Long-Term Variations of Ozonosphere: Physical Model and Forecast into XXI Century

V. V. Zuev
Institute of Atmospheric Optics
Russian Academy of Sciences
Tomsk, Russia

Introduction

Because of its ability to effectively absorb the shortwave portion of solar ultraviolet (UV) radiation, ozonosphere plays an important role in determining the radiation budget of the atmosphere. Therefore, general circulation model (GCM) predictions of climate change cannot be made correctly without adequate treatment of real tendencies in ozonosphere behavior. The widely accepted anthropogenic theory of ozonosphere destruction fails to completely explain present-day tendencies.

Current Behavior of Ozonosphere

Figure 1 shows the global distribution of total ozone trends (in percent per decade), calculated from EP/Total Ozone Mapping Experiment Spectrometer (TOMS) data for periods of observation from August 1996 to July 2000. From the figure, we clearly see the positive trend throughout most of the tropical zone and at Northern Hemisphere midlatitudes. This is in contrast with the commonly accepted anthropogenic hypothesis that, because of long-lived technogenic freons and halons released into the troposphere before 1987 Montreal protocols, the negative total ozone trend must persist for a few more decades.

At Siberian Lidar Station (SLS), Tomsk, between 1996 and 1999, we performed optical observations of total ozone and vertical ozone distribution (VOD) in the stratosphere. We found that a weak positive total ozone trend (Figure 2) is determined by an ozone increase only in the lower stratosphere (Figure 3), where ozone is just a conservative admixture, a tracer of dynamical processes. This is again contrary to views of the prevailing role of photochemical processes in long-term changes of ozonosphere (i.e., what the anthropogenic hypothesis relies upon).

New Version: Physical Model

A new hypothesis is proposed here of the relationship between long-period variations of ozonosphere and slow changes in atmospheric general circulation under impact of secular solar cycle (Zuev 1998). It is based on the fact that the solar activity plays an important role in slow changes in the earth's rotational velocity (Kazimirovsky 1983). These changes, together with associated alterations of Coriolis force, influence the difference in zonal transport velocities at the axis of subrotation in the intratropical

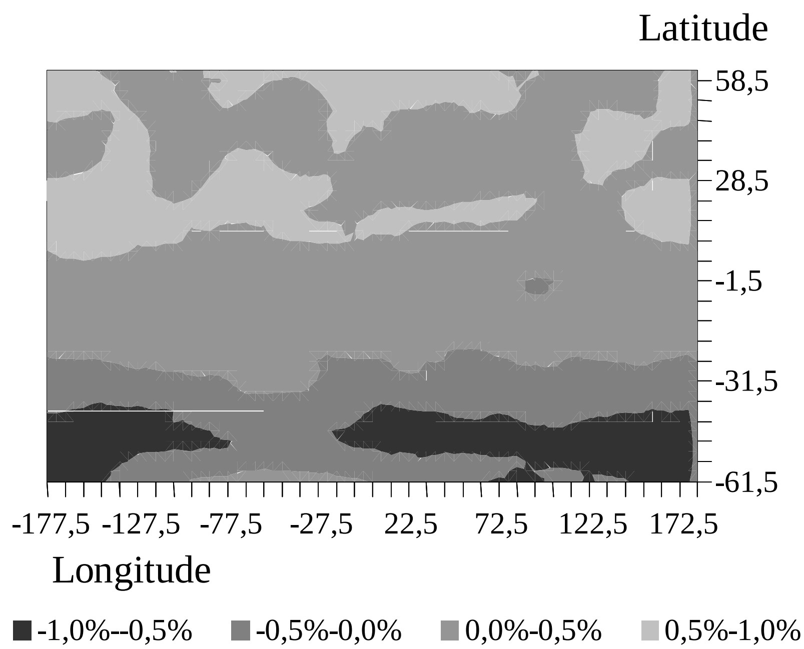

Figure 1. Global total ozone variation according to EP/TOMS data for periods of observation from August 1996 to July 2000.

