Assessment of ACTM global model performance using CONTRAIL aircraft observations of greenhouse gases

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Concentrations of greenhouse gases in the upper troposphere are influenced by surface fluxes, vertical mixing in the troposphere, stratosphere-troposphere exchange (STE) and their chemical losses. This study presents an analysis of the measurements of Carbon dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O) and Sulfur hexafluoride (SF_6) from CONTRAIL aircraft observations over western pacific and northern Eurasia regions in the upper troposphere for the period during 2012-2014 compared with the simulations by JAMSTEC's atmospheric chemistry-transport model (ACTM). Air sample collections onboard the Japan Airlines (JAL) aircrafts have been carried out using the Automatic air Sampling Equipment (ASE) (Machida et al., 2008; Matsueda et al., 2008) and the Manual air Sampling Equipment (MSE). In this study we used observed results from the flights between Narita (NRT), Japan to Sydney (SYD) and between Paris (France) and Haneda (Japan), and only from February and May in 2013 between Moscow (Russia) and Narita (Japan). We used the ACTM for forward simulations is run with horizontal resolution of T42 (~2.8 x 2.8^o), 67 sigma-pressure vertical levels for CO_2, CH_4, N_2O and SF_6 (Patra et al., 2011; Patra et al, 2016, Ishijima et al., 2010; Patra et al., 2009).

Figures 1 shows the latitudinal annual averages calculated at latitude of 6^o bin for the period 2012-2014. It is clear that the higher values of concentrations of these gases were observed in the northern hemisphere as compared to the southern hemisphere, which are well reproduced by the global model simulations. But there are some model-observation mismatches observed in the extra tropics in both hemispheres. These are likely to be due to the stratosphere–troposphere exchange or north-south emission balance of these gases in the model. Lower concentrations are observed for all species around 30^{o}N, which the model overestimates slightly due to uncertainties in transport around the tropopause modelled by ACTM.

