# Wind-Induced Subduction at the South Atlantic Subtropical Front

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Projeto SUBMESO

Projeto REMARSUL

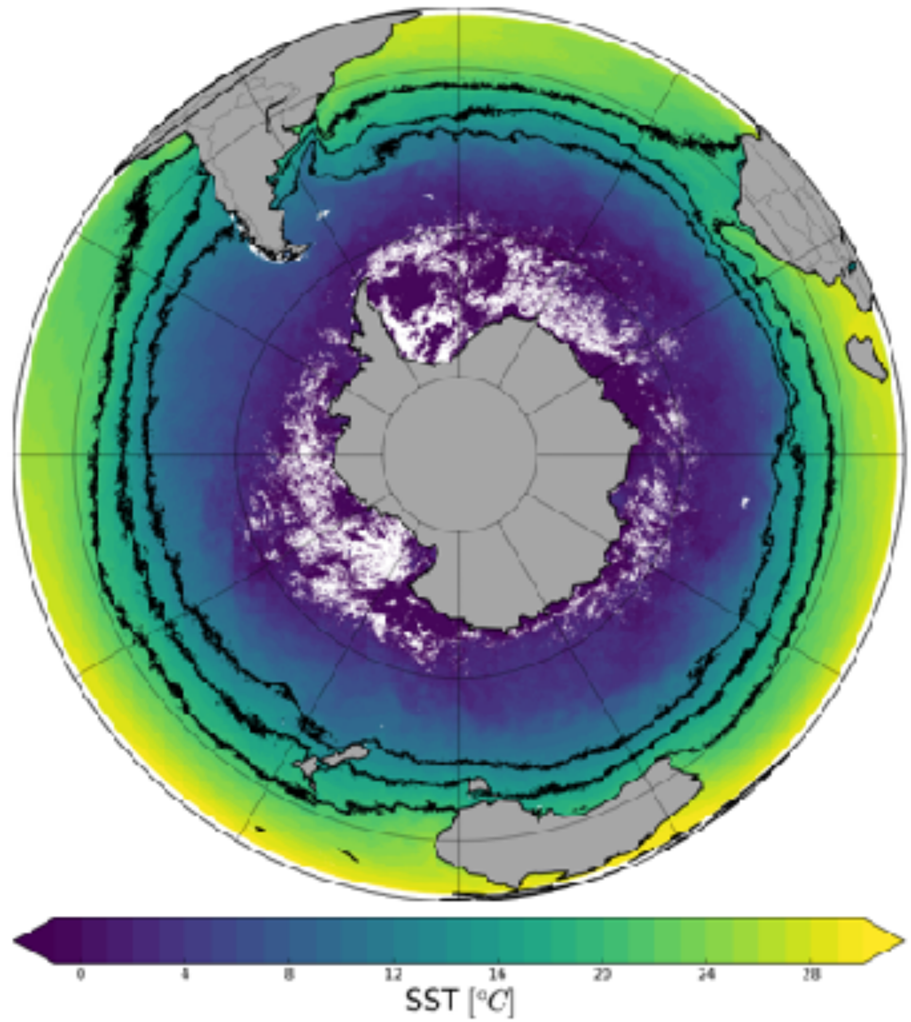
# Subtropical Fronts

Transition zones between the subpolar and subtropical gyres.

Usually associated with broad zonal, baroclinc jets associated with relatively large density gradients.

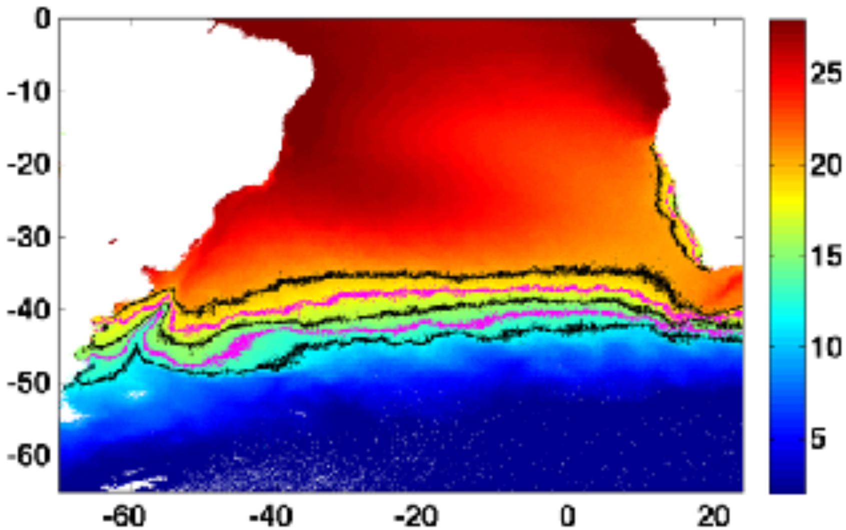
Quasi-circumpolar feature in the Southern Hemisphere.

Modulate property exchange and changes in water mass .

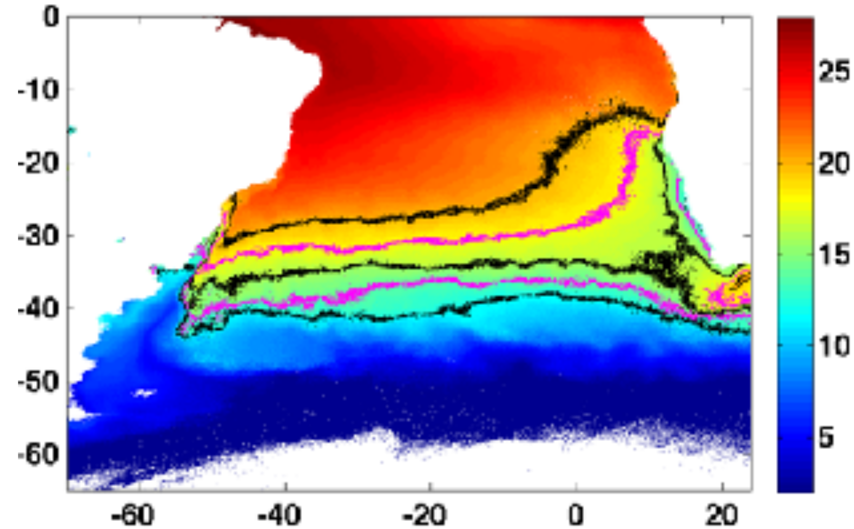


# Convergence of Subtropical and ACC waters

SST JANUARY




SST AUGUST

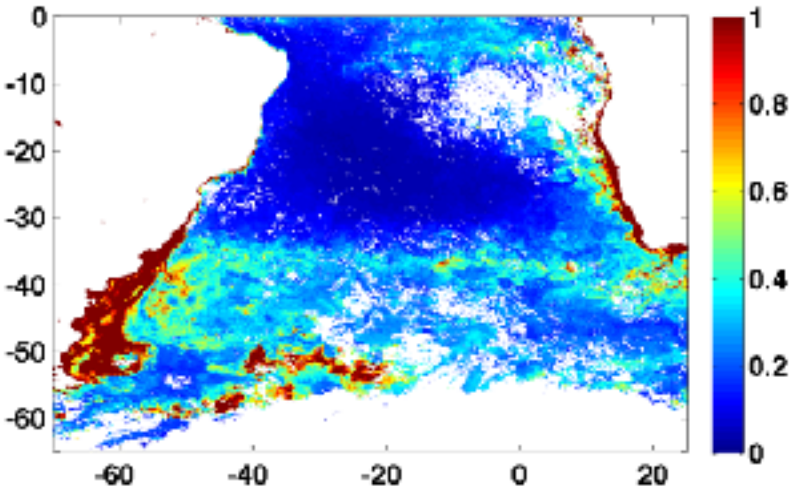



Convergence of nutrient-limited, subtropical waters and nutrient-rich southern waters together with water column stability will help sustain higher biomass .

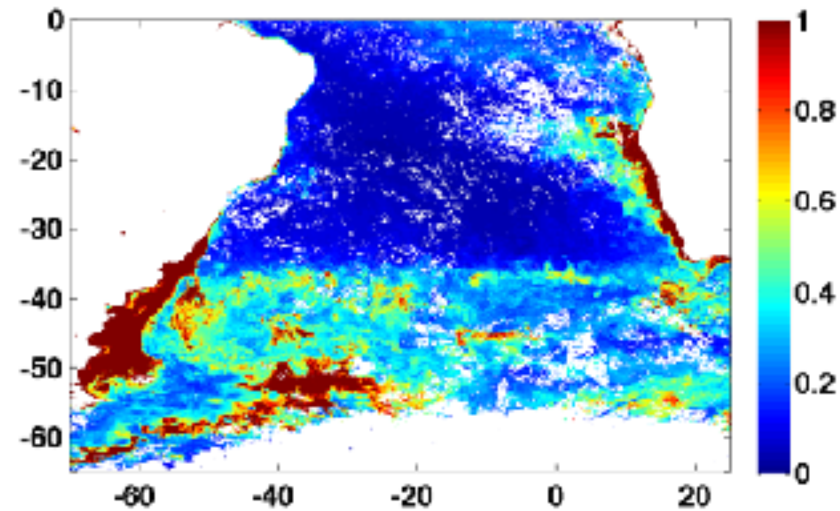
Processes that affect frontal intensification and water column stability should be appropriately sampled and modeled.

