Preview of Award 1331841 - Annual Project Report

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Accomplishments

* What are the major goals of the project?

The overarching question guiding LCZO2 is: ***How do hot spots and hot moments in weathering, biogeochemical cycling, hydrologic processes, and atmospheric inputs drive landscape evolution and CZ function in a humid tropical forest?***

Our research is organized into four inter-related focal areas. Focal Area 1 explores the importance of knickpoints and different landscape positions as hot spots for weathering, soil development, and biogeochemical cycling. Focal Area 2 addresses the role of hot spots and hot moments in redox cycling that contributes to the dynamics of weathering, and to the retention and loss of C and nutrients in soils over a range of spatial and temporal scales. Focal Area 3 determines the role of hot moments in the transport of sediment, C, and nutrients in stream flow, and hot spots that determine the distribution of material across the landscape. Focal Area 4 scales up hot spots and hot moments in time and space using climate and hydrologic modeling, and identifies the role of key atmospheric inputs in clouds and rain. Taken together, the research proposed in LCZO2 will provide a well-integrated assessment of critical zone properties and processes that scale from microsites to catenas, watersheds, landscapes, and the region, and from minutes to hours, days, months, and years. The data collected and synthesized as part of LCZO2 will contribute to our understanding of the controls on weathering, soil development, C and nutrient storage and loss, soil and sediment transport, and ultimately landscape evolution and effects of climate change. Through collaborations with local and federal agencies and educational institutions, we will conduct workshops and outreach activities to inform policy makers and other stakeholders of our research findings and the significance of the Critical Zone in the Luquillo Mountains of Puerto Rico.

Our goal is to address each of the specific hypotheses listed below. Participants responsible for each focal area and hypothesis are also included.

Focal Area 1: Hot spots and hot moments in the deep critical zone (*Brantley Focal Area Lead*)

- H1.1: The higher chemical weathering flux and depletion of rock-derived elements from soils in QD above the knickpoint results from the penetration of high-O2 waters into fractures that promote rapid weathering. Below the knickpoint, relatively low-O2 waters effectively lower reaction rates. In contrast, in the VC rocks, O2 is consumed relatively high in the profile throughout the watersheds and deep dissolution of silicates outpaces deep Fe oxidation. As a result, VC-derived soils above and below the knickpoint show less variation than their QD-derived counterparts (*Brantley*, Comas, Buss)
- H1.2: Hot spots of rock-derived nutrient availability are best predicted from denudation rates and lithology. The transition from reaction limitation (below the knickpoint) to supply limitation (above the knickpoint) will result in much higher phosphorus and cation availability lower in the landscape (*Porder*)

Focal Area 2: Hot Spots and Hot Moments in Redox Dynamics and Associated Fe-C interactions (*Silver Focal Area Lead*)

- H2.1: Patterns in rainfall, drainage, and biological activity drive the distribution of redox environments in the critical zone (*Silver*)
- H2.2a: Rapid, high magnitude redox fluctuations create hot spots and hot moments of decomposition by stimulating Fe reduction and associated C decomposition (*Silver*, Thompson, Plante)
- H2.2b The storage and stabilization of soil organic matter in LCZO soils is controlled by hot spots of Fe-C interactions rather than the bulk mineral matrix. (*Plante*, Thompson, Silver)

Focal Area 3: Watershed scale hot spots and hot moments (*Jerolmack* Focal Area Lead)

- H3.1: Particulate carbon, fine sediment and bed material each have different characteristic transit times within a watershed. Particles with short residence times are generated at hot spots in the landscape, and particles with long residence times are eroded and transported from relatively stable parts of the landscape during hot moments. Because of differences in landscape stability, these characteristic time scales will differ with position above or below knickpoints (*Willenbring*, Jerolmack, Shanley, González)
- H3.2: Floods are hot moments that may be treated as 'impulses' that drive sediment transport. The availability of sediment is strongly variable in space due to hot spots associated with physical landscape discontinuities, mainly knickpoints. Sediment transport hysteresis curves allow estimation of time- and space-varying sediment availability. Feedbacks between transport and topography maintain hot spots. (*Jerolmack*, Willenbring)
- H3.3: Hot spots in stream chemistry are associated with recent landslides; hot moments are associated with high flow events that can dilute or enrich various solutes. Watershed lithology controls spatial and temporal variability of solute chemistry through its influence on landslides and subsurface flow paths (*McDowell*, Shanley)

Focal Area 4: Hydrologic and Atmospheric Hot Spots and Hot Moments (*McDowell* Focal Area Lead)

- H4.1: The distribution of hydrologic hot spots like sediment sources and landslides will vary with watershed soils, vegetation, and channel knickpoints; the occurrence of hot spots will vary as a function of storm intensity and frequency (hot moments) (*Bras*, Wang, González)

- H4.2: Orographic precipitation in the LM has decreased during historic times as a consequence of climatic warming. Orographic rains make a disproportionately large contribution to base flow (critical to municipal water supplies), and more so in VC than QD. Cloud level has likewise changed, resulting in smaller cloud inputs of moisture and nutrients to the Luquillo Mountains with important biotic consequences (*Scholl*, González, Gould, Shanley)
- H4.3: Intercontinental transport of African dust alters incoming radiation and cloud formation, and provides nutrient inputs that are significant relative to those from rain events during periods without dust in the atmosphere (H4.2) (*Mayol-Bracero*, Scholl, González).

The major milestones anticipated during the course of LCZO2 are outlined in a supporting file (attached as a PDF).

The core research teams that comprise the LCZO2 and the tasks to meet the goals for each focal area are outlined in a supporting file (attached as a PDF).

*** What was accomplished under these goals (you must provide information for at least one of the 4 categories below)?**

Major Activities:

As outlined in our management plan, our approach for integrating research among the 4 different focal areas and for managing partners and participants was to form an executive committee that met every two months and to host regular LCZO meetings. The LCZO executive committee was formed in December 2013 and met for the first time on January 3, 2014. The executive committee has met at least every 6-8 weeks since. The first all-hands LCZO meeting was held January 10, 2014 from 11:00 am to 4:00 pm eastern via web-broadcast using GoToMeeting and 19 project presentations were given by various participants including graduate students, post-docs, PIs and senior personnel. Additional 2 hour all-hands LCZO meetings were held using GoToMeeting on February 28, 2014 and April 25, 2014 which featured one presentation from each focal area and open discussion. The annual all-hands LCZO meeting in Puerto Rico was held from June 1-3, 2014. The meeting started with a field trip where participants travel by boat down the Rio Espritu Santo. During the course of the remaining two days, 25 presentations were given by various participants including graduate students, post-docs, PIs and senior personnel, discussions were had regarding cross-cutting themes and project administration and participants visited field sites for the 4 cross-cutting themes.

Below are accomplishments specific to each focal area and represent activities from December 1, 2014 through the August 8, 2014.

<u>Focal Area 1:</u> **Hot spots and hot moments in the deep critical zone**

Installation of pressure transducers to measure water level in 2 of 4 actively studied groundwater wells in Rio Icacos was completed. Pump tests were conducted on groundwater wells to determine aquifer properties. Groundwater was extensively sampled and analyzed of groundwater. We completed approximately 5 kilometers of GPR profiles along Rte. 191 in both common midpoint and common offset modes, and have mapped lineaments within the Rio Icacos watershed. We have analyzed all data. We are also writing two papers on the work. We also collected soils from a series of subwatersheds to analyze the relationship between geomorphic position, denudation rate, and soil weathering. The analyses of these soils is done, and two manuscripts are currently in preparation.

<u>Focal Area 2:</u> Hot Spots and Hot Moments in Redox Dynamics and Associated Fe-C interactions

Silver's group has installed soil oxygen, moisture, and temperature sensors. They plan to install automated chambers in the fall, and will be begin sampling soil Fe species in the fall as well. Plante's group has completed a set of selective dissolution and extraction experiments on a subset of surface soils spanning the LCZO Soil Network. Soils were extracted to isolate several forms and phases of Fe/Al oxide minerals and the organic matter associated with them. Thompson's group has conducted redox fluctuation experiments as a function of O2 flux during the oxidation half-cycle and measured the subsequent rate of Fe reduction and during the reducing half-cycle. In addition, we have extracted DOC from the LCZO soils and used that material in Fe2+ catalyzed Fe-oxide re-crystallization experiments.

<u>Focal Area 3:</u> Watershed scale hot spots and hot moments

- Completed field and experimental activities on the mechanics of pebble abrasion, and its contribution to fine sediment production.
- Completed field study and theoretical development on sorting, transport distances and thresholds of motion of pebbles in a flashy tropical channel.
- Created first prototype of a new "smart rock" to measure pebble impacts at high resolution during storms.
- Upgraded in-stream sensor array and quality controlled existing fluorescent dissolved organic matter (FDOM) and turbidity data.
- Collected and analyzed water samples in support of development of DOC-FDOM and particulate carbon-Turbidity relations.
- Installed new sensors in three watersheds to measure temperature, oxygen, and specific conductance.
- Measured erosion rates upstream and downstream of knickpoints, and as a function of soil mineralogy and nutrients.
- Measured grain sizes of sediments upstream of knickpoints.

<u>Focal Area 4:</u> Hydrologic and Atmospheric Hot Spots and Hot Moments

Continuous measurements of basic meteorological parameters (including visibility, and cloud properties such as liquid water content, size distributions of droplets, and cloud base height were begun at Pico del Este to determine annual, seasonal, and diurnal variations.. We anticipate continuing these measurements for 3-4 years to obtain long-term information. A sequential time-integrated precipitation isotope collector and an active-strand cloudwater collector were also deployed at Pico del Este. The instruments sampled cloud water at 30-minute intervals for three 48-hour periods. Sample volumes yielded an estimate of cloud water deposition rate, which will be converted to water balance inputs using liquid water content measurements from the site. Samples were analyzed for stable isotopes of cloud water, and a subset was reserved for ion and nutrient chemistry analysis by E. Torres, in the Mayol research group. Ongoing measurement of cloud base height were obtained from the Sabana Field Station, yielding the first year of continuous ceilometer data. We started the calculation of the HYSPLIT back trajectories in July 2014.

