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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Transport mechanisms for synoptic, seasonal and interannual SF_6 variations in troposphere" *by* P. K. Patra et al.

Anonymous Referee #2

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General Comments

This article examines the evolution of SF6 in the atmosphere. Since SF6 is inert and has emissions that do not vary seasonally, comparison with observations at sites around the world provides a means to test the simulation of transport by chemical transport models. The authors used several existing techniques to compare their simulations with 6 monitoring site observations. The absolute value and multi-annual trend at the six sites is simulated to within the error of the measurements. The simulation of the seasonal cycle and daily averages is not so good at some of the sites and in general the variability is under-represented by the model. The interhemispheric exchange rate defined using a simple two-box model was estimated from the SF6 data and simulated SF6 distribution and is shown to be consistent with previous estimates in the literature.

A tracer simulation was used to estimate the mean age of air as a function of latitude and altitude. Finally the local tendencies in SF6 mixing ratio are partitioned by process into advection, convection and sub-grid scale turbulence.

The model, diagnostic techniques used and results obtained were not particularly original. Thus in the main this article serves as a model validation exercise for the ACTM used. However, it is clear that the model has a high integrity and appears to produce reasonable simulations of long-lived tracers, although somewhat hindered by the low resolution used. Therefore, the paper would be of use in future applications of the model or in model intercomparison exercises. The most interesting aspect for me was Figure 4 showing the mean age estimated for the troposphere and lowermost stratosphere. Age is a useful concept and means to compare models, although obviously cannot be observed directly. It would have been useful to show the sensitivity of the simulated age distribution to changes in the model (i.e., an estimate of model error).

I recommend that the paper is accepted subject to minor revisions mainly concerning the discussion of results and quality of the figures.

Specific Comments

1. Sec 2.1, l.8: This paragraph is contradictory. It is stated that the advantage of the ACTM is that it can be run at higher resolution than the re-analysis but then it is run at much lower resolution.
2. Sec 2.4, l.15: You mean “parameterized transport” rather than “parameterized diffusion” since the term includes the effects of the convection parameterisation.
3. Sec 3.1, l.13: You mention “nudged ACTM”. How is it nudged? You should mention this earlier.
4. Sec 3.2 and Fig.4: You refer to an “upper tropospheric mixing barrier” but from the figures you are referring to the tropopause which slopes from near 100 hPa

ACPD

8, S7281–S7284, 2008

in the tropics down to about 300 hPa near the poles. The age gradients coincide with the tropopause and therefore pontential vorticity gradients. This explains why the subtropical jets are necessarily on the equatorward side of the sloping tropopause (note l.3 should read “poleward” rather than “equatorward”). The high values of age (> 90 days) are clearly in the stratosphere. In general, the discussion of this figure is rather loose. For example, it is stated that the mixing barrier lies further north during the Asian summer monsoon because of convection near the Tibetan Plateau. The crucial thing is that the Asian monsoon is associated with a large-scale anticyclone at upper levels, which is in part caused by convection mixing air throughout the tropospheric column. The anticyclone extends further north than the convection itself. The authors discuss oscillation over the Pacific tracking with the solar insolation. This is conjecture and partly wrong because the ITCZ over the East Pacific tends to stay in the Northern Hemisphere throughout the year (a topic of much research).

5. p.12750, l.10: “IH gradients” should be replaced by “IH contrasts” since a gradient refers to a change over a specific distance.

6. Sec 3.3: I was confused by the “pronounced seasonal cycles” in the interhemispheric exchange time diagnostic. Since tau-ex is greater than a year, exchange clearly takes much longer than one month or season on average and even longer than a complete seasonal cycle. How do you interpret the diagnostic? It seems that the 2-box system given by eqns (1) and (2) is inadequate for this purpose.

7. Sec 3.4: I was not convinced by the usefulness of Figure 6 showing the zonal and monthly average of SF6 tendencies. In particular, its relation to zonal and monthly average winds is problematic. As is well known, the meridional mean circulation obtained by averaging at fixed points in pressure coordinates does not reflect the paths that air mass trajectories take in the meridional plane (even on average). In other words the Eulerian mean circulation is very different from the Lagrangian

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8, S7281–S7284, 2008

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mean. For example, the Eulerian mean motion shows a Ferrel cell poleward of the Hadley cell with a circulation in the opposite sense. The Lagrangian mean circulation does not show a Ferrel cell and the direct (Hadley) cells extend all the way to the poles. The reasons for this are discussed at length in the literature (e.g., see Middle Atmosphere Dynamics, Andrews, Holton and Leovy, 1987).

Also, the different components of the tendency in Figure 6 clearly oppose one another such that their sum is close to zero. This simply reflects the fact that the SF6 tendencies averaged over a month are much smaller than their instantaneous values because the SF6 distribution does not have a strong systematic change across the month. It does not really quantify the effects that advection, convection and diffusion have in maintaining the SF6 distribution or its slow trend seen in Fig.2. Proper account of the effects of each process would involve accumulating tendencies following air mass trajectories, rather than at fixed points.

In contrast, Figure 7 showing the partition of tendencies at single sites is of value because it is not made obscure by zonal averaging. You could show the annual average tendencies to emphasise the systematic properties of each process.

8. On a related point, the model simulates the SF6 distribution well but this does not imply that the relative influence of advection and convection is an accurate reflection of the real world. Much more work would be required to show this.

Technical Corrections

1. Figures 2 and 3 are too grainy presumably because they are low resolution images. Their quality needs to be improved.

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 12737, 2008.