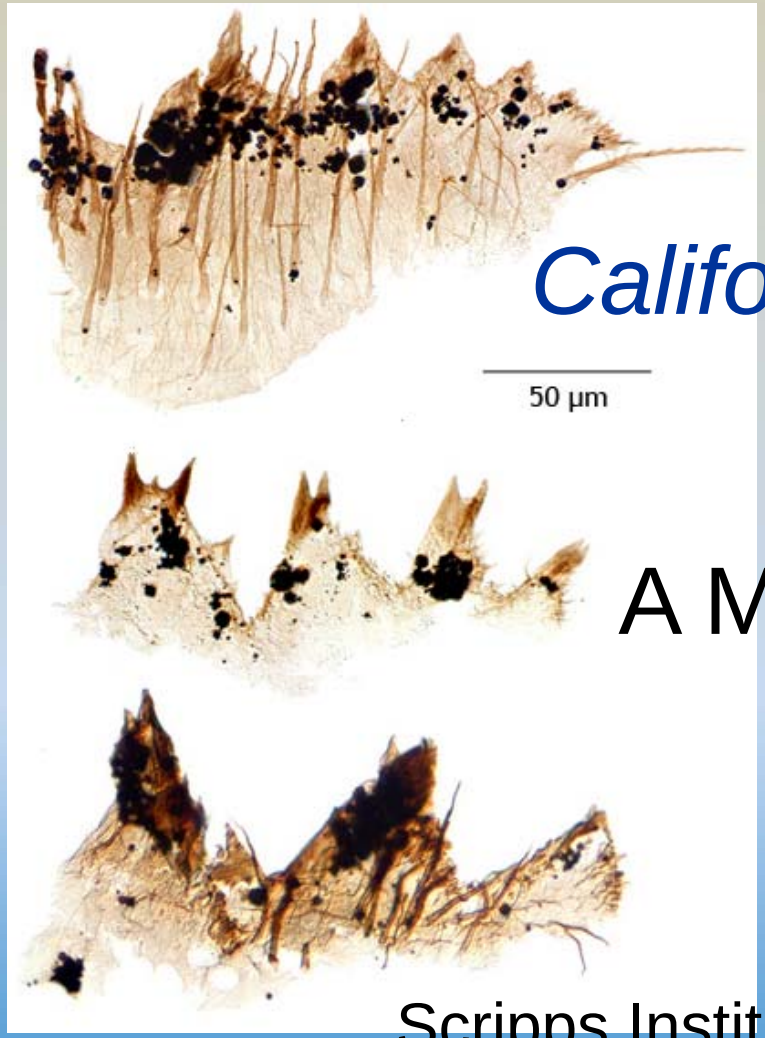


California Current Ecosystem Dynamics

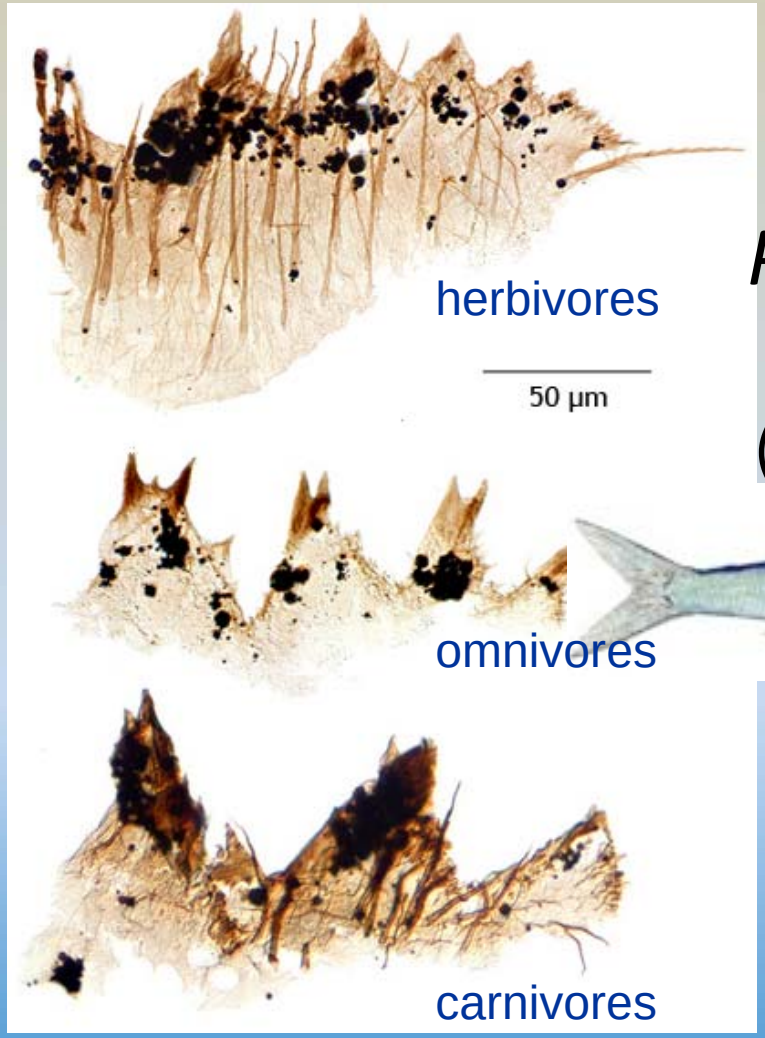
A Multi-scale Perspective

Mark D. Ohman

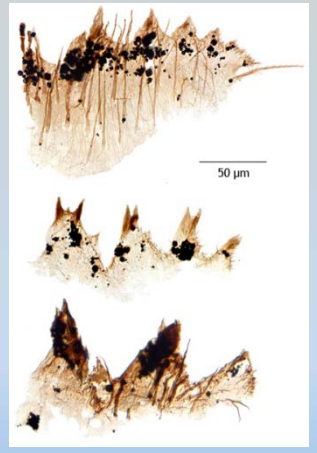
Scripps Institution
of Oceanography

CCE-LTER site

Copepod jaws (mandibles)



Predation by bony fishes
(250-200 M.y.a.)



Modern ocean

Middle-to-late Cambrian

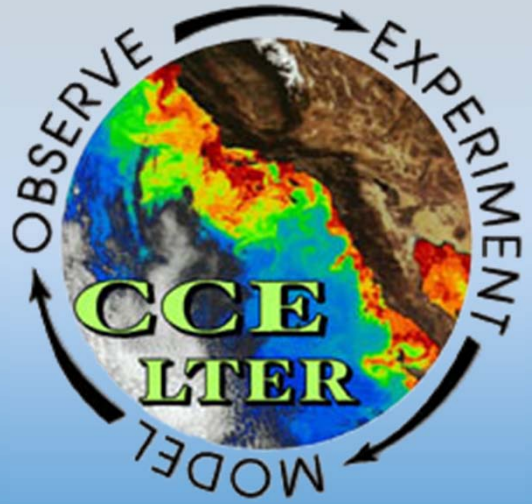
490-510 M.y.a.

Deadwood Formation

Marine sediments, Western Canada

Harvey et al. 2012 PNAS

California Current Ecosystem
Long Term Ecological Research site

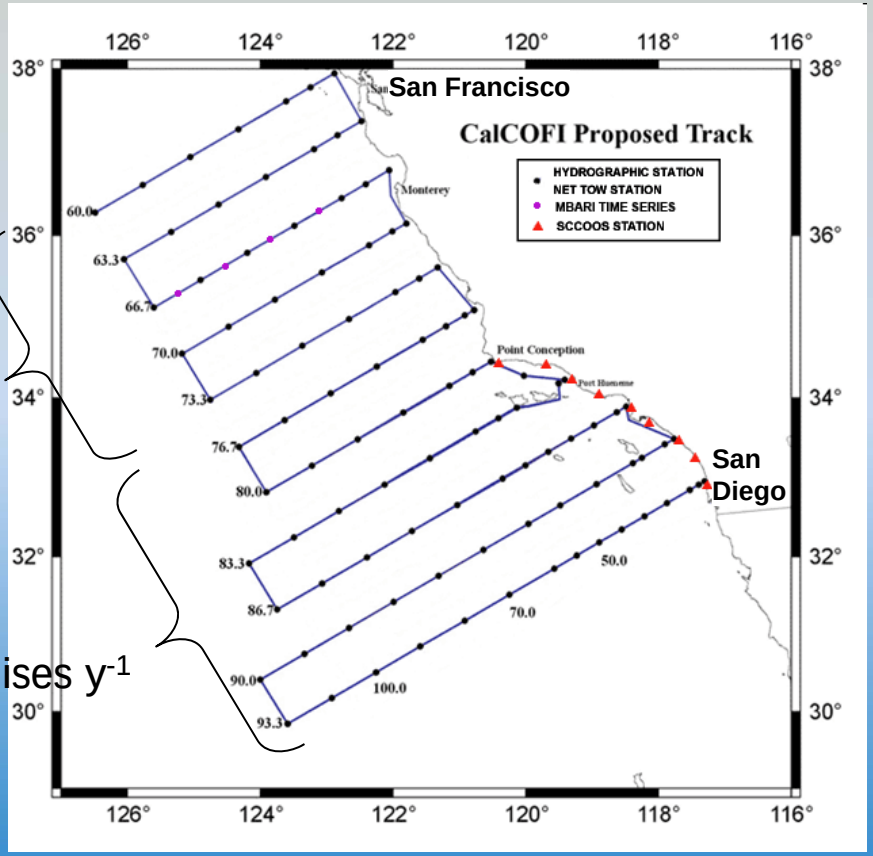


CCE-LTER Partnership with CalCOFI: a *space-resolving* time series

4 cruises year^{-1}

winter, spring cruises

all 4 cruises y^{-1}



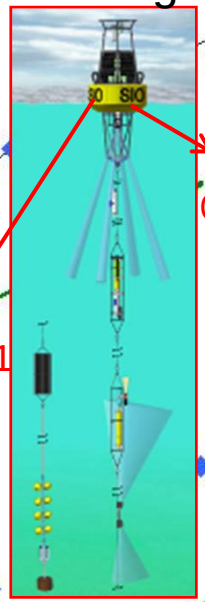
since 1949

See OCB News article by R. Goericke & T. Koslow

CCE-LTER Station Plan

Benthic time series
Sta. M (K. Smith)

Moorings



Pt. Conception

CCE2

CCE1

77

80

83

87

Ocean Institute

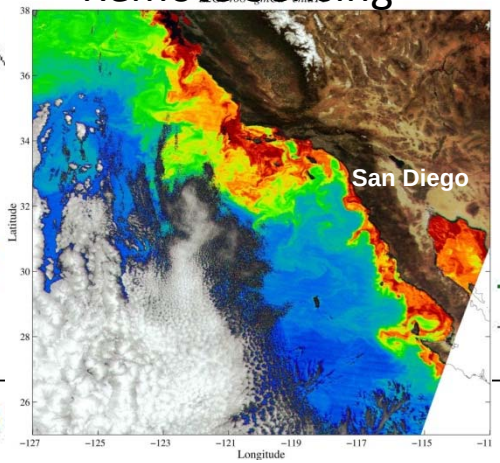
Scripps pier

Diego

Augmented CalCOFI

Spray gliders

Remote Sensing



35.5

31.5

29.5

-125

-123

-119

-117

http://ccelter.sio.ucsd.edu

Scripps Institution of Oceanography/U.C.S.D.

