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Mapping a Transboundary Flood from the USA to Canada using Space-Air-Ground Remote Sensing

Bing Lu [a,*], Ian McDonald[a]

[a] *Department of Geography, Simon Fraser University, Burnaby, Canada, Bing Lu – b_lu@sfu.ca, Ian McDonald - ian_mcdonald_2@sfu.ca,*

* Corresponding author

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Abstract:

Transboundary flooding caused by unique terrains can result in catastrophic damages across multiple countries and political complications in flooding responses and managements. A severe flooding occurred in mid-November, 2021, in Washington (WA), USA, triggered by intense atmospheric rivers, heavy rainfall, and river outflows. The floodwaters flowed northeast from Washington to British Columbia (BC), Canada, causing massive damages and losses in both regions. These include at least five fatalities, thousands of flooded homes, tens of thousands of evacuated residents, and hundreds of thousands of livestock deaths (Gillett et al. 2022; Watterodt and Doberstein 2023). The huge economic losses made this event one of the most expensive disasters in the history of Canada (CleanBC 2021).

The atmospheric rivers and associated intense rainfalls were essential reasons of the devastating floods. Atmospheric rivers are a type of meteorological event transporting concentrated moisture from tropical or extratropical areas to other regions via long and narrow corridors, often leading to massive precipitation (Ralph et al. 2018). Under climate change, such extreme weather events can be more frequent and severe. For example, a study conducted by the United Nations found that the number of significant flood disasters worldwide between 2000 and 2019 (3,254) was doubled that of period from 1980 to 1999 (1,389) (United Nations Office for Disaster Risk Reduction 2020). Therefore, it is critical in document and map such floods and other extreme events, understand their underlying mechanisms, and take effective measures to mitigate risks and potential damages.

Remote sensing is an effective tool for monitoring flood patterns, tracking their spatio-temporal changes, and supporting near-real-time and long-term flood responses and managements (Figure 1). Multitype remote sensing images collected by different platforms – such as optical, Radar, and LiDAR images obtained by unmanned aerial vehicles (UAVs), airplanes, and satellites – can all contribute to the flood mapping and investigations. These sensors and platforms have varying strengths and limitations in terms weather resilience, spatial coverage, spatial and temporal resolution, and the complexity in image acquisition and interpretation (Oniga et al. 2020). Therefore, it is valuable to integrate multi-sensor and multi-platform images to investigate flood events in a more comprehensive and robust manner. Together with geographic information system (GIS), different flood features, including flood extent and water depth, can be extracted and analyzed. Such results and maps are critical for assessing flood damages and long-term impacts (Chatrabhuj et al. 2024).

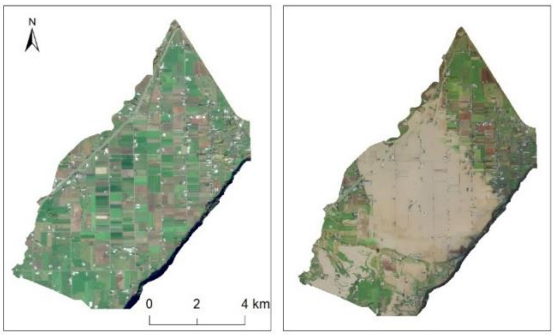

Figure 1 Example images showing pre- and post-flood conditions

To investigate the 2021 flood disaster in WA and BC, this research collected a time series of multi-sensor and multi-platform images to investigate pre-, during-, and post-flood features and understand associated influencing factors (Figure 1). The images included satellite-based optical and radar images covering the entire study area, airplane-based

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optical images of severely flooded regions, UAV-based optical images covering critical infrastructure controlling flood patterns (e.g., dikes and their failures), as well as LiDAR digital elevation model (DEM) data of the study area. Water extents were extracted from the time series of images to monitor flood progression (Feng, Liu and Gong 2015; Anusha and Bharathi 2020; Psomiadis, Diakakis and Soulis 2020). Water depths were then estimated using the water extent maps and local DEM. Areas that experienced prolonged flooding and deeper water depths – and thus suffered greater damages – were identified.

The results demonstrate that integrating multi-sensor and multi-platform images is essential for monitoring flood dynamics. The time series of water extent maps clearly captured the flood progression, improving our understanding of this flood event and enabling the calculation of inundation area and duration in a specific region. The water depths were also successfully estimated, providing a more detailed interpretation of water distributions and accumulations. The patterns of water extent and depth reveal the impacts of terrain and flood-control infrastructure (e.g., dikes, ditches) on water movements and stagnations. These findings improve our understanding of flood regimes in the transboundary region and impacting factors, offering valuable insights to local policymakers, engineers, communities, and other stakeholders to mitigate flood risks in both countries and enhance preparedness for future flood events.

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