Jet Propulsion Laboratory
California Institute of Technology

Center for Western Weather and Water Extremes

Characteristics and predictability of US West Coast atmospheric ridging events

NOAA 43rd Climate Diagnostic and Prediction Workshop

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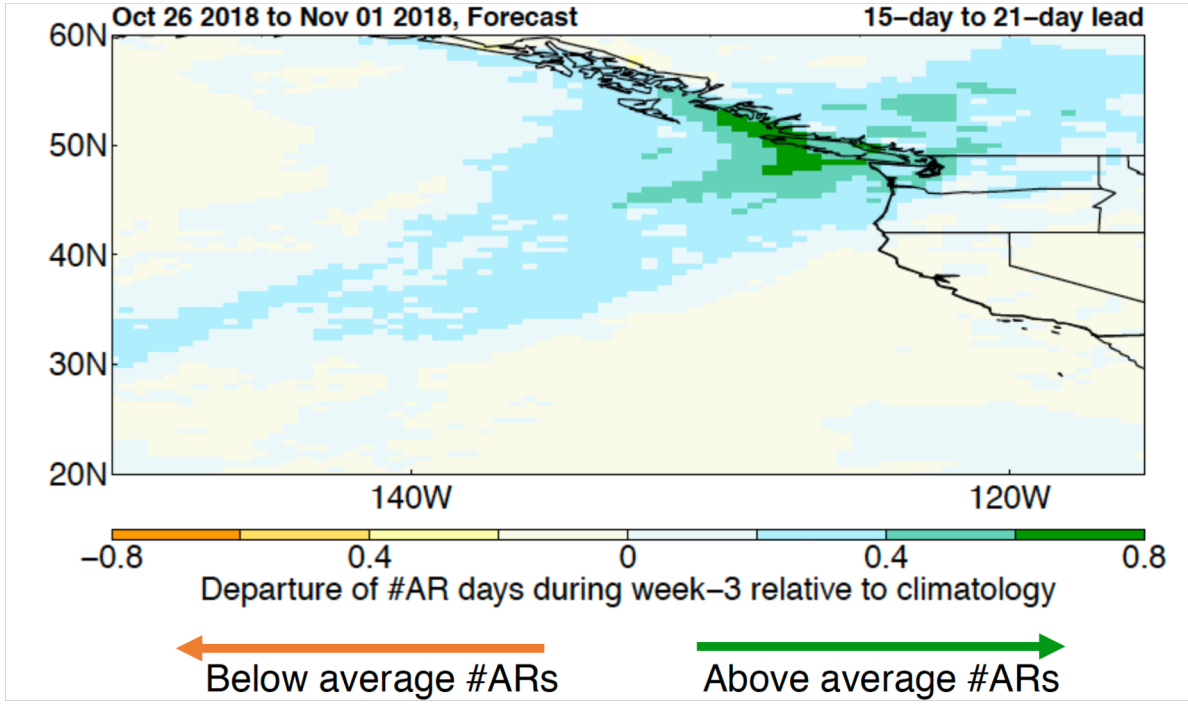
Scripps CW3E: Marty Ralph, Aneesh Subramanian, David Pierce

California Department of Water Resources (DWR): Jeanine Jones

Motivation and background

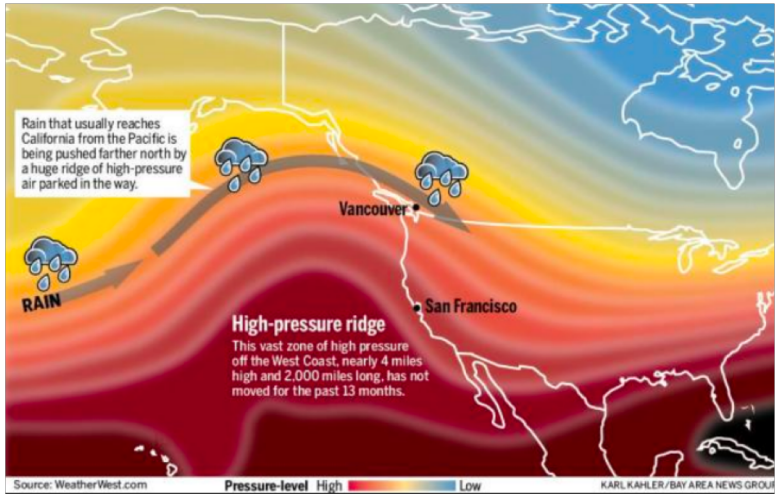
- JPL/CW3E/DWR has been working on assessing and implementing operational forecast products for atmospheric rivers (ARs) – ***Mike DeFlorio talked on this morning***
- Goal to contribute to suite of operational AR products disseminated by CW3E for DWR
- This approach is now being extended to forecasting **atmospheric ridging events** (the conditions associated with rainfall deficits)
- *Potential for* models to have better skill in S2S range for ridges compared to ARs (but remains to be tested/quantified)

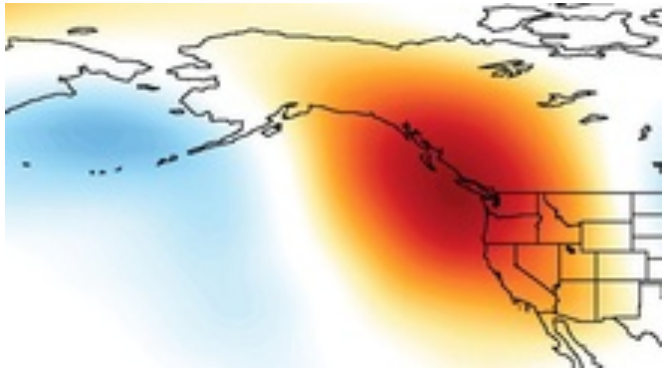
EXPERIMENTAL week3: ECMWF (51-member)



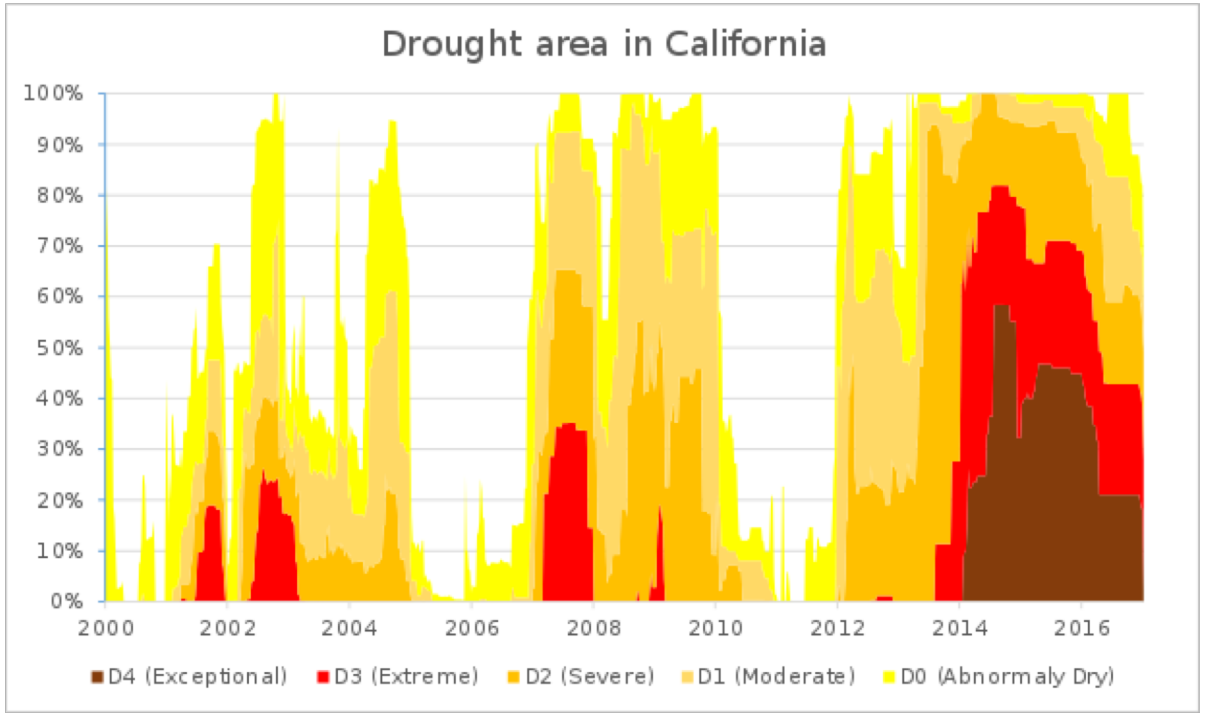
Winter ridge events influence where and how it rains

- Synoptic-scale ridging events in winter off the west-coast of USA
- These ridge events are known to divert ARs and other rain-bearing systems away from CA



