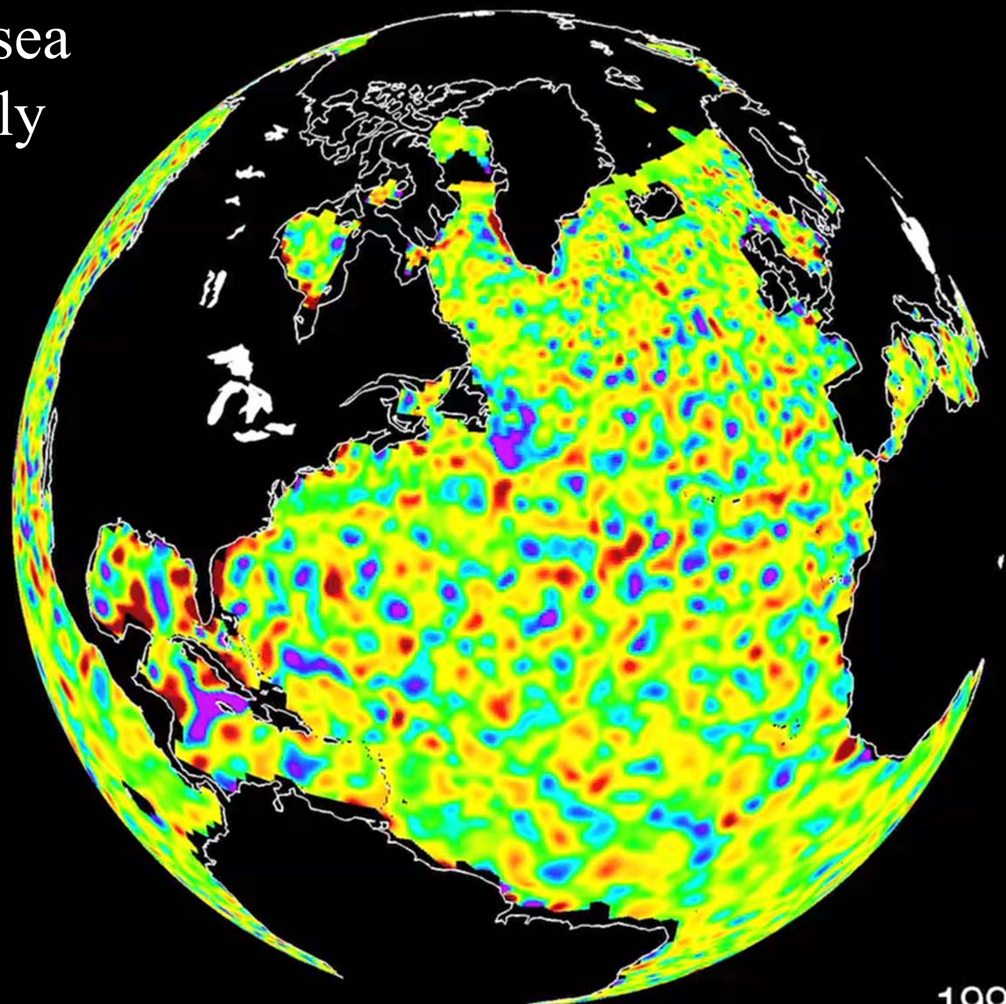
Mesoscale and submesoscale physical-biogeochemical interactions in the North Atlantic

Satellite altimetry:
normalized sea
level anomaly



1992-10-14

Peter Gaube
pgaube@whoi.edu

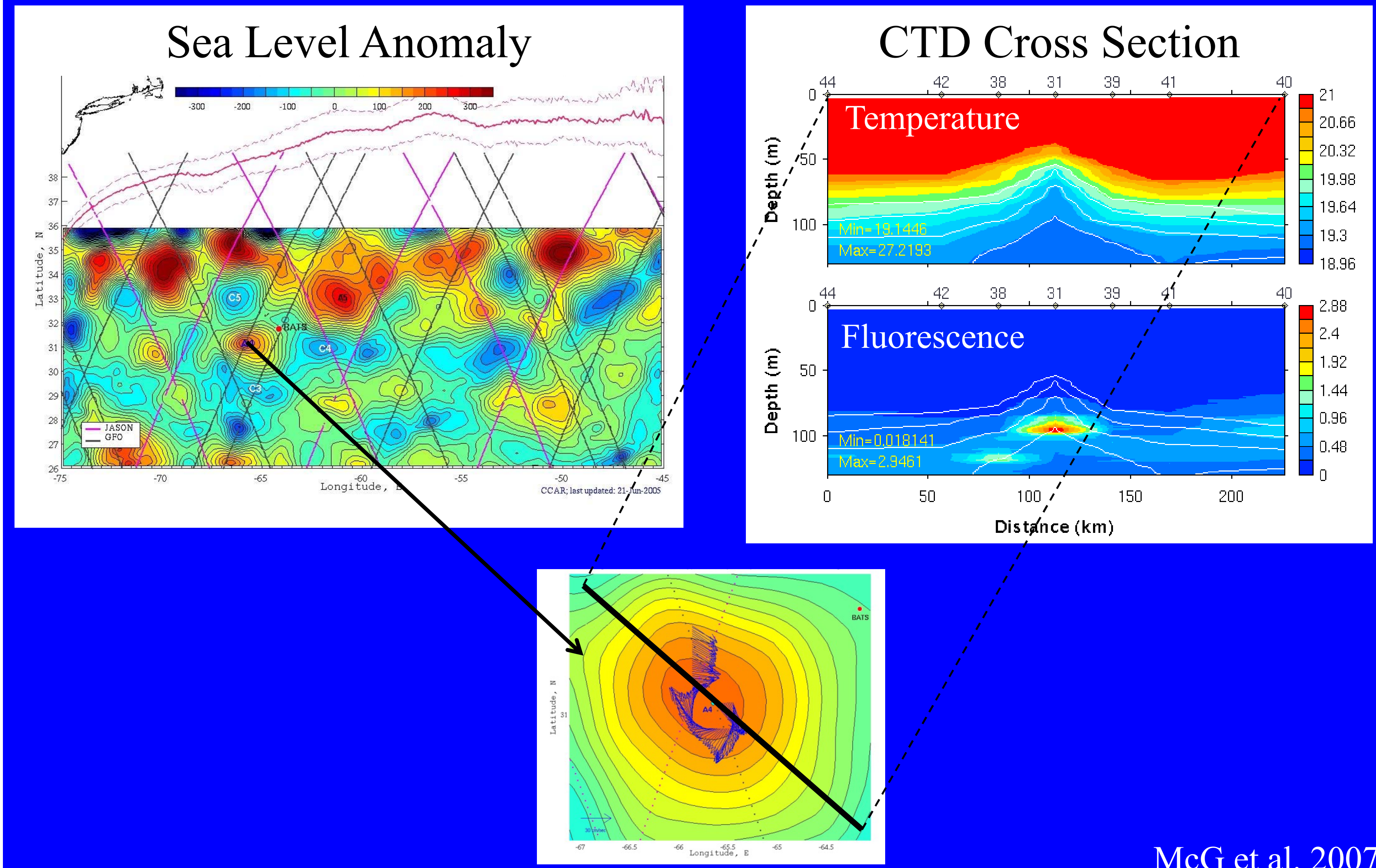
Eddy tracks: lifetimes > 11 weeks

2004/2005 EDDIES Cruises

Ten different eddies sampled, five more than once

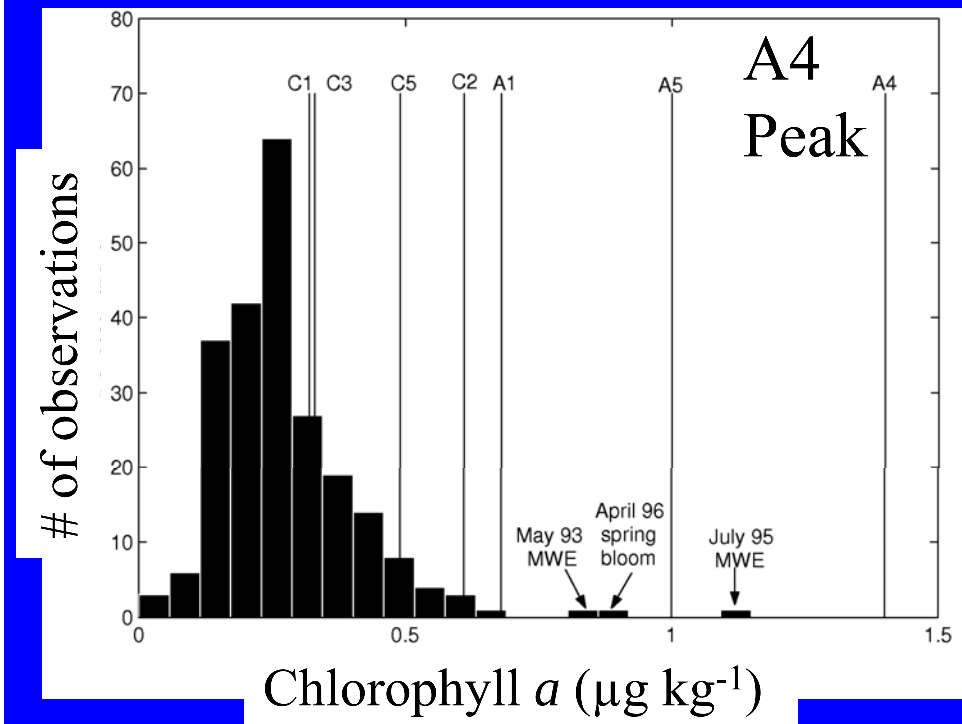
Cyclones	Occupations
C1 – OC404-1 (3), OC404-4 (1)	4
C2 – OC404-1, OC404-4	2
Cold-core GS Ring	1
C3 – OC415-1	1
C5 – OC415-1 (2)	2
Anticyclones	
“Regular”	
A2 – OC404-1 (XBT/ADCP/VPR only)	1
A3 – OC404-1 (XBT/ADCP/VPR only)	1
18° Mode-water eddy	
A4 – OC415-1 (2), OC415-2, OC415-3 (2), OC415-4	6
16° Mode-water eddies	
A1 – OC404-1	1
A5 – OC415-1, OC415-3	2

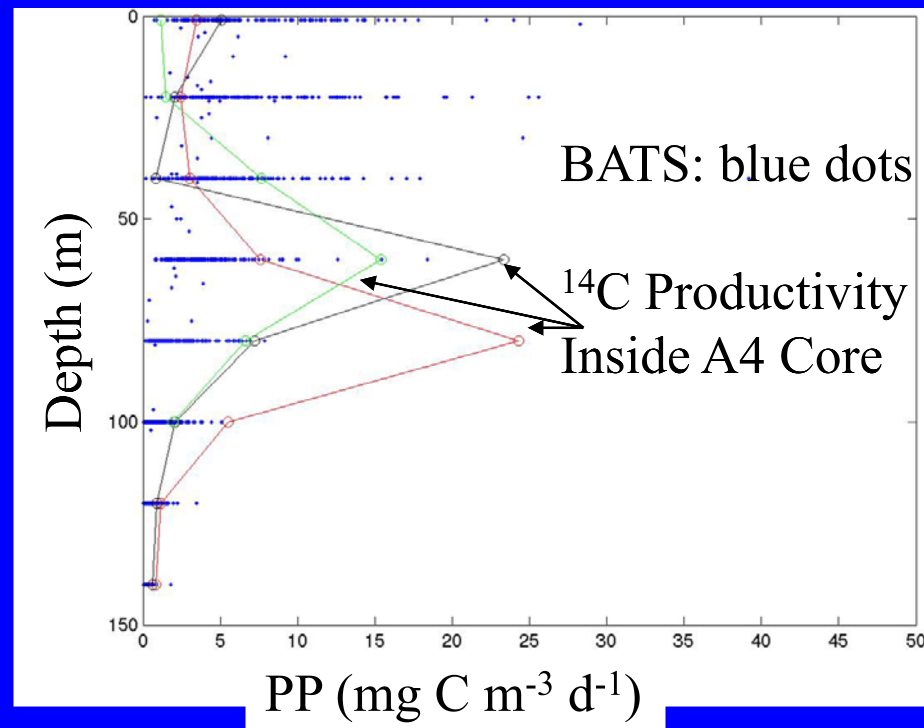
Adaptive sampling of eddy features in the Sargasso Sea using real-time satellite altimetry



