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Federal Agency and Organization Element to Which Report is Submitted:	4900
Federal Grant or Other Identifying Number Assigned by Agency:	1331841
Project Title:	Luquillo CZO: The role of hot spots and hot moments in tropical landscape evolution and functioning of the critical zone
PD/PI Name:	William H McDowell, Principal Investigator Grizelle Gonzalez, Co-Principal Investigator Alain F Plante, Co-Principal Investigator Whendee Silver, Co-Principal Investigator
Recipient Organization:	University of New Hampshire
Project/Grant Period:	12/01/2013 - 11/30/2018
Reporting Period:	12/01/2014 - 11/30/2015
Submitting Official (if other than PD\PI):	William H McDowell Principal Investigator
Submission Date:	09/01/2015
Signature of Submitting Official (signature shall be submitted in accordance with agency specific instructions)	William H McDowell

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 quartz diorite (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 volcaniclastic (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:

The LCZO team has made great progress toward achieving our major goals. We have produced over 40 scientific publications and given over 100 presentations at scientific and public meetings over the course of the project. In 2015, the team published 19 papers, 1 book chapter, and made 52 presentations at national and international meetings. The LCZO is actively training students and young professionals in the field. Seven graduate students served as authors on the papers produced in 2015, and 26 graduate students contributed to, or were lead authors, on the presentations made in 2015. Graduate students have also produced three dissertations thus far. Five post-doctoral researchers served as authors on the papers published in 2015, and 14 post-doctoral researchers contributed to, or were lead authors, on presentations given in 2015. Results from these products are highlighted in the Products Supporting File 4 PDF.

Integration of research among the 4 different focal areas and the coordination of efforts among all our partners and participants occurs through our executive committee and by hosting regular LCZO meetings. The executive committee consists of the PI and co-PIs, and has met at least every 6-8 weeks since it was formed in December 2013. Each LCZO co-PI has had special responsibilities in the following areas, with reporting of progress and opportunities to the full Executive Committee:

- Site Management, local operations – González
- Data management, information transfer, engagement - Plante
- Cross-site CZO activities and new research initiatives - Silver

LCZO personnel attended general LCZO meetings via web-broadcast using GoToMeeting approximately every 8 weeks. These meetings were approximately 1.5 hours in length and were structured to present results from the 4 major focal areas and encourage integration across focal areas. The annual all-hands LCZO meeting in Puerto Rico was held from June 1-3, 2015. During the first two days overview presentations were given on the four focal groups, 29 “lightning” presentations on LCZO research were given by each project participant in

attendance (including graduate students, post-docs, PIs and senior personnel), and extensive discussion occurred about ways to foster the development of cross-cutting themes that integrate across focal areas. We also used the meeting to address cross-CZO initiatives that would further our project goals, and project administration. The advisory committee was present throughout the meeting. They presented their assessment of the LCZO and made valuable suggestions for ways in which the project might be improved. On the third day of the meeting, a group of project participants and advisory board members visited NEON field sites, where we discussed how to best leverage the NEON efforts to meet the overarching goals of the Luquillo CZO. The agendas for the LCZO All-Scientist webinars and the LCZO annual all-hands meeting are attached in the Accomplishments Supporting File 3 PDF.

To foster public outreach, engagement and education, an independent contract has been established with The Learning Partnership to integrate units based on Critical Zone Science into the existing educational software and curricular package entitled "Journey to El Yunque" (http://elyunque.net). Additional avenues for curricular development to enhance the existing Luquillo Schoolyard LTER (LUQ sLTER) program with addition of units on Critical Zone Science will be explored by The Learning Partnership through participation in teacher workshops in Puerto Rico in fall 2015 and 2016. The Learning Partnership has partnered with a local educational technology company called Forward Learning, which has recently received an official endorsement from the science director at Puerto Rico Department of Education that allows teachers to get approval from their principals to attend the teacher workshops. For additional outreach and engagement activities, refer to the "How have the results been disseminated to communities of interest?" portion of the Accomplishments section.

The accomplishments of the LCZO from August 9, 2014, through August 3, 2015 are further described within the framework of our milestones by hypothesis as outlined in the LCZO management plan. These major activities are contained within the Accomplishments Supporting File 2 PDF.

Efforts to promote cross-CZO science are described in the Additional Reporting Requirements contained within the Accomplishments Supporting File 1 PDF.

Specific Objectives: Specific objectives for each focal area and hypothesis are listed below.

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

H1.1

- Use GPR in combination with additional indirect geophysical methods to understand fracture distribution in the context of weathering and erosion.
- Analyze mechanisms and rates of weathering along fracture surfaces on borehole rock samples and correlate these data with regolith, pore water, ground water and stream water data.

H1.2

- Understand the role of geomorphology in shaping soil properties and nutrient availability in the Luquillo Mountains.

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

H2.1

- Use the sensor array and automated gas flux chambers to determine the spatial and temporal dynamics (hot spots and hot moments) of redox-sensitive biogeochemistry and the correspond controls.
- Use this information to inform models and laboratory experiments on C and N cycling in response to climate, mineralogy, and ecological dynamics.
- Our depth profile data will also inform models and laboratory assays with a specific focus on the depth of hot spots and hot moments.

H2.2a

- Use redox oscillation experiments to determine the influence of variation in periods of anoxic (and oxic) hot spots on iron reduction rates (used as an electron acceptor for carbon oxidation) and ultimately loss of soil carbon.

H2.2b

- Use dissolution experiments is to extract and quantify various Fe-derived soil minerals phases (e.g., amorphous, crystalline, etc.) and to quantify the amount of organic carbon associated with those mineral phases. These Fe-derived are hypothesized to be hot spots of soil C storage.

Focal Area 3: Watershed scale hot spots and hot moments

H3.1, H3.2 and H3.3

- Understand flood impulses and their relation to climate.
- Determine if extreme discharge fluctuations cause differences in channel shape.
- Determine quantitative and general relations between pebble shape and transport distance
- Understand abrasion using the shape of particles.
- Determine river particulate organic carbon (POC) and particulate nitrogen (PN) yields for the Mameyes Puente Roto and the Rio Icacos catchments.
- Determine the physical origins of the universal distribution of fragment shapes produced by abrasion.
- Examine whether dissolution is the dominant means of erosion in the Icacos River.
- Estimate the percent crystallinity of suspended sediment samples in the Mameyes and Icacos rivers, and how this changes over the hydrograph during a flood.
- Evaluate in stream turbidity as a proxy for POC and PN to quantify loads.
- Establish changes in specific conductance, temperature, and dissolved oxygen in streams in response to hydrologic extremes

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

H4.1

- Simulate landscape evolution and predict hydrologic hot spots and hot moments at the Mameyes and Icacos watersheds within the LCZO.
- Develop a spatially-explicit model of soil organic carbon dynamics within an existing hydro-geomorphic model to link hot spots and hot moments in sediment

sources with soil organic carbon dynamics.
- Modify and refine existing physically-based hydro-geomorphic models to include the interaction of forest roads with slope stability.

H4.2

- Characterize the differences between cloud base heights measured by the ceilometer in Luquillo and the cloud base heights measured by the ceilometers in the rest of Puerto Rico, to report what makes Cloud Forest unique.
  - Characterize the differences annually and diurnally.
  - Start trying to understand the reasons behind regional uniqueness of the cloud forest by comparing the measured ceilometer data with measured climate data.
- Understand how the ceilometer-measured cloud heights correspond with a human-observer's definition of being immersed in clouds by correlating time-lapse photography with ceilometer data (The ceilometer records clouds at a single point in the sky every 30 seconds; a human observer incorporates information at a larger range).
- Determine short-term precipitation and temperature trends along an elevation gradient in northeastern Puerto Rico
- Quantify cloud deposition and stream response: we now have four sets of 30 minute resolution data collected during 4 dry season periods to date. The next steps are to quantify cloud water deposition on an areal basis, and develop a hillslope groundwater model to test streamflow response threshold to small cloud water events.
- Cloud cam project: We have identified the main image attributes that identify an image as cloudy or clear during nighttime and daytime and developed an index using 4 parameters. Python programs have been written to process the images and cull unusable data. The next steps are to develop an index of optical density for the images.

H4.3

Improve our understanding of

- the impact of African dust on radiation
- the role of dust in cloud formation and properties
- how clouds remove dust
- dust nutrient inputs at Pico Este TMCF.

Significant Results: Several results in each focal area were obtained that all address our overarching question: "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?" In the key outcomes or achievements section we also highlight the biogeochemical and hydrologic response to a recent extreme drought in Puerto Rico.

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

H1.1

We used GPR, terrain conductivity and ERI surveys in the three major lithologies (volcaniclastics (VC), quartz diorite (QD), and hornfels) and have a conceptual model of the architecture of the system.

We calculated weathering rates from elemental profiles in pore water, regolith, and

across bedrock fractures. We obtained additional mechanistic information from synchrotron-based analyses and Mg isotope data. We determined that the chlorite that makes up about 25 wt% of the VC rock is isotopically heavy relative to the rock, in contrast to the only published Mg isotopic data for chlorite in the literature. This indicates that the heavy Mg isotopic signature previously measured in the Bisley stream derives from chlorite and is sourced from the deep CZ as chlorite is absent in the regolith and soil.

H1.2

The first knickpoint research manuscript was published this year (Porder et al. 2015). The data show that QD derived soils below the knickpoint have lost fewer cations relative to the parent material than soils above the knickpoint. These soils have ~2× more exchangeable Ca below the knickpoint than those above it. The landscape underlain by VC does not exhibit a regional knickpoint and VC-derived soils have lost 90% of all base cations relative to parent material. These results were highlighted in a talk given by Porder at ESA (2014).

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

H2.1

Soil O2 declined and soil moisture increased predictably but non-linearly along the topographic gradient with a significant effect at the slope break in the lower topographic positions. Patterns in Fe, P, and pH followed patterns in redox and moisture in ridges, slopes, and valleys.

H2.2a

Predicting the rate of iron reduction (and associated carbon mineralization) during intermittent anoxia requires knowledge of previous redox dynamics, including the rate that O2 is re-introduced into the soil and the propensity of previous anoxic events. The mechanisms governing this process range from the size and reactivity of the recently regenerated iron minerals and the microbial adaptation to the fluctuating conditions.

H2.2b

Surface and deeper soil samples were treated with five different extractants targeting different soil Fe-derived minerals. Dissolved Fe, Al, Si and C were measured in the extracts, and organic C was measured in the solid residue. Mineral specific surface area (a major driver of organic matter stabilization) was measured in the untreated and extracted soil samples.

Focal Area 3: Watershed scale hot spots and hot moments

We demonstrated that brittle fracture theory can explain the distribution of daughter products of abrasion, revealing the dominant mechanism of physical weathering in river sediment transport. Rivers in a variety of climatic, tectonic and lithologic settings have identical distributions of flood impulses and this is a generic consequence of the adjustment of river channels to near-threshold transport conditions. Bed-load abrasion produces a robust and general relation between pebble shape and mass loss. This was used to estimate the distance traveled by rounded pebbles on Mars. We observed that the limited availability of ‘tools’ to cut through river channels is because of decreasing grain size as weathering

progresses, showing that soil weathering exerts a control on river incision through knickpoint retreat.

