SEASONAL VARIATION OF THE 11 YEAR SOLAR CYCLE EFFECT ON THE MIDDLE ATMOSPHERE; ROLE OF THE QUASI BIENNIAL OSCILLATION

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1. Introduction

Before the introduction of the Quasi Biennial Oscillation (Q.B.O.) in the study of the solar-atmosphere relationship by LABITZKE (1987) and LABITZKE and VAN LOON (1988), the only region of the atmosphere where an effect of a change in solar activity was generally admitted was the mesosphere. The response of the mesosphere, in phase with the solar activity, was found to be about one order of magnitude above model expectancy (around 10 to 20 Kelvin). It was observed independently of the season and maximized around 70 km (Chanin et al. 1987). On the other hand, from the same study, it was shown that the response of the stratosphere of opposite sign, clearly seen during winter and autumn, was at the threshold of detection in spring and summer. In the stratosphere, it was shown later that the separation of the data taking into account the sign of the Q.B.O. amplifies the negative correlation of the stratospheric temperature with solar activity in winter; it then becomes more significantly negative for the East phase of the Q.B.O. than when the data are all mixed (Labitzke and Chanin 1988). The studies of the seasonal response of the atmosphere to solar effect is crucial to understand the possible mechanism responsable of such a solar activity-Q.B.O. relationship, knowing that the global dynamic circulation is quite different according to the seasons. The purpose of this paper is to inquire if such separation of the data according to the phase of the Q.B.O. has any impact on the solar response of the middle atmosphere for seasons other than winter.

2. Description of the data set

The data used for this study are the temperature profiles obtained from the Rayleigh lidar which has been in operation at the Observatory of Haute-Provence (O.H.P. FRANCE, 44°N-6°E) for the period 1979-1988 and at Biscarrosse (44°N-1°E) for the period 1986-1988. The method has been already described in several publications (Chanin and Hauchecorne 1984) but it is worth noticing that the performances in term of range and accuracy have been largely improved since 1984. The height range reached from both stations is nowadays 90 km instead of 75 km before 1984. However the stratospheric data were disturbed in the post El Chichon period (from April 1982 to February 1984) in the height range 30-34 km and even up to 38 km at the time immediately after the eruption; therefore, for this analysis, the data corresponding to the altitudes where aerosols were present were eliminated from the data set. The downward extension from 30 km to ground level is obtained by using the data from the two near-by radio sonde stations. The quantity which is considered here is the temperature deviation of each monthly averaged value from the corresponding mean value calculated for the whole period of 1979 to 1988. The 10.7 cm radio solar flux is used as the solar activity index. Even it is not the best solar parameter, the other ones (i.e. the UV flux around 205 nm) are not available during the whole period and the 10.7 cm radio solar flux has been shown to be reasonnably well correlated with the solar UV flux, when looking for long term variation (LONDON et al. 1984).

The data were grouped according to the sign of the Q.B.O. from the classification of LABITZKE and VAN LOON (1988), and in 4 periods of 3 months each: December-January-February (DJF) for Winter, March-April-May (MAM) for Spring, June-July-August (JJA) for Summer, and September-October-November (SON) for Autumn. The number of temperature monthly means used in this study was 112 using a total number of 799 profiles.

3. Seasonal variation

The response of the atmosphere to change in solar activity is given for different seasons in Figure 1 for the Westward phase of the Q.B.O. and in Figure 2 for the Eastward phase. As expected, the atmosphere responds positively in the mesosphere in all cases even though with different amplitudes. The largest amplitudes between the minimum and maximum of the solar activity are observed in Winter and Summer for both Q.B.O. signs, as already shown when the data were not sorted out according to Q.B.O. (Chanin et al. 1987).

