THE SUN'S ROTATION AND PERTURBATIONS OF
GEOPOTENTIAL HEIGHT AND TEMPERATURE FIELDS IN
THE STRATOSPHERE*

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Abstract. The morphology of a solar activity effect apparently connected with the Sun's rotation and showing up in 25-day and 13.6-day oscillations of stratospheric geopotential and temperature fields is analysed in this study. The used data cover the height range between roughly 20 and 30 km and a timespan from July 1965 to October 1971. Most prominent responses are found for zonal harmonic wave number 1 at the oscillation period of 25 days (solar rotation period modulated by seasonal changes) and for the zonally averaged meteorological quantities at the oscillation period of 13.6 days. Additional statistically significant effects show up in the zonal harmonics with wave number 1 and 3 at half the solar rotation period and in the zonal means with periodicities near 25–27 days. The results point towards a modulation of the quasistationary stratospheric planetary wave with a positive geopotential anomaly around roughly 180° longitude by solar activity changes. The direct physical mechanisms of this Sun-climate relationship are not yet clear, but it can be concluded that atmospheric dynamics is an important factor for its morphology and that downward propagation of such effects seems possible and should be investigated in future studies.

1. Introduction

The importance of solar activity changes for the energetics and dynamics of the upper atmosphere down to mesospheric heights is generally recognised. Furthermore, it is generally anticipated that the basic physical mechanisms like electromagnetic and corpuscular radiation absorption and the respective contribution to heating and chemical processes are understood or can at least relatively easily by derived from theoretical considerations.

On the other hand, there is a steadily increasing number of papers claiming that Sun-weather or Sun-climate effects (that means reactions of the atmosphere on solar activity changes) also play an important role in the troposphere. This is an extremely controversial subject especially since most studies of troposphere Sun-weather relationships are purely statistical (often with too careless a use of statistical methods) and because no completely convincing physical mechanism controlling those relationships has yet been proposed. Besides, a principal conflict appears to exist between most working hypotheses guiding the statistical studies about the mechanisms involved and the physical principles of tropospheric dynamics. This conflict concerns the small energy ratio between assumed forcing and the studied reactions as well as time delay between input and output signal of the atmospheric


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system. For instance, solar flares represent a minor disturbance of radiative forcing of tropospheric and lower stratospheric dynamics. Nevertheless, based on statistical evidence it has been claimed that they cause clear large-scale circulation changes no later than 12 hr after their appearance (Schuurmans, 1979). Or sector boundary passages of the solar wind which certainly do not directly contribute to the energetics of the troposphere to any measurable degree are found to precede significant specific variations in the vorticity field of the middle troposphere by about one day (Roberts and Olson, 1973).

Regarding the many conflicting results and ideas about Sun-weather effects in the lower atmosphere it is clear that more diagnostic and theoretical work is needed before a clear decision about the reality and meteorological relevance of such effects can be made. This paper is intended as a contribution to the solution of the puzzle. The principal question guiding our study is how far solar activity influences on the atmosphere can be traced downward in the atmosphere. In a first step we tried to find the answer for the middle stratosphere between 50 and 10 mbar (roughly 20–30 km altitude).

Thus the region of interest is located approximately in the middle of the levels where solar activity doubtlessly contributes to atmospheric variability – say down to 60 or 70 km altitude (e.g. Ramakrishna and Seshamani, 1973, 1974) – and where the relevance of Sun-weather effects still has to be proven – say below the tropopause. Furthermore, the study is concerned with quasiperiodic phenomena and, therefore, also somewhat apart from the other mentioned area of conflict, namely the problem of the energy ratio between cause and effect and of the time delay between solar input and atmospheric output of the Sun-weather system. For the response of the stratosphere to external forcing includes – from the viewpoint of planetary wave theory (Longuet-Higgins, 1968) – possible resonant or nearly resonant oscillations which may be generated by only weak periodic perturbations of solar energy input.

Following such considerations it is logical to concentrate on the study of principal periodicities in solar activity variations, that is the 27.2-day and the 13.6-day oscillations resulting from the Sun’s rotation, as is done in this paper. Yet we would like to emphasize that the dynamics of the responding system ‘atmosphere’ may as well lead to significant reactions on solar activity fluctuations at other periodicities corresponding to eigenfrequencies of the system. This is apparently the case for the 15- or 16-day wave of the atmosphere (Schwister and Ebel, 1980).

The specific dynamic behaviour of the stratosphere with respect to solar activity variations already became apparent in a former study by Ebel and Bätz (1977). They found a very pronounced correlation between solar activity and mean zonal wind changes at 10 mbar (30 km) for oscillations with periods near 13.6 days but no coherent signal for a period of 27.2 days where a considerably larger solar activity oscillation exists. There were indications that, in spite of its absence in the zonal means, the latter period might be more pronounced in longitudinal or regional