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


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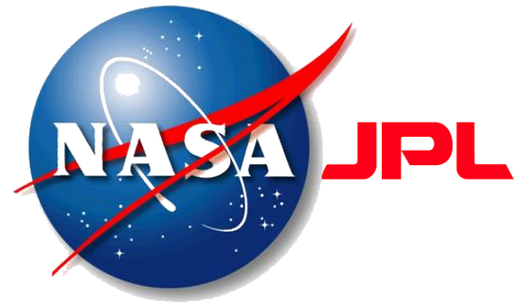
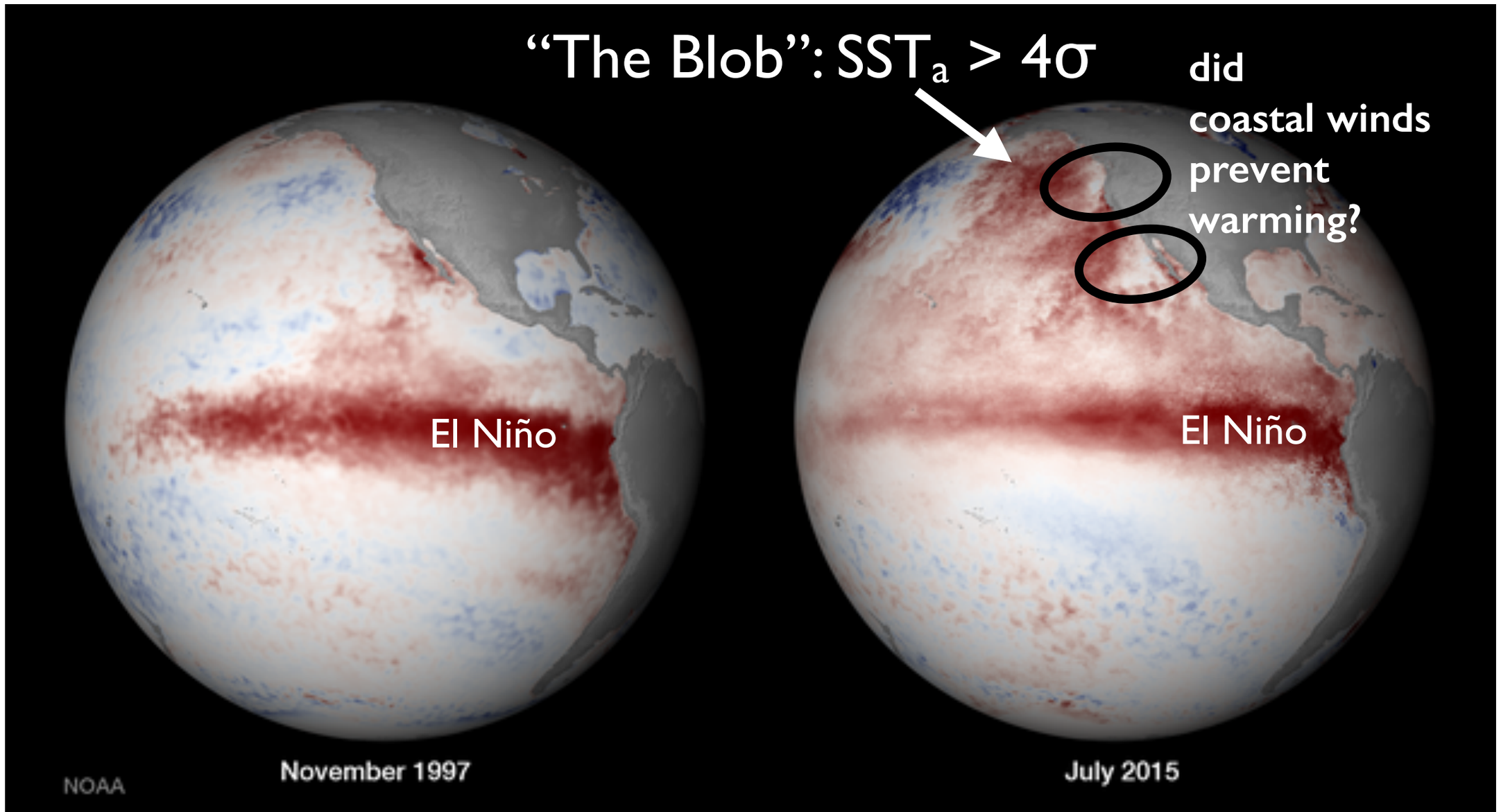
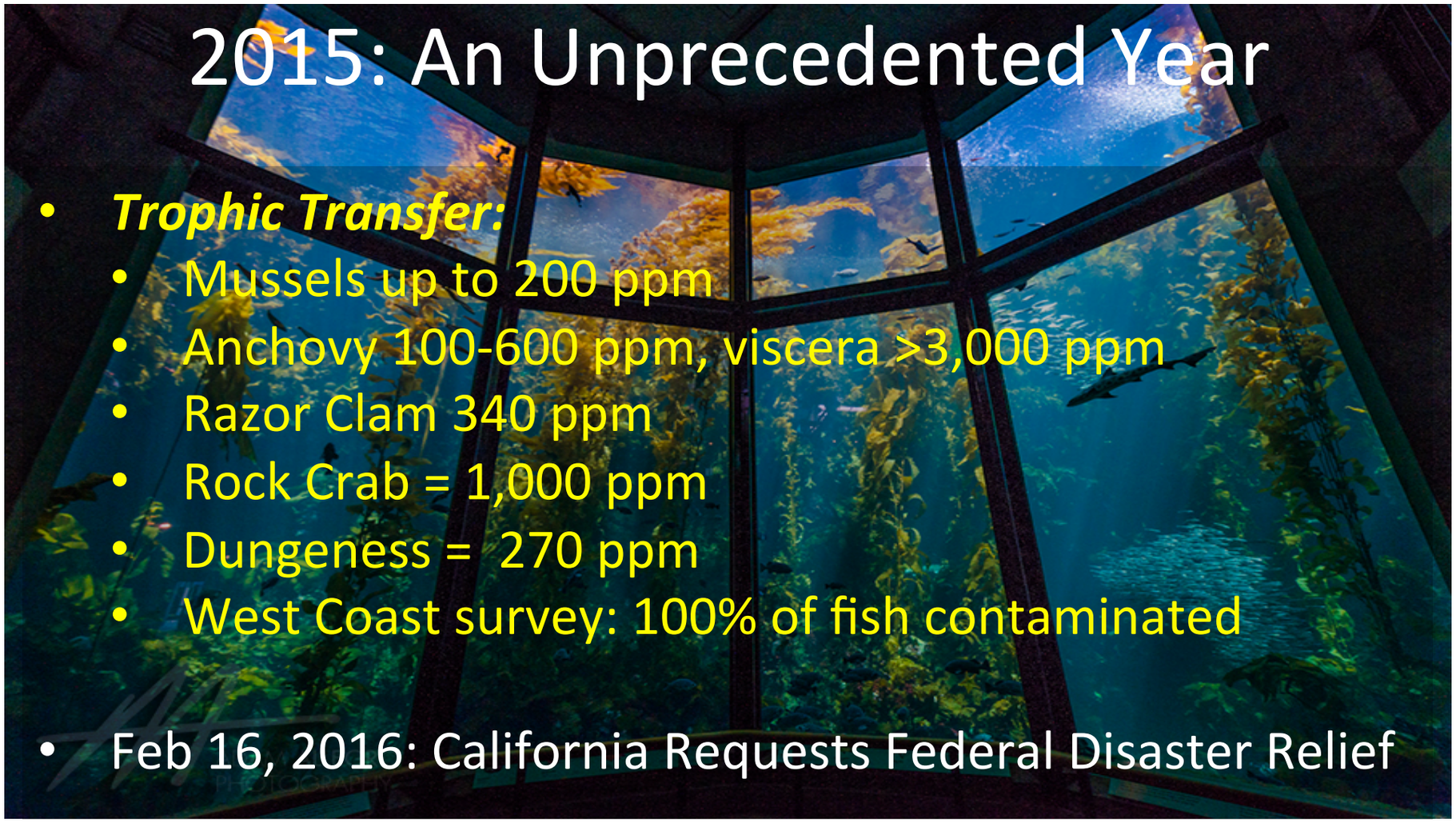


