On the Joint Use of High Resolution Tracer Images and Altimetric Data for the Control of Ocean Circulations

Lucile Gaultier, Jacques Verron, Jean-Michel Brankart and Pierre Brasseur

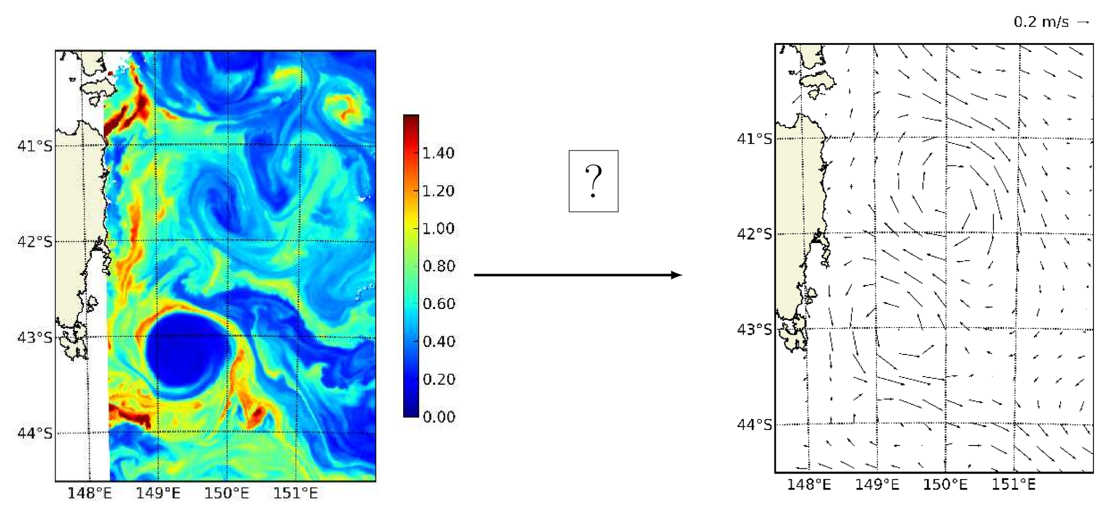
Laboratoire de Glaciologie et Géophysique de l'Environnement, CNRS, F-38041 Grenoble, France
e-mail: lucile.gaultier@legi.grenoble-inp.fr

CONTEXT

➢ Lack of resolution in time and space for current altimetric data → Observation of the sub-mesoscale resolution (≃ 50 km) is not possible
➢ Sub-mesoscale filaments can be observed using tracer sensors (SST or Ocean Color image, resolution of image≃ 1 km and a map a day)

How to complement altimeter data using sub-mesoscale tracer observations from space?

