Multi-parameter/multivariate techniques and diagnostic models for the retrieval of the 3D ageostrophic currents at mesoscale from combined satellite and in situ measurements

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Presented by

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GLOBCURRENT

2009 MyOcean CALL for R&D proposals

MEsoSCale dynamical Analysis through combined model, satellite and in situ data

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Main objective

MESCLA project (2010-2012) is focused on the estimation and analysis of the vertical exchanges associated to MESOSCALE DYNAMICS and of their interannual variability, concentrating on a

Three **key factors** are needed to correctly describe **mesoscale processes** (i.e. temperature, salinity, velocity fields) :

- **Sufficiently high horizontal resolution**
- **Knowledge of their vertical structure**
- **Proper dynamical framework (at least quasi-geostrophic approximation)**

Starting point of the study: The ARMOR3D/SURCOUF3D T/S/U/V fields produced at CLS

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Approach

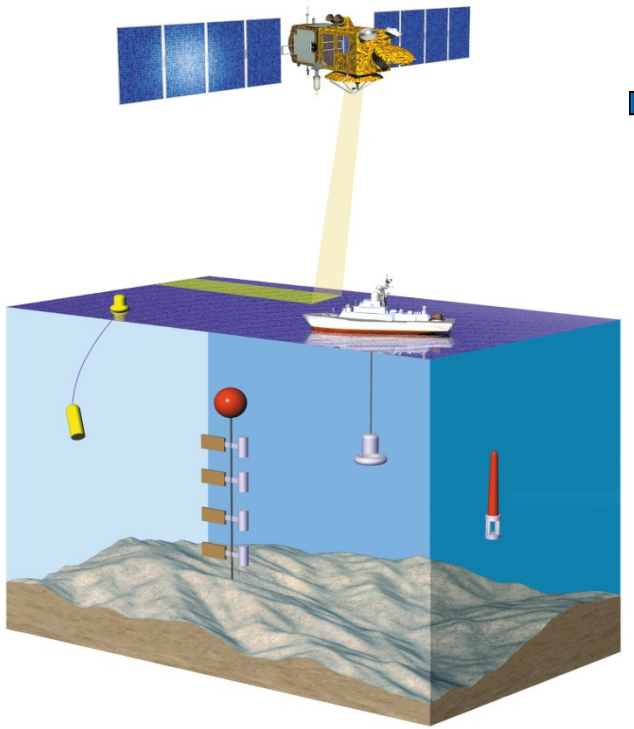
Global T/S ➔ Armor3D - Method

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

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)

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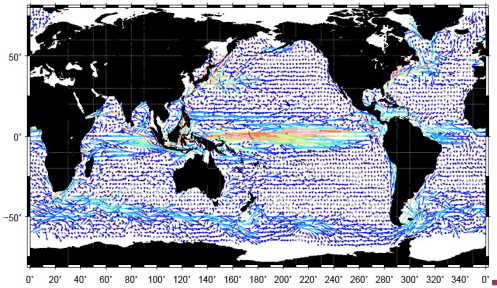
Guinehut et al, 2012

