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Editorial: Critical Zone (CZ) Export to Streams as Indicator for CZ Structure and Function

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Editorial on the Research Topic

Critical Zone (CZ) Export to Streams as Indicator for CZ Structure and Function

The critical zone (CZ) is commonly defined as the zone of life, spanning from the tops of the tree canopy down to the actively cycled ground water (Brantley et al., 2007; Chorover et al., 2007; Richter and Mobley, 2009). Considering the CZ as an open thermodynamic system, where energy and matter can exchange freely, precipitation is one of many important CZ inputs, while stream exports dissipate energy and matter (Chorover et al., 2011).

Traditionally, investigations of the Earth's surface are limited to separate parts of the CZ (e.g., the biosphere, lithosphere or hydrosphere) that are analyzed outside of their context. However, streams are integrators of the physical structure and connected nature of subsurface pore space in the CZ as well as the biogeochemical reactions that play out along the multitude of flow paths. In order to decipher such pathways and related CZ processes, we need to investigate CZ processes within the catchment context.

For example, we know that relief and soil thickness play a large role in determining hydrologic flowpaths, fluid residence time, and soil drainage class (Maher, 2011). These processes can result in changes in soil dynamics, including biogeochemistry, that cascade through the system and ultimately control stream water composition (Perdrial et al., 2015).

To probe stream water dynamics, high-frequency datasets are now increasingly generated and long-term datasets are used to identify changes in CZ processes (Crowther et al., 2016; Robinson et al., 2016; Hirmas et al., 2018). For example, many streams show long-term changes in fluxes of dissolved organic carbon (Raymond and Saiers, 2010; Perdrial et al., 2014; Zarnetske et al., 2018), weathering solutes (McIntosh et al., 2017), and nutrients (Björnerås et al., 2017; Jarvie et al., 2018), which have been related to changes in climate drivers, land use, and overall soil conditions. In particular, investigations of the relationships between solutes and their discharge regimes have shown strong potential to understand the impacts of extreme perturbations (Chorover et al., 2017; McIntosh et al., 2017) and the sensitivity of CZ processes to these changes (Abbott et al., 2018; Sullivan et al., 2018). The goal of this special topic issue is to highlight opportunities as well as limitations of streams as indicator of CZ structure and processes.

Several contributions highlight how relief, topography, and soil thickness affect CZ evolution and are reflected in stream composition. Cincotta et al. and Armfield et al. found that CZ

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composition varies drastically with landscape position in a northeastern United States forested headwater catchment, and that near stream environments disproportionally affect stream water response. Bailey et al. found that, along stream segments, the connectivity to shallow and deep upslope soils strongly impacted stream water geochemistry. Resulting elluvial soil processes were found to control stream chemistry in shallow soil environments while illuvial soil processes persisted in deep soils. Using a refined model and two contrasting forested sites, Billings et al. explored linkages between upland and depositional environments and the impact of soil organic carbon (SOC) erosion and burial on carbon budgets within watersheds on decadal to centennial time scales. They noted that the reactivity and distribution of SOC across watersheds is necessary to predict carbon storage across the landscape.

Several Critical Zone Observatory (CZO) studies reveal the importance of biotic processes and storm event magnitude in controlling elemental behavior. Olshansky et al. found that concentration-discharge patterns during snowmelt in the Jemez River Basin CZO in New Mexico indicate biologically mediated silicate weathering that propagates from the shallow CZ down through groundwater and strongly impacts stream water composition. A logical extension of this work is that processes impacting root/microbial respiration and biologically generated acids will alter both silicate weathering and stream water composition. Using sensor data from the Luquillo CZO in Puerto Rico, Wymore et al. found transport vs. supply limitation using concentration-discharge patterns of specific conductance and turbidity. The authors note that these relationships are especially influenced by the magnitude of events (including the category 5 Hurricane Maria) and CZ lithology.

Variations in bedrock lithology are also a theme in a cross site comparison of oxyanion dynamics at several CZOs (including Boulder Creek, Calhoun, Luquillo, and Southern Sierra). The study by Richardson et al. emphasizes the importance of deep bedrock and transport processes within the CZ as controls for stream water dynamics. The role of land use (agricultural and restored prairie) is investigated in the contribution by Dere et al., where solute fluxes through soils and to streams in Nebraska and Iowa are quantified. Their results indicate that changes in land use propagate to streams and drive weathering product export less than 50 years after land use change.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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