The contribution of wind stress and curl weakening to recent marine heat waves along North America

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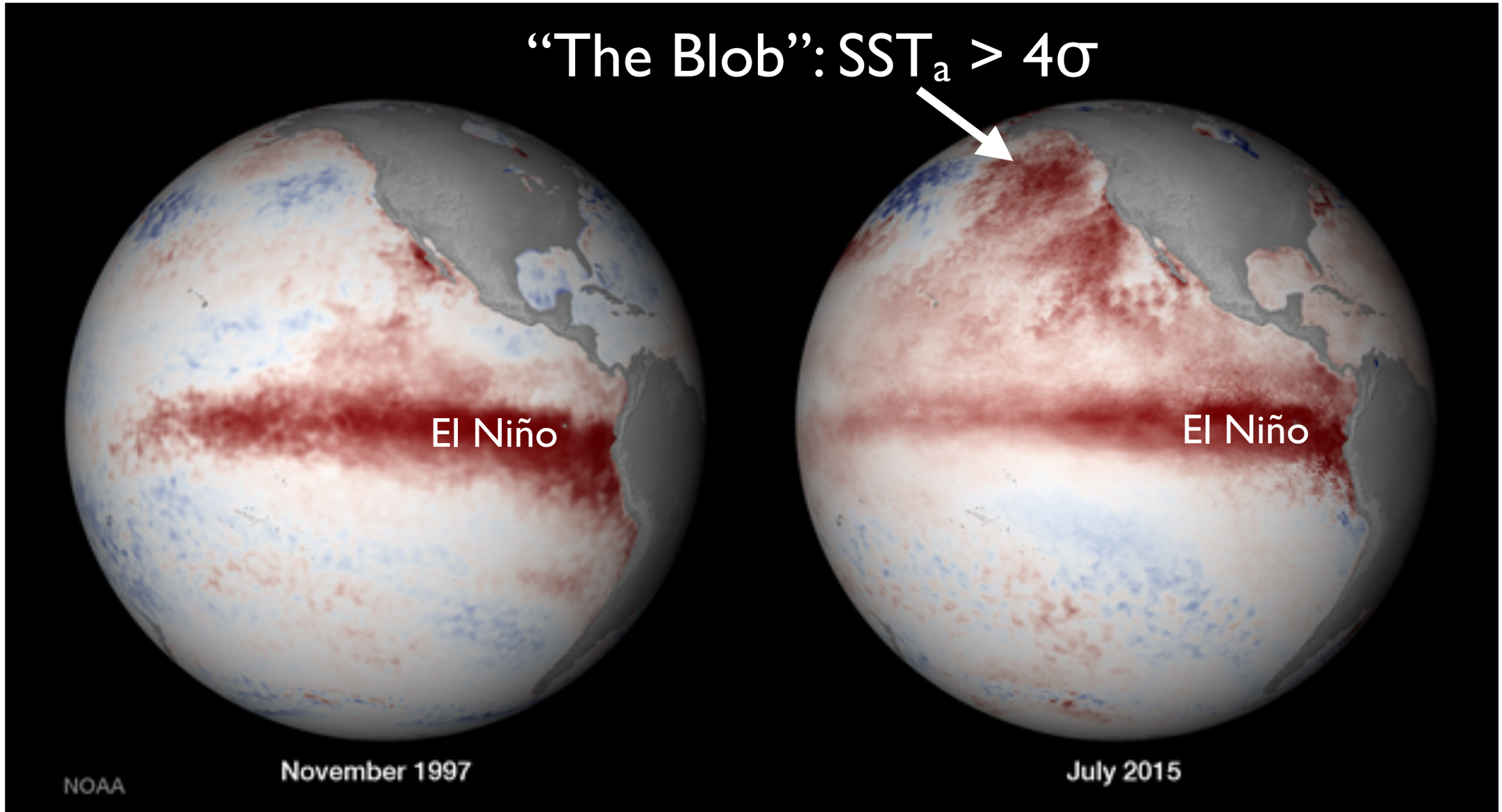
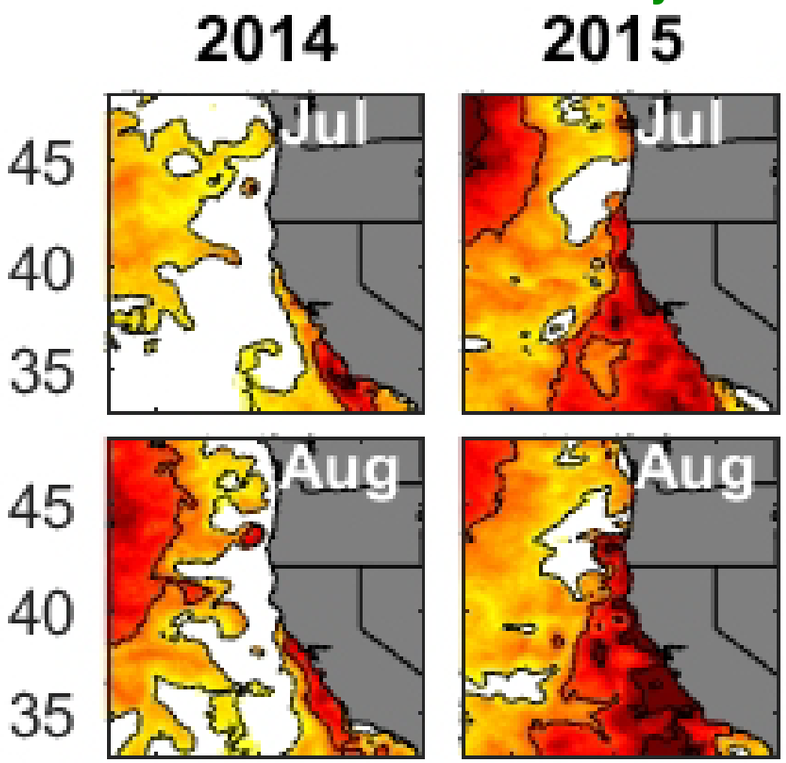


The Blob

A marine heat wave
in the northeast Pacific
2013-2016

What happened along the coast?

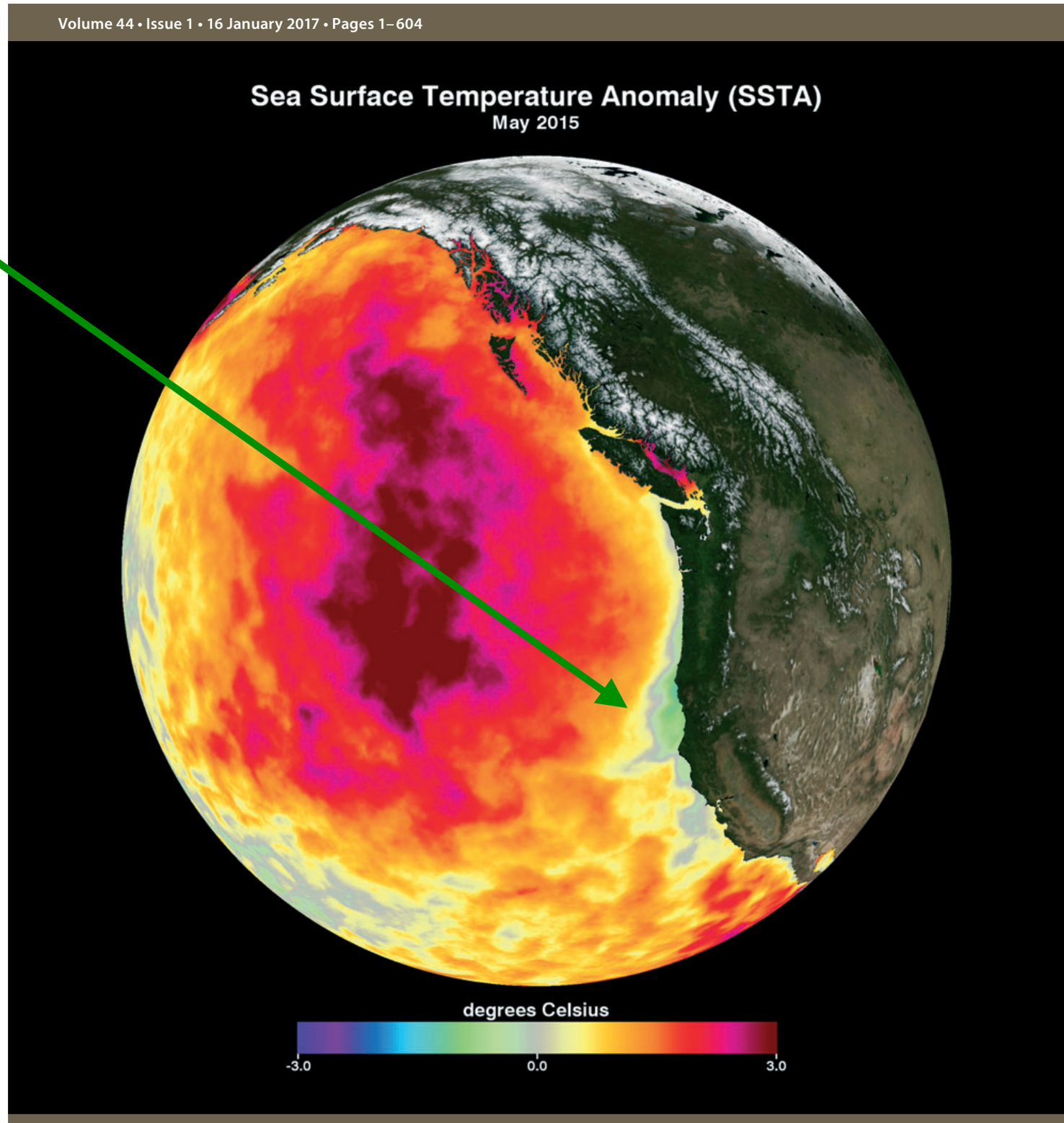
The heat wave was worse
in the southern half
of the California Current System.



Gentemann, Fewings, and García-Reyes
Geophysical Research Letters, 2017

Why?

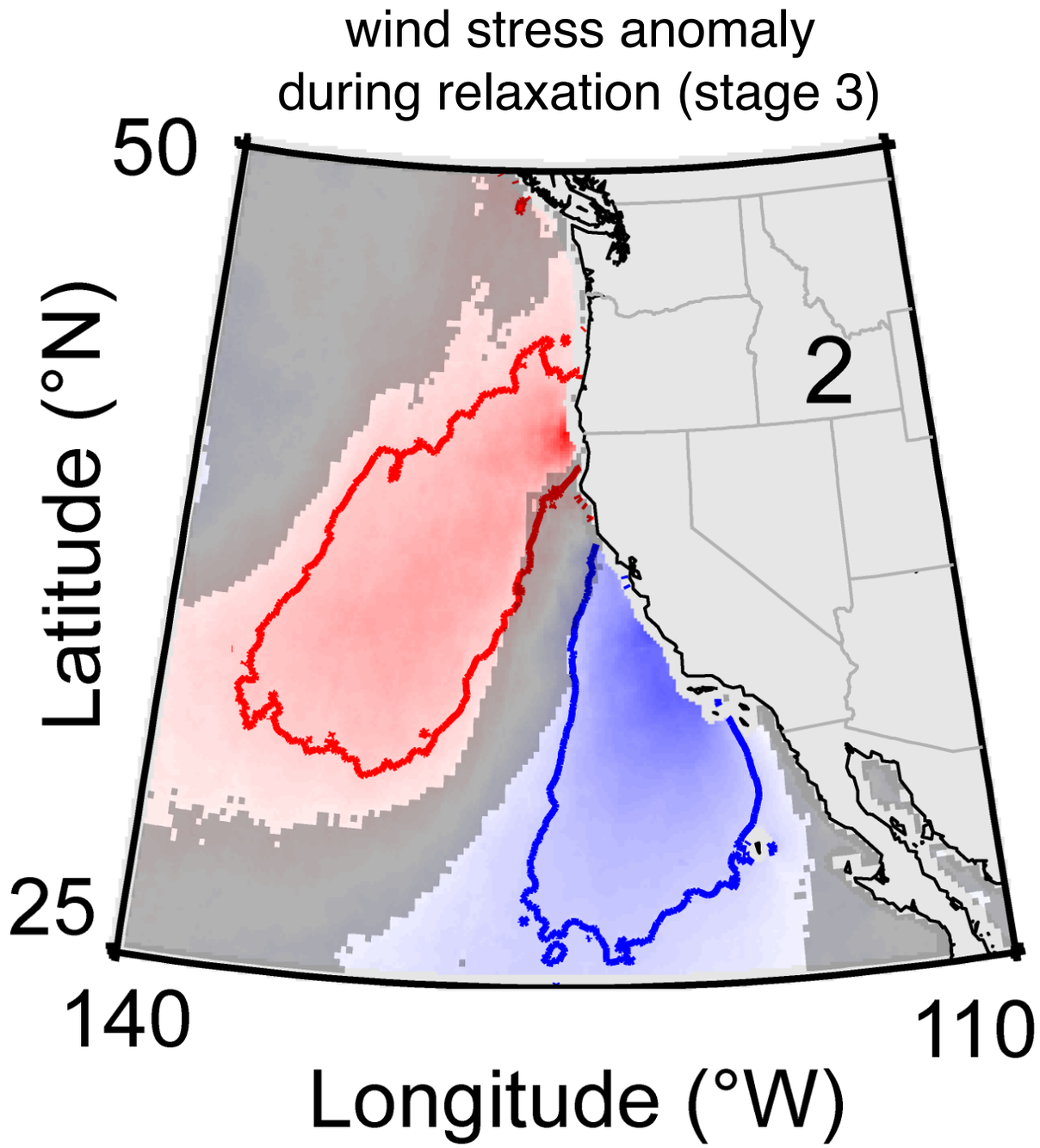
Geophysical Research Letters
AN AGU JOURNAL
Volume 44 • Issue 1 • 16 January 2017 • Pages 1–604



