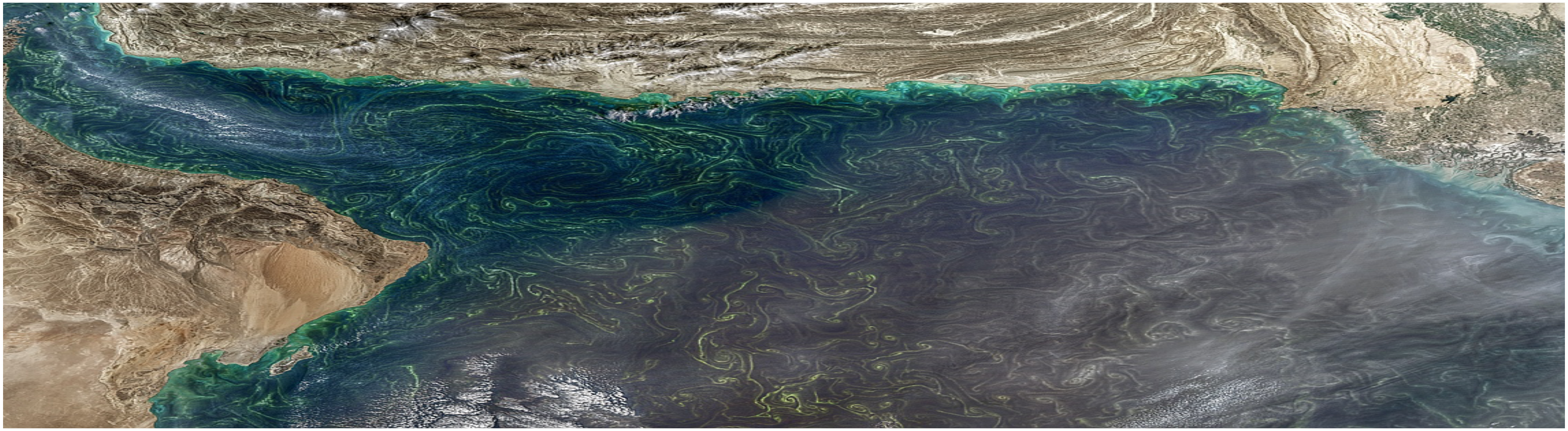


SIO 210: Eastern boundary currents

Dynamics

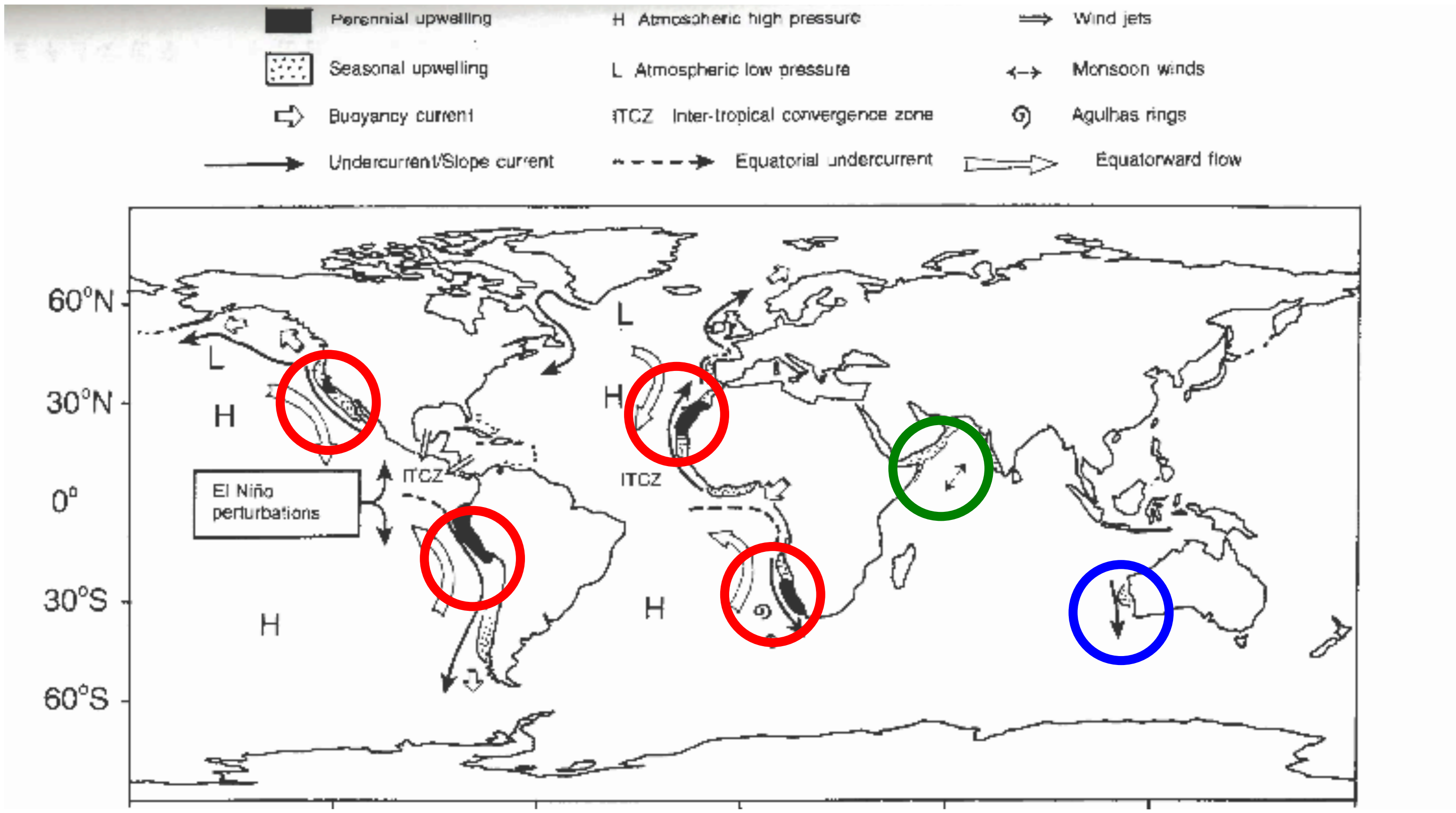
California Current System

Peru-Chile Current System

Separate: Arabian Sea upwelling system (not at an eastern boundary, but very similar wind forcing and ocean conditions)

READING:
DPO: S7.9.1 (eastern BC's), 10.3.1 and 10.4.1 (Pacific EBCs), 11.3 (Arabian Sea)

Eastern boundary current systems plus

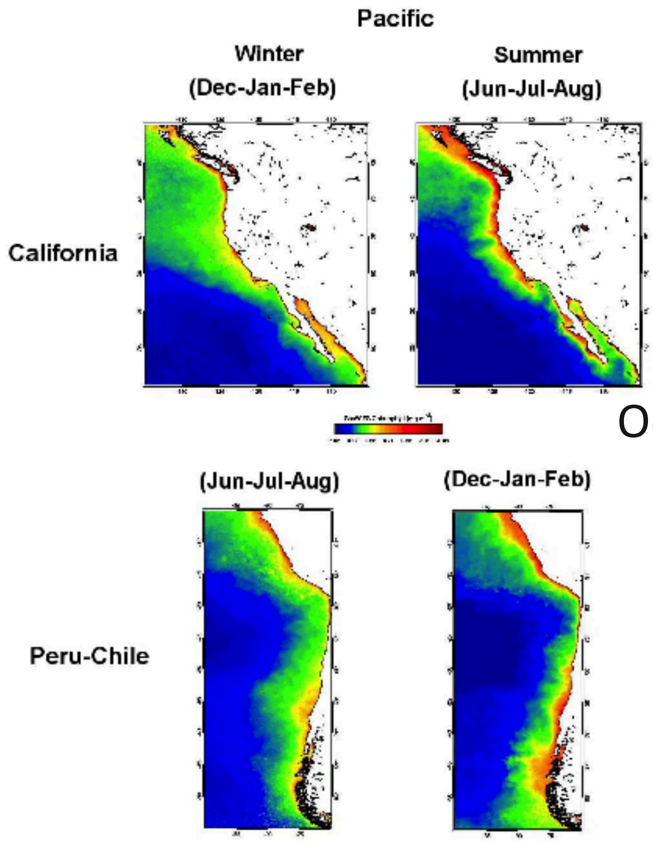


Subtropical eastern boundary upwelling system

Arabian Sea upwelling system

Subtropical eastern boundary without upwelling

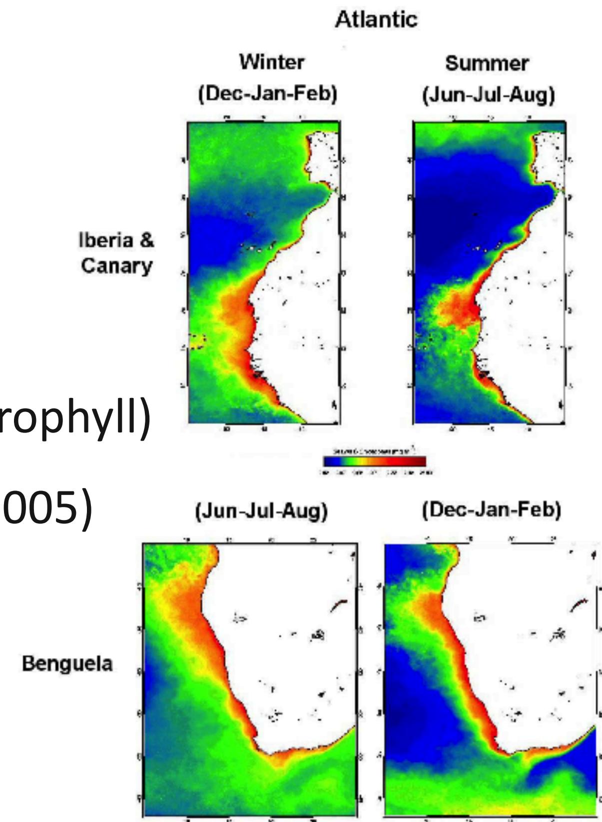
Eastern boundary current systems: highly productive due to upwelled nutrients



2.3 Comparisons of six-year averaged (1997-2003) winter and summer season distributions of SeaWiFS surface chlorophyll piment concentrations in the Pacific EBCU regions: California Current (top) and Peru-Chile Current (bottom); winter (left) and summer (right).

