SPURS Update

July, 2013
CLIVAR Summit
Annapolis

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WHOI

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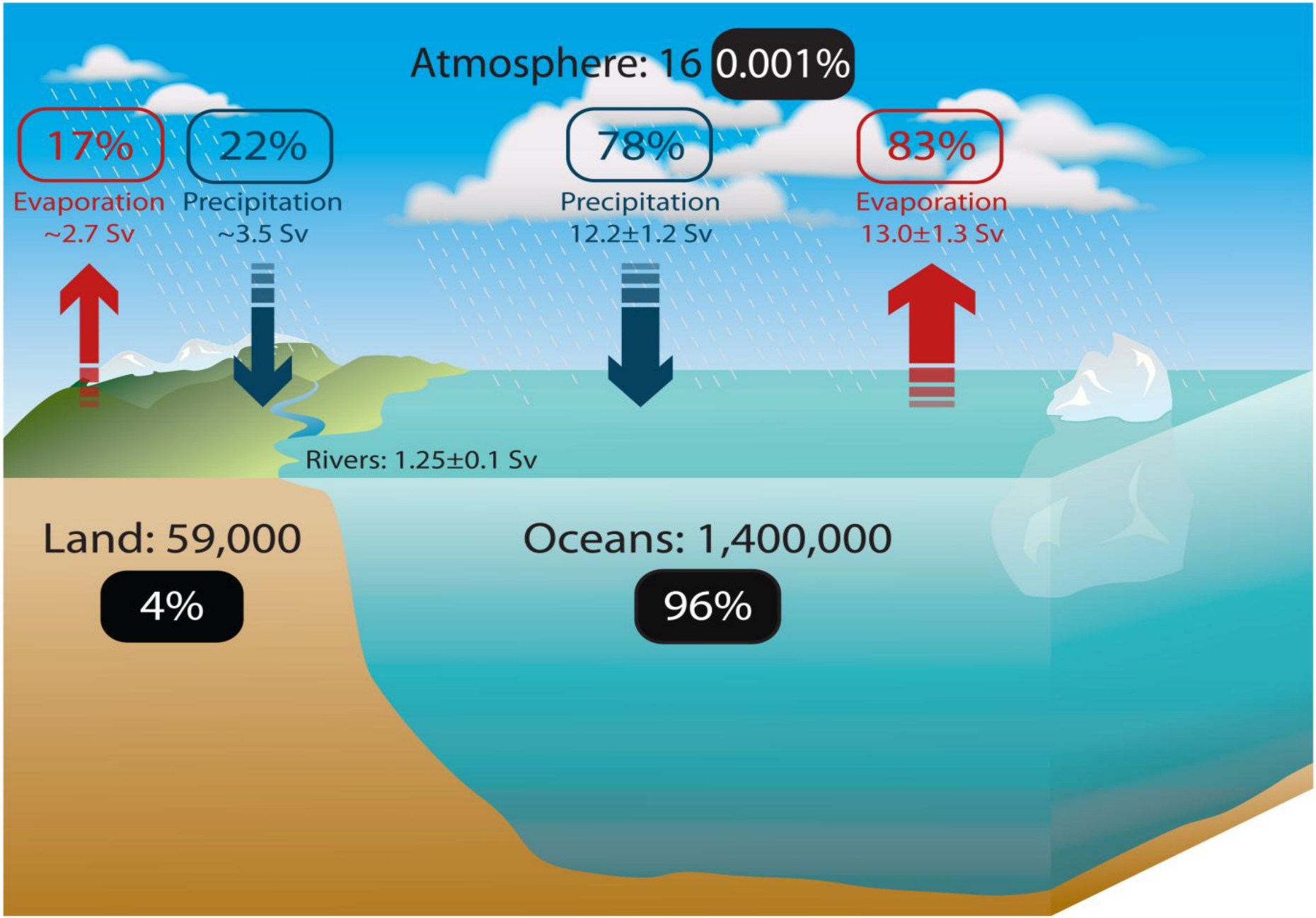
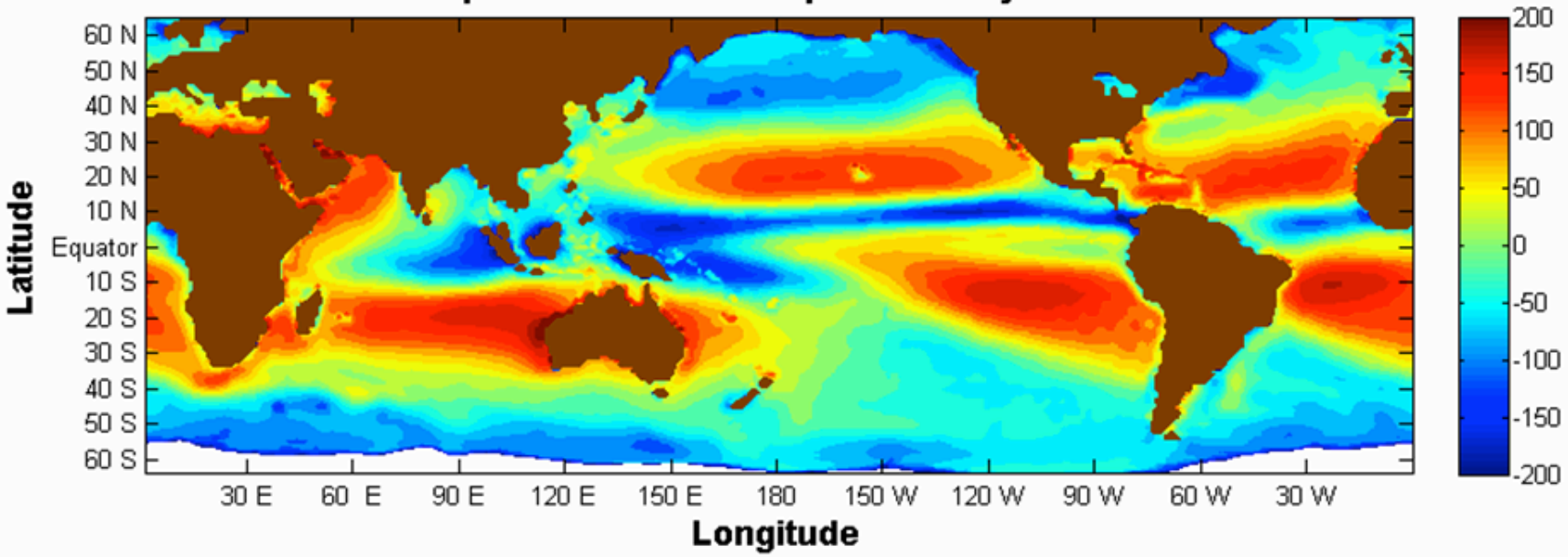


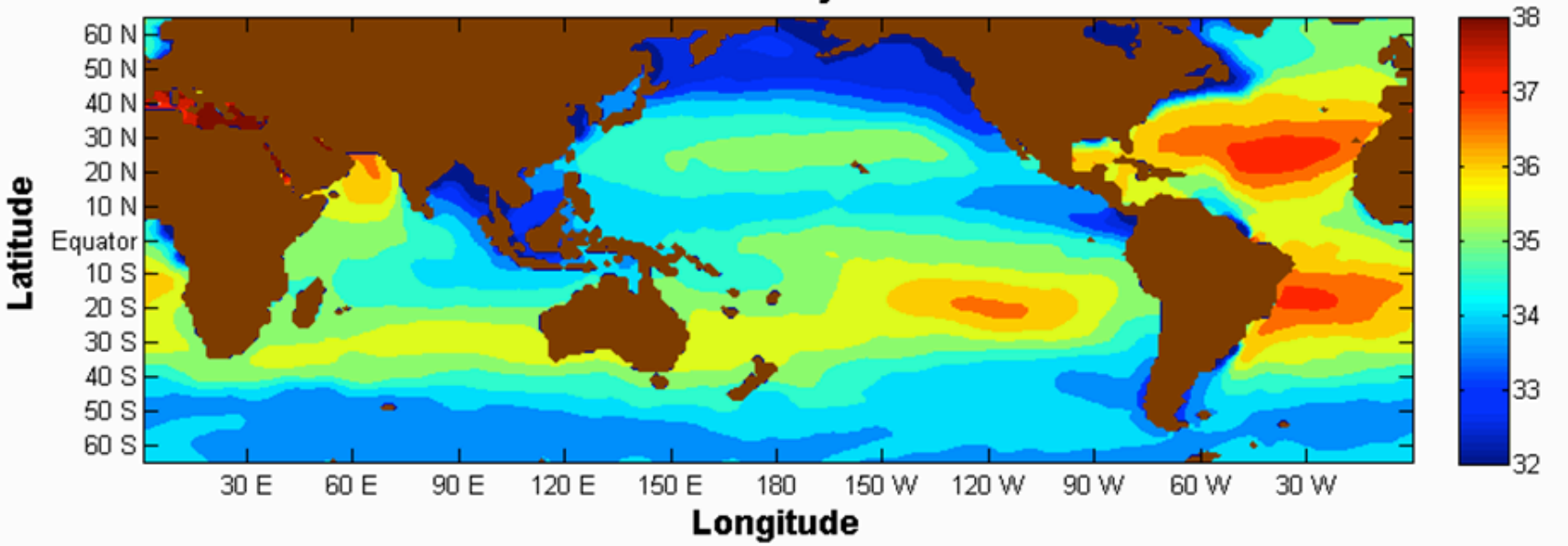
Reservoirs represented by solid boxes: 10^3 km^3, fluxes represented by arrows: Sverdrups (10^6 m^3 s^{-1})

Sources: Baumgartner & Reichel, 1975; Schmitt, 1995; Schanze et al., 2010

Evaporation Minus Precipitation cm/yr CI = 20



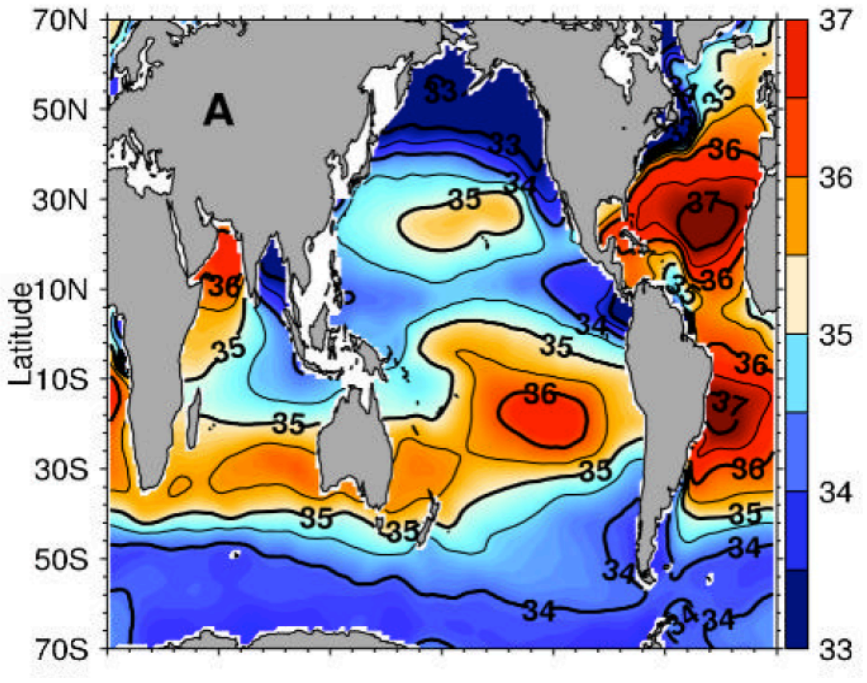
Salinity



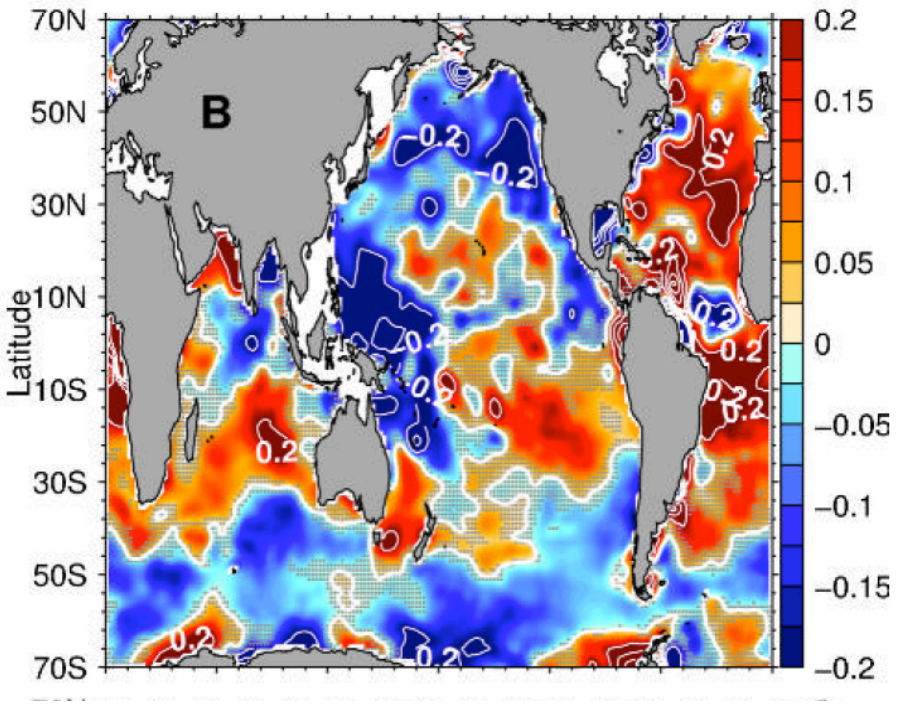
Durack and Wijffels, 2010

J. Climate

Mean SSS



50 yr trend in SSS



Salinity trends indicate significant changes are underway in the global water cycle:

- High salinity regions getting saltier
- Low salinity regions getting fresher
- The best evidence we have for an intensification of the global water cycle!
- The rate of intensification is *much* larger than models predicted.

Motivation for SPURS:

- Salinity appears to be a very sensitive indicator of change in the water cycle.
- Salinity trends indicate WC intensification is much greater than models can explain. This is a key global change issue!
- In order to understand these trends oceanographers have to determine how ocean salinity processes (mixing, subduction) are responding to warming, increasing winds and water cycle intensification. SPURS is designed to address such physics on diurnal to seasonal time scales.

"Salinity Processes in the Upper Ocean Regional Study" (SPURS)

Outgrowth of:

- US CLIVAR Salinity Working Group (May 2006 meeting and 2007 report)
- "Salinity" issue of *Oceanography* (Mar. 2008)
- NASA Workshop at JPL (Dec. 2009)
- Aquarius Salinity Satellite (June 2011 launch)
- SPURS Planning Meetings (Yearly, most recently Miami, Jan 16-18, 2013)

A Salinity and Water Cycle Experiment

- Surface Salinity is closely linked to the water cycle
- Salinity satellite Aquarius provides new tool for monitoring SSS in the global ocean
- ARGO array is now providing accurate S(z) profiles
- Salinity sensors can be placed on surface drifters
- Initial site: Salinity maximum region of the North Atlantic Key question: How is the S-Max maintained?
- SPURS come in pairs, a freshwater experiment is envisioned for ~2015

S-Max location for the process study

Objectives:

What processes maintain the salinity maximum?

Where does the excess salt go?

What processes give rise to temporal variability?

What is the larger impact on the shallow overturning circulation?

Location advantages:

>Low $\nabla \cdot (\vec{U}S)$

>Low precip

>Modest eddy activity

} 1D phys.

