Backwater effects from river ice jams observed with SWOT pixel cloud data

DTU Space
Technical University of Denmark

Linda Christoffersen[1], Louise Sandberg Sørensen[1], Ole Baltazar Andersen[1], Peter Bauer-Gottwein[1,2] and Karina Nielsen[1]

1: Technical University of Denmark, DTU Space, Division of Geodesy and Earth Observation
2: Department of Geosciences and Natural Resource Management, Geology, Faculty of Science, University of Copenhagen

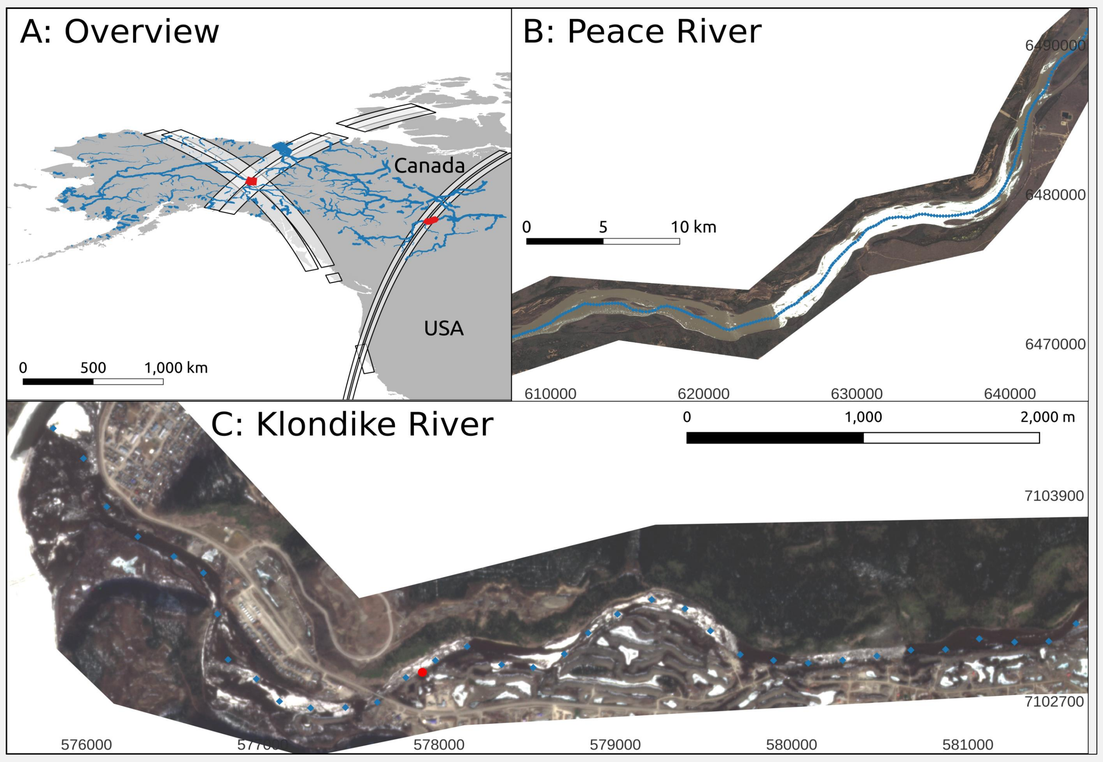
River ice jams

River ice jams often happen during spring break-up where chunks of ice clump together to block the flow of a river. The jam can accumulate water upstream of the jam resulting in a severe rise in water level.

An ice jam is a very short-lived phenomena that only lasts a couple of days. Detecting ice jams with remote sensing require favourable timing.

Ice jam on the Vermilion River in Ohio, 2014. https://www.dailymail.co.uk/news/article-2568597/Arctic-ice-jams-wrecking-property-Midwest.html, Updated: 22:39 BST, 26 February 2014.

