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Modeling surface currents in the Eastern Levantine Mediterranean

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Abstract

We consider the problem of reconstructing the meso-scale features of the currents in the Eastern Levantine Mediterranean from combining in-situ and satellite altimetry data. Mathematically, this is an inverse problem where the objective is to invert Lagrangian trajectories, which are positions of drifters launched at sea, in order to improve the coarse Eulerian velocity, provided by the altimetry satellite measurements. We shall use a variational assimilation approach, whereby the Eulerian velocity correction is obtained by minimizing the distance between the simulated position from a velocity background and actual observations. One important property of our approach is that it is model-free, hence inexpensive and can be easily cast into real-time oceanic operational products.

1. Data

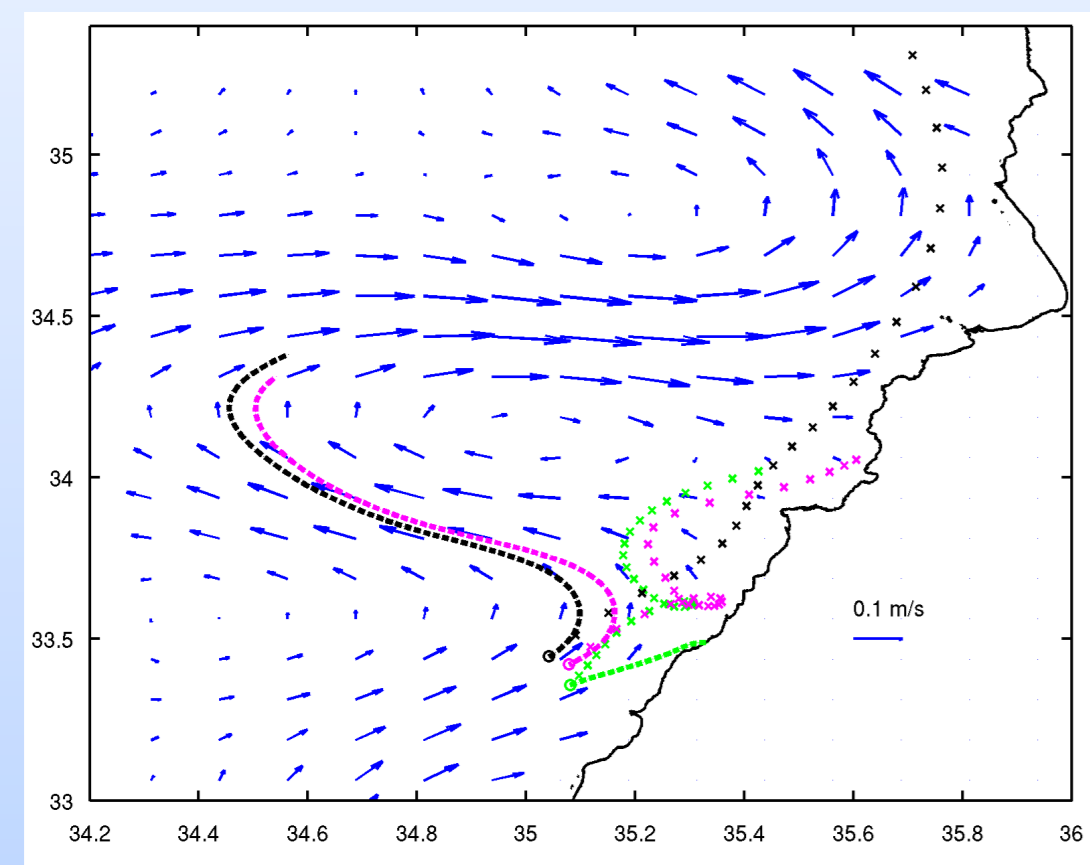


Figure 1. Velocity field from altimetric data and 3 drifter trajectories (real and simulated) for one week starting on 2013 August, 28.

Altimetric data :
Merged Mediterranean Sea Gridded Absolute Geostrophic Velocities SSALTO/Duacs L4 product

Lagrangian data :
Drifter trajectory deployed by Lebanese marine research center, corrected from inertial oscillation.

