Characterizing Compound Inland flooding Over North America

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Institute for Catastrophic Loss Reduction
Building resilient communities

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Background

- Hydroclimatic extreme events arise from complex interactions!

- When multiple drivers (that is, climatic processes such as weather systems) and/or hazards combine, their impacts are often amplified.

- These compound events cause severe economical, societal and environmental damage, but their investigation is difficult as they occur rarely and are multivariate.

- *So comprehensive design of flood- protection infrastructure like dams must take into account the dependence between multiple flood drivers*

Background

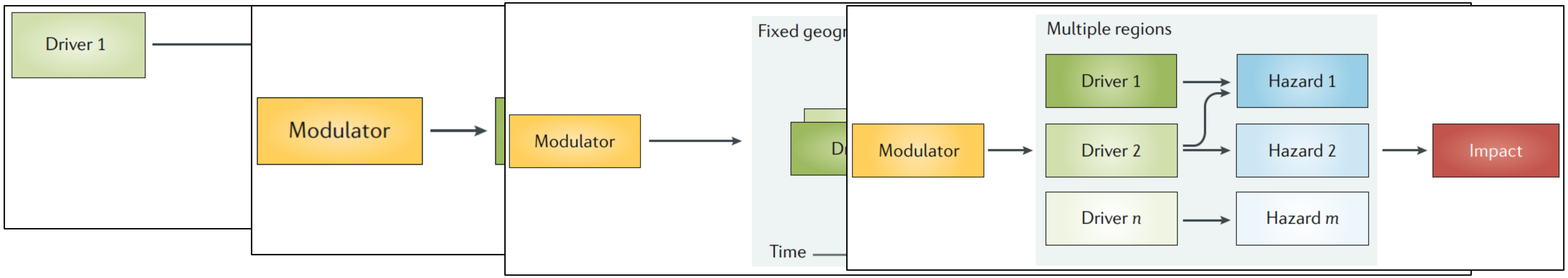
- Zscheischler et al. (2022) organized the highly diverse compound event types according to four themes:

i. **Preconditioned**, where a weather-driven or climate-driven precondition aggravates the impacts of a hazard; e.g., *Heavy precipitation on saturated soil, Rain on snow*

ii. **Multivariate**, where multiple drivers and/or hazards lead to an impact; e.g., Compound coastal and fluvial flooding, compound drought and heat

iii. **Temporally compounding**, where a succession of hazards leads to an impact; e.g., Temporal clustering of precipitation events

iv. **Spatially compounding**, where hazards in multiple connected locations cause an aggregated impact; e.g., Spatially concurrent precipitation extremes/floods at regional scale



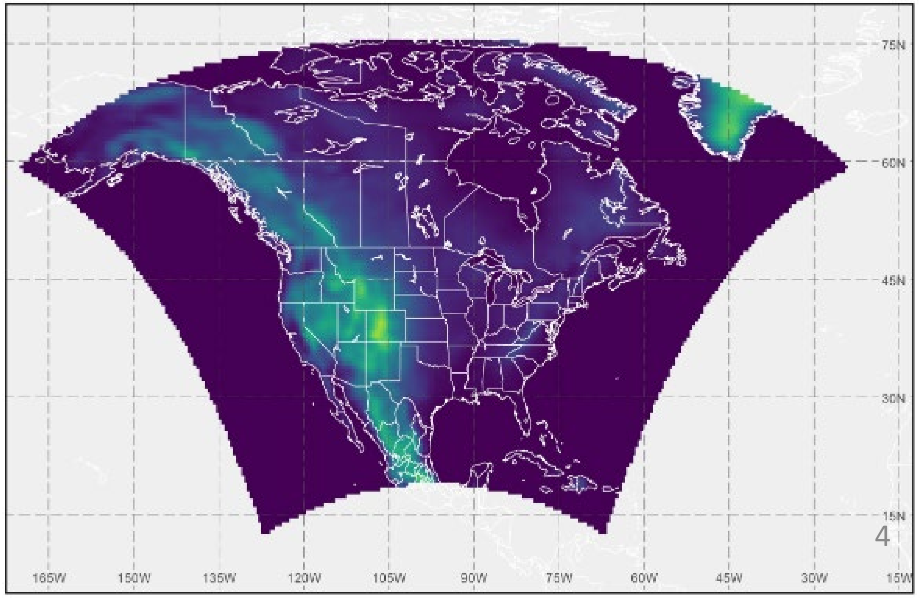
Objectives

- ***The objectives*** of this study:

