21 YEARS OF REPROCESSED LYAPUNOV EXPONENTS FROM ALTIMETRY AVAILABLE ON AVISO+

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Ssalto/Duacs system processes data from all altimeter missions to provide a consistent and homogeneous catalogue of products for varied applications, both near real time applications and offline studies.

During the past 21 years, in parallel with the altimeter Level2 measurement (a.k.a [O/I]GDR) to Level3 and Level4 (along-track cross-calibrated SLA, and multiple sensor merged maps) processing, different applications and derived Level4+ products were distributed by AVISO+. In order to better serve the users' need, and in collaboration with different laboratories (LOCEAN and CTOH), the Altimetry-derived maps of Lyapunov exponents (LEs) and vectors are computed over the 21-year altimeter period and over the global ocean within the SALP/CNES project. We present here these product methodology and characteristics.

Lyapunov Exponents presentation

Surface current-derived maps of Lyapunov exponents (LEs) provide proxies of (sub-)mesoscale transport fronts. The LEs give the exponential rate of separation of particle trajectories initialized nearby and advected by surface currents. Large LEs values underline regions where the stretching induced by surface current is strong. It corresponds for instance to (sub-)mesoscale eddy line contours and filaments.

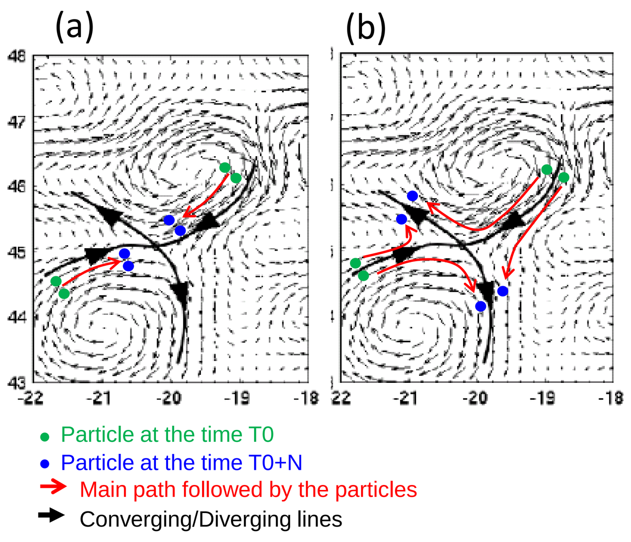

Fig 2: *Example of geostrophic currents, with converging/diverging lines underlined*
a) Two close particles located on the same side of the front are advected by the stream and remain quite close from each other.
b) Two close particles located on opposite side of the front are advected by the stream and separate quickly.

Their calculation however is more complex than standard Eulerian diagnostics, because it requires a Lagrangian algorithms which integrates the velocity field. The LE λ is computed by assuming an exponential separation between the initial separation δ_0 and a final separation δ_f in a time t

$$\delta_f=\delta_0 \exp(\lambda t)$$

$$\lambda= t^{-1}. \log(\delta_f/\delta_0)$$

The LE λ gives the timescale of the exponential stretching, i.e., the timescale of frontogenesis between the scale δ_f and δ_0

