

The Environment - Ocean Patterns

*If we knew
the hue of
the blue ...*

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SST during upwelling season

The Environment - Ocean Patterns

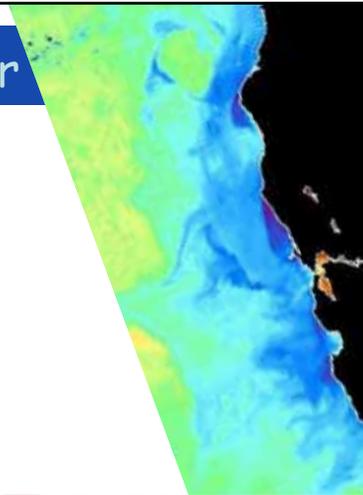
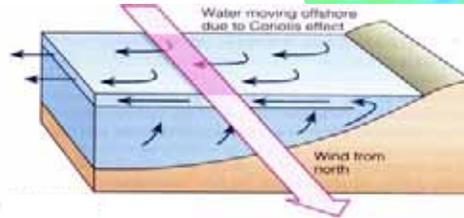
Patterns of dispersal and pelagic habitat ...
Area characterized by upwelling & mediterranean climate.

- ⊗ The **Upwelling** Story ...
 - ... upwelling center at Point Arena;
 - ... retention areas;
 - ... time & space scales of phytoplankton blooms.
- ⊗ The **Bay Outflow** Story ...
- ⊗ The **Estuary** Story ...
 - ... outflow;
 - ... inflow.
- ⊗ *The Wave Exposure Story.*
- ⊗ The Story of **Temporal Variability.**



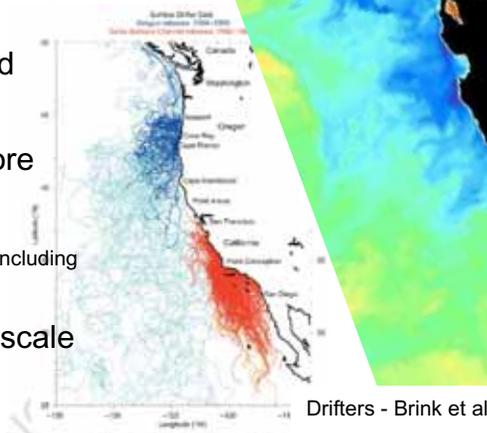
The Upwelling Center

- Point Arena is a strong and persistent upwelling center.
- Area of active upwelling expands and contracts.
- Cold water streams south to Point Reyes, Cordell Bank, Farallones Islands and Gulf of the Farallones.
- Cold upwelled water is loaded with nutrients.



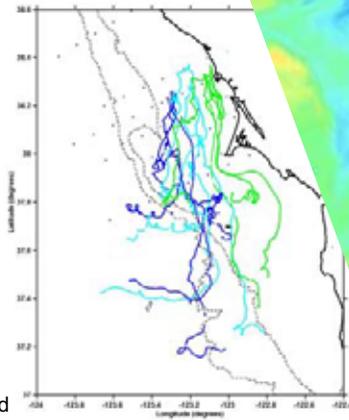
Retention Areas

- Drakes Bay is primary retention zone (“upwelling shadow”) ... but, note shallow thermocline, influence of bay outflow, and nearshore upwelling.
- Also, water may be retained in Bodega-Tomaes system.
- “Detention” along north shore of Point Reyes.
- Nearshore boundary layer including small coves and indentations.
- Retention in offshore mesoscale eddies.



