# SOLAR ACTIVITY INFLUENCE ON CLIMATIC VARIATIONS OF STRATOSPHERE AND MESOSPHERE IN MID-LATITUDES

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The direct modulation of temperature of the mid-latitude mesosphere by the solar-cycle EUV variation, which leads to greater heat input at higher solar activity, is well established. In an earlier paper (von COSSART and TAUBENHEIM, 1987) we have analyzed more than 500 rocket-measured temperature profiles in the height range 20-80 km over Volgograd (latitude 49 N), covering almost two solar cycles from 1963 through 1983. Averaging over all seasons and times of day, we found a maximum response of temperature to the solar cycle near the altitude level of 65 km, with an amplitude of about 6 K between low (solar 10.7 cm radio flux F < 100) and high (F > 160) solar activity. With decreasing height in the middle atmosphere, this response falls to zero near 50 km. In an independent, somewhat different evaluation of the same Volgograd rocket data, MOHANAKUMAR (1987) found the same height dependence, but a slightly larger solar-cycle amplitude of 17 K near 65 km. These results have been excellently corroborated by temperature profiles derived by CHANIN et al. (1987) from air density data measured with the Rayleigh Lidar at Haute Provence (latitude 44 N), which again indicate a maximum solar-cycle response near 65 km altitude, but with still larger amplitudes up to about 25 K for winter, and 10 K for spring months.

At heights below 50 km, in the stratosphere, temperatures seem to be negatively correlated with the phase of the solar cycle. The amplitude of this variation is small, statistically not significant in the rocket data (von COSSART and TAUBENHEIM, 1987), but marginally significant with a few K in the Lidar data (CHANIN et al., 1987). Presumably this anti-phase variation of mid-latitude stratosphere temperatures, if it is real, must be produced by the dynamics of middle atmosphere circulation: It is well known that in medium and high latitudes there is an anticorrelation between mesopause and stratopause temperatures, not only in the seasonal variation but also in variations on shorter time scales, e.g., stratospheric warmings (cf. TAUBENHEIM, 1983). It seems not unreasonable to assume that such dynamical compensation mechanism could function on the longer time scale of an 11-yr variation as well.

Middle atmosphere temperature modulation by the solar cycle is independently confirmed by the variation of reflection heights of low-frequency radio waves in the lower ionosphere, which are regularly monitored over about 30 years at our Observatory of Atmosphere Research at Kuehlungsborn (geographic coordinates 52 N, 12 E). As explained elsewhere in detail (TAUBENHEIM and Von COSSART 1987), these reflection heights depend on the geometric altitude of a certain isobaric surface (near 80 k), and on the solar ionizing Lyman-alphe radiation flux. Knowing the solar-cycle variation of Lyman-alpha (e.g., ROTTMAN 1988) we can calculate how much the measured reflection heights would be lowered with the transition from solar minimum to maximum, if the vertical baric structure of the neutral atmosphere would remain unchanged. This expected reflection height variation is shown in the first line of the Table below, while the second line gives the observed height change (Von COSSART 1984), which obviously is markedly smaller. This discrepancy between expected and observed height change must be explained by an uplifting of the isobaric level from solar minimum to maximum, caused by the temperature rise in the mesosphere. By integrating the solar-cycle temperature changes over the height region of the middle atmosphere, and assuming that the lower boundary (tropopause) has no solar cycle variation, we can estimate the magnitude of this uplifting. It is given in the last two lines of the table, for the Lidar-derived and for the rocket-measured temperature variations, respectively. Comparison of these figures with those in the third line of the table suggests that the real amplitude of the solar-cycle temperature variation in the mesosphere is underestimated when using the rocket data, but probably overestimated with the Lidar data.

Table 1: Solar minimum-to-maximum change of radio wave reflection heights (in km) in the mid-latitude lower ionosphere

| | winter | summer |
|---|---|---|
| Calculated from Lyman-alpha variation only | - 1.8 | - 1.5 |
| Observed | - 0.8 | - 1.0 |
| Difference (interpreted as isobaric level uplifting) | + 1.0 | + 0.5 |
| Estimated from Lidar data | + 1.3 | + 0.85 |
| Estimated from rocket data | + 0.35 | + 0.25 |

Correlations between solar cycle and stratospheric winter temperatures in dependence on the QBO, as found by LABITZKE (1987) and discussed by LABITZKE and Van LOON (1988) seem to represent quite another kind of interaction between solar activity and middle atmosphere, rather than the direct EUV-induced modulation. This can be seen from fig. 1, where we have plotted the minimum geometric altitudes (in decameters) of the 30 hPa isobaric surface over the Northern Hemisphere in January/February, i.e., the height of the center of the winter polar vortex, versus the Zurich sunspot numbers (R). The data base is the same as used by LABITZKE (Daily maps of the 30 hPa surface, issued by the Institute of Meteorology of the Free University, Berlin-West). Each winter in the period 1961 to 1987 is representd by a symbol 'E' or 'W', indicating the phase of the quasi-biennial oscillation (QBO). These symbols, however, have been put in parenthesis in those cases when a major stratospheric warming occurred in January or

February, leading to enhanced mean temperature of this 2-month interval.

