On the use of sub-mesoscale tracer information for the improvement of altimetry-derived velocity fields

A Data Assimilation strategy

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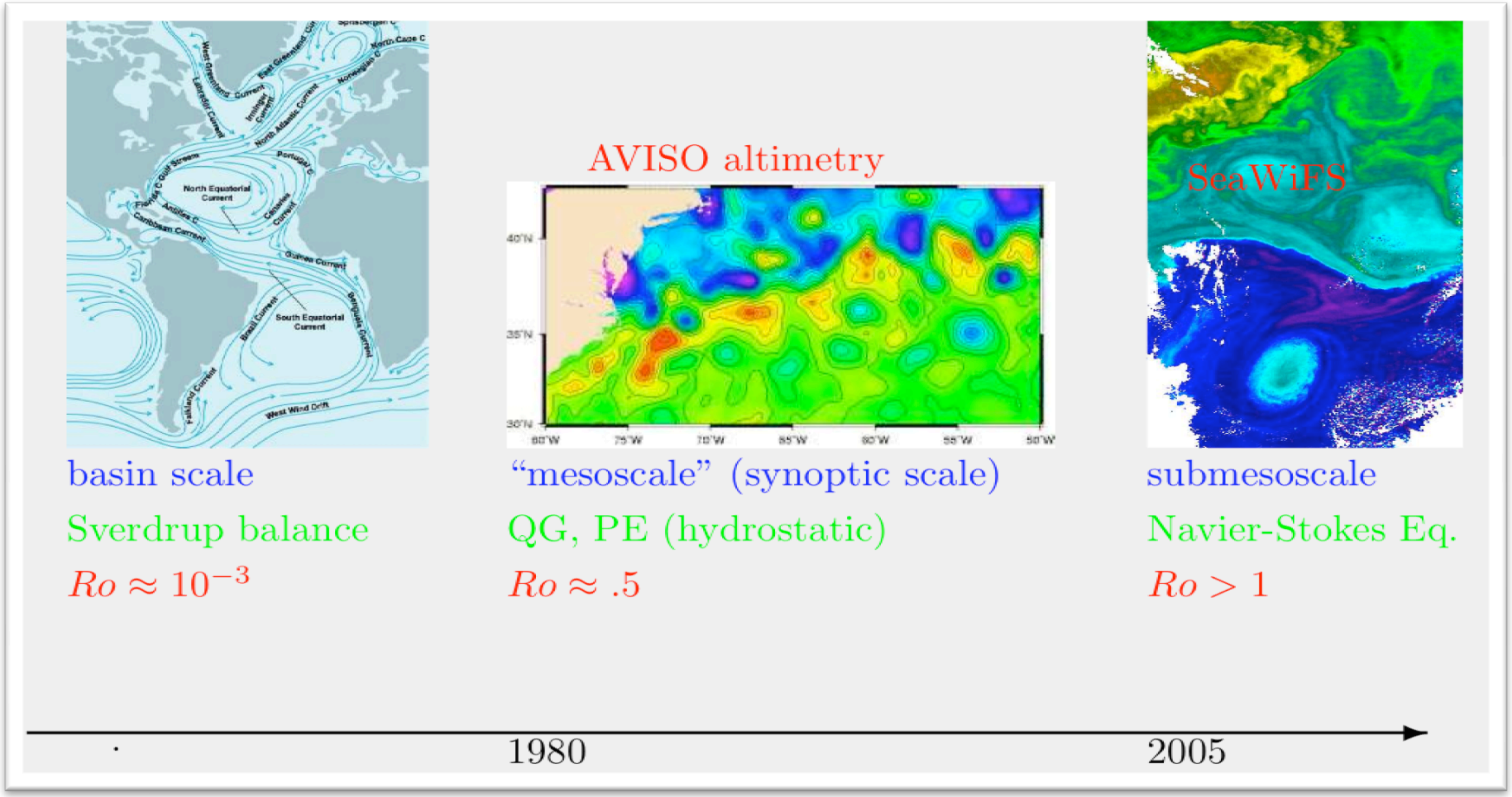
Motivations

- Use of all sort of (satellite) data, mix different scales, physics and biogeochemistry, ...
- Think Data Assimilation accordingly
- **A way to improve our knowledge of ocean currents ?**

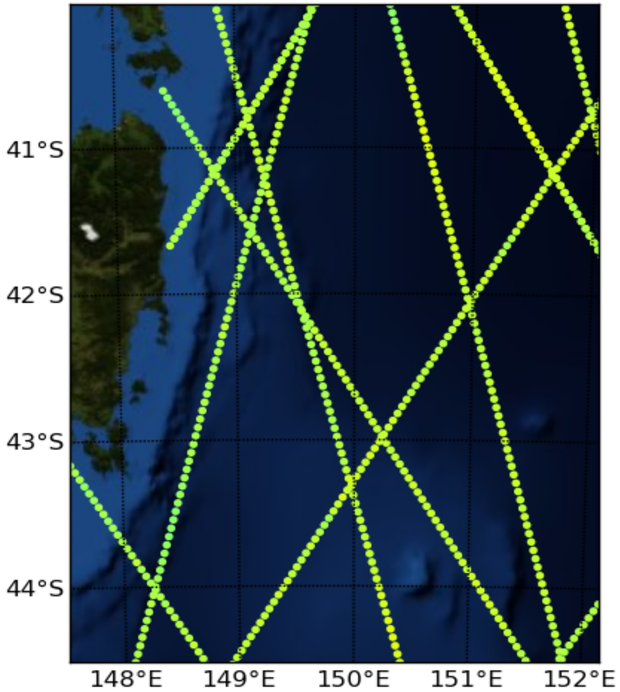
Submesoscales ?

