Record ozone minimum over middle and high latitudes of the northern hemisphere during winter-spring season 1992/93.

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During the past two winter-spring seasons total ozone over large parts of the northern hemisphere middle to high latitudes and between 45°N and 65°N reached record minimum values. Ozone deficiencies ranged between about 11% and 13% below the long-term normal and the cumulative ozone decline since winter-spring of 1969/70 was about 14%. The number of days in these seasons with ozone values deviating below the long-term mean, beyond statistical expectation, was ten times higher compared to the mean of the pre-1990 period. As to the causes there is evidence that transport of ozone-poor air masses originating from lower latitudes and forced by vertical motions as well as cold air advection (known to have excess CIO content) which moved over sun lighted regions, which facilitated chemical ozone destruction, can account for most of the observed low-ozone cases. Both the rates of decline and the prevailing low ozone values, did not reach or even approach the extreme phenomena describing the Antarctic spring ozone hole.

Total ozone above the northern hemisphere middle and high latitudes has been steadily declining since the late 1960's and through 1990 when the chlorine loading of the stratosphere exceeded certain levels [1-5]. Long-term trends of winter-spring seasons (December through March) in the 1070's and 1980's were 3.1±0.4% per decade over North America and Europe and slightly less over Asia and the Far East [3]. If, however, one extends the period so as to include the last three winter-spring seasons, the cumulative ozone decline since December 1969 through March 1993 is close to -14% for North America, Europe and Siberia between 45%N and 65%N [5]. Acceleration of the ozone decline was deduced from the satellite TOMS data [4] (December 1978 to March 1991) which show a statistically stable decline of over 5% for above regions. However, the last two winter-spring seasons (1991/1992 and 1992/1993) did show an exceptionally low ozone amount and have contributed to the sharp increase of the cumulative ozone decline since 1969.70.

For this analysis ground total ozone data have been used as deposited to the WMO World Ozone Data Centre (WO_3DC) in Toronto, and for the last four month provisional ozone values were extracted from the daily total ozone maps distributed to all participating GO_3OS stations by the provisional WMO Centre for near-real-time ozone mapping located at the Laboratory of Atmospheric Physics, University of Thessaloniki, most of which have been recently revised. From the point of geographical locations three continental-size regions, between 45°N and

65°N, being also under the influence of similar macro-synoptic atmospheric circulation patterns are discussed: North America (60.4°W, 113.5°W), Europe (5.3°W, 57.1°E) and Siberia (60.6°E,129.7°E) having 10, 29, and 11 ozone stations respectively. At least 12 days of data throughout each of the regions were required to calculate monthly means at individual stations, although in reality always more than double that number of days were available. Total ozone departures in percent were based on long-term means and corresponding standard deviations of daily values during the entire 1959-90 observational period.

A survey within the 35 years of ozone records for the winter-spring (DJFM) season shows that there have been on an average only slightly less than one day per year for the 40°N-50°N and two days per year for the 50°N-60°N when the area averaged total ozone over the North America or Europe show ozone values below the -2σ value. This number is unexpectedly high during the last two winter-spring seasons where they did show a massive of days with ozone values below -2σ seen in Table 1. It also indicates that the seasonal average ozone in all regions of continental size have been about 11% and 13% below the long-term normal for the winter-spring seasons of 1991/92 and 1992/93 respectively. In order to put the extremely low ozone values of the last two winter-spring seasons in perspective, Figure 1 shows, for each region the histogram of mean seasonal deviations together with the $\pm 2\sigma$ confidence limits derived from the seasonal values of all the years through 1990. It is clear that the winter-spring values of the last two years are record low

