Correlation of N2O and Ozone in the Southern Polar Vortex during the Airborne Antarctic Ozone Experiment

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In situ N2O mixing ratios, measured by an airborne laser spectrometer (ATLAS), have been used along with in situ ozone measurements to determine the correlation of N2O and ozone in the Antarctic stratosphere during the late austral winter.

At all latitudes, N2O has a constant mixing ratio of ~300 ppbv in the troposphere, but decreases with increasing altitude above the tropopause. Ozone has a very mixing ratio in the troposphere, which increases rapidly above the tropopause and peaks near 35 km; its mixing ratio decreases above 35-40 km. In the lower stratosphere, where they are neither produced or destroyed, N2O and ozone are conservative tracers. Their strong anticorrelation provides a signature of lower stratospheric air. Regions where this correlation is altered may serve as a diagnostic for sites of ozone loss.

During the 1987 Airborne Antarctic Ozone Experiment (AAOE), N2O data were collected by a laser absorption spectrometer on board the ER-2 on five ferry flights between Ames Research Center (37°N) and Punta Arenas, Chile (53°S), and on twelve flights over Antarctica (53°S to 72°S). Vertical profiling between 14 and 20 km on the flight of September 29 (flying from 53°S to 41°S) produced an average stratospheric correlation coefficient for N2O and ozone of -0.87(23). Averaging over all AAOE flights south of Punta Arenas between 53°S and 56°S, the correlation coefficient of N_2O and ozone was -0.81(25).

The first flight out of Punta Arenas, on August 17, revealed N_2O/O_3 correlations between 53°S and 67°S that were similar to those observed on the ferry flights. However, from August 23 to September 22, all flights reveal a different yet consistent pattern of information. Between 53°S and 72°S, we observed that the N_2O/O_3 correlation coefficient is always positive at the edge of the polar vortex as defined by the wind speed maximum. Inside the vortex, in the lower wind region where wind speed drops by a factor of 2 or more from the maximum, N_2O and ozone have a negative correlation. The low ozone mixing ratios observed inside the vortex, however, differentiate this air from negatively correlated lower stratospheric air outside the vortex. The lowest ozone mixing ratios observed each flight were usually found inside the vortex in the lower wind region, near the boundary with the high wind region.

Of all the trace gas species measured by instruments on board the ER-2, only one showed a relationship to the N_2O/O_3 correlations in the vortex. With few exceptions, positive N_2O/O_3 correlations coincided with total water mixing ratios of greater than 2.9 ppmv, and total water mixing ratios of less than 2.9 ppmv corresponded to negative correlations. The lower water mixing ratios, or "dehydrated regions," are colocated with the negative correlations within the vortex, while the wetter regions always occur near the vortex edge.

N_2O mixing ratios in the vortex range from 85 to 200 ppbv between 17 and 21 km. According to global averages [WMO, 1982], these mixing ratios correspond to seasonally averaged midlatitude observations at altitudes of 22 to 31 km. Because the anti-correlation of N_2O and ozone extends to roughly 40 km, regions of positively correlated air are not evidence of subsidence. Changes in N_2O mixing ratio may be used to indicate regions of ozone loss, even when ozone mixing ratios remain constant, due to the strong anticorrelation that N2O and ozone exhibit in unperturbed lower stratospheric air. We conclude that regions of positive correlation between N2O and ozone may be interpreted as either evidence of a chemical depletion process, which may have occurred elsewhere, or as evidence of horizontal mixing of normal lower stratospheric air with ozone-depleted vortex air. Because air outside the vortex is relatively high in both N2O and ozone, and air within the vortex is low in both N2O and ozone, horizontal mixing between these two regions would produce a "transition zone" where N2O and ozone both decrease, resulting in positive correlation. The return to negative correlation within the vortex, while ozone mixing ratios remain low, implies a region of less severe ozone depletion because the ozone is increasing.

The relationship between N2O/O3 correlation and water mixing ratio is a striking phenomenon. The positively correlated regions with low ozone and high water near the vortex edge may be in a region of horizontal mixing, perhaps in the process of "mixing out" of the vortex, having already been chemically processed. The low ozone, dehydrated regions with negative correlation within the vortex may point to regions of ongoing ozone loss.