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Understanding and parametrizing downscaling and mixing analyses from altimeter-derived oceanic currents

V. Resseguier, B. Chapron, E. Mémin

ABSTRACT

Ocean eddies play an important role in the transport of heat, salt, nutrients or pollutants. During a finite-time advection, the gradients of these tracers can increase or decrease, depending on finite-time Lyapunov exponents (FTLE). Numerous studies on mixing and/or tracer downscaling methods rely on satellite altimeter-derived ocean velocities. Filtering most oceanic small-scale eddies, those resulting Eulerian velocities are often stationary during the characteristic time of tracer gradient growth (~ 1 week). Using finite-time advectons, the averaged tracer gradients can then only increase. Thus, such methods can be described analytically & are sometimes unrealistic.

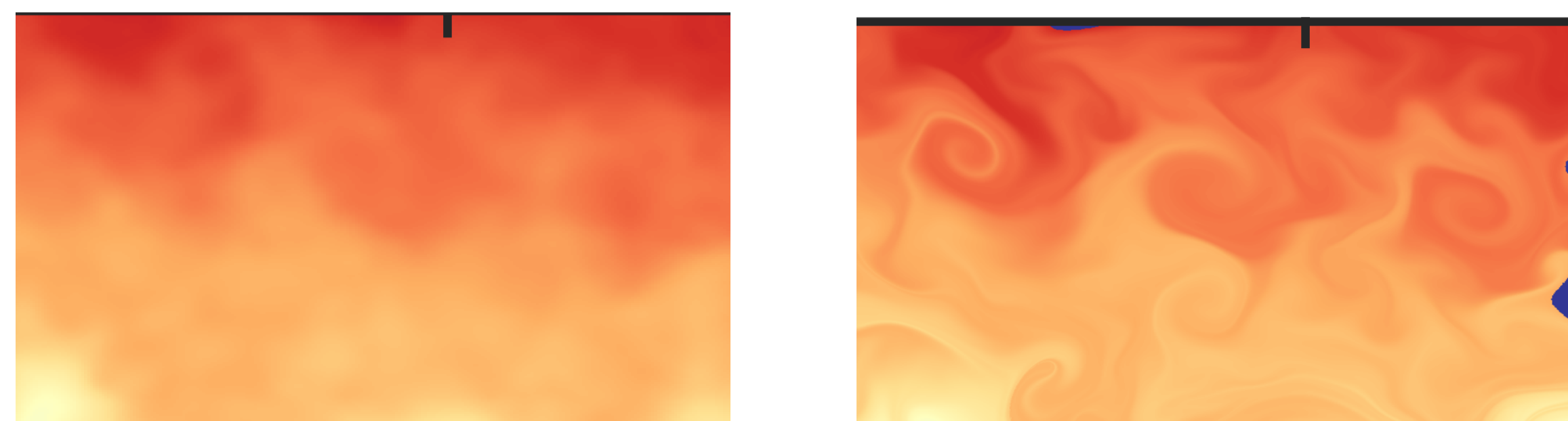


Figure 1 : SST measured by satellite (left) and after 10-day advection downscaling (right) (1st of January 2011, lon = 130° ± 5°, lat = 45° ± 3°)