Additional work on cloud events focused on using terrestrial-based sensors to determine cloud conditions. Five cameras were installed at 100 m intervals from 600 to 1000 m elevation in the Mameyes watershed of the Luquillo Mountains. Relative humidity sensors were installed at the 700 and 1000 m sites. Images taken every 30-60 minutes will be used to determine the spatial extent, frequency, duration and intensity of cloud immersion.

Our study has produced a database of raw monthly climate indices and hourly surface meteorological data. Data are from the National Oceanic and Atmospheric Administration's (NOAA) Earth System Research Laboratory (ESRL) and National Climate Data Center (NCDC). Meteorological data were taken from weather stations at the San Juan International airport (Lat.:+18.433 N Long: -66.011 Elev.: 2.4 m) and the Roosevelt Roads Naval Station (Lat.:+18.255 N Long: -65.641 N Elev.: 11.6 m). Hourly cloud ceiling, air temperature, relative humidity and dew point data cover the time period from 1955 to 2012. Monthly Atlantic Multi-decadal Oscillation (AMO), North Atlantic Oscillation (NAO) and Southern Oscillation Index (SOI) data span from 1866 to 2012. These data were used to construct quarterly averages for the variables used in the analysis.

To determine whether cloud water deposition contributed to stream discharge, water level and specific conductance loggers were installed and stable isotope samples were taken in a perennial headwater stream located down slope from the Pico del Este site (Fajardo A, 872 m). The stable isotope data will be used to trace cloud water recharge through the hydrologic system.

Martha Scholl, Olga Mayol-Bracero, Grizelle Gonzalez (co-PI's) and Elvis Torres (graduate student) met April 9, 2014 to report progress and discuss research approaches for Focal Area 4 tasks.

The effort to improve the DEM for the LCZO using Light detection and ranging (LiDAR) is described in a supporting file (attached as a PDF).

Specific Objectives:

Focal Area 1: Hot spots and hot moments in the deep critical zone

- Use GPR to understand the depth of the weathering interface at several scales of measurement (from m to km).
- Use laboratory analyses to understand the extent of weathering and important weathering processes/pathways.
- Couple in situ measurement of erosion rate using 10Be with soil weathering and cation availability.

Focal Area 2: Hot Spots and Hot Moments in Redox Dynamics and Associated Fe-C interactions

- Determine patterns in soil redox dynamics across the landscape using the installed oxygen sensors.
- Determine relationships with Fe reduction and associated carbon oxidation.
- Quantify and characterize the organic matter associated with the various Fe/Al mineral phases in comparison with the bulk soil matrix.
- Characterize the linkage between Fe oxidation rate and C decomposition during subsequent Fe reduction events.

Focal Area 3: Watershed scale hot spots and hot moments

- Determine a universal mass loss curve for pebble abrasion by accounting for effects of impact energy and lithology.
- Provide an estimate of bed load transport from event to annual scale in unsteady flows.
- Develop ability to measure grain-grain collisions and estimate the threshold of bed load motion.

Focal Area 4: Hydrologic and Atmospheric Hot Spots and Hot Moments

- Determine short-term precipitation and temperature trends along an elevation gradient in northeastern Puerto Rico.

Significant Results:

Focal Area 1: Hot spots and hot moments in the deep critical zone

We discovered that sulfur deposition into the soils increases with elevation in El Yunque. We also discovered EM velocity contrasts between bedrock and weathered material and that the use of GPR is most effective on the quartz diorite and volcaniclastic sediments and that the depth to weathering increases with elevation. Groundwater response to large rainstorms (hot moments) is varied. In some locations, groundwater response is near instantaneous with increases in precipitation rate. In other locations, response to major precipitation events is barely recorded. The groundwater system is complex, but has clear impacts on solute fluxes out of watersheds. Residence time of most groundwater is short (typically less than 5 years). We found that there are series of linked ridges that vary in weathering status but not in denudation rate. This provides data for the hypothesis that ridge width, independent of denudation rate, controls soil weathering via differences in soil redox and thus mineral dissolution.

Focal Area 3: Watershed scale hot spots and hot moments

- Demonstrated how lithology controls abrasion rate of pebbles, and found that fine sediments produced from abrasion follow a universal size distribution for all rock types.
- Developed and demonstrated a generalized framework for determining bed load transport from a hydrograph, and verified a theory for downstream grain-size sorting.
- Showed that grain-size sorting of gravel and sand has a generalized form on alluvial fans, that is a consequence of the influence of sand on the threshold of motion of gravel.
- Demonstrated from a compilation of data that both bedrock and alluvial rivers organize their geometry to the threshold of motion for bed load, and that this puts a “speed limit” on the potential erosion rate of bedrock rivers.
- Despite expectations, FDOM measurements are still valid (correctable) at all but the very highest turbidity conditions in Rio Icacos.
- TSS-PC and DOC flux calculations in progress.
- Correlated stream erosion rates with soil mineralogy and the availability of nutrients.
- Developed a fine-sediment geochemical fingerprinting technique.

<u>Focal Area 4:</u> Hydrologic and Atmospheric Hot Spots and Hot Moments

An analysis of wettest and driest months of the rainfall seasons showed a small increasing trend in the precipitation of the driest months, and no trend in the precipitation of the wettest months. There was strong evidence that precipitation in the driest months of each rainfall season increased faster at higher elevations, and some evidence for the same pattern in precipitation in all months of the year.

The biogeochemical hotspot at the soil–regolith interface may affect weathering rates at deep weathering hotspots (e.g., fracture zones) by dramatically depleting O2, a key weathering reactant.

In the deep weathering hotspots of the volcaniclastics, which occur as weathering rinds surrounding corestones and lining bedrock fractures, oxidative weathering of minor sulfide minerals (pyrite, chalcopyrite) is the first weathering reaction. This reaction occurs inboard of the visible weathering rinds and produces sulfuric acid that contributes to weathering of primary silicate minerals within the rock. This weathering mechanism is fundamentally different to those operating within the saprolite or soil where sulfide minerals are absent.

Mg isotope ratios in Bisley 1 stream water during a storm event indicates that in addition to Mg from rain, there is a significant contribution of heavy Mg at the beginning of the storm and during base flow. We think this reflects dissolution of chlorite at the deep weathering hotspots. This indicates the dominance of deep flowpaths in the Bisley volcaniclastics with overland flow during storm events, similar to what was determined for the Rio Icacos (quartz diorite) watershed previously (Kurtz et al., 2011).

Dosseto et al. (2014) used U-series isotopes to determine that river sediments (Rio Icacos and Rio Sabana, quartz diorite; Rio Mameyes, volcaniclastic) were derived from deep saprolite, likely landslide derived, and that the mode of erosion (shallow or deep) affects the weathering rates measured on river sediments.

Balan et al. (2014) measured concentration, isotopic composition and fluxes of S in Rio Icacos and Bisley. Bedrock contributions to baseflow S in Bisley 1 stream water were found, but none were found in Rio Icacos stream water. Rainfall and topography strongly affected soil S cycles, but lithology had little to no effect. Cycles of N and S in soils are decoupled at the LCZO, with S showing greater sensitivity to redox fluctuations.

Buss et al. (2013) documented the deep subsurface CZ and examined weathering along corestone surfaces and bedrock fractures. We showed that weathering depth (and hence, CZ formation) in Bisley is not controlled by the stream level as weathering extends 20+ m deeper. This also indicates that not all of the water in the watershed is discharged via the Bisley 1 stream. We also showed that although exposed corestones are relicts of subsurface weathering, they do not reflect all weathering and saprolite formation mechanisms and rates that occur in the subsurface because their weathering rinds spall off, preventing diffusion limitation.

Analysis from the cloud base study thus far has yielded the following results: Cloud base at both of our study sites showed a sustained upward rise in mean cloud base of approximately 200 to 250 meters in the early to mid-1980s. Cloud base altitude at Roosevelt Roads rose from an average of 600 meters in the 1960s through the early 1980s to approximately 800 meters from the late 1980s through 2012. At San Juan International Airport, cloud base altitude on average rose from 700 meters in the late 1950s through the 1970s to 900 meters in the early 1980s through 2012. Our analysis produced quarterly mean climate index values. AMO, NAO and SOI are significant drivers of change in mean quarterly cloud base at Roosevelt Roads. A quarterly predictive model based on all three oscillations explained as much as 50% of the variability in cloud base at Roosevelt Roads. The same model explained 53% of the variability in cloud base at San Juan International airport. With the quarterly model and oscillation data dating back to the late 19th century, we were able to back predict cloud base at Roosevelt Roads. Results suggest an anomalous period of low cloud base between the late 1950s and the late 1980s. Cloud base since the late 1980s has been higher than the long term average of approximately 725 meters.

Key outcomes or Other achievements:

Focal Area 1: **Hot spots and hot moments in the deep critical zone**

One master's student completed his master's degree. Three undergraduates at Brown finished their honors theses and graduated, and graduate student Almaraz will present her findings at the Ecological Society of America Meeting in Aug 2014.

Focal Area 3: **Watershed scale hot spots and hot moments**

- Three papers published or in press related to pebble abrasion, sorting and bed load transport.
- All data generated has been posted on the LCZO website and is freely available.
- Developed several theoretical frameworks for interpreting LCZO data that may be applied much more generally to other CZO sites and beyond.
- Initiated collaboration with LCZO collaborator A. Thompson, to develop unified understanding of the modulation of environmental impulses by reaction and transport in geochemical and geophysical systems.
- Proof-of-concept for successful in-stream sensor deployment under challenging conditions (e.g. successful data from May 2014 10-year flood event).
- Two papers submitted related to knickpoint migration and two papers in preparation for submission.
- One paper submitted on the residence times of water in the landscape and one paper near submission on the source of suspended sediments in streams and the relation to water cycle speed.
- Discovered that the large-scale landscape template on which the soils develop and vegetation grows is key predictor for ecological state.

