ISSN 1028-334X, Doklady Earth Sciences, 2007, Vol. 417, No. 8, pp. 1243–1246. © Pleiades Publishing, Ltd., 2007.
Original Russian Text © G.I. Gorchakov, E.N. Kadygrov, A.A. Isakov, A.V. Karpov, E.A. Miller, 2007, published in Doklady Akademii Nauk, 2007, Vol. 417, No. 1, pp. 90–93.

GEOPHYSICS

Influence of a Solar Eclipse on Thermal Stratification and the Turbulence Regime

G. I. Gorchakov[a], **E. N. Kadygrov**[b], **A. A. Isakov**[a], **A. V. Karpov**[a], **and E. A. Miller**[b]

Presented by Academician G.S. Golitsyn December 21, 2006

Received January 23, 2007

DOI: 10.1134/S1028334X07080259

During the total solar eclipse on March 29, 2006 [1], researchers in Kislovodsk measured variations in the flux of the total shortwave radiation, meteorological elements (wind speed and direction and relative air humidity), and turbulence parameters in the surface atmospheric layer, vertical profiles of air temperature in the layer 0–600 m, functions of particle size distribution (0.20–1.50 μm), and concentrations of light ions. It was found that the decrease in the maximum air temperature caused by the eclipse reached 3.5°C in the surface atmospheric layer and approximately 2°C at an altitude of 600 m a.s.l. After the full phase of the eclipse, turbulent kinetic energy decreased by a factor of 2.5, dispersion of the vertical component of the wind speed decreased by a factor of 2.3, turbulent heat flux decreased by a factor of 3.5, and dispersion of turbulent pulsations of air temperature decreased by a factor of 10.

Despite the long history of investigations of eclipses [2], the influence of the solar eclipses on processes in the boundary atmospheric layer has not yet been studied sufficiently enough [3–5]. It is clear that a solar eclipse should lead to variations in the thermal regime of the boundary atmospheric layer, increase in the relative air humidity, and consequent increase in the size of aerosol particles. Variations in the parameters of aerosol along with other factors can change notably the electric characteristics of the surface atmosphere [6]. Decrease in the near-surface air temperature can also lead to variations in the turbulence regime.

In order to study the quantitative variations in the above-mentioned parameters of the lower atmosphere during the total solar eclipse in the last decade of March in Kislovodsk (altitude ~900 m a.s.l.), the following measurements were carried out at the urban meteorological station: flux F of total shortwave radiation (CNR1 net radiometer (Kipp and Zonen, Netherlands); accuracy ±10 W/m^2), meteorological parameters (accuracy of measurements: air temperature ±0.3°C, relative humidity ±5%, components of wind speed ±0.15 m/s), turbulent pulsations (digitization step 0.1 s) of three components of wind speed and air temperature using a Meteo-2M acoustic meteorological station (Institute of Atmospheric Optics, Tomsk), vertical profiles of air temperature (time averaging 5 min, spatial averaging 50 m, accuracy of measurements ±0.5°C) in layer 0–600 m (MTP-5 UHF microwave profiler of the Central Aerological Observatory [8]), concentrations of negative light ions using a SIGMA-1 counter of aeroions (accuracy of each measurement ±30%, time constant 1.5 s, mobility of ions >0.4 cm^2/ W · s), and distribution function of the dry base of aerosol particles in the size range 0.20–1.50 μm (LAS-P laser spectrometer of aerosols, averaging time of differential countable concentrations of particles 15 s, and random error of measurements of countable concentrations 20%). Calibration of the laser spectrometer was carried out using nuclear filters, which allowed us to increase the accuracy of determination of the boundaries of the particle size ranges determined by the spectrometer.

The solar eclipse in Kislovodsk on March 29, 2006, started at 14:04 LT and ended at 16:29 [1]. The total phase of the eclipse continued approximately for 2.5 min from 15:16:31 to 15:19:03 (hours, minutes, and seconds, respectively). The clearest manifestation of the eclipse was observed in the variation of flux F of the total shortwave (0.3–3.0 μm) solar radiation (Fig. 1). Rare clouds and inhomogeneities in the aerosol optical thickness did not influence strongly the variations in the radiation flux F. The figures demonstrate the beginning, middle of the total phase, and end of the eclipse.

