

**Boulder Creek Critical Zone Observatory (BcCZO-II)**  
**Annual report, year 1 (2014)**

- i. **lists of CZO participants**, including postdoctoral fellows, and undergraduate and graduate students, and summary of any changes to prior approved personnel. Information will include demographic data and disciplinary background;

<b>First (Middle)</b>	<b>Last</b>	<b>Project role</b>	<b>Disciplinary background,</b>
Suzanne	Anderson	Principal Investigator	Geomorphology, weathering, hydrology
Greg	Tucker	Co-PI	Geomorphology, modeling
Harihar	Rajaram	Co-PI	Hydrology, reactive transport modeling
Robert	Anderson	Co-PI	Geomorphology, geochronology
Noah	Molotch	Co-PI	Snow hydrology
Holly	Barnard	Co-Investigator	Ecohydrology, forest evapotranspiration
Alex	Blum	Co-Investigator	Geochemistry and mineralogy
Daniel	Doak	Co-Investigator	Ecology, biological roles in transport processes
Noah	Fierer	Co-Investigator	Microbial ecology
Diane	McKnight	Co-Investigator	Biogeochemistry and organic matter
Sheila	Murphy	Co-Investigator	Fire, water, water quality
Anne	Sheehan	Co-Investigator	Applied geophysics
Kamini	Singha	Co-Investigator	Hydrogeology and geophysics
Alexis	Templeton	Co-Investigator	Geobiology and incipient weathering
Adrian	Harpold	Postdoctoral Fellow	Snow and hydrology; coordinator of cross-CZO graduate group
Christina	Zetterholm	Other Professional	Accounting technician for PI Anderson
Chad	Stoffel	Technician	IT support
Nathan	Rock	Technician	Field manager, sensor network and sampling
Colin	Millar	Technician	Lab manager, sampling and analysis
Wendy	Roth	Technician	Sediment lab coordinator
Chi	Yang	Technician	Data manager (leaving July 2014)
Jeri	Tebbetts	Technician	Data manager (started June 2014)
Eric	Parrish	Technician	GIS-graphics specialist
Eric	Carpenter	Other Professional	Education designer- K-12 outreach and teacher professional development
Hester	Nadel	Other Professional	Admin support for education outreach
Alex	Rose	Other Professional	Manager outreach Field science and Citizen science
Val	Sloan	Other Professional	Outreach communication & planning (REU proposal writing)
Rachel	Gabor	Graduate Student (RA)	Dissolved organic matter, contributions to K-12 outreach
Abigail	Langston	Graduate Student (RA)	Long-term landscape evolution, contributions to K-12 outreach
Melissa	Foster	Graduate Student (RA)	Soil geomorphology, mentor high school students
Taylor (Joe)	Mills	Graduate Student (RA)	Aqueous geochemistry, hydrology
Eric	Winchell	Graduate Student (RA)	Bio-geomorphic interactions
Sachin	Pandey	Graduate Student (RA)	Reactive transport modeling
Kristen	Medina	Technician	Field assistant

Kelley	Rich	Undergraduate Student	EnvS work study field assistant
Kelly	Gjestvang	Undergraduate Student	EnvS work study field assistant
Satya	Akquia	Undergraduate Student	Geog work study field assistant
Fiona	Maguire	Undergraduate Student	EBio work study field assistant
Kristina	Cowell	Undergraduate Student	Geog work study field assistant
Brett	Heithusen	Undergraduate Student	Geog work study field assistant
Michael	Johnson	Undergraduate Student	Temporary field/lab assistant
William (Ryan)	Currier	Undergraduate Student	Temporary field/lab assistant
James	Smith	Undergraduate Student	LSU field assistant for USGS
Devon	Theune	Undergraduate Student	Field assistant for USGS
Jorge	Marquez	REU Participant	REU student- research on landsliding
David	Schellhase	REU Participant	REU student- research on landsliding
Amanda	Brenner	REU Participant	REU student- research on bio-geomorphology
Scott	Anderson	Non-Student RA	Geomorphology, landsliding
Barbara	Monday	Other Professional	Managing RECCS REU program

### Changes to personnel:

- a) Data manager Chi Yang is moving to Singapore in July. She is being replaced by Jeri Tebbetts, who started in June. Ms. Tebbetts has a 2014 BA in Geology and 13 years experience in IT and database support, including two seasons at the South Pole, and stints doing ice-core lab work. Her first activity was to attend the CZO Integrated Data Management meeting in Delaware (late May 2014).
- b) Researcher Brian Ebel moved from CU to a position at Colorado School of Mines, and has tapered his involvement in CZO. We still invite him to meetings, but have taken him out of our budget for the present.
- c) Researcher Scott Anderson was hired for 1 month on a RAPID grant to work on landsliding from the September 2013 storms. We will support him at 50% level until August 2014, to complete manuscripts from the analysis he has done.

ii. **summary of status and results of research projects** supported by the CZO and undertaken by participants, including web links to abstracts, theses, publications, and reports and products;

*Note:* underlined and italicized section headings are taken from our proposal text.

Interface and Zone 1: Land Surface and Mobile Regolith R.S. Anderson, D. Doak, H. Barnard, N. Molotch, S. Murphy, A. Blum, G. Tucker, S.P. Anderson, D. McKnight, N. Fierer, A. Harpold

*Lumps and blocks: Patchiness in the landscape.* R.S Anderson produced a **paper** (Anderson, RS, *Geology*, in press) on the lumpy nature of glaciated valley floors, which reflects a combination of underlying fracture spacing and competing mechanisms of glacial erosion. He has explored a possible satellite site in Pikes Peak granite, in which the rock is more massive, more homogeneous, but in same climate as Boulder Creek. With non-CZO graduate students Andy Wickert and Katie Barnhart, he is deploying **instrumentation** for monitoring of permafrost dynamics along edge of Green Lakes Valley, on Niwot Ridge. These observations and data can inform the next version of a hillslope **numerical model** in development that acknowledges the role of discrete blocks in general hillslopes settings (not just glaciated). Anderson presented on this work at GSA Annual Meeting (Denver, CO, Oct 2013) and the 2<sup>nd</sup> Nordic Cosmogenic Workshop (Aarhus, Denmark, Jun 2014).

*Transport of mobile regolith: The roles of biology.* Both trees and gophers have been studied in the context of mobile regolith transport. Undergraduate researcher Ben Hoffman **published** his study of impacts of tree growth on hillslopes (Hoffman and Anderson, *Geology*, 2014). Graduate student Eric Winchell is working with Dan Doak and R.S. Anderson to **monitor** and **model** the gopher-meadow-forest system in the subalpine forests of Green Lakes valley. Winchell planted trees to measure herbivory, and has mapped decimeter scale topography over time to document locations of gopher burrowing and relationship to trees. The longitudinal study shows how these dynamics change over seasons. Winchell is planning to add soil temperature measurements to examine how thermal properties play a role in the system. Winchell **presented** the work at the GSA Annual Meeting (Denver, Oct 2013) and AGU Fall Meeting (San Francisco, Dec 2013).

*Surface Hydrology: Infiltration, runoff, and water balance.* We now have four complete water years of **monitoring** of snow, soil moisture, water table dynamics, and runoff in Gordon Gulch watershed through above-average, below average, and “normal” precipitation years. S.P. Anderson is analyzing these rich datasets to develop conceptual models of precipitation-runoff in this watershed. She has a **manuscript** in preparation for submission in summer 2014 (Anderson, SP et al, *Water Resources Research*, in prep). Anderson **presented** this work at the AGU Fall Meeting (San Francisco, Dec 2013).

*Snow in the BcCZO.* Noah Molotch, post-doc Adrian Harpold, and graduate student Theo Barnhart are exploring how changes in snowmelt timing, snowpack magnitude, and snowmelt intensity affect the partitioning of snowmelt between evapotranspiration and runoff. More specifically, they have used **observations** of snowmelt and evapotranspiration to investigate the sensitivity of evapotranspiration to the timing and intensity of snowmelt as well as to snowpack magnitude. They plan to use a **physically-based hydrologic model** to more explicitly explore how different ensembles of snowmelt timing, snowmelt intensity, and snowpack magnitude affect the partitioning of snowmelt between runoff and evapotranspiration. They plan to carry out this **modeling experiment** first at the Como Creek and Gordon Gulch catchments and then at progressively larger scales within Boulder Creek, CO. They are currently parameterizing the Regional Hydro-Ecologic Simulation System (RHESSys) for implementation in the Boulder Creek Watershed. Once that is complete they will compare the simulated estimates of snowpack, streamflow, and evapotranspiration to observations made as part of the CZO program. We will also be performing scenario analyses whereby we will explore the spatial variability in the various hydrologic fluxes and associated sensitivities to regional warming. Parts of this work are **published** (Harpold et al., *Water Resources Research*, 2014; Burns et al., *J. Hydrometeorology*, 2014), and some parts are **in press** (Trujillo and Molotch, *Water Resources Research*; Molotch, *AGU Monograph on Remote Sensing of the Terrestrial Water Cycle*), and four manuscripts are **in review** (Kirchner et al., *Hydrology and Earth System Science*; Livneh et al, *Water Resources Research*; Harpold et al., *Hydrological Processes*; Perrot et al., *Water Resources Research*). Molotch **presented** this work in two invited talks at the AGU Fall Meeting (San Francisco, Dec 2013) and the EGU General Assembly (Vienna, Austria, Apr-May, 2014).

*Forest Evapotranspiration (ET).* Holly Barnard worked with DOE-funded post-doc Erin Berryman to **analyze** soil respiration data collected in previous years. Graduate student Margaret Burns, also supervised by Diane McKnight, completed a **thesis** on soil water dissolved organic carbon and its transformations and connections to stream water DOC. Barnard and her group maintain **sap flow sensors** in 9 plots from Betasso, Gordon Gulch and Niwot Ridge. Barnard also supervised DOE-supported student Hallie Adams in a **thesis** on tree growth rates and water use efficiency in Gordon Gulch. Parts of this work are in review

(Barnard et al, *Hydrological Processes*). Burns **presented** her work at the AGU Fall Meeting (San Francisco, Dec 2013).