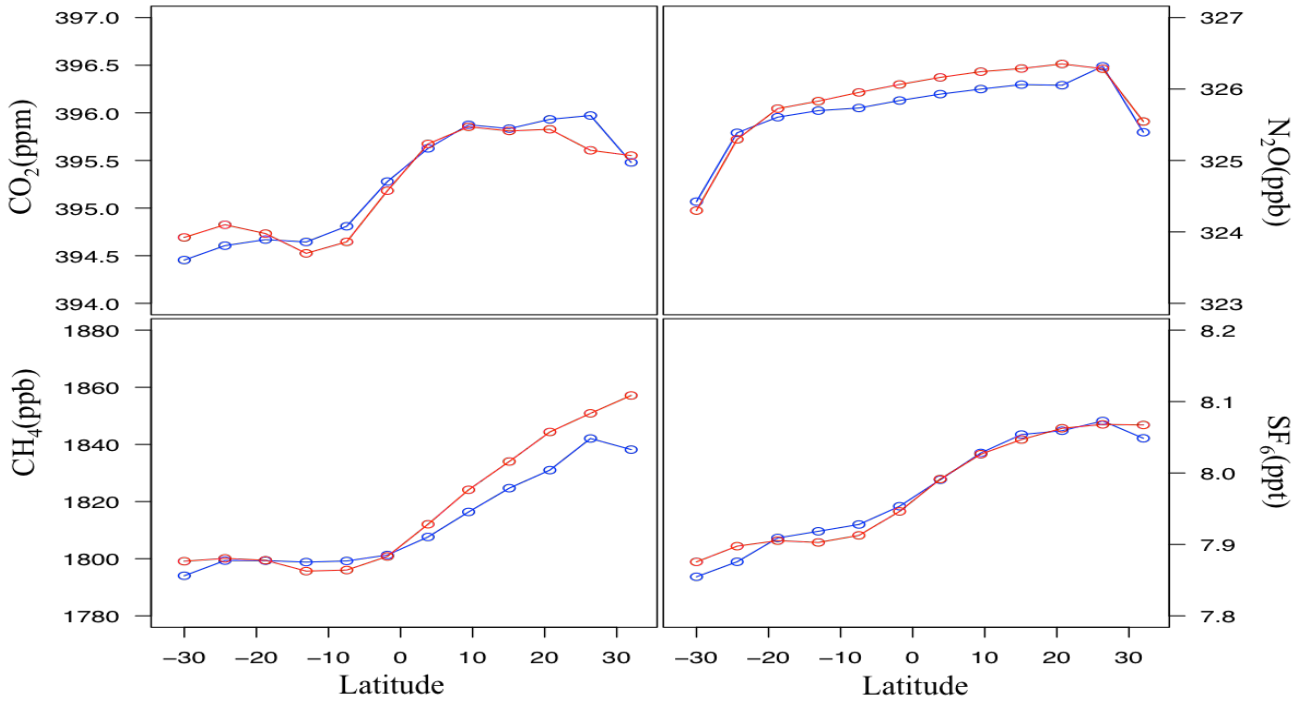

Figure 1: Latitudinal distributions of annual average of the concentrations of greenhouse gases over CONTRAIL aircraft observations along with the model comparisons for the period 2012-2014. Blue lines shows observations and red represents ACTM model

The north-south gradient (mean of values north of 20^{o}N – mean of values south of 20^{o}S) of CO_2 is 1.3ppm in observations and ~1pm in model, for CH_4 that is 30 and 45 ppb, respectively, for observations and model, gradient for N_2O are 0.6ppb and

1ppb, respectively, and SF_6, gradients are 0.17ppt for both the model and observation. In order to understand the relationship between model and observations correlation coefficients are calculated at each latitude bin having the higher correlations for CO_2 and SF_6 with nearly ~0.9, and for N_2O it is nearly ~0.8 where as in the case of CH_4 correlation at each latitude band is variable with minimum correlations among all the species with nearly ~0.6. The analysis of greenhouse gases over northern mid-latitudes observed the higher mixing ratios along with the higher variabilities in all the species. The model reproduces the observed variations relatively well, especially for the timing of the high and lower values of the mixing ratios but sometimes with weaker amplitudes

References

Ishijima, K., P. K. Patra, M. Takigawa, T. Machida, H. Matsueda, Y. Sawa, P. Steele, P. Krummel, R. Langenfelds, S. Aoki and T. Nakazawa, The stratospheric influence on seasonal cycle of nitrous oxide in the troposphere as deduced from aircraft observation and model, J. Geophys. Res., 115, D20308, 2010.

Machida, T., H. Matsueda, Y. Sawa, Y. Nakagawa, K. Hirotani, N. Kondo, K. Goto, T. Nakazawa, K. Ishikawa, and T. Ogawa (2008), World wide measurements of atmospheric CO_2 and other trace gas species using commercial airlines, J. Atmos. Oceanic Technol., 25(10), 1744–1754,doi:10.1175/2008JTECHA1082.1.

Matsueda, H., T. Machida, Y. Sawa, Y. Nakagawa, K. Hirotani, H. Ikeda, N. Kondo, and K. Goto (2008), Evaluation of atmospheric CO_2measurements from new flask sampling of JAL airliner observations, Pap. Meteorol. Geophys., 59, 1–17.

Patra, P. K., M. Takigawa, G. S. Dutton, K. Uhse, K. Ishijima, B. R. Lintner, K. Miyazaki and J. W. Elkins, Transport mechanisms for synoptic, seasonal and interannual SF_6 variations and "age" of air in troposphere, Atmos. Chem. Phys., 9, 1209-1225, 2009.

Patra, P. K., Y. Niwa, T. J. Schuck, C. A. M. Brenninkmeijer, T. Machida, H. Matsueda, and Y. Sawa, Carbon balance of South Asia constrained by passenger aircraft CO_2 measurements, Atmos. Chem. Phys., 11, 4163-4175, 2011.

Patra, P.K., T. Saeki, E.J. Dlugokencky, K. Ishijima, T. Umezawa, A. Ito, S. Aoki, S. Morimoto, E. A. Kort, A. Crotwell, K. Ravi Kumar, T. Nakazawa, Regional emission and loss budgets of atmospheric methane (2002-2012), J. Meteorol. Soc. Jpn., 94, 83-105, 2016.