A climatology of surface filaments derived from altimetry

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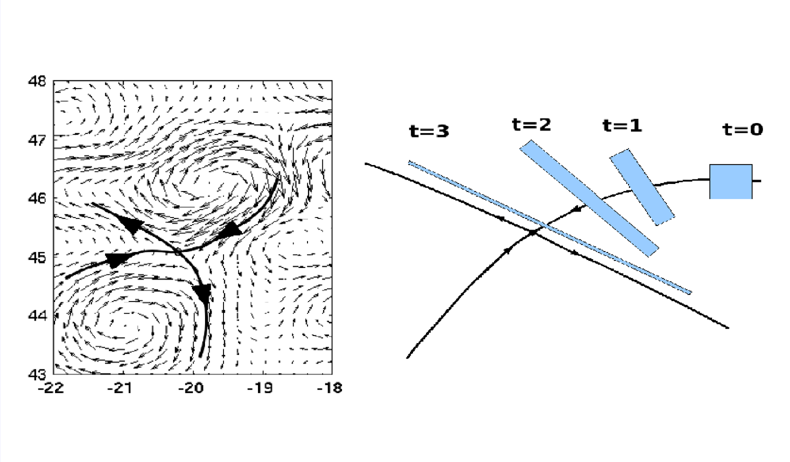
Lagrangian methods like the Lyapunov exponent calculation allow to study the effects of the mesoscale turbulence on the dispersion of a tracer. In particular, by exploiting both the spatial and the temporal variability of the velocities, the Lyapunov exponent has been shown to predict part of the surface submesoscale dynamics, predicting the location of observed cross-streamline chlorophyll and sea surface temperature filaments from altimetry data at subgrid resolution. Here we show how the Lyapunov exponent can be potentially used to validate altimetry products and to extract subgrid information on horizontal mixing.

THE LYAPUNOV EXPONENT

What does the local Lyapunov exponent measure?

The local Lyapunov exponent measures the local dispersion of particles initialised nearby. By computing the exponent on a grid, one can construct a map of local dispersion rates. These maps typically show maxima of Lyapunov exponent along lines, that can interpreted as frontal regions.



The intensity of the Lyapunov exponent provides the inverse timescale at which a tracer front is developed.

Tracer submesoscale filaments from altimetry data

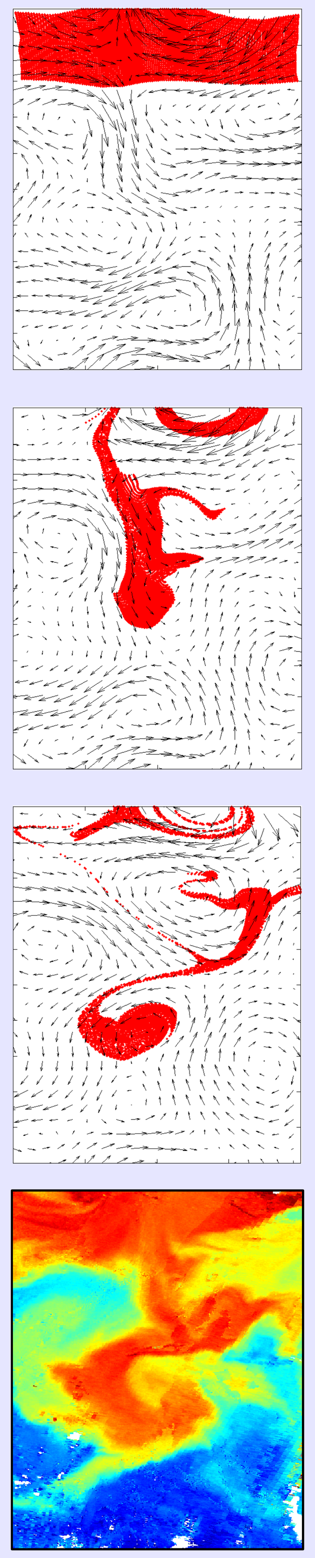
One of the main advantage of the Lyapunov exponent is that it depends on both the spatial and the temporal variability of the velocity field. This allows to recover part part of the *submesoscale* variability of tracers like chlorophyll or sea surface temperature from the *mesoscale* eddies of altimetry data. In this example, a chlorophyll pattern is reconstructed by the advection with altimetry velocities of a synthetic tracer on a high resolution grid. Maxima of Lyapunov exponents (black lines) provides the fronts that bound the filament. Tracer scales smaller than the scale of the velocity field appear, due to the temporal dynamics.

