QBO signal in winter northpole temperature at 30 mb and in southwest monsoon Indian rainfall

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A study of 32 years' (1957–1988) data for northpole temperature at 30 mb during winter and Indian summer monsoon rainfall (June–September), by using the traditional harmonic analysis technique[1], has revealed existence of the QBO in the northpole temperature as well as in the summer monsoon rainfall. A phase difference observed from the analysis suggested possible influence of northpole temperature during winter on the following summer monsoon rainfall over India, corroborating an earlier finding[2] by using other techniques.

INTERANNUAL variability of the lower stratosphere in the high latitude during winter has been reported[3–5]. Equatorial QBO, which is a dominant oscillation in the lower stratosphere, has been a subject of investigation by many workers[6, 7]. Mukherjee *et al.*[8] have suggested an association of the phases of the low-latitude QBO in the stratospheric zonal wind with the summer monsoon rainfall over India. The modulation of southern oscillation–South African rainfall with the quasi-biennial oscillation in tropical stratospheric zonal wind has been reported[9]. They have shown that the high phase wet conditions occur over the summer rainfall region in January–March only when the quasi-biennial oscillation is in the westerly phase and the low phase dry conditions occur in the easterly phase of the QBO. The relationship is inverse when the winter rainfall is considered. Holton and Tan[10] have given some indications of the existence of a QBO signal in stratospheric planetary waves in the higher latitudes and have indicated that the strengthening of the planetary wave number 1 is dependent on the phases of the equatorial QBO during winter. Quasi-biennial oscillation in the polar night jet has also been detected by them. The investigation of Angell and Korshover[11, 12] has also revealed existence of quasi-biennial oscillation in the zonal wind at polar lower stratosphere. They have pointed out that the polar QBO is out of phase with the oscillation in the temperate and tropical latitudes.

Using harmonic analysis technique, an attempt has been made here to further confirm the QBO signal in the northpole temperature during November–March and in the Indian rainfall during the following summer monsoon (June to September). The period November–March is considered to represent the winter condition in the northpole temperature.

We have used in this study a monthly mean 30 mb northpole temperature for a period of 32 years from 1956 to 1987 for November and December and 1957 to 1988 for the month of January–March. The rainfall data for the summer monsoon (June to September) during the period of 32 years from 1957 to 1988 are also made use of. The rainfall data are obtained from the work of Parthasarathy[13]. Both the north pole temperature data and rainfall data for 32 years are subjected to harmonic analysis.

The harmonic analysis of the monthly mean winter northpole temperature at 30 mb during November to February for 32 years suggested that the maximum percentage variances (about 20%) observed during the four months are associated with the waves showing periodicities 2.4 to 2.6 years. Also amplitudes of these waves enhance progressively from 2.5° to 6.4°C. The phases of the waves are 241° in November, 181° in December, 122° in January and 45° showing a monotonic decrease in phase angles. From above, the monotonic decrease in phase angles in northpole temperatures from November–February indicates increase in the intensity of the QBO signal. It could be due to interference in the QBO signals by the large scale planetary waves during winter. The amplitude and phase of the wave during March are respectively 4.4°C and 258°.

Similar computational procedure has been adopted using Indian summer monsoon rainfall data for 32 years. The analysis revealed that the maximum percentage variance observed in the rainfall data series was about 20%. These are associated with waves of periodicities 2.46 to 2.66 years. The amplitude and the phase angles of the two waves were 6.43 cm and 5.74 cm and 204° and 260° respectively.

The study has pointed out that the QBO signal could be detected in the northpole temperature in the lower stratosphere during each month from November to March (winter). The periodicity of this QBO varies from 2.4 to 2.6 years. The percentage contributions of the variances by the waves showing QBO are maxima and their values varied from 18 to 22%. The QBO signal in temperature, wind and rainfall were observed over equator by various workers. The present study also showed strong QBO signal in the summer monsoon rainfall over India. The presence of QBO signals in the northpole lower stratospheric temperature during winter and in the summer monsoon rainfall encourages one to investigate whether there exists a relationship between these two QBOs. For this, the QBO oscillation in the lower stratospheric northpole temperature for March is plotted separately with the QBO oscillation in rainfall and shown in Figure 1*a*, *b*. The northpole temperatures in March are only taken into account here to represent winter condition since the characteristics of oscillation in all the months are alike.