# Convergence of Subtropical and ACC waters

October 2015




November 2015

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# Convergence of Subtropical and ACC waters

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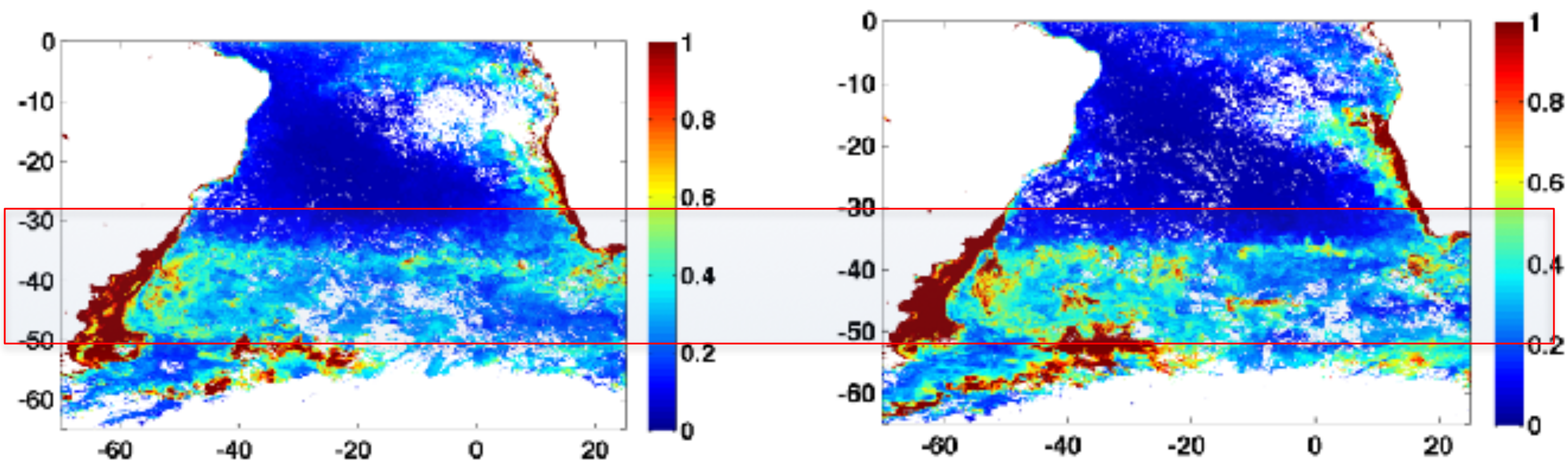


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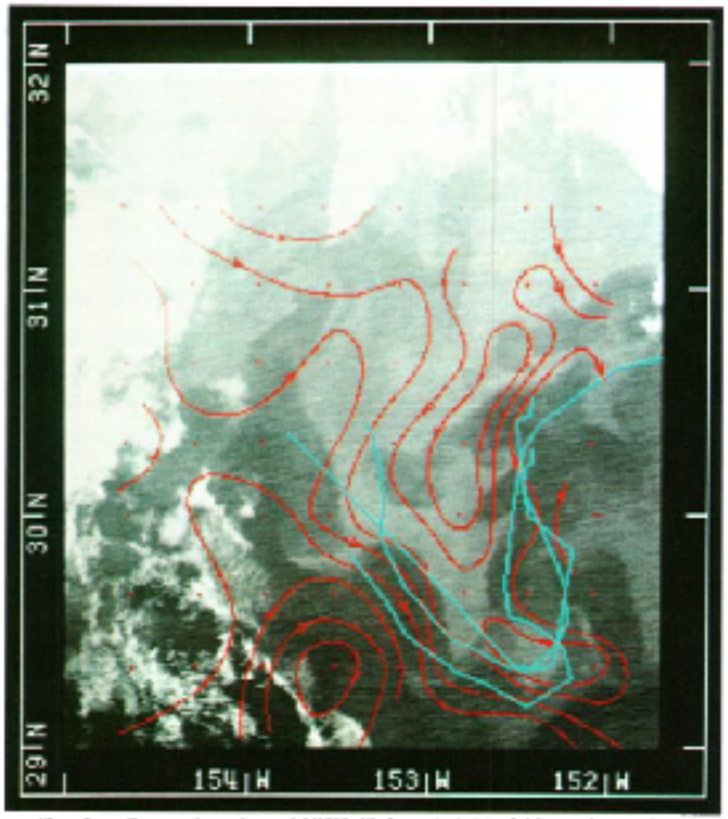
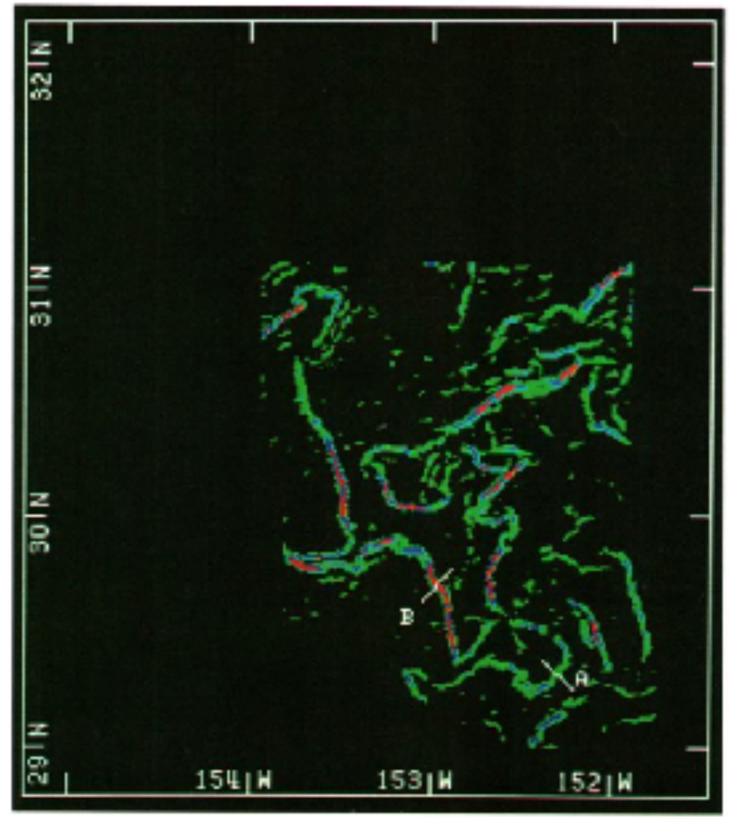
Processes that affect frontal intensification and water column stability should be appropriately sampled and modeled.

# Observational Evidence of Smaller Scale Features

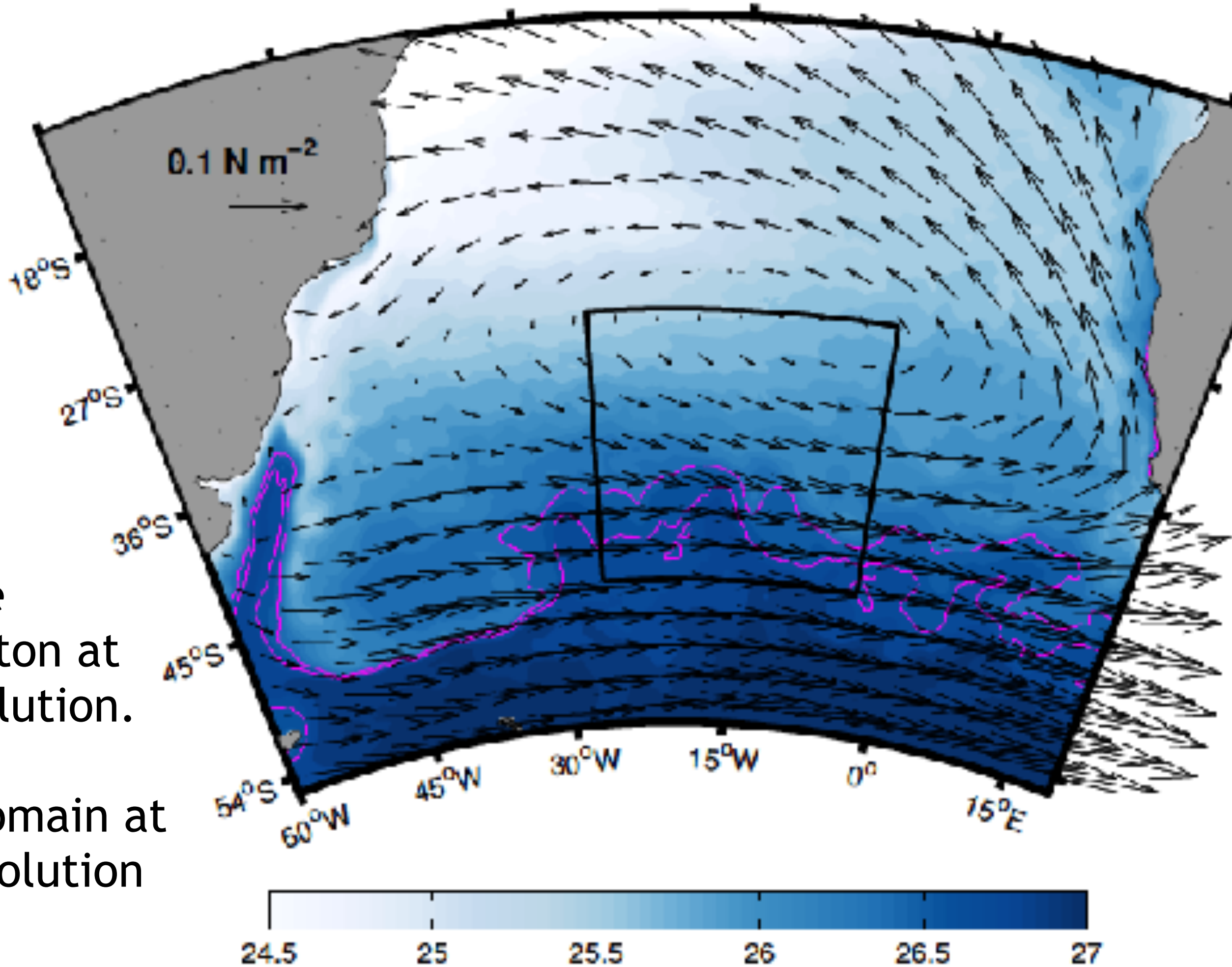



Van Moert 1982

Eddy interaction generates filaments and intensify existing horizontal density gradients

