Anomalous oceanic conditions along the US West Coast in 2014: inferences from a high-resolution regional ocean model

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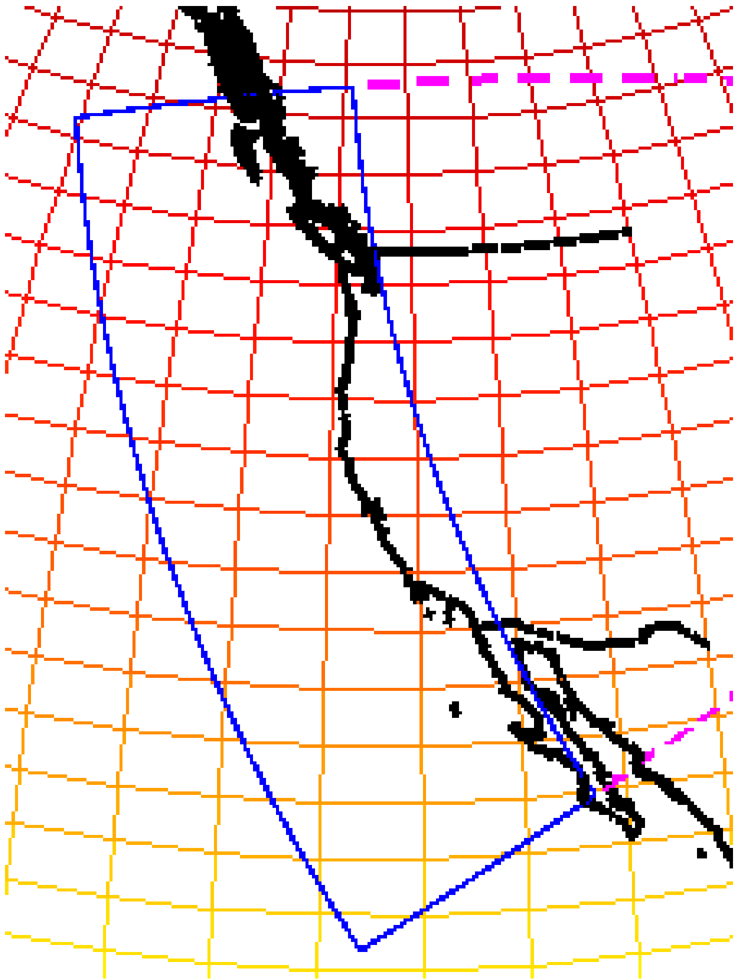
/ support: NOAA WCOFS project

West Coast Ocean Forecast System (WCOFS): based on Regional Ocean Modeling System (ROMS, www. myroms.org)

Horizontal resolution: 2-km
Vertical resolution: 40 terrain-following layers

Forcing:
- Surface winds and heat flux (12-km NOAA NAM)
- @open boundary: global model (HYCOM/RTOFS)
  + tides (Oregon State Tidal Inverse Soft.)
- River inputs: Columbia R., Fraser R., Puget Sound

Skill assessments: 6+ -year model run without data assimilation, Oct 2008 thru Dec 2014 (daily-averaged outputs)



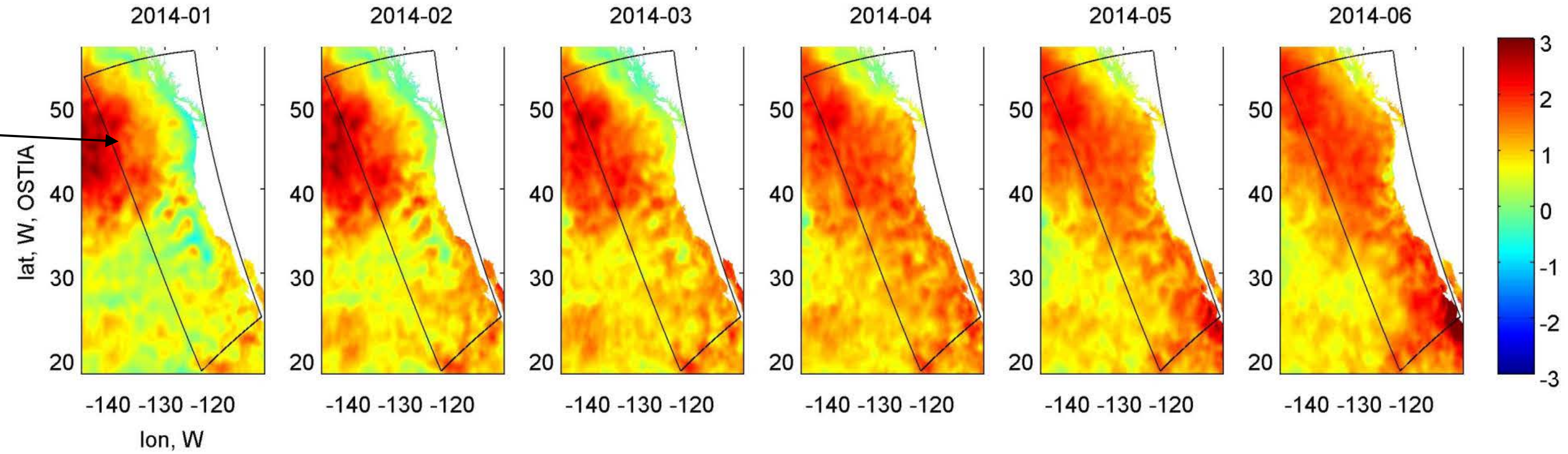
This talk:
- *Anomalous warming in NEP in the beginning of 2014*
- *Variability along the continental slope, on isopycnal surface* σ_θ*=26.5 kg/m*^{3}

Strong temperature anomalies emerge in NEP 2014 (and these would persist until the end of 2015)

Satellite OSTIA SST anomaly, w /respect to 2009-2013 climatology (OSTIA)

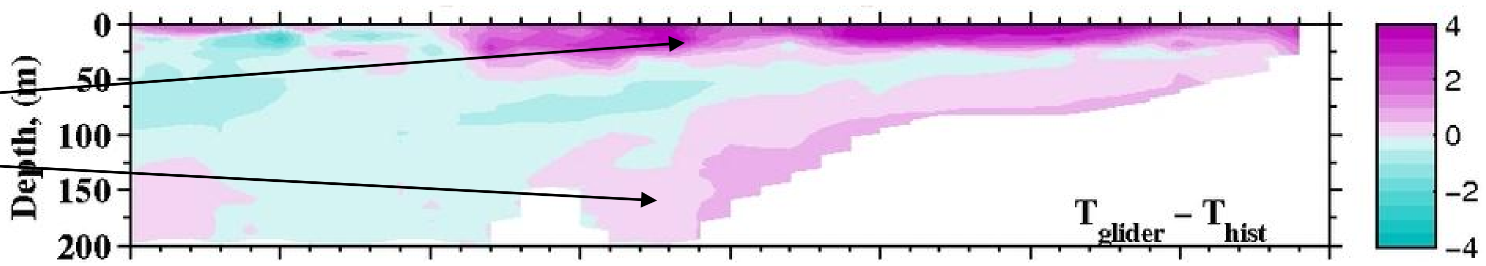
"Warm blob"

(*Bond et al.* 2015)

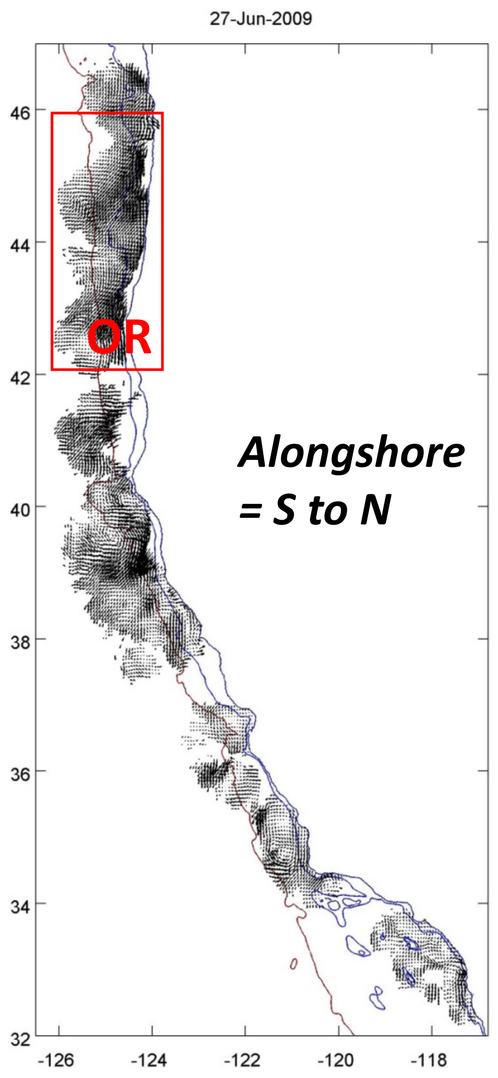


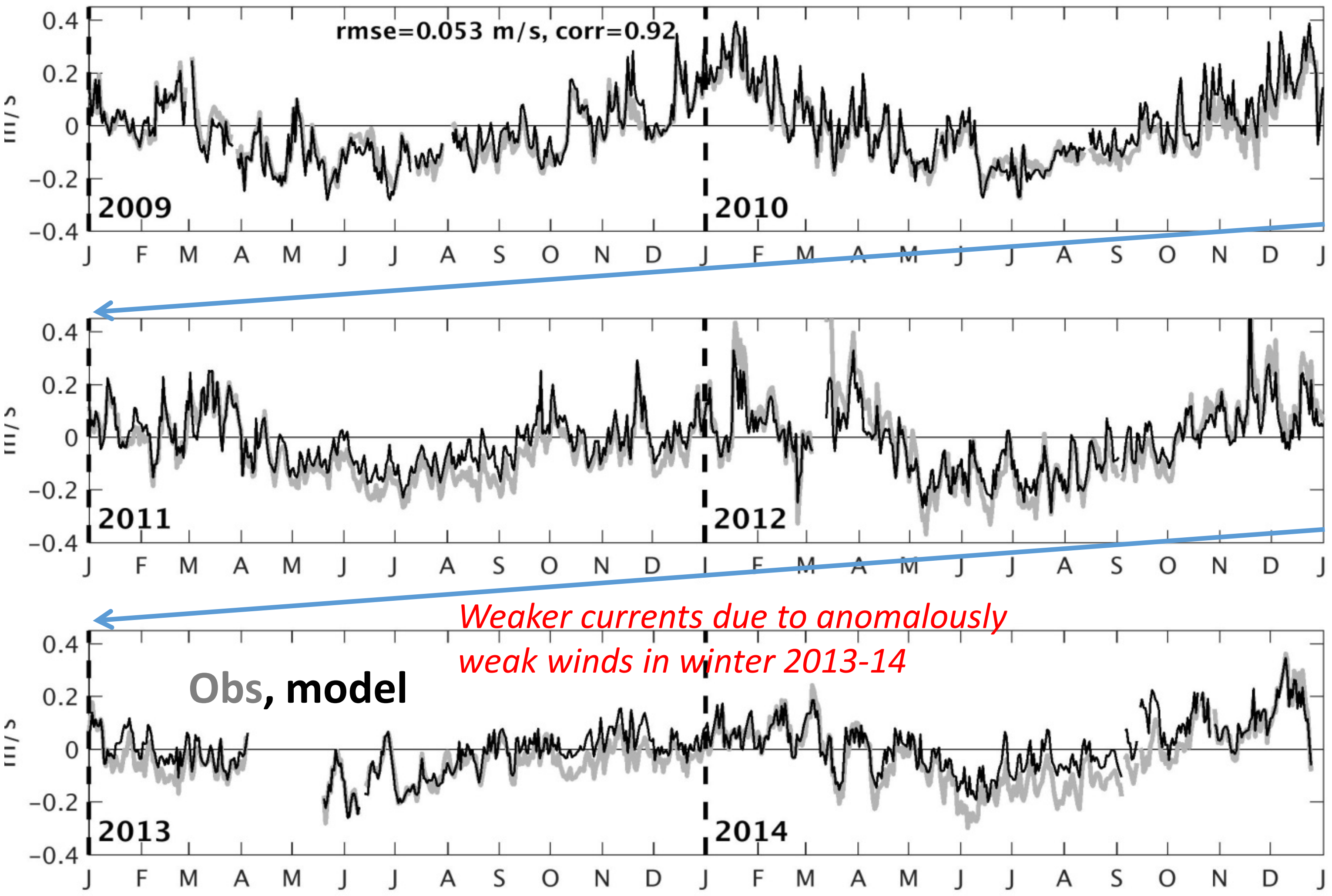
Glider temperature anomaly off Oregon, 44.6N (September 2014) [Barth, OSU]

Strong anomalies at the surface and over the slope



HF radar vs. WCOFS surface currents (area-averaged, daily-averaged alongshore currents… *sim. to Durski et al. Oc. Dyn. 2015***):** variability is predicted on temporal scales from several days to seasonal and interannual





