State of the ozone layer

Over the last several decades, the clearly visible changes in the quantity and spatial distribution of ozone in the atmosphere has become a significant problem at the global scale. They caused much concern both of the scientific communities, and the public, mostly because ozone absorbs ultraviolet solar radiation, which is harmful to human health and the environment (UV-B).

According to the provisions of the Convention for the Protection of the Ozone Layer, signed in Vienna in 1985, to protect human health and the environment against the adverse effects resulting or likely to result from human activities which modify or are likely to modify the ozone layer, the parties shall, in accordance with the means at their disposal and their capabilities, "co-operate by means of systematic observations, research and information exchange in order to better understand and assess the effects of human activities on the ozone layer and the effects on human health and the environment from modification of the ozone layer."
Furthermore, the parties declare in the Montreal Protocol to „protect the ozone layer by taking precautionary measures to control equitably total global emissions of substances that deplete it, with the ultimate objective of their elimination."

The content of ozone in the atmosphere greatly determines the volume of ultraviolet radiation (UV-B) reaching the surface of the Earth. As is known, the radiation may be harmful to all living organisms, and the increase in its intensity may cause damage to natural ecosystems, including also adverse effect on human health (rise in cancer and cataract rates and adverse impact on crops and livestock). Moreover, it is of significant importance that the changes in spatial distribution of ozone may contribute to changes in atmospheric circulation both at a regional and global scale by modification of the thermal structure of the atmosphere. It is generally agreed that the main cause for the occurrence of shortages of ozone in the stratosphere is the presence of anthropogenic chemicals in the atmosphere, particularly chlorine and bromine, which, as a result of a whole chain of chemical processes, in certain meteorological conditions, may lead to mass decomposition of ozone particles. Although, thanks to the meeting the recommendations of the Montreal Protocol, the pace of inflow to the atmosphere of compounds containing chlorine and bromine, such as freons and halons, has been reduced, due to their long lifetime, their concentration in the stratosphere remains high.
The time of "repair" of the ozone layer may be extended due to the cooling of stratosphere caused by greenhouse gases (the greenhouse effect causes increase in the temperature in the troposphere and decrease in the stratosphere). Therefore, in conducive meteorological conditions, significant shortages of ozone may exist for many years.
Measurements of the total content of ozone have been carried out for over 40 years in many research centres all around the world. As a result of human activities, at the global scale, the level of total content of ozone was in 1995 lower by 3.5%, and in 2008 by 2.5% than the average value from the years 1964-1980, when the ozone layer was not under such strong anthropopressure. An increase in the total ozone content by about 1% in the years 1995-2008 at the scale of the globe is probably a result of the decrease in the content of substances depleting the ozone layer in the atmosphere.

Since the beginning of the 1980s, the ozone layer has been significantly depleting, except for tropical regions. At the northern hemisphere, in 2008, the average level of total ozone content was lower by 3.2% (max. 5% - in winter, min. 2.5% - in summer) in comparison to the average values from the years 1964-1979. At the southern hemisphere, in the belt of mid-latitudes, the shortages of the total ozone content amounted in 2008 to 7% (max. 7.7% - in summer, min. 6.4% - in autumn), so they did not show much variation during the year. In the polar zone at the southern hemisphere, each year, at the end of winter and the beginning of spring, there occurs ozone depletion lasting until the end of spring with average shortages of the total ozone content reaching 60%. Over the Arctic, during extremely cool winter, there is observed locally low values of ozone, but in the winter period, on average, the total content of ozone decreased by 10% in relation to the values from before 1980.
In Poland, measurements of the total ozone content have been carried out since March 1963 in the Central Geophysical Observatory of the Institute of Geophysics of the Polish Academy of Sciences in Belsk. As results from the research performed there, the ozone values are typical for mid-latitudes at the northern hemisphere (Fig. 5.7.1.). The content of ozone over Poland, in the period December-February, is now 8% lower than in the years 1963-1979 (that is before the period of intense polluting of the atmosphere with substances depleting the ozone layer). In summer and autumn, the thickness of

the ozone layer was only about 3% lower than in the years 1963-1979.

