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THE TROPOSPHERIC RESPONSE PATTERN TO SOLAR ACTIVITY FORCING

C.J.E. Schuurmans

Royal Netherlands Meteorological Institute
De Bilt, The Netherlands

INTRODUCTION

Twenty years ago (SCHUURMANS and OORT, 1969) the northern hemispheric response pattern of the height of the 500 mb level to strong solar flares was published. Although comparisons were possible for limited areas (see later on), full hemispheric comparisons for independent data have never been made. Recently, however, VAN LOON and LABITZKE (1988) published the results of an association between the 11-year solar cycle, the QBO and the northern hemisphere 700 mb height. Surprisingly, their Figure 12b, presenting lines of equal correlation between the 700 mb height and the 10.7 cm solar clux, for easterly QBO winter months, shows a pattern which is very similar to the one we found for the change of the 500 mb level after strong solar flares.

Of course, pattern similarity alone does not prove anything. According to studies on atmospheric teleconnections and low frequency fluctuations.

Such patterns do seem to be quite common and do not need an external cause for their excitation. Furthermore, VAN LOON and LABITZKE's result describes a possible long-term variation, while the effect of solar flares is essentially a short term reaction.

Notwithstanding this critizism it is tempting to speculate on the possibility that solar flares sometimes are the initial cause of an atmospheric disturbance, which cumulative effect may give rise to a correlation at the 11-year timescale.

HORIZONTAL PATTERN

The response pattern of the 500 mb level to solar flares referred to above is shown in Fig. 1. Like Fig. 2 and 3 it is reprinted form SCHUURMANS and OORT, 1969. Fig. 1 does show positive anomalies in the latitude belt 40-70 °N, with maxima over Europe, Eastern Asia-Western Pacific and Californian area, and negative anomalies over the polar regions, much like the pattern of positive correlations between the 700 mb height field and the 10.7 cm solar flux for easterly QBO, shown by VAN LOON and LABITZKE (1988). Why it is the east phase of QBO which correlates best with our flare results, remains a problem. The 81 flare cases are from the IGY-period (June 1957 till December 1959). It may be possible that during most of this period the QBO was in its east phase (which according to preliminary data available seems to be true). Comparison with results of other studies, however, shows that the reaction pattern at 500 mb after solar flares, above Europe always seems to be of positive sign. Here I refer to the pioneering studies of DUELL and DUELL (1948) and of the Czechoslowakian VALNICEK (1953), which for the area limited to the Eastern Atlantic and Europe, a positive height change of the 500 mb level observed as an average response to some 50 flares, occurring during 1936-41 and 1949-50, respectively.

Subsamples of the 81 flares used in our case, invariably showed a nearly the same reaction pattern, even for a subdivision of flare cases in winter and summer (SCHUURMANS, 1979).

VERTICAL PROFILE

The vertical profile of positive height changes after solar flares shows a maximum at about 300 mb (Fig. 2). In areas of negative height changes at 500 mb the vertical variations were found to be negligible. For this reason further study of the solar flare impact was concentrated upon the areas of positive height change. The warming of the troposphere, which could be expected from the observed height rises of constant pressure levels (on the basis of the assumption of hydrostatic equilibrium) was verified on the basis of observed temperature changes after solar flares. As clearly indicated in Fig. 3 tropospheric warming with a maximum at 500 mb does take place, along with a pronounced cooling of the lower stratosphere. Statistically this cooling is more strongly signficant than the warming of the troposphere.

DEVELOPMENT IN TIME

The changes discussed above occur within 24 hours after a flare. In fact 24-hour time changes were studied, always taking the difference between the first observation after a flare and the aerological observation 24 hours earlier. So on average the reaction pattern refers to a time-lag which is even less than 12 hours! In order to see the development of the effect in time several individual cases were studied. In Fig. 4 an example of this is given. The immediate response is clearly indicated as well as its continuation for at least 36 hours. The 24-hour temperature change at the first observation after the flare is also given. Note the nearly tenfold larger effect as for the sample average presented in Fig. 3. It should be pointed out that the flare case of June 1, 1960, to which Fig. 4 refers is not included in the IGY-sample of 81 flare cases.