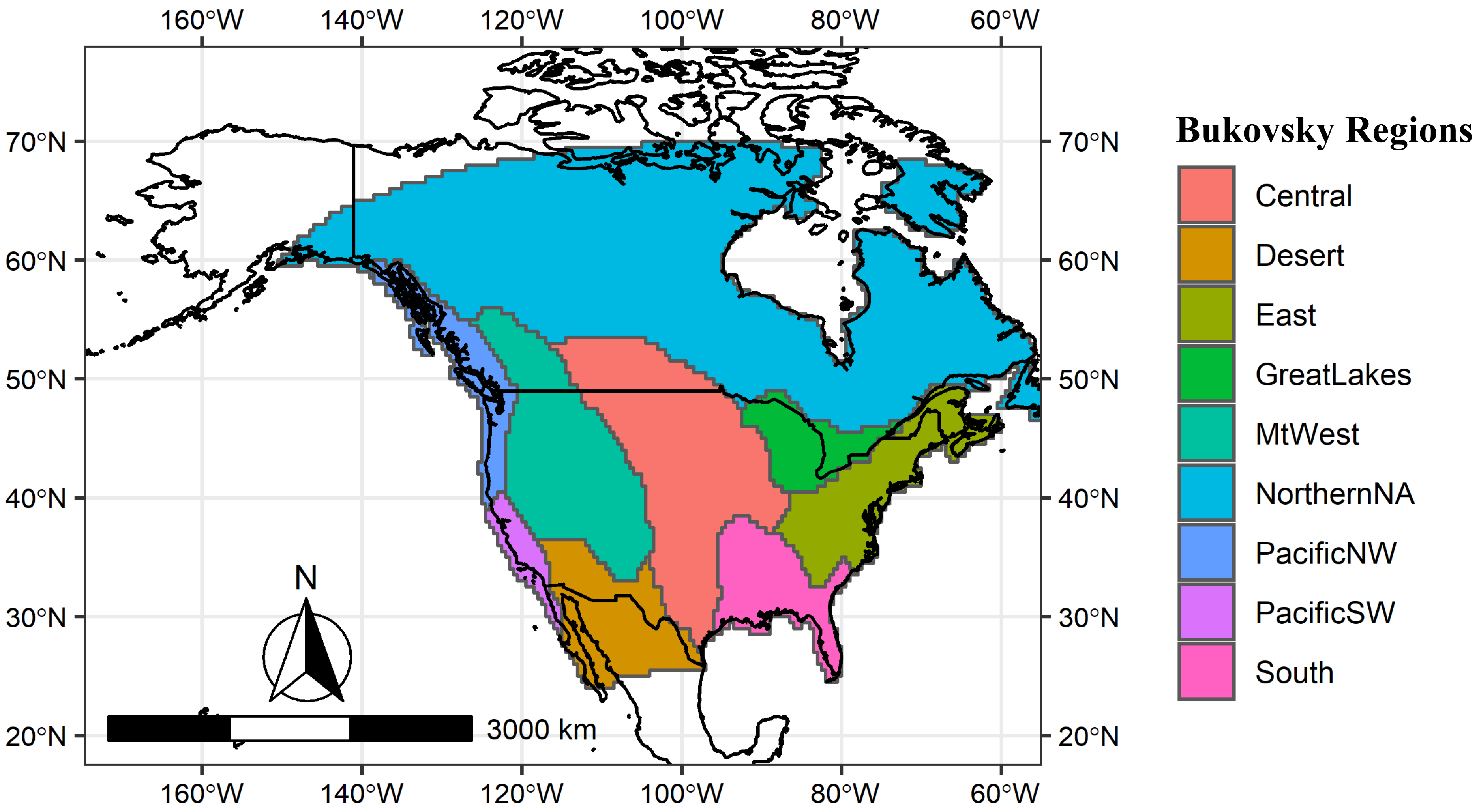
    - **C**haracterize three types of compound inland flooding
    - **I**dentify How these events contribute to maximum surface runoff
    - **E**valuate the contribution of internal climate variability to the total uncertainty

- Main **data**: CanRCM4-Large Ensemble

CanRCM4 large ensemble is a:
--50-member ensemble from 1950-2100 with all historical forcings for the North American Domain.
--A regional simulations that dynamically downscale global outputs from CanESM2 LE onto a 0.44° grid.



