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CZO: Luquillo Critical Zone Observatory

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Recipient Organization:

University of Pennsylvania

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Submitting Official (if other than PD\PI):

Alain F Plante
Principal Investigator

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12/31/2013

Signature of Submitting Official (signature shall be submitted in accordance with agency specific instructions)

Alain F Plante

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Accomplishments

* What are the major goals of the project?

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”.

This project will establish a monitoring network in two watersheds of the Luquillo Experimental Forest in Puerto Rico to evaluate the physical, chemical, hydrological and biological processes involved in weathering of bedrock and the evolution of the soil environment. This site will be part of the Critical Zone Observatories (CZO) Network that is being initiated at various locations in North America. The Luquillo CZO will use the natural laboratory of the Luquillo Mountains to quantify and contrast how critical zone processes in watersheds underlain by granodiorite and volcaniclastic bedrock are affected by climatic conditions and hydrologic, geochemical and biogeochemical cycles. A set of interrelated hypotheses,sampling sites, and a unified data management system will allow critical zone processes to be contrasted by bedrock, landscape position (ridge, hillslope, riparian), depth (surface to bedrock), forest type (Tabonuco, Colorado, Cloud) and location (upland to coastal).

Changing climate affects many processes, including the breakdown of rocks into soil, which is of fundamental importance to the development of the critical zone. Changes in climatic conditions may also affect water flow in rivers, as well as erosion of surficial materials. Sediment is already the nation's largest water quality pollutant and modern land uses are eroding soils and sculpting bedrock in unprecedented ways. The Luquillo Critical Zone Observatory will provide the infrastructure and baseline studies needed to evaluate short and long-term impacts of this erosion on soil and water resources. The Observatory will also support integrated, multi-institutional and multicultural exchanges among a diverse cadre of scientists, who will collaborate to determine the effects of climate change and other drivers on the structure and function of the critical zone in this tropical system.

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

Major Activities:

LCZO Surface Soil Studies and Soil Network Infrastructure

A soil sampling network was completed in January 2011 and additional sites were added or re-sampled in 2012. In 2013, over 1000 soil samples were processed, and analyzed for C, N, and nutrient cations. A Masters student project determined which state factors influenced soil texture, using the 20-50 cm depth increment, which is the main depth where clay accumulates in some of these soils. Extractable iron in the surface (0-20 cm) samples was determined by extractions using dithionate and oxalate. A subset of soil samples have been used in an intensive study on trends in microbial biomass, microbial community composition and enzyme activity as a function of soil depth as part of a PhD thesis. A combined field and laboratory experiment was completed on the controls on litter decomposition using 14-month litter transplantation field incubations.

Researchers from UC Berkeley intensively sampled soils across a ridge/slope/valley catena in the Bisley watershed to investigate controls on soil organic C pools and turnover, along with relationships to hypothesized biogeochemical drivers (reactive iron and aluminum minerals, reducing conditions, and root production), which were measured in soil chemical extractions. Roots were sampled by wet-sieve methods. Density fractionated soils were analyzed for 14C. In separate laboratory experiments they evaluated the impact of fluctuating oxygen regimes on the turnover of 13C-labeled lignin using measurements of 13CO2 production.

Cosmogenic Dating

Dr. Willenbring and postdoctoral researcher Brocard and a PhD student collected and processed LCZO rock, soil, and suspended sediment samples for cosmogenic analysis at the Penn-Cosmogenic Isotope Lab. These samples were collected to understand transient nature of the landscape and soil stability in Puerto Rico Critical Zone observatory over timescales of a single storm event and the timescale of a pulse of uplift that took place millions of years ago. The Willenbring lab group has also analyzed the isotopic composition and Mercury within water from rain and streams at various flows to understand flow paths, water residence times and source of water and Hg contamination. These efforts have revealed synchronized paths for the fine sediment, Hg and the storm-event water delivered to local streams.

LCZO Weathering Studies and Deep Observation Wells

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. In March and April 2013, we drilled another deep borehole along the watershed divide between the Río Icacos and Río Mameyes watersheds. Penn State teamed with DOSECC Exploration Services (http://www.dosecc-ex.com/) technicians. A well was installed for sampling deep groundwater (~38 meters below land surface). We also performed a pumping test on the boreholes that were drilled in 2012 to estimate the transmissivity, storativity, and hydraulic conductivity of a 6 meter thick, highly weathered zone, which is about 15 m below land surface. All existing wells were sampled for environmental tracers (CFCs, SF6, tritium) as possible to constrain the residence time of deep groundwater in the Río Icacos watershed.

Mg isotope ratios were analyzed in Bisley 1 pore waters, stream waters, rain and solids (regolith, rock). Thin sections from the boreholes drilled in Bisley 1 were also analyzed to identify weathering reactions in order of occurrence, as functions of depth and distance from fractures; and to trace mass transfer of mobile elements across weathering rinds formed along fractures.

Studies were also completed on the microbiology of the VC saprolite with depth.

Fluvial and Hydrologic Studies

We have now completed work on tracer pebble studies from the main stem Mameyes River, and its tributary Bisley 3. The movement of tagged cobbles was tracked over 3 years, and resurveyed more than 10 times, to assess the conditions under which particles move and to understand the mechanics of sediment transport during floods. Our work shows that pebble motion in the stream is superdiffusive - i.e., that the plume of pebbles disperses faster than one would expect from a simple (directed) random walk.

During 2013, we observed sorting of sediment tracer particles over many floods, which demonstrates how size determines particle mobility in a stream bed. Additionally, work on pebble abrasion resulting from sediment transport is nearing completion.

Laboratory experiments on binary collisions of pebbles are completed. We have shown that abrasion produces a universal grain size distribution of daughter products - in the sand and smaller range - that is consistent with predictions from brittle fracture theory. This occurs for any lithology of rock, and therefore is a universal feature of abrasion by bed load transport.

We have completed an analysis of long-term patterns in stream chemistry from 1983-2010. This analysis shows the importance of bedrock type, and associated differences in soil and riparian zone structure, in regulating nitrogen losses from Luquillo Mountain watersheds. Long-term patterns in precipitation chemistry at several stations were also studied, revealing substantial seasonal patterns in rain chemistry, as well as differences between the windward and leeward sides of the Luquillo Mountains.

Coastal and Sea Level Rise Studies

Sampling transects and study sites in coastal mangroves of the LCZO watersheds were established in 2010 and 2011. In 2012, the group of UPenn researchers returned 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, cored an additional mangrove forest, and returned to the sites in 2013 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. In the last project-year, additional core samples from Sabana Seca were collected to complete gaps in the Holocene relative sea-level and paleoenvironmental reconstruction undertaken along the northern coast of Puerto Rico.

Atmospheric and climate studies

Coordinated weekly sampling and continuous monitoring with the LTER and UPR African Dust program continued through 2013. The LCZO weather stations also continued to be upgraded and improved. In cooperation with USFS-IITF, the LCZO installed a ceilometer to make continuous measurements of the cloud base of the Luquillo Mountains.

Periodic sampling for stable isotopes of water at rainfall and stream sites continues with USGS and USFS personnel. During the dry season, in March 2013, cloud water deposition was quantified and correlated with visibility, ceilometer data, and horizontal precipitation on Pico del Este to determine whether cloud water deposition affected stream discharge. Cloud water deposition rates were estimated using the CASCC, and were quite high for this rain-free period.

Cloud base measurements from San Juan and Roosevelt Roads were compiled and analyzed from 1955 to the present. Both stations show that from the late 1980's through the mid '90's there was a large, significant increase in cloud base height, and cloud base remained at an average elevation of

about 800 m until the present compared to the period before 1985 when cloudbase averaged about 600 m. Implications of this shift in cloud base for forest vegetation are currently being examined.

