Forecasting ridging events relevant to Western US water resources

WY 2019: Feast or Famine. UC Irvine

NASA-JPL: Peter Gibson, Duane Waliser, Bin Guan

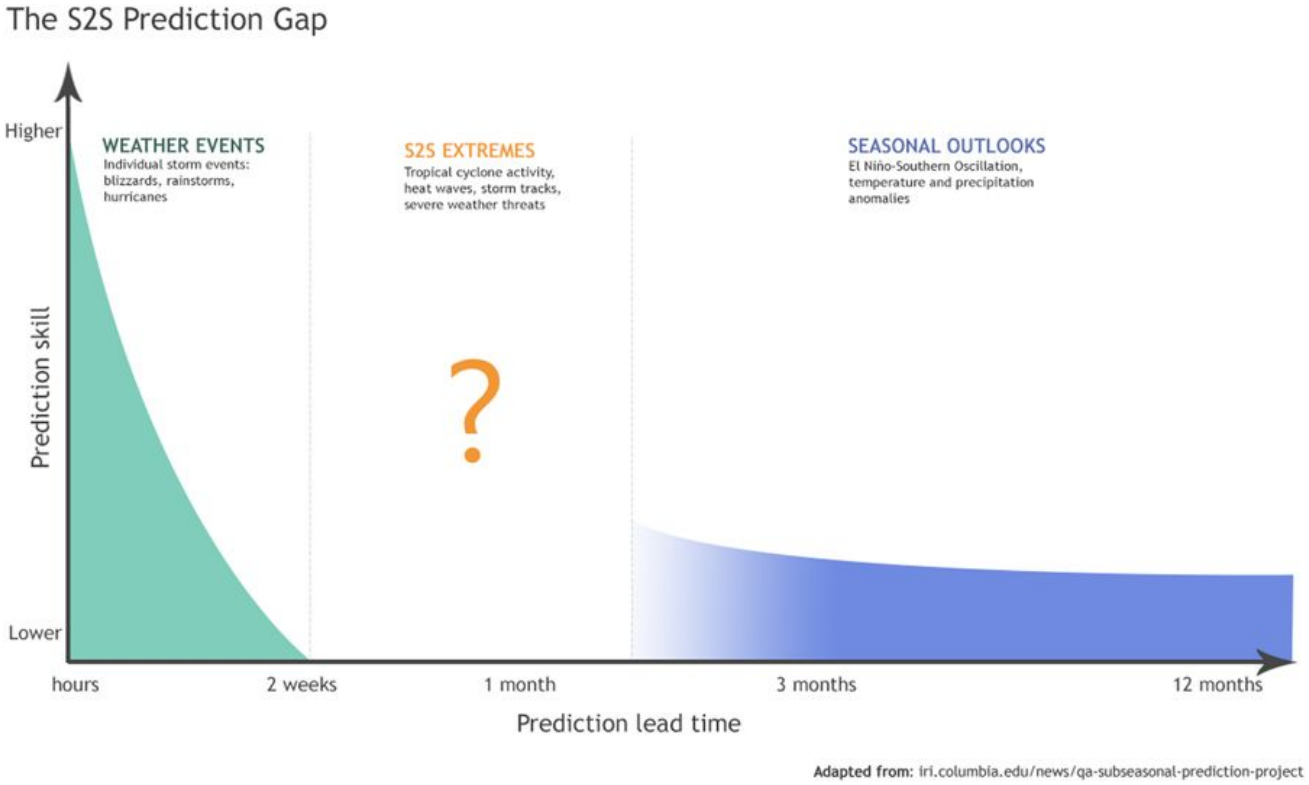
Scripps CW3E: Marty Ralph, Aneesh Subramanian, David Pierce, Mike DeFlorio,

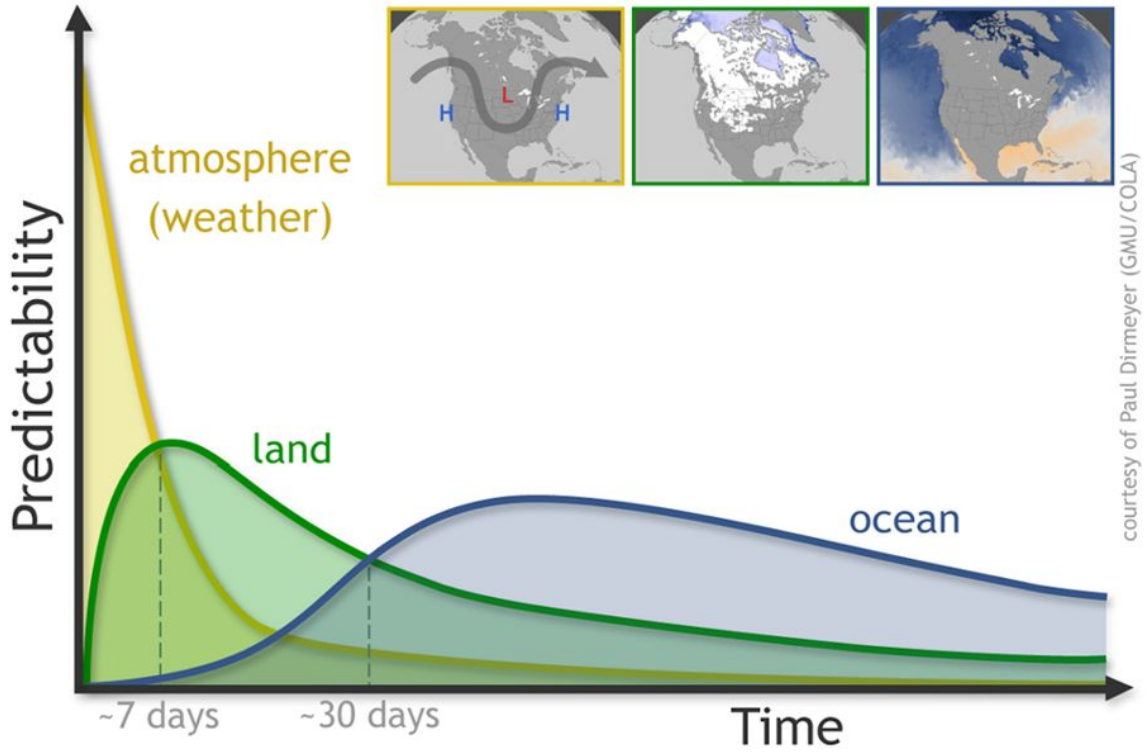
California Department of Water Resources (DWR): Jeanine Jones

Talk outline

- What are “ridging events” and why should you care about them?
- What drives them?
- Is there hope for predicting them on time-scales useful to decision making?

S2S: A major challenge and opportunity for the weather/climate research community





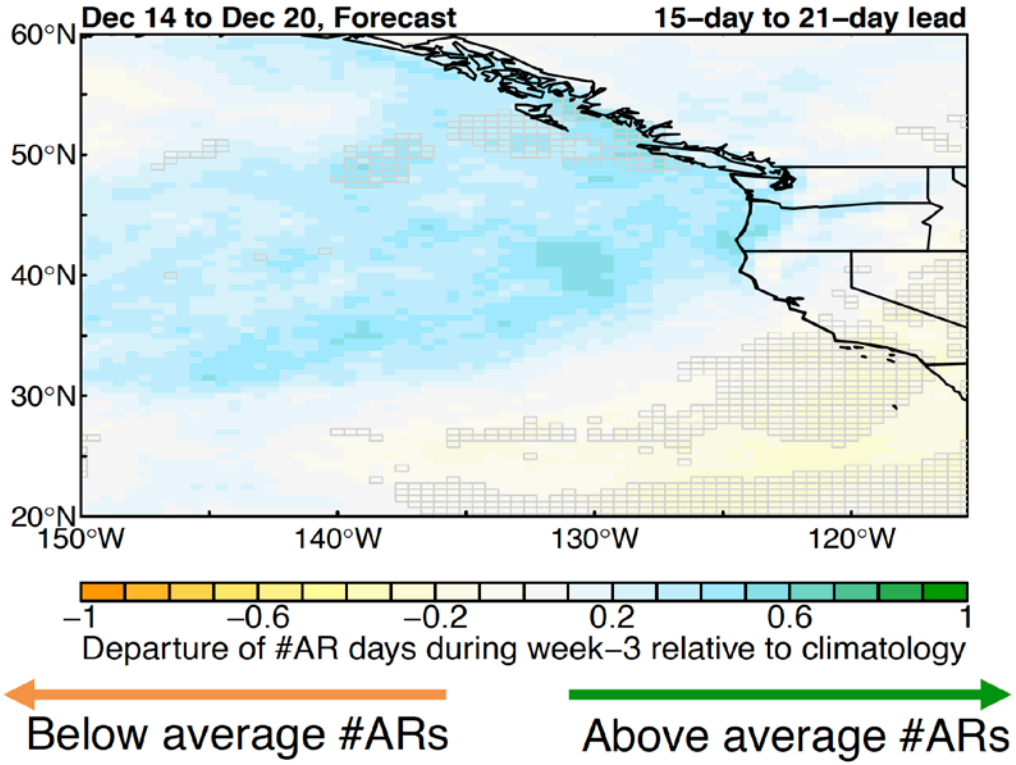
Mariotti et al. (2018), Nature

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** (the conditions associated with rainfall deficits)
- ***Potential for*** models to have better skill in S2S range for ridges compared to ARs or rainfall (but remains to be tested/quantified)

