

CLIMATE SENSITIVITY OF EXTREME SNOWFALL EVENTS

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Introduction

- Climate change is projected to increase temperatures, influencing the fraction of precipitation that falls as snow and snowmelt timing. Increases in total precipitation and precipitation intensity are also projected for many regions, including the western United States (IPCC, 2012).
- Extreme snowfall events are particularly important to annual snowpack and water resources and are also particularly sensitive to warming.
- The combined impact of increases in temperature and changes in precipitation regime on extreme snowfall events in the West has implications for water resource management in the coming decades.

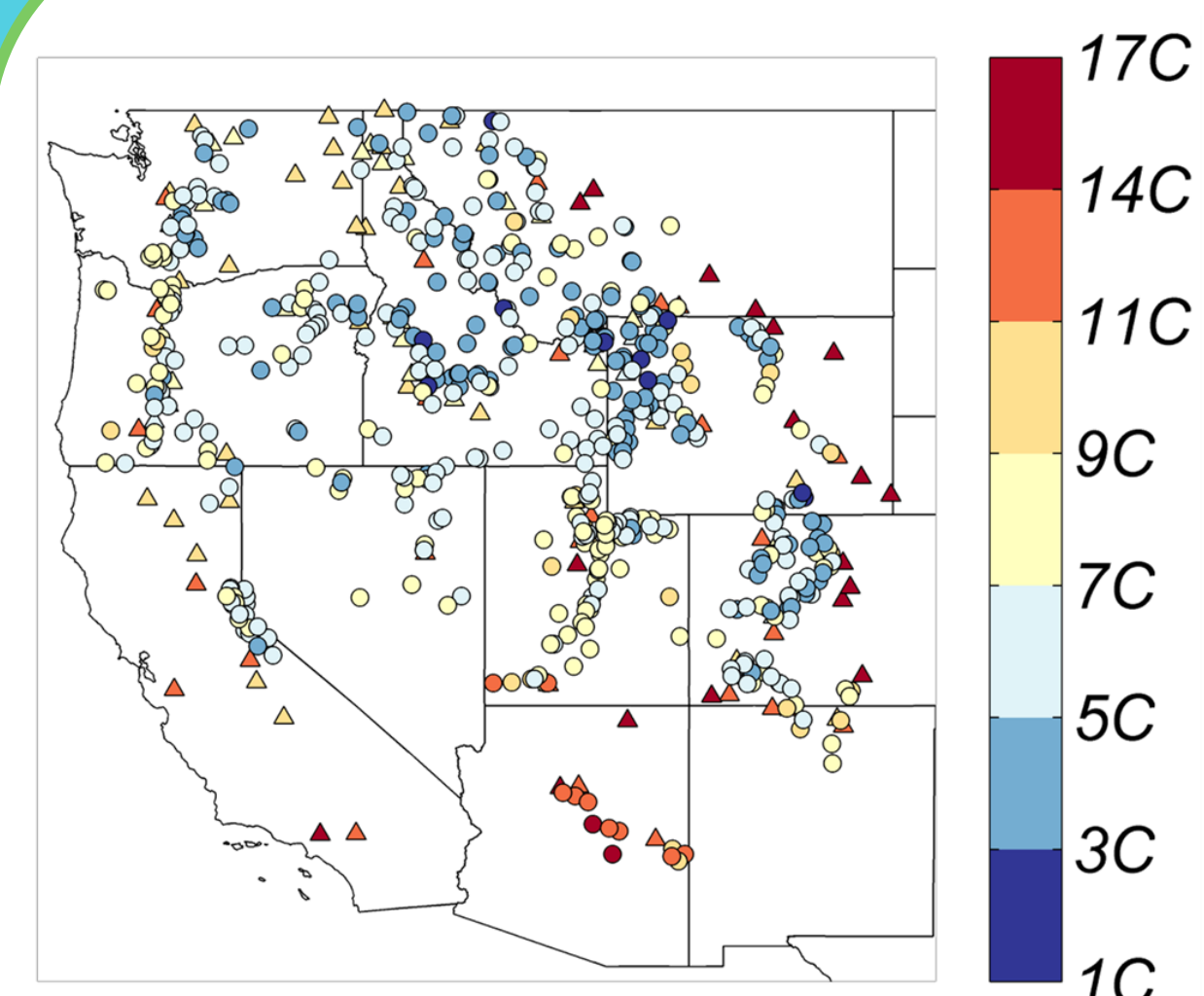


Figure 1: Mean coincident average winter (Nov-Mar) temperature on days when precipitation exceeded 5mm during the historical period.

Data

- Global Climate Models:** 20 CMIP5 models (Taylor et al. 2012)
- Scenarios:** RCP 4.5 and RCP 8.5
- Variables:** Temperature and Precipitation
- Time Period:** 1950-2100
- Downscaling:** statistically downscaled using the Multivariate Adaptive Constructed Analogs (MACA) method (Abatzoglou and Brown, 2011)
- Temporal Resolution:** Daily
- Spatial Resolution:** 4km
- Station Data:** downsampled data was bias corrected for 504 SNOTEL and 108 COOP stations in the 11 Western states with quality controlled data.

Methods

- Daily snowfall water equivalent (SFE) was derived from downsampled temperature and precipitation using an empirically based temperature dependent precipitation phase function [Dai 2008].
- Snowfall events were defined as three day accumulations of SFE.
- Extreme Snowfall Events:
 - Leading Event: largest event each year
 - Top Three Events: sum of the three largest non-overlapping events each year
 - Top Decile Events: largest 10% of non-overlapping events over the historical record
- Variables:
 - Annual SFE- water equivalent of all snowfall each water year
 - SFE of extreme events
 - Percent of annual SFE contributed by extreme events
- Multi-model means (MMM) of differences between the historical period (1950-2005) and the end of the century (2070-2099) were calculated for each station and each RCP scenario.