U.S. LTER Network - 26 sites

including terrestrial, aquatic, & human-dominated ecosystems

California Current Ecosystem

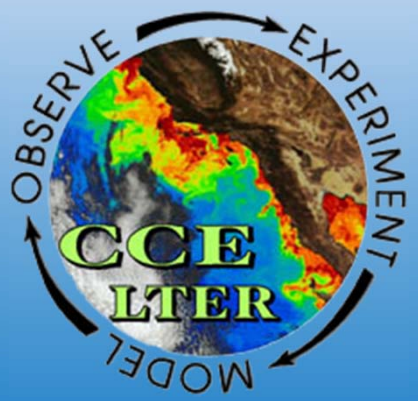
U.S. LTER Network - 26 sites

including terrestrial, aquatic, & human-dominated ecosystems

8 marine (or estuarine) sites

Multiple Time Scales of Ecosystem Response

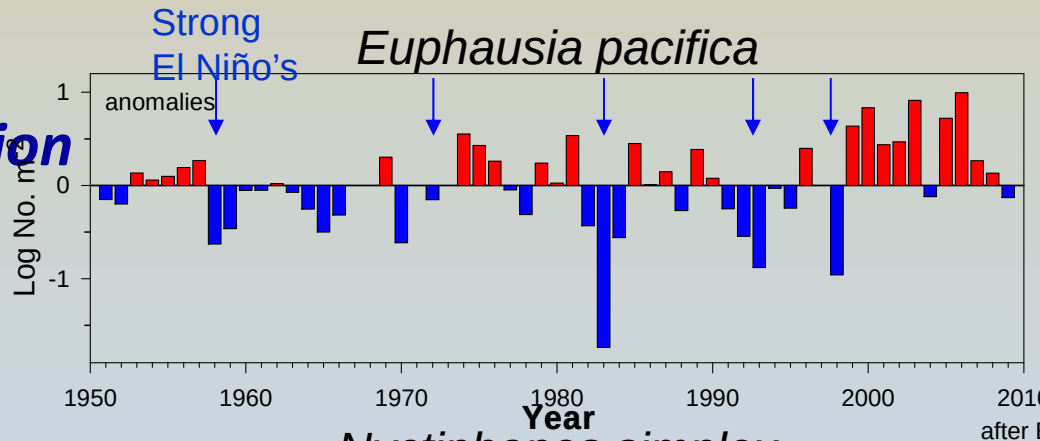
Spatial Structuring on Multiple Scales

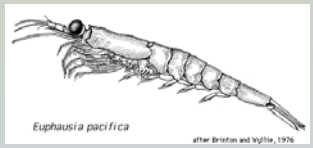


Multiple time scales of ecosystem forcing (and biotic response) in the California Current System

Interannual variation

especially ENSO

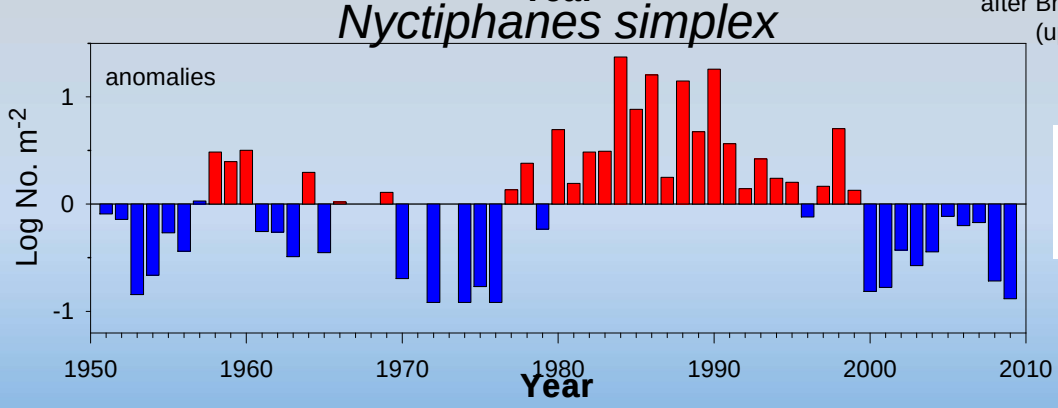


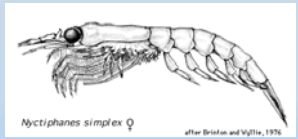


krill

after Brinton & Townsend 2003 (updated, M.Ohman)

(multi-) Decadal variation





krill

Secular trend

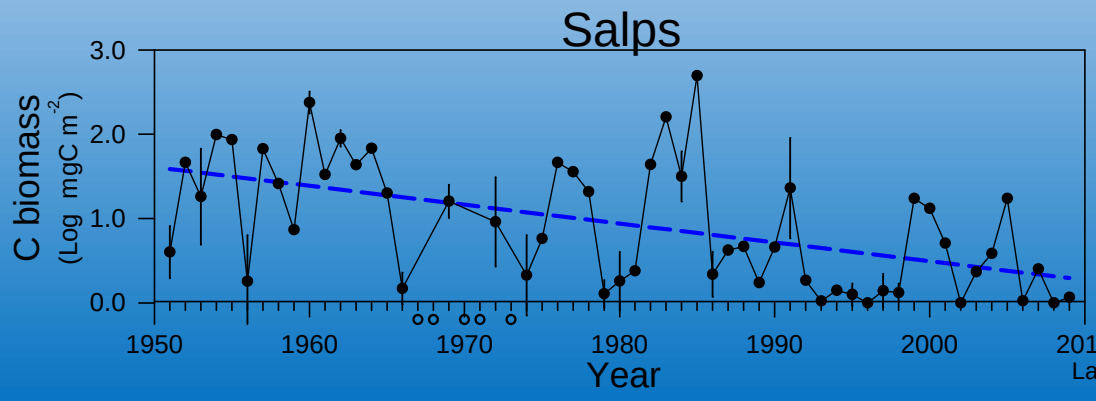
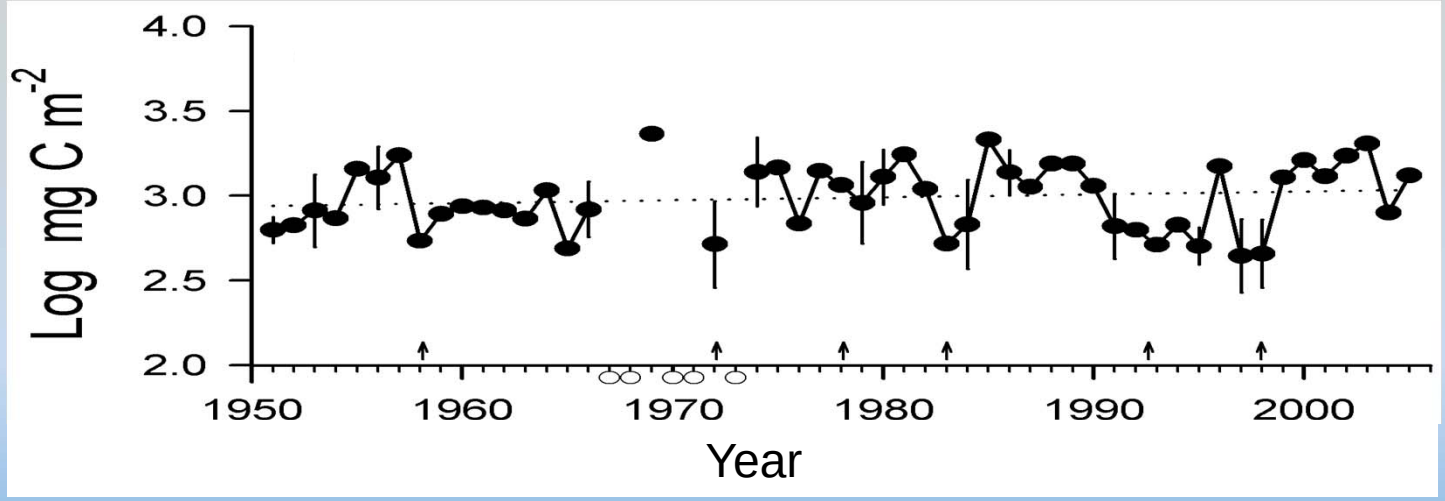


photo: D.Wrobel

Lavaniegos & Ohman 2007 (updated)

Total Zooplankton Carbon Biomass



CalCOFI samples
spring cruises
So CA
Lavaniegos and Ohman (2007)

