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ABSTRACT FOR MEETING ON POLAR OZONE, ASPEN, COLORADO, MAY 9-13, 1988

WINTER-TIME LOSSES OF OZONE IN HIGH NORTHERN LATITUDES

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Total column ozone data over the past 22-30 years from ground-based Dobson and filter ozonometer stations between 30°N and 80°N have been analyzed for residual trends remaining after allowance for the known geophysical variations corresponding to: (a) the yearly change of seasons; (b) the quasi-biennial oscillation; and (c) the 11-year solar sunspot cycle. Examination of the data from several ground stations between 45°N and 55°N indicated a seasonal difference in the long-term ozone series, with statistically significant losses in several winter months. Accordingly, the data from individual stations were analyzed with multiple regression analysis, seeking trends on a monthly basis after allowance for the known geophysical cycles. Previous statistical analyses have been conducted as tests of one-dimensional model calculations which do not show any differences with the seasons, and which therefore any trend toward change in ozone concentrations is expressed in a yearly trend without seasonal variation. Such a model is inappropriate for calculations with a data set which exhibits a pronounced tendency toward seasonal differences in the trends. Comparisons with model calculations then require two-dimensional models into which seasonal and latitudinal differences can readily be programmed.

Multiple regressions have been calculated for the ozone data from about 30 individual Dobson stations, and for latitudinal band averages covering four latitude ranges from 30°N to 80°N. Table 1 shows the magnitude of the residual linear trends for individual months that correspond to ozone changes in these bands since 1969 after allowance for the QBO, solar cycle and seasonal effects. The correlation of ozone change with the QBO is known to be dependent upon latitude and this conclusion is confirmed with the sign change in Table 1. The ozone response to the solar cycle is as large as 2%, minimum to maximum. The residual linear trends show a measurable decrease in the annual average total column ozone of 1.7% to 3.0% in all latitude bands from 30°N to 80°N from 1969 to 1986. The decreases are largest during the winter months (2.3% to 6.2%) of December through March, and contrast with smaller changes (+ 0.4% to - 2.1%) in the summer months of June through August.

The winter/summer differences are especially large in the two most northerly bands in Table 1, with winter-time losses appreciably larger than can be explained by model calculations. An obvious possibility is that the winter-time losses are enhanced through heterogeneous chemical processes analogous to those found in the Antarctic ozone hole. The time distribution of such effects would be quite different in the Arctic because of the difference in meteorology. In contrast to the tight polar vortex in the south which effectively retains the same air over Antarctica all winter long, the Arctic air masses tend to pass through the polar night and back into sunlight again. Any chemical effects causing ozone depletion in the Arctic winter air would therefore be distributed over a much larger total volume of air than in the constricted Antarctic; the much lesser abundance of polar stratospheric clouds in the north, and the shorter exposure time of individual air masses to the polar night, may substantially reduce the total amount of ozone depletion induced by such stratospheric chemical reactions.

The typical set of Dobson data from a station north of 30°N shows a much larger standard deviation for the monthly average values during winter months than in the summer. Treatment of such data with a multiple regression requiring that all months have the same trend over time for changes in total ozone emphasizes the less-noisy summer data, and down-weights the noisier wintertime measurements. The chief consequence of this statistical circumstance is that the yearly trend values calculated for a particular set of data show significantly smaller trends than given by the average of the monthly trends, as also shown in Table 1.

Table 1

Coefficients of Multiple Regression Statistical Analysis of Re-analyzed Dobson Measurements of Total Ozone Concentrations Collected into Latitudinal Band Averages. (Data are expressed in total percent changes for the period 1969-1986.)

	Latitude Band			
Month	60-80°N	53-64°N	40-52°N	30-39°N
January	- 7.4 ± 2.4	- 8.3 ± 2.2	- 2.6 ± 2.1	- 2.2 ± 1.5
February	- 8.9 ± 3.7	- 6.7 ± 2.8	- 5.0 ± 2.2	- 1.2 ± 1.9
March	- 3.2 ± 1.6	- 4.0 ± 1.4	- 5.6 ± 2.3	- 3.5 ± 1.9
April	- 1.8 ± 1.6	- 2.0 ± 1.4	- 2.5 ± 1.7	- 1.7 ± 1.3
May	- 2.9 ± 1.1	- 2.1 ± 1.2	- 1.3 ± 1.1	- 1.7 ± 0.9
June	+ 0.2 ± 0.9	+ 1.1 ± 0.9	- 1.8 ± 1.0	- 3.3 ± 1.0
July	- 0.7 ± 1.0	+ 0.0 ± 1.1	- 2.2 ± 1.0	- 1.3 ± 1.0
August	+ 0.1 ± 1.0	+ 0.2 ± 1.2	- 2.4 ± 1.0	- 1.0 ± 1.0
September	- 0.3 ± 1.1	+ 0.2 ± 1.1	- 2.9 ± 1.0	- 1.0 ± 0.9
October	- 0.6 ± 1.8	- 1.1 ± 1.2	- 1.5 ± 1.5	- 0.9 ± 0.8
November	+ 1.3 ± 2.1	+ 1.5 ± 1.8	- 2.4 ± 1.3	- 0.1 ± 0.8
December	- 5.4 ± 2.9	- 5.8 ± 2.3	- 5.5 ± 1.7	- 2.1 ± 1.1
Annual Average	- 2.7 ± 0.9	- 2.3 ± 0.7	- 3.0 ± 0.8	- 1.7 ± 0.7
Winter Average	- 6.2 ± 1.9	- 6.2 ± 1.5	- 4.7 ± 1.5	- 2.3 ± 1.3
Summer Average	- 0.1 ± 0.9	+ 0.4 ± 0.8	- 2.1 ± 0.7	- 1.9 ± 0.8
QBO*	- 2.2 ± 0.6	- 2.0 ± 0.6	- 1.3 ± 0.6	+ 1.9 ± 0.6
Solar*	+ 2.0 ± 0.6	+ 1.8 ± 0.6	+ 0.8 ± 0.7	+ 0.1 ± 0.6

* Percent changes per cycle, minimum-to-maximum. All uncertainties are expressed with one sigma statistical significance.

Average of Monthly Ozone Trends in Dobson Units per year and Percent change in 17 Years:

	60-80°N	53-64°N	40-52°N	30-39°N
Dobson Units per year	- 0.57±0.20	- 0.52±0.16	- 0.63±0.17	- 0.32±0.14
Percent change in 17 years	- 2.7±0.9	- 2.3±0.7	- 3.0±0.8	- 1.7±0.7

Uniform Trend in Ozone Change Assumed throughout the year, in Dobson Units per year and in Percent Change in 17 years):

	60-80°N	53-64°N	40-52°N	30-39°N
Dobson Units per year	(- 0.17±0.15)	(- 0.14±0.13)	(- 0.47±0.13)	(- 0.17±0.11)
Percent change in 17 years	(- 0.8±0.7)	(- 0.7±0.6)	(- 2.3±0.7)	(- 0.9±0.6)