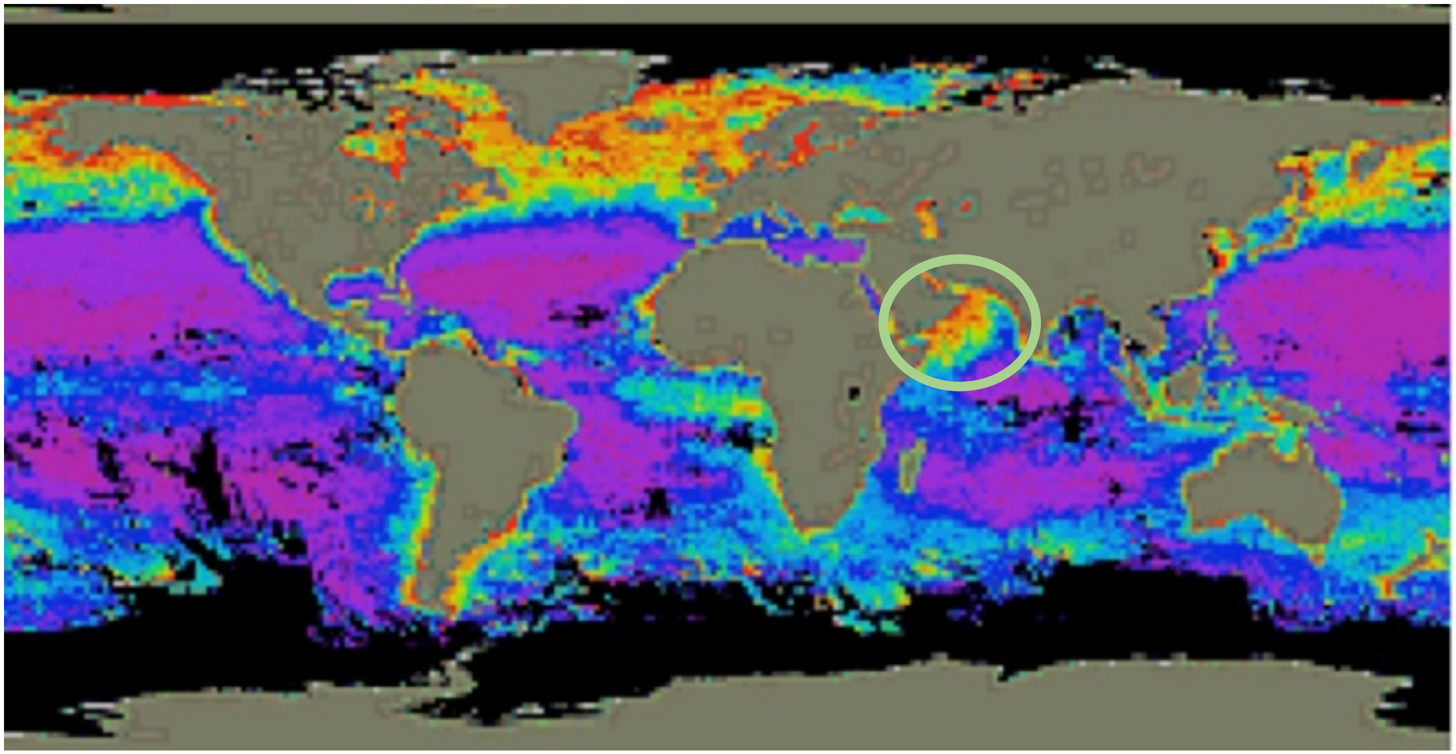
Ocean color (chlorophyll)

Mackas et al (2005)



2.4 Comparisons of six-year averaged (1997-2003) winter and summer season distributions of SeaWiFS surface chlorophyll pigment concentrations in the Atlantic EBCU regions: Iberia/Canary Current (top) and Benguela Current (bottom); winter (left) and summer (right).

Surface chlorophyll: productivity related to upwelling

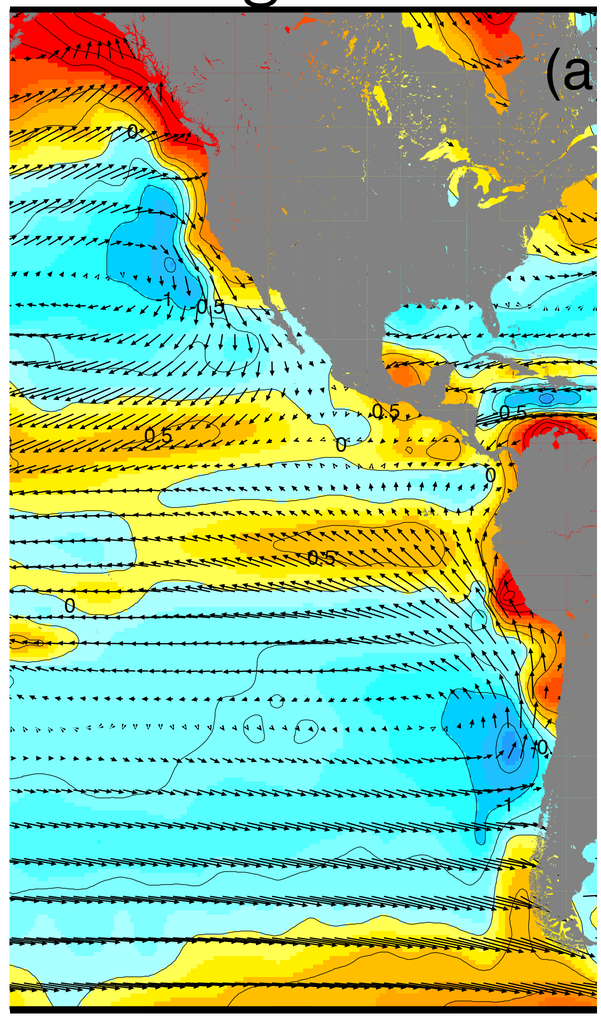


DPO Figure 4.28 Global images of chlorophyll derived from the Coastal Zone Color Scanner (CZCS). July–September only *Source: From NASA (2009a)*.

Arabian Sea upwelling system

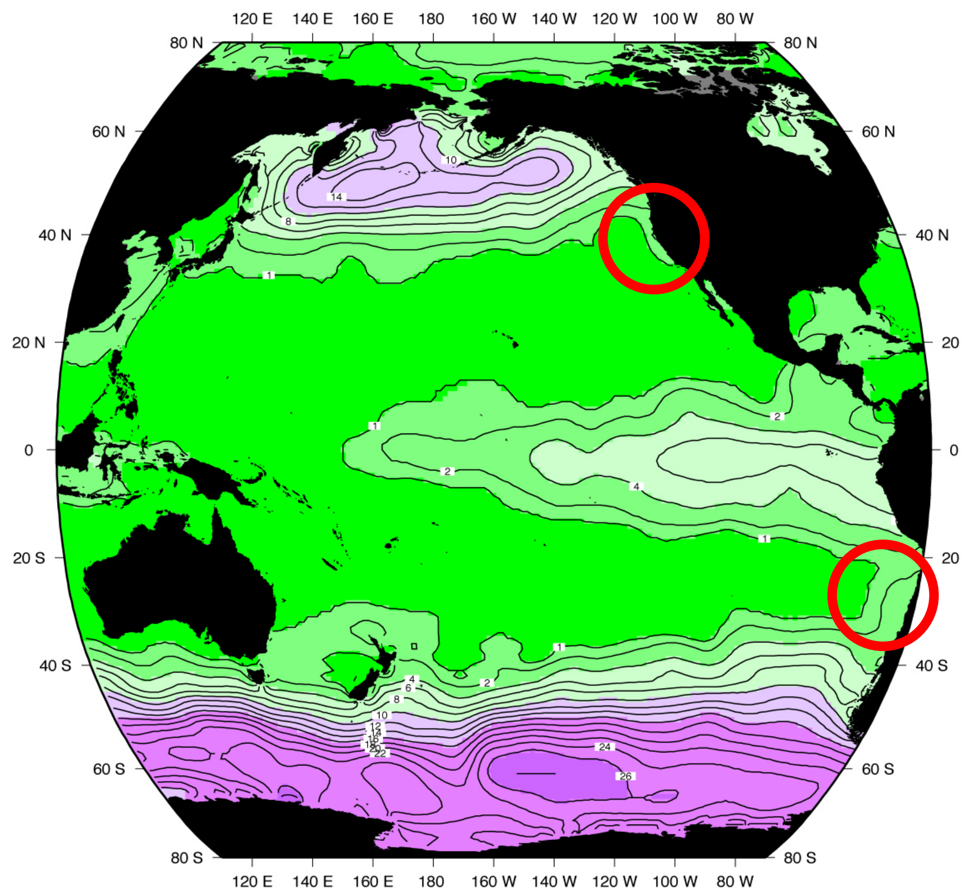
Eastern boundary currents: wind forcing

- Winds have strong along-shore component when they reach the eastern boundary
- US coast and Peru-Chile have equatorward winds
- Coastal circulation set up by these winds: eastern boundary current system
- Equatorward winds cause offshore Ekman transport, upwelling at coast
- Upwelling feeds cold water and nutrients into surface layer



DPO Fig. S5.10a

Ekman-induced upwelling/downwelling

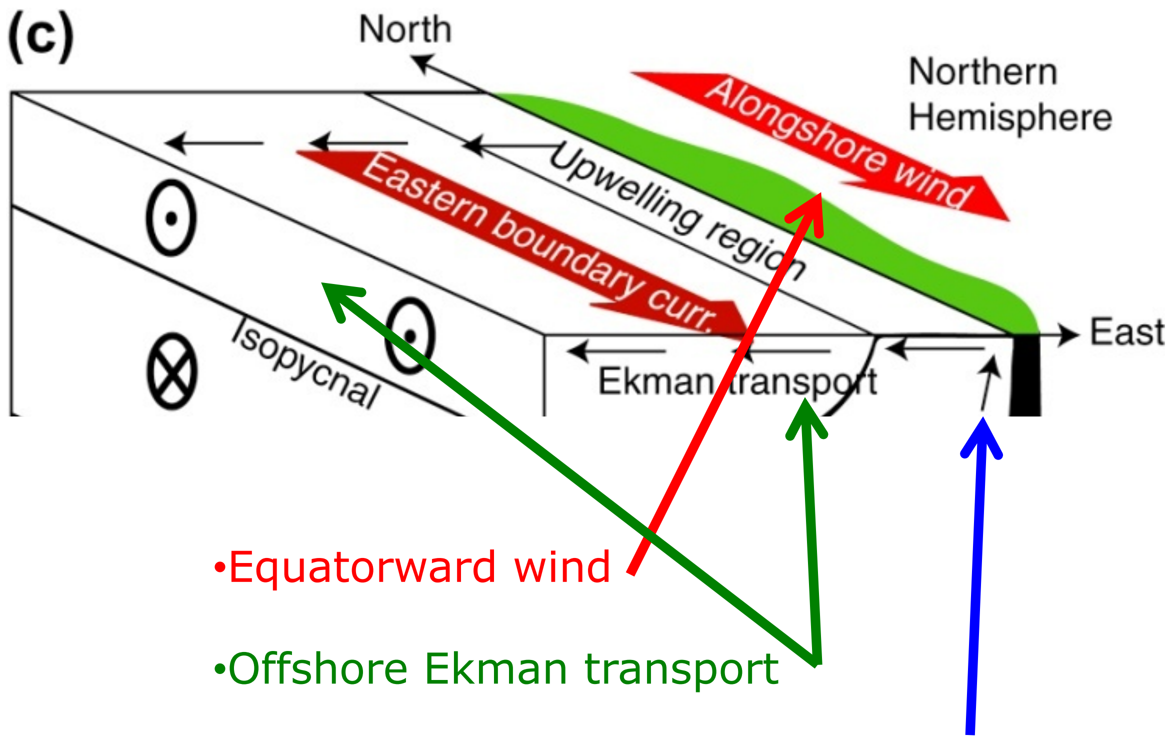


Coastal upwelling causes nutrient-rich waters below euphotic zone to come to sea surface

Nitrate at 10 m depth.