Specific Objectives:
Significant Results:

LCZO Surface Soil Studies and Soil Network Infrastructure

Parent material was found to be the primary factor influencing clay content (with volcaniclastic soils having greater clay content than quartz diorite soils). Surprisingly, landscape position also influenced texture with ridges having more clay than slope or valley profiles, and valleys more sand than ridges or slopes. The ridge sites have been shown by Brocard's work to be older than slopes and valleys, hence there is a longer time to move clay into the B horizon.

Results of enzymatic activity and microbial community structure studies found exponential decreases in both enzymes and biomass, but these trends reverse when normalized by soil C or microbial biomass. Most importantly, a viable microbial and active microbial population was found down to 140 cm.

We found relatively rapid turnover of mineral-associated C, with the majority of C decomposing over timescales of 9-25 years. Turnover rates did not differ by topographic position and did not scale with drivers of soil C concentrations (reactive iron and aluminum and fine root biomass). On a per-sample basis, C turnover showed a negative association with an index of reducing conditions.

In the laboratory labeled substrate experiment, we found that oxygen fluctuations increased the relative contribution of lignin mineralization to CO2relative to a fluctuating oxygen regime, and overall rates of methoxyl lignin mineralization did not differ during the first four weeks of incubation.

Cosmogenic Dating

Over the course of a long tectonic uplift event such as the uplift of Puerto Rico, the Willenbring group determined that the rock type is inherently linked to the speed that the landscape responds. These ideas have spurred an NSF proposal (in review) to compare these landscapes with those in the new N. California Critical Zone Observatory.

LCZO Weathering Studies and Deep Observation Wells

Weathering extends 10's of meters below the level of the Bisley stream channel demonstrating that the stream is not the only outlet within the catchment. Borehole profiles are consistent with a model of corestone and regolith development proposed by Fletcher and Brantley 2010 (AJS). The borehole was drilled to 40 mbls, and the water table was encountered at 25 mbls. The results from drilling revealed a thick package of saprolite and corestones above bedrock. We see evidence of oxidation down to 38 mbls in the borehole drilled along the watershed divide. The deepest groundwater sampled has residence times <23 years based on the CFC content of the water. The tritium data indicate that the oldest groundwater occurs along ridges at the head of the drainage in contact metamorphic rocks.

Over the regolith profile, both total and heterotrophic bacterial cell counts generally increase from the bedrock to the surface. The dominant phyla detected were Proteobacteria, Acidobacteria, Planctomycetes, and Actinobacteria. Despite the fact that Acidobacteria dominated surficial communities while Proteobacteria dominated near bedrock, the near-surface and near-bedrock communities were not statistically different in structure but were statistically different from mid-depth communities. Several lines of evidence are consistent with biotic Fe oxidation occurring at the regolith-bedrock interface. In this and other deep weathering profiles, chemolithoautotrophic bacteria that use Fe for energy may play an important role in initiating disaggregation of bedrock.

Mg isotope profiles in VC regolith document ongoing release of Mg from bedrock (at depth) and secondary clays (throughout regolith) into the regolith pore waters with a significant isotopic excursion at the soil-saprolite transition. This transition coincides with textural, mineralogical and chemical changes. Mg isotopes in the Bisley stream sampled during a storm event reveal a bedrock signature early on with progressive mixing with shallow runoff and direct rainfall during the course of the storm.

Fluvial and Hydrologic Studies

The dispersion of tracers in a river was found to be governed by burial and excavation of pebbles due to erosion and deposition of the river bed. Importantly, the dispersion implies that very long time and space averaging must be applied to recover a meaningful bed load transport rate.

Results provide the first field confirmation of a size-selective sediment transport theory advanced by Paola and colleagues over the last two decades. Data from the very steep Bisley 3 channel and the much more gently sloping Mameyes collapse onto a single curve - suggesting that we are approaching a complete theoretical understanding of the rate of transport of pebbles in a natural stream.

A recent theoretical breakthrough occurred in collaboration with colleagues at the Budapest Technical University, showed that pebble abrasion may be described as a curvature-driven flow problem modeled by the diffusion equation; and this model predicts two phases of abrasion. Results provide the first field confirmation of two-phase abrasion. In the headwaters where streams have no storage, pure abrasion occurs. Lower down where the streams begin to develop floodplains and deposition is possible, we can see abrasion rate slow down (through pebble shape data) and size-selective transport become dominant. We provide the first realistic field estimates of mass loss due to abrasion, which also allows us to estimate the production of fine sand and silt that would result from this abrasion.

Work has also shown how the rate of mass loss from a parent particle undergoing abrasion may be understood from the kinetic energy of impact, shape and lithology. Results show a previously unquantified effect of shape, which is that abrasion rates are initially high for angular particles but become constant once corners reach a critical roundness value.

Differences in bedrock across the Luquillo Mountains appear to be an important determinant of stream nitrogen dynamics following major hurricanes. In volcaniclastic terrain, the response of stream chemistry to catastrophic hurricane disturbance is a sharp increase in nitrate concentrations. Following the hurricanes, nitrate concentrations return to baseline conditions after about 18 months. Similar or even larger increases in nitrate were observed in the quartz diorite terrain, but the recovery to baseline takes a decade or more. This fundamental difference in the resilience of the forest landscape to disturbance is driven by interactions between the disturbance regime and lithology. With shallow and patchy distribution of oxic and anoxic microsites in the volcaniclastic terrain, nitrogen is effectively conserved within the system or lost as nitrogenous gases. In contrast, in the quartz diorite terrain, only the riparian zone immediately adjacent to the stream has areas in which groundwater encounters highly reducing conditions, and nitrogen bleeds through the riparian zone into the stream channel (McDowell et al. 2013).

Atmospheric and climate studies

Stable isotopes indicated no direct contribution of cloud water to streamflow at this location. There were some difficulties: the water level data logger malfunctioned, so no data were obtained on diurnal variation in stream discharge. However, the stable isotope composition of cloud water was very distinctive, similar each night and correlated well with temperature, and the stream results looked promising for future work.

The implications of the upward shift in cloud base for forest vegetation are substantial. The shift is large, and a large percentage of the Luquillo Mountains lies in the elevation band affected by this shift. Expansion of the study to other Caribbean sites is underway.

Key outcomes or Other achievements:

A special session on Critical Zone Processes and the Geology of Puerto Rico at the Geological Society of America Southeastern Section meeting, San Juan, PR. The session was dedicated to the memory of Fred Scatena.

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

Over 49 individuals have directly contributed at least 160 hrs since the start of the project in 2009. In the last year of the project, at least 2 postdoctoral researchers, 15 graduate students and 16 undergraduates have been involved in the research efforts. Several peer reviewed publications and numerous posters have been published or presented in workshops and conferences by students. One PhD dissertation will be defended at Penn in December 2013 and two more are expected in the first quarter of 2014.

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

The results of the research stemming from LCZO have been disseminated through a wide range of channels and to a wide range of audiences. A large numbers of peer-reviewed scientific papers have been published (see separate listing). Oral and poster presentations are regional, national and international conferences, workshops and symposia have also been made (see separate listing). As part of a cross-CZO effort, we also generated three short summaries (“nuggets”) for the broader public audience (see attachments). Project results are also publicly available from the project website (www.criticalzone.org/luquillo), where project contributors and collaborators can post summaries of findings and provide links to specific products. The website also represents a storehouse of primary data streams (e.g., streamflow, meteorology, etc.) that are available for download and use by the scientific community and general public. Some of these datasets were used to generate curricular materials for College prep and Honors-level courses in mathematics/statistics and environmental/earth science at Radnor High School and Lower Merion High School, through a collaboration with Penn’s Office of Scientific Outreach (see attachments).

