The impact of upwelling filaments on carbon cycling and advection of coastal zooplankton

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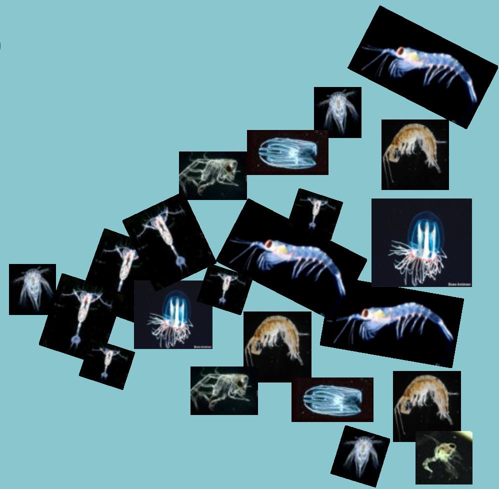
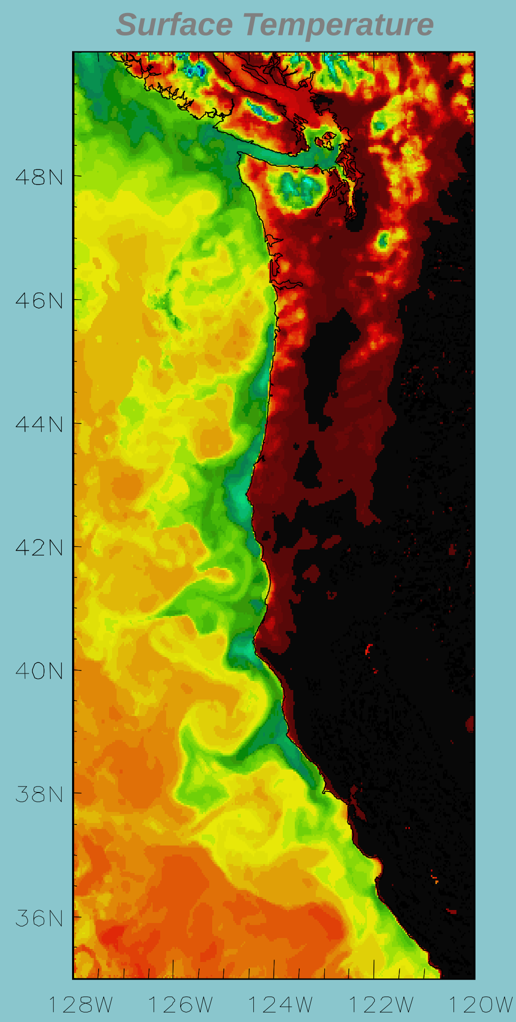
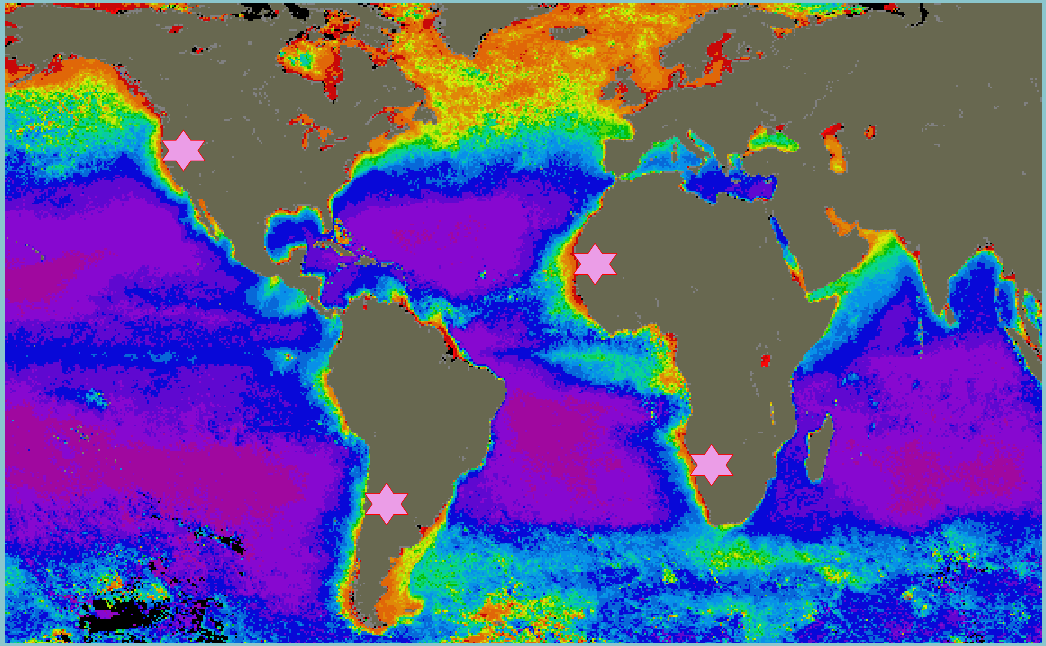
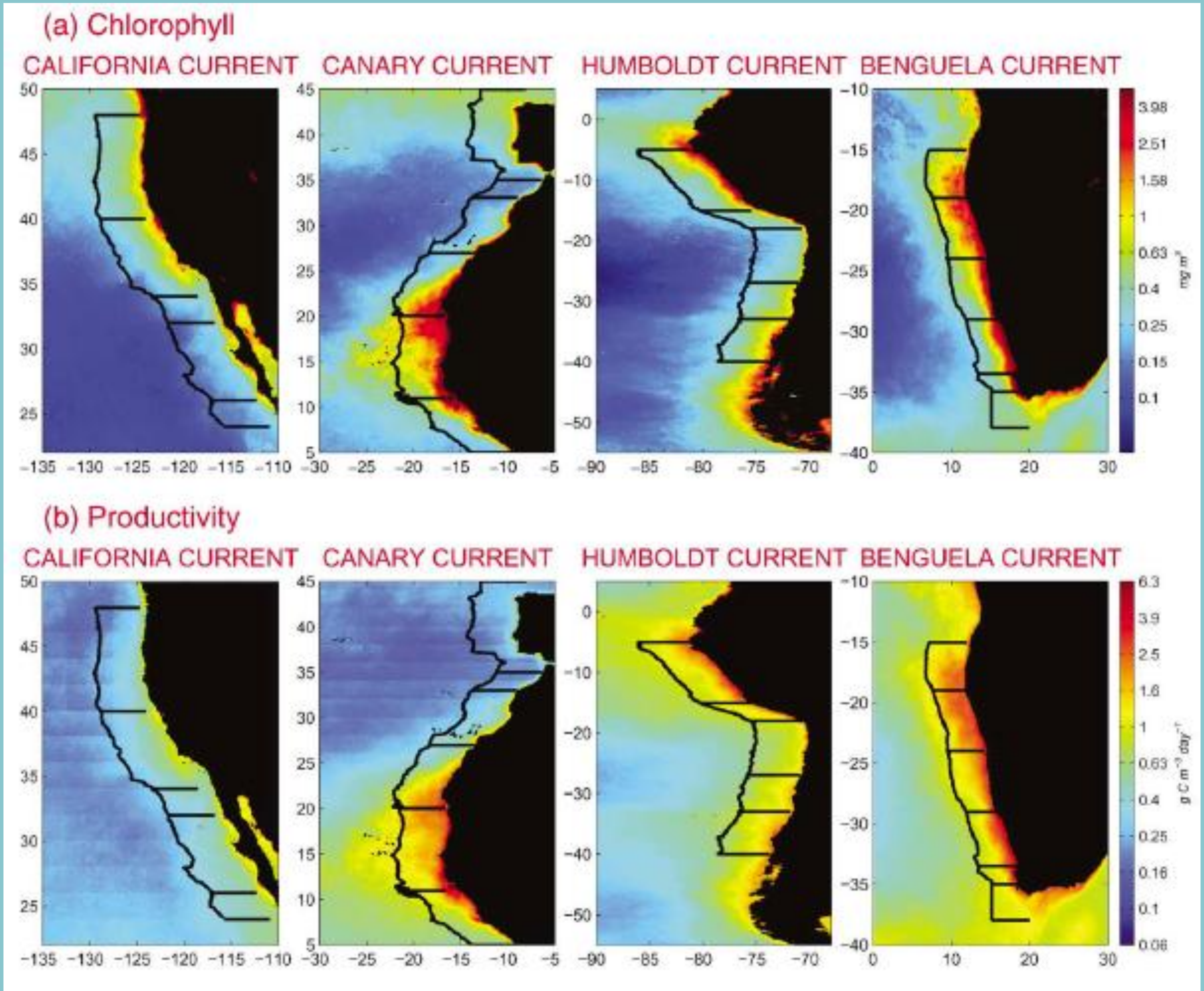




