T1Q

Ordering interfluves: a simple proposal for understanding critical zone evolution and function

t1,3,4

Zachary S. Brecheisen, Xing Chen, Daniel deB. Richter

Nicholas School of the Environment, Duke University, Durham, NC 27708, USA

Abstract

As we begin research in the Sumter National Forest (Figure 1) at the Calhoun Critical Zone Observatory (CCZO) in South Carolina, we propose an interfluve ordering system envisioned as a reciprocal to the Hortonian-Strahler (1) ordering of streams: the broadest and highest elevation interfluves are a 0th order and increase in rank through interfluve dissection and narrowing (Figures 1, 2, 3). Interfluve order attends to the structure and functions of residual porous-solid systems in the transport of water, solutes, and eroded solids in the CZ (Figure 2). Interfluve ordering seems to have great potential in linking recent work in the fields of geochemistry and geomorphology regarding bedrock weathering front dynamics. Land use history and human impacts further strengthen the potential for an interfluve ordering system. With LiDAR and DEM mapping enabling new quantitative research of landscape and critical zone structure and function, we propose that many physiographic regions will benefit from a system that orders interfluves.

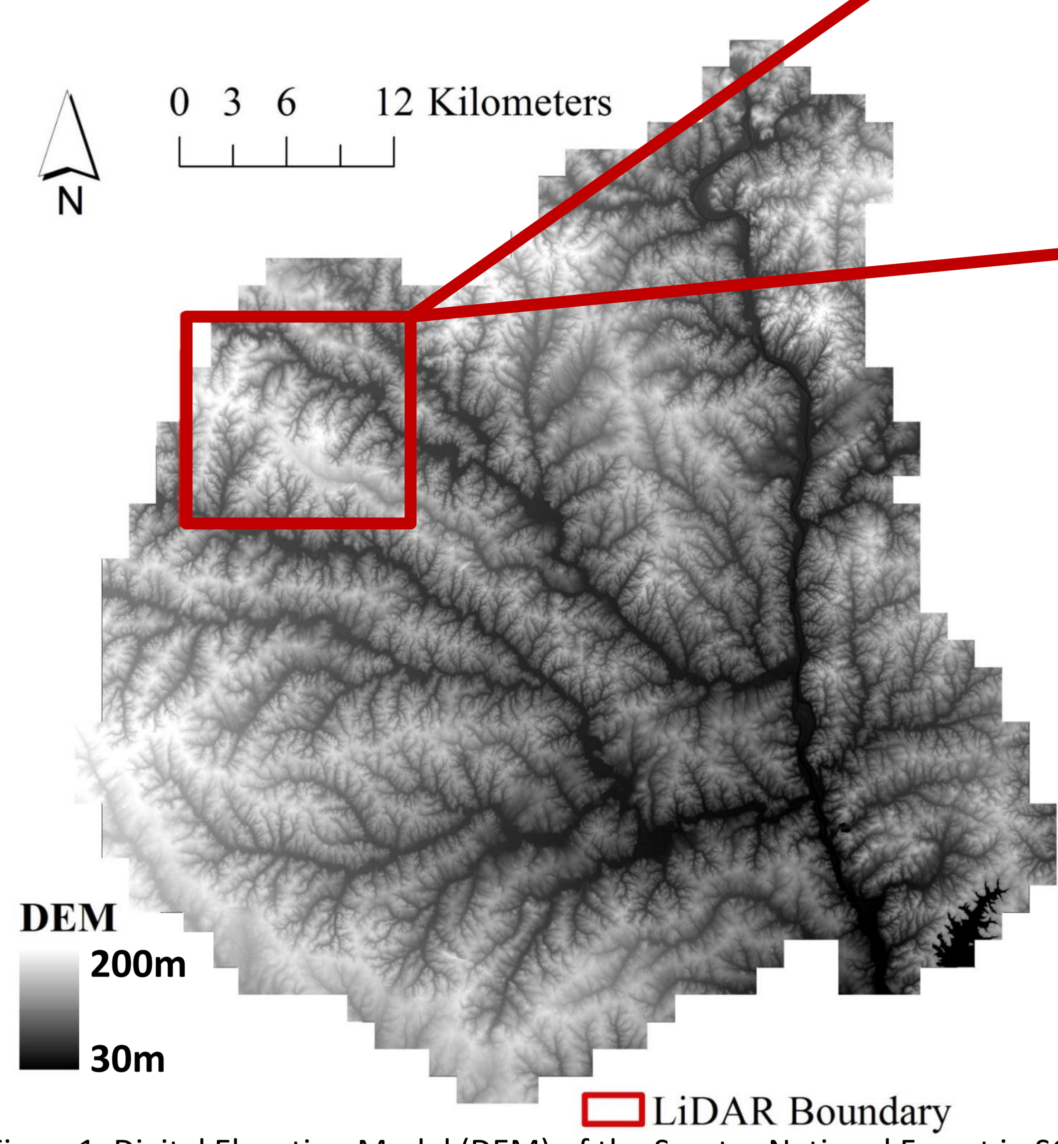


Figure1: Digital Elevation Model (DEM) of the Sumter National Forest in SC

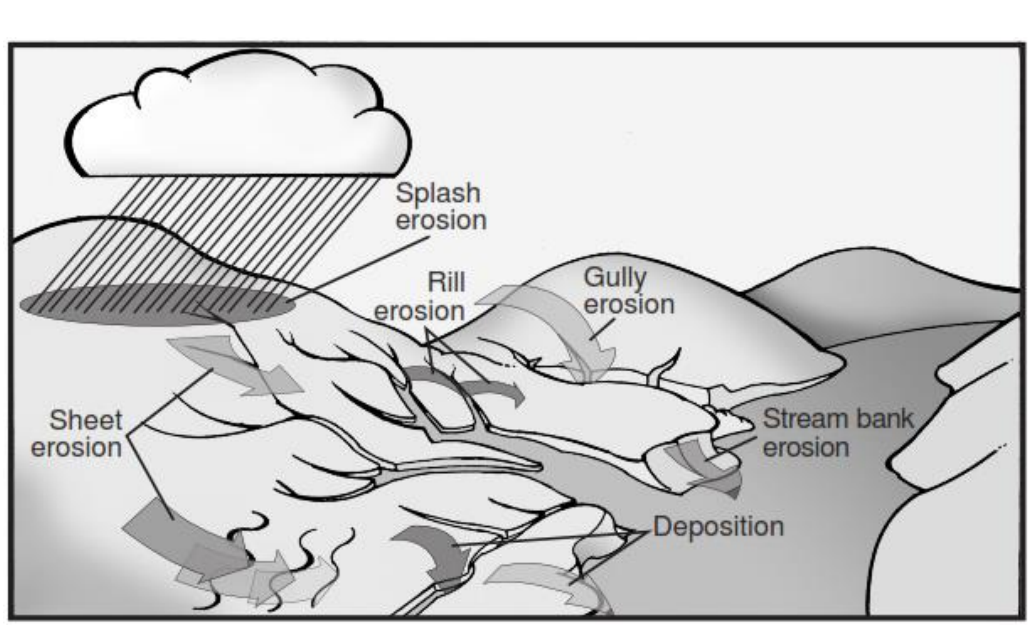
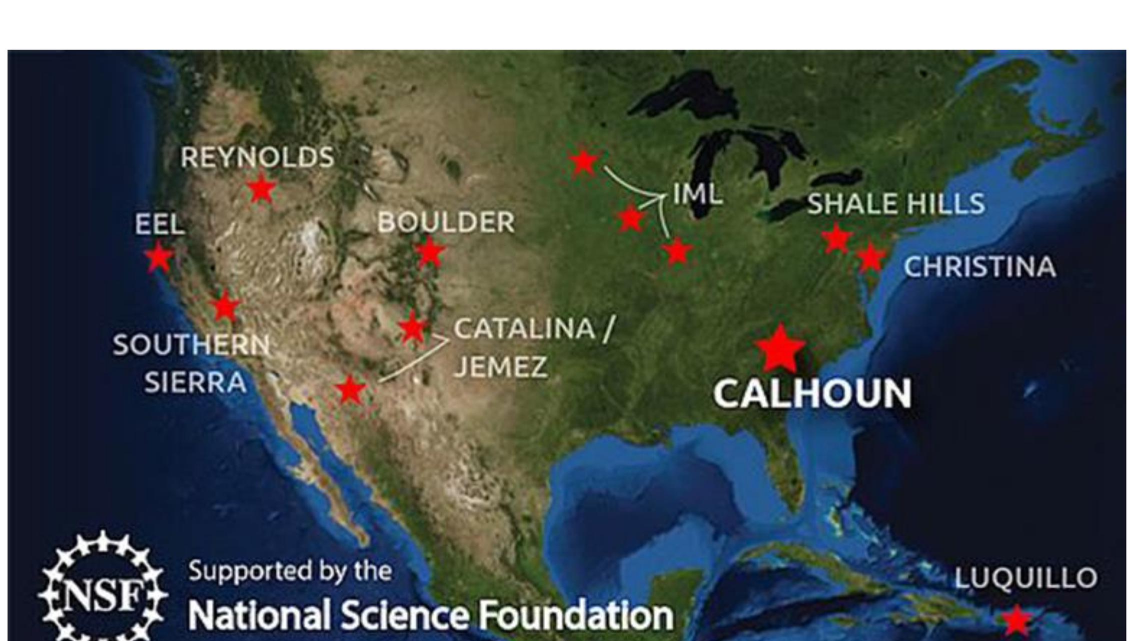


