Reliability of LCS detection depending on HF-radar velocity dataset

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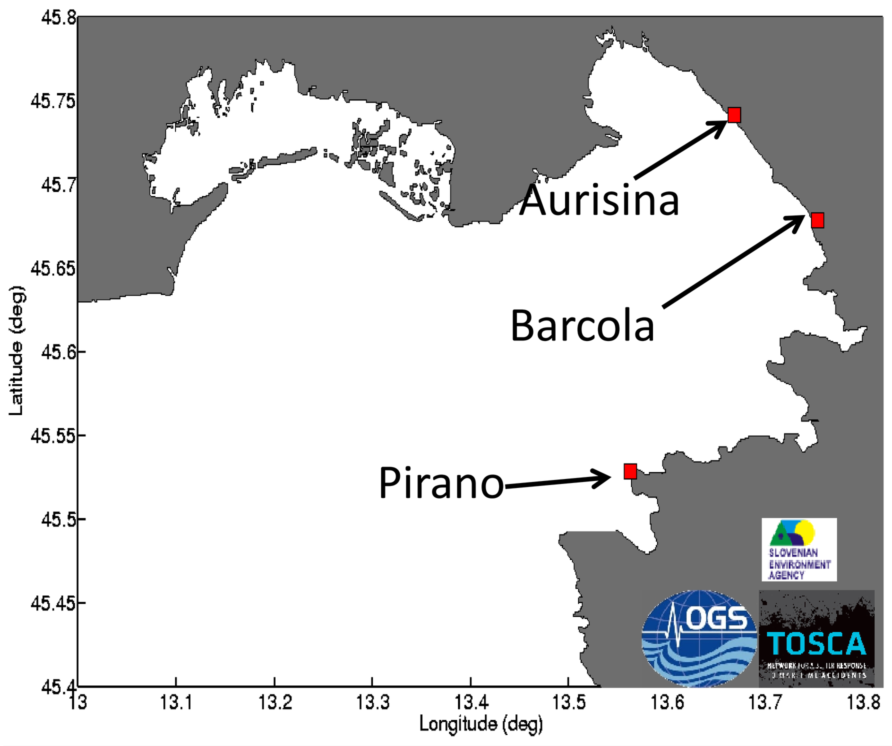
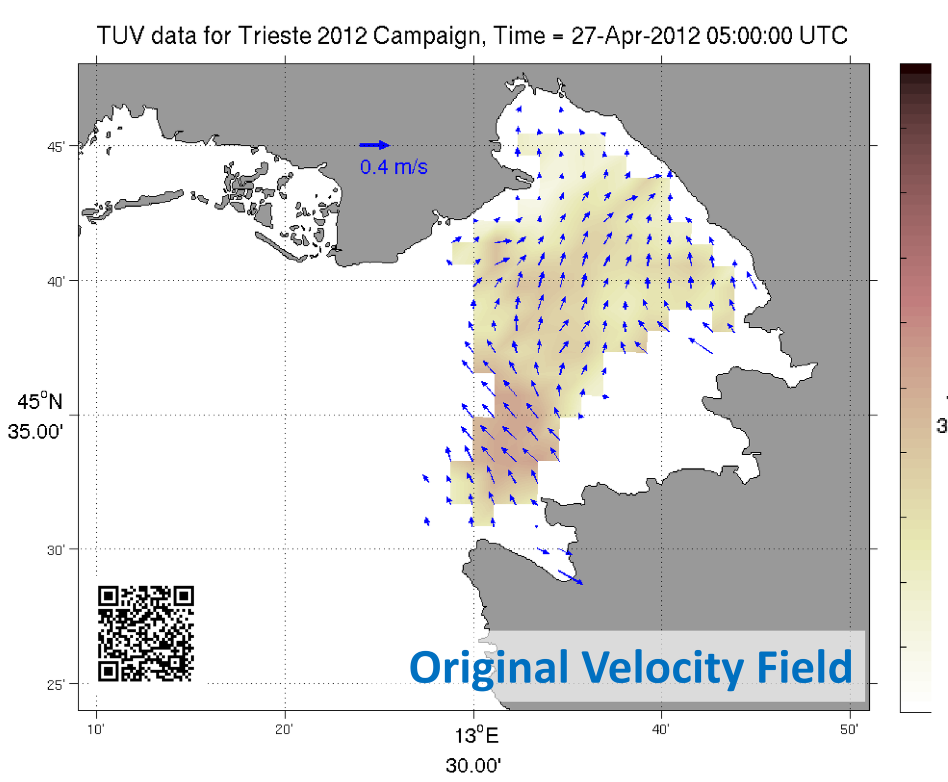
Introduction