Upwelling Plume

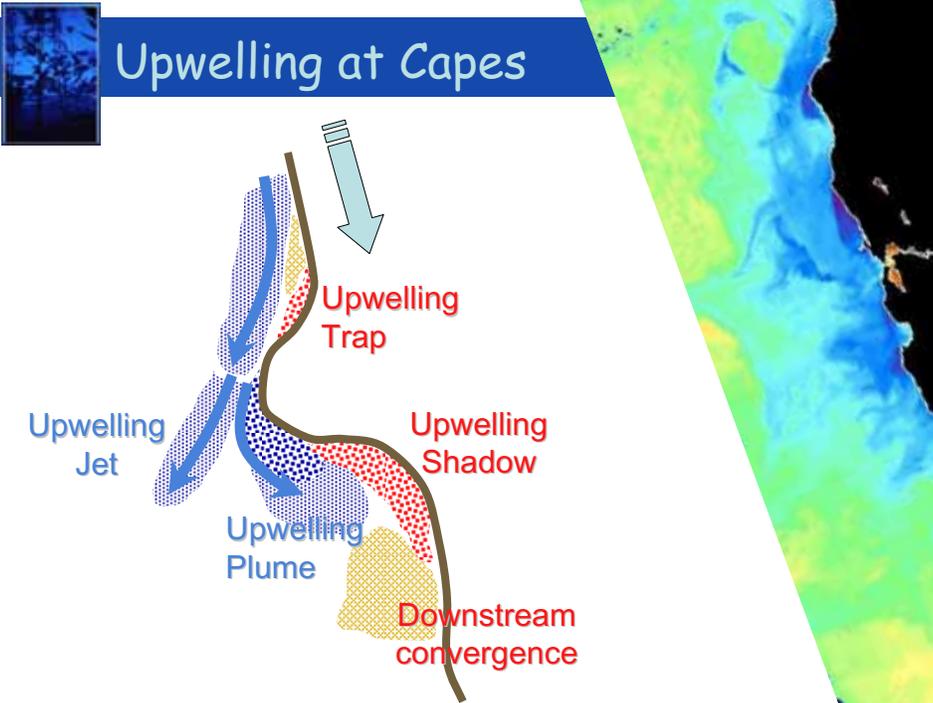
- Upwelling plume - a plume of cold, nutrient-rich water - streams south from Pt Arena.
- Plume is deflected by Pt Reyes, exporting material offshore.



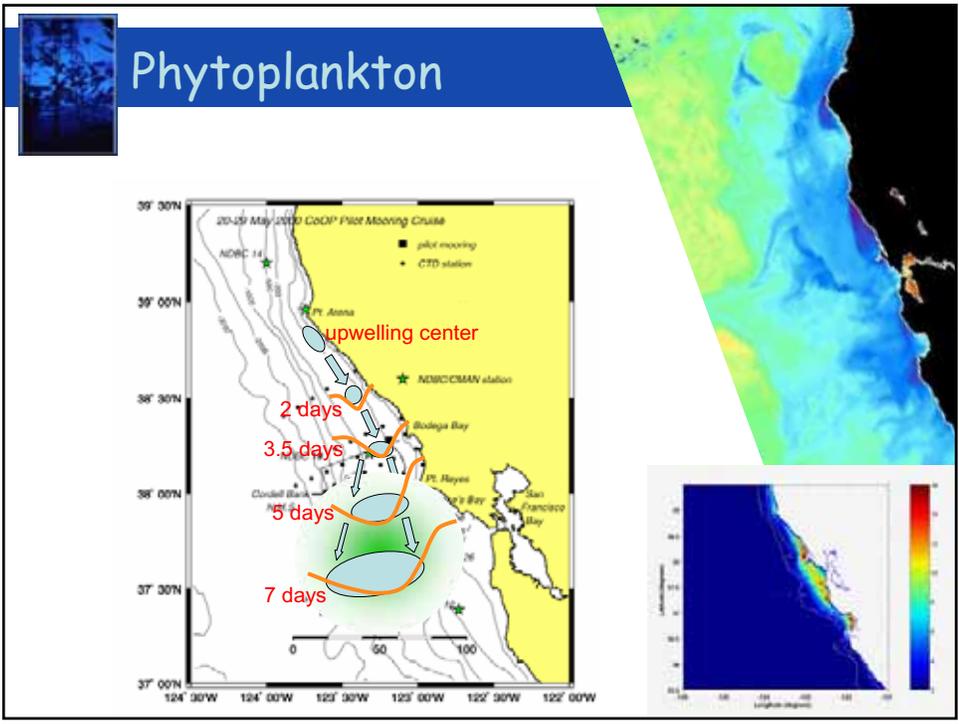
Drifters deployed off Bodega Head

The slide features a blue header with the title 'Upwelling Plume' and a small satellite image of a coastline. To the right is a vertical cross-section of the ocean showing a color gradient from blue (cold) to yellow (warm). Below the text is a map showing the tracks of drifters in blue and green lines, starting from the coast and moving south and then west. The map includes latitude and longitude coordinates.