From the above figure as well as from the difference in the phase angles it could be noticed that the northpole

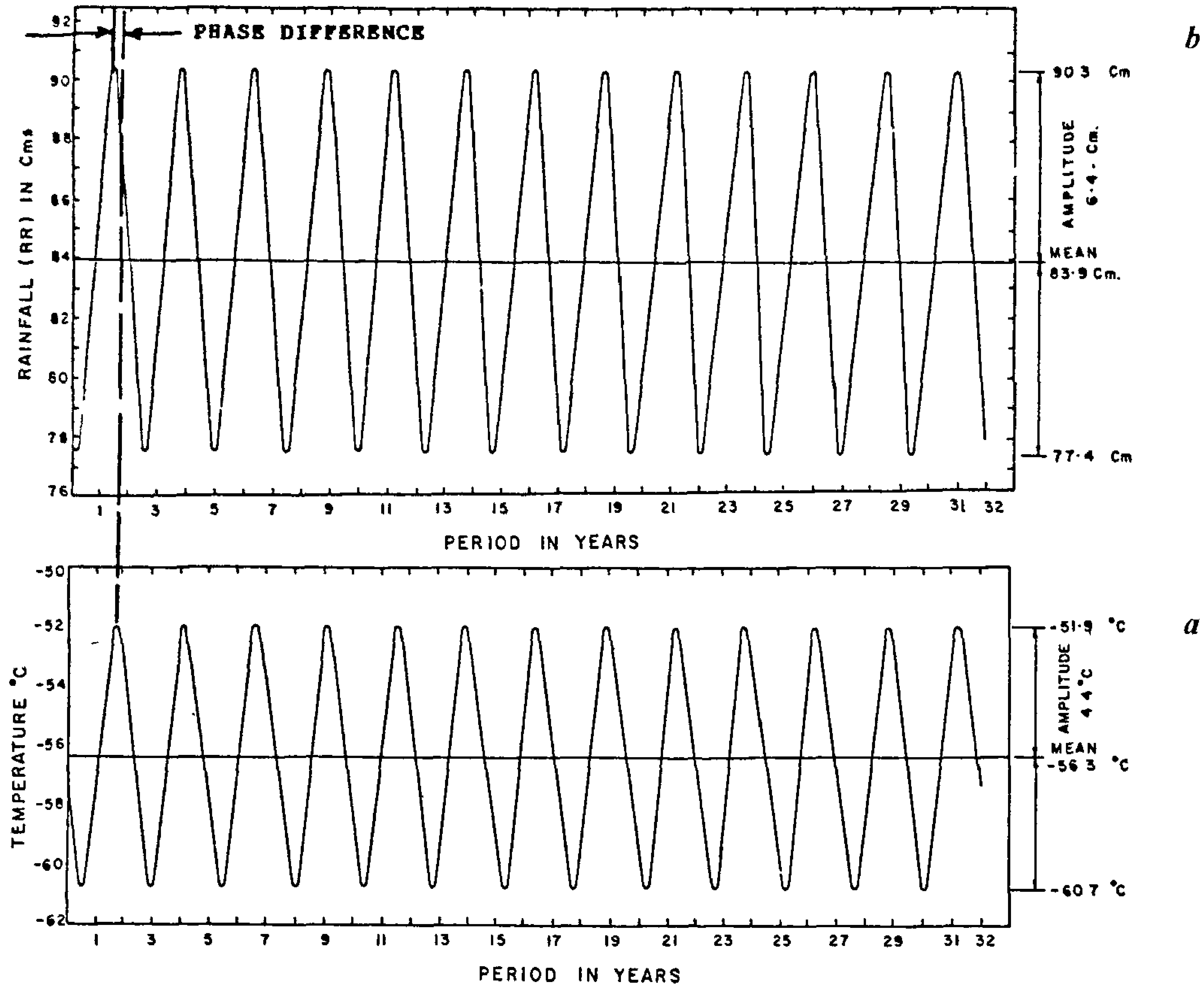

Figure 1. *a*, Amplitude and phase of wave no 13 (periodicity 2 5 year) of northpole temperature during March for 32 years (1957–88); *b*, Same as above but for southwest monsoon rainfall over India during June–September for 32 years (1957–88).