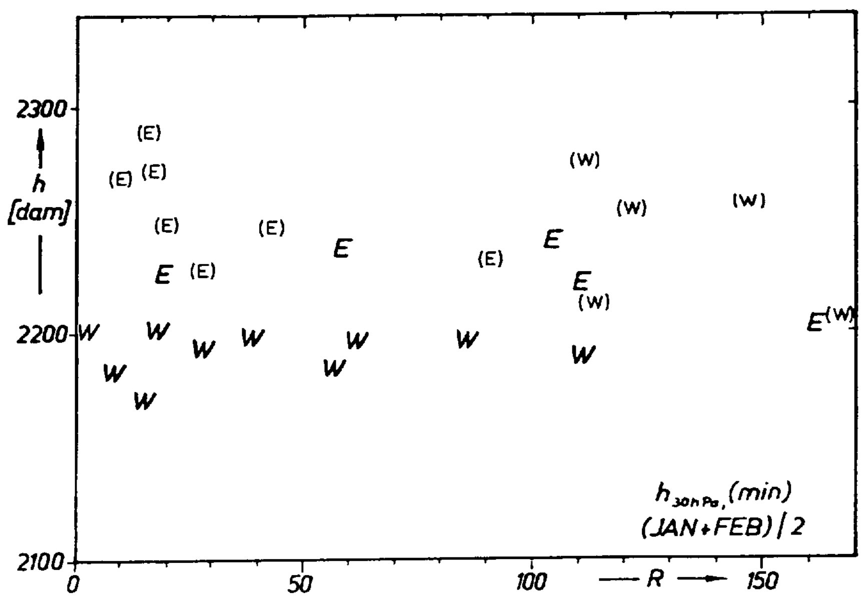


Fig. 1

The symbols 'E' and 'W' without parenthesis are in general accordance with the earlier findings of HOLTON and TAN (1980), that the winter polar vortex is stronger (the vortex center is deeper) during a 'W' phase than during an 'E' phase of the QBO. Obviously, the symbols without parenthesis do not show any significant dependence on solar activity, neither for 'E' nor for 'W' phase, while those in parenthesis generally lie above them, as to be expected in the case of major warming of the stratosphere. From the distribution of symbols with parenthesis in fig. 1, the following relations between major stratospheric warming, QBO, and sunspot numbers become immediately apparent: As pointed out by LABITZKE (1982) already several years ago, the probability of occurrence of major midwinter stratospheric warmings is higher in 'E-phase' than in 'W-phase' winters. This rule, however, holds true only for low and medium solar activity. Higher solar activity seems to 'suppress' the proneness of E-phase winters to major warmings. On the other hand, higher solar activity seems to 'unlock' some destabilizing mechanism, which allows stratospheric warmings to evolve during W-phase winters where they are 'forbidden' at low solar activity. Clearly there is a threshold of solar activity where the occurrence of major warmings switches over from E-phase preference to W-phase preference. Fig. 2 shows the curve of yearly mean Zurich sunspot numbers since 1950, and in the bottom strip, the occurrence of major stratospheric warmings indicated by full and open rectangles for W and E phase winters, respectively. The above-mentioned threshold may be placed near a sunspot number of R = 90, represented by the horizontal line.

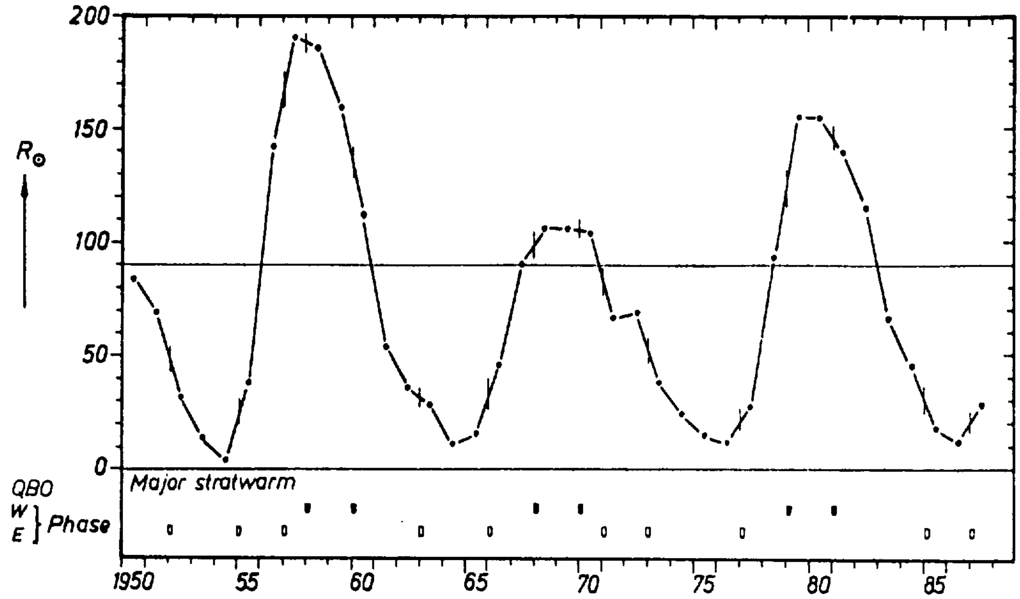


Fig. 2

In conclusion we should like to state that it seems not appropriate to discuss solar forcing of the winter mid-latitude stratosphere in terms of regression or correlation of temperature with solar activity indices. Rather, it might be more helpful to think of a solar activity-dependent 'locking' and 'unlocking' of trigger mechanisms for polar vortex breakdowns.

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