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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Transport of aerosol pollution in the UTLS during Asian summer monsoon as simulated by ECHAM5-HAMMOZ model" *by* S. Fadnavis et al.

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Replies to Reviewer-II

In this paper, the authors study the transport of aerosols from surface to the UTLS during the Asian Summer Monsoon. This study is based on the analysis of ECHAM5-HAMMOZ simulations for the year 2003. The work presented in the paper is of interest. The main concern on this paper is the lack of focus of the result analysis linked to a lack of focus of the paper objectives. Several other major comments also need to be addressed before acceptance for publication.

Reply: Authors' thank anonymous reviewer II for insightful comments on the

manuscript. The reviewer's useful comments have helped to improve the quality of the manuscript. The detailed responses to reviewer's comments are outlined below. In order to increase clarity and focus of the paper we have changed the abstract and the text to highlight the new results in our paper. The paper is now re-organized under a suitable title manuscript (the revised manuscript is attached as a supplement). The main objective of the paper is to study "transport of aerosols into the UTLS region due to ASM convection and impact of aerosols over the Asian monsoon region".

Major comments

The objectives of this paper are not fully clear and the analysis of the model simulations does not fully fit with the paper title since the impact of aerosols in the UTLS on the microphysics and dynamics is also studied. The results are commented with regards to previous studies (which is interesting) but the way the paper is presented does not sufficiently highlight the important and/or new results.

Reply: We have modified the abstract and the text to highlight the new results in this paper. There are two major results: 1) the formation of a convective transport conduit over the southern flanks of the Himalayas around 100OE and 2) the formation of an aerosol arch feature spanning from the northern hemisphere subtropics to the southern hemisphere subtropics. This arch feature is not a trivial result and other models have difficulty reproducing the observed transport pattern (see Figure 13 in Park et al. (2013), HCN is a proxy for aerosol transport since it has localized ASM sources in JJA). The identification of the southern slope of the Himalayas as a major convective transport conduit that injects water vapour and aerosols into the TTL and lower stratosphere is sufficiently novel as previous modeling studies were primarily based on CTMs, which are not fully coupled or GCMs with prescribed aerosol fields (Lau et al., 2006). There is some debate about the source region for aerosol and trace gas injection into the tropical tropopause region and our results contribute by identifying the aerosol feedback on convection as significant factor. Our results agree with the observational study of Fu et al. (2006) but at the same time they do not contradict the CTM study of Park et al.

(2009). This point is now discussed in the text.

The new title of our paper is: Transport of aerosols into the UTLS and their impact on the Asian monsoon region as seen in a global model simulation.

Section 3.1 page 30091/92 : discussion of figure 5 : The comparison with observations is important to evaluate the quality of the simulation. There are large differences between the model and the observations in the 16-18km layer around the equator, with large values in the observations. What could explain these differences ? The signature in the observations is likely related to transport by deep convetion in the 20S-20N latitude band. The model signature show maxima in the subtropics likely linked to other processes.

Reply: Since aerosol extinctions are wavelength dependent and wavelengths of HALOE (5.26μm), SAGE II (0.525 μm) and Model (0.550μm) are different. Hence it is difficult to evaluate model simulations and satellite observations quantitatively. Since wavelength of SAGE II (0.525 μm) and Model (0.550μm) are relatively closer to each other, signature of Northern hemispheric subtropical maximum is seen is SAGE II and model simulations.

Both the model and the observations show an aerosol arch feature between 18 and 24 km in the tropics extending from 20°N to 30°S over the equator. This was the focus of this plot and is clearly not a purely convective transport feature. The mean height of tropical convection between 60°E and 120°E and 20°S to 20°N is not 18 km and is, in fact, below 15 km (Folkins and Martin, 2005). Overshooting convection that penetrates above 15 km is quite rare and is typically around 5% of the total deep convective activity (Alcala and Dessler, 2002).

In addition, there is large scale upward transport in the region from 15°N to 35°N above the zero heating surface at about 15 km, which is distinct from convection. The model results are consistent with SAGE II observations as the major source of aerosols is the region deep convective transport around 20-30°N. There is a clear aerosol minimum

between 20°S and 20°N in the 17 to 20 km layer.

Figure 5 (figure 6 in the revised manuscript) is also comparing an ensemble average to real world observations. Our simulations are free runs not constrained to the observed dynamical state of the atmosphere and averaging of ensemble members blurs out any fine structure in the individual realizations. Convective transport extending to 18 km near the equator seen in the observations in all likelihood reflects a sampling bias and is not likely to be climatological (Alcala and Dessler, 2002). Also, the model could be underestimating overshooting convection near the equator due to the coarse resolution but that does not affect the formation of the aerosol arch feature.

We have revised the text in the manuscript to add a discussion of these points including the one raised by the reviewer pertaining to Rossby waves:

Alcala, C. M., and Dessler, A. E.: Observations of deep convection in the tropics using the TRMM precipitation radar, J. Geophys. Res., 107(D24), 4792, doi:10.1029/2002JD002457, 2002.

Folkins, I., and Martin, R. V.: The vertical structure of tropical convection and its impact on the budgets of water vapor and ozone. J. Atmos. Sci., 62, 1560–1573, doi: 10.1175/JAS3407.1, 2005.

Section 3.1 page 30090, line 27-29. Rossby wave breaking in the lower tropical tropopause is given as the most important source of transport in the study. One would expect that during the monsoon season, deep convection would be the main driver. This is also what the observations indicate (see Fig 5). A stronger argumentation on the relative role of deep convection and Rossby wave breaking is required.