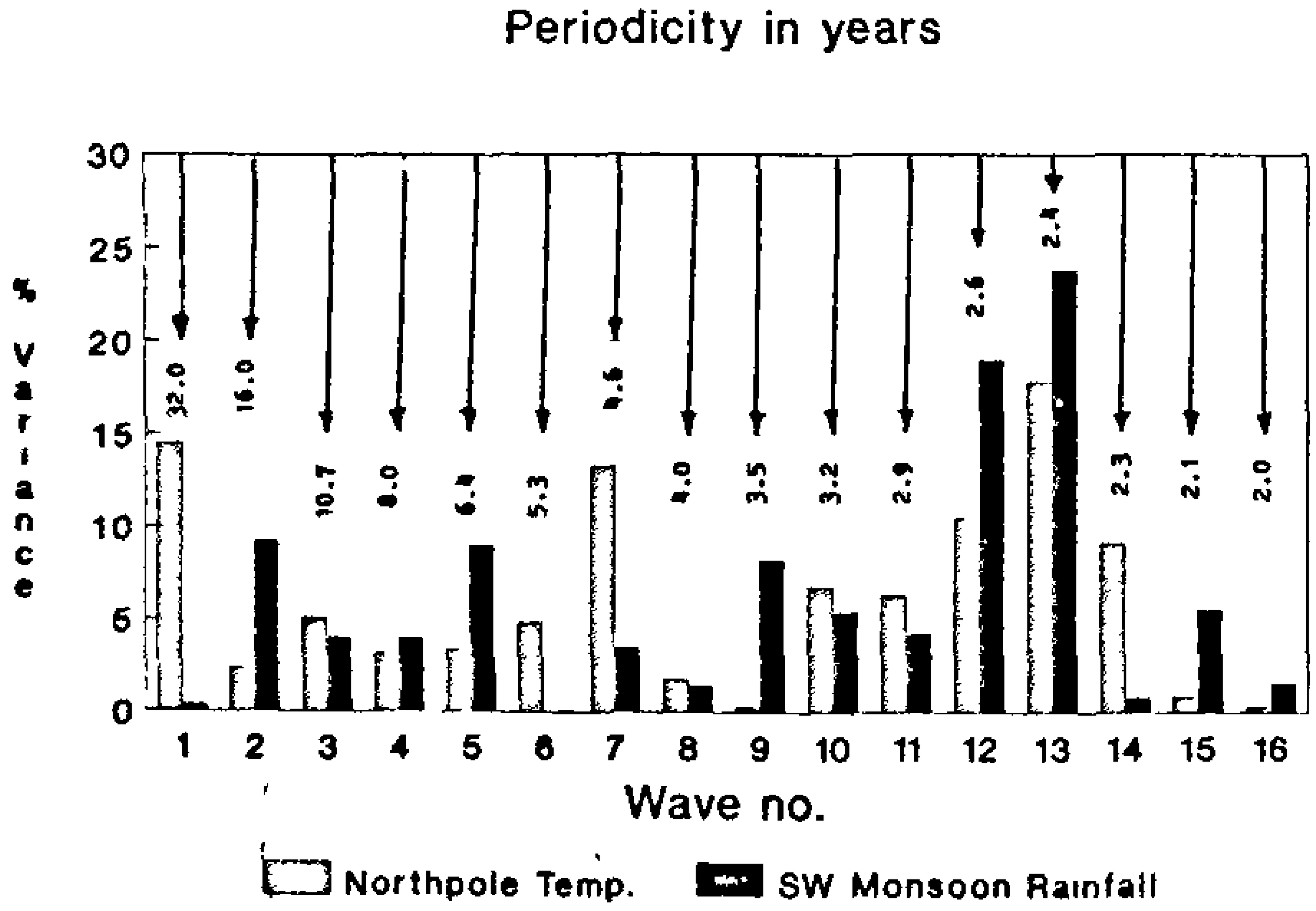

Figure 2. Periodicity diagram showing contributions of variances by wave numbers (1–16) for northpole temperature at 30 mb during March and for southwest monsoon rainfall over India during June–September (1957–88) Variances contributed by wave no 13 (periodicity 2 4 year) are considered in this study

temperature during March was in phase with the following summer monsoon rainfall over India. That is, the QBO in the summer monsoon rainfall in India was preceded by the QBO in the lower stratospheric northpole temperature during March.

