Ridging associated with drought in western US: characteristics, trends and predictability

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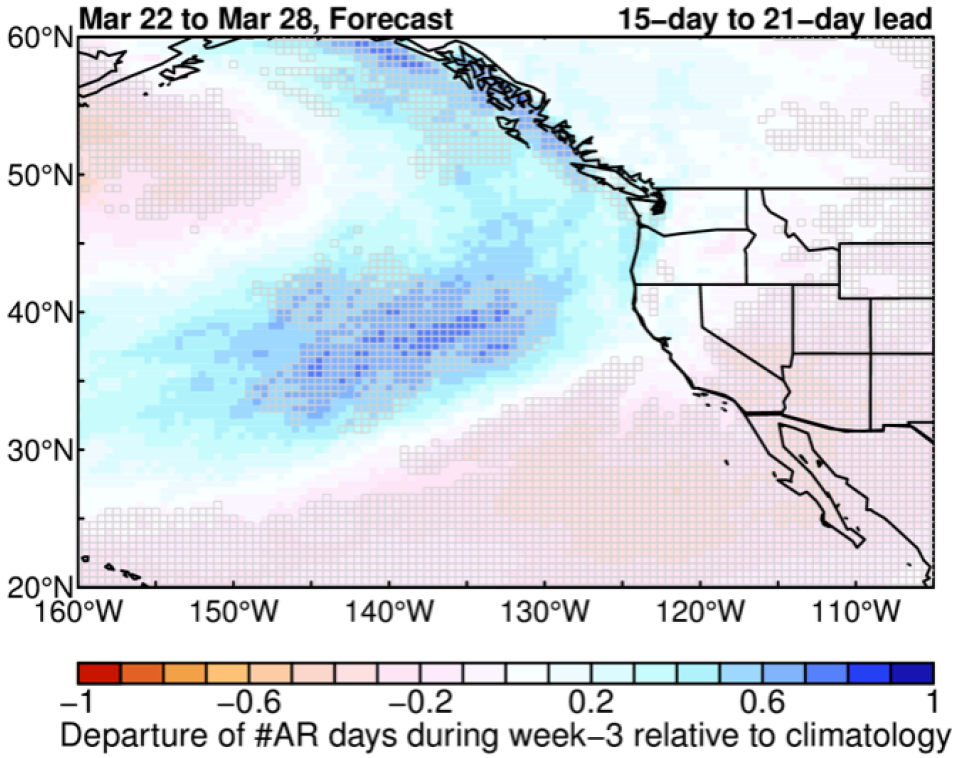
Motivation and background

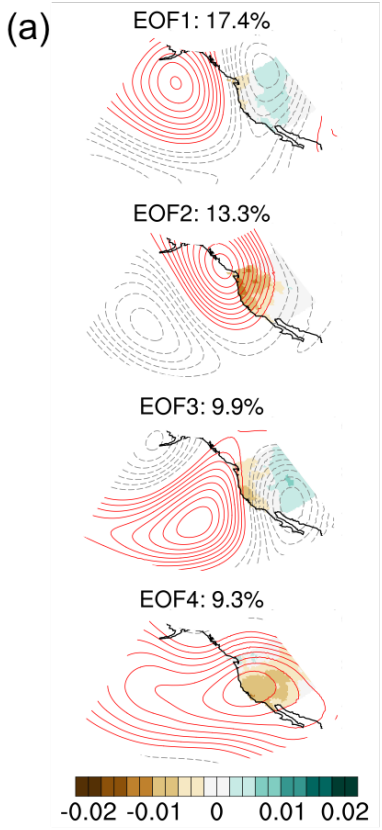
- JPL/CW3E/DWR has been working on assessing and implementing operational forecast products for atmospheric rivers (ARs)
- This approach is now being extended to forecasting **atmospheric ridging events** (i.e. conditions associated with rainfall deficits)
- ***Potential for*** models to have better skill in S2S range for ridges compared to ARs themselves (but remains to be tested/quantified)

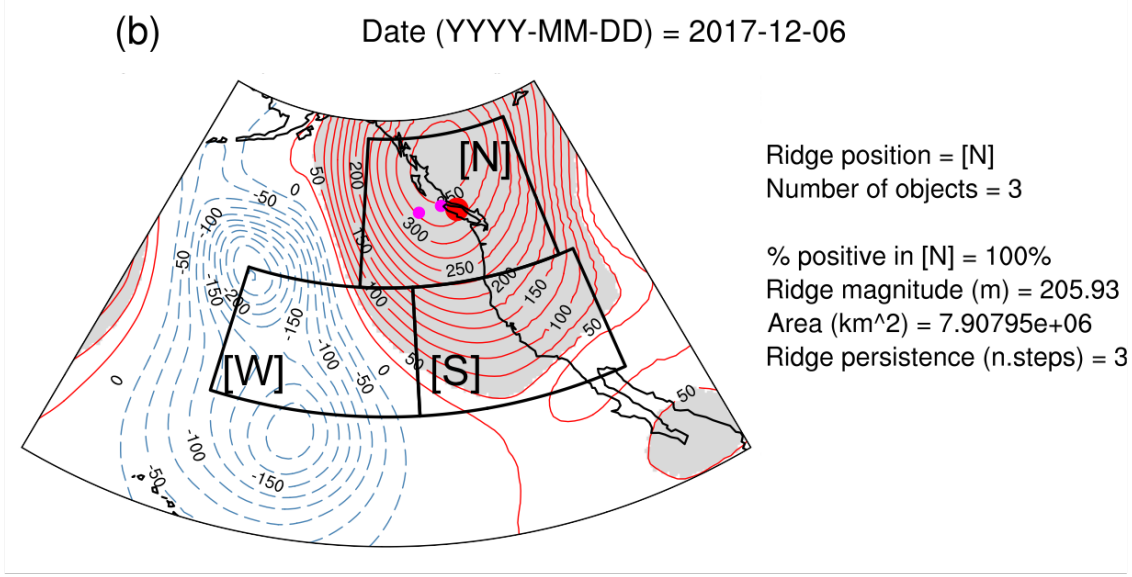
EXPERIMENTAL week3: ECMWF (51-member)