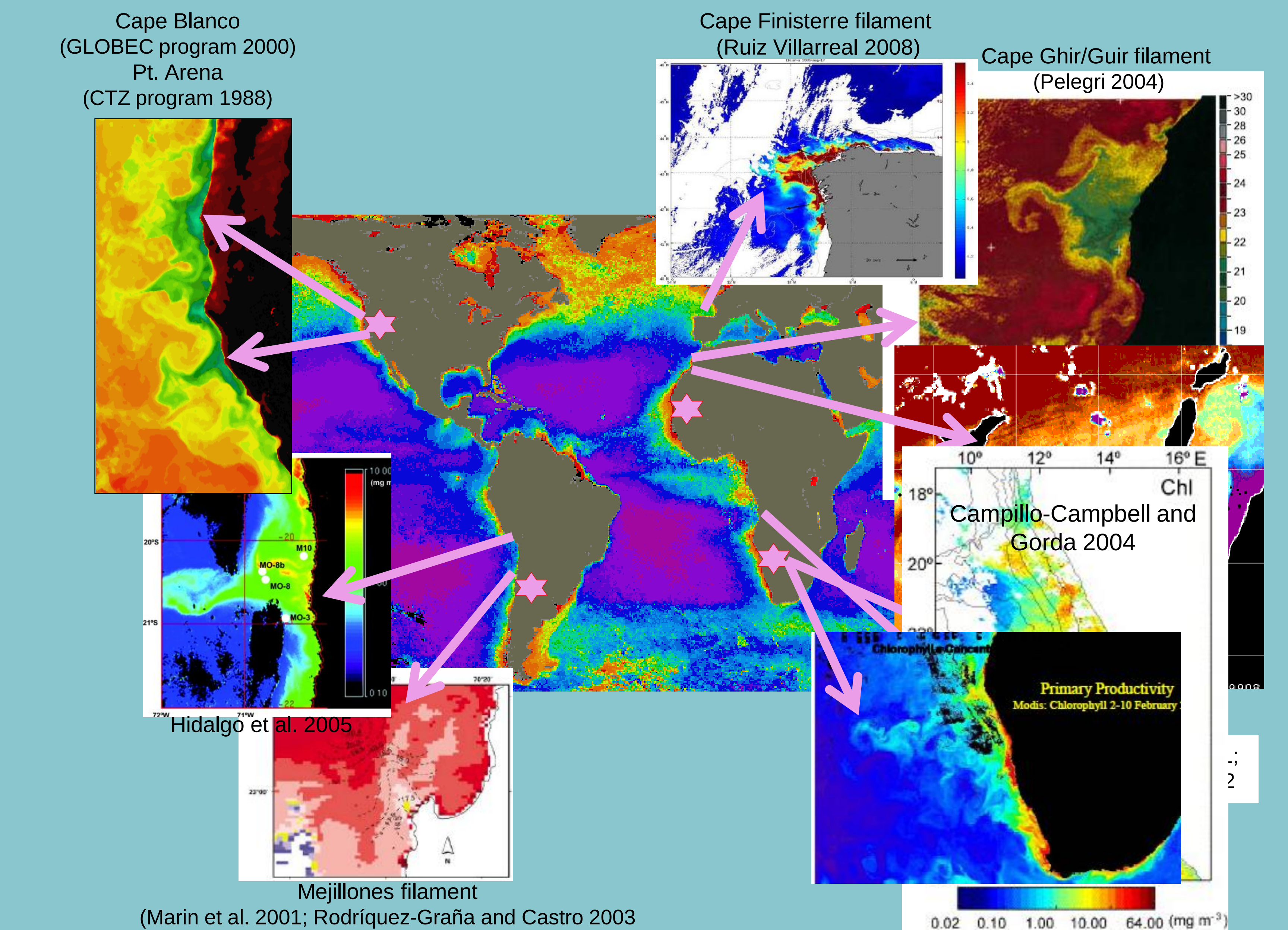
Although ocean margins cover <8% of the total ocean surface, they support 18–33% of the global net primary production and 27–50% of the global export production

- Eastern Boundary Upwelling systems are <1% of the world ocean, but account for ~11% of global new production.

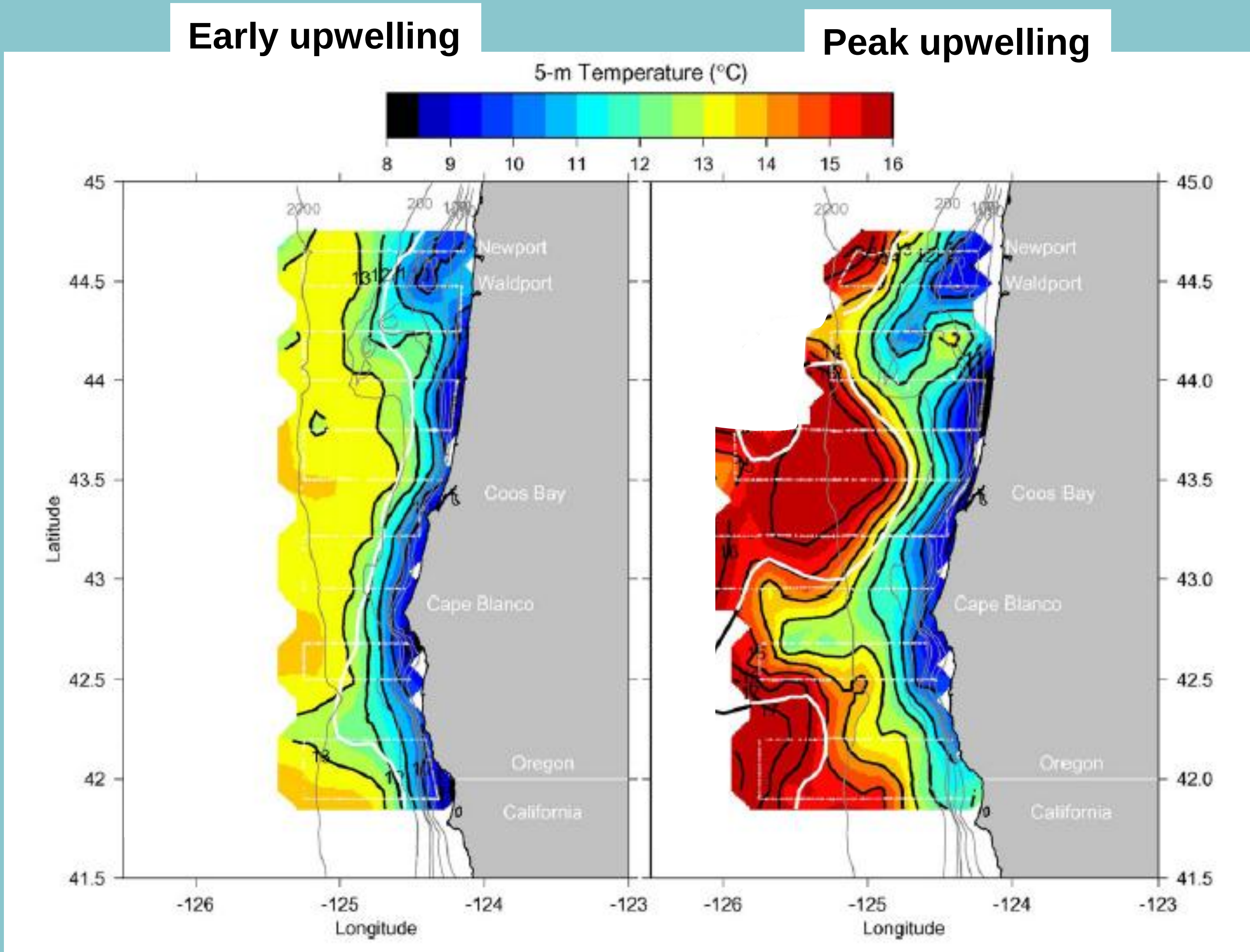



(a) Chlorophyll
CALIFORNIA CURRENT
CANARY CURRENT
HUMBOLDT CURRENT
BENGUELA CURRENT
mg m⁻³
(b) Productivity
CALIFORNIA CURRENT
CANARY CURRENT
HUMBOLDT CURRENT
BENGUELA CURRENT
g C m⁻² day⁻¹