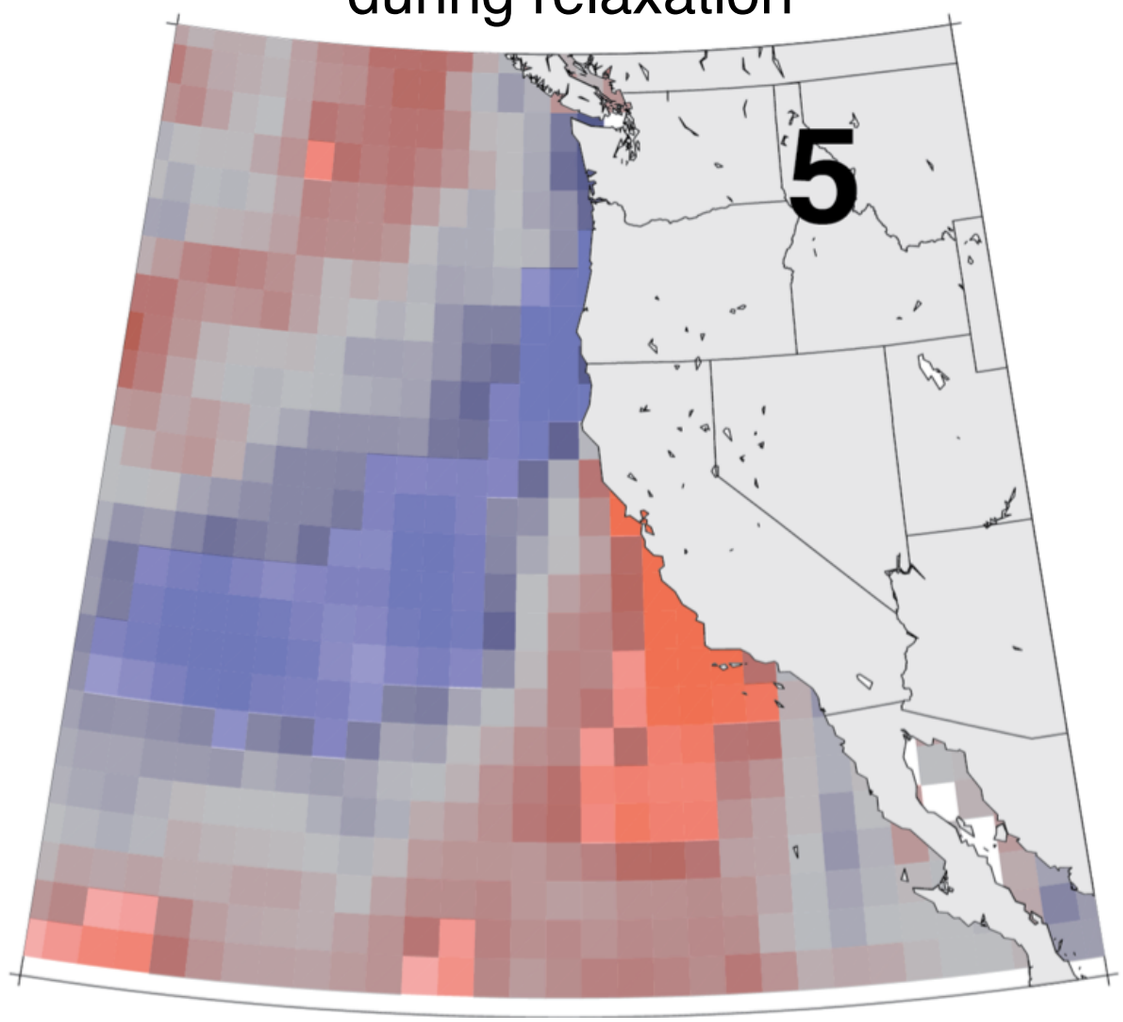
AGU PUBLICATIONS
WILEY

Were winds south of Mendocino in late 2014 and 2015 in a persistent relaxation state?

