SUBMESOSCALE FRONTS AND FILAMENTS CALCULATED FROM LYAPUNOV EXPONENTS

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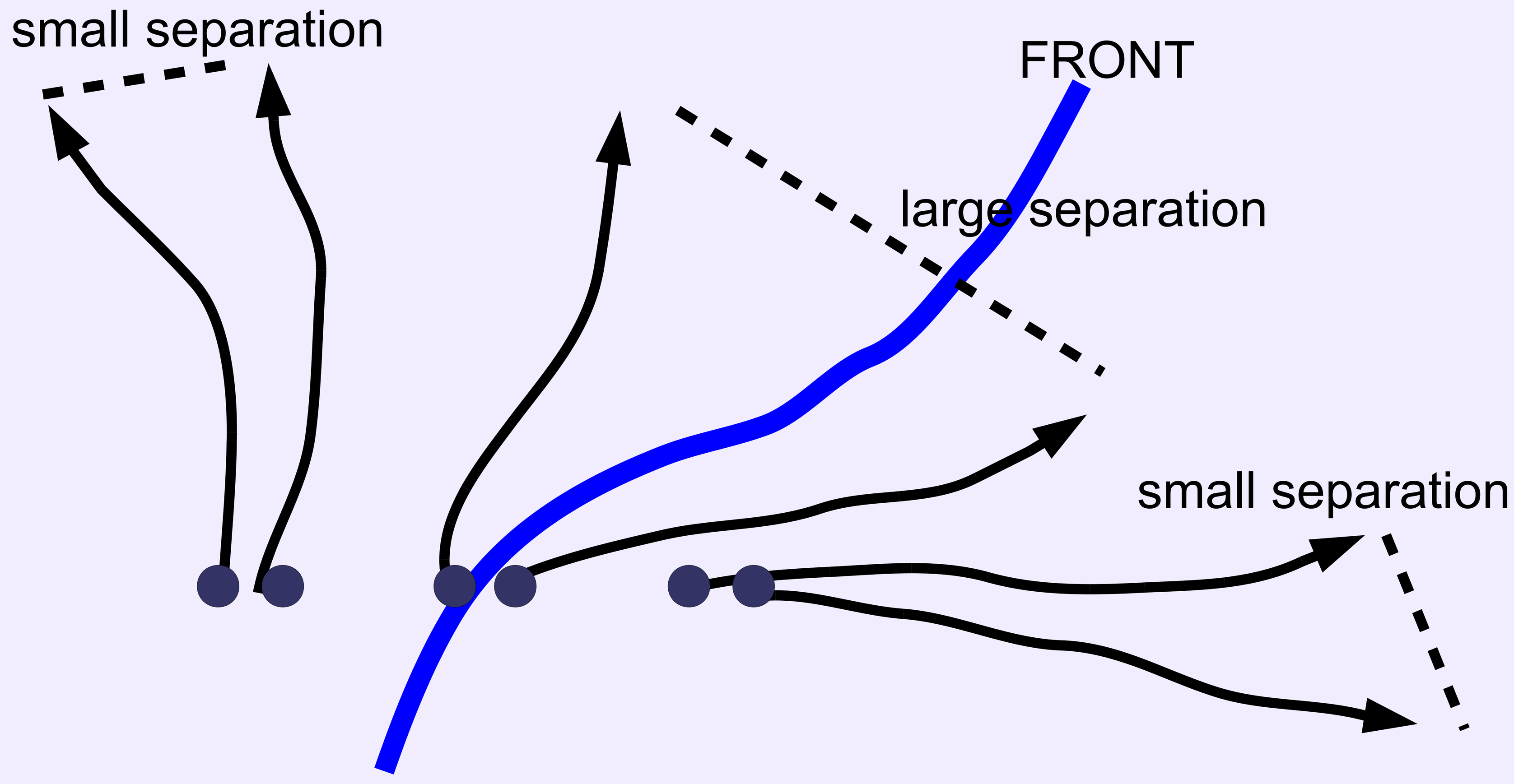
Lyapunov exponent

The calculation of the Lyapunov exponent is a robust diagnostic that can be applied to altimetry-derived geostrophic currents, in order to extract the position and strength of sub-mesoscale fronts and filaments induced on any advected tracer by the mesoscale turbulence. Applications include climatological analysis of stirring and mixing, front and filament detection for in-situ research campaign studies, and validation for models.