Non-stationary time series

1. Resolving the mode of propagation of El Niño 2009/10 to mid-latitudes

Advection

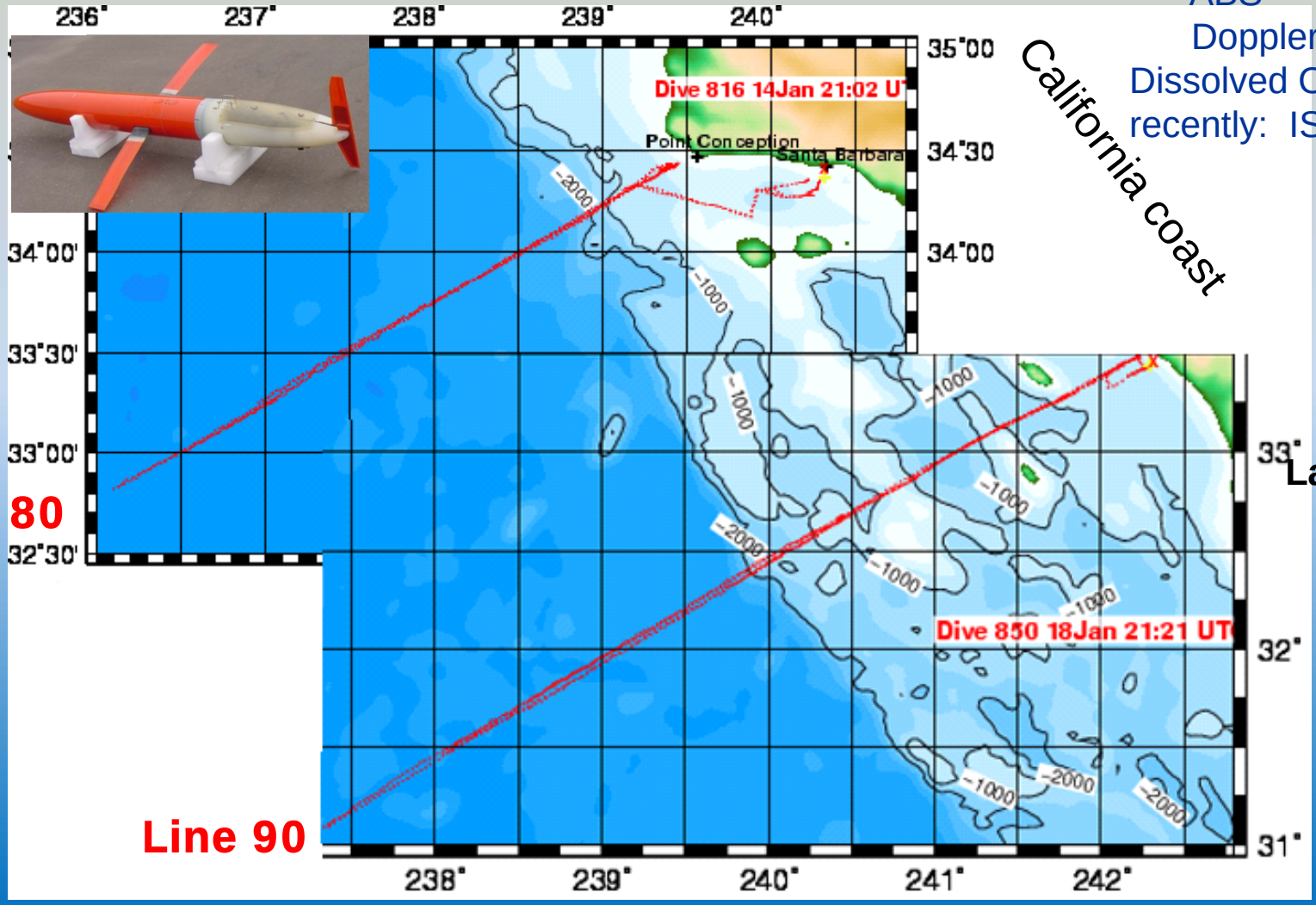
Coastally trapped waves

Atmospheric teleconnections

Spray ocean gliders – Russ Davis, Dan Rudnick, Mark Ohman SIO

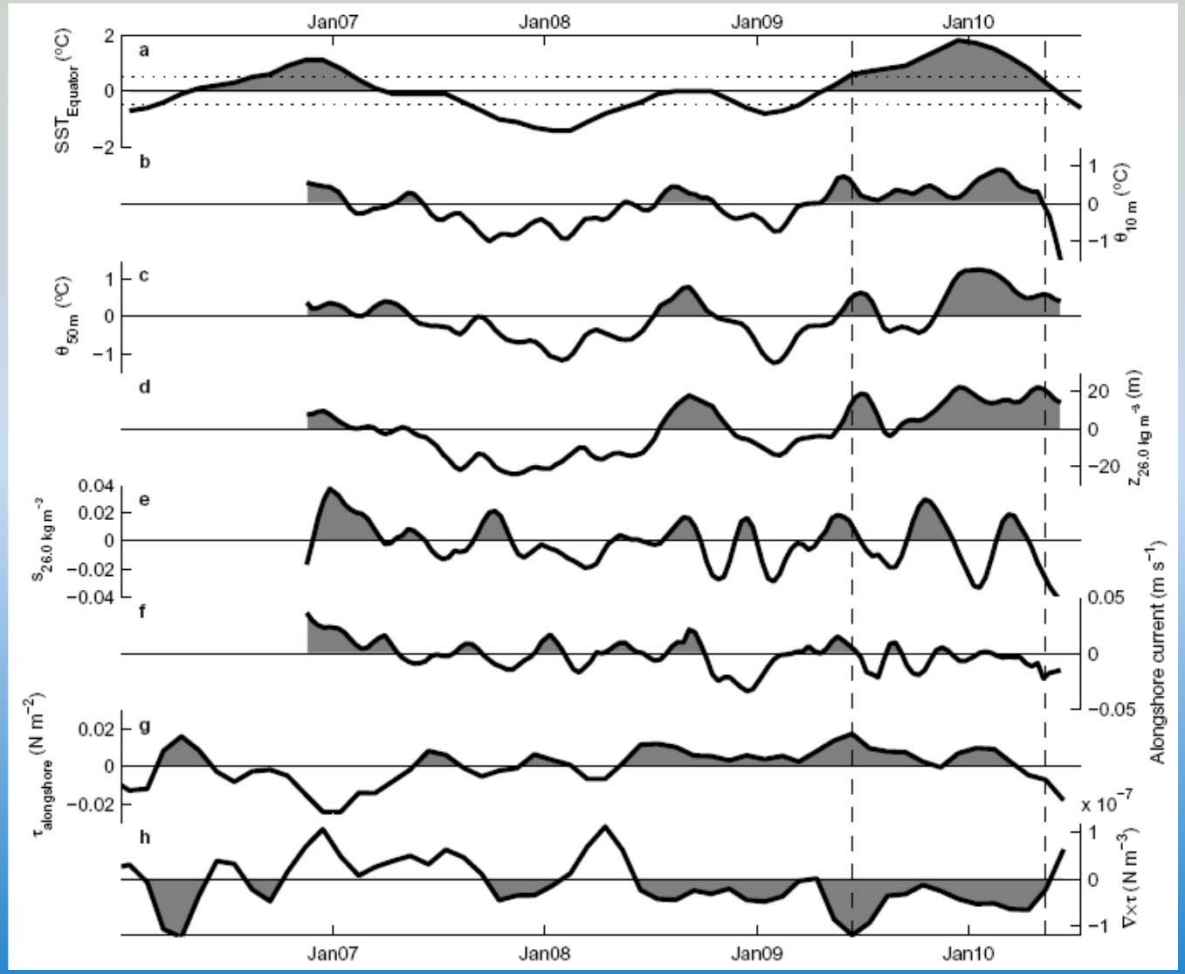
initiated: Oct. 2005
continuous since late 2006

Pumped CTD
Fluorometer
ADP – 750 kHz
ABS
Doppler shear
Dissolved O_2
recently: ISUS NO_3



2009-10 California Niño: warm temp., deep isopycnals but no anomalous water masses

⇒ *likely propagation via atmospheric teleconnections*



ONI (tropics)

