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SHORT CONTRIBUTION

Effects of the quasi-biennial oscillation and the southern oscillation on the northern hemisphere circulation

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The mean 500 mb anomaly pattern for winter 1976 (December 1975 to February 1976) is shown in Fig. 1 (based on data supplied by the Meteorological Office, Bracknell). Among the most interesting features are the positive anomaly centred over the east Atlantic, which was associated with more anticyclonic and drier than normal weather over much of Europe especially England and France, and the enhanced upper westerly winds between Iceland and Britain which can be regarded as a contributory cause of the severe gales that affected North Europe on several occasions during the season.

The need to account for the features of seasonal patterns such as this is an essential preliminary to the understanding of climatic changes and to making seasonal forecasts. One approach is to analyse a set of such patterns, by techniques such as principal component analysis, to obtain characteristic patterns of variation which may then be explainable in physical terms (for example, Trenberth 1975).

An alternative approach is to start with known modes of variation of the atmosphere, find the characteristic patterns associated with these, then investigate what part they play in the individual season. The only two such phenomena sufficiently documented at present are the Quasi-Biennial Oscillation (QBO) and the Southern Oscillation (SO). As a pilot study, it was decided to investigate the part played by these oscillations in the Northern Hemisphere extratropical 500 mb pattern in winter.

1. The QBO and the SO

The QBO is a fluctuation of winds and temperatures in the lower stratosphere over the Equator. At any level from 60 mb to 10 mb alternate spells of easterly and westerly winds are experienced, with period usually close to 2 years but with occasional longer cycles. A comprehensive review may be found in Newell et al. (1974). Significant associations with the QBO have been noted in many tropospheric features (e.g. Ebdon 1975). A convenient indicator of the phase in any year may be obtained by identifying the first month of a spell (easterly or westerly) in the zonal wind component at 50 mb at any equatorial station. On this basis two groups of years may be recognized: Group A (the years 1954, 1956, 1958, 1960, 1965, 1968, 1970, 1972 and 1974), in all of which the first month of an easterly spell occurred between May and September inclusive; and Group B (the years 1955, 1957, 1959, 1961, 1966, 1969, 1971 and 1973), in all of which the first month of a westerly spell occurred between March and August inclusive. Other years were omitted because the phase of the QBO was not classifiable into either group. The mean winter 500 mb pattern for group A minus the mean for group B years (Q) is shown in Fig. 2. (Values in the Pacific are based on only about half the period and are less reliable.) Of the 167 points with complete data, 15 were significantly different from zero at the 5 % level by the Welch test. It is difficult to confirm the significance of the pattern as a whole, due to the short period of data and the strong spatial correlation; the fact that other workers have identified significant correlations provides additional justification for further analysis. On average in the years studied,

