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Changing water pathways generates new loci for nutrient release in the Critical Zone: perspective from the Arctic

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The thin veneer extending from the top of the vegetation canopy down to the bottom of aquifers, the Critical Zone (CZ), is at the heart of major changes. The Earth is beyond most planetary boundaries, and hence outside of the safe operating space for humanity. Which CZ processes are the most affected? How fast is this happening? What are the consequences for carbon and nutrient cycling through the CZ? Element transfer at the surface of the Earth is driven by hydrological pathways but dictated by a number of environmental properties controlling soil-water interactions. This is why better constraining CZ geochemical processes requires crossing disciplines towards geochemistry, geophysics, geomatics, geomorphology, microbiology, climatology, numerical modeling, etc. Changing water pathways in the CZ generates new loci and new time periods for chemical weathering reactions and nutrient release. Increased chemical weathering releases metals and forms secondary mineral surfaces, thereby creating significant potential for mineral-organic carbon (OC) interactions. This is particularly relevant in the Arctic where the air temperature increase is four times faster than the global average and where the ongoing permafrost thaw is generating new water pathways. Changing water saturation upon thawing has an impact on mineral-OC interactions, which concerns between 30 and 80 % of permafrost OC. Depending on temperature and moisture environmental variables, a centennial to millennial-year old carbon pool can be mobilised, thus accelerating the feedback to climate change. The evolution of mineral-OC interactions with permafrost thaw is a potentially important player for the modulation of permafrost carbon emissions by affecting the availability of OC for microbial decomposition, thereby amplifying or mitigating permafrost carbon emissions. Arctic regions are used here to provide a perspective on the cascade of implications that the release of metals or the generation of new mineral surfaces have for the carbon sequestration. The rate of the changes in the Arctic CZ was not previously anticipated and calls for (i) geochemical tracers to identify new water pathways, (ii) geophysical constraints on geochemical processes, and (iii) an inter-disciplinary and a multi-dimensional (temporal, spatial) understanding of the processes at play.