# Μέθοδοι παρατήρησης και πρόγνωσης στη Φυσική Ωκεανογραφία

## 2. Observing and Forecasting methods in Physical Oceanography

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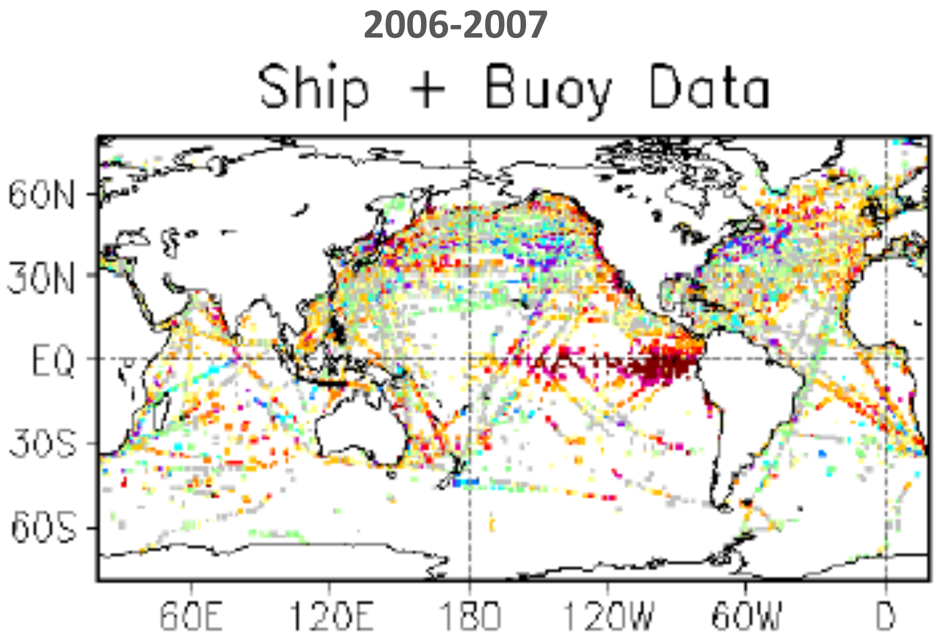
**Dept. of Physics, University of Athens**

a. Basic observational platforms

b. Oceanographic instrumentation
- Hydrography
- Dynamic parameters

c. Ocean Modeling




**DEFINING THE PROBLEM:**

- Observations of the oceanic properties are costly and difficult to acquire.
- Spatio-temporal coverage is the main problem in oceanographic observations (compared to other forms of error/uncertainty)

In order to overcome the problem, oceanographic observations aim at:

- “Cheaper” observing methods (get as much data as possible covering large spatial and temporal scales)
- Multi-instruments/multi-platforms
- Emphasis on the observing methodologies/strategies
- Combinations

## Investigating a scientific question in the ocean:

Platforms (how do we observe the ocean?)

Instruments (what do we observe in the ocean?)

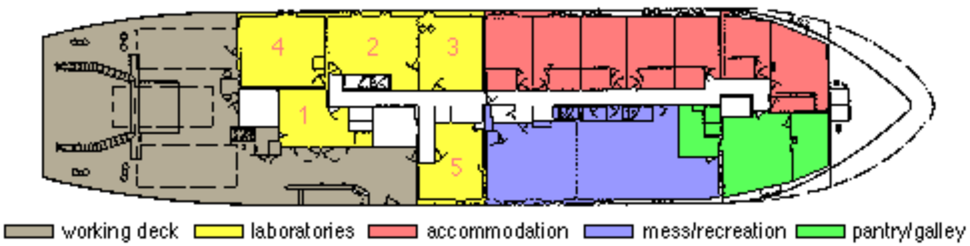
| | Platforms/instruments |
|---|---|
| **Platforms** | •Research vessels (R/V)<br>•Ships of opportunity (SOOP)<br>•Moorings<br>•Lagrangian instruments<br>•Satellites |
| **Hydrography** | •CTD<br>•Nansen και Niskin bottles<br>•Thermosalinograph<br>• Satelite SST (and SSS) |
| **Dynamical observations** | •Current meters<br>• Pressure gauges - Wave measurements<br>•Lagrangian instruments<br>•Altimetry |

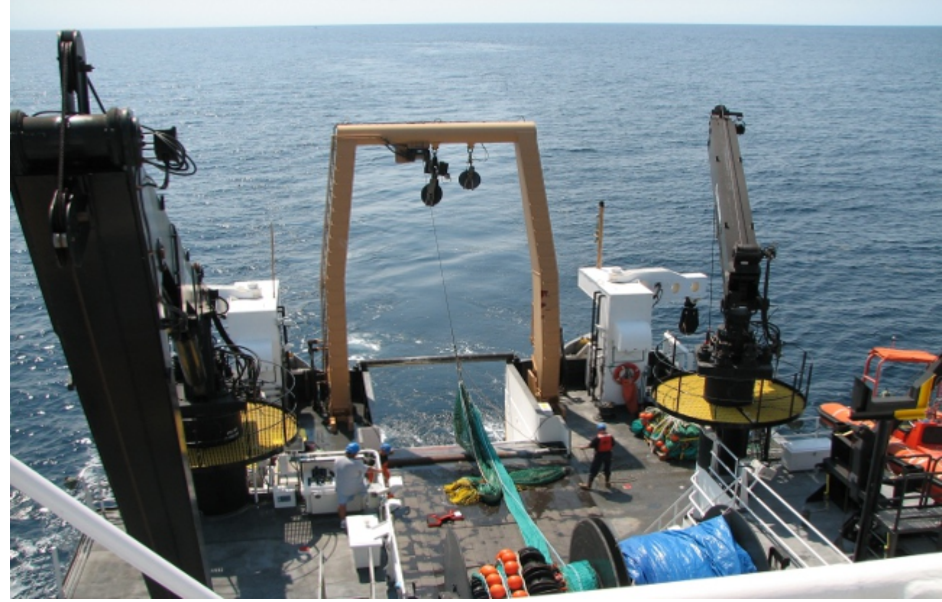
University-National Oceanographic Laboratory System

# Research vessels (R/V)



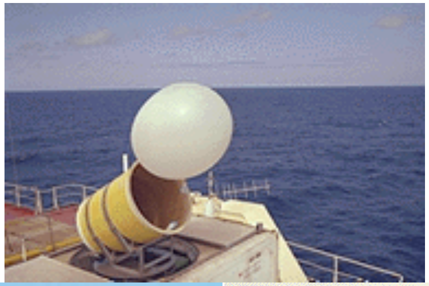
# Research vessels (R/V)

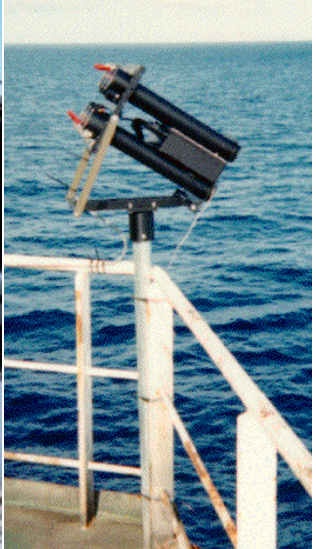


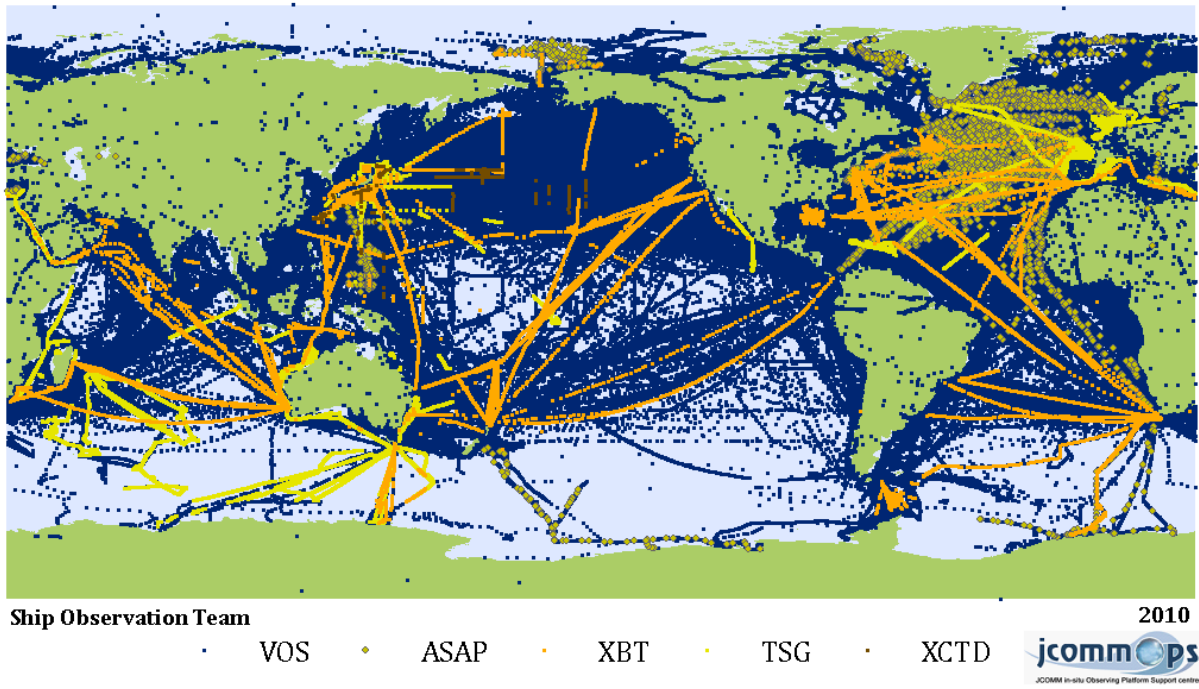



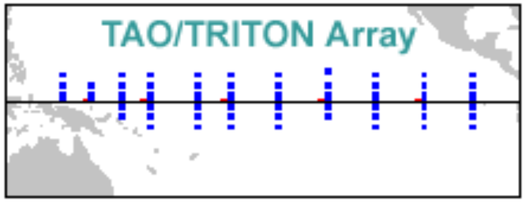
SOOP
Ship-of-Opportunity Programme

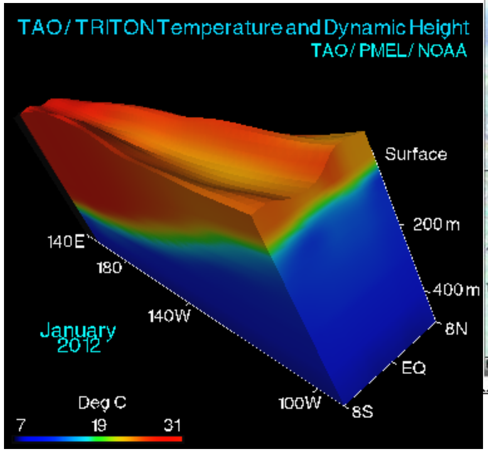
# Ships of opportunity (SOOPs)



