3rd of 5 Annual Reports for NSF Project:

Human and Natural Forcings of Critical Zone Dynamics and Evolution at the Calhoun Critical Zone Observatory

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Accomplishments

* What are the major goals of the project?

A. Overall goal of Calhoun CZO

In 2001, the USA's National Research Council described the interdisciplinary science of Earth's "critical zone" to be one of the most compelling research areas for the Earth sciences in the 21st century. The excitement embodied in this claim springs from the need and opportunity for the Earth sciences to advance understanding of how the planet from local to global scales is being rapidly transformed by humanity.

At the Calhoun CZO, our overall goal is to marshal the Earth and ecological sciences to understand how critical zones as structures "from tree-top to bedrock" and as dynamic fluids "from the atmosphere to the deepest aquifers" are being transformed from natural to human-natural systems (Richter and Billings, 2015). We see the Calhoun CZ as having three phases in its evolution: a) the evolution of the *ancient*, deep, and highly

weathered natural system, which on the most geomorphically stable surfaces of the Calhoun CZO have residence times of several million years; b) the changes affected by the *historic* human-natural system, initiated by Native Americans but greatly accelerated by severe agricultural erosion and sedimentation between about 1800 and the 1930s, mostly from cotton-based farming; and c) the *contemporary* human-natural system, marked by reforestation of severely eroded soils, gullied runoff channels, and floodplains that are inundated with meters-deep legacy sediments.

Calhoun research is thus motivated by the growing need to understand and manage Earth's critical zones "in the face of land use change … to inform strategies for sustaining a wide range of human activities" (from NSF's CZO Program Solicitation, NSF 12-575). Ultimately, we seek integration of the sciences and broader scholarships within the Calhoun CZO and also across all CZOs.

B. Five specific goals of Calhoun CZO

In our third annual report, we respond to our Virtual Site Visit Review of late 2015 and early 2016, including a suggestion to reorganize our hypotheses and goals. The Calhoun CZO now aims to fulfill five specific goals: three of which are directed at research and test scientific hypotheses, a fourth to promote CZ education and outreach, and a fifth to stimulate cross-CZO science and education. Each of these is briefly described here and addressed in more detail throughout the report.

1. Hypothesis on Hydro-biogeochemical Decoupling and Regeneration of the CZ following Land Degradation. *In CZs altered by land degradation and severe erosion, hydrologic and biogeochemical processes in surficial volumes of CZs become decoupled from those at depth, with system recoveries dependent on re-establishment of macroporosity, hydrologic networks, rooting, macroinvertebrate activity, and aggregate formation.*

2. Hypothesis on Erosion-Induced Carbon Dynamics. *Delayed oxidation of eroded soil organic carbon (SOC) buried in alluvial sediments represents a substantial fraction of erosion-induced alterations of soil C cycling.*

3. Hypothesis on Persistence of Alternative States. *CZs altered by land degradation, erosion, gullies, and reductions in infiltration, deep rooting, macroinvertebrates, and aggregate formation are impeded by self-reinforcing feedbacks in re-establishing biological productivity and environmental services.*

4. Education and Outreach Goals. *While our main focus is to facilitate research and educational opportunities for undergraduates at four-and two year colleges, the Calhoun CZO actively encourages field trips and reaches out nationally and internationally via a variety of media, materials, and events.*

5. Cross-CZO Goals. *We encourage and prioritize a variety of cross-CZO relationships and participate in new and on-going projects that involve our PIs and students or data- and sample-sharing.*

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

Major Activities:

A. Key activities associated with the five CCZO project goals

1. Hydro-biogeochemical Decoupling and Regeneration of the CZ following Land Degradation

a) Deep Geophysics and Geochemistry. Collaboration with WyCEHG has helped us quantify the structure of the deep Calhoun CZ and resulted in the *Science* paper on regolith structure and bedrock fractures (St. Clair et al. 2015). In 2016 WyCEHG returned to the Calhoun CZO in Feb and Aug for nearly 50-person-days of work with many Calhoun researchers to deploy new instrumentation (see ATTACHED FILE #1). A new manuscript is being coauthored by Drs. Holbrook, Brantley, Richter and Bacon that explicitly integrates geophysics and geochemistry data. A research proposal for NSF's IES program will build on St. Clair et al. (2015) and the new geophysics-geochemistry paper.

b) Land-Use History. Environmental anthropologists and historians are assembling a story of changes in the land at the Calhoun CZO. Historical records, aerial and on-ground photography, and census data are assembled, modeled and interpreted.

c) Land-Use History Comparison of CZs. Nine sites are intensively instrumented to quantify structure and function of CZs affected by contrasting land use histories: three sites each are in old-field pine forests that are 60 to 90 years from farm abandonment, in uncultivated reference hardwoods that exhibit minimal farming impacts, and in currently cultivated fields. In these plots, we log soil moisture, temperature, CO_2, and O_2 sensors at 0.5- and 1.5-m, and measure moisture by neutron probe and four gases down to 5-m. In Oct 2016, we are excavating these sites to 3-m depth with backhoe to sample rooting depths, water-stable aggregates and Ksat.

d) Long-term Experimental Watersheds. Measurements of rainfall and streamflow continue on the reinstrumented watersheds that historically operated from the 1940s to the early 1960s. An array of new groundwater wells with water sensors

operate throughout the catchment and within Holcombe's Branch legacy sediments. The reinstrumentation of the three Calhoun watersheds will allow us to quantify changes in hydrologic responses of eroded and gullied catchments as they have been reforested over the decades. Historic strip charts continue to be analyzed by a number PIs and students with the help of the US Geological Survey and Coweeta Hydrologic Lab.

e) Calhoun Long-Term Soil-Ecosystem Experiment (LTSE). Preparations are being made for the 11th soil sampling from the 60-year LTSE plots in 2017. In 2016, plots prepared for sampling in 2017. Of interest in the 2017 collection will be studies of temporal dynamics of organic carbon throughout the upper CZ and structural re-aggregation in the clayey B horizon.

2. Erosion-Induced Carbon Dynamics

a) Observations. Samples of legacy sediments are collected from channels of Holcombe's Branch to estimate the C contents of these remarkable sediments. Buried A horizons can be found in many profiles, and not a small amount of C has accumulated in incipient A horizons under regenerating forests. A senior thesis provided an opportunity for our initial estimates of C content in the historic alluvium, and a Duke PhD student is leading the research toward a peer-review paper. Of major interest are changes in microbiology and biogeochemistry of soil organic matter as it is buried in legacy sediments.

b) Modeling. Modeling of the process of carbon loss during erosion and gain during agriculture and reforestation has led to a published paper and a second related and submitted manuscript on the uncertainties of model estimates. The model is directly derived from the geomorphology model tRIBs.

3. Persistence of Alternative States

Environmental historians and anthropologists have met throughout the year, working with modelers to better understand changing land and human dynamics, frame several papers, and prepare for a research proposal to NSF's Coupled Human Systems program. The investigators have visited each other's campuses for multiple days of collaboration.

4. Education and Outreach Program

A variety of educational modules illustrate CZ science concepts. Interactive iBooks use GIS-based maps, images, and video based on the Calhoun CZO. Materials on CZ science are disseminated at professional development meetings for educators. A new CZ science class has been made a permanent part of the

curriculum at Roanoke College; course materials will be broadly shared with undergraduate educators. CCZO field tours have been given throughout our existence. In the field, we find people to be captivated by CZ science, the Calhoun landscape and its history, and changes on-going today. Interest has been high among REUs studying soils at North Carolina State University as well as soil conservation veterans.

5. Cross-CZO Projects

In addition to collaborating with WyCEHG which collects geophysics data at many CZOs, Calhoun PIs and students actively participated in several cross-CZO workshops of 2015, and are contributing to the post-workshop publications. Several of our students have dissertation chapters based on multiple CZOs. Our E&O leader PI O'Neill has been especially active with the NO and the national E&O team. Our data manager participates in communications with the national team of data managers.

B. Six activities that support the project at large

1. Calhoun CZO Executive Committee. At the suggestion of the Virtual Site Review, five PIs representing most of the subcontracts and institutions have met electronically nearly every month since February. This has helped with communication, governance, and raising new business such as our recent revision of our data sharing policy (below).

2. Calhoun CZO Research Areas. We have developed seven major research areas across the CZO, areas in which most or our on-the-ground activities are based. These sites are being developed as long-term research areas. In addition, we have a network of ten hillslopes and catchments across the Sumter National Forest, each of which have paired sites that are intensively and less intensively impacted by historic land use.

3. Calhoun CZO-USFS Relations. Much of the CZO is located on the Sumter National Forest. In 2016, we successfully updated our USFS research permit under NEPA. PI Richter and USFS managers interact often and a copy of the USFS Permit is attached to this report (see ATTACHED FILE #2). We believe USFS managers are earnestly interested in helping our project succeed and they are especially impressed with our students. We may well expand collaborations with USFS managers in the future, for example with a USFS-CZO Field Day at a local K-12 school.

4. Third Annual Calhoun Summer Science Meeting. In May 2016, investigators met at Musgrove Mill State Historic Site (where the mill's foundation was recently

excavated below 2-meters of legacy sediment) to present results, discuss initiatives, and make decisions about the project. In previous annual meetings, our objective was to educate all investigators on critical zone science but also in the details of on-going work. This summer we organized researchers to give talks in the context of the five project goals, with extensive discussions occurring on hypotheses, E and O, and cross-CZO research.

5. Calhoun CZO Website. Our website describes our observatory's growing research, infrastructure, data, models, publications, people, and E and O programs. Our data manager is coordinating year-three updating of the website's descriptions.

6. Data Policy and Management. Our data-sharing policy has been strengthened *within our Observatory*. The Executive Committee approved an acceleration from 12 to 6 months as the maximum time data can be held without sharing amongst investigators. Our data manager and PI Richter are working with an outside firm, DataMesh, to help design a data management platform to both analyze and report CZO data. The system is designed to be R and Matlab compatible and to streamline data QA/QC and entry into a database.

Specific Objectives:

Specific objectives, like major activities above, are organized by our five specific project goals.

1. Hydro-biogeochemical Decoupling and Regeneration of the CZ following Land Degradation.

a) Deep Geophysics and Geochemistry. To use advanced instrumentation and techniques in geophysics and geochemistry to evaluate the structure of the deep, highly weathered Calhoun CZ.

b) Land-Use History. To geographically coordinate historic and contemporary social, land-use, and land-cover data, including aerial photography and remote sensing data, deed chains, census data, and individual farm records, all to describe, evaluate, and model changes in the Calhoun CZ through time, emphasizing how historic land uses shape the contemporary and future of the land, including its management and human livelihoods.

c) Land-Use History Comparisons of CZs. To sample, instrument, and model CZ profiles that have experienced contrasting land-use impacts, all to better understand historical legacies, depth dependence, and regeneration rates of hydro-biogeochemical processes that connect the surface and the deep subsurface of the Calhoun CZ.

d) Long-term Experimental Watersheds. To reinstrument historic experimental watersheds and thereby continue precipitation and streamflow records of watersheds as they evolve from eroded gullied watersheds in the 1940s through 1960s to fully reforested contemporary catchments. Intensive up-instrumentation will allow us to model the intra-watershed hydrologic changes over decadal time scales.

e) Calhoun Long-Term Soil-Ecosystem Experiment (LTSE). To use an eddy flux tower to monitor heat, CO_2, and water fluxes in the midst of our LTSE plots. To resample soils and trees in 2017, the 60th year following conversion of cotton fields to pine forests. Our specific objectives will be to focus on changes of organic carbon at depth and changes in soil macroporosity and aggregation over the decades.

2. Erosion-Induced Carbon Dynamics. To directly estimate and model the carbon budget of the Calhoun CZO's Holcombe's Branch watershed from 1800 to the present, especially accounting for erosional losses and reaccruals on uplands, and burial, storage, and reaccruals on alluvial floodplains that are now inundated with legacy sediments.

3. Persistence of Alternative States. To better understand and model how CZs respond to severe land disturbance that threatens their resilience and regeneration.

4. Education and Outreach. To promote awareness and discussion of CZ science in the wider undergraduate communities that ultimately play the citizen's role in shaping land use and public policy.

5. Cross-CZO Research and Projects. To encourage, develop, and prioritize the most transformative of cross-CZO opportunities for research, sample and data sharing, and other projects. Specifically, to contribute to cross-site modeling, hydrologic analyses, biogeochemistry, forest ecology, flux measurements, pedogenesis, environmental history, systems science, organic carbon cycling, and E&O.

Significant Results:

Results are organized with the same structure as project specific goals, activities, and objectives.

1. Hydro-biogeochemical Decoupling and Regeneration of the CZ following Land Degradation.

a) Deep geophysics and geochemistry of the Calhoun CZ. As shown in the attached FILE #1, a remarkable set of multidisciplinary data sets of the deep Calhoun weathering profile are being assembled and fit almost hand in glove. That is, the geophysical structure of the 70-m weathering profiles support many of the geochemical changes we observe. A high visibility paper is being rapidly written based on these results.

b) Land-Use History. History and impacts of land-use change are being studied by social scientists and environmental historians who have gathered data that help all of us appreciate that many cotton farmers were not miners, simply exploiting the land, but that they extensively terraced and intimately interacted with the erosion they accelerated as they farmed. This probably extended far back into the 19th c. and is an interpretation strongly supported by 1933 aerial photography and contemporary LiDAR imagery.

c) Land-Use History Comparisons of CZs. Our monitoring of nine replicate sites that have experienced a range of land-use histories indicate that land use history strongly affects CZ processes of weathering, hydrology, and land-atmosphere and land-bedrock fluxes of water and gases. A full year of quarterly sampling for soil macroinvertebrates in the nine plots suggests major difference in communities and in soil bioturbation among the land uses.

d) Historic Experimental Watersheds. Time-series data of over 2-years are being collected from surface streams and from the subsurface in the historic Calhoun watersheds and these inform data-rich explorations of watershed hydrology both within the high-gradient, seriously-eroded watersheds and within the low-gradient zones of legacy sediments that often mediate flow from uplands into high-order streams. The experimental watersheds exhibit highly dynamic seasonal storm response as well as high variability in 3D with spatial response controlled by landscape position and soil depth. Legacy sediment deposits often control the transition between surface flow to subsurface flow and in so doing partially or fully sever the surface connections between low-order watersheds and higher-order streams. Conceptual modeling is underway to help elucidate the implications of the convolution of the dynamic, flashy upland responses with the more moderated transport through depositional zones at the scale of higher-order streams and even regional rivers.

e) Calhoun Long-Term Soil-Ecosystem Experiment (LTSE). A CO_2, heat, and water flux tower has been erected in the Calhoun LTSE and is now collecting data. The tower is in the midst of the 60-year old field study whose soils will be resampled for the 11th time in 2017, when the study of reforestation effects on cultivated soils will be 60 years in age. Tower results will greatly enrich observational data of soil change, results of which to date are summarized in our book and in dozens of peer-review papers.

2. Erosion-Induced Carbon Dynamics.

a) Observations. Initial estimates of organic carbon stored in legacy sediments of the Holcombe's Branch were made by mid-2016. A senior honors thesis was developed using these data, which indicate large buried organic carbon under 50 to 200 cm of legacy sediments. Spectacular buried profiles were discovered and excavated for education and demonstration.

b) Modeling. Results of watershed-scale modeling were published from a spatially and depth-explicit model of soil organic carbon (SOC) dynamics developed for the tRIBS model (Triangulated Irregular Network-based Real-time Integrated Basin Simulator) and applied to Calhoun CZO's Holcombe's Branch. Results indicated that SOC erosion and its replacement exhibit significant topographic variation at small scales of <10s of meters. Net atmospheric C exchange from the Calhoun's Holcombe's Branch watershed is estimated to range from a source of 14.5 g $m^{-2}y^{-1}$ to a sink of 18.2 g $m^{-2}y^{-1}$. The small-scale complexity of SOC erosion and burial driven by topography exerts a strong control on the landscape's capacity to serve as a C source or a sink.

3. Persistence of Alternative States. We extended the previous formulation of the dynamical system describing the interaction of ecohydrological and human dynamics in agroecosystems at the Calhoun, with special attention to the history of land use, its land degradation and subsequent reforestation. In particular, the group led by co-PI Porporato at Duke has made the model spatially explicit in order to describe the development of agricultural activities starting from the more fertile and accessible bottomlands, and then subsequently expanding upland towards hillslopes and ridges. Porporato's group is currently calibrating the model using data obtained by archeological and anthropological research by the UGA group (led by co-PI Nelson). We expect to find mathematically the conditions (possibly indicated by thresholds in the soil biogeochemical variables) leading to the agricultural collapse and abandonment as a function of the external pressures induced by the cotton market. We then plan to model spatially the phase of degradation and regeneration with particular attention to the nonlinear interactions between social and ecohydrological processes.

4. Education and Outreach. Results include successful development of educational modules derived from spatial datasets using ESRI Story Maps and .kml files for use with Google Earth, cloud-based formats widely available at no cost to educators. We believe these to demonstrate the feasibility to serve as a template for other CZOs. Our E&O leader, Dr. Kathy O'Neill has participated actively with the NO and the National Education and Outreach team with whom she has helped move several E&O projects ahead. The Calhoun CZO is affiliated with NSF's REU in Soil Science run by North Carolina State and two full-day field trips have now been given to a total of 23 REU undergrads discussing CZ science, soils, and the Calhoun CZO.

5. Cross-CZO Research and Projects. More than half of the CCZO PIs are involved with active cross-CZO research projects. Results are accumulating across sites from field-based mineral weathering experiments led by our Japanese colleagues, soil microbial and biogeochemistry studies, and hydrologic modeling with PIHM. Redox-related experiments have been conducted in several CZOs and will be part of at least two PhD student's dissertations. We support the cross-site post-doc who will investigate hydrologic partitioning, and we support several cross-site E&O projects including the co-authoring a published paper in *The Earth Scientist* that describes opportunities for integrating CZ science into environmental science courses at the undergraduate and high school levels. Our geophysics and geochemistry data from our 70-m weathering profile has proven of such interest that it has drawn scientists from other observatories and research centers to write several papers about the close relations of the geophysical and geochemistry data.

Key outcomes or Other achievements:

Five exciting outcomes from across the CCZO include.

1. The establishment of a "mini-CZO" with funding from German and non-Calhoun CZO support. One of our PhD students, Zach Brecheisen, travelled to the University of Koblenz-Landau (Prof. Hermann Jungkunst) and installed moisture and biogeochemical sensors and logging equipment, training master's students and scientific technicians. Data loggers are monitoring dynamics of the critical zone to 8.5 meters depth, under beech forest, vineyard, and maize.

2. The German government supported the travel of PI Richter to travel with Brecheisen to attend a workshop in which he discussed the new 21st century science of Earth's critical zone.

3. Our USFS scientist colleague on the Calhoun CZO team, Dr. Mac Callaham, has recruited a PhD student who is now working at the CZO on the soil ecology of

forest regeneration. Mac also was named the Director of the Calhoun Experimental Forest in 2016.

4. Five Duke PhD students working at the Calhoun CZO now have support from the NSF-IGERT program entitled WISeNet.

5. One of our PIs, Prof. Paul Schroeder, returned from a year-long sabbatical in Turkey during which he waved the CZO flag among many geosciences organizations throughout the country. Schroeder successfully led the signing of University of Georgia's first ERASMUS+ agreement, which will generously fund exchange of Turkish and American faculty and students, all to promote CZO science.

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

All across the Calhoun CZO, PIs are committed to linking research wherever possible with training both in the lab and the field.

Examples of 2016 opportunities for training and professional development include:

1. High school student education. At Duke and University of Georgia, high school students have been included in research. At Duke, a honors student from the North Carolina School of Science and Mathematics is mentored by a Calhoun CZO PhD student, Anna Wade, over nearly one year. The student has already orally presented her work and will write it up as a senior thesis. The experience has deeply influenced her interests and future trajectory. At the University of Georgia, a high school student was hired to work in a soil physics lab and another worked with the environmental anthropology team as an intern helping with data organization and analysis. At Roanoke College, K-12 educators participated in four science pedagogy meetings at which our E&O PI gave a presentation about CZ and environmental science.

