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CHANGES OF ATMOSPHERIC AEROSOL DENSITY AFTER EARTH TRANSITS OF THE HELIOSPHERIC CURRENT SHEET

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Abstract. The variations of optical density of atmospheric aerosols in 369 nm, atmospheric spectral transparency in 530 nm and Junge index at 8 stations of Russian Ozonometric Network, situated to the North from 55 deg, were investigated by superposed epoch analyses for time interval 6 days before - 6 days after heliospheric current sheet crossings. Two periods were chosen: 1983-1986 after El Chichon eruption, and 1978-1982 & 1987-1989 without volcanic activity. It was found that two days later HCS crossing the aerosol extinction decreases and the transparency increases for the period of 1983-1986, and this effect does not take place for another period. We connect it with the decrease in relativistic electrons following the HCS crossing.

The determining size of aerosols Junge index does not depend on HCS crossing, but it is smaller after El Chichon eruption. In 1983-1986 the transparency is higher and the aerosol extinction is smaller than in another period, that may be connected with solar activity effect.

1. Introduction

Wilcox et al. [1973] have found that when the Earth transits the heliospheric current sheet (HCS), or the solar magnetic sector structure, the average area of high positive absolute vorticity at the 300-mbar level (9 km) decreases during the first day, in other words the cyclone activity subsides. This phenomenon was observed for the winter season in the Northern Hemisphere and was named the Wilcox effect. It concerns the accuracy of weather forecasts, and so meteorologists dedicate many papers to it. The Wilcox effect appeared for a few years following volcanic eruptions that injected sulfate material into the stratosphere [Tinsley et al., 1994; Kirkland et al., 1996], and it was shown to be closely associated with reductions in relativistic electron precipitation into the mesosphere, and in reductions in associated X-ray bremsstrahlung that penetrated down to about 30 km level. The stratospheric sulfuric acid vapor and aerosols reduce the stratospheric conductivity, so that the additional reduction associated with the reduced X-ray bremsstrahlung at HCS crossings may be sufficient to make the stratospheric column resistance non-negligible in comparison to the tropospheric column resistance. When this happens, the ionosphere-earth current density J_z is reduced. It has been shown [Tinsley, 1996] that reductions in J_z are observed at HCS crossings and correlate with the observed reductions in the area of high vorticity at the 500 mbar (5 km) and 300 mbar levels. A possible mechanism for this is reductions in the rate of electrically enhanced contact ice nucleation in supercooled clouds [Tinsley et al., 2000].

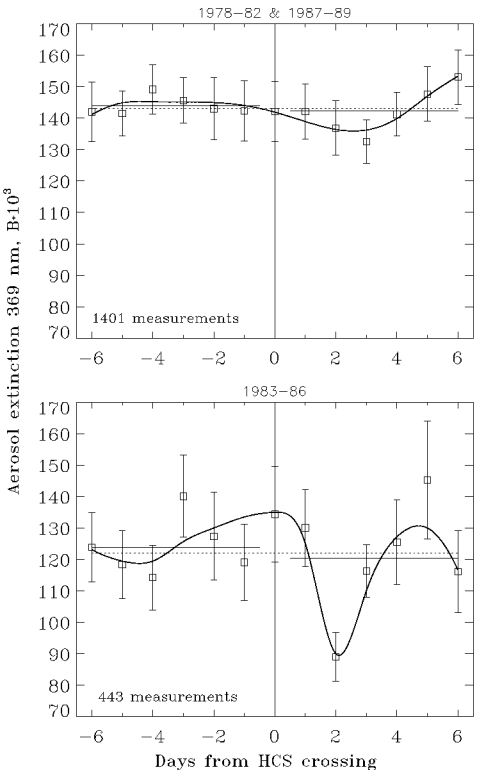

Fig.1 Superposed epoch analyses of aerosol extinction using HCS crossings as the key date set.

In the troposphere aerosol, particles consisting mostly of water (haze particles) usually determine atmospheric transparency in the absence of visible clouds. The connection of these aerosols content with the solar activity is found recently by Roldugin and Starkov [1998, 2000]. Therefore it is of interest to investigate, whether the water aerosol content reacts upon HCS crossings by Earth.