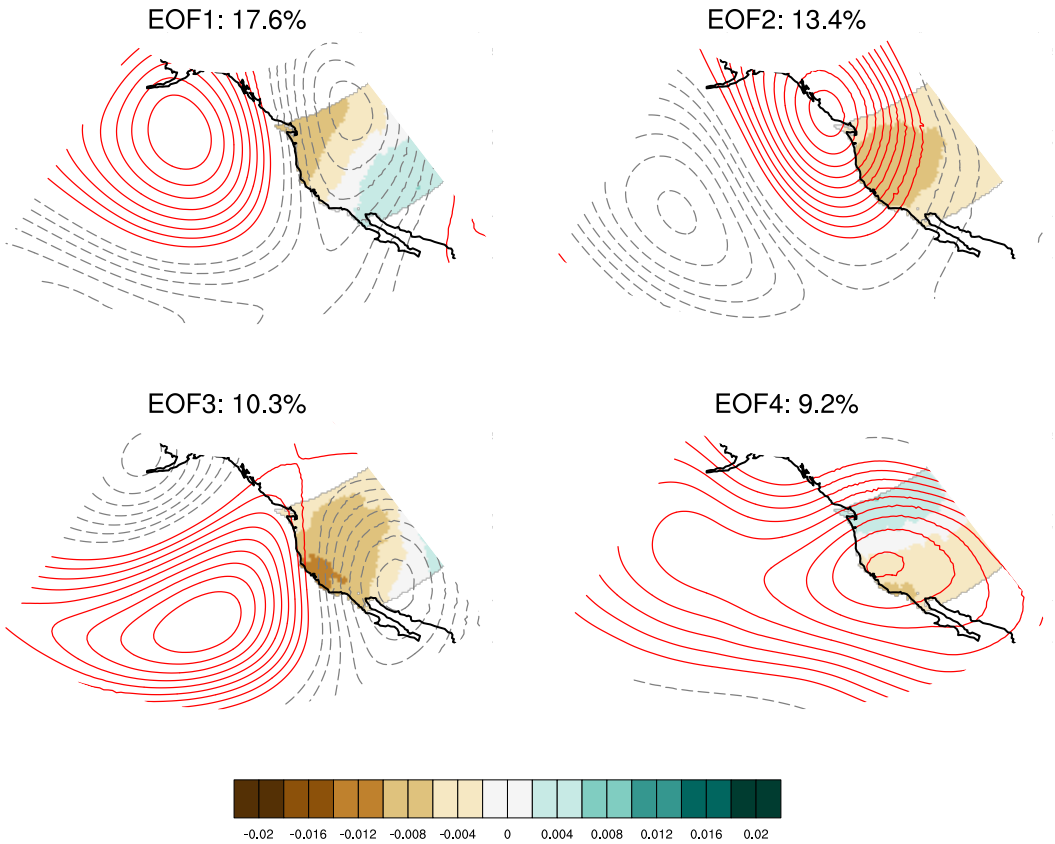


The '**Ridiculously Resilient Ridge**' January 2014 (90-day running mean z500 anomaly)



https://droughtmonitor.unl.edu/

Combined EOF: daily z500 anomaly with **daily AR IVT magnitude** (ONDJFM months)



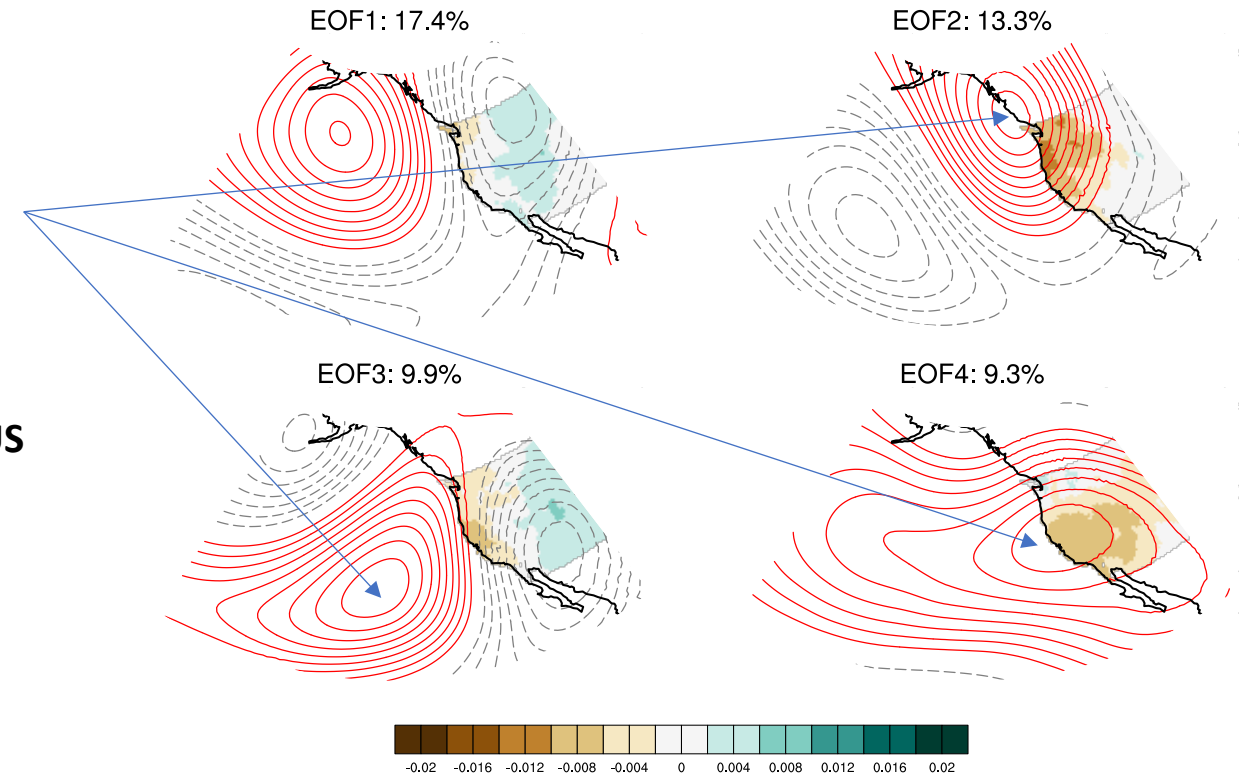
Use combined EOFs here to investigate the primary ridge locations that are associated with atmospheric river (AR) deficits

- Details 4 primary ridge locations of importance
- EOF4 resembles the semi-permanent North Pacific High responsible for dry California summers

$$\mathrm{IVT} = \frac{1}{g}\int_{p_{\mathrm{sfc}}}^{100\,\mathrm{hPa}} q\mathbf{V}\,dp$$

Combined EOF: daily z500 anomaly with **daily precipitation total** (ONDJFM months)

Important locations for ridging, in terms of precip/AR deficits for US West Coast

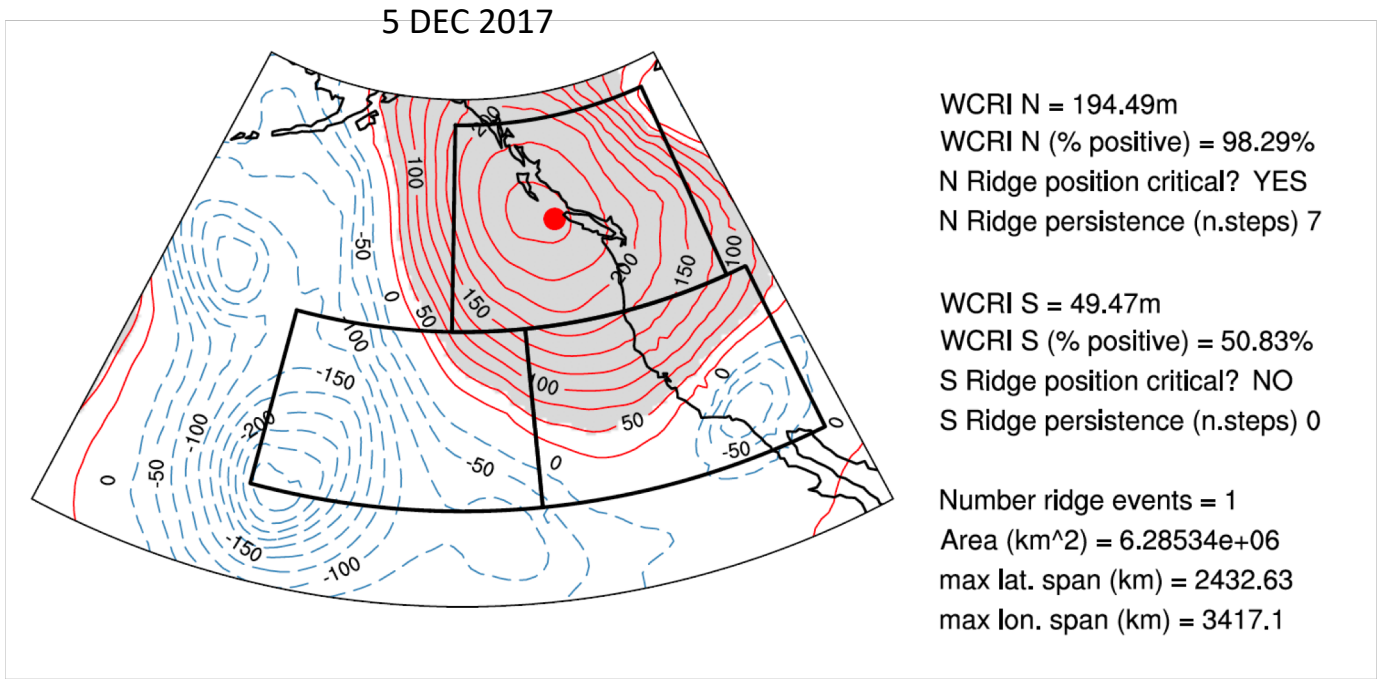


- EOF1 is less important for precipitation deficits in western States
- Suggests that ridge locations depicted by EOF2-4 are most relevant