- Uncertainty was quantified using t-tests comparing all historic years to all end of century years. If at least 50% of models showed a significant difference ($\alpha=0.05$) and at least 80% of those models predicted a change of the same sign, the value was considered more certain. All other cases were considered less certain.

Findings

- Annual SFE is projected to decline at all locations, with the strongest declines (of up to 95%) in the Cascades, Arizona, and at low elevation COOP stations.
- The least vulnerable locations are high, cold, interior locations including the Middle Rockies. In these locations the size of extreme snowfall events may increase.
- The most vulnerable locations are low elevation COOP stations, Arizona, and the Southern Cascades. Extreme snowfall events at many sites in these areas are projected to decline by more than 50% in the RCP 8.5 scenario.
- Generally, the three event classes are projected to change by similar magnitudes, although results for the top decile events are slightly less certain.
- With a few exceptions, extreme events will contribute a significantly greater portion of SFE in the future, despite drastic reductions in the size of these events. This is particularly true for the Cascades, where the top three events may contribute 40% more of the annual snowpack in the future.
- By the end of the century, snowpack in the West will be greatly diminished and will be more dependant on extreme snowfall events. Water resource management will require additional reservoir space as precipitation comes as rain instead of snow.

Results

Figure Key: Marker colors reflect MMM difference between historical and end of century periods. Marker size reflects certainty, with larger (smaller) markers indicating more (less) certainty. SNOTEL stations are represented by circles, COOP stations are represented by triangles.

	delta winter mean Temperature	delta winter cumulative precipitation
RCP 4.5	+3C \pm .5C	+13% \pm 10%
RCP 8.5	+5C \pm .9C	+24% \pm 18%

Table 1: MMM (plus or minus two standard deviations) change averaged over all stations in mean winter (Nov through Mar) temperature (C) and cumulative winter precipitation (%) between historical period and end of century for RCP 4.5 and RCP 8.5.