Carr (2001)

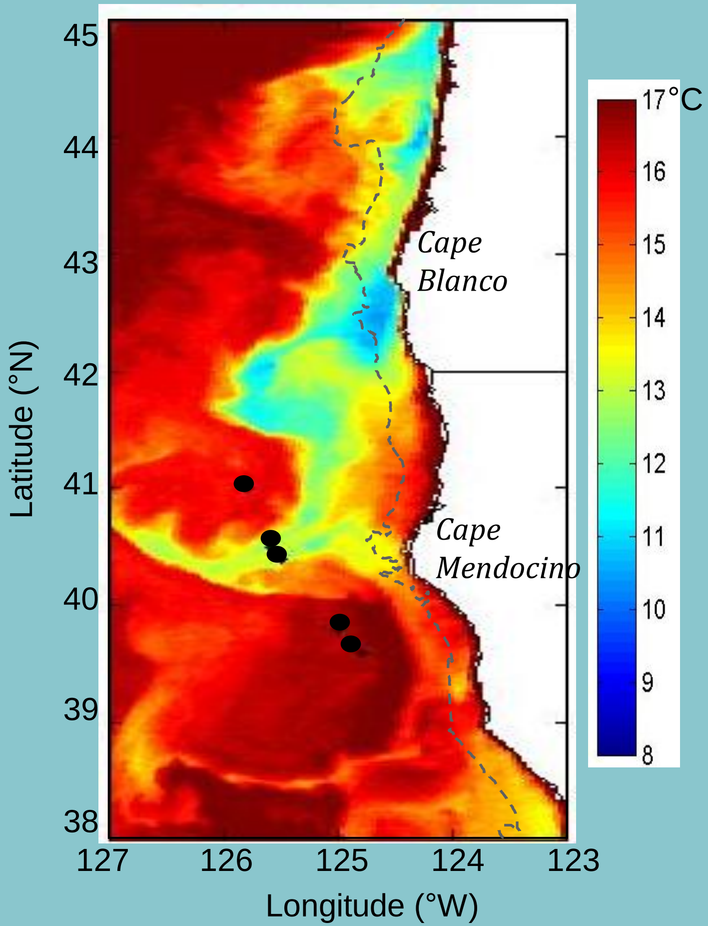


Cape Blanco
(GLOBEC program 2000)
Pt. Arena
(CTZ program 1988)
Cape Finisterre filament
(Ruiz Villarreal 2008)
Cape Ghir/Guir filament
(Pelegri 2004)
>30
30
28
26
25
24
23
22
21
20
19
10º
12º
14º
16º E
18º
20º
Chl
Campillo-Campbell and
Gorda 2004
Primary Productivity
0.02
0.10
1.00
10.00
64.00 (mg m-3)
10.00
MO-8b
MO-8
MO-3
M10
20ºS
21ºS
72ºW
71ºW
Hidalgo et al. 2005
Mejillones filament
(Marin et al. 2001; Rodríquez-Graña and Castro 2003



Early upwelling
Peak upwelling
5-m Temperature (°C)
8
9
10
11
12
13
14
15
16
Newport
Waldport
Coos Bay
Cape Blanco
Oregon
California
Latitude
Longitude
45
44.5
44
43.5
43
42.5
42
41.5
45.0
44.0
43.0
42.0
-126
-125
-124
-123

24 July 2006



UW vessel

R/V Thomas G. Thompson

<u>Zooplankton net tows</u>:

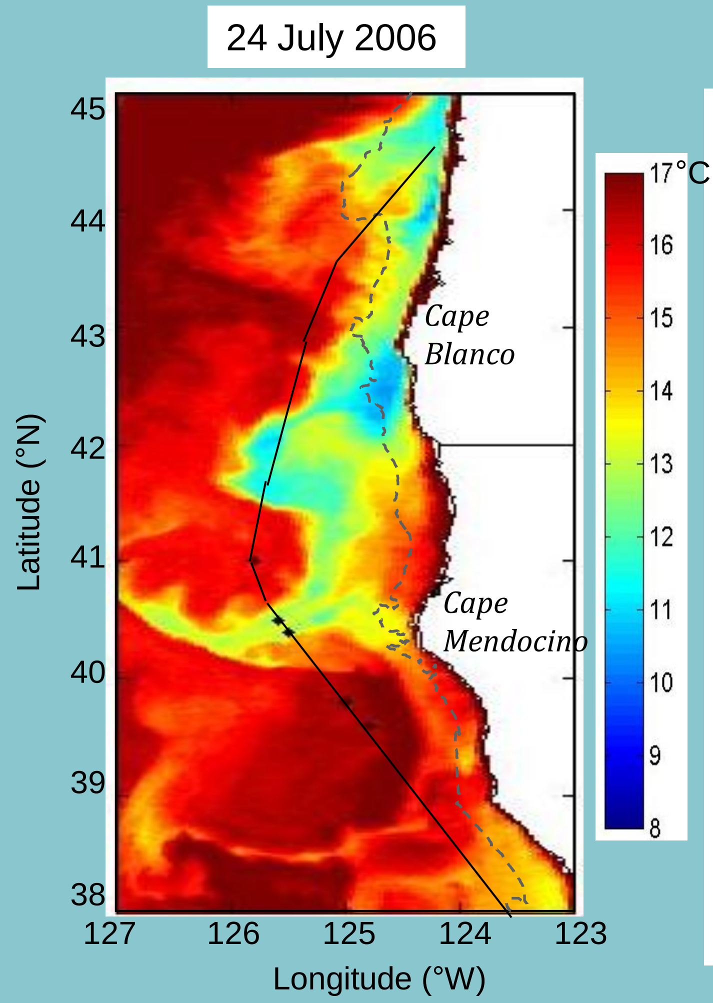
Vertical tows

(½ -m diameter ring, 202-μm mesh, integrated over upper 100 m)

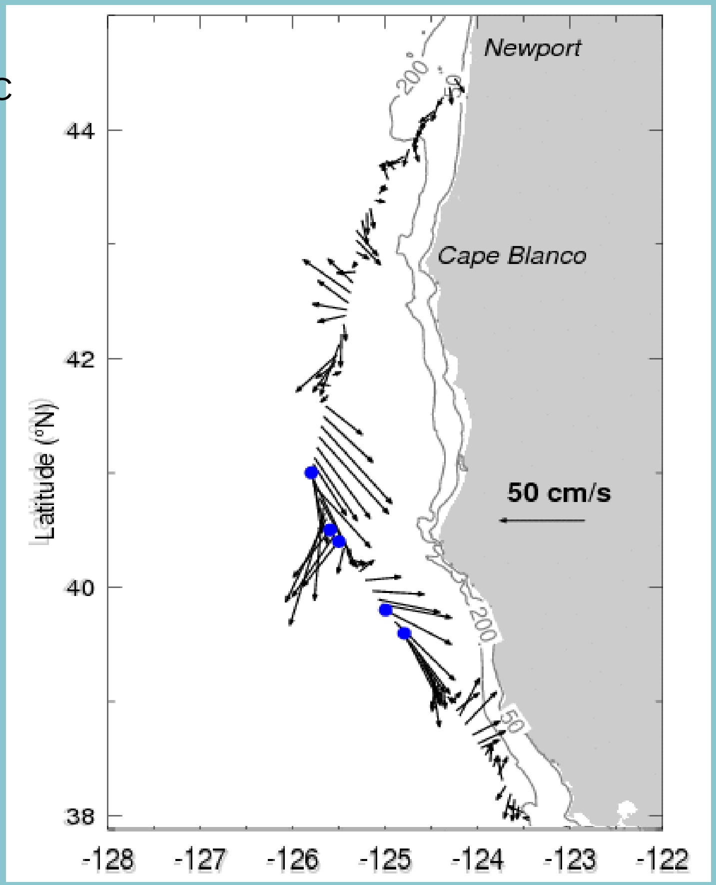
<u>ADCP data</u>: Processed by Steve Pierce

