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LONG-TERM OZONE VARIATIONS AND CHANGES OF POLAR VORTEX

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Abstract. April values of the total ozone content in Arctic stations Tromso, Murmansk and Tixi bay have been compared with a characteristic of the polar vortex called a potential vorticity gradient. The high negative values of correlation coefficients are found: -0.92 in Tromso for 8 years, -0.88 in Murmansk for 14 years, and -0.82 in Tixi for 7 years of the date occurrence.

1. Introduction

The ozone in the lower stratosphere at high latitudes is brought there from low latitudes by poleward winds during winter and spring. One of the peculiarities of the global air circulation is the polar vortex which exists during a winter season at about 70^0. The influence of the vortex on the total ozone content is expected to be significant. Firstly, it does not permit the ozone rich air from the middle latitudes to reach the high latitudes. Then, there is an exchange of air masses of vortex with air in the middle latitudes during winter time, and the poor ozone air from the vortex exhausted by PSC is ejected into the middle latitudes what decreases the ozone in there. The vortex is stronger in the Southern hemisphere than in the Northern one, and this difference is the cause of low ozone content in Antarctic and of so-called 'ozone holes' there. Some changes of the vortex must be reflected in ozone changes at the high latitudes.

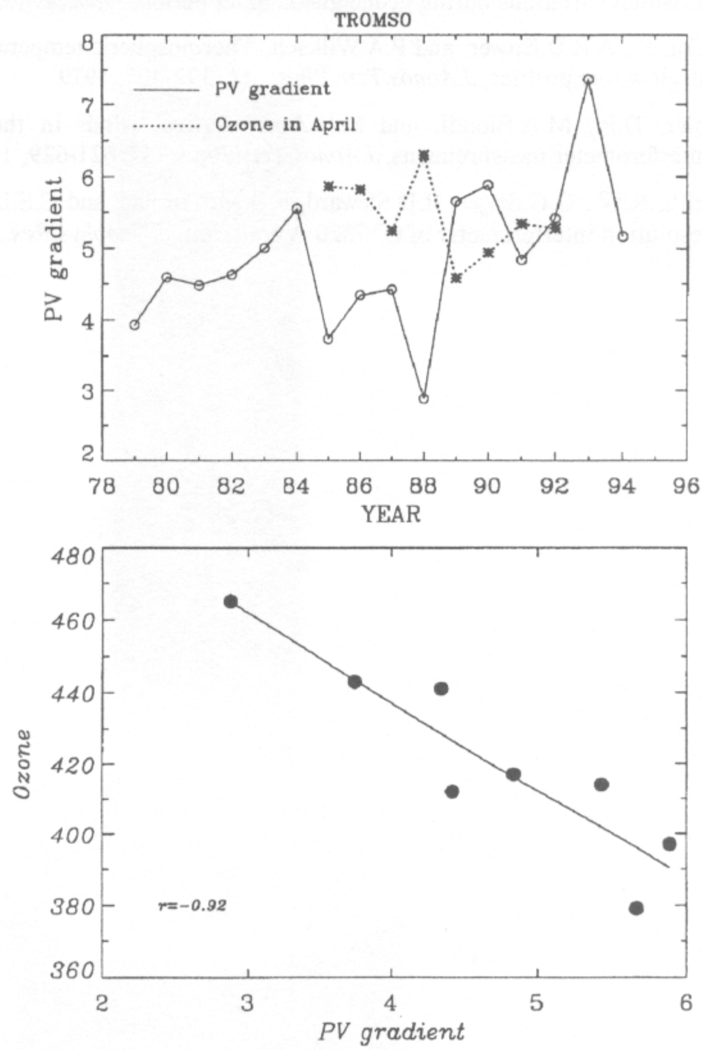

Fig.1. Comparison between the PV gradient in the polar vortex and the total ozone content in Tromso in time-dependent (top) and correlation field (bottom) patterns. PV gradient is shown in 10^{-6} [deg s]$^{-1}$ units. The correlation coefficient *r* is shown.

Behaviour of the Arctic polar vortex during last winters is a subject of thorough investigations. *Dahlberg and Bowman* [1994] have examined ejection of vortex air and entertainment of mid-latitude air into the vortex in the lower stratosphere for 14 winters from 1978-79 until 1991-92. Big differences in this exchange were found both between adjacent months and for different years as well. The transported air flux varies from 0 to 100% within a month. *Manney et al.* [1994] investigated a position and value of the Arctic vortex during 16 winters, from 1978-79 till 1993-94. They calculated area integrals of potential vorticity (PV) on the 465 K isentropic surface for each day of the time interval from 1 December through 29 April, and have presented 11 levels of them as contours in time-latitude coordinates for each winter. It is seen in those pictures that during this 16 years period the vortex becomes predominantly stronger and stronger and moves southward.

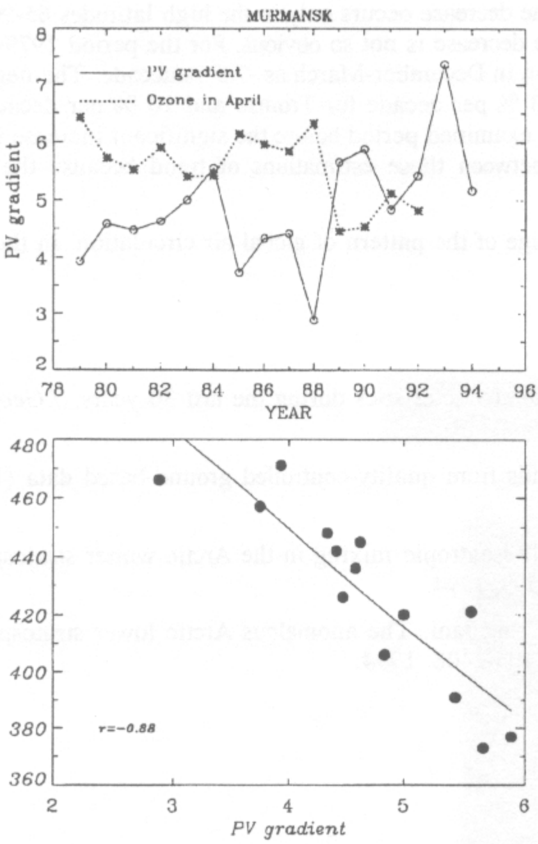

Fig.2. Comparison between the PV gradient and the total ozone content, as in Figure 1, for Murmansk