Ridge detection algorithm

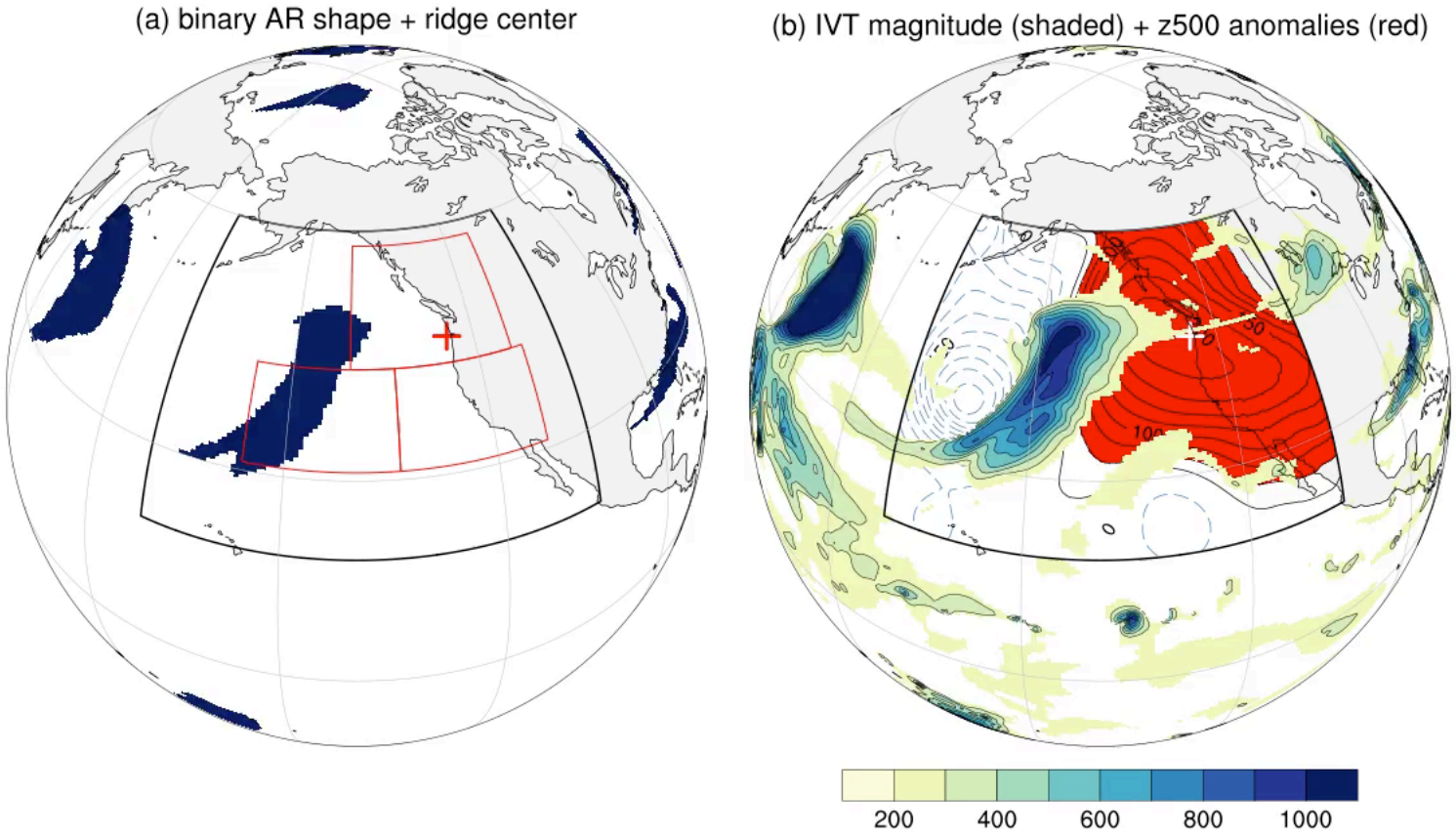
- Applied on daily z500 anomalies from MERRA-2
- Reports the *magnitude, extent, location, persistence* of large z500 anomalies > 50m
- Outputs information with respect to 3 regions: N,S,W
- Ridge occurrence is 'counted' for region if anomaly covers > 75% of domain



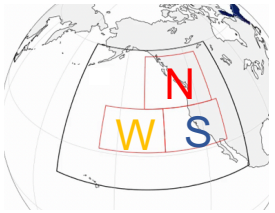


Tracking ridge events and AR events concurrently

1 Oct 1980



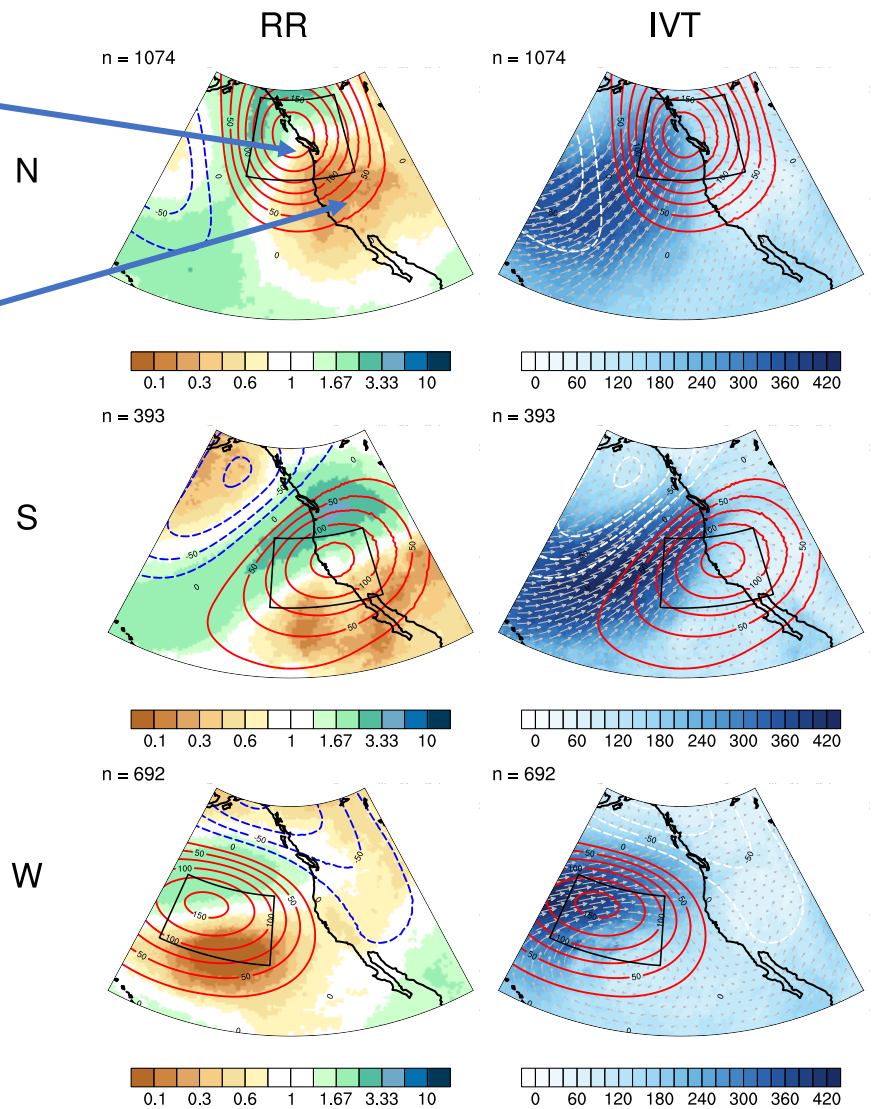
Likelihood (Relative risk) of AR occurrence given Ridge occurrence

