Observations of Submesoscale Activity at Ocean Fronts
Past and Future

Eric D'Asaro   Craig Lee   Luc Rainville

University of Washington

Leif Thomas

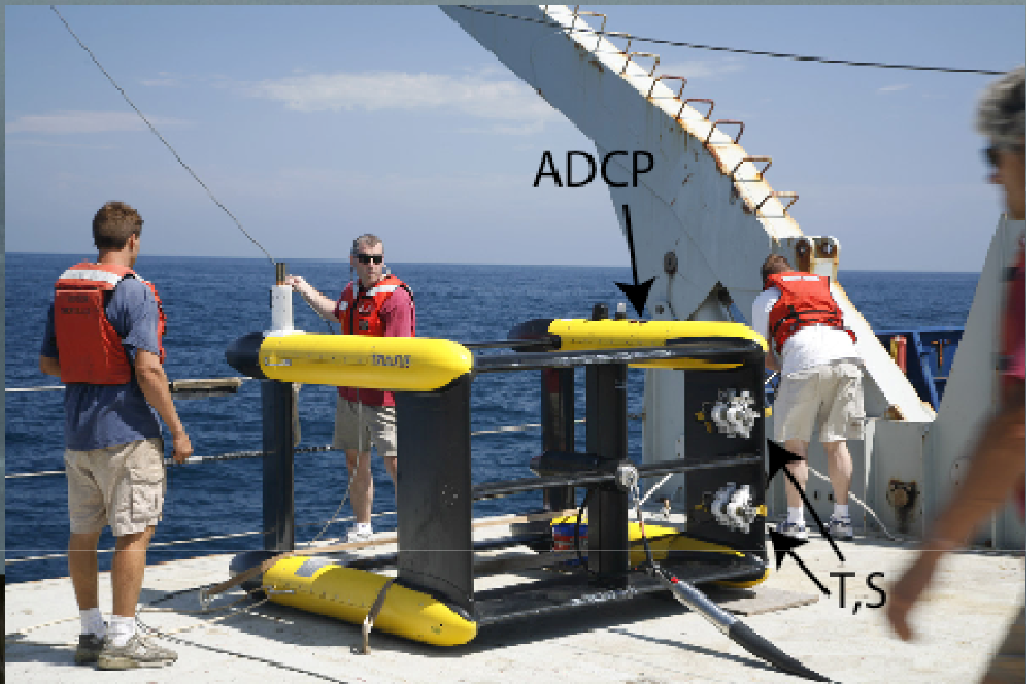
Stanford University

New observational tools for measuring submesoscale

Observations of symmetric instability at a front

Future plans - opportunity for altimetry

Technology 1 - Triaxus Towed Profiling from Ship



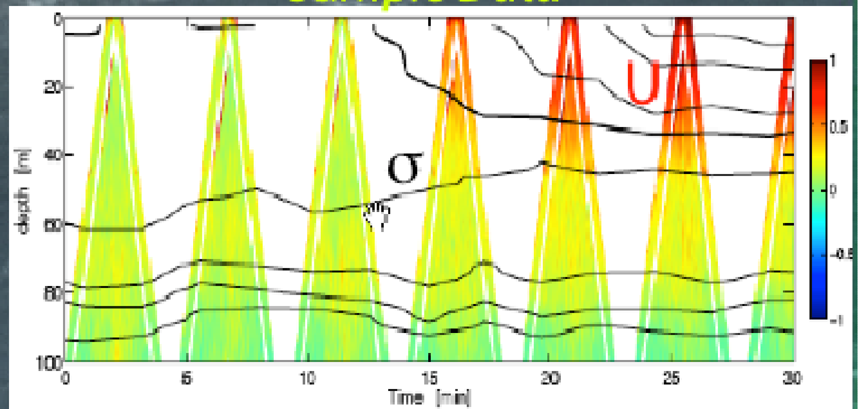
Next generation towed vehicle

Survey temperature, salinity and velocity with horizontal resolution of ~500m to depths of 150m at 3 m/s

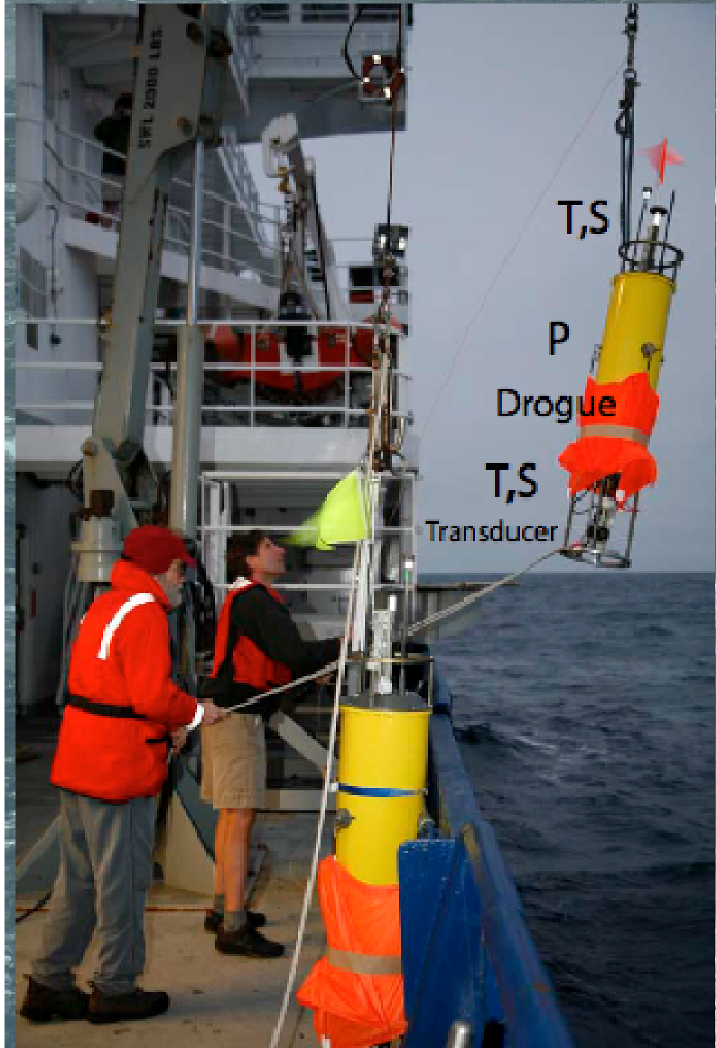
Combine with ship's ADCP and navigation.