- A large range of scales between the mesoscales (≈ 100 km) and the dissipative scales (≈ 1cm) that seem quite energetic and that we do not know much about …



Observations of submesoscales

Submesoscales are not resolved by synoptical observations



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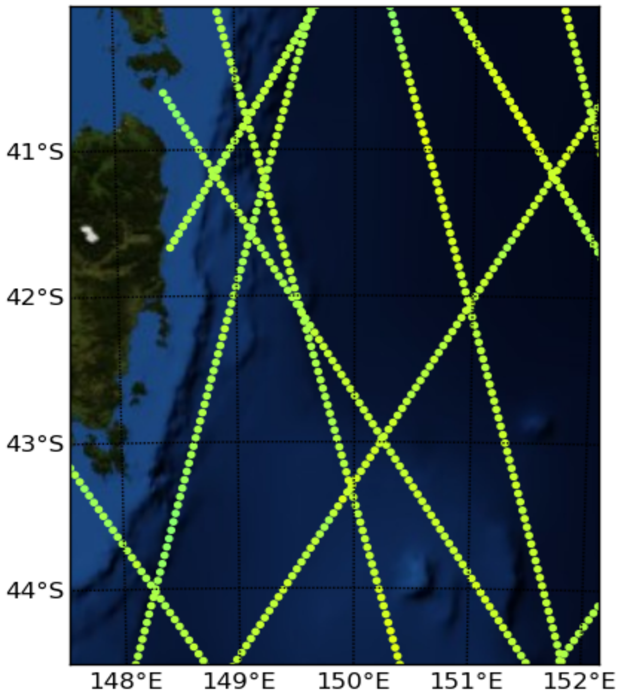
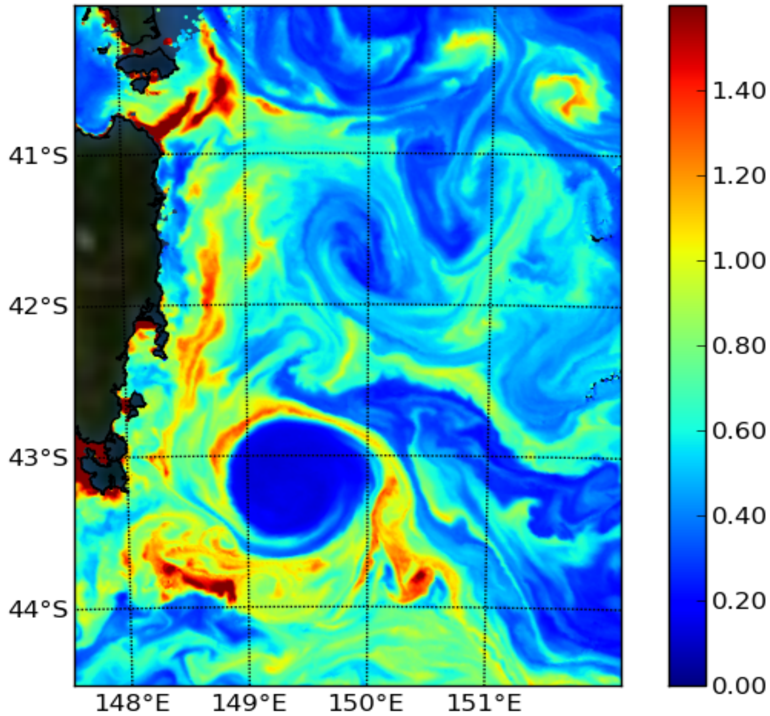
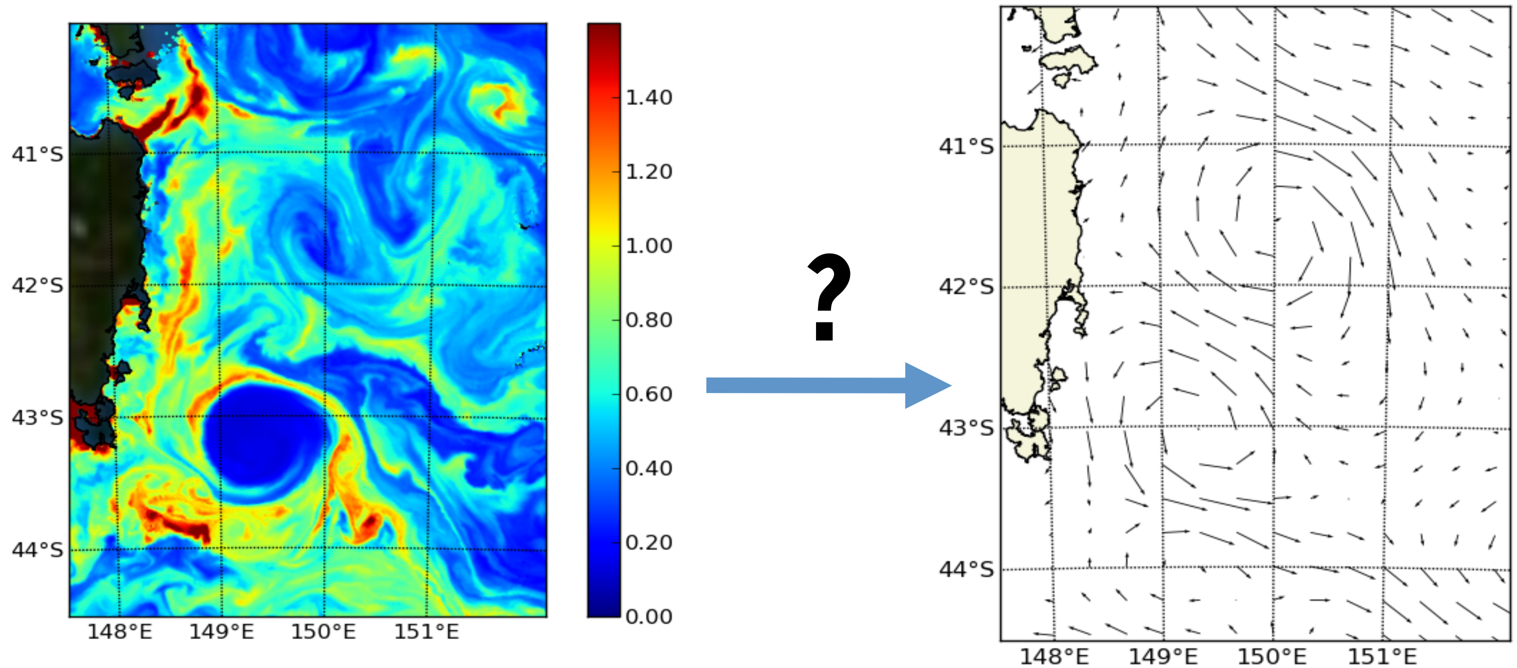