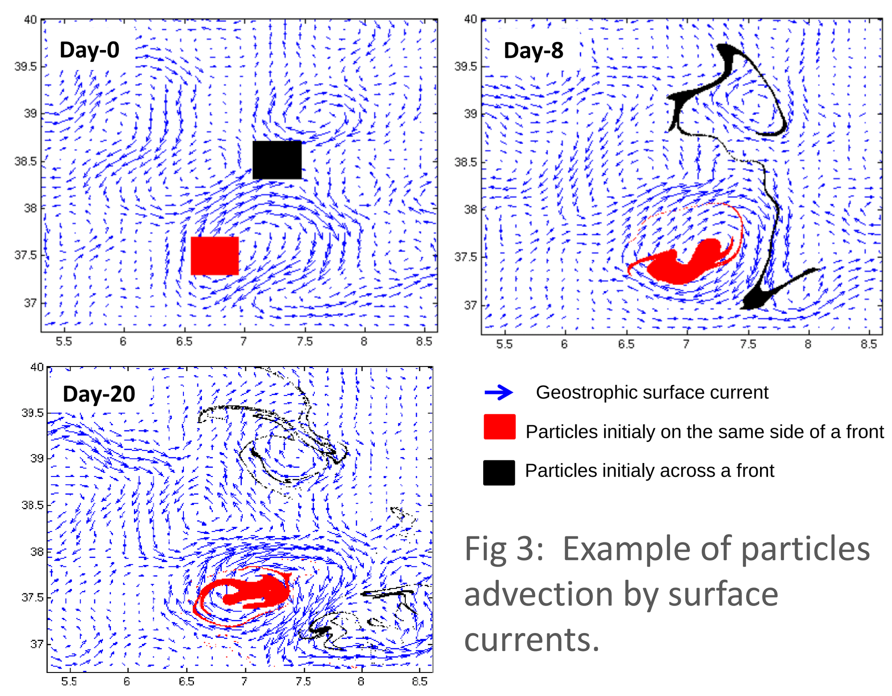

Fig 3: Example of particles advection by surface currents.

Converging/diverging lines underlined with LEs result on the effect of the velocity field on any advected tracer. They correspond to candidates of tracer fronts. LEs are often in good agreement with filaments of biogeochemical tracers affected by horizontal advection.

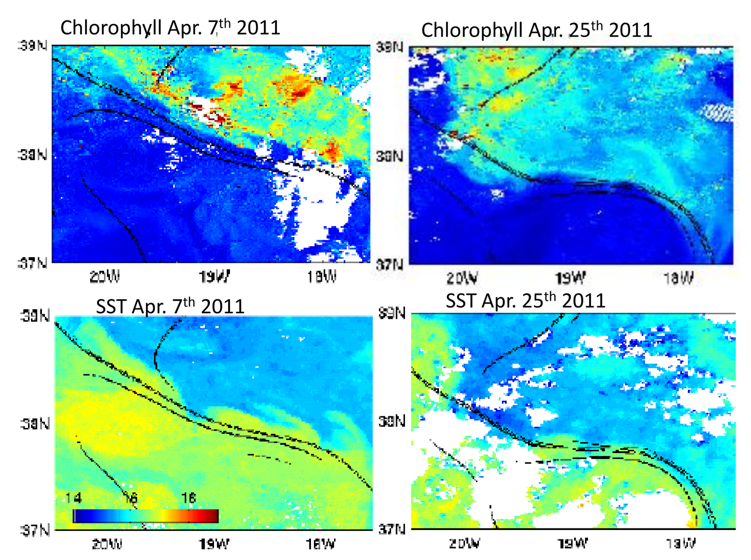

Fig 4: Chlorophyll and SST maps (color scale) and high level FSLEs (black lines) for days 7 a,d 25 April 2011 (Lehahn et al, 2007).
The time evolution of a phytoplankton front is controlled by the evolution of lines of large LEs.

