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

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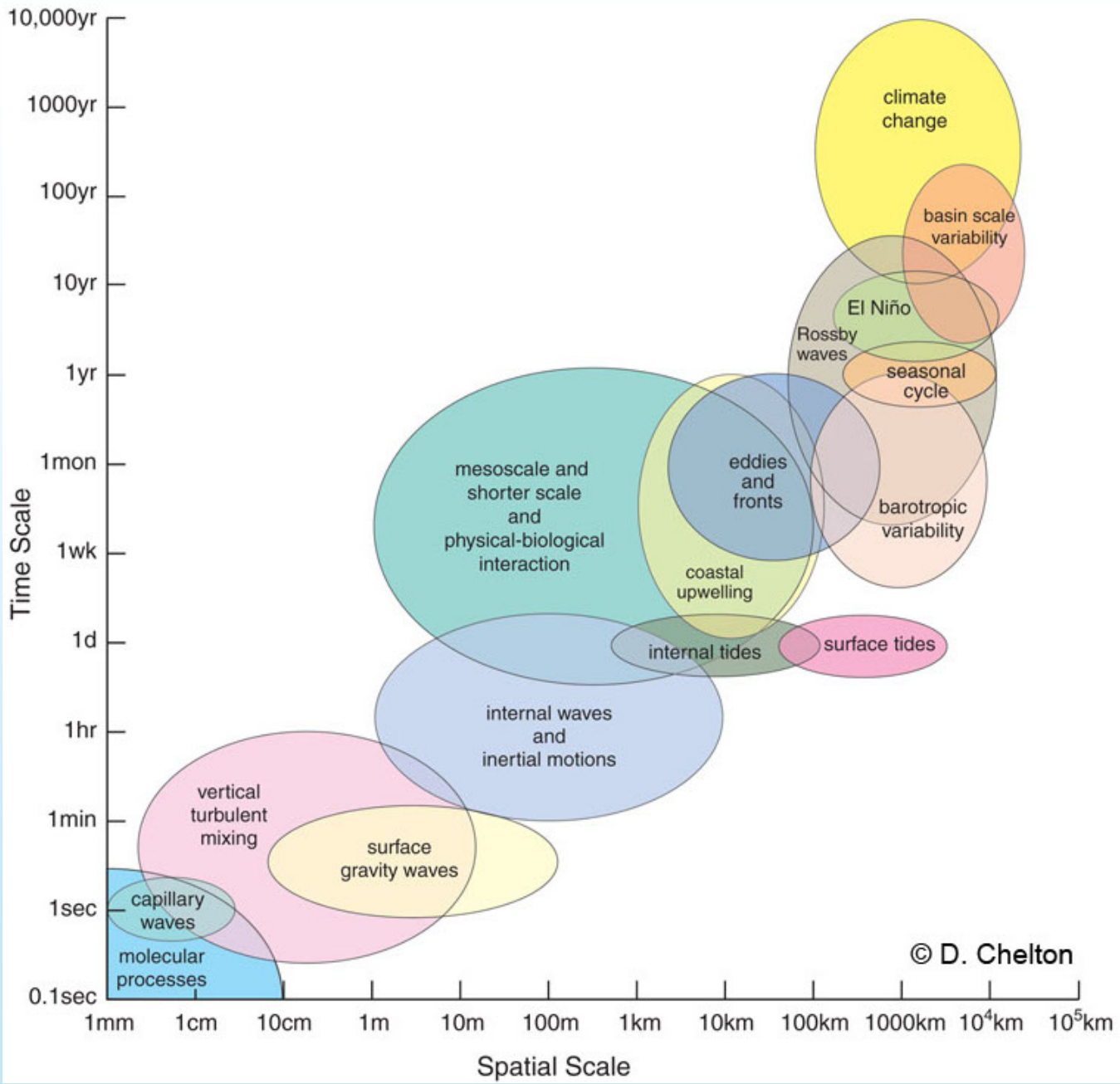
April 12, 2011