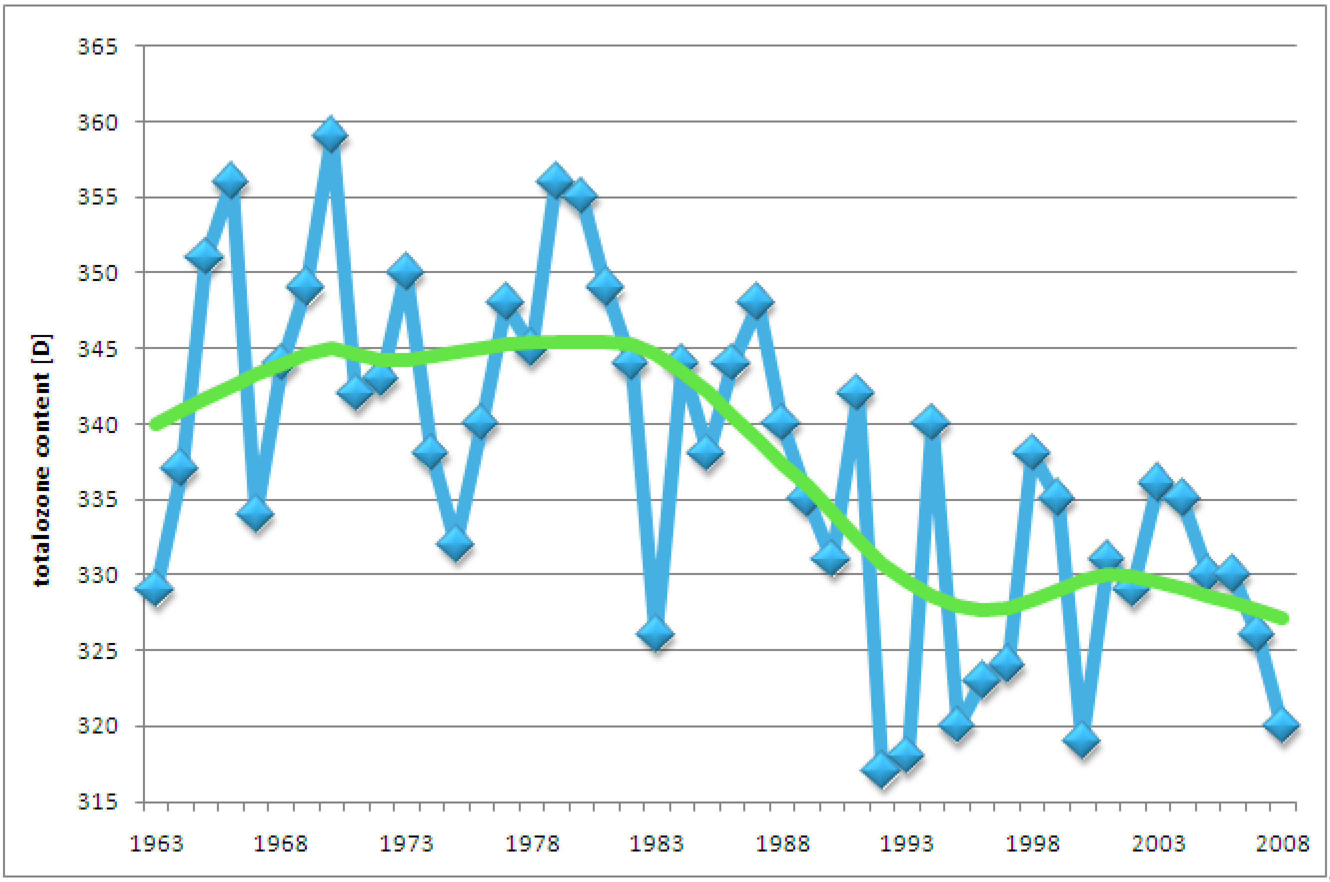
