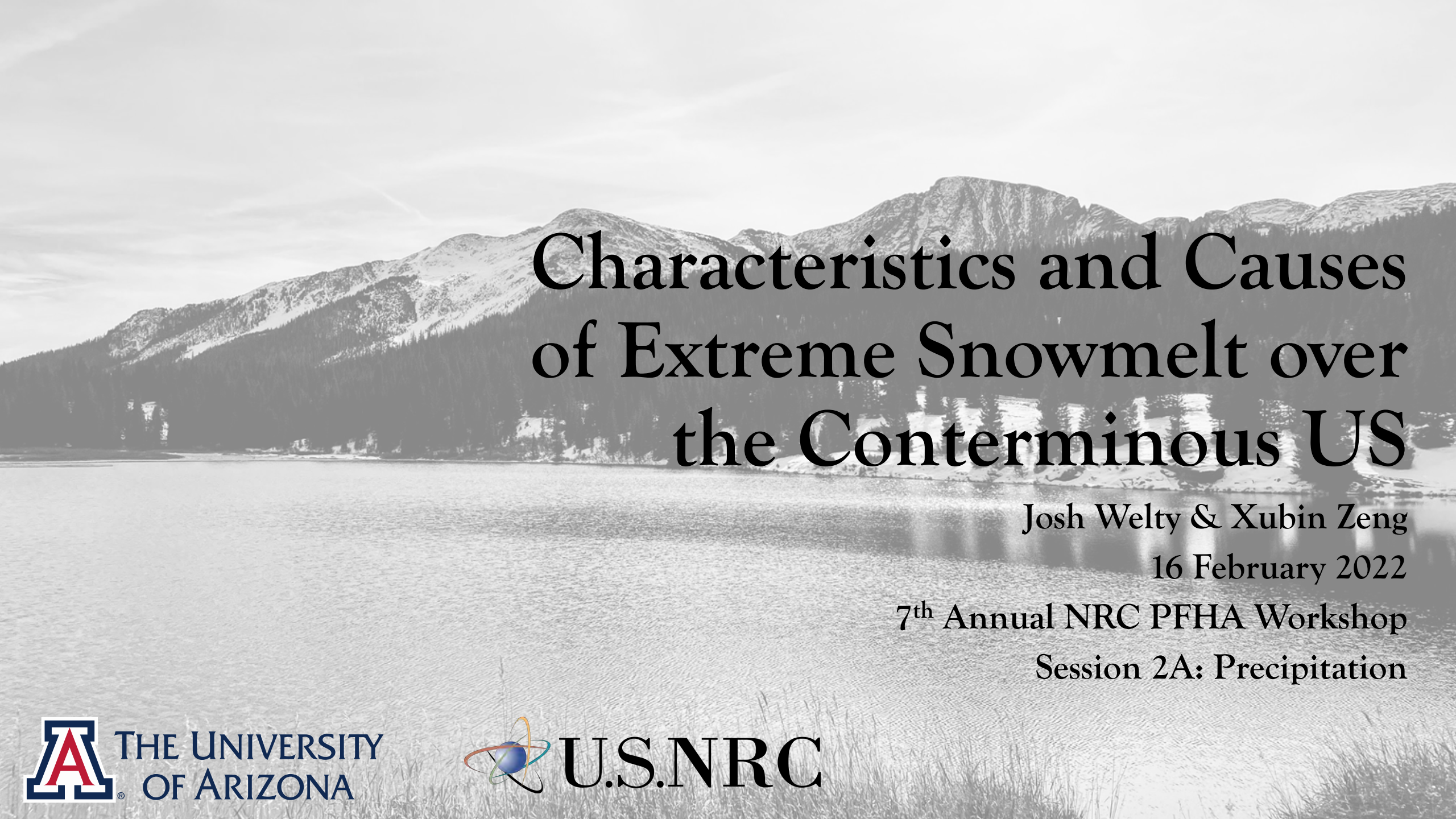

Characteristics and Causes of Extreme Snowmelt over the Conterminous US

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Session 2A: Precipitation

THE UNIVERSITY OF ARIZONA

U.S.NRC

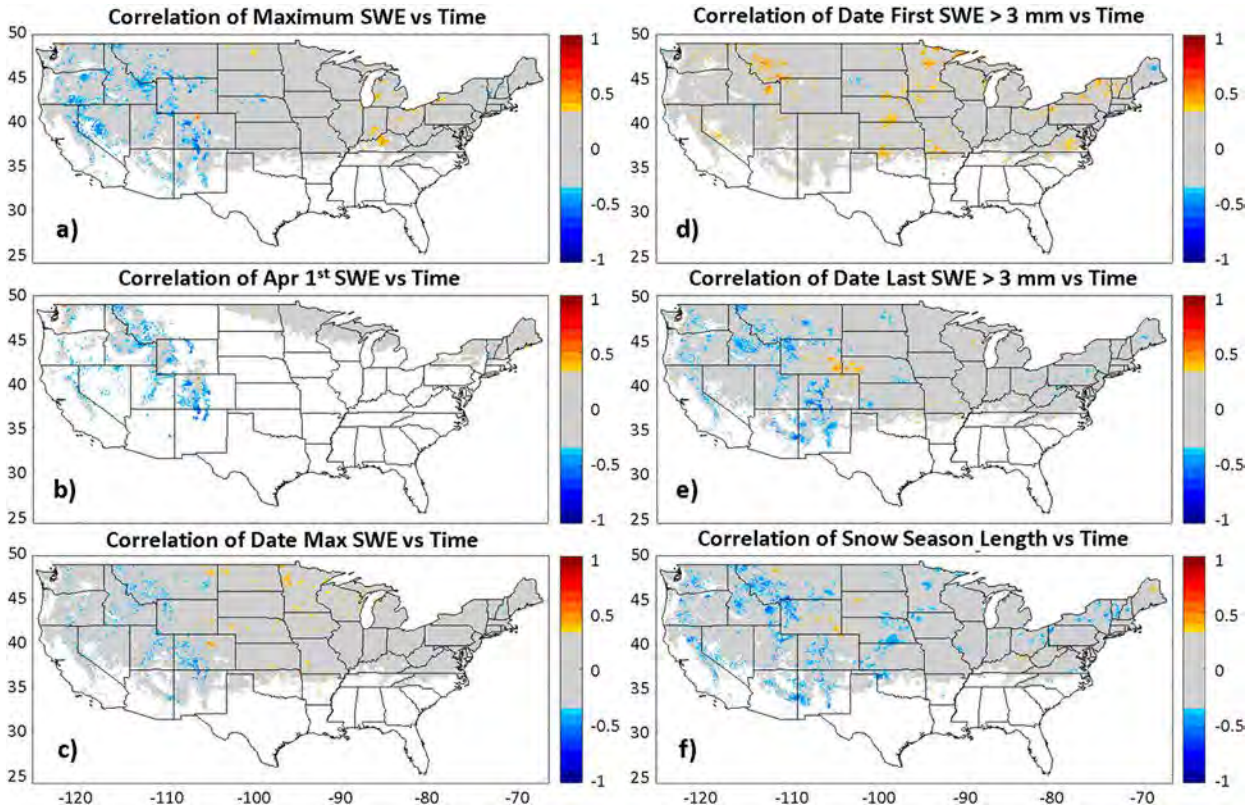

Overview
Characteristics
Cases
'Causes'

Why is snowpack important?