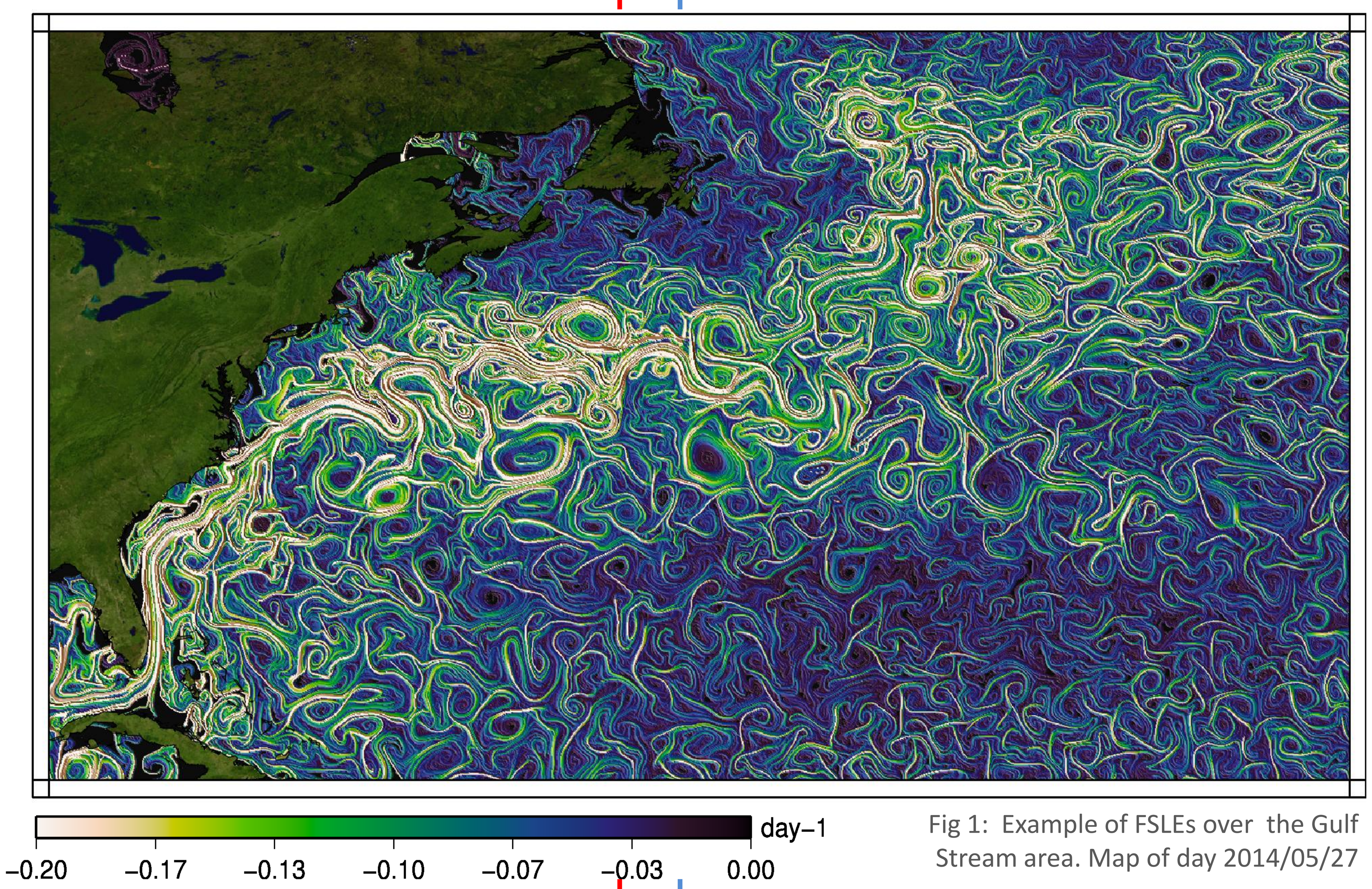

Fig 1: Example of FSLEs over the Gulf Stream area. Map of day 2014/05/27

As velocities fields are time dependant, the LEs can underline structures smaller than the structures observed on the velocity field itself (e.g. submesoscale filaments). These structures do not align necessarily with instantaneous streamlines.

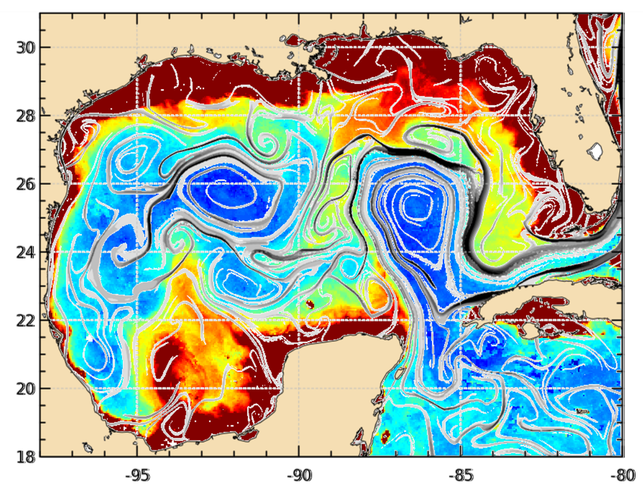

Fig 4: Map of Chlorophyll concentration (color scale) and FSLEs (gray/black lines).
Ocean color fronts, induced by surface horizontal stirring, also correspond with fronts underlined with FSLEs.

