Luquillo Critical Zone Observatory Activities and Accomplishments

2012 Annual Report

This report is focused on accomplishments between July 2011 and July 2012.

Overview and sampling strategy

The overarching goal of the Luquillo Critical Zone Observatory (LCZO) is to develop the infrastructure platform and information base that allows geoscientists to address the overarching question of *"how critical zone processes differ in landscapes with contrasting lithology but similar climatic and environmental histories"*. As of July 2012 we have met, or exceeded, the time line of activities and goals that was detailed in the original proposal (http://www.sas.upenn.edu/lczo/proposals.html) and in the supplementary financial plan we submitted in early 2012. Specific accomplishments and activities in the past year are detailed below.

Personnel: Over 65 individuals have directly contributed at least 160 hrs since the start of the Observatory (i.e. between 10/2009 and 7/2012). Specifics of the participation between *July 2011 and July 2012* are described below and include 12 new students (6 undergraduates, 5 Masters, and 1 PhD) and five letters of support for externally funded projects.

Undergraduates in 7/2011-7.2012: 6 new undergraduates have worked 160 hrs or more
Overall over 16 UPenn undergrads have directly participated in LCZO field, lab, or course work. Additional undergraduates from the University of Puerto Rico, Penn State, UC Berkeley, and the U. New Hampshire have also participated in the project.

Graduate Students in 7/2011-7/2012: 14

Fully supported by the LCZO: 7 PhD's; partly supported by LCZO: 7 (4 PhD, 4 Masters)

Post Doctorial or Post-Masters Researchers in 7/2011-7.2012: 4

Professional Staff in 7/2011-7/2012: 6 FTE's

Directly supported by LCZO; 1 FTE Information manager, 1 FTE Field Technician

Supported by USFS, USGS, or UPenn: 4 FTE's

Co-PI's (individuals who receive direct support from the LCZO for their research): 12

UPenn: 5, Penn State: 1, U. New Hampshire: 1, U.C. Berkley: 1; USGS: 4

Others Collaborators who receive direct support for data collection or field expenses: 15

Brown University =2, Boston U. =2, U. Puerto Rico = 2; U. Georgia =1; British Geology Survey = 1; USFS = 1, U.C. Berkeley = 2, Penn State = 1, UPR-LTER = 1, U. Bristol = 2

Information Management

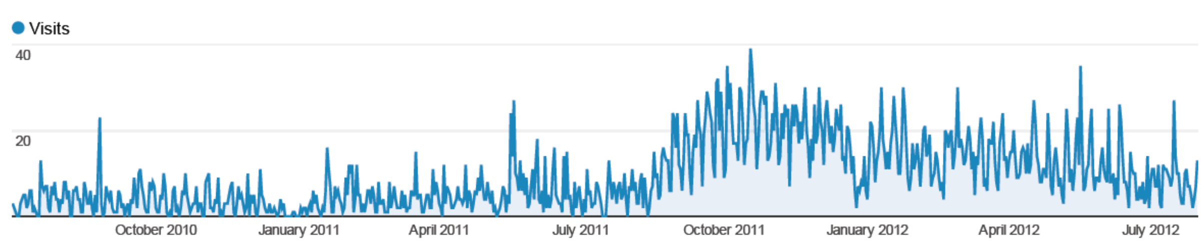
A searchable LCZO web page and data management system was established in April 2010 (Figure 1). A unique aspect of the system is that it allows individual investigators to update their data files and documentation (http://www.sas.upenn.edu/lczo/index.html). As of July 15, 2012, 38 project descriptions that contain a total of 63 data sets were online. Between July 15, 2011 and July 15, 2012, the LCZO web page had 2,927 independent visits by 1,420 unique visitors who came from 79 different countries. On average, 2.49 pages were viewed per visit. The large increase in visits starting in October 2011 corresponds to the addition of published references on the page that are linked to data sets.

In the past year, (July 2011-July 2012) the LCZO Information Manager, Miguel Leon, expanded a web-based system for generating standardized meta-data that allows the aggregation of all LCZO related data by the Spatial Information Systems Laboratory at the San Diego Supercomputer Center. By July 15th, 2012, 12 LCZO data sets that contain 76 variables and 3,671,653 observations have been posted to the CZO Central Web Service Catalog (http://water.sdsc.edu/czocentral/)

Geochemical data from Luquillo soil surveys has been posted on the CZEN.org Geochemical and Geophysical Data site (http://www.czo.psu.edu/data_agreement.html). Additional data from the 2010 soil survey of the entire Luquillo Mountains, and past surveys from the LCZO riparian sites will also be posted at this site in the next 2 years.

The LCZO Information manager also participated in conference calls with other CZO information managers. He also attended the GeoChem workshop in Montreal at the 2012 Goldschmidt conference to learn how to integrating more of our geochemical data into the GeoChem database. This will make the data readily available to a wide range of researchers. He also attended a Sensor network software training workshop in New Mexico that was sponsored by the LTER network office. This workshop introduced a number of techniques for improved QA/QC for sensor derived data which are now being implemented in the LCZO. These activities furthered the CZO goals by facilitating the application and improvement of geochemical, meteorological and hydrologic information systems and related tools and techniques.