MECHANISM

In search for an explanation of the observed reaction profile after solar flares I have tried a model consisting of a vertical circulation system (Fig. 5) forced from above. Following my computations (SCHUURMANS, 1969) some source of diabatic cooling in the lower stratosphere, causing horizontal convergence of air and consequently downward motions in the troposphere, may explain the observed (adiabatic) warming of the troposphere. The mechanism causing the diabatic cooling source, however, remained obscure. The very short time lag between the flare and the observed response is certainly not in favor of an electromagnetic radiation process. Rather, some at present still unknown process, involving energetic solar particle radiation has to be explored.

CONCLUDING REMARKS

Reporting of just old results is certainly not elegant. Reasons to reconsider the possible relevance of solar flare response studies are stated in the introduction. The discovery of the apparently decisive role of the QBO in establishing the atmospheric response pattern to solar forcing may throw new light on some of the earlier published relations. Re-analysis of old data in some cases may be advisable.

The purpose of this paper was to show that data on solar flares and their effects on the earth's atmosphere might be a promising candidate for this.

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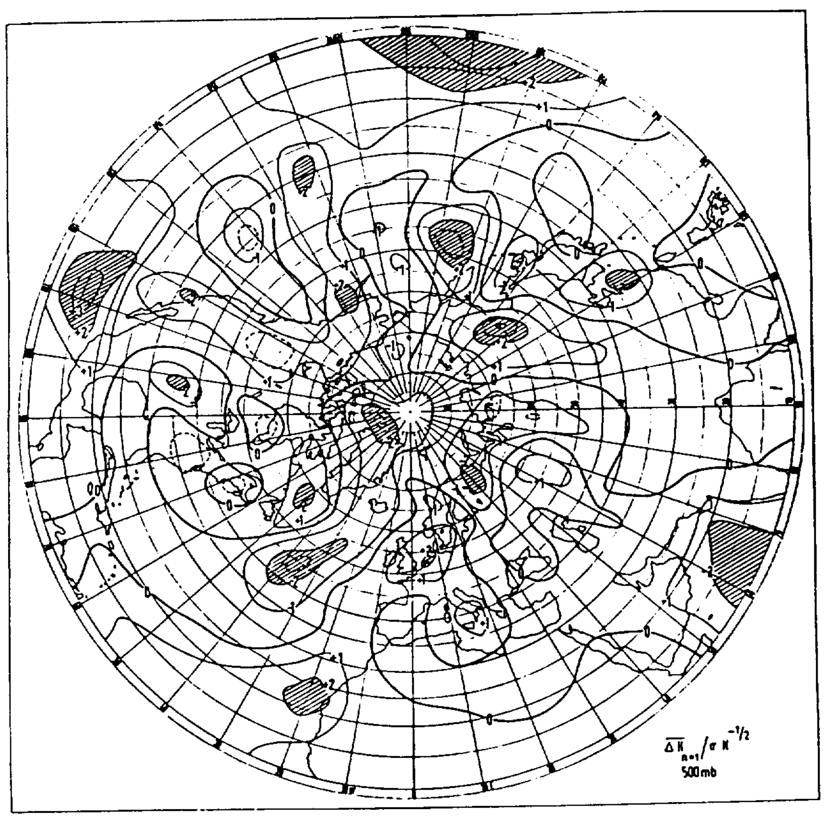

Fig. 1. Mean height change of the 500 mb level after solar flare outbursts. The map gives isolines of the mean change in 24 hours after 81 flares, divided by the standard error of the mean.

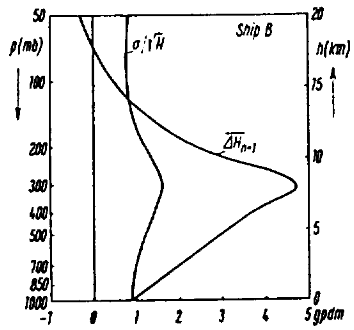

Fig. 2. Mean 24-hr height change of pressure levels after solar flares at Ship B (56°30'N, 51°W).