2. Data

The list of dates on which the HCS swept across the Earth is taken from Kirkland et al. [1996], where the crossings for 1978-1994 are given with indication of their polarity. The spectral optical density of atmospheric aerosol in 369 nm region was used as a measure of aerosol content. It was measured on the ozonometric net stations of the USSR and was published in year-books edited by Gushchin [1978-1992]. This parameter was used earlier by Roldugin and Starkov [1998, 2000]. As in these articles, the same 8 stations were chosen for analysis: Arkhangelsk, Leningrad, Markovo, Moscow,

Murmansk, Nagayevo, Pechora and Sverdlovsk. The spectral atmospheric transparency in 530 nm, taken from the same source, was treated also for control.

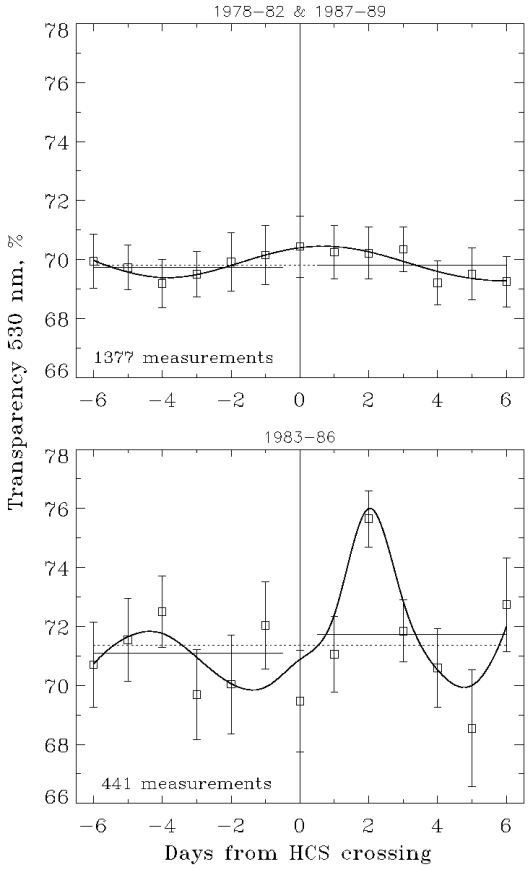

Fig.2. Superposed epoch analyses of atmospheric transparency in 530 nm.

The data handling applies superposed epoch method. The HCS crossings were used as key days, the averaging was made in the time interval '6 days before – 6 days after the crossing. The data of all 8 stations were summed up without any weight coefficients. We took into account all cases of aerosol observation, without taking notice to how many of them occurred in the 13-day interval for a single crossing, one or several. The total number of HCS crossings, for which the data of spectral aerosol density were in hand, was found to be 115 cases, so in principle the possible number of measurements may be 115 x 8 x 13=11960, but we found only 1844, i.e. 15%. We used data for all months not only winter ones. These optical observations are carried out under direct sun and at its high zenith angles, therefore the most of data have occasions in summer months.

3. Results

The data were divided into two groups according to time intervals: a) 1983-1986, after El Chichon eruption, and b) 1978-1982 and 1987-1989, out of the El Chichon aerosol period. The result for spectral optical density in 369 nm is shown in Fig.1 in the two panels. In each panel the dotted horizontal line represents the total mean value, two solid lines are mean values before and after HCS crossing, and the vertical lines show standard errors. During the period out of the eruption, see the top panel, the maximal deviation from the mean value, occurred on the third day after HCS crossing, exceeds the standard error by only one and a half time and is not significant statistically. In the period following the eruption, the deviation on the second day after key day exceeds the standard error 4.2 times and is significant.

Analogous picture was received also for spectral atmospheric transparency in 530 nm shown in Fig. 2. In the period out of El Chicon aerosols no deviation from the 13 ones exceeds standard error, but in the period of 1983-1986 the transparency on the second day after HCS crossing deviates from the mean value by 4.5 standard errors. The transparency increase above the mean level is equal to 4% in transparency percentage.

Both values, spectral transparency and spectral optical density, are calculated on the base of the same initial measurements and are not completely independent. The correlation coefficient between them is very high; it is equal to -0.89. The presented in Gushchin's year-books spectral transparency and optical density are correlated well for all of six wavelengths on the common physical reason: the occurrence of small aerosols. The exception is the Junge coefficient, which is published there also and characterizes the size distribution of aerosol particles. The smaller it is, the bigger is the relative content of coarse aerosol particles. The correlation coefficient between Junge index and the spectral optical density in 369 nm for our arrays is equal to –0.36. The superposed epoch analyses of Junge index for the both periods are shown in Fig. 3. One point from twenty six (the fourth one from zero in the top panel) deviates from the average by two standard errors, but it remains in the limits of insignificance yet.