*The role of fire.* Sheila Murphy continues **monitoring** runoff and water quality in the aftermath of the 2010 Fourmile Canyon wildfire. The burned region was also within the highest rainfall regions hit with catastrophic rain in the millennial storm that affected the Front Range in September 2013. Murphy has **analyzed** discharge and precipitation records along Boulder Creek from that event, and has been called upon to present her findings in several **high-profile venues** on fires, floods, and climate change. She has a manuscript that will be **submitted** this summer (Murphy et al., *Nature Climate Change*). Her **presentations** include an invited talk at the Joint Aquatic Sciences Meeting (Portland, OR, May 2014), the Hydrologic Sciences Symposium (CU Boulder, Apr 2014), CIRES Climate Change Webinar (Boulder, CO, Nov 2013), UNAVCO Science seminar (Boulder, CO, Nov 2013), and the Geological Society of America Annual Meeting (Denver, 2013).

*Unanticipated opportunities from the September 2013 storm.* Some of the most exciting findings from the last 9 months have arisen from the ~450 mm of rain that fell between Sept 9-14, 2013 in Boulder, breaking rainfall records at every timescale from 24-hr to annual totals (although, interestingly, not at shorter time intervals). Heavy rains fell everywhere from Golden to Fort Collins, Colorado. Our instrumentation survived this inundation quite well; one stream gage was washed out, but otherwise we suffered little damage. A **RAPID grant** we wrote (Anderson, Anderson, Tucker) funded some aspects of water sample analysis and analysis of landsliding. We collected water samples at locations we could access during and immediately following the storm (many roads were closed), and therefore have a suite of **water samples analyzed** that show solute, colloid, and dissolved organic matter concentrations through this event. Researcher Scott Anderson is producing an analysis of LiDAR data collected in 2010 and that collected by FEMA in November 2013 is yielding an unprecedented view of **sediment evacuation by landsliding and debris flows** in an extreme rainfall event. In addition, the groundwater well at Betasso created from our “drill-the-ridge” coring project in January 2013 yielded important data on the **groundwater response** to this event, which we will follow over the next several years. We have engaged two of the RECCS REU students to examine landslide headscarps and debris flow chutes. CU undergraduate student Satya Akquia is conducting a senior thesis on **bedrock channel incision** on the Plains during this storm. One manuscript will be **submitted** this summer (Anderson, SW et al., *Nature Geoscience*), and more are planned.

Interface 2: Base of mobile regolith and weathered rock/saprolite R.S. Anderson, G. Tucker, S.P. Anderson

*Lowering rates.* Graduate student Melissa Foster, working with R.S. Anderson and S.P. Anderson has **samples** in process for  $^{10}\text{Be}$  analysis to determine denudation rates at our Betasso field site. This cosmogenic radionuclide (CRN) data will complement U-series analyses that collaborator François Chabaux (Univ. Strasbourg, France) has done. Foster has a **manuscript in review** from her CRN analyses in Gordon Gulch (Foster et al., *GSA Bulletin*).

*Rock fracture and Entrainment.* We do not have any graduate students working on these topics at present, and so have no new findings to report here. Greg Tucker, working on the Landlab modeling project (funded by NSF Cyberinfrastructure's "SI2" program), has produced a proof-of-concept **cellular automaton model** of weathering of fractured granite, inspired by CZO data (basically, a more advanced version of my earlier weathering model, but with a stronger foundation). Kamini Singha has begun a **collaboration** with external investigators Taylor Perron (MIT) through an Army grant, and with Steve Martel (U Hawaii) and Steve Holbrook (U Wyoming) in which the role of sheet fracturing and topographic stress is being



explored in Gordon Gulch this summer.

*Hydrology and chemical weathering of saprolite.* Graduate student Joe Mills, working with S.P. Anderson, is **analyzing data** from several years of water chemistry from Gordon Gulch watershed (stream, groundwater, springs, precipitation, snow, and a small number of lysimeter samples) to examine the interplay of weathering and water flow paths in the watershed. He has conducted several **experiments** to show that a significant fraction of the silica flux during winter and fall is in the form of colloidal material that has a clay (Si and Al-rich) composition. Mills will work with WEBMOD, a **coupled geochemical-hydrologic model** to investigate the roles of evapotranspiration, mechanism of precipitation delivery (e.g. rain vs. snow), slope aspect, and hydrologic flowpaths on chemical weathering rates in four main compartments in the critical zone in Gordon Gulch (tree canopy, soil, fractured bedrock, and stream). Mills is working on a **manuscript** to be submitted over the summer (title and journal to be determined). Graduate student Sachin Pandey, working with Hari Rajaram, set up the **reactive transport model** PFLOTRAN for Gordon Gulch type conditions. This effort was inspired in part by the VS2DT modeling done by graduate student Abigail Langston with Greg Tucker, and reported in the manuscript to be submitted this summer (Langston et al., *Earth Surface Processes and Landforms*). Pandey and Rajaram wanted to use a more sophisticated representation of the flow system in saprolite and fractured rock than was possible in VS2DT.

Interface 3: Deep Weathering Front A. Templeton, N. Fierer, K. Singha, D. McKnight, H. Rajaram, A. Sheehan, S.P. Anderson

A key set of questions about the deep critical zone revolves around the roles of microbes in the chemical evolution of rock far below the surface. We have not begun to work on these geobiology questions, for lack of a graduate student or post-doc prepared to work on them. The variation in depth to the deep weathering front (interface between fresh and weathered rock) across differing **slope aspects**, and how this difference develops, is also a key question on the deep weathering front. S.P. Anderson has **submitted an extended abstract** summarizing observations on how parameters and conditions vary with aspect in Gordon Gulch for her invited talk at the Geochemistry of the Earth's Surface meeting in Paris, in August 2014 (Anderson, et al., *Procedia Earth and Planetary Science*). Our groundwater data set from the "drill-the-ridge" borehole in Betasso is an important set of **observations** on the movement of water at >25 m depth below the surface. The work that Kamini Singha is undertaking in Gordon Gulch this summer with Steve Holbrook (WyCEHG), Steve Martel, and Taylor Perron, will yield new observations and researchers who can help push on the geometry and dynamics of this interface.

Science Implementation: Integrative activities

We set out modeling objectives in our proposal that will integrate across the interfaces discussed above, and across disciplinary boundaries (e.g., geomorphology, hydrology, geobiology, ecohydrology). We laid out plans for integrative modeling in three areas: water, landscape evolution, and future-casting. At this point, our integrative modeling efforts have been directed primarily at landscape evolution. Graduate student Melissa Foster, working with R.S. Anderson, has been **building histories** of the exhumation of the Plains through dating fluvial landforms and an ancient earth flow with CRNs and optically-stimulated luminescence (OSL), and through analyses of soil development on alluvial surfaces. Foster **presented** this work at the Geological Society of America Annual Meeting (Denver, 2013) and AGU Fall Meeting (San Francisco, Dec 2013), while R.S. Anderson gave an **invited presentation** in a Pardee Session at the Geological Society of America Annual Meeting (Denver, 2013). Graduate student Abigail Langston, working with Greg Tucker, has been **interpreting climate-modulated processes** of terrace development along the Colorado Front Range using a

landscape evolution model. She is **developing a model** of lateral fluvial erosion in Landlab to improve the representation of exhumation of the Plains. Langston **presented** this work at the International Association for Geomorphology meeting (Paris, Aug 2013), and the Geological Society of America Annual Meeting (Denver, 2013). Tucker gave an **invited presentation** on his simple decaying mountain-foreland model at the Geological Society of America Annual Meeting (Denver, 2013). Former post-doc Cam Wobus also gave an **invited presentation** (with co-authors Tucker and R.S. Anderson) on the connections between sediment flux and incision of the High Plains at the Geological Society of America Annual Meeting (Denver, 2013).

- iii. **summary of status and results of education and outreach activities** supported by the CZO, including student training and post-doc mentoring, meetings and lectures, abstracts and other publications;

#### **K-12 outreach**

*STEM science workshop:* K-12 outreach is done in partnership with CU's Science Discovery program. Together we developed a STEM workshop in 2011 called "Earth Systems Science: Exploring Change in the Critical Zone". Science Discovery has delivered that workshop in a variety of formats ever since, both locally, in the Denver metro area, and "on the road", traveling to rural parts of the state. In some cases, the material is delivered directly to students, teachers, and chaperones, either in a central location (such as CU's University Memorial Center), or in one school within a district. In other cases, the material is delivered to teachers only as a Professional Development workshop. In both of these styles, teachers are given resources such as curriculum, powerpoints, and supplies for activities. Science Discovery has also adapted the day-long workshop into shorter programs, and incorporated it into afterschool and summer classes. Curriculum, additional reading material, and supporting videos (some featuring school children as presenters) can be found on Science Discovery's website:

<http://sciencediscovery.colorado.edu/resources/teacher-resources/czo-workshop/>

Total numbers and formats used over the whole period 2011-2014, are summarized below:

1st-12th Grade Learners: 3523

College-Aged Learners: 155

K-12 Teachers and Professionals: 366

Adults and Chaperones: 468

*Total Contact Time:* 9947.8 hours

#### *Formats:*

11 Science Explorers and STEM Workshops

24 Classroom Presentations

7 Teacher Professional Development Workshops

8 Science Discovery Summer and After School Programs

9 Science Discovery's STEM Outreach and Events

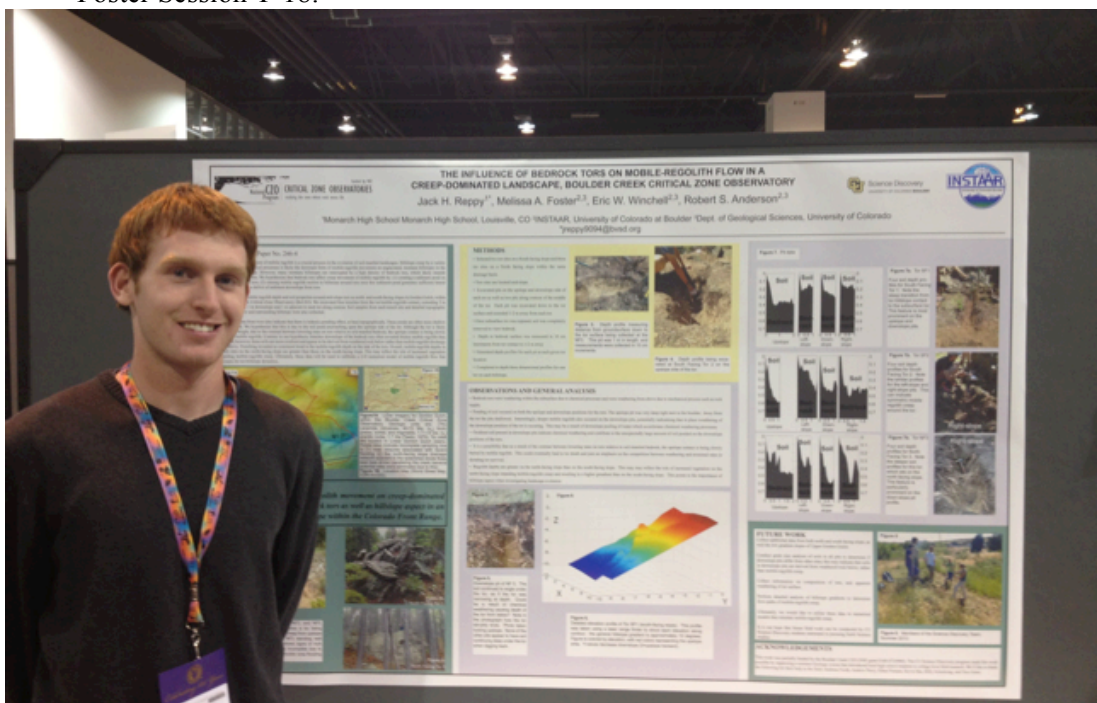
*Teacher Professional Development 3-day workshop:* New in 2014, we will offer a 3-day workshop for 12 teachers in STEM science. Teachers will earn PD credit, and receive a stipend. The draft curriculum for the workshop, which will be held July 15-17 at CU's Mountain Research Station, will be uploaded in our Research.gov annual report. Several researchers and graduate students will be involved in some of the field activities.

*High School Student Research Experience:* We began offering a 5-day research experience for 12 high school learners, based at CU's Mountain Research Station in 2013.

See <http://sciencediscovery.colorado.edu/class/mrsfieldcourse-2/>

One student from the summer 2013 course continued to work with his graduate student mentor (Melissa Foster, Geological Sciences), and presented his work in a poster at the Geological Society of America Annual Meeting in October, 2013:

Reppy, Jack H., Foster, M.A., Winchell, E.W., and Anderson, R.S. (2013): The influence of bedrock tors on mobile-regolith flow in a creep-dominated landscape, Boulder Creek Critical Zone Observatory. *Geological Society of America Abstracts with Programs*, Poster Session T-18.



Monarch High School (Louisville, Colorado) student Jack Reppy with his GSA poster.

### Post-doc training

We have had one NSF Earth Sciences Postdoctoral Fellow, Adrian Harpold, associated with BcCZO-II in 2014. Adrian has worked closely with mentor Noah Molotch, meeting on a regular basis for science and career advising. In addition, Adrian has been an active participant in the BcCZO-II science team. He organized a hydrology seminar/discussion group in spring 2014, and has led the cross-CZO Graduate student group.

### REU program

Our Education and Outreach Research Associate, Val Sloan, spearheaded an REU proposal writing effort even before BcCZO-II funding began. The proposal, which was a joint effort between BcCZO-II and CIRES Western Water program, was not funded. However, CIRES provided pilot money and we are receiving a supplement to run a program for 7 students total (3 supported by this project) in summer 2014. Val Sloan has moved on to a full-time job at UCAR, and so is not involved in the effort this summer. We have contracted with science education specialist Barbara Monday to help with the administration of this program this summer.

*RECCS: Research Experience for Community College Students*, is a non-residential 8-week program for Colorado community college students. Week 1 was devoted to orientation through field trips, lab tours, and initial skills training. Over the program, the students will have weekly skills training in communication (delivered by and tailored to community college students by

SOARS trainer Bec Batchelor, see [http://www.soars.ucar.edu/inside/communications\\_workshop.php](http://www.soars.ucar.edu/inside/communications_workshop.php)), in using spreadsheet software (Excel) and basic statistics, and weekly conversations on college, graduate school, science careers, and science ethics, with PI Suzanne Anderson, and CIRES E&O professionals Dr. Lesley Smith and Dr. Anne Gold. Each student will work with a mentor over the program, and will have a research project and will be exposed to a variety of research experiences. They will deliver a poster, an oral presentation, and a short written report on their activities and findings at the end of the program. These will be delivered in a SOARS poster session, and to a CZO-hosted meeting in early August.



RECCS students and program leaders during orientation week, June 11, 2014.

### Student Training

PI Suzanne Anderson offered graduate seminar on “Extreme events in the Critical Zone” in spring 2014 (1 cr; ~12 attended each week, 5 for credit)

Co-I Holly Barnard offered graduate seminar on the Critical Zone in spring 2013 (1 cr; 5 enrolled)

Graduate student Melissa Foster lectured on mentoring to her fellow graduate students in the Graduate Teacher Training program at CU. Her power point presentation (which is very good!) is posted in the Research.gov version of this report.

- |            |   |
|------------|---|
| <p>iv.</p> | <p><b>summary of status and results of cross-CZO activities</b> supported by the CZO, including working-group activities, data efforts, field and laboratory measurements, meetings and workshops, student training and post-doc mentoring, outreach, abstracts and other publications;</p> |
|------------|---|

1) Post-doc Adrian Harpold works in the Jemez-Santa Catalina CZO as well as BcCZO, has led the cross-CZO graduate group, and has published the following cross-CZO paper:

**\*\*Harpold, A.A., Guo, Q., Molotch, N., Brooks, P., Bales, R., Fernandez-Diaz, J.C.,**

**\*Musselman, K.N., Swetnam, T., Kirchner, P., Meadows, M., Flannagan, J., and Lucas, R.**



(2014): A LiDAR derived snowpack dataset from mixed conifer forests in the Western U.S. *Water Resources Research*, 50: 2749-2755, doi:10.1002/2013WR013935.

2) We supported the NSF-Postdoctoral Fellowship proposal of Nikki West in Fall 2013. Her project on “Quantifying the relative contributions of bioturbation and viscous creep in landscape evolution at the Boulder Creek Critical Zone Observatory”, would have connected cosmogenic radionuclide researchers from Shale Hills CZO and Boulder Creek CZO. Nikki’s proposal was not funded.

3) We are supporting the NSF-Postdoctoral Fellowship proposal of Jill Marshall to be submitted in July 2014. She is developing a proposal that will entail instrumenting trees in two CZOs (Boulder Creek CZO and Eel River CZO), and will probably undertake some additional (more limited) measurements in Southern Sierra CZO. Jill plans to divide her time between Berkeley and Boulder, and so can contribute to community at both locations, as well as science of trees and critical zone evolution at all CZOs.

v. **summary of status and results of activities supported by the CZO and initiated by the CZO-NO**; including brief descriptions of activities hosted by the CZO;

Nothing to report: CZO-NO not yet established.

vi. **tabulation of defined performance metrics for the period** and comparison with proposed goals;

Goal 1

Interface and Zone 1: R.S. Anderson, D. Doak, H. Barnard, N. Molotch, S. Murphy, A. Blum, G. Tucker, S.P. Anderson, D. McKnight, N. Fierer

Metrics:

*Maintain surface monitoring (meteorology, soil moisture and temperature, runoff, water chemistry, sapflow, snow depth)*

✓ Done.

*Produce papers on surface water hydrology, ecohydrology, biologic influences on sediment transport, landscape evolution*

✓ 5 papers published, 3 in press, 5 submitted, 4 planned for submission this summer

\*\*Hinckley, E.-L., Ebel, B.A., \*\*Barnes, R.T., Anderson, R.S., Williams, M.W., and Anderson, S.P. (2014): Aspect control of water movement on hillslopes near the rain-snow transition of the Colorado Front Range, U.S.A. *Hydrological Processes* 28: 74-85, doi: 10.1002/hyp.9549. (published online 17 October 2012).

\*\*\*Hoffman, B. and Anderson, R.S. (2014) Tree root mounds and their role in transporting soil on forested landscapes. *Earth Surface Processes and Landforms*, 39 (6): 711-722, doi:10.1002/esp.3470.

\*Gabor, R.S., \*Eilers, K.G., McKnight, D.M., Fierer, N., and Anderson, S.P. (2014): From the litter layer to the saprolite: Chemical changes in water-soluble soil organic matter and their correlation to microbial community composition. *Soil Biology and Biochemistry* 68: 166-176, DOI: 10.1016/j.soilbio.2013.09.029

\*\*Harpold, A.A., Guo, Q., Molotch, N., Brooks, P., Bales, R., Fernandez-Diaz, J.C., \*Musselman, K.N., Swetnam, T., Kirchner, P., Meadows, M., Flannagan, J., and Lucas, R. (2014): A LiDAR derived snowpack dataset from mixed conifer forests in the Western U.S. *Water Resources Research*, 50: 2749-2755, doi:10.1002/2013WR013935.