Upwelling at Capes

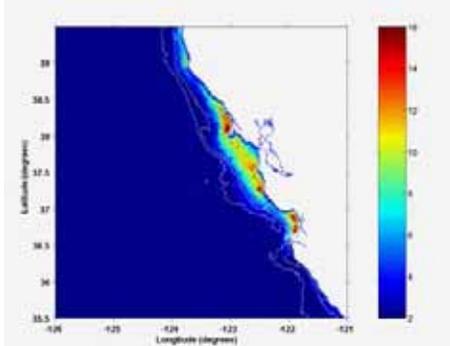


The diagram illustrates the oceanographic features at a cape. A grey arrow points to the 'Upwelling Trap' at the top of the cape. A blue arrow labeled 'Upwelling Jet' points south along the coast. A blue shaded area represents the 'Upwelling Plume'. A red shaded area represents the 'Upwelling Shadow'. A yellow shaded area at the bottom of the cape is labeled 'Downstream convergence'.



Phytoplankton Response

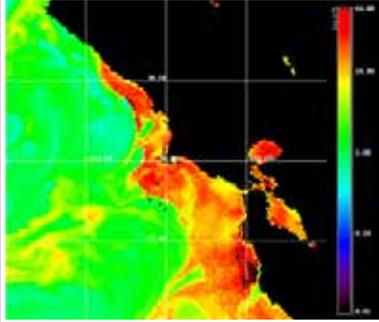
- Phytoplankton response time is several days.
- This is seen as a plume of chlorophyll, attaining maximum concentrations 50-100km downstream of upwelling center.
- Cordell Bank, Pt Reyes, Farallones Islands and Gulf of the Farallones are supported by Pt Arena upwelling.



Average chlorophyll concentration from SeaWiFS
(courtesy Andrea Vander Woude)

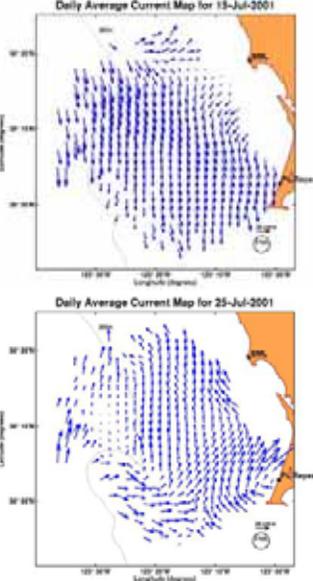
Phytoplankton & Relaxation

- Relaxation of the wind leads to phytoplankton blooms - shallow stratified surface layer.



HF radar maps of surface current during upwelling and relaxation.

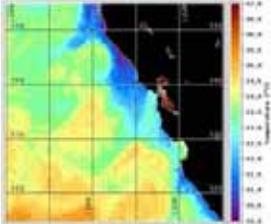
SeaWiFS image of chlorophyll concentration.



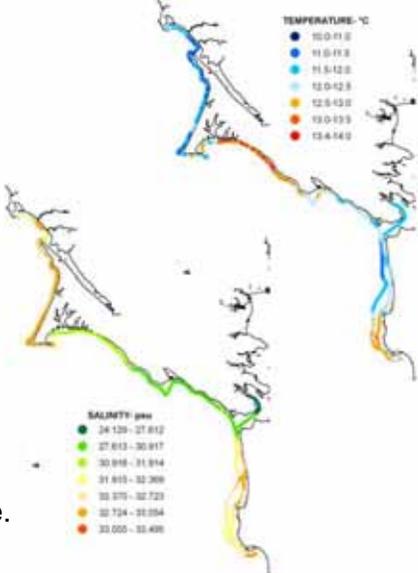
Daily Average Current Map for 18-Jul-2001

Daily Average Current Map for 25-Jul-2001

San Francisco Bay Outflow



- Moves south during upwelling - minimal contact with shore.
- Found attached to shore up to Bolinas (frontal feature) & low-salinity surface water up to Pt Reyes.
- Moves north during weak or southerly winds & after strong freshwater flow - contact with shore. Not washed out of Drakes Bay during upwelling.