- Initial position of the drifters
- × Real drifter position (every 6 hour)
- Simulated position using altimetric velocity

Causes of discrepancy :

- 1) Only geostrophic
- 2) Errors of altimetry near the coast
- 3) Low resolution of altimetry data

3. Twin experiment

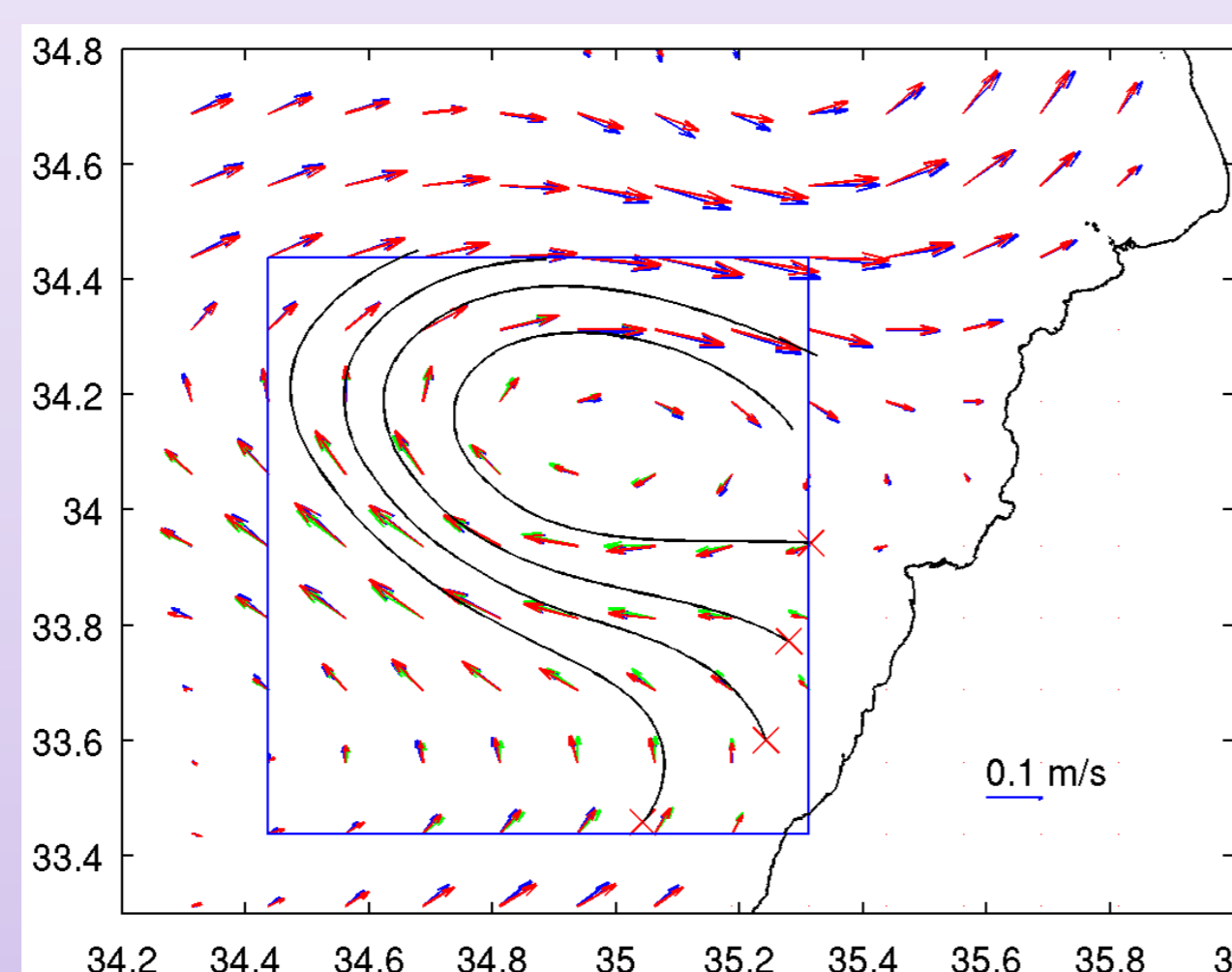
To test the validity of the approach, we conduct some twin experiments (see Figure 2.) :

- The drifter positions is simulated using velocity field from altimetry starting on August 31, 2013 for a period of 7 days (with a time step of 1h), considered as the "truth".
- The background state to adjust is the velocity field from altimetry starting on August 28, 2013.
- Filter length (matrix B) is 20 km.

