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

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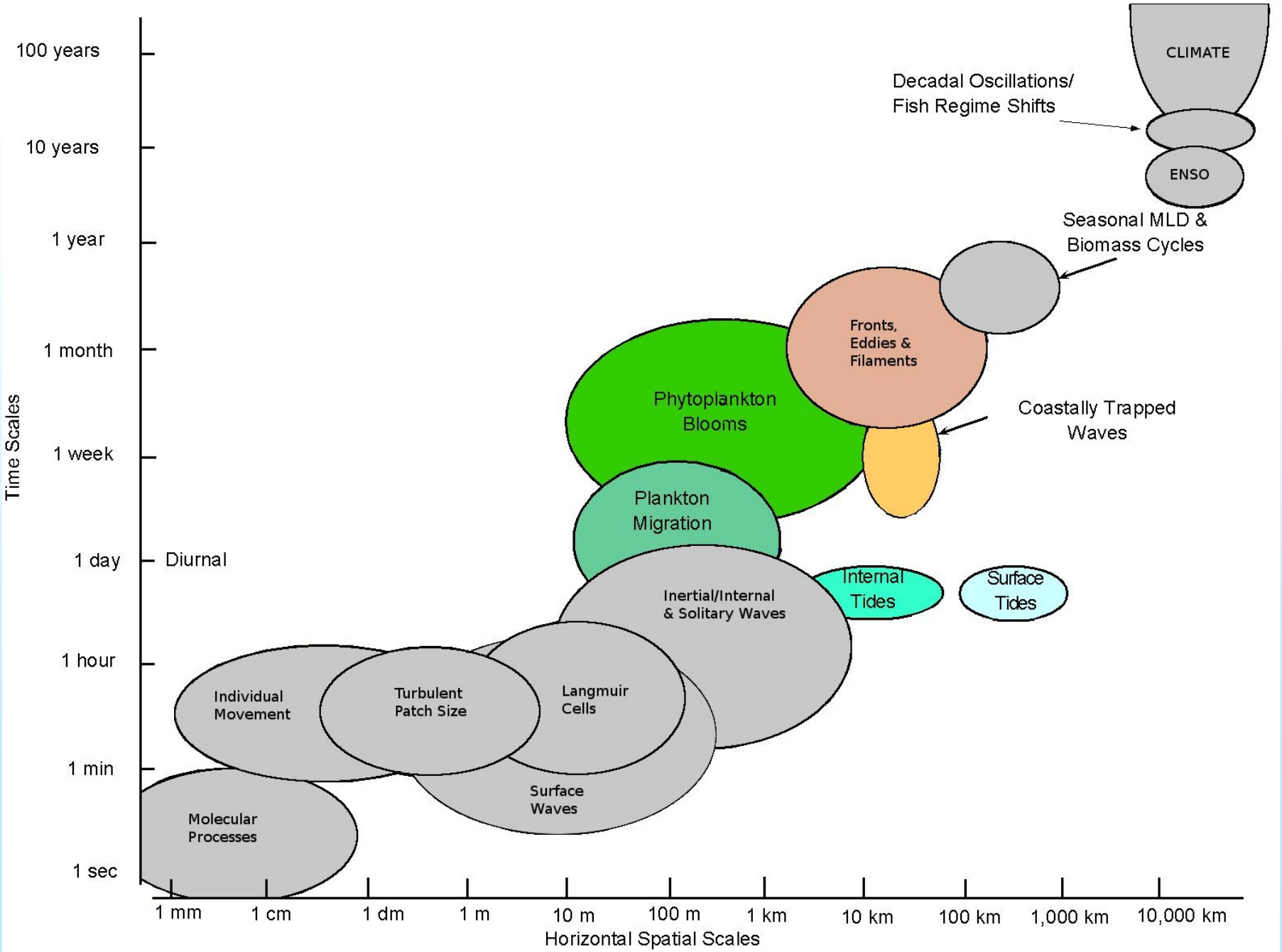
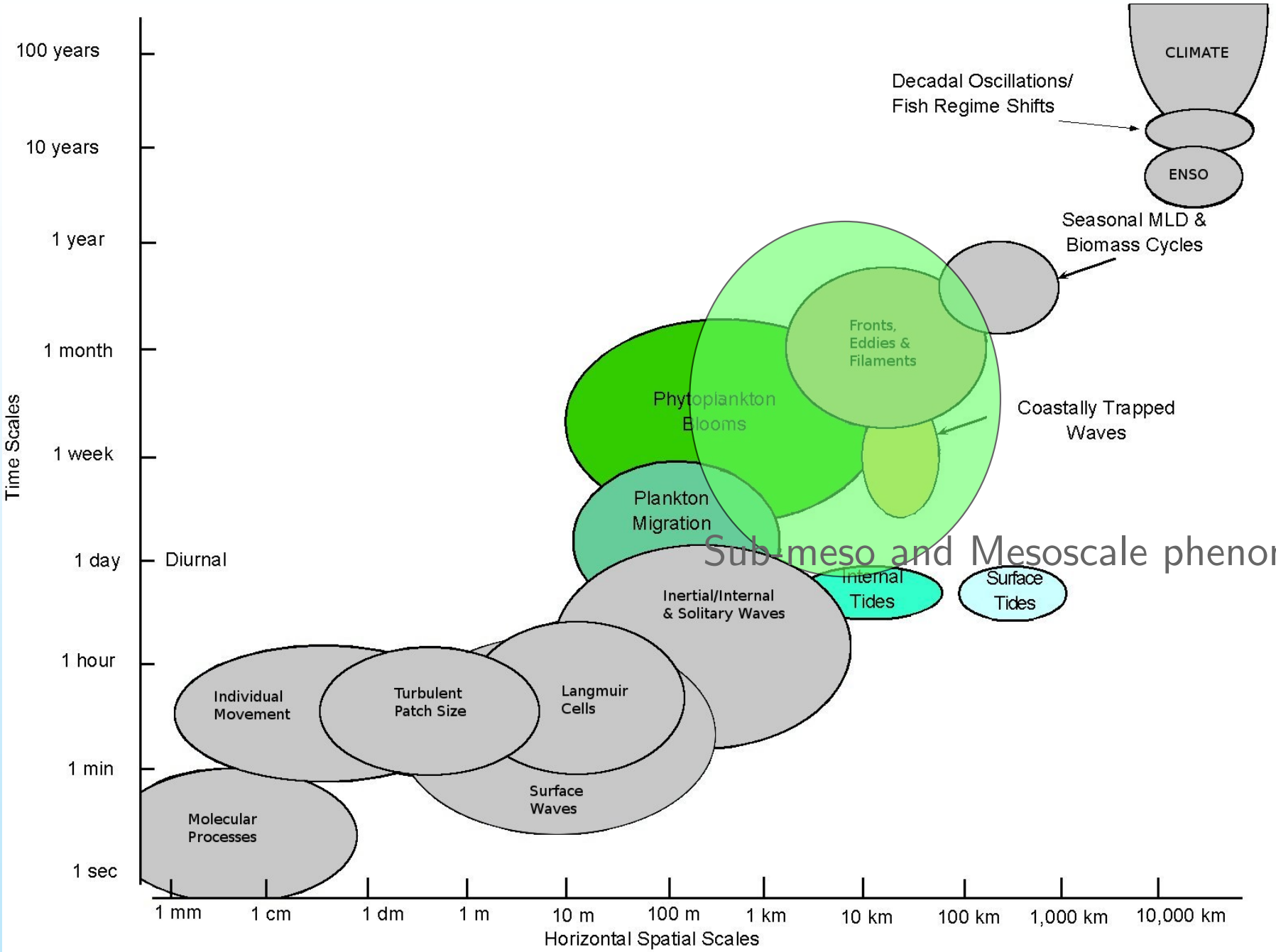
December 2, 2011

