LONG-PERIOD OSCILLATIONS OF OZONE AND STRATOSPHERIC AND TROPOSPHERIC METEOROLOGICAL PARAMETERS AS A RESULT OF EVOLUTION OF CLIMATE-FORMING ACTION CENTERS IN THE ATMOSPHERE

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The paper reviews work on investigation into the influence of Açores High and its evolution on the stratospheric and tropospheric meteorological parameters and total ozone (TO) in Europe and their evolution. Preliminary results have been obtained that indicate the close relationship between regions with minimum TO and the Siberian anticyclone. Based on 105-year observations of the Siberian anticyclone parameters, the sharp pressure rise in the center of the anticyclone has been revealed recently. It has also been found that the center of pressure travels to the west.

Regions with anomalously low ($\sigma > 2.5$) total ozone are usually connected with a baric ridge in the troposphere or in the lower stratosphere[1] (up to 100 hPa level) or with a center of a circumpolar cyclone in the middle stratosphere.[2] In the first case the TO deficiency is due to low ozone concentration in the lower stratosphere below the ozone maximum and in the second case – due to low ozone concentration in the middle stratosphere above the ozone maximum.

In Europe, the second factor practically does not influence the TO depletion because the circumpolar low center is close to this region and its longitudinal travel may lead only to the TO increase. In recent years we have published a series of papers concerning the effect of the first factor on the winter TO depletion in Europe.[3–5] It was found out that a baric ridge in the troposphere and in the lower stratosphere was observed in the periods of the so-called Açores High action, i.e., travel of the anticyclone or its ridge from the subtropical zone of the Atlantic to Europe or to the North Atlantic, which is identified with a high latitude of the surface high-pressure center φ, a high pressure P in its center, and a good correlation between φ and P.

Açores High possesses two “quantumB states. It may affect only the lowest tropospheric layers and in this case, its effect on the TO field is negligible, or its influence may spread up to levels of about 100 hPa. The latter situation is observed at $P \geq 1030$ hPa and $\varphi \geq 40°$N. When such a situation arises on the map of average monthly baric topography, average negative values of TO deviation in Eastern Siberia exceed 30 Dobson units (D.u.). Otherwise, the TO deviations are positive or small negative.

The main argument of proponents of the theory of anthropogenic influence on ozone depletion is the obvious fact of sharp ozone depletion in recent years. Not a bit embarrassed by too short period of observation, the proponents call the TO depletion the negative ozone trend. But if the period is short, it is possible to use the parameters that define TO or related parameters.

A 103-year series of pressure P recorded in January in London and a 113-year series of the ground temperature deviations are shown in Fig. 1. In both cases, short-period oscillations were preliminary filtered out. A quadratic approximation of the average annual TO series measured at the station Arosa in Switzerland is shown here too. We can clearly see oscillations of the parameter P with 80-year period that are opposite in phase to the secular change of solar activity. The amplitude of oscillations is extremely high (it reaches 5 hPa). Especially sharp pressure rise P has been observed in recent years when the TO depletion in Europe becomes most pronounced. Thus, during 90 years since 1891 till 1980, the pressure P exceeded its critical value in January (1030 hPa) 10 times (11% recurrence), during 13 years since 1981 till 1993, such excess was observed 7 times (54% recurrence). From the stated above it is reasonable to suppose that TO oscillations with the same period but opposite in phase also occurred in Europe. The longest series of TO observations was obtained at the station Arosa in Switzerland (since 1927).