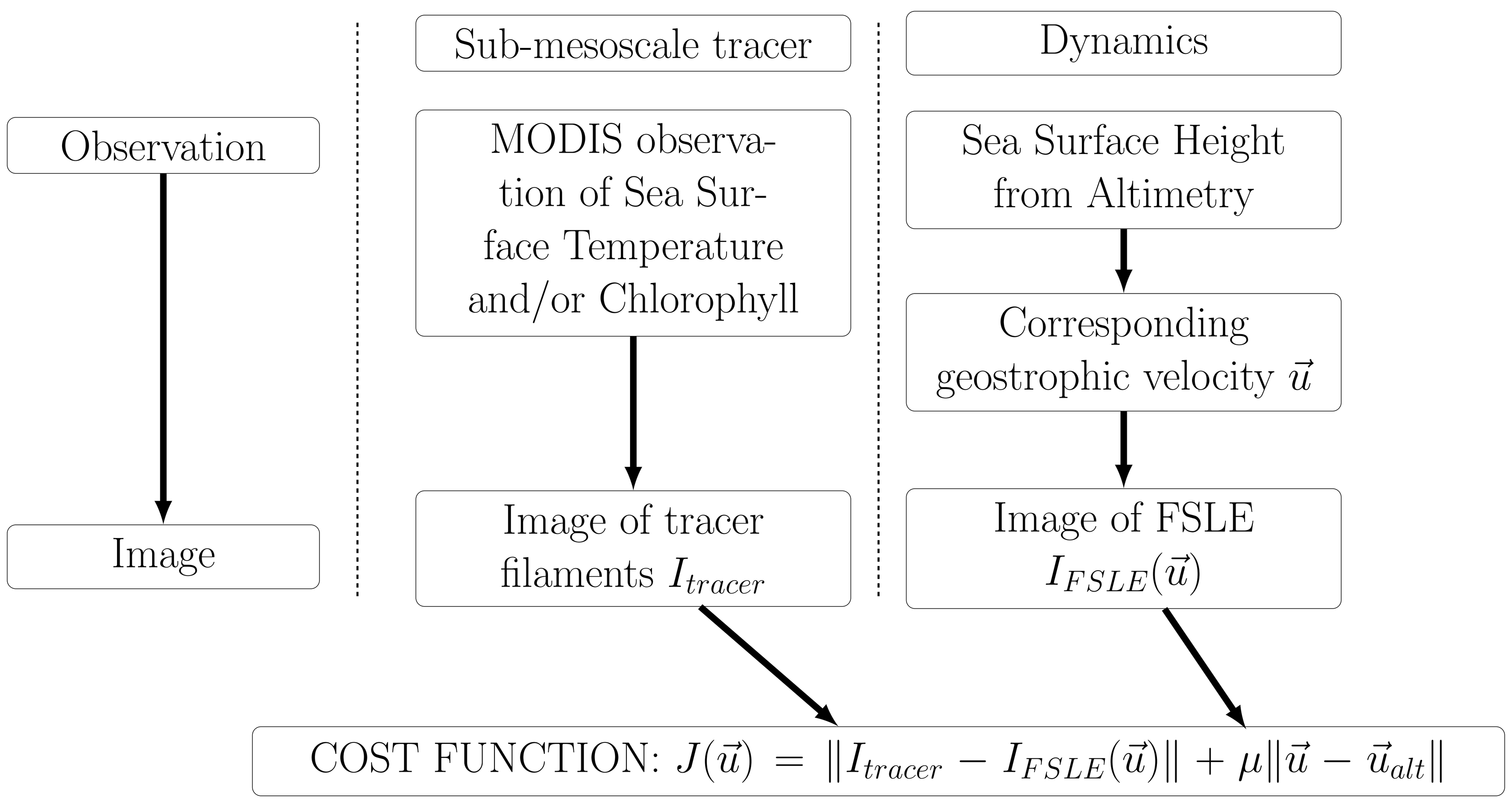
➢ Some studies brought to light the connection between mesoscale velocities and tracer patterns (d'Ovidio et al., 2004; Lehahn et al., 2007), but correcting mesoscale velocities using tracer images has never been done before.



Chlorophyll, Tasmania region, December 22, 2004 — Velocity map, Tasmania region, December 22, 2004

➢ Use Finite-Size Lyapunov Exponents (FSLE) as a go-between variable.

DATA IMAGE ASSIMILATION

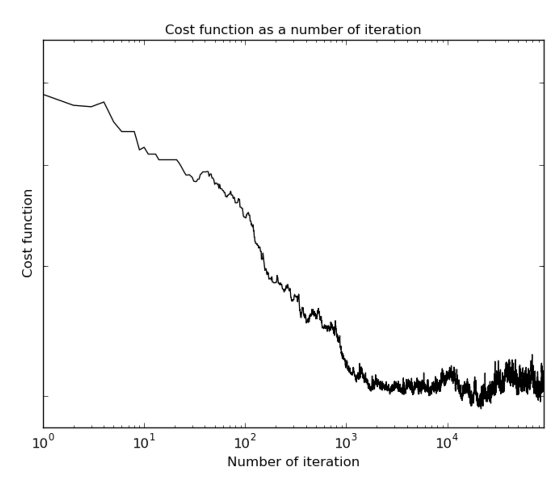


Goal: Find the optimal velocity $\vec{u}$ that minimizes the cost function J.

