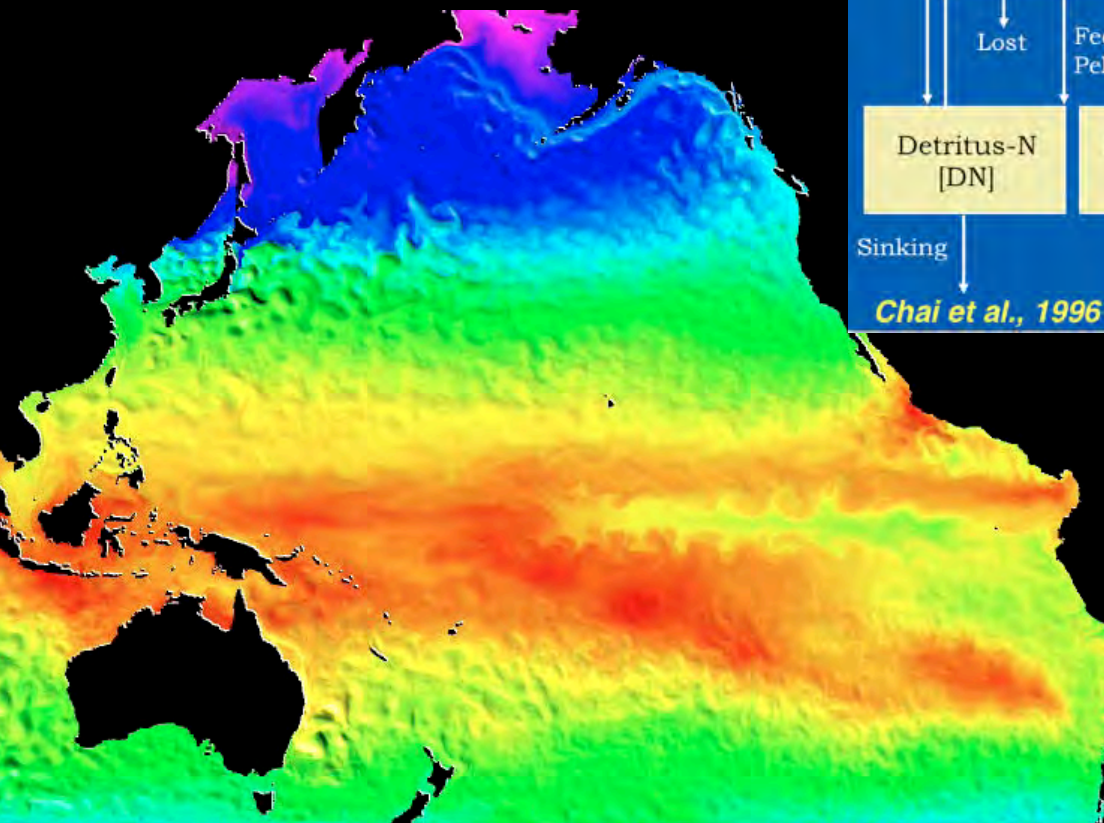# *Modeling Impacts of Mesoscale Eddies on Biogeochemical Processes in South China Sea and Gulf of Alaska*
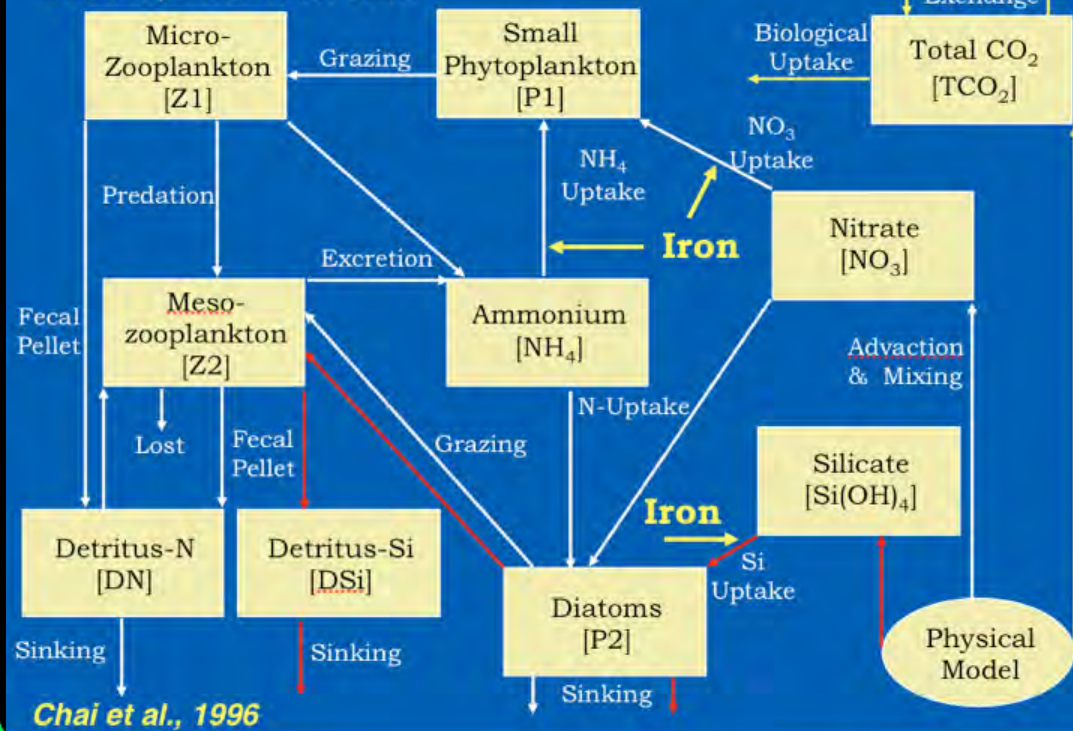
Prof. Fei CHAI (柴扉)
University of Maine

- Eddies and biological responses in the SCS
- Eddy transporting iron in Gulf of Alaska
- Iron fertilization with a Haida eddy - August 2012

Regional Ocean Model System (ROMS) 1/8 deg. (~12km) (1991 to 2013)



Time(year)
93 94 95 96 97 98 99 00 01 02 03 04

Carbon, Silicate, Nitrogen Ecosystem Model (CoSiNE)

(Chai et al., 2002, 2003, 2007, 2009; Fujii and Chai, 2007; Liu and Chai, 2009; Xiu and Chai, 2011, 2014; Palacz et al., 2011; Guo, Chai et al, 2014)

Carbon, Silicate, Nitrogen Ecosystem Model CoSiNE, Chai et al. 2002

Chai et al., 1996

Eddies in the South China Sea (1993 – 2007)
Xiu, Chai et al., JGR, 2010

18 Aug 2002

SSHA
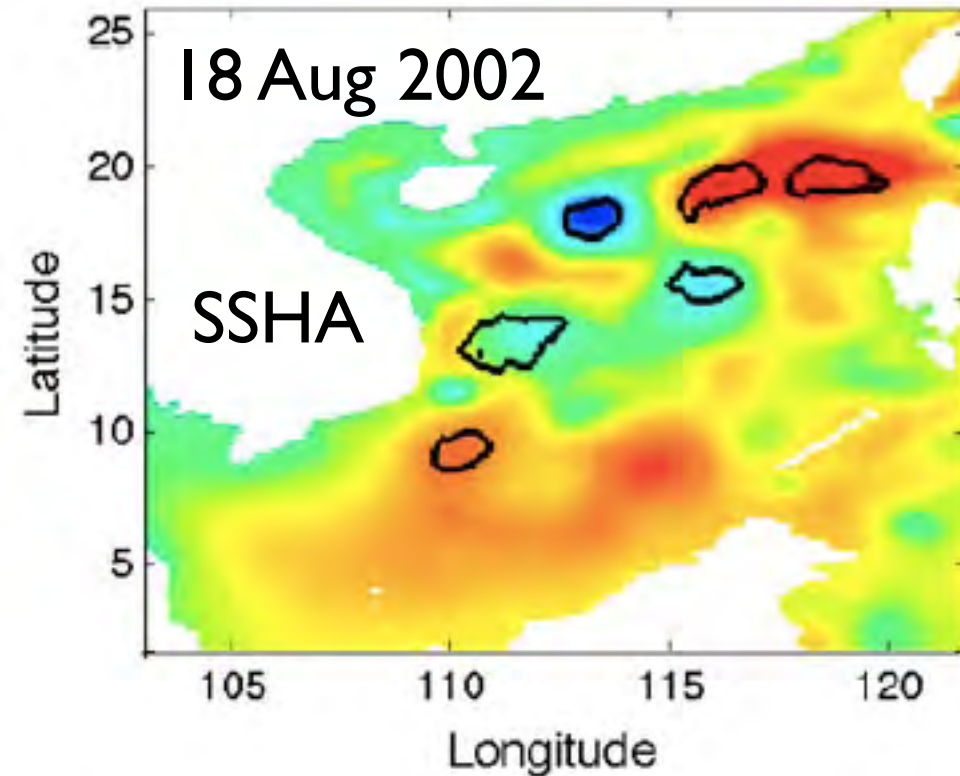
- 1st guess: W < -0.2 σ_W

- Geometric center

- Mean SLA and distances to the center

- Search the area limited by the maximum distance for points where SLA greater/less than the mean SLA