In the stratospere, the Spring and Winter correlations are identical and negative for Q.B.O. West, whereas Summer and Autumn correlations are positive; for the Q.B.O. East, the Spring is the only season where the response is positive. The amplitudes around 40 km of the negative dependence for Q.B.O. East are decreasing from Winter to Autumn and Summer but are larger in general than Q.B.O. West.The only periods for which the correlation coefficient is significant above the 95% confidence level in the stratosphere are the Autumn and Winter for Q.B.O. East (Figures 3 and 4) and the Spring for Q.B.O. West (Figure 5) and the larger correlation coefficient is found in Autumn for Q.B.O. East: 0.78. The more noticeable feature is the opposite behaviour of the Spring responses for the two different signs of the Q.B.O., which should be related to the way the atmosphere recovers after the final warning. The response of the stratosphere may then be partly smoothed out when all the data are used independently of the Q.B.O..

At that point it is worth comparing these results with the ones obtained in summertime by LABITZKE and VAN LOON (1989 b). They conclude from the analysis performed at 30 mb that it was not necessary to sort out the data to obtain a positive statistically significant response to solar activity. This is not in contradiction with the results of Figures 1 and 2 where the response for both Q.B.O. responses are shown to be positive at 24 km (30 mb). However figures 6 and 7 indicate that a more significantly positive value is observed at this altitude for Q.B.O. West than for Q.B.O. East. There is therefore an indication that the behaviour in the stratosphere is sensitive to the sign of the Q.B.O., even though differently for each season, and the regular alternance of positive and negative responses as a function of altitude seen during winter is not always observed for the other seasons.

4. Mean annual dependence

As the signs of the solar dependency are not systematically opposite for the East and West phases of the Q.B.O. one can wonder what is the response of the atmospheric temperature to solar activity when all the seasons are considered and all the years are taken into account independently of the sign of the Q.B.O.. The answer is given in Figures 8 and 9 in terms of correlation coefficient and solar dependence. The correlation coefficient in the stratosphere varies from +0.25 to -0.25 from 20 to 40 km, to reach +0.6 in the mesosphere. These values are much lower than the ones mentionned before, but due to the large quantity of data, they are above the 95% confidence level. The amplitude of the response for minimum to maximum are about +2 K at 20 km, -4 K at 40 km, and +10 K at 65 km. This value are not negligeable compared to the temperature trends observed for a decade, which are close to -0.5 K at 20 km and -2 K at 40 km. Theses results obtained at a specific site is not expected to be valid on a global mean if, as shown by LABITZKE and VAN LOON, the response to solar activity follows a regional pattern. However it is an indication that the data have to be used carefully when looking at long term trend unless the data set covers several solar cycles and allows a separation of both solar and long term effect. It is yet to be seen if a solar cycle response exists on a global mean, in the upper stratosphere and mesosphere: the long series of data available for such a study are mainly provided by the existing rocket stations, which are known not to be uniformely spread, even in the North hemisphere, and we feel that those data cannot be used safely to estimate global temperature trends.

5.Conclusion

A more complete study of the response of the whole middle atmosphere to changes in solar activity is needed to get a global view of the solar influence on the stratosphere, and to conclude about the role of the Q.B.O.. From this study, it seems that significant negative or positive responses of the stratosphere are Q.B.O. dependent, while the systematic positive response of the mesosphere is only slightly amplified for Q.B.O. East. The role of the Q.B.O. in summer and autumn periods is puzzling as the filtering role of the stratospheric winds, existing in Winter and slightly less in Spring, is less likely to be of any importance during the rest of the years. A result which could be important for stratospheric trend study is the indication that a significative influence of the 11 year solar cycle is seen, at least at some specific sites, which, as it is likely due to dynamics, have not be expected from the models.