Data suggests that the carbon yield for the Mameyes at Puente Roto is 1 to 8 tons C km-2 yr-1. We found that suspended sediment concentrations during floods in both the Mameyes and Icacos follow the hydrograph, but show hysteresis. At Rio Icacos, an extremely challenging site due to high sediment load, we demonstrated nearly 100% success in correcting the optical fluorescent signal for attenuation and scattering by particles, using concurrent turbidity measurements. In several small streams, we observed striking changes in oxygen concentrations and diel oxygen variability associated with low flows.

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

H4.1

We refined a hydro-geomorphic model that efficiently represents the hydrology and the sediment yield at the Icacos and Mameyes watersheds. Results indicate that the effects of sediment transport on soil organic carbon redistribution in the Mameyes and Icacos watersheds exhibit significant topographic variability and that spatial variability of soil moisture has a significant control on the spatial dynamics of nutrients.

H4.2

The cloud base appears to rise when the trade winds hit the mountains from the coast. The cloud base over Luquillo (2 years of data) shows a bimodal pattern annually whereas the rest of Puerto Rico shows a more annual pattern. The lower clouds seem to correlate with the dry season and the higher clouds seem to correlate with the wet season. The diurnal pattern of the (lower) dry season clouds agree more with the clouds to the east, and the diurnal pattern of the (higher) wet season clouds agree more with the clouds to the west.

The minimum of the ceilometer measurements every hour gives a cloud base height that agrees more with the human observer and photography estimate than the hourly average ceilometer measurements, which are much higher. The difference between the minimum and hourly average is comparable to the difference between the lifting condensation level (from radiosonde data) and the hourly average ceilometer data reported by the automatic weather stations.

From the Cloud cam project we have determined that cloud base is higher than the lifting condensation level, and higher than previously assumed in water balance calculations. Seasonal variation in cloud base is indicated by the ceilometer data from our site in the foothills. Cloud immersion is generally at night at all sites, and is present during all hours except midday at the highest altitude site (1006 m).

Isotope analyses of cloud water and stream water at PDE indicate that high-elevation headwater streams have a large component of cloudwater relative to convective precipitation.

H4.3

Visibility data show high-density cloud events for most of the summer sampling period. Cloud microphysical properties and dust presence were not correlated, although in some cases it was observed that LWC, diameter and size distribution were lower for dust influenced days than for non-dust influenced days. More data

are needed to better understand how these properties behave.

Cloud water pH was less acidic (though not statistically significant) for high dust samples (6.4) relative to low dust samples (6.0). Conductivity was higher for high dust cloud water relative to low dust samples (82.2 and 37.1 µS/cm). No significant differences were found in the concentration of TOC, DOC, TN, and DN for high dust samples relative to low dust samples. Results suggest that most of the TOC is DOC and concentrations measured are very low. Concentrations of ions and trace metals in both cloud and rainwater samples were greater in high dust samples relative to low dust samples. This was particularly remarkable for Ca2+, Mg2+, Al and Fe in both cloud and rain water samples.

Key outcomes or Other achievements:

Integrating Soils and Streams: A key challenge for any multi-faceted research program such as a Critical Zone Observatory is to integrate each of the individual elements into a coherent overview that bridges across the full critical zone. Here we highlight the biogeochemical and hydrologic response to an extreme drought currently occurring in Puerto Rico, as it provides insights into the overall functioning of this mountain landscape that would not be clear without such an integrated approach. Using the soil and stream sensor networks that were installed and are maintained by LCZO funding, we have been able to document an intriguing flip-flop in biogeochemical conditions in soils and streams. After several months of near-record low rainfall, soils are drying out and have become more oxygenated at all catena positions (Fig. 1a and 1b). In contrast, the streams are drying out (Fig. 2a and 2b) and are experiencing declines in dissolved oxygen that appear to be due to in-stream or hyporheic metabolic processes. Evidence for this enhanced metabolic control on stream oxygen levels is provided by the strong diel periodicity in oxygen levels that is commonplace in streams with high ecosystem respiration (Fig. 3a and 3b), but this variability is swamped at higher flow by turbulent exchange across the air-stream interface, as well as the shorter residence time of water in the groundwater flowpath, which reduces the impact of metabolic oxygen consumption on groundwater oxygen concentrations.

We are continuing to monitor conditions in the soils and streams, as the drought is ongoing. Some predictions suggest that the 2015 drought will be the largest in the last 50 years, and based on meteorological conditions, the drought could persist through the end of the year. The drought response is described in Focal Areas 2 and 3 below and figures are included in the Accomplishments Supporting File 4 PDF.

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

One significant result is that we now know that there are deep fracture zones (tens of meters deep) that cross cut the Rio Icacos watershed and are spaced about every 50 m or so. These zones correspond with channels that may be the sites of spheroidally weathered boulders or may be local deposits of these boulders. New evidence seems to point towards the fact that such fracture distribution may be different above and below the nickpoint.

Another significant accomplishment was the publication of a manuscript in Geoderma entitled ‘Linking geomorphology, weathering and cation availability in the Luquillo Mountains of Puerto Rico.’ The ideas developed there are now guiding field work, stimulating theoretical developments, and helping bring together researchers from disparate fields. For example, a recent analysis of tree heights (obtained with LIDAR) show a pronounced shift at the knickpoint – with lower tree heights above the knickpoints, where soil cations are also lower. This finding conforms with what

we would expect based on biogeochemical theory and the data that have come out of this project so far.

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

H2.1

We captured a significant drought event with the sensor array that showed dramatic rapid increases in soil O2 at all topographic positions and corresponding declines in soil moisture (Fig. 1a and 1b). The lowest topographic zones were considerably less sensitive to drought than the rest of the catena. Concentrations of Fe(II) declined significantly during the drought as did labile P.

H2.2a

We found that when the anoxic periods were reduced to less than 10 h, the iron reduction rates increased substantially. In addition, we found that the rate of iron reduction was directly related to the rate of iron oxidation in the previous oxic period.

H2.2b

Preliminary results indicate that Fe-derived mineral phases (as quantify by selective dissolution) contribute a substantial proportion of mineral surface area. The largest amount of Fe was extracted with dithionite, and the smallest amount with pyrophosphate, while the trend was reversed for C. Contrary to expectations, the amount of organic C released following dissolution of the Fe-mineral phases was a small fraction of the total C in the soil. It is possible the Fe extractants—which are acidic—liberated the C from the mineral surface, but were not able to solubilize the organic C—which is most soluble at high pH. To evaluate these results further, we have repeated our experiments and followed our extractions with an additional high pH wash. The solutions are currently under analysis.

Focal Area 3: Watershed scale hot spots and hot moments

We have developed several theoretical frameworks for interpreting LCZO data that may be applied much more generally to other CZO sites and beyond. Shanley has 30 months of high-quality turbidity sensor data from the Rio Icacos showing how suspended sediment responds to floods, and is preparing this work for submission. We have 7Be and 10Be data on TSS over storm hydrographs and are analyzing this in conjunction with variations in Hg concentration to determine the relative age of the sediments associated with the high Hg export in LEF streams.

We have stream sensors deployed in the Sonadora, Prieta and Icacos watersheds and these sensors show that as soil moisture decreases and soil oxygen increases (Accomplishments Supporting File 4, Fig. 1a and 1b), we also see an increase in conductivity (Accomplishments Supporting File 4, Fig. 4) and lower dissolved oxygen (Accomplishments Supporting File 4, Fig. 3a and 3b) as streams are fed by deeper and deeper groundwater. We also see that as streams dry out, they also appear to be getting warmer (Accomplishments Supporting File 4, Fig. 5).

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

The cloud base at Luquillo looks significantly different (in annual and diurnal patterns) from the rest of Puerto Rico, and the data could not have been

interpolated from the cloud base data collected at other sites in Puerto Rico.

The minimum measurement by the ceilometer every hour appears to be measuring the lifting condensation level, or the level at which clouds can form. This height also corresponds with the height at which an observer “feels he is in the cloud forest”.

We developed a time-lapse photographic method with quantitative image processing to measure cloud immersion in remote mountain forests using inexpensive game cameras. Our method replaces instruments that require 120V AC power and cost $6,000 to $40,000 each. Data collected so far show that stream baseflow is maintained by cloud water deposition, in the absence of measureable rainfall. To our knowledge, this is the first demonstration of this phenomenon and has implications for cloud forest ecosystems worldwide.

We have successfully applied the method developed by Prospero for the determination of dust concentrations on HiVol samples. We have also successfully applied the method on filter samples collected with stacked-filter units and are now applying the method on size-resolved impactor samples. Quantifying the amounts of dust in different size fractions is important for understanding their effects on local climate, cloud formation, and nutrient deposition. We are collecting physical samples from each sampler for laboratory analysis. Preliminary results for a few samples collected on the same date at our site and in Barbados show that total dust concentrations are similar at the two Caribbean sites.

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

The Luquillo CZO continues to aggressively build significant opportunities for training and mentoring. There were 10 undergraduate students, 20 graduate students and 7 post-doctoral researchers involved in the LCZO in year 2 (please refer to the participants section for more detailed information). Students and post-doctoral researchers receive one-to-one and group mentoring by LCZO PIs and other senior personnel.

A two-day “Early Career Critical Zone Workshop” was hosted at UNH and focused on proposal developed, specifically for early career CZ scientists (post-docs and assistant professors). The theme of the workshop was broadly: Critical Zone Resilience and Resistance. The workshop was funded by Critical Zone Science Across Virtual Institutes (SAVI) funds. 18 participants from around the United States joined the workshop. Organizers and Conveners included: Adam Wymore (Luquillo CZO, UNH), Diana Karwan (University of Minnesota), Julia Perdrial (University of Vermont), and Adrian Harpold (University of Nevade Reno). The agenda for this early career workshop is included in the Products Supporting File 1 PDF.

Post-doc Adam Wymore and PhD student Rich Brereton taught a course entitled Introduction to Critical Zone Science as an upper division course at UNH (NREN 795, spring 2015, 8 students). The curriculum was designed collaboratively with other CZ scientists through a project called, INTEGRATE at Carleton College. INTEGRATE is a NSF funded project to support the building of Geoscience-related university courses and curricula. Our group was charged with building a course focused on Critical Zone Science and the Critical Zone Observatories. Curriculum will be live online to the public ~June 2016.

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

University of Bristol PhD student Oliver Moore attended the WUN Summer School on Critical Zone Soil Science and Climate Change. Buss is developing a new 3rd year undergraduate course in Soils and the Critical Zone at the University of Bristol and attended the NSF Deep Critical Zone Work Salon in Colorado in June 2015. University of Bristol PhD students Oliver Moore and Maria Chapela Lara attended the Goldschmidt Conference in 2014 to present their LCZO research and attended, with Buss, a reactive transport modelling training workshop at Stanford.