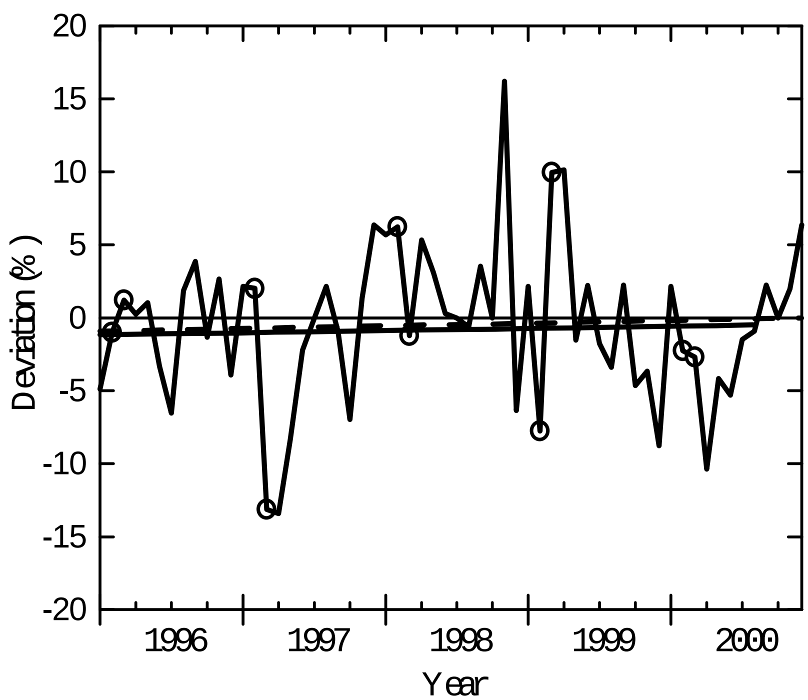

Figure 2. Total ozone variation over Tomsk according to ground-based observations from 1996 to 2000. Data for February and March are shown by circles. Linear trends are calculated both for entire measurement series and for total ozone measurements from February to March.

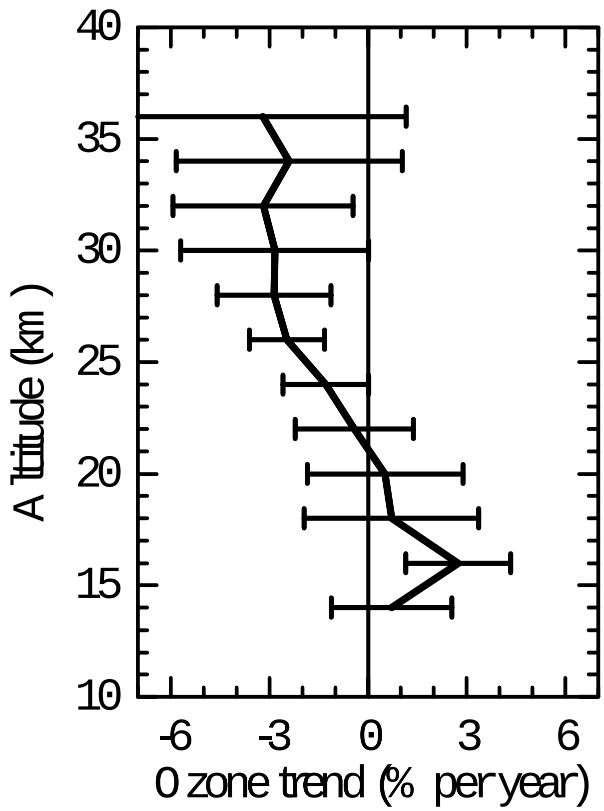

Figure 3. Vertical ozone distribution variation over Tomsk according to data of lidar observations from February to March 1996-1999.

convergence zone and at two axes of superrotation (in the Southern and Northern Hemispheres) in the regions of subtropical jet streams, the backbone of atmospheric general circulation (Monin and Shishkov 1999).

Thus, the secular cycle of solar activity modulates the long-term variations of atmospheric general circulation, which in turn, show up in long-term variations of ozonosphere.

The hypothesis proposed here agrees well with the behavior of the total ozone time series at Arosa from 1927 to 1999. This time series, smoothed using an 11-year running mean, is presented in Figure 4. In Figure 4, we clearly see the total ozone maximum in the 1940s to 1950s. From the standpoint of this new hypothesis, the time behavior of total ozone reflects an incomplete phase of long-period quasi-cyclic oscillation of ozonosphere. If a sinusoid is used to fit this time series, its period is about 97 years, comparable with the secular cycle of solar activity.

Also, the above-described mechanism by which secular solar cycle influences slow variations of atmospheric general circulation explains clearly the high negative correlation (-0.81) between the total ozone time series at Arosa and January mean pressure at the center of Azores High, first pointed out by Kruchenitskii et al. (1996).