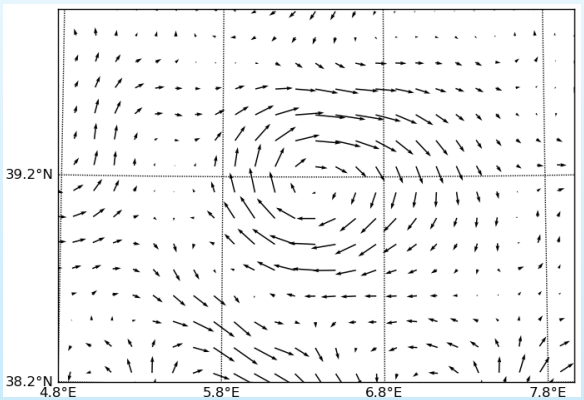
Mesoscale dynamics cascade into sub-mesoscale dynamics

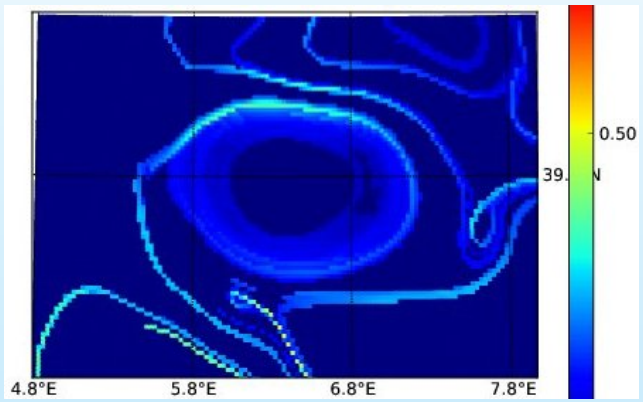


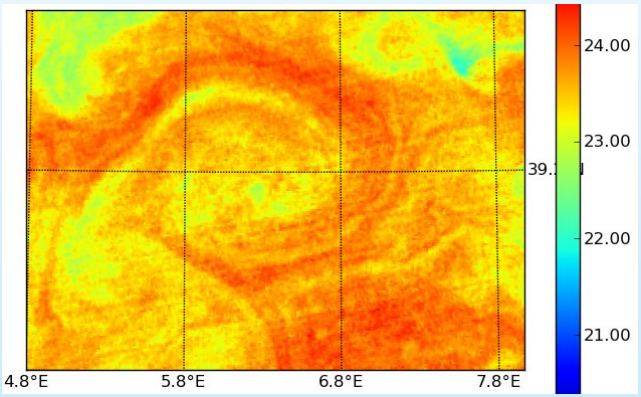
Context of this study

- Lyapunov exponents can be seen as a proxy for tracers (d'Ovidio & al (2004), Lehahn& al (2007)):