# South Atlantic ROMS model Configuration



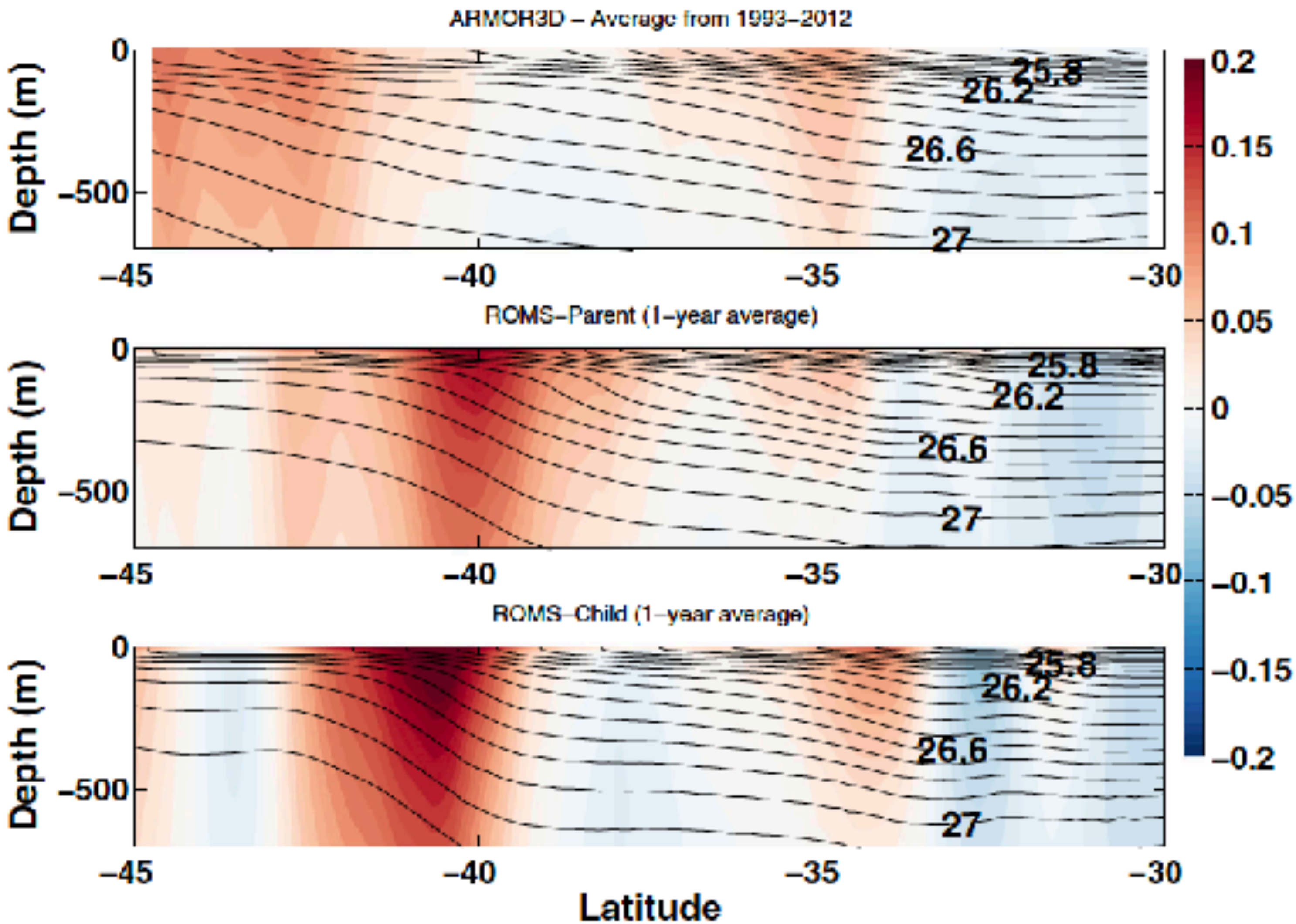

Basinwide configuraton at 1/8° resolution.

Nested domain at 1/24° resolution

Climatological Surface Momentum (QuikSCAT) and hear/freashwater fluxes (COADS).
Open Boundaries – SODA climatology.
PISCES Biogeochemical Model .

Developed and run @ DinaMO's VLPC

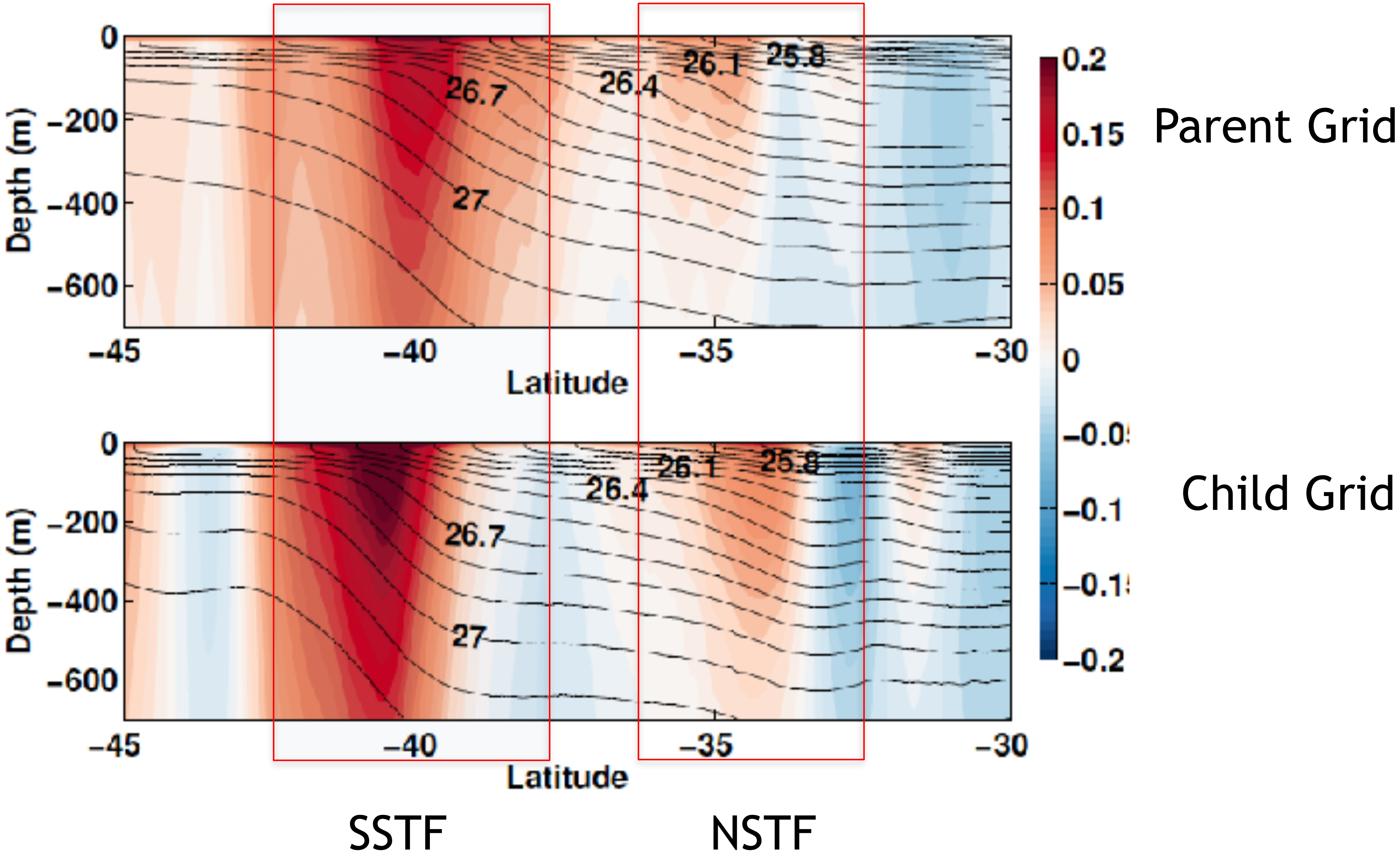
# Zonal Average (10º W to 20º W) of Zonal Velocity



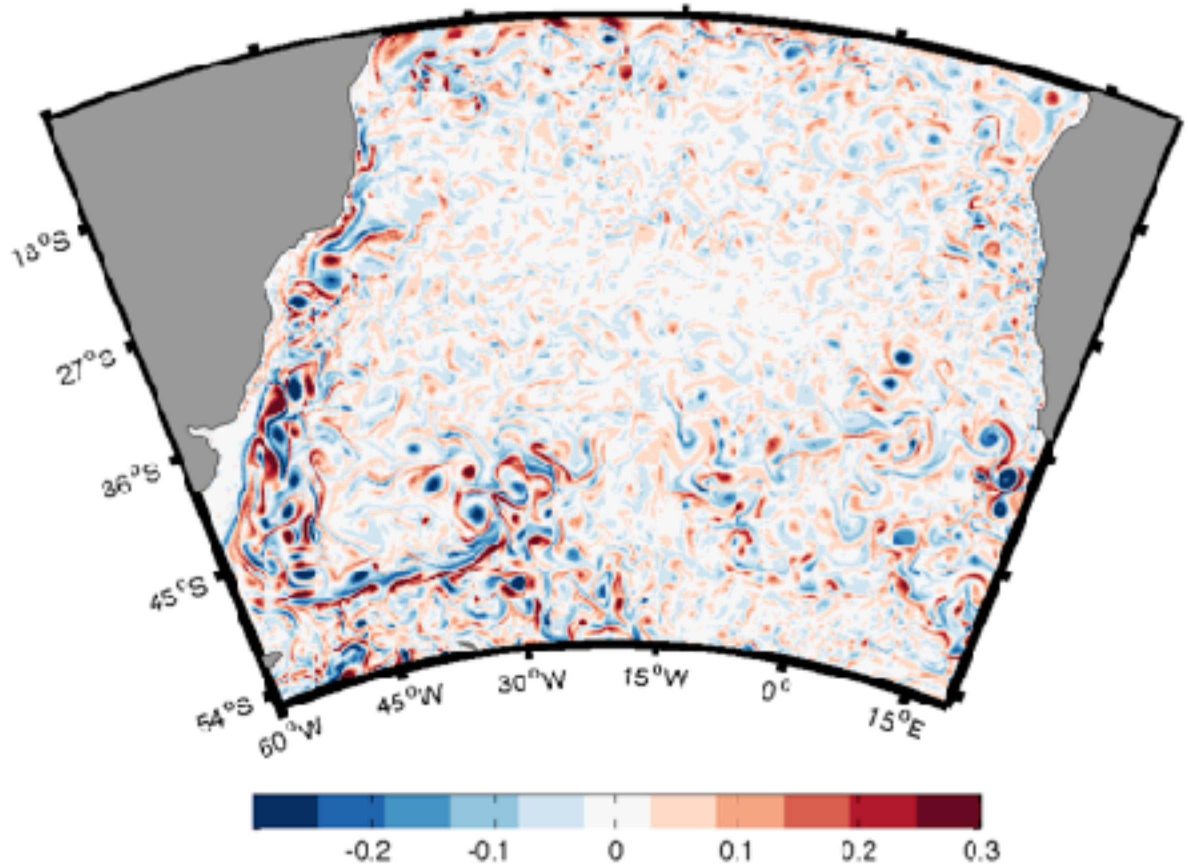

Parent Grid

Child Grid

# Zonal Average (10º W to 20º W) of Zonal Velocity



# O(1) Rossby Numbers in an Otherwise Quiescent Frontal Region




$$Ro = \frac{\zeta}{f}$$

Climatological Surface Momentum (QuikSCAT) and hear/freashwater fluxes (COADS)
OBC's – SODA
PISCES Biogeochemical Model