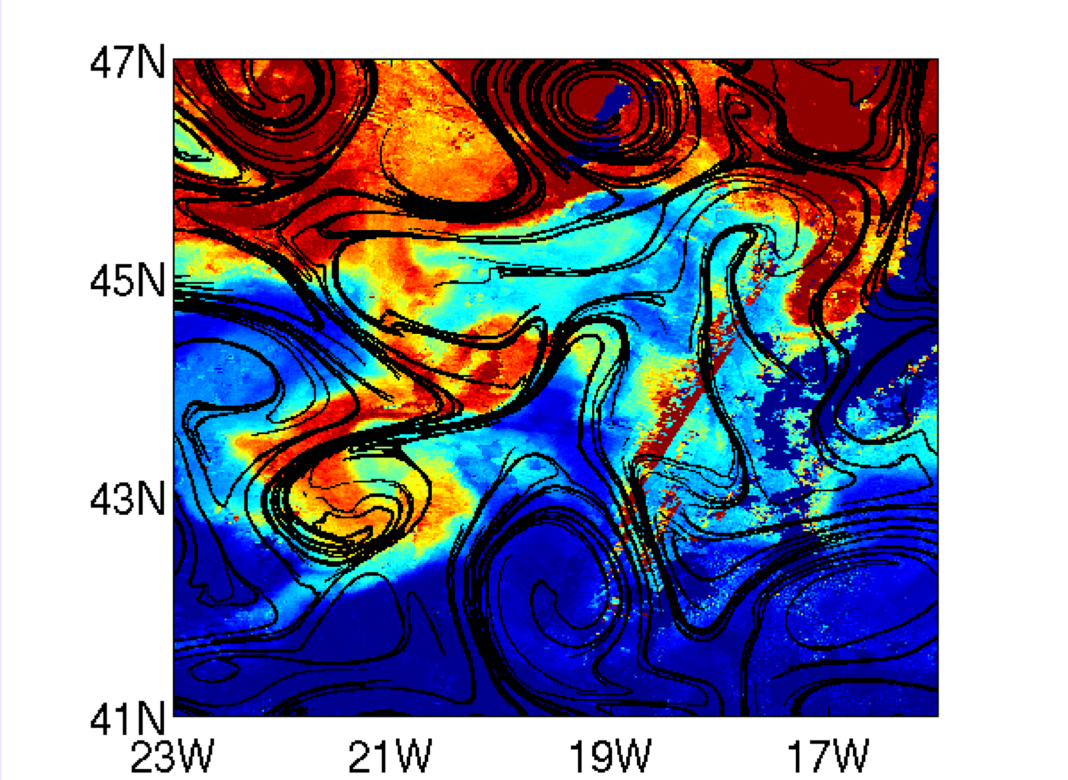
Day 0

Day 10

Day 15

Observed pattern

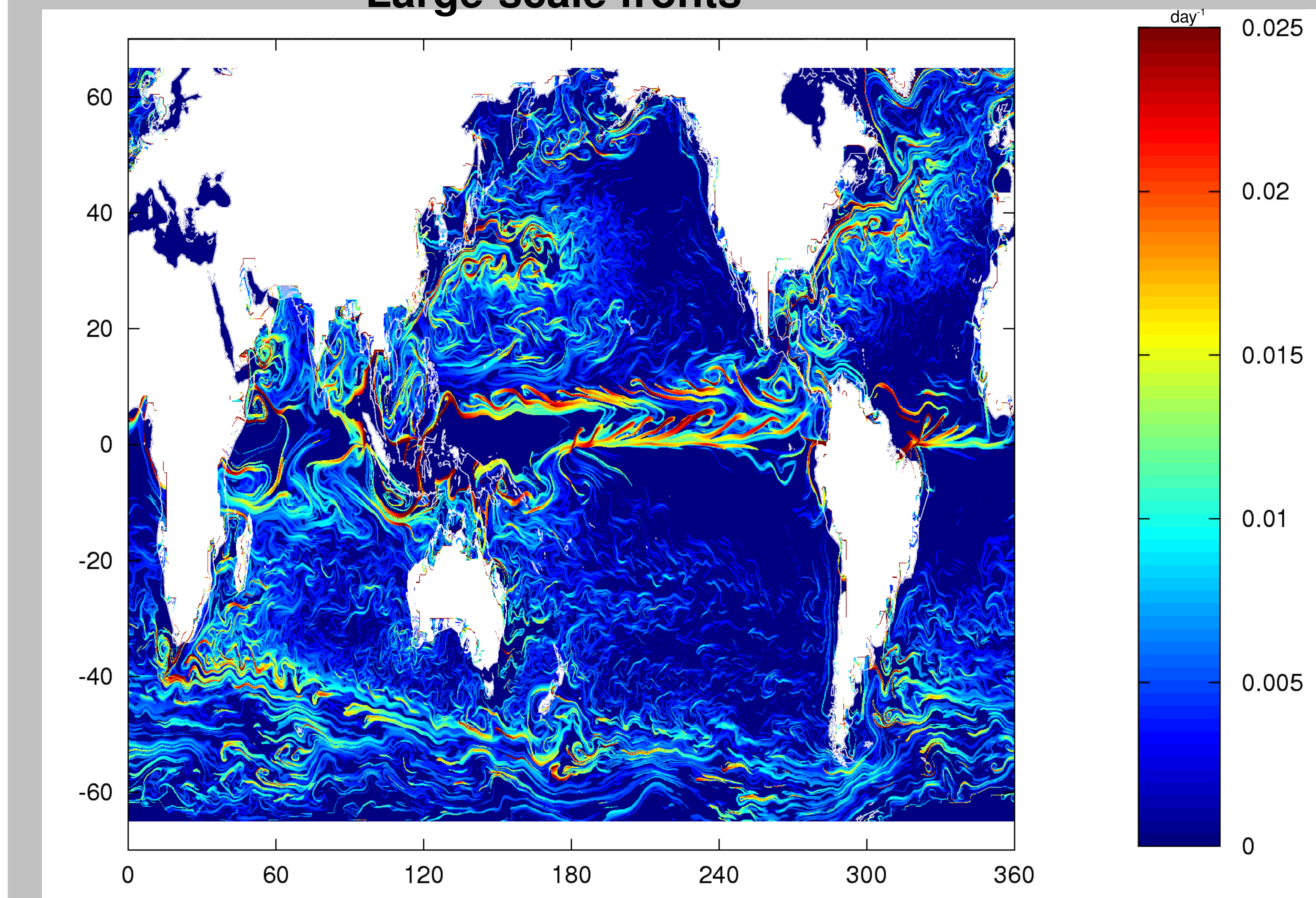