Data from gridded climatology, NODC (Levitus and Boyer, 1994)

EBC Dynamics Step 1: Coastal upwelling system
Direct response to alongshore wind



- Equatorward wind
- Offshore Ekman transport
- Upwelling at coast to balance mass

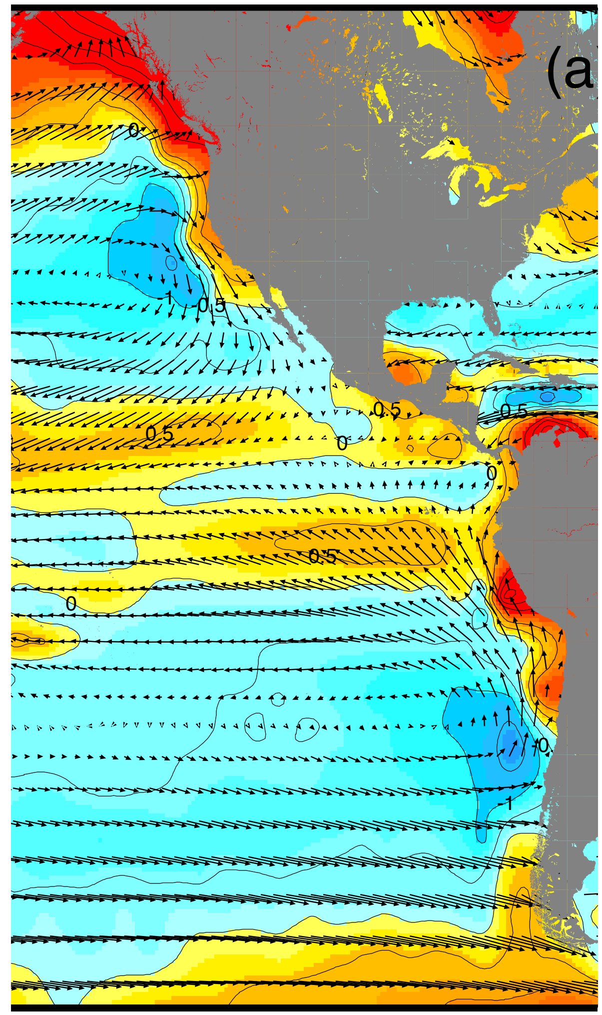
DPO FIGURE S7.13

EBC Dynamics Step 2: Wind stress curl forcing - expanded upwelling region

Two separate wind-driven mechanisms for upwelling:

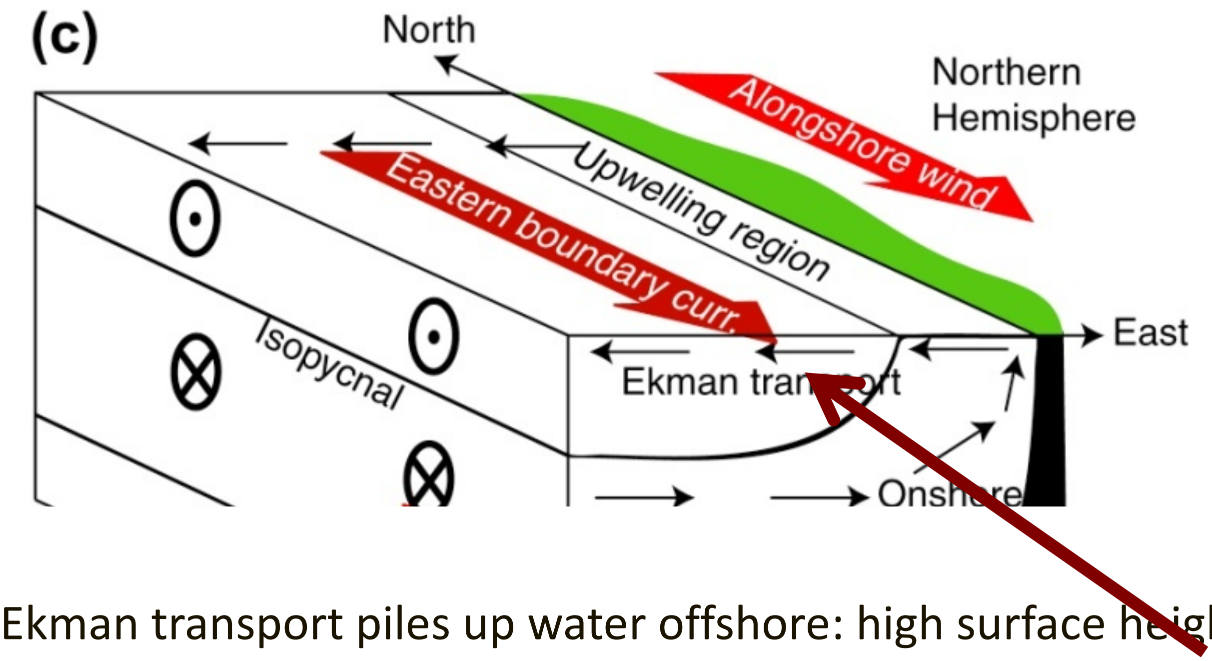
1. Offshore Ekman transport (creates narrow upwelling band right at the coast – about 10 km wide)

2. Ekman divergence offshore (wind stress curl) causes much wider offshore region of upwelling, about 200-300 km wide.



DPO Fig. S10.2a

EBC Dynamics Step 3: Equatorward alongshore geostrophic current

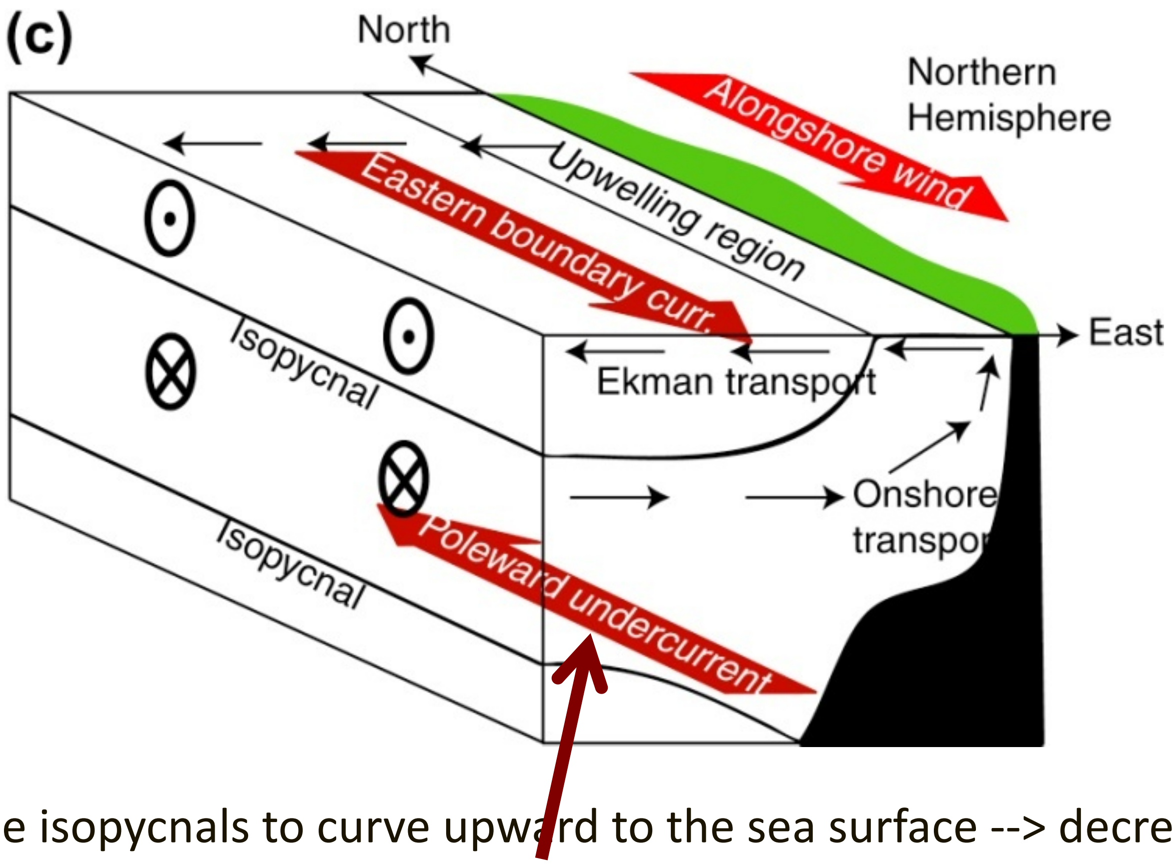


1. Offshore Ekman transport piles up water offshore: high surface height offshore, low surface height onshore --> southward geostrophic flow at surface (California Current)