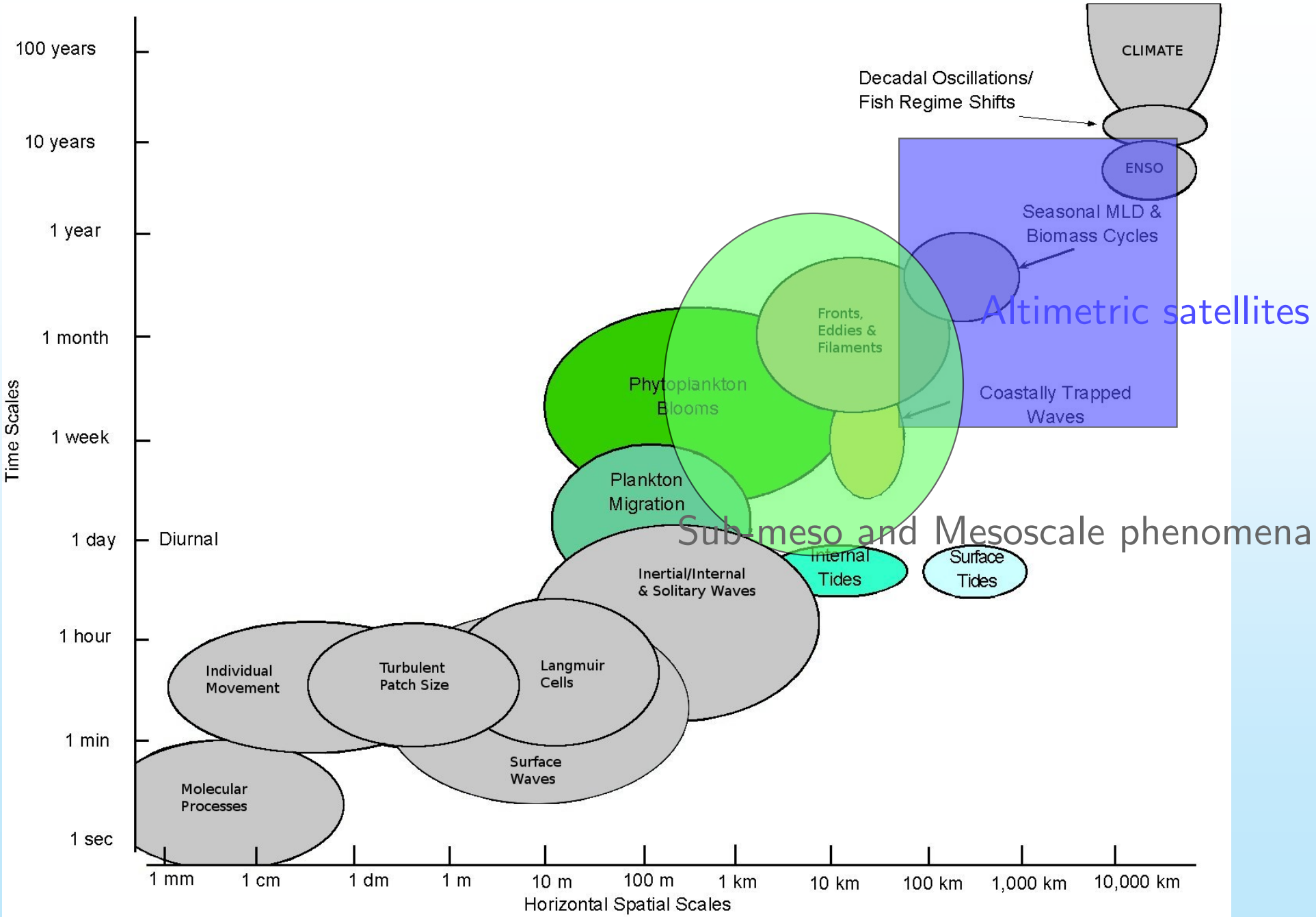
Mesoscale and sub-mesoscale dynamics



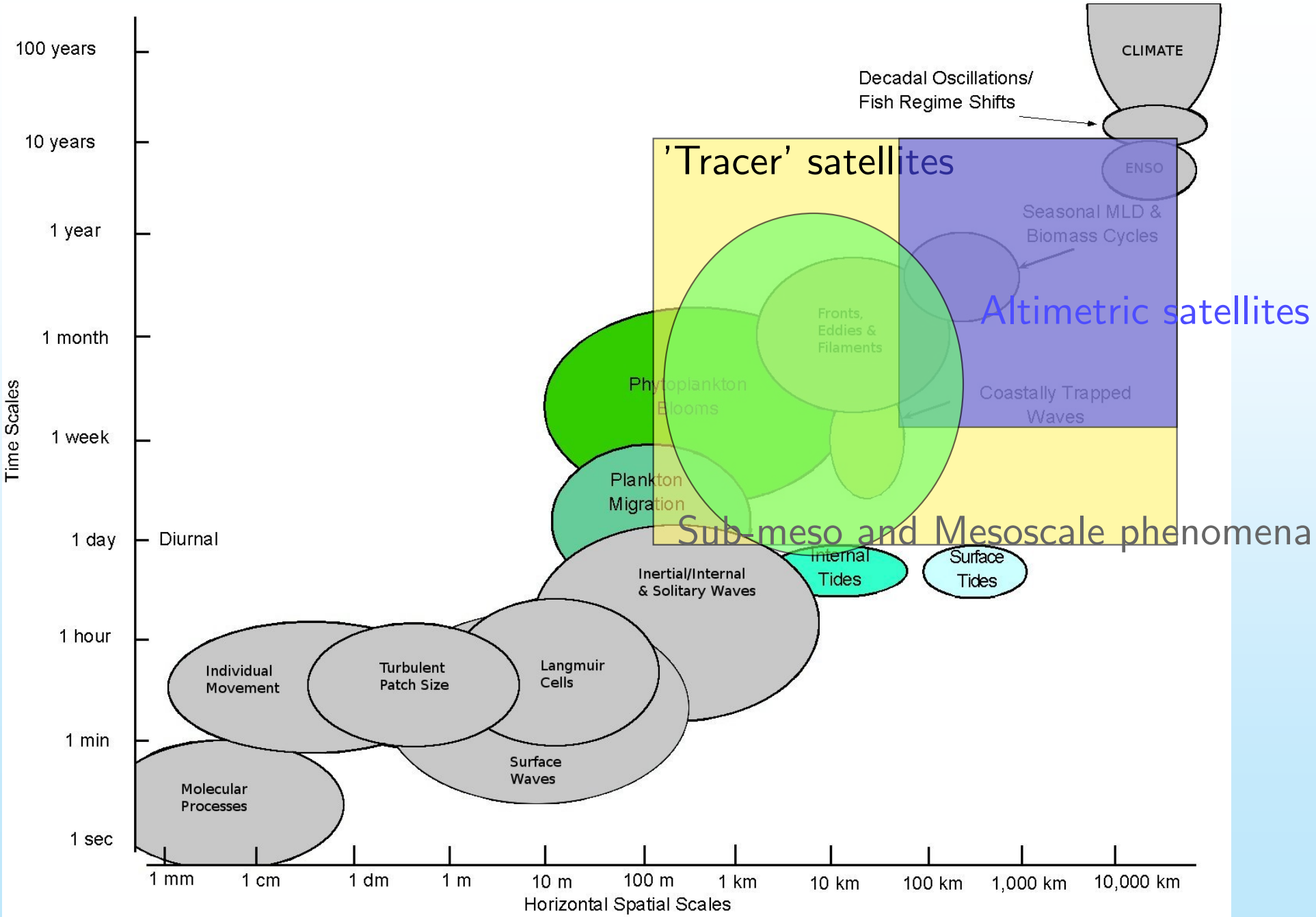
Mesoscale and sub-mesoscale dynamics



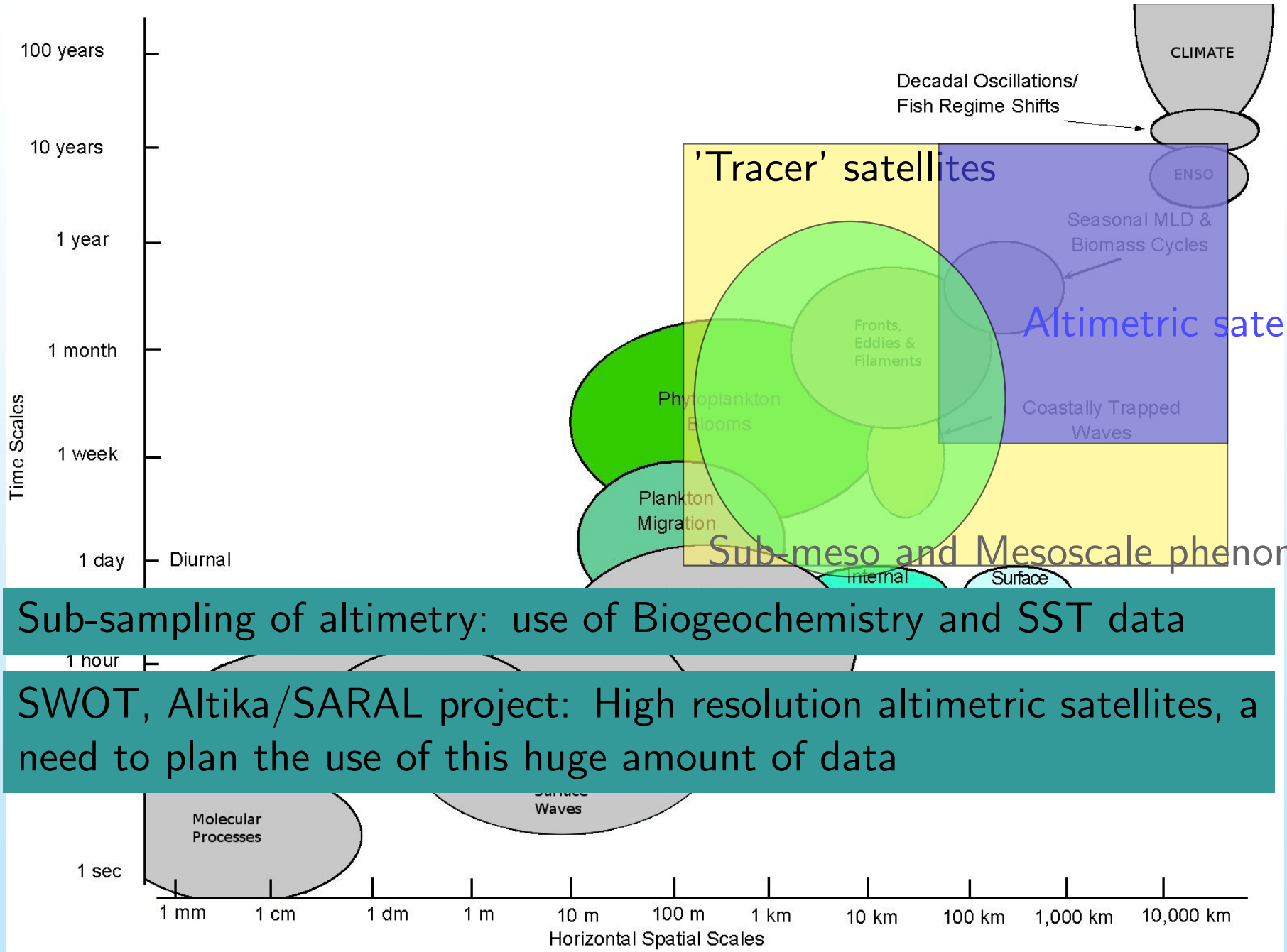
Mesoscale and sub-mesoscale dynamics



Mesoscale and sub-mesoscale dynamics



Mesoscale and sub-mesoscale dynamics



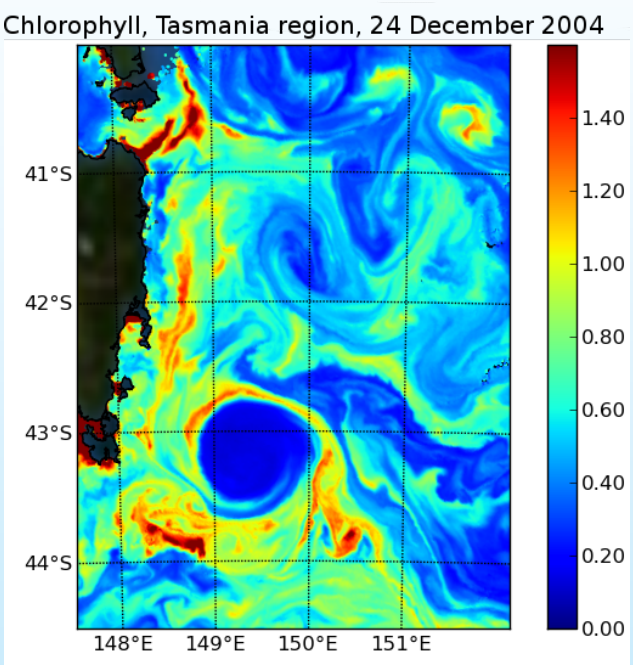
Sub-sampling of altimetry: use of Biogeochemistry and SST data