McG et al. 2007

BATS Chlorophyll *a* and ^{14}C Productivity 1988-2003





BATS: mean=.28; std=0.14; max=1.15

$$Max(Chl(z)_{A4}) = \overline{Max(Chl(z)_{BATS})} + 8\sigma$$

McG et al. 2007
Ledwell et al. 2008
Martin and Richards, 2001

Export flux in mode-water eddy A4

Particle export typical of BATS

Sediment Trap Flux
150m PITS
mg m^{-2} day^{-1}

	Mass	**C**	**N**
EDT3 - Array A	81.2	17.2	2.6
EDT3 - Array B	61.0	14.6	2.2
EDT4 - Array A	68.0	12.5	2.2
EDT4 - Array B	59.0	12.3	2.0
BATS Climatology (summer 1988-2003)	107.8±39.0	27.2±8.0	4.3±1.5

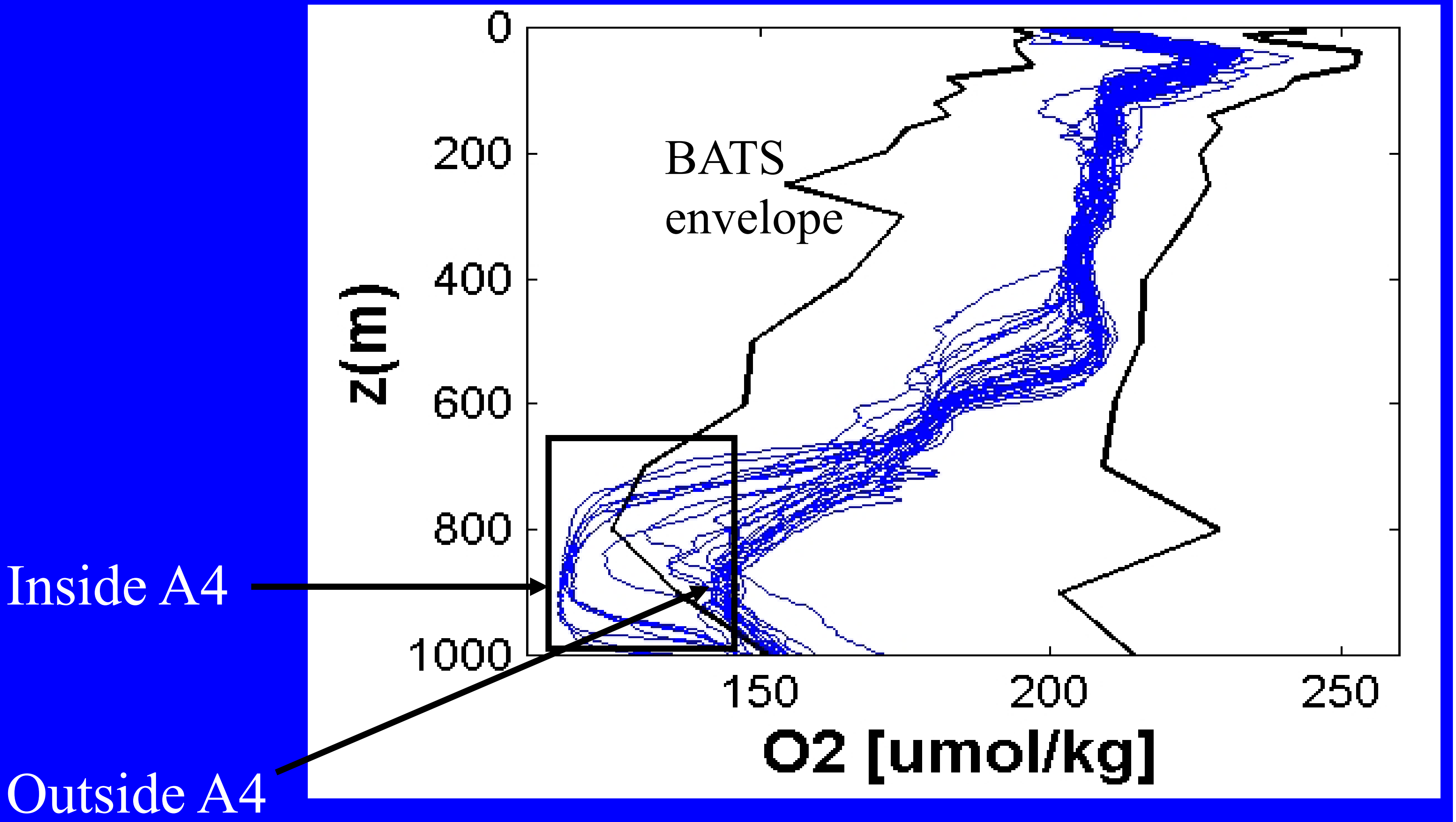