INVERSION METHOD

The strategy built up for the inversion of a tracer image is the following:

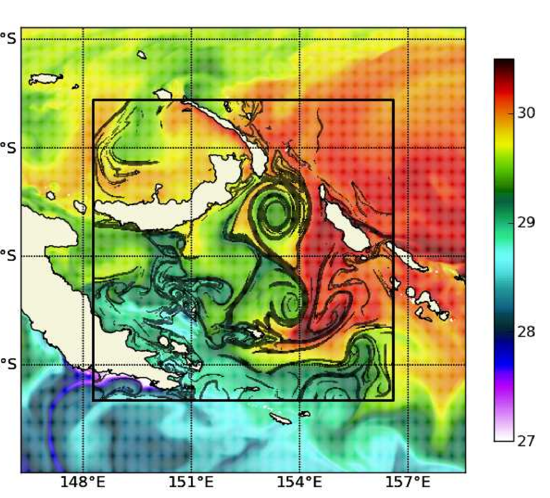
- Compute a subspace of error to perturb the velocity
- Explore the subspace of error
- Use a simulated annealing algorithm to decrease the cost function:
- Use a Gibbs sampler to assess possible solutions around the minimum of the cost function: As several perturbations result in similar values of the cost function, we compute a sample of all the potential solutions.



Cost function as a function of the number of iteration (log-log plot)

(See Gaultier et al. (2013) for more details)

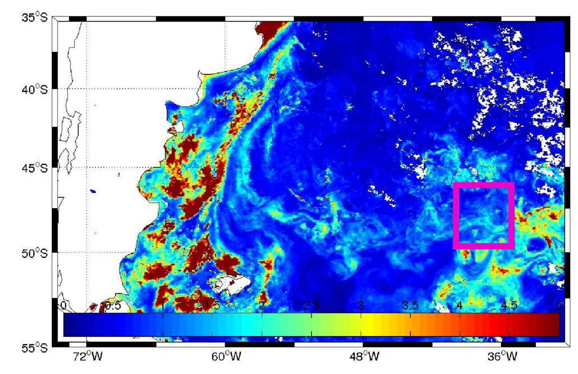
Finite Size Lyapunov Exponents (FSLE)



FSLE maximum lines plotted over SST, data provided by a realistic high resolution model of the Solomon sea

➢ FLSE is the exponential rate at which two particles separate from a distance δ_0 to δ_f: $\lambda = \frac{1}{\tau} \ln \frac{\delta_f}{\delta_0}$.
It is a connection between sub-mesoscale dynamics and tracer stirring.
➢There are similar patterns between the maximum lines of FSLE (computed backward in time) and the tracer frontal structure (the norm of the gradient)
➢To compare the dynamics and the tracer image, the FSLE field and the normalized SST gradients are binarized: $\hat{\lambda} = \begin{cases} 0 \; if \; \lambda < \lambda^s \\ 1 \; if \; \lambda \geq \lambda^s \end{cases}$