# The warm water anomalies had severe ecological effects

- 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

domoic acid regulatory limit: 20 ppm




Slide courtesy Raphael Kudela, UC Davis

also:

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

## 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?

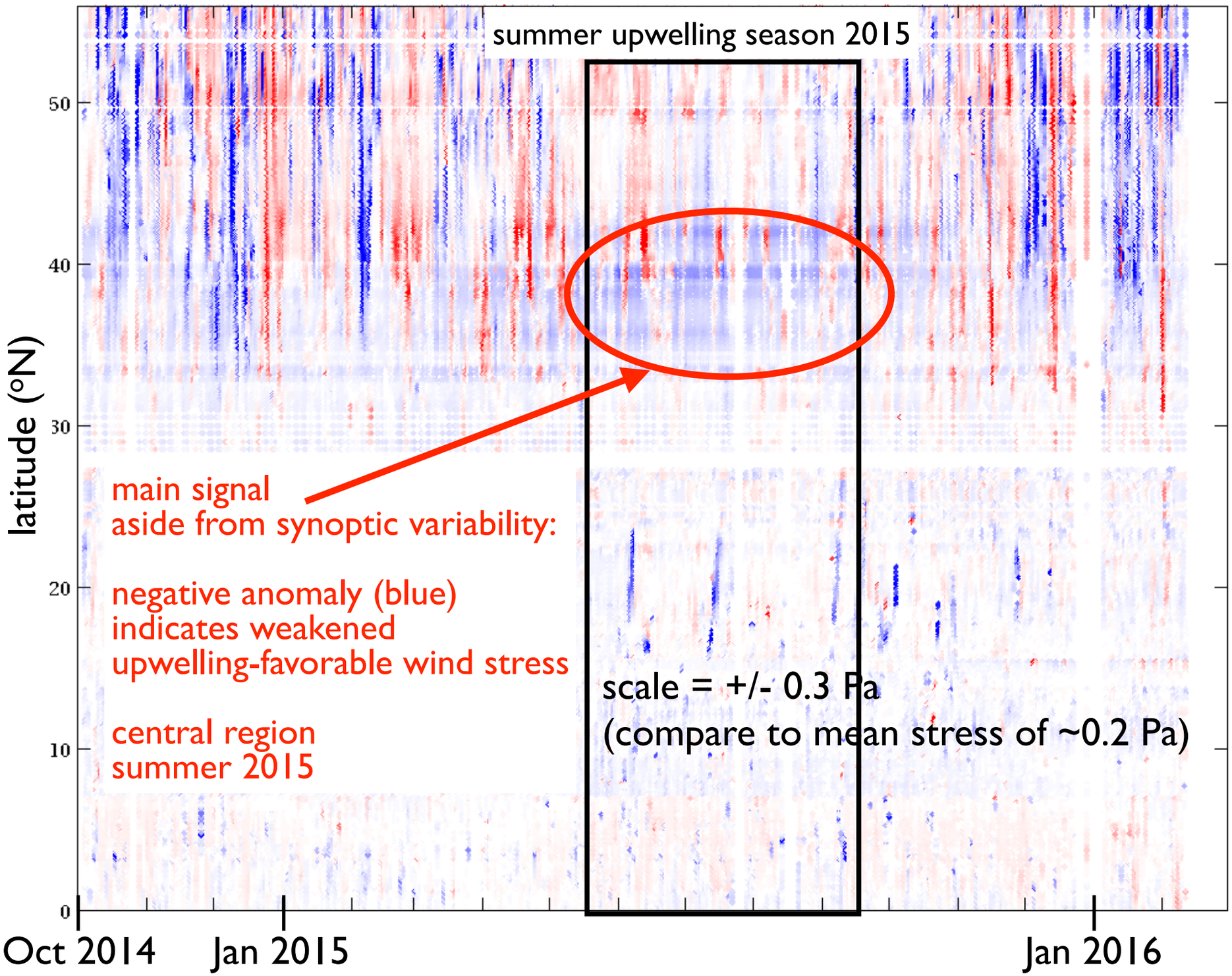
**Approach:**

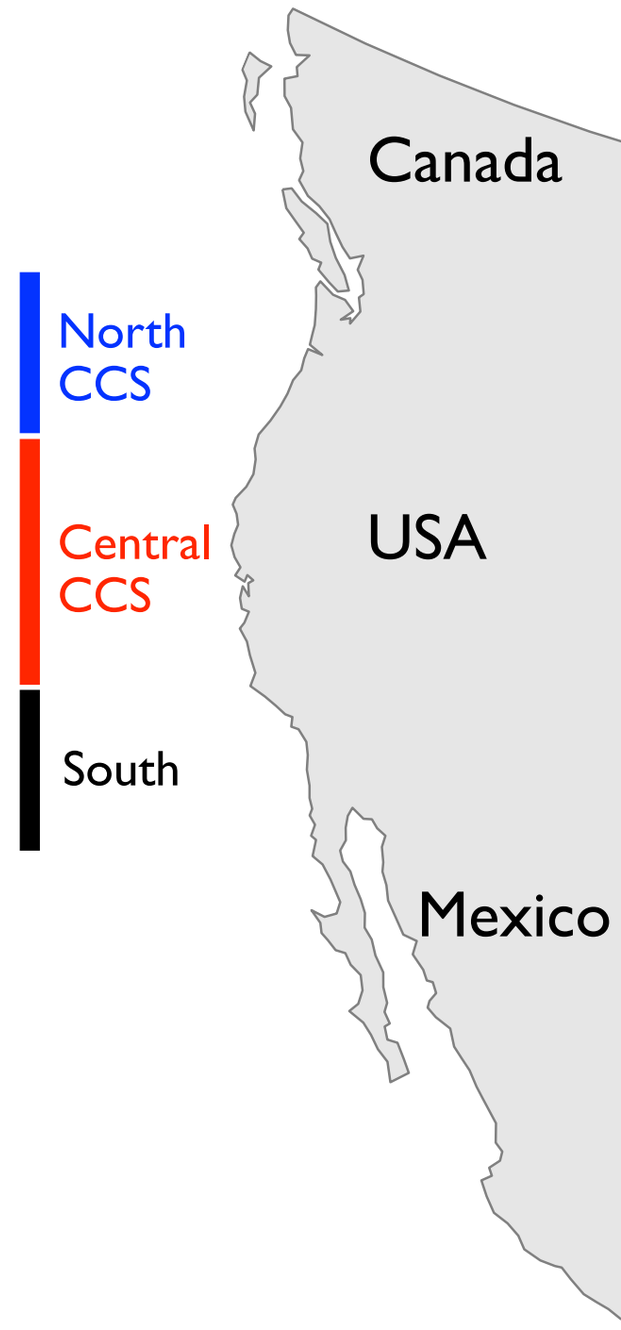
Our RapidSCAT project began in February 2016