- Only those eddies with life span > 30 days, radius > 45 km, water depth > 1000m
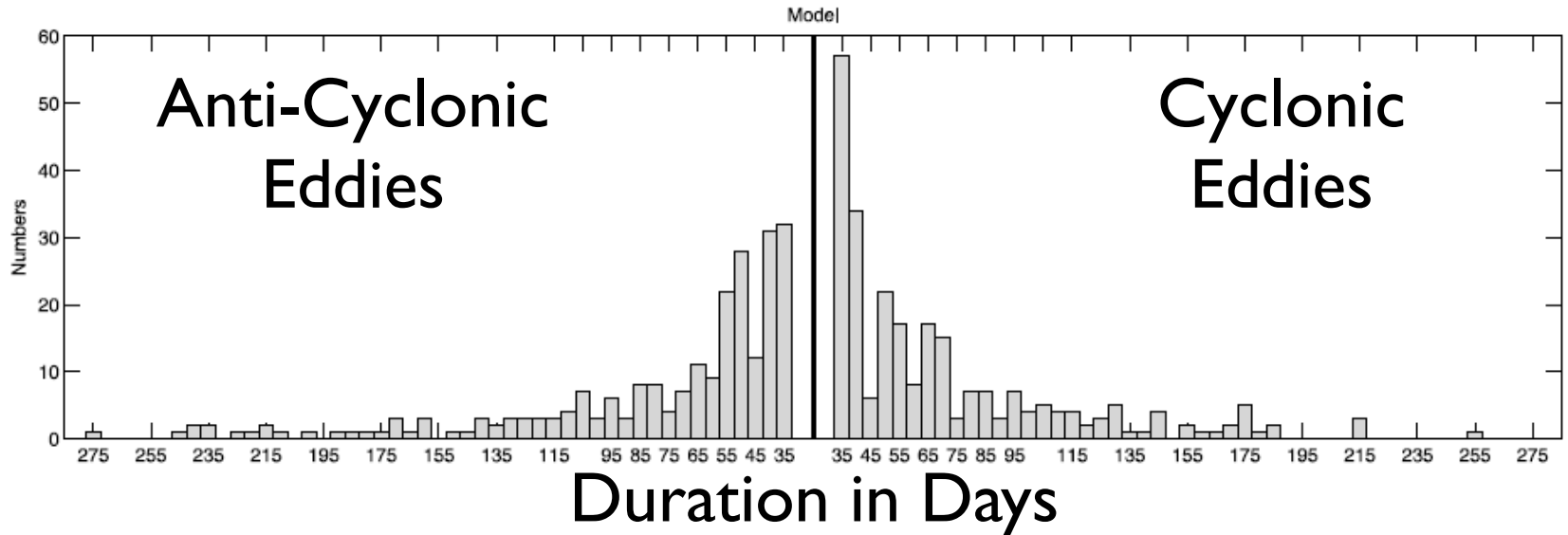
Okubo-Weiss parameter

$$W = s_n^2 + s_s^2 - \omega^2$$

$$s_n = \frac{\partial u}{\partial x} - \frac{\partial v}{\partial y}, \quad s_s = \frac{\partial v}{\partial x} + \frac{\partial u}{\partial y}, \quad \omega = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}$$
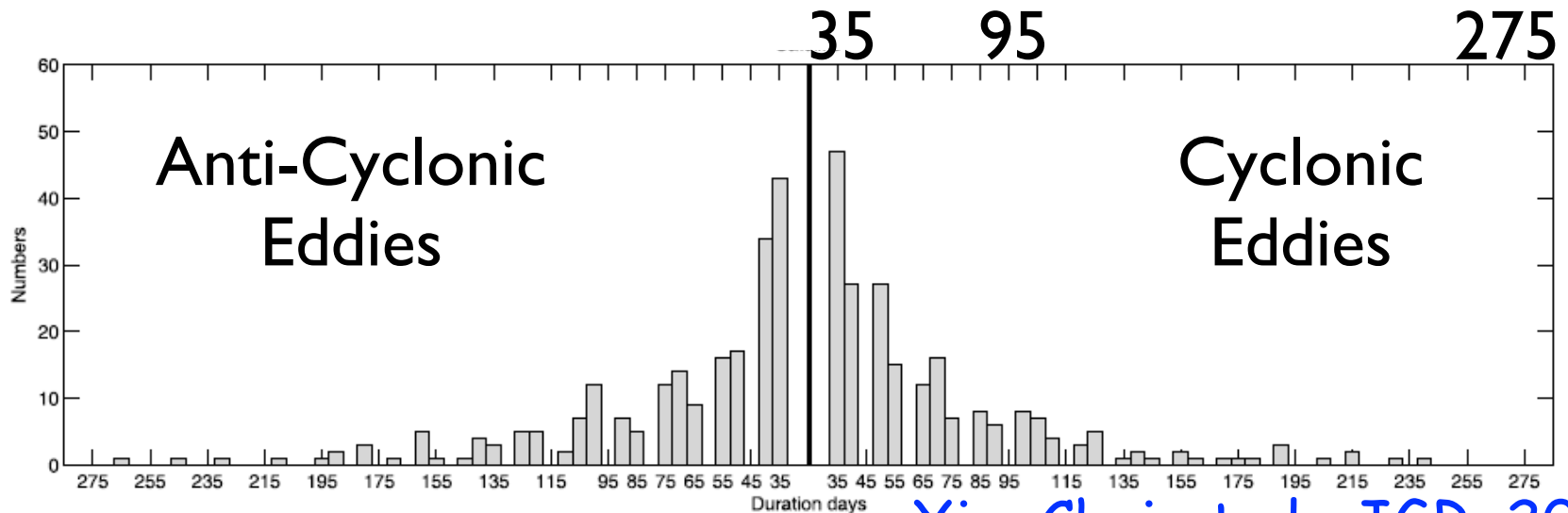
Eddies in the South China Sea
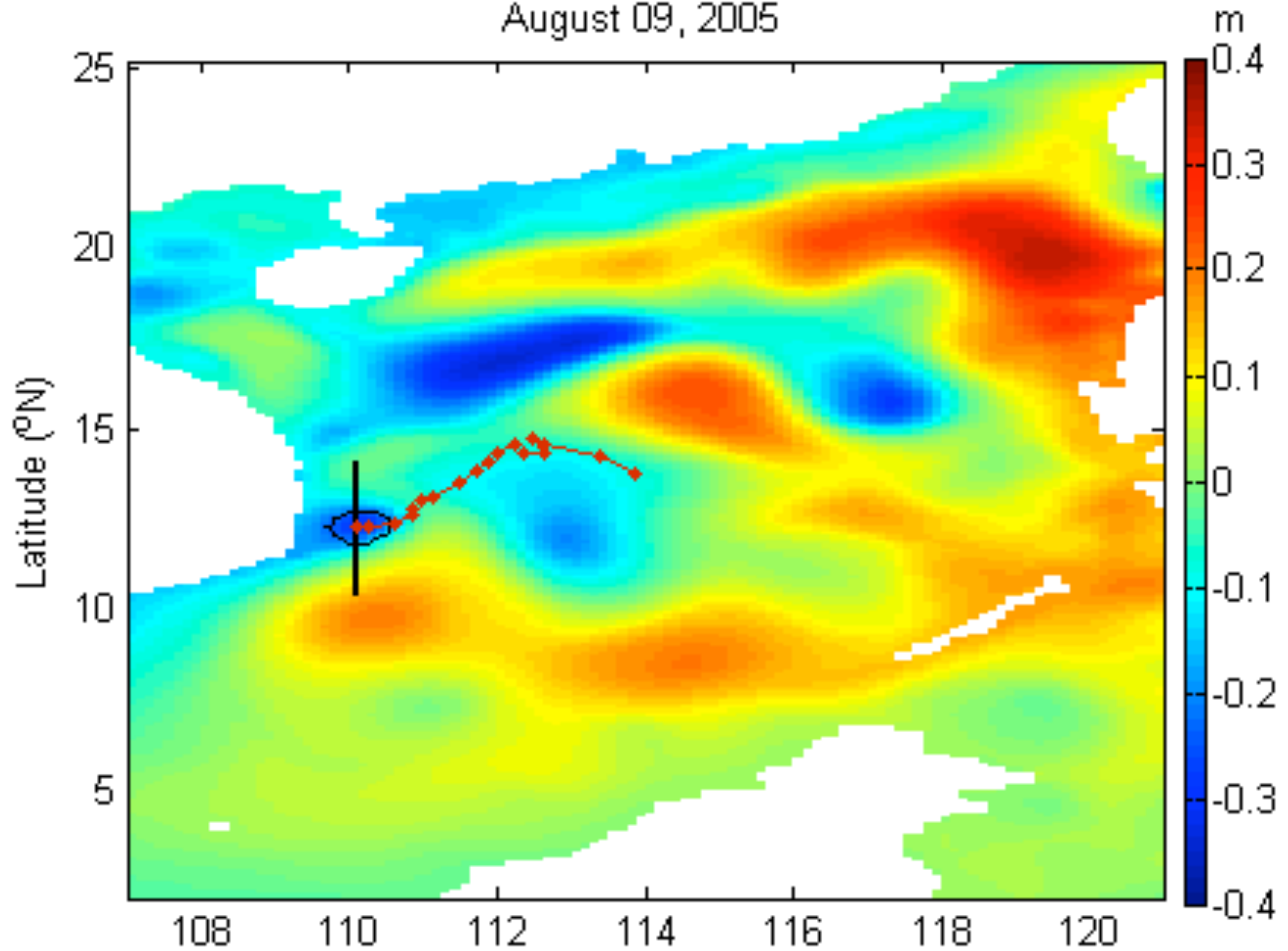
Numbers: 27-38/yr (33);   Area: 10% of the total area

Xiu, Chai et al., JGR, 2010
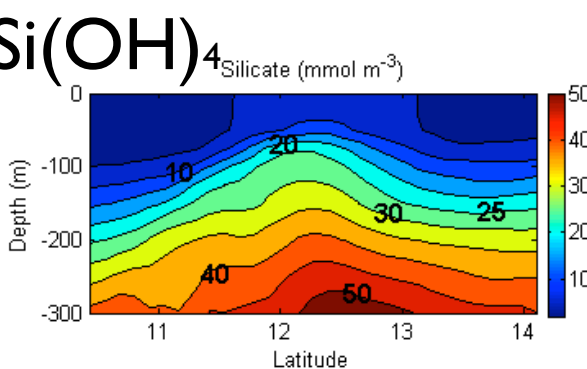
Biological Impact of Eddies