2. Undergraduate education. At Roanoke College, Duke, the University of Georgia, and the University of Kansas, undergraduates were involved in various ways with CZ science and the Calhoun CZO. At Roanoke College, PI O'Neill has provided training and opportunities for professional development to undergrads by supporting eight independent studies and research projects, including two senior theses related to CZ science. Laboratory and classroom activities have been developed and tested as part of the development of CZ educational materials that have been part of the education of more than 50 undergraduate Roanoke College students in the last 18 months. One Roanoke undergraduate was enthusiastic enough to volunteer to work on two hot very arduous

Calhoun summer field trips "in order to get field experience." At Duke, a new interdisciplinary course entitled "Environment in Literature, Law, and Science" was given to more than 50 undergraduates, and the Earth's critical zone was made a cornerstone of the science in the class. Also at Duke, twelve undergraduates in North Carolina State University's REU in Soil Science were given a day-long field tour in CZ science. At UGA, undergraduates were trained by a Calhoun CZO PhD student in the soil judging competition in which the undergraduate team achieved national-level awards. Undergraduates also worked in a soil physics laboratory, completed a senior thesis, and three interned in a clay mineralogy lab processing CZO samples for isotope analyses. An undergraduate from DePauw University interned with a UGA CZO lab to satisfy his experiential learning requirement for his degree program. At the University of Kansas, three undergraduates were trained to use lab equipment to analyze soil sample incubations.

3. Graduate education. At Duke, Georgia Tech, Mississippi State, the University of Georgia, and the University of Kansas, graduate students are involved in significant ways with our CZ science and the Calhoun CZO. At Duke, seven PhD students are working on CZ biogeochemistry, hydrology, and systems modeling. Five have earned support from an NSF IGERT program in wireless technologies. At Georgia Tech, graduate students work in Rafael Bras' and Jingfeng Wang's laboratories with highly talented post-docs and visiting research scientists at the flux tower, in model development and simulation, and data production, processing, and analysis. At Mississippi State, a graduate student has worked to collect and analyze environmental history data. At the University of Georgia, graduate students are trained to collect and analyze field EMI, electrical resistivity, stream chemistry, and soil phosphorus data. At the University of Kansas, graduate students are trained in the use of soil and enzyme incubation techniques to assess soil microbial activities. All of these graduate students are presenting their results and integrated CZ science at a wide variety of forums, from AGU and EGU to local science and 4-H clubs. Calhoun PIs try to interact with all of these graduate students *across institutions*. They are publishing papers in flagship science journals such as *Water Resources Research*, receiving awards the interdisciplinary training that is needed for the next generation of Earth scientists.

4. Postdoctoral scientists. At Duke, the University of Georgia, and the University of Kansas, postdoctoral scientists are involved in important ways with our CZ science and the Calhoun CZO. At Duke, Dr. Jay Austin has moved from the University of Georgia to Duke in the last year and has moved into a position that will decidedly broaden his range of expertise. Well trained as a clay mineralogist, Jay is now monitoring groundwater, sampling and analyzing soil and water chemistry, and expanding his purview of CZ science. Also at Duke, Anthony Parolari has been involved in all aspects of the CZO research. He has helped mentor graduate students, helped reconstruct the experimental Calhoun watersheds, and conducted a variety of modeling projects with long-term Calhoun data. Dr. Parolari has recently moved to an assistant professor position at

Marquette University. At the University of Kansas, postdoc Dr. Christoph Lehmeier is involved in soil incubations and analyzing microbial abundance and community composition. Christoph has worked at the Calhoun on a number of occasions where he has readily learned a variety of field skills. He has helped plan what is called the Calhoun Big Dig Fall 2016 which will compare deep soil profiles of CZs that have experienced contrasting land use histories. He is mentored mainly by PI Billings but also PI Richter.

One very grave tragedy of 2016, was that we lost a beloved University of Georgia PhD student, Ashley Block, who was killed by an impaired driver while riding her bicycle. Ashley was a dynamo with infectous smile, an earnest interest in the Calhoun CZO and its potential for science and broader impacts, a 25-year old with enormous future potential. This is a tragic loss to her family, her friends, to UGA, and to the Calhoun CZO and entire CZ community.

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

Calhoun CZO research is being published in the leading international science journals, including *Science*, *Water Resources Research*, *Global Biogeochemical Cycles*, and *New Phytologist* as examples. We are presenting talks to many university groups and scientific conferences (see Products for details). In addition, PIs of the Calhoun CZO have explictly reached out to Earth science, environmental, engineering, and ecological communities to explain the details and the need for an integrated critical zone science. Some examples follow.

Hydrologists: PI Porporato and his students and postdocs continue to do a remarkable job in promulgating the CZ concept in a variety of hydrology forums. His student Mark Bartlett presented his work at AGU and EGU and at a CUAHSI symposium. As a CUAHSI Board of Director, PI McGlynn is a bridge from CZ science to the CUASI program and his hydrology student John Mallard won an "outstanding student presentation award" at the 2016 EGU general assembly.

Ecologists: 1) To promote more concrete collaboration between the CZO, LTER, and NEON programs, PI Richter with Tim White, Bill McDowell, and Peter Groffman are leading the drafting of a peer-review paper to be submitted to BioScience. This was a direct outgrowth of their Working Group at the All Scientists Meeting of LTER in late August 2015. 2) PIs Billings and Richter's review, "One Physical System" for the *New Phytologist* was cited 15 times in its first year. 3) Calhoun CZO research was presented by Kansas PhD student KJ Min at the International Society of Microbial Ecology.

Earth scientists: We gave talks and posters on CZ science and the Calhoun CZO at the meetings of AGU and EGU.

Clay mineralogists: PI Schroeder was a principle host of the Clay Minerals Society meeting held in Atlanta, in which he helped sponsor a session of talks entitled, "Clays in the Critical Zone". A field trip to the Calhoun CZO was organized.

Stratigraphers: PI Richter gave a talk on Earth's critical zone to the International Commission on Stratigraphy's Anthropocene Working Group, who met in Oslo, Norway in May 2016.

Environmental history: PIs Giesen, Nelson, and postdoc Coughlan all advance the interdisciplinary critical zone science as they see the latent importance of critical zone history across many of the CZOs. They have discussed the possibility of initiating a discussion on environmental history as a Cross-CZO working group.

Environmental humanities: PI Richter co-taught a new Duke class entitled, "Environment in Literature, Law, and Science", an interdisciplinary class taught at high intellectual level to 50 Duke undergrads. In the fall of 2016, PI Richter is working full time on the Calhoun CZO but has an office in the Franklin Humanities Institute (FHI), engaging environmental humanities scholars with critical zone science. Richter is collaborating with FHI's videographer Eric Barstow on a 20- to 30-min video surrounding the discussions between about a dozen humanities scholars and philosopher Bruno Latour, who visited the Calhoun CZO and Duke in September 2015. The video is called, "The Critical Zone Education of Bruno Latour."

Geology and environmental science educators (undergraduates and advanced high school): PI O'Neill and her students continue to disseminate materials via presentations at national and regional scientific and pedagogical meetings, Professional Development Institutes for educators, classroom and laboratory teaching, site visits, public outreach events, and on the CZO website. O'Neill is most focused on building bridges with geology and environmental science professors at small liberal arts institutions.

International geologists: PI Schroeder was invited to give a talk about the Iznik Lake CZO at the 7th International Geochemistry Symposium held in Antalya, Turkey in May 2016. PI Richter invited UNAM Prof. Christina Siebe to Duke and to the 2015 AGU meeting, as she is Lead-PI of the very impressive Mezquital Valley CZO near Mexico City.

International science: Both PIs Schroeder and Richter have been active in giving talks and participating in international discussions to advance CZ science. PI Schroeder gave another talk in Turkey in 2016, following his 10 invited lectures at universities and conferences while on sabbatical in Turkey during 2015.

Postdoc and graduate student communities: Many formal and informal presentations were given to student groups and organizations by Calhoun CZO students across many disciplines.

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

A. Year four plans are organized using the five specific goals of the CCZO project.

1. Hydro-biogeochemical Decoupling and Regeneration of the CZ following Land Degradation

a) Deep Geophysics and Geochemistry. We will continue to collaborate writing papers with WyCEHG and a drilling-related proposal of observation and modeling the deep, ancient critical zone across the Calhoun CZO. Particularly of value is to test the unexpected conclusions reached in St. Claire et al. (2015). Encouraged by our Virtual Site Visit review in late 2015, we will continue to install groundwater wells in and around the 70-m well. Rare earth elements are being measured to expand geochemical information of the 70-m core.

b) Land-Use History. Environmental anthropologists and historians are continuing to assemble the history of changes in the land at the Calhoun CZO. Historical records, aerial and on-ground photography, and census data are used in geographically explicit models to interpret human forcings that accelerated and decelerated soil erosion on uplands and hillslopes and sedimentation of valley bottoms.

c) Land-Use History Comparison of CZs. Nine sites will continue to quantify the structure and function of CZs affected by contrasting land use histories: three sites in old-field pine forests that are 60 to 90 years from farm abandonment, three in uncultivated reference hardwoods that have minimal farming impacts, and three in currently cultivated fields. We will continue to log soil moisture, temperature, CO_2, and O_2 at 0.5- and 1.5-m, and measure moisture by neutron probe and four gases down to 5-m. We will estimate Ksat throughout soils and upper saprolite of the nine sites, and initiate the broadcast to the internet via modem of some of our logged data.

d) Long-term Experimental Watersheds. Measurements of rainfall and streamflow continue on the reinstrumented watersheds in addition to the array of groundwater wells with water sensors throughout Watershed 4 and within Holcombe's Branch legacy sediments. Analysis of historic strip charts will be completed with the help of instruments at the US Geological Survey and Coweeta Hydrologic Lab.

e) Calhoun Long-Term Soil-Ecosystem Experiment (LTSE). The 16 LTSE plots will be resampled in 2017, and samples archived 60 years from the initiation of the field study. Analyses will focus on temporal dynamics of organic carbon throughout the upper CZ and structural re-aggregation in the clayey B horizon.

2. Erosion-Induced Carbon Dynamics

a) Observations. Our first manuscript on legacy sediments will be produced in 2017, a paper focused on the sediment inundation of soil organic carbon (SOC) in Holcombe's Branch. Studies will be conducted in the laboratory of the changes in microbiology and biogeochemistry of soil organic matter as it is buried in legacy sediments.

b) Modeling. The update of the distributive model tRIBS-ECO will be initiated updating the initial simulations with much more data that have been gathered as the research teams have studied the Calhoun. We actually anticipate that in year five this paper will be written and submitted but a deliberate approach to the model which can in years 4 and 5 include many more PIs and students will be well worth the effort.

3. Persistence of Alternative States

Environmental historians and anthropologists will be producing at least two papers during the year, and also working with modelers to better quantify the history of changing land and human dynamics. This team intends to submit a research proposal to NSF's Coupled Human Systems program. The investigators will continue to visit each other's campuses for multiple day of collaborations.

4. Education and Outreach Program

Classroom test educational materials for the new undergraduate course in CZ science. Publish educational materials that integrate interactive maps, text, imagery, and video. Document pedagogical materials and assessments in a manuscript that will be submitted to a pedagogical journal. Publish outreach materials using cloud-based and distributed formats. Collaborate on cross-CZO E&O teams coordinated through the National Office. Continue and expand recruitment of undergraduate students, especially from underrepresented groups, to assist with Calhoun research.

5. Cross-CZO Projects

PIs and students will continue to actively participate in several cross-CZO projects, specifically the soil biogeochemistry, hydrology, and E&O projects. Our data manager will continue to participate in the Cross-CZO effort to promote program-wide data management. Intensive measurement of O_2, redox potential, Fe(II), DOC, and pH will be conducted at the Calhoun over six weeks to match a study successfully completed at the

Luquillo CZO, to demonstrate the widespread importance of redox fluctuations in upland CZs.

B. Plans that support the project at large

1. Calhoun CZO Executive Committee. The Executive Committee will continue to meet once a month, with the sole objective of getting the most scientific and societal impact from our CZO.

2. Calhoun CZO-USFS Relations. We will continue to work closely with the managers of the Sumter National Forest.

3. Fourth Annual Calhoun Summer Science Meeting. The Executive Committee will be in charge of organizing this coming year's Summer Science Meeting. We are considering coordinating research activities along with the meeting.

4. Calhoun CZO Website. Our website will continue to be the focus for our observatory's growing research, infrastructure, data, models, publications, people, and E and O programs.

5. Data Policy and Management. We will work to implement our accelerated data-sharing policy *within our Observatory*. Our data manager and PI Richter will continue to work with an outside firm, DataMesh, to design a data management platform to both analyze and report CZO data. The system will be R and Matlab compatible and will aim to streamline data QA/QC and entry of data into the Calhoun data base.

Supporting Files

	Filename	Description	Uploaded By	Uploaded On
(Download)	FILE #1. Fusing geochemistry & geophysics at Calhoun.pdf	FILE #1. Calhoun CZ 70-m geochemistry & geophysics	Daniel Richter	09/28/2016
(Download)	FILE #2. CalhounCZO_Research_Permit_2016.pdf	FILE #2. USFS Research Permit	Daniel Richter	09/28/2016
(Download)	Dialynas_YG2016-Global_Biogeochemical_Cycles.pdf	FILE #3. PhD student Dialynas'	Daniel Richter	09/29/2016

	Filename	Description	Uploaded By	Uploaded On
		paper in Global Biogeochemical Cycles		
(Download)	2016 CCZO Supplementary Subm.pdf	Supplemental Information 2015-16	Daniel Richter	10/04/2016

Products

Books

- Intergovernmental Technical Panel on Soils led by Montanarella, L. and eight editors with nearly 200 contributing authors including D. deB. Richter. (2015). *Status of the World's Soil Resources Report* Food and Agriculture Organization of the United Na. Rome, Italy. Status = PUBLISHED; Acknowledgment of Federal Support = No ; Peer Reviewed = Yes

Book Chapters

- Richter, D. deB., A.R. Bacon, S.A. Billings, D. Binkley, M. Buford, M.A. Callaham, A.E. Curry, R.L. Fimmen, A. S. Grandy, P.R. Heine, M. Hofmockel, J.A. Jackson, E. LeMaster, J. Li, D. Markewitz, M.L. Mobley, M.W. Morrison, M.S. Strickland, T. Waldrop, and C. G. Wells (2014). Evolution of Soil, Ecosystem, and Critical Zone Research at the USDA FS Calhoun Experimental Forest. *USDA Forest Service Experimental Forests and Ranges: Research for the Long Term* D.C. Hayes, S.L. Stout, R.H. Crawford, A.P. Hoover. Springer Verlag. New York. 405. Status = PUBLISHED; Acknowledgement of Federal Support = No ; Peer Reviewed = Yes ; ISBN: 978-1-4614-1817-7.
- Richter, D.deB. (2016). The Crisis of Environmental Narrative in the Anthropocene. *Whose Anthropocene?* Robert Emmett and Thomas Lekan. Rachel Carsen Center. Munich. 97. Status = PUBLISHED; Acknowledgement of Federal Support = Yes ; Peer Reviewed = Yes ; ISSN: 2190-5088.

Inventions

Journals or Juried Conference Papers

- Austin, Jason C., Amelia Perry, and Paul A. Schroeder (2016). Clay minerals from adjacent hardwood, pine, and pasture sites in the Calhoun Critical Zone Observatory, South Carolina, USA. *Clays and Clay Minerals*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Bartlett, M.S., A.J. Parolari, J.J. McDonnell, and A. Porporato (2016). Beyond the SCS-CN method: Theoretical framework for spatially-lumped rainfall-runoff response. *Water Resources Research*. 52 (6), 4608. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/2015WR018439
- Bartlett, M.S., A.J. Parolari, J.J. McDonnell, and A. Porporato (2016). Framework for event-based semidistributed modeling that unifies the SCS-CN method, VIC, PDM, and TOPMODEL. *Water Resources Research*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/2016WR019084
- Bartlett, M.S., E. Daly, J.J. McDonnell, A.J. Parolari, A. Porporato (2015). Stochastic rainfall-runoff model with explicit soil moisture dynamics. *Proceedings of the Royal Society A*. 471 (2183), 20150389. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1098/rspa.2015.0389
- Brevik, E.C., D.deB. Richter, E.P. Verrecchia, J. Ryan, R.M. Poch, O. Crouvi, D. Sauer, J. Waroszewski, E. Solleiro-Rebolledo, C. Monger, F. Ottner, V. Targulian (2016). The influence of Dan H. Yaalon: His impact on people. *Catena*. 146 147. Status = PUBLISHED; Acknowledgment of Federal Support = No ; Peer Reviewed = Yes ; DOI: 10.1016/j.catena.2015.10.012
- Campbell, J.H., L.A. Morris, and D. Markewitz (2015). Combining electromagnetic induction and resistivity imaging with soil sampling to investigate past soil disturbance at Wormsloe State Historic Site, Savannah, GA. *Soil Horizons*. 56 (6), 1. Status = PUBLISHED; Acknowledgment of Federal Support = No ; Peer Reviewed = Yes ; DOI: 10.2136/sh15-07-0015
- Cherkinsky, A., and Wallace K. (2016). Radiocarbon Age of Soil Organic Matter Fractions Buried by Tephra in Alaska. *Radiocarbon*. . Status = PUBLISHED; Acknowledgment of Federal Support = No ; Peer Reviewed = Yes ; DOI: 10.1017/RDC.2016.47
- Coughlan, Michael R., Donald R. Nelson, Michael Lonneman, Ashley Block (2016). Socioecological dynamics of land degradation and agricultural transition in South Carolina's Piedmont Critical Zone. *Landscape and Urban Planning*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Cyle, K.T., N. Hill, K. Young, T. Jenkins, D. Hancock, P.A. Schroeder, A. Thompson (2016). Substrate quality influences organic matter accumulation in the soil silt and clay fraction. *Soil Biology and Biochemistry*. 103 138. Status =

PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.soilbio.2016.08.014

- Dialynas, Y. G., R. L. Bras, and D. deB. Richter (2016). Hydro-geomorphic perturbations on the soil-atmosphere CO2 exchange: How (un)certain are our balances?. *Water Resources Research*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Dialynas, Y. G., S. Bastola., R. L. Bras, S. A. Billings, D. Markewitz, and D. deB. Richter (2016). Topographic variability in the influence of soil erosion on the carbon cycle. *Global Biogeochemical Cycles*. 30 (5), 644. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/2015GB005302
- Huang, S.-Y., and J. Wang (2016). A coupled force-restore model of surface temperature and soil moisture using the maximum entropy production model of heat fluxes. *Journal of Geophysical Research Atmospheres*. 121 (13), 7528. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/2015JD024586
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- Lehmeier, C.A., F. Ballantyne IV, K. Min, and S.A. Billings (2016). Temperature-mediated changes in microbial carbon use efficiency and 13C discrimination. *Biogeosciences*. 13 3319. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.5194/bg-13-3319-2016
- Liu, Y., and M. Kumar (2016). Role of meteorological controls on interannual variations in wet-period characteristics of wetlands. *Water Resources Research*. 52 (7), 5056. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/2015WR018493
- Mau, Y. and A. Porporato (2016). Optimal control solutions to sodic soil reclamation. *Advances in Water Resources*. 91 37. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.advwatres.2016.02.014
- McEwen, A.R., H. Hsu-Kim, N.A. Robins, N.A. Hagan, S. Halabie, O. Barras, D.deB. Richter, J.J. Vandenberg (2016). Residential metal contamination and potential health risks of exposure in adobe brick houses in Potosí, Bolivia. *Science of the Total Environment*. 562 237. Status = PUBLISHED;

Acknowledgment of Federal Support = No ; Peer Reviewed = Yes ; DOI: 10.1016/j.scitotenv.2016.03.152

- Mobley, Megan L., Kate Lajtha, Marc G. Kramer, Allan R. Bacon, Paul R. Heine, and Daniel deB. Richter (2015). Surficial gains and subsoil losses of soil carbon and nitrogen during secondary forest development. *Global Change Biology*. 21 (2), 986. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1111/gcb.12715
- O'Neill, K.P., and D.deB. Richter (2016). Learning from the "deep changes in the land": The Critical Zone perspective in environmental science education. *The Earth Scientist*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Parolari, A.J., M.L. Mobley, A.R. Bacon, G.G. Katul, D.deB. Richter, and A. Porporato (2016). Boom and bust carbon-nitrogen dynamics during reforestation. *Biogeochemistry*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Parolari, A.J., Porporato, A. (2016). Forest soil carbon and nitrogen cycles under biomass harvest: Stability, transient response, and feedback. *Ecological Modelling*. 326 64. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.ecolmodel.2016.03.003
- Pascale, S.; Lucarini, V.; Feng, X.; Porporato, A.; Hasson, S. (2016). Projected changes of rainfall seasonality and dry spells in a high greenhouse gas emissions scenario. *Climate Dynamics*. 46 (3), 1331. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1007/s00382-015-2648-4
- Pelak, N.F., A.J. Parolari, and A. Porporato (2016). Bistable plant-soil dynamics and biogenic controls on the soil production function. *Earth Surface Processes and Landforms*. 41 (8), 1011. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/esp.3878
- Porporato, A., and S. Calabrese (2016). Comment on "Storage selection functions: A coherent framework for quantifying how catchments store and release water and solutes" by Rinaldo et al.. *Water Resources Research*. 52 (1), 613. Status = PUBLISHED; Acknowledgment of Federal Support = No ; Peer Reviewed = Yes ; DOI: 10.1002/2015WR017846
- Richter, D.deB. and 15 geo- and bioscientists (). What would Darwin and Lyell Say? Fully Integrating the biogeosciences in long-term environmental networks. *BioScience (under review by authors)*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Shahnaz, S., and J. Wang (2016). Carbon fluxes estimated from surface CO2 concentration. *Geophysical Research Letters*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- St. Clair, J., T. Perron, C. Riebe, W.S. Holbrook, S. Martel, S. Moon, B. Carr, C. Harman, K. Singha, and D.deB. Richter (2015). Geophysical imaging reveals topographic stress control of bedrock weathering. *Science*. 350 (6260), 534.

Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1126/science.aab2210

- Steffen, W. and 27 co-authors including D.deB. Richter. (2016). Stratigraphic and Earth system approaches to defining the Anthropocene. *Earth's Future*. 4 . Status = PUBLISHED; Acknowledgment of Federal Support = No ; Peer Reviewed = Yes ; DOI: 10.1002/2016EF000379
- Waters, C.N., and 23 co-authors, including D. deB. Richter (2016). The Anthropocene is functionally and stratigraphically distinct from the Holocene. *Science*. 351 (6269), 137. Status = PUBLISHED; Acknowledgment of Federal Support = No ; Peer Reviewed = Yes ; DOI: 10.1126/science.aad2622
- Yin, J., J.D. Albertson, J.R. Rigby, A Porporato (2015). Land and atmospheric controls on initiation and intensity of moist convection: CAPE dynamics and LCL crossings. *Water Resources Research*. 51 (10), 8476. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/2015WR017286
- Zalasiewicz J., and 23 co-authors, including D. deB. Richter (2015). Disputed start dates for Anthropocene. *Nature*. 520 436. Status = PUBLISHED; Acknowledgment of Federal Support = No ; Peer Reviewed = Yes ; DOI: 10.1038/520436b
- Zalasiewicz, Jan, et al. including D. deB. Richter (2015). Colonization of the Americas,'Little Ice Age' climate, and bomb-produced carbon: Their role in defining the Anthropocene. *The Anthropocene Review*. 2 117. Status = PUBLISHED; Acknowledgment of Federal Support = No ; Peer Reviewed = Yes ; ISSN: 20530196
- Zi, T., Kumar, M., Kiely, G., Lewis, C., and Albertson, J. (2016). Simulating the spatio-temporal dynamics of soil erosion, deposition, and yield using a coupled sediment dynamics and 3D distributed hydrologic model. *Environmental Modelling & Software*. 83 316. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.envsoft.2016.06.004

Other Conference Presentations / Papers

- Richter, Daniel deB. (2014). *"One Physical System": Why soil is critical to Earth's critical zone*. North Carolina State University. Raleigh, NC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Richter, D. deB., and Billings, S. A. (2015). *"One Physical System": Tansley's Ecosystem Concept as Earth's Critical Zone*. Calhoun CZO Summer Science Meeting. Union, SC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Richter, D deB and Billings SA. (2014). *"One Physical System": Tansley's Ecosystem as Earth's Critical Zone*. Berkeley Univ California. Berkeley, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

- Cherkinsky, A. (2015). *14C and 137Cs distribution in the Ultisol profile*. Calhoun CZO Summer Science Meeting. Union, SC. Status = PUBLISHED; Acknowledgement of Federal Support = No
- Cherkinsky, A., R. Ehlinger (2016). *14C comparative analyses of different SOM fraction in Ultisol, Calhoun CZO*. Calhoun CZO 2016 Summer Science Meeting. Clinton, SC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Brecheisen, Z., and Cook, W. (2015). *1933 CCZO aerial photography mosaic*. Calhoun CZO Summer Science Meeting. Union, SC. Status = PUBLISHED; Acknowledgement of Federal Support = No
- Dialynas, Y. G., Bastola, S., Bras, R. L., Billings, S. A., Richter, D. deB., and Markewitz, D. (2015). *A Coupled Spatially Explicit Modelling Approach to Assess the Influence of Soil Erosion and Deposition on the Redistribution of Soil Organic Carbon at the Watershed Scale*. Southeastern Biogeochemistry Conference. Georgia Tech, Atlanta, GA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Richter, D. (2015). *A Proposal for a Calhoun Drilling Program: Where geophysics meets (bio)geochemistry*. Calhoun CZO Summer Science Meeting. Union, SC. Status = PUBLISHED; Acknowledgement of Federal Support = No
- Porporato, A.; Parolari, A. (2015). *A lumped, macroscopic approach to modeling soil moisture, CO2 transport, and chemical weathering in the critical zone*. American Geophysical Union Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Ehlinger R; Cherkinsky A. (2016). *AMS analysis of soil organic matter fractions of Ultisol separated by density and size*. University of Georgia Center for Undergraduate Research Opportunities Symposium. Athens, GA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Billings, S.A., Richter, D. deB. (2014). *Accelerated erosion and soil atmospheric CO2 exchange: the Calhoun Critical Zone as a model for historically farmed soils*. National Science Foundation's Critical Zone Observatories' All-Hands meeting. Tenaya Lodge, California. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- O'Neill KP and H Morrison (2016). *Adventures in the Earth' critical zone: The Calhoun Critical Zone Observatory*. Virginia Association of Science Teachers. Williamsburg VA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Lonneman. M. (2016). *Agent-based modeling of land use decision-making and soil erosion*. Society for Applied Anthropology. Athens, GA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Thompson A (2015). *Behavior of natural iron nanoparticles in soils*. Georgia State University Geology Seminar Series. Atlanta, GA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

- Giesen, James C. (2015). *Burying King Cotton: Environment and Culture in the Post-Cotton South*. invited address for University of South Carolina "Year of Cotton" Program. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Austin, J., Bacon, A., Billings, S.A., Cherkinsky, A., Richter, D. deB., Schroeder, P. (2014). *CZ-tope at the Calhoun CZO*. National Science Foundation's Critical Zone Observatories' All-Hands meeting. Tenaya Lodge, California. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Mallard, J., B. McGlynn, D. Richter, D. Markewitz, Z. Brecheisen (2014). *Calhoun CZO: understanding critical zone evolution after a legacy of degradation*. Consortium of Universities for the Advancement of Hydrologic Sciences (CUAHSI) Biennial Colloquium. Shepherdstown, WV. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Cherkinsky, A., and Markewitz, D. (2015). *Carbon turnover rates in soils with the different history of land use*. Calhoun CZO Summer Science Meeting. Union, SC. Status = PUBLISHED; Acknowledgement of Federal Support = No
- Austin, J. C. (2016). *Changes in clay mineralogy of the Calhoun related to changes in land-use*. Calhoun CZO 2016 Summer Science Meeting. Clinton, SC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Thompson A (2015). *Chemical behavior of natural iron nanoparticles in soils*. University of Georgia Chemistry Seminar Series. Athens, GA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Foroughi, M. (2016). *Chemical composition of Calhoun streams 2014 to 2016*. Calhoun CZO 2016 Summer Science Meeting. Clinton, SC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Moraes, A.; J. C. Austin; and P. A. Schroeder (2016). *Clay mineral concentration with depth and land use history in the Critical Zone In Calhoun South Carolina*. Geological Society of America. Denver, CO. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Austin, J. C. (2016). *Clay mineralogy of the deep core*. Calhoun CZO 2016 Summer Science Meeting. Clinton, SC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Cherkinsky A; Ehlinger R. (2016). *Comparative analysis of soil organic matter fractionation in Ultisols, Calhoun CZO*. American Geophysical Union Fall Meeting. San Francisco, CA. Status = ACCEPTED; Acknowledgement of Federal Support = Yes
- Coughlan, M., and Nelson, D. (2015). *Comparison of piedmont and mountain fire regimes during forest transition periods*. Calhoun CZO Summer Science Meeting. Union, SC. Status = PUBLISHED; Acknowledgement of Federal Support = No
- Richter, D.deB. and S.A. Billings (2015). *Congruent Core Concepts of the Ecological and Earth Sciences*. LTER All Scientist Meetings. Estes Park. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

- Bacon, A.R. (2016). *Corresponding geochemical and geophysical weathering indices at the Calhoun Critical Zone Observatory*. Calhoun CZO 2016 Summer Science Meeting. Clinton, SC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Dialynas, Y. G., S. Bastola, R. L. Bras, S. A. Billings, D. Richter, D. Markewitz (2015). *Coupled spatially explicit modelling approach to assess the influence of soil erosion and deposition on the redistribution of soil organic carbon at the watershed scale*. 2nd Annual Southeastern Biogeochemistry Symposium. Atlanta, GA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Bastola, S. (2015). *Coupling of Carbon-Nitrogen cycle on a physically based distributed hydrological model, tRIBS*. Calhoun CZO Summer Science Meeting. Union, SC. Status = PUBLISHED; Acknowledgement of Federal Support = No
- Schroeder, P. A. (2015). *Creating deep soil core monoliths: Beyond the Solum*. Calhoun CZO Summer Science Meeting. Union, SC. Status = PUBLISHED; Acknowledgement of Federal Support = No
- Schroeder, P. A., Ö. I. Ece, and N. C. Balci (2015). *Critical Zone Observatories: Overview and current research activities in Turkey and the United States*. 68th Turkish Geological Congress. Ankara, Turkey. Status = PUBLISHED; Acknowledgement of Federal Support = No
- Thompson, A. (2015). *Critical zone research at the University of Georgia*. Departmental Seminar, University of Padua. Padua, Italy. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Bartlett, M. S. and Porporato, A. (2016). *Crop water use and runoff in agricultural watersheds under hydro-climatic variability*. invited talk at North Carolina State University. Raleigh, NC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Mallard, J., McGlynn, B. (2015). *Current Calhoun Hydrologic Sensor Network, Selected Data, and next steps!*. Calhoun CZO Summer Science Meeting. Union, SC. Status = PUBLISHED; Acknowledgement of Federal Support = No
- Schroeder, Paul A.; Jason C. Austin; and Daniel deB. Richter (2016). *Deep regolith bulk mineralogy of the Calhoun Critical Zone Observatory using x-ray powder diffraction*. Clay Minerals Society Annual Meeting. Atlanta, GA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Dypvik, L.R.H., R. Sørlie, N. Oberhardt, P. Tan, K. Stangvik, S. A. A.-E-M. Naqvi, P. A. Schroeder, A. Begonha, and R. Ferrell (2015). *Deeply buried Mesozoic weathering profiles from the Norwegian North Sea*. EuroClay2015. Edinburgh, Scotland. Status = PUBLISHED; Acknowledgement of Federal Support = No
- Dypvik, L.R.H., R. Sørlie, N. Oberhardt, P. Tan, K. Stangvik, S. A. A.-E-M. Naqvi, P. A. Schroeder, A. Begonha, and R. Ferrell (2015). *Deeply buried Mesozoic weathering profiles from the Norwegian North Sea*. Geological Society

of America Annual meeting. Baltimore, MD. Status = PUBLISHED; Acknowledgement of Federal Support = No

- Thompson, A.; Hodges, C.A.; Chadwick, O. (2015). *Delineating climatic regions where upland soil iron reduction is potentially important at the ecosystem scale*. American Geophysical Union Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Thompson, A. (2016). *Depth variation of iron crystallinity at the Calzone*. Calhoun CZO 2016 Summer Science Meeting. Clinton, SC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Thompson, A., Barcellos, D., Wilmoth, J., and Richter, D. (2015). *Depth variation of soil iron crystallinity at the Calhoun CZO*. Calhoun CZO Summer Science Meeting. Union, SC. Status = PUBLISHED; Acknowledgement of Federal Support = No
- Pelak, N. (2015). *Description of topographically-derived spatial soil moisture patterns and finding optimal sampling points*. Calhoun CZO Summer Science Meeting. Union, SC. Status = PUBLISHED; Acknowledgement of Federal Support = No
- O'Neill, KP (2014). *Disturbance and management impacts on the Critical Zone. Coast Dynamics: Stewardship through Problem and Place-based Learning.*. Invited webinar for teacher development series. Portsmouth, VA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Schroeder, P. A. and J. C. Austin (2015). *Dynamics of mineral recrystallization at the Earth's surface: Evidence from Utisols, kaolins, and paleosols with implications for the ages of rocks*. Euroclay2015. Edinburgh, Scotland. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Richter, D. deB., Billings, S.A. (2014). *Earth's Critical Zone as Expanded Ecosystems*. National Science Foundation's Critical Zone Observatories' All-Hands meeting. Tenaya Lodge, California. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Richter, D.deB. and James Giesen (2014). *Earth's Critical Zone as Interdisciplinary Research Ground*. University of South Carolina History Center. Columbia, SC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Richter, D.deB. (2014). *Earth's Critical Zones in the Anthropocene*. International Commission on Stratigraphy's Working Group on the Anthropocene Meeting. Berlin, Germany. Status = PUBLISHED; Acknowledgement of Federal Support = No
- O'Neill, K., and Ramey, A. (2015). *Education and Outreach at the Calhoun CZO: Updates and Request for Input*. Calhoun CZO Summer Science Meeting. Union, SC. Status = PUBLISHED; Acknowledgement of Federal Support = No
- Lehmeier, C.A., Min, K., Good, H., Heroneme C., Billings, S.A. (2015). *Effects of temperature on microbial transformation of organic matter - comparing stories told by purified enzyme assays, chemostat experiments and soils*. American

Geophysical Union Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

- O'Neill KP; Ramey AJ (2015). *Engaging students through virtual field trips: Calhoun CZO*. Virginia Association of Science Teachers. Chantilly, VA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Majasalmi, T., Palmroth, S., Cook, W., Brecheisen, Z., Richter, D. (2015). *Estimation of LAI, fPAR and AGB based on data from Landsat 8 and LiDAR at the Calhoun CZO*. Calhoun CZO Summer Science Meeting. Union, SC. Status = PUBLISHED; Acknowledgement of Federal Support = No
- O'Neill KP (2016). *Exploring landscape processes in South Carolina's southern Piedmont using data from the Calhoun Critical Zone Observatory*. South Carolina Science Council Conference. Columbia SC. Status = ACCEPTED; Acknowledgement of Federal Support = Yes
- Mallard, John M. (2014). *Field to forecast: Leveraging wireless environmental sensor networks to facilitate real-time hydrologic prediction*. CUAHSI 2014 Biennial Colloquium. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Zimmer MA and BL McGlynn (2015). *Flowpath and stream network activation threshold influences on Piedmont runoff generation and biogeochemistry*. Gordon Research Conference on Catchment Science. Andover, NH. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Richter, Daniel deB. (2014). *From "The Changing Model of Soil" to "The Changing Model of Ecosystems"*. Virginia Tech. Blacksburg, VA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Richter D deB, Bacon AR, Brantley SL, Holbrook S (2015). *Geophysical and chemical weathering signatures across the deep weathered-unweathered granite boundary of the Calhoun Critical Zone Observatory*. American Geophysical Union Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Richter, D.deB. (2014). *Global Soil Change: Perspectives from Long-Term Experiments and Critical Zone Science*. Keynote address for UNAM's International Soil's Day Colloquium. Mexico City. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Markewitz, D. and D. Richter (2014). *Historic rainfall-runoff relationships in the Calhoun and Future Critical Zone Research*. Southern Sierra Critical Zone Observatory All Hands Meeting. Fish Camp, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Coughlan, M. (2016). *Historical land use and land use change in and around the Calzone*. Calhoun CZO 2016 Summer Science Meeting. Clinton, SC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Cherkinsky A. (2015). *How 14C signature in SOM change with depth and chemical bonding with minerals*. Workshop: Fate of old carbon in the next

centuries. Hamburg, Germany. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

- Min, K. J., Lehmeier, C. A., Billings, S. A. (2015). *How deep and persistent are the influences of aboveground disturbance on soil microbial activities at the Calhoun CZO?*. Calhoun CZO Summer Science Meeting. Union, SC. Status = PUBLISHED; Acknowledgement of Federal Support = No
- Nelson, D.R. (2016). *Human behavior and the CZO*. Calhoun CZO 2016 Summer Science Meeting. Clinton, SC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Coughlan, M., and D. R. Nelson (2016). *Human niche construction and legacy effects at the Calhoun CZO: The relationship of land use legacies and historical settlement patterns*. Southeastern Archaeological Conference. Athens, GA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Mallard, J.M., B.L. McGlynn, and T.P. Covino (2016). *Hydrologic and biologic influences on stream network nutrient concentrations: Interactions of hydrologic turnover and concentration-dependent nutrient uptake*. European Geosciences Union General Assembly. Vienna, Austria. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Porporato, A.M., and J. Yin (2015). *Impact of cloud timing on surface temperature and related hydroclimatic dynamics*. American Geophysical Union Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Dialynas, Y. G., Bras, R. L., and Richter, D. deB. (2016). *Influence of erosion and deposition on soil organic carbon dynamics*. Calhoun CZO Summer Science Meeting. Union, SC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Baer, S.B., and M.A. Callaham (2016). *Integrating soil ecological knowledge into restoration: How relevant is theory to practice?*. Ecological Society of America Annual Meeting. Ft. Lauderdale, FL. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Noto, L. V., S. Bastola, Y. G. Dialynas, and R. L. Bras (2015). *Integration of fuzzy logic and image analysis for the detection of gullies in the Calhoun critical zone observatory using airborne LiDAR data*. American Geophysical Union Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Noto, L. V., Dialynas, Y., Bastola, S., and Bras, R. L. (2015). *Integration of fuzzy logic and image analysis for the detection of gullies in the Calhoun forest using airborne LiDAR data*. Calhoun CZO Summer Science Meeting. Union, SC. Status = PUBLISHED; Acknowledgement of Federal Support = No
- Wade, A. (2016). *Introduction to legacy sediments*. Calhoun CZO 2016 Summer Science Meeting. Clinton, SC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

- Thompson A (2015). *Iron dynamics at the Luquillo and Calhoun Critical Zone Observatories: Proposed linkages to C cycling*. University of Vermont Biogeochemistry Symposium Series. Burlington, VT. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Lehmeier, C. A., Min, K. J., Billings, S. A. (2015). *Is δ13C of respired CO2 dependent on growth rate? Exploring carbon isotope discrimination in soil microbes*. Calhoun CZO Summer Science Meeting. Union, SC. Status = PUBLISHED; Acknowledgement of Federal Support = No
- Giesen, J. C. (2015). *Jack's Cave: A Critical Zone Story*. Calhoun CZO Summer Science Meeting. Union, SC. Status = PUBLISHED; Acknowledgement of Federal Support = No
- Buchanan, C and KP O'Neill (2014). *Land use and the Critical Zone in the southern Piedmont: A GIS analysis*. Roanoke College Showcase of Research and Creativity. Roanoke, VA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Cherkinsky, Alex (2014). *Lecture on 14C analyses of soil fractions*. Soil Science seminar at UGA. Athens, GA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- O'Neill, KP (2014). *Linking human activity and CZ processes in undergraduate educational modules at the Calhoun CZO*. National Critical Zone All Hands Meeting, Southern Sierra CZO. Fish Camp, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Hodges C; Markewitz D; Thompson A (2015). *Linking spatial and temporal patterns of soil moisture with iron reduction*. American Geophysical Union Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Hodges C; Markewitz D; Thompson A (2016). *Linking spatial and temporal patterns of soil moisture with iron reduction at the Calhoun CZO*. University of Georgia Agronomy Graduate Student Association Annual Poster Session. Athens, GA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Hodges C; Markewitz D; Thompson A (2016). *Linking spatial and temporal patterns of soil moisture with iron reduction at the Calhoun CZO*. Soil Science Society of Georgia Annual Meeting. Athens, GA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Ryland, R. (2016). *Mapping depth to argillic horizon*. Calhoun CZO 2016 Summer Science Meeting. Clinton, SC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Hodges, C., Markewitz, D., and Thompson, A. (2015). *Mapping the Potential for Iron Reduction Using Electromagnetic Induction*. Southeastern Biogeochemistry Symposium. Atlanta, GA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Gutierrez-Jurado, H.A., H. Guan, J. Wang, H. Wang, R.L. Bras, and C.T. Simmons (2015). *Maximum Entropy Production modeling of evapotranspiration*

partitioning on heterogeneous terrain and canopy cover: advantages and limitations. American Geophysical Union Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

