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Lyapunov diffusion and transport barriers

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Transport barriers are often associated with persistent jets in geophysical fluid dynamics and diagnosed as extrema in stretching or Lyapunov exponents. However, transport barriers are also associated with minimum of quantities measuring exchanges and mixing. Effective diffusivity is a semi-Lagrangian method which provides directly an estimate of diffusion on isentropic surfaces in equivalent latitude but to the price of a contour averaging that masks any longitudinal variation. It is also difficult to adapt this notion to oceans with complicated basin boundaries.

We introduce the Transverse Lyapunov Exponent which predicts local intensification of gradient upon the well verified assumption of alignment of tracer contours with the local unstable manifold. Unlike the standard Lyapunov exponent which is often anticorrelat ed with effective diffusivity, this transverse Lyapunov exponent correlates with effective diffusivity and can be turned into a Lyapunov diffusion, a quantity with the dimension of a diffusion, which matches effective diffusivity on the average but is independent on contour averages and provides a local Lagrangian estimate of mixing.

We present applications to the meridional transport in the atmosphere, showing how ENSO modulates a transport gate across the subtropical range over a limited longitudinal range. We also presents application to mixing in the Mediterranean Sea and North Atlantic.