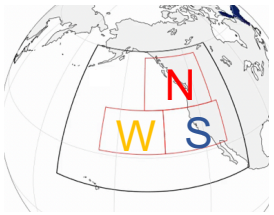


When ridging occurs here

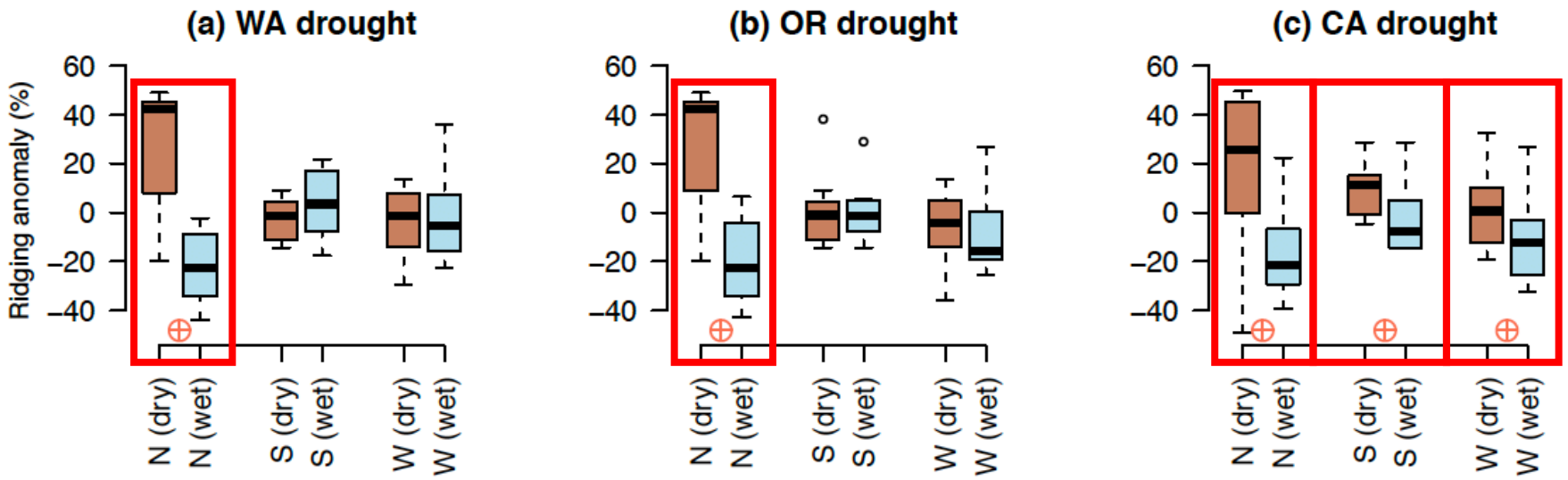
=

Less chance of AR here





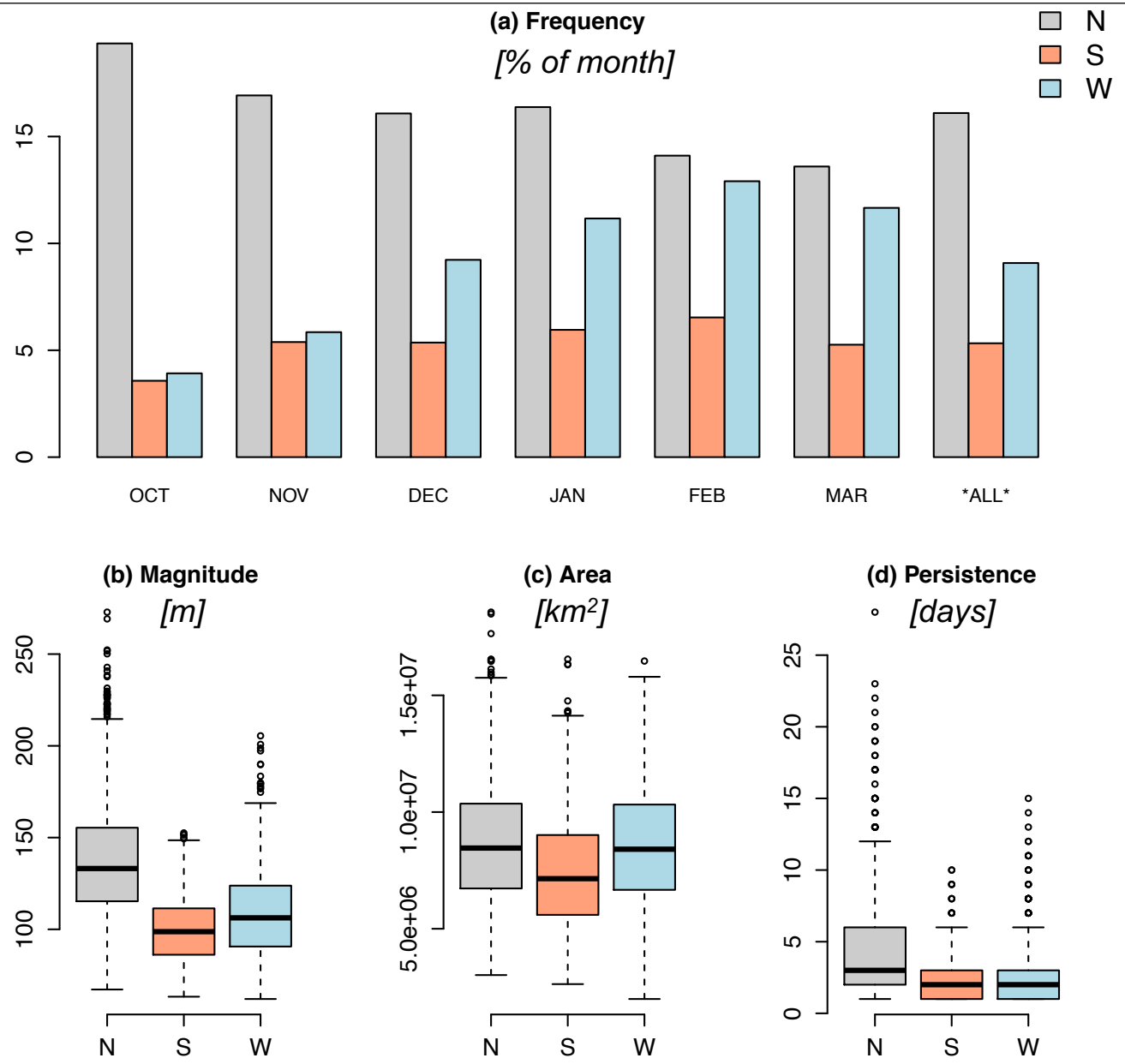
Ridge frequency in a month versus drought (SPI-3, by region)



- In WA, OR and CA, the N ridge is much more frequent during periods of meteorological drought
- S and W ridge are less relevant to WA and OR

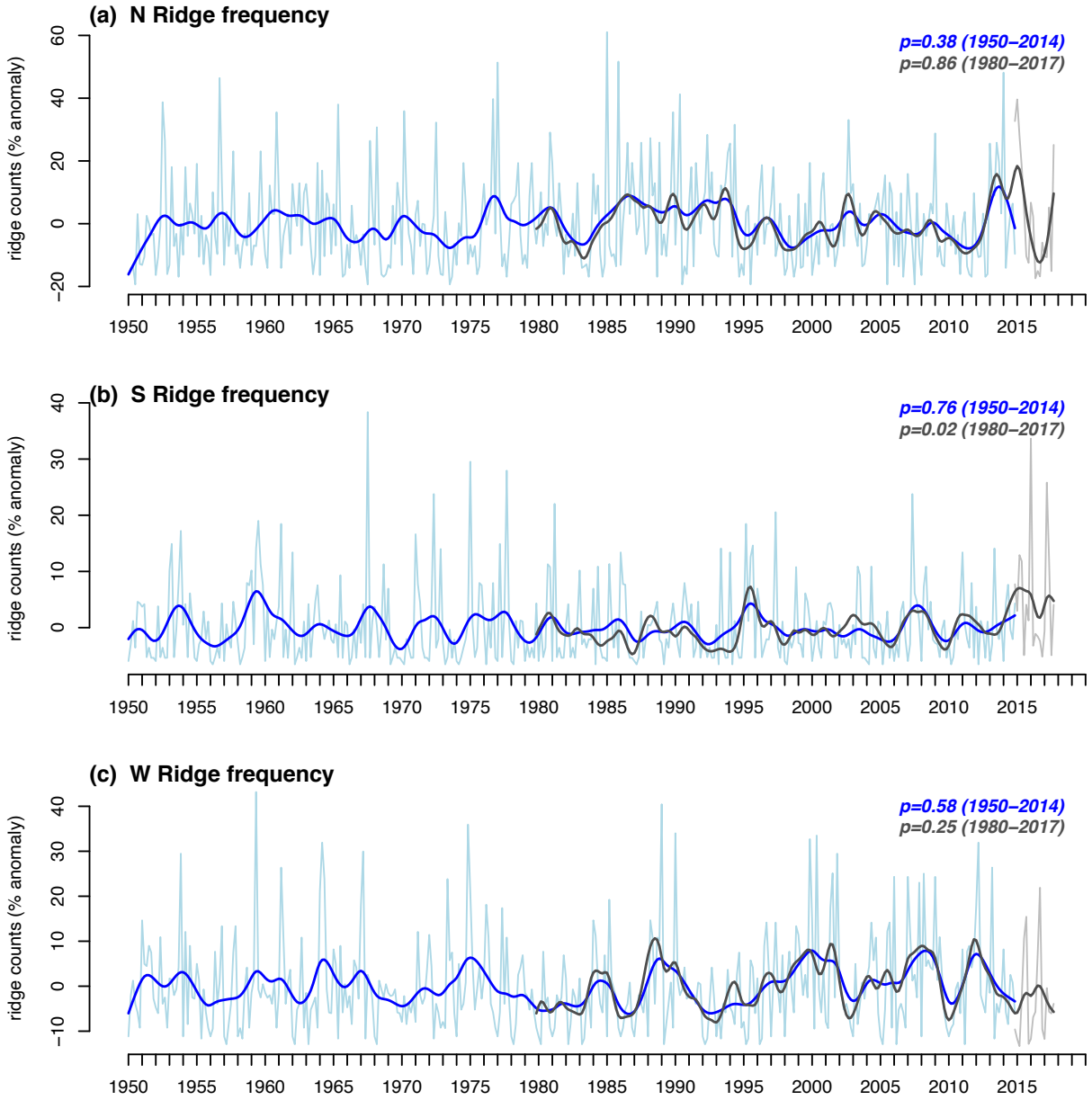
General ridge characteristics

- A reasonable amount of within season variability for frequency over ONDJFM months
- N Ridge tends to be larger and more persistent