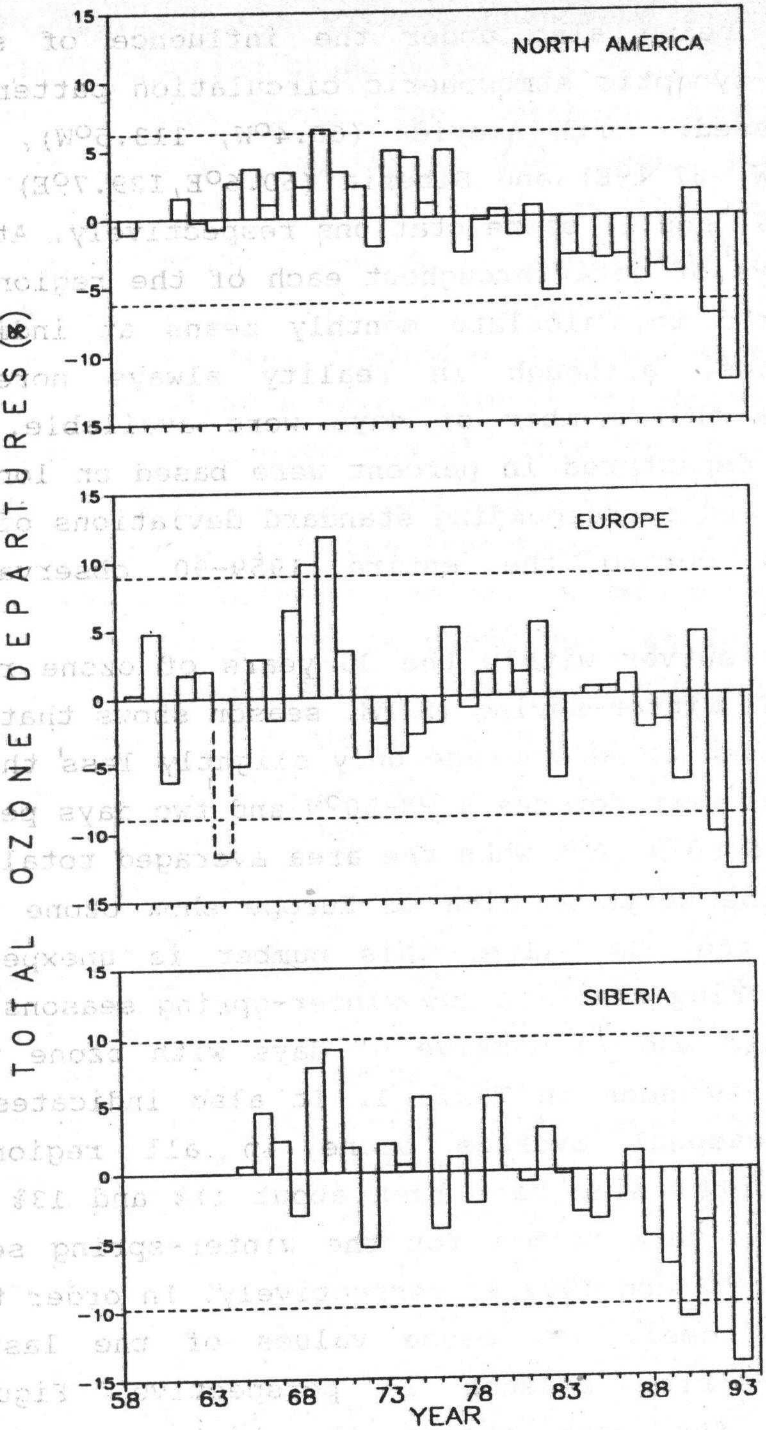

Figure 1: Histogram of mean (DJFM) total ozone and its ±2σ confidence limits during 1959-1993 expressed as percent departures from the long term mean. The dashed bar centered in 1964 indicates fewer available observations during that period.

values, being even below the 2σ level which assures that they are indeed extreme events.

TABLE 1

Mean seasonal (DJFM) total ozone (m-atm-cm), departures from normal (in %) and number of days (N) per season with ozone values below the 2σ limit.

45°N-65°N	Long-term normal	1991/92 average	%	N	1992/93 average	%	N
North America	387	355	-8.2	17	336	-13.1	50
Europe	358	321	-10.3	11	310	-13.4	25
Siberia	388	341	-12.1	23	334	-13.9	17

As to the spatial distribution of the ozone anomalies during the last winter-spring season in 1993, Bojkov et al [5] have shown that the largest negative deviations (exceeding the 2σ limits) were 20% over Northern Europe and Western Scandinavia and about 15% and 25% over North America and Siberia respectively. However we should mention here that the departures are smaller over the polar region and large parts of the oceans as confirmed also by the TOVS daily maps [6]. Also any differences seen in the percent departures of Table 1 in this study and Table 1 in Bojkov et al [5] are due not only to the inclusion of revised data but also due to additional data which in this paper go through the 31st of March as compared to the 18th March which marked the end of the earlier calculations by Bojkov et al [5]. Figure 2 shows an example of time series at Potsdam a station that is located in the centre of the European region. As it appears from this figure distinct days with large negative departures at