<u>CTD casts</u>

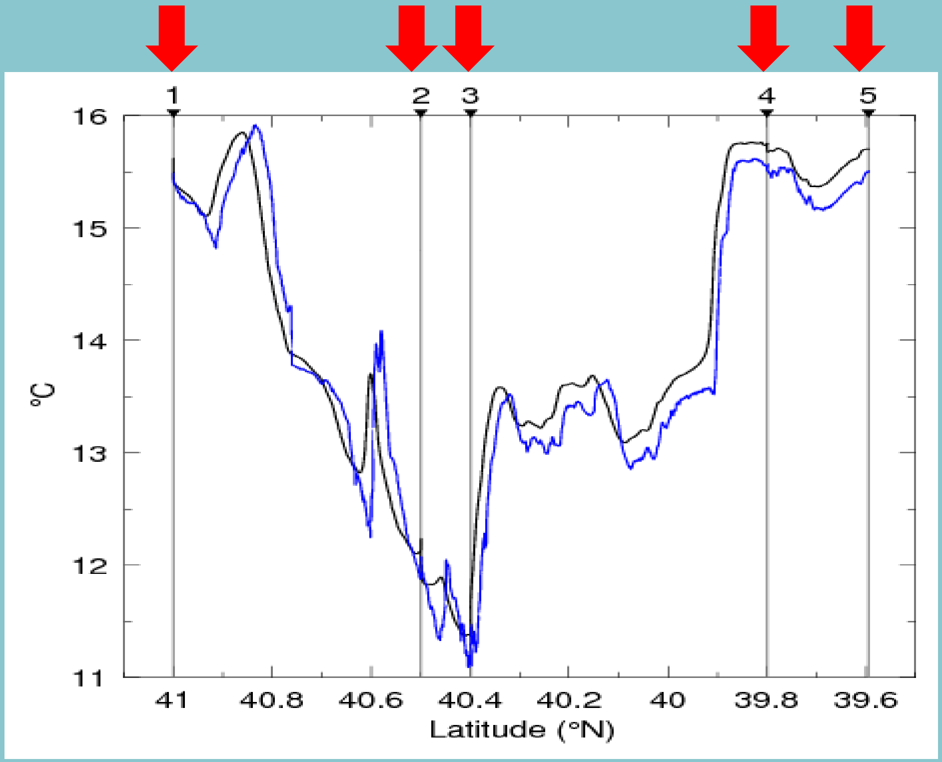
<u>Copepods</u>: ID'd to species and life stage in lab