- Reflects potentially long-term changes in temperature and/or precipitation
- Represent 'water towers' for regions like the drought-prone western CONUS
- Conversely, can prove hazardous when melting process is rapid

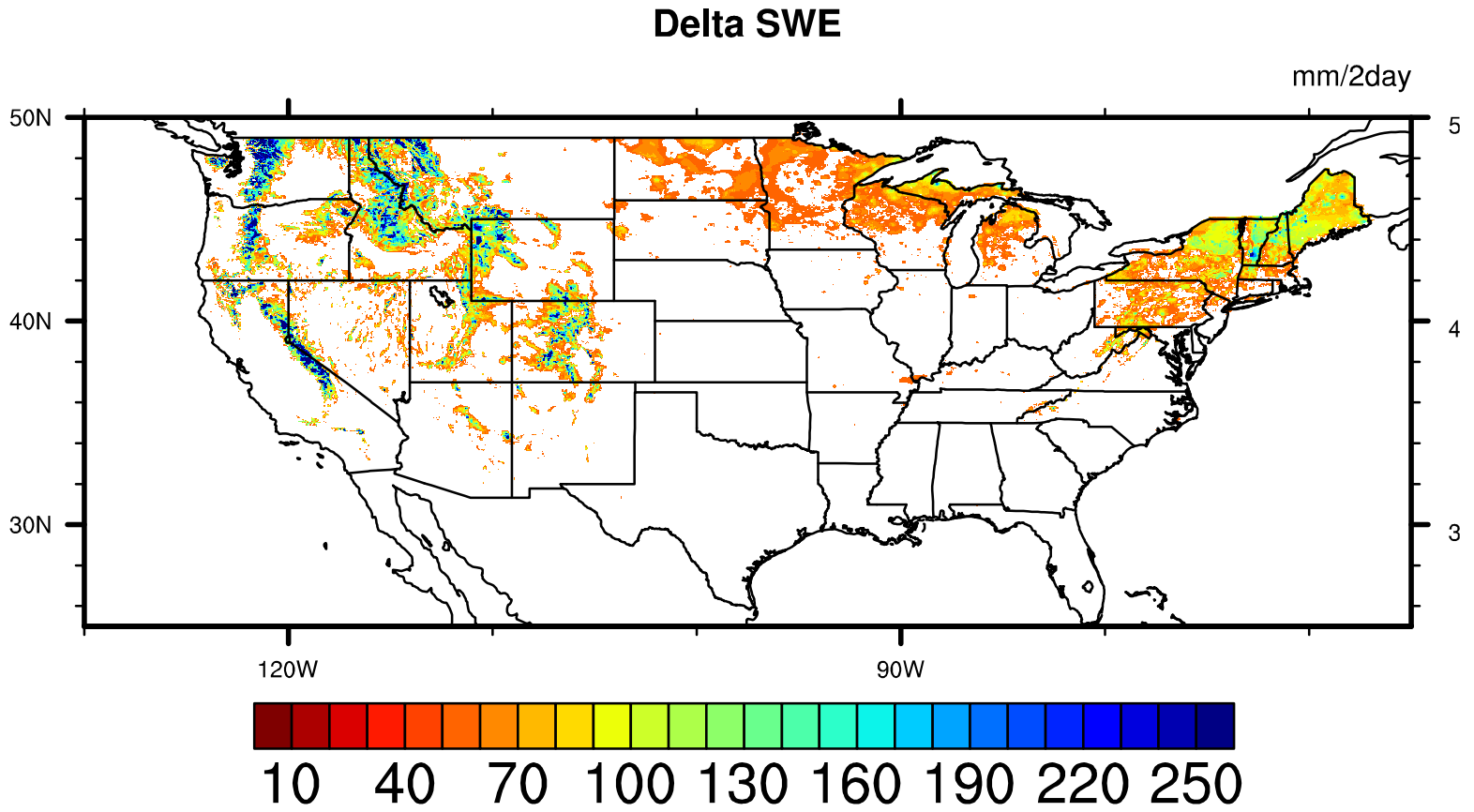
What can be done with snowpack data?

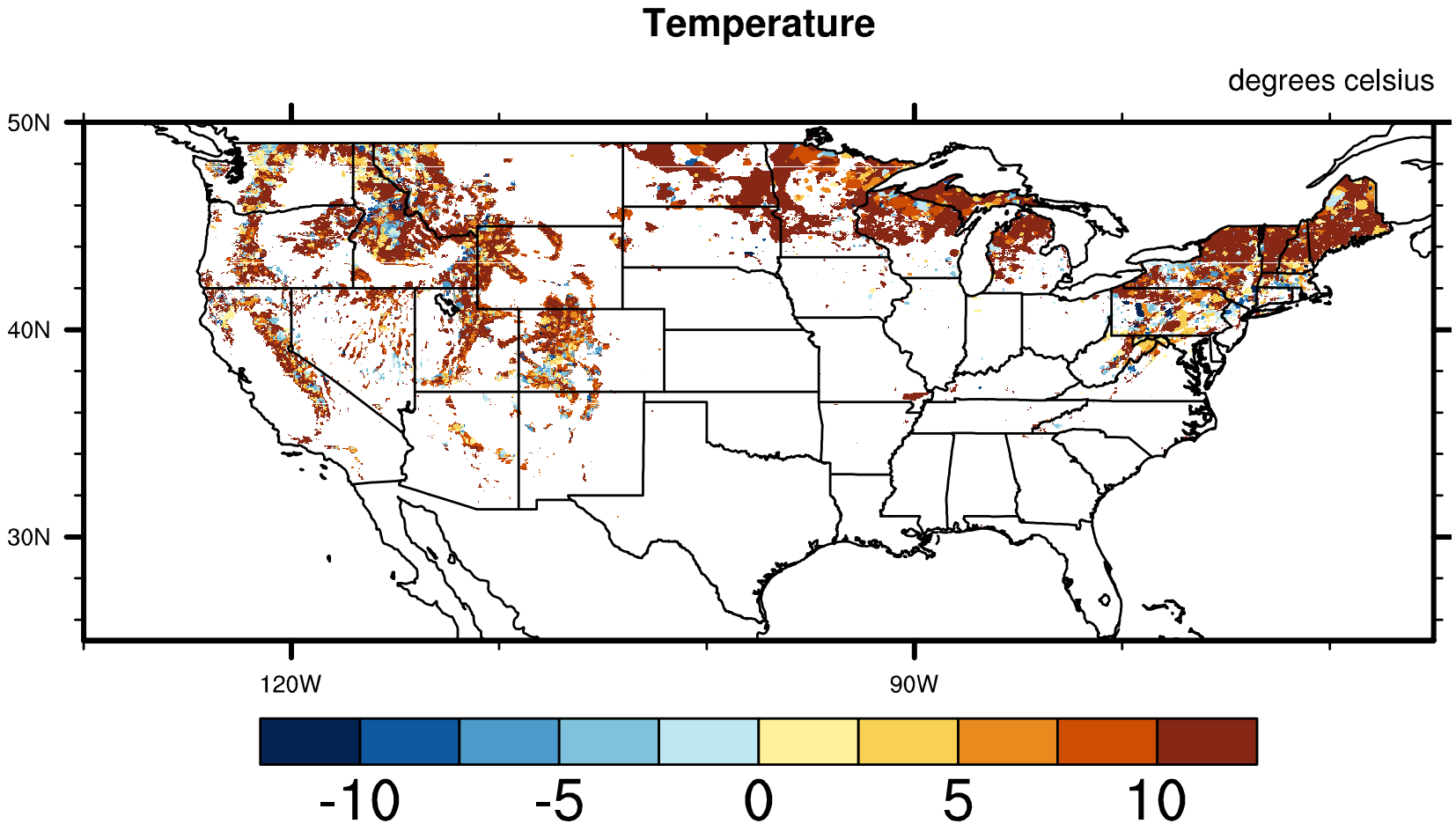
- Spatial representation / heterogeneity of snowpack over the US[1]
- **Long-term trends in snowpack[2]**
- Evaluation of model representation of SWE relationship w.r.t. temperature and precipitation[3]
- Post-processing of near-surface variables for soil moisture and drought monitoring[4]
- Characterization of ablation in terms of magnitude, timing, and synoptic weather conditions[5]