10 m Temp

50 m Temp

$Z_{26.0}$

$Salinity_{26.0}$

Alongshore currents

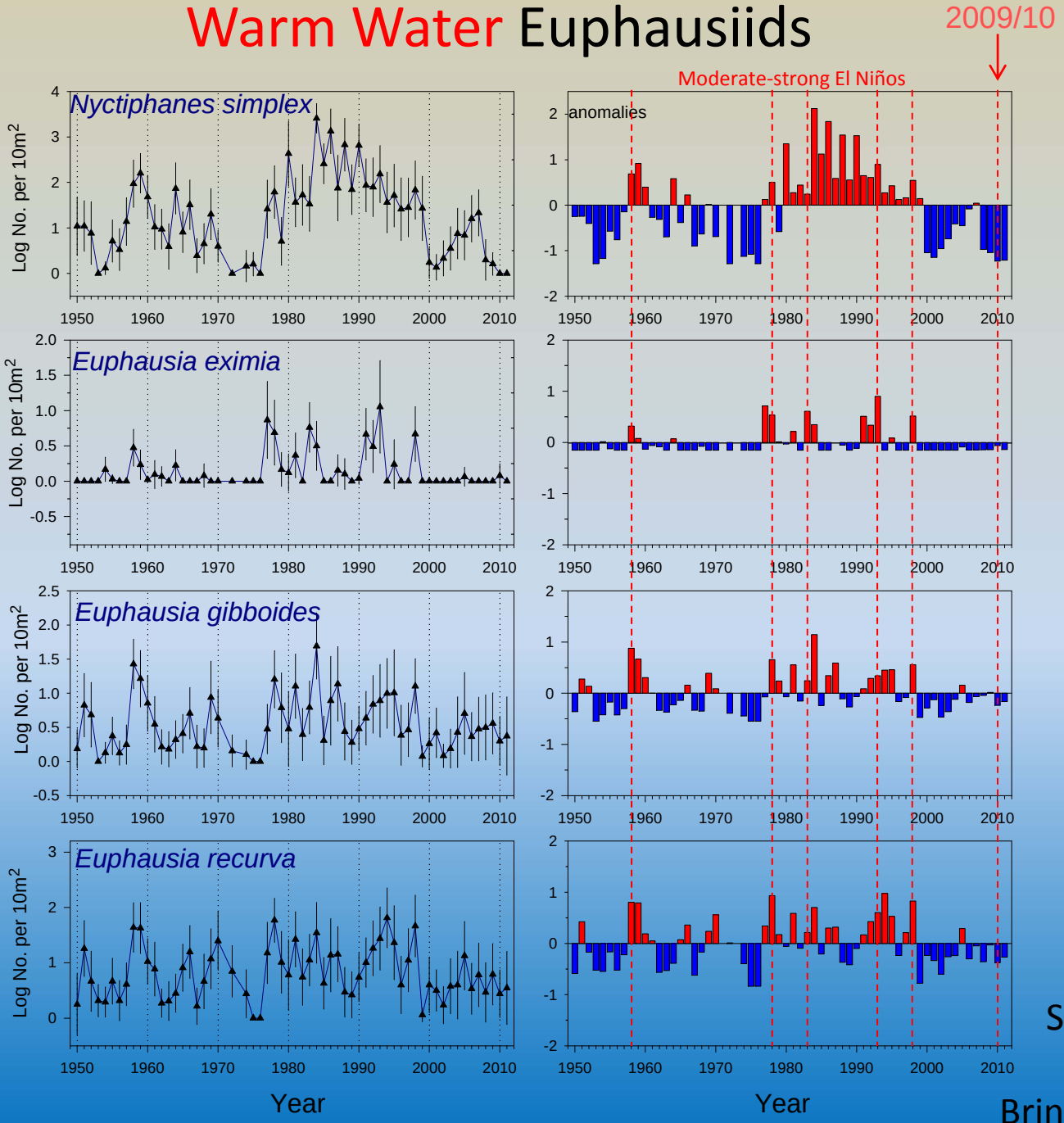
Wind stress

Wind stress curl

off California

Todd, R.E., Rudnick, D.L., Davis, R.E. and Ohman, M.D. 2011. GRL

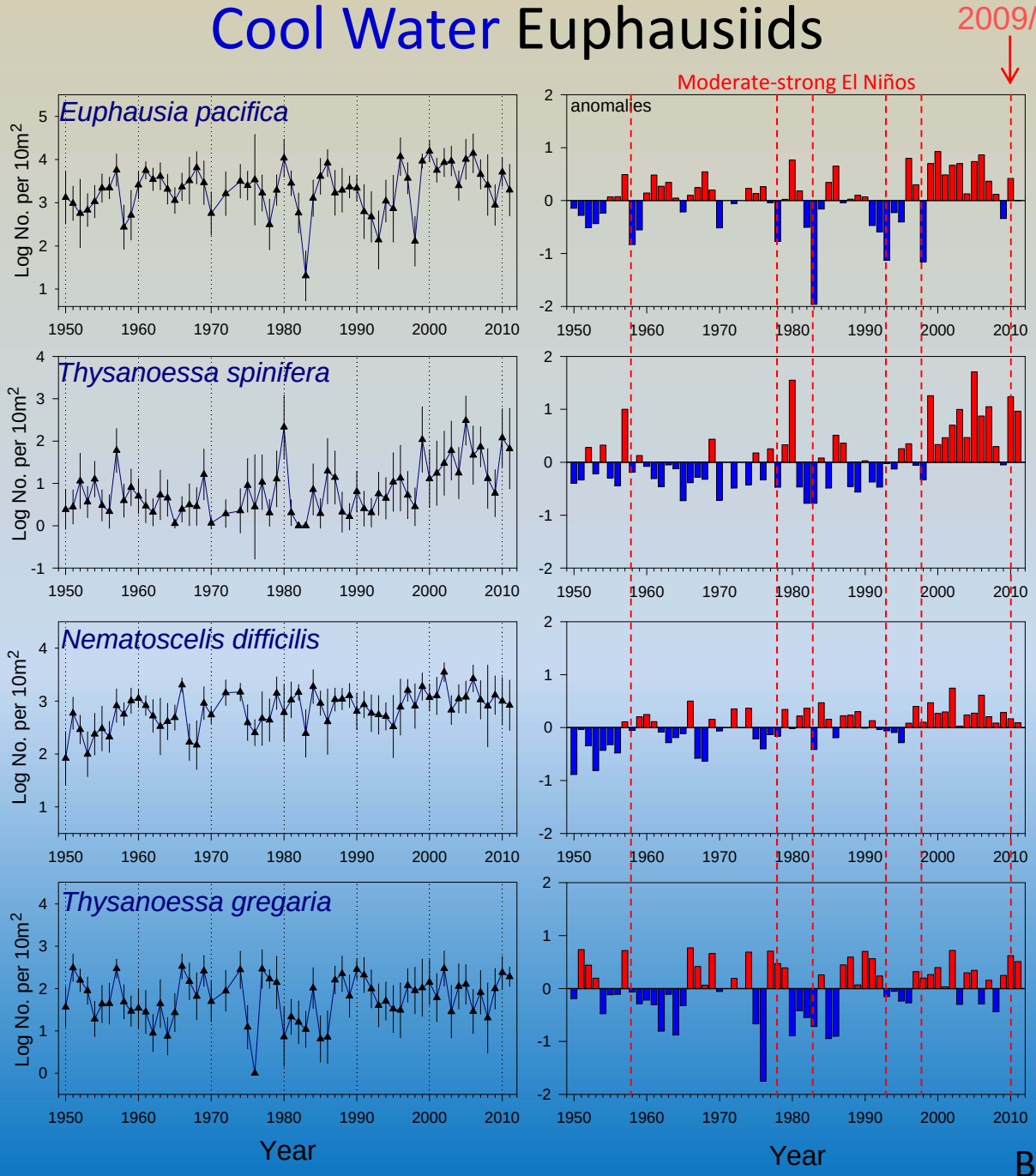
Warm Water Euphausiids



CalCOFI
Spring cruises

Brinton data source

Cool Water Euphausiids



Consistent w/:
Atmospheric Teleconnections

Not w/:
oceanic advection

Cannot rule out:
coastally trapped waves

CalCOFI
Spring cruises

Brinton data source

Non-stationary time series

2. The salp decline and biogeochemical consequences

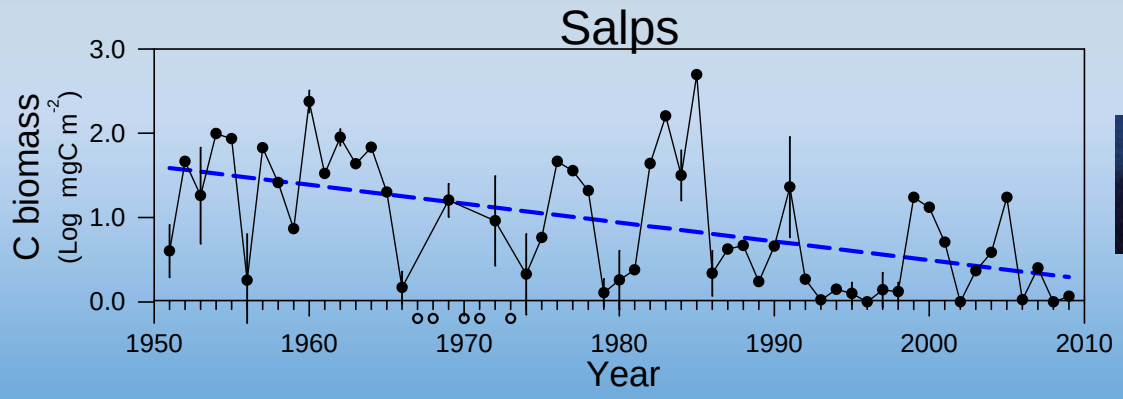


photo: D.Wrobel

Lavaniegos & Ohman 2007
(updated)

Spring, 2012 CalCOFI zooplankton sample

photo: MDO

So CA, offshore

"...incredible distribution and biomass of salps and pyrosomes. We have sampled from close inshore out to 160 miles offshore and we are being inundated with salps. Every trawl, every bongo tow, and at times the pairovet and the manta come up full....

...a 30 minute trawl of over 900 kg and we were 120 nm offshore..."

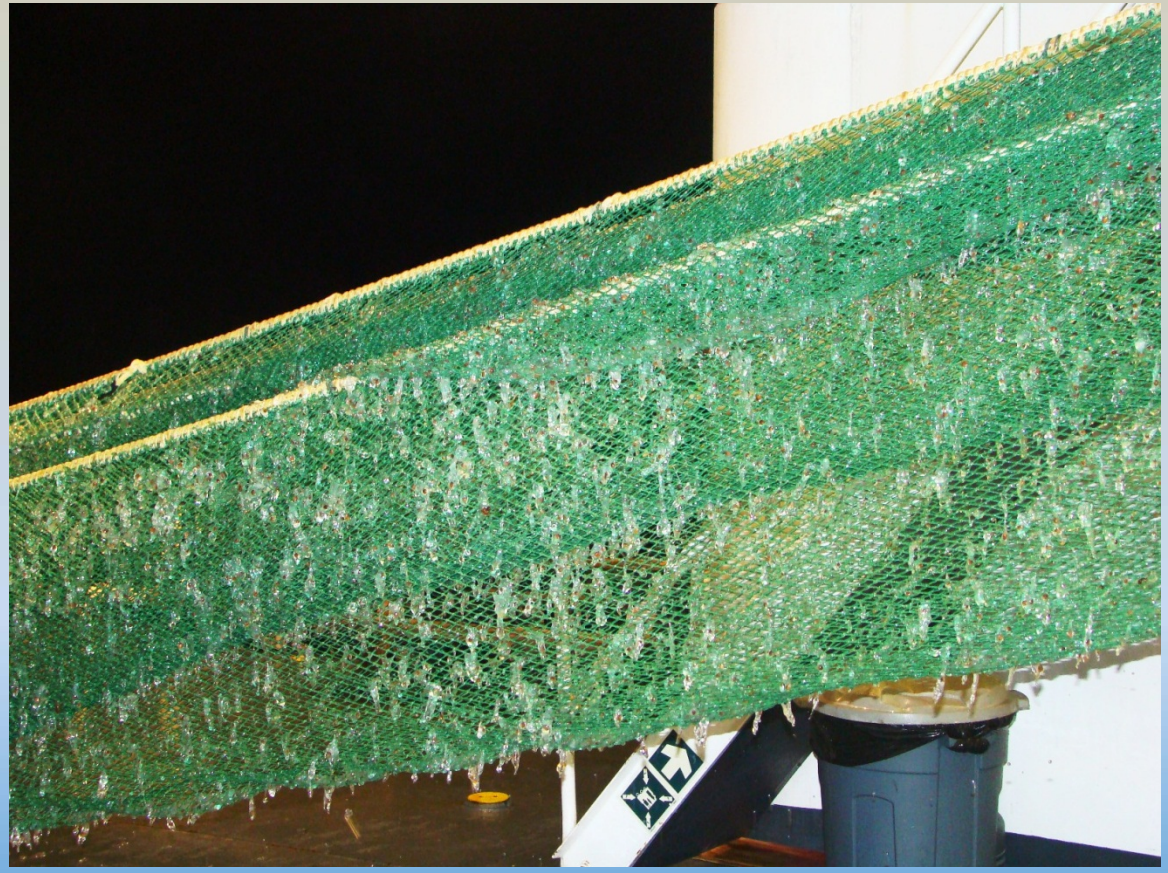
D. Griffith, SWFSC - 17 April 2012

somewhere between Mendocino and the Mexican border

Spring, 2012 SWFSC/NMFS Coastwide Survey
Nordic trawl

photo: Andrew Thompson

photo: Andrew Thompson



"...some hauls have had over half a million salps in them"

J. Field - Central CA - 5 June 2012

Sta. M - Abyssal sea floor (~ 4,000 m) Ken Smith

Laser separation: 29 cm Field of view: 0.37 m2

"….a unique data set of sediment community oxygen consumption (SCOC) at 87 sites over the 7 month period from November 2011 to June 2012 at Sta. M.

These data show a remarkable increase in rates beginning in March when the salp pulse became evident in the sediment traps and on the sea floor and continued until we recovered the rover in early June."

Ken Smith
Email, 11 July 2012

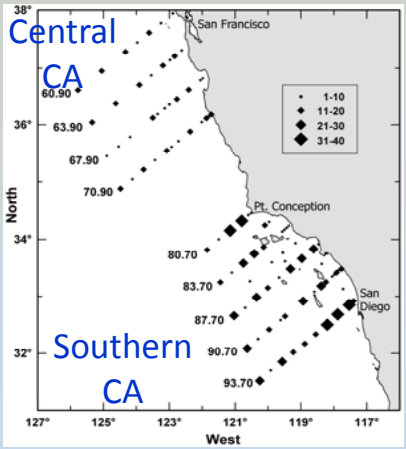
Non-stationary time series ?

3. Trends in calcareous holozooplankton in the CCS ?

Evidence for Declines of Calcareous Zooplankton?