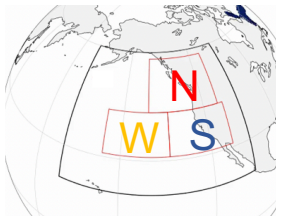


Trends in ridging frequency?

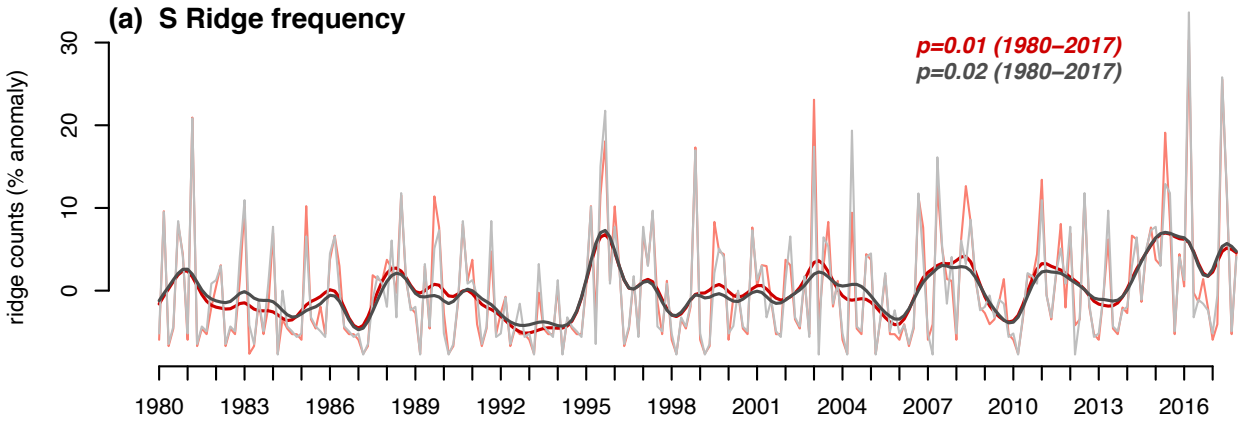
- Trends computed via Mann-Kendall, controlling for AC
- Reasonable agreement between reanalysis in terms of variability (blue = 20CRV2c since 1950; grey = MERRA2 since 1980)
- Only slight evidence of upward trend in S Ridge frequency since 1980 in MERRA-2
- *.....check consistency against ERA-INT?*

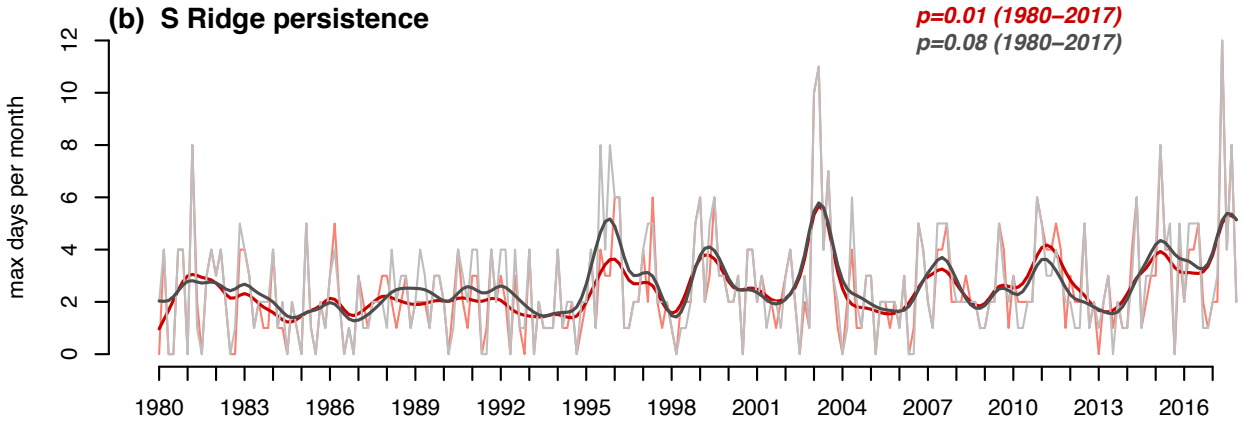


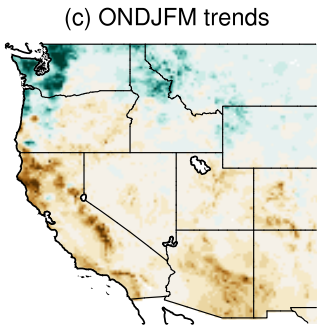
Trends in ridging frequency?

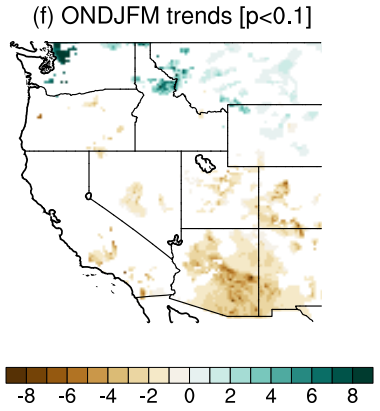


- Additional comparisons with ERA-INT (red) confirm a slight upward trend in S Ridge frequency and persistence