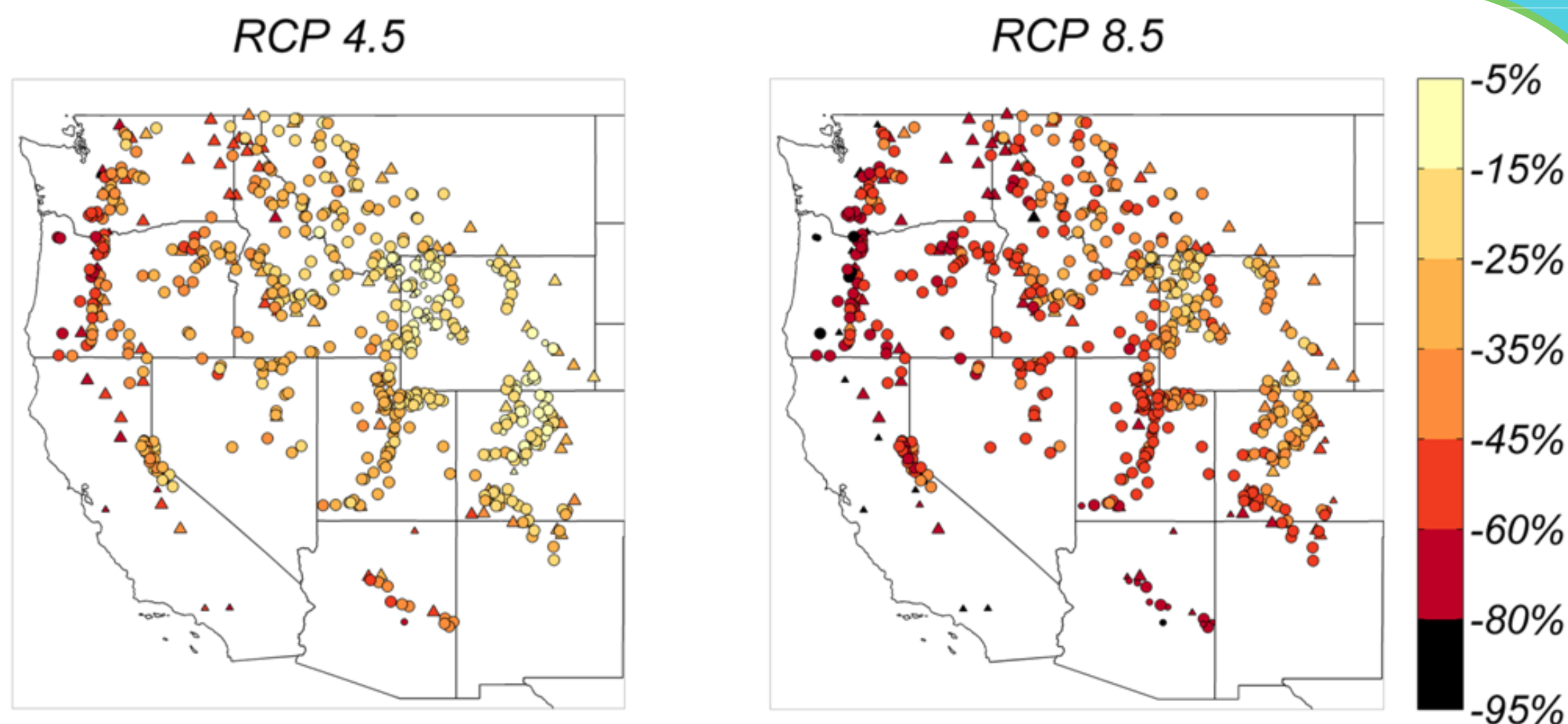


Figure 2: Percent change in mean annual SFE between historical and end of century for RCP 4.5 and RCP 8.5.