Supporting Files

	Filename	Description	Uploaded By	Uploaded On
(Download)	LCZO Summaries.pdf	Three short summaries of LCZO activities generated for distribution to the broader public.	Alain Plante	12/13/2013
(Download)	LCZO Curriculum Materials.pdf	Two high school curricular activities designed using LCZO data.	Alain Plante	12/13/2013

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Products

Books

Book Chapters

White A.F., Buss H.L. (2013). Natural Weathering Rates of Silicate Minerals. *Surface and Ground Water, Weathering and Soils* Drever, J.I,. Elsevier Science. . Status = AWAITING_PUBLICATION; Acknowledgement of Federal Support = Yes ; Peer Reviewed = Yes ; ISBN: 9780080959757.

White, A.F., Buss, H.L., (). Natural Weathering Rates of Silicate Minerals. *Surface and Ground Water, Weathering and Soils* . Status = AWAITING_PUBLICATION; Acknowledgement of Federal Support = Yes ; Peer Reviewed = Yes ; ISBN: 9780080959757.

Inventions

Nothing to report.

Journals or Juried Conference Papers

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

Brantley S.L., Holleran, M.E., Jin, L., Bazilevskaya, E. (2013). Probing deep weathering in the Shale Hills Critical Zone Observatory, Pennsylvania (USA): the hypothesis of nested chemical reaction fronts in the subsurface. *Earth Surface Processes and Landforms*. 38 (11), 1280. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/esp.3415

Brocard G.Y., Willenbring J. (2013). Headward migration of knickpoints along the rivers of the Luquillo Mountains and their effects on erosion rates and weathering processes. *Earth and Planetary Science Letters*. . Status = SUBMITTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Buss H.L., Brantley S.L., Scatena F.N., Bazilievskaya E.A., Blum A., Schulz M., Jimenez R., White A.F. (2013). Probing the deep critical zone beneath the Luquillo Experimental Forest, Puerto Rico. *Earth Surface Processes and Landforms*. . Status = SUBMITTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Buss H.L., Brantley S.L., Scatena F.N., Bazilievskaya E.A., Blum A., Schulz M., Jimenez R.,White A.F., Cole D., (2013). Probing the deep critical zone beneath the Luquillo Experimental Forest, Puerto Rico. *Earth Surface Processes and Landforms*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/esp.3409

Gioda, A.,Mayol-Bracero O.L. , Scatena, F.N., Weathers K.C., Mateus, V.L., William H. (2013). Chemical constituents in clouds and rainwater in the Puerto Rican rainforest: potential sources and seasonal drivers. *Atmospheric Environment*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.atmosenv.2012.11.017

Hall, S.J., Silver W.L. (2013). Iron oxidation stimulates organic matter decomposition in humid tropical forest soils. *Global Change Biology*. 2804. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1111/gcb

Johnson A.H., Xing Hao, Scatena F.N. (2013). Vegetation and Topography control the distribution of soil carbon in the subtropical moist and wet forests of the El Yunque National

Forest in eastern Puerto Rico. *Soil Science Society of America Journal*. . Status = SUBMITTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
Kristen M. DeAngelisa, Dylan Chivian, Julian L. Fortneye, Adam P. Arkin, Blake Simmons, Terry C. Hazen, Whendee L. Silver (2013). Changes in microbial dynamics during long-term decomposition in tropical forests. *Soil Biology and Biochemistry*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: http://dx.doi.org/10.1016/j.soilbio.2013.06.010
Liermann, L.J., Brantley, S.L., Albert, I. Buss, H.L., and Minyard M. (2013). Relating microbial community structure and geochemistry in deep regolith developed on volcaniclastic rock in the Luquillo Mountains, Puerto Rico. *Geomicrobiology Journal*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
Mage S.M., Porder S. (2013). Parent Material and Topography Determine Soil Phosphorus Status in the Luquillo Mountains of Puerto Rico. *Ecosystems*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1007/s10021-012-9612-5
Malvadkar, U., Scatena, F.N., and Leon, M. (2013). A Comparison of Connectivity Metrics on Watersheds and Implications for Water Management. *Rivers Research and Applications*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
McDowell, W.H., Brereton R.L., Scatena F.N. Shanley J.B., Brokaw N.V., Lugo A.E. (2013). Interactions between lithology and biology drive the long-term response of stream chemistry to major hurricanes in a tropical landscape.. *Biogeochemistry*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1007/s10533-013-9916-3
Navarre-Sitchler A., Cole D., Rother G., Jin L., Buss H.L., Brantley S. (2013). Porosity and surface area evolution during weathering of igneous rocks. *Geochim. Cosmochim. Acta*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.gca.2013.02.012
Navarre-Sitchler A., Cole D., Rother G., Jin L., Buss H.L., Brantley S. (2013). Porosity and surface area evolution during weathering of igneous rocks.. *Geochimica et Cosmochimica Acta*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: http://dx.doi.org/10.1016/j.gca.2013.02.012
Phillips C.B., Martin R. L. (2013). Impluse framework for unsteady flows reveals superdiffusive bed load transport. *Geophysical Research Letters*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/grl.50323

Porder, S.,,Johnson, A., Xing Hao, Brocard G., Goldsmith S. (2013). Linking geomorphology, weathering and cation availability in the Luquillo Mountains of Puerto Rico.. *Ecosystems*. . Status = SUBMITTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
Stone M.M., Plante A.F., Casper, B.B. (2013). Plant and nutrient controls on microbial functional characteristics in a tropical Oxisol. *Plant and Soil*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1007/s11104-013-1840-8

Licenses

Nothing to report.

Other Conference Presentations / Papers

Conor A. Sullivan; Steven T. Goldsmith; Stephen Porder (2013). *A landscape-scale assessment of nutrient limitation in the tropical forests of Luquillo, Puerto Rico*. AGU 2013 Session: Linking Geomorphology to Biogeochemistry and Nutrient Cycles I Posters. San Fransisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
Yannis G. Dialynas; Elisa Arnone; Leonardo V. Noto; Rafael L. Bras (2013). *A probabilistic approach for shallow rainfall-triggered landslide modeling at basin scale. A case study in the Luquillo Forest, Puerto Rico.*. AGU 2013 Session: Mechanisms, Vulnerability, Hazard, and Risk: From Shallow to Deep Seated Slope Deformation II. San Fransisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
TAKAGI, Kenneth and KURTZ, Andrew (2013). *APPLICATION OF STABLE CALCIUM ISOTOPES TO CA CYCLING AT THE LUQUILLO CRITICAL ZONE OBSERVATORY*. GSA Southeastern Section. San Juan, PR. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
BROCARD, Gilles Y (2013). *CHANGES IN EROSION RATE AND EROSION PROCESSES INDUCED BY THE PASSAGE OF HEADWARD MIGRATING KNICKPOINTS IN THE LUQUILLO CZO: INSIGHTS FROM DETRITAL COSMOGENIC 10BE*. GSA Southeastern Section. San Juan, PR. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
McDowell, W.H., F.N. Scatena, A. Ramirez, and J.D. Potter. (2013). *Carbon losses from the Critical Zone: Quantifying the effects of lithology and urbanization on concentrations of organic and inorganic carbon in coastal montane tropical rivers*. SE Section Annual Meeting, Geological Society of America. SE Section Annual Meeting, Geological Society of A. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Delgado, E.T. C.J. Valle Diaz, T. Lee, J. Collett, E. Fitzgerald, L. Cuadra, K.A. Prather, M.J. Sanchez, W.H. McDowell and O.L. Mayol-Bracer R. (2013). *Chemical speciation of water soluble ions and metals of cloud and rain eater during the Puerto Rico African Dust and Clouds Study (PRADACS) Campaigns.*. AGU Spring meeting. Cancun, Mexico. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Robert F. Stallard (2013). *Considerations of erosion and storage of carbon, focusing on tropical landscapes in Puerto Rico and Panama (Invited)*. AGU 2013 Session: Soil Erosion, Transport and Deposition and Their Control Over Biogeochemical Cycling of Essential Elements II. San Fransisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Stallard, R.F. (2013). *Disequilibrium Erosion in Eastern Puerto Rico – Is this How Many Clastic Sediment deposits are made?*. GSA Annual Meeting. Denver, CO. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Orlando, J.J., Hynek, S.A., Comas, X., Buss, H.L., Brantley, S.L. (2013). *Drilling and GPR in the Rio Icacos Watershed if the Luquillo CZO, Puerto Rico: Weathering Processes and Architecture of the Deep Critical Zone*. GSA Annual Meeting. Denver, CO. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Elisa Arnone; Yannis G. Dialynas; Leonardo V. Noto; Rafael L. Bras (2013). *Effect of DEM resolution on rainfall-triggered landslide modeling within a triangulated network-based model. A case study in the Luquillo Forest, Puerto Rico*. AGU 2013 Session: . Landslide Triggering and Runout Mechanics: Physical, Hydrological, and Geotechnical Approaches II Posters. San Fransisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Goldsmith, S.T., Porder, S., Kurtz, A., and Takaji, K. (2013). *Evaluation of shallow flow pathways and relative contributions to solute fluxes in a tropical small mountainous river: Luquillo, Puerto Rico.*. GSA Annual Meeting. Denver, CO. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