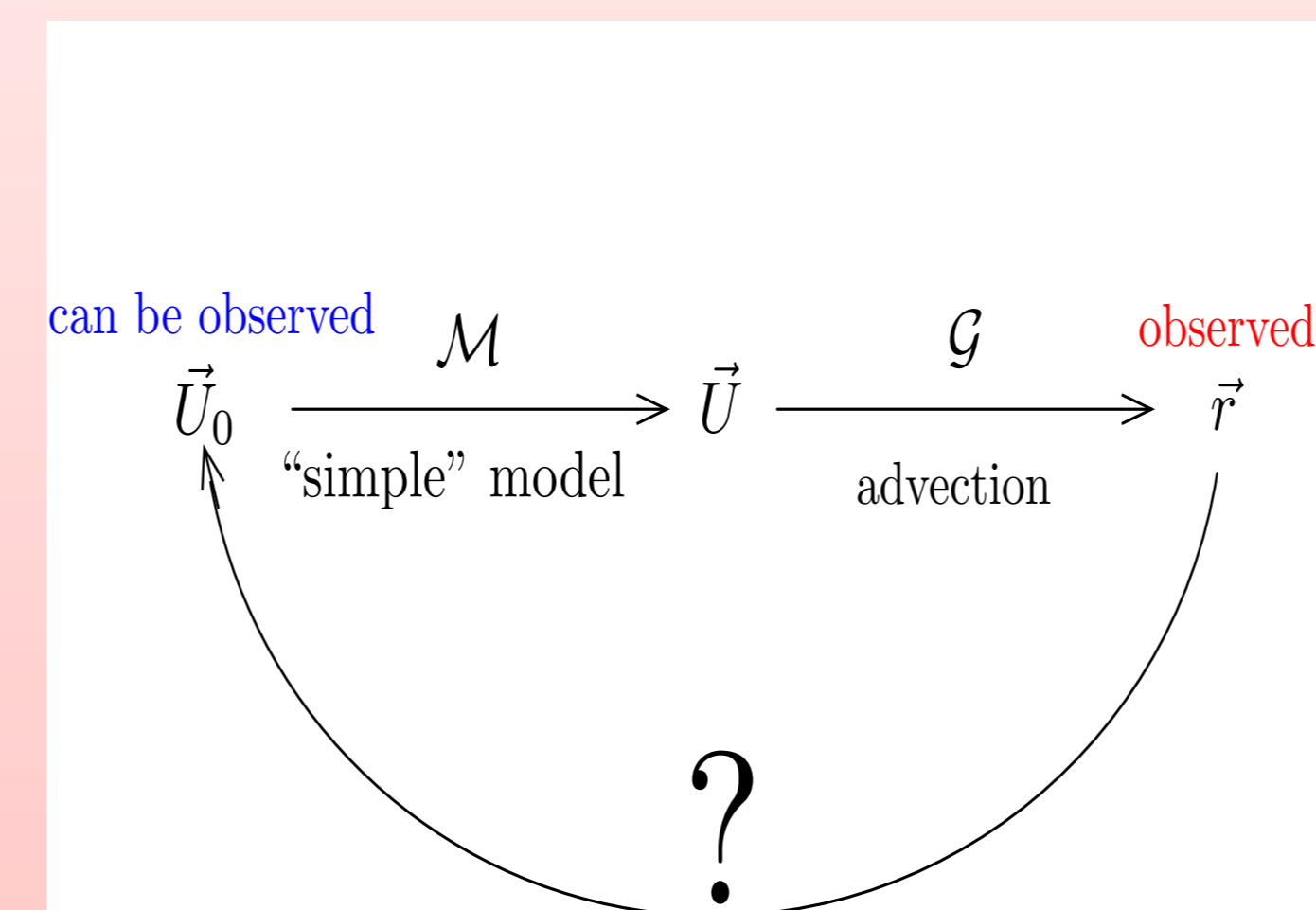
Configuration :

Frequency : 1 observation every 6h
Number of drifters : 4
Assimilation window : 42h

- True velocity field
- Background
- Corrected
- × Initial position
- Domain used to calculate error (Fig 3-5)



2. Assimilation method



\vec{U}_0 : velocity vector to adjust
 \vec{U}_b : background velocity vector given by altimetry
 \mathcal{M} : interpolation
 \mathcal{G} : advection
 \vec{r}^o : observed position of the drifter

With $i = 1, \dots, N_{drift}$
And $m = 1, \dots, T_L/\Delta t$; T_L is the autocorrelation period of drifters (1-3 days)

The Objective is to minimize :

$$\mathcal{J}(\vec{U}_0) = \frac{1}{2} \left\{ \sum_{i,m} \|\mathcal{G}\mathcal{M}(\vec{U}_0) - \vec{r}_i^o(m\Delta t)\|^2 + \|\vec{U}_0 - \vec{U}_b\|_B^2 \right\}$$