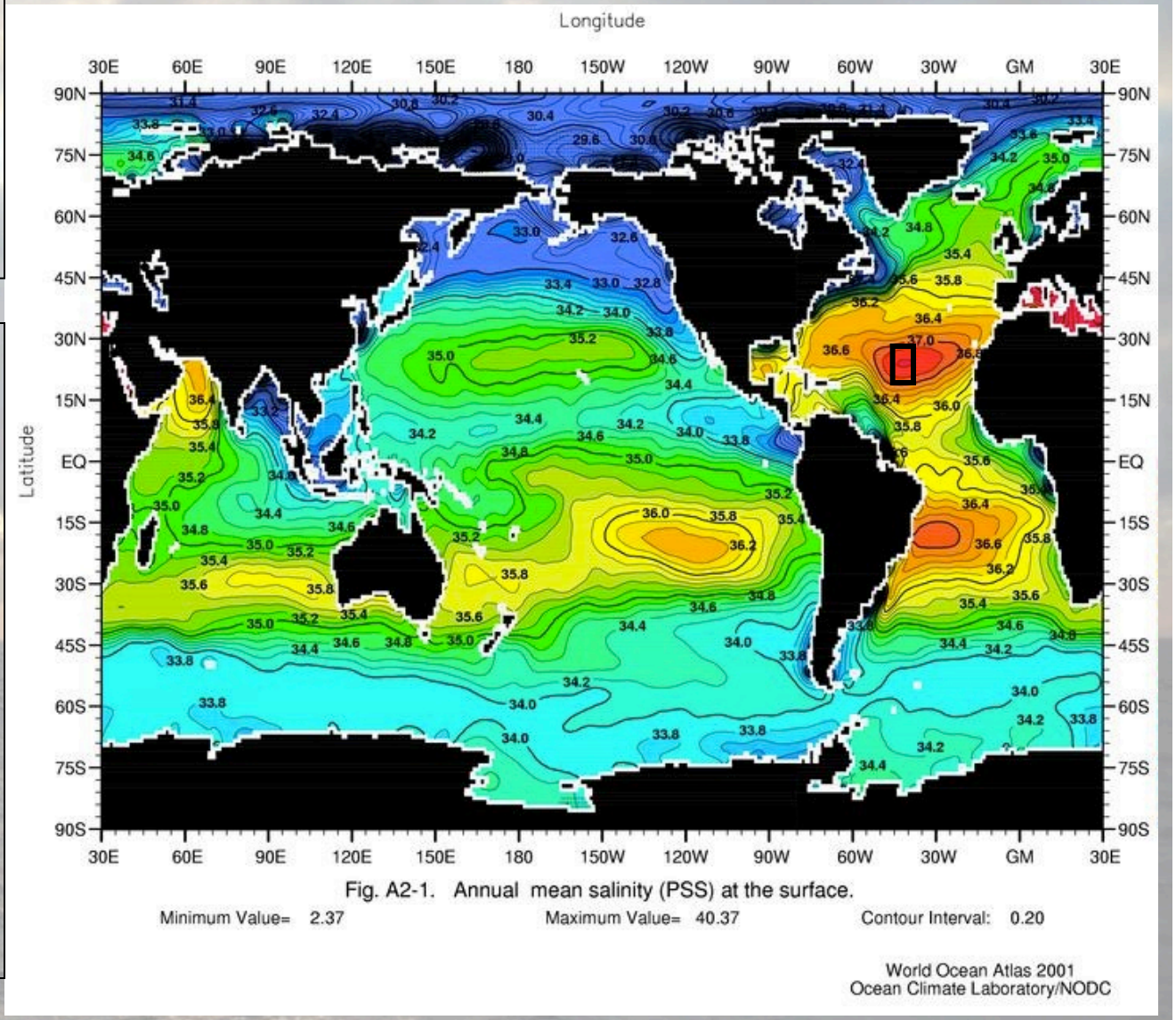
>Source of water for northern tropical thermocline

>Stable S for Cal-Val

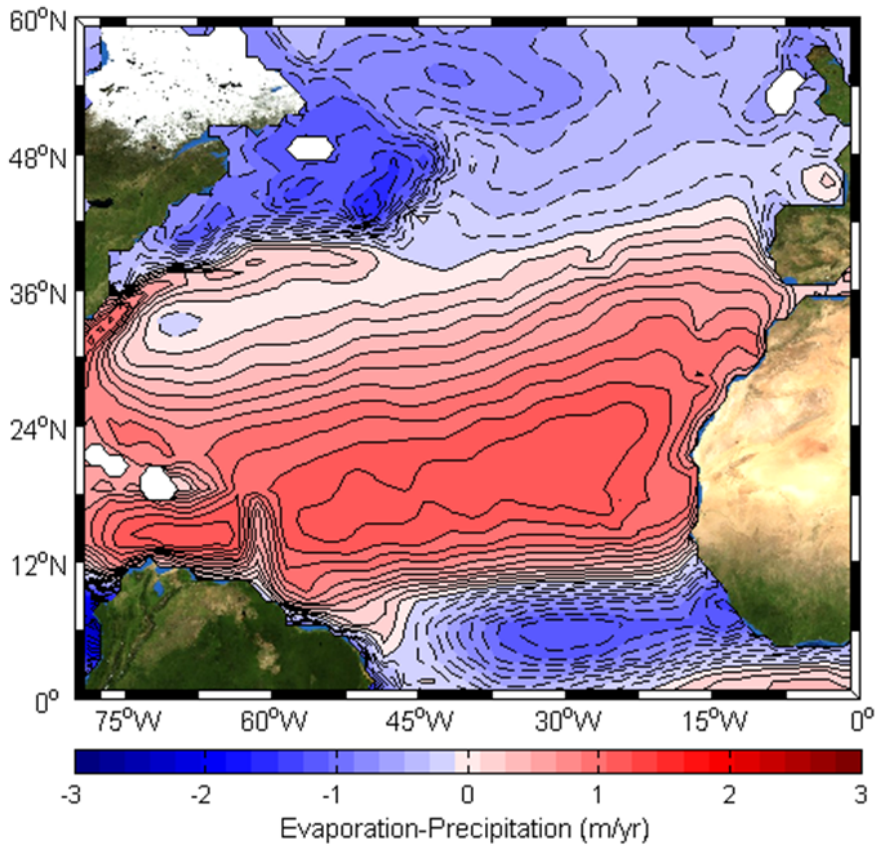
> Warm (better for Aquarius)

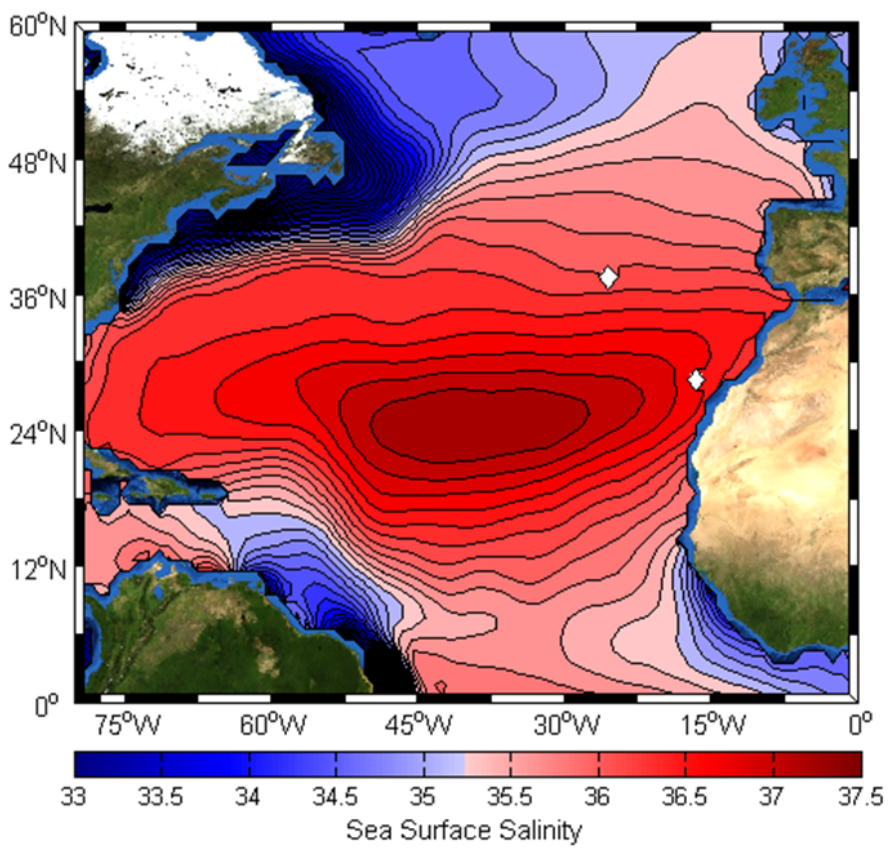
> Leverages other resources: 24 N section, Pirata Array, ESTOC time series (Canary Islands)

> Logistically tractable



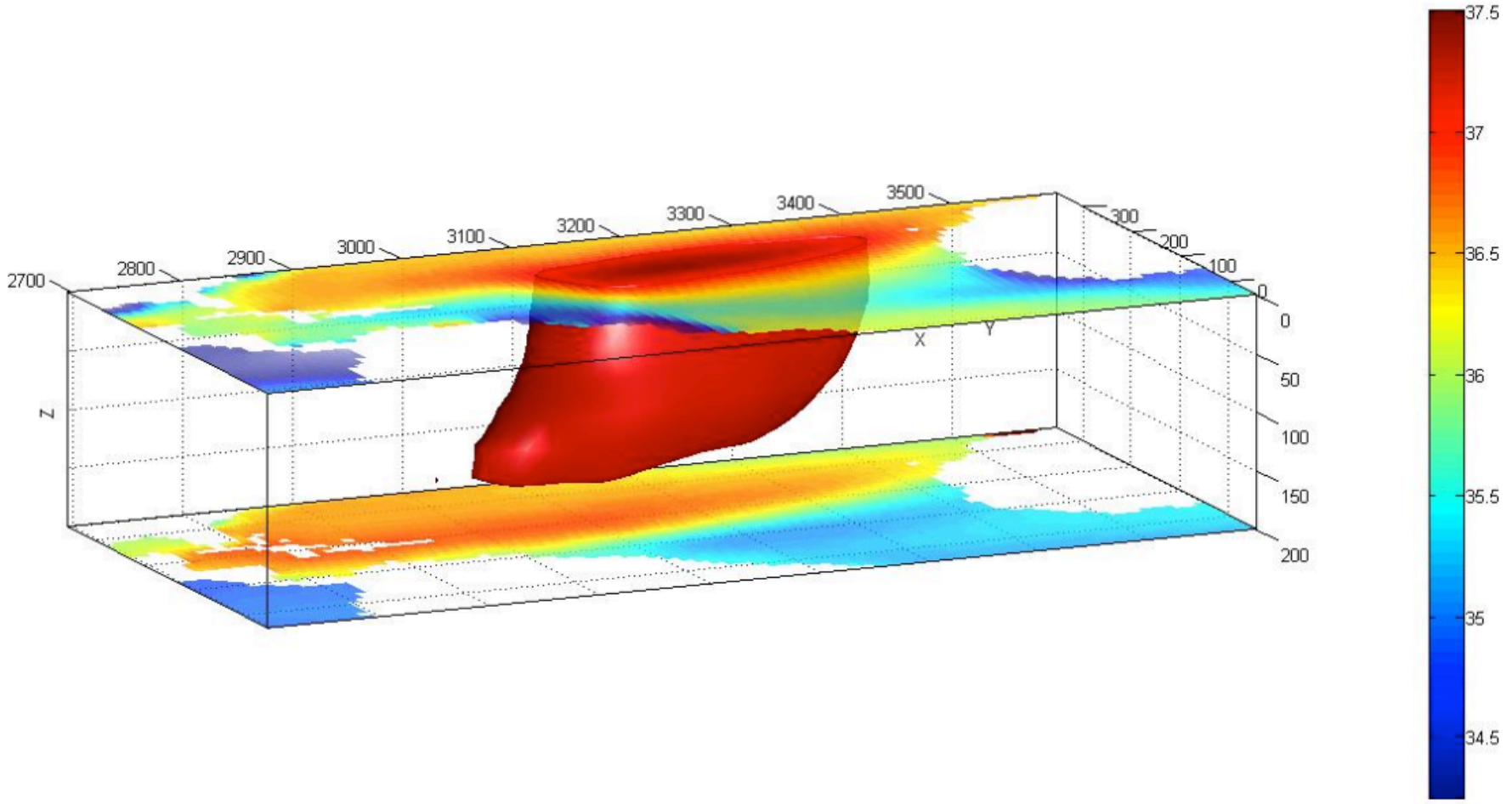
N. Atlantic Evaporation-Precipitation and Salinity are highly correlated



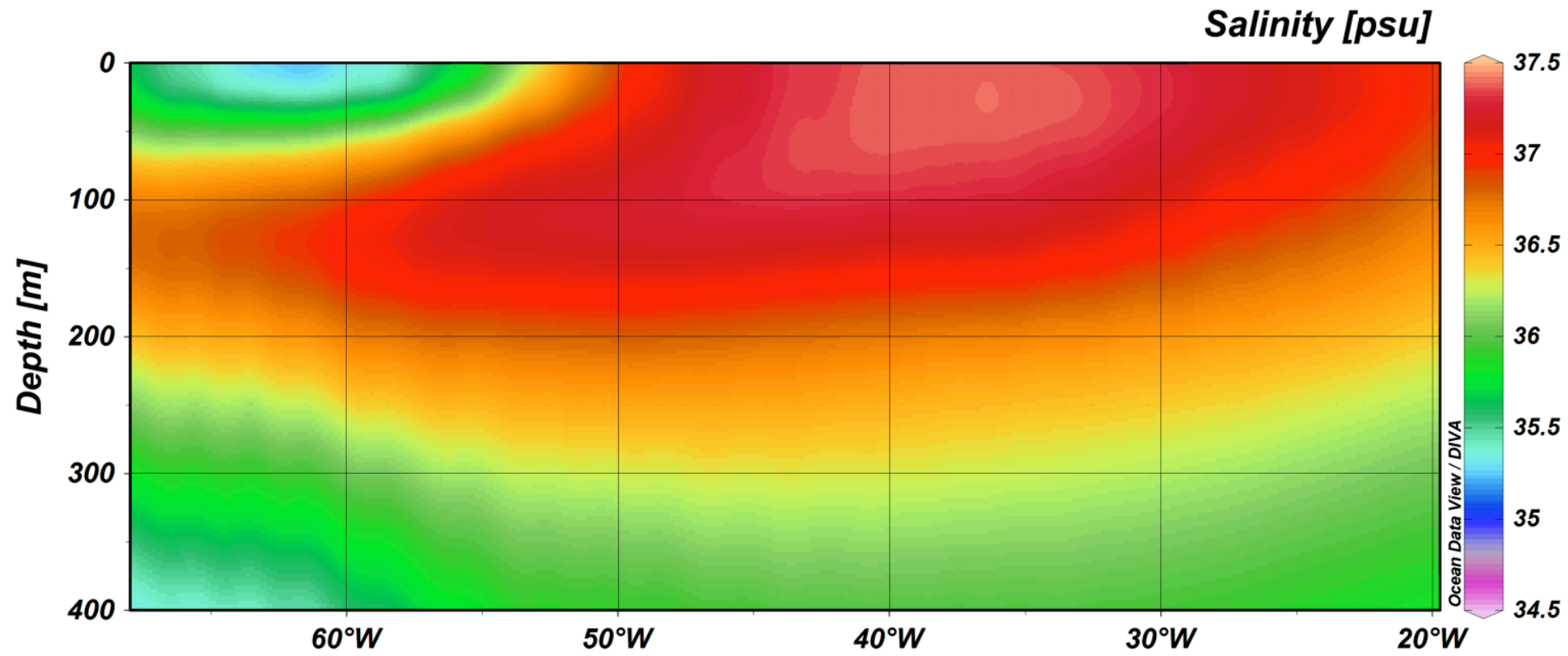


Note: the E-P zero line is close to the forest/desert boundary in Africa

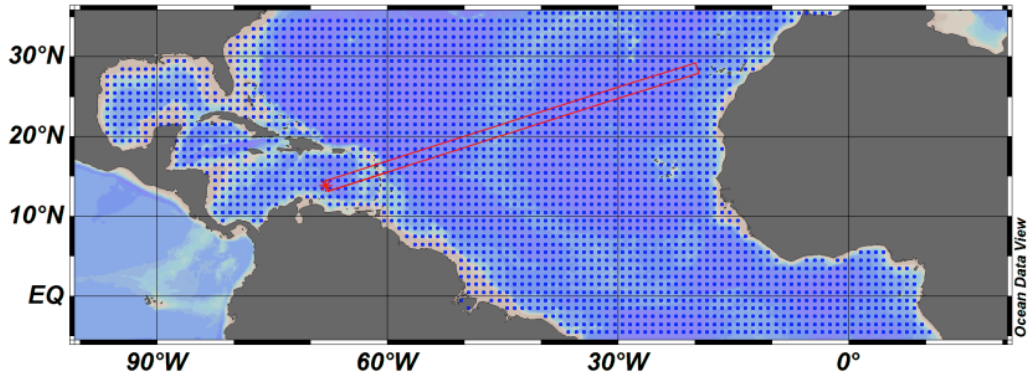
Shape of the 37.0 Salinity Contour in the North Atlantic (to 200m depth) (From WOA Climatology)



