On the inversion of sub-mesoscale information to correct mesoscale velocity

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May 4, 2011

Prerequisites

Altimetry

Data Assimilation

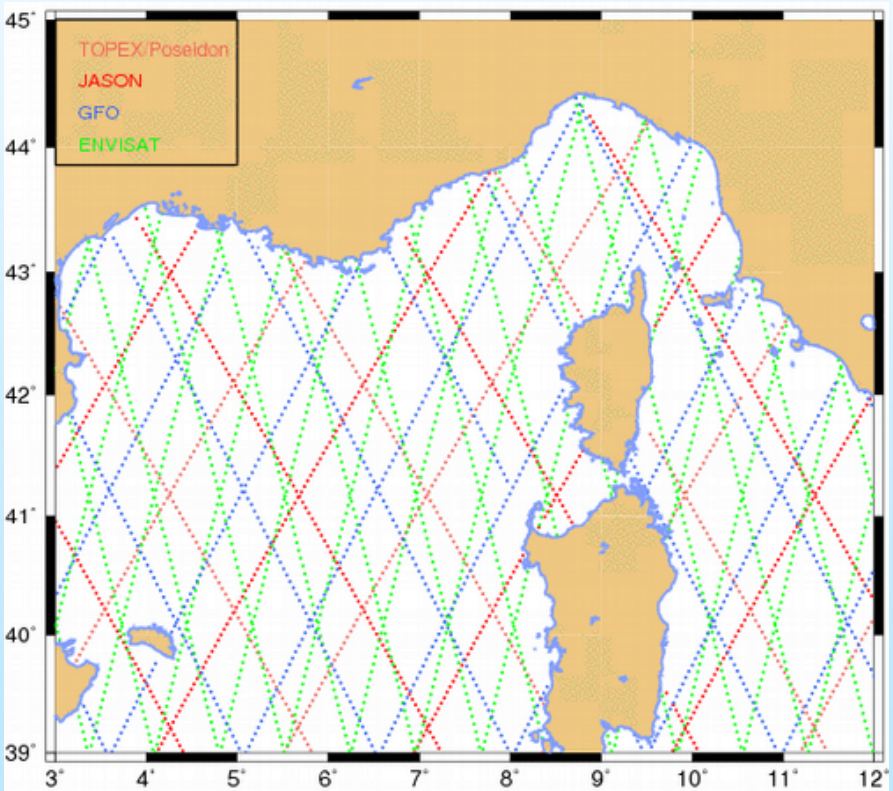
Sub-mesoscale

Tracer

Prerequisites

Altimetry

Altimetry :
- Measure of sea surface height along track
- Geostrophic velocity derived from ssh gradients
- Data: e.g. AVISO (interpolated maps, velocity, ssh)



Prerequisites

Altimetry

Data Assimilation

Data Assimilation aims at finding an optimal compromise between information of different natures, space and time sampling.
The sources are generally some observations (satellite, in-situ) and a numerical model.

Sub-mesoscale

Tracer

Prerequisites

Altimetry

Data Assimilation

Sub-mesoscale

Sub-mesoscale: intermediate scale between Mesoscale and dissipative scales. Energetic and Dynamic importance have been recently brought to light (Capet & al, 2008, Thomas & al, 2008, Klein & al, 2008)