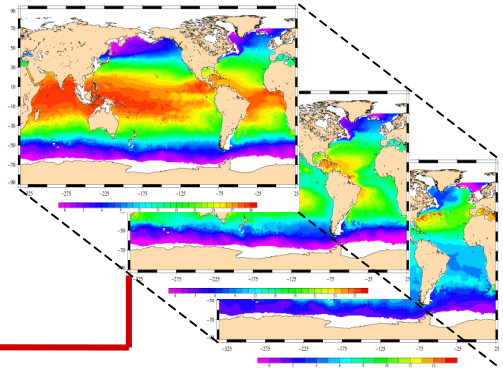
Approach

Global U/V ➔ Surcouf3D - Method

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

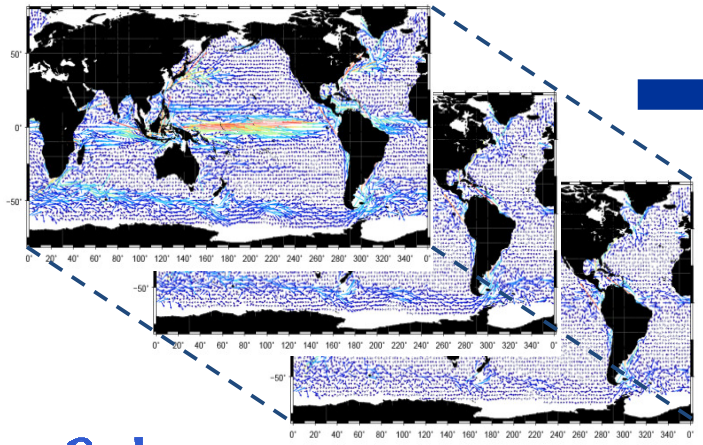


Armor3D :
3D T/S fields
weekly - 1/3° - [0-1500]m



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

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



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

Mulet et al, 2012

Approach

Which improvements within MESCLA?

•Improve existing observational 3D fields (ARMOR) by testing other multivariate extrapolation techniques, merging in situ and satellite data and improving the resolution

➢the development of new methodologies to interpolate in situ **sea surface salinity (SSS) at high resolution** (preliminary tests also on **ADT**)→CNR
Buongiorno Nardelli B., 2012: A novel approach to the high resolution interpolation of in situ Sea Surface Salinity, submitted to J. Atmos. Ocean. Tech.

➢the adaptation of the Myocean observation-based **ARMOR3D** (1/3°) processing chain to ingest **high resolution SST and SSS L4 products** (up to 1/10° res.)→CLS

➢the test of **mEOF-r methodology** for the retrieval of vertical profiles from surface data (Buongiorno Nardelli et al. 2006)→CNR
B.Buongiorno Nardelli et al., 2012: Towards high resolution mapping of 3D mesoscale dynamics from observations: preliminary comparison of retrieval techniques and models within MESCLA project, submitted to Oc. Sci. (special issue on Myocean Project)

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Approach

Which improvements within MESCLA?

•High resolution observation based 3D fields used to retrieve the vertical component of the ageostrophic flow through the quasi-geostrophic Omega equation →IMEDEA

High resolution 3D fields
Temperature
Salinity
Density

Q-vector formulation of the OMEGA equation

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

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

w → Vertical velocity
U, V → Horizontal geostrophic velocities

High resolution 3D velocity fields

TEST PERFORMED ON LIMITED DATABASE/AREA

NOT NECESSARILY GOING TO WORK

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Results

Multi-parameter high resolution interpolation of surface data

→HR SSS needed by new 3D reconstruction methods

→new product potentially useful in combination with SMOS data

Hypothesis:

high **correlation** between **sea surface temperature (SST)** and **sea surface salinity (SSS)** variations can be expected (in the open ocean) **at scales significantly smaller than the ones dominating atmospheric variability**

Proposed technique:

optimal interpolation (Bretherton-like) algorithm that includes satellite (spatially high-pass filtered) SST differences in the covariance estimation

$$\mathbf{x}_{analysis} = \mathbf{x}_{background} + \mathbf{C}(\mathbf{R}+\mathbf{C})^{-1}(\mathbf{y}_{obs} - \mathbf{x}_{background})$$

$$C(\Delta r, \Delta t, \Delta SST) = e^{\left(-\frac{\Delta t}{\tau}\right)^2} e^{\left(-\frac{\Delta r}{L}\right)^2} e^{\left(-\frac{\Delta SST_{filtered}}{T}\right)^2}$$

Covariance function parameters (i.e. spatial (L), temporal (τ) and thermal (T) decorrelation scales and spatial filtering) **determined empirically minimizing errors vs independent surface observations**