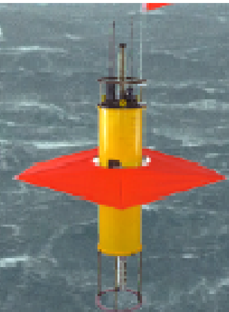
Acoustic tracking of vehicle position relative to ship

Sample Data



Technology 2 - Lagrangian Float





Follows 3-D motion of water

- *Active neutral buoyancy*
- *High drag*
- *Acoustically tracked*

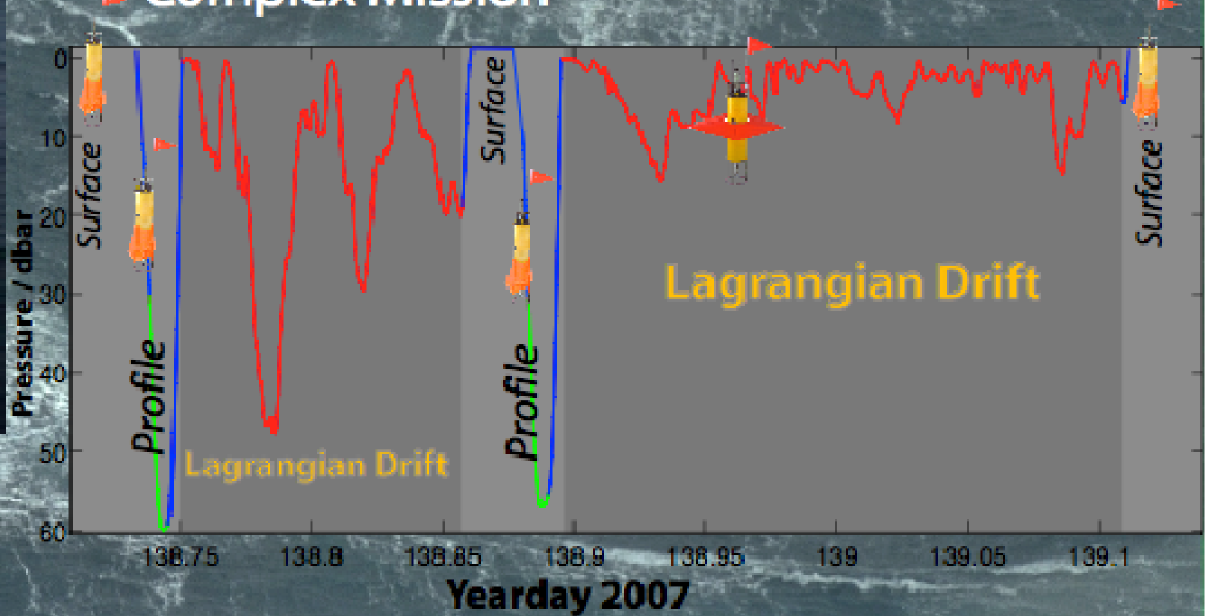
Measures vertical velocity

- *Naturally filters surface waves*

Measures turbulence statistics

- *VKE, heat and salt fluxes*
- *Energy and scalar dissipation rates*

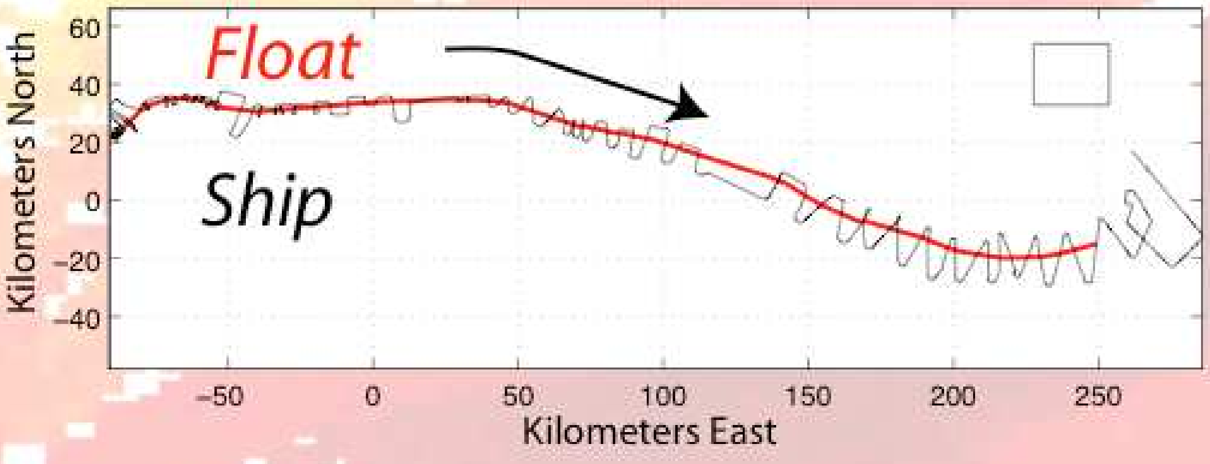
Complex Mission



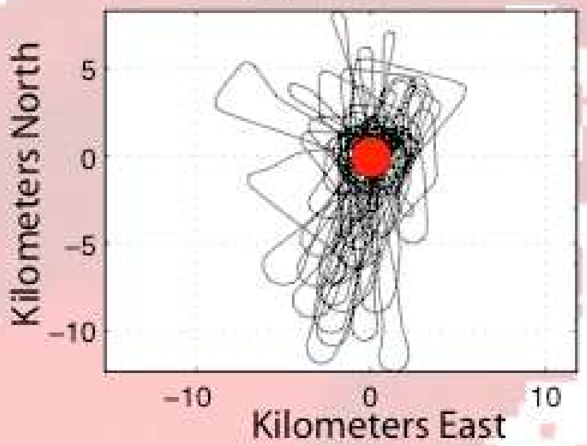
Lagrangian Sampling Strategy for Fronts

Use SST and altimeter data to pick a front
Do a short Triaxus section to find exact frontal position
Deploy float in front
Survey around float with with Triaxus
Quit & repeat