TEMPERATURE - °C

- 10.0-11.0
- 11.0-11.5
- 11.5-12.0
- 12.0-12.5
- 12.5-13.0
- 13.0-13.5
- 13.4-14.0

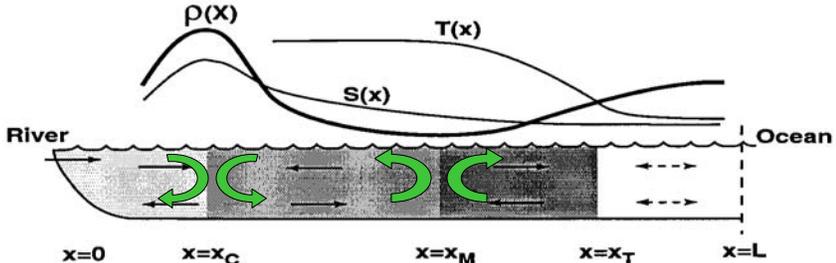
SALINITY - psu

- 24.129 - 27.812
- 27.813 - 30.817
- 30.818 - 31.814
- 31.815 - 32.208
- 32.209 - 32.723
- 32.724 - 33.034
- 33.035 - 33.439

Estuaries



- **Low-inflow estuaries**, like Tomales Bay and Bodega Harbor.
- Long residence, clear longitudinal zonation - protection of "backwaters"

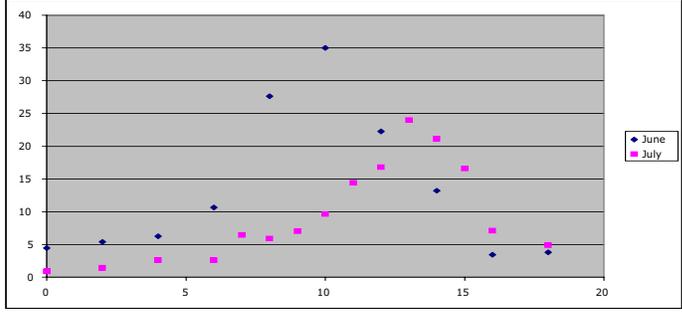


$x=0$	$x=x_C$	$x=x_M$	$x=x_T$	$x=L$
RIVERINE	HYPERSALINE	THERMAL	MARINE	
$\partial_x S > 0$	$\partial_x S < 0$	$\partial_x T < 0$		
$\partial_x \rho > 0$	$\partial_x \rho < 0$	$\partial_x \rho > 0$		$\partial_x \rho \sim 0$

Estuaries



- **Low-inflow estuaries**, like Tomales Bay and Bodega Harbor.
- Nutrient supply from ocean - spatial pattern of phytoplankton.



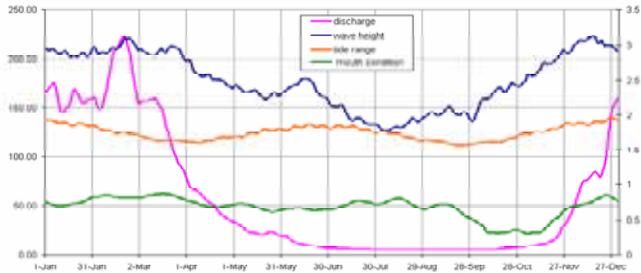
Month	Marine (x=0-5)	Thermal (x=5-10)	Hypersaline (x=10-20)
June (Blue Diamonds)	~5	~10, ~28, ~35	~14, ~4
July (Pink Squares)	~2	~6, ~15	~24, ~21, ~17, ~8, ~5

Chlorophyll fluor. data
(courtesy David Kimbro)

Estuaries



- **Bar-built estuaries**, like Russian River, Gualala, Salmon Creek.
- Highly stratified at times, leading to high T and low DO.
- Deep pools on curves vs shallow sections.
- Salinity intrusion.
- Residence time.
- Mouth closure.
- Outflow plumes (Stewarts Point 2007).

