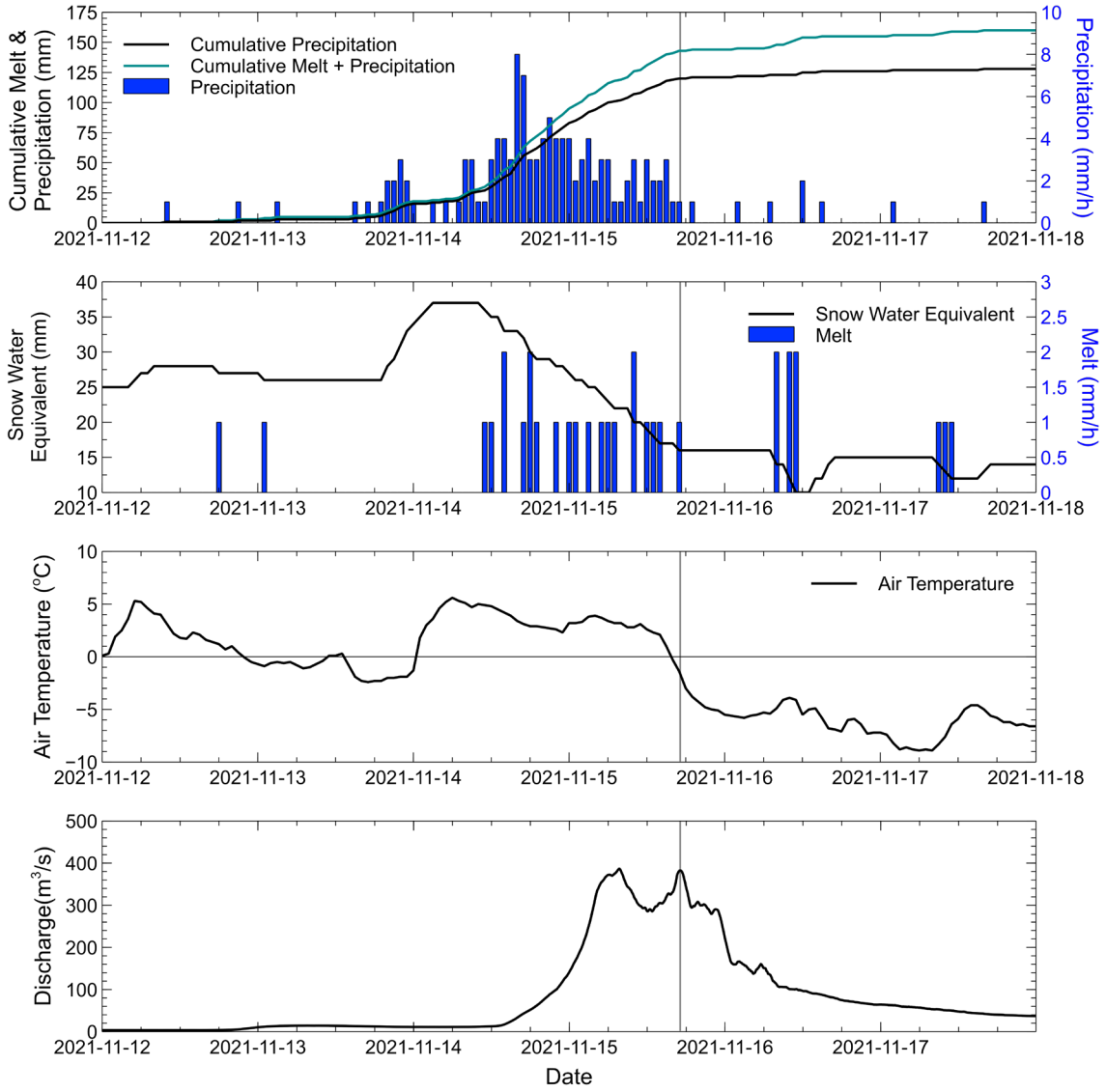
Streamflow

Hydro-meteorological Overview

Coldwater Basin

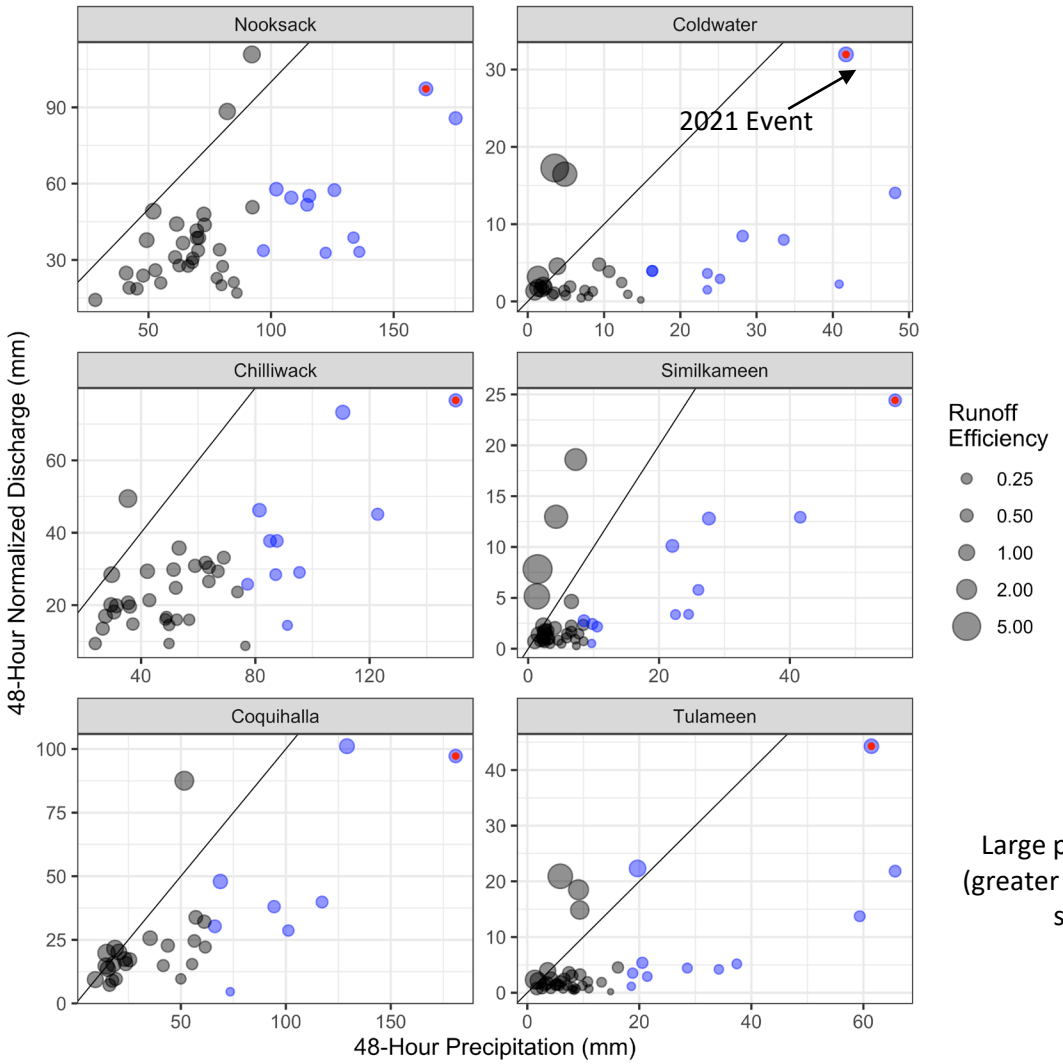


Point observations of precipitation, snow water equivalent (SWE), and streamflow collected at meteorological and hydrometric sites in the Coldwater basin.

- Total melt and precipitation over the 48-hour period ending on November 16th, 00:00 PST, were 21 mm and 83 mm respectively
- The effective precipitation (melt plus precipitation) was 104 mm with a snowmelt contribution (melt ratio) of 20%.
- Rain-on-snow conditions, where streamflow was generated by precipitation (predominantly as rainfall) augmented by snowmelt associated with a rapid rise in temperature.

