Coastal ocean response to ENSO from models and observations

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Critical contributions by many more:

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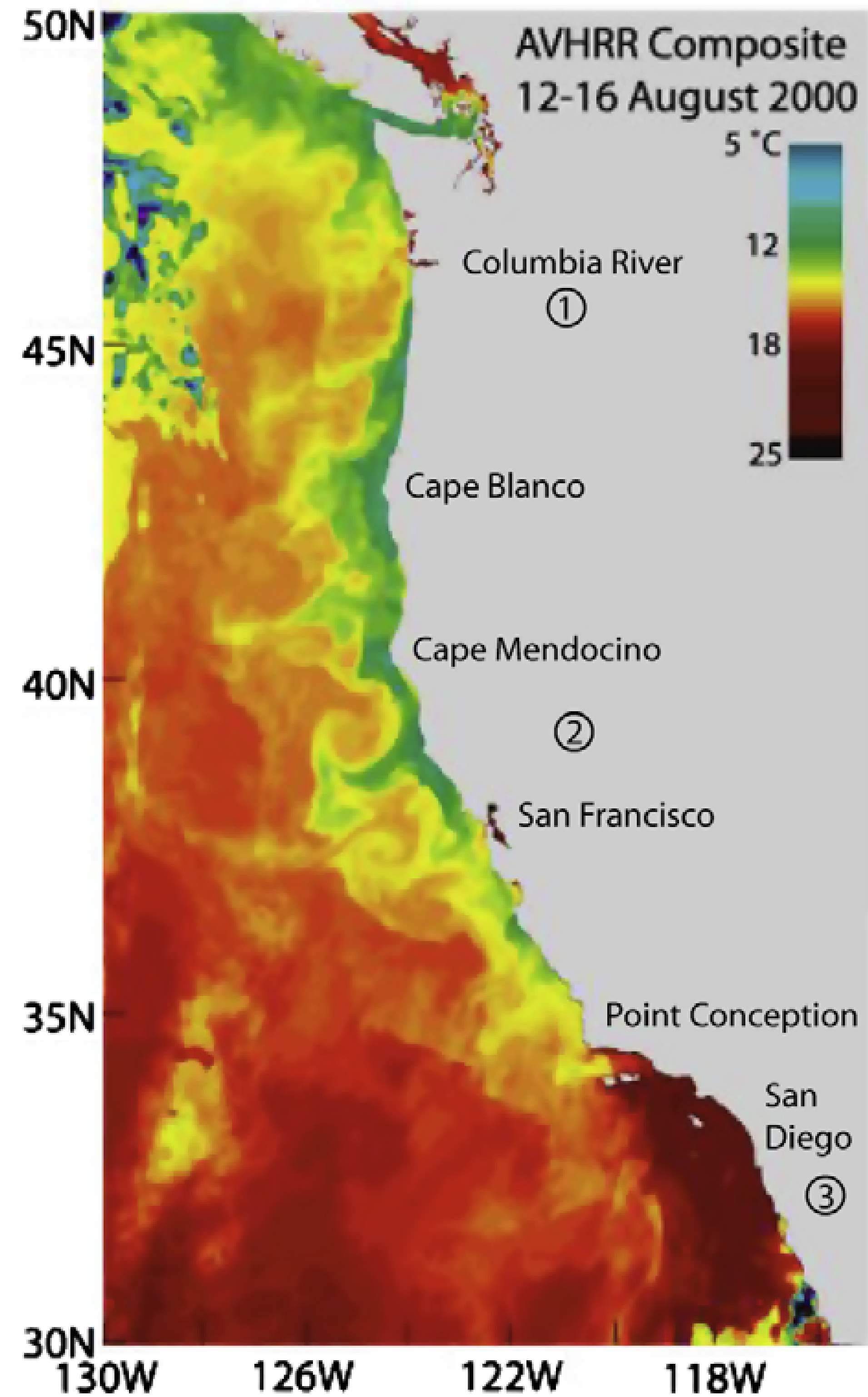
Jerome Fiechter (UCSC)

Katherine Zaba (SIO)

CLIVAR ENSO Meeting

Scripps Institution of Oceanography

August 10-11, 2016



Mechanisms

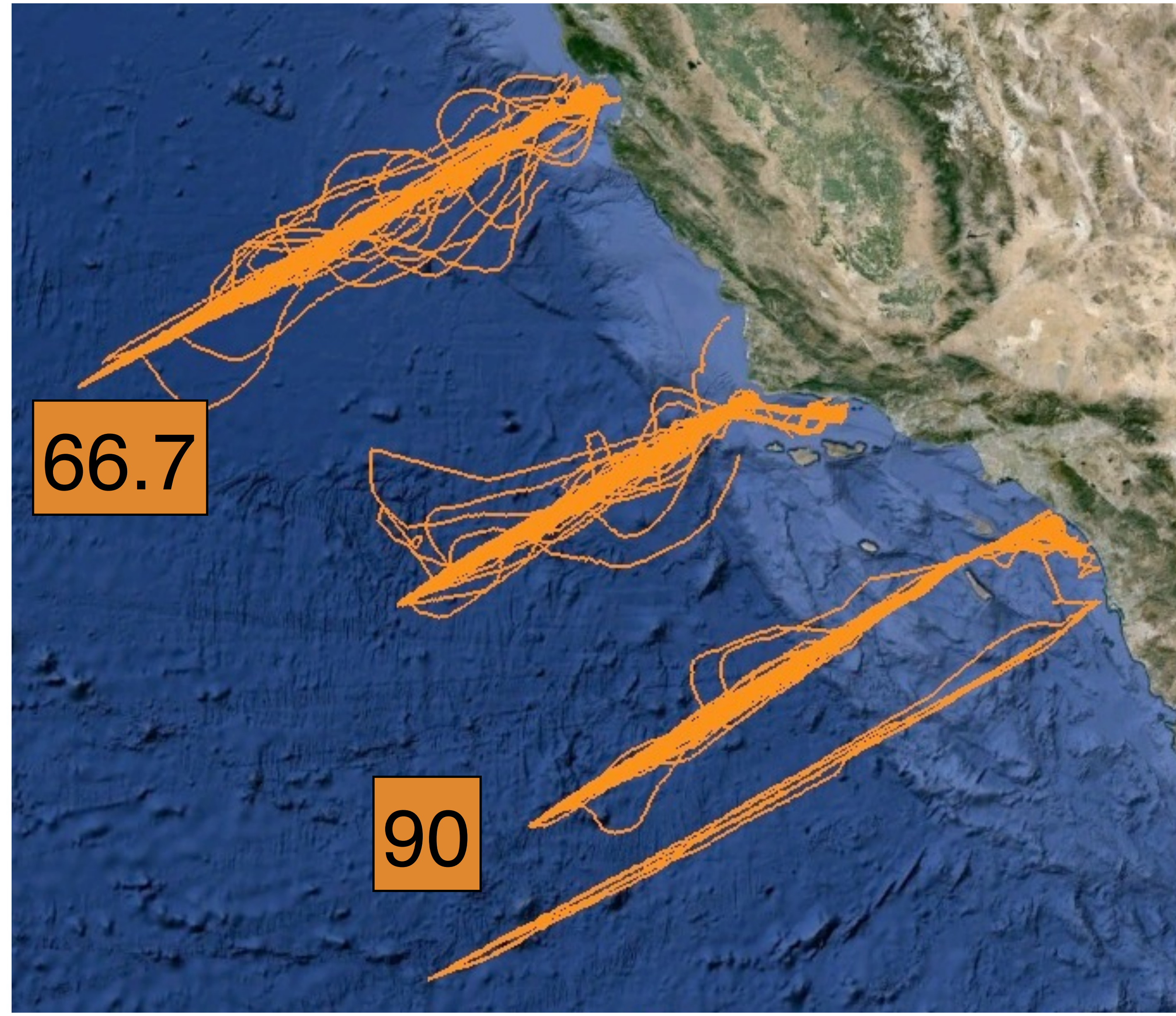
$$\frac{\partial T}{\partial t} + \mathbf{u} \cdot \nabla T \quad = \quad K_v \frac{\partial^2 T}{\partial z^2} + K_H \left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} \right) + Q_T$$

- Local rate of change
- Advection
- Mixing
- Surface heat flux

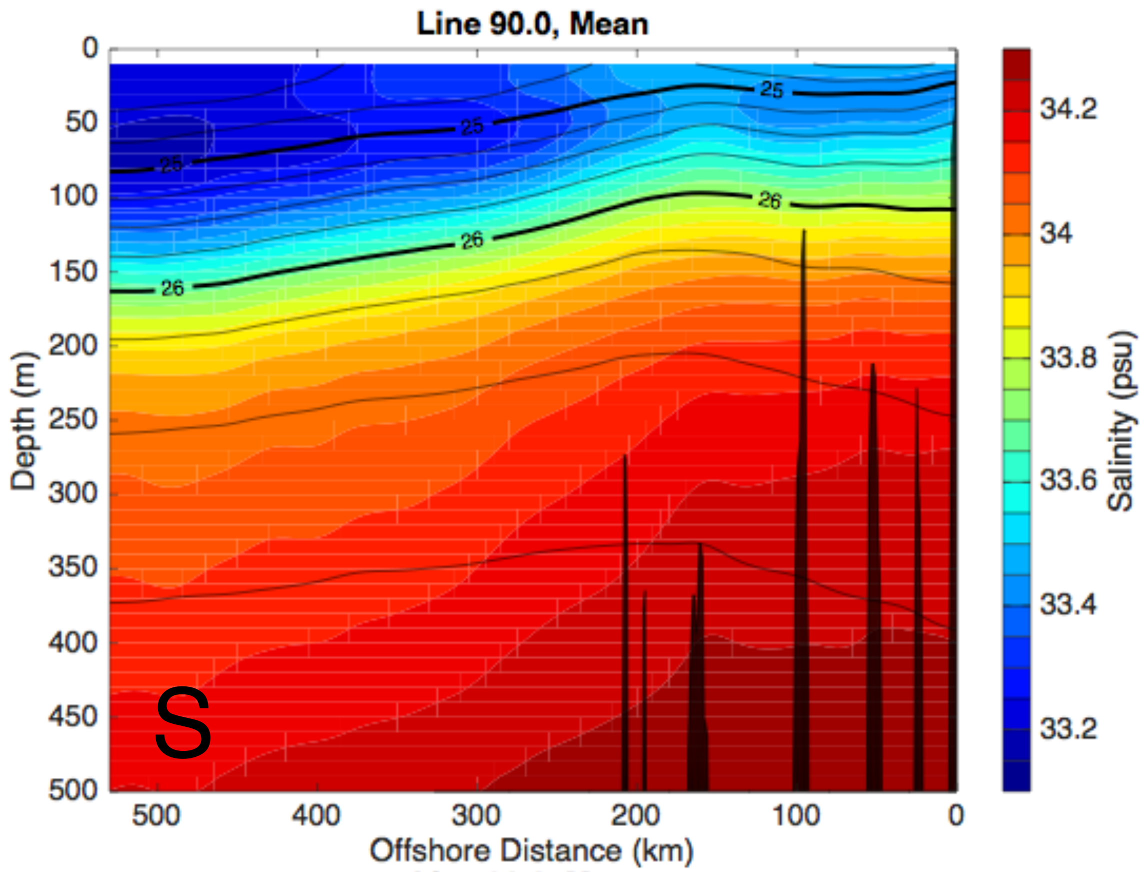
- Atmospheric teleconnections
- Coastally trapped waves
- Advection