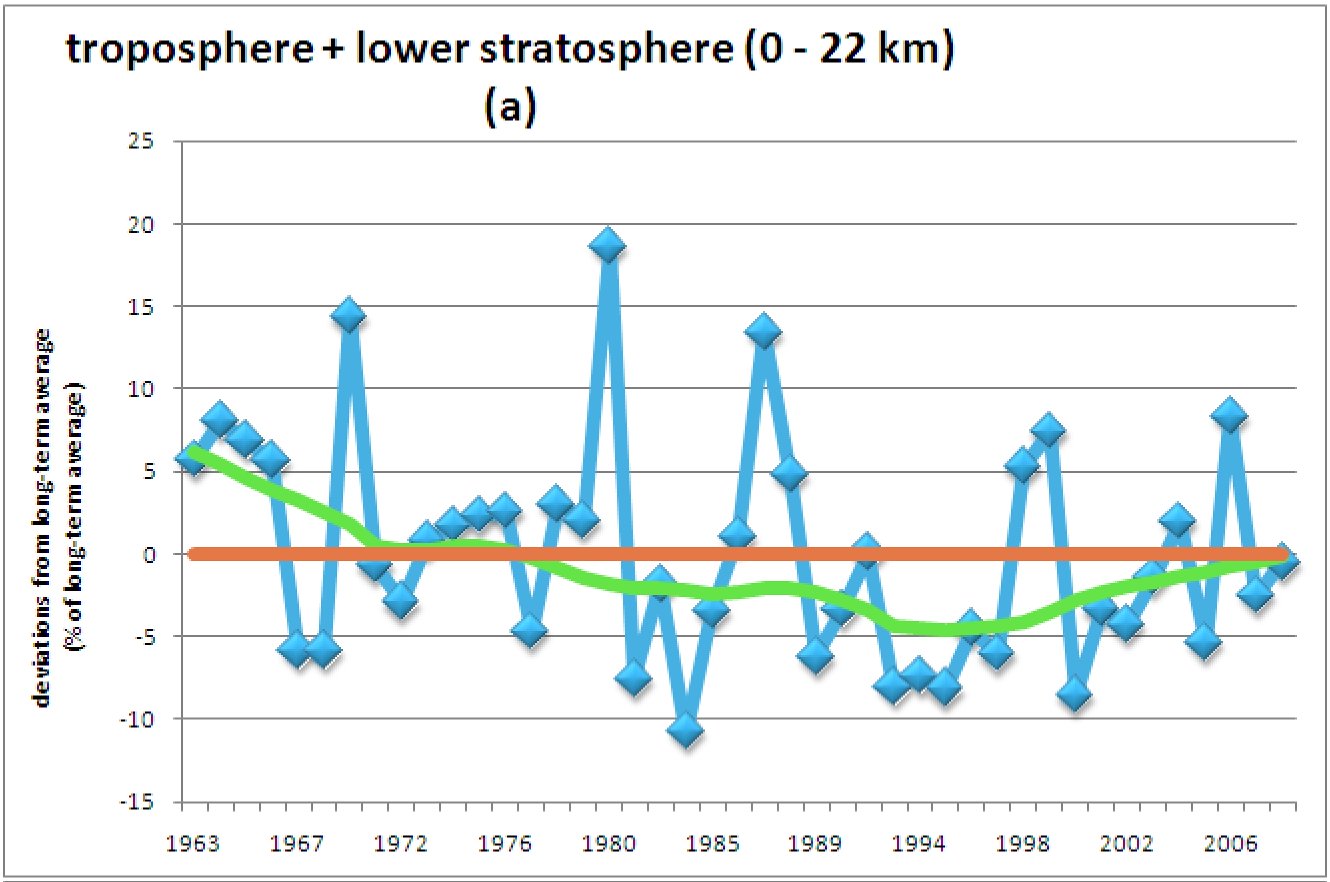