BECK, H.E.1, BRUIJNZEEL, L.A.1, VAN DIJK, A.I.J.M.2, SCATENA, Frederick N.3, SCHELLEKENS, J.4, and MCVICAR, T.R (2013). *FOREST REGENERATION AND STREAMFLOW IN PUERTO RICO: A MULTIPLE-CATCHMENT ANALYSIS*. GSA Southeastern Section. San Juan, PR. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Carlos J. Valle-Diaz; Elvis Torres-Delgado; Taehyoung Lee; Jeffrey L. Collett; Luis A. Cuadra-Rodriguez; Kimberly A. Prather; Olga L. Mayol-Bracero (2013). *Impact of Long-Range Transported African Dust Events on Cloud Chemistry at a Caribbean Tropical Montane Cloud Forest*. AGU 2013 Session: Mineral Dust Aerosols: From Small-Scale

Insights to Large-Scale Understanding I Posters. San Fransisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Stephen Porder; Arthur H. Johnson; Hao Xing; Gilles Y. Brocard; Steven T. Goldsmith (2013). *Linking geomorphology, weathering and cation availability in the Luquillo Mountains of Puerto Rico (Invited)*. AGU 2013 Session: Soil Erosion, Transport and Deposition and Their Control Over Biogeochemical Cycling of Essential Elements II. San Fransisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Odalys Martínez-Sánchez; Olga L. Mayol-Bracero; Pamela Sepulveda-Vallejo; Andrew Heymsfield (2013). *Low and Mid Level Tropical Atmosphere Characterization during African Dust Outbreaks Using Particle Size Distribution Data Retrieved from ICE-T and PRADACS Field Studies*. AGU 2013. San Fransisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

DERE, Ashlee L. (2013). *MINERALOGICAL TRANSFORMATIONS DURING SHALE WEATHERING FROM PUERTO RICO TO WALES*. GSA Southeastern Section. San Juan, PR. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Chapela Lara, M., Buss, H.L., Pogge Von Strandman, P.A.E., Dessert, C. Gaillardet, J. (2013). *Mg isotopes: insights into weathering in tropical volcanoclastic regolith.*. Goldschmidt 2013. Florence Italy.. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

SCHOLL, Martha A. (2013). *PRECIPITATION PATTERNS AND STREAMFLOW RESPONSE IN THE LUQUILLO MOUNTAINS, EASTERN PUERTO RICO*. GSA Southeastern Section. San Juan, PR. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

MCDOWELL, William H (2013). *QUANTIFYING THE EFFECTS OF LITHOLOGY AND URBANIZATION ON CONCENTRATIONS OF ORGANIC AND INORGANIC CARBON IN COASTAL MONTANE TROPICAL RIVERS*. GSA Southeastern Section. San Juan, PR. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Buss, H.L., Moore, O.W., Chapela Lara M., Schulz, M., White, A.F (2013). *Relating Grain-Scale Weathering Observations to Catchment-Scale Critical Zone Morphology*. Goldschmidt 2013. Florence Italy.. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Gilles Y. Brocard; Jane Willenbring; Frederick N. Scatena (2013). *Slow erosional response of a steep wet tropical mountain to a pulse of rock uplift in the Luquillo Critical Zone Observatory, Puerto Rico*. AGU 2013 Session: Exploring the Interplay Between Solid Earth Tectonics and Surface Processes From Mountains to the Sea I Posters.. San Fransisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

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

McDowell, W.H. (2013). *Soils and stream chemistry: When, where and why are they linked?*. European Geophysical Union Annual Meeting. Vienna, Austria. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Brereton, R.L. (2013). *Spatial variation of dissolved weathering products nutrients, and carbon in a rapidly weathering tropical watershed, Luquillo Mountains, Puerto Rico*. GSA Annual Meeting. Denver, CO. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Banwart, S., Chorover, J., Gaillardet, J., Sparks, D., White, T., et al. (2013) (2013). *Sustaining Earth's Critical Zone - Basic Science and Interdisciplinary Solutions for Global Challenges*. International Critical Zone Meeting. University of Delaware. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

KHAN, Nicole, VANE, Christopher H., HORTON, Benjamin P., and SCATENA, Fred (2013). *THE APPLICATION OF δ13C AND C/N OF MANGROVE SEDIMENTARY ORGANIC MATTER TO RECONSTRUCT FORMER RELATIVE SEA LEVEL AND PALEOENVIRONMENT, PUERTO RICO*. Southeastern Section GSA. San Juan, PR. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Omar Gutiérrez del Arroyo; Tana E. Wood; Ariel E. Lugo (2013). *Temperature-driven seasonal and diel variation in soil respiration in a moist subtropical forest in Puerto Rico*. AGU 2013 Session: Beyond Changes in Mean Climate: The Impacts of Climate Variabilities on Terrestrial Ecosystems III Posters. San Fransisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

HYNEK, Scott A., ORLANDO, Joseph J., SULLIVAN, Pamela, and BRANTLEY, Susan L. (2013). *The Architecture of Deep Weathering at Two CZOs: Groundwater, Regolith, and Solutes at Susquehanna Shale Hills and Luquillo Experimental Forest* .. GSA Annual Meeting. Denver, CO. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Bernadett Weinzierl; Albert Ansmann; Oliver Reitebuch; Volker Freudenthaler; Thomas Müller; Konrad Kandler; Dietrich Althausen; Reinhold Busen; Maximilian Dollner; Andreas Dörnbrack; David A. Farrell; Silke Gross; Katharina Heimerl; Andre Klepel; Thomas B. Kristensen; Olga L. Mayol-Bracero; Andreas Minikin; Damien Prescod; Joseph M. Prospero; Stephan Rahm; Markus Rapp; Daniel N. Sauer; Andreas Schaefler; Carlos Toledano; Mark Vaughan; Matthias Wiegner (2013). *The Saharan Aerosol Long-range Transport and Aerosol-Cloud-Interaction Experiment SALTRACE 2013 – Overview and Early Results (Invited)*. AGU 2013 Session: Mineral Dust Aerosols: From Small-Scale Insights to

Large-Scale Understanding III. San Fransisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Other Products

Databases.

A database of Geospatial data for northeastern puerto rico is being developed. An ArcGIS server hosted on an Amazon EC2 server instance is generating web based maps for the use of researchers, students and the general public.

A sample can be viewed at:

http://criticalzone.org/luquillo/infrastructure/sample-collection-resources-luquillo/

Additional maps and resources are being developed.

Databases.