To take into account small linearity in a numerically efficient way, the incremental formulation is minimized, assuming:

$$\vec{r} = \vec{r}^b + \delta\vec{r} \quad \text{and} \quad \vec{U}_0 = \vec{U}_b + \delta\vec{U}$$

The function to minimize is :

$$\mathcal{J}(\delta\vec{U}) = \frac{1}{2} \left\{ \sum_i \sum_m \|\vec{r}_i^b + \delta\vec{r}_i(\delta\vec{U}) - \vec{r}_i^o(m\Delta t)\|^2 + \|\delta\vec{U}\|_B^2 \right\}$$

about the variance-covariance B matrix :

- Dual purpose : regularization and information spreading (smoothing)
- Implementation : diffusion filter [Weaver and Courtier 2001]

4. Sensitivity studies

Frequency of observations

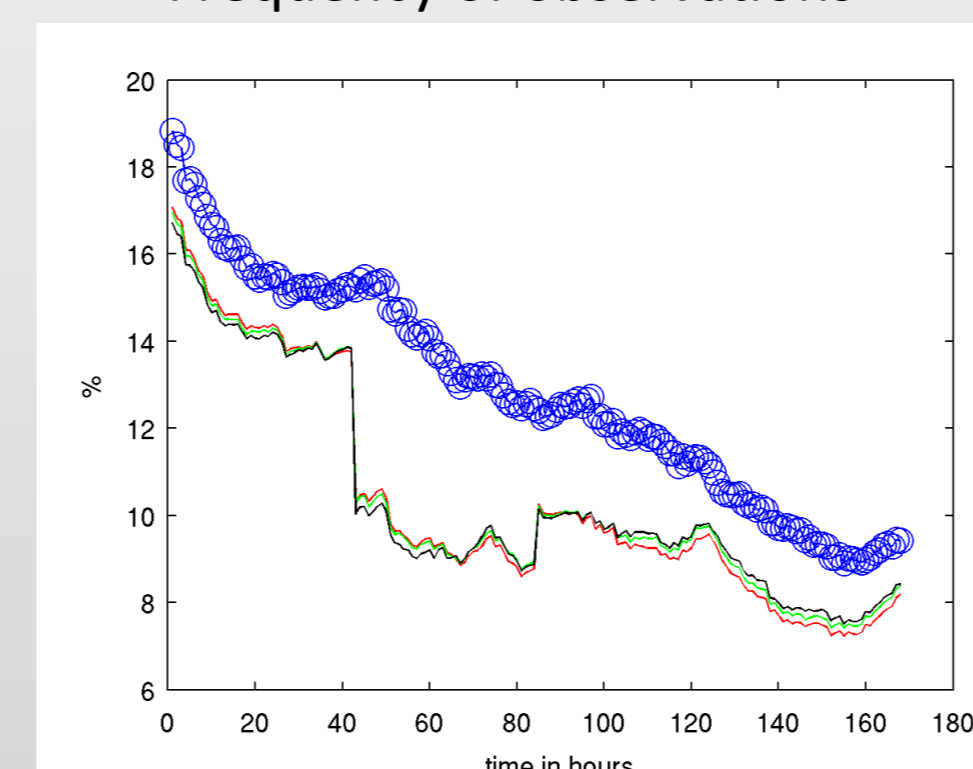


Figure 3
Background error
One observation every 1h
One observation every 2h
One observation every 6h

