

Streamflow and water quality responses to winter weather whiplash events at long-term research sites



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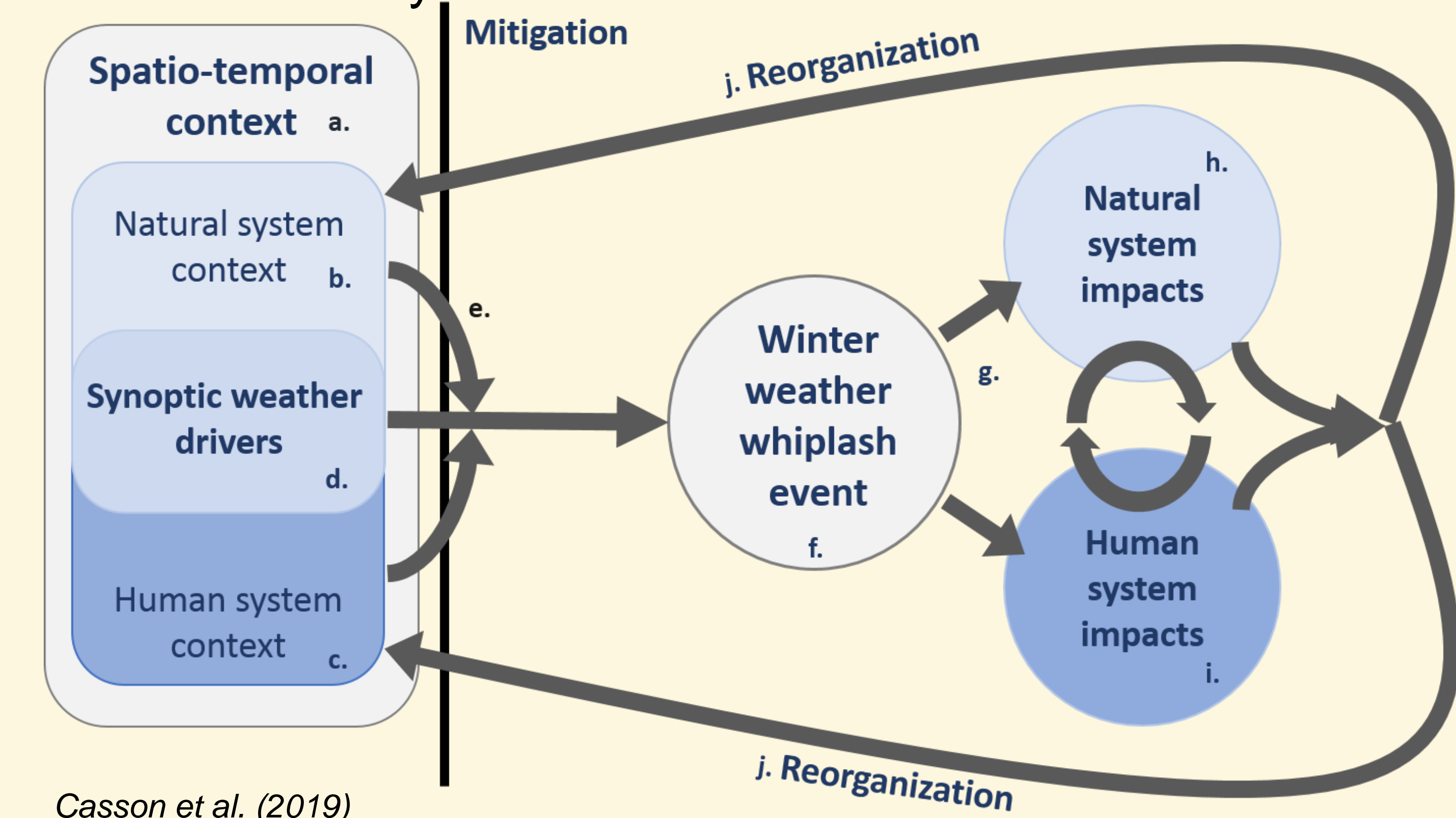
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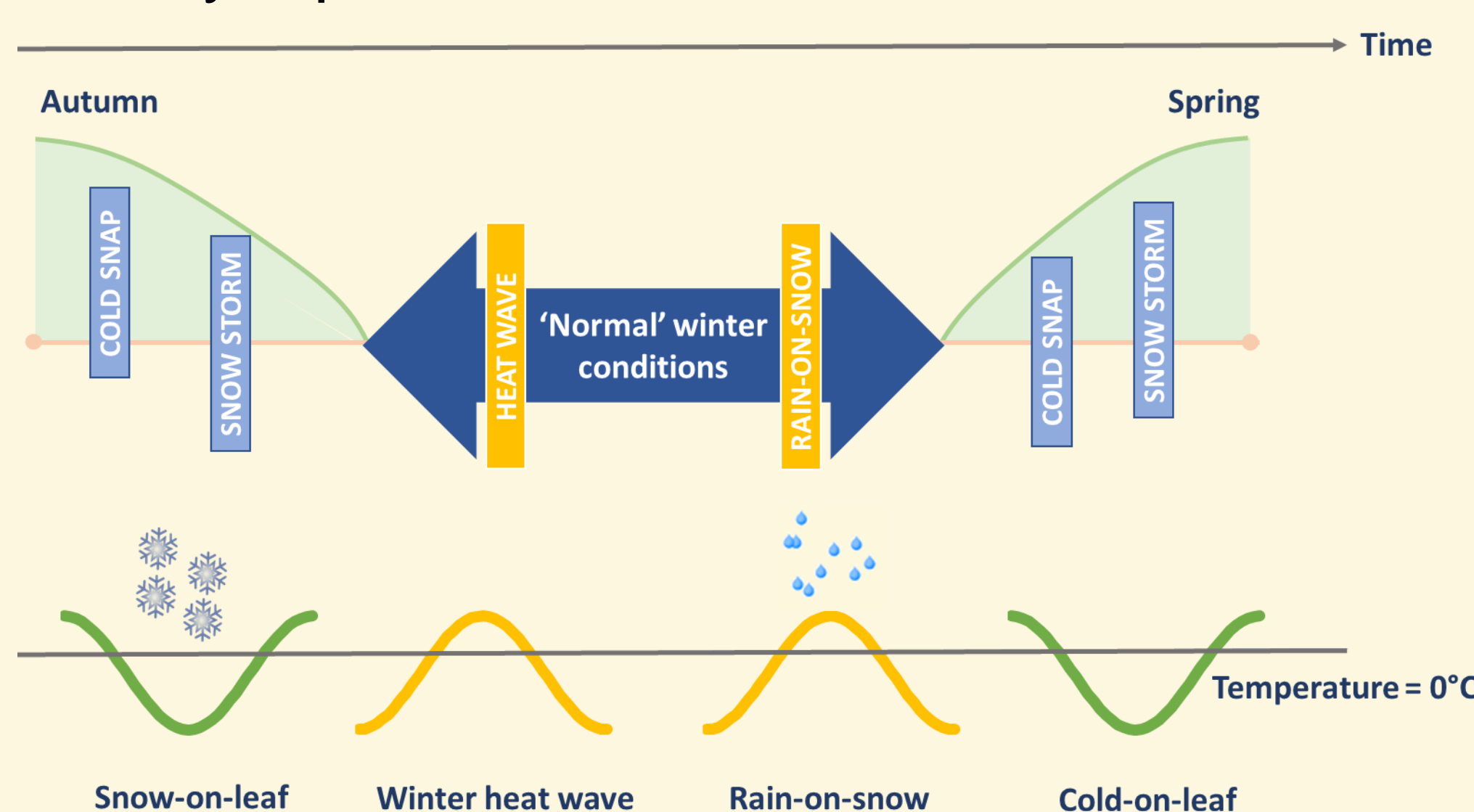
Winter weather whiplash events

