Teleconnections and Topography: How the Use of Sea Surface Temperature Data to Predict Snow Water Equivalent Varies within Small Watersheds in the Western US

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Intro/Research Topic

-For much of the Western US, spring mountain snow-water equivalent (SWE) is the single best predictor of water supply through the Summer, and is especially crucial for cities and agriculture in dry regions dependent on surface water. Water agencies would like to better predict SWE in advance so that they can choose how to operate their facilities to optimize water storage and flood protection.

-This is complicated by the fact that areas of the Western US between ~ 36 and 41 N, including areas such as Northern CA and CO, have lower and more variable correlations with ENSO, and so SWE prediction using SST has been a challenge.

Intro/Research Topic

We would like to analyze how to best use sea-surface temperature (SST) data to predict small-scale variation in snow-water equivalent (SWE) in mountainous regions of the US.

This project aims to investigate:

-The effect of elevation/aspect within a given range on correlation with a given prediction center.

-Why prediction center location and strength varies by immediate location.

-How to best choose prediction centers for a given location.

-Long-term temporal shifts in the above.

Data Used

Sea Surface Temperature: NOAA Extended Reconstruction SST dataset: Ship logs before 1980, satellite after. Two Degree lat/lon cells. Monthly.

-Anomalies taken relative to average temperature at each location over analysis period 1985-2021.

Snow Water Equivalent: NASA UCLA Snow Reanalysis: Satellite SWE data in 225x225 points per one degree lat/lon cell, ~500 m lat x 400 m lon. Daily.

-Analyzing Apr 1 SWE, May 1 SWE and daily for each month Dec-Apr.

Coursened into 5x5 cells, ~2.5 km lat x 2.0 km lon. More recently, grouped by watershed/elevation instead. Plan to split along valleys as well.

Atmospheric Variables: ERA 5 Hourly: Compiled over 24 hour periods from UTC 0 through UTC 23.

UCLA Snow Reanalysis

-Includes SWE, snow depth and percent snow cover.

-Finest resolution snow dataset available for the entire Western US.

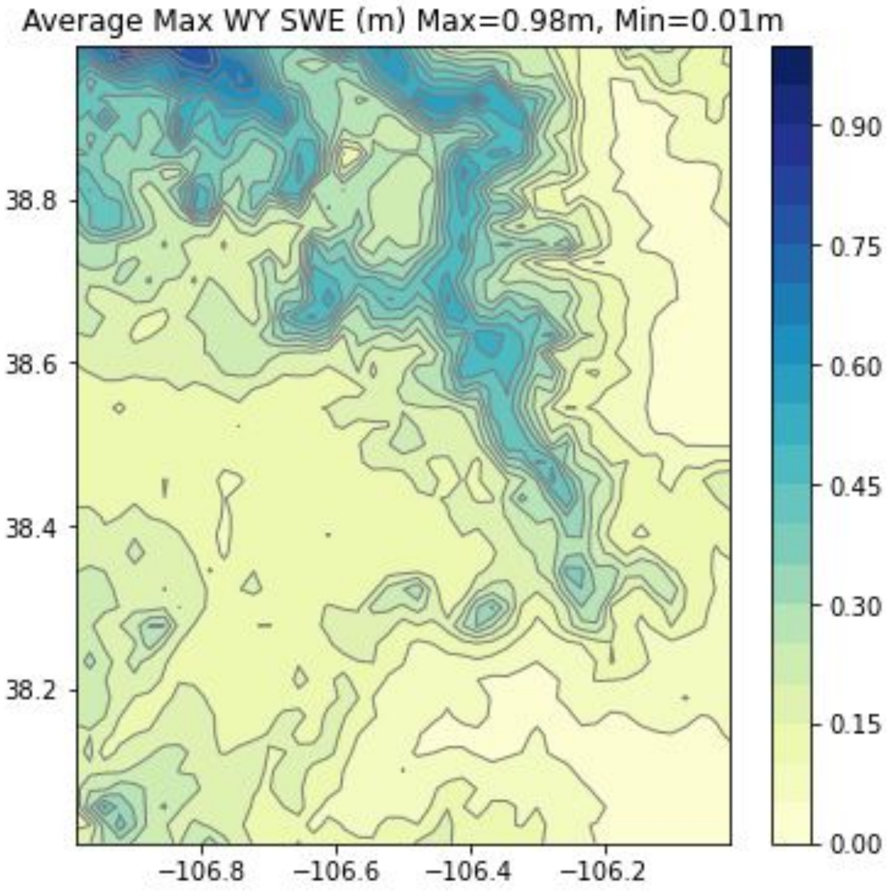
-Created from 3- Landsat sensors.