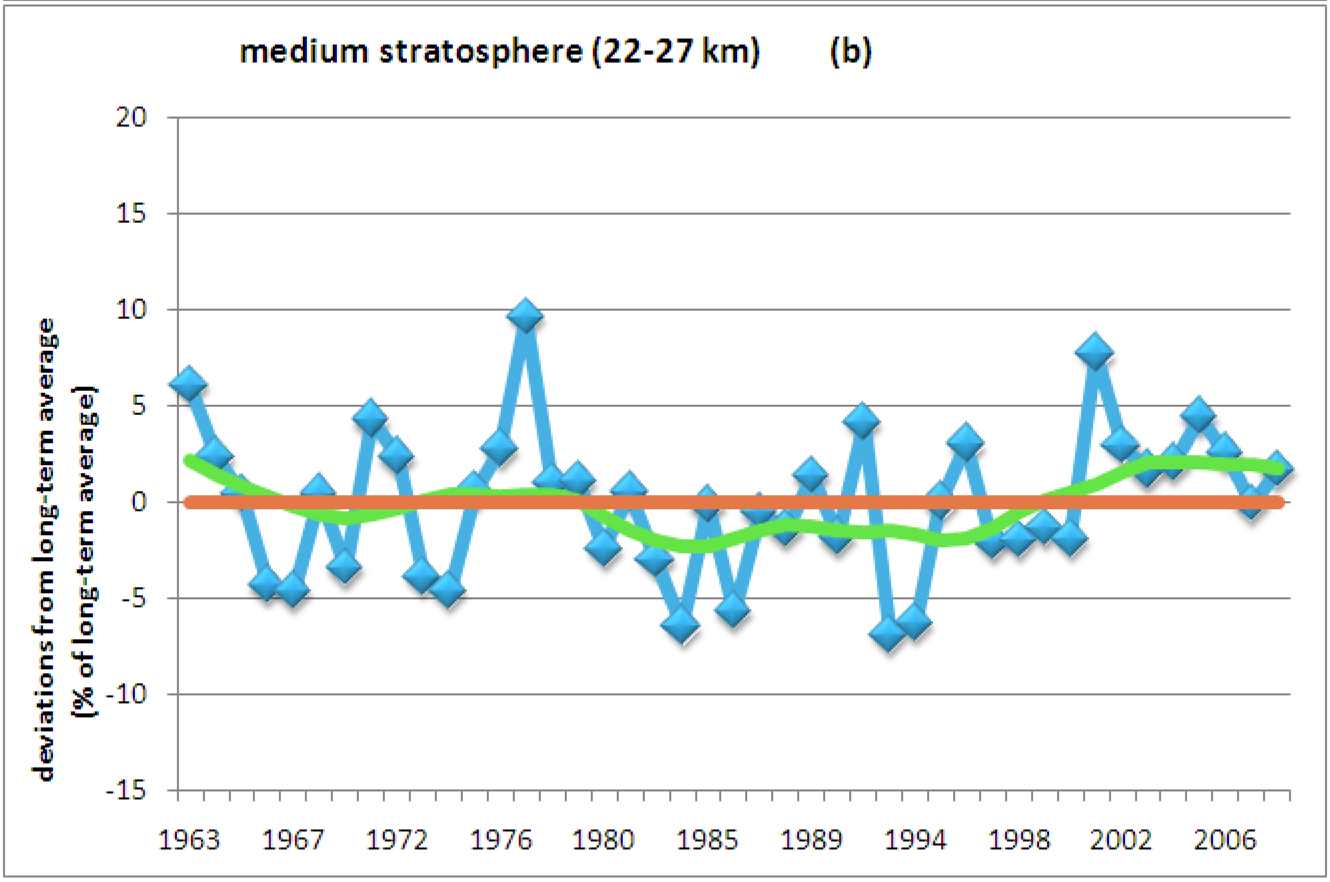
Fig. 5.7.1. Changes in the total ozone content in the atmosphere (annual average) measured in Belsk in the years 1964-2008 (source: CIEP/SEM)