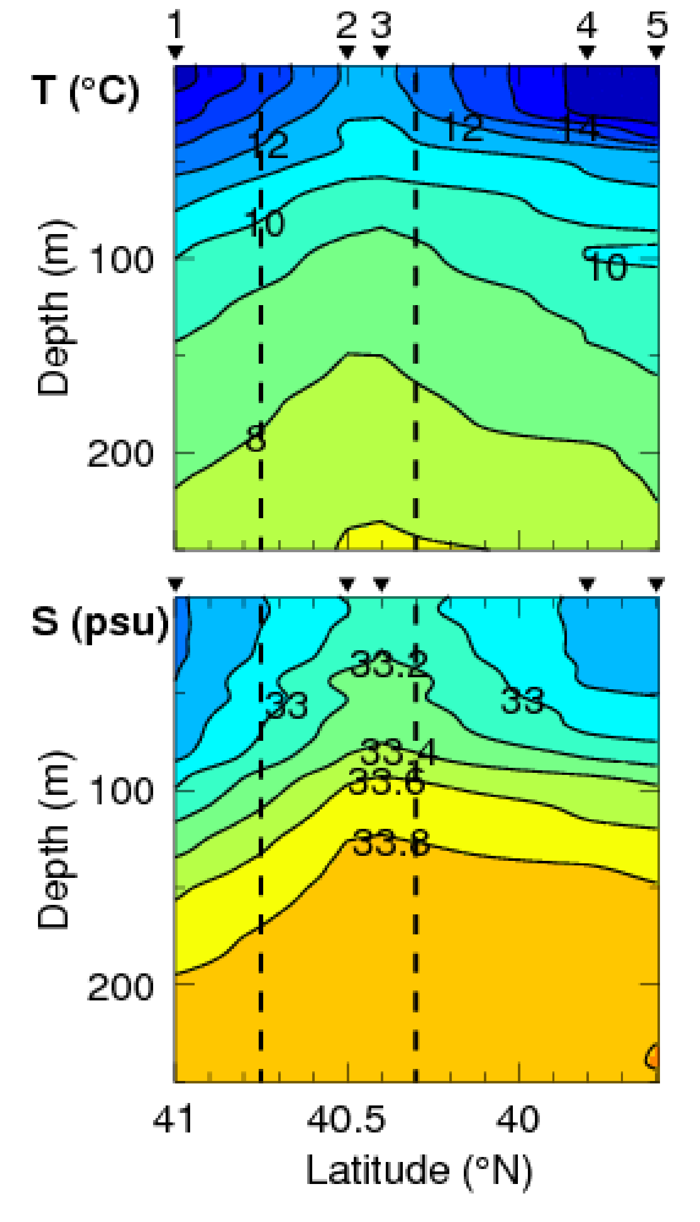


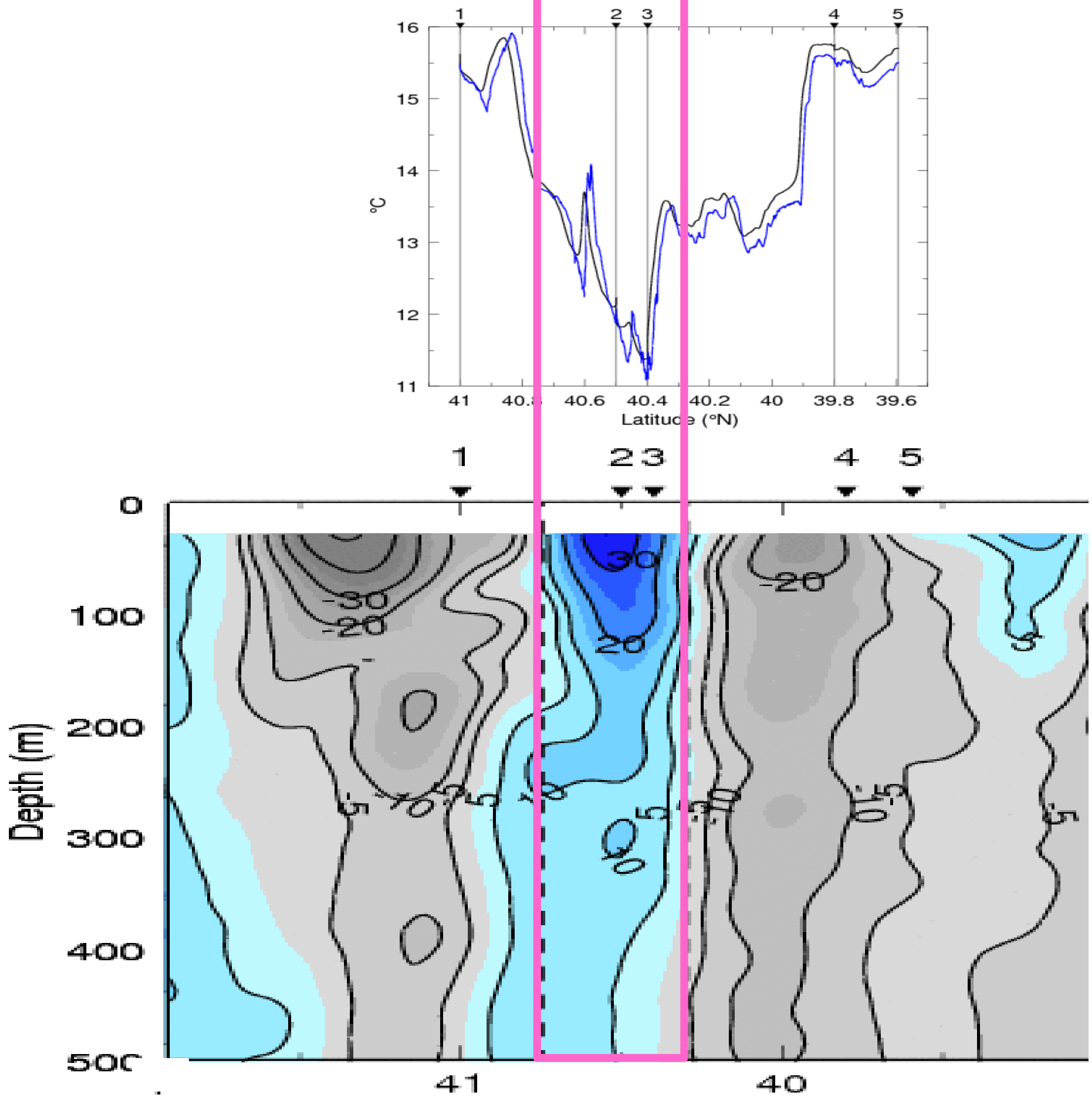
0-100 m ADCP velocities



Underway flow-through temperature
used to choose station locations





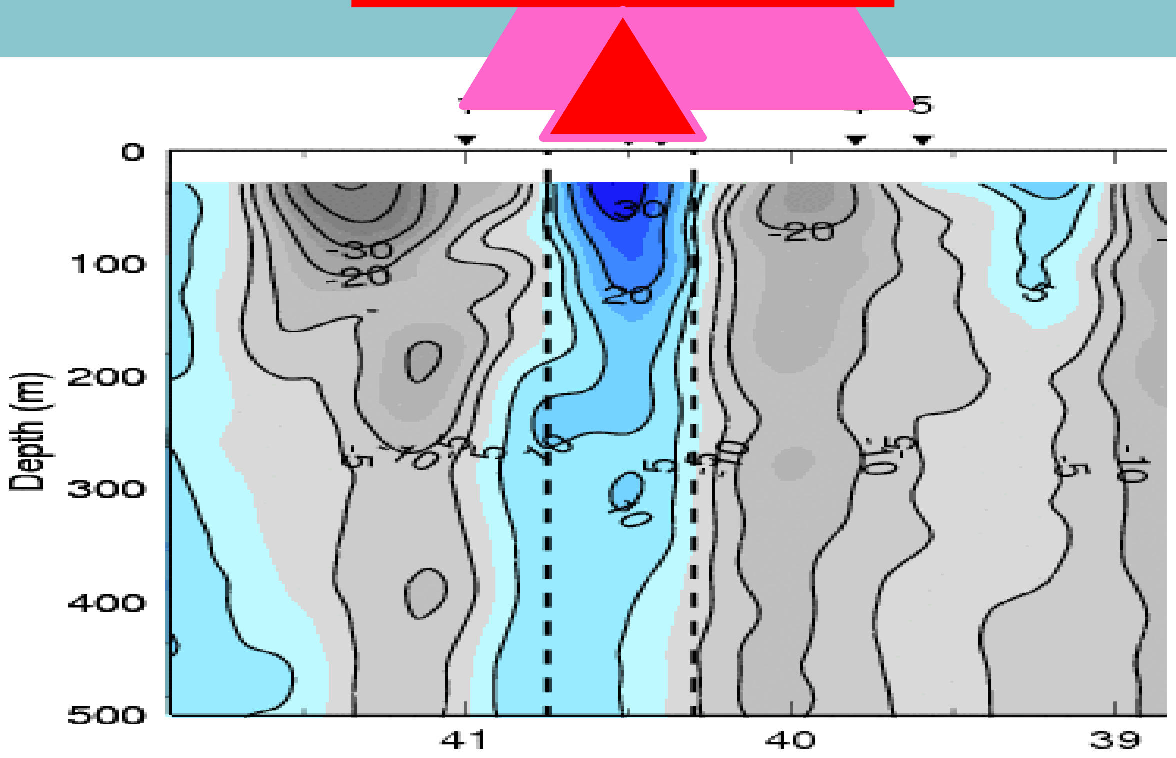


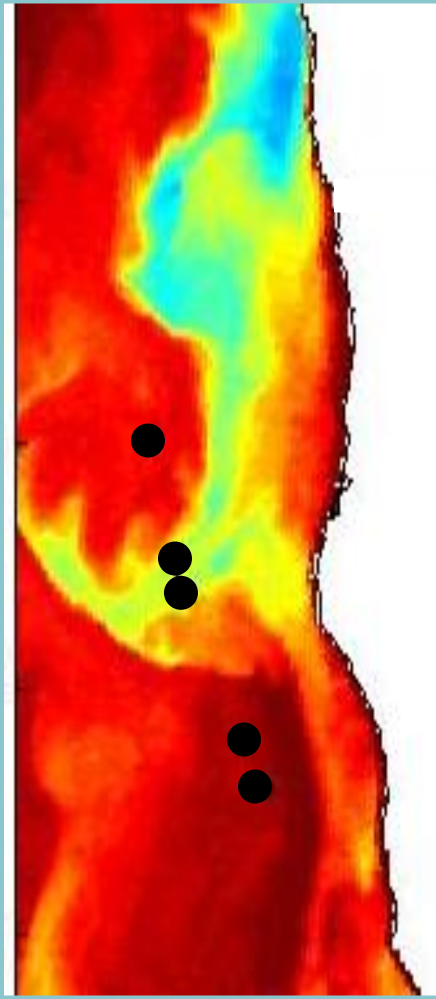
°C
Latitude (°N)
Depth (m)

0 to 100 m depth transport :