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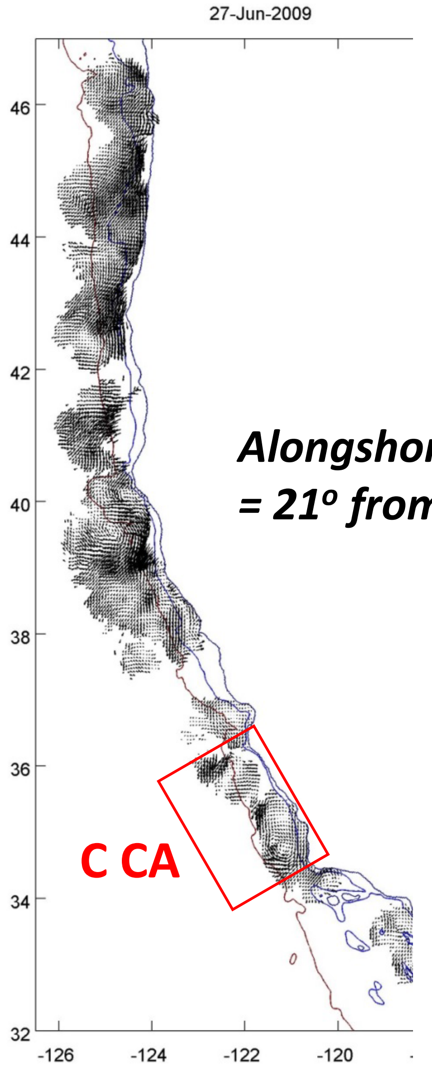
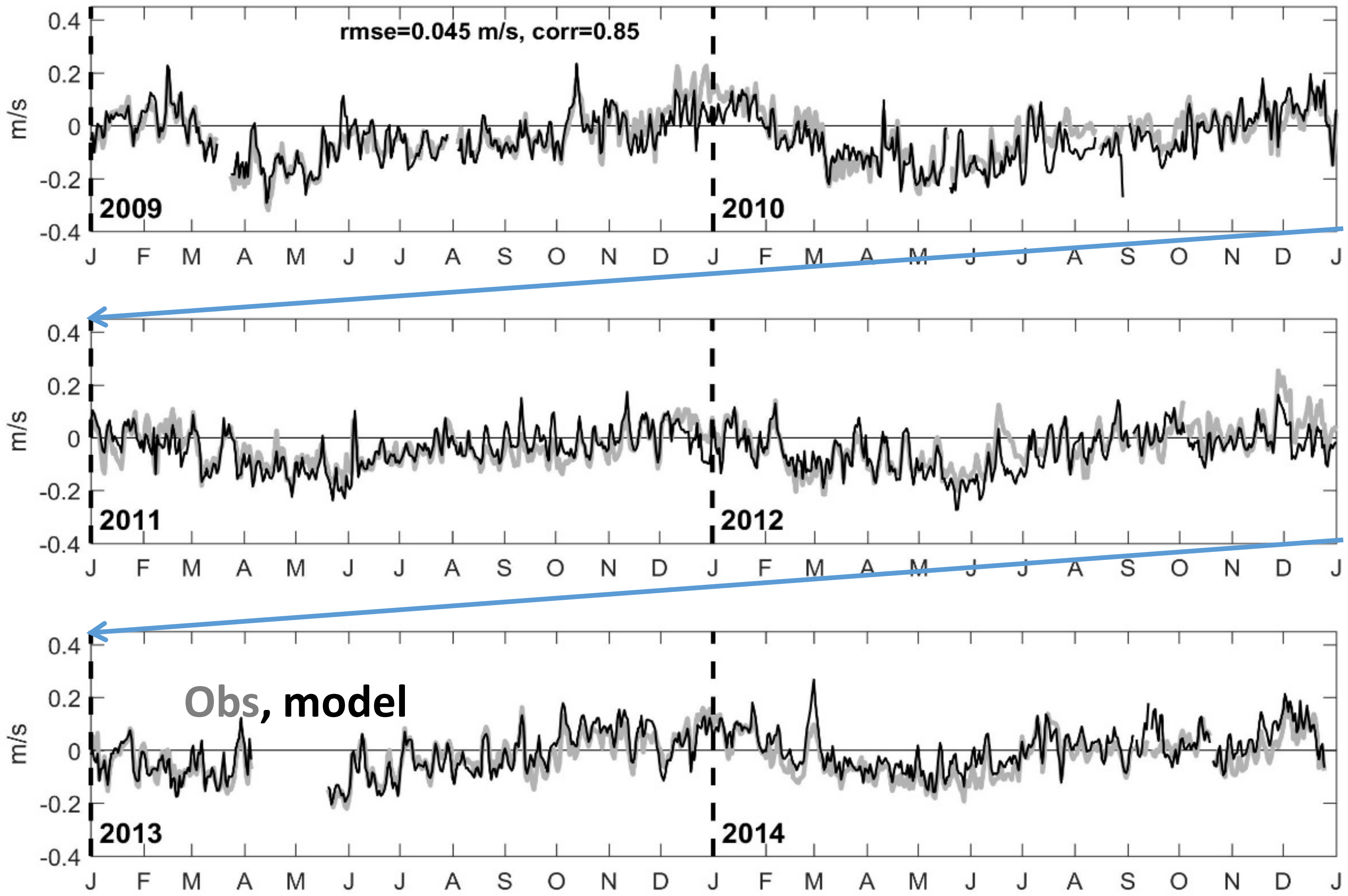


Alongshore = 21^o from N



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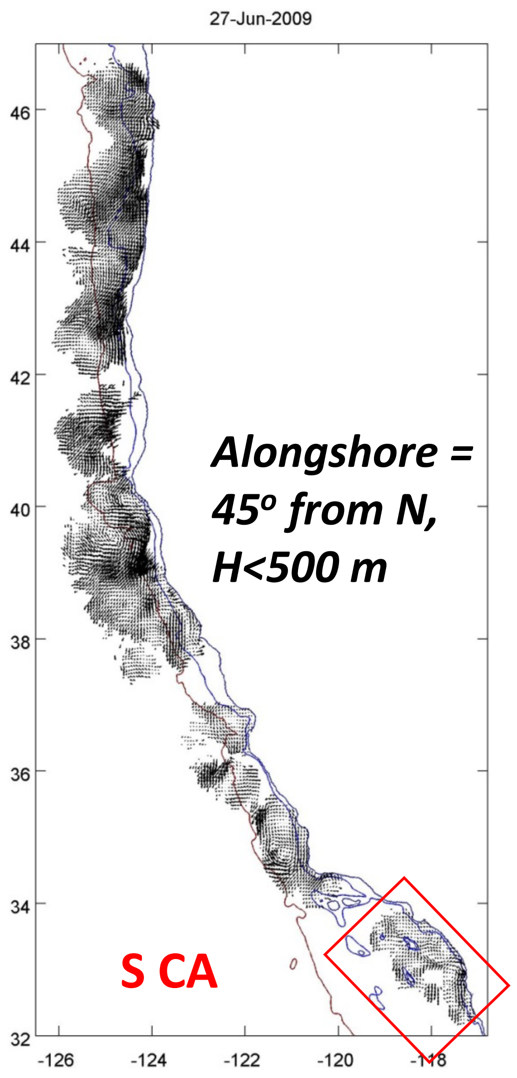
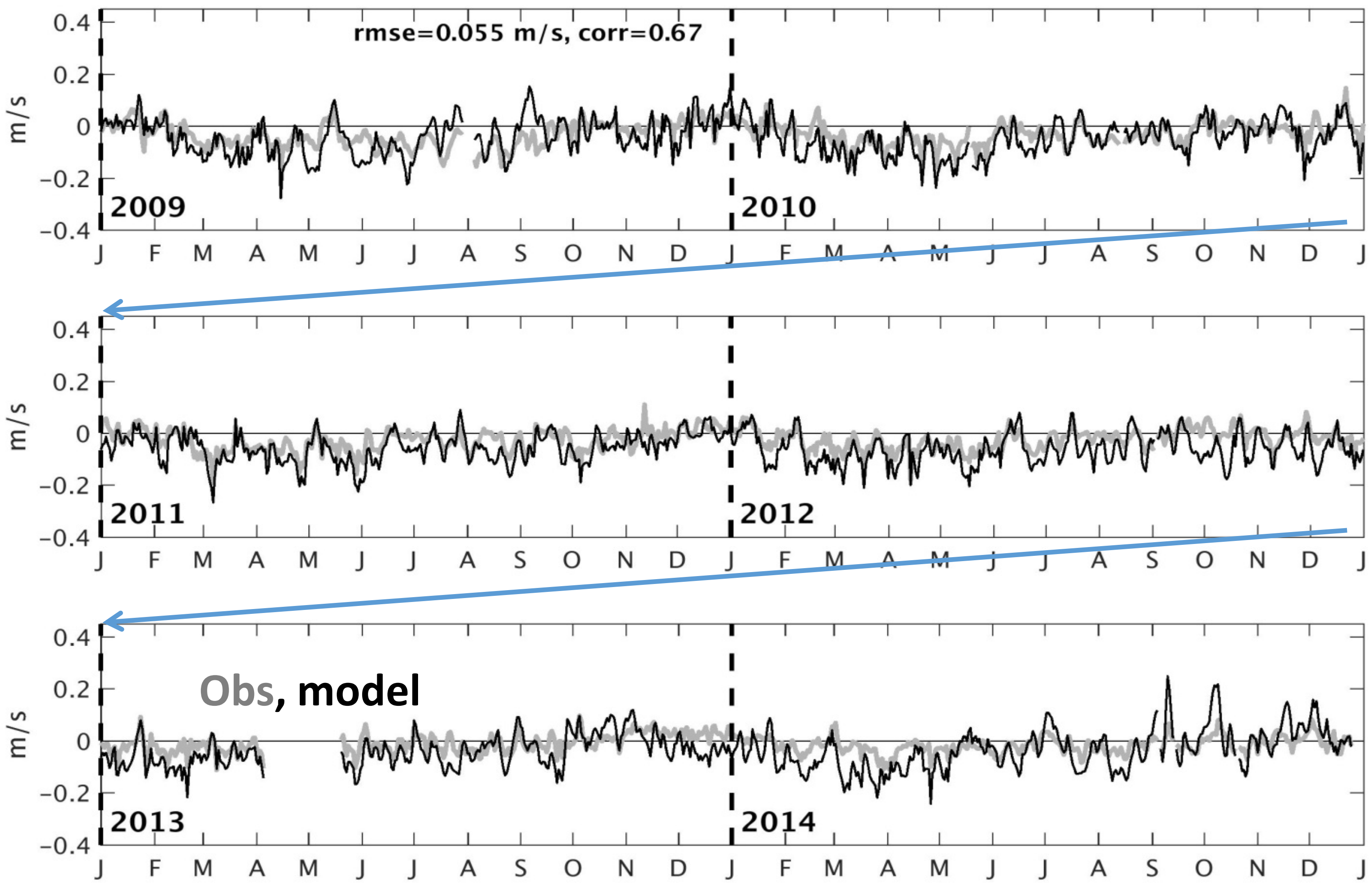
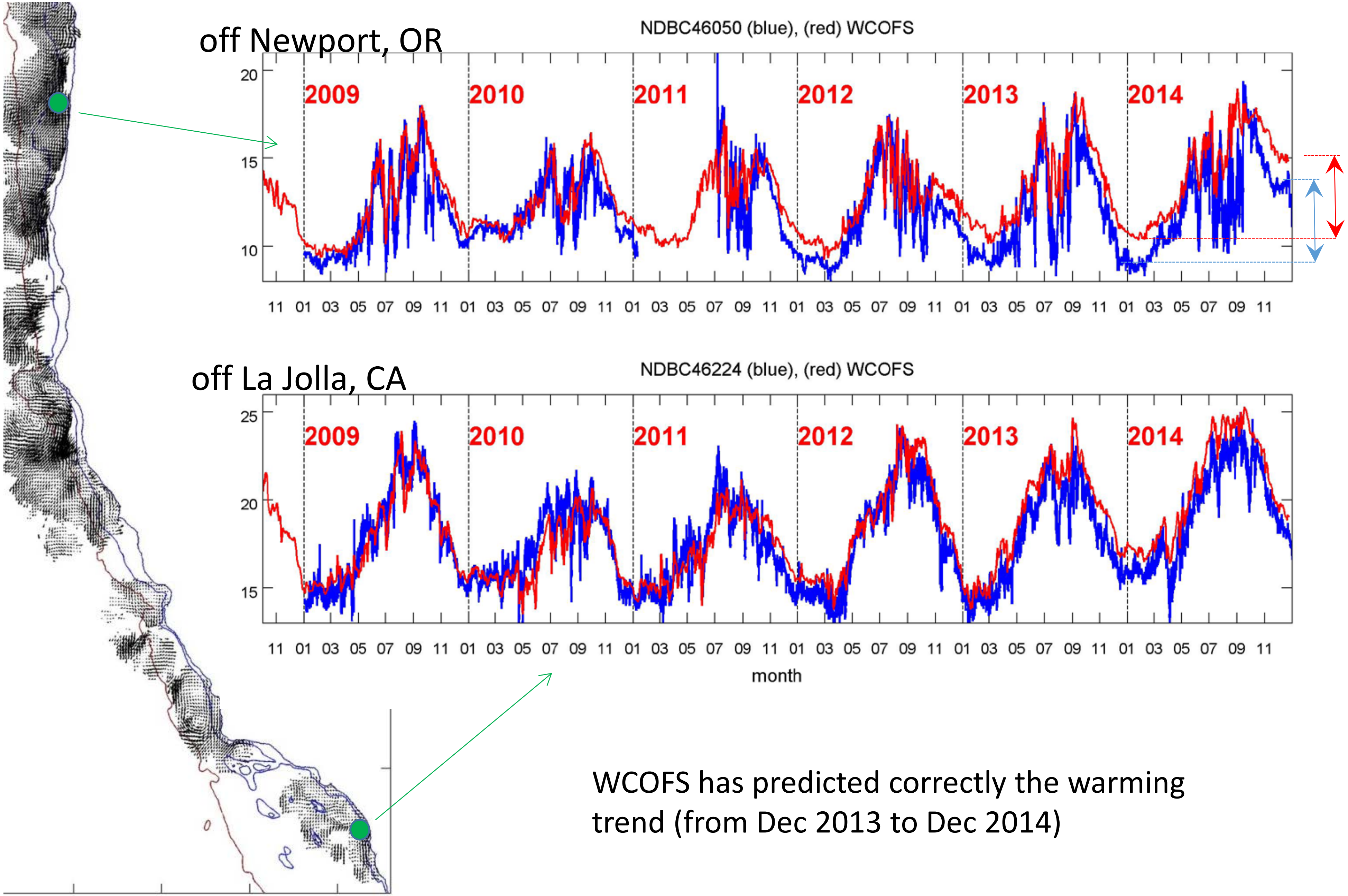