Submesoscales are observed with satellite tracer sensors



Question: altimetry and high resolution tracer observations

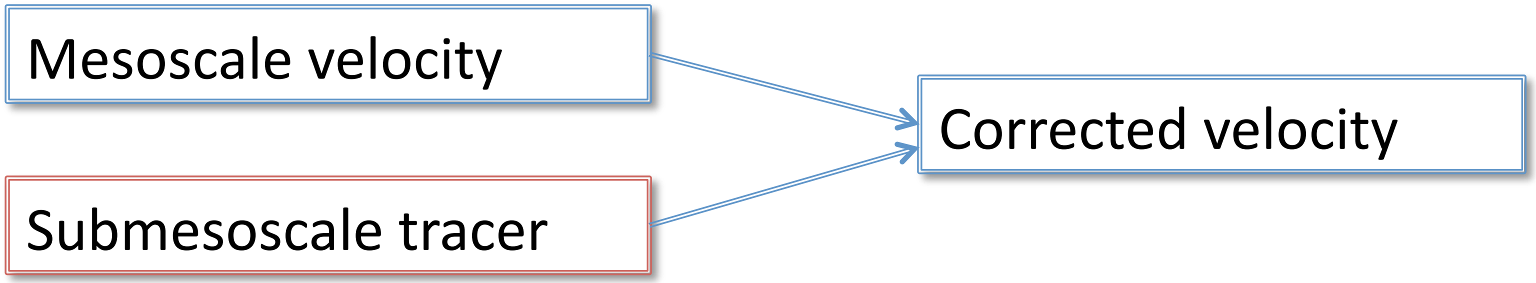


- Is the use of submesoscale tracer information to correct for the mesoscale velocity field feasible ?

Outline

- **Method**
  - A proxy between tracer and velocity
  - Inversion of submesoscale information
- **A Test case**
  - Cost function
  - Corrected velocity field
- **Conclusions**

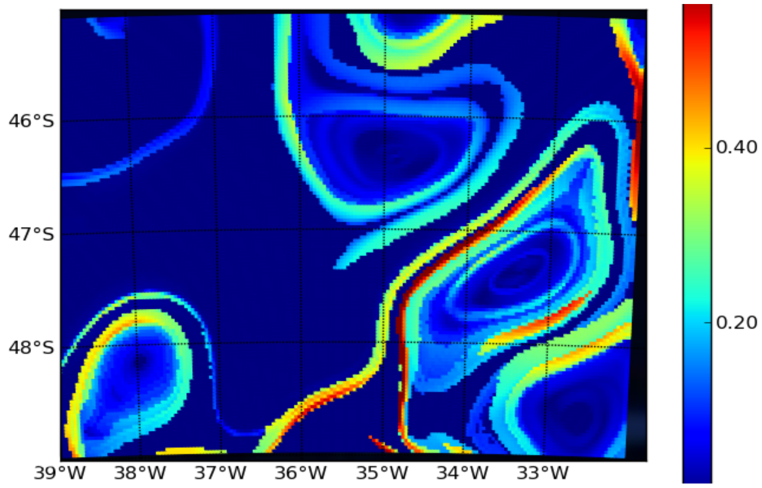
Find a proxy between tracer and velocity