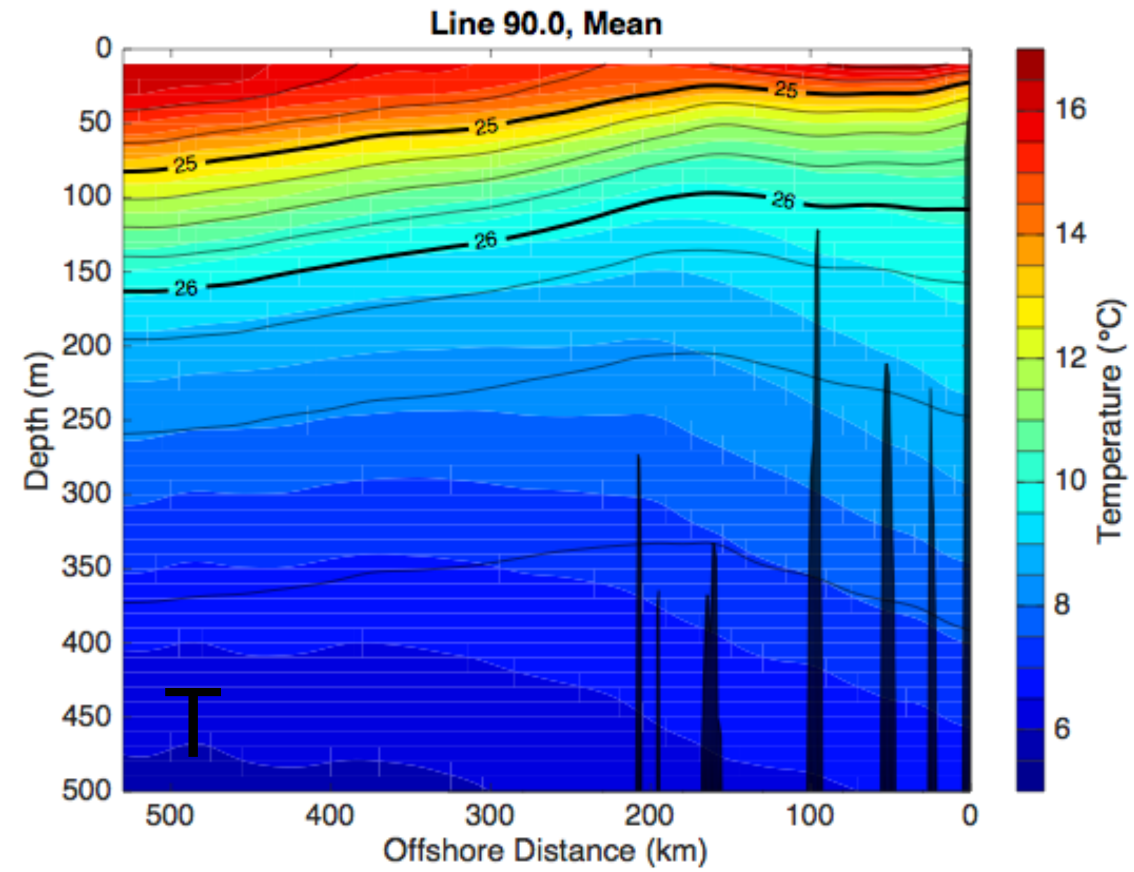
California Underwater Glider Network

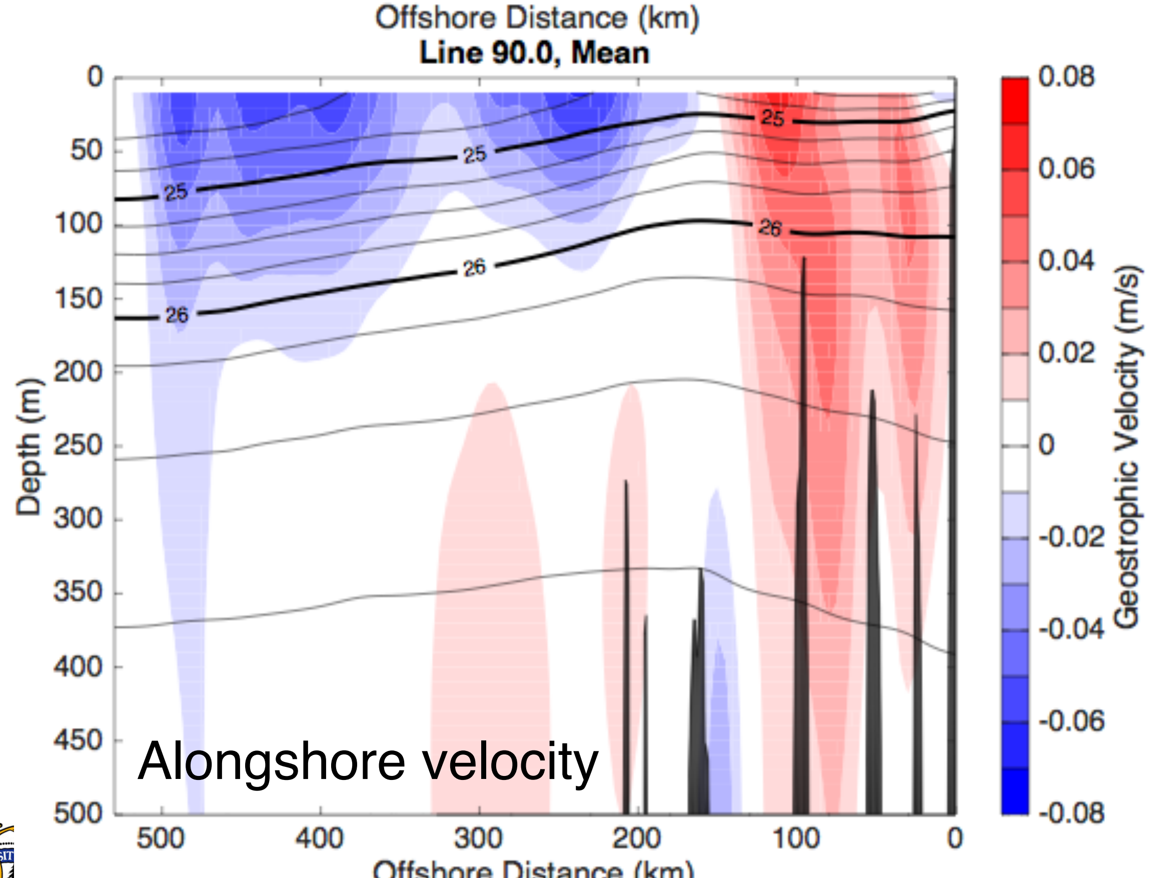
- Climate effects on region
- Lines 90, 80, since 2006
- Line 66.7, since 2007
- Data distributed in real time, assimilated in several models
- 28 glider-years, 200,000 km, 95,000 dives
- Gridded climatology