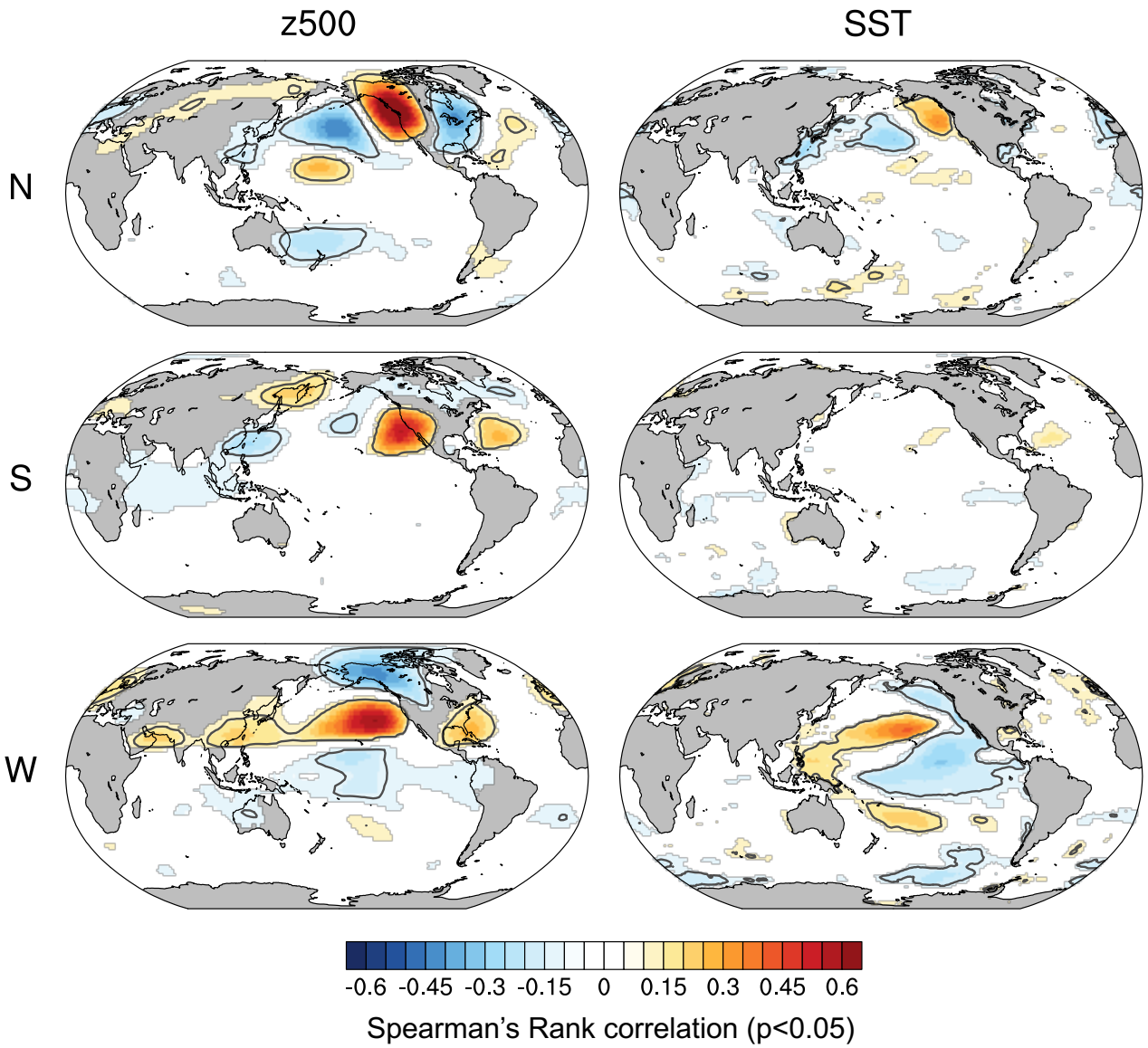






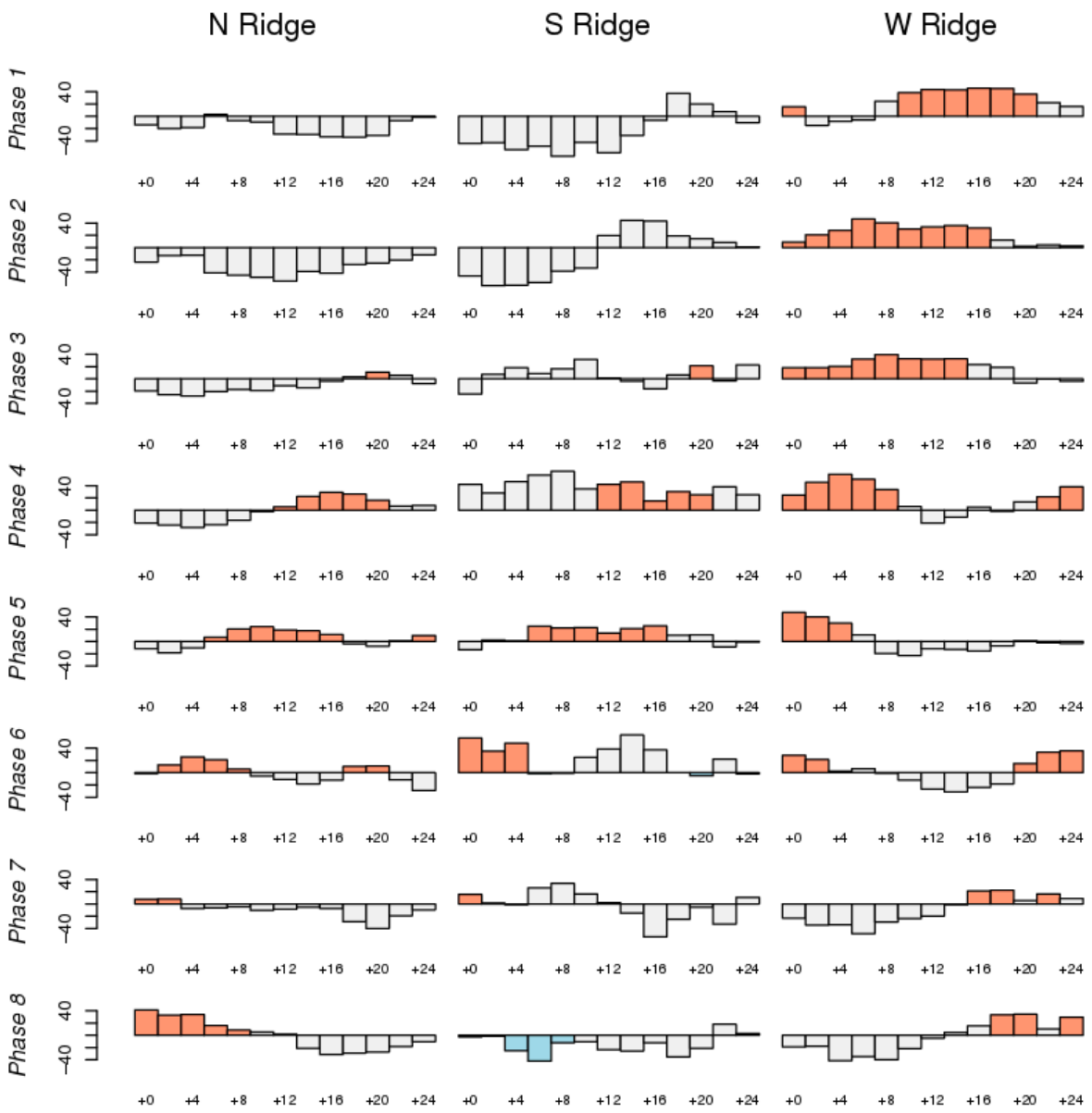
Drivers of monthly frequency variability?

- N ridge is strongly related to a PNA-like/pattern wave-train from the tropics
- S ridge related to a mid-latitude wave train with little relationship to tropics
- W ridge La-Nina/PDO like