2. Upwelling cause isopycnals to curve upward to the sea surface --> decrease in southward flow with depth

DPO FIGURE S7.13

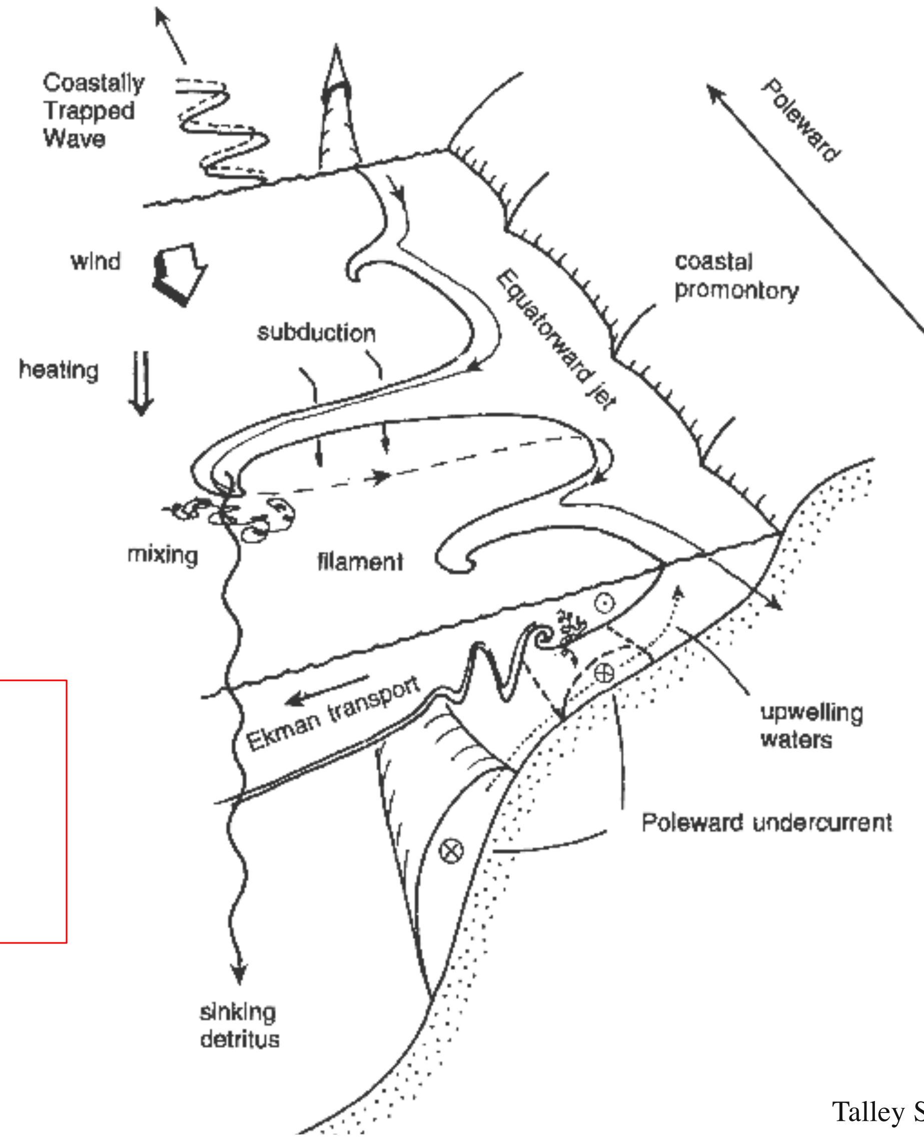
EBC Dynamics Step 4: Upwelling isopycnals, [southward geostrophic transport, northward pressure gradient force,] leading to poleward undercurrent



Upwelling cause isopycnals to curve upward to the sea surface --> decrease in southward flow with depth, reversing to a Poleward Undercurrent at about 200 m depth

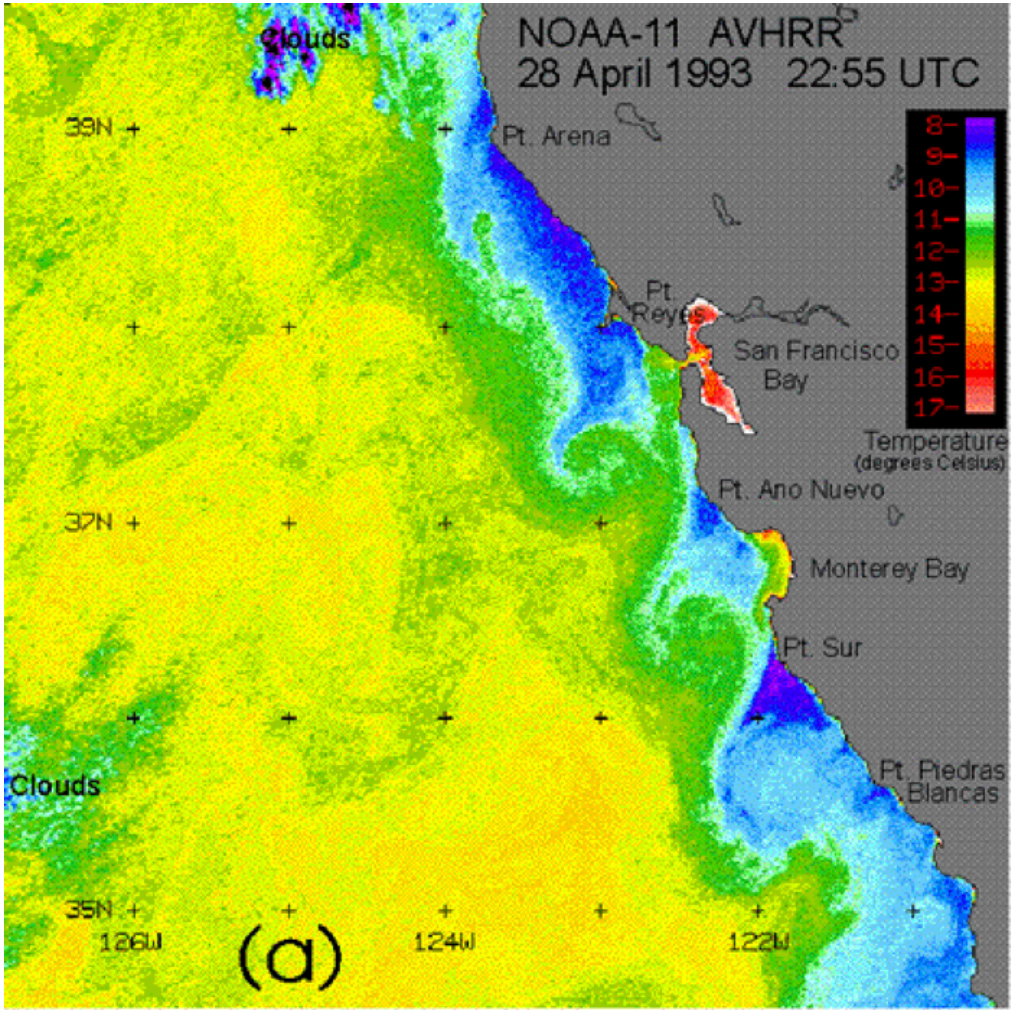
EBC Dynamics Step 5: Schematic of an upwelling system including the filaments, jets, eddies, mixing, poleward undercurrent

Response to the wind is much more complicated than the simple along-shore picture: effects due to coastal geography, flow instabilities



California Current: surface temperature

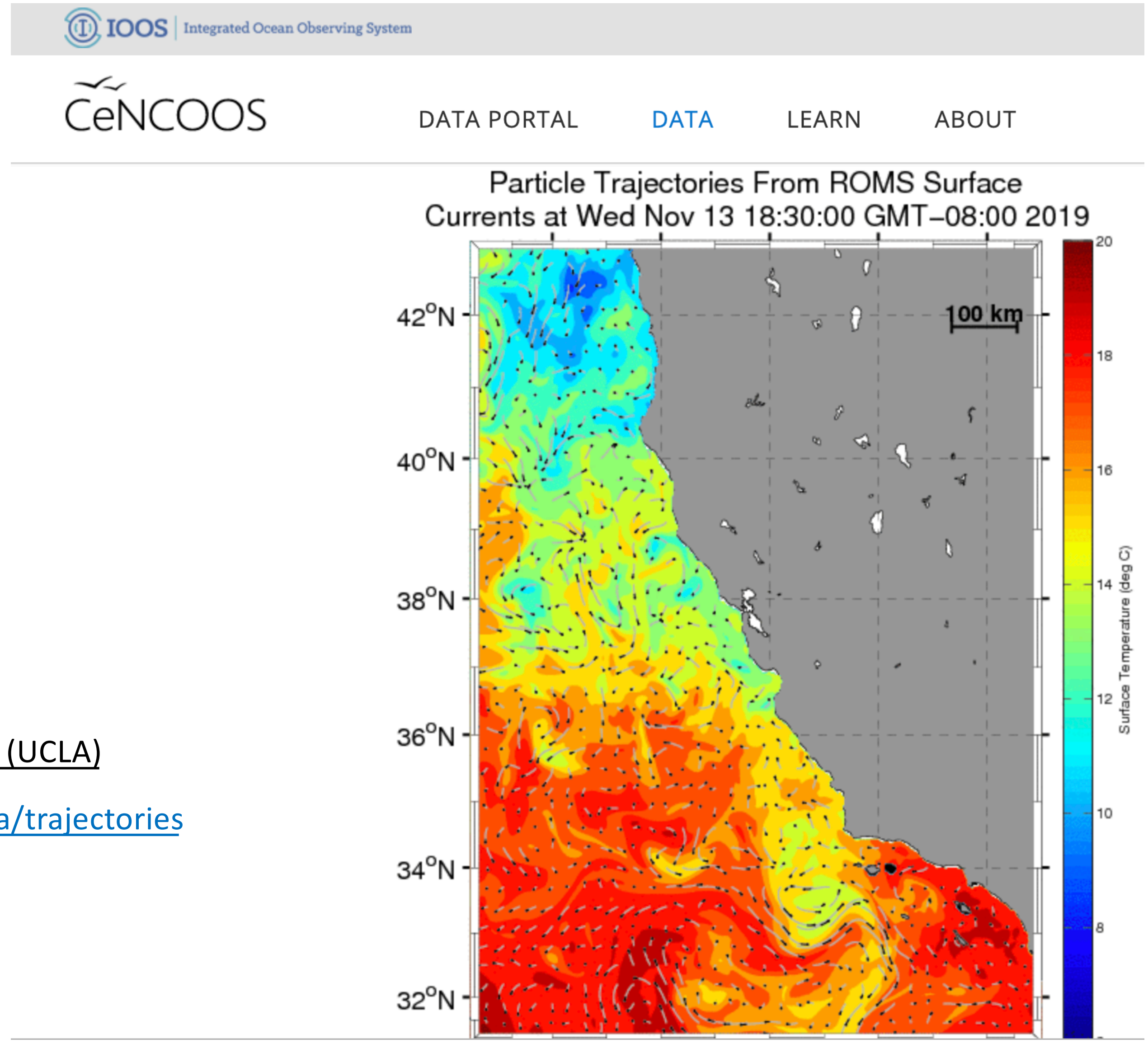
Eastern boundary currents are characterized by localized upwelling and filaments of upwelled water moving offshore.



DPO Fig. 10.21

California Current: surface temperature

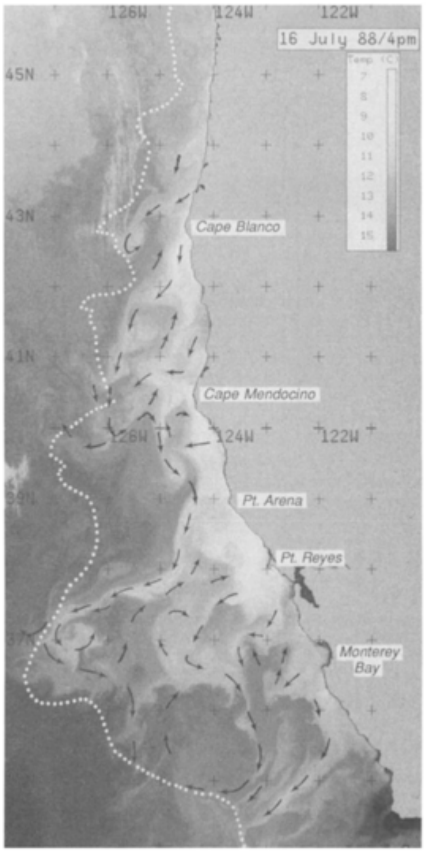
Eastern boundary currents are characterized by localized upwelling and filaments of upwelled water moving offshore.