What is particularly interesting is the variability of the trend in vertical profile, as it is believed that repair of the ozone layer will start from the high-temperature areas in high stratosphere, where changes in the processes of chemical destruction of ozone are easiest to observe due to limited impact of changes in the dynamics of atmosphere and chemical composition of the atmosphere on the concentration of ozone at those heights.

It should be noticed that the tendency of ozone content in the upper layer of the atmosphere is still downwards, unlike the tendency in the middle layer of the atmosphere (positive tendency since the mid-1990s) and troposphere and the lower layer (stabilisation of the level of ozone since the mid-1990s) (Fig. 5.7.2.). It suggests that lack of deterioration of the downwards tendency in atmospheric ozone in mid-latitudes is also a result of changes in the dynamics of the atmosphere, rather than only a result of decreasing of the content of substances depleting ozone in the stratosphere.



troposphere + lower stratosphere (0 - 22 km)
(a)
deviations from long-term average
(% of long-term average)
25
20
15
10
5
0
-5
-10
-15
1963
1967
1972
1976
1980
1985
1989
1994
1998
2002
2006



medium stratosphere (22-27 km)
(b)
deviations from long-term average
(% of long-term average)
20
15
10
5
0
-5
-10
-15
1963
1967
1972
1976
1980
1985
1989
1994
1998
2002
2006

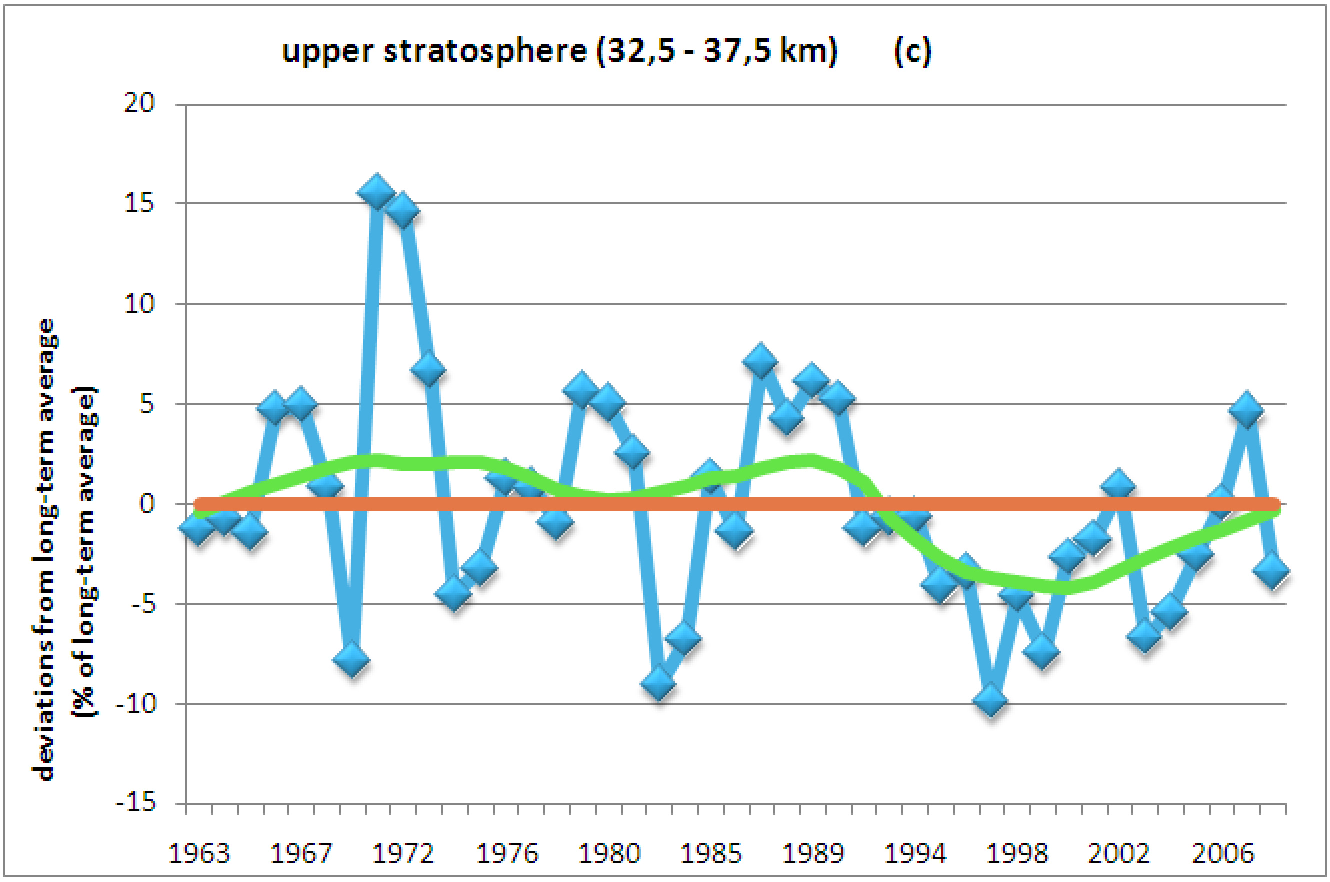


Fig. 5.7.2.Changes in the ozone content in different layers of the atmosphere (source: CIEP/SEM)