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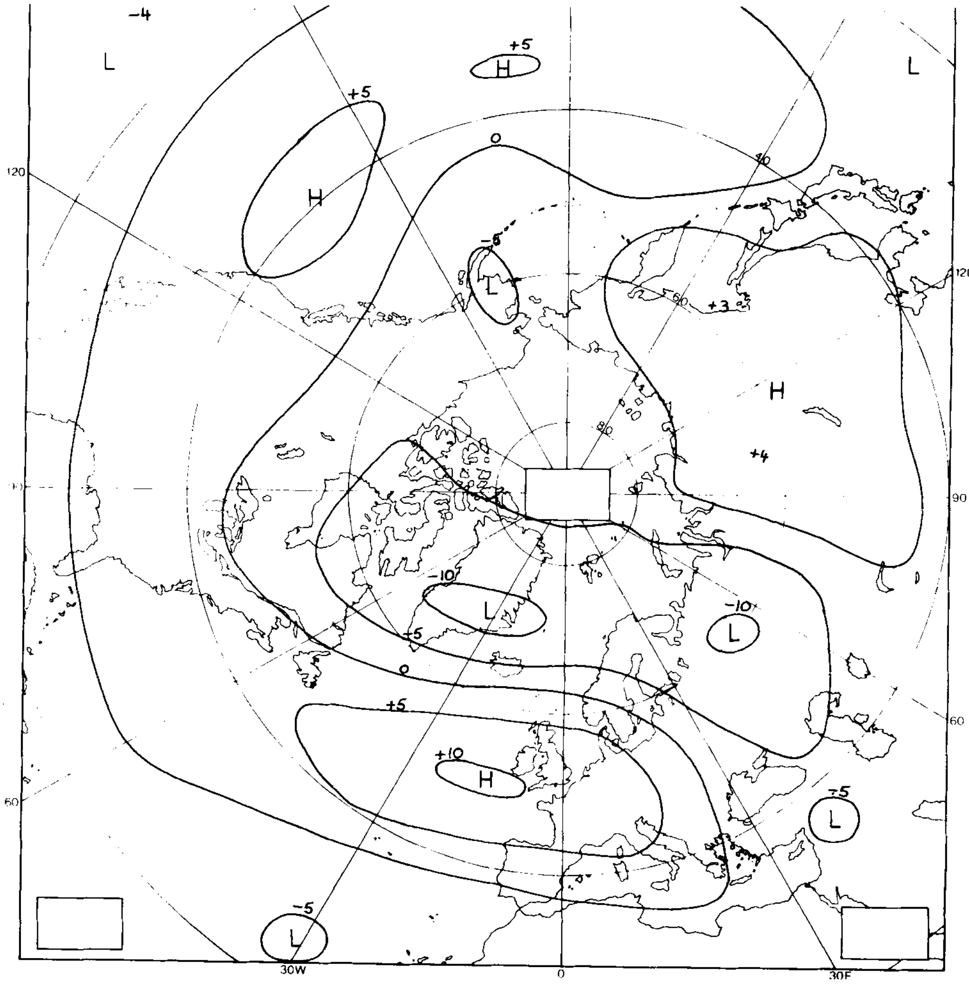

Fig. 1. Anomaly (dekametres) of 500 mb height in winter 1976 (December 1975 to February 1976) relative to datum period 1951–70 (*W*).

the 500 mb pattern included a contribution of 0.5 *Q* in an *A* year, and minus 0.5 *Q* in a *B* year. If the relationship is real, one will expect to find similar contributions in years not used in the sample.

The SO is an oscillation with irregular period based essentially on the equatorial Pacific Ocean, where sea surface temperatures vary coherently over a wide area (Newell et al., 1974, Chapter 9). An index of the SO has been devised, based on pressures at tropical stations but not sensitive to the choice of stations (Wright 1975). The effects of the SO on pressures, temperatures and rainfalls are global in scale and are highly significant in many areas, and the effects on the 500 mb pattern are consistent with those on pressure. Fig. 3 shows the pattern of association of the SO with 500 mb height in winter(s); it represents the regression coefficients of 500 mb values on the index, based on the period 1946–74. (Pacific values are again less reliable than the rest.) One would expect that, in a particular winter, the contribution to the anomaly pattern would be the value of the index times *S*.

2. Multiple regression

The contributions made by *Q* and *S* to Fig. 1 (*W*) were determined by a multiple regression analysis, in which each chart was represented by values at 164 grid points spaced approximately uniformly over the zone 85–25 N. The best estimate (*W'*) of

