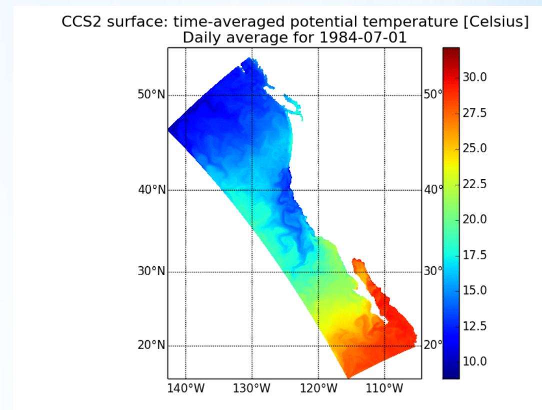
Physical Oceanography of the Abalone System: Observations and Models



Dale Haidvogel (Rutgers University)

RCN Disease Modeling and Transmission Workshop

13 May 2015

Questions

- What are the primary transport pathways within the abalone system?
- What physical mechanisms produce these pathways and their variability?
- Are these mechanisms local or remote?
- How are variations in the tracer fields (e.g., temperature) produced?
- How much variability can we explain with “simple” models?

Answers depend upon …

- Region (e.g., Southern California Bight vs Central CA)
- Where within region (inner shelf, shelf, slope)
- Year (and time of year)
- Frequency band (tidal, sub-tidal, seasonal, interannual, …)

Forces & Processes

(without equations)

- Changes in circulation: use F=ma (Newton's Law)

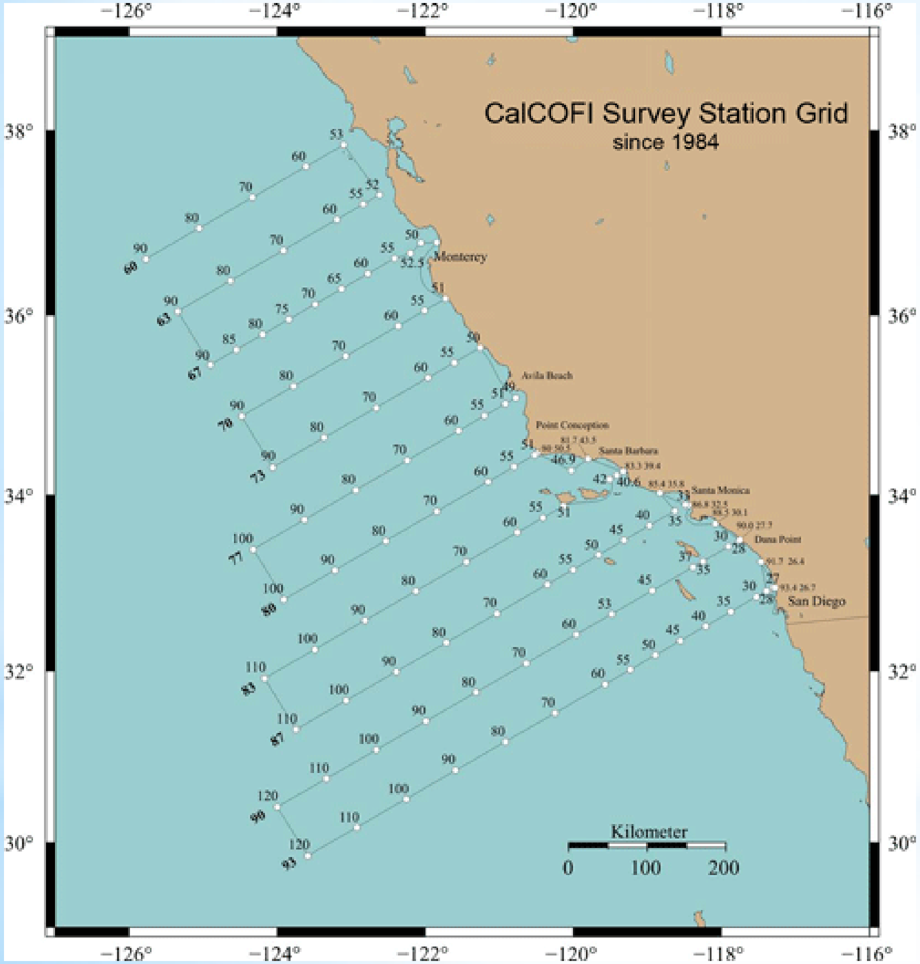
  change in u,v = horizontal transport +
  vertical transport +
  rotation (Coriolis force) +
  pressure gradient +
  wind stress +
  mixing and dissipation

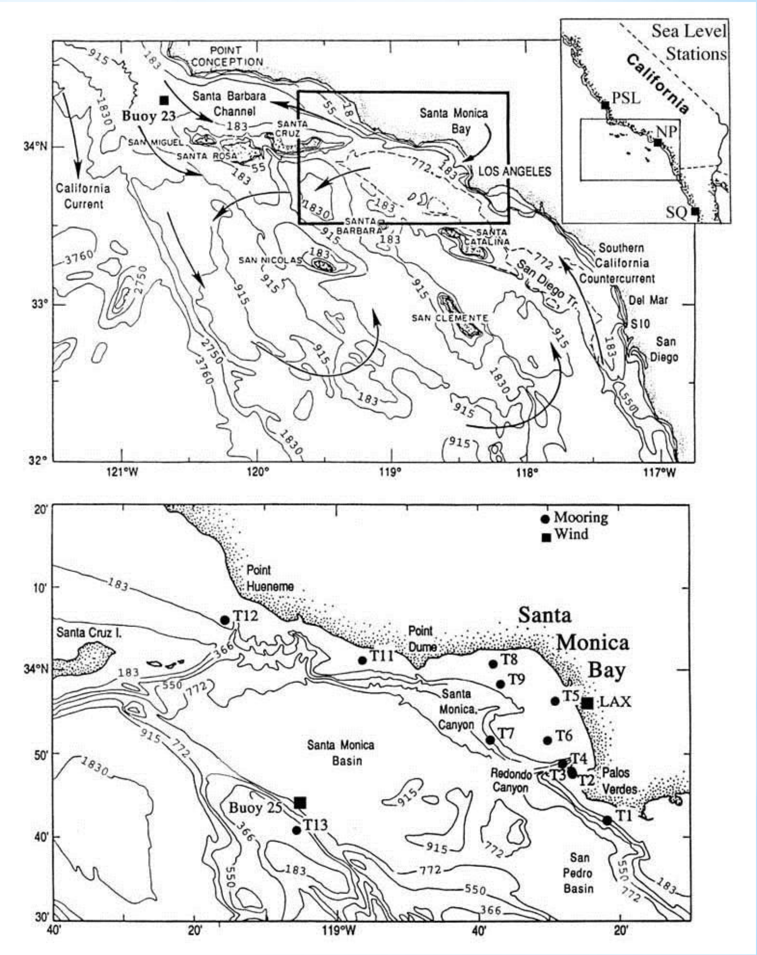
- Changes in temperature: use conservation law