That could explain the larger SST anomalies in the southern region



Fewings et al., JGR 2016

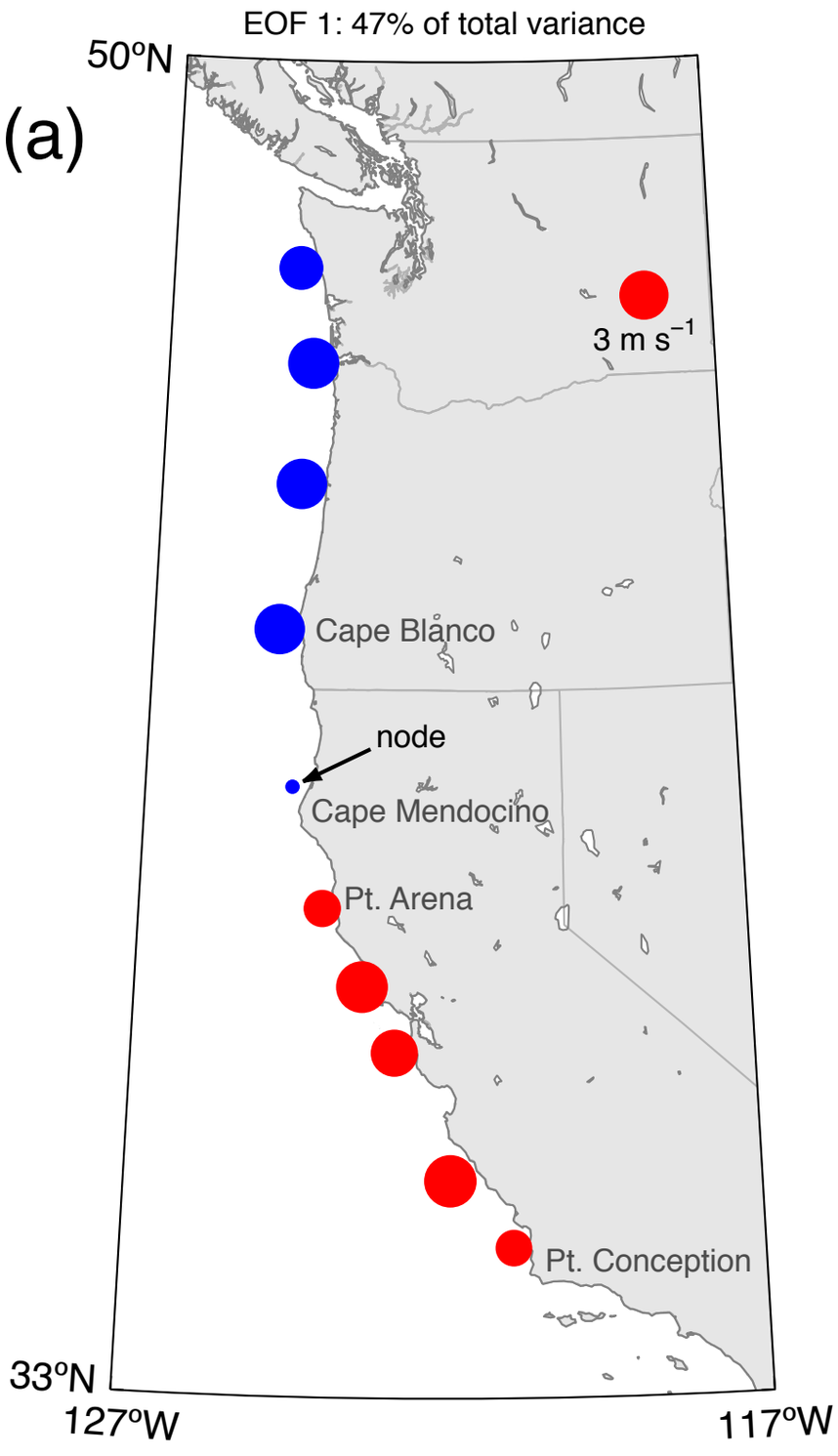


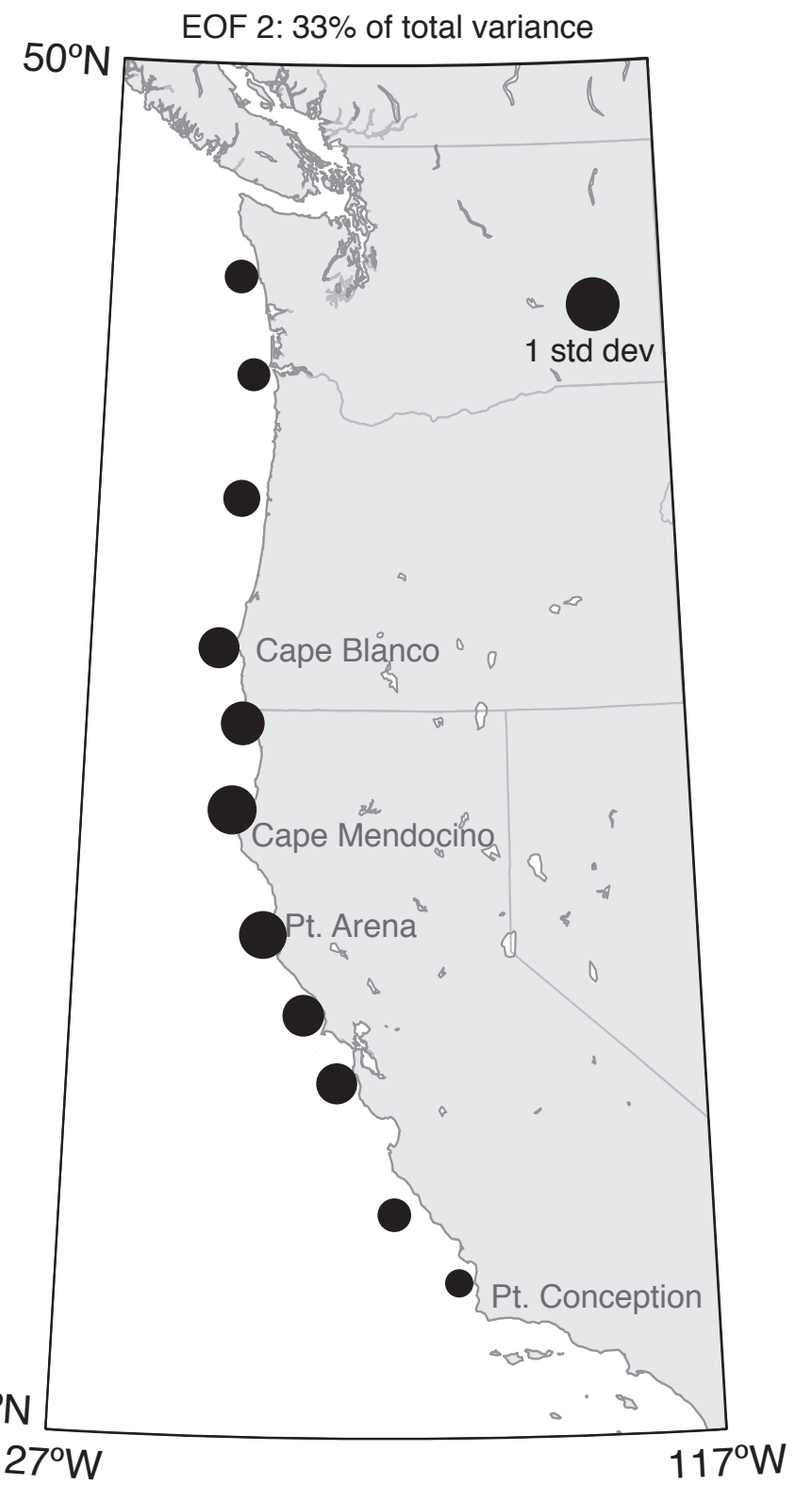
Flynn, 2016
Flynn et al., JGR 2017

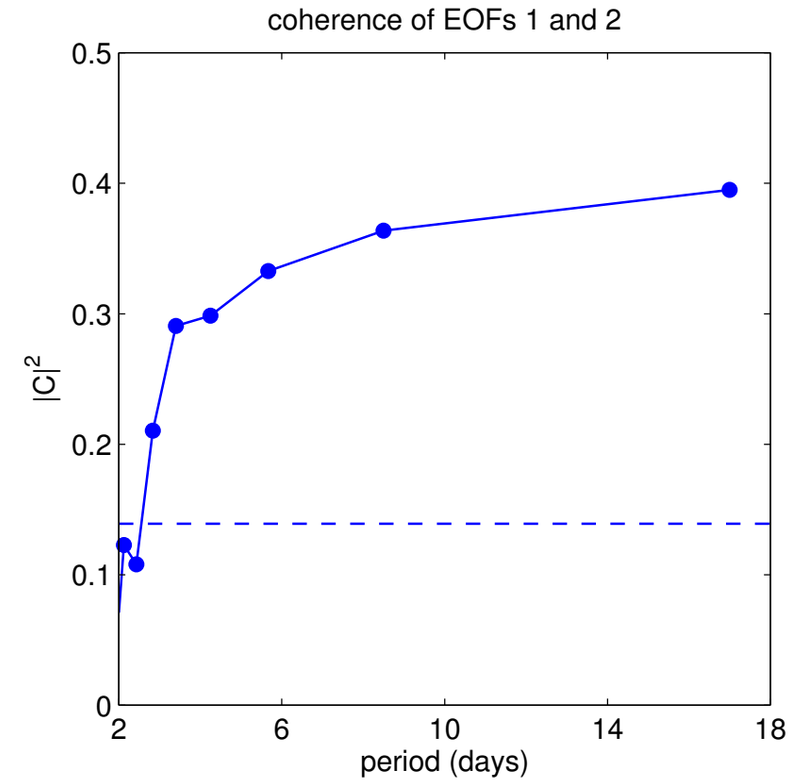
When central California winds are relaxed, winds off Oregon tend to be intensified. Can we make a time series index?

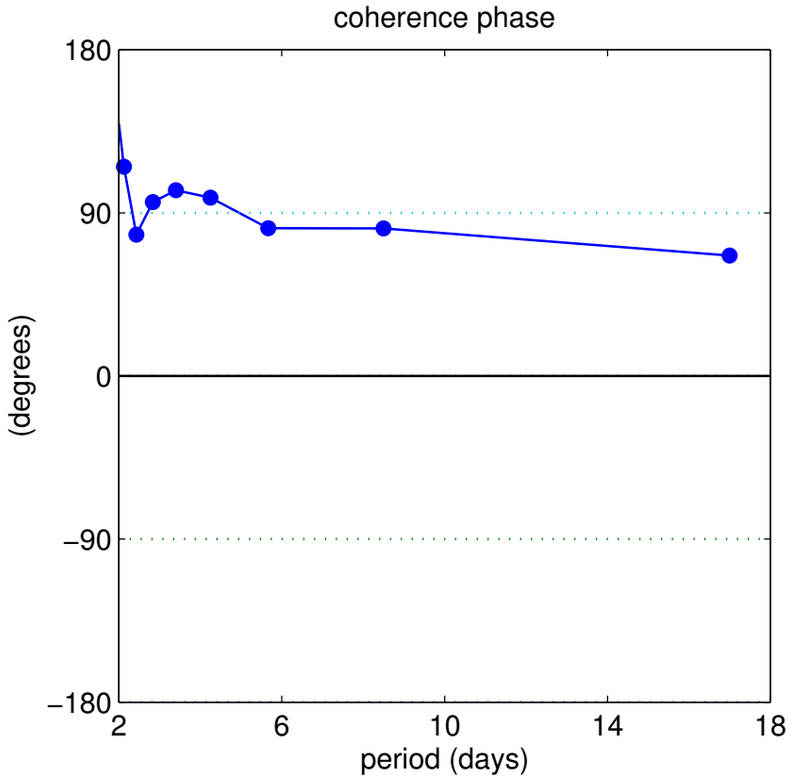
Yes, first EOF of buoy winds is a dipole! …but we can't ignore EOF 2

(a)





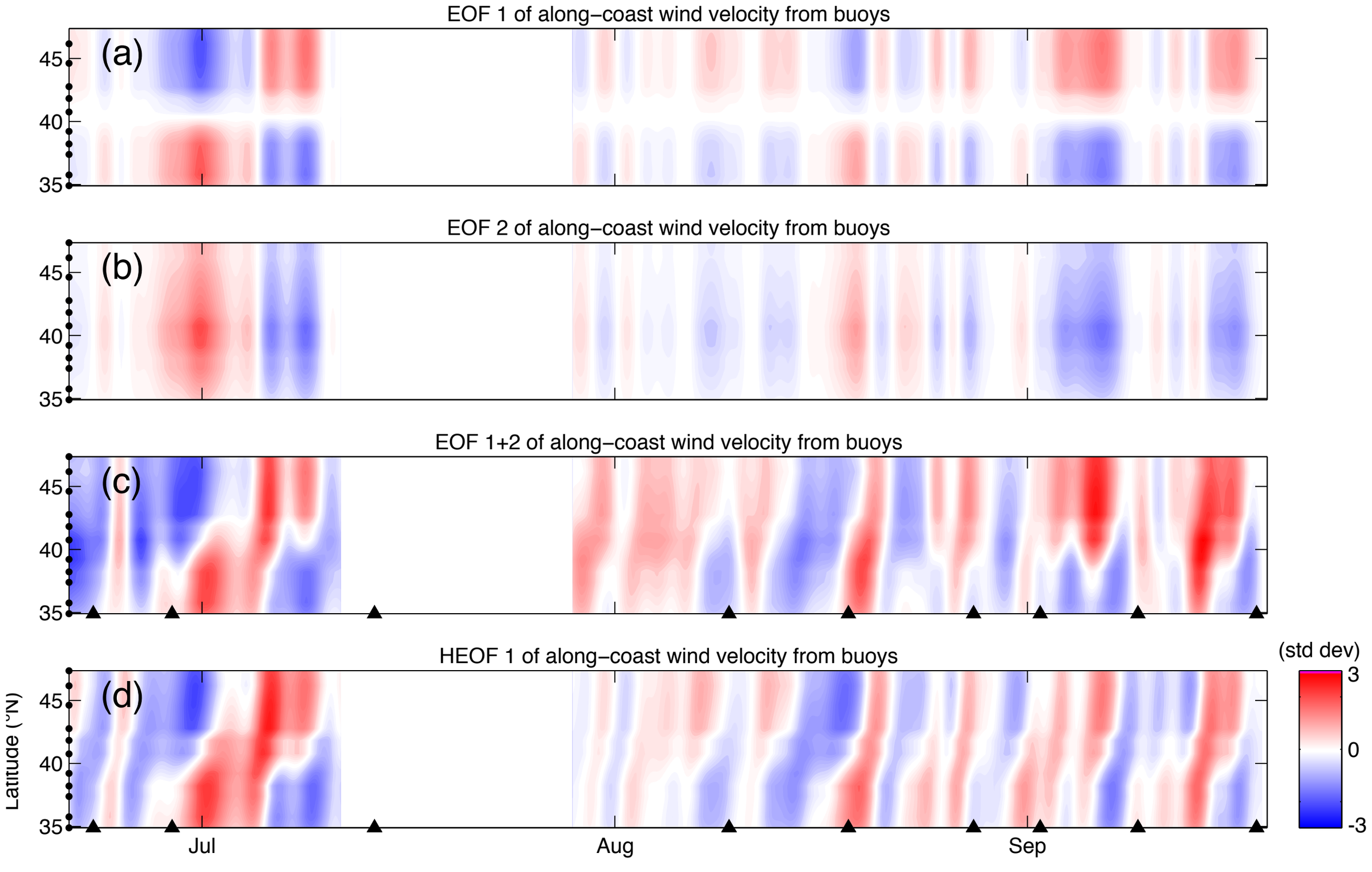




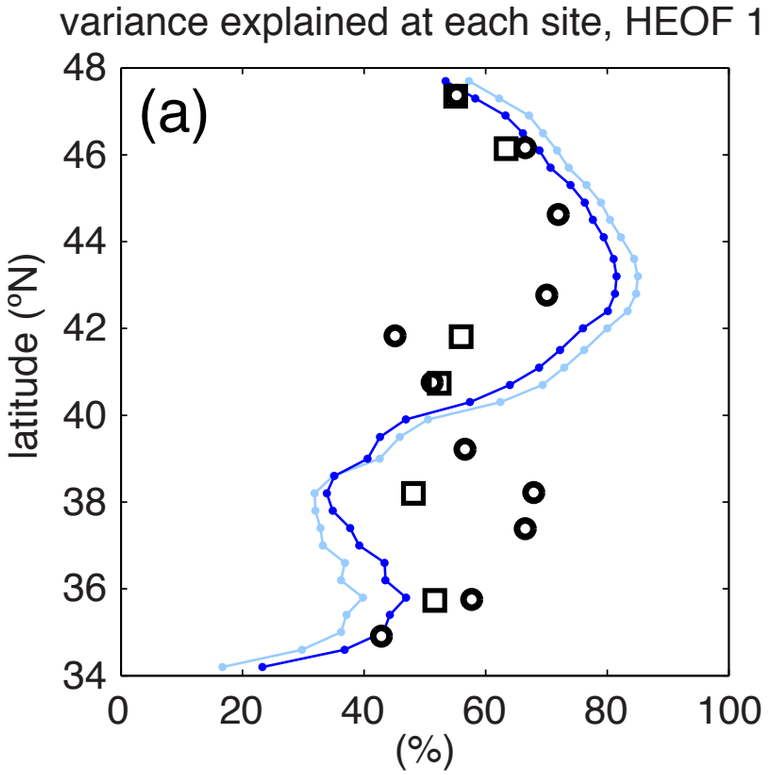
Fewings, submitted to
Monthly Weather Review

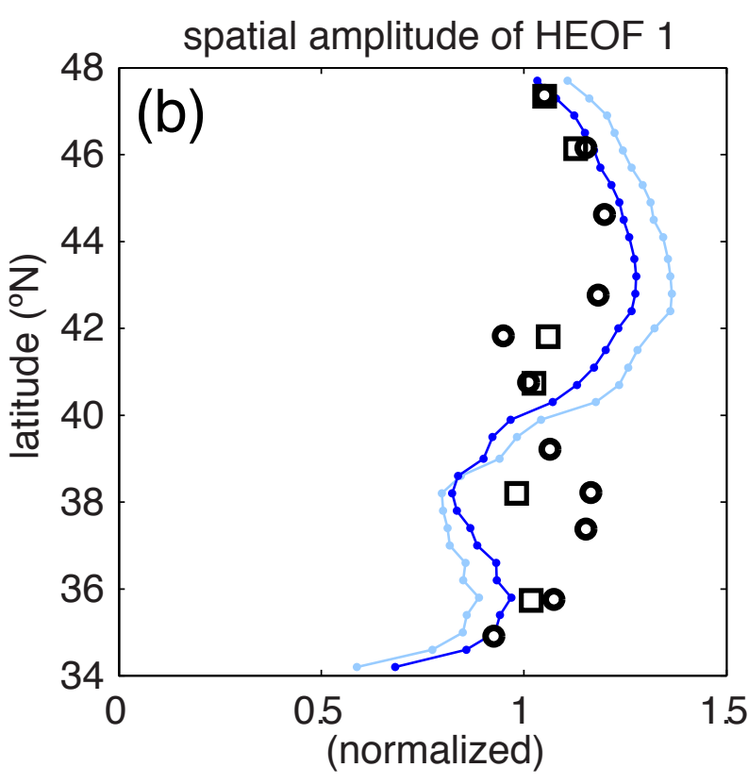
The wind anomalies are actually propagating up the coast.