The thermal regime of the atmosphere changes owing to a decrease in the illumination of the underlying surface during the eclipse. Figure 2 shows the diurnal cycle of the near-surface temperature T_0 on the day

---

[a] *Obukhov Institute of Atmospheric Physics, Russian Academy of Sciences, Pyzhevskii per. 3, Moscow, 109017 Russia; e-mail: gengor@ifaran.ru*

[b] *Central Aerological Observatory, ul. Pervomaiskaya 7, Dolgoprudnyi, Moscow oblast, 141700 Russia*

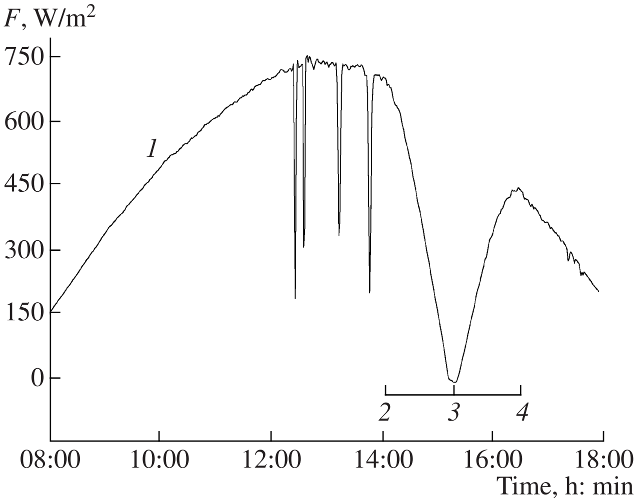

Fig. 1. Variations in the flux (time of averaging is 1 min) of the total shortwave radiation (*1*) in Kislovodsk on March 29, 2006. (*2, 3*, and *4*) Beginning, middle time of the total phase, and end of the eclipse, respectively.

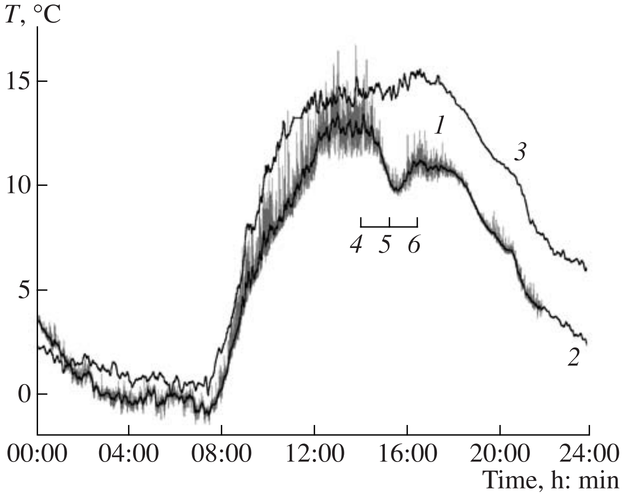

Fig. 2. Time variability (*1*) of the near-surface temperature in Kislovodsk on March 29, 2006 (time of averaging is 1 min), and smoothed (time of averaging is 5 min) variations in near-surface temperature on March 29, 2006 (*2*), and March 30, 2006 (*3*). (*4, 5*, and *6*) Beginning, middle time of the total phase, and end of the eclipse, respectively.

of the eclipse with time averaging of 1 s (1) and 5 min (2). Diurnal evolution of T_0 is also shown for comparison (3) on March 30, 2006 (time averaging 5 min). Table 1 presents average values of the air temperature T_0 (°C) and absolute values of the wind speed V (m/s) in the surface atmospheric layer based on the measurements on March 29, 2006, for six periods of time. The minimal air temperature was observed approximately 20 min after the middle phase of the eclipse. The decrease in the near-surface temperature ΔT_0 caused by the eclipse was ~3°C based on the Meteo-2M meteorological station data.

Significant variations in the surface wind speed V were also observed during the solar eclipse. However, it is not possible thus far to separate reliably the variations in wind speed from low-frequency variations of V of another nature.

A notable decrease in air temperature was observed at all altitudes in the layer 0–600 m. Figure 3 shows diurnal cycles of air temperature based on the observation data using a MTP-5 microwave profiler in the surface layer (*1*) and at altitudes of 100 m (*2*), 200 m (*3*), 400 m (*4*), and 600 m (*5*). It is easy to understand that a notable decrease in air temperature in the atmospheric boundary layer caused by the solar eclipse was observed up to an altitude of 600 m. The decrease in air temperature ΔT based on the MTP-5 data was equal to 3.9°C in the surface layer and 2°C at 600 m. The difference between the observed ΔT_0 values based on the measurements using Meteo-2M and MTP-5 profilers can be caused by the spatial difference (~50 m) in the distribution of air volumes, in which temperature T_0 was measured, as well as by the spatial structure of ascending and descending fluxes in a town with complex topography and dense location of buildings. On average, the temperature decrease ΔT_0 in the surface atmospheric layer was equal to 3.4 ± 0.5°C. The onset of the minimal temperature (relative to the minimum of radiation flux F) also increases with altitude up to 40 min at altitudes of 200 m or more (*6* in Fig. 3).