Since a backward-in-time separation corresponds to a convergence when observed forward in time, lines of large FSLEs can be used to locate confluence regions. FSLEs underline physical barrier for particles horizontal stirring.

Characteristics of the products available on AVISO+

The products available on AVISO+ are backward-in-time Finite Size Lyapunov exponents (FSLEs). They have been derived from Ssalto/Duacs delayed time global ocean absolute geostrophic currents (« all-sat-merged » DT2014 products version) using the following parameters:

- Initial separation: 0.04 deg
- Final separation: 0.6 deg
- Maximum integration window: 200 days
- Backward advection
- Time span: 1994-2014
- Temporal resolution: 4 days
- Spatial resolution: 0.04 deg
- Spatial coverage : global

FSLEs based on the maximum eigenvalue of the Cauchy-Green strain tensor and Orientation of the associated eigenvector are both provided.

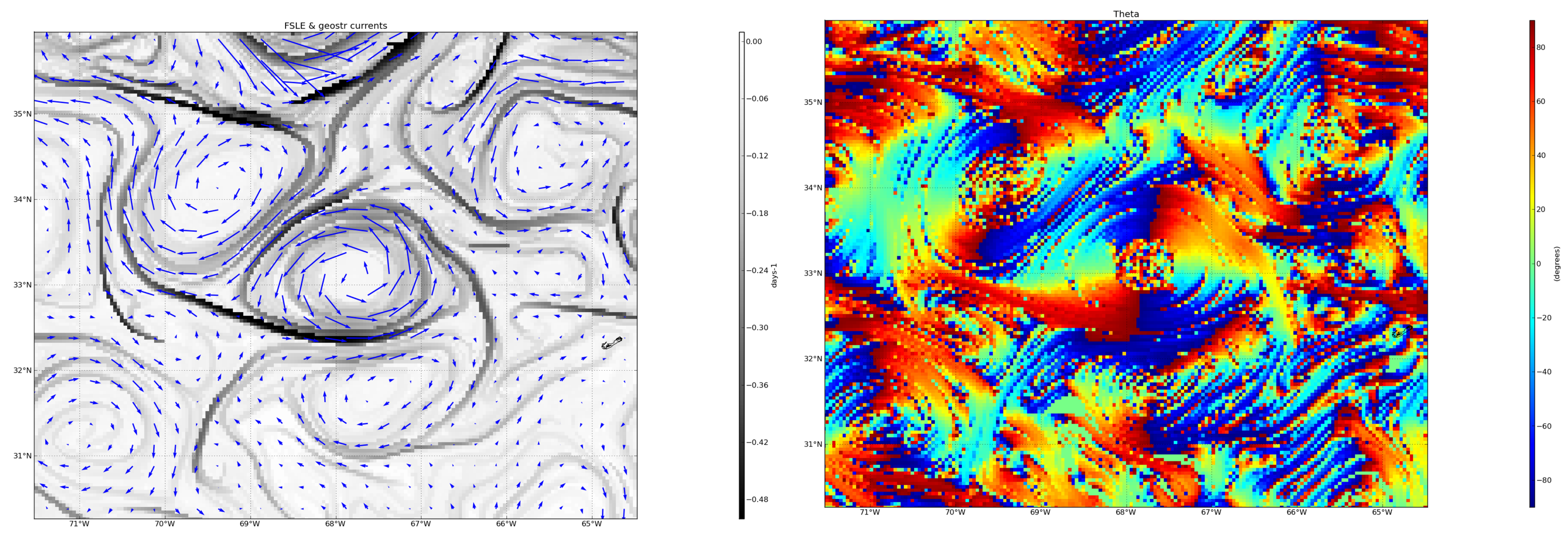

Fig 6: Example of FSLEs & geostrophic currents (left) and FSLEs associated orientation (right)

FSLEs products are available on AVISO+ ftp in a NetCDF CF-4-Classic format.