Xiu and Chai, JGR, 2011

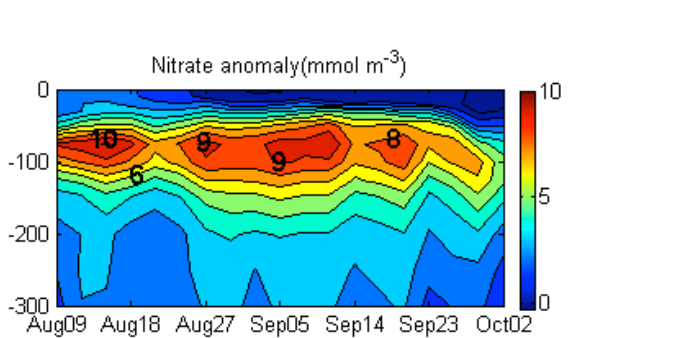August 09, 2005

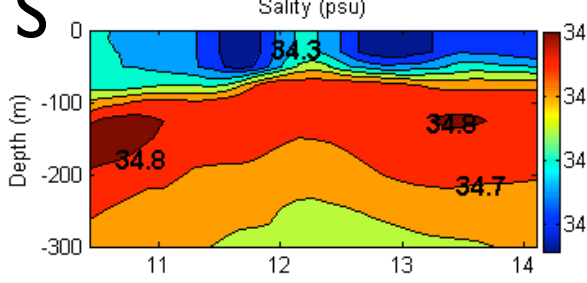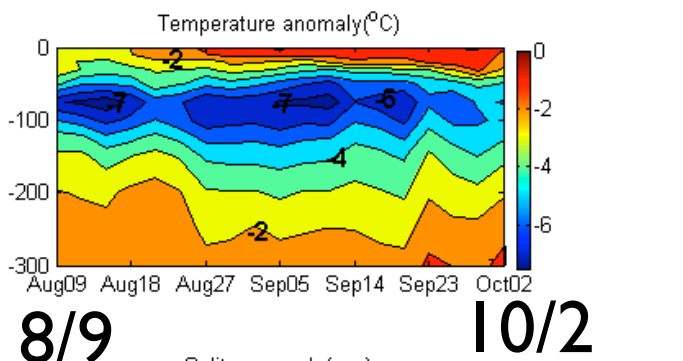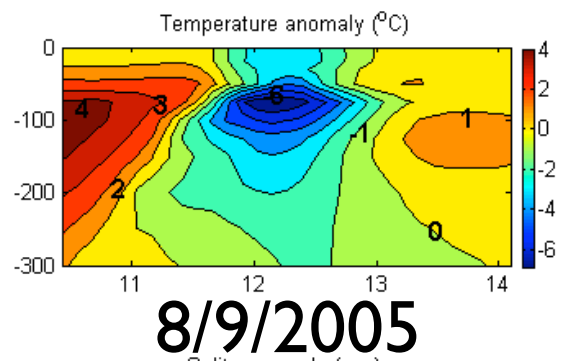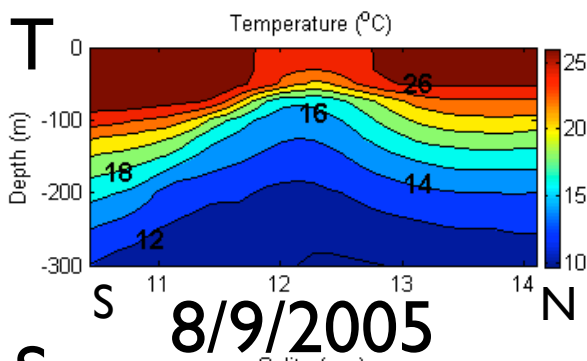Vertical Profiles | Vertical Anomalies | Time Series of Anom.
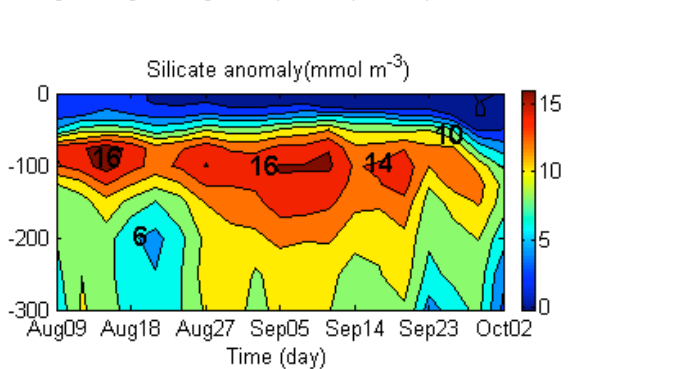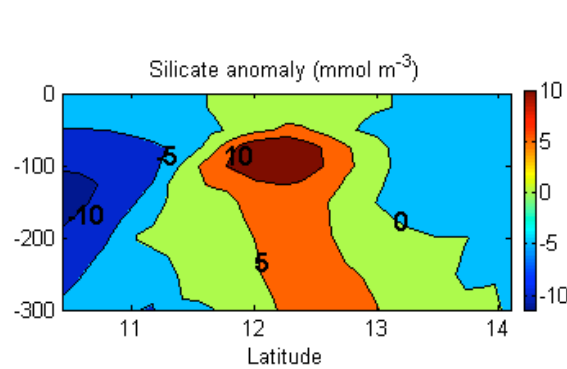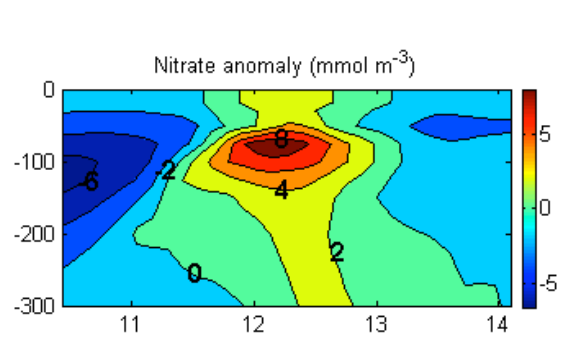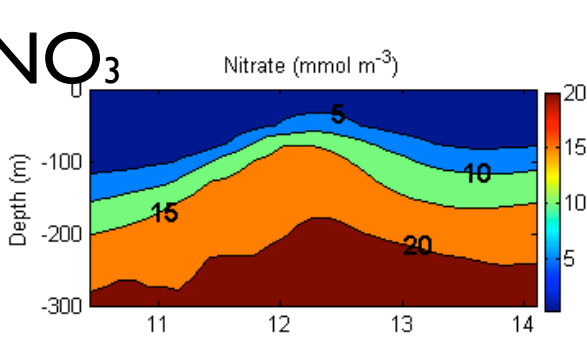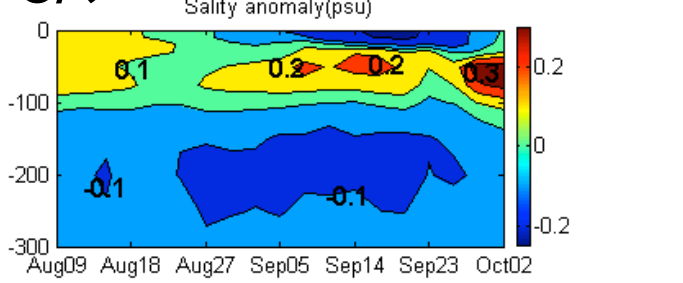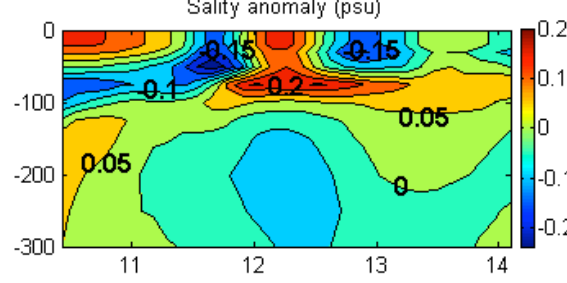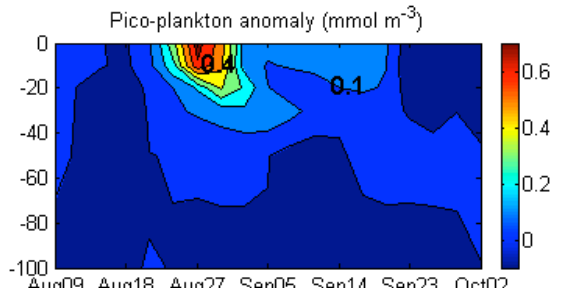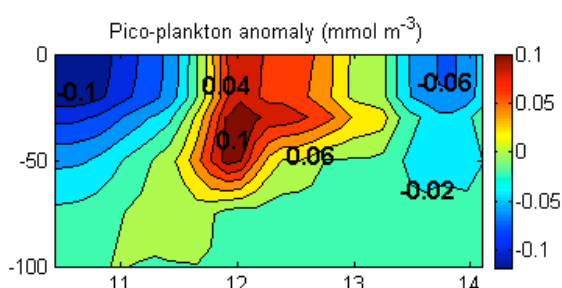
T — S — 8/9/2005 — N