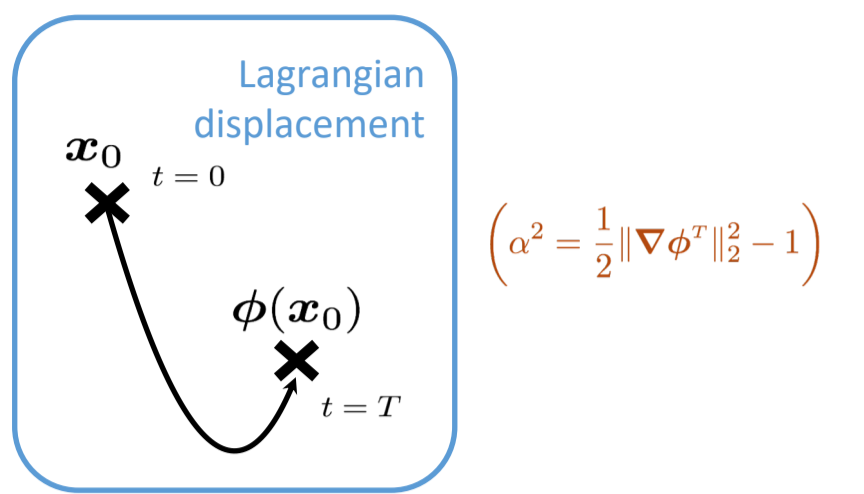
ANALYTIC DESCRIPTION

Tracer stretching $\overline{\|\nabla T\|^2} = ?$ ($\bar{\cdot}$: spatial average)

Assumption 1: low-spatial resolution of SSH and SST

$$\frac{\overline{\|\nabla T\|^2}}{\overline{\|\nabla T_0\|^2}} \approx 1 + \overline{\alpha^2} (> 1)$$

Local growth rate of gradient strengthening (related to FTLE)



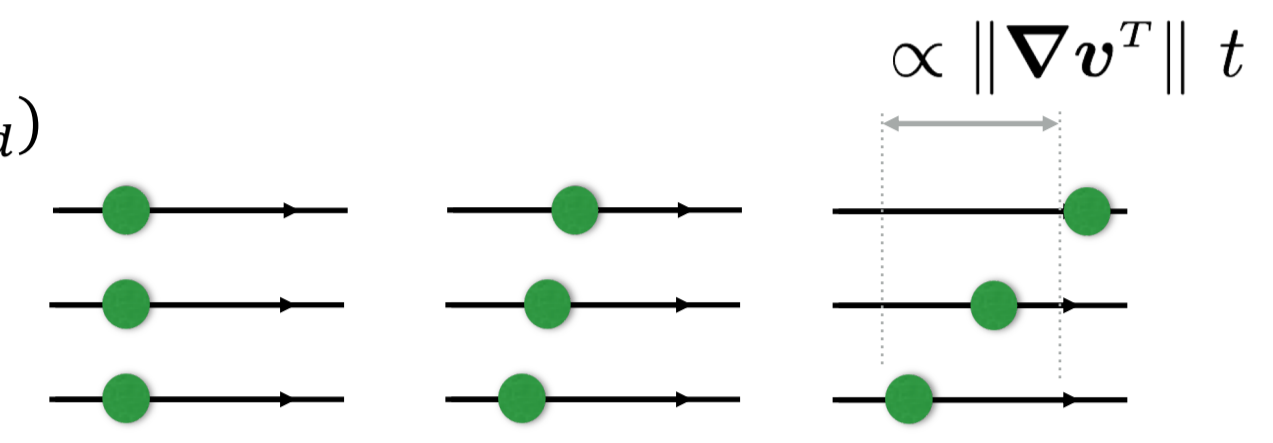
Stretching growth rate $\alpha^2(x, t) = ?$ (t : advection duration)

How to estimate it from a single velocity snapshot $v(x, t = 0)$?