Definition: A collision of unexpected conditions that produces a forceful, rapid, back-and-forth change in winter weather which may induce an unexpected impact on coupled human-natural systems



Casson et al. (2019)
Figure 1: Conceptual model of winter weather whiplash events

- Impacts of winter weather whiplash events (f) depend on the severity of the weather (d) and on their context (a-c)
- Natural system impacts (h) may include tree loss, flooding or disruption of wildlife. Human system impacts (i) may include damage to property or power outages
- Feedbacks between the two systems may include tree branches falling on power lines
- These events may reorganize the coupled human-natural system context (j), (e.g. by changing forest structure or economic activities)
- Mitigation strategies may be designed to reduce the future influence of synoptic weather conditions



Casson et al. (2019)
Figure 2: Winter weather whiplash events can occur both within and outside of the winter season
1) Cold or snowy winter conditions that occur during the shoulder seasons of spring and fall
2) Warm or rainy weather that takes place within the winter season

Research question

Winter weather whiplash events have the potential to cause substantial and unexpected flooding. How do rain-on-snow and winter heatwave events affect streamflow in catchments of varying sizes and climates?

Frequency of events

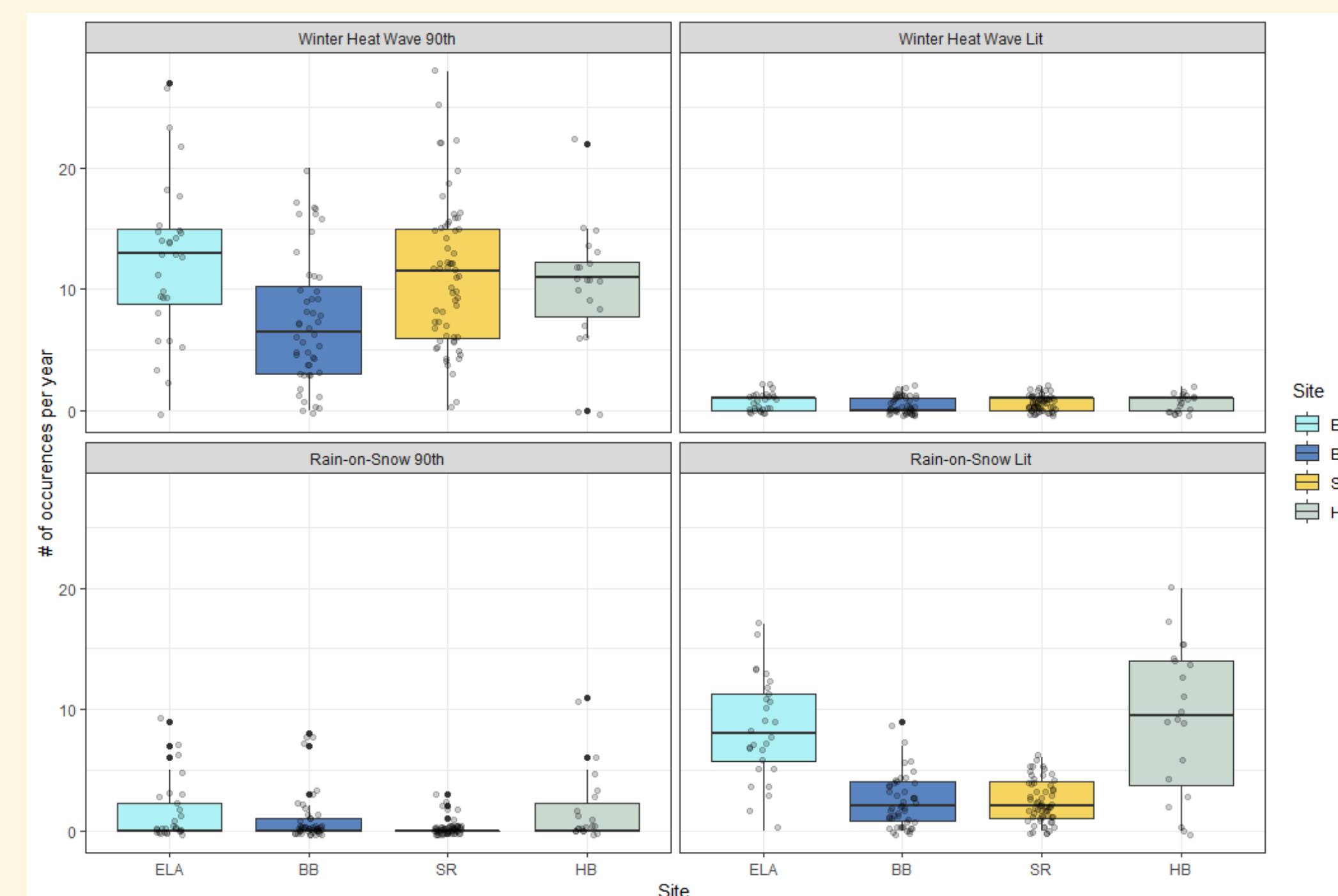


Figure 3: Occurrences per year of four types of winter weather whiplash events

- Rain-on-snow events are more common at ELA (due to persistence of snowpack) and HB (due to frequency of rain events)
- Using the literature criteria, winter heat waves are very rare (0-1 events per year at all sites)