Focal Area 4: **Hydrologic and Atmospheric Hot Spots and Hot Moments**

- Images, temperature and dewpoint data successfully collected since March 2014.

- Cloud water deposition compares well with data collected in 2013; results show cloud water events contribute a substantial amount of precipitation to the top of the mountain during dry periods.
- Trends in precipitation in the Luquillo Mountains were assessed and related to climate change projections, published in Water Resources Research (Scholl and Murphy, 2014).

*** What opportunities for training and professional development has the project provided?**

<u>Focal Area 1:</u> Hot spots and hot moments in the deep critical zone

One master's student completed a master's degree and one postdoctoral student has furthered their education by becoming involved in water chemistry, weathering, and GPR investigations. Both master's student and the postdoctoral student attended an NSF sponsored workshop on Drilling and Imaging the Deep Critical Zone. The postdoctoral student has also attended to LCZO onsite meeting in June 2014.

<u>Focal Area 2:</u> Hot Spots and Hot Moments in Redox Dynamics and Associated Fe-C interactions

Silver's group recently hired Dr. Leilei Ruan as the postdoctoral scholar of this research project. They also hired Ryan Saladay as a technician on the project. Ryan recently finished his BA degree, and hopes to apply to graduate programs next fall. Elizabeth Coward began her PhD research in the fall of 2013 and is leading the work on soil Fe-organic matter characterization under the supervision of Plante and Thompson. Diego Barcellos began his PhD research in May 2014 on this project and Jared Wilmoth in midway through his PhD research on the impact of oxidation rates on coupled Fe reduction and C decomposition. Maddie Stone will be completing her PhD dissertation research on organic matter, microbial communities and enzyme activities in LCZO soil profiles. The Plante group has also hired two undergraduate students (Crespo, Traxler) to work on LCZO soils-related project over the summer of 2014. The graduate students and postdoc have attended several professional meetings thus far including the LCZO investigator's meeting where they presented their study plans and project results. Silver, Plante and Thompson meet regularly with the students and postdocs to discuss project development and help with skill development. They are also developing mentoring skills through working with the undergraduates and technicians.

<u>Focal Area 3:</u> Watershed scale hot spots and hot moments

- PhD student Phillips has led cross-CZO graduate student group on coordinating research on geomorphology, and co-organized AGU session on cross-CZO activities.
- PhD student Lee participated in LCZO PI meeting and is coordinating research with students from diverse scientific backgrounds.
- PhD student Lee is collaborating with agricultural engineers at University of Georgia in developing smart rocks.
- Postdoc Ortiz engaging with physicists, engineers and geologists to develop and deploy smart rocks to solve diverse scientific problems.
- PhD students and postdocs in Jerolmack's group are presenting research at AGU and Gordon Research Conference on granular physics.
- Shanley has engaged a newly-minted B.S. and a tech-savvy high school student in the quality control and analysis of in-stream sensor time series.
- PhD student Harrison will attend the All hands meeting in September 2014.
- B.S. on-site LCZO coordinator Mr. Geoff Schwaner will be attending Wireless Sensor Camp, August 2014; he has also begun work on a manuscript assessing the effects of watershed position and bedrock lithology on soil C and N content.
- Post-doctoral scientist Adam Wymore worked on a project to develop a CZO curriculum for use at the university level.

<u>Focal Area 4:</u> Hydrologic and Atmospheric Hot Spots and Hot Moments

Training of graduate student in the use of the LWC (liquid water content sensor), the BCP (backscatter cloud probe), cloud and rainwater sampling, and a WIBS (Wideband Integrated Bioaerosol Sensor). The WIBS training was performed at the company that manufactures the instrument (Droplet Measurement technologies), using funds from the fellowship the student has (PRLSAMP). The student also participated in the 2014 Summer Workshop on Data Analysis of Cloud Microphysical Measurements that was held in the multipurpose room of the Massachusetts Institute of Technology Media Lab in July.

*** How have the results been disseminated to communities of interest?**

Numerous presentations made by students, post-docs, PIs and senior personnel on research plans and results have been given at project meetings and at national and international conferences. Project results have also been submitted for publication and published in the peer-review scientific literature. Please see the products section for list of presentations and publications. Data have also been archived on LCZO website.

As part of our engagement with the National CZO network, Andy Neal, Scott Hynek, Susan Brantley, Whendee Silver, Jane Willenbring, William Gould, Sebastian Martinuzzi, and Colin Phillips have been involved in cross-CZO efforts. Here are some examples of how individuals have been involved:

- PhD Student Colin Phillips has participated in a cross-CZO graduate student working group on geomorphology.
- We are working across CZOs on the “Drill the Ridge” campaign, led by Brantley, to understand what controls the depth of weathering. Brantley was asked to give a talk about this campaign, including Luquillo, at the Deep Drilling workshop at GSA led by Cliff Riebe. Techniques used in Luquillo are being disseminated to other CZOs.
- Investigator Willenbring has rebooted the cross-CZO cosmogenic nuclide measurements team and initiated a database expansion and data reporting guideline effort.
- The cross-CZO cosmogenic nuclide investigators, led by Willenbring, came up with metrics for standard reporting of meteoric 10Be concentrations. These reporting guidelines go online through the Geochron database in late August. This marks the first instance of a long-awaited national data-archive to store cosmogenic nuclide data.
- Alain Plante is leading a soil organic matter cross-CZO effort.[DM1]

Several activities were undertaken to reach members of communities not usually aware of these research activities which include:

- PhD student Dylan Lee participates in science mentoring of elementary school children in West Philadelphia.
- Bill McDowell met with Steven McGee to strategize on how to incorporate a Critical Zone component into the Journey to El Yunque, which is planned for the next budget year.
- Post-doc Adam Wymore worked on a college level CZO curriculum with Tim White and other CZO and non-CZO participants.

A number of letters of support were provided for partners seeking funding to engage in LCZO efforts.

*** What do you plan to do during the next reporting period to accomplish the goals?**

We will continue to facilitate research among the 4 different focal areas by holding regular executive committee meetings (every 6-8 weeks) and all-hands CZO meetings (every other month via GoToMeeting and once annually in Puerto Rico). We will continue with efforts outlined in our management plan for engaging in cross-CZO efforts and with the broad research community through working with partner organizations (USFS, USGS, and UPR) and other partners through the partners program. We will also continue efforts outlined in our management plan to support public outreach and education activities. Three sub-committees of the executive committee have been established to support these goals:

- Site Management, local operations (Led by González)
- Data management, outreach, engagement (Led by Plante)
- Cross-site CZO activities and new research initiatives (Led by Silver)

Tasks to meet the goals for each focal area during the next reporting period are outlined below.

Focal Area 1: Hot spots and hot moments in the deep critical zone

We will complete two papers, one first authored by Joe Orlando and one first authored by Scott Hynek.

Focal Area 2: Hot Spots and Hot Moments in Redox Dynamics and Associated Fe-C interactions

The Silver group will continue to collect data on soil redox dynamics and begin to samples soils for Fe pools and fluxes as soon as our permit is approved. The Plante group will complete an enzyme sorption study to determine the stability of enzymes in Luquillo soils, as well as further characterization of Fe-C associations through analysis of the extracts for organic matter composition and the mineral composition of the extracted residue. Thompson's group will work with the Plante group to characterize the Fe-C associations through characterization of the Fe mineral phases using Mössbauer spectroscopy, continue the oxidation rate experiments, and conduct experiments characterizing C mineralization as a function of the time soil is oxic vs. anoxic.

Focal Area 3: Watershed scale hot spots and hot moments

- Complete development of smart rocks through collaboration with U. Georgia engineers, and deploy these rocks in the stream.
- Produce first measurements of the forces necessary to estimate abrasion and bedrock erosion rates from field data.
- We will deploy an automated water sampler for collection of samples during high-flow events (when physical visits to the sites are often unsafe) for analysis of TSS and dissolved organic matter to develop relations to optical sensor output. These in turn will aid in process interpretation and accurate stream flux calculations.
- We have discovered that the grain-size of the sediment upstream of the knickpoints is a first-order predictor of the retreat rate of the knickpoints. Our future work entails understanding what grain-sizes are produced through weathering and the mechanism of knickpoint retreat.
- Student Emma Harrison and postdoc Kathryn Clark will begin work understanding the timescales of development and purging of fine sediment and particulate carbon through the landscape to the ocean.

Focal Area 4: Hydrologic and Atmospheric Hot Spots and Hot Moments

- We plan to add radiation measurements to the meteorological parameters we monitor on a continuous manner. The radiation sensors for the weather station will be purchased during the next reporting period.
- Campaign-based measurements of cloud properties during months with and without African dust events will be made. Ideally we should try to sample cloud droplet residuals, interstitial aerosols, and no-cloud aerosols. We will also collect rainwater samples in collaboration with M. Scholl (USGS). Chemical analyses (Ion Chromatography and Inductively Coupled Plasma) will be performed in collaboration with G. Gonzalez at the IITF and with W. McDowell at UNH. Focus of the chemical analyses will be on African dust markers and nutrients. The objectives here will be to improve our understanding on (a) the impact of African dust on radiation, (a) the role of dust in cloud formation and properties, (b) how clouds remove dust, and (d) dust nutrient inputs at Pico Este TMCF.
- We are currently conducting our summer campaign (started July 2014). Completion of this activity will be by year 4.
- Construction of the interstitial inlet will be completed in year 2.
- HYSPLIT model will be used to determine the origin of sampled air masses.
- Calculation of HYSPLIT back trajectories will continue and this will be completed in year 4.