Changes in the profile of ozone are, beside total ozone content, one of the factors affecting the value of UV-B radiation reaching the Earth's surface. Measurement results reveal a correlation between the fall in the total ozone content in the atmosphere and the growth in the intensity of solar UV-B radiation at the Earth's surface (Fig. 5.7.3.). The trend for UV-B radiation is positive and statistically relevant. At our latitudes, the effect is often weakened by cloud cover.

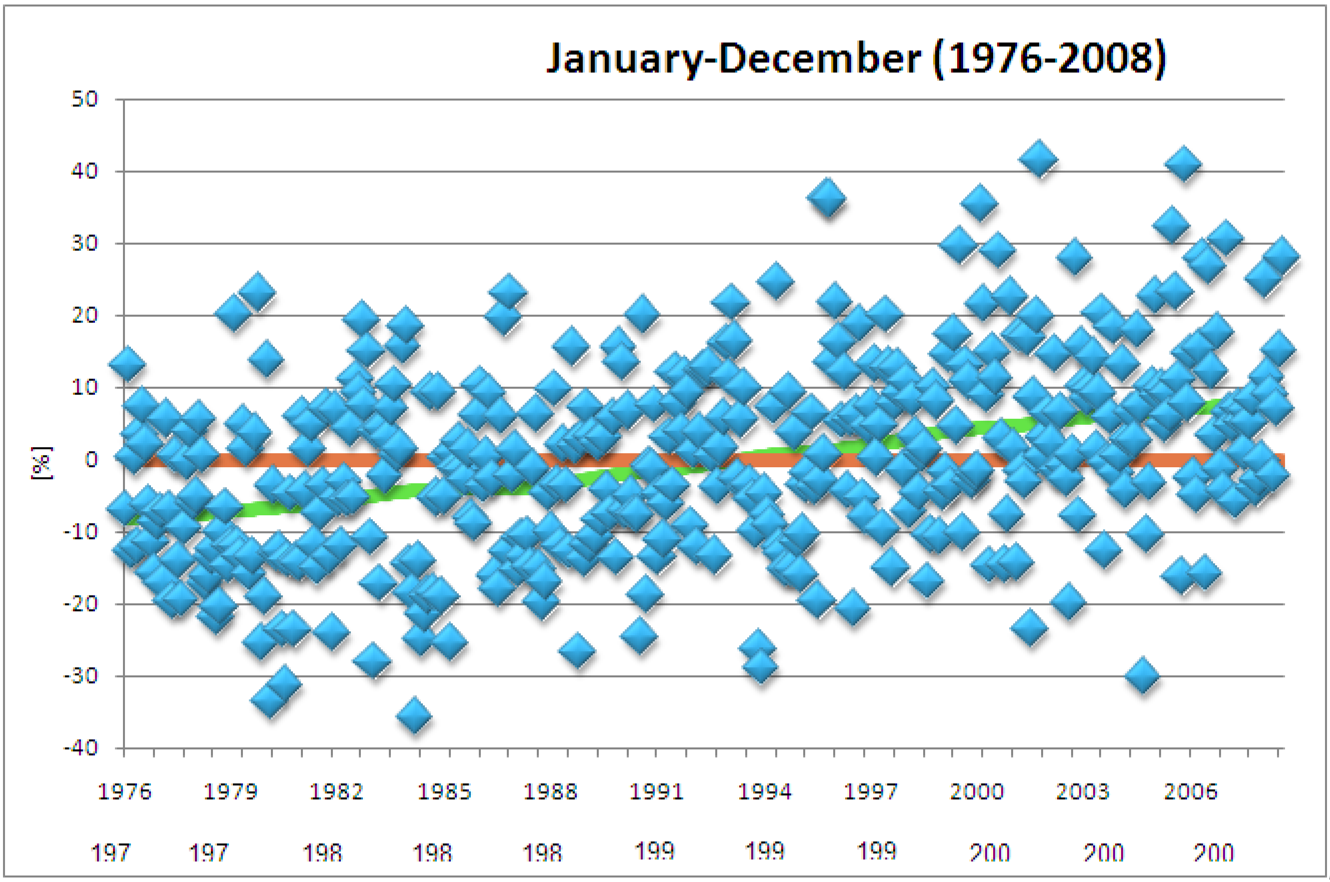


Fig.