S — 8/9/2005 — 8/9 — 10/2

NO$_3$

Si(OH)$_4$
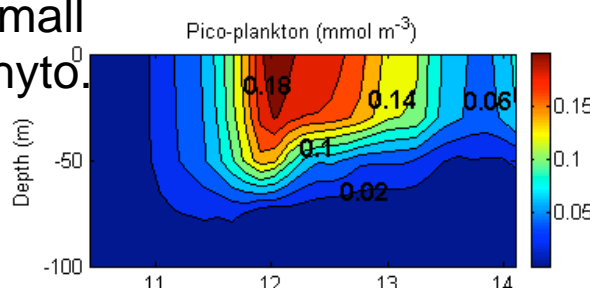
Vertical Profiles — Vertical Anomalies — Time Series of Anom.
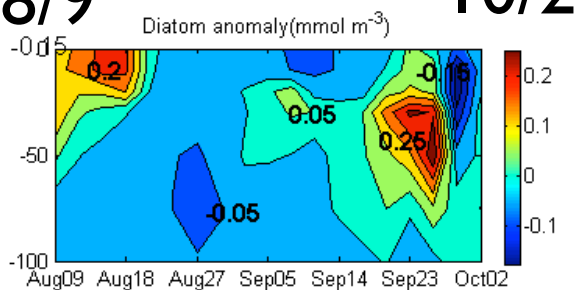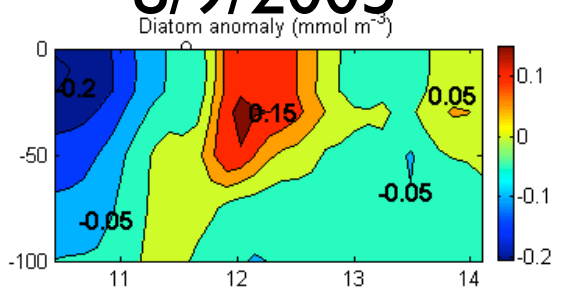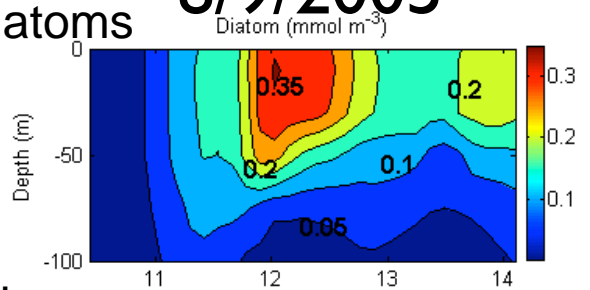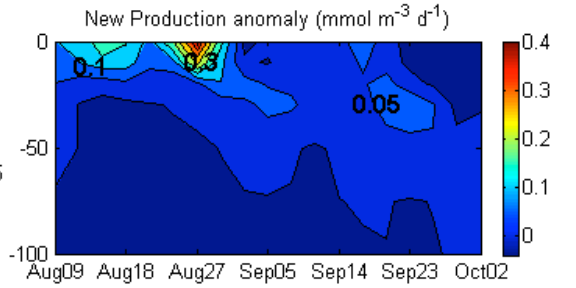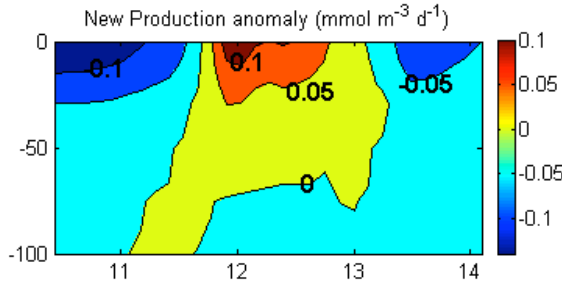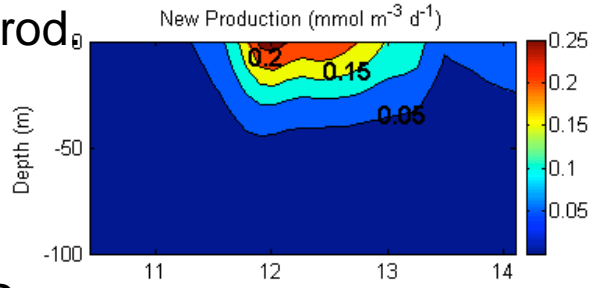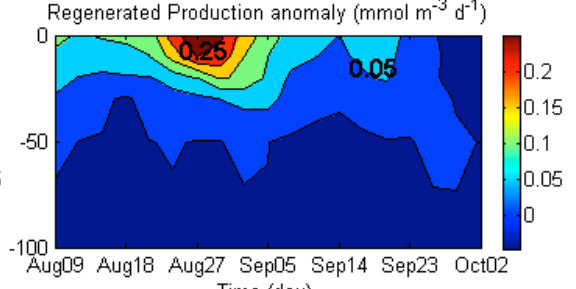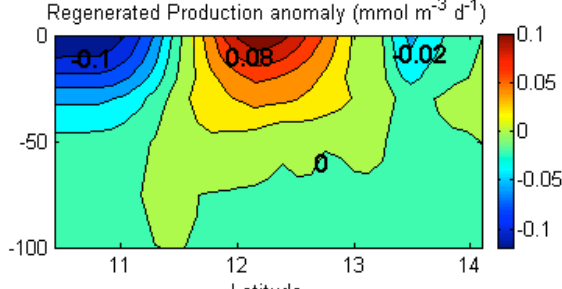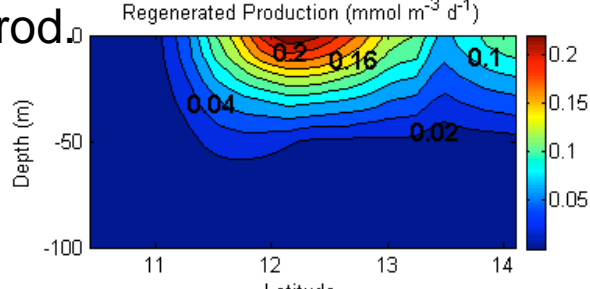
Nitrate at 125 m (mmol m^{-3})

NO₃ at 125m

August 2005
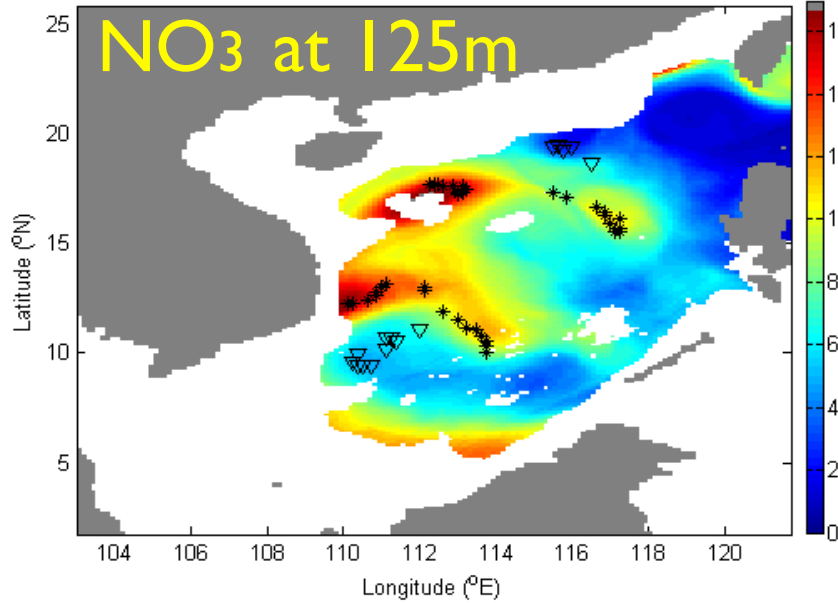
Silicate at 125 m (mmol Si m^{-3})

Si at 125m
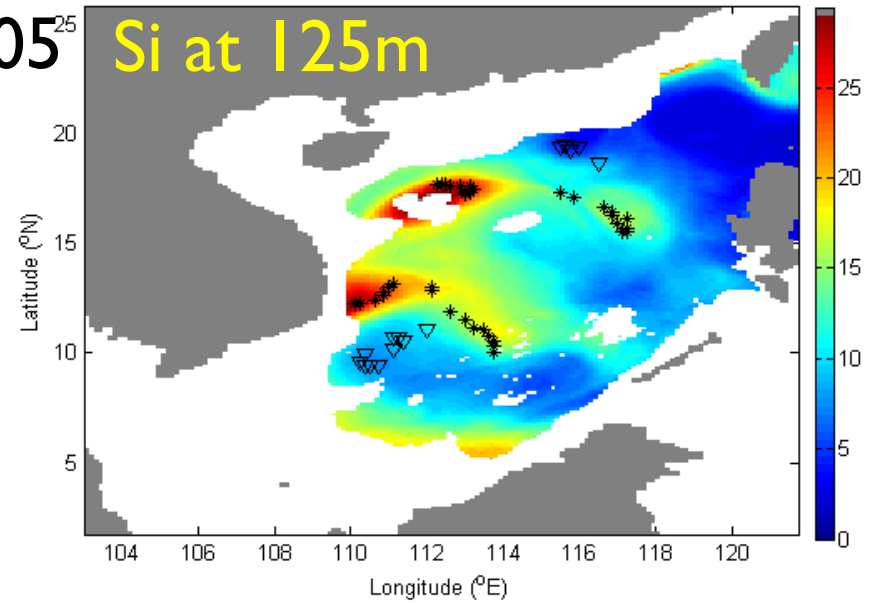
Impact of Cyclonic and Anti-Cyclonic on N, P, Z

Depth-integrated Chlorophyll (mg m^{-2})
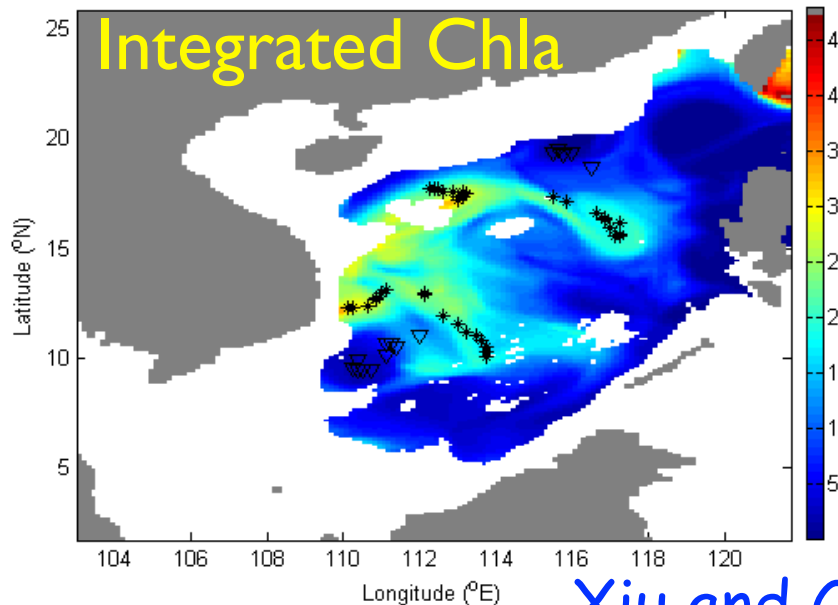
Integrated Chla

Depth-integrated Zooplankton (mmol m^{-2})
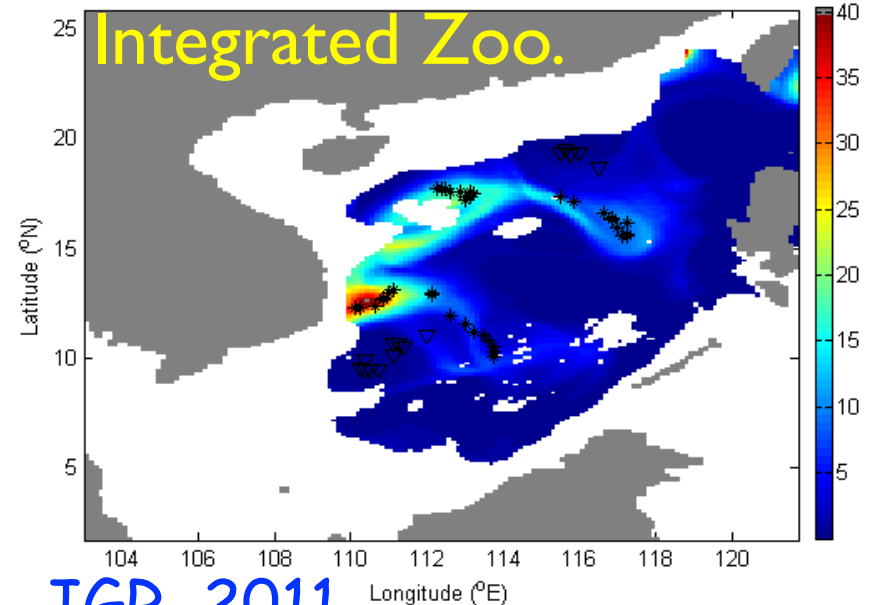
Integrated Zoo.