Tracer

Prerequisites

Altimetry

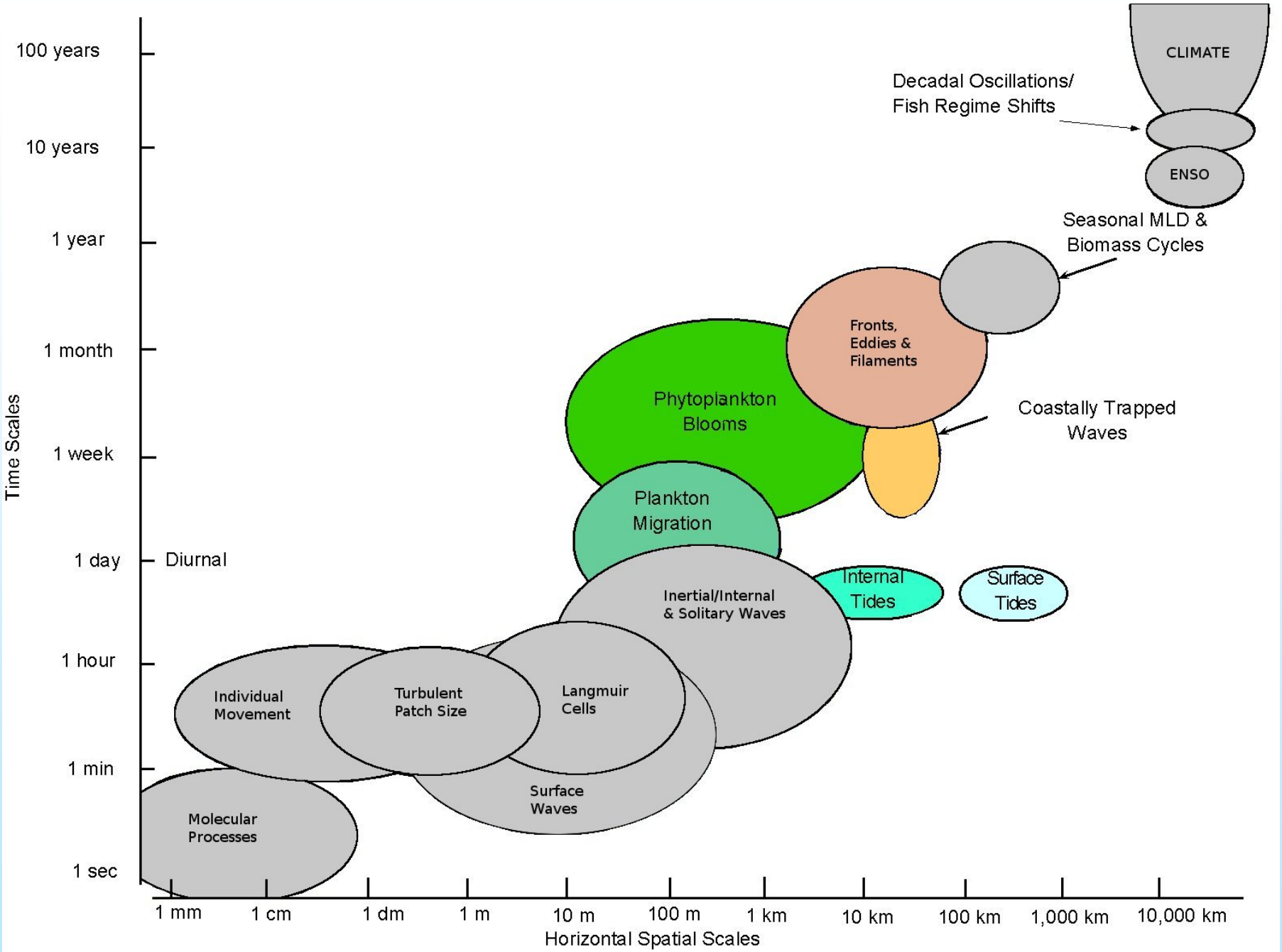
Data Assimilation

Sub-mesoscale

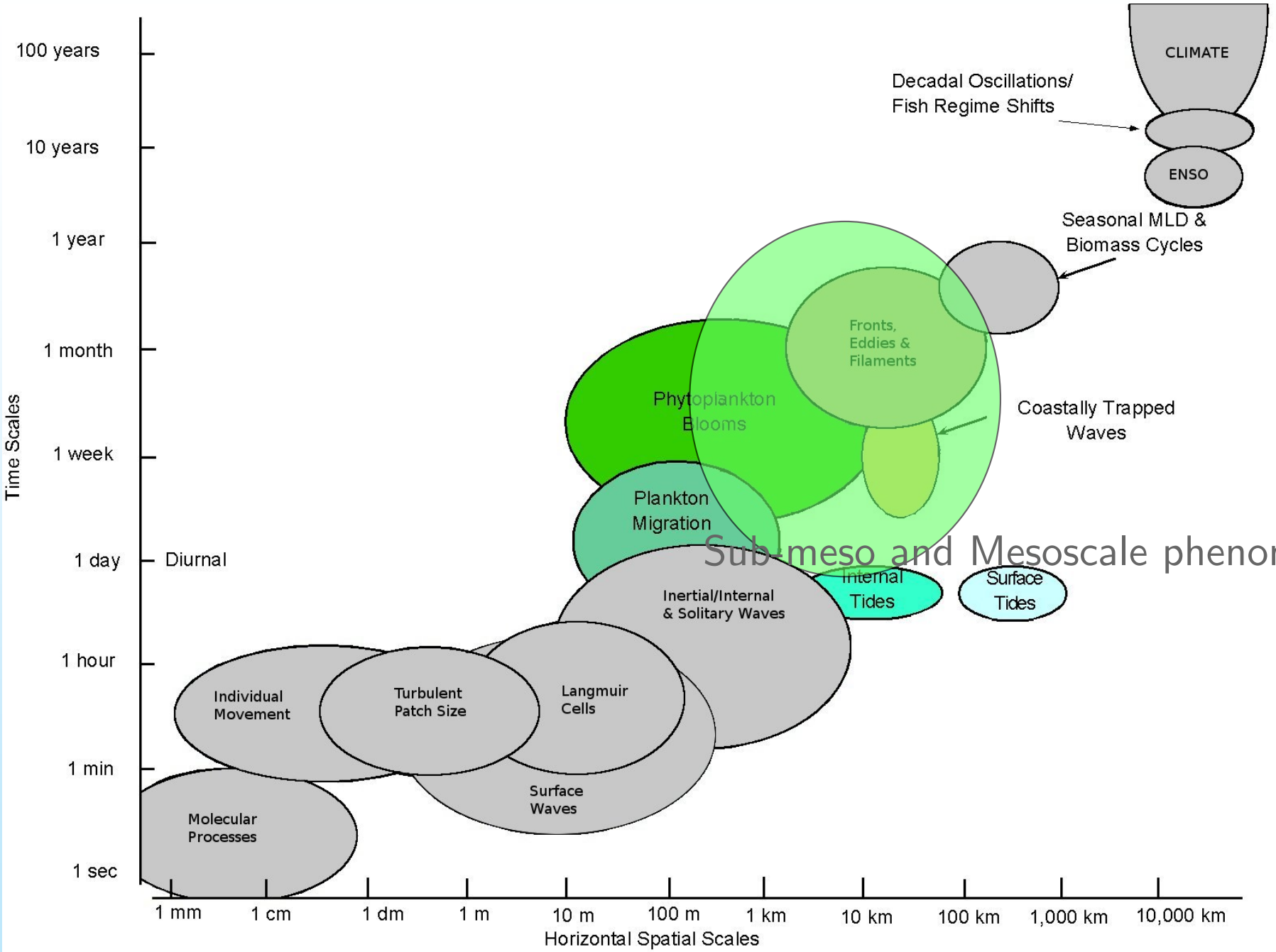
Tracer

We are interested in tracers visible from space:
Sea Surface Temperature
Ocean Color: Chlorophyll