5.7.3. Changes in the UV -B radiation in the years 1976-2008, deviations from monthly average doses of UV from long-term averages (source: CIEP/SME)

The state of the ozone layer is greatly affected by emissions to the atmosphere of anthropogenic chemical compounds containing chlorine and bromine, such as freons and halons. The compounds at the Earth's surface level seem to by neutral and very durable, while elevated high into the stratosphere under the influence of intense solar radiation they decompose releasing chlorine and bromine, destroying the ozone exponentially. Very low temperature (below – 78^{o}C) is a factor contributing to such processes, enabling the occurrence of the so-called polar stratospheric clouds. As a result of the reactions on the surface of particles of those clouds, the number of particles of active chlorine rises, and, as a consequence, the destruction of ozone particles intensifies. Despite the fact that the pace of inflow to the atmosphere of compounds containing chlorine and bromine (e.g. freons and halons) was decelerated, due to their lifetimes, their concentrations in the stratosphere still remain high. In conducive meteorological conditions, significant shortages of ozone may occur in the nearest years in polar and mid-latitudes of both the southern and northern hemispheres.
Compounds containing chlorine and bromine are still used in various kinds of devices in the cooling, insulation, pharmaceutical and cosmetic industries. In Poland, in the years 1986-2007, there took place a clear decrease in the use of substances depleting the ozone layer, that is: HCFCs (fully substituted chlorine derivatives of hydrocarbons), CFCs (partially substituted chlorine derivatives of hydrocarbons), carbon tetrachloride, halons and methyl bromide. Their consumption dropped from 7960 tonnes in 1986 to 1560 tonnes in 2007 (Fig. 5.7.4.).