Mesoscale velocity → Lyapunov exponents → Sub-mesoscale image tracer







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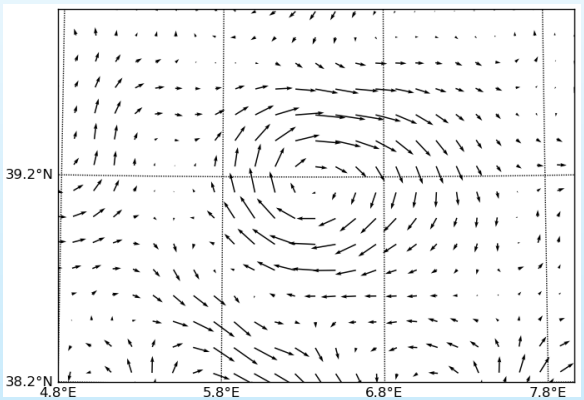
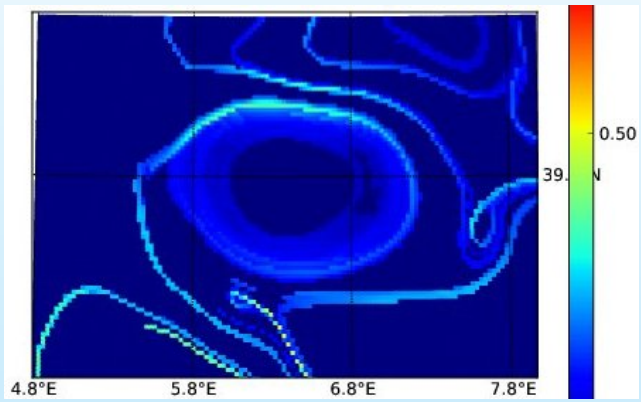
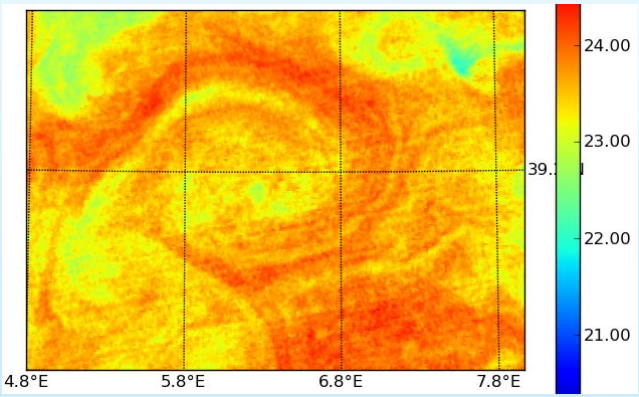




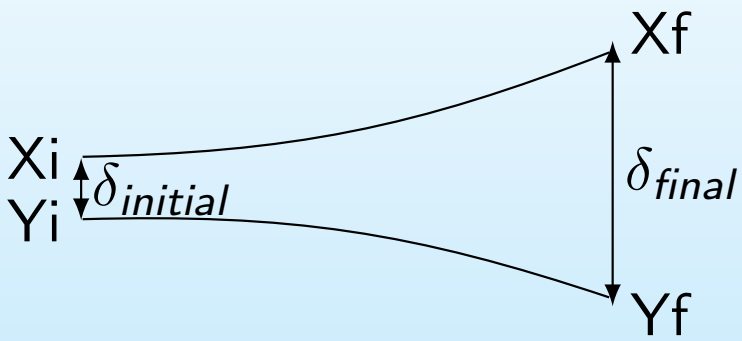


- Inversion of sub-mesoscale tracer information to correct mesoscale velocity

Outline

Physical meaning of Lyapunov Exponents

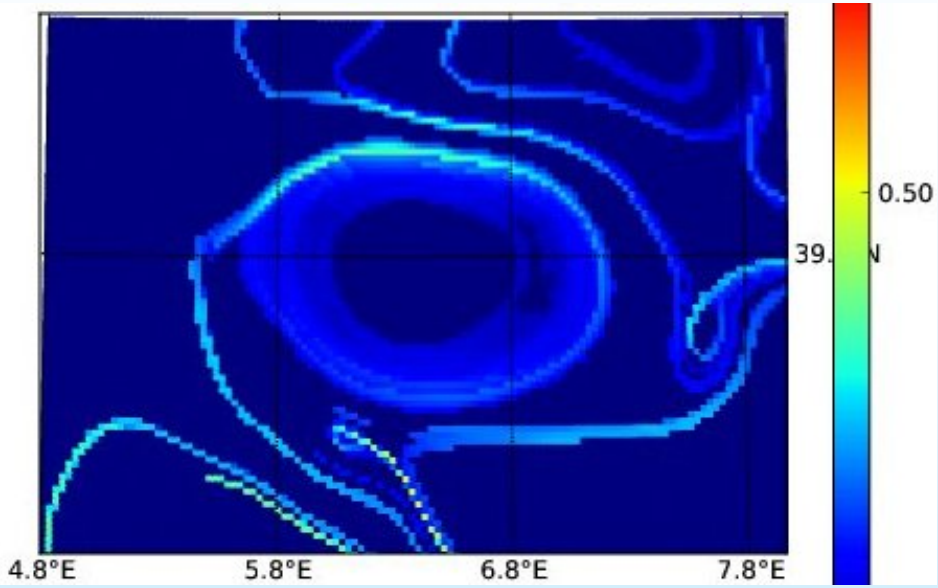
Lyapunov exponents are defined as the exponential rate of separation, averaged over time