A quadratic approximation of average annual TO recorded at the station Arosa in Switzerland is shown in Fig. 1. The data were borrowed from Ref. 6. The fact that curves *2* and *3* are opposite in phase confirms our supposition. Certainly, annual averaging of TO values smooths out the effect. Presented in Ref. 6 coefficients of TO regression since 1927 till 1970 for different seasons

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confirm this conclusion. For the examined period, the coefficient of regression of the average annual TO values is equal to +0.06, and for average winter TO values this coefficient equals +0.17. Curve *1* shows the ground temperature deviations recorded in London over a period of many years. Its behavior is similar to curve *2* (with the exception for the 50 s). It is not surprising, because during Açores High action southern flows and descending motions are observed all over Europe (see below). So the two most important meteorological problems for Europe, i.e., ozone depletion and increased recurrence of warm winters in recent years connected with the increase of concentration of freons and carbonic acid gas in the atmosphere, should be considered as a single problem, especially so because the relationship of pressure, temperature, and TO was established already in the 30s (see Ref. 7). If the secular cycle of Açores High action really exists, now we will be close to its maximum and will expect the TO increase and the decreased recurrence of warm winters in Europe.

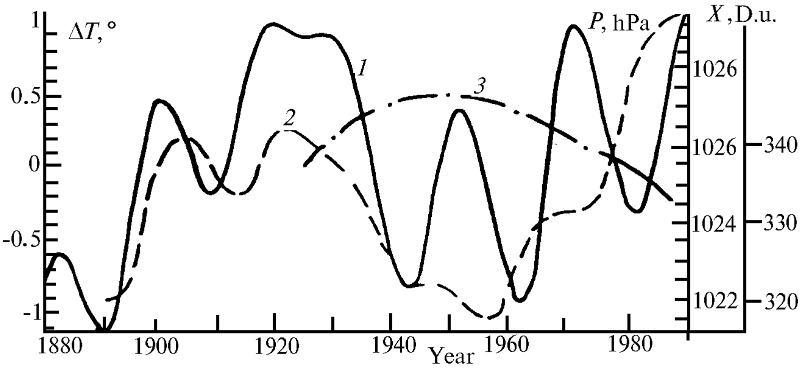

FIG. 1. Long-period oscillations of deviations from the norm of the ground temperature in London in January averaged over period of many years (curve 1), pressure in the center of the Açores High P (2), and quadratic approximation of average annual values of TO at the station Arosa (3).

Coefficients of regression were calculated for the parameters of Açores High P and φ as well as for the ground temperature in London since 1891 till 1993 (for 103-year period) and since 1979 till 1993 (for the last 15 years). It turned out that during the 103-year period all these parameters were insignificant, but in the last fifteen years they have increased 10–100 times and according to the Fisher criterion, become significant for a confidence level of 80% and more. With TO trends, the situation is similar. The results clearly illustrate the obvious fact that a conclusion about anthropogenic origin of the ozone trend drawn on the basis of observed large TO trend in recent years is controversial because the period of observations was too short. Nevertheless, this conclusion has received much recognition of Russian and foreign scientists. The large positive trends of P, φ, and ground temperature in London and the negative trend of TO in Europe observed recently probably should be considered as ascending and descending branches of a secular periodic function. Oscillations of Açores High parameters with 11 and 2 year periods were also recorded, but their amplitudes were small as compared with oscillations in the secular cycle.

Calculations with the use of the hydrodynamic equations revealed that vertical currents in the region of Açores High action were descending in the troposphere (with a velocity of 1–2 cm/s) and ascending in the middle stratosphere (with a velocity of 2–3 cm/s). This fact is of great importance for understanding of the relationships between atmospheric layers. In the middle stratosphere the ascending currents cause not only the TO depletion in accordance with the Normand–Dobson law (one-third of the TO deficiency is due to these currents and two–thirds are due to the southern flows), but the temperature drop as well. On the synoptic maps the regions with low temperature (the temperature deviations may reach 10°) were recorded on 50, 30, and 10 hPa levels, i.e., above the region of baric perturbation that reach 100 hPa level. Probably the increased recurrence of Açores High action in the last few years is one of the reasons for the negative temperature trend in the middle stratosphere observed recently.[3,8] The existing system of vertical currents has helped to elucidate the well-known TO correlation relationships with meteorological parameters, namely, its negative correlation with the pressure and temperature in the troposphere and positive correlation with these parameters in the middle stratosphere.

So in the region of Açores High action along with TO depletion the descending currents and temperature rise (including the ground temperature rise) are observed in the troposphere. Ascending currents and temperature drop are observed in the middle stratosphere.