-Constrained by posterior snow measurements.

-Land cover, elevation data, and meteorological forcing data from MERRA also used, mainly to improve accuracy for heavily forested areas.

-Artifacts in Pacific Northwest due to continuously cloudy periods.

-Useful for uncovering small-scale SWE patterns.



Previous Research

-Higher elevations tend to have stronger teleconnections (maximum correlation with sea-surface temperature anomalies), especially for very distant locations because air traveling at higher altitudes receives less interference from the surface (Moore et. al. 2003).

-However, the correlations vary enormously by immediate sampling location (Hidalgo et. al., 2003). This was shown for ENSO for the Upper Colorado River Basin.

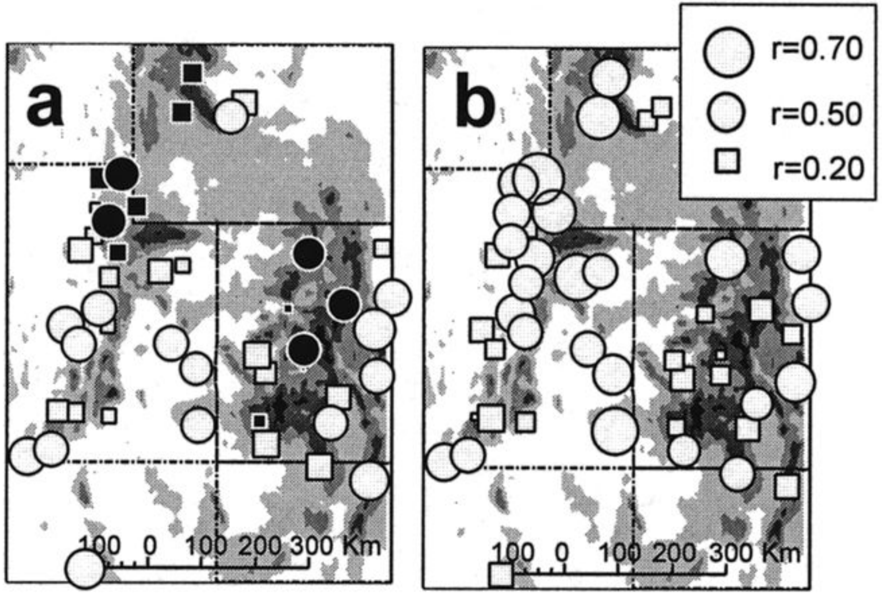


Fig. 7.

Correlation coefficients (1909–98) between (a) Jun–Nov Niño-3 SST variations (lag four) and cold season (Oct–Nov) precipitation, and (b) warm season (Apr–Sep) Niño-3 SST variations and coincident (lag zero) warm season precipitation for stations around the UCRB. The symbol convention is the same as in Fig. 2

Previous Research

-Different elevation bands and different sides of a prominent crest have different correlations with oceanic oscillations. This has been shown for many locations, including Puerto Rico (Torres-Valcarcel, 2018) and Hawaii (Frazier et. al., 2017).