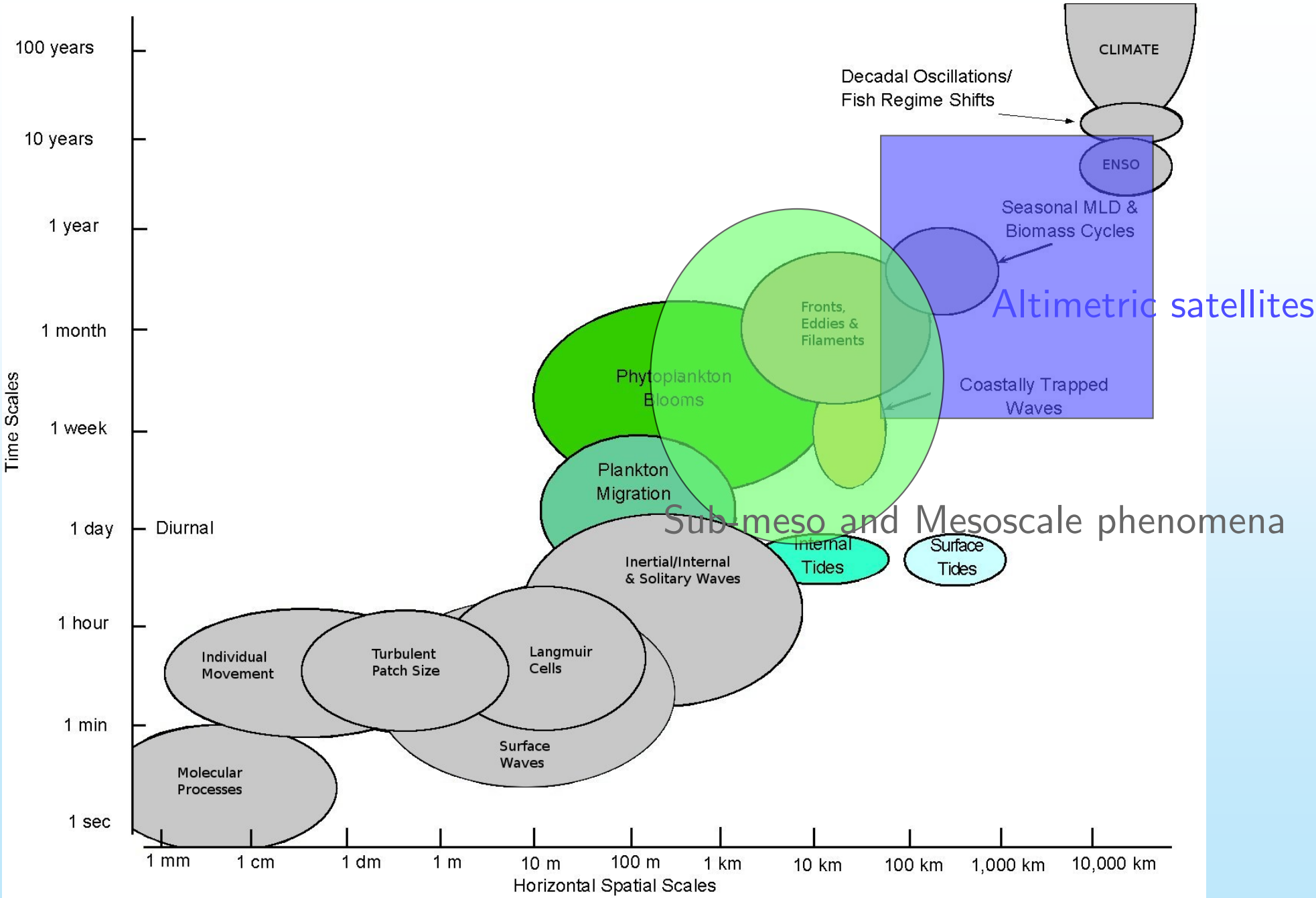
Mesoscale and sub-mesoscale dynamics



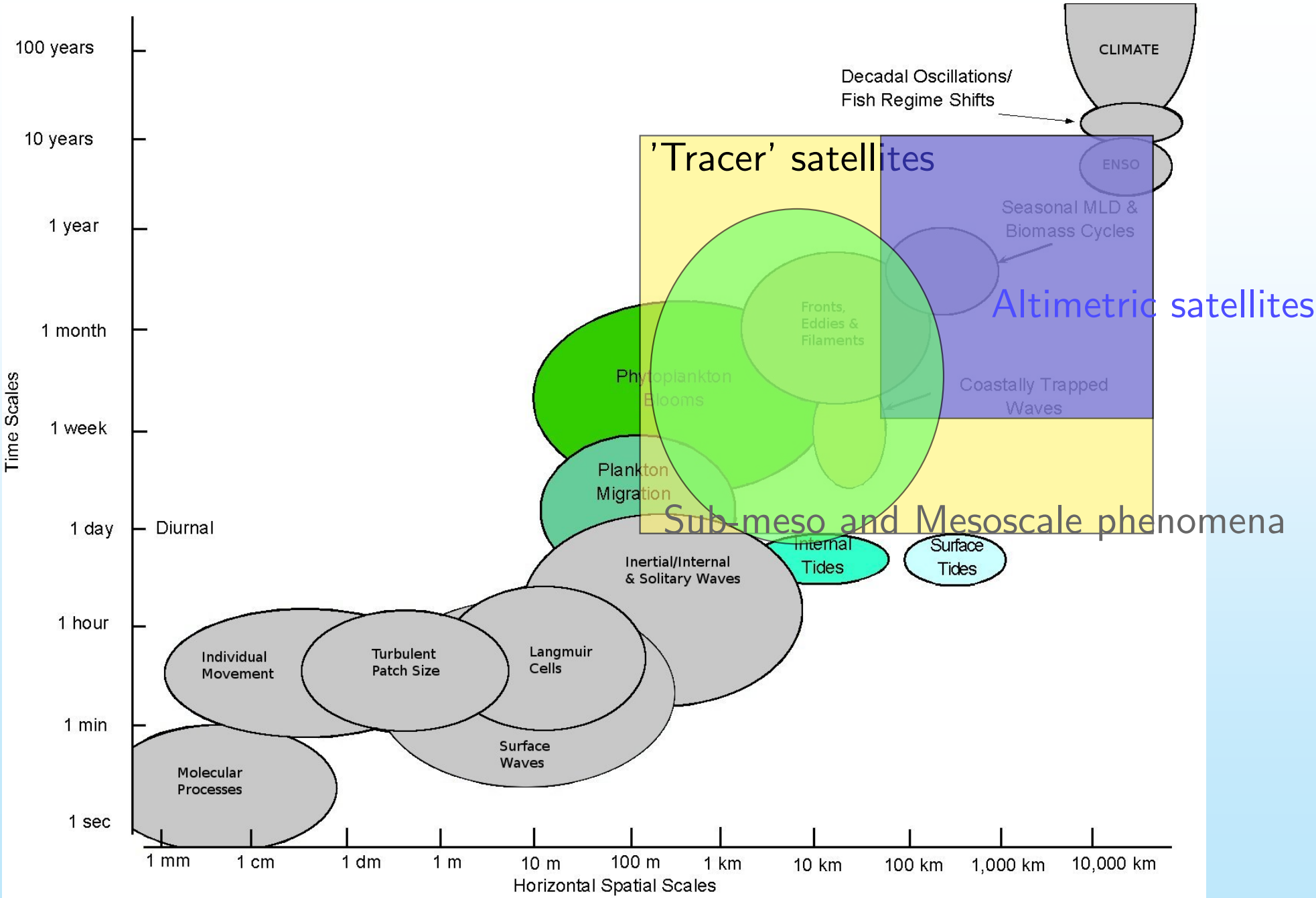
Mesoscale and sub-mesoscale dynamics



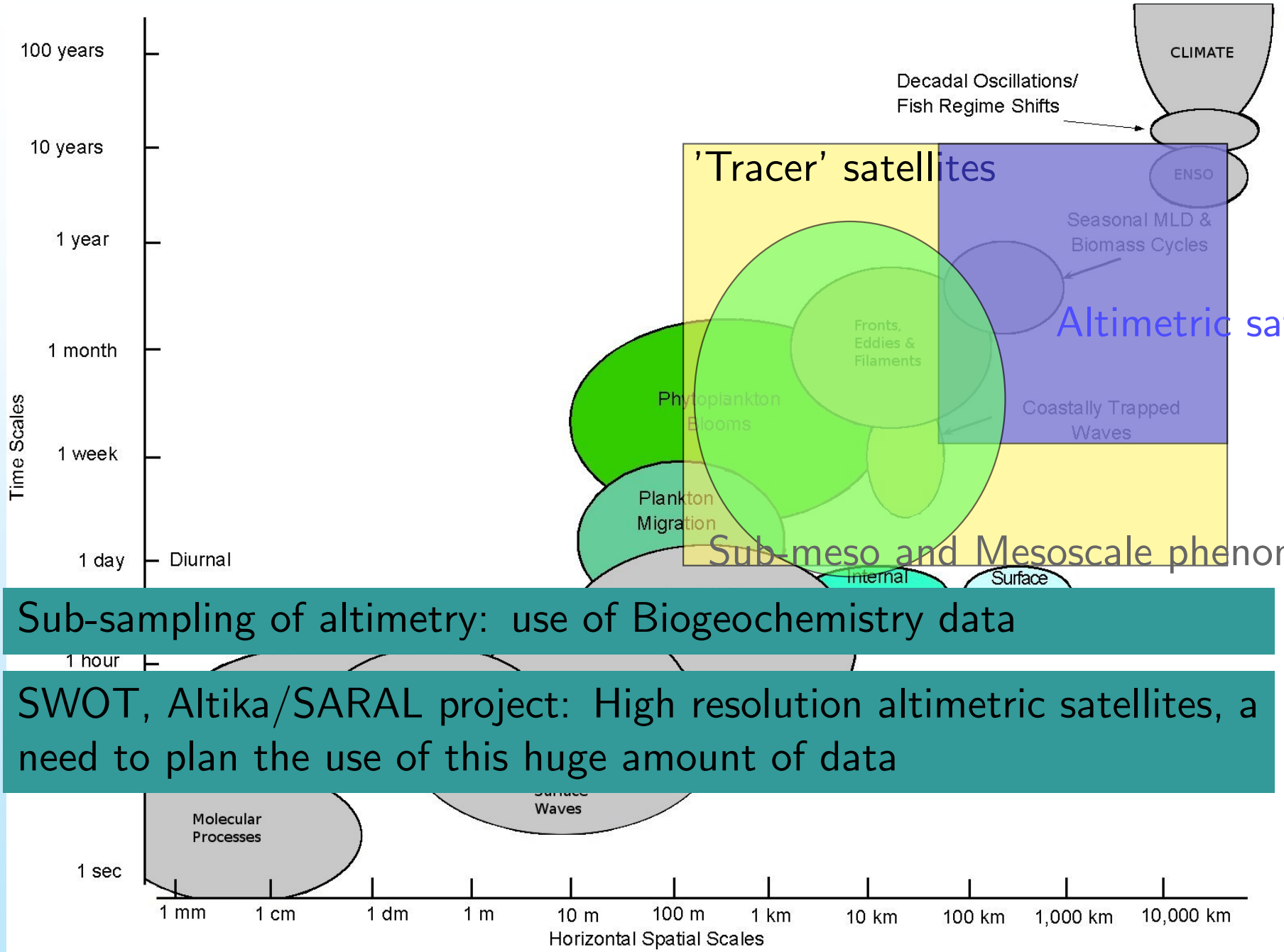
Mesoscale and sub-mesoscale dynamics



Mesoscale and sub-mesoscale dynamics



Mesoscale and sub-mesoscale dynamics



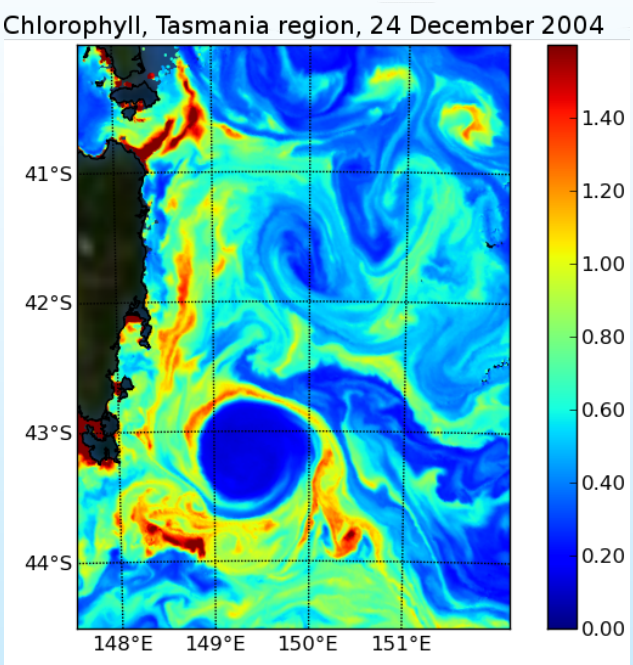
Sub-sampling of altimetry: use of Biogeochemistry data

SWOT, Altika/SARAL project: High resolution altimetric satellites, a need to plan the use of this huge amount of data

Outline

Philosophy of the study

Sub-mesoscale tracer image



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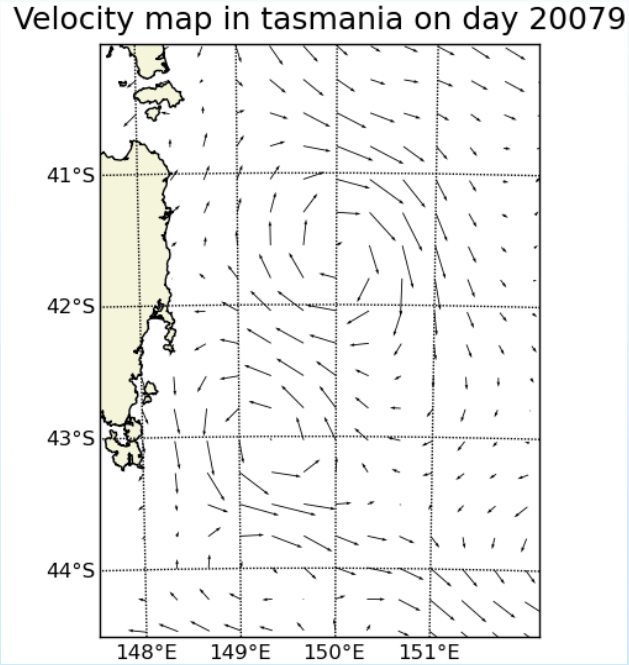
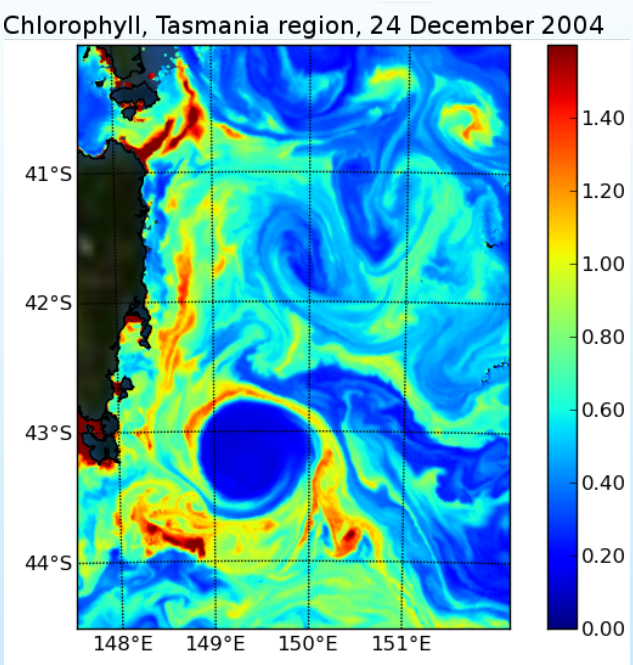
Mesoscale field



