Monitoring the ocean from observations

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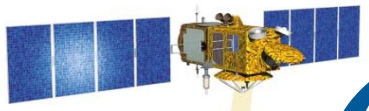
Introduction

- Our approach :
  - Consists of estimating 3D-thermohaline and current fields **using ONLY observations and statistical methods**
  - Represents a **complementary approach** to the one developed by forecasting centers – based on model/assimilation techniques
  - "Observation based" component of the Global MyOcean Monitoring and Forecasting Center lead by Mercator Océan

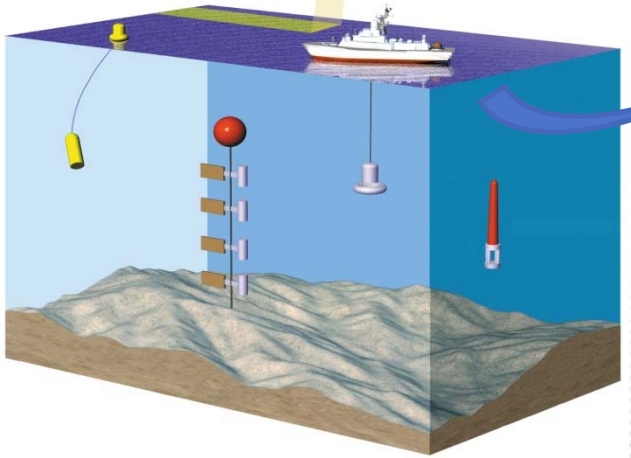
- Previous studies have shown the capability of such approaches :
  - In producing reliable ocean state estimates (Guinehut et al., 2004; Larnicol et al., 2006)
  - In analyzing the contribution and complementarities of the different observing systems (in-situ vs. remote-sensing) (2nd GODAE OSE Workshop, 2009)

The principle

The observations



Altimeter, SST, winds, Geoid

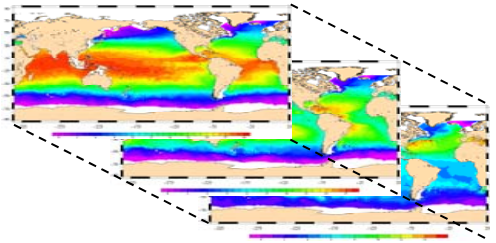


T/S profiles, surface drifters

The method

Guinehut et al., 2004
Guinehut et al., 2006
Larnicol et al., 2006
Rio et al., 2011
Mulet et al, submitted

The products



Global 3D Ocean State
[T,S,U,V,H]
Weekly – 1993-2009
[0-1500m] 24 levels
[1/3°]

➔ **MyOcean V1 RT/RAN**

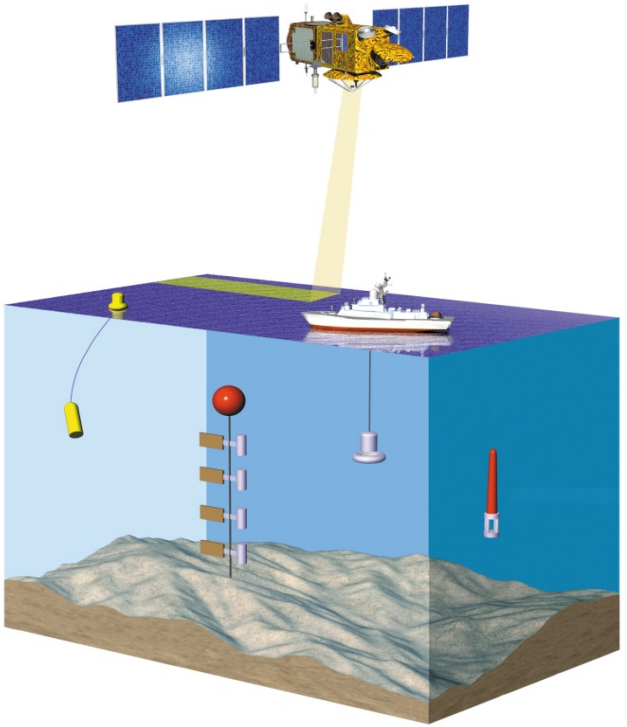
Intercomparison with independent data sets and model simulations
Analysis of the ocean variability
Observing System Evaluation

Global T/S ➔ Armor3D - Method

1 **vertical projection** of satellite data (**SLA**, **SST**)

$$T(x,y,z,t) = \alpha(x,y,z,t).SLA_{steric} + \beta(x,y,z,t).SST' + T_{clim}(x,y,z,t)$$
$$S(x,y,z,t) = \alpha'(x,y,z,t).SLA_{steric} + S_{clim}(x,y,z,t)$$

2 **combination** of synthetic and in-situ profiles



SLA, SST

multiple linear regression 1

synthetic T(z), S(z)

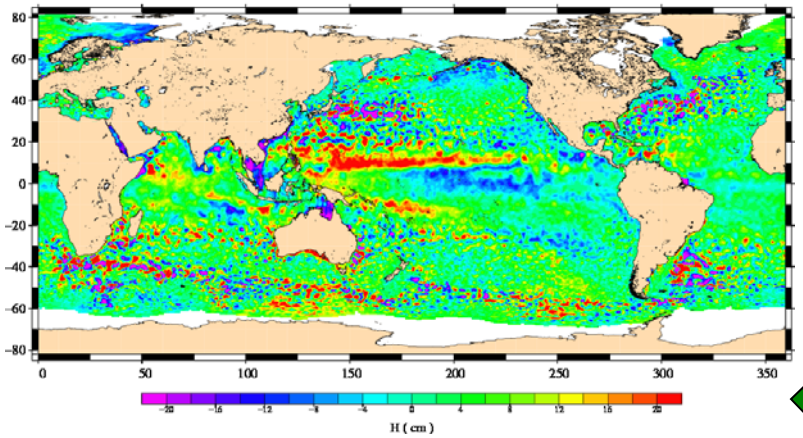
optimal interpolation 2

in-situ T(z), S(z)

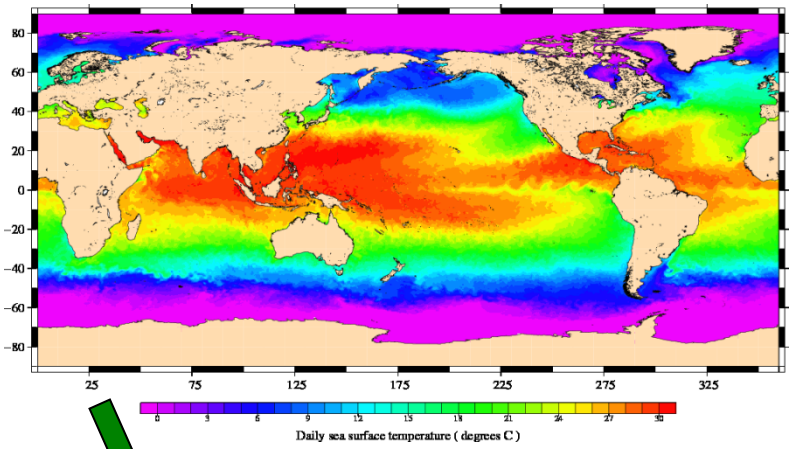
Armor3D T(z), S(z)