Figure 2: landform variation and erosion potential from Broz et al.



Interfluve ordering approaches

A striking pattern emerges when considering the road network across the CCZO. As roads follow the highest elevation flat and stable landforms (interfluves), the forking and branching pattern is reminiscent of a stream network (Figure 3). A quantitative approach to interfluve orders classification may rely on DEM slope characteristic data (Figure 4).

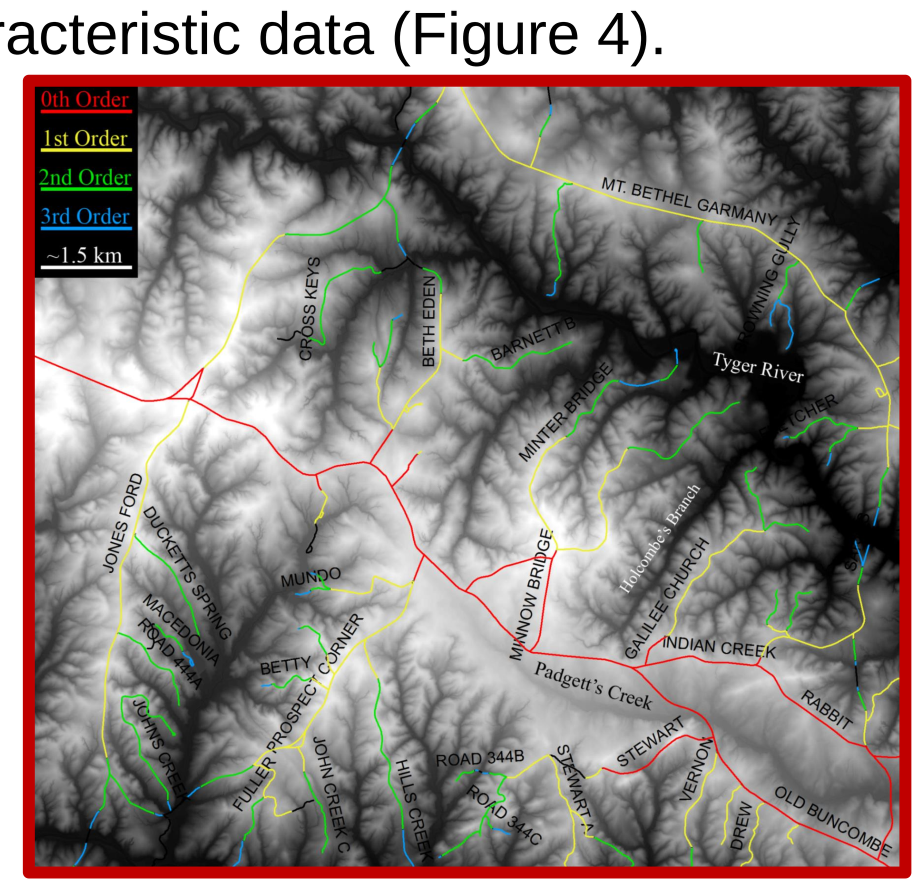


Figure 3: Interfluve networks mapped on roads in the CCZO

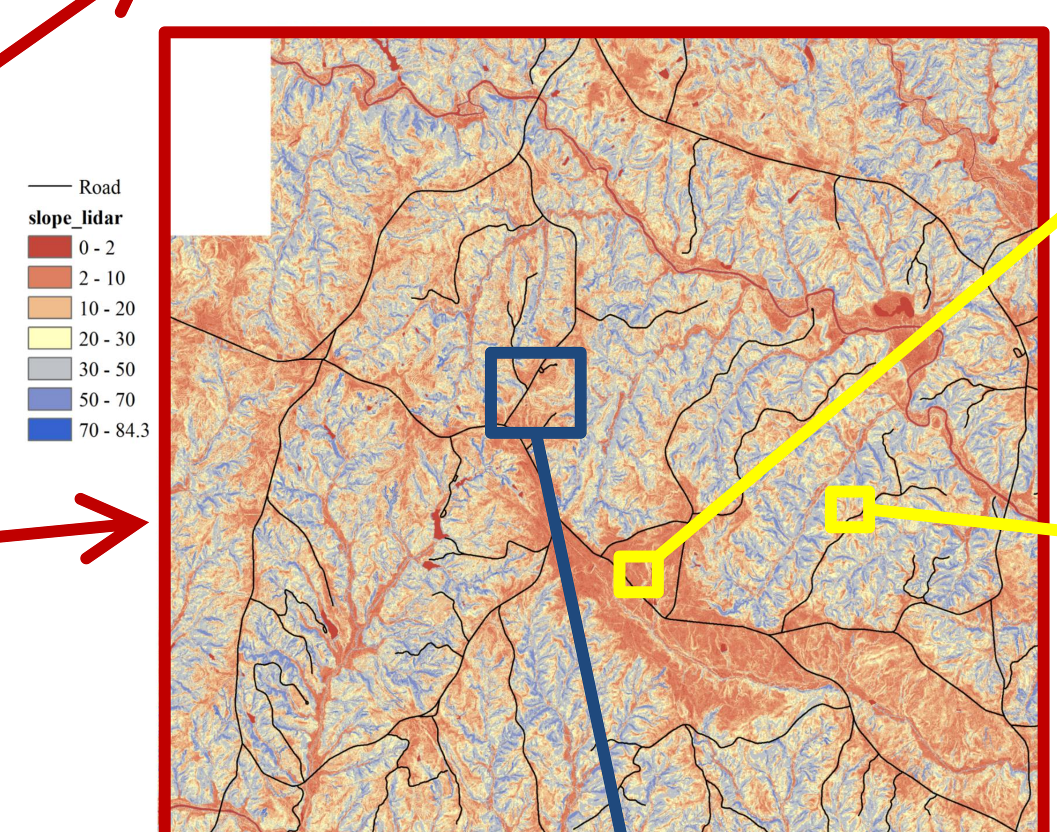


Figure 4: LiDAR slope range map of the CCZO

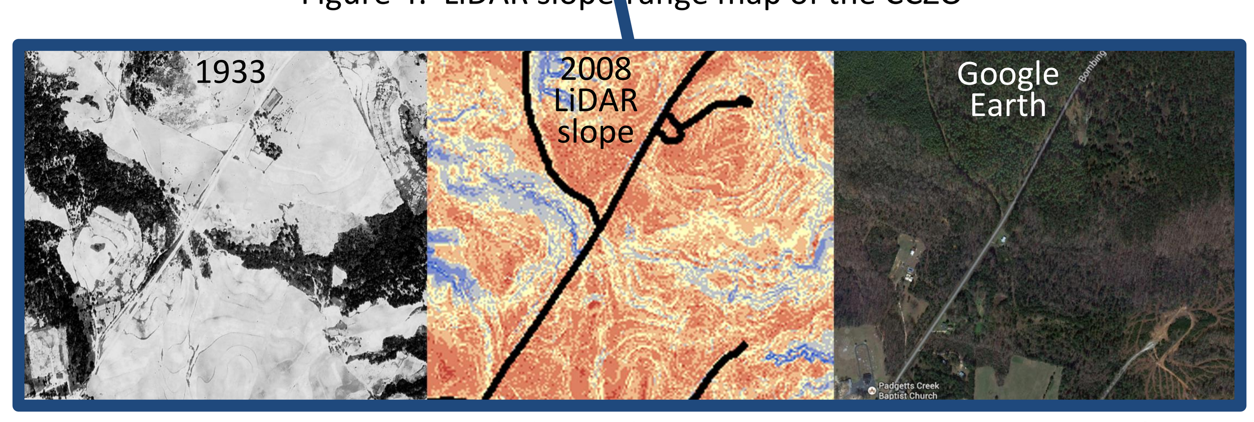


Figure 5: Historic 1933 aerial photo, slope-map, and contemporary pine forest

Interfluves, land use, and CZ recovery

Interfluves on the pre-Euro/Afro Southern Piedmont were incredibly stable with erosion rates between 3.5×10^{-5} and 3.0×10^{-4} cm yr^{-1} (2,3). CCZO soils and saprolites are extremely weathered on the order of 30m in total depth above solid granitic gneiss bedrock (Figure 6) with multi-million year residence times (2).

Historic deforestation and ~200 years of plantation agriculture on interfluves greatly degraded the CZ's hydrology and biogeomorphic stability (Figure 5, left panel). Increased runoff from agricultural fields deeply incised channels as gully systems expanded upward into drainages (4), (Figure 2).

Following agricultural abandonment ~1920, old-field succession has begun to regenerate CZ processes (Figure 5, right panel). Biogeomorphic restabilization is attributed to anchoring of soils by roots, a protective pine needle O-horizon, the regeneration hydraulic conductivity through biotic macropore networks, and through the increase of forest evapotranspiration.

Interfluve orders and CZ structure

Interfluve order seems likely to also be correlated to depth to weathering front of bedrock based on the recent work of the Dietrich group at the Eel River CZO (6). Figures 6 & 7 from geophysical studies conducted by Dr. Holbrook and colleagues through the WyCEHG program at the CCZO suggest that bio-geomorphology, bio-geochemistry, and eco-hydrology interact such that relatively constant bedrock saturation impedes weathering in drainages. Interfluves are alternately dried and saturated with a deeper vadose zone resulting in a deeper bedrock weathering front.