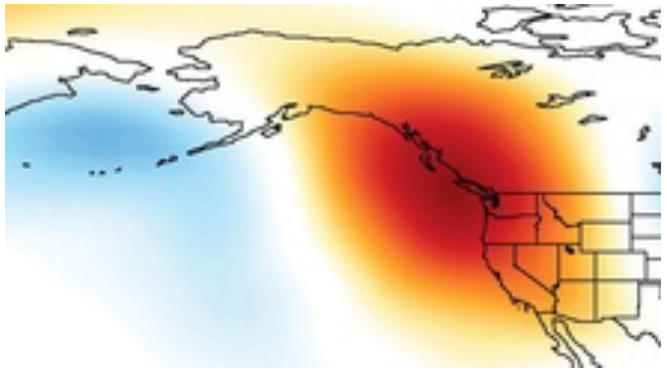


MJO association with Ridge frequency

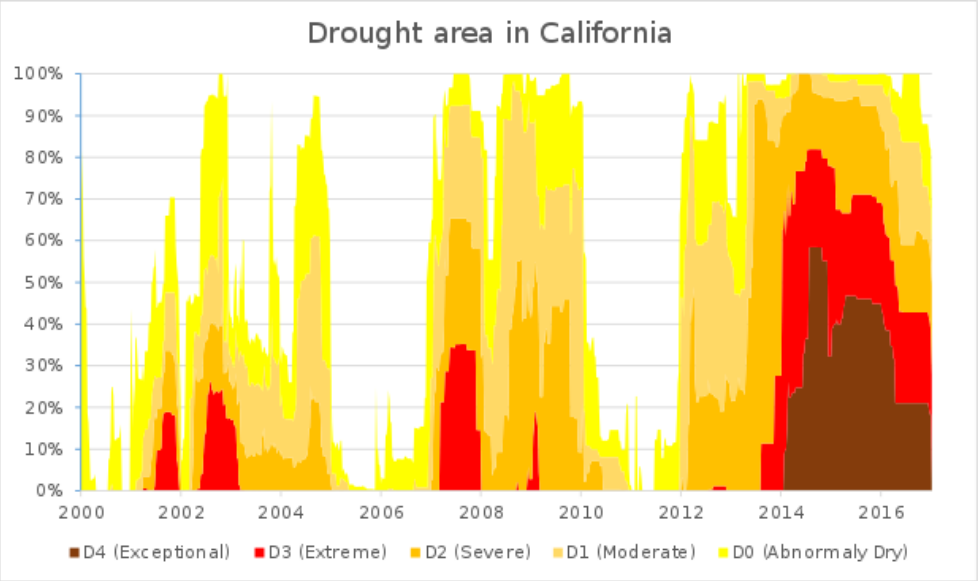
- Potential for MJO to offer probabilistic ridge prediction out to S2S
- MJO phase 1-3 for W Ridge
- MJO phase 4-5 for N and S Ridge



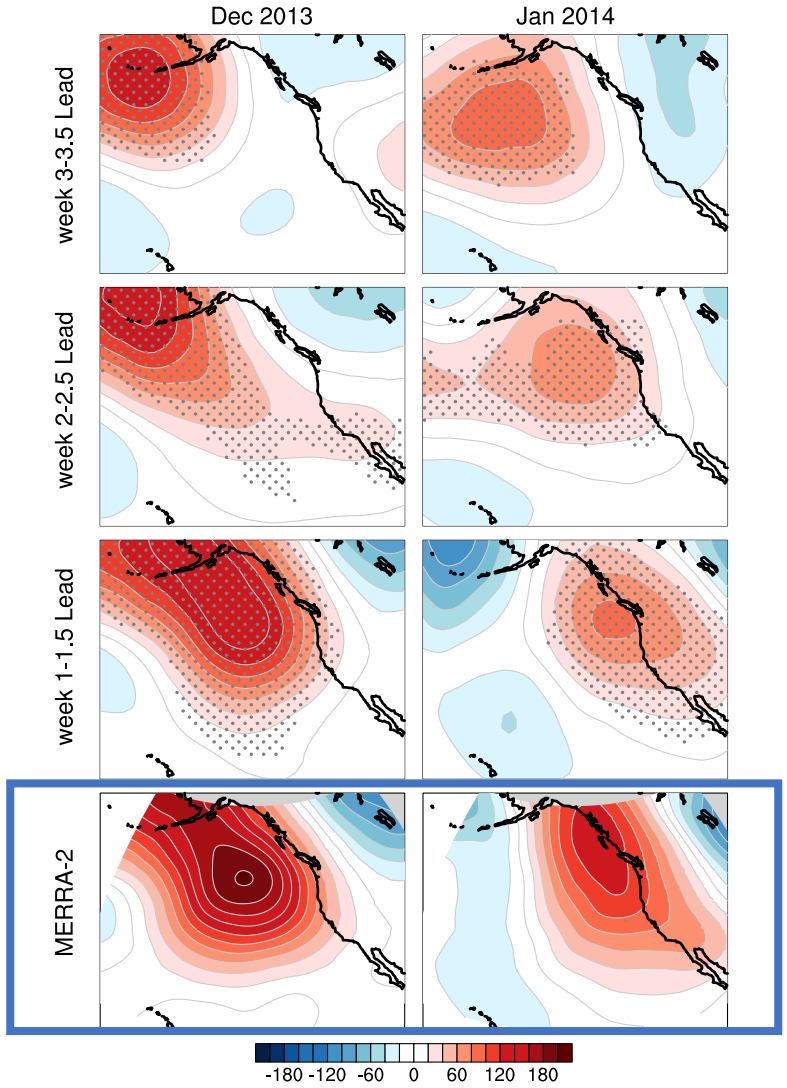
Case Study of ECMWF skill



The '**Ridiculously Resilient Ridge**' January 2014 (90-day running mean 500mb geopotential height anomaly)

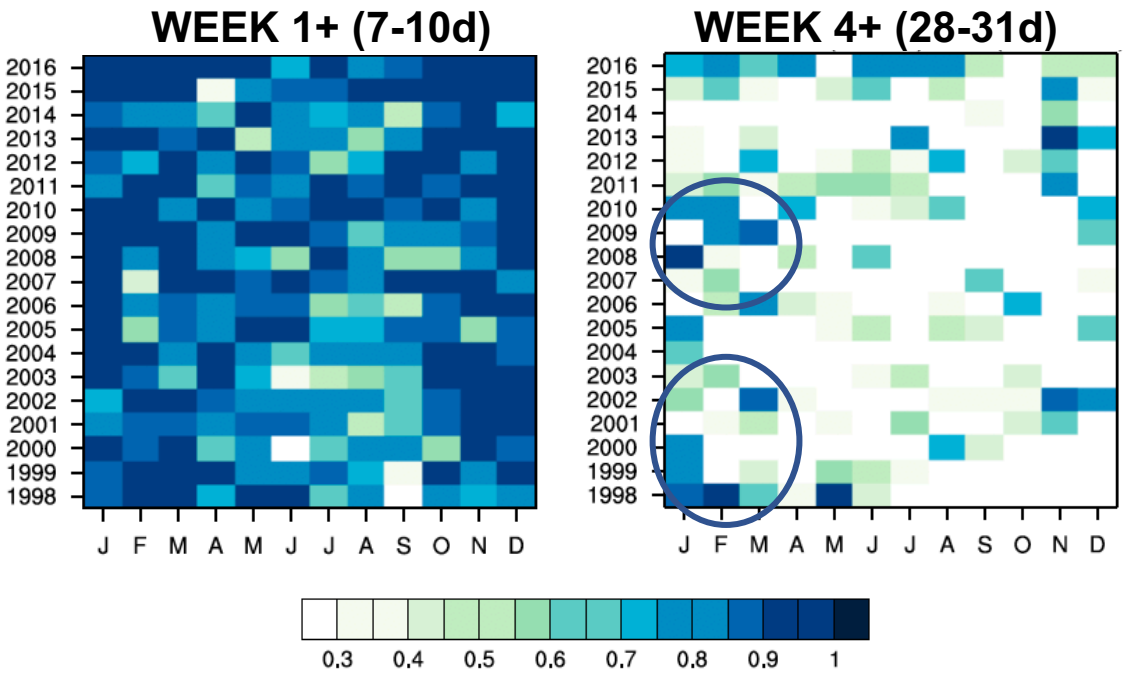


ECMWF (wk1,2,3) z500 anomaly prediction of RRR (dots >90% directional argeement)



ECMWF skill – all years

- As expected week1+ skill is very good (weather forecast skill)
- There are some select months where the week 3 and 4 forecast is fairly good (ACC > 0.7)
- This is for 1 model only (other models might do better/worse in this region)



Summary

- There are different ‘flavors’ of ridging that impact W/SW United States differently
- They influence ARs, precipitation and drought likelihood
- Different flavors of ridging have different characteristics and trends (or lack of)
- They have different opportunities for S2S based on our analysis of their drivers

Ongoing work

- Quantify hindcast **prediction skill** from S2S/SubX ensemble of models
- Prediction skill in terms of (a) broad time-averaged z500 patterns (b) counts of ridge occurrences
- Can prediction skill be improved through ML by combining models and observations is a more optimal way?
- Experimental week3+ forecast products for CW3E website to benefit DWR and CPC week3/4 outlook discussions