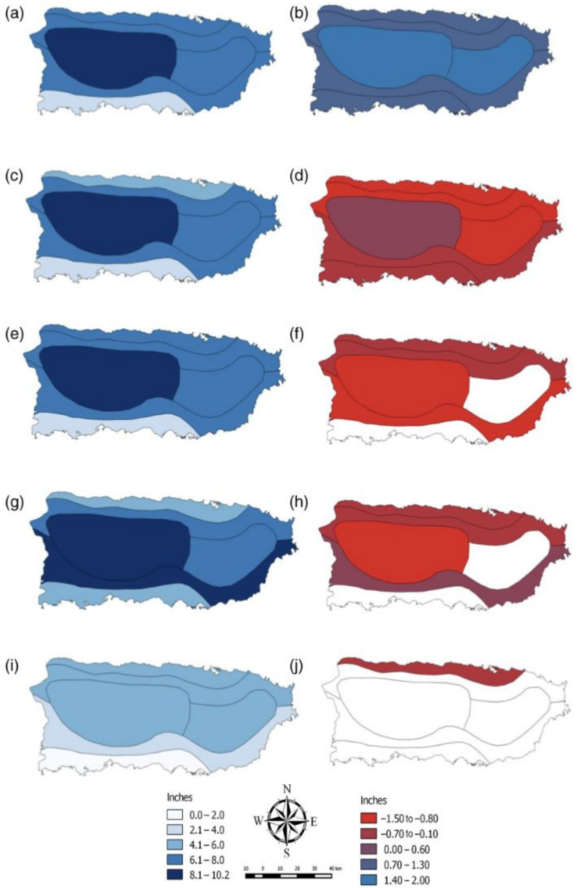
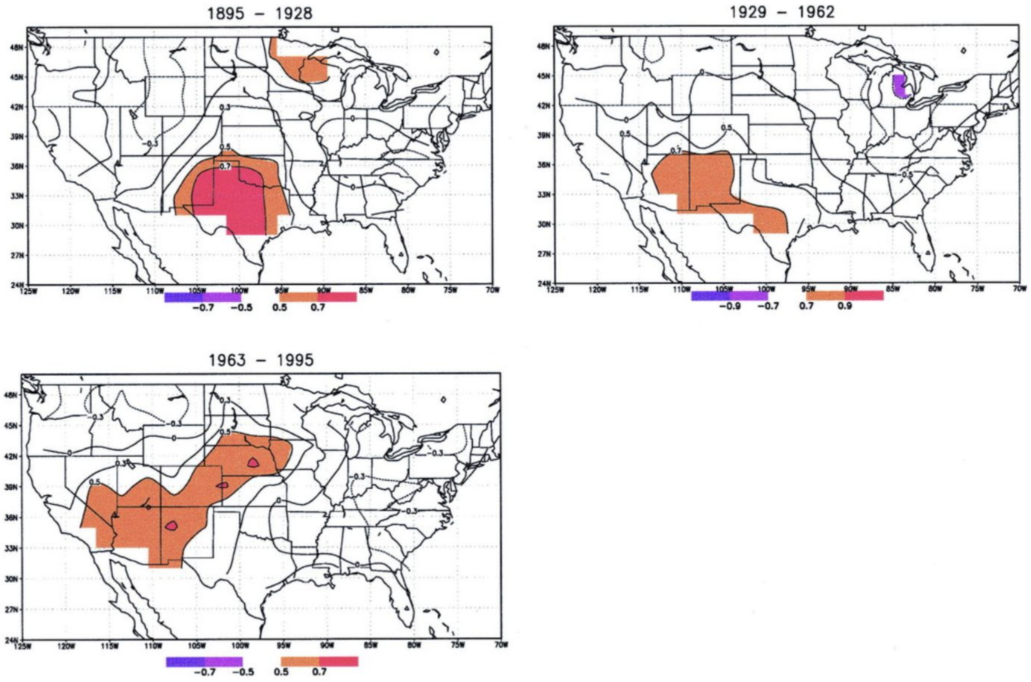


Figure 11. Climate regions monthly rainfall ENSO-detected impacts. Figures to the left show total rainfall for the month, figures to the right show rainfall actual impacts. May (a, b), August (c, d), September (e, f), October (g, h), and December (i, j). Uncoloured regions on the right figure mean no significant statistics at 0.05.