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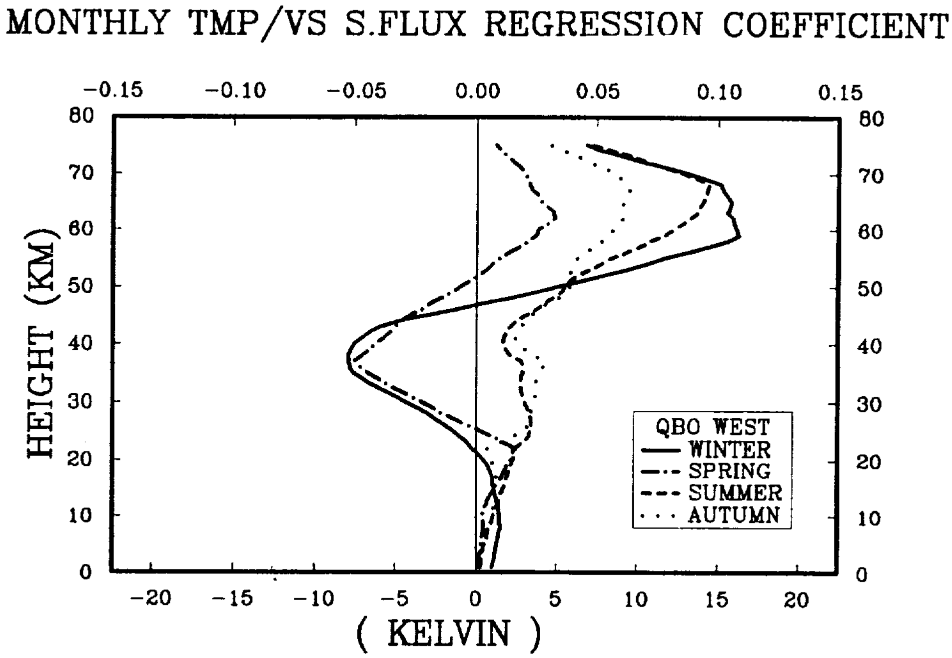

Figure 1: **Seasonal** amplitude of the solar temperature dependence over Southern France expressed in Kelvin and in Kelvin by unit of solar flux given for the **Westward** phase of the Q.B.O..

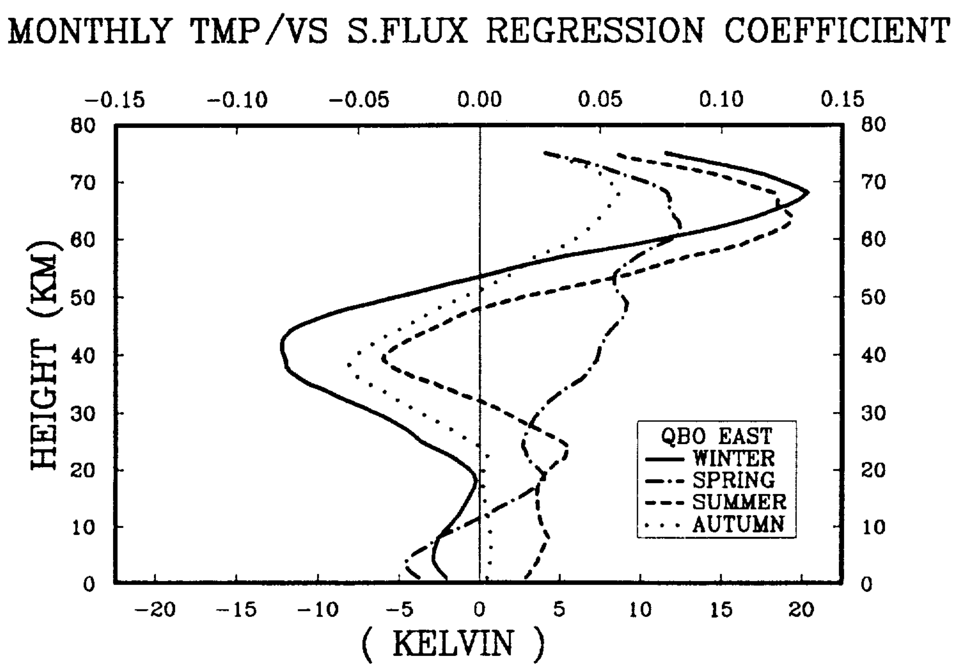

Figure 2: Same as Figure 1 given for the **Eastward** phase of the Q.B.O..

