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Lower Stratospheric N_2O Distributions in the Early and Late Vortex Years

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1. Introduction

Recently, using the PV and contour advection (CA) analysis, Waugh and Rong [2002] studied the inter-annual variability of the Arctic vortex decay and its mixing with the mid-latitude air over the period 1958-2000. Their results suggested that there were large differences in the mixing of vortex air into the surrounding middle latitudes between early and late vortex breakup years. Their analyses mainly concentrated on the winter and spring since the time scale of the PV in the lower stratosphere is shorter than the interseasonal time scale. In this study, the year-to-year variation of N_2O distribution before and after the Arctic vortex decay is investigated with a time scale of year. The objectives are 1) to find a relationship between year-to-year N_2O distributions and the Arctic vortex breakup time, and 2) to examine how the year-to-year N_2O distribution is affected by the vertical advection and the horizontal diffusion. N_2O distributions for 24 years from 1979 to 2002 are analyzed with the probability distribution function (PDF) technique.

2. Data

The data used here are from a simplified version of CCSR/NIES nudging CTM (Akiyoshi et al., 2002). In the model, N_2O was calculated by the equation: $\partial N_2O/\partial t = -J_{N_2O}[N_2O] + k[O(^1D)][N_2O] + transport$, where J_{N2O} is photolysis rate for N_2O, k chemical reaction coefficient for the reaction between $O(^1D)$ and N_2O, and $O(^1D)$ was calculated by a parameterized Chapman cycle (Akiyoshi and Uryu, 1992). The model has a horizontal resolution of T42 (2.8×2.8) and the vertical domain extended from the surface to 70 km with 30 layers. The year of 1987 and 1997 were selected to represent the early and late vortex breakdowns, respectively [Waugh and Rong, 2002].

3. Results

Figure 1 shows that the N_2O concentration has year-to-year variation. No trend is found in the year-to-year N_2O variation during the period. This indicates that the N_2O amount in the model has already reached a steady state.

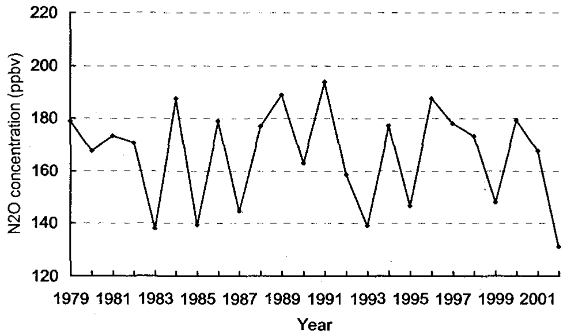

Figure 1. Year-to-year variation of N_2O concentration in May from 1979 to 2002 at the 600-K isentropic surface averaged north of 45°N.

Figures 2 shows there are large differences between 1987 and 1997. In 1987, from winter to early spring, the maximum N_2O probability shifts from higher N_2O values (around 200 ppbv) to lower (around 140 ppbv). After the vortex breakup, the maximum probability is located around 140 ppbv during the summer. The N_2O concentration is distributed from around 60 ppbv to 260 ppbv, representing the high spatial variability of the N_2O concentration. Compared with that in 1987, the N_2O PDF in 1997 shows lower spatial variability after the vortex breakup, with the maximum probability around 180 ppbv.

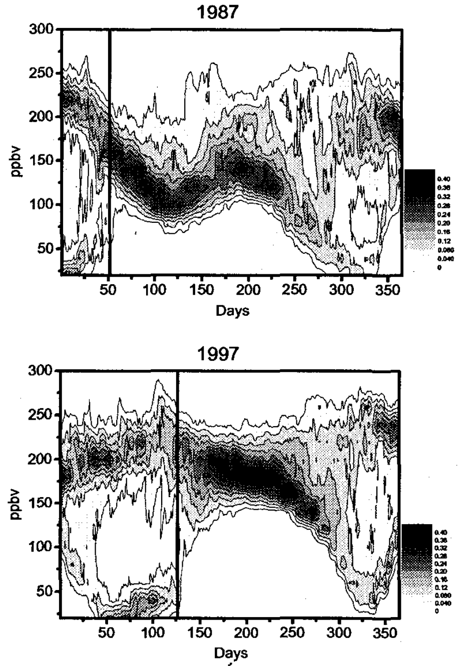

Figure 2. PDFs of N_2O concentration in 1987 (left) and 1997 (right), north of 45°N at the 600-K isentropic surface. Vertical solid lines indicate the vortex breakup dates.

4. Discussion and Conclusion

Results showed that there are large N_2O differences between the early and late vortex breakup years. In the early breakup years, the N_2O shows lower concentration compared with that in late years. We also examined the effects of vertical advection and horizontal diffusion. Results showed that vertical advection is a main contributor to the differences of the N_2O distribution between the early and late vortex breakup years.

References

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