Atmos. Chem. Phys. Discuss., 8, S7516–S7521, 2008
www.atmos-chem-phys-discuss.net/8/S7516/2008/

Atmospheric Chemistry and Physics Discussions

ACPD

8, S7516–S7521, 2008

Interactive Comment

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

P. K. Patra et al.

Received and published: 26 September 2008

We thank the reviewer for providing us insightful comments, which have provoked us to carry out further analysis and improve clarity in our discussions. Below we have provided replies to the comments.

Reply to General comments

We checked the sensitivity of the ACTM simulated age of air by nudging to NCEP2 and ERA40 meteorology, and also with no cumulus convection. The results shows small impact (mostly within 5%, and a maximum of 20% near the convective regions) of the selection of meteorology products, but large differences in age simulations with and without the cumulus convection. These results will be discussed in the revised ACP version (see also our Reply to Comment 4 below).

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

Replies to the Specific Comments:

Reply 1:

We do not believe this paragraph is completely contradictory as we use the 32 layer ACTM, using NCEP2 reanalysis at 17 standard pressure layers. In other studies, we have run the model at 67 vertical layers if the chemical species has stratospheric loss. It may be pointed out here that the CTMs do not generally deal with the stratospheric dynamics and chemistry explicitly. Thus we plan to add the following sentence and reference at the end of Para 2 (p.12741):

The ACTM vertical resolution (67 layers) and model-top ($\sim$90km altitude) can also be increased, while the meteorology is nudged between 1000-10 mb (NCEP/DOE reanalysis) only, for simulating the chemical constituents with stratospheric photo-chemical loss (Patra et al., 2008b).

Patra, P. K., Takigawa, M., Ishijima, K., Choi, B.-C., Cunnold, D., Dlugokencky, E. J., Fraser, P., Gomez-Pelaez, A. J., Goo, T.-Y., Kim, J.-S., Krummel, P., Langenfelds, R., Meinhardt, F., Mukai, H., O'Doherty, S., Prinn, R. G., Simmonds, P., Steele, P., Tohjima, Y., Tsuboi, K., Uhse, K., Weiss, R., Worthy, D., Nakazawa, T.: Growth rate, seasonal, synoptic and diurnal variations in lower atmospheric methane, J. Metorol. Soc. Jpn., submitted, 2008.

Reply 2:

This part will be changed to "parameterized convection and diffusion".

Reply 3:

Beginning part of the first para of Sec 2.1 will be modified as:

The CCSR/NIES/FRCGC AGCM is nudged with analyzed/reanalyzed meteorology

ACPD

8, S7516–S7521, 2008

Interactive Comment

using a simple Newtonian relaxation method (Hoke and Anthes, 1976) for driving the chemical tracer transport. In this process the ACGM simulated meteorology is forced towards the analyzed horizontal winds (U and V components) and temperature (T) with relaxation times of 1 and 2 days, respectively, at every 6-hourly timesteps of the analyzed products (except the top and bottom model layers). For the ACTM simulations presented in this study, we use reanalysis products (U, V, T) from National Center for Environmental Prediction(NCEP)/DOE AMIP-II Reanalysis (Kanamitsu et al., 2002) and European Centre for Medium-Range Weather Forecasts (ERA40, Uppala et al., 2005). The AGCM is also supplied with interannually varying monthly-mean sea ice and sea-surface temperature (SST), from the Met Office Hadley Centre observational datasets (Rayner et al., 2003), for estimating heat and moisture exchange fluxes at the earth's surface.

Hoke, J. E ., and Anthes, R. A.: The initialization of numerical models by a dynamic initialization technique. Mon. Wea. Rev., 104, 1551-1556, 1976.

Uppala, S.M., et al.: The ERA-40 re-analysis. Quart. J. R. Meteorol. Soc., 131, 2961-3012, doi:10.1256/qj.04.176, 2005.

Rayner, N. A., Parker, D. E., Horton, E. B., Folland, C. K., Alexander, L. V., Rowell, D. P., Kent, E. C., Kaplan, A.: Global analyses of sea surface temperature, sea ice, and night marine air temperature since the late nineteenth century. J. Geophys. Res., 108(D14), doi:10.1029/2002JD002670, 2003.