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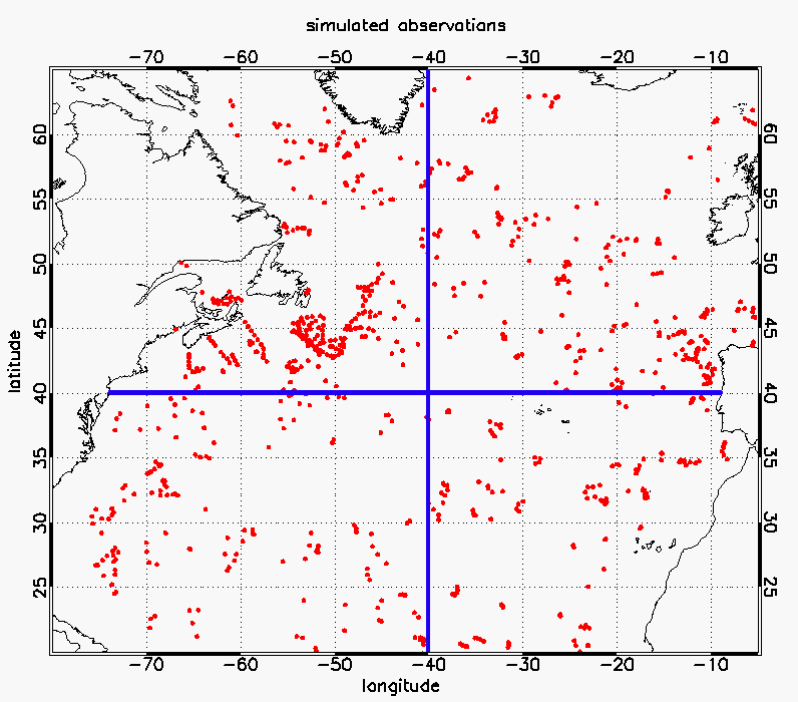
Results

Simulated Test datasets

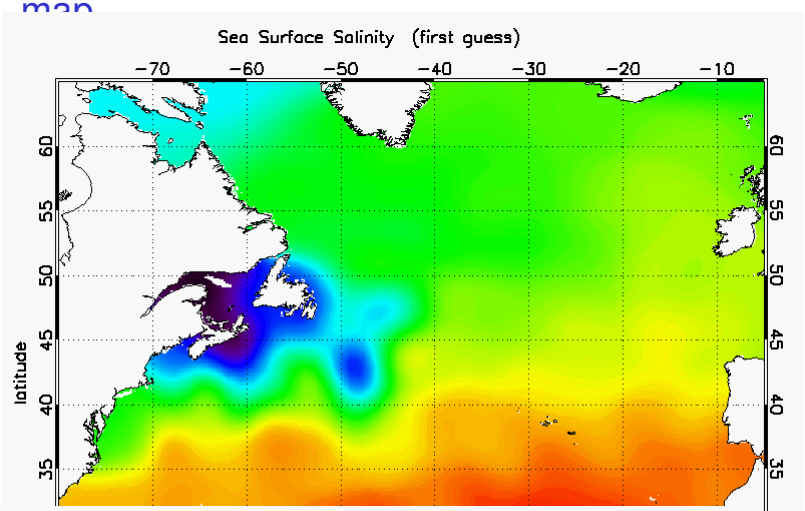


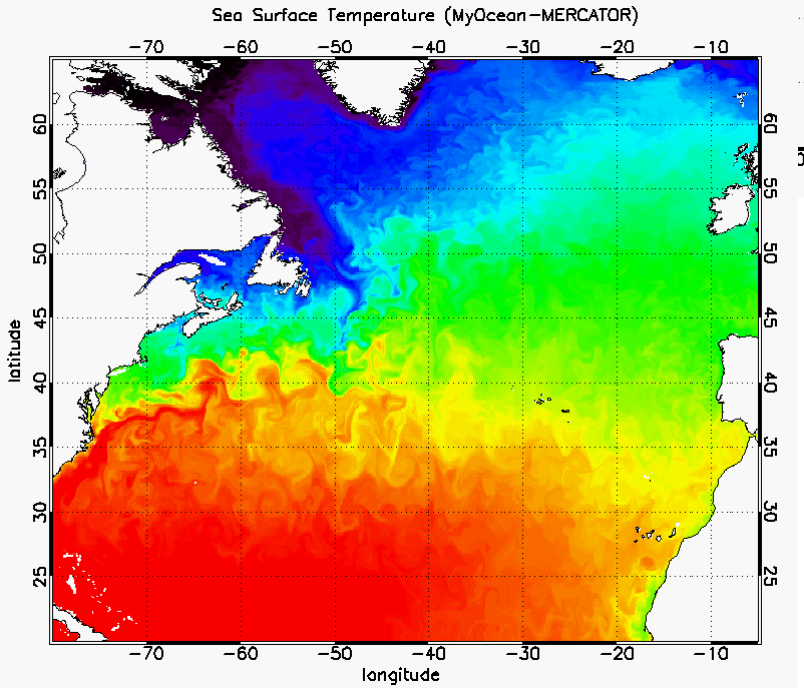
Red dots (input) 30 days window, centered on interpolation day→ **MERCATOR data resampled on INSITU profiles location (space/time)**