- Nutrient inputs (N, P, C) from African dust will be calculated using estimates of the atmospheric volume scavenged during rain events, derived from radar echo tops and measured airborne dust concentrations. In collaboration with M. Scholl. This will start in the next few months after chemical analyses of the first collected samples are completed.
- Quantification of the relative importance of dust nutrient input compared to that of rainfall will start year 2

The cloud base results will be utilized to help better understand the importance of cloud level in structuring vegetation (H4.2:5). We would like to see if there have been any significant changes to vegetation with a lifting cloud base. Measurements of cloud base altitude from our observed data sets will also be compared to radiosonde and ceilometer measurements at other locations on the island (H4.2:4). A future study will compare cloud base measurements within the forest to cloud base at other study sites. Cloud base is a property important for the study of African dust incursion (H4.3:2). Our analysis yielded seasonal, yearly and multi-decadal changes in cloud base. Future study will explore if changes relate to months with African dust incursion (May to August) and those without (October to December) Cloud base and climate index data sets can be used for horizontal precipitation and rain event studies. We would like to see if higher or lower cloud base tells us anything about precipitation amounts. Further study will address if seasonal variation in precipitation amounts in or around the Luquillo Mountains can be explained by changes in these climate indices. We would also like to address the question of whether or not long term trends in cloud base are related to global warming. Future geophysical study of distal climate drivers and cloud base will help us strengthen our understanding how oscillations affect cloud base and forest dynamics. Such a study will consider the underlying physical mechanisms related to these climate oscillations (i.e. pressure, wind velocity, temperature…etc.). It will address long term changes in cloud base in the Caribbean and other regions of the Atlantic known to be affected by these climate oscillations.

Supporting Files

Filename	Description	Uploaded By	Uploaded On
LCZO2 milestones.pdf	The major milestones anticipated during the course of LCZO2 are outlined in the attached PDF.	Steve Frolking	08/19/2014
Focal area teams and tasks.pdf	The core research teams that comprise the LCZO2 and the tasks to meet the goals for each focal area are outlined in the attached PDF.	Steve Frolking	08/19/2014
LiDAR DEM.pdf	Efforts to improve the DEM for the LCZO using Light detection and ranging (LiDAR) is described in a separate attachment.	Steve Frolking	08/19/2014

Products

Books

Book Chapters

White A.F. and Buss H.L (2014). Natural Weathering Rates of Silicate Minerals.. *In Drever, J.I., ed. Surface and Ground Water, Weathering and Soils, Treatise on Geochemistry 2nd Edition, Elsevier.* 115. Status = PUBLISHED; Acknowledgement of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/B978-0-08-095975-7.00504-0.

Conference Papers and Presentations

Torres, E. and O. L. Mayol-Bracero (2014). *African Dust and Clouds at Pico Este Tropical Montane Cloud Forest: Cloud Chemistry and Microphysics, June 2, 2014, All-hands Meeting of the Luquillo Critical Zone Observatory, Luquillo, PR. (oral)*. All-hands Meeting of the Luquillo Critical Zone Observatory. Luquillo, PR. Status = ACCEPTED; Acknowledgement of Federal Support = Yes

Omar Gutierrez del Arroyo (2014). *African dust inputs and cloud chemistry*. All-hands Meeting of the Luquillo Critical Zone Observatory, Luquillo, PR. Luquillo, PR. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Hall, S. J. and W. L. Silver (2013). *An ecosystem approach to understanding soil C in humid tropical forests: influences of minerals, microbes, and roots.*. ESA Annual Meeting. Minneapolis, Minnesota. Status = OTHER; Acknowledgement of Federal Support = Yes

Rafael Jimenez (2014). *Analysis of historical records of Cloud Base*. All-hands Meeting of the Luquillo Critical Zone Observatory, Luquillo, PR. Luquillo, PR. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Stone MM & Plante AF (2014). *Changes in carbon stability and chemistry along deep tropical soil profiles at the Luquillo Critical Zone Observatory*. Ecological Society of America Conference. Sacramento, CA. Status = ACCEPTED; Acknowledgement of Federal Support = Yes

Grizelle Gonzalez (2014). *Cielometer / data streams*. All-hands Meeting of the Luquillo Critical Zone Observatory, Luquillo, PR. Luquillo, PR. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Miguel Leon (2014). *Composite Method; Report from LiDAR workshop; CZO Cyber Meeting at Stroud*. All-hands Meeting of the Luquillo Critical Zone Observatory, Luquillo, PR. Luquillo, PR. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Whendee L. Silver , Steven J. Hall, Grizelle González (2014). *Differential effects of canopy disturbance and litter deposition on litterfall and nutrient dynamics following a simulated hurricane in a tropical forest*. 99th ESA Annual Meeting. Sacramento, California. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Silver, W. L., S. J. Hall, and G. Gonzalez (2013). *Differential effects of canopy disturbance and litter deposition on litterfall and nutrient dynamics following a simulated hurricane in a tropical forest. (oral presentation).*. ESA Annual Meeting. Minneapolis, Minnesota. Status = OTHER; Acknowledgement of Federal Support = Yes

Coward EK (2014). *Fe-C associations and soil organic matter stability*. All-hands Meeting of the Luquillo Critical Zone Observatory, Luquillo, PR. Luquillo, PR. Status = OTHER; Acknowledgement of Federal Support = Yes

Coward EK & AF Plante (2014). *Fe-C associations and soil organic matter stability in tropical soils of two contrasting parent materials*. SOM6 workshop. Kiawah Island, SC. Status = OTHER; Acknowledgement of Federal Support = Yes

Thompson A., Tishchenko V., Meile C., Scherer M., Pasakarni T. (2014). *Fe2+ catalyzed iron atom exchange and re-crystallization in soils from the Luquillo Critical Zone Observatory*. Goldschmidt2014. Sacramento, California. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Scott Hynek (2014). *GPR and Geophysics*. All-hands Meeting of the Luquillo Critical Zone Observatory, Luquillo, PR. Luquillo, PR. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Tamayo C.D., Brocard G., Porder S. (2014). *Geomorphologic influences on tropical soil weathering and nutrient status.*. 99th ESA Annual Meeting. Sacramento, California. Status = ACCEPTED; Acknowledgement of Federal Support = Yes

Matt Larsen (2014). *Introduction to STRI*. All-hands Meeting of the Luquillo Critical Zone Observatory, Luquillo, PR. Luquillo, PR. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Stone M.M., Plante A.F. (2013). *Invited: Soil Organic Matter and Microbial Activity in Critical Zone of Tropical Soils from Luquillo, Puerto Rico*. Goldschimdt 2013. Florence Italy. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Hall, S. J., G. McNicol, and W. L. Silver. (2013). *Iron Redox Cycling Drives Decomposition of Mineral-Associated C in Humid Tropical Forest Soils*. AGU Fall Meeting. San Fransisco, CA. Status = OTHER; Acknowledgement of Federal Support = Yes

Almaraz, M., Lu H.S., Goldsmith S., Porder S. (2014). *Landscape-scale variation in nitrogen cycling across the Luquillo Experimental Forest, Puerto Rico*. 99th ESA Annual Meeting. Sacramento, California. Status = ACCEPTED; Acknowledgement of Federal Support = Yes

Sebastian Martinuzzi (2014). *LiDAR MCC Analysis*. All-hands Meeting of the Luquillo Critical Zone Observatory, Luquillo, PR. Luquillo, PR. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

McDowell, W. H. (2014). *Long-term N dynamics in a tropical forest: Observations, inferences, and unanswered questions.*. USGS National Headquarters Reston, VA. USGS National Headquarters Reston, VA. Status = OTHER; Acknowledgement of Federal Support = Yes

Brocard G., Willenbring J., Scatena F.N. (2014). *Long-term increase in local relief enhanced by forest competition: detrital 10Be and LiDAR topographic evidence in the tropical rainforest of Puerto Rico, Luquillo CZO*. EGU General Assembly 2014. Vienna, Austria. Status = OTHER; Acknowledgement of Federal Support = Yes

Brocard G., Willenbring J., Johnson A., and Scatena F.N. (2014). *Migration of a slow wave of erosion and its effect on nutrient availability in a tropical rainforest: detrital 10Be signature and soil mineralogy, Luquillo CZO, Puerto Rico*. EGU General Assembly 2014. Vienna, Austria. Status = OTHER; Acknowledgement of Federal Support = Yes

McNicol, G. and W.L. Silver. (2013). *Non-linear response of soil carbon gas (CO2, CH4) flux to oxygen availability.*. AGU Fall meeting. San Fransisco, CA. Status = OTHER; Acknowledgement of Federal Support = Yes

McNicol, G. and W.L. Silver (2013). *Non-linear response of soil carbon gas (CO2, CH4) flux to oxygen availability.*. ESA Annual Meeting. Sacramento, California. Status = OTHER; Acknowledgement of Federal Support = Yes

Leilei Ruan (2014). *O2 – sensor array*. All-hands Meeting of the Luquillo Critical Zone Observatory, Luquillo, PR. Luquillo, PR. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Geoff Schwaner (2014). *Sensor Networks*. All-hands Meeting of the Luquillo Critical Zone Observatory, Luquillo, PR. Luquillo, PR. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Dylan Lee (2014). *Smart Rocks*. All-hands Meeting of the Luquillo Critical Zone Observatory, Luquillo, PR. Luquillo, PR. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Stephen Porder (2014). *Soil Nitrogen*. All-hands Meeting of the Luquillo Critical Zone Observatory, Luquillo, PR. Luquillo, PR. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Aaron Thompson (2014). *Soil carbon and Iron*. All-hands Meeting of the Luquillo Critical Zone Observatory, Luquillo, PR. Luquillo, PR. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Diego Barcellos (2014). *Soil carbon and Iron*. All-hands Meeting of the Luquillo Critical Zone Observatory, Luquillo, PR. Luquillo, PR. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Erika Marin-Spiotta (2014). *Soil carbon dynamics*. All-hands Meeting of the Luquillo Critical Zone Observatory, Luquillo, PR. Luquillo, PR. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Xavier Comas (2014). *Soil geophysics*. All-hands Meeting of the Luquillo Critical Zone Observatory, Luquillo, PR. Luquillo, PR. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

