On the use of sub-mesoscale tracer information and mesoscale altimetric field for the control of ocean circulations.

A Data Assimilation strategy

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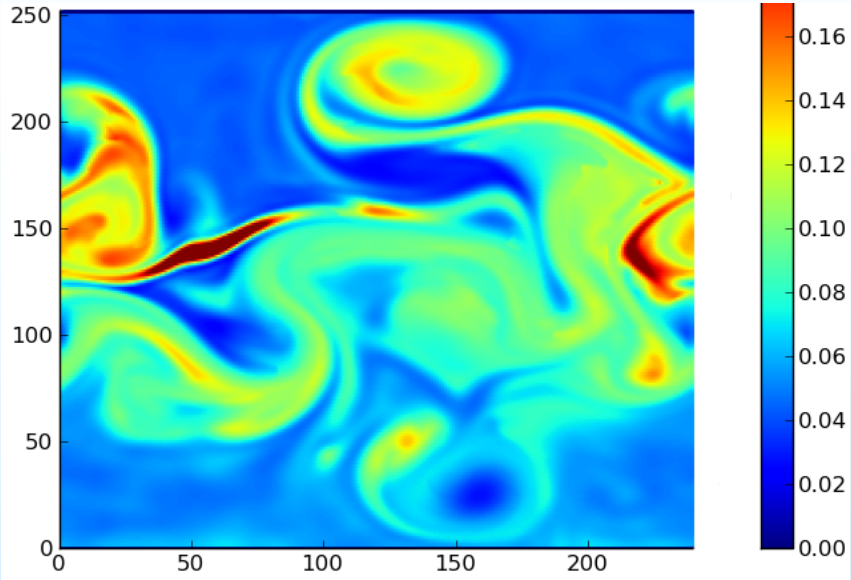
Sub-mesoscales

- Intermediate scale between Mesoscale and dissipative scales.
- Filaments length : 1-10 km.

Generation of sub-mesoscales

- Frontogenesis.
- Unforced instabilities such as ageostrophic baroclinic instability.
- Forced motions such as flows affected by buoyancy fluxes.



Baroclinic instability in an idealized model (Chlorophyll)

Importance of sub-mesoscales

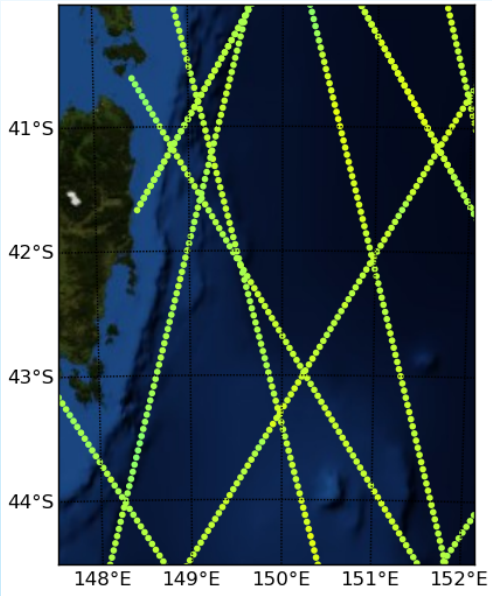
➢ Impact on larger scale circulation

➢ Energetic importance

(Capet & al, 2008, Thomas & al, 2008, Klein & al, 2008, Ferrari & al, 2008)

Observation of sub-mesoscales

Sub-mesoscales are not resolved by altimetry.

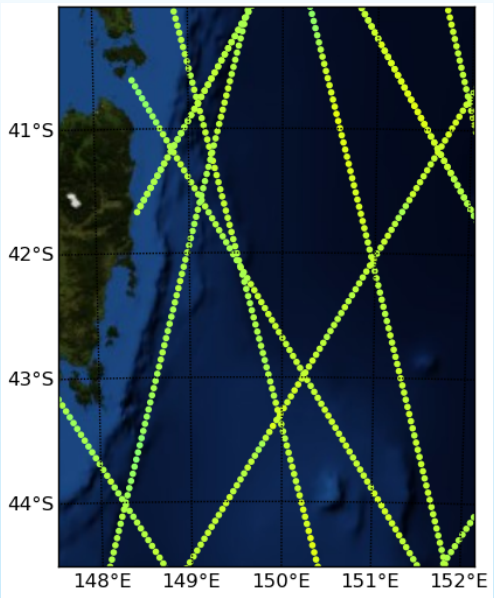


Jason and Envisat tracks, 15 days around December 22, 2004, Tasmania region

Observation of sub-mesoscales

Sub-mesoscales are not resolved by altimetry.

Sub-mesoscales are observed using satellite tracer sensors.



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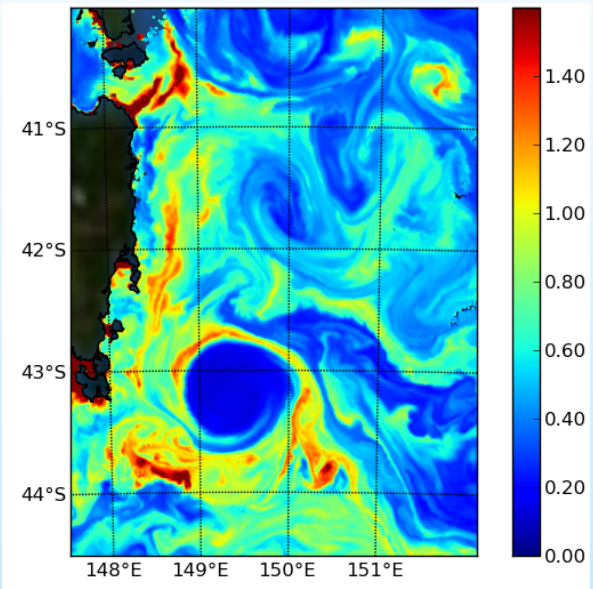


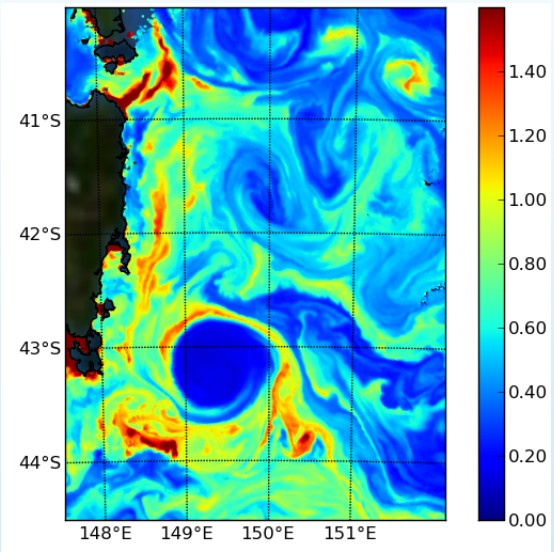
Chlorophyll, December 22, 2004, Tasmania region

Joint use of altimetry and high resolution tracer observation to improve the assessment of the dynamic.