  change in T = horizontal transport +
  vertical transport +
  heating/cooling

Southern California Bight

Observations We Will Use

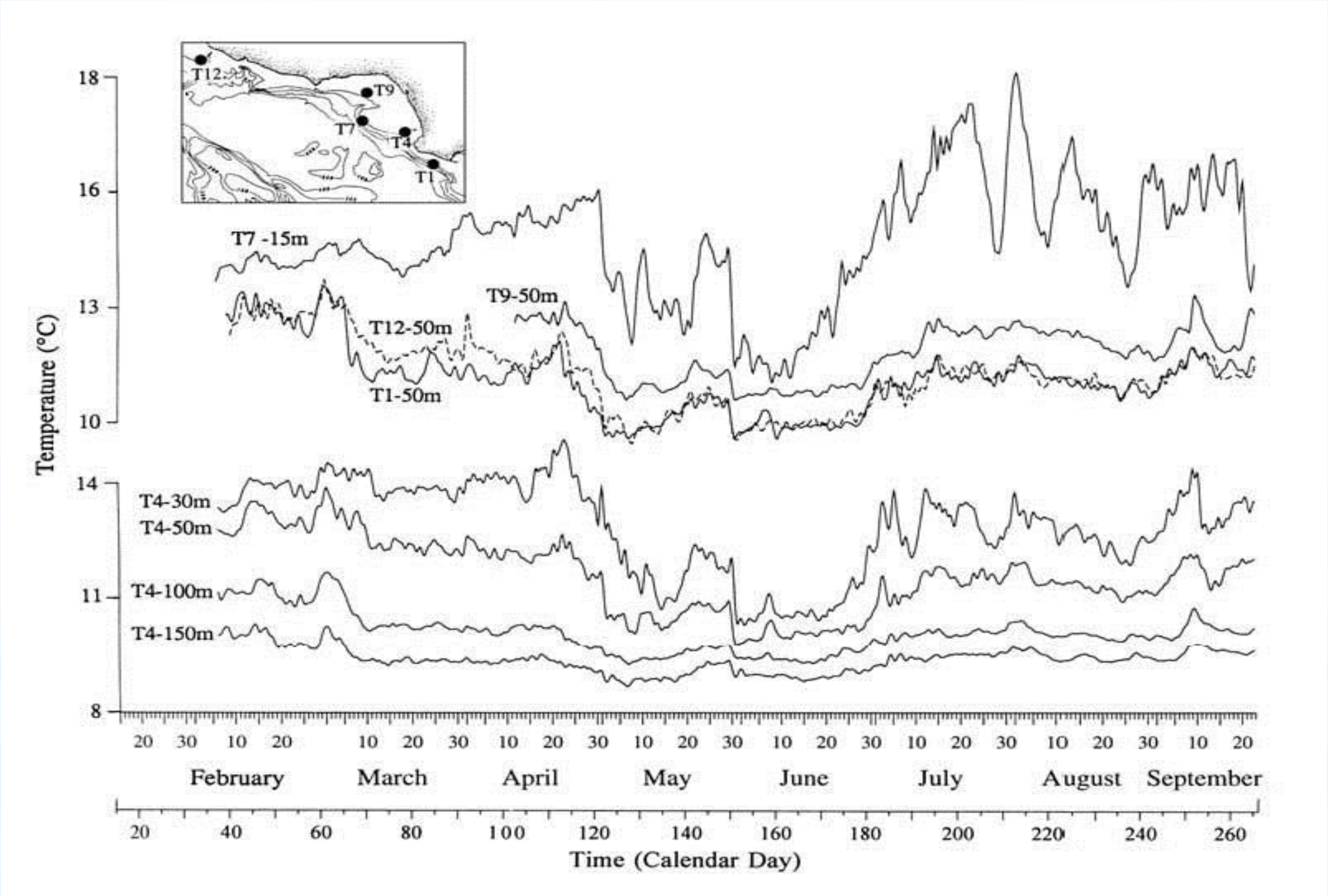