Mean on line 90

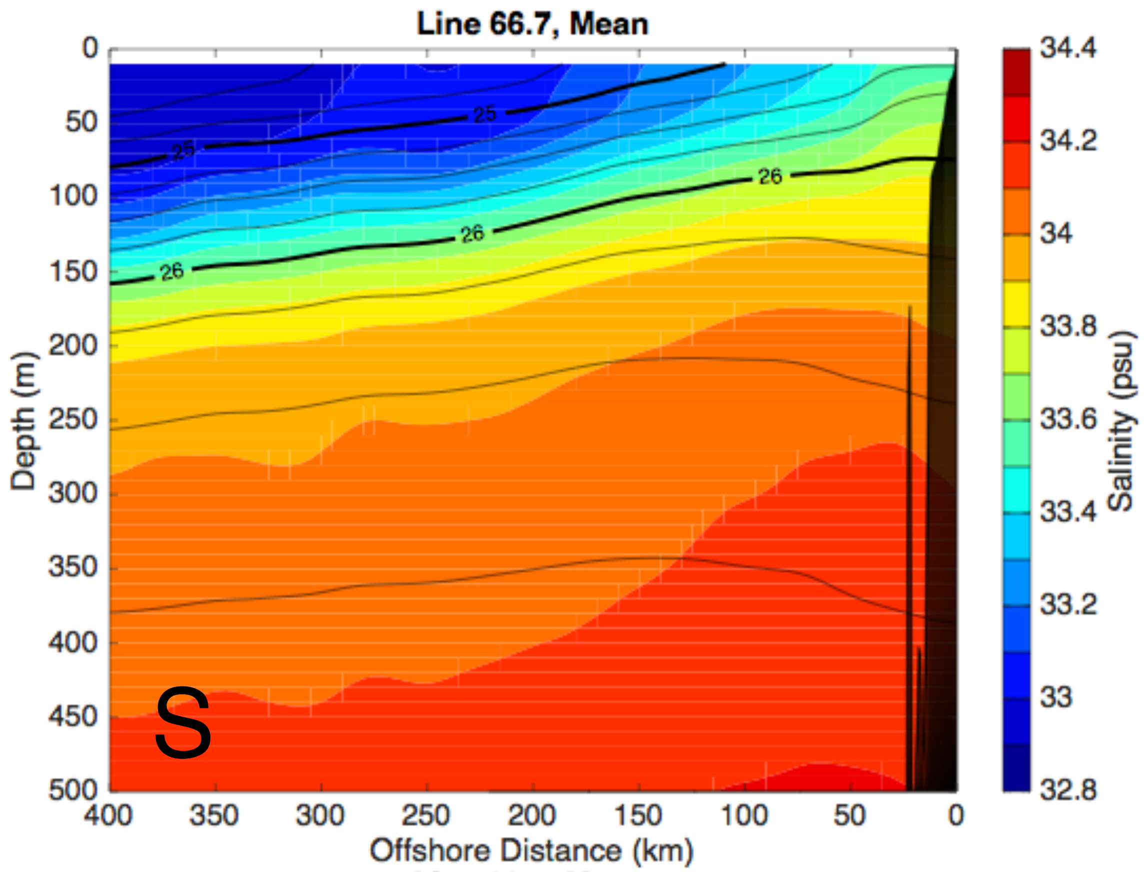


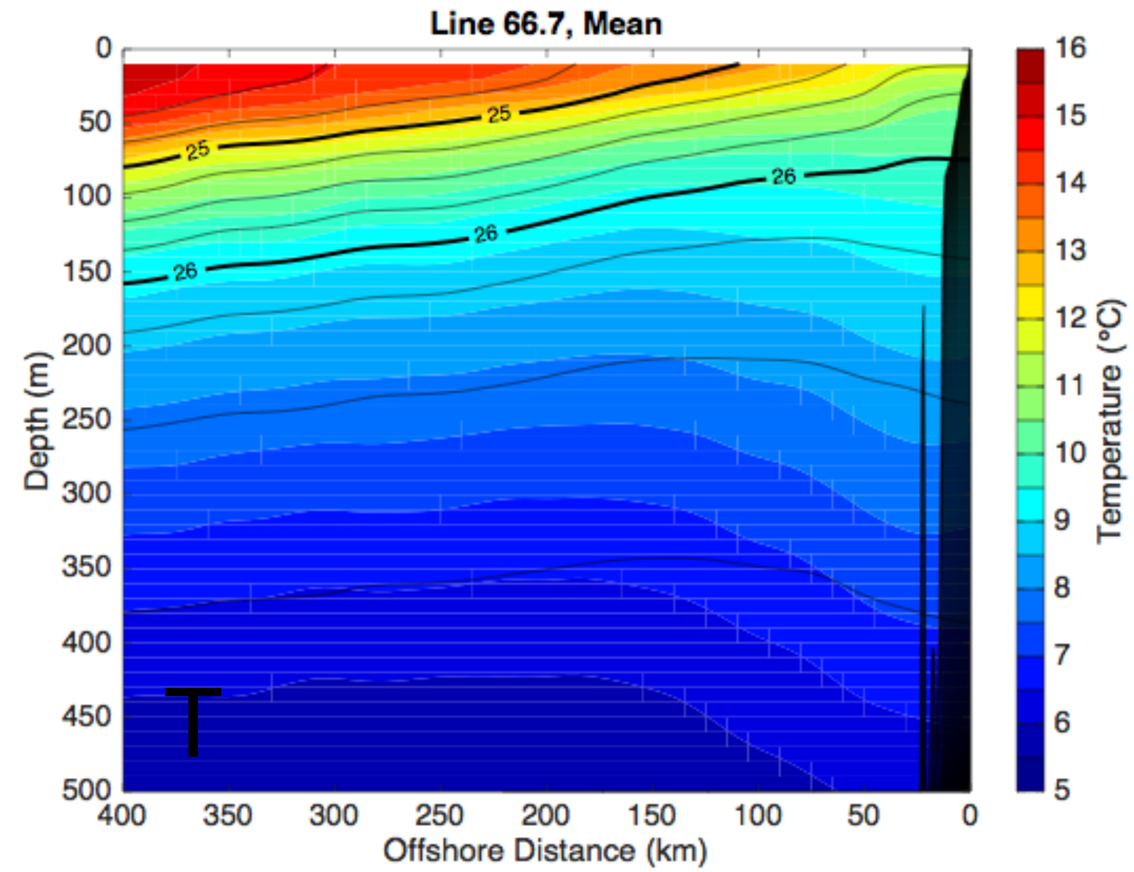


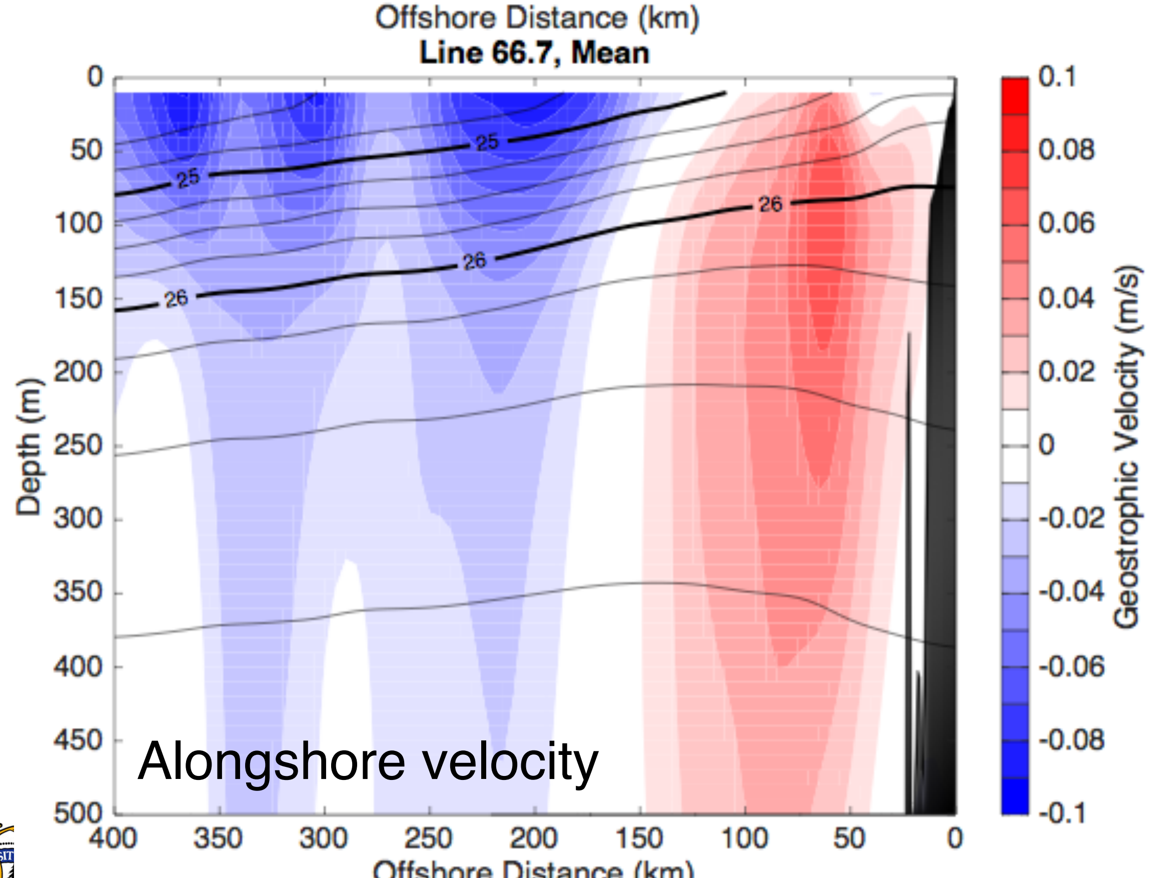


- Cores of poleward undercurrent
- Equatorward California current
- Maximum poleward flow at surface

Mean on line 66.7

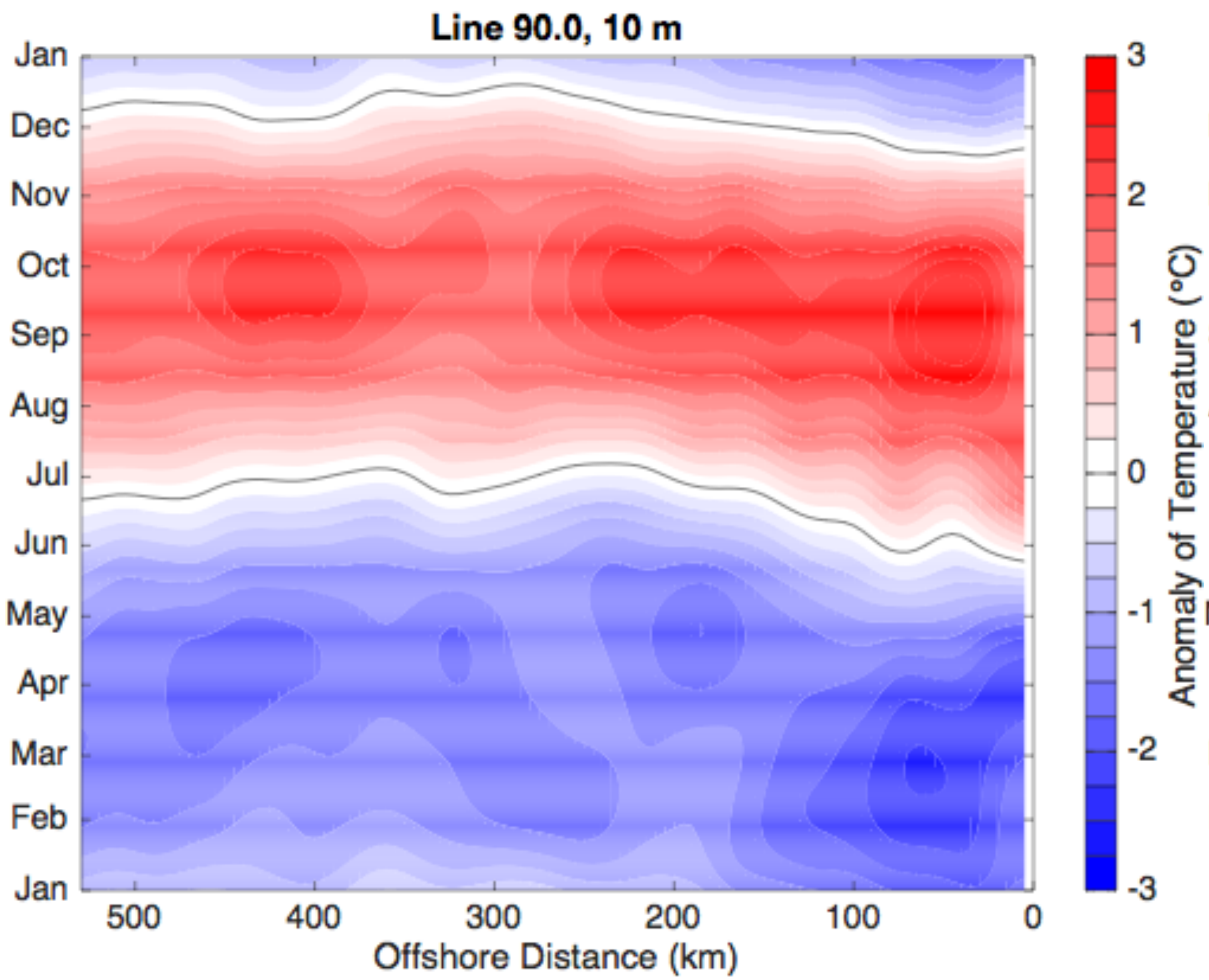


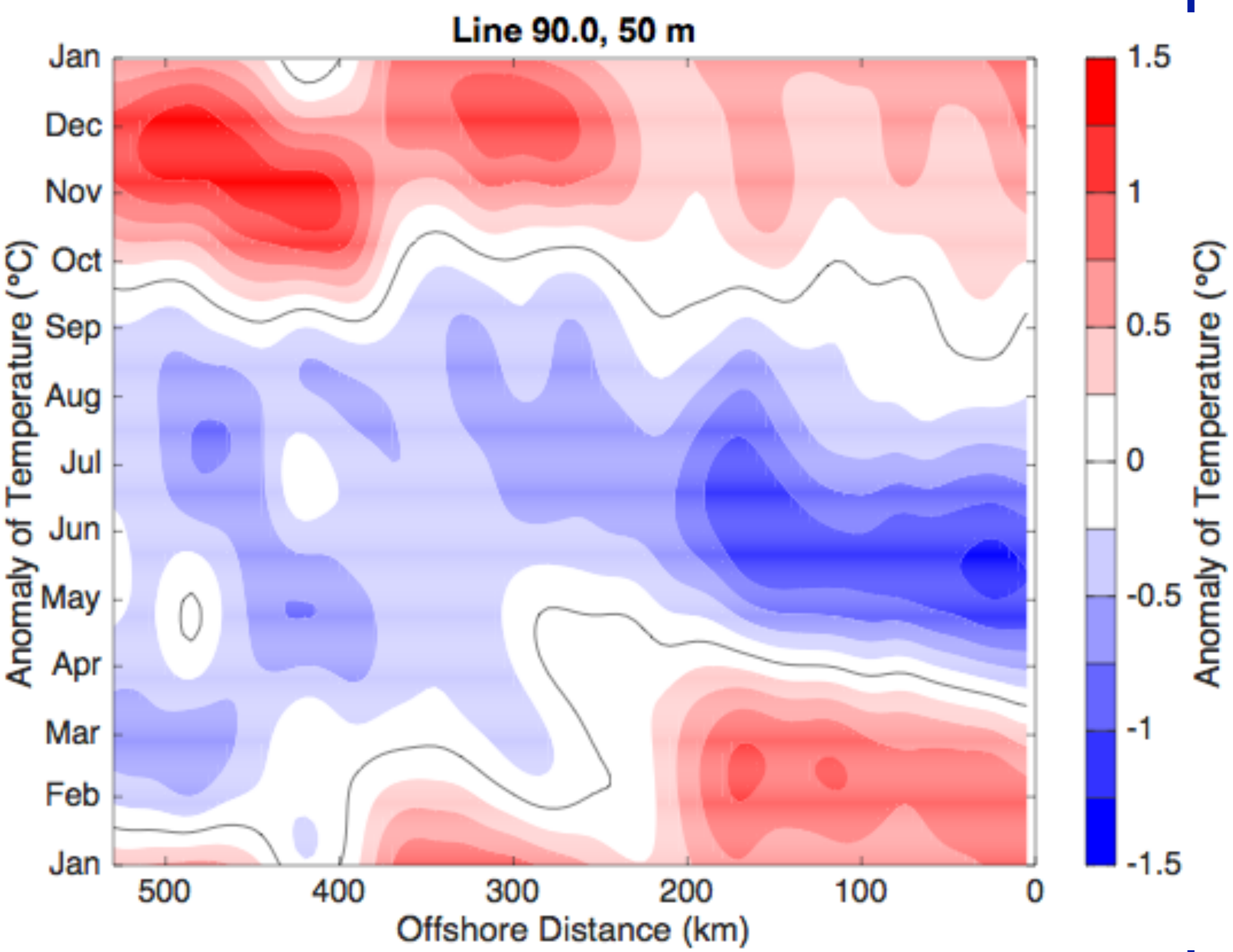




- Poleward undercurrent
- Equatorward California current
- Undercurrent maximum near 100 m