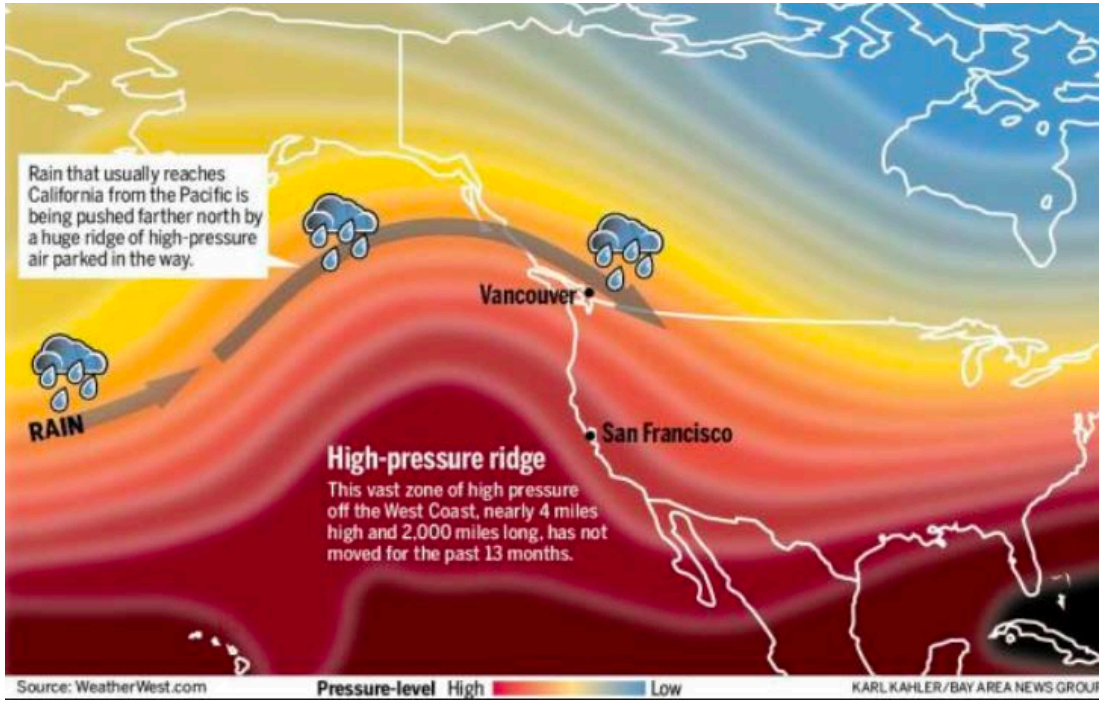
*****EXPERIMENTAL*****

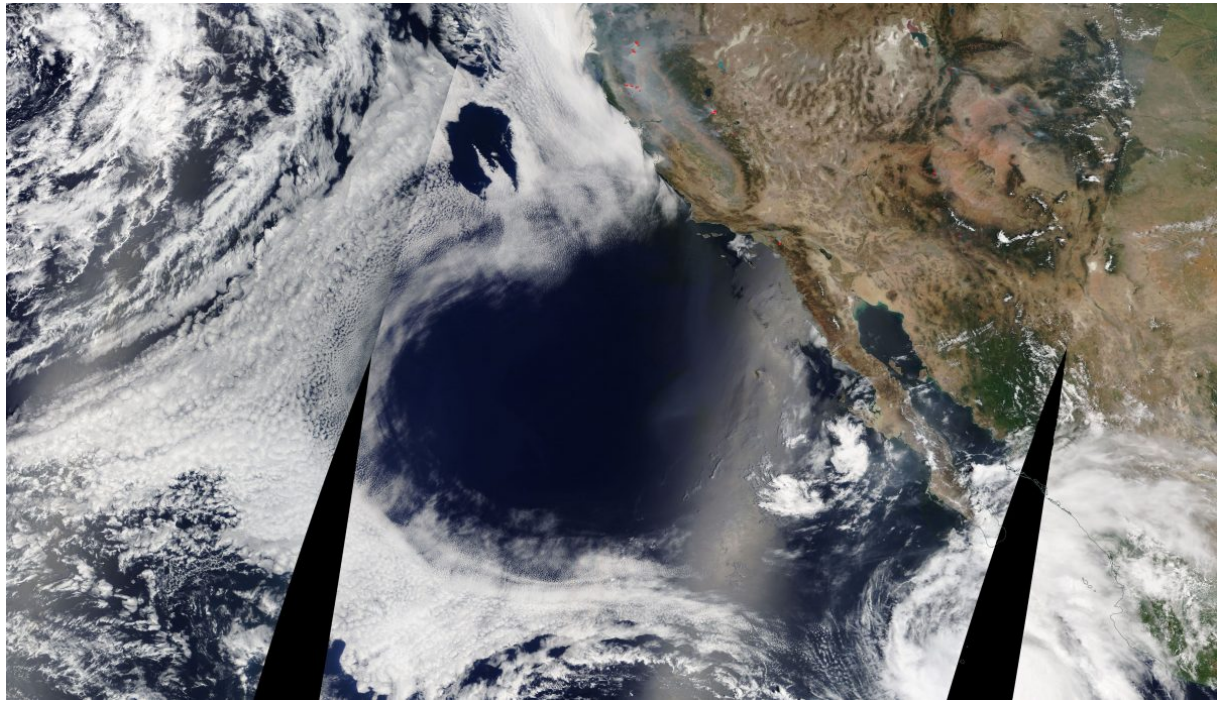
week3: ECMWF (51-member)



Winter ridge events influence where and how it rains

- Ridging events often occur (and sometimes persist) in winter off the west-coast of USA
- These ridge events divert important rain-bearing systems away from California

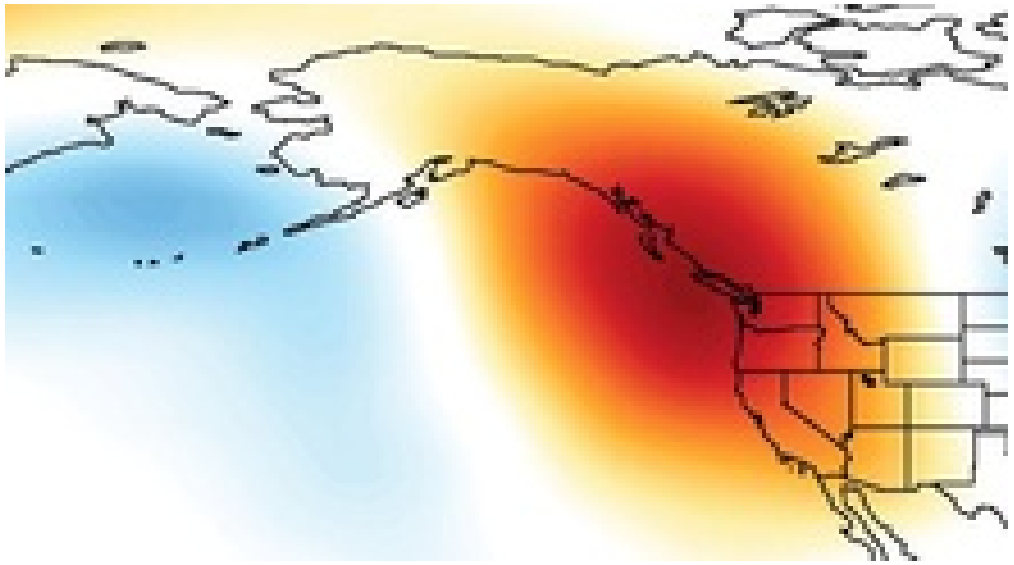




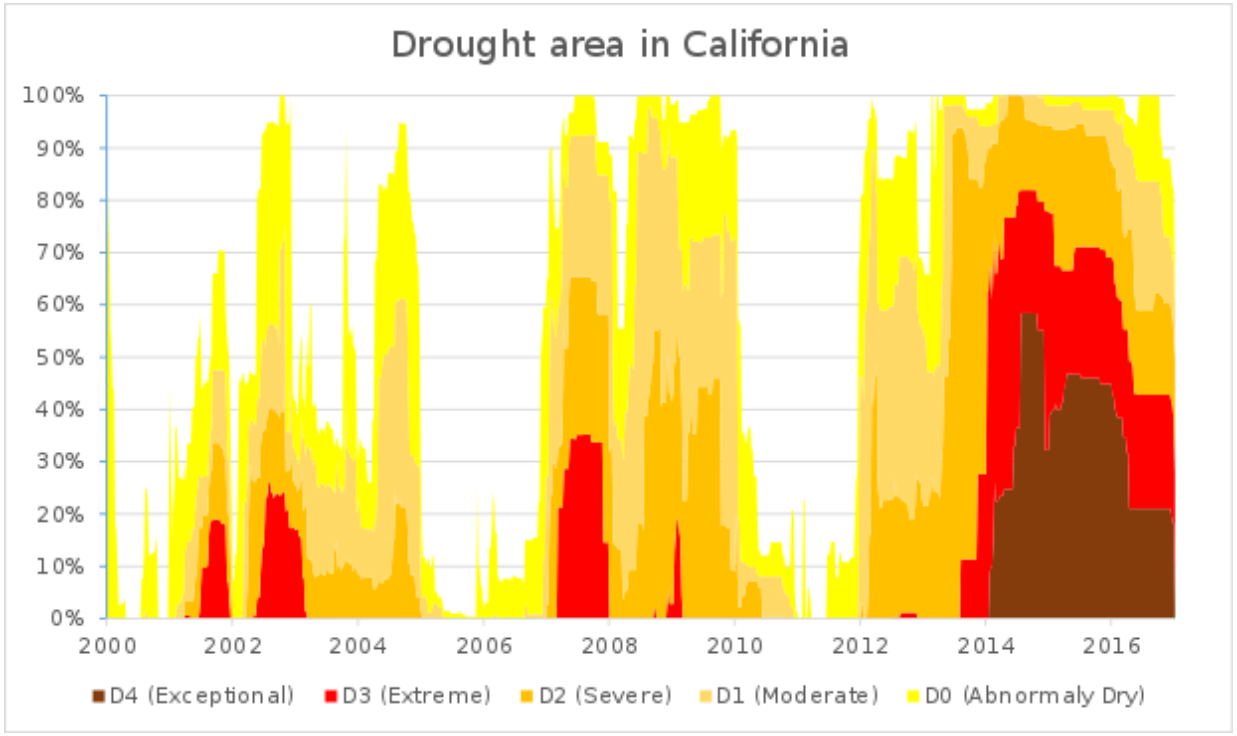
From NASA Terra satellite – August 7 2018