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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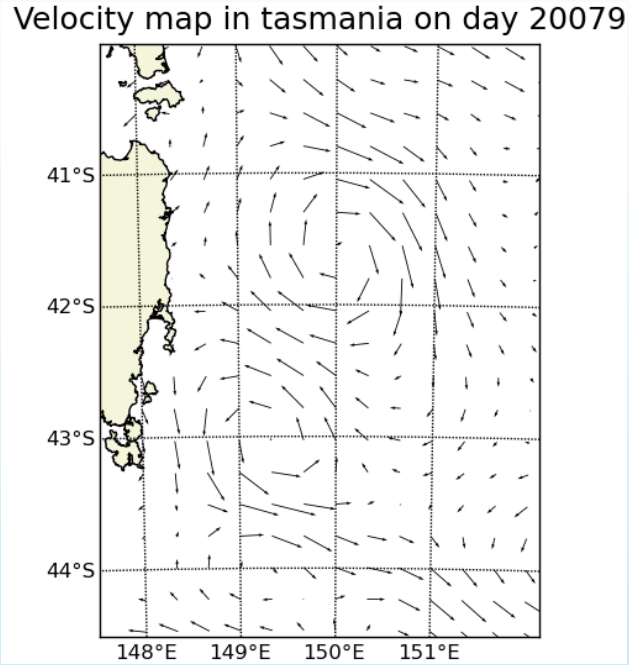
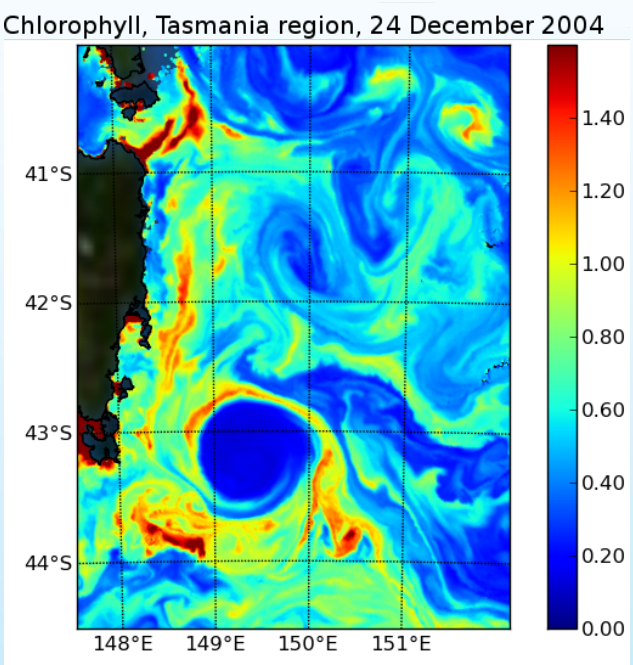
Mesoscale field



Philosophy of the study

Sub-mesoscale tracer image



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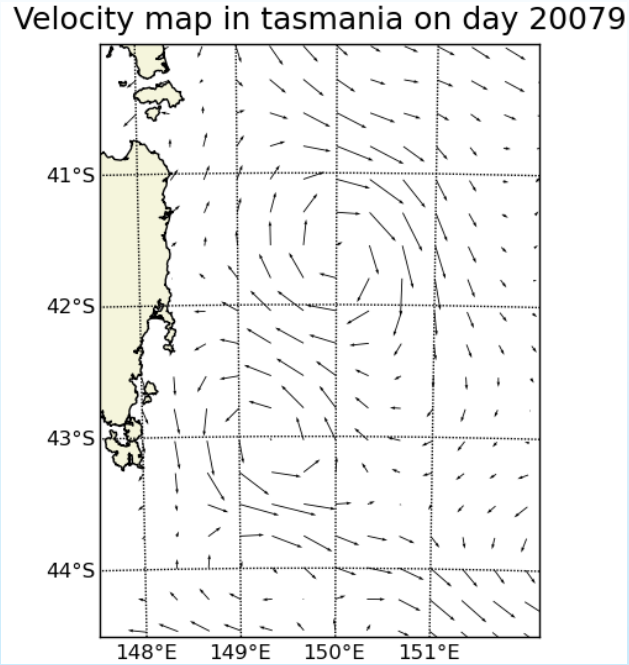
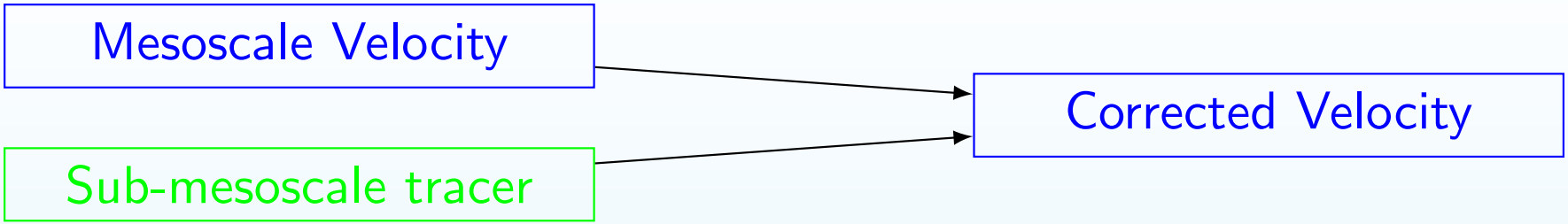
Mesoscale field