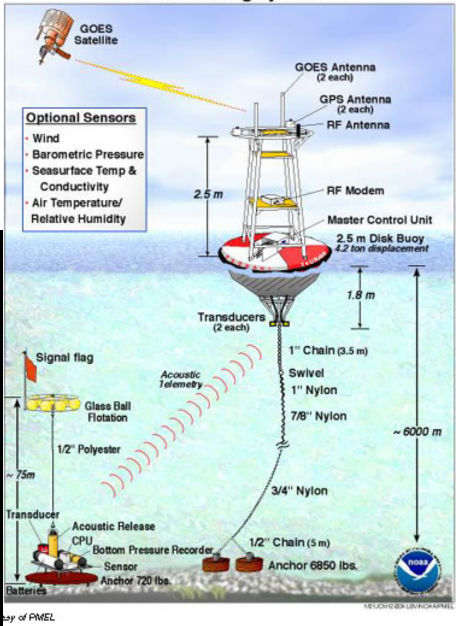




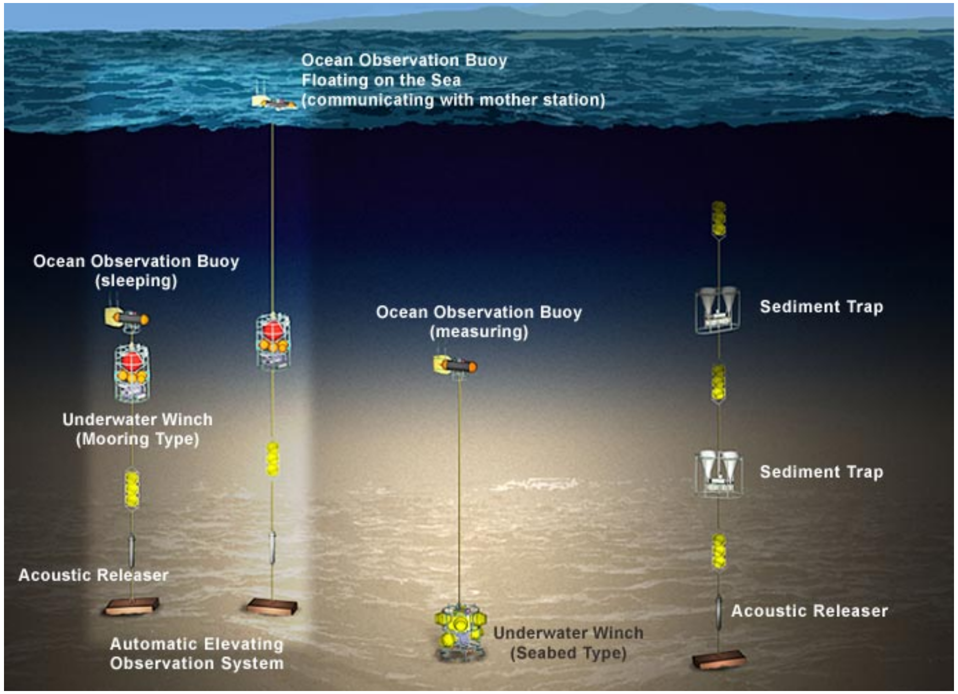


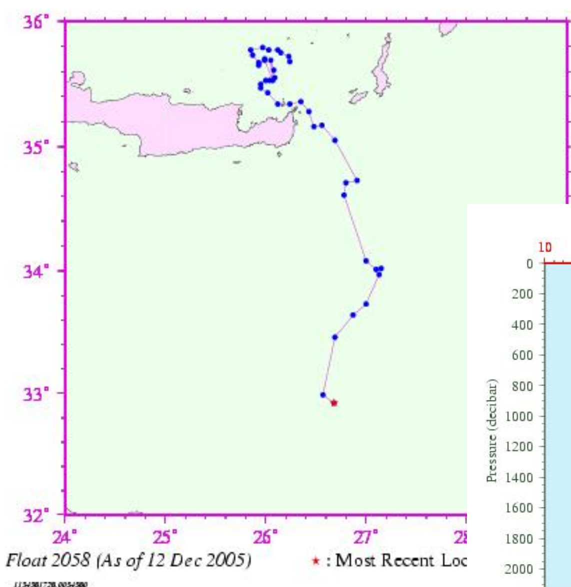

DART Mooring System

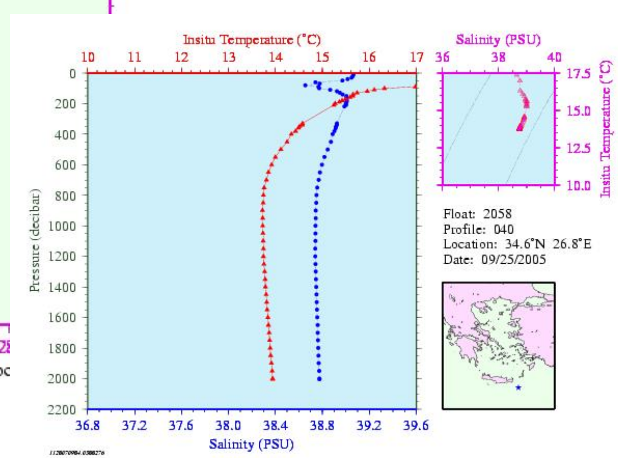



# Moorings (the Eulerian approach)

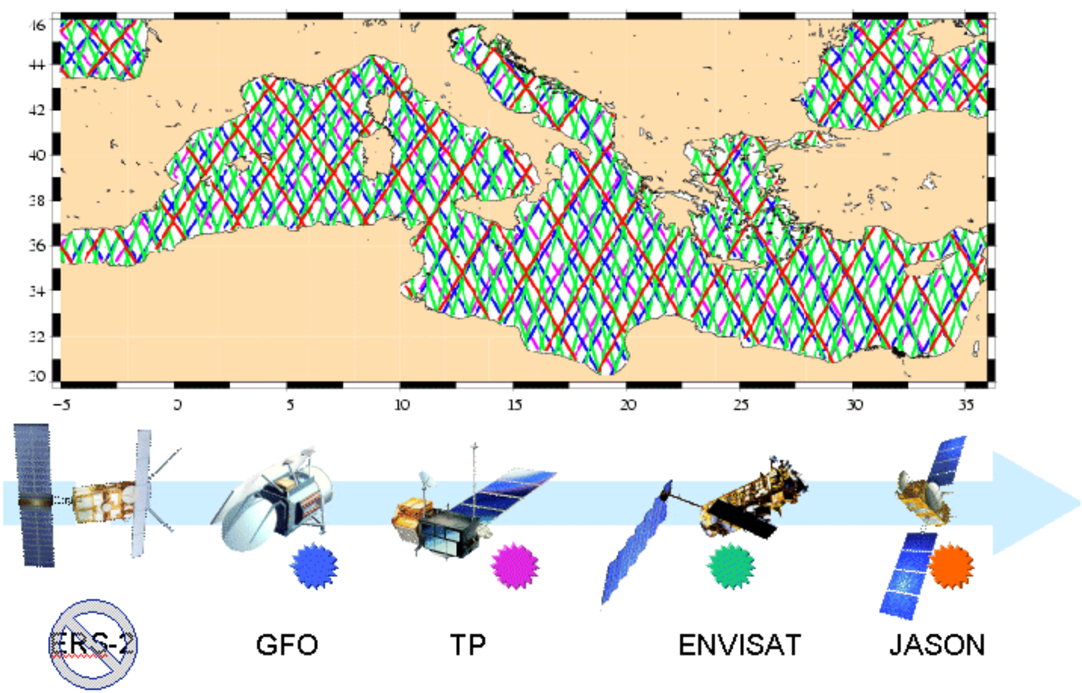


# Drifting instruments
# (the Lagrangian approach)




# Remote Sensing (Satellites)




SST

Altimetry

Ocean color

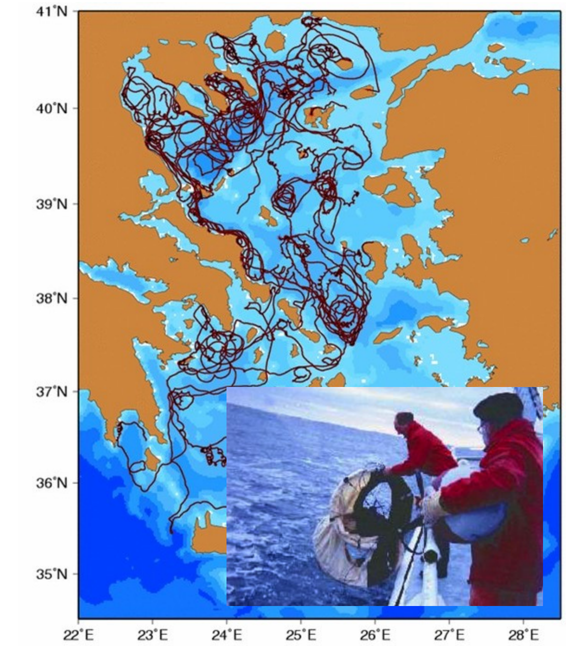
Wind

Rain

SSS

Turbidity

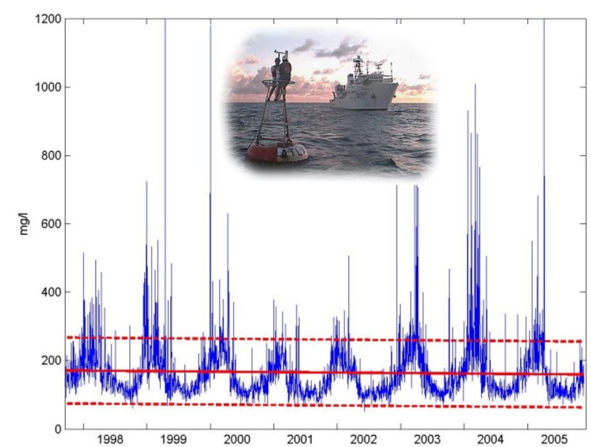
| Platforms | •R/Vs<br>•SOOPs<br>•Moorings<br>•Lagrangian<br>• Satellite |
| --- | --- |




How can we define the proper platform(s) for our experiment:

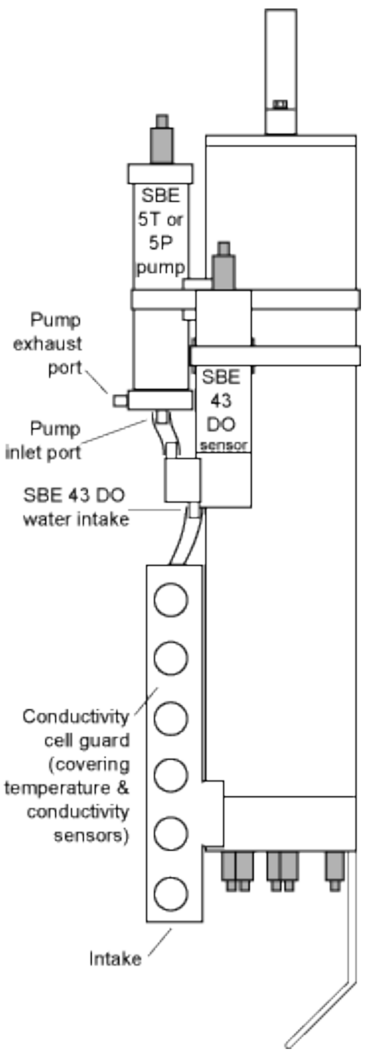
- Scientific question
  - Area/process of interest
    - Spatial/temporal coverage required
      - Resources/Expertise
        - Other requirements