Plan: use these primary locations to guide a ridge detection algorithm

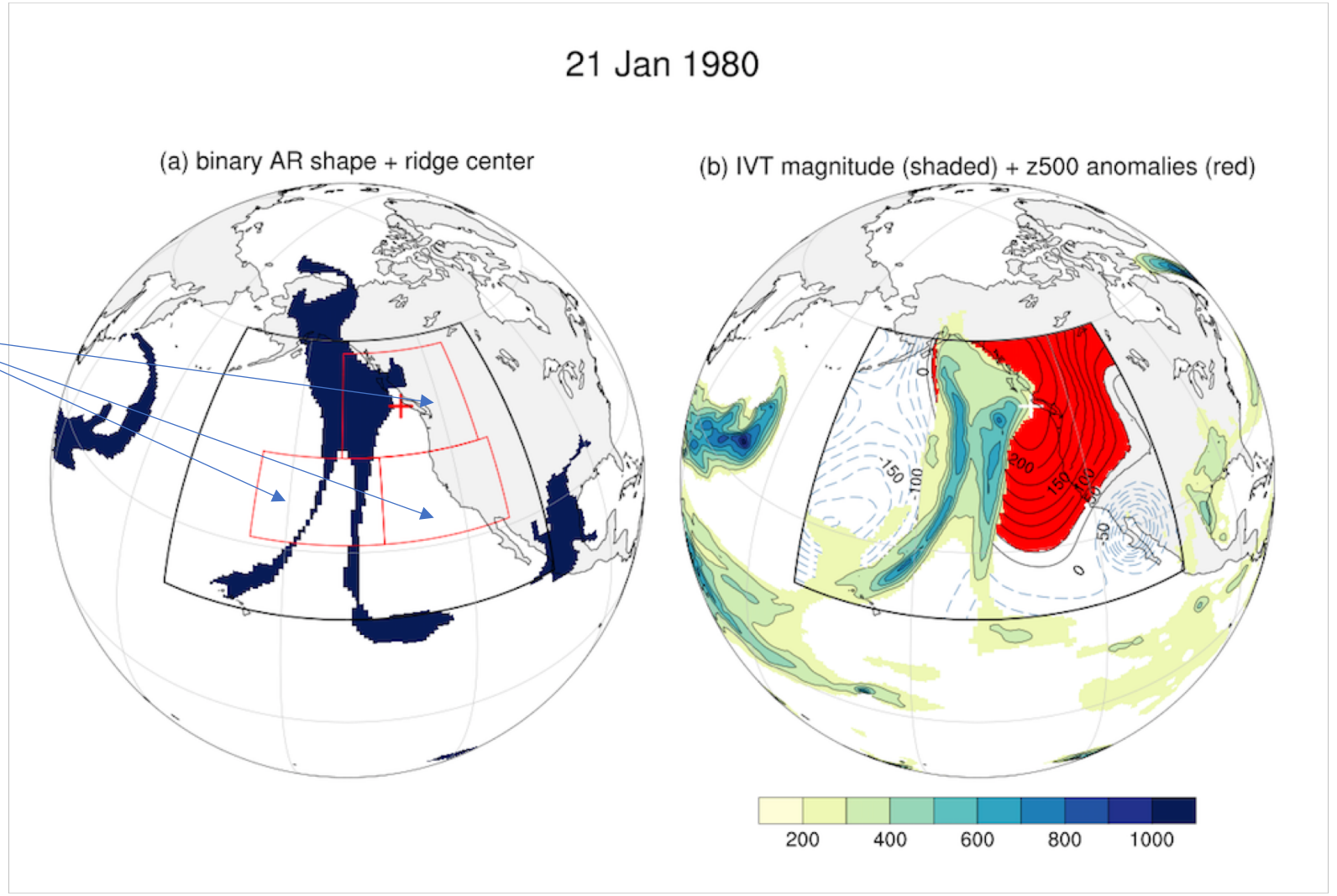
To characterize and quantify: Ridge detection algorithm

- Applied on daily z500 anomalies from MERRA-2
- Reports the *magnitude, extent, location, persistence* of 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



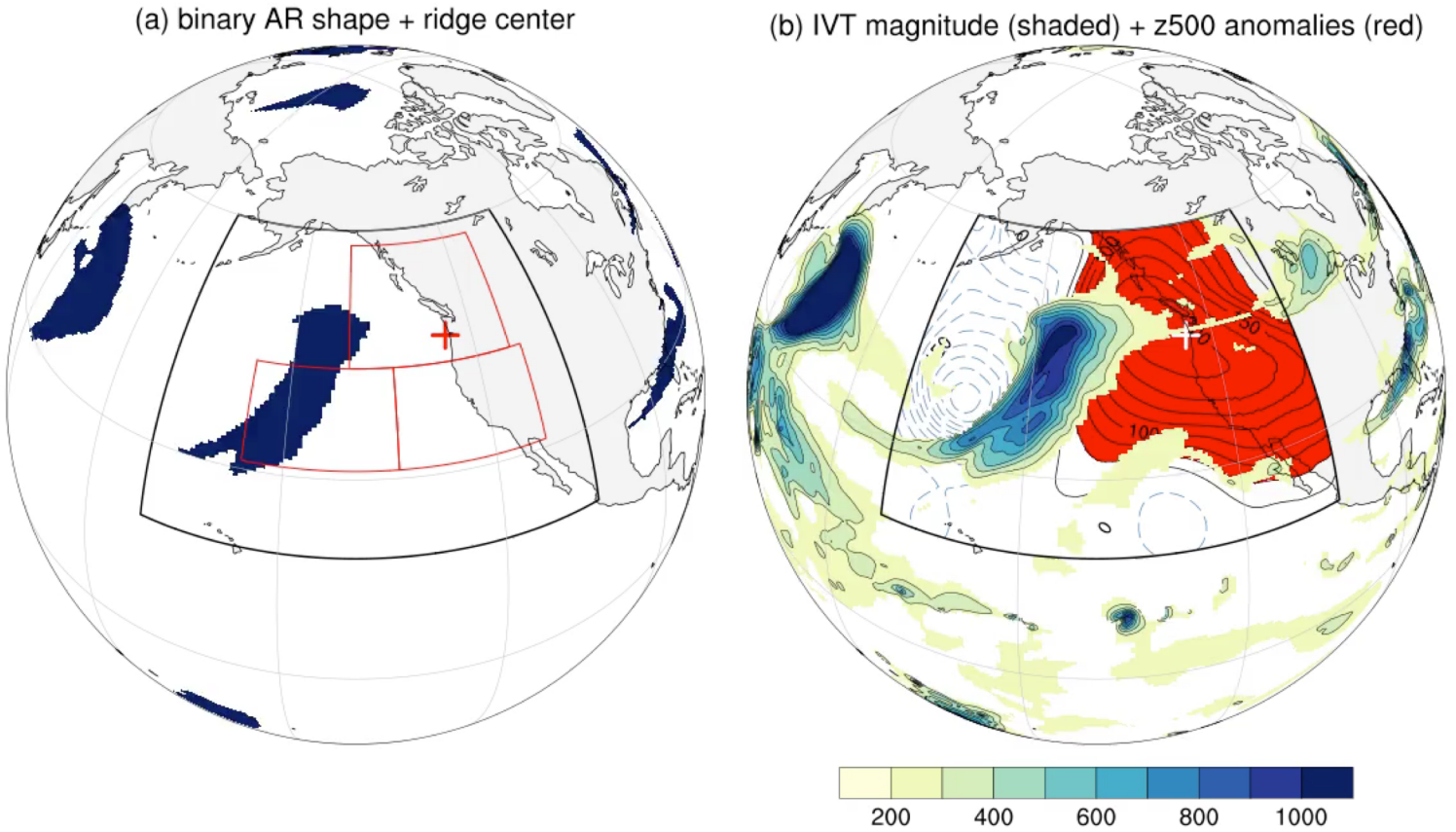
Tracking ridge events and AR events concurrently