Rod Johnson, BBSR

^{234}Thorium-based Carbon Flux
mg C m^{-2} day^{-1}

	C
EDT3	15±5
EDT4	22±9

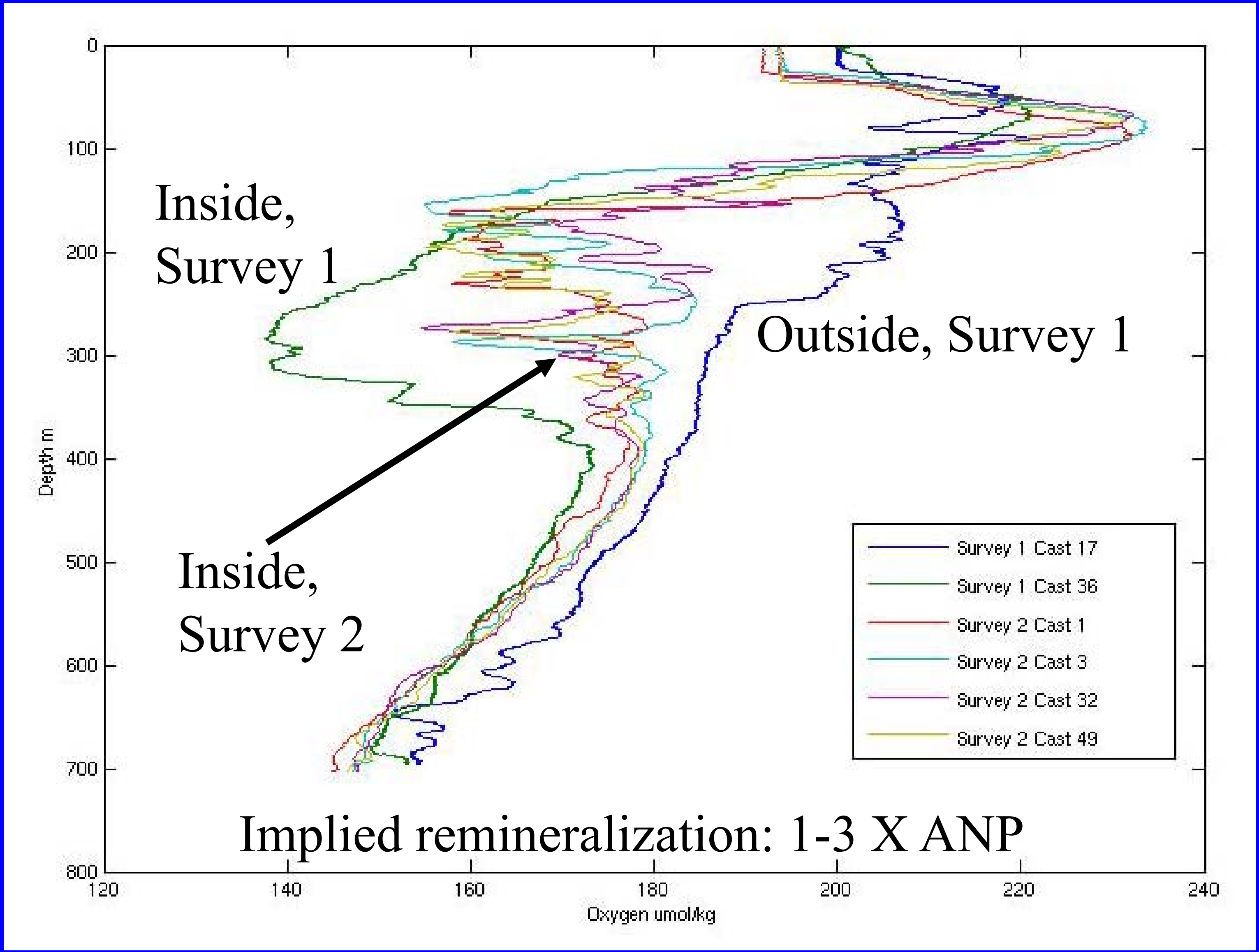
Buesseler et al. 2008

A4 Deep Oxygen Deficit

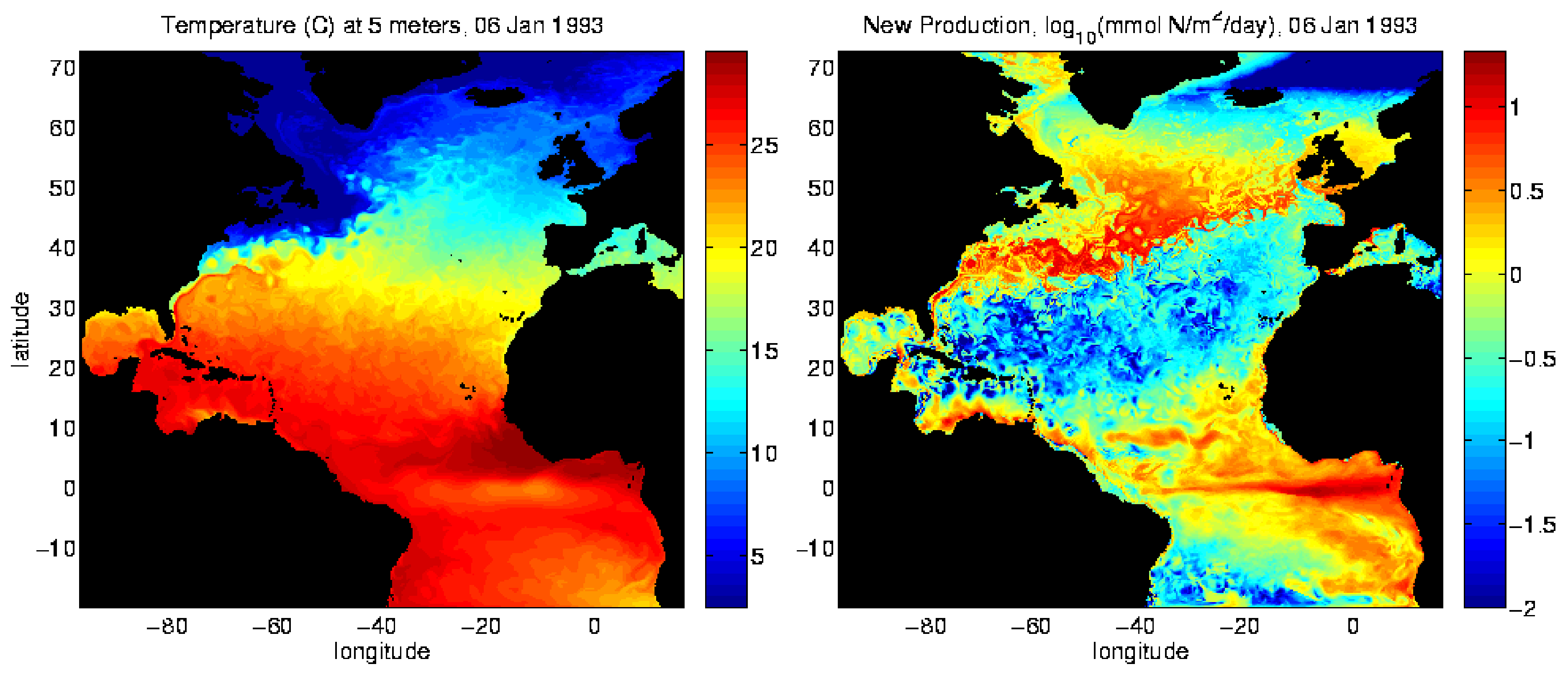


A4 oxygen deficit: 1.6 X annual new production

Cyclone C1 oxygen profiles



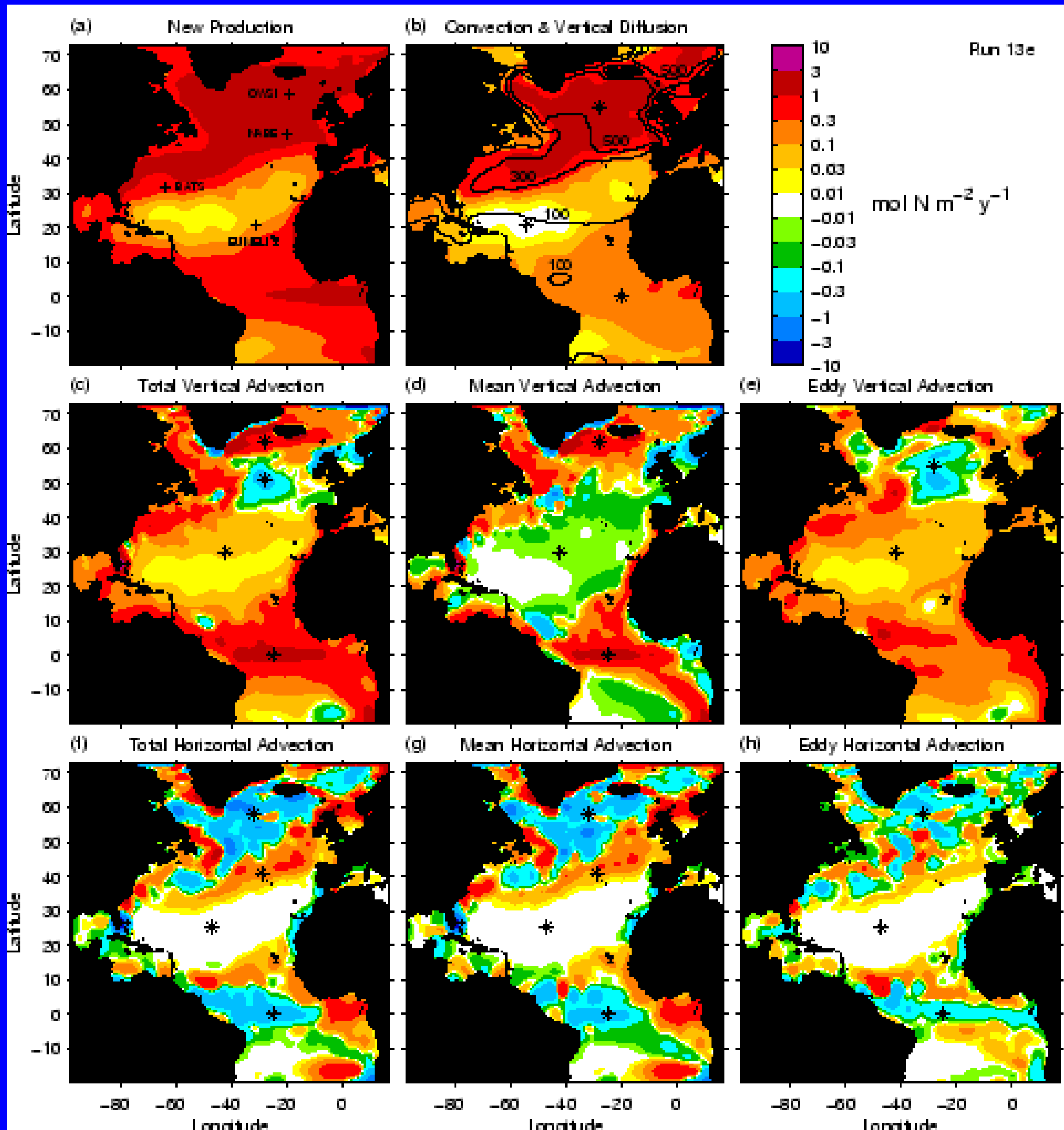
A 0.1° Resolution Model of the North Atlantic



McG et al. 2003

Annual New Production and Nutrient Budgets

New Prod   Conv + Diff



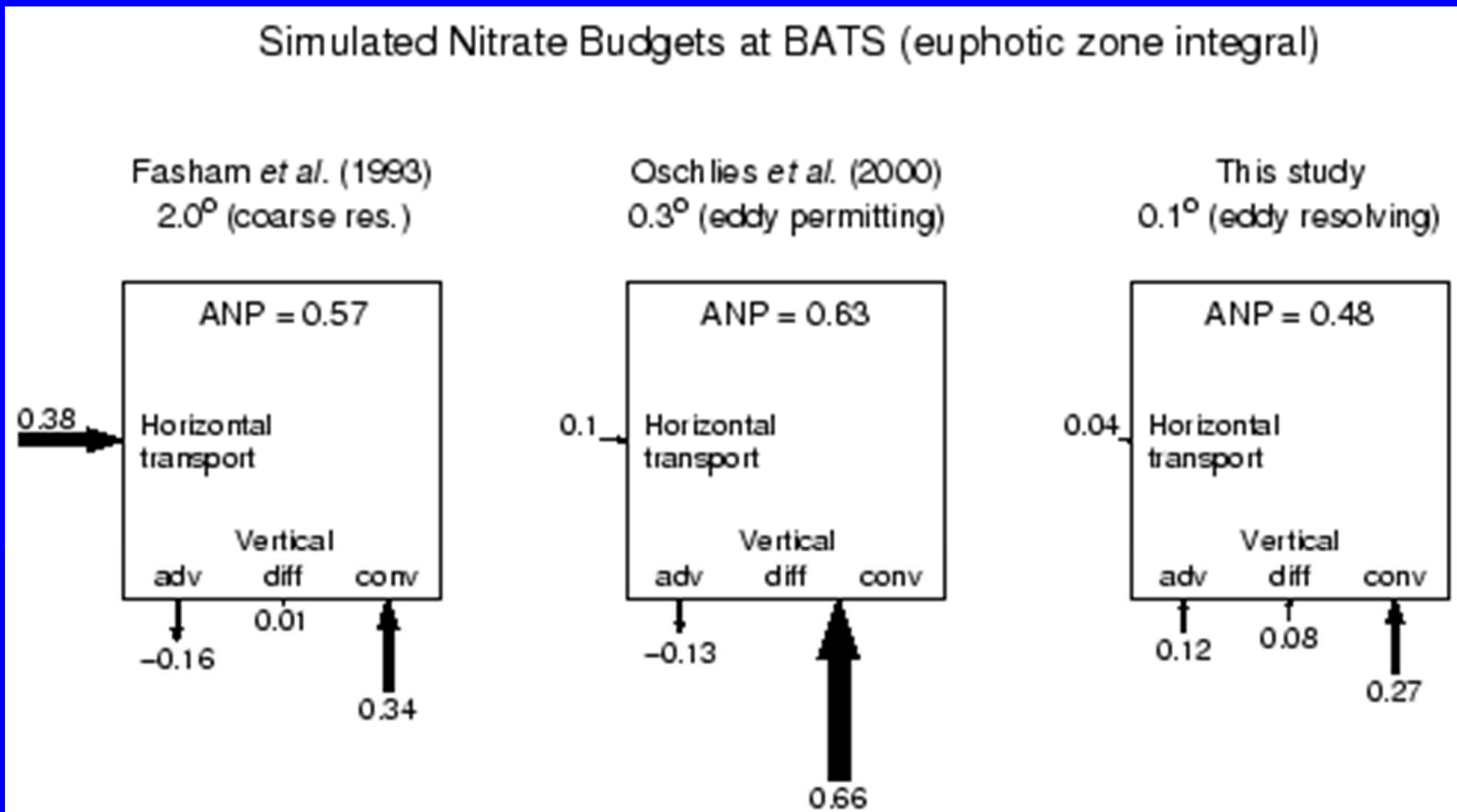
Vertical advection

Horizontal advection

Total   Mean   Eddy

New Production at BATS:

Three Models, Three Different Nutrient Transport Pathways

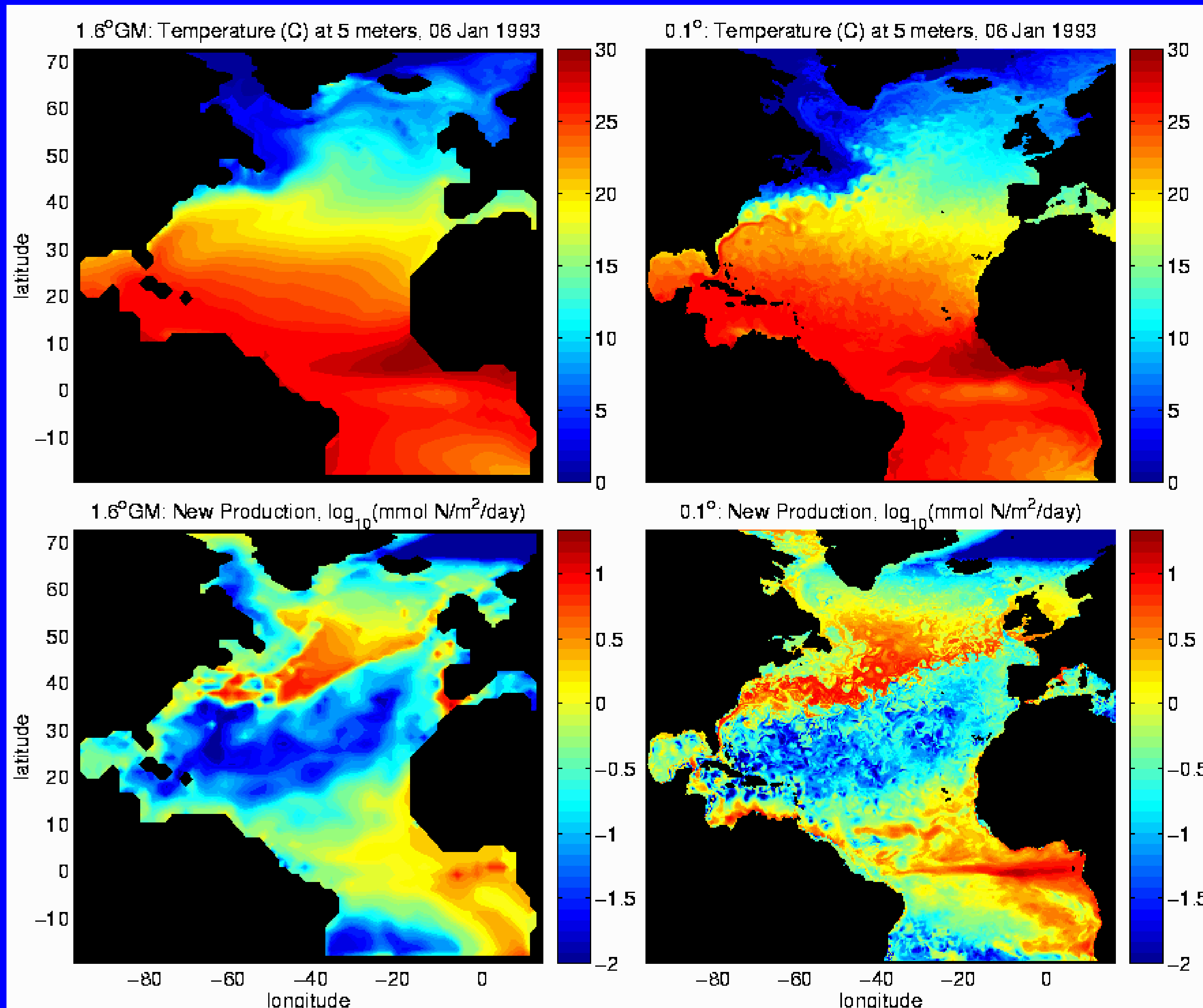


Observed Annual New Production = 0.5 mol N m^{-2} yr^{-1}

Coarse (1.6°) Eddy-resolving (0.1°)

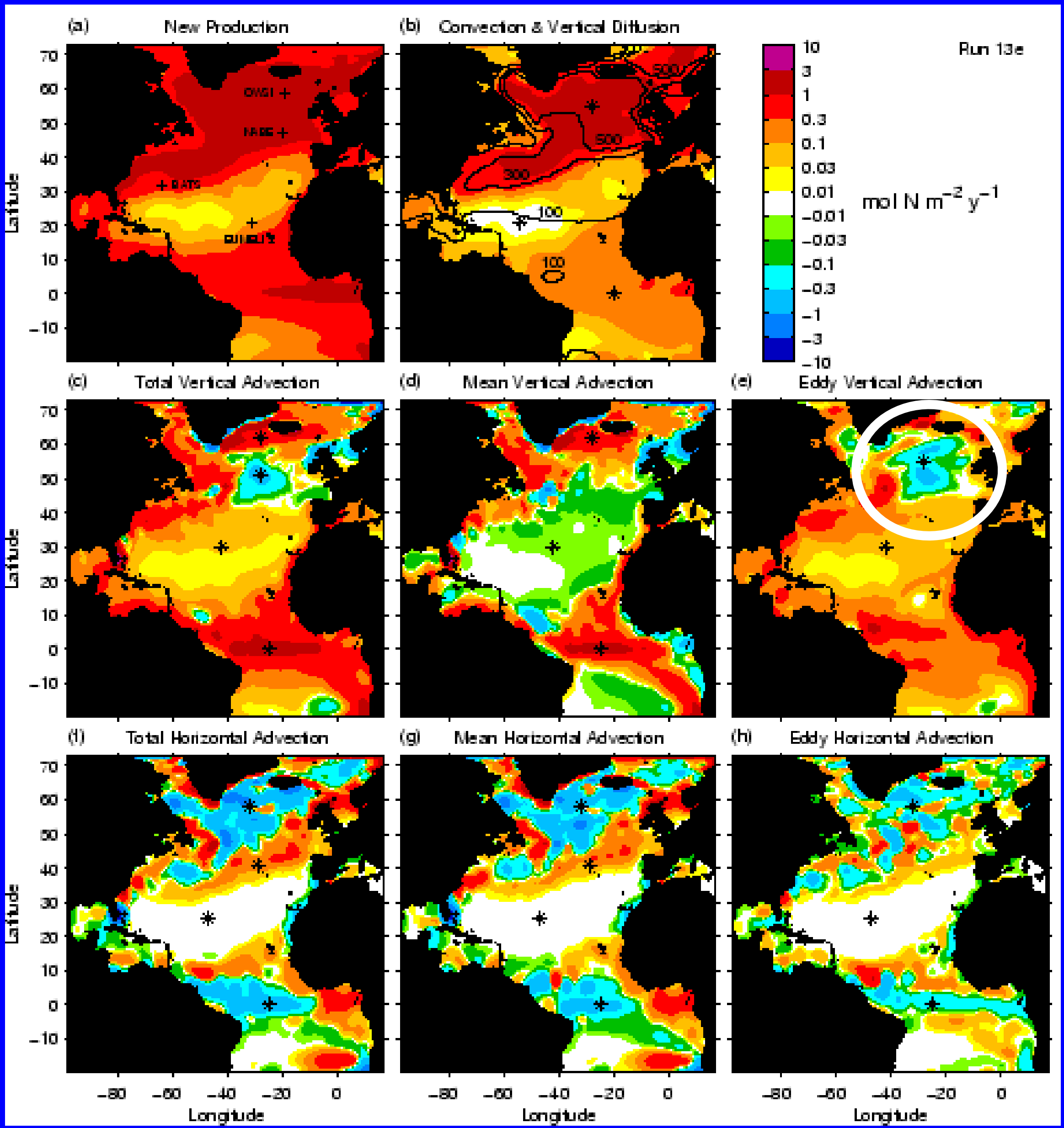
Sea Surface Temperature

log (New Production)



New Prod Conv + Diff

Are eddies a sink of nutrients in the subpolar gyre?

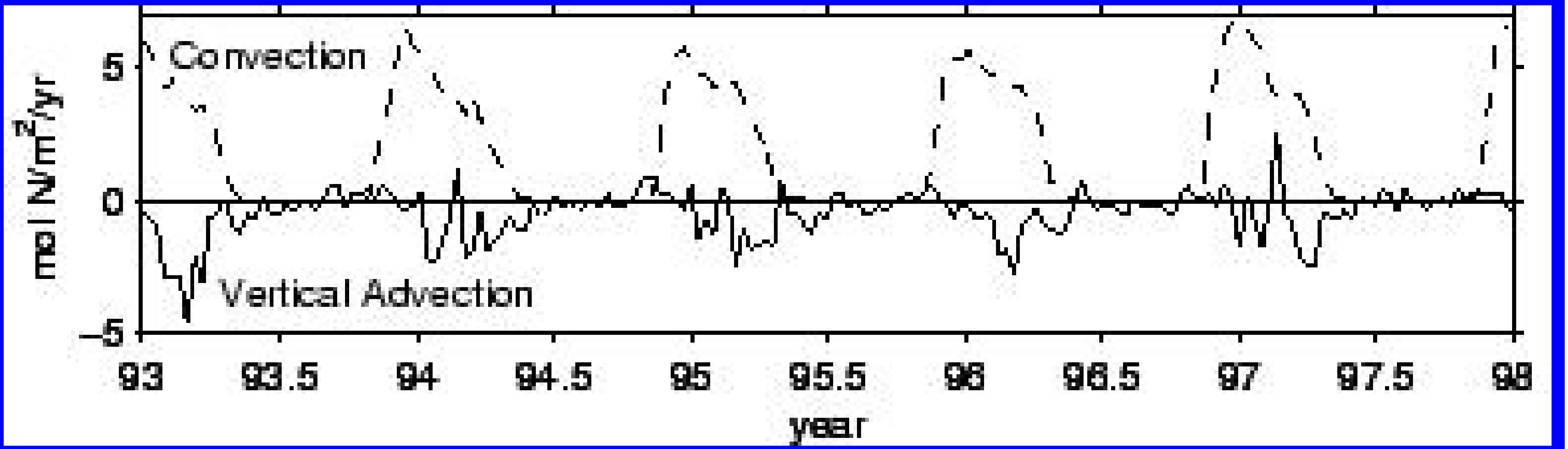


Vertical advection

Horizontal advection

Total Mean Eddy

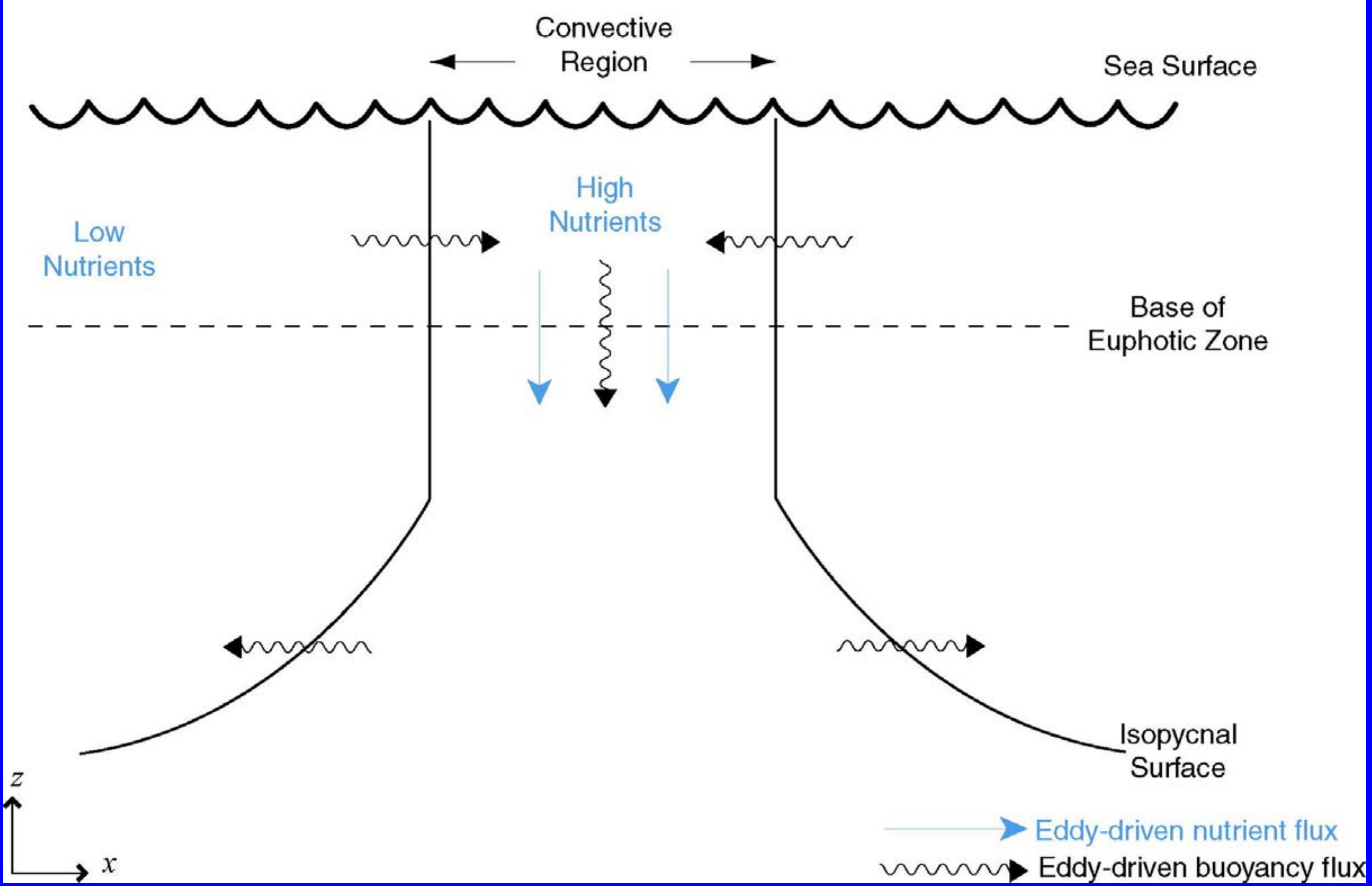
Time-series of terms in the blue spot
51N, 28W: 105m