Extreme winter ridge conditions can determine feast of famine

- Especially strong and persistent ridging conditions during extreme drought

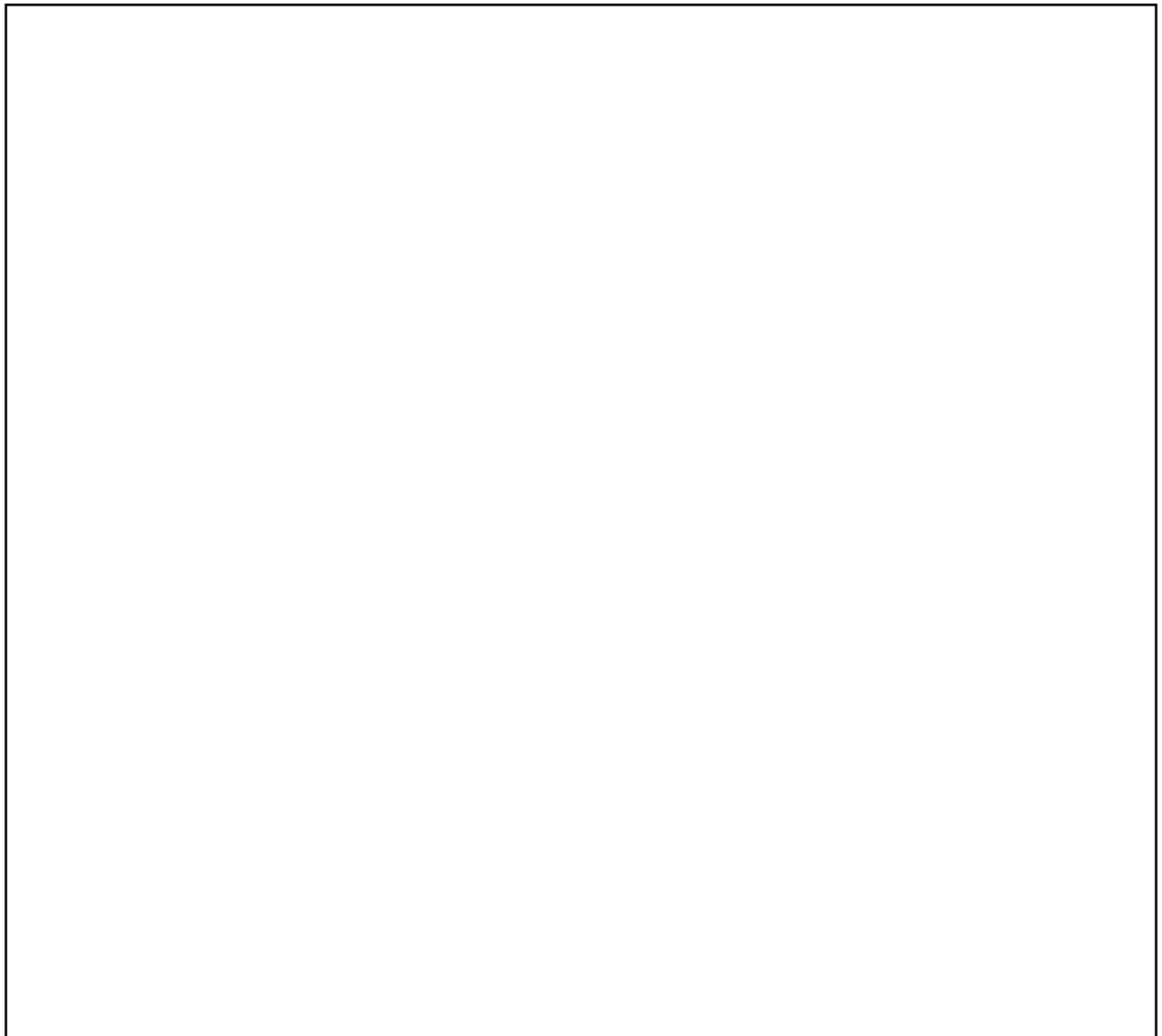


The '**Ridiculously Resilient Ridge**' January 2014
(90-day running mean z500 anomaly)

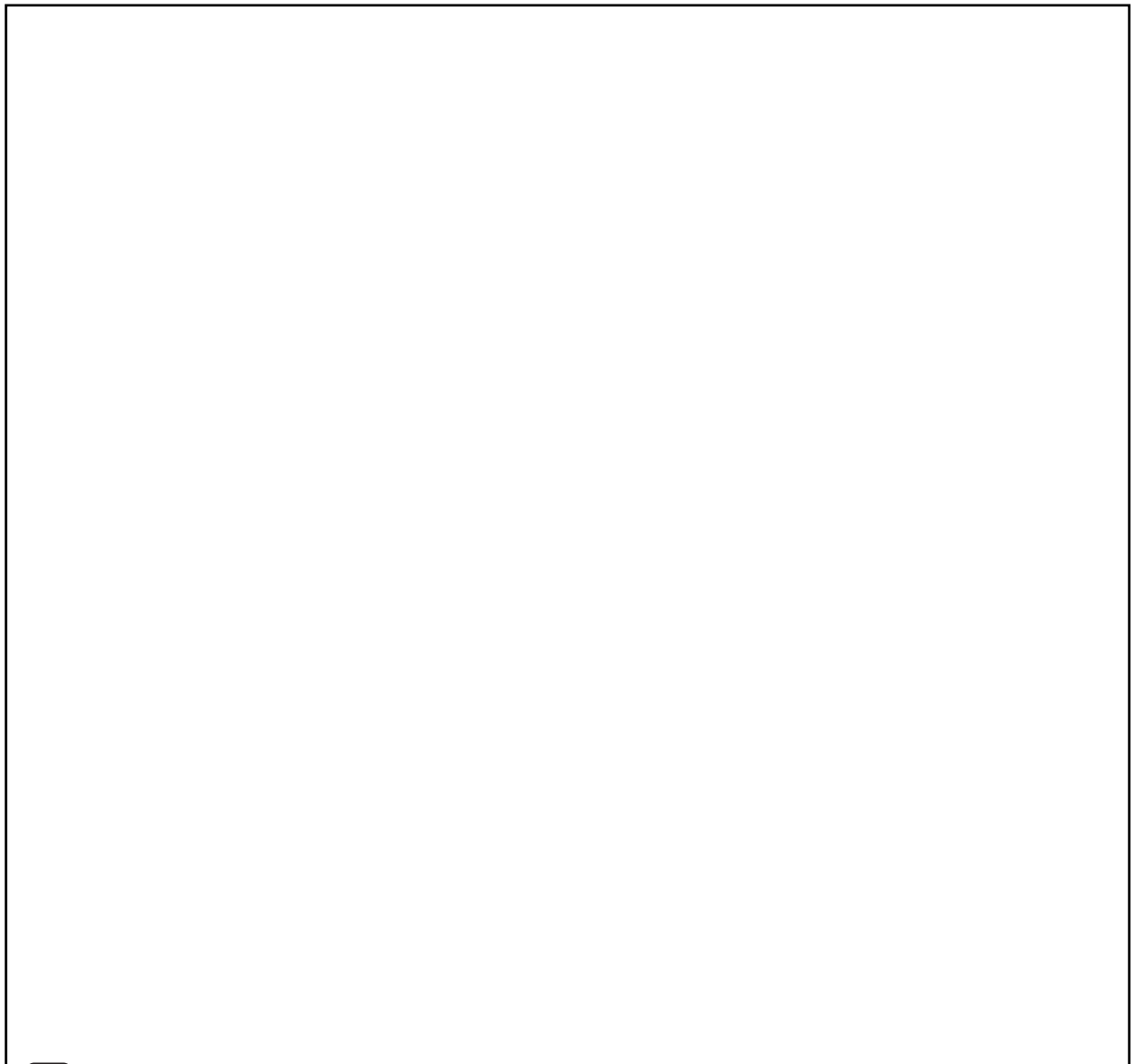


https://droughtmonitor.unl.edu/

Tracking ridge events with observational data



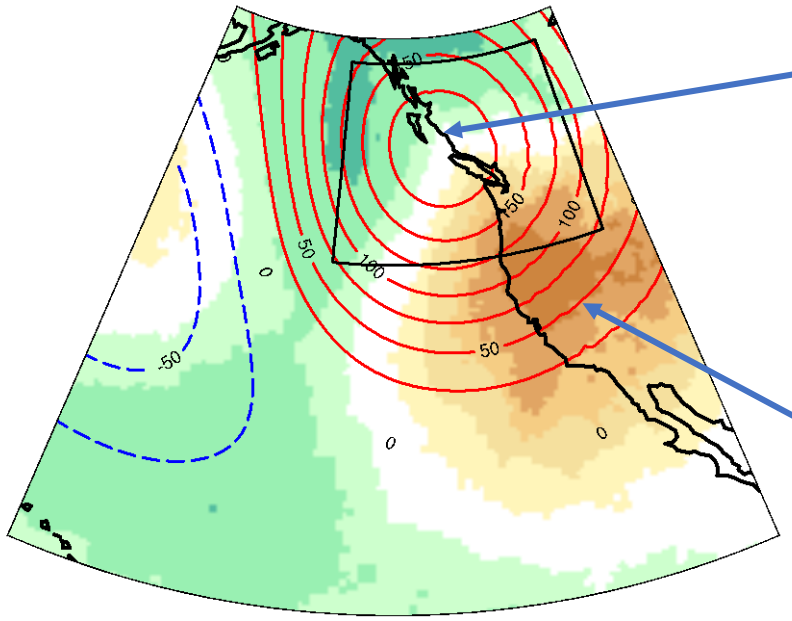
Tracking ridge events with observational data