A graduate student from Florida Atlantic University, a minority serving institution, joined the summer campaign in late

May. A team from Rutgers University composed of Research Professor Ntarlagiannis and two undergraduate research students also joined the summer campaign. The two students came funded through Rutgers University on a grant for underrepresented minority students and provided a unique experience while spending a week in the field learning about the application of geophysical methods to critical zone studies.

At Penn State one Master's thesis was completed.

Maya Almaraz, a minority woman Ph.D. candidate at Brown, has been funded by the LCZO grant. Her work investigates controls on the nitrogen cycle in the Luquillo Landscape. She presented her results at ESA and AGU last year, and will do so again this year.

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

Our work on Fe-redox cycling contributed to four dissertations (Hall, Gutierrez del Arroyo, Barcellos and Wilmoth) and the work of a postdoctoral scholar (Ruan). The experimental work on Fe-C associations represents the dissertation research of Coward. Two undergraduate research assistants were trained and involved in the dissolution experiments and one graduate student was trained in dissolved organic carbon measurements (Taylor Cyle; MS, 2015) and optimized the methodology for the unique extract matrices. Two graduate students (Wilmoth and Coward) were trained in collecting soils and making Mössbauer measurements to characterize soil iron.

Focal Area 3: Watershed scale hot spots and hot moments

PhD student Lee (Jerolmack's group) participated in LCZO All Hands meeting and is coordinating research with students from diverse scientific backgrounds. PhD student Lee is collaborating with an electrical engineer at Drexel University in developing smart rocks. Postdoc Ortiz (Jerolmack's group) is engaging with physicists, engineers and geologists to develop and deploy smart rocks to solve diverse scientific problems. Postdoc Szabo won a competitive fellowship from the Hungarian national government to work at Penn (Jerolmack's group), and led research efforts to understand pebble shape evolution under abrasion, and to link Luquillo river rocks to Mars. PhD student Emma Harrison and undergraduate Aria Kovalovitch (Willenbring's group) are conducting collaborative and interdisciplinary research combining field and laboratory techniques and interact with Grizelle Gonzalez (USFS). Postdoc Kathryn Clark is working with three PIs at Penn (Plante, Willenbring and Jerolmack) and numerous collaborators across LCZO to assemble physical and chemical records of water and sediment in the Mameyes. Postdoc Brocard (Willenbring's group) is collaborating with LTER scientists to link the geologic history of the Luquillo Mountains to ecosystem structure and function across the mountain landscape. All PhD students and postdocs are presenting their research at AGU, and smaller workshops and conferences.

Post-doc Adam Wymore at University of New Hampshire (UNH) is taking a leading role in inter-site activities and is developing a collaborative research program with the Slavkov Forest CZO, Czech Republic. Post-doctoral researcher Adam Wymore will attend the CZO Workshop "Biogeochemistry across the CZ Network", September 28/29 at UC Riverside. The focus is on biogeochemically related review papers and/or proposals. He will also attend the CZ Workshop in Guiyang, China from October 5-11. About 20 US scientists will be traveling to Guiyang, China to attend a week-long workshop focused on international Cross-CZO proposals and projects.

UNH graduate student Koenig is developing field, lab, and modeling approaches to understanding stream nitrogen dynamics and gas evasion. UNH graduate student Richard Brereton is developing field and laboratory techniques to quantify riparian zone influence on solute delivery to streams. Under-represented minority Katie Swan and Matt Bosiak recently received their Bachelor of Science degrees and both work as technicians at the University of New Hampshire and receive guidance and training from laboratory manager Jody Potter. Geoffrey Schwaner received his Bachelor of Science degree in 2012 and has served as a field technician on this project. Both Dr. McDowell and Jody Potter have provided guidance and training to Geoffrey.

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

A graduate student (Yannis Dialynas) and two post-docs (Elisa Arnone and Van Beusekom) have received one-to-one and group mentoring on LCZO research in Focal Area 4.

Maoya Bassiouni, formerly USGS, currently a student at Oregon State University, worked on the image processing programming and interpretation for Focal Area 4. Training of minority graduate student (Elvis Torres) in data evaluation of the instruments at CSJ atmospheric observatory was conducted at NOAA ESRL Aerosol Lab, Boulder, Colorado (May 2014; accidentally omitted in last-year's annual report). As part of Elvis Torres' development plan, he attended 4 different conferences (the 2014 13th Quadrennial ICACGP Symposium 13th IGAC Science Conference on Atmospheric Chemistry – Brazil; the 2015 Latin American and Caribbean Aerosol Measurements School: From measurements technologies to applications – Bolivia; the 2015 European Geosciences Union General Assembly - Austria, and the 2015 35rd Puerto Rico Interdisciplinary Scientific Meeting 50th Junior Technical Meeting – Puerto Rico) where he presented his results. He has submitted an abstract to AGU (Dec 2015) where he plans to present his latest results.

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

Numerous presentations (>100 total) 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 (e.g., AGU, ESA, ATBC, EGU). Students and postdocs are presenting results at major international conferences, including CZO special sessions at AGU and ESA. Project results have also been submitted for publication and published in the peer-review scientific literature (>40 total). Research is being published in top technical and multi-disciplinary journals. The LCZO also held webinar meetings approximately every 8 weeks where we discussed and explored our ongoing research findings. Webinar presentations have been published on YouTube for viewing by our members and the general public. For a detailed list of webinars, with links to videos of the presentations, see Accomplishments Supporting File 3 pdf. A number of collaborations have been established both with partner organizations and individual collaborators. Please see the "Participants & Other Collaborating Organizations" section for more details. The LCZO maintains a twitter feed with 75 followers and 149 tweets and retweets since early 2014. The twitter feed helps the CZO communicate information about upcoming presentations, posters and recent journal publications. The feed also helps us communicate with our members and the general public about news stories relevant to the CZO such as storms and other events impacting the region. Our feed can be found at https://twitter.com/luqczo. Lead PI McDowell has contributed to 6 different press releases reaching a broad range of audiences. Please see the products section for a detailed list of presentations, publications and other products. Data have also been archived on the LCZO website.

The LCZO cooperated with the American Geosciences Institute (AGI) to create a hands-on learning exercise using CZO data for use in secondary education classrooms: "How African dust feeds the Puerto Rico ecosystem" created by Adam Wymore, William H. McDowell and Nick Guy. The one-page, double-sided exercises are included in AGI's Earth Sciences Week packets and sent to teachers nationwide. American Geosciences Institute (AGI) Earth Sciences Week activity: http://criticalzone.org/national/news/story/learning-exercise-how-african-dust-feeds-the-puerto-rico-ecosystem/. June 10, 2015. A PDF of the learning exercise is included the Products Supporting File 1 PDF.

Other dissemination activities of interest include:

- After consultation with the LCZO executive committee PI McDowell provided comments on the USFS El Yunque National Forest Proposed Action Management Strategies document.
- Heather Buss gave an invited departmental seminar on her LCZO research at the University of Leeds-UK in Dec 2014.
- Jerolmack, Willenbring, McDowell and Scholl have been invited to give talks at the Fall American Geophysical meeting and multiple abstracts from this project have been submitted.
- PhD student Lee participates in science mentoring of elementary school children in West Philadelphia.
- PhD student Harrison has prepared a professionally shot video demonstration on "What makes rain?" with a local STEM education group for K-4 classes.
- PhD student Lauren Koenig co-lead the NH Envirothon Aquatics portion (training day). Approximately 75 middle to high school students and 5-10 secondary ed. teachers were in attendance from across NH. Sanborn Farm, Pittsfield, NH. April 5, 2014.
- PhD student Lauren Koenig served as an instructor for the STEM mini-course offered August 25-29th, 2014 through the CONNECT program at UNH (http://www.unh.edu/connect/). The objective of the course is to help incoming freshmen that come from groups with historically low retention in STEM majors (e.g. low-income, multicultural, first-

generation college students) build skills that are needed to succeed in their academic programs (e.g., writing of lab/research reports, basic math and statistics for analyzing scientific data). There were 12 students in the class, but the broader CONNECT program serves approximately 100 students. Students measured soluble reactive phosphorus (SRP) concentrations across sites with different land uses for their project. They had to give a general presentation to the entire CONNECT program (including non-STEM majors) and to best communicate their study, they chose to combine a traditional science powerpoint presentation with a music video. Their version of "These boots were made for sampling": http://www.youtube.com/watch?v=lQCZ4XEwj7c&feature=share.

- PhD student Lauren Koenig will serve as an instructor again for the STEM mini-course offered August 24-28, 2015 through the CONNECT program at UNH (http://www.unh.edu/connect/).
- Silver co-organized a special session "Ecology in the Critical Zone" at the 2015 Ecological Society of America meeting. Plante gave an invited presentation at this session and Yang et al. also presented LCZO data in this session.
- An invited presentation was given by Scholl at the 2015 Ecological Society of America meeting that included a brief overview of the H4.2 research.
- A paper was published in a special issue of Applied Geochemistry on Tropical Hydrology (Scholl, M.A., Shanley, J.B., Murphy, S.F., Willenbring, J.K., Occhi, M., and González, G. (2015): Stable-isotope and solute-chemistry approaches to flow characterization in a forested tropical watershed, Luquillo Mountains, Puerto Rico. Appl. Geochem. DOI: 10.1016/j.apgeochem.2015.03.008) detailing the response of the windward LCZO watershed, the Rio Mameyes, to rainfall events of varying intensity and size. Stable isotopes showed that overall, about 25% of rainfall leaves the system within a week as runoff, and that there is a substantial contribution of orographic rain and cloud water to the watersheds.
- The LCZO developed an annotated bibliography that highlights the science of the LCZO. This was provided to Tim White for use in developing an article on CZ science and the CZOs to be published in Oxford Bibliographies in Environmental Science. See Products Supporting File 3.pdf for the annotated bibliography and Products Supporting File 4.pdf for data slides highlighting the science described in the annotated bibliography.
- The LCZO regularly updates criticalzone.org with events such as upcoming presentations, posters and group webinars. This helps us inform our members, the broader community and the general public about our dissemination efforts. News posts and references for journal publications are also added on a regular basis.

*** 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 6-8 weeks 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. We will also continue efforts outlined in our management plan to support public outreach and education activities.

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 plan to use more geophysical tools to further elucidate deep critical zone architecture. This includes expanding ERI measurements with increased electrode separation in order to increase depth of penetration. Also, we plan to deploy shallow seismic surveys and potentially magnetic surveys to further investigate fracture distribution. We will also do pinpointed geochemical measurements of soils and waters. We will complete our analysis of existing samples (H1.2).

We anticipate submitting at least 3 new papers for publication presenting the volcaniclastic Mg isotope data (Chapela Lara et al., in prep), the volcaniclastic regolith and pore water profiles and the weathering rates derived from them (Buss et al., in prep), and the weathering mechanisms and rates in fractured borehole rocks (Moore et al., in prep). In collaboration with P.A.E. Pogge von Strandmann (Univ. College London) we will analyze Li isotope ratios to more fully exploit the Mg isotope data already collected. For H1.2 we anticipate submitting 2 additional new papers. One is specific to the site, the other a larger cross site synthesis on the role of geomorphology in shaping nutrient availability.