Meteorological elements and turbulence parameters in the surface atmospheric layer (Kislovodsk, March 29, 2006)

Time	T_0, °C	V, m/s	E, m²/s²	σ_w^2, m²/s²	σ_T^2, (°C)²	R, W/m²
12:20–12:50	12.5	1.8	2.90	0.60	0.33	110
13:35–14:15	12.9	2.5	3.70	0.68	0.42	170
14:30–15:00	12.5	3.0	2.50	0.50	0.25	160
15:16–15:19	11.4	2.5	2.00	0.43	0.14	56
15:30–16:15	10.0	2.4	1.45	0.30	0.04	50
16:15–16:45	10.9	2.1	1.50	0.37	0.11	100
17:35–18:05	10.9	2.9	1.70	0.47	0.04	65

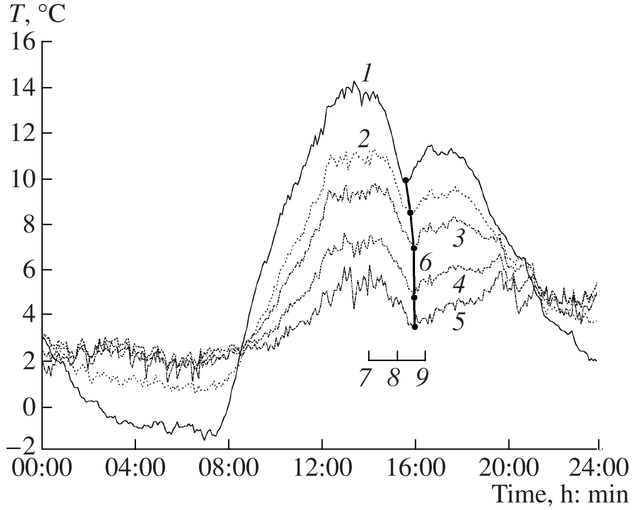

Fig. 3. Variations in the air temperature on March 29, 2006, in Kislovodsk in the atmospheric boundary layer at levels 0, 100, 200, 400, and 600 m (curves *1, 2, 3, 4*, and *5*, respectively); (6) line connecting the points of minimal temperatures. (*7, 8*, and *9*) Beginning, middle time of the total phase, and end of the eclipse, respectively.

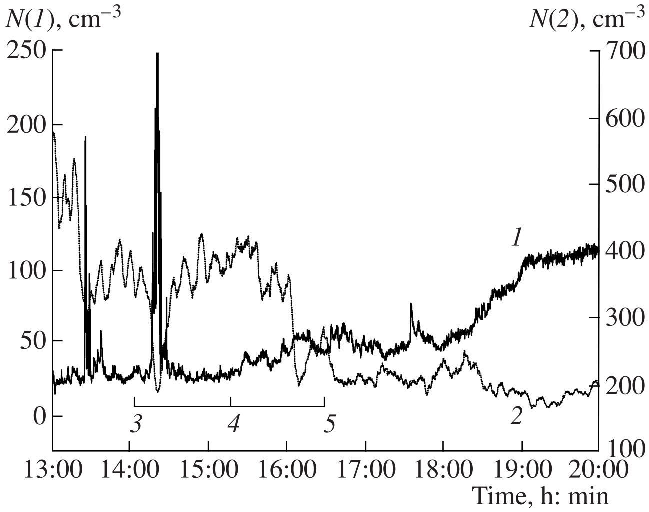

Fig. 4. Variations in the differential countable concentrations (*1*) of aerosol particles with sizes 0.20–0.25 μm (averaging time is 15 s) and concentration of (*2*) light negative ions (averaging time is 5 min) on March 29, 2006, in Kislovodsk. (*3, 4*, and *5*) Beginning, middle time of the total phase, and end of the eclipse, respectively.