González G., Lodge D.J.,McGinley K., Jennings L.N., Heartsill-Scalley T.,Wood T.E. (2014). *Tropical forest responses to Global change: Evidence from the Luquillo Experimental Forest.*. 99th ESA Annual Meeting. Sacramento, California. Status = ACCEPTED; Acknowledgement of Federal Support = Yes

Stone MM, Hockaday W & Plante AF (2014). *Using 13C NMR to evaluate the chemical nature of subsoil organic matter in tropical forest soils.*. SOM6 Workshop. Kiawah Island, SC. Status = ACCEPTED; Acknowledgement of Federal Support = Yes

Jennifer Pett-Ridge (2014). *Warming Experiment Microbiology*. All-hands Meeting of the Luquillo Critical Zone Observatory, Luquillo, PR. Luquillo, PR. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Tana Wood (2014). *Warming Experiments*. All-hands Meeting of the Luquillo Critical Zone Observatory, Luquillo, PR. Luquillo, PR. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Elisa Arnone, Yannis Dialynas (2014). *Watershed Hydrologic modeling*. All-hands Meeting of the Luquillo Critical Zone Observatory, Luquillo, PR. Luquillo, PR. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Mayol-Bracero, O. L. (2013). *frican Dust and Clouds at Pico del Este: The Puerto Rico African Dust and Cloud Study*. AGU Fall Meeting. San Fransisco, CA. Status = OTHER; Acknowledgement of Federal Support = Yes

Inventions

Journals

Arnone, E., Dialynas Y.G., Noto L.V., and Bras R.L. (2014). Parameter Uncertainty in Shallow Rainfall-Triggered Landslide Modeling at Basin Scale: a Probabilistic Approach. *Procedia Earth and Planetary Science*. 9 101. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.proeps.2014.06.003

Bouskill, N. J., H. C. Lim, S. Borglin, R. Salve, T. E. Wood, W. L. Silver, and E. L. Brodie. (2013). Pre-exposure to short-term drought increases the resistance of subtropical forest soil bacterial communities to extended drought. *ISME Journal*. 7 384. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1038/ismej.2012.113

Chabaux F., Blaes E., Stille P., di Charia Roupert R., Dosseto A., Pelt E., Ma L., Buss H.L, and Brantley SL. (2013). Regolith formation rate from U-series nuclides: Implications from the study of a spheroidal weathering profile in the Rio Icacos watershed (Puerto Rico).. *Geochim. Cosmochim. Acta.*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.gca.2012.09.037.

Dosseto A., Buss H.L., and Chabaux F (2014). Age and weathering rate of sediments in small catchments: the role of hillslope erosion. Geochim. Cosmochim. Acta. 132, 238-258. DOI:. *Geochim. Cosmochim. Acta.*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.gca.2014.02.010.

Hall, S. J., J. Treffkorn, and W. L. Silver (2014). Breaking the enzymatic latch: Impacts of reducing conditions on hydrolytic enzyme activity in tropical forest soils. *Ecology*. . Status = AWAITING_PUBLICATION; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1890/13-2151.1

Hall, S. J., W. H. McDowell, and W. L. Silver (2013). When wet gets wetter: decoupling of moisture, redox biogeochemistry, and greenhouse gas fluxes in a humid tropical forest soil.. *Ecosystems*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1007/s10021-012-9631-2

Koenig, L.E., A.J. Baumann, and W.H. McDowell (2014). Improving automated phosphorus measurements in freshwater: an analytical approach to eliminating silica interference. *Limnology and Oceanography: Methods. Limnology and Oceanography: Methods*. 12 223. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.4319/lom.2014.12.223

McNicol, G. and W. L. Silver (2014). Separate effects of flooding and anaerobiosis on soil greenhouse gas emissions and redox sensitive biogeochemistry.. *JGR-Biogeosciences.*. (April 2014), . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/2013JG002433

Miller, Reitz and Jerolmack (2014). Generalized sorting profile for alluvial fans. *Geophysical Research Letters*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Miller, Szabo, Jerolmack and Domokos (2014). Quantifying the significance of abrasion and selective transport for downstream grain size evolution. *J. Geophysical Research*. . Status = AWAITING_PUBLICATION; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Navarre-Sitchler A., Cole D., Rother G., Jin L., Buss H.L., and Brantley S. (2013). Porosity and surface area evolution during weathering of igneous rocks. *Geochim. Cosmochim. Acta.*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.gca.2013.02.012

Phillips, C. B. and Jerolmack, D. J. (2014). Dynamics and Mechanics of bed load tracer particles. *Earth Surface Dynamics Discussion*. 2 . Status = AWAITING_PUBLICATION; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.5194/esurfd-2-429-2014

Riebe, C. S., Hahm, W. J., Brantley, S. L. (). Going deep to quantify limits on weathering in the Critical Zone. *Earth Surface Processes and Landforms*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Scholl M.A., Murphy S.F. (2014). Precipitation isotopes link regional climate patterns to water supply in a tropical mountain forest, eastern Puerto Rico. *Water Resources Research*. 4305. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/2013WR014413

Scholl, Martha A., Shanley, James B., Murphy, Sheila F., Willenbring, Jane K., Occhi, Marcie, and González, Grizelle (2014). Stable-isotope and solute-chemistry approaches to flow characterization in a forested tropical watershed, Luquillo Mountains, Puerto Rico. *Applied Geochemistry*. . Status = SUBMITTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Stone MM & AF Plante (2014). Changes in phosphatase kinetics with soil depth across a variable tropical landscape. *Soil Biology and Biochemistry*. 71 (April 2014), 61. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.soilbio.2014.01.006

Stone MM, DeForest JL & AF Plante (2014). Changes in extracellular enzyme activity and microbial community structure with soil depth at the Luquillo Critical Zone Observatory.. *Soil Biology and Biochemistry*. 75 (8-2014), 237. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.soilbio.2014.04.017

Stone MM, Plante AF & BB Casper (2013). Plant and nutrient controls on microbial functional characteristics in a tropical Oxisol. *Plant and Soil*. 373 (1-2), 893. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1007/s11104-013-1840-8

Van Beusekom, A., González, G., and Rivera, M.M. (2014). short-term precipitation and temperature trends along an elevation gradient in northeastern Puerto Rico. *Earth Interactions.*. . Status = ACCEPTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Wood, T. E., M. Detto, and. W. L. Silver (2013). Sensitivity of Soil Respiration to Variability in Soil Moisture and Temperature in a Humid Tropical Forest. *PLoS ONE*. 8 (12), . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1371/journal.pone.0080965

Yang, W. H., W. C. McDowell, P. D. Brooks, and W. L. Silver (2014). New high precision approach for measuring 15N-N2 gas fluxes from terrestrial ecosystems. *Soil Biology and Biochemistry*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.soilbio.2013.11.009

Yi-Balan, S.A., Amundson, R., Buss, H.L. (2014). Decoupling of sulfur and nitrogen cycling due to biotic processes in a tropical rainforest. *Geochimica et Cosmochimica Acta*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/ j.gca.2014.05.049

Licenses

Other Products

Other Publications

Patents

Technologies or Techniques

Thesis/Dissertations

Phillips, C.B., Jerolmack, D.J.. *The Control of Grain-Scale Mechanincs on Channel Form Landscape Dynamics, and Climatic Perturbations in Gravel-Bedded Rivers*. (2014). University of Pennsylvania. Acknowledgement of Federal Support = Yes

Websites

Participants/Organizations

What individuals have worked on the project?

Name	Most Senior Project Role	Nearest Person Month Worked
Frolking, Steve	PD/PI	1
Plante, Alain	Co PD/PI	1
Silver, Whendee	Co PD/PI	3
Brantley, Susan	Co-Investigator	1
Bras, Rafael	Co-Investigator	1
Buss, Heather	Co-Investigator	3
Comas, Xavier	Co-Investigator	2

Name	Most Senior Project Role	Nearest Person Month Worked
Gonzalez, Grizelle	Co-Investigator	2
Jerolmack, Doug	Co-Investigator	3
Mayol, Olga	Co-Investigator	1
Porder, Stephen	Co-Investigator	2
Thompson, Aaron	Co-Investigator	1
Willenbring, Jane	Co-Investigator	1
Hall, Steven	Faculty	1
Marin-Spiotta, Erika	Faculty	1
McDowell, William	Faculty	1
Pett-Ridge, Julie	Faculty	1
Szabo, Timea	Faculty	3
Arnone, Elisa	Postdoctoral (scholar, fellow or other postdoctoral position)	3
Brocard, Gilles	Postdoctoral (scholar, fellow or other postdoctoral position)	6
Clark, Kathryn	Postdoctoral (scholar, fellow or other postdoctoral position)	6
Hynek, Scott	Postdoctoral (scholar, fellow or other postdoctoral position)	3
Ruan, Leilei	Postdoctoral (scholar, fellow or other postdoctoral position)	3
Wymore, Adam	Postdoctoral (scholar, fellow or other postdoctoral position)	3
Daley, Michelle	Other Professional	1
Jimenez, Rafael	Other Professional	6

Name	Most Senior Project Role	Nearest Person Month Worked
Leon, Miguel	Other Professional	12
Potter, Jody	Other Professional	1
Sallady, Ryan	Technician	3
Schwaner, Geoff	Technician	6
Gould, William	Staff Scientist (doctoral level)	1
Martinuzzi, Sebastian	Staff Scientist (doctoral level)	1
Scholl, Martha	Staff Scientist (doctoral level)	3
Shanley, Jamie	Staff Scientist (doctoral level)	2
Wood, Tana	Staff Scientist (doctoral level)	1
Almaraz, Maya	Graduate Student (research assistant)	6
Barcellos, Diego	Graduate Student (research assistant)	6
Brereton, Rich	Graduate Student (research assistant)	6
Chapela Lara, Maria	Graduate Student (research assistant)	12
Coward, Elizabeth	Graduate Student (research assistant)	3
Dialynas, Yannis	Graduate Student (research assistant)	6
Gutiérrez del Arroyo, Omar	Graduate Student (research assistant)	1
Koenig, Lauren	Graduate Student (research assistant)	3
Lee, Dylan	Graduate Student (research assistant)	6
Litwin-Miller, Kim	Graduate Student (research assistant)	6
McClintock, Matthew	Graduate Student (research assistant)	1
Moore, Oliver	Graduate Student (research assistant)	12
Orlando, Joe	Graduate Student (research assistant)	6