Precipitation, Runoff and Runoff Efficiency

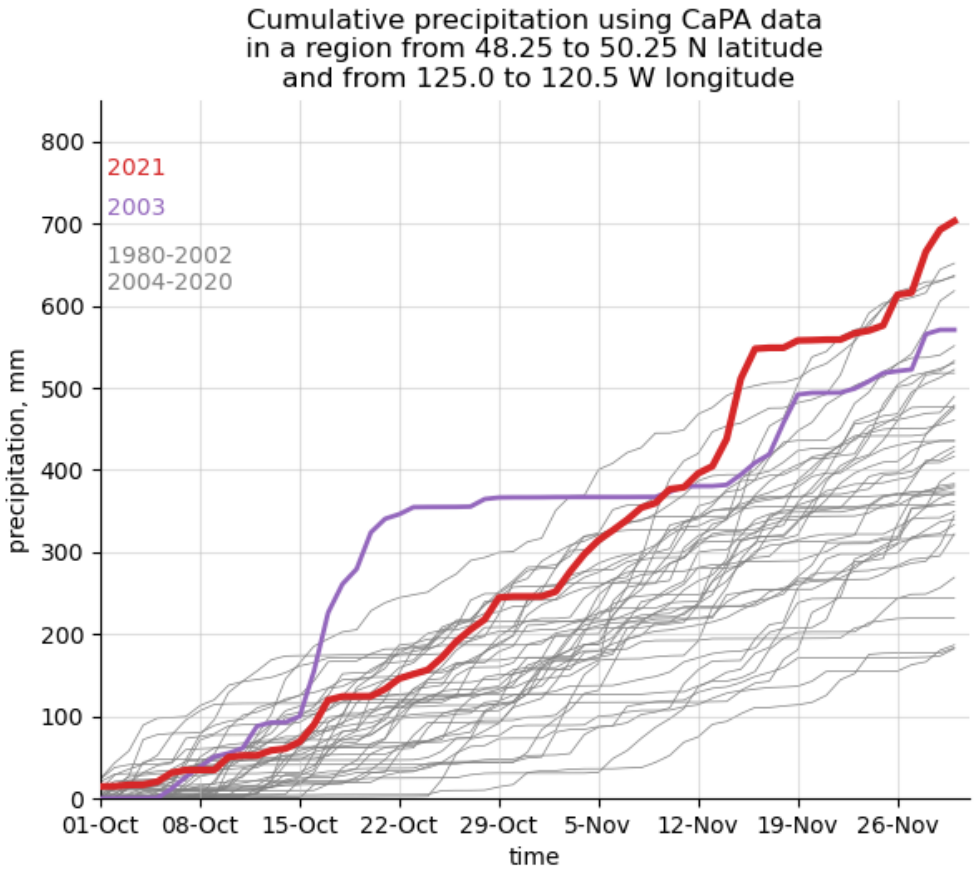
48-hour precipitation, streamflow and runoff efficiency for October-December

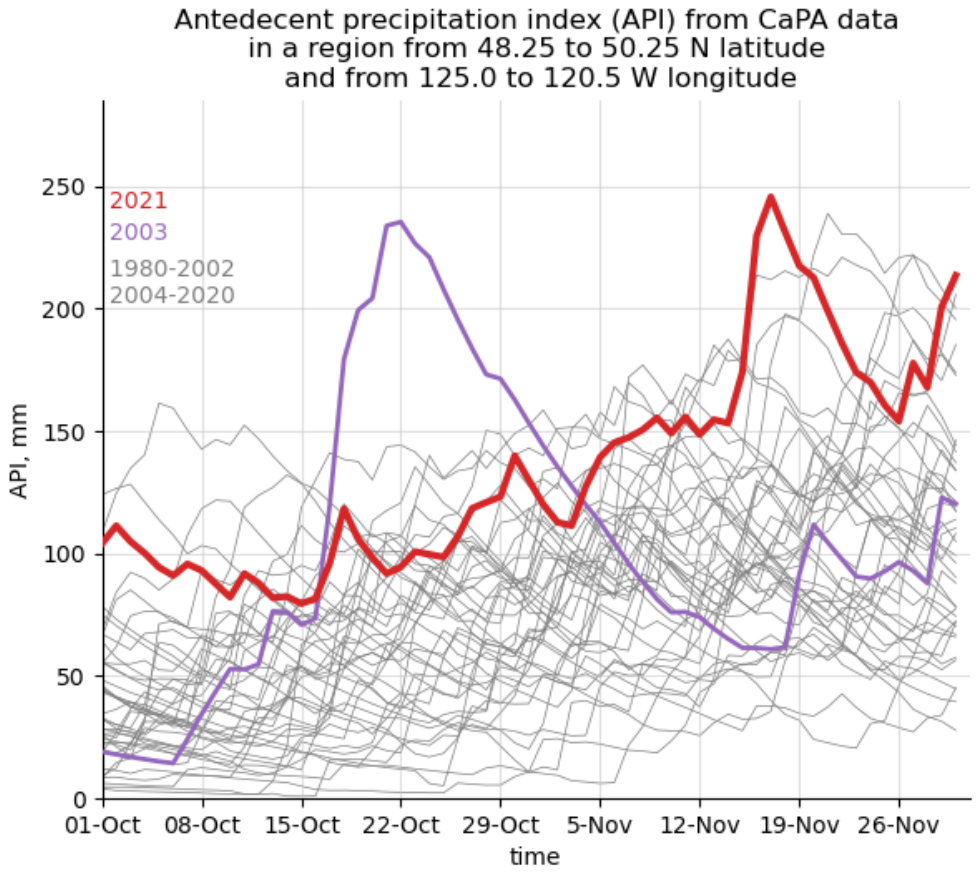


- Discharge increases with the magnitude of event precipitation, but considerable variation is evident which can be explained by variation in runoff efficiency.
- Both 48-hour discharge (Q_{48}) and 48-hour precipitation (P_{48}) volume in 2021 rank in the top two events of all observed years.
- Runoff efficiencies for the 2021 AR event were modest, ranging from 0.43 (Similkameen) to 0.76 (Coldwater).