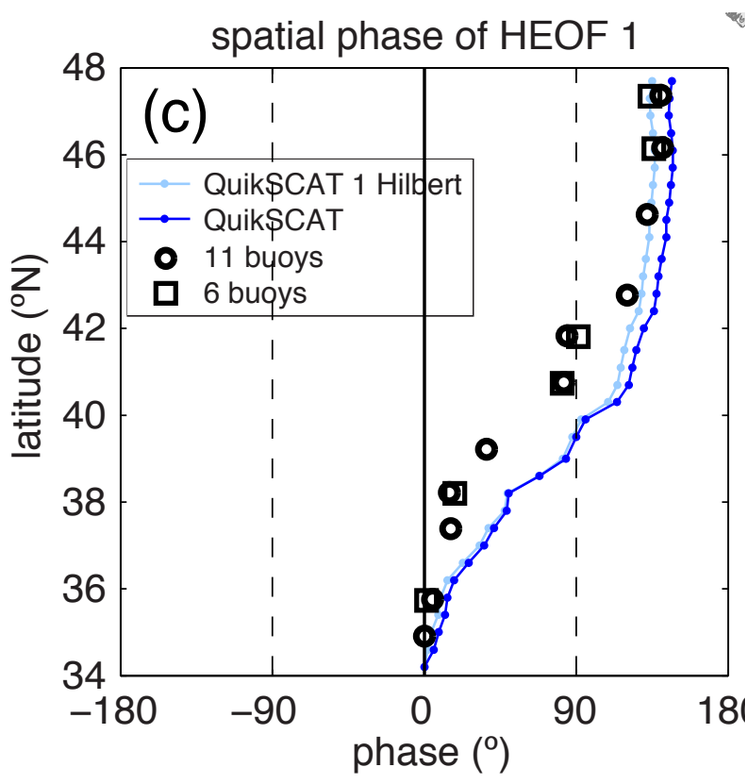
Standard EOFs are not good for describing propagation.
We need complex EOFs: Hilbert EOFs.

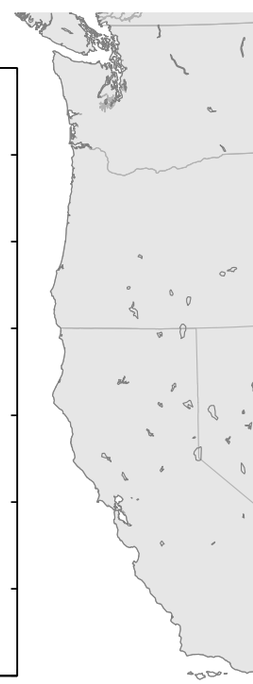


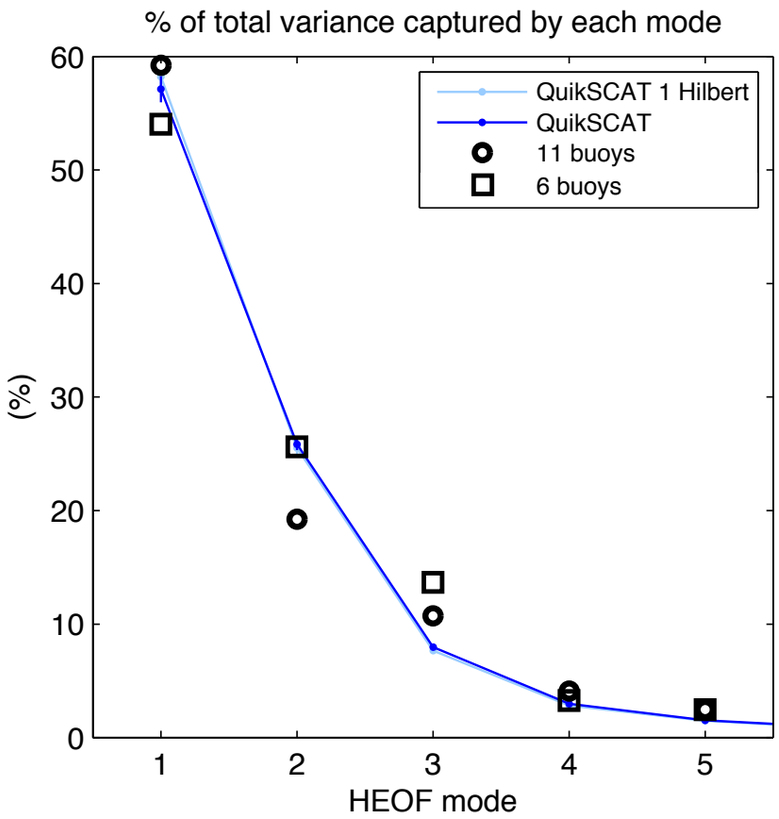
60% of the wind velocity variance is captured in a single Hilbert EOF











dominant wind fluctuations
in north and south
are almost 180° out of phase.

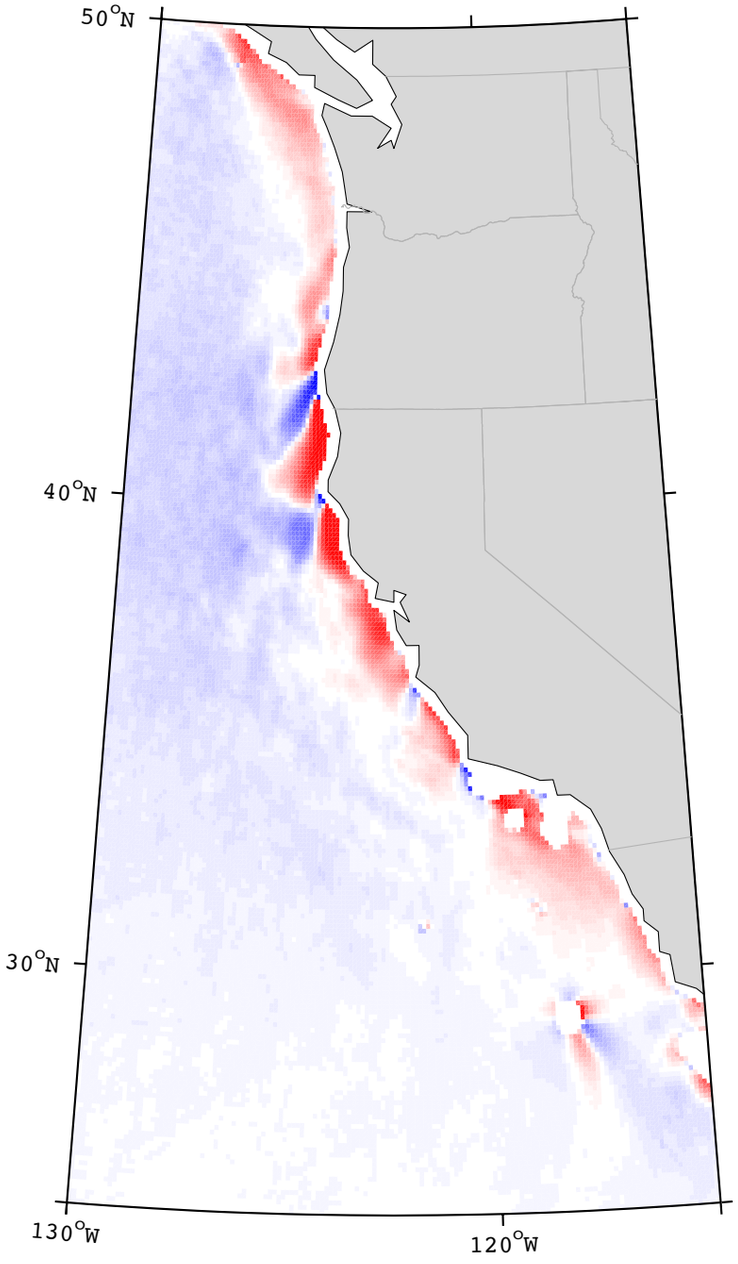
- consistent with known 3-stage wind cycle
  (Mass and Bond 1996, Nuss 2007, Fewings et al. 2016)

- with LCR QuikSCAT v3.1, closer to coast the phase progressively approaches buoy phase

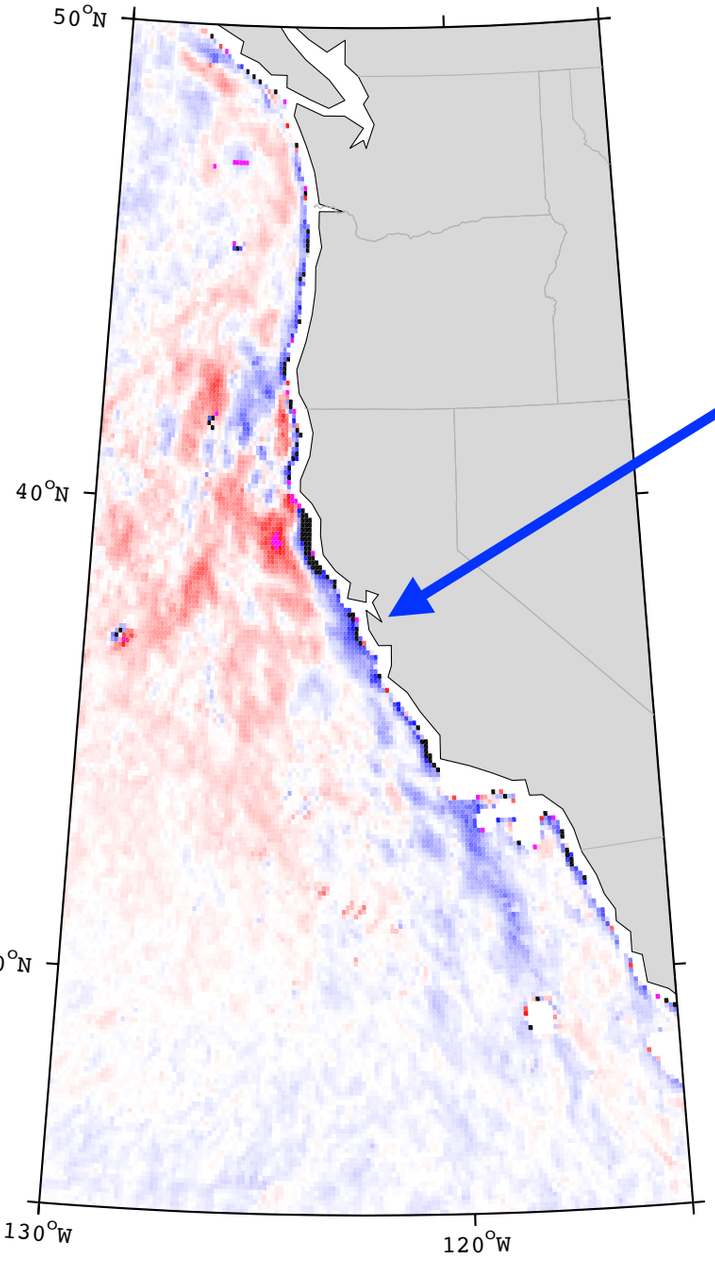
Fewings, submitted to *Monthly Weather Review*

The wind stress curl anomalies are also stronger in the south

QuikSCAT wind stress curl
mean JJA 2000-2009



wind stress curl anomaly, JJA 2015
RapidSCAT minus
QuikSCAT climatology



scale = +/- 10^{-6} Pa/m
= +/- 1 m/day of upwelling

strong negative anomaly in Central and South regions = reduced upwelling ...helps explain warmer SST

- Pickett and Paduan 2003:
curl-driven upwelling is ~50% of total

- need for coverage closer to coast

- gridded but no smoothing or filling

Ongoing and Future Work

Develop a time index of the alternating relaxations through 2016

can this shed light on the marine heat waves?