Name	Most Senior Project Role	Nearest Person Month Worked
Phillips, Colin	Graduate Student (research assistant)	6
Rodriguez, Josely	Graduate Student (research assistant)	3
Stone, Maddie	Graduate Student (research assistant)	6
Torres, Elvis	Graduate Student (research assistant)	3
Wilmoth, Jared	Graduate Student (research assistant)	6
Crespo, Ashley	Undergraduate Student	3
Stien, Rebekah	Undergraduate Student	3
Sullivan, Conor	Undergraduate Student	3
Tamayo, Cooper	Undergraduate Student	3
Traxler, Emily	Undergraduate Student	3
Zhou, Mengzhou	Undergraduate Student	1

Full details of individuals who have worked on the project:

Steve Frolking
Email: steve.frolking@unh.edu
Most Senior Project Role: PD/PI
Nearest Person Month Worked: 1

Contribution to the Project: PI, Executive Committee Chair

Funding Support: UNH

International Collaboration: No
International Travel: No

Alain F Plante
Email: aplante@sas.upenn.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 1

Contribution to the Project: Oversees research in soil carbon quality and dynamics. Supervises 2 PhD student and co-supervises 1 post-doc. Has established cross-CZO working group in organic matter research.

Funding Support: Penn

International Collaboration: No
International Travel: No

Whendee Silver
Email: wsilver@berkeley.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 3

Contribution to the Project: Soil Trace Gases, Iron Redox. Oversees a Post-doc and graduate students.

Funding Support: Uc-Berkeley

International Collaboration: No
International Travel: No

Susan L Brantley
Email: brantley@eesi.psu.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Investigates chemical and physical processes associated with the circulation of aqueous fluids in shallow hydrogeologic settings. Supervises a Post-Doc and Masters student.

Funding Support: Penn State

International Collaboration: No
International Travel: No

Rafael Bras
Email: rlbras@gatech.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Hydrologic modeling; landslide modeling.

Funding Support: Georgia Tech

International Collaboration: No
International Travel: No

Heather Buss
Email: h.buss@bristol.ac.uk
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 3

Contribution to the Project: Consulted on borehole drilling, analysis of borehole samples, measurement and analysis of weathering profiles through deep CZ

Funding Support: University of Bristol, LCZO

International Collaboration: Yes, United Kingdom
International Travel: No

Xavier Comas
Email: xcomas@fau.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 2

Contribution to the Project: Work on GPR, deep critical zone science.

Funding Support: Florida Atlantic University

International Collaboration: No
International Travel: No

Grizelle Gonzalez
Email: ggonzalez@fs.fed.us
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 2

Contribution to the Project: Monitoring of climate and hydrological data, ceilometer data interpretation

Funding Support: USDA FS

International Collaboration: No
International Travel: No

Doug Jerolmack
Email: sediment@sas.upenn.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 3

Contribution to the Project: Oversees research related to sediment transport and fluvial processes. Established 3 sediment transport monitoring stations and co-supervises a PhD student.

Funding Support: UPenn

International Collaboration: No
International Travel: No

Olga Mayol
Email: omayol@ites.upr.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Analysis of African Dust Inputs

Funding Support: UPR

International Collaboration: No
International Travel: No

Stephen Porder
Email: stephen_porder@brown.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 2

Contribution to the Project: Nitrogen and Phosphorus Cycling and limitation

Funding Support: Brown

International Collaboration: No
International Travel: No

Aaron Thompson
Email: AaronT@uga.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Oversees research in soil carbon quality and dynamics. Supervises 2 PhD students. Has established cross-CZO working group in Fe research.

Funding Support: UGA

International Collaboration: No
International Travel: Yes, Germany - 0 years, 0 months, 7 days

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Jane Willenbring
Email: erosion@sas.upenn.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Conducting and coordinating all cosmogenic dating studies in the LCZO. Receives direct support for 1 graduate student and 1 post-doctoral student.

Funding Support: UPenn

International Collaboration: No
International Travel: No

Steven Hall
Email: steven.j.hall@utah.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: Iron Redox

Funding Support: University of Utah

International Collaboration: No
International Travel: No

Erika Marin-Spiotta
Email: marinspiotta@wisc.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: Mechanisms of soil organic matter stabilization Hydrologic controls on carbon & nutrient transport

Funding Support: University of Wisconsin

International Collaboration: No
International Travel: No

William H McDowell
Email: Bill.McDowell@unh.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: Executive Committee Member, responsible for intellectual project integration and stream sensor network

Funding Support: NSF

International Collaboration: No
International Travel: No

Julie Pett-Ridge
Email: Julie.Pett-Ridge@oregonstate.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: Chemical weathering, soil formation, and biogeochemical cycling

Funding Support: Oregon State

International Collaboration: No
International Travel: No

Timea Szabo
Email: tszabo.hu@gmail.com
Most Senior Project Role: Faculty
Nearest Person Month Worked: 3

Contribution to the Project: Field and theoretical investigations of pebble abrasion

Funding Support: Hungarian Gov.

International Collaboration: Yes, Hungary
International Travel: No

Elisa Arnone
Email: elisa.arnone@gmail.com
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 3

Contribution to the Project: Hydrologic modeling; landslide modeling.

Funding Support: Government of Italy

International Collaboration: Yes, Italy
International Travel: No

Gilles Brocard
Email: gbrocard@sas.upenn.edu
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 6

Contribution to the Project: Conducting cosmogenic dating studies in the LCZO and operating the UPenn cosmogenic lab.

Funding Support: UPenn

International Collaboration: No
International Travel: No

Kathryn Clark
Email: kathryn.clark@ouce.ox.ac.uk
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 6

Contribution to the Project: Synthesis postdoc working on dynamics and properties of fine sediment transport in LCZO streams.

Funding Support: None

International Collaboration: No
International Travel: No

Scott Hynek
Email: scott.hynek@gmail.com
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 3

Contribution to the Project: Post-doc working on geochronology, geochemical tracers, and isotope geochemistry to understand processes and pathways in modern environments.

Funding Support: Penn State

International Collaboration: No
International Travel: No

Leilei Ruan
Email: ruanleil@msu.edu
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 3

Contribution to the Project: Iron Redox

Funding Support: UC-Berkeley

International Collaboration: No
International Travel: No

Adam Wymore
Email: Adam.Wymore@unh.edu
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 3

Contribution to the Project: Stream Solutes

Funding Support: None

International Collaboration: No
International Travel: No

Michelle Daley
Email: michelle.daley@unh.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 1

Contribution to the Project: assists with grant and sub-contract management including reporting

Funding Support: UNH

International Collaboration: No
International Travel: No

Rafael Jimenez
Email: ajz@sas.upenn.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 6

Contribution to the Project: Conducting research on decadal-scale changes in cloud base.

Funding Support: UPenn

International Collaboration: No
International Travel: No

Miguel Leon
Email: leonmi@sas.upenn.edu

Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12

Contribution to the Project: data manager, responsible for expanding datasets online, working with other CZO managers to ensure comparability of datasets, communications, field work scheduling, and work on data products

Funding Support: None

International Collaboration: No
International Travel: No

Jody Potter
Email: jody.potter@unh.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 1

Contribution to the Project: lab manager, responsible for training UNH graduate students in laboratory analyses, and providing ongoing QA/QC of all analytical work for which UNH has responsibility

Funding Support: UNH

International Collaboration: No
International Travel: No

Ryan Sallady
Email: rsalladay@berkeley.edu
Most Senior Project Role: Technician
Nearest Person Month Worked: 3

Contribution to the Project: Instrument installation

Funding Support: US-Berkeley

International Collaboration: No
International Travel: No

Geoff Schwaner
Email: gwj4@wildcats.unh.edu
Most Senior Project Role: Technician
Nearest Person Month Worked: 6

Contribution to the Project: Responsible for field sampling in Puerto Rico in support of all CZO projects

Funding Support: None

International Collaboration: No
International Travel: No

William Gould
Email: wgould@fs.fed.us

Most Senior Project Role: Staff Scientist (doctoral level)
Nearest Person Month Worked: 1

Contribution to the Project: Planning, data collection, analyses, presentation, and publication of results

Funding Support: USDA FS

International Collaboration: No
International Travel: No

Sebastian Martinuzzi
Email: sebamartinuzzi@gmail.com
Most Senior Project Role: Staff Scientist (doctoral level)
Nearest Person Month Worked: 1

Contribution to the Project: LiDAR analyses and interpretation

Funding Support: University of Wisconsin

International Collaboration: No
International Travel: No

Martha Scholl
Email: mascholl@usgs.gov
Most Senior Project Role: Staff Scientist (doctoral level)
Nearest Person Month Worked: 3

Contribution to the Project: Isotope Hydrology

Funding Support: USGS

International Collaboration: No
International Travel: No

Jamie Shanley
Email: jshanley@usgs.gov
Most Senior Project Role: Staff Scientist (doctoral level)
Nearest Person Month Worked: 2

Contribution to the Project: Mercury and Carbon Biogeochemistry

Funding Support: USGS

International Collaboration: No
International Travel: No

Tana Wood
Email: wood.tana@gmail.com
Most Senior Project Role: Staff Scientist (doctoral level)
Nearest Person Month Worked: 1

Contribution to the Project: Warming experiment

Funding Support: USDA FS

International Collaboration: No
International Travel: No

Maya Almaraz
Email: maya_almaraz@brown.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 6

Contribution to the Project: Nitrogen Cycling

Funding Support: Brown

International Collaboration: No
International Travel: No

Diego Barcellos
Email: diego.barcellos@yahoo.com.br
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 6

Contribution to the Project: Conducting research on iron redox processes in LCZO soils.

