Predicting hydrologic extremes in a changing climate

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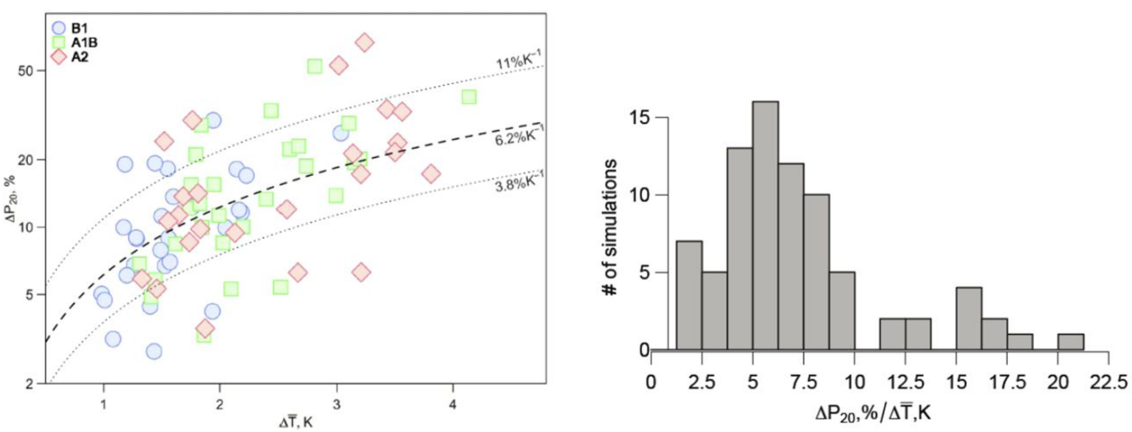
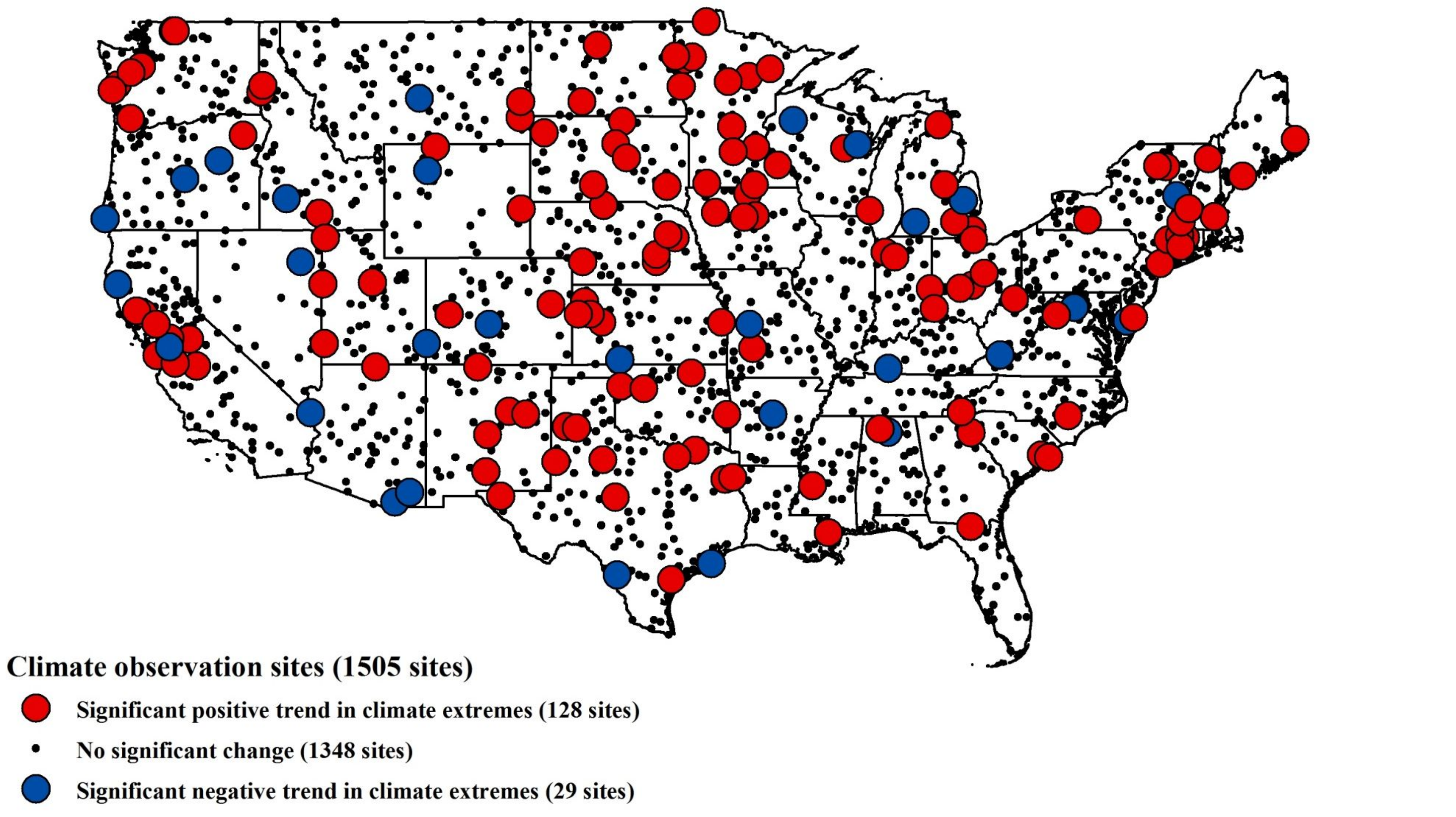
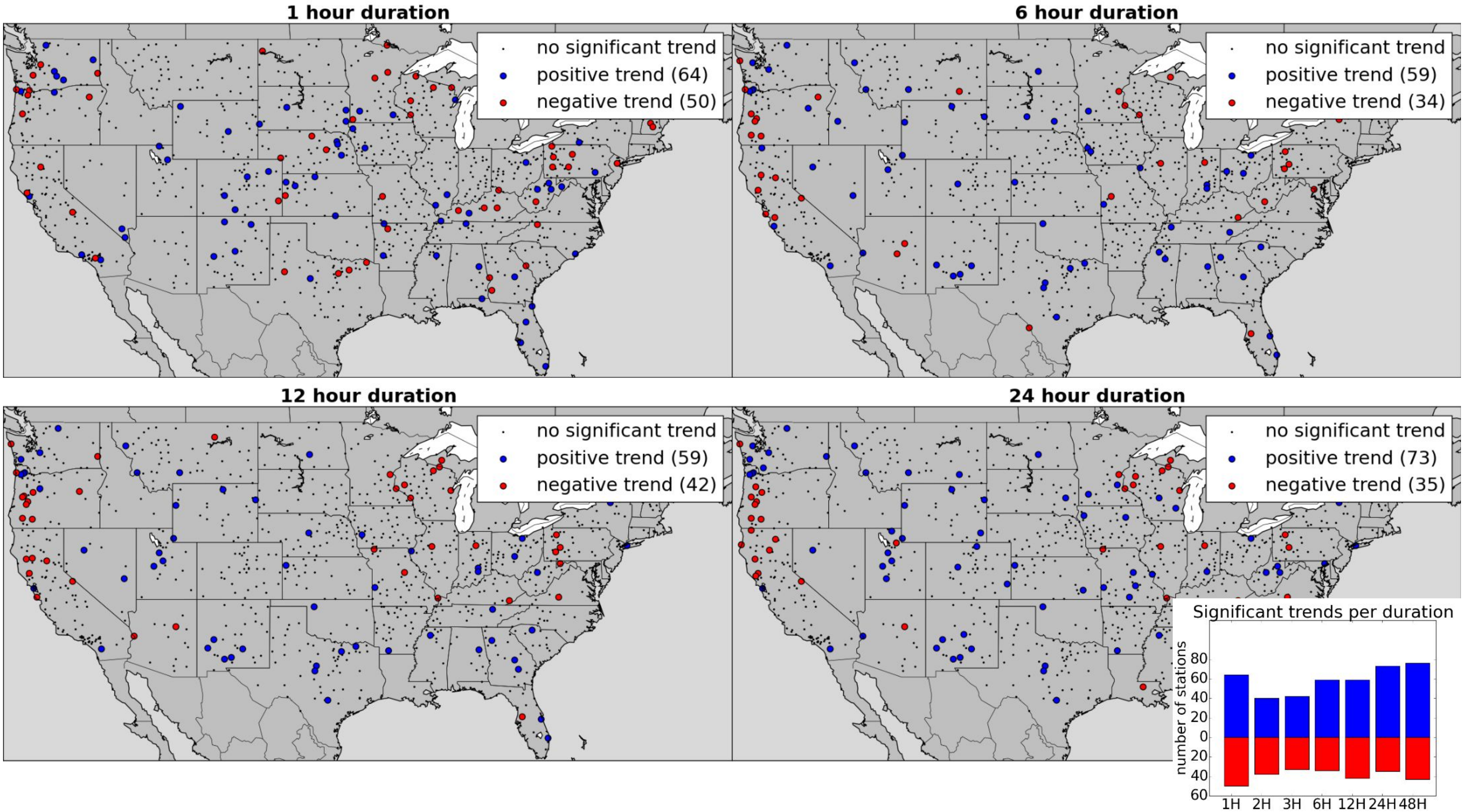


