Final Report

for

国家自然科学基金委员会
National Natural Science Foundation of China

National Science Foundation
WHERE DISCOVERIES BEGIN

Sino-U.S. CZO Workshop

GUIYANG, CHINA

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I. Executive Summary

The National Natural Science Foundation of China (NSFC) and the National Science Foundation of the U.S. (NSF) jointly convened this workshop to bring together Critical Zone (CZ) scientists from the two countries to discuss topics of common research interest, with the goal to network Critical Zone Observatories (CZOs) in the U.S. and China and to develop a bilaterally coordinated and supported CZ science program. The objective of the proposed bi-national program is to promote CZ science internationally, educate future leaders in global CZ science and policy, and address major societal challenges related to CZ services by leveraging diverse scientific perspectives and unique institutional resources afforded by a more fully integrated U.S.-China initiative. A total of 35 Chinese scientists and 18 U.S. scientists spent two days in the workshop and three additional days in field trips to two CZO sites in China. Representatives from the NSFC and NSF, plus 10 students from the host institution (the Institute of Geochemistry, the Chinese Academy of Sciences), also attended the workshop and field trips. This report highlights the scientific discussions and collaborative strategies developed through this meeting, and presents some recommendations as summarized in the following.

1. **A China-U.S. scholar exchange program in CZ science can advance Sino-U.S. collaboration and educate future leaders in global CZ science and policy. We recommend to the NSFC to work with the Chinese Scholarship Council to jointly support Ph.D. students, postdocs, and/or visiting scholars for studies in the U.S. CZOs. Meanwhile, U.S. scientists can seek support from the Fulbright Scholar program, the NSF, and other agencies to work in China CZOs. This specifically targeted area of scholarly exchange should be an integral part of a successful bi-laterally coordinated CZ science program;**

2. **An annual meeting between U.S. and China CZ scientists is recommended for the next decade to maintain strong ties between the two countries' scientists to better advance CZ science and to develop joint solutions to major societal and global challenges. Each year a theme may be targeted and some concrete advances could be achieved through joint efforts. Such an annual meeting may be coordinated through existing avenues such as AGU Fall meeting or other meetings to be held in the U.S. or China;**

3. **Workshop participants look forward to continued collaboration between NSF- and NSFC-funded scientists on CZ science research. CZ science is enriched by bi-national interactions, and these collaborations will enable valuable and influential contributions to international CZ science. Meanwhile, Chinese scientists can work with the NSFC to seek for support to move forward with this initiative, while U.S. scientists can consider various existing NSF programs to develop joint proposals as first steps towards a more fully developed program.**

II. Introduction

Earth's Critical Zone (CZ) is the thin layer of the Earth's surface from the top of vegetation to the bottom of aquifers that sustains life and humanity. It is under increasing pressures from rapid growth of human and livestock populations, land use intensifications, global environmental changes, and expanding consumption patterns. Critical Zone Observatories (CZOs), established first in the U.S. in 2007 and now being developed in China, provide physical infrastructures that are the foci for interdisciplinary investigations of complex interactions among rock, soil, water, air, organisms, and human activities over a broad range of spatial and temporal scales.

The CZ is critical for the following reasons:

- It provides nearly every life-sustaining resource upon which terrestrial life originates, evolves, and thrives;
- It is the zone where humans live and work and thus dictates human livelihood. In the meantime, it is also most susceptible to human perturbations;
- It is the crucial interface among all the spheres of the Earth system, and thus is a key to understanding their coupled dynamics; and
- It is a critical region of the solid Earth readily accessible to direct observations, and hence is crucial to revealing Earth's history.

Following up from two previous international CZ meetings held in 2012 and 2014, the National Natural Science Foundation of China (NSFC) and the National Science Foundation of the U.S. (NSF) jointly convened this third bi-lateral workshop, with the goal to bring together CZ scientists from the two countries to discuss topics of common research interest that would lead to the networking of CZOs in the U.S. and China and to the development of a bilaterally coordinated and supported CZ program. The objective of the proposed bi-national program is to promote CZ science internationally, educate future leaders in global CZ science and policy, and address major societal challenges related to the Earth's CZ by leveraging diverse scientific perspectives and unique institutional resources afforded by a more fully integrated U.S.-China initiative. The workshop addressed the following topics:

- Current conceptions of the scope of CZ science, the requirements for a CZO, and the opportunities and challenges of creating an internationally networked CZO program;
- Identification of major opportunities and knowledge gaps in advancing the frontiers of CZ science jointly in China and the U.S.;
- A plan of action and a possible schedule of steps to develop a coordinated program of CZ research between China and the U.S.

A total of 53 scientists active in CZ research (35 from China and 18 from the U.S.) spent two days in the workshop and three days in field trips. Representatives from the NSFC and NSF, plus 10 students from the host institution (the Institute of Geochemistry of the Chinese Academy of Sciences), also attended the workshop and field trips. This meeting greatly enhanced mutual understanding as well as stimulated enthusiasm for collaboration among the participants from the two countries. The feedback received was overwhelmingly positive, and all the participants expressed strong interest in moving this joint initiative forward. This report documents the scientific discussions and collaborative strategies developed through this meeting.

III. Scientific Discussions

A wide range of scientific issues was discussed throughout the meeting, guided by the goal of the workshop. These are summarized here using five key questions: 1) what makes a CZO a CZO; 2) how can CZ services complement and enrich ecosystem services; 3) why do we need a global CZO network; 4) what are possible operational and analytical standards to be adopted by global CZOs; and 5) how to develop a library of CZ models and a shared database for use by the global community.

1. What makes a CZO a CZO

Understanding the CZ requires a systems approach across disciplines, including hydrology, soil science, biology, ecology, geology, geomorphology, geochemistry, geophysics, and others. Scaling across space and time is fundamental to CZ science, which ranges from the rock or soil pore scale to the Earth system and from the geological past to the present and into the future. There are three general questions shared among the ten CZOs funded in the U.S.:

- What *controls* CZ properties and processes?
- What will be the *response* of the CZ structure, and its stores and fluxes of energy and matter, to climate and land use change?
- How can improved understanding of the CZ *be used* to enhance ecosystem resilience and sustainability, and restore ecosystem function?