Figure 1. Time series of visits to the Luquillo CZO web site.



Ongoing accomplishments and activities that were outlined in the original proposal:

LCZO Surface Soil Studies and Soil Network Infrastructure

In accordance with Hypothesis 2 of the proposal, a soil sampling network was established across the LCZO. The basic sampling of the network was completed in January 2011 and additional sites were added and/or re-sampled in early 2012 to obtain additional measurements of bulk density and soil properties and microbial community composition to a depth of 1m. To date over 250 quantative soil pits and 1000 soil samples have been collected processed for C, N, cations, bulk density and grain size. The first paper using this data was submitted in the Spring of 2012 and was focused on the distribution of soil P (Porder & Mage 2012). Data analysis has been completed for other papers and writing is underway. A series of papers using this network will be submitted to a special edition in early 2013.

In accordance with Hypothesis 4 of the proposal, 24 Prenart Super Quartz tension lysimeters and accompanying soil oxygen probes were installed at various locations in the LCZO in 2011 and 2012. After an initial calibration period, surface soil redox conditions have been manipulated and the response of greenhouse fluxes and soil solution chemistry quantified. This project is part of a PhD thesis by Stephen Hall of UC Berkeley that is being supervised by Professor Silver. The samples are being analyzed at the Water Quality Laboratory of the University of New Hampshire under the supervision of Professor W. McDowell, who is an external advisor to the Mr. Hall.

Cosmogenic Dating

In accordance with Hypothesis 1 and 6, Dr Willenbring and students have collected and processed LCZO rock, soil, and suspended sediment samples for cosmogenic dating at the Penn-Cosmogenic Isotope Lab. This lab, which is partly supported by LCZO funds via funds for post-doctoral researchers, PhD students, and undergraduates, had an excellent first year in operation including low initial chemical blank measurements with blank ratios of the comsogenic isotope to the native isotope that average $4x10^{-15}$ - the same as existing cosmogenic nuclide labs in the country and similar to the ratio of the carrier itself. During the year the lab processed approximately 200 LCZO samples that have been sent to the NSF-sponsored AMS facility at Purdue and the DFG-sponsored AMS facility in Cologne, Germany.

LCZO Weathering Studies and Deep Observation Wells

In accordance with Hypothesis 1 of the proposal, and with additional financial support of the USGS WEBB program, three deep observation wells were drilled and sampled in the LCZO during July-August 2010. In the summer of 2012 an additional well was drilled near the contact of the quartz diorite and the volcaniclastic rocks. A Penn State PhD candidate, Joe Orlando has been supervising the drilling and a new collaborator, Dr. Javier Comas conducted shallow geophysics at the new site in May 2012.

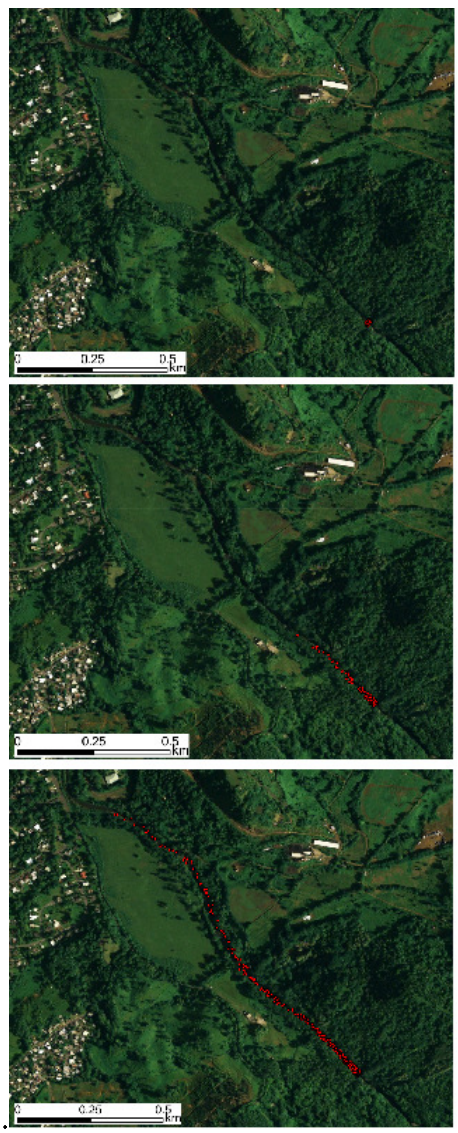
Water from the wells have been sampled monthly by LCZO technicians and provided to LCZO collaborators at UCB, Cornell, and Boston University. A publication on the initial drilling was also submitted (Buss et al 2012).