Important locations for ridging, in terms of precipitation /ARs



Tracking ridge events and AR events concurrently

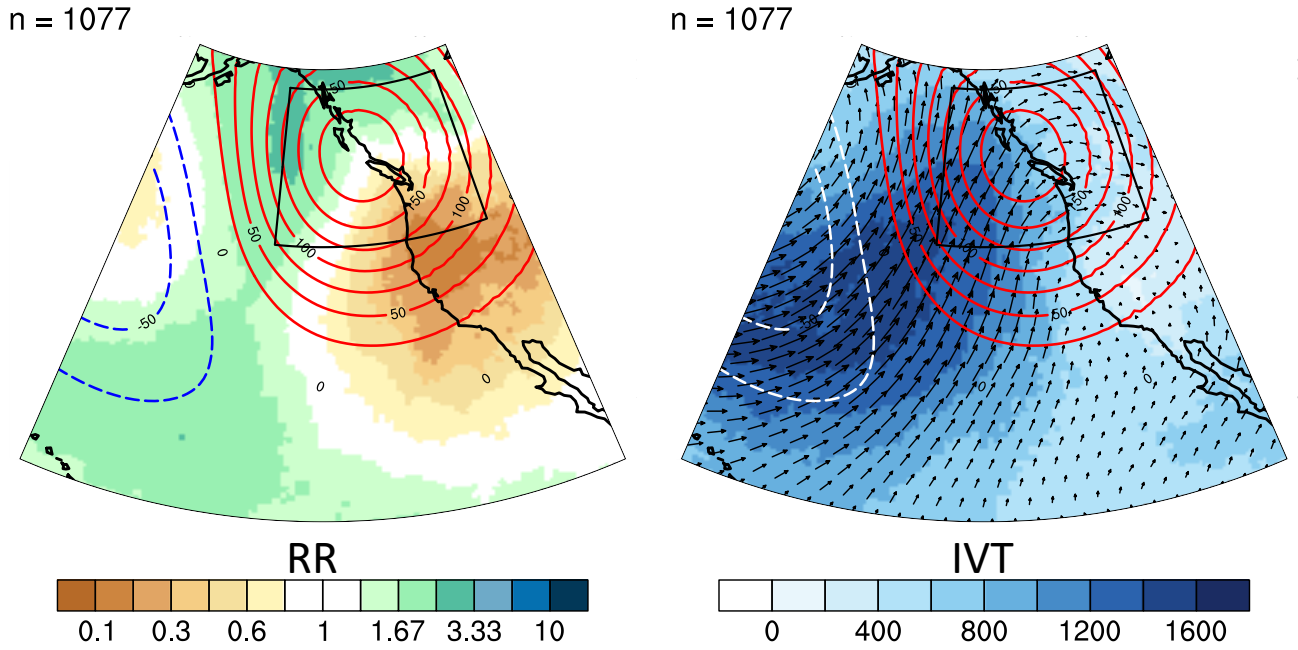
1 Oct 1980



Likelihood (Relative risk) of AR occurrence given Ridge occurrence

Northern Ridging:

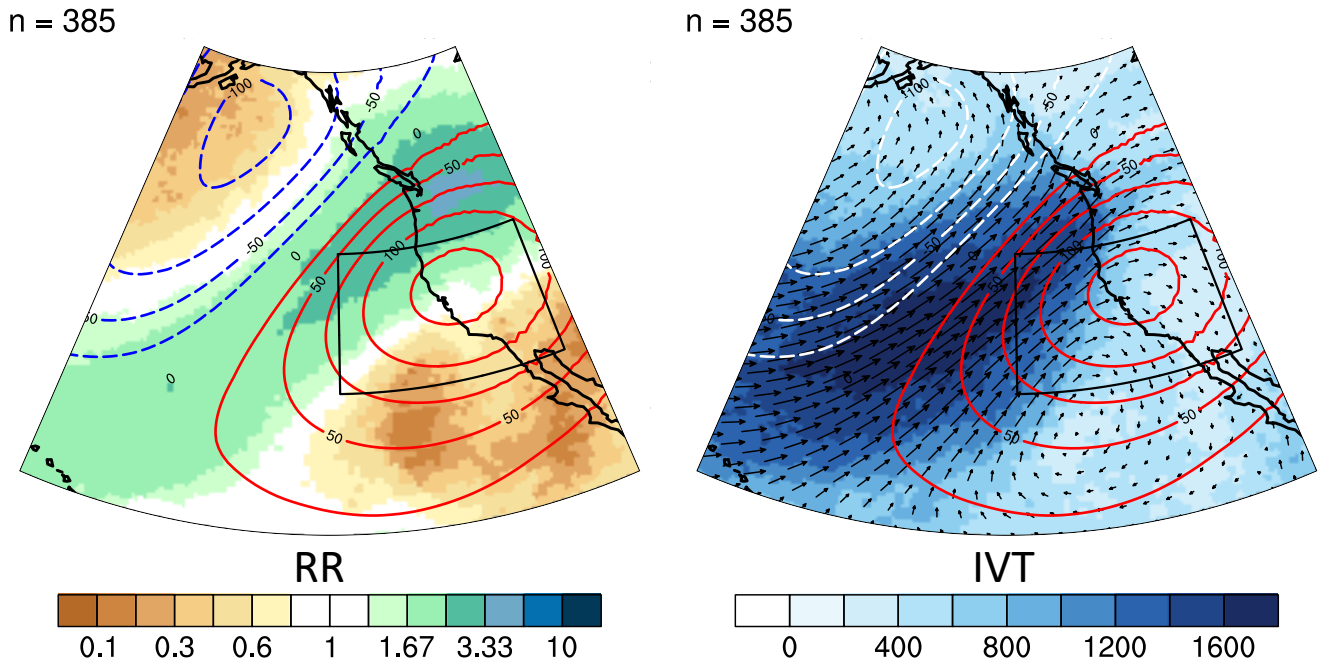
- Up to 10-fold *reduction* (RR=0.1) in probability of AR occurrence over much of West Coast
- Up to 5-fold *increase (*RR=5*)* in AR occurrence over Canada/Alaska



Likelihood (Relative risk) of AR occurrence given Ridge occurrence

Southern Ridging:

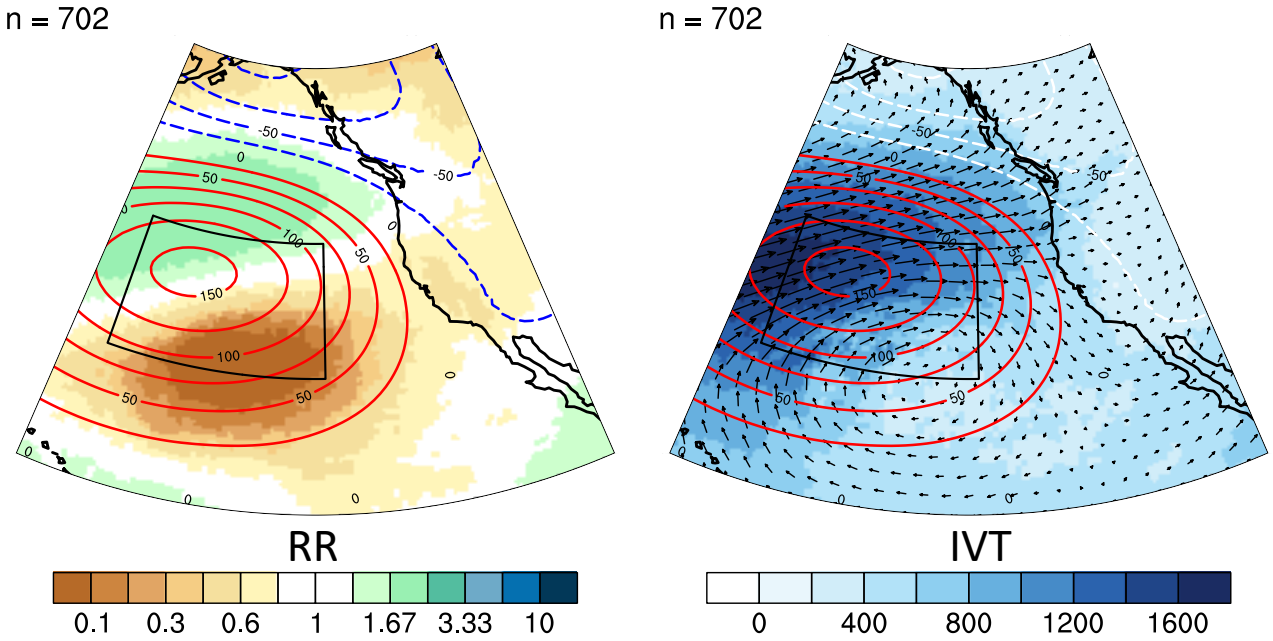
- Around 3-fold *reduction* (RR=0.33) in probability of AR occurrence over SoCal+AR
- Around 5-fold *increase (*RR=5*)* in AR occurrence over WA+OR