- L2B RapidSCAT v1.0 (climate-quality) wind stress anomalies
  relative to QuikSCAT L2B v3 climatology
- GHRSST 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?

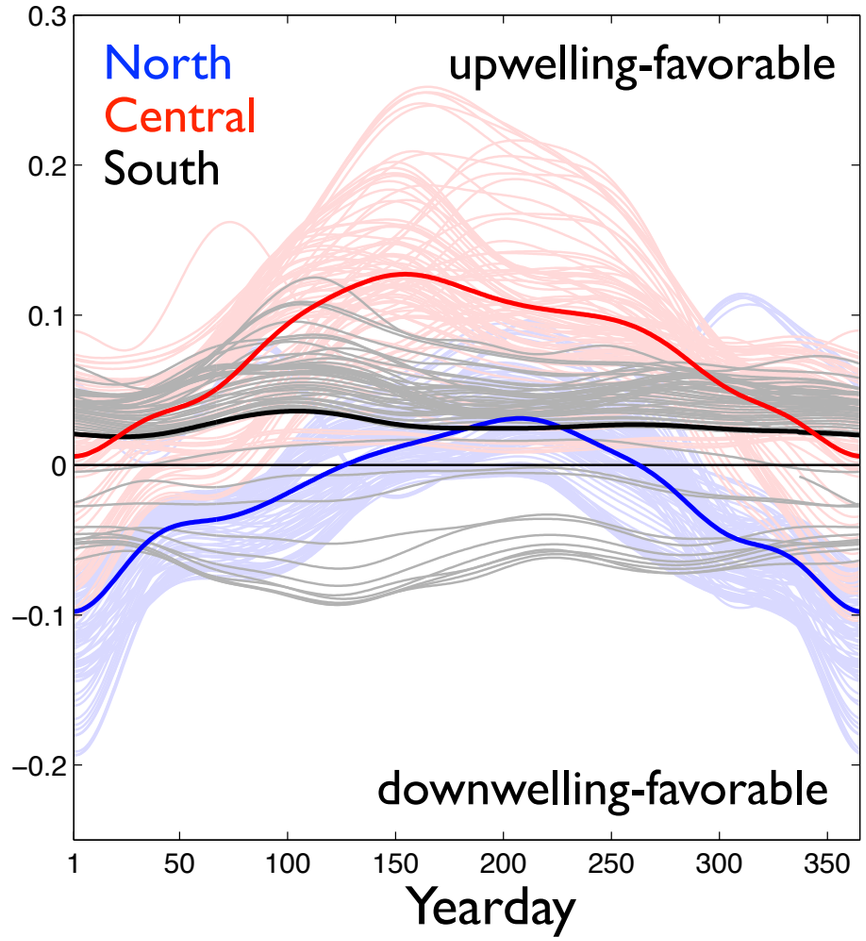
RapidSCAT along-coast wind stress anomaly ~50 km offshore
relative to QuikSCAT climatology