Fluvial Studies

In accordance with Hypothesis 6 of the original proposal we have tracked the transport of almost one thousand cobbles over distances up to 1.5 km, in four streams draining the Luquillo Mountains, using Radio Frequency IDentifier (RFID) tags embedded in natural river rocks (Fig. 2). The Mameyes River site, from a watershed draining primarily volcaniclastic rocks, is a lower-gradient (slope ~0.01) channel in the alluvial plain with well-developed floodplain and a primarily cobble bed. Two tributaries to the Mameyes have much steeper slopes (up to S ~ 0.1), are dominated by interlocking boulders that form steps in the channels, and are cutting into bedrock valleys – allowing us to compare transport in different stream morphologies. The site on the Blanco River is comparable to the Mameyes site but drains primarily quartz diorite rocks. The recovery rates for tracer particles in three of the four streams are greater than 90%, with the lowest recovery rate still over 80% - sufficient to generate good statistics on particle dispersion. Detailed grain size distribution measurements have been conducted, at 200-meter spacing, on the Mameyes River to assess potential sorting of tracer particles. In addition, detailed channel morphology surveys at all study sites were completed.

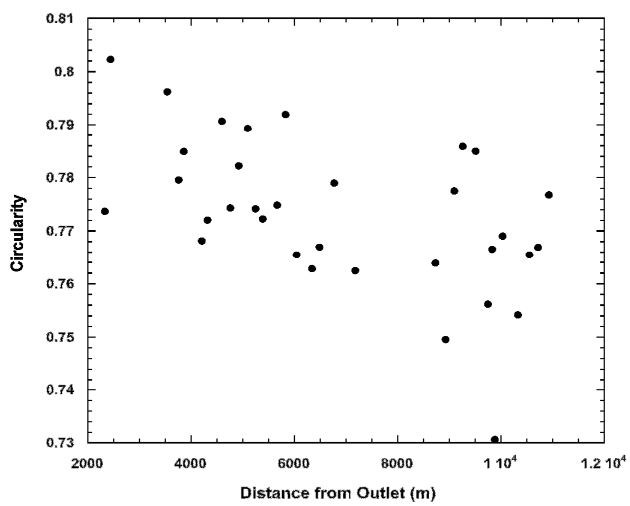
Treating particle motion as a series of 'flights' and 'rests', we can assess the statistical behavior of bed load tracers during individual floods and the cumulative effect of many floods – and use this to infer the dominant physical processes driving bed load motion as the result of floods. At the single flood scale, tracer particles flight lengths scale linearly with excess shear velocity. This provides the first field confirmation of laboratory and theoretical results from Lajeunesse et al. [2010], indicating that fluid momentum determines the velocity of particles in motion. Tracer particles show poor size sorting at the individual flood scale, but at longer timescales smaller particles move significantly farther downstream, so results may be used to determine the rate of longitudinal grain size sorting resulting from transport. Data comparing flood magnitude to the fraction of tracer particles that moved for a given flood allow direct determination of the threshold fluid stress for initiation of motion – a key quantity for predicting sediment transport and erosion rates. Results show that at long (many flood) timescales, bed load tracer particles disperse super diffusively when accounting for both flood magnitude and duration. These results are in contrast with the standing paradigm of bed load tracers behaving subdiffusively at long timescales, but are in good agreement with our recent laboratory studies. Bed load tracer particles appear to behave similarly to tracers in other geophysical flows, where particle 'rest' times are dominated by heavy-tailed distributions. We infer that the rest time distribution is driven by the timescale of burial and excavation of particles, by comparison to our previous experiments. Finally, our results – with some assumptions – can be used to provide the first estimate of bed load flux values from flood to annual timescales. These data are not only useful for understanding how floods connect to long-term erosion rates, but also provide valuable context for ongoing LCZO studies aiming to understand chemical and physical weathering from short to long time scales.

Figure 2. Position of RFID-tagged cobbles in the Mameyes River showing dispersion as a result transport during floods. (Top) Initial placement in Summer 2010; (Middle) Summer 2011, and; (Bottom) Summer 2012. Flow is from bottom right to top left, total distance traveled about 1.3 km.



