Physical Oceanography of the Abalone System: Observations and Models

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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)
  
  \[
  \text{change in } u,v = \text{horizontal transport} + \\
  \quad \text{vertical transport} + \\
  \quad \text{rotation (Coriolis force)} + \\
  \quad \text{pressure gradient} + \\
  \quad \text{wind stress} + \\
  \quad \text{mixing and dissipation}
  \]

- Changes in temperature: use conservation law
  
  \[
  \text{change in } T = \text{horizontal transport} + \\
  \quad \text{vertical transport} + \\
  \quad \text{heating/cooling}
  \]
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 $u,v = \text{horizontal transport} + \text{vertical transport} + \text{rotation (Coriolis force)} + \text{pressure gradient} + \text{wind stress} + \text{mixing and dissipation}$
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)

  \[ \text{change in } u,v = \text{horizontal transport} + \text{vertical transport} + \text{rotation (Coriolis force)} + \text{pressure gradient} + \text{wind stress} + \text{mixing and dissipation} \]
What Produces Temperature Changes?

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

- Changes in temperature: use conservation law

\[
\text{change in } T = \text{ horizontal transport} + \text{ vertical transport} + \text{ heating/cooling}
\]

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 $90^\circ$ 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.
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.

  

![Graph showing PDO Index: 1900-2008]

- **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.

1. Sea Level Pressure and Wind Vector Anomalies during PDO positive phase
2. Upwelling depth index
   - Positive indicates shallow upwelling cell
   - PDO Index
   - Upwelling depth index
   - 1970 to 2000

Chhak and Di Lorenzo, 2007

3. Sea Level Pressure and Wind Vector Anomaly during NPGO positive phase
4. Upwelling depth index
   - Negative indicates shallow upwelling cell
   - NPGO Index
   - Upwelling depth index
   - 1970 to 2000

Chhak and Di Lorenzo, in prep.
North Pacific Gyre Oscillation (NPGO)

- Tracks changes in gyre circulation
- NPGO Index explains California Current
- Correlation (Satellite SSHa, NPGO Index)
- North Pacific Current (NPC)
- Kuroshio-Oyashio Extension (KOE)

Gulf of Alaska Observations
- NPGO Salinity
  - R = 0.56
- NPGO NO₃
  - R = 0.51
- NPGO Chl-a
  - R = 0.47

Line PO Observations
- NPGO Salinity
  - R = 0.4
- NPGO NO₃
  - R = 0.68

 reproduc ed 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/](https://www.myroms.org/)
References


- [http://www.o3d.org/npgog/](http://www.o3d.org/npgog/)
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CCS2 surface: time-averaged potential temperature [Celsius]
Daily average for 1984-07-01

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