Blue dots (validation) (only for interpolation day)
MERCATOR DATA

Background SSS

Mono-parameter SSS objectively analyzed map





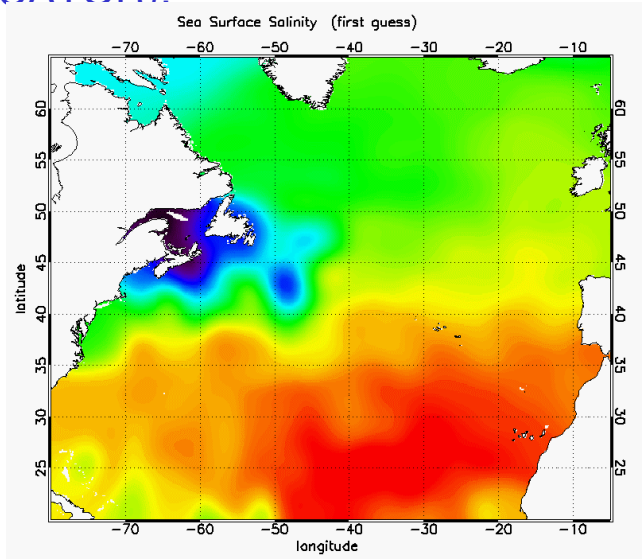
INPUT L4 SST (MERCATOR)

Results

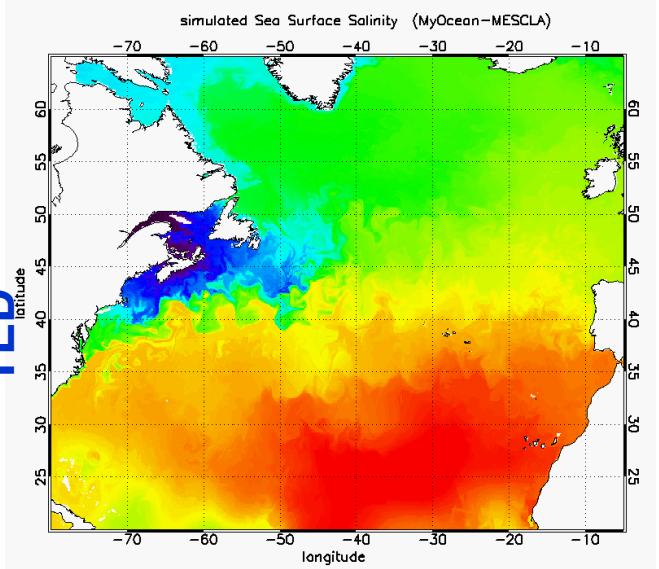
Qualitative and quantitative results:

Simulated MESCLA high resolution SSS field and derived **SSS gradient** reproduce most of the smaller scale structures visible in the simulated observations (MERCATOR).