Detecting thresholds of change

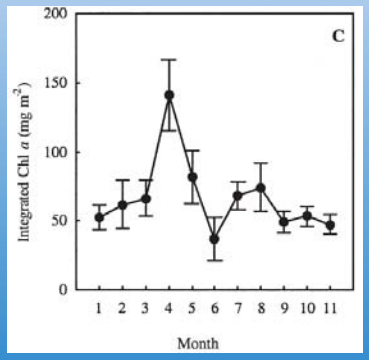
CalCOFI

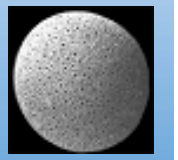


Wrobel & Mills

Wrobel & Mills

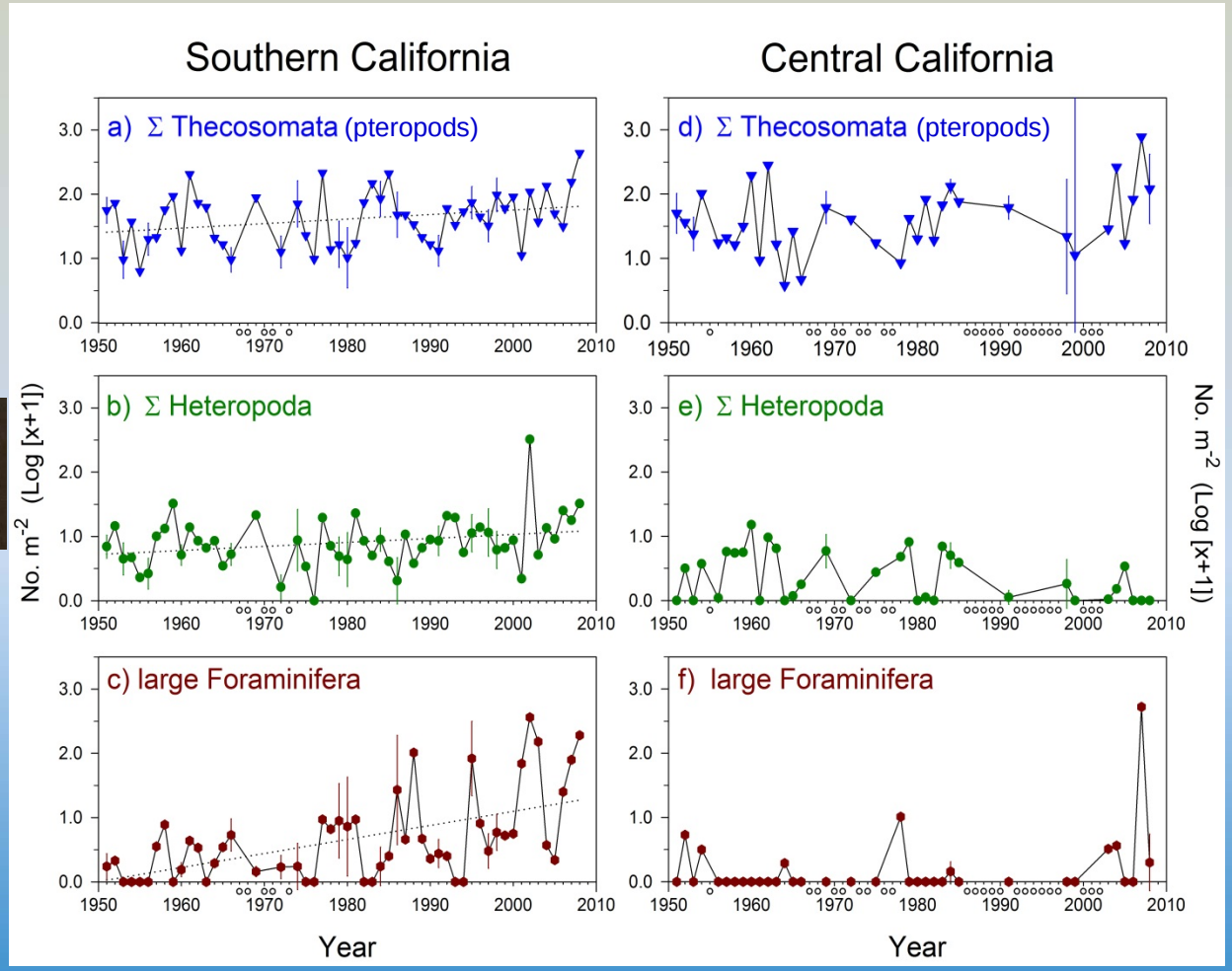
spring cruises





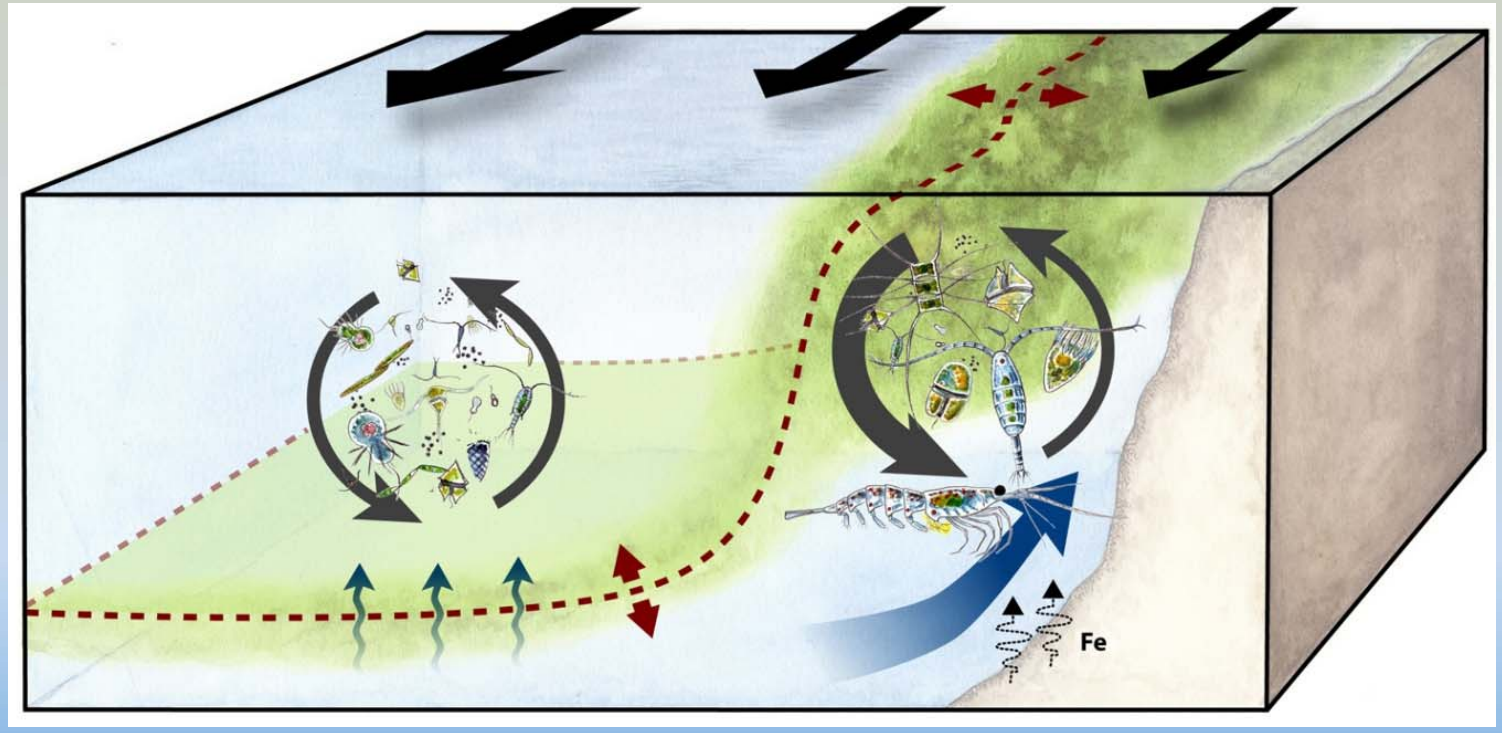
D.B. Field

Aksnes, Ohman, Rivière (2007) L&O



Ohman, Lavaniegos, and Townsend (2009) GRL

Spatial Structuring of the CCS Food Web

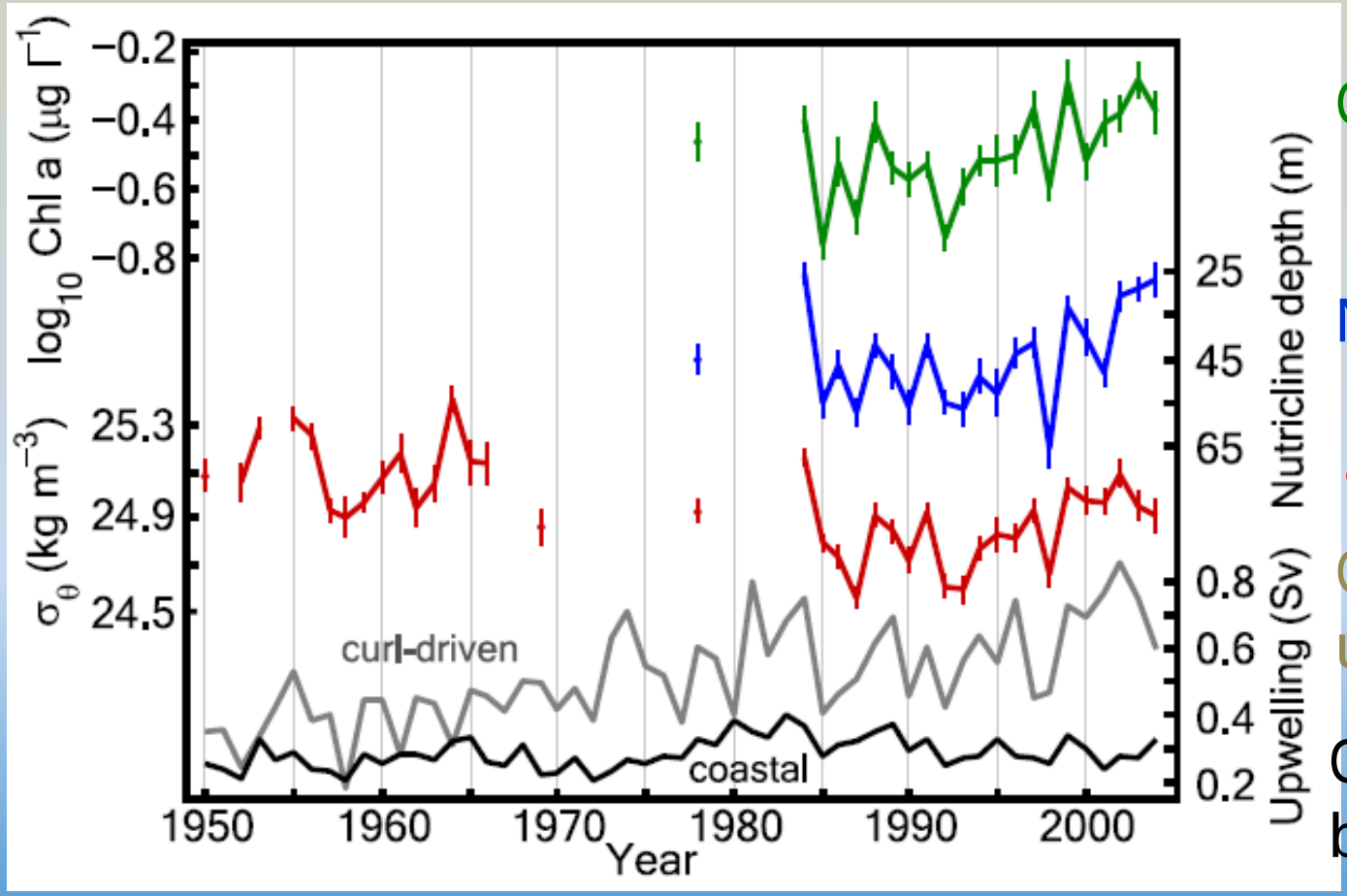


M. Landry, K. Carlson

Wind-stress curl upwelling

Coastal boundary upwelling

Long-term increase in curl-driven upwelling



Chl*a*

Nutricline depth

σ_θ

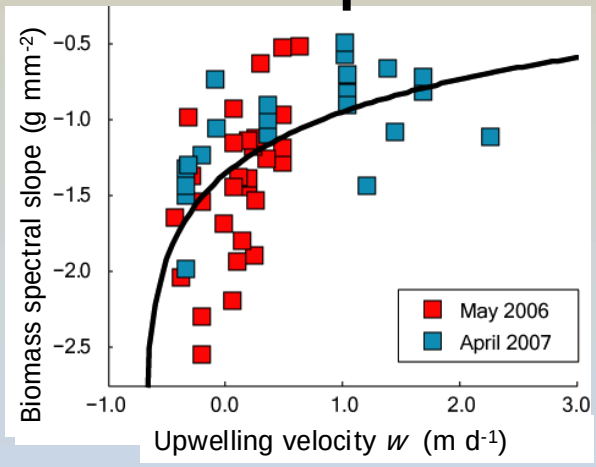
Curl-driven upwelling

Coastal boundary upwelling

Rykaczewski and Checkley (2008) PNAS

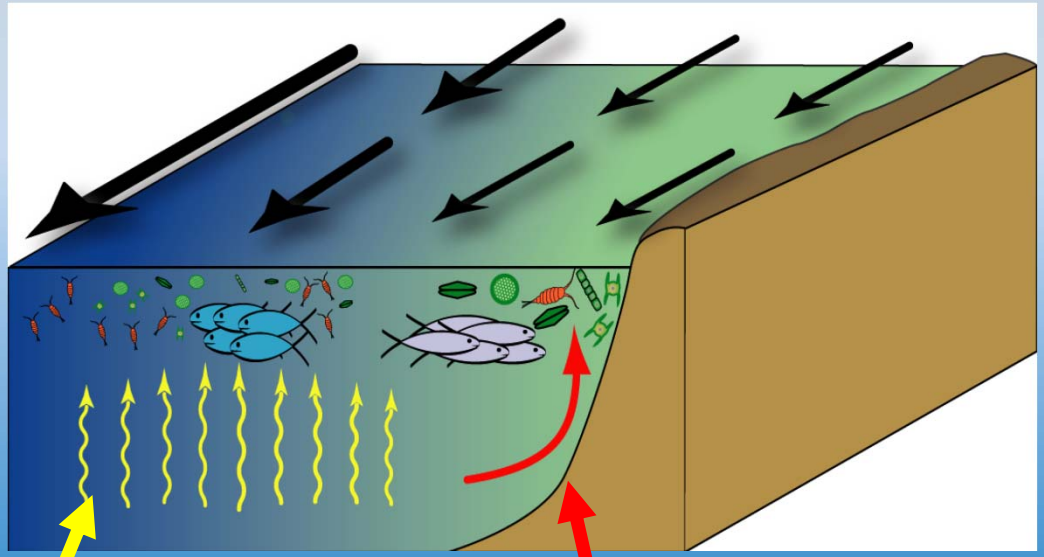
Zooplankton body size is proportional to upwelling velocity