Philosophy of the study

Sub-mesoscale tracer image



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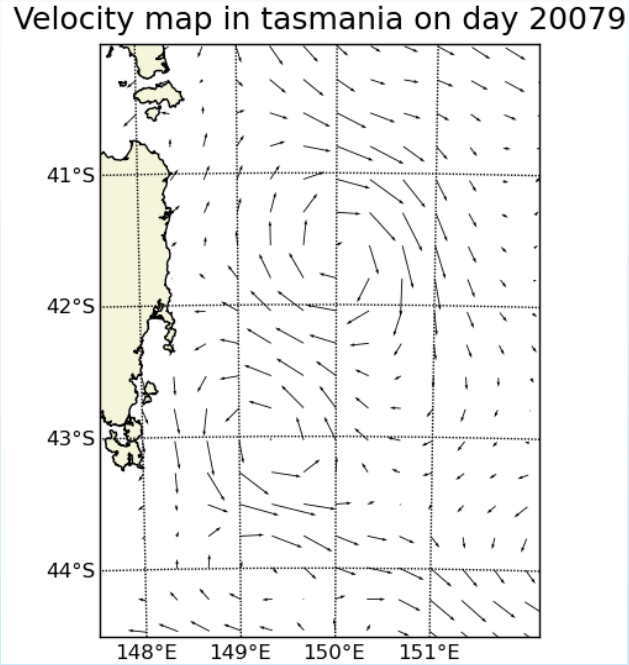
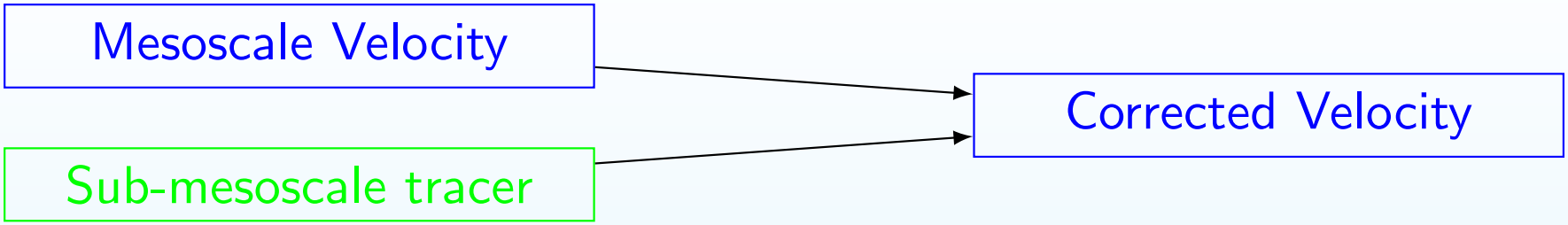
Mesoscale field



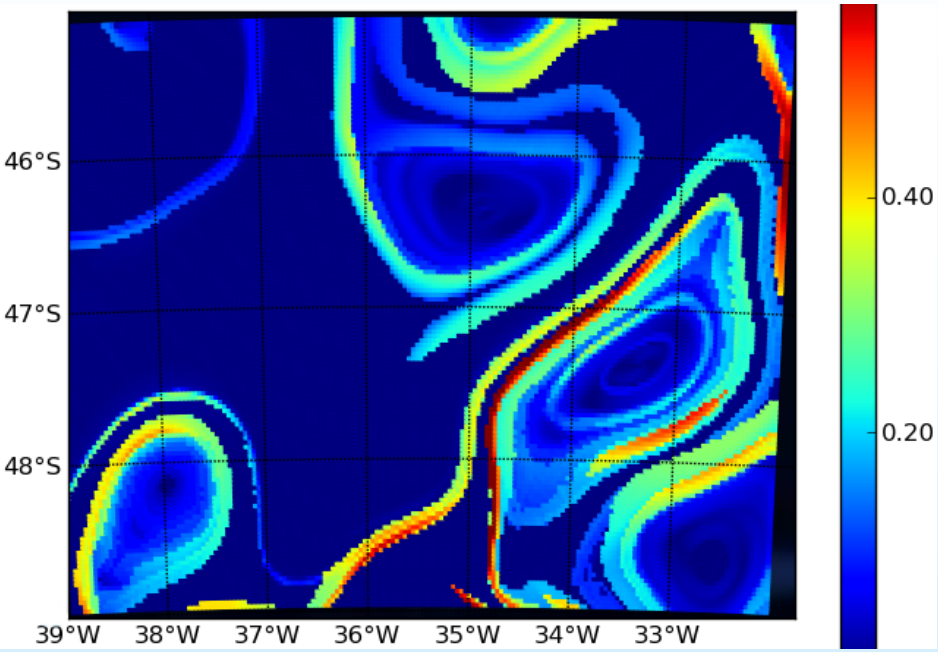
The inversion of sub-mesoscale tracer information to correct mesoscale velocity has never been done before



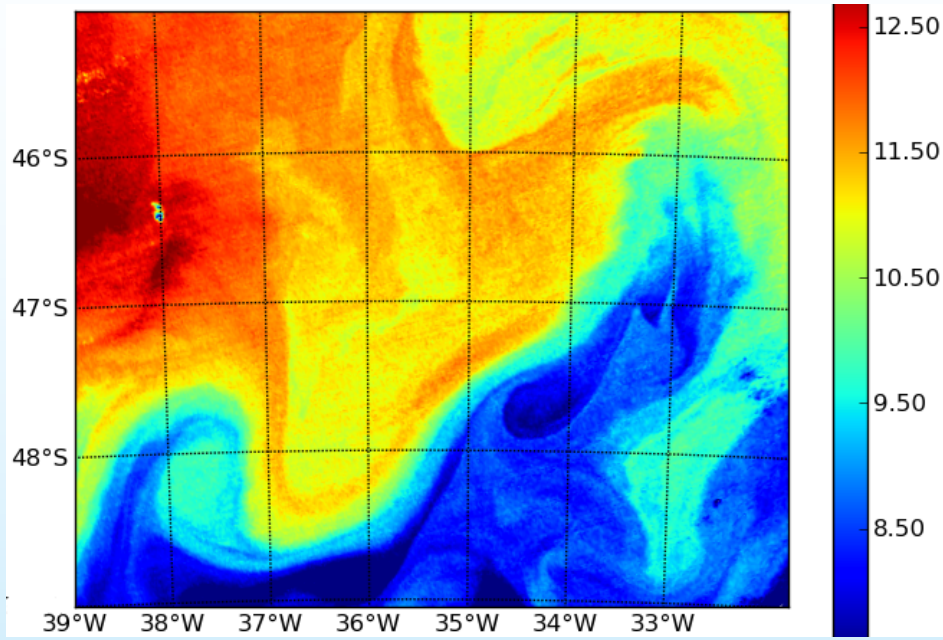
Find the correction of this background the most compatible with tracer information

- The direct measure of the distance between $\vec{\mathbf{u}}$ and **Tracer** is not possible
- Need to find a go-between variable
- Use of Finite-Size Lyapunov Exponents as a proxy (FSLE)

Are Lyapunov exponents a reliable proxy/image?



FSLE, South Atlantic region, December 27, 2006



Tracer (SST), South Atlantic region, December 27, 2006

Lyapunov measures stirring in a fluid
→ Link between sub-mesoscale dynamics and biologic stirring.
(Lehahn & al, 2008, d'Ovidio & al, 2004)

Methodology

- Cost function:

$$J(u) = \|\lambda(u) - \lambda_{obs}\| + \textit{background term}$$

The cost function is strongly non linear, with many local minima.

- Explore sub-space of errors to find the velocity that minimizes the cost function.

Velocity panel using Principal Component Analysis with all velocity fields available:

$$\mathbf{u}_k = \bar{\mathbf{u}} + \sum_{i=0}^{n} \underbrace{a_k^i}_{Eigenvalue} \underbrace{\mathbf{u}^i}_{EOF}$$

The number of degrees of freedom is reduced, using only 100 or less EOFs.

An exploratory study

- **Step 1**: Is FSLE the right proxy for this study?

  Inversion of synthetic sub-mesoscale images to larger scale ocean circulation (twin experiment approach)

- **Step 2**: Link real information with sub-mesoscale proxy

  Inversion of sub-mesoscale tracer to larger scale ocean circulation

Choice of a Study area

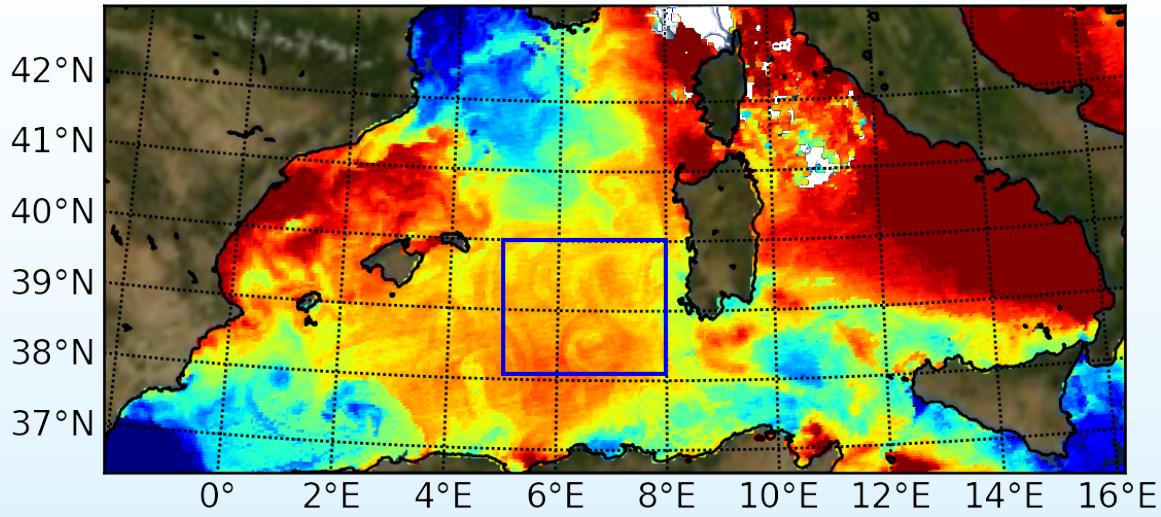
Required by a tracer

- Low cloud cover: Visible and Near IR wavelengths do not go through clouds
- Strong filament signature

Needed by FSLE

- Being far from any coast : Computing problems with particules advection in the presence of land
- Being far from any upwelling or downwelling