- use HEOF 1 to interpret 2015: stuck in 1 phase of the dipole mode all summer, like long-term wind relaxation?
- link to larger-scale atmospheric circulation: position of North Pacific High

Wind stress curl anomalies

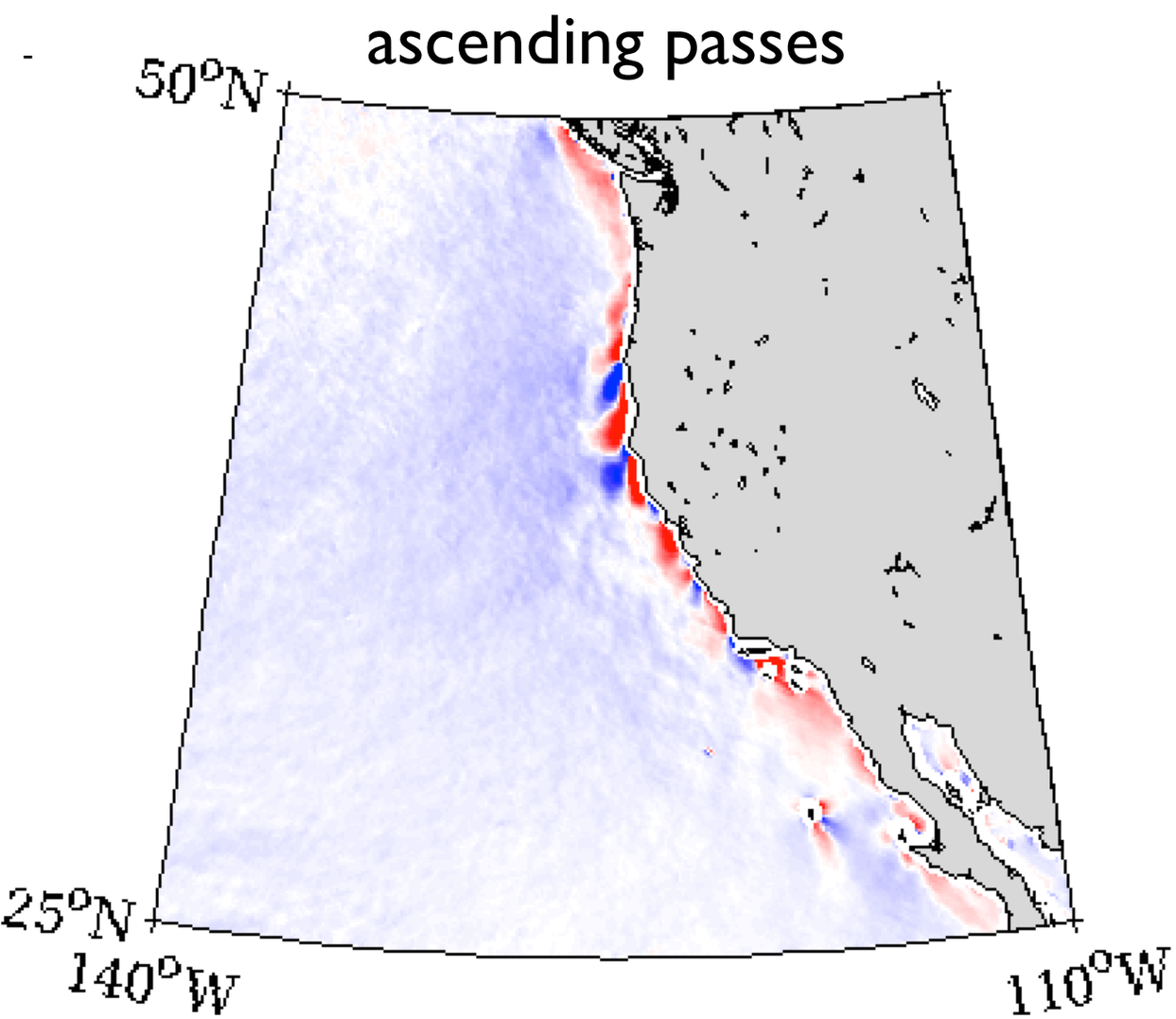
- curl-driven upwelling is ~50% of total?
- north-south differences in curl anomalies
- (H)EOFs of wind stress curl from QuikSCAT, RapidSCAT, + ASCAT (approach)

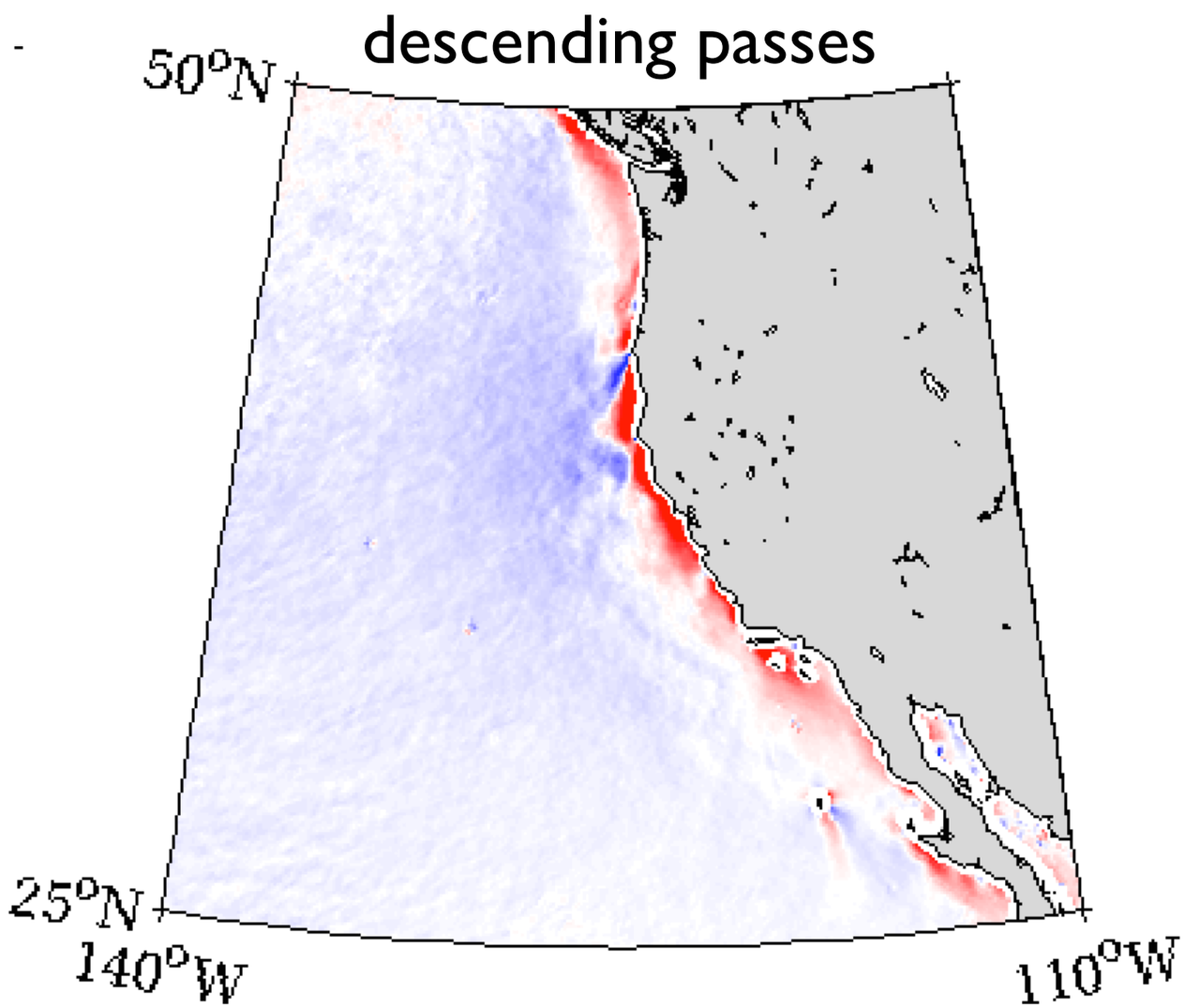
Acknowledgments:

NASA Ocean Vector Winds Science Team Grant

NASA / Jet Propulsion Laboratory RapidSCAT Mission

Mean summer wind stress curl from QuikSCAT v3 shows strong diurnal variations near coastal capes





Conclusions Part II: wind forcing in upwelling systems

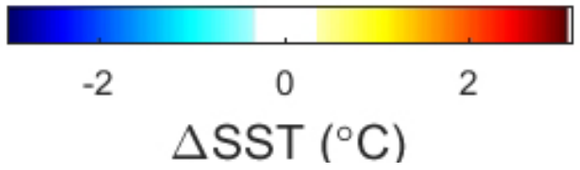
Over half the wind velocity variance is coherent
over the entire California Current System

Wind fluctuations in the north and south ends of the CCS
tend to alternate in time

Weaker wind stress AND curl south of Cape Mendocino in summer 2015
help explain the stronger SST anomalies during The Blob