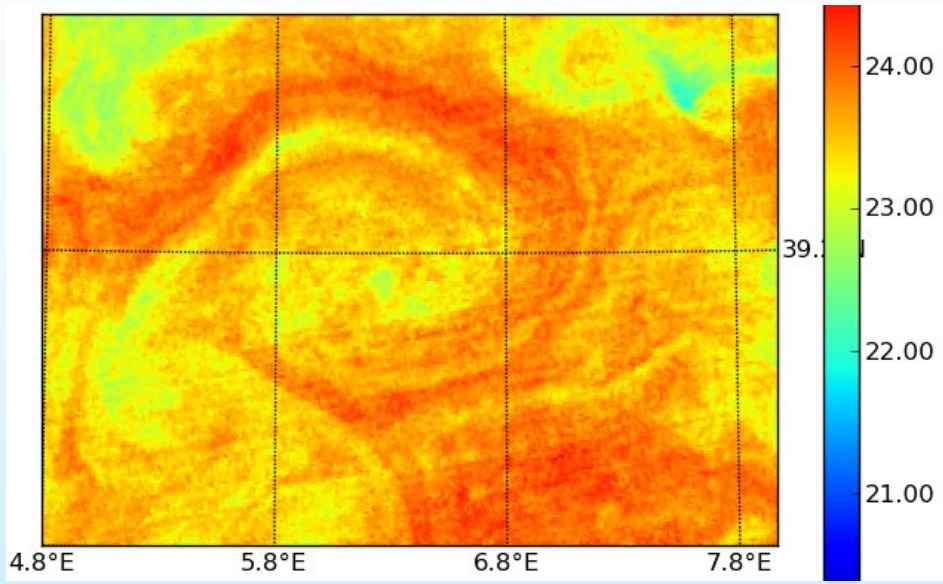
$$\lambda = \frac{1}{T} \times log(\frac{\delta_{final}}{\delta_{initial}})$$

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

Are Lyapunov exponents a reliable proxy/image?



FSLE, June 30, 2004



Sea Surface Temperature, July 03, 2004

Maximum lines of Lyapunov exponents and frontal tracer structures present similar patterns (d'Ovidio & al (2004)).

An exploratory study

- **Step 1**: Inversion of synthetic sub-mesoscale images to larger scale ocean circulation (twin experiment approach)
- **Step 2**: Inversion of sub-mesoscale ocean color or sea surface temperature to larger scale ocean circulation

Methodology

• 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.