Figure 4.6.1: Relative changes in 20-yr return values averaged over the global land area of annual 24-h precipitation maxima (Δ*P*20) as a function of globally averaged changes in mean surface temperature for B1, A1B, and A2 global emissions scenarios, with results pooled from 14 GCM runs and for 2046–65 and 2081–2100 relative to 1981-2000. In the left panel, the pooled results are shown along with the median slope of 6.2%/^{o}C and the 15th and 85th percentiles (dashed and dotted lines, respectively). The right panel shows the results as a histogram. Replotted from Kharin et al (2007; Figure 16).

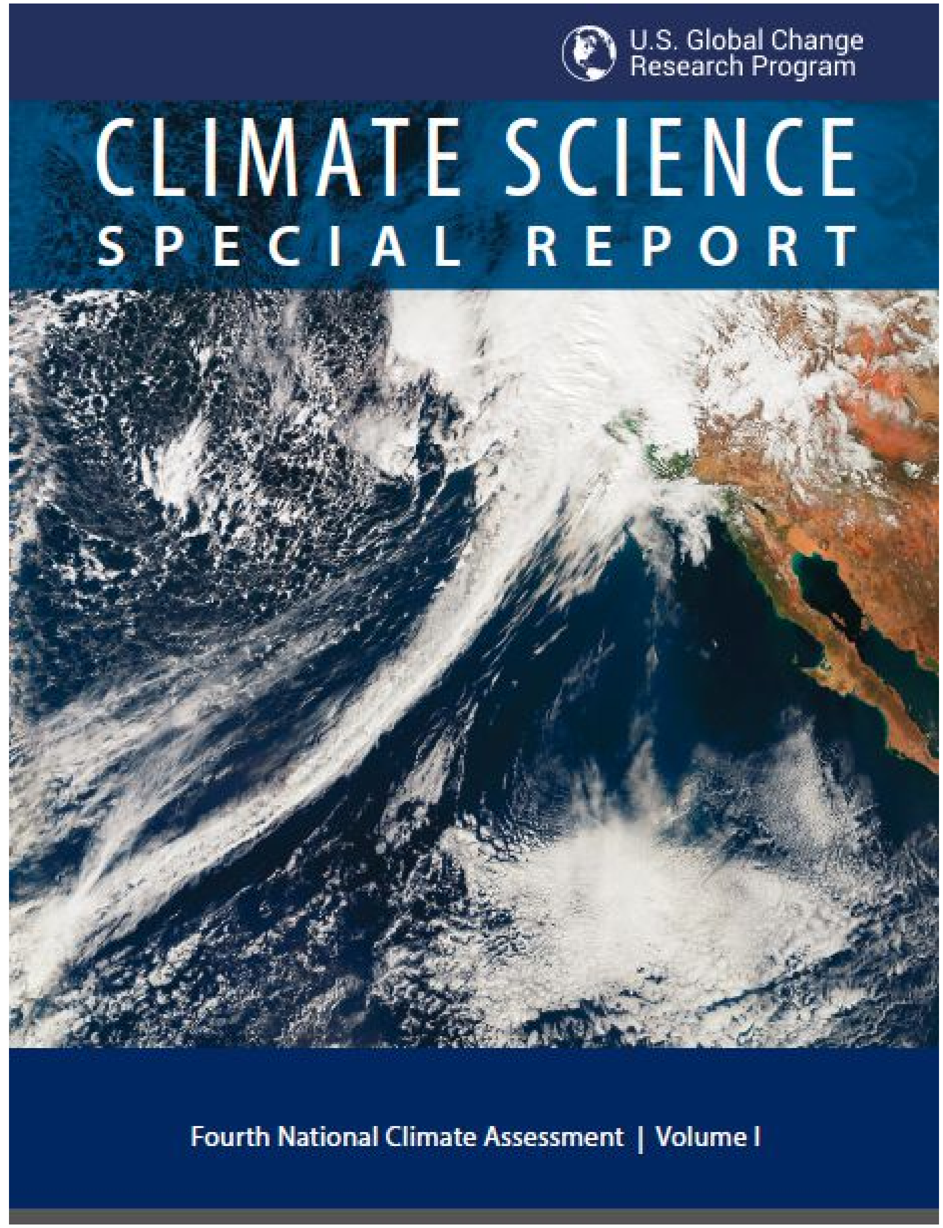
Relationship between annual daily maximum precipitation distribution and global mean temperature (red significantly positive, blue significantly negative, other no relationship)