Reply: The aerosol arch feature above 18 km cannot be explained by convection alone and observations do not support it being formed directly via convective transport. There is a clear gap separating the aerosol below the tropical tropopause and that above it between 40°S and 15-20°N in both HALOE and SAGE II observations. As noted in the reply to the previous comment, there is a sampling bias that exaggerates the aerosol seen in the lower TTL compared to the model. James et al. (2008) investigated the processes involved in the formation of the water vapour maximum at 100 hPa above the ASM and find that large scale advective transport (related to Rossby wave breaking and other processes) is responsible for this feature. Gettelman et al. (2004) also demonstrate that an H2O bulge forms between 20°N and 40°N extending above 100 hPa via large scale circulation transport in a CTM. Aerosols would be transported above 100 hPa between 20°N and 40°N in the same manner. The main difference is that aerosols such as BC, OC and dust would not experience freeze-out when traversing the so-called cold trap around the equator.

Gettelman, A., D. E. Kinnison, T. J. Dunkerton and G. P. Brasseur: The Impact of Monsoon Circulations on the Upper Troposphere and Lower Stratosphere, J. Geophys. Res., Vol. 109, No. D22, D22101, doi:10.1029/2004JD004878, 2004.

James, R., M. Bonazzola, B. Legras, K. Surbled, S. Fueglistaler: Water vapor transport and dehydration above the convective outflow during Asian monsoon, Geophys. Res. Lett., 35, L20810, doi:10.1029/2008GL035441, 2008.

Other comments

Section 2.1 page 30087: The argumentation on the choice of the year 2003 is weak. On one hand, this is argued that intrusions of subtropical and extratropical air are expected. On the other hand, the authors say that Â′n monsoon circulation effects are well marked during the year 2003 ÂËŹz. This is somehow contradictory. The objective behind to study the impact of the monsoon on the aerosols in the UTLS and induced effects, a year with little subtropical and extratropical intrusion would seem more adequate.

Reply: Since the above sentence was creating confusion we have rewritten it as: ECHAM5-HAMMOZ simulations were performed for a typical boreal summer season. Synoptic-scale Rossby wave breaking is not an intermittent feature of transport in the

tropics and is in fact a characteristic aspect of the dynamics in the UTLS. Our results are based on ensemble runs so that they should not be an accidental result of convective intermittency.

The simulation mainly used is a 8-member ensemble. Nowhere it is explained the setup of the 8 simulations used in the ensemble and the method used to calculate the ensemble. The interest of using a 8-member ensemble in this study should be argued.

Reply: In order to converge model output obtained from free runs, we carried out eight member ensemble. The set-up of the ensemble is now discussed in more detail in the revised manuscript. Various other studies, for example Ramnathan et al. (2005), Meehl et al. (2008), also reported results from five and six member runs respectively.

Ramanathan, V., Chung, C., Kim, D., Bettge, T., Buja, L., Kiehl, J. T., Washington, W. M., Fu, Q., Sikka, D. R., and Wild M.: Atmospheric Brown Clouds: Impacts on South Asian Climate and Hydrological Cycle. PNAS, 102, 15, 5326-5333, doi :10.1073/pnas.0500656102, 2005.

Meehl, G.A., Arblaster,J.M., and Collins, W.D., Effects of Black Carbon Aerosols on the Indian Monsoon. J. Clim, 21, 2869-2882, DOI: 10.1175/2007JCLI1777.1

Since the monsoon is an important driver of the aerosol vertical transport and the effect of aerosols on ice is discussed in the paper, information on the convection and the large scale cloud/precipitation parameterizations used in the model would be useful.

Reply: As suggested brief information on convective and precipitation parameterizations is now incorporated in the revised manuscript. For the CTRL case there are additional references included and for the NOAER case we have added the following text:

Precipitation formation in warm clouds, cold clouds and mixed phase clouds is discussed in details in the report 349 " The atmospheric general circulation model ECHAM 5, part-I" in section 10.3.4.

http://www.mpimet.mpg.de/fileadmin/publikationen/Reports/max_scirep_349.pdf

Section 2.1 Page 30087: The simulation uses 31 vertical levels up to 10hPa. No information is given on the vertical spacing of the vertical levels. As shown previously in several studies, this is particularly important to have a relatively fine resolution in the UTLS (ïĄ¿1km) since this is a layer with large gradients (including large gradients of aerosol concentrations).

Reply: The vertical resolution of the model is 50 m near surface and 1 km near tropopause. This is now mentioned in the revised manuscript.

Secondary organic aerosols are not considered in this study. What is their expected influence on the results ?

Reply: Secondary organics are not explicitly included. A certain amount of SOA is included (AEROCOM, Dentener, 2006) directly as particulate organic matter (OC) in the emissions. Influence of secondary organic aerosols cannot be quantified from our model simulation.

Dentener, F.,. Kinne, S., Bond, T., Boucher, O., Cofala, J., Generoso, S., Ginoux, P., Gong,S., Hoelzemann, J. J., Ito, A., Marelli, L., Penner, J. E.,. Putaud, J.-P, Textor, C., Schulz, M., van der Werf, G. R., and Wilson, J.: Emissions of primary aerosol and precursor gases in the years 2000 and 1750 prescribed data-sets for AeroCom, Atmos. Chem. Phys., 6, 4321–4344, 2006.

Please also note the supplement to this comment:
http://www.atmos-chem-phys-discuss.net/12/C13603/2013/acpd-12-C13603-2013-supplement.pdf

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Interactive comment on Atmos. Chem. Phys. Discuss., 12, 30081, 2012.