http://www.calcofi.org/

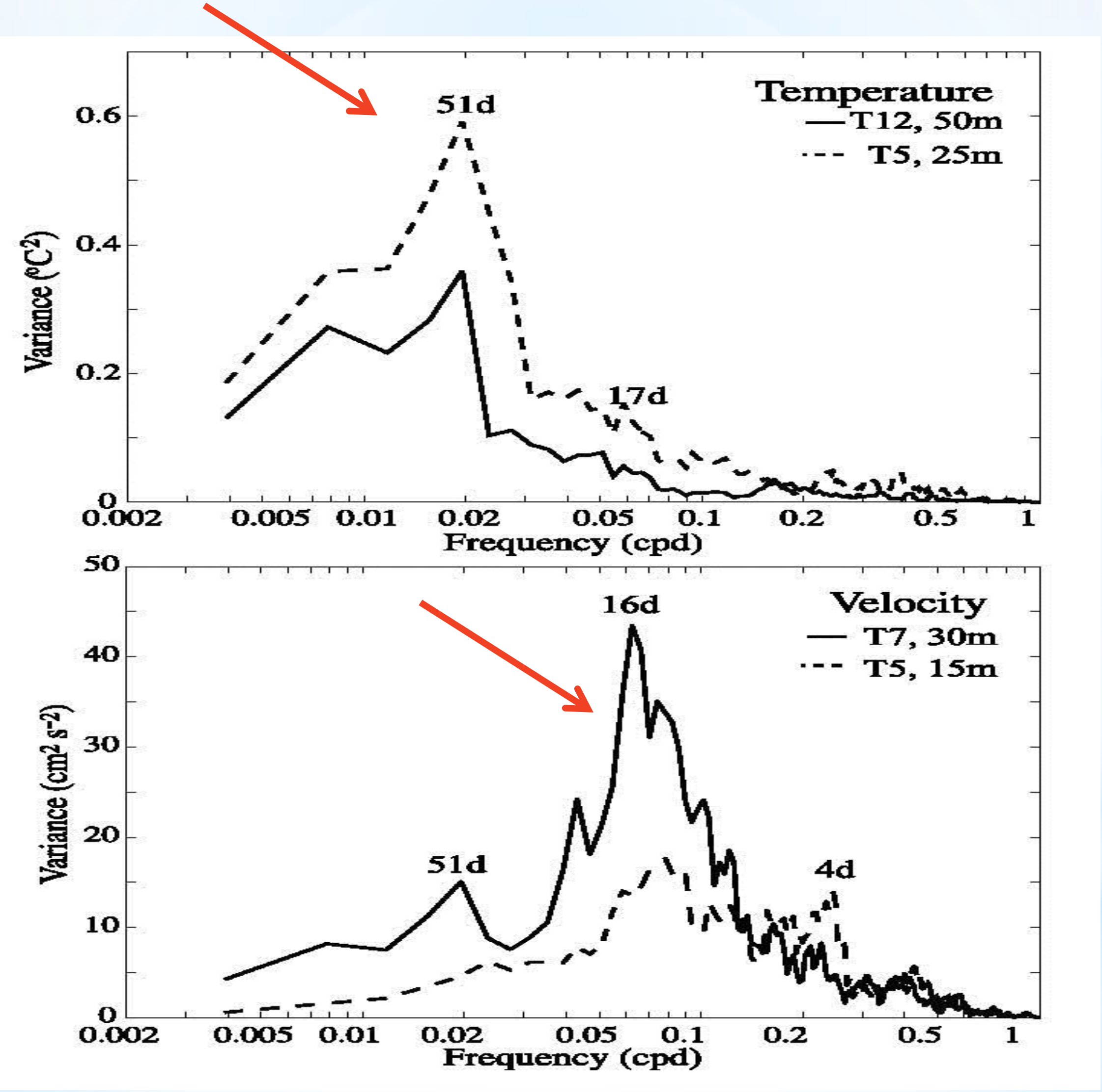
Hickey et al. (2003)

Time series of Temperature (1988)



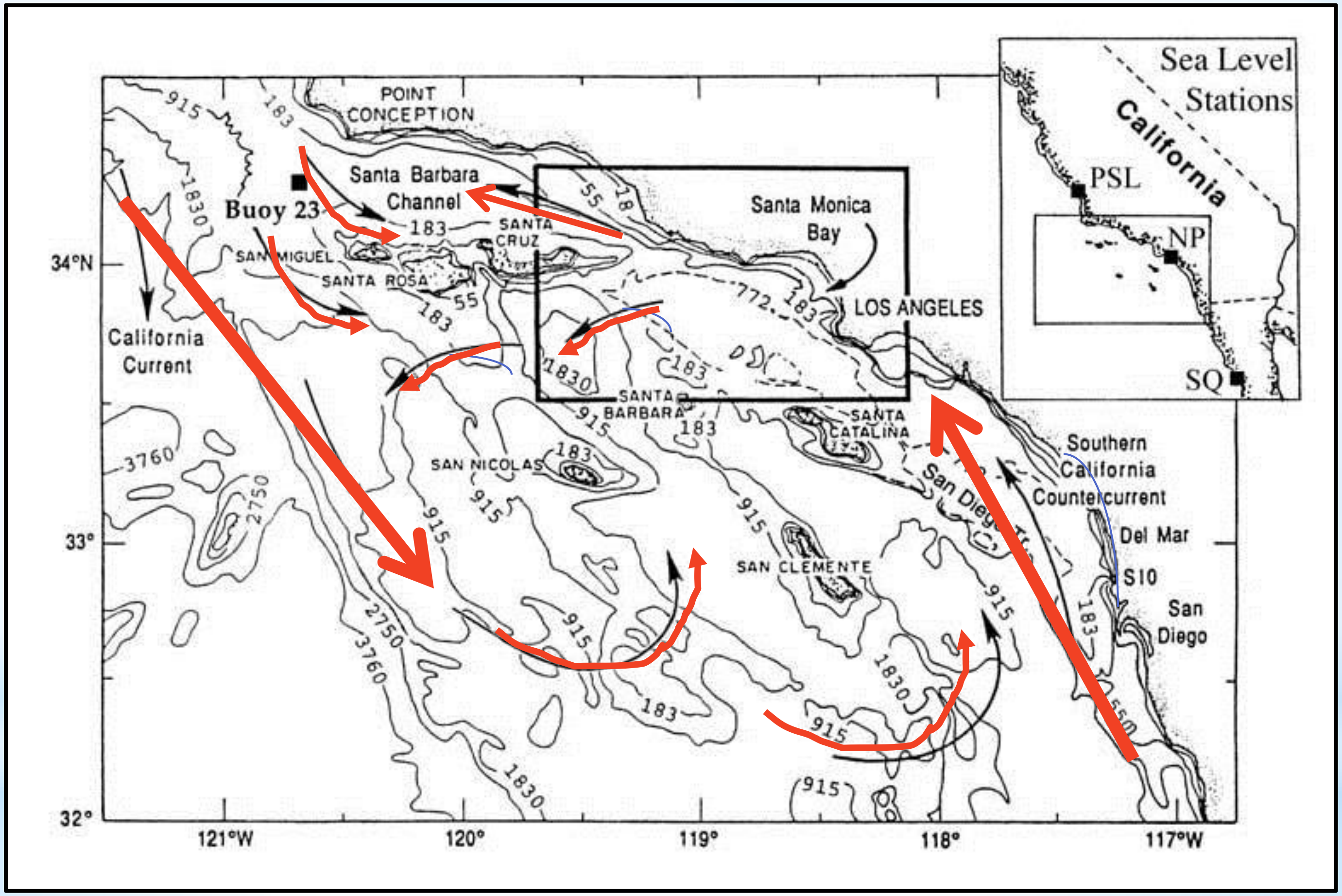
Hickey et al. (2003)