Study Area



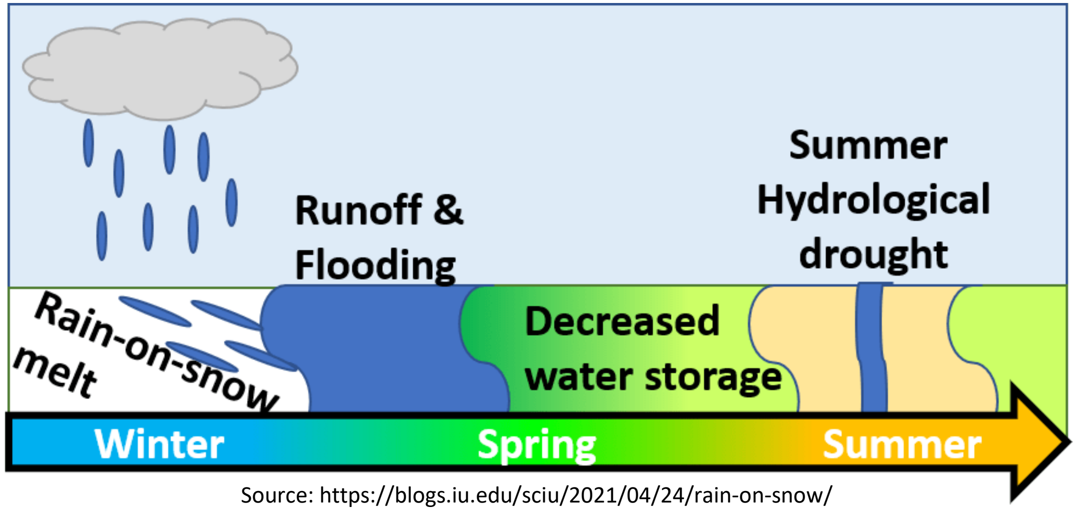
- Bukovsky regions reflect, at a large scale, roughly consistent temperature, precipitation and storm track climatologies (Alaya et al. 2019)

Methods: Compound Event Definition

- Three type of compound events are considered in this study:

i. ***Rain on snow*** as a preconditioned compound events
ii. ***Saturation excess flooding*** as a preconditioned compound events
iii. ***Series of precipitation*** as temporally compound flooding

❑ Rain on Snow (**ROS**) event: A day will be considered ROS day if:
  - Rainfall and SWE $\geq$ 10mm/day
  - Snowmelt $\geq$ 20% (Snowmelt + Rainfall)
  - Magnitude of ROS $\gg$ the sum of Rainfall and Snowmelt (mm/day)



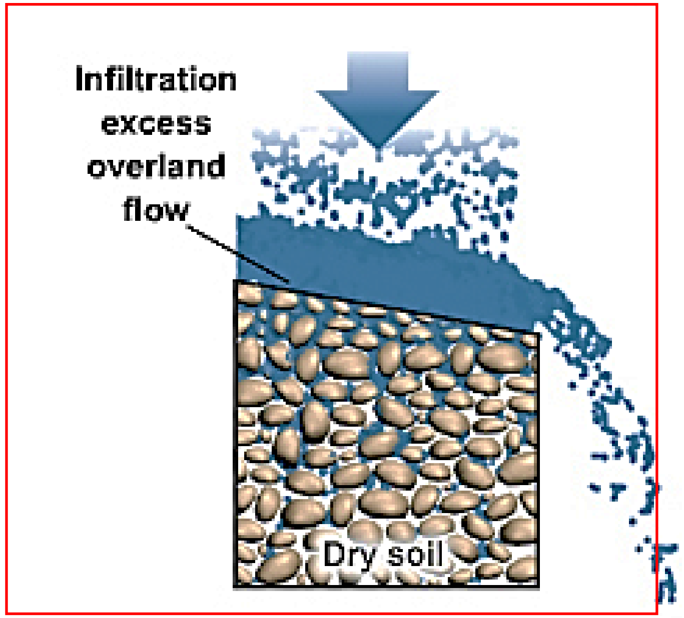
Source: https://blogs.iu.edu/sciu/2021/04/24/rain-on-snow/

Methods: Compound Event Definition

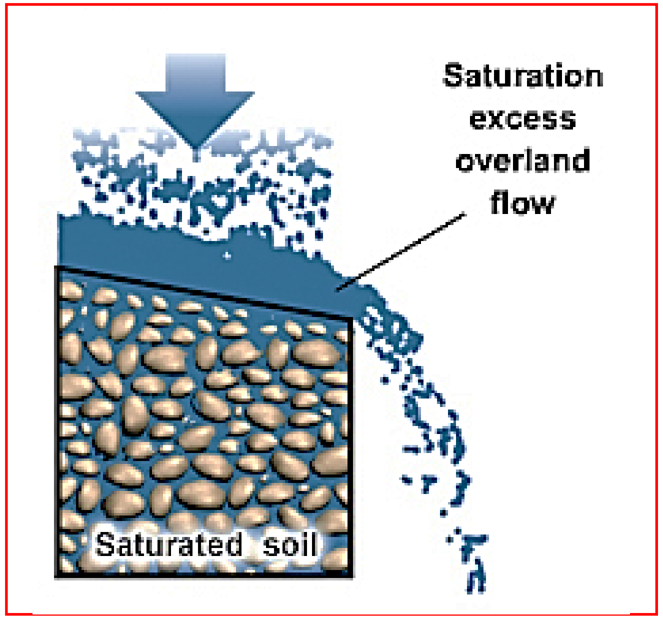
- Saturation Excess Flooding (**SEF**) event: If
  - Rainfall And total soil moisture content ≥ their 98th percentiles
  - Previous five day's accumulated rainfall (AMC) < 23mm,
  - Surface runoff ≥ 1 mm/day

- Series of Precipitation (**SOP**) event: If
  - Rainfall ≥ its 98th percentile
  - Previous five day's accumulated rainfall (AMC) > 40mm
  - Surface runoff ≥ 1 mm/day