0.06 Sv transport *onshore*

1.54 Sv *offshore* transport

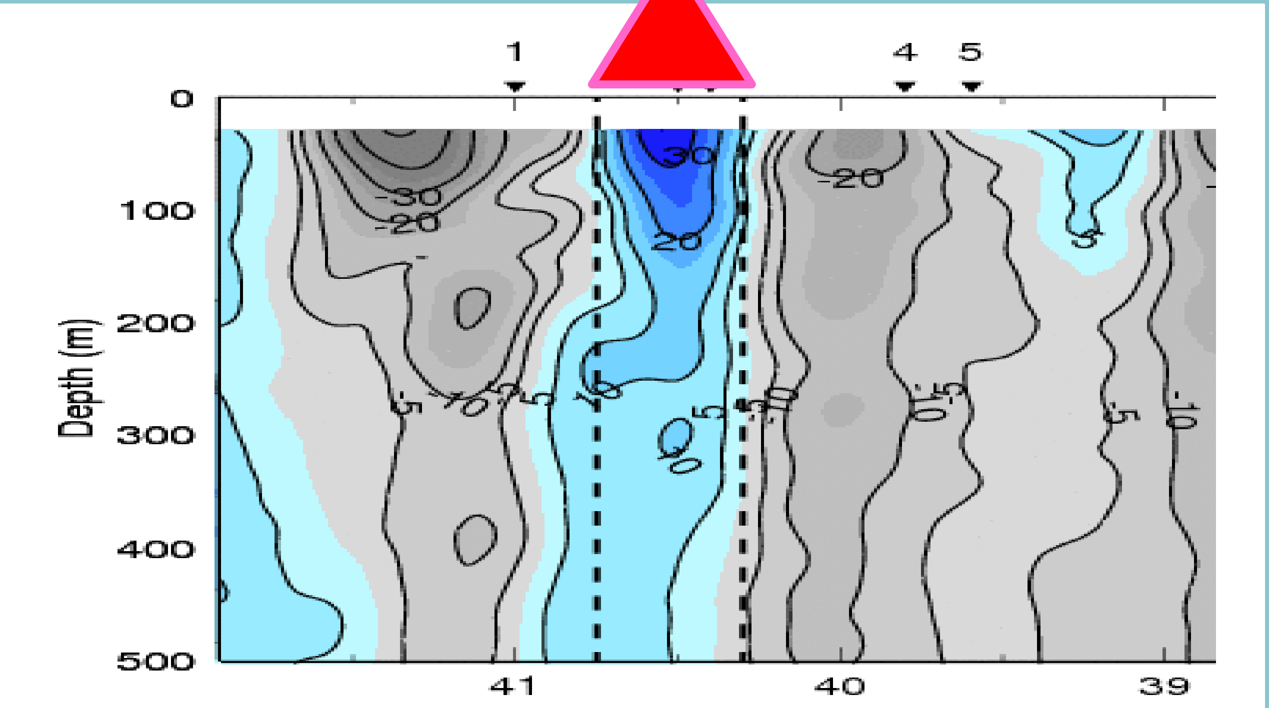


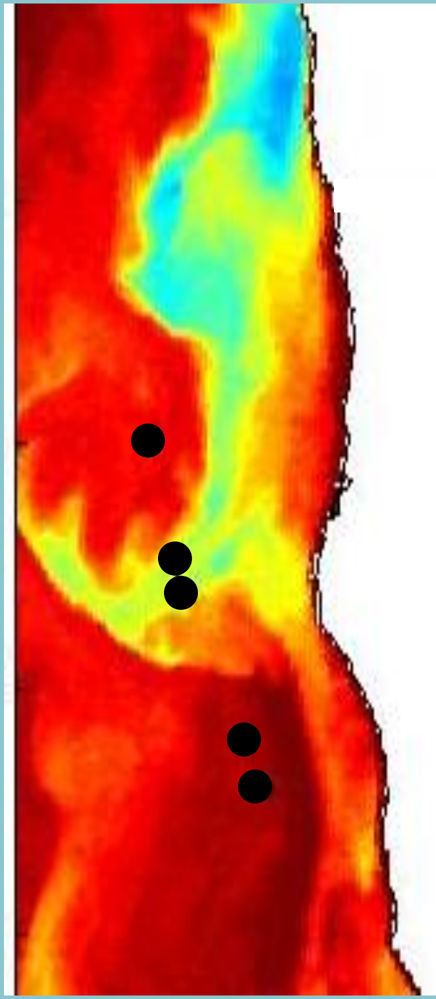


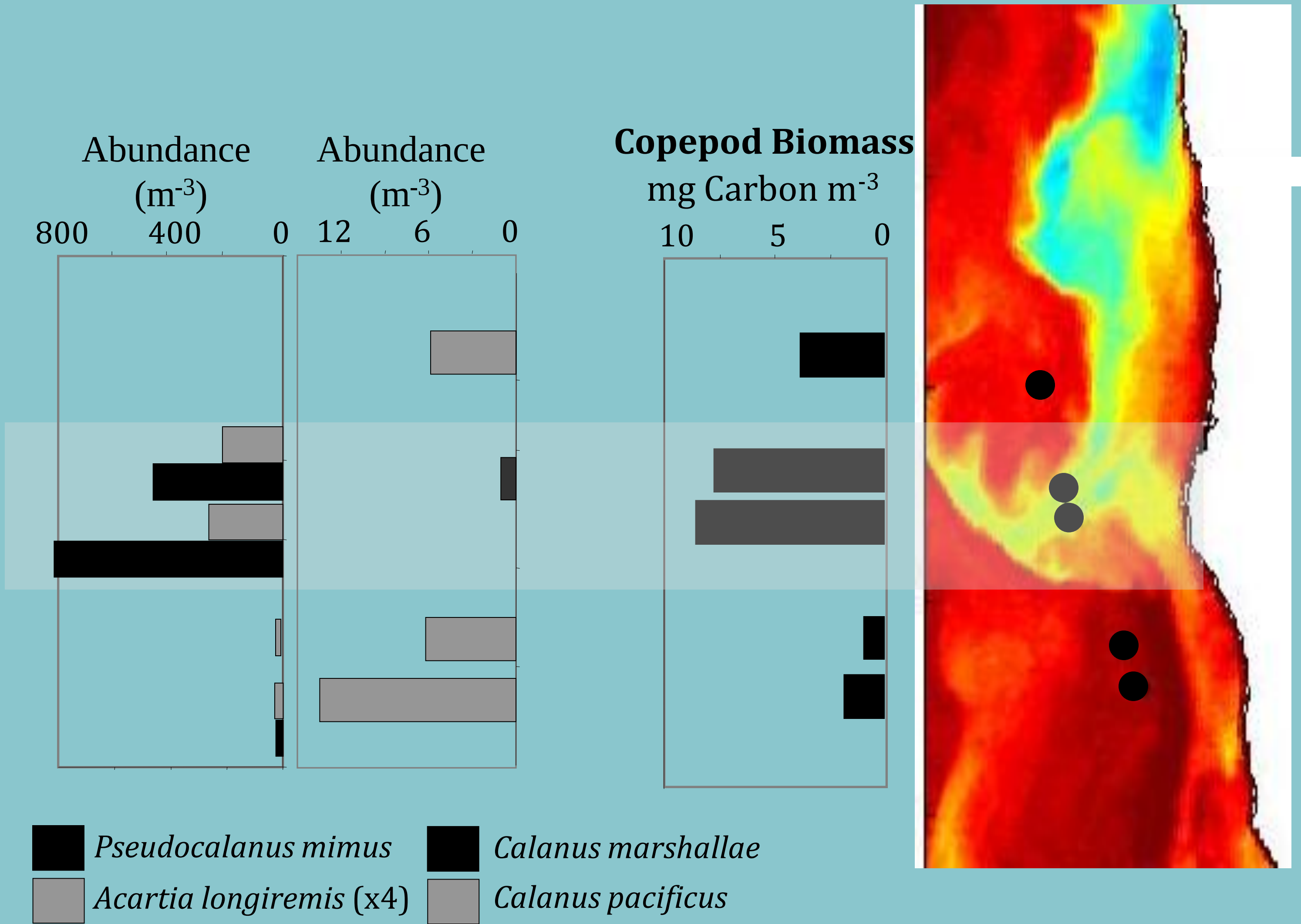
(1 Sv =10^6 m^3/s)

0 to 500 m transport :

3.64 Sv *offshore* transport







Abundance (m^{-3})
800 400 0
Abundance (m^{-3})
12 6 0
Copepod Biomass
mg Carbon m^{-3}
10 5 0
Pseudocalanus mimus
Acartia longiremis (x4)
Calanus marshallae
Calanus pacificus

In this (and other) studies:

Temperature : Biomass correlation R^2= 0.91

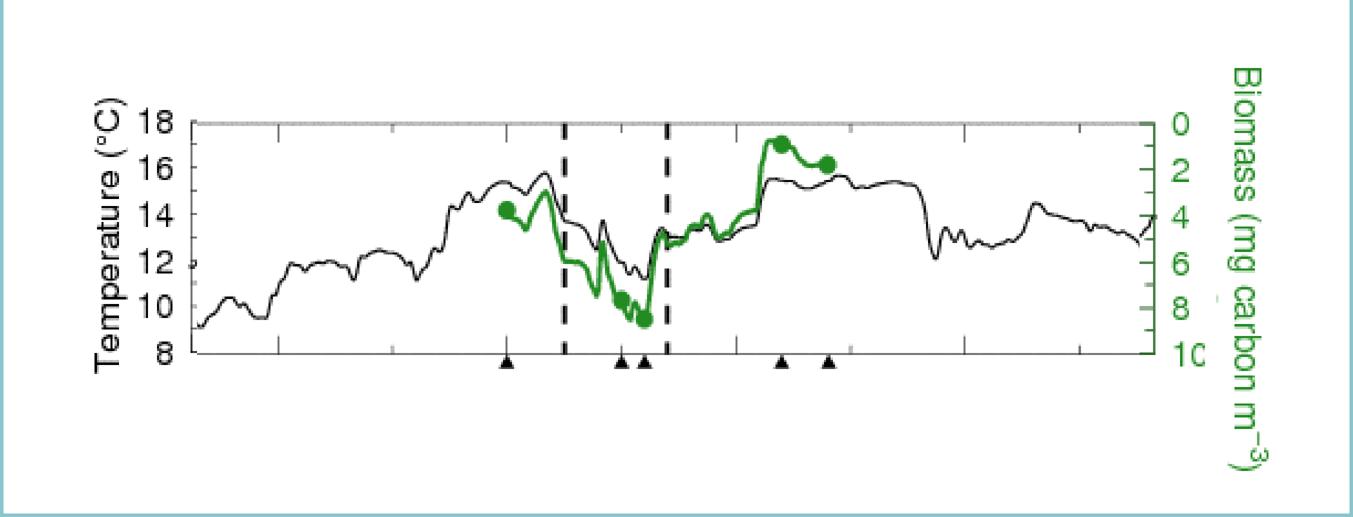
Exploit to interpolate biomass between stations using temperature