Monthly SST anomalies relative to the 2002–2012 climatology

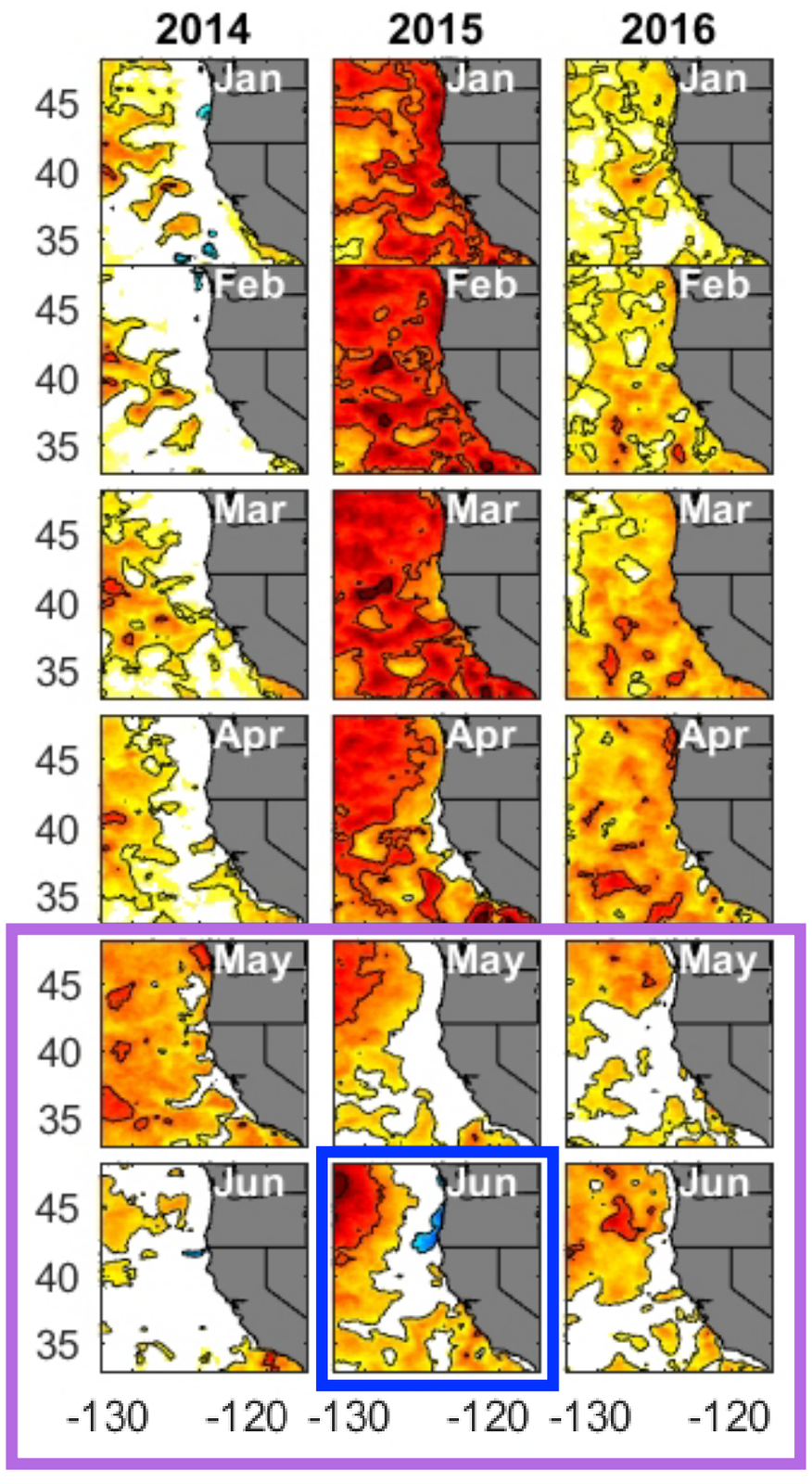
white: anomaly < 1 std dev

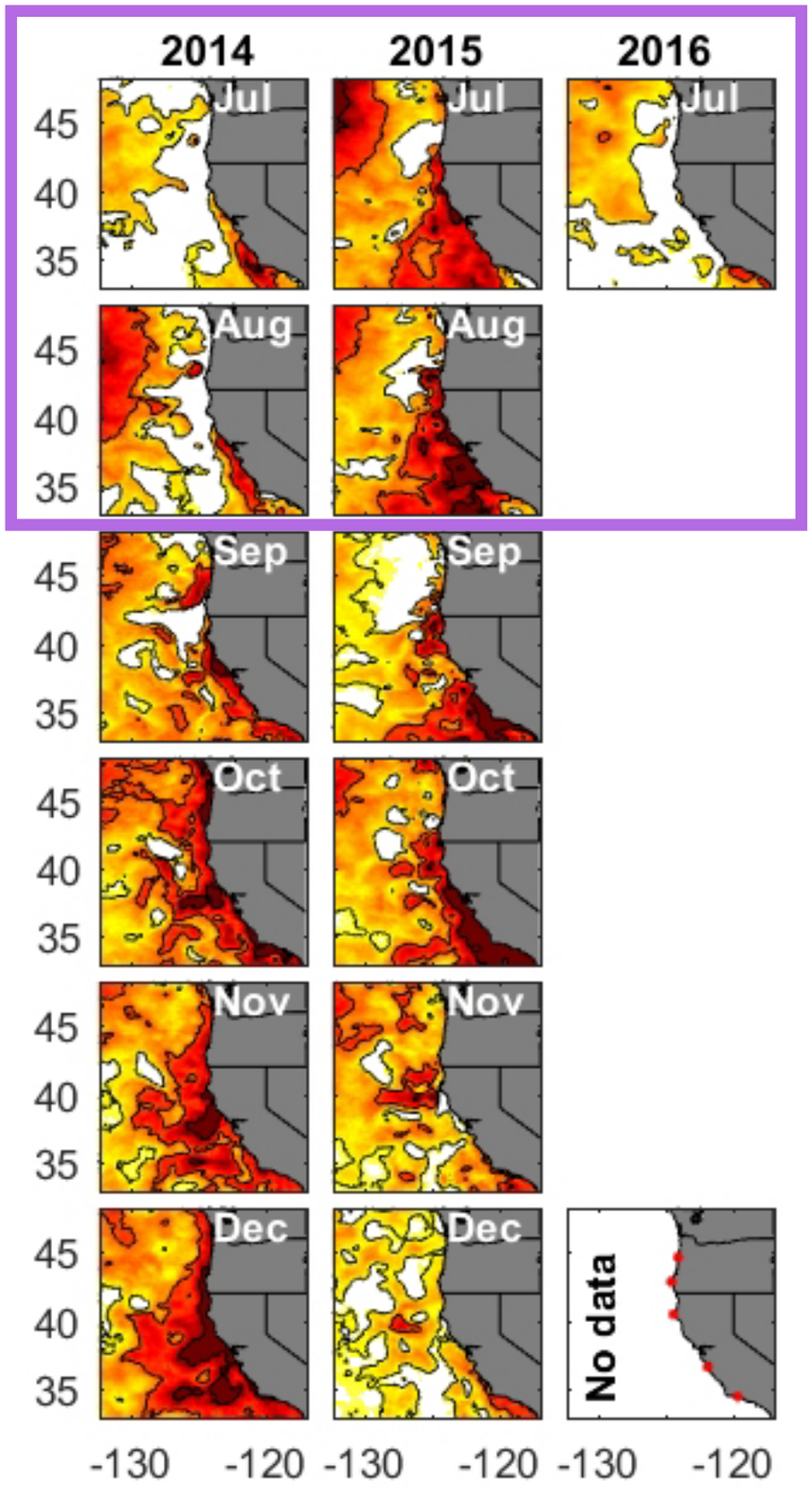


SST anomaly disappears during peak upwelling season, esp. 2014 & 2016

summer SST anomaly is more persistent south of Cape Mendocino

only 1 cold anomaly in 2.5 years!

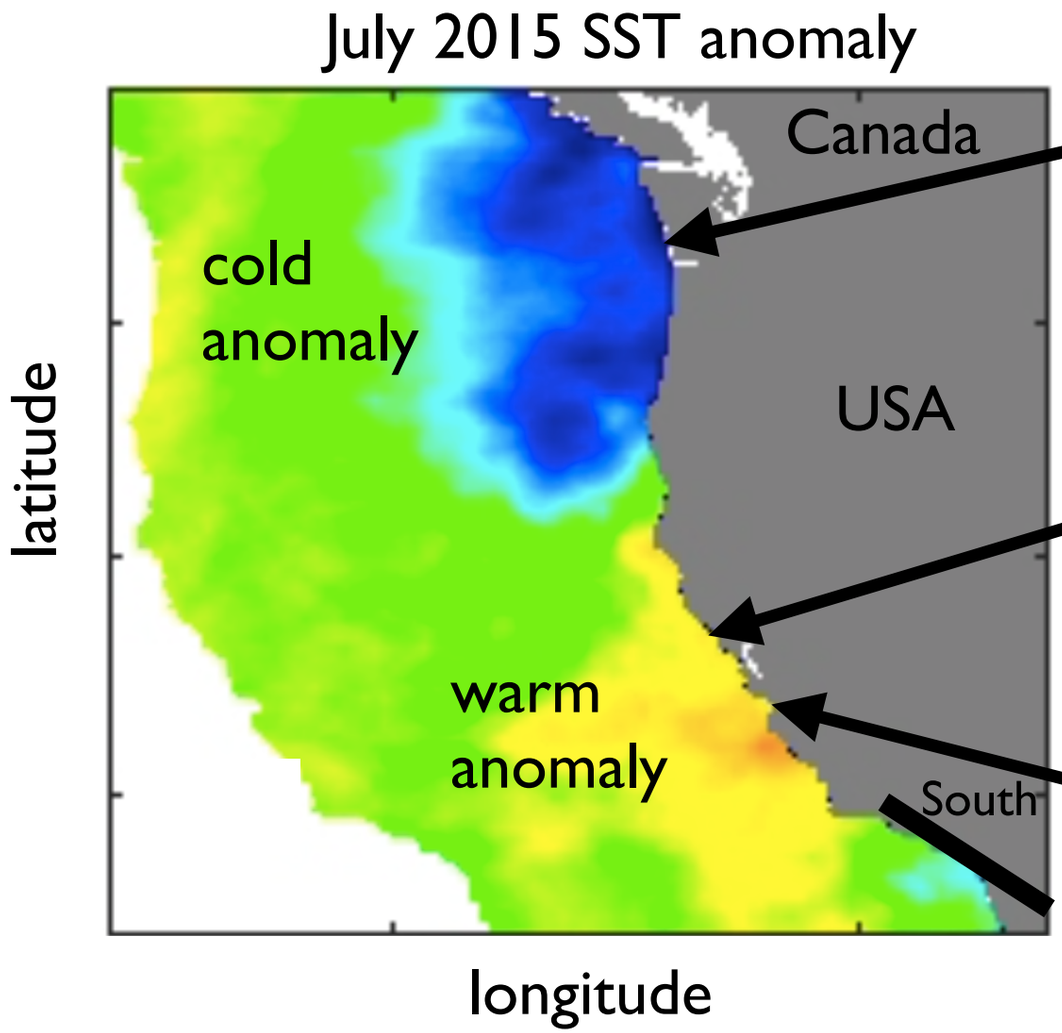


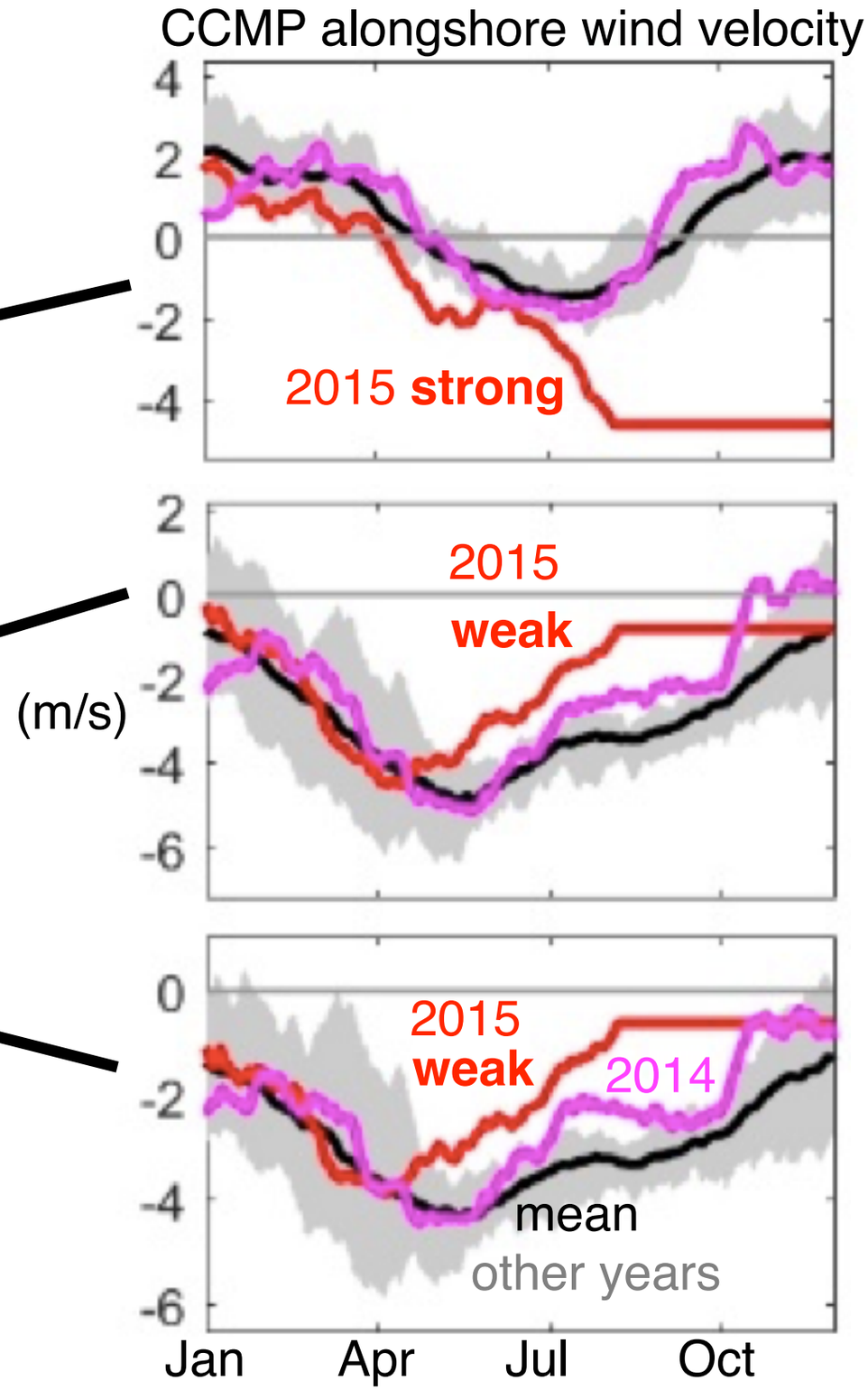


Gentemann, Fewings, and Garcia-Reyes, submitted

In the regions where coastal SST behaved differently, were the wind stress anomalies different? Yes

SST and CCMP wind stress anomalies
indicate weak upwelling
south of Mendocino in summer 2015