Atmospheric river (AR) occurrence during ridging events

Northern Ridging 'flavor':

n = 1077



If ridging events occur HERE

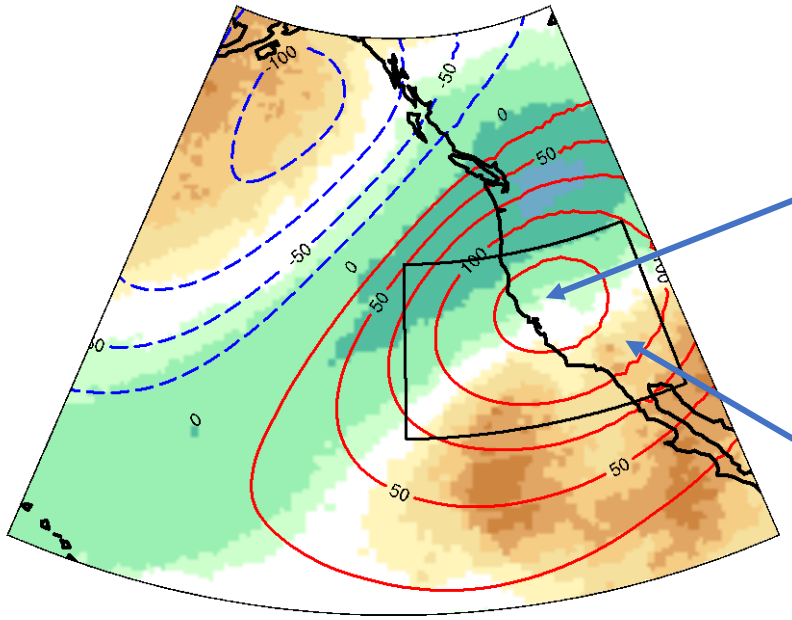
=

Less chance of rainfall HERE

Atmospheric river (AR) occurrence during ridging events

Southern Ridging 'flavor':

n = 385

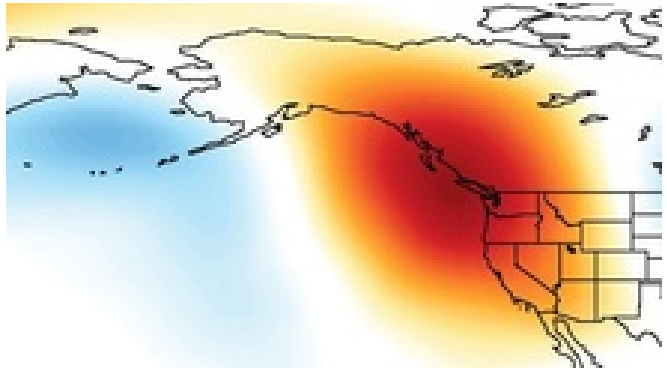


If ridging events occur HERE

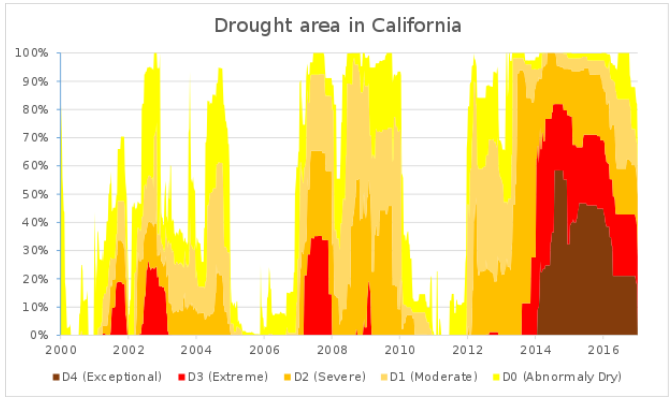
=

Less chance of rainfall HERE

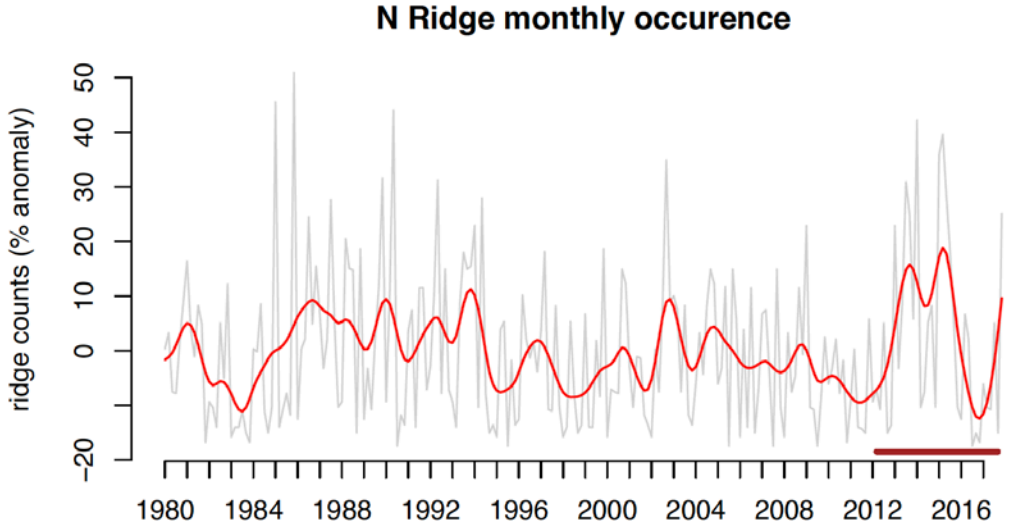
Ridiculously Resilient Ridge (RRR) case study – Ridge occurrence

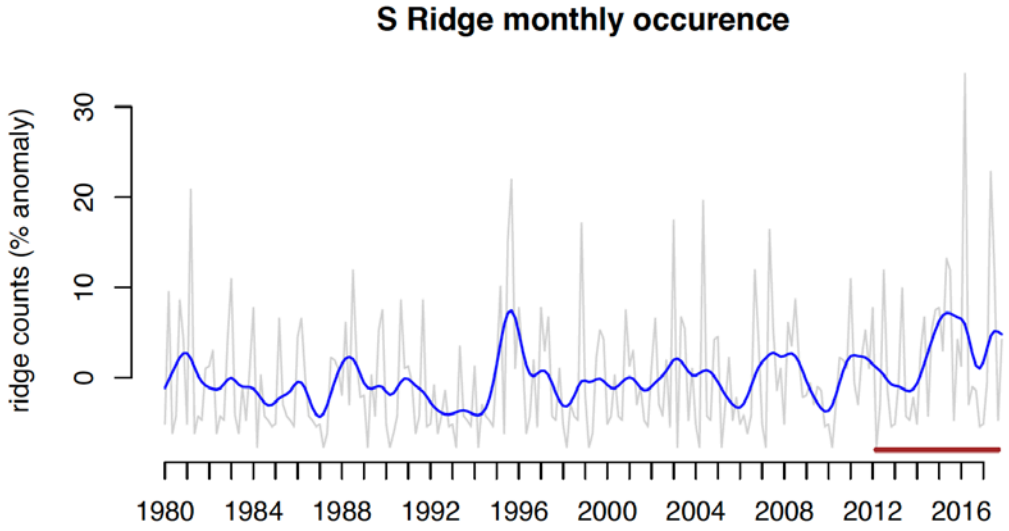


The '**Ridiculously Resilient Ridge**' January 2014 (90-day running mean z500 anomaly)