Supplementary Slides

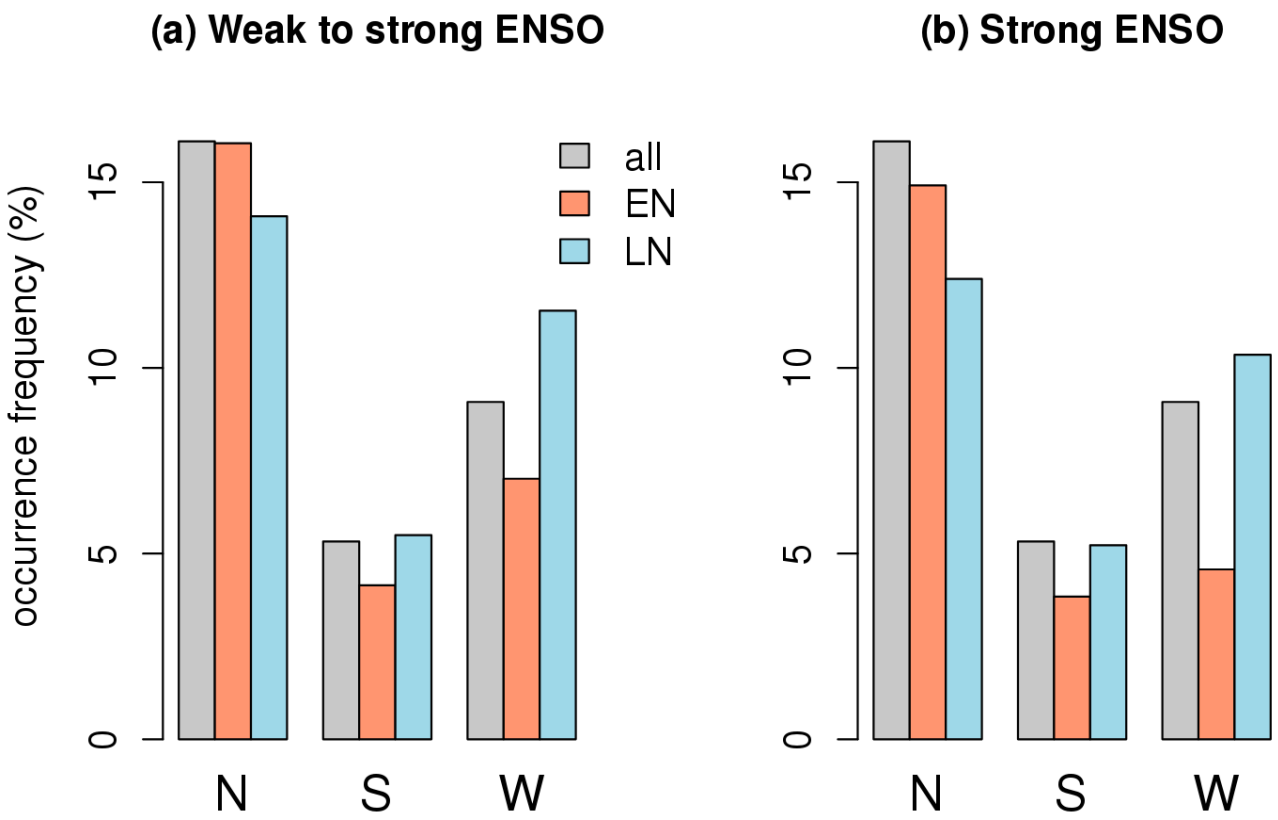


Figure 8: Ridge frequency by ESNO phase for (a) weak-to-strong ENSO events and (b) strong ENSO events. Weak-to-strong ENSO events were classified based on a monthly SOI threshold of 7. Strong ENSO events are classified based on a 3-monthly mean SOI threshold of 10.

Supplementary Slides

Extreme ridge event occurrences

- Find days where ridge exceeds the 90th percentile of magnitude and persists for 3+ days
- Analyze composites of wave activity flux, tropical precipitation, velocity potential
- Analyze composites w.r.t onset (t=0), first 3 days (t=0-3), maturity (t=time of 90th percentile)

$$\mathbf{W} = \frac{p}{2|\mathrm{U}|}\begin{pmatrix} U(\psi_x'^2 - \psi'\psi'_{xx}) + V(\psi'_x\psi'_y - \psi'\psi'_{xy}) \\ U(\psi'_x\psi'_y - \psi'\psi'_{xy}) + V(\psi_x'^2 - \psi'\psi'_{yy} \end{pmatrix}$$

- WAF = Vector quantity that describes the approximate path of a Rossby wave packet

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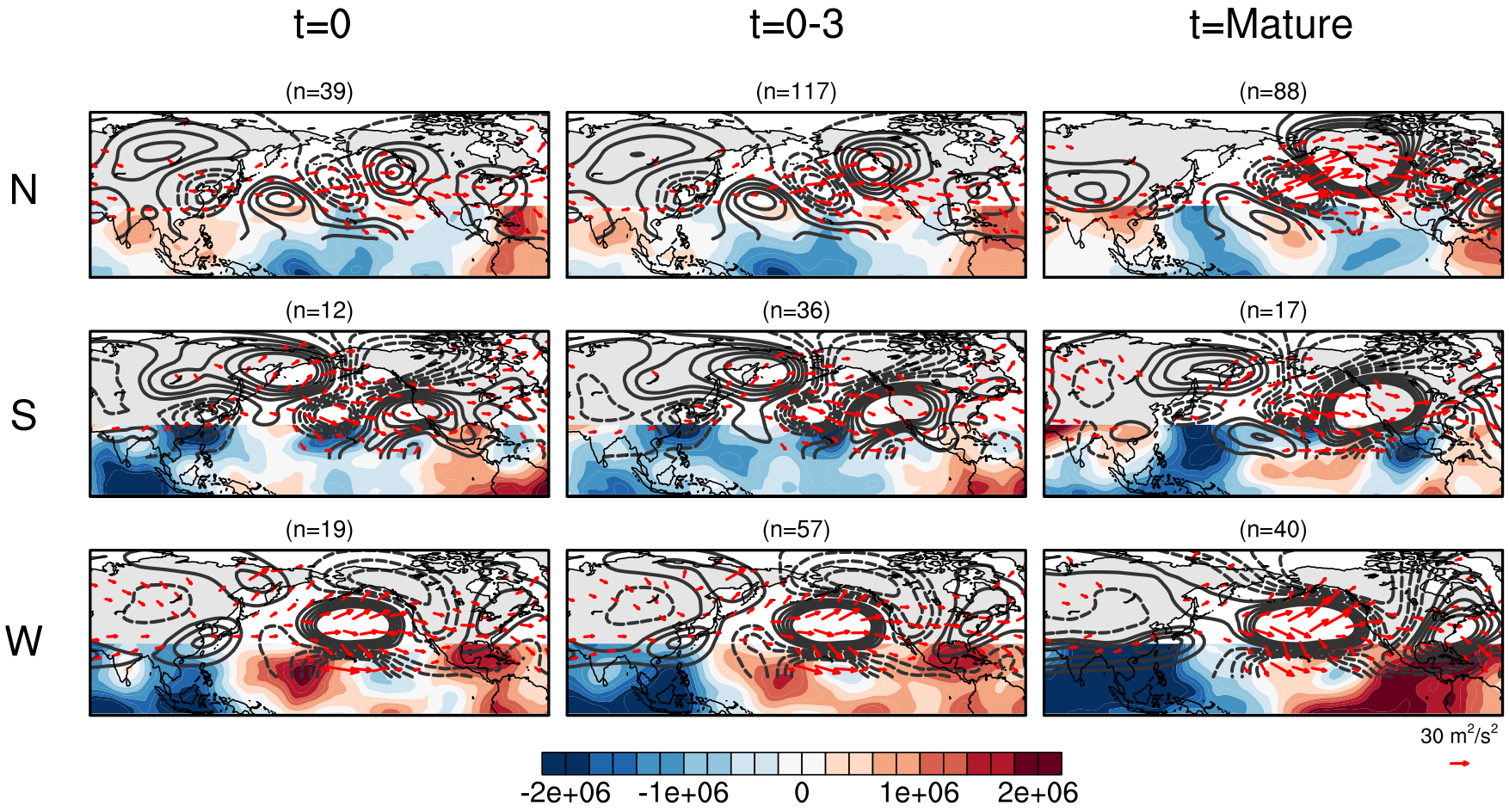
Extreme ridge event occurrences