Assumption 2: low-temporal resolution of SSH

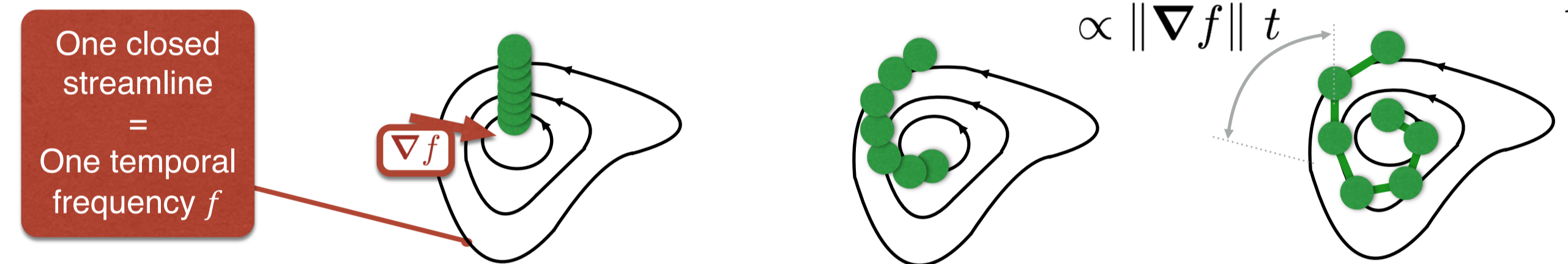
- Small streamline curvature ($R(x) \leq R_{threshold}$)