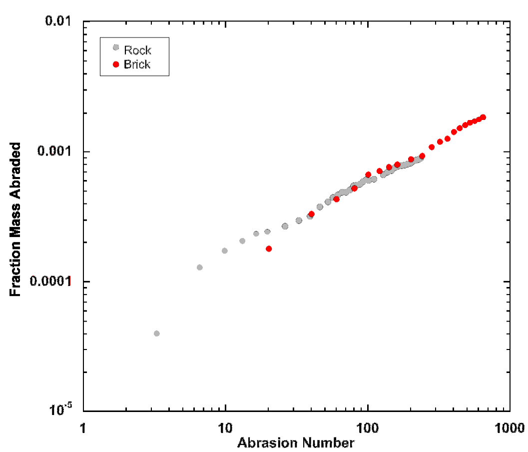
Research has also been undertaken to determine the relative importance of abrasion versus selective transport in causing downstream fining of river sediments, and to examine the production of daughter products in order to understand controls on grain size and erosion in the Luquillo Mountains. An important control on abrasion rates is lithology, so studies are carried out in the Mameyes and Blanco watersheds, dominated by volcaniclastic and quartz diorite rocks, respectively. We characterize grain shape with standardized shape parameters, as well as Fourier analysis, which allows us to track changes in grain roughness at a variety of length scales. Shape data has been collected at 71 locations within the Rio Mameyes by images of the two dimensional projection of 40 randomly selected grains at each site. We have also collected fine material on the bed at each of these sites, as well as at 22 sites in the Rio Blanco watershed. Finally, to determine changes in the strength properties of the grains, we took 20 Schmidt Hammer (SH) measurements at 61 locations within the Mamayes watershed. In further examine the mechanism behind abrasion, laboratory experiments are being conducted at the University of Pennsylvania to tease apart the controls of lithology, collision energy, and grain shape on the rates and styles of abrasion. We have built a double-pendulum apparatus that allows us to simulate abrasion of grains due to direct impact. We measure the impact energy of collisions using a high-speed camera and monitor abrasion rate by measuring the mass loss. We also characterize the size and shape of the daughter products of abrasion.

Figure 3. Average circularity values computed from each survey site on the Mameyes River, plotted as distance from the mouth of the river where it empties into the ocean (at 0 m). Rocks with lower circularity values have a perimeter that is larger than that expected for a circle of the same area, indicating that they are rougher and/or more elongated than a circle. River rocks become more circular with distance downstream, indicative of abrasion.



Preliminary results of our field shape analysis study from 41 locations within the Rio Mamayes watershed shows a distinct pattern of rounding of grains (Figure 3). Schmidt Hammer strength test results for the main stem of the Rio Mamayes do not show a systematic behavior however within the Bisley tributary the rocks display a strengthening as they move downstream suggesting that weaker, more weathered dominated rocks are located closer to their source. Hardness values saturate at a maximum value that is nearly constant along the mainstem of the Mameyes, suggesting that particles maintain weathering rinds close to their source, but that transport batters them away such that "only the strong survive" in downstream sections of channel. In laboratory experiments, mass loss of volcaniclastic rocks and bricks subject to successive collisions in the Newton's cradle apparatus has been measured (Figure 4). This result suggests that the underlying mechanics of abrasion for both materials are the same and that the relationship does not display the linear trend expected from pure energetics. Image shape analysis has and is been conducted on the daughter products from the rock abrasion tests for both materials. Surprisingly, the particle size distributions (PSDs) for volcaniclastic and brick fragments show the same functional form, a power-law relation that is expected for brittle materials undergoing fragmentation. This suggests that brittle fracture theory describes the abrasion of river sediments, and may allow us to search for the signature of abrasion in size (and shape) distributions of sand and silt particles in natural streams. These results have broader implications to LCZO activities, as they contribute to our understanding of the relative importance of physical and chemical weathering in landscape erosion.

Figure 4. Mass loss of laboratory rocks through successive collisions. The abrasion number on the *x* axis represents the cumulative energy from collisions normalized by material properties, while the *y* axis shows the total mass lost normalized by initial mass of the rock. The curves for Volcaniclastic rocks and bricks fall on top of each other when normalized for material properties, indicating that the mechanics of abrasion are the same for both materials.



In accordance with hypothesis 3 and 5, a coordinated storm sampling effort was conducted in May 2012. The effort was coordinated by UPenn PhD student Marci Occhi and involved 10 participants, three stream locations, and 3 rain sample collectors and followed a design that was similar to the May 2011 sampling effort. Samples are now being processed at the USGS, UNH, Brown University and UPenn for Be10, Hg, basic isotopes, cations and anions (http://www.sas.upenn.edu/lczo/index.html). However, an unusually dry May/June 2012 has required them to re-sample later in the fall of 2012. Current plans are for an additional coordinated sampling expedition in Aug/September 2012. In the meantime, legacy suspended sediment samples that were collected by the USFS & LTER between 1999-2012 are being analyzed at the LCZO laboratories at UPenn.

A special sampling campaign was launched in the Spring of 2012 called the "The Year of Carbon" and is being managed by Co-PI Bill McDowell of the University of New Hampshire. This represents a concerted effort by the CZO to measure all major fluxes of carbon in our two core CZO watersheds, the Rio Mameyes (volcaniclastic) and Rio Icacos (quartz diorite). As part of this sampling campaign, we are measuring dissolved inorganic carbon (DIC; acidification and sparging with NDIR detection), dissolved organic carbon (DOC; high temperature combustion), particulate organic carbon (POC; elemental analyzer), dissolved CO_2 and CH_4 (gas chromatography), and DOC quality (SUVA and fluorescence spectra or EEMS). In collaboration with Dr. Peter Hernes (UC Davis) we are also measuring dissolved and particulate lignin. Samples are taken weekly, and some high flow events have and will continue to be sampled.