- Wang, J. (2016). *Maximum entropy production model of heat fluxes - an application of information theory in modeling earth system*. Workshop on Information Theory and the Earth System. Germany. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Bartlett, M. S. and Porporato, A. (2016). *Mean field approach to watershed hydrology*. CUAHSI 2016 Biennial Colloquium. Shepherdstown, WV. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Bartlett, M. S. and Porporato, A. (2016). *Mean field approach to watershed hydrology*. European Geophysical Union General Assembly. Vienna, Austria. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Porporato, A., M. Bartlett (2016). *Mean field approach to watershed hydrology*. Calhoun CZO 2016 Summer Science Meeting. Clinton, SC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Ramos, A and KP O'Neill (2014). *Modeling soil erosion potential (RUSLE) in a southern piedmont landscape using GIS*. Roanoke College Showcase of Research and Creativity. Roanoke, VA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Nelson, D., and Coughlan, M. (2015). *Multitemporal Human Forcings in the Calhoun CZO*. Calhoun CZO Summer Science Meeting. Union, SC. Status = PUBLISHED; Acknowledgement of Federal Support = No
- Law, D. L., and Hansen, W. F. (2015). *Native Plants and Fertilization Help to Improve Sites and Stabilize Gullies on the Sumter National Forest*. Calhoun CZO Summer Science Meeting. Union, SC. Status = PUBLISHED; Acknowledgement of Federal Support = No
- Parolari AJ; Pelak N; Katul GG; Richter D; Porporato A (2014). *Non-linear dynamics in plant-soil interactions and implications for critical zone processes*. Critical Zone Observatory All Hands Meeting. Fish Camp, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Krapu, C. (2015). *Nonlinear Clustering of Spatially Distributed Hydrometric Data*. Calhoun CZO Summer Science Meeting. Union, SC. Status = PUBLISHED; Acknowledgement of Federal Support = No
- Cherkinsky, A. (2015). *Old soil carbon in Calhoun Ultisols*. Max Plank Institute workshop. Hamburg, Germany. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Brecheisen, Z.R., J.M. Mallard, N.F. Pelak (2014). *Optimizing Hydrologic and Biogeochemical Sensor Networks in the Calhoun Critical Zone Observatory*. 2nd Annual Workshop on Wireless Intelligent Sensor Networks. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Brecheisen, Zachary S., Xing Chen, and Daniel deB. Richter (2014). *Ordering interfluves: a simple proposal for understanding critical zone evolution and*

function. CZO Network 2014 All Hands Meeting. Fish Camp, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

- O'Neill KP (2016). *Outreach talk with discussion of CZ science*. Virginia Master Naturalists. Roanoke VA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Cook, C. W. (2015). *Overview of Sampling Sites at the Calhoun CZO*. Calhoun CZO Summer Science Meeting. Union, SC. Status = PUBLISHED; Acknowledgement of Federal Support = No
- Thompson A., and Wilmoth, J. (2015). *Oxygen flux modulates net rates of Fe reduction and Fe solid phase composition in redox dynamic soils*. American Chemical Society National Meeting. Denver, CO. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Lonneman, M. (2016). *Parcel-level land use change at the Calhoun CZO*. Calhoun CZO 2016 Summer Science Meeting. Clinton, SC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- O'Neill KP (2016). *Place-based exploration of the southern Piedmont: The Calhoun Critical Zone Observatory*. North Carolina Science Teachers' Association. Greensboro NC. Status = ACCEPTED; Acknowledgement of Federal Support = Yes
- Cherkinsky, Alex (2014). *Posters on 14C analyses of soil fractions*. 2014 CZO All Hands meeting at the Southern Sierra CZO. Fish Camp, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Austin, J.C., and P.A. Schroeder (2015). *Preliminary interpretations of differences in the clay mineralogy of the Calhoun CZO between 'pristine' and eroded soils at the Long-Term Pine Plots*. Calhoun CZO Summer Science Meeting. Union, SC. Status = PUBLISHED; Acknowledgement of Federal Support = No
- Cherkinsky, Alex (2014). *Presentation about 14C age of soil fractions*. Alaska Anthropological Association. Fairbanks, AK. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Cherkinsky, Alex (2014). *Presentation on AMS analyses of different soil fractions from paleosols buried by tephra, Alaska*. AMS-13 conference. Aix-en-Provence, France. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Hodges C; Thompson A (2016). *Probing iron reduction from cm to km scales in forested ecosystems*. Soil Science Society of America Annual Meeting. Minneapolis, MN. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Shahnaz, S., Shen, Y., Wang, J. (2015). *Processing High Resolution Hydrologic Data from Historic Records at the Calhoun CZO*. Calhoun CZO Summer Science Meeting. Union, SC. Status = PUBLISHED; Acknowledgement of Federal Support = No
- Foroughi, M. (2015). *Proposal: Assessing soil phosphorus status over time and under different land uses*. Calhoun CZO Summer Science Meeting. Union, SC. Status = PUBLISHED; Acknowledgement of Federal Support = No

- Huang, S.-Y., Y. Deng, and J. Wang (2014). *Re-evaluation of the Earth's Surface Energy Balance using a New Method of Heat Fluxes*. AGU Fall Meeting. San Francisco. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Schroeder, Paul A.; Ö.I. Ece; Cansu Demirel; and Adam Milewski (2016). *Reconnaissance oxygen and hydrogen stable isotope geochemistry of waters from the critical zone in the Iznik Lake basin region, Turkey*. 7th International Geochemistry Symposium. Antalya, Turkey. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Bartlett MS; Parolari AJ; McDonnell JJ; Daly E; Porporato A (2015). *Runoff production in stochastic soil moisture models: saturation-excess threshold and soil moisture-dependent progressive partitioning*. Gordon Research Conference for Catchment Science: Interactions of Hydrology, Biology & Geochemistry. Andover, NH. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Foroughi, M., D. Markewitz, and C. A. Hodges (2015). *Sample Modeling for Soil Phosphorus at the Calhoun CZO via GIS Applications*. Calhoun CZO Summer Science Meeting. Union, SC. Status = PUBLISHED; Acknowledgement of Federal Support = No
- Hansen, W. F., and Law, D. L. (2015). *Sediment from a Small Ephemeral Gully in South Carolina*. Calhoun CZO Summer Science Meeting. Union, SC. Status = PUBLISHED; Acknowledgement of Federal Support = No
- O'Neill, K. P. (2015). *Seeing is believing: Exploring land use/land cover change in the southern Piedmont using virtual field trips*. Association for Environmental Studies and Sciences. San Diego, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Austin, Jason C.; Paul A. Schroeder; and Daniel deB. Richter (2016). *Semi-quantitative deep regolith clay mineralology of the Calhoun Critical Zone Observatory using NEWMOD 2*. Clay Minerals Society Annual Meeting. Atlanta, GA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Parolari, A.J. (2016). *Social-ecological modeling*. Calhoun CZO 2016 Summer Science Meeting. Clinton, SC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Billings, S. A. (2016). *Soil C transformations and translocation at the Calzone*. Calhoun CZO 2016 Summer Science Meeting. Clinton, SC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Powell I; Ryland R; Thompson A (2016). *Soil Particle Fractionation Variances by Depth and Toposequence at Calhoun CZO*. University of Georgia Young Scholar Program. Athens, GA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Osota E O; Ryland R; Thompson A (2016). *Soil Particle Size Distribution and Landscape Position*. University of Georgia Undergraduate Research Symposium. Athens, GA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

- Giesen, James C., Daniel d.B. Richter (2014). *Soil as Time Machine: The Calhoun Critical Zone Observatory*. History Center/SEOE, University of South Carolina. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Austin, Jason C. and Schroeder, Paul A. (2014). *Soil depth dependence of stable and radiogenic carbon and stable oxygen isotopes in gibbsite (Al(OH3)) occluded CO2 as an indicator of recovery after anthropogenic disturbance*. Southern Sierra Critical Zone Observatory All Hands Meeting. Fish Camp, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Calabrese, S., A.J. Parolari, A. Porporato (2016). *Soil formation and weathering modeling*. Calhoun CZO 2016 Summer Science Meeting. Clinton, SC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Parolari, A. J., Pelak, N. F., Porporato, A. (2015). *State transitions in coupled social-ecological agro-ecosystem models*. Calhoun CZO Summer Science Meeting. Union, SC. Status = PUBLISHED; Acknowledgement of Federal Support = No
- O'Neill, KP (2014). *Sustaining Earth's life support system: Soils and the Critical Zone*. Roanoke College Coffee Shop talks (public outreach). Roanoke, VA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- O'Neill KP (2016). *Teaching in the zone: Engaging students through place-based, interdisciplinary science and research at the Calhoun Critical Zone Observatory*. Association of Environmental Studies and Sciences. Washington DC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Billings, S., Lehmeier, C., Min, K., Ballantyne, F. (2014). *Temperature and substrate C:N drive microbial carbon use efficiency and 13C discrimination*. Soil Science Society of America annual meeting. Long Beach, California. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Markewitz, D. (2015). *Temporal electrical resistivity imaging for assessing subsurface water flow at multiple watershed scales*. Calhoun CZO Summer Science Meeting. Union, SC. Status = PUBLISHED; Acknowledgement of Federal Support = No
- Chen, X. (2015). *Testing of streamflow prediction using storage-discharge relation*. Calhoun CZO Summer Science Meeting. Union, SC. Status = PUBLISHED; Acknowledgement of Federal Support = No
- Richter, D deB and Billings Sharon A. (2014). *The Changing Models of Soil, Ecosystems, and Earth's Critical Zones*. Stanford University. Palo Alto, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- O'Neill, K. P., and Richter, D. D. (2015). *The Earth's Critical Zone as an integrating theme for undergraduate environmental science courses: A case study at the Calhoun Critical Zone Observatory*. Association for Environmental Studies and Sciences. San Diego, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Bras, R., Dialynas, Y., Billings, S., Richter, D., & Markewitz, D. (2015). *The dependence on topography of the influence of soil erosion and deposition on the*

carbon cycle at the Calhoun Critical Zone Observatory. American Geophysical Union Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

- Thompson, A. (2016). *The multiple roles of short-range-ordered iron minerals in soils*. Cornell University Biogeochemistry Seminar Series. Ithaca, NY. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Callaham, M. A. (2015). *The new Calhoun CZO at the Calhoun Experimental Forest: An exemplary collaboration between managers and scientists*. Joint meeting of USDA FS Southern Region leadership teams. Asheville, NC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Zimmer M.A., B.L. McGlynn (2014). *The role of groundwater and stream network dynamics in baseflow and stormflow generation*. Consortium of Universities for the Advancement of Hydrologic Sciences (CUAHSI) Biennial Colloquium. Shepherdstown, WV. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Pelak, Norman F. (2014). *Theoretical considerations for stochastic soil moisture dynamics and the optimal design of soil moisture sensor networks*. CUAHSI 2014 Biennial Colloquium. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Bartlett MS; Parolari AJ; McDonnell JJ; Porporato A (2015). *Theory of event based rainfall-runoff models: Spatially variable runoff generate by threshold or progressive partitioning over stochastic source areas*. Gordon Research Conference for Catchment Science: Interactions of Hydrology, Biology & Geochemistry. Andover, NH. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Thompson A., Ginn, B., Meile, C., Wilmoth, J, Barcellos, D. (2015). *Timescales of soil redox oscillations and the role of iron in the critical zone*. American Chemical Society National Meeting. Denver, CO. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Foroughi, M., and D. Markewitz (2016). *Topographic influences on phosphorus redistribution in the Calhoun CZO, South Carolina*. Workshop: Phosphorus Cycling in Terrestrial Ecosystems: Advancing our fundamental understanding through a model-data connection. Townsend, TN. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Dialynas, Y. G., Bastola, S., Bras, R. L., Billings, S. A., Richter, D. deB., and Markewitz, D. (2015). *Topographic variability in the influence of soil erosion on the carbon cycle*. Calhoun CZO Summer Science Meeting. Union, SC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Coughlan, M., D.R. Nelson, T. Gragson (2015). *Transitioning from livelihood fire to fire suppression in the US Southeast: Causes and consequences of fire regime transition in two forested landscapes*. Fire Ecology and Management Congress. San Antonio, TX. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

- Cook, C.W. (2016). *Tree age distribution at the Calhoun CZO*. Calhoun CZO 2016 Summer Science Meeting. Clinton, SC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Cook, C. W. (2015). *Trees of the Enoree District*. Calhoun CZO Summer Science Meeting. Union, SC. Status = PUBLISHED; Acknowledgement of Federal Support = No
- Hodges, C., Markewitz, D., and Thompson, A. (2015). *Using Electromagnetic Induction to Determine Spatial and Temporal Patterns of Iron Reduction at the Calhoun CZO*. Calhoun CZO Summer Science Meeting. Union, SC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Hodges, C. (2016). *Variation of iron reduction with depth over time at the Calhoun CZO*. Calhoun CZO 2016 Summer Science Meeting. Clinton, SC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Chen, X. (2015). *Variations in streamflow response to large hurricane-season storms in a southeastern US watershed*. Calhoun CZO Summer Science Meeting. Union, SC. Status = PUBLISHED; Acknowledgement of Federal Support = No
- Bastola, S, Y. G. Dialynas, and R. L. Bras, Noto, L. V. (2016). *Vegetation control on gully erosion*. Calhoun CZO Summer Science Meeting. Union, SC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Richter, D. deB. (2016). *Volume and carbon contents of legacy sediments in the Holcombe's Branch watershed - The "discovery" of a novel biogeochemical system*. Calhoun CZO 2016 Summer Science Meeting. Clinton, SC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Brecheisen, Z. (2015). *Watersheds and Landsheds: Bringing Hortonian Stream Ordering to Upland Systems*. Calhoun CZO Summer Science Meeting. Union, SC. Status = PUBLISHED; Acknowledgement of Federal Support = No
- Callaham, M. (2015). *What about earthworms? Human influence on earthworm communities at the Calhoun Experimental Forest*. Calhoun CZO Summer Science Meeting. Union, SC. Status = PUBLISHED; Acknowledgement of Federal Support = No
- Richter, D. deB., Billings, S.A., Plante, A., and members of the cross-CZO Soil Organic Matter Working Group (2014). *What controls organic carbon in and flux from the critical zone?*. National Science Foundation's Critical Zone Observatories' All-Hands meeting. Tenaya Lodge, California. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- O'Neill K.P. (2016). *Where 'life meets rock': A Critical Zone perspective on water management*. National Capital Region American Water Resources Association. Rethinking the value of water: Innovations in research, technology, policy, and management. Washington DC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Austin, J. C. and Schroeder, P. A. (2015). *Young C-14 age of the carbonate component of natural goethite (Fe(O,CO3)OH) from the Upper Ordovician Neda*

Fm., Neda, Wisconsin, USA. EuroClay2015. Edinburgh, Scotland. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Other Publications

- Smith, Robin A. (2016). *Duke collection a time capsule of Piedmont soil conditions*. Newspaper Piece with photo about the Calhoun story in the Raleigh News and Observer SciTech section, May 8, 2016, http://www.newsobserver.com/news/technology/article76183367.html. Status = PUBLISHED; Acknowledgement of Federal Support = No
- Smith, Robin A. (2016). *Legacies of Cotton, Atomic Age Linger in Soil*. Article in Duke Today about the Calhoun soil archive, published May 3, 2016 https://today.duke.edu/2016/05/piedmontsoilsaftercotton. Status = PUBLISHED; Acknowledgement of Federal Support = No
- James, A., D. Richter, A. Cherkinsky (2015). *Working Paper: Analysis of Radiocarbon on Holcombe's Branch*. Describes the initial characterization of the historic floodplain sediments in the CZO's major watershed, that of Holcombe's Branch.. Status = PUBLISHED; Acknowledgement of Federal Support = No

Technologies or Techniques

- A technician and post-doctoral scholar, Dev Hiripatayage and Dr. Samik Bagchi (University of Kansas), have developed DNA extraction protocols and analytical pipelines specific to Calhoun soils to obtain assessments of microbial community compositional variation for both bacterial and fungal communities.
- Postdoctoral research associate Christoph Lehmeier has developed a technique to test how microbial growth rate influences C and C isotope flow through microbes and into the atmospheric CO2 pool. The technique is established, data sets are obtained and in the coming year he will continue with experimentation, analysis of the data and publication of the results.

Thesis/Dissertations

- Ramey, A.. *Development of an interactive Virtual Field Experience for teaching Critical Zone concepts (undergraduate senior honors thesis in Environmental Studies)*. (2015). Roanoke College. Acknowledgement of Federal Support = Yes
- Bacon, AR.. *Pedogenesis and Anthropedogenesis on the Southern Piedmont*. (2014). Duke University. Acknowledgement of Federal Support = No
- Parisien, Alexandra. *Soil carbon contents of legacy sediments in the Calhoun Critical Zone Observatory (undergraduate senior honors thesis)*. (2016). Duke University. Acknowledgement of Federal Support = Yes

Websites

Supporting Files

	Filename	Description	Uploaded By	Uploaded On
(Download)	Dialynas_YG2016-Global_Biogeochemical_Cycles.pdf	PhD Student Yannis DIalynas GBC 2016 paper	Daniel Richter	09/27/2016
(Download)	Bartlett_MS2016-Water_Resources_Research.pdf	PhDStudent Mark Bartlett 2016 Paper	Daniel Richter	09/27/2016
(Download)	Lehmeier_CA2016.pdf	PostDoc Christoph Lehmeier's 2016 BGS Paper	Daniel Richter	09/27/2016
(Download)	Porporato's group Summary 2016 (2).pdf	2016 Working Papers on Calhoun CZ science by PhD students and Postdocs	Daniel Richter	09/27/2016

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Participants/Organizations

What individuals have worked on the project?