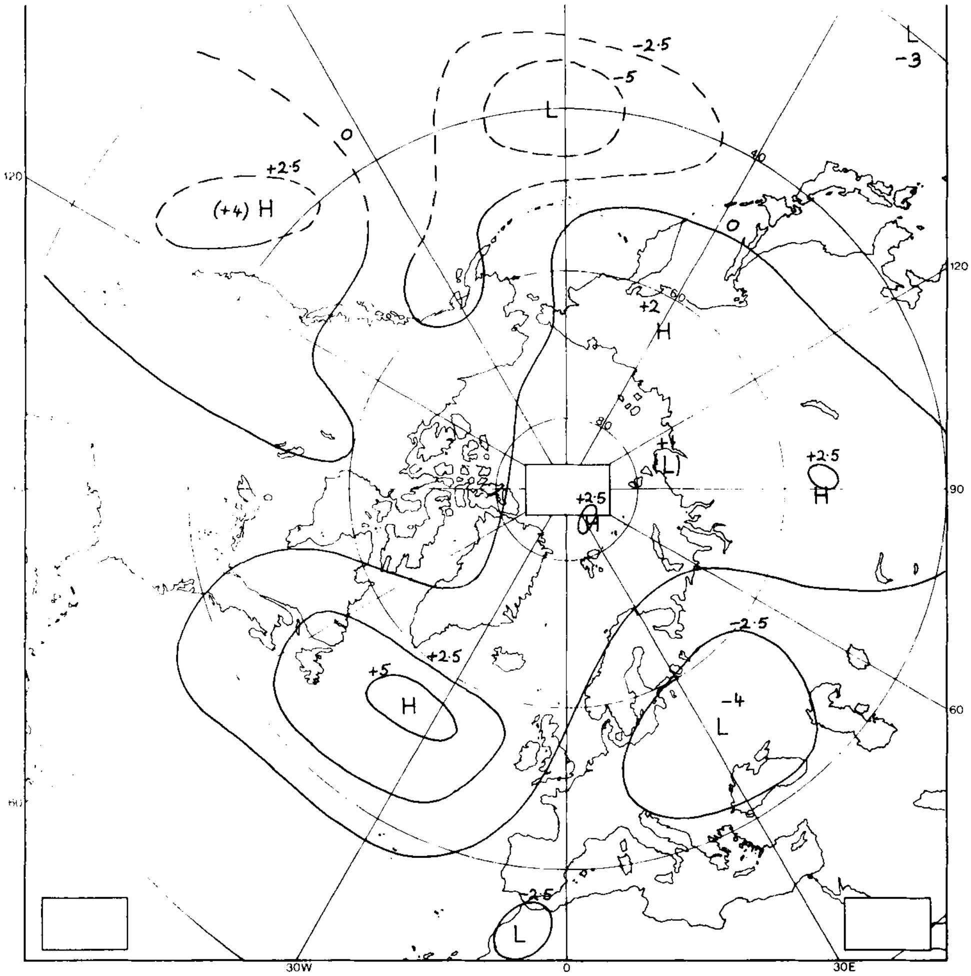

Fig. 2. 500 mb anomaly pattern (dekametres) in winter associated with the Quasi-Biennial Oscillation in the equatorial stratosphere (Q).

W was found in the form

$$W' = C + C_Q Q + C_s S$$

The multiple correlation coefficient (R) of W' with W, and the correlations of W with $Q(R_Q)$ and with $S(R_s)$ were obtained. The analysis was repeated for each winter 1966 to 1976, the only years for which complete 500 mb data were available. Results are tabulated in Table 1. D_Q represents the phase of the QBO, the "expected" value of C_Q; D_s is the SO index, the "expected" value of C_s. C is in Dekametres.

Consider first the results for 1975 and 1976, years which were not used in obtaining Q and S. It is encouraging that all four coefficients were of the expected sign (the probability of this occurring by chance is 0.06) and moreover were of the right order of magnitude in three cases. For the years 1966 to 1974, C_Q had the expected sign in 7 out of 8 cases, and C_S in 7 out of 9, providing support for the other results; however these data were used in obtaining Q and S (except 1967 for Q) so a strict significance test cannot be applied. The magnitude of the coefficient of the QBO was encouragingly similar to the expected value in most years, including 1967 when a low value occurred in a year which was neither A nor B; however the similarities in 1966 and 1974 were not good. For the SO the