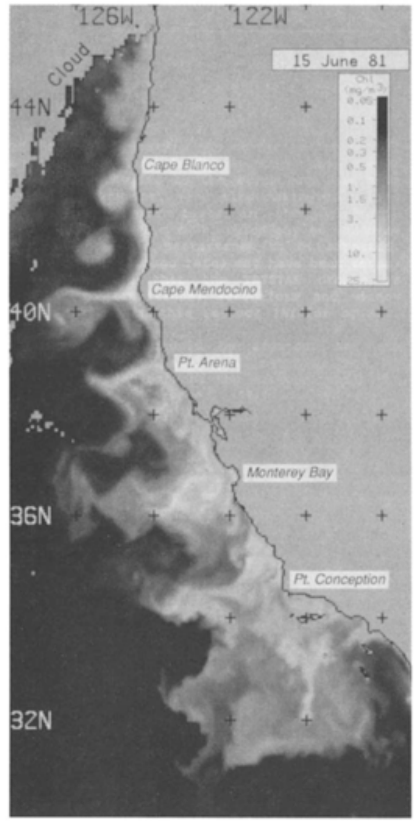
Real-time modeled SST and particle trajectories (UCLA)

https://www.cencoos.org/data/models/roms/ca/trajectories

California Current System



SST/currents



Ocean color

CA Current is full of filaments, related to capes/coastal geography

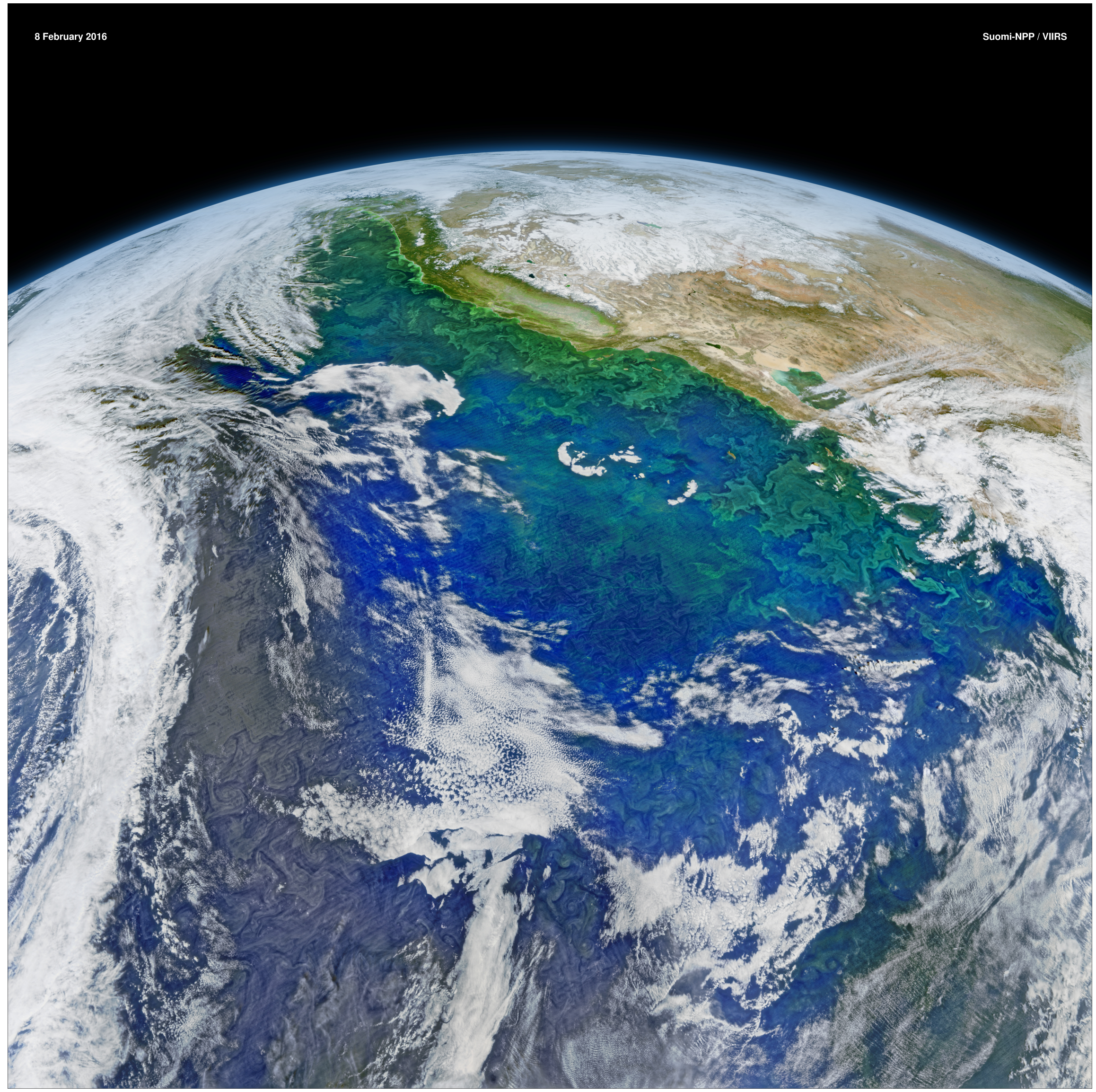
Upwelled water is cold, and high chlorophyll content

Strub et al. (1991)

DPO Fig. 10.6

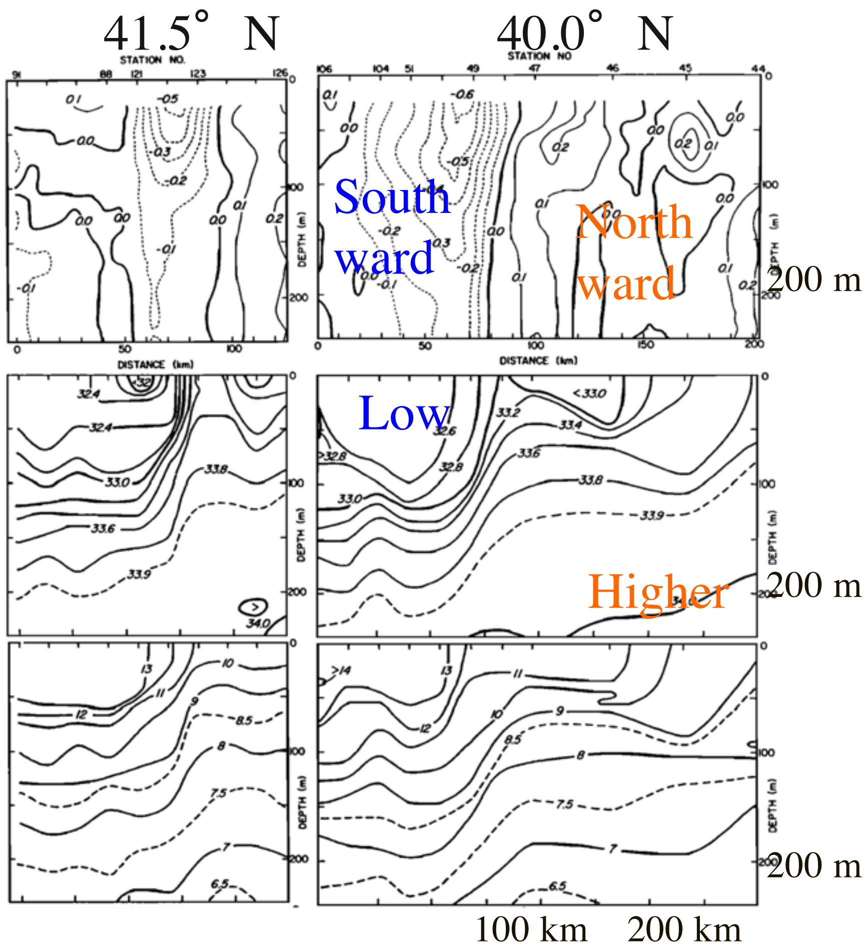
California Current: surface temperature

Eastern boundary currents are characterized by localized upwelling and filaments of upwelled water moving offshore.



NASA image:
Ocean color
Feb. 2016

California Current System



DPO Fig. 10.7

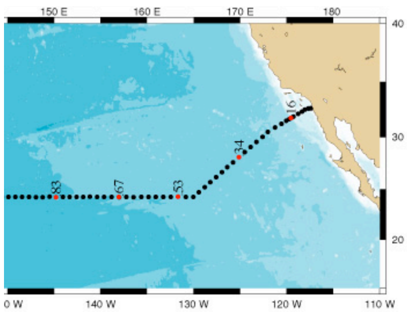
Velocity (cm/sec)

Salinity

Temperature

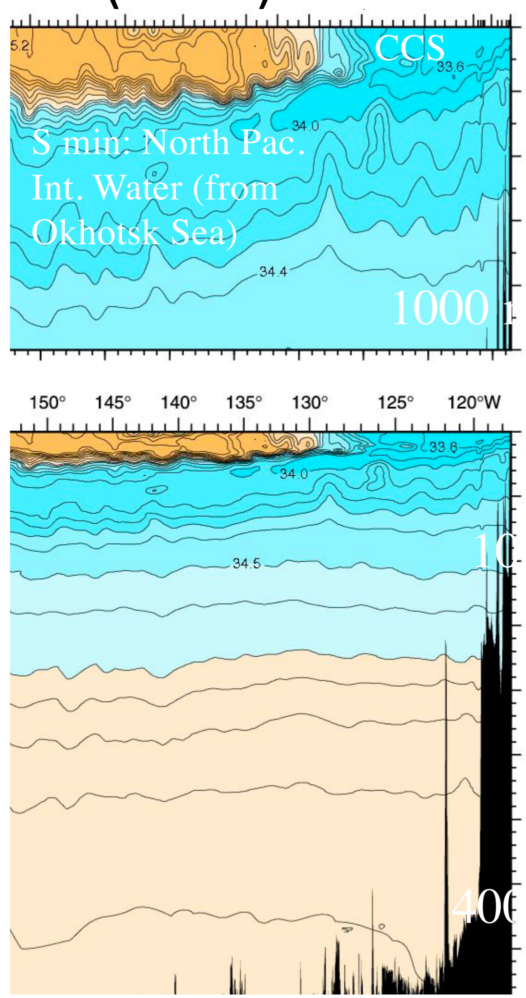
Off Oregon (Kosro et al., 1991)

California Current System (CCS)