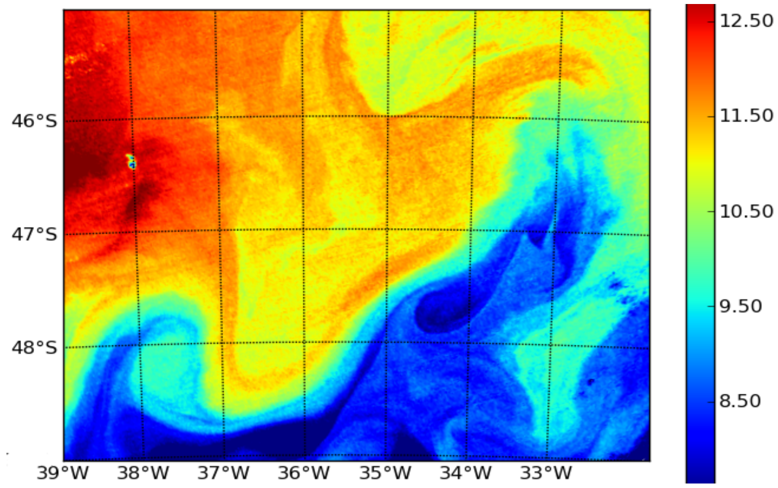
Find the correction the most compatible with tracer information

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

Lyapunov exponents as a (reliable ?) proxy



FSLE, South Atlantic, Dec 28, 2006



SST tracer, South Atlantic, Dec 28, 2006

- Lyapunov measures fluid stirring
- Link between submesoscale dynamics and biologic stirring
- (Lehahn et al., 2008, D'Ovidioo et al., 2004)

Methodology

- **Cost function**

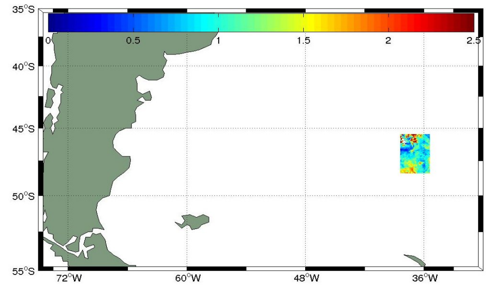
$$J(u) = \| \mathcal{I}_{FSLE}(u) - \mathcal{I}_{OBS} \| + \text{background term}$$

strongly non-linear cost function with local minima

- Explore subspace errors to find the velocity that minimizes the cost function: using EOFs analysis with all velocity fields available (≈ 100 EOFs used)

$$u_k = u_{mean} + \sum a^f_k \, u^f$$

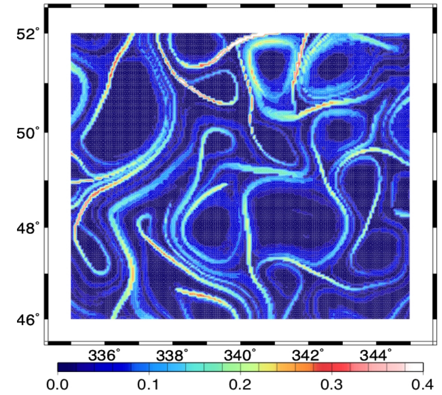
Test case : a small region in the South Atlantic ocean



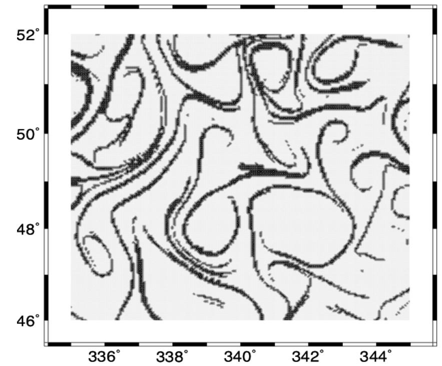
- **Time Range :** from 1998 to June 2009, 595 velocity maps
- **Velocity field :** AVISO, Altimetric data
- **Resolution :** 1/3°, grid points : 13*17
- **FSLE Resolution :** 1/48°, grid points : 99*130
- **Tracer field :** SST or Chlorophyll data (MODIS sensor, L2 product)
- **Resolution :** ≈ 1/100°

Transform the Lyapunov exponents into (simple) images

- Observed image structures are extracted using a binarization of the gradient norm
- Y= 1 if ‖ δY ‖ > σ otherwise Y=0
- The threshold σ is chosen such a given percentage of pixels are kept (80%)