Negative vertical advection of nitrate associated with post-convective adjustment

McG et al. 2003

An Eddy-driven Nutrient Sink: Mesoscale Restratification After Deep Convection



McG et al. 2003

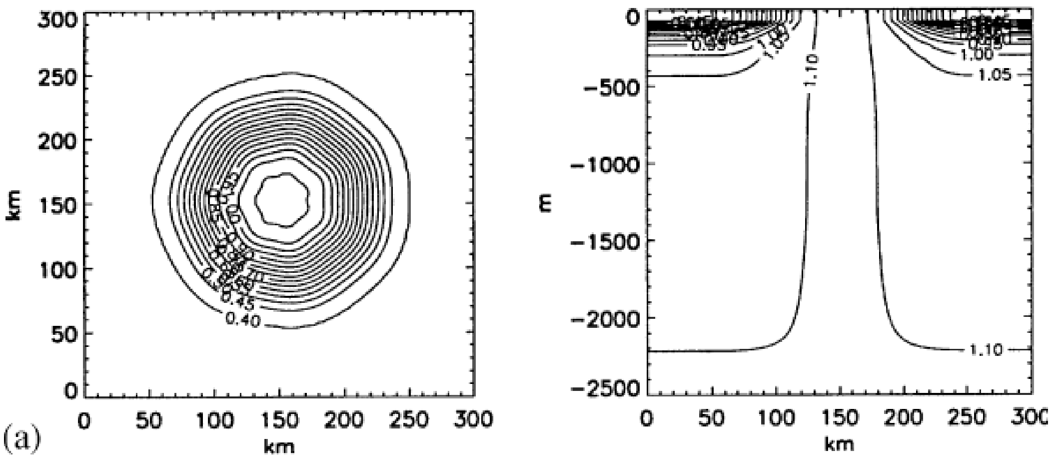
Magnitude of the eddy-induced sink comparable to biological uptake term

Eddy-driven impacts on restratification following deep convection

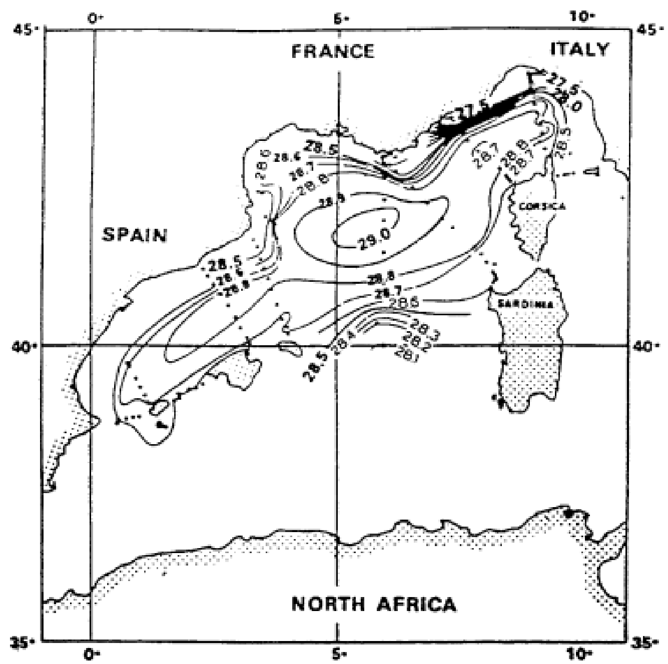
Density plan view

Density vertical section

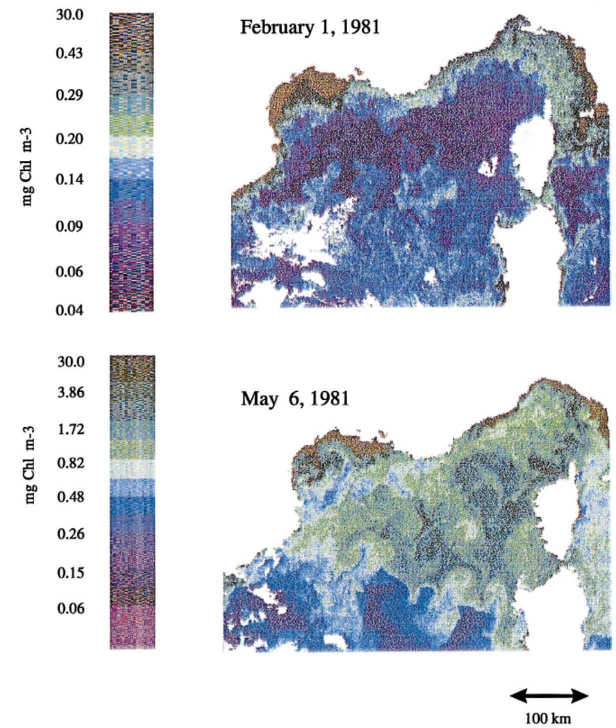
2.5 km resolution model



(a)

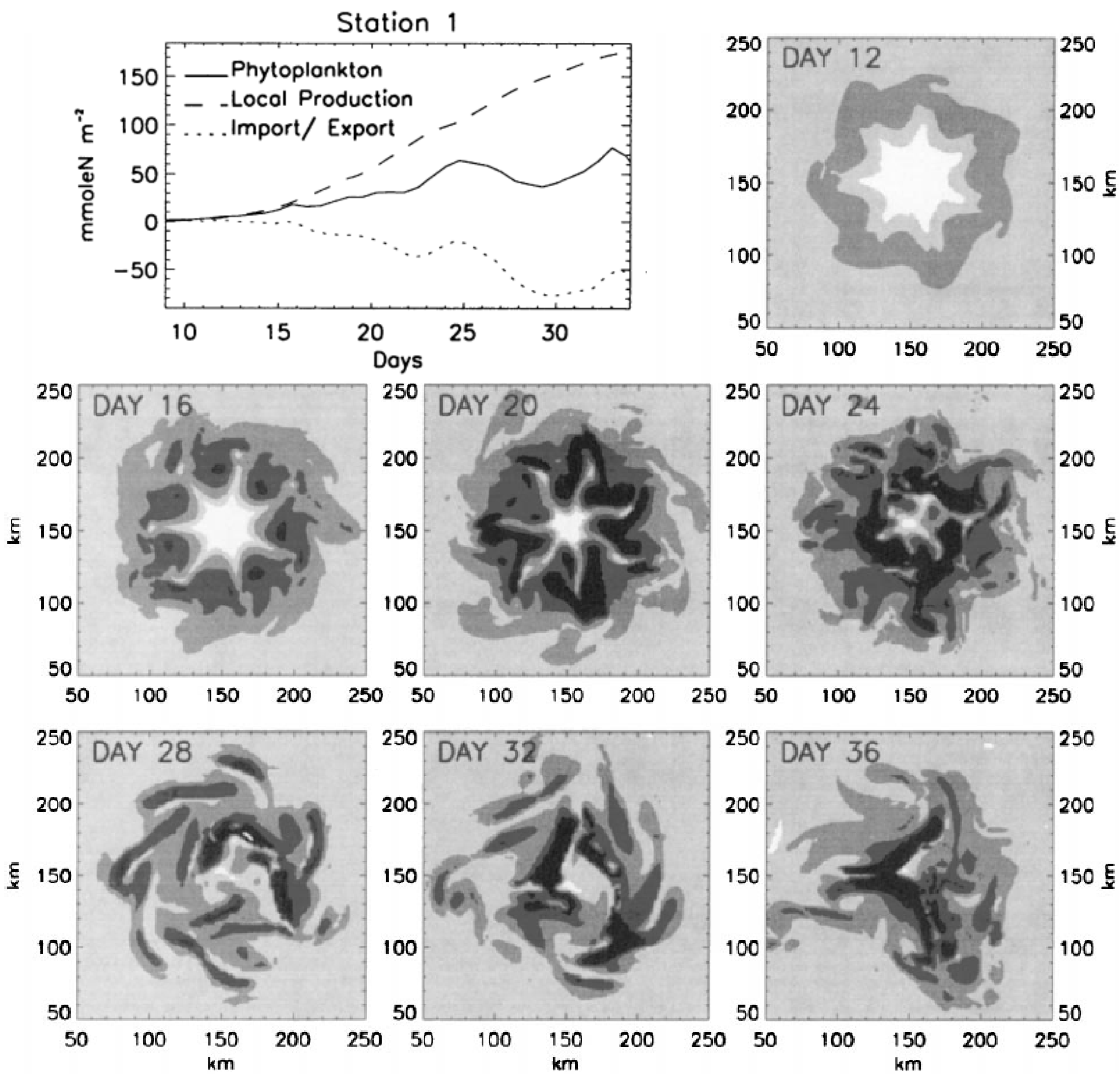


(b)

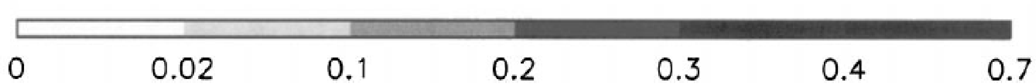


Levy et al. 1998

Frontal stratification and subduction



Surface Primary Production (mmol N m^{-3} d^{-1})