SOP



SEF



Source: http://www.faculty.luther.edu/~bernatzr/RainfallRunoff/comet/hydro/basic/Runoff/print_version/02-pathstorunoff.htm

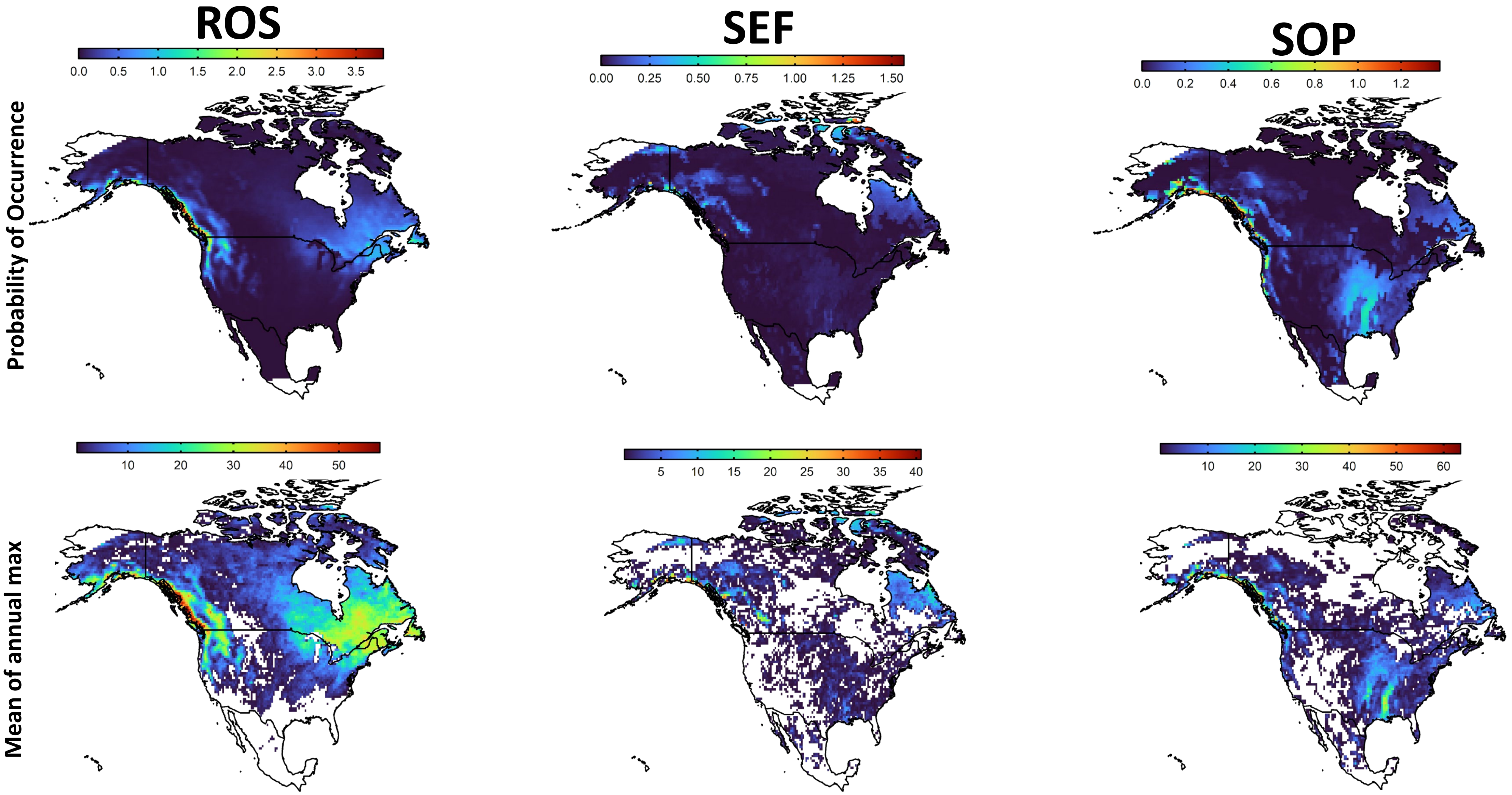
Methods

- Characterising each types of events based on:
  - Probability of occurrence (PO)
  - Monthly variation of frequency and magnitude
  - Joint probability of occurrence with surface runoff
  - Internal climate variability of the PO as the standard deviation of the ensemble of 50 runs.