**e.g. Lagrangian vs Eulerian**

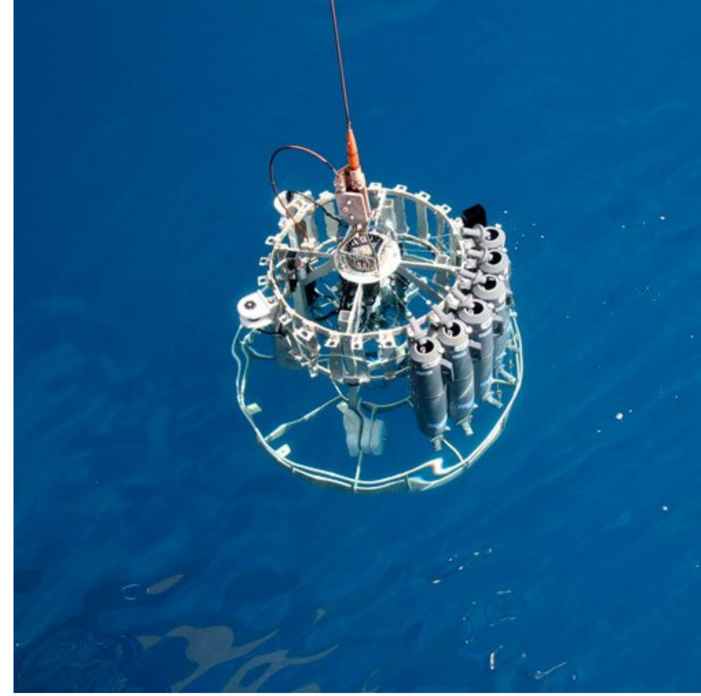


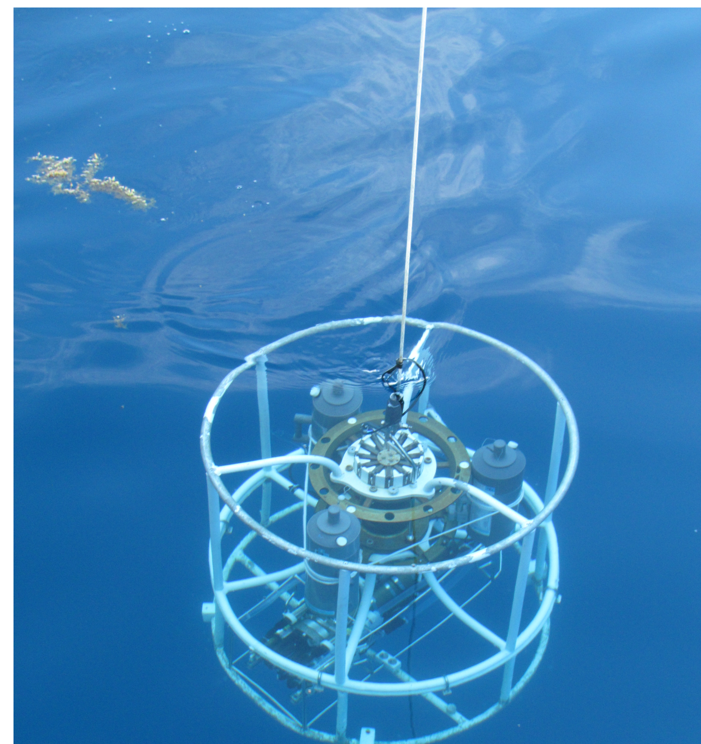
# I. HYDROGRAPHY

## *C*onductivity, *T*emperature and *D*epth

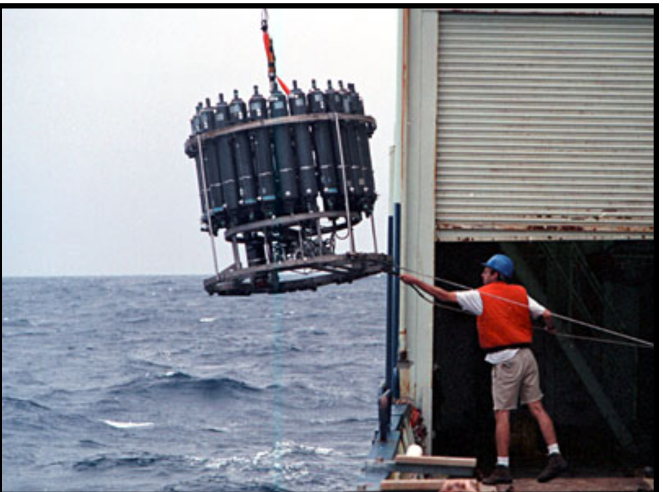


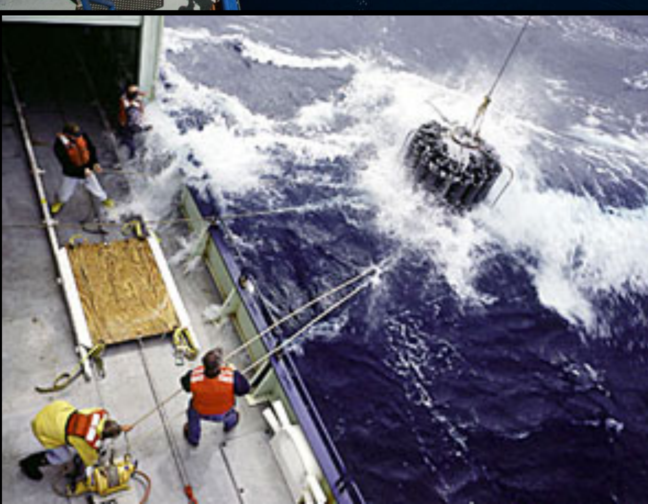




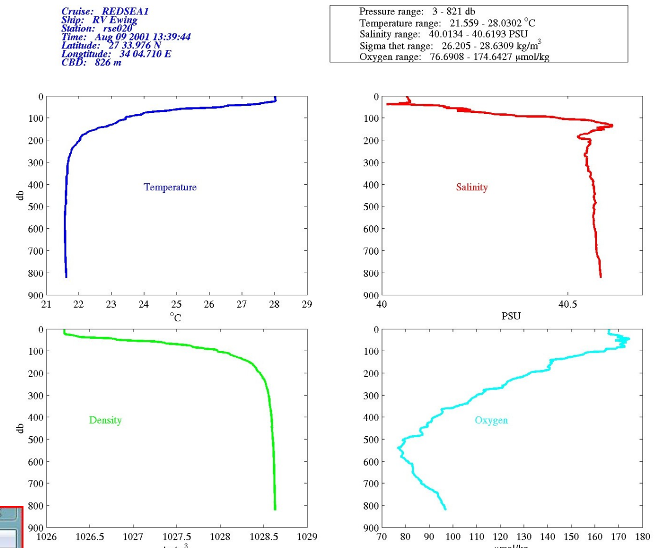


# Conductivity, Temperature and Depth

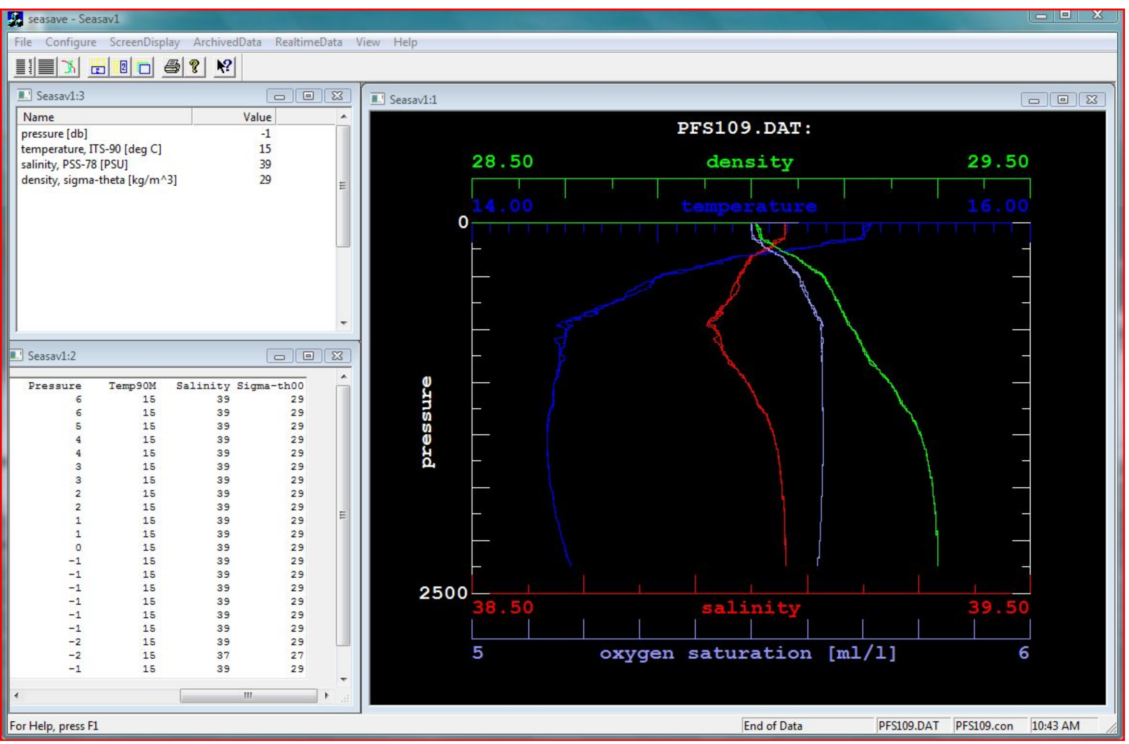