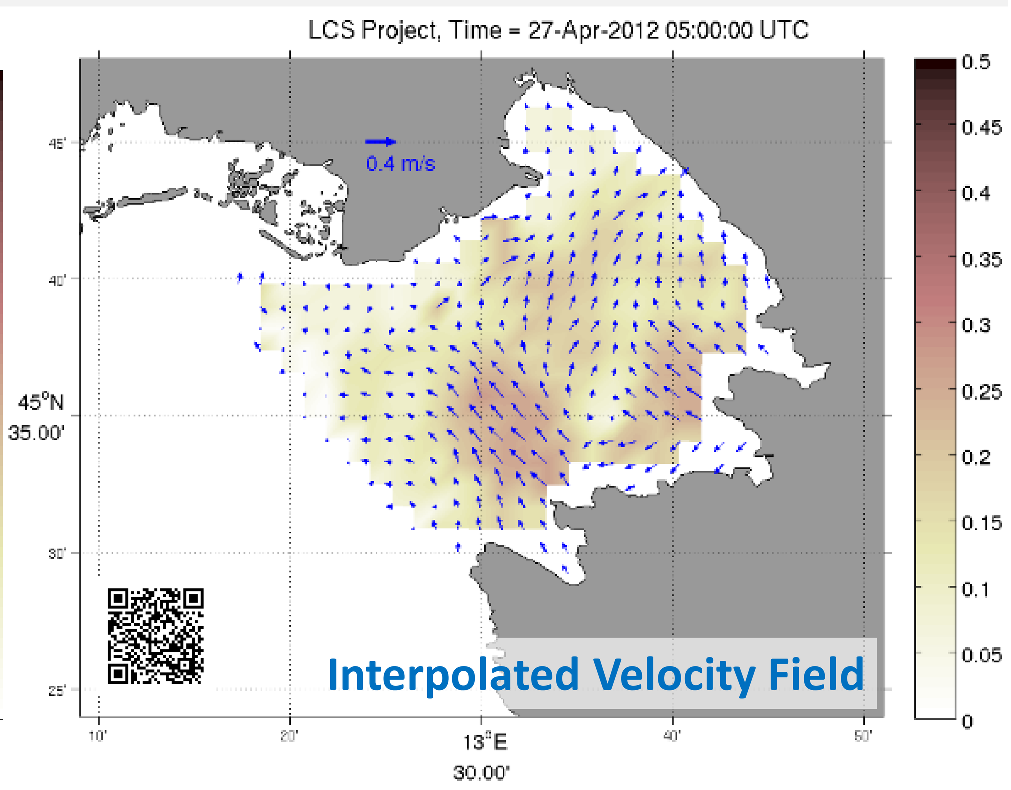
Lagrangian Coherent Structures (LCSs) are detected from 2D surface velocities measured by high-frequency (HF) coastal radars in the Gulf of Trieste (northern Adriatic Sea). The work is within the framework of the TOSCA (Tracking Oil Spills & Coastal Awarness Network) project. Synthetic trajectories are compared with observations from drifters deployed within the Gulf and influenced by chaotic stirring (transport and stretching) in agreement with the detected barriers. Synthetic trajectories are influenced by the accuracy of velocity fields and the error with respect to observations becomes more evident when radar measurements are missing.



The Gulf of Trieste case

A network of three CODAR HF-antennas located in Aurisina, Barcola and Pirano measures the surface velocity fields within the Gulf. The Trieste TOSCA experiment period is considered, i.e. from April 23 to 30, 2012. Time and spatial resolutions are one hour and 1.5km, respectively. Linear interpolation in space and in time is used to fill gaps which may be present in the velocity dataset due to bad weather conditions. An example of the interpolation process is shown in the images below.