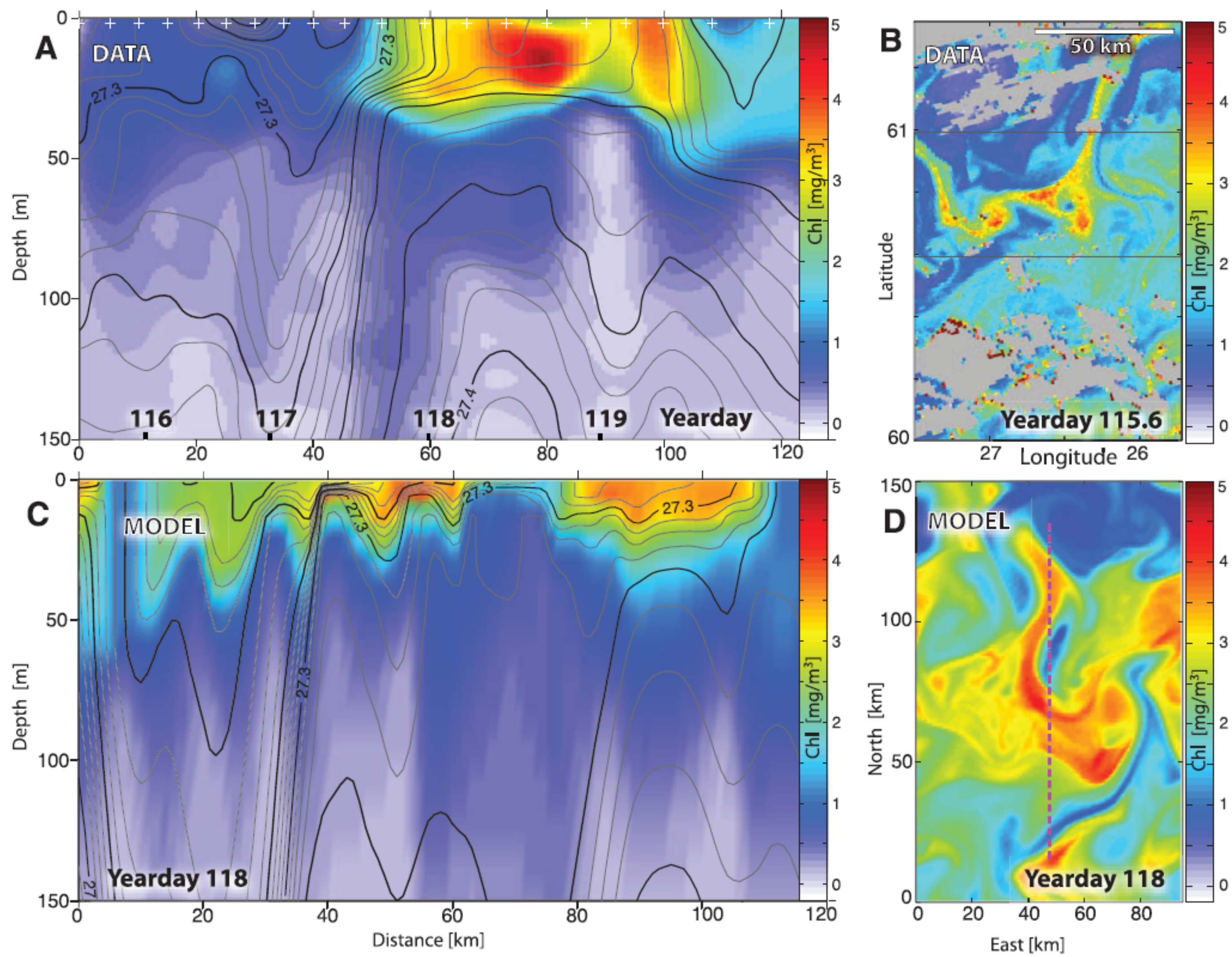


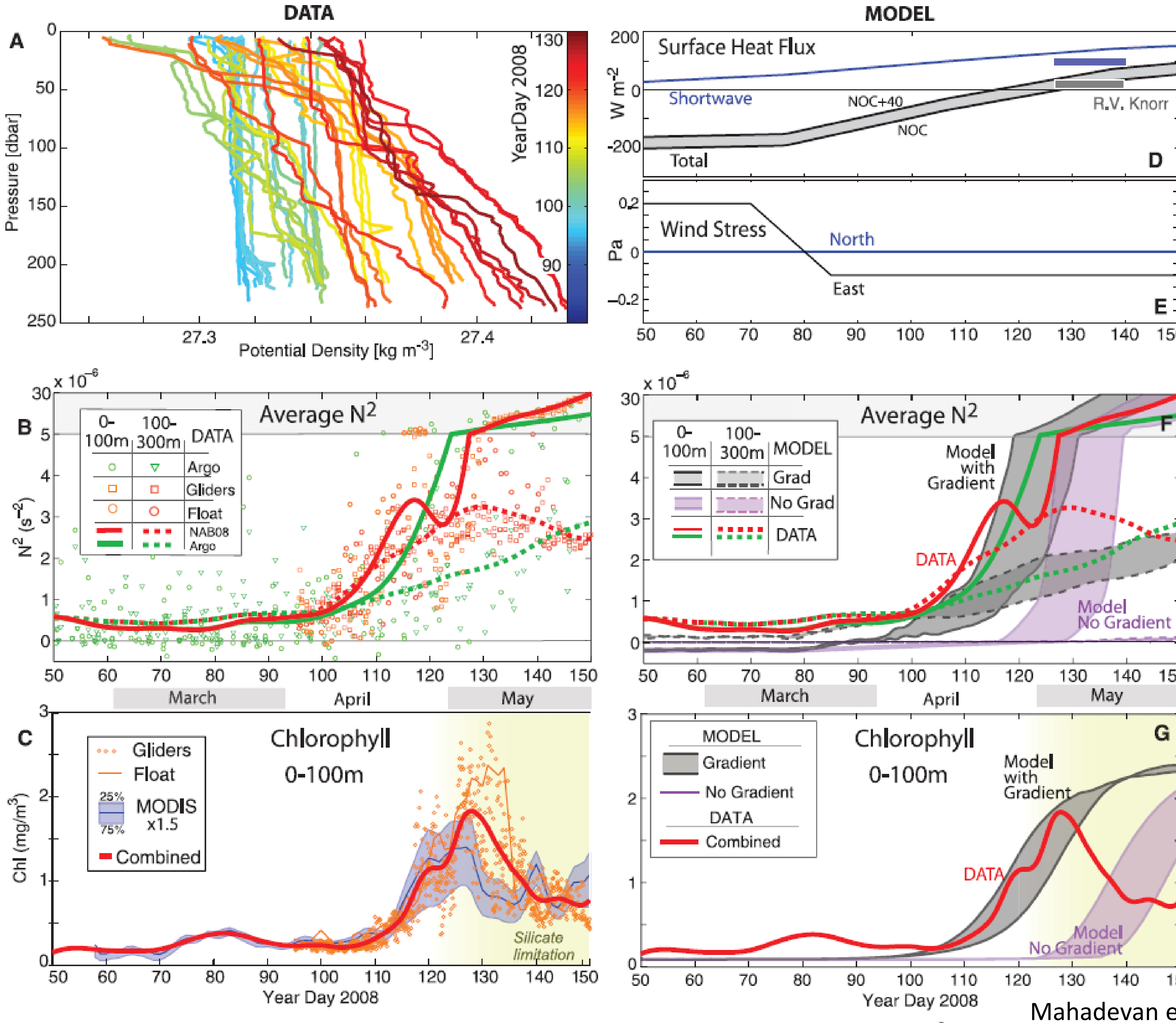
Levy et al. 1998

SCIENCE VOL 337 6 JULY 2012

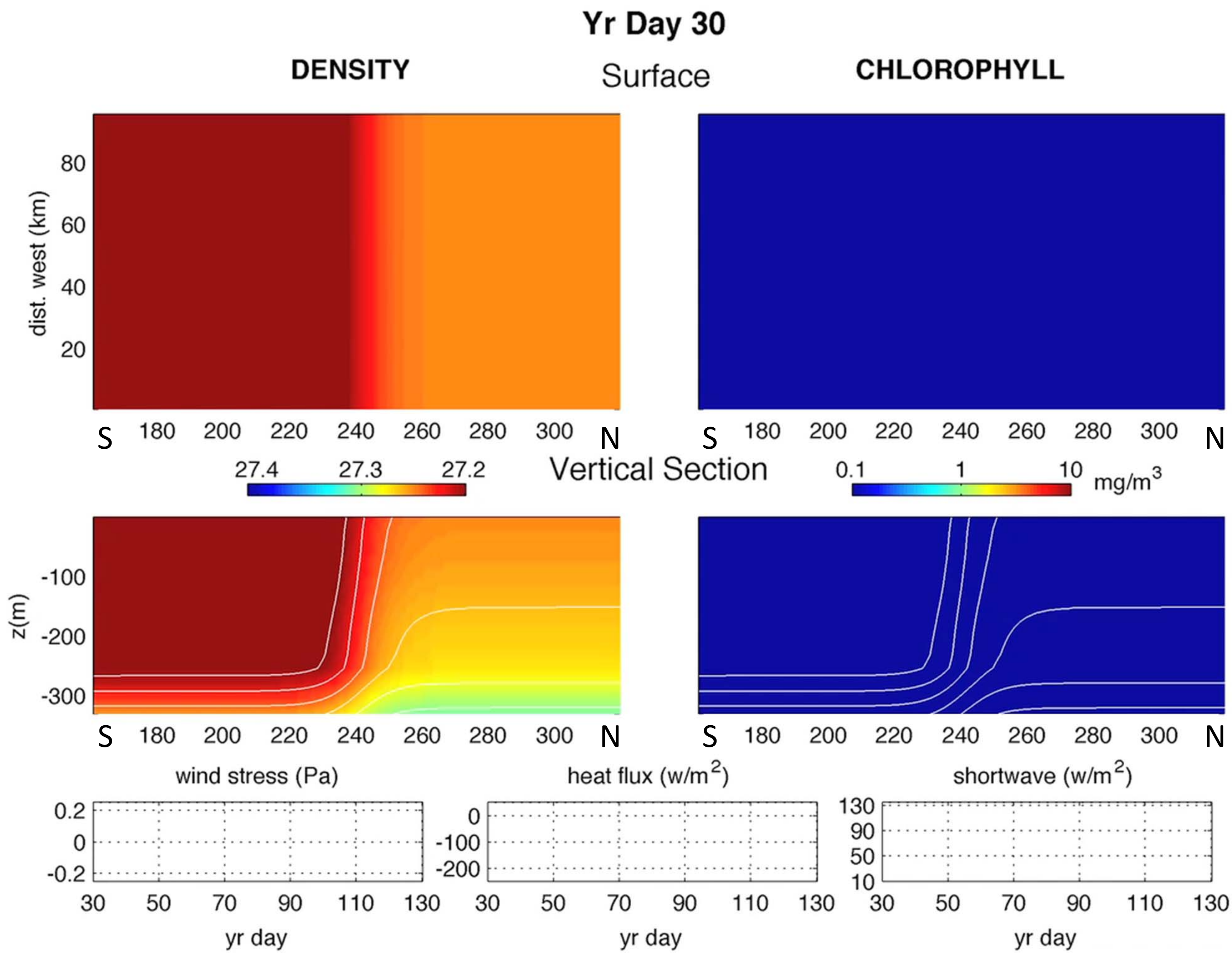
Eddy-Driven Stratification Initiates North Atlantic Spring Phytoplankton Blooms

Amala Mahadevan,[1] Eric D'Asaro,[2]* Craig Lee,[2] Mary Jane Perry[3]





Mahadevan et al. 2012



Mahadevan et al. 2012

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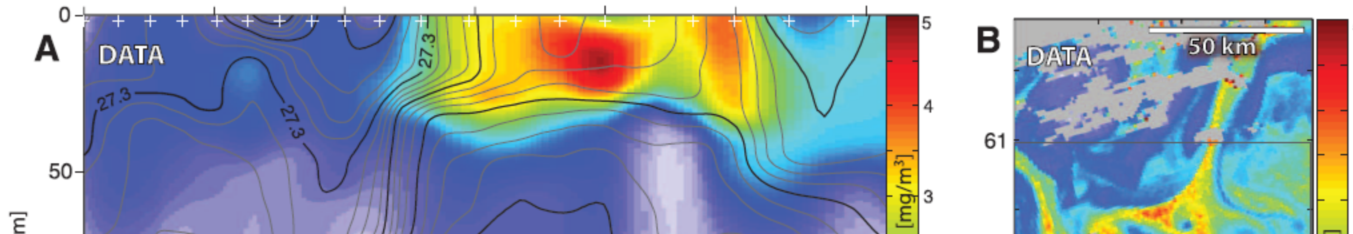
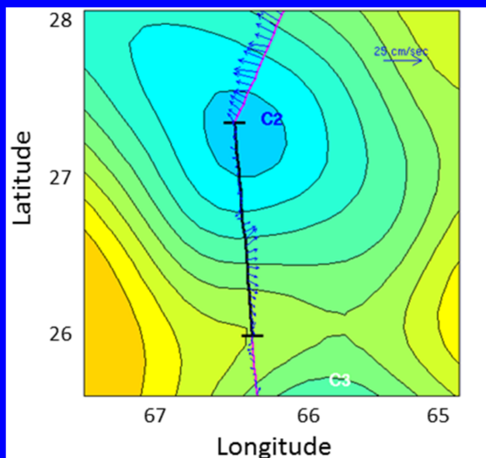


to the shallow surface layer, limiting access to and shading the nutrient-rich waters below. Thus although our simulations do not include nutrient effects, we anticipate that enhanced nutrient fluxes into surface waters due to ML eddies will lead to an overall increase in carbon fixation.