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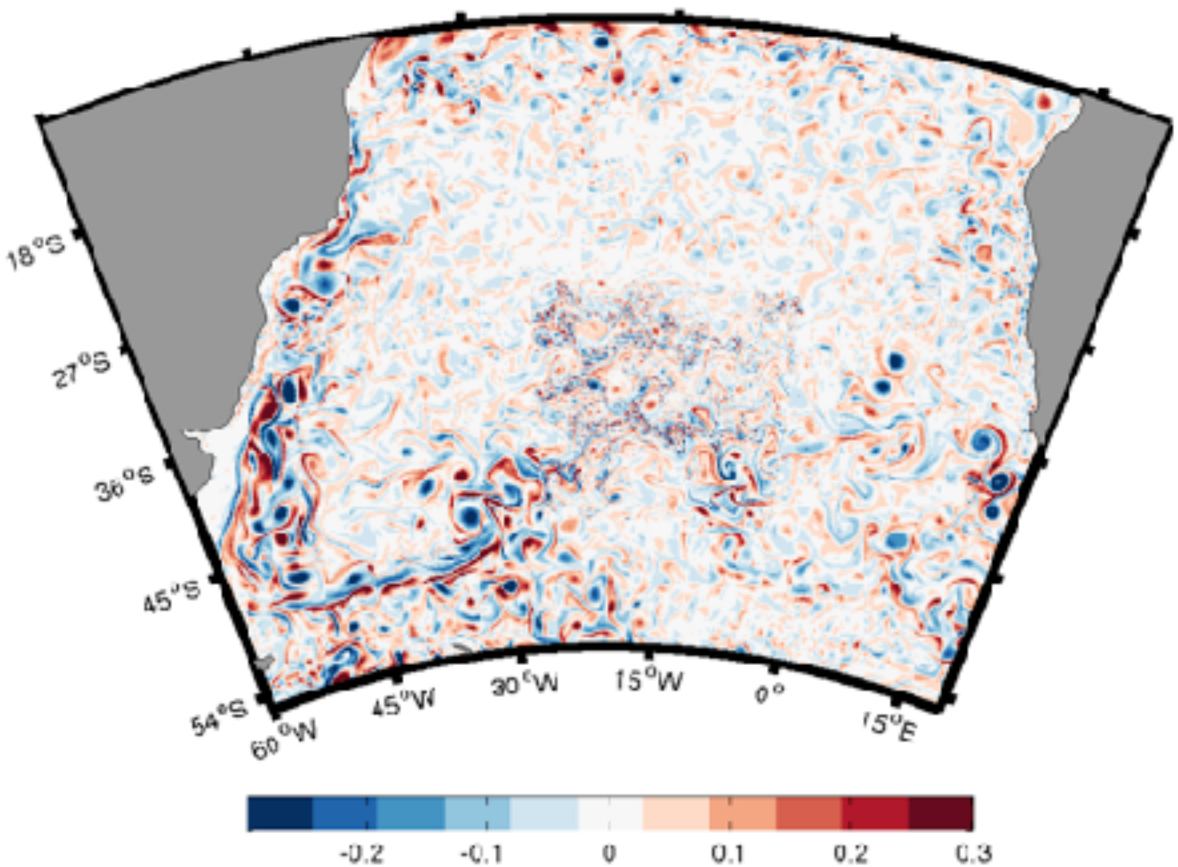


Climatological Surface Momentum (QuikSCAT) and hear/freashwater fluxes (COADS)
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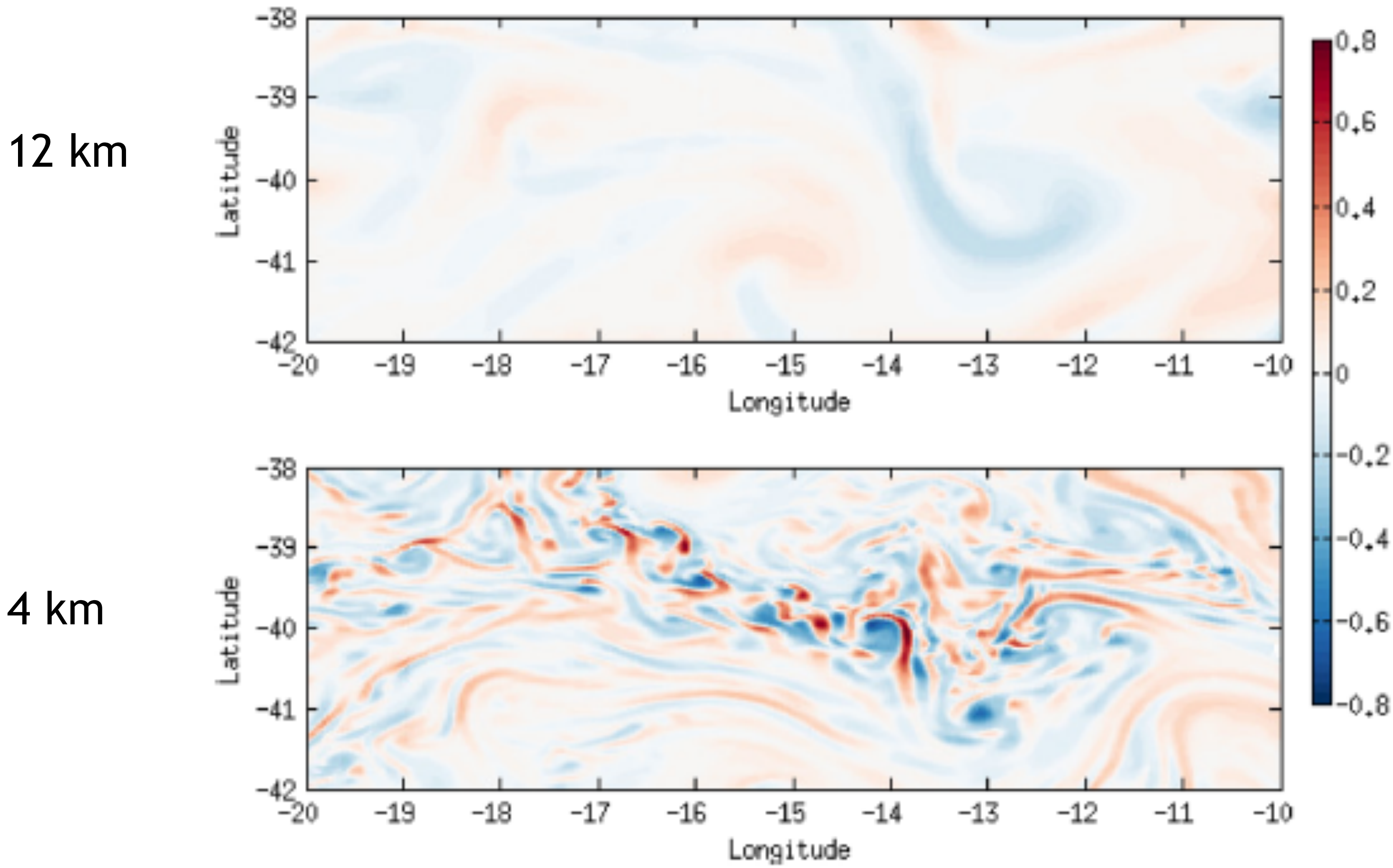
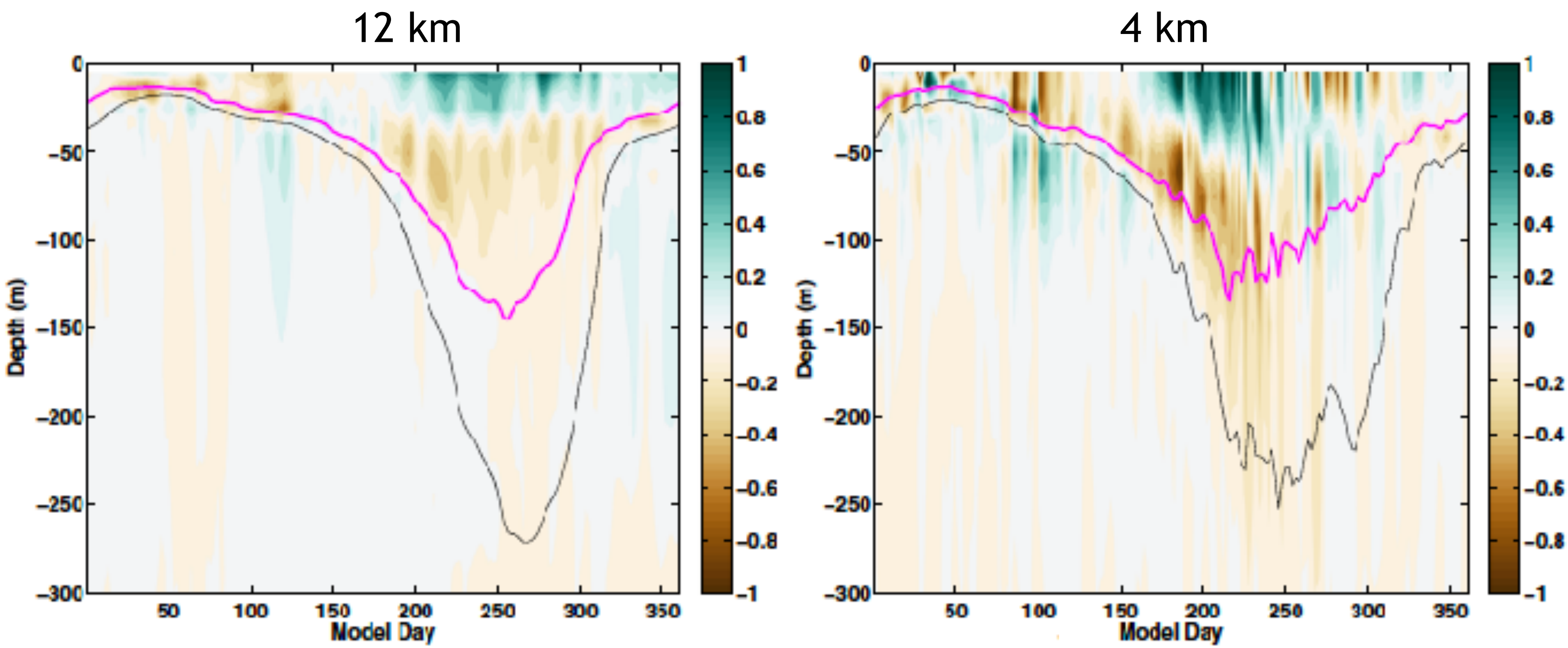
# Zoom in the Frontal Region




O(1) Rossby numbers associated with surface ocean fronts.