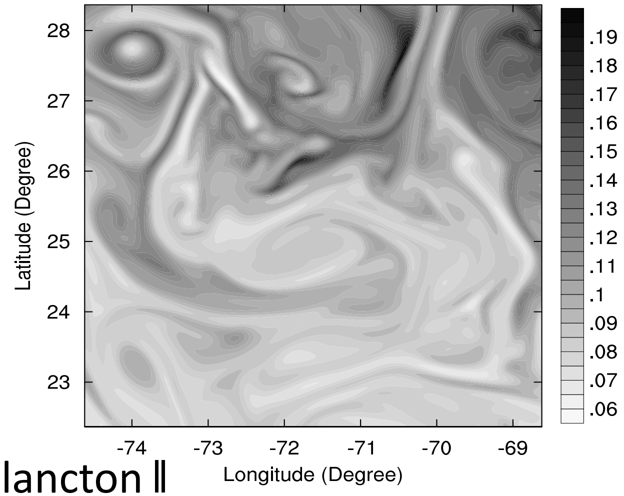
‖ δFSLE ‖



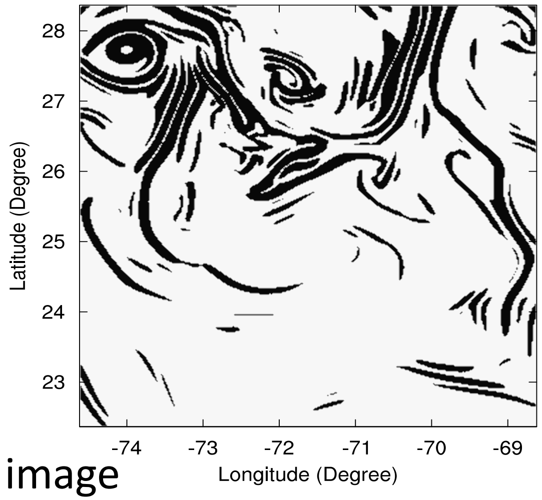
Skeleton image

Generation of phytoplancton (or SST) images

- Observed image structures are extracted using a binarization of the gradient norm
- Y= 1 if ‖ δY ‖ > σ otherwise Y=0
- The threshold σ is chosen such a given percentage of pixels are kept (e. g. 80%)