In addition, weekly sampling of water from climate and stream nodes for cations and different isotopic studies continued and was expanded to include additional sampling for Research Hydrologist M. Scholl of the USGS, Graduate student Simona Balan of the University of California at Berkeley, Professor L. Derry of Cornell University, and University of Boston graduate student Ken Takagi.

Coastal and Sea Level Rise Studies

In accordance with the objectives of Hypothesis 7, sampling transects and study sites in coastal mangroves of the LCZO watersheds were established in 2010 and 2011. In January 2012 the group of UPenn researchers returned to the transects to collect litter and root decomposition bags that had been placed to quantify digenetic changes in plant tissue during burial in the critical zone. They also established sampling transects and cored an additional mangrove forest. In May 2012 they returned to the sites to collect additional cores and obtain geophysical information on the site to obtain the information needed to calculate net carbon accumulation at the site since the late Holocene. From April 1-April 27, 2012, Nicole Khan the PhD student working on the project, worked at the National Ocean Science Accelerator Mass Spectrometer Facility at Woods Hole Oceanographic Institute making high precision C14 dates of samples from the various cores. Overall 76 samples were analyzed, the oldest of which had a date of 7631 +/- 73 cal yrs BP. In addition she is preparing an additional 300 samples this summer that will be sent so the British Geological Survey for isotopic analysis.

Atmospheric and climate studies

Coordinated weekly sampling and continuous monitoring with the LTER and UPR African Dust program continues. The LCZO weather stations also continue to be upgraded and improved. The 2 Bisley walk-up climate towers were inspected for safety issues in conjunction with the USFS in the summer of 2012 and were approved after minor changes in their guy wires. The rain gage designed for windy conditions that was installed in the upper Bisley tower in April 2011 and has been operating successfully. Soil moisture probes that were also installed in the Bisley watersheds in 2011 and have been calibrated during the course of the year. In cooperation with USFS-IITF, the LCZO is purchasing a $32k celiometer that will make continuous measurements of the cloud base of the Luquillo Mountains. This is expected to be operational by Fall of 2012.

Improvements to physical infrastructure:

In addition to the infrastructure improvements discussed above, the LCZO has been directly involved in providing the following infrastructure improvements:

Meteorological Stations: Belfort Instruments Model 6500 Visibility Sensor was purchased and installed in the East Peak climate node in June 2012. This sensor is being used in cooperative studies with the LCZO and the NSF sponsored "Impact of African Dust on Clouds and Precipitation in a Caribbean Tropical Montane Cloud Forest". An aerosol particle size analyzer is also being purchased for the site and is expected to be operational in 2012. A SBS-500 tipping bucket rain gauge was purchased and installed in Bisley upper tower for improved above canopy rainfall measurement. Rain gauge is designed to reduce precipitation loss due to wind and replaced a less sensitive rain gage that had been managed by the USGS.

Stream gage upgrades: A automated water conductivity probe (CS547A-L15-NW), a water conduct Reflectometer (CS616-l40), and new pressure transducer (CS450-L15-A-29-NC) were installed in the Bisley watersheds in 2011 and are similar to those installed on the Icacos stream gage in 2010. During the past year these sensors and soil moisture probes have been operation and undergoing calibration. Specifically, during the summer of 2012 a University of Puerto Rico undergraduate has been manually collecting data each week to calibrate the sensors. Handheld dissolved oxygen and conductivity sensors were also purchased for the Sabana lab to be used to calibrate the stream sensors and for a University of Turabo PhD student's project in the LCZO.

Facilities: Landslides on the paved road to one of the long-term stream gages, the Icacos watershed, has permanently limited access to the site. Fortunately with the cooperation of LCZO technicians and UGSG and USFS personnel we have been able to continue weekly sampling using bicycles and a 1hr hike. The LCZO also purchased an air conditioner for one of the newly renovated Sabana labs. This allows the LCZO researcher to use the lab during the summer heat.

Education and outreach

In 2012 we initiated collaboration with UPenn School of Arts and Sciences Office of Science Outreach to develop and test high school and undergraduate level homework assignments that use LCZO environmental data. The assignments are being developed from proto-types we developed last year and will be tested in high schools in the Fall of 2012 and will be online in 2013. In these assignments, the students use actual LCZO climatic and hydrologic data in assignments where they learn skills in regression and graphical analysis. This effort is an extension of an earlier effort that developed assignments for UPenn undergraduate courses.

Collaborative Studies and Synergetic Activities

In the past year the LCZO has written letters of support for at least 5 proposals seeking funds to work at the LCZO. In addition, the following activities were not specified in the original grant nor have they been completely funded by the LCZO. Instead they have developed from synergetic interactions with LCZO collaborators and PI's.

Coordinated Environmental Monitoring: Specific examples of synergistic studies are similar to those in 2011 and include:

Weekly rain and stream water sampling with the Luquillo LTER program continue collecting weekly samples from these sites using the same protocol and procedures as the LTER.

Environmental Monitoring: The Luquillo LTER project has been actively involved in monitoring climate and forest dynamics in the El Verde section of the Luquillo Mountains. The LCZO complements these efforts with soil and biogeochemical sampling.