Effects of forest disturbances on stream nitrate concentrations in sites participating in StreamChemDB

Data available at:

http://web.fsl.orst.edu/streamchem/database/download-data

Argerich, A., .S.L. Johnson, S.D. Sebestyen, C.C. Rhoades, E. Greathouse, P.M. Wohlgemuth, F.N. Scatena, W.H. McDowell, G.E. Likens, J.D. Knoepp,J.B. Jones, G.G. Ice, J.L. Campbell, D.M. Amatya, and M.B. Adams. 2012. Effects of forest disturbances on stream nitrate concentrations in sites participating in StreamChemDB. LTER All Scientists Meeting, Estes Park, CO, September 2012.

Educational aids or Curricula.

Curricula were developed and used by two High Schools in the metro Philadelphia area. Students used LCZO datasets to explore the subject "What is the Relationship Between Water Hardness and Conductivity?"

Other Publications

Harpold, A.A., D. Karwan, J. Perdrial, J.A. Marshall, J. Driscoll, A. Neal, and C. Phillips (2013). *Graduate Research Group White Paper: Cross-CZO Research Potential*. This white paper summarizes the work accomplished by the Critical Zone (CZ) graduate research group (GRG) towards developing and implementing cross-site research. We lay out several tractable research questions and hypotheses developed from group discussions. We identify the Critical Zone Observatory (CZO) datasets that are currently most useful for cross-site

research. We also speak to potential pitfalls and opportunities that future GRG efforts will likely encounter engaging in cross-site research. Finally, we suggest how the GRG plans to involve a wider community in its cross-site research efforts.. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Patents

Nothing to report.

Technologies or Techniques

Nothing to report.

Thesis/Dissertations

Websites

CriticalZone.org
http://criticalzone.org/luquillo/
This is the general public facing website for the Luquillo Critical Zone Observatory and the other critical zones. This provides researchers, students and the general public with news, resources, data, publications and upcoming events.
Luquillo Critical Zone Observatory Data REpository
https://www.sas.upenn.edu/lczodata/
Provides researchers, students and the general public with a rich resource to discover data resources, publications and information about ongoing research.
Real-Time Landslide Warning System for Northeastern Puerto Rico
http://landslidepr.com/
Provides a framework for understanding risks of Landslide hazards in Puerto Rico.

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Participants/Organizations

What individuals have worked on the project?

Plante, Alain	PD/PI	1
Brantley, Susan	Co PD/PI	1
White, Art	Co PD/PI	1
Comas, Xavier	Co-Investigator	1
Gonzalez, Grizelle	Co-Investigator	1
Heather, Buss	Co-Investigator	1
Horton, Ben	Co-Investigator	1
Jerolmack, Doug	Co-Investigator	1
Johnson, Arthur	Co-Investigator	1
Kurtz, Andrew	Co-Investigator	1
Mayol, Olga	Co-Investigator	1
McDowell, William	Co-Investigator	1

Porder, Stephen	Co-Investigator	1
Scholl, Martha	Co-Investigator	1
Shanley, James	Co-Investigator	1
Silver, Whendee	Co-Investigator	1
Thompson, Aaron	Co-Investigator	1
Willenbring, Jane	Co-Investigator	1
Kaczmar, Peter	K-12 Teacher	1
Thomas, Jeffery	K-12 Teacher	1
Brocard, Gilles	Postdoctoral (scholar, fellow or other postdoctoral position)	9
Hynek, Scott	Postdoctoral (scholar, fellow or other postdoctoral position)	9
Horwitz, Jane	Other Professional	1
Jimenez, Rafael	Other Professional	9
Leon, Miguel	Other Professional	12
Estrada, Carlos	Technician	3

Brereton, Rich	Graduate Student (research assistant)	9
Chapela Lara, Maria	Graduate Student (research assistant)	9
Evaristo, Jaivime	Graduate Student (research assistant)	9
Hall, Steven	Graduate Student (research assistant)	4
Hao, Xing	Graduate Student (research assistant)	9
Kahn, Nicole	Graduate Student (research assistant)	9
Kaizad, Patel	Graduate Student (research assistant)	2
Litwin, Kimberly	Graduate Student (research assistant)	9
Mage, Susanna	Graduate Student (research assistant)	1
Occhi, Marcie	Graduate Student (research assistant)	6
Orlando, Joe	Graduate Student (research assistant)	1
Phillips, Collin	Graduate Student (research assistant)	9
Stone, Maddie	Graduate Student (research assistant)	9
Takagi, Ken	Graduate Student (research assistant)	9
Wilmoth, Jared	Graduate Student (research assistant)	1

Vizcarrondo, Raul	Non-Student Research Assistant	6
Ali, Princess Lydia	Undergraduate Student	2
Chen, Zhiyu	Undergraduate Student	2
Costacamps, Carmelo	Undergraduate Student	2
Haak, Catherine	Undergraduate Student	2
Jesse, Franklin	Undergraduate Student	2
Markel, David	Undergraduate Student	2
Morco, Samantha	Undergraduate Student	4
Ramirez, Jean Carlo	Undergraduate Student	2
Salladay, Ryan	Undergraduate Student	4
Salter, Gerald	Undergraduate Student	2
Sullivan, Conor	Undergraduate Student	4
Tamayo, Cooper	Undergraduate Student	4
Urban, Jonathan	Undergraduate Student	2

Veloso, Jefferson	Undergraduate Student	2
Washington, Kirstin	Undergraduate Student	2
Zhou, Mengzhou	Undergraduate Student	4

Full details of individuals who have worked on the project:

Alain F Plante

Email: aplante@sas.upenn.edu

Most Senior Project Role: PD/PI

Nearest Person Month Worked: 1

Contribution to the Project: Oversees research in soil carbon quality and dynamics. Supervises 1 PhD student, several undergraduates and co-supervises 1 post-doc. Has established collaborative carbon research with Christina CZO.

Funding Support: None.

International Collaboration: No

International Travel: No

Susan L Brantley

Email: brantley@essc.psu.edu

Most Senior Project Role: Co PD/PI

Nearest Person Month Worked: 1

Contribution to the Project: Weathering, deep critical zone nutrient cycling. Supervises two PhD students and a Post-doc. Sue is a cross CZO participant with the Shale Hills CZO.

Funding Support: Shale Hills CZO

International Collaboration: No

International Travel: No

Art F White

Email: afwhite@usgs.gov

Most Senior Project Role: Co PD/PI

Nearest Person Month Worked: 1

Contribution to the Project: Collaborator through the National Research Program of the Water Resources Discipline. Studied mineral weathering/soil development as part of the Water Energy Biogeochemstry (WEBB) field site.

Funding Support: USGS WEBB

International Collaboration: No

International Travel: No

Xavier Comas

Email: xcomas@fau.edu

Most Senior Project Role: Co-Investigator

Nearest Person Month Worked: 1

Contribution to the Project: Has worked with the LCZO in collecting shallow geophysical data.

Funding Support: ---

International Collaboration: No

International Travel: No

Grizelle Gonzalez

Email: ggonzalez@fs.fed.us

Most Senior Project Role: Co-Investigator

Nearest Person Month Worked: 1

Contribution to the Project: USFS-IITF - Project Leader - Research Ecologist

Funding Support: USDA-USFS-IITF

International Collaboration: No

International Travel: No

Buss L Heather

Email: H.Buss@bristol.ac.uk

Most Senior Project Role: Co-Investigator

Nearest Person Month Worked: 1

Contribution to the Project: Biogeochemistry, deep weathering.

Funding Support: ---

International Collaboration: Yes, United Kingdom

International Travel: No

Ben Horton

Email: bphorton@sas.upenn.edu

Most Senior Project Role: Co-Investigator

Nearest Person Month Worked: 1

Contribution to the Project: Sea level change research.

Funding Support: ---

International Collaboration: Yes, United Kingdom

International Travel: No

Doug Jerolmack

Email: sediment@sas.upenn.edu

Most Senior Project Role: Co-Investigator

Nearest Person Month Worked: 1

Contribution to the Project: Oversees research related to sediment transport and fluvial processes. Established 3 sediment transport monitoring stations and supervises 2 PhD students. I iterate between mathematical modeling, laboratory experiments and field observations in order to elucidate the minimum number of ingredients that are required to explain physical phenomena. While my interests are wide ranging, they share a common theme: to understand the internally-generated dynamics of sedimentary systems, to characterize the response of these complex systems to changes in boundary conditions such as climate, and to develop methods for accurately separating the two signals.