Eddy restratification is effective in this area of the Icelandic basin due to the existence of deep

Submesoscale hotspots in fluorescence and O_2

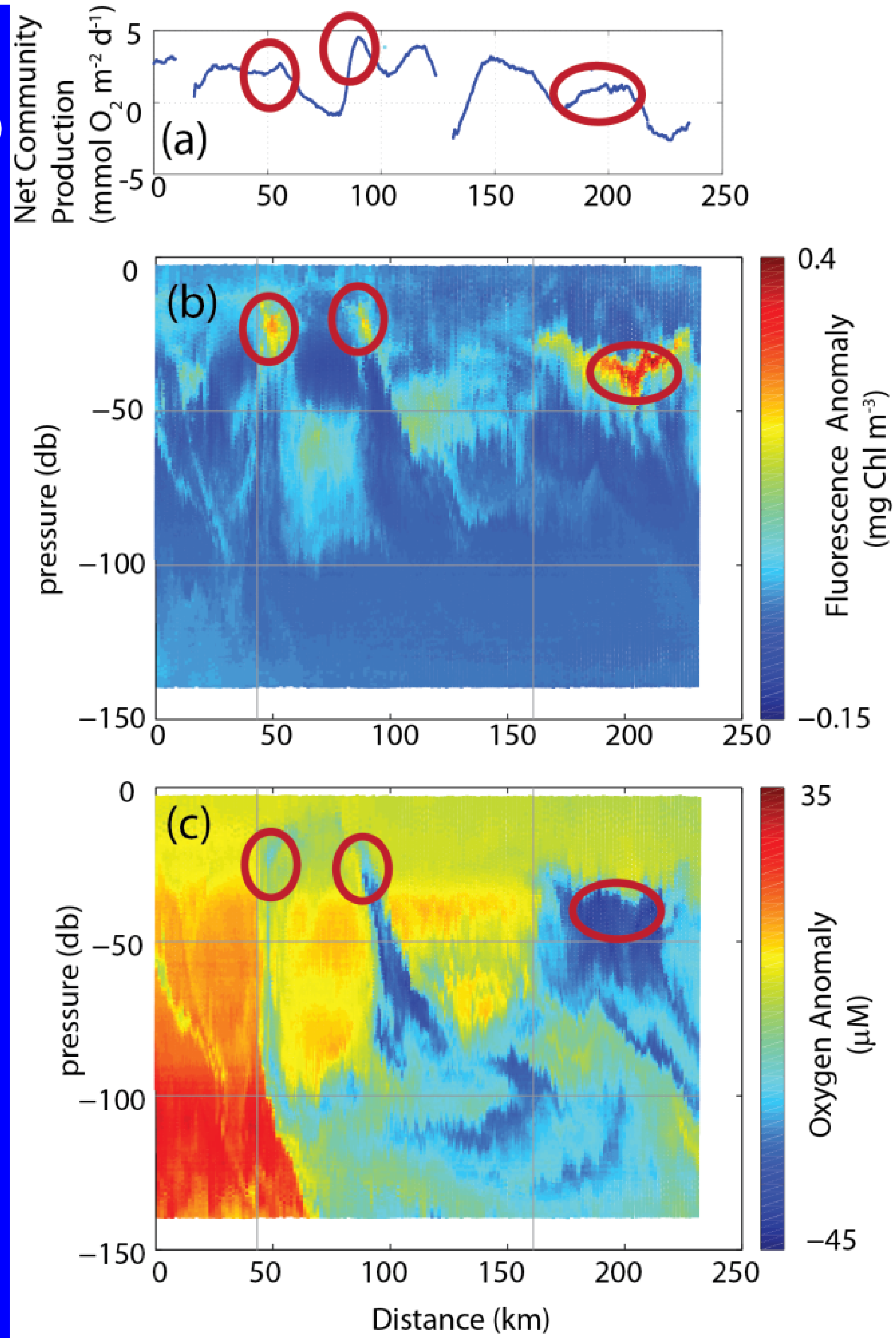


Video Plankton recorder
(Davis et al., 2005)

NCP
(EIMS O_2/Ar)

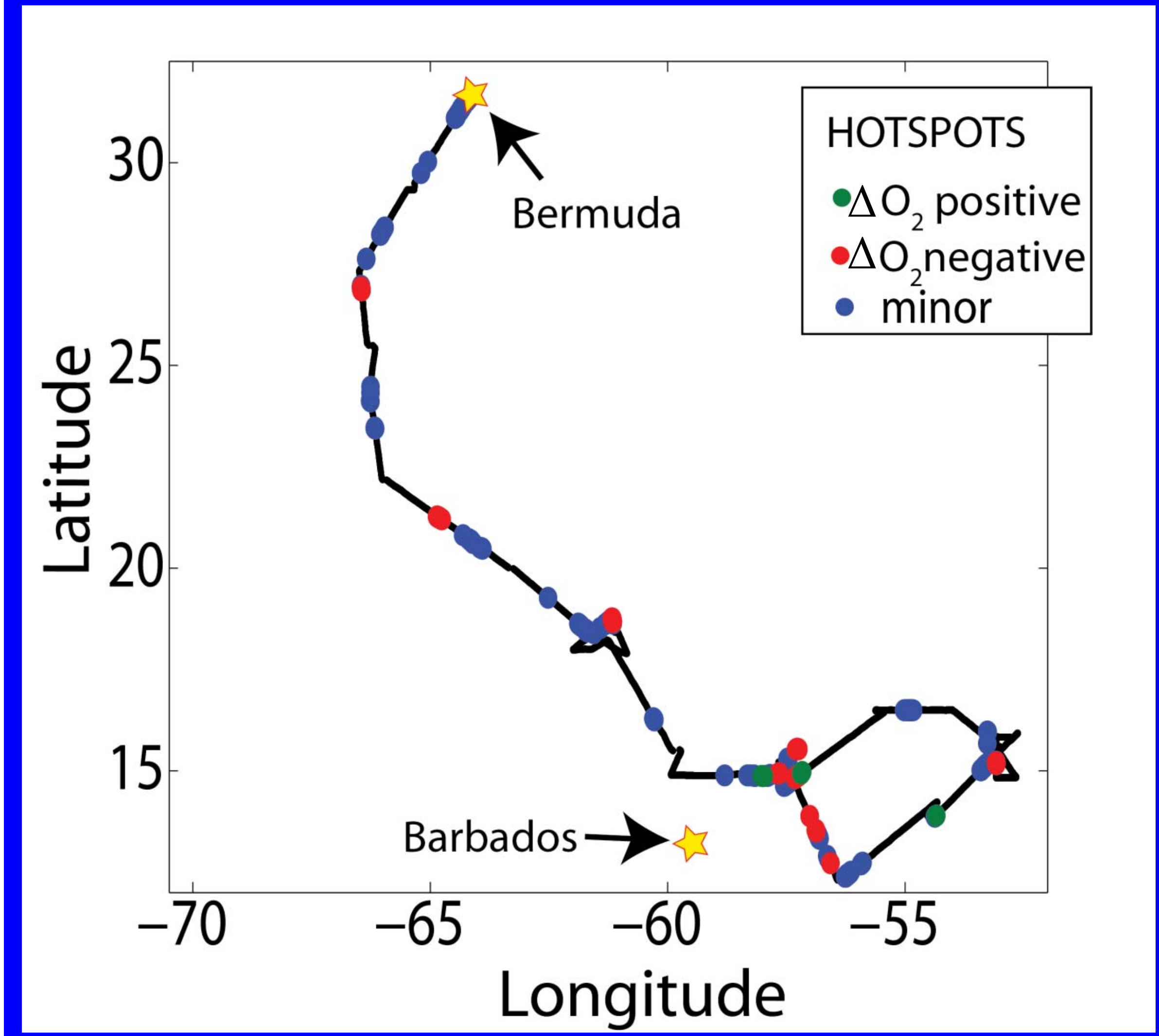
Fluorescence
Anomaly

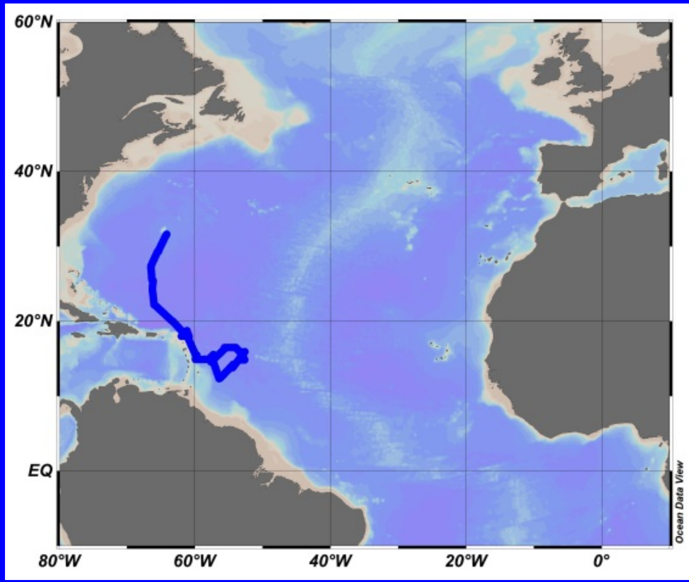
Oxygen
Anomaly



Stanley and McG, in prep

Submesoscale hotspots ubiquitous in a survey of subtropical and tropical Atlantic





