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# *INFLUENCE OF THE EL CHICHON ERUPTION ON THE STRATOSPHERE AFTER SUMMER 1982*

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## RESUMEN

En Quiroz (1983) se atribuyó un calentamiento de 1 - 3° a 30 mb, entre los 35°N y el ecuador, a la erupción de El Chichón para el verano de 1982. Dos interrogantes se consideran aquí, una posible influencia de este calentamiento sobre la oscilación estratosférica cuasibianual (QBO) y la extensión del calentamiento después del verano de 1982 a 50 - 10 mb. La distribución meridional del calentamiento deducido para el verano de 1982 no sugiere una influencia importante en el viento sobre el QBO. La aparición de un periodo de contracción en 1982 - 83 es congruente con tales contracciones después de la máxima solar previa desde 1951 y no refleja necesariamente una influencia debida a la erupción. Se dan algunas indicaciones de calentamiento máximo a 30 mb para el otoño de 1982. Es difícil determinar el cambio en la temperatura relacionado con el volcán, a 50 y 10 mb, después del verano y el otoño de 1982, debido a la presencia de fuertes influencias no volcánicas.

## ABSTRACT

In Quiroz (1983) warming by 1 - 3°C at 30 mb, between 35°N and the equator, was ascribed to the El Chichón eruption by summer 1982. Two questions are considered here, a possible influence of this warming on the stratospheric quasibiennial oscillation (QBO) and the extent of warming after summer 1982 at 50 - 10 mb. The meridional distribution of the warming deduced to summer 1982 does not suggest an important influence on the QBO in wind. The appearance of a contracting period in 1982 - 83 is consistent with such contractions after previous solar maxima since 1951 and does not necessarily reflect an influence due to the eruption. Some indications are given of maximum warming at 30 mb by fall 1982. At 50 and 10 mb the volcano-related temperature change after summer and fall 1982 is difficult to determine because of the presence of strong non-volcanic influences.

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## INTRODUCTION

After taking into account dynamical, quasibiennial, and oceanic influences on the stratospheric temperature, Quiroz (1983a) determined that warming by approximately 1 - 3°C between 35°N and the equator was due to the eruption of El Chichón. This amount of warming, subject to an error of about 0.75°C, was estimated to have occurred by summer 1982 at the 30-mb level (about 24 km).

Of the non-volcanic influences mentioned above, the quasibiennial oscillation (QBO), which showed an amplitude close to the equator of nearly 3°C at 30 mb, was the most troublesome. Figure 1, from Quiroz (1983a), illustrates the structure of the QBO in temperature during 1975 - 81. In this figure, extra-tropical latitudes show reduced amplitude and nearly opposite phase, through 1981, relative to the