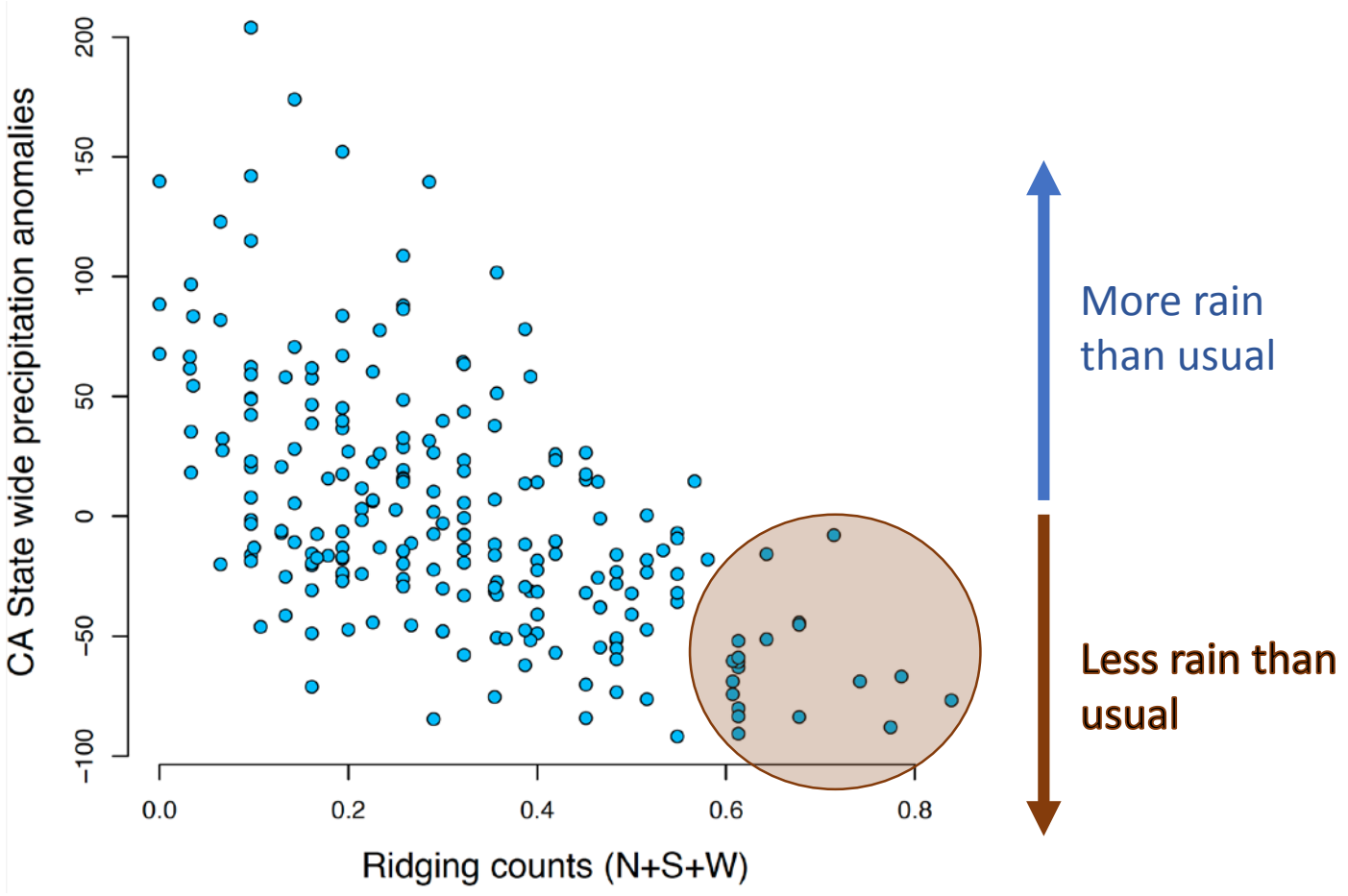
https://droughtmonitor.unl.edu/





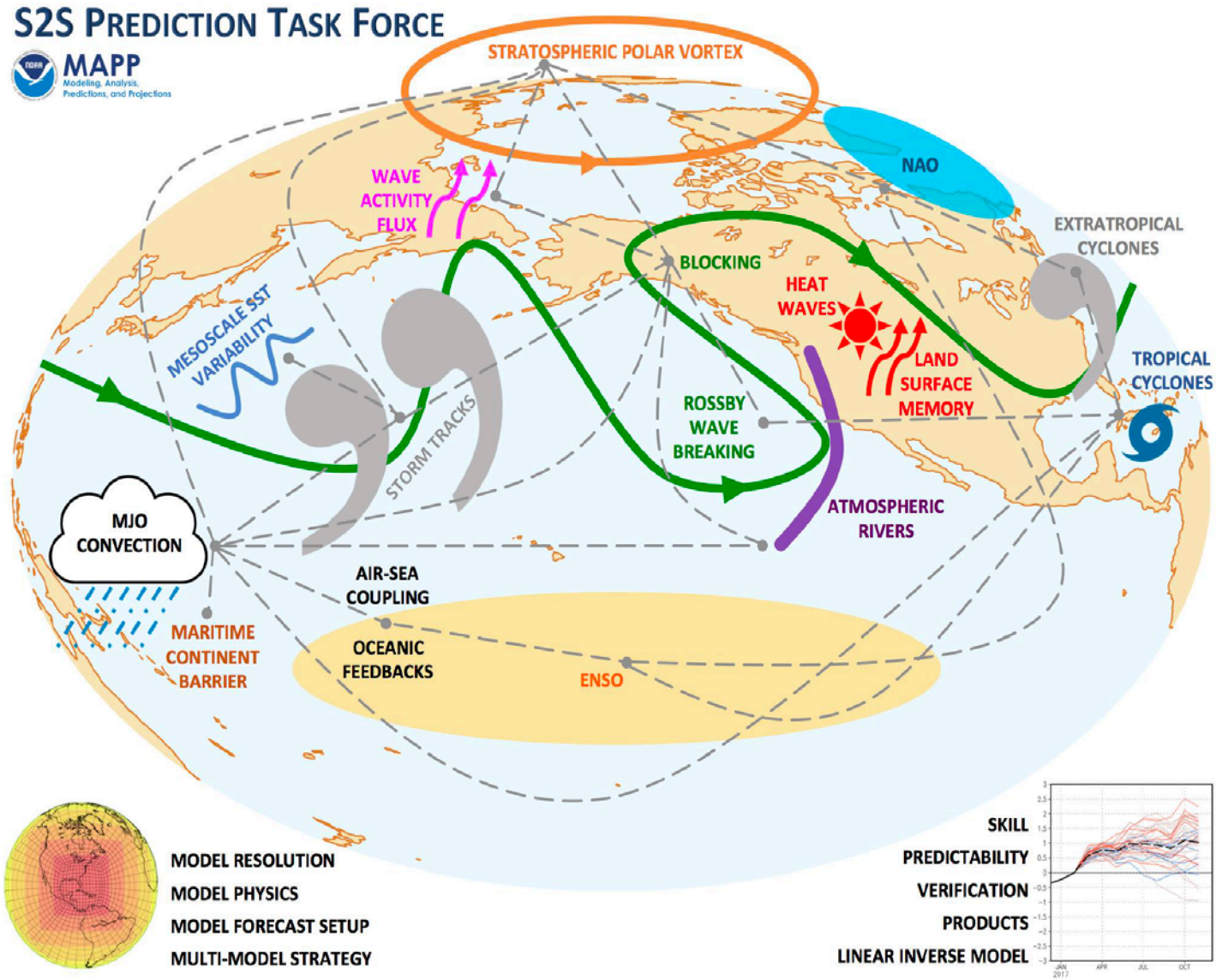
- Winters of 2013-2015 were associated with very high occurrences of N ridging (and above average S ridging)
- This coincided with significant area of CA affected by extreme drought
- Slight upward trend in S ridging, will it continue?

Months with more ridging events = less rain across CA



The climate system puzzle

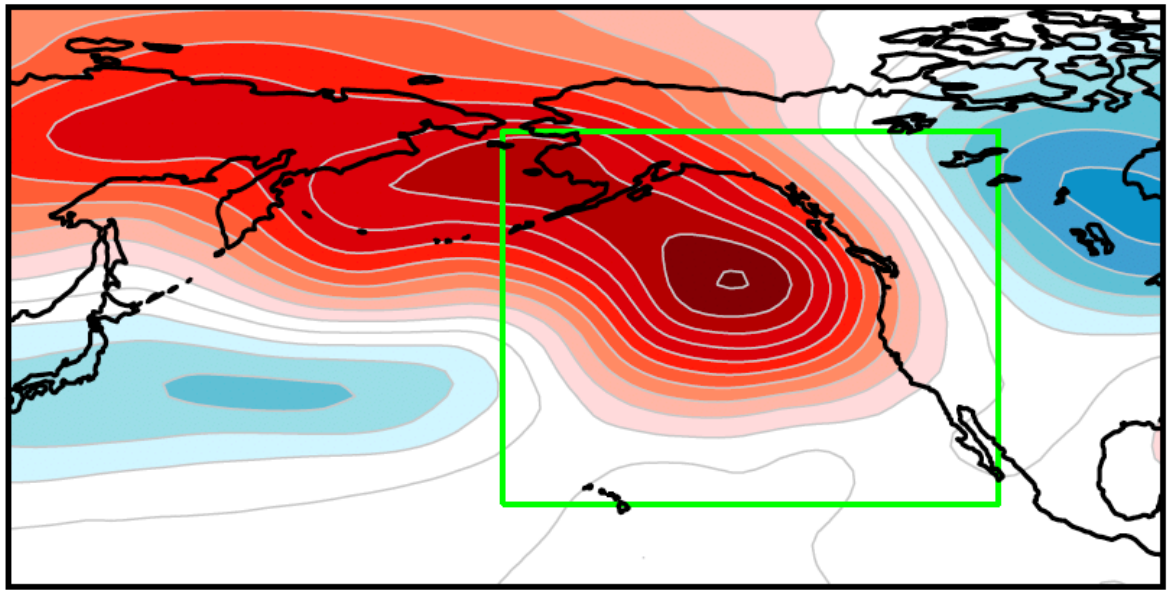
- Lots of moving parts
- What happens in remote locations can influence what happens ‘down-stream’ at a later time
- these moving parts (and their interactions) can help us extend our predictions

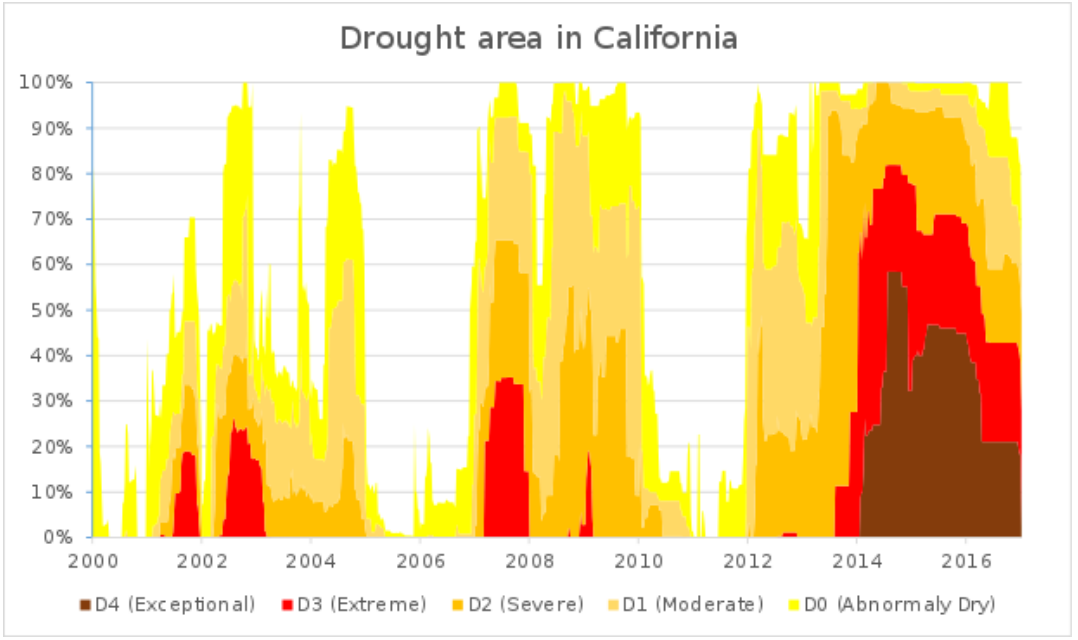


Courtesy of MAPP S2STF

case study of model skill at predicting the ‘Ridiculously Resilient Ridge’

MERRA-2 (DEC 2013)