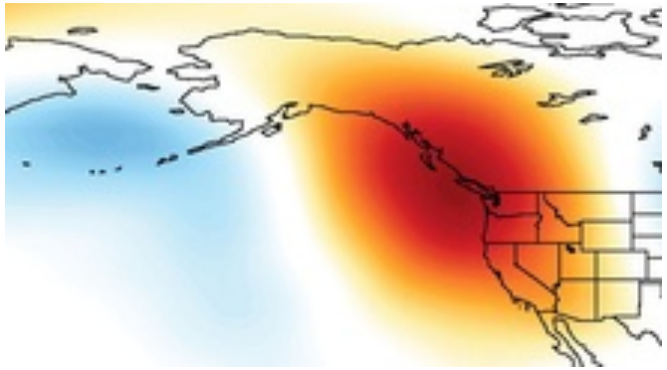
Likelihood (Relative risk) of AR occurrence given Ridge occurrence

West/offshore (W) Ridging:

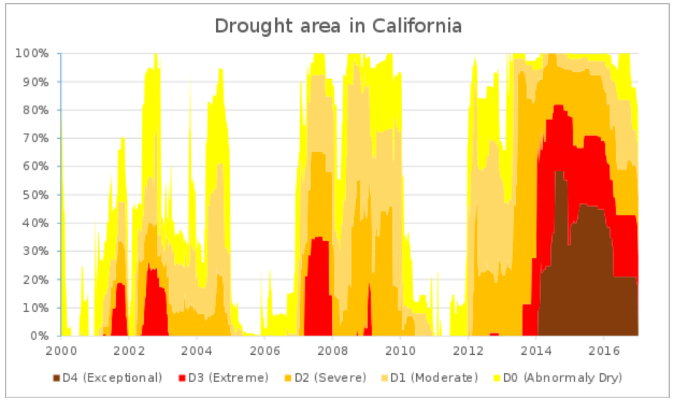
- Up to 2-fold *reduction* (RR=0.5) in probability of AR occurrence over parts of CA



Ridiculously Resilient Ridge (RRR) case study – Ridge occurrence



The '**Ridiculously Resilient Ridge**' January 2014 (90-day running mean z500 anomaly)



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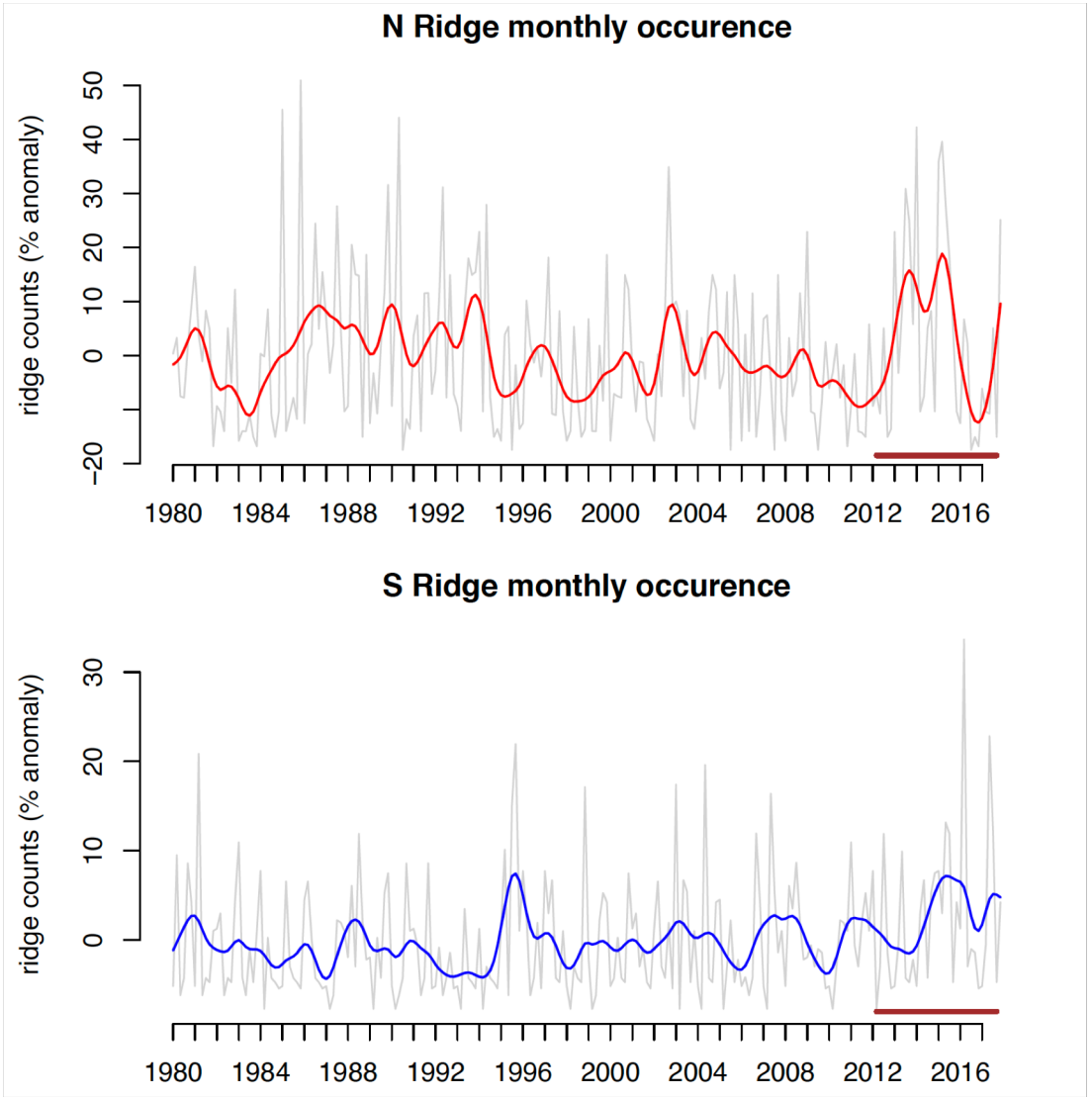
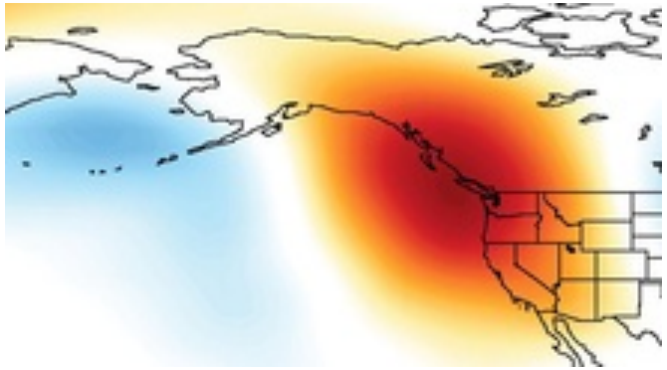


- Winters of 2013-2015 were associated with very high occurrences of N ridging (and above average S ridging)
- This coincided with significant area of CA affected by extreme drought

Ridiculously Resilient Ridge (RRR) case study – Ridge persistence



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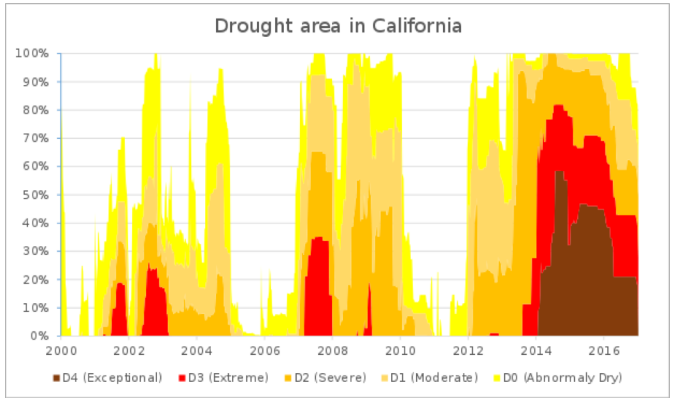