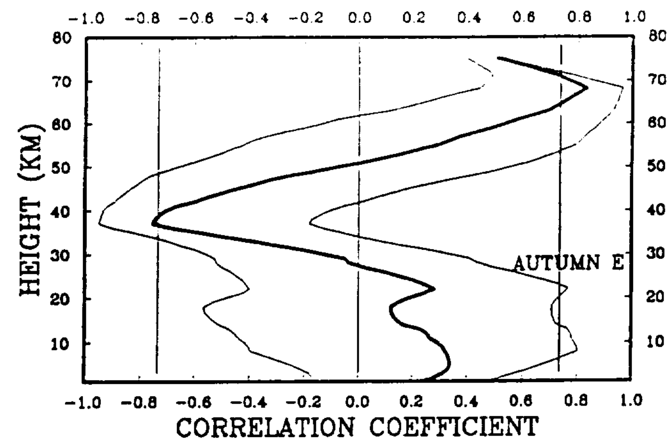

Figure 3: Correlation coefficient between **Autumn** temperature variations and the 10.7 cm solar flux for the **East** phase of the Q.B.O.. The vertical lines indicate the 95% confidence level.

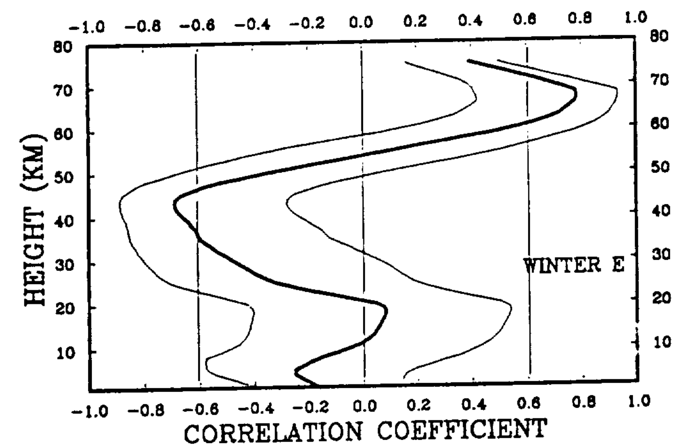

Figure 4: Same as Figure 3 given for **Winter** and for the **East** phase of the Q.B.O..

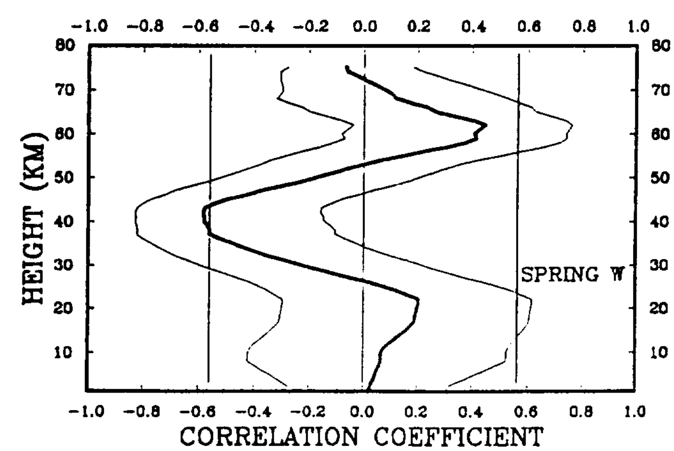

Figure 5: Same as Figure 3 given for **Spring** and for the **West** phase of the Q.B.O..