Armor3D - 1993-2009 reanalysis

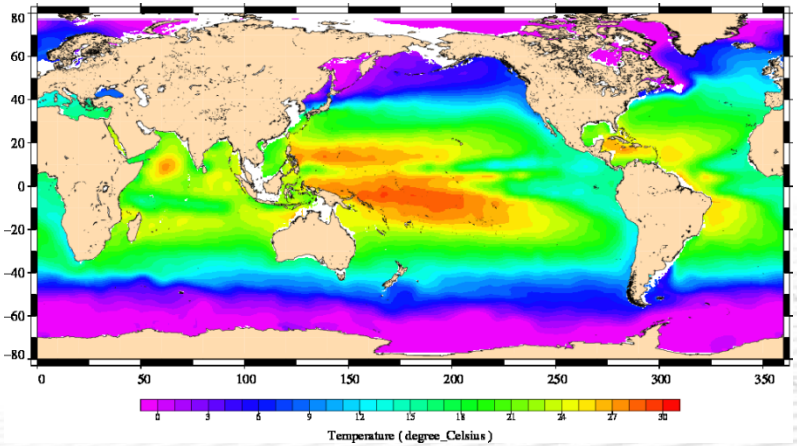
SSALTO-DUACS MSLA 1/3° weekly DT - 04/07/2007



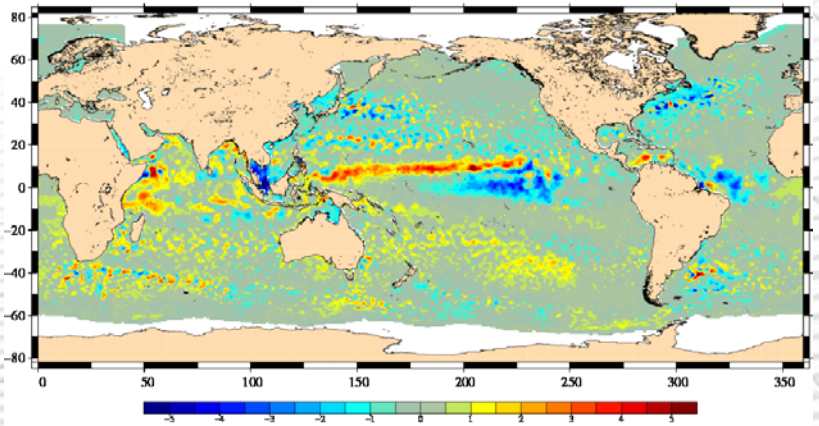
NCEP Reynolds OI-SST 1/4° daily - 04/07/2007



Arivo climatology – July – T at 100 m

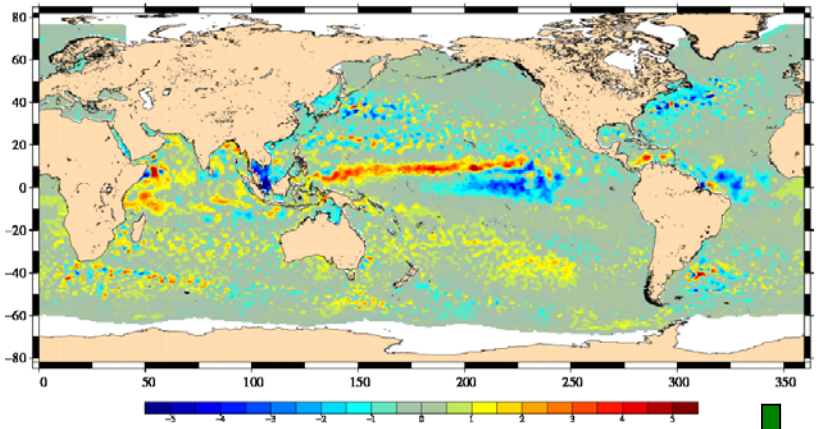


Synthetic T' – at 100m

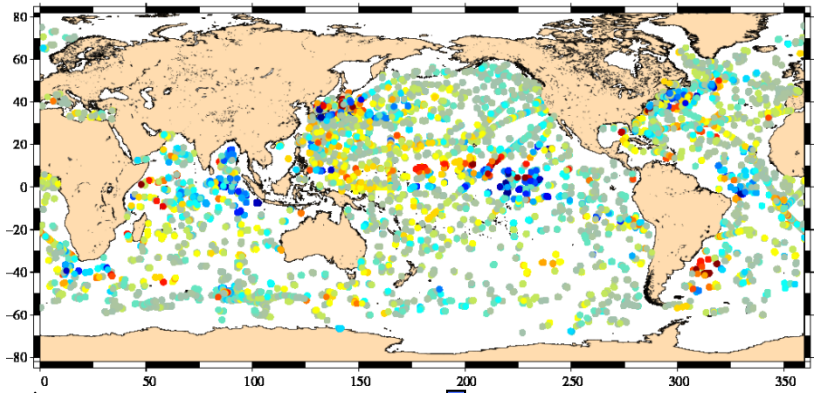


Armor3D - 1993-2009 reanalysis

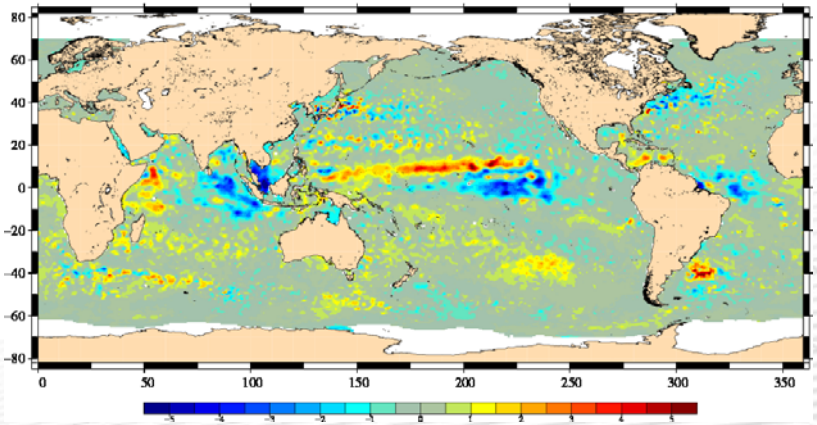
Synthetic T' – at 100m



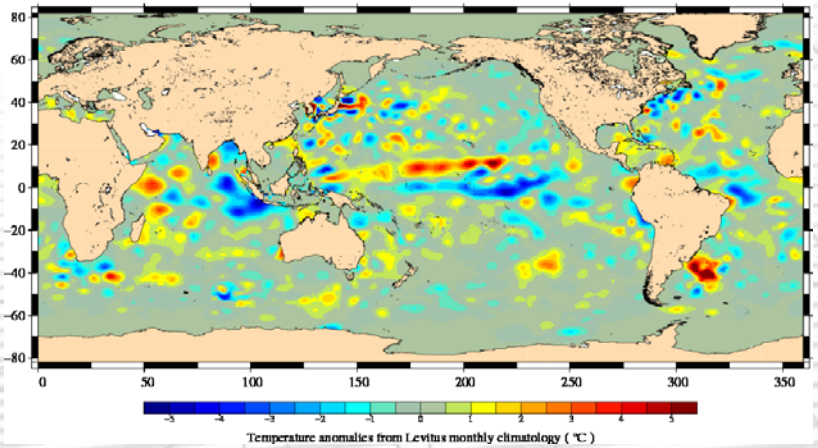
In-situ observations – Coriolis data center



Armor3D T'

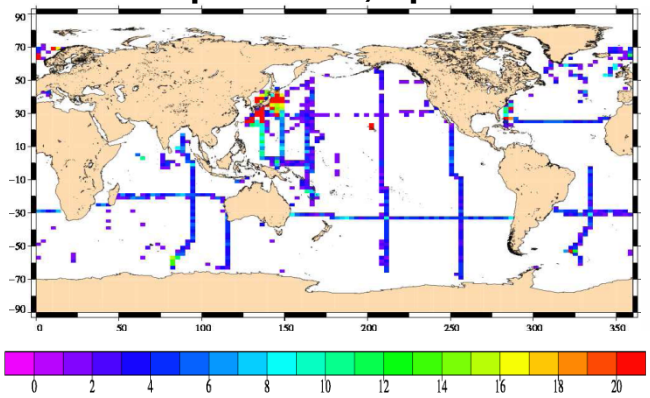


Argo T'



