

LONG-PERIOD VARIATIONS OF WIND PARAMETERS IN THE
MESOPAUSE REGION AND THE SOLAR CYCLE DEPENDENCE

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A solar-cycle dependence of wind parameters below 100 km was found for the first time, by SPRENGER and SCHMINDER (1969) on the basis of long-term continuous ionospheric drift measurements in the l.f. range at the observatories in Kühlungsborn and Collm. They observed during the winter a positive correlation of the prevailing wind with solar activity, whereas the amplitude of the semi-diurnal tidal wind showed a negative correlation. This result was confirmed later on by radar meteor wind measurements (method D2) at Obninsk and further D1-measurements at Kühlungsborn and Collm (PORTNJAGIN et al., 1977) and, for the prevailing wind, by DARTT et al., (1983).

Prevailing wind: The continuation of D1-measurements at Collm and the beginning of continuous D2-measurements at Kühlungsborn in 1976 made possible the further investigation of such long-periodic variations in the middle atmosphere. During the years of maximum solar activity (1979-1981) we did not observe the expected large westerly wind velocities in winter; on the contrary, the velocities were as low as during the solar minimum of 1964/65. For the winter periods from 1975/76 to 1983/84, the correlation of the average prevailing wind V_0 (zonal component) with the 10.7 cm radio emission of the sun $F_{10.7}$ now became negative with correlation coefficients as high as -0.93 for D2 and -0.76 for D1-measurements (As winter we took the average of November, December and January).

For the meridional prevailing wind no significant variation was found in this investigation. The same comparison as for winter was done for summer (June, July, August) where the previous investigations gave no correlation. Now the D2 values, too, showed a significant negative correlation of the zonal prevailing wind with solar activity ($r = -0.83$) for the years 1976-1983. The D1-results of Collm have the same tendency but a larger dispersion due to the lower accuracy of the harmonic analysis because of the shorter daily measuring interval in summer (night-time measurements). The same sense of the long-term variation of V_0 in winter and in summer let us expect that it is rather a manifestation of an annual characteristic. Therefore we have estimated annual averages approximating the seasonal variation of V_0 by a mean value V_{00} and an annual and semi-annual harmonic which are the essential terms. The course of the variation of V_0 since 1964 (solar minimum) up to 1984 is reproduced in Fig. 1 in the upper part and compared with annual averages of the solar 10.7 cm radio flux $F_{10.7}$. Here we can see a positive correlation for the years from 1964 to 1973 and a negative one later on with an indication of new change in 1984. (The annual and semi-annual harmonics of the prevailing wind showed no distinct long-term variation as also found by