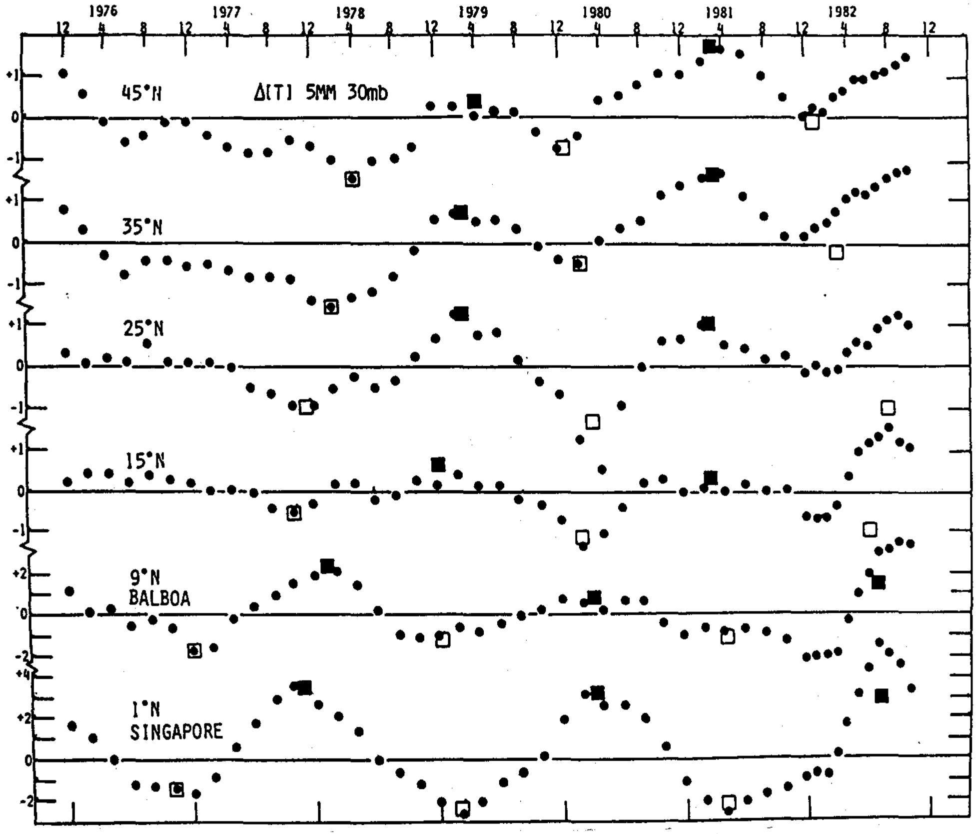


Fig. 1. Anomaly (5-month running means plotted bi-monthly except in 1982; base period 1976 - 81) in 30-mb zonal mean temperature at 15 - 45°N and at stations indicated. Squares denote QBO minima (open) and maxima (filled), with QBO extremes for 1982 estimated as described in Quiroz (1983a).

near-equatorial QBO, consistent with past knowledge of the better-documented QBO in wind. In contrast, 1982 shows uniform warming at all latitudes. At Singapore ($1^{\circ}N$), the total observed anomaly in mid-1982 was 3.5 standard deviations above the normal summertime temperature (Fig. 1 of Quiroz, 1983a). Figure 2 further shows the excess in temperature rise after El Chichón over the observed temperature rise in 7 QBO cycles, 1964 - 81, at Balboa ($9^{\circ}N$).

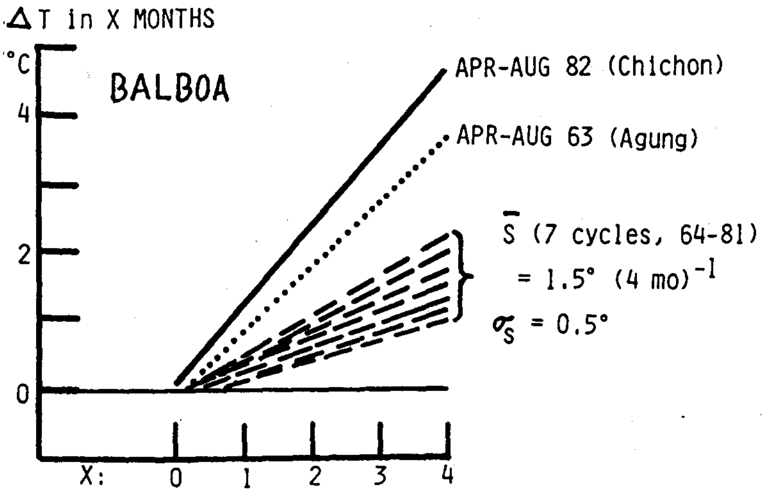


Fig. 2. Linear fit to Balboa 30-mb temperature anomalies for El Chichón and Mt. Agung years, compared with 4-month period of maximum slope (S) in 7 QBO cycles. From Quiroz (1983a). Chichón slope exceeds mean slope in 7 cycles by seven standard deviations at Balboa.

Figure 1 also shows, for 1982, projected QBO temperature minima at 15 - $45^{\circ}N$ and maxima near the equator at Balboa and Singapore. These indicate, for example, that a large part of the observed temperature anomaly should have been due to the QBO. As discussed in Quiroz (1983a), the QBO projections were based on the observed amplitude and phase of the QBO in temperature during 1975 - 81. The residual warming ascribed to the El Chichón eruption was estimated primarily from the difference between the observed temperature anomalies in 1982 and the projected QBO anomalies. For the near-equatorial stations at Singapore and Balboa, the residual was also estimated by two other methods (Table 1 of Quiroz, 1983a), which gave similar results. One was based on the difference between the observed temperature increase in 1982 (as in Fig. 2) and the mean increase in 7 QBO cycles, 1964 - 81. The other was based on the use of QBO wind data to estimate the QBO phase in temperature; for details see Quiroz (1983a).