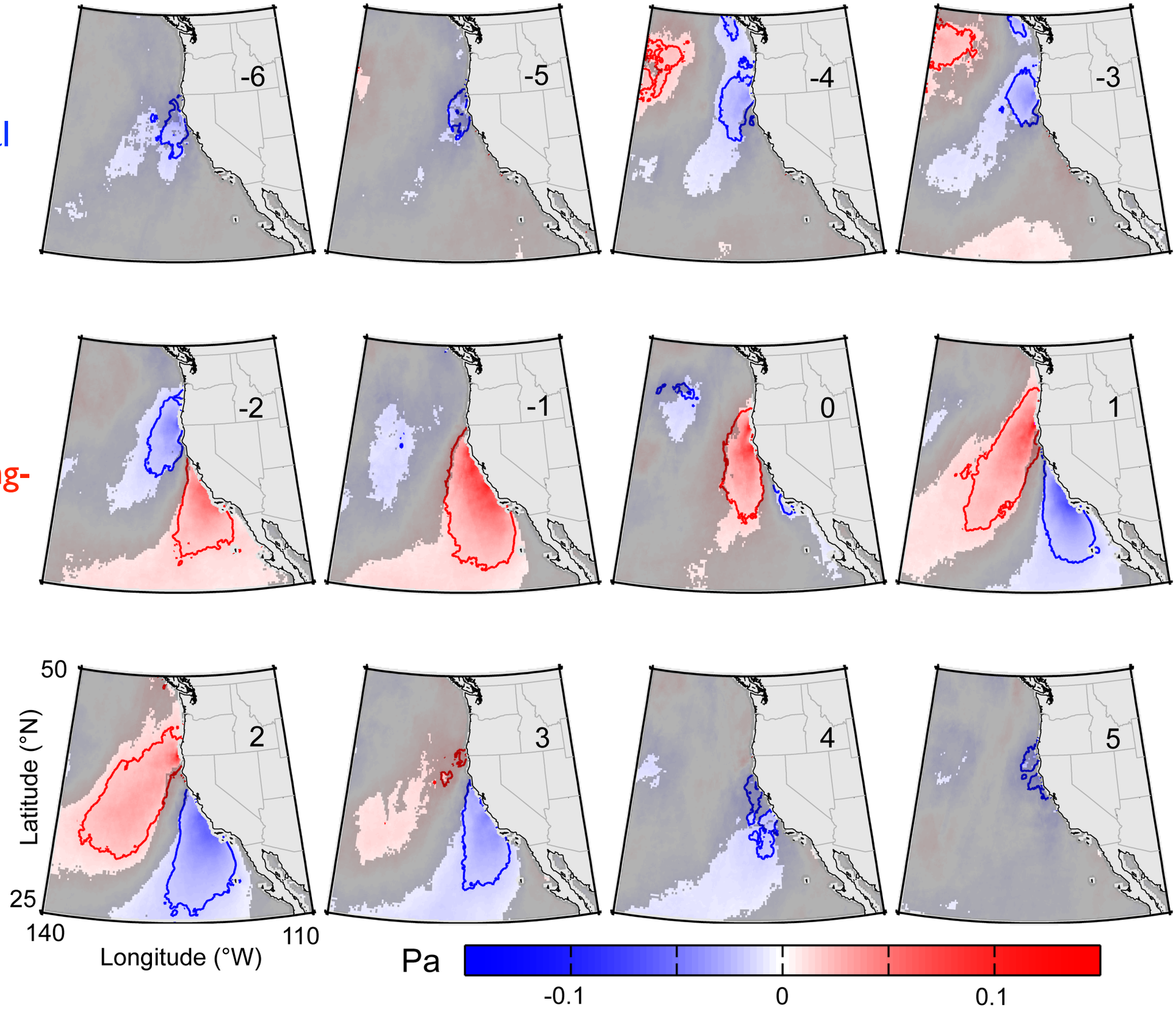


A wind relaxation cycle: composite wind stress anomalies from QuikSCAT

stage 1:
relaxation/reversal
off Oregon

stage 2:
intensified upwelling-
favorable wind

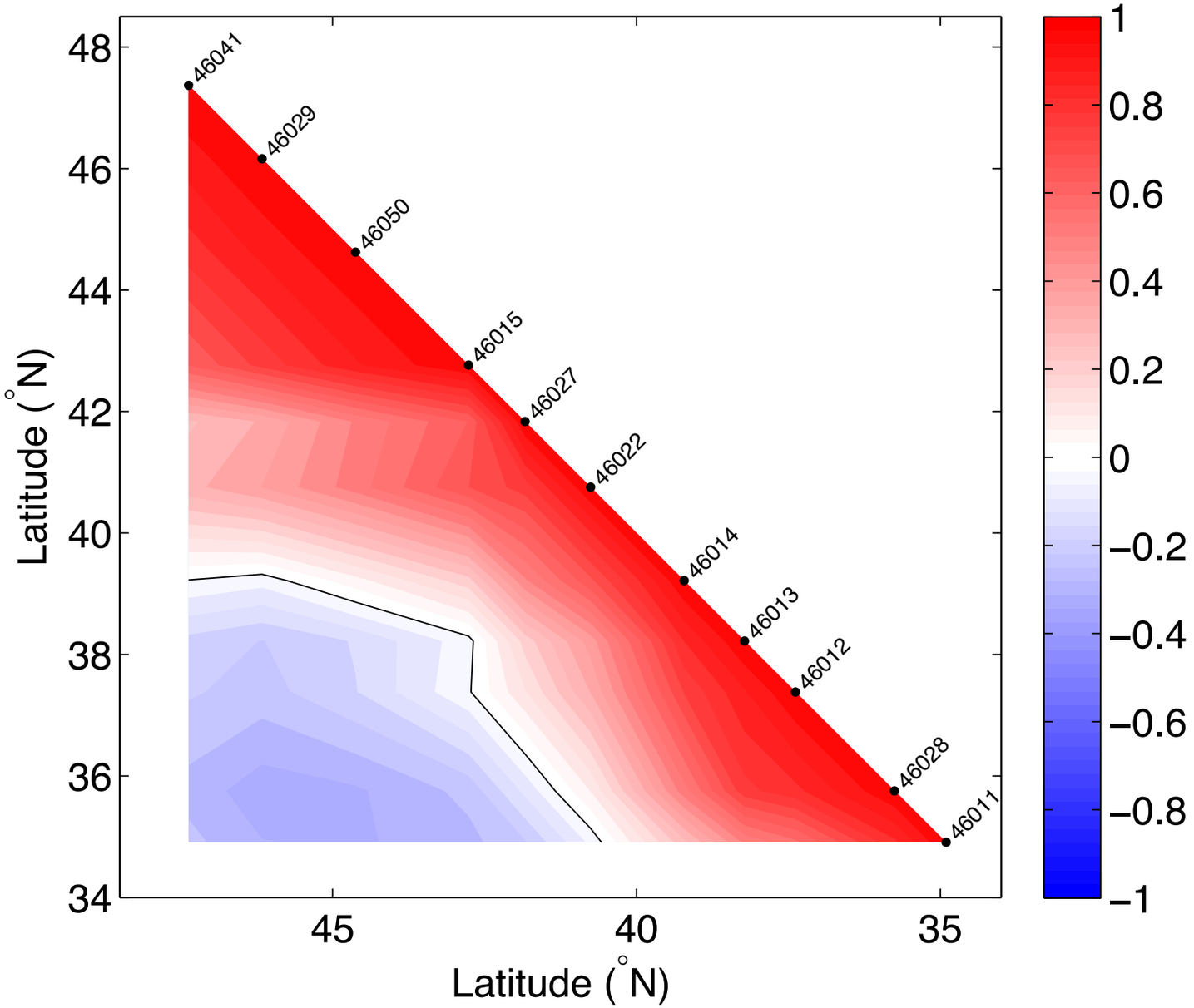
stage 3:
relaxation at
Pt. Conception



Fewings et al., *J. Geophysical Research - Oceans*, 2016

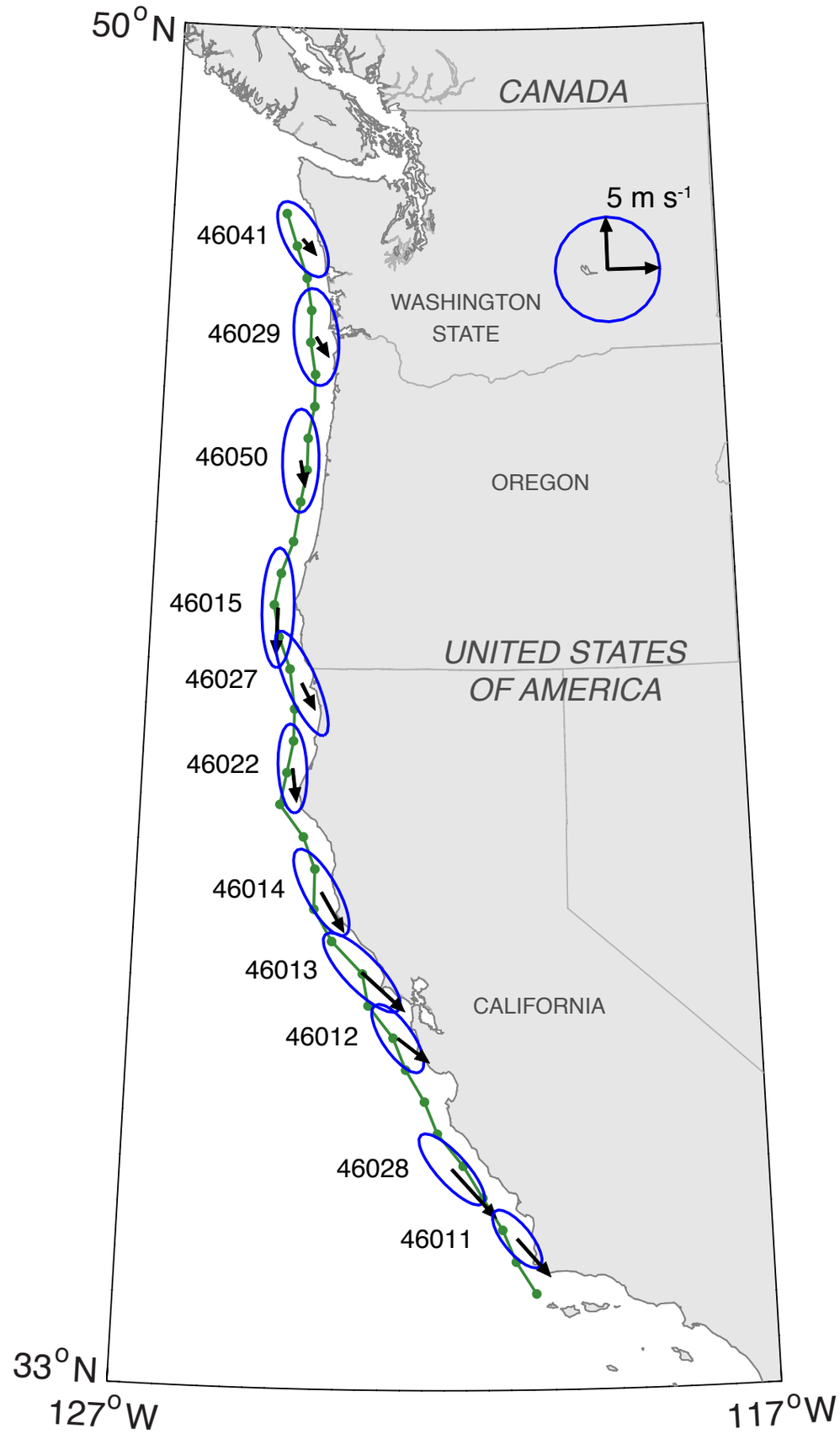
Is there really a wind relaxation “cycle”?

the correlation between buoy pairs
drops off at Cape Mendocino



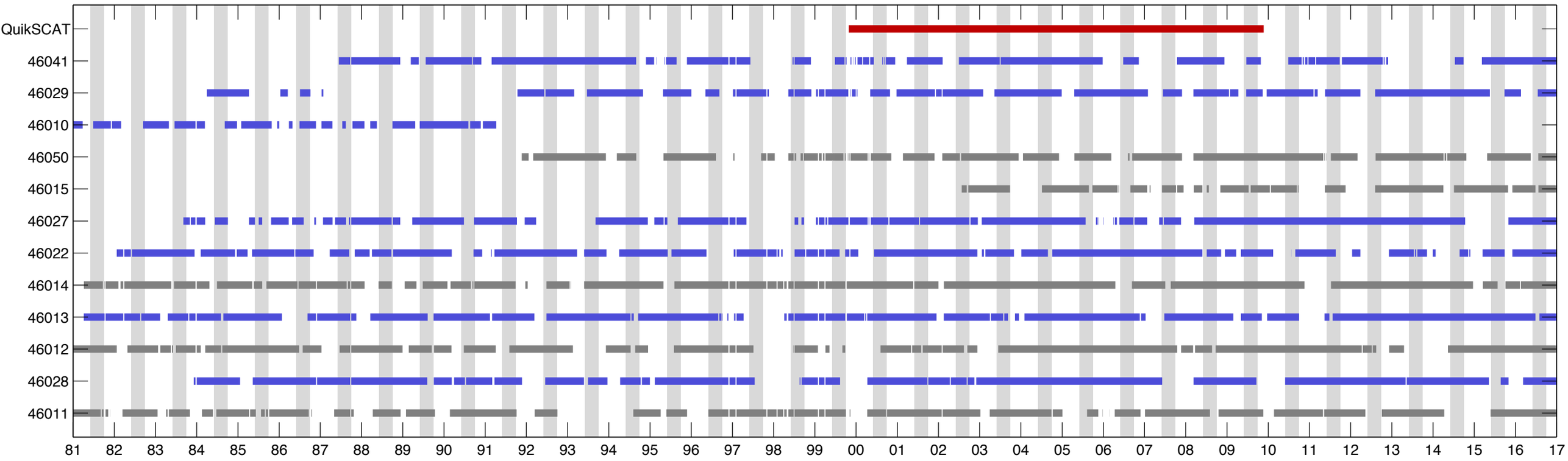
following Halliwell and Allen, 1987

mean and std dev of wind vel



Fewings, submitted to
Monthly Weather Review

35 years of hourly NOAA buoy data along the West Coast… but there are a lot of gaps!