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

We will continue to collect data from the soil sensor array to explore the longer-term effects of drought and post-drought environment. We will perform additional redox fluctuation experiments involving isotopic tracers to de-convolute the mechanisms governing Fe-C coupling during C mineralization. The selective dissolution experiment will be extended to include temperate soil samples from the Calhoun CZO. In addition, characterization of the mineral and organic phases before and after the different dissolution experiments will be conducted using advanced analytical techniques such as x-ray diffraction (XRD, mineral), Mossbauer spectroscopy (mineral), scanning electron microscopy, fluorescence spectroscopy (organic) and high resolution mass spectrometry (organic).

Focal Area 3: Watershed scale hot spots and hot moments

We will complete development of smart rocks and deploy these rocks in a stream. We will produce the first measurements of the forces necessary to estimate abrasion and bedrock erosion rates from field data. We will integrate suspended sediment samples from the LTER, LCZO and USGS datasets to determine suspended sediment yields over a 25-year period. We will also perform experiments to understand formation of dissolution pits in bedrock, in order to assess their contribution to weathering of the knickpoint on the Icacos River. We will analyze suspended sediment samples for %C and %N on an isotope ratio mass spectrometer (IRMS), and examine composition using X-ray diffraction. We also plan to develop higher spatial resolution estimates of varying erosion rate in the Icacos, using cosmogenic radionuclides. We will also develop predictive relations for DOC, TSS, POC, and PN from continuous turbidity and fluorescence data and compute fluxes for three years in Río Icacos. In the coming year we will also analyze storm dynamics of TSS and DOC, particularly hysteresis, at Rio Icacos to infer sources of carbon and sediment on the landscape.

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

For H4.1 we will calibrate and apply biogeochemical models developed within existing hydro-geomorphic models (tRIBS). We will analyze dynamic feedbacks of shallow landslide occurrence and erosional processes on soil organic carbon dynamics. We will also assess effects of different factors (e.g., vegetation and biogeochemical characteristics of soil) on the impact of sediment redistribution on soil organic carbon dynamics. Finally we will analyze hydrological controls of hydrological hot spots and hot moments that affect carbon and nitrogen cycling.

For H.2 For the cloud cam study, we will be completing analysis of images collected to date from the Cloud Cam project and assembling the methods and results into a peer-reviewed journal paper in the next few months. We will be working closely with Ashley Van Beusekom (postdoc w/ USFS Gonzalez) to calibrate image data to ceilometer data to detect trends in the altitude of cloud base that may signal climate changes. For the cloud water deposition studies, we will develop complementary GIS –based water budget calculations to quantify cloud water amounts in the water budget for the Luquillo Mountains.

For H4.3 we will continue to improve our understanding on (a) the impact of African dust on radiation, (b) the role of dust in cloud formation and properties, (c) how clouds remove dust, and (d) dust nutrient inputs at Pico Este. This will be completed in year 4. The interstitial inlet construction will be completed during the 2015/2016 academic year.

Supporting Files

Filename	Description	Uploaded By	Uploaded On
Accomplishments Supporting File 1.pdf	Additional reporting requirements and year 3 budgets and budget justifications. Budgets for UNH, UPenn and FAU have been modified slightly since the original proposal submission and FIU was recently added as a new subaward.	William Mcdowell	09/01/2015
Accomplishments Supporting File 2.pdf	LCZO milestones, research teams and major activities.	William Mcdowell	09/01/2015

Accomplishments Supporting File 3.pdf	Schedule of executive committee meetings (with agenda topics), LCZO webinars (with links to YouTube videos), the annual meeting agenda, annual meeting evaluation summary and the advisory board report (following the annual meeting).	William Mcdowell	09/01/2015
Accomplishments Supporting File 4.pdf	Luquillo CZO response to drought (Fig. 1-5) and pictures of streams drying out, plants wilting and algae and diatoms in streams.	William Mcdowell	09/01/2015

Products

Books

Book Chapters

Navarre-Sitchler, A., Brantley, S.L. and Rother, G. (2015). How porosity increases during incipient weathering of crystalline silicate rocks. *Pore-scale Geochemical Processes* Steefel, C.. Mineralogical Society of America - Geochemical Soc. . Status = PUBLISHED; Acknowledgement of Federal Support = No ; Peer Reviewed = Yes ; ISBN: 978-0-939950-96-6.

Perdrial, J., Thompson, A., and Chorover, J. (2015). Chapter 6: Soil Geochemistry in the Critical Zone: Influence on Atmosphere, Surface- and Groundwater Composition. *Principals and Dynamics of the Critical Zone.* Giordano, J.R., and Houser, C.. Elsevier, Amsterdam, Netherlands.. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes ; Peer Reviewed = Yes ; ISBN: 9780444633699.

White A.F., Buss H.L (2014). Natural Weathering Rates of Silicate Minerals.. *urface and Ground Water, Weathering and Soils, Treatise on Geochemistry 2nd Edition* Drever, J.I.. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes ; Peer Reviewed = Yes

Conference Papers and Presentations

Phillips (2014). *, 2014 - The Threshold of Motion Filters Extreme Climatic Fluctuations in Gravel Bedded Alluvial and Bedrock Rivers Resulting in Near-Threshold and Transported-Limited Systems*. AGU Fall Meeting 2014. San Francisco. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Harrison, E.J. (2015). *10Be in the landscape*. LCZO Meeting 2015. Luquillo, PR. Status = OTHER; Acknowledgement of Federal Support = Yes

Brantley, S. L. (2015). *25th Anniversary Talk of Theme 5: Weathering and Surface Processes*. Annual Goldschmidt Conference, Prague, CZ, August 16-21, 2015. Prague, CZ. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Wilmoth, J. and Thompson, A. (2015). *57Fe isotope labeling of reactive Fe solid phases during redox transitions in a tropical forest soil using variable temperature Mössbauer spectroscopy.*. Southeastern Biogeochemistry Symposium. Atlanta, GA, USA. MAR 2015.. Atlanta, GA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Bassiouni M., Scholl M. (2015). *A Local Index of Cloud Immersion in Tropical Forests Using Time-Lapse Photography*. AGU Fall Meeting 2015. San Francisco. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

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 = OTHER; Acknowledgement of Federal Support = Yes

Mayol O. (2014). *African Dust and Clouds at Pico del Este*. LCZO Cyber Seminar February 28, 2014. GoToMeeting. Status = OTHER; Acknowledgement of Federal Support = Yes

Elvis Torres Delgado (2015). *African dust inputs*. LCZO Meeting 2015. Luquillo, PR. Status = OTHER; Acknowledgement of Federal Support = Yes

Anthony Dosseto, Heather Buss, François Chabaux (2014). *Age and weathering rate of sediments in small catchments: the role of hillslope erosion*. AGU Fall Meeting 2014. San Francisco. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Silver W., Ruan L. (2015). *An Instrumented Hillslope.*. LCZO Meeting 2015. Luquillo, PR. Status = OTHER; 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 = PUBLISHED; Acknowledgement of Federal Support = Yes

Lee, D. (2015). *Bringing a Smart Rock to Luquillo*. LCZO Meeting 2015. Luquillo, PR. Status = OTHER; Acknowledgement of Federal Support = Yes

Lee D. (2014). *Bringing a Smart Rock to Luquillo - A Tool to Constrain the Onset of Motion and Gravel Bed Impact Energies*. LCZO Cyber Seminar October 3rd, 2014. GoToMeeting. Status = OTHER; Acknowledgement of Federal Support = Yes

Sue Brantley (2014). *CZ-Tope: Using Measurements of Multiple Isotopes in One Setting to Understand Critical Zone Processes Occurring over Different Timescales (invited)*. AGU Fall Meeting 2014. San Francisco. Status = OTHER; Acknowledgement of Federal Support = Yes

Stone, M.M., Hockaday, W. & Plante, A.F. (2014). *Changes in Carbon Chemistry and Stability Along Deep Tropical Soil Profiles at the Luquillo Critical Zone Observatory*. AGU Fall Meeting 2014. San Francisco. 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 = PUBLISHED; Acknowledgement of Federal Support = Yes

Stone M.M., Plante A.F. (2014). *Changes in phosphatase kinetics with soil depth across a variable tropical landscape.*. ESA 2014. Sacramento. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Stone M.M., Plante A.F. (2014). *Changes in phosphatase kinetics with soil depth across a variable tropical landscape.*. LCZO Meeting 2014. Luquillo, PR. Status = OTHER; Acknowledgement of Federal Support = Yes

Plante, Stone & Hockaday (2015). *Characterization of organo-mineral associations from tropical soil profiles using solid-state 13C-NMR and thermal analysis*. Soil interfaces for sustainable development 2015. McGill University, Montréal, Québec, Canada. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Gonzalez, G. (2014). *Cielometer / data streams*. LCZO Meeting. Luquillo, PR. Status = OTHER; Acknowledgement of Federal Support = Yes

Van Beusekom, A. (2015). *Cielometer and other cloud height measurements*. LCZO Meeting 2015. Luquillo, PR. Status = OTHER; Acknowledgement of Federal Support = Yes

Shanley, J. (2015). *Comparing stream DOC fluxes from sensor- and sample-based approaches*. AGU Fall Meeting 2015. San Francisco. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Brereton, R., A.Wymore, J. Potter, W.H. McDowell (2015). *Concentration-discharge relationships in a wet tropical landscape: Luquillo Mountains, Puerto Rico. Cross-CZO SAVI Workshop: Concentration-discharge relations in the critical zone: Implications for understanding critical zone structure, function and evolution.*. CZO C-Q workshop. University of New Hampshire. Status = OTHER; Acknowledgement of Federal Support = Yes

Lee D., Jerolmack, D. (2014). *Connecting grain motion to large-scale fluctuations in bed load transport: The role of collective dynamics*. AGU Fall Meeting 2014. San Francisco. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Yang, W. H., Treffkorn, J., Liptzin D. (2015). *Controls on potential iron reduction in soils from diverse ecosystems*. ESA Annual Meeting 2015. Baltimore, Maryland. Baltimore, Maryland. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Thompson A. (2015). *Critical zone research at the University of Georgia*. Invited talk. University of Padua, Italy June 19, 2015. Padua, Italy.. Status = OTHER; Acknowledgement of Federal Support = Yes

Buss H.L., Moore O., Chapela Lara M. Schulz M. and White A.F. (2014). *Critical zone weathering hotspots*.. Goldschmidt 2014. Sacramento. Status = OTHER; Acknowledgement of Federal Support = Yes

Chapela Lara M., Buss H.L., Pogge von Strandmann P.A.E. (2014). *Delimiting the soil/saprolite transition using a multi-tracer approach*. Goldschmidt 2014. Sacramento. 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 = PUBLISHED; Acknowledgement of Federal Support = Yes

