facing slope.

Wildfire

CZO worked with USGS to establish a set of 4 stream gauges in Fourmile Creek in the aftermath of the Fourmile Canyon wildfire (Sept 2010). ISCO samplers and manual sampling of water for sediment and nutrient analyses were conducted in summer 2011 and have been continued in 2012.

Biogeochemistry

- 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, and one-time sampling of soil profiles allow analysis of spatial and temporal variability of the quality of organic matter on slopes and in streams. Gabor collaborated with scientists from Jemez-Santa Catalina CZO on a manuscript (Perdrial et al., in press) on methods of leaching organic matter from soils.

Microbial Ecology

-Post-doc Maria del Carmen Portillo and Noah Fierer published a paper on microbial populations in free-flowing stream and spring samples from 2008-2009.

Geophysics

- The team from the Technische Universität München (Völkel and Leopold) were present for a field season in summer 2012. They worked with a Keck undergraduate student on locations of permafrost on Niwot Ridge.

-Anne Sheehan supervised a team of undergraduate students, including RESESS intern Angel Torrens-Bonano, on an electrical resistivity survey of Betasso.

Weathering and geochemistry

-David Dethier, working with undergraduate James McCarthy, analyzed dithionate extractable Fe and clay contents of soils in stable locations in Boulder Creek headwaters, as well as in soils on hillslopes. The data can be used to construct a residence time for materials in the weathering zone. They published results: Dethier et al., 2012, *Geomorphology*.

-S.P. Anderson took samples of Boulder Creek granodiorite from Betasso to France for U-series isotope analysis with François Chabaux at University of Strasbourg. The data will be used to assess chemical weathering rates, and will be compared with denudation rates deduced with planned 10Be analyses in the same profile.

-S.P. Anderson with grad student Joe Mills 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, which we must understand before we can analyze weathering processes and their spatial and temporal variation. The samples to be used in

this analysis include those from the groundwater wells, stream water, spring waters and soil waters from sites in Gordon Gulch.

Spatial analysis

-LiDAR data was acquired in 2010 from 600km^2 of Boulder Creek watershed in May (snow-on) and August (snow off). The snow-off data was made available on our website soon after the processed data arrived from NCALM, and was made available on OpenTopography in March 2012 (along with full metadata descriptions, and added value data). Holly Barnard and undergraduate Breanna Skeets analyzed raw point clouds for tree height distributions based upon differences between first and last returns.
The snow-on data took much more post-processing and work with NCALM to produce a useful product. The data was acquired over a period of 1 month, during which time the snowcover changed considerably. GIS specialists Eric Parrish and Leanne Lestak worked with NCALM to come up with a way to break data into sets collected over short time periods, and to include date of acquisition as an important component of the metadata. The snow-on data was made available through OpenTopography in September 2012, after these issues were resolved.

-Technician Eric Parrish created a new Google maps interface to see where instrumentation and sampling locations are located. The interface also links to our database, so it is now possible to search for data by location. See http://czo.colorado.edu/geGIS/ge_data_v120127.shtml.

Undergraduate researchers in Keck Geology Program

Eight undergraduate researchers participated in the one-month summer field season with the Keck Geology Program in 2012, under the supervision of David Dethier (Williams) and Will Ouimet (Univ. Connecticut). Matthias Leopold mentored one student.

Last name,	First name	Home institution	Project title
Purinton	Ben	Wesleyan University	Post-wildfire erosion and sediment transport in Fourmile Canyon, Boulder County, CO
Lewis	Gabriel	Williams College	Using electrical resistivity tomography to study permafrost in the CZO
Boateng	Timothy	Amherst Collge	Using the Donath press and thin-section analysis to study how weathering weakens rock
Mondrach	Hannah	University of Connecticut	Short-term isotope analysis of hillslope transport, Colorado Front Range
Patton	Annette	Whitman College	Manganese (Mn) in soils and vegetation of the Boulder Creek Critical Zone, Colorado
Nesbitt	Ian	Williams College	Snowmelt hydrology of the Saddle and Martinelli snowfields, Green Lakes Valley, Front Range, CO
Corona	Claudia	Williams College	Geochemical response of two adjacent alpine streams, Green Lakes Valley, in a low snow year
Halcsik	Christopher	Beloit College	Mapping late Pleistocene and historic flood deposits along Caribou Creek, Colorado

Presentations at Conferences

In year 5, Boulder Creek CZO was represented at the following conferences:

American Chemical Society National Meeting 2011
American Geophysical Union Fall Meeting 2011
Ecological Society of America National Meeting 2011
Geological Society of America National Meeting 2011
Geological Society of America Rocky Mountain Section meeting 2012
German Geomorphological Society Annual Meeting 2011
French Academy of Sciences symposium "L'érosion : des mécanismes élémentaires aux conséquences géodynamiques", held 2012
European Geosciences Union meeting, 2012
V.M. Goldschmidt Conference 2012

Abstracts from these meetings:

Bold: BcCZO personnel; *Grad student or Post-doc; **NSF Post-doc; †Undergrad.