Xiu and Chai, JGR, 2011

Annual Mean Integrated New Production in the SCS, 1993-2007
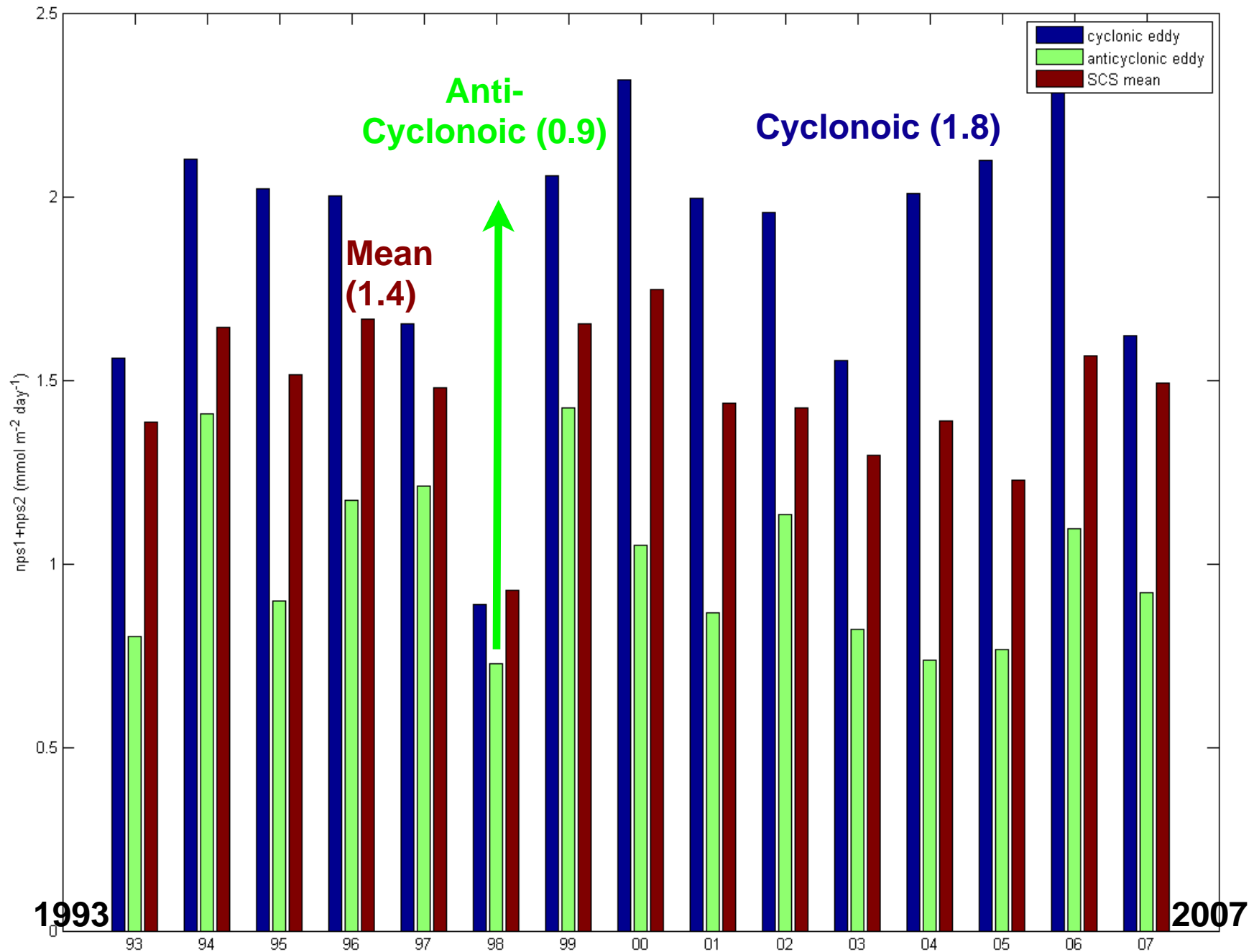
Modeling Impacts of Mesoscale Eddies on Biogeochemical Processes
in South China Sea and Gulf of Alaska

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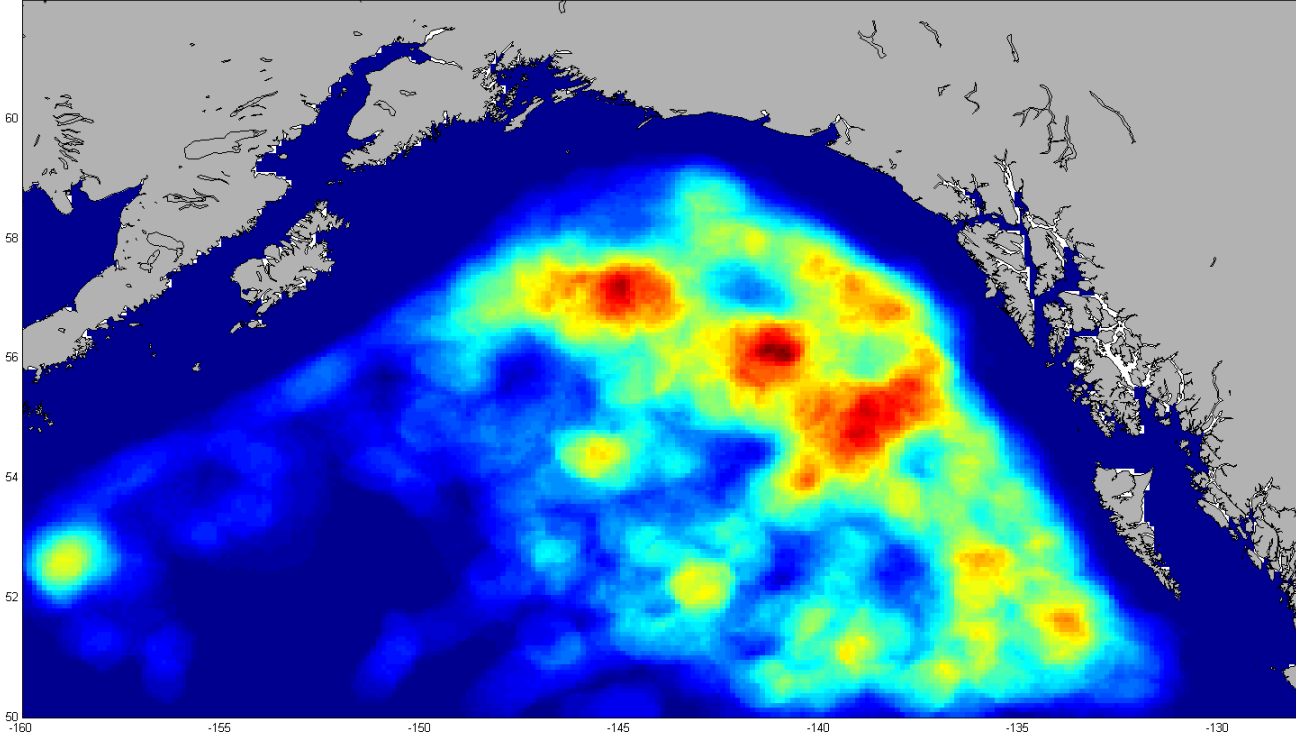
Modeled Eddies Occurrence