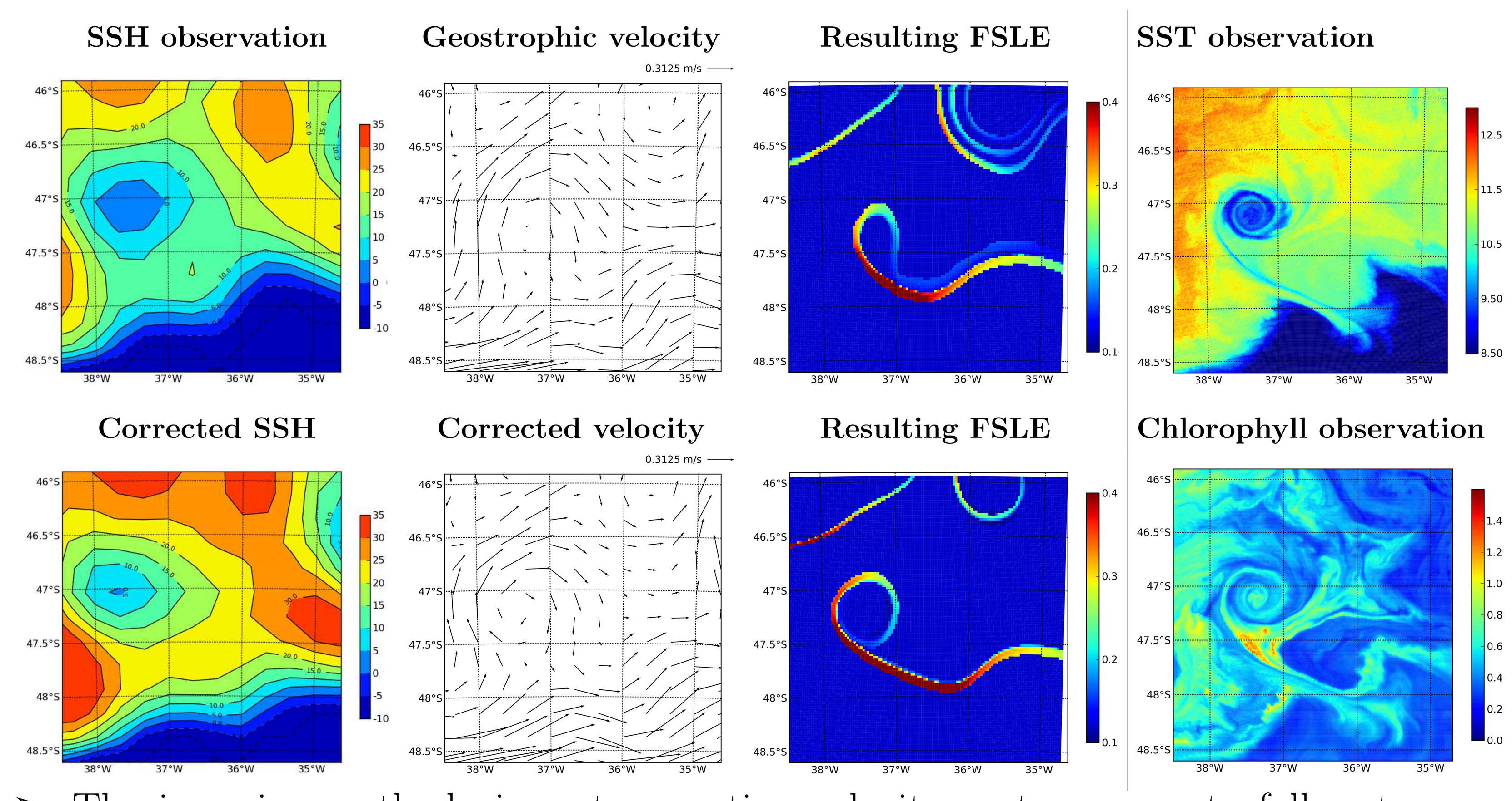
TEST CASE: SOUTH ATLANTIC



Chlorophyll, in the South Atlantic Ocean. The study area is inside the pink frame

- Time Range to build a subspace of error: 1998-2009, 595 velocity maps from AVISO (altimetric data)
- Background Velocity: AVISO map on 01/18/2006
- Velocity resolution: $1/3^o$, grid points : 18*16
- Tracer field: SST or Chlorophyll data (MODIS sensor, L2 product) on 01/19/2006
- Resolution of the Tracer field: $1/50^o$
- FSLE Resolution: $1/50^o$, grid points : 130*120