- \*Burns, S.P., P.D. Blanken, M.W. Williams, N.P. Molotch, B. Seok, J.K. \*Knowles, R.K. Monson, A.A. Turnipseed (2014): Snow temperature changes within a seasonal snowpack and their relationship to turbulent fluxes of sensible and latent heat. *Journal of Hydrometeorology*, 15, 117-142, doi:10.1175/JHM-D-13-026.1.
- \*\*Hinckley, E.-L., \*\*Barnes, R.T., Anderson, S.P., Williams, M.W., and Bernasconi, S. (in press): Ecosystem N retention and transport differ by hillslope aspect at the rain-snow transition of the Colorado Front Range, *Journal of Geophysical Research Biogeosciences*.
- Trujillo, E., N.P. Molotch (in press): Snowpack Regimes of the Western United States, *Water Resources Research*.
- Molotch, N.P. (in press): Snow cover depletion curves and snow water equivalent reconstruction: six decades of hydrologic remote sensing applications, *AGU Monograph on Remote Sensing of the Terrestrial Water Cycle*.
- Barnard, HR, \*\*\*BA Skeets, \*HR Adams, CJ Crosby, WB Ouimet. Using stable isotopes of trees to examine moisture dynamics in bedrock outcrops of a semi-arid catchment. *Hydrological Processes*, submitted June 5, 2014.
- \*Kirchner, P.B., R.C. Bales, N.P. Molotch, J. Flanagan, Q. Guo, Seasonal snow accumulation along an elevation gradient in the southern Sierra Nevada, California, *Hydrology and Earth System Science*, in review.
- Livneh B., J.S. Deems, D. \*Schneider, J. Barsugli, and N.P. Molotch (2014), Filling in the Gaps: Inferring Spatially Distributed Precipitation from Gauge Observations over Complex Terrain. *Water Resources Research*, in review.
- \*\*Harpold, A.A., N.P. Molotch, K.N. \*Musselman, R.C. Bales, P.B. \*Kirchner, M. Litvak, and P.D. Brooks, Soil Moisture Response to Snowmelt Timing in Mixed-Conifer Subalpine Forests, *Hydrological Processes*, in review.
- \*Perrot D.P., N.P. Molotch, M.W. Williams, J.O. Sickman, Relationships between stream nitrate concentration and spatially distributed snowmelt in high elevation catchments of the western United States, *Water Resources Research*, in review.
- \*Langston, A. L., G. E. Tucker, R. S. Anderson and S. P. Anderson, Evidence for climatic and hillslope-aspect controls on vadose zone moisture and saprolite weathering (planned for *Earth Surface Processes and Landforms*)
- Murphy, S.F., Writer J.W., McCleskey, R.B., and Martin, D.A.: Fires, floods, and the future of water quality in the Western U.S. Planned for *Nature Climate Change*.
- \*\*Harper, A.A., and Molotch, N.P. Timing of snowmelt differentially influences soil moisture response in Western U.S. mountain ecosystems. Planned for *Ecohydrology*.
- Anderson, SP, \*Mills, TJ, et al.: Hydrology of a catchment with ephemeral snow: When does rain dominate over snow? Planned for *Water Resources Research*.
- Train at least 2 graduate students in surface water hydrology, ecohydrology, surficial processes*
- ✓ Abigail Langston, PhD expected Dec 2014 (surficial processes)
  - ✓ Margaret Burns, MA 2014 (surface water and ecohydrology)
  - ✓ Joe Mills, PhD student (surface water hydrology and aqueous geochemistry)
  - ✓ Theo Barnhart, PhD student (surface water hydrology and snow)

## Goal 2

Interface 2: R.S. Anderson, G. Tucker, S.P. Anderson

Metrics:

*Measure mobile regolith production rates in Betasso, measure fracture patterns in rock underlying this interface*

- ✓ Samples being processed for mobile regolith production rate at present.
- ✓ We have not measured fracture patterns yet.

Produce papers on regolith production across BcCZO, role of fracturing in mobile regolith production

- ✓ 3 papers published, 1 submitted.

Anderson, R.S., Anderson, S.P., and Tucker, G.E. (2013): Rock damage and regolith transport by frost: An example of climate modulation of critical zone geomorphology. *Earth Surface Processes and Landforms*, 38: 299-316, doi:10.1002/esp3330. (Published online 18 Oct 2012).

Leopold, M., Völkel, J., Huber, J., and Dethier, D. (2013): Subsurface architecture of the Boulder Creek Critical Zone Observatory from electrical resistivity tomography. *Earth Surface Processes and Landforms*, doi:10.1002/esp.3420.

\*\*\*Hoffman, B. and Anderson, R.S. (2014) Tree root mounds and their role in transporting soil on forested landscapes. *Earth Surface Processes and Landforms*, 39 (6): 711-722, doi:10.1002/esp.3470.

\*Foster, M., R. S. Anderson, \*\*\*C. E. Wyshnytzky, W. B. Ouimet, D. P. Dethier, Using <sup>10</sup>Be to deduce rates of landscape evolution and mobile-regolith residence times in Gordon Gulch, Boulder Creek CZO, Colorado, *GSA Bulletin*, submitted March 2013; revised April 2014.

Train at least 1 graduate student in the area of mobile regolith production

- ✓ Melissa Foster, PhD expected Spg 2015 (surficial processes & soils)
- ✓ Eric Winchell, PhD student (bio-geomorphology)

### Goal 3

Interface 3: A. Templeton, N. Fierer, K. Singha, D. McKnight, H. Rajaram, A. Sheehan

Metrics:

*Maintain groundwater monitoring, plan new drilling program, initiate study of geobiology of deep weathering front*

- ✓ Groundwater monitoring done
- ✓ Kamini Singha will be drilling in Gordon Gulch, summer 2014
- ✓ We have not initiated study of geobiology of deep weathering front (no student at present)

*Produce papers on geohydrology of fractured rock, and geobiology in rock hosted systems*

- ✓ 1 paper will be submitted in summer 2014, addresses water flow in fractured rock
- \*Langston, A. L., G. E. Tucker, R. S. Anderson and S. P. Anderson, Evidence for climatic and hillslope-aspect controls on vadose zone moisture and saprolite weathering (for *Earth Surface Processes and Landforms*)

*Train at least 1 graduate student in deep CZ processes*

- ✓ No students at present. Alexis Templeton has recruited one for 2014, who may be brought in.

vii. <b>lists of all publications and products from activities within the past year</b> , including categories for published, accepted, and submitted;
--

### Journal articles, book chapters

(\*Graduate student, \*\*Postdoctoral researcher, \*\*\*Undergraduate student)

### Published (n=15)

Anderson, R.S., Anderson, S.P., and Tucker, G.E. (2013): Rock damage and regolith transport by frost: An example of climate modulation of critical zone geomorphology. *Earth Surface Processes and Landforms*, 38: 299-316, doi:10.1002/esp3330. (Published online 18 Oct 2012).

- Rhoades, C.C., McCutchan, J.H. Jr., \*Cooper, L.A., Clow, D., Detmer, T.M., Briggs, J.S., Stednick, J.D., Veblen, T.T., Ertz, R.M., Liken, G.E., and Lewis, W.M. Jr. (2013): Biogeochemistry of beetle-killed forests: Explaining a weak nitrate response. *Proceedings of the National Academy of Science*, doi:10.1073/pnas.1221029110.
- Leopold, M., Völkel, J., Huber, J., and Dethier, D. (2013): Subsurface architecture of the Boulder Creek Critical Zone Observatory from electrical resistivity tomography. *Earth Surface Processes and Landforms*, doi:10.1002/esp.3420.
- \*Cullis J.D.S., Crimaldi J.P. and McKnight D.M. (2013): Shear removal function for the nuisance stalk forming diatom *Didymosphenia geminata*. *L&O: Environments and Fluids* 3: 256-268, doi: 10.1215/21573689-2414386.
- Anderson, S.P., Anderson, R.S., Tucker, G.E., and Dethier, D.P. (2013): Critical zone evolution: Climate and exhumation in the Colorado Front Range. In Abbot, L.D. and Hancock, G.S., eds., *Classic Concepts and New Directions: Exploring 125 Years of GSA Discoveries in the Rocky Mountain Region*: Geological Society of America, Field Guide 33, p. 1-18, doi:10.1130/2013.0033(01).
- Leopold, M., Völkel, J., Dethier, D. P., and Williams, M.W. (2014): Changing mountain permafrost from the 1970s to today—comparing two examples from Niwot Ridge, Colorado Front Range, USA. *Zeitschrift für Geomorphologie, Supplementary Issue*, 58 (1): 137-157, doi:10.1127/0372-8854/2013/S-00129.
- \*\*Hinckley, E.-L., Ebel, B.A., \*\*Barnes, R.T., Anderson, R.S., Williams, M.W., and Anderson, S.P. (2014): Aspect control of water movement on hillslopes near the rain-snow transition of the Colorado Front Range, U.S.A. *Hydrological Processes* 28: 74-85, doi: 10.1002/hyp.9549. (published online 17 October 2012).
- \*\*\*Hoffman, B. and Anderson, R.S. (2014) Tree root mounds and their role in transporting soil on forested landscapes. *Earth Surface Processes and Landforms*, 39 (6): 711-722, doi:10.1002/esp.3470.
- \*Gabor, R.S., \*Eilers, K.G., McKnight, D.M., Fierer, N., and Anderson, S.P. (2014): From the litter layer to the saprolite: Chemical changes in water-soluble soil organic matter and their correlation to microbial community composition. *Soil Biology and Biochemistry* 68: 166-176, DOI: 10.1016/j.soilbio.2013.09.029
- \*Anderson, L.S., Roe, G.H., and Anderson, R.S. (2014): The effects of interannual climate variability on the moraine record. *Geology* 42(1): 55-58, doi:10.1130/G34791.1.
- \*Cullis, J.D.S., \*Stanish, L.F., and McKnight, D.M. (2014): Diel flow pulses drive particulate organic matter transport from microbial mats in a glacial meltwater stream in the McMurdo Dry Valleys. *Water Resources Research* 50: 86-97, doi:10.1002/2013WR014061.
- Dethier, D.P., Ouimet, W., Bierman, P.R., Rood, D.H., and Balco, G. (2014): Basins and bedrock: Spatial variation in <sup>10</sup>Be erosion rates and increasing relief in the southern Rocky Mountains, USA. *Geology* 42 (2): 167-170, doi: 10.1130/G34922.1.
- \*\*Harpold, A.A., Guo, Q., Molotch, N., Brooks, P., Bales, R., Fernandez-Diaz, J.C., \*Musselman, K.N., Swetnam, T., Kirchner, P., Meadows, M., Flannagan, J., and Lucas, R. (2014): A LiDAR derived snowpack dataset from mixed conifer forests in the Western U.S. *Water Resources Research*, 50: 2749-2755, doi:10.1002/2013WR013935.
- \*Burns, S.P., P.D. Blanken, M.W. Williams, N.P. Molotch, B. Seok, J.K. \*Knowles, R.K. Monson, A.A. Turnipseed (2014): Snow temperature changes within a seasonal snowpack and their relationship to turbulent fluxes of sensible and latent heat. *Journal of Hydrometeorology*, 15, 117-142, doi:10.1175/JHM-D-13-026.1.
- \*Gabor, R.S., A Baker, DM McKnight, \*MP Miller (2014). Fluorescence Indices and their Interpretation. In *Aquatic Organic Matter Fluorescence*, Coble, P.G., Lead, J., Baker, A., Reynolds, D.M., and Spencer, R.G.M., eds., Cambridge University Press, p. 303-339, isbn: 9781139897907. (available July 2014)



