

Ozone loss rates and PSC occurrence in the Arctic winter stratosphere during 1994-2000 observed by POAM II/III and ILAS

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Quantitative chemical ozone loss rates at the 475 K isentropic surface inside the Arctic polar vortex are evaluated for six winters (January through March) using a satellite-based Match technique. Satellite observational data are taken from the Polar Ozone and Aerosol Measurement (POAM) II for 1994-1996, the Improved Limb Atmospheric Spectrometer (ILAS) for 1997, and the POAM III for 1999-2000. The largest ozone loss rates occurred in January 1995 (50 ppbv/day), February 1996 (40-50 ppbv/day), February 1997 (40 ppbv/day), January 2000 (60 ppbv/day), and early March 2000 (40 ppbv/day). Large derived ozone loss rates were typically associated with air masses that experienced low temperatures (187-195 K) within the previous 10 days. The ozone loss rates clearly increase with decreasing the minimum temperature. The particularly large ozone losses of 9+/-3 ppbv/sunlit-hour in February 1996 and January 2000 were associated with very low minimum temperatures of 187-189 K, simultaneously with high PSC probabilities.

We have quantified the probability of polar stratospheric cloud (PSC) existence at the 475 K level using aerosol extinction coefficient (AEC) data from POAM II/III and ILAS. The results show that patterns of high PSC probabilities are very similar to those of high ozone loss rates. The highest positive correlations between monthly PSC probabilities and ozone loss rates per sunlit hour occurred in February ($r^2=0.88$) and January ($r^2=0.64$). No correlation is found for March; however, this lack of correlation is solely due to small ozone loss rates in 1996. A correlation is found for March when considering only 1995, 1997, and 2000 ($r^2=0.91$). This relationship demonstrates that interannual variability (IAV) in the magnitude of ozone losses is tied to IAV in PSC probabilities. The regression coefficient between the PSC probabilities and ozone loss rates per sunlit hour was almost constant throughout JFM, however, for ozone loss rates per day, the seasonal increase from January to February/March in the regression coefficient was found due to more sunlight in late winter to spring. Regression analysis for the full JFM season indicates that, on average, an absolute increase of 10% in the PSC probability contributes an additional ozone loss of approximately 25+/-6 ppbv/day or 3.2+/-0.7 ppbv/sunlit-hour. Relationships between average Arctic winter ozone loss rates and various PSC- and temperature-related indices are investigated, including the area of polar vortex that is colder than the threshold temperature for PSC existence (APSC; e.g., Rex et al., 2004), the PSC formation potential (PFP), and the potential for activation of chlorine (PACl) (Tilmes et al., 2008). Of these three, PACl provides the best proxy representation of interannual variability in Arctic ozone loss at the 475 K level.

We used HALOE H₂O and POAM/ILAS AEC to calculate the IAV in the threshold temperature for activation of chlorine (TACl; Drdla and Mueller, 2010). TACl decreased from 194.6+/-0.6 K during the winter of 1994 to 193.3+/-0.8 K during the winter of 2000. This decrease is associated with reductions in background sulfate aerosols. The decrease is interrupted in 1997 and 1998, when weak diabatic descent inside the vortex led to higher SAD, which in turn led to higher TACl. The low value of TACl in 1996 (193.6+/-0.9 K) caused the decrease in PACl, which significantly contributed to the higher correlation between ozone loss and PACl rather than PFP. Our observational evidence shows the high correlation between Arctic ozone loss and TACl/PACl, as well as Tilmes et al. (2008). The injection of sulfate aerosols into the stratosphere either by huge volcanic eruptions or by "geoengineering" schemes to counteract global warming would lead to increases in TACl, probably resulting in enhanced ozone loss in the Arctic winter stratosphere.

Keywords: stratospheric photochemistry, polar stratospheric cloud, satellite measurement, polar vortex, stratospheric temperature