Distribution of Lyapunov maps

The calculation of the Lyapunov exponent is more demanding than traditional diagnostics, requiring the construction of particle trajectories by interpolation and integration of the surface currents. In a joint collaboration between the CTOH-LEGOS in Toulouse, LOCEAN-IPSL and the Institute of Complex Systems (ISC) in Paris, we are constructing maps of Lyapunov exponents from satellite based surface velocity fields, producing filament-resolving (4-10km), daily maps. These will be obtained using the delayed-time and near-real-time AVISO altimetry-derived geostrophic velocities, and using the CTOH geostrophic and Ekman near-surface currents. The fine-resolution Lyapunov maps and the code to generate them will be distributed to scientific users via the CTOH and LOCEAN web sites under a joint license.

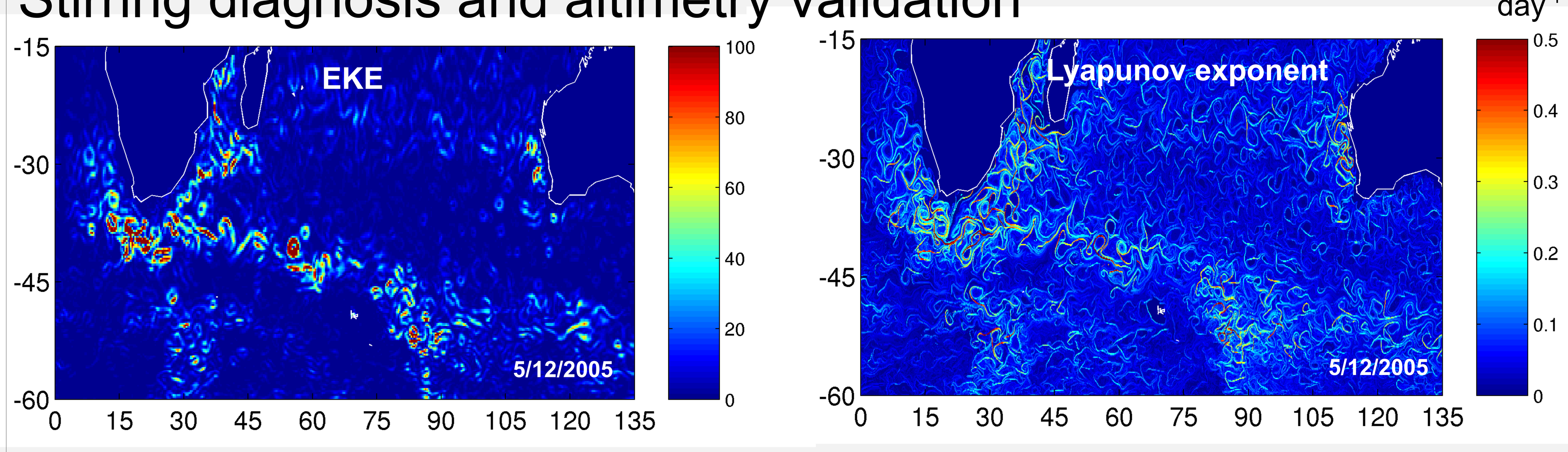
An intuitive definition of Lyapunov calculations



The lyapunov exponent measures the rate of separation of particle trajectories. When the exponent is computed backward-in-time over a grid, fronts that separate water masses of different origin can be detected as regions of large Lyapunov exponents, since couples of particles initialized over the front come from region further apart than couples of particles on the same side of the front.