Funding Support: UGA

International Collaboration: No
International Travel: No

Rich Brereton
Email: rich.brereton@unh.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 6

Contribution to the Project: work describing how riparian flow paths affect stream chemistry

Funding Support: UNH

International Collaboration: No
International Travel: No

Maria Chapela Lara
Email: m.chapelalara@bristol.ac.uk
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: Mg isotope analysis, analysis of decoupling of surface and deep nutrient cycles

Funding Support: CONACYT (Mexico) PhD Scholarship

International Collaboration: Yes, United Kingdom
International Travel: No

Elizabeth Coward
Email: ecoward@sas.upenn.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 3

Contribution to the Project: Conducting research on iron-organic matter interactions in LCZO soils.

Funding Support: UPenn

International Collaboration: No
International Travel: No

Yannis Dialynas
Email: ydialynas@gatech.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 6

Contribution to the Project: Hydrologic modeling; landslide modeling.

Funding Support: Georgia Tech

International Collaboration: No
International Travel: No

Omar Gutiérrez del Arroyo
Email: omar.gutierrezdela@gmail.com
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: Beginning Phd at UC-Berkley with Whendee Silver

Funding Support: UC-Berkeley

International Collaboration: No
International Travel: No

Lauren Koenig
Email: Lauren.Koenig@unh.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 3

Contribution to the Project: Stream Solutes

Funding Support: NSF Fellowship

International Collaboration: No
International Travel: No

Dylan Lee
Email: dylanlee@sas.upenn.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 6

Contribution to the Project: Developing smart rocks for bedload transport analysis

Funding Support: UPenn

International Collaboration: No
International Travel: No

Kim Litwin-Miller
Email: klitwin@sas.upenn.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 6

Contribution to the Project: Conducting research on sediment transport in the LCZO.

Funding Support: UPenn

International Collaboration: No
International Travel: No

Matthew McClintock
Email: mmcclintock316@gmail.com
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: Chemical weathering, soil formation, and biogeochemical cycling

Funding Support: Oregon State

International Collaboration: No
International Travel: No

Oliver Moore
Email: oliver.moore@bristol.ac.uk
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: Analysis of deep CZ weathering

Funding Support: NERC (UK) PhD Fellowship

International Collaboration: Yes, United Kingdom
International Travel: No

Joe Orlando
Email: jjo167@psu.edu

Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 6

Contribution to the Project: Research on deep CZO geochronology, tracers.

Funding Support: Penn State

International Collaboration: No
International Travel: No

Colin Phillips
Email: colinp@sas.upenn.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 6

Contribution to the Project: Conducting research on sediment transport and exports of Luquillo streams.

Funding Support: UPenn

International Collaboration: No
International Travel: No

Josely Rodriguez
Email: josely_rodriguez313@hotmail.com
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 3

Contribution to the Project: African Dust Inputs

Funding Support: PRLSAMP fellowship

International Collaboration: No
International Travel: No

Maddie Stone
Email: mmstone83@gmail.com
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 6

Contribution to the Project: Conducting research on microbial ecology and organic matter characterization in LCZO soils.

Funding Support: NSF-GRF

International Collaboration: No
International Travel: No

Elvis Torres
Email: elvis.torres810@gmail.com
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 3

Contribution to the Project: African Dust Inputs

Funding Support: UPR

International Collaboration: No
International Travel: No

Jared Wilmoth
Email: jared.wilmoth@gmail.com
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 6

Contribution to the Project: Conducting research on iron redox processes in LCZO soils.

Funding Support: UGA

International Collaboration: No
International Travel: No

Ashley Crespo
Email: acrespo@sas.upenn.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 3

Contribution to the Project: Assisting with laboratory experiments on organic matter characterization in LCZO soils.

Funding Support: None

International Collaboration: No
International Travel: No

Rebekah Stien
Email: unknown@notsure.com
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 3

Contribution to the Project: Nitrogen Cycling

Funding Support: Brown

International Collaboration: No
International Travel: No

Conor Sullivan
Email: unknown2@notsure.com
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 3

Contribution to the Project: Nitrogen and Phosphorus limitation

Funding Support: Brown

International Collaboration: No
International Travel: No

Cooper Tamayo
Email: unknown3@notsure.com3
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 3

Contribution to the Project: nutrient cycling

Funding Support: Brown

International Collaboration: No
International Travel: No

Emily Traxler
Email: etraxler@purdue.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 3

Contribution to the Project: Assisting with laboratory experiments on organic matter characterization in LCZO soils.

Funding Support: None

International Collaboration: No
International Travel: No

Mengzhou Zhou
Email: mengzhou@sas.upenn.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 1

Contribution to the Project: Assist in development of web based mapping system.

Funding Support: None

International Collaboration: No
International Travel: No

What other organizations have been involved as partners?

Name	Type of Partner Organization	Location
Budapest University of Technology and Economics	Academic Institution	Budapest, Hungary

Full details of organizations that have been involved as partners:

Budapest University of Technology and Economics

Organization Type: Academic Institution
Organization Location: Budapest, Hungary

Partner's Contribution to the Project:
In-Kind Support
Facilities
Collaborative Research
Personnel Exchanges

More Detail on Partner and Contribution: Collaborator Domokos serves as mentor and external advisor to LCZO PhD student Litwin, and Domokos' PhD student has performed research at LCZO.

Have other collaborators or contacts been involved? Yes

Impacts

What is the impact on the development of the principal discipline(s) of the project?

- We have shown that the use of drilling and GPR, combined with chemical analysis, can reveal how weathering proceeds in the tropics.
- We have shown that linking in situ 10Be measurements with soil properties is a promising route for understanding the role of denudation in determining landscape-scale variation in soil weathering and nutrient availability.
- We have developed a generalized theoretical framework for predicting bed load transport in response to floods that connects event scales to annual and longer scales. This framework will be useful for interpreting data sets of sediment tracers at many field sites, and for modeling long-term landscape erosion in response to floods.
- We have helped to settle the longstanding debate regarding the importance of abrasion vs. sorting in the downstream fining of gravels in rivers, which is an important control on erosion and channel geometry. Our work also demonstrates that abrasion is an important source of fine sediment that has been neglected.
- We have developed a new type of “smart rock” that is cheap and easy to use, and can provide direct measurements of particle motion that are key to understanding particle transport and erosion during floods.
- Our work has shown that the threshold of bed load motion is the key organizing principle in both bedrock and alluvial rivers.
- The fine time step (5-min) in-stream turbidity time series in conjunction with discrete sampling for cosmogenic isotopes and carbon is leading to refined understanding of sources and delivery processes of suspended sediment to fluvial systems.
- Our work understanding the role of waterfalls on the island to refresh the nutrient-depleted landscape links the old, weathered soils on the summits of the mountain to a cascade of rejuvenating processes and impacts downstream; the ecology and hydrology and even the persistence of the mountains themselves is better understood by understanding the bedrock backbone of the island.

What is the impact on other disciplines?

- Understanding deep weathering will aid in understanding ecosystems and water flow.
- The frequency of bed load transport is a key determinant of habitat suitability in rivers (shrimp in LCZO, and fish in many places), so our work identifying the frequency and magnitude of bed load transport using tracers can help in studies of river ecology.
- Also, our work on fine sediment production from abrasion may have ecological implications, as fine sediment may be pollutant or an important determinant of bed substrate.

What is the impact on the development of human resources?

- Two students were trained. One PhD student and three undergraduates were trained at Brown.
- Jerolmack has advised 3 PhD students and one postdoc on work related to LCZO; they have engaged in interdisciplinary research and have developed an extended network of Earth scientists that simply would not have been possible without LCZO support. These young researchers have also presented research in small, productive workshops and large international conferences, some of which have led to postdoc opportunities.
- Willenbring has advised 1 postdoc and 1 masters student on work related to the LCZO.
- McDowell has advised 2 PhD students on CZO-related research.

What is the impact on physical resources that form infrastructure?

- In February of 2014 data logging devices for measuring barometric pressure, water level, and water temperature were installed and have been continuously logging data since installation. In February and March, 2014 a pilot test was also run for the installation of two data loggers for water level and temperature in groundwater wells with pre-installed vibrating wire transducers. At present the feasibility of the installation and its expense are not favorable. This work was undertaken in collaboration with Andy Neal from Shale Hills CZO.
- Jerolmack's laboratory has developed two new experimental setups for the study of abrasion due to collision during bed load, supported by LCZO. In addition, the development of smart rocks has created a technology that is finding application in both earth science and also granular physics.
- Collaboration with USGS-Sacramento sensor group has resulted in new guidelines for successful application of in-stream optical sensors in a harsh environment (high flow, high sediment load).

What is the impact on institutional resources that form infrastructure?

- A college level CZO curriculum is being developed by post-doctoral scientist Adam Wymore, Tim White and other CZO and non-CZO participants.

What is the impact on information resources that form infrastructure?

- All data generated have been organized and deposited on the LCZO website, with associated meta-data to make it discoverable and searchable by researchers.
- We are inputting chemical data into CZChem.db

What is the impact on technology transfer?

- Smart rocks are being developed with agricultural engineers at the University of Georgia, and our group is learning state of the art techniques for fabricating micro-electronics.

What is the impact on society beyond science and technology?

- As climate change causes water supplies to change into the future, we will need to understand how to guard water resources. Our work will allow a better understanding of aquifers.
- Understanding sediment fluxes over time is a critical component of identifying and ultimately mitigating anthropogenic impacts on landscapes. On Puerto Rico, the impacts of fine sediment are particularly important for coral reef community health.