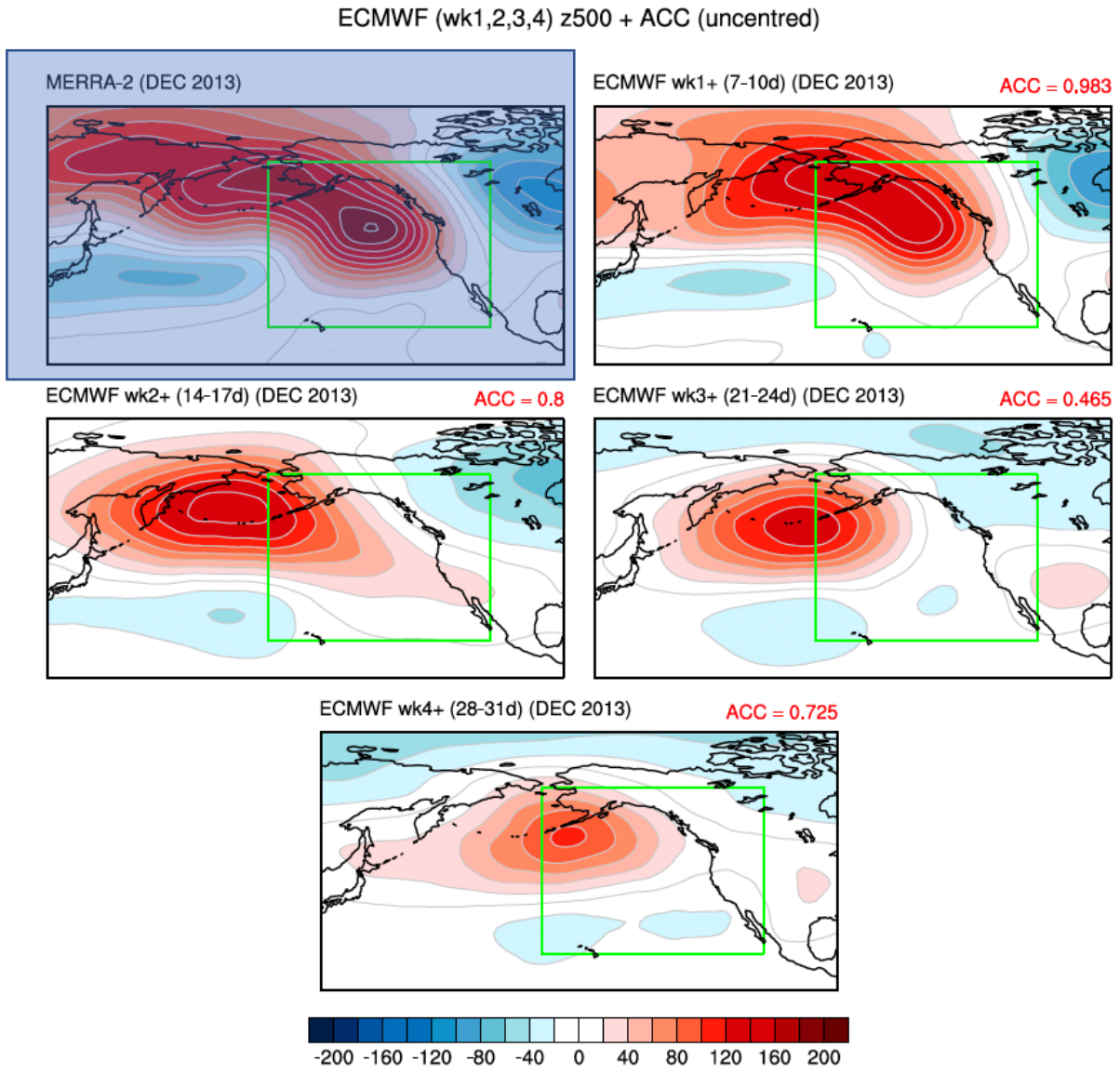




This was one of the most intense ridging events in the satellite-era. How was it predicted by models?

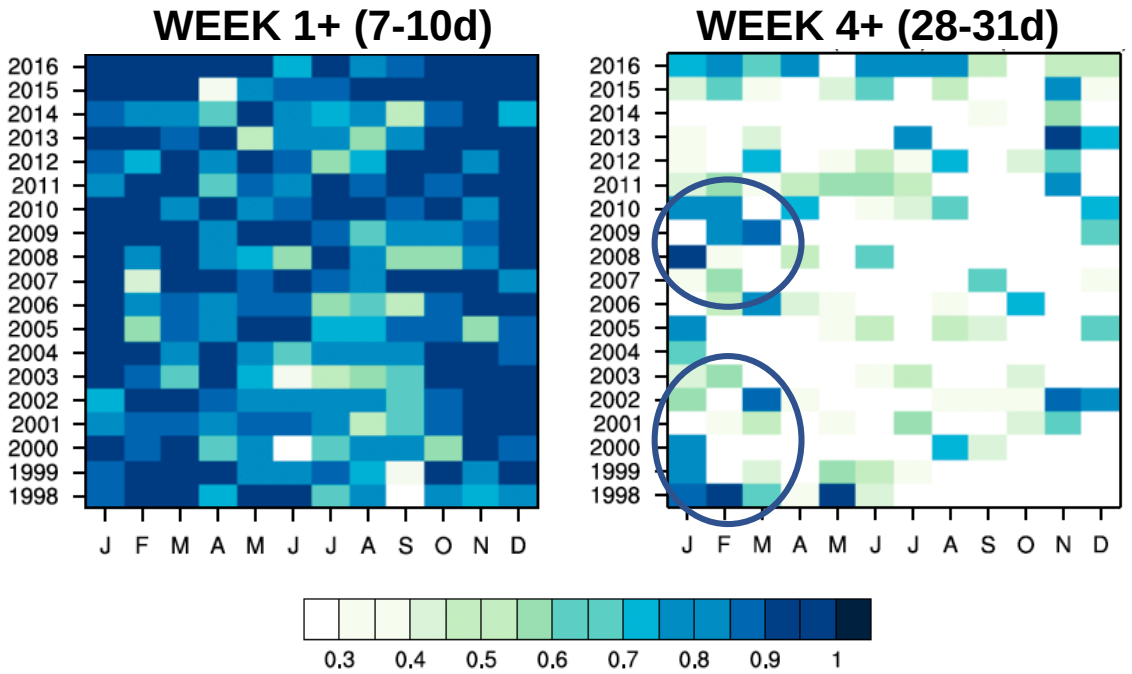
case study of ECMWF skill (EXPERIMENTAL)

- at weeks 3 and 4 there was a strong ridge predicted in the models (good!)
- However, the position of the ridge was shifted (not good!)
- What about other events over the historical period?



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)
- Ongoing work to understand these “windows of opportunity” in the models
- This is for 1 model only (other models might do better in this region)



Ongoing work: can we squeeze more out of the models to help decision makers?

- Assessing "**windows of opportunity**" – when certain conditions in the climate system line up well to allow more accurate forecasts
- **Machine learning** might be a useful avenue for finding these windows, with the model 'learning' when the forecast is likely to be good or bad and then adjusting or flagging these conditions ahead of time
- **Precision vs accuracy tradeoff** – we might not be able to say with any accuracy 6-8 weeks ahead of time the exact number/size/duration of ridging events, but perhaps we can say *useful* things about direction (e.g. "more ridging events or less ridging events than usual for the upcoming WY")

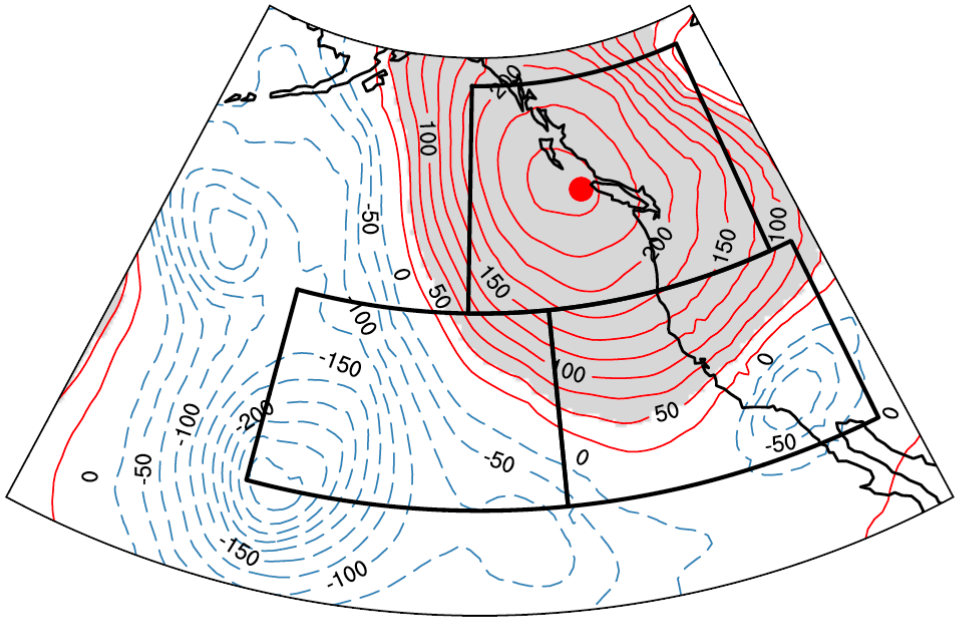
Summary

- Ridging events (and their different “flavors”) play a **critical role** in determining whether a water year will be a **feast or a famine**
- There are **sources of predictability** in the climate system that offer hope for extending our prediction window (ENSO, MJO, QBO)
- Understanding these “**windows of opportunity**” will be crucial for extending prediction skill into the S2S domain
- **Machine learning** and statistical post-processing applied to model output *may* help us capitalize on these windows (not comprehensively examined in the research community to date)

To characterize and quantify different **flavors of ridging**: 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