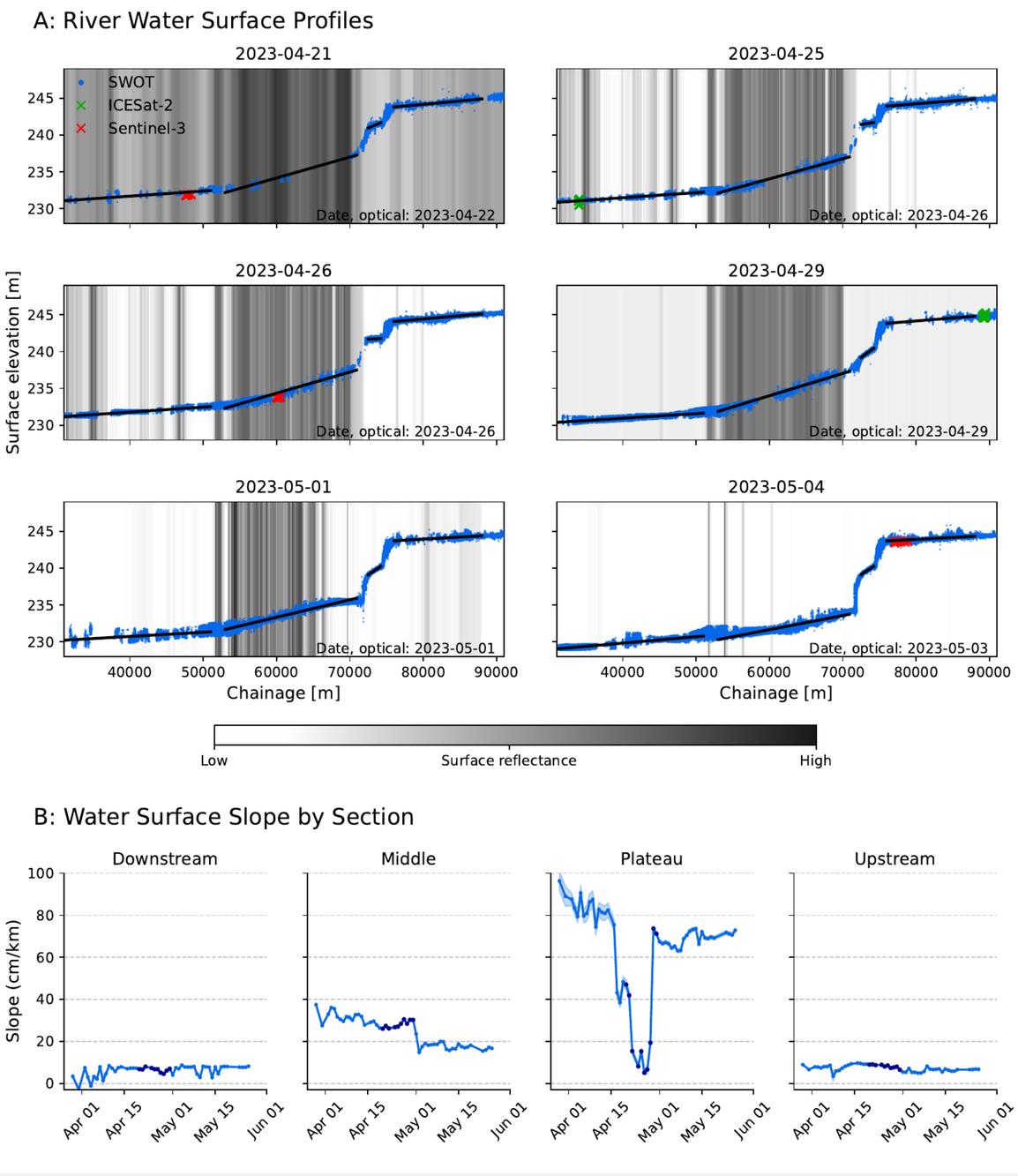
Societal impact:
These rapid increases of several meters across only a couple of days can have a severe impact on the lives of people living along the river.
Often people must flee from their homes as they flood for several days.



Peace River, April 26th - April 30th, 2023

The study area on the Peace River, Alberta, Canada, spans 85 km with a width of 1–2 km around Vermilion Falls. It is covered by SWOT pass 013 during the cal/val period, with a daily revisit time.