replotted from Westra et al., *J Clim*, 2013

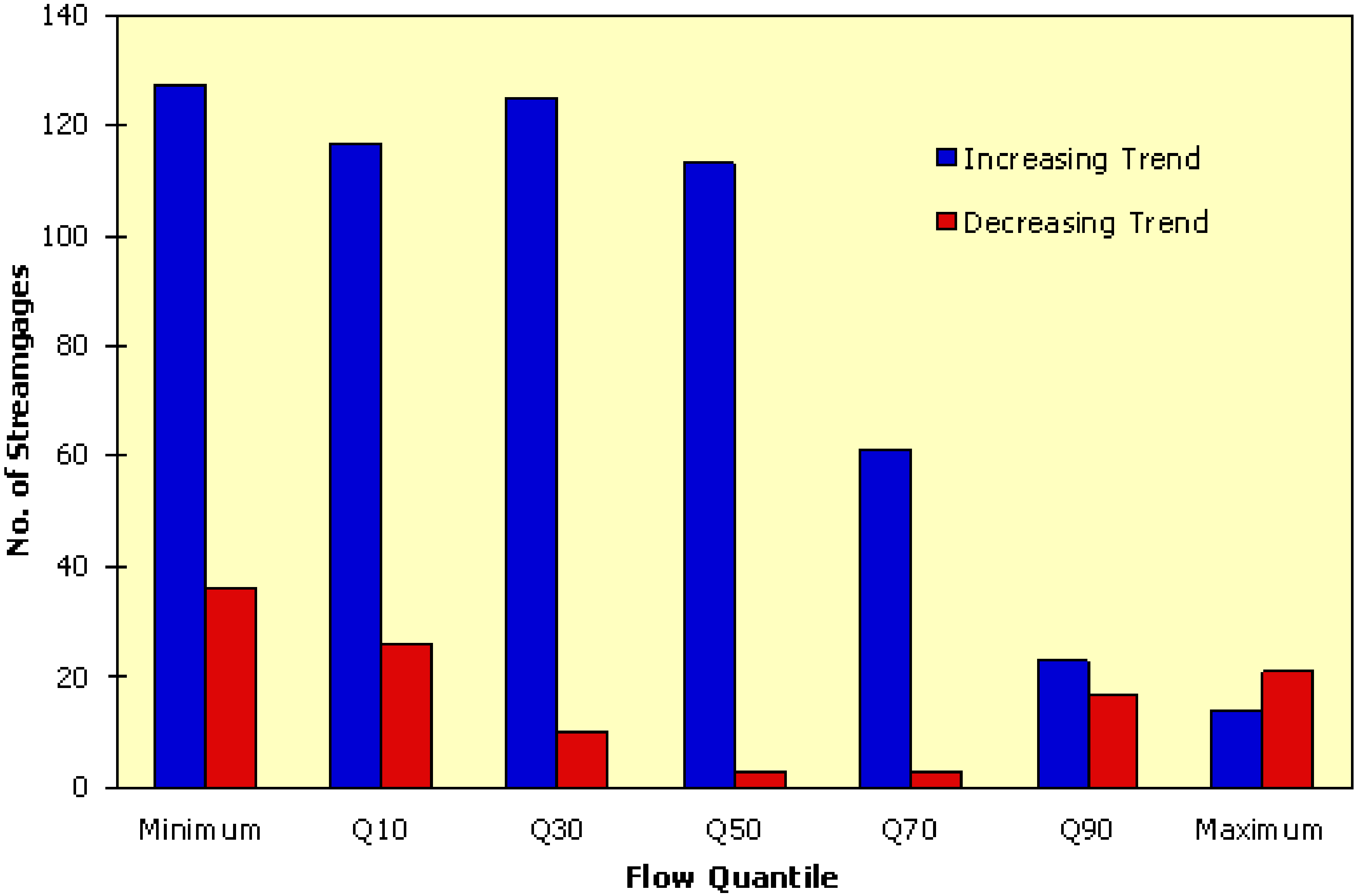

1 hour duration
no significant trend
positive trend (64)
negative trend (50)
6 hour duration
no significant trend
positive trend (59)
negative trend (34)
12 hour duration
no significant trend
positive trend (59)
negative trend (42)
24 hour duration
no significant trend
positive trend (73)
negative trend (35)
Significant trends per duration
number of stations
80
60
40
20
0
20
40
60
1H
2H
3H
6H
12H
24H
48H

Heavy precipitation events in most parts of the United States have increased in both intensity and frequency since 1901 (high confidence)

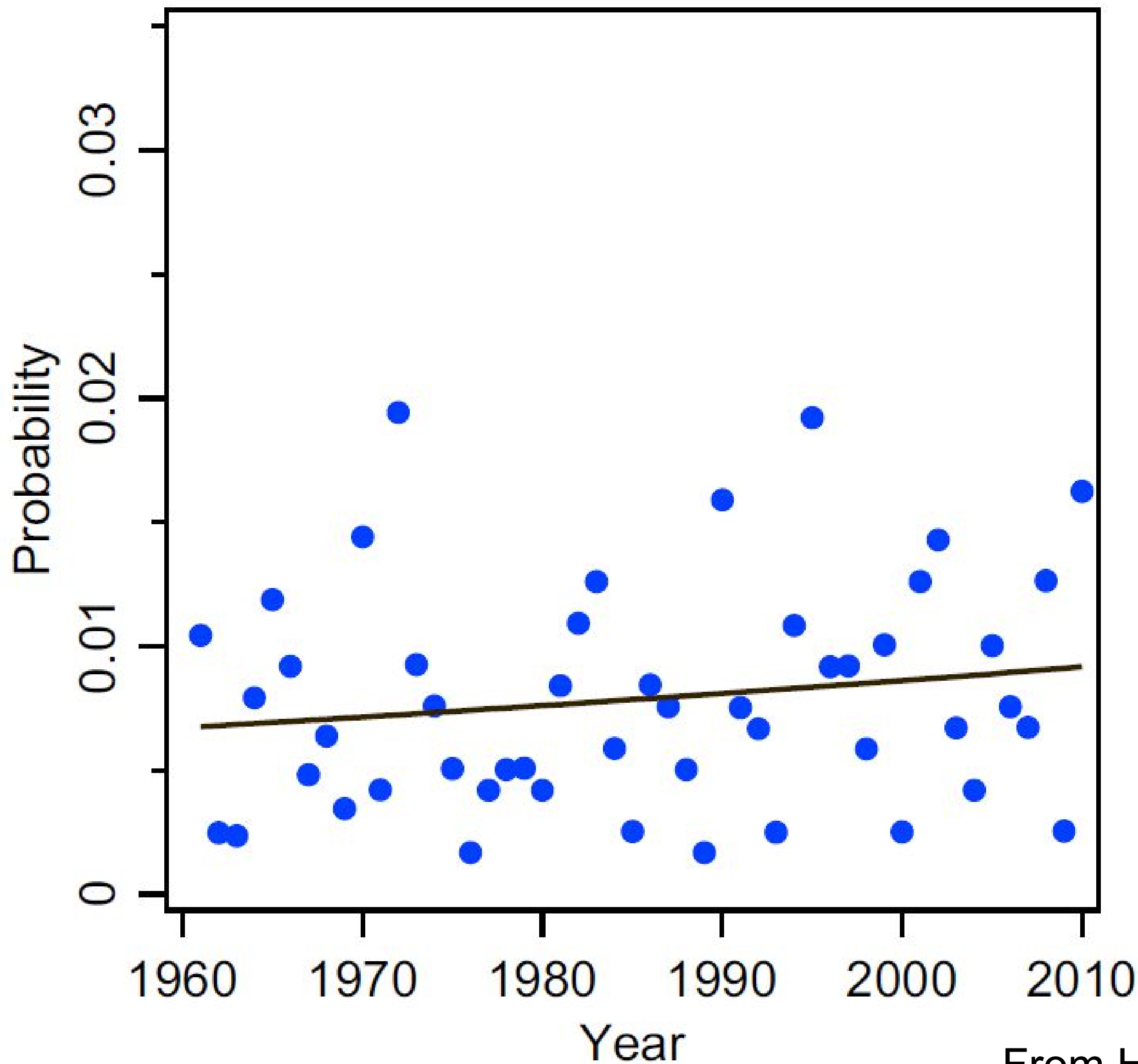


CLIMATE SCIENCE

U.S. Streamflow trends, 1944-1993 (from Lins and Slack, *GRL*, 1999)



Probability of floods exceeding Q100 by year for 1204 large river basins in North America and Europe, 1961-2010



From Hodgkins et al., 2017

Trends in (left) magnitude and (right) number of floods over 1962-2011 in the upper Midwest

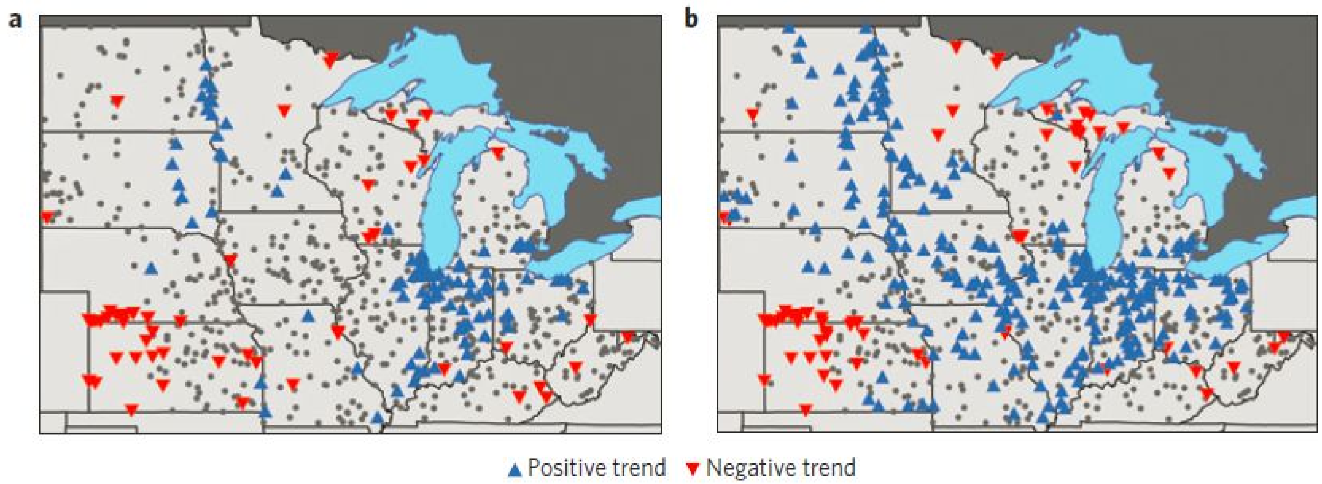


Figure 1 | Trends in the magnitude and frequency of flood events at the annual scale. a,b, Maps summarizing the results for trends in the magnitude (**a**) and frequency (**b**) of flood events. The blue (red) triangles indicate the location of the stations with increasing (decreasing) trends at the 5% level. There are 264 (101) stations with increasing trends in frequency (magnitude) and 66 (57) stations with decreasing trends in frequency (magnitude). The grey circles refer to the location of the stations that did not experience statistically significant changes (at the 5% level). These results refer to the common 1962–2011 time period.

from Mallakpour and Villarini, 2015

Increase in number of floods, but not severity?