Salinity Section from Caribbean through S Max

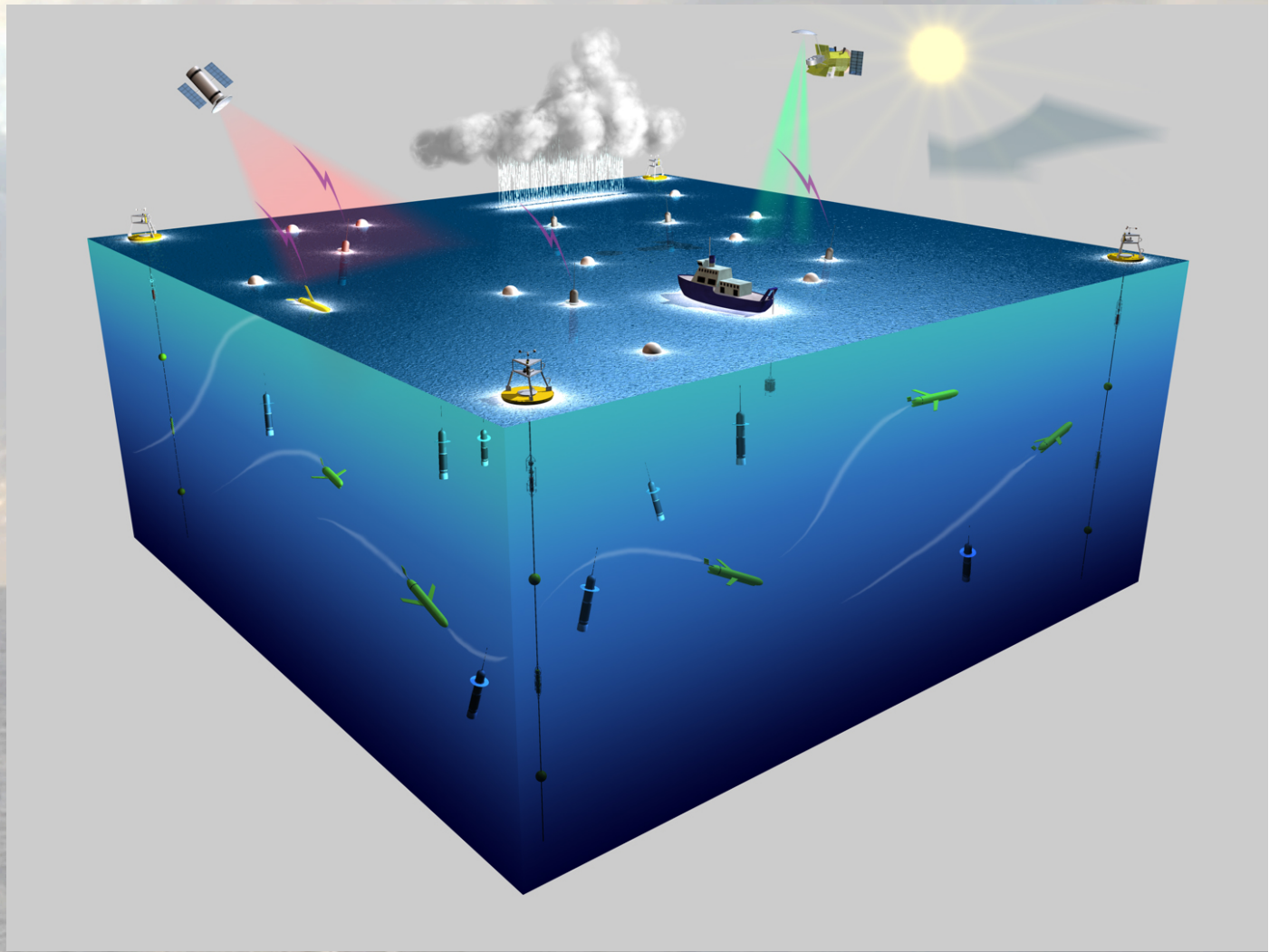


Dataset: WOA 09 Annual



Tools for the Study:

- Floats
- Gliders
- Drifters
- Moorings
- Ships
- AUVs
- Satellites
- CTD & Micro-structure profiling



Central Question: Can we constrain the upper-ocean salinity (and thus water) budget with new salinity sampling tools?

- This will be most tractable where horizontal advection is weak. Thus the choice of the salinity maximum region, where the salinity balance must become one dimensional, and precipitation is small.

$$\underbrace{h\frac{\partial\langle S\rangle}{\partial t}}_{a} = \underbrace{-h\langle\vec{u}\rangle\bullet\nabla\langle S\rangle - \nabla\bullet\int_{-h}^{0}\hat{\vec{u}}\hat{S}dz}_{b,c} - \underbrace{\left(\langle S\rangle - S_{-h}\right)\left(\frac{\partial h}{\partial t} + \vec{u}_{-h}\bullet\nabla h + w_{-h}\right)}_{d} + \underbrace{\left(E-P\right)S_0}_{e} + \underbrace{SSM}_{f}$$

- Future project (SPURS II) will address high precipitation regions (which generally have large horizontal advection as well).

SPURS

- Multi-agency (NASA, NOAA, NSF)
- Multi-national (US, Spain, France, Ireland)
- Designed to exploit new autonomous technology (Floats, gliders, wavegliders, drifters etc.)
- Linked to but not dependent on Aquarius salinity satellite

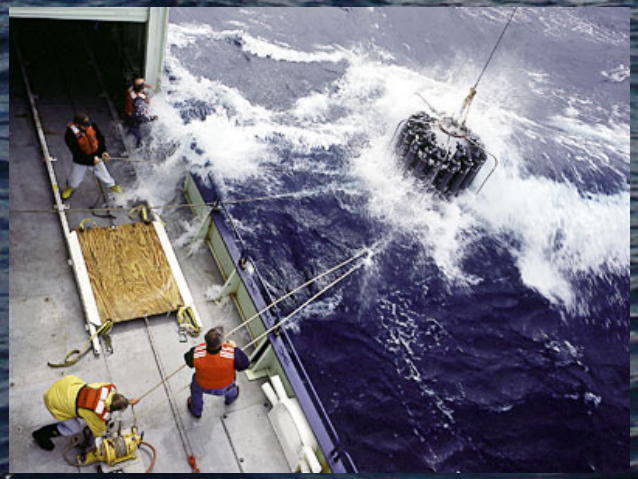
SPURS Cruises:

- **French -Thalassa 8/16/12 – 9/13/12, Canaries - Azores**
- **US - Knorr 9/6/12-10/9/12, Woods Hole – Azores (asset deployment)**
- **US - Endeavor 3/15/13 -4/15/13, Narragansett – Narragansett (asset service)**
- **Spanish - Sarmiento de Gamboa 3/16/13-4/13/13, Canaries - Azores**
- **US - Endeavor 9/19/13-10/16/13, Azores – Narragansett (asset recovery)**

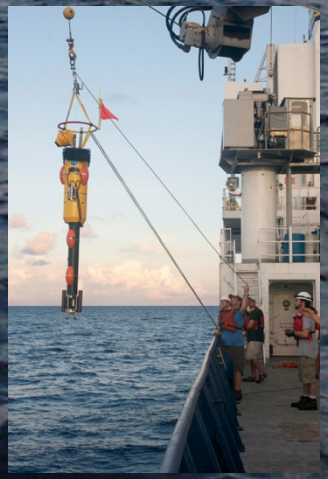
Web site: http://our ocean.jpl.nasa.gov/SPURS/tindex.jsp

Ship-based measurements

Wind speed and direction
Air and sea temperature
Surface temperature and salinity
Ocean currents



CTD rosette

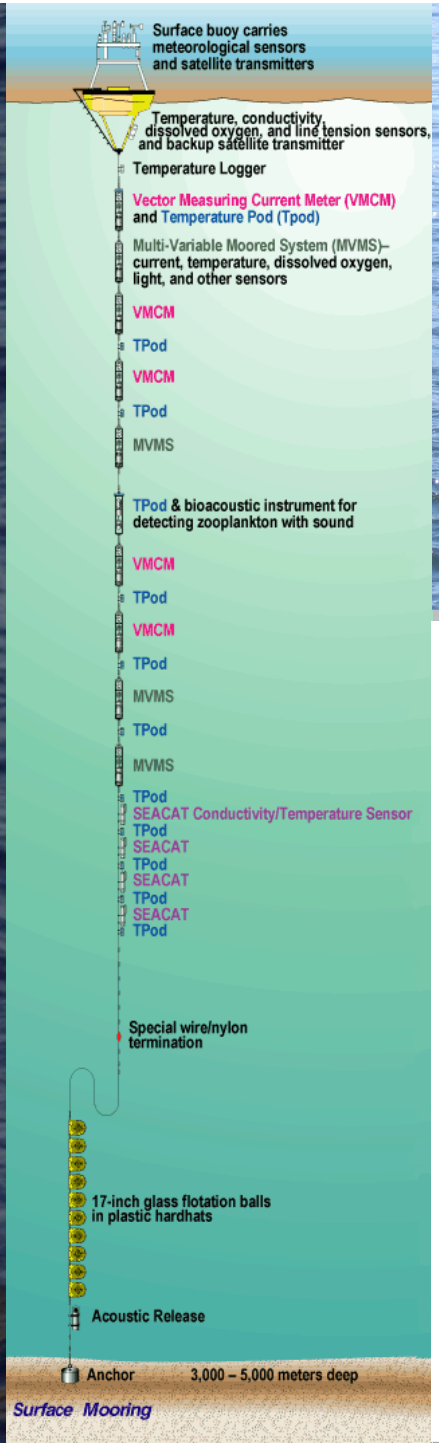


Microstructure Profiler

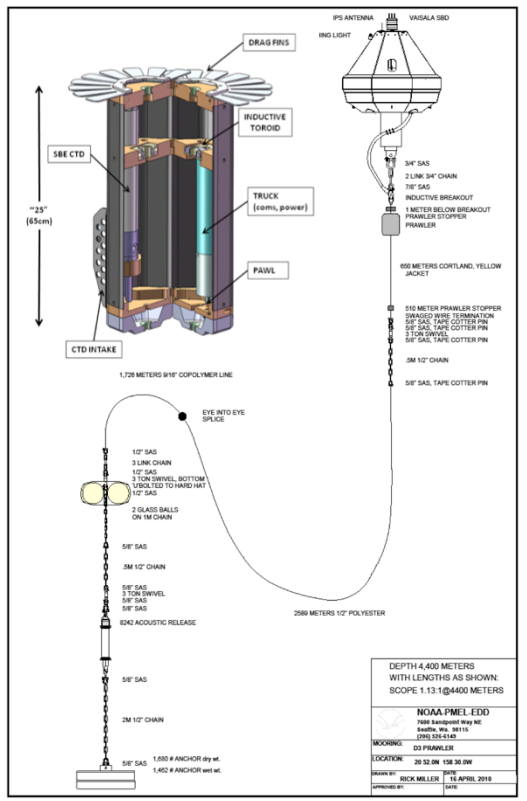
Underway CTD

Moored observations

Surface flux mooring

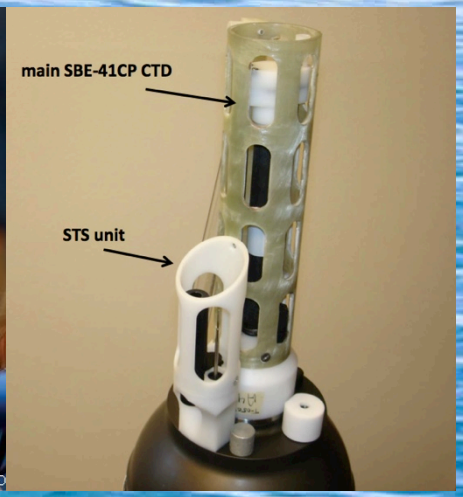


Prawler mooring

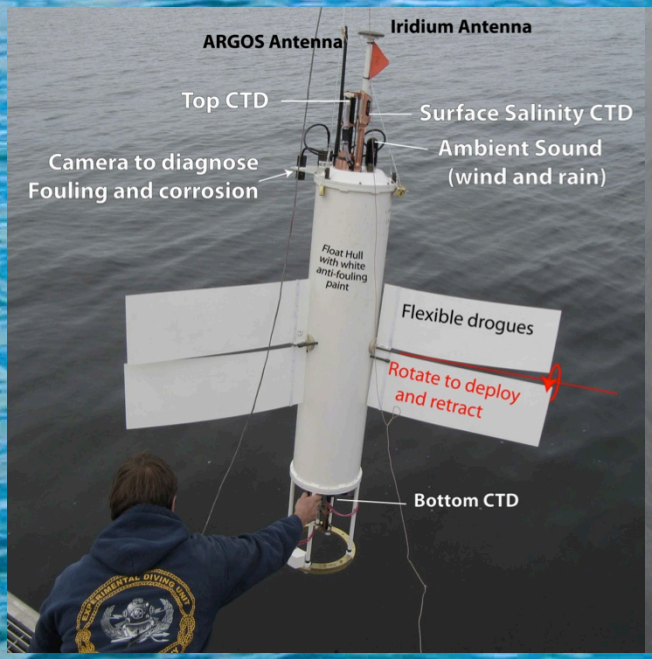


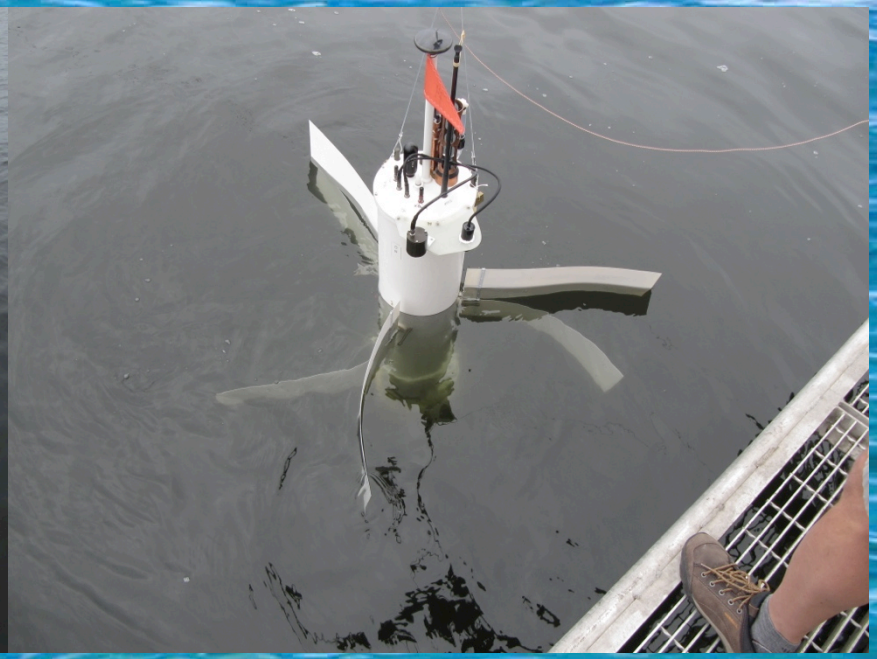
Drifting Instruments

Surface drifter



Profiling float

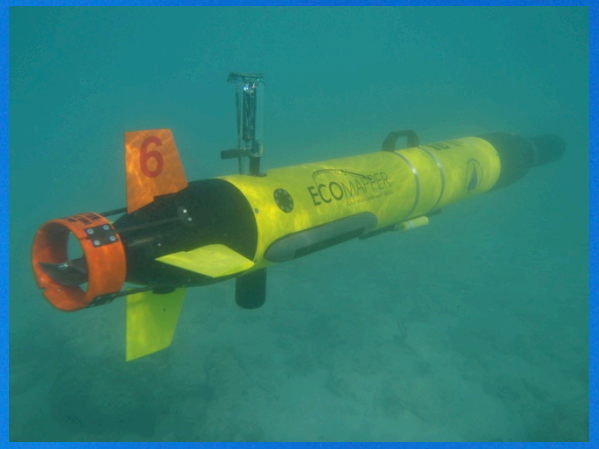




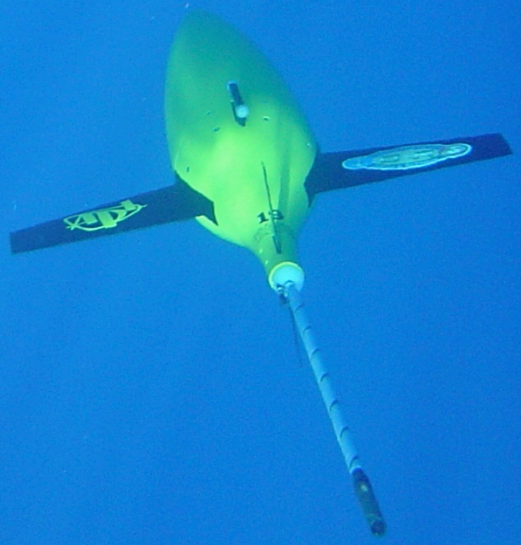
Lagrangian drifter

Autonomous Underwater Vehicles (AUVs)