Red Area: 15-20%

Satellite Derived Eddies Occurrence

Xiu, Chai et al., DSR, 2012
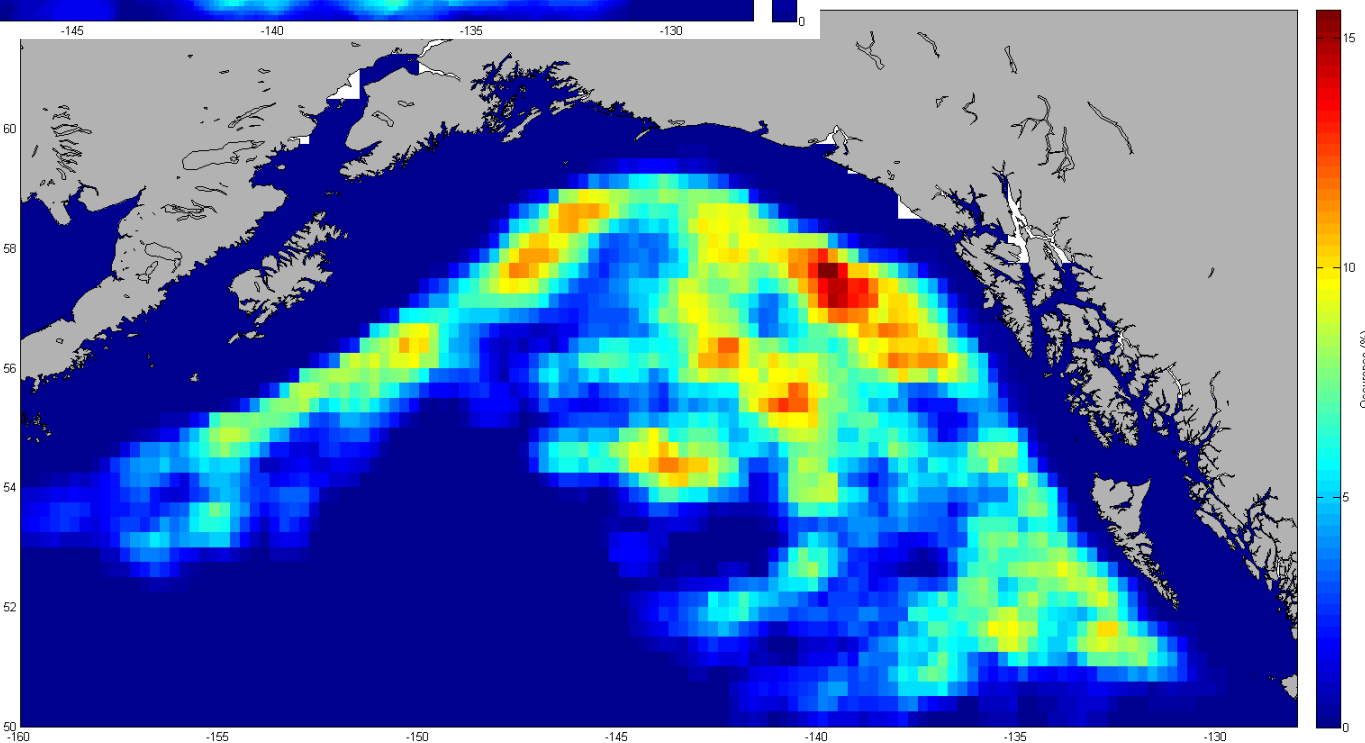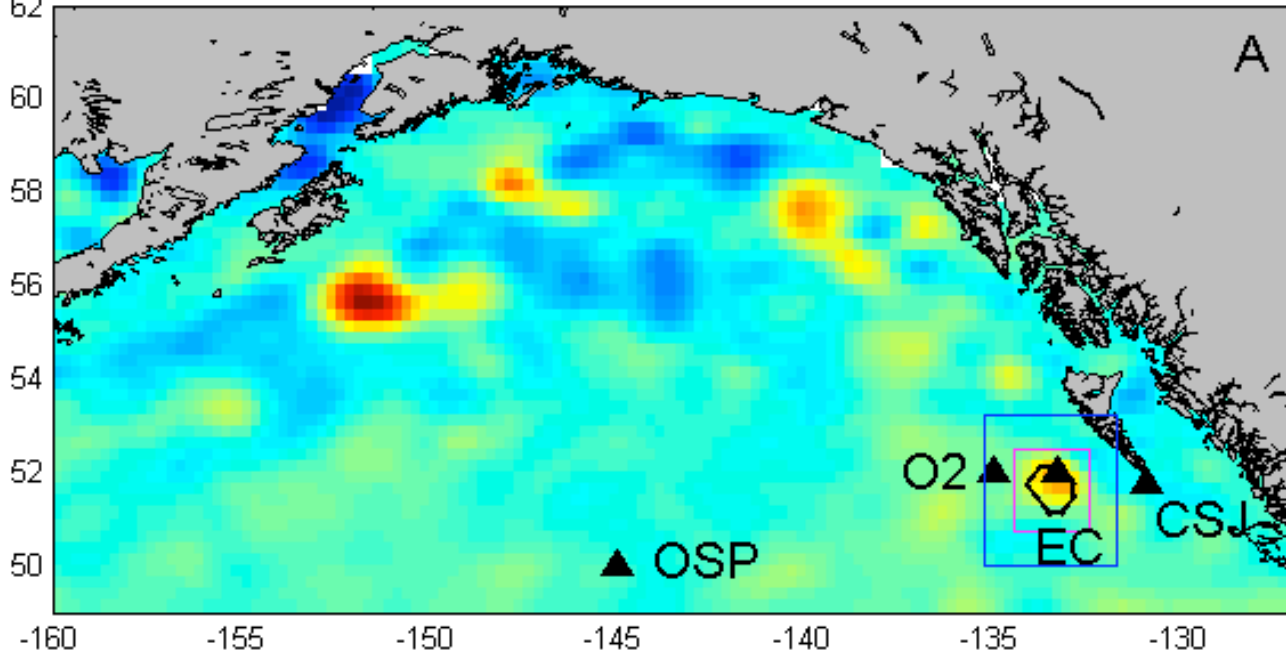
Sea Surface Height Anomaly (cm)

A

B

Yakutat

Sitka
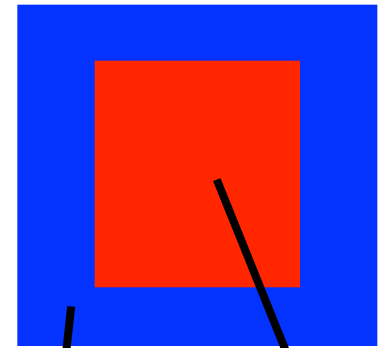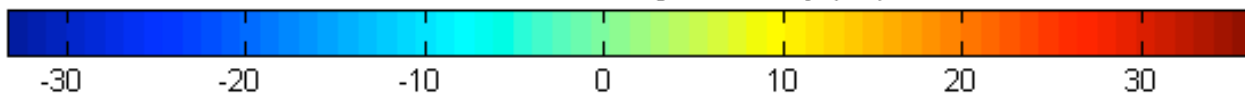
Haida

Eddy Box
100km X 100km

Reference
Area
150km X 150km
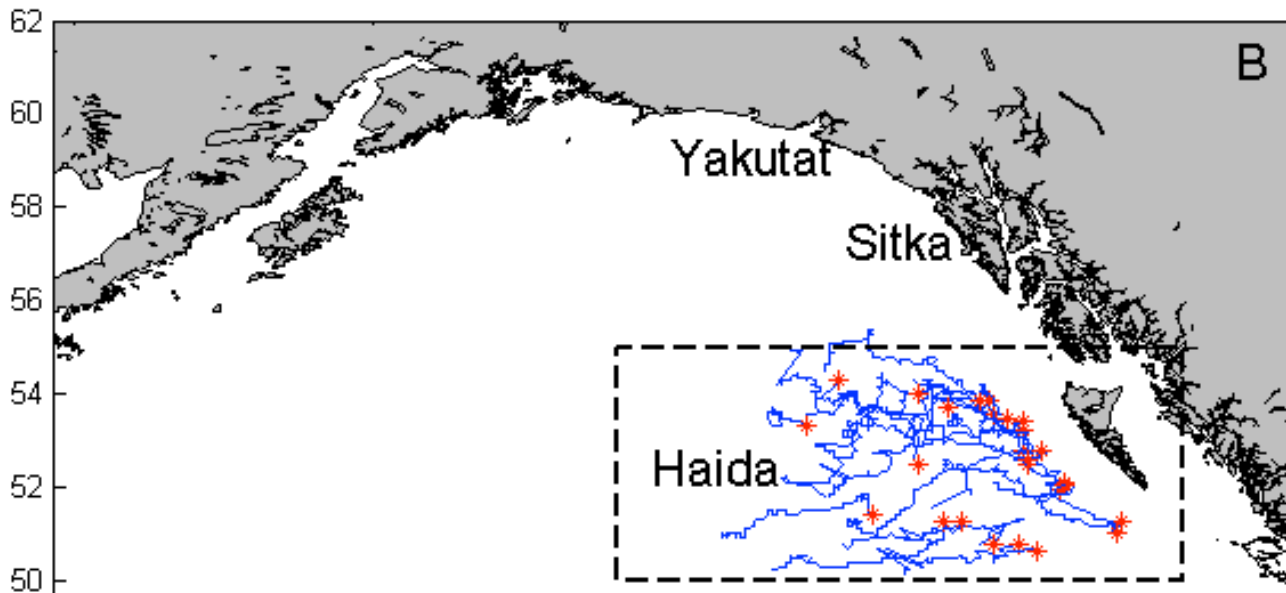
A total of 26 westward
moving Haida eddies (16
years), 280 days averaged
life span

Xiu, Palacz, Chai et al,
GRL, 2011

Averaged Vertical Velocity (m/day) (only positive)
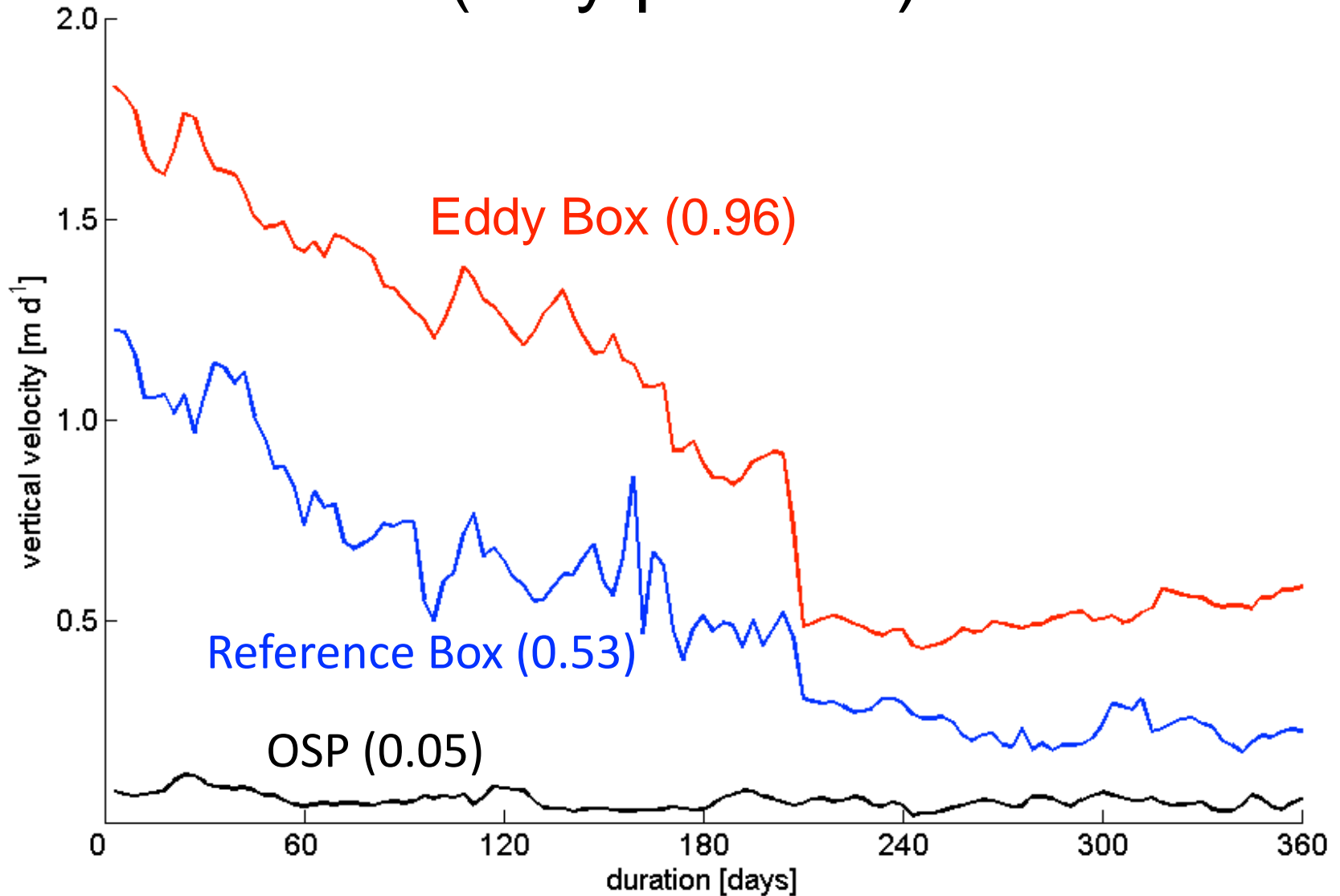
Dissolved Fe Concentration along the Cross Section
June 2007, a three-month old Haida eddy