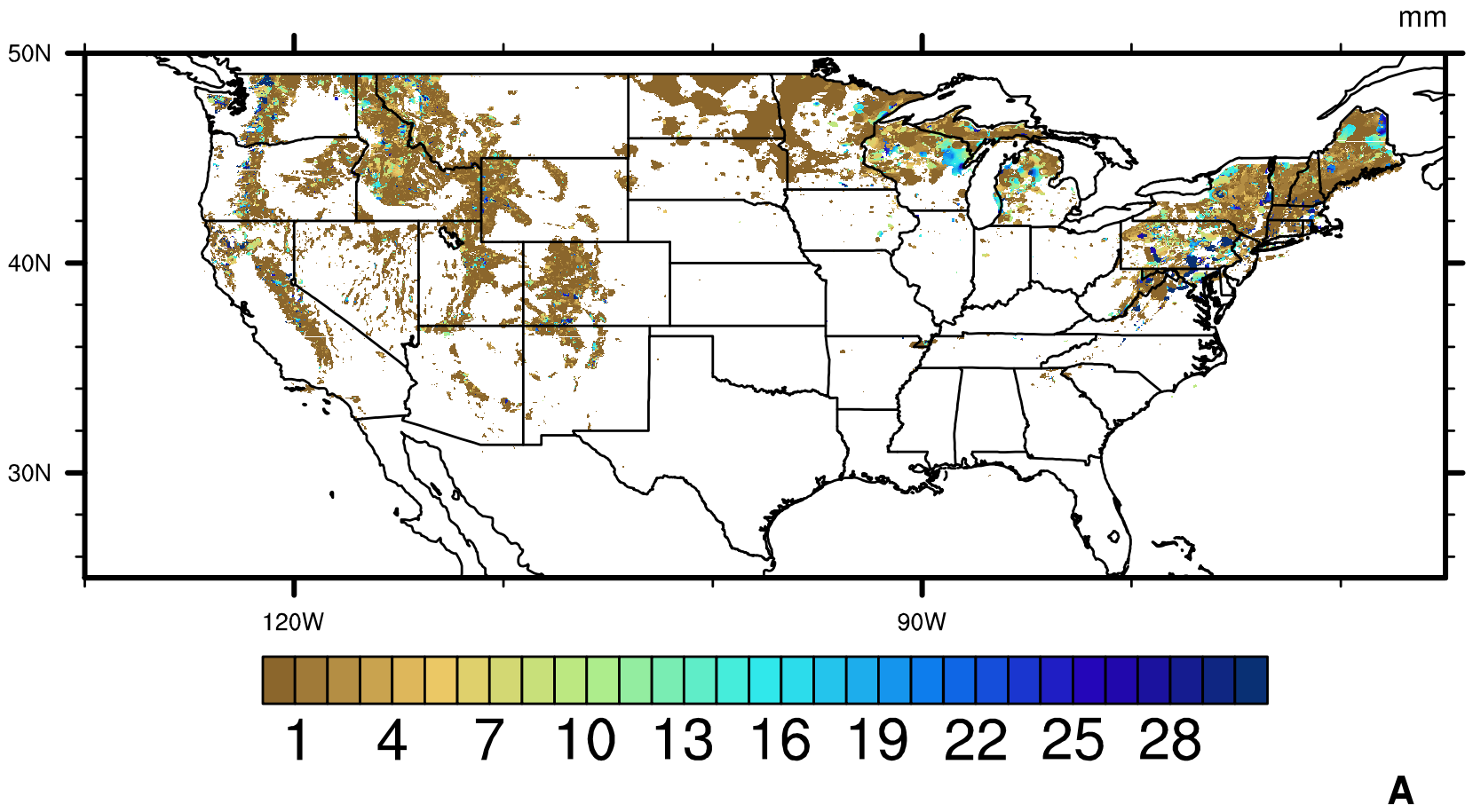
Maximum snowmelt magnitude

- Delta SWE: largest 2-day snow loss for the 30-year period at each pixel
- Largest over high elevations in the western CONUS and portions of eastern CONUS