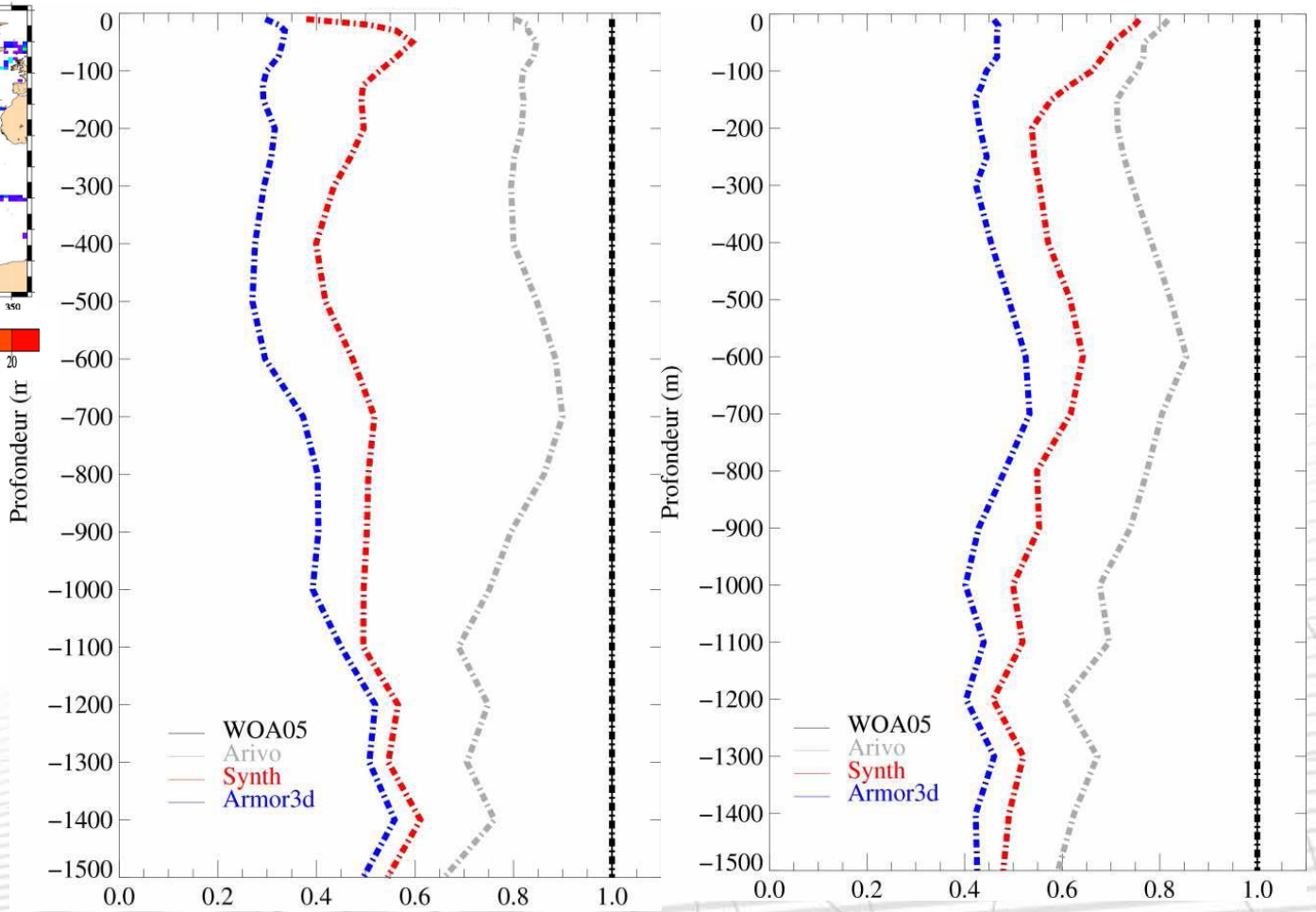
Armor3D - VALIDATION

Independent T,S profiles



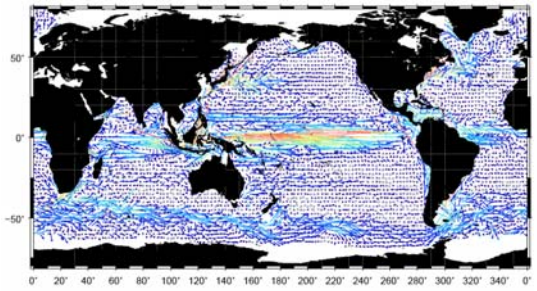
Geographical distribution in 1°x1° boxes of 2002-2008 in-situ T and S profiles used for the validation, for a total of 3400 profiles.

Rms error (% variance) in predicting subsurface T (left) and S (right) anomalies

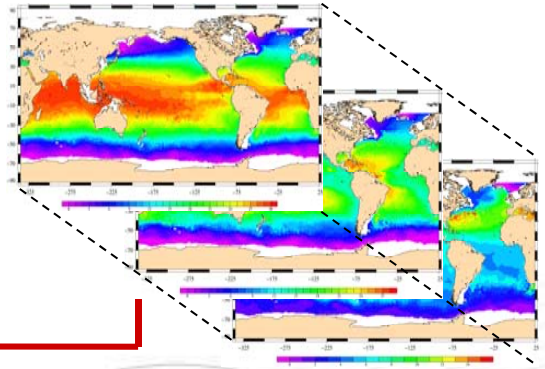


Global U/V/H ➔ Surcouf3D - Method

Altimetry :
Field of absolute geostrophic surface currents
weekly - 1/3°



Armor3D :
3D T/S fields
weekly - 1/3° - [0-1500]m

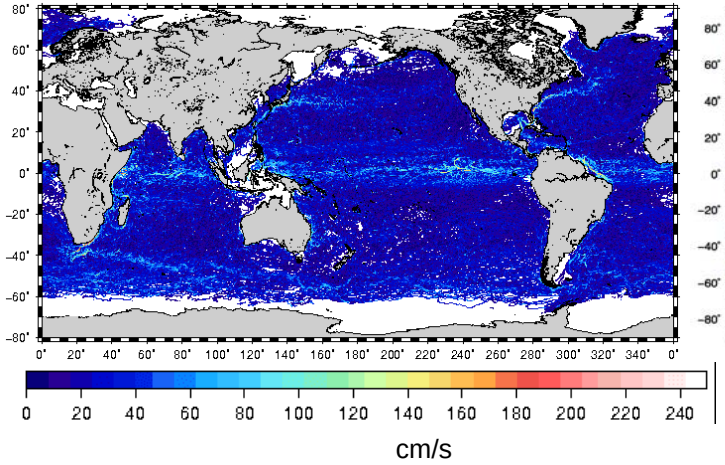


$$u(z=z_i) = u(z=0) + \frac{g}{\rho f}\int_{z=0}^{z_i} \frac{\partial}{\partial y}\rho'(z)dz$$

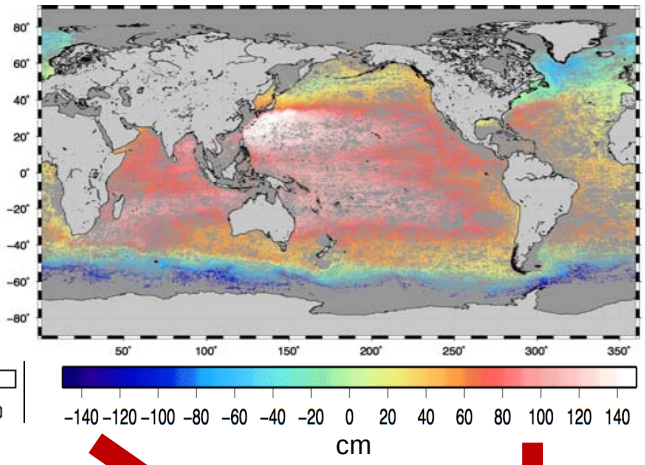
$$v(z=z_i) = v(z=0) - \frac{g}{\rho f}\int_{z=0}^{z_i} \frac{\partial}{\partial x}\rho'(z)dz$$