# Sampling/Processing

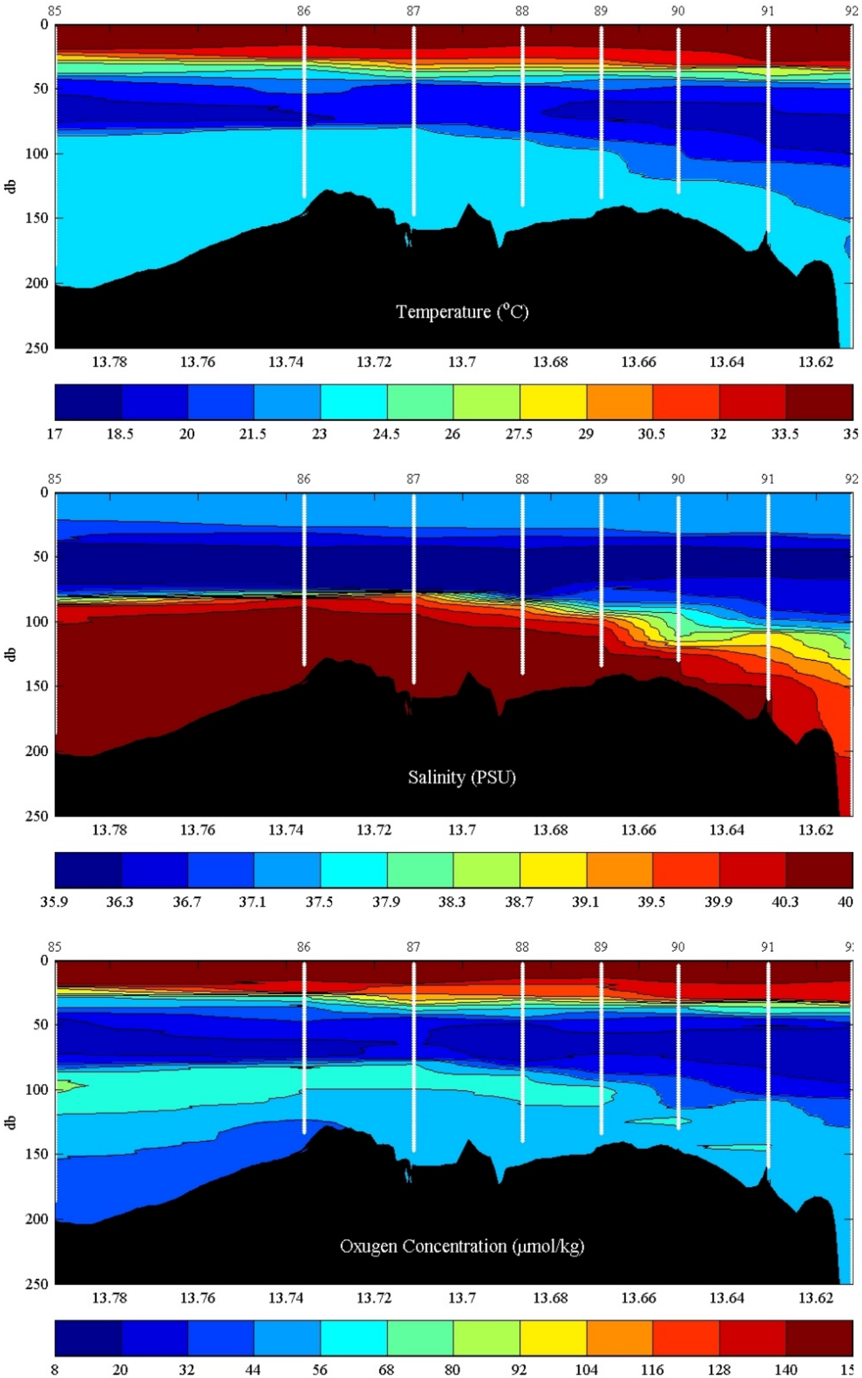


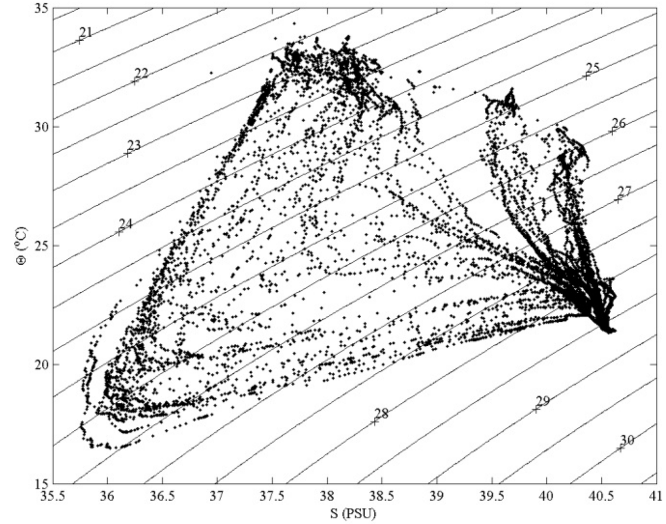

Conductivity, *T*emperature and *D*epth



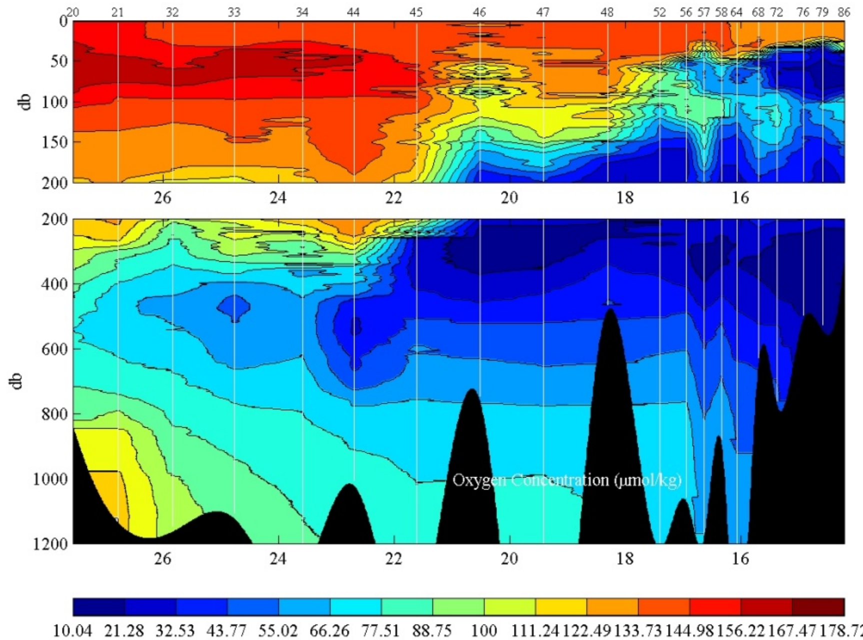

- Check/remove upcast
- Remove spikes
- Subsample
- Smooth
- Archive Data/Headers/Bottles
- Plot

# Conductivity, Temperature and Depth




## Analyzing



# Nansen and Niskin

## Bottles

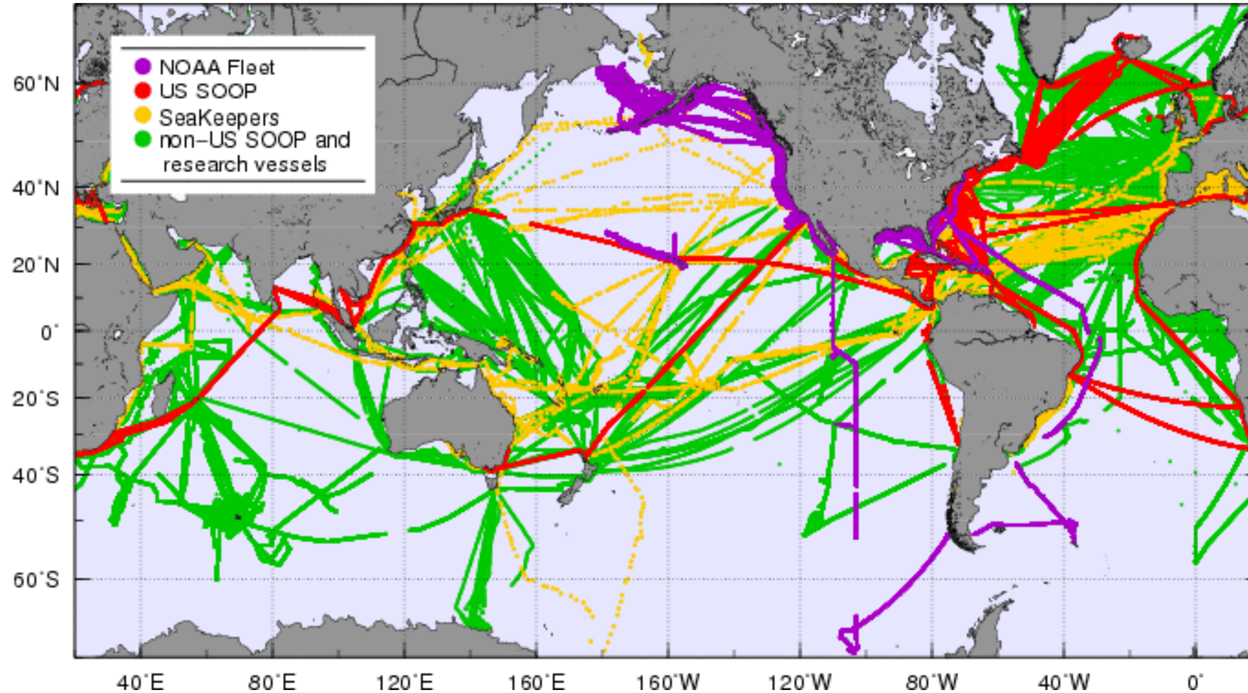
Calibration (T, S, $O_2$)

