SOME RESULTS FROM STUDIES ON RELATIONSHIPS BETWEEN THE OPTICAL-METEOROLOGICAL PARAMETERS AND SOLAR ACTIVITY. 2. DEVELOPMENT OF THE PROBLEM OF SOLAR FORCING

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A set of complex spectral, actinometric and meteorological data obtained in the periods of heightened solar activity (1981 and 1988) has been considered in order to reveal the atmospheric component affected by solar emissions in the troposphere and lower stratosphere. For the first time, it has been found out that water vapour molecules can be transformed, under the impact of corpuscular and microwave solar emissions, from the free state to the bound one (association into clusters), and vice versa. The transition of water vapour molecules into the bound state results in a decrease of spectral optical thickness in the visible, near IR and IR spectral regions, and an appearance and deepening of the cluster absorption bands at wavelengths 330-340, 365, 380-390, and 480 nm.

In a brief paper (STP Newsletter, 1989-I) a possibility has been discussed of the effect of a rapid corpuscular component emitted during the sun flares on the microphysical state of water vapour molecules in the middle and upper troposphere. The results of complex spectral measurements have shown that the total water vapour content (W cm of precipitated water), under the influence of solar emissions, can change substantially (by 30% and more) every 15-20 minutes either after an optical flare at geoeffective solar longitudes and latitudes or after a powerful radioburst at wavelengths 2 to 10 cm. However, assessments of the scale of ionization processes needed for water vapour molecules to transform into 0.35 cm of precipitated water, have shown that the solar corpuscular component does not ensure a needed abundance of the processes of ionization of nitrogen molecules and processes of association of water vapour molecules into multi-molecular clusters, and furthermore, the processes of a rapid dissociation of the latter.

Interesting phenomena in the microphysical state of water vapour were observed during observations on July 29, 1981 on the last day of a 9-day period of a heightened solar activity. The absence of strong flares and different times of sub-flares and radiobursts have ensured a reliable referencing of the events on the sun to the events in the troposphere. A set of radiobursts at 11:06 local time (08:06 UT) was followed by a substantial decrease of W from 2.2 cm to 1.6 cm of precipitated water. A synchronous decrease has taken place in the spectral optical density. A second set of radiobursts at 14:13 local time (11:13 UT) raised W up to 2.2 cm. Radiobursts at wavelengths 2 to 5 cm corresponded to H_2O molecules to be released from the cluster. These events in the diurnal change of W show that radiobursts govern, apparently, the state of a considerable amount of water vapour in the middle and upper troposphere and in the lower stratosphere.

As seen from the recent studies of the spectrum of radiobursts in the frequency interval 1 to 18 GHz (M. Stahly, D.E. Cary, G.J. Hurford, BAAS, 1988, vol. 20, p. 678), in 80% of the cases the radiobursts have several peaks in the frequency spectrum simultaneously, whose location on the frequency scale is practically constant during the radioburst's lifetime. Bearing all this in mind, the radiobursts may, presumably, excite the molecules due to the presence of two or more components at close and definite frequencies. The phenomenon of broad-band excitation, found out by A.V. En'shin and S.D. Tvorogov (Atmospheric Optics, 1989, N5, p. 456--in Russian) in studies using the laser sources of biharmonic emission, has made it possible to look at the interaction between microwave emission and the medium from a new angle.

In connection with the fact that, upon the fixation of the event on the sun, the process of water vapour transformation continues 15 to 20 minutes, quasi-relativistic protons and neutrons of solar origin can be supposed to take part in a rapid change of water vapour concentration in the upper troposphere and hence, a rapid change in the optical characteristics of the atmosphere in the UV, visible, and IR spectral regions.

Note that synergism in the effects of solar emissions on the microphysicsl state of water vapour is not, apparently, confined to the effect of radiobursts and corpuscular fluxes but is supported by UV-emission bursts which follow the solar flares.

The second period of observations in October 1-12, 1981, was also rich in flares and radiobursts. The data for 11 and 12 October demonstrate still stronger effects of the flares and radiobursts on the troposphere, compared to 27 and 28 July. Extremely interesting are data for October 12, 1981, which testify to the strongest perturbation of active components of the troposphere and, naturally, its optical characteristics. A combined effect of strong flares (2B and 3B) and multiple powerful radiobursts have led to anomalous optical characteristics of the troposphere. Before noon, the total content of water vapour remained 0.15 cm of precipitated water. An interesting fact never observed before is a reversed location of τ_{411}, τ_{471}, τ_{557} on the scale of residual (aerosol) optical densities and extremely low values of τ_{411} (0.01) and τ_{471} at noon. Such a super-anomalous transparency in the UV should be connected either with practically complete removal of submicron aerosol fraction from the atmosphere or with a 20% flare of UV solar emission. Results of measurements at the Station Solnechnaya on 16 October 1988 demonstrate not only the effect of anomalous reduction in the spectral interval 330-380 nm but also show the diurnal dynamics of the spectral maximum of reduction. A sharp decrease of spectral thicknesses with a rapid increase of total water vapour content between 10:00 and 11:00 is associated with a disintegration of clusters with a high degree of association, which makes it possible to assess the cross-section of absorption for large clusters in the wavelength interval 330-380 nm (see the table).

Between 11:30 and 13:00, the reduction with a maximum at 378 nm is in-phase with the change in W, which can be explained by large amounts of water vapour getting to the atmosphere upon the sublimation of a thick layer of frost covering the objects and plants.

Table The Absorption Cross-Sections of Water Clusters in the Interval 330-380 nm (estimates).

λ, nm	$\sigma \times 10^{21}$	λ, nm	$\sigma \times 10^{21}$	Remarks
331	4.0 ± 2.5	352	3.4 ± 2.5	
333	4.3 ± 2.5	360	3.1 ± 2.0	n = 50
336	4.1 ± 2.5	370	3.0 ± 2.0	
340	3.9 ± 2.5	380	2.4 ± 2.0	
347	3.7 ± 2.5			

Unfortunately, the lack of spectral data between 12:30 and 15:30 did not allow one to monitor variations in the reduction in the period of W approaching a maximum and a subsequent decrease.

Anomalies in the values and in the diurnal change of solar emission reduction on October 16, 1988 are explained by a specific meteorological situation on that day. With a high transparency in the visible and IR spectral regions (high integral fluxes) and with negative air temperatures at morning hours, additional water vapour from the surface provided ideal conditions for the development of large clusters in the early morning, for their afternoon disintegration, the afternoon growth of clusters with a lesser degree of association, and an appearance of a third maximum of reduction at about 16:00, characterized by special spectral features.

Summing up, one can state that the effect of solar activity on the tropospheric radiation fields has been found for the first time to be mainly manifested through the processes of transition of a part of water vapour molecules (30% and more) from the free state to the bound one, and vice versa. In these processes, their contribution to radiation transfer in the UV, visible and IR solar radiation spectrum changes substantially as well as the transfer of longwave emission of the Earth's surface and atmosphere.

In connection with the complexity and variety of the effects of solar emissions on the troposphere, combined efforts are needed to carry out observations at various locations over the globe (using instruments with close measuring parameters).

Our observations show that the solar-tropospheric effects intensify in mountain regions. In this connection, it would be useful to organize coordinated observations at the Caucasus, in the Alps, in the Pyrenees, as well as in the Rocky Mountains, and at Mauna Loa Station.

It is rather perspective to include portable instruments in the measuring complexes for the microwave radiosounding of the atmosphere, used now by the U.S. Meteorological Service.