A time series showing periodicity of the wave nos 1–16 for the northpole temperatures and the following summer monsoon rainfall over India are also presented here to highlight the contributions by different variances and shown in Figure 2.

The analyses by different workers[11, 12, 14] have revealed existence of extratropical QBO in the middle and high latitudes, amplitude variations being more at polar region. Holton and Tan[15] found out apparently significant QBO in the amplitude of stationary planetary wave of zonal number 1 in the early winter. The larger wave amplitudes occurred during the easterly phase of the equatorial QBO at 50 mb. They found that the strength of the polar night jet around 60°N was significantly more during the westerly phase of the equatorial QBO than the easterly phase of 50 mb level, suggesting existence of an apparent QBO at the high latitudes during winter. All these studies may drive us to conclude that QBO exists at high latitude and this oscillation is prominent during winter. Holton and Tan[10] suggested that Rossby waves could be a linking mean between equatorial QBO and the QBO observed in the general circulation at the extratropical latitudes during winter. Since the phases of the quasi-biennial oscillation at the equator during summer (June–September) can be apprehended by observing the mode of oscillation during preceding winter, it may not be far-fetched to conjecture that the QBO at the latitudes during winter is linked with the QBO at the equator during ensuing summer to influence the rainfall activity over India during the summer monsoon as reported earlier (Mukherjee *et al.*[8]).

This result could suggest association of cold stratospheric polar temperature with the deficient rainfall and warm stratospheric polar temperature with the excess rainfall over India during the following summer monsoon. van Loon *et al.*[16] suggested agreement between High Dry (HD) winters with strong polar vortex and vice versa. Their HD winters are characterized by the high pressure in South Pacific as compared to Indonesia and tropical Australia and below normal precipitation in the equatorial central Pacific. Such winters coincide with the episodes of below normal sea surface temperatures in the equatorial central Pacific. Their 'Low Wet (LW)' winters are characterized by opposite conditions[17], i.e. low pressure in the south Pacific as compared to Indonesia and tropical Australia and above normal precipitation in the equatorial central Pacific which also coincides with the episodes of below normal sea-surface temperatures in the equatorial central Pacific[18].

Investigation undertaken here has hinted that there is a tendency of occurrence of less rainfall over India during the summer monsoon when the lower stratospheric temperatures at the pole are cold and occurrence of enhanced rainfall when the polar stratospheric temperature are warm during the preceding winter.

QBO is observed in the low-latitude rainfall (June–September) as well as in the winter north pole temperature (November–March). A direct relationship between the northpole temperature and the rainfall during the following summer monsoon over India may exist. More data is required to arrive at some definite conclusion. Also, the QBO noticed at the two regions are nearly in the same phase. However, the driving mechanism of QBO in low-latitude rainfall and high-latitude temperature may be different. QBO is a predominant phenomenon observed at the low latitudes and its phases are driven by the dynamical processes resulting from the anomalous behaviour in the large scale cumulus convection. This QBO may be responsible for driving the QBO in the high latitudes. A clearcut picture has yet to emerge to link the extratropical QBO with the well-documented QBO observed in the equator.

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Received 4 April 1994; accepted 1 July 1994

Geological framework of Sankara dyke swarm forming a part of Malani Suite of igneous rocks in western Rajasthan

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The Malani Suite of rocks exposed around Sankara, in district Jaisalmer, represents probably the closing phase of Proterozoic magmatism in southwestern Rajasthan. On the basis of field relations, four different magmatic episodes have been identified in the area. These appear to be widely spaced in time and are not related to each other.

THE Malani volcanics and the associated intrusives in western and southwestern Rajasthan are spread over an