To gain a better understanding of the mechanism of amplification of such large-scale non-zonal perturbations of the Açores High type and their penetration into the middle atmosphere, we used the method of numerical simulation and the model of planetary waves. In numerical experiments, we considered the effect of the lower boundary condition specified as perturbation of the geopotential and temperature on 500 hPa level on the latitudinal-longitudinal structure of the planetary wave. The calculated spectral characteristics of the planetary wave operator allow us to conclude that maximum amplification of non-zonal perturbation associated with Açores High action is observed when the latitudinal structure of a source at the lower boundary is close to that of the first eigenfunction of the planetary wave operator. Such a situation occurs in the 40°–50°N latitude belt when longitudinal temperature contrasts increase on the lower boundary, i.e., in the latitudes toward which the Açores High travels during periods of its action.

From the above it follows that the main reason for the ozone depletion in Europe in recent years is the increased recurrence of the Açores High action.

By now the results have been obtained concerning the evolution of another climate-forming action center – the Siberian High. In Figs. 2 and 3, the examples are shown that illustrate the relationship of TO with the baric situation that arose after spreading of perturbation due to the Siberian High into the troposphere and lower stratosphere in winter and spring of 1995 when the extremely low TO was observed in Siberia. The solid curves in these figures show TO isopleths recorded with the M-124 device. The dashed lines in Fig. 2 show the geopotential on a level of 300 hPa and in Fig. 3 – on a level of 500 hPa. The last level is taken because since 1995 the Russian Committee on Hydrometeorology ceased to produce maps of average monthly geopotential on levels of 300 and 200 hPa. But the structure of geopotential on these levels is practically identical. The data shown in Fig. 2 were recorded on February 2, 1995. Average monthly fields of TO and geopotential recorded in April of the same year are shown in Fig. 3. The similarity between the fields is obvious; moreover, the behavior of TO fields is the same as in the presence of the baric ridge due to Açores High action. However, there are some differences in the behavior of the Siberian and Açores Highs. Thus, the Siberian High travels along the latitude and the Açores High – along the longitude.

On the maps of average monthly baric topography the ridge in the troposphere and lower stratosphere induced by the Siberian High occurs more rarely than that induced by Açores High. Spreading of the perturbation due to the Açores High is more frequently observed in January and due to the Siberian High – in April. By the way, the baric ridge shown in Fig. 3 is most clearly seen.

Furthermore, in all maps of baric topography the ridge in the troposphere and lower stratosphere due to the Siberian High is situated to the west of 70°E, although the longitude of its center averaged over many years is at 100°E in winter, 95°E in March, 85°E in April, and 71°E in May. The 105-year changes of pressure in the center of the Siberian High are shown in Fig. 4 by the solid curve. The longitude of its center for January is also shown by the dashed curve in this figure with filtered-out short-period (up to 15 years) oscillations. Sharp pressure rise and rapid travel of the Siberian High center to the east are observed recently. We can only suppose that due to these effects the probability is increased of baric field perturbation penetration into the troposphere and lower stratosphere, i.e., in this region TO decreases. At the same time, the latitudinal trend of the Siberian High center is practically absent.

The main conclusion that can be drawn is the following. In recent years, we have observed sharp change of circulation. Obviously, this change is global in character. It encompasses the troposphere and therefore the stratosphere. So, not denying the possibility of anthropogenic influence on the ozone depletion observed recently, we should emphasize that without careful study of the effect of circulation change on the ozone field variations the conclusion about the decisive role of the anthropogenic influence on the TO depletion seems to be premature. The more so that according to the Montreal protocol this conclusion leads to such expensive projects as reorganization of industry.