> Stretching by velocity shear $\alpha \approx \frac{t}{\tau_s(x)}$

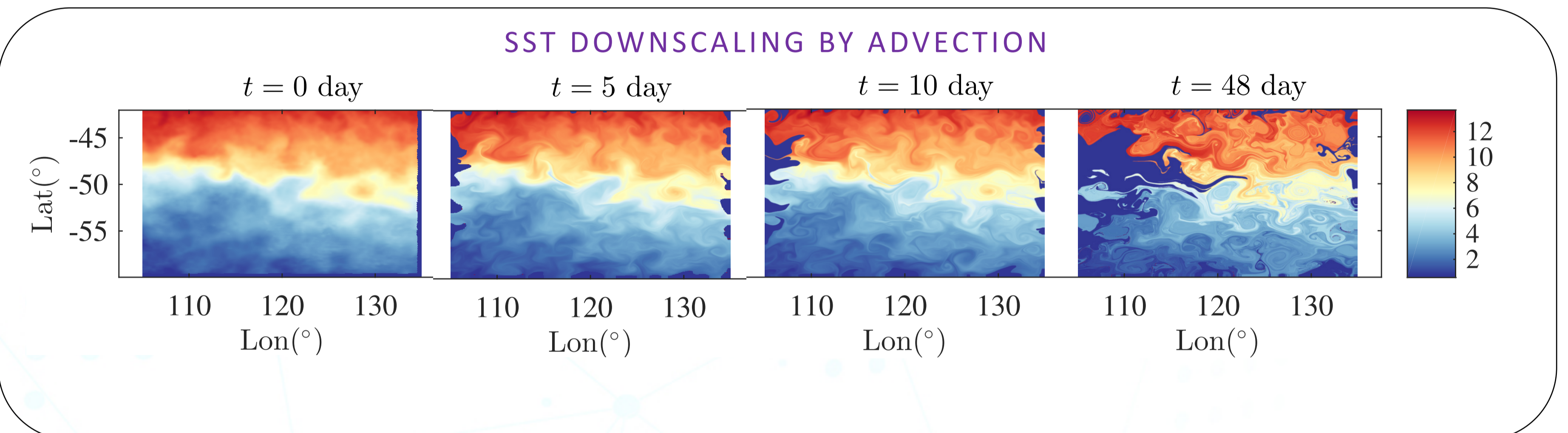
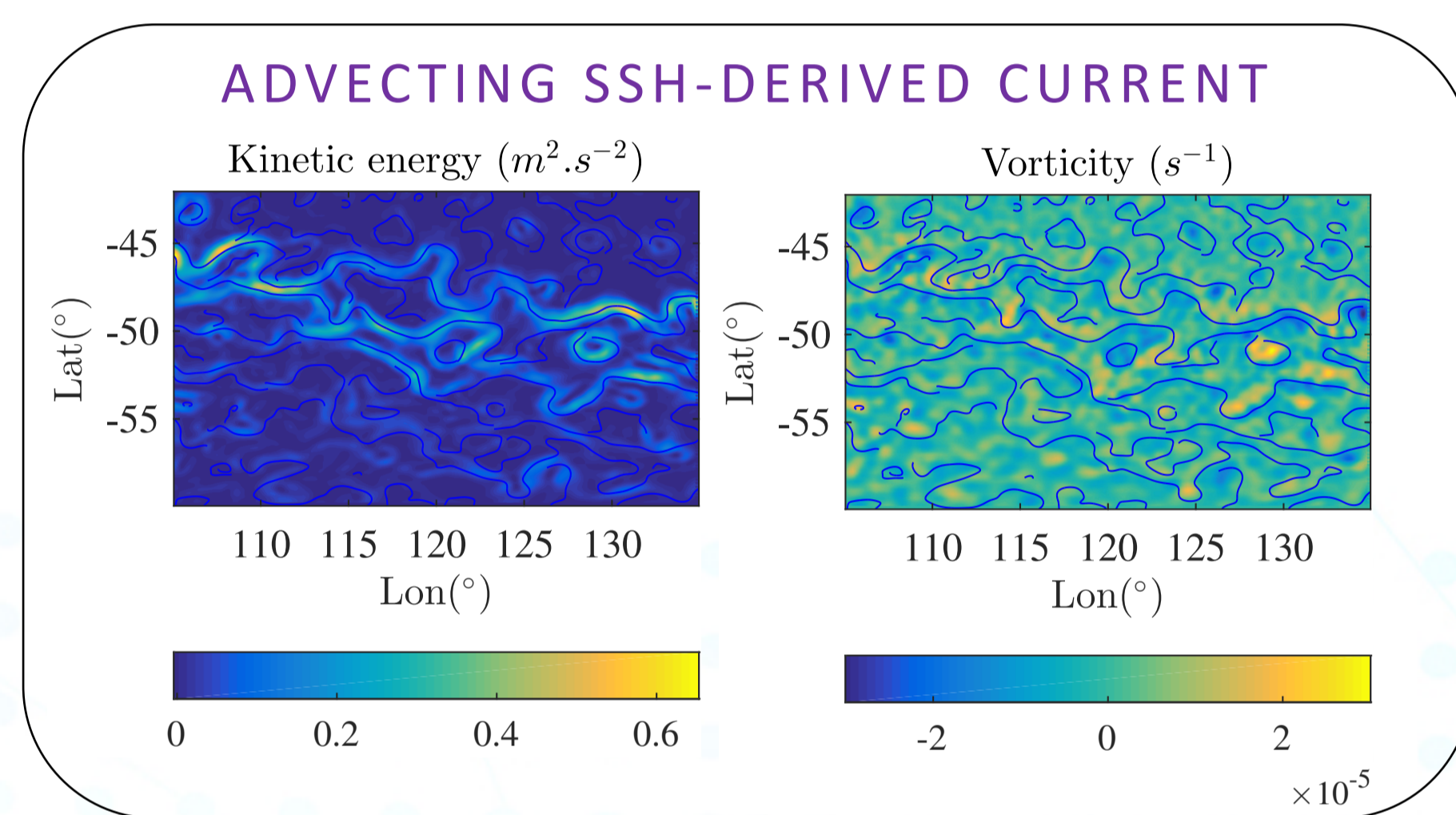


- Large streamline curvature ($R(x) > R_{threshold}$)