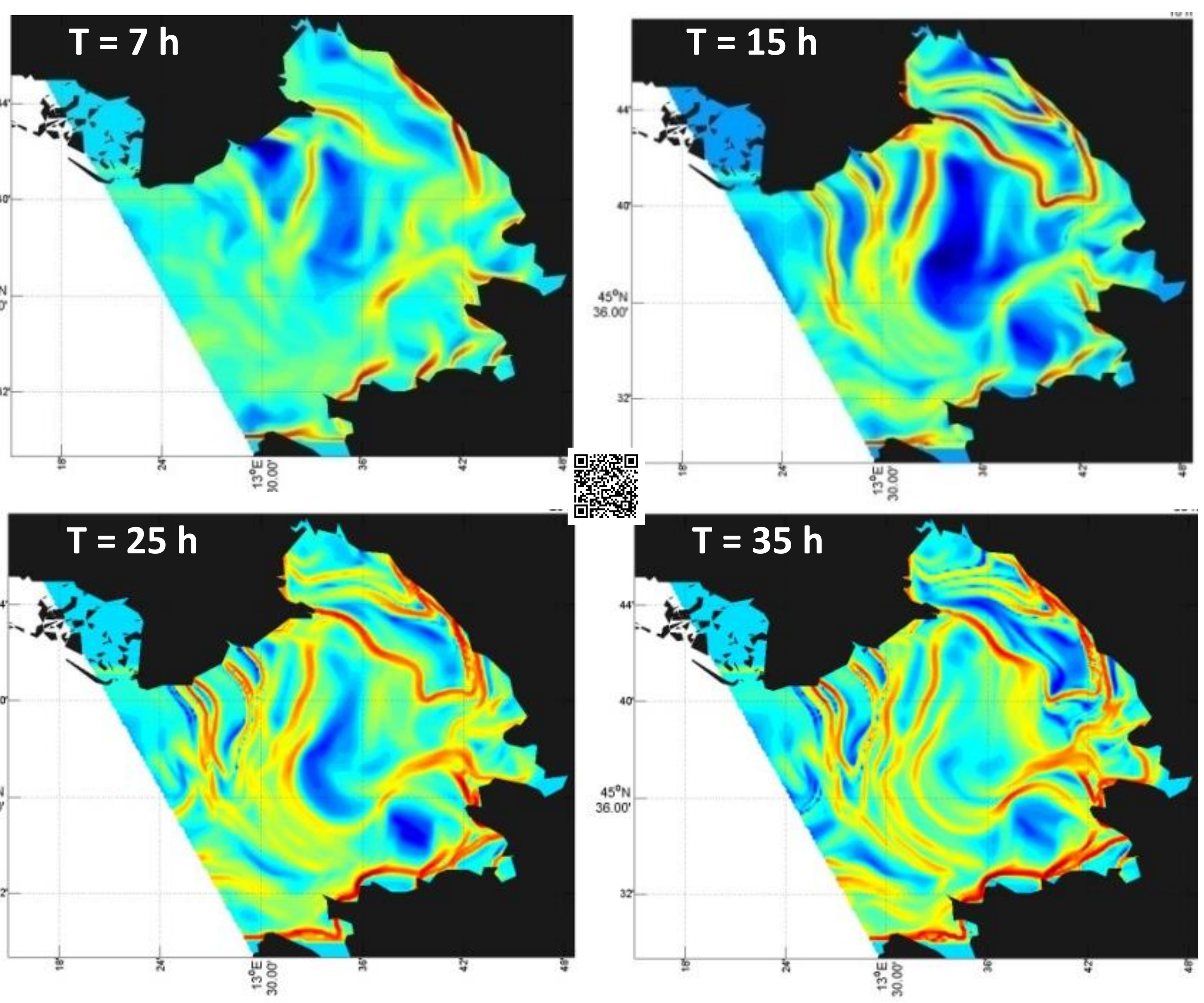


LCS detection

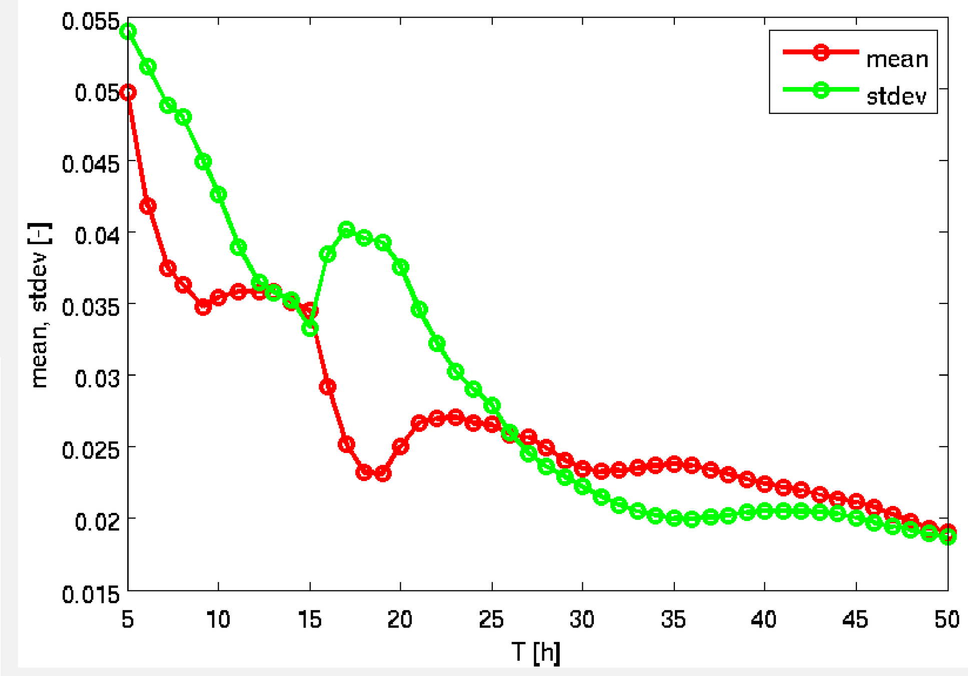
LCSs are a mean to identify material lines that shape trajectory patterns, dividing the flow field into regions with different dynamical behaviours. In this work the early definition of LCS by Shadden et al. (2005) based on the Finite-Time Lyapunov Exponents (FTLE) is used.

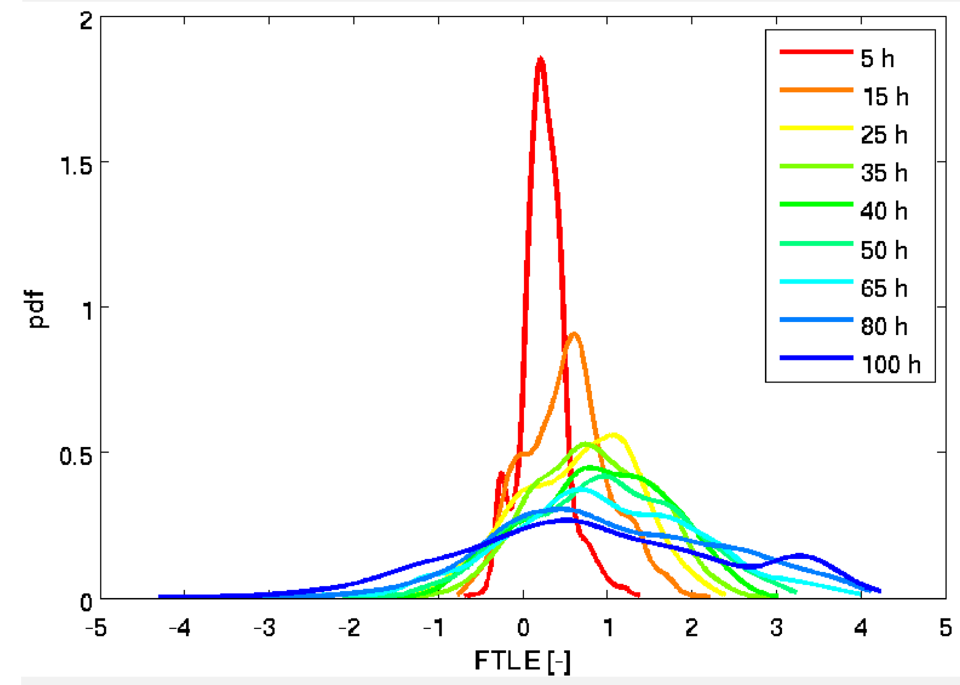
$$\sigma_{t_0}^{t_0+T}(\boldsymbol{x}) = \frac{1}{|T|}\log\sqrt{\lambda_{max}(\boldsymbol{CG})}$$

It should be noted that, as pointed out in Karrasch and Haller (2013), such a definition cannot be considered definitive. The detected LCSs can be divided into two types: repelling structures evaluated with a forward integration, and attractive structures, evaluated with a backward integration. An increase of integration time T leads to an increase of the number of structures as shown in the pictures below.