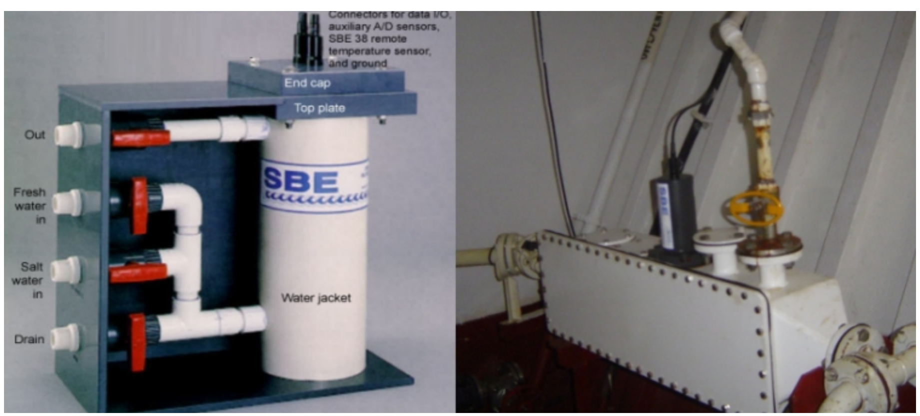
**Rosette**

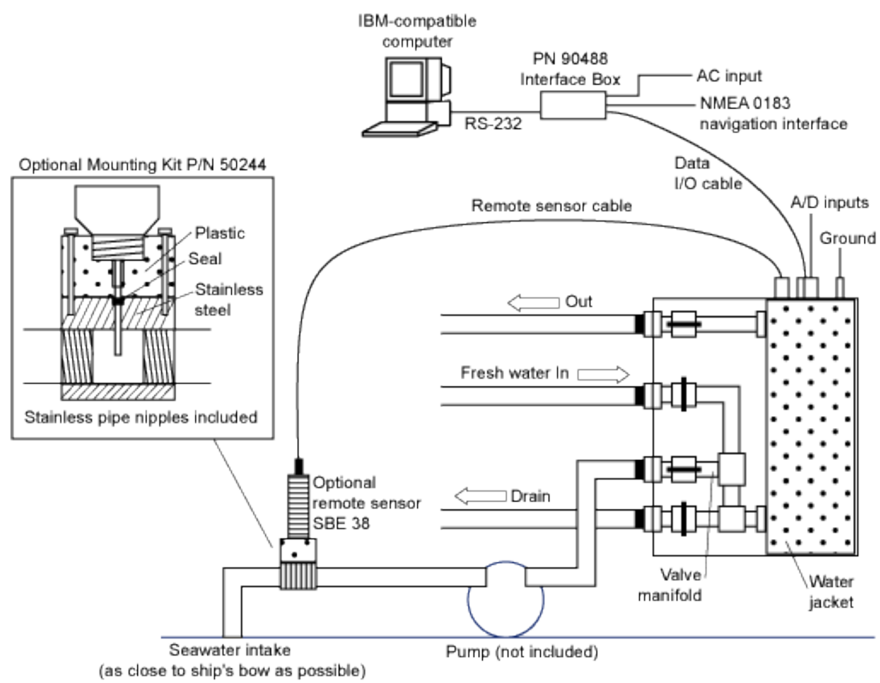

TSG observations since 2001

# Thermosalinograph

# (TSG)

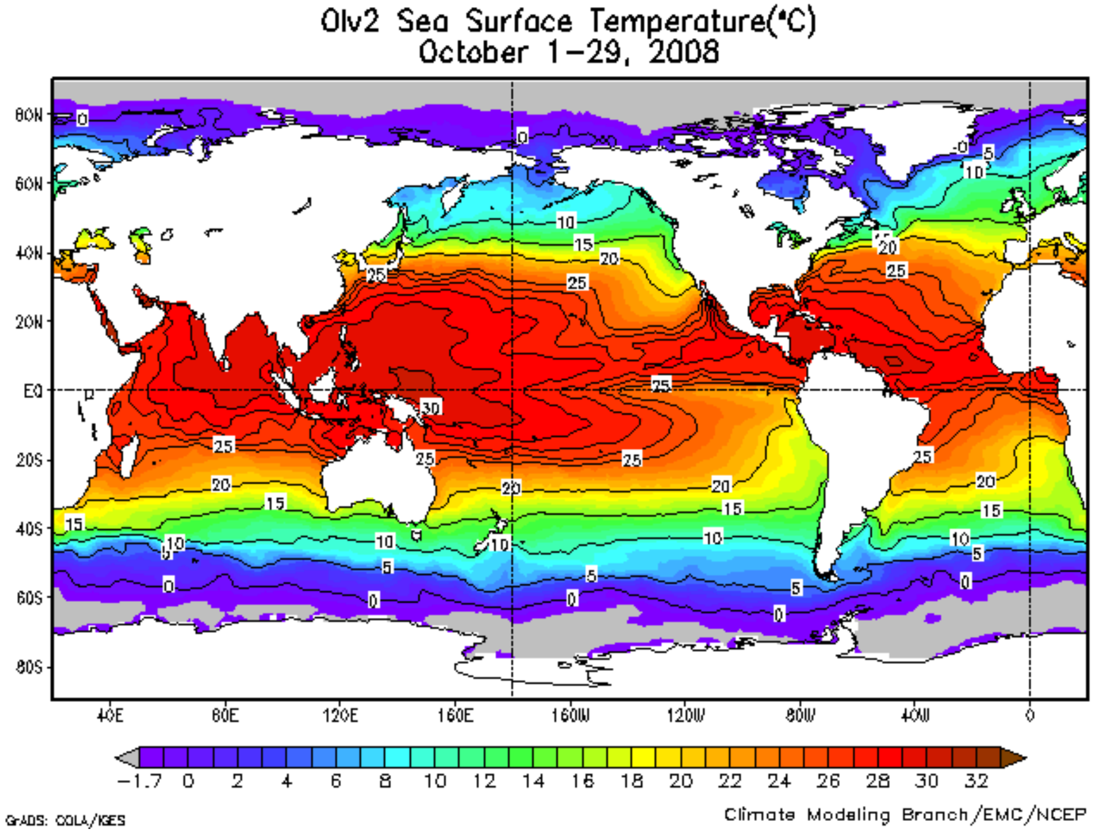


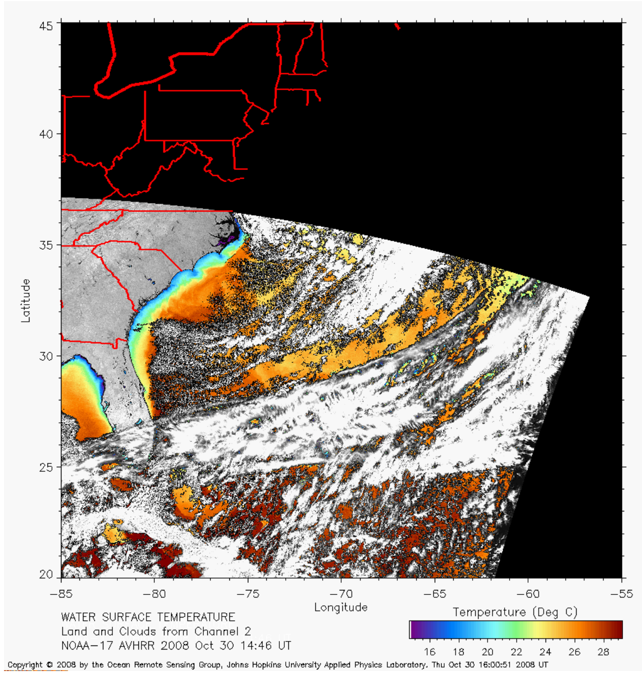



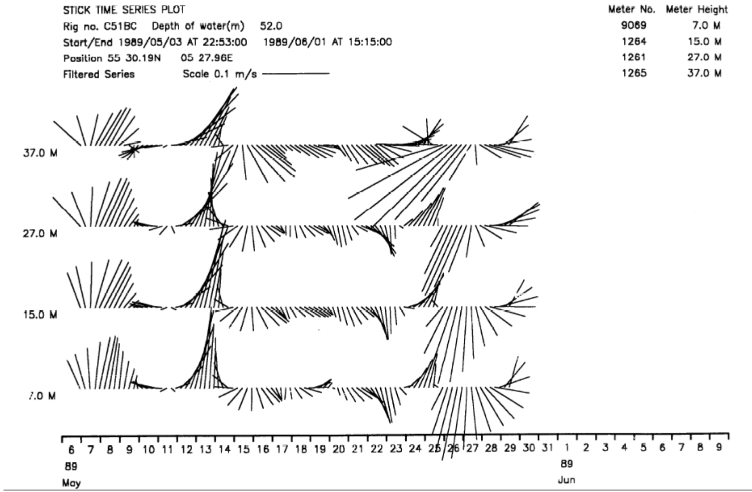
# Satellite SST (and SSS)

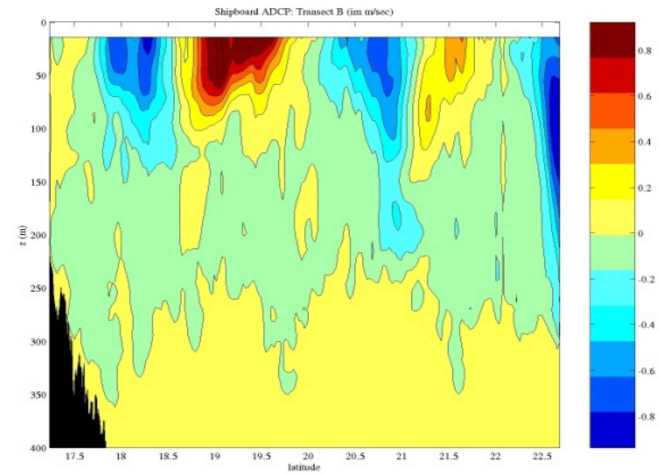
Radiometers that operate in the infrared are used to measure sea surface temperature. Their resolution has steadily increased over the years; the AVHRR (Advanced Very High Resolution Radiometer) has a resolution that comes close to 0.1°C.



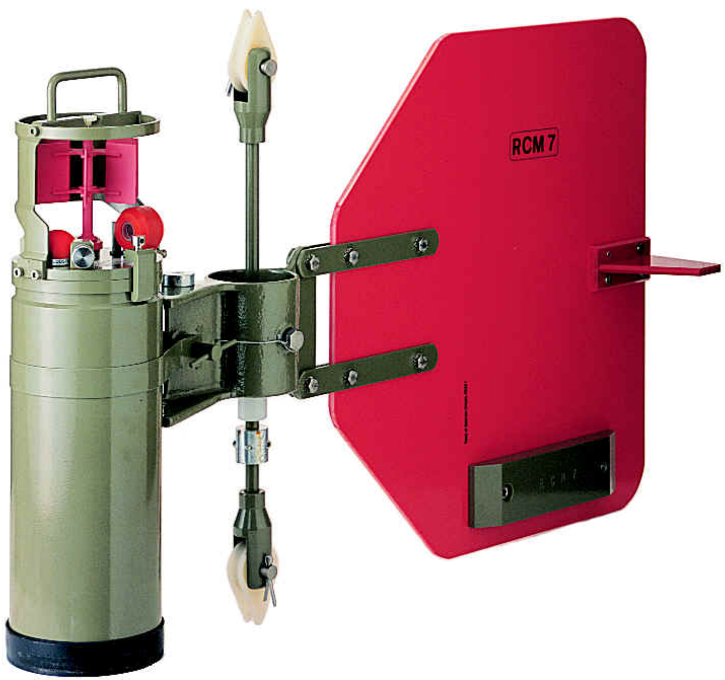



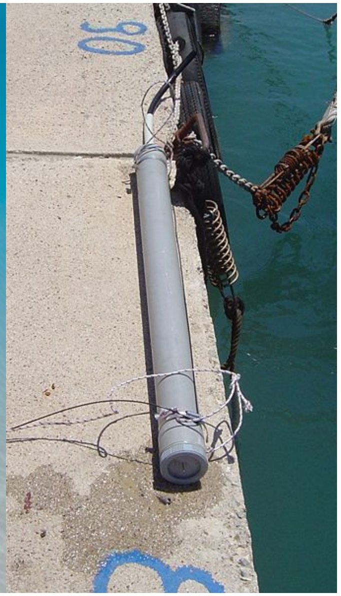
# II. DYNAMICS
# Current meters



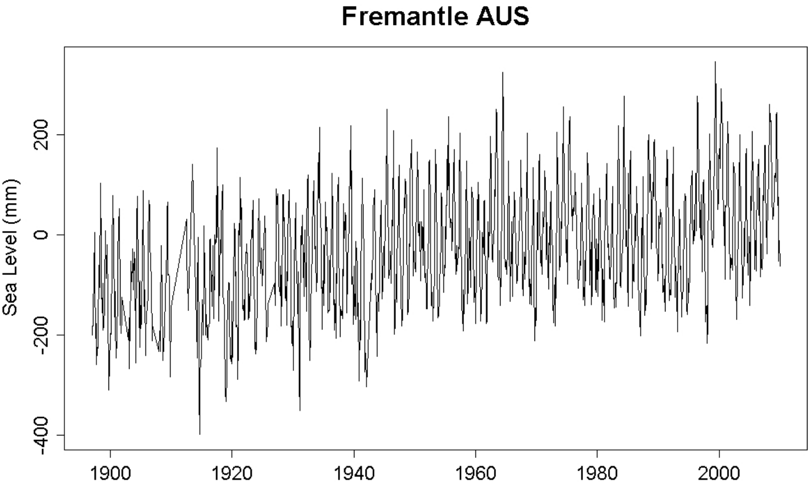



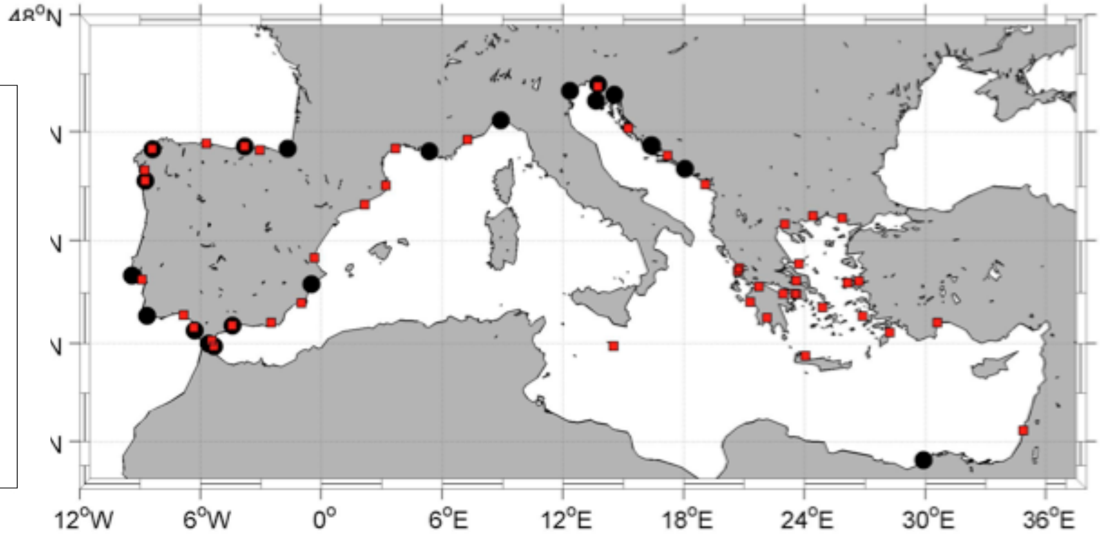

Mechanical
A.D.C.P.