**In press (n=4)**

- \*\*Hinckley, E.-L., \*\*Barnes, R.T., Anderson, S.P., Williams, M.W., and Bernasconi, S. (in press): Ecosystem N retention and transport differ by hillslope aspect at the rain-snow transition of the Colorado Front Range, *Journal of Geophysical Research Biogeosciences*.
- Anderson, R.S. (in press): Evolution of lumpy glacial valleys, *Geology*
- Trujillo, E., N.P. Molotch (in press): Snowpack Regimes of the Western United States, *Water Resources Research*.
- Molotch, N.P. (in press): Snow cover depletion curves and snow water equivalent reconstruction: six decades of hydrologic remote sensing applications, *AGU Monograph on Remote Sensing of the Terrestrial Water Cycle*.

**Submitted (n=7)**

- \*Foster, M., R. S. Anderson, \*\*\*C. E. Wyshnytzky, W. B. Ouimet, D. P. Dethier, Using  $^{10}\text{Be}$  to deduce rates of landscape evolution and mobile-regolith residence times in Gordon Gulch, Boulder Creek CZO, Colorado, *GSA Bulletin*, submitted March 2013; revised April 2014.
- Barnard, HR, \*\*\*BA Skeets, \*HR Adams, CJ Crosby, WB Ouimet. Using stable isotopes of trees to examine moisture dynamics in bedrock outcrops of a semi-arid catchment. *Hydrological Processes*, submitted June 5, 2014.
- Anderson, SP, \*\*Hinckley, E-L, \*Kelly, P, \*Langston, A: Variation in critical zone processes and architecture across slope aspects, *Procedia Earth and Planetary Science*. Submitted June 8 2014, for invited talk at Geochemistry of the Earth's Surface meeting, Paris, August 2014.
- \*Kirchner, P.B., R.C. Bales, N.P. Molotch, J. Flanagan, Q. Guo, Seasonal snow accumulation along an elevation gradient in the southern Sierra Nevada, California, *Hydrology and Earth System Science*, in review.
- Livneh B., J.S. Deems, D. \*Schneider, J. Barsugli, and N.P. Molotch (2014), Filling in the Gaps: Inferring Spatially Distributed Precipitation from Gauge Observations over Complex Terrain. *Water Resources Research*, in review.
- \*\*Harpold, A.A., N.P. Molotch, K.N.\*Musselman, R.C. Bales, P.B. \*Kirchner, M. Litvak, and P.D. Brooks, Soil Moisture Response to Snowmelt Timing in Mixed-Conifer Subalpine Forests, *Hydrological Processes*, in review.
- \*Perrot D.P., N.P. Molotch, M.W. Williams, J.O. Sickman, Relationships between stream nitrate concentration and spatially distributed snowmelt in high elevation catchments of the western United States, *Water Resources Research*, in review.

**Submission planned for summer 2014**

- \*Langston, A. L., G. E. Tucker, R. S. Anderson and S. P. Anderson, Evidence for climatic and hillslope-aspect controls on vadose zone moisture and saprolite weathering (for *Earth Surface Processes and Landforms*)
- Murphy, S.F., Writer J.W., McCleskey, R.B., and Martin, D.A.: Fires, floods, and the future of water quality in the Western U.S. For *Nature Climate Change*.
- \*\*Harper, A.A., and Molotch, N.P. Timing of snowmelt differentially influences soil moisture response in Western U.S. mountain ecosystems. For *Ecohydrology*.
- Anderson, SW, Anderson, SP, Anderson, RS, Tucker, G: Landscape lowering during an extreme rainfall event, Colorado Front Range. For *Nature Geoscience*.
- Anderson, SP, \*Mills, TJ, et al.: Hydrology of a catchment with ephemeral snow: When does rain dominate over snow? For *Water Resources Research*.

**Theses (n=2)**

- Gabor, Rachel (2013): *A spectroscopic investigation of the chemistry of organic matter during biogeochemical cycling through the soil, groundwater, and surface water of the Boulder*

*Creek watershed.* PhD dissertation, Environmental Studies, University of Colorado, Boulder.

Burns, Margaret (2014): *Hillslope Dissolved Organic Matter Transport and Transformation in a Semi-Arid Headwater Catchment.* MA thesis, Dept. of Geography, University of Colorado, Boulder.

### **Other products**

Model: Landlab project (of Greg Tucker, funded by NSF Cyberinfrastructure's "SI2" program) has produced a proof-of-concept cellular automaton model of weathering of fractured granite, inspired by CZO data.

Audio product: Radio interview of PI Suzanne Anderson with Maeve Conran, KGNU, for the "Flood Show"; archived at <http://www.kgnu.org/flood>. Interviewed 4/1/14, broadcast 4/6/14. Discussed the September 2013 storm produced landslides and what may happen in spring 2014.

### **Presentations (n=28)**

The 28 conference presentations by members of BcCZO-II are listed in the Research.gov report

viii. <b>an assessment of progress towards meeting the goals for engaging</b> the broader community that are established in the CZOMP;
--

### **Goals for engagement and our progress on these goals:**

1) We will advertise annually on listservs (geomorphlist, czen, gilbert club) that BcCZO welcomes outside researchers.

*Progress:* Announcements inviting researchers to use BcCZO and the CZO network were posted to all three list-servs (geomorphlist, czen.org, and gilbert club) on June 15, 2014.

2) BcCZO researchers will visit other institutions along the Front Range corridor to promote using BcCZO for research.

*Progress:*

Sheila Murphy presented at the UNAVCO Science Seminar, Nov 8, 2013 "Temporal and spatial controls on post-wildfire water quality"

Sheila Murphy presented at CIRES webinar, Nov 13, 2013 "Water in the West - Too little or too much? Drought, Wildfires, and Flood in Colorado."

Noah Molotch presented at the NOAA CIRES Western Water Assessment Annual Stakeholder meeting.

3) We will invite our Advisory Board members to present at our annual science meetings. The Advisory Board members will be drawn from local institutions, and can serve as ambassadors.

*Progress:*

Identification of Advisory Board members not complete. We have started discussing individuals to invite in our Executive Committee, and have touched on this in a full group meeting.

4) We will host field trips. These will include both informal small-group visits and larger field trips associated with national and international conferences.

*Progress:* Two major field trips, ~100 participants total:

1) The BcCZO team led the Kirk Bryan field trip during the Geological Society of America Annual Meeting on Oct. 30, 2013. This day-long outing was the largest field trip of the meeting, attended by 75 people, transported in 7 vans. We produced a published field guide:

Anderson, SP, Anderson, RS, Tucker, GE, and Dethier, DP (2013): Critical zone evolution: Climate and exhumation in the Colorado Front Range. *In* Abbot, LD and Hancock, GS, eds., *Classic Concepts and New Directions: Exploring 125 Years of GSA Discoveries in the Rocky Mountain Region*: Geological Society of America, Field Guide 33, p. 1-18, doi:10.1130/2013.0033(01).

We sponsored a topical session at the GSA meeting of the same title: “Critical zone evolution: Climate and exhumation” (Topical session T18). The session included 14 oral presentations.

The field trip was tweeted while we were running it. An early morning tweet from participant Kyle House was “featured” by GSA in the post-meeting edition of the Daily News emailed to all members:

[http://www.geosociety.org/GSA\\_Connection/special/13Den/post-mtg.htm](http://www.geosociety.org/GSA_Connection/special/13Den/post-mtg.htm):



There wasn't a contest (maybe there should be!), but this could win "best annual meeting Twitter photo." **Kyle House** (@drjerque) tweeted it, with the caption, "One of those geotrips requiring faith in the leaders' description of the view of the field area."



Kirk Bryan field trip “Critical zone evolution: Climate and exhumation” finally gets some sun on Oct. 30, 2013

2) BcCZO team members Suzanne Anderson and Brian Ebel led two (of four) stops in the GSA Field Trip “Rocky Mountain Unsaturated Zones--Exploring Fire-Earth-Sky Connections”, held on Oct. 26, 2013. The field trip was attended by 25 participants. Anderson took them to view a soil profile and discuss unsaturated-saturated zone responses to the September rain event (using data from our newly drilled well). Ebel led a stop to view effects of the 2010 Fourmile Canyon wildfire on unsaturated zone hydrology.

ix.	<b>summarized results of evaluation forms submitted</b> by participants of supported activities;
-----	--

Nothing to report; no supported activities with evaluations completed at this time.

x.	<b>information on any additional funding that impacts and/or overlaps</b> the activities of the CZO, making clear the distinction between on-going research activities that are funded by other NSF awards, other agencies and/or organizations and the work done under the CZO award;
----	--

**Funded projects working in BcCZO:**

1) Carbon-water cycling in the critical zone: understanding ecosystem process variability across complex terrain. U.S. Dept. of Energy Terrestrial Ecosystem Science. \$647,020. 9/15/11 - 9/14/14. PI – HR Barnard, co-PI – PD Brooks

2) Taylor Perron and Kamini Singha (co-PIs) “small” Army Research Office grant, that will fund the drilling work in Gordon Gulch in June.