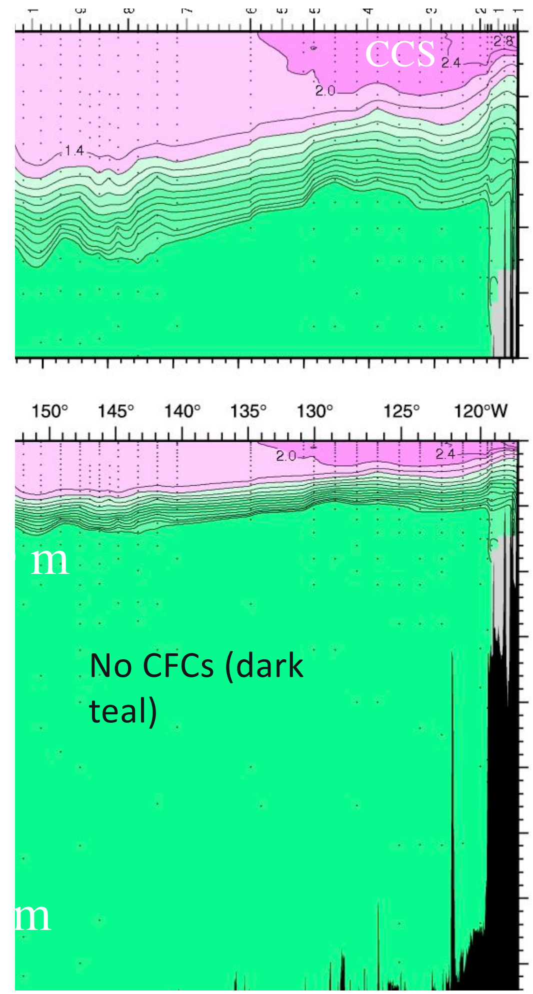


Low salinity, high CFC waters in the coastal system (1000 km wide strip) – source from the north

WOCE Pacific Atlas



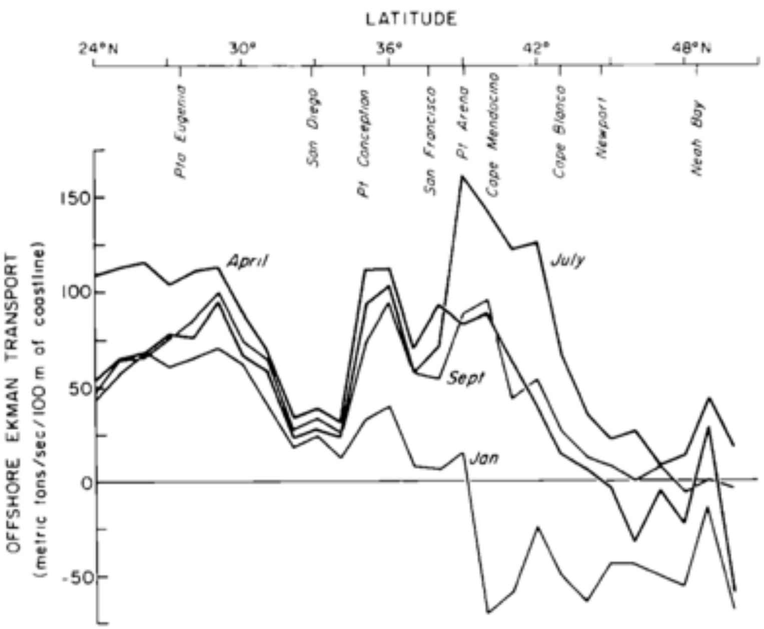
Salinity



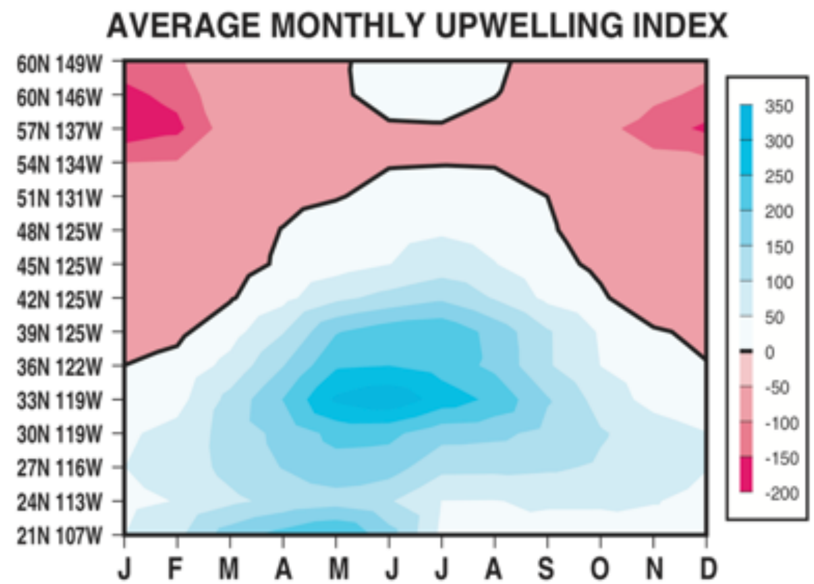
CFCs

California Current System

Wind stress: strong seasonal signal
Upwelling favorable winds: late spring and summer (May, June, July)



Huyer (1983)



Schwing et al. (1996)

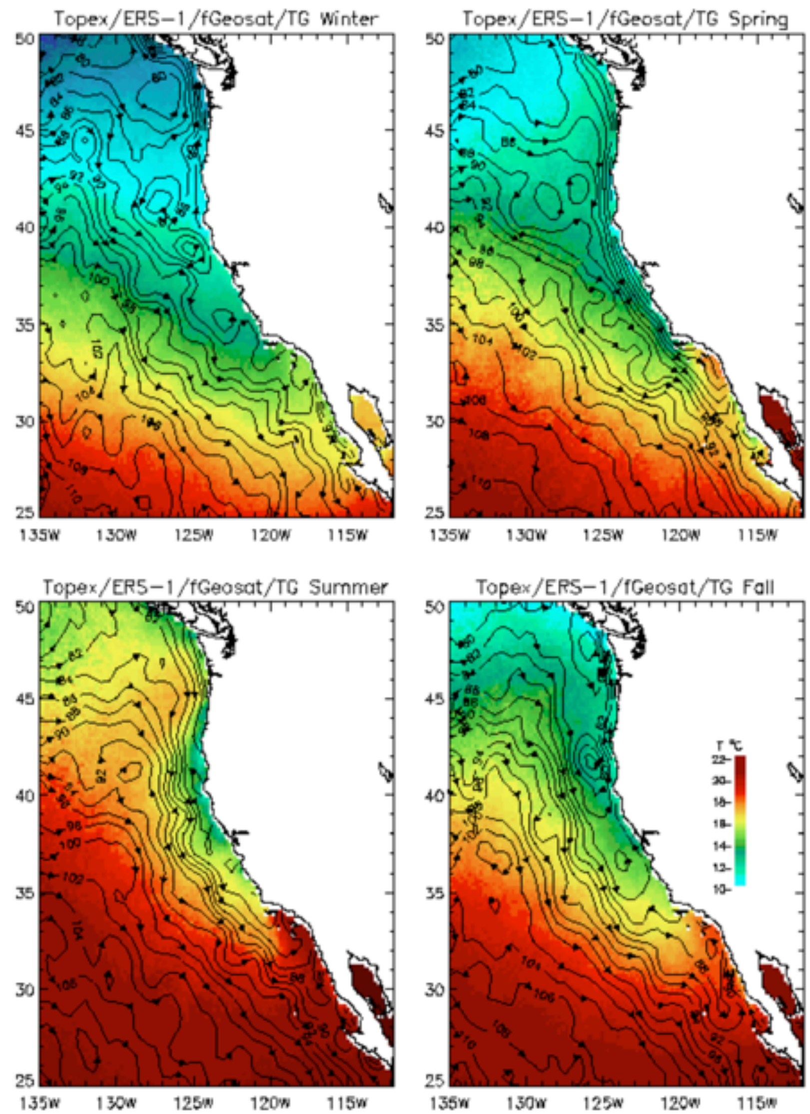
DPO Fig. 10.9

California Current System. Seasonal variability

Upwelling season: Summer

Figures from Hickey (1998) and Strub and James (2000, 2009)

DPO Fig. 10.5



Peru-Chile Current System

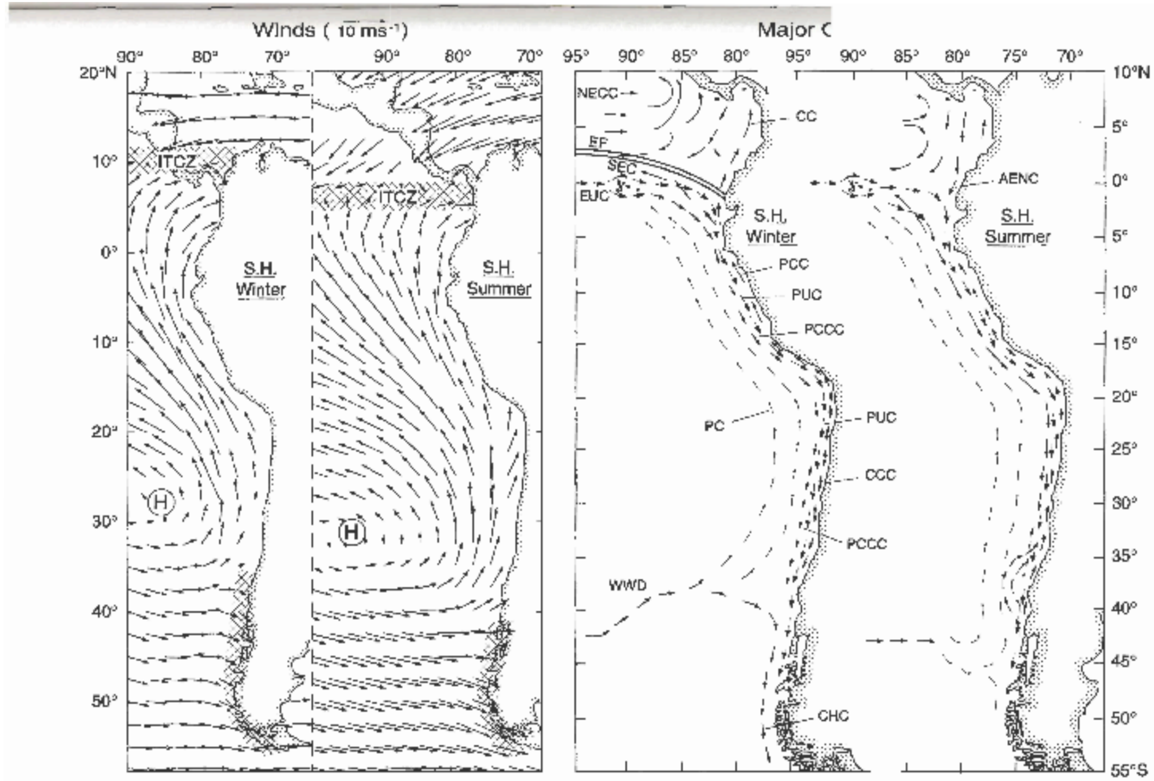
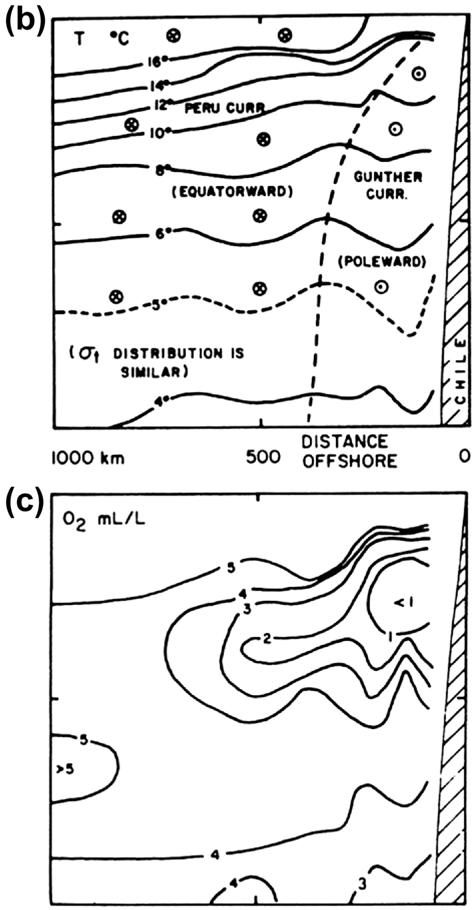


