

## Comparison of quasi-biennial oscillations of stratospheric winds and atmospheric temperatures at different altitudes

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सार — 1959-89 के दौरान, 50 हेक्टापास्कल क्षेत्रीय पवनों के 12 महीनों के गतिमान माध्यमान उत्तरी और दक्षिणी गोलार्ध में चार ऊँचाई के स्लैबों (950, 850-300, 300-100 और 100-50 है. पा.) पर औसत वायुमंडलीय तापमान, प्रशांत और अटलांटिक महासागरों के समुद्र सतह तापमान (एस. एस. टी.) और उत्तरी ध्रुव में 30 है. पा. तापमान तथा 10 अंश से 90 अंश उ. के औसत तापमानों से द्विवार्षिक अर्ध दोलनों (क्यू. बी. ओ.) का पता चलता है। यद्यपि पवन क्यू. बी. ओ. का औसत अंतराल 29 महीने रहा है, जबकि केवल 300-100 है. पा. पर तापमान और अटलांटिक समुद्र सतह तापमान का औसत अंतराल इसी तरह का रहा है। अन्य तापमानों तथा दक्षिणी दोलन (एस. ओ.) सूची (ताहिती - डार्विन वायुमंडलीय दाब द्वारा प्रस्तुत) का औसत अंतराल भी अधिक रहा। स्पैक्ट्रल विश्लेषण से पता चलता है कि टी = 2.33 वर्ष पर प्रमुख उच्च पवन क्यू. बी.ओ. केवल एक ही रहा, जबकि प्रशांत समुद्र सतह तापमान और 30 है. पा. उत्तर ध्रुव तापमान को छोड़कर जिसका टी = 2.3 वर्ष पर अधिकतम क्यू. बी. ओ. लघु रहा है, अन्य प्राचलों का क्यू. बी. ओ. टी = 2.5 - 2.6 वर्ष के लगभग क्षीण रहा है। 3-6 वर्ष में सभी तापमानों का क्यू. बी. ओ. अधिकतम रहा है जो दक्षिणी दोलन सूची के इसी तरह के अधिकतम से मिलता जुलता है। इस तरह के भी कुछ संकेत मिले हैं कि समतापमंडलीय पवन क्यू. बी. ओ. का उष्णकटिबंध की सभी ऊँचाइयों के प्राचलों के साथ और उत्तरी ध्रुव के प्राचलों के साथ कुछ संबंध हैं जबकि एलनिनो दक्षिणी दोलन का अन्य अक्षांशों/ऊँचाइयों के प्राचलों पर पर्याप्त प्रभाव रहा है।