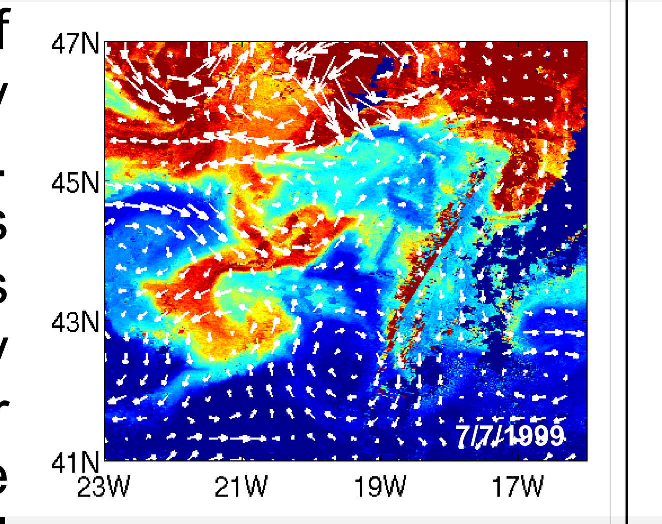
Delayed-time altimetry re-analysis

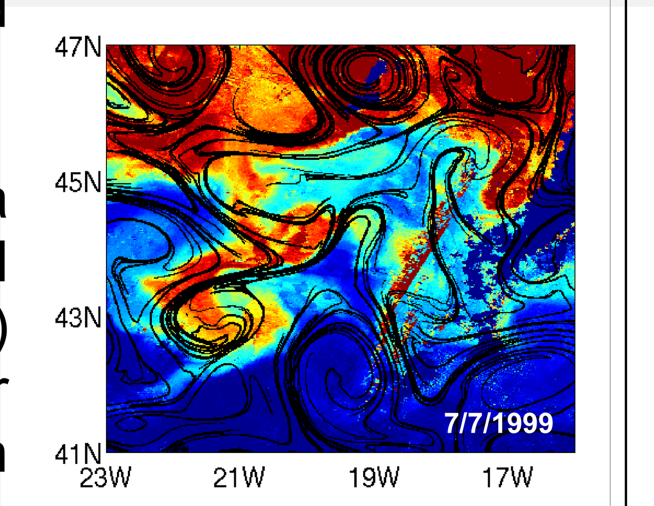
Stirring diagnosis and altimetry validation



We are reprocessing the historical datasets of delayed-time altimetry data. We plan to release daily maps of Lyapunov exponents at 4-10 km resolution. By looking at the relative dispersion of trajectories initialized around each grid point, the filaments induced by mesoscale turbulence on a passively advected tracer can be reconstructed at a higher spatial resolution than provided by altimetry, since large mesoscale structures can stretch advected tracers into much thinner structures.