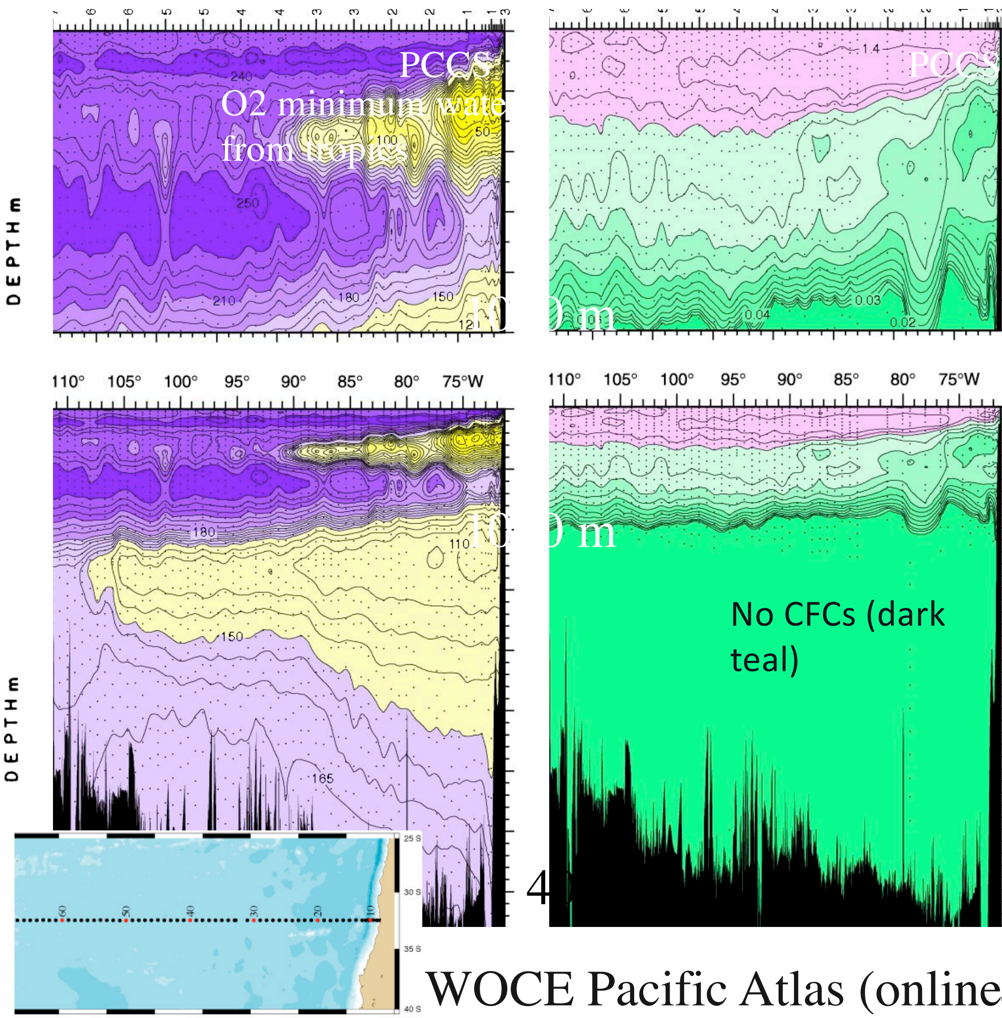
Fig. 10.2. Climatological winds and currents during austral winter and summer. Winds are from the NCEP reanalysis at 1000 mb, averaged over austral summer (December–February) and winter (June–August). Regions of heavy precipitation are shown by hatching. Schematic vectors are drawn to indicate the location and relative strengths of the currents described in the text. Subsurface currents are shown in gray. The primary currents of interest (starting offshore) are the West Wind Drift (WWD), the Peru Current (PC), the Peru Chile Countercurrent (PCCC), the Poleward Undercurrent (PUC), the Peru Coastal Current (PCC), the Chile Coastal Current (CCC) and the Cape Horn Current (CHC).

Strub et al. (1998) (DPO 10.13)

Peru-Chile Current: vertical sections

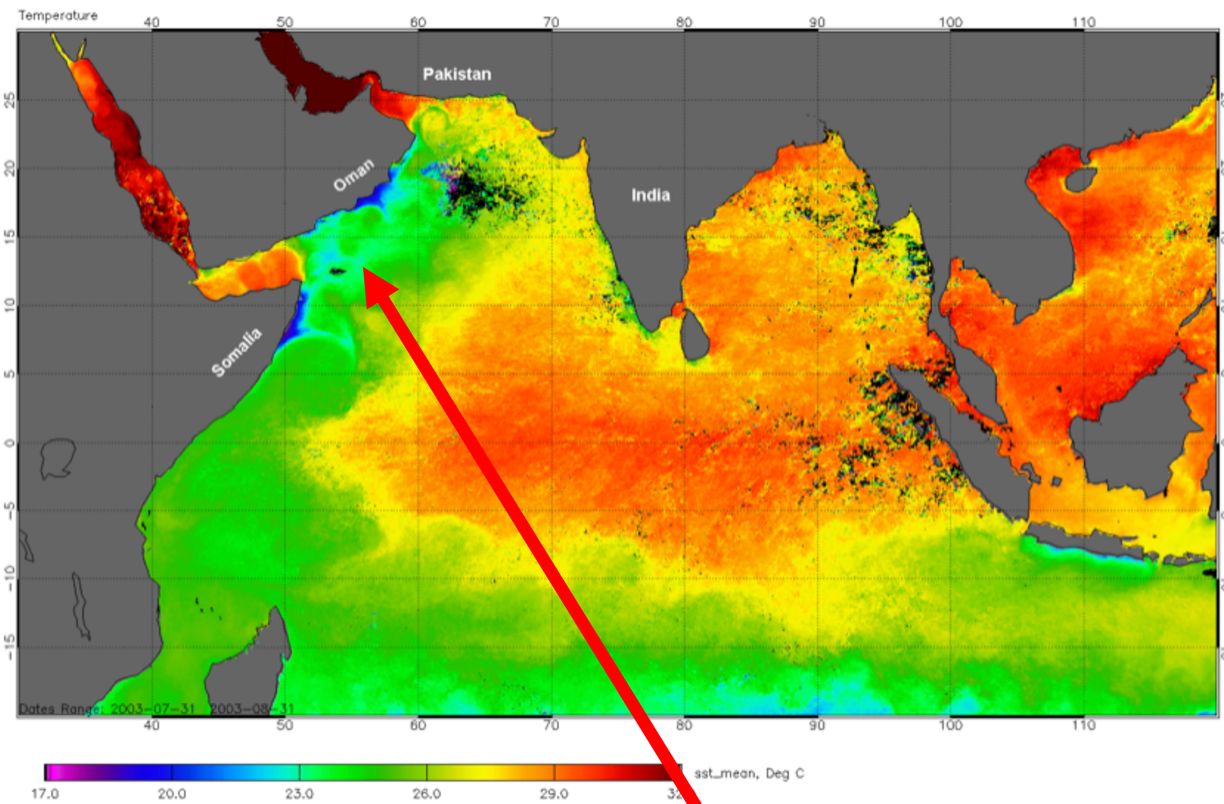


DPO FIGURE 10.13



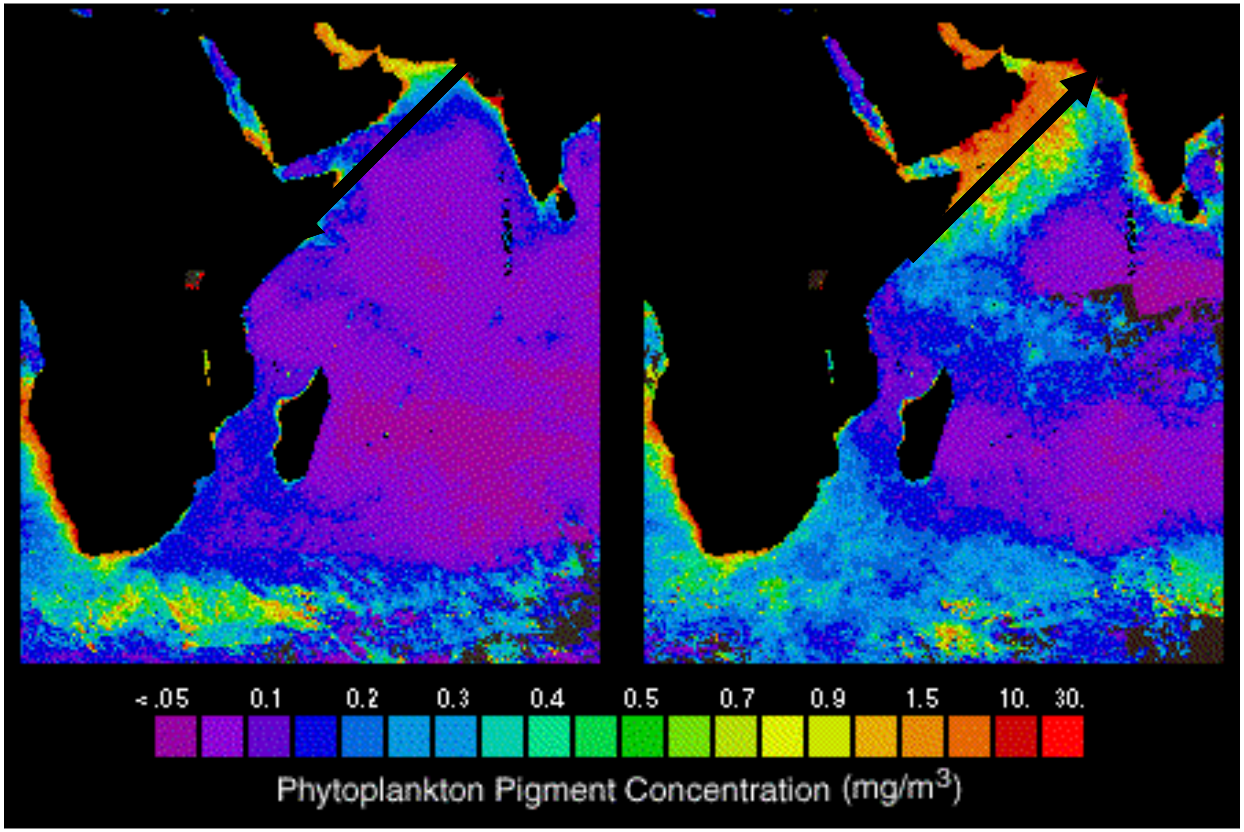
WOCE Pacific Atlas (online)