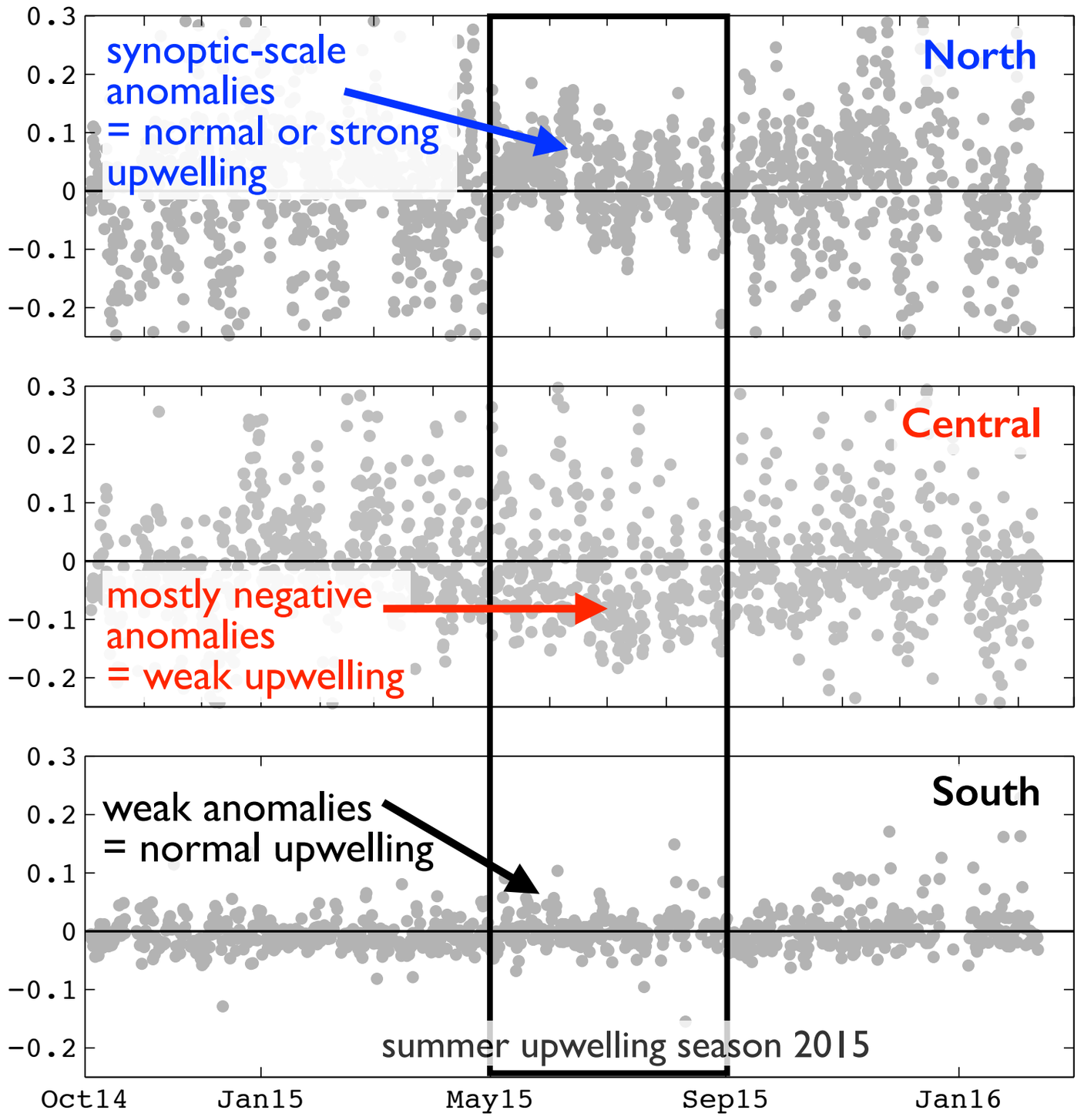



# Time series of wind stress anomalies in the 3 regions

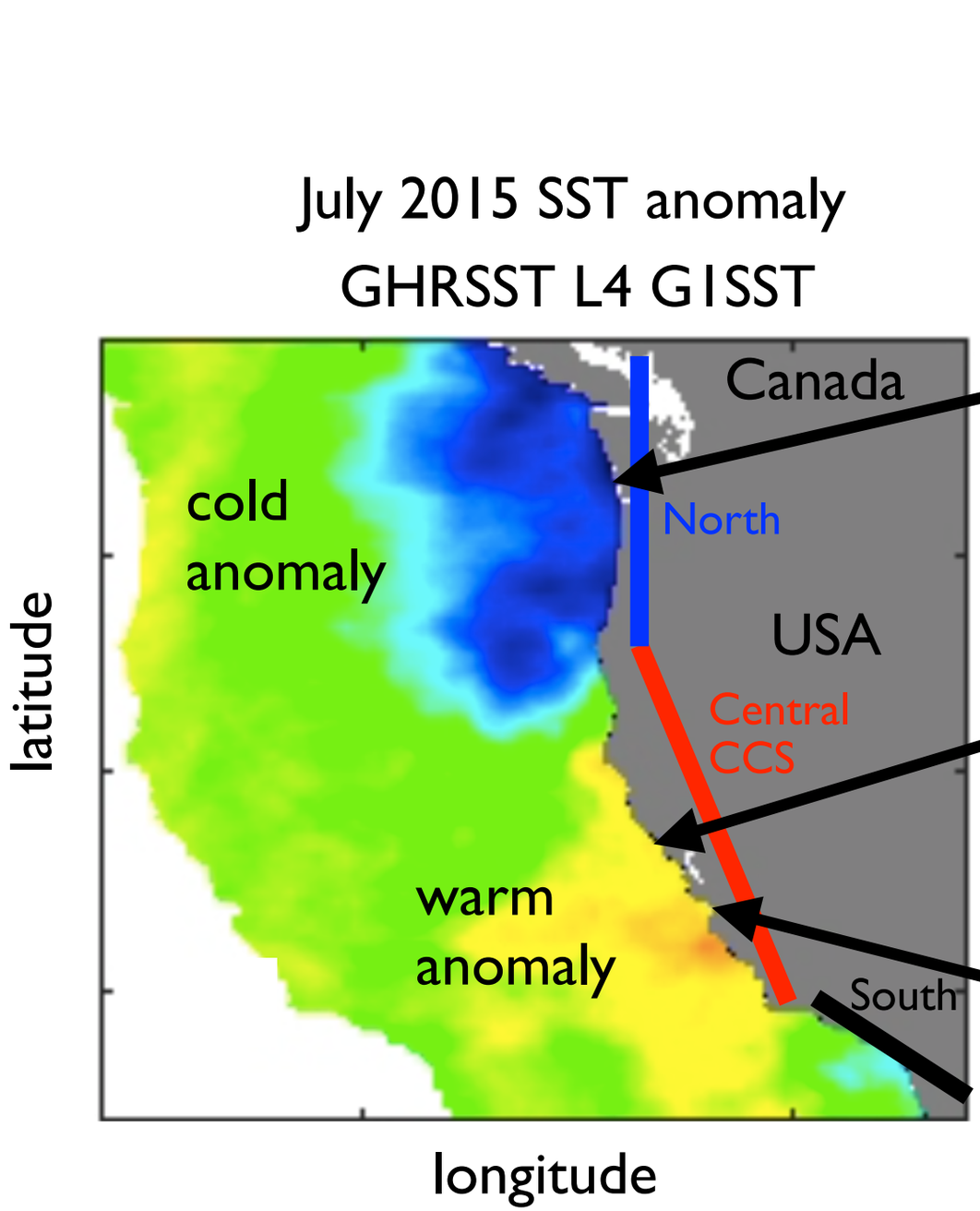
QuikSCAT along-coast wind stress climatology (Pa)