- Results are provided for four warming levels in 31-year time frames as follows:
  - [1986-2016] as **Baseline** corresponding to +1 ℃ Global mean temperature change (GMTC) compared to pre-industrial level (1850-1900)
  - [2001-2031] as **WL1.5** corresponding to +1.5 ℃ GMTC
  - [2013-2043] as **WL2** corresponding to +2 ℃ GMTC
  - [2053-2083] as **WL4** corresponding to +4 ℃ GMTC
- A robust analysis with a database of 1550 years of climate simulations

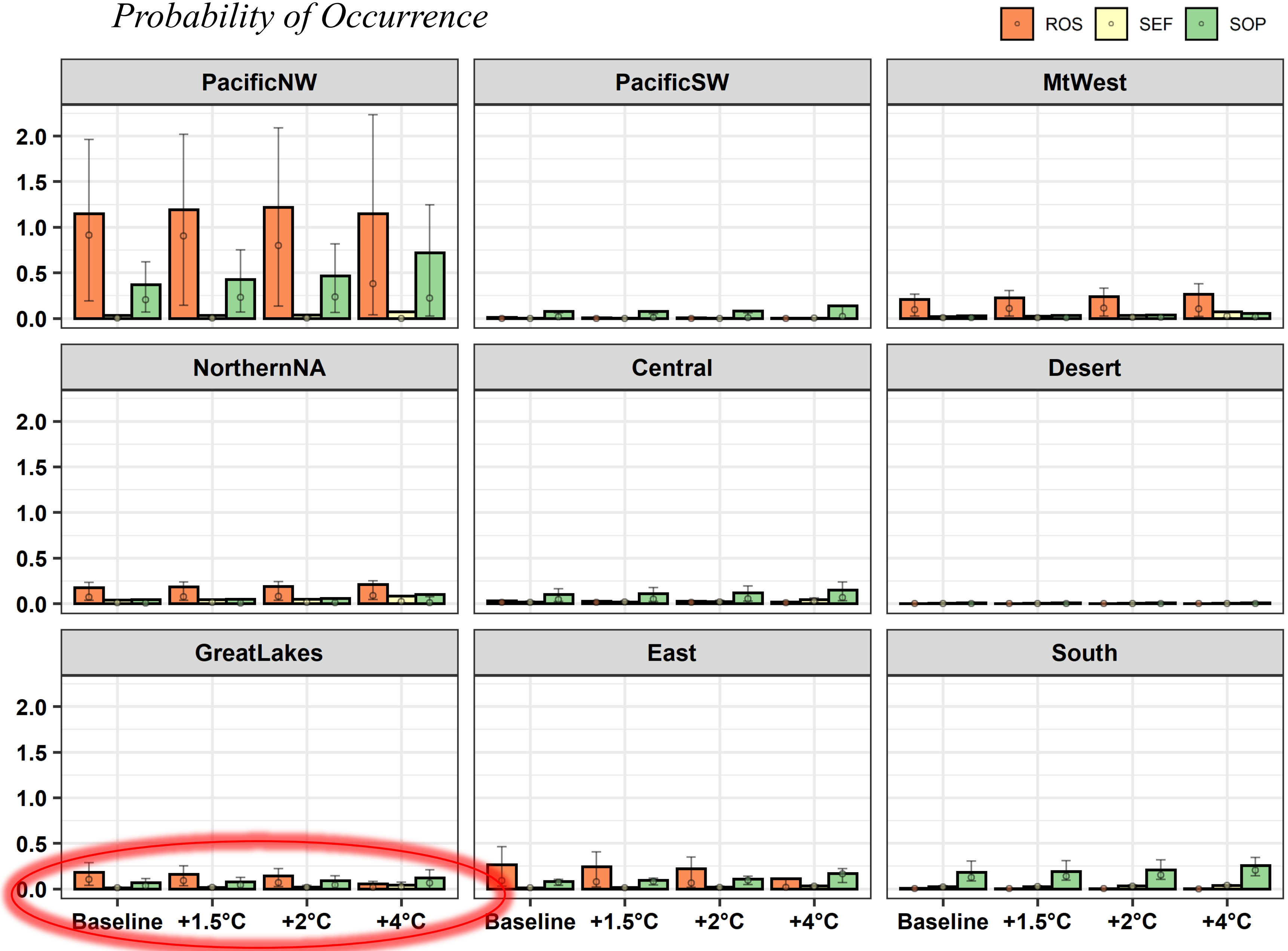
Results

Probability of Occurrence and magnitude for baseline period



Results

Probability of Occurrence



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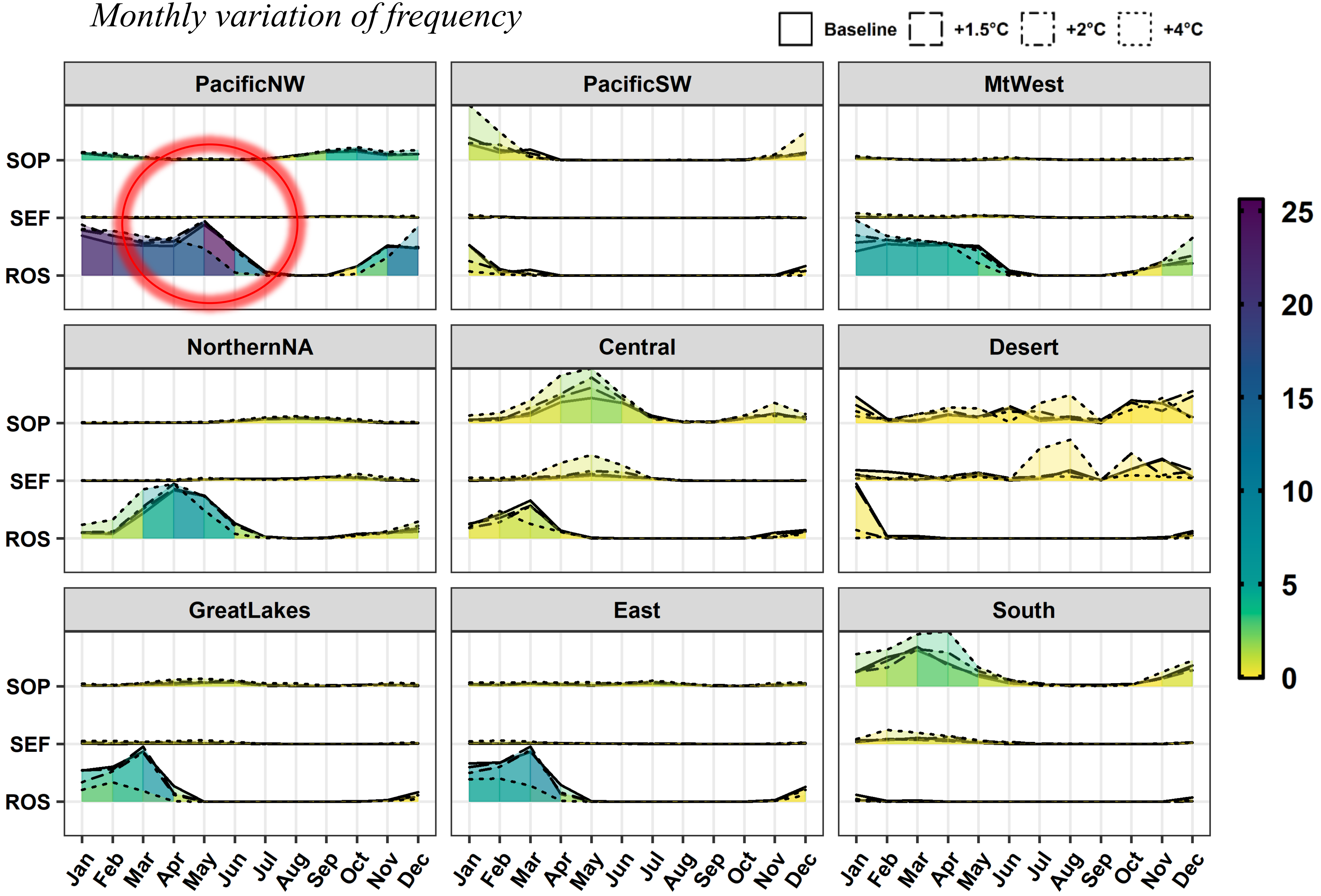
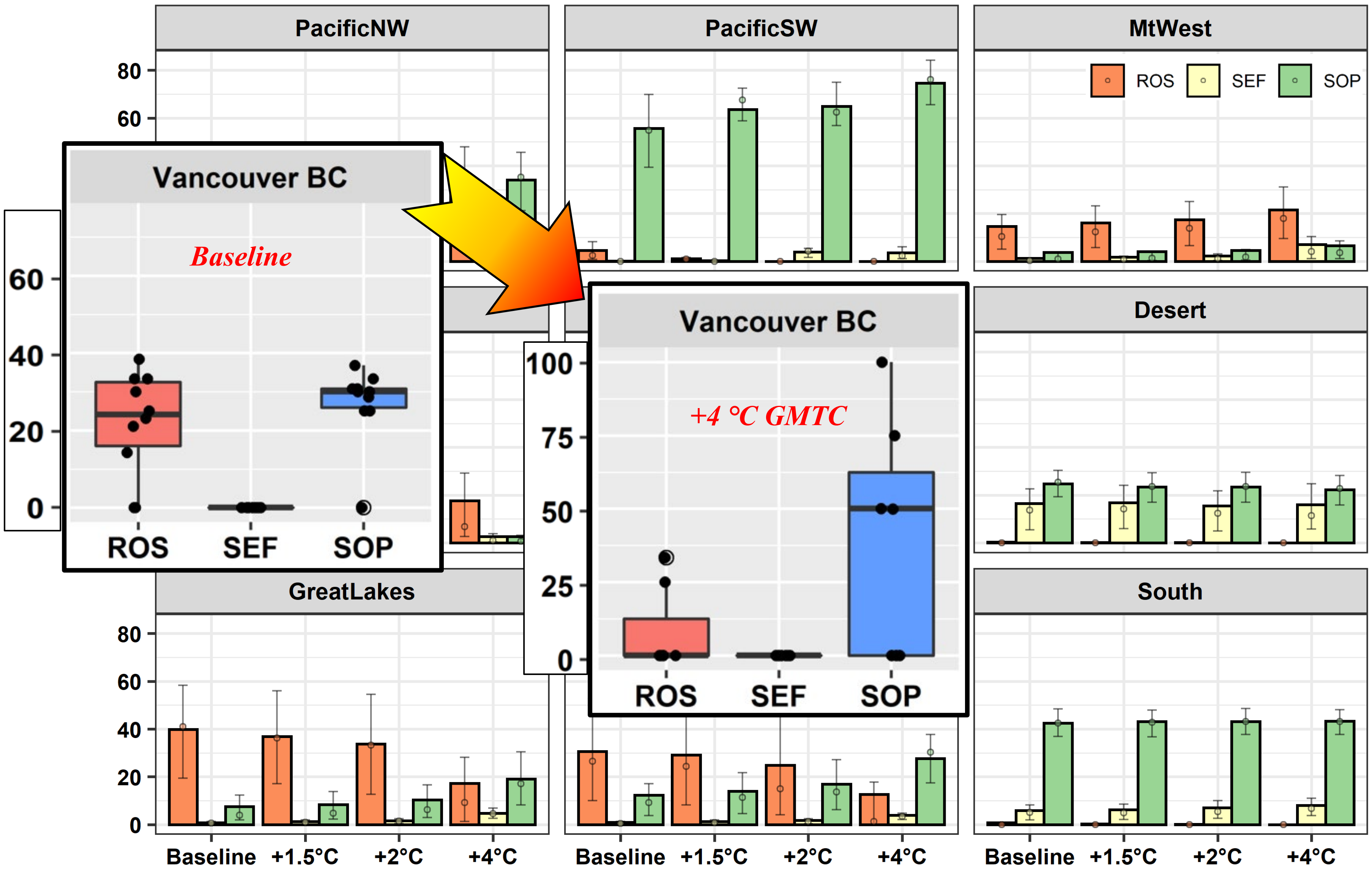
Results