Murphy, S., and Writer, J. (2011):, Spatial and temporal variations in stream chemistry after wildfire. American Chemical Society National Meeting, Denver, Colorado, August 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. *AGU Chapman conference* on The Galápagos as a Laboratory for Earth Science, Puerto Ayora, Galápagos, Ecuador, July, 2011.

****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* annual meeting abstract.

Anderson, Robert S., ***Dühnforth, Miriam**, Colgan, William and Anderson, Leif (2011): Far-flung moraines and ridge-capping tills: exploring the feedbacks of long-term alpine glacial landscape modification. *Geological Society of America Abstracts with Programs*, Vol. 43, No. 5, p. 216.

Dethier, D, †McCarthy, J.A., and Ouimet, W.B. (2011): Revisiting long-term dustfall rates and chemistry, Colorado Front Range. *Geological Society of America Abstracts with Programs*, Vol. 43, No. 5, p. 336.

†Skeets, B.A., and Barnard, H.R. (2011): Transpiration source water and geomorphological potential of root growth in the Boulder Creek Critical Zone Observatory, Colorado. *Geological Society of America Abstracts with Programs*, Vol. 43, No. 5, p.

Leopold, M., Vôlkel, J., and Dethier, D. (2011): Ein Sedimentarchiv aus der Rocky Mountains Front Range in Colorado, USA - Charakterisierung und mögliche klimatische Interpretationen. Book of abstracts. Annual meeting of the German Geomorphological Workgroup.

Anderson, R.S., Anderson, S.P., and Tucker, G.E. (2011): Of Rock Damage and the Regolith Conveyor Belt: A Geomorphologist's View of the Critical Zone. *Eos Trans. AGU* 92 (52), Fall Meeting Suppl., Abstract EP44B-02.

Byers, A., ****Harpold, A**., and **Barnard, H.R**. (2011): Ecohydrology of Lodgepole Pine Forests: Connecting Transpiration to Subsurface Flow Paths and Storage within a Subalpine Catchment, *Eos Trans. AGU* 92 (52), Fall Meeting Suppl., Abstract H33E-1366.

Cowie, R., **Williams, M.W**., Zeliff, M., and Parman, J. (2011) Hydrologic flowpaths and biogeochemical cycles in the subalpine Como Creek catchment, Colorado Front Range, USA, *Eos Trans. AGU* 92 (52), Fall Meeting Suppl., Abstract H13C-1220.

Driscoll, J.M., Meixner, T., **Molotch, N.P**., Sickman, J.O., **Williams, M.W**., McIntosh, J.C. and Brooks, P.D. (2011): Inverse Geochemical Reaction Path Modelling and the Impact of Climate Change on Hydrologic Structure in Snowmelt-Dominated Catchments in the Southwestern USA, *Eos Trans. AGU* 92 (52), Fall Meeting Suppl., Abstract H13C-1221.

***Foster, M.A., Anderson, R.S.,** *Duhnforth, M., and *Kelly, P.J. (2011): Constraining Regolith Production on a Hillslope Over Long Timescales: Interpreting In Situ ^{10}Be Concentrations on an Evolving Landscape, *Eos Trans. AGU* 92 (52), Fall Meeting Suppl., Abstract EP23C-0776.

***Kelly, P.J**., **Anderson, S.P., Anderson, R.S., Blum, A.E., *Foster, M.A**., and ***Langston, A.L**. (2011): Subsurface Evolution: Weathering and Mechanical Strength Reduction in Bedrock of Lower Gordon Gulch, Colorado Front Range. *Eos Trans. AGU* 92 (52), Fall Meeting Suppl., Abstract EP43C-0713.

***Langston, A.L**. **Tucker, G.E., Anderson, R.S.,** and **Anderson, S.P.** (2011): Turning rock into saprolite: Linking observations and models of vadose zone dynamics and chemical weathering. *Eos Trans. AGU* 92 (52), Fall Meeting Suppl., Abstract EP23C-0768.