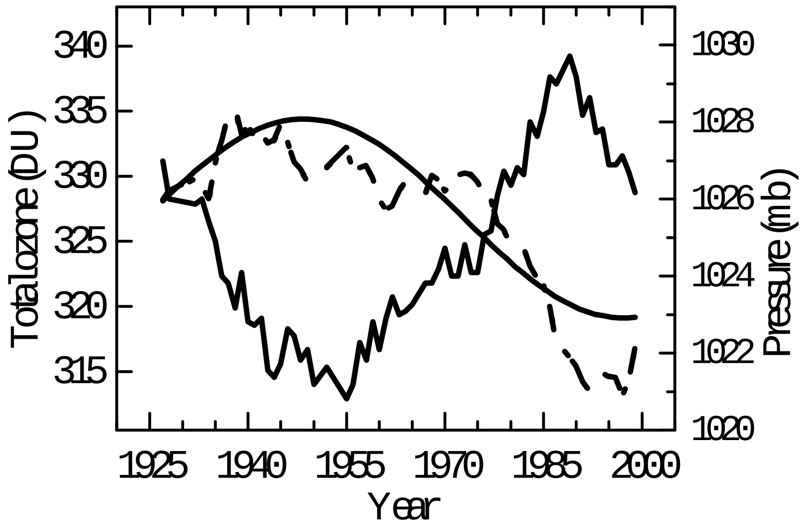

Figure 4. 11-year running-average total ozone at Arosa (dashed line) and January mean pressure at the center of Azores High (solid line) for the period 1927 - 1999, together with sinusoidal fit of total ozone time series.

The Azores High is classified as a quasi-stationary center of atmospheric action. Its formation mechanism is associated with Helmholtz instability due to anticyclonically sheared velocities of zonal transport between super- and sub-rotation axes in the Northern Hemisphere (Monin and Shishkov 1999). Thus, the slow changes in activity of Azores High are also modulated by secular solar cycle, like the corresponding total ozone variations at Arosa.

Discussion and Summary

The suggested version of hypothesis of long-period global variations of ozonosphere under impact of secular cycle of solar activity indicates that, at the frontier of the 20th to 21st centuries, there occurs a change in phase of variations. In the future, we should expect a gradual growth of total ozone, primarily at mid- to high-latitudes, with forthcoming passage through the next maximum in the middle of the 21st century.

An attempt has also been made to interpret this same total ozone time series at Arosa from an official anthropogenic hypothesis perspective, as illustrated in Figure 5 (reproduced from http://www.lapeth.ethz.ch/doc/chemie/tpeter/totozon.html). The “hockey-stick”-shaped trend identifies the steady-state region of ozonosphere until the 1970s, followed by period of its destruction.

As was already noted above, this model contradicts the actual current development of ozonosphere. The official anthropogenic and new natural hypotheses predict opposite tendencies of the development of ozonosphere in the first half of the 21st century; and in the 2030s and 2040s of the21st century they may diverge by more than 20 percent. Thus, incorrect treatment of tendencies of ozonosphere development may lead to large biases in prognostic estimates of 21st century climate change.

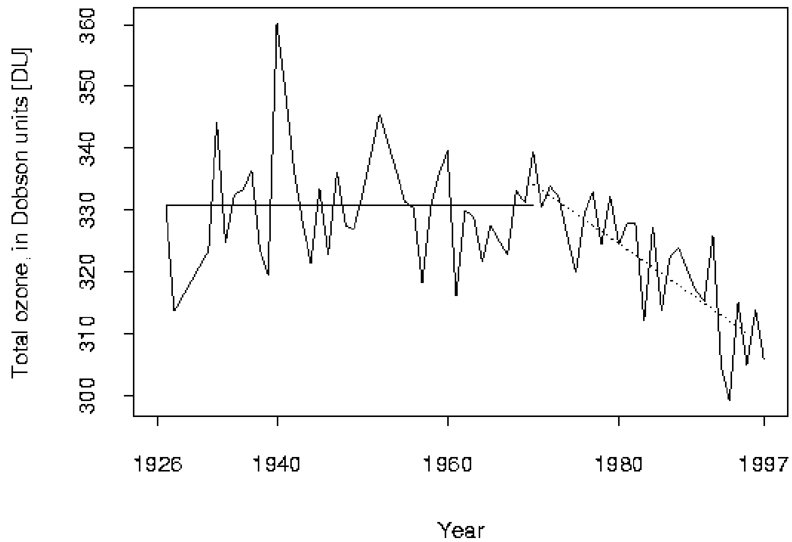

Figure 5. Total ozone yearly means at Arosa in 1926-1997 (reproduced from http://www.lapeth.ethz.ch/doc/chemie/tpeter/totozon.html).

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