More details on the AVISO+ web page (see below)

Source code

The code used to compute LE, developed in collaboration between LOCEAN and CLS, is available under GNU General Public License. See dedicated AVISO page :

http://www.aviso.altimetry.fr/en/data/products/value-added-products/fsle-finite-size-lyapunov-exponents.html

Enjoy yourself!!

Example of application

LEs can be used for many different applications, especially in physical and biogeochemical sciences.

For instance, LEs was successfully used to qualify the contribution of different altimeters, already in orbit or planned in the next years:

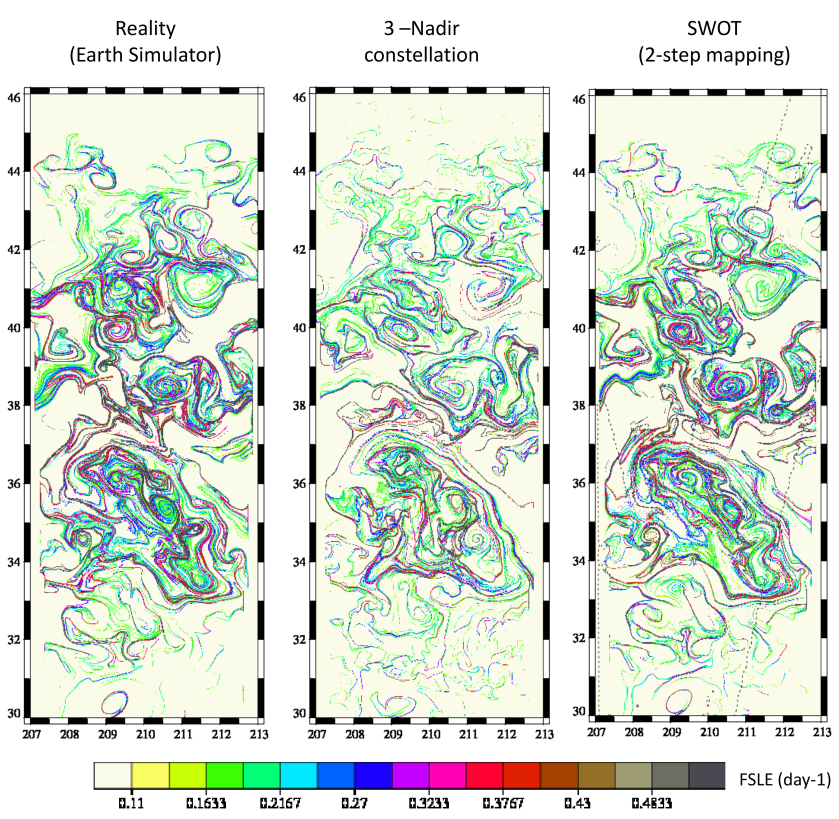

Fig 7: Map of FSLE derived from Earth Simulator (ES) output (left). ES was used as a reference field for an end-to-end simulation: ES surface SSH field is sampled by different altimeters constellation and then reconstructed by optimal interpolation-based methods. Maps of FSLE derived from the reconstructed surface field when sampled with an historical 3-altimeter constellation (middle) or with the future SWOT wide swath mission (right). (Le Traon et al, 2011 SWOT TOSCA meeting)

In Summary

A new altimetry-derived FSLEs dataset is available on AVISO+ for scientific applications:

✓ Based on DT2014 Global absolute geostrophic currents
✓ Delivered via ftp
✓ New NetCDF-CF4-Classic format

➔Contact AVISO to download these products and don't hesitate to send us your feedback.
aviso@altimetry.fr

Product access on the AVISO website
www.aviso.altimetry.fr