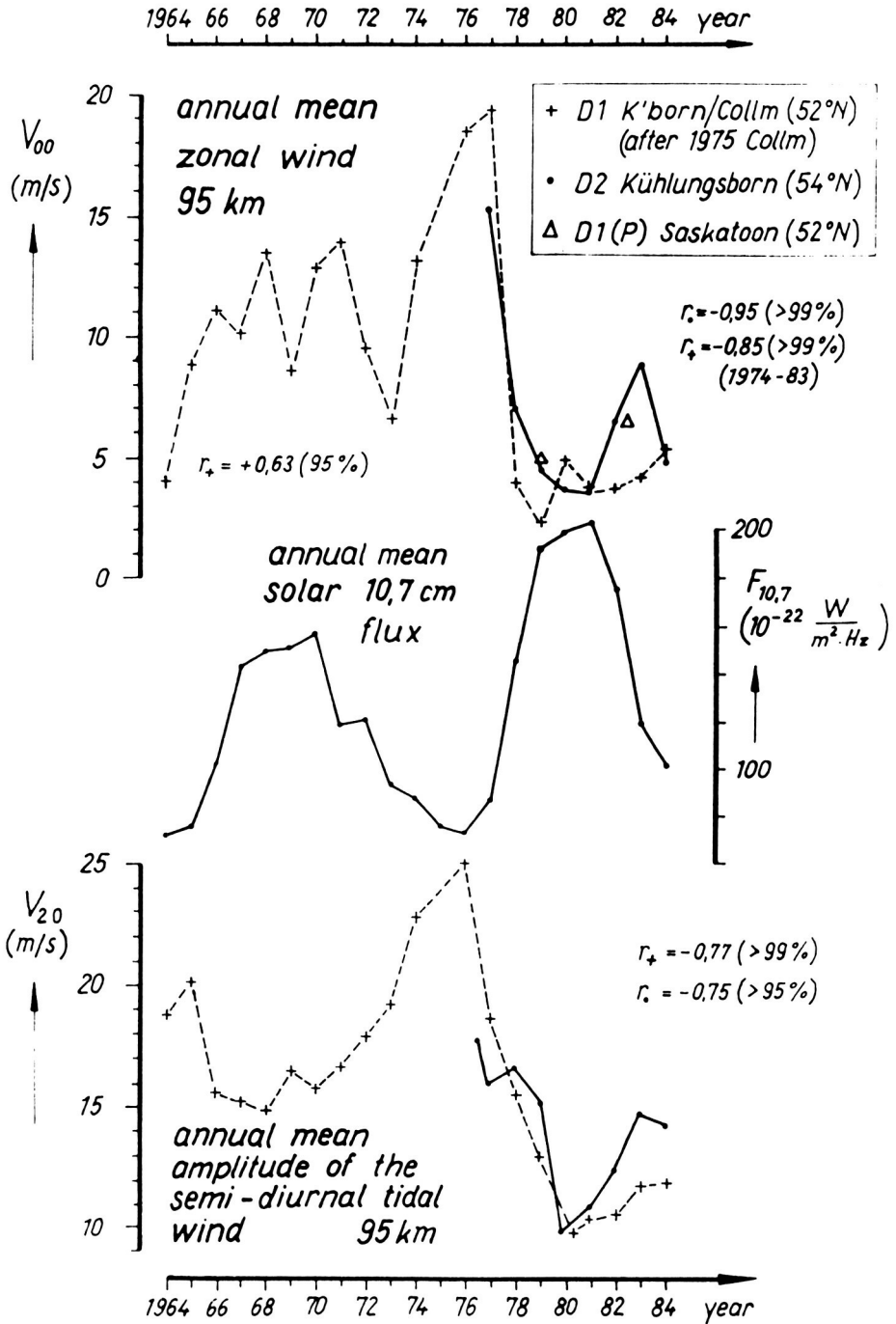


Fig. 1 Variation of annual means of the zonal prevailing wind, amplitude of the semi-diurnal tidal wind (both at 95 km and at medium latitudes) and solar 10.7 cm radio flux for 1964-1984.

DARTT et al., 1983). The corresponding V_{00} values of Saskatoon for 1979 and 1982/83 (taken from the literature and analyzed in the same way) confirm the low velocities during the last solar maximum found by the measurements at Kühlungsborn and Collm. Summarizing one can say that the average circulation (annual mean) of the upper mesopause region exhibits a distinct long-term variation which for some series of years seems to have close connections with solar activity variations. But, in reality, such an alternating mechanism of direct solar control seems to be very improbable. We therefore conclude that the long-periodic variations found in the prevailing circulation in 90-100 km at medium latitudes have essentially an internal atmospheric cause and are of climatic character with a time-scale of about 10 years. The source of these variations could be the recently intensively investigated mechanism of momentum deposition and generation of turbulence by breaking internal gravity waves (LINDZEN, 1981, MATSUNO, 1982, HOITON and ZHU, 1984). This mechanism is very likely the dominating factor for determining the strength and direction of the relatively weak prevailing circulation in the mesopause region.

Semi-diurnal tidal wind: In contrast to the prevailing wind variations we found for the semi-diurnal tidal wind no change in the dependence on solar activity. On the basis of the radar meteor wind measurements at Kühlungsborn we can now show that the same anti-correlation as in winter exists also in summer. The D1 results for summer have a large dispersion and give, as previously, no correlation. But from the D2 results one can suppose that the solar cycle dependence of the semi-diurnal tidal wind is not seasonal and should exist also for annual means. Concerning D1 results one can expect that the relatively short summer period with values of large dispersion will not qualitatively influence an annual characteristic. We estimate (as for the prevailing wind) by harmonic analysis of the seasonal variation an annual mean of the semi-diurnal tidal amplitude V_{20} as well as an annual and semiannual harmonic. In the lower part of Fig. 1 we see the course of V_{20} since 1964 from D1 results and since 1976 from D2 results. The comparison with the variation of the solar 10.7 cm flux shows a clear anti-correlation. The D1 results of V_{20} give a significant correlation coefficient $r = -0.77$ for almost two solar cycles (1964-1984). The D2 results confirm this with $r = -0.75$ for the last solar cycle.

Direct solar control of the amplitude of the semi-diurnal tidal wind which is a manifestation of the thermally excited solar semi-diurnal atmospheric tide seems to suggest itself. The thermal excitation takes place mainly by absorption of the solar UV in the wave length range 200-370 nm due to ozone in the stratopause region. But after recent satellite measurements we have only a weak enhancement of O_3 and UV (some percents) from solar minimum to maximum and, moreover, our observations show a decrease of the tidal wind amplitude with increasing solar activity. The semi-diurnal tidal wave may be influenced further by the propagation conditions between the excitation layer and the level of observations; that is by the temperature profile and the background zonal wind. As can be seen from recent numerical models of the semi-diurnal tide (WALTERSCHEID et al., 1980) these factors must have variations during the solar cycle of the same order as their seasonal ones in order to cause effects of the observed magnitudes (percent variation 50-100 %). But solar cycle variations of temperature and zonal wind in the upper stratosphere and mesosphere, found up to now, are too small and not in the right sense to explain our results.

Continuous wind observations in the upper mesopause region over more than twenty years revealed distinct long-term variations, the origin of which cannot be explained with our present knowledge. But, for a climatology of the middle atmosphere, they are of great interest. Further studies are therefore desirable, both theoretical and observational. It has been shown that lower ionospheric drift measurements and the radar meteor wind method are valuable tools for a continuous monitoring of the wind field at the top of the middle atmosphere over a time period of climatological extent.

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