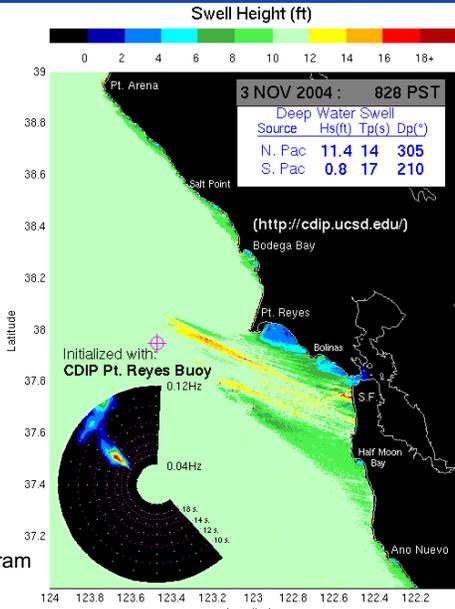


The graph plots four variables over a 12-month period from January to December. The left y-axis represents discharge (0.00 to 250.00), and the right y-axis represents wave height, tide range, and high/low tide (0 to 3.5). Discharge (pink line) peaks in March and has a secondary peak in November. Wave height (blue line) shows a seasonal cycle with a peak in winter and a minimum in summer. Tide range (orange line) is relatively constant around 1.5. High/low tide (green line) shows a regular semi-diurnal oscillation.

Wave Exposure



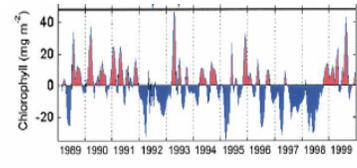
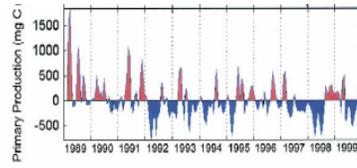
- Deep-sea “swell” refract and diffract.
- Also, “sea” from local winds.
- Alongshore transport - zone of impact associated with land runoff.



The map displays swell height data for the San Francisco Bay region. A color scale at the top indicates swell height in feet, ranging from 0 (dark blue) to 18+ (red). A data box for 3 NOV 2004 at 8:28 PST shows: Deep Water Swell Source Hs(ft) Tp(s) Dp(*) with values for N. Pac (11.4, 14, 305) and S. Pac (0.8, 17, 210). The map is initialized with CDIP Pt. Reyes Buoy data at 0.12Hz. A circular inset shows a detailed view of the buoy area with a 0.04Hz frequency and depth markers (18s, 14s, 12s, 10s). The map includes labels for Pt. Arena, Salt Point, Bodega Bay, Pt. Reyes, Bolinas, S.F., Half Moon Bay, and Año Nuevo. The URL <http://cdip.ucsd.edu> is provided.

Temporal Variability



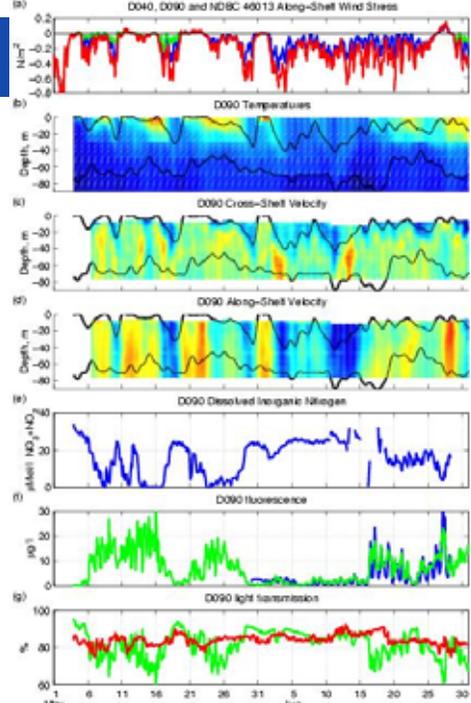



MBARI/Chavez data, 1989-99

- Have described spatial patterns.
- Recognize temporal variability - diurnal, synoptic, seasonal, interannual, trend.
- **Short-term variability** characterizes the suitability of habitat - need high-resolution monitoring.
- **Long-term variability** characterizes fluctuations in a population - need long-term monitoring.
- Interaction of time scales, e.g., timing of spring transition, match-mismatch ideas (salmon smolts entering ocean).

t-variability





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