Wind stress and curl anomalies along western North America during the extreme warm ocean events of 2014-16

“The Blob”: \( \text{SST}_a > 4\sigma \)

did coastal winds prevent warming?

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El Niño

El Niño

NOAA  
November 1997

July 2015
The warm water anomalies had severe ecological effects

- Record-breaking harmful algal bloom *Pseudonitzschia* along the U.S. West Coast
- Closure of shellfish, crab, finfish fisheries
- Persistence of domoic acid toxin in seafloor sediments; crabs ingest it

**2015: An Unprecedented Year**

- **Trophic Transfer:**
  - Mussels up to 200 ppm
  - Anchovy 100-600 ppm, viscera >3,000 ppm
  - Razor Clam 340 ppm
  - Rock Crab = 1,000 ppm
  - Dungennes = 270 ppm
  - West Coast survey: 100% of fish contaminated

- Feb 16, 2016: California Requests Federal Disaster Relief

Domoic acid regulatory limit: 20 ppm

also:

- **whale** foraging patterns
- **zooplankton** species shifts (warm-water species off Oregon)
- Massive **seabird** die-offs due to mis-timed phenology of forage species

Slide courtesy Raphael Kudela, UC Davis
At the NE Pacific Anomalies workshops, reports of anomalies in wind stress and oceanic upwelling varied by product and region.

Research Questions:

• What were the wind stress anomalies along the coast in 2014-2016?

• What were the anomalies in upwelling, as measured by the cross-coast SST gradient?

• Can the SST anomalies be explained by the wind stress anomalies?

Approach:

Our RapidSCAT project began in February 2016
• L2B RapidSCAT v1.0 (climate-quality) wind stress anomalies relative to QuikSCAT L2B v3 climatology
• GHRSSST G1SST SST gradients
• CCMP v2.0 winds (Scott et al., 2016), no RapidSCAT
In the 3 regions where SST behaved differently, was the wind stress anomalous?

RapidSCAT along-coast wind stress anomaly ~50 km offshore relative to QuikSCAT climatology

main signal aside from synoptic variability:
- negative anomaly (blue) indicates weakened upwelling-favorable wind stress
- central region summer 2015

scale = +/- 0.3 Pa (compare to mean stress of ~0.2 Pa)
Time series of wind stress anomalies in the 3 regions

QuikSCAT along-coast wind stress climatology (Pa)

North
Central
South

upwelling-favorable
downwelling-favorable

Yearday

RapidSCAT along-coast wind stress anomalies (Pa)

North
Central
South

synoptic-scale anomalies = normal or strong upwelling
mostly negative anomalies = weak upwelling
weak anomalies = normal upwelling

summer upwelling season 2015

Oct14 Jan15 May15 Sep15 Jan16
SST and CCMP wind stress anomalies also indicate weak upwelling in Central region in summer 2015.

CCMP alongshore wind velocity

July 2015 SST anomaly

GHRSSST L4 GISST

longitude

latitude

cold anomaly

warm anomaly

Canada

USA

North

Central CCS

South

2015 strong

2015 weak

2014

mean other years

Jan Apr Jul Oct
Preliminary wind stress curl anomalies June-August 2015

negative wind stress curl anomaly (BLUE) in Central region = reduced upwelling

This will also contribute to the warm water anomaly

scale = +/- 10^{-6} \text{ Pa/m} = +/- 1 \text{ m/day of upwelling}
Coastal winds did prevent warming in the North and South regions. We now understand why the Central region DID show a warm anomaly!
Conclusions

In summer 2015, 3 regions of California Current System had different wind anomalies and resulting upwelling anomalies:

• **North** of Cape Blanco
  - wind stress anomalies weak or positive except on synoptic time scales
  - warm water held offshore by upwelling (except during synoptic wind reversals)

• **Central** = Cape Blanco to Point Conception
  - reduced upwelling-favorable wind stress
  - reduced wind stress curl
  - warm water anomalies at coast due to reduced upwelling
  - massive harmful algal bloom

• **South** = Baja California
  - wind stress anomalies weak
  - warm water held offshore by normal weak upwelling

In fall 2015, strong warm water anomalies developed off Baja…

air-sea heat flux anomalies and along-shelf advection?
Ongoing and Future Work

• wind stress curl anomalies along the coast
  - switch to Holbach/Bourassa circulation method (L2 swath data)
  - incorporate new QuikSCATcoastal product and ASCAT

• what were the relative sizes of 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?
  - link to larger-scale atmospheric circulation: position of North Pacific High