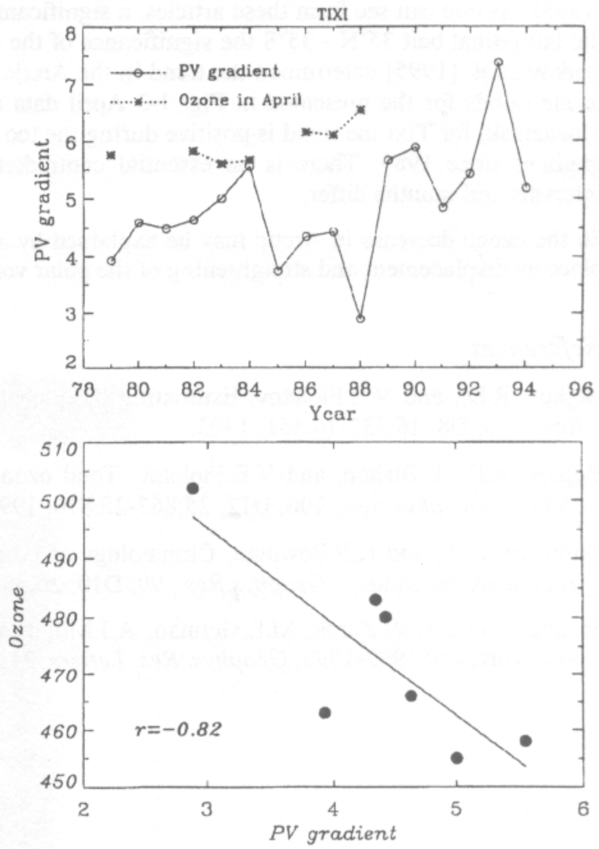

Fig.3. Comparison between the PV gradient and the total ozone content, as in Figure 1, for Tixi.

2. Discussion of results

It is interesting to compare vortex changes with the total ozone variations at high latitude stations. *Manney et al.* [1994] have presented the average PV latitudinal gradient for each winter as a simple scalar characteristic of the vortex. We have used the total ozone data of Arctic stations Tromso (69.8^{0}N, 19.0^{0}E), Murmansk (69.0^{0}N, 33.0^{0}E) and Tixi bay (71.6^{0}N, 128.9^{0}E) for this 16 years period. Here maxima of ozone occur in April as a rule. Before the April the south wind brings the ozone, after April the polar vortex does not exist. The April ozone value shows how much of ozone has been brought during winter-spring to the high latitudes. So the comparison of the total ozone content and the PV gradient was made for April. For Tromso we have only 8 Aprils during the years of 1985-1992, for Murmansk we have 14 Aprils and for Tixi there were 7 Aprils for the period of 1979-1992.

PV gradient was drawn out from Fig.3 of *Manney et al.* [1994]. The authors perform 3 types of PV gradient; we have used PV gradient excluding zero data, but this is not essential, because two others show very similar dependence. Units are 10^{-6} [deg s]$^{-1}$.

In Fig.1 the picture for Tromso is shown. The comparison is performed both in time-dependence form (top) and in correlation field form (bottom). Very good negative correlation is seen visually, the correlation coefficient is -0.92. The similiar picture for Murmansk is shown in Fig.2. The apparent anticorrelation is seen also, the correlation coefficient is -0.88. For Tixi, see Fig.3, the correspondence is the same, and the correlation coefficient is equal -0.82. The regression coefficients have the same order: for Tromso it is 25, for Murmansk it is 34 and for Tixi it is 17 DU per 1.0 10^{-6} [deg s]$^{-1}$.

Such a comparison was made also for high-latitude Reykjavik (64.1^{0}N, 21.9^{0}W) with 12 Aprils in the mentioned interval. The result differs too much from the previous ones: strong scattering on the correlation field, insignificant positive correlation +0.23. The same situation is obtained for other mid-latitudinal stations: Leningrad, Moscow, Aral Sea, Karaganda.

As *Manney et al.* [1994], we connect the ozone decrease in the last years with replacement and strengthening of the polar vortex. The global ozone changes were investigated by *Bojkov and Fioletov* [1995] and by *Bojkov et al.*

[1995]. As one can see from these articles, a significant ozone decrease occurs only in the high latitudes 65-90^0; in the latitudinal belt 35^{0}N - 35^{0}S the significance of the ozone decrease is not so obvious. For the period 1979-1994 Bojkov et al. [1995] determined the trend in the Arctic region in December-March as -7.5 %/decade. The negative ozone trends for the presented in Figs.1-3 April data are 13 % per decade for Tromso and 10 % per decade for Murmansk; for Tixi the trend is positive during the too short examined period before the significant increase in PV gradient since 1989. There is no essential contradiction between these estimations of trend because the used intervals and months differ.

So the ozone decrease in Arctic may be explained by a change of the pattern of global air circulation, in the first place by displacement and streightening of the polar vortex.

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