Graduate Research Group: Cross-CZO Research Potential

This white paper summarizes the work accomplished by the Critical Zone (CZ) graduate research group (GRG) towards developing and implementing cross-site research. We lay out several tractable research questions and hypotheses developed from group discussions. We identify the Critical Zone Observatory (CZO) datasets that are currently most useful for cross-site research. We also speak to potential pitfalls and opportunities that future GRG efforts will likely encounter engaging in cross-site research. Finally, we suggest how the GRG plans to involve a wider community in its cross-site research efforts.

Research Questions:

The following research questions (*in italics*) and testable hypotheses (below each question) reflect the interests and backgrounds of GRG members. As a group we asked "What is one possible hypothesis, given a research question, that is testable with cross-CZO datasets?". We developed this list after deliberation of available datasets and uncertainties across the CZO network.

Answering the questions below and generating additional hypotheses requires considering the opportunities created due to the wide range of lithologies, soils, climate/weather, and hydrology across the CZO network. Because of the observational detail and breadth at each CZO site, the need for rigid experimental controls (e.g. uniform parent rock, similar soil, etc.) can be relaxed and research questions focused more broadly on CZ process behavior.

1. *What are the first order controls on carbon storage within the CZ?*
- Climatic gradients control CZ carbon storage mechanisms.
2. *What are the primary drivers of solute fluxes within the CZO network?*
- Climate and landscape characteristics exert overall control on CZ solute effluxes.
3. *Do short and long-term erosion rates have similar generating mechanisms (i.e. do erosional mechanisms possess characteristic timescales)?*
- Short- term erosion rates reflect catastrophic changes in land cover, such as urbanization, landslides, and forest fires, while long term erosion rates represent continuous processes such as frost cracking, and hill slope diffusion.
4. *How does EEMT compare to measurements of abiotic processes through time (e.g. fluxes and states)?*
- Fluxes of present-day weathering-derived solutes are related to EEMT and climate.
- High resolution DEMs can be used to track deviations between present-day measurements of EEMT and landscape response to climate, biotic and abiotic forcing through time.
5. *What are the primary factors affecting chemical erosion rates?*
- The rate of water and carbon inputs to the saprolite controls chemical erosion rates.
6. *On what time-scales do sediment/suspended materials exit a watershed?*

- Grain size distribution, slope, sediment supply and frequency of frequency/duration of flood producing storm events are the principal controls on sediment transport.
- The variability in the ratio of diffusive to advective processes controls the time-scales of material storage and exit from a watershed.

7. *Do variations in hydrograph shape affect suspended and bed load sediment transport rates?*

- The primary effect of different hydrograph shapes is in their ability to mobilize coarse sediment and catchment wide availability of suspended sediment.

8. *What causes the variations in grain size distributions between hillslopes and channels?*

- The fraction of landscape subject to bedrock to soil conversion via biota-bedrock coupling and threshold transport processes such as land sliding control the supply of durable grains from hillslope to channel.

9. *What are the primary mechanisms that partition precipitation to evaporation, transpiration, and runoff?*

- The amount and timing of precipitation control hydrologic partitioning.
- Watershed storage and downslope hydrologic connectivity control water available for ET versus runoff.

10. *Are plant-water relationships consistent across climate/topography/soil?*

- Plant-water relationships are sensitive to energy and water limitations.

11. *When are upland hillslopes hydrologically connected to stream channels?*

- Hillslopes connections are limited by storage thresholds.

12. *What characteristics of the watershed control surface and subsurface connectivity?*

- Recharge of upslope groundwater heads controls surface-groundwater interactions.
- The morphology of the stream channel controls surface-groundwater interactions.

13. *What are the hydrologic transit times of soil and stream water and how do they vary based on vegetation/pedologic/lithologic/climatic changes?*

- More water-limited systems will have longer transit times.

14. *What are the first order controls on vegetation rooting depths?*

- Rooting depths (and associated shallow CZ processes) are limited by both erosion rates (high erosion rates = thin soils) and lithologic variations in saprolite attributes such as grussification (no limits to rooting depth) or fracture density.

Cross-Site Datasets:

This list summarizes the cross-site datasets with the most potential for answering the research questions without additional data collection. Significant work will be required to ensure quality control and/or compare datasets in most cases, particularly with regard to inter- and intra-site differences measurement frequency (e.g. weekly versus monthly grab samples). Additional datasets are less complete across sites, but could be used to compare a subset of sites or bolstered to compare across all sites. The Google spreadsheet is available at http://goo.gl/BPwXyu

Atmosphere and Vegetation:
Growing-season, non-growing season LiDAR (terrain, snow depth, and vegetation information)
Remote sensing datasets (e.g. NDVI, MOD17, etc)
Climate products (e.g. NLDAS, PRISM, etc)
Micro-meteorological measurements (precip, radiation, temperature/RH, wind speed)
Eddy-flux of water and C (not at all sites)
Sap-flux (not at all sites)
Hydrology:
Stream discharge (at small 0 to 2nd order catchments)
Soil moisture (at multiple locations and depths)
Matric potential (not at all sites)
Groundwater levels (not at all sites)
Geology/Geomorphology:
Soil temperature (at multiple locations and depths)
Soil texture and physical characterization
Soil elemental composition and mineralogy
Bedrock petrology and mineralogy
Water Chemistry:
Soil and bedrock (saprolite) organic matter content
Stream water chemistry (ions, nutrients, isotopes, etc.)
Soil water chemistry (ions, nutrients, isotopes, etc.)