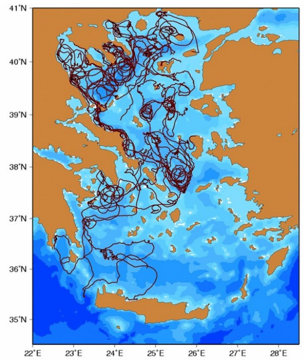



# Pressure (tide) gauges and wave measurements

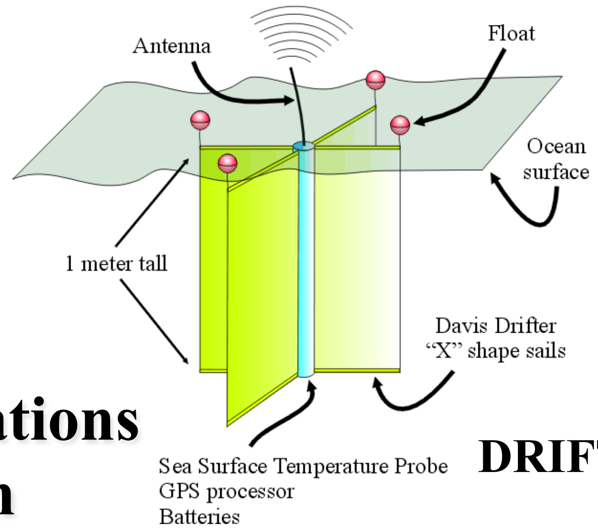


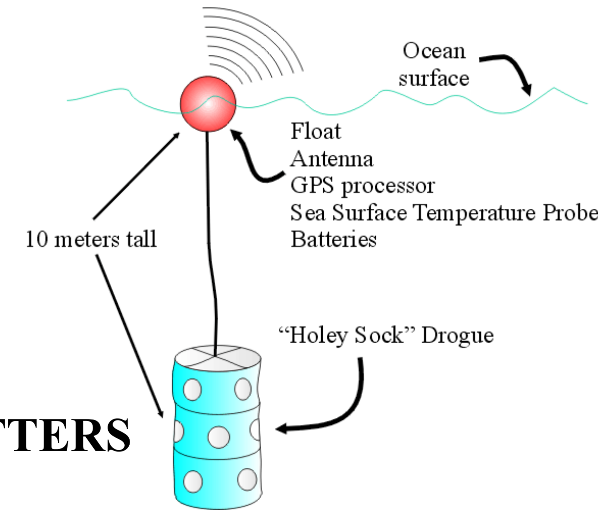



# Lagrangian observations of water motion

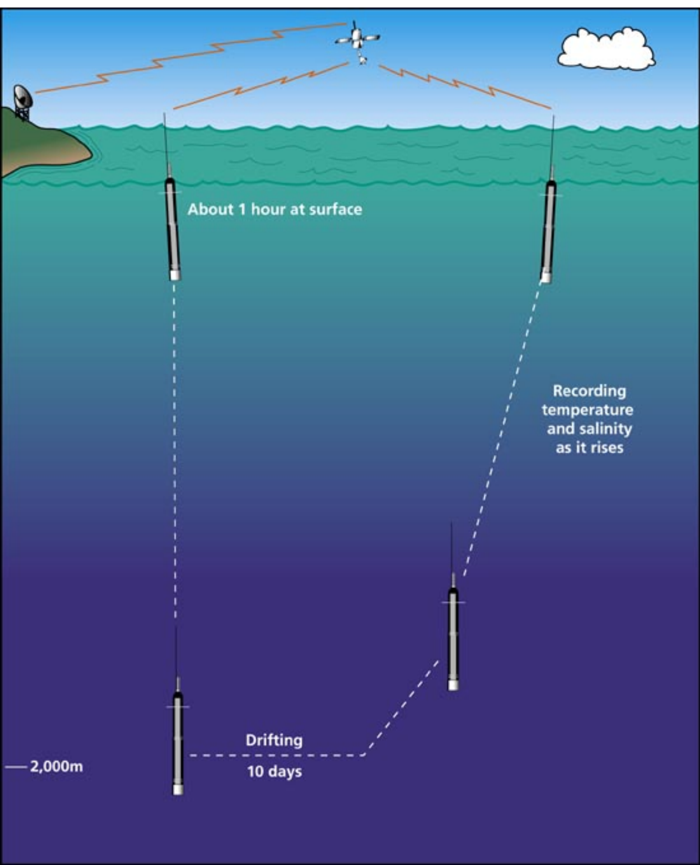


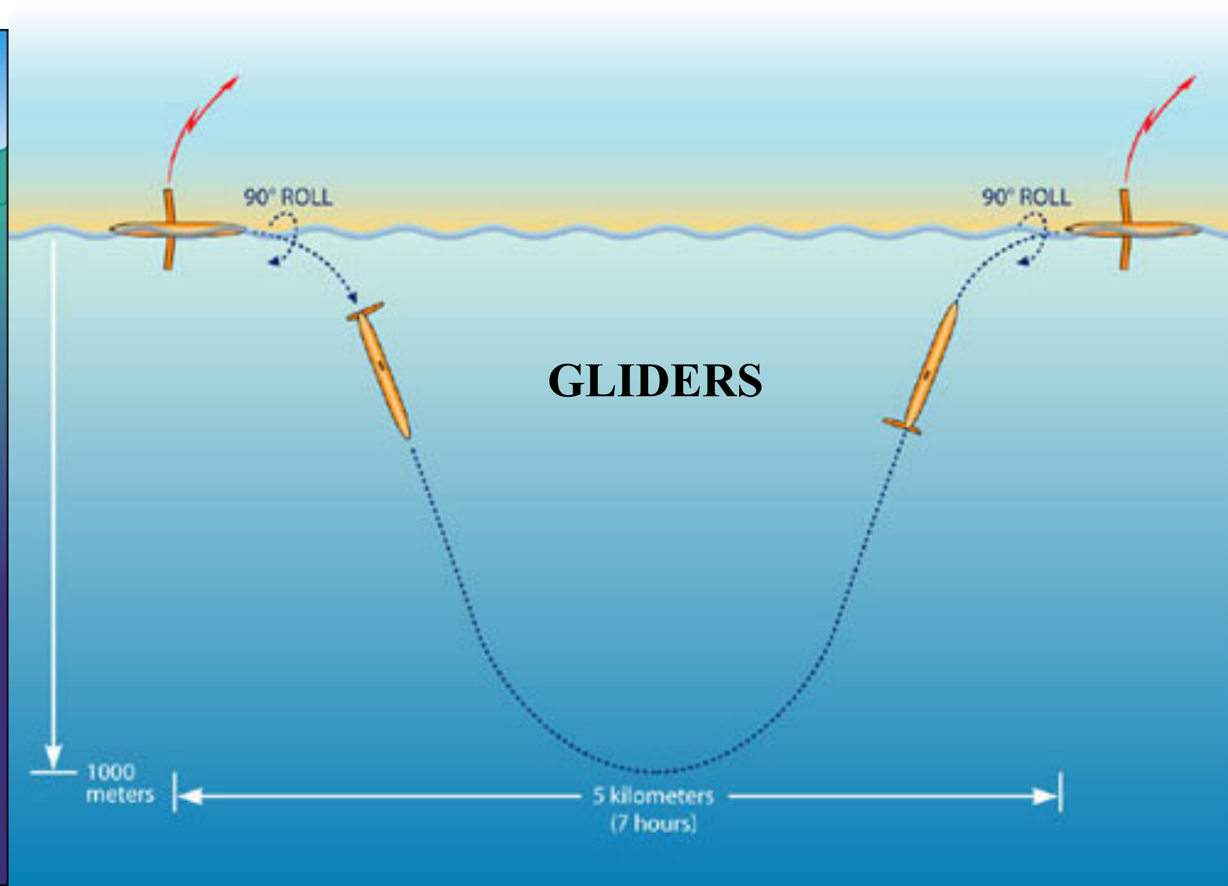

## DRIFTERS



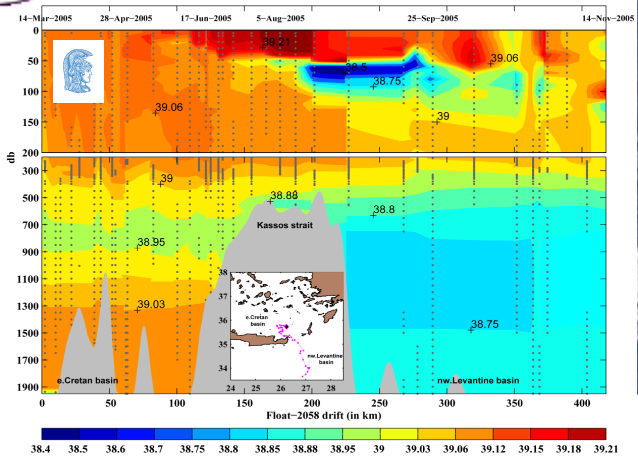



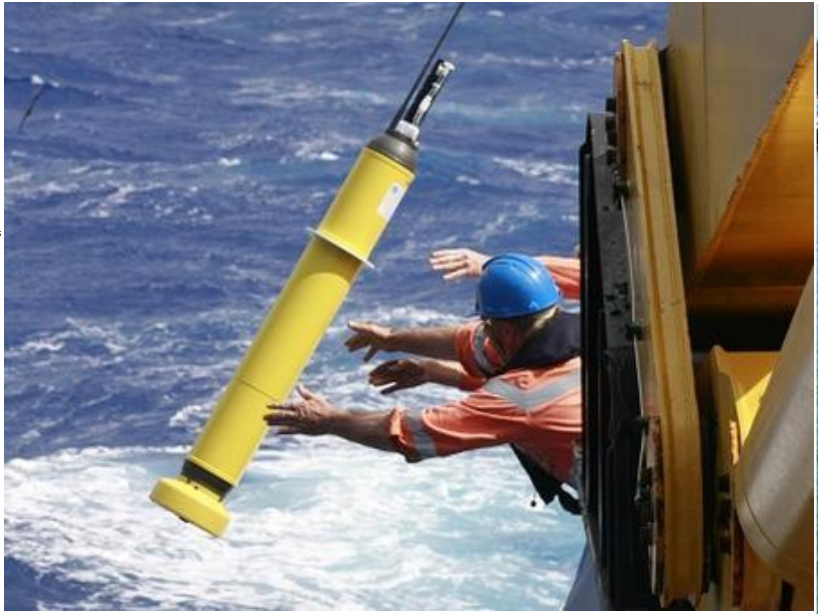

## FLOATS

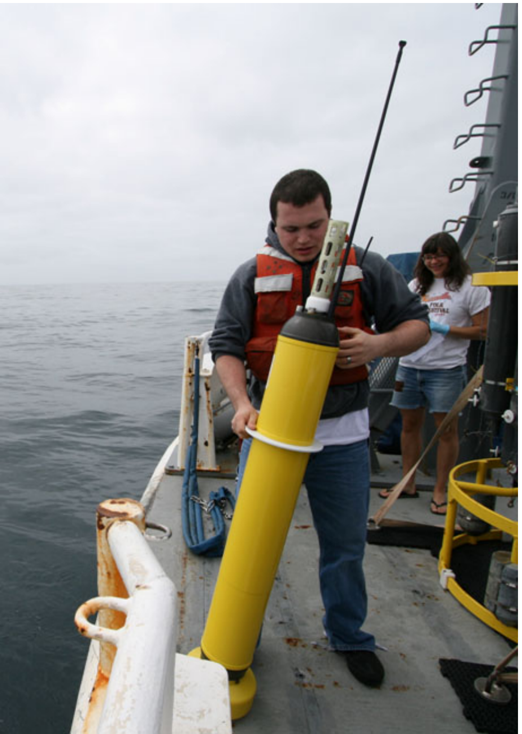


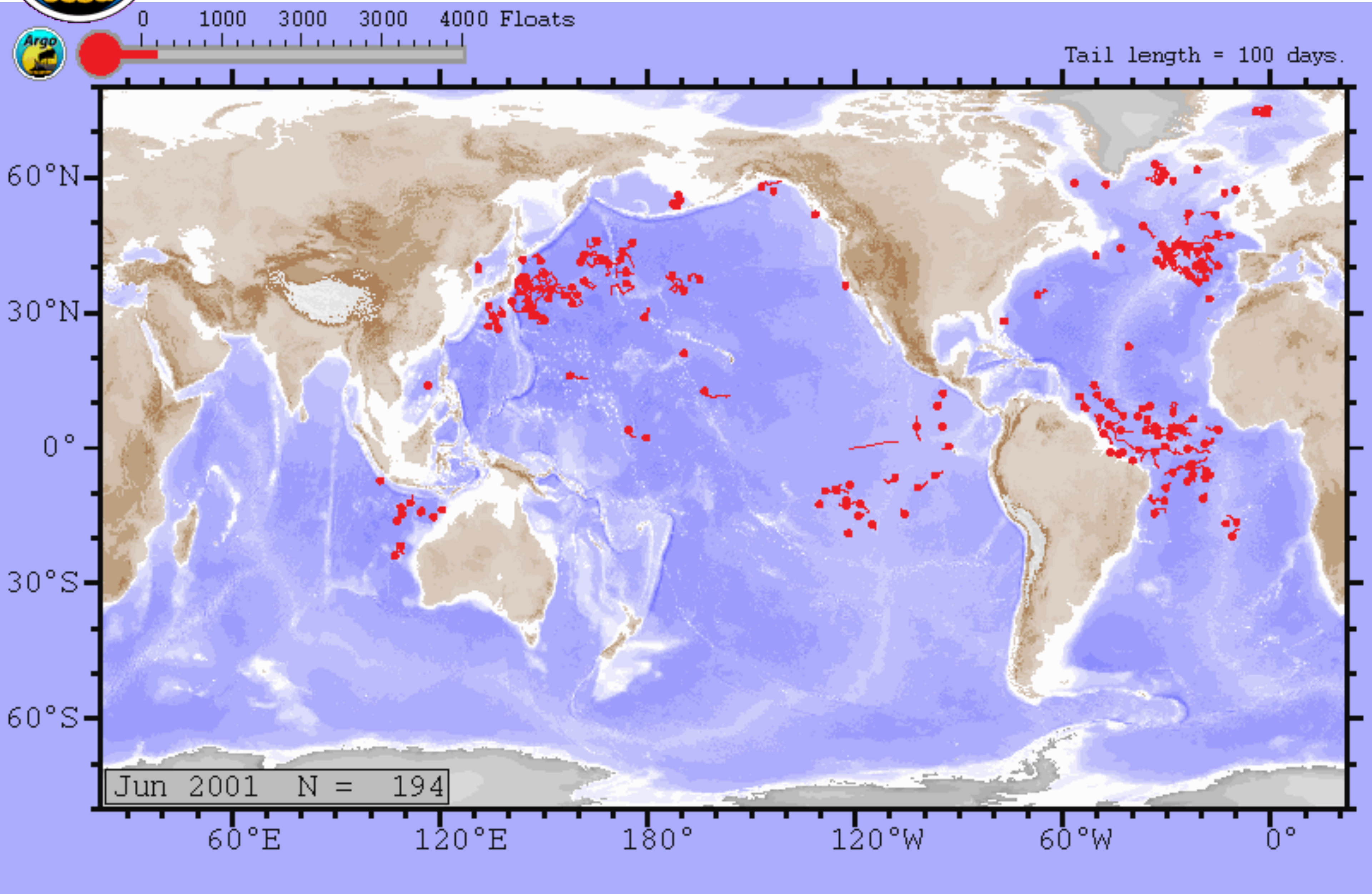
# The *ARGO* initiative



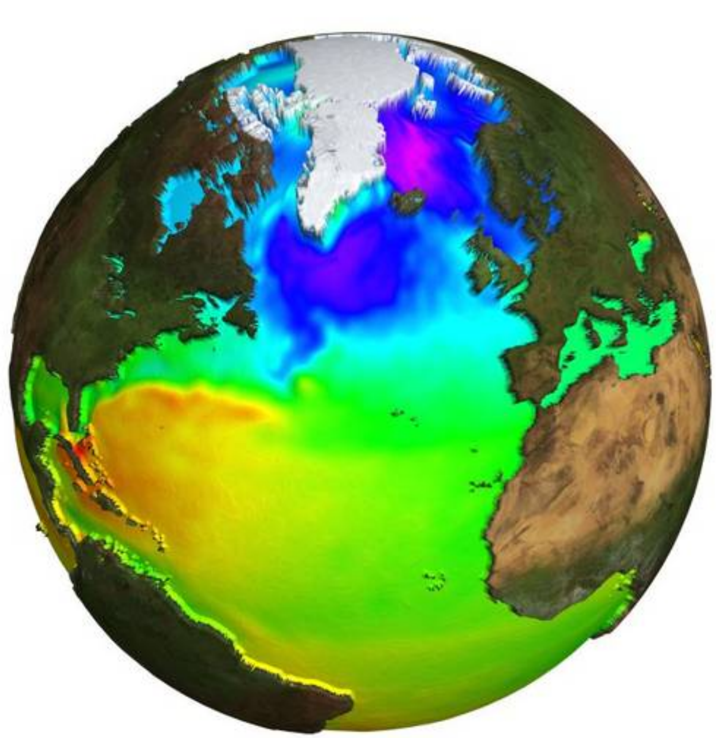