Changes/Problems

Changes in approach and reason for change

We may drill another deep borehole in El Yunque but we have yet to determine where this is feasible.

Actual or Anticipated problems or delays and actions or plans to resolve them

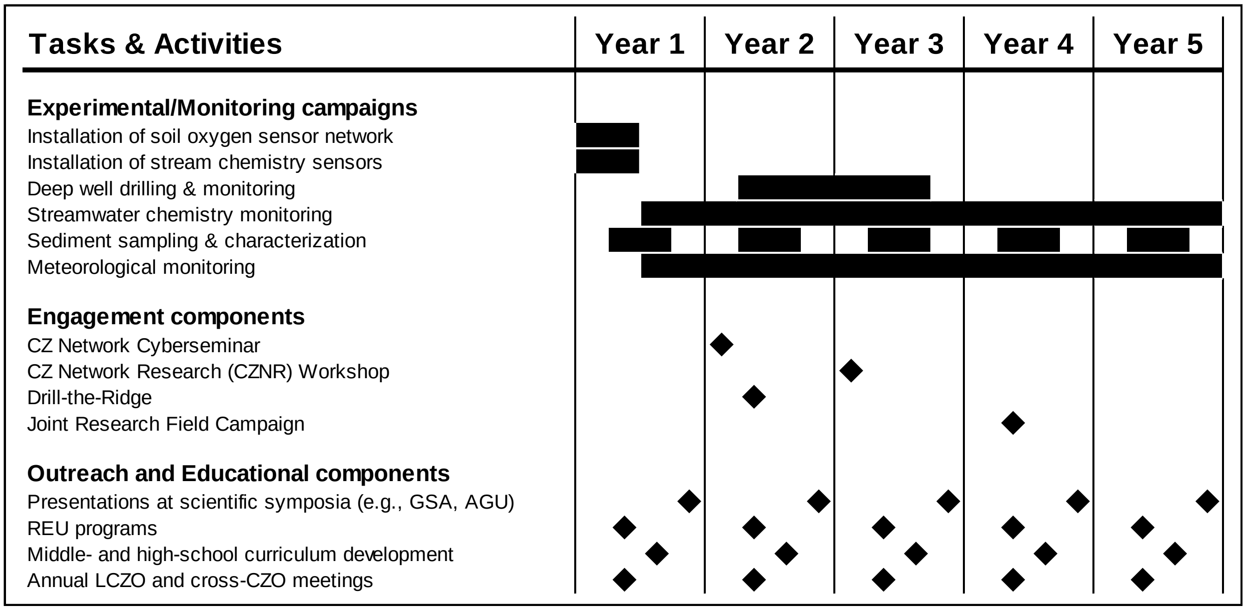
We have not yet identified a location for another borehole.

Changes that have a significant impact on expenditures
Nothing to report.

Significant changes in use or care of human subjects
Nothing to report.

Significant changes in use or care of vertebrate animals
Nothing to report.

Significant changes in use or care of biohazards
Nothing to report.


Tasks & Activities
Year 1
Year 2
Year 3
Year 4
Year 5
Experimental/Monitoring campaigns
Installation of soil oxygen sensor network
Installation of stream chemistry sensors
Deep well drilling & monitoring
Streamwater chemistry monitoring
Sediment sampling & characterization
Meteorological monitoring
Engagement components
CZ Network Cyberseminar
CZ Network Research (CZNR) Workshop
Drill-the-Ridge
Joint Research Field Campaign
Outreach and Educational components
Presentations at scientific symposia (e.g., GSA, AGU)
REU programs
Middle- and high-school curriculum development
Annual LCZO and cross-CZO meetings

The four Focal Areas of the planned research will be executed by several research teams that will be responsible for field work, laboratory analyses, data analysis, synthesis, and dissemination of results. The core research teams that comprise the LCZO2 are outlined in the table below.

Research team	Tasks
Focal Area 1: Deep CZ	
Brantley	deep well drilling and monitoring
Comas	GPR survey around each deep well
Buss, Brantley, Porder	analyze regolith weathering profiles around nickpoints
Porder	develop regression-model of nutrient P and cation availability
Focal Area 2: Redox & Fe-C	
Silver	field and laboratory Fe redox dynamics
Plante, Thompson	Fe-C interactions, soil organic matter and Fe species characterization
Focal Area 3: Watersheds	
Willenbring, Jerolmack, Shanley	origin, residence time, transit of sediment
Jerolmack, Willenbring	field study and modeling of abrasion at knickpoints
McDowell, Shanley	spatial and temporal variability in stream chemistry
Focal Area 4: Hydro & Atmos	
Bras, Wang, Gonzalez	tRIBS-VEGGIE modeling of landslides and hotspots
Scholl, Gonzalez, Gould, Shanley	weather pattern analysis, including orography and cloud base
Mayol-Bracero, Scholl, Gonzalez	African dust inputs

Tasks to meet the goals for each focal area are to:

<u>Focal Area 1:</u> Hot spots and hot moments in the deep critical zone

- Understand what controls the depth of weathering on three different lithologies in the Luquillo Mountains, Puerto Rico.
- Understand the link between those controls and ecosystem properties at the surface.

<u>Focal Area 2:</u> Hot Spots and Hot Moments in Redox Dynamics and Associated Fe-C interactions

- Address the hypothesis that patterns in rainfall, drainage, and biological activity drive the distribution of redox environments in the critical zone.
- Explore if rapid, high magnitude redox fluctuations create hot spots and hot moments of decomposition by stimulating Fe reduction and associated C oxidation.
- Determine if the storage and stabilization of soil organic matter in contrasting tropical soils is controlled by hot spots and hot moments of Fe-C interactions rather than the bulk mineral matrix, and if these interactions are more frequent in valleys than ridges.
- Expose a broad community in Puerto Rico to the concepts of the critical zone and engage students at all levels in the field science.

Focal Area 3: Watershed scale hot spots and hot moments

- Determine the controls on residence times of solutes and sediments in river systems.
- Connect event to millennial scales to understand erosion.
- Determine the contribution of landscape hot spots (knickpoints and landslides) and hot moments (storms) to sediment production and erosion.

Focal Area 4: Hydrologic and Atmospheric Hot Spots and Hot Moments

- Facilitate the use of specialized remote sensing technologies (i.e., LiDAR) for characterization of ground surfaces and forest structure of the Río Mameyes watershed within the LZCO study area.
- Determine seasonal variation in ceilometer measurements of cloud base altitudes in northeastern Puerto Rico to then i) compare with existing climate data and ii) address the importance of cloud level in structuring vegetation at the Luquillo Mountains.
- Quantify cloud water deposition in the water budget, including:
    - Determine the footprint of cloud immersion in the mountains using time-lapse photographic monitoring, ceilometer and radiosonde data.
    - Determine frequency, duration and liquid water content of cloud immersion.
    - Quantify cloud water contributions to recharge and headwater streamflow.
- Assess trends in atmospheric parameters that affect trade-wind orographic precipitation.
- Test if Intercontinental transport of African dust alters incoming radiation and cloud formation, and provides nutrient inputs that are significant relative to those from rain events during periods without dust in the atmosphere (Hypothesis 4.3).

Light detection and ranging (LiDAR) provides powerful information about the bare earth and the 3D structure of ecosystems across landscapes. The availability of LiDAR data for the LCZO that can be consistently analyzed with other CZO LiDAR datasets will enable valuable cross site comparisons. The core of El Yunque National forest is made of high peaks frequently shrouded in clouds. This, together with the dense vegetation in the tropical rainforest and ground surface roughness associated with very large core stones beneath the forest canopy makes LiDAR acquisition challenging. We are assessing the bare earth models produced using methodologies applied at other CZO sites, which provide inconsistent results for the LZCO, with other algorithms for obtaining a digital elevation model from LiDAR point cloud data (Fig. 1, 2).

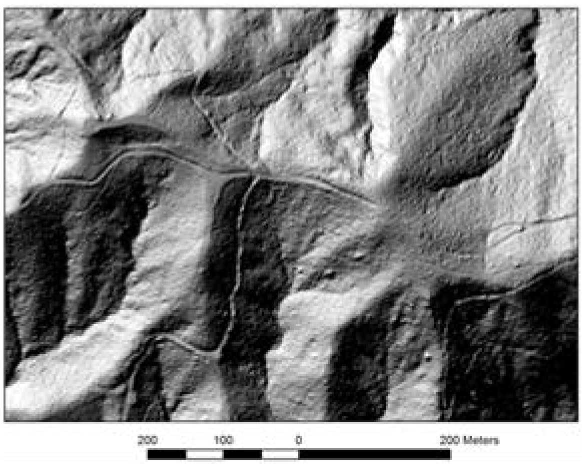


Figure 1. Lidar-derived digital elevation model in a forested region with high density of ground returns.

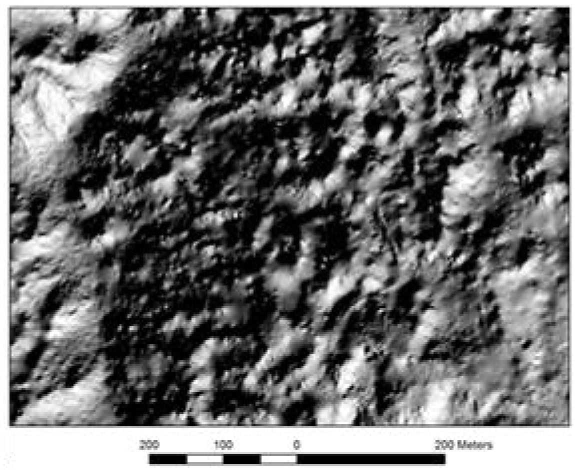


Figure 2. Lidar-derived digital elevation model in a forested region with pockets of low density of ground returns.

We are testing algorithms to see if we can produce a superior DEM to the original produced by the CZO National program (Fig. 2).