Monthly variation of frequency



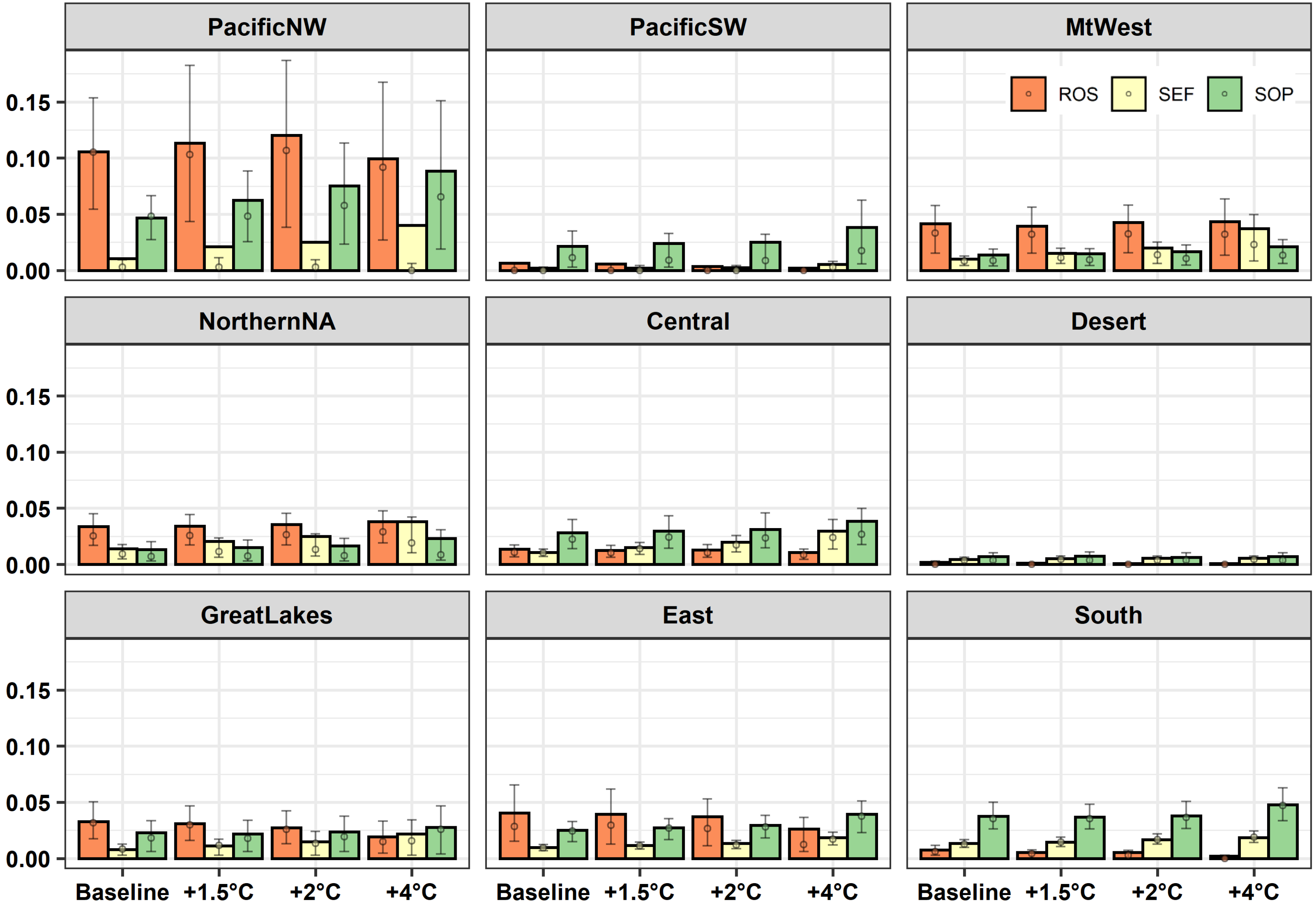
Results

Joint probability of occurrence of compound events and very heavy runoff (98th Percentile)



Results

Internal climate variability of probability of occurrence



Conclusion

- Compound weather and climate events are an integral part of almost all climate-related risks
- Therefore, better understanding and modelling of compound events is crucial for better risk assessment
- This research examined three major causes of inland flooding and their potential interactions.
- It seems more likely that widespread ROS occurrences, rather than SEF and SOP, will occur in North America.
- At greater degrees of warming, the peak flow/frequency of all compound floods might move from month to month.
- In many regions, like the Great Lakes and Eastern North America, ROS occurrences are contributing less to maximum runoff. The impact of SOP and SEF occurrences becomes more significant as temperatures rises.