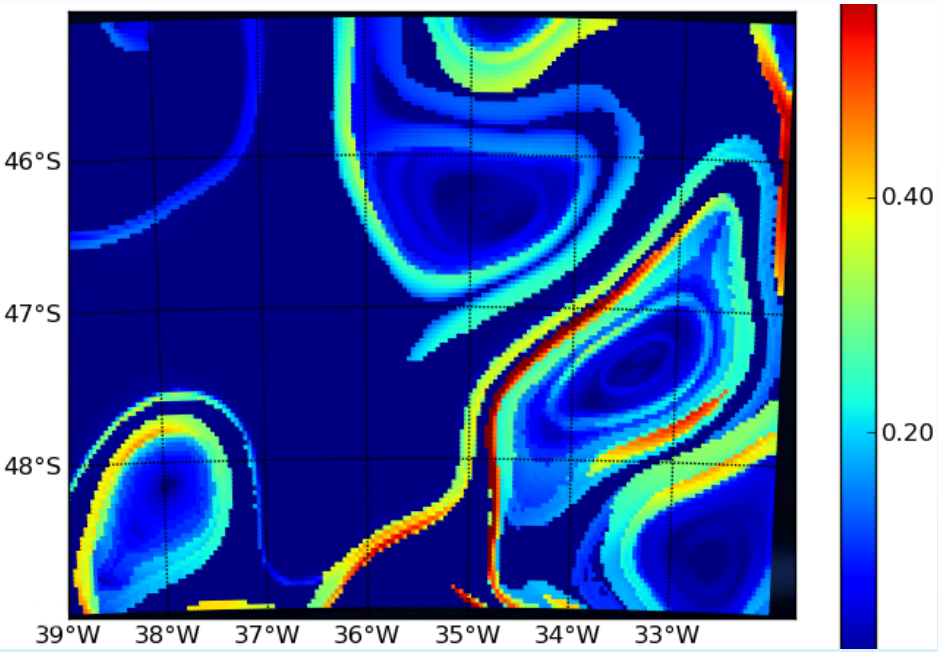
The inversion of sub-mesoscale tracer information to correct mesoscale velocity has never been done before



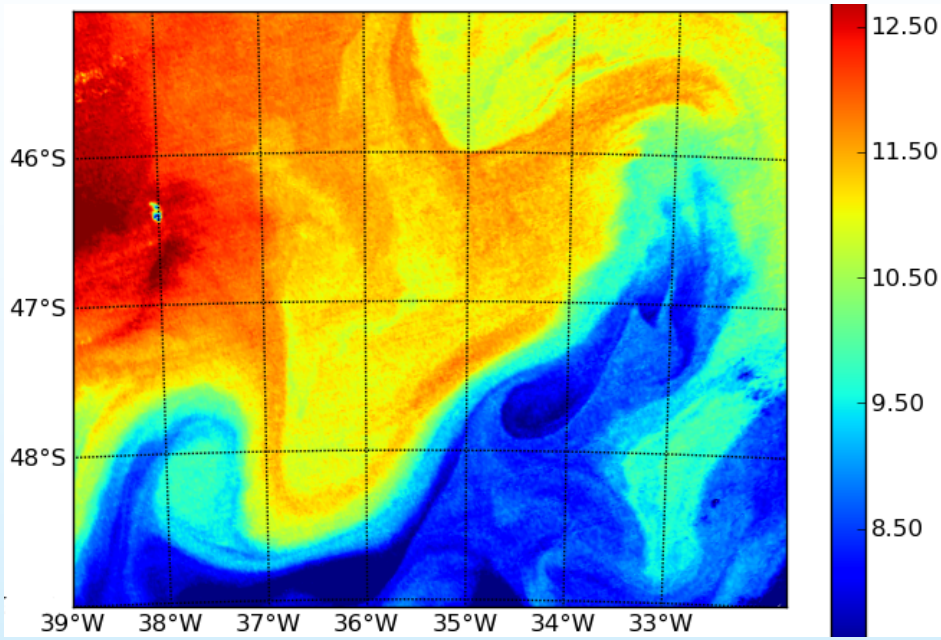
Find the correction of this background the most compatible with tracer information

- 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
$\rightarrow$ 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

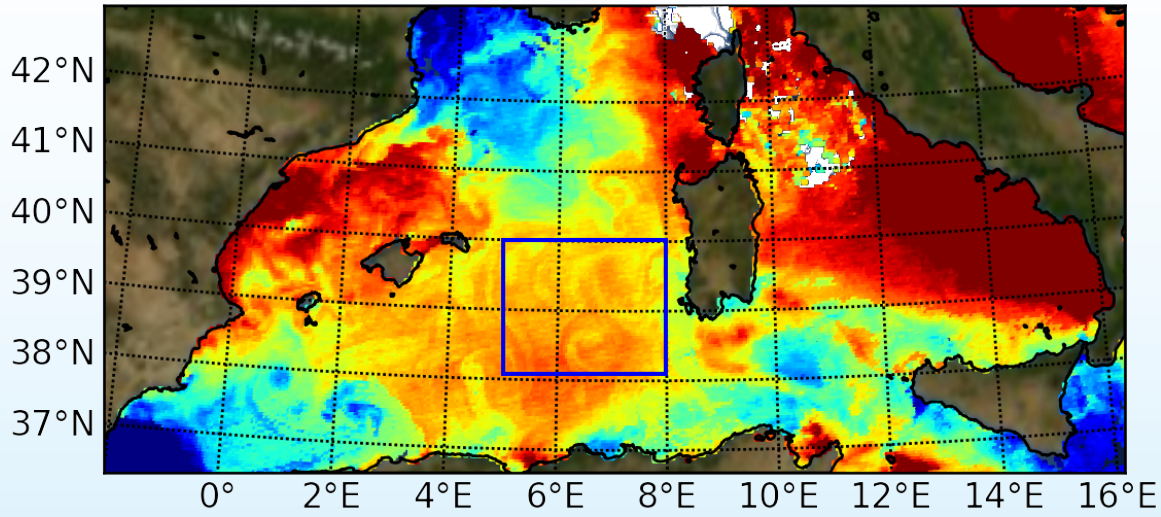
- **Step 1**: Is FSLE the right proxy for this study?