Eulerian Track



Lagrangian Track



Ertel Potential Vorticity

$$Q = \omega_a \cdot \nabla b \qquad \omega_a = f\hat{k} + \vec{\nabla} \times \vec{u} \qquad b = -g\rho / \rho_0$$

Ignoring horizontal f, 1% effect

$$Q = (f + \zeta_z)N^2 + \left[\frac{\partial u}{\partial z}\frac{\partial b}{\partial y} - \frac{\partial v}{\partial z}\frac{\partial b}{\partial x}\right]$$

Vertical

Horizontal

Key Properties

Downfront stress removes PV from ocean- rate $\frac{\tau}{\rho H} \times \frac{\nabla b}{H}$

Q<0 is unstable to 'symmetric' instability (Taylor & Ferrari, 2010)

Turbulence is driven by geostrophic shear, not wind

Boundary layer is stratified

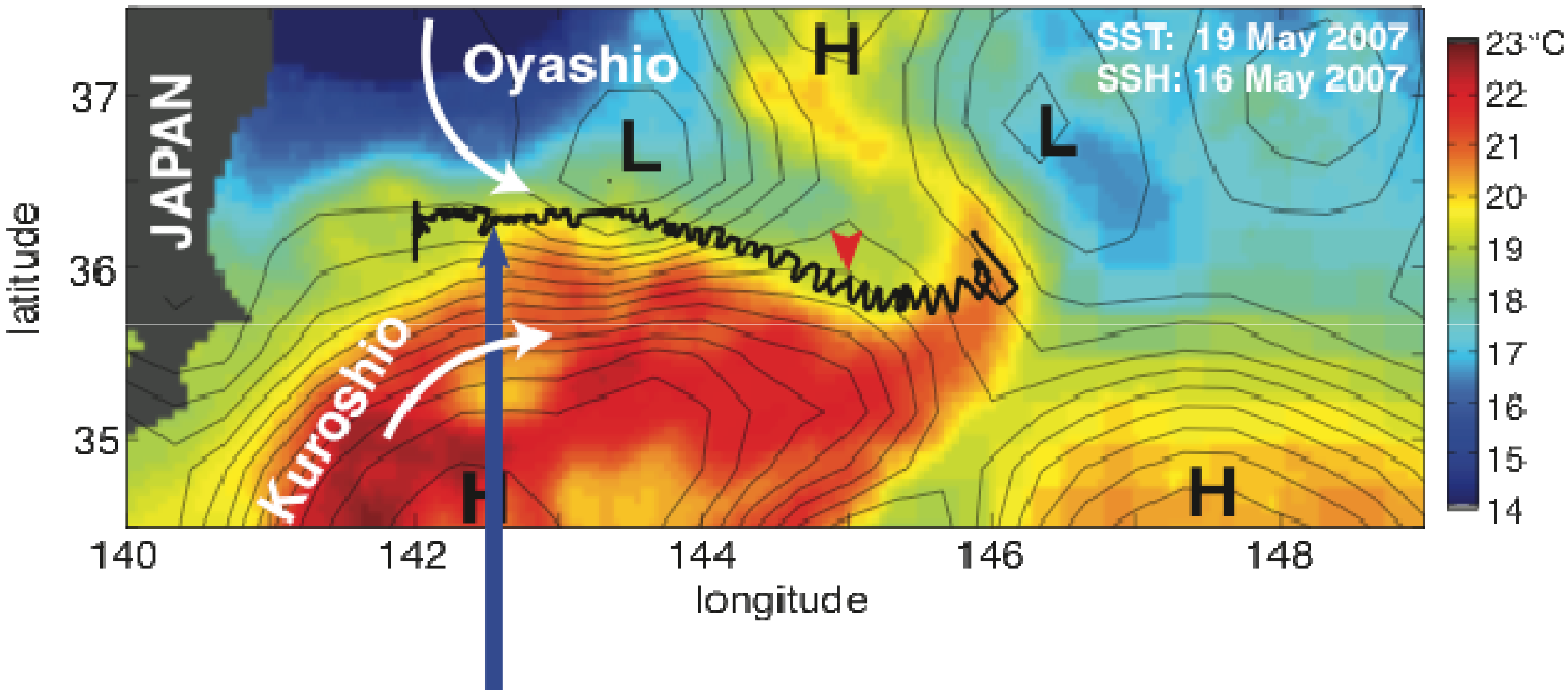
Instability dissipates energy at a rate (Thomas & Taylor, 2010)