Interpolation model: Biomass = $a + bT + cy + dy^2 + ey^3$

where T is temperature,

y is latitude (to force data through the original points),

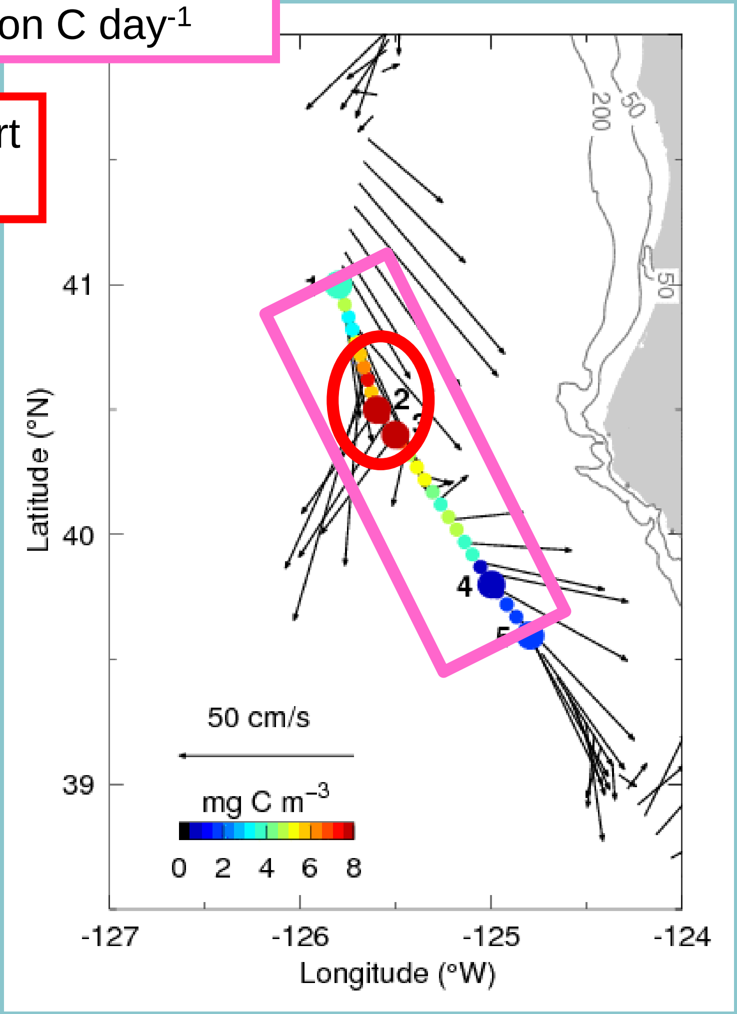
solving for the 5 coefficients a-e

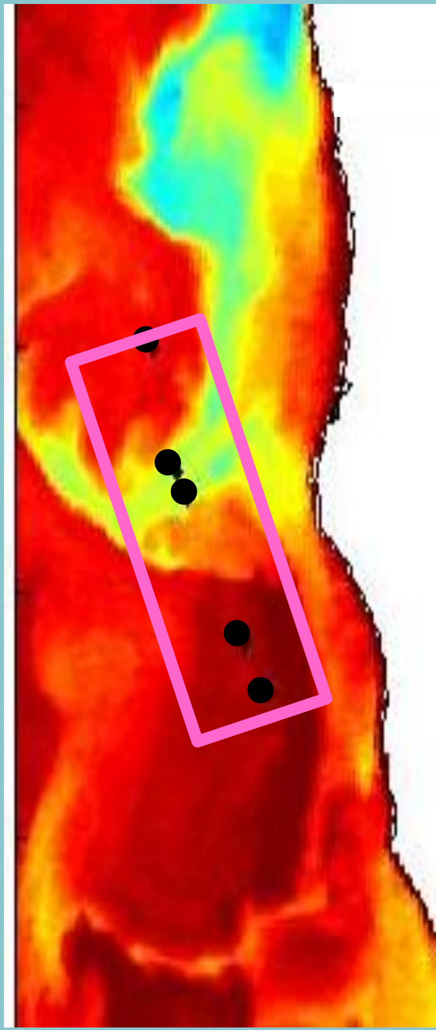


0.06 Sv transport *onshore*
500 tonnes zooplankton C day^{-1}

1.54 Sv *offshore* transport
940 tonnes C day^{-1}

Estimated total (to 500 m) transport:
>3.6 Sv

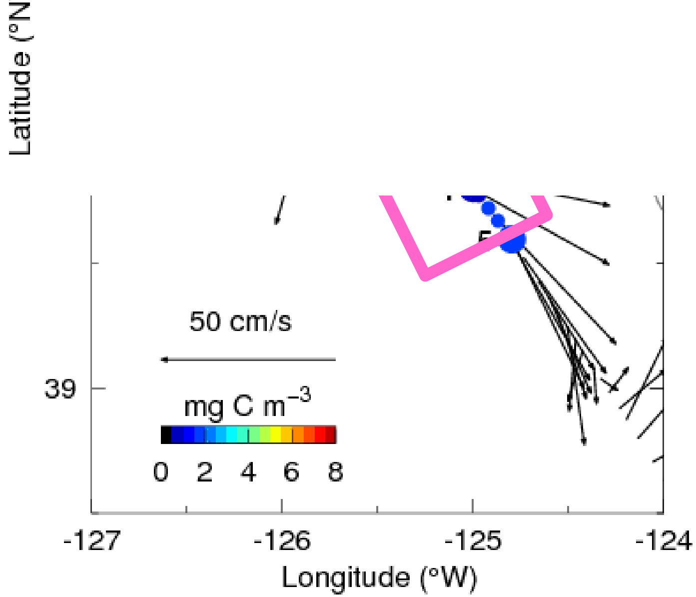


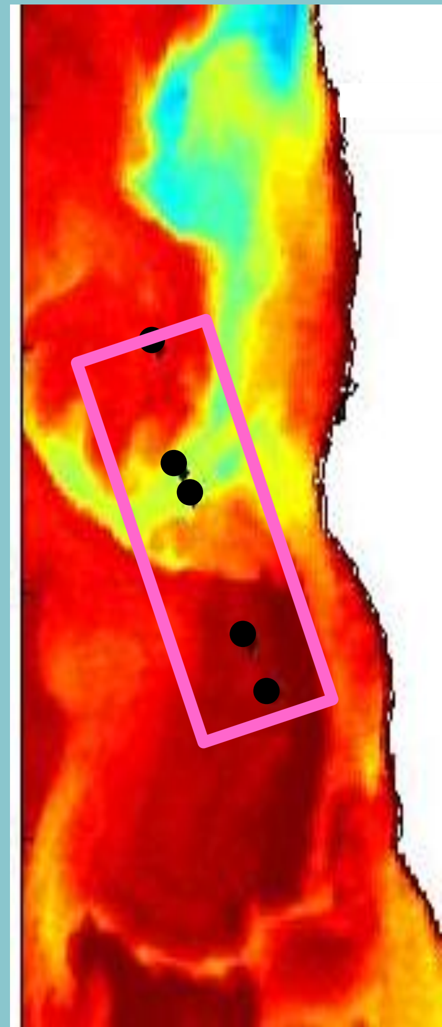


0.06 Sv transport *onshore*
500 tonnes zooplankton C day^{-1}

1.54 Sv *offshore* transport
940 tonnes C day^{-1}

- Transport timing
- Transport location
- Transport volume/velocity
- Coastal biomass