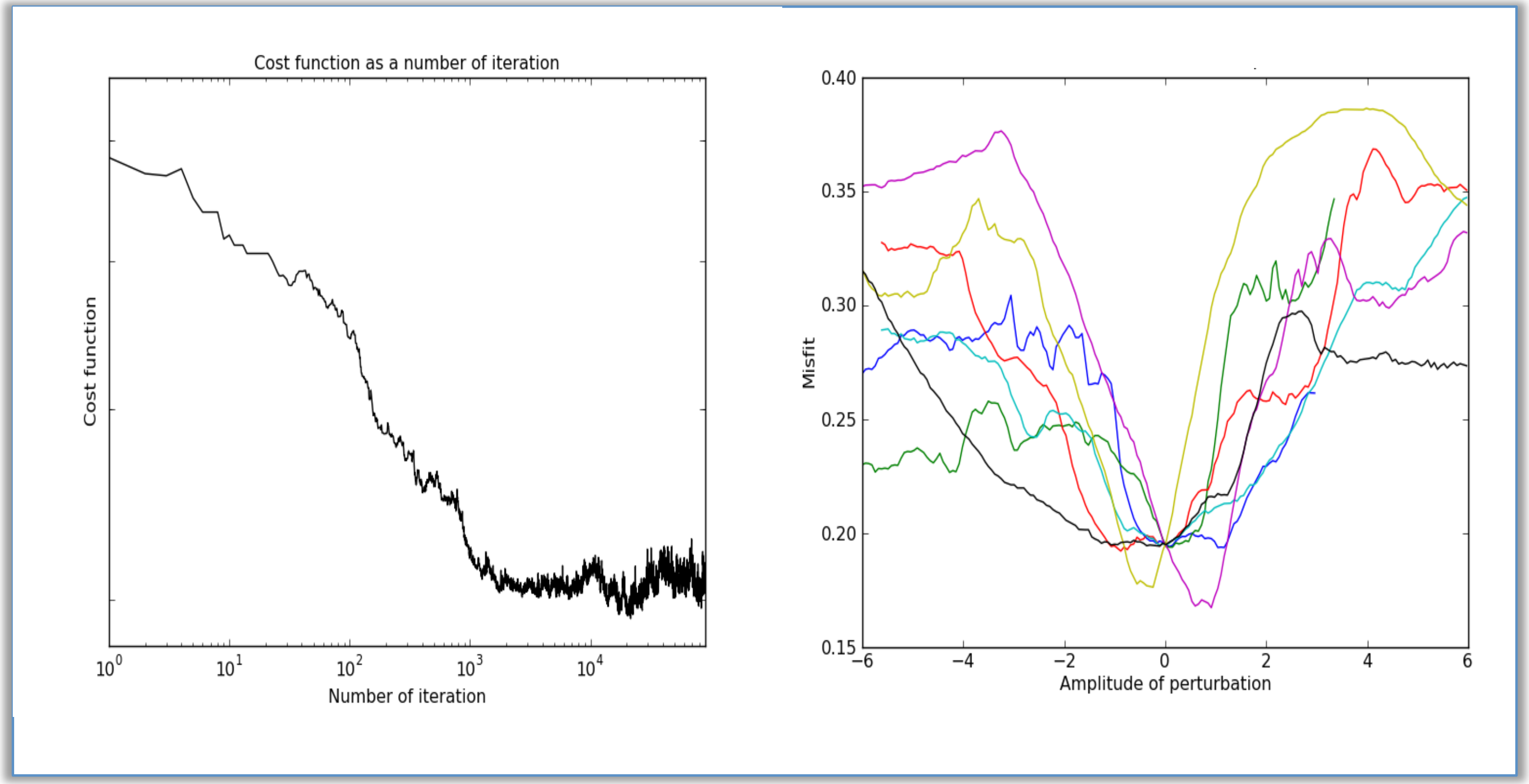
‖ δPhytoplancton ‖



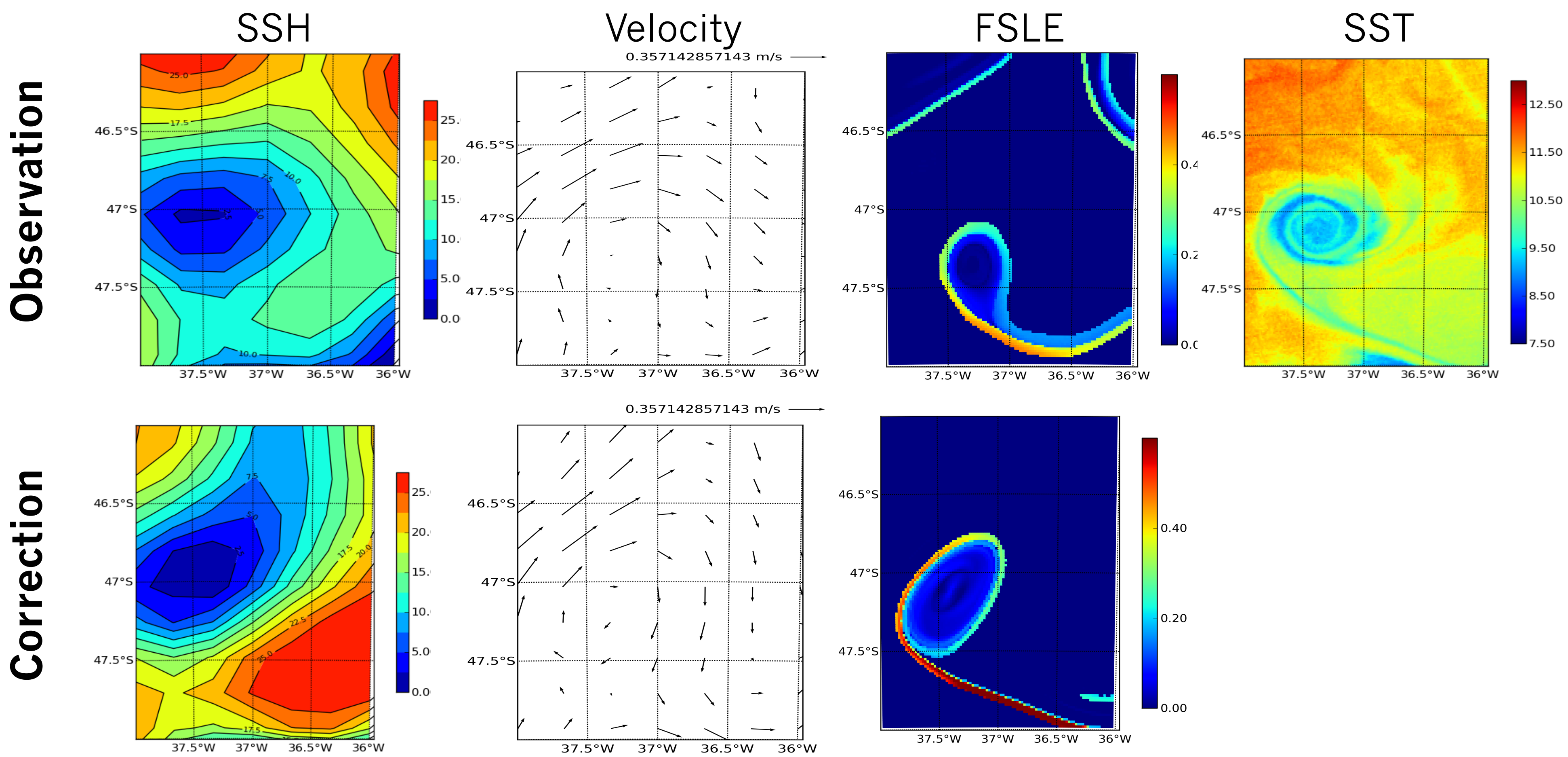
Skeleton image

Cost function study: inversion

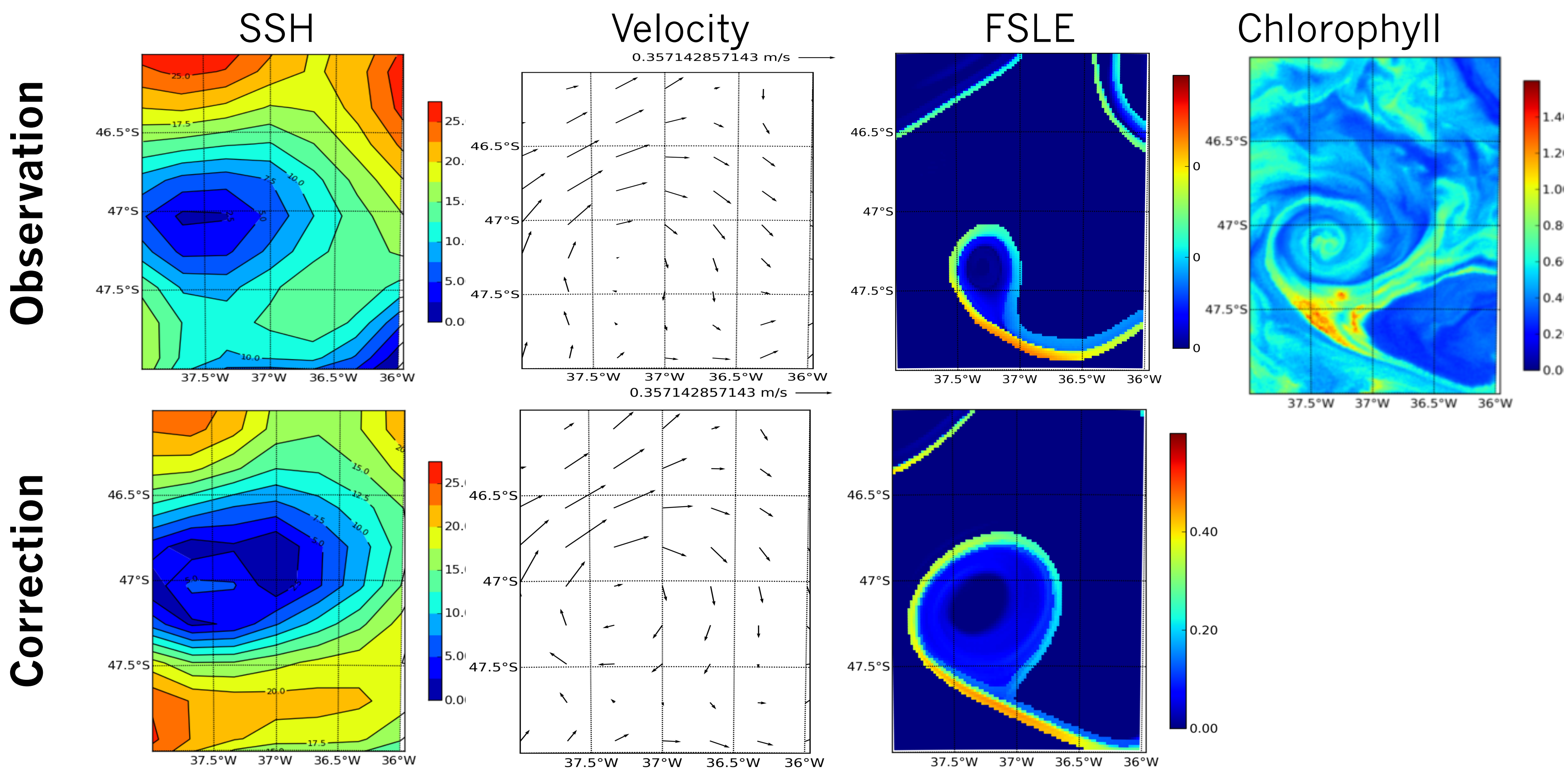