Funding Support: ---

International Collaboration: No

International Travel: No

Arthur H Johnson

Email: ahj@sas.upenn.edu

Most Senior Project Role: Co-Investigator

Nearest Person Month Worked: 1

Contribution to the Project: Oversees research in surface soil biogeochemistry and coordinates the establishment and maintenance of the LCZO soil network. Supervises 1 PhD student. Our research program addresses nutrient cycling in forests, primarily (1) the proximate and ultimate sources of macronutrients necessary for forest growth, and (2) the role of nutrients in limiting growth.

Funding Support: None.

International Collaboration: No

International Travel: No

Andrew Kurtz

Email: kurtz@bu.edu

Most Senior Project Role: Co-Investigator

Nearest Person Month Worked: 1

Contribution to the Project: Research into chemical weathering of rocks, which liberate nutrients to ecosystems, produce soils, and regulate the carbon dioxide content of the atmosphere on geologic timescales.

Funding Support: ---

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: Research Interests are in the chemical, physical and optical properties of atmospheric aerosols; impact of aerosols on climate; size-resolved chemical composition and sources of aerosols in tropical regions; carbonaceous aerosols; organic aerosols and their role in cloud condensation nuclei properties; impact of atmospheric aerosols on the ecosystem, the degradation of structures and health.

Funding Support: ---

International Collaboration: No

International Travel: No

William H McDowell

Email: Bill.McDowell@UNH.EDU

Most Senior Project Role: Co-Investigator

Nearest Person Month Worked: 1

Contribution to the Project: Responsible for analysis of LCZO water samples. Research in the McDowell lab focuses on understanding controls on biogeochemical cycles in streams, forests, and watersheds. Specifically, we study long-term changes in the water quality of forested, suburban, and urban watersheds in both temperate and tropical watersheds. Our primary long-term study sites include the Lamprey River and other suburban watersheds in southern New Hampshire, the Luquillo Experimental Forest and urban sites in Puerto Rico, and forested watersheds in New England and the Czech Republic. Understanding the impact of people on water quality, especially impacts on the nitrogen cycle, is a long-term goal in many of our research projects. Primary funding comes from the National Science Foundation, the EPA Clean Air Division, the USDA, and other Federal agencies.

Funding Support: ---

International Collaboration: No

International Travel: No

Stephen Porder

Email: aplante@sas.upenn.edu

Most Senior Project Role: Co-Investigator

Nearest Person Month Worked: 1

Contribution to the Project: Our research is focused on understanding the drivers of biogeochemical variation among terrestrial ecosystems, and mostly in the tropics. Ecosystem ecologists and biogeochemists have long recognized that tropical systems function differently than their temperate counterparts, and exhibit remarkable biogeochemical heterogeneity. As the community has worked to develop a framework for explaining the causes of this variability, most investigators have taken one of two general approaches: parsing out underlying drivers from observed spatial patterns across large regions, or isolating single drivers of ecosystem properties with less emphasis on scaling up to broader regions. Our group seeks to do both simultaneously, an approach we believe will help quantify and explain the biogeochemical diversity that typifies tropical ecosystems.

Funding Support: ---

International Collaboration: No

International Travel: No

Martha A Scholl

Email: mascholl@usgs.gov

Most Senior Project Role: Co-Investigator

Nearest Person Month Worked: 1

Contribution to the Project: USGS Hydrologist/Geochemists responsible for isotopic studies to determined flow paths of water. Is conducting weekly rainwater sampling.

Funding Support: USGS

International Collaboration: No

International Travel: No

James B Shanley

Email: jshanley@usgs.gov

Most Senior Project Role: Co-Investigator

Nearest Person Month Worked: 1

Contribution to the Project: USGS research hydrologist responsible for Mercury studies and WEBB hydrologic sites.

Funding Support: USGS

International Collaboration: No

International Travel: No

Whendee Silver

Email: wsilver@berkeley.edu

Most Senior Project Role: Co-Investigator

Nearest Person Month Worked: 1

Contribution to the Project: Professor Silver is responsible for studies in soil biogeochemistry and soil oxygen dynamics. Supervises 1 PhD student and was responsible for installing soil oxygen nodes in study watersheds. Studies Iron cycling, Nitrogen Cycling, Redox.

Funding Support: Sub-contract to UC-Berkeley.

International Collaboration: No

International Travel: No

Aaron Thompson

Email: aaront@uga.edu

Most Senior Project Role: Co-Investigator

Nearest Person Month Worked: 1

Contribution to the Project: Our overall goal is to delineate the functional roles of iron (Fe) in soils characterized by variable redox conditions. We focus first on the dynamics of microbially-labile Fe and second on the coupled roles of phosphorus (P) and carbon (C).

Funding Support: ---

International Collaboration: No

International Travel: No

Jane Willenbring

Email: erosion@sas.upenn.edu

Most Senior Project Role: Co-Investigator

Nearest Person Month Worked: 1

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

Funding Support: ---

International Collaboration: No

International Travel: No

Peter Kaczmar

Email: KACZMAP@lmsd.org

Most Senior Project Role: K-12 Teacher

Nearest Person Month Worked: 1

Contribution to the Project: High school teacher who has implemented some lesson plans utilizing Luquillo CZO datasets.

Funding Support: ---

International Collaboration: No

International Travel: No

Jeffery Thomas

Email: Jeffrey.Thomas@rtsd.org

Most Senior Project Role: K-12 Teacher

Nearest Person Month Worked: 1

Contribution to the Project: High school teacher who has implemented some lesson plans utilizing Luquillo CZO datasets.

Funding Support: ---

International Collaboration: No

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: 9

Contribution to the Project: Geomorphology, Cosmogenic dating, GIS

Funding Support: ---

International Collaboration: No

International Travel: No

Scott Hynek

Email: sah376@psu.edu

Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)

Nearest Person Month Worked: 9

Contribution to the Project: geochronology, geochemical tracers, and isotope geochemistry to understand processes and pathways in modern environments and to constrain the evolution and distribution of ancient environments

Funding Support: ---

International Collaboration: No

International Travel: No

Jane Horwitz

Email: janeh@sas.upenn.edu

Most Senior Project Role: Other Professional

Nearest Person Month Worked: 1

Contribution to the Project: Facilitates outreach to K-12 STEM by bringing together UPenn staff with K-12 teachers.

Funding Support: ---

International Collaboration: No

International Travel: No

Rafael Jimenez

Email: ajz@sas.upenn.edu

Most Senior Project Role: Other Professional

Nearest Person Month Worked: 9

Contribution to the Project: Worked on deep critical zone drilling analysis and a geochemical model of redox reactions in two geomorphologically distinct watersheds.

Funding Support: ---

International Collaboration: No

International Travel: No

Miguel Carlos Leon

Email: leonmi@sas.upenn.edu

Most Senior Project Role: Other Professional

Nearest Person Month Worked: 12

Contribution to the Project: Data Manager for the Luquillo Critical Zone Observatory.Collects and redistributed data through websites and personal communication. Provides GIS and web based GIS data distribution, analysis, and support. Works on data collection automation and sensor networks. Provides general support for data aggregation, analysis, and QA/QC.

Funding Support: ---

International Collaboration: No

International Travel: No

Carlos Estrada

Email: cestrada@fs.fed.us

Most Senior Project Role: Technician

Nearest Person Month Worked: 3

Contribution to the Project: USFS Hydrologic technician responsible for managing Bisley Watersheds and Luquillo Climate stations.