While there are many characteristics of a CZO, common emphasis on three foci can be used to differentiate CZOs from other terrestrial environmental observatories:

- *Deep time* (i.e., geologic timescale to reconcile long- and short-timescale processes), with the recognition that the present landscape has been shaped by a geologic history and understanding that history as recorded in the CZ helps inform future projections;
- *Deep depth* (i.e., deep into weathered bedrock), which is deeper than the classical perception of soils (perceived as 1-2 m deep with a focus on the root zone) and much deeper than surface soils traditionally emphasized in ecosystem research;
- *Deep coupling* (i.e., interactions and feedbacks) among geologic, pedologic, hydrologic, chemical, biologic, atmospheric, and anthropogenic processes, especially those mediated by the flux of freshwater and conditioned by geology.

There were considerable discussions at this meeting on similarities and differences between CZOs and the Long-Term Ecological Research (LTER) sites and the Chinese Ecosystem Research Network (CERN) sites. However, it was also clearly recognized that interactions between them can foster a more integrated and robust terrestrial environmental observing system. Measurements and approaches that can facilitate the inclusion of both LTER/CERN and CZO research at a site include the following:

- Addressing water, energy, and element processes and budgets at scales from soil profiles to hillslopes, catchments, and river basins

- Considering 3D volumes from treetop to aquifer and the inclusion of geophysical perspectives and tools
- Investigating landscape evolution and soil formation, including weathering processes, which can involve a number of isotope techniques for determination of age and rates of cycling
- Assessing the dynamics of CZ function and sustainability under human impacts and climate change

Fundamentally, it is the *integration* of landscape evolution, soil genesis, hydrology, geochemistry, and ecology at multiple spatial and temporal scales that is key to the CZO concept, and sets it apart from other terrestrial environmental observatories. This integration may be best obtained through co-located sites in which multiple scientific communities study aspects of the CZ specific to their individual disciplines. This understanding forms the consensus of the meeting participants regarding what makes a CZO a CZO.

2. CZ services

The intensification of natural resource extraction from the Earth's CZs is accelerating and in many cases without adequate knowledge—or with a disregard—of the limits and capacity of the supporting ecosystems, water resources, air quality, and soil health. Rapid growth in human population, changing consumption patterns, and global climate change all are intensifying the pressures on the CZ. Sustainable management of the CZ for global human prosperity in the face of natural and manmade stresses requires a holistic understanding of CZ structure and function across scales. To facilitate the application of CZ science to sustainability practices, we advocate the new concept of CZ services that complements and enriches the established concept of ecosystem services. Connecting ecosystem services with CZ services calls for enhanced efforts to address a grand challenge in integrating bio- and geo-sciences.

Ecosystem services encompass provisioning, regulating, supporting, and cultural services. This concept, for the most part, is biologically focused, including especially biodiversity, biological cycles, and renewable resources. In comparison, the concept of CZ services expands and integrates biological services with soil generation, landscape evolution, and water cycling, emphasizing geological processes and nonrenewable resources on the scale of a human life span. In essence, CZ services extend the context for ecosystem services in two important aspects: 1) explicitly addressing how the physical structure of the terrestrial Earth surface (e.g., parent material, topography, and orography) provides a broader spatial and temporal template that determines the coevolution of physical, chemical, and biological processes in ecosystems; and 2) special emphasis on the rate limiting processes of ecosystem services that is fundamentally constrained by CZ processes, such as soil formation, nutrient supply, hydrologic partitioning, and streamflow generation. Overall, CZ services are where CZ science can truly develop its applications.

3. CZ networks

The Earth's CZ has a nearly infinite range of physical, chemical, and biological characteristics that have evolved through a wide range of time scales and processes. Thus, if CZ science is to fulfill its mission to understand comprehensively the basic function, carrying capacity, and vulnerability of the Earth's terrestrial environment, it must develop a systems understanding of diversity of Earth surficial systems, which is necessary to developing a realistic global perspective. We advocate that scientific communities work toward a global network of CZOs to leverage both the diversity of CZs and the intellectual and technological resources available.

A global network of CZOs may include networks of sites, people, ideas, data, and tools. Scientifically, a global network of CZOs may be designed and organized following environmental or perturbation gradients (such as climate and anthropogenic impacts), and/or based on intrinsic or unique environmental or geological settings (such as cryosphere or glaciated sites in the U.S. or the Loess Plateau and Tibet Plateau in China). Comparable CZOs can also be developed to cross examine similar environmental settings but under different land uses.

4. CZ standards

It was evident throughout the meeting that some level of standardization in methods, equipment, protocols, databases, and models is needed to maximize the potential of a global network of CZOs. Common features and infrastructures of CZOs include:

- Operation at the catchment or watershed scale
- Geophysical investigations of 3D volumetric architecture of the CZ
- Isotopes and other tracers of water, particles, and chemicals
- Real-time monitoring of energy, water, solutes, and sediment fluxes across CZ components and boundaries
- Systematic characterization of CZ storages and their changes over different time scales
- Open data access with adequate metadata

Partnerships among scientists and laboratories can contribute to such needed standards, including joint CZ working groups on methods in various areas such as:

- Geophysical instrumentations
- Inorganic and organic geochemistry
- Isotope applications
- Biological technologies
- Remote sensing and LiDAR
- Sample collections and archives
- Model development, use, and testing

The participants in this meeting suggested that a small amount of money could be used to begin the effort of assembling methods for comparison.

5. CZ models and data

CZ science requires data synthesis and modeling using similar and contrasting observatories. Three data and modeling needs were identified that could lead to substantial advancements in CZ science: 1) developing and testing common models across sites, 2) creating model and data libraries, and 3) providing better tools for querying and sharing datasets. If common models are made available in a model library, it would provide a platform to both test and improve models across a variety of site conditions. This effort could ultimately lead to models that are more transferrable to conditions outside of those in which they were developed or in which extensive monitoring data are available. This effort can also lead to models that are more capable of solving challenges associated with polygenesis. CZ science and the larger Earth science community are facing the challenges of data sharing that arise from the diversity of data streams, lack of sufficient metadata, lack of online repositories, and hesitations in sharing unpublished datasets. Development of international collaborations and networks in particular will have to solve data sharing challenges to meet their full potential.