Large precipitation events (greater than 75th percentile) shown in blue

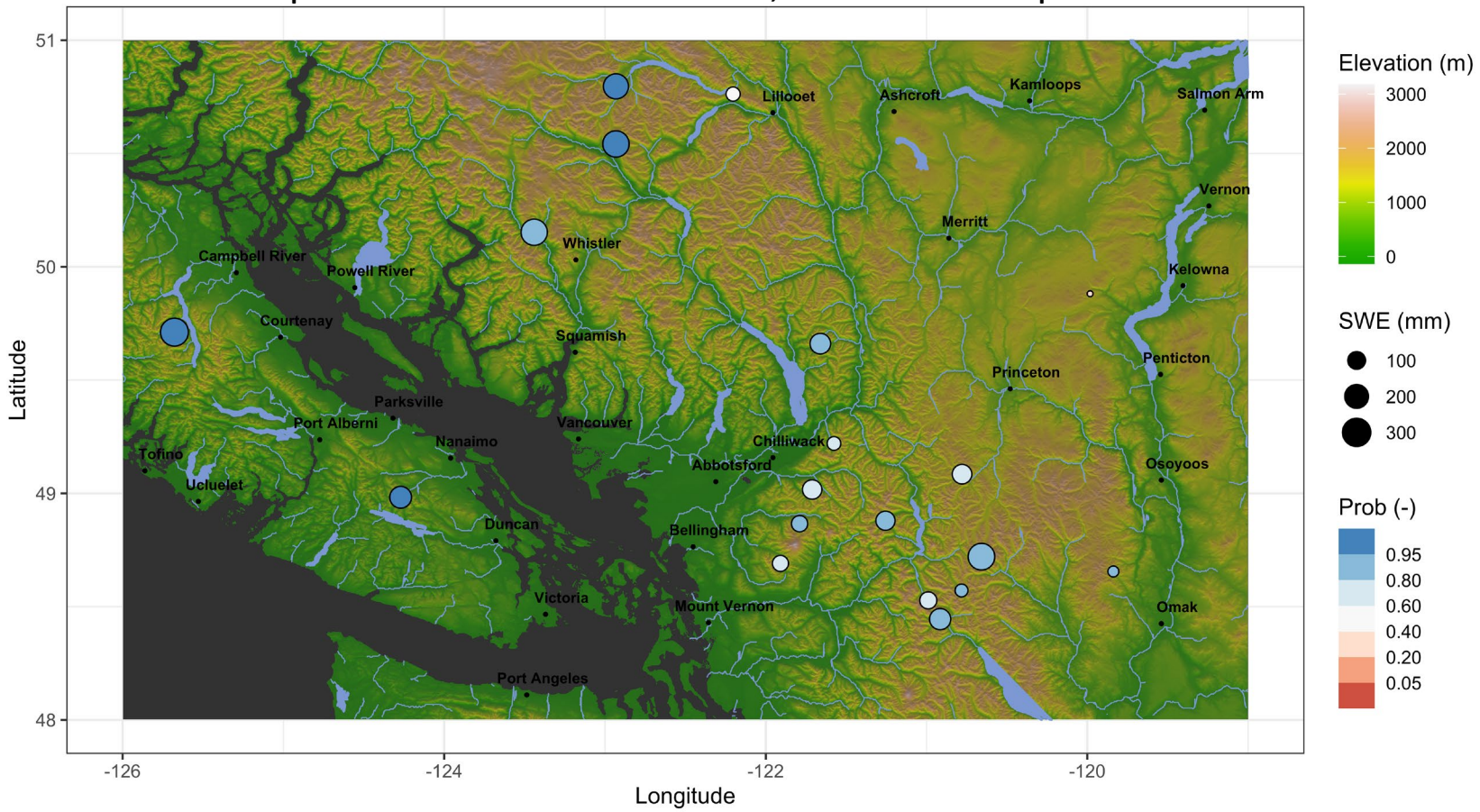
Antecedent Conditions - Precipitation





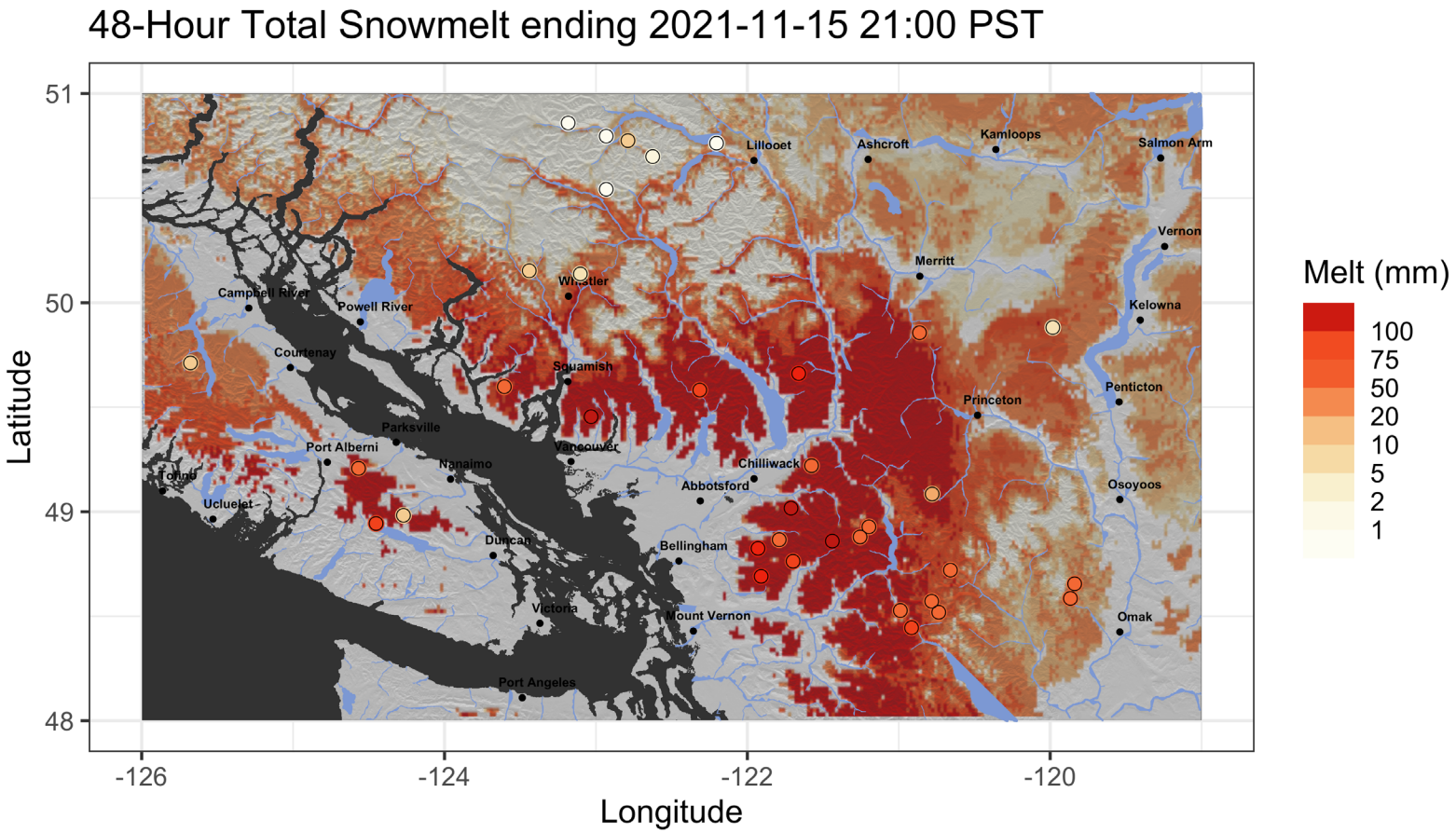
Antecedent Conditions – Snow Water Equivalent

SWE as percentile on November 13, 2021 at snow pillows sites



- Antecedent SWE on November 13th 2021 was higher than normal, but not extreme
- Values ranged between the 70th and 90th percentile of historical daily observations for the 3-day period centred on November 13th.