Context of inversion of information

Data Assimilation

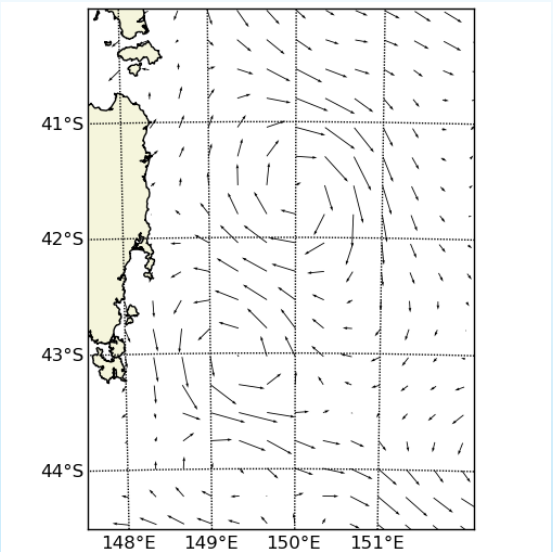
➢ aims at finding an optimal compromise between information of different natures, space and time sampling.



Chlorophyll image

?

Tasmania region, December 22, 2004



Velocity map

Context of inversion of information

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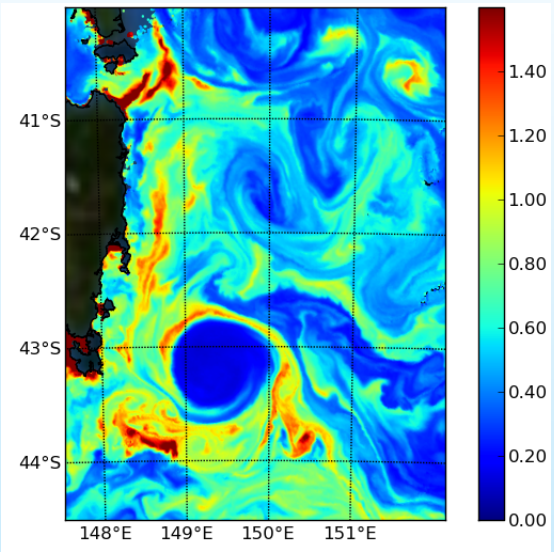

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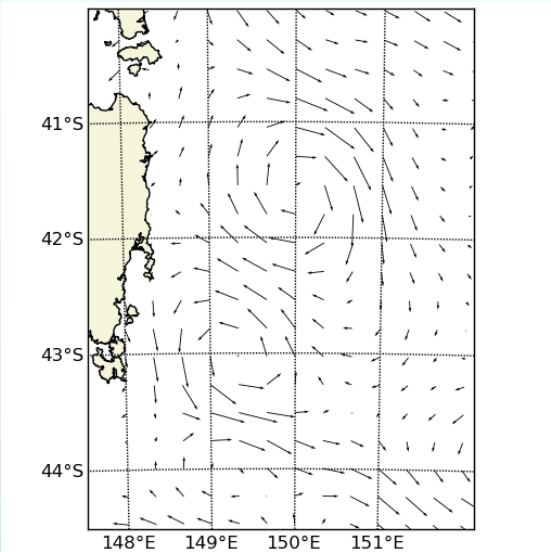


Velocity map

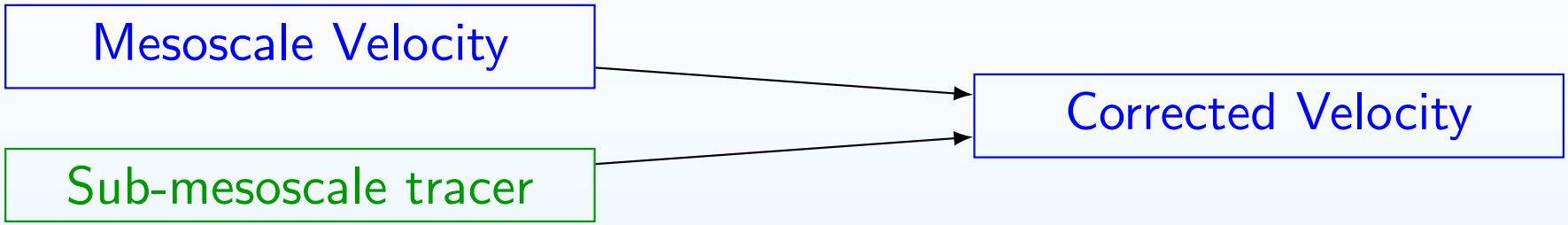
Use of a Data Assimilation approach

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

Outline

1. Context and objectives
   - Sub-mesoscales
   - Observation from space
2. Combining altimetric data and tracer images
   - Find a proxy between tracer and velocity
   - Inversion of sub-mesoscale information
3. Test Case
   - Study of the cost function
   - Corrected velocity field
4. Conclusion