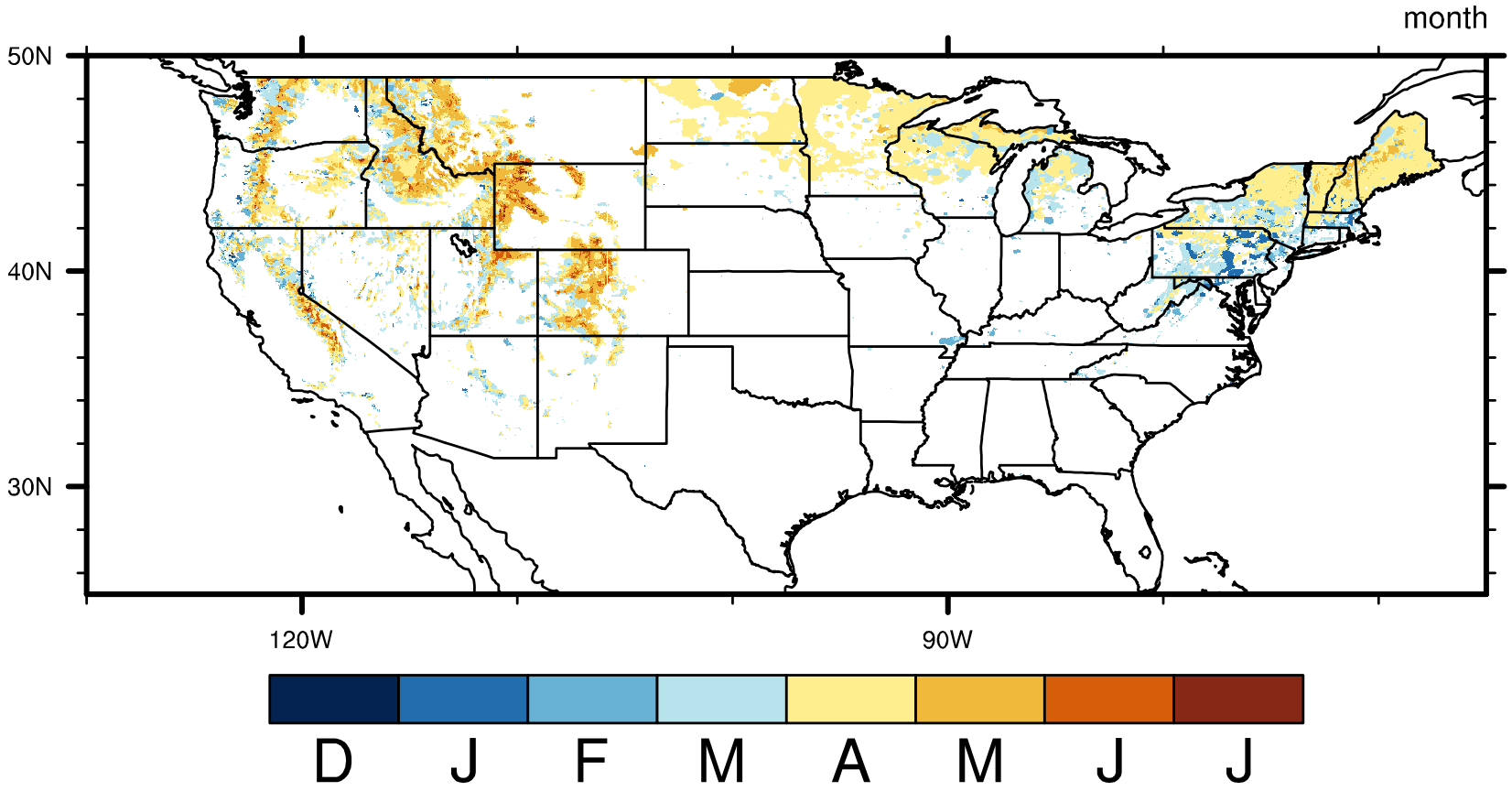


Above-freezing temperatures are most pervasive

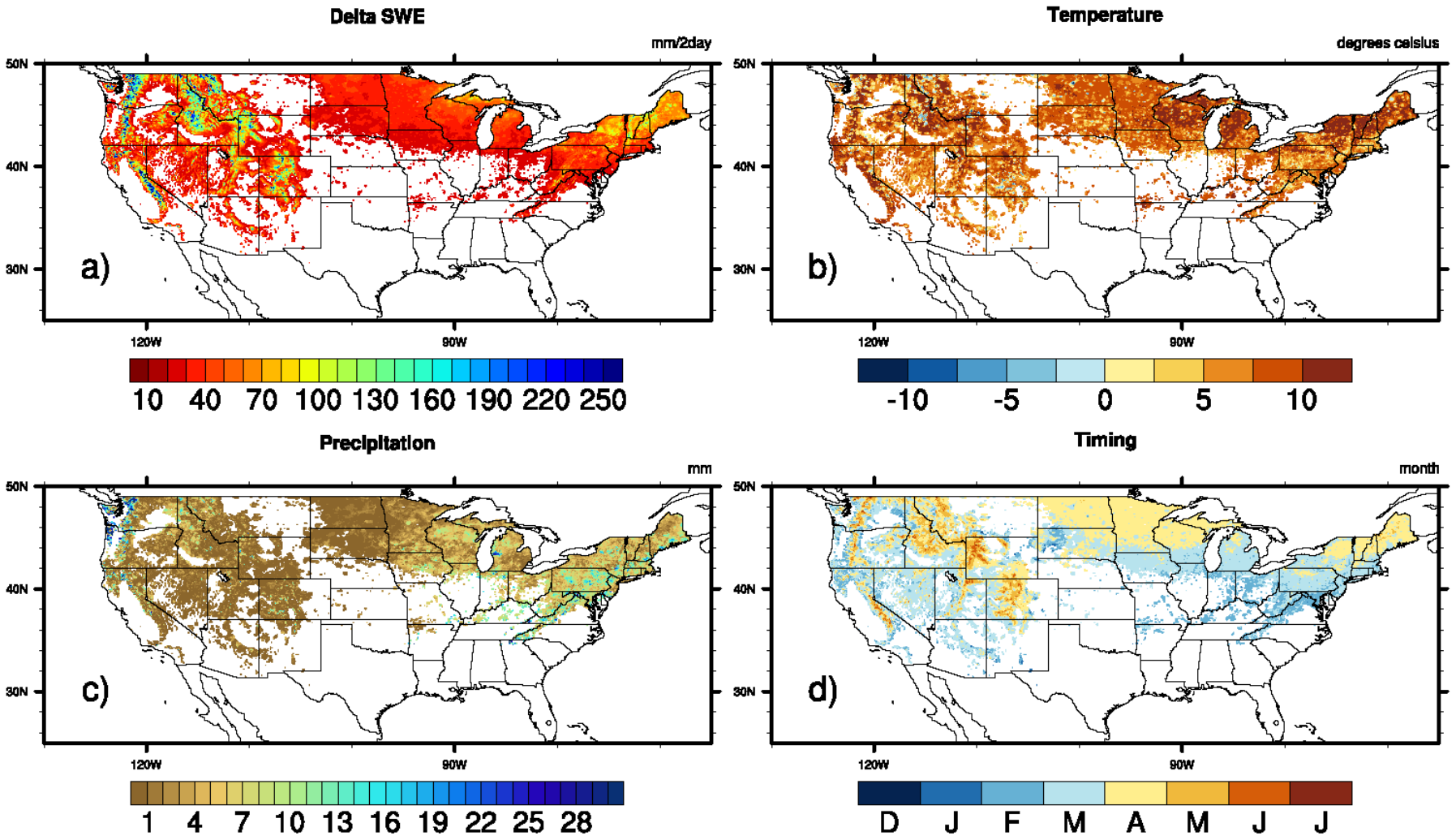


Limited precipitation is associated with snowmelt in most regions

Timing



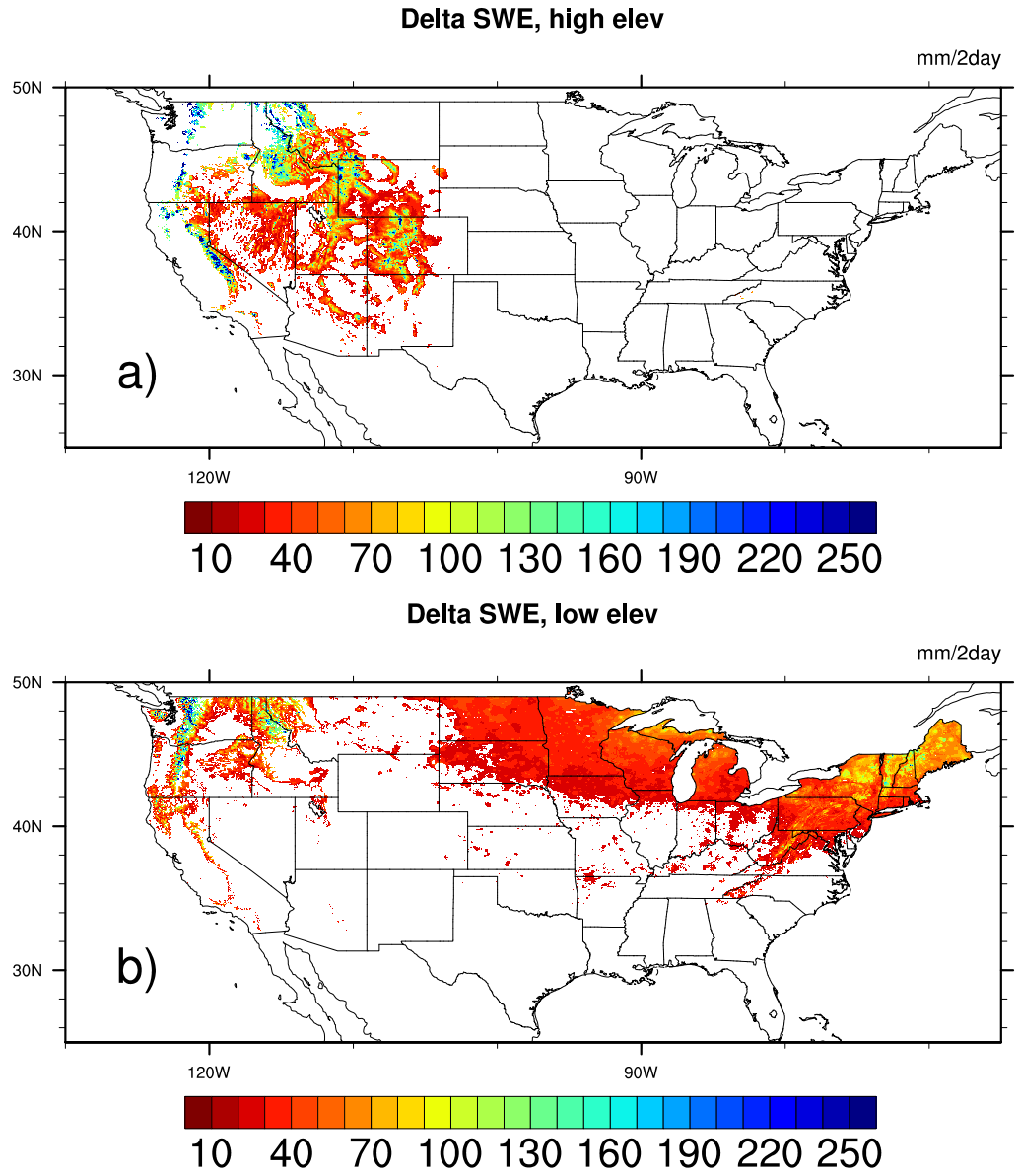
Timing usually during mid- to late spring, though more southerly regions and windward sides of mountains exhibit earlier timing