The CNES-CLS09 MDT

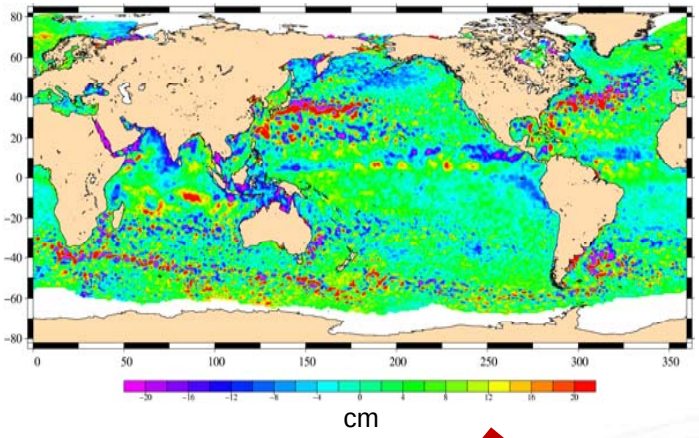
SVP drifting buoy velocities
1993_2008



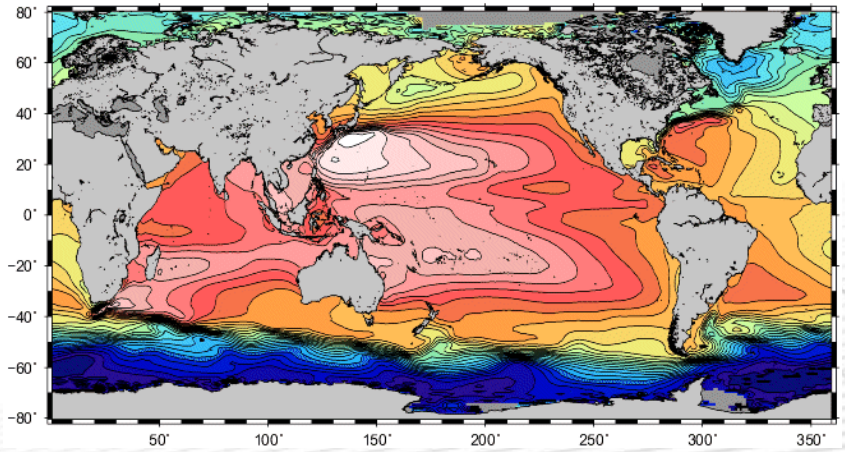
Argo, CTD T/S profiles
1993_2008



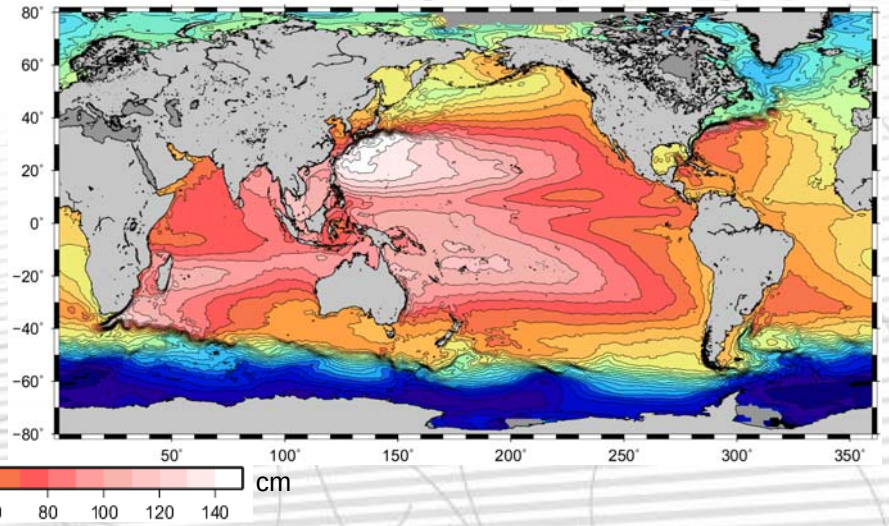
Aviso maps of altimetric
Sea Level Anomalies



MSS CLS01 – GRACE 400 km resolution



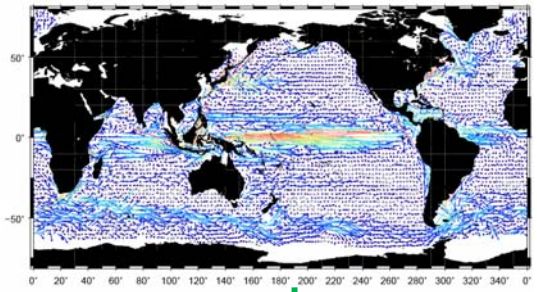
CNES-CLS09 ¼° MDT



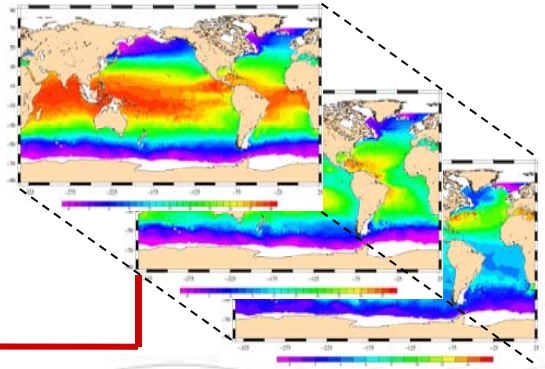
Rio et al, 2011

Global U/V/H ➔ Surcouf3D - Method

Altimetry :
Field of absolute geostrophic surface currents
weekly - 1/3°



Armor3D :
3D T/S fields
weekly - 1/3° - [0-1500]m



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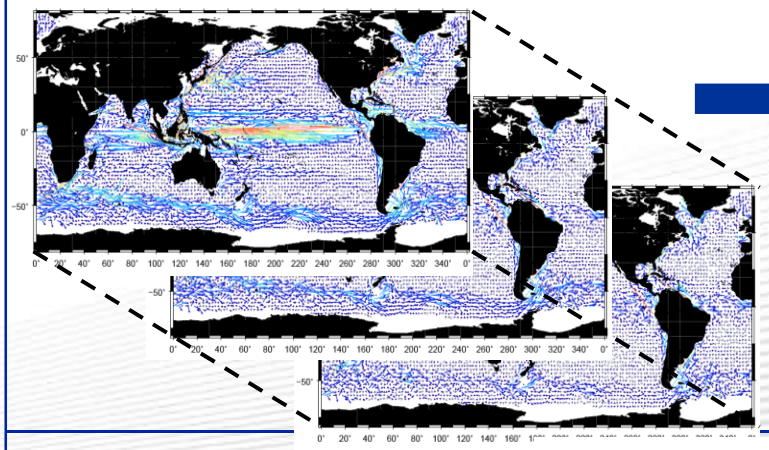