Funding Support: USFS

International Collaboration: No

International Travel: No

Rich Brereton

Email: rich.brerton@unh.edu

Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 9

Contribution to the Project: stream and groundwater chemistry

Funding Support: ---

International Collaboration: No

International Travel: No

Maria Chapela Lara

Email: mariachapela@ymail.com

Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 9

Contribution to the Project: cycling of nutrients in the critical zone, focusing on Mg in the Bisley 1 catchment

Funding Support: ---

International Collaboration: Yes, United Kingdom

International Travel: No

Jaivime Evaristo

Email: evaristo@sas.upenn.edu

Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 9

Contribution to the Project: Tracing source areas of water and sediment, as well as in measuring residence times of water using stable isotopes and other novel techniques.

Funding Support: University of Pennsylvania Graduate Fellows

International Collaboration: No

International Travel: No

Steven Hall

Email: stevenhall@berkeley.edu

Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 4

Contribution to the Project: Biogeochemsitry, Iron Oxidation research.

Funding Support: ---

International Collaboration: No

International Travel: No

Xing Xing Hao

Email: haoxing@sas.upenn.edu

Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 9

Contribution to the Project: Soil sample analysis.

Funding Support: University of Pennsylvania Graduate Fellows

International Collaboration: No

International Travel: No

Nicole Kahn

Email: khann@sas.upenn.edu

Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 9

Contribution to the Project: Sea level change research.

Funding Support: ---

International Collaboration: Yes, United Kingdom

International Travel: No

Patel Kaizad

Email: kzad89@gmail.com

Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 2

Contribution to the Project: Soil Texture analysis.

Funding Support: ---

International Collaboration: No

International Travel: No

Kimberly Litwin

Email: klitwin@sas.upenn.edu

Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 9

Contribution to the Project: Studying abrasion due to energetic binary collisions in stream systems.

Funding Support: University of Pennsylvania Graduate Fellows

International Collaboration: No

International Travel: No

Susanna Mage

Email: susannamage@gmail.com

Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 1

Contribution to the Project: Soil phosphorus cycling.

Funding Support: ---

International Collaboration: No

International Travel: No

Marcie Occhi

Email: mocchi@sas.upenn.edu

Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 6

Contribution to the Project: I am interested in understanding fine sediment transport through watersheds on a variety of time scales. In Puerto Rico I am primarily focused on how single episodic storm events erode watersheds of varying lithology (volcanoclastics and quartz diorite) by analyzing suspended sediment samples collected over a storm hydrograph. In order to determine provenance, I employ multiple cosmogenic isotopes (7Be, 210Pb, 10Be) as tracers to characterize source areas and suspended sediments. I am also interested in using cosmogenic isotopes to understand fine sediment residence time on the hillslope and within the channel.

Funding Support: University of Pennsylvania Graduate Fellows

International Collaboration: No

International Travel: No

Joe J Orlando

Email: joejorlando@gmail.com

Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 1

Contribution to the Project: Deep weathering, Regolith formation, ground water and solute work.

Funding Support: ---

International Collaboration: No

International Travel: No

Collin Phillips

Email: kcolinp@sas.upenn.edu

Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 9

Contribution to the Project: I am generally interested with the propagation of signals through a landscape from precipitation to bed load transport, and how changes in the catchment landscape filters, alters or shreds those signals. In order to understand the propagation of that signal in its entirety it is paramount to determine the dynamics of bed load transport within a single flood, and a series of floods. These tie into a greater interest in understanding how climate and variability in the types of rainfall events (input signal variability) effect bed load fluxes and the evolution of landscapes.

Funding Support: University of Pennsylvania Graduate Fellows

International Collaboration: No

International Travel: No

Maddie Stone

Email: mmstone83@gmail.com

Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 9

Contribution to the Project: I am broadly interested in the role of microbial communities in terrestrial carbon cycling, particularly the interactions between soil microbes and soil organic matter (SOM) composition and stability. My dissertation research takes an interdisciplinary approach to carbon biogeochemistry. I am measuring SOM quantity and chemical quality along ~1.5 meter-deep soil profiles in order to understand how soil carbon changes with depth and age. This work will involve physical and chemical fractionations as well as thermal analysis and 13C NMR to characterize SOM functionalities. In conjunction with this work I am using a suite of molecular techniques and biochemical assays to profile microbial community diversity, structure and functional characteristics spanning the same depth profiles.

Funding Support: University of Pennsylvania Graduate Fellows

International Collaboration: No

International Travel: No

Ken Takagi

Email: katakagi@bu.edu

Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 9

Contribution to the Project: Hydrology research.

Funding Support: ---

International Collaboration: No

International Travel: No

Jared Wilmoth

Email: jared.wilmoth@gmail.com

Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 1

Contribution to the Project: Iron cycling, redox.

Funding Support: ---

International Collaboration: No

International Travel: No

Raul Vizcarrondo

Email: unknown@notsure.com

Most Senior Project Role: Non-Student Research Assistant

Nearest Person Month Worked: 6

Contribution to the Project: Research assistant

Funding Support: ---

International Collaboration: No

International Travel: No

Princess Lydia Ali

Email: unknown@notsure.com

Most Senior Project Role: Undergraduate Student

Nearest Person Month Worked: 2

Contribution to the Project: Undergraduate research assistant.

Funding Support: ---

International Collaboration: No

International Travel: No

Zhiyu Chen

Email: unknown@notsure.com

Most Senior Project Role: Undergraduate Student

Nearest Person Month Worked: 2

Contribution to the Project: Lab assistant

Funding Support: ---

International Collaboration: No

International Travel: No

Carmelo Costacamps

Email: ccostacamps@gmail.com

Most Senior Project Role: Undergraduate Student

Nearest Person Month Worked: 2

Contribution to the Project: Research Assistant

Funding Support: ---

International Collaboration: No

International Travel: No

Catherine Haak

Email: unknown@notsure.com

Most Senior Project Role: Undergraduate Student

Nearest Person Month Worked: 2

Contribution to the Project: Undergrad research assistant.

Funding Support: ---

International Collaboration: No

International Travel: No

Franklin Jesse

Email: unknown@notsure.com

Most Senior Project Role: Undergraduate Student

Nearest Person Month Worked: 2

Contribution to the Project: Lab assistant.

Funding Support: ---

International Collaboration: No

International Travel: No

David Markel

Email: unknown@notsure.com

Most Senior Project Role: Undergraduate Student

Nearest Person Month Worked: 2

Contribution to the Project: Undergrad research assistant.

Funding Support: ---

International Collaboration: No

International Travel: No

Samantha Morco

Email: smorco@berkeley.edu

Most Senior Project Role: Undergraduate Student

Nearest Person Month Worked: 4

Contribution to the Project: Lab assistant.

Funding Support: ---

International Collaboration: No

International Travel: No

Jean Carlo Ramirez

Email: unknown@notsure.com

Most Senior Project Role: Undergraduate Student

Nearest Person Month Worked: 2

Contribution to the Project: Research assistant

Funding Support: ---

International Collaboration: No

International Travel: No

Ryan Salladay

Email: rsalladay@berkeley.edu

Most Senior Project Role: Undergraduate Student

Nearest Person Month Worked: 4

Contribution to the Project: Lab assistant.

Funding Support: ---

International Collaboration: No

International Travel: No

Gerald Salter

Email: not@known.com

Most Senior Project Role: Undergraduate Student

Nearest Person Month Worked: 2

Contribution to the Project: Undergrad research assistant.

Funding Support: ----

International Collaboration: No

International Travel: No

Conor Sullivan

Email: unkown@notsure.com

Most Senior Project Role: Undergraduate Student

Nearest Person Month Worked: 4

Contribution to the Project: Lab Assistant.

Funding Support: ---

International Collaboration: No

International Travel: No

Cooper Tamayo

Email: unkown@notsure.com

Most Senior Project Role: Undergraduate Student

Nearest Person Month Worked: 4

Contribution to the Project: Lab assistant.