Leopold, M., Vôlkel, J., and Dethier, D. (2011): Imaging the architecture of the Critical Zone at Boulder Creek Critical Zone Observatory, Rocky Mountains Front Range of Colorado, USA. *Eos Trans. AGU* 92 (52), Fall Meeting Suppl., Abstract H52A-05.

McKnight, D.M. Khan, A., Hohner, A., and Rosario, F. (2011): Climate Change and Nutrient Loading: Controls on Phytoplankton Growth and Dissolved Organic Matter Quality in Lakes in Colorado, *Eos Trans. AGU* 92 (52), Fall Meeting Suppl., Abstract H54A-08.

Molotch, N.P., Jepsen, S.M., **Williams, M.W**., Trujillo, E., Sickman, J.O., and Rittger, K.E. (2011): Snowmelt and the geological and ecological filters modulating climate variability and streamflow response, *Eos Trans. AGU* 92 (52), Fall Meeting Suppl., Abstract H24D-04.

Ouimet, W.B., **Dethier, D.P.,** Bierman, P.R., **†Wyshnytsky, C.,**and Rood, D.H. (2011): Unexpected Delivery of Meteoric ^{10}Be to Critical Zone Soils, Front Range, Colorado, *Eos Trans. AGU* 92 (52), Fall Meeting Suppl., Abstract EP52D-06.

†Skeets, B., **Barnard, H.R.,** Byers, A. (2011): Water uptake of trees in a montane forest catchment and the geomorphological potential of root growth in Boulder Creek Critical Zone Observatory, Rocky Mountains, Colorado, *Eos Trans. AGU* 92 (52), Fall Meeting Suppl., Abstract B21H-0366.

Van der Beek, P., and **Tucker, G.E.** (2011): A Simple Model for the Post-Orogenic Evolution of Mountain Ranges and Foreland Basins, *Eos Trans. AGU* 92 (52), Fall Meeting Suppl., Abstract EP41D-0637.

Vôlkel, J., **Leopold**, M., & Huber, J. (2011): Slope deposits of different genesis and ages in the Colorado Front Range (Rocky Mts.) and their significance for the relief and the interflow within the critical zone. *Eos Trans. AGU* 92 (52), Fall Meeting Suppl., Abstract EP21C-0718

Whitenack, T, I. Zaslavsky, **MW Williams**, KA Lehnert, DG Tarboton, K Schreuders, A Aufdenkampe, E Mayorga (2011): Prototype cross-domain cyberinfrastructure for the Critical Zone Observatories. *Eos Trans. AGU* 92 (52), Fall Meeting Suppl., Abstract IN11C-1305.

Anderson, S.P., **Anderson, R.S**., and **Tucker, G.E**. (2012): Landscape scale linkages in critical zone evolution. French Academy of Sciences symposium "L'érosion : des mécanismes élémentaires aux conséquences géodynamiques", Paris, 26-27 March. (Invited)

Banwart, S.A., **Anderson, S.P**., Aufdenkampe, A.K., Bernasconi, S.M., Brantley, S.L., Chadwick, O.A., Chorover, J., Dietrich, W.E., Duffy, C.J., Gaillardet, J., Goldhaber, M.B., Lehnert, K.A., Nikolaidis, N.P., Ragnarsdottir, K.V., Sparks, D.L., and White, T.S. (2012):

An international initiative for critical zone observatories (CZO) and research along environmental gradients. *Eurosoil* 2012.

Anderson, S.P., **Anderson, R.S.,** *Kelly, P.J., **Tucker, G.E.,** and Wickert, A. (2012): Frost weathering: Climate control of regolith production and critical zone evolution. *Geophysical Research Abstracts* 14, EGU2012-.

Duhnforth, M., **Anderson, R.S**., Ward, D.J., and **Blum, A.E**. (2012): Unsteady late Pleistocene incision of streams bounding the Colorado Front Range from measurements of meteoric and in situ 10Be. Geological Society of America *Abstracts with Programs*, Vol. 44, No. 6, p. 31.