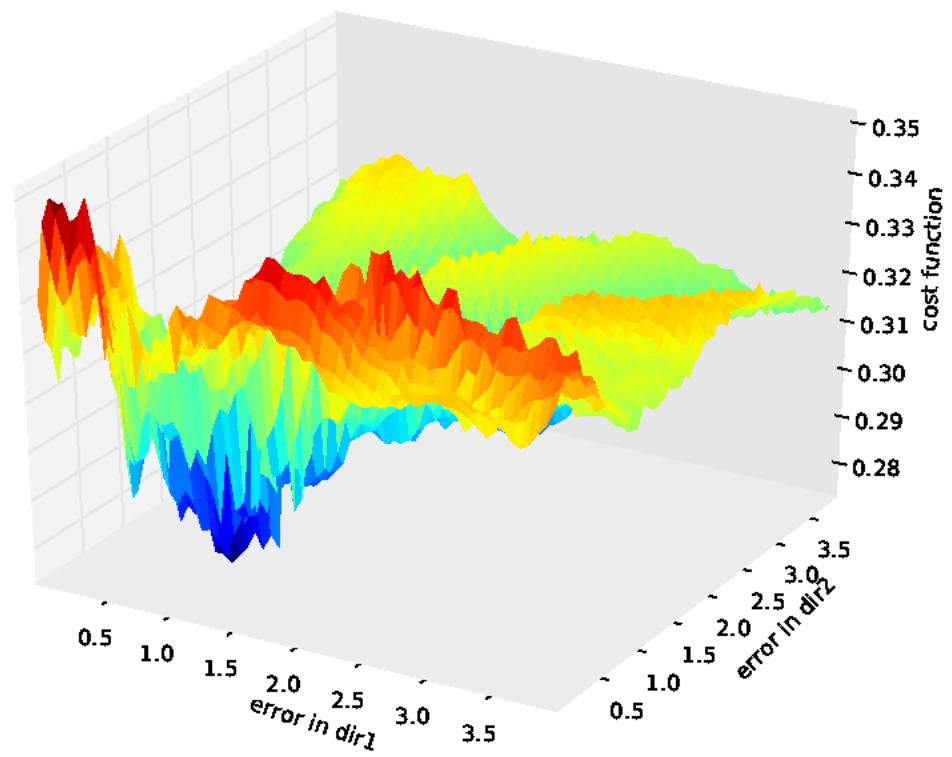
• Assumption of the gaussianity of the velocity error panel: The velocity errors are normally distributed with 0 mean and covariance $\mathbf{P}$ (the covariance of the time sequence) $\delta\mathbf{u} \simeq \mathcal{N}(0, \mathbf{P})$

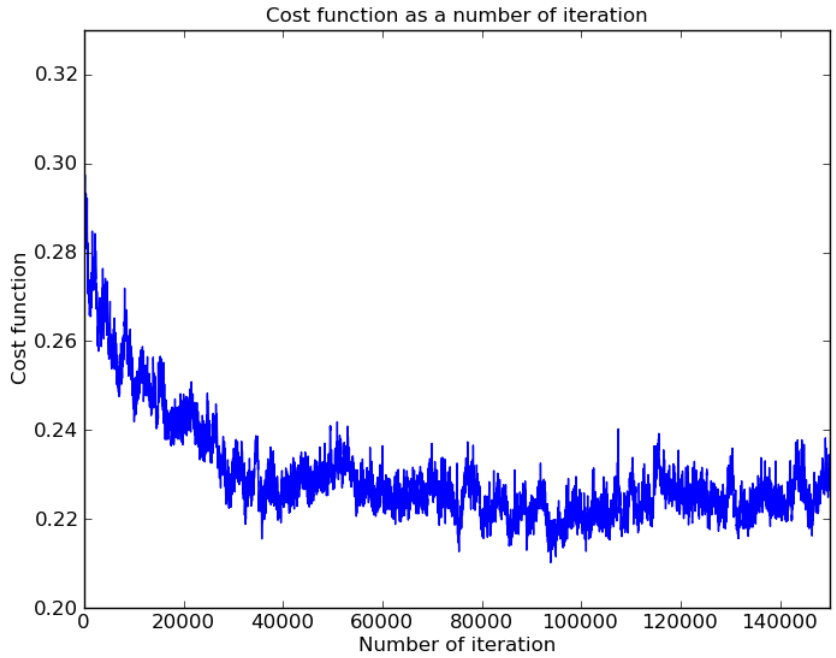
• Integration of trajectories to derive Lyapunov exponents: $\lambda = \frac{1}{T} \times log(\frac{\delta_f}{\delta_i})$
• The Cost function is the distance between the model and the observation