USGS Mercury Contamination Studies: As a follow up to a recently published paper that documented high mercury levels in Luquillo rain and stream water (Shanley et al 2008), Cindy Nawal a UPenn Masters student surveyed historic mine sites for Mercury contamination using a hand-help XRF. This sampling indicated that the historic placer mines are not zones of elevated Mercury. In the summer of 2012 additional stream water samples were and will be taken during storm flow and analyzed at the University of Connecticut with LCZO funds.

Nutrient cycling studies: Nutrient cycling within Luquillo forests has been studied for several decades. Nevertheless, no study has explicitly focused on the role of bedrock lithology nor has there been an explicit connection been made between weathering studies and nutrient availability. The LCZO is helping to close this information gap by providing logistical support to several new studies, including:

Brown University Phosphorous cycling studies: Assistant Professor S. Porder and Post Doctoral Research Associate S. Goldsmith have separate funding from the A.J. Mellon foundation and NSF to study P cycling on granites in tropical environments. In 2011-2012 the Brown team returned to collect additional samples and install root cores across the LCZO to monitor nutrient uptake.

UC Berkeley Sulfur cycling studies: The LCZO is collecting weekly and monthly samples for UC Berkeley graduate student Simona Balan and her advisor Professor Ron Amundson for separately funded studies on sulfur cycling. The LCZO is one of many sites they are comparing in this study.

Boston University Silica cycling studies: The LCZO is assisting University of Boston graduate student Ken Takagi and his advisor Professor Andrew Kurtz studies on silica cycling under watersheds with contrasting lithology. They had done earlier studies in Luquillo quartz diorites and are now conducting comparable studies on the volcaniclastics. They spent 2 weeks in July 2012 collecting water samples from LCZO sites and will be given water from the storm sampling planned for Aug/September 2012.

African Dust Monitoring: The LCZO is conducting coordinated monitoring and atmospheric sampling studies with a NSF supported project "Impact of African Dust on Clouds and Precipitation in a Caribbean Tropical Montane Cloud Forest". This study is being managed by Associate Professor Dr. Olga L. Mayol-Bracero of the Institute for Tropical Ecosystem Studies (ITES) of the University of Puerto Rico. Since the two projects work at the same station at the top of the LM, the LCZO has purchased 2 instruments in 2012 that will used by both group (see above).

Caribbean Sea-Level Rise Studies: Understanding local variations in sea-level rise is critical to understanding the fate of sediment and the stream channel physiography in the volcaniclastic and granodiorite landscapes of the LCZO. In addition, it is critical to understanding regional tectonics and global climate change. Fortunately, the LCZO sea-level rise studies headed by Co-PI Horton are being done in collaboration with studies in Belize, Florida, and Eastern North America. These studies are separately funded by the Smithsonian Institution, NSF and the USGS.

External Fellowships for 2011-12: The following LCZO scientists and graduate students have received the following fellowships to conduct LCZO related research in the past year:

A student of LCZO Co-PI Dr. Heather Buss at Bristol University UK received a fellowship to study Ca isotope in Luquillo.

UPenn graduate student Nicole Khan received a NOSAMS Graduate student internship from the Woods Hole Oceanographic Institution and spent most of April 2012 processing samples at the laboratory. The internship allowed her to make radiocarbon measurements on samples she has taken in the LCZO. Funds covered all analytical costs for a modest number of analyses, round-trip travel, accommodation and subsistence at Woods Hole. The LCZO is supporting her field work and field sampling.

Ken Kakagi, a PhD graduate student at Boston University, received a CUAHSI travel grant to collect samples at the LCZO for a comparative study with the Hubbard Brook LTER site. The LCZO provided additional travel support for his Professor, A. Kurtz to work in the field with him.

Peer-Reviewed Journal Publications: July 2011 to July 2012

Brantley S.L., Buss H., Lebedeva M., Fletcher R.C., and Ma L. (2011) Investigating the complex interface where bedrock transforms to regolith. *Applied Geochemistry*, 26, S12-S15.

Blaes E., Chabaux F., Stille P., di Charia Roupert R., Dosseto A., Ma L., Buss H.L., Pelt E., and Brantley SL. Regolith formation rate from U-series nuclides: Implications from the study of a spheroidal weathering profile in the Rio Icacos watershed (Puerto Rico). *Submitted to Geochim. Cosmochim. Acta. In Revision.*

Buss H.L., Brantley S.L., Scatena F.N., Bazilievskaya E.A., Blum A., Schulz M., Jimenez R., White A.F., Probing the deep critical zone beneath the Luquillo Experimental Forest, Puerto Rico Earth Surface Processes and Landforms. In review

Buss H.L., Brantley S.L., Scatena F.N., Bazilievskaya E.A., Blum A., Schulz M., Jimenez R., and White A.F. Probing the deep critical zone beneath the Luquillo Experimental Forest, Puerto Rico. *Submitted to Earth Surface Processes and Landforms. In Revision.*

Buss H.L. and White A.F. Weathering Processes in the Rio Icacos Watershed. In: Stallard R.F. and Murphy S.F., eds., *Water Quality and Landscape Processes of Four Watersheds in Eastern Puerto Rico:* U.S. Geological Survey Professional Paper. In Press.