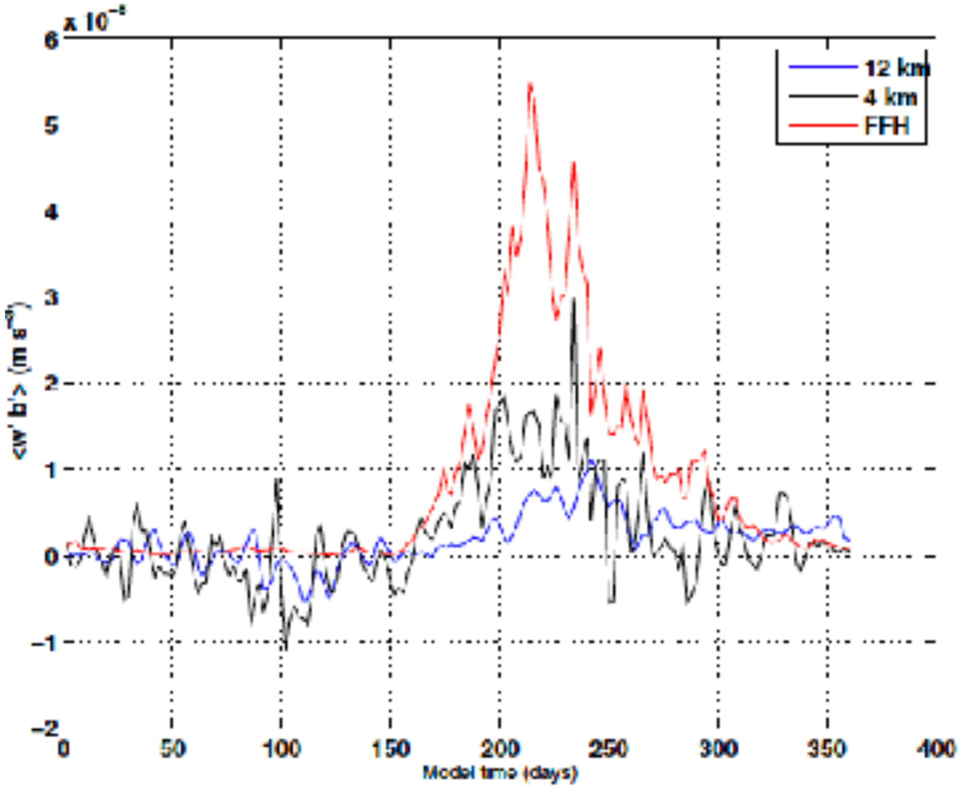
# Divergence of the Eddy Buoyancy Flux in the Frontal Region




$$\frac{\partial}{\partial z} < w'b' > \times 10^{-9}$$

Stronger tendency for re-stratification at higher resolution

## Buoyancy Fluxes Averaged over the Frontal Region

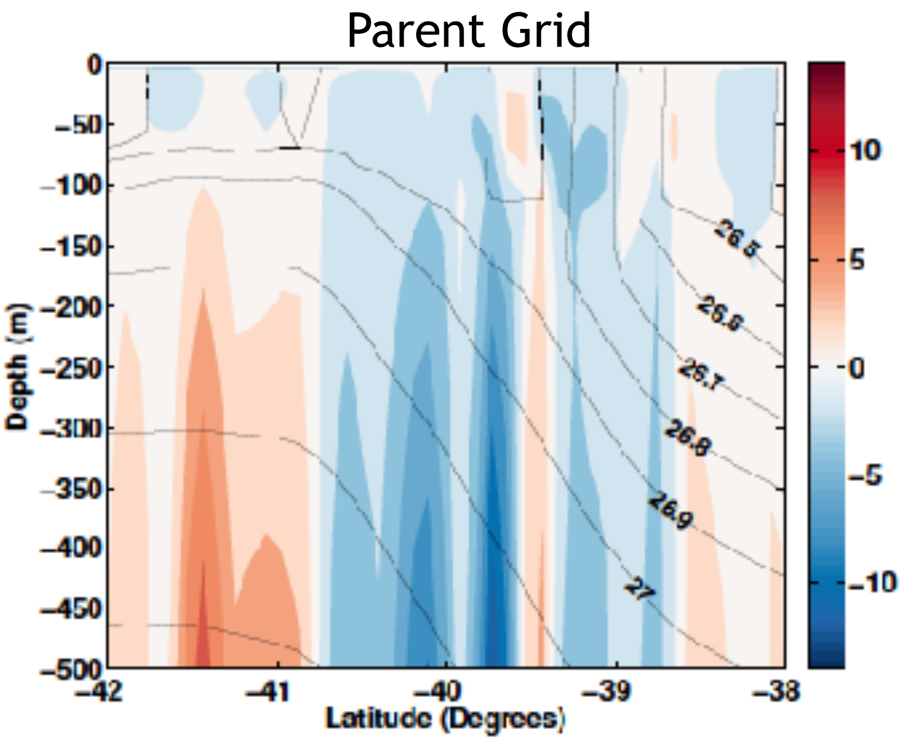


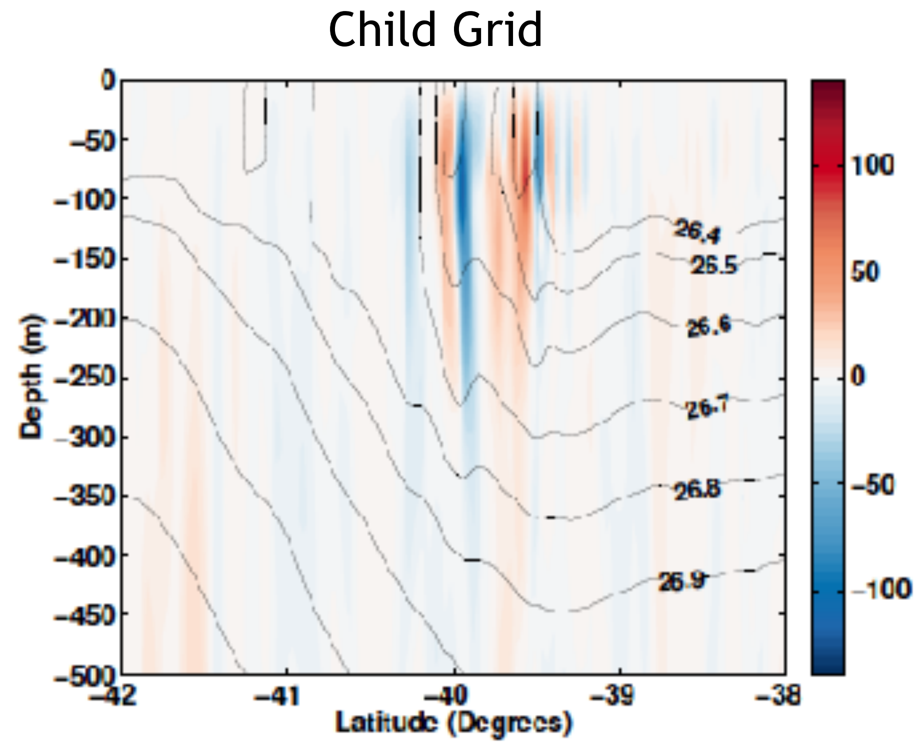

MLE parameterization

$$0.06\ H^2\ \overline{b_y}/f.$$

Comparison with Fox-Kemper et al. 2008 MLI's parameterization shows that 4 km may not be enough.

# Large Vertical Velocities in the Frontal Region



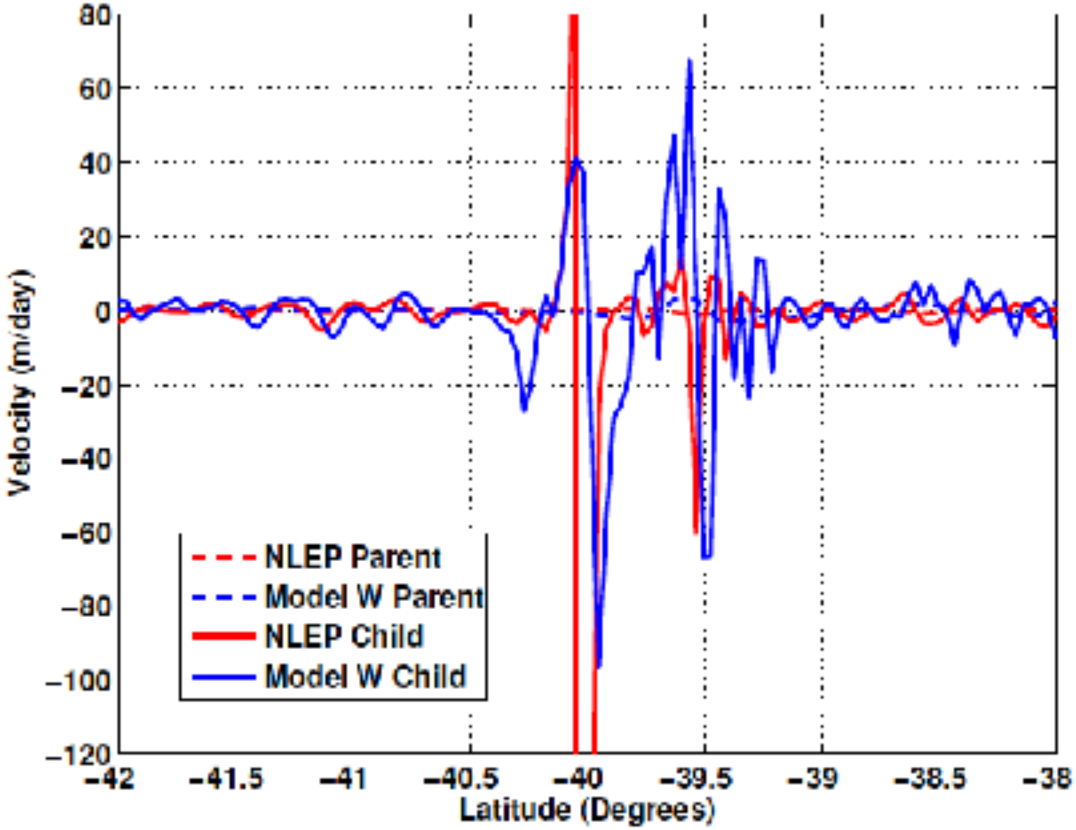




Low Resolution – larger w at thermocline level. Consistent with mesoscale, baroclinic instability (i.e. larger spatial and temporal scales).

High Resolution - Very large w within the mixed layer concentrated in the frontal region.

Consistent with mixed layer instabilities, frontogenesis, non-linear Ekman pumping.