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

Minimization of this cost function complex because of many local minima

Methodology





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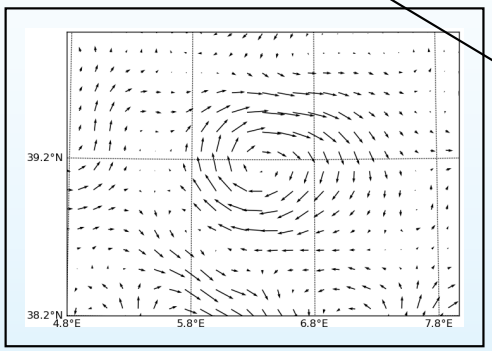
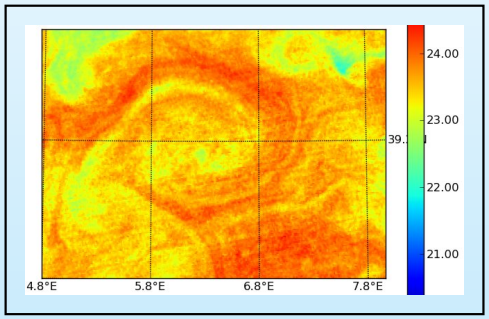
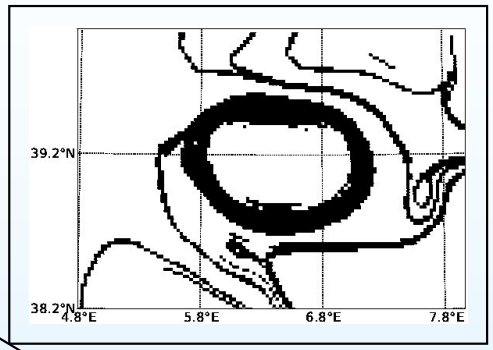
Inversion algorithm

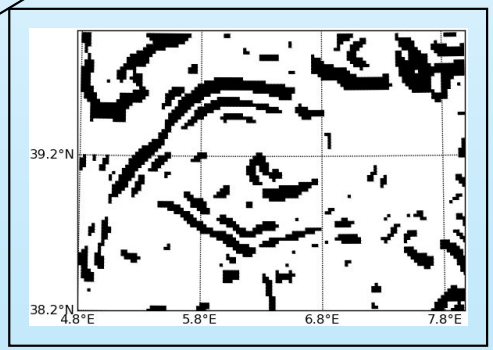
Mesoscale Velocity





Tracer Image





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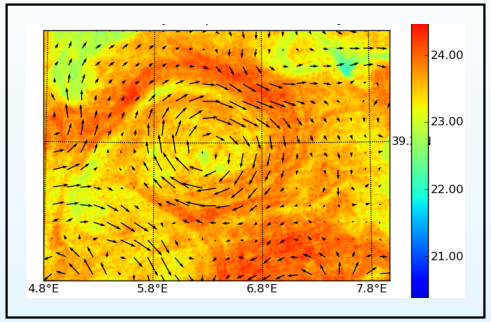


Corrected Velocity

Choice of a Study area

Required by Lyapunov exponent

- Being far from any coast : Problem with particules advection in the presence of land
- Being far from any upwelling or downwelling : Vertical velocity is not taken into account in the calculation of Lyapunov exponent

