

Interactive comment on “Variability of the Lagrangian turbulent diffusivity in the lower stratosphere” by B. Legras et al.

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General:

The paper gives a very detailed and versatile analysis of stratospheric diffusivity based on experimental data and theoretical investigations. The paper is well-written, extensive figures support well the text, even if some parts of the text require a more detailed explanations (see minor comments). The main results described in the abstract are important for the scientific community, the paper is worth to be published after 2 major comments and a list of minor comments have been addressed by the authors:

Major comments:

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1. The main criticism points to the quality of the vertical velocities in the meteor. fields (here ECMWF) and on the use of the hybrid/pressure coordinates for the calculation of the backward trajectories. The stratospheric vertical velocities, in particular in isentropic coordinates, are of the order 100 smaller than the horizontal velocities and if derived from the divergence equation (mass conservations) are dominated by numerical noise mainly caused by small, inevitable errors in the horizontal winds. The quality of the vertical velocities derived from the mass conservation may be more reliably in the troposphere where these velocities are larger, in particular in regions of strong convection, and where this approach was successfully discussed in many papers, e.g. Stohl et al and Wernli et al. On the other side, in the stratospheric community, the radiation approach is widely used (Schoeberl et al., SLIMCAT, CLaMS, Rex et al.) ensuring a stable and more reliable behavior of transport in particular within the vortex.

Furthermore, the use of the isentropic coordinates instead of the pressure/sigma coordinates minimize the numerical diffusion associated with the interpolations because the motion of the air parcels in the lower stratosphere is mostly isentropic (see e.g. Mahowald et al., JGR, 2002). In other words, within the stratosphere, the main task of the integration in pressure coordinates is to "keep the air parcels" on levels with constant potential temperature, that of course has its "numerical price".

Thus, probably, a significant part of the "numerical variability" of the backward trajectories considered in the paper is due to those both effects, and that these "systematic errors" significantly affect the presented estimation of the turbulent diffusion. Although the authors are aware of the first problem, the second one is not discussed in the paper. With respect to the reliability of the vertical velocities, it would be instructive to compare the diabatic displacement of the backward trajectories for the considered ER-2 flights with the results obtained from the radiation scheme for different values of τ measuring the length of backward trajectories.

2. Another important question of the presented approach is the concept of the average vertical Lagrangian turbulent diffusion. The authors are aware of the fact that strato-

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spheric mixing occurs inhomogeneously in time and space however they do not couple in Eq (1) the stochastic mixing term with the flow properties describing dispersion as (shear, strain, Lyapunov exponent) or instabilities as bulk Richardson number. Here, I would suggest to clarify the motivation for this approach (simplicity ?).

Specific comments:

(-) page 1, right col, second para.

It is instructive to mention that in the theoretical fluid-dynamics community (Haynes and Vanneste, JAS, 2004), flow regime where the small-scales are dominated by the large-scale velocity fields is called the "Batchelor regime".

(-) page 1, right col, 4-th para.

Why does it seem reasonable to use a "mean diffusivity" D to estimate the turbulent diffusion that is patchy in space and time (see major comment) ?

(-) page 2, right col, last para.

In principle, $\eta(t)$ can be controlled by some dispersion or diffusion parameters of the flow. Here some remarks are necessary why the authors did not implement it and what is the motivation for a constant stochastic mixing intensity.

(-) page 3, left col eqs (3) to (5).

Even if it seems to be intuitively true that the stochastic approach based on eq (1) is related to eq (5), some references or some explanations or a weaker formulation than "the statistical average of mixing ratio over random backward trajectories is equivalent to solving eq (5)" are necessary, This is an example of a difficult theoretical problem connecting "microscopic approach" (statistical average over trajectories) with the "macroscopic equation" like the diffusion equation (3).

(-) page 3, left col

replace Rex 2202 by Rex 2002

(-) page 4, right col, second para.

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Here some critical remarks on the transformation of the "tropospheric approach" like FLEXPART to the stratosphere (isentropic transport, vertical velocities) would be desirable.

(-) page 4, left col, second para.

why are the fluctuations proportional to $\sqrt{(D/N)}$?, units, more explanation ?

(-) page 4, right col, second para.

Why is the size of tracer jumps bounded by $\sqrt{(\gamma/D)}$? I also do not understand the subsequent explanation that the reconstruction is only sensitive to the largest scales of the initial tracer distribution?

(-) page 4, right col, last para.

the deviation between the ER-2 O3 observation and REPROBUS simulation in Fig 4a is really large. Are the authors sure that the chemically active ozone and NOT passive ozone transported in REPROBUS is shown?

(-) page 5. Fig 3.

For a better comparison, it would be favorable if in all panels (b) to (i), the ER-2 observation would be overlaid, e.g. as a gray background line.

(-) page 6, right col, Fig 5.

what are the black paraboles in Fig 5 (around time=0.4) Caption: replace "osculating" by "oscillating"

(-) page 6, right col, first para.

not appropriate formulation: "The REPROBUS model provides a good large-scale fit". Please use e.g.: The large-scale properties of the observed N2O are reproduced fairly well by the REPROBUS model.

(-) page 6, right col, last para.

the meaning of the offset σ in the definition of the roughness is not sufficiently explained.

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(-) page 7, right col, last para in section 7

Why do the authors expect that the persistence of sharp variations in the averaged Lagrangian diffusivity indicates the presence of a transport barrier.?

According to the Nakamura concept and studies of Haynes and Shuckburgh, JGR, 2000, the transport barrier manifests by a weak, persistent effective diffusivity across the barrier with smallest values within the barrier.

(-) page 8, Fig. 6

Plots of the roughness g), h), o), p) What is the definition and meaning of σ shift in these plots? Something seems to be wrong with the notation: best agreement within the vortex between red and blue curve implicates $D=0.1$ m²/s whereas outside the vortex the agreement between the red and the green curve is the best one, i.e. $D=0.01$ m²/s. Thus, mixing outside is smaller than inside that is a contradiction to the abstract.

(-) page 8, first sentence in section 8.1

please remove "that"

(-) page 8, left col last para.

It is not clear how the ellipsoid was fitted to the cloud of N particles. I do not expect that the position of particles after 20 days (!) can be approximated by an ellipsoid. What does it mean 5 and 95 % distribution. This part of text is difficult to understand

(-) page 10, right col, first sentence

wrong spelling for "backwards"

(-) page 11, begin of section 9

"3-hourly winds obtained by interleaving first guesses with ECMWF analysis"- here a more detailed explanation of this procedure is necessary.

(-) page 13, right col, 4-th para.

you mean probably significant biases or signatures of high-frequency fluctuations (and not aliases)

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(-) page 13, right col, 4-th para.

It is still unclear, why 3-hours temporal resolution of the winds is better than 6 or 24 hours. What is the physical explanation for it? What is the difference between the spurious mixing in the analyzed winds and the mixing induced by “white noise” in eq (1).?

Interactive comment on Atmos. Chem. Phys. Discuss., 4, 8285, 2004.

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