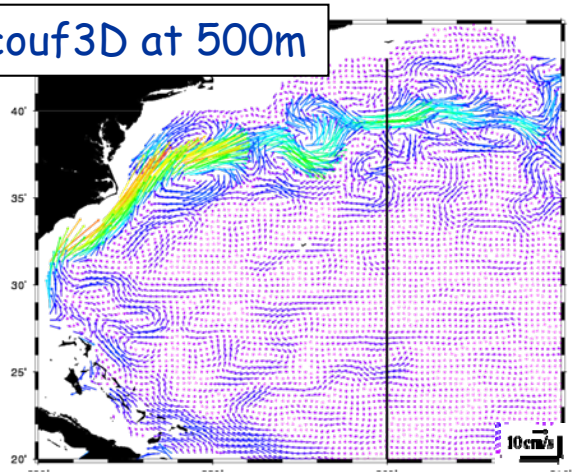
Surcouf3D
3D geostrophic current fields
weekly (1993-2008)
1/3° - 24 levels from 0 to1500m

In the following, unless specified, the synthetic T,S estimates are used

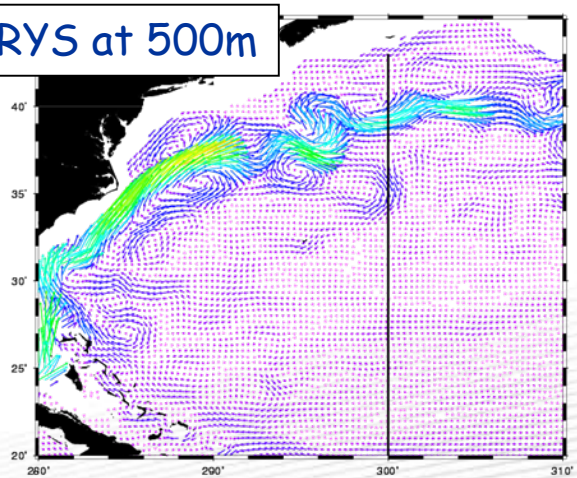
Surcouf3D - Comparison with model outputs

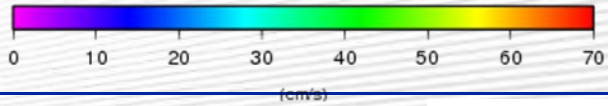
- Vertical section at 60°W, in 2006

Surcouf3D at 500m



GLORYS at 500m

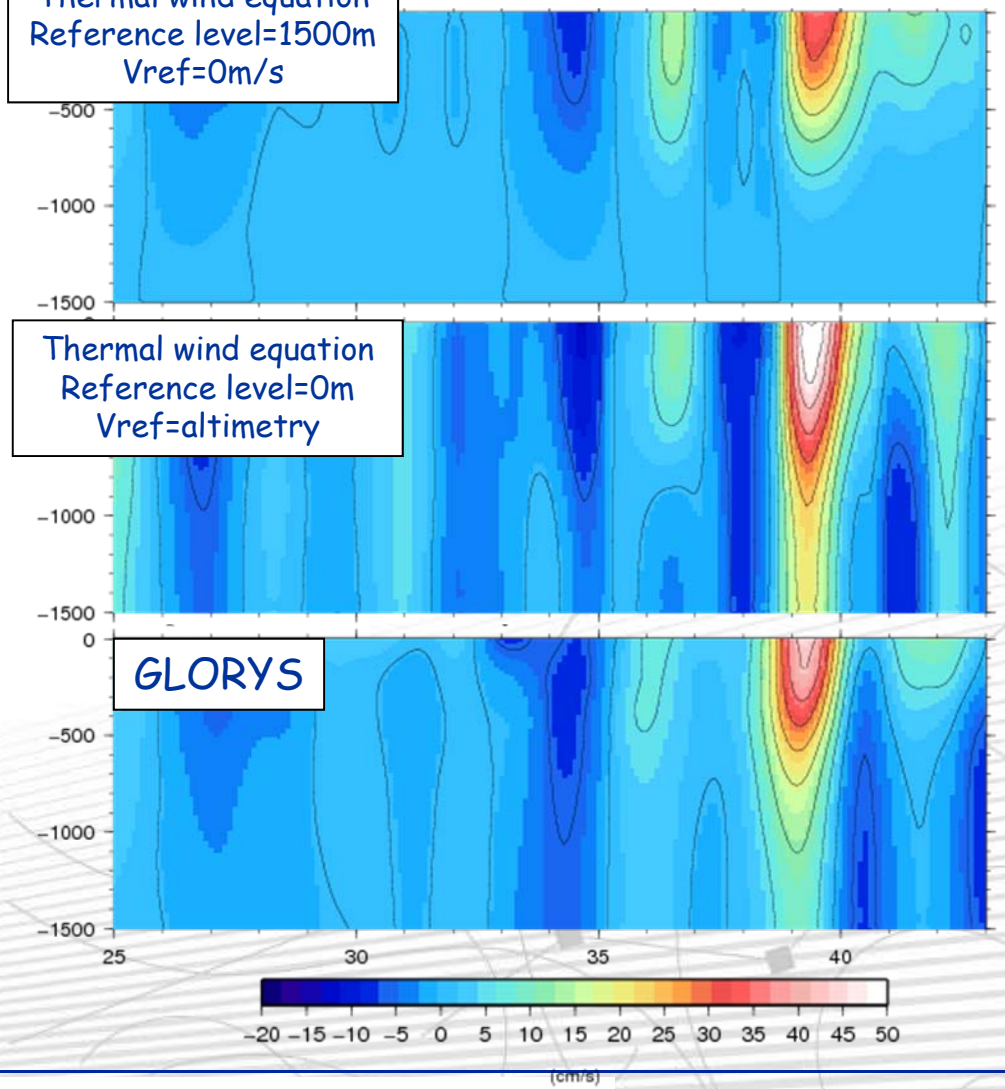




Thermal wind equation
Reference level=1500m
Vref=0m/s

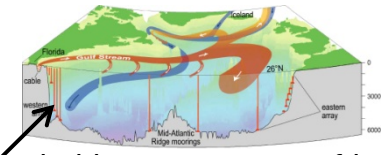
Thermal wind equation
Reference level=0m
Vref=altimetry