# Nonlinear Ekman Pumping




$$M_e = -\frac{\tau^x}{\rho_0 f(1+Ro)}$$

Stern 1965, Hart 1996, Thomas and Lee 2005

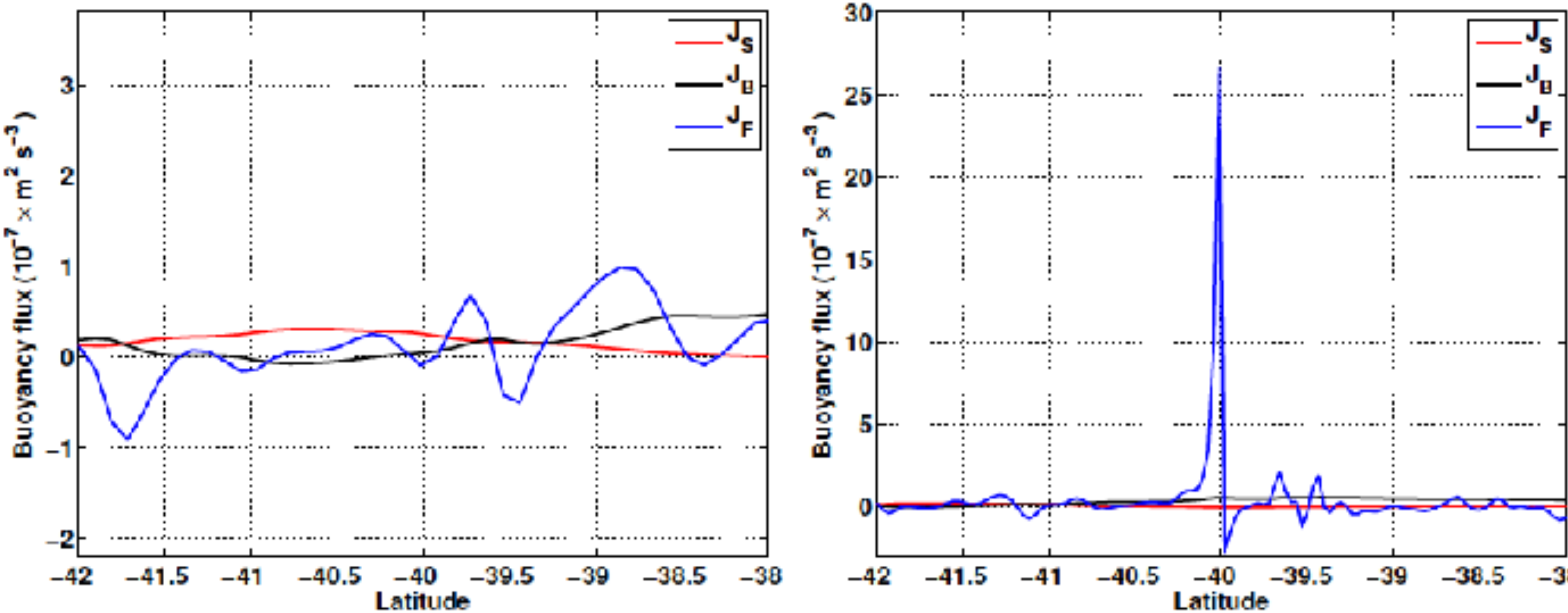
$$w_{NLEP} = -\frac{1}{\rho_0(f+\zeta)}\frac{\partial \tau^x}{\partial y} + \frac{\tau^x}{\rho_0(f+\zeta)^2}\frac{\partial \zeta}{\partial y}$$

Where, $\zeta = -\frac{\partial u_g}{\partial y}$

Good agreement with model vertical velocities at 50 m-depth indicates NLEP is an important process at the frontal region.

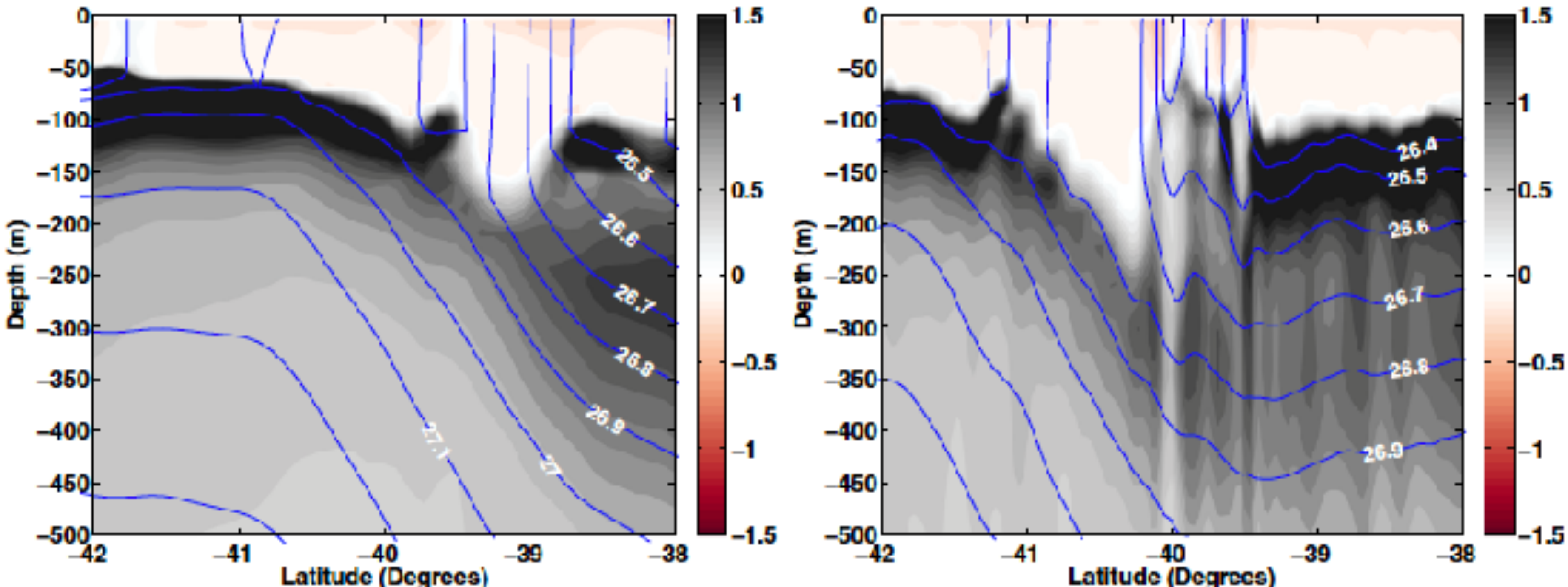
No such large values occur in the low resolution run.

# PV extraction due to wind-driven buoyancy flux




$$J = -\frac{g\alpha Q_0}{\rho c_p} + g\beta(E - P)S_0 + M_e\frac{\partial b}{\partial y}$$

# Negative PV in the Frontal Region




PV x $10^{-13}\ s^{-4}$

$$q = f(\omega_a \cdot \nabla b)$$

2D PV used in the frontal region

$$q = f\left(f - \frac{\partial u_g}{\partial y}\right)N^2 + f\frac{\partial u_g}{\partial z}\frac{\partial b}{\partial y}$$

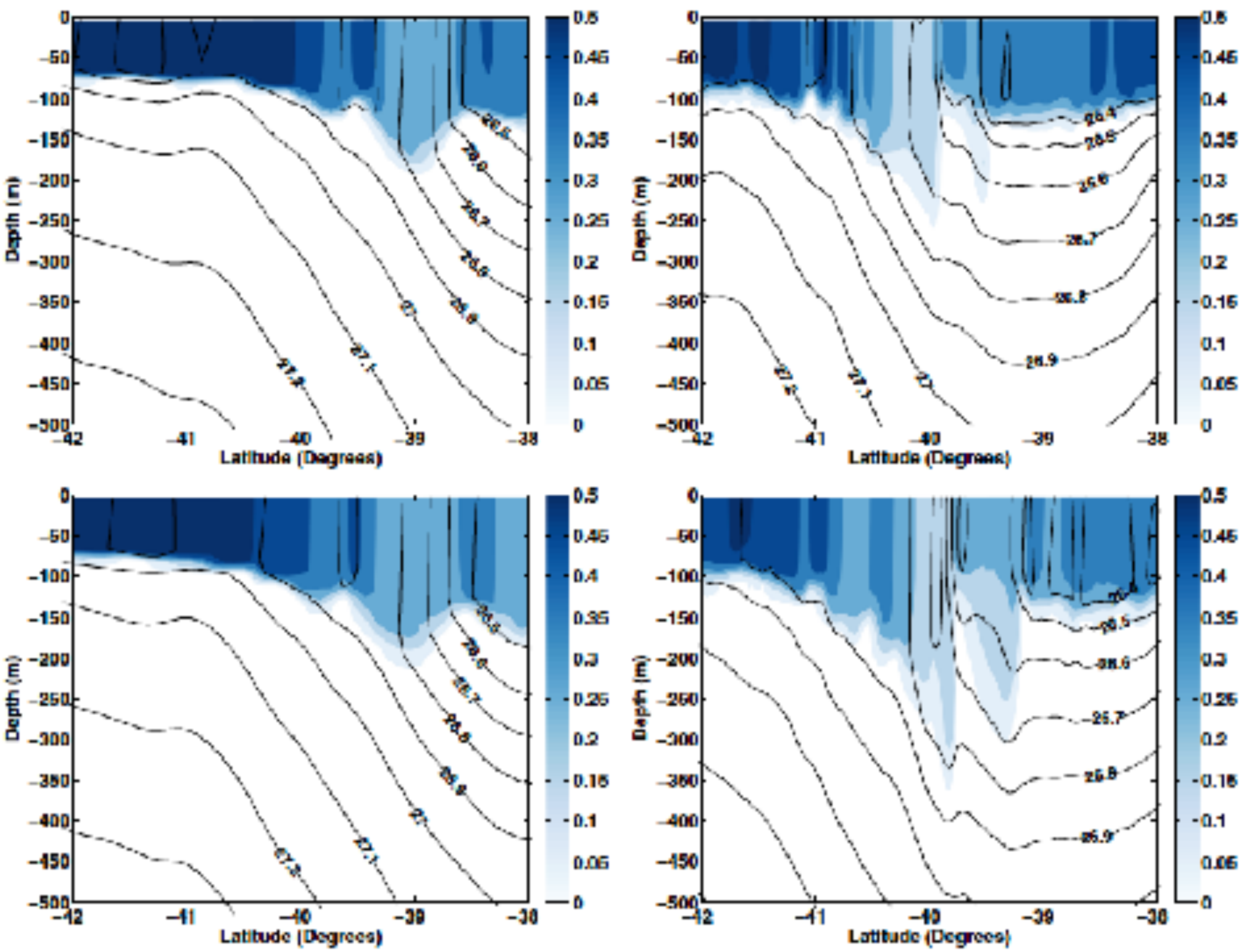
Convergence and subduction induced by symmetric instability