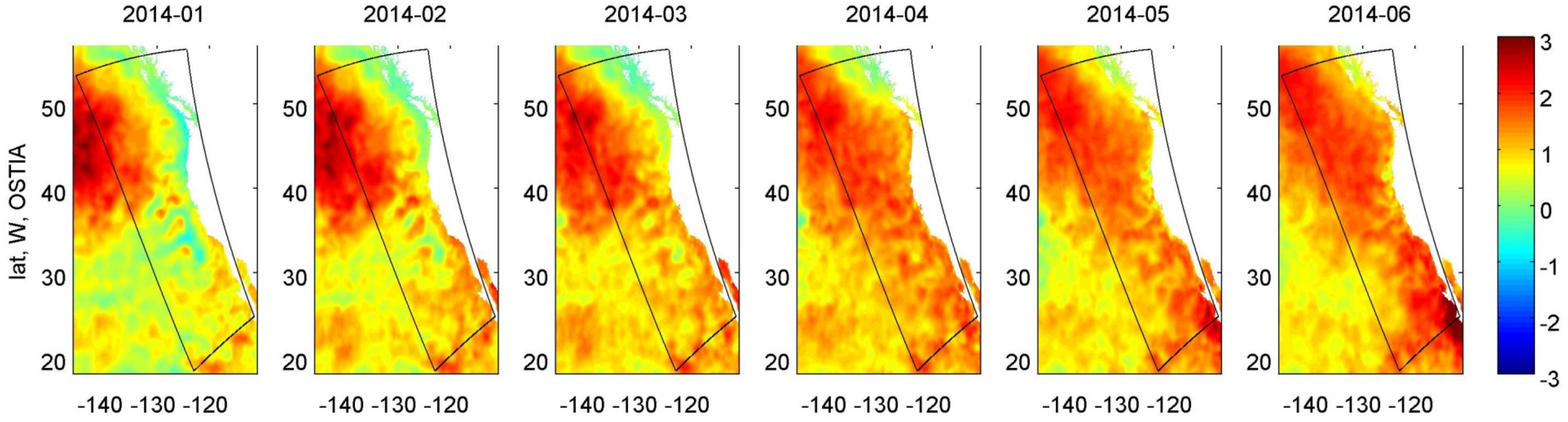
Near-surface T (NDBC shelf moorings) / WCOFS comparison:



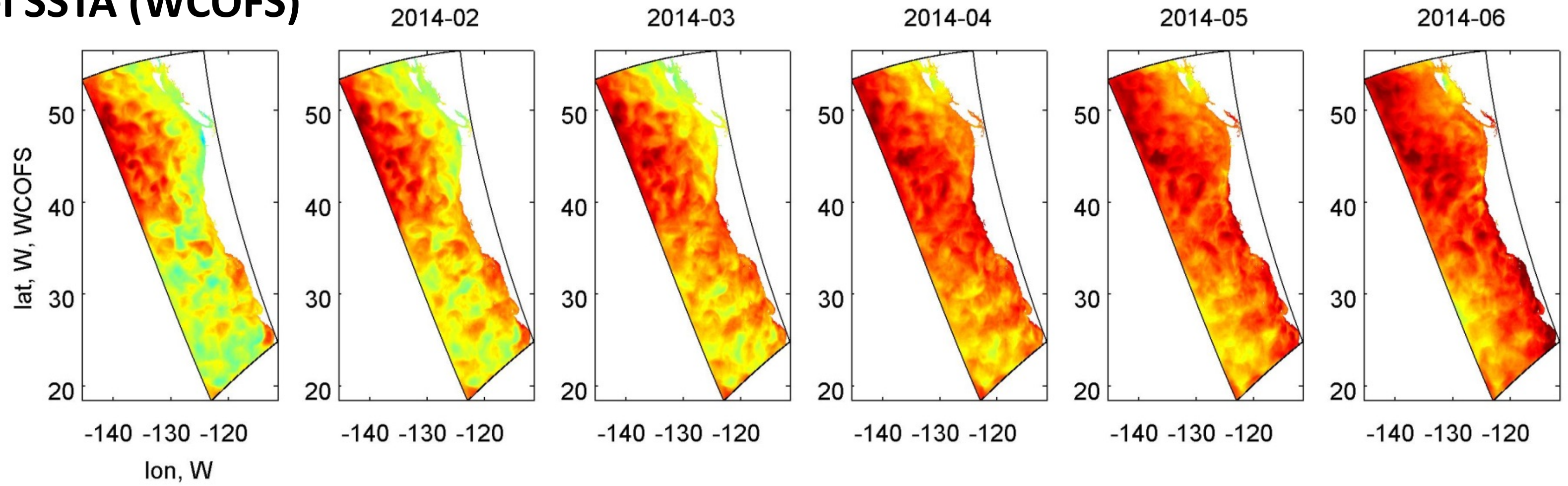
WCOFS has predicted correctly the warming trend (from Dec 2013 to Dec 2014)

Compared to sat. SST anomaly, WCOFS predicts the appearance of the warm blob by Jan 2014, and wide-spread warming along the US Coast by summer 2014

Satellite SSTA (OSTIA)

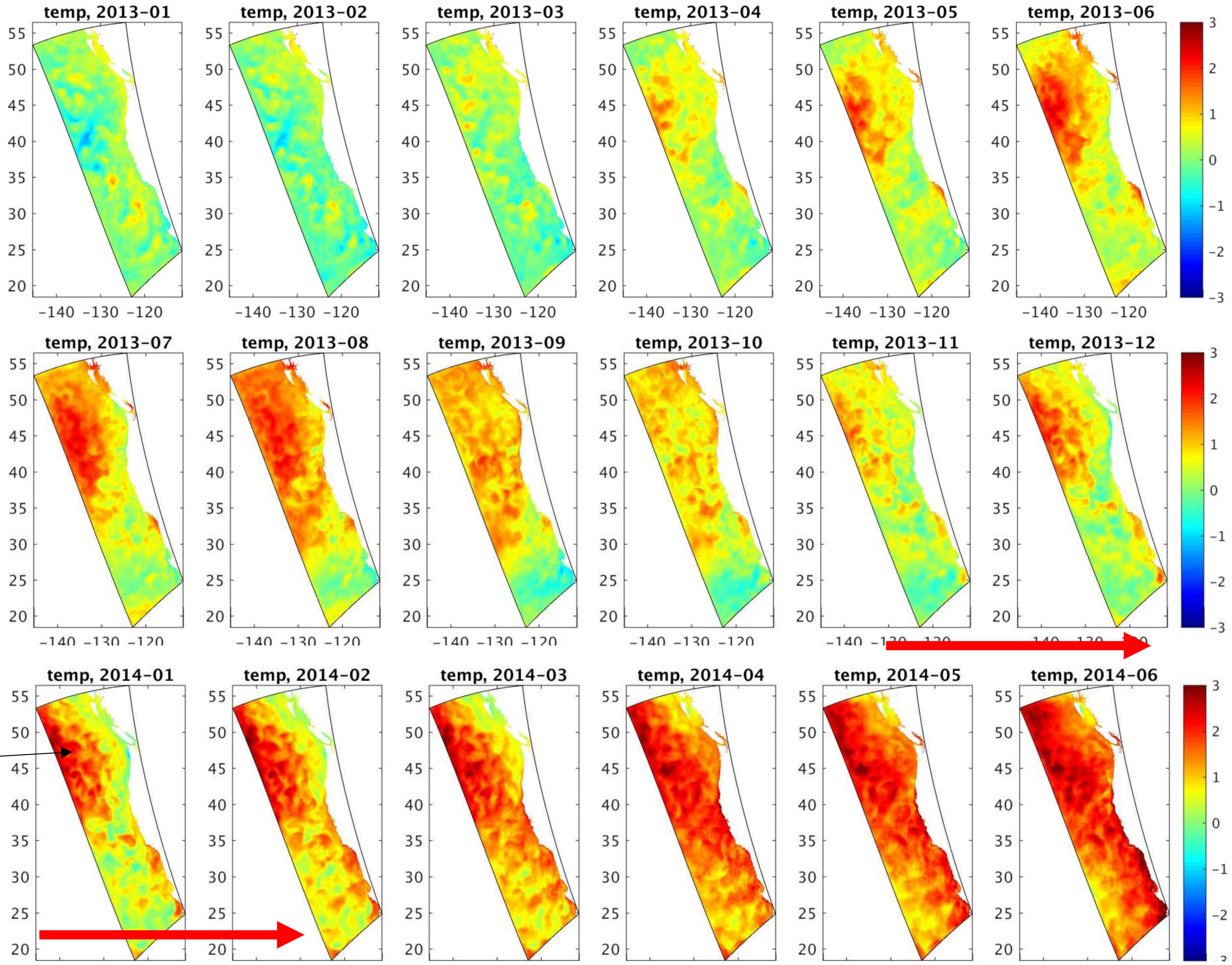


Model SSTA (WCOFS)



Anomaly w/ respect to 2009-2013 climatology (computed similarly for sat. and model)

ROMS SST anomaly, Jan 2013 through Jun 2014 (w resp to 2009-2013 clim, 3-mo running ave)



Warming during Dec 2013 – Jan 2014 – Feb 2014

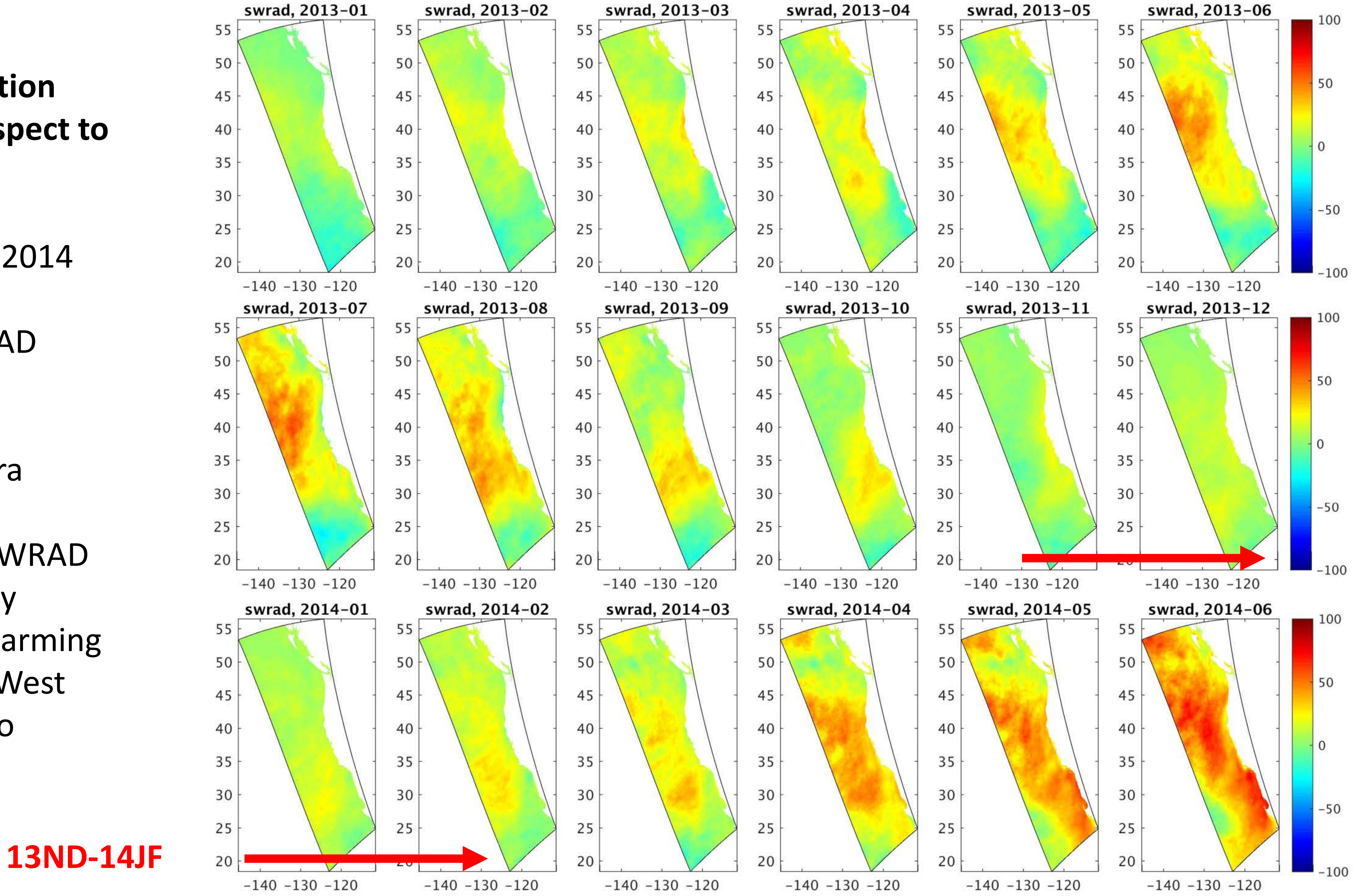
13ND-14JF

Anomaly in net shortwave radiation (SWRAD), w /respect to 2009-2013:

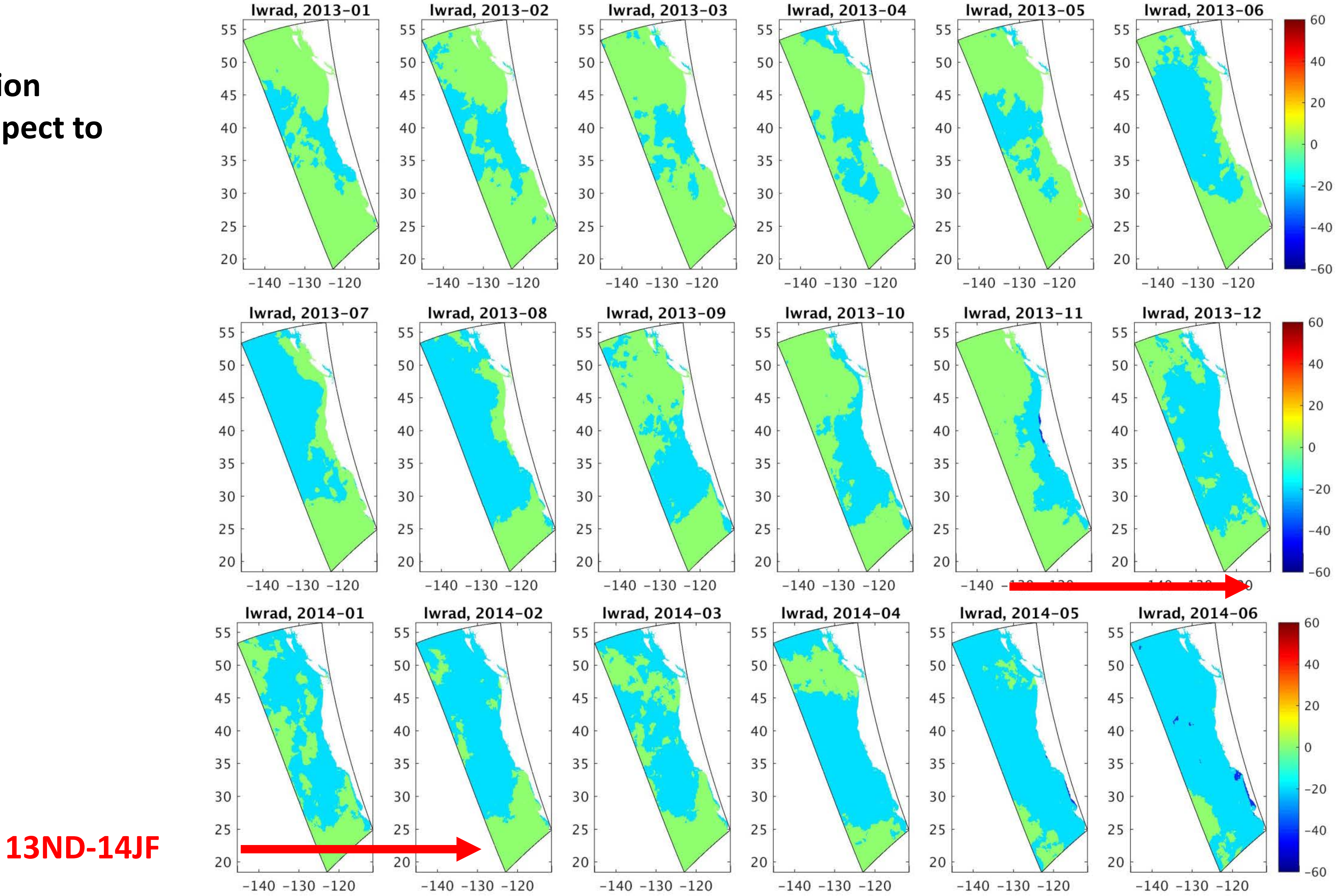
Fall 2013-winter 2014 does not receive anomalous SWRAD

Summer 2013:
30-50 W/m2 extra

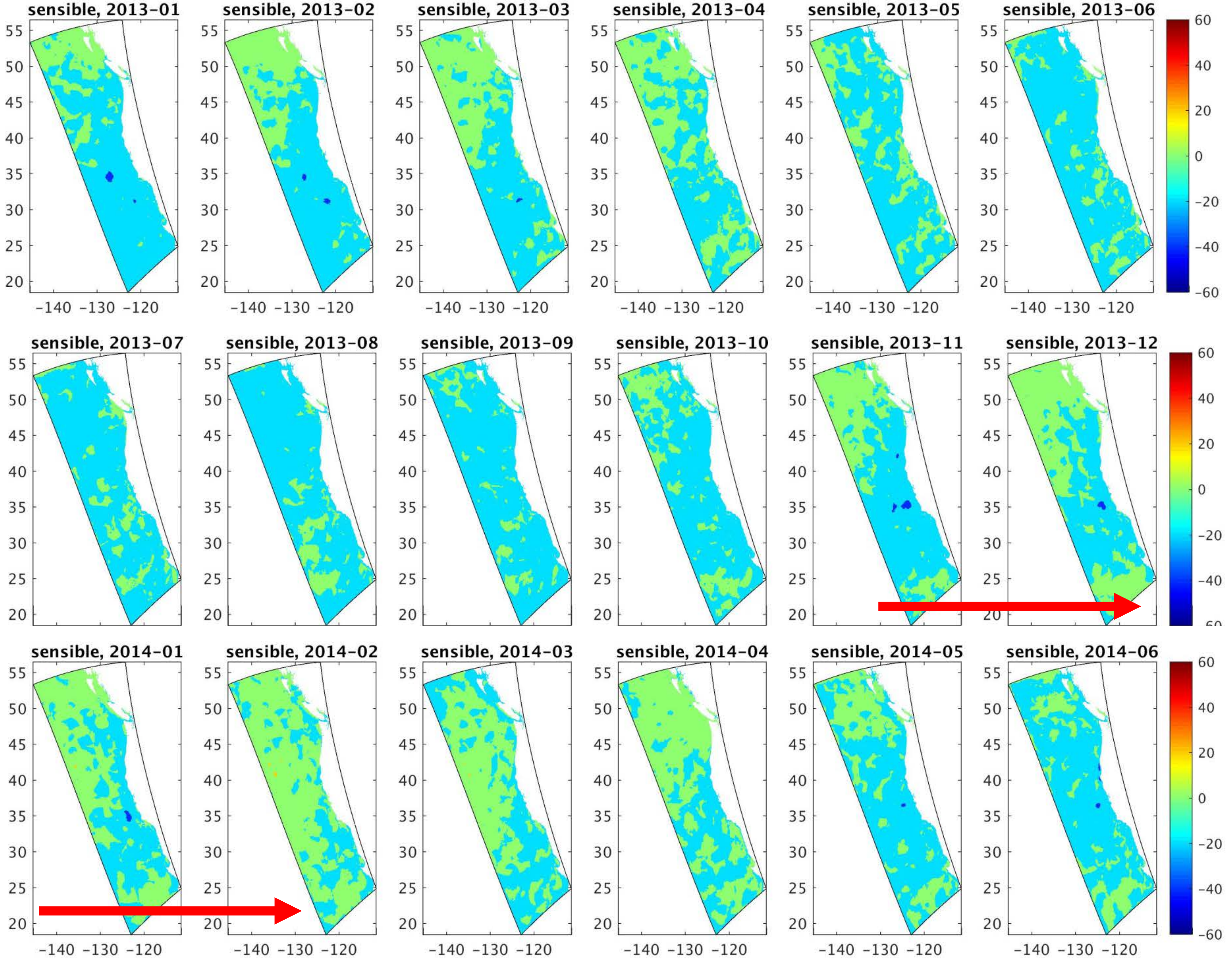
Summer 2014: SWRAD anomaly certainly contributed to warming all along the US West Coast and Mexico



Anomaly in net longwave radiation (LWRAD), w /respect to 2009-2013:

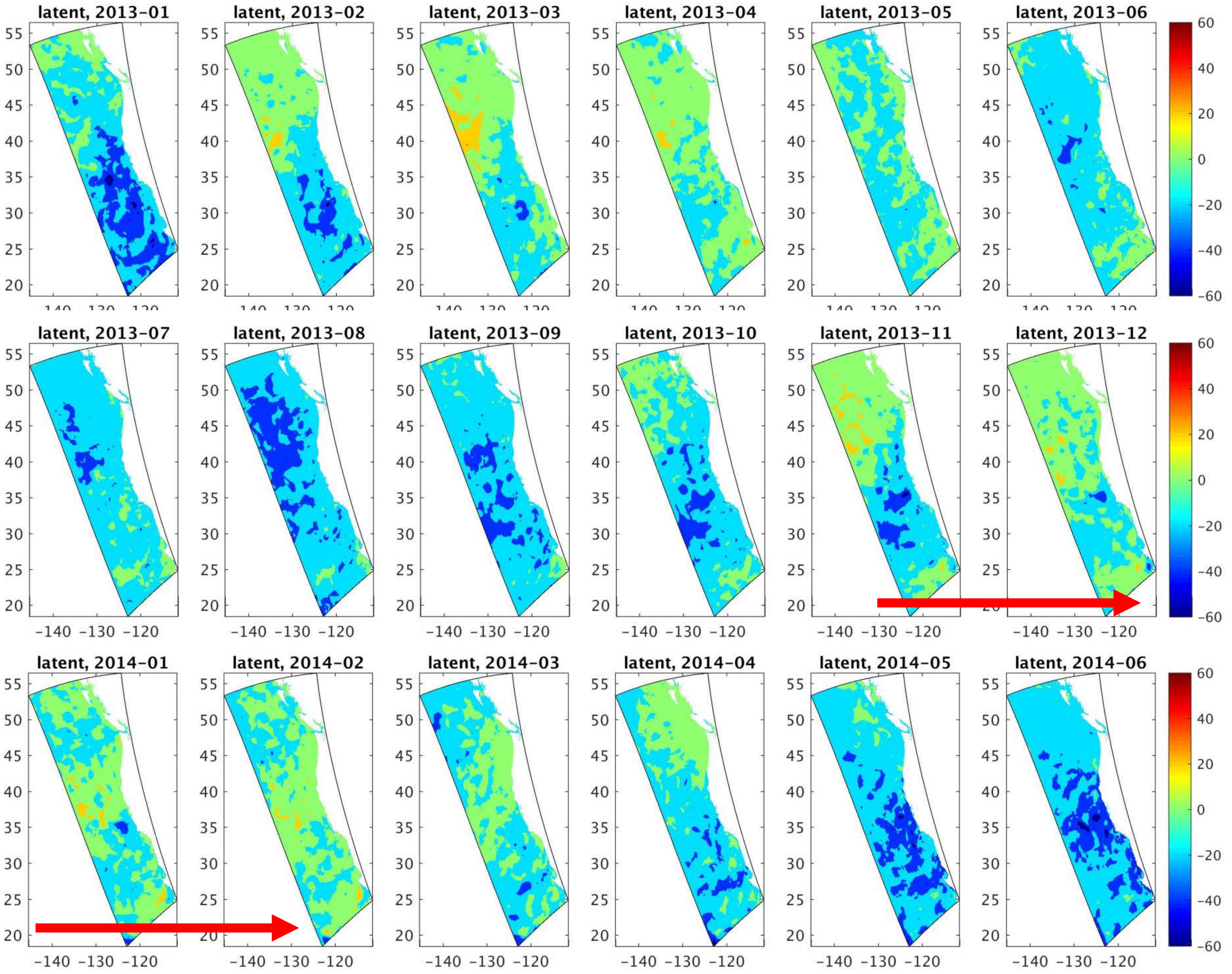


Anomaly in sensible heat flux, w /respect 2009-2013:



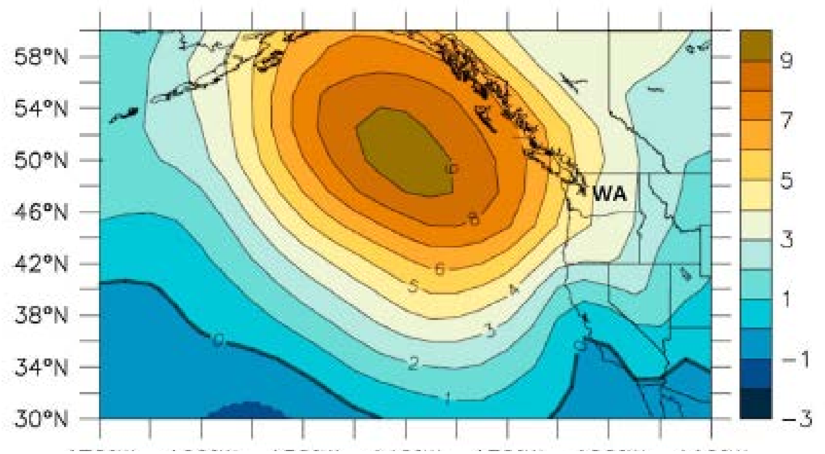
13ND-14JF

Anomaly in latent he flux, w /respect to 2009-2013:

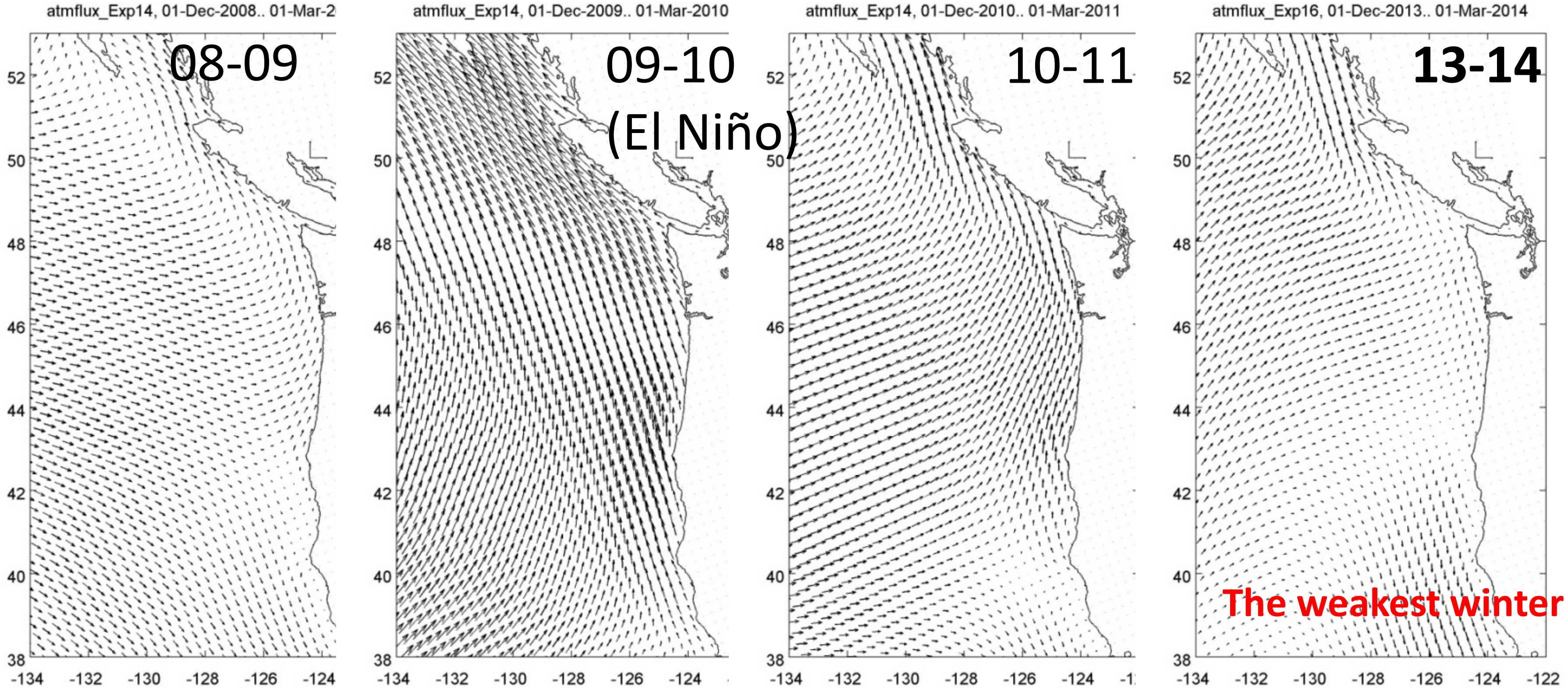


13ND-14JF

Figure 2 from ***Bond, Cronin, Freeland & Mantua, GRL, 2015:*** *Mean Sea Level P anomaly (hPa) Oct 2013-Jan 2014, relative to 1981-2011 mean*

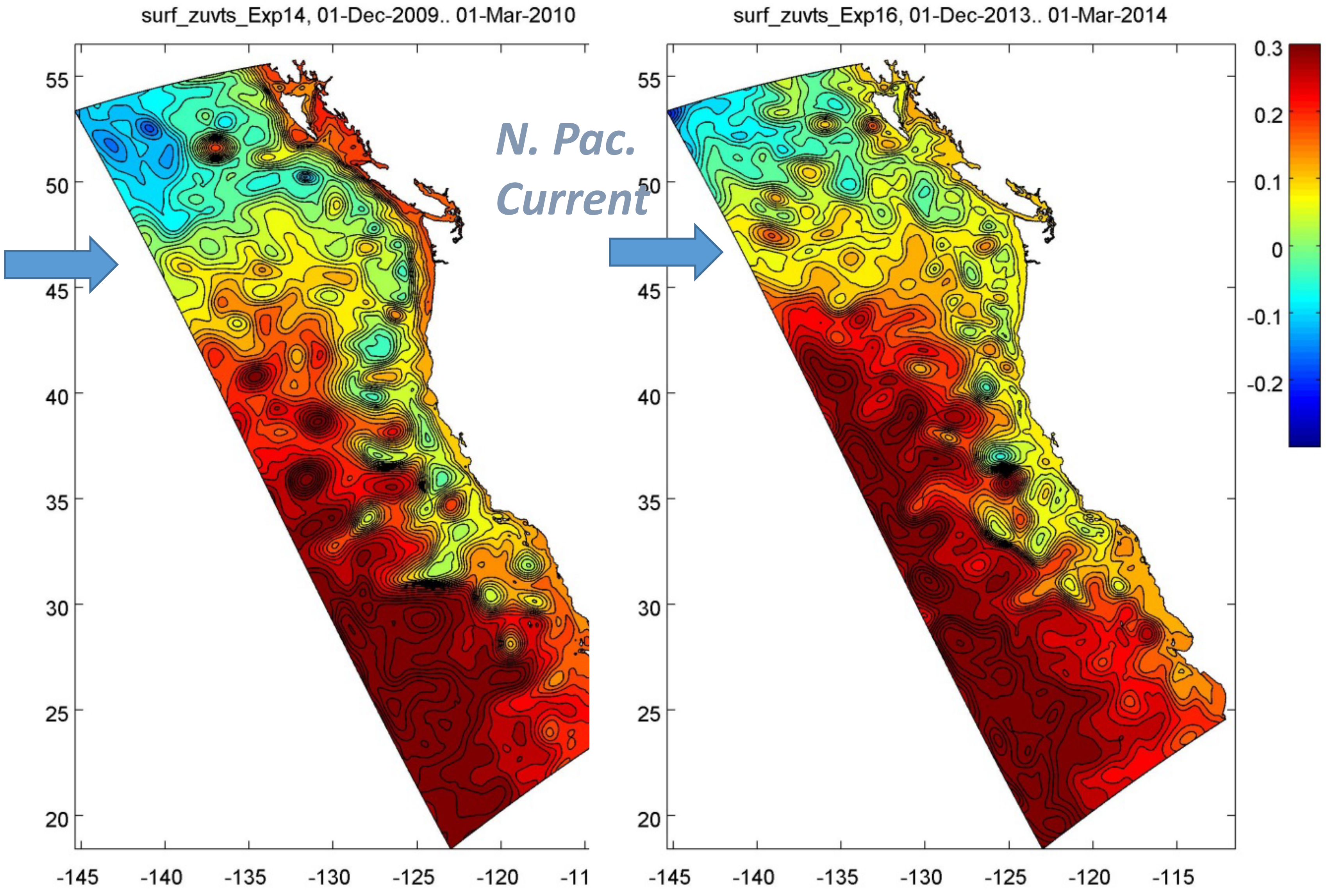


model wind stress, 3-mo ave. (DJF)



DJF ave SSH: 2009-10 and 2013-14:

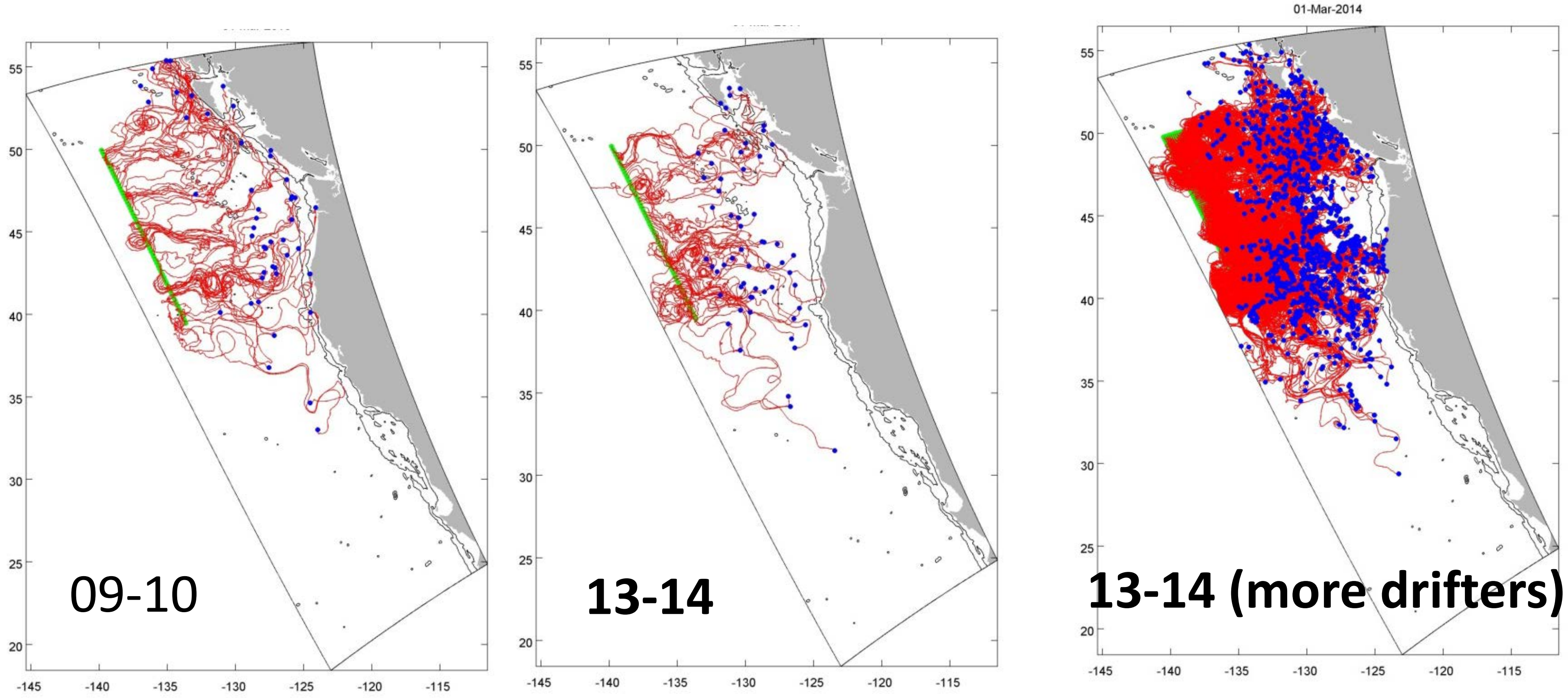
Onshore surface transport =
geostrophic + Ekman



Winter w strong winds

Winter w weak winds

Surface Lagrangian transport (1 Oct to 1 Mar):