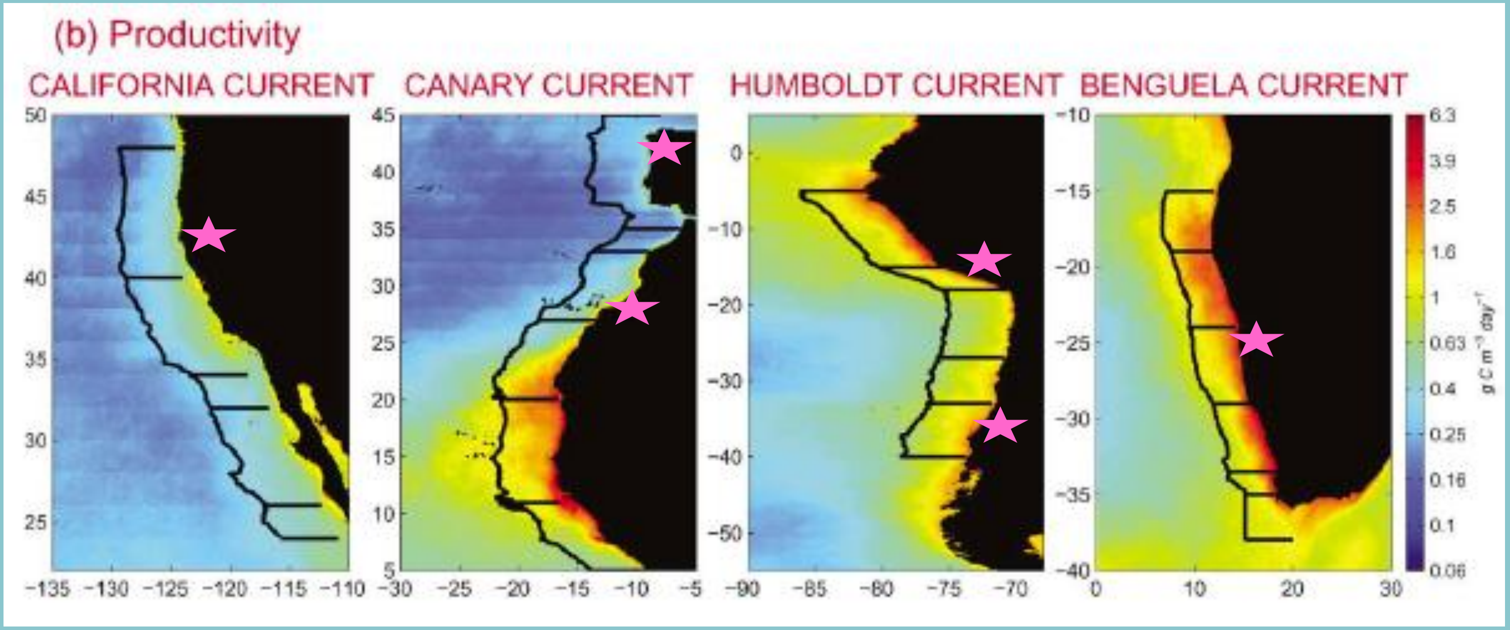


Estimated total (to 500 m) transport:
>3.6 Sv

Filament characteristics:

	Length (km)	Width (km)	Depth (m)	Velocity (cm/s)	Transport (Sv)	References
California Current						
Northern	>100	20 km	>100 m	30-50 cm/s	0.5 Sv	GLOBEC NEP; Barth et al 2003
Central	>500 km	70-100 km	200-500 m	40-80 cm/s	2-4 Sv	CTZ study
Canary Current						
NW Iberia	150 km	60 km	50 m	30-40 cm/s	1-1.5 Sv	Álvarez-Salgado et al. 2001/2007;
Humboldt Current						
	10-50 km	<100 km	<150 m	15-20 cm/s	0.6 Sv	Marin et al .2001; Hidalgo et al. 2005
Benguela Current						
	>1000 km	50 km	>100 km	40-80 cm/s	>1.5 Sv	Lutjeharms et al. 1991; Shillington et al 1992

Estimated productivity using SeaWiFS:
(Carr 2001)



0.04 Gt C yr^{-1} 0.33 Gt C yr^{-1} 0.20 Gt C yr^{-1} 0.37 Gt C yr^{-1}

Carr (2001)

Zooplankton Biomass - Comparison among EBUS

System	Method	Period	Biomass (g C m^{-2})	Reference
Canary	Review, not listed; 0-200m	Review	**Zooplankton**: Coastal upwelling = 2.6–7.0 Canary Island waters = 0.2-0.4	Hernandez-Leon et al. (2007)
S Benguela Central West Coast (31-33°S),	Vertical Bongo, 200 µm, 0-200m	Biannual 1988-2003	**Copepods**: Shelf Mean = 3.2 Spring = 4.0; Winter = 2.8	This study
S Benguela St Helena Bay (33°S),	Vertical WP2, 200 µm, 0-200m	Monthly July 2001 – Feb 2003	**Zooplankton (<1600; >1600 um):** Shelf Mean = 13 (8.9; 3.7)	E. Koch & L. Hutchings pers. comm.
California Southern (32-34°N); Central (35-38°N)	Double oblique, 505/550 µm, 0-210m	1951-2005 Spring (March-May)	**Zooplankton:** Southern = 1 Central = 1.5	Lavaniegos & Ohman (2007)
Humboldt Central Chile (36.51°S)	Oblique tows 200 µm 80-0m	Monthly Aug 2002 – June 2007	**Zooplankton:** Mean = 2.9 Upwelling = 4 Non-upwelling = 2	R. Escribano pers comm; 2007 P. Hidalgo (this meeting)

Slide courtesy of Jenny Huggett

Production and transport - Comparison among EBUS

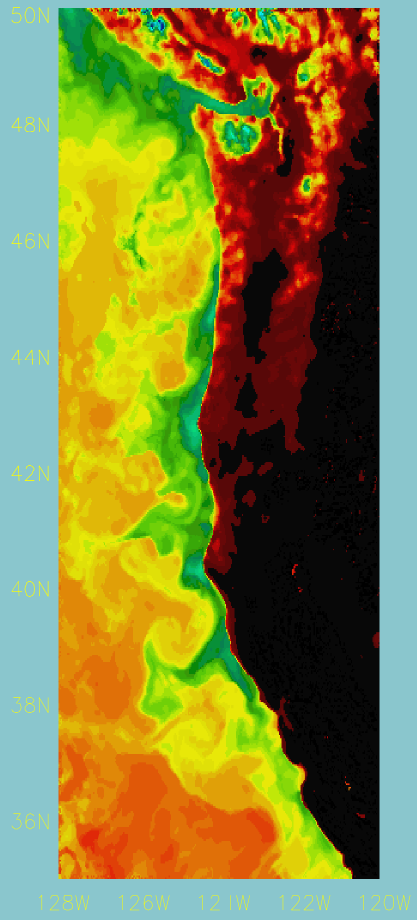
System	Component	PP g C/ m2/day	Transport	% of coastal production	Reference
Canary	Phytoplankton Zooplankton **	2	9.6×10^{9} g C /day 8.6×10^{7} g C /day	45%* 20-60%	Hernández-León et al. (2007); Aristegui et al. Álvarez-Salgado et al. 2001
Benguela					Peterson data available?
California	Phytoplankton Zooplankton	1.2	1.4×10^{8} g C /day 9×10^{8} g C /day	 2-9% /day	Chavez et al. 1991 Keister et al. 2008
Humboldt	Phytoplankton Zooplankton	1	1.6×10^{12} g C /day ??	5-12%*	Marin et al (2003) Morales data available?

*Fisher et al (2009) estimated that offshore flux contributed 70% of C to offshore in winter/spring.

** Estimated from published data

Conclusions:

- Single upwelling filaments can advect high biomass of organic (and very labile) carbon offshore
- The cross-shelf transport is of a magnitude to be relevant in carbon cycling
- Filament structure and carbon transport differ among boundary currents
- This carbon input to the oligotrophic ocean either enters the pelagic food web or contributes to export production



More research needed on:

The fate of the advected coastal zooplankton and their contribution to export production

The role of transport on oligotrophic ocean ecosystems (“hot spots”? benthic production?)

The effects of filament transport on maintenance of shelf populations (significant losses?)

Relative importance among boundary systems

The links between climate variability and circulation/zooplankton populations

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Chris Wingard

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