Asian (Indian) monsoon - effect of SW monsoon upwelling on surface temperature



July 2003 SST: Low along Somalia and Arabian peninsula during SW monsoon. (NASA MODIS satellite, NASA GSFC)

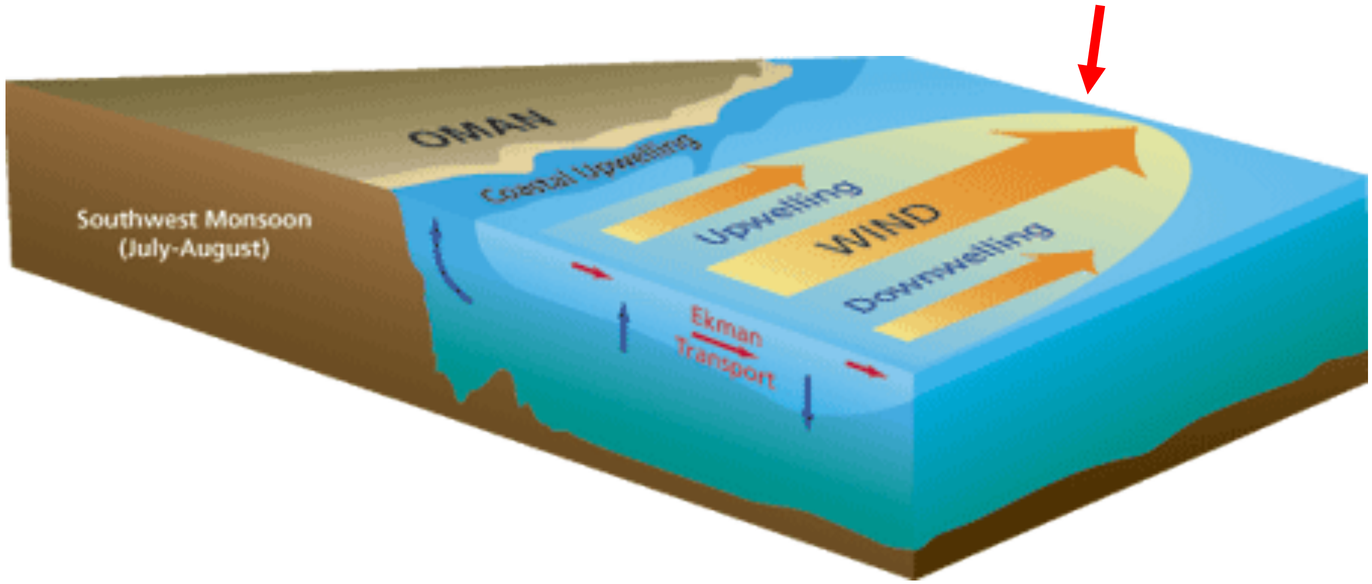
Asian (Indian) monsoon - effects of upwelling on biomass



Ocean color: high values indicate more phytoplankton. Note Arabian Sea upwelling signature during the SW monsoon. (NASA SeaWifs ocean color project)

Arabian Sea upwelling during the SW Monsoon - coastal effects

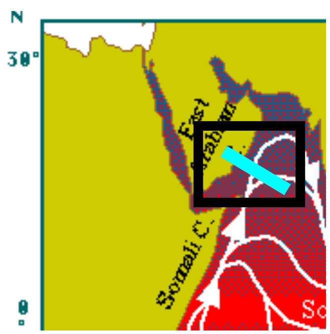
Somali Jet (or "Findlater jet")

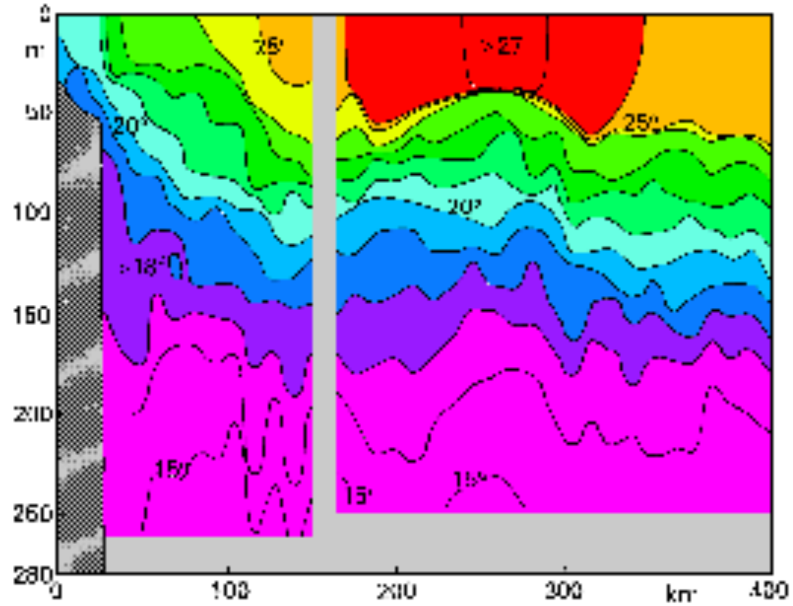


Honjo et al (1997)

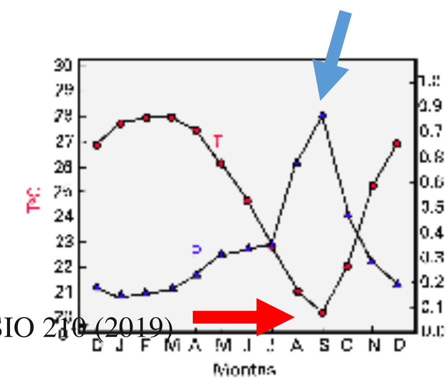
Arabian Sea upwelling during SW monsoon

- Upwelling along coast of Arabia during southwest monsoon (due to offshore Ek transport)





- Results in decrease in temperature and in biological productivity



(Figs. from Tomczak & Godfrey)

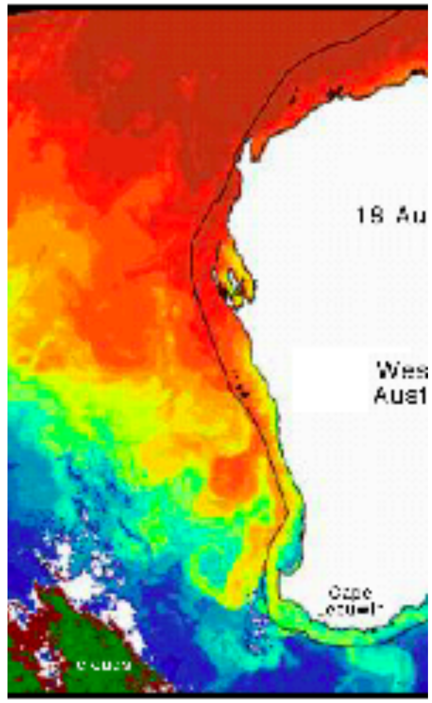
See also DPO Fig. 11.6

Fig. 11.9. Monthly mean temperature at 50 m depth (*T*) and zooplankton biomass (*P*) on the western Indian shelf between 8°N and 15°N. From Murty (1987).

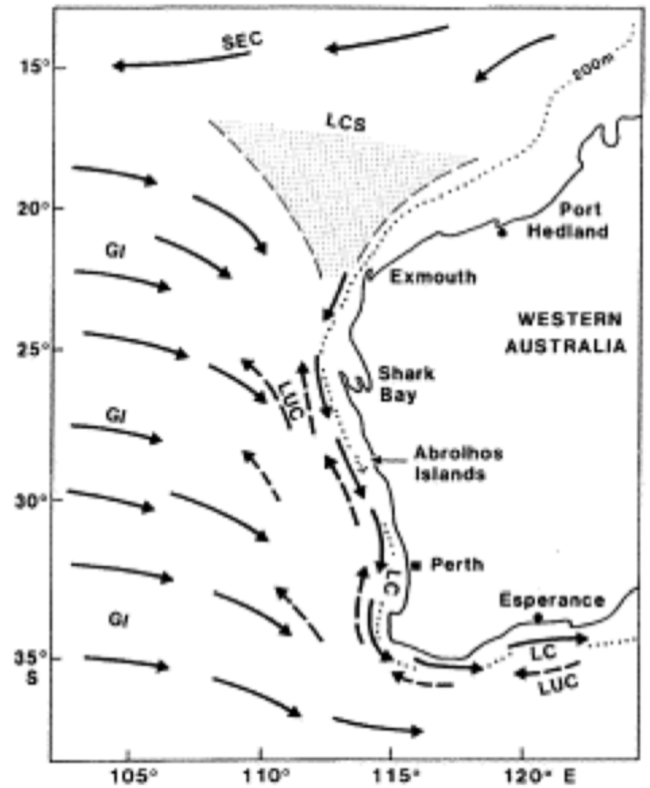
Eastern Boundary Current without upwelling: Leeuwin Current

Poleward flow due to pressure gradient around Australia, partially driven by Indonesian Throughflow.

(NOTE that winds are upwelling favorable, like any other eastern boundary – next slide)



SST showing southward advection of warm water (Tomczak and Godfrey online text)



DPO Fig. 11.9 from Schott and McCreary, 2001

Subtropical (South) Indian Ocean - wind driven gyre circulation

Annual mean wind stress and Ekman pumping DPO Fig. S11.3

Winds in S. Indian look like any other subtropical ocean, and are upwelling favorable. However, southward flow due to pressure gradient from Indonesian throughflow dominates.