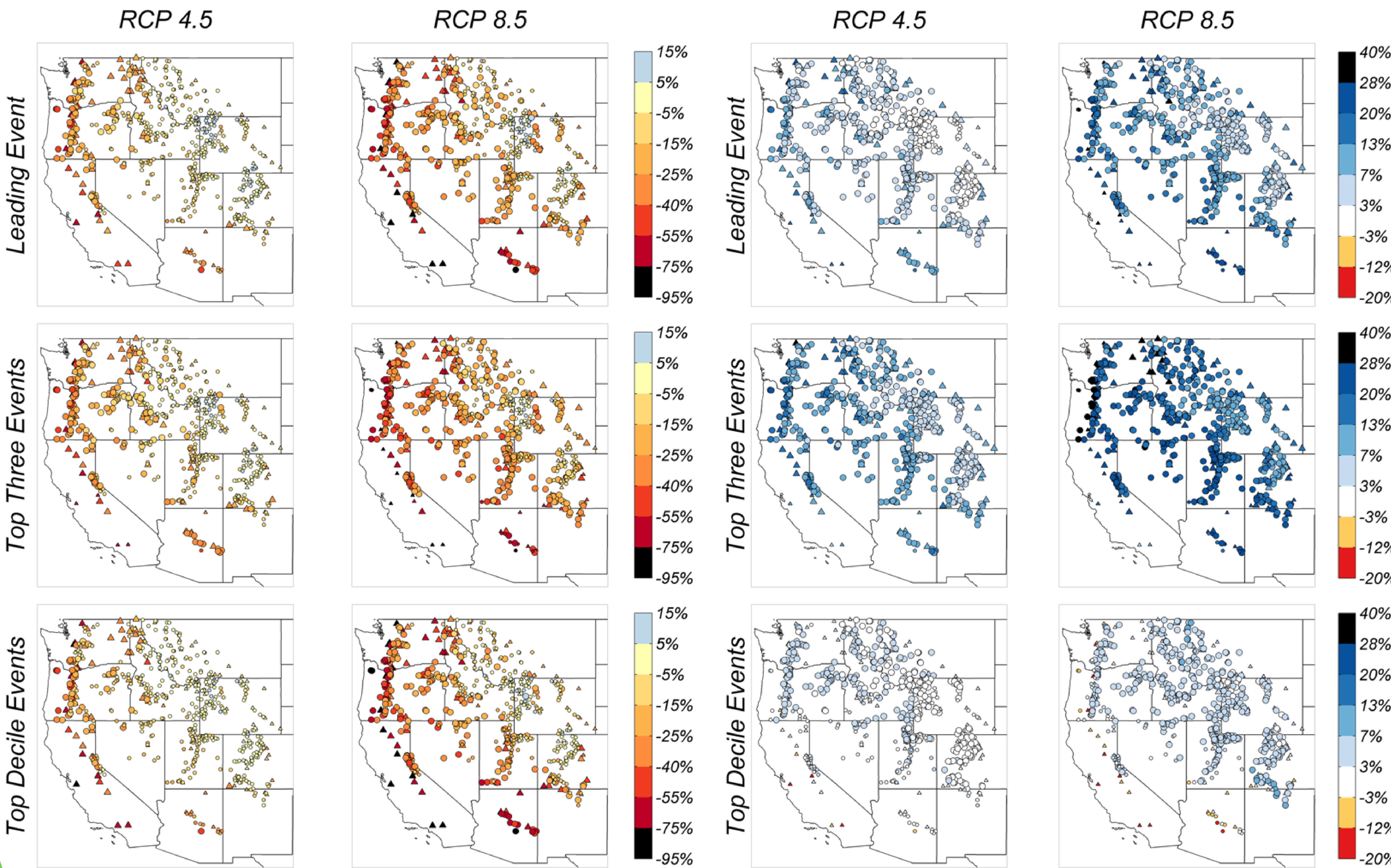


Figure 3: Projected changes in size of extreme snowfall events for RCP 4.5 and RCP 8.5.

Figure 4: Projected changes in percent of annual SFE contributed by extreme snowfall events for RCP 4.5 and RCP 8.5.

References

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