  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

Test case : Mediterranean Sea

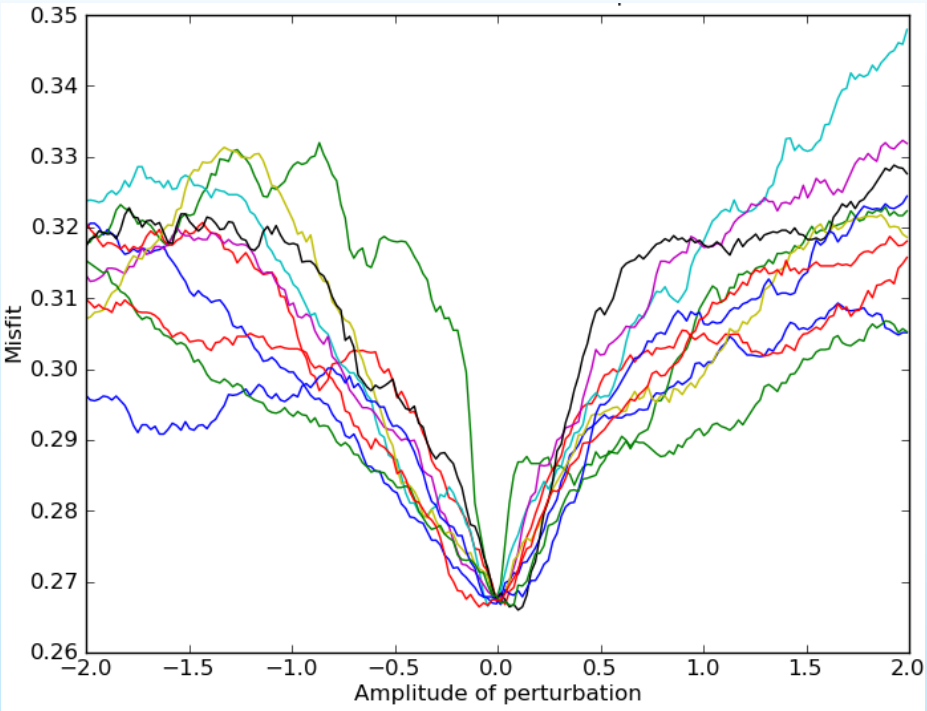


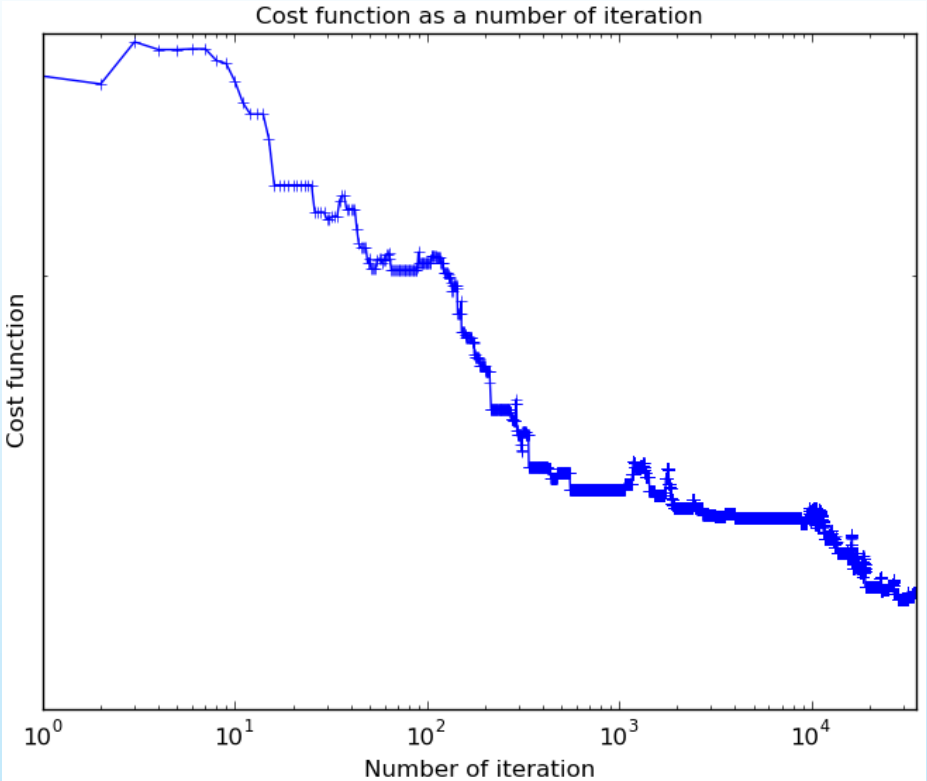
- **Time Range**: from 1998 to June 2009, 595 velocity maps
- **Velocity fields**: AVISO, altimetric data
- **Resolution**: 1/8°, grid points: 26*17
- **FSLE Resolution**: 1/48°, grid points: 119*86

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

Study of the cost function: Full inversion

STEP 2





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

Study of the cost function: Full inversion

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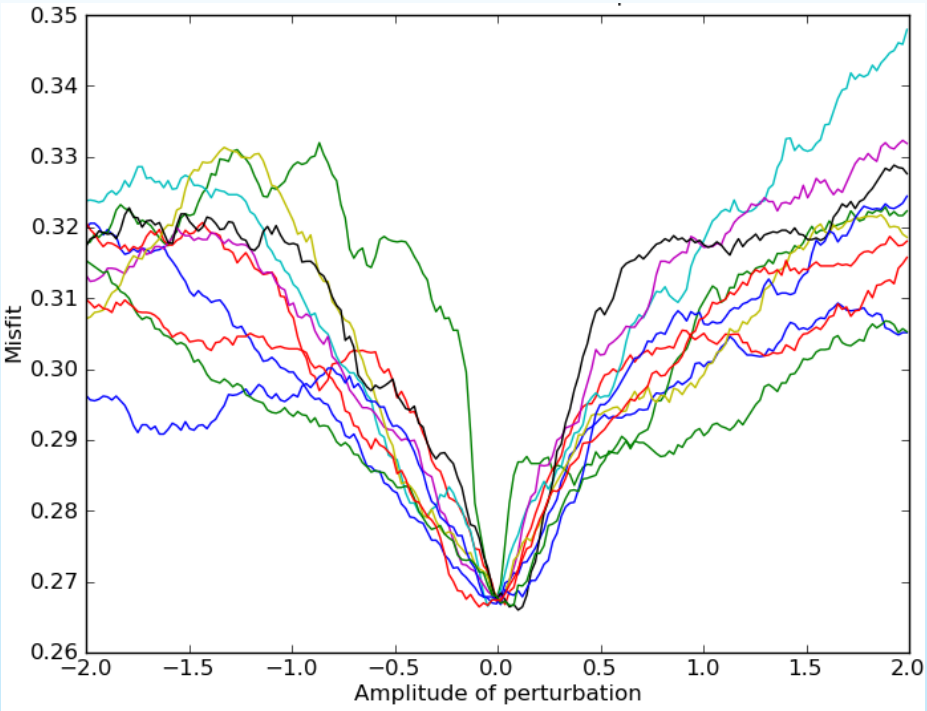
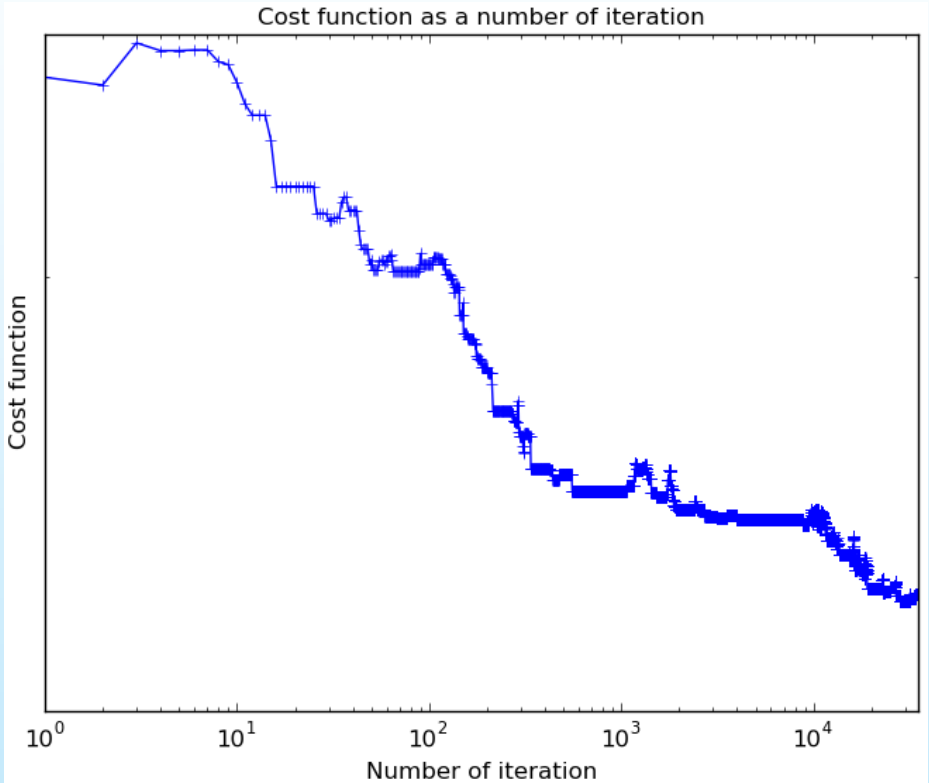
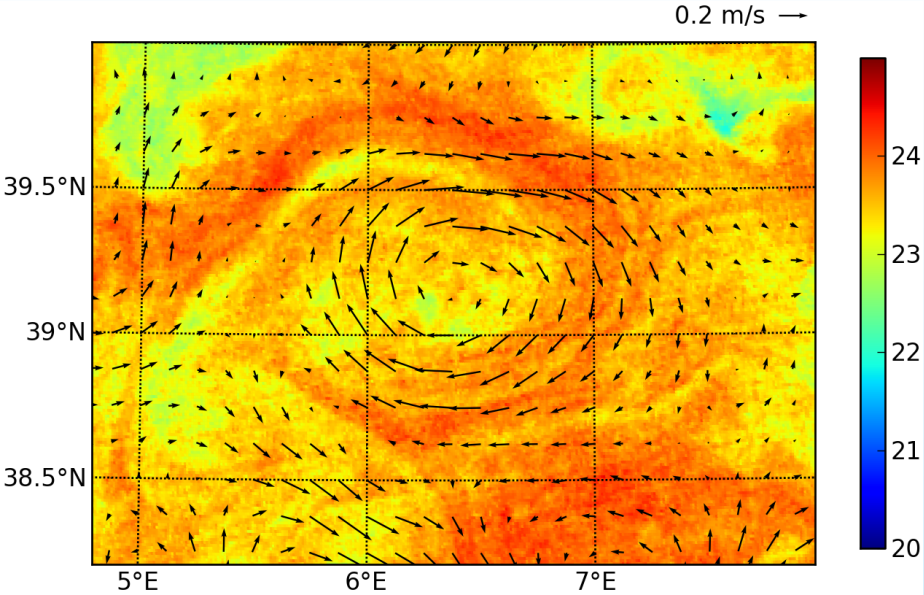