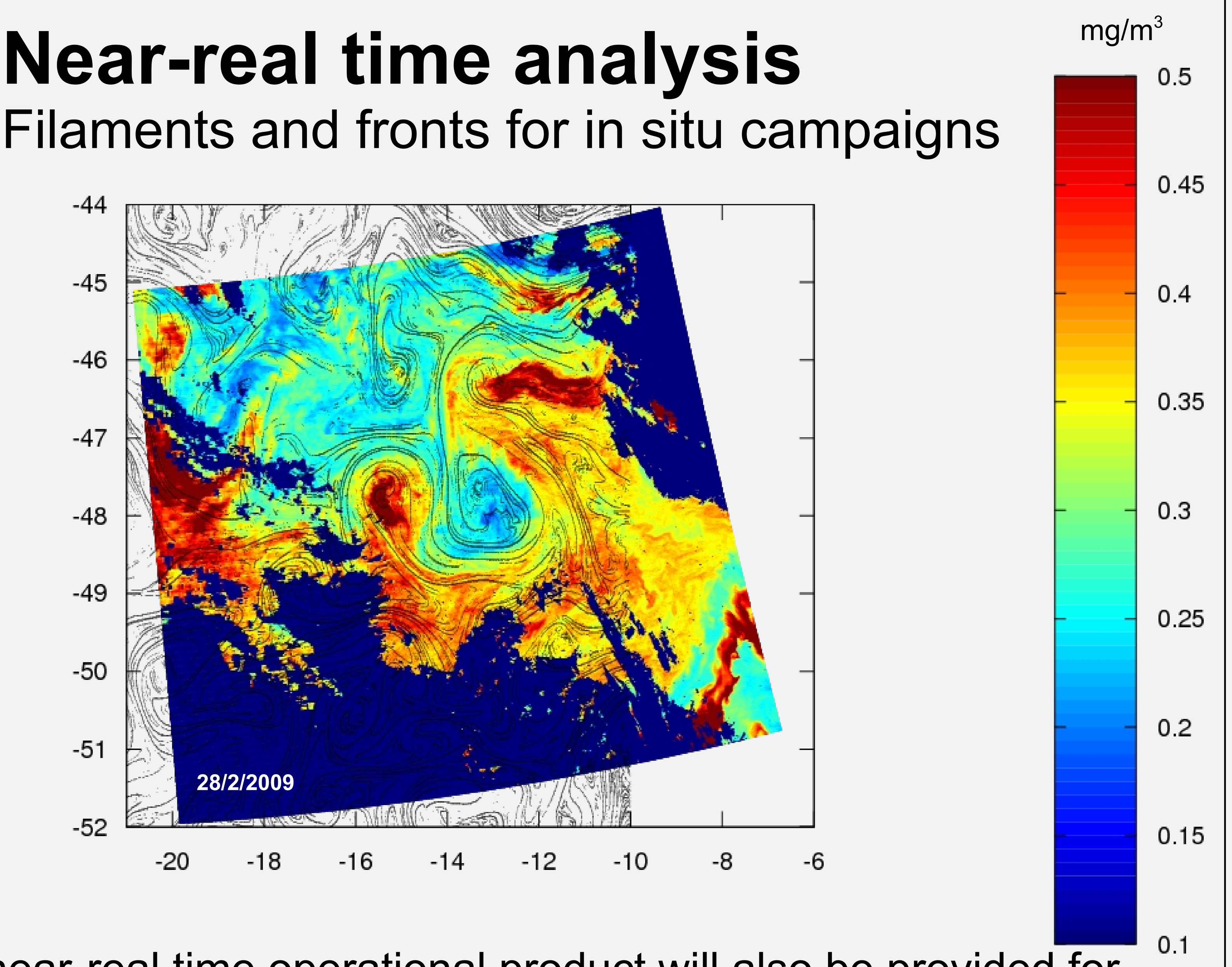
The delayed-time product is intended as a submesoscale resolving complement to traditional diagnostics such as (i) eddy kinetic energy (above) for ocean circulation analysis and (ii) for intercomparisons of altimetry with high resolution features in SST or chlorophyll images (right panels).