Roy and Wells, 2011
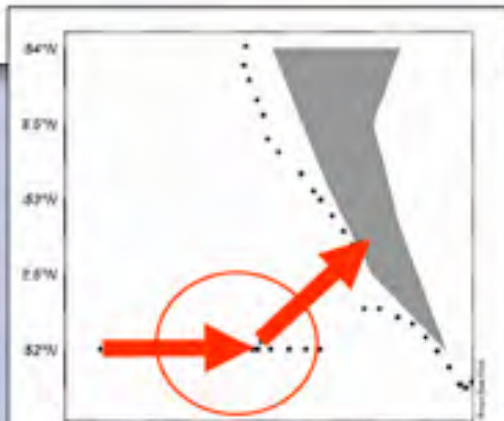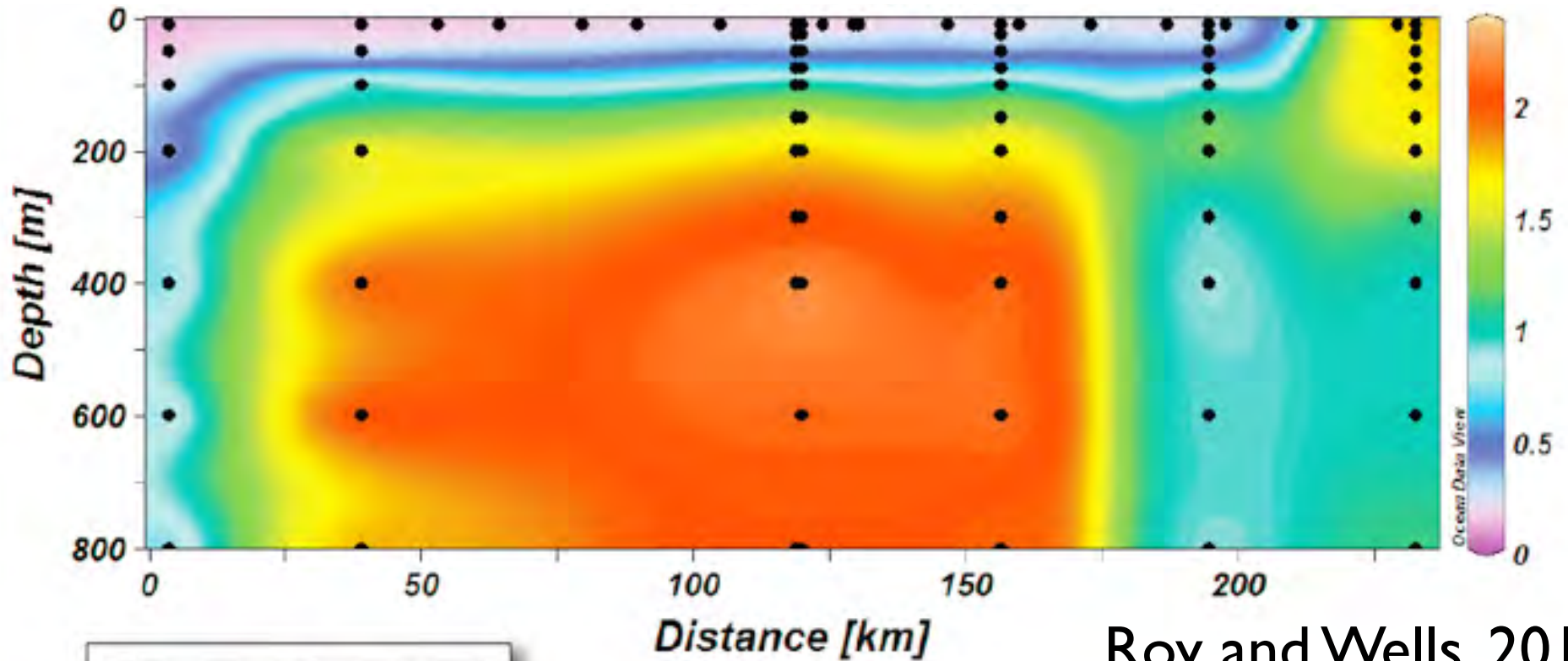
Particulate Fe concentrations
are ~ 3 x higher

Dissolved Iron Supplies to Upper Ocean (100m) (umol m^{-2} day $^{-1}$)

Xiu, Palacz, Chai, et al., GRL, 2011

Langmann et al, JGR, 2010

Palacz et al., DSR II, 2011

2008   *2012*

July   July

2008/JUL   2012/JUL

Aug.   Aug.
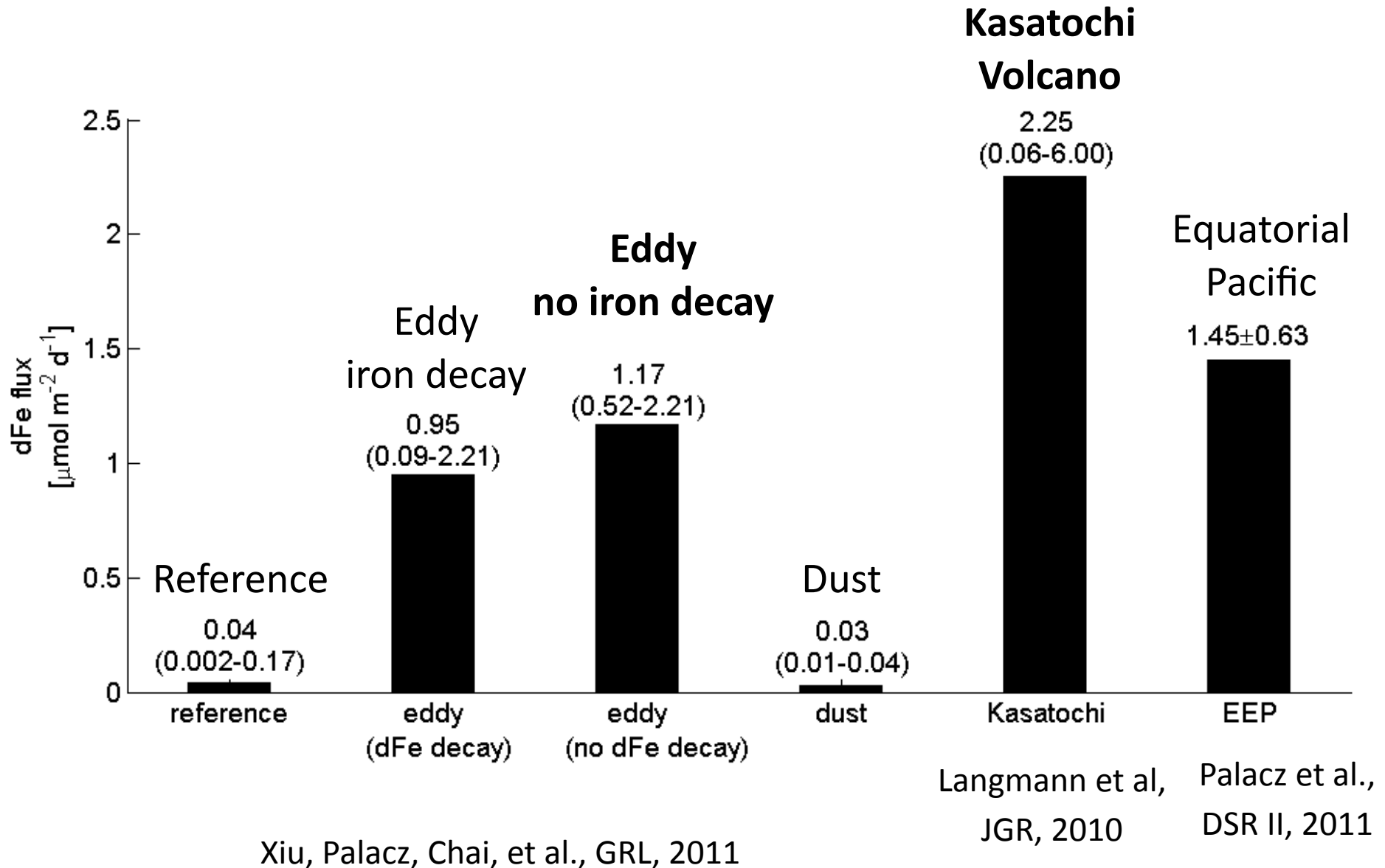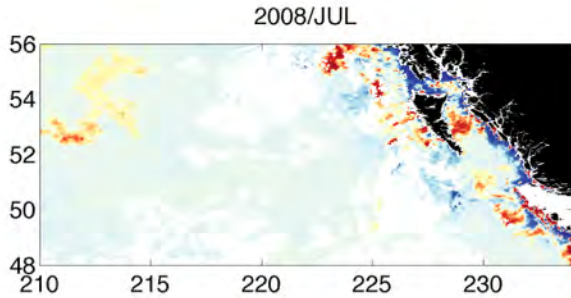
2008/AUG   2012/AUG
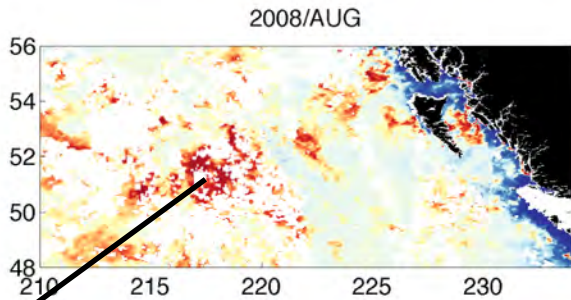
Volcanic
ash induced   **Chlorophyll Anomaly**   Artificial iron
                                                fertilization
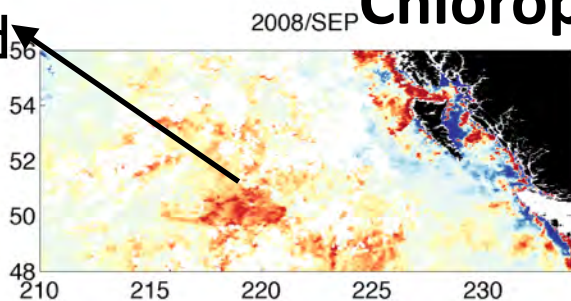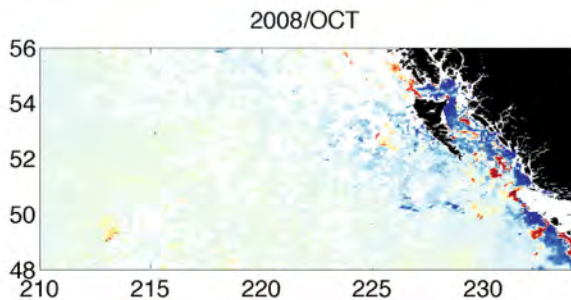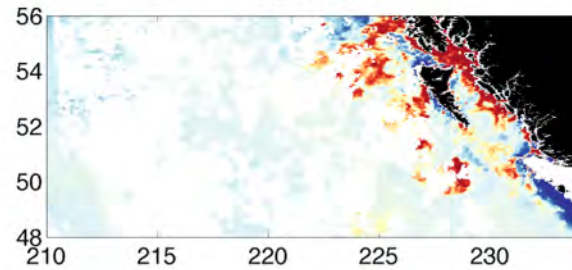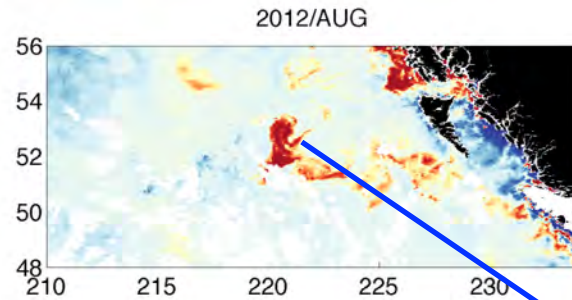
Sept.   Sept.