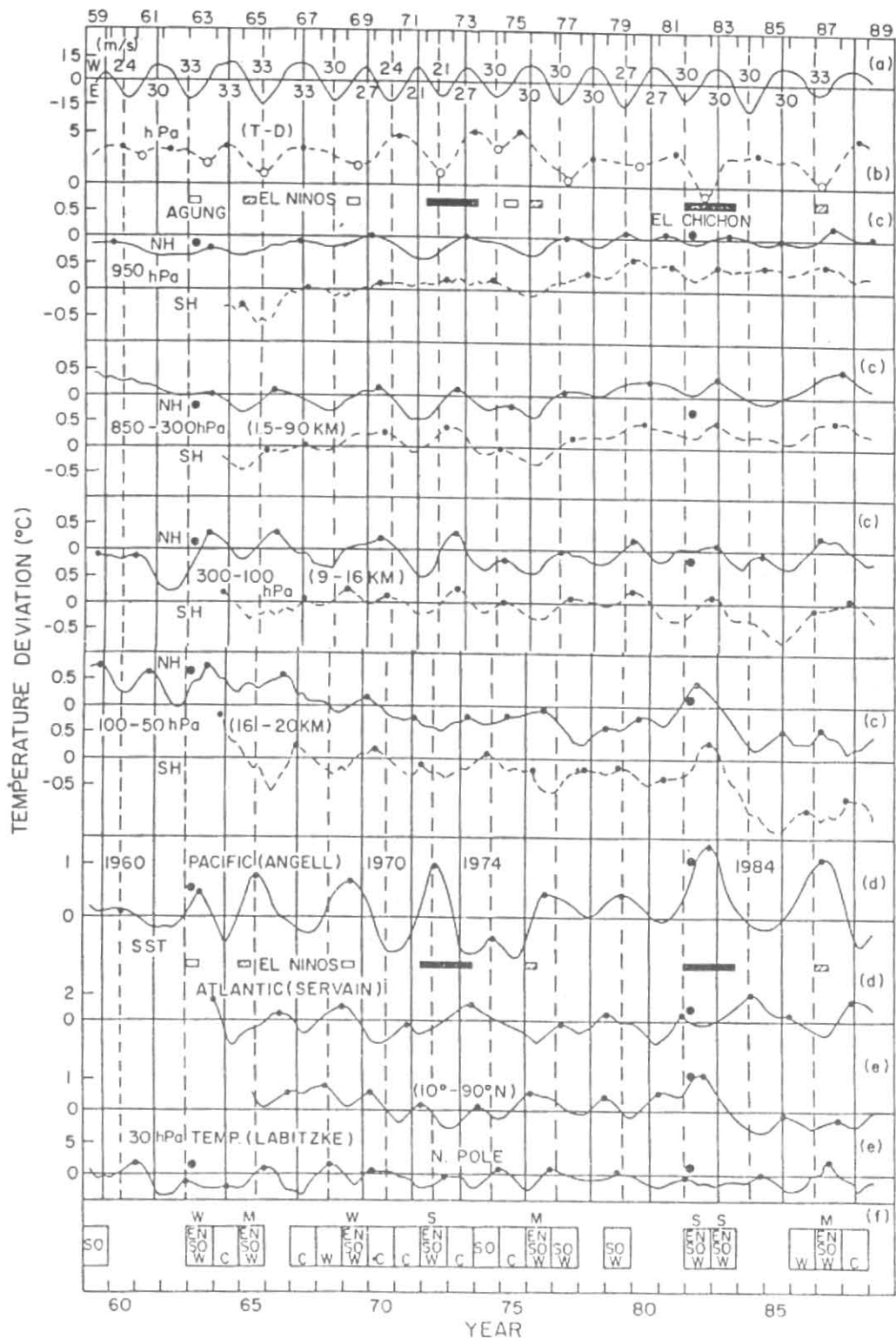
**ABSTRACT.** During 1959-89, the 12-month running means of 50hPa zonal winds, the average atmospheric temperatures in the northern and southern hemisphere at four altitude slabs (950hPa, 850-300hPa, 300-100hPa and 100-50hPa), Pacific and Atlantic sea surface temperature (SST) and 30hPa temperatures at North Pole and average for (10°-90°N), all showed quasi-biennial oscillations (QBO). However, whereas the wind QBO had an average spacing of 29 months, only temperatures at 300-100hPa and Atlantic SST had similar average spacing. Other temperatures as also SO index (represented by Tahiti minus Darwin atmospheric pressure) had larger average spacing. Spectral analysis showed that whereas wind QBO had only one prominent peak at  $T=2.33$  years, other parameters had weak QBOs near  $T=2.5-2.6$  years except Pacific SST and 30hPa North Pole temperature which had small peaks near  $T=2.3$  years. All the temperatures had prominent peaks in the 3-6 year region which matched with similar peaks in the SO index. There is some indication that stratospheric wind QBO had some relation with parameters at all altitudes in tropics and with North Pole, while ENSO had considerable influence at other latitudes/altitudes.

**Key words** — Quasi-Biennial Oscillation (QBO), El-Nino Southern Oscillation (ENSO), Sea Surface temperature (SST), Stratospheric wind, Running means.