Test case : Mediterranean Sea

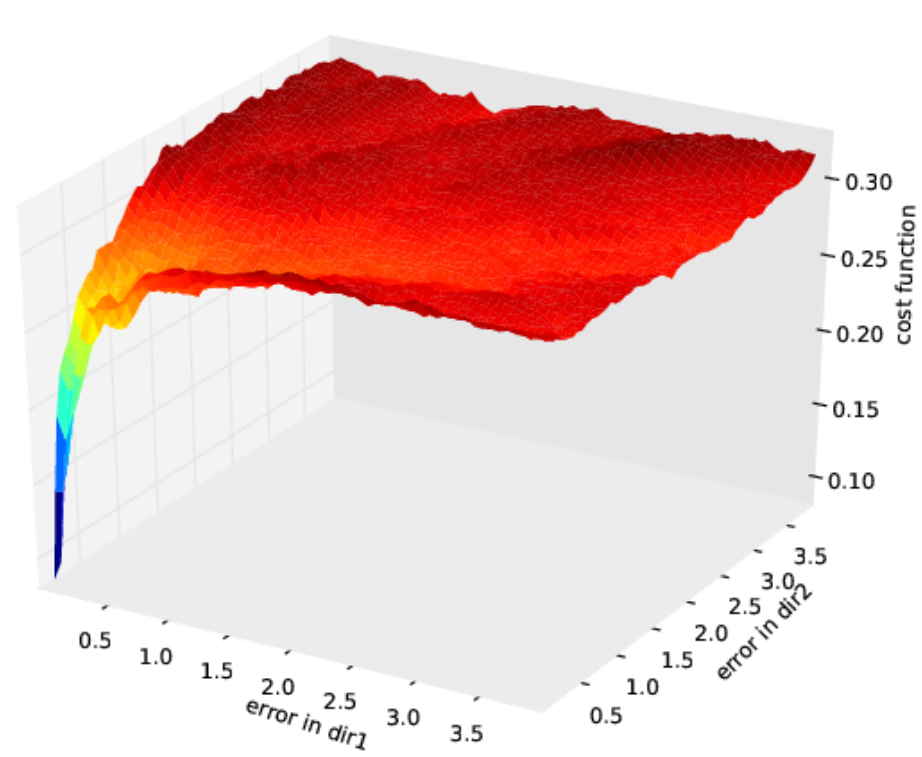


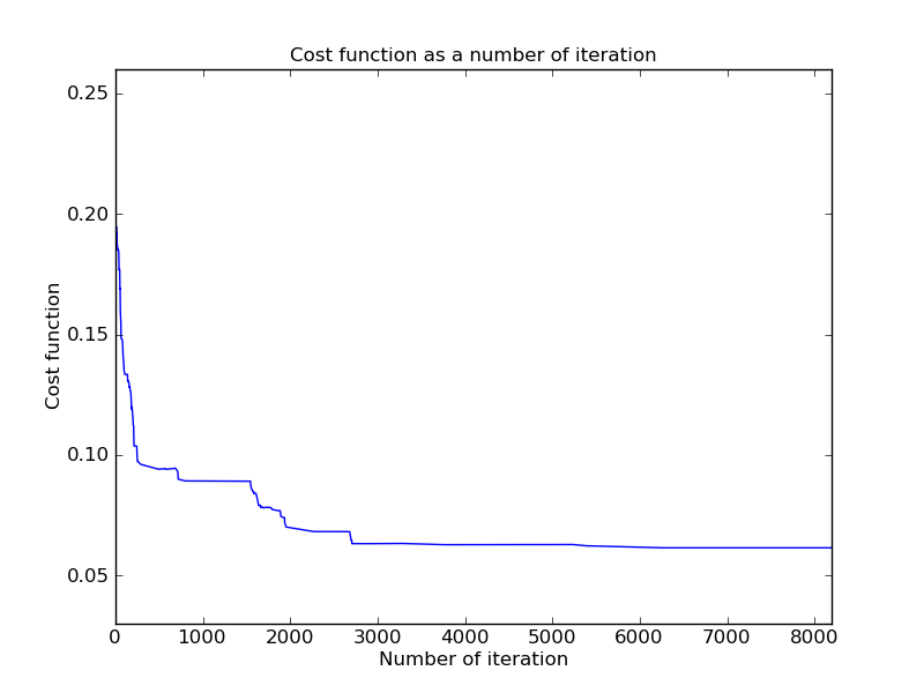
- **Time Range**: from 1998 to June 2009, 595 velocity maps
- **Velocity fields**: AVISO, altimetric data
- **Resolution**: 1/8°, grid points: 26*17
- **FSLE Resolution**: 1/48°, grid points: 119*86

- **Tracer field**: SST data from MODIS captor, L2 product
- **Resolution needed to detect filament**: 1/100°

Study of the cost function: Inversion of FSLE

STEP 1

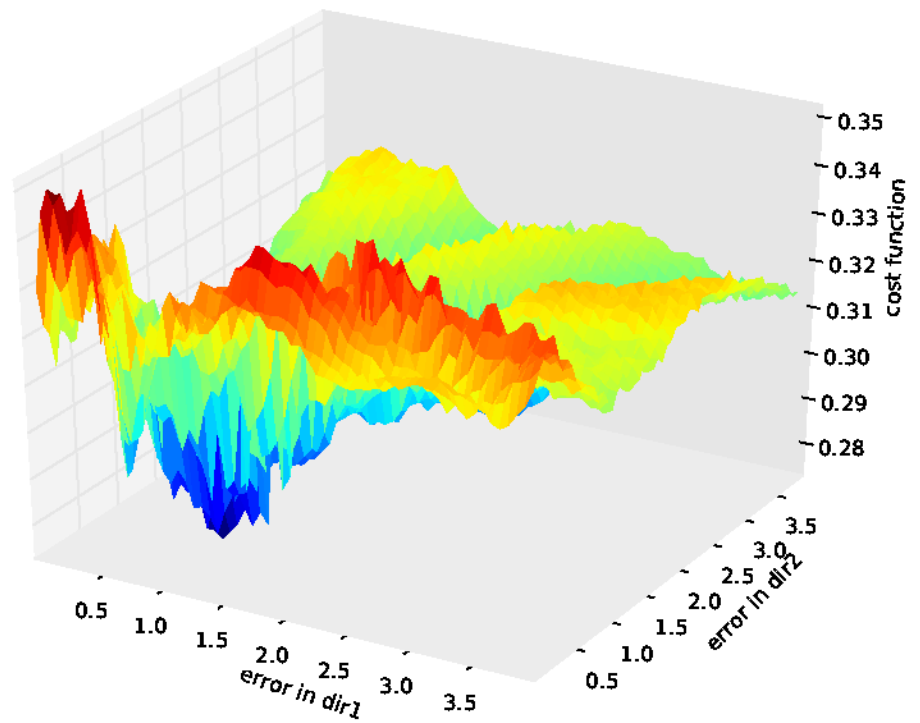


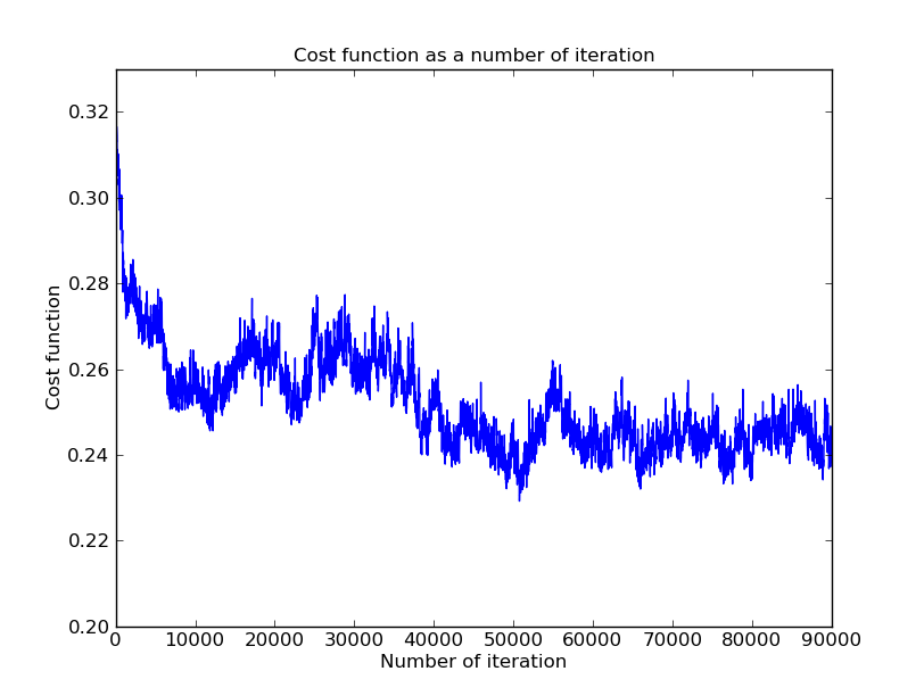


Cost function: $J(u) = \|\lambda(u) - \lambda_{obs}\| + \textit{background term}$