Name	Most Senior Project Role	Nearest Person Month Worked
Richter, Daniel	PD/PI	9
Kumar, Mukesh	Co PD/PI	2
McGlynn, Brian	Co PD/PI	1
Palmroth, Sari	Co PD/PI	1
Porporato, Amilcare	Co PD/PI	2
Billings, Sharon	Co-Investigator	5

Name	Most Senior Project Role	Nearest Person Month Worked
Bras, Rafael	Co-Investigator	1
Callaham, Mac	Co-Investigator	1
Cherkinsky, Alexander	Co-Investigator	1
Giesen, James	Co-Investigator	2
Markewitz, Daniel	Co-Investigator	2
Nelson, Donald	Co-Investigator	1
O'Neill, Katherine	Co-Investigator	5
Schroeder, Paul	Co-Investigator	2
Thompson, Aaron	Co-Investigator	2
Wang, Jingfeng	Co-Investigator	1
Bacon, Allan	Faculty	1
Hancock, Gregory	Faculty	1
Austin, Jason	Postdoctoral (scholar, fellow or other postdoctoral position)	12
Chen, Chunmei	Postdoctoral (scholar, fellow or other postdoctoral position)	3
Coughlan, Michael	Postdoctoral (scholar, fellow or other postdoctoral position)	11
Lehmeier, Christoph	Postdoctoral (scholar, fellow or other postdoctoral position)	5
Parolari, Anthony	Postdoctoral (scholar, fellow or other postdoctoral position)	2
Cook, Charles	Technician	12
Heine, Paul	Technician	12
Bastola, Satish	Staff Scientist (doctoral level)	3
Sutter, Lori	Staff Scientist (doctoral level)	2
Barcellos, Diego	Graduate Student (research assistant)	9
Bartlett, Mark	Graduate Student (research assistant)	3
Biesel, Shelly	Graduate Student (research assistant)	2
Block, Ashley	Graduate Student (research assistant)	7
Brecheisen, Zachary	Graduate Student (research assistant)	12
Calabrese, Salvatore	Graduate Student (research assistant)	2
Carrera-Martinez, Roberto	Graduate Student (research assistant)	4

Name	Most Senior Project Role	Nearest Person Month Worked
Chen, Xing	Graduate Student (research assistant)	8
Dialynas, Yannis	Graduate Student (research assistant)	3
Foroughi, Maryam	Graduate Student (research assistant)	12
Hauser, Emma	Graduate Student (research assistant)	1
Hodges, Caitlin	Graduate Student (research assistant)	12
Huang, Shih-Yu	Graduate Student (research assistant)	1
Huo, Jinge	Graduate Student (research assistant)	4
Krapu, Christopher	Graduate Student (research assistant)	12
Liu, Yanlan	Graduate Student (research assistant)	12
Lonneman, Michael	Graduate Student (research assistant)	9
Mallard, John	Graduate Student (research assistant)	10
Matthew, George	Graduate Student (research assistant)	3
Min, Kyungjin	Graduate Student (research assistant)	3
Noor, Nadia	Graduate Student (research assistant)	1
Pelak, Norman	Graduate Student (research assistant)	1
Ryland, Rachel	Graduate Student (research assistant)	12
Shahnaz, Sabina	Graduate Student (research assistant)	1
Tang, Yao	Graduate Student (research assistant)	6
Thomas, Aaron	Graduate Student (research assistant)	1
Wade, Anna	Graduate Student (research assistant)	6
Wang, Dongdong	Graduate Student (research assistant)	1
Arroyo, Eva	Undergraduate Student	1
Barger, Keelan	Undergraduate Student	1
Craghead, Lewis	Undergraduate Student	3
Ehlinger, Rachel	Undergraduate Student	5
Elledge, Samantha	Undergraduate Student	1
Heroneme, Carl	Undergraduate Student	2
Krzyston, Joseph	Undergraduate Student	2
Martin, Conor	Undergraduate Student	3
Moraes, Anthony	Undergraduate Student	1
Morrison, Holly	Undergraduate Student	1
Osota, Elizabeth	Undergraduate Student	4
Parisien, Alexandra	Undergraduate Student	1
Ramey, Alexandra	Undergraduate Student	1

Name	Most Senior Project Role	Nearest Person Month Worked
Richards, David	Undergraduate Student	1
Ryang, Junmo	Undergraduate Student	1
Steiner, Peter	Undergraduate Student	1
Svoboda, Samuel	Undergraduate Student	1
Thibideaux, Matthew	Undergraduate Student	3
Villalobos, Samantha	Undergraduate Student	1
Meyers, Zach	High School Student	1
Powell, Isaac	High School Student	2
Tang, Tiffany	High School Student	2

Full details of individuals who have worked on the project:

Daniel deB Richter
Email: drichter@duke.edu
Most Senior Project Role: PD/PI
Nearest Person Month Worked: 9

Contribution to the Project: Lead PI and responsible for all aspects of the Observatory.

Funding Support: This project, Duke University

International Collaboration: Yes, china
International Travel: No

Mukesh Kumar
Email: mukesh.kumar@duke.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 2

Contribution to the Project: Guide and oversee research with graduate students. The research included data analyses, model development, and manuscript preparation.

Funding Support: None

International Collaboration: No
International Travel: No

Brian L McGlynn
Email: brian.mcglynn@duke.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 1

Contribution to the Project: McGlynn has provided guidance and collaboration on watershed hydrology field research including installation of stream gauging stations, nested well networks, precipitation gauges, and soil water content monitoring stations. Additionally he has supported management and analysis of collected and historic data along with serving as a contact to facilitate implementation of CUAHSI's data model for the CCZO hydrologic data. He continues to integrate findings at the CCZO satellite location in Duke Forest with the larger CCZO project. CCZO Executive Committee member.

Funding Support: Duke University salary and lab startup funds

International Collaboration: No
International Travel: No

Sari Palmroth
Email: sari.palmroth@duke.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 1

Contribution to the Project: Planning, advising

Funding Support: None

International Collaboration: Yes, finland
International Travel: No

Amilcare Porporato
Email: amilcare.porporato@duke.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 2

Contribution to the Project: Organization and supervision of all aspects of modeling of ecohydrology, biogeochemistry and social dynamics at Calhoun. Project coordination and mentoring of Postdoc and PhD students working in the CCZO research project. Direction of the Duke Wisent NSF-funded IGERT project with explicit collaborations with the CCZO for wireless sensoring. CCZO Executive Committee member.

Funding Support: None

International Collaboration: No
International Travel: No

Sharon A Billings
Email: sharon.billings@ku.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 5

Contribution to the Project: Billings helped contribute ideas about the categories of land use history investigated for the project and assists in the design of soil organic matter investigations conducted at UGA, Georgia Tech, and Duke. She designed soil incubations, initiated and built the 2-D erosion/deposition model, assisted in interpretation of 3-D model output and that work's manuscript writing, trained the research associate, post-doc, graduate student, technician and undergraduate students at U. Kansas, conducted multiple consultations with graduate students at Duke and Georgia Tech, and assisted the KU Research Associate in experimental design for laboratory experiments. Billings also is a contributor to three cross-CZO Working Groups (CZ-TOPE (isotopes at CZOs), Biogeochemistry, and Organic Matter). She serves on the Organizing Committee for the Cross-CZO Organic Matter Workshop at Purdue to be held in October 2015, the Calhoun CZO executive committee, and will assist in teaching graduate students and national and international participants in a soil erosion class at the workshop. Billings is responsible for all aspects of the project sub-contracted to the University of Kansas. CCZO Executive Committee member.

Funding Support: Partial month this award

International Collaboration: Yes, switzerland
International Travel: No

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

Contribution to the Project: Dr. Bras serves as the co-PI of GT team supervising all team members and coordinating collaborations of research and education activities. Given his extensive expertise and experience, Dr. Bras worked on the eco-hydrological recovery theme through design of field experiment, model development and simulation.

Funding Support: This award only.

International Collaboration: No
International Travel: No

Mac Aaron Callaham
Email: mcallaham@fs.fed.us
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Completed one year of soil invertebrate sampling on land-use legacy plots at Calhoun CZO

Funding Support: USDA Forest Service, Center for Forest Disturbance Science

International Collaboration: No
International Travel: No

Alexander Cherkinsky
Email: acherkin@uga.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: The sample collection and analyses for 14C and d13C composition of soil organic matter to estimate the turn over rates on the sites with different land use history.

Funding Support: This award only.

International Collaboration: No
International Travel: Yes, germany - 0 years, 0 months, 5 days

James C Giesen
Email: jcg245@msstate.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 2

Contribution to the Project: Continuing research on land use history.

Funding Support: This award only.

International Collaboration: No
International Travel: No

Daniel Markewitz
Email: dmarke@uga.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 2

Contribution to the Project: Field work, professional mentoring. CCZO Executive Committee member.

Funding Support: This award only.

International Collaboration: No
International Travel: No

Donald R Nelson
Email: dnelson@uga.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Responsible for activities in the human-CZO theme and contributes to interdisciplinary modeling activities. Contributed to data collection, overseeing graduate work, and professional mentoring

Funding Support: NSF

International Collaboration: No
International Travel: No

Katherine P O'Neill
Email: oneill@roanoke.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 5

Contribution to the Project: Education and outreach. CCZO Executive Committee member.

Funding Support: Roanoke College Environmental Studies program, Roanoke College Dean's Office

International Collaboration: No
International Travel: No

Paul A Schroeder
Email: schroe@uga.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 2

Contribution to the Project: Field work, professional mentoring, planning of international symposium.

Funding Support: UGA Provost International Travel Fund

International Collaboration: Yes, japan, turkey
International Travel: Yes, turkey - 0 years, 0 months, 5 days

Aaron Thompson
Email: aaront@uga.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 2

Contribution to the Project: Overseeeing graduate student and postdoctoral research. Field soil collection and analysis.

Funding Support: This award only.

International Collaboration: No
International Travel: Yes, japan - 0 years, 0 months, 14 days

Jingfeng Wang
Email: jingfeng.wang@ce.gatech.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Dr. Wang serves as the lead co-PI of GT team responsible for daily operation of research and education activities. Dr. Wang focused on the eco-hydrological recovery theme for the test of the Eco-hydrological Recovery Hypothesis (H1) through design of field experiment, model development/simulation, and data processing and archiving. CCZO Executive Committee member.

Funding Support: This award only.

International Collaboration: No
International Travel: No

Allan R Bacon
Email: allan.bacon@ufl.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: Attended two workshops; assisted with manuscript preparation related to past dissertation research on pedogenesis and anthropedogenesis in the Southern Piedmont.

Funding Support: University of Florida

International Collaboration: No
International Travel: No

Gregory Hancock
Email: greg.hancock@newcastle.edu.au
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: Working on landscape evolution modeling at Calhoun.

Funding Support: Visiting scholar; funding is from the University of Newcastle (Australia)

International Collaboration: Yes, australia
International Travel: No

Jason C Austin
Email: austinj1@uga.edu
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 12

Contribution to the Project: Field work, X-ray diffraction, stable isotope sample collection and analysis, undergrad student mentoring.

Funding Support: This award only.

International Collaboration: Yes, japan
International Travel: No

Chunmei Chen
Email: cmchen@uga.edu
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 3

Contribution to the Project: Field and laboratory research on iron and carbon in soils

Funding Support: Other NSF

International Collaboration: No
International Travel: Yes, japan - 0 years, 0 months, 14 days

Michael Coughlan
Email: coughlan@uga.edu
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 11

Contribution to the Project: Fieldwork and database development

Funding Support: University of Georgia

International Collaboration: No
International Travel: No

Christoph Lehmeier
Email: christoph.lehemeir@gmail.com
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 5

Contribution to the Project: Lehmeier has assisted in field installations of gas wells and soil coring, conducted laboratory incubations and performed incubation sampling for extracts and gas samples, analyzed exo-enzyme activities, designed and performed microbial growth experiments, developed a poster presentation for the American Geophysical Union fall meeting, and served as a co-author for manuscripts emanating from this award. He also has assisted in the training of the graduate student and three undergraduates.

Funding Support: This award

International Collaboration: No
International Travel: No

Anthony Parolari
Email: anthony.parolari@duke.edu
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 2

Contribution to the Project: Development of all aspects of modeling of ecohydrology, biogoechemistry and social dynamics at Calhoun. Co-mentoring of PhD student Pelak working in the CCZO research project.

Funding Support: NSF EAR hydrology grant

International Collaboration: No
International Travel: No

Charles W Cook
Email: cwcook@duke.edu
Most Senior Project Role: Technician
Nearest Person Month Worked: 12

Contribution to the Project: Field lab manager in charge of field construction, operations, sample collection, and data management for diverse field experiments at the Calhoun CZO.

Funding Support: This project only.

International Collaboration: No
International Travel: No

Paul Heine
Email: pheine@duke.edu
Most Senior Project Role: Technician
Nearest Person Month Worked: 12

Contribution to the Project: Field, laboratory, data, and website contributions.

Funding Support: This award only.

International Collaboration: No
International Travel: No

Satish Bastola
Email: satish.bastola@ce.gatech.edu
Most Senior Project Role: Staff Scientist (doctoral level)
Nearest Person Month Worked: 3

Contribution to the Project: Model development and simulation of the effects of soil erosion and deposition on the carbon cycle.

Funding Support: This award only.

International Collaboration: No
International Travel: No

Lori A Sutter
Email: lsutter@uga.edu
Most Senior Project Role: Staff Scientist (doctoral level)
Nearest Person Month Worked: 2

Contribution to the Project: Laboratory management, field work, professional mentoring.

Funding Support: Dr. Sutter is partly supported by the Warnell School at UGA.

International Collaboration: No
International Travel: No

Diego Barcellos
Email: barcello@uga.edu

Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 9

Contribution to the Project: Field and laboratory research on iron and carbon in soils.

Funding Support: other NSF

International Collaboration: No
International Travel: Yes, japan - 0 years, 0 months, 14 days

Mark Bartlett
Email: mark.bartlett@duke.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 3

Contribution to the Project: Edge detection work at CCZO and all aspects of modeling of watershed modeling.

Funding Support: IGERT grant and another NSF award.

International Collaboration: No
International Travel: No

Shelly Biesel
Email: shelly.biesel@gmail.com
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 2

Contribution to the Project: Data collection, organization, analysis.

Funding Support: UGA Graduate Research Opportunity scholarship

International Collaboration: No
International Travel: No

Ashley Block
Email: ashley.block25@uga.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 7

Contribution to the Project: Data collection, organization, analysis.

Funding Support: UGA Graduate Research Assistant scholarship

International Collaboration: No
International Travel: No

Zachary S Brecheisen
Email: zachary.brecheisen@duke.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: Geospatial analysis, soil and tree coring, plot mapping, and helping construct wireless sensor network.

Funding Support: NSF IGERT – WISeNet traineeship DGE-1068871

International Collaboration: No
International Travel: Yes, germany - 0 years, 2 months, 0 days

Salvatore Calabrese
Email: salvatore.calabrese@duke.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 2

Contribution to the Project: Development of all aspects of modeling of ecohydrology, biogoechemistry and social dynamics at Calhoun. Reconstruction of weirs for streamflow measurement at the Calhoun CZO.

Funding Support: This grant, graduate school fellowship, and IGERT grant.

International Collaboration: No
International Travel: No

Roberto Carrera-Martinez
Email: rcarrmart@gmail.com
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 4

Contribution to the Project: Field and laboratory research

Funding Support: NSF

International Collaboration: No
International Travel: No

Xing Chen
Email: xing.chen@duke.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 8

Contribution to the Project: Working on: (a) Role of full and weak coupling on model accuracy; (b) Using storage-discharge relation for hydrologic prediction.

Funding Support: NSOE TA-ship; Mukesh Kumar's Startup Fund

International Collaboration: No
International Travel: No

Yannis G Dialynas
Email: ydialynas@gatech.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 3

Contribution to the Project: Model development and simulation of the effects of soil erosion and deposition on the carbon cycle.

Funding Support: Luquillo CZO (half)

International Collaboration: No
International Travel: No

Maryam Foroughi
Email: mforoughi@uga.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: Field and laboratory research, water chemistry.

Funding Support: This award only.

International Collaboration: No
International Travel: No

Emma Hauser
Email: emhauser@ku.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: Hauser joined the Billings lab in August 2016. She is being trained on laboratory equipment to become adept at multiple biogeochemical assays, including inorganic N and phosphate soil extractions and quantification, exo-enzyme assays, and microbial biomass assays.

Funding Support: Teaching assistantship

International Collaboration: No
International Travel: No

Caitlin Hodges
Email: chodges@uga.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: Field and laboratory research on redox processes in soils.

Funding Support: This award only.

International Collaboration: No
International Travel: No

Shih-Yu Huang
Email: shuang83@gatech.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: Modeling soil temperature and soil moisture dynamics and surface water and energy budget under ecohydrological recovery (H1).

Funding Support: This award only

International Collaboration: No
International Travel: No

Jinge Huo
Email: huojinge@gatech.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 4

Contribution to the Project: Historical data digitization and processing and analysis (stream-flow and rainfall) (H1).

Funding Support: None

International Collaboration: No
International Travel: No

Christopher Krapu
Email: clk27@duke.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: Identification of optimal sensor network locations for prediction quick flow at the watershed outlet.

Funding Support: IGERT: Training Program in Wireless Intelligent Sensor Networks (WISeNet) at Duke University, NSF Award Number: 1068871

International Collaboration: No
International Travel: No

Yanlan Liu
Email: yanlan.liu@duke.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: Understanding the controls on wetland groundwater dynamics in the piedmont region of south-eastern US.

Funding Support: This project only.

International Collaboration: No
International Travel: No

Michael Lonneman
Email: mlonneman@gmail.com
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 9

Contribution to the Project: Data collection, organization, analysis.

Funding Support: NSF

International Collaboration: No
International Travel: No

John McDevitt Mallard
Email: john.mallard@duke.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 10

Contribution to the Project: Ongoing installation of sensor network; field hydrologic measurements; Hydrologic data acquisition, maintenance, and analysis.

Funding Support: This award and IGERT: Training Program in Wireless Intelligent Sensor Networks (WISeNet) at Duke University, NSF Award Number: 1068871

International Collaboration: Yes, australia
International Travel: No

George Matthew
Email: gmathew022@gmail.com
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 3

Contribution to the Project: Field and laboratory assistance

Funding Support: None

International Collaboration: No
International Travel: No

Kyungjin Min
Email: kjmin21@gmail.com
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 3

Contribution to the Project: Min has conducted laboratory incubations with soils collected from Calhoun CZO, and performed gas/exo-enzyme measurements. Also, along with this incubation, she conducted lab experiments in which varying substrate stoichiometry and temperature modifies microbial C flows, developed a poster presentation for the Calhoun CZO workshop, and served as a co-author for a manuscript emanating from this award. She also has assisted in the training of three undergraduates and one REU student.

Funding Support: This award only.

International Collaboration: No
International Travel: Yes, canada - 0 years, 0 months, 5 days

Nadia Noor
Email: nadianoor63@gmail.com
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: Laboratory research on methods to determine carbon associated with iron phases.

Funding Support: UGA and other NSF

International Collaboration: No
International Travel: No

Norman F Pelak
Email: norman.pelak@duke.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: Models of erosion vegetation feedback and effects of soil management on soil loss and sustainability.

Funding Support: NDSEG graduate fellowship.

International Collaboration: No
International Travel: No

Rachel Ryland
Email: rryland@uga.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: Field and laboratory research on determining the depth the clay horizon

Funding Support: University of Georgia

International Collaboration: No
International Travel: No

Sabina Shahnaz
Email: sshahnaz3@gatech.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: Retrieving and processing historical hydrometeorological data (stream-flow and rainfall)(H1).

Funding Support: This award only.

International Collaboration: No
International Travel: No

Yao Tang
Email: tangyao1208@gatech.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 6

Contribution to the Project: Retrieving and processing historical hydrometeorological data and modeling gas fluxes (stream-flow and rainfall)(H1).

Funding Support: None

International Collaboration: No
International Travel: No

Aaron Thomas
Email: tat233@msstate.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: Historical document research.

Funding Support: None

International Collaboration: No
International Travel: No

Anna Wade
Email: anna.wade@duke.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 6

Contribution to the Project: Planning and execution of Calhoun CZO Summer Science Days. Worked in laboratory on sample preparation and analysis.

Funding Support: NSF IGERT – WISeNet traineeship DGE-1068871

International Collaboration: No
International Travel: No

Dongdong Wang
Email: dongdong.wang@duke.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: Working on Calhoun watershed modeling.

Funding Support: Duke University

International Collaboration: No
International Travel: No

Eva Arroyo
Email: eva.arroyo@duke.edu

Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 1

Contribution to the Project: Worked on legacy sediments at Holcombe's Branch.

Funding Support: None

International Collaboration: No
International Travel: No

Keelan Barger
Email: k337b844@ku.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 1

Contribution to the Project: Barger develops protocols for and runs inorganic nutrient analyses of Calhoun CZO samples in addition to contributing to general lab upkeep.

Funding Support: This award only.

International Collaboration: No
International Travel: No

Lewis Craghead
Email: lewisc@uga.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 3

Contribution to the Project: Field and laboratory assistance

Funding Support: None

International Collaboration: No
International Travel: No

Rachel Ehlinger
Email: rme@uga.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 5

Contribution to the Project: Field and laboratory assistance.

Funding Support: None

International Collaboration: No
International Travel: No

Samantha Elledge
Email: samanthaelledge@gmail.com
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 1

Contribution to the Project: Elledge contributes to general lab upkeep, performs multiple administrative tasks, and assists with processing of incubation samples.

Funding Support: This award only.

International Collaboration: No
International Travel: No

Carl Heroneme
Email: carl.heroneme@gmail.com
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 2

Contribution to the Project: Heroneme serves as a general lab assistant, and has been instrumental in the development of lab protocols for Calhoun-specific sample types. He also analyzes samples for microbial biomass C and N, and assists in all aspects of incubations.

Funding Support: This award only.

