N89-14584

The QBO and Interannual Variation in Total Ozone

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I. QBO modulation of the spring ozone decline rate

Introduction

Garcia and Solomon (1987) have noted that the October monthly mean minimum total ozone amounts south of 30S were modulated by a quasibiennial oscillation (QBO) signal. The precise mechanism behind this effect, however, is unclear. Is the modulation brought about by the circulation-produced QBO signal in the ozone concentration itself, or does the temperature QBO modulate the formation of polar stratospheric clouds (PSCs), leading to changes in the chemically induced Antarctic spring ozone decline rate? Or is some other phenomenon involved?

To investigate the means through which the QBO effect occurs, a series of correlation studies has been made between polar ozone and the QBO signal in ozone and temperature.

Analysis and results

It seems likely that variations in polar ozone would be more directly affected by the QBO in the Southern midlatitudes than by the tropical QBO. Therefore, quasibiennial signals from 66 S to the equator were extracted by digital filtering zonally averaged daily TOMS maps and NMC layer mean temperature fields. To better establish the link between these filtered data and the tropical QBO, both a narrow bandwidth filter (designed to isolate the QBO) and a broad bandwidth filter (retaining most signals with periods longer than the annual cycle) were used. The filtered data were correlated with the 30 and 50 mb winds over Singapore. Total ozone between 15 and 50 S and the 50-30 mb layer mean temperatures between 30 and 50 S are strongly anticorrelated with the 30 mb Singapore winds.

To obtain a picture of the evolution in time of the ozone within the polar vortex, daily minima poleward of 30 S were extracted from gridded TOMS data. The resulting time series was smoothed, and the spring decline rate for each year was determined by a linear least squares fit from September 1 to October 5. As shown in Figure 1, the decline rate shows an overall increase in magnitude from 1979 to 1987 but fluctuates with a period of about two years.

The filtered zonal mean total ozone is highly correlated with the polar ozone decline rate anomalies in the Southern midlatitudes and anticorrelated with the tropical QBO (Figure 2). The NMC 30-50 mb layer mean temperatures show similar results.

If the decline rates and the October mean ozone values were modulated directly by a QBO in the ozone superimposed on the overall decline, the slope of the midlatitude QBO should be associated with a decline rate deviation of the same sign. In fact, however, the two are poorly correlated; moreover, the slopes of the QBO signal for August-September (at most 0.03 DU/day) are too small to account for the decline rate deviations (about 0.4 DU/day). An alternative explanation is that a QBO in the temperature modulates the formation of PSCs, thereby affecting the rate of chemical destruction of ozone over the pole. This hypothesis seems better to account for the observed deviations in the decline rate, but cannot be proven from this data set.

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Such a QBO signal in the temperature may be due to a direct circulation similar to that described for lower latitudes by Plumb and Bell (1982) and Plumb (1984), or it may be the result of a QBO modulation of midlatitude eddy activity (Holton and Tan, 1982; Dunkerton, 1988; Newman and Randel, 1988).

The sensitivity of the spring Antarctic decline rate to the QBO (whatever the precise mechanism) and the fact that the decline rate anomalies are a significant fraction of the decline rate itself indicates how strongly the Antarctic depletion can be modified by midlatitude processes. Thus, while the basic ozone depletion mechanism appears to be chemical, the overall chemistry is apparently highly sensitive to the dynamics of the Austral winter stratosphere.

II. The dilution effect

It has been suggested (M. Ko, personal communication) that, upon breakup of the polar vortex in the Southern late spring, subsequent transport and mixing of its depleted-ozone air could result in lower ozone levels at other latitudes (the dilution effect).

Zonal mean TOMS data from 1979 to 1987 have been averaged over months bracketing the Antactic ozone depletion event and differenced in an effort to separate such an effect from an overall secular decline or instrument drift. If the high ozone region just outside the polar vortex is reduced by the dilution effect, one would expect such differences to be positive over the vortex and negative over the high-ozone region, with an overall decrease from year to year. Figure 3 shows the December-September difference as a function of latitude and year. Some weak evidence for the dilution effect can be seen, but a large QBO signal in the data tends to obscure straightforward interpretation.