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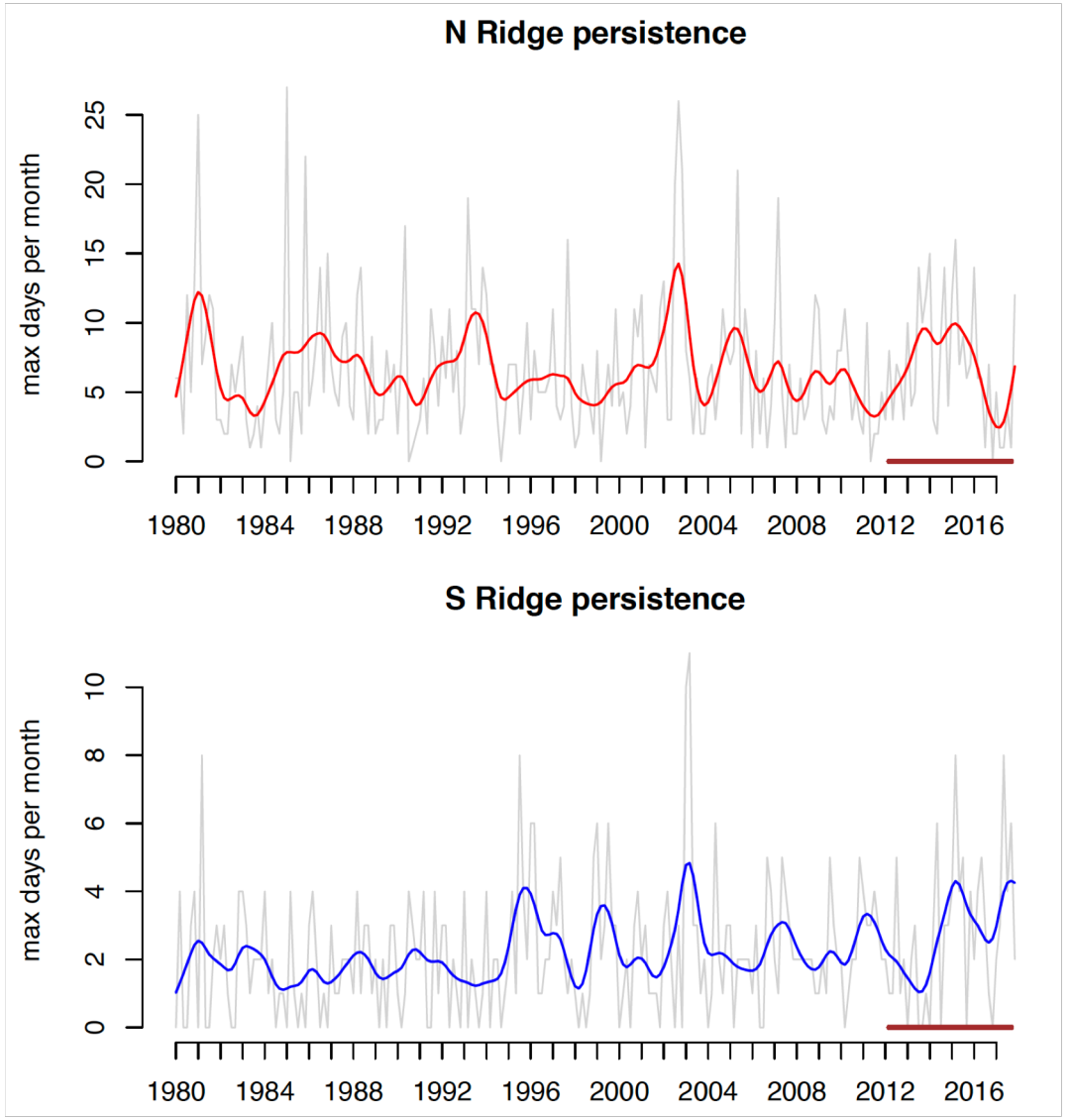
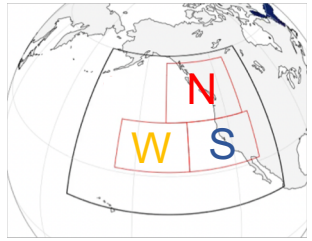
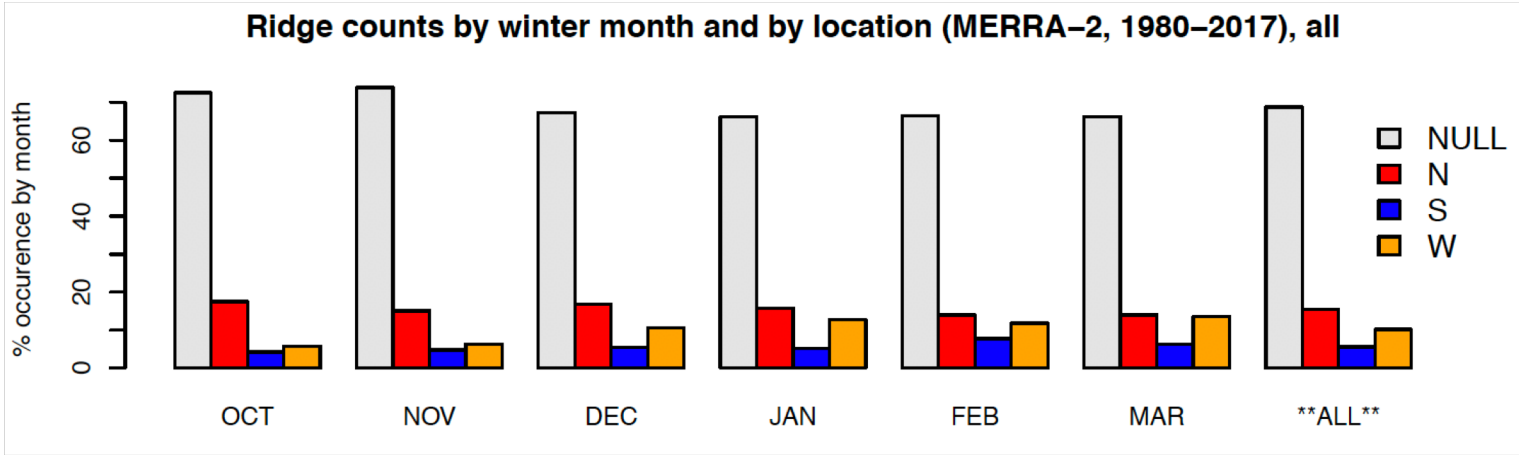


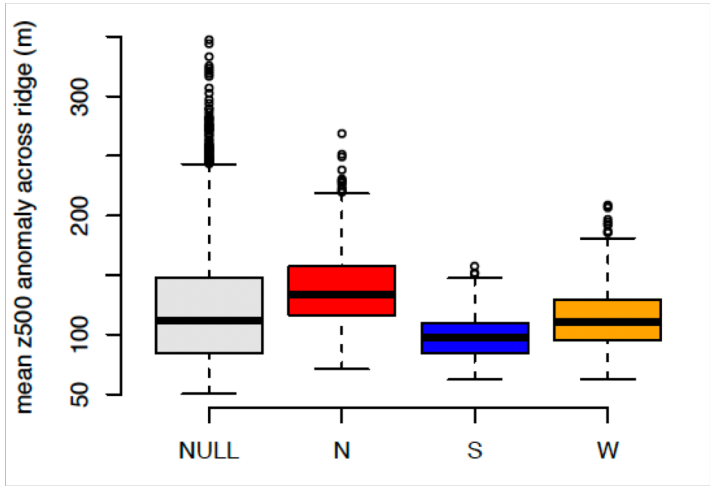
- This period was also associated with above average persistence of N ridging (events were more stationary than usual – not just more frequent)
- Possible indication of a slight positive upward trend in S ridge persistence (but lots of inter-annual variability)

Climatology of daily ridge counts (N,S,W) and characteristics

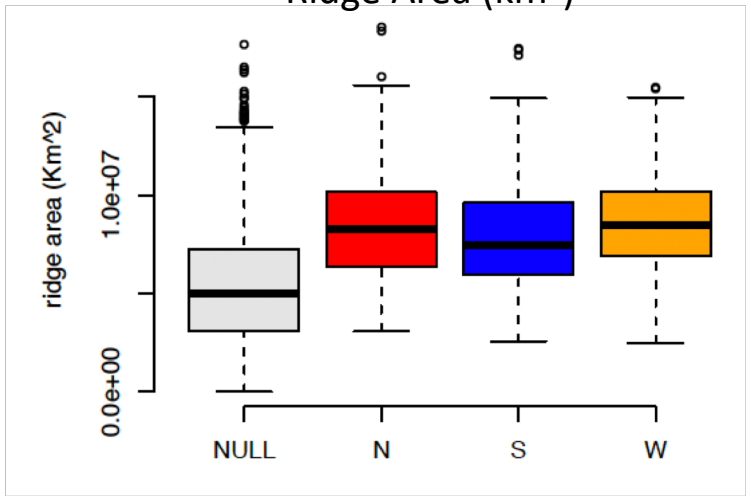




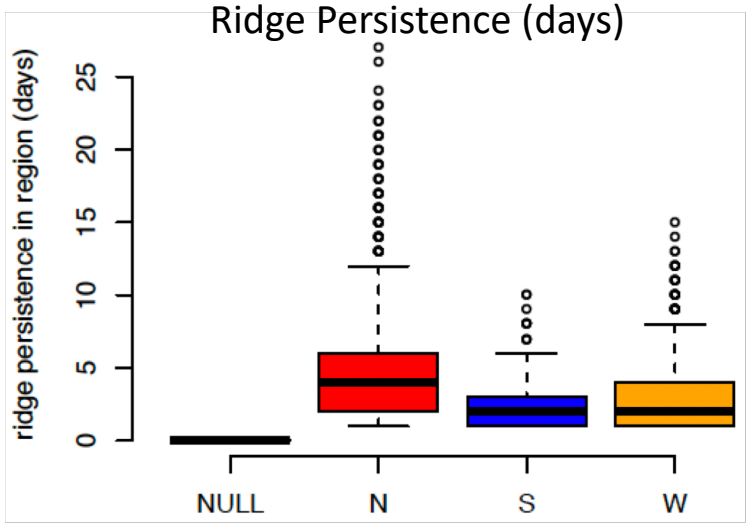
Ridge Magnitude (m)