Previous Research

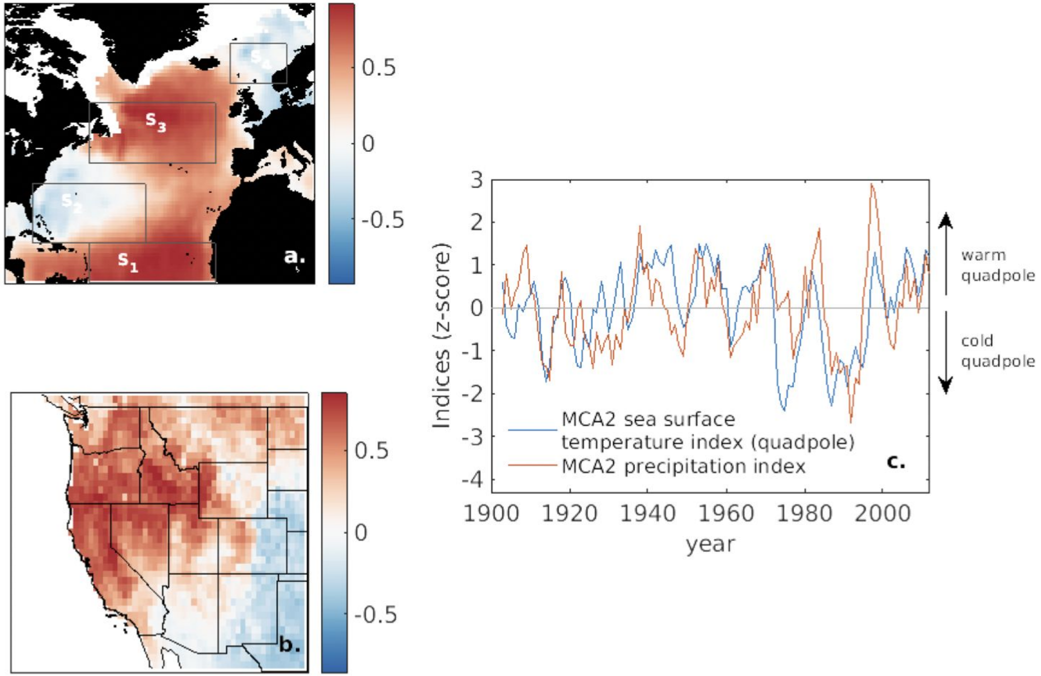
-Different regions have different teleconnections, and the Upper Colorado River Basin is better predicted by the North Temperate Pacific East-West Dipole than the Traditional ENSO Region (Zhao et. al., 2021)

-Regional correlations with El Nino vary on a decadal level due to both decadal oscillations and long-term shifts (Rajagopalan et. al., 2000).



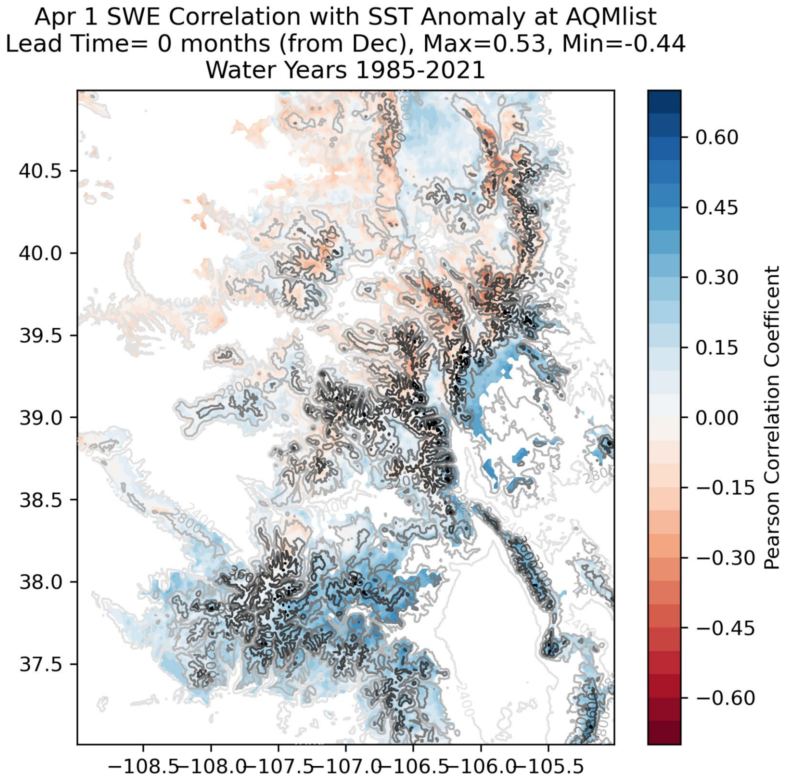
Previous Research

-Prediction can be improved for the Western US, especially the mid-latitudes with low ENSO correlation, by including the Atlantic Quadpole Moment in prediction. This is because Atlantic pressure patterns affect the trajectory of storms, whether they drift north or south (Strong et. al., 2020).