Bastola S., Dialynas Y. (2014). *Distribution of hot spot in sediment transport behavior in a humid tropical forest using tRIBS-VEGGIE*. LCZO Cyber Seminar February 28, 2014. GoToMeeting. Status = OTHER; Acknowledgement of Federal Support = Yes

Satish Bastola (2015). *Distribution of hot spots in sediment transport and coil moisture in a humid tropical forest using tRIBS model*. LCZO Meeting 2015. Luquillo, PR. Status = OTHER; Acknowledgement of Federal Support = Yes

Brantley, S. (2014). *Drilling Deep*. LCZO Cyber Seminar October 3rd, 2014. GoToMeeting. Status = OTHER; Acknowledgement of Federal Support = Yes

Brantley, S. (2014). *Drilling to Explore the Transformation of Bedrock into Soil in the Deep Critical Zone*. technical seminar, Kansas State University, Manhattan, KS, October 16, 2014. Manhattan, KS. Status = OTHER; Acknowledgement of Federal Support = Yes

Gonzalez, Henareh, McGinley, and Lodge (2015). *Ecological and social aspects of Tropical Forest Responses to Climate Change in the LEF, PR*. Association for Tropical Biology and Conservation 2015. Honolulu, Hawaii. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Plante & Stone (2015). *Exploring relationships between microbial ecology and soil organic matter stability in deep tropical soil profiles*. ESA 2015. Baltimore, Maryland. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Brantley S. (2014). *Exploring the Transformation of Bedrock into Soil in the Deep Critical Zone*. Invited talk, UC-Riverside, Apr 8, 2014. UC-Riverside. Status = OTHER; Acknowledgement of Federal Support = Yes

Brantley S. (2014). *Exploring the Transformation of Bedrock into Soil in the Deep Critical Zone*. Invited technical lecture, 11th Annual Noel Potter Lectures, The Department of Earth Sciences, Dickinson College, Carlisle, PA, November 18, 2014. Carlisle, PA. Status = OTHER; Acknowledgement of Federal Support = Yes

Brantley, S. (2014). *Exploring the transformation of bedrock into soil in the deep critical zone*. Invited seminar, Lamont Doherty Earth Observatory, Columbia University, Palisades, NY, September 15-16, 2014. Palisades, NY. Status = OTHER; Acknowledgement of Federal Support = Yes

Shanley, J. (2015). *FDOM DOC and Turbidity*. LCZO Meeting 2015. Luquillo, PR. 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

Coward, E.K.., Thompson, A., and Plante, A.F. (2015). *Fe-C associations and soil organic matter stability in two tropical soils of contrasting parent materials.*. Soil Interfaces for Sustainable Development 2015. McGill University, Montréal, Québec, Canada. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Coward, E.K.,Thompson, A. (2014). *Fe-C interactions and soil organic matter stability in two tropical soils of contrasting parent materials*. AGU Fall Meeting 2014. San Francisco. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Coward E.K., Thompson A., Plante A.F. (2014). *Fe-C interactions and soil organic matter stability in two tropical soils of contrasting parent materials (B23I-07)*. AGU Fall Meeting 2014. San Francisco. 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*. Goldschmidt 2014. Sacramento. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Brocard, G.,Willenbring, J.,Scatena, F.N. (2014). *Form follows function: can tropical mountain forest competition drive the growth of topography?*. AGU Fall Meeting 2014. San Francisco. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

McDowell, W.H. (2015). *Freshwater Science: Lessons Learned and Looking Ahead.*. First Annual Symposium on Aquatic Science. University of Maine, Orono, Maine.. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Silver W. (2014). *Frontiers in Critical Zone Science: Science Advances for the Next 10 Years*. AGU Fall Meeting 2014. San Francisco. Status = PUBLISHED; Acknowledgement of Federal Support = No

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

Comas, X. (2015). *Geophysical Surveying*. LCZO Meeting 2015. Luquillo, PR. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Bastola S., Dialynas Y. (2015). *Hot spots of sediment sources and links to Soil Organic Carbon Dynamics*. LCZO Cyber Seminar February 20, 2015. GoToMeeting. Status = OTHER; Acknowledgement of Federal Support = Yes

Brereton R., McDowell, W.H. (2015). *Identifying Hot Spots and Hot Moments of Nitrogen Cycling in Riparian Groundwater and Streams*. LCZO Meeting 2015. Luquillo, PR. Status = OTHER; Acknowledgement of Federal Support = Yes

Wymore, A., Kalbitz, K., Daley, M., Koenig, L., Miller, S., McDowell W.H. (2014). *Identifying the Sources of Dissolved Organic Matter in Streams Using Elemental Analysis Isotopic Ratio Mass Spectroscopy (EA-IRMS) Across a Land Use Gradient.*. AGU Fall Meeting 2014. San Francisco. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Torres-Delgado, E., C. J. Valle-Diaz, D. Baumgardener, W. H. McDowell, G. González, O. L. Mayol-Bracero (2015). *Impact of African dust on cloud and rain chemistry and cloud microphysics in Caribbean cloud forest*. 35rd Puerto Rico Interdisciplinarity Scientific Meeting 50th Junior Technical Meeting, Universidad de Puerto Rico, Río Piedras Campus, San Juan, Puerto Rico, 29 Mar 2015.. San Juan, Puerto Rico. Status = OTHER; Acknowledgement

of Federal Support = Yes

Bastola S., Dialynas Y. Arnone, E. Wang, J., Bras, R.L. (2014). *Integration of Slope stability module into landscape evolution model (tRIBS erosion) to simulate sediment yield at watershed influenced by shallow landslides: A case study in the Luquillo Forest, Puerto Rico*. CZO All hands meeting 2014. Luquillo, PR. Status = OTHER; Acknowledgement of Federal Support = Yes

Hall S. (2015). *Interactions between biological and physical processes generate complex redox dynamics*. LCZO Meeting 2015. Luquillo, PR. Status = OTHER; Acknowledgement of Federal Support = Yes

Brocard, G., Willenbring J. (2015). *Interplay of forest and topography during the growth of the Luquillo Mountains*. LCZO Cyber Seminar January 16, 2015. GoToMeeting. Status = OTHER; 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 = PUBLISHED; Acknowledgement of Federal Support = Yes

Barcellos, D.; Wilmoth, J.; Thompson, A. (2015). *Iron reduction rate increases during shorter redox fluctuations in soil slurries of Luquillo CZO soils.*. Southern Biogeochemistry Symposium. Atlanta, GA. March 2015.. Atlanta, GA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Coward E.K. (2015). *Iron-mediated C stability in two tropical soils*. LCZO Cyber Seminar January 16, 2015. GoToMeeting. Status = OTHER; Acknowledgement of Federal Support = Yes

Brocard, G. (2015). *Knick Points and Landscape evolution*. LCZO Meeting 2015. Luquillo, PR. Status = OTHER; Acknowledgement of Federal Support = Yes

Willenbring, J. (2015). *Landscape Response to Uplift: Delayed or Immediate*. LCZO Meeting 2015. Luquillo, PR. 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 = PUBLISHED; Acknowledgement of Federal Support = Yes

McDowell, W.H. (2014). *Linking CZO, LTER, and NEON- Putting Biology into the Critical Zone*. AGU Fall Meeting 2014. San Francisco. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

McDowell, W.H. (2015). *Long Term Nitrogen Dynamics in a Tropical Landscape*. Keynote address at Northeast Alliance for Graduate Education and the Professoriate - No longer a dream deferred! 8th NEA Science Day,. University of Puerto Rico, Mayagüez, Puerto Rico.. Status = OTHER; Acknowledgement of Federal Support = Yes

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Inventions

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Licenses

Other Products

Databases.

LCZO Soil Network samples have been catalogued at System for Earth Sample Registration (SESAR) and have International Geo Sample Number (IGSN) numbers and barcodes. This makes these samples discoverable through the web while barcoding facilitates the maintance of our sample library.

Software or Netware.

The R package Loadflex

The LCZO has developed the R package loadflex for stream solute flux estimation. This package implements several of the most common methods for modeling and predicting watershed solute fluxes and concentrations, including interpolation and regression models, period-weighted averaging, and the composite method. loadflex integrates with the USGS's rloadest package and with native R regression models. It offers a uniform interface for a variety of model types, with which you can quickly fit models, generate predictions, and aggregate to monthly or annual values. This package is open source and is freely available on github.com.

https://github.com/McDowellLab/loadflex

Connecticut Public Radio.

McDowell, W.H. 2014. Interviewed live by John Dankosky from Connecticut Public Radio along with Dr. Kaushal on “Understanding the Urban Ecosystem”. September 12, 2014: http://sciencefriday.com/segment/09/12/2014/understanding-the-urban-ecosystem.html.

Earth Cube Use Case.

A dynamical watershed model for concentration and discharge in a highly weathered tropical site (Luquillo CZO)

Authors: Lara M.C., Duffy C.

This effort resulted in a publicly available use case for Earth Cube. The scientific objective of this use case is as follows:

To develop a relatively simple dynamical model for simulating the water balance and residence time of chloride ion in the Bisley 1 catchment of the Luquillo Critical Zone Observatory. The aim is to understand the time evolution of flow paths and residence times, from rainfall to runoff, and to establish a control for her geochemistry research in the catchment. The dynamical model will use the historical precipitation, discharge and potential evapotranspiration data as well as chloride concentration data that were collected under the NSF LTER and CZO funding. Long term data is available that suggests a strong random or stochastic component as well as seasonal to interannual components in rainfall, Cl concentration and temperature.

Interview.

McDowell, W.H. 2015. Interviewed by Gayathri Vaidyanathan, a reporter from ClimateWire, on carbon sinks in tropical forests. Interviewed May 2015.

Interview for newspaper article.

The city is an ecosystem, pipes and all. What scientists are finding when they treat the urban landscape as an evolving environment of its own. McDowell, W.H. interviewed for article on October 6, 2014. Published in The Boston Globe on November 7, 2014. http://www.bostonglobe.com/ideas/2014/11/07/the-city-ecosystem-pipes-and-all/HjLVemBs9nPiuE53PjPSLK/story.html.

NSF press release.

McDowell, W.H. 2014. A river runs through it: U.S. cities' waterways show consistent patterns of evolution. NSF press release. September 10, 2014. http://www.nsf.gov/discoveries/disc_summ.jsp?cntn_id=132583&org=NSF

UNH press release.

McDowell, W.H. 2014. UNH Scientists Find Urban Ecosystems “Evolve,” Require Sustainable Management. University of New Hampshire press release. September 10, 2014. http://www.unh.edu/news/releases/2014/09/ds10evolve.cfm#ixzz3D10ttLHP.

University of Maryland's independent student newspaper.

McDowell, W.H. 2014. Interviewed for the “University of Maryland professor tailors watershed test to urban areas like College Park” press release. The Diamondback. The University of Maryland’s Independent Student Newspaper. September 23, 2014. http://www.diamondbackonline.com/news/article_5128a2e2-42b5-11e4-b909-001a4bcf6878.html.