Number of drifters

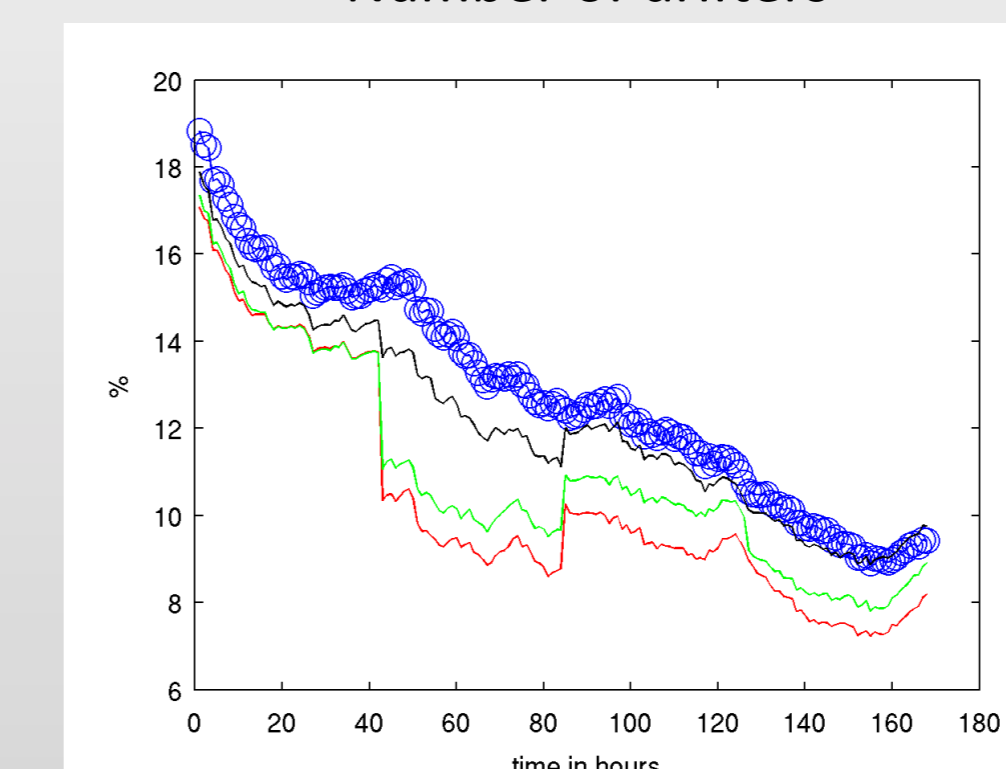


Figure 4
Background error
4 drifters
2 drifters
1 drifter

Assimilation window

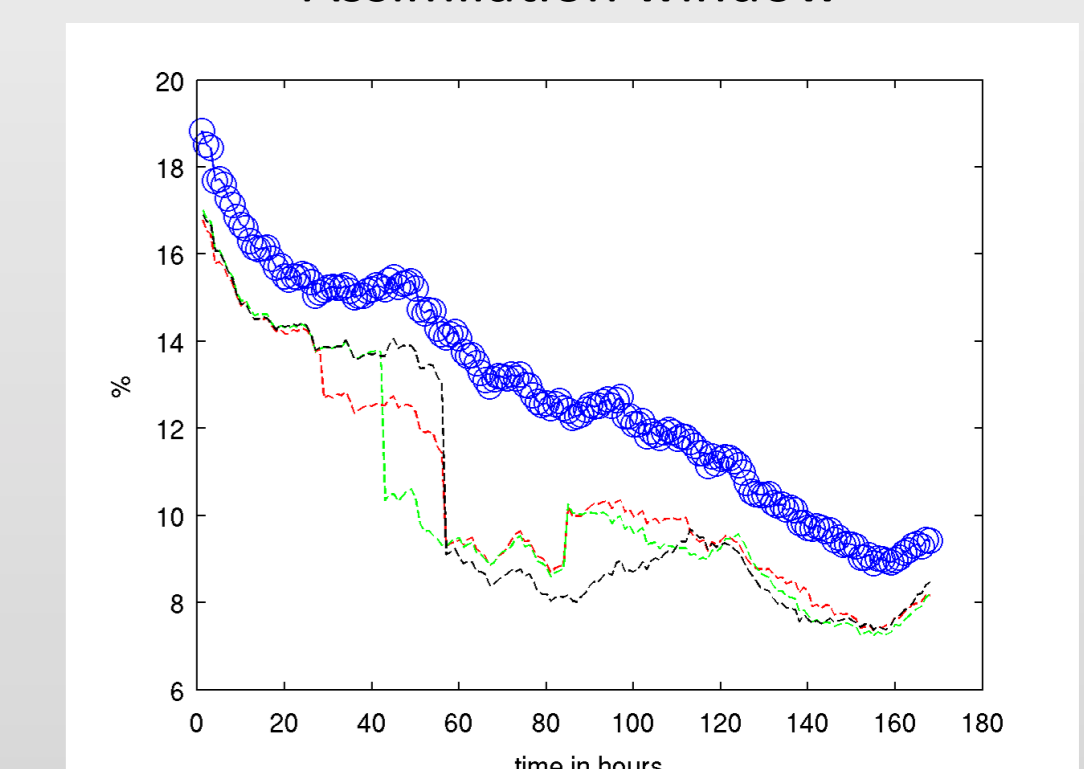


Figure 5
Background error
28h
42h
56h

Conclusion

- A fast and robust algorithm was proposed to correct velocity using observation of drifter positions.
- The algorithm was validated on twin experiments.
- The performance of the algorithm will be tested on real data.
- The possibility of correcting model output will also be investigated or model may be used for validation of correction?

Acknowledgement

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