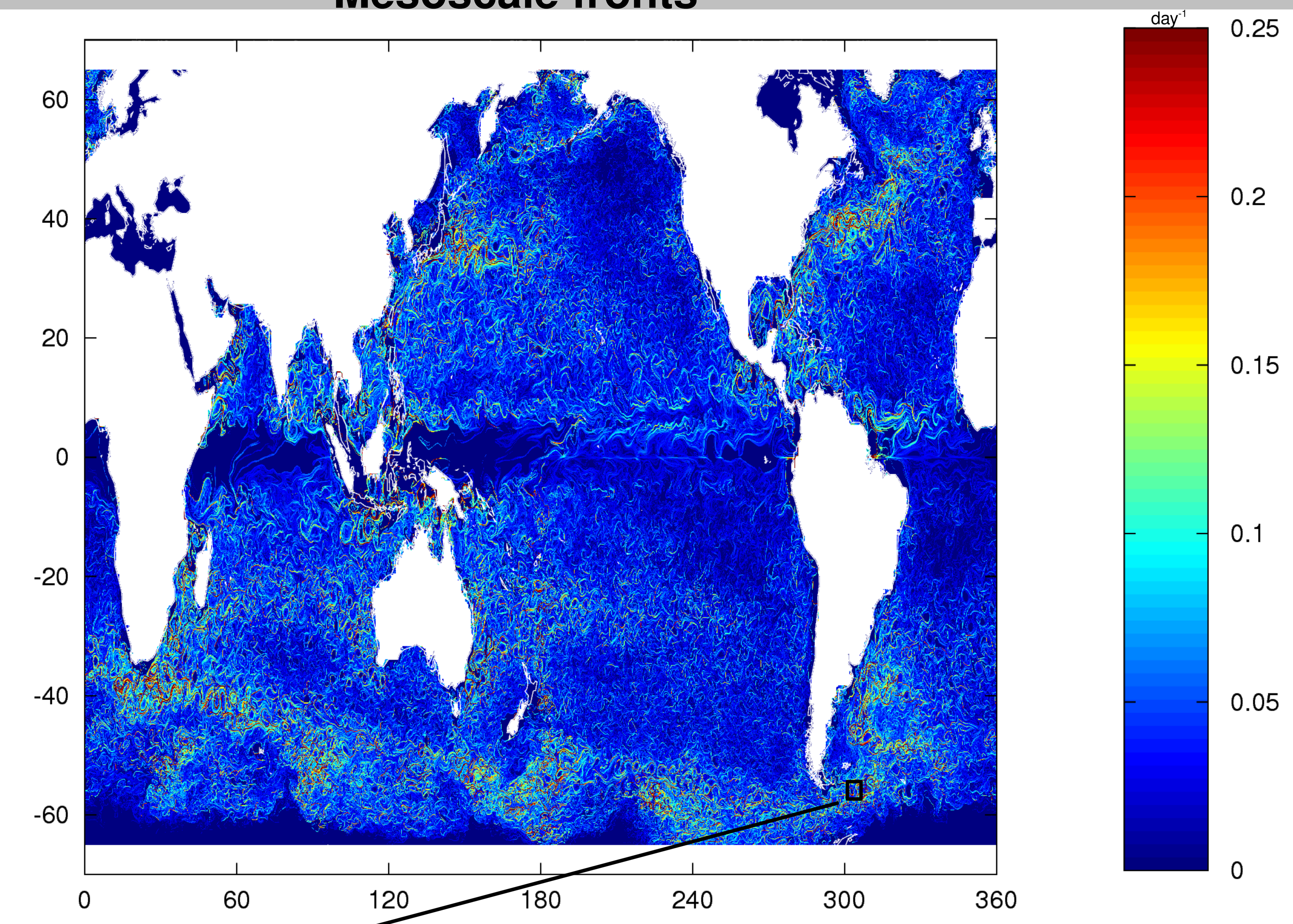
Chlorophyll pattern on 7 July 1999 (SeaWiFS, NE Atlantic spring blomm)

