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Scale dependent and independent mechanisms regulating aquatic carbon across the boreal landscape

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Carbon in aquatic systems has experienced increasing scientific attention the last decades. This interest has been spurred by the importance of both dissolved organic (DOC) and inorganic carbon (DIC) to biotic and abiotic processes in aquatic systems, but also because of their importance to the carbon balance of catchments. The most limiting factor in our ability to understand the present and predict the future fate of aquatic carbon is a lack of process based understanding of the mechanisms that regulate concentrations and fluxes of different forms across heterogeneous landscapes. This is especially true in organic carbon rich boreal ecosystems because of their inaccessibility and long winters. To help overcome this deficiency, we synthesize 30 years of aquatic carbon research from one of the most studied boreal landscapes in the world – the Krycklan Catchment Study in northern Sweden. We show that hydrology exerts strong and often contrasting controls over aquatic DOC and DIC across the soil/surface water interface, that these forms have distinct terrestrial origin and that their downstream fate does not follow the same scaling rules. Our work shows that the origin, dynamics, and fate can be decomposed into catchment scale dependent and independent mechanisms that regulate DOC and DIC to various extents across heterogeneous boreal landscapes. Scale dependent mechanisms include 1) the constitution of dominant source layers in near stream soils, 2) the spatial arrangement of groundwater input zones that govern water and solute fluxes at reach- to segment-scales, and 3) increasing contribution of deep groundwater downstream with distinct biogeochemical characteristics. Scale independent mechanisms include 1) proportion of mineral and peat soils hydrologically connected to surface water causing terrestrial source heterogeneity 2) the occurrence of lakes that provide hotspots for C gas storage and evasion, as well as for photo-oxidation and mineralization of DOC, and 3) turbulent stream segments (rapids) that cause outgassing of CO_2 and CH4. We suggest that resolving these scale dependent and independent processes are important for our conceptual understanding of how DOC and DIC are regulated, but also for predicting how, when, and where different environmental changes may influence their dynamics within river networks.