GLORYS



Surcouf3D - Validation

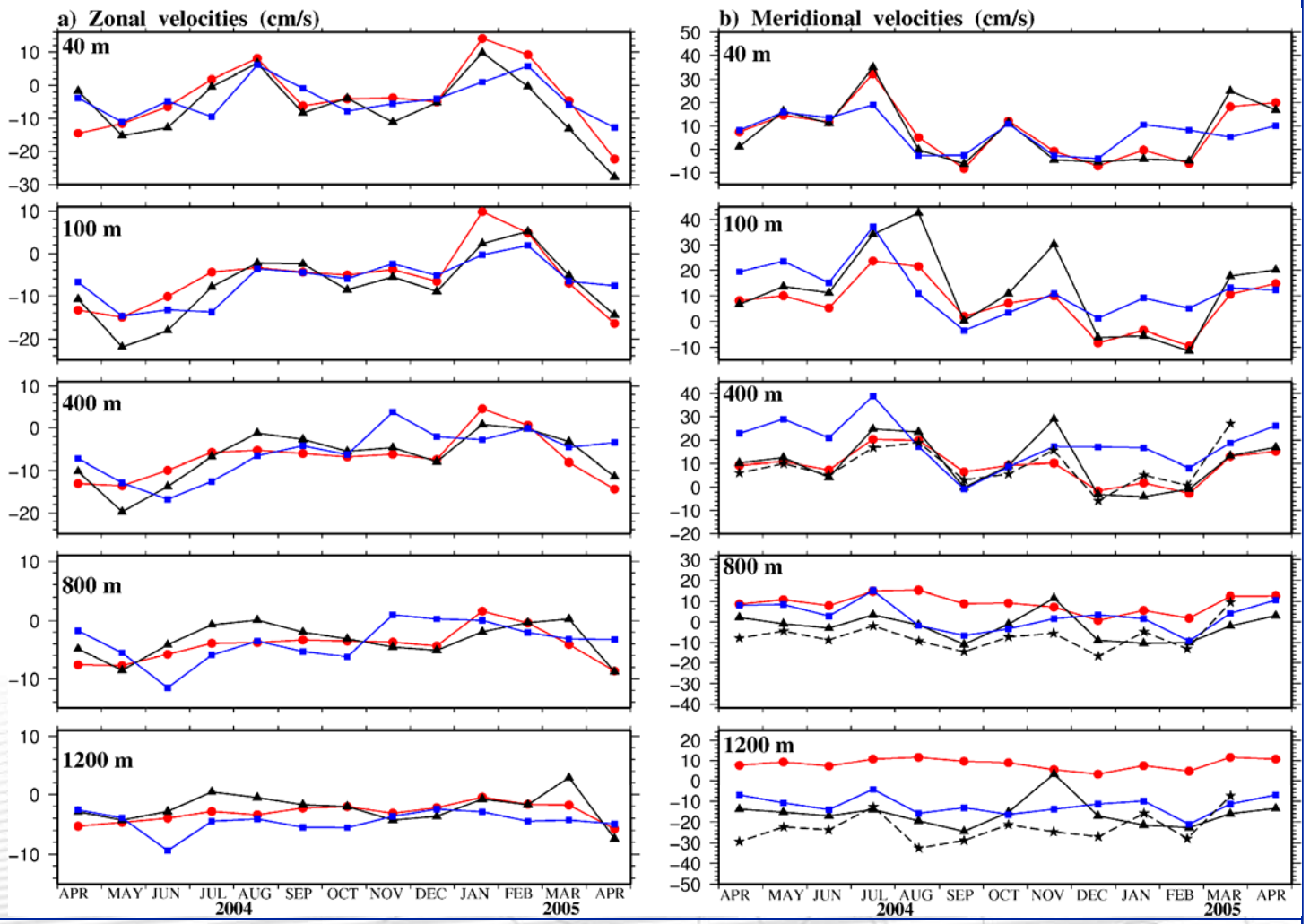
❑ Comparison with **RAPID current-meters** in the Western boundary current off the Bahamas from April 2004 to April 2005



26.5°North
76.5°West

SURCOUF3D
RAPID (current meters)
GLORYS

➔ Good correlation with independent obs., and with GLORYS



Surcouf3D - Validation

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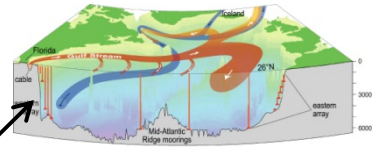
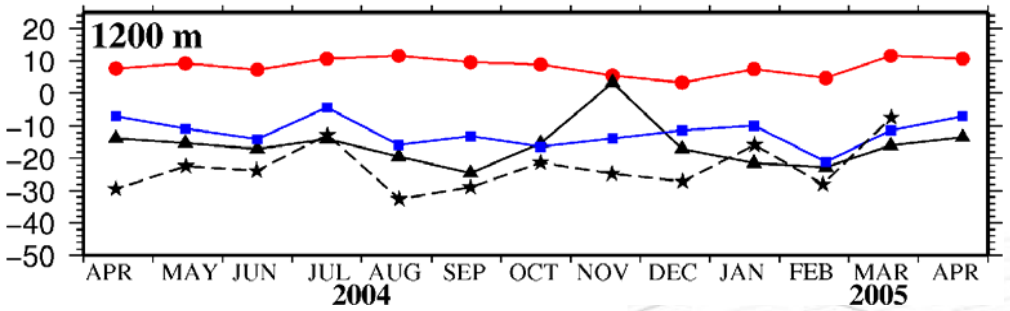


26.5°North
76.5°West

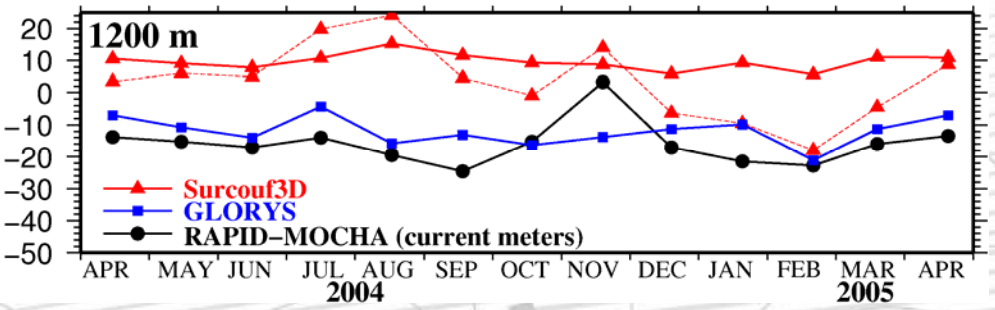
SURCOUF3D (synthetic T,S)
RAPID (current meters)
GLORYS

RAPID (currentmeter at 100m + T,S using the thermal wind equation)

Meridional velocities (cm/s)



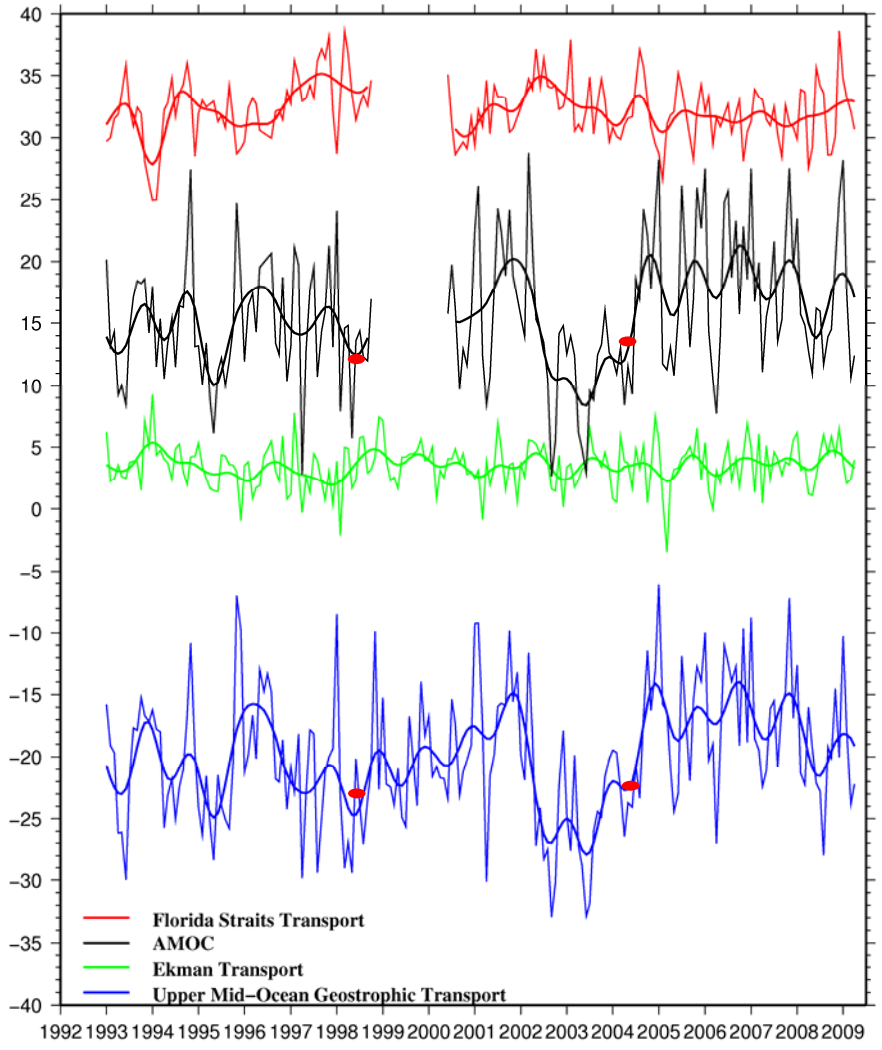
SURCOUF3D (synthetic T,S)
SURCOUF3D (synthetic T,S + Argo)
RAPID (current meters)
GLORYS