2008/SEP   2012/SEP

Oct.   Oct.

2008/OCT   2012/OCT

-2   -1.5   -1   -0.5   0   0.5   1   1.5   2

Surface Chlorophyll (color) & SSHA (contour)
9/27/2011 - 8/27/2012
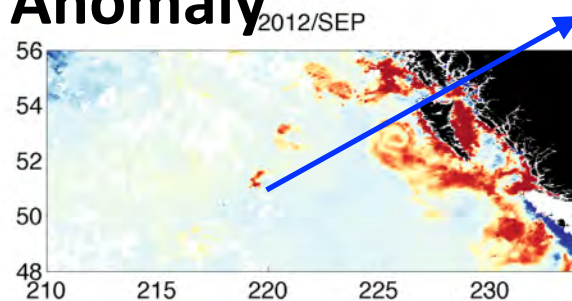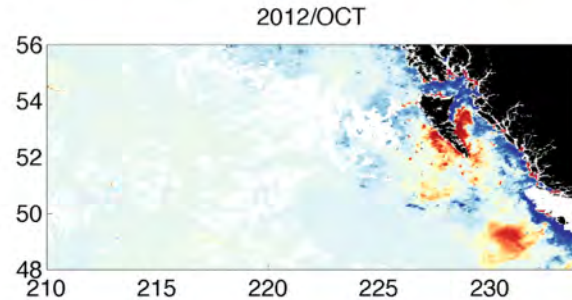
Surface Chlorophyll (color) & SSHA (contour)
9/27/2011 - 8/27/2012

CHL-20110927-20111004
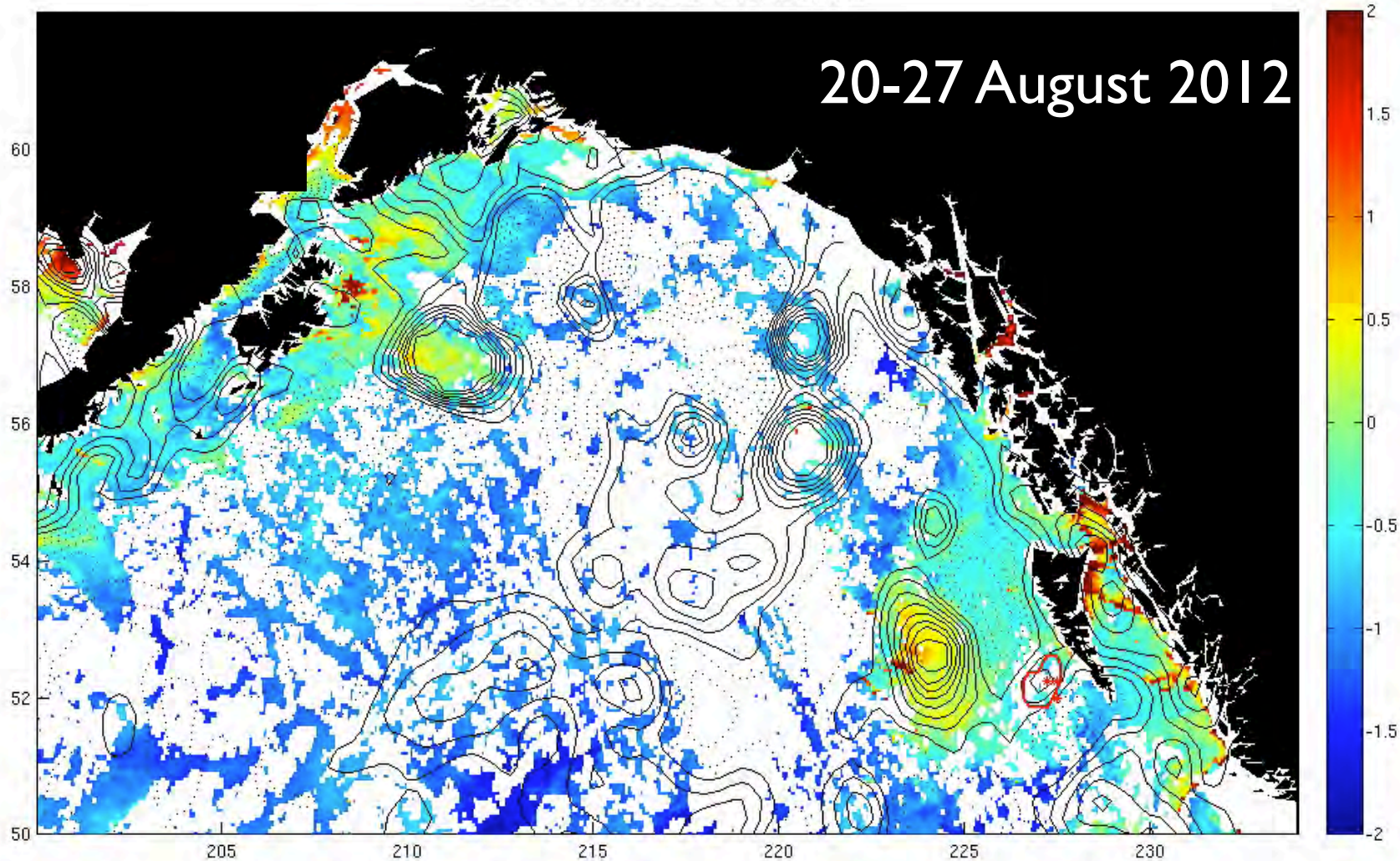
20-27 August 2012

Modeling Impacts of Mesoscale Eddies on Biogeochemical Processes in South China Sea and Gulf of Alaska

Modeling Impacts of Mesoscale Eddies on Biogeochemical Processes in South China Sea and Gulf of Alaska

- Eddy characteristics in SCS and GoA (ROMS and Satellite)

  numbers (33 vs. 7), duration (60 vs. 280 days), 2/year

Modeling Impacts of Mesoscale Eddies on Biogeochemical Processes in South China Sea and Gulf of Alaska

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  long-lived in GoA, locations & tracks, interannual variability
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  depth issue, history of eddy, different phytoplankton groups
- Cyclonic eddies enhance transporting nutrients & production
  30% higher inside cyclonic eddies (1.8 vs. 1.4 mmol/m^2/day)
- GoA anticyclonic eddies
  phytoplankton biomass elevated, decadal trend, iron profiles
  supplying iron (umol/m^2/day): 1 (eddy) vs. 0.03 (dust)

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in South China Sea and Gulf of Alaska

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Modeling Impacts of Mesoscale Eddies on Biogeochemical Processes in South China Sea and Gulf of Alaska

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Mesoscale (10-100km) and Sub-mesoscale (1-10km) physical processes are important in regulating nutrient transport and biological productivity, and iron works