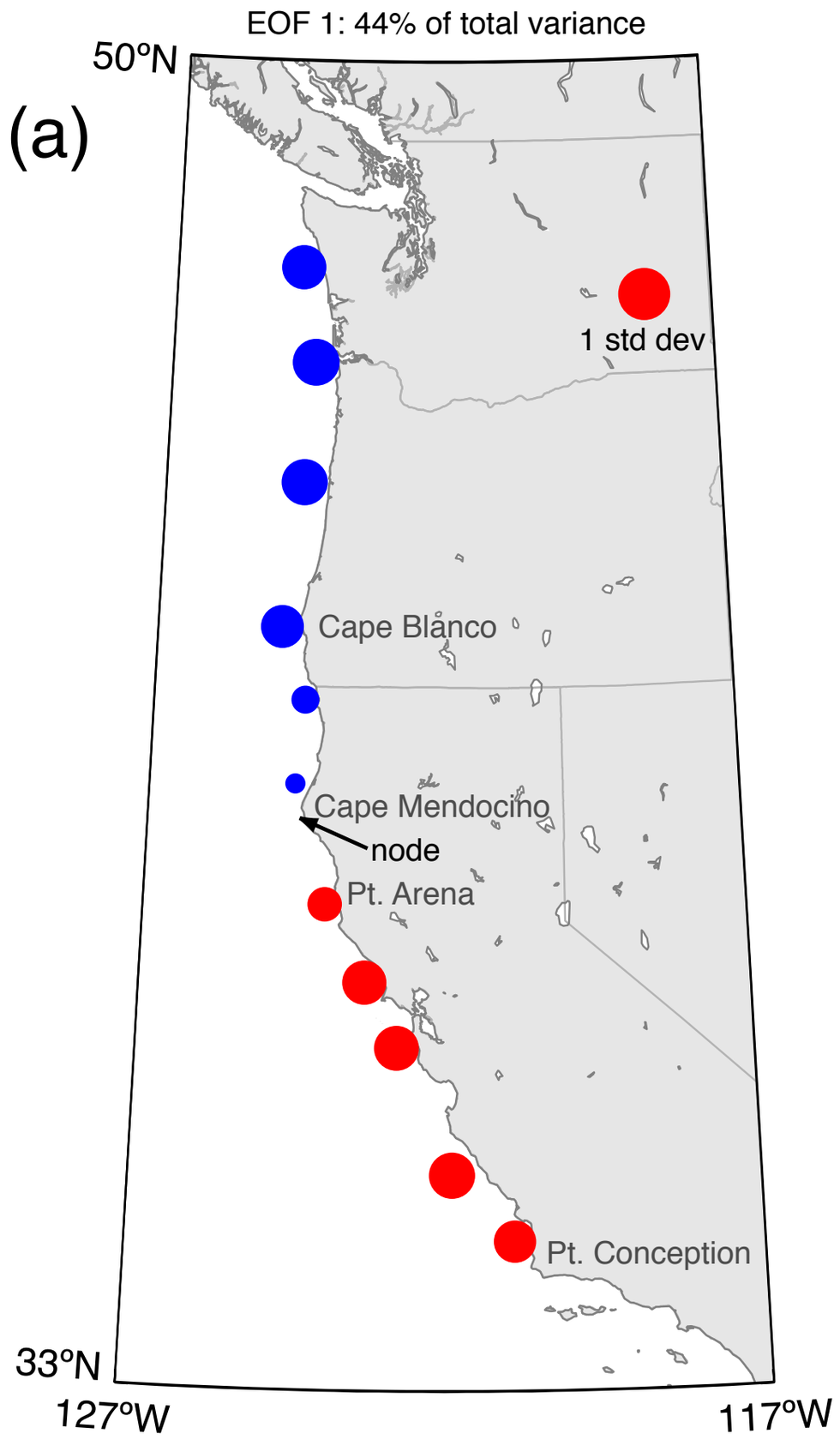


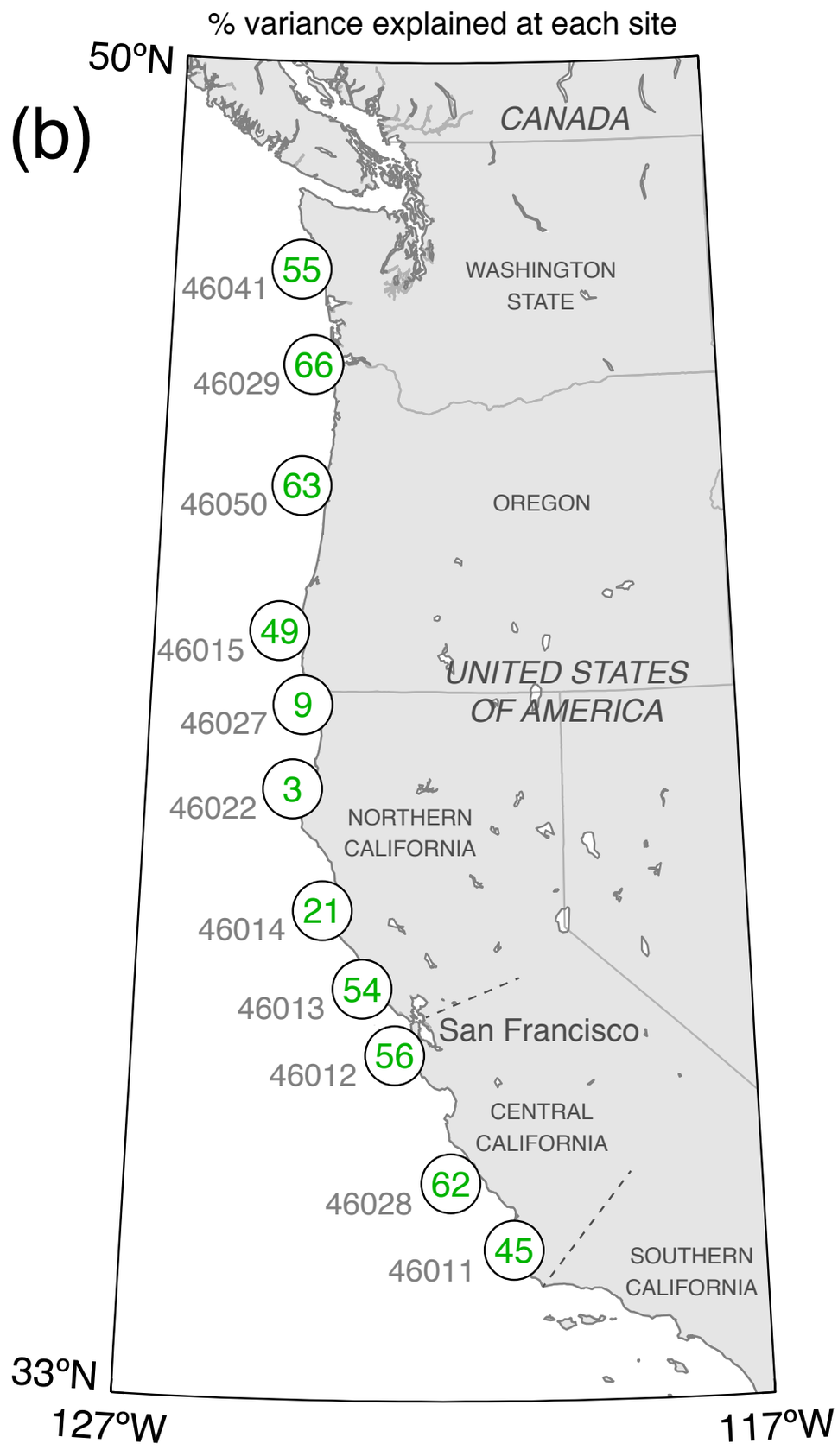
Fewings, submitted to
Monthly Weather Review

The coastal buoys show the alternating wind fluctuations!

first
Empirical
Orthogonal
Function

of
along-coast
wind velocity

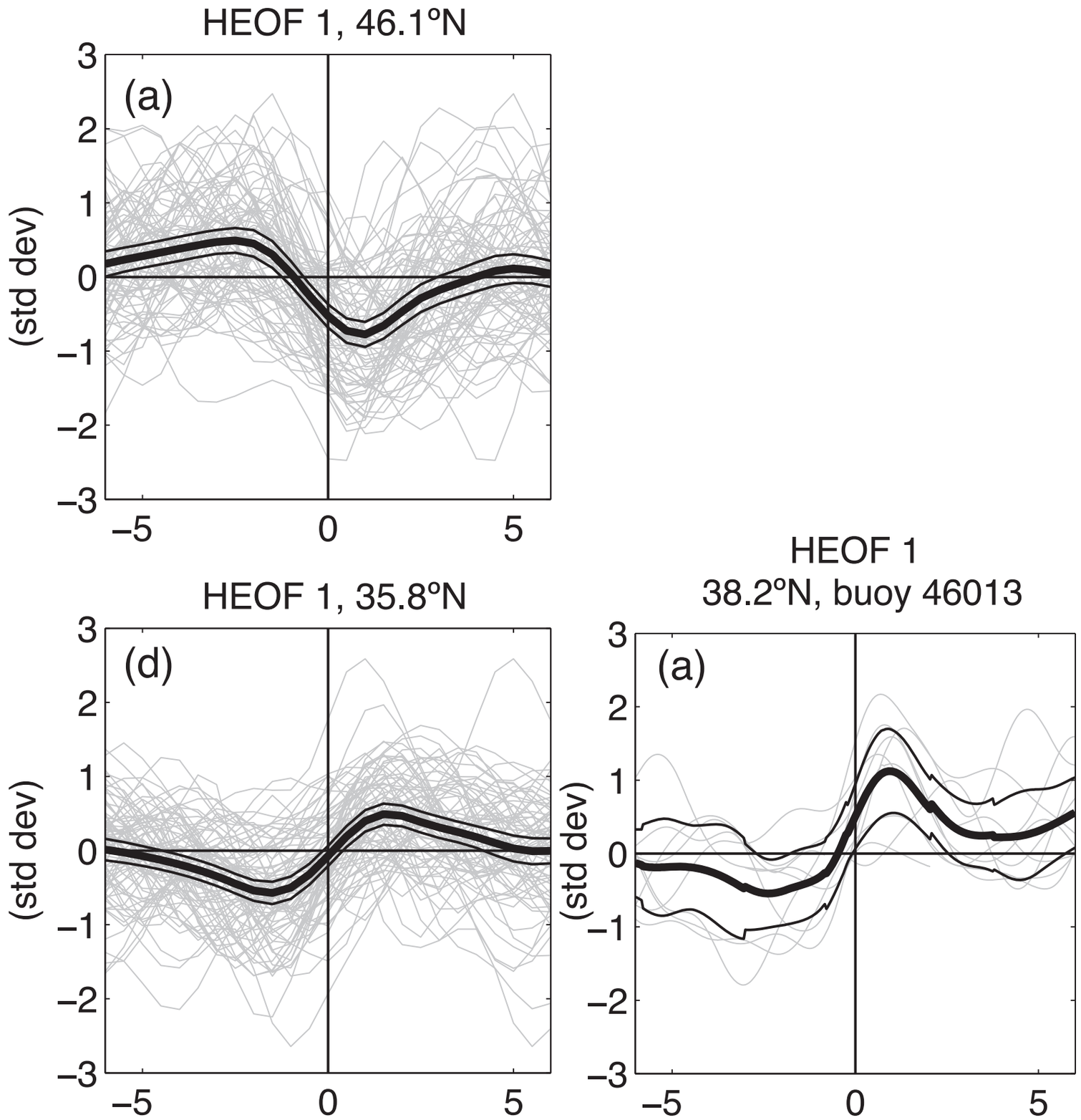




Fewings, submitted to
Monthly Weather Review

HEOF 1 is mainly representing the alternating north and south wind relaxations.

time series of HEOF 1 composited over known wind relaxation times based on Melton et al., 2009



Ongoing and Future Work

- wind stress curl anomalies along the coast
  - switch to Holbach/Bourassa circulation method (L2 swath data)
  - incorporate new QuikSCAT coastal product

- what were the relative sizes of predicted SST anomalies in **coastal upwelling** vs. **upwelling driven by wind stress curl**?

- link to larger scales via dipole wind EOF along coast
  - separate project: coupled synoptic wind stress fluctuations in North and Central regions
  - there is a dipole pattern in buoy and CCMP winds
  - use this to interpret 2015: stuck in 1 phase of the dipole mode all summer, like long-term wind relaxation?
  - link to larger-scale atmospheric circulation: position of North Pacific High