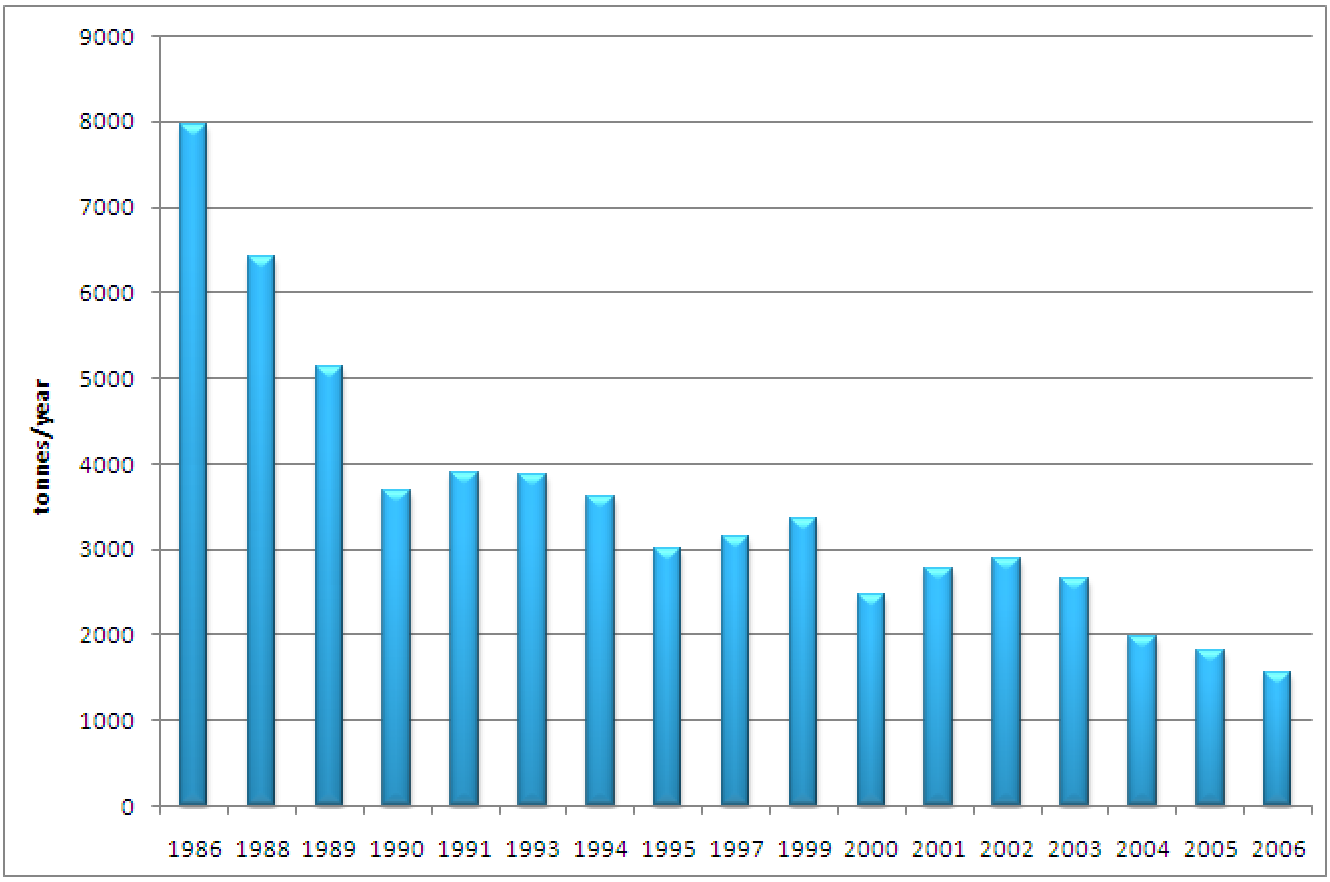


Fig. 5.7.4. Consumption of the ozone layer depleting substances in Poland (source: CSO)

The basic actions aimed at prevention of the depletion of the ozone layer are related to meeting the obligations under the Montreal Protocol, the major objective of which is complete reduction of manufacturing and use of substances that deplete the ozone layer. The substances covered by control of the Montreal Protocol belong to the group of chlorine derivatives of hydrocarbons and have various abilities to destroy ozone. Amendments to the Montreal Protocol made it necessary to replace compounds destroying the ozone layer with other less aggressive substances, according to the principle of "cleaner production." The strategy of reduction of production and consumption of substances depleting the ozone layer in Poland is consistent with the Montreal Protocol and its amendments, which has been legally determined in the Act of 20 April 2004 on substances that deplete the ozone layer. The basic regulation of the Act on substances that deplete the ozone layer is full adjustment of the Polish law in the scope of the problem of treatment of substances that deplete the ozone layer to the law of the European Union.

The Act on substances that deplete the ozone layer lays down:

- the principles of using and trading in substances that deplete the ozone layer, hereinafter referred to as “controlled substances,” as well as products, devices and installations that contain these substances,
- the obligations of entities using or trading in the controlled substances and products, devices and installations containing these substances,
- the bodies and entities competent in issues related to the treatment of the controlled substances.

A list of controlled substances is included in the Regulation (EC) No 1005/2009 of the European Parliament and of the Council of 16 September 2009 on substances that deplete the ozone layer (Text with EEA relevance). It includes, among others, substances from the groups of: HCFCs, which are used mainly in the cooling and air-conditioning sector, CFC freons or carbon tetrachloride, halons or methyl bromide. The compounds, due to their harmful effect on the natural environment, may be used only in closed systems, so that they would not get to the atmosphere. Industrial plants, which manufacture, use or consume the substances, have been forced to re-consider their application, and eventually give up using them. It also pertains to CFCs and HCFCs, which contribute both to the destruction of the atmospheric ozone layer, and contribute to the occurrence of the so-called greenhouse effect.

Measurements of the content of substances that deplete the ozone layer, in particular freons and halons, indicate that their concentrations at the Earth’s surface are systematically decreasing, while the increase in their content has not been found in the high layers of the atmosphere. It testifies to the efficiency of international actions to protect the ozone layer.

During the last few years, the relations between the issue of the fall in ozone concentration and climate change have been examined more closely.