Hydrological impacts

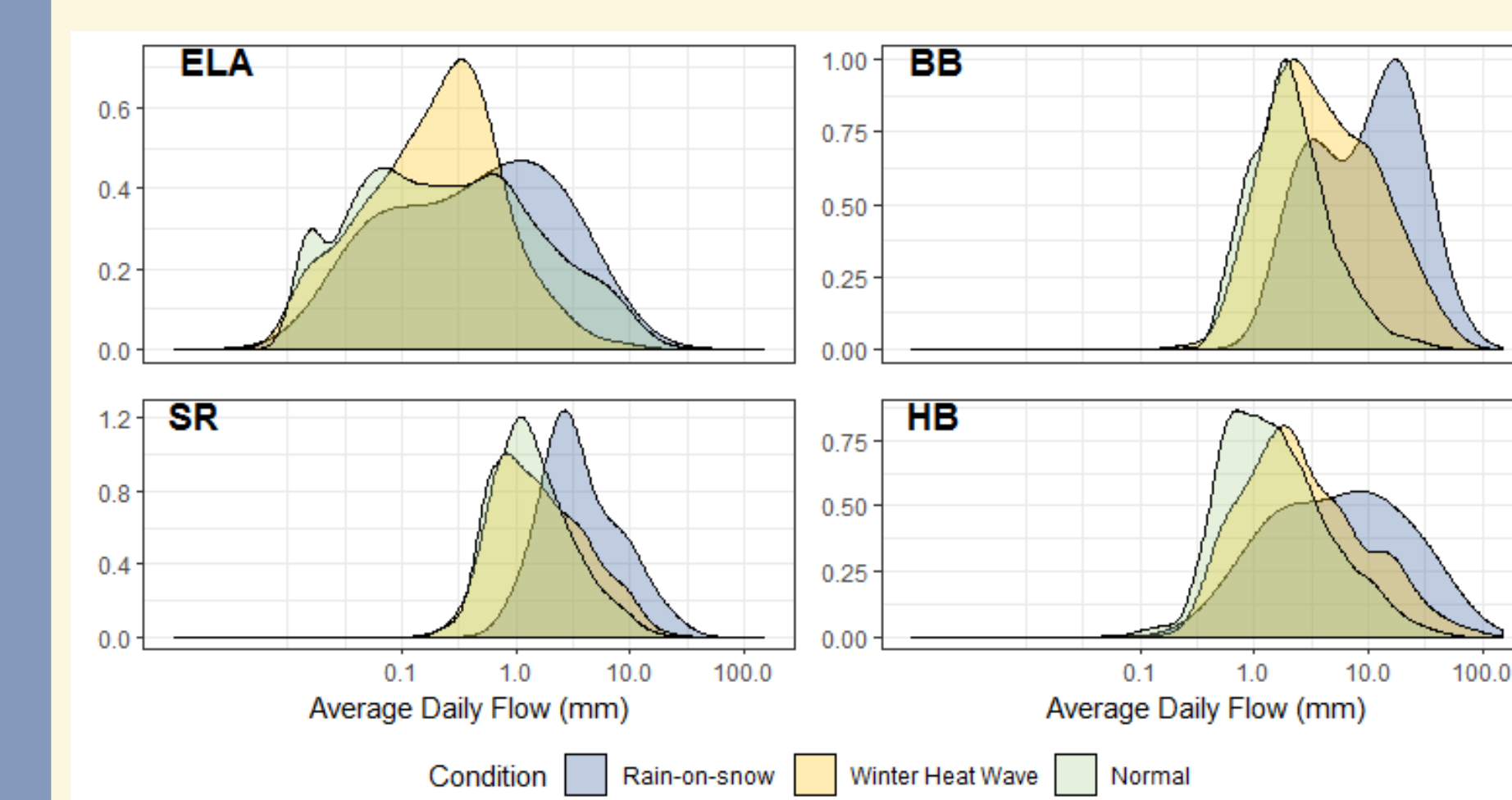


Figure 4: Distributions of daily flow data show the impact of different types of winter weather whiplash events on streamflow

Site name	Condition	# of Annual max flow events	# of days >99 th percentile winter flow
IISD-Experimental Lakes Area (ELA)	Rain-on-snow	0	74
	Winter heat wave	0	1
Sleepers Rivers (SR)	Rain-on-snow	6	30
	Winter heat wave	0	1
Biscuit Brook (BB)	Rain-on-snow	11	43
	Winter heat wave	1	1
Hubbard Brook (HB)	Rain-on-snow	14	74
	Winter heat wave	0	1

- Rain-on-snow events have significantly higher flow than non-event days at all sites except for ELA
- Days with extremely high (>99th percentile) flow were associated with rain-on-snow events, which sometimes even exceeded spring melt

Methods



Figure 5: Study sites used in this analysis

Site name	Record length (years)	Catchment area (ha)	Mean winter temp (°C)	Total winter precip (mm)
IISD-Experimental Lakes Area (ELA)	47	56.4	-13	77
Sleepers Rivers (SR)		11100	-8.4	290
Biscuit Brook (BB)	28	990	-5.8	359
Hubbard Brook (HB)		13.2	-6.0	330

Crossman et al. 2018

- Measured minimum/maximum temperature, precipitation and stream discharge
- Simulated snow depth, snowfall and rainfall values (Kokkonen et al., 2006)
- Identified events using meteorological data

Event type	Threshold Criteria
Rain-on-snow	90th: Both snow depth & rainfall ≥ 90th percentile Lit: Snow depth ≥ 10 mm of SWE & rainfall ≥ 3 mm (Freudiger et al., 2014)
Winter Heat wave	90th: Max Temp ≥ 90th percentile & next 5 day median is <1 SD of historical record Lit: Max Temp ≥ 18°C & next 5 day median is < 1 SD of historical record

Casson et al. (2019)

Future research questions

- How are the frequency and distribution of winter weather whiplash events changing through time and space across seasonally-snow covered regions?
- How can we quantify impacts of winter weather whiplash events that are not simultaneous with the event?
- How do winter weather whiplash events impact stream water quality and solute export?
- How do these streamflow and water quality impacts affect downstream aquatic ecosystems?

References: Casson et al. (2019) Earth's Future; Crossman et al. (2018) Biogeochemistry, 130(3) 247-265; Freudiger (2014) Hydrology and Earth System Sciences, 18(7): 2695-2709; Kokkonen et al. (2006) International Congress on Environmental Modelling and Software, 73