$\rho_o^{-1}\vec{\tau}_w \cdot \partial \vec{u}_g / \partial z$ =*Ekman buoyancy flux - EBF*

We will test these predictions

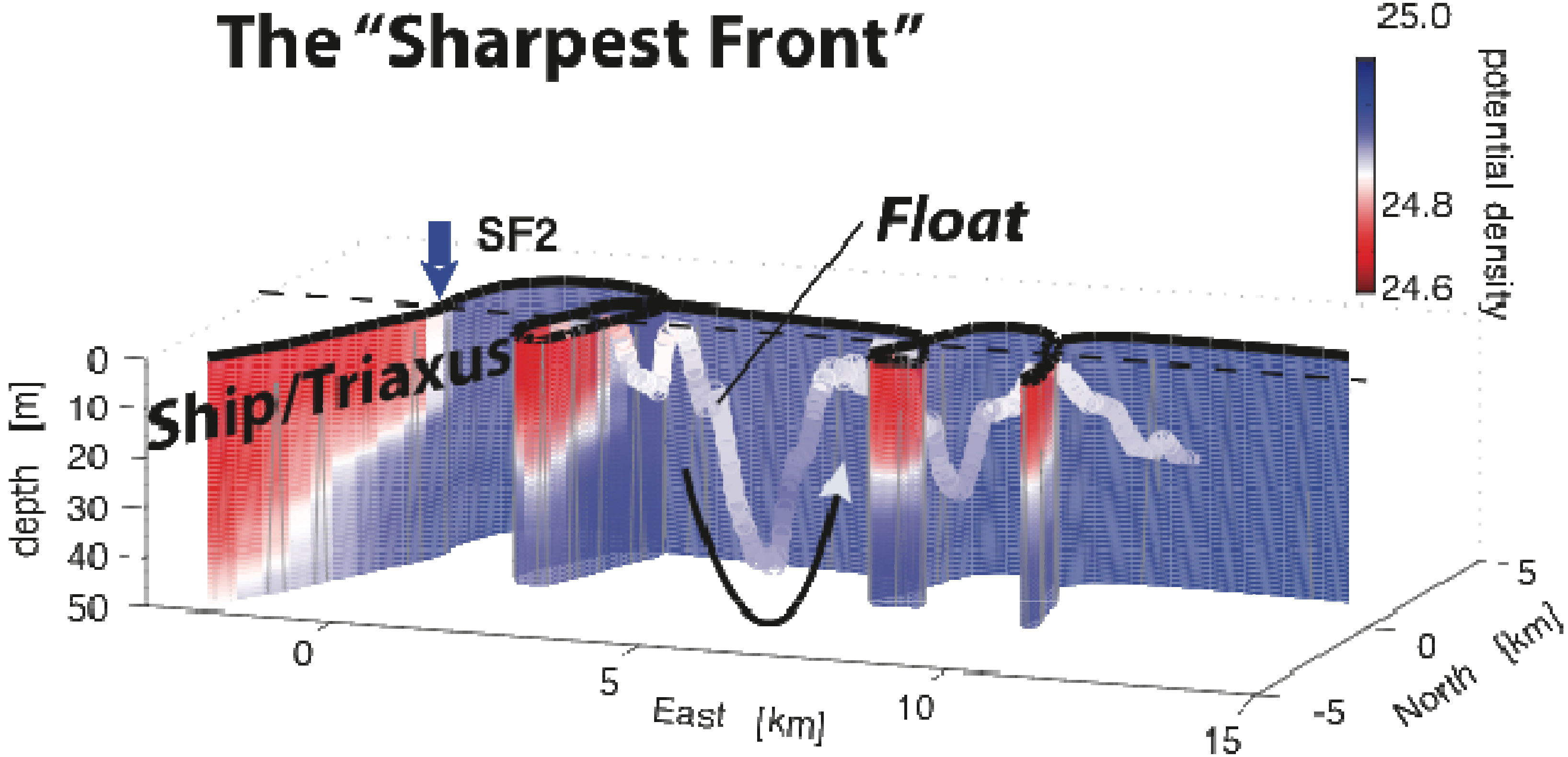
May 2007 at Kuroshio Front

Strong frontogenesis at convergence of Kuroshio and Oyashio