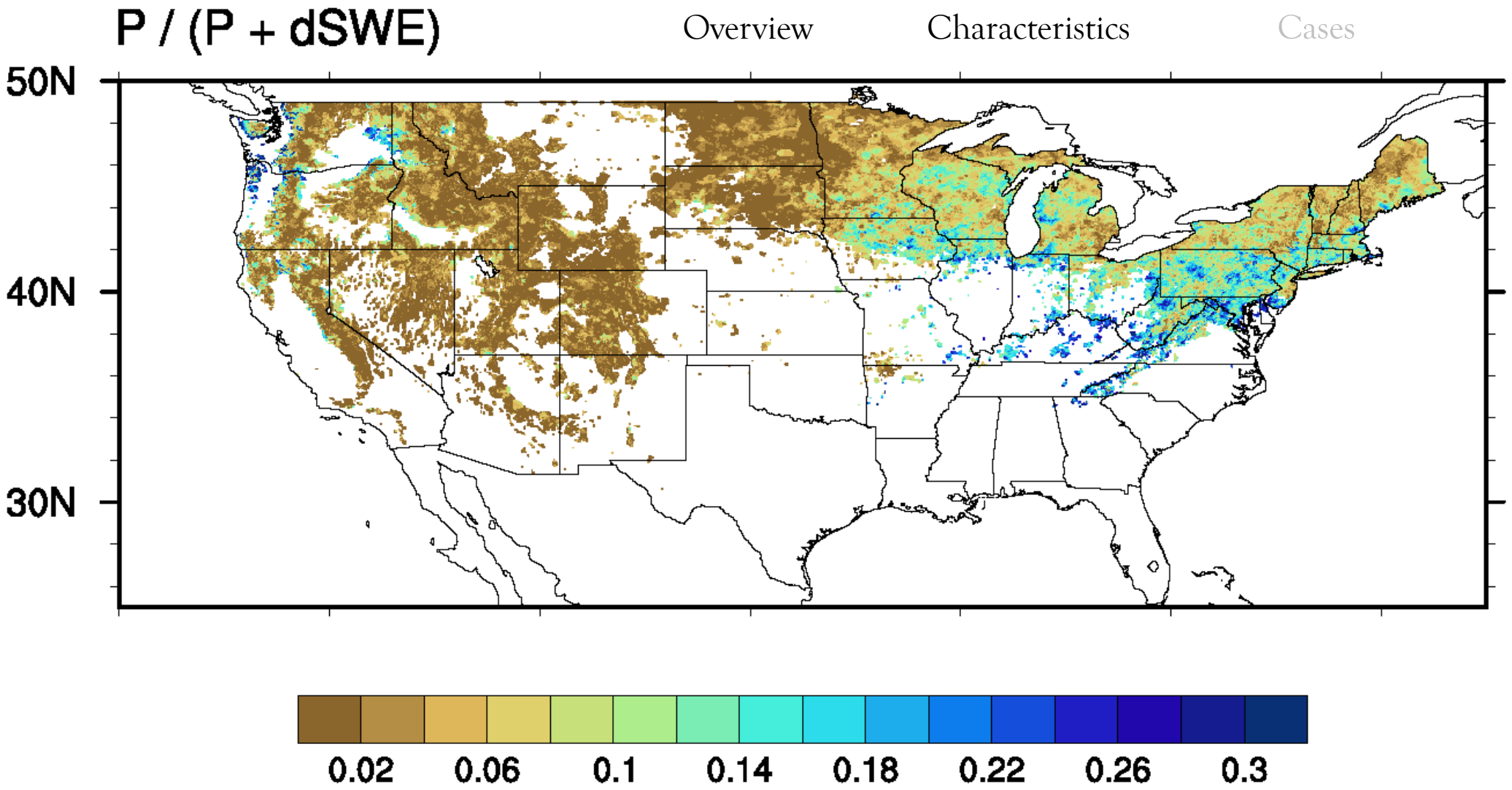


Analysis also performed for top 10 extreme events at each pixel (mean value for the 10 events at each pixel shown)

Elevation impacts

- As expected, highest magnitude events tend to occur at higher elevations over western CONUS.
- Distribution is much more heterogeneous over variable topography

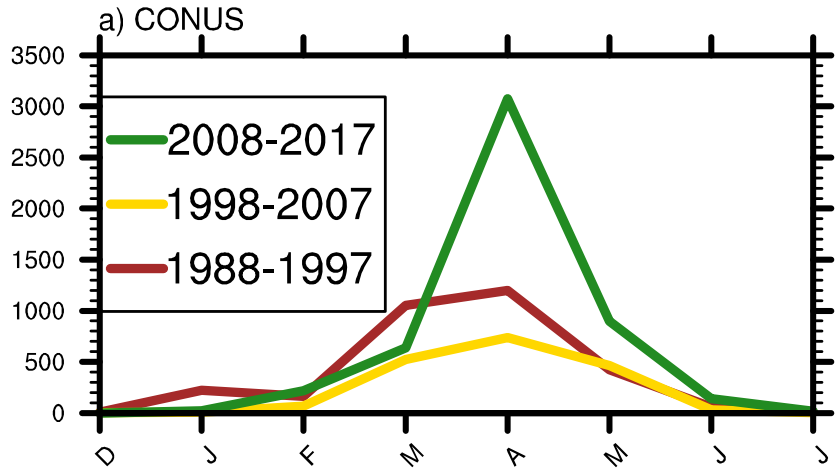




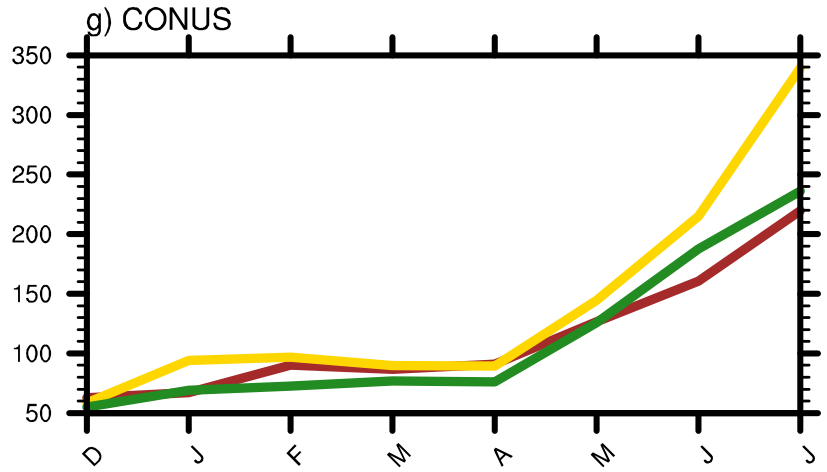
Average contribution of precipitation to runoff potential for the top 10 snowmelt extremes at each pixel. The pattern mirrors climatology, with larger values residing over the Pacific Northwest and the eastern CONUS.

Trends

- There is a positive trend (p=0.25) in the occurrence of snowmelt extremes over the CONUS throughout the period, particularly during the month of May (p=0.03). Also, a positive trend in rain-on-snow occurrence (p=0.19)
- Though there is a weakly positive trend in frequency, no notable pattern for magnitude

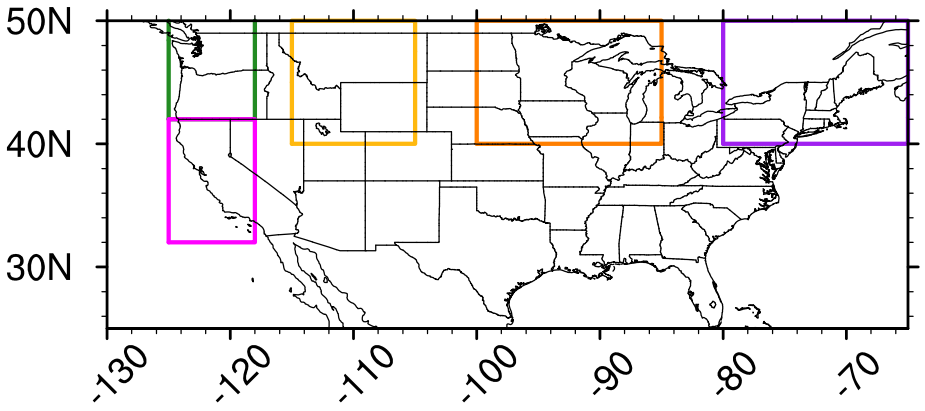


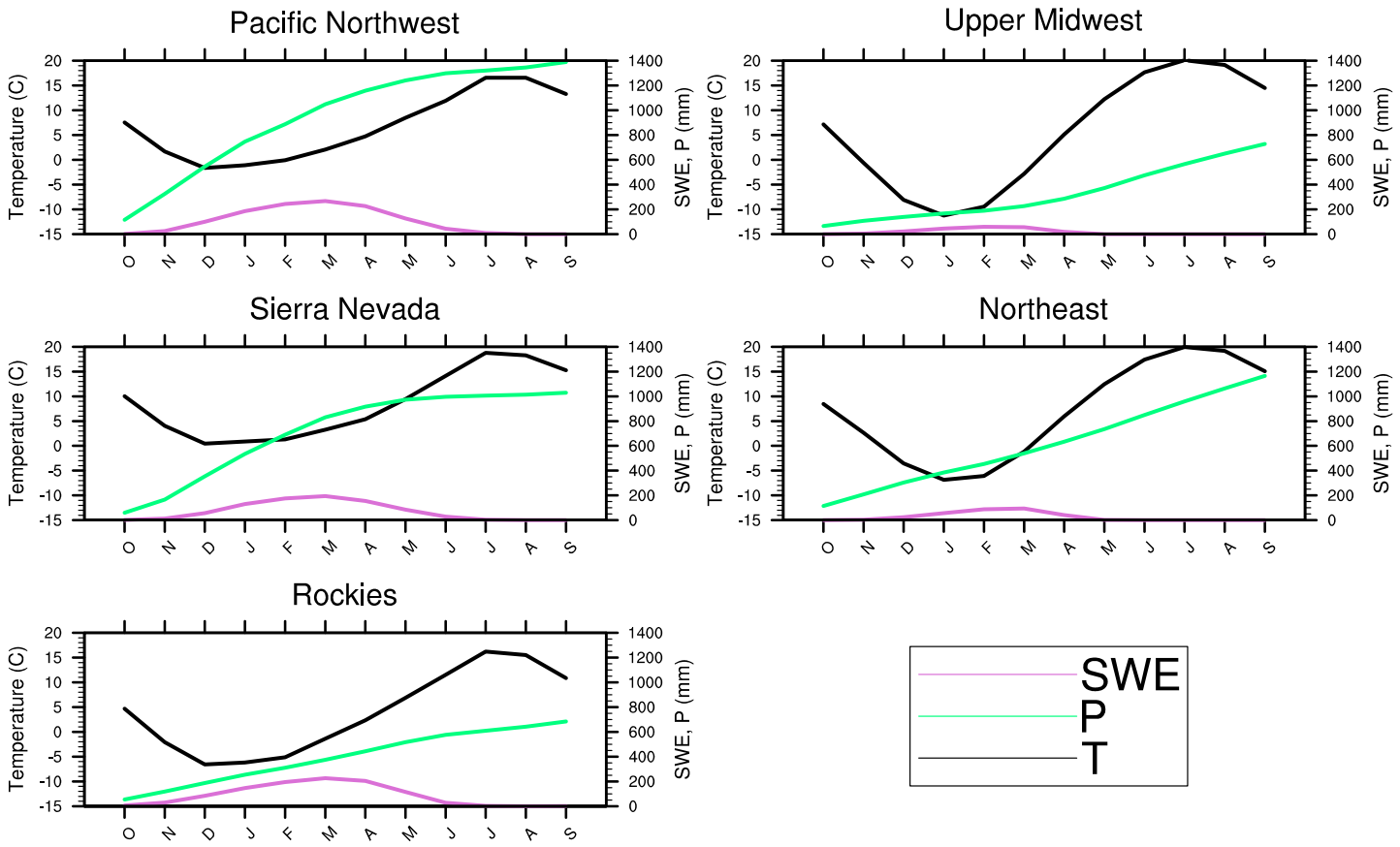
Average annual cycle of extreme snowmelt **occurrence** (pixel number) by decade