Study of the cost function: Full inversion

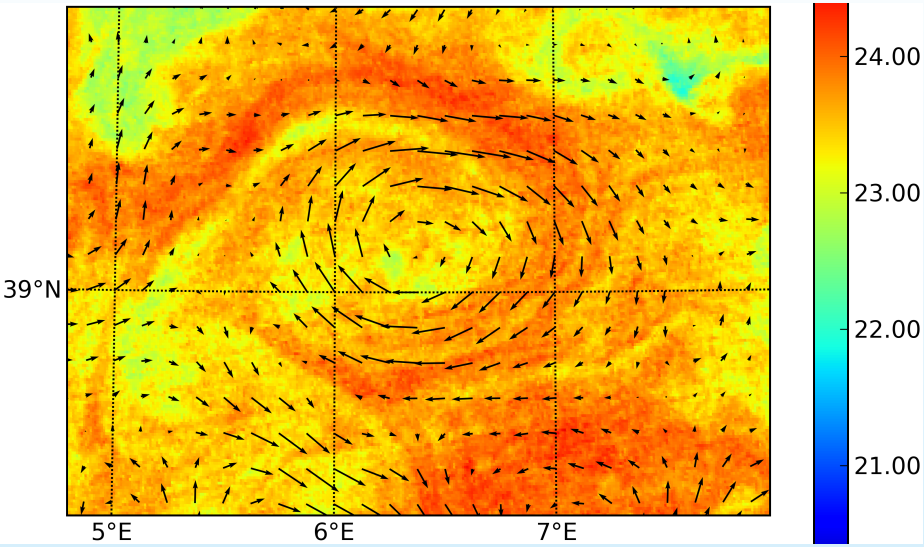
STEP 2



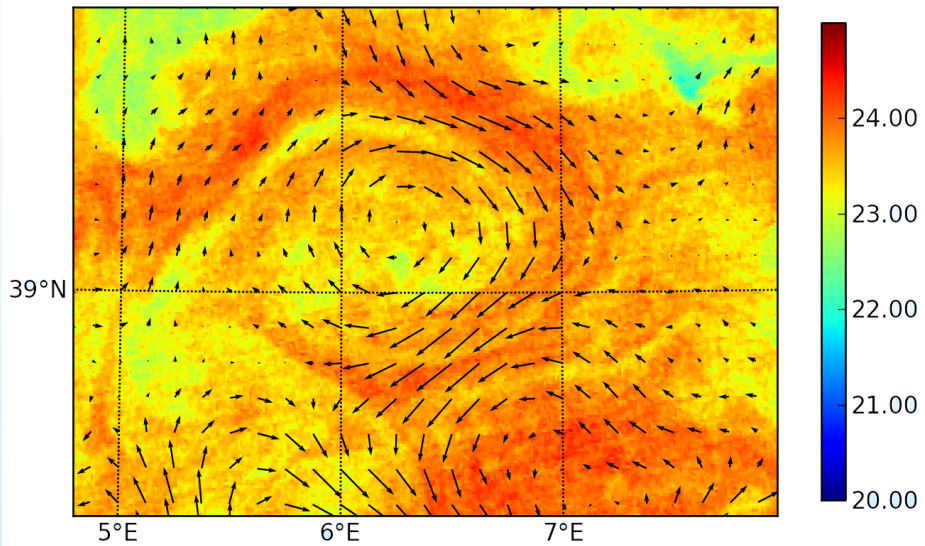


Cost function: $J(u) = \|\lambda(u) - \lambda_{obs}\| + \textit{background term}$

Results: correction on velocity

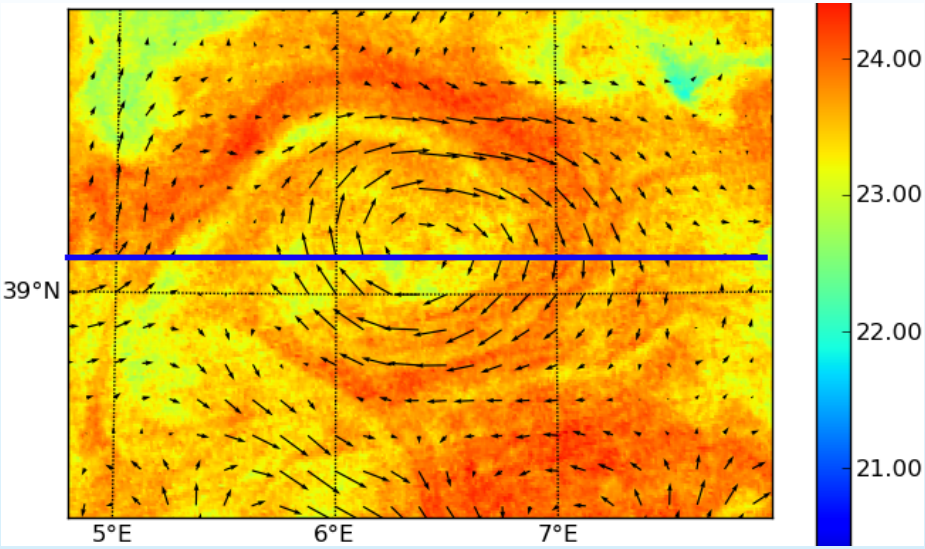


Aviso velocity and Tracer (SST), cost function: 0.33



Corrected velocity and Tracer (SST), cost function: 0.23

Results: correction on velocity



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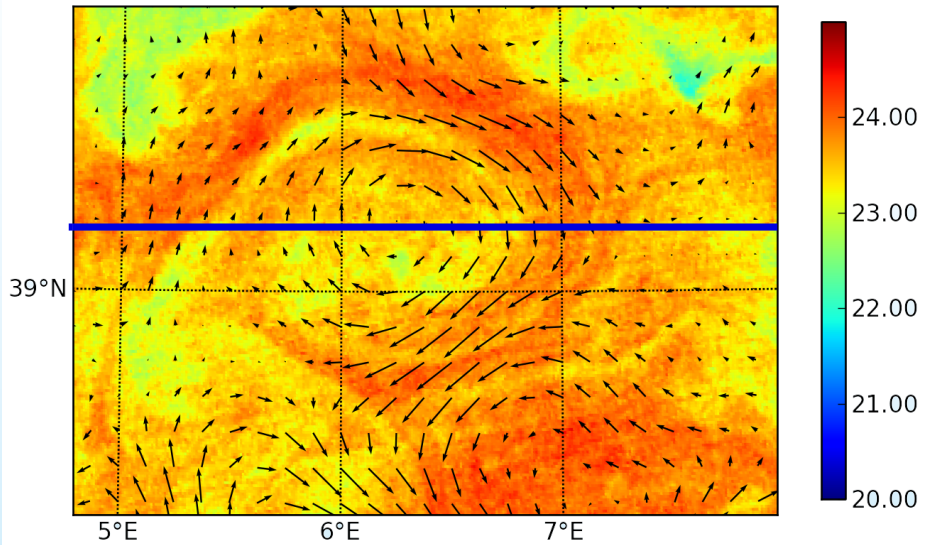
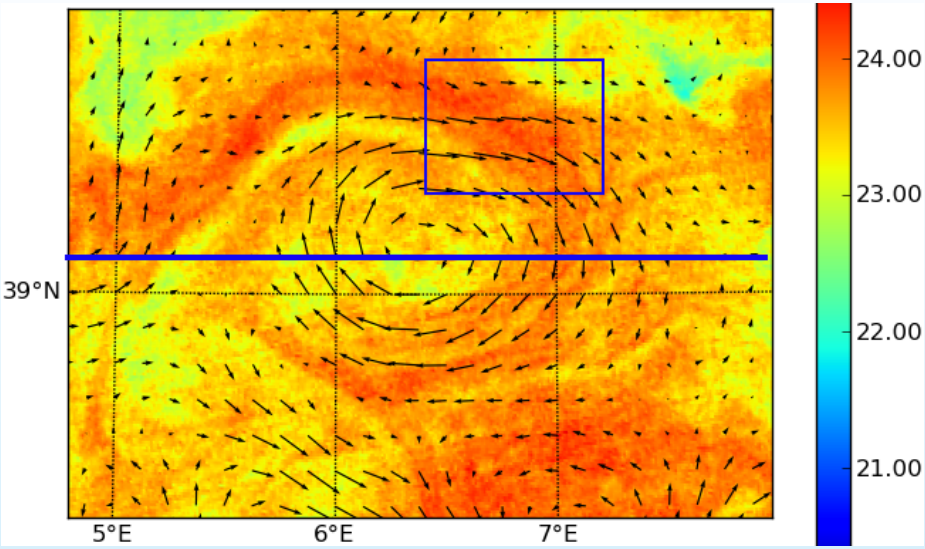