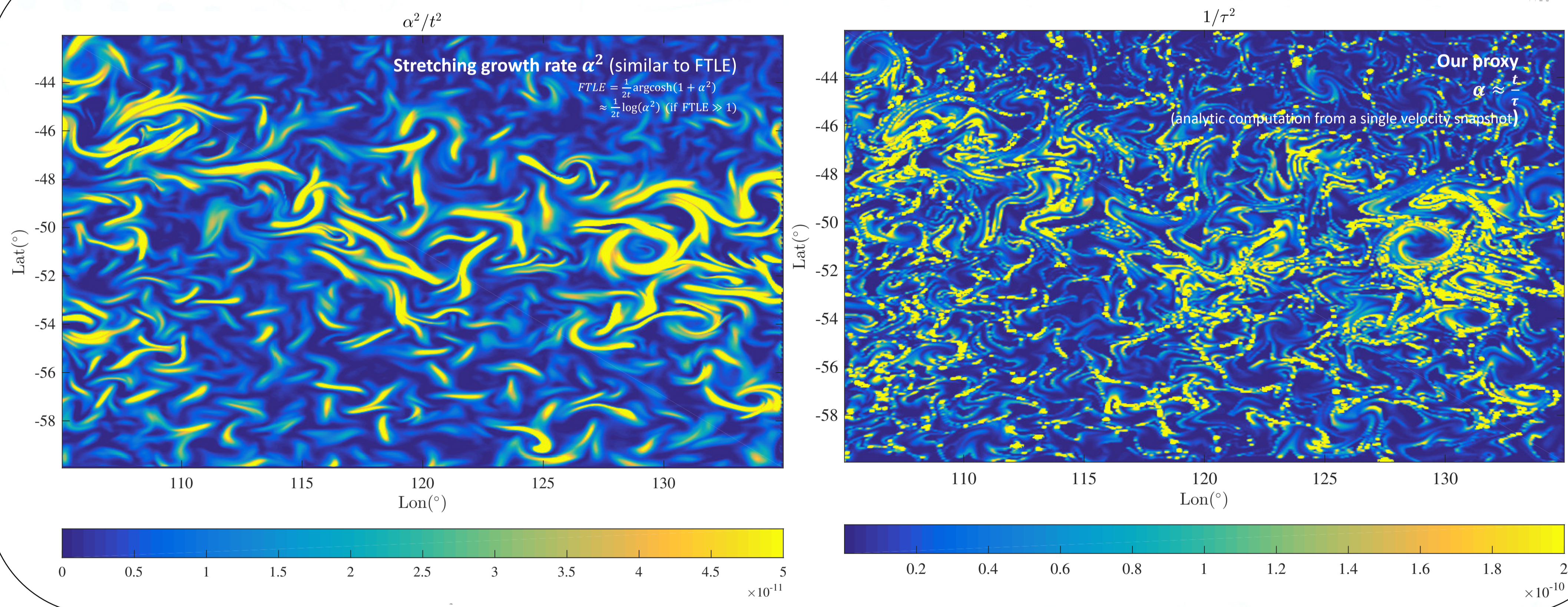
> Stationary convective cells with shear of angular velocity $\alpha \approx \frac{t}{\tau_f(x)}$