# Passive Tracer Experiment

12 km | 4 km

Aug 10

Aug 20

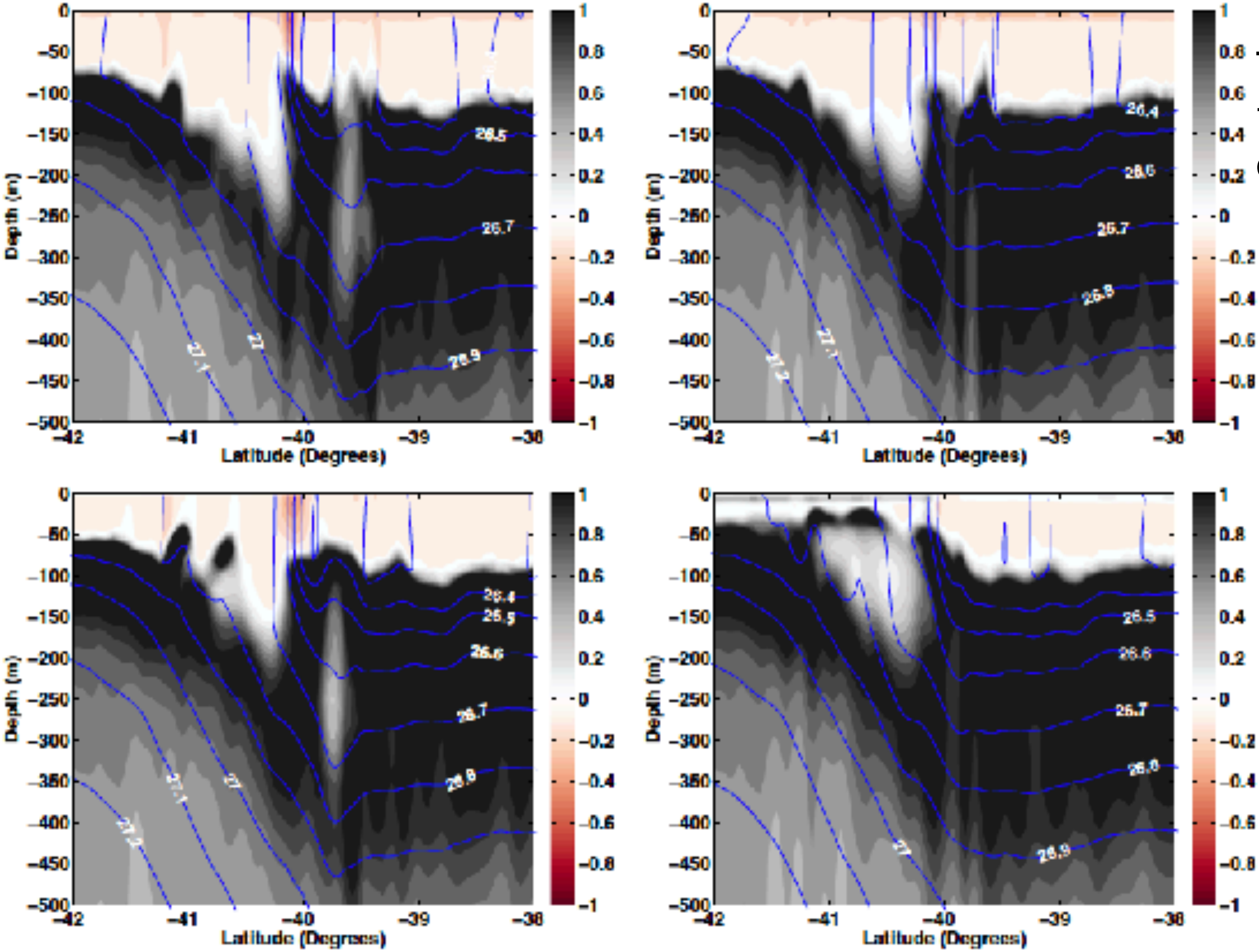



Released in the upper 50 m.

Nonzero concentrations found down to 350 m in the high-resolution run beneath the frontal region.

# Dependence of Subduction of low PV waters on the Surface Forcing

Control — No Wind




No Heat Flux — No Wind, No Heat Flux

Tracer released in the upper 50 m on Aug 1.

Aug 20
in all cases

# Dependence of Subduction of low PV waters on the Surface Forcing

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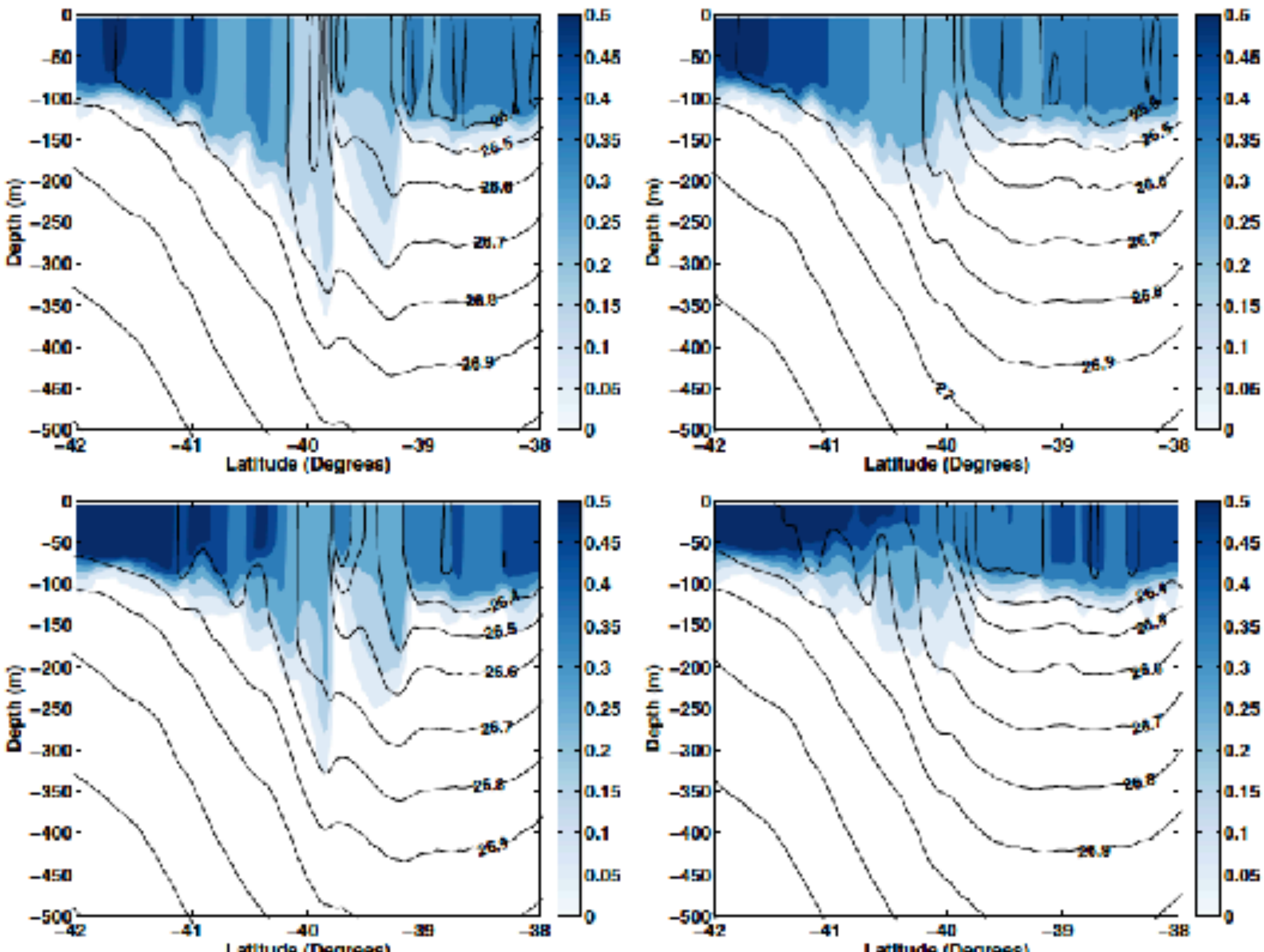
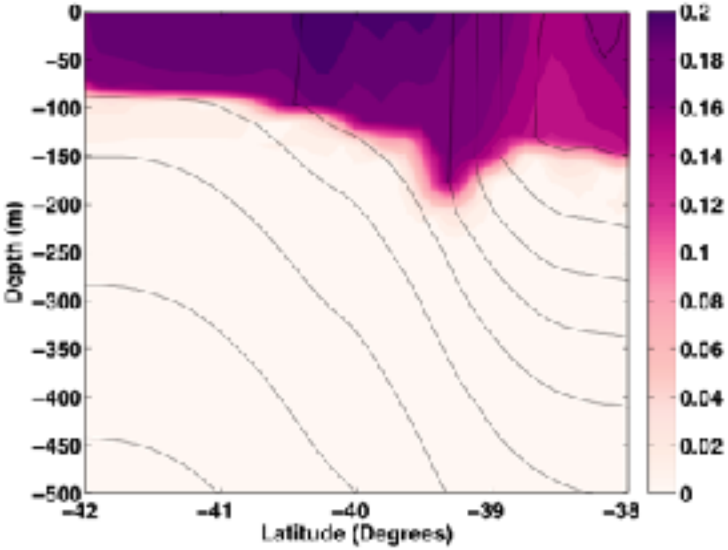
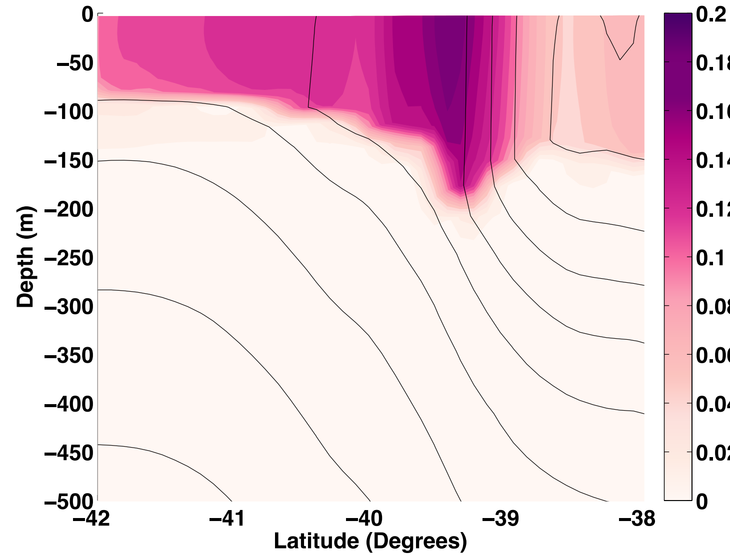
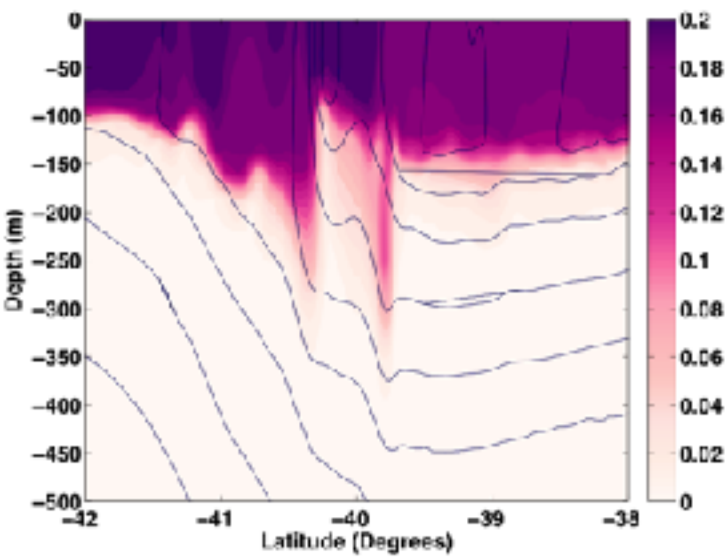
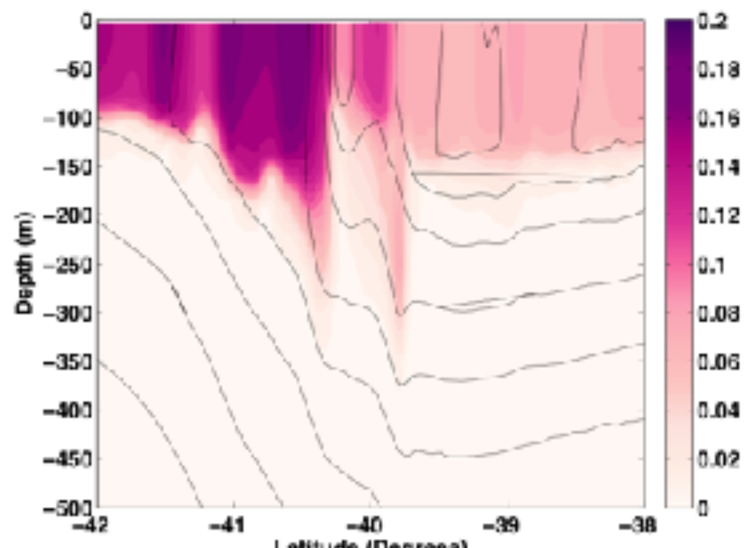