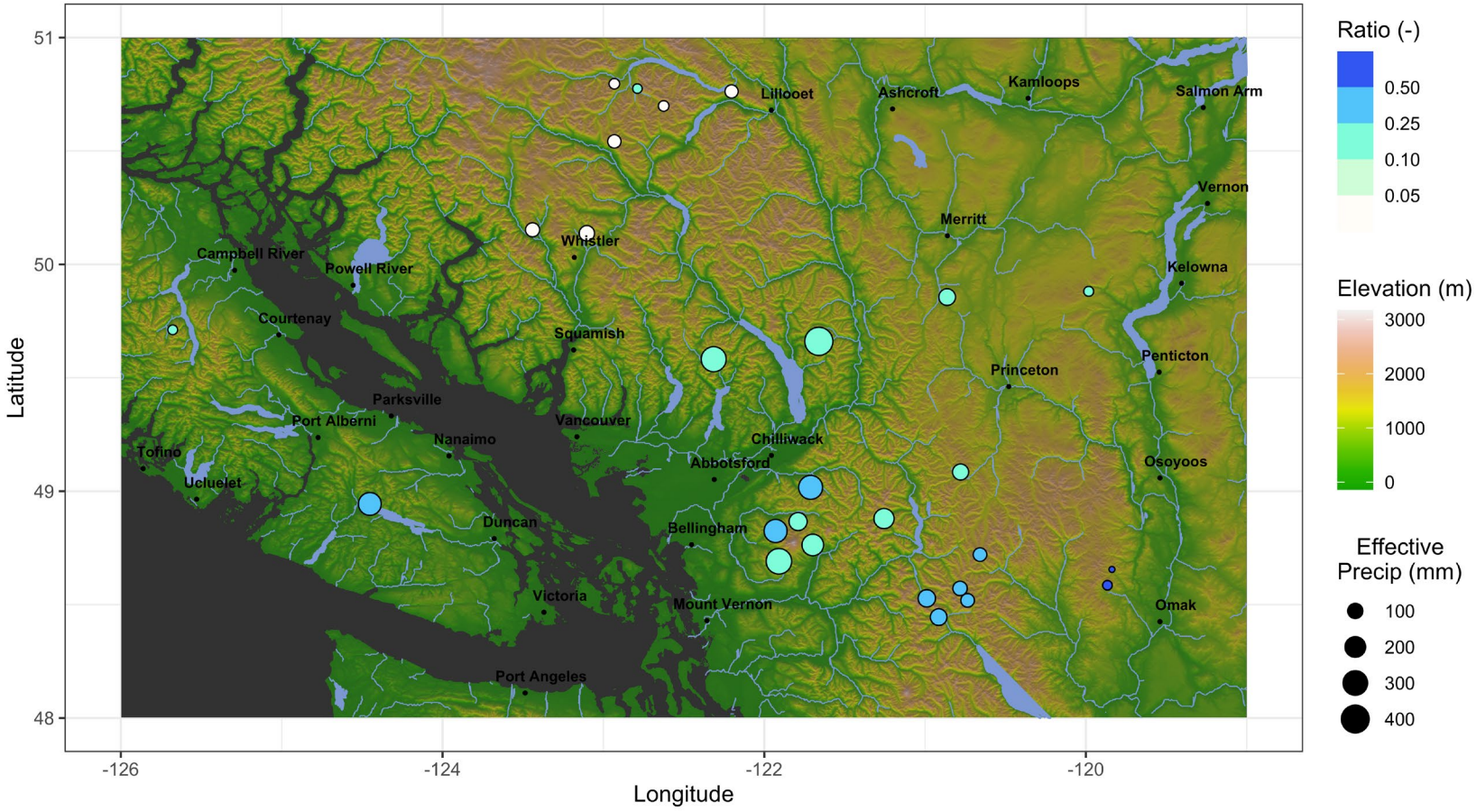
Snowmelt



- Melt rates are highest (in places > 100 mm) within a belt along the windward side of the southern Coast Mountains and Cascade Range
- Melting/freezing altitude had risen to at least ~2000 m.
- Widespread melt suggests precipitation occurred as rain, not snow.