Other Publications

Karen Stocks, Maria Chapela Lara, Christopher Duffy (2015). *EarthCube Use Case: A dynamical watershed model for concentration age discharge in a highly weathered tropical site (Luquillo CZO).*. EarthCube Use Case: To develop a relatively simple dynamical model for simulating the water balance and residence time of chloride ion in the Bisley 1 catchment of the Luquillo Critical Zone Observatory. The aim is to understand the time evolution of flow paths and residence times, from rainfall to runoff, and to establish a control for her geochemistry research in the catchment. The dynamical model will use the historical precipitation, discharge and potential evapotranspiration data as well as chloride concentration data that were collected under the NSF LTER and CZO funding. Long term data is available that suggests a strong random or stochastic component as well as seasonal to interannual components in rainfall, Cl concentration and temperature.. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Patents

Technologies or Techniques

Thesis/Dissertations

Stone M.M. *Soil microbial communities and soil organic matter: composition and ecological functions in the Luquillo Critical Zone*. (2014). University of Pennsylvania. Acknowledgement of Federal Support = Yes

Miller K.L., Jerolmack D.J.. *The Causes and Consequences of Particle Size Change in Fluvial Systems*. (2014). University of Pennsylvania. Acknowledgement of Federal Support = Yes

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

Joseph Orlando. *The anatomy of weathering profiles on different lithologies in the tropical forest of northeastern Puerto Rico: from bedrock to clouds. M.S. Thesis*. (2014). The Pennsylvania State University. Acknowledgement of Federal Support = Yes

Websites

LCZO Data Catalog
https://www.sas.upenn.edu/lczodata/

The Luquillo CZO data repository contains data from ongoing and completed research spanning critical zone science. This site also includes an extensive research knowledge base of past publications from the Luquillo Experimental Forest and a field work calendar to help coordinate ongoing research collaboration in the field. Here you can find out about ongoing research in the CZO and find data related to these projects.

LCZO GIS Catalog
http://ec2-50-19-46-248.compute-1.amazonaws.com/mappingApp/index.html

This site provides an interactive web interface for browsing and Downloading Luquillo CZO GIS data.

ODM2 Administration for LCZO datasets
http://odm2lczo.miguelcleon.com/ODM2/odm2testapp/admin/

As part of our collaboration with Tana Wood's USFS/DOE warming experiment: “Tropical Responses to Altered Climate Experiment (TRACE)" a new data management system is in development. This new data management system is based on CUAHSI's ODM2 and allows for the creation of extensive metadata for datasets, equipment maintance, tracking of laboratory procedures and other metadata relavent to maintaining fully described datasets. The LCZO and TRACE will maintain seperate copies of the ODM2 Administration web application and ODM2 database.

ODM2 Administration for the TRACE Project
http://odm2trace.miguelcleon.com/admin2/admin

As part of our collaboration with Tana Wood's USFS/DOE warming experiment: “Tropical Responses to Altered Climate Experiment (TRACE)" a new data management system is in development. This new data management system is based on CUAHSI's ODM2 and allows for the creation of extensive metadata for datasets, equipment maintance, tracking of laboratory procedures and other metadata relavent to maintaining fully described datasets.

Supporting Files

Filename	Description	Uploaded By	Uploaded On
Products Supporting File 1.pdf	Special education initiatives â?? â??Introduction to Critical Zone Scienceâ?? UNH course syllabus, LCZO AGI learning exercise â?? How African dust feeds the Puerto Rico ecosystemâ?? and the â?? Early Career Critical Zone Workshopâ?? agenda.	William Mcdowell	09/01/2015
Products Supporting	Cross-CZO SAVI Workshop Agenda for Concentration-discharge relations in the critical zone: Implications for understanding critical	William Mcdowell	09/01/2015

Supporting File 2.pdf	relations in the critical zone: Implications for understanding critical zone structure, function and evolution.	Mcdowell	
Products Supporting File 3.pdf	Annotated bibliography that highlights the science of the LCZO. This was provided to Tim White for use in developing an article on CZ science and the CZOs to be published in Oxford Bibliographies in Environmental Science.	William Mcdowell	09/01/2015
Products Supporting File 4.pdf	LCZO highlights and figures from recent products.	William Mcdowell	09/01/2015

Participants/Organizations

What individuals have worked on the project?

Name	Most Senior Project Role	Nearest Person Month Worked
McDowell, William	PD/PI	3
Gonzalez, Grizelle	Co PD/PI	2
Plante, Alain	Co PD/PI	3
Silver, Whendee	Co PD/PI	2
Brantley, Susan	Co-Investigator	1
Bras, Rafael	Co-Investigator	1
Buss, Heather	Co-Investigator	2
Comas, Xavier	Co-Investigator	1
Jerolmack, Doug	Co-Investigator	2
Mayol, Olga	Co-Investigator	1
Porder, Stephen	Co-Investigator	2
Thompson, Aaron	Co-Investigator	2
Willenbring, Jane	Co-Investigator	2
Bastola, Satish	Faculty	2
Fernandez, Denny	Faculty	1
Hall, Steven	Faculty	1

Hall, Steven	Faculty	1
Marin-Spiotta, Erika	Faculty	1
Pett-Ridge, Julie	Faculty	2
Wang, Jingfeng	Faculty	1
Arnone, Elisa	Postdoctoral (scholar, fellow or other postdoctoral position)	0
Brocard, Gilles	Postdoctoral (scholar, fellow or other postdoctoral position)	4
Clark, Kathryn	Postdoctoral (scholar, fellow or other postdoctoral position)	12
Hynek, Scott	Postdoctoral (scholar, fellow or other postdoctoral position)	4
Ruan, Leilei	Postdoctoral (scholar, fellow or other postdoctoral position)	12
Szabo, Timea	Postdoctoral (scholar, fellow or other postdoctoral position)	2
Van Bueusekom, Ashley	Postdoctoral (scholar, fellow or other postdoctoral position)	12
Wymore, Adam	Postdoctoral (scholar, fellow or other postdoctoral position)	12
Brown, Josh	Other Professional	7
Daley, Michelle	Other Professional	2
Jimenez, Rafael	Other Professional	0
Leon, Miguel	Other Professional	12
Potter, Jody	Other Professional	2
Bosiak, Matt	Technician	2
Diazgranados, Jorge	Technician	12
Sallady, Ryan	Technician	6
Schwaner, Geoff	Technician	5

Swan, Katherine	Technician	2
Gould, William	Staff Scientist (doctoral level)	3
Martinuzzi, Sebastian	Staff Scientist (doctoral level)	3
Scholl, Martha	Staff Scientist (doctoral level)	3
Shanley, Jamie	Staff Scientist (doctoral level)	3
Wood, Tana	Staff Scientist (doctoral level)	3
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)	12
Cyle, Taylor	Graduate Student (research assistant)	4
Dialynas, Yannis	Graduate Student (research assistant)	12
Gutiérrez del Arroyo, Omar	Graduate Student (research assistant)	6
Harrison, Emma	Graduate Student (research assistant)	4
Hodges, Caitlin	Graduate Student (research assistant)	4
Koenig, Lauren	Graduate Student (research assistant)	6
Lee, Dylan	Graduate Student (research assistant)	12
Litwin-Miller, Kim	Graduate Student (research assistant)	2
McClintock, Matthew	Graduate Student (research assistant)	4
Moore, Oliver	Graduate Student (research assistant)	12
Orlando, Joe	Graduate Student (research assistant)	0
Phillips, Colin	Graduate Student (research assistant)	0
Rodriguez, Josely	Graduate Student (research assistant)	6

Rodriguez, Jessy	Graduate Student (research assistant)	0
Stone, Maddie	Graduate Student (research assistant)	0
Torres, Elvis	Graduate Student (research assistant)	12
Wilmoth, Jared	Graduate Student (research assistant)	4
Crespo, Ashley	Undergraduate Student	0
Kovalovitch, Aria	Undergraduate Student	2
Pereira, Michelle	Undergraduate Student	2
Silver, Heather	Undergraduate Student	8
Stien, Rebekah	Undergraduate Student	8
Sullivan, Conor	Undergraduate Student	0
Tamayo, Cooper	Undergraduate Student	0
Traxler, Emily	Undergraduate Student	0
Zhou, Mengzhou	Undergraduate Student	0
Morales, Flavia	Consultant	1

Full details of individuals who have worked on the project:

William H McDowell
Email: bill.mcdowell@unh.edu
Most Senior Project Role: PD/PI
Nearest Person Month Worked: 3

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

Funding Support: UNH

International Collaboration: No
International Travel: No

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

Contribution to the Project: Monitoring of climate and hydrological data, ceilometer data interpretation. Provides logistical support.

Funding Support: USDA FS

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: 3

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

Funding Support: UPenn

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

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Whendee Silver
Email: wsilver@berkeley.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 2

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: 2

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: 1

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

Funding Support: Florida Atlantic University

International Collaboration: No
International Travel: No

Doug Jerolmack
Email: sediment@sas.upenn.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 2

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: 2

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: No

Jane Willenbring
Email: erosion@sas.upenn.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 2

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

Satish Bastola
Email: Satish.bastola@ce.gatech.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 2

Contribution to the Project: Hydrologic modeling; landslide modeling.

Funding Support: Georgia Tech

International Collaboration: No
International Travel: No

Denny Fernandez
Email: dsfernandez@gmail.com
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: Impacts of African dust on radiation.

Funding Support: UPR-Humacao

International Collaboration: No
International Travel: No

Steven Hall
Email: stevenjh@iastate.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: Iron Redox

Funding Support: Iowa State University

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

Julie Pett-Ridge
Email: Julie.Pett-Ridge@oregonstate.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 2

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

Funding Support: Oregon State

International Collaboration: No
International Travel: No

Jingfeng Wang
Email: jingfeng.wang@ce.gatech.edu
Most Senior Project Role: Faculty

Nearest Person Month Worked: 1

Contribution to the Project: Hydrologic modeling; landslide modeling.

Funding Support: Georgia Tech

International Collaboration: No
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: 0

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: 4

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: 12

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: 4

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: 12

Contribution to the Project: Iron Redox

Funding Support: UC-Berkeley

International Collaboration: No
International Travel: No

Timea Szabo
Email: tszabo.hu@gmail.com
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 2

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

Funding Support: Hungarian Gov.

International Collaboration: Yes, Hungary
International Travel: No

Ashley Van Bueusekom
Email: ashley.vanbeusekom@gmail.com
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 12

Contribution to the Project: responsible for work on cloud ceiling and its effects on forest ecosystems.

Funding Support: USDA FS

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: 12

Contribution to the Project: Stream Solutes

Funding Support: None

International Collaboration: No
International Travel: Yes, China - 0 years, 0 months, 6 days

Josh Brown
Email: luquillo.czo@mail.com
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 7

Contribution to the Project: Assists all LCZO personnel in field work and sample processing in Puerto Rico.