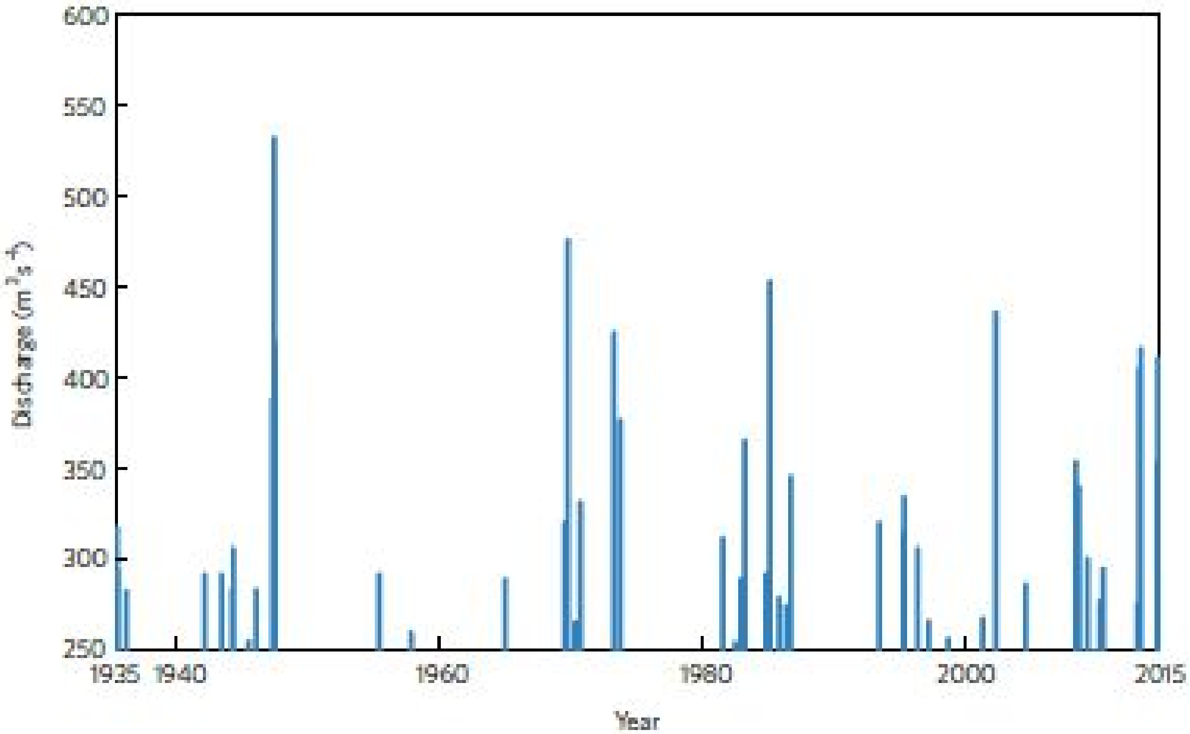
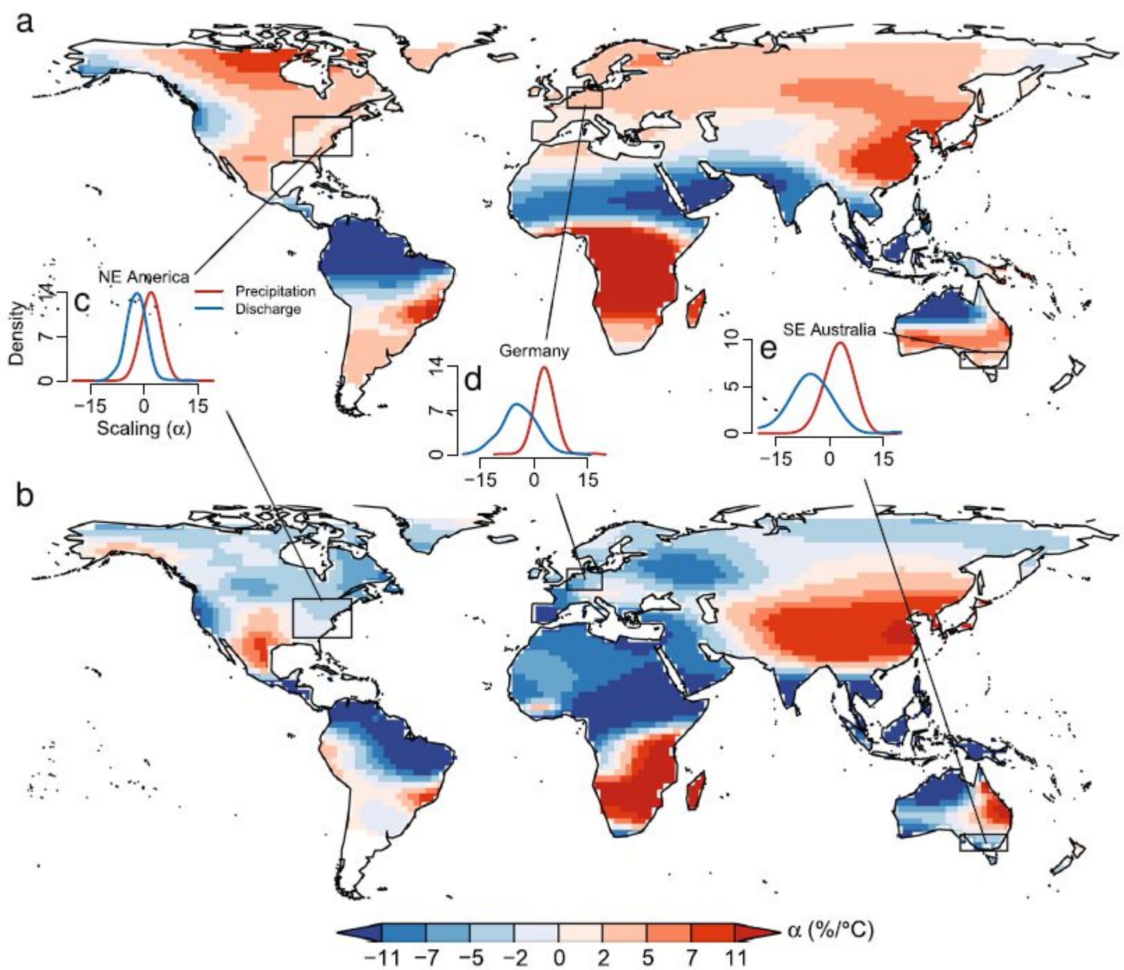


Figure 1 | Time series from one site in the central United States showing high streamflow events. The timing and magnitude of high-streamflow days (discharge of more than 250 $m^3 s^{-1}$) for the South Fabius River near Taylor, Missouri, for 1935–2014 (data from US Geological Survey) are shown. The record indicates a high degree of clustering of high-flow events with multi-year periods of no events and multi-year periods of many events. The frequency of high-flow events seems to have increased over the 60-year period, but the magnitude of the events shows no overall trend. Mallakpour and Villarini's analysis[7] of peaks-over-threshold records show that these features are common to many streamflow records across the central US.