### 1. Introduction

Equatorial stratospheric winds and temperatures show a strong quasi-biennial oscillation (QBO), first documented by Reed *et al.* (1961), Veryard and Ebdon (1961) and Angell and Kroshover (1962). Systematic phase changes of the wind QBO with latitude and height have been reported (*e.g.*

Naujokat 1986). Similar QBO - like oscillations have been reported in the troposphere also, for winds and many other parameters (Trenberth 1980 and references therein). Yasunari (1989) presented evidence for a possible link between the QBOs of the stratospheric and tropospheric winds and sea surface temperature in the tropics. However, in most of



**Figs.1(a-f).** Plots of the 12-month running means for 1959-1989. (a) The 50hPa zonal wind, (b) the SO index, represented by Tahiti minus Darwin atmospheric pressure and the accompanying El Ninos. Volcanic eruptions Agung (March 1963) and El Chichon (April 1982) are marked, (c) northern hemisphere (NH) and southern hemisphere (SH) temperatures for 950, 850-300, 300-100 and 100- 50hPa slabs, (d) sea surface temperature (SST) in the tropical Pacific and Atlantic regions, (e) the 30hPa temperatures for (10°-90°N) and for North Pole and (f) characterization of years as having El Niño (EN) (strength S, M, W), Southern Oscillation minimum (SO), equatorial eastern Pacific temperatures warm (W), cold (C) where full circles indicate maxima.

these studies, QBO is considered in a spectral *band* and finer details are ignored. Thus, the stratospheric wind QBO may have an average spacing of ~ 28 months but the successive peak separations may vary in a wide range (21-33 months). If this pattern is not reflected in the other parameters, even allowing for lags or slight distortions, common origin needs to be ruled out. There is another well known phenomenon, viz., El Nino-Southern Oscillation(ENSO) which has primarily a long-term (3-7 year) period but also has a QBO (Barnett 1989, Rasmusson *et al.* 1990), which may not be similar to the stratospheric wind QBO (Kane 1992). Trenberth (1980), identified at least one parameter, viz., the regional meridional index of the sea level atmospheric circulation in the southern hemisphere, which had a QBO which seemed to be unrelated to the wind QBO. In this communication, we examine the data for atmospheric temperatures at different latitude and altitude bands and check whether these exhibit QBO and if so, how do these compare with the stratospheric wind QBO and with the SO index.

## 2. Data and methodology

For stratospheric winds, we used the 50hPa zonal wind monthly mean data given in Venne and Dartt (1990) as a four-station average, viz., Gan (0.7°S, 73.2°E), Balboa (8.9°N, 79.6°W), Singapore (1.4°N, 103.9°E) and Canton (2.8°S, 171.7°W). Data regarding El Ninos (EN) were obtained from Quinn *et al.* (1987). As a measure of the southern oscillation (SO) index, we used Tahiti (18°S, 150°W) minus Darwin (12°S, 131°E) atmospheric pressure difference (T-D) (Parker 1983 and Meteorological Data Reports). Upper air temperature data averages for the northern and southern hemispheres for 950, 850-300, 300-100 and 100-50hPa layers were obtained from Oort and Liu (1993), who have presented a new global data set (GFDL), much more exhaustive than the earlier network of 63 stations used by Angell (1988). Pacific SST (2°N-12°S, 180° - 90°W) data were obtained from Angell (1981 and further private communication) while Atlantic SST (5°N-20°S, 10°E- 40°W) were read from Servain (1991). The 30hPa temperature data for (10°-90°N) and for the North Pole were obtained from Labitzke and Van Loon (1991) and further private communication. To eliminate seasonal variations, 12-month running means were evaluated for all the data (including 50hPa winds and SO index).

## 3. Results and discussion

### 3.1. Plots of time series

Fig.1 shows the plots of the 12-month running means, (centered 3 months apart, *i.e.*, 4 points per year for some parameters, and centered 4 months apart, *i.e.*, 3 points per year for Labitzka data) for 1959-89 (31 years). The top plot (Fig.1a) is for the 50hPa zonal wind and the vertical full and dashed lines mark the west and east wind maxima respec-

tively. The numbers indicate spacings between successive maxima in months. As can be seen, the spacing varied in a wide range (21 to 33 months).

The next plot (Fig. 1b) is for (T-D), *i.e.*, Tahiti minus Darwin atmospheric pressure. The maxima are indicated by full circles and minima by open circles. The minima are generally associated with El Ninos as indicated by the rectangles (full=strong, hatched=moderate, blank = weak). The volcanic eruptions of Mount Agung, Indonesia (March 1963) and El Chichon, Mexico (April 1982) are also indicated.