CZ science offers new modeling opportunities and data sharing, and forges a new thinking in in a number of ways, such as:

- How to share models, how to share datasets, how to find models for specific efforts, how applicable a model is across sites, and how to learn from model failures
- Establishing a library of models instead of one supermodel for all CZ science. Model libraries can include links between pedogenesis and landscape evolution, connections between aboveground and belowground, joining of geophysics and geochemistry, coupling of hydrology and biogeochemistry, and integration of anthropogenic and natural processes
- Linking databases to model systems, data fusion with different resolutions, and calibration datasets for a suite of models
- The need to advance both conceptual and numerical models, and to address model adequacy and gaps, including difficulty of modeling with future uncertainty in human dimensions and management decisions
- Cyberinfrastructure for modeling and data management, and the need to include new high computational capacity previously impossible
- Using model to extrapolate to unmonitored sites and to access global quantification of CZ services
- Uncertainty issues and their quantifications in models and predictions

The participants in this meeting agreed that model comparisons and data synthesis efforts provide an efficient way to begin China-U.S. CZ collaborations. In particular, small amounts of funding to support model testing across several U.S. and China CZO sites could be quite fruitful. Additionally, funding to support targeted synthesis efforts (e.g., in the model of the USGS Powell Center) has the potential to connect scientists and existing datasets around high impact questions using site inter-comparisons.

IV. Collaboration Discussions

A number of bi-lateral collaboration strategies were discussed, among which five main categories are summarized in the following: 1) common scientific interests; 2) sister and unique CZOs; 3) visiting scholars and students; 4) bi-national scientific working groups; and 5) international funding opportunities.

1. Common scientific interests

There were wide-ranging topics discussed in this meeting in terms of scientific interests. Many were shared among the scientists from both countries. Besides the general desire and a clear enthusiasm to advance CZ science together, several topics were identified as initial common interests for potential collaborations. The network of CZOs between China and the U.S. is considered most meaningful when either gradients (e.g., environmental or perturbation gradients) or intrinsic characteristics (e.g., geological formations or soil orders) are used to link CZOs in the two countries. A cross Sino-U.S. field experimental design can allow for the exploration of CZ response, recovery, and restoration under various influences, such as:

- *Atmospheric deposition* (e.g., acid deposition, N deposition, contaminants, and dust), which is a common air pollution problem in the two countries. Atmospheric deposition plays an important role in CZ functions, and recent economic growth in China exacerbates the strain that atmospheric deposition places on the CZ and its services. Some of the U.S. CZOs are already recovering from certain types of atmospheric inputs (e.g., acid rain) while a recovery in China is not yet in sight. Comparison of CZOs between the two countries thus can offer useful guidance to recovery and restoration.
- *Intensive agriculture* and the associated effects on water quality, erosion, greenhouse gas emission, and biodiversity. China has a much longer history of intensive anthropogenic impacts on its land and water than the U.S., and this distinction can offer useful perspectives on long-term impacts and provide guides to sustainable practices. Sino-U.S. collaboration can present gradients of anthropogenic disturbances from less to highly impacted landscapes.
- *Emerging contaminants* (e.g., hormones and antibiotics). Both China and the U.S have serious pollution problems (including emerging contaminants) that pose threats to the CZ and its services but with distinct differences grounded in types of pollutants, the length and extent of exposure, and the policies dictating use and clean up.

There were additional cutting-edge topics that were identified as common scientific interest during this meeting, which can also significantly advance CZ science, including:

- Integration of geochemistry, geophysics, and geobiology in the CZ
- Coupling hydropedology and biogeochemistry across scales in the CZ
- Organic matter dynamics and its storage and reactivity in the CZ
- Synthesis methods for large and complex dataset analysis in CZ science
- Use of multiple isotopes for tracking various processes in the CZ

- Quantification of CZ services and their impacts
- Effects of vegetation restoration and related human interventions on CZ processes, functions, and services
- Microbial communities within the CZ – including communities found in the deep CZ – and their role in regulating energy and matter fluxes

To maintain strong ties between U.S. and China CZ scientists we recommend an annual meeting in conjunction with AGU Fall meeting or another international meeting where those already working together in the U.S. and China CZOs can meet and report on their accomplishments and future plans. Each year, a theme may be targeted and some concrete advances could be achieved through bi-lateral joint efforts.

2. Sister and unique CZOs

CZs are as different as they are similar. The range of CZs and their evolutionary development may be nearly infinite. China and the U.S. share some similar soils as well as contrasting ecosystems. Thus both sister and unique CZOs have been suggested as a way to facilitate Sino-U.S. collaborations.

Sister CZOs share common features (such as comparable soils, intensive management and modification, climate, or terrain), such as:

- Red Soil CZO in China and Calhoun CZO in the U.S.
- Karst CZO in China and Susquehanna Shale Hills CZO and/or Konza Prairie LTER site in the U.S.
- Loess CZO in China and IML CZO in the U.S.

Unique CZOs have special features and significance that are not replicable in another country. Such examples may include:

- Tibetan plateau in China (the 3rd pole of the Earth)
- Loess plateau in China (the most highly erodible soil on the Earth and the cradle of Chinese civilization)
- The black soil region in northeast China (one of the key grain production areas in China, which has been subject to severe erosion by wind, water, and tillage)
- Glaciation in the northern regions of U.S. (whereas only limited influence by glaciation in China)

It was recommended during the meeting to develop a summary of characteristics of various existing and potential CZOs in both the U.S. and China to facilitate the evaluation of potential similarities and differences. It could include basic setting information, available measurements and instrumentation, and existing databases and models associated with each CZO. This effort may be linked to the site seeker tool being developed through the CZ Exploration Network (CZEN).