Variance-preserving Frequency Spectra



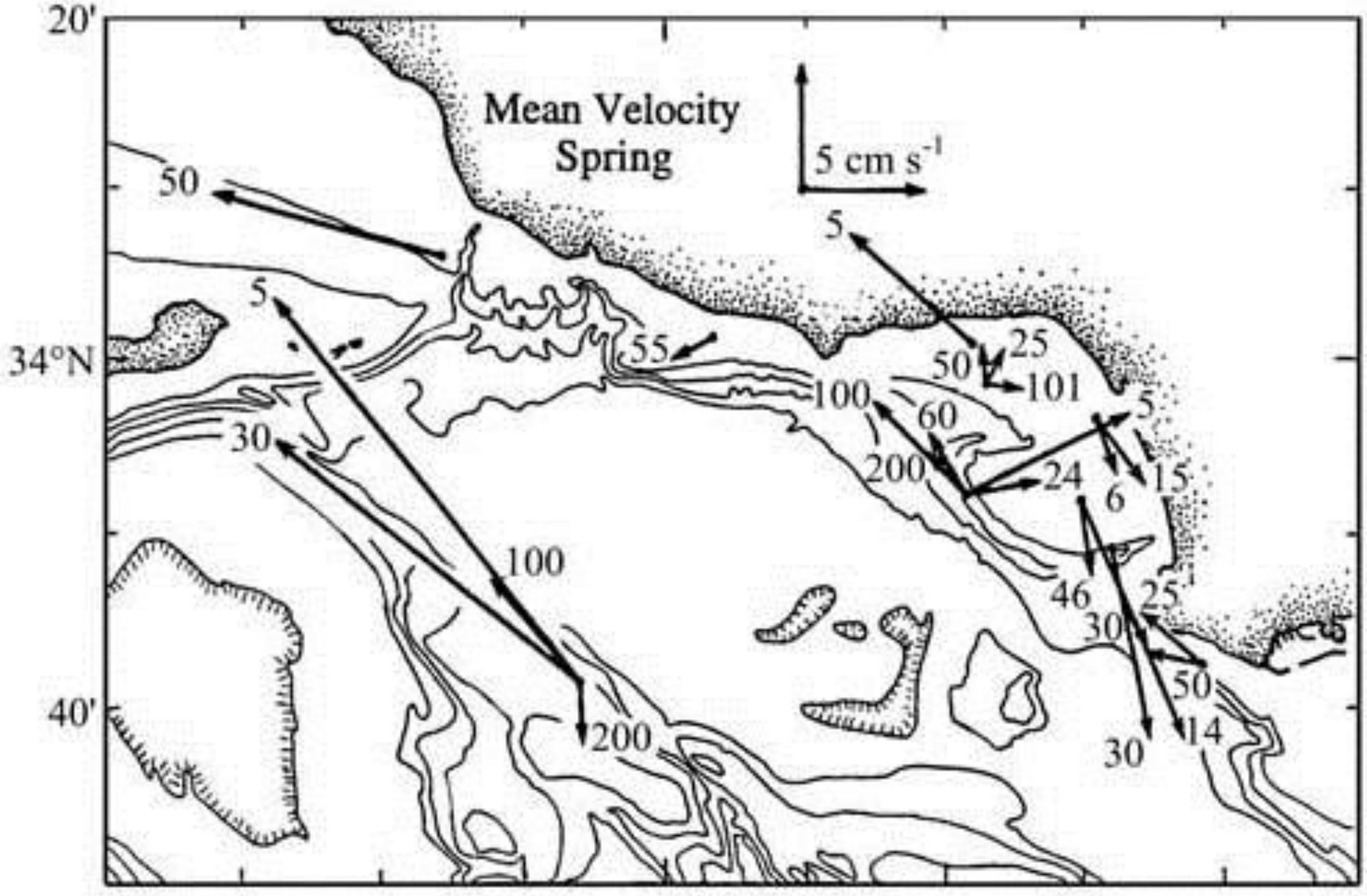
T5: inner SM Bay; T7: upper slope; T12: upper slope, N of Bay; “sub-tidal”

Long-term Time-mean Currents



Hickey et al. (2003)

Inner Southern CA Bight



Hickey et al. (2003)

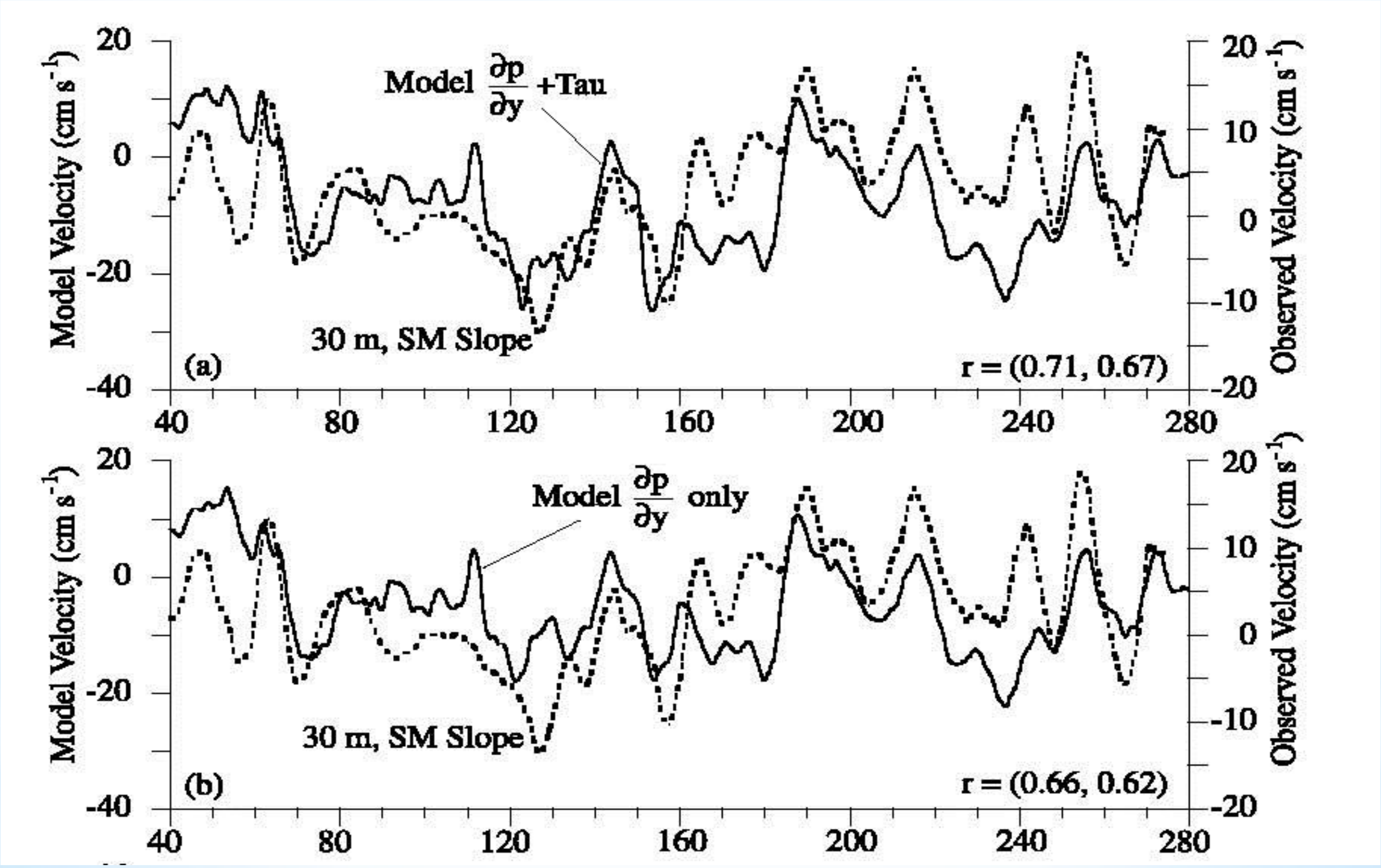
What drives sub-tidal Currents?