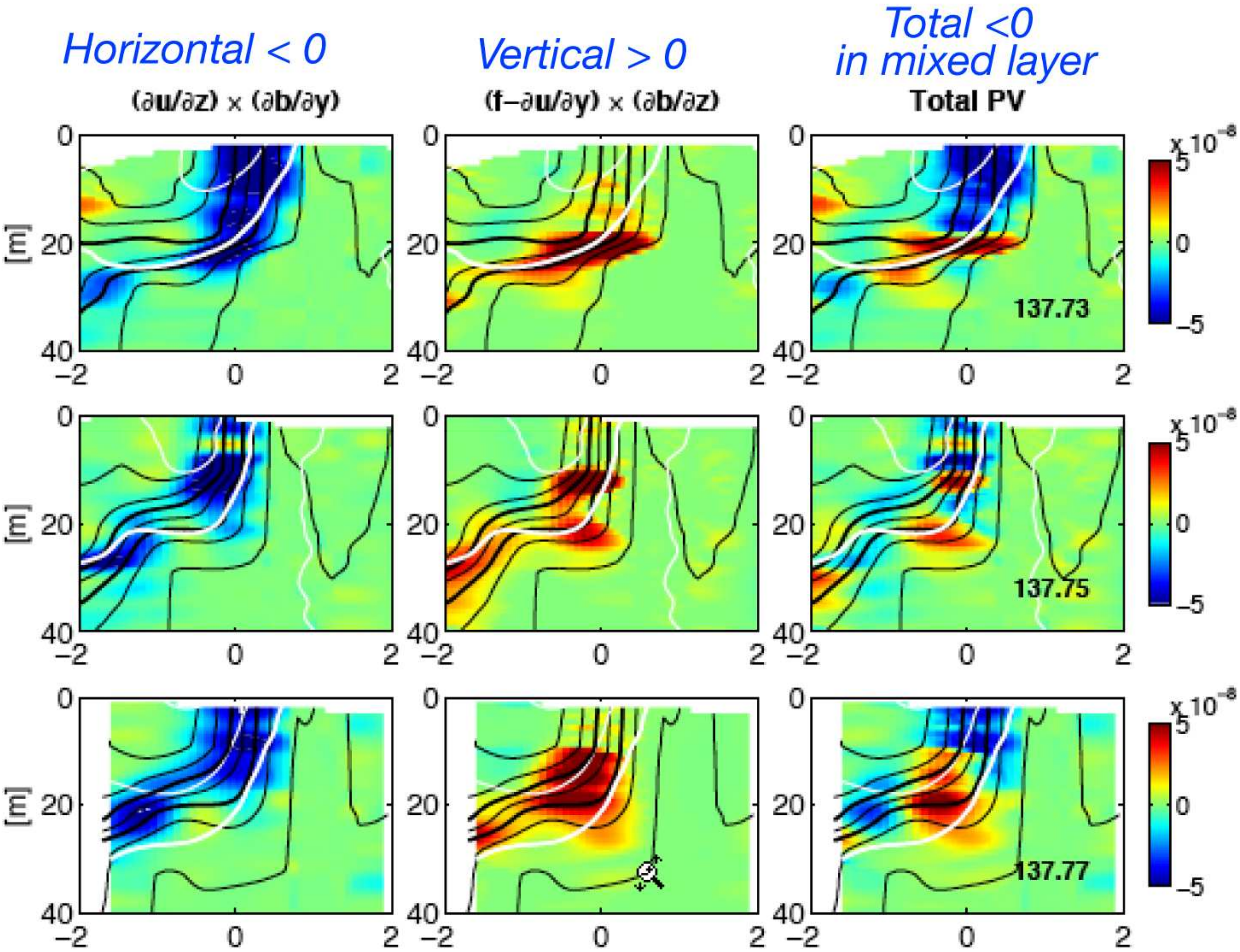
"Sharpest Front"

The “Sharpest Front”



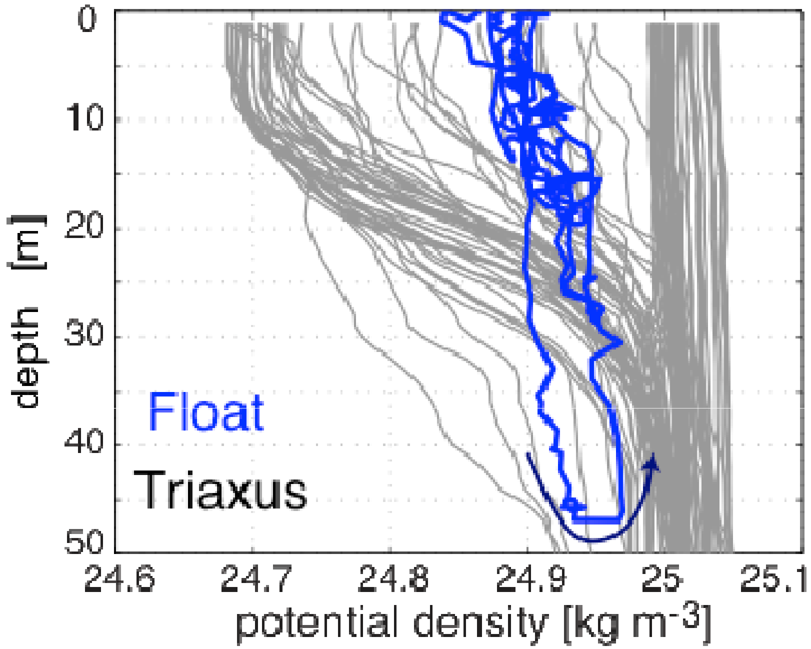
Strong density gradient - *measured by Triaxus*
Float is at the front - *measures the turbulence*
Wind is downfront - *should drive Q lower*