Find a proxy between tracer and velocity

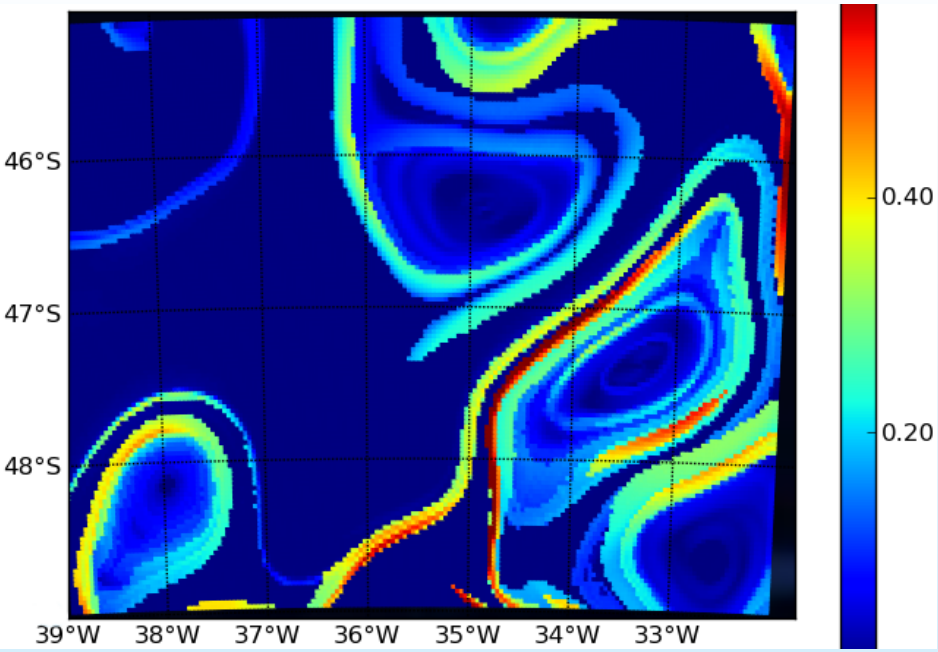


Find the correction of this background the most compatible with tracer information

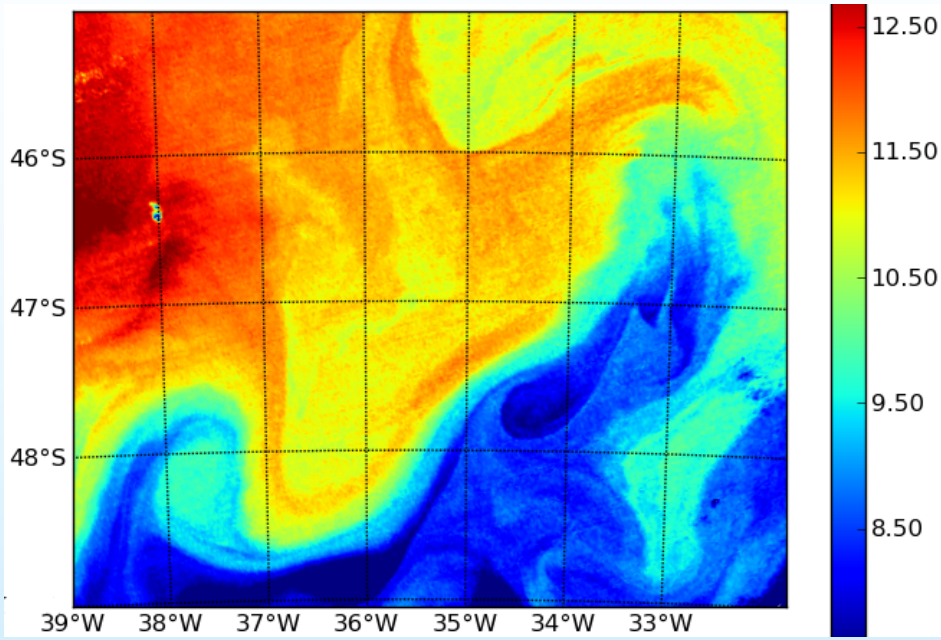
- The direct measure of the distance between $\vec{\mathbf{u}}$ and **Tracer** is not possible
- Need to find a go-between variable
- Use of Finite-Size Lyapunov Exponents as a proxy (FSLE)

See Gaultier & al, 2012 for details

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 :

$$J(u) = \|\mathcal{I}_{FSLE}(u) - \mathcal{I}_{OBS}\| + \textit{background term}$$

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

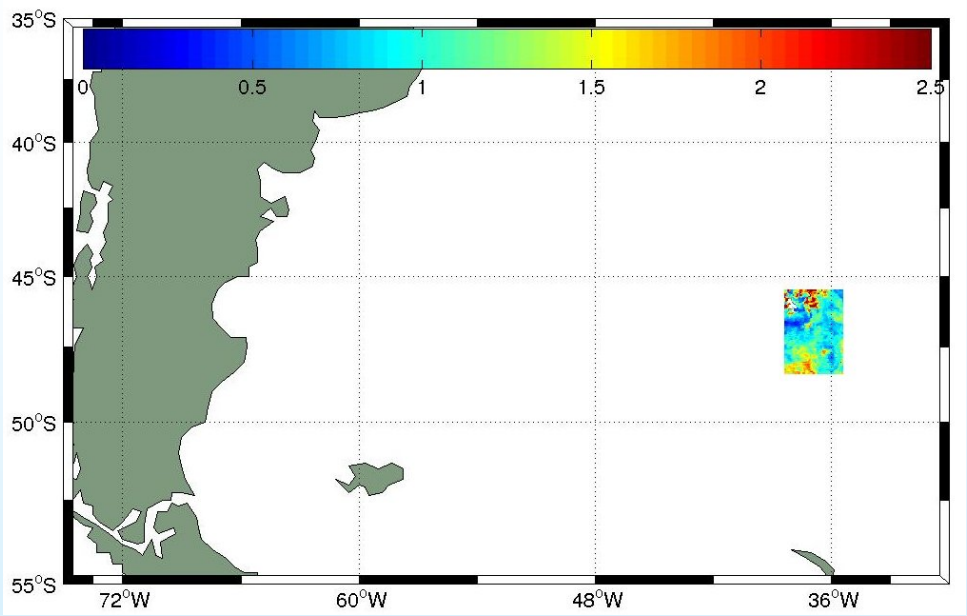
- Explore sub-space of errors to find the velocity that minimizes the cost function.

Velocity panel using EOF 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.