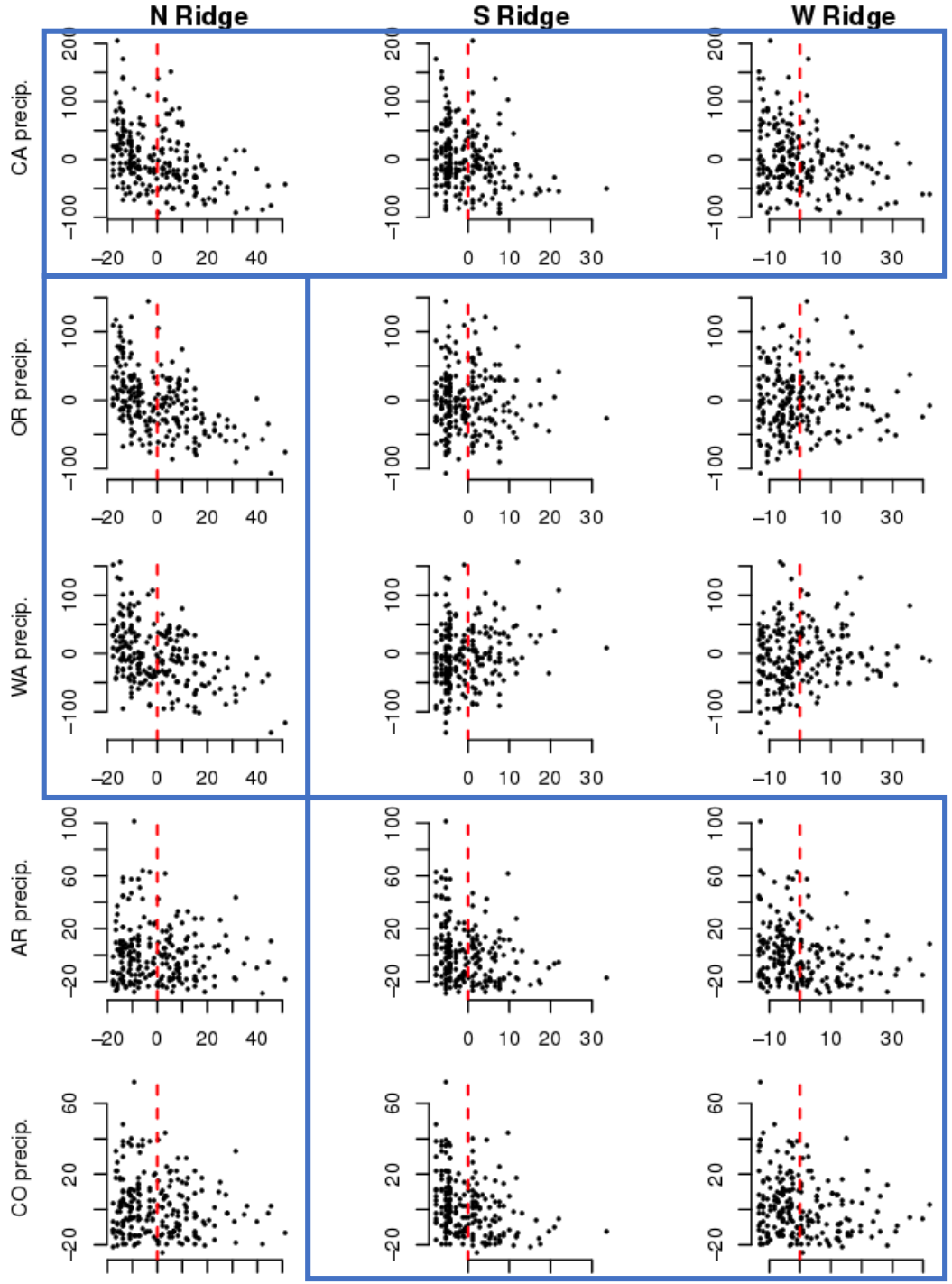
5 DEC 2017



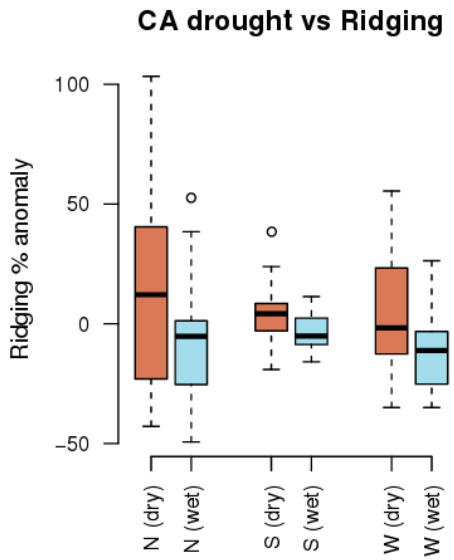
WCRI N = 194.49m
WCRI N (% positive) = 98.29%
N Ridge position critical? YES
N Ridge persistence (n.steps) 7

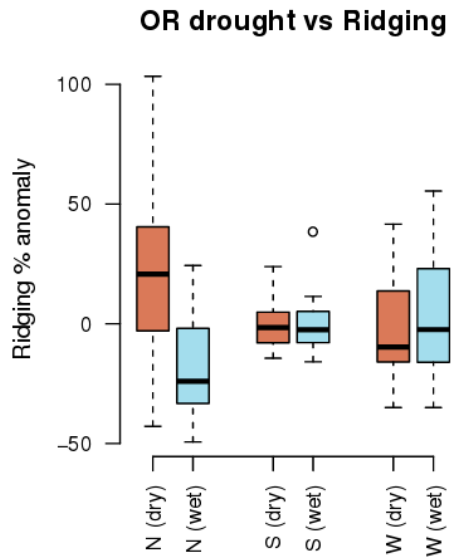
WCRI S = 49.47m
WCRI S (% positive) = 50.83%
S Ridge position critical? NO
S Ridge persistence (n.steps) 0

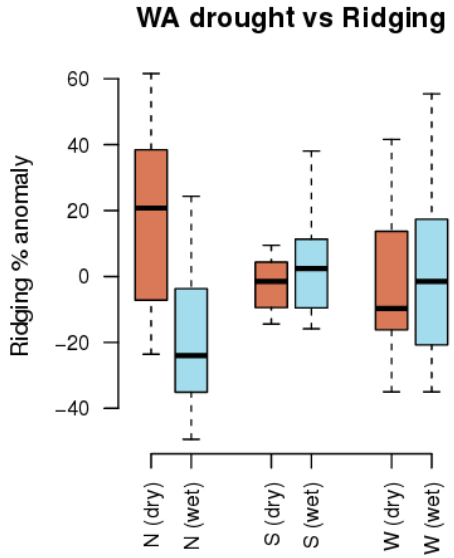
Number ridge events = 1
Area (km^2) = 6.28534e+06
max lat. span (km) = 2432.63
max lon. span (km) = 3417.1


N Ridge
S Ridge
W Ridge
CA precip.
OR precip.
WA precip.
AR precip.
CO precip.

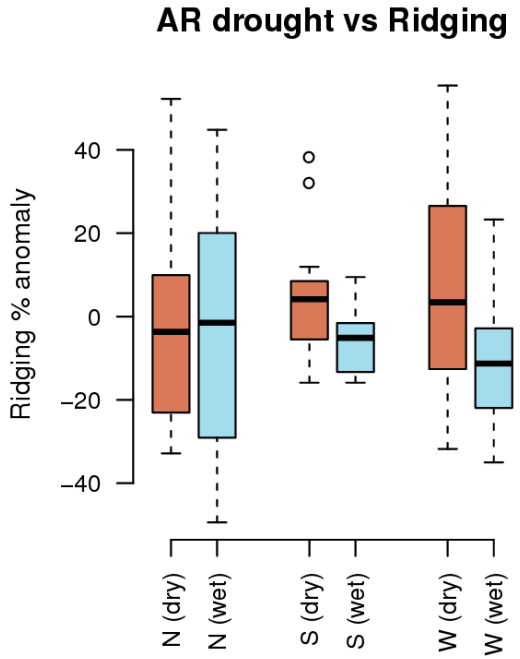
- CA: during drought there is a larger number of N,S,W ridging conditions
- OR+WA: during drought the main signal is in N ridging
- For WA – the W and S ridging occurs more often during wet periods (ARs pushed north)

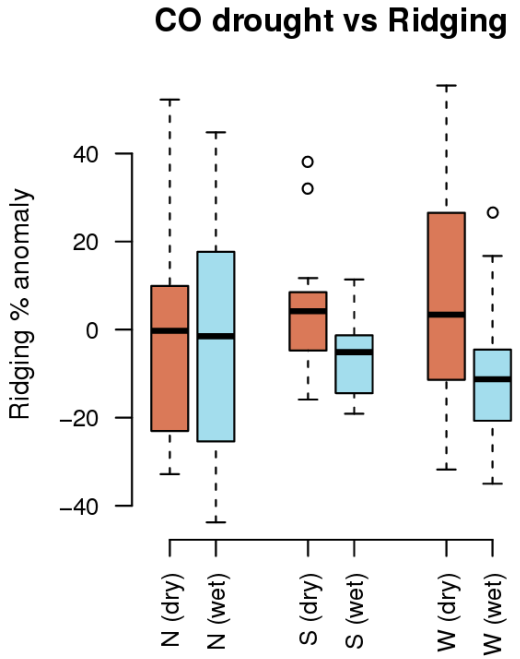


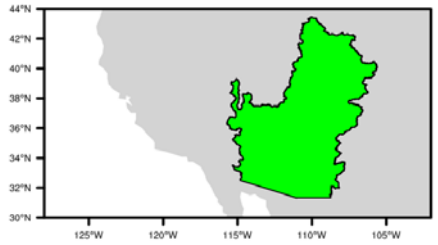




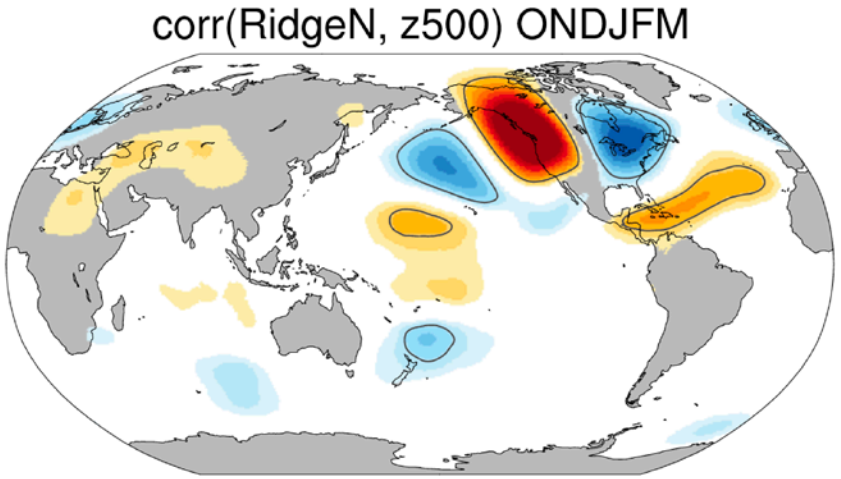
- For Arizona and Colorado (Basin) N ridging is less important during drought years – but W and S are especially important