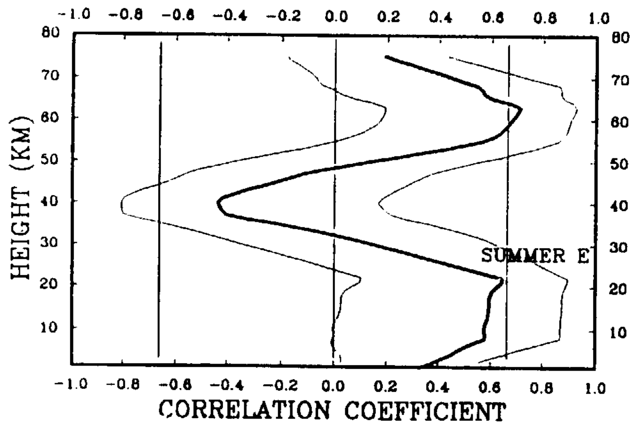

Figure 6: Same as figure 3 for **Summer** and for the East phase of the Q.B.O..

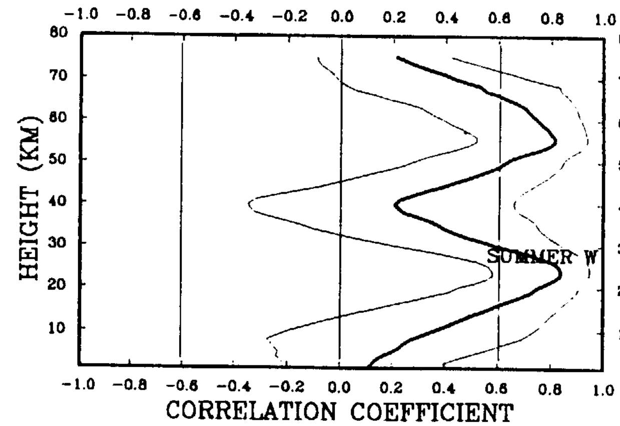

Figure 7: Same as figure 3 for **Summer** and for the West phase of the Q.B.O..

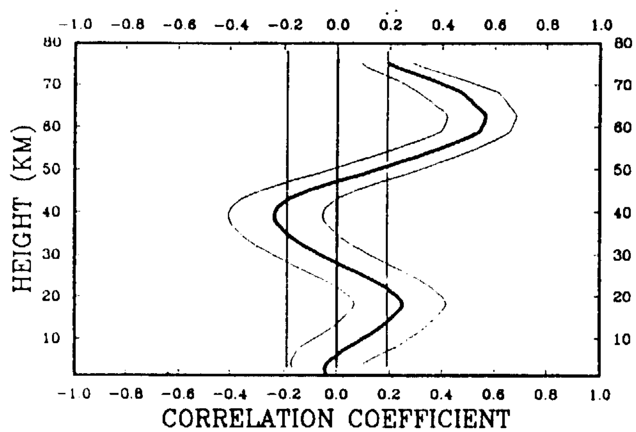

Figure 8: Same as figure 3 for all seasons and independently of the Q.B.O..

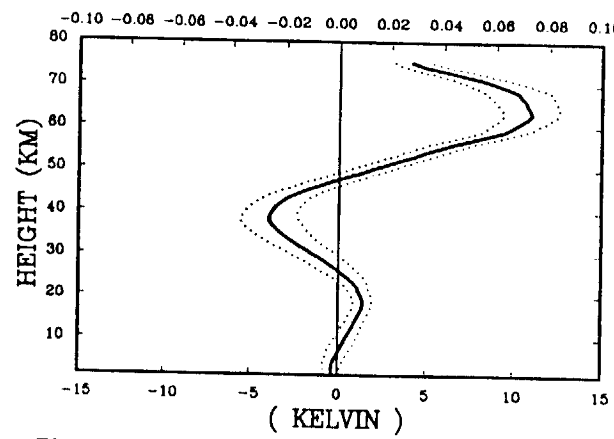

Figure 9: Amplitude of the solar temperature dependence expressed in Kelvin and in Kelvin by unit of solar flux for all seasons and independently of the Q.B.O..