Release: on the path of N. Pac. Current

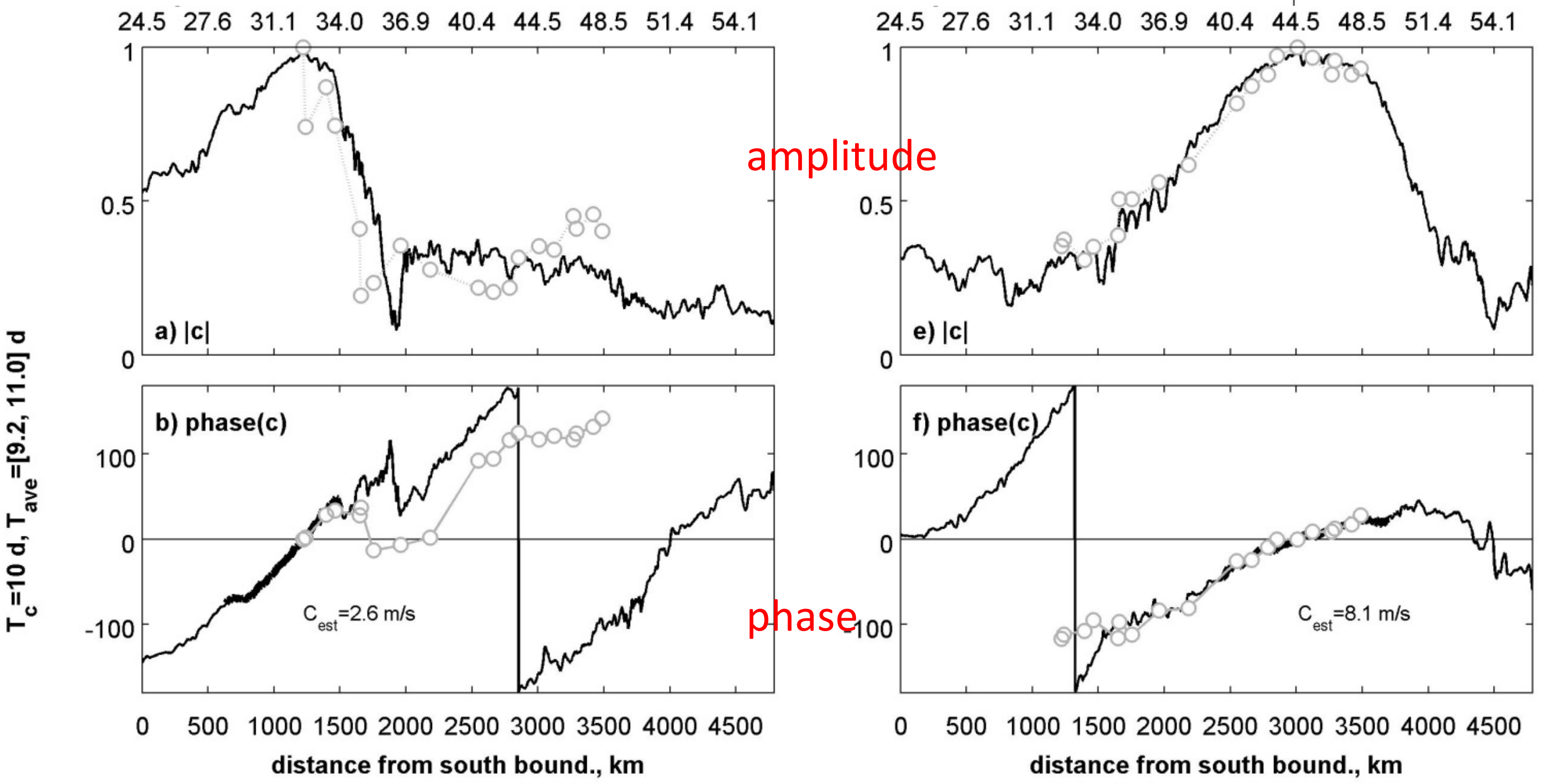
In 2013-14, these surface drifters avoid OR-WA (weaker onshore Ekman transport)

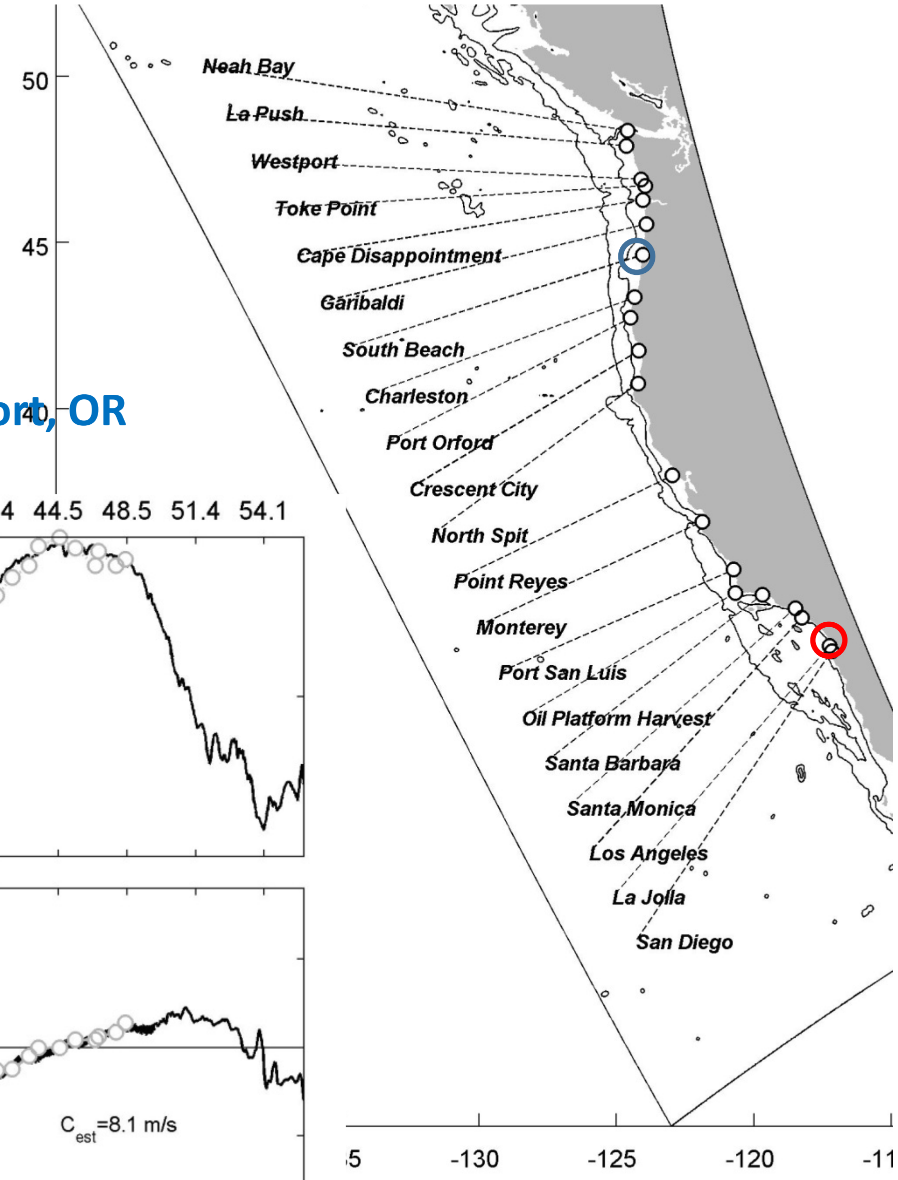
Coastal trapped waves express themselves, e.g., in the along-coast coherence in the coastal sea level (tide gauge, model)

Coherence = correlation in a specified frequency range

Shown here for the range of periods close to 10 days

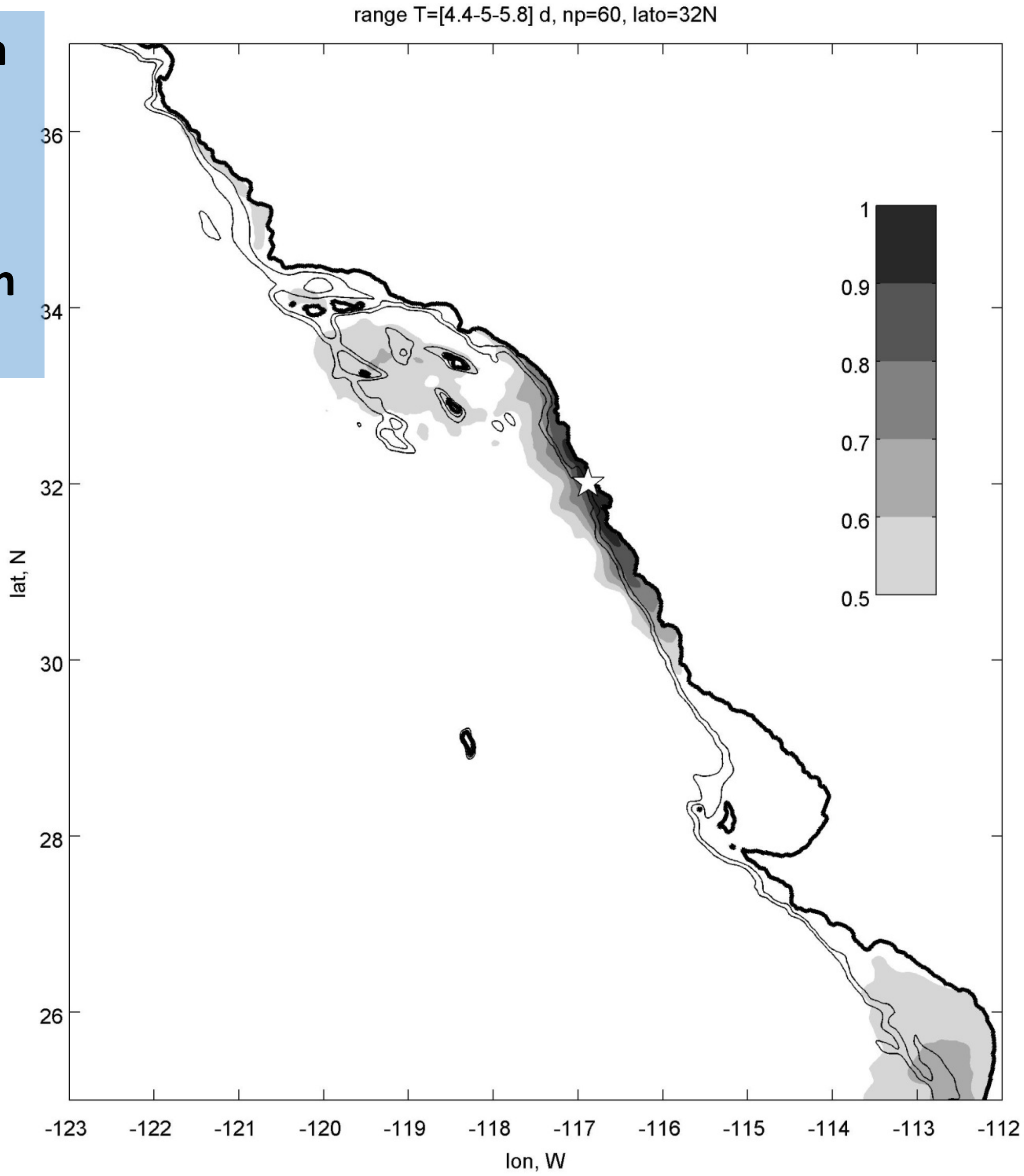
w/ resp. to San Diego, CA w/ resp to Newport, OR





(Kurapov et al., 2016)

Using the 6-year model solution, we can compute 2-dimenstional SSH coherence amplitude maps and learn about spatial structure of the long coastal trapped waves (conduits of the signal from south to north)