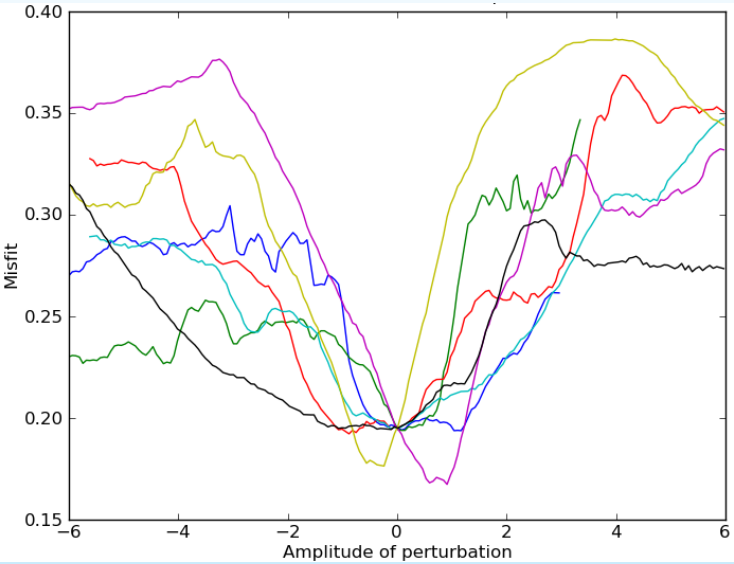
Test case : small area in the South Atlantic ocean



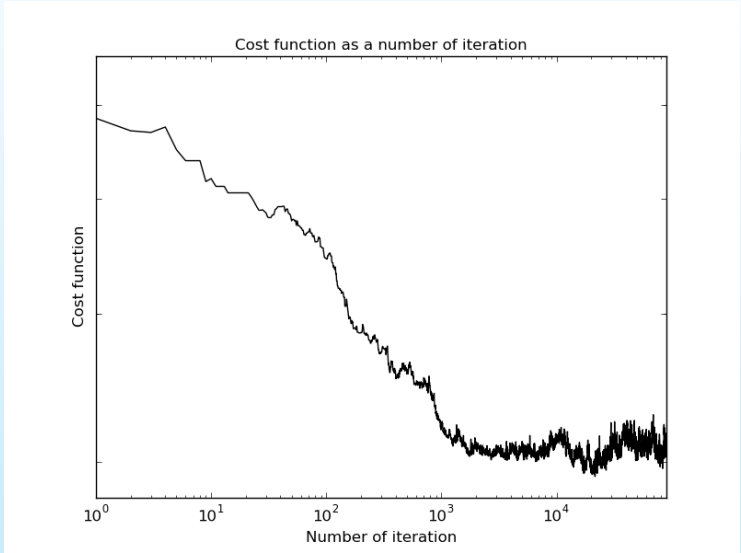
- **Time Range** : from 1998 to June 2009, 595 velocity maps
- **Velocity field** : AVISO, Altimetric data
- **Resolution** : $1/3^o$, grid points : 13*17
- **FSLE Resolution** : $1/48^o$, grid points : 99*130
- **Tracer field** : SST or Chlorophyll data (MODIS sensor, L2 product)
- **Resolution needed to detect filaments** : $1/100^o$

Cost function study

Explore the cost function around the solution



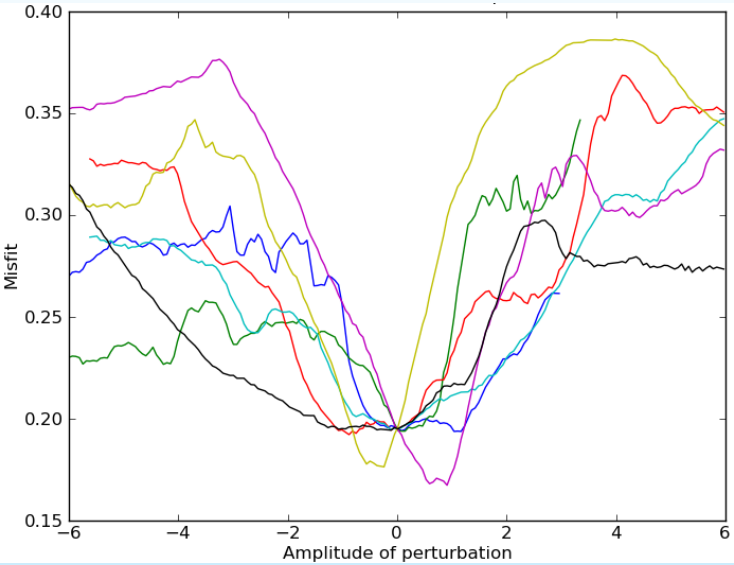
Cost function as a function of the number of iterations



Cost Function : $J(u) = \|\mathcal{I}_{FSLE}(u) - \mathcal{I}_{OBS}\| + \textit{background term}$

Cost function study

Explore the cost function around the solution



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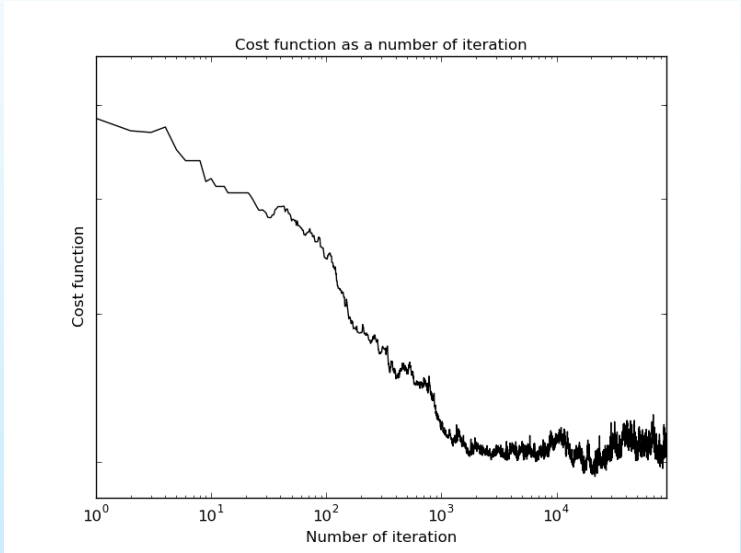
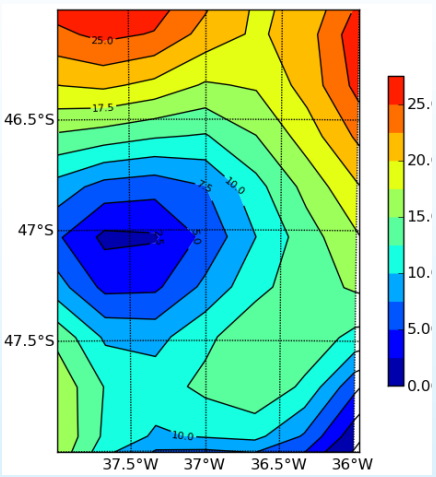