RESULTS

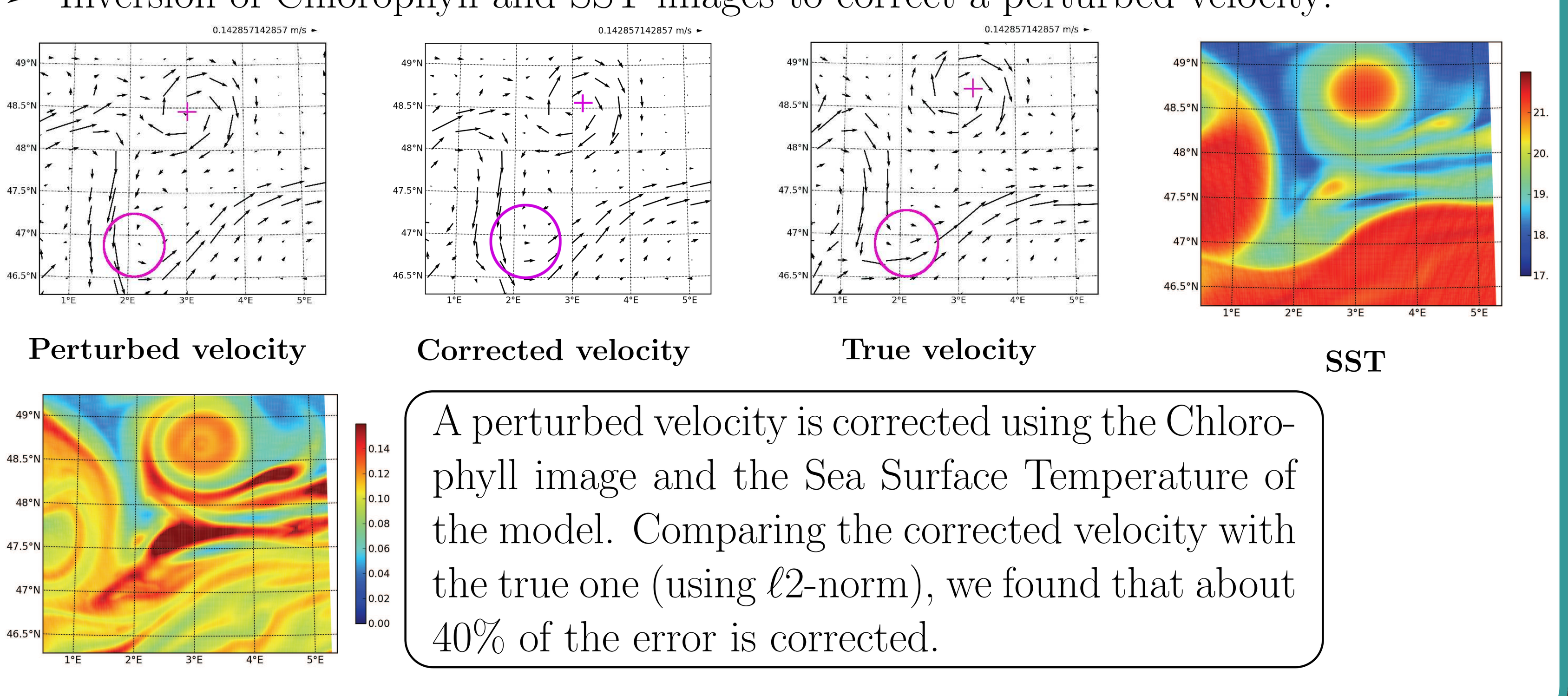


➢ The inversion method aims at correcting velocity vectors so as to follow tracer frontal structures.
➢ Looking at the tracer images and the FSLE computed using the observed AVISO velocity, we can clearly see that the eddy is shifted in AVISO data.
Looking at the corrected velocity and the corresponding FSLE, we can see that the eddy is well corrected. The corrected velocity is a better match to the tracer frontal structure than the AVISO derived velocity.

INVERSION IN A COUPLED PHYSICAL-BIOGEOCHEMICAL MODEL

➢ An idealized model is set up to confirm the efficiency of the method:
- NEMO (dynamics) + LOBSTER (biogeochemics) models.
- Channel domain: 478 km × 500 km × 4 km, horizontal resolution: 2km
- Unstable baroclinic jet dynamics

➢ Inversion of Chlorophyll and SST images to correct a perturbed velocity:



A perturbed velocity is corrected using the Chlorophyll image and the Sea Surface Temperature of the model. Comparing the corrected velocity with the true one (using ℓ2-norm), we found that about 40% of the error is corrected.

CONCLUSION

We succeeded in correcting an altimetric mesoscale velocity field using a sub-mesoscale tracer observation from space

➢ The corrected velocity is more consistent with the tracer field than the background AVISO velocity derived from altimetry alone, and the uncertainty on this result is small. However, the method still needs to be improved, since some areas of the velocity field are not accurately corrected.
➢ We used a high resolution model with biogeochemics and physics coupled to refine the method. Knowing the true sub-mesoscale velocity, nearly 40% of the error on the velocity can be corrected during the tracer inversion process.
➢ Similar results are found inverting Sea Surface Temperature and Sea Surface Salinity images from a sub-mesoscale permitting realistic model of the Solomon sea.
➢ This study opens the way for the use of very high resolution altimeter data (in the context of SWOT and SARAL projects). The strategy proposed in here will also be helpful to handle huge amount of data in models.

References

d'Ovidio, F., et al., 2004: Mixing structures in the Mediterranean Sea from finite-size Lyapunov exponents. *Geophysical Research Letters*, **31**, 17 L17203. URL http://dx.doi.org/10.1029/2004GL020328.
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