Ground-based ozone data relevant for the AASE campaign in 1989

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Abstract

The Airborne Arctic Stratospheric Expedition (AASE) carried out measurements from Jan. 3 to Feb. 15, 1989. Enhanced levels of chlorine compounds were found in the Arctic stratosphere, and on two single flights ozone decrease of 17% were measured, interpreted as essential features of the Arctic stratosphere, caused by a combined effect of enhanced amounts of chlorine compounds and presence of polar stratospheric clouds. Related model calculations also indicate extended ozone depletion maximizing in late March 1989 and amount to 5-8% in column at 70^{o} N. Ground-based ozone measurements, however, show that the most characteristic features during this period are temporal variations and a strong enhancement of ozone, probably due to an extended stratospheric warming. From these measurements it is hard to see any effect of an eventual enhanced burden of stratospheric chlorine, which might show up as an extended and long-lasting decrease of stratospheric ozone, but its eventual existence is masked by the temporal variations. As ever, theoretical predictions and model calculations can be really misleading when proper account of relevant data is omitted.

Introduction

The ozone layer has an important role as shield against harmful solar ultraviolet radiation. Already twenty years ago there was much concern for the depletion of the ozone layer due to exhaust gases of stratospheric transport (SST) (Wayne, 1985). However, more than ten years ago it became evident that SST was no threat against the ozone layer, partly because the fleet of SSTs remained small, and the alarming predictions were probably based on inaccurate rate coefficients.

Ozone depletion has really been a public matter after the paper of Farman et al. (1985), showing that in Antarctica there was an ozone hole under development, and indicating that man-made chlorofluorocarbons may play an essential part. Major field campaigns have recently concluded that chlorine is an

essential catalyst in a complex mechanism of polar meteorology, heterogeneous chemistry and solar light, destroying ozone (see Turco et al. 1990 and references therein). Still the origin of the stratospheric chlorine has to be found, and it seems to be too early to indicate that the presence is majorly due to man-made emissions.

Volcanic eruptions may place every year as much chlorine in the stratosphere as the entire global industrial production, which is $2 \cdot 10^{12}$ g by the order of magnitude (Symonds et al., 1988). Still greater amounts are emitted into the troposphere from the sea and the biosphere, but the ability to reach the stratosphere before washed out is limited.

The Antarctic ozone hole is indeed an interesting geophysical phenomenon, and therefore search for a similar Arctic ozone depletion has been carried out. It is evident that the Antarctic ozone hole, funded by the study of Farman et al. (1985), was present in the Antarctic already by the first ozone measurements during IGY, 1956-59 (Dobson, 1968). However, the pioneering study of Dobson (1968) was not cited by Farman et al. (1985), and therefore the long-term perspective of ozone development in Antarctic is not properly noticed (Larsen and Henriksen, 1991).

An eventual Arctic ozone hole will have stronger biospherical impact, since in the Arctic more open water and life are present. As a consequence of the importance of the behaviour of the Arctic ozone content AASE was performed, having base at Sola Airport in Southern Norway. It used aircrafts passing Norway and neighbouring areas of the Arctic with in situ, integrating, and remote sensing stratospheric measurements. Results from this expedition are published in March Supplement of Geophysical Research Letters, 1990. The results are presented without any reference or comments to the long-term ozone measurements carried out in the northern European sector. Therefore we would like to show the data as they may be useful as reference for short-term studies as AASE.

Ground-based ozone measurements in the Scandinavian sector

Ground-based measurements of the atmospheric content of ozone have been carried out in Tromso since 1935. Most of the time the Dobson spectrophotometer no. 14 has been used. The data until 1969 has been normalized by Bojkov (1988) and statistical analysis of the data set is carried out by Henriksen et al. (1992), showing no depletion in the ozone content. The weekly or monthly variations can exceed 50%, indicating that the Arctic ozone layer is dynamic and strongly varying. It needs much research to physically understand its behaviour, but many of the large scale variations can be related to stratospheric winds and transport (Rabbe and Larsen, 1992a).

In the Scandinavian sector three additional ozone observing stations have been established since 1978. They are Norrkoping, Sodankyla, and Oslo. Murmansk, St. Petersburg, and Reykjavik have been operating since IGY. The ozone variations measured in the Scandinavian stations are strongly correlated, showing correlation coefficients around 0.9 (Taalas and Kyro, 1992). This high correlation indicates that the daily ozone variations appearing on each station, are caused by large scale processes affecting the whole area.

In connection with the cyclonic development in the North-Atlantic Ocean tropospheric and stratospheric air are mixed, causing both ozone increase and decrease (Rabbe and Larsen, 1992b). Therefore during a few days variations exceeding 50 per cent in total ozone column densities often happens. Because of these great natural variations ozone trend analysis must be based on many years of data. It is most likely impossible to determine lasting depletion of stratospheric ozone by anthropogenic impact during short-period campaigns.

During the AASE campaign large ozone variations were measured in Scandinavia and Iceland and shown in Fig. 1. The winter high appeared one month earlier than normal, and in late January a mini-hole appeared recently discussed by Larsen and Henriksen (1990).