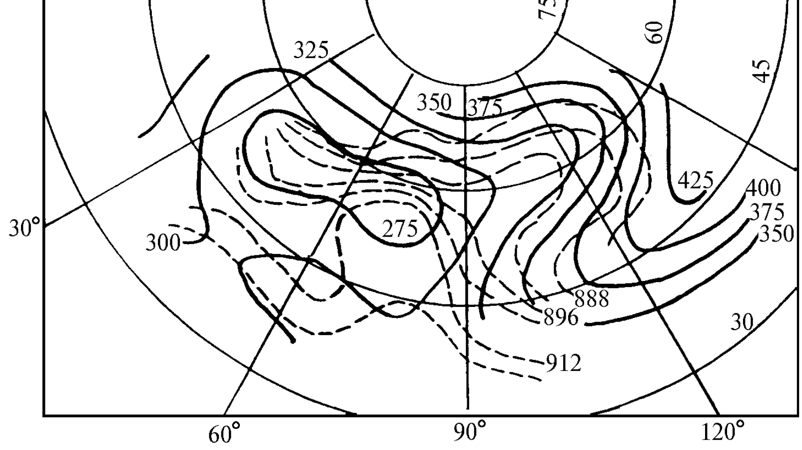

FIG. 2. TO fields (solid curves) and geopotential on 300 hPa *level (dashed curves) in Siberia on February 2, 1995.*

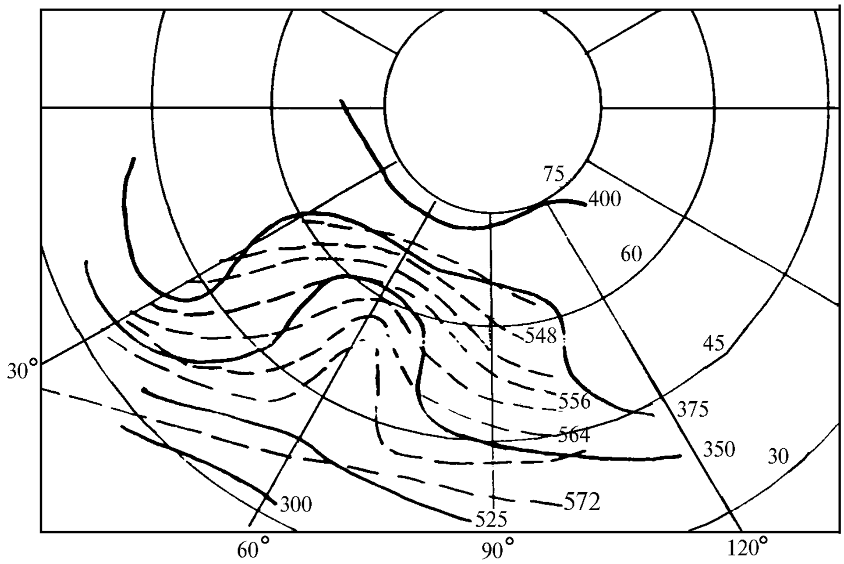

FIG. 3. TO fields averaged over April 1995 (solid curves) and geopotential on 500 hPa *level (dashed curves).*

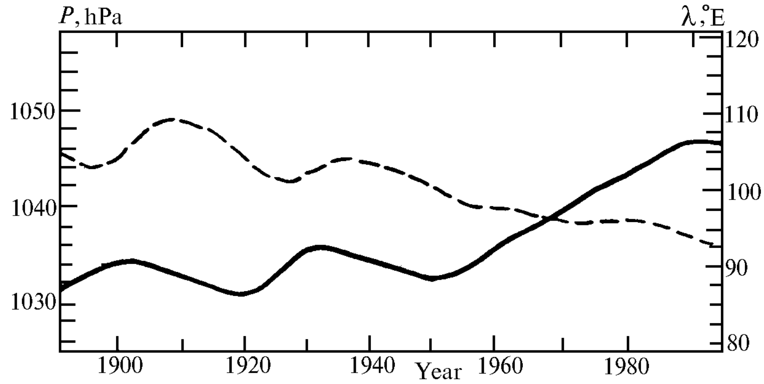

FIG. 4. Time variations of pressure P in the center of Siberian High (solid curves) and of the longitude of its center λ in January (dashed curves).

By analogy, we may exemplify the problem of the Caspian Sea when attempts at its saving from shallowing are now replaced by the problem of saving its coastal regions from flooding.

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