Recommendations for Cross-CZO Research:

The GRG worked to develop a list of common measurements and explored research questions over Spring and Summer 2013. Several recommendations have come out of that experience:

1. *Need to balance personal expertise with ownership*: A successful cross-site project requires disciplinary expertise to answer the research questions posed. If expertise is held only by one person collaboration is difficult. If research overlaps with ongoing external research by one or more members, others may feel that they have little to contribute and therefore excluded. Conversely, those with ongoing research may feel like their ideas are being used without sufficient recognition. We suggest facilitating skill transfer where possible, involving multiple expertises, and not overlapping directly with ongoing research wherever possible.
2. *Need to choose simple questions to answer:* The novelty of cross-site work means that science questions are inherently broad. Even if a particular science question has been answered for one site, exciting opportunities exist for cross-site comparison. The novelty of applying questions to new sites is reflected in the relatively basic science questions we have posed above.

3. *Consideration of existing datasets is necessary when choosing a cross-CZO research question*: Some datasets are more mature and/or more consistently collected across sites (listed above). These datasets provide the 'low-hanging fruit' that should be the basis for developing a research project. In some cases, the data will not be directly comparable across sites, but qualitative comparisons may be sufficient. In addition, researchers should recognize that the meta-data and quality control of datasets varies and that significant time may be required to develop the necessary final datasets. An important future contribution to the CZO program would be the development of easily queriable consistent meta-data. Finally, we note that the existing CZO data inventory lack available information on subsurface CZ architecture and processes (such as depths of soils and saprolite, deep groundwater heads, and residence times of short and long-lived isotopes). We recommend support for short-term field campaigns targeted to bolster these datasets for advancing cross-site work.
4. *Need to develop hypotheses that exploit cross-site variability*. Hypothesis development should make the best use of differences/gradients across the CZO sites. For example, differences in climate, land-use/human impacts, and bedrock lithology should be considered in the development of hypotheses. The best cross-CZO hypotheses are those that take advantage of the uniqueness of place of each CZO site.
5. *Need for face-to-face meetings between collaborators*. It is terrific to make use of electronic communications for developing research questions and hypotheses. However, it is clearly advantageous to have collaborators meet to further their research in person over the matter of a few days to a week. These meeting between collaborators should also take advantage of large international meetings, as was done for the 2012 AGU Fall Meeting. The GRG identified the need for funds for travel of this sort as a potential hindrance to future success. In addition, graduate students (and post-docs to a lesser extent) often do not have [paid] time to put into cross-site work, even if the potential benefits are high. We suggest monies to 'buy-out' both CZO and non-CZO funded persons to contribute 1-2 months of cross-site research by soliciting 1-2 page research proposals. This work could be done at individual CZO's (as started at Shale Hills CZO) or administered by the National Office of the CZO Program.

Using GRG to Advance Cross-CZO Research

The GRG is positioned to address two types of research questions: (1) synthetic research that harnesses existing data to explore similarities and differences in CZ processes across sites and (2) short, intensive field studies that can apply simple methods at all CZOs. The capacity for synthetic research is clear from recommendations 3 and 4. Synthetic research offers an opportunity to open new lines of inquiry across sites and/or across disciplines. Field studies offer similar benefits but at greater logistical costs. Thus, we advise that future work by the GRG focus on the potential of synthetic research while still in its early stages.

To facilitate synthesis, we recommend moving the development of cross-site CZO research to a ‘crowd-sourcing’ model that allows for multiple project development and builds a strong, diverse CZO community. We plan to develop a Wiki website site to allow the broader GRG community to add and comment on our starter research ideas and common dataset template. The website will also provide an easy way for diverse and geographically separate groups of researchers to form around common interests and expertise. People will assign their names to groups and ideas, and everyone will have a chance to comment on the feasibility and originality of each group’s ideas. After the groups form, we will encourage monthly online meetings to discuss ideas and progress. The groups will be tasked with gathering the necessary datasets from the sites, as well as documenting the cross-site datasets for future use. We hope to build towards a workshop or meeting in Spring 2014 to actualize the cross-site analyses and begin writing peer-reviewed research papers.

GRG Committee Spring and Summer 2013

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