On the inversion of submesoscale information from SST and Ocean Color to improve larger scale dynamics deduced from altimetry

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CONTEXT

➢ It is difficult to access the sub-mesoscale using altimetric satellites since they provide data along distant tracks whereas tracer sensors provide images at a resolution as low as 200 m. For example, Satellite observations of Sea Surface Temperature (SST) or Ocean Color show sub-mesoscale dynamics.

How to correct altimetric mesoscale velocity 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 so far.

➢ Some studies have shown that

- In accordance with the implemented method, velocity vectors are corrected so as to follow tracer frontal structures. For instance, the North East of the eddy in the corrected velocity (blue rectangle) is much more consistent with the SST frontal structure than the North East of the eddy in the observed AVISO velocity.
- Nevertheless, there are some limits to this method. Indeed, in some areas (such as the West border of the image, green oval), the correction applied on the velocity is not consistent with the SST patterns. This may be due to the over-simplicity of the algorithm of contours detection, which is a mere binarization of the normalized SST gradient.
- The variance of all the possible velocities is rather small compared to the value of the velocity and the correction. It means that the result is quite reliable, even though the cost function is complex and seems to have several solutions.

REFERENCES


TEST CASE

➢ Domain: [38.2°N ; 40°E] × [4.8°E ; 8°E]
➢ Good quality of the data set
➢ Strong filament signature
➢ Study date: July 2nd, 2004
➢ Time Range to estimate the variability of the velocity: 1998-2009, 595 velocity maps

Two satellite observation data sets are considered:

Tracer used as a dynamic information:

- high resolution SST images from MODIS sensor at 1 km resolution.

Background velocity to be corrected:

- AVISO altimetric observations at 1/8° resolution.

A neat eddy can be observed in both pictures. The FSLE are computed at 1/48° resolution. The SST image is filtered and coarsened at the same resolution (1/48°).

RESULTS

➢ Method:

- Finite-Size Lyapunov Exponents (FSLE)
- FSLE measure stirring in a fluid. It is a connection between sub-mesoscale dynamics and tracer stirring.
- FSLE is the exponential rate at which two particles separate from a distance δf to δf: λ = ln2 δf/δf.

- We want to find the FSLE field as close as possible to the normalized tracer gradient. Therefore, the FSLE field and the normalized SST gradients are binarized in order to compare those two physically different variables.

- The cost function J measures the distance between the binarized normalized SST λ and the binarized FSLE λ(u) (as a proxy of the velocity u).

- A velocity sub-space is created using Principal Component Analysis with an ensemble of velocities. Let S = [u(1), u(2), ..., u(k)] be the first k EOFs. The velocity errors are considered with zero mean and covariance of the ensemble of velocities S ≈ N(0, SS). Then, a perturbed velocity is u(k + δ) = u(k) + δ(k) with δ(k) a perturbation vector.

- We aim at decreasing the cost function, exploring the sub-space of velocity errors previously defined. Nevertheless, the cost function J(u) is quite irregular and many local minima can be found. To avoid being stuck in one of them, the minimization of the cost function is performed using a Simulated Annealing.

- Technical issues to find the optimal solution:

- At each step, a perturbation is computed and the resulting cost function is calculated, if it is lower than the previous one, the perturbation is adopted, otherwise, the perturbation is rejected with a certain probability.

- As several perturbations result in similar values of the cost function, we need to find a strategy to compute accurately the final result. To do so, a Gibbs Sampler is used. In other words, all the perturbations which are potential solutions to the problem are assessed. An optimal solution is given by the velocity that has the lowest cost function among all the potential solutions. The variance of all the potential solutions indicates how reliable an optimal solution is.

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 observed one, and the uncertainty on this result is small. The method still needs to be improved, since some areas of the velocity field do not seem consistently corrected.

- We plan to use a high resolution model to refine the method. Indeed, knowing the true sub-mesoscale velocity, we can assess accurately how much the corrected velocity is a better match to the tracer than the mesoscale ‘observed’ velocity.

- 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 enables us to handle huge amount of data in models.