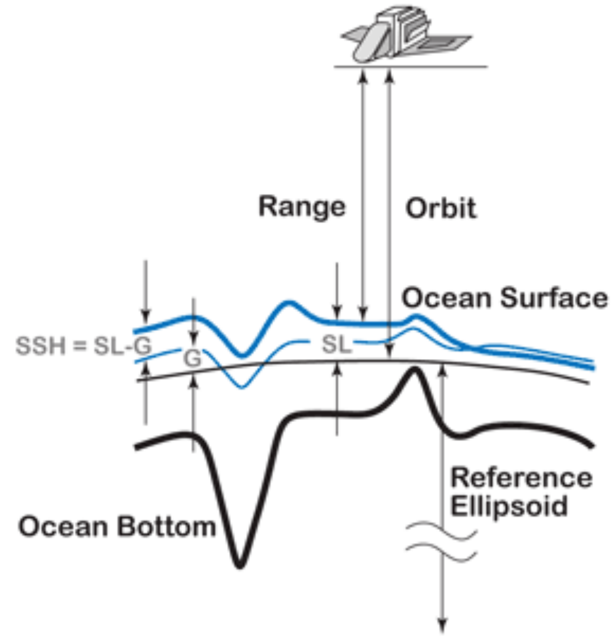


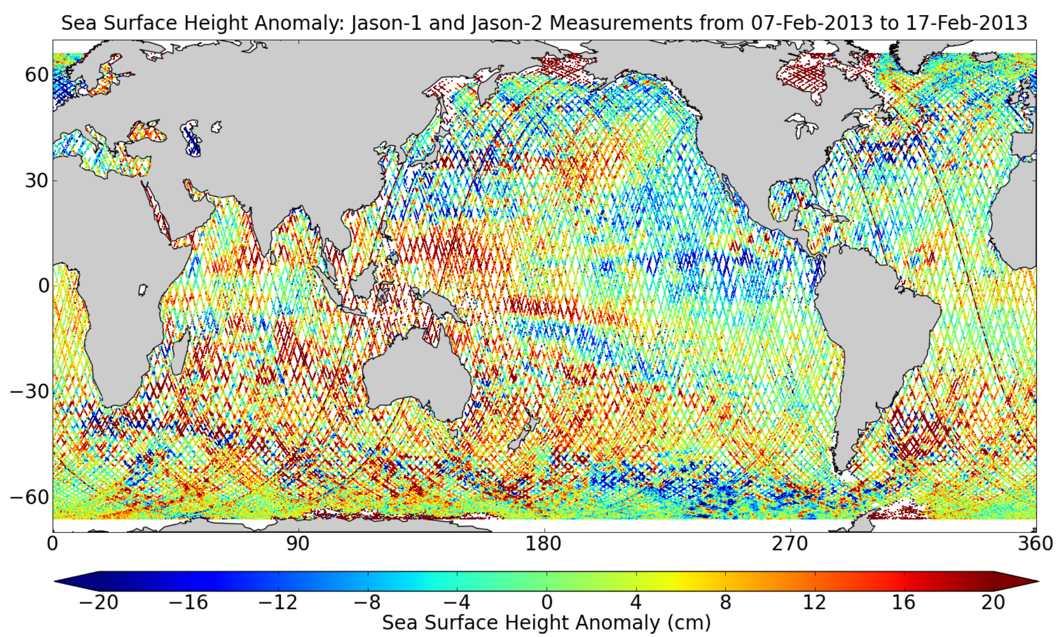
# The *ARGO* initiative

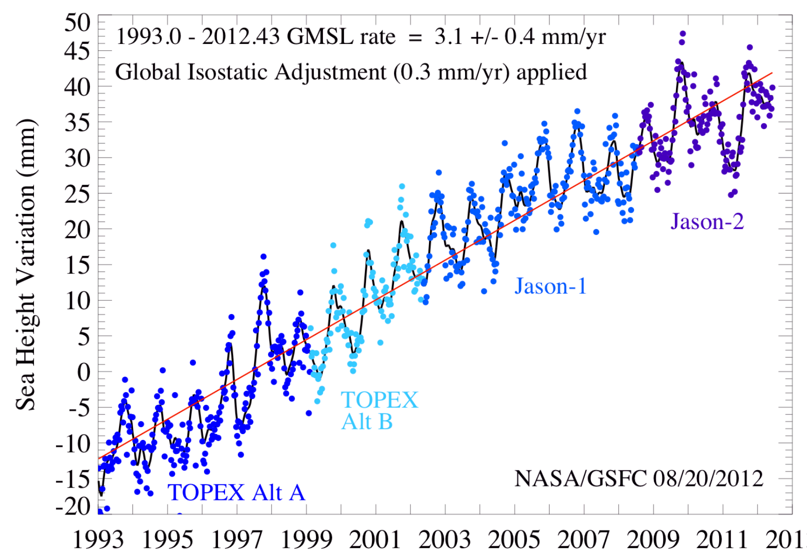


# Altimetry



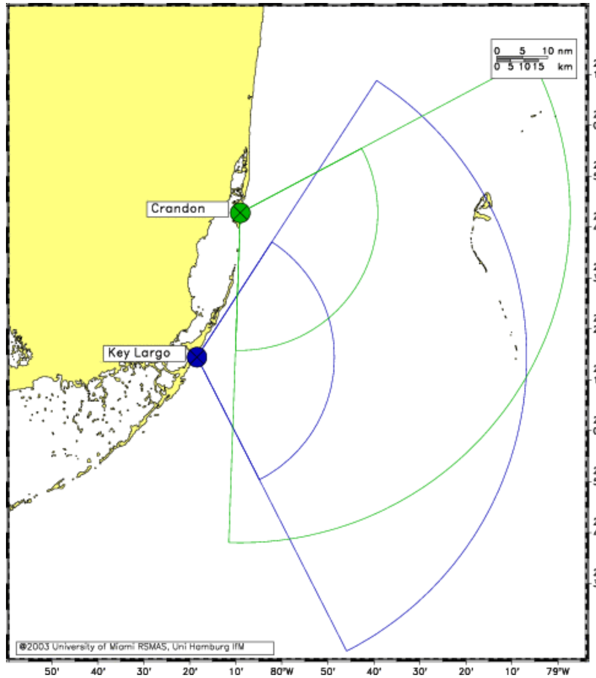

Range
Orbit
Ocean Surface
SSH = SL-G
G
SL
Reference
Ellipsoid
Ocean Bottom

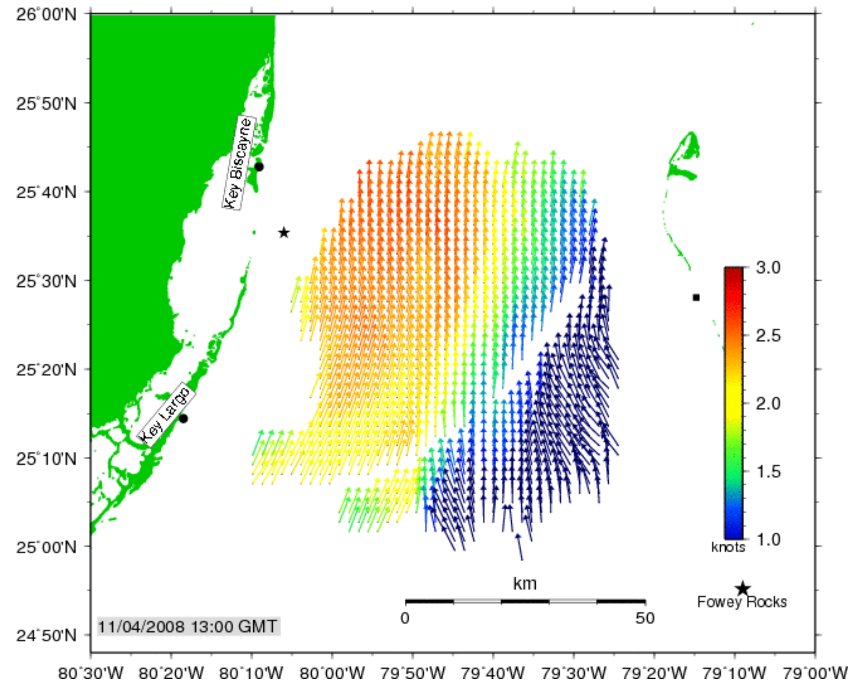

Sea Surface Height Anomaly: Jason-1 and Jason-2 Measurements from 07-Feb-2013 to 17-Feb-2013
60
30
0
−30
−60
0
90
180
270
360
−20
−16
−12
−8
−4
0
4
8
12
16
20
Sea Surface Height Anomaly (cm)