Annual cycle of temperature on line 90





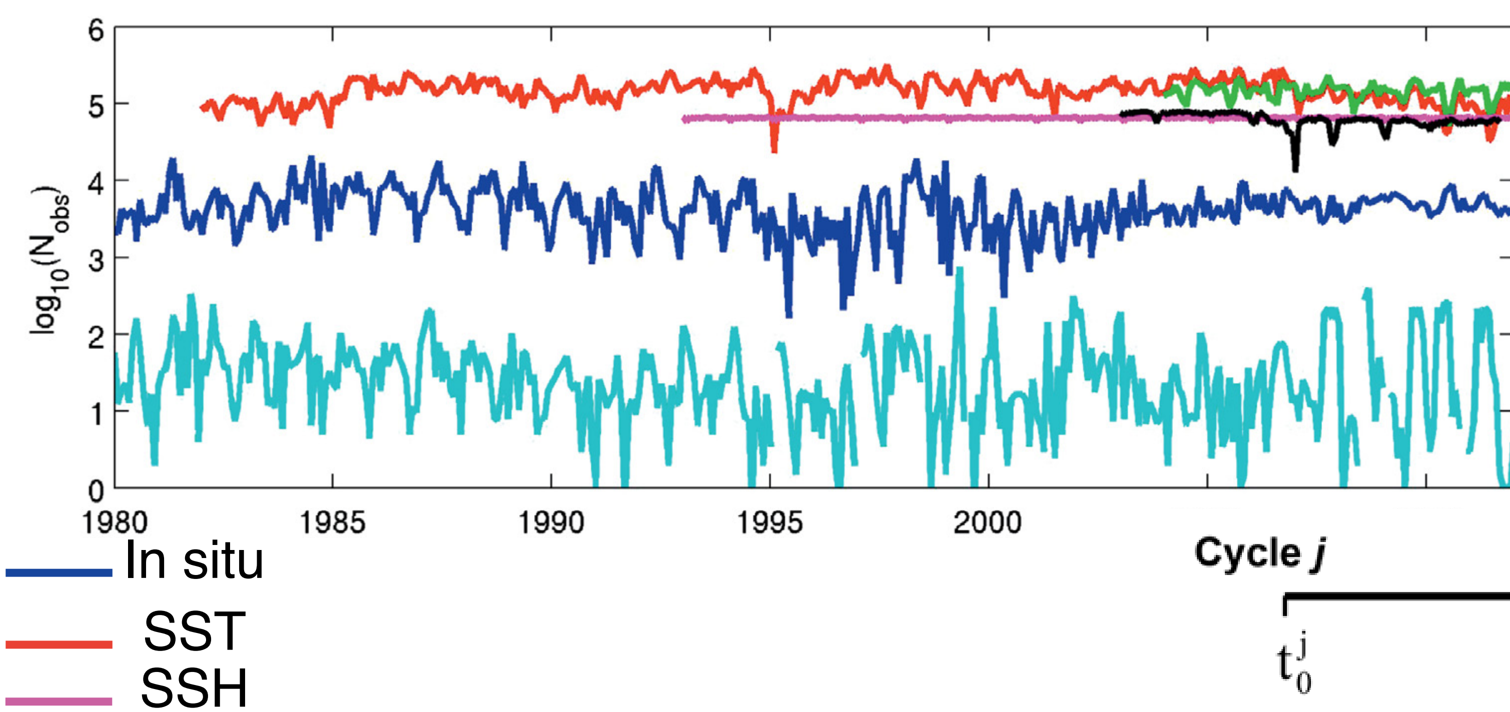
- Surface driven by heat flux from atmosphere
- Thermocline driven by wind stress (curl)

Data Assimilative CCS Reanalyses 1980-2010 (Andy Moore)

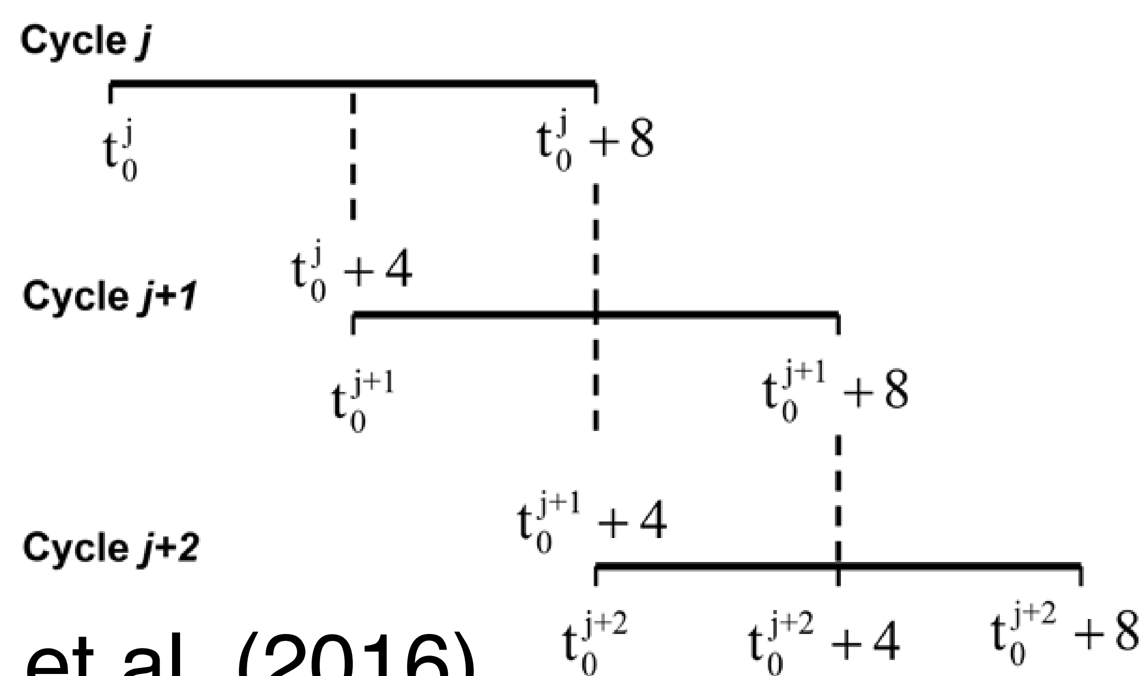
Table 1
A summary of the observation types, observing platforms, data sources, the nominal measurement errors, and the period covered.

Observation Type	Observing platform	Source	Instrument error	Period covered
SSH	Altimeter	Aviso, 1 day average	0.04 m	1993–2012
SST	AVHRR/ Pathfinder	NOAA Coast watch	0.6 °C	1981–2012
SST	AMSR-E	NOAA Coast watch	0.7 °C	2002–2010
SST	MODIS-Terra	NASA JPL	0.3 °C	2000–2012
Hydrographic data	Various	UK Met Office	0.5 °C for T 0.1 for S	1950–2012

- **ROMS 4D-Var (PSAS)**
- **SODA BCs**
- **Controls: IC, BCs, Forcing**



- **8-day assimilation cycles**
- **4-day overlap**
- **1 outer, 15 inner loops**



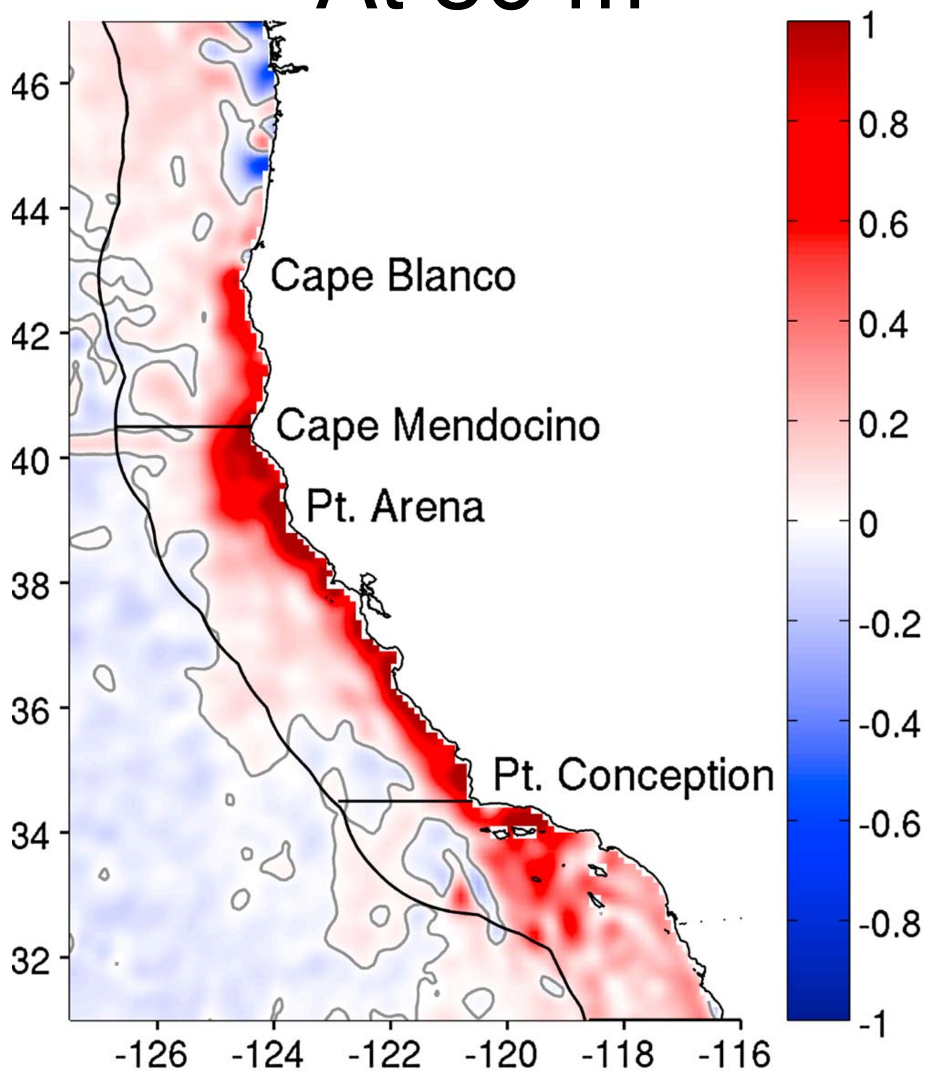
CCSRA31 Forcing:

ERA40, ERA-Interim, CCMP (25 km)