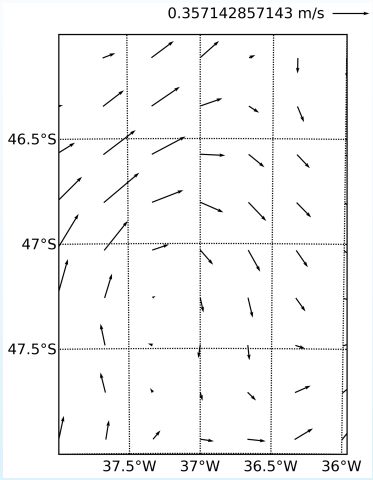
Use of Simulated Annealing to decrease the cost function.
Use of Gibbs' sampler to get a sample of the potential solutions.

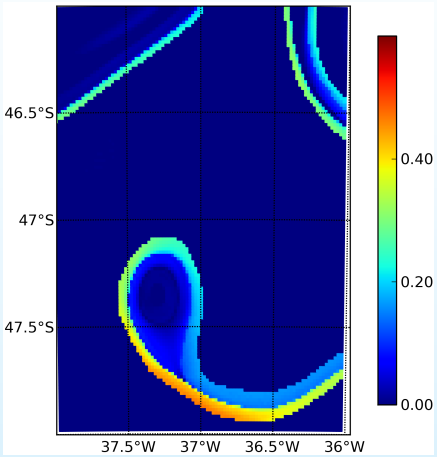
Results : Velocity field correction calculated using the SST

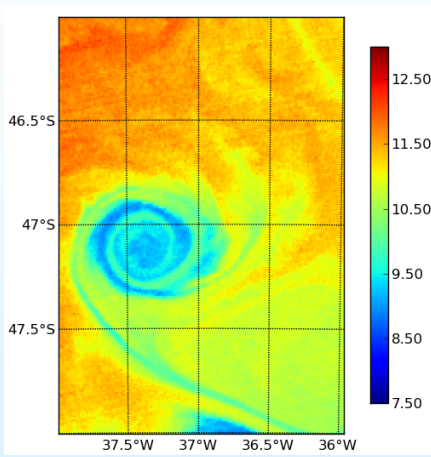
SSH | Velocity field | FSLE | SST

OBSERVATION

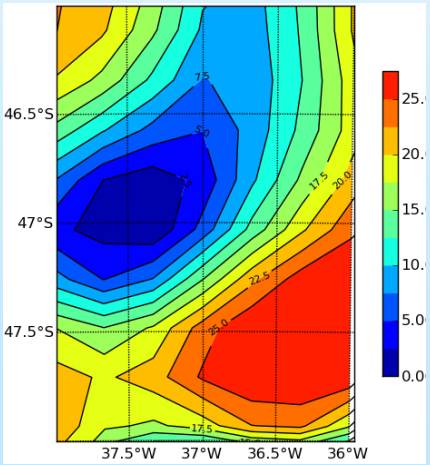


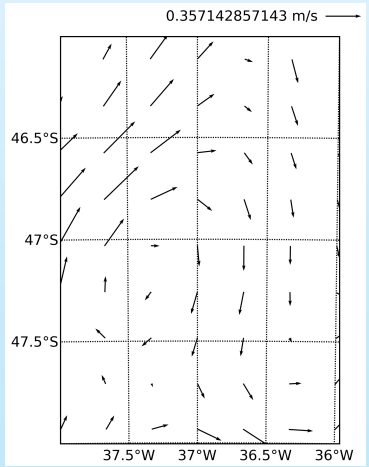


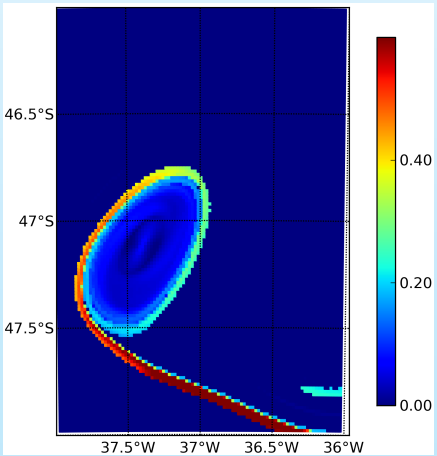




CORRECTION







Results : Velocity field correction calculated using the Chl

SSH | Velocity field | FSLE | Chlorophyll

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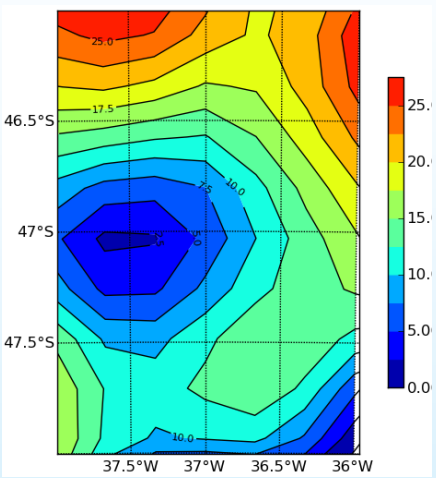

