Project Title: Advancing northern high-latitude hydrological science through SWOT water surface elevation mapping

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The northern high latitudes contain the greatest abundance of terrestrial surface water bodies on Earth. They are important for ecosystems, the carbon cycle, and humans and are sentinels of climatic change. Remote sensing studies indicate that many Arctic lakes are disappearing, and that the region's numerous large anastomosing (multi-channel) rivers are prone to ongoing avulsions (channel captures) that reconfigure water flow across complex, low-relief floodplains and deltas. Lack of vertical water surface elevation (*WSE*) observations limits our understanding of both processes. SWOT's all-weather, dense orbital coverage toward the poles thus presents a unique opportunity to advance scientific understanding of the world's most extensive yet inaccessible surface-water systems.

The proposed research seeks to answer two exciting science questions about northern high latitude lakes and rivers through SWOT observations: 1) *Is the spatial distribution of freshwater storages in Arctic lakes influenced by permafrost state*? 2) *What are the spatial and temporal dynamics of water fluxes through anastomosing river systems, and how do they impact passage of water and sediment through complex, ecologically important northern deltas and floodplains?* The first question, addressed at the circum-Arctic scale, will determine if solid wintertime freezing of lakes protects freshwater lake storages in permafrost terrain. We hypothesize that conflicting reports of remotely sensed lake trends in continuous permafrost is caused by presence of taliks (thaw bulbs) beneath some lakes but not others, due in part to bedfast (solidly frozen) lake ice in winter. The second, addressed at the local to regional scale, will determine if in-progress river avulsions can be remotely identified from space. We contend that SWOT observations of *WSE,* water surface slope *(WSS),* discharge *(Q)* and stream power

(ω) portend a powerful way to map gradients in energy and water flux critical to channel evolution and the success or failure of river avulsions.

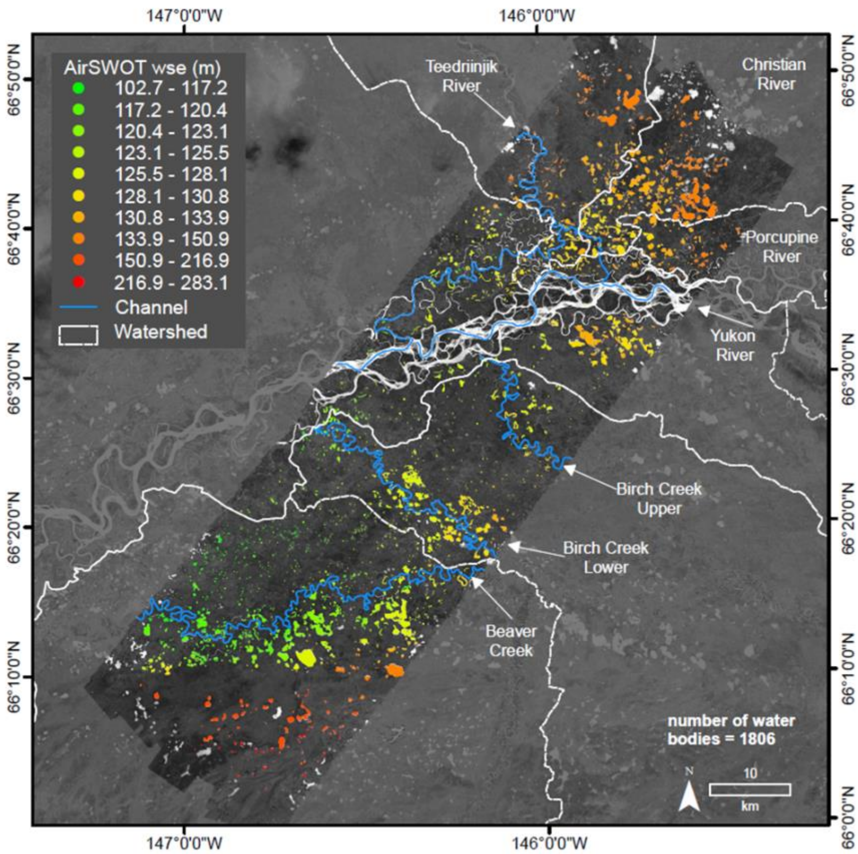

Figure 1: A first demonstration of SWOT-like water surface elevation *(WSE)* measurements over northern lakes (Yukon Flats, Alaska), obtained using airborne AirSWOT interferometric radar data (*Pitcher et al., Water Resources Research, 2019*). The SWOT mission will acquire similar types of observations over millions of northern lakes and rivers globally.

Both science questions will be tackled through pre- and post-launch research activities. Pre-launch activities include mapping bedfast lake ice throughout the continuous permafrost zone using Sentinel-1 C-band radar. Because taliks do not develop beneath bedfast ice, this will identify lakes that likely lose water storage to infiltration vs. those that do not, an idea that can then be tested with SWOT *WSE* measurements post-launch. Other pre-launch activities involve refining the SWOT Rivers Database (SWORD, the mission's global a priori river map) for 25-30 northern floodplains and deltas so that all long (>10 km) anastomosing river reaches are sampled by SWOT; and analyzing AirSWOT imagery and field data from the Peace-Athabasca Delta, Canada. Hypothesis-driven post-launch activities include analysis of SWOT *WSE* observations over lakes; and *WSE*, *WSS*, *Q*, and derivative ω over rivers. Three field trips will collect in situ measurements needed to confirm or refute inferred areas of enhanced river erosion and avulsion potential from these observations.

This project responds to 3 (of 5) Core SWOT Hydrology Science Questions and to broader NASA priorities, including Core Context #3 ("Safeguarding and Improving Life on Earth") of Strategic Goal 1.1 ("Understand the Sun, Earth, Solar System, and Universe") of the NASA Strategic Plan 2018; and Recommended Observation Capability #4 ("Trends in water stored on land") of the 2017 Decadal Survey for Earth Observation from Space. The investigators have deep expertise in hydrological remote sensing and field work in northern environments. The PI has actively participated in SWOT's development since conception, and has proven track record of studying high-latitude hydrological science questions and recruiting talented, diverse young scientists into the remote sensing hydrology community. Prospective graduate students, postdoctoral scholars, and collaborators interested in SWOT and northern hydrology are encourage to visit https://northernchange.brown.edu.