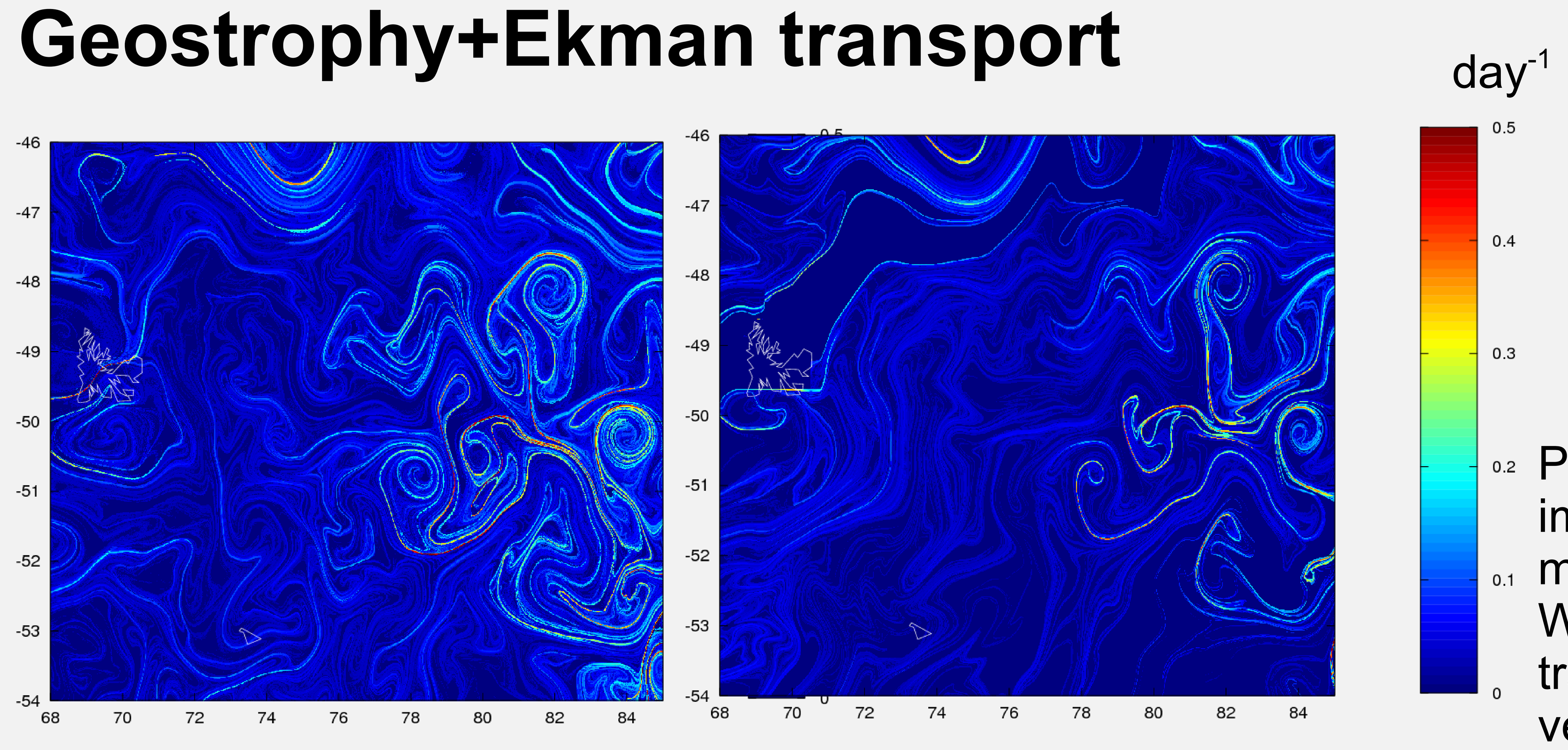
Near-real time analysis

Filaments and fronts for in situ campaigns



A near-real time operational product will also be provided for campaign studies. This product is intended as a support to in situ sampling of (sub-)mesoscale fronts and filaments. As a feasibility study, NRT maps of Lyapunov exponents have been used during the LOHAFEX fertilization campaign in order to choose and monitor an eddy with a well isolated core in the South Atlantic. The image above shows the excellent agreement between NRT altimetry-derived fronts (black lines) and chlorophyll distribution.

Geostrophy+Ekman transport



Prolonged perturbations of geostrophic currents may have a large impact on advective properties even if instantaneously the mesoscale structure of the velocity field is only marginally modified. We are testing the response of the stretching imposed by Ekman transport by analyzing with the Lyapunov technique near-surface velocities based on altimetry plus a Quickscat-derived Ekman component. The example in the left panel shows the case of the filaments around the Kerguelen plateau.

Timeline

	2009	2010	2011
DT	10-year re-analysis (10km) restricted access (test)	15-year re-analysis (10km) open access	15-year re-analysis (4km) open access
NRT	Regional (4km) restricted access (test)	Regional (4km) open access	Global (4km) open access

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References

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