- Hypothesis: local wind and along-shore pressure gradient

- Changes in circulation: use F=ma (Newton's Law)

change in u,v = horizontal transport +
vertical transport +
rotation (Coriolis force) +
pressure gradient + ←
wind stress + ←
mixing and dissipation

Observed Variation of Currents vs Linear, Depth-averaged Model



T7: Upper slope, Santa Monica, @ 30 m depth; r = (spring, summer); model + 2 days

What drives sub-tidal Currents?

- Question: OK – local pressure gradient drives the currents. But what drives the pressure gradients?

- Changes in circulation: use F=ma (Newton's Law)

change in u,v = horizontal transport +
vertical transport +
rotation (Coriolis force) + ← Propagation
pressure gradient + ← Local
wind stress + ← Non-local
mixing and dissipation

What Produces Temperature Changes?

❖ Hypothesis: Wind-driven upwelling and along-shore advection of heat control temperature changes

❖ Changes in temperature: use conservation law

change in T = horizontal transport + ← Along-shore advection
vertical transport + ← Upwelling†
heating/cooling

†Coastal upwelling of cold water occurs when along-shore winds cause surface flow away from the coast. Simple Ekman dynamics dictate that net surface flow should be directed 90° to the right of the wind stress in the Northern Hemisphere. Thus, coastal upwelling along the US West Coast is expected for winds to the south.

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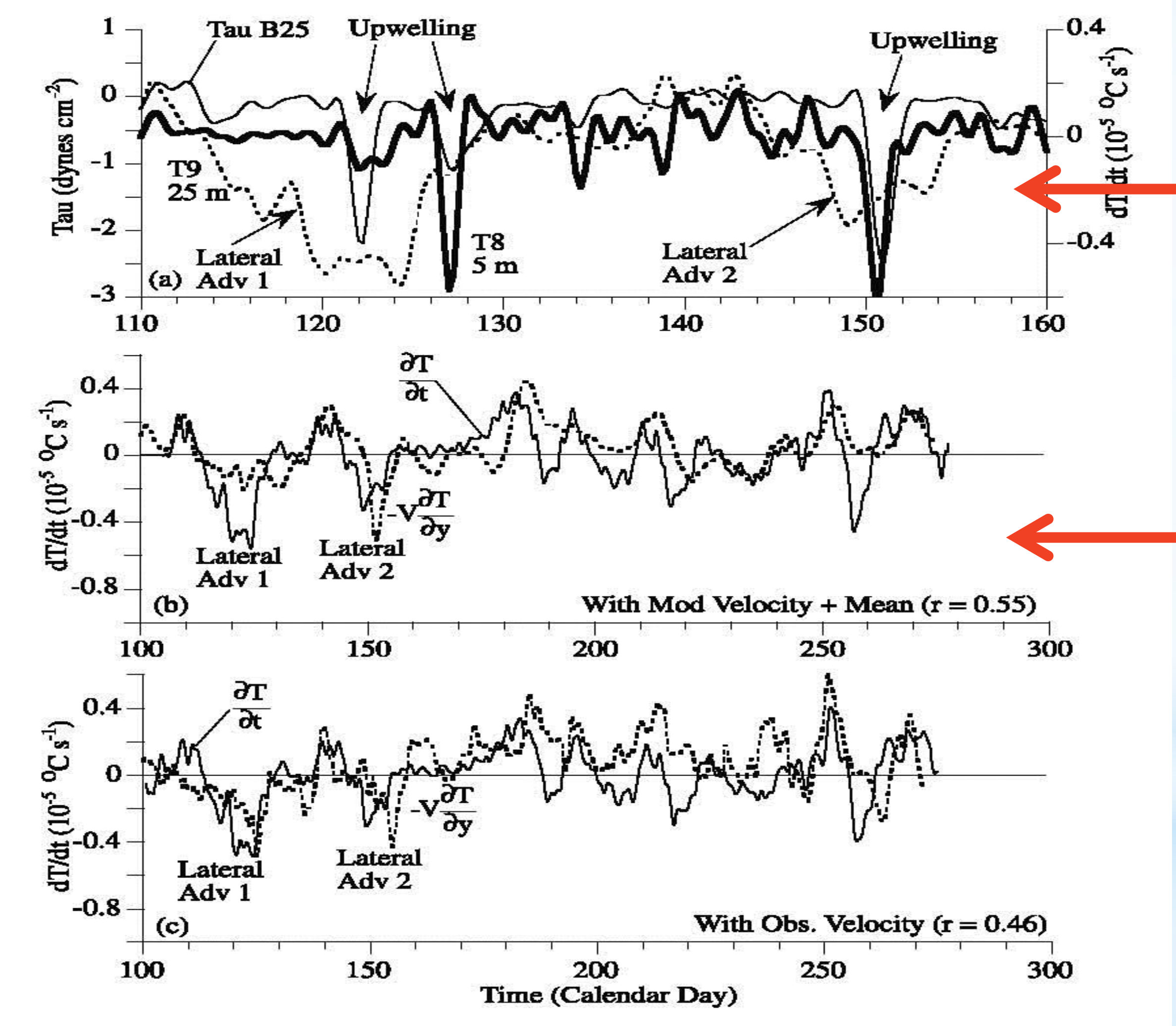
Temperature Variations