It is noteworthy that the stability of the atmosphere increases during the eclipse, which leads to a notable variation in the turbulence regime in the atmospheric surface layer. On the day of the eclipse, pulsations (deviations from the mean values) of u', v', and w' (the longitudinal, transversal, and vertical components of wind speed), and pulsations T' of air temperature were measured using a Meteo-2M acoustic meteorological station. For 15-min intervals of observations, the turbulence parameters [9] were determined: turbulent kinetic energy $E = 0.5[\overline{(u')^2} + \overline{(v')^2} + \overline{(w')^2}]$ $(\mathrm{m}^2/\mathrm{s}^2)$; dispersions [10] σ_w^2 $(\mathrm{m}^2/\mathrm{s}^2)$ and σ_T^2 $(°\mathrm{C})^2$ of turbulent pulsations of the vertical component of wind speed w and air temperature T; the turbulent heat flux $R = \rho c_p \overline{w'T'}$ $(\mathrm{W/m}^2)$, where the overbar indicates time averaging, ρ is air density, and c_p is its heat capacity at constant pressure. The table presents the values of the above parameters of turbulence for seven time periods on March 29, 2006, including the period of the total eclipse phase (15:16–15:19). We shall consider the parameters of turbulence measured during the period from 13:35 to 14:15 (table) as parameters before the eclipse.

The minimal values of turbulence parameters were observed after the total phase of the eclipse in the period from 15:30 to 16:15. Figure 2 clearly shows a sharp decrease in the amplitude of fluctuations of the near-surface temperature during the solar eclipse. The calculations demonstrated that dispersions of air temperature pulsations during the eclipse decreased more than 10 times (table). The intensity of the dynamic turbulence also decreased strongly. The turbulent kinetic energy E and dispersion of the pulsations of the vertical component of the wind speed decreased 1.5 and 2.3 times, respectively. The turbulent heat flux decreased 3.5 times.

During the solar eclipse, the relative humidity increased by ~10% and reached the daily maximum equal to ~55%. At such low relative humidity, its influence on parameters of the atmospheric aerosol is insignificant. Therefore, variations in the aerosol parameters during the solar eclipse on March 29, 2006, in Kislovodsk could be caused by other factors, including variations in the regime of mesoscale circulation and advection of nonuniformly polluted air masses.

Figure 4 presents the results of measurements of the counted concentration (*1*) of aerosol particles N with sizes 0.20–0.25 μm (time resolution 15 s). It is seen that the concentration of particles N started to increase during the eclipse. Sharp peaks in the $N(t)$ plot, where t is time approximately 13:30 and 14:20, are caused by the transport of smoke from grass fires to Kislovodsk, which are frequently observed near Kislovodsk in the last decade of March. The concentration of light negative N^- ions decreased approximately two times after the eclipse (*2* in Fig. 4). Sharp decreases in the N^- concentrations were also observed during the transport of smoke aerosol at 13:30 and 14:20. It is likely that a notable decrease in the concentration of light ions after the eclipse was caused not only by an increase in the concentration of particles of submicrometer aerosol, but also by a decrease in the concentration of radon and products of its decay in the atmospheric surface layer.

ACKNOWLEDGMENTS

We thank G.S. Golitsyn for useful consultations and Z.V. Kortunova and G.A. Kurbatov for assistance in the experiment.

This work was supported in part by the Department of Earth Sciences of the Russian Academy of Sciences (program no. 5 “Geophysics of Interactions between Geospheres”) and the Russian Foundation for Basic Research (project nos. 05-05-65288a, 04-05-67048b, 06-05-79100k, and 06-05-79001k).

REFERENCES

1. Celestial Calendar, March–April 2006, Zemlya Vselennaya, No. 1, 77 (2006).
2. A. A. Mikhailova, *Theory of Eclipses* (Gostekhizdat, Moscow, 1954) [in Russian].
3. V. L. Potemkin, Izv. Akad. Nauk SSSR. Fiz. Atmos. Okeana **19**, 212 (1983).
4. A. S. Britaev, N. F. Elanskii, V. V. Lukshin, and I. N. Plakhina, Izv. Akad. Nauk SSSR. Fiz. Atmos. Okeana **19**, 209 (1983).
5. E. Hanna, Weather **50**, 430 (2000).
6. V. V. Smirnov, *Ionization in the Troposphere* (Gidrometeoizdat, St. Petersburg, 1992) [in Russian].
7. V. A. Gladkikh, I. V. Nevzorova, S. L. Odintsov, and V. P. Fedorov, Optika Atmosf. Okeana **15**, 902 (2002).
8. E. N. Kadygrov and D. R. Pick, Meteorol. Appl., No. 5, 393 (1998).
9. A. M. Oboukhov, *Turbulence and Atmosphere Dynamics* (Gidrometeoizdat, Leningrad, 1988) [in Russian].
10. N. V. Smirnov and I. V. Dunin-Barkovskii, *Brief Manual of Mathematical Statistics for Technical Applications* (Fizmatgiz, Moscow, 1959) [in Russian].