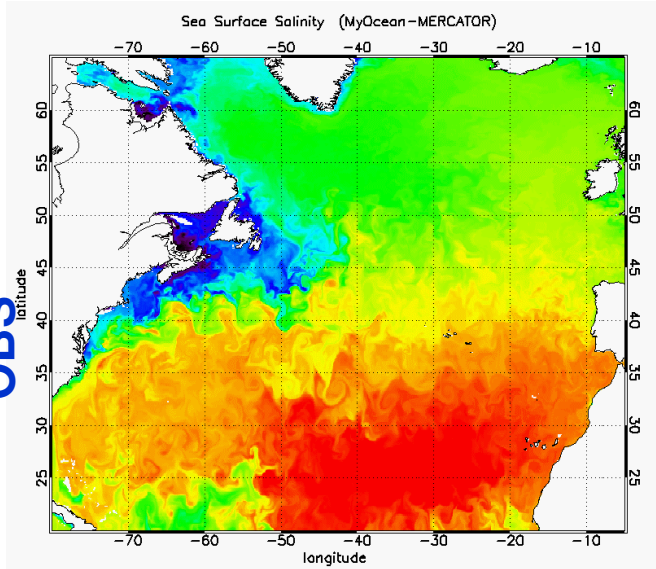
Standard OI



INTERPOLATED

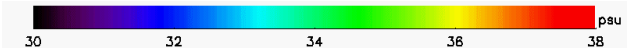


Simulated OBS



OI parameters:
L= 475km τ=10 days T=1.75 °C
signal-to-noise=0.3

HR SSS RMSE reduced to **<50%**
of background SSS RMSE in Gulf Stream area



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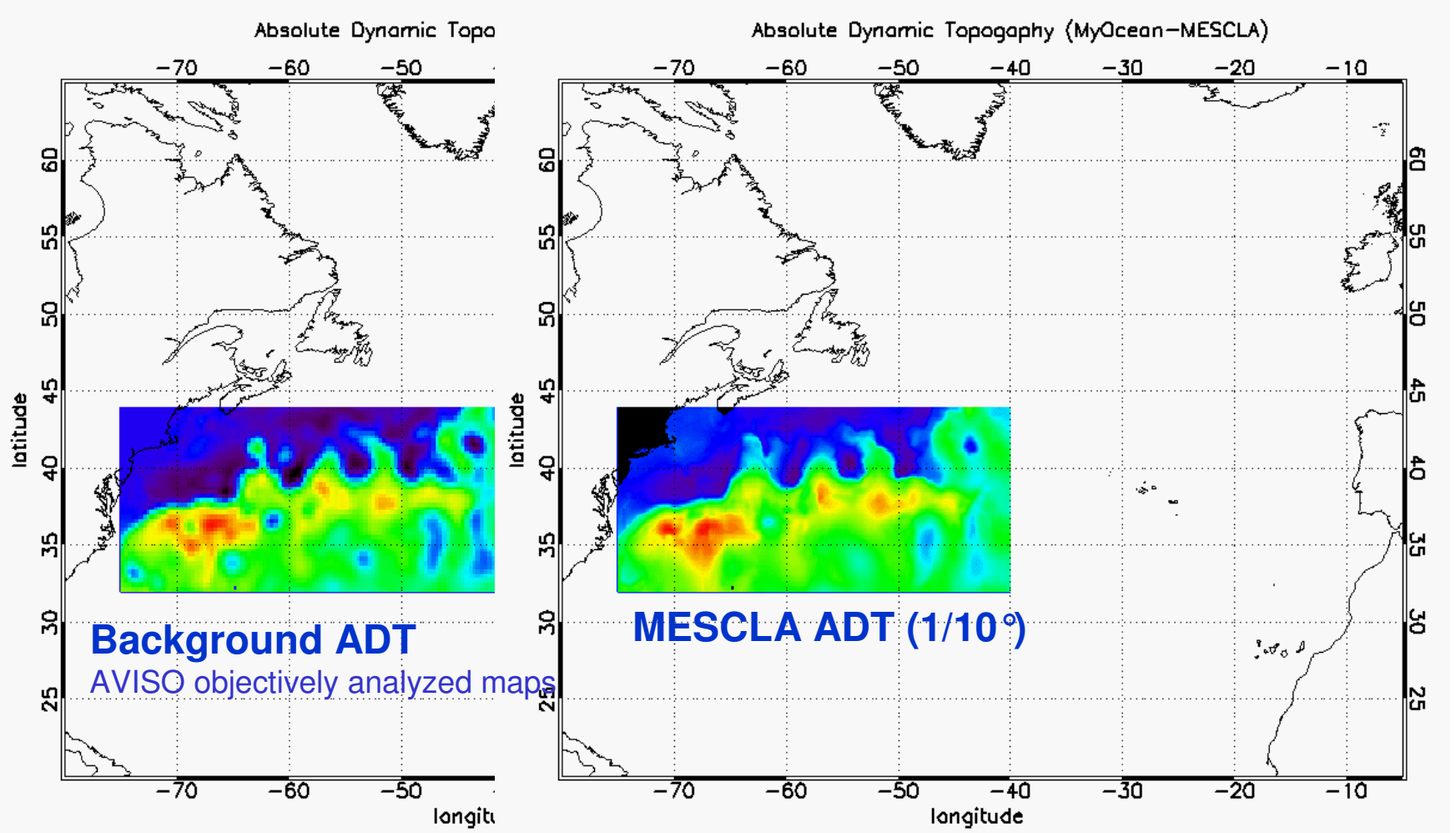
Results

Development of a high resolution Absolute Dynamic Topography (ADT) L4 product

- Same technique as for SSS
- now need to work on tuning/validation vs independent observations (i.e. using a reduced number of sensors) and/or GDR data