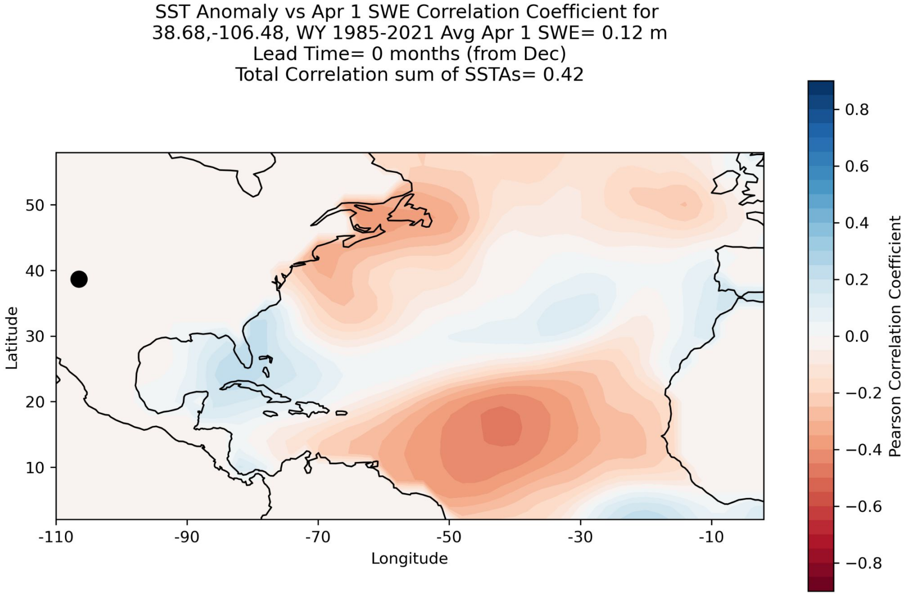


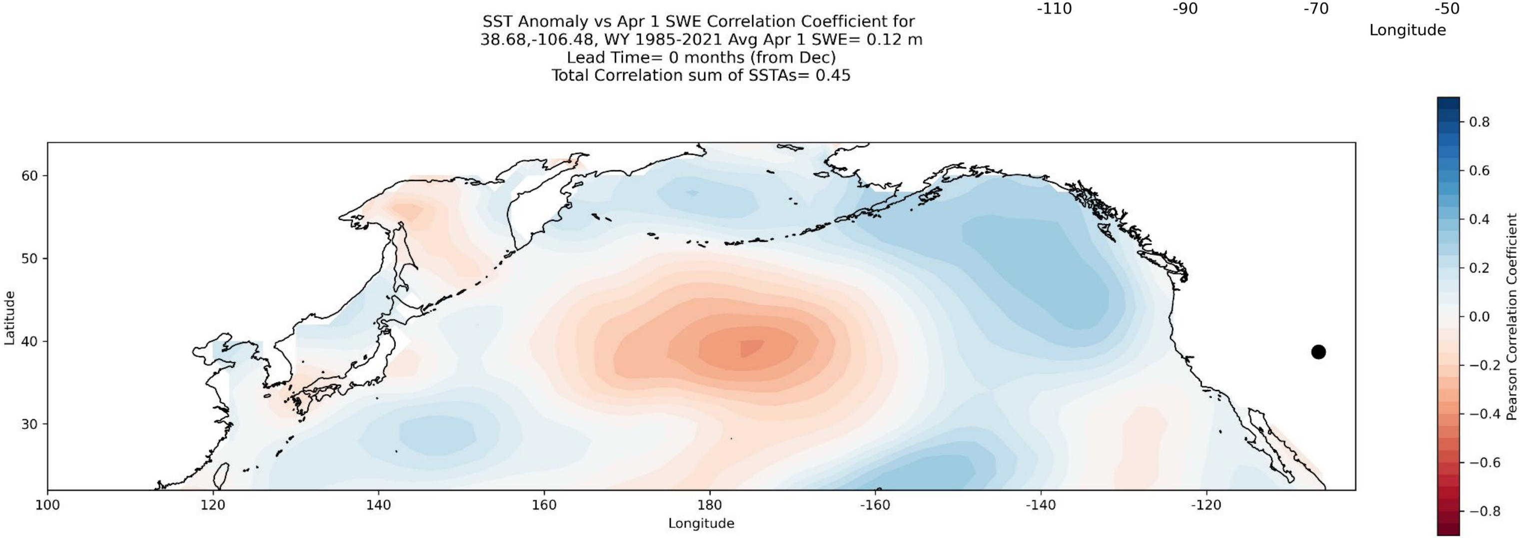
Research Gaps

1. The variation of SST/SWE correlation as a function of elevation and side of a given range.
2. The variation in the location of prediction centers by immediate location.
3. How to best integrate the above information with temporal shifts in location and strength of prediction centers.