3) Steve Holbrook (WyCEHG), with Steve Martel (U Hawaii), Taylor Perron (MIT), and Kamini Singha will spend 2 weeks doing shallow geophysics in Gordon Gulch in June 2013. Not sure of all the funding involved (in particular, how Martel is funded).

4) Project Title: Growth Dynamics in the Climate Control of Tree-Ring Variability for Paleoclimatology

Principle Investigators: Dr. Malcolm Hughes, Laboratory of Tree-Ring Research, University of Arizona, Tucson ([mhughes@ltrr.arizona.edu](mailto:mhughes@ltrr.arizona.edu)); Dr. Peter M. Brown, Rocky Mountain Tree-Ring Research, Ft Collins CO ([pmb@rmtrr.org](mailto:pmb@rmtrr.org)); Dr. Kiyomi Morino, Laboratory of Tree-Ring Research, University of Arizona, Tucson ([kmorino@ltrr.arizona.edu](mailto:kmorino@ltrr.arizona.edu))

Sampling is planned in Betasso, and the team will use sap flow and meteorological data from BcCZO.

5) Lou Derry, NSF, “*A Cross Site Study of Silica Dynamics in the Critical Zone*”. Lou and a graduate student will visit in June 2014 to collect water and rock samples from Gordon Gulch and Betasso.

6) Greg Tucker, NSF-GLD EAR-0952247; Graduate student Francis Rengers mapped erosion after the Fourmile fire. Among other things, he used CZO lidar as the basis for calculating overland flow shear stress.

7) Noah Molotch, NSF WSC grant; Graduate student Theo Barnhart will be supported 50% by BcCZO and 50% by Molotch’s NSF/USDA WSC grant, and will work across both projects.

- 8) RAPID grant to S.P. Anderson, R.S. Anderson and G. Tucker, “Effects of an extreme rain event in the Boulder Creek CZO. \$22,142. The project uses BcCZO LiDAR data as a basis to study erosion in the storms of September 2013, as well as providing support for extra water analyses from storm samples.
- 9) RAPID grant to Will Ouimet on post-storm erosion and sedimentation in Fourmile Canyon.
- 10) USDA/NSF - \$1.4M PI-Molotch: Snowpack and Ecosystem Dynamics: The Sustainability of Inter-basin Water Transfers under a Changing Climate (2012 – 2016).
- 11) NSF - \$256,625 PI-Molotch: Climatic controls on snow-vegetation interactions across an elevational gradient (2012 – 2015).
- 12) NSF grant “Quantifying Near-Surface Patterns of Bedrock Fractures and Assessing Controls on Fracture Formation” with Brian Clarke and Doug Burbank. This team plans geophysical characterization of subsurface architecture across opposing slope aspects on Niwot Ridge.
- 13) NSF Keck Geology Program, 2014-2015 project on “Fire and catastrophic flooding, Fourmile catchment, Front Range, Colorado”, led by David Dethier (Williams College), Will Ouimet (Univ. Connecticut), and James Kaste (College of William and Mary) will support 6 undergraduate researchers. (Dethier was explicitly a team member of BcCZO in the past, but wanted a break from supervising undergraduate researchers every summer. However, he must have changed his mind, because he did obtain funding with colleagues Ouimet and Kaste to run another Keck Program REU program this summer; this time BcCZO is not and was not asked to provide support funding.)

xi.	<b>unanticipated collaborations, research projects, and other endeavors</b> enabled or stimulated by the CZO or CZO-NO;
-----	---

The most unanticipated project enabled by CZO is #4 above (“Growth Dynamics in the Climate Control of Tree-Ring Variability for Paleoclimatology”), as it was unknown to us until the project was funded. At that point, the investigators contacted us about logistics. We will endeavor to learn more about their questions and findings.

All of the projects listed in the previous item (#1-13 under point x.) can be construed as stimulated by the CZO.

xii.	<b>other impacts of the CZO activities</b> , including local community engagement, and policy;
------	--

- 1) Sheila Murphy was quoted in: *New York Times*, August 27, 2013, “San Francisco girds for possible threat to water from wildfire,” by Henry Fountain.
- 2) Sheila Murphy is a member of the US Geological Survey Southwest Region Wildfire Science Plan working group.
- 3) Sheila Murphy co-presented in a highly attended session at the Geological Society of America Annual Meeting, Denver, CO, October 29, 2013. “Colorado Front Range flooding: Long-term perspective and short-term observations of Boulder Creek Watershed’s response during September 2013” presented by Bob Jarrett and Sheila

- Murphy in the late-breaking session “The 2013 Colorado flood event- a perfect storm hits a dynamic landscape: causes, processes, and effects.”
- 4) Sheila Murphy presented in University of Colorado’s Cooperative Institute for Research in Environmental Sciences (CIRES) Climate Change Webinar, November 13, 2013, “Water in the West - Too little or too much? Drought, Wildfires, and Flood in Colorado.”
  - 5) PI Suzanne Anderson led a field trip on effects of September 2013 storm and flood in Boulder for Prof. Michael Kudas’ graduate Environmental Journalism class. Nov. 18, 2013. Eight students
  - 6) PI Suzanne Anderson was interviewed by local radio station KGNU on the landsliding due to the 2013 flood. Radio interview with Maeve Conran, KGNU, for the “Flood Show”; see <http://www.kgnu.org/flood>. Interviewed 4/1/14, broadcast 4/6/14. Discussed the September 2013 storm produced landslides and what may happen in spring 2014
  - 7) Sheila Murphy is serving as Science advisor for Pine Brook Hills Water Department's source water planning assessment

### xiii. **data management**

We continue to build our Oracle database. Time-series data from our field dataloggers is added to the database on a roughly monthly basis. Other data sets take longer to QA/QC and post. A continuing challenge is designing ways to incorporate other types of datasets. The following additions have been made this year:

- a) Electrical resistivity tomographic-based interpreted cross sections can be viewed, in an interface that has Google Earth functionality. Users can now view images of interpreted cross sections from both electrical resistivity and shallow seismic refraction on the same Google Earth application. The raw data can be accessed on request.
- b) We have posted snow sensor data for water year 2012. This data type goes through initial QA/QC at the end of the snow season, but requires attention from a researcher to go through the final steps before release.
- c) We maintained time-lapse camera datasets (4 cameras). Highlights this year include time lapse of our lower Gordon Gulch gage being washed out, and young Elk bucks chewing on our snow sensors for the camera.
- d) Snow pit data uploading will be upgraded to include snow water equivalent (SWE) calculations, and show data in time-series graphics.
- e) Precipitation chemistry data will be added to the database in summer 2014.
- f) In fall 2013, we migrated all data base information from our previous website ([www.czo.colorado.edu](http://www.czo.colorado.edu)) to the nationally-hosted website ([www.criticalzone.org/boulder/data](http://www.criticalzone.org/boulder/data)).

Total traffic on <http://criticalzone.org/boulder/> since June 14, 2013 show that ~1/3 of our web traffic is for data pages:

	Page views	Unique page views
All pages	28,726	21,220
Data pages	10,120	6,631

Chi Yang has participated in all Integrated Data Management teleconferences, and has kept up with the developments in that group. She is focusing on training our in-coming Data Manager Jeri Tebbetts for the month of June (see section i. above for description of this personnel change).



xiv. **Comparison of expenditures versus budget by program area/activity (with explanation of cost overruns), and indication of leveraging from other sources;**