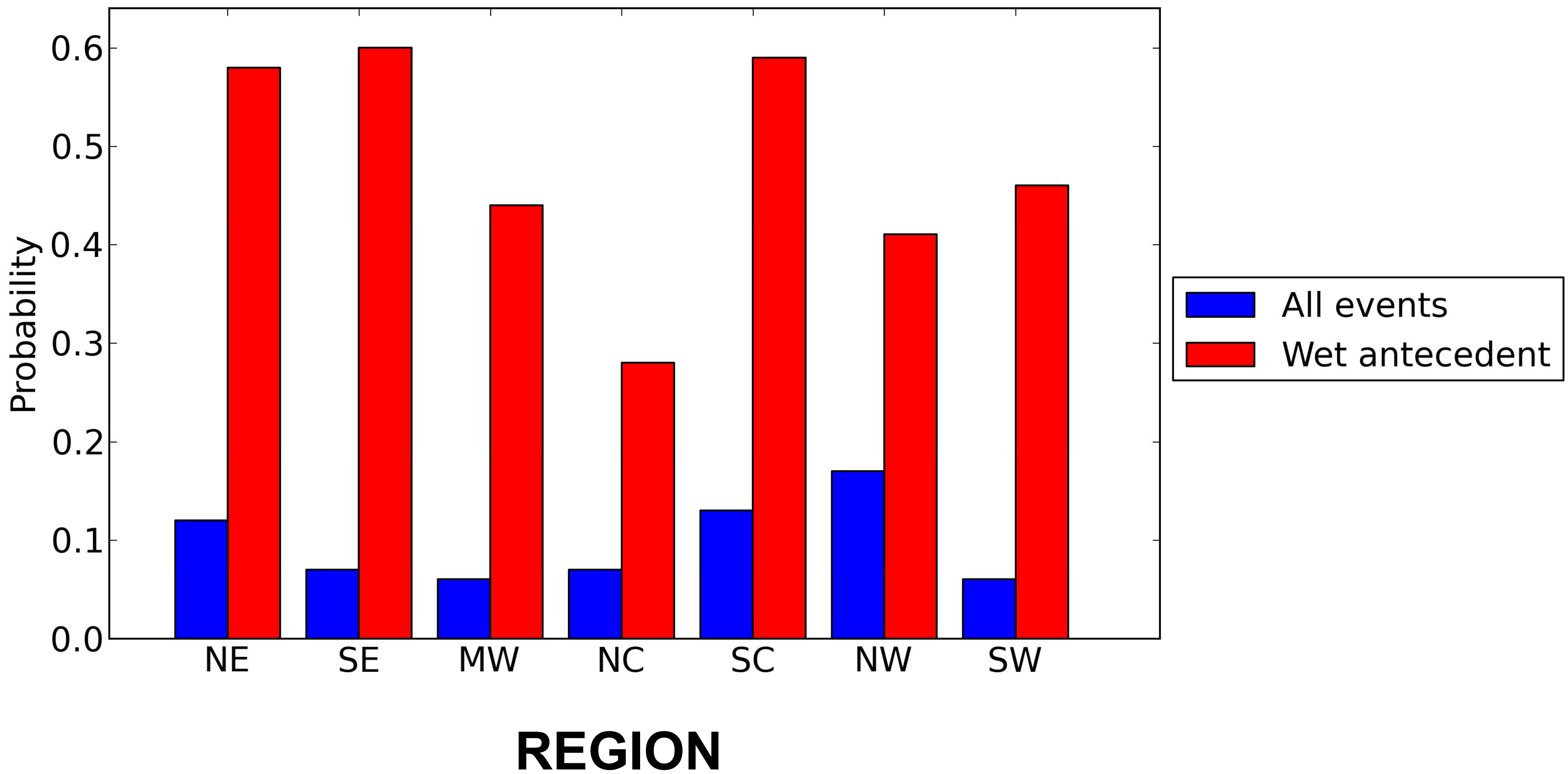
from Hirsch and Archfield, 2015

Precipitation (upper) and streamflow (lower) scaling with temperature for 99th percentile precipitation and streamflow events globally



from Wasko and Sharma, 2017

Fraction of upper 99th percentile U.S. precipitation events that lead to upper 99th percentile runoff events



replotted from Ivancic and Shaw, *Climatic Change*, 2016

Evidence that warmer Australian storms have a) higher intensity and b) reduced spatial extent

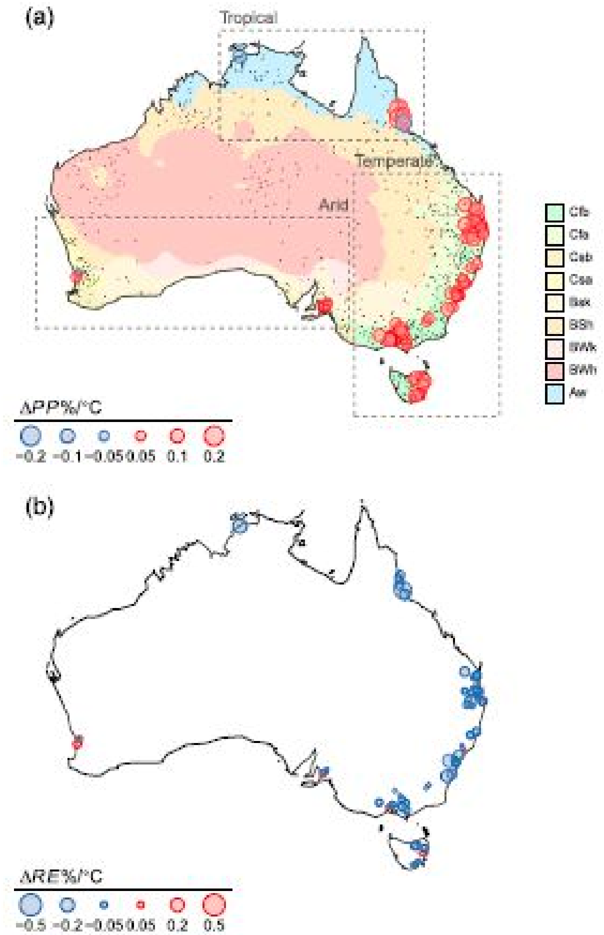


Figure 2. Scaling of the peak precipitation and effective radius for 1 h duration events. Positive scaling is shown in red and negative scaling in blue. (a) Circles show the scaling of peak precipitation, while the background shading denotes the Koppen climate classification [*Peel et al.*, 2007]. General climatic zones are also shown. All the gauge sites used in the analysis are shown as grey dots. (b) Circles show the scaling of effective radius.