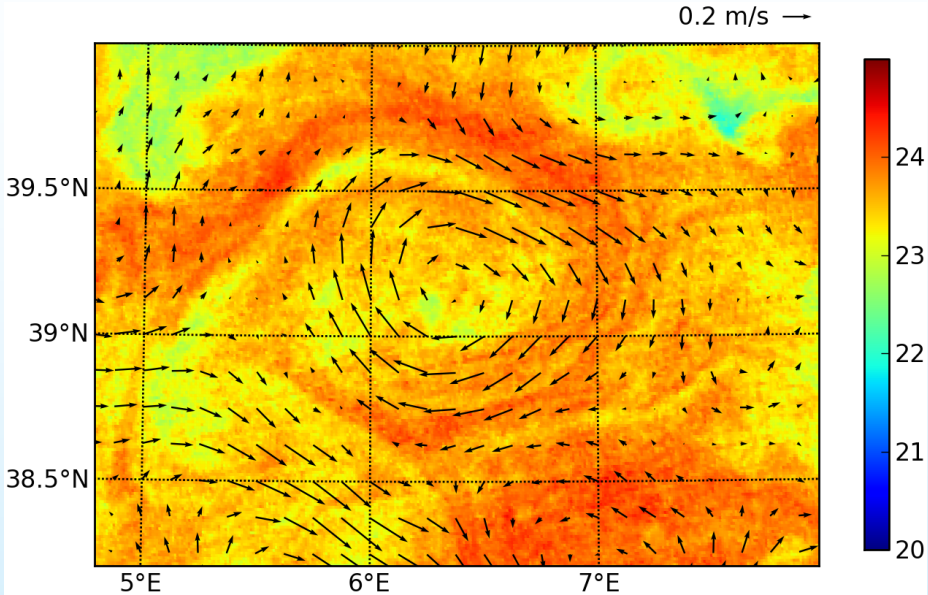


Simulated Annealing to decrease the cost function without being stuck in a local minimum

Results: correction on velocity



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

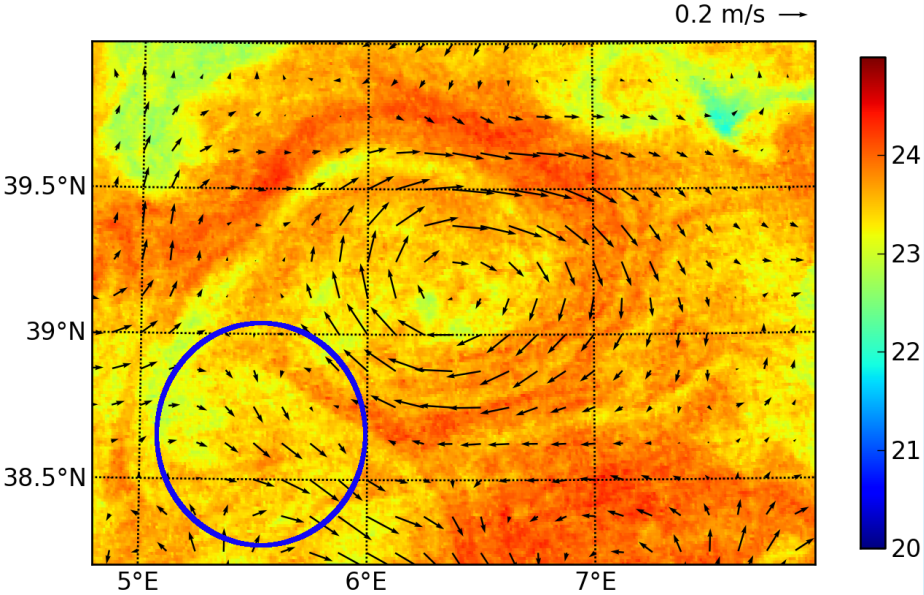


Corrected velocity and Tracer (SST), cost function: 0.23

Calculation of the corrected velocity

- Get a sample of all the potential solutions using Gibbs' Sampler.
- Optimal solution: the velocity that has the lowest cost function
- Reliability: variance of all the potential solutions.

Results: correction on velocity



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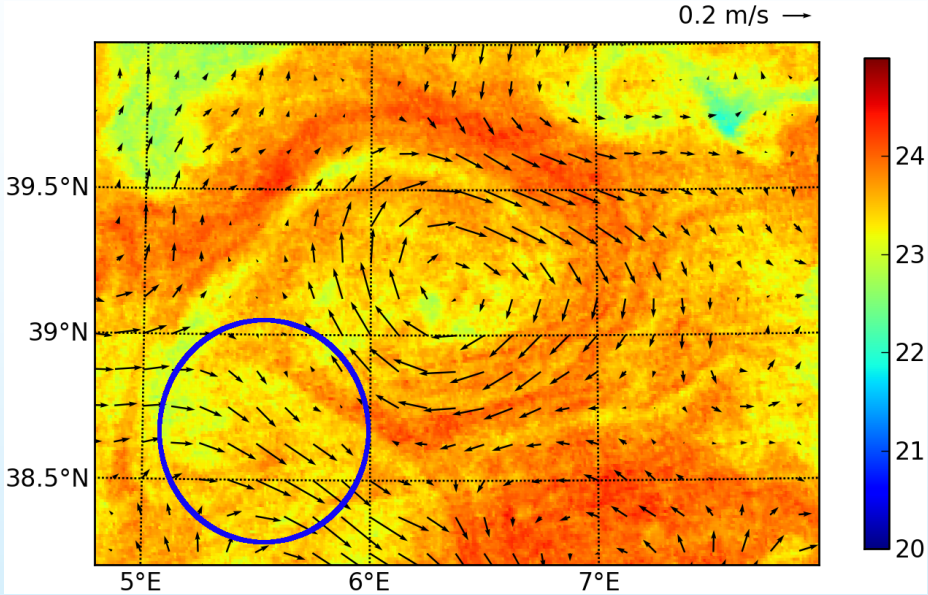
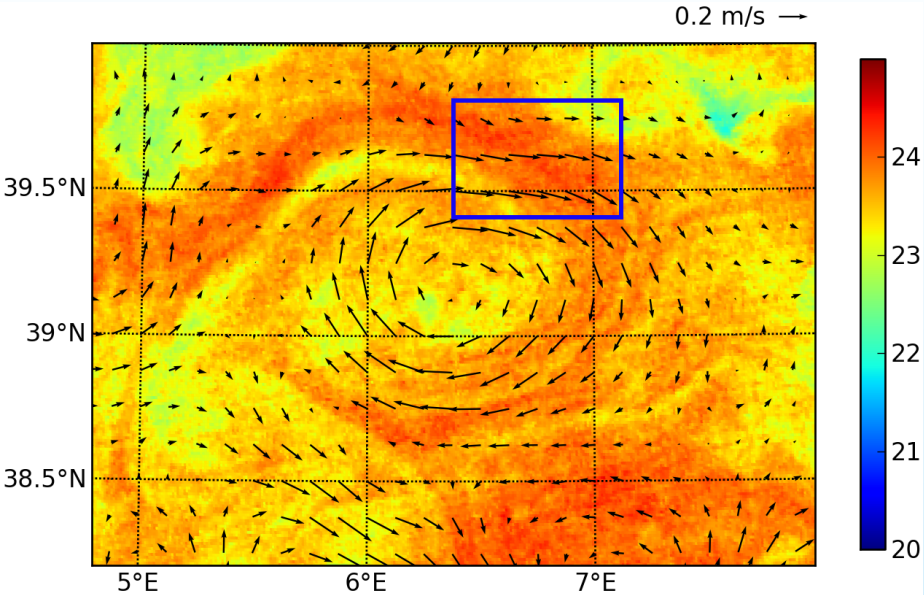


Corrected velocity and Tracer (SST), cost function: 0.23

- Eddy is a better match to the tracer structure
- Velocity strengthen in the South West of the picture
-