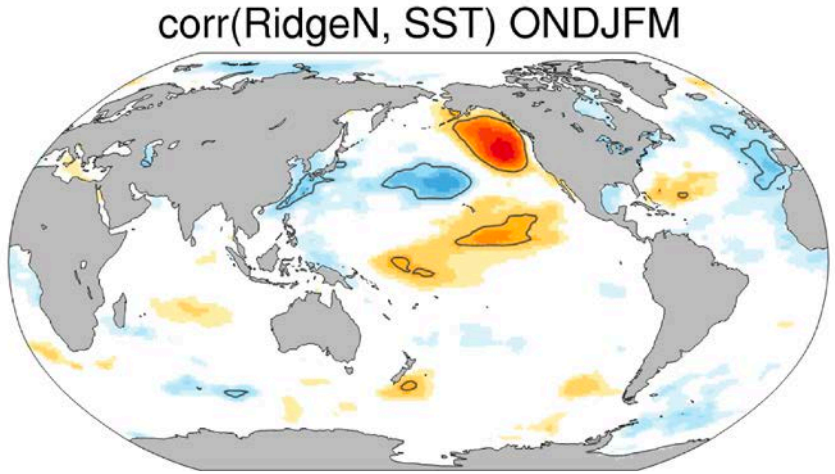


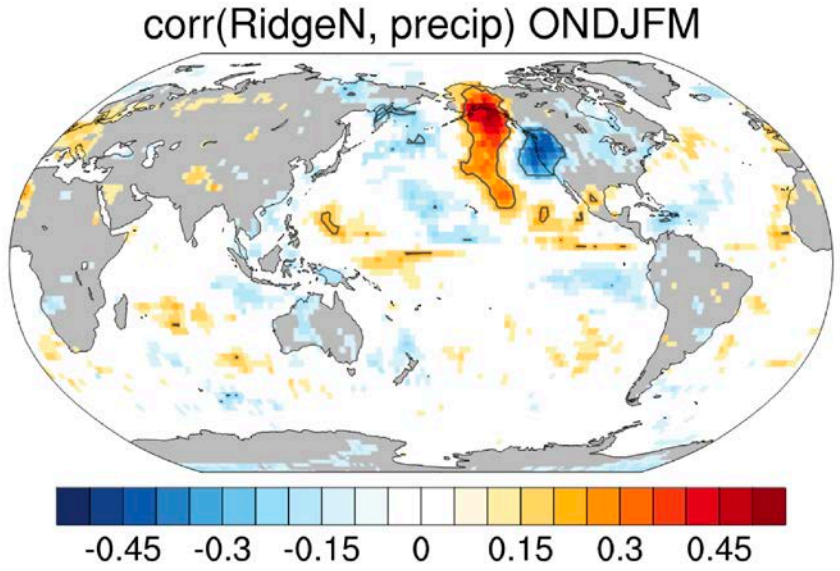




Teleconnections to monthly **N ridge counts**?

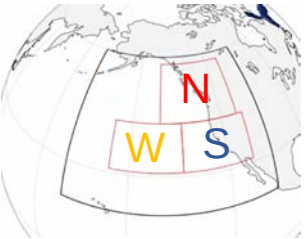




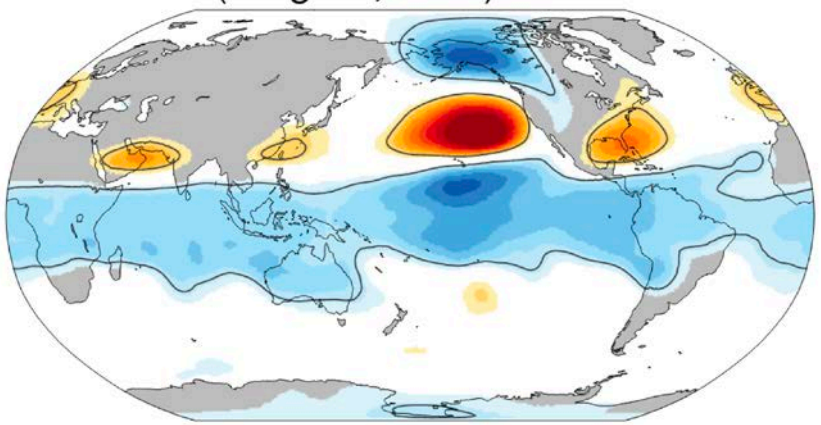


- Evidence of ~consistent wave train pattern
- Potential link to tropical SSTs outside of Nino3.4

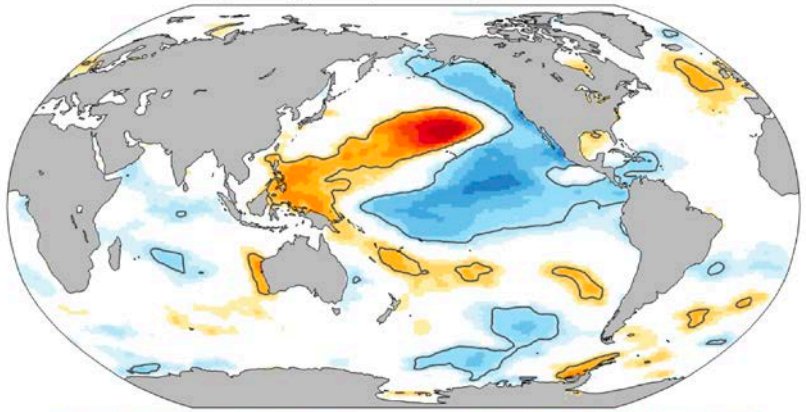
Teleconnections to monthly **W ridge counts**?



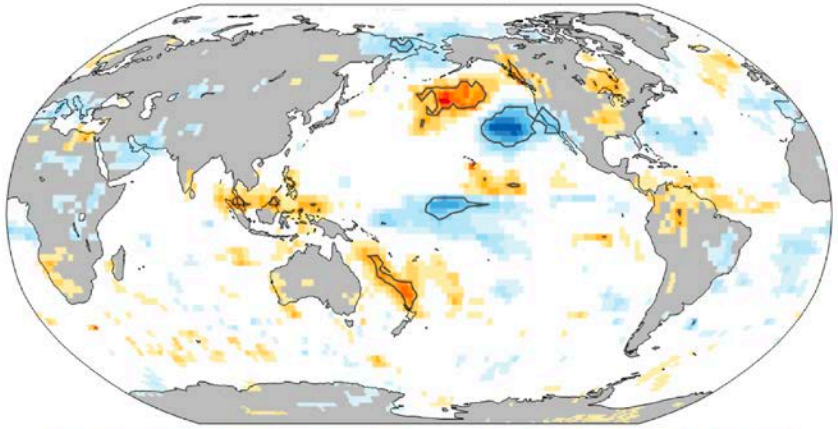
corr(RidgeW, z500) ONDJFM

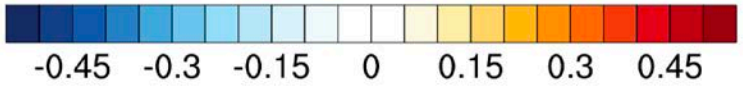


corr(RidgeW, SST) ONDJFM

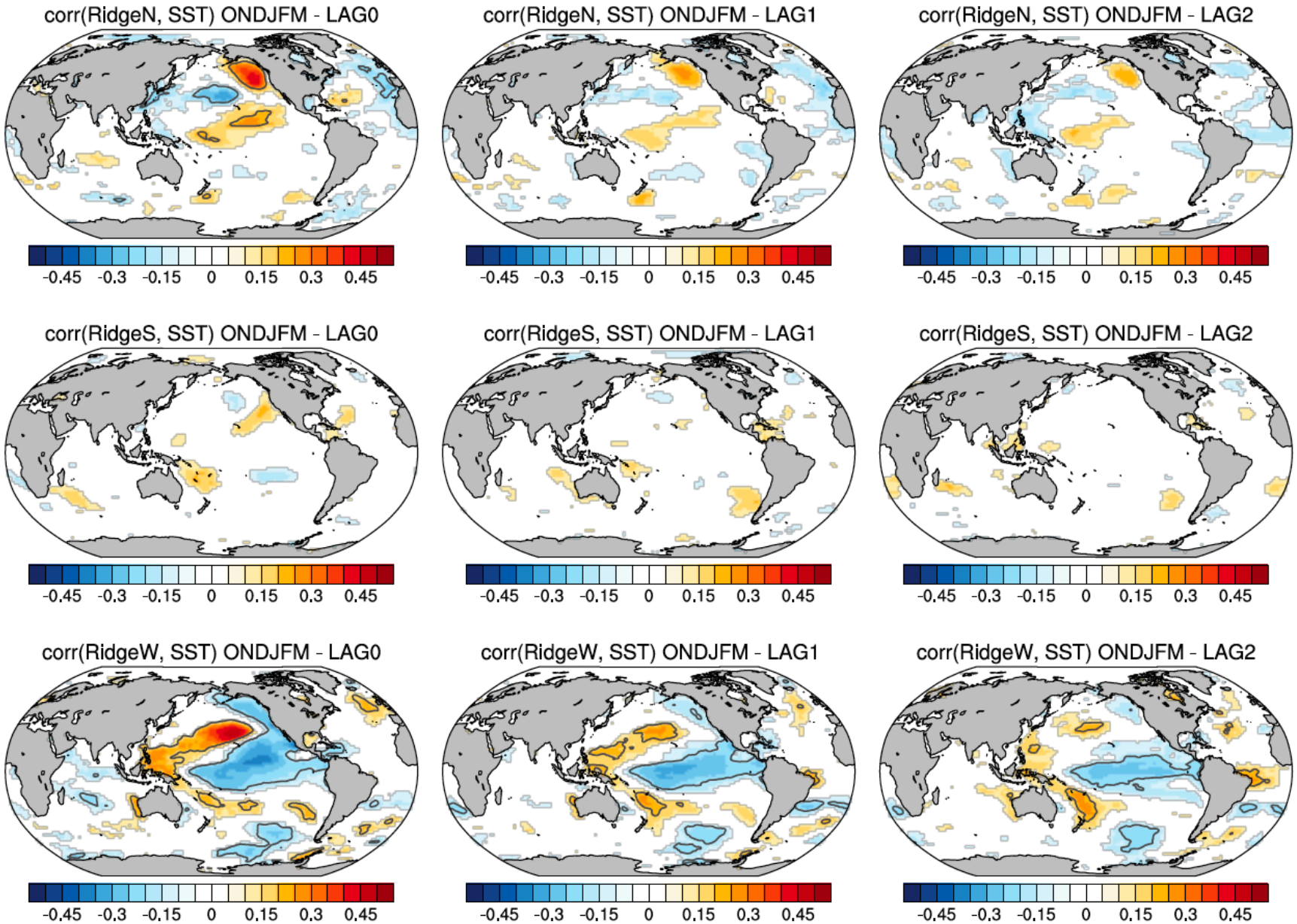


corr(RidgeW, precip) ONDJFM





- Strong link to tropical SSTs (La Nina)


corr(RidgeN, SST) ONDJFM - LAG0
corr(RidgeN, SST) ONDJFM - LAG1
corr(RidgeN, SST) ONDJFM - LAG2
corr(RidgeS, SST) ONDJFM - LAG0
corr(RidgeS, SST) ONDJFM - LAG1
corr(RidgeS, SST) ONDJFM - LAG2
corr(RidgeW, SST) ONDJFM - LAG0
corr(RidgeW, SST) ONDJFM - LAG1
corr(RidgeW, SST) ONDJFM - LAG2
-0.45 -0.3 -0.15 0 0.15 0.3 0.45