→ not possible to do it within MESCLA



Results

Increasing the resolution of 3D observation based products

Synthetic ARMOR3D

→ multiple linear regression T=T(z,SST, ADT); S=S (z,ADT)

adapted to HR SST L4 (here Odyssea, 1/10°)

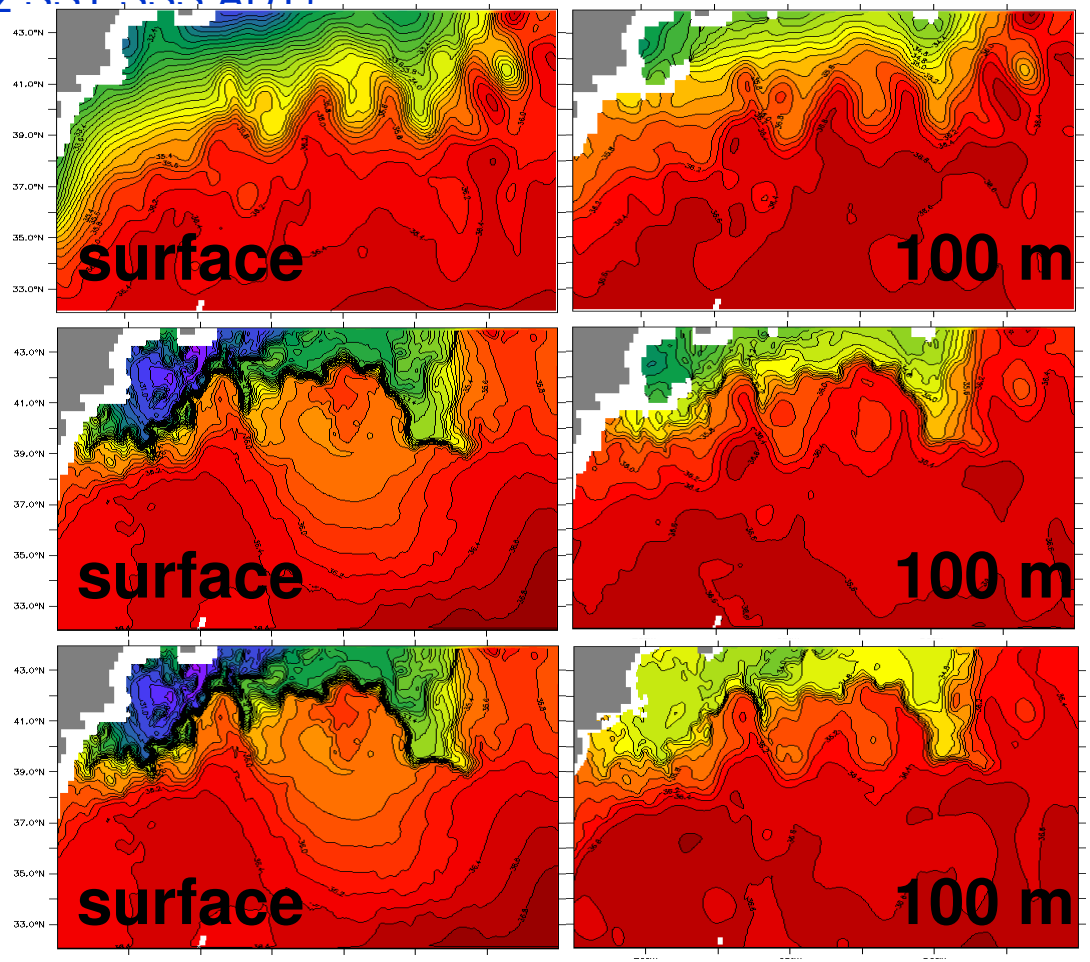
adapted to HR SSS L4 (MESCLA, 1/10°) → S=S(z,ADT,SSS)

MESCLA3D (1/10°)

→ multivariate EOF-reconstruction T=T(z,SST, SSS, ADT);