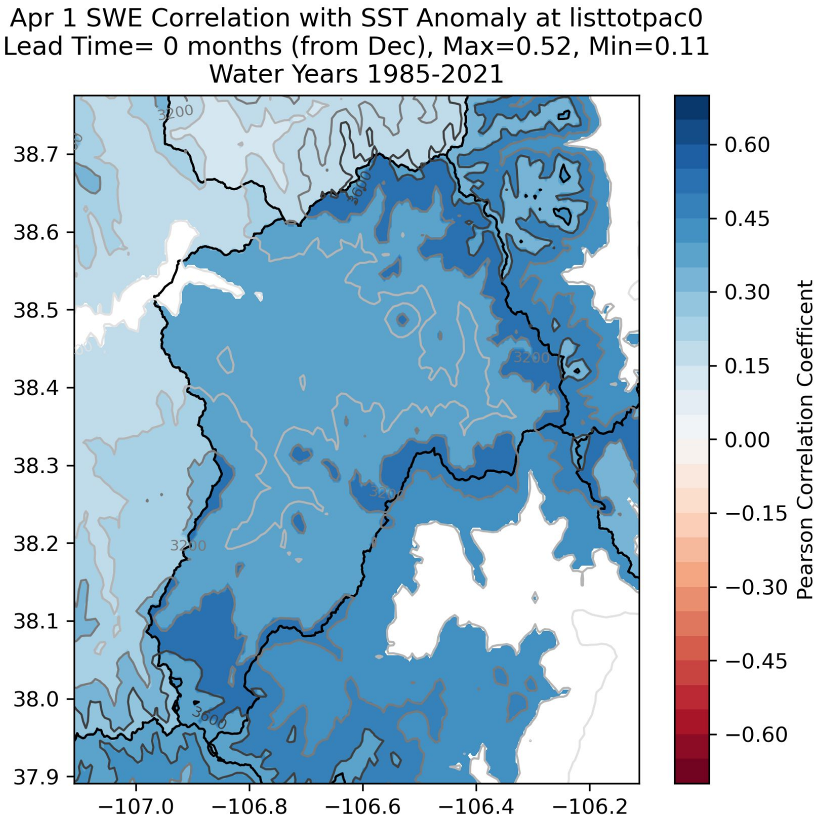


Tomichi Watershed Correlation between Apr 1 SWE and Dec SST anomaly

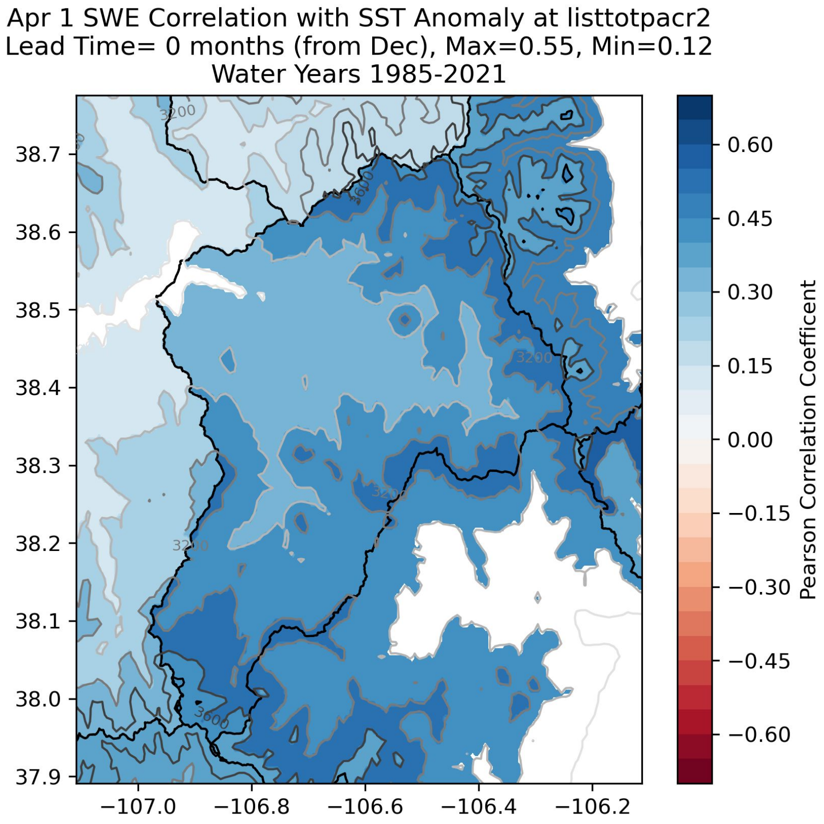