Funding Support: ---

International Collaboration: No

International Travel: No

Jonathan Urban

Email: unknown@notsure.com

Most Senior Project Role: Undergraduate Student

Nearest Person Month Worked: 2

Contribution to the Project: Undergrad research assistant.

Funding Support: ---

International Collaboration: No

International Travel: No

Jefferson Veloso

Email: unknown@notsure.com

Most Senior Project Role: Undergraduate Student

Nearest Person Month Worked: 2

Contribution to the Project: Undergrad research assistant.

Funding Support: ----

International Collaboration: No

International Travel: No

Kirstin Washington

Email: kirstin.e.washington@gmail.com

Most Senior Project Role: Undergraduate Student

Nearest Person Month Worked: 2

Contribution to the Project: Undergraduate Research Assistant.

Funding Support: ---

International Collaboration: No

International Travel: No

Mengzhou Zhou

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Most Senior Project Role: Undergraduate Student

Nearest Person Month Worked: 4

Contribution to the Project: Assisted data manager in creating python scripts for data collection and web mapping.

Funding Support: ---

International Collaboration: No

International Travel: No

What other organizations have been involved as partners?

US Geological Survey	Other Organizations (foreign or domestic)	Luquillo, PR
USFS International Institute of Tropical Forestry	Other Organizations (foreign or domestic)	Luquillo, PR

Full details of organizations that have been involved as partners:

US Geological Survey

Organization Type: Other Organizations (foreign or domestic)

Organization Location: Luquillo, PR

Partner's Contribution to the Project:

Financial support

In-Kind Support

Facilities

Collaborative Research

Personnel Exchanges

More Detail on Partner and Contribution: The USGS Water, Energy, and Biogeochemical Budgets (WEBB) program provided direct financial support of approximately $100,000 to drill and instrument three deep observations wells, provided basic research and transportation support for 4 Research Scientists (Buss, Scholl, White, Shanley) and several local hydrologists and technicians (J. Rodriquez, M. Figueroa), provided direct support to manage and upgrade stream gages and in collecting hydrologic information for the Icacos and Guaba watersheds.

USFS International Institute of Tropical Forestry

Organization Type: Other Organizations (foreign or domestic)

Organization Location: Luquillo, PR

Partner's Contribution to the Project:

Financial support

In-Kind Support

Facilities

Collaborative Research

Personnel Exchanges

More Detail on Partner and Contribution: USDA-Forest Service International Institute of Tropical Forestry provided basic research support for the participation of three Research Scientists (Gould, Gonzales, Heartsill-Scally) and three hydrologic technicians (Estrada, Moya, Torrens). Dr. W. Gould, Research Ecologist participated in the LIDAR planning and providing access to existing remote sensing data. He will also co-supervise future graduate student in remote sensing of the LCZO site. Dr. G. Gonzales, Research Ecologist, participated in the planning of the LCZO soil network and has provided access and data from a set of permanent vegetation plots that span the Luquillo elevational gradient.

What other collaborators or contacts have been involved?

NO

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Impacts

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

An important impact of the various experiments on soil carbon biogeochemistry contribute to a re-evaluation of the soil carbon cycle in humid tropical forests. Mineral-associated C is often thought to cycle over timescales of centuries in temperate forests; in our tropical forest sites, a large proportion of annual litterfall NPP (20 – 30%) is added to the mineral fraction. Furthermore, the same factors that control C stocks do not appear to control C turnover—thus, it appears that the magnitude of plant C inputs, not factors controlling decomposition, are the dominant drivers of mineral-associated C stocks in this forest. These findings suggest that surface soil C may respond much more rapidly to global change factors than previously thought. We also found that lignin, a biochemically recalcitrant compound, decomposes rapidly in humid tropical forest soils, and preferentially in soils subjected to fluctuating redox conditions. Furthermore, lignin decomposition does not appear as sensitive to oxygen availability as was previously thought. Our finding of increasing relative lignin decomposition in a fluctuating-redox environment provides a mechanistic explanation for recent observations of relatively short turnover times of lignin in soils.

What is the impact on other disciplines?

The synergies created by the CZ concept itself, and the combination of research from diverse disciplines within and outside of the geosciences has created a novel platform for the development of synergistic, synthesizing science. As one example, studies examining microbial populations in surface soils and deep saprolite performed by microbial ecologists, soil scientists and geochemists have generated new questions about microbial life in low-energy systems that will likely be important to a wide range of disciplines.

What is the impact on the development of human resources?

The LCZO has had a significant impact on the development of human resources. It has improved the research opportunities for under-represented groups of faculty and graduate and undergraduate

students such as females, Hispanics and African-Americans. It has also provided career development for Hispanic professionals in the area of data management. Our education deliverables have enhanced STEM teaching and learning at the high school level by providing curricular activities using project data.

What is the impact on physical resources that form infrastructure?

The LCZO has been directly involved in providing the following infrastructure improvements:

Meteorological Stations: All LCZO meteorological stations have been upgraded with new sensors, a tri-pod tower was replaced at East Peak and independent safety inspections were conducted on the 2 Bisley walk-up towers where water samples are collected. Their guy wires were replaced and both towers were deemed safe by the USFS Safety officer. A new ceilometer was installed in 2013.

Stream gage upgrades: The LCZO has purchased and is installing upgraded data loggers, new water level sensors, new conductivity sensors, and soil water probes for 2 of the Bisley Watersheds. In addition, the USGS has purchased a similar conductivity probe for one of the streams graining the granodiorite.

Equipment Purchases: The LCZO has purchased a range of equipment and instruments for the use of all LCZO researchers, including: a gamma-ray counter for dating studies, 2 portable water quality sensors (i.e. Hydrolabs), Trimble GPS units, electronic tracking equipment to record boulder movement in streams, soil coring and sampling equipment, and field scales.

What is the impact on institutional resources that form infrastructure?

The LCZO provides insight into management of tropical landscapes that has helped to enhance environmental quality and environmental sustainability.

What is the impact on information resources that form infrastructure?

The LCZO web site provides a vital resource for data preservation and data accessibility that documents the role of the Critical Zone in maintaining environmental quality in a tropical landscape.

What is the impact on technology transfer?

Information on the water flow and water quality of the Luquillo Mountains has been instrumental in public agency decisions regarding engineered water resources infrastructure. Construction of off-channel storage of water in the last several years (Rio Blanco reservoir near Naguabo, Puerto Rico), for example, relied on an understanding of the storm flow, sediment load, and water quality of the Icacos-Blanco system that the LCZO and its collaborators provided.

What is the impact on society beyond science and technology?

Effective management of coastal areas in the Caribbean requires an understanding of factors controlling sediment and nitrogen delivery from steep, montane watersheds. Excessive sediment and nitrogen both harm the estuaries and coral reefs that are centrally important to the economic and ecological vitality of coastal communities. Our data provide important insight into the controls on erosion and nitrogen delivery to the coast, as they demonstrate the variability in these parameters that can be expected under relatively natural (undeveloped) conditions. These data thus provide a benchmark against which the effects of human activity in the critical zone can be assessed.

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Changes/Problems

Changes in approach and reason for change

Because of the requirement of ARRA, the original five-year project was shortened into four years. This caused substantial changes in the way the project was executed, though without substantial changes in the overall objectives and accomplishments. In addition, the original lead PI of the project (Dr. Fred Scatena) passed away in January 2013. As a result, Dr. Alain Plante became the lead PI of the project during its final year.

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

Nothing to report.

Changes that have a significant impact on expenditures

The shortening of the project from five to four years resulted in substantial changes to how funding was spent. The project needed to spend the total project funds in less time. As a result, more project

funds were allocated to graduate student support than originally anticipated. Other funds were used to purchase equipment that would be used to strengthen the LCZO infrastructure and would be essential in ongoing research.

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.

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Special Requirements

Responses to any special reporting requirements specified in the award terms and conditions, as well as any award specific reporting requirements.

Nothing to report.