S=S(z,SST,SSS,ADT)

salinity



ARMOR3D
Reynolds 1/3°

Synthetic ARMOR3D
MESCLA SSS

mEOF-r
Odyssea + MESCLA SS

Results

Increasing the resolution of 3D observation based products

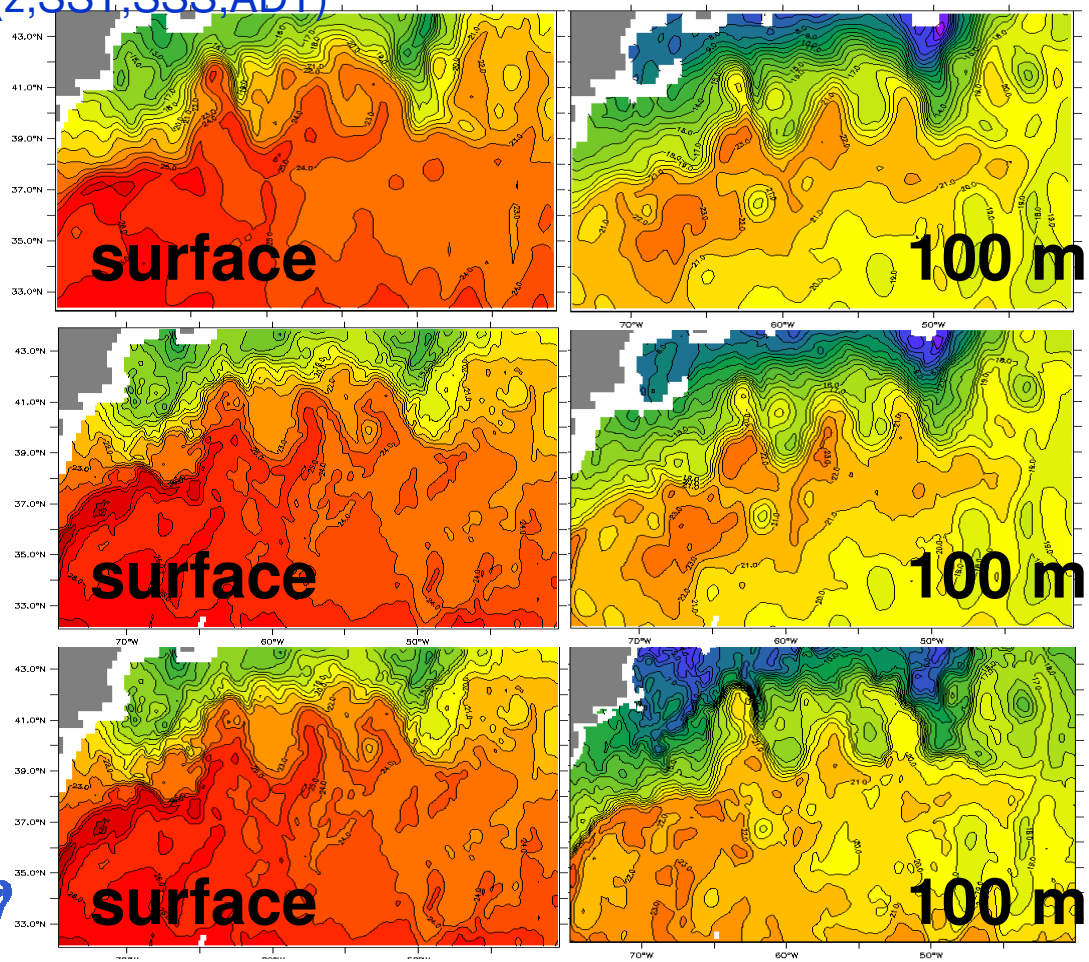
Synthetic ARMOR3D

→ multiple linear regression T=T(z,SST, ADT); S=S (z,ADT)
adpted to HR SST L4 (here Odyssea, 1/10°)
adapted to HR SSS L4 (MESCLA, 1/10°) → S=S(z,ADT,SSS)

MESCLA3D (1/10°)