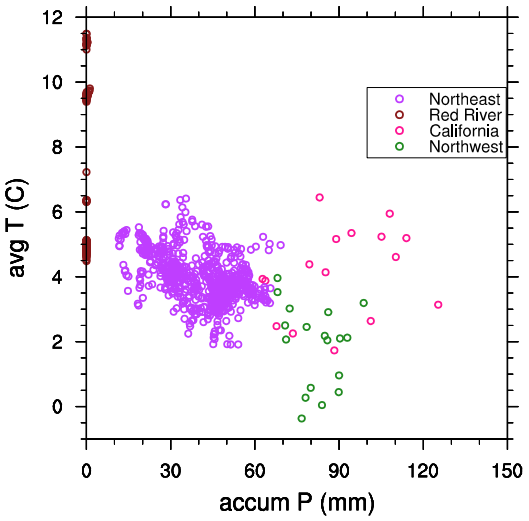


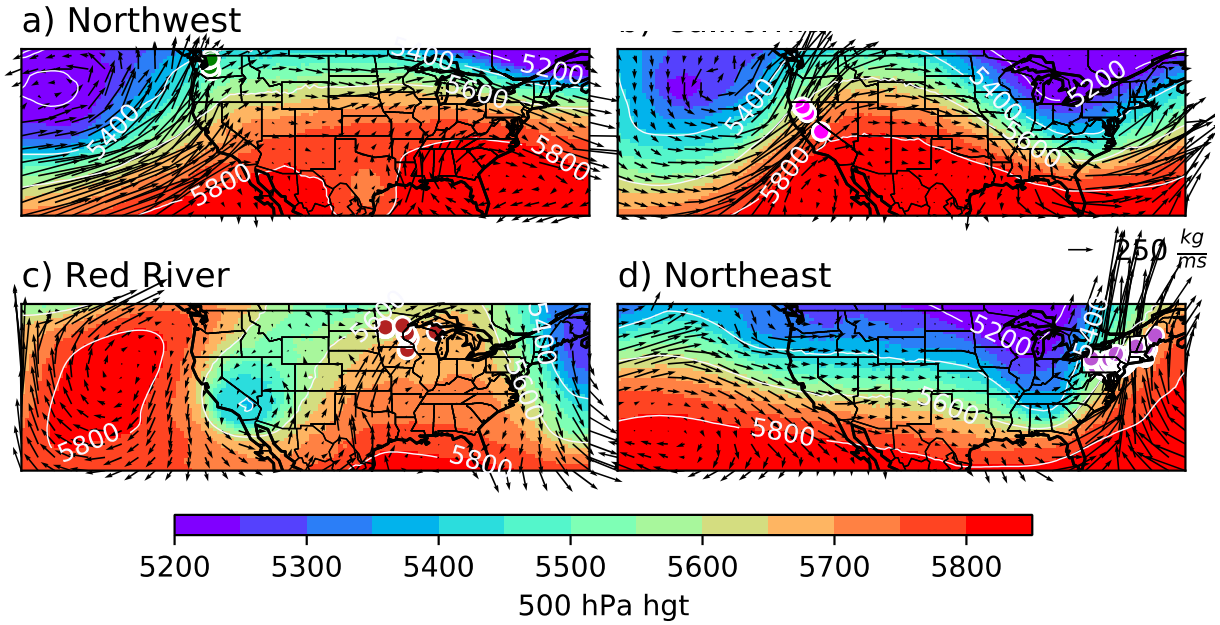
Average annual cycle of extreme snowmelt **magnitude** by decade

How do snowmelt extremes vary by region?