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: 2

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: 0

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: 2

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

Matt Bosiak
Email: mwz28@wildcats.unh.edu
Most Senior Project Role: Technician
Nearest Person Month Worked: 2

Contribution to the Project: Technician in the UNH Water Quality Analysis Labratory where stream and groundwater samples are analyzed

Funding Support: UNH WQAL

International Collaboration: No
International Travel: No

Jorge Diazgranados
Email: jorge.diazgranados@upr.edu
Most Senior Project Role: Technician
Nearest Person Month Worked: 12

Contribution to the Project: Impacts of African dust on cloud chemical composition and microphysics at Pico Este. Impacts of African dust on radiation. Determination of dust concentrations

Funding Support: UPR-RP

International Collaboration: No
International Travel: No

Ryan Sallady
Email: rsalladay@berkeley.edu
Most Senior Project Role: Technician
Nearest Person Month Worked: 6

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: 5

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

Katherine Swan
Email: Katherine.Swan@unh.edu
Most Senior Project Role: Technician
Nearest Person Month Worked: 2

Contribution to the Project: Technician in the UNH Water Quality Analysis Labratory where stream and groundwater samples are analyzed

Funding Support: UNH WQAL

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: 3

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: 3

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: 3

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: 3

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: Yes, Australia - 0 years, 0 months, 14 days

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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: 12

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

Funding Support: UPenn

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

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Taylor Cyle
Email: unkown@notsure.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 4

Contribution to the Project: dissolved organic carbon measurements. Worked to optimize the methodology for the unique extract matrices.

Funding Support: UC- Berkeley

International Collaboration: No
International Travel: No

Yannis Dialynas
Email: ydialynas@gatech.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: Hydrologic modeling; landslide modeling.

Funding Support: Georgia Tech, 2006T95, 2006V31

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: 6

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

Funding Support: UC-Berkeley

International Collaboration: No
International Travel: No

Emma Harrison
Email: haem@sas.upenn.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 4

Contribution to the Project: BE10 Cosmogenic dating at landscape scales.

Funding Support: UPenn

International Collaboration: No
International Travel: No

Caitlin Hodges
Email: chodges@uga.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 4

Contribution to the Project: conducting field-level assessments of iron reduction potential.

Funding Support: University of Georgia

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: 6

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: 12

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: 2

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: 4

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: Yes, Australia - 0 years, 0 months, 14 days

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Joe Orlando
Email: jjo167@psu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 0

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: 0

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: 6

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: 0

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: 12

Contribution to the Project: African Dust Inputs

Funding Support: UPR

International Collaboration: No
International Travel: Yes, Austria - 0 years, 0 months, 7 days; Bolivia - 0 years, 0 months, 7 days; Brazil - 0 years, 0 months, 7 days

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Jared Wilmoth
Email: jared.wilmoth@gmail.com
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 4

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: 0

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

Funding Support: None

International Collaboration: No
International Travel: No

Aria Kovalovitch
Email: unkown@notsure2.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 2

Contribution to the Project: Collaborative and interdisciplinary research combining field and laboratory techniques and interact with Grizelle Gonzalez

Funding Support: UPenn

International Collaboration: No
International Travel: No

Michelle Pereira

Email: pereiram@sas.upenn.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 2

Contribution to the Project: Assisting with laboratory experiments on fine sediment characterization in LCZO streams.

Funding Support: UPenn

International Collaboration: No
International Travel: No

Heather Silver
Email: silverh@sas.upenn.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 8

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

Funding Support: UPenn

International Collaboration: No
International Travel: No

Rebekah Stien
Email: unknown@notsure.com
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 8

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: 0

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: 0

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: 0

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: 0

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

Funding Support: None

International Collaboration: No
International Travel: No

Flavia Morales
Email: fmorales.upr@gmail.com
Most Senior Project Role: Consultant
Nearest Person Month Worked: 1

Contribution to the Project: Determination of dust concentrations

Funding Support: UNH

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

Columbia University	Academic Institution	New York, NY
Hebrew University of Jerusalem, Israel	Academic Institution	Jerusalem, Israel
Oregon State University	Academic Institution	Corvallis, OR
University of Miami	Academic Institution	Miami, Florida
University of Puerto Rico at Mayagüez	Academic Institution	Mayagüez, Puerto Rico
University of Puerto Rico – Humacao	Academic Institution	Humacao, Puerto Rico
University of Wollongong	Academic Institution	Wollongong, Australia
Università degli Studi di Palermo	Academic Institution	Palermo (PA), Italy

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.

Columbia University

Organization Type: Academic Institution
Organization Location: New York, NY

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

More Detail on Partner and Contribution: Maria Uriarte from Columbia University has a postdoc who just started (May 2015) and is interested in working with the CZO LiDAR data. Their interests are primarily in quantifying vegetation structure (e.g., biomass, LAI) and examining underlying drivers (e.g., topography, elevation, etc). LiDAR-derived vegetation metrics will be used for models.

Hebrew University of Jerusalem, Israel

Organization Type: Academic Institution
Organization Location: Jerusalem, Israel

Partner's Contribution to the Project:

Facilities

More Detail on Partner and Contribution: Dr. Alon Angert, Hebrew University of Jerusalem, Israel, is an expert on phosphorus in dust and he and his group are collaborating with H4.3 to identify airborne sources of phosphorus using stable isotopes of dust aerosol samples.

Oregon State University

Organization Type: Academic Institution
Organization Location: Corvallis, OR

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution:

University of Miami

Organization Type: Academic Institution
Organization Location: Miami, Florida

Partner's Contribution to the Project:
Facilities
Collaborative Research

More Detail on Partner and Contribution: Dr. Prospero's group from the University of Miami is collaborating with H4.3 for the determination of the dust concentrations.

University of Puerto Rico at Mayagüez

Organization Type: Academic Institution
Organization Location: Mayagüez, Puerto Rico

Partner's Contribution to the Project:
Collaborative Research
Other: Led part of the annual meeting field trip to introduce meeting participants to the caves.

More Detail on Partner and Contribution:

University of Puerto Rico – Humacao

Organization Type: Academic Institution
Organization Location: Humacao, Puerto Rico

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution: Dr. Denny Fernandez, from the University of Puerto Rico – Humacao is collaborating with H4.3 on the impact of African dust on radiation at Pico del Este.

University of Wollongong

Organization Type: Academic Institution
Organization Location: Wollongong, Australia

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution:

Università degli Studi di Palermo

Organization Type: Academic Institution
Organization Location: Palermo (PA), Italy

Partner's Contribution to the Project:
Collaborative Research
Personnel Exchanges

More Detail on Partner and Contribution:

What other collaborators or contacts have been involved?

Dr. Anthony Dosseto, University of Wollongong, Australia; Dr. Philip Pogge von Strandmann, University College London, UK; Dr. Katherine Maher, Stanford University; Dr. Jan Schuessler, GFZ Potsdam, Germany; Dr. Andrew Kurtz, Boston University; Dr. Julie Pett-Ridge, Oregon State University and Dr Dimitrios Ntarlagiannis, Rutgers University are all collaborating with Focal Area 1.

Maria Uriarte from Columbia University has a postdoc who just started (May 2015) and is interested in working with the CZO LiDAR data. Their interests are primarily in quantifying vegetation structure (e.g., biomass, LAI) and examining underlying drivers (e.g., topography, elevation, etc). LiDAR-derived vegetation metrics will be used for models.

Tom Miller from the University of Puerto Rico at Mayagüez attended the annual LCZO meeting and has been collaborating with Gilles Brocard by showing him around caves in Puerto Rico. Dr. Miller led part of the annual meeting field trip to introduce meeting participants to the caves.

Dr. Elisa Arnone, from Università degli Studi di Palermo, was a visiting scholar at Georgia Tech from February 2013 to January 2014 and continues to collaborate with H4.1.

Dr. Leonardo V. Noto, from Università degli Studi di Palermo, has collaborated with H4.1 by providing suggestions, reviews and contributing to papers.

Dr. Alon Angert, Hebrew University of Jerusalem, Israel, is an expert on phosphorus in dust and he and his group are collaborating with H4.3 to identify airborne sources of phosphorus using stable isotopes of dust aerosol samples.

Dr. Prospero's group from the University of Miami is collaborating with H4.3 for the determination of the dust concentrations.

Dr. Denny Fernandez, from the University of Puerto Rico – Humacao is collaborating with H4.3 on the impact of African dust on radiation at Pico del Este.

Impacts

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

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

Within H1, we have impacted the fields of geochemistry, ecology and microbiology by showing that although surface and sub-surface nutrient cycles have long been thought to be decoupled in deep soils, they still affect one another by way of an oxygen gradient from the surface, where vegetation grows and decomposes, to the deep, underlying bedrock, where minerals dissolve and produce soil. The surface organisms consume oxygen, reducing the amount that reaches the bedrock, affecting the rate at which new soil is created. We have also impacted the field of near surface geophysics by deploying a unique array of geophysical methods for investigating the regolith-bedrock interface at different scales of measurement. The application of near surface geophysical methods in other CZOs has been so far limited.

The role of geomorphology in shaping tropical ecosystems is widely acknowledged but little understood. The LCZO has made possible a far more detailed understanding than in any other tropical landscape because we have such a high density of cosmogenic nuclide-based erosion rates. That allows us to generate fine-scale hypotheses about patterns in nutrient status that can be rigorously tested. The data density generated by LCZO is so much higher than anywhere else in the tropics that it is likely to yield insights far beyond what has been possible in other tropical landscapes.

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

Our work is documenting for the first time patterns in redox dynamics in space and time and showing how these dynamics are linked to soil chemical, physical, and biological properties, as well as with climate. Our work goes on to show how redox dynamics drive C, N, and P biogeochemistry. The role and contribution of Fe-derived mineral phases to soil organic matter stabilization is not yet well understood. The results of this work contribute substantially to our understanding of the degree to which Fe-minerals retain organic C in deep tropical soils.

Focal Area 3: Watershed scale hot spots and hot moments

We developed a relation between pebble shape and mass loss, which can be used to determine the significance of abrasion from particle shape alone – on Earth and other planets.

We have shown that river channel geometry is insensitive to climate, because of the generic self-organization of rivers to near-threshold transport conditions. We determined that physical weathering is predominantly by brittle fracture, allowing us to bring a well-developed theory from materials science to bear on geomorphological problems. We have identified a new mechanism that determines how quickly knickpoints migrate through landscapes. This mechanism couples soils and rivers to show how weathering in soils actually decreases the ability for rivers to incise. We have shown that the knickpoints exert a fundamental control on soil nutrients and that below the knickpoints, nutrients are sourced from bedrock but in the headwater soils, the nutrients are derived from Saharan dust and aerosols.

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.

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

Characterization of hydrologic feedbacks to hot spots and hot moments in landslide occurrence and sediment transport, and feedbacks to biogeochemical processes are the most important points of this work. Process based models, as developed and implemented in this project, are advantageous over empirical approaches as they represent underlying physical laws of soil dynamics and hydrologic processes in data-scarce spatially complex built terrains. The analysis spans a range of scales, capturing the small scale complexity of sediment transport in assessing the watershed integrated response in terms of soil organic carbon fluxes.