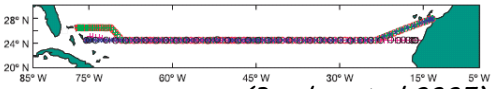


➔ Importance of in-situ T/S profiles observations at depth for correctly resolving the inversion of the current

Surcouf3D - AMOC variability at 25°N

❑ Comparison with Bryden et al, 2005 (section at 24.5° from Africa to 73°W and at 26.5°N off Bahamas)





(Bryden et al,2005)

Floride Strait Transport from electrical cable

AMOC = Geost + Ekman + Florida
(Surcouf3D, Bryden et al., 2005)

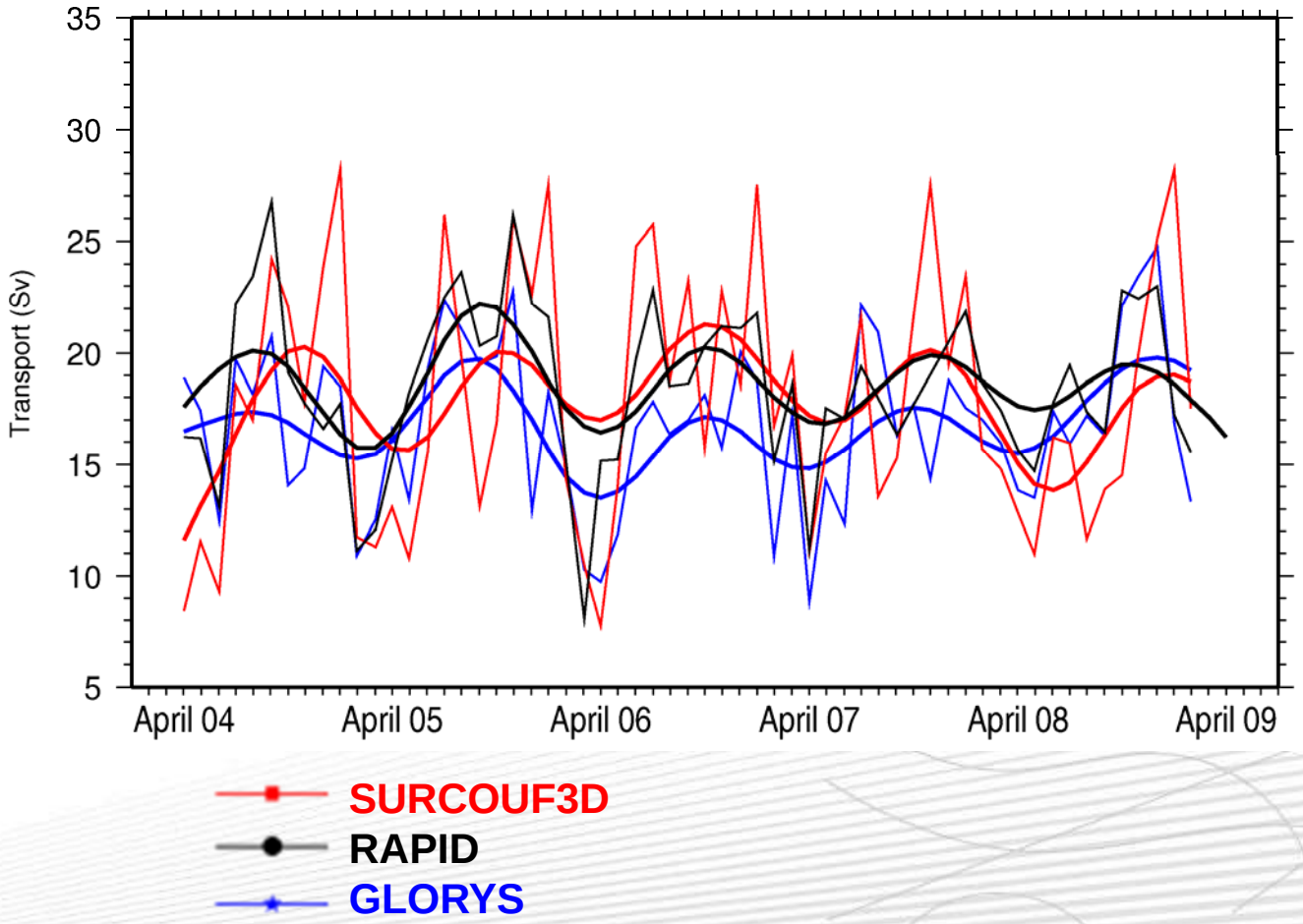
Ekman Transport from wind stress ERAInterim

Geostrophic Transport **from 75°W to 15°W** and **from the surface to 1000m** **(Surcouf3D, Bryden et al., 2005)**

➔Very consistent with Bryden et al, 2005
➔Hight inter-annual variability
➔Hard to distinguish a long-term trend

Surcouf3D - AMOC variability at 26.5°N

❑ Comparison with **RAPID** and **GLORYS** from April 2004 to April 2009
(monthly means + 12-month filtered)



➔ Similar seasonal cycle
➔ Amplitude differences ~ 10%

➔ Higher variability in Surcouf than in Glorys

➔To be updated with recent RAPID measurements

Application – Mesoscale Vertical motion

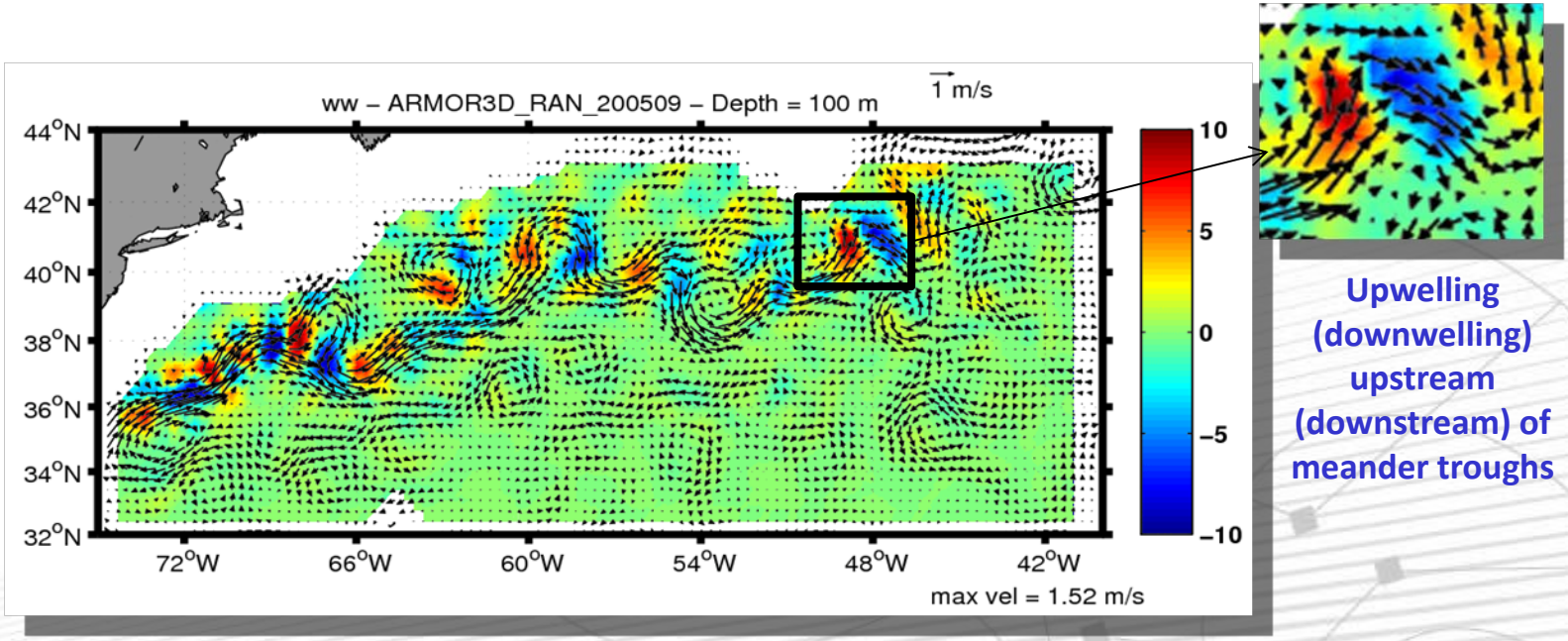
See Pascual et al. 2011 (poster OSTST)