International Collaboration: No
International Travel: No

Joseph Krzyston
Email: jakrzyston@mail.roanoke.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 2

Contribution to the Project: Communication and writing in support of Education and Outreach .

Funding Support: Roanoke College Environmental Studies program

International Collaboration: No
International Travel: No

Conor Martin
Email: cjmartin@mail.roanoke.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 3

Contribution to the Project: GIS analysis in support of education and outreach, field work, photography, building spatial topologies.

Funding Support: Roanoke College Office of Student Research

International Collaboration: No
International Travel: No

Anthony Moraes
Email: wolfbane@uga.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 1

Contribution to the Project: Working with Dr. Paul Schroeder to better describe the clay mineralogy and weathering processes at the CCZO.

Funding Support: None

International Collaboration: No
International Travel: No

Holly Morrison
Email: hamorrison@mail.roanoke.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 1

Contribution to the Project: K-12 education and outreach.

Funding Support: None

International Collaboration: No
International Travel: No

Elizabeth Osota
Email: elizabeth.osota25@uga.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 4

Contribution to the Project: Internship work assisting in many aspects of the project including conducting particle size analysis of soils.

Funding Support: University of Georgia

International Collaboration: No
International Travel: No

Alexandra Parisien
Email: alexandra.parisien@duke.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 1

Contribution to the Project: Completed a Duke senior honors thesis on legacy sediments at Holcombe's Branch.

Funding Support: None

International Collaboration: No
International Travel: No

Alexandra Ramey
Email: ajramey@mail.roanoke.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 1

Contribution to the Project: Development of prototype electronic educational module.

Funding Support: Roanoke College Office of Student Research

International Collaboration: No
International Travel: No

David Richards
Email: david.richards25@uga.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 1

Contribution to the Project: Working with Dr. Paul Schroeder on analyzing soil samples; rare earth elements.

Funding Support: None

International Collaboration: No
International Travel: No

Junmo Ryang
Email: junmo.ryang@duke.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 1

Contribution to the Project: Assisted with analysis of Holcombe's Branch legacy sediments.

Funding Support: None

International Collaboration: No
International Travel: No

Peter Steiner
Email: petersteiner_2017@depauw.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 1

Contribution to the Project: Working with Paul Schroeder on analyzing soil samples.

Funding Support: None

International Collaboration: No
International Travel: No

Samuel Svoboda
Email: samueljsvoboda@gmail.com
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 1

Contribution to the Project: Working with Paul Schroeder to analyze soil samples.

Funding Support: None

International Collaboration: No
International Travel: No

Matthew Thibideaux
Email: mlt10722@uga.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 3

Contribution to the Project: Field and laboratory assistance

Funding Support: None

International Collaboration: No
International Travel: No

Samantha Villalobos
Email: samantha.villalobos@duke.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 1

Contribution to the Project: Assisted with analysis of Holcombe's Branch legacy sediments.

Funding Support: None

International Collaboration: No
International Travel: No

Zach Meyers
Email: zacharymeyers@clarke.k12.ga.us
Most Senior Project Role: High School Student
Nearest Person Month Worked: 1

Contribution to the Project: Data collection

Funding Support: Clarke County School District

International Collaboration: No
International Travel: No

Isaac Powell
Email: isaac.powell25@uga.edu
Most Senior Project Role: High School Student
Nearest Person Month Worked: 2

Contribution to the Project: Summer work internship conducting particle size analysis of soils

Funding Support: University of Georgia

International Collaboration: No
International Travel: No

Tiffany Tang
Email: tang17t@ncssm.edu
Most Senior Project Role: High School Student
Nearest Person Month Worked: 2

Contribution to the Project: Worked on legacy sediments at Holcombe's Branch.

Funding Support: North Carolina School of Science and Mathematics

International Collaboration: No
International Travel: No

What other organizations have been involved as partners?

Name	Type of Partner Organization	Location
Anthropocene Working Group	Other Nonprofits	Various
Coweeta Hydrologic Lab	Other Organizations (foreign or domestic)	Otto, NC
Franklin Humanities Institute	Academic Institution	Duke University
NSF-REU in Soil Science (North Carolina State Univ)	Academic Institution	Calhoun CZO & Duke Forest
Rose Hill Plantation State Historic Site and SC State Parks	State or Local Government	Union and Columbia, SC
South Carolina State Parks	State or Local Government	Columbia, SC
Sumter National Forest, Enoree District	Other Organizations (foreign or domestic)	Union and Whitmire, SC
USFS Southern Research Station	Other Organizations (foreign or domestic)	Athens, GA
WyCEHG: Wyoming Cent Environmental Hydrology & Geophysics	Academic Institution	University of Wyoming

Full details of organizations that have been involved as partners:

Anthropocene Working Group

Organization Type: Other Nonprofits
Organization Location: Various

Partner's Contribution to the Project:
Other: Platform for advancing critical zone science

More Detail on Partner and Contribution: The relations of the proposed Anthropocene and critical zone science are many and to date relatively little explored.

Coweeta Hydrologic Lab

Organization Type: Other Organizations (foreign or domestic)
Organization Location: Otto, NC

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

More Detail on Partner and Contribution: Training given to PhD student for a summer's work (2015) digitizing historic strip chart data. Coweeta hydrologists provided some oversight as well of the progress to the work.

Franklin Humanities Institute

Organization Type: Academic Institution
Organization Location: Duke University

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

More Detail on Partner and Contribution: FHI co-sponsored a 2-day visit to the Calhoun by Bruno Latour, widely renowned philosopher of science. FHI entirely sponsored lunch for about 100 scholars at a high-visibility public event we called "The Critical Zone Education of Bruno Latour." A professional videographer was assigned to the two day visit to the Calhoun and is in the final stages of video creation. FHI has also provided an office for PI Richter on his Fall 2016 sabbatical.

NSF-REU in Soil Science (North Carolina State Univ)

Organization Type: Academic Institution
Organization Location: Calhoun CZO & Duke Forest

Partner's Contribution to the Project:
Personnel Exchanges

More Detail on Partner and Contribution: The Calhoun CZO is an affiliate of the NCSU REU Program in Soil Science, whose director is Prof. Josh Heitman. For the second of three years, we have given a whole day field trip in Critical Zone science to about a dozen high potential students. In both years, by days end they have been very intrigued and excited by the experience.

Rose Hill Plantation State Historic Site and SC State Parks

Organization Type: State or Local Government
Organization Location: Union and Columbia, SC

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

More Detail on Partner and Contribution: The South Carolina State Park Service issued the CCZO a research permit on the grounds of the Rose Hill Plantation State Historic Site and have interests in our work with the old hardwood forest to the north of the Gist home and in exploring the seriously gullied old fields of the Gist plantation. In 2016, our CZO has agreed to help the SC State Parks with a reinterpretation of Rose Hill, a long-term project that will be led by the University of South Carolina.

South Carolina State Parks

Organization Type: State or Local Government
Organization Location: Columbia, SC

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution: Our project's LiDAR-derived data and our interpretation of geomorphological features and human-land impacts are being shared with local Park employees and with the State Park system itself, all to enrich the understanding of the remarkable history of South Carolina.

Sumter National Forest, Enoree District

Organization Type: Other Organizations (foreign or domestic)
Organization Location: Union and Whitmire, SC

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

More Detail on Partner and Contribution: The USDA Forest Service is responsible for managing research activities on the Calhoun Experimental Forest and in 2014 began the permitting of research activities that were contained in 30-page Research Plan. In 2015 we gave a half-day tour to two prominent USFS managers.

USFS Southern Research Station

Organization Type: Other Organizations (foreign or domestic)
Organization Location: Athens, GA

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

More Detail on Partner and Contribution: Dr. Mac Callaham participates in our observatory as a soil biologist

WyCEHG: Wyoming Cent Environmental Hydrology & Geophysics

Organization Type: Academic Institution
Organization Location: University of Wyoming

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

More Detail on Partner and Contribution: Collaboration on geophysical measurements and modeling with 2nd and 3rd visits to Calhoun in 2016. Writing a 2016 research proposal for a Calhoun drilling research.

What other collaborators or contacts have been involved?

Mac Callaham sponsored two visiting scholars, who assisted with soil macroinvertebrate sampling at Calhoun: Meixiang Gao of Harbin Normal University, China and Yuanyuan Li of Nanjing Forestry University, China, with funding from their home universities and additional support from the USDA Forest Service International Programs office.

Dan Richter sponsored one visiting scholar, Dr. Li Li of Beijing Normal University, who visited the Calhoun research areas.

Impacts

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

The principal fields of scholarship at the Calhoun CZO are geology and geomorphology; geophysics, geochemistry, pedology, and biogeochemistry; hydrology and ecohydrology; ecology and ecosystem science; environmental history and anthropology; and Earth systems science and straddling all of the above, environmental modeling. The combination and integration of disciplines represented in the work of the 15 PIs, their students, and collaborators, ensure that research planning, techniques, results, and interpretations impact all principle fields of the Calhoun CZO.

For example, the full value of: a) the high resolution LiDAR-DEM data from the Calhoun CZO flight in July 2014 and the super-high resolution ground-return data from the flight in Feb 2016, b) the geophysics data sets obtained from WyCEHG instruments deployed

in Calhoun's Geophysics Weeks I and II in April 2014 and February 2016; c) the time-series observations of CZ metabolism (gas concentration data that begin in 2015 down to 8.5-m depth; and d) the spatially explicit models using data from sources as seemingly disparate as archeology, geo-historical records from maps and aerial photography, geospatial soils data, LiDAR data, dendrochronology, and environmental history, will only be realized when results of these interdisciplinary models are circulating among the Earth and ecosystem sciences, and the scholarly communities of environmental historians and anthropologists. NSF's invests in critical zone science to integrate the Earth sciences and scholarships, something widely recognized to be potentially transformative but all too rarely practiced except with the most modest approaches.

Our project's E&O efforts mainly strive to use our specific CZ developments to create new approaches for teaching Earth and environmental sciences at the undergraduate level. Even still, Calhoun's program in E&O reaches a much wider audience than undergrads, and includes advanced high school students, graduate students, and the general public.

What follows is a sample of how eight of our PIs see their work's impact on "the principal disciplines of the project", with quotations taken from our PI's 2016 annual reports and with only slight rewording.

- Our models of coupled weathering and ecohydrologic dynamics and the related theoretical analyses offer insight into the coupling of hydrology, biogeochemistry, and ecology. The models may be used to assess nutrient availability to plants and soil degradation.
- Our work helps identify and quantify the depth and persistence of historic human alterations of landscapes and CZs. By having field and laboratory components to the research, we work across temporal scales and scales of complexity. These approaches help reveal patterns of land use history's impact on biogeochemistry and the mechanisms driving them.
- We develop ground-based tools, i.e., EMI, resistivity, and NIRS, through a digital soil mapping framework that helps us parameterize ecohydrological and biogeochemical models with much greater spatial intensity.
- We advance understanding of social, political, and cultural dimensions of human forcings of the CZ, and are particularly interested in understanding the complexity and legacy of these forcings of the CZ.
- The portable gas sampling and analyzer system I designed can be patented and further developed for much broader utility.
- My multilayered geo-pdf maps allow non-GIS researchers and the public to explore and understand the CZ like never before.
- Understanding and quantifying hydrologic interactions with sediment transport and soil organic dynamics is one of the highlights of our research. Process-based models, developed and implemented in this project, are advantageous over

empirical approaches as they represent physical theory and hydrologic processes in data-scarce, spatially heterogeneous terrains.

- Educational materials contribute to new pedological approaches in the Earth and environmental sciences. The pedagogy of the CZ is new and has the potential to transform teaching, especially with regards to interdisciplinary Earth sciences, coupled human and natural systems, and the environmental sciences.

What is the impact on other disciplines?

One of the most exciting and potentially fruitful aspects of critical zone science is its capacity to span the disciplines and marshal scientists with disciplinary skills and perspectives to interact in new and important ways. The CZOs are ambitious integrative projects and are in the act of creating a new Earth science as an *interdiscipline*.

This interdisciplinary vision is articulated directly in the 2001 NRC report led by Thomas Jordan, Gail Ashley, and others; it is articulated indirectly by the growing number of CZOs that are being established internationally on all continents (Giardino and Houser 2015). At the Calhoun CZO, it is not only the Earth scientists who are enthused by the interdisciplinarity of the challenges we face, but even our humanity's scholar, an environmental historian, has expressed his enthusiasm and amazement as well, saying: "Environmental history is a relatively new field of history and for all of its growth and impact, only with my involvement in the CZO have I become convinced that environmental scientists see that a human-historical perspective to their sciences is necessary."

And from one of our environmental engineers, "the theory of age and residence time of Earth's integrated surface systems is of great interest not only to hydrology and geophysics but to chemical engineering, population dynamics, and statistical and fluid mechanics."

At the Calhoun CZO, the PIs are fascinated and excited by the positive interactions between the integrative CZ science and the traditional academic disciplines.

What is the impact on the development of human resources?

The Calhoun CZO has 15 PIs based at six universities and colleges as well as the USDA Forest Service. These institutions and PIs involve a very large number of students from many backgrounds, students from high schools to graduate schools who are heading in

many directions. These are listed in detail and quantified in other parts of our annual report.

The Calhoun CZO held its third all-hands science meeting in 2016 ("Calhoun Summer Science Days"), but we also hold all-hands calls to work at the site such as our three "Calhoun Geophysics Weeks", in which a wide variety of students (including underrepresented students) were invited to assemble at the Calhoun to help scientists from WyCEHG who have travelled from Wyoming to work at the Calhoun. Similarly, in 2016 we hosted two "Calhoun Big Digs", efforts to attract a variety of students and scientists to work together on deep hand-coring to install gas reservoirs at 8.5-m depth and to sample backhoe-excavated soil and saprolite pits across sites with contrasting land-use histories. We are working with Dr. Justin Richardson (of Cornell University and the CZO National Office) on two research projects that involve rare earth elements in the Calhoun CZO's 70-m deep core. In the past, many or most of the assembled scientists camp together, which leads to science discussions late into the evenings. We are constructively demanding on our scientists and scholars, but one and all experience not only the hard work but also the intense joy of scientific investigation.

Educational and outreach from our Calhoun project targets mainly students and teachers at small 4-year and 2-year collegiate institutions. Representation of the Earth sciences at these institutions is typically low-level compared to many research universities. Providing educational opportunities in the Earth sciences within these collegiate communities directly "enhances development of human resources in Earth sciences." The re-organization of the Environmental Science program at Roanoke College, led by PI O'Neill, will be useful in advancing CZ education in years ahead.

What is the impact on physical resources that form infrastructure?

The Calhoun CZO leverages nearly 75 years of research (1947 to present) of land, vegetation, and water at the USFS Calhoun Experimental Forest, a landscape of long and on-going scientific interest due to the serious impacts of about 150 years of agricultural use from about 1800 to 1950. While the USDA Forest Service initiated the Calhoun research program in 1947, in 1962 the USFS dismantled all scientific infrastructure at the Calhoun Experimental Forest, despite 15 years of highly productive research by soil, ecology, and hydrology scientists (Richter et al. 2014). Fortunately, two USFS researchers kept working at two field experiments from 1962 to 1989, when they invited PI Richter and soon after PI Markewitz to join them at the Calhoun. The latter two have marshalled nearly continuous financial support from the National Science Foundation (Biological and Geosciences Directorates), several USDA research programs, and the Andrew Mellon, Wallace, and Trent Foundations to keep the Calhoun's long-term experiments alive and productive.

With the support of our CZ colleagues, we have very significantly re- and up-instrumented hydrologic and biogeochemical investigations all across the Calhoun CZO. Not only are we re-instrumenting four historic experimental catchments, but we have significantly up-instrumented the Calhoun watersheds with intensive and highly sophisticated hydrologic instrumentation. An inverted flux tower is constructed and collecting data from above and deep belowground data streams aimed to quantify legacies of land-use impacts on critical zone hydrology, geomorphology, biology, and biogeochemistry. While the USFS recognized the special values of the Calhoun Experimental Forest, they were institutionally unable to keep it funded. Thus, NSF's CZO program has been able to build upon a strong research foundation and indeed reconstitute a powerful research site that would otherwise have dwindled or even been lost.

What is the impact on institutional resources that form infrastructure?

The Calhoun CZO unites and strengthens our diverse institutions in many ways. The institutions include a small undergraduate college (Roanoke), land-grant universities (Mississippi State and University of Georgia), an EPSCoR university (Kansas), large public research universities (Kansas, UGA, Georgia Tech, and Mississippi State), and a private research university (Duke).

Within each institution, PIs and students are based at a variety of departments (e.g., History, Geology, Engineering, Environmental Sciences and Policy, Anthropology, Biology, and Earth Sciences). We use this diversity to contribute to the project at large. For example, in the fall of 2013, PI Aaron Thompson organized a set of web-based CZ science seminars among the PIs and their students. While the science was useful and interesting for certain, this activity was a study of contrasting academic cultures as well. In the fall of 2016, our remote e-discussions are on a bi-weekly basis. With data sets maturing, this is an exciting format to involve scientists of all stripes!

Perhaps the most remarkable example of CZO impact on institutions is at Roanoke College, a small 4-year liberal arts college and home to the Calhoun's E&O program. At Roanoke, PI O'Neill has affected with her colleagues a redesign of the interdisciplinary Environmental Studies curriculum with Earth's Critical Zone as one of the organizing themes. All three of the introductory courses in the Environmental Studies curriculum (Environmental Science, Environment and Society, and Environment and Culture) address different perspectives of the Earth's critical zone. In autumn of 2016, 81 Roanoke undergraduates are enrolled in these classes. Currently Roanoke has about 50-60 majors in the program. The introductory courses moreover reach an audience from across the college since these are used to fulfill general education requirements. The college catalog has been revised to include critical zone in course descriptions, and the major's natural

science track is now entitled, “Conservation and the Earth’s critical zone”. A new upper-level course is now being offered entitled, "Critical Zone Science and Management". Roanoke College may thus be the first liberal arts college in America to have critical zone science become a formal track within the environmental major. These programmatic changes are being documented and disseminated in journal articles and presentations to provide a model for other institutions.

What is the impact on information resources that form infrastructure?

In addition to the near constant circulation of email, discussions by telephone and Skype, we have used two websites for project management and communication, CZEN.ORG and CRITICALZONE.ORG. While the CZEN.ORG site was an initial repository for proposals, data sets, figures, miscellaneous documents, and communications among Calhoun PIs, we have moved to a Google-based system of communications, including Calhoun CZO Google Maps, Calendar, Docs, and Sheets that share writing, maps, sampling locations, and to facilitate general communications. Calhoun staff (Will Cook, Paul Heine) build the Calhoun website on CRITICALZONE.ORG. Many data sets are uploaded, but we have recently modified our data policy to speed this process which we see as important to enhancing scientific integration within the project. We also anticipate positive impacts from our Calhoun Data Management Platform in 2017.

What is the impact on technology transfer?

Technology transfer is both research and education based.

The visit of WyCEHG scientists during Calhoun’s three Geophysics Weeks (one in 2014, two in 2016) has been greatly stimulating to our geophysics expertise within the CZO. Our PIs with geophysics equipment and experience (Markewitz and Schroeder), have developed collegial relationships with WyCEHG scientists and have worked with a University of Wyoming graduate student who is investigating GPR data from the Calhoun landscape. During the first WyCEHG visit, our colleagues in regional offices of the National Resource Conservation Service (NRCS) visited the Calhoun and were extremely interested in WyCEHG instrumentation and data analysis. These same NRCS personnel are involved in our Big Dig! Fall 2016, in which they plan to formally describe soil profiles and help us with Ksat measurement and education.

Educational materials continue to be disseminated to undergraduate educators and students and field tested with the new critical-zone courses and curriculum offered at Roanoke College as part of the college's Environmental Studies program (discussed

above). The Calhoun E&O has developed outreach materials to help K-12 educators link critical zone concepts to national and state standards in order to transfer critical zone science to the K-12 and undergraduate classrooms.

What is the impact on society beyond science and technology?

Amilcare Porporato, the CCZO's Co-Lead PI, perhaps answers this question best.

"Simple models of social-CZ dynamics have the potential to capture the imagination and interest of the scientific and general public, providing simple and tantalizing explanations for long-term land-management practices. At the Calhoun CZO, we link social-land practices to a remarkable history of soil and land degradation of historical and national importance. Such cross-disciplinary approaches are important to educating citizens about a more respectful use of water and soil and to encourage the next generation to appreciate the usefulness of quantitative tools that address environmental problems."