Results: correction on velocity



Aviso velocity and SST,

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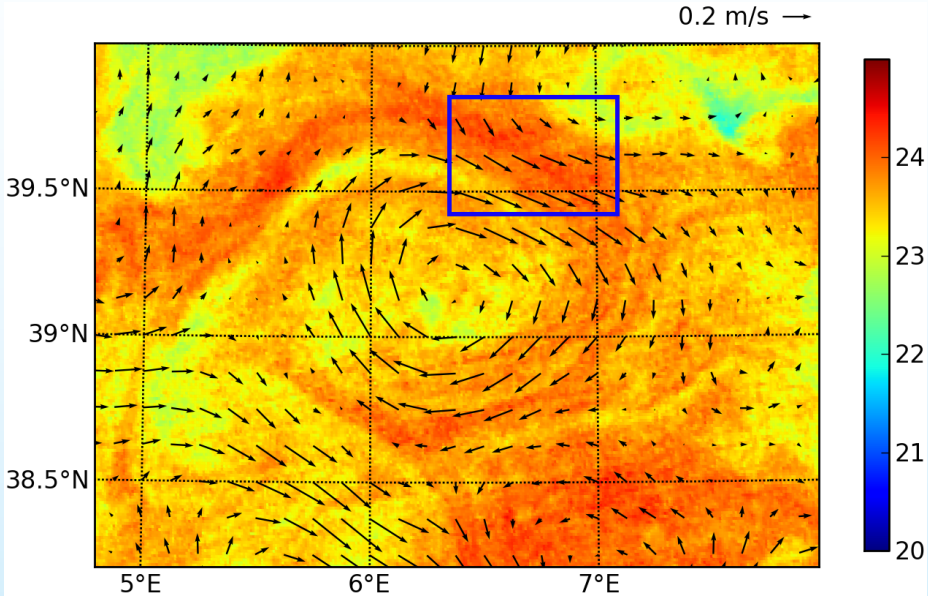
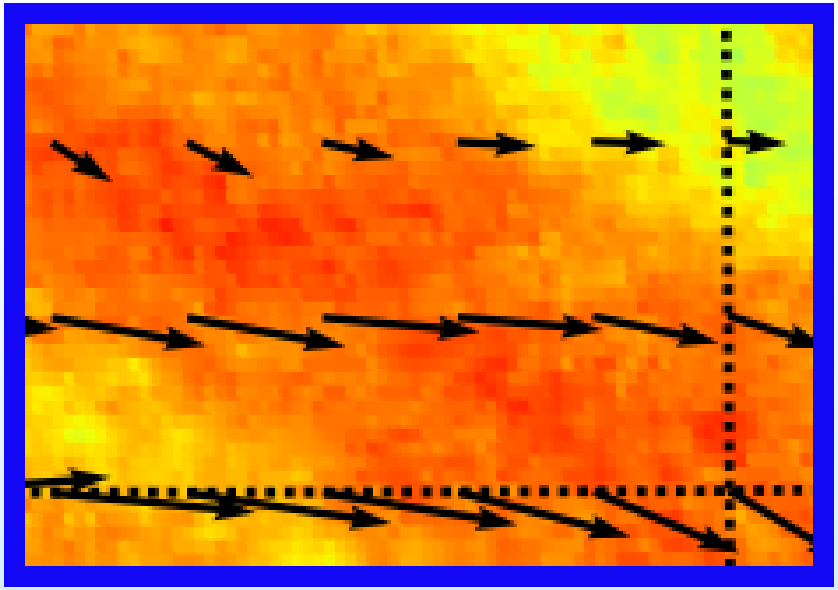


Corrected velocity and SST,

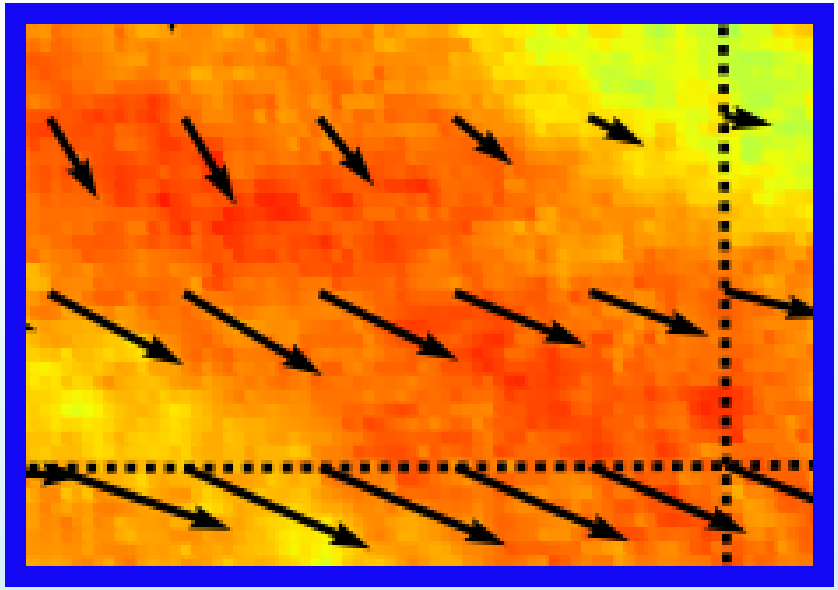
cost function: 0.23

- Gyre moved upward
- Velocity strengthen in the South West of the picture
-

Results: correction on velocity



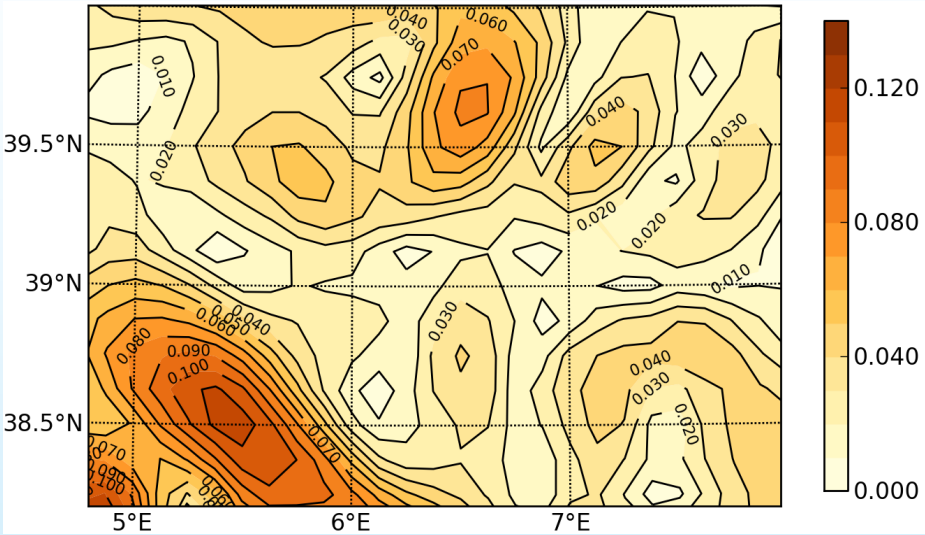
Aviso velocity and SST,
cost function: 0.33



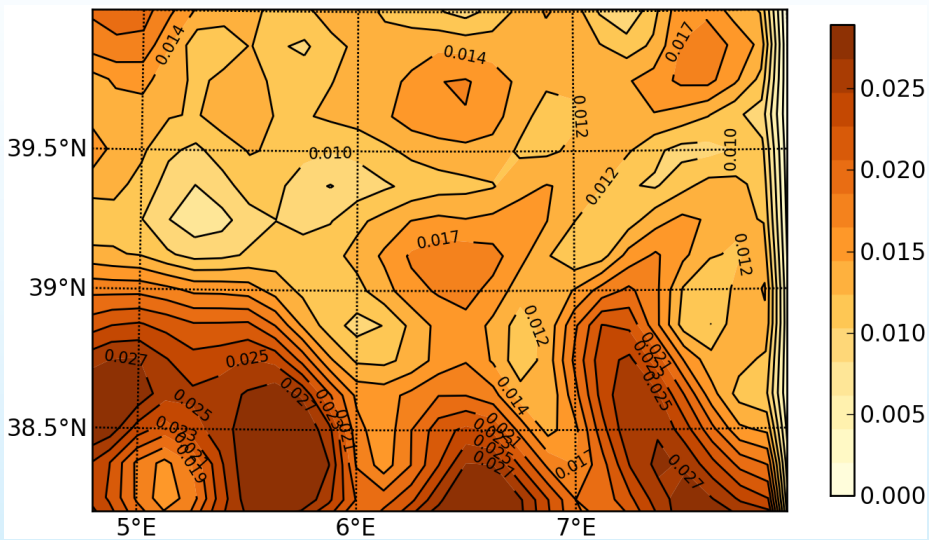
Corrected velocity and SST,
cost function: 0.23