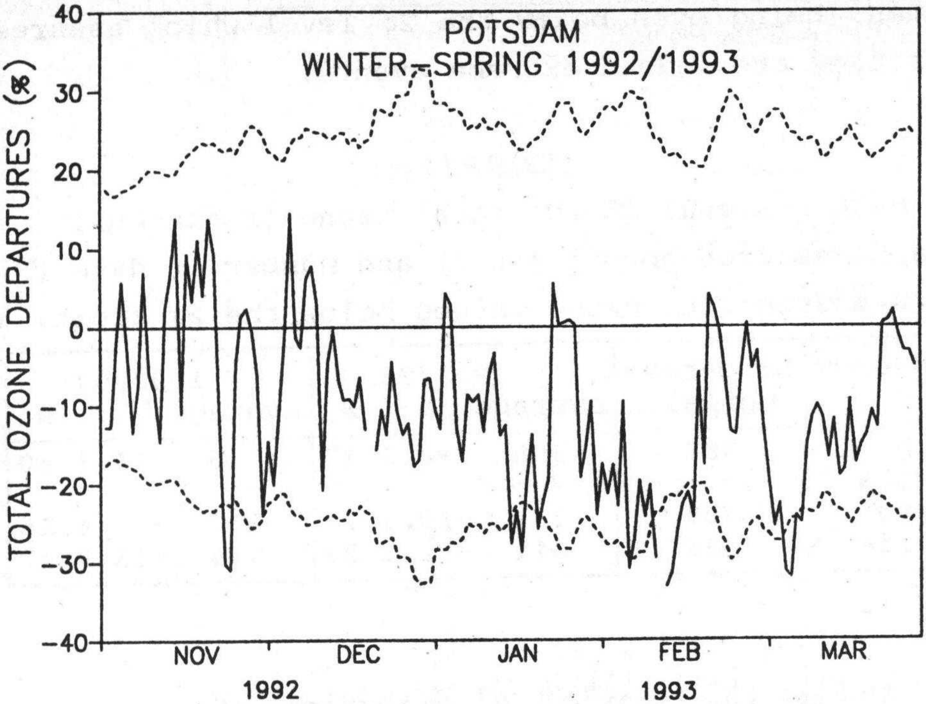

Figure 2: Time series of daily total ozone observations expressed as percent of the long term mean continuous line) and the ±2σ confidence limits (dashed line) for Potsdam.

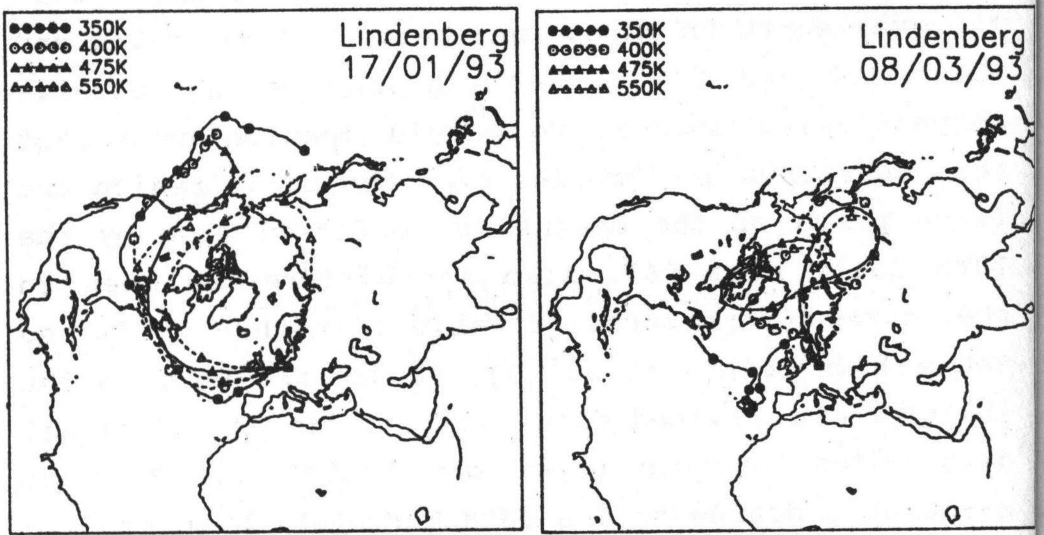

Figure 3: 10-day trajectories on potential temperature surfaces for the dates indicated for Lindenberg

Potsdam correspond to the dates 17/1/93 and 8/3/93. Hints on the causes of these large negative departures can be provided by the time history of the trajectories ending at Lindenberg, a station close to Potsdam. Figure 3 shows 10-day trajectories on potential temperature surfaces [7] for the dates 17/1/93, 8/3/93, which correspond to two of the lowest ozone negative departures of the last winter-spring season over Potsdam. It is evident from Figure 3 that naturally poor of ozone air that was transported from the subtropical latitudes and lifted into the lower stratosphere,as well as, air masses chemically disturbed and containing ClO, transported from the polar vortex over the sunlighted upper middle latitudes [8], can possibly explain these large deviations.

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