3. Visiting scholars and students

A China-U.S. scholar exchange program in CZ science can advance Sino-U.S. collaboration and educate future leaders in global CZ science and policy. This specifically targeted area of scholarly exchange is an integral part of a successful bi-laterally coordinated CZ science. It would be valuable to develop a database of CZ scientists and their expertise for this exchange program.

Effective approaches to Sino-U.S. scholar exchange that were discussed during the meeting include:

- Co-supervision of Ph.D. students (which requires structure and clear expectations)
- Cross-CZO postdoc positions
- Training workshop for Ph.D. students with joint field trips
- Summer field-courses housed in different CZOs that actively engage students in CZ research, and can generate university credits
- Establishing virtual working groups (via online system), targeting cross-CZOs processes
- Involving U.S. scientists in the development of newly identified China CZOs, and inviting Chinese scientists to the U.S. CZOs and related working groups

4. Bi-national scientific working groups

To help frame common questions and supporting common metrics and standardization across the U.S. CZOs, the NSF has helped support scientific working groups in a number of areas of common scientific interests. These working groups, populated by volunteer membership from across the U.S. CZO network who are experts in respective areas, actively help shape cross-CZOs science through regular meetings and workshops. For instance, results from a recent workshop on LTER-CZO partnership in the U.S. were presented at this meeting in Guiyang and initiated extensive discussions. In fact, members of the emerging China CZO network team who were present at this meeting voluntarily participated in one of the 2015 cross-CZOs workshops on organic matter dynamics held at Purdue University in Oct. 22-24, 2015. We recommend that an effort be made to form complimentary working groups between the U.S. and China CZO networks to help facilitate the integration and coordination efforts for bi-national Sino-U.S. CZ science. Such working groups can also facilitate annual meetings between the U.S. and China CZ scientists.

5. International funding opportunities

The NSFC has continuously stressed the importance of international scientific cooperation and exchange, thus has established various mechanisms to facilitate the participation of Chinese scientists in international cooperation and exchange. Different opportunities are also available in the NSF Office of International Science and Engineering for developing collaborations between scientists in China and the U.S. Research programs in NSF Directorates can also support international activities. Below is a partial list of existing NSF programs that supports U.S. participants in international collaborations:

- International Research Fellowship Program (IRFP): http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5179&org=OISE&from=home
- International Research Experience for Students (IRES): http://www.nsf.gov/pubs/2012/nsf12551/nsf12551.htm
- East Asia and Pacific Summer Institutes for U.S. Graduate Students (EAPSI). http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5284&WT.mc_id=USNSF_39&WT.mc_ev=clickInternational Research Experiences for Undergraduates (iREU): http://www.nsf.gov/publications/pub_summ.jsp?WT.z_pims_id=5517&ods_key=nsf13542
- Partnerships for International Research and Education (PIRE): http://www.nsf.gov/pubs/2014/nsf14587/nsf14587.htm

V. Recommendations

Three main recommendations are suggested here. We recommend to implement Sino-U.S. CZO collaborations in multiple phases leveraging existing resources and infrastructures.

1. People

A China-U.S. scholar exchange program in CZ science can advance Sino-U.S. collaboration in CZOs and educate future leaders in global CZ science and policy. We recommend to the NSFC to work with the Chinese Scholarship Council to jointly support Ph.D. students, postdocs, and/or visiting scholars for conducting joint research in the U.S. CZOs. In the meantime, U.S. scientists can also seek support from the a variety of U.S. and China-based resources such as the Fulbright Scholar program in the U.S. and the Senior Visiting Scholars Program in China to conduct joint research in China and U.S. CZOs. This specifically targeted area of scholarly exchange must be an integral part of a successful bi-laterally coordinated CZ science program. Bi-national working groups on specific CZ science questions could form the basis for such a visiting scholar network.

2. Meeting

An annual meeting between U.S. and China CZ scientists is recommended for the next decade to maintain strong ties between the two countries' scientists in order to better advance CZ science and to develop joint solutions to major societal and global challenges. Each year, a theme may be targeted and some concrete advances could be achieved through joint efforts. Such an annual meeting may be coordinated through existing avenues such as American Geophysical Union (AGU) fall meeting or related international meetings to be held in the U.S. or China.

3. Funding

A China-U.S. bi-laterally coordinated and funded CZ science program is valuable, globally influential, and achievable. Opportunities for peer to peer U.S.-China cross CZO funding do exist within the NSF and should be leveraged. We encourage U.S. scientists to consider existing NSF programs to develop joint proposals as first steps towards a more fully developed joint program. In the meantime, Chinese scientists are also encouraged to work with the NSFC to seek for further supports to move forward with this joint effort.

VI. Appendices

1. Workshop schedule and agenda

Oct. 5th	Registration
Oct. 6th-7th	Workshop Sessions
Oct. 8th	Field trip: Puding Karst Ecological Research Station
Oct. 9th	Trip from Guiyang to Yingtan Red Soil Station
Oct. 10th	Field trip: Yingtan Red Soil Station
Oct. 11th	Departure

Day 1: Oct. 6, 2015 (Tue.)

Morning:

Session I: Opening (Chairs: Bojie Fu, Henry Lin)

8:00 – 8:30 am Welcome and opening remarks by NSFC and NSF (Dr. Congqiang Liu, Dr. Carol Frost)

8:30 – 8:45 am Self-introduction of all participants

8:45 – 9:00 am Group photo

9:00 – 9:30 am Coffee/tea break

Session II: Plenary (Chairs: Katherine Maher, Ganlin Zhang)

Note: Each Plenary talk consists of 60 min presentation plus 15 min discussion

9:30 – 10:45 am Plenary talk 1 – ***What makes a CZO a CZO? A U.S. Perspective***

Presenters: Dan Richter, Lou Derry, Suzanne Anderson, Praveen Kumar, William McDowell, Tim Filley, and Henry Lin

10:45 – 12:00 am Plenary talk 2 – ***What makes a CZO a CZO? A China Perspective***

Presenters: Bojie Fu, Dali Guo, Xinhua Peng, Tao Peng, and Yihe Lv

Afternoon:

Session III: Discussion I

Three categories of topics are suggested for discussions: 1) ***sciences and outlooks*** (common questions, overarching theories, conceptual frameworks, possible breakthroughs, network science, etc.), 2) ***data, models, and applications*** (common measurements, basic infrastructures, modeling needs, cross-site comparisons, site-specific features, CZ services, societal impacts, sustainability practices, etc.), and 3) ***Sino-USA cooperation strategies*** (common interests, sister CZOs, unique opportunities, knowledge exchanges, visiting scholars, co-funding possibilities, etc.).