- Simulated annealing to minimize the cost function
- Gibbs' sampler to get a sample of the potential solutions



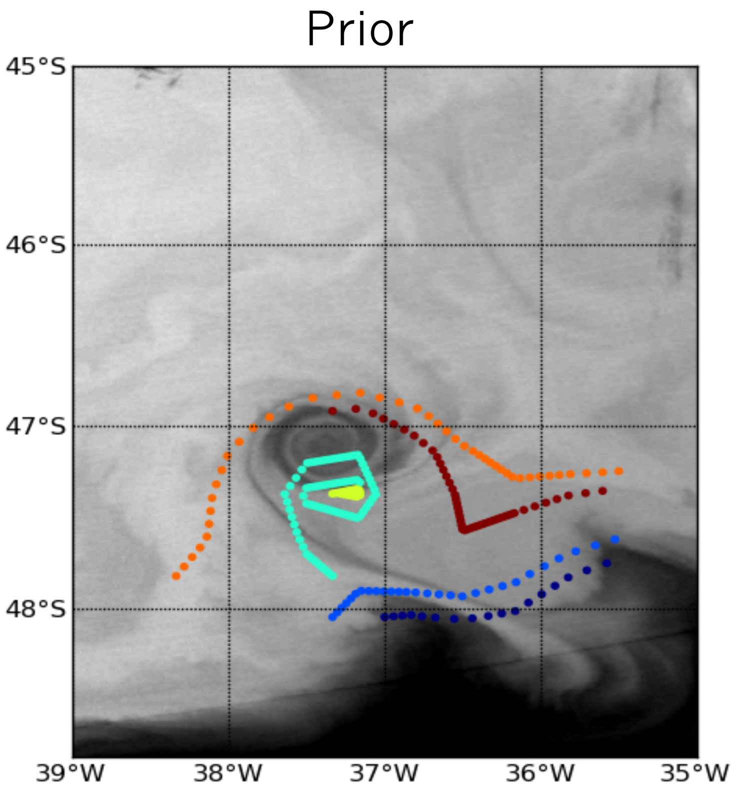
Results: Velocity correction calculated using SST