Required by tracer

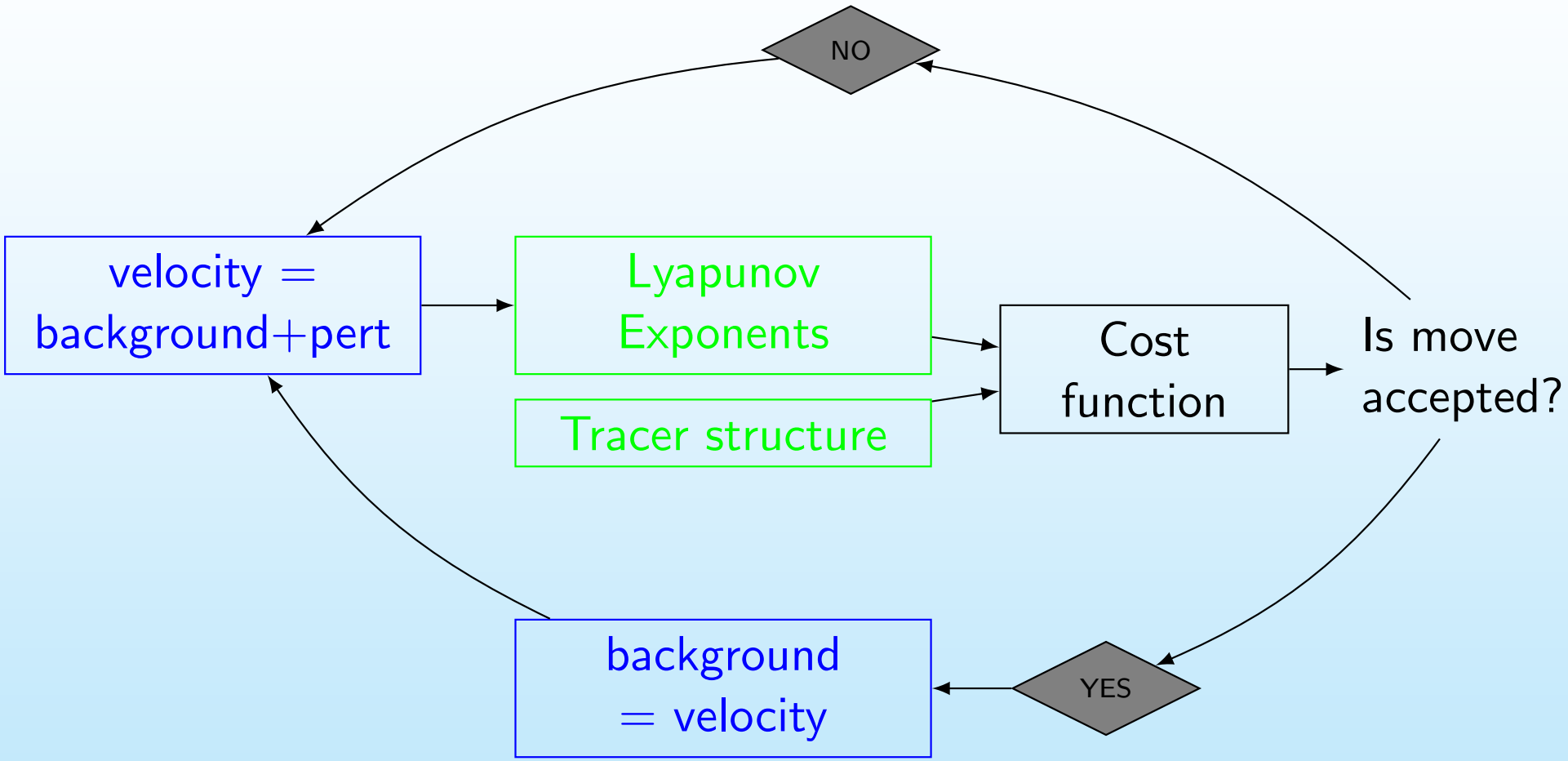
- Presence of heterogeneity in the tracer to detect filament
- Low cloud cover: Visible and Near IR wavelength do not go through clouds
- Presence of an unstable manifold