Several discussion sessions are arranged, with each session framed by a theme and some questions. All participants will be divided into three smaller groups (each with mixed U.S. and China scientists) to provide a setting that encourages open and in-depth discussions. Prior to the splitting into groups, short presentations (~5-15 min each, from both the U.S. and China) will be given to provide food for thoughts to catalyze discussions. These short presentations should address the theme and questions framed for each session. The three groups will then come together near the end to synthesize the information and develop recommendations. Chairs for each session (one from the U.S. and one from China) will facilitate/lead the discussions, while rapporteurs (one from the U.S. and one from China) will help take notes and give reports. It is suggested that the chairs and rapporteurs for each session are distributed among the three groups to facilitate, lead, and record the discussions.

Chairs: Suzanne Anderson, Yongguan Zhu; Rapporteurs: Julia Perdrial, Yihe Lv

2:00 – 3:30 pm Group discussions I. **Theme: Sciences and Outlooks**

Questions:

- What are exciting opportunities in CZ science and the network of CZOs?
- How would CZ science look like in the next 5-10 years?

Short presentations:

- Exciting Opportunities in CZ Science? (Suzanne Anderson etc.)
- Integrating International LTER and CZO networks (William McDowell etc.)
- A talk from China
- *… (Other possible short presentations – 5 min each: Few slides for a topic related to the theme that any of the U.S. and China participants feels important to discuss; please see the session chairs to include your presentation here if you so desire)*

3:30 – 4:00 pm Coffee/tea break

Chairs: Praveen Kumar, Chunmiao Zheng; Rapporteurs: Adrian Harpold, Xing Li

4:00 – 5:30 pm Group discussions II. **Theme: Data, Models, and Applications**

Questions:

- What should be included in 4D characterization of CZ architecture and functions?
- What societal impacts can CZ science and a global network of CZOs have?

Short presentations:

- Critical Zone modeling from ground up (Praveen Kumar etc.)
- Critical Zone services: Complementary to ecosystem services (Henry Lin etc.)

- A talk from China
- *… (Other possible short presentations – 5 min each: Few slides for a topic related to the theme that any of the U.S. and China participants feels important to discuss; please see the session chairs to include your presentation here if you so desire)*

Day 2: Oct. 7, 2015 (Wed.)

Morning:

Session IV: Discussion II

Chairs: Tim Filley, Dali Guo; Rapporteurs: Diana Karwan, Siliang Li

8:00 – 8:30 am   Recap of the 1st day discussions

8:30 – 10:00 am   Group discussions III. **Theme: Sino-U.S. Cooperation Strategies**

Questions:

- What are unique areas in China and the U.S. that can significantly advance CZS globally?
- How can physical and virtual scholar exchanges advance Sino-U.S. collaboration in CZS?

Short presentations:

- Transformation of the Calhoun ecological research site into the Calhoun CZO (Dan Richter etc.)
- Possible mechanisms and benefits of a CZ Visiting Scholars network (Tim Filley etc.)
- A talk from China
- *… (Other possible short presentations – 5 min each: Few slides for a topic related to the theme that any of the U.S. and China participants feels important to discuss; please see the session chairs to include your presentation here if you so desire)*

10:00 – 10:30 am   Coffee/tea break

10:30 – 12:00 pm   Group discussions IV. **Theme: Overall discussions**
(A suggested idea is ***Sister CZOs*** between the U.S. and China. Other ideas are also welcome. There are now 10 CZOs in the U.S., some of which contain multiple sites in one CZO – see http://criticalzone.org/national/. Various potential CZO sites are being developed/considered in China.)

Afternoon:

Session V: Summary (Chairs: Yongguan Zhu, Dan Richter)

2:00 – 3:30 pm   Groups synthesize information, develop recommendations, and prepare report

3:30 – 4:00 pm   Coffee/tea break

4:00 – 4:30 pm Group reports: 10 min per group

4:30 – 5:00 pm Wrap-up by NSF and NSFC (Dr. Enriqueta Barrera, Dr. Congqiang Liu)

5:00 – 5:30 pm Logistics and previews of field trips (Jian Ni and Xinhua Peng) – 15 min each for the two sites to be visited

2. Group discussions

All participants were divided into three smaller groups (each with mixed U.S. and China scientists and mixed senior and junior scientists) to provide a setting that encourages open and in-depth discussions. The grouping is suggested in the following table. Each discussion session follows a targeted theme (along with some key questions), except the last session that will be comprehensive.

Group #	**Group 1**	**Group 2**	**Group 3**
Room #	**B401**	**B406**	**B407**
Group chairs	Suzanne Anderson Yongguan Zhu	Praveen Kumar Chunmiao Zheng	Tim Filley Dali Guo
Rapporteurs	Julia Perdrial Yihe Lv	Adrian Harpold Xing Li	Diana Karwan Siliang Li
Participants	Bojie FU Fangbai LI Xueyan LIU Zaihua LIU Jian NI Mingan SHAO Wenfeng TAN Henry Lin Katherine Maher Daniella Rempe Adam Wymore	Xi CHEN Guilin HAN Xiaoyan LI Genxing PAN Xinhua PENG Zhaoliang SONG Shijie WANG Asmeret Asefaw Berhe Louis Derry Jill Marshall Nicole West	Benjamin Chetelat Zhangdong JIN Gangjian WEI Guirui YU Sheng YU Ganlin ZHANG Zhiqi ZHAO Lin Ma William McDowell Daniel Richter Pamela Sullivan

3. Field trips

Field Trip 1: Puding Karst Ecological Research Station

Puding Karst Ecosystem Research Station (PUKERS) is located in Shawan (26°22′07″N, 105°45′06″E, 1176 m), 5 km north to the Puding city in central Guizhou Province, southwestern China. It lies in the watershed region between the Yangtze River and the Pearl River on the Guizhou Plateau. Under influences both from the East Asian Monsoon and Indian Monsoon, the middle subtropical climate here is warm and humid. The mean annual temperature is 15.1 °C along with the January and July temperatures of 5.4 °C and 22.9 °C, respectively. The mean annual sunshine duration is 1,177.3 hour, which is relatively unfavorable to the growth of evergreen plants. The mean annual precipitation is 1,396.9 mm, in which more than 70% is fallen from May to September.