CCE-LTER process cruises



Rykaczewski & Checkley 2008

PNAS



Wind stress curl driven upwelling: sardine

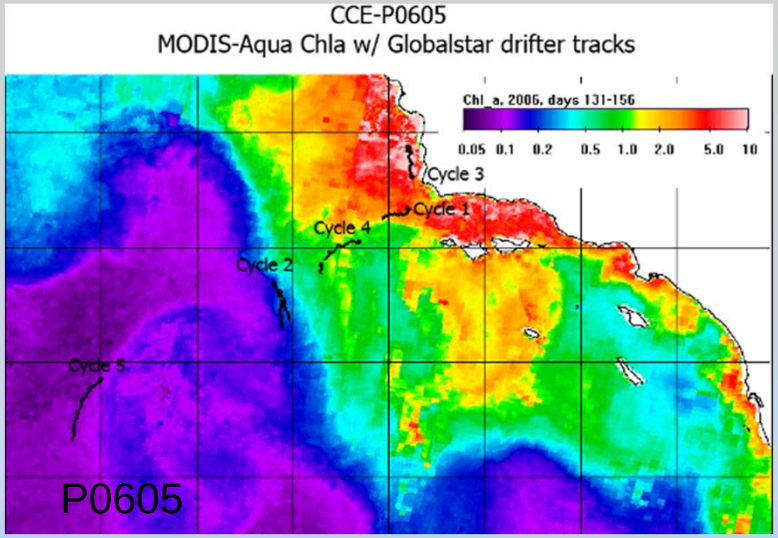
Coastal boundary upwelling: anchovy

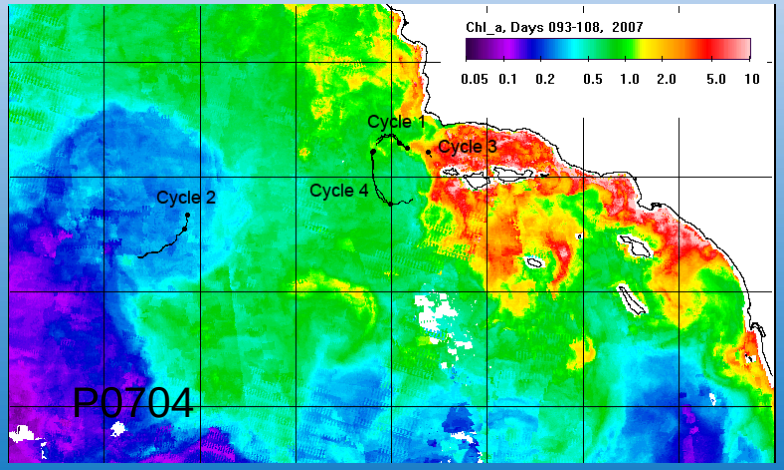
Exploiting Spatial Structure of the CCS Food Web

CCE-LTER *Process Cruises*

Rate and Fate of Primary Production

Grazing? Aggregation/sinking? Lateral Export? Viral attack?



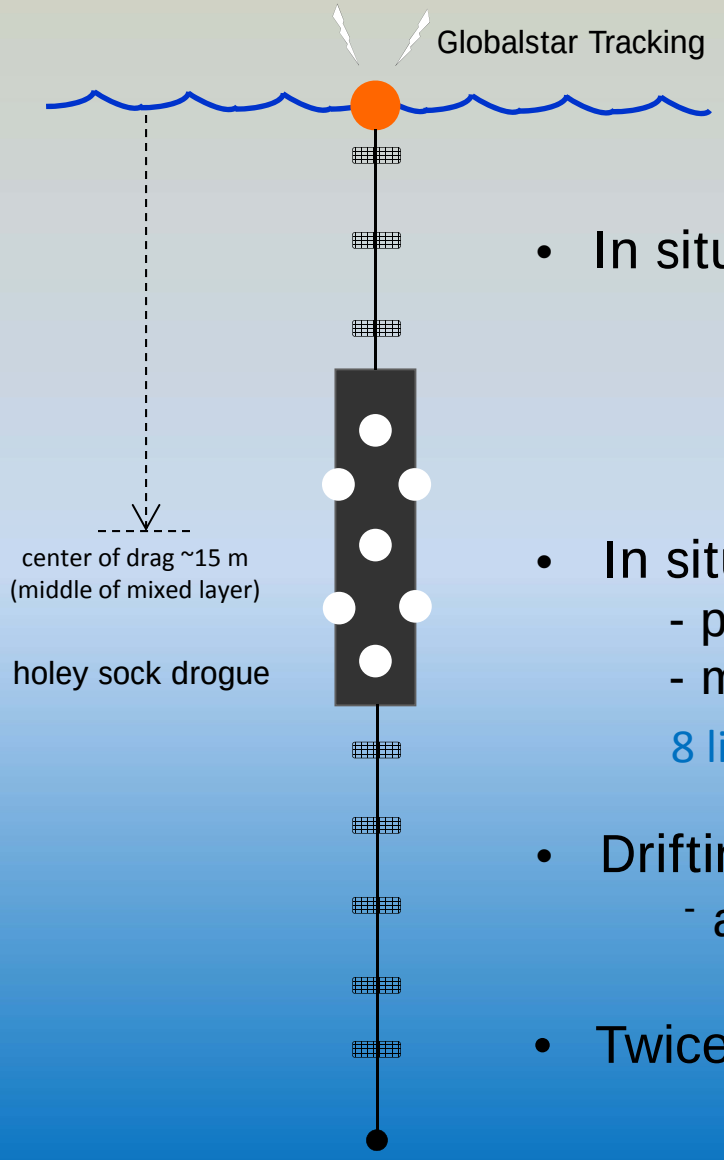


Quasi-Lagrangian
Tracking of Water Parcels

Images courtesy of M. Kahru, SIO

In situ

Phytoplankton Growth and Zooplankton Grazing



- In situ mesozooplankton grazing (Ohman)
  size-fractionated gut fluoresence;
  vertically integrated bongo samples

Drift arrays

- In situ Seawater Dilution Experiments (Landry)
  - phytoplankton μ
  - microzooplankton m

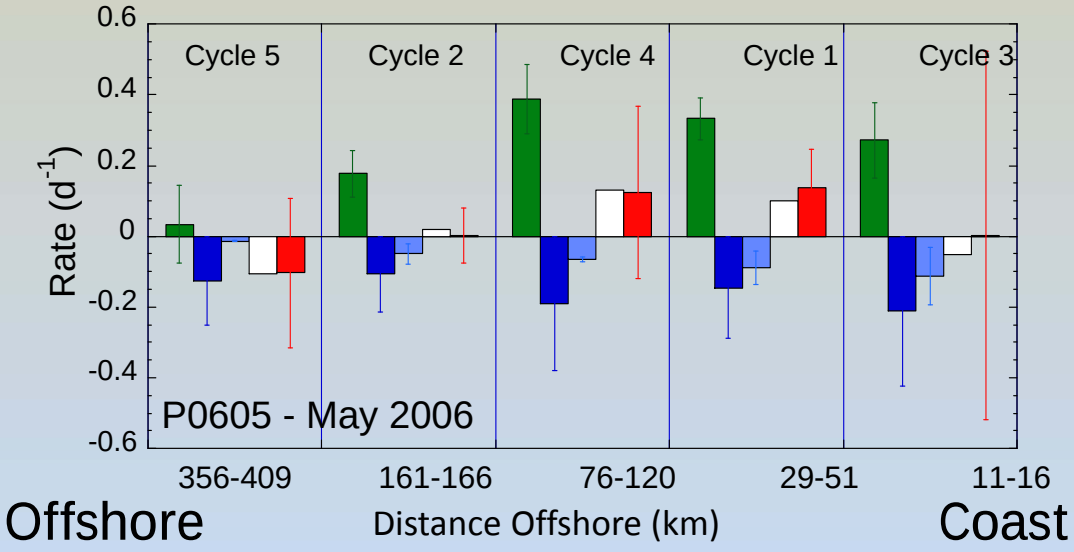
  8 light depths, in situ light & temperature

- Drifting sediment traps (Stukel)
  - also $^{234}Th/^{238}U$ disequilibria

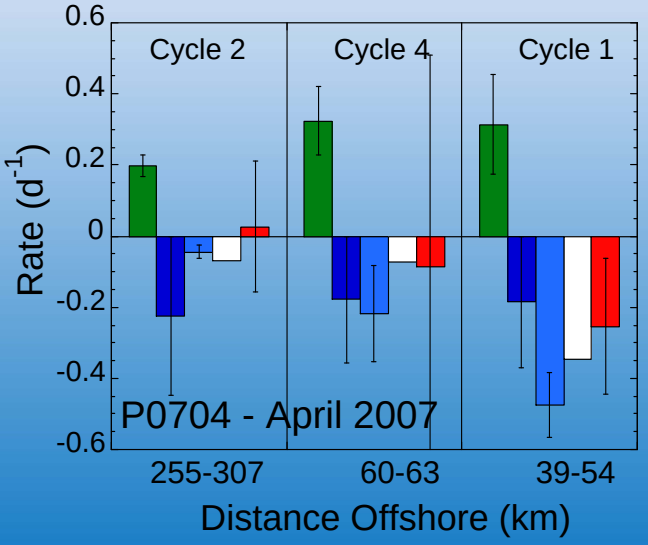
- Twice daily measurements in ambient water

Quasi-Lagrangian Drift Arrays: Fate of Primary Production

P0605
positive net growth



P0704
negative net growth



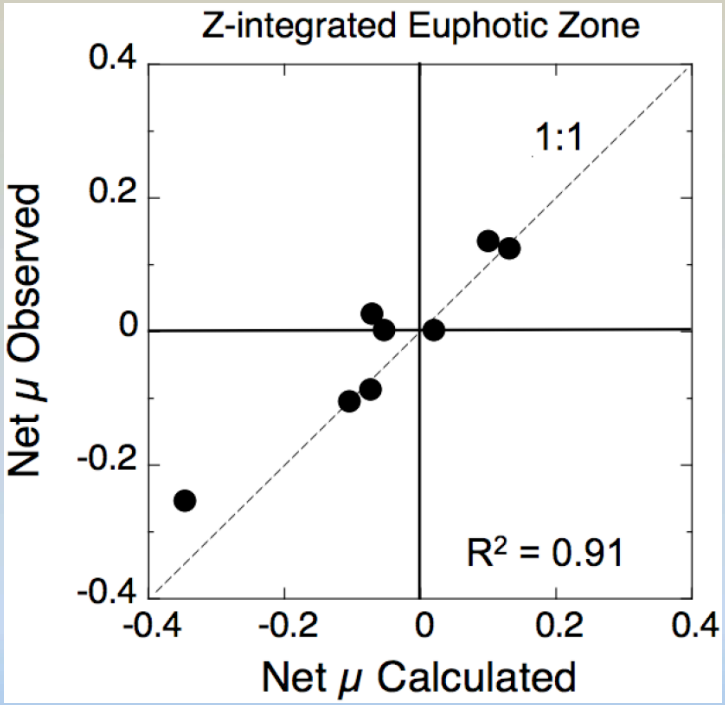
Phyto growth
Micro grazing
Meso grazing
Net Calculated
Net Observed

- (from in situ
- dilution expts at 8 light depths)
- (Δ on successive nights)

Landry, Ohman, Goericke, Stukel, Tsyrklevitch (2009) Progr. Oceanogr.