Slocum Glider



IVER2/Ecomapper



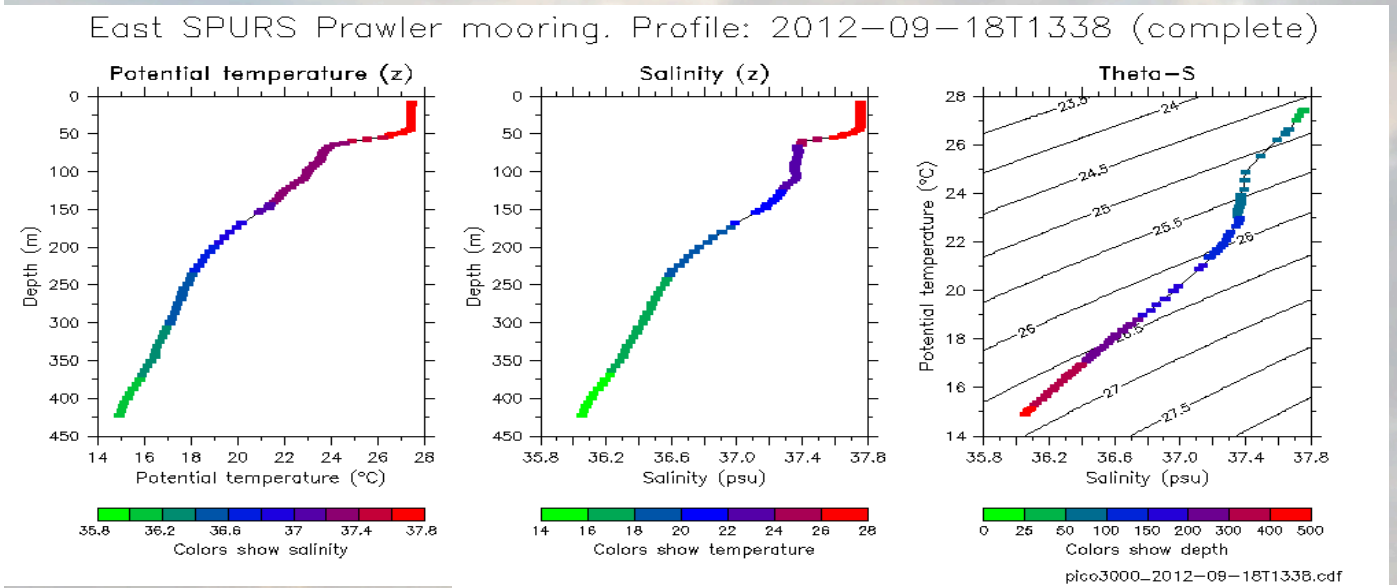
Seaglider

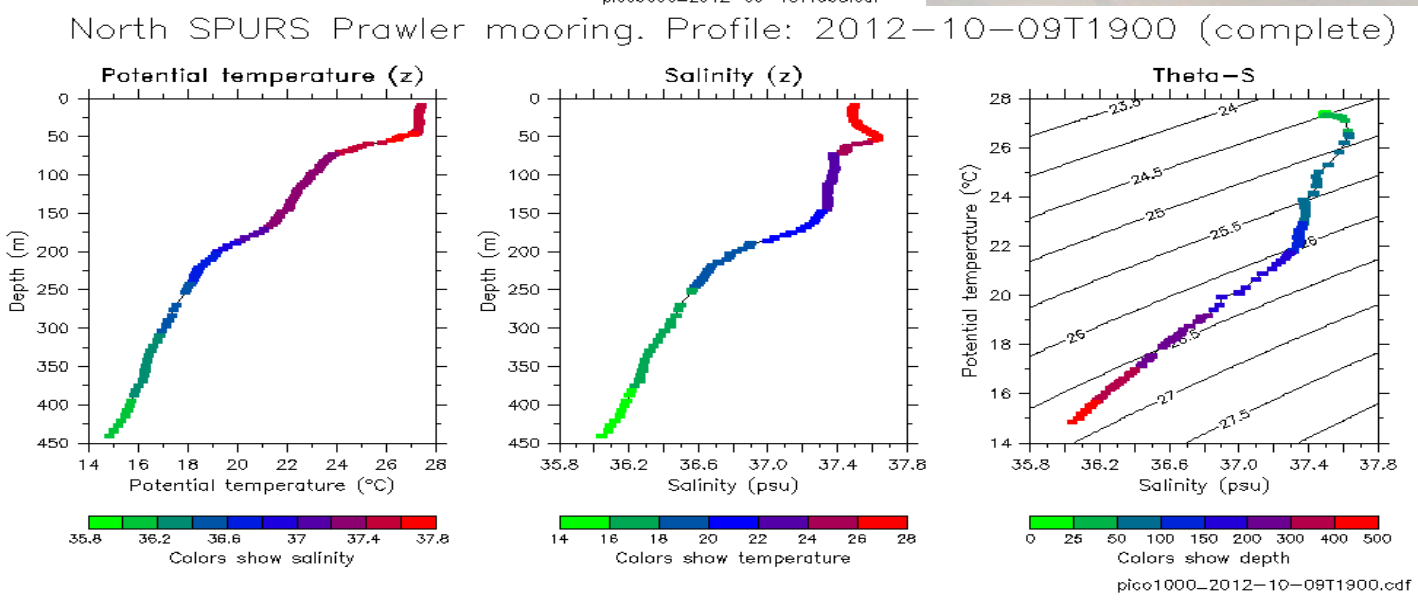
Autonomous Surface Vehicles

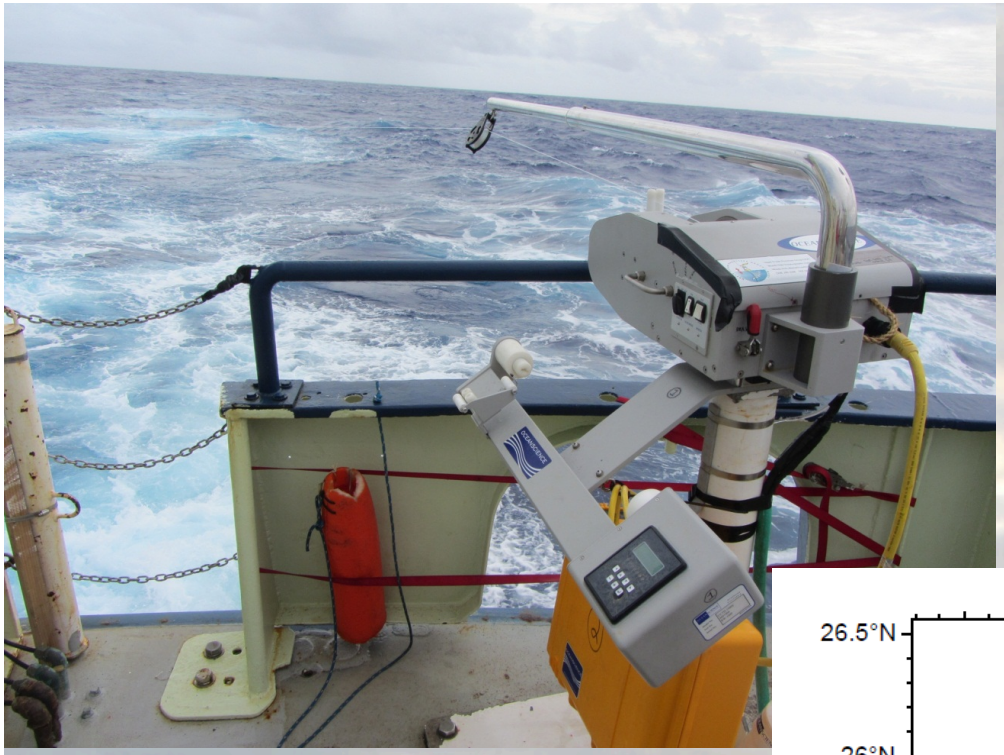
Wave Glider

“Prawler” Mooring (NOAA)