4. Changes of mean levels

The Figures 1-3 demonstrate also differences of the mean levels between the two time intervals for all three parameters. At the chosen stations the spectral transparency in 530 nm after El Chichon eruption was higher, the spectral aerosol density in 369 nm was lower, and the size of aerosol particles was bigger, than out of the period of volcanic aerosols. We connect the changes of the first two parameters with the solar activity variations, but not with volcanic particles. Roldugin and Starkov [2000] showed that the atmospheric transparency at high latitudes decreases in maximum solar activity years. According to this paper, the mean value of transparency in 530 nm in May-August during the period of 1978-1982 & 1987-1989 was equal to 70.8%, and in the period of 1983-1986 it was 71.7%, which corresponds well with 69.9% and 71.4% in Fig.1. The mean value of spectral optical density in 369 nm for the first period was equal to 134, and for the second one it was 117 mB, what corresponds to data of Fig.1, i.e. 143 and 122 mB too.

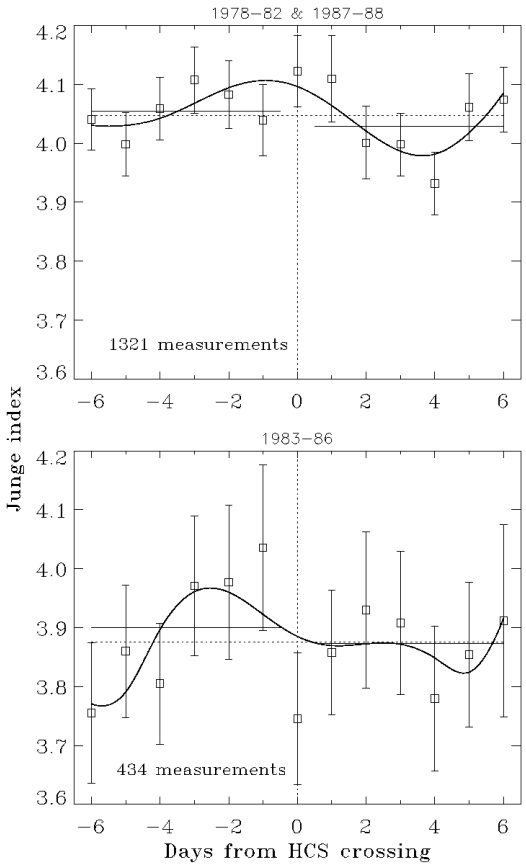

Fig.3. Superposed epoch analyses of Junge index for El Chichon period (bottom panel) and out of El Chichon period (top panel).

The spectral transparency and spectral density are determined both by small particles of the size of about 0.08 - 10 micron, which are water aerosols. The El Chichon eruption did not affect essentially their density, which is controlled most likely by charges in the atmosphere. The Junge index decrease may be connected with a relatively small contribution of larger particles into the size distribution of all aerosols.

5. Discussion

Both the transparency and the aerosol extinction at the net stations above 55° N reveal the statistically significant increase of aerosol content in the atmosphere after the HCS crossing by Earth. The bottom panels of both pictures resemble the corresponding picture from Wilcox et al. [1973] for the vorticity index VAI with the only difference that VAI extreme occurred on the first day, whereas our extreme values occurred on the second day. However, the difference can be explained by two circumstances: 1) the VAI index is determined twice a day, and the optical parameters only once a day, and 2) the aerosol observations are carried out mainly in universal time interval 5h – 15h , and VAI is determined at 0h and 12h UT, i.e. with a lateness.

The physics of this phenomenon is not understood yet. The decrease of aerosol extinction after the HCS crossing appears to be related to the finding [Tinsley et al., 1996] that after the HCS crossing the ionosphere-earth current density J_z decreases, in years with high concentrations of stratospheric sulfuric acid vapor and aerosol particles. It is possible that for larger J_z, which increases the charge on nuclei, thin layers of supersaturated water vapor at high levels are more likely to condense onto the nuclei. Alternatively, perhaps thin layers of supercooled droplets (supercooled haze or larger particles) are more likely to be converted into thin layers of ice crystals when there is more charge on them or on nearby nuclei. Ice crystals persist longer (because of lower saturated vapor pressure) than liquid droplets. In either case the transparency would be increased with J_z decreases at HCS crossings.

6. Conclusion

In the period after the El Chichon eruption, on the second day after Earth transit of the heliospheric current sheet the content of water aerosols in the atmosphere decreases, and the spectral transparency in 530 nm rises by 4%.

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