PV Sections from Sharpest Front



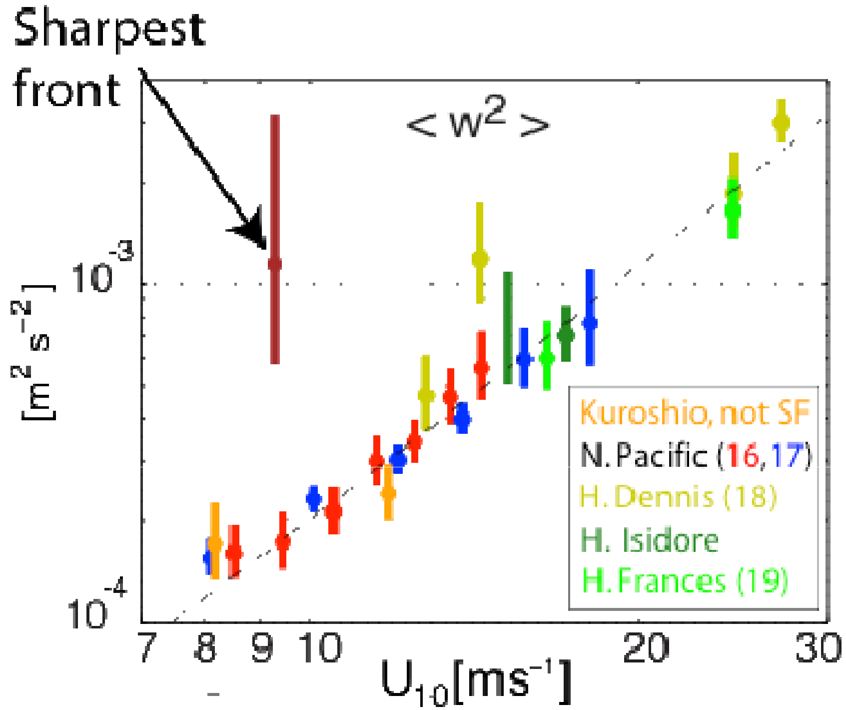
Boundary layer at the 'Sharpest Front' is different