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

Results: correction on velocity



Norm of the difference between the observed velocity and the corrected one



Norm of the variance of the ensemble sample which characterizes the PDF of the solution

- Velocity strengthen in the South West of the picture
- Good accuracy on the correction of the eddy

Conclusion

Sub-mesoscale information are invertible to control larger scales dynamics

- Altimetry and tracer observations 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

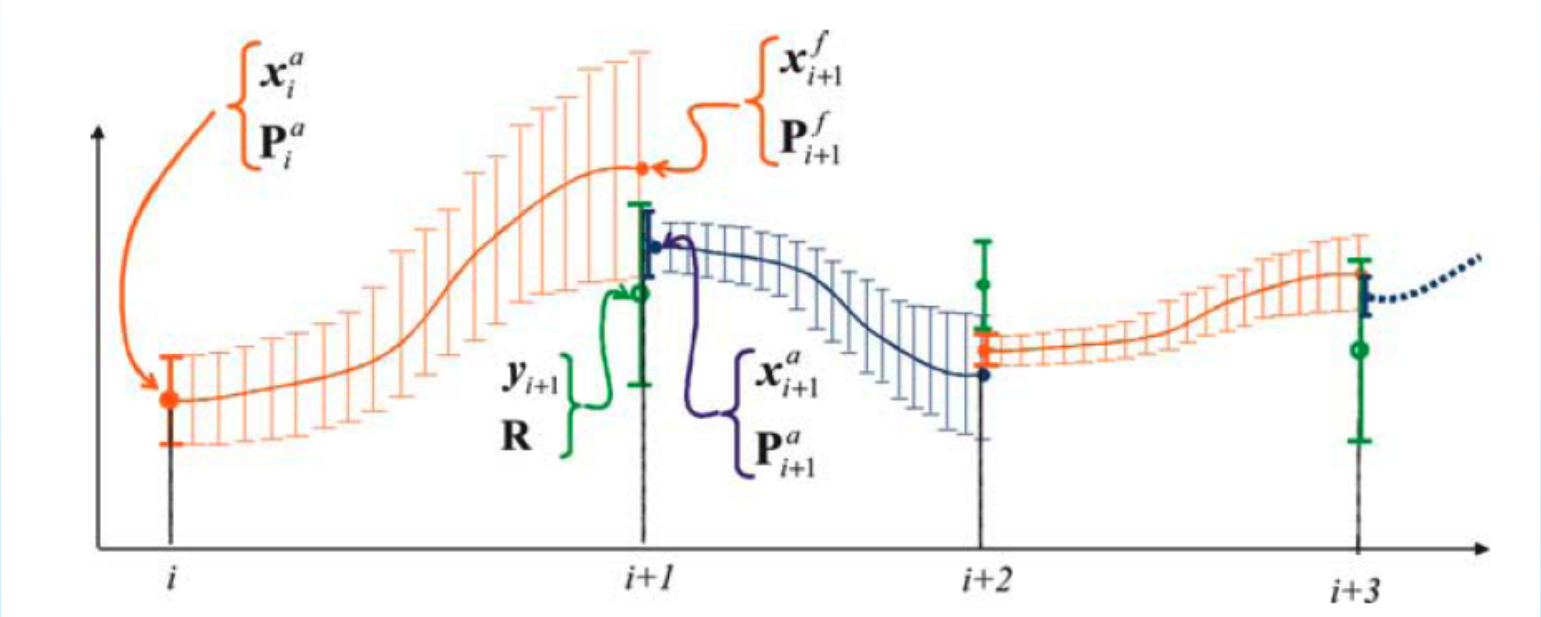
- Inversion of image in a coupled physico-biogeochemical model.
- Quantify the contribution of the corrected velocity, knowing the truth.

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

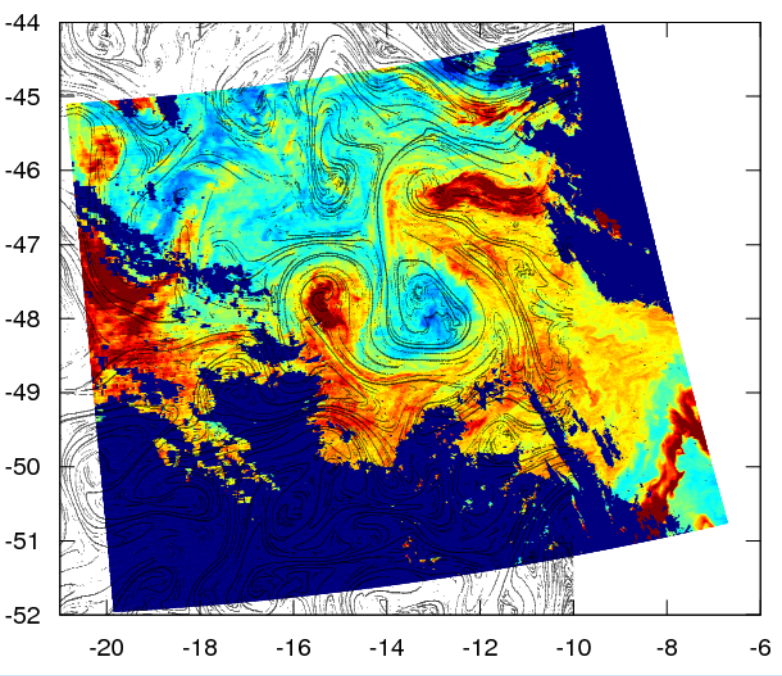
$$R_o = \frac{inertial\ force}{Coriolis\ force} = \frac{U}{fL}$$

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

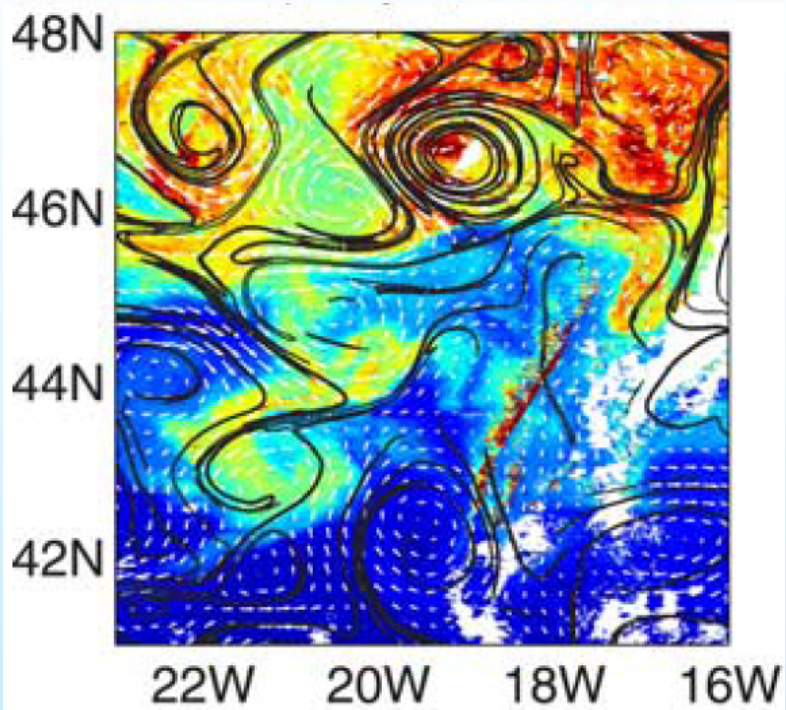
Three major ingredients:

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

Connection between FSLE and tracer filaments



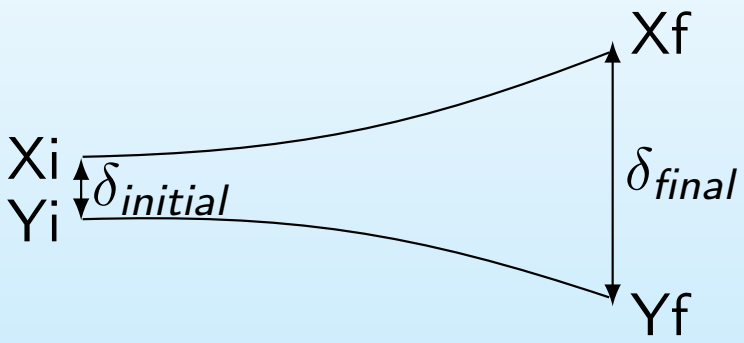
Chlorophyll, South Atlantic, d'Ovidio & al, 2004



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)).