No Heat Flux | No Wind, No Heat Flux

Tracer released in the upper 50 m on Aug 1.

Aug 20
in all cases

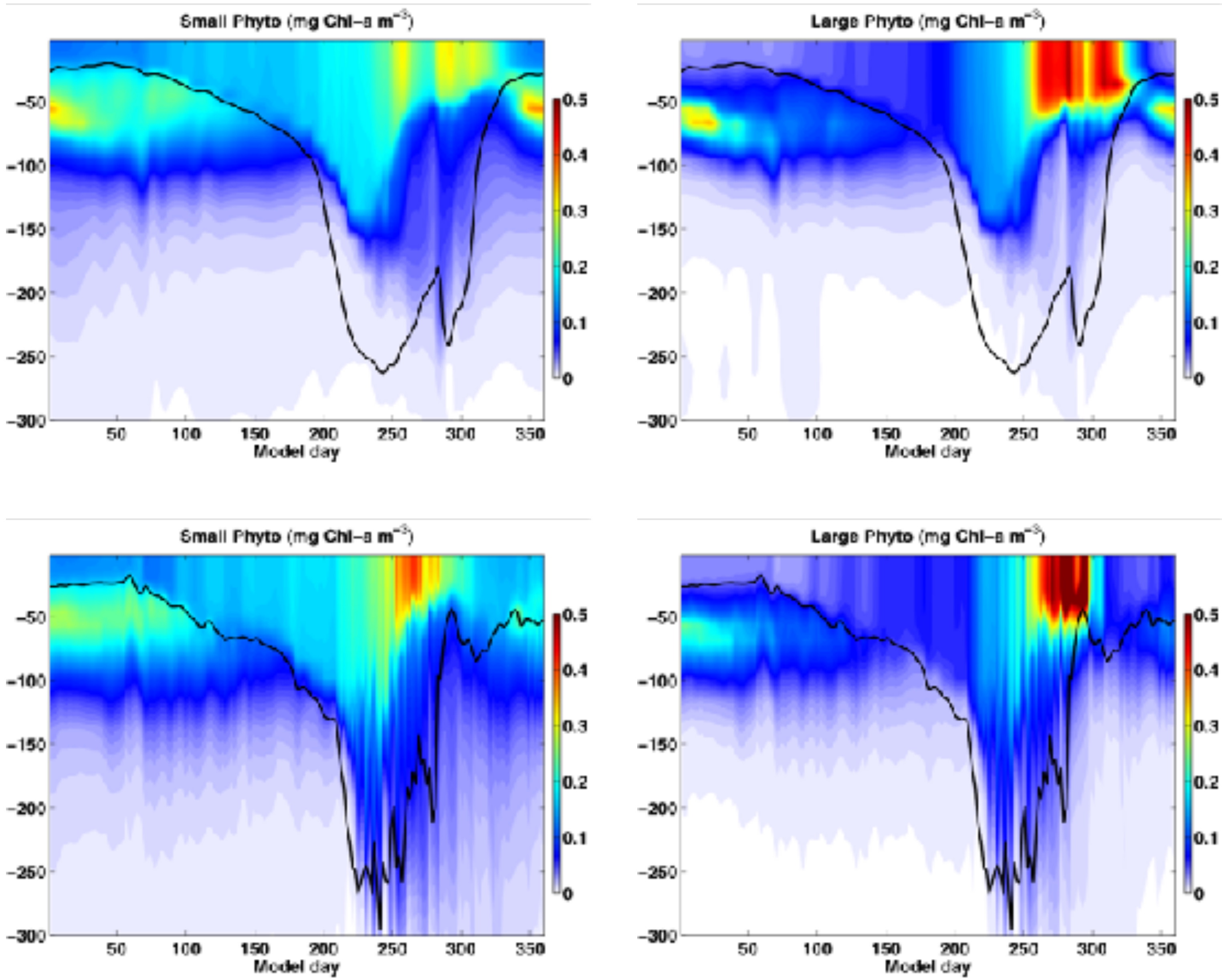
# Impact of “shallow” subduction on Biochemical Properties

| Small Phytoplankton | Large Phytoplankton | |
|---|---|---|
|  |  | Parent |
|  |  | Child |

# Spring Bloom in the Frontal Region

PARENT

CHILD



# Spring Bloom in the Frontal Region

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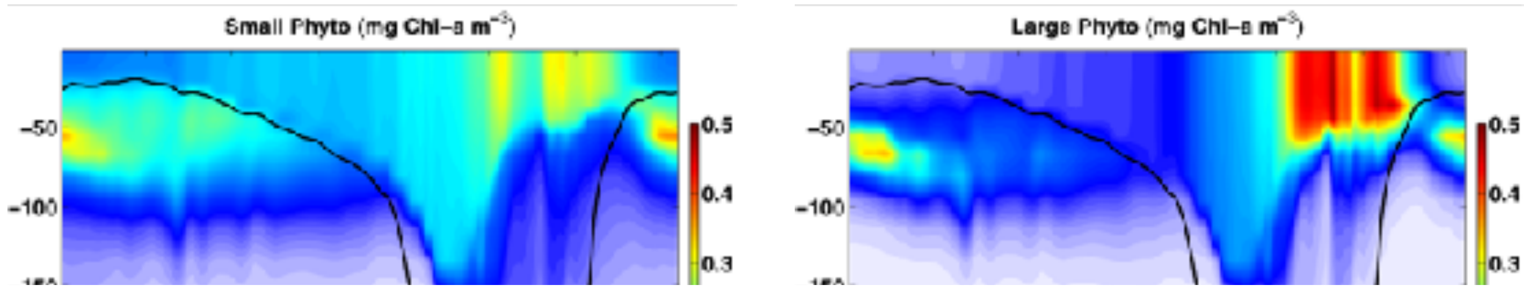


*J. Plankton Res.* (2015) 37(3): 500–508. First published online April 8, 2015 doi:10.1093/plankt/fbv021

# HORIZONS

# Spring blooms and annual cycles of phytoplankton: a unified perspective

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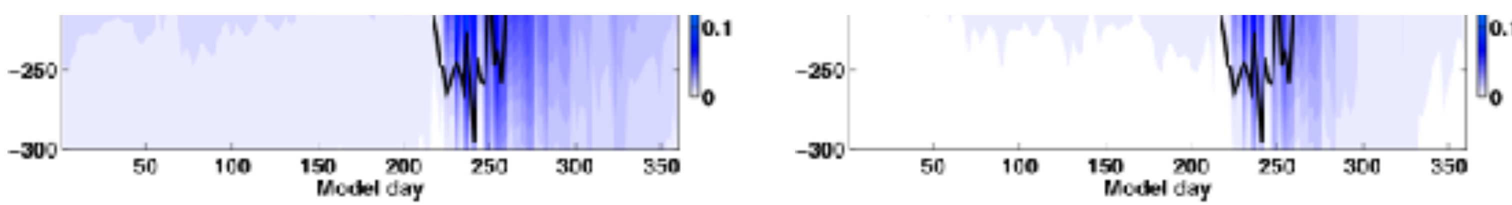
CHILD



# Conclusions

As resolution is increased, surface-intesified, nonlinear processes become important and alter the mean flow.

Wind-induced subduction  of surface, low PV waters at the South Atlantic STF is much stronger at higher resolution. Occurs as episodic bursts due to frontal intensification.

Subduction of water masses  will have Implications for processes such as water mass transformation, subtropical mode water formation, absorption of anthropogenic carbon, ocean ventilation.

Subduction events affect biochemical variables and may have long-term consequences.

High-resolution, observational studies in this key region of the world's oceans are (to my knowledge) non-existent. Confirmation or refutation of the importance of smaller scale processes on the general circulation depends on such measurements.

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# Wind-induced subduction at the South Atlantic subtropical front

**Paulo H. R. Calil**[1]

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