Changes/Problems

Changes in approach and reason for change

Developing the Calhoun CZO on the USDA Forest Service's Sumter National Forest has required a considerable effort on the part of the Lead PI and selected PIs and students to interact with managers and NEPA coordinators and to comply with environmental assessment requirements. Our CZO decided early on that we would operate in full compliance with USFS's requirements. USFS managers allowed us to operate right from the start of our project, and by the fall of 2014 we received a formal Research Permit for most of our proposed research, based on a decision of "nominal environmental impact". In 2015 and 2016, we continue to work with USFS managers on annual permit amendments as the CCZO continues to grow and develop.

One example of the latter point is that we have redesigned the flux tower components in our research plan to comply with USDA Forest Service concerns. We were able to get this approved in 2016 and our flux tower was rapidly erected. PIs consider that we have turned this permitting process to our advantage as we seem to be enjoying a level of trust on the part of the USFS managers.

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

Described above.

Changes that have a significant impact on expenditures

Nothing to report.

Significant changes in use or care of human subjects

Nothing to report.

Significant changes in use or care of vertebrate animals

Nothing to report.

Significant changes in use or care of biohazards

Nothing to report.

Supplementary Information for Calhoun CZO
Year 2: 1 Dec. 2015 – 30 Nov. 2016
from Terms and Conditions for CZOs (NSF 12-575)

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

For further details with lists of names and organizations in Research.gov Annual Report, Participants/Organization.

Participant category	Number	Gender		Disciplinary background
		male	female	
Total participants	77	48	29	
Main personnel	23	19	4	Accelerator mass spectrometry (1), Anthropology (1), Biogeochemistry (3), Biology (1), Clay mineralogy (1), Ecophysiology (1), Ecosystem ecology (1), Environmental education (1), Environmental fluid mechanics (1), Environmental history (1), Forest ecosystem ecology (2), Geochemistry (1), Geomorphology (1), Geomorphology modeling (1), Hydrologic modeling (1), Hydrology (1), Pedology (2), Soil ecology (1), Systems science modeling (1)
Postdoctoral	4	3	1	Anthropology (1), Biogeochemistry (1), Geomorphology modeling (1), Plant and microbial ecophysiology (1)
Graduate students	27	13	14	Anthropology (3), Biogeochemistry (5), Ecosystem Ecology (1), Environmental fluid mechanics (4), Environmental history (1), Geomorphology modeling (1) Hydrologic modeling (4), Hydrology (1), Pedology (3) Systems science modeling (3)
Undergraduate students	20	11	9	Chemistry (2), Environmental Education (4), Environmental Science (1), Forest ecosystem ecology (3), Geochemistry (4), Mass Spectrometry (1), Pedology (5)
High school students	3	2	1	Anthropology (2), Pedology (1)
External participants	14	11	3	Anthropology (1), Archaeology (1), Ecosystem Ecology (1), Geoarchaeology (1), Geoecology (1), Geomorphology (1), Geophysics (2), Hydrology (2), Soil physics (1)

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

For further details and list of authors, titles, etc. see: Research.gov Annual Report, Products.

New Research Products	# 2016	3-y total
Total	104	255
Journals	34	60
Conference papers and presentations	62	177
Doctoral dissertations	0	1
Undergradate honors thesis	2	2
Book chapters	2	5
Books	0	1
Web portals for data storage and dissemination	0	1
Websites for outreach and education	0	1
Educational aids or Curricula	0	1
Other Products	0	1
Other Publications	2	3
Technologies or Techniques	2	2

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

For further details see many references to E&O in Research.gov Annual Report, E&O Objectives, Results, etc.

The Calhoun CZO project strives to link all research activities with training and education, both in the field and laboratory. We run an active E&O project that focuses on undergraduate education and all our "students" from high school to postdocs receive special attention and training. The loss of one of our CCZO PhD students, Ashley Block, to a bicycle accident, hit all of us in September with how tenuous is life and how valuable is our time together as educators and scientists.

CCZO E&O

A variety of educational modules illustrate CZ science concepts. Interactive iBooks use GIS-based maps, images, and video based on the Calhoun CZO. Materials on CZ science are disseminated at professional development meetings for educators. A new CZ science class has been made a part of the curriculum at Roanoke College, an environmental curriculum whose redesign was led by PI O'Neill to feature critical zone science. The new course's materials will be broadly shared with undergraduate educators. CCZO field tours have been given throughout our existence. In the field, we find people to be readily captivated by CZ science, the Calhoun

landscape and its history, and changes on-going today. Interest in these tours is high whether tours are given to REUs studying soils at North Carolina State or soil conservation veterans.

Some specific results include the successful development of educational modules derived from spatial datasets using ESRI Story Maps and .kml files for use with Google Earth, cloud-based formats widely available at no cost to educators. We believe these to demonstrate the feasibility to serve as a template for other CZOs. Our E&O leader, Dr. Kathy O'Neill has been active participating with the NO and National Education and Outreach team and she has helped the NO in various ways to move E&O agendas ahead program-wide. The Calhoun CZO is affiliated with the REU in soil science run by North Carolina State and two full-day field trips have now been taken to discuss CZ science, soils, and the Calhoun CZO.

Classroom test educational materials for the new undergraduate course in CZ science. Publish educational materials that integrate interactive maps, text, imagery, and video. Document pedagogical materials and assessments in a manuscript that will be submitted to a pedagogical journal. Publish outreach materials using cloud-based and distributed formats. Collaborate on cross-CZO E&O teams coordinated through the National Office. Continue and expand recruitment of undergraduate students, especially from underrepresented groups, to assist with Calhoun research.

Student training and mentoring

1. High school student education. At Duke and University of Georgia, high school students have been included in research. At Duke, a honors student from the North Carolina School for Science and Math is mentored by a Calhoun CZO PhD student, Anna Wade, over nearly one year. The student has already orally presented her work and will write it up as a senior thesis. The experience has deeply influenced her interests and future trajectory. At the University of Georgia, a high school student was hired to work in a soil physics lab and another worked with the environmental anthropology team as an intern helping with data organization and analysis. At Roanoke College, K-12 educators participated in four science pedagogy meetings at which our E&O PI gave a presentation about CZ and environmental science.

2. Undergraduate education. At Roanoke College, Duke, the University of Georgia, and the University of Kansas, undergraduates were involved in various ways with CZ science and the Calhoun CZO. At Roanoke College, PI O'Neill has provided training and opportunities for professional development to undergrads by supporting eight independent studies and research projects, including two senior theses related to CZ science. Laboratory and classroom activities have been developed and tested as part of the development of CZ educational materials that have been part of the education of more than 50 undergraduate Roanoke College students in the last 18 months. One Roanoke undergraduate was enthusiastic enough to volunteer to work on two hot very arduous Calhoun summer field trips "in order to get field experience." At Duke, a new interdisciplinary course entitled "Environment in Literature, Law, and Science" was given to more than 50 undergraduates, and the Earth's critical zone was made a cornerstone of the the science in the class. Also at Duke, twelve undergraduates in North Carolina State University's REU in Soil Science were given a day-long field tour in CZ science. At UGA, undergraduates were trained by a Calhoun CZO PhD student in the soil judging competition in which the

undergraduate team achieved national-level awards. Undergraduates also worked in a soil physics laboratory, completed a senior thesis, and three interned in a clay mineralogy lab processing CZO samples for isotope analyses. An undergraduate from Depauw University interned with a UGA CZO lab to satisfy his experiential learning requirement for his degree program. At the University of Kansas, three undergraduates were trained to use lab equipment to analyze soil sample incubations.

3. Graduate education. At Duke, Georgia Tech, Mississippi State, the University of Georgia, and the University of Kansas, graduate students are involved in significant ways with our CZ science and the Calhoun CZO. At Duke, seven PhD students are working on CZ biogeochemistry, hydrology, and systems modeling. Five have earned support from an NSF IGERT program in wireless technologies. At Georgia Tech, graduate students work in Rafael Bras' and Jingfeng Wang's laboratories with highly talented post-docs and visiting research scientists at the flux tower, in model development and simulation, and data production, processing, and analysis. At Mississippi State, a graduate student has worked to collect and analyze environmental history data. At the University of Georgia, graduate students are trained to collect and analyze field EMI, electrical resistivity, stream chemistry, and soil phosphorus data. At the University of Kansas, graduate students are trained in the use of soil and enzyme incubation techniques to assess soil microbial activities. All of these graduate students are presenting their results and integrated CZ science at a wide variety of forums, from AGU and EGU to local science and 4-H clubs. Calhoun PIs try to interact with all of these graduate students *across institutions*. They are publishing papers in flagship science journals such as *Water Resources Research,* receiving awards the interdisciplinary training that is needed for the next generation of Earth scientists.

4. Postdoctoral scientists. At Duke, the University of Georgia, and the University of Kansas, postdoctoral scientists are involved in important ways with our CZ science and the Calhoun CZO. At Duke, Dr. Jay Austin has moved from the University of Georgia to Duke in the last year and has moved into a position that will decidedly broaden his range of expertise. Well trained as a clay mineralogist, Jay is now monitoring groundwater, sampling and analyzing soil and water chemistry, and expanding his purview of CZ science. Also at Duke, Angthony Parolari has been involved in all aspects of the CZO research. He has helped mentor graduate students, helped reconstruct the experimental Calhoun watersheds, and conducted a variety of modeling projects with long-term Calhoun data. Dr. Parolari has recently moved to an assistant professor position at the University of Pittsburgh. At the University of Kansas, postdoc Dr. Christoph Lehmann is involved in soil incubations and analyzing microbial abundance and community composition. Christoph has worked at the Calhoun on a number of occasions where he has readily learned a variety of field skills. He has helped plan what is called the Calhoun Big Dig Fall 2016 which will compare deep soil profiles of CZs that have experienced contrasting land use histories. He is mentored mainly by PI Billings but also PI Richter.

A few other CCZO education and training activities include:

1) The five Calhoun CZO PhD students who earned admission and a high-level of financial support from the two-year Duke WISEnet IGERT Training Program in intelligent sensor networks

2) Supported by a German research agency, one PhD student worked for the summer at the

University of Koblenz-Landau in Germany, helping to establish a mini-CZO with PI Richter and Prof. Dr. Hermann Jungkunst. The CCZO student installed and trained German master's students and technicians with sensor technologies and in operating dataloggers.

3) The two CCZO PhD students, four research professors, and a high school student who visited Franklin and Marshall University and North Carolina State University on field trips led by Drs. R. Walter, D. Merritts, and K. Wegmann to learn first hand about legacy sediments from these scientists who have been studying human-altered geomorphology of stream systems for decades. The trips are directly related to our erosion-carbon research at the Calhoun CZO and a potential research proposal is being discussed among these scientists that would aim at quantifying the N-S regional gradients in legacy sediment formation and movement in the Eastern USA.

5) The two field visits to the Calhoun CZO made by WyCEHG during the year, near-weeklong visits we called Calhoun Geophysics Weeks II and III, for which we assembled as many personnel from the CCZO as we could, to work alongside these world-class geophysicists.

Supplement iv. Summary of status and results of cross-CZO activities supported by the CZO, including working-group activities, data efforts, field and laboratory measurements, meetings and workshops, student training and post-doc mentoring, outreach, abstracts and other publications.

For further details see many references to Cross-CZO activities described in Research.gov Annual Report, Cross-Site CZO Objectives, Results, etc.

Our CCZO objectives for cross-CZO activities are to encourage, develop, and prioritize the most transformative of cross-CZO opportunities for research, sample and data sharing, and other projects. Specifically, our strengths and potentials are to contribute to cross-site modeling, hydrologic analyses, biogeochemistry, forest ecology, flux measurements, pedogenesis, environmental history, systems science, organic carbon cycling, and E&O.

To date, more than half of the CCZO PIs are involved with cross-CZO research projects. Results are accumulating across sites from field-based mineral weathering experiments led by our USG PIs and their Japanese colleagues, soil microbial and biogeochemistry studies led by our Kansas PIs, and hydrologic modeling with PIHM led by Duke PIs. Redox-related experiments have been conducted in several CZOs including the CCZO and are part of at least two PhD student's disserations. We support the cross-site hydrology post-doc who will investigate hydrologic partitioning, and we support several cross-site E&O projects including the co-authoring a published paper in *The Earth Scientist* that describes opportunities for integrating CZ science into environmental science courses at the undergraduate and high school levels. Our geophysics and geochemistry data from our 70-m weathering profile has proven of such interest that it has drawn scientists from other observatories and research centers to our data and sites for collaboration on several papers about the intimate relations of geophysics and geochemistry in the critical zone.

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

CZO-NO initiated activities	Description of activities hosted by CCZO
Participated in the CZO Strategic Planning meeting in Boulder. Committed to leading a paper in which we explore the synergies of NSF's long-term environmental networks for promoting biogeosciences of the environment. Participated in CZO-PI Meeting at RCZO (September 2016) As an followup to the China-USA CZO workshop in Oct 2015, the CCZO proposed and was accepted by Red Soil Ecological Experiment Station in becoming sister CZOs. CCZO PIs participated in several workshops supported by the NO-led Science Across Virtual Institutes (SAVI). Our E&O PI O'Neill and data manager Cook participated at the direction of the NO in regular e-meetings.	Continued to host university students, professional societies, and international visitors for day-long and half-day educational, research, or outreach tours at the Calhoun CZO (see Research.gov Major Activities A.4 for details) Hosted for the second summer NCSU's Soil Science REU program Hosted working-trips to the CCZO for experts who are archeologists, public historians, geomorphologists, mineralogists, geophysicists, pedologists, etc. We typically invite or students to these ventures. Calhoun Summer Science Days was the third all-hands meeting at the Calhoun where we share new data, plan new initiatives, and take field trips to important sites. Calhoun 2016 Big Digs were two projects that combine research and eduction. In one we hand augered to 8.5 m to install gas reservoirs in preparation for our large-scale future clearcutting experiment.

Supplement vi. Tabulation of defined performance metrics for the period and comparison with proposed goals.

We use a UC-derived performance measurement system in our CCZO. Our performance objectives and goals are to make progress toward fulfilling our three major research objectivs and our objectives with E&O and cross-CZO activities. Our criteria and measures are keyed to third-year performance.

The organization of the table follows that in the Annual Report on Research.gov. See for example Specific Objectives section in Accomplishments.

Performance objective	Criteria for accomplishment	Measures of accomplishment
Hydro-Biogeochemical Decoupling and Regeneration of the CZ following Land Degradation	Geophysics and Geochemistry: Deploy advanced geophysics & geochemistry to quantify the structure of the CCZ.	Manuscript draft under review. Research proposal to be submitted
	Land-Use History: Geographically coordinate historic data to model changes in the human-landscape	Spatially explicit model built, data still being collected; manuscript due by mid-2017
	Environmental history of Rose Hill plantation	Draft manuscript due mid-2017
	Comparisons of Land-Use Affected CZs: Sample, instrument, and monitor replicated CZs with contrasting land-use histories.	Continued collections of time-series data throughout year. Hold Big Dig to sample & measure eco-hydrology of upper CZs in mid Oct 2016.
	Long-term Experimental Watersheds: Re- & up-instrument experimental catchments; train students	Three catchments instrumented to measure precipitation and streamflow; The intensively studied watershed of the three has soil moisture sensors and >30 groundwater wells all logging data; initiated PIHM modeling; complete digitization of historic hydrology records; trained students
	Calhoun Long-Term Soil-Ecosystem Experiment (LTSE): Eddy flux and 60th year resampling	Erect and initiate sampling from eddy flux tower. Prepare long-term plots for resampling in 2017.
Erosion-induced carbon dynamics	Sampling of Holcombe's Branch Watershed:	First estimates of organic carbon in legacy sediments of Holcombe's Branch; train students.
	Modeling of Holcombe's Branch: 1800-present carbon budget of watershed, uplands & bottoms	Publish papers of model of erosion-affected soil organic carbon flux in Holcombe's Branch (t-RIBS-ECO).
Persistence of alternate states	Collage historic land and human data for modeling of how CZs respond to severe land disturbance that threatens their resilience and regeneration	Host in-person meetings for agreement on first-order socio-ecologic models and manuscript drafts.
E&O	Launch new undergraduate CZ course within the newly redesigned Roanoke College Environmental Science major.	Circulate the course's educational modules that are developed to be broadly useful at scientific and pedagogical meetings, in classes and

	O'Neill is interested in discussing Roanoke's newly redesigned environmental program, now focused on CZ science, with geology and environmental science professors at small liberal arts institutions.	labs, at CCZO site visits and public outreach events, and on the CZO website.
Cross-CZO	More than half of the CCZO PIs are involved with cross-CZO research projects. We need to prioritize these efforts to maximize scientific and broader impacts of such collaboration.	Lead and participate in soil biogeochemistry, hydrologic partitioning, redox reactions, and E&O cross-CZO projects.

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Supplement vii. Lists of all publications and products from activities within the past year, including categories for published, accepted, and submitted.

See Research.gov (Products) where details of this information are reported.

	Sum	Published	Accepted	Submitted
Products	104	93	3	8
Journals	34	26	1	8
Conference papers & presentations	62	59	3	0
Doctoral dissertations	0	0	0	0
Book chapters	2	2	0	0
Books	1	0	1	0
Web portals for data storage and dissemination	0	0	0	0
Websites for outreach & education	0	0	0	0
Educational aids or Curricula	0	0	1	0
Other Products	0	0	0	0
Other Publications	2	2	0	0
Technologies or Techniques	2	2	0	0

Supplement viii. An assessment of progress towards meeting the goals for engaging the broader community that are established in the CZOMP.

Engaging broader communities is a high priority to the CCZO. Some communities are included in the following table; more are described in the Annual Report, especially in Accomplishments section answering the question, "How have the results been disseminated to communities of interest?"

Community	Activity
National & university scientists, includes outreach to Earth scientists, soils, hydrology, conservation, ecologists, LTER, mineralogy, microbial, education, and modeling communities	Presentations to scientific and professional societies and universities, colleges, and high school educators throughout the year
International scientists & science policy Professionals	China's Red Soil Ecological Experiment Station has agreed to join the Calhoun CZO as a sister-CZO to promote education and visitors between the two CZOs and plan future collaborative research. PI Richter continues to encourage Prof. Christina Siebe of UNAM in her effort to create and fund the Mesquital Valley CZO, adjacent to Mexico City. Richter invited Siebe to Duke during the last year. At AGU, the CCZO participated in planning and in the meeting of international CZO scientists on the Sunday prior to the main week of meetings.
USDA Forest Service managers	Continuing interaction with USDA Forest Service managers, especially at Sumter National Forest
Undergraduate & advanced high school educators	Developed and field-testing web-based CZ educational materials
Anthropocene Work Group of the International Commission on Stratigraphy	PI Richter was invited to join the working group as a representative from the soil and critical zone science communities
Environmental humanities	Following 2015's visit to the Calhoun CZO by Prof. Bruno Latour, philosopher of science, we are in the last stages of a 20-30-min video. Among Duke humanities scholars, the Earth's critical zone has become a concept for the environment; they feature the critical zone in posters and various events, and are using the concept to help initiate a new Environmental Humanities program.
South Carolina State Parks	At Rose Hill State Park, entirely within the Calhoun CZO and which features the plantation home of the successionist governor of South Carolina, we participated in what we called Rose Hill History Day, a day-long field tour with local and high-level state park officials to develop an environmental re-interpretation of Rose Hill to

	include land use history and Earth's critical zone. We are supporting a larger re-interpretation project led by the Public History Program at the University of South Carolina.
Union County Historical Society	PI Richter is a member, uses the Society's collections, and interacts with several of the Society's officers and members.
Local citizens of the Union and Cross Keys SC communities	Several of our research sites are on private lands and as a consequence we regularly talk and share data with our neighbors.

Supplement ix. Summarized results of evaluation forms submitted by participants of supported activities.

PIs did not use evaluation forms at any activities.

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

We developed and submitted several research proposals during the year. The Duke-based NSF-IGERT in wireless sensing technologies has funded at high level five of our Duke PhD students. This program has heavy course-work training, group-based projects, but full-financial support for two years. Another stream of financial support come from a successful proposal to Duke research administration to increase opportunities for large-grant proposals. We are submitting a proposal to NSF's IES program in November 2016 for a Calhoun-CZO-based drilling program that combines geophysics, geochemistry, geomorphology, geobiology, and modeling and crosses scales from the regional-continental to the ridge and interfluve to the soil profile.