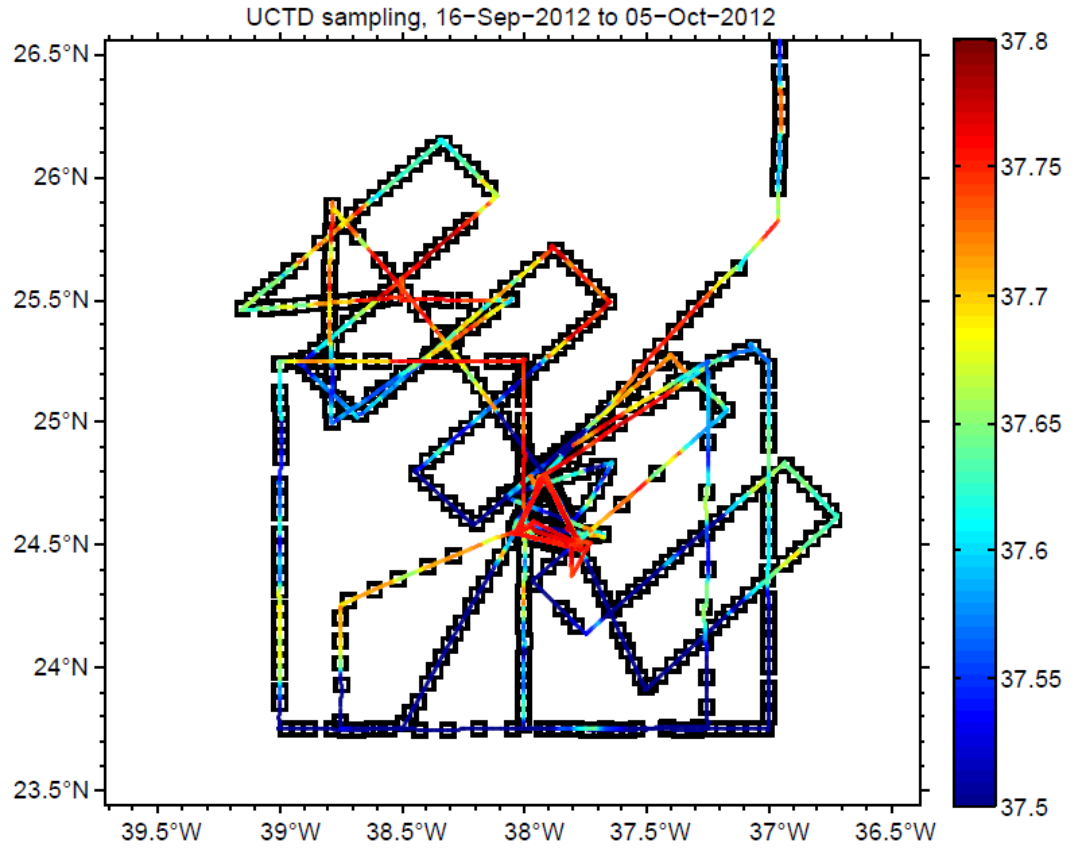
- B. Kessler, J. Shanley, A. Meyer



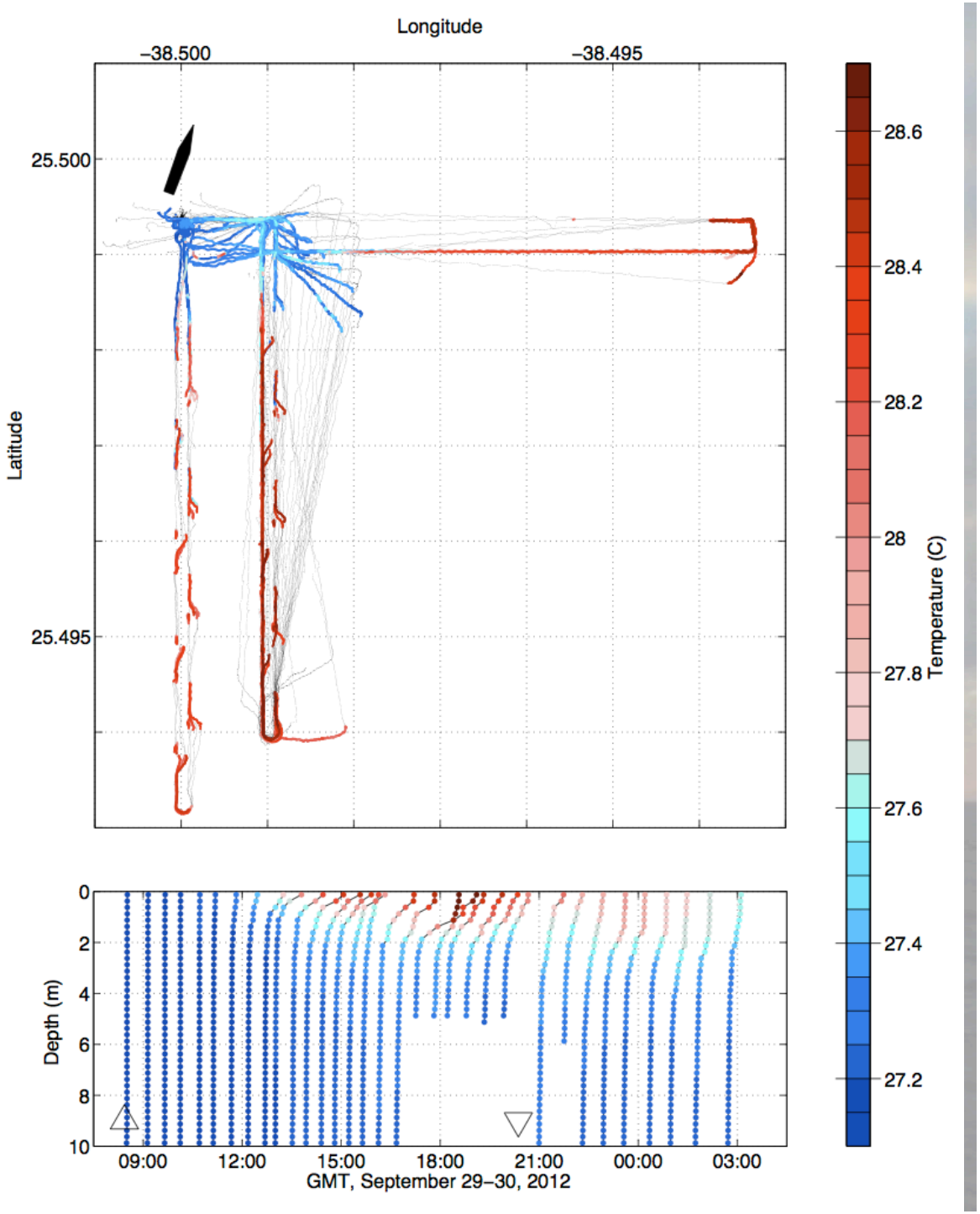




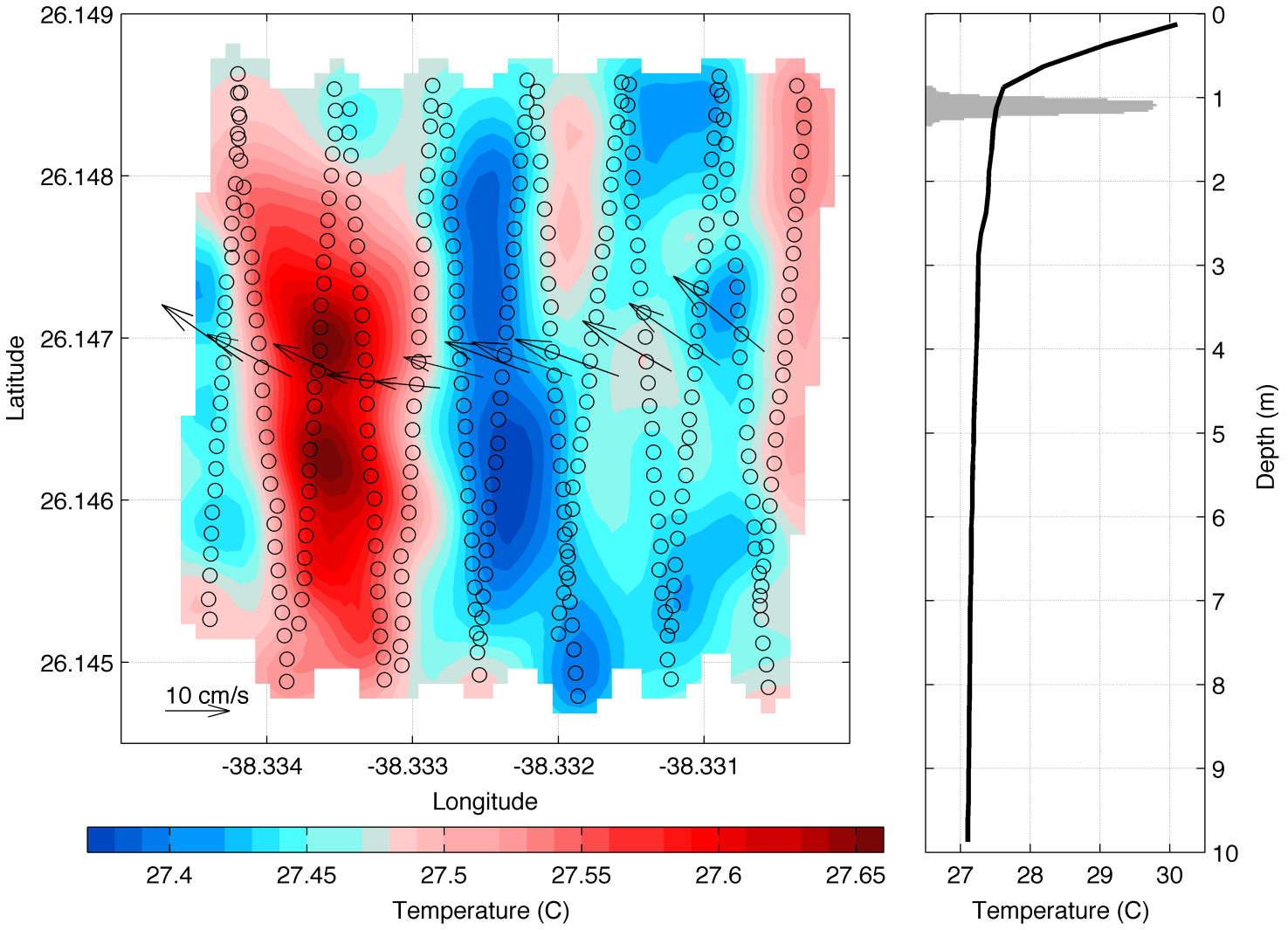
Underway CTD
-T. Farrar et al



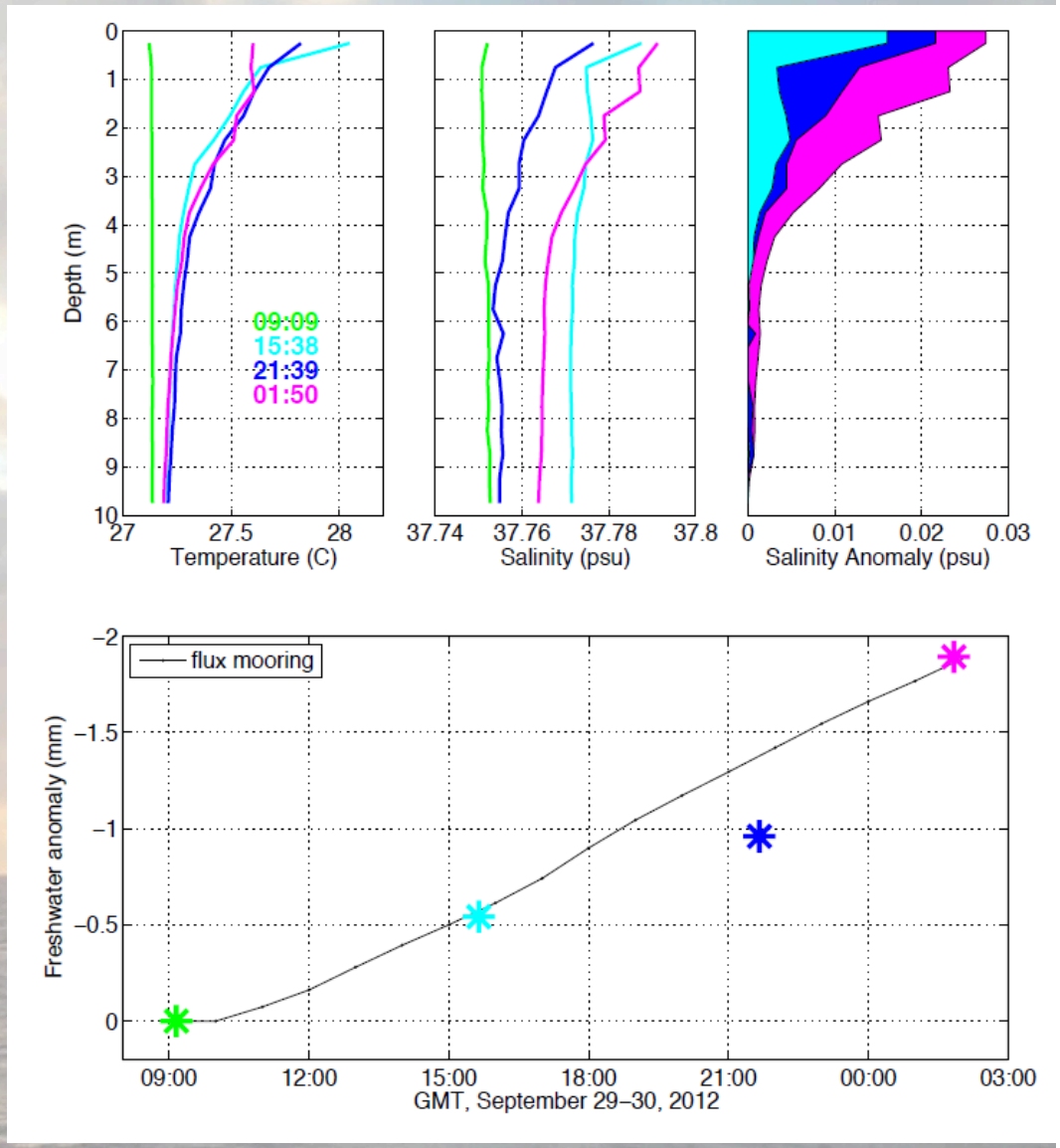
Eco-mapper: Ship disturbs surface stratification with its thrusters.



Internal waves found in stable surface boundary layer



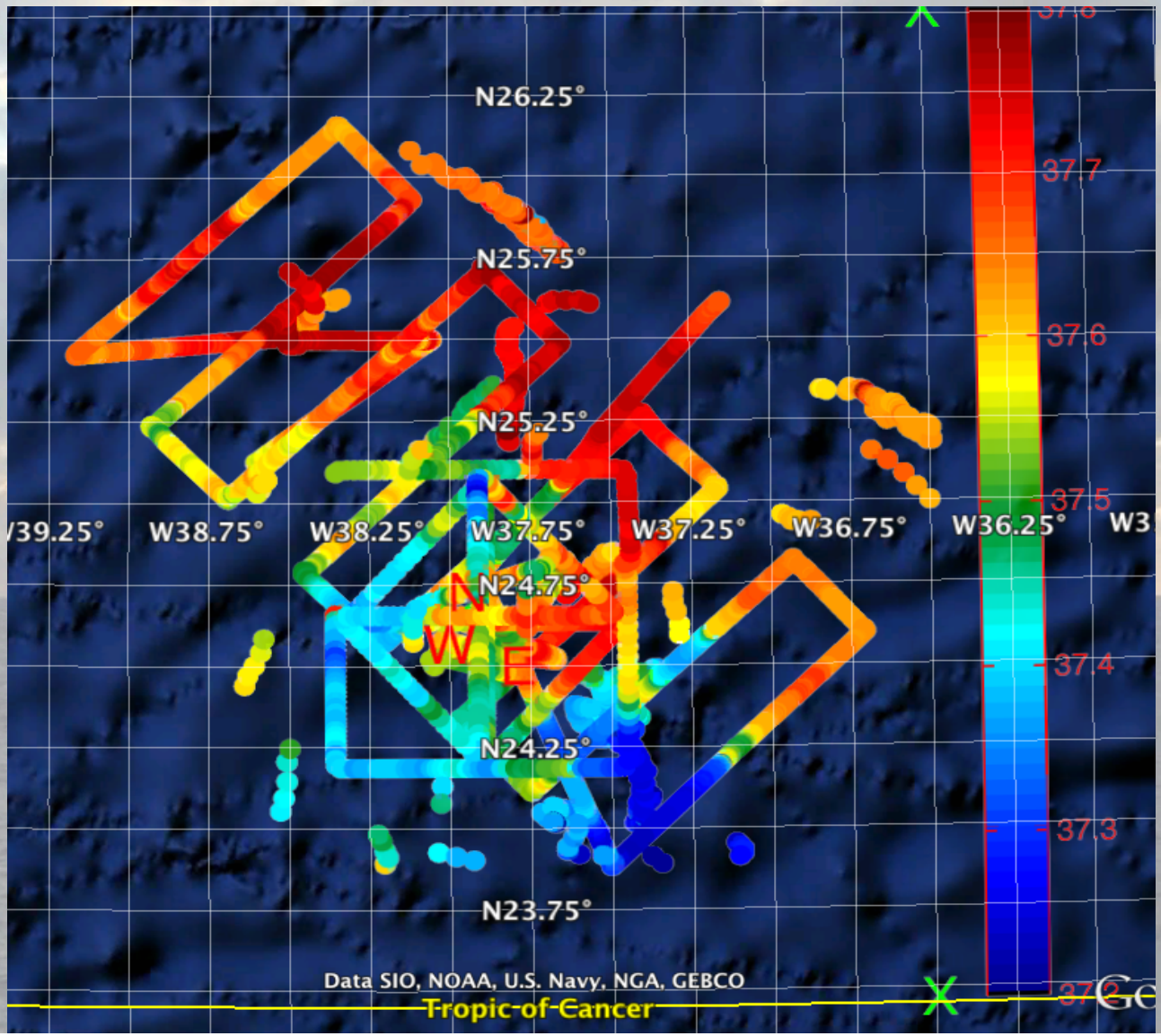
Numerous calm sunny days displayed surficial warming and salinification. This was observed by Salinity Surfboard, Wavegliders, AUVs and TSGs.

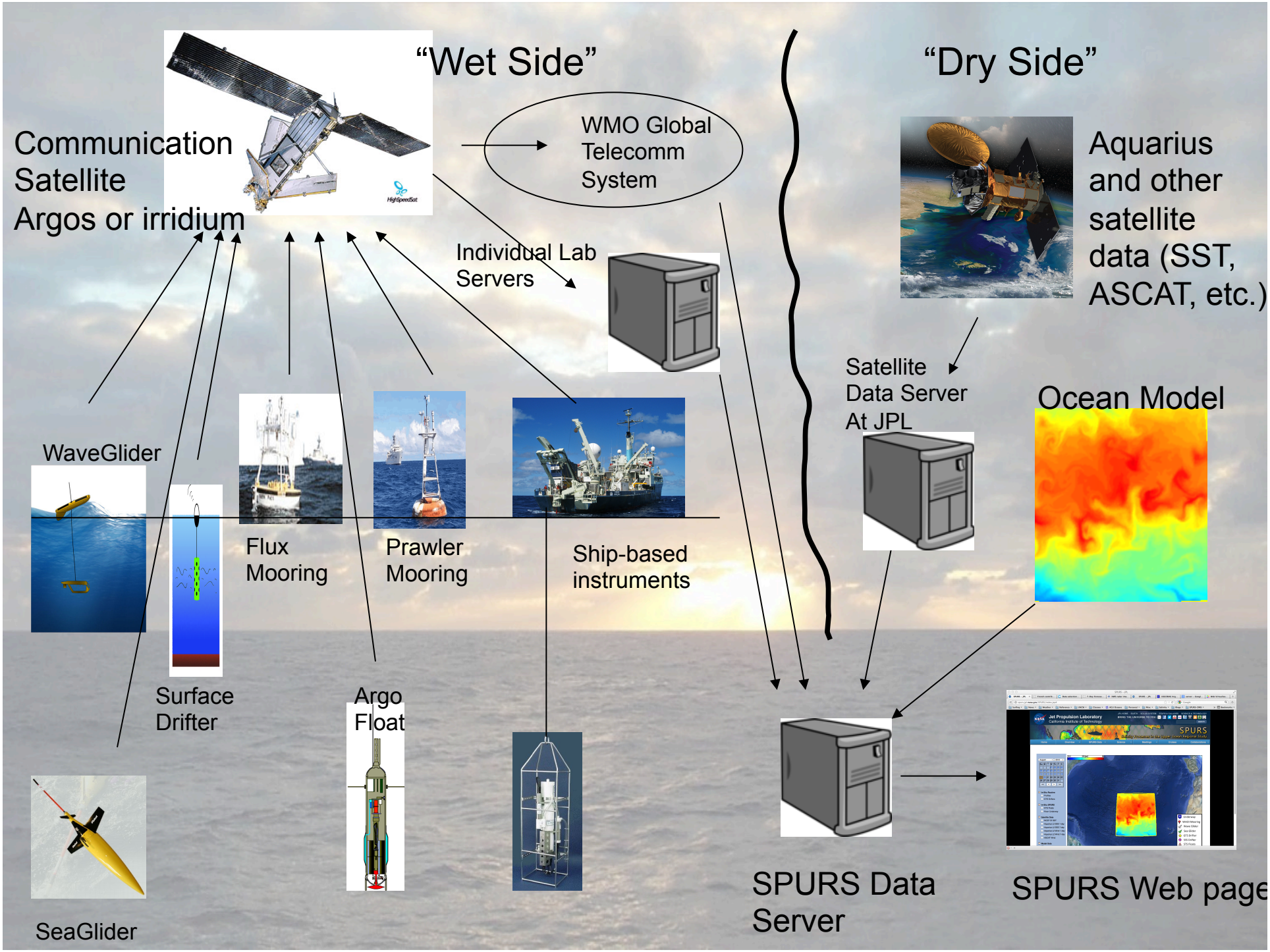


Hodges & Fratantoni, 2013, (Submitted)