The residual warming by summer 1982 ascribed to the El Chichón eruption is shown as a function of latitude in Figure 3. Data for Antofagasta, Chile, did not indicate any warming at its latitude ($23^{\circ}S$) (Figure 10 of Quiroz, 1983a). This latitudinal pattern of warming at 30 mb conforms qualitatively to the latitudinal dust distribution indicated by measurements in summer to fall 1982 (see, e.g., Fig. 6 of McCormick and Swissler, 1983). The dust distribution was skewed equatorward from the latitude of El Chichón (17°N), with an abrupt dropoff near 10°S and a reduction in middle northern latitudes. By December 1982 there was evidence, along 120°W longitude, of a minimum near 25°N and an increase poleward to at least 55°N (Dutton and DeLuisi, 1983).

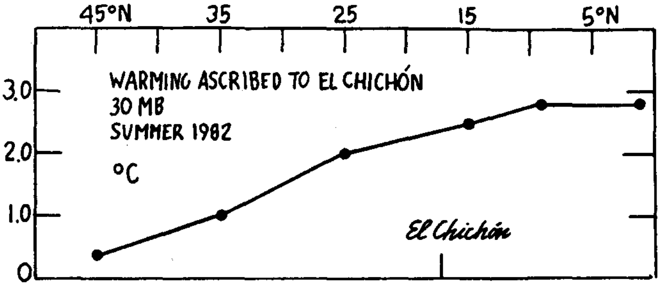


Fig. 3. Plot of residual warming ascribed to El Chichón eruption (from Table 1 of Quiroz, 1983a).

Two major questions addressed here are: (1) Was there a significant influence on the volcano-related stratospheric warming on the QBO wind structure? If so, this might hereafter further complicate the process of separating temperature change due to the eruption from QBO effects. And (2) was there a volcano-related temperature change after summer 1982 and was there an effect at altitudes other than 30 mb?

## QBO INTERACTION

Dunkerton (1983), having noted a lengthened QBO wind cycle after the eruption of Mt. Agung in March 1963, has shown that localized tropical diabatic heating can have an effect on the wind QBO similar to the apparent effect in 1963 - 65. The wind QBO is substantially in thermal wind balance (Quiroz, 1983a); its phase varies slowly within about 10 deg of the equator and then shifts rapidly north of that latitude. Accordingly, the wind structure at places like Singapore (1°N) and Balboa (9°N) depends on the meridional temperature variation within about 15 deg of the equator. Figure 3 showed that the heating ascribed to the El Chichón eruption was not localized but spread over at least 30 deg lat, and in the region 0 - 15°N the meridional temperature gradient would have been only weakly affected. Thus we do not anticipate an important effect on the wind QBO due to the Chichón warming to mid-1982.

Figure 4 shows the QBO wind structure observed at Balboa through September 1983. While at 10 mb there is a slight lengthening of period for the easterly cycle 81 - 83, relative to the preceding cycle, the major change is the appearance of a dramatic shortening of period in 82 - 83 at 30 and 50 mb. One might be tempted to infer an influence of the eruption on the QBO, but it should be noted that: (1) The suggested change in cycle length is opposite in sign to that modeled by Dunkerton (1983). And (2) very short QBO periods have been observed previously after the solar sunspot maxima of 1957 - 58 and 1968 - 70 (Quiroz, 1981). (The most recent solar maximum was around winter 1979 - 80). Thus from the data we have examined, it does not appear that the stratospheric warming due to the Chichón eruption has had an important influence on the QBO thus far.