Observed μ vs. Calculated μ

Net Δ in Ambient water



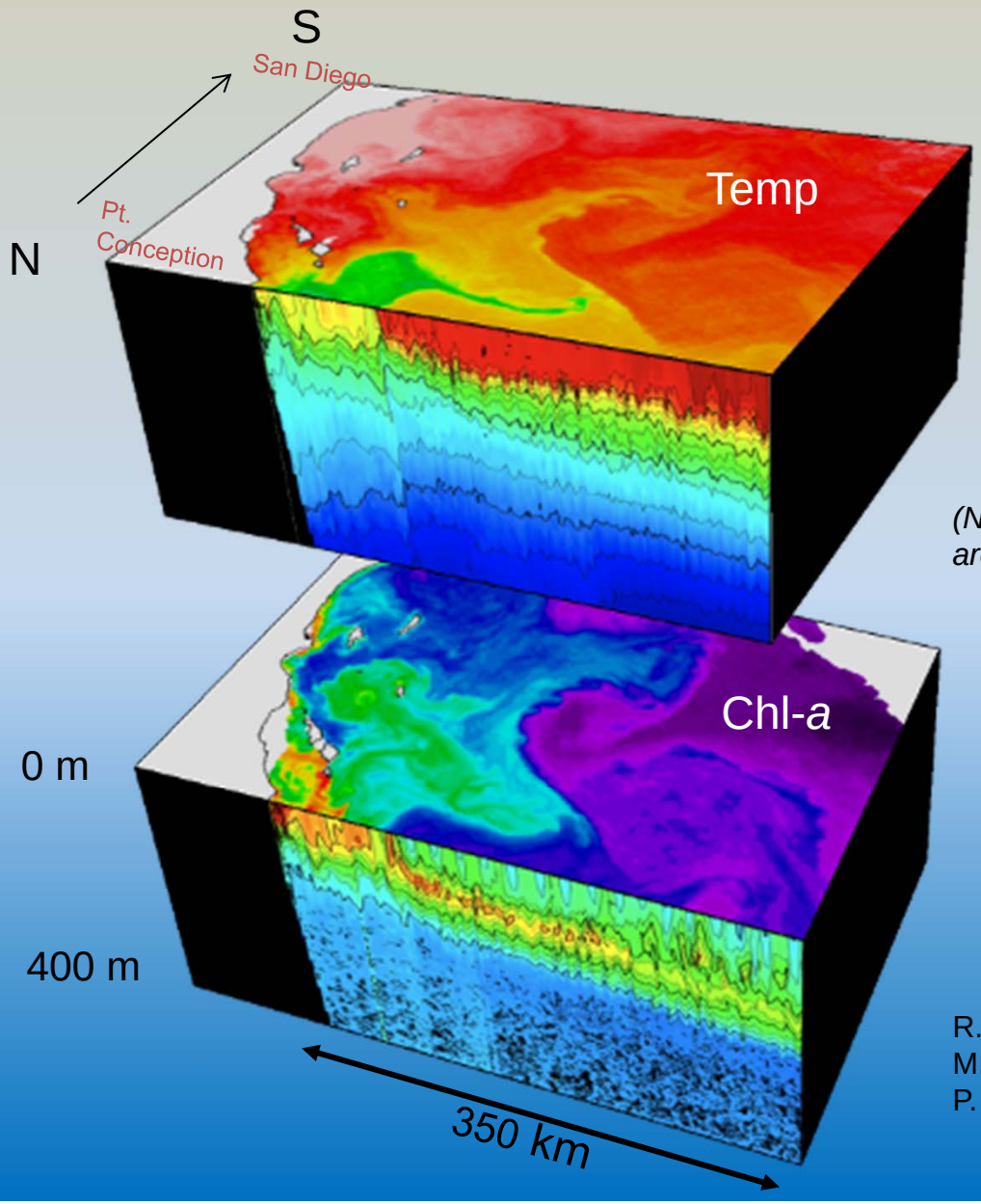
Resultant of experimental rates

Implies: Fate of most Primary Production is to be grazed

Balance of Mesozoop vs. Microzoop grazing varies in space and time

Landry, Ohman, Goericke, Stukel, Tsyrklevitch (2009) *Progr. Oceanogr.*

Mesoscale & sub-mesoscale Features



(N.B. glider and SeaWifs images are on different color scales)

R. Davis, M. Ohman - glider image
M. Kahru – satellite images
P. Franks - composition

Biophysical gradients at ocean fronts

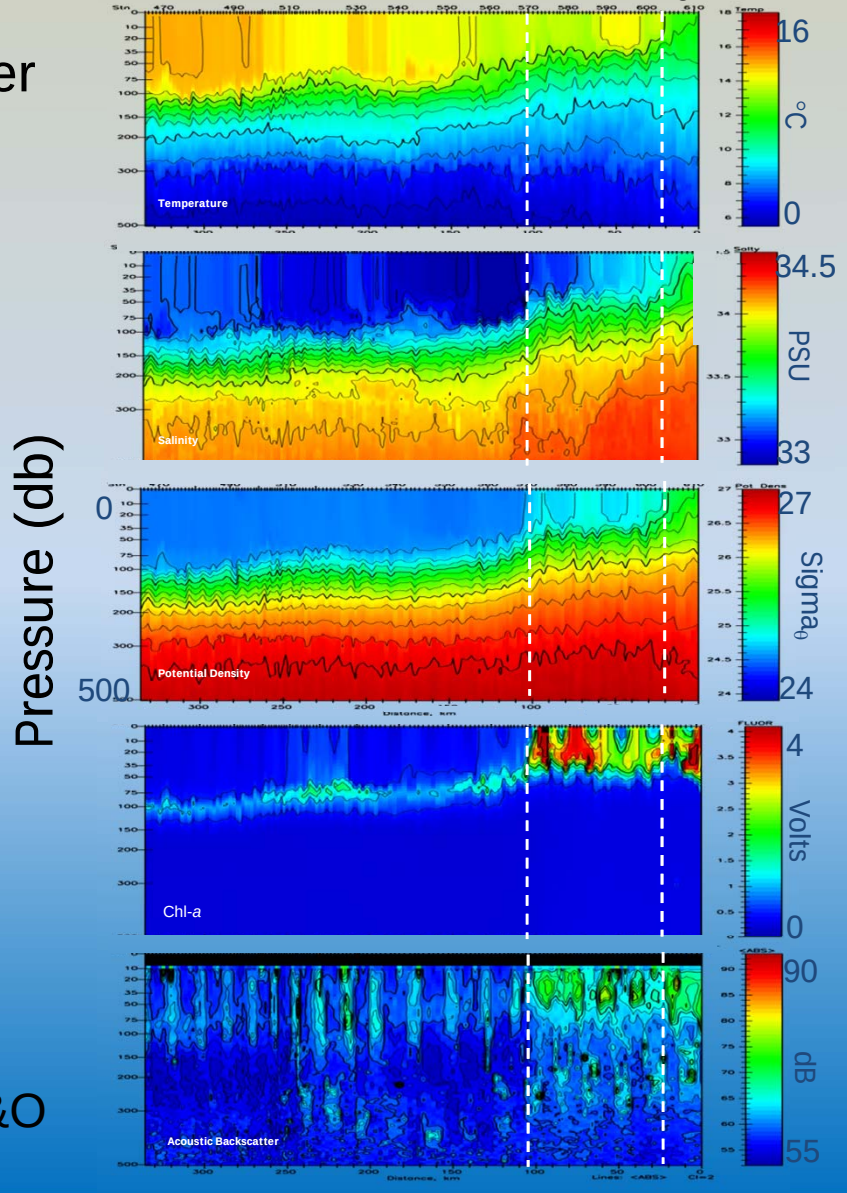
offshore — Line 80 Section — nearshore (off Pt. Conception)