The PUKERS as one of stations of CERN (Chinese Ecosystem Research Network) aims generally to long-term, permanently monitor and investigate karst ecosystems in three-dimension and comprehensive ways. The structure and functions, patterns and processes of karst ecosystems on the Guizhou Plateau will be revealed through long-term monitoring and control experiments of material cycles and energy flows at different spatial and temple scales and under various perturbations of human activities. The key monitoring sites of the station is distributed in the Houzhai River catchment, a reprehensive of karst morphology, hydrology, soil and ecosystem on the Guizhou Plateau surface. The basic lithology is carbonate rock (mainly limestone and dolomite). Under intensive human disturbances (fire, grazing, cutting and firewood collection), the original, azonal evergreen-deciduous broadleaved mixed forest does not exist anymore in this region. Secondary mixed forest and low forest grow only in small areas with less human disturbances. The thorn scrubland and tussock cover mostly in karst terrain. The monitoring network of the PUKERS is set up mainly in the Houzhai River catchment, at one primary site (Tianlongshan), four subsidiary sites (Chenqi, Zhaojiatian, Shawan, and Chenjiazhai), and some investigation points.

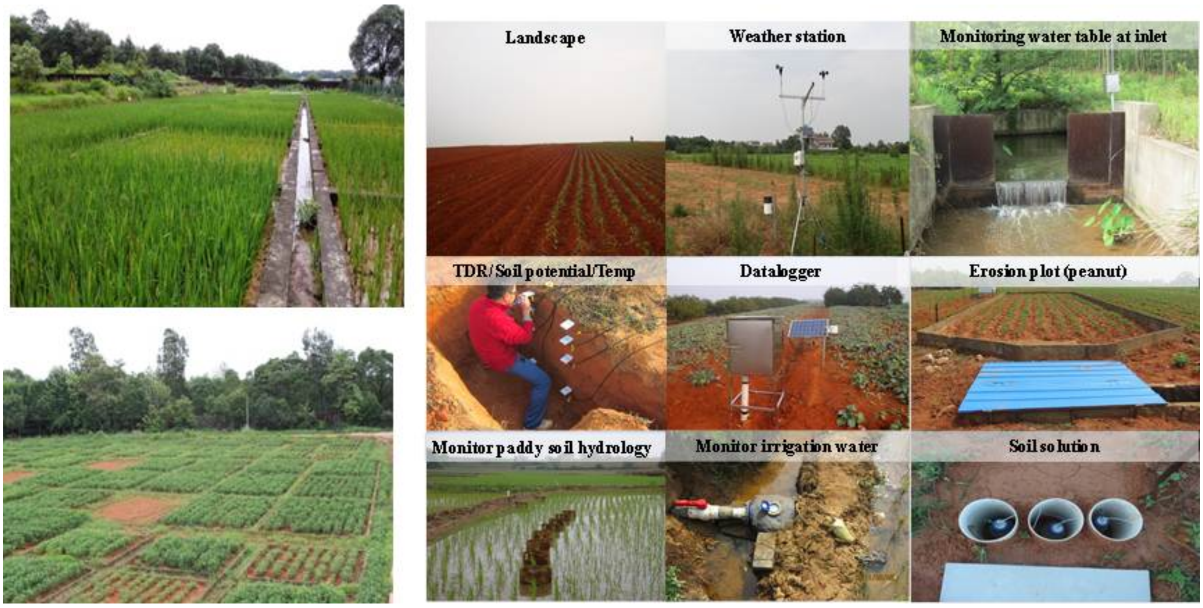
Physiognomy of monitoring plots (A-E), main station (F), and simulation test field (G) at PUKERS

Field Trip 2: Yingtan Red Soil Ecological Experimental Station

Red Soil Ecological Experimental Station (Red Soil Station) is affiliated to the Institute of Soil Science, Chinese Academy of Sciences. Red Soil Station was established in December 1985, and became as a key station of Chinese Ecological Research Network (CERN) in 1989. In 2002, Red Soil Station was approved to become an important experimental base of red soil ecosystem in Jiangxi province. In 2005, Red Soil Station joined the field observation station of national agricultural ecosystem network. In China, the study of red soils is incredibly important as they support 40% of the population, account for 50% of national agricultural production value and cover 20% of the land area.

Red Soil Station represents of hilly red soil region. Red Soil Station is located at Liujiazhan, Yujiang County, Yingtan city, Jiangxi Province (116°5′30″and 28°5′30″, altitude 45 m a.s.l), 135 km away from Nanchang city, and 13 km away from Yingtan city. The Station has an typical subtropical moist climate, with an annual rainfall of 1795 mm, an annual mean air temperature of 17.8 ℃, an annual accumulative temperature (>10℃) of 5528℃, and 262 days free of frost. Typical crops are double-rice in the paddy field and peanuts for upland. Its environment is typical for the hilly region of red soil in Subtropical China, and suitable for research of this kind of ecosystem on experimental biology.