Figure Captions.

1. August-September decline rates of the daily map minimum in total ozone for each year (solid line), with their linear least squares fit (dashed line).

2. Correlation coefficient versus latitude of ozone decline rate deviations with zonal mean total ozone, filtered to extract the QBO. Dotted line is the correlation of the decline rate deviations with the rate of change of filtered zonal mean total ozone.

3. December-September difference of monthly mean zonally averaged total ozone for each year.

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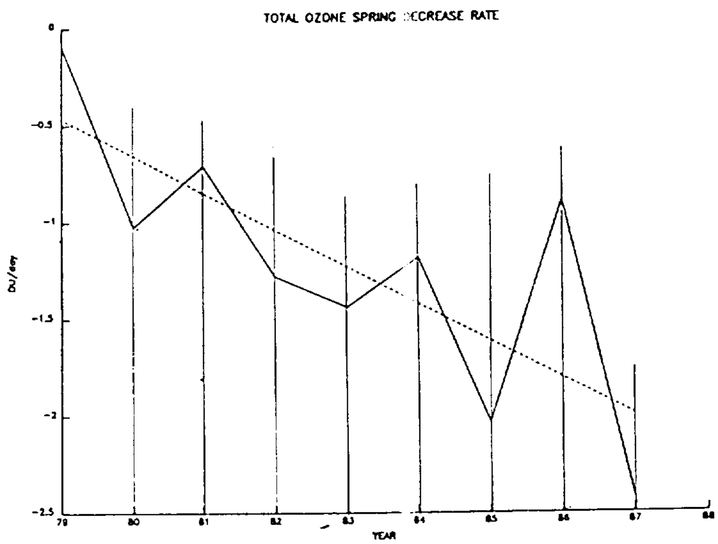

Figure 1.

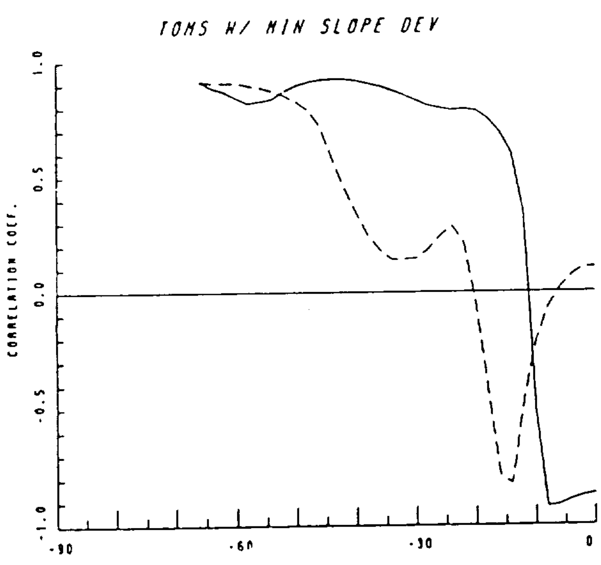

Figure 2.

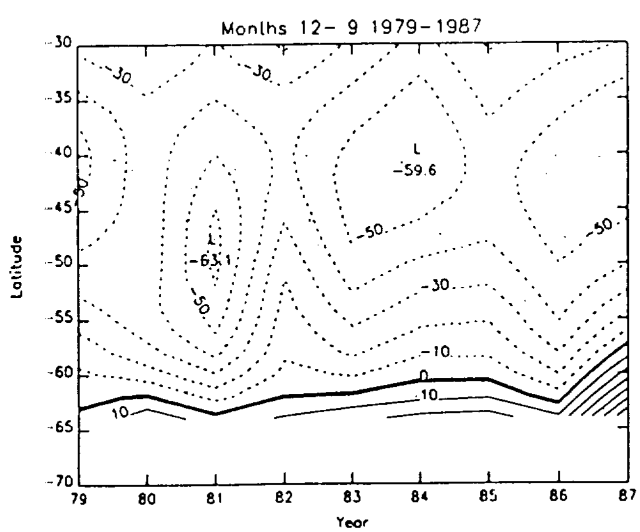

Figure 3.

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