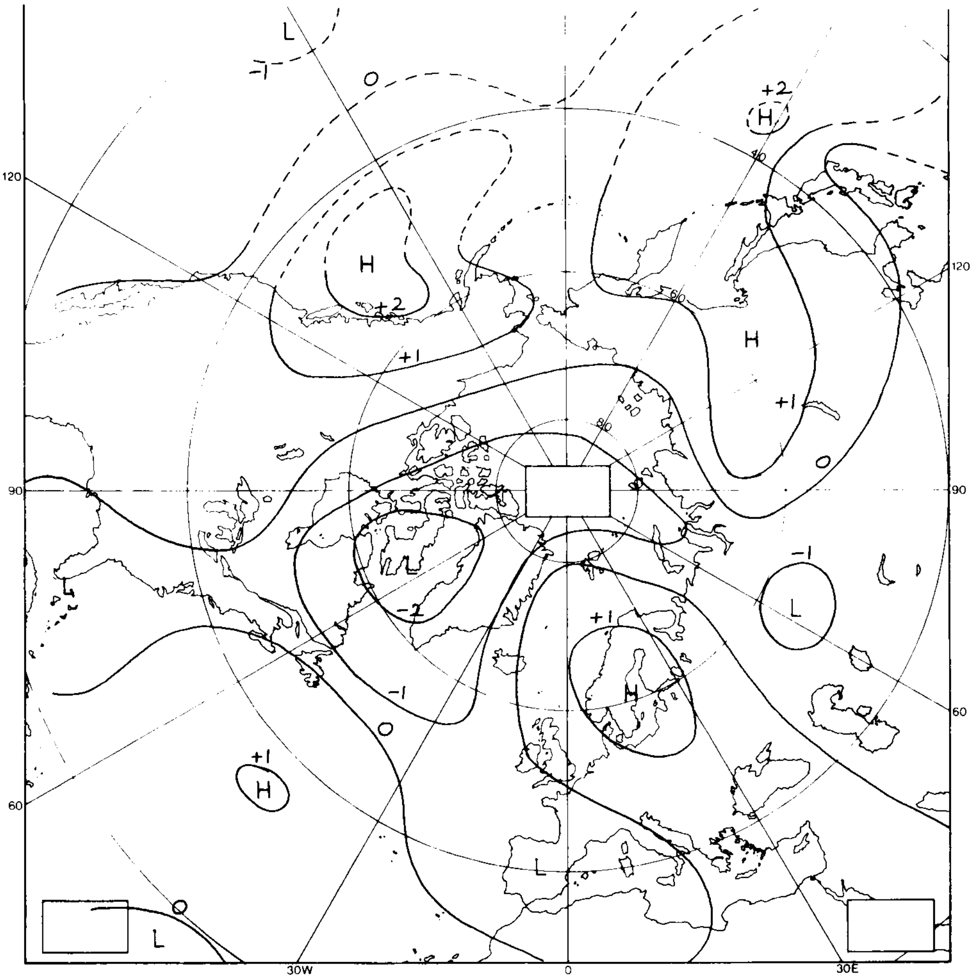

Fig. 3. 500 mb anomaly pattern (dekametres) in winter associated with the Southern Oscillation (*S*).

Table 1. *Results of multiple regression analyses*

Y	C	C_Q	D_Q	R_Q	C_s	D_s	R_s	R
1966	−1·07	−1·49	−0·5	0·60	−1·98	−0·89	0·31	0·74
1967	−0·01	+0·18	0	0·12	+0·09	+0·74	0·00	0·13
1968	+0·25	+0·98	+0·5	0·46	+0·41	+0·04	0·00	0·47
1969	+0·01	−0·86	−0·5	0·25	−1·91	+0·46	0·29	0·43
1970	+0·79	+0·73	+0·5	0·41	−0·98	−0·21	0·31	0·47
1971	−0·33	−0·23	−0·5	0·19	+0·51	+1·60	0·21	0·26
1972	−0·76	−0·41	+0·5	0·27	+2·93	+1·06	0·57	0·59
1973	−0·50	−0·70	−0·5	0·43	+1·98	−0·74	0·54	0·63
1974	−0·11	+0·01	+0·5	0·02	+0·41	+2·16	0·13	0·13
1975	−1·27	−0·46	−0·5	0·23	+0·60	+0·04	0·17	0·27
1976	−0·72	+0·54	+0·5	0·18	+1·42	+1·2*	0·26	0·35

* Estimated.

magnitudes bore less similarity to the values of the index.

3. Concluding remarks

The atmosphere is extremely complex, and it would not be expected that two phenomena based on the Equator could account for most of the 500 mb height variability. Nevertheless they seem to play an appreciable (occasionally, as in 1966, almost dominant) part, and should be taken into account in any forecasting scheme. There are other factors that remain to be found.

It is interesting to note that this analysis has revealed the phase of the QBO on at least 8 occasions out of 11 based only on 500 mb heights north of 20N. This suggests that one might be able to discover the phase of the QBO in years before 1954. If the method were found to be equally successful on pressure, one could extend this identification back for several decades. Analysis of the other three seasons could be performed, to verify the method and to improve the accuracy of the estimates.

4. Acknowledgements

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