There are a lot of long term sites in the station, including long-term fertilization experiment, cropping system experiment, experimment of effects of organic materials input on soil erosion, Sunjia Agricultural Watershed. The agricultural watershed is located 4 km away from the Ecological Experimental Station of Red Soil. It is representative of the topography and land use of hilly red soil region. This catchment covers an area of 50.5 ha with gently sloping terrain, exhibits an altitudinal range of 15 m and had a slope inclination up to 8%. The land use includes paddy field, upland fields (peanut, sweet potato, water melon and so on, and orchards (citrus, and grape). Paddy fields accounted for 20%of the total area, whereas peanut fields comprised 50%, and orchards 17%, and others 3%. However, recently, grape orchard has expanded very fast.



The photos showing long term experiment and monitoring sites

4. List of Participants

Scientific Committee

Co-Chairs: Bojie Fu, Cong-Qiang Liu, Henry Lin, Enriqueta Barrera

Members

Lou Derry (Cornell Univ.)
Timothy Filley (Purdue University)
Bojie Fu (Research Center for Eco-Environmental Science, CAS, China)
Henry Lin (Pennsylvania State University)
Daniel Richter (Duke University)
Ganlin Zhang (Institute of Soil Science, CAS)
Chunmiao Zheng (Peking University)
Yongguan Zhu (Institute of Urban Environ, CAS, China)
Congqiang Liu (CAS, Institute of Geochemistry, China; NSFC)
Enriqueta Barrera (National Science Foundation)

Secretariat:

LIU Xiuping (National Natural Science Foundation of China)
ZHU Qiong and LI Siliang (Institute of Geochemistry, CAS)
PENG Xinhua (Institute of Soil Science, CAS)

Participants – Chinese Side

Dr. **Bojie FU**
Professor, Academician of CAS,
Research Centre for Eco-Environmental Sciences, Chinese Academy of Sciences
18 Shuangqing Road, Haidian District, Beijing, 100085, China
Email: fubj@nsfc.gov.cn

Dr. **Congqiang LIU**
Professor, Academician of CAS,
Institute of Geochemistry, CAS
No. 99 Linchengxi Road, Guanshanhu District, 550081, China
Email: liucongqiang@vip.skleg.cn

Dr. **Chen XI**
Professor, State Key Laboratory of Hydrology, Water Resources and Hydraulic Engineering
Hohai University
1 Xikang Road, Nanjing, 210098, China
E-mail: xichen@hhuedu.cn

Dr. **Dali GUO**
Professor, Key Laboratory of Ecosystem Network Observation and Modeling
Institute of Geographic Sciences and Natural Resources Research of CAS
11A, Datun Road, Chaoyang District, Beijing, 100101, China
Email: guodl@igsnrr.ac.cn

Dr. **Guilin HAN**
Professor, School of Water Resources and Environment
China University of Geosciences
29 Xueyuan Road, Haiding District, Beijing 100083, China
Email: hanguilin@cugb.edu.cn

Dr. **Zhangdong JIN**
Professor, State Key Laboratory of Loess and Quaternary Geology
Institute of Earth Environment, CAS
No. 97 Yanxiang Road, Xi'an 710061, Shaanxi, China
Email: zhdjin@ieecas.cn

Dr. **Fangbai LI**
Professor, Guangdong Key Laboratory of Agro-Environment Integrated Control
Guangdong Institute of Eco-environmental and Soil Sciences
No. 808 Tianyuan Road, Tianhe District, Guangzhou, 510650, China
Email: cefbli@soil.gd.cn

Dr. **Siliang LI**
Professor, State Key Laboratory of Environmental Geochemistry
Institute of Geochemistry, CAS
No. 99 Linchengxi Road, Guanshanhu District, 550081, China
Email: lisiliang@vip.skleg.cn

Dr. **Xiaoyan LI**
Professor, College of Resources Science & Technology
Beijing Normal University
No. 19, XinJieKouWai St., HaiDian District, Beijing,100875, China
xyli@bnu.edu.cn

Dr. **Xin LI**
Professor,
Cold and Arid Regions Environmental and Engineering Research Institute, CAS
No. 320 Donggangxi Road, Lanzhou, 730000, China
Email: lixin@lzb.ac.cn

Dr. **Xinrong LI**
Professor, Shapotou Desert Research and Experimental Station
Cold and Arid Regions Environmental and Engineering Research Institute, CAS
No. 320 Donggangxi Road, Lanzhou, 730000, China
Email: lxinrong@lzb.ac.cn

Dr. **Xueyan LIU**
Professor, Institute of Surface Earth System Science,
Tianjin University
No. 92 Weijin Road, Nankai District, Tianjin, 300072, China
Email: liuxueyan@vip.skleg.cn

Dr. **Zaihua LIU**
Professor, State Key Laboratory of Environmental Geochemistry
Institute of Geochemistry, CAS
No. 99 Linchengxi Road, Guanshanhu District, 550081, China
Email: liuzaihua@vip.gyig.ac.cn

Dr. **Yahai LU**
Professor, College of Urban and Environmental Sciences
Peking University
No.5 Yiheyuan Road Haidian District, Beijing, 100871, China
Email: luyh@pku.edu.cn

Dr. **Yihe LV**
Professor, State Key Laboratory of Urban and Regional Ecology

Research Centre for Eco-Environmental Sciences, Chinese Academy of Sciences
18 Shuangqing Road, Haidian District, Beijing, 100085, China
Email: lyh@rcees.ac.cn

Dr. **Jian NI**
Professor, State Key Laboratory of Environmental Geochemistry
Institute of Geochemistry, CAS
No. 99 Linchengxi Road, Guanshanhu District, 550081, China
Email: nijian@vip.gyig.ac.cn

Dr. **Genxing PAN**
Professor, College of Resources and Environmental Sciences
Nanjing Agricultural University
No.1 Weigang Road, Nanjing, 210095, China
Email: pangenxing@aliyun.com

Dr. **Mingan SHAO**
Professor, Key Laboratory of Ecosystem Network Observation and Modeling
Institute of Geographic Sciences and Natural Resources Research of CAS
11A, Datun Road, Chaoyang District, Beijing, 100101, China
Email: shaoma@igsnrr.ac.cn