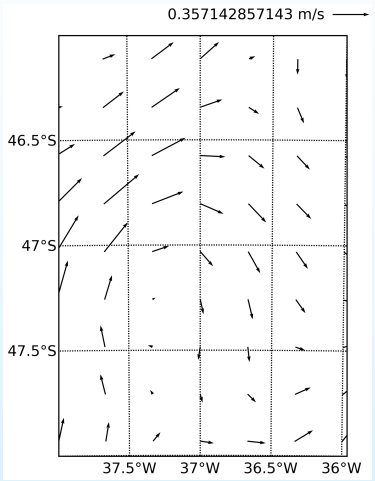

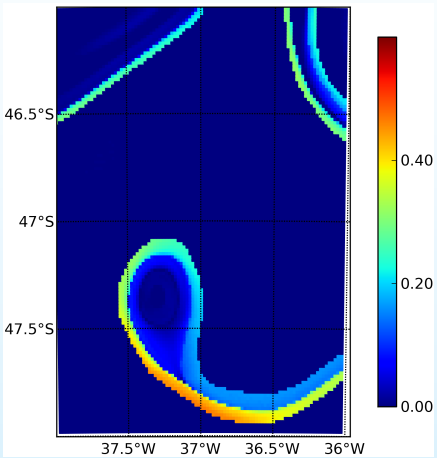

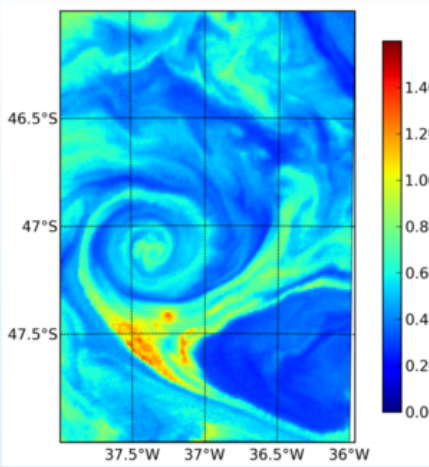

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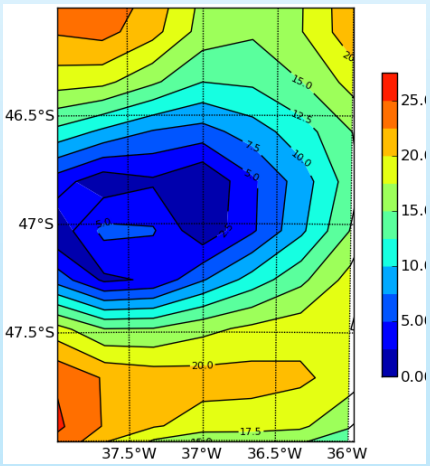
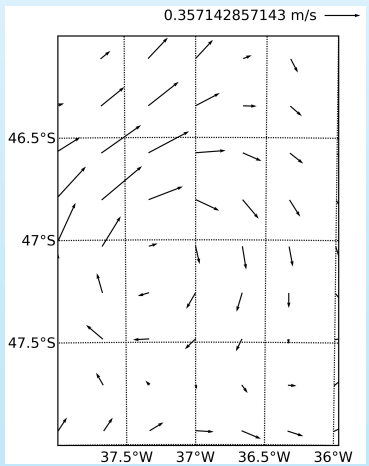
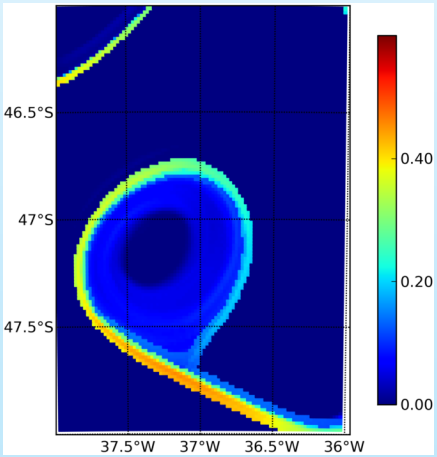
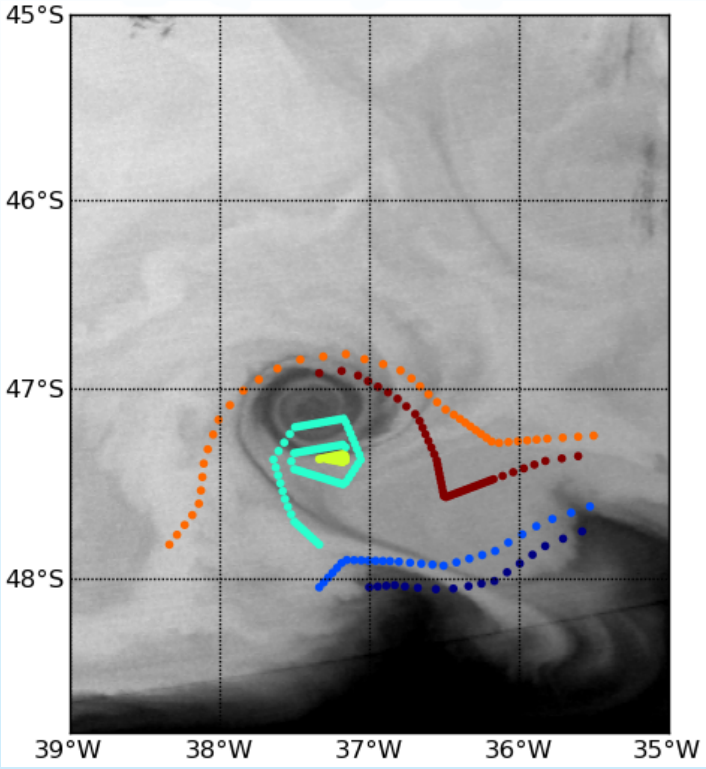


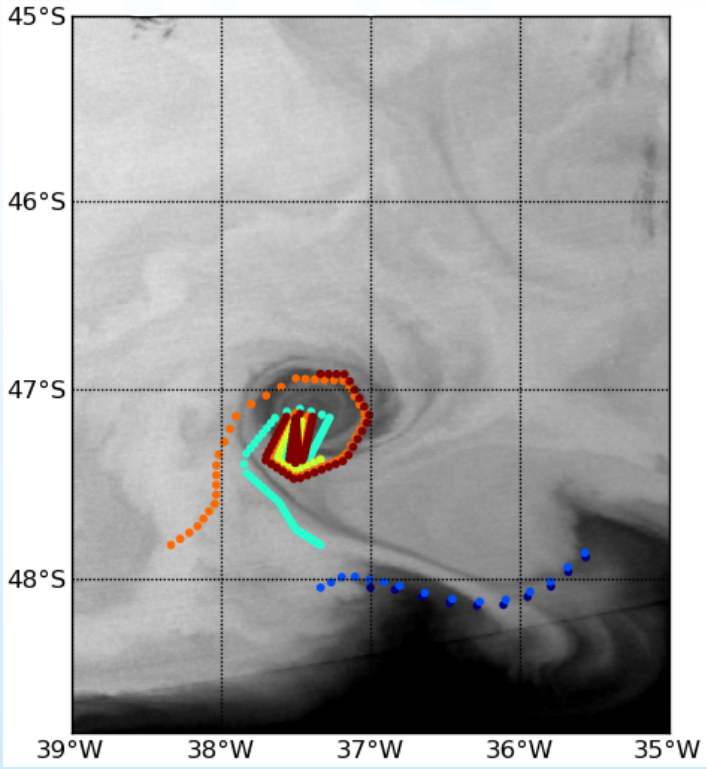




Results : Lagrangian trajectories (tracer : SST)