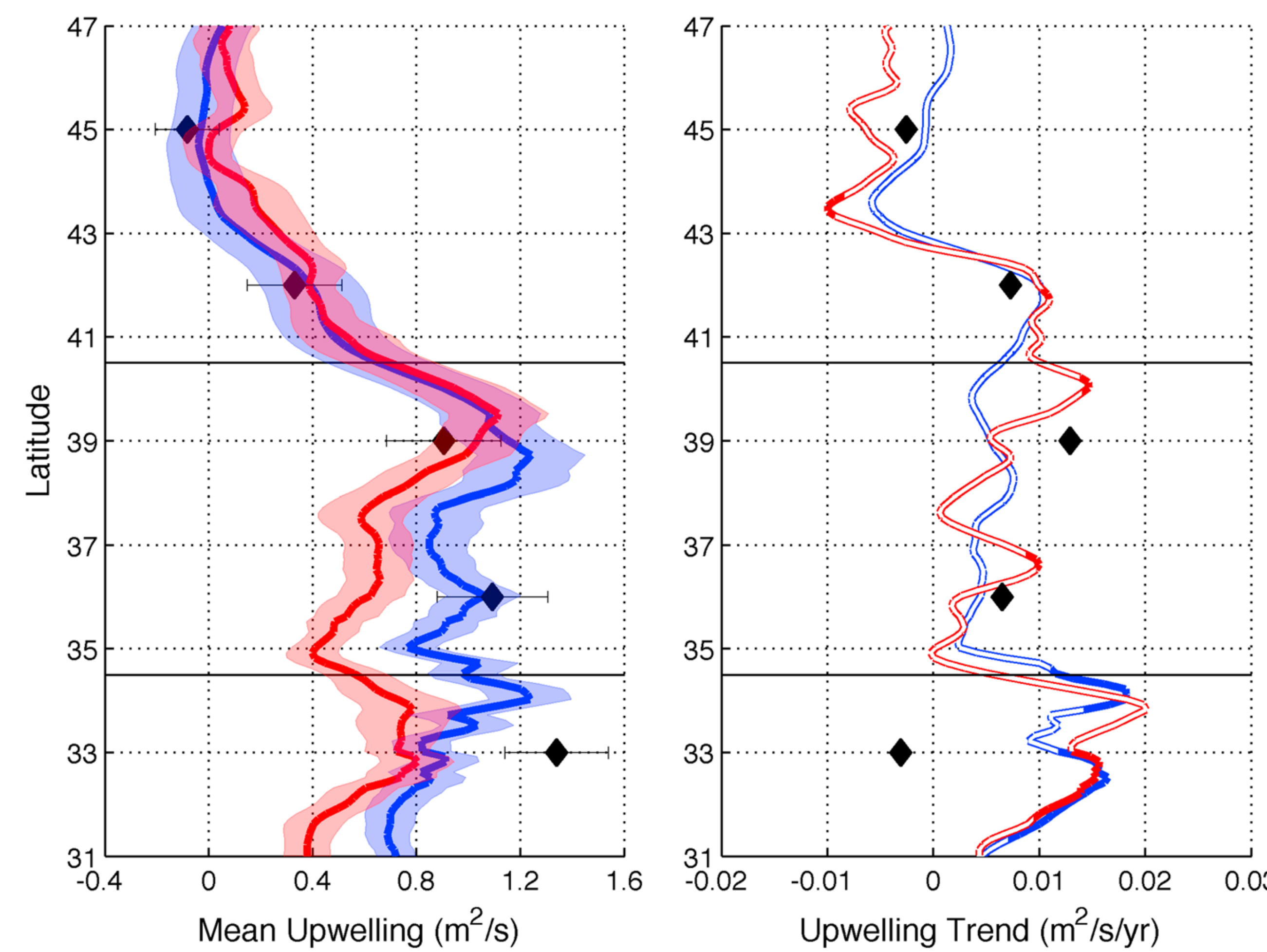
Moore et al. (2013), Neveu et al. (2016)

Model vs. wind-estimated upwelling

Mean upwelling velocity At 50 m



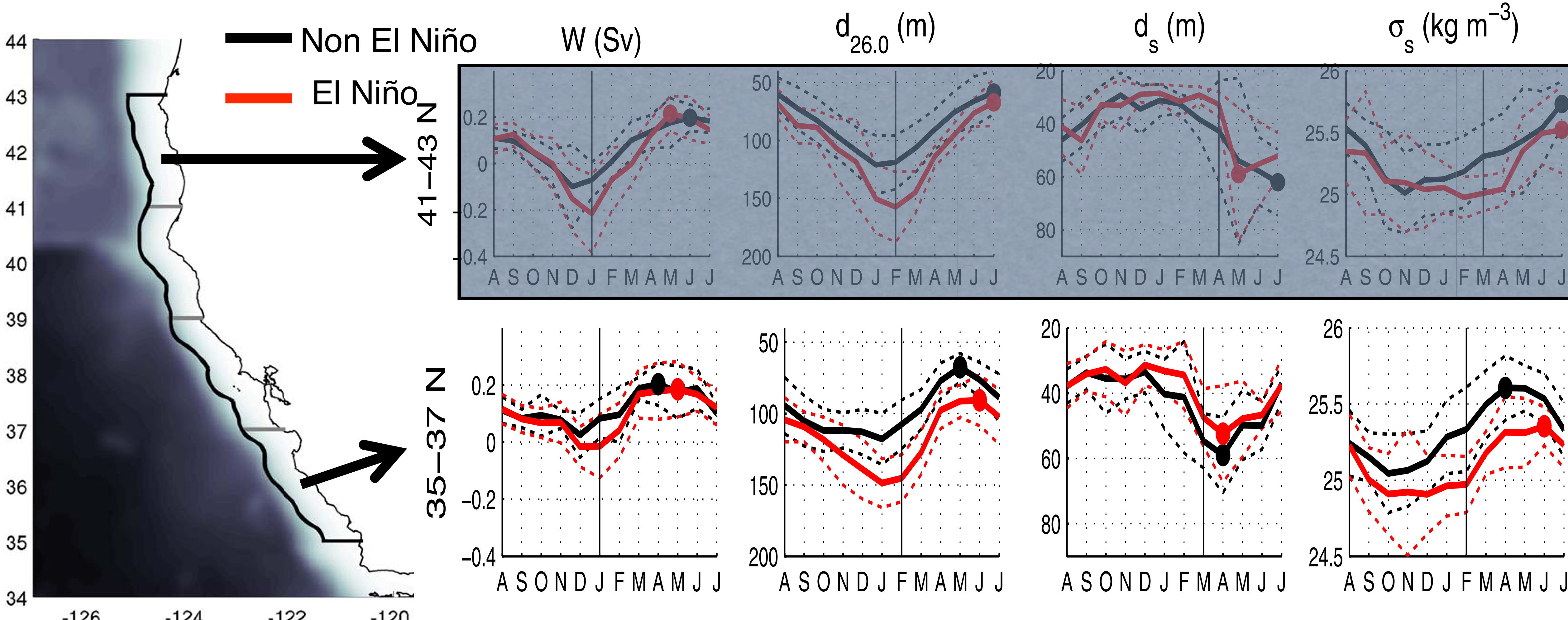
Upwelling



Jacox et al. (2014)

What does the CCS look like during El Niño?

- Coastal averages (2 degree meridionally and 50 km from shore)
- W: Vertical transport across 40 m depth
- $d_{26.0}$: depth of the 26.0 kg m^{-3} isopycnal
- d_s: a measure of depth of upwelled source water 30 days prior
- σ_s: a measure of density of source water 30 days prior

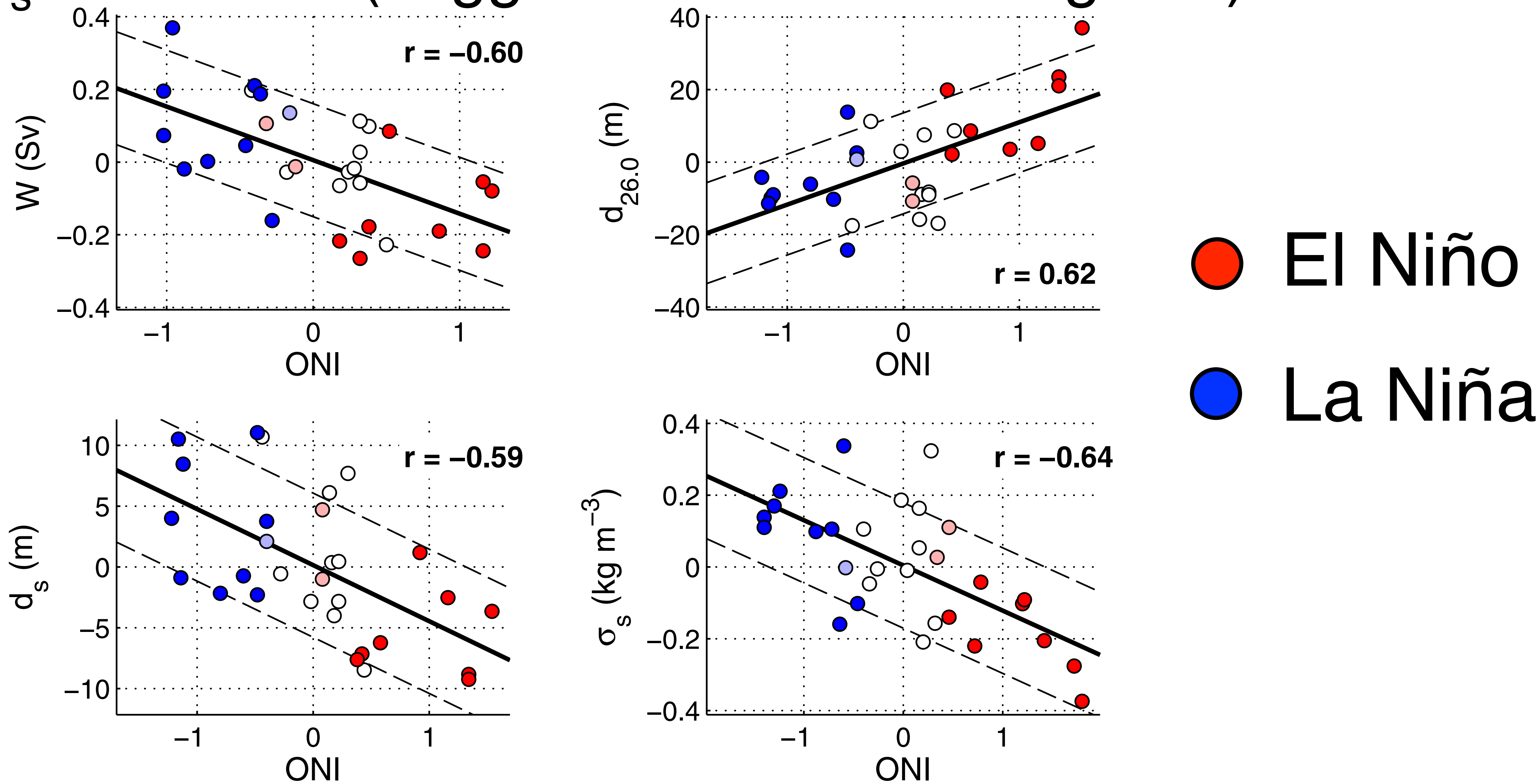


Jacox et al. (2015)