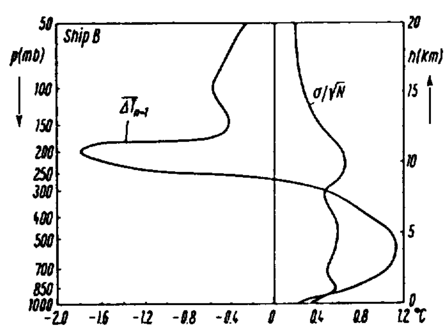

Fig. 3. The same as Fig. 2 for temperature changes.

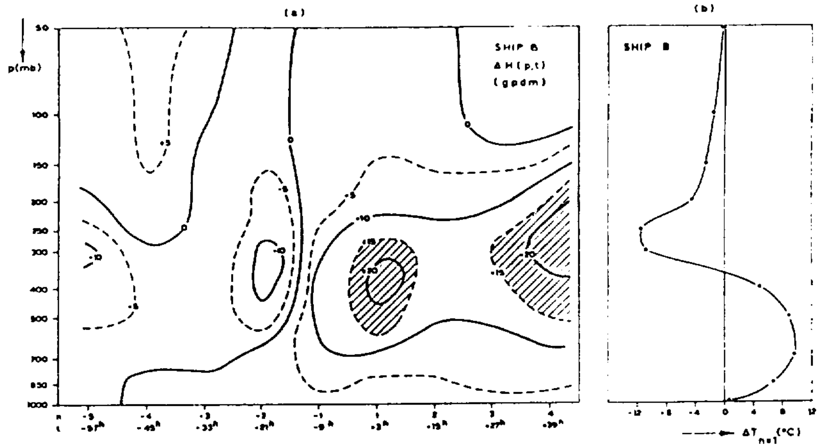

Fig. 4. Height and temperature changes at Ship B, related to the solar flare of June 1, 1960.

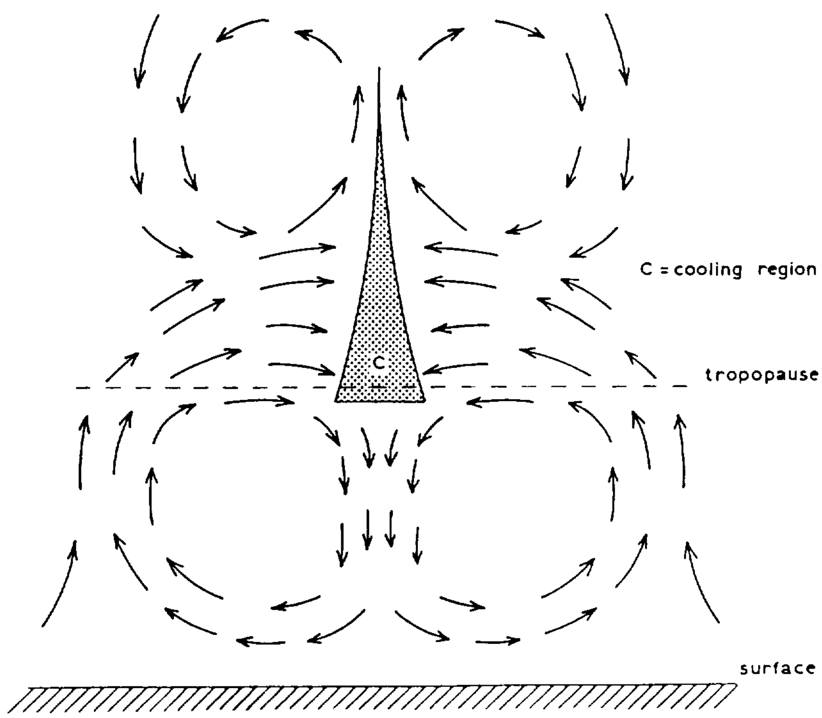

Fig. 5. Proposed circulation system, initiated by a solar particle induced heat sink a the tropopause.