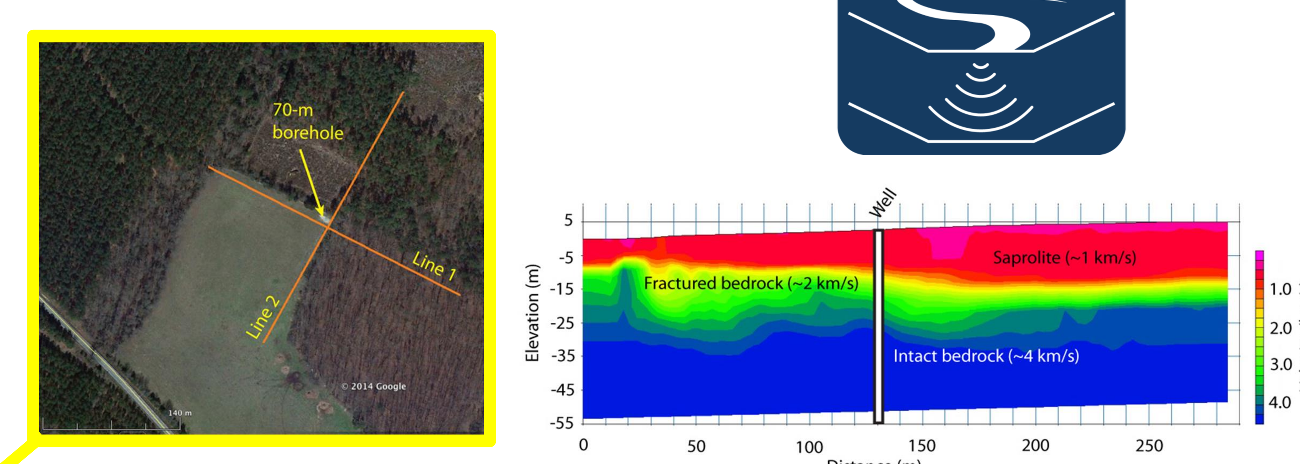


Figure 6: Line 1 seismic transect across 0th order interfluve from WyCEHG

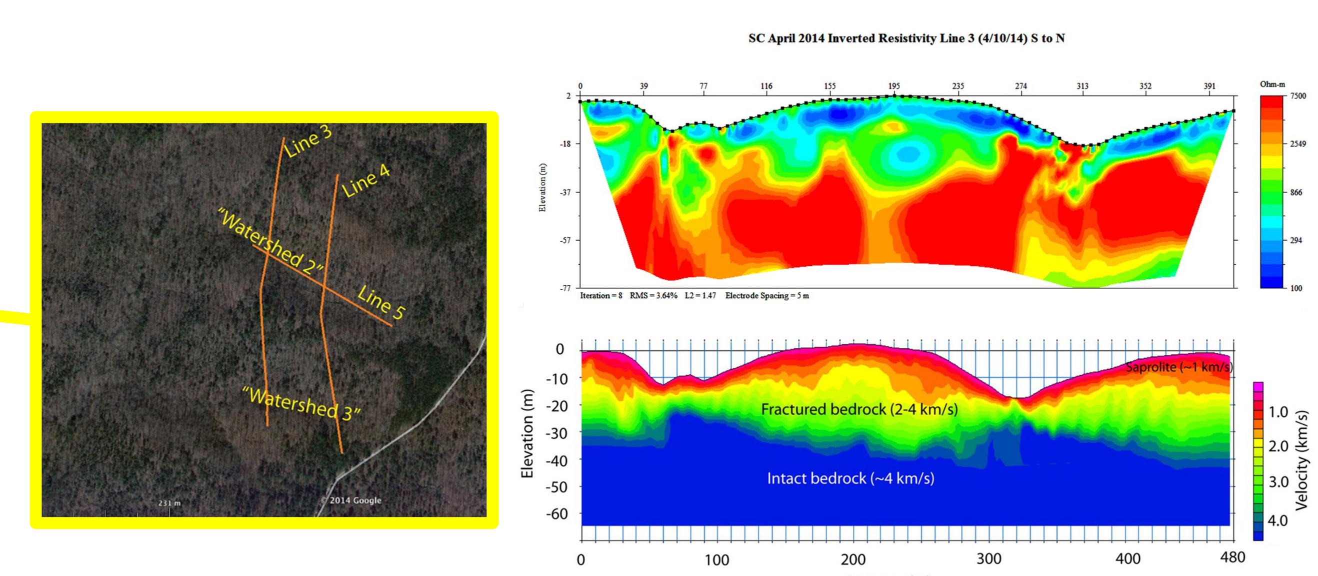


Figure 7: Line 3 resistivity and seismic transect across 2nd order interfluve from WyCEHG

Interfluve ordering applications

CZ research could benefit from this system as it may connect various processes of the Earth's surface with regard to the slow drivers of geomorphology and the rapid impacts of human land use. Here we posit that interfluve orders could:

- Inform us of dynamic soil erosion potential due land use change (Fig. 2)
- Connect environmental history to the landscape through the interplay between geomorphology and human activities (Fig. 5)
- Influence the interaction of soil formation, erosion, ecohydrology, biogeomorphology, and biogeochemistry across landscapes and down into CZ's (Fig. 6)
- Aid in the selection and preparation of chronosequence sites for CZO sampling and instrumentation

Citations

1. Horton, R. Erosional Development Of Streams And Their Drainage Basins; Hydrophysical Approach To Quantitative Morphology. *Geological Society of America Bulletin* 1945.
2. Bacon A R, Richter DD, Bierman P R, Rood D H. Coupling Meteoric ^{10}Be with Pedogenic Losses of ^{9}Be to Improve Soil Residence Time Estimates on an Ancient North American Interfluve. *Geology* 2012.
3. Trimble S, Goudie A. *Man-induced Soil Erosion on the Southern Piedmont*, 1700-1970. Ankeny, IA: Soil and Water Conservation Society; 2008.
4. Richter D, Markewitz D. *Understanding soil change: soil sustainability over millennia, centuries, and decades*. Cambridge University Press; 2001.
5. Broz B, Pfost D, Thompson A. *Controlling Runoff and Erosion at Urban Construction Sites*. MU extension; University of Missouri; 2003.
6. Rempe D, Deitrich W. A bottom-up control on fresh-bedrock topography under landscapes. *PNAS* 2013

IGERT INTEGRATIVE GRADUATE EDUCATION AND RESEARCH TRAINEESHIP