Reply: 4

It is actually the "equatorward" edges of the subtropical jet stream to which we meant to refer – thanks for catching that. The latitude and height for this location are about 30-35^o latitude and $\sim$500-150 mb height range. This will be clarified by modifying this sentence as:

The upper tropospheric locations of the steepest meridional age gradients are coincident with the rapid change in zonal winds (black contours) corresponding to the equatorward edges of the subtropical jet steams (Fig. 4; approximately 30^o latitude in

ACPD

8, S7516–S7521, 2008

Interactive Comment

both Hemispheres and in the range of ∼500-150 mb height).
Also, the overplots of vertical and horizontal winds on latitude-longitude distributions of age of air at 200 mb show excellent correspondence between the younger age of air and upward motion at all locations (we plan to include age and vertical velocity plot and associated discussion in the revised ACP version). But the locations of anticyclonic motion do not always correspond to the youngest age of air at 200 mb height (not shown).
Our simulations without convection confirm that the sharp age of air gradients at around 30^o latitudes and low value in the tropical upper troposphere are caused by the cumulus convection as parameterized in the ACTM.
We were a bit unclear in the discussion of the ITCZ and its seasonality. While the eastern Pacific ITCZ remains in the Northern Hemisphere throughout the year, its intensity changes greatly with seasons. This can be seen by plotting OLR. The ITCZ is weaker during the boreal winter to spring seasons (owing to cooler SST) and stronger in the boreal summer and autumn (warmer SST). The link between insolation and ITCZ intensity should be thought only as the leading order effect, but it's certainly not how the whole system works, i.e., SST, interactions with land masses may also have large impacts.

Reply: 5
This change will be made in the revised version.

Reply: 6
We understand the source of confusion. We interpret the seasonality as indicating that the IHT is slower in the equinoctal seasons. Put another way, the circulation that exists during these seasons is less conducive to interhemispheric exchange. We note that, at least in models, we can look at more direct measures of IHT, e.g., integrated over all longitudes and vertical levels along the equator. This supports the seasonality

ACPD
8, S7516–S7521, 2008

Interactive Comment

as seen in the exchange time.
We would argue as well that the seasonality represents a useful diagnostic for model intercomparison–it provides an additional piece of information with which to analyze transport models: e.g., if a model exhibits an exchange time that's too large, is this reflected across the year or only in certain seasons? This could give some clue as to what mechanisms or processes may be responsible for the behavior.

Reply: 7
One aim in showing Figure 6 is to understand why the we obtain the seasonality in IHT time as depicted in Figure 5. This seasonality has been shown before, but has not been (fully) understood its origin, in our opinion. We would like to keep this figure as it is (or after adding a bottom panel showing the annual mean transport of SF_6 due to all transport components and SF_6 transport routes).
Also note that these average plots show direction of particular transport effect at site level on an average basis, e.g., at SMO convection and diffusion tend to increase SF_6 mixing ratio while the advection works in opposite phase.
Using the transformed Eulerian mean residual circulation (Andrews and McIntyre, 1978), which approximately represents the Lagrangian circulation, we have confirmed that Stokes drift is very small in the tropical troposphere (different from the extratropical troposphere and stratosphere), and thus the Eulerian mean circulation is a good approximation to the Lagrangian transport by the tropical mean Hadley circulation.
In the extratropics, as the reviewer has indicated, the Ferrel circulation represented by the Eulerian circulation does not represent the Lagrangian transport realistically. We will add the following sentence to underscore this point:
Note that the Eulerian mean circulation does not provide an accurate Lagrangian circulation in the extratropics due to the presence of Stokes drift caused by Rossby waves (Matsuno, 1980).
Matsuno, T.: Lagrangian motion of air parcels in the presence of planetary waves. Pure Appl. Geophys., 118, 189-216, 1980.

ACPD
8, S7516–S7521, 2008

Interactive Comment

ACPD

8, S7516–S7521, 2008

Interactive Comment

Reply: 8

The reviewer is correct about not drawing the inference that an accurately simulated SF6 distribution alone implies that the relative influences of advection and convection is accurate.

We we have checked fundamental model properties by comparing other meteorological parameters, such as outgoing long-wave radiation (OLR). The location and intensity of convective cells, ITCZ, SPCZ, solar insolation etc. are fairly comparable for the nudged ACTM output and NOAA uninterpolated OLR at daily or monthly averages (plots available).

We also have performed additional sensitivity studies to check the performance of nudged-ACTM vs. free running ACTM and for various species. The nudged-ACTM looks more realistic (see for example, www.jamstec.go.jp/frcgc/research/d4/prabir/papers/poster_jpgu07.pdf).

We do not have further relevant observables to identify and validate the relative partitioning of advection and convection.

We agree that more research is need in this direction, and the discussion of advection, convection and diffusion components as simulated by the models at site level is a step in that direction. The dynamical component separation for multiple species with different lifetime and emission characteristics (^{222}Radon, CO_2, SF_6) may provide useful information.

Reply: Tech.

This appears to be a word processing problem at EGU during ACPD publication (because all the Figures are provided in EPS format); we will confirm better quality in the ACP publication phase.

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