from Wasko and Sharma, 2016

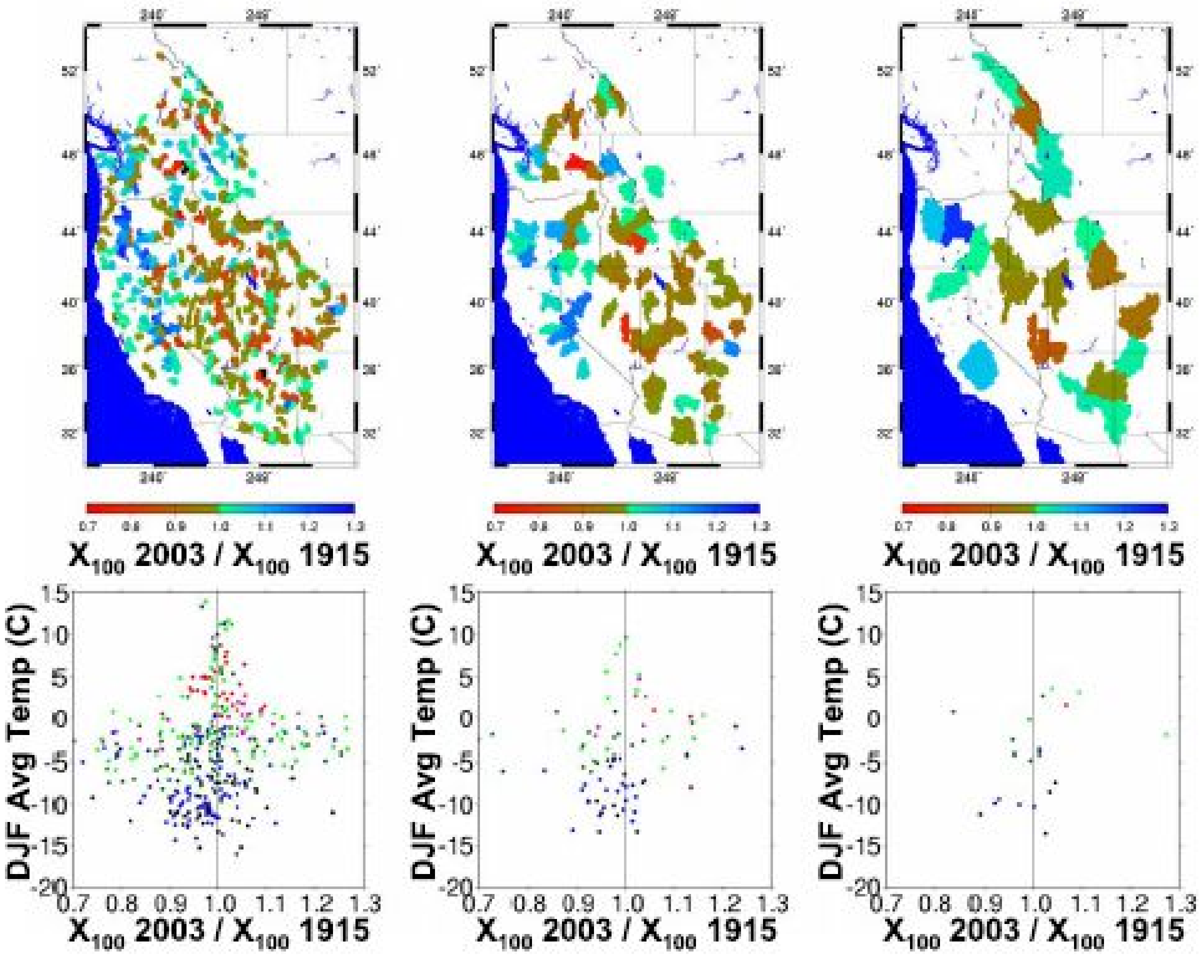
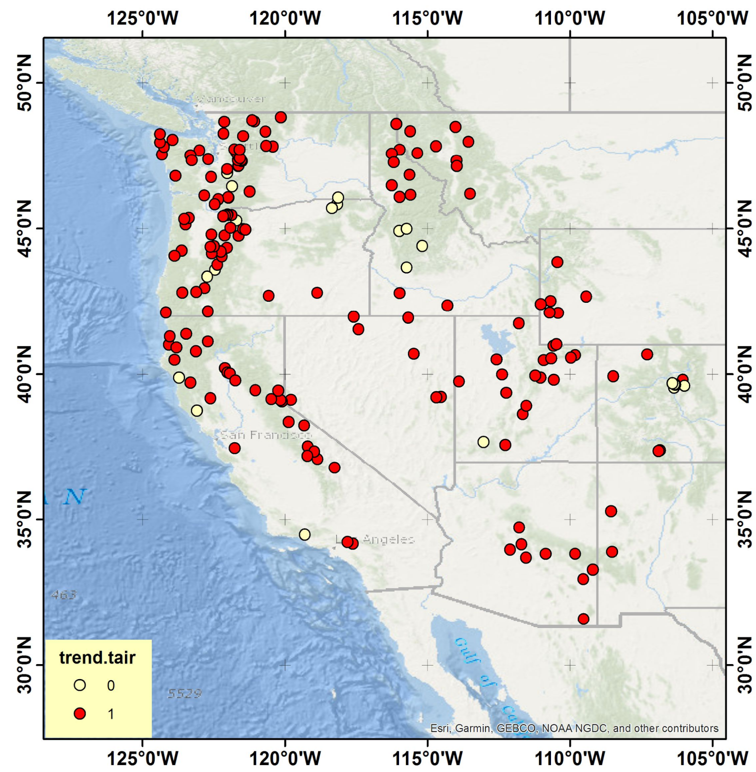


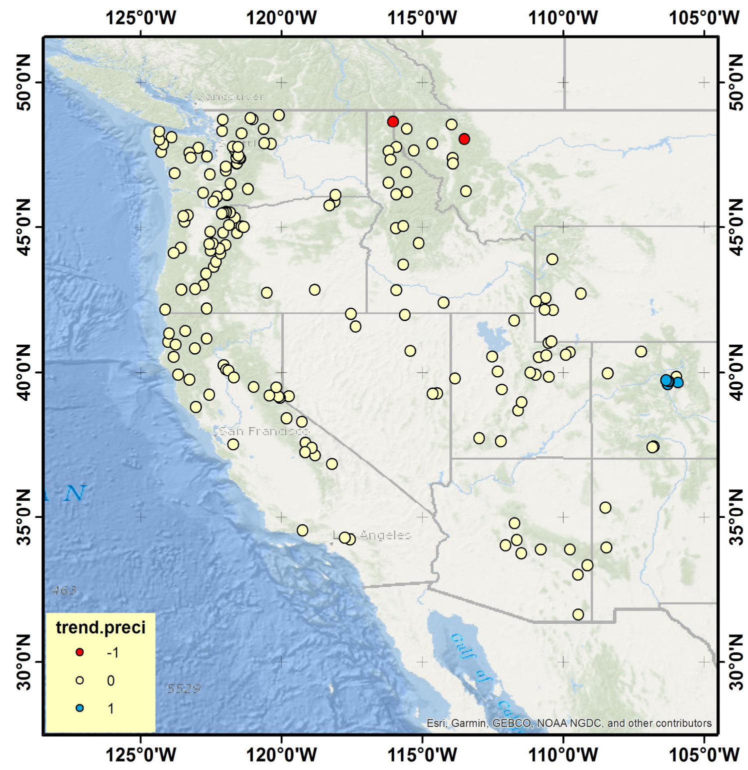
Figure 6. Ratio of estimated 100-year flood quantiles (2003 temperature regime/1915 temperature regime) shown as a spatial plot (upper row of panels) and a scatterplot showing the ratio as a function of DJF average temperatures in each basin (lower row of panels). Three basin sizes are shown: 12–25 cells (left), 50–100 cells (center), and 200–400 cells (right). Color-coding in the scatterplots identifies the month when flooding typically occurs in the simulations: red = January, purple = February, light green = March, dark green = April, blue = May, black = June.