Comparison of expenditures versus budget by program area/activity

	Budget	Expenditures through 6/13/14	Expenditures encumbered through 8/31/14	Funds remaining (Overruns)	Notes
<b>A. Senior Personnel</b>					
PI: Suzanne Anderson, 1.5 mo	\$ 13,902	\$ -	\$ 13,902	\$ -	
Co.PI: Robert Anderson,	\$ 1,500		\$ 1,500	\$ -	
Co. PI: Noah Molotch	\$ 1,500		\$ 1,500	\$ -	
Co.PI: Hari Rajaram	\$ 1,500		\$ 1,500	\$ -	
Co.PI: Greg Tucker,	\$ 1,500	\$ 283	\$ 1,217	\$ -	
Sr. Personnel: Holly Barnard	\$ 1,500		\$ 1,500	\$ -	
Sr. Personnel: Daniel Doak	\$ 1,500		\$ 1,500	\$ -	
Sr. Personnel: Brian Ebel (RA)	\$ 1,500			\$ 1,500	Moved to Colorado School of Mines
Sr. Personnel: Noah Fierer	\$ 1,500		\$ 1,500	\$ -	
Sr. Personnel: Diane McKnight	\$ 1,500		\$ 1,500	\$ -	
Sr. Personnel: Anne Sheehan	\$ 1,500		\$ 1,500	\$ -	
Sr. Personnel: Alexis Templeton	\$ 1,500		\$ 1,500	\$ -	
<b>B. Other Personnel</b>					
Research Associate: E&O Mgt. Val Sloan	\$ 7,000	\$ 4,198	\$ 2,802	\$ -	
Research Associate: Post-doc TBN	\$ 41,667		\$ -	\$ 41,667	Postdoc to be hired
Research Associate: Post-doc TBN	\$ -		\$ -	\$ -	
PRA:Field manager (Nate Rock)	\$ 39,978	\$ 30,484	\$ 13,548	\$ (4,054)	Raise since original budget written
PRA: Lab manager (Colin Millar)	\$ 36,720	\$ 27,999	\$ 12,444	\$ (3,723)	Raise since original budget written
PRA: Data Manager (Chi Yang)	\$ 46,901	\$ 35,692	\$ 15,863	\$ (4,655)	Raise since original budget written
PRA: Graphics/GIS staff (Eric Parrish)	\$ 20,704	\$ 8,411		\$ 12,293	Paid by Integrated Data Management grant
Science Discovery Coordinator: Hester Nade	\$ 4,994	\$ 2,287.61		\$ 2,706	Summer expense
Science Discovery Education Designer: Eric Carpe	\$ 10,000			\$ 10,000	Summer expense
Science Discovery Manager, Field Science and Citi	\$ 3,427			\$ 3,427	Summer expense
GRA: 50% time, 3 students	\$ 67,304	\$ 34,564.01	\$ 17,381.70	\$ 15,358	One student held TA position this year
Undergraduate Students, hourly	\$ 27,720	\$ 10,180.54		\$ 17,539	Have not encumbered summer pay
Science Discovery Undergraduate Student Hi	\$ 1,200			\$ 1,200	Summer expense
Lab Coord. (Wendy Roth) 2 months at 50% ti	\$ 4,678	\$ 4,978.56		\$ (300)	
System Administrator: Chad Stoffel	\$ 7,745	\$ 2,619.46	\$ 1,309.73	\$ 3,816	
Project Accounting Asst.: Sedrick Frazier	\$ 15,490	\$ 1,131.47	\$ 1,131.47	\$ 13,227	
<b>Total Salaries and Wages (A + B)</b>	<b>\$ 365,928.92</b>	<b>\$ 162,828.11</b>	<b>\$ 93,099.94</b>	<b>\$ 110,001.97</b>	
<b>C. Fringe Benefits</b>	<b>\$ 87,967.00</b>	<b>\$ 39,137.58</b>	<b>\$ 19,349.51</b>	<b>\$ 29,479.91</b>	
<b>D. Equipment</b>					
New Truck	\$ 17,500.00	\$ -	\$ 17,500.00	\$ -	Truck delivery expected July
<b>E. Travel</b>	<b>\$ 6,340.00</b>	<b>\$ 2,113.08</b>	<b>\$ 2,000.00</b>	<b>\$ 2,226.92</b>	
<b>F. Participant Support</b>					
Stipends	\$ 3,600.00		\$ 3,600.00	\$ -	
Travel	\$ 1,000.00		\$ 1,000.00	\$ -	
Subsistance	\$ 5,310.00		\$ 5,310.00	\$ -	
Other	\$ 1,200.00		\$ 1,200.00	\$ -	
Total number of participants: 24 expected					
<b>G. Other Direct Costs</b>					
Materials and Supplies	\$ 21,400.00	\$ 7,131.45	\$ 210.90	\$ 14,057.65	Lab supplies not purchased yet
Publication/Documentation/Dissemination	\$ 3,500.00	\$ 114.12		\$ 3,385.88	
Consultant Services				\$ -	
Computer Services	\$ 7,500.00	\$ 812.75		\$ 6,687.25	UnixOps charge not in yet
Subawards	\$ 25,178.00		\$ 25,178.00	\$ -	
Other	\$ 96,553.00	\$ 15,581.76	\$ 2,400.00	\$ 78,571.24	Analytical costs not yet charged
<b>Total Other Direct Costs</b>	<b>\$ 154,131.00</b>	<b>\$ 23,640.08</b>	<b>\$ 27,788.90</b>	<b>\$ 102,702.02</b>	

xv. **a plan for remedial action where project milestones in the CZOMP have been significantly impacted;**

A significant area in need of remediation is establishment of our local Advisory Committee. PI Anderson will meet with her Executive Committee in June 2014 to develop list of names of

people to invite onto Committee, and will seek input with other team members. We will then schedule our annual meeting; this year it has to fit around the Geochemistry of the Earth's Surface meeting in Paris (August 13-22, with field trip) and activities at the start of the school year (classes begin August 25).

xvi. **problems likely to delay accomplishment** of annual, strategic goals;

Nothing to report.

xvii. **description of programmatic goals and objectives** with specific activities/timetable to be accomplished in the upcoming year; and

Interface and Zone 1: R.S. Anderson, D. Doak, H. Barnard, N. Molotch, S. Murphy, A. Blum, G. Tucker, S.P. Anderson, D. McKnight, N. Fierer

Metrics:

Maintain surface monitoring (meteorology, soil moisture and temperature, runoff, water chemistry, sapflow, snow depth)

Produce papers on surface water hydrology, ecohydrology, biologic influences on sediment transport, landscape evolution, impacts of September 2013 storm

Train at least 2 graduate students in surface water hydrology, ecohydrology, surficial processes

Timetable:

Monitoring- ongoing

SP Anderson will produce surface water hydrology paper summer 2014

Grad student Joe Mills will produce paper on surface water hydrology & geochemistry by Dec 2014

New grad student recruited to work on water: Theo Barnhart

Interface 2: R.S. Anderson, G. Tucker, S.P. Anderson

Metrics:

Measure mobile regolith production rates in Betasso, measure fracture patterns in rock underlying this interface

Produce papers on regolith production across BcCZO, role of fracturing in mobile regolith production

Train at least 1 graduate student in the area of mobile regolith production

Timetable:

Mobile regolith production rates determined by Dec 2014

Recruit student to work on fractures in regolith production by 2015

Paper accepted on mobile regolith production rates by 2015

Interface 3: A. Templeton, N. Fierer, K. Singha, D. McKnight, H. Rajaram, A. Sheehan

Metrics:

Maintain groundwater monitoring, plan new drilling program, initiate study of geobiology of deep weathering front

Produce papers on geohydrology of fractured rock, and geobiology in rock hosted systems

Train at least 1 graduate student in deep CZ processes

Timetable:

Recruit student to work on geobiology by 2015



- xviii. **Projected budget** with detailed justification that breaks down costs according to activity and includes individual budget subawards using the NSF Budget Form 1030 along with appropriate budget justifications (budget detail is to be provided offline in a spreadsheet).

**Projected budget: Year 2**

**Title:** Boulder Creek  
CZO II: Evolution,  
Form, Function and  
Future of the Critical  
Zone

**CU Proposal No. 0213.05.0211B**

(Revised 06/13/14)			
<b>PI:</b>	Suzanne Anderson	10/1/13-9/30/18	
		<b>Duration: 5 years</b>	
<b>A. Salaries and Wages</b>			<b>Year 2</b>
	PI: Suzanne Anderson, 1.42 mo		14319
	Co.PI: Robert Anderson,	3.6% time summer	1545
	Co. PI: Noah Molotch	5% time summer	1545
	Co.PI: Hari Rajaram	3.7% time summer	1545
	Co.PI: Greg Tucker,	5.5% time summer	1545
	Sr. Personnel: Holly Barnard	5.8% time summer	1545
	Sr. Personnel: Daniel Doak	2.9% time summer	1545
	Sr. Personnel: Brian Ebel (RA)	3% time /year	
	Sr. Personnel: Noah Fierer	5.5% time summer	1545
	Sr. Personnel: Diane McKnight	3.2% time summer	1545
	Sr Personnel: Anne Sheehan	4.1% time summer	1545
	Sr. Personnel: Alexis Templeton	5.1% time summer	1545
	Research Associate: E&O for REU, position TBD		7210
	Research Associate: Post-doc TBN	100% time	50000
	PRA:Field manager (Nate Rock)	100% time	41677
	PRA: Lab manager (Colin Millar)	100% time	38322
	PRA: Data Manager (Jeri Tebbetts)	100% time	48308
	PRA: Graphics/GIS staff (Eric Parrish)	50% time	21870
	Science Discovery Coordinator: (Hester Nadel)	10% time	5144
	Science Discovery Education Designer: (Eric Carpenter)	20% time	10300
	Science Discovery: Field and Citizen Science: (Alexandra Rose)	5% time	3530
	GRA: 9 mos. AY, 50% time, 3 students	<b>Lowest Base Rate</b>	52119
	GRA: 3 mos. Summer, 50% time, 3 students	<b>Lowest Base Rate</b>	17204
	Undergraduate Students academic year	1080 hours (3 students x 10 hrs/wk x \$11.33/hour)	12236
	Undergraduate Students summer	1440 hours (3 students x 40 hrs/wk x	16315

		\$11.33/hr)	
	Science Discovery Undergraduate Student Hourly	120 hrs x \$10/hr	1236
	Lab Coord.: Wendy Roth	2 months at 50% time	4819
	System Administrator: Chad Stoffel		7978
	Project Accounting Asst.: Christina Zetterholm		15955
	<b>Total Salaries and Wages</b>		<b>383990</b>
	<b>B. Fringe benefits</b>		
	PI: 27.5%		3938
	Co.PI: 27.5%		425
	Co.PI: 27.5%		425
	Co.PI: 27.5%		425
	Co.PI: 27.5%		425
	Sr. Personnel: 27.5%		425
	Sr. Personnel: 27.5%		425
	Sr. Personnel: 30.9%		477
	Sr. Personnel: 27.5%		425
	Sr. Personnel: 27.5%		425
	Sr. Personnel: 27.5%		425
	Sr. Personnel: 27.5%		425
	Research Assoc.: 30.9%		2228
	Research Assoc.: 30.9%		15450
	PRA: Field manager: 30.9%		12724
	PRA: Lab manager: 30.9%		11687
	PRA:Data manager: 30.9%		14927
	PRA: Graphics/GIS staff: 30.9%		6589
	SD Coordinator: 30.9%		1589
	SD Educ. Design.: 30.9%		3183
	SD Manager: 30.9%		1091
	GRA: 7.9%		4117
	GRA: 7.9%		1359
	Undergrad: 1.0%		286
	Undergrad: 1.0%		12
	Lab Coord: 30.9%		1489
	Sys. Adm.: 30.9%		2465
	Prjt. Acctg. Asst.: 30.9%		4930
	<b>Total Fringe benefits</b>		<b>92790</b>
	<b>C. Equipment</b>		
	<b>Total Equipment Costs</b>		<b>0</b>
	<b>D. Travel (all domestic)</b>		
	PI meetings, travel for 2 people, 2 trips		