The next plot (Fig. 1c) are for average temperatures for the northern (full lines) and southern (dashed lines) hemispheres for 950, 850-300, 300-100 and 100-50hPa levels. These are followed by SST in the eastern Pacific and Atlantic (Fig. 1d) and by 30hPa temperatures for (10°-90°N) and for North Pole (Fig. 1e). On each plot, the full circles represent temperature maxima.

It is usually assumed that El Ninos (EN), southern oscillation minima (SO) and warm water episodes in the eastern equatorial Pacific occur simultaneously. The rectangles in the bottom part (Fig. 1f) indicate the status of each year. As can be seen, there were only 8 years of ENSOW, where the EN had strengths S = Strong, M = Moderate, W = Weak marked above the rectangles. There were 2 SOW, 2 SO, 2 W, 7 C (Cold Pacific SST, La Nina) and 10 non-events.

### 3.2. Average characteristics

A glance at the various plots shows that the various temperature maxima (full circles) do show QBOs, but do not have any fixed position relative to the wind maxima (vertical lines), which are themselves unevenly spaced. Table 1 gives the *average* spacing characteristics for the various plots. The 50hPa wind has an average spacing of 29 months. This is nearly equalled only by 300-100hPa temperatures (in both hemispheres) and Atlantic SST. In general, northern and southern hemispheres have similar average spacings, lesser than the 50hPa wind for 100-50hPa level (-4, -3), equal for 300-100hPa level (+1, 0) and larger for 850-300hPa level (+7, +4). For the level near ground, 950hPa shows mixed results (+4, -2) for the northern and southern hemispheres. The discrepancy may be related to the data problems for this level, discussed by Oort and Liu (1993). In any case, some of the spacings at different levels differ considerably from the spacing for the 50hPa wind. Even the 30hPa North Pole and (10°-90°N) spacings are lower (-2, -4).

### 3.3. Lags and leads

If the various temperature maxima are associated with the wind maxima, a superposed epoch analysis (Panofsky and Brier 1958) can be conducted, as was done by Angell (1992) for SST in eastern equatorial Pacific. We use a simpler version of the same, viz., study the frequency distri-