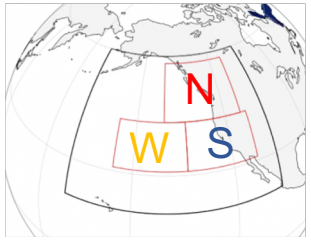


Ridge Area (km^2)

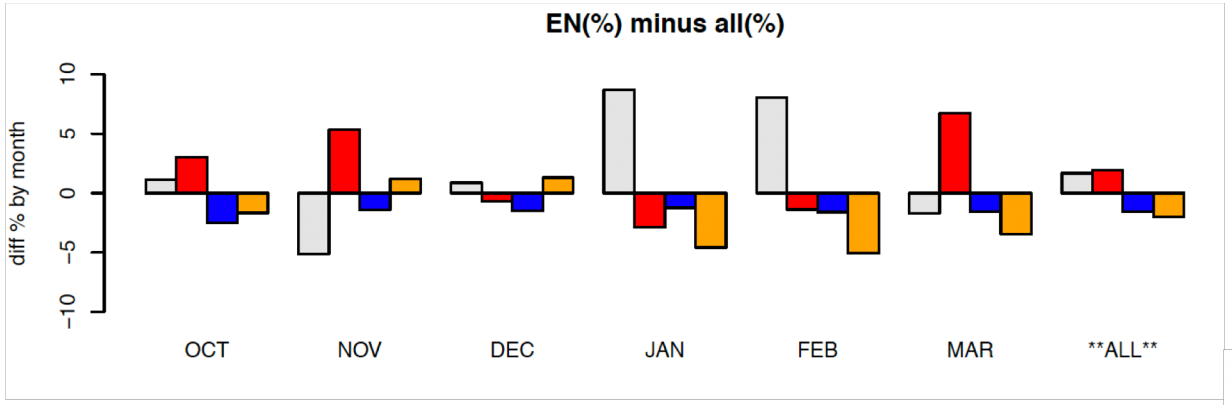


Ridge Persistence (days)

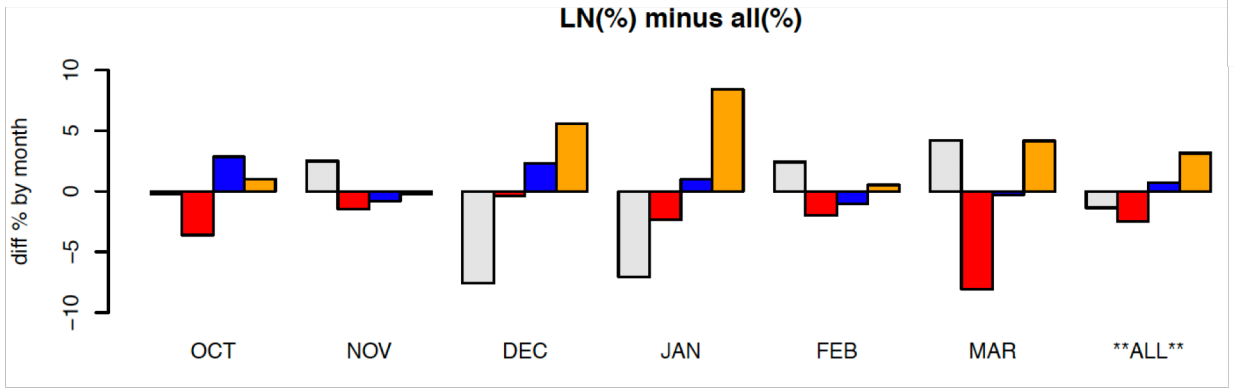


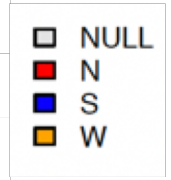


Ridge counts (N,S,W) by ENSO phase



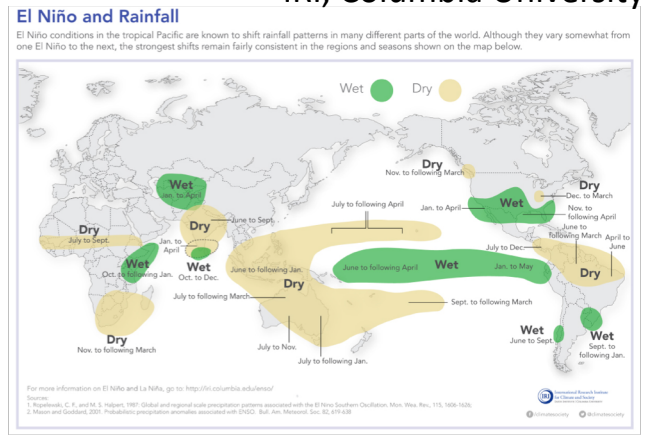
Wet South (less S+W), Dry North (more N) – with strong dependence on month