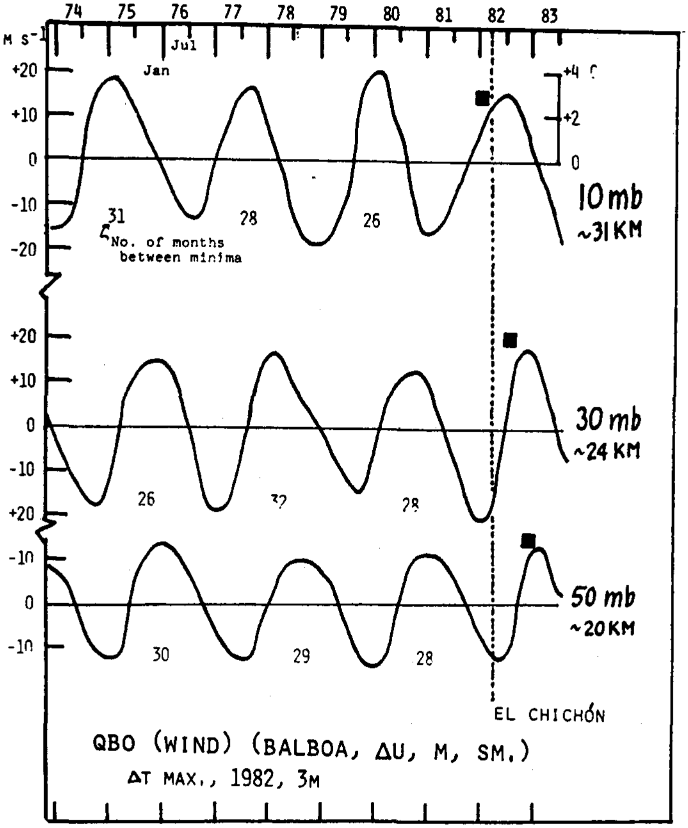


Fig. 4. QBO in wind as defined by visual fit to zonal wind anomaly for Balboa (base period 1951 - 80 except 1958 - 80 at 10 mb). Recent QBO temperature maxima are denoted by filled squares.

## WARMING AFTER SUMMER 1982, AT 50 - 10 MB

The separation of a volcanic signal from non-volcanic effects is increasingly difficult after summer 1982, owing primarily to renewed dynamic influences around winter 1982 - 83 together with a probable stratospheric effect associated with the "El Niño" ocean warming of 1982 - 83 (Quiroz, 1983b), an effect which should be appreciable by winter 1982 - 83 through the following summer.

Figure 5 shows latitude-month cross-sections of the anomaly in zonally averaged temperature at 50, 30, and 10 mb (about 20, 24, and 31 km). This figure suggests