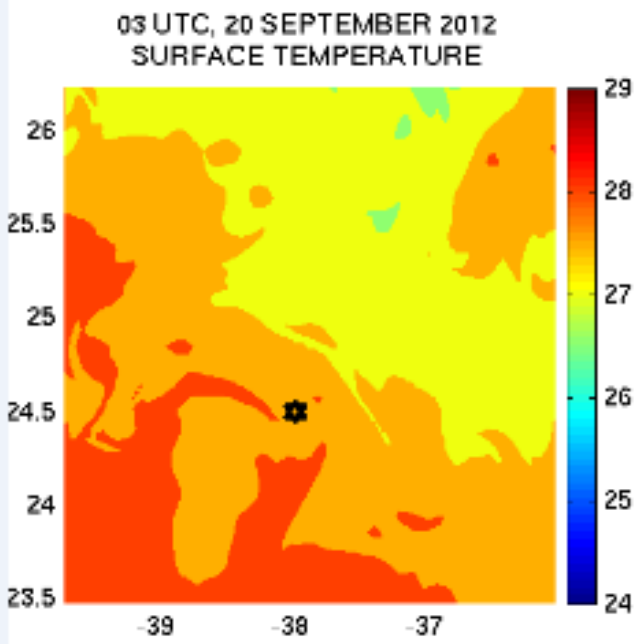
Data visualization & situational awareness

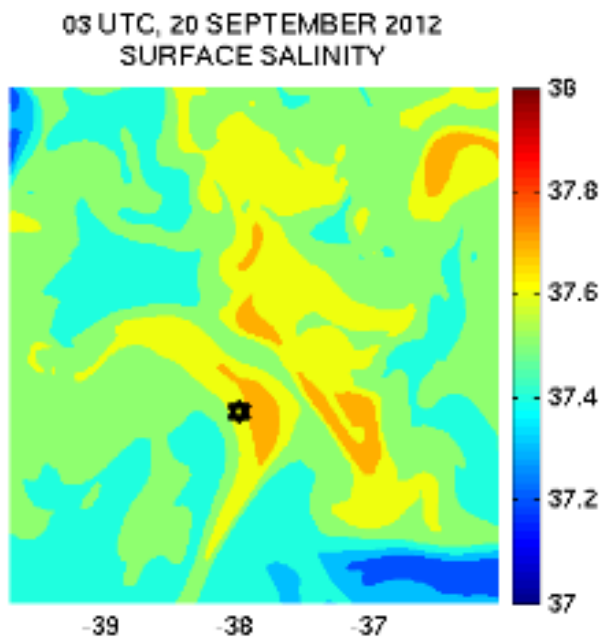
- F. Bingham

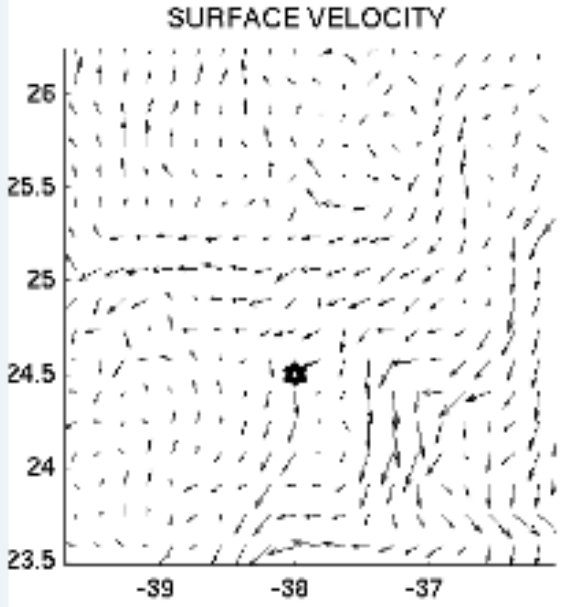


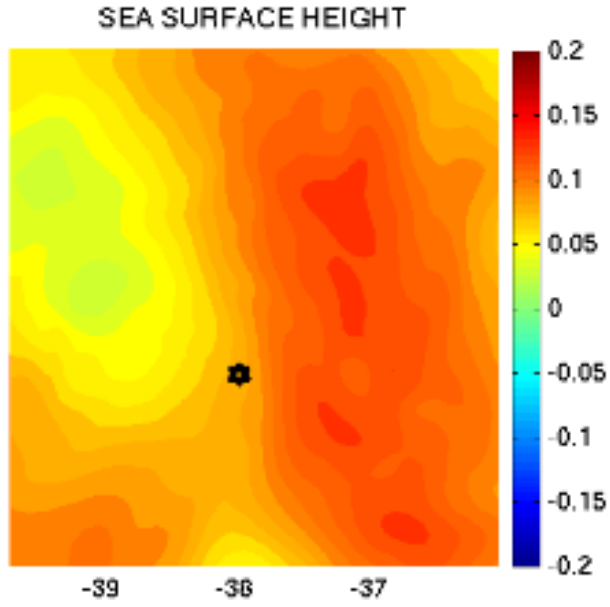

"Wet Side"
"Dry Side"
Communication Satellite Argos or irridium
WMO Global Telecomm System
Individual Lab Servers
Aquarius and other satellite data (SST, ASCAT, etc.)
Satellite Data Server At JPL
Ocean Model
WaveGlider
Flux Mooring
Prawler Mooring
Ship-based instruments
Surface Drifter
Argo Float
SeaGlider
SPURS Data Server
SPURS Web page

From Modeling Group at JPL S. Li, Y. Chao

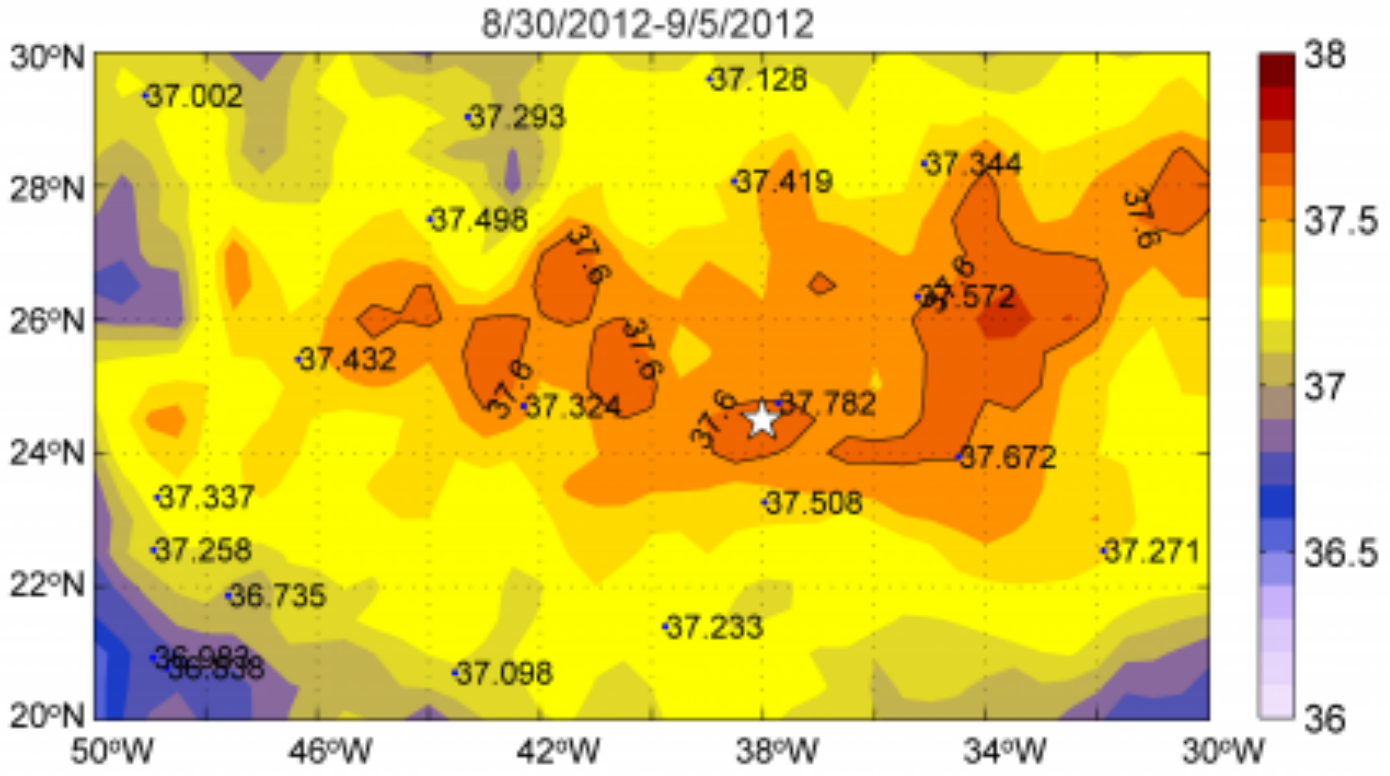








Hi- Res Aquarius Data
N. Maximenko, U. Hawaii



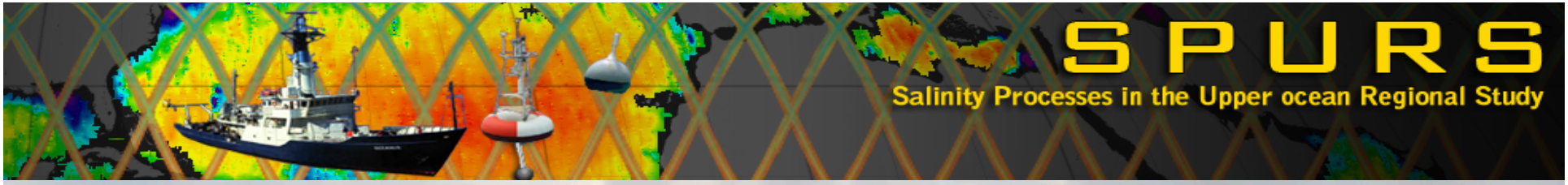
SPURS Outreach

← E. Lindstrom Blog

http://earthobservatory.nasa.gov/blogs/fromthefield/category/spurs/

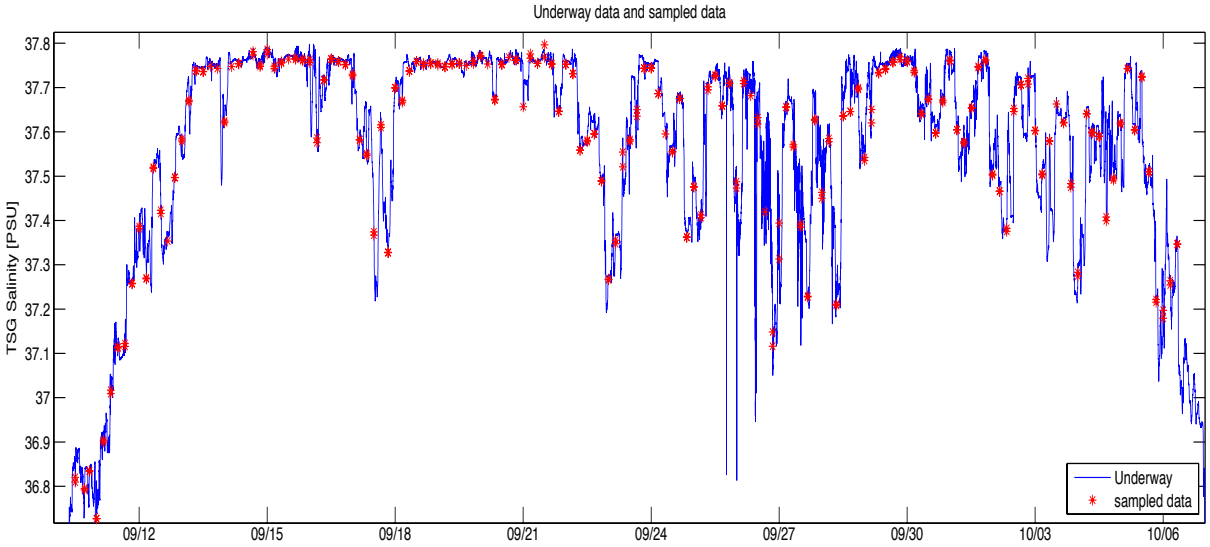
Phone call with

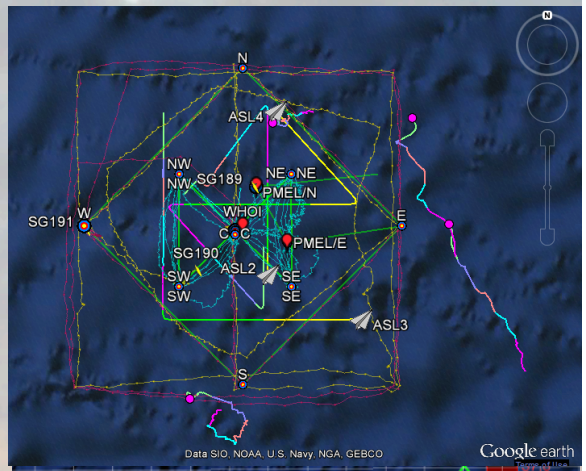
International Space Station

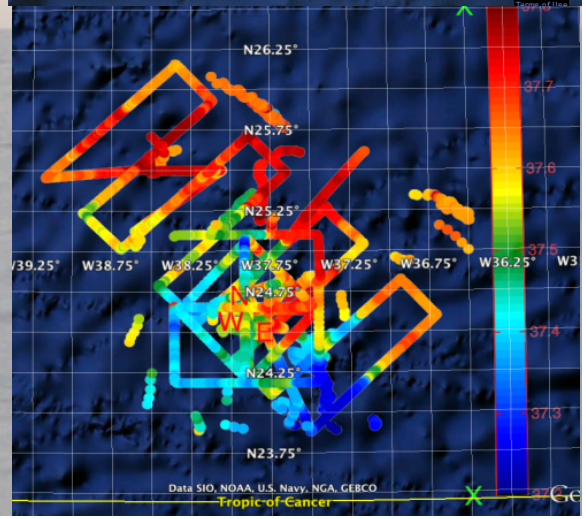


SPURS field program started in N. Atlantic Salinity Maximum with Sept.-Oct. cruise of R/V Knorr

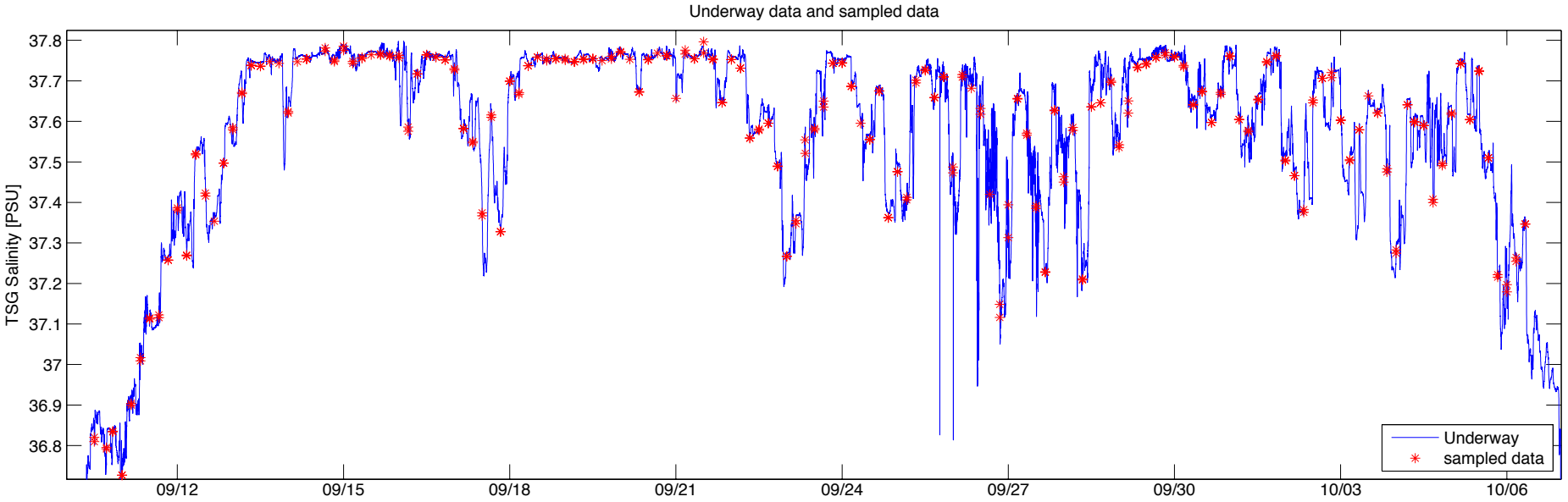
- All assets deployed successfully: moorings, gliders, floats, drifters, Wave Gliders, mixed layer float, etc.
- Salinity max surveyed and found to have record high salinity ~37.8