Anderson, S.P., *Mills, T.J., and *Gabor, R. (2012): Hydrochemistry of a variably snow-covered catchment. *Goldschmidt Conference, Mineralogical Magazine Suppl.* (Invited)

Presentations without published abstracts

Robert Anderson

"Glaciers and glacial landscapes: from natural to numerical experiments", U. Texas Austin February 2012

"Hillslope evolution in frost-dominated landscapes" U. Texas Austin February 2012

"Edges matter: erosion of landscapes by migration of edges", INSTAAR, CU Boulder, April 2012

Suzanne Anderson

CUAHSI (Consortium of Universities for the Advancement of Hydrologic Science, Inc) cyberseminar, "Boulder Creek CZO: Natural experiments to study Critical Zone evolution and function", October 25, 2011. http://www.cuahsi.org/sem-archive.html

Design of Global Environmental Gradient Experiments using International CZO Networks workshop. EU and NSF funded workshop. University of Delaware, Nov 7-9, 2011. (*Lead one of six breakout groups.*)

University of Strasbourg, LHyGeS seminar, "Boulder Creek CZO: Natural experiments to study Critical Zone evolution and function" April 5, 2012.

University of Texas, Austin, Oct 2012, to discuss CZO program.

Holly Barnard

Critical Zone Observatories in China, Wuhan, China, Sept 2012.

Noah Molotch

CUAHSI (Consortium of Universities for the Advancement of Hydrologic Science, Inc) cyberseminar, "Snowmelt as a Driver of Ecohydrological Processes: Low-hanging Fruit for Cross-CZO Research" April 6, 2012. http://www.cuahsi.org/sem-archive.html

Sheila Murphy

University of Colorado Environmental Engineering seminar, January 2012, "Fourmile Canyon wildfire: Effects on water quality and the aquatic ecosystem."

U.S. Geological Survey National Research Program seminar, December 2011, "Water quality of Fourmile Creek in the year after the Fourmile Canyon Fire: Preliminary results."

Meetings with local water providers on post-fire water quality of Fourmile Creek, February and October 2011.

Joerg Völkel

TERENO-Workshop 2012 of the Helmholtz Association of German Science Centers at Potsdam, Germany (24-25 January 2012). Völkel, J.: Concepts and Objectives of Critical Zone Observatories - Soils and Geomorphology as Crucial Parts (The BC-CZO Example, Colorado)

Bavarian Academy of Science, Commission for Geomorphology, Munich, Germany (9 February 2012), Völkel, J.: Concepts and Objectives of Critical Zone Observatories - Soils and Geomorphology as Crucial Parts (The BC-CZO Example, Colorado)

Proposals funded

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. $61582. 4/1/12-3/31/13.

NSF EAR-1239281 Boulder Creek Critical Zone Observatory Renewal: Weathered profile development in a rocky environment and its influence on watershed hydrology and biogeochemistry. PI: SP Anderson, Co-PI: RS Anderson, N Molotch, H Rajaram, GE Tucker. $1,000,000. 9/1/12-8/31/13.

Proposals submitted

NSF-IGERT: Interdisciplinary Modeling and Analysis for the Anthropocene. PI: James P. Syvitski, Co-PI: Bengt Fornberg, John Hauser, Elizabeth R. Jessup, Gregory E. Tucker (R.S. Anderson, S.P. Anderson among the senior personnel) $3,379,297. 7/1/13-6/30/18. (60 months)

NSF/BIO: Collaborative research: Geomorphic control of lowland tropical forest nitrogen cycle. PI: RS Anderson, collaborative with Alan Townsend, Stephen Porder and Cory Cleveland, $756,114, submitted September 2012.

NSF/EAR/GLD: Edges matter: the importance of edges and blocks in the evolution of landscapes. PI: RS Anderson, $297,000, submitted July 2012.

Wrote letters of support for the following proposals (Sept 2011-Aug 2012)*:*

Lou Derry, Cornell, proposal to NSF: "*A Cross Site Study of Silica Dynamics in the Critical Zone*". July 2012

Grit Steinhoefel, GFZ German Research Centre for Geosciences, Potsdam, proposal to DFG (German Research Foundation) "Identification of deep weathering processes in granitic bedrock using novel stable isotope systems". Field sites will be in Boulder Creek CZO and Grimselpass in the Swiss Alps. February 2012.

Brian Clarke and Doug Burbank, UC Santa Barbara, proposal to NSF: "Quantifying Near-Surface Patterns of Bedrock Fractures and Assessing Controls on Fracture Formation". January 2012. Funded.

Martyn Clark, NCAR, proposal titled "The fate of snow in complex terrain: Implications for water resources" submitted to the NSF Hydrological Sciences. November 2011.