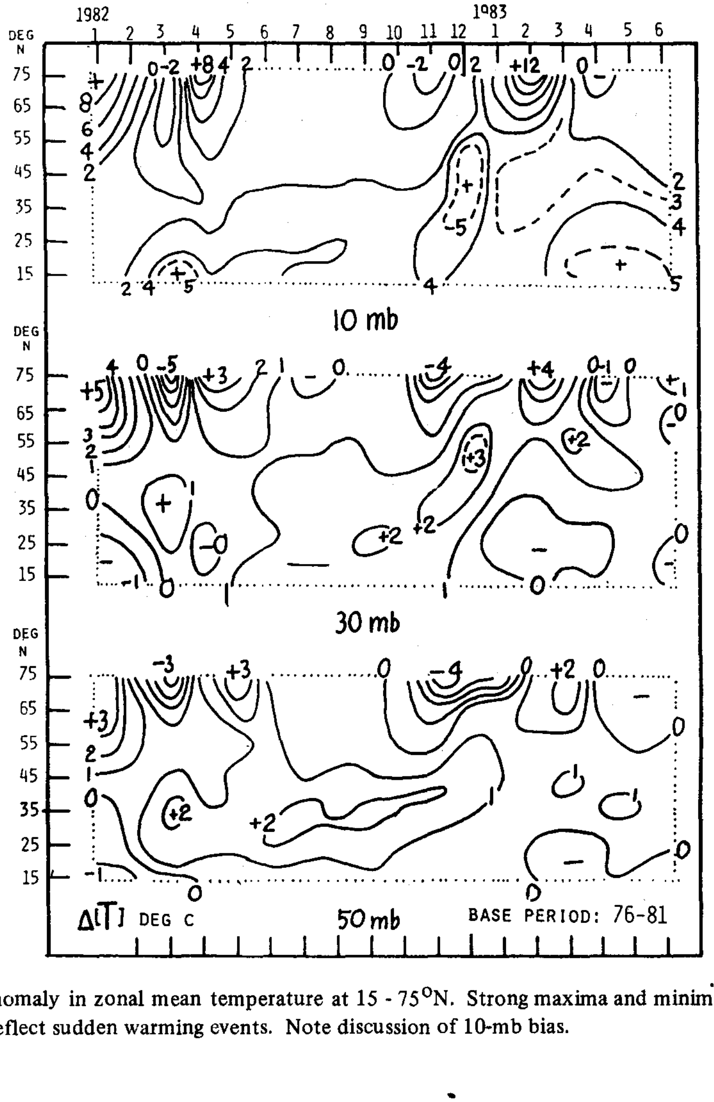


Fig. 5. Anomaly in zonal mean temperature at 15 - 75°N. Strong maxima and minima in high latitudes reflect sudden warming events. Note discussion of 10-mb bias.

the cessation of warming in low latitudes at 50 and 30 mb by winter 1982 - 83 and possibly a continuation of warming at 10 mb in 1983. At certain individual stations (Fig. 6), maximum warming is suggested around August-October 1982. At near-equatorial stations (Fig. 7), an apparent delay of warming to October-December is evidently associated with the downward phase propagation of the QBO and therefore does not necessarily reflect an effect of the volcanic eruption.

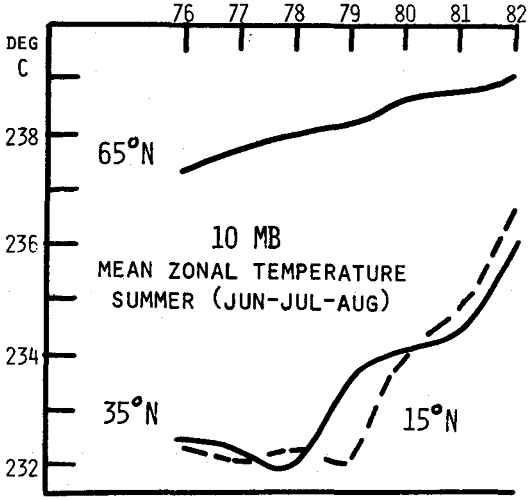


Fig. 6. Three-month running means of monthly temperature anomaly at 30 mb at specified stations.

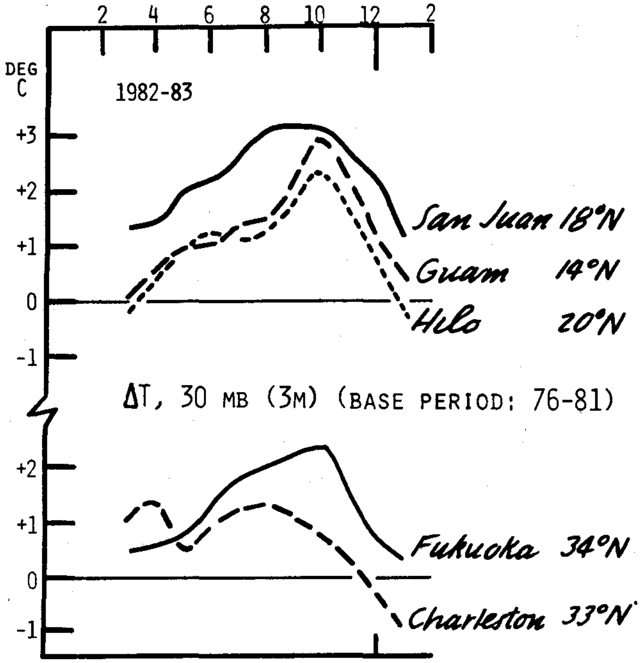
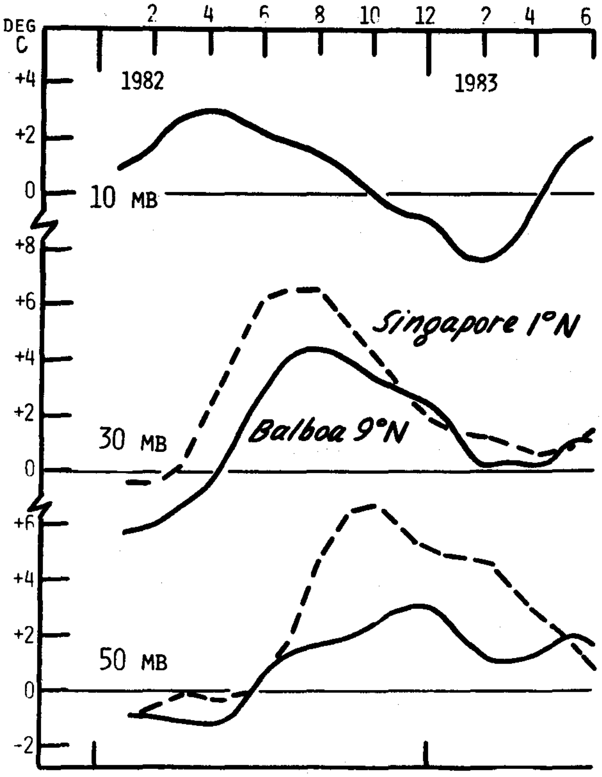