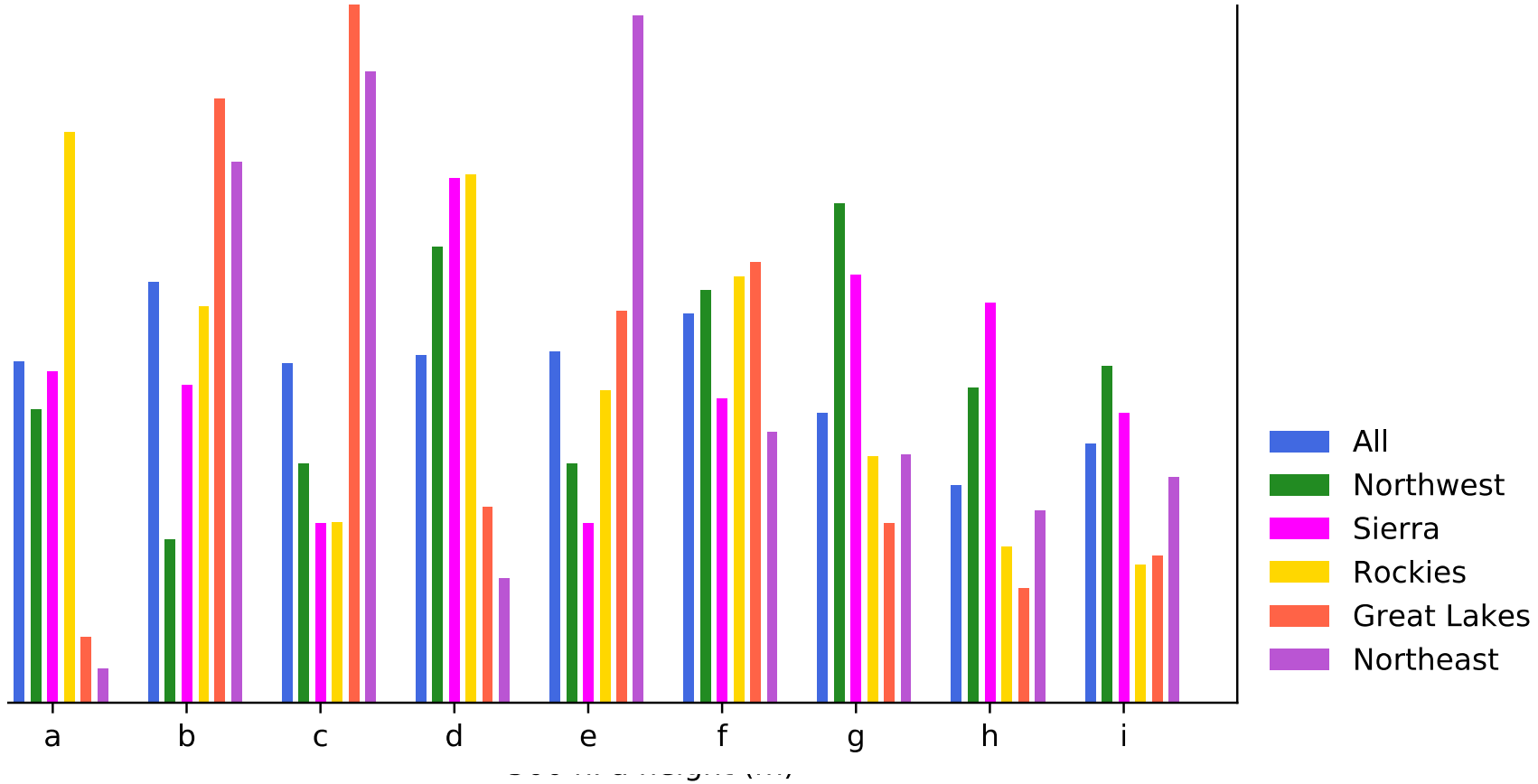






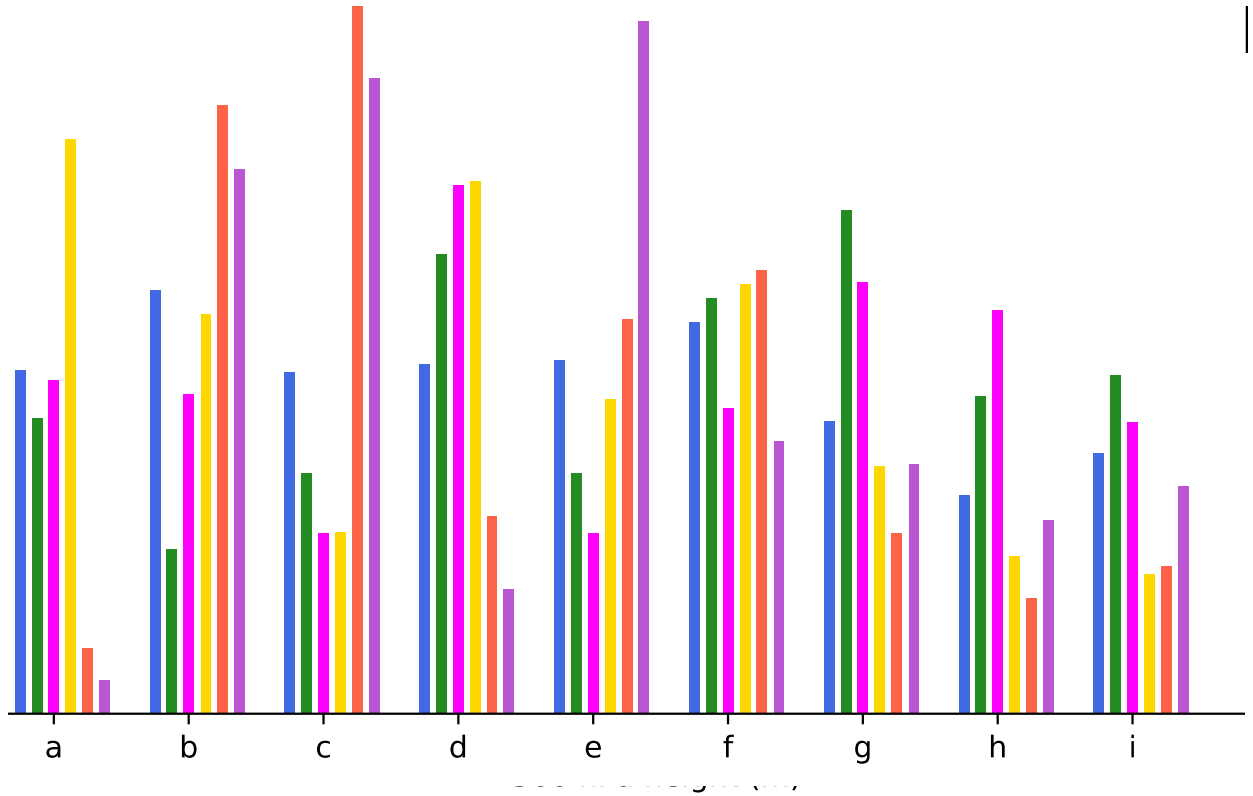
- Four high-impact flooding events over different regions
- In three out of the four case studies (exception being Northwest), dSWE>P contribution to runoff
- In some cases (e.g. Red River, burgundy dots in top, figure 'c' in bottom), dSWE>>P

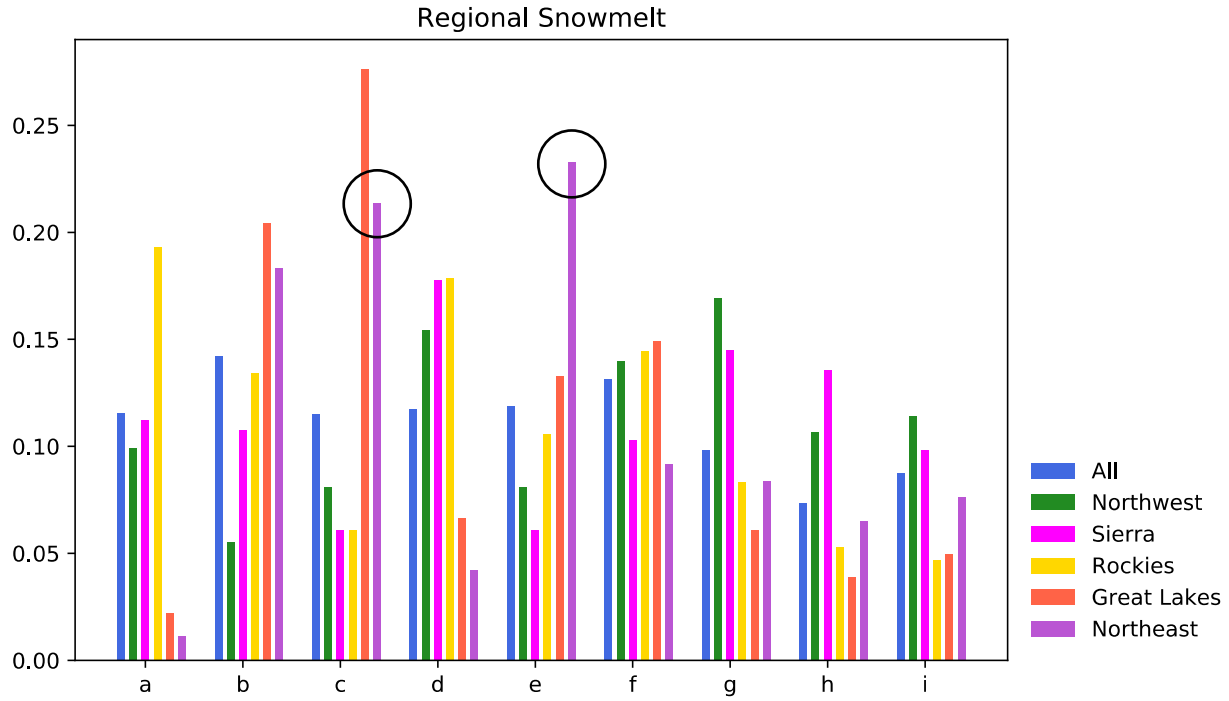
Weather



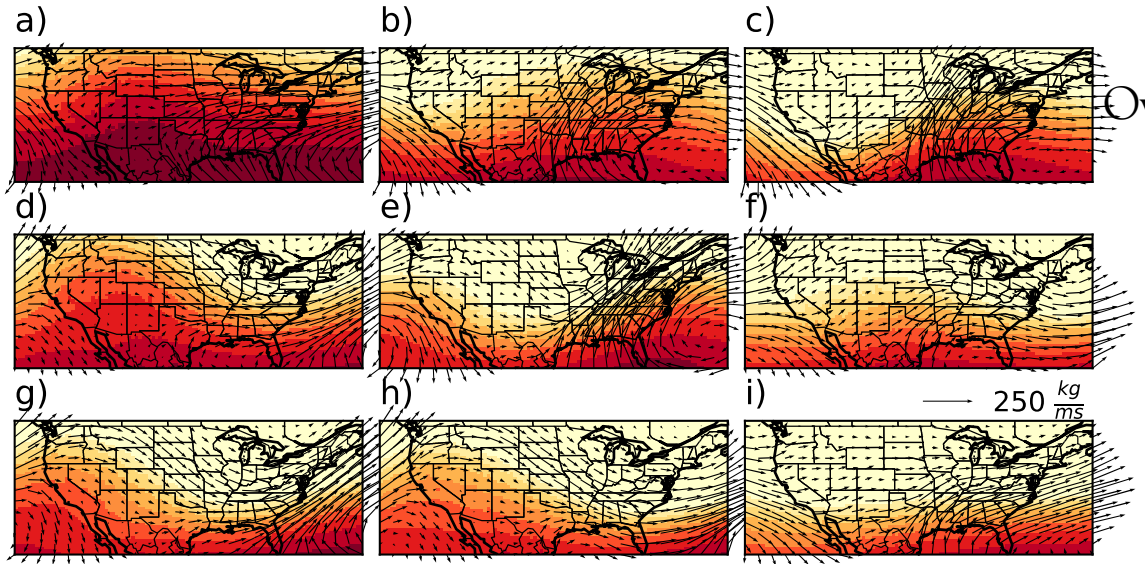
- Used self-organizing maps to produce nine dominant patterns associated with extreme snowmelt over the CONUS
- These maps served as template to classify regional snowmelt extremes