Attention must be paid to the choice of integration time T: long enough to have defined LCS and short enough to limit computational cost. It is then useful to plot the standard deviation and the mean of the values of the FTLE fields vs T.

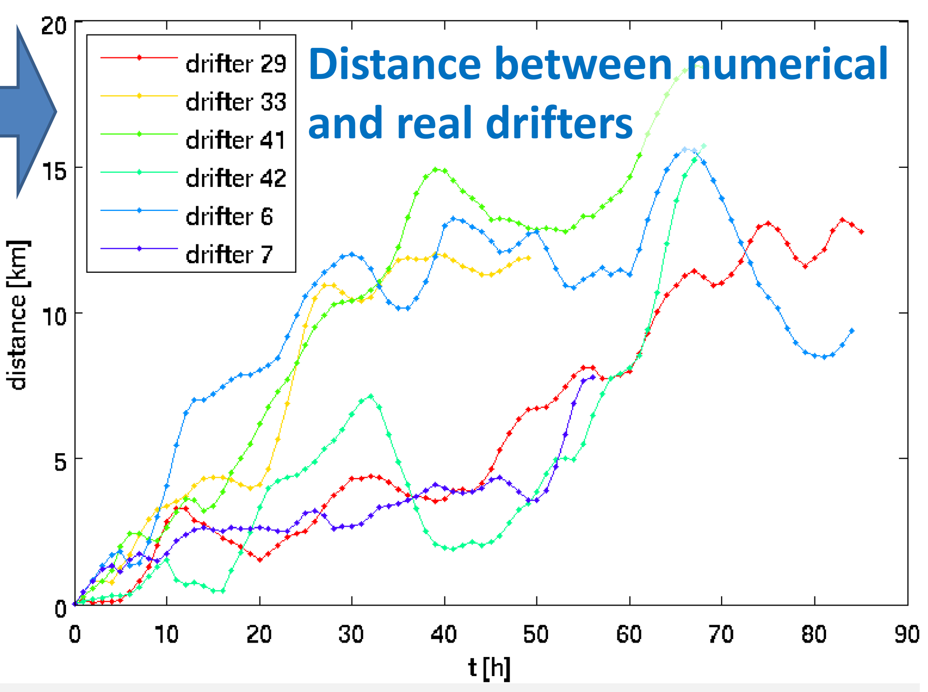


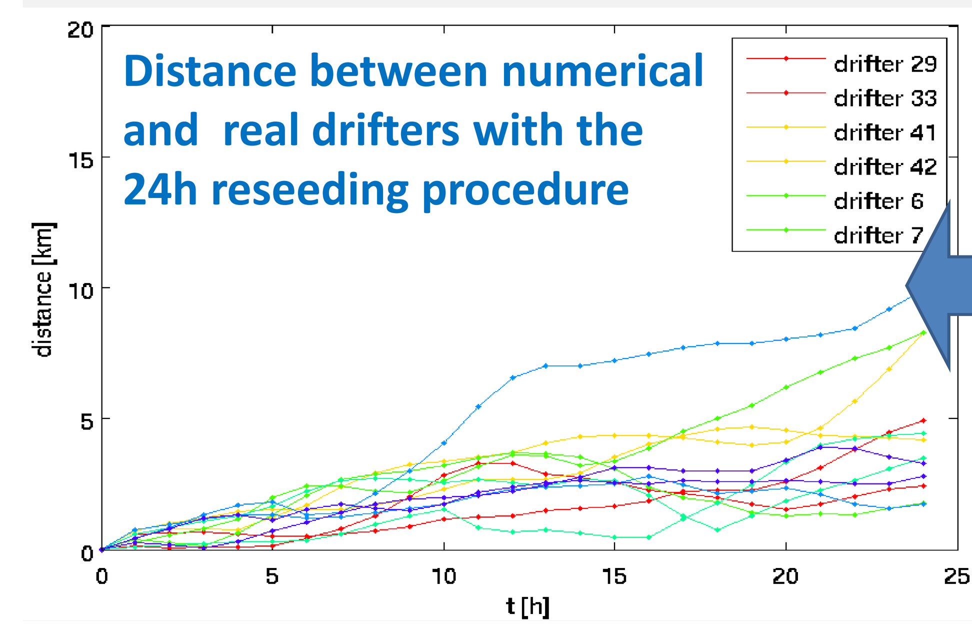


In this study T=15 hours, because at this time Lagrangian barriers start to be clearly visible and the standard deviation of the FTLE fields suddenly