Trends in air temperature and precipitation, 1960-2015

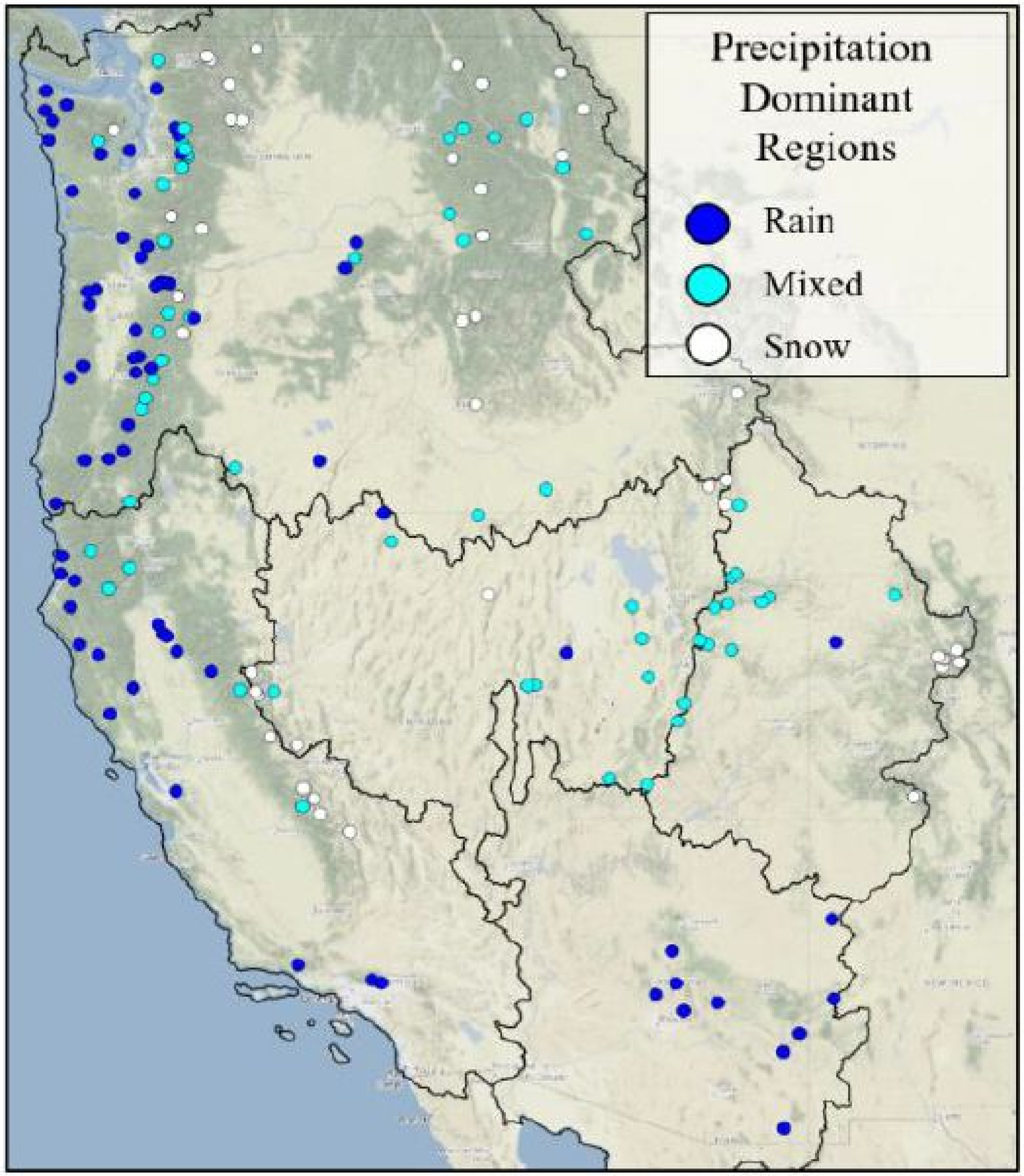
Temperature



Precipitation

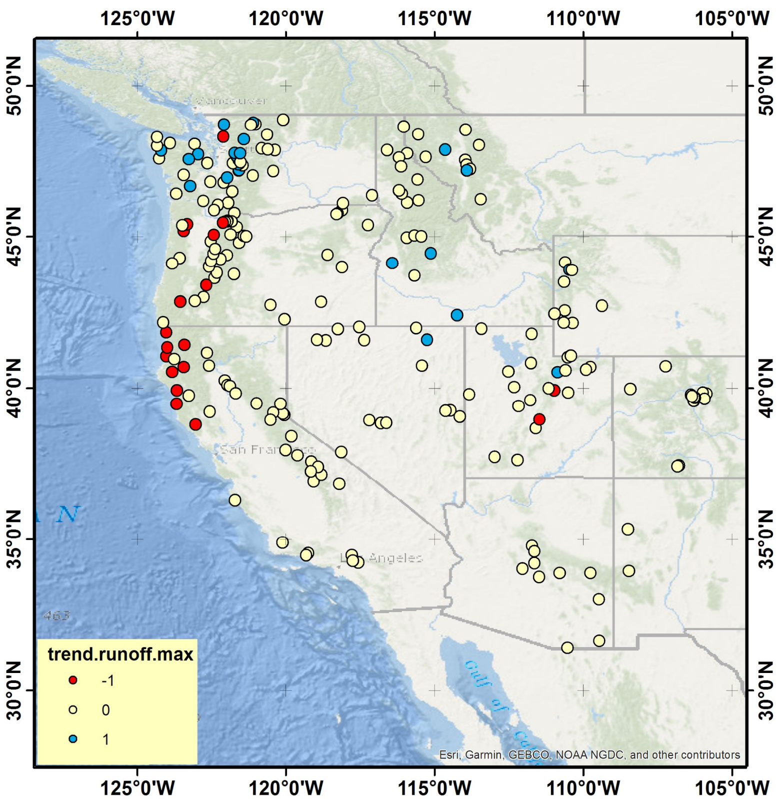


Runoff mechanisms (rain/mixed/snow dominant)