Corrected velocity and Tracer (SST), cost function: 0.23

- Gyre moved upward
-

Results: correction on velocity



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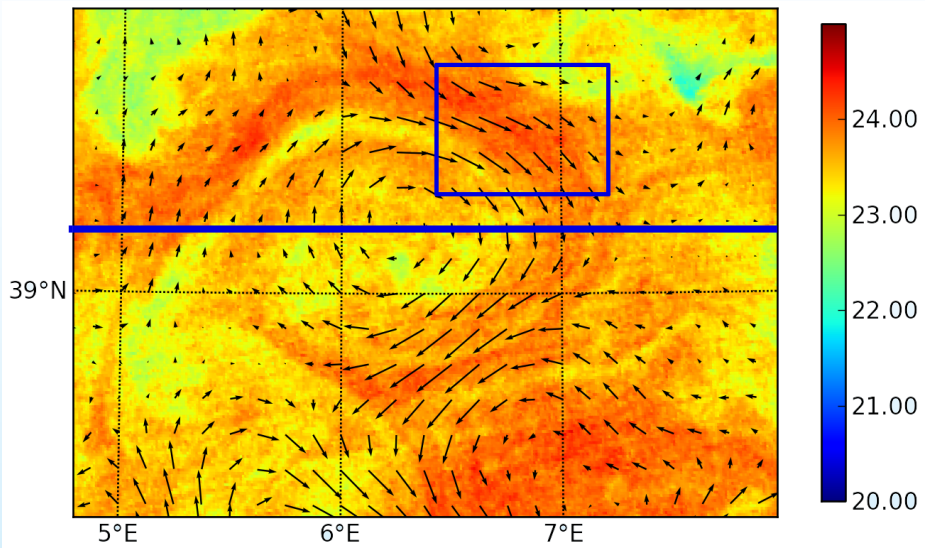
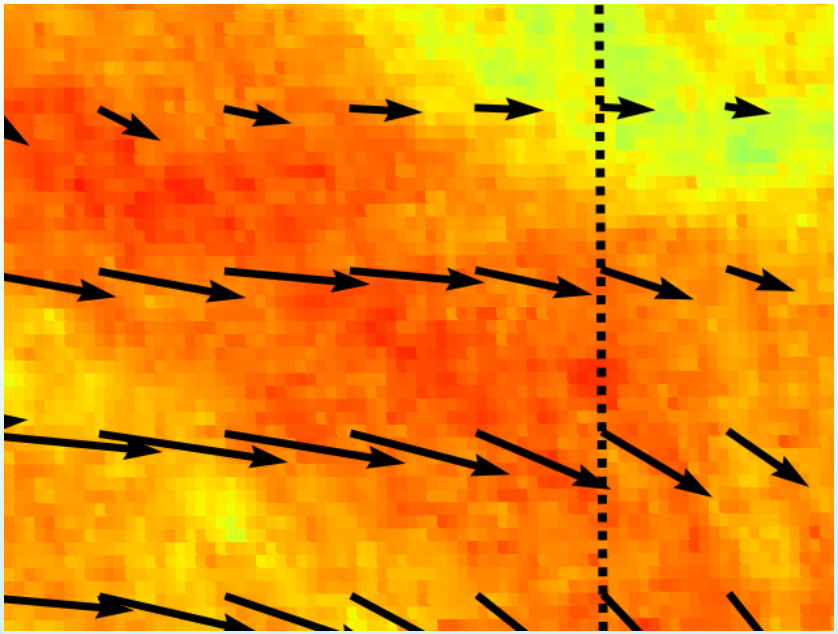


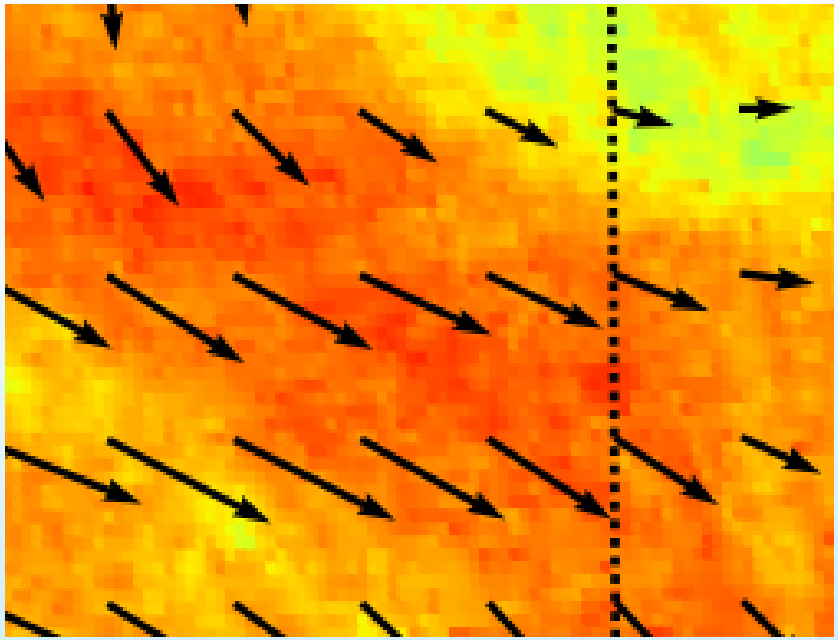
Corrected velocity and SST,
cost function: 0.23

- Gyre moved upward
- Velocity strengthen in the south East of the picture
-

Results: correction on velocity



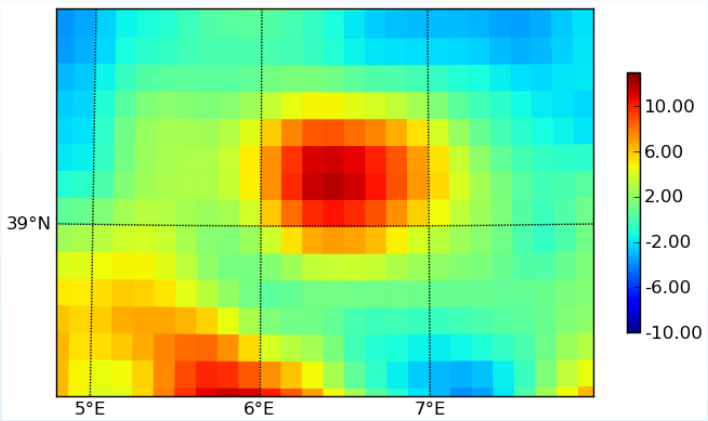
Aviso velocity and SST,
cost function: 0.33



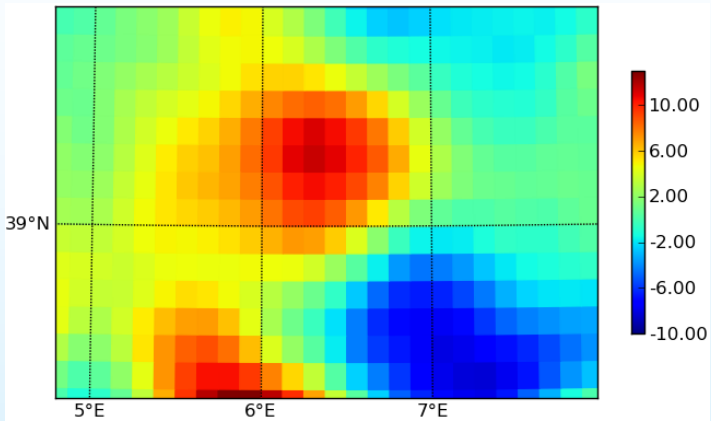
Corrected velocity and SST,
cost function: 0.23

- Gyre moved upward
- Velocity strengthen in the south East of the picture
- Velocity does not cross frontal structure anymore

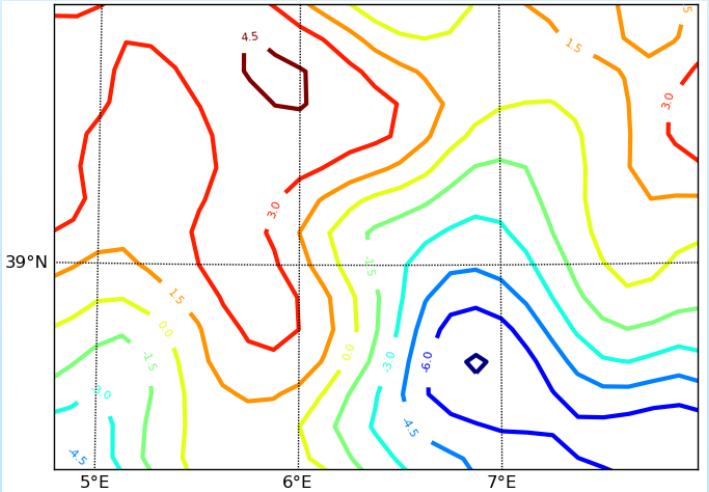
Correction to the ssh



Aviso SSH

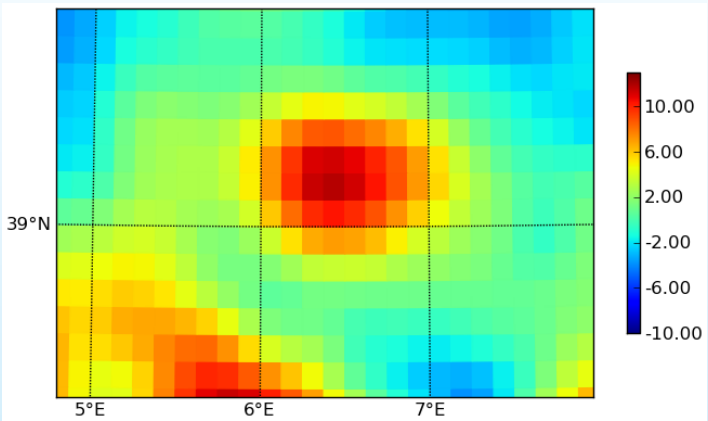


Corrected SSH

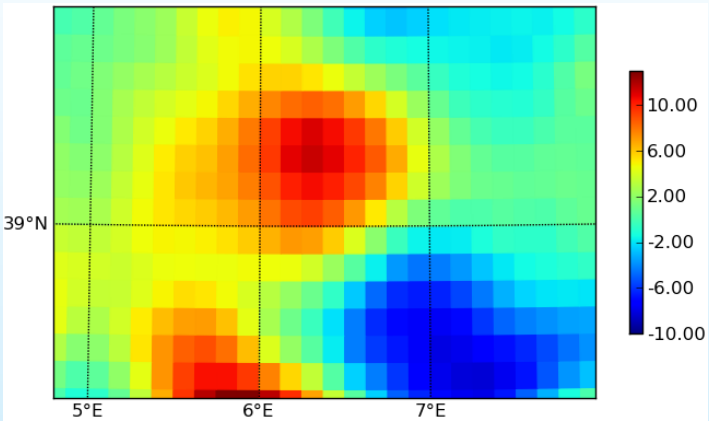


Resulting correction

Correction to the ssh



Aviso SSH



Corrected SSH

High resolution tracer data makes the improvement of AVISO products possible.