Supplement xi. Unanticipated collaborations, research projects, and other endeavors enabled or stimulated by the CZO or CZO-NO.

We continue to expand the number of individuals who are interacting with us at the CCZO, individuals with whom we have had no previous relationship prior to funding in December 2013. These interactions have greatly enriched the internal and external operation of the Observatory. All of these unexpected colleagues are expected to continue to interact with our project in years ahead.

Unexpected collaborators	Description
Paul Sutter	Sutter is a environmental historian of the agricultural history of the American South, now a Professor at the University of Colorado. We invited Sutter as a featured guest at our first all-hands field meeting of the CCZO in June 2014, and we have engaged him in several ways since then. Sutter is the author of a forthcoming book, *Let Us Now Praise Famous Gullies*, which is about land use history of the South, and which deals explicitly with the Calhoun Experimental Forest and the Sumter National Forest. We nominated Sutter to be a honorary speaker at Duke University in November 2015.
Alan James	James is a professor of alluvial geomorphology at the University of South Carolina, and is fascinated by our CZO. James has visited the CCZO four times in the last 18 months, once for a project introduction, the second as an all-day work trip, third to help lead a exploration with about 20 students and scientists of the legacy sediments along Holcombe's Branch, and in late August an initial sampling trip of 11 profiles which we expect will be a publishable paper. James recently won the AAG's Gilbert Award for his 2015 paper on legacy sediments.
Mike Harmon	Harmon is a long-time archeologist on the Sumter National Forest and has not only taken a special interest in our CZO, but has visited us in the field on at least four occasions, communicated regularly by email, and volunteered a spectacular set of 100s of high resolution, black and white aerial photos taken in 1933 prior to the purchasing of the farms that became the Sumter National Forest. We scanned and georectified the photos; these are proving invaluable to reconstructing the land use history of the CCZO. Harmon is helping us expand the historical window of the CCZO back to Mississippian and Woodland periods, prior to settlement by Europeans and Africans.
Kay Savage Terry Ferguson	Savage and Ferguson are professors at nearby Wofford College and voluntarily attended our 2016 Calhoun Summer Science Days in May. They have interests in environmental and Earth science education and both see the Calhoun CZO as an excellent destination for their college's students. We toured several of Ferguson's field sites in August 2016 and are planning on writing a CZO-REU with their collaboration.
Josh Heitman	Heitman is a professor of soil physics at North Carolina State University and lead PI of the REU at NCSU in soil science of which the Calhoun CZO is affiliated.
Bruno Latour	Latour is a highly influential philosopher of science and technology and recently has taken a keen interest in Earth's critical zones. He gave a talk at the 2014 Geochemistry meetings in Paris, and is author of a humanity's take on the CZ that we believe to be a special achievement. PI Richter has developed a close relationship with Latour and helped him schedule visits to the Eel River and Southern Sierra CZOs in the summer of 2015. Latour visited the CCZO in September 2015, on a multi-day field tour in which he observes and questioned scientists working in the field and develop a reaction to the project. We are completing a video based on his nearly four-day visit to

	Duke and Calhoun.
Hermann Jungkunst	Jungkunst is a professor of physical geography at the University of Koblenz-Landau. He has experience with greenhouse gas chemistry and fluxes from the soil and is advising us on lab and field methods. He also has expertise in thermal analysis of soil organic carbon combustion. He is an active participant in Future Earth, a Working Group charged with understanding and promoting positive interactions of human management and the Earth system. Prof. Jungkunst has initiated a mini-CZO nearly his university with the help of CZO PhD student Zach Brecheisen.

Supplement xii. Other impacts of the CZO activities, including local community engagement, and policy.

Calhoun CZO scientists are most interested in the local communities in and around the Calhoun CZO. We are finally renting a small house, our Calhoun CZO Headquarters, which has affected many interactions with neighbors. Having a headquarters facilitates our research among our colleagues, as it is a 3- to >5-hour drive to the Calhoun from Duke, UGA, Georgia Tech, and Roanoke and a number of researchers are not campers, especially in summer and winter. See Supplement viii for additional details.

Supplement xiii. Data management.

More than 30 data sets are uploaded on the Calhoun CriticalZone.org website. The CCZO Executive Committee has amended our data sharing policy to shorten the period for researchers *within the Calhoun CZO* to upload data sets from 12 months after creation to 6 months. Our goal is that by the end of the third year, we will have all contemporary data streams (within six months of creation) being uploaded across the project.

Our long-term project goal is a web server that can efficiently host a variety of data types: from geo-referenced historical aerial photography (back to 1933), to LiDAR derived data sets (from the July 2014 flight), to live streams of hydrological and soil water and gas data, to the diversity of geophysics and geochemistry datasets. Our data manager has now uploaded historical 1933 aerial photographs, both sets of high=resolution LiDAR data sets, time series of hydrological and gas concentration data, and several geophysics and geochemistry data sets.

Over nearly a year, the data manager and PI Richter have worked with a private IT firm, DataMesh, to help us develop a data management platform. The DataMesh platform is now under development and aims to be fully compatible with the slowly emerging data management program across the CZOs (e.g., ODM2, HIS, R, and Matlab compatible). The platform is easy to use and efficient at QA/QC and in uploading a diversity of datsets into a common data base, and it takes advantage of the latest developments in the rapidly moving field of big data management. Working with DataMesh, we are using the common vocabulary and we have developed a Data Management Platform description that we insert here in italix for these supplementary materials.

Calhoun CZO Data Management Platform
Initial Development Status

A. General information:

1) The Data Management Platform consists of 6 components:
   a. A private and secure cloud data repository (ownCloud).
   b. The Linux operating system (CentOS).
   c. A relational database (MySQL).
   d. A web server (Apache).
   e. The R language and environment.
   f. The MATLAB language and environment.
2) Configuration tables (Loader and Transfer) on the RDB determine how data will be processed.
3) Linux scripts control process and data flow from parameters in the configuration tables.
4) The system design is intended to comply with appropriate components of ODM2, especially Controlled Vocabulary and unit names/definitions, while minimizing the impact on end users.
5) Multiple methods are available to provide user access.

B. User Operating Procedures:

1) User contacts system administrator to obtain credentials to access ownCloud.
2) User downloads and installs the ownCloud Client.
3) User copies the file to be included into the ownCloud repository. User must:
   a. Ensure that the file headers are a registered type, or
   b. Contact a system administrator to define and register the file type.
4) User updates the configuration tables in the database to provide processing instructions.
5) Upon updating the tables, the system will automatically process the data according to the instructions in those table.
6) When successfully completed, the data table will be added to the database. Additionally, an R file and/or a MATLAB file can be placed in the users' directories.
7) Users can access R files locally or via the server (which has R Studio server installed and operating).
8) Spreadsheets, R Studio, and MATLAB can be linked directly to the server (database tables or files) with proper credentials and passing network security measures.

C. Detailed Process Flow:

1) A file transfer script runs periodically (specified in Linux's cron program).
2) Scripts obtain processing parameters from the loader configuration table which include:
   a. ConfigId – A unique, auto assigned number that represents the distinct configurations.
   b. LoadActive – set as 0 if inactive, 1 if active to turn off load while saving parameters.
   c. DataDirectory – Temporary working directory which holds files in process.
   d. SampleSize – The number of records the loader reads when trying to determine the header information.
   e. DbTable – The staging table to load data prior to modifying production tables.
   f. Delimiter – how the file will be split
   g. DbServer – Server address the database resides on
   h. DbUser – The MySQL user to login with
   i. DbDatabase – The database to use

j. *ArchiveDirectory – Where to store the files after loading*
k. *LoadProcessComment – Comment to help keep track of configurations.*
l. *RExportActive – Set to 1 if it needs to export R file.*
m. *RFileName – Where and what the R file should be called.*
n. *MatLabExportActive – Set to 1 if it needs to export MatLab file.*
o. *MatLabFileName – Where and what the MatLab file should be called.*
p. *MultiHeaderFile – Set to 1 to identify the triple header files, to 0 for all other file types.*
q. *FormatDirectory – The working directory that the MySQL bulk load accesses.*

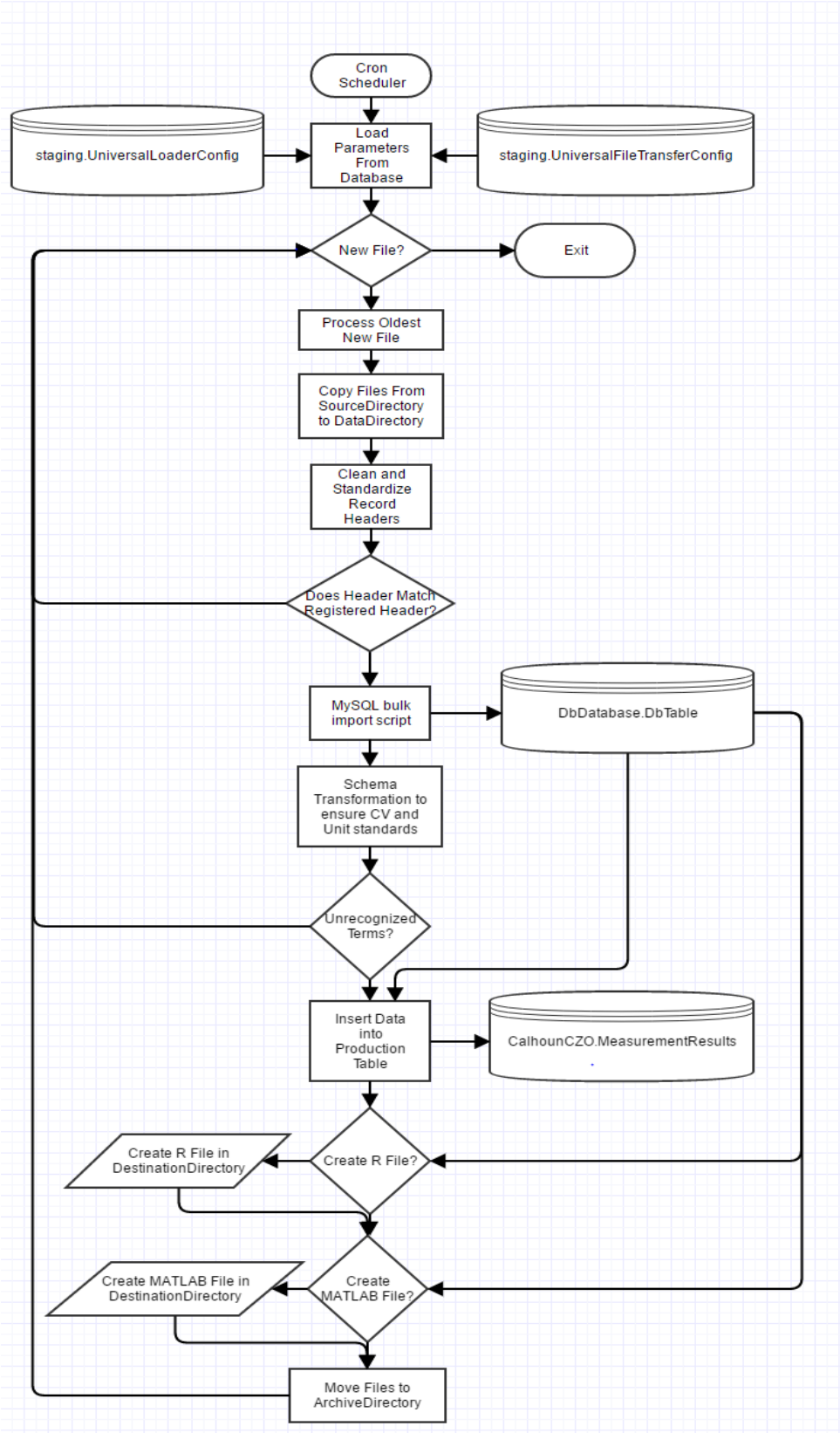
3) *Scripts obtain processing parameters from the transfer configuration table which include*
   a. *TransferID – An auto assigned number that represents the configuration*
   b. *TransferActive – Set to 1 if the transfers are active, 0 if disabled*
   c. *SourceDirectory – The directory where the raw files are stored.*
   d. *SearchWildCard – If the directory will contain multiple types of files, the wildcard can be used to pull only files containing whatever text is in this column.*
   e. *DestinationDirectory – Directory to provide user access to R and MATLAB files.*
   f. *Comments – Comments to help keep track pertinent notes.*

3) *A loader script runs which obtains operating parameters from the configuration tables and processes the new file(s) based on the registered file type.*
4) *Process all new files from the oldest to the newest.*
5) *Copy files from the SourceDirectory to the DataDirectory.*
6) *Clean and standardize header records.*
7) *Compare the cleaned header to the registered table header to ensure consistency.*
8) *If header does not does not match the registered table header exactly, the next file is processed.*
9) *If the header matches, then the file is copied to the FormatDirectory and calls the MySQL bulk import script using the DbUser's credentials to the location specified in DbServer, DbDatabase, and DbTable.*
10) *A script is called to perform schema transformation to ensure Controlled Vocabulary standards. The script also converts units into standardized values for consistency. If there are unknown units or unrecognized terms, the next file is processed.*
11) *When the table data is conformed to comply with naming standards, the data is inserted from the DBTable to the production table.*
12) *If specified in the configuration table, R and MATLAB files are created and stored in the DestinationDirectory (usually the users ownCloud directory).*
13) *All files are moved from the FormatDirectory to the ArchiveDirectory.*
14) *If additional files are indicated in the configuration table, the next file is processed.*

D. Future Direction of Data Management Platform.

1) *Provide complete integration with ODM2, HIS, and other systems with automated system integration to compliant data repositories.*
2) *Create automated data consumption from data sensors via API and web services.*
3) *Create automated synchronization processes between the CZO website and the data management platform.*
4) *Provide users a web based dashboard to control process flows and to directly access the data.*

Process Flow Diagram of the Data Management Platform



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

The CCZO has no budgetary overruns across its five programic activities of Recovery, Erosion-Carbon, Human-CZ, Alternative States, and Education and Outreach.

Supplement xv. A plan for remedial action where project milestones in the CZOMP have been significantly impacted.

As explained in past reports, our planned research has been reorganized in response to the mandatory permitting now required by USDA Forest Service to work on National Forests, even the USFS Experimental Forests such as the Calhoun Experimental Forest. These reorganizations have not altered our research objectives or scope of research. They have involved taking a more collaborative approach with USFS managers who must give us formal approval of our research plans and actions. While we had proposed to rapidly move into a "CZO construction phase" in year one, we were delayed by USDA Forest Service review procedures to begin activities such as flux tower construction and large ground-disturbing activities after NEPA approval. While we received a "nominal impacts" decision from the USFS in the first year, our research is now formally permitted. Only the proposed experimental clearcut has yet to be approved, an action we hope will occur late in year four or in year five of our project.

Supplement xvi. Problems likely to delay accomplishment of annual, strategic goals.

No problems will likely delay accomplishment of annual strategic goals.

Supplement xvii. Description of programmatic goals and objectives with specific activities/timetable to be accomplished in the upcoming year.

Organized by the five specific project goals and goals for the CZO at large.
See reply to the question, "What do you plan to do during the next reporting period to accomplish the goals?" in Research.gov in Accomplishments section of Project Report.

A. Year four plans organized by the five specific goals of the CCZO project.

1. Hypothesis 1: Hydro-biogeochemical Decoupling and Regeneration of the CZ following Land Degradation

a) Deep Geophysics and Geochemistry. We will continue to collaborate writing papers with WyCEHG and a drilling-related proposal of observation and modeling the deep, ancient critical zone across the Calhoun CZO. Particularly of value is to test the unexpected conclusions reached in St. Claire et al. (2015). Encouraged by our Virtual Site Visit review in late 2015, we will continue to install groundwater wells in and around the 70-m well. Rare earth elements are being measured to expand geochemical information of the 70-m core.

b) Land-Use History. Environmental anthropologists and historians are continuing to assemble the history of changes in the land at the Calhoun CZO. Historical records, aerial and on-ground photography, and census data are used in geographically explicit models to interpret human forcings that accelerated and decelerated soil erosion on uplands and hillslopes and sedimentation of valley bottoms.

c) Land-Use History Comparison of CZs. Nine sites will continue to quantify the structure and function of CZs affected by contrasting land use histories: three sites in old-field pine forests that are 60 to 90 years from farm abandonment, three in uncultivated reference hardwoods that have minimal farming impacts, and three in currently cultivated fields. We will continue to log soil moisture, temperature, CO_2, and O_2 at 0.5- and 1.5-m, and measure moisture by neutron probe and four gases down to 5-m. We will estimate Ksat throughout soils and upper saprolite of the nine sites, and initiate the broadcast to the internet via modem of some of our logged data.

d) Long-term Experimental Watersheds. Measurements of rainfall and streamflow continue on the reinstrumented watersheds in addition to the array of groundwater wells with water sensors throughout Waterhshed 4 and within Holdcombe's Branch legacy sediments. Analysis of historic strip charts will be completed with the help instruments at the US Geological Survey instrumentation and Coweeta Hydrologic Lab.

e) Calhoun Long-Term Soil-Ecosystem Experiment (LTSE). The 16 LTSE plots will be resampled in 2017, and samples archived 60 years from the initiation of the field study. Analyses will focus on temporal dynamics of organic carbon throughout the upper CZ and structural re-aggregation in the clayey B horizon.

2. Hypothesis 2: Erosion-Induced Carbon Dynamics

a) Observations. Our first manuscript on legacy sediments will be produced in 2017, a paper focued on the sediment inundation of soil organic carbon (SOC) in Holcombe's Branch. Studies will be conducted in the laboratory of the changes in microbiology and biogeochemistry of soil organic matter as it is buried in legacy sediments.

b) Modeling. The update of the distributive model tRIBS-ECO will be initiated updating the initial simulations with much more data that have been gathered as the research teams have studied the Calhoun. We actually anticipate that in year five this paper will be written and submitted but a deliberate approach to the model which can in years 4 adn 5 include many more PIs and students will be well worth the effort.

3. Hypothesis 3: Persistence of Alternative States

Environmental historians and anthropologists will be producing at least two papers during the year, and also working with modelers to better quantify the history of changing land and human dynamics. This team intends to submit a research proposal to NSF's Coupled Human Systems program. The investigators will continue to visit each other's campuses for multiple day of collaborations.

4. Education and Outreach Program

Classroom test educational materials for the new undergraduate course in CZ science. Publish educational materials that integrate interactive maps, text, imagery, and video. Document pedagogical materials and assessments in a manuscript that will be submitted to a pedagogical journal. Publish outreach materials using cloud-based and distributed formats. Collaborate on cross-CZO E&O teams coordinated through the National Office. Continue and expand recruitment of undergraduate students, especially from underrepresented groups, to assist with Calhoun research.

5. Cross-CZO Projects

PIs and students will continue to actively partipate in several cross-CZO projects, specifically the soil biogeochemistry, hydrology, and E&O projects. Our data manager will continue to participate in the Cross-CZO effort to promote program-wide data management. Intensive measurements of O_2, redox potential, FeII, DOC, and pH will be conducted at the Calhoun over about six weeks to match a study successfully completed at the Luquillo CZO, to demonstrate the widespread importance of redox fluctuations in upland and bottomland CZs.

B. Plans that support the CCZO at large

1. Calhoun CZO Executive Committee. The Executive Committee will continue to meet once a month, with the sole objective of getting the most scientific and societal impact from our CZO.

2. Calhoun CZO-USFS Relations. We will continue to work closely with the managers of the Sumter National Forest.

3. Fourth Annual Calhoun Summer Science Days. The Executive Committee will organize the coming year's All-Hands Summer Science Days. We are considering combining research activities along with the meeting.

4. Calhoun CZO Website. Our website will continue to be the focus for our observatory's growing research, infrastructure, data, models, publications, people, and E and O programs.

5. Data Policy and Management. We will work to implement our accelerated data-sharing policy *within our Observatory*. Our data manager and PI Richter will continue to work with an outside firm, DataMesh, to design a data management platform to both analyze and report CZO data. The system will be R and Matlab compatible and will aim to streamline data QA/QC and entry of data into the Calhoun data base.

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