Interannual variability

Significant lagged correlations of anomalies with ONI

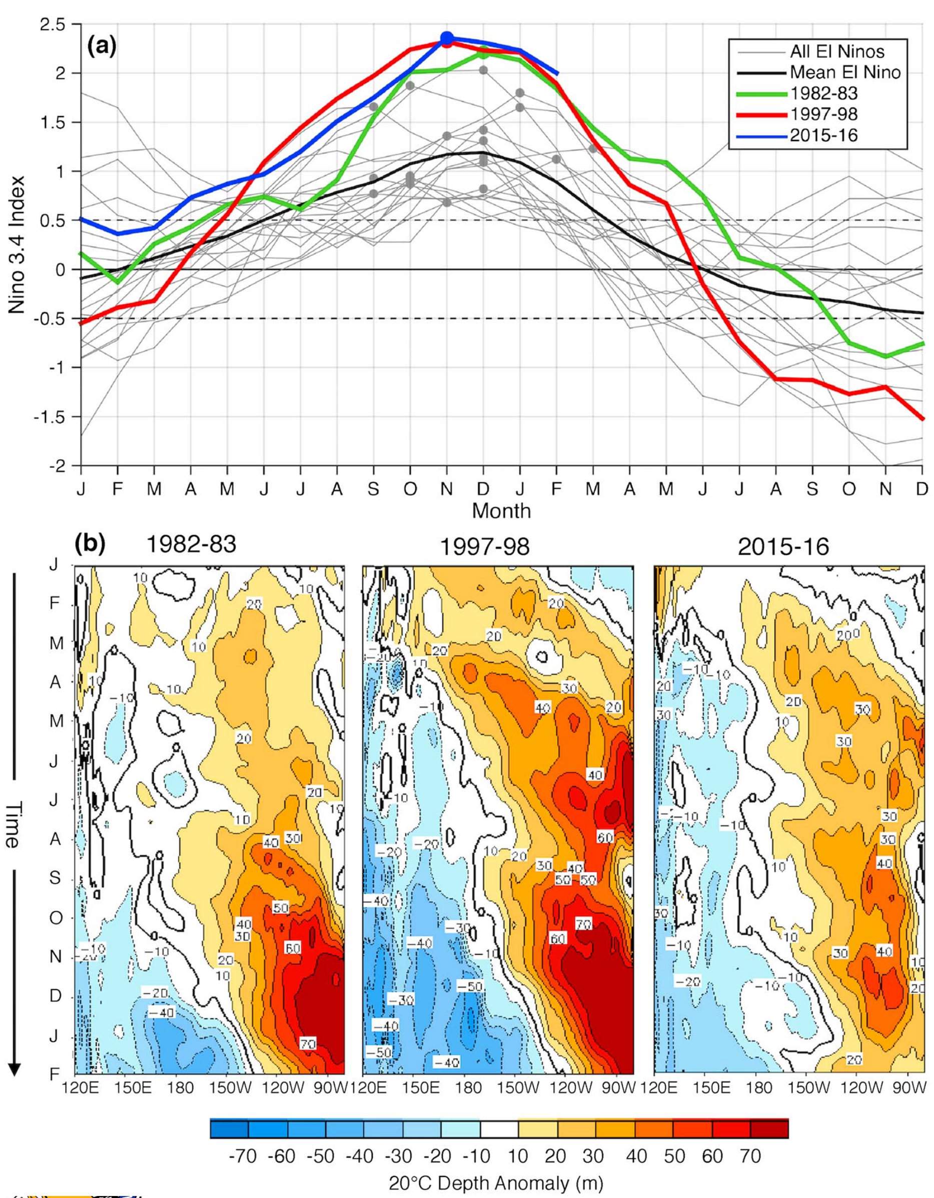
- W: 1 months (suggests atmospheric teleconnections)
- d_s: 2 months (suggests indirect atmospheric teleconnections)
- $d_{26.0}$: 2 months (suggests indirect atmospheric teleconnections)
- σ_s: 3 months (suggests oceanic waveguide)



Jacox et al. (2015)

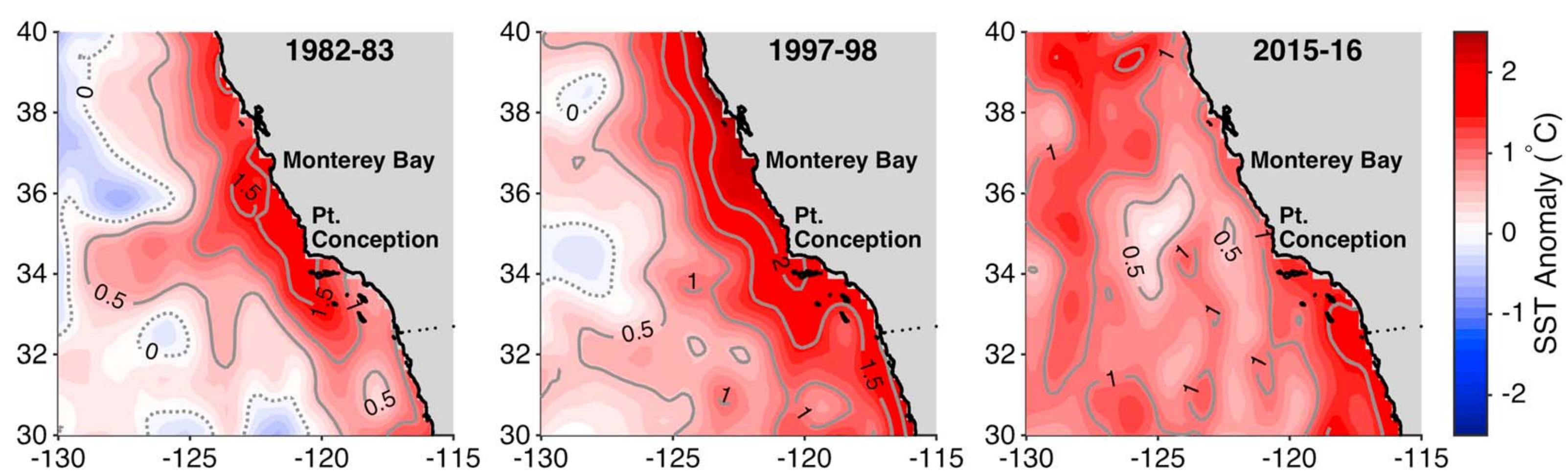
The 2015-16 El Niño

Tropical Pacific
Niño 3.4 and $d_{20.0}$



- Among strongest events by tropical Pacific surface indices
- Subsurface signature much weaker
- Local CCS surface signature much weaker

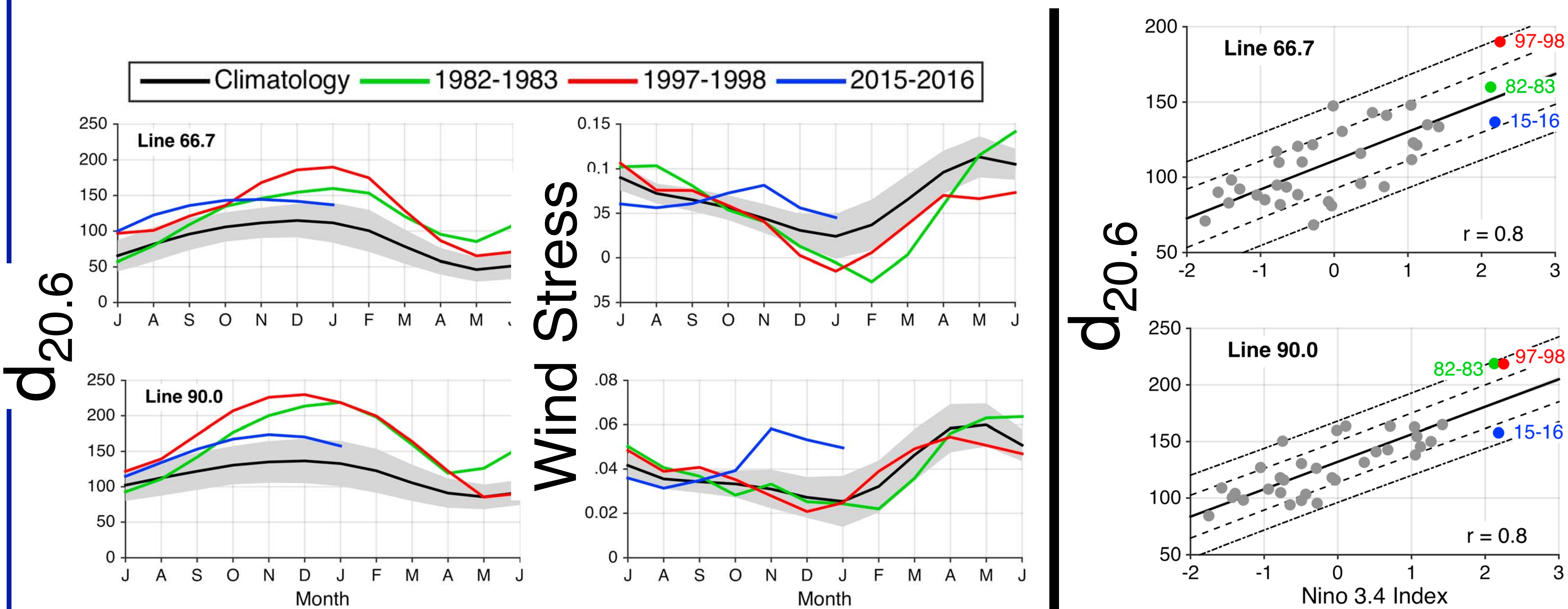
CCS SST anomalies
(NOAA OISST)



Jacox et al. (2016)

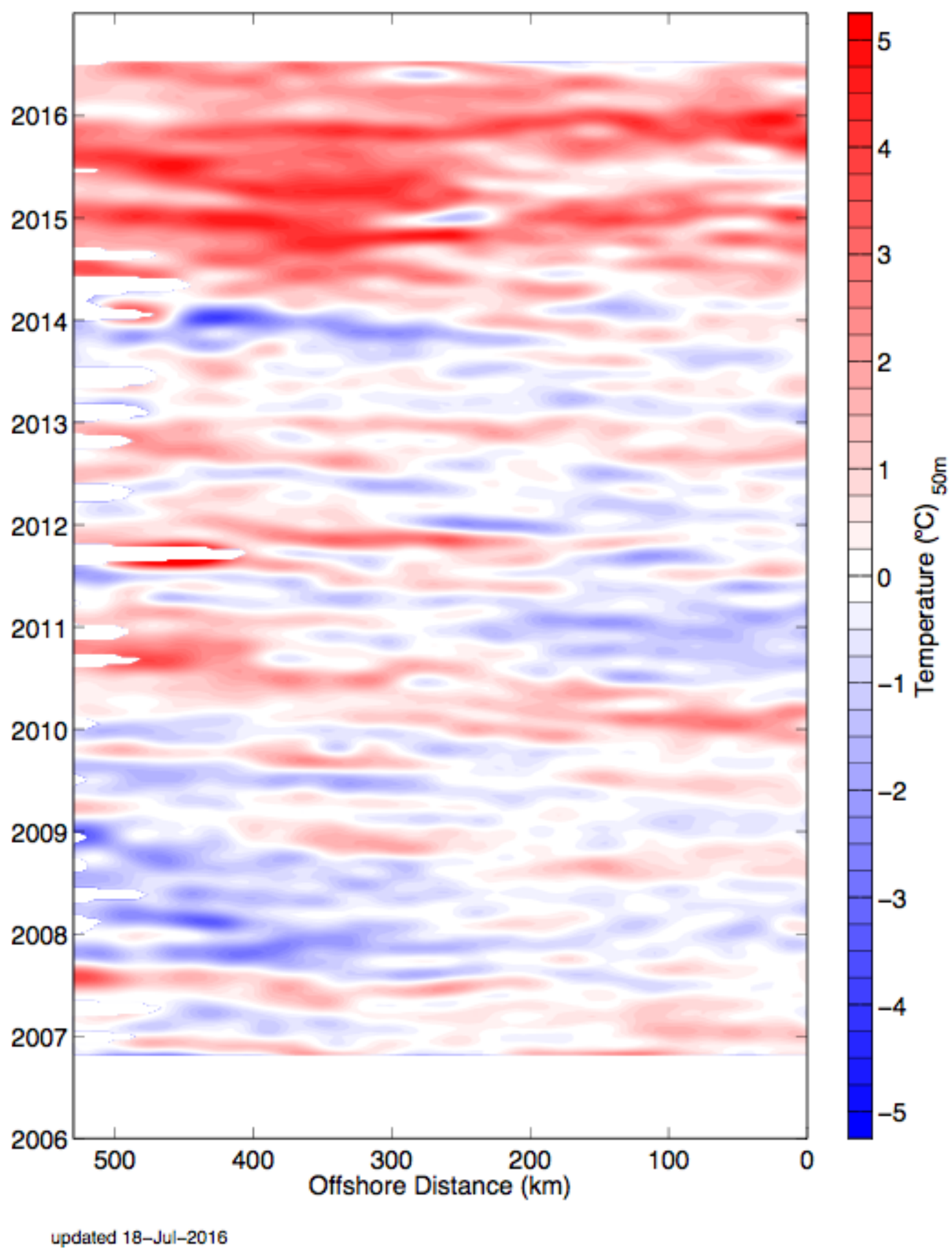
2015-2016 El Niño showed weak CCS response