Snowmelt Contribution

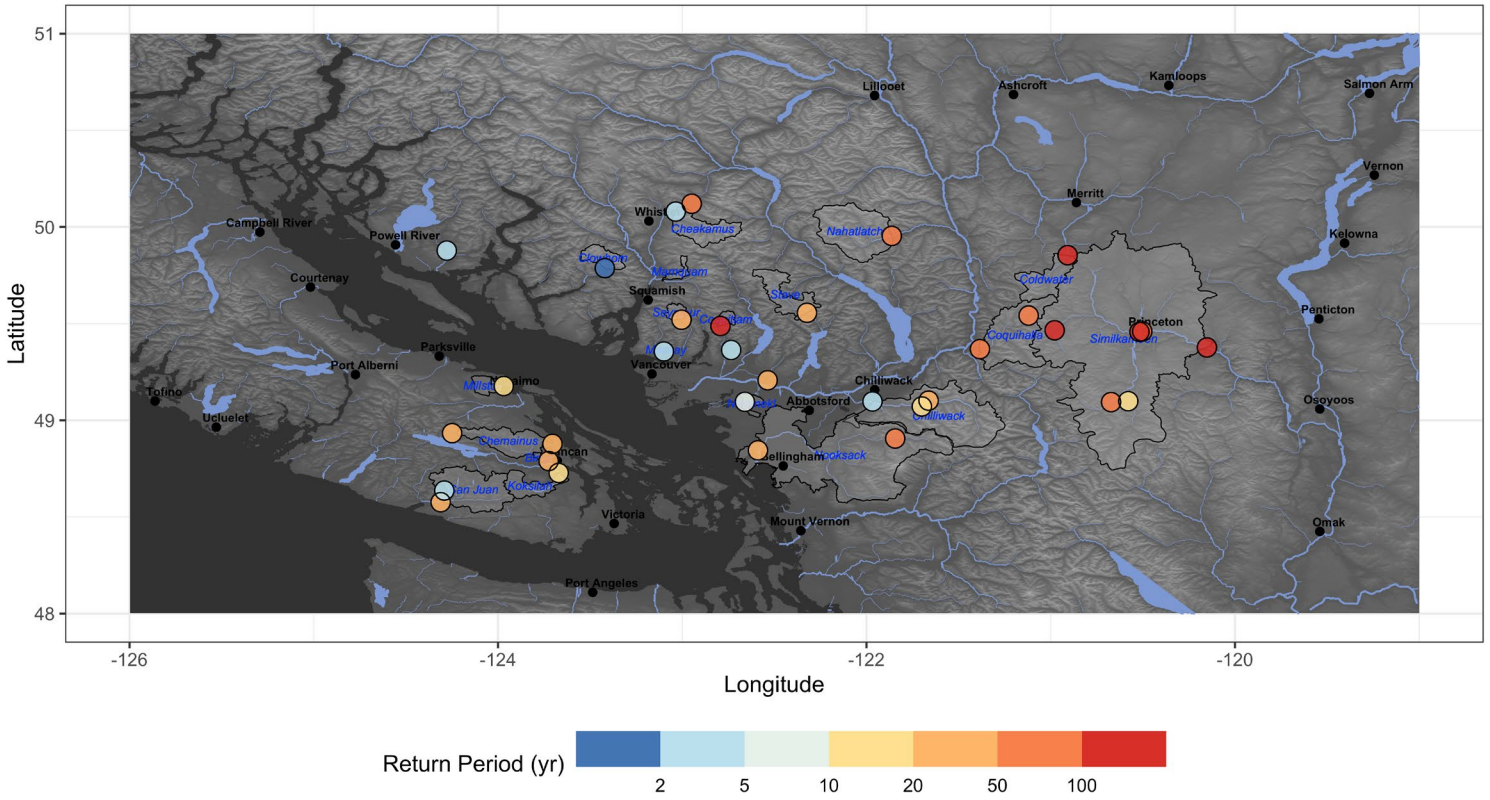
Ratio of snowmelt to the effective precipitation (precipitation plus snowmelt) for the 48-hour period ending November 15th 2021



- For most sites located south of 50°N, melt ratios were between 10% and 25%.
- Melt ratios at windward sites with effective precipitation exceeding 150 mm ranged from 17% (lower Fraser) to 36% (Chilliwack River).