De Graff J.V., Sidle R.C., Ahmad R. Scatena F.N., 2011 Recognizing the importance of tropical forests in limiting rainfall-induced debris flows. Envionmental Earth Science. DOI 10.1007/s12665-012-1580-8

Dosseto A., Buss H.L., and Suresh P.O. (2011) The delicate balance between soil production and erosion, and its role on landscape evolution. Applied Geochemistry, 26, S24-S27.

Dosseto A., Buss H.L., and Suresh P.O. (2012) Rapid regolith formation over volcanic bedrock and implications for landscape evolution. Earth and Planetary Science Letters, 337-338, 47-55.

Holwerda F., Bruijnzeel L.A., Scatena F.N., Vugts H.F., Meesters A.G.C.A. 2012. Wet canopy evaporation from a Puerto Rican lower montane rain forest: the importance of realistically estimated aerodynamic conductance. Journal of Hydrology Vol. 414-415. Pages 1-15

Johnson K.D, Scatena F.N., Silver W.L. 2011 Atypical soil carbon distribution across a tropical steepland forest catena. Catena 87 (2011) 391–397 ISSN 0341-8162, DOI: 10.1016/j.catena.2011.07.008.

Lepore, C. Kamal, S. A., Shanahan, P. Bras, R. L., 2011 Rainfall-induced landslide susceptibility zonation of Puerto Rico. Environmental Earth Science, 2011. DOI 10.1007/s12665-011-0976-

Minyard M.L., Bruns M.A., Liermann L.J., Buss H.L., and Brantley S.L. (2012) Bacterial associations with weathering minerals at the regolith-bedrock interface, Luquillo Experimental Forest, Puerto Rico. *Geomicrobiology J.,* 29(9), In Press.

Minyard M.L., Bruns M.A., Martinez C.E., Liermann L.J., Buss H.L., and Brantley S.L. (2011) Halloysite nanotubes and bacteria at the saprolite–bedrock interface, Rio Icacos Watershed, Puerto Rico. *Soil Sci Soc Amer J.* 75, 348-356.

Navarre-Sitchler A., Cole D., Rother G., Jin L., Buss H.L., and Brantley S. Porosity and surface area evolution during weathering of igneous rocks*, Submitted to Geochim. Cosmochim. Acta.*

Phillips C., Scatena F.N., In review, Stream channel response to urbanization in the humid tropical region of Northeast Puerto Rico. Submitted to Earth Surface Processes and Landforms in June 2012

White A.F. and Buss H.L. Natural Weathering Rates of Silicate Minerals. *In* Drever, J.I., ed., Surface and Ground Water, Weathering and Soils, Treatise on Geochemistry 2nd Edition, Elsevier. *In Revision.*

Peer Reviewed Books and other onetime publications

Scatena, F.N., Gupta, A., 2012. Streams of the montane humid tropics. In: Shroder, J., Jr., Wohl, E. (Eds.), Treatise on Geomorphology. Academic Press, San Diego, CA, vol. 9

Dissertations and Master's Thesis

Jiménez RA (2011) A Geochemical Model of Redox Reactions in a Tropical Rain Forest Stream Riparian Zone: DOC Oxidation, Respiration and Denitrification. Masters Capstone hesis. University of Pennsylvania.

Fife, G. 2012. Understanding Tropospheric Ozone in Montane Tropical Rainforests; An analysis of Ozone Levels in the Luquillo Mountains of Puerto Rico. Masters of Environmental Studies Capstone paper Department of Earth and Environmental Science, University of Pennsylvania

Stachowiak L., 2012 An Investigation of the Influences of Bedrock Lithology and Vegetation on Low=order Stream Frequency in the Luquillo Mountains of Puerto Rico. Masters of Environmental Studies Capstone paper Department of Earth and Environmental Science, University of Pennsylvania

Poster and Oral presentations at Professional Societies:

In addition to the presentations detailed in the attached Field Guide to the LCZO; the following presentations have been given:

Balan S., Amundson R., uss H.L Sulfur Cycling in the Rainforest of Puerto Rico. B33G. Interdisciplinary Science in Critical Zone Observatories I Posters. AGU Fall Meeting Dec 2012

Buss H.L., Brantley S.L., Scatena F.N., Schulz M., White A.F, Blum A. and Jimenez R. Probing the deep critical zone beneath the Luquillo Experimental Forest, Puerto Rico. *Goldschmidt Conference, Montreal, 2012 (talk).*

Buss H.L., White A.F, Blum A., Schulz M.S., and Vivit D. Long-term versus short-term weathering fluxes in contrasting lithologies at the Luquillo Critical Zone Observatory, Puerto Rico. *Goldschmidt Conference, Prague, 2011 (poster).*