(from combined glider data/model reanalysis)

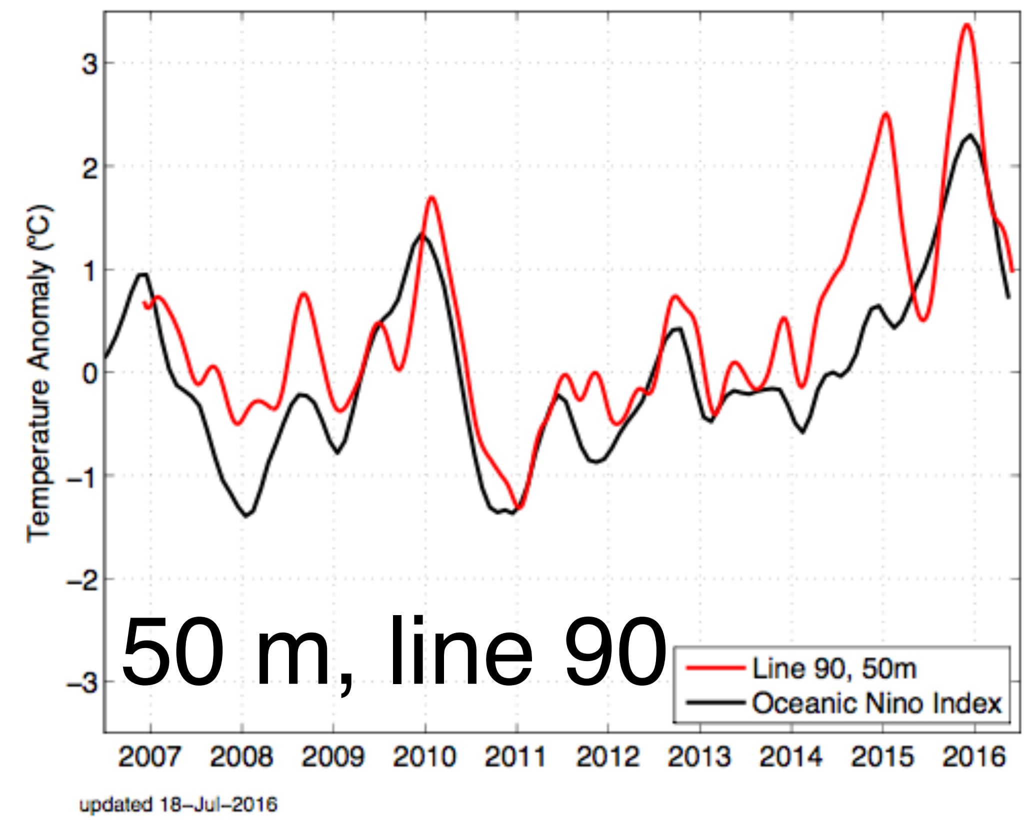


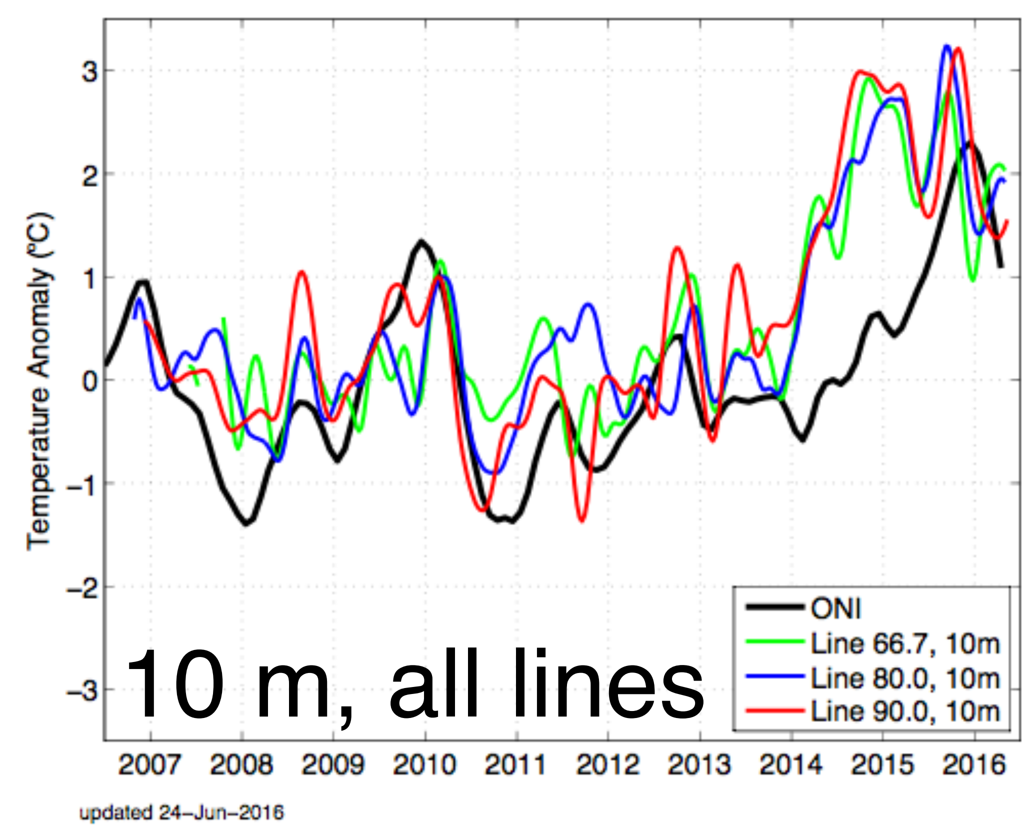
Jacox et al. (2016)