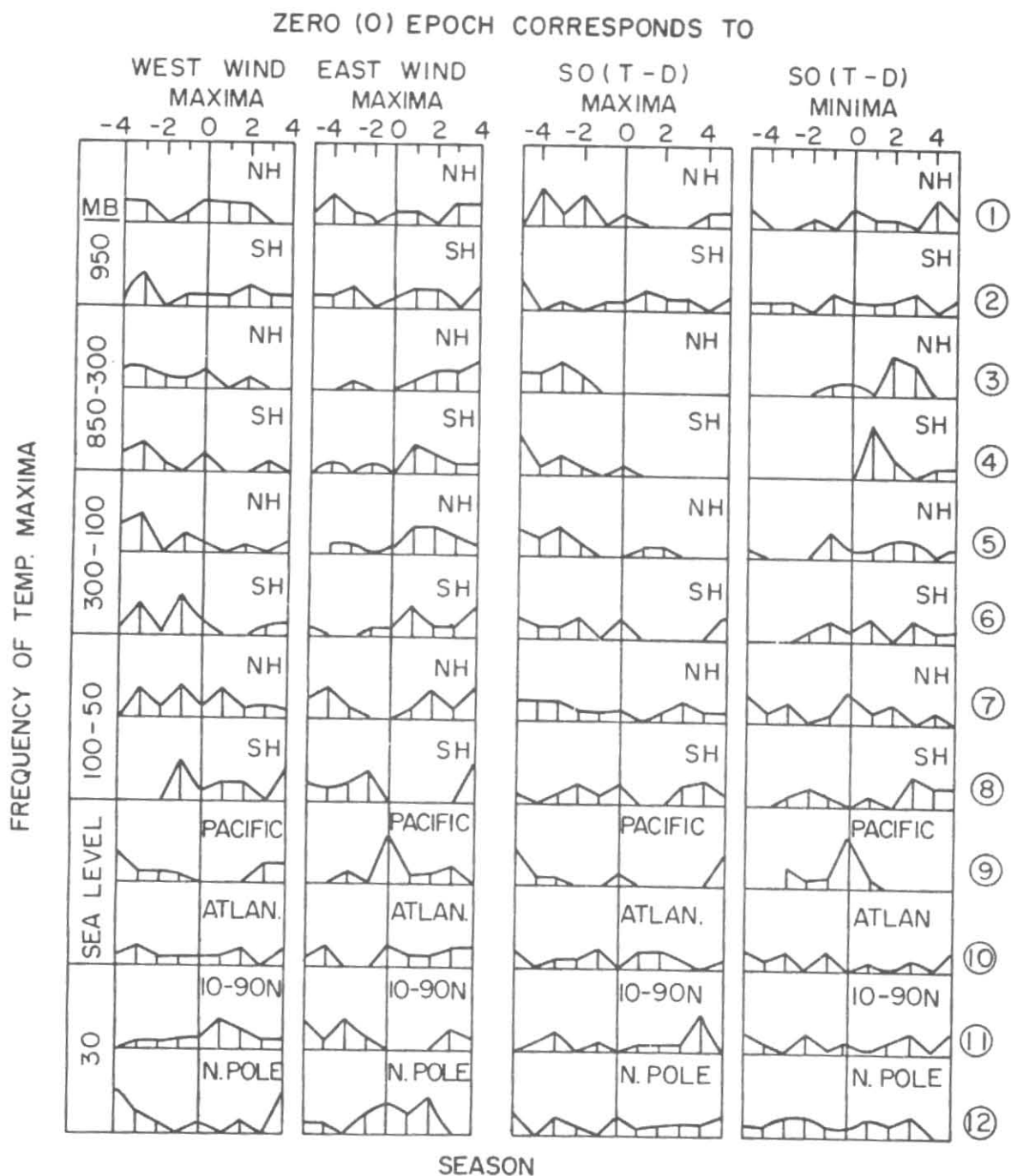


Fig.2. Lag and lead distributions of the temperature maxima with respect to zero epochs as west wind maxima (first column), east wind maxima (second column), SO index maxima (third column) and SO index minima (fourth column). NH and SH indicate northern and southern hemispheres.

bution of the spacing difference between the wind maxima and the various temperature maxima. Fig.2 shows the distributions, using for zero epochs the west wind and east wind maxima (vertical full lines and dashed lines in Fig.1) and the SO index (T-D) maxima (full circles) and minima (open circles) in our fig.1. In Fig.2, the first column has west-wind maxima as zero epochs and the ditribution is studied from 4

seasons (trimesters) before (-4) to 4 seasons after (+4) for the 12 west wind maxima. The second column has east-wind maxima as zero epochs. The third and fourth columns have the SO index (represented by Tahiti minus Darwin pressure, T-D) maxima and minima respectively as zero epochs.

The distributions in Fig.2 are mostly very diffuse. For wind maxima zero epochs (first and second columns), only

TABLE 1  
Average spacing (months) for the maxima of the various parameters

S.No.	Parameter	No. of peaks	Interval (months)	Average spacing (month)	Deviation from 50hPa wind (months)
1.	50hPa wind	12	345	29	0
2.	(Tahiti - Darwin)	10	339	34	+5
3.	950hPa Temperature (NH)	10	333	33	+4
4.	950hPa Temperature (SH)	10	270	27	-2
5.	850-300hPa Temperature (NH)	8	291	36	+7
6.	850-300hPa Temperature (SH)	8	261	33	+4
7.	300-100hPa Temperature (NH)	11	333	30	+1
8.	300-100hPa Temperature (SH)	10	288	29	0
9.	100-50hPa Temperature (NH)	13	330	25	-4
10.	100-50hPa Temperature (SH)	11	288	26	-3
11.	Pacific SST	9	321	36	+7
12.	Atlantic SST	10	294	29	0
13.	30hPa Temperature (10°- 90°N)	10	249	25	-4
14.	30hPa Temperature (N. Pole)	12	318	27	-2