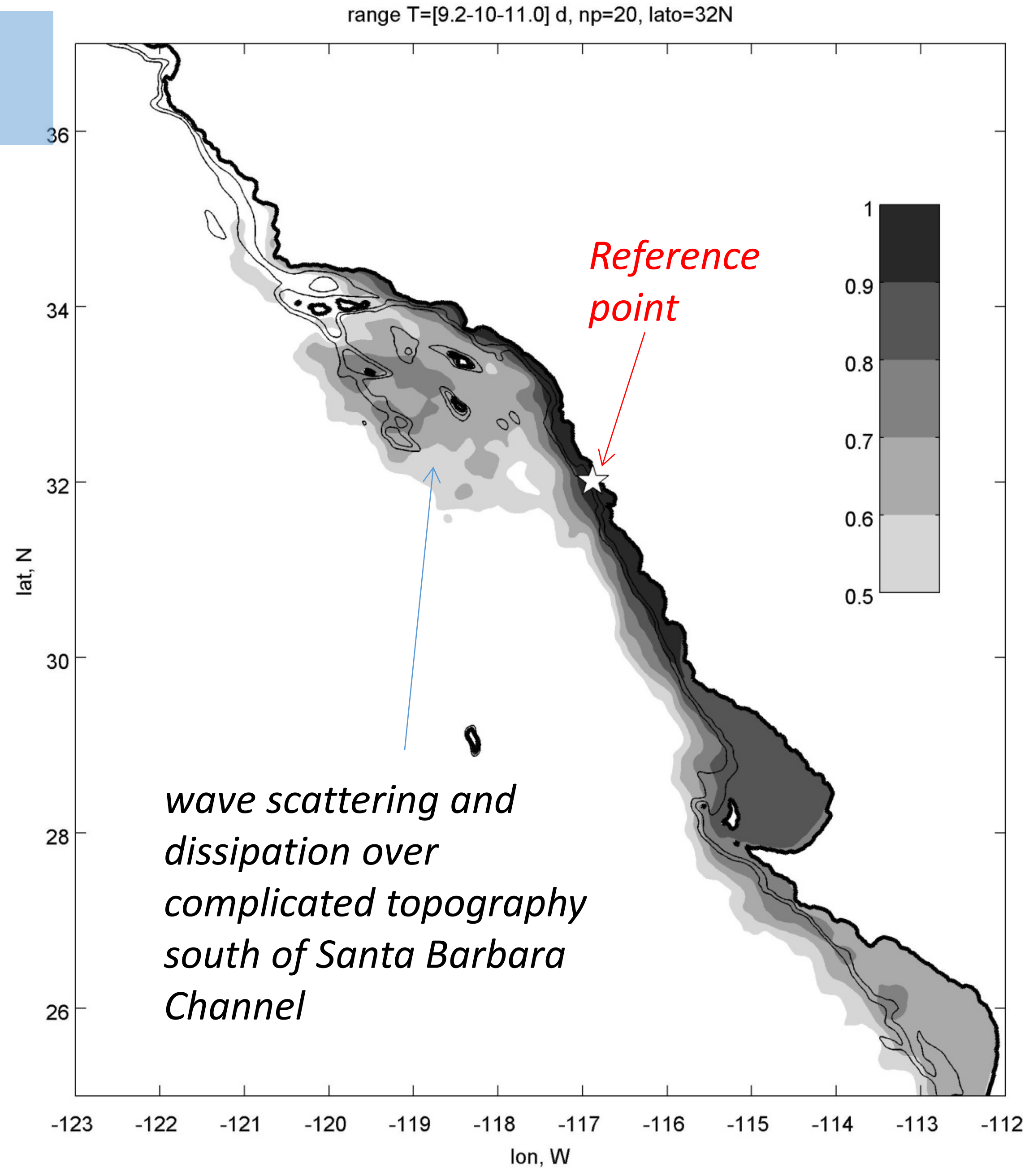


Frequency range centered on $\omega=1/5\ d^{-1}$

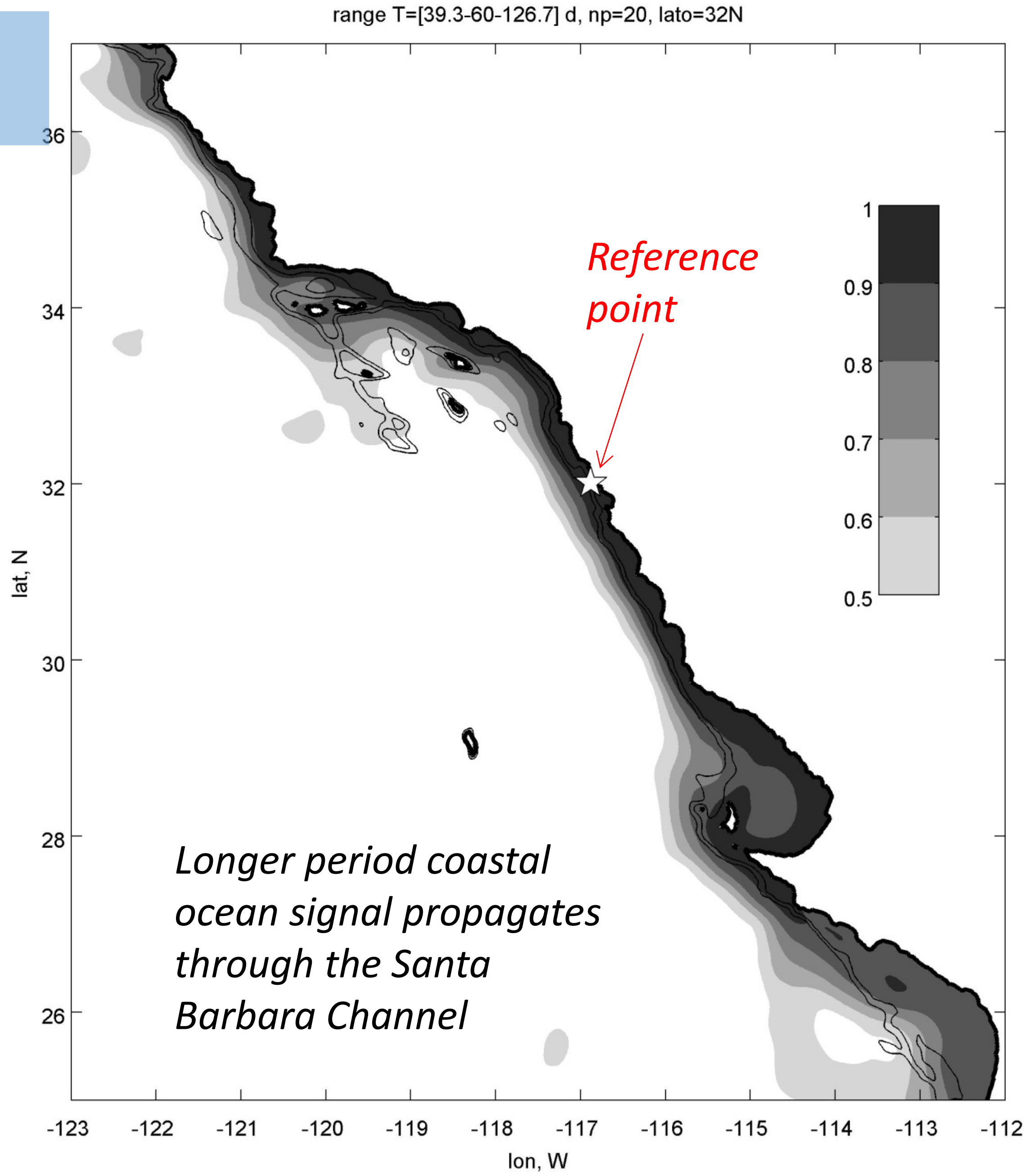
Kurapov et al., Oc. Dyn. 2016

The SSH coherence amplitude map

Frequency range centered on ω=1/10 d^{-1}



The SSH coherence amplitude map



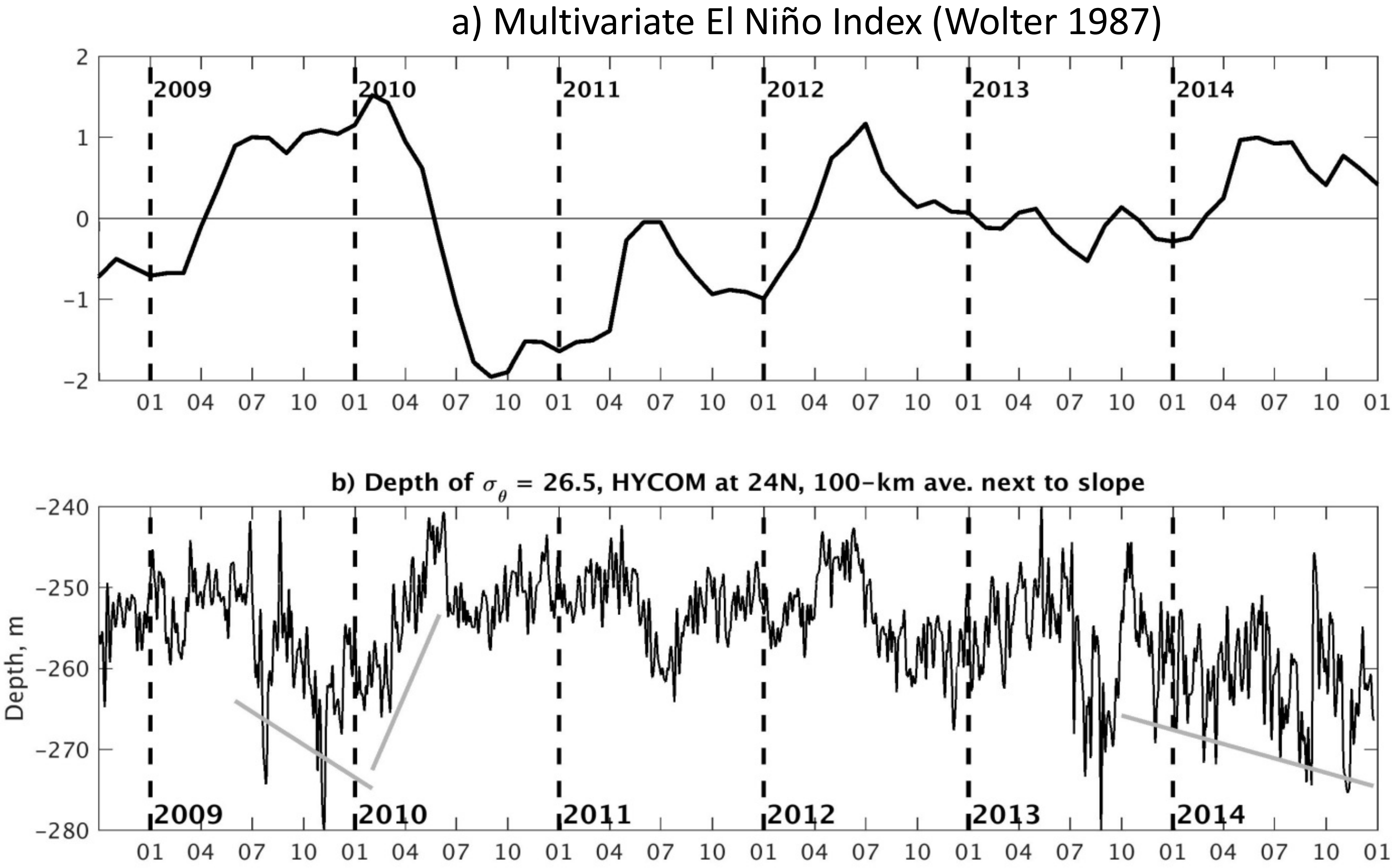
Frequency range centered on ω=1/60 d^{-1}

(40-126 days)

Low frequency signals from the southern boundary (24N) can influence coastal and slope variability in CA, OR, WA, BC

What kind of signal is found in the southern boundary conditions?

Depth of σ_θ=26.5 HYCOM at 24N
(averaged between 0-100 km from cont. slope)



WCOFS: T and S are nudged to the global HYCOM solution in a 100-km wide band around the WCOFS open boundary

Properties on the isopycnal surface 26.5

In the entire domain, for each day, at each grid point we obtain

- depth of the isopycnal surface, $z(x,y,t)$
- T, S, u, v on this surface, PV

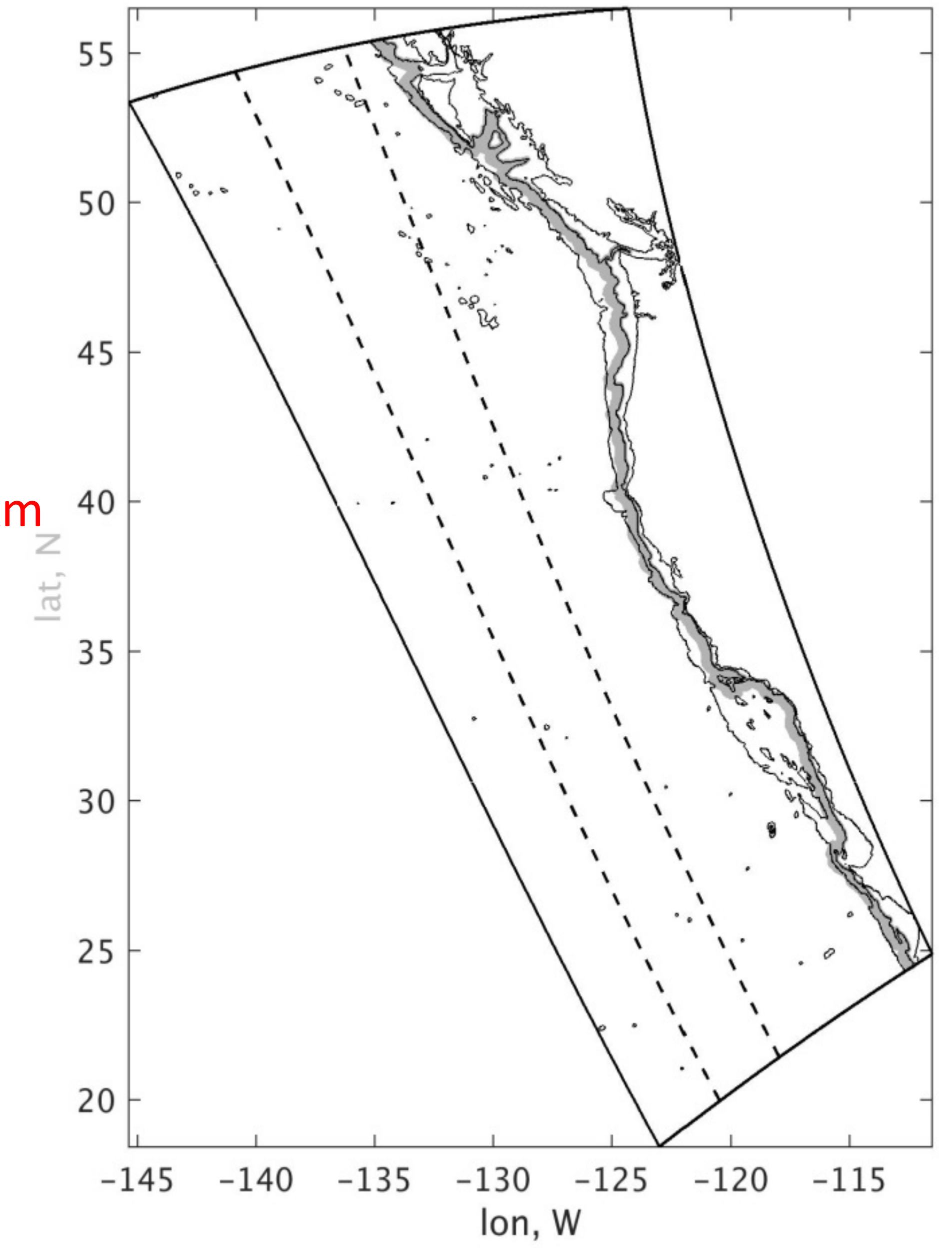
Average properties in cross-shore direction between 0-30-km offshore of the 200-m isobath (see gray shade in the figure)