Conclusion

Sub-mesoscale information are invertible to control larger scales dynamics

- Altimetry and tracer observation are complementary.
- Tracer information can compensate for the lack of SSH resolution in time and space.
- High resolution Sea Surface Temperature or Ocean Color data are usefull to control ocean physics.

Conclusion

Next

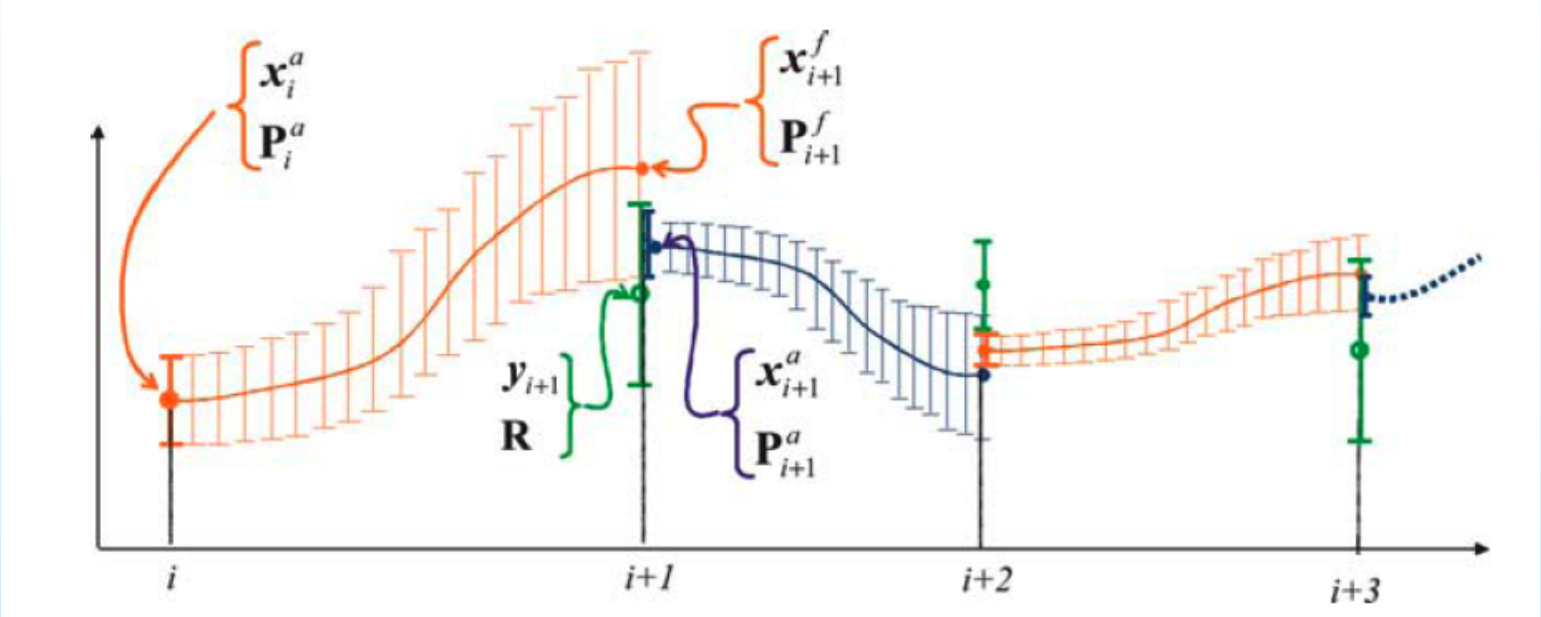
- Quantify the error made on the estimated velocity.
- Inversion of image in a coupled physico-biogeochemical model.

Prospects

- Data Assimilation of image in a coupled physico-biogeochemical model.

Thank you for your attention

Data Assimilation



Conceptual representation of filtering with sequential assimilation, Brasseur, 2006

Sub-mesoscale

Sub-mesoscales are scales defined by a Rossby number of order one

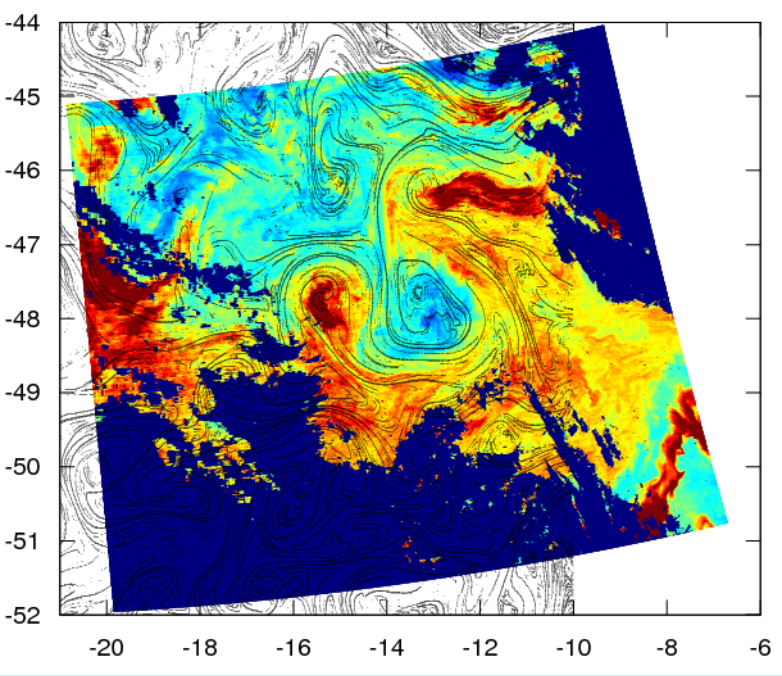
$$R_o = \frac{inertial\ force}{Coriolis\ force} = \frac{U}{fL}$$

It is caracterized by ageostrophic circulation: strain dominates over rotation.

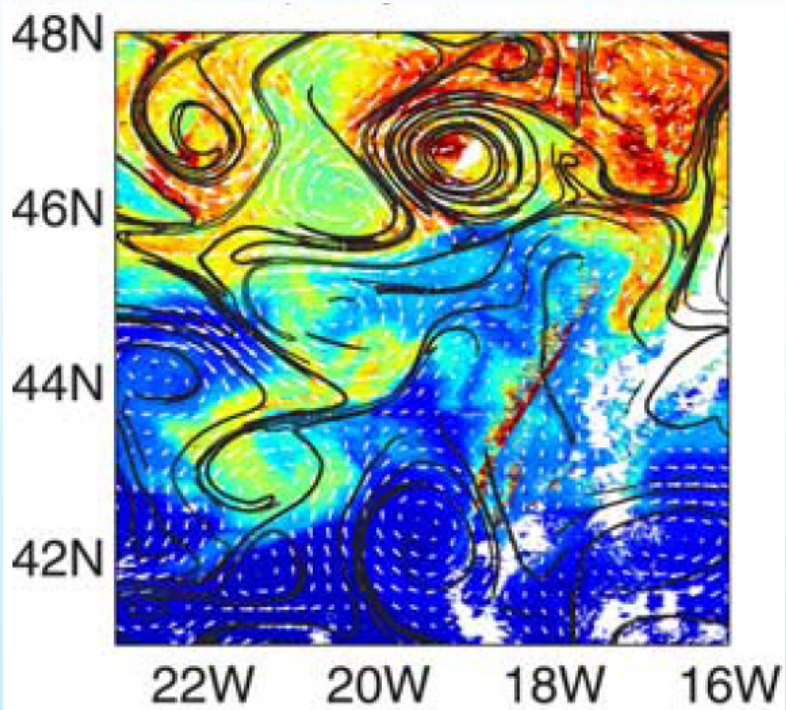
Three major ingredients:

- frontogenesis
- straining by the mesoscale turbulent field
- sub-mesoscale baroclinic instability.

Connection between FSLE and tracer filaments



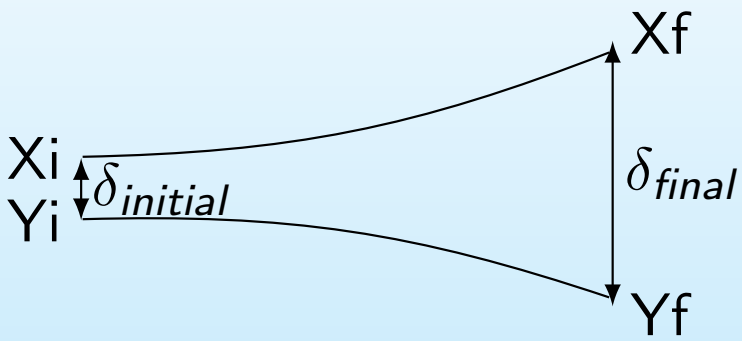
Chlorophyll, South Atlantic, d'Ovidio & al, 2004



Chlorophyll, Pomme area, Lehahn & al, 2008

Physical meaning of Lyapunov Exponents

Lyapunov exponents are defined as the exponential rate of separation, averaged over time



FSLE

$$\lambda = \frac{1}{T} \times log(\frac{\delta_{final}}{\delta_{initial}})$$

Lyapunov exponents constitute Lagrangian transport barriers between different regions (Lehahn & al (2007)).