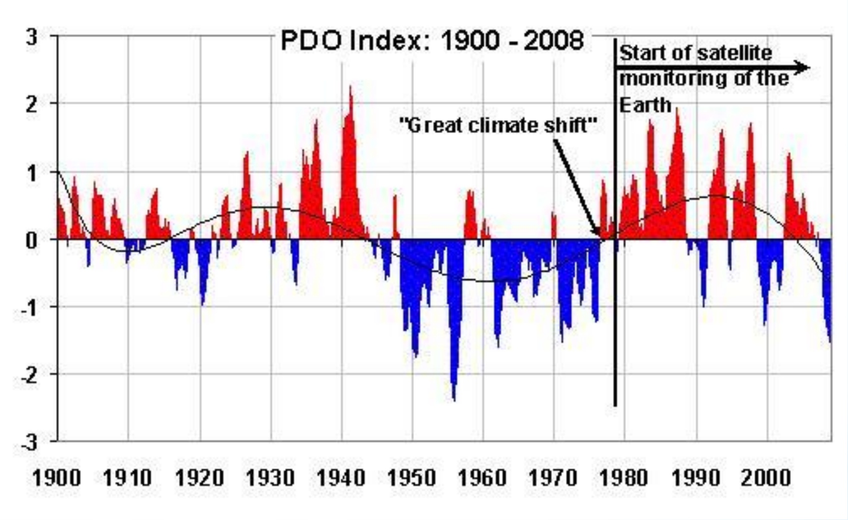


Inner shelf (< 5 km)

Outer shelf

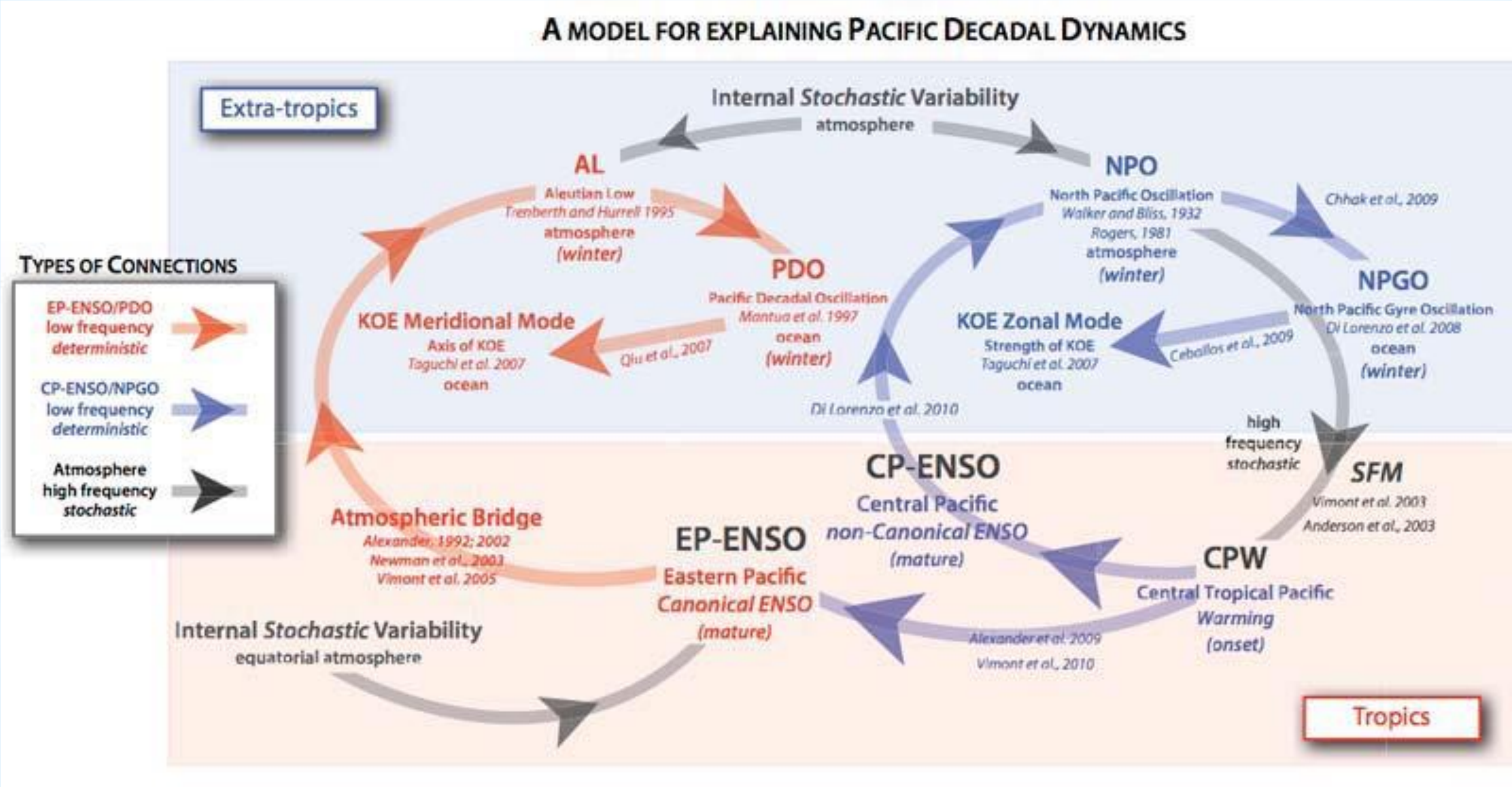
Basin-scale Climate Influences

- The Pacific Decadal Oscillation: the leading empirical orthogonal function (EOF) of monthly sea surface temperature anomalies over the North Pacific (poleward of 20° N) after the global mean SST has been removed.