Fig. 7. Same as Fig. 6 but near-equatorial stations Balboa (solid curves) and Singapore (dashed). Adequate data not available at 10 mb for Singapore.

These patterns are unfortunately complicated by: (1) the expectancy of some cooling at 50 and 30 mb associated with the El Niño event, as much as 1 - 2°C at 50 mb near the equator (determined by a compositing procedure as in Quiroz, 1983a); (2) low-latitude cooling associated with dynamically-produced sudden warming activity in high latitudes mainly in winter (see Quiroz, 1983b, his Fig. 26); and (3) the effect of the QBO, especially near the equator. Yet another contribution is due to the fact that the temperatures at the highest level shown, 10 mb, had risen significantly from 1978 to 1981, by 2 - 3°C before El Chichón (Fig. 8). Thus the 5° anomalies at 10 mb (Fig. 5) are partly due to a bias in the reference data (1976 - 81). The warming at 10 mb relatable to El Chichón therefore appears to be in the vicinity of 2°C.



ΔT (3M) (BASE PERIOD: 64-81)

Fig. 8. Summer zonal mean temperature at 10 mb, 1976 - 82. Strong increase at 15 - 35°N before El Chichón eruption is discussed in text. Other seasons show similar trend.

Particularly interesting is the poleward propagation of warming indicated by the 3° and 5° anomaly lines in November-December 1982, at 30 and 10 mb, respectively (Fig. 5), since this feature would be consistent with a poleward increase in dust concentration in late 1982 (Dutton and DeLuisi, 1983). Some poleward propagation of warming can generally be seen in dynamical sudden warming events, but the close association of the feature seen in Fig. 5 with the earlier warming sustained after April 1982 suggests that it is related to the eruption. (Details of the temperature behavior *before* April 1982 are discussed in Quiroz, 1983a).

## SUMMARY AND REMARKS

In Quiroz (1983a) it was determined with reasonable certainty that warming by 1 - 3°C at 30 mb, between 35°N and the equator, was due to the El Chichón eruption, by summer 1982. The meridional distribution of the deduced warming is such (Fig. 3) that no important influence on the QBO wind structure was anticipated. The appearance of a contracting QBO wind period in 1982 - 83 (in contrast to a lengthened period after the Mt. Agung eruption) is consistent with earlier contractions following the two previous solar maxima since 1951, and therefore does not necessarily indicate an influence of the eruption on the QBO.

Indications were given of maximum warming in sub-tropical latitudes by fall 1982 at 30 mb (Fig. 6). Near the equator (Fig. 7), the delayed temperature maximum to October-December is largely explainable by the downward phase propagation of the QBO. The extent of volcanic warming after summer and fall 1982 is difficult to determine because of the presence of strong non-volcanic influences. At 50 and 10 mb, the volcano-related warming thus far does not appear to exceed about 2°C.

We have alluded to short QBO periods after solar maxima. This is but one aspect of a general relationship reported by the author (1981), between QBO period and the 11-year sunspot cycle. This relationship, involving a negative correlation near −0.8 (the sun leading by 2 years) was based on data for 1951 - 79, during 2.5 solar cycles; but because of the small number of effective degrees of freedom could be judged significant only at the 90% level. The QBO behavior since 1979 appears to lend further support to this relationship and thus offers promise for the future use of a regression equation incorporating solar data to estimate the "undisturbed" QBO properties in the presence of volcanic signals.

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