The distributed hydro-geomorphic model used in this project resolves important physical processes in both space and time, at scales relevant to landslide occurrence and to the dynamics of soil organic carbon. With increasing availability

of high resolution topography, geological and biogeochemical datasets, the models developed in this work are able to reproduce spatiotemporal distributions of sediment transport and of soil organic carbon content at different soil profiles. The coupled spatially-explicit formulations can be used in landslide studies and landslide warning systems, in addition to assessments of effects of road infrastructure to slope stability. The distributed model discussed above is also the integrator of carbon dynamics and nutrient cycling at watershed scale. The fate of eroded soil organic carbon and the rate of carbon deposition at the floodplains of Mameyes and Icacos rivers are estimated in this modelling work.

The work utilizing isotope hydrology tools to understand cloud forest hydrology and impacts of climate change are of interest in regions that have mountain watersheds as important components of the water resource for human use.

What is the impact on other disciplines?

The impulse-channel geometry work links climate with geomorphology in a concrete way. The generic shape evolution of pebbles links Earth and planetary science, using new concepts from applied mathematics. The work linking fine-sediment production from abrasion with fragmentation shows how concepts from materials science and solid mechanics can be employed to understand geomorphological problems. The nexus between geology and biology occurs in the critical zone, and we are slowly making progress toward quantifying the influence of each on the other. The work measuring 10Be in multiple grain-sizes will inform the cosmogenic nuclide community on a previously unknown process of sourcing grain sizes from soils and deeper parts of soil profiles above and below the knickpoints. Work dating the uplift of the island from caves has informed studies of the genetics of frog populations and the timing of the inception of the rainforest.

What is the impact on the development of human resources?

There were 10 undergraduate students, 20 graduate students and 7 post-doctoral researchers involved in the LCZO in year 2 (please refer to the participants section for more detailed information). Students and post-doctoral researchers receive one-to-one and group mentoring by LCZO PIs and other senior personnel. See also the opportunities for training and professional development in the accomplishments section.

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

Two PhD students (one Hispanic) at the University of Bristol have participated in LCZO research, developed their scientific technical skills and writing/presentation skills as well as developed global networks of contacts within the CZ community. Four University of Bristol undergraduates have participated in LCZO research by performing optical petrography of LCZO samples. LCZO research has also contributed to lecture material in three undergraduate courses taught by Buss at the University of Bristol including Year 1 Global and Environmental Change (70 students), Year 2 Soils and the Critical Zone (15 students), and Year 3 Geomicrobiology (30 students). This year's field work also contributed to the direct training in the use of geophysical methods in the field and data post-processing/interpretation of two undergraduate students from underrepresented minority groups.

The University of Bristol LCZO PhD students are developing reactive transport modelling skills and Synchrotron XAS skills. Several FAU, Penn State and Rutgers graduate and undergraduate students have been learning about deployment of geophysical methods in the field and basic data processing and interpretation.

PhD student Maya Almaraz at Brown University, is a Hispanic woman who is the first in her family to go to college.

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

This project has trained two female graduate students and several undergraduate research assistants. Aspects of the iron reduction experiments and field deployment of sensors were taught to a high-school student (Serena Mon) as part of the Univ. Georgia Young Scholars program, which lasted six weeks in the summer of 2015.

Focal Area 3: Watershed scale hot spots and hot moments

Jerolmack has advised 2 PhD students and 2 postdocs on work related to LCZO in the past year. Willenbring has advised 2 postdocs, 1 PhD student and 1 undergraduate. 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.

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

The project has contributed significantly to the development of modelling skills and expertise of personnel involved (Elisa Arnone, Satish Bastola, and Yannis Dialynas). It has familiarized the personnel involved in the project with new and improved datasets and their utility in studying critical zone processes.

Graduate student Maoya Bassiouni worked on the LCZO in a temporary summer position. She learned about cloud forest hydrology issues and developed her programming skills. She will be presenting the work at the 2015 AGU conference. She will be entering a PhD program at Oregon State University.

The project contributed to the training of PI, technician, graduate and undergraduate students in the use of instruments for measuring, sampling, and analyzing chemical and physical properties of aerosol, cloud, and rain water; in the use of new software and programming languages; and in the processing of the data generated with those instruments and/or with those analytical techniques. Puerto Rican participants (students, technician, PI) are all minority and most of the outreach carried out in Focal Area 4 is to Puerto Rican university and precollege students, and to the general public in Puerto Rico.

Because the project includes collaborators at the national and international levels, it provides opportunities for graduate and undergraduate students to interact with collaborators/researchers from different institutions, background training, and field of expertise. These interactions create foundations for better scientific critical analyses and communication that are the basis for research, education, and networking for all people involved.

What is the impact on physical resources that form infrastructure?

Soil sensor networks and stream sensor networks have been established.

Jerolmack's laboratory (Focal area 3) 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).

This project allowed the purchase of a muffle furnace, filters, and other materials at the University of Puerto Rico. These resources are dedicated to measuring dust concentrations on aerosol filter samples. The project also supported continued operation of instrumentation at sampling stations (CSJ and PDE).

Results from this project have strengthened our possibilities of funding for the proposed Cape San Juan Atmospheric Observatory new facilities as well as for the Pico del Este facilities. The project has the support of the Puerto Rico Conservation Trust and of UPRRP. Successful completion of the Observatory would provide a significant enhancement of infrastructure at a major minority serving institution.

What is the impact on institutional resources that form infrastructure?

Introduction to Critical Zone Science is an Upper division Natural Resources & the Environment (NREN course 795) course taught spring semester 2015. The course was taught by Adam Wymore and co-taught by Rich Brereton (CZ PhD student). 8 students participated in the course this year. The curriculum was designed collaboratively with other CZ scientists through a project called, INTEGRATE at Carleton College. INTEGRATE is a NSF funded project to support the building of Geoscience related university courses and curriculum. Our group was charged with building a course focused on Critical Zone Science and the Critical Zone Observatories. Curriculum will be live to the public ~June 2016.

CZO activity has provided cross-training opportunities to strengthen skill sets among USGS and USFS staff engaged

in supporting activities (stream gaging, landslide mapping, water quality sampling, etc.) on site.

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. We are inputting soil samples into SESAR, System for Earth Sample Registration, generating IGSN numbers for soil samples and printing barcodes as well as QR codes for soil samples. By labeling samples with QR codes anyone can scan a label with a smart phone and bring up information about the sample over the web from SESAR. This has both made the samples discoverable over the web and made storage of samples easier to maintain. We are developing a new data management platform based on CUAHSI ODM2, this is being developed with an open source software stack and is freely available on github at https://github.com/miguelcleon/odm2djangoadmin

What is the impact on technology transfer?

Smart rocks are being developed, and our group is learning state of the art techniques for fabricating micro-electronics.

The set of Python scripts developed for the Cloud Cam project image processing will be internally reviewed by the USGS and then they will be made available to the public. These will be of interest to the cloud forest research community.

Aerosol data generated through this project, particularly data related to the aerosol optical properties (i.e., scattering, absorption, Angstrom exponent) in the presence and absence of LRTAD, is planned to be used in the development of a product that could be useful for the media (e.g., TV, newspaper) and for public health authorities concerned with levels of air pollutants.

The LCZO has developed the R package loadflex for stream solute flux estimation (Appling et al. 2015). This package implements several of the most common methods for modeling and predicting watershed solute fluxes and concentrations, including interpolation and regression models, period-weighted averaging, and the composite method. loadflex integrates with the USGS's rloadest package and with native R regression models. It offers a uniform interface for a variety of model types, with which you can quickly fit models, generate predictions, and aggregate to monthly or annual values. This package is open source and is freely available on github.com.

What is the impact on society beyond science and technology?

Understanding sediment fluxes over time is a critical component of identifying and ultimately mitigating anthropogenic impacts on landscapes. In Puerto Rico, the impacts of fine sediment are particularly important for coral reef community health. Understanding the biologic and geologic controls on - and mechanisms for - landscape stability for slope failure will result in a societal and infrastructure benefit.

Aerosol data generated through this project will help inform the general public about the influence of African dust on Puerto Rico. This is very important since Puerto Rico in the summer months received huge amounts of African dust that produce a significant impact on air quality (degradation of visibility and health problems particularly in elderly, children, and people with respiratory conditions).

Changes/Problems

Changes in approach and reason for change

There were two unanticipated collaborations that were stimulated by the LCZO:

- A PhenoCam was established at the El Verde site through LCZO collaboration. The latest image can be viewed at: http://phenocam.sr.unh.edu/data/latest/elverde.jpg
- Data Manager Miguel Leon will serve as an ODM2 collaborating consultant for Tana Wood's USFS/DOE warming

experiment: “Tropical Responses to Altered Climate Experiment (TRACE)”. TRACE is funded by U.S. Department of Energy, Office of Science, Office of Biological and Environmental Research, Terrestrial Ecosystem Sciences Program, Award Number DE-SC-0011806. As part of this collaboration, a new data management web application based on CUAHSI’s ODM2 (EAR-1224638) data model is under development. This application will be jointly developed, tested and implemented by the LCZO and TRACE.

H1.1

After extensive discussions with focal area 1 participants and the executive committee, we have decided that instead of drilling an additional well (which has been difficult to site), funds will be re-allocated to additional imaging of the subsurface by our team member Xavi Comas, of Florida Atlantic University. The goals of the research are identical, but imaging rather than drilling now appears to be the most effective approach to meet our goal of characterizing the deep critical zone.

The conclusions derived from the geophysical work so far have been far-reaching. We are discovering and mapping the frequency and nature of fractures within the Icacos watershed and relating these fractures to the weathering of the quartz diorite. One paper has been just submitted on this topic and two more are currently in preparation.

The goal for additional geophysics measurements in year 3 and beyond is to expand upon geophysical methods currently used to now include: 1) ground penetrating radar (GPR); 2) terrain conductivity; 3) electrical resistivity imaging; 4) induced polarization; 5) shallow seismic; and 6) magnetic measurements. These six near-surface geophysical methods represent a wide variety of scales of measurement and resolutions that, when combined with geological surveys, will provide unparalleled insights into the deep critical zone. The expansion would also bring in another faculty member (Ntarlagiannis) and undergraduates from both Rutgers and a graduate student from FAU. This change in emphasis can be made with no significant impact on other core activities.

H2

Advanced analytical characterization of mineral and organic phases in the untreated and extracted soil samples has been delayed due to lack of success in proposal submission for beamline time at CLS and for instrument time at EMSL. New/revised proposals are in preparation for submission.

H4.3

We have not started yet with the determination of the nutrient inputs (N, P, C) from African dust because we have not completed the chemical analyses of dust samples. We moved to new enhanced lab facilities last summer but there has been a delay in bringing all our instrumentation back online.

Actual or Anticipated problems or delays and actions or plans to resolve them
Nothing to report.

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.