Temperature anomalies



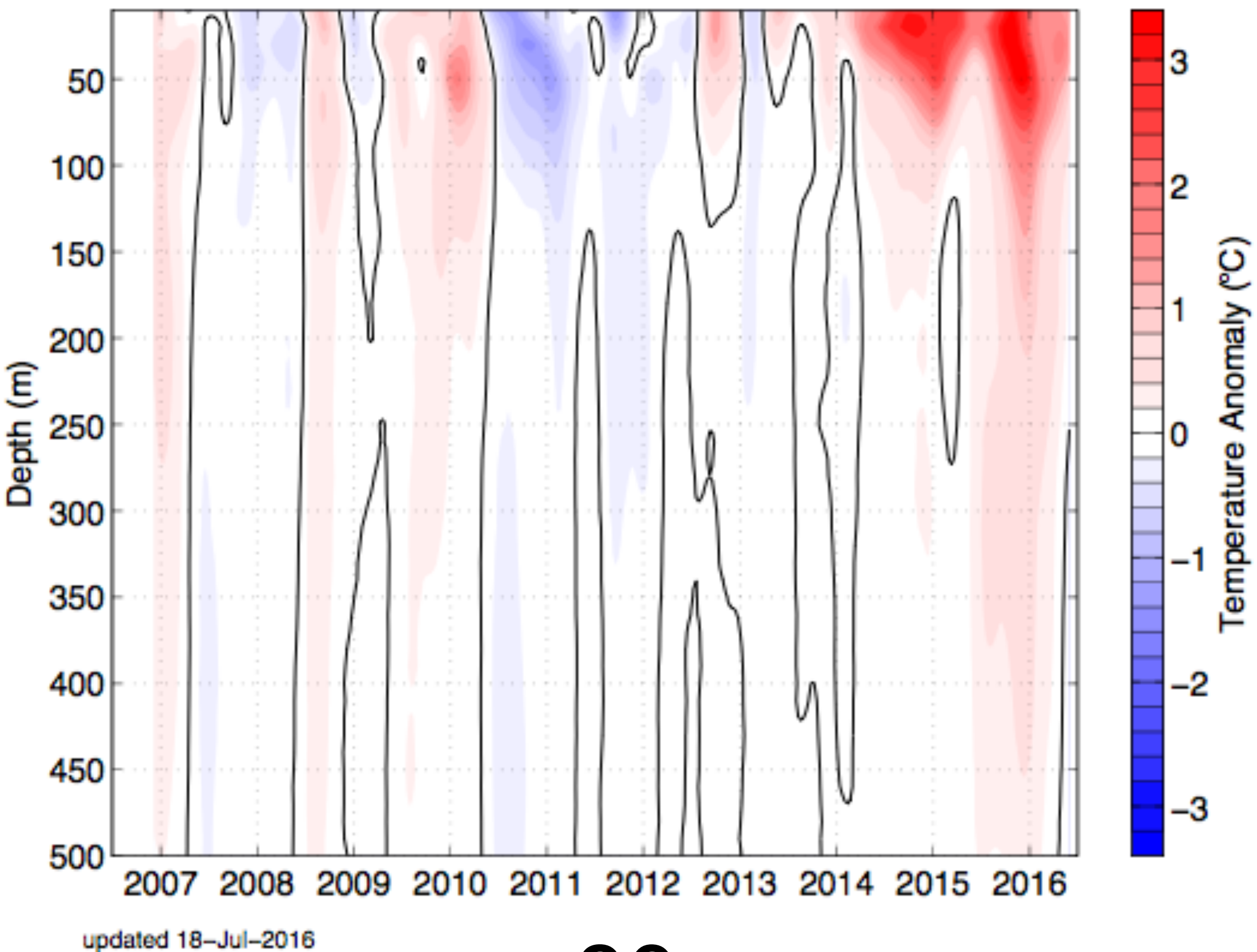
50 m, line 90



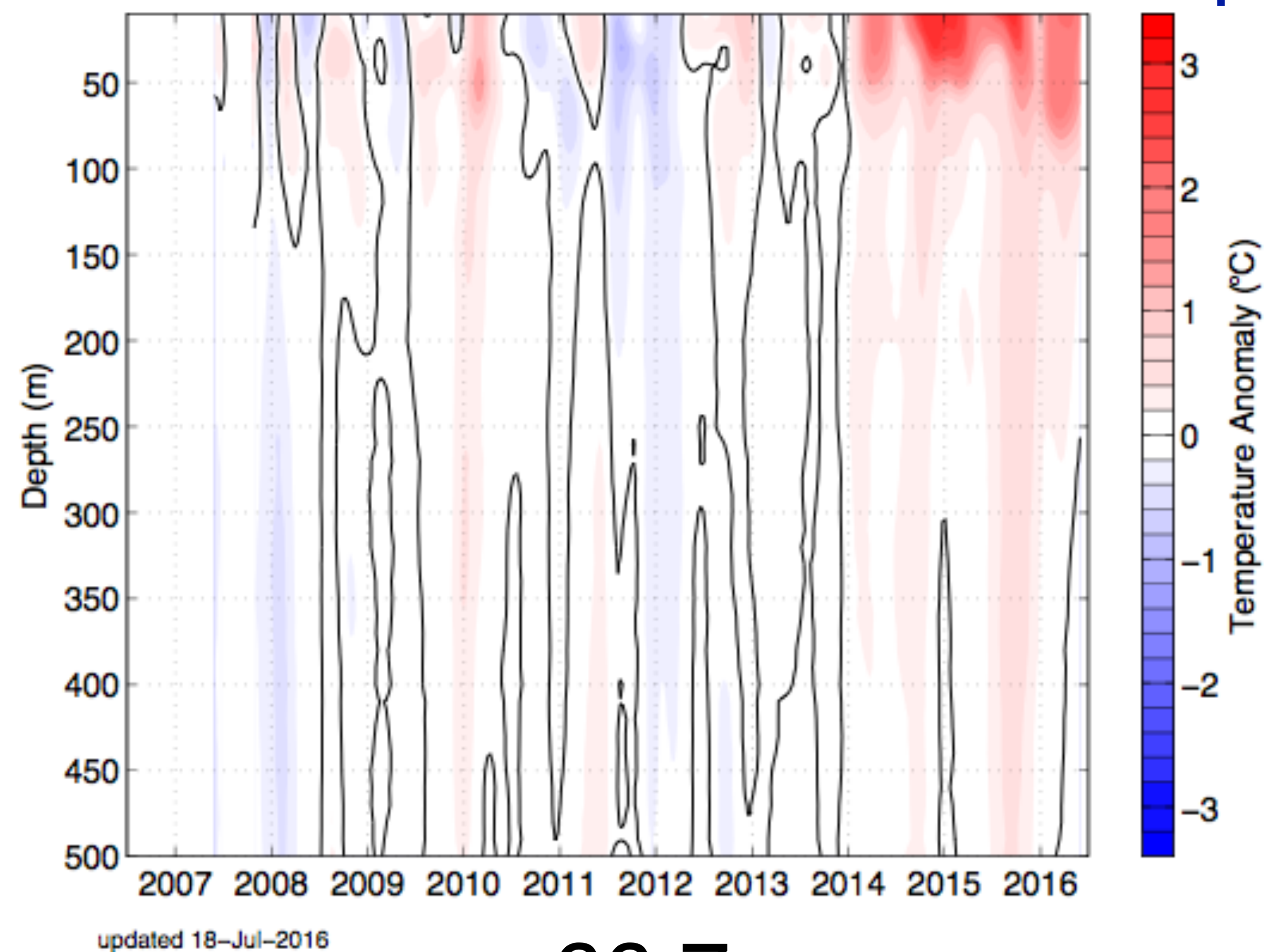


See Zaba and Rudnick (2016)

Temperature anomalies vs. time, depth



90

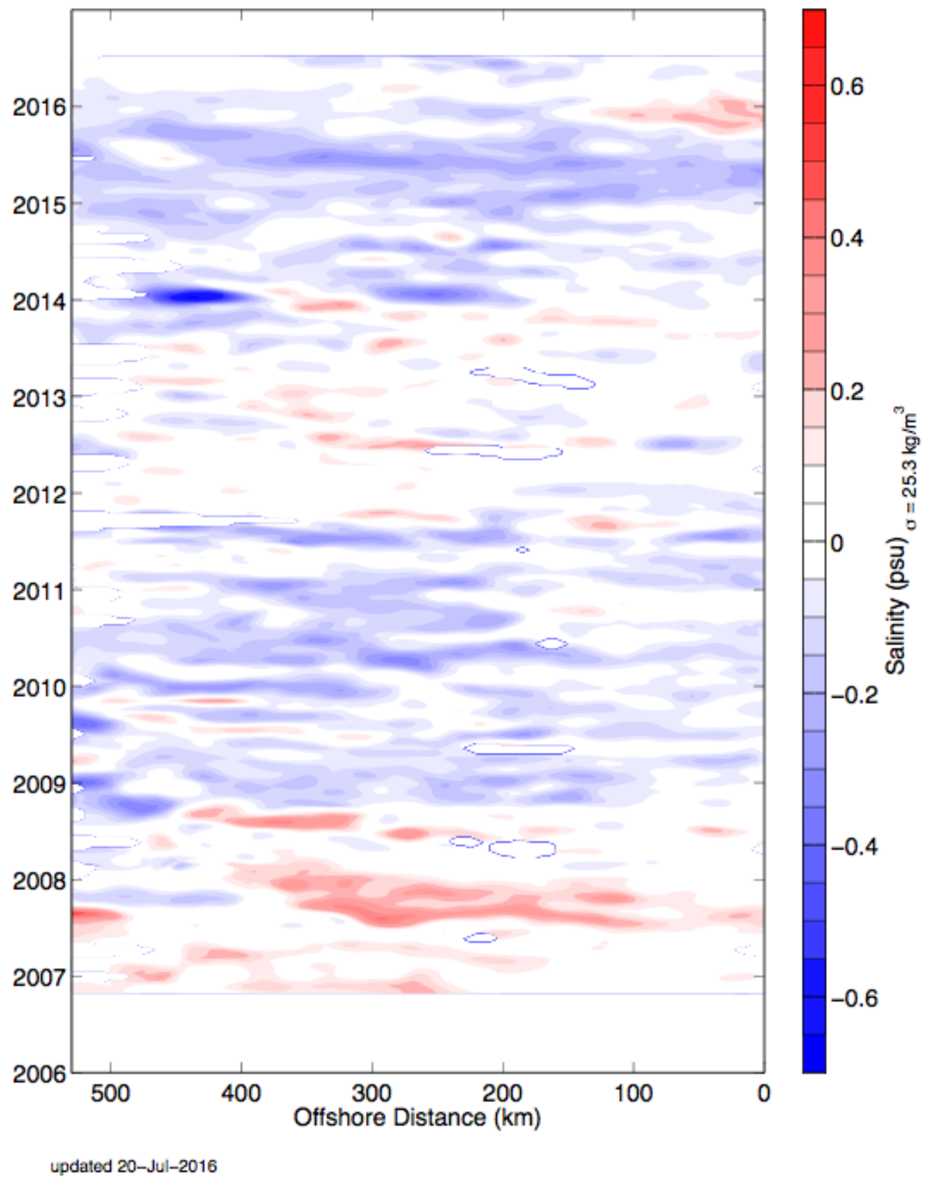


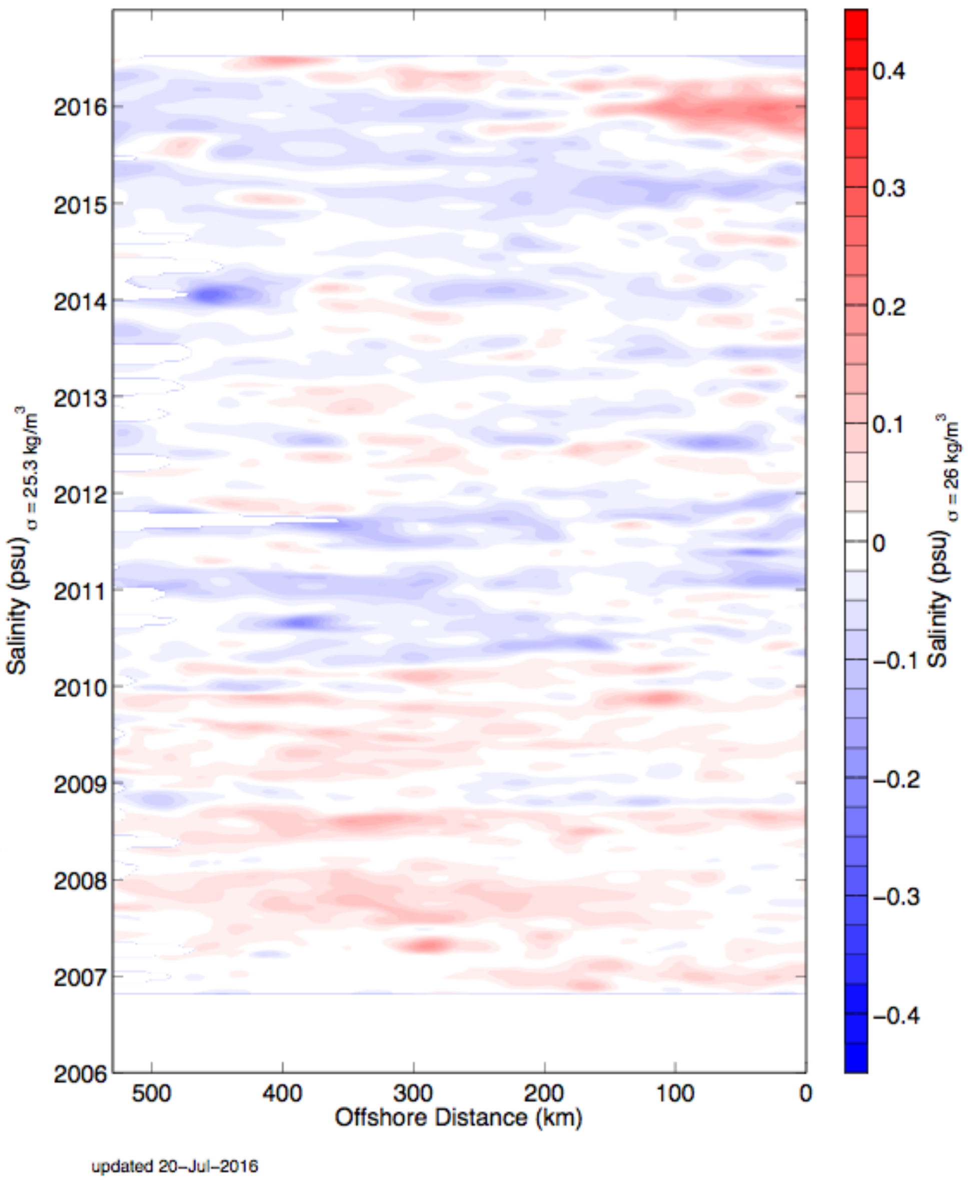
66.7

- Inshore 200 km
- Line 90: 2009-10 El Niño
- 2014-15 anomalies near surface
- 2015-16 anomalies penetrate deeply, especially on 90

Isopycnal salinity anomalies on line 90 (evidence of advection)

25.3





26.0

- Fresh on 25.3 during 2014-2015
- Salty on 26.0 during 2015-2016

Summary

- CCS has a robust annual hydrographic cycle at both surface and thermocline depths.
  - Driven by local surface fluxes.
- CCS interannual variability is strongly linked to tropical Pacific anomalies.
  - Atmospheric teleconnections (weeks).
  - Oceanic waveguide influences (months).
- Predictive skill for local impact of ENSO events based on trpical Pacific indices is significant, but individual responses do vary.
- 2015-2016 event locally much weaker than expected, in part due to pre-warming by 2014-2015 warm blob and in part due to different character of this years El Niño.