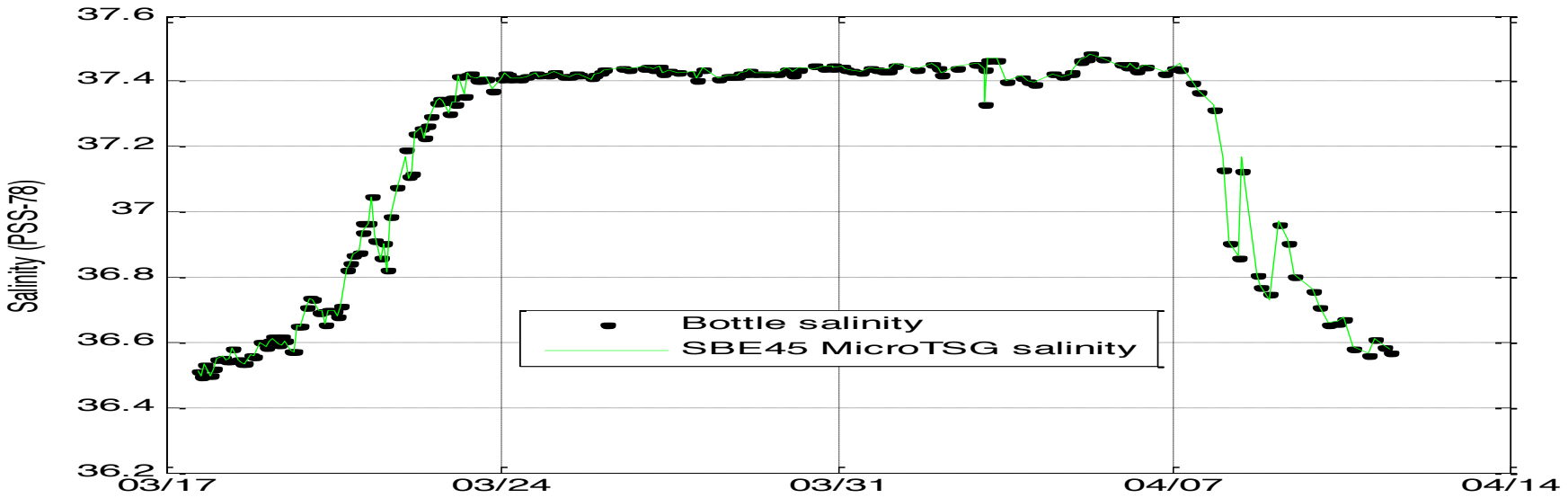






Salinity plateau structure is unexplained.

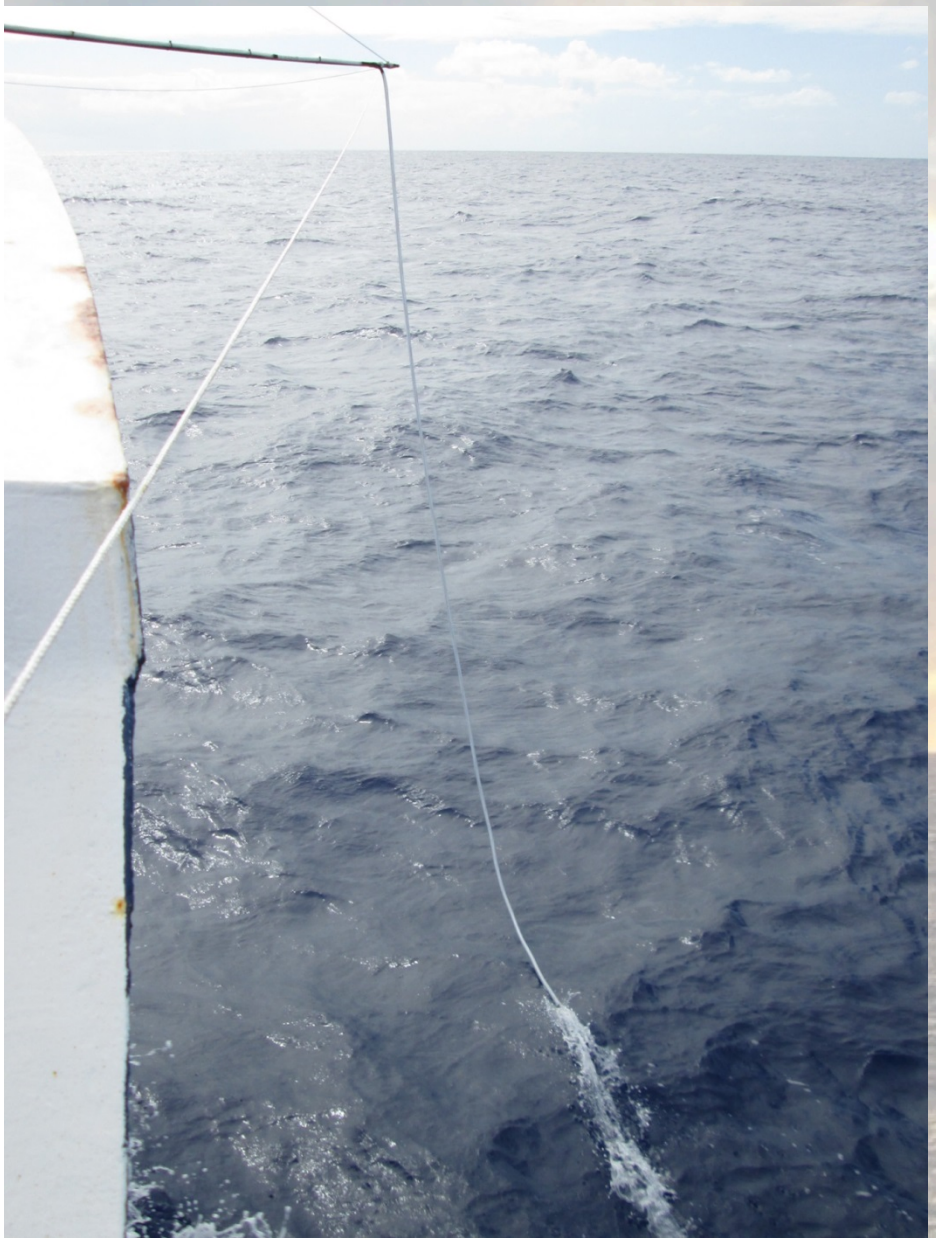


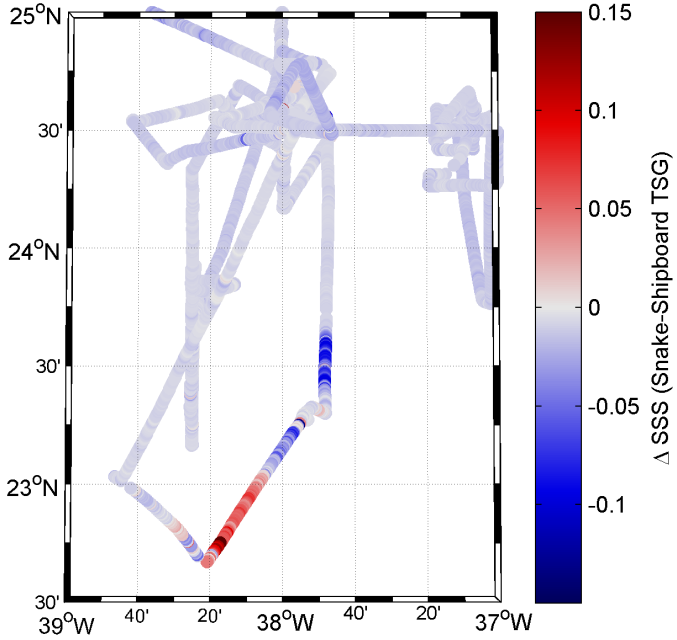


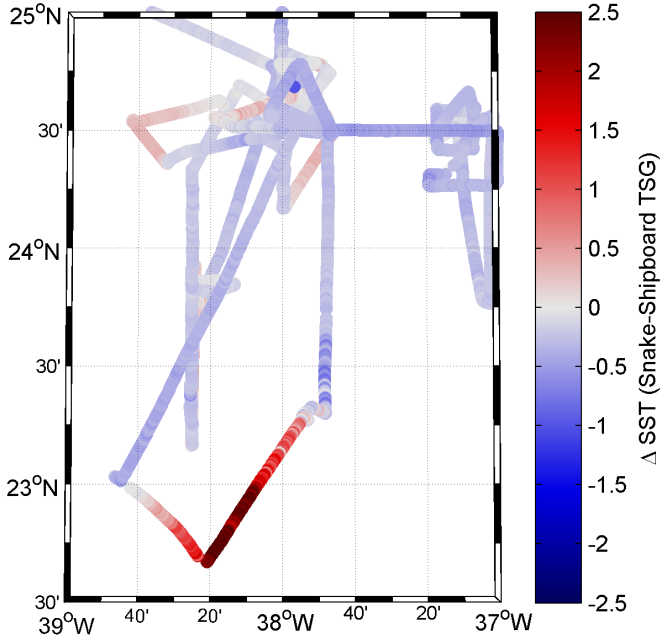
Spring Cruise: Endeavor 522

- **WHOI Mooring Redeploy**
- **Pico Mooring Retrieval and Redeploy & Prawler Replacement**
- **SeaGlider Retrieval and Replacement**
- **WaveGlider Retrieval, Refurbishment and Redeploy**
- **Microstructure Profiling and Gliders**
- **Joint work with ASIP from Sarmiento**
- **SST and SSS “Snakes” for Surficial T and S**
- **CTD Casts (~50)**
- **Underway TSG, ADCP, U-CTD and Met**
- **Mixed Layer Float Retrieval and Replacement**
- **SSS Drifter Deployments (6)**
- **STS-ARGO float retrievals (2)**