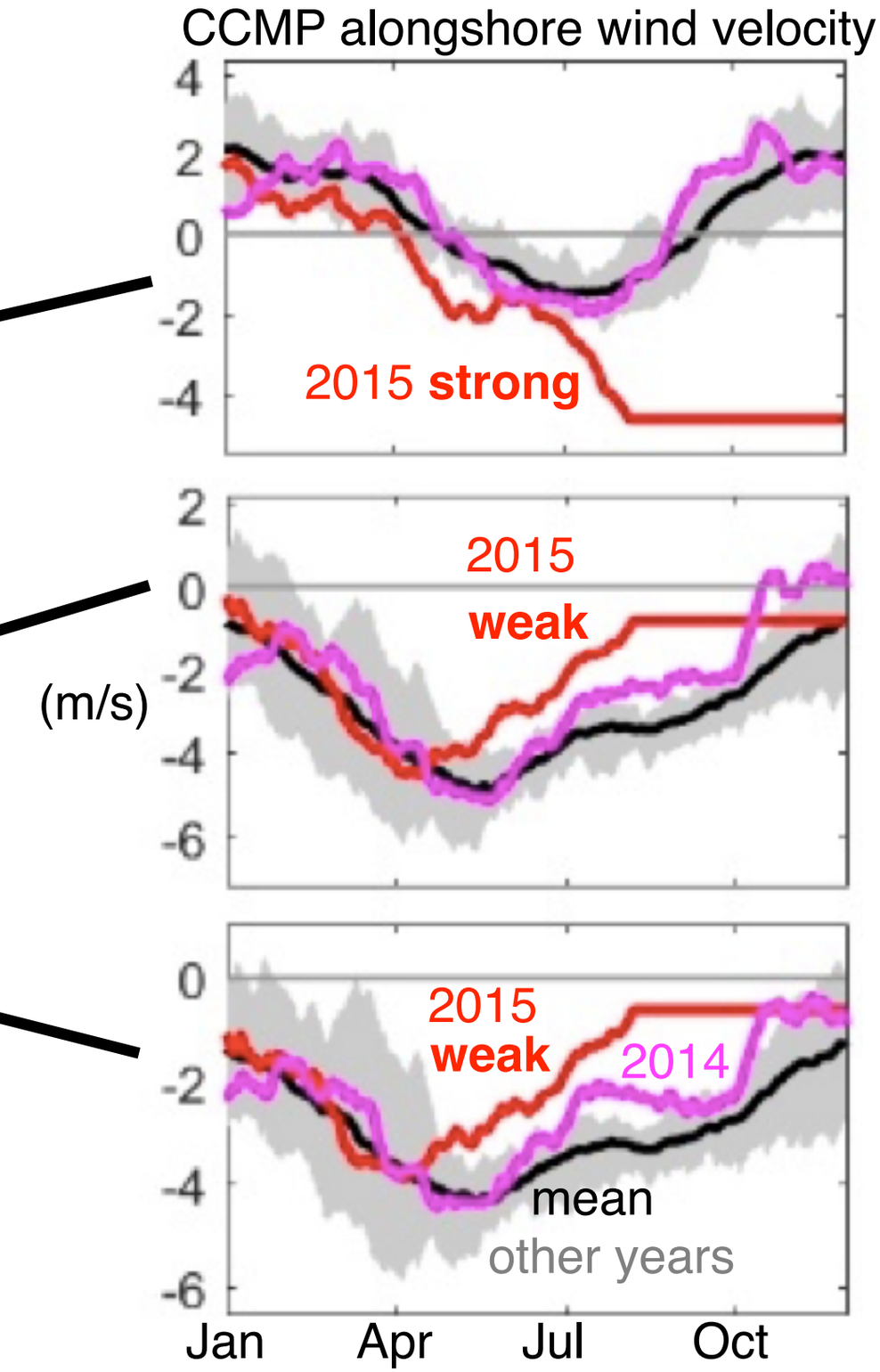



RapidSCAT along-coast wind stress anomalies (Pa)