increases. The analysis of the probability density function confirms this choice: an increase of the integration time leads to values of FTLE uniformly distributed, hence revealing the presence of the ridges.

Numerical vs. real drifters

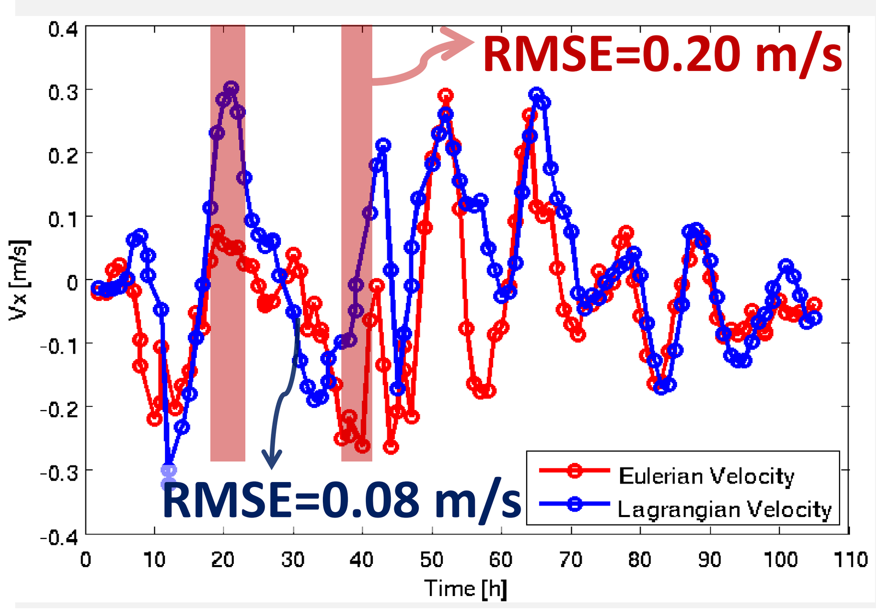
Numerical drifter positions are obtained integrating radar velocities via 4[th]-order Runge-Kutta scheme and compared to observations. Separation between numerical and real drifters increases with time.

