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A three-dimensional climatology of atmospheric mixing in the UT/LS

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Small-scale mixing in the UT/LS region is conditioned by tracer gradients generated by quasi-isentropic stirring by synoptic and mesoscale motion. Effective diffusivity and Lyapunov exponents are two methods which have been proposed to provide estimates of isentropically driven mixing. The effective diffusivity is a semi-Lagrangian method which provides directly an estimate of diffusion in equivalent latitude but to the price of a contour averaging that masks any longitudinal variations. The LEs on the other hand allow to localize more sharply mixing structure but is dominated by shear induced dispersion and hence fails in the detection of mixing barriers associated with strong jets. In order to solve this problem, we propose a measure of mixing that combines Lyapunov exponents and concentration gradients of passive tracers. This is done by combining together forward calculations (that contain the information of the Lagrangian stretching) with backward calculations (that describe the distribution of an advected passive scalar) into a measure of gradient intensification. This new method is applied to the period 1964-2002 of the ERA-40 dataset for the isentropic transport in the 330-470 K region. The measure is shown to well distinguish between region of strong mixing and mixing barriers both associated with strong shear. Barrier properties of the subtropical and polar jets identified by effective effective diffusivity are recovered but barrier breaks are also found along the longitudinal direction in connection with strong baroclinic activity. It is also found that summer mixing differs strongly between the two hemispheres. A climatology of mixing will be presented showing the modulation of the barriers and the barrier breaks in connection with ENSO.