Overview — Characteristics — Cases — ‘Causes’





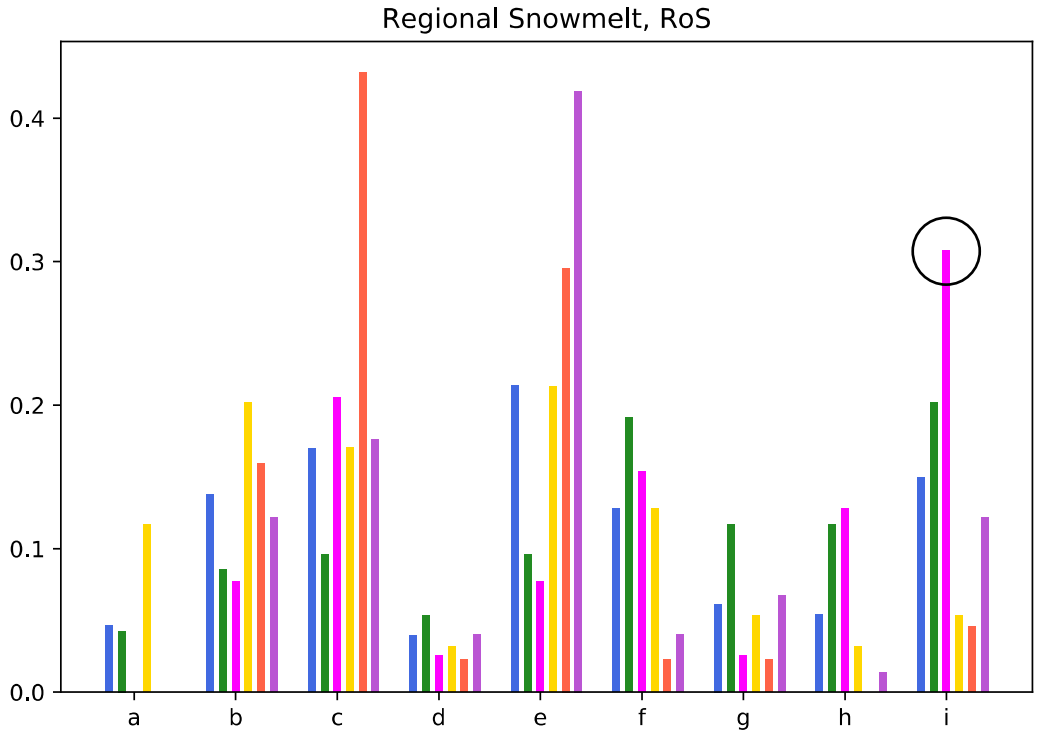
Part of the utility of this approach is that there are more than one ‘meaningful’ pattern associated with snowmelt over a given region (e.g. maps ‘c’ and ‘e’ for the Northeast)

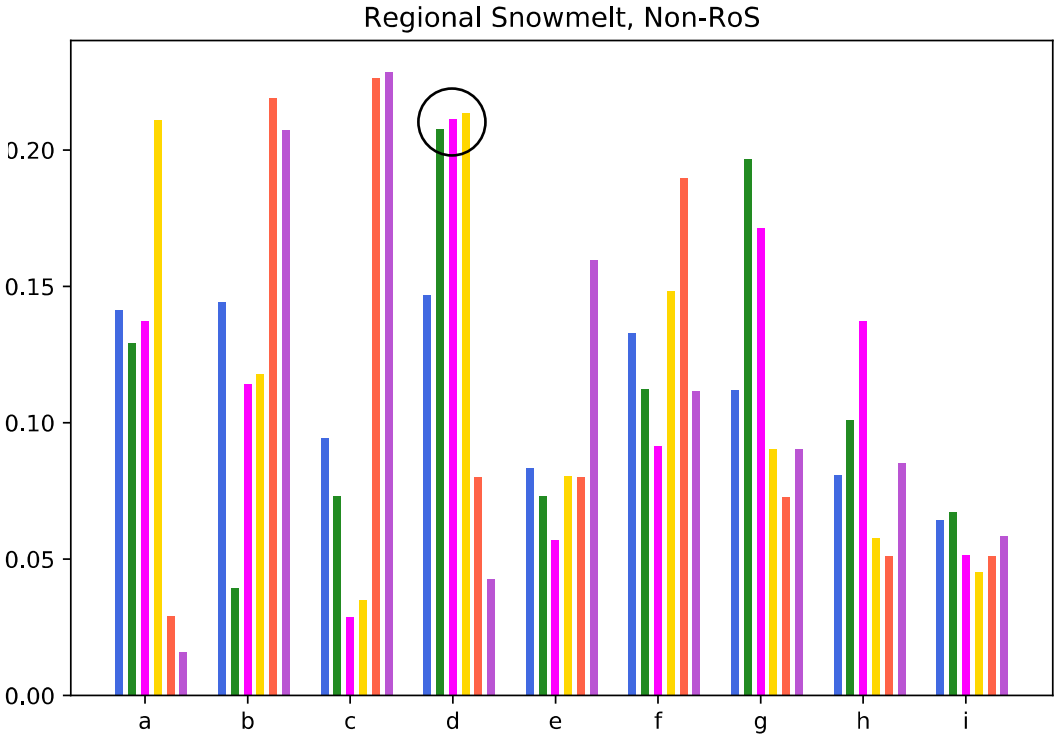


Overview — Characteristics — Cases — ‘Causes’

We can also use the maps to classify other specific events, like RoS vs. non-RoS.

For example, majority of Sierra Nevada RoS (non-RoS) events correspond to map ‘i’ (‘d’) which exhibit very different synoptic setups.



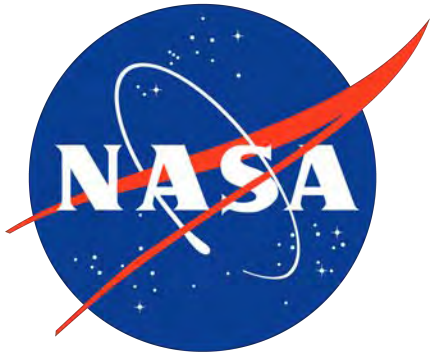


Takeaways

- Large variation in the meteorological conditions associated with regional events
  - Over the western CONUS, anomalous high pressure and upstream AR activity
  - Over the eastern CONUS, frontal passage, Gulf warm air advection, and precipitation
- In many cases, SWE loss exceeds the precipitation contribution to runoff
- There is a weakly increasing trend in the frequency of extreme snowmelt events over the US

Acknowledgments/References

- UA SWE data are available from the National Snow and Ice Data Center (https://nsidc.org/data/nsidc-0719/versions/1). PRISM data can be downloaded from the PRISM Climate Group (https://prism.oregonstate.edu/). MERRA-2 data are available from the Goddard Earth Sciences Data and Information Services Center (https://disc.gsfc.nasa.gov/).



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[1]Broxton, P. D., N. Dawson, and X. Zeng, 2016: Linking snowfall and snow accumulation to generate spatial maps of SWE and snow depth. *Earth Space Sci.*, **3**, 246–256, https://doi.org/10.1002/2016EA000174.

[2]Zeng, X., P. Broxton, and N. Dawson, 2018: Snowpack change from 1982 to 2016 over conterminous United States. *Geophys. Res. Lett.*, **45**, 12 940–12 947, https://doi.org/10.1029/2018GL079621.

[3]Brunke, M., Welty, J., & Zeng., X. (2020). Attribution of snowpack error sensitivities to simulated temperature and precipitation in E3SMv1 over the contiguous United States. https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2021MS002640?af=R

[4]Arévalo, J., Welty, J., Fan., Y., & Zeng, X. (2021). Implementation of Snowpack Treatment in the CPC Water Balance Model and Its Impact on Drought Assessment. https://journals.ametsoc.org/view/journals/hydr/aop/JHM-D-20-0201.1/JHM-D-20-0201.1.xml

[5]Welty, J., & Zeng, X. (2021). Characteristics and Causes of Extreme Snowmelt over the Conterminous United States. https://journals.ametsoc.org/view/journals/bams/aop/BAMS-D-20-0182.1/BAMS-D-20-0182.1.xml