Research Updates

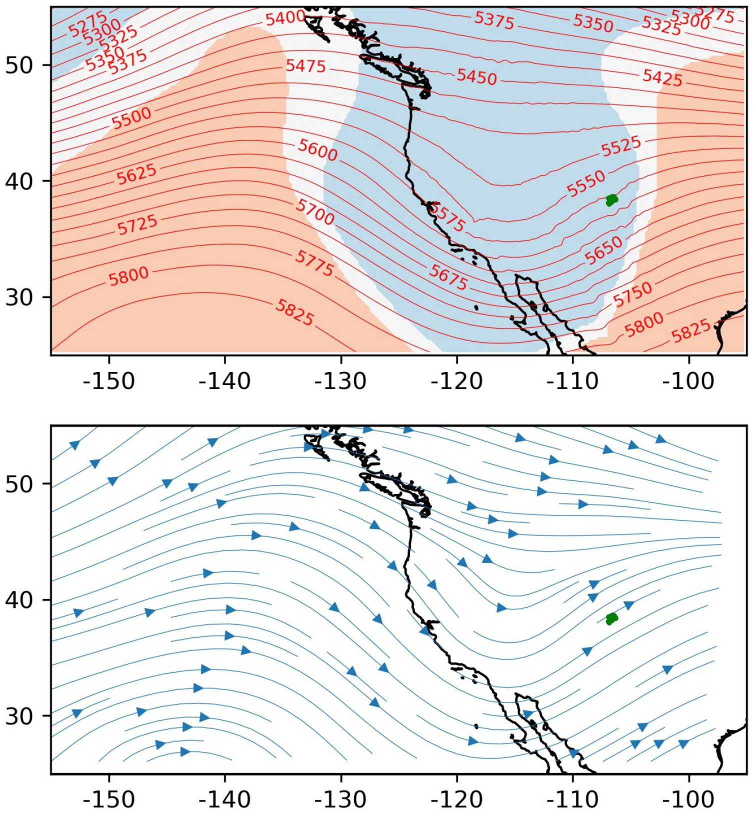


R(Apr 1 SWE, Dec SSTA)

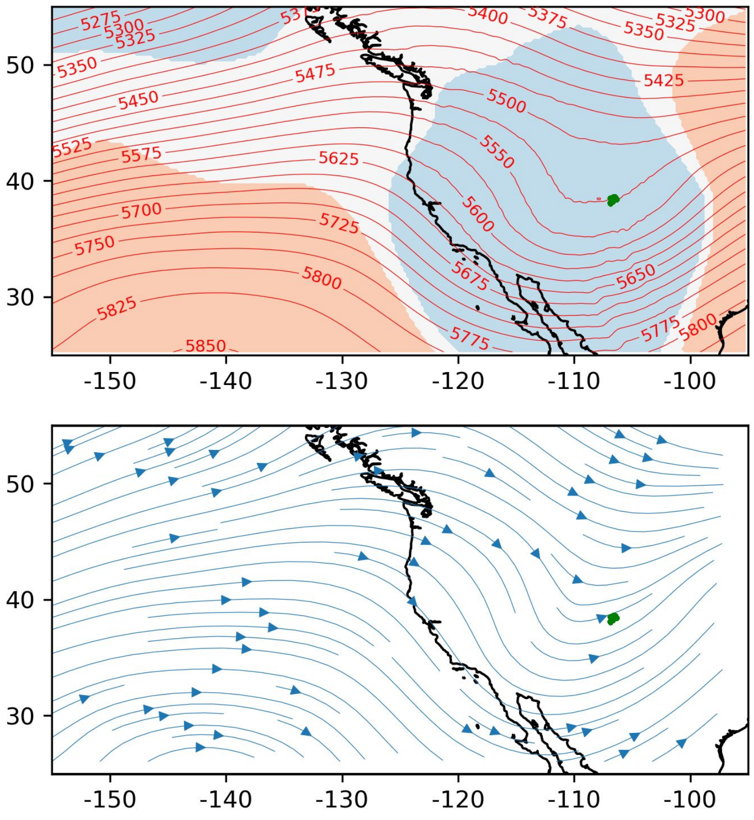


R(Apr 1 SWE, Dec SSTA (factored by R2))