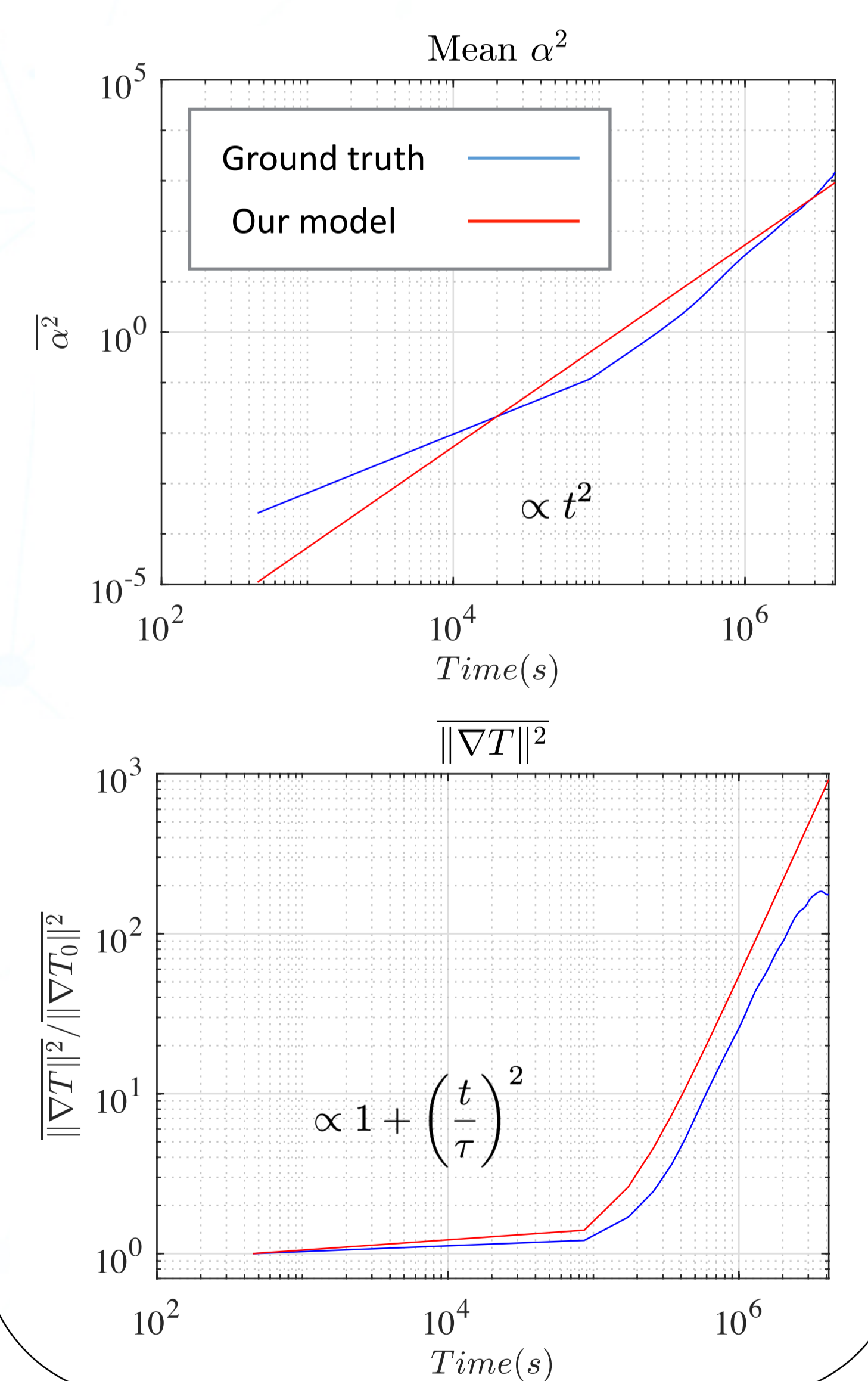
RESULTS WITH SATELLITE IMAGES



SPATIAL DISTRIBUTION OF STRETCHING GROWTH RATE AND ITS PROXY



TEMPORAL EVOLUTION OF STRETCHING AND ITS PROXY



Reference

Resseguier, V., Chapron, B., & Memin, E. (2022). Effects of smooth divergence-free flows on tracer gradients and spectra: Eulerian prognosis description. *Journal of Physical Oceanography*, 52(1), 53-74.

CONCLUSION

Using finite-time advectons by the SSH-derived surface oceanic currents, the averaged tracer gradients can then only increase – possibly without bound – with local growth rate independent of the initial coarse-scale tracer distribution.

The key mixing processes are then only governed by locally uniform shears and foldings around stationary convective cells.

To predict the tracer deformations and the evolution of their 2nd-order statistics ($\overline{\|\nabla T\|^2}$, SST spectrum, etc), an efficient proxy is proposed. Applied to a single velocity snapshot, this proxy extends the Okubo-Weiss criterion. For the Lagrangian advection-based downscaling methods, it successfully predicts the evolution of tracer spectral energy density after a finite time, and the optimal time to stop the downscaling operation.