“Salinity Snake” to sample the surface waters



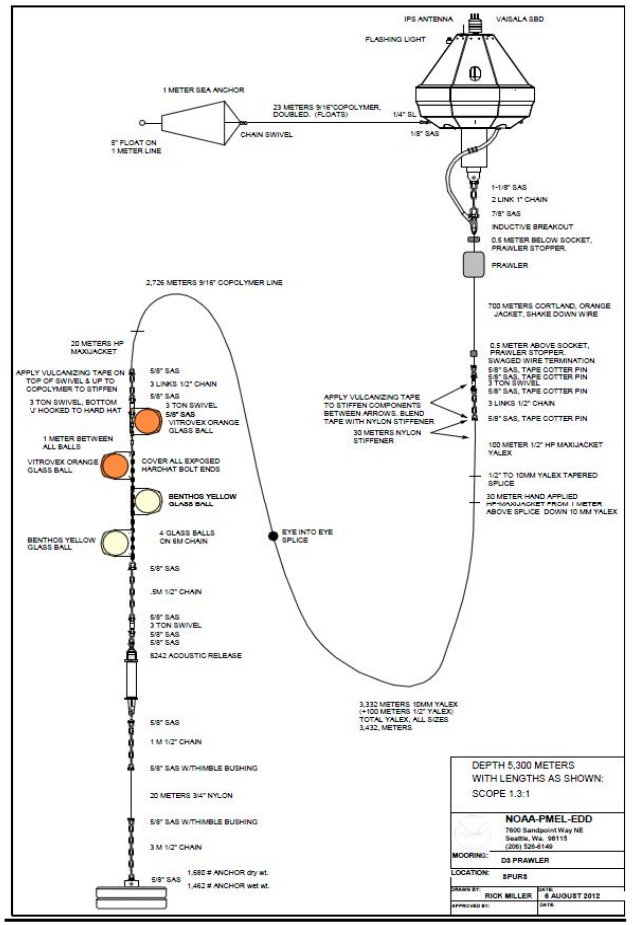


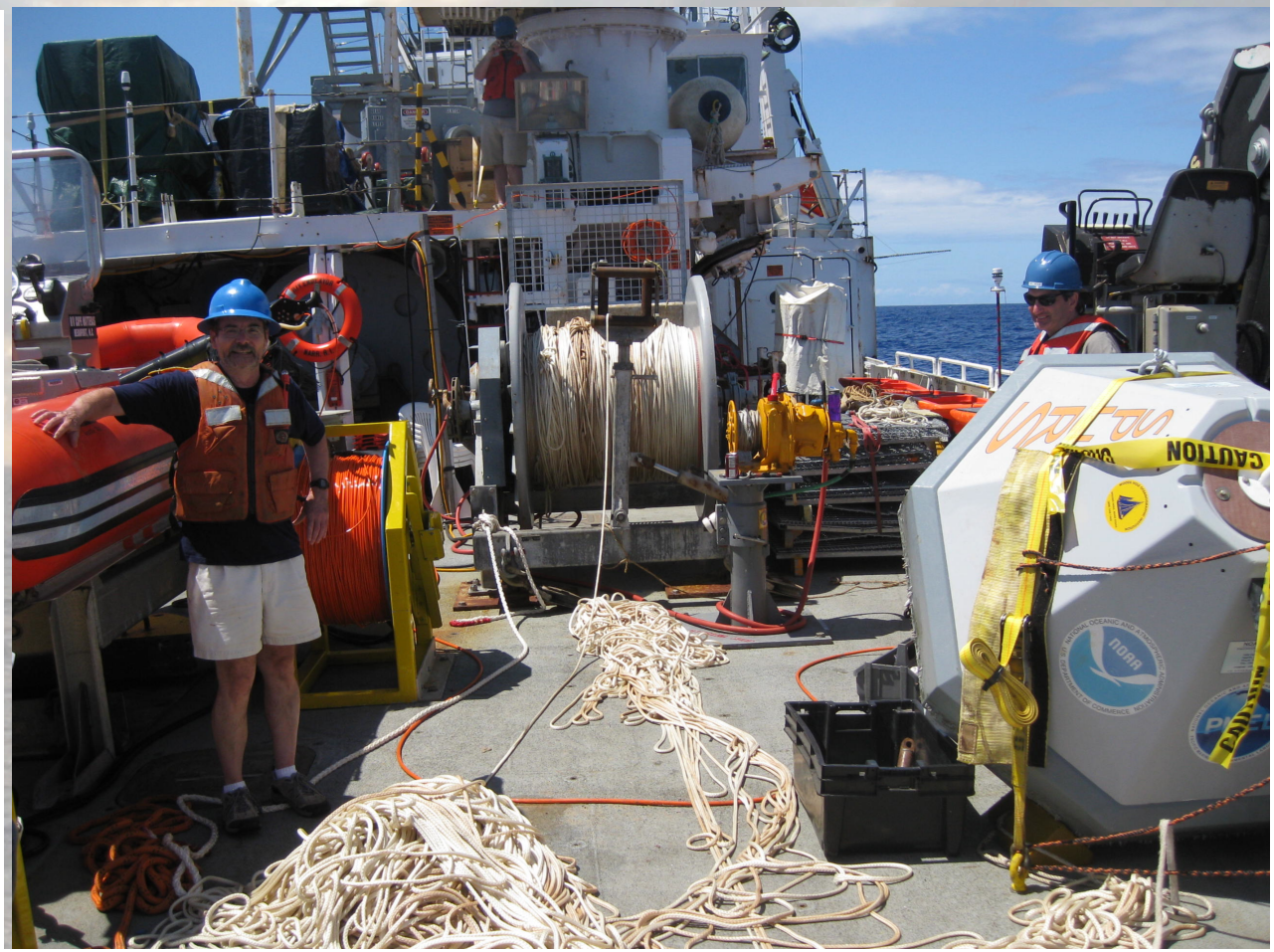


Straying Instruments

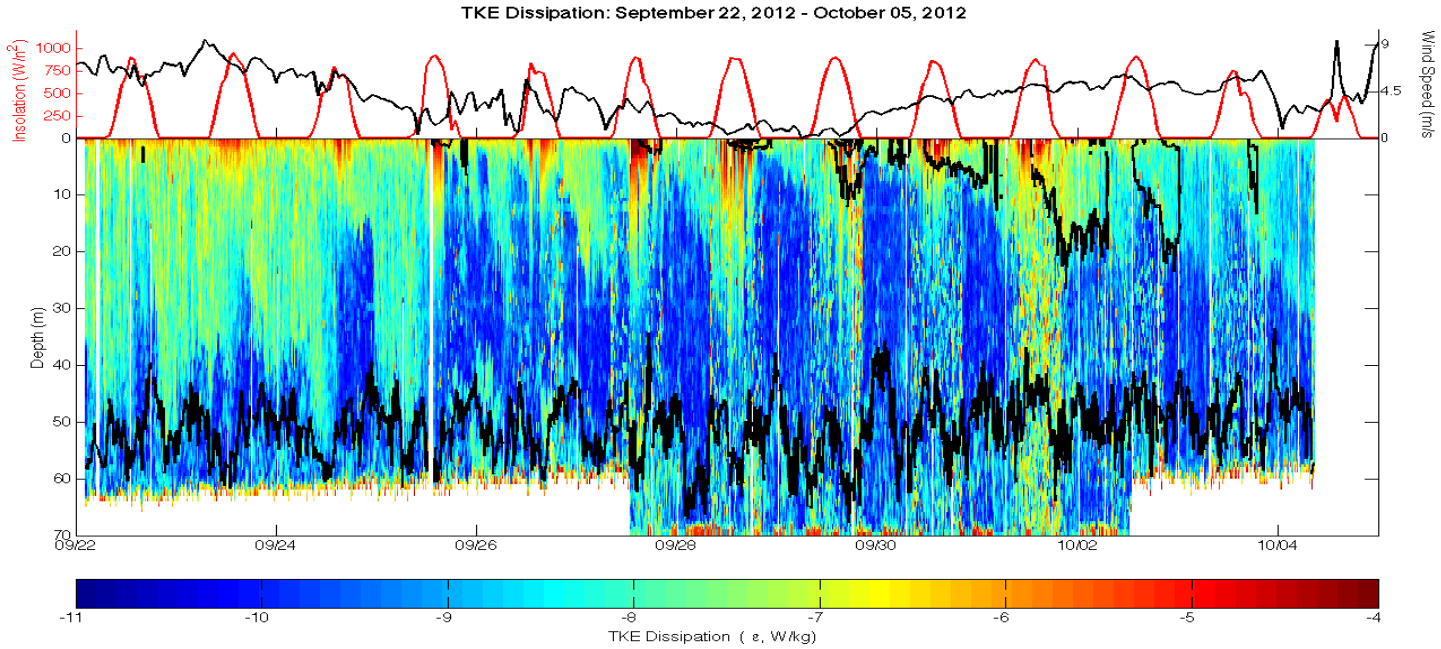
- PICO North mooring line had parted (in two places!) and it had drifted ~100km south
- A Seaglider had a low battery and was drifting at the surface
- Mixed Layer Float was having ballasting issues
- Leakage problem with ARGO STS floats had arisen so we retrieved 2 floats

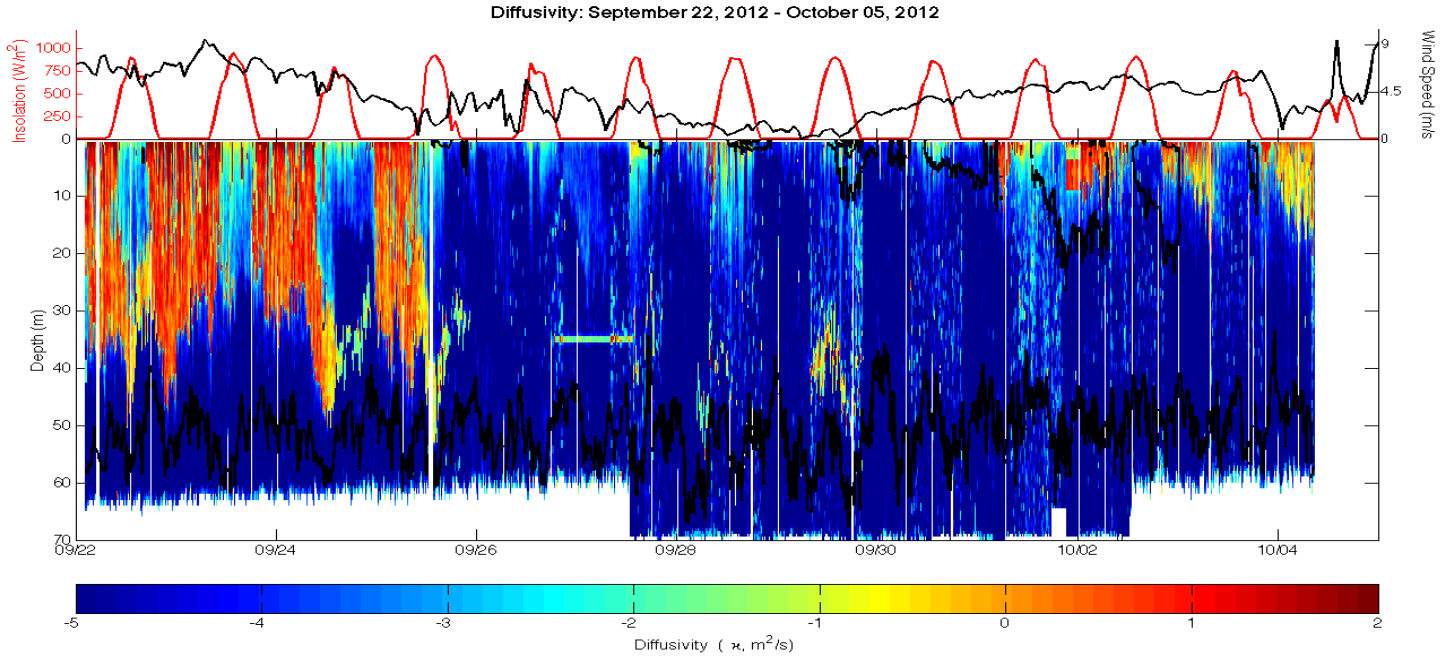
Prawler mooring re-deploy was challenging…..



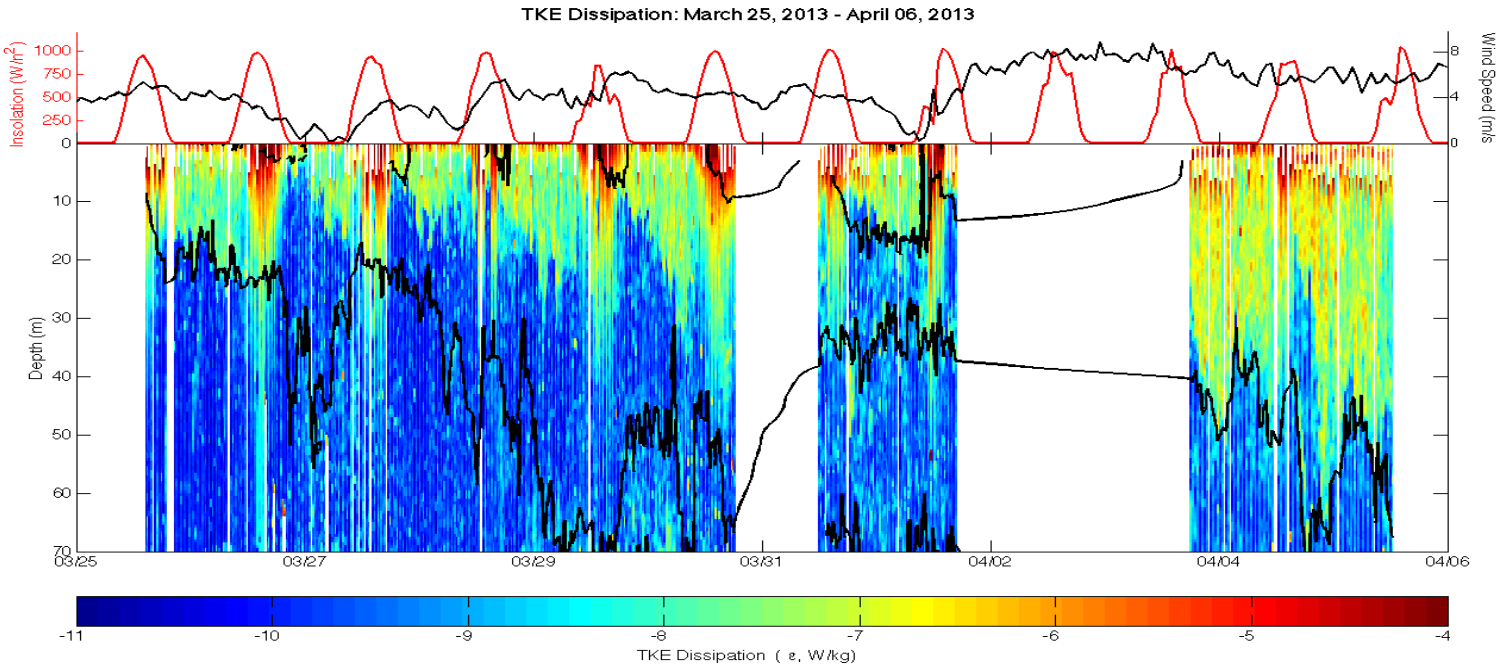


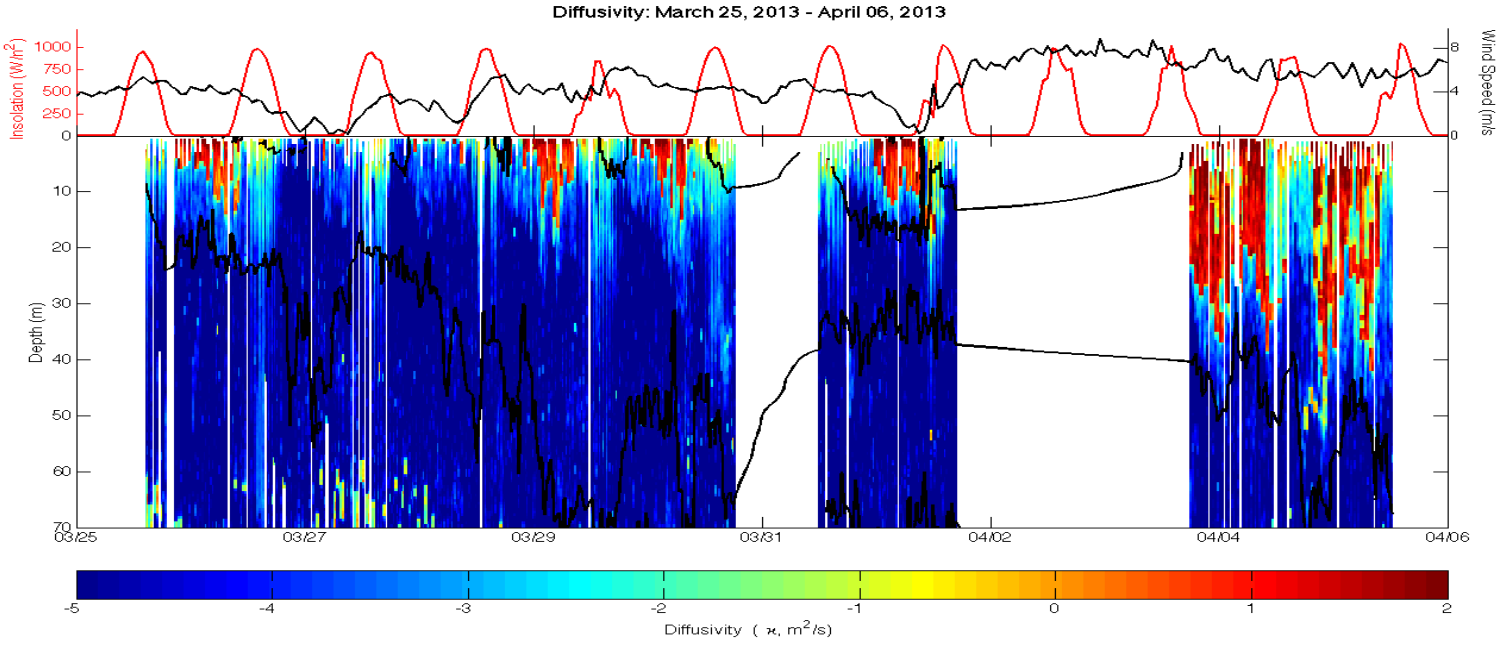
Dissipation enhanced at the surface during diurnal warming





Spring Cruise

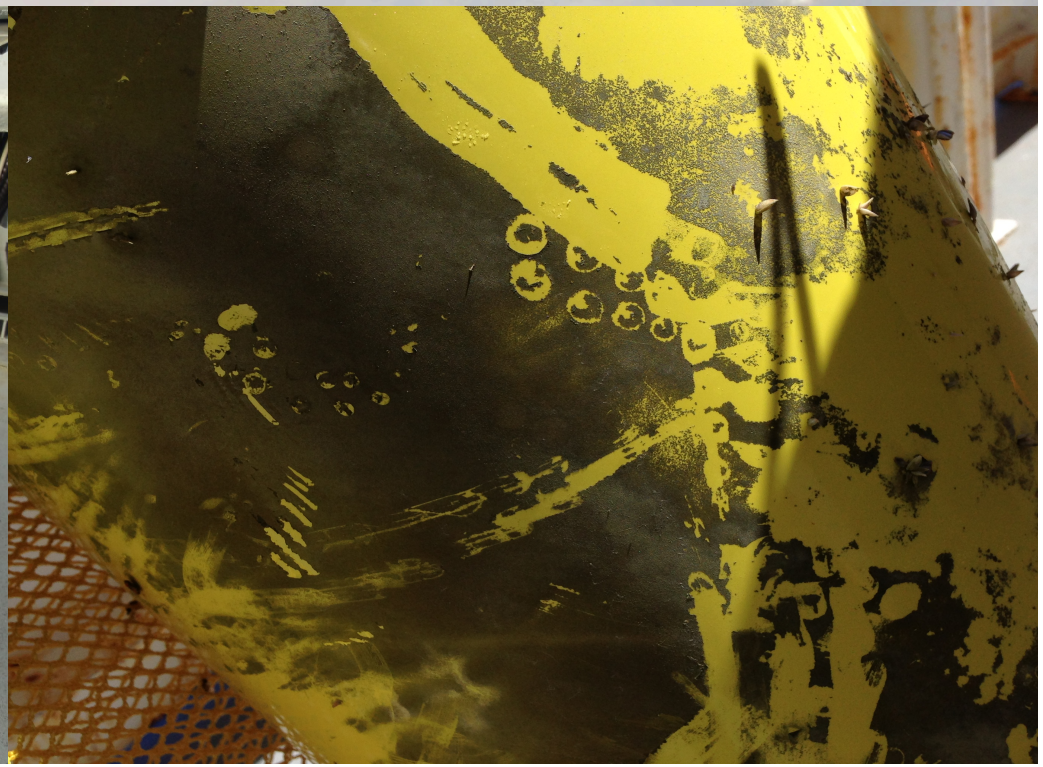




Bio-fouling remains a challenge for long term observations…

Barnacles on WaveGlider

Octopus tracks and ink on SeaGlider



Early Results:

SPURS
Salinity Processes in the Upper ocean Regional Study

- SPURS sampling array was deployed successfully, with all systems working well initially. Spring cruise reset moorings and renewed gliders.
- Survey revealed very high summer SSS, possibly a record ~37.8. Spring cruise had SSS ~ 37.4
- The S-max appeared as a hard-limited high, with the appearance of a distinct well-mixed core, in contrast to the eddy-stirred salinity fronts found nearby. Convection may explain the vertical homogeneity, but what maintains the horizontal homogeneity within the SSS core?
- The high SSS we found reinforces the salinity trends identified by Durack and Wijjfels (2010), supporting idea that a substantial intensification of the water cycle is underway.
- Surficial salinification was observed on calm sunny days, with implications for remote sensing.
- High dissipation was observed in the diurnal warm layer, possible due to shear and double diffusion.
- Mixing in the thermocline was characterized by modest salt fingering and turbulence.

SPURS next steps:

- Fall Recovery Cruise, Endeavor, Sept./ Oct. Azores to Narragansett, D. Fratantoni - Chief Scientist
- SPURS Analysis and Planning Proposals due at NASA Dec. 2, 2013
- Ocean Sciences Meeting Session and SPURS meeting (Feb. 2014)