- Contours are 250hPa stream function anomalies
- Arrows are Wave activity Flux
- Shading are 250hPa velocity potential anomalies (-ve = enhanced deep convection)

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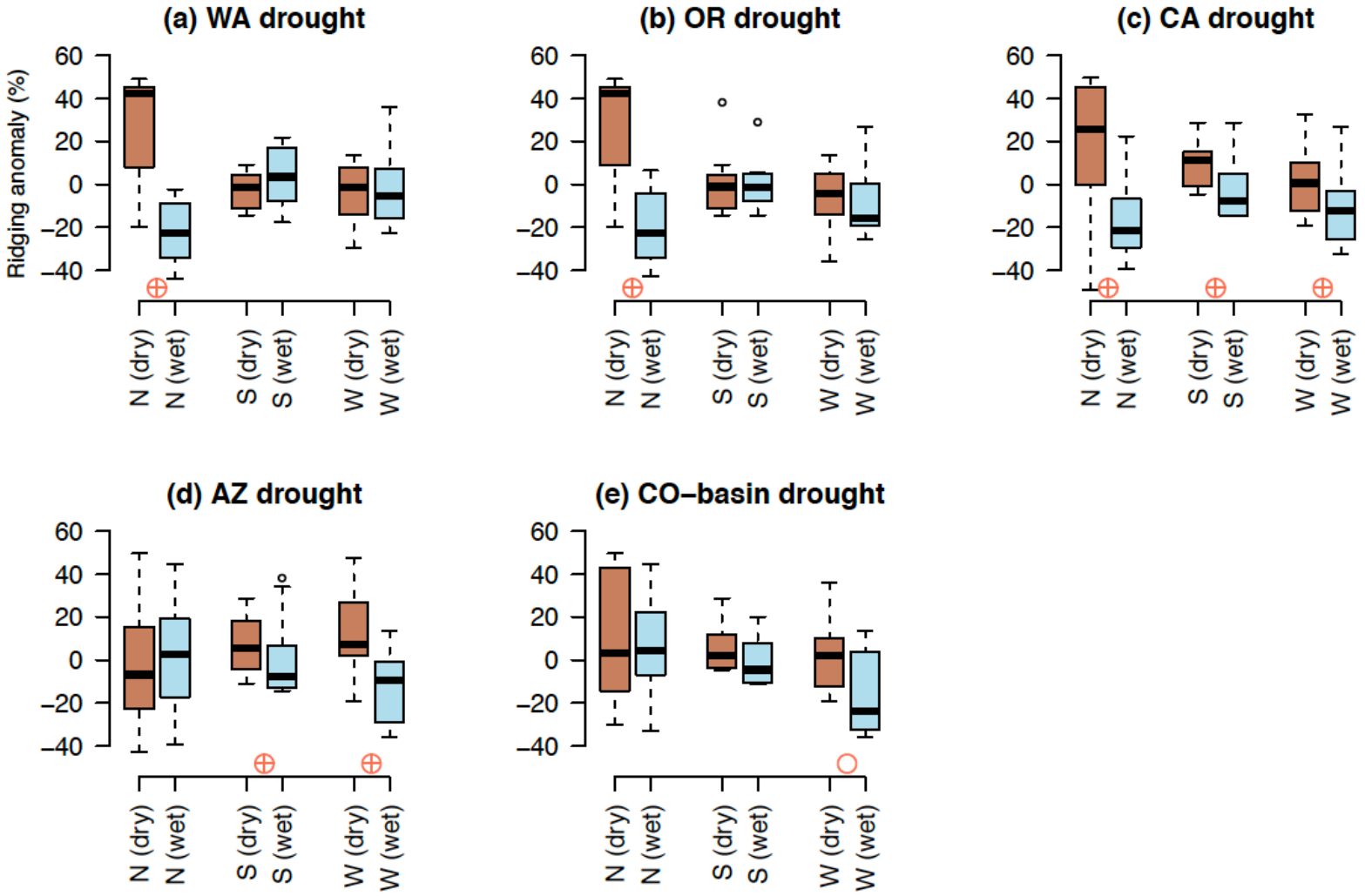

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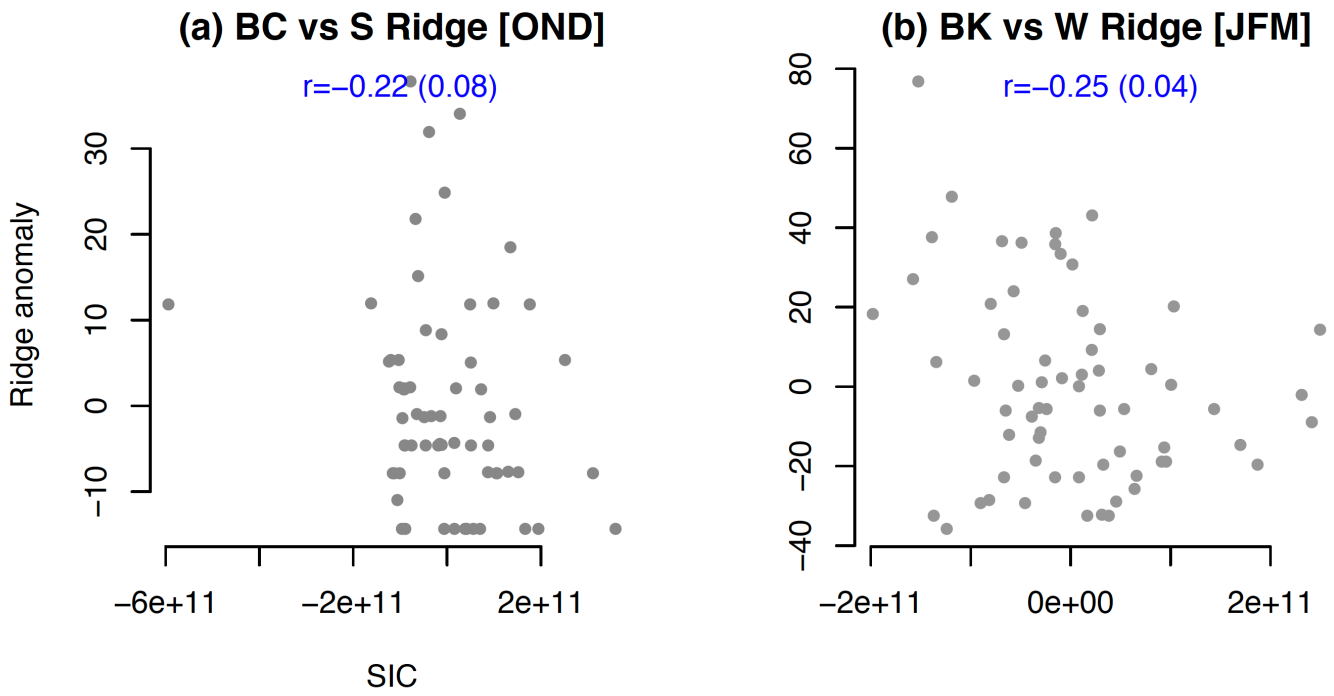

Figure S5: Scatterplot of sea ice concentration anomalies (SIC) (see section 2.1) and ridging anomalies (% frequency) for the Bering/Chukchi region (BC) and Barents/Kara region (BK) over months OND and JFM. Only the strongest correlations are shown here from all ridge types and seasons examined. Pearson's r (p-value) are shown in blue.