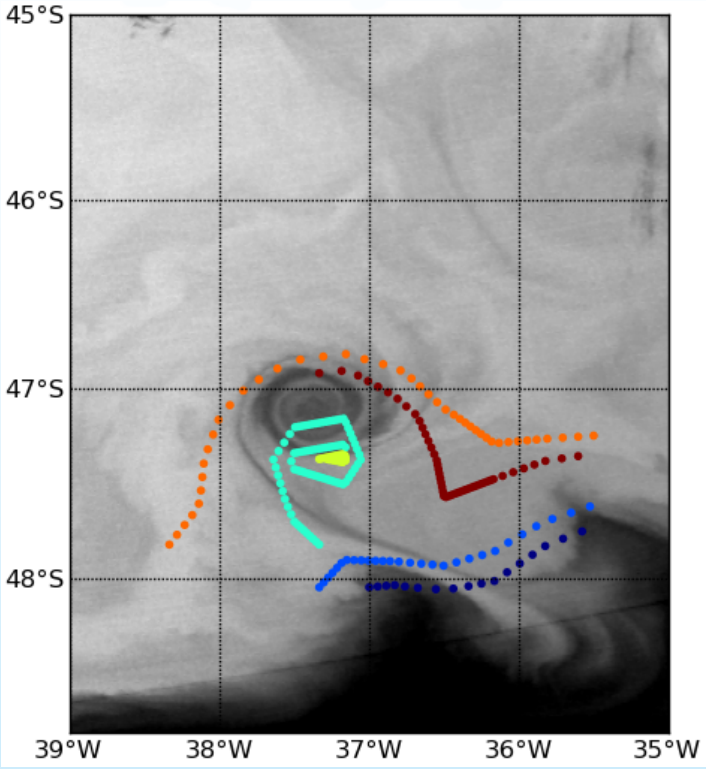
Lagrangian trajectories from the observed velocity field



Lagrangian trajectories from the corrected velocity field

- The trajectory of six particles are represented over the SST
- These trajectories are similar to the filaments observed in SST

Results : Lagrangian trajectories (tracer : Chl)



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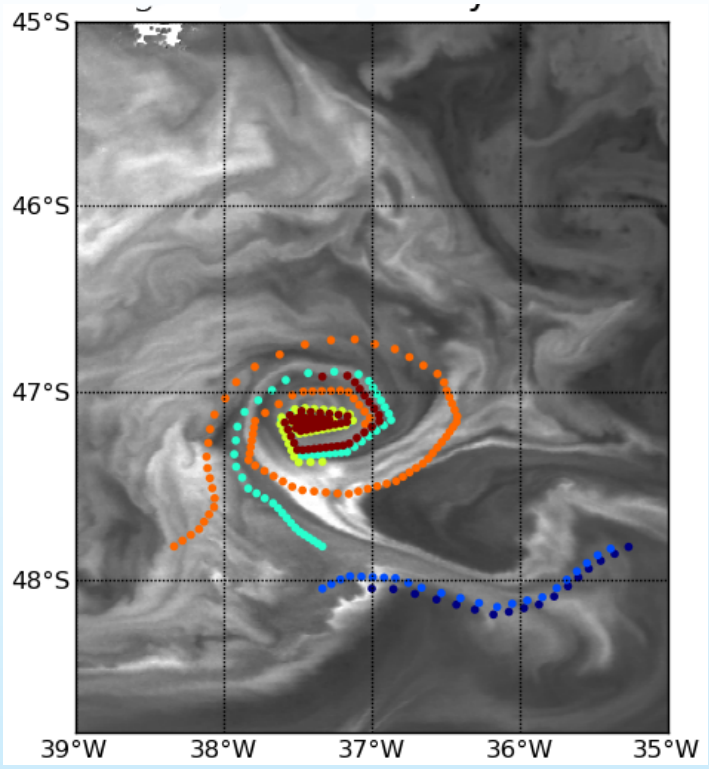


Lagrangian trajectories from the corrected velocity field

- The trajectory of six particles are represented over the Chlorophyll
- These trajectories are similar to the filaments observed in Chlorophyll