→ multivariate EOF-reconstruction T=T(z,SST, SSS, ADT); S=S(z,SST,SSS,ADT)

temperature



ARMOR3D
Reynolds 1/3°

Synthetic ARMOR3D
Odyssea

mEOF-r
Odyssea + MESCLA SS

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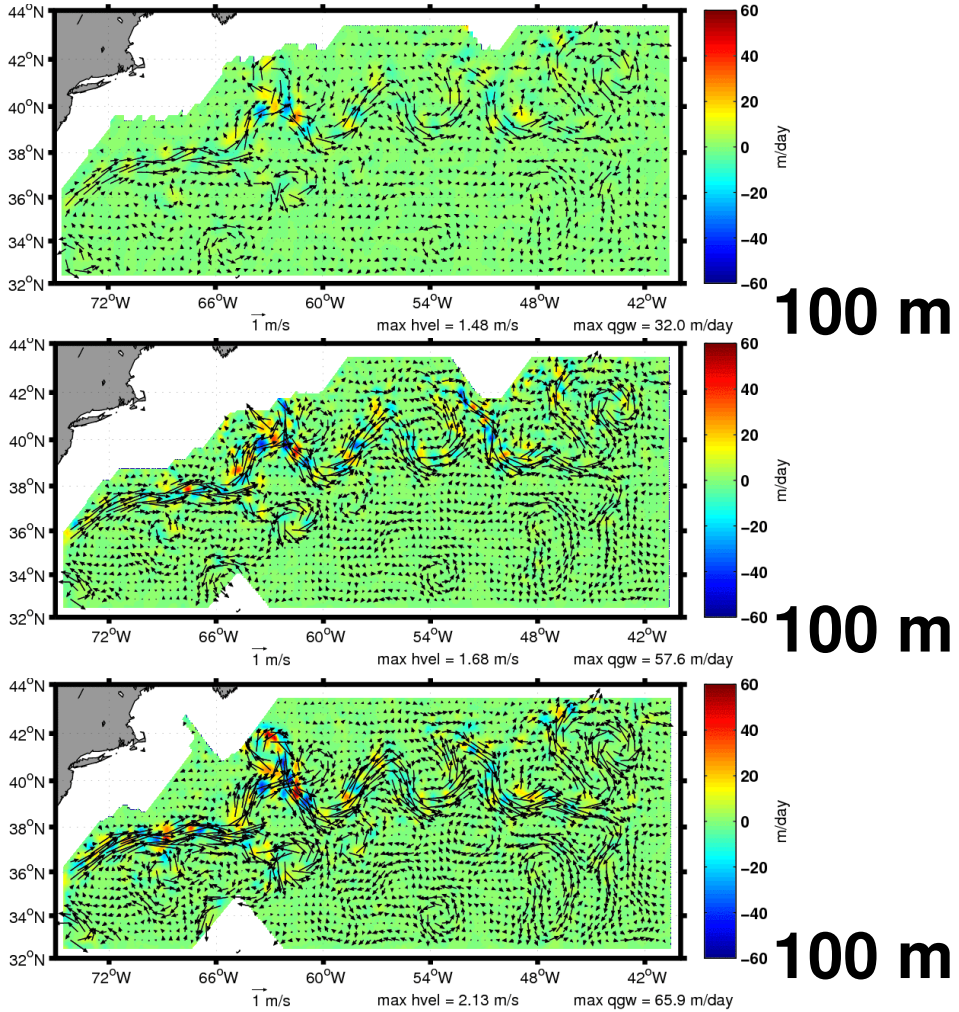
Results

Increasing the resolution of 3D observation based products

- The **quasi-geostrophic omega equation** has been applied to the **synthetic ARMOR3D** and to the **MESCLA experimental products**:

→ stronger vertical exchanges are estimated as resolution is increased and more advanced extrapolation techniques are used

QG vertical velocity



100 m

100 m

100 m

ARMOR3D
Reynolds 1/3°

Synthetic ARMOR3D
Odyssea + MESCLA SS

mEOF-r
Odyssea + MESCLA SS

MESCLA Conclusions

MESCLA project showed that:

- Multi-parameter/multivariate techniques can be used to increase the horizontal resolution of sparse in situ (and perhaps altimeter) observations

- Multivariate techniques allow to retrieve 3D structure from surface data

- Quasi-geostrophic diagnostic equations can be used to describe mesoscale dynamics beyond geostrophic balance

- Not shown: A semi-geostrophic diagnostic model has now been implemented. Significant improvements of the vertical velocity estimates are obtained compared to the quasi-geostrophic approximation.

- TESTS PERFORMED ON LIMITED DATASETS

- TUNING/CALIBRATION/VALIDATION FOR OTHER AREAS NEEDED

- NOT G
OBSERVATIONAL LIMITS

Is there any interest to apply some of these techniques in the framework of GlobCurrent?

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