Title: Analysis of Observations of the Middle Atmosphere from Satellites

Investigators and Institutions:

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Abstract of Research and Objectives

Satellite data are being used to investigate problems in middle atmosphere chemistry and dynamics. Efforts have been focused primarily on studies to determine the quality of observed distributions of trace species and derived dynamical quantities. Those data have been used as diagnostics for model-derived constituent profiles and fields and for improving our understanding of some of the fundamental processes occurring in the middle atmosphere.

Summary of Progress and Results

Temperatures and derived winds from Nimbus 7 LIMS data have been compared with long-time series of rawinsonde data at Invercargill, New Zealand, and Berlin, West Germany, and the results are excellent for both quantities. It has also been demonstrated that more highly-derived dynamical quantities can be obtained reliably from those LIMS fields. Furthermore, both the diabatic and residual-mean circulations derived using LIMS data agree qualitatively with changes in the distribution of trace species determined independently with the Nimbus 7 SAMS and LIMS experiments. Subsequently, an examination of LIMS data at mid to high latitudes of the Southern Hemisphere has revealed a synoptic-scale, upper stratospheric instability during late autumn that is associated with the development of the stratospheric polar jet. Investigation of this phenomenon continues with Stratospheric Sounding Unit (SSU) data sets.

The LIMS distributions of nitrogen dioxide and water vapor have been reported with a greater degree of certainty, and they provide the basis of a proposed reference atmosphere for those species. The apparent day/night difference in LIMS water vapor has been attributed to non-local thermodynamic equilibrium effects which degrade the daytime LIMS results; the nighttime data are considered more accurate. Extensive studies were performed to determine the quality of several satellite ozone and temperature data sets in the stratosphere as part of the Ozone Trends Study Report. Generally, there was excellent (better than 5 percent) agreement in the mid to upper stratosphere between SBUV, LIMS, and SAGE data of 1978/79. Larger (10 to 20 percent) differences were found in the lower stratosphere; there are uncertainties due to ozone absorption coefficients and to algorithm effects there.

An exploratory study has been conducted to determine seasonal variations in ozone transport in the lower stratosphere using a combination of LIMS ozone profile data plus SBUV total ozone. The technique involves integrating LIMS ozone above the 440K potential temperature surface (just above the tropopause) and then subtracting that amount from a co-located SBUV total ozone measurement. First results indicate excellent agreement at Northern Hemisphere mid latitudes with similar findings from more limited balloon data sets. Whereas the ballon data are concentrated at specific locations in the Northern Hemisphere, the satellite results cover both hemispheres with much more complete spatial coverage each day.

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NASA Biennial Research Summary for Grant NAGW–992

An Observational Study of Recent High-Latitude Ozone Variations

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Research Objectives

The purpose of the work being conducted under this grant is to diagnose the stratospheric circulation, especially in the southern hemisphere, primarily by using data from the Total Ozone Mapping Spectrometer (TOMS) on Nimbus 7. The work is motivated by two observations. The first is that the seasonal cycles of ozone (and therefore the stratospheric circulations) are very different in the northern and southern hemispheres. Thus we have two different environments in which to test theories of the stratospheric circulation and ozone photochemistry. The TOMS data is extremely valuable for this purpose, because it provides daily, near-global maps of total ozone and is the largest single body of data on southern hemisphere ozone. The second observation is the remarkable downward trend in total ozone detected over Antarctic in the spring season (the ozone hole).

Progress and Results

1) Eight years of data from the Total Ozone Mapping Spectrometer (TOMS) on Nimbus 7 were used to estimate globally- and zonally-averaged trends in total ozone over the period 1979 through 1986 (Bowman, 1988). Results were similar to those of the NASA Ozone Trends Panel. The decreases were found to be largest in middle and high latitudes and to occur in all seasons of the year. The decreases were comparable in magnitude to fluctuations observed in the 1960's. Drift in the TOMS instrument calibration introduced considerable uncertainty into the trend estimates.

2) Nine years of total ozone measurements from the TOMS were used to study the global structure of the quasi-biennial oscillation (QBO) in total ozone (Bowman, 1989a). Interannual variability of total ozone near the equator (10° S to 10° N) is dominated by the QBO. The equatorial ozone anomalies are independent of season and are well correlated ($r > 0.8$) with the equatorial zonal wind. In both hemispheres, midlatitude anomalies are two to three times larger in winter than in summer. Global patterns of the ozone QBO are identified by computing lagged correlations between the zonal-mean equatorial ozone and ozone elsewhere on the globe. Correlations between equatorial and extratropical ozone are weak during the summer season ($r \sim 0$) and large and negative during the winter ($r < -0.8$ in the southern hemisphere and $r < -0.6$ in the northern hemisphere). There are nodes or phase shifts in the correlation patterns at ±10° latitude, at 60° S, and at 50° N. Large negative correlations extend to the poles in both winter hemispheres. There are indications of a correlation between wave activity, as measured by the eddy variance of the total ozone field, and the QBO, although the variability of the eddy activity is large and the sample size is small. The correlations support the accepted view that equatorial ozone anomalies result from vertical transport by the QBO circulation. The correlation patterns do not support the theory that extratropical ozone anomalies on the QBO time-scale are the result of either advection of equatorial ozone anomalies by the climatological circulation or quasi-horizontal mixing of the equatorial anomalies by planetary waves. Instead, the ozone anomalies resemble a seasonally-modulated standing oscillation, possibly resulting from quasi-biennial wave forcing of the planetary-scale mean meridional circulation and the associated vertical advection of ozone.

3) Nine years of total ozone measurements from the TOMS were used to estimate the meridional transport of ozone during the springtime (September-October-November) breakdown of the Antarctic polar vortex (Bowman, 1989b). Because the vortex breakdown in the Antarctic occurs after the equinox (unlike the Arctic), daily maps of total ozone over the Antarctic region are available for the entire breakdown period. Planetary-scale waves, especially zonal wavenumbers 1 and 2 dominate the eddy variance and ozone transport. Wavenumber 1 is quasi-stationary, while wave number two is eastward moving with a period of ~10 days. During the early spring, vertically-propagating, planetary-scale waves alternately transport ozone poleward and equatorward as their local amplitude increases and decreases. Because the waves propagate through the lower stratosphere, the transport is largely reversible. As the spring season proceeds, the jet weakens and moves poleward and downward in response diabatic processes and forcing by the waves, and the region of wave absorption descends into the middle and lower stratosphere. The interaction between waves and the mean flow then occurs in the lower stratosphere, where non-conservative processes produce irreversible mixing of ozone as the dynamical vortex breaks down. The vortex breakdown and accompanying ozone transport mark the end of the Antarctic ozone hole.

Publications

Bowman, Kenneth P., 1988. Global Trends in Total Ozone, *Science*, **239**, 48-50.

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