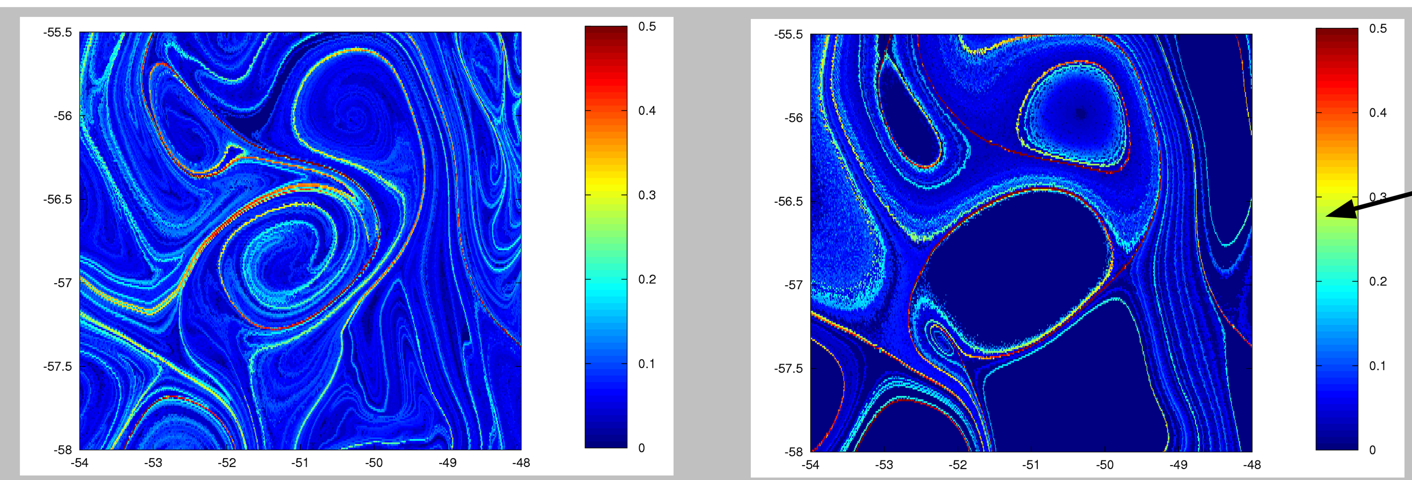
DETECTION OF FRONTS AT THE GLOBAL SCALE

Large-scale fronts



Mesoscale fronts





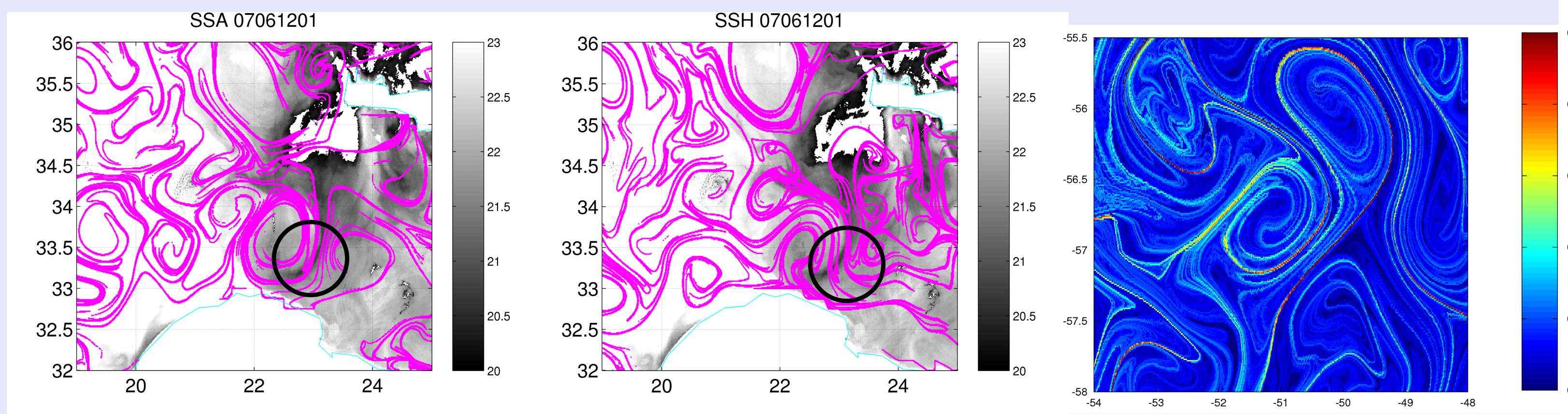
Spatial+temporal variability   Spatial variability only (frozen velocity field)

The re-analysis of global altimetry maps provides the distribution of both climatological and mesoscale fronts induced by the circulation observed by satellite.

Since tracer filaments depend on the temporal variability of the velocity field, the process of filament formation can be isolated and quantified by comparing a Lyapunov map with a map recalculated on a frozen velocity field. This can be used to estimate *mixing.*