350 km ◄ 0 km

Spray ocean glider

Russ Davis,
Dan Rudnick,
Mark Ohman

Jesse Powell
Scripps, CCE
graduate student



Temperature

Salinity

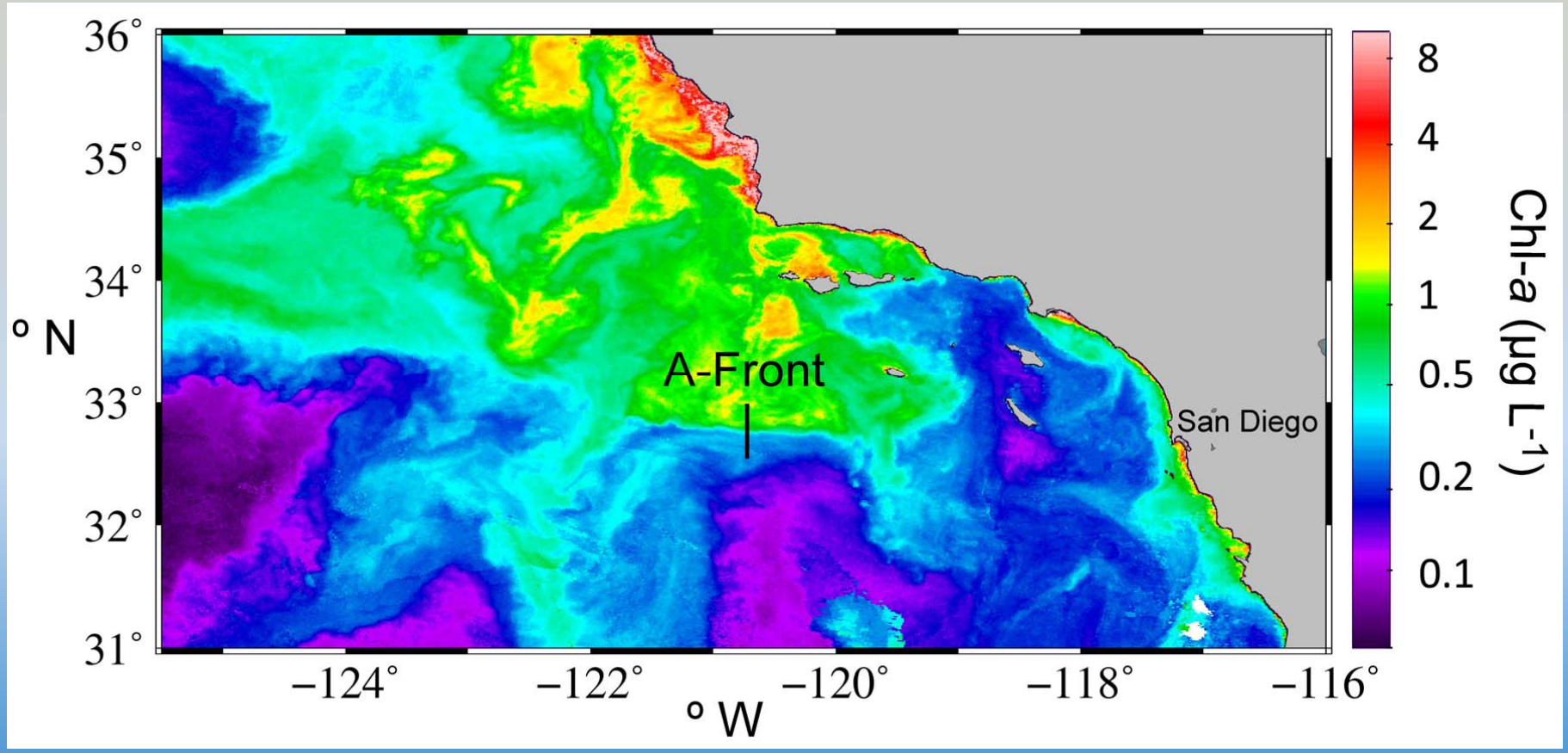
Potential Density

Chlorophyll-*a*

Acoustic Backscatter
(750 kHz)

Davis et al. (2008) L&O

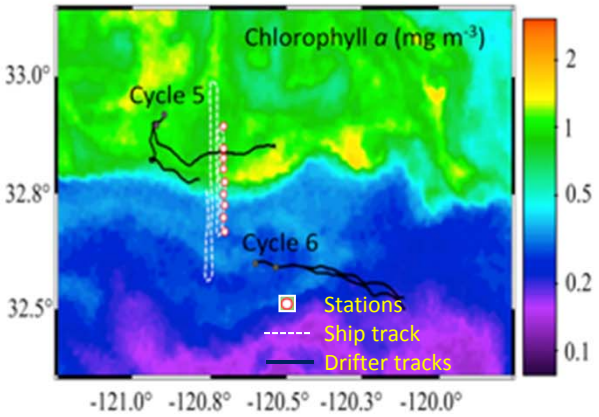
CCE-LTER A-Front study

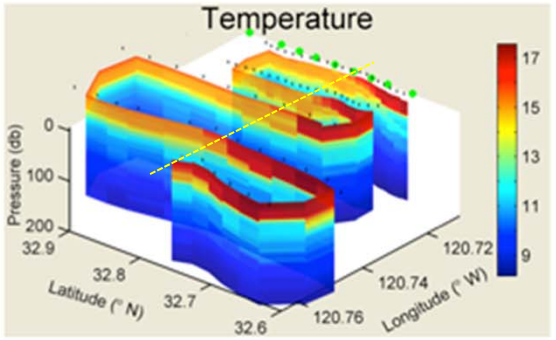


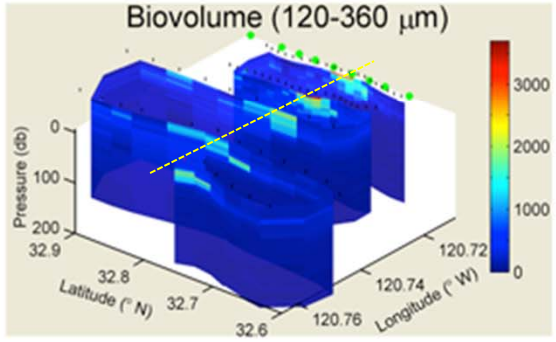
24-25 Oct. 2008

Cluster of papers in press, *Journal of Plankton Research,* 2012

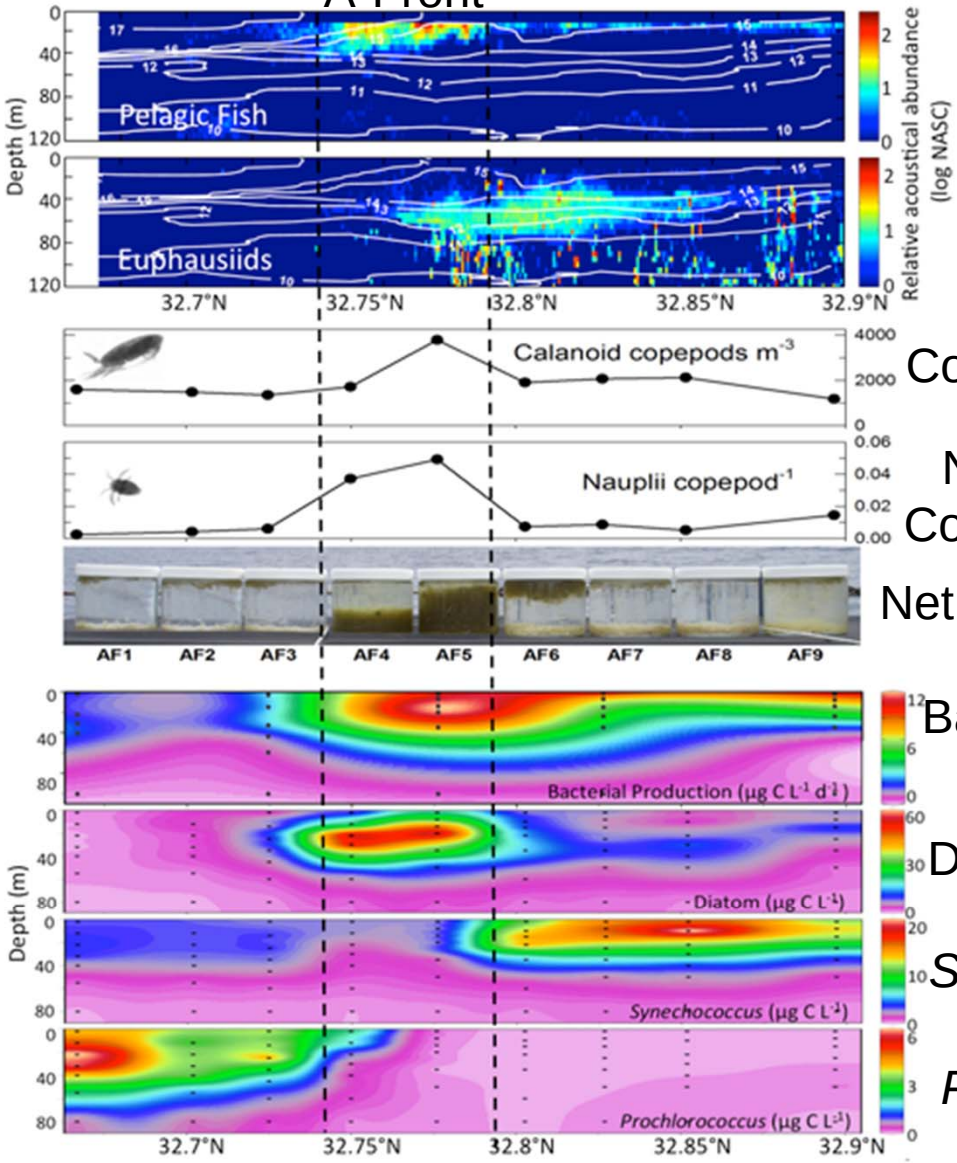
California Current Ecosystem-LTER A-Front Study







A-Front



Fish

Krill

Copepods

Nauplii Copepod^{-1}

Net plankton

Bacterial Prod.

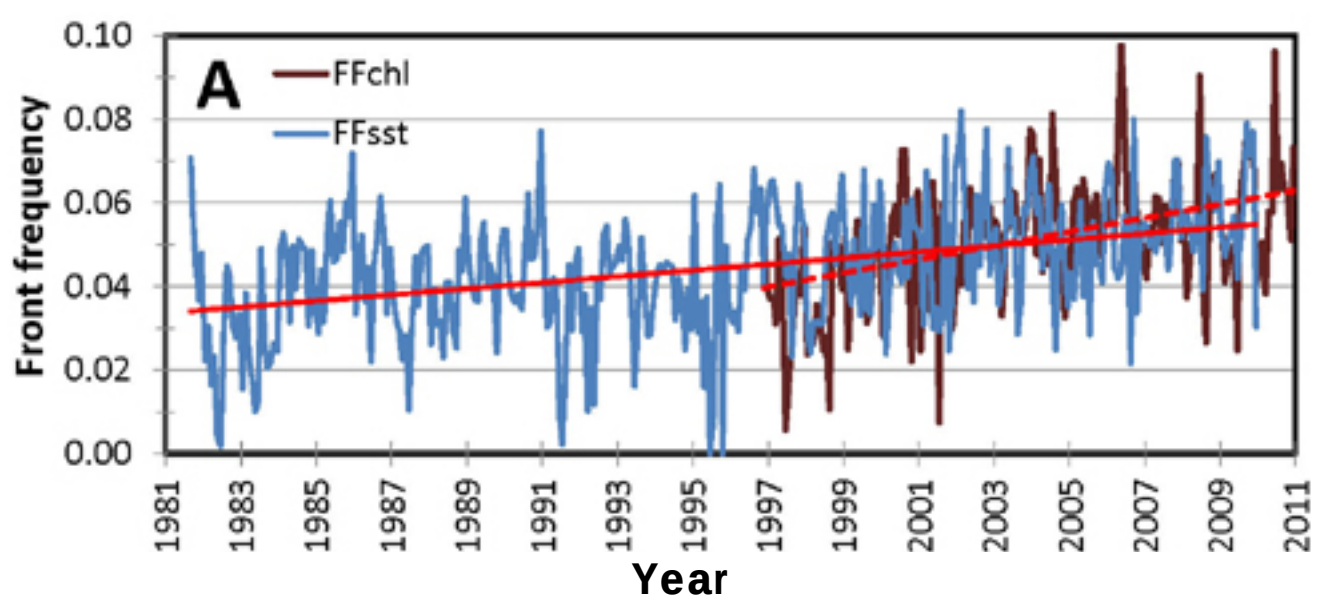
Diatoms

Synech.

Prochl.

Integration of time and space:

Multi-decadal increase in Front Frequency in the CCE region



Kahru et al (2012)

SST and Chl-*a* satellite imagery
Histogram method of Cayula and Cornillon (2002)

Ecosystem responses in the CCE

Multiple time scales:

- *Interannual, Decadal, Secular Trends*
- *Time series may be non-stationary*

  Causal mechanisms may change over time

Spatial structuring:

- *Wind-stress curl vs. Coastal Bdy upwelling*
- *Mesoscale variations & fate of 1^{o} production*
- *Nonlinearities assoc. w/ sub-mesoscale fronts*

fin