Discussion

Since the observing ozone stations in the Scandinavian sector have several years with daily measurements, the annual variations are obtained and should be used as reference for measurements obtained in shorter periods. During the AASE campaign ozone decreases as much as 100 DU in late January and in February increases 100-200 DU rela- tive to the used annual mean curve, see Fig. 1. In this study data from Reykjavik, Oslo, Tromso, Sodankyla, Murmansk, St. Petersburg, and Heiss Island are used. In one of the graphs the mean annual ozone density curve obtained at Tromso is used as reference, but in Reykjavik the reference curve is derived from the Reykjavik data during the period 1977-1990. The ozone increase in February 1989 was also measured by lidar in Ny-Alesund, Svalbard (79° N, 12° E) and classified as stratospheric warming by Neuber and Kruger (1990). This ozone increase was also observed by TOMS (Newman et al., 1990).

During the AASE campaign Browell et al. (1990) measured a 17 per cent decrease in the southern part of the polar vortex relative to the ozone amount closer to the pole on the flights on February 9 and February 17. These decreases were considered as essentially caused by chemical 0_3 destruction. The decrease is not relative to an established bias, but relative to the instantly measured density at latitudes north of 80° N.

Enhanced levels of chlorine compounds (Brune et al., 1990) and presence of polar stratospheric clouds (Newman et al., 1990) were observed during AASE, and Isaksen et al. (1990) used these measurements in a two-dimensional model

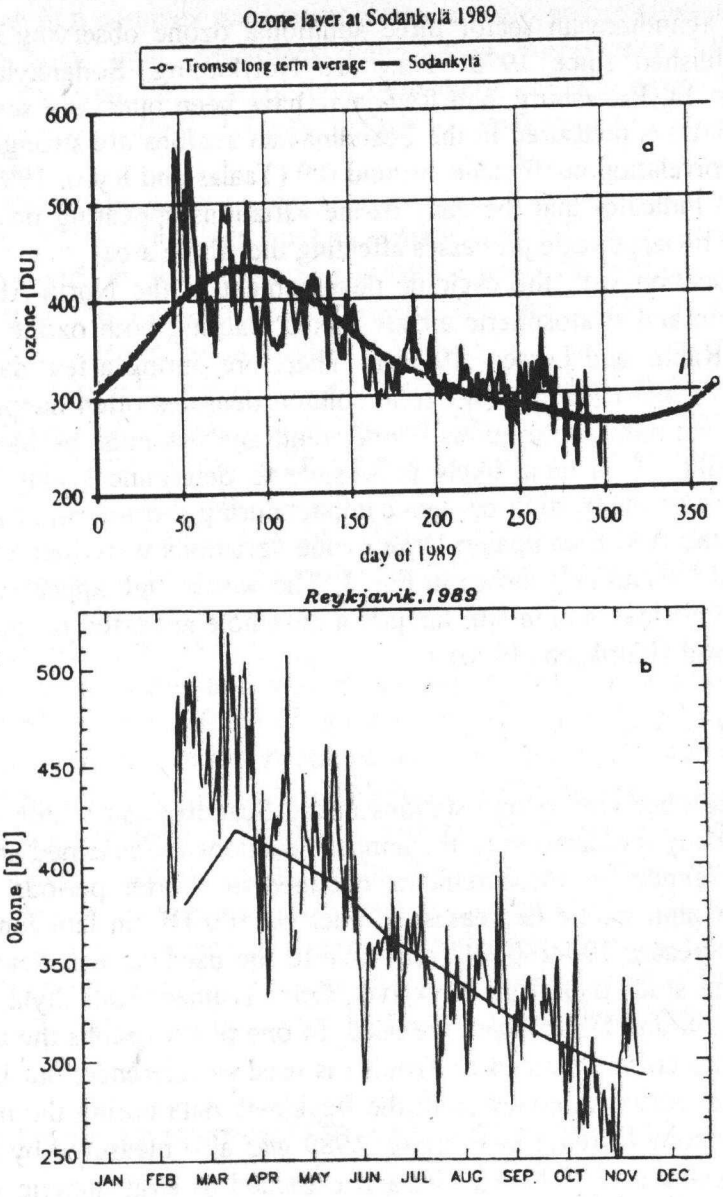

Fig. 1. Ground-based ozone measurements of the ozone column density at a) Sodankyla and b) Reykjavik. The graphs for Sodankyla is shown with the annual variation obtained in Tromso during the period 1935- 1969 as a reference, and in panel b) data from Reykjavik during the period 1977-1990 are used for the mean annual variation.

giving a 5-8 per cent ozone decrease in late March at 70° N. The model calculations of Isaksen et al. (1990) do not tell anything about enhancements and large temporal variations throughout March, and these variations efficiently mask an eventual minor chemically caused depletion. Studying the long-term

measurements it is really hard to point out any variations to be essentially due to chemical destruction, knowing the dynamic behaviour of the region. The spatially limited 17 per cent decrease reported by Browell et al. (1990) is not the characteristic feature for this period, but the 100-200 DU ozone increase r elative to long-term means.

It is evident that the ozone of the Arctic behaves different from the ozone of the Antarctic. This is documented more than twenty years ago (Dobson, 1968; Larsen and Henriksen, 1991). The large variations in the polar regions are most likely caused by combination of chemical and dynamic processes. There is of course need for future in situ expeditions which can reveal the acting chemical and physical mechanisms, but trends and reliable references can only be obtained by long-term measurements.

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