Use turbulence measurements from Lagrangian Float



Boundary layer is stratified & turbulent

As predicted for symmetric instability by Taylor & Ferrari, 2010

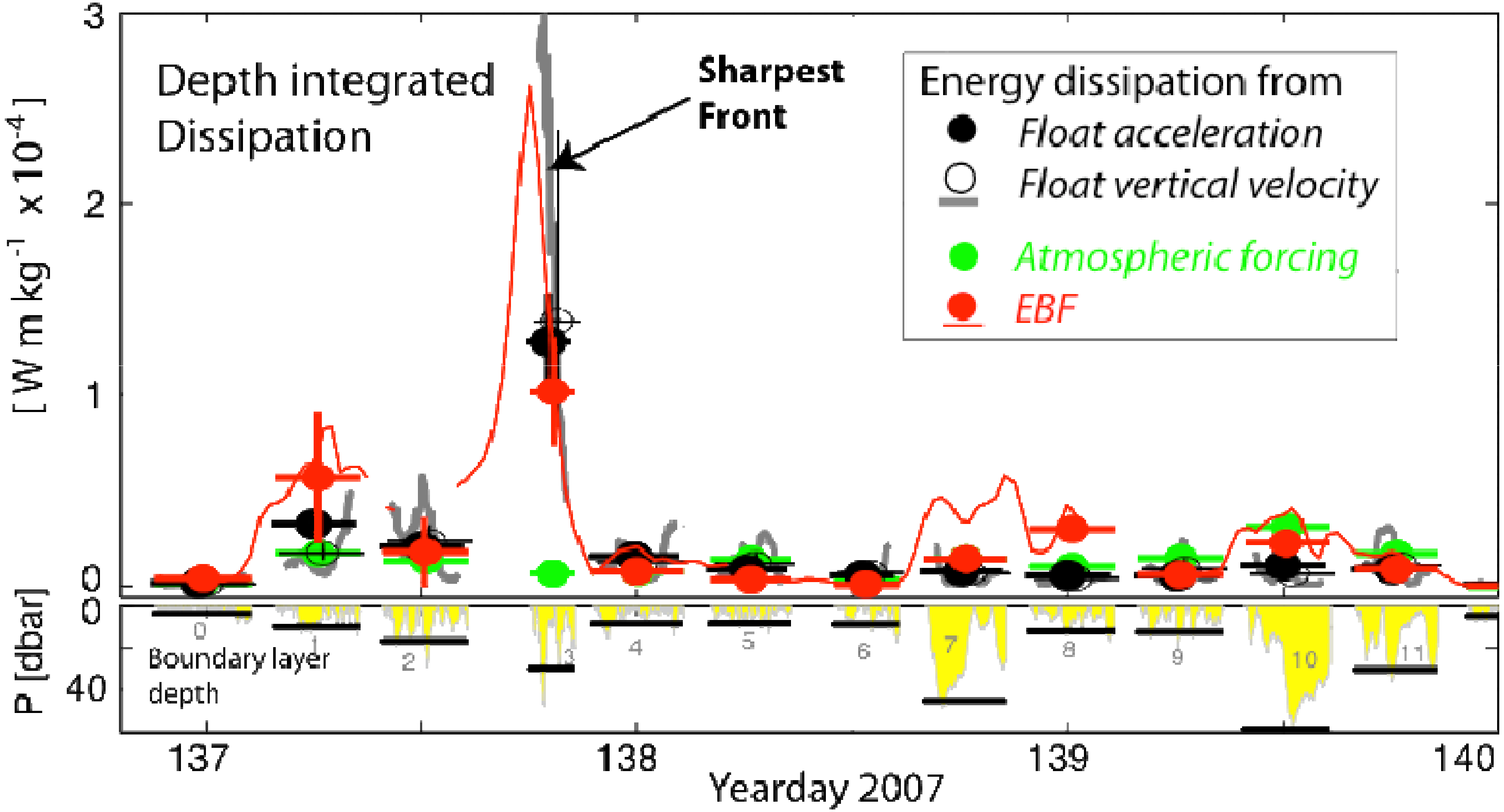


Boundary layer dissipation rate is much higher than predicted by wind alone

Energy must come from the front, not the atmosphere

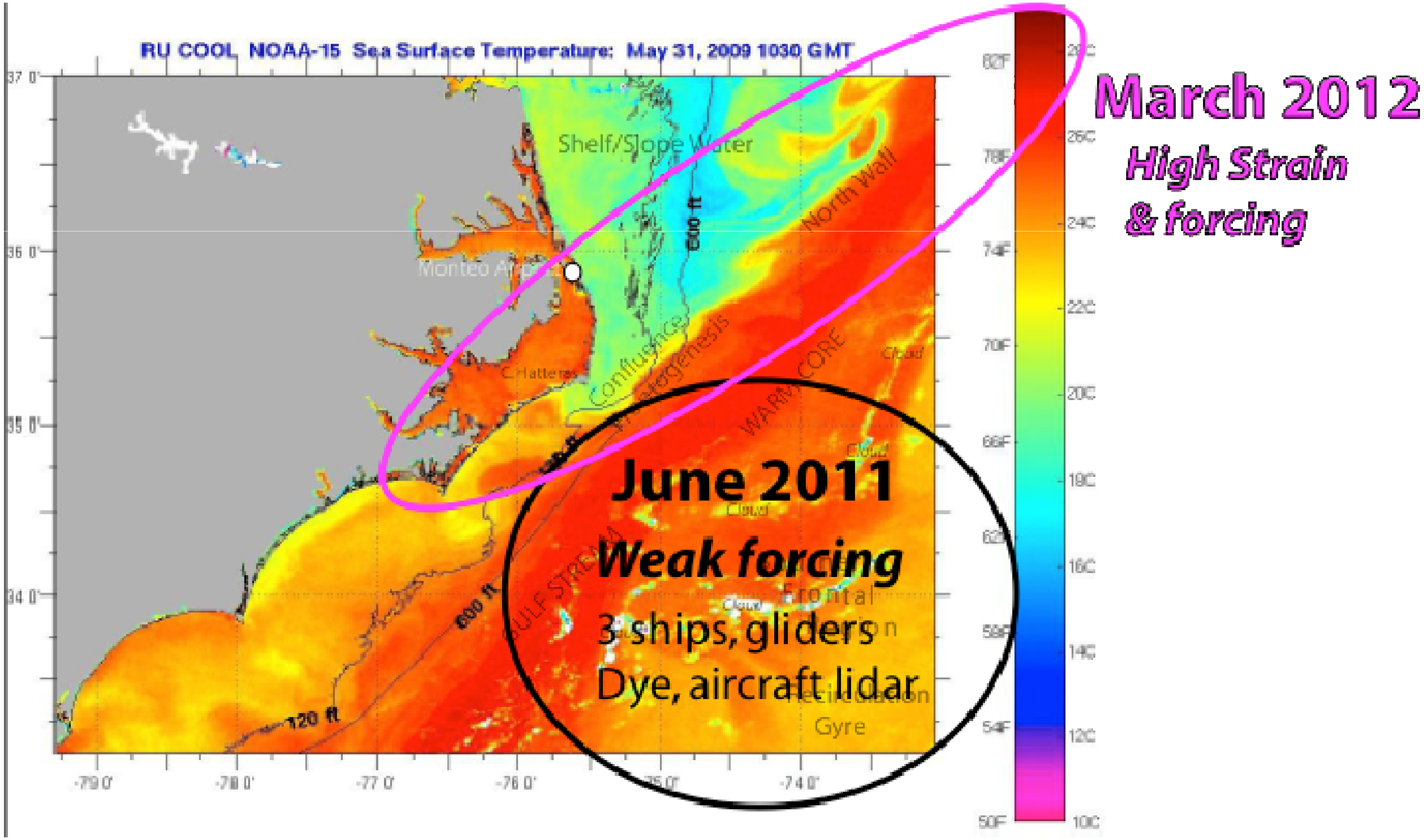
Dissipation rate approximately equals EBF