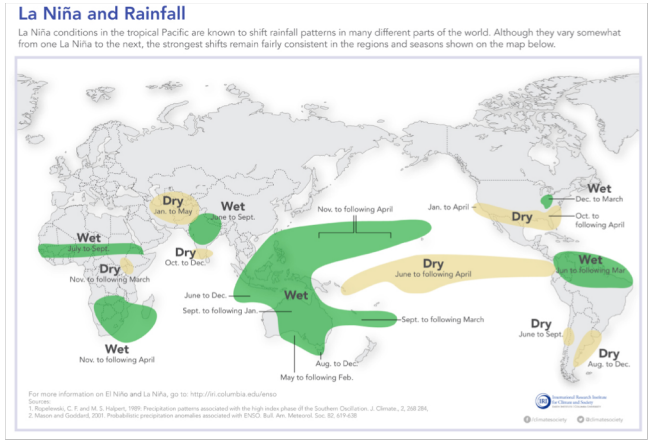


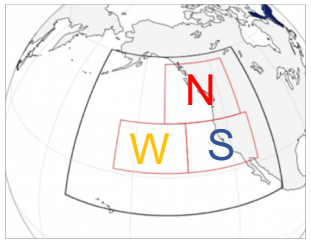


Dry South (more W and S) – with strong dependence on month

IRI, Columbia University

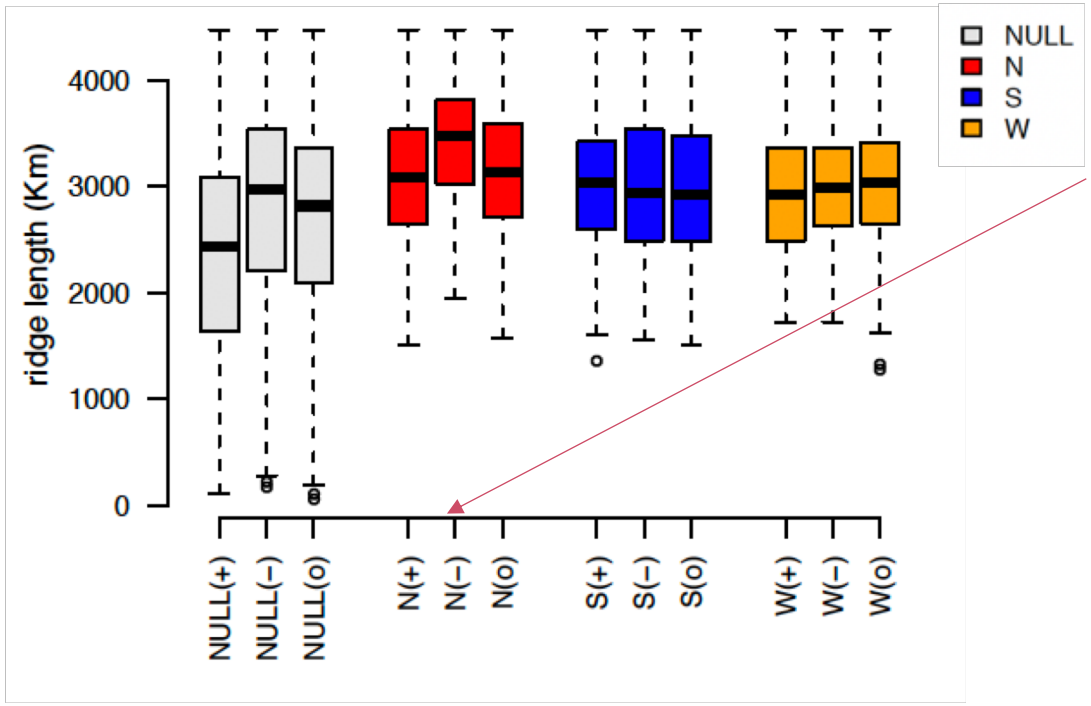






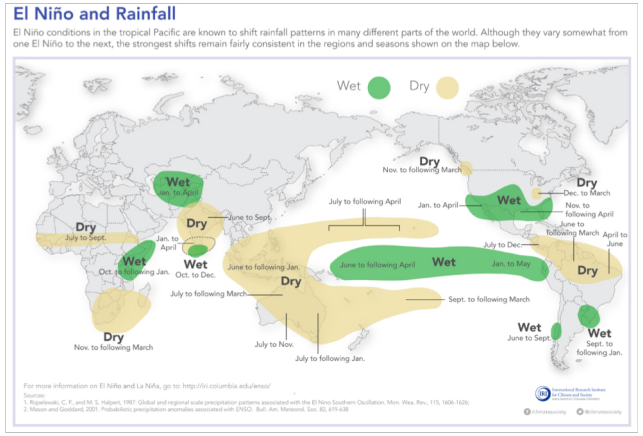
Other Ridge characteristics (N,S,W) by ENSO phase

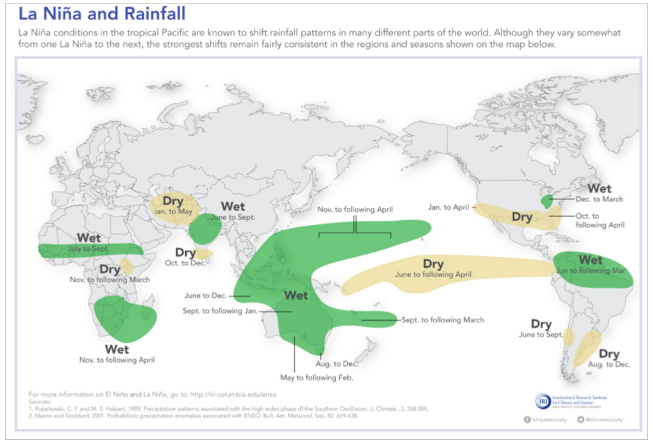
One example …..



Suggestion that During La Nina the N ridge is elongated further south, may contribute to drying in SoCal

IRI, Columbia University

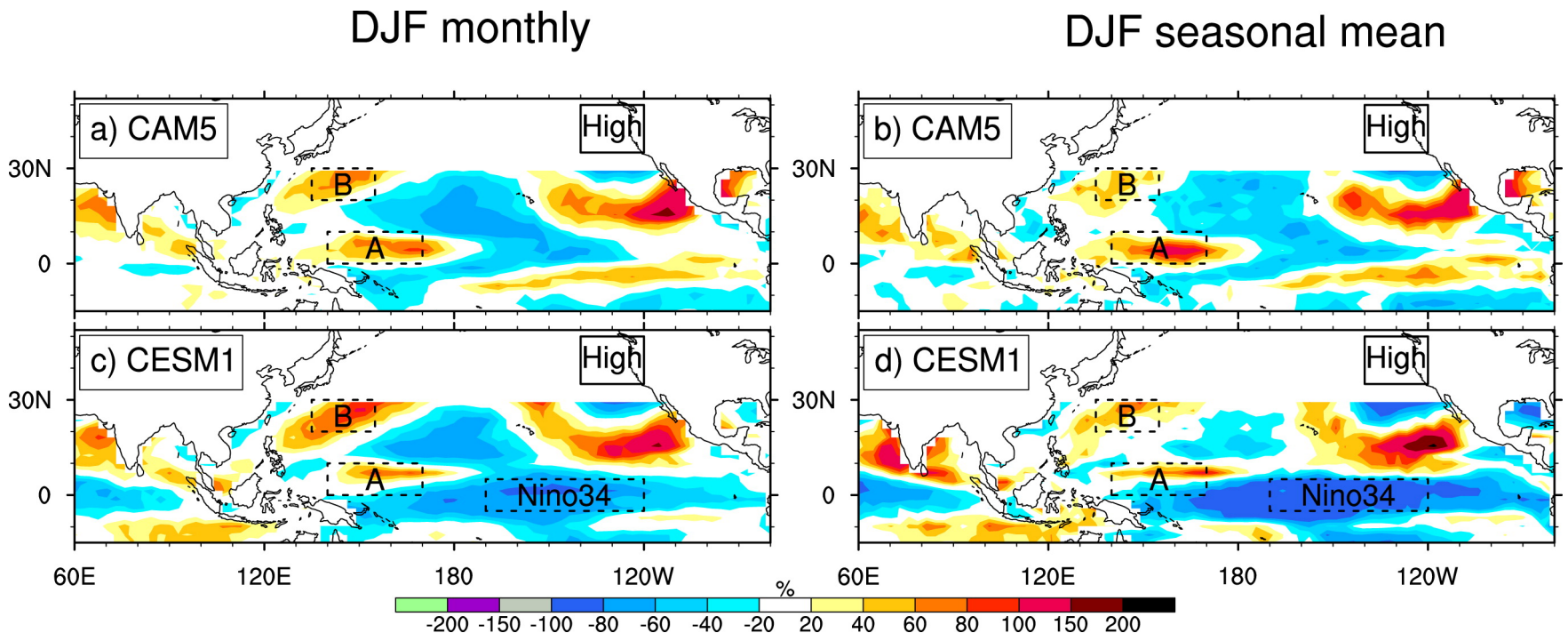




Ongoing work

- Explore QBO/MJO/western Pacific SST in influencing ridge counts and characteristics
- Quantify reference prediction skill from S2S/SubX ensemble of models
- Explore potential opportunities to improve S2S model skill by post-processing/machine learning applied to model output
- Based on model skill – assess and implement RT observational monitoring and model forecasting products (aligned with AR products)

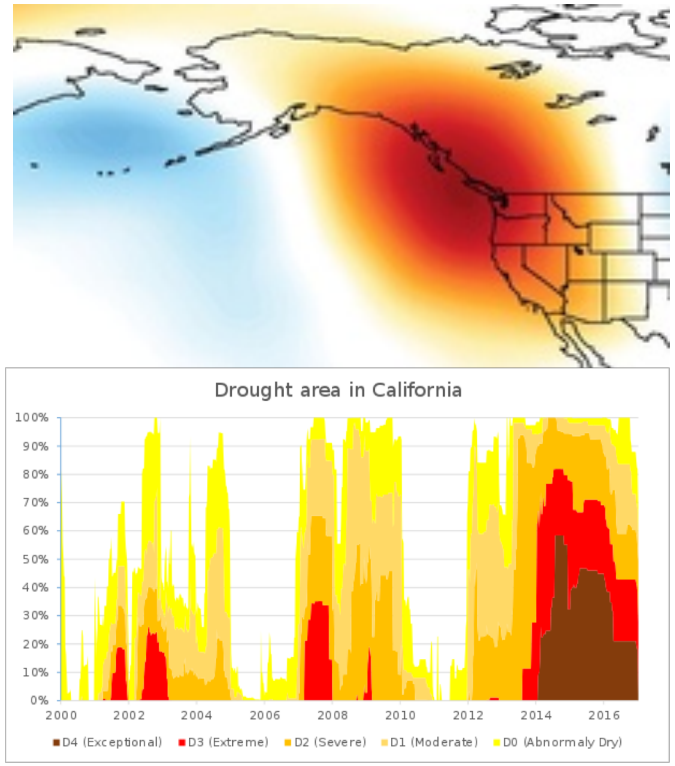
Recent evidence that western Pacific SSTs (sometimes outside of major ENSO events) important also…



Teng and Branstator, J. Clim (2017)

FIG. 8. Percentage change in the probability of extreme ridges at 35°–50°N, 140°–120°W (outlined by the box labeled "High") from P_0 = 10% to P_1 upon extreme local precipitation at any 5° × 5° latitude–longitude boxes over the tropical ocean, in the form $100(P_1 - P_0)/P_0$ for (a),(b) CAM5 and (c),(d) CESM1. (left) Extreme DJF monthly ridges and (right) extreme seasonal ridges.

Supplementary



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)