Test case : Mediterranean Sea

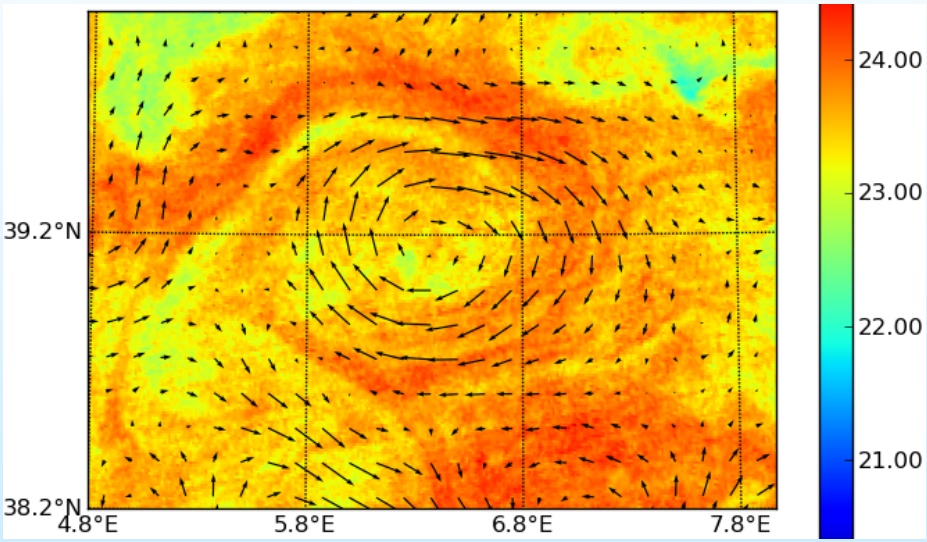
- **Region**: Mediterranean Sea, from $4.8^o E$ to $8^o E$, from $38.2^o N$ to $40.^o N$
- **Time Range**: from 1998 to June 2009, 595 velocity maps
- **Velocity fields**: AVISO altimeter data
- **Resolution**: $1/8^o$, grid points: 26*17
- **FSLE Resolution**: $1/48^o$, grid points: 119*86

- **SST field**: Data from MODIS captor, L2 product
- **Resolution needed to detect filament**: $1/100^o$

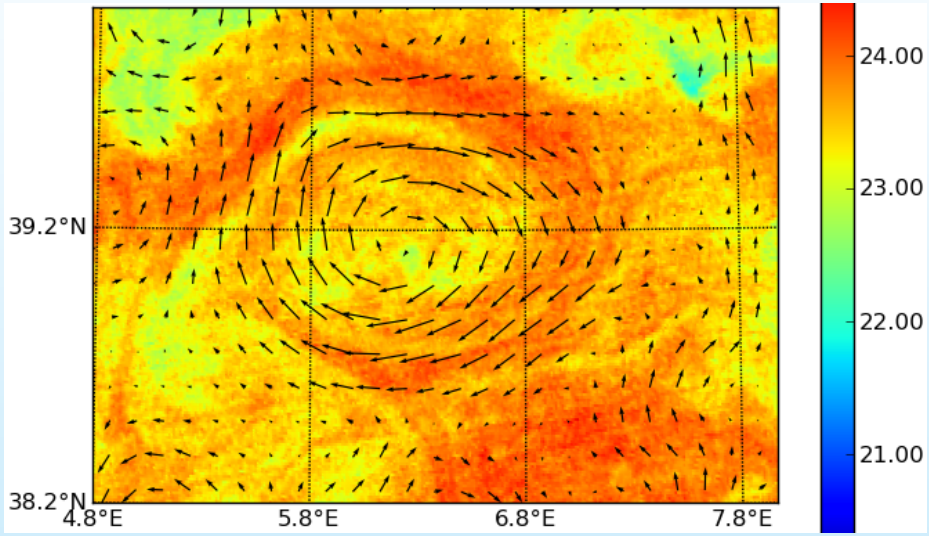
Inversion algorithm



Results



Aviso velocity, June 30, 2004, cost function: 0.33



Corrected velocity, cost function: 0.23, number of iterations: 30000

Conclusion

Sub-mesoscale tracers invertible to larger scales

- Sub-mesoscale tracers inversion to mesoscale velocity is feasible using Lyapunov exponents as a proxy.
- High resolution Sea Surface Temperature or Ocean Color data are usefull to control ocean physics.

Next

- Quantify the error made on the estimated velocity
- Avoid the degradation of the corrected velocity with the number of iterations

Prospects

- Assimilation of image in a coupled physico-biogeochemical model
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Thank you for your attention