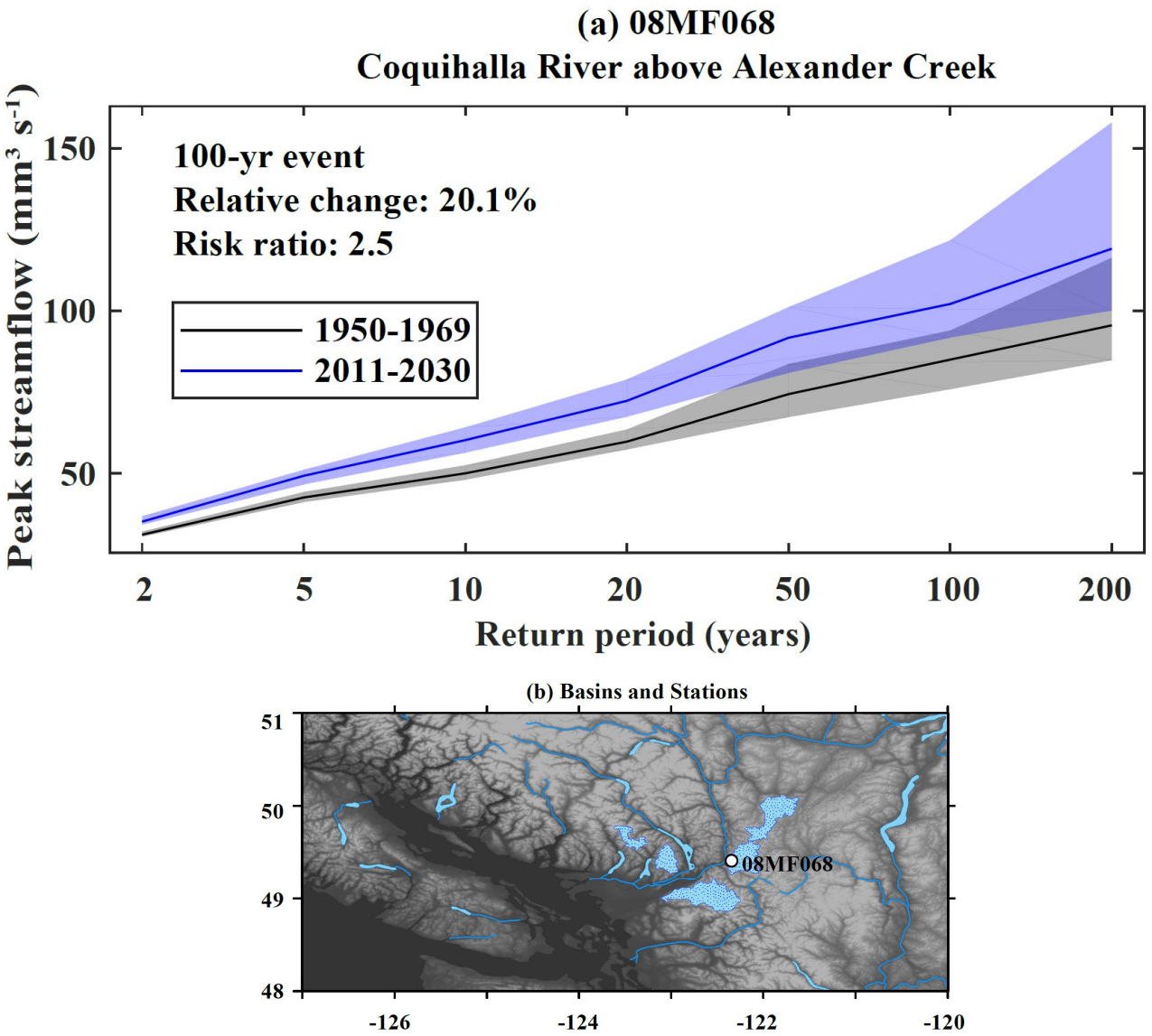
Streamflow – Return Periods

Streamflow return periods for the November 2021 peak flows at hydrometric stations



- Estimated peak river flow at many stations exceeded historical records by a large margin.
  - Coldwater River near Brookmere: 82% more than its 53-year record
  - Tulameen River below Vuitch Creek: 152% more than its 39-yr record
- Of the 32 unregulated stations
  - 20 experienced at least a one in 20-year event
  - 11 at least a 1-in-50 year event
  - 5 experienced more than a 1-in-100 year event.

Peak Flow Events and Climate Change



- Human-induced climate change is estimated to have increased the probability of October-December extreme streamflow events by a factor of 2-4 based (best estimate)
  - Using hydrologic model simulations driven by a large ensemble of CanESM2 climate model simulations
- Analyses of several other rivers show similar results to the figure on the right.

Conclusions

- Rarity of the November 14-15, 2021 event:
    - Atmospheric river: about a 1-in-10 year event
    - Two-day precipitation: about a 1-in-50 to 1-in-100 year event
    - Streamflow: exceeded a 1-in-100 year event in some locations
- Runoff generated by “rain-on-snow” conditions, but precipitation was the dominant factor for the extreme streamflow.
- Human-induced climate change substantially increased the probability of the atmospheric river event and the resulting precipitation and flooding.

Conclusions

- This is the first study of a flooding event in Canada to link human-induced climate change to all of the main constituent elements of the event.

- Such events, including the atmospheric river, extreme precipitation, and flooding, will become more likely in the future with additional warming.

- Rebuilding, and infrastructure development in general, must take climate change into consideration.

Contributors

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