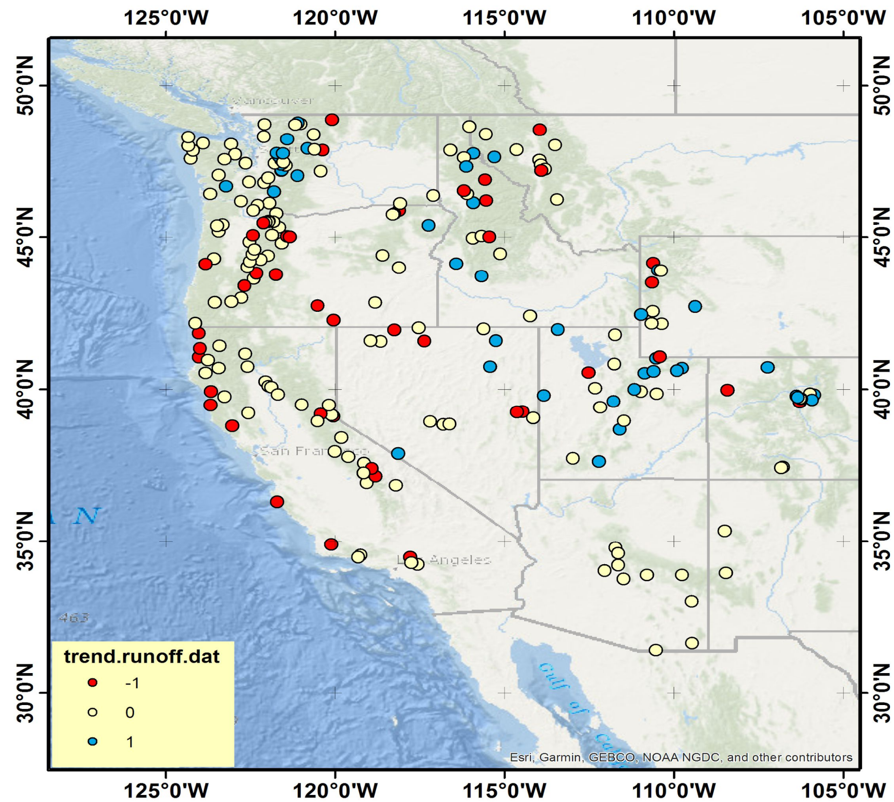


Western U.S. flood magnitude trends, 1960-2015

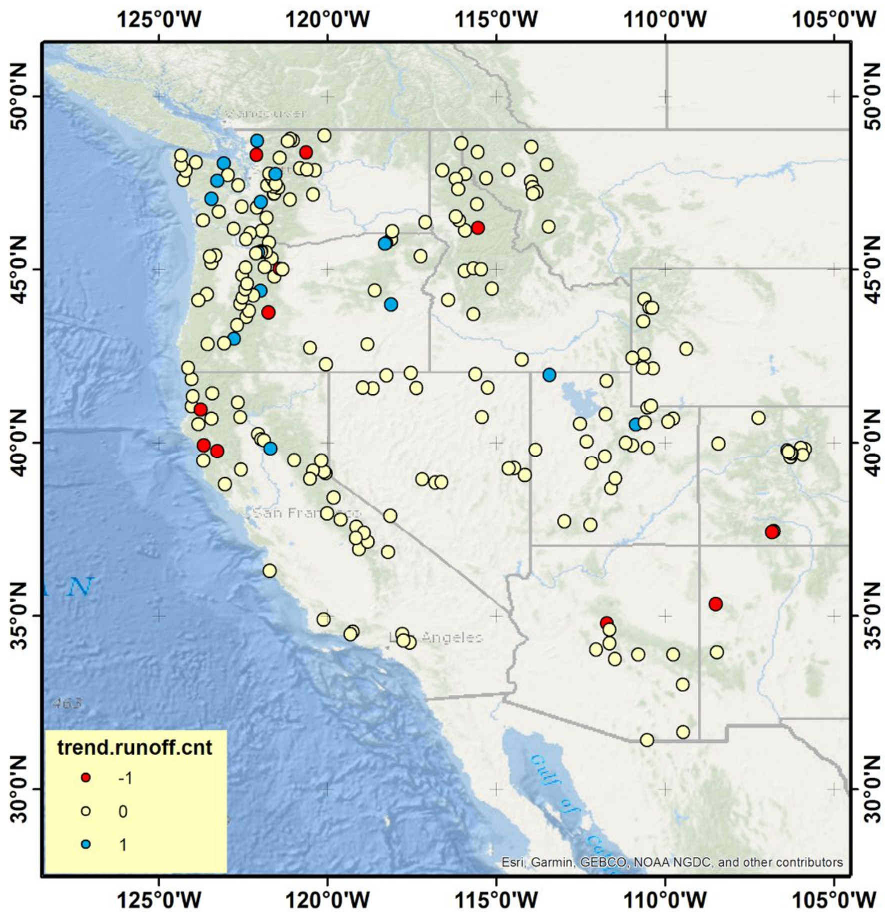
Annual Maxima



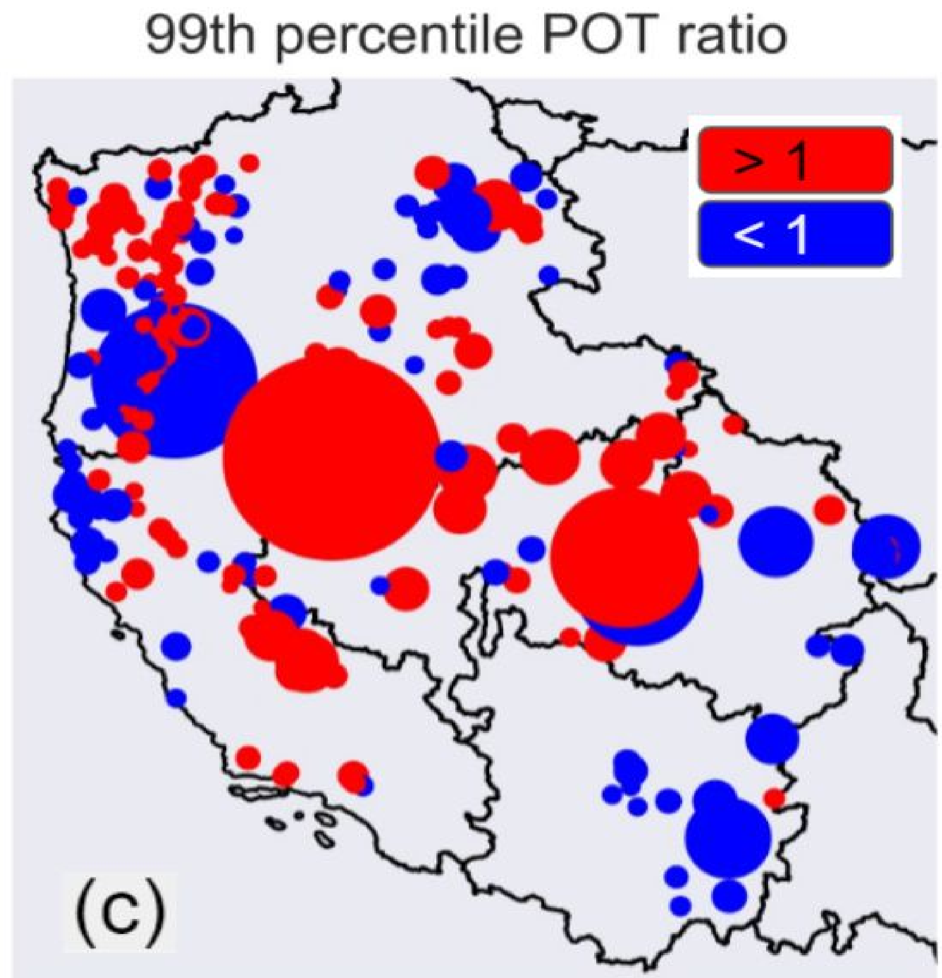
Peaks over threshold



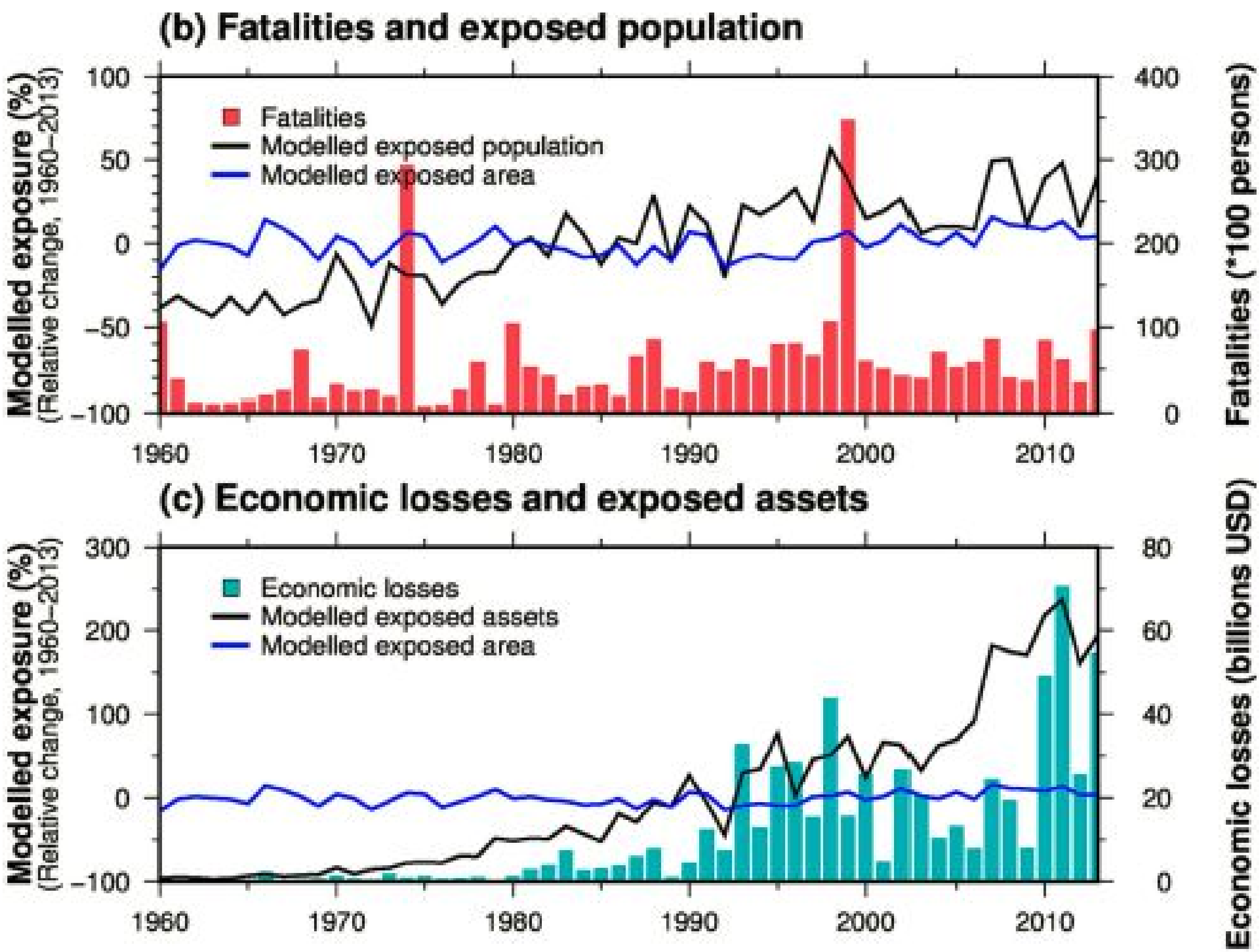
Western U.S. peaks over threshold count trends, 1960-2015



POT ratios (number of exceedances of 99th percentile daily flow for 2nd half of record/first half of record) for Western U.S. streams with minimum record length 30 years



Global loss of life and economic losses due to flooding, 1960-2015



From Tanoue et al., 2016

Conclusions

1) Evidence of (modest) changes in extreme precipitation intensity and duration isn't accompanied by observed changes in extreme flood frequency
2) Antecedent (soil moisture) almost certainly plays a role, which probably is scale dependent
3) Western U.S. flood relationships should reflect changes in rain/snow mix (esp. in winter-dominant precipitation regimes) but signal is sketchy