VALIDATION OF ALTIMETRY PRODUCTS

SSA vs SSH   Topex/Poseidon only

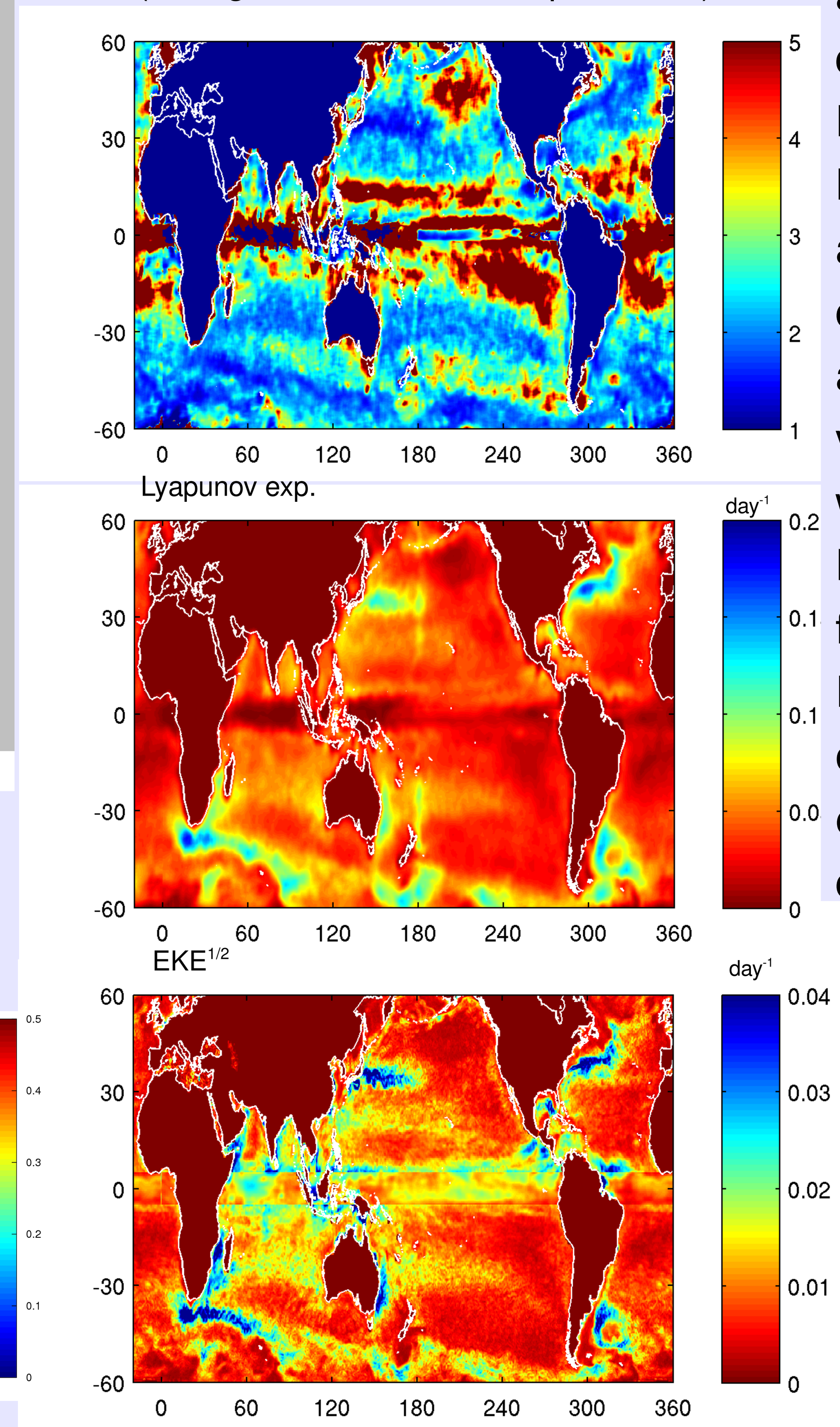


The comparison of fronts detected from altimetry with the Lyapunov technique can be used to validate the spatial *and* temporal variability of altimetry data in combination with high-resolution SST images. In the example above left (Eastern Mediterranean, in collaboration with V. Taillandier, I. Taupier-Letage, and L. Mortier) the addition of a mean dynamic topography appears in fact to degrade the satellite observation along the coast.

Other applications may include the comparisons of monomissions vs. multimission products (top right).

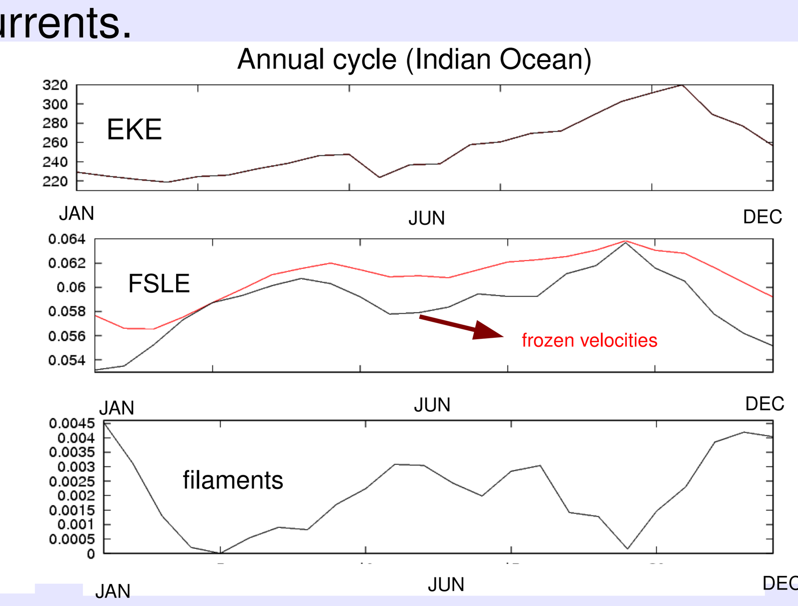
HORIZONTAL MIXING

Mixing
(background diffusion amplification)



A systematic Lyapunov re-analysis of altimetric data can also lead to the quantification of mixing.

Here we show 1996-2006 means of Lyapunov exponents, eddy kinetic energy, and mixing. Mixing is obtained by comparing the Lyapunov calculation with and without temporal variability of the velocity field. Lyapunov exponents appear well correlated with energetic regions. However, the analysis shows that filament formation (mixing) is anticorrelated to the EKE. This is consistent with the observations of large tracer gradients along energetic structures like the boundaries currents.



References

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