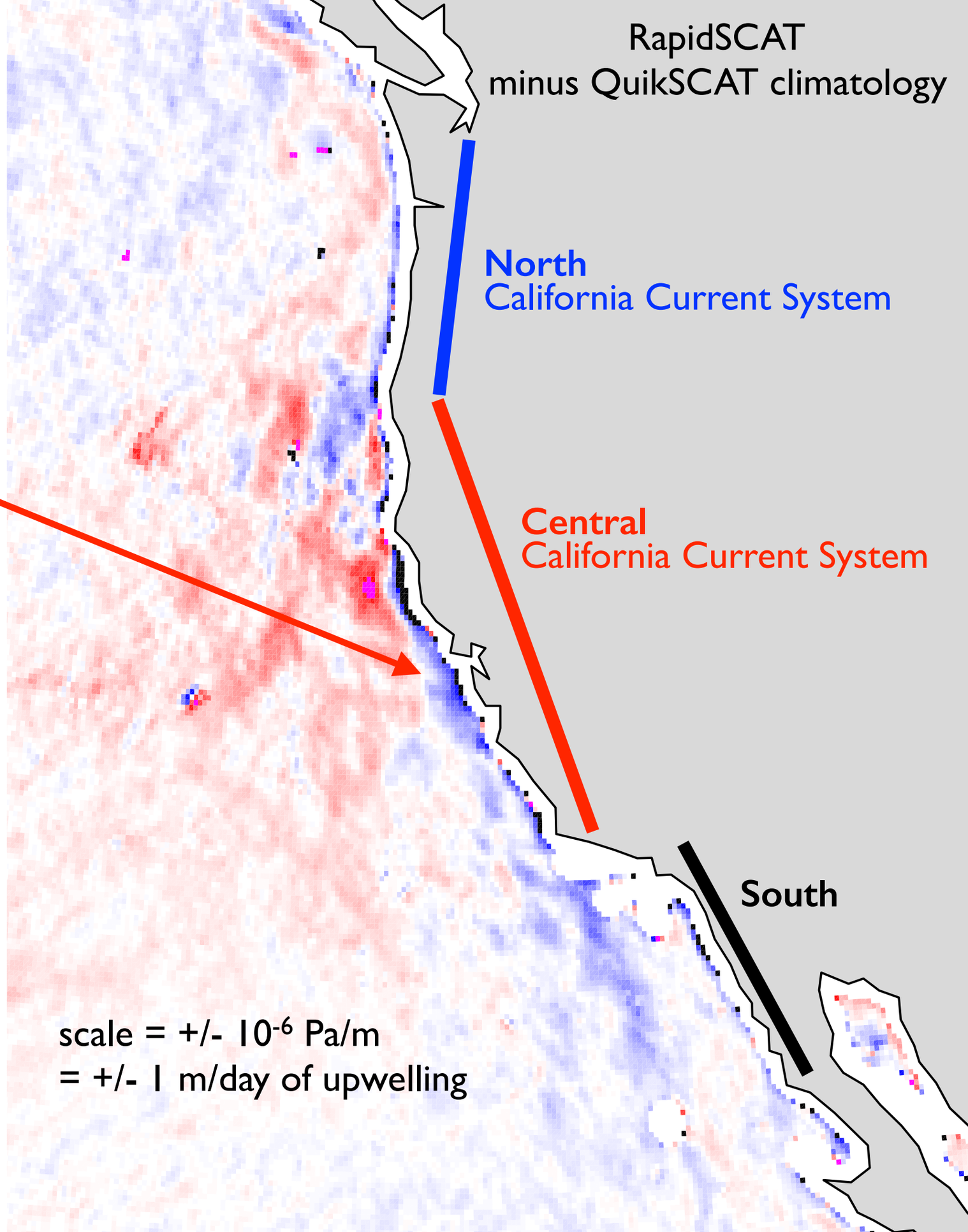



# SST and CCMP wind stress anomalies also indicate weak upwelling in Central region in summer 2015



# 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**

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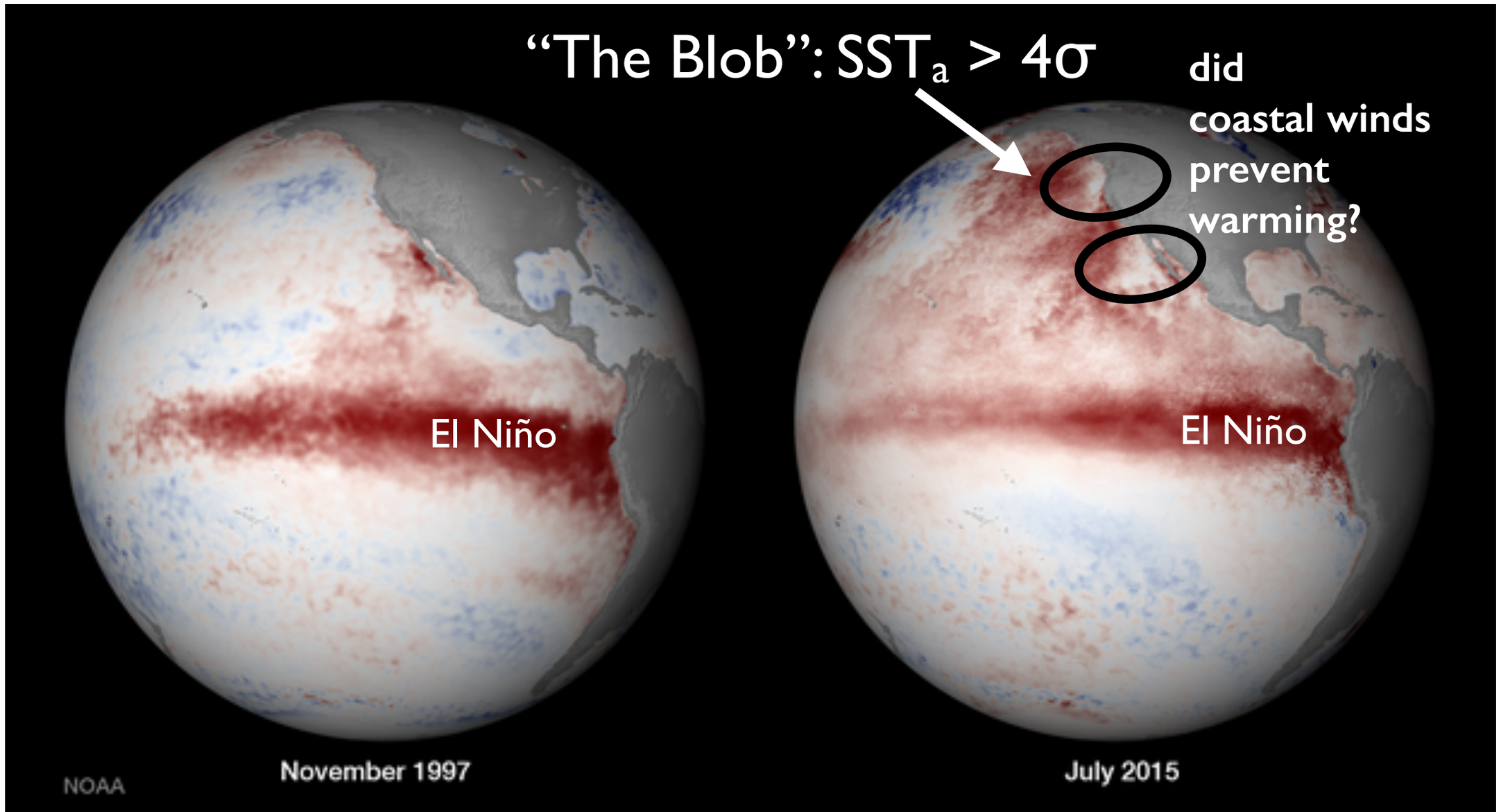
Coastal winds did prevent warming in the North and South regions.
We now understand why the Central region DID show a warm anomaly!



# 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 QuikSCAT coastal 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