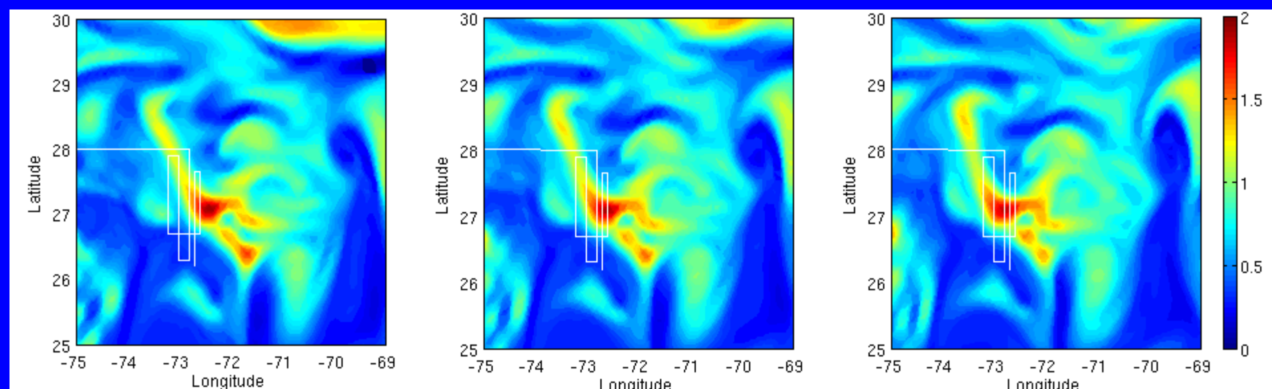
Stanley and McG, in prep

Can we resolve 3-D structure of such features with towed instrumentation?
An Observing System Simulation Experiment

March 15 March 17 March 19

Export
mmol N m^{-2} d^{-1}

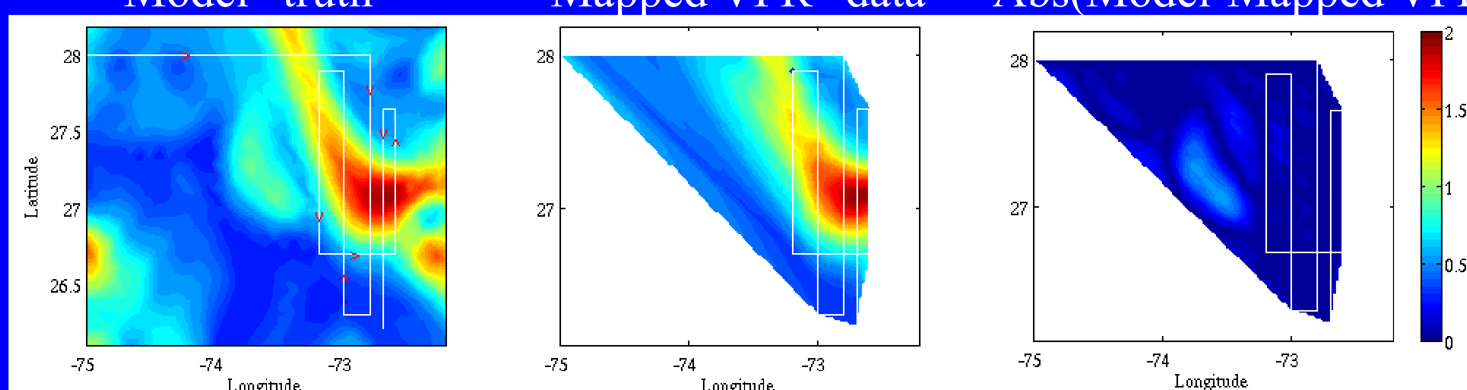
1/54° model output
Courtesy of M.Levy
(Resplandy et al. 2012)



Model "truth" Mapped VPR "data" Abs(Model-Mapped VPR)

Simulated VPR survey:

1084 km
58 hours
10 knots



Large-scale impacts of submesoscale dynamics on phytoplankton: Local and remote effects

Ocean Modeling (2012)

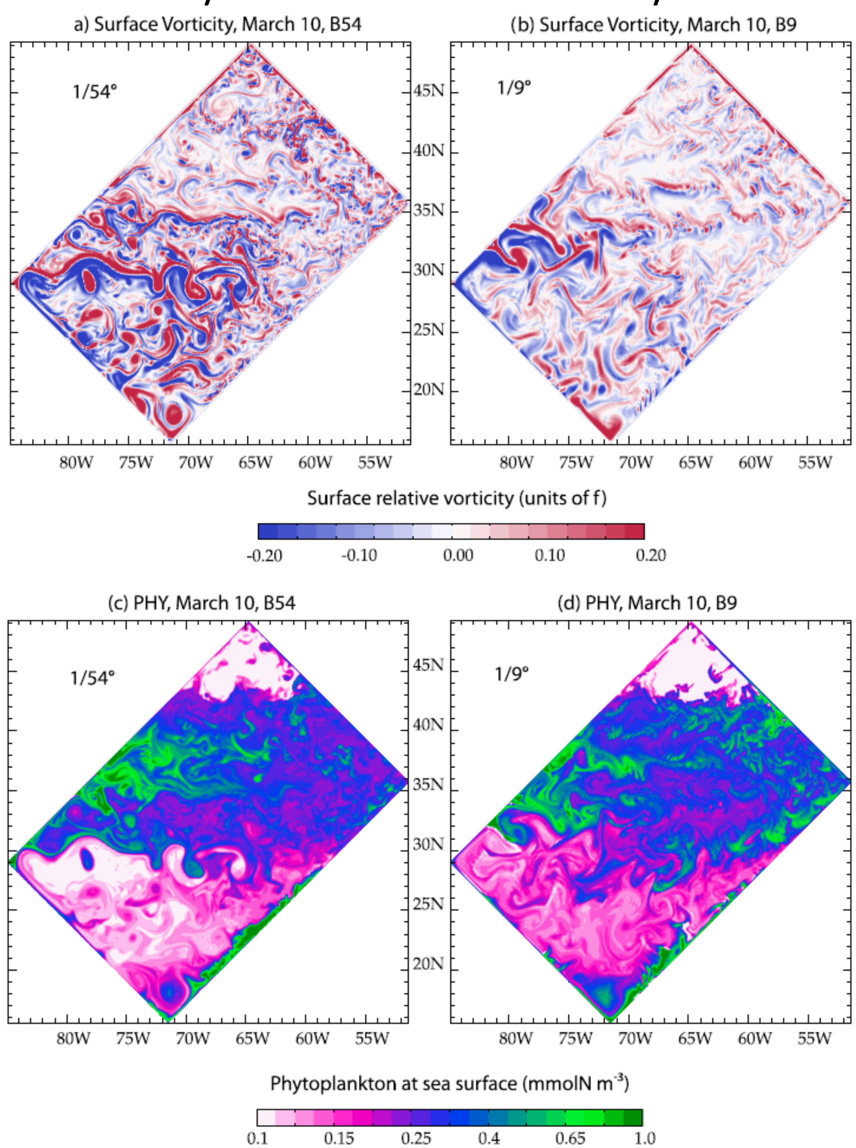
M. Lévy [a,*], D. Iovino [a], L. Resplandy [a], P. Klein [b], G. Madec [a], A.-M. Tréguier [b], S. Masson [a], K. Takahashi [c]

1/54° 1/9°

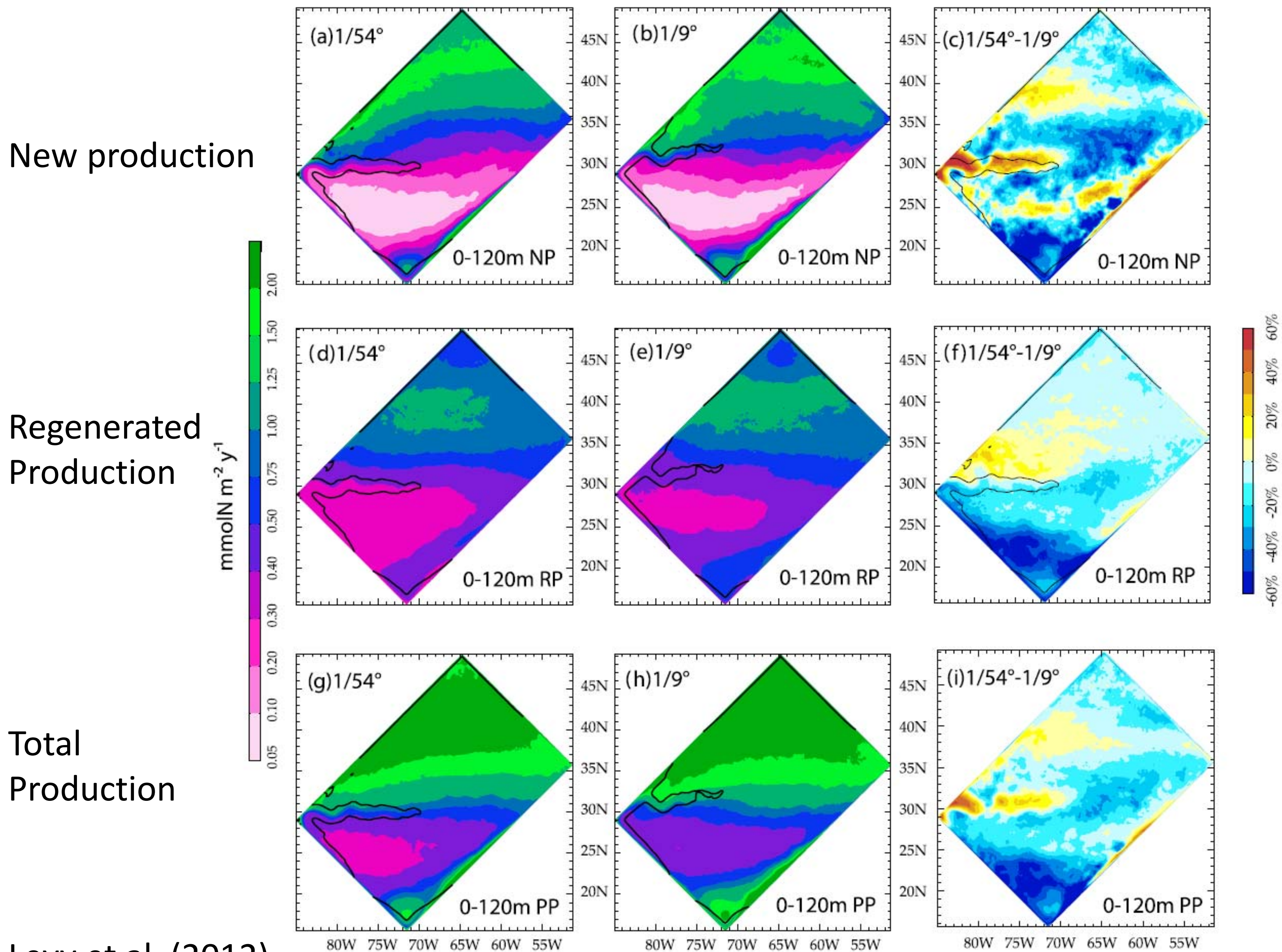
Surface Vorticity

Surface Phytoplankton

Snapshots



50 year equilibration followed by 5-year averages



Levy et al. (2012)

Summary

Mesoscale & submesoscale processes

- Drive variability
- Impact mean biogeochemical fluxes
  - Subtropics: nutrient source
  - Subpolar: nutrient sink? source?

The enigma of export flux

- Aphotic zone O_2 anomalies: The Smoking Gun?
- Where /when does the export happen?

What processes determine ecosystem response to eddy-driven perturbations of the physical and chemical environment?

END