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Nitrous oxide seasonal variations between the surface and the upper troposphere

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For understanding global nitrous oxide (N2O) cycles, surface flux, photochemical loss in the stratosphere and stratosphere-troposphere exchange (STE) have to be considered. Since N2O flux is spatially and temporally variable at regional scale, top-down methods such as inverse modeling are effective to quantify global flux distribution. However, recent modeling studies have identified STE as the largest source of error in estimating N2O surface fluxes. In this study, we employ the CCSR/NIES/FRCGC AGCM-based chemistry-transport model (ACTM), which is capable of simulating the N2O loss in the stratosphere and STE through the physical mechanisms.

The ACTM simulations of atmospheric N2O variations between the earth's surface and the lower stratosphere are compared with aircraft and satellite observations. The vertical profiles observed using aircrafts over four sites, namely, Surgut, West Siberia (by NIES, Japan), Japanese islands (by Tohoku University, Japan), Cape Grim, Australia (by CSIRO, Australia) have been used in quantifying relative importance of surface fluxes and STE in simulating N2O seasonal cycles at different altitude levels. The latitudinal profiles in the upper troposphere (UT)/lower stratosphere (LS) using the Tokyo-Sydney JAL commercial flight (CONTRAIL-ASE by NIES and MRI, Japan) have been used for validating the N2O STE near tropopause.

ACTM well reproduced the stratospheric concentration gradient from tropics to higher latitudes and altitudes observed by the satellite. The regions of enhanced N2O upwelling from the troposphere into the stratosphere were seen at the latitude of 0-30 degrees in the summer hemisphere both in the satellite observation and the model. Low N2O concentration events in the UT region, which frequently occurred in spring around 30 degrees as observed by CONTRAIL-ASE, are well simulated by ACTM, both in terms of the timing and strength. Such low concentration events are also noted in the simulations and observations of other greenhouse gases such as methane and can be attributed to the STE by analyses of the ACTM results. It has been established that intrusion of the N2O-depleted air from the stratosphere to the troposphere is the most important for N2O seasonal cycle simulation in the UT region, while the representation of emissions is the most important factor for the seasonal cycle simulation near the surface.