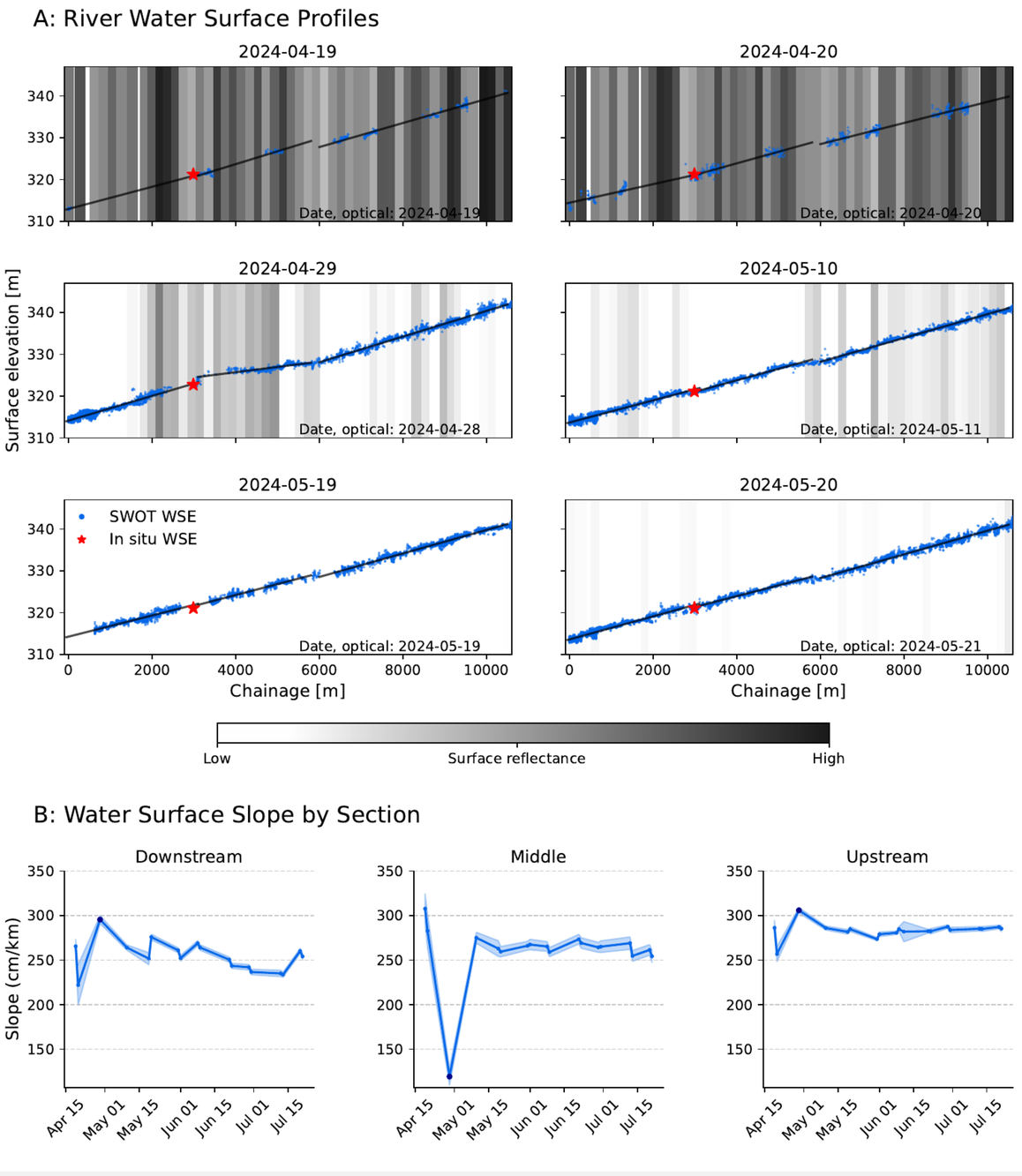
Water surface profiles from SWOT over 8 days,
- Sentinel-3A/B and ICESat-2 ATL13 for reference.
- Between April 25 and May 1, the middle section is ice-covered, while upstream and downstream remain ice-free.



Klondike River, April 29th, 2024

Lower Klondike River near its confluence with the Yukon River at Dawson City, Canada. The reach is 16 km long and is 50–80 m wide.

Figure shows water surface profiles over six days in April 2024.
- Dark shading indicates river ice cover from optical data.
- On the jam day, chainage 2000–5000 m is ice-covered; upstream and downstream sections are ice-free.
- The surface profile reveals ice blockage causing backwater upstream of the jam.
- The red star marks the in situ water surface elevation (WSE).



Backwater effects

The water surface slopes (WSS) show significant changes at the time of the ice jams.

The drop in WSS in the middle sections of the profiles demonstrate the backwater effects from the ice jams.

The middle section of the Klondike River, WSS dropped from approximately 300 cm/km to 150 cm/km, with a backwater curve extending roughly 2.5 km upstream.

In contrast, the Peace River's WSS decreased from 80 cm/km to 10 cm/km

Conclusions

- Demonstrates SWOT's capability to monitor the effects of dynamic events like spring ice jams.
- Comparison with in situ gauges, ICESat-2, and Sentinel-3A/B high-lights SWOT's strength in capturing continuous river profiles.
- SWOT's accuracy significantly degrades under ice cover, challenging cryospheric and Arctic hydrology studies.
- Analysis of water surface slope variations reveals substantial flow disruptions and altered hydraulic gradients.