Pacific SST shows some piling at zero epoch (5 points out of 10) for east wind maxima (second column, 9th plot) and roughly agrees with Angell (1992) whose superposed epoch diagram showed that average SST was  $-0.5^{\circ}\text{C}$  warmer one season after the east wind maxima. For SO index maxima and minima zero epochs too (third and fourth column), the distributions are diffuse, except for 850-300hPa northern and southern hemisphere temperatures (fourth column, 3rd and 4th plots) where some piling near +1 and +2 seasons is indicated and for Pacific SST (fourth column, 9th plot) where some piling at 0 season is indicated. The eastern Pacific SST increases (warm episodes W) are generally related with SO index minima and El Ninos, but not always, as shown at the bottom of Fig. 1. Hence, some piling at zero epoch of (T-D) minima in column 4, plot 9 is understandable. Why eastern Pacific SST should show a similar relationship with east wind maxima (column 2, plot 9) is not clear, specially when temperatures at other altitudes and latitudes, or even at North Pole do not show any such piling at any lag or lead. Could it be that parameters in the low latitude regions (tropics only) at all altitudes (sea level to stratosphere) are interrelated but relationships become obscure for other (extra tropical) latitudes? The results of Yasunari (1989) probably indicate such a restricted relationship.

In the 12 month running means (Fig.1), the effects of the volcanic eruptions of Agung (March 1963) and El Chichon (April 1982) do not seem to be very striking.

#### 3.4. Spectral analysis

Whereas the stratospheric winds show predominantly a QBO, the SO index is known to have periodicities in other bands. We conducted a Maximum Entropy Spectral Analysis (MESA) for detecting periodicities accurately. Since MESA does not give amplitude estimates correctly (Kane and Trivedi 1982), these were estimated by a multiple

regression analysis (Bevington 1969). The following was noted:

- (i) 50hPa wind had one prominent peak at  $T=2.33$  years and a subsidiary peak at  $T=2.68$  years.
- (ii) The SO index (T-D) had prominent peaks at  $T=3.61$  years (Quasi-triennial oscillation) and  $T=4.8$  and  $6.4$  years and only small peaks in the QBO regions ( $T=2.44$  and  $2.81$  years). Thus, the SO index seems to be unrelated to stratospheric wind.
- (iii) Most of the temperature series did have QBOs but near  $T=2.60$  years which did not match with the wind main QBO ( $T=2.33$  years). However, the North Pole 30hPa temperature had QBOs at  $T=2.31$  years and  $T=2.77$  years but with almost equal amplitudes. So, some resemblance with 50hPa wind is seen.
- (iv) Pacific SST had small QBO peaks at  $T=2.1, 2.4, 2.8$  years, thus having some resemblance with stratospheric wind QBO. Atlantic SST had small QBO peaks at  $T=2.5$  and  $2.8$  years, not similar to wind QBO and causing the diffuse distributions of Fig.2 (column 1 and 2, plot 9) in spite of the average spacing being almost the same (29 months) for Atlantic SST and wind (Table 1).
- (v) All the temperature series (including Pacific and Atlantic SST), had prominent peaks in the 3-6 year range which seemed to match with the SO index peaks. Thus, SO index certainly has a substantial contribution to temperature variations.

#### 4. Conclusions

A comparison of the QBOs of equatorial stratospheric wind and atmospheric temperatures shows that the two probably have some relationship in the low latitudes, but not

much in extra-tropical latitudes, except for North Pole stratospheric temperature where relationship is better. The temperatures have more significant periodicities in the 3-6 year range, which match with similar periodicities in the southern oscillation index. Overall, one gets an impression that the stratospheric wind QBO and the southern oscillation (SO) are unrelated to each other while temperatures are affected more by the southern oscillation than the stratospheric winds. Attempts have been made recently to evolve mechanisms wherein stratospheric QBO and ENSO variability may influence each other (Geller and Zhang 1991, Gray *et al.* 1992). If such mechanisms are really operative, atmospheric parameters might be sharing the properties of both (wind QBO and ENSO) but in different proportions (more of one than the other) depending upon latitude and altitude. It is interesting to note that another atmospheric phenomenon, viz., Indian summer monsoon rainfall has been reported to be associated with QBO of the low latitude stratospheric zonal wind (Mukherjee *et al.* 1985) as also with SO index (Bhalme and Jadhav 1984), suggesting a possible linkage between the stratospheric winds and ENSO. On the other hand, the strength of the stratospheric polar vortex is related to the stratospheric low latitude wind QBO (Holton and Tan 1980; Van Loon and Labitzke 1987 and also with SO index (Wallace and Chang 1982). Thus, stratospheric winds and ENSO might be connected in a global circulation pattern.

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