Characteristics and predictability of US West Coast atmospheric ridging events

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JPL: Peter Gibson, Duane Waliser, Mike DeFlorio, Bin Guan
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)
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

\[
IVT = \frac{1}{g} \int_{p_{sfc}}^{100 \text{hPa}} q \mathbf{V} \, dp
\]
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
Important locations for ridging, in terms of precipitation/ARs
Tracking ridge events and AR events concurrently

1 Oct 1980

(a) binary AR shape + ridge center

(b) IVT magnitude (shaded) + z500 anomalies (red)
Likelihood (Relative risk) of AR occurrence given Ridge occurrence

Northern Ridging:

• Up to 10-fold \textit{reduction} (RR=0.1) in probability of AR occurrence over much of West Coast
• Up to 5-fold \textit{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

- 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

The ‘Ridiculously Resilient Ridge’ January 2014 (90-day running mean z500 anomaly)

https://droughtmonitor.unl.edu/
Ridiculously Resilient Ridge (RRR) case study – Ridge persistence

The ‘Ridiculously Resilient Ridge’ January 2014 (90-day running mean z500 anomaly)

https://droughtmonitor.unl.edu/

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

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

One example .....
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 agreement)