1993.0 - 2012.43 GMSL rate = 3.1 +/- 0.4 mm/yr
Global Isostatic Adjustment (0.3 mm/yr) applied
Sea Height Variation (mm)
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
TOPEX Alt A
TOPEX
Alt B
Jason-1
Jason-2
NASA/GSFC 08/20/2012

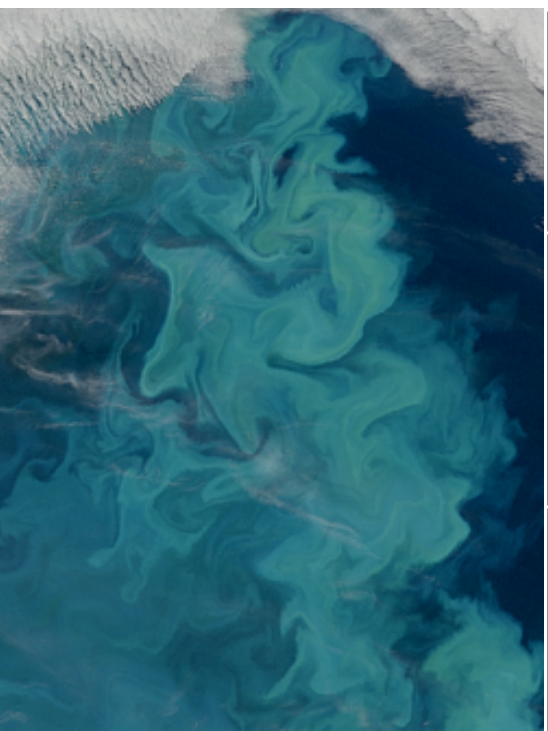
Radars

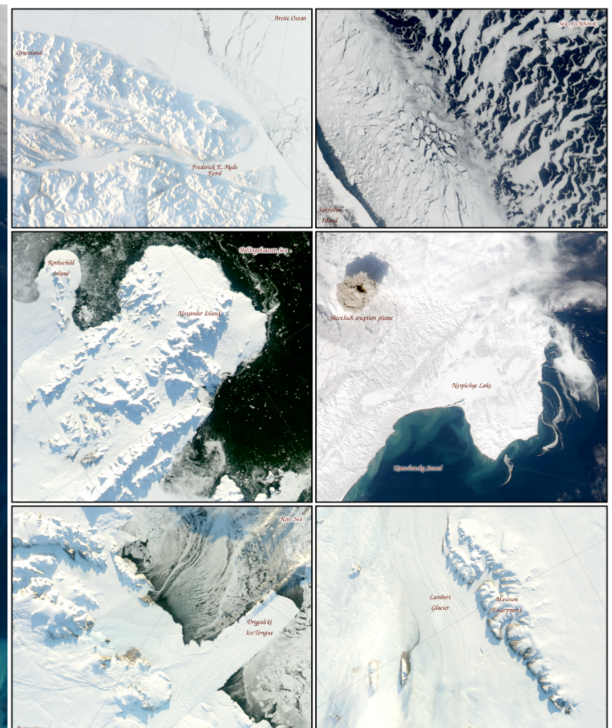
**Many more ….**



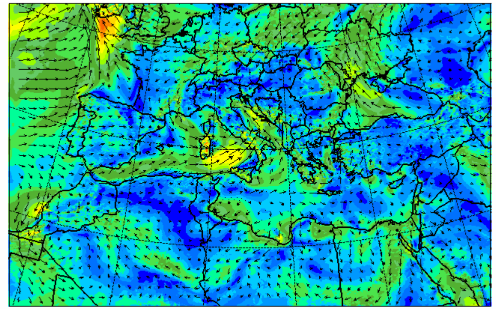

Satellite sensors

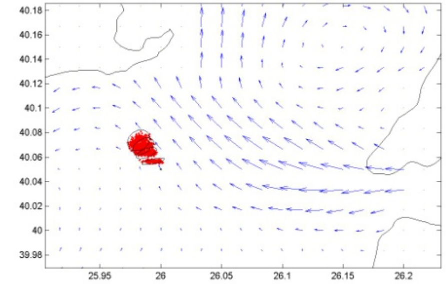




Microprofilers

# Numerical models and Ocean forecast





**Atmospheric Forcing**

$$\frac{\partial}{\partial t}\left(u\frac{\partial p}{\partial Z}\right)+\frac{\partial}{\partial x}\left(uu\frac{\partial p}{\partial Z}\right)+\frac{\partial}{\partial y}\left(vu\frac{\partial p}{\partial Z}\right)+\frac{\partial}{\partial Z}\left(\frac{\partial Z}{\partial t}u\frac{\partial p}{\partial Z}\right)-fv\frac{\partial p}{\partial Z}=g\left(\frac{\partial p}{\partial x}\frac{\partial z}{\partial Z}-\frac{\partial p}{\partial Z}\frac{\partial z}{\partial x}\right)$$

$$\frac{\partial}{\partial t}\left(v\frac{\partial p}{\partial Z}\right)+\frac{\partial}{\partial x}\left(uv\frac{\partial p}{\partial Z}\right)+\frac{\partial}{\partial y}\left(vv\frac{\partial p}{\partial Z}\right)+\frac{\partial}{\partial Z}\left(\frac{\partial Z}{\partial t}v\frac{\partial p}{\partial Z}\right)+fu\frac{\partial p}{\partial Z}=g\left(\frac{\partial p}{\partial y}\frac{\partial z}{\partial Z}-\frac{\partial p}{\partial Z}\frac{\partial z}{\partial y}\right)$$

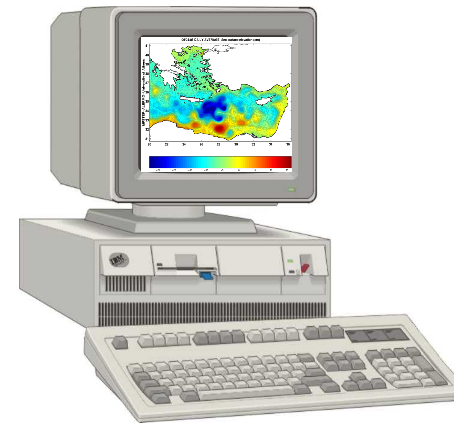
$$\frac{\partial p}{\partial Z}=-g\rho\frac{\partial z}{\partial Z} \qquad (5.1)$$

$$\frac{\partial}{\partial t}\left(T\frac{\partial p}{\partial Z}\right)+\frac{\partial}{\partial x}\left(uT\frac{\partial p}{\partial Z}\right)+\frac{\partial}{\partial y}\left(vT\frac{\partial p}{\partial Z}\right)+\frac{\partial}{\partial Z}\left(\frac{\partial Z}{\partial t}T\frac{\partial p}{\partial Z}\right)=0$$

$$\frac{\partial}{\partial t}\left(S\frac{\partial p}{\partial Z}\right)+\frac{\partial}{\partial x}\left(uS\frac{\partial p}{\partial Z}\right)+\frac{\partial}{\partial y}\left(vS\frac{\partial p}{\partial Z}\right)+\frac{\partial}{\partial Z}\left(\frac{\partial Z}{\partial t}S\frac{\partial p}{\partial Z}\right)=0$$

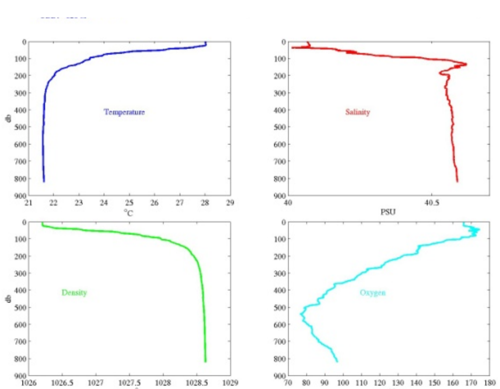
$$\frac{\partial}{\partial t}\left(\frac{\partial p}{\partial Z}\right)+\frac{\partial}{\partial x}\left(u\frac{\partial p}{\partial Z}\right)+\frac{\partial}{\partial y}\left(v\frac{\partial p}{\partial Z}\right)+\frac{\partial}{\partial Z}\left(\frac{\partial Z}{\partial t}\frac{\partial p}{\partial Z}\right)=0$$

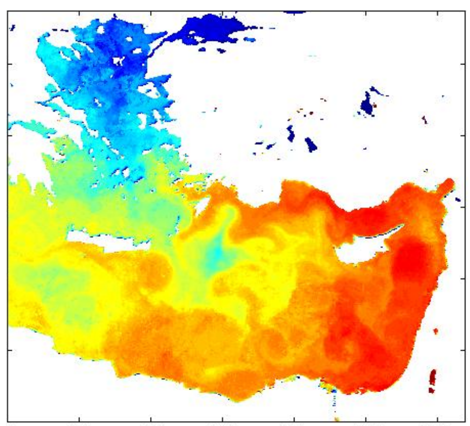
$$u_j^{n+1}=u_j^n-\frac{c\Delta t}{\Delta x}\left[\frac{u_{j+1}^n}{2}-\frac{u_{j-1}^n}{2}-\frac{u_{j+1}^n}{2}+\frac{2u_j^n}{2}-\frac{u_{j-1}^n}{2}\right]=$$
$$=\Delta t\left[-c\frac{u_{j+1}^n-u_{j-1}^n}{2\Delta x}+\frac{c\Delta x}{2}\frac{u_{j+1}^n+u_{j-1}^n-2u_j^n}{(\Delta x)^2}\right]$$

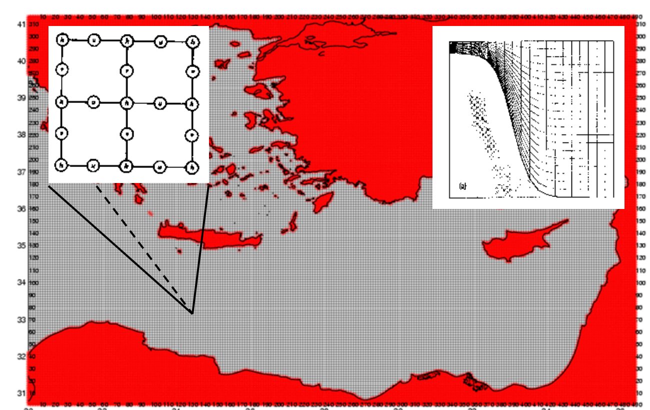


**Initialization Data Assimilation**

**GRID**





# Coupled models and Climate prediction