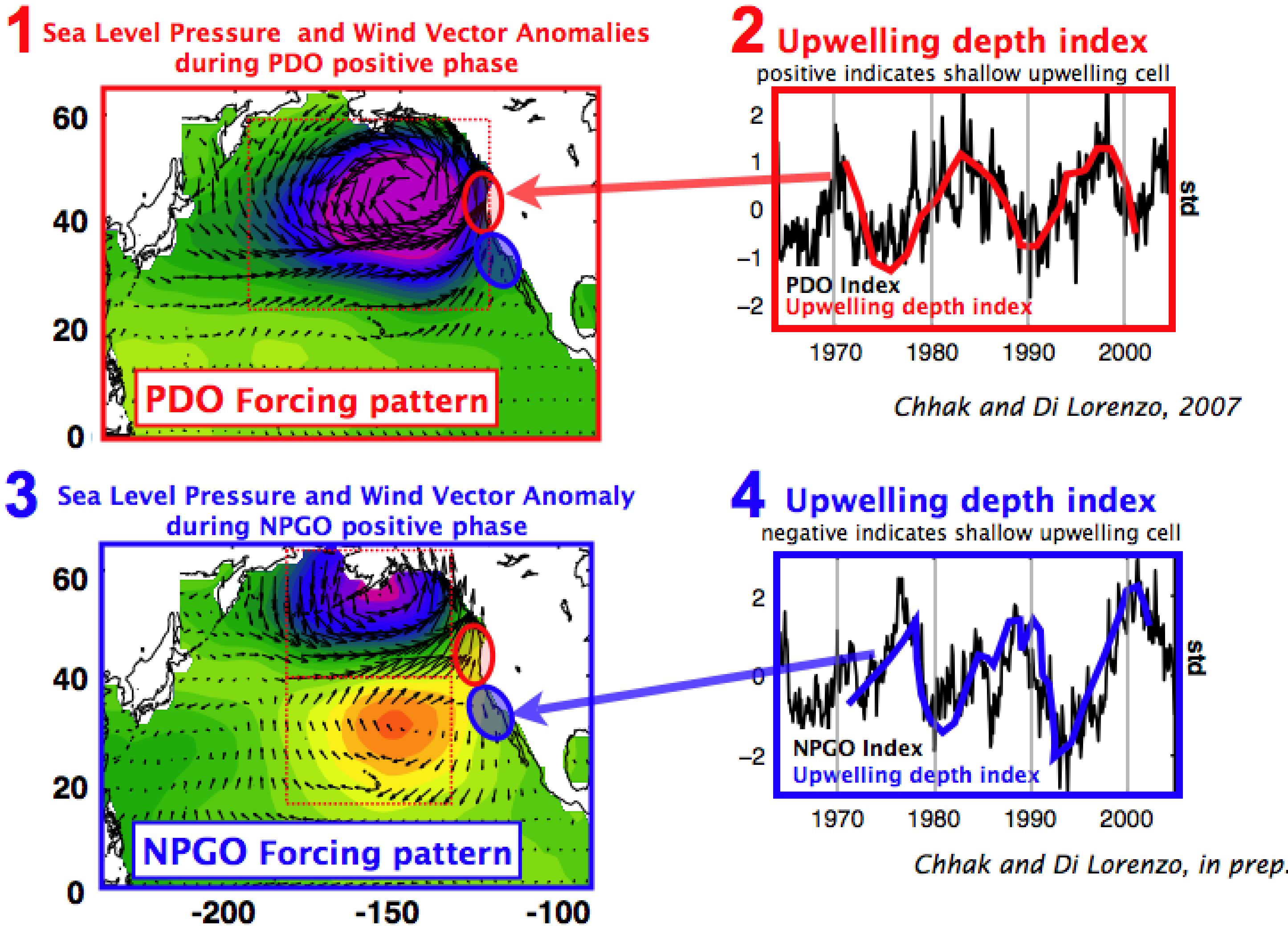


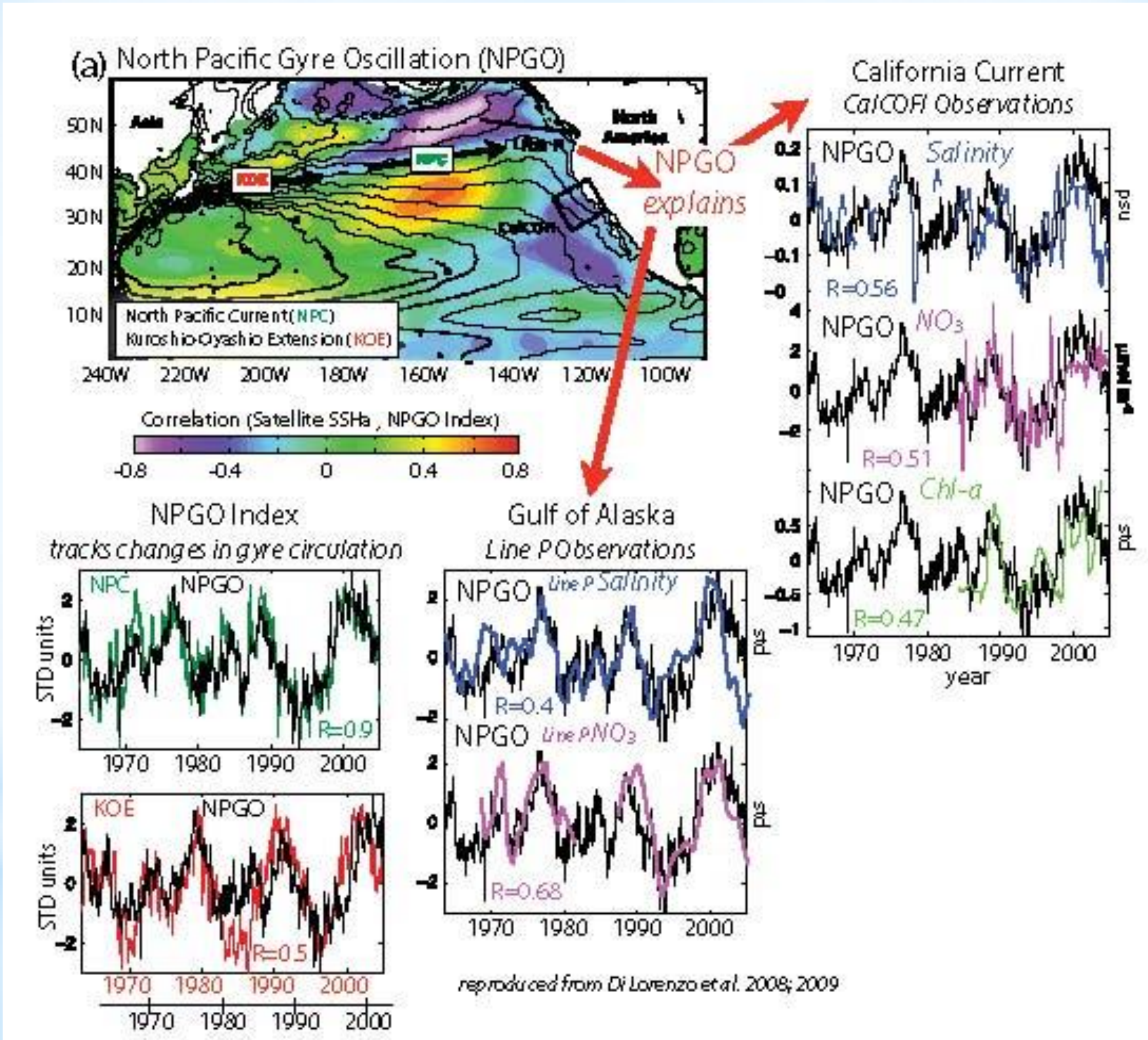
- The North Pacific Gyre Oscillation: the second empirical orthogonal function (EOF) of monthly sea surface temperature anomalies over the North Pacific.