Dosseto A., Uranium-series isotopes in riverborne material from small catchments – tracers and chronometers of erosion processes. Session: EP51F. Innovative Isotope Methods for Characterization of Earth Surface Processes II. Oral Presentation AGU Fall Meeting Dec 2012

Hall S., Breaking The Enzymatic Latch: Do Anaerobic Conditions Constrain Decomposition In Humid Tropical Forest Soil? Session: B22E. Soil Organic Matter and Climate Change II. Oral Presentation Room 2004 Moscone West, 10:35 AM to 10:50 AM. AGU Fall Meeting Dec 2012

Interdisciplinary Science in Critical Zone Observatories Session AGU Fall Meeting Dec 2012 Oral and poster session had over 20 contributions, jointly sponsored by Shale Hills, S. Sierra, Luquillo

Jerolmack D.J., 2012. The signature of granularity in landscape dynamics, Gordon Research Conference – Frontiers in Granular Physics, July 2012.

Liermann L., Brantley S., Albert I., Buss H., Minyard M. Relating microbial community structure and geochemistry in the Bisley watershed, Puerto Rico. *Goldschmidt Conference, Montreal, 2012 (talk).*

Litwin K., D.J. Jerolmack, 2012 Investigating abrasion due to energetic binary collisions, Soil to Sea Geomorphology Symposium, May 2012.

Litwin K., M.D. Reitz and D.J. Jerolmack, Investigating selective transport and abrasion on an alluvial fan using quantitative grain size and shape analysis, American Geophysical Union Fall Meeting, December 2011.

Litwin K.,, D.J. Jerolmack, 2012 Downstream fining of river sediments due to binary grain collisions, University of Pennsylvania Department of Physics Pebble Workshop, May 2012

Occhi M.E. , J.K. Willenbring, F.N. Scatena, J. Kaste, J.B. Shanley, M. Scholl, W.D. McDowell, H. Lee – *How does a single precipitation event erode a landscape? Suspended sediment sampling in NE Puerto Rico* Amtrak Club - Soil to Sea Geomorphology Symposium, May 2012.

Occhi M.E., J.K. Willenbring, F.N. Scatena, J. Kaste, J.B. Shanley, M. Scholl W.D. McDowell, H. Lee. 2012. *Sediment and Carbon Fingerprinting with Meteoric 10Be, Fallout Radionuclides and Carbon Isotopes over a Hydrograph, El Yunque National Forest, Puerto Rico* AAG annual meeting –New York

Phillips C.B., Jerolmack D.J., Coarse sediment mobility over flood and annual timescales in a mountain river, Amtrack Club Soil to Sea Geomorphology Symposium, May 2012.

Phillips C.B., Jerolmack D.J., Particle mobility over flood and annual timescales in mountain streams of the Luquillo Critical Zone Observatory, American Geophysical Union Fall Meeting, December 2011.

Phillips C.B.; Particle mobility over flood and annual timescales in mountain streams of the Luquillo Critical Zone Observatory. Session: EP27. The Morphodynamics of Mountain Streams: Fluvial, Debris Flow, and Hillslope Processes. Oral Presentation AGU Fall Meeting Dec 2012

Scatena F.N. 2012 Geomorphology and Disturbance Ecology of the Luquillo Mountains, Wesleyan University Department of Earth and Environmental Science

Scatena F.N., 2012 The Luquillo CZO: linking lithology to Critical Zone Processes; CUAHSI 2012 Cyberseminar series.

Scatena F.N., Geomorphology and Soil of Tropical Montane Forests; Plenary speajer XLVI Colombia Congress of Biological Sciences, Medellin Colombia, October 12, 2012

Shanley J., Marvin-Dipasquale M., Willenbring J., Saraceno J., Lane O., Arendt W., McDowell W., Hall S., Pellerin B., Intensive mercury cycling in the Luquillo Experimental Forest, Puerto Rico Trace element biogeochemistry and ecosystem impact session Biogeomon Conference - http://www3.villanova.edu/conferences/biogeomon/program.html

Silver W., The Iron Redox Engine Drives Carbon, Nitrogen, and Phosphorus Cycling in Terrestrial Ecosystems. Session: B11F Coupled Biogeochemical Cycles in Terrestrial and Aquatic Ecosystems. AGU Fall Meeting Dec 2012

Stone M., 2012 "Plant-soil feedbacks and nutrient availability mediate microbial decomposition in a nutrient-poor tropical forest", ESA Oregon August 2012

Torres E., Size-resolved Chemical Composition of Cloud and Rain Water Collected during the Puerto Rico African Dust and Clouds Study (PRADACS). Campaign; Session: GC51G. Land Use Change III Posters. AGU Fall Meeting Dec 2012

Yang W. Controls on N2 production via iron reduction coupled to anaerobic ammonium oxidation. Session: B43E The Bioatmospheric N cycle: N Emissions, Transformations, Deposition, and Ecosystem Impacts I Posters. AGU Fall Meeting Dec 2012