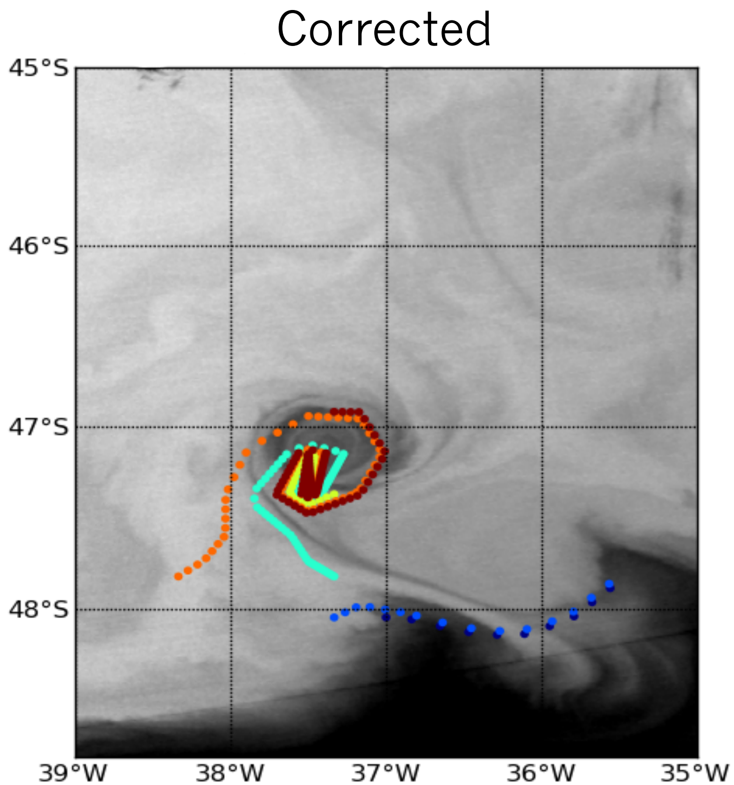


Results: Velocity correction calculated using Chlorophyll



Results: Lagrangian trajectories / SST tracer





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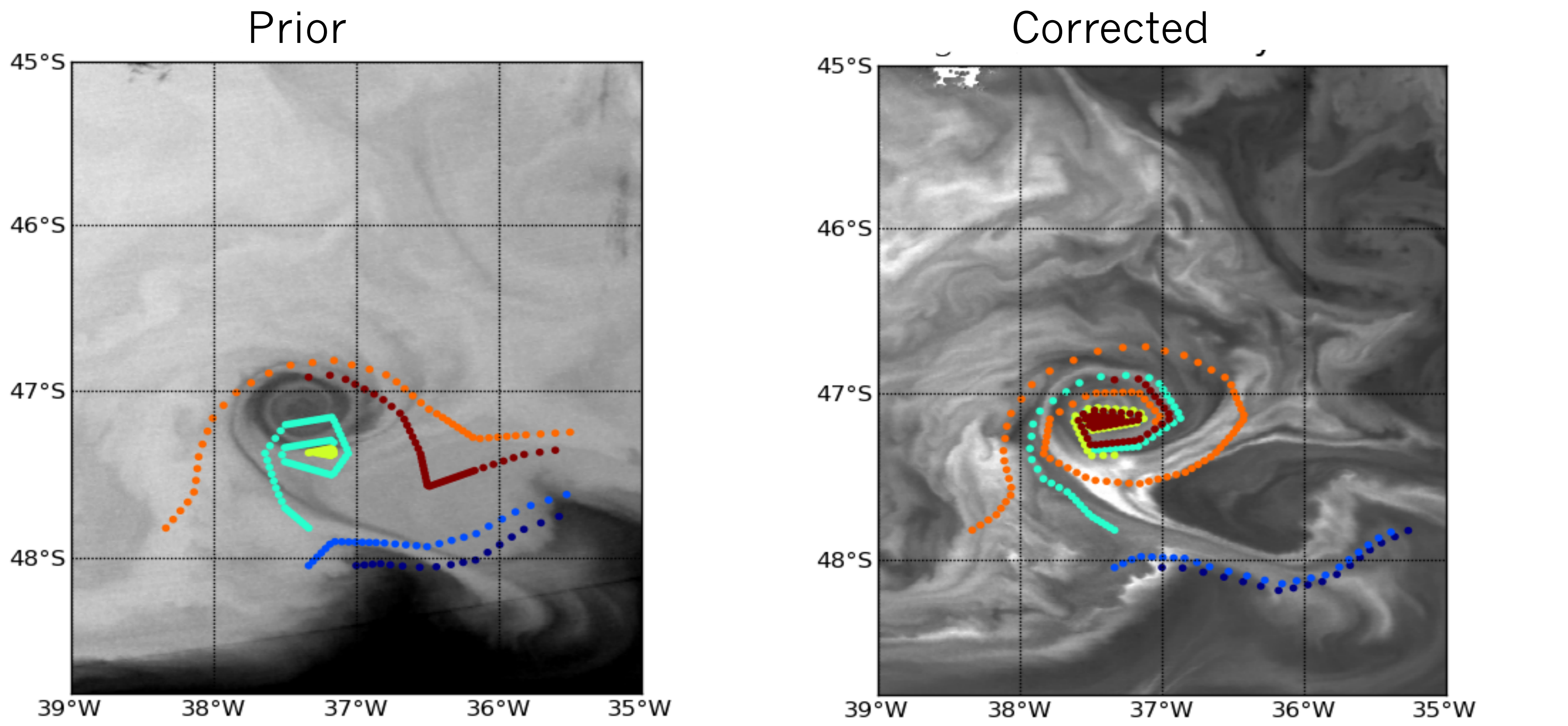

Conclusion

- 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, in particular ocean currents

Conclusions (cont.)

- Future work
  - Explore joint SST + Chlorophyll inversion
  - Set up an idealized coupled physico-biogeomichal model to assess the submesoscale control in a twin experiment context
  - Full (image + actual data) data assimilation in a coupled model