Basin-scale Climate Influences



The atmospheric forcing of the PDO and NPGO drive different responses in coastal upwelling




(a) North Pacific Gyre Oscillation (NPGO)
Asia
North America
North Pacific Current (NPC)
Kuroshio-Oyashio Extension (KOE)
50N
40N
30N
20N
10N
240W
220W
200W
180W
160W
140W
120W
100W
NPGO explains
Correlation (Satellite SSHa , NPGO Index)
-0.8
-0.4
0
0.4
0.8
California Current
CalCOFI Observations
NPGO
Salinity
R=0.56
NO3
R=0.51
Chl-a
R=0.47
1970
1980
1990
2000
year
NPGO Index
tracks changes in gyre circulation
NPC
R=0.9
STD units
KOE
R=0.5
Gulf of Alaska
Line P Observations
Line P Salinity
R=0.4
Line P NO3
R=0.68
reproduced from Di Lorenzo et al. 2008; 2009

Conclusions and Comments

- Much of the sub-tidal regional circulation can be understood with simple conceptual "models"

- However, these simple balances are mediated by
  - non-local processes
  - complex geometry and topography
  - larger-scale climate fluctuations

➔ Need for more complex (numerical) models

- Caution on model complexity: when do you have "enough"?

- Community models for disease transmission
  https://www.myroms.org/

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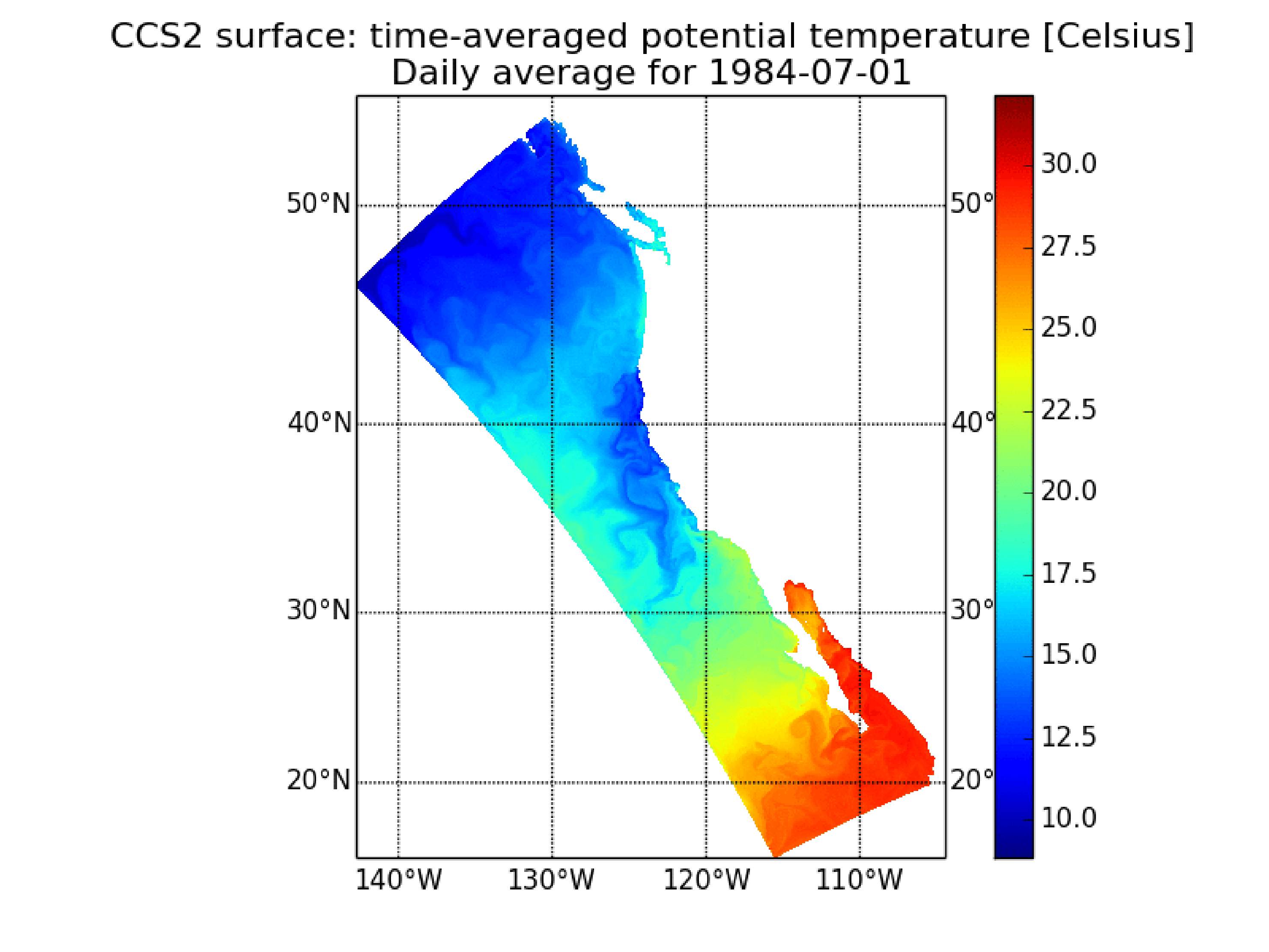
References

- Hickey, B., E. Dobbins and S. Allen, 2003. Local and remote forcing of currents and temperature in the central Southern California Bight, 2003. *J. Geophys. Res.*, **108**, doi:10.1029/2000JC000313.
- Di Lorenzo, E., V. Combes, J.E. Keister, P.T. Strub, A.C. Thomas, P.J.S. Franks, M.D. Ohman, J.C. Furtado, A. Bracco, S.J. Bograd, W.T. Peterson, F.B. Schwing, S. Chiba, B. Taguchi, S. Hormazabal, and C. Parada. 2013. Synthesis of Pacific Ocean climate and ecosystem dynamics. *Oceanography* **26**(4):68–81, http://dx.doi.org/10.5670/oceanog.2013.76.
- http://www.o3d.org/npgo/

Fin



3-km simulation of US West Coast (courtesy, E. Curchitser)