Conclusion

Sub-mesoscale information are invertible to control larger scales dynamics

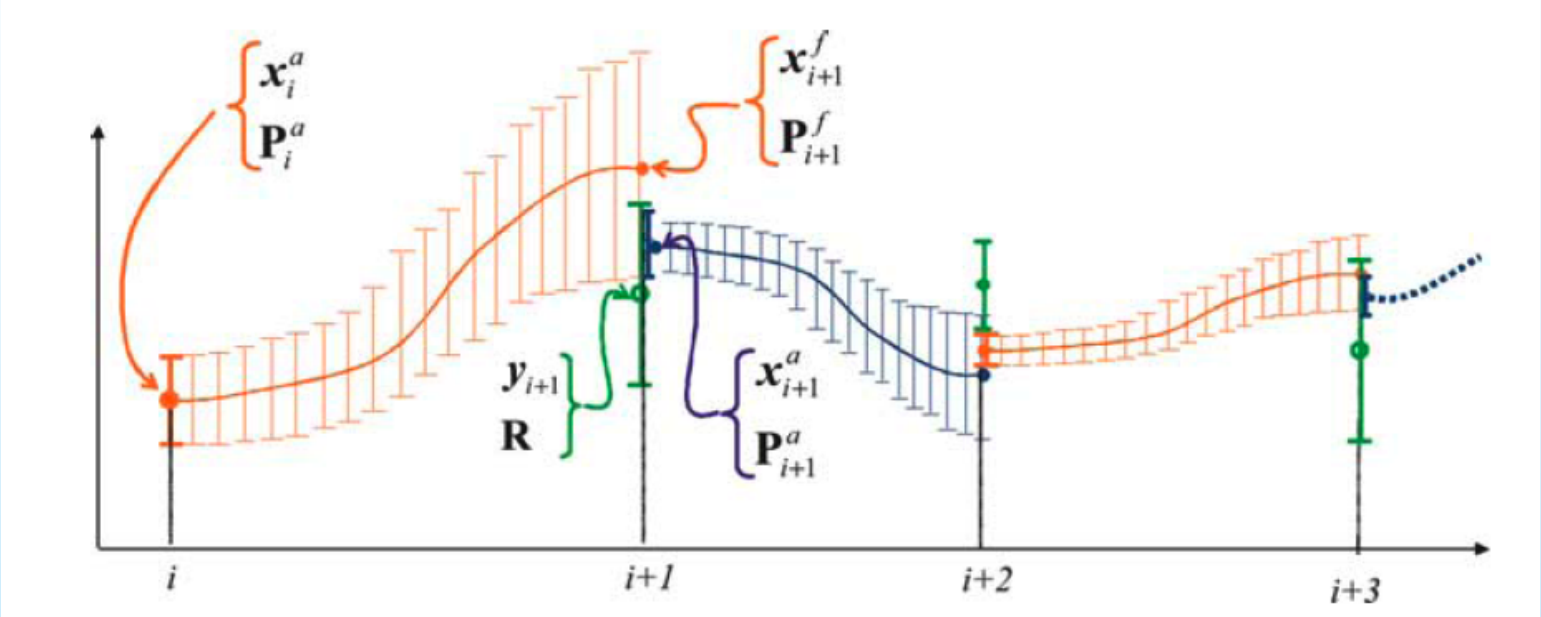
- Altimetry and tracer observations are complementary.
- Tracer information can compensate for the lack of SSH resolution in time and space.
- High resolution Sea Surface Temperature or Ocean Color data are useful to control ocean physics.

Future work

- Twin experiment in an idealized coupled physico-biogeochemical model to assess the quality of the correction.
- Data Assimilation of image in a coupled physico-biogeochemical model.

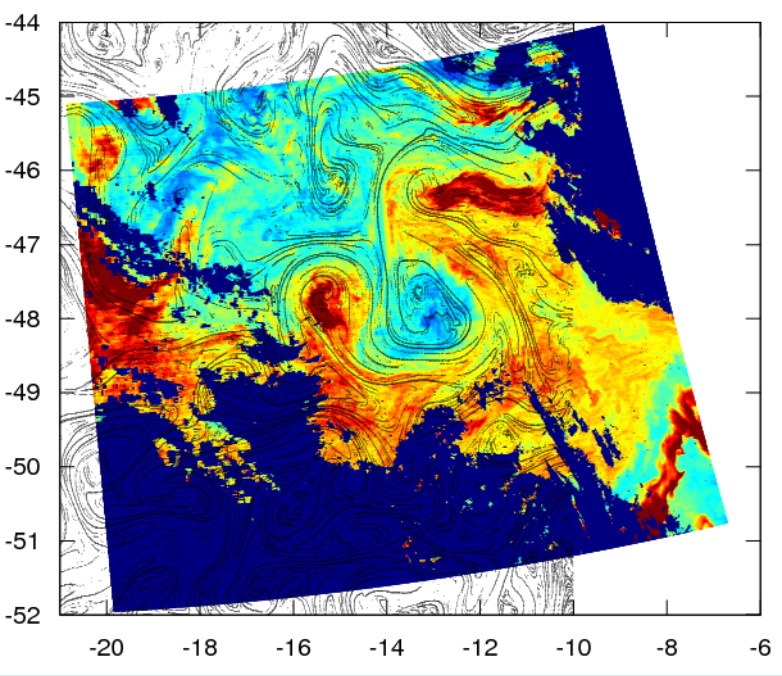
Thank you for your attention

Data Assimilation

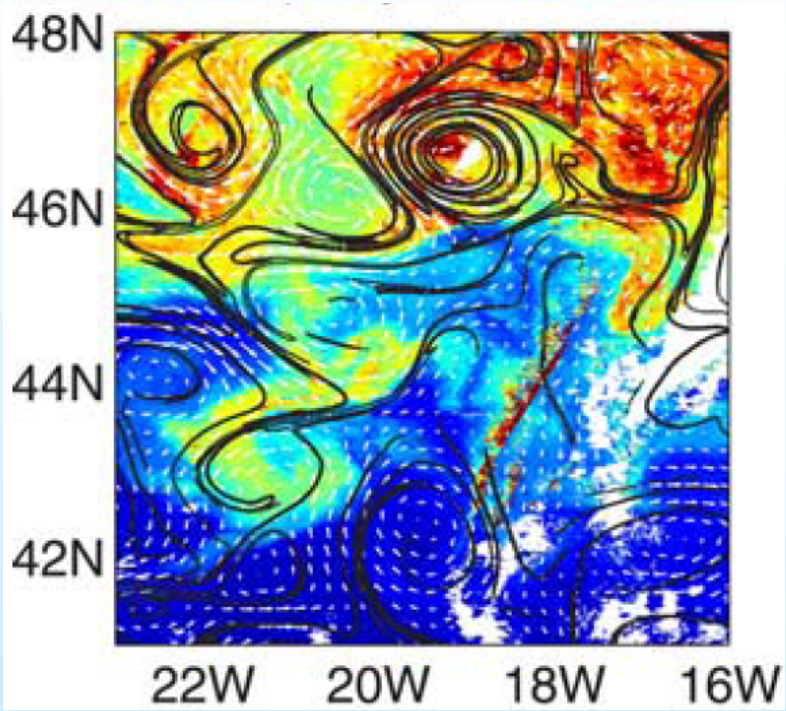


Conceptual representation of filtering with sequential assimilation, Brasseur, 2006

Connection between FSLE and tracer filaments



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



Chlorophyll, Pomme area, Lehahn & al, 2008