		RT airfare, \$515, 2 trips	2060
		Meals & lodging, 3 days/trip, \$144/day	865
	Cross-CZO: Modeling (7.1K total for this activity over grant)		
		Travel allowance for 2 modelers to visit CZOs	1188
	Cross-CZO: CZ Network Research Workshop ( \$15K total for this activity)		
		Travel Allowance: \$600 per trip/12 people	7200
		Housing: \$120/night, 3 nights, 12 people	4320
		Meals: \$60/day, 3 days, 12 people	2160
		Rental vans	900
	Travel for Geobiologists (Templeton and Student) to light source		
		\$515 allowance x 2 people	1030
	Students to professional meetings (AGU, ESA, etc)		
		\$500 allowance x 5 students	2500
	Science Discovery: Mileage to Schools		515
	<b>Total Travel Costs</b>		<b>22738</b>
	<b>E. Participant Support Costs</b>		
	Science Discovery: 3-Day PD workshop for teachers at MRS		
		Stipends (12 participants, \$100/day, 3 days)	3600
		Vans	412
		Lodging - 2 nights + 1 add'l day	1066
		Meals - 3 days, \$25.75/day, 12 teachers	927
		Materials and Supplies for workshop (12x100)	1200
	Science Discovery: 5-Day High School student field course		
		Vans	618
		Lodging 4 nights + 1 add'l day	1931
		Meals - 5 days, \$25.75/day,	1545
	<b>Total Participant Costs</b>		<b>11299</b>
	<b>F. Other Direct Costs</b>		
	<b>Materials and supplies</b>		
	Batteries, Cables, Datalogger Maintenance, Tools, Calibration		4326
	Dionex Lab Supplies		3090
	Filters, Bottles		7210
	Deionized Water		1133

	Misc Lab supplies		4223
	Science Discovery Programs		2000
	<b>Publication costs</b>		2500
	<b>Computer Services</b>		
	OIT Managed Services and Consulting		7725
	<b>Subawards</b>		
	USGS (Blum and Murphy)	520 hrs student help, vehicle costs, lab costs; 57.3% USGS overhead	25933
	<b>Other costs</b>		
	CrossCZO: Meeting space and printing for CZ Network Research Workshop		420
	BcCZO Annual Meeting (room, refreshments)		500
	Computer Upgrades(server)		761
	Software		1300
	Data Loggers		4000
	Field Instrument Budget (New and Replacements)		1200
	Poster printing		500
	Vehicle Maintenance		1854
	Vehicle Fuel		1545
	Vehicle Admin/Risks		1030
	Chemical Analysis of Waters (LEGS)	\$8/sample, 1500 samples/year	12180
	stable Isotope Analysis	\$5/sample, 800 samples/year	4000
	Cosmogenic Radionuclide Sample Prep and Analysis	\$375/sample, 10 samples/year	3750
	Cross-CZO Drill the Ridge Core Drilling		6000
	Microbial Community Sequencing		6090
	Communication		206
	Duplication		314
	Express mail/postage		100
	Tuition, resident	<b>Lowest base rate</b>	32208
	<b>Total Other Direct Costs</b>		<b>136098</b>
	<b>G. Total Direct Costs</b>		<b>646916</b>
	<b>H. Total Indirect Costs</b>		
	On Campus: 52.5%		<b>303176</b>
	<b>I. Total Costs</b>		<b>\$950,092</b>

## Justification- Year 2

**Salaries and wages:** PI Anderson will receive 1.42 mo summer salary, a reduction from the 1.5 mo in year 1, owing to a significant raise in her pay rate. All co-PIs and senior personnel will

each receive \$1545 summer salary, which ranges from 3-6% (0.09-0.18 mo) of summer salary. This is token salary support; we feel it is more important to share students and post-docs, access to support staff, lab and field resources, and cross-CZO opportunities.

We shall support 3 *grad students* with 50% time GRA (Grad Research Assist) appointments in the academic year and summer. We are supporting students at a low pay rate; INSTAAR has moved this year (spring 2014) to level grad student pay rates (which vary across schools and departments), which should mean higher rates. But we did not build our budget a year ago with this in mind, so will have to stay at the lower rate for the present. We have support from the Graduate School for 1 additional student.

Four years of *Post-Doc Research Assoc.* support is planned, envisioned as supporting 2 individuals for 2 years each. The request is spread across all years as: 10 mo in yr 1, 12 mo in yr 2-4, and 2 mo in yr 5.

*Education and outreach:* In total, we include 4.2 mo/yr support for 4 individuals working on E&O as follows. For undergrad outreach, we will convert \$7210 that had been earmarked to support Dr. Val Sloan in this position into salary for others (probably at a slightly lower pay rate) to oversee a community-college focused REU program. We will need to write a supplement request or proposal for the REU, building on experience from the REU Supplement funded program we are running presently. Funds for this administrative work and for faculty/students assisting is absolutely essential for such a program to succeed, as the time demands outweigh other benefits. For K-12 outreach, we support Science Discovery personnel, including 10% time (1.2 mo) for Teacher Program coordinator, 20% time (2.4 mo) for Education Designer, and 5% time (0.6 mo) for a Citizen Science/Field coordinator. These personnel work with our grad students and faculty to develop and deliver outreach activities described in the proposal.

Full-time PRA (Pro. Research Assist.) staff include *field manager*, *lab manager*, and *data manager*; 50% (6 mo) for our *graphics/GIS specialist*.

INSTAAR's *system administrator* and *project accounting* assistant are budgeted according to established practices.

**Equipment:** No equipment funding is planned in year 2.

**Travel:** Expenses are requested for PI and one other person to travel to Fall AGU meeting and to one other National CZO PI meeting each year. Total request is \$2840 per year (incremented by 3%/yr) for airfare and per diem for 2 travelers.

*Cross-CZO modeling:* Per agreement with other CZO PIs, we include funds for modelers in our group to travel. We have \$1188 budgeted for this activity; we anticipate that this money will be used by the post-doctoral researcher we plan to hire in Year 2.

*Cross-CZO CZ Network Research Workshop:* Per agreement with other CZO PIs, we budgeted \$15k for a research workshop in yr 2 to bring 12 researchers from outside BcCZO for a 3 day intensive research workshop.

*Travel to lightsource:* Travel allowance for geobiologist Templeton and student to travel to lightsource for sample analysis \$1030.

*Student meeting travel:* We budget a total of \$2500 to defray costs of attending professional meetings for students and post-doc.

**Participant Support Costs:** Two activities fall in this budget category.

*Science Discovery Professional Development teacher workshop:* We will offer a 3-day PD class for 12 teachers, providing stipends (\$100/d, 3 d, 12 teachers), subsistence meals and lodging (\$1993), materials and supplies (\$100/teacher), a van for field trips (\$412).

*Science Discovery High School student summer class:* We offer a 5-day summer science field class for 12 high school students at the Mountain Research Station. We provide subsistence meals and lodging (\$3476) and vans for transporting to field sites (\$618).

**Other Direct Costs:** These include *Materials and Supplies* that are primarily for our field monitoring and sampling program. We have \$2000 budgeted for materials and supplies for Science Discovery programs that do not constitute participant support costs. This covers materials for the Middle School workshops on critical zone science that travel around the state for instance. We budgeted \$2500 for *Publication costs*. We include \$7725 for CU's Office of Information Technology *Managed Services and Consulting* program, an internal service center that contracts its expertise to meet the computational needs of CU PIs. BcCZO contracts its server software and hardware support needs, licenses, and memory backup cycling for our database to Managed Services and Consulting. *Other costs* include a small budget for refreshments for local BcCZO meetings (\$500), a small increment for server upgrades (\$761), and a budget for software (\$1300) like a Rivertools license, upgrades to Adobe suite, etc. We plan to replace some field dataloggers, so that all our monitoring is on CR-1000's (\$4000), and have a small budget (\$1200) for replacement and expansion of field instrumentation. We anticipate costs for vehicle maintenance (\$1854), for fuel (\$1545), and for insurance/admin (\$1030). The latter cost is set by CU's Transportation Services. We collect ~1500 water samples each year, and so budget \$12180 for chemical analyses of water, and an additional \$4000 for stable isotope analyses. We plan on processing 10 cosmogenic samples this year, at a total cost of \$3750. We budget \$6090 for microbial community sequencing. We have planned \$6000 in spending on costs associated with drilling and geophysical measurements. We have a tiny budget for poster printing (\$500), and a similar amount for any communication costs (duplication, postage, teleconferencing) (\$620). Finally, tuition for our graduate students is \$32208.

**USGS Subcontract:** Our USGS team members are responsible for continued follow-up work on the Fourmile fire (Murphy) and for geochemical analysis of soil and rock (Blum). Their \$25933 subcontract includes 520 hours of student field assistance (\$13/hr, including fringe benefits), field vehicle costs (\$500), field supplies (\$2000), meeting travel (\$1000), and analytical costs (XRF, XRD, trace metals) (\$6000). The USGS indirect cost rate is 57.36%.

#### INSTAAR BUDGET JUSTIFICATION

The Institute of Arctic and Alpine Research (INSTAAR) is a unique unit of the University of Colorado, solely dedicated to research and completely separate, though complementary, to the traditional academic department. INSTAAR is an interdisciplinary institute, designed to house large and complex research programs. Each individual investigator has access to a depth and broad range of scientific expertise that complements his/her research.

Support is requested for *System Administration*. The System Administrator's tasks include maintenance and upgrades for computer networking, printers, communication, network access, software installation, maintenance of INSTAAR'S servers and poster printing.

Support is also requested for *Project Accounting* technical assistance that is necessary for executing, administering and accounting for the proposed project. This position provides administrative support in the areas of grant administration, finance, budget, and accounting (including payroll, travel, purchasing, accounts receivable/payable, inventory, etc.)

*Communication, duplication, and postage* include such items as toll calls, postage, fax charges, telephone equipment and photocopies that specifically support this project. CU maintains telecommunications services that include the capability of tracking expenses to specific projects. INSTAAR maintains photocopy services that include capability of tracking expenses to specific projects.