As predicted by boundary layer driven by symmetric instability
Thomas and Taylor (2010)



ONR Lateral Mixing DRI

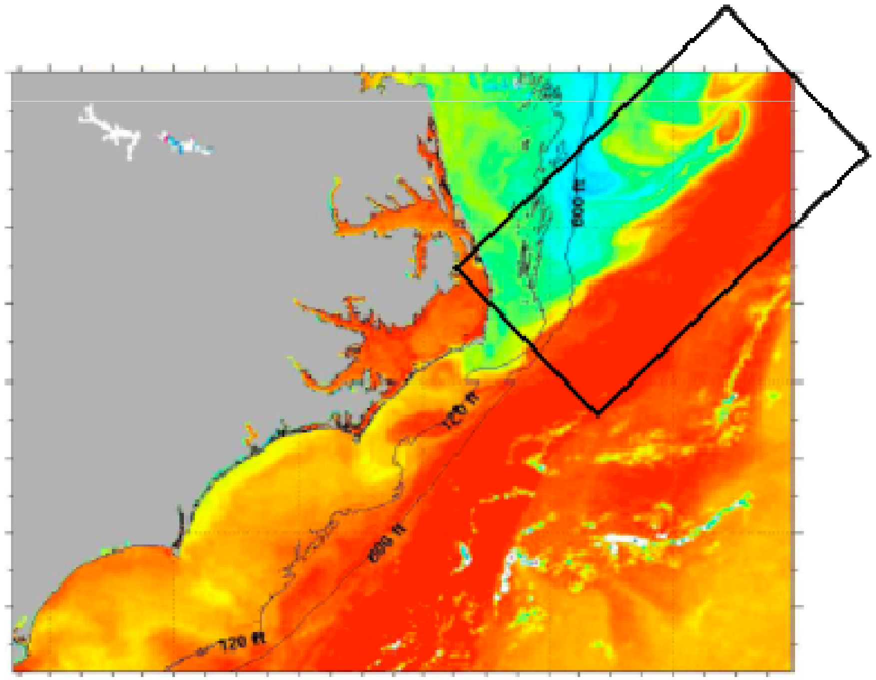
Submesoscale and internal wave mechanisms of lateral mixing

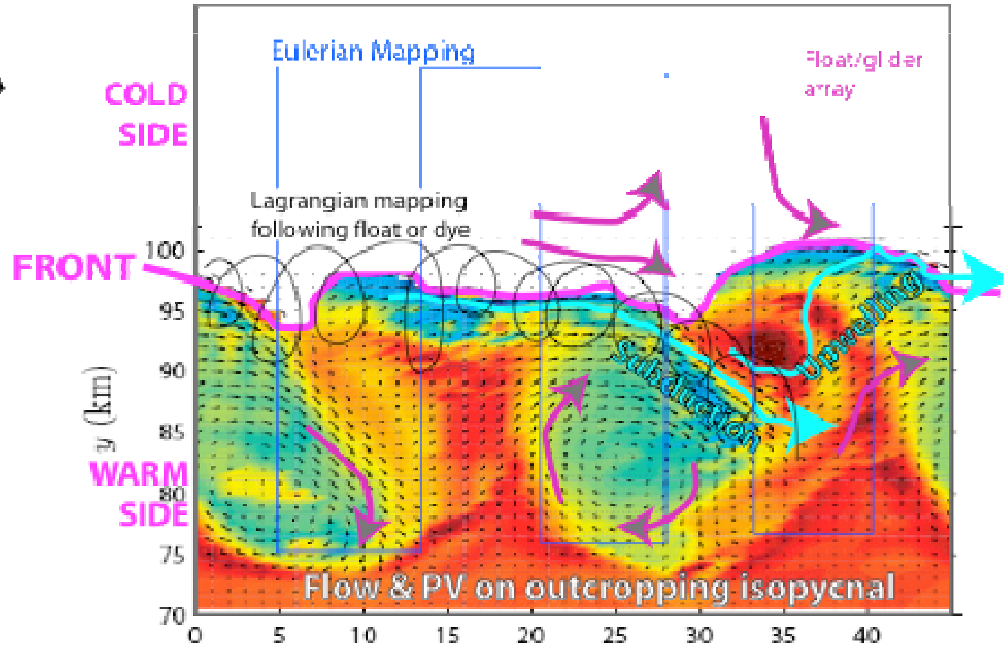


2012 Lateral mixing Experiment

Gulf Stream Front
March 2012
2 Ships
- *Eulerian survey, microstructure*
- *Lagrangian survey - floats & dye*

Excellent opportunity for aircraft altimetry surveys
- *Ship survey targetting*
- *Context for ship measurements*
- *Demonstration of high resolution ocean altimetry*





Craig Lee *craig@apl.washington.edu*   *Eric D'Asaro* *dasaro@apl.washington.edu*

Summary

We have new tools for measuring details of ocean submesocale,
especially in the boundary layer.

In the Kuroshio front, they revealed a flux of energy from the front into the boundary layer and thus a new path for dissipating the large scale circulation.

They are microscopes, looking very closely at a small region

High resolution altimetry can provide context for such measurements

The ONR Lateral Mixing DRI, especially the 2012 experiment, is an opportunity to demonstrate this.