- In terms of internal climate variability, SEF and SOP occurrences show a clear upward trend at higher degrees of warming, but ROS does not exhibit a continuous reducing and rising tendency.

Thank you for your attention!

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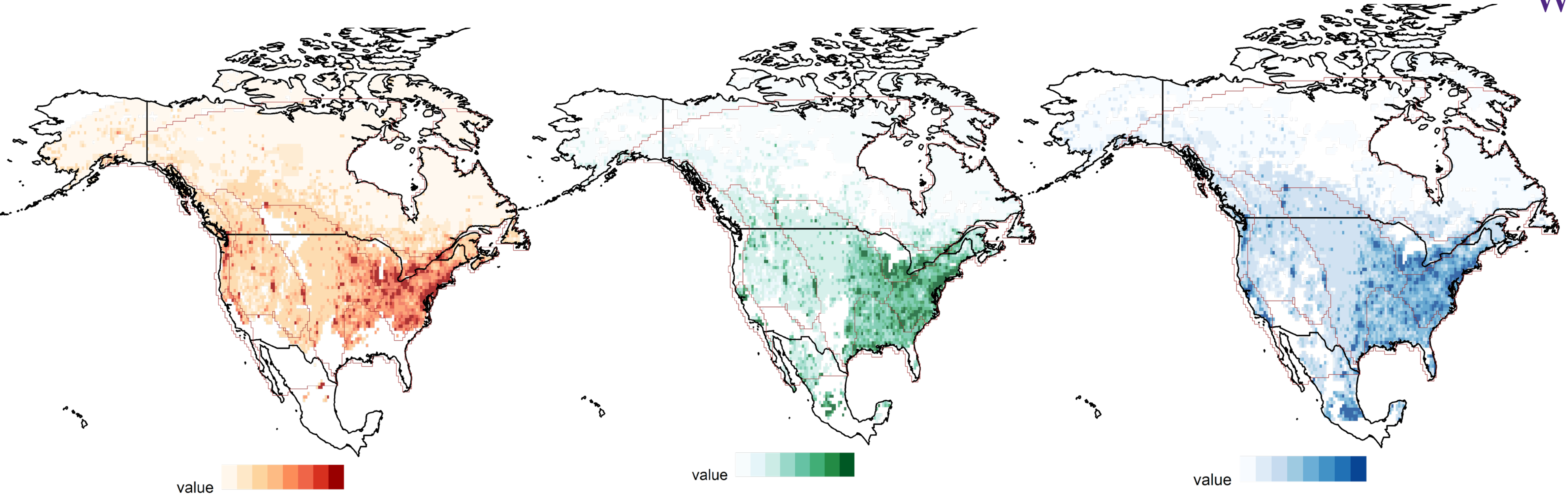
Results

Physical Exposure (Hazard × Exposure)



Background

How does climate change affect?

- Climate- change effects can manifest as
  - changes in preconditioning variables (preconditioned events),
  - changes in dependence between variables (multivariate events),
  - changes in temporal structure (temporally compounding)
  - and changes in dependence between different locations (spatially compounding).

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