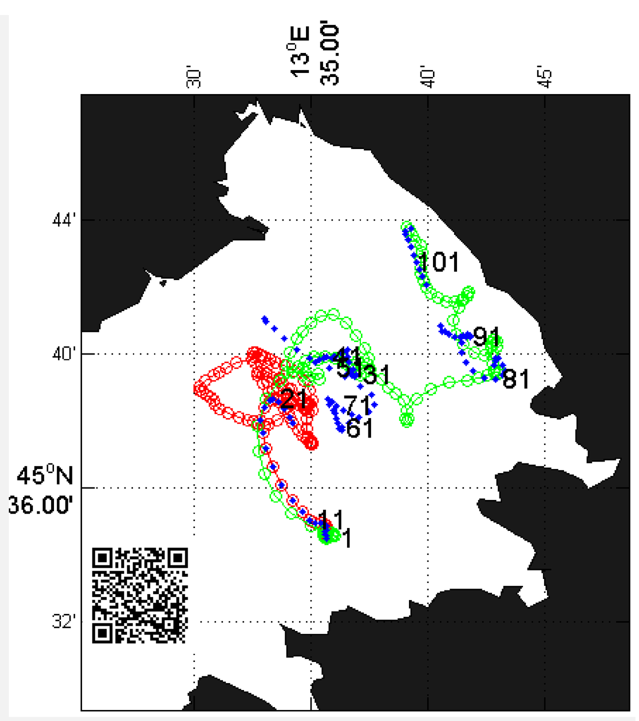


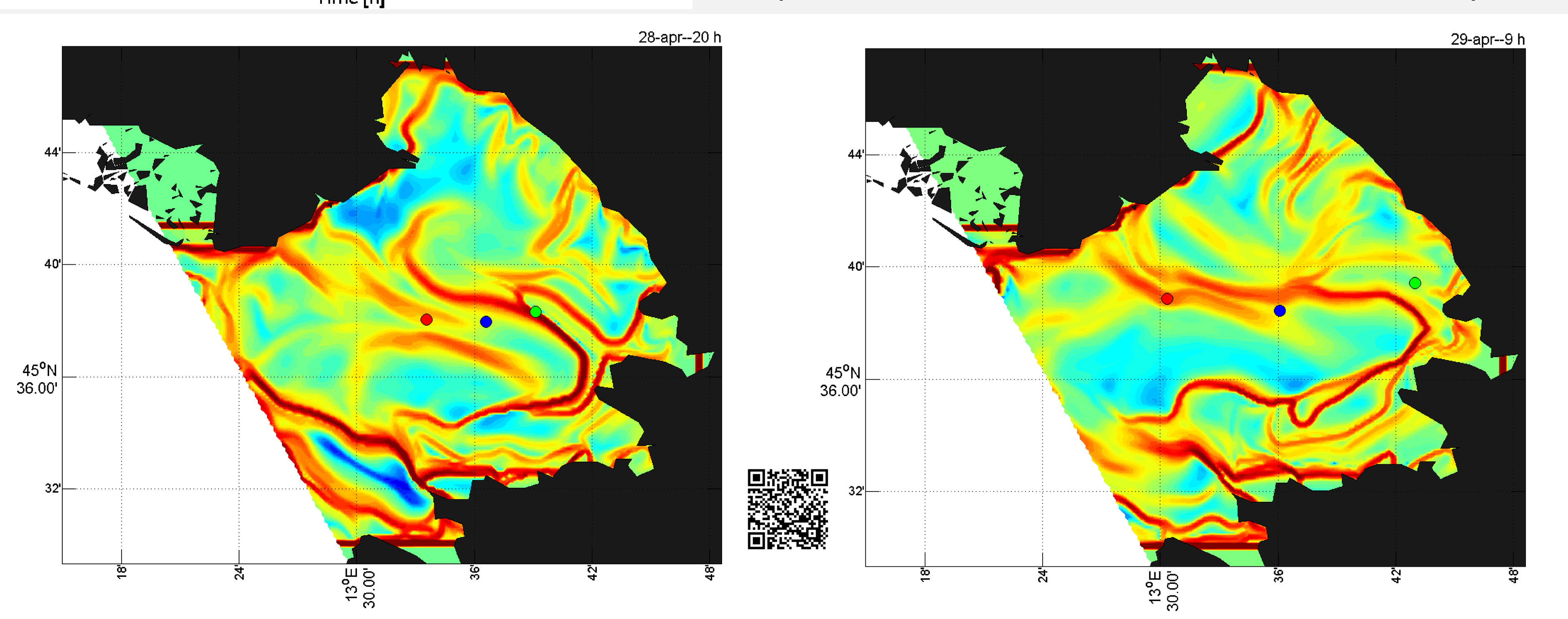


"Reseeding" procedure: every 24 hours numerical trajectories are forced to start from the positions of the real drifters. The mean error for numerical reseeded drifters is below 6km after 24h.

The image on the right shows one example of the comparison between numerical and real drifters. In green the real drifter, in blue and red the numerical ones with and without the reseeding procedure. Drifters strongly diverge after 20 hours because of velocity gaps at the drifter position as confirmed also by comparison between radar and drifter velocity.







Conclusions

The comparison of real and numerical trajectories shows a clear divergence that is not only due to dynamical chaos but mostly to small errors in the velocity fields. This application shows that the reliability of LCS detection may be strongly undermined when gaps are present in the velocity observations.

Shadden S.C., Lekien F., Marsden J.E. (2005) Definition and properties of Lagrangian coherent structures from finite-time Lyapunov exponents in two-dimensional aperiodic flows. *Physica D: Nonlinear Phenomena* **212** (3–4): 271–304

Karrasch D., Haller G. (2013) Do Finite-Size Lyapunov Exponents detect coherent structures? *Chaos: An Interdisciplinary Journal of Nonlinear Science* **23**:4, 043126