$\Rightarrow$ e.g., $z(s,t)$, $T(s,t)$ where s = distance from southern boundary

T(s,t)= time_ave_T(s) + seasonal_T(s,t)+anomaly_T(s,t)

seasonal_T = harmonic fit (annual + semi-annual)

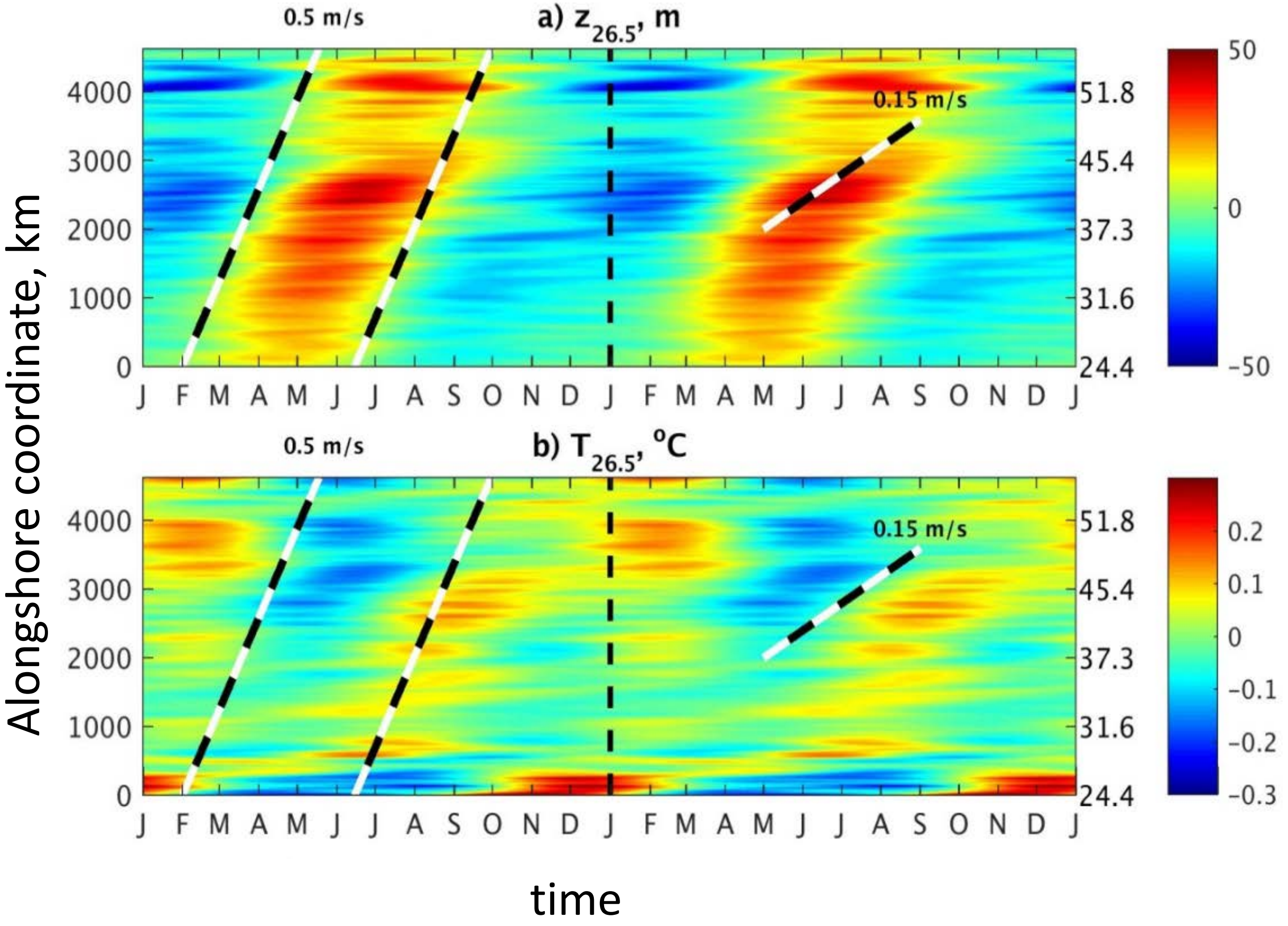
Effect of CTW? Effect of undercurrent?
Climatology, anomalies?



Seasonal patterns
(2 identical years shown):

Isopycnal depth: ±30 m, propagating pattern (0.5 m/s)

Temperature: subarctic waters are displaced by undercurrent waters (0.15 m/s), apparent in CA-OR-WA

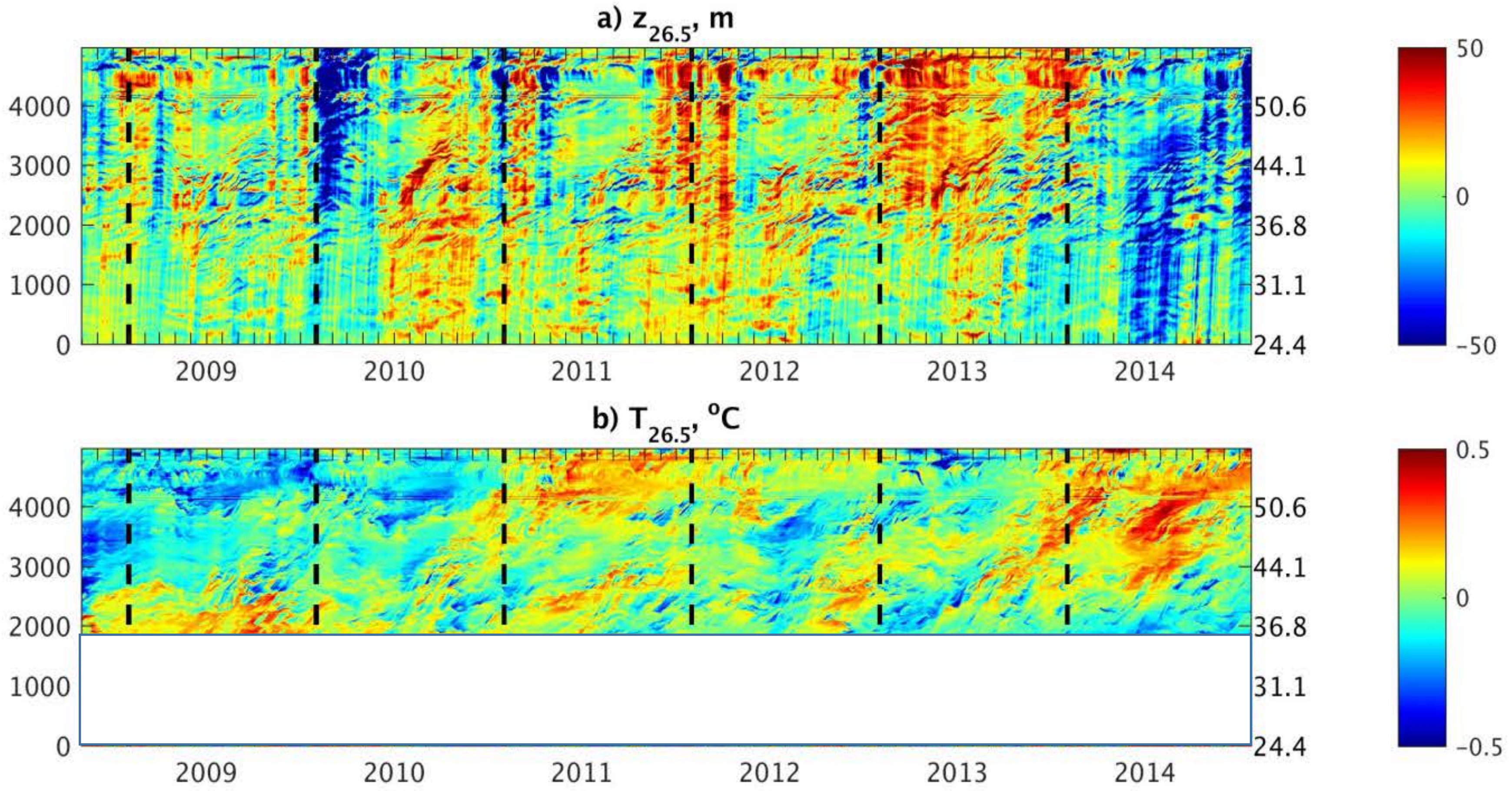


Anomalies in the properties on the 26.5 isopycnal over the continental slope:

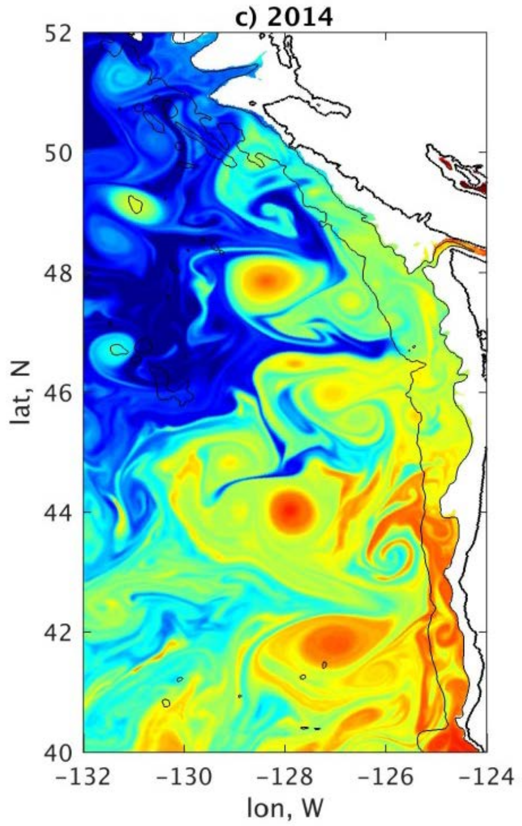
z:

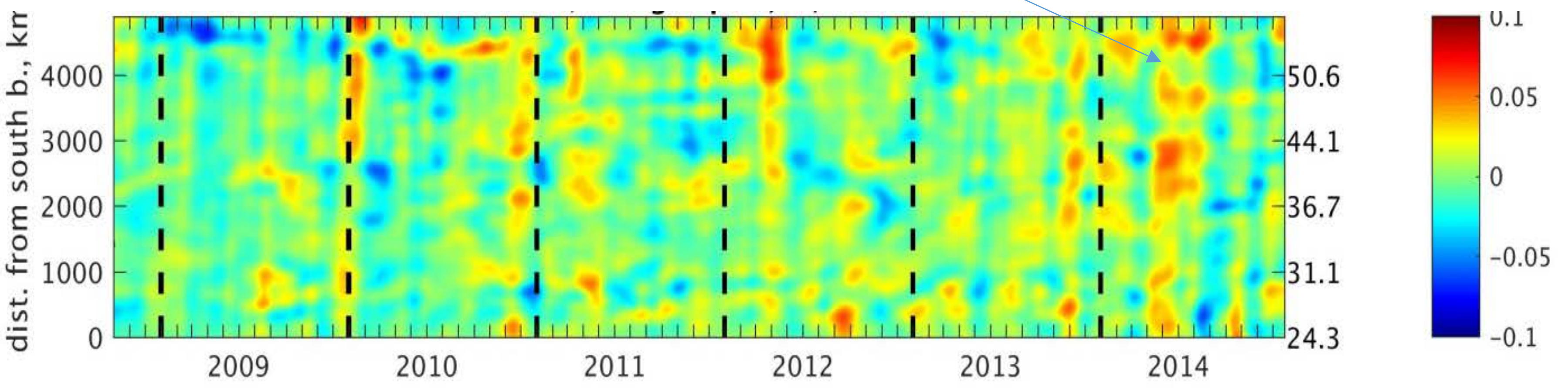
- fast propagating CTW
- El Niño effect in winter 2010 (atm. teleconnection)
- El Niño effect in summer 2014: propagation from the southern boundary

T: warmer in OR-WA-BC



Anomaly from the seasonal cycle in alongslope current on 26.5: average across 0-100 km from 200 m isobath (i.e. average across the width of eddies separated from the undercurrent): the 2014 anomaly in v on the isopycnal is seen better





(*A snapshot of T on the isopycnal surface, 1 Jun 2014: Coastal undercurrent eddies “cuddies” are apparent over the slope and in the adjacent ocean interior on the 26.5 isopycnal surface*)

SUMMARY:

- A 2-km resolution regional ocean model of the West Coast from Mexico to BC has been developed as the base component of the NOAA West Coast Ocean Forecast System (WCOFS)

- Warm blob anomaly in NEP in Jan 2016 is not associated with anomaly in the atmospheric heat flux

- The wide-spread warming along the US West Coast in spring-summer 2014 is associated with the anomalous SWRAD

- Warm anomaly over the OR slope in summer-fall 2014 can be associated with the deepening of subsurface isopycnal surfaces over the continental slope in Mexico (24N), the CTW propagation, isopycnal surface depression in the north and the resulting stronger undercurrent

- The seasonal cycle in the depth of the 26.5 isopycnal shows a south-to-north propagating pattern, with the speed of 0.5 m/s. Temperature and PV show patterns characteristic of advection by the undercurrent (0.1-0.15 m/s)