3D fields
Horizontal geostrophic currents from SURCOUF3D

$$\nabla^2\left(N^2 w\right) + f^2 \frac{\partial^2 w}{\partial z^2} = 2\nabla \cdot \vec{Q}$$

$$\vec{Q} = \left[f\left(\frac{\partial V}{\partial x}\frac{\partial U}{\partial z} + \frac{\partial V}{\partial y}\frac{\partial V}{\partial z}\right), -f\left(\frac{\partial U}{\partial x}\frac{\partial U}{\partial z} + \frac{\partial U}{\partial y}\frac{\partial V}{\partial z}\right)\right]$$

QG vertical velocitiy reanalysis
1993-2009
Pilot zone: Gulf Stream



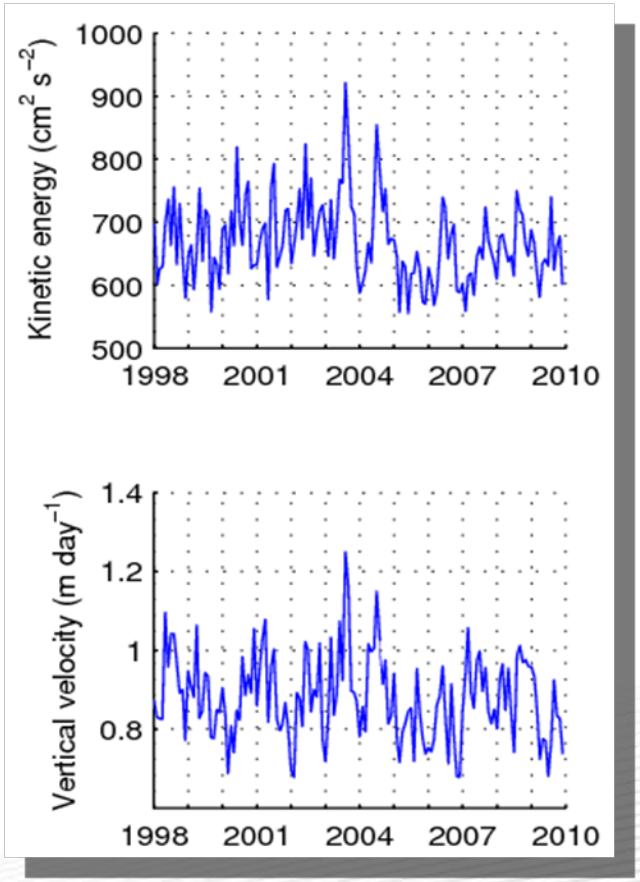
Upwelling (downwelling) upstream (downstream) of meander troughs

Vertical velocities of the order of ±10 m/day.
~100 times larger than linear Ekman pumping.

Application – Mesoscale Vertical motion

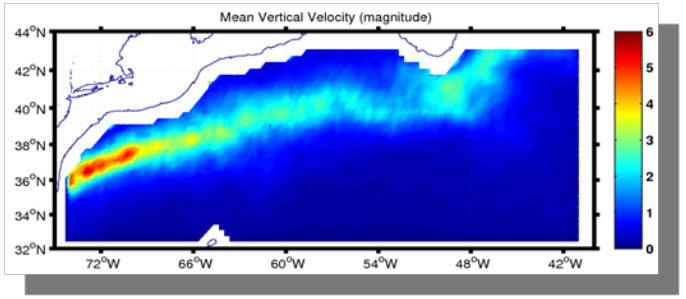
See Pascual et al. 2011 (poster OSTST)

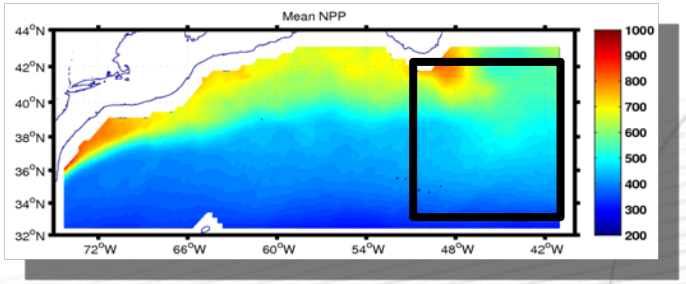
Spatial mean

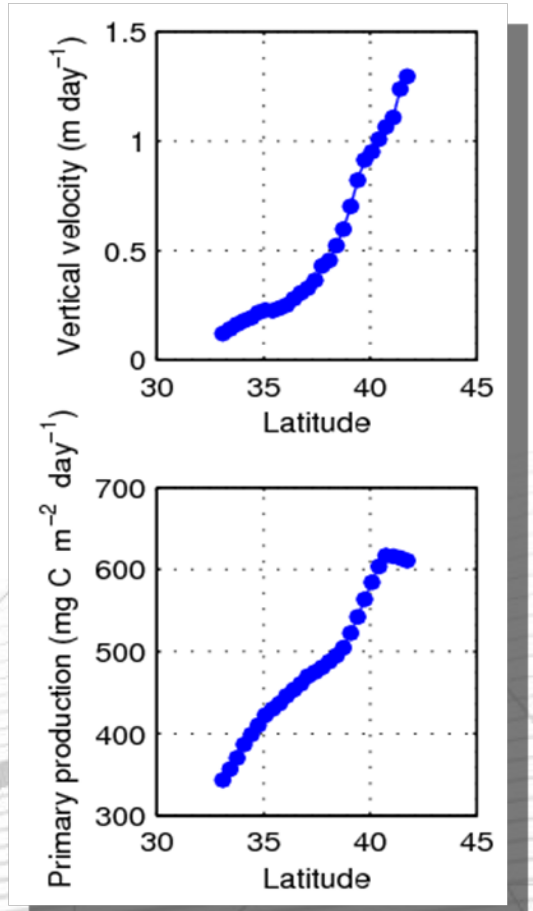


High temporal correlation between EKE and w (magnitude)

Time mean







High spatial correlation between w and NPP (black box)

Conclusions / Perspectives

- All available observations of the ocean (satellite observations as SLA, SST, geoid and in-situ observations as T/S profiles and drifting buoy velocities) are merged to produce weekly 3D maps of Temperature, Salinity, and horizontal velocities from the surface to 1500m depth.

- Armor3D/Surcouf3D reanalysis are distributed as part of the MyOcean project

  They are very useful :

  - to study the interannual variability of the hydrographic patterns, the AMOC …
  - to perform intercomparison exercices

  This will be continued in the future

- The relevance and accuracy of the Armor3D/Surcouf3D estimates depends strongly on the existence of a complete (satellite + in-situ), homogeneous, and sustainable observations system