Dr. **Zhaoliang SONG**
Professor, Institute of Surface Earth System Science,
Tianjin University
No. 92 Weijin Road, Nankai District, Tianjin, 300072, China
Email: songzl78@163.com

Dr. **Wenfeng TAN**
Professor, College of Resources & Environment
Huazhong Agricultural University
No.1 Shizishan Street, Hongshan District, Wuhan, 430070, China
Email: tanwf@mail.hzau.edu.cn

Dr. **Shijie WANG**
Professor, State Key Laboratory of Environmental Geochemistry
Institute of Geochemistry, CAS
No. 99 Linchengxi Road, Guanshanhu District, 550081, China
Email: wangshijie@vip.skleg.cn

Dr. **Gangjian WEI**
Professor, State Key Laboratory of Isotope Geochemistry
Guangzhou Institute of Geochemistry, CAS
No. 511 Kehua Street, Tianhe District, Guanzhou, 510640, China

Email: gjwei@gig.ac.cn

Dr. **Guirui YU**
Professor, Key Laboratory of Ecosystem Network Observation and Modeling
Institute of Geographic Sciences and Natural Resources Research of CAS
11A, Datun Road, Chaoyang District, Beijing, 100101, China
Email: yugr@igsnrr.ac.cn

Dr. **Ganlin ZHANG**
Professor, State Key Laboratory of Soil and Sustainable Agriculture
Institute of Soil Science, CAS
NO.71 East Beijing Road, Nanjing, 210008, China
Email: glzhang@issas.ac.cn

Dr. **Chunmiao ZHENG**
Professor, School of Environmental Science and Engineering
South University of Science and Technology of China
No 1088, xueyuan Rd., Xili, Nanshan District, Shenzhen, Guangdong, China 518055
Email: zhengcm@sustc.edu.cn

Dr. **Yongguan ZHU**
Professor, Key Laboratory of Urban Environment and Health
Institute of Urban Environment, CAS
1799 Jimei Road, Xiamen 361021 China
Email: ygzhu@iue.ac.cn

Participants – American Side

Dr. **Suzanne Anderson**
Associate Professor, Department of Geography
University of Colorado Boulder
Boulder, Colorado 80309-0260, USA
E-mail: Suzanne.Anderson@colorado.edu

Dr. **Asmeret Asefaw Berhe**
Associate Professor, Dept. of Soil Biogeochemistry, Life and Environmental Sciences
University of California, Merced
Merced, CA 95343
E-mail: AABerhe@UCMerced.edu

Dr. **Louis Derry**
Professor, Department of Earth and Atmospheric Sciences
Cornell University

Ithaca, New York 14850
E-mail: lad9@cornell.edu

Dr. **Timothy R. Filley**
Professor, Department of Earth, Atmosphere and Planetary Sciences
Purdue University,
West Lafayette, IN 47907
E-mail: filley@purdue.edu

Dr. **Adrian Harpold**
Assistant Professor, Department of Natural Resources and Environmental Science
University of Nevada
Reno, Nevada 89557
Email:aharpold@cabnr.unr.edu

Dr. **Diana L. Karwan**
Assistant Professor, Department of Forest Resources
University of Minnesota
301G Green Hall
St. Paul, MN 55108
E-mail: dlkarwan@umn.edu

Dr. **Praveen Kumar**
Professor, Department of Civil and Environmental Engineering
University of Illinois
Urbana, IL 61801
E-mail: kumar1@illinois.edu

Dr. **Hangsheng (Henry) Lin**
Professor, Department of Ecosystem Science and Management
Pennsylvania State University
University Park, PA 16802
E-mail: henrylin@psu.edu

Dr. **Lin Ma**
Assistant Professor, Department of Geological Sciences
University of Texas at El Paso
El Paso, TX 79968 USA
E-mail: lma@utep.edu

Dr. **Katherine Maher** (member of the CZO Steering Committee)
Assistant Professor, School of Earth, Energy & Environmental Sciences
Stanford University
Stanford, CA 94305-2210

E-mail: kmaher@stanford.edu

Dr. **Jill Marshall**
Postdoctoral Researcher, Department of Earth and Planetary Sciences
University of California, Berkeley
Berkeley, California 94720-4767
E-mail: jmarshall@berkeley.edu

Dr. **William H. McDowell**
Professor, Department of Natural Resources and the Environment
University of New Hampshire
Durham, NH 03824
E-mail: bill.mcdowell@unh.edu

Dr. **Julia Perdrial**
Assistant Professor, Department of Geology
University of Vermont
180 Colchester Ave.
Burlington, VT 05405 U.S.A.
E-mail: jperdria@uvm.edu

Ms. **Daniella Rempe**
PhD Candidate , Department of Earth and Planetary Science
University of California, Berkeley
Berkeley, California 94720-4767
E-mail: Daniella.Rempe@berkeley.edu

Dr. **Daniel DeB. Richter**
Professor, Nicholas School of the Environment
Duke University
Durham, North Carolina 27708-0328
E-mail: drichter@duke.edu

Dr. **Pamela Lee Sullivan**
Assistant Professor, Department of Geography
University of Kansas
Lawrence, Kansas 66045
E-mail: plsullivan@ku.edu

Dr. **Nicole West**
Post-Doctoral Scholar, Earth and Environmental Systems Institute
Pennsylvania State University
University Park, PA 16802.
E-mail: nxw157@psu.edu

Dr. **Adam Wymore**
Postdoctoral Researcher, Department of Natural Resources and the Environment
University of New Hampshire
Durham, New Hampshire 03824
E-mail: adam.wymore@unh.edu

Dr. **Carol Frost**
Director, Division of Earth Sciences
National Science Foundation
4201 Wilson Boulevard
Arlington, VA 22230
Email: CFROST@nsf.gov

Dr. **Enriqueta Barrera**
Program Director, Geobiology and Low-Temperature Geochemistry
Division of Earth Sciences
National Science Foundation
4201 Wilson Boulevard
Arlington, VA 22230
Email: ebarrera@nsf.gov

Dr. **Nancy Sung**
Director
Beijing Office
Email: nsung@nsf.gov