Physical Mechanisms

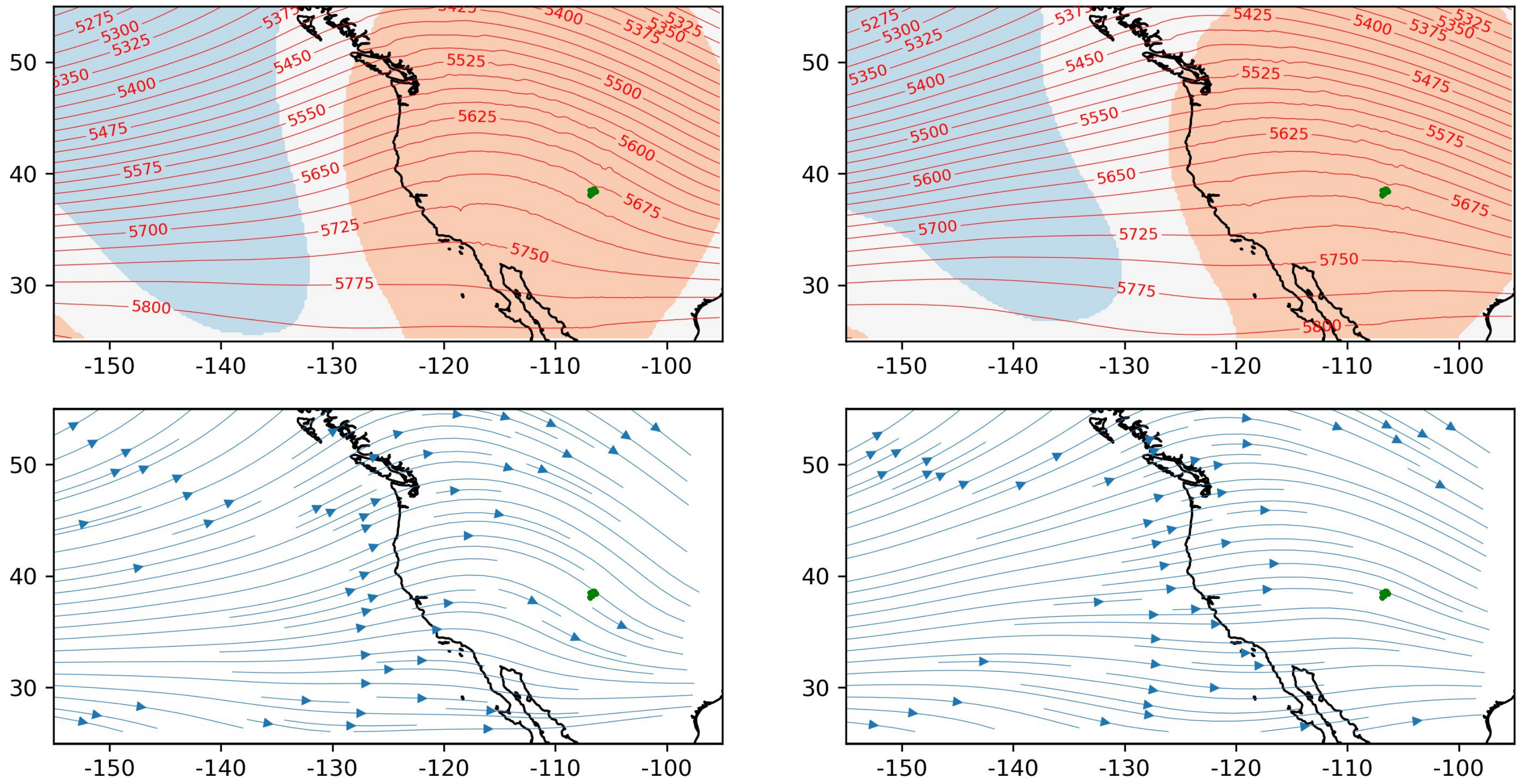


500 hPa accum- prev day



500 hPa accum- same day

Physical Mechanisms



500 hPa no accum- prev day

500 hPa no accum- same day

Next Steps

-Analyze ocean correlations and wind and geopotential patterns for SWE accumulation for various watersheds in Colorado, Utah and California.

-Analyze ocean pattern effect on wind and geopotential patterns as well as cyclone tracks.

-Compare degree of similarity for pairs of mountain slopes across North-South and East-West Divides.

-Quantify significance of Pacific and Atlantic teleconnections for elevation bands within and across watersheds.

-Incorporate Decadal Oceanic Oscillations in above.