

Interactive comment on “Trends and variability in stratospheric mixing: 1979–2005” by H. Garny et al.

Anonymous Referee #1

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This paper analyzes the mixing properties of the stratosphere for 1979–2005 using the finite-time Lyapunov exponents computed from the NCEP/NCAR reanalysis winds. The length of the dataset allows the authors to perform a meaningful multiple regression analysis, which includes the climatology, linear trend, QBO, solar cycle, and ENSO. The climatology and the QBO signals agree reasonably well with the previous studies based on shorter datasets. The trends in the Lyapunov exponents and in the zonal mean winds are new, which reveal interesting features such as increased mixing in summertime southern surf zone in the lower stratosphere. Although the paper does not contain substantive results on the solar cycle and ENSO signals, the overall treatment is thorough and the paper is publishable with minor revisions. I do have a few comments/questions concerning the analysis techniques.

(1) In Section 5.6 averaging along equivalent latitude is introduced and it is shown to improve the definition of the Arctic vortex. (The same point is emphasized again in Section 6.) If equivalent latitude improves the analysis, why not use it from the beginning? Perhaps more to the point, the paper does not quantify the improvement brought about by the equivalent latitude (other than showing the differences from the zonal-mean analysis). An important point is that after one month of advection, the particle pair can drift significantly from the original latitude. Thus, the 30-day Lyapunov exponent does not necessarily represent the stretching rate at the fixed latitude. Associating it to the original latitude and taking the zonal averaging will introduce errors. This problem will be (in principle) alleviated by using equivalent latitude, because the particle pair should stay close to the original PV level (equivalent latitude) as long as the particles and PV are advected by the same wind. Thus, the question is whether the meridional dispersion of particles from the original latitude after 30 days is indeed smaller if equivalent latitude is used. The modest difference between Figs.8a and 11 suggests this may not be the case in most of the domain due, for example, to the nonadvective sources/sinks of PV. On a related matter, does the lack of strong mixing in the summer NH subtropics on 450 K (Section 5.2) and of ENSO signal (Section 5.5) change when equivalent latitude is used?

(2) The authors use five predictors with specified basis functions in their regression, and in this framework, their analyses are thorough. I wonder if they also considered EOF analysis. Given that the observation is incorporated for the QBO and ENSO, and that the annular mode (not included) has no preferred frequency, there may be a merit to letting the data determine their own basis functions. I am not suggesting that the authors should use EOFs, but given the available choices, some rationale for the current regression method would be nice.

Other points:

p.6193 LL9-10: Would backward trajectory calculation give similar results (mixing should represent the history of particle trajectory of recent past)?

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p.6194 LL9-10: “Only diffusion and not advection is accounted for” This is confusing because the method is purely advective. Please rewrite as “Only differential and not mean advection is accounted for”

p.6194 LL18-20: The disagreements occur not necessarily when the scales are small, but when the residence time of the particle pair in the region of interest is shorter than the time used to compute the exponent (in this case 30 days).

p.6195 L6: There should be some rationale for $\Delta x(0) = 1$ km. From Fig.3, it appears that a reasonable upper bound for the Lyapunov exponents is ~ 0.2 (1/day). This will give a separation of ~ 400 km at the end of the 30-day period. This final separation must be smaller than the size of the region of interest. For example, this is sufficiently smaller than the radius of the polar vortex.

Interactive comment on Atmos. Chem. Phys. Discuss., 7, 6189, 2007.

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