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Stratosphere Troposphere Interaction Over Tropical Monsoon Region

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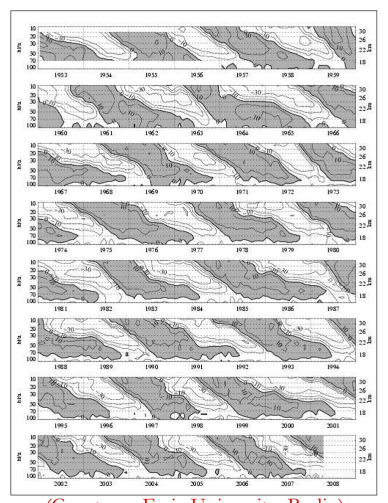
Introduction

The stratosphere is conventionally viewed as responding passively to changes in circulation in the troposphere. There has been evidence from modeling and observational studies that the tropospheric circulation is sensitive to changes in the stratosphere.

Several studies indicate a strong correlation in the circulation between the troposphere and stratosphere, with time lags indicating a stratospheric influence on the troposphere (Mohanakumar 2008). Stratospheric circulation may provide useful information in the increase in medium-range forecasting skill for tropospheric weather.

The dynamical processes that might give a tropospheric response to a change in the stratosphere are still uncertain. A better understanding of the association between the features of stratospheric QBO and the tropospheric circulation over the monsoon region will be useful for the long-term prediction of the Indian summer monsoon.

Quasi-Biennial Oscillation (QBO)



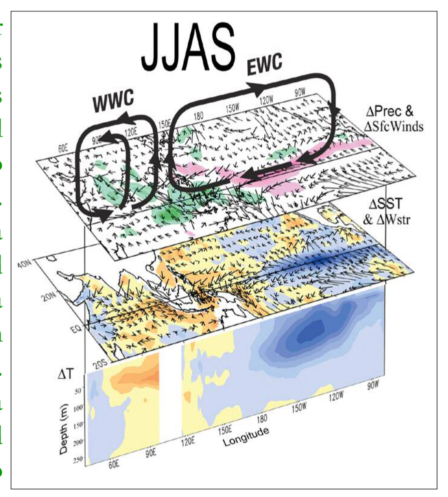
(Courtesy : Freie University, Berlin)

QBO is a predominant phenomenon in the tropical stratosphere with a periodicity of roughly 26 months. Easterlies propagate from upper stratosphere to lower stratosphere during one half and they are replaced by westerly winds during the other half .

They start at 10 hPa and descend to 100 hPa and maximum amplitude is at 20 hPa. Westerlies move down faster than easterlies. There is considerable variability in period and amplitude of QBO. QBO driven by upward propagating gravity, inertia-gravity, Kelvin, and Rossby- gravity waves.

Tropospheric Biennial Oscillation (TBO)

Quasi- biennial oscillation is observed for various of ocean- atmosphere parameters in the tropical region. This oscillation is named as Tropospheric Biennial Oscillation (TBO) in order to differentiate from stratospheric QBO. TBO is defined as the tendency of a relatively strong monsoon to be followed by a weaker one and vice versa. So it is a flip-flop from back and forth; not an oscillation (Meehl and Arblaster 2002). TBO is the result of strong air-sea interaction over the tropical Indian and Pacific Ocean region and is related to Asian-Australian monsoon region.



A strong TBO year monsoon season pattern (Meehl and Arblaster 2002)

QBO-TBO Connection

There are many studies relating both TBO and QBO, while some others are of the opinion that the two are entirely different modes, only have almost same periodicity. Brier (1978) and Nicholls (1978) proposed that QBO and TBO are two different modes. Yasunari (1989) suggested a possible link between biennial oscillations in the stratosphere and troposphere over the Asian monsoon region and SST in the equatorial Pacific using station data from Singapore and Pacific SST. Ropelewski et al. (1992) identified the association of stratospheric QBO with interannual variability of coupled air-sea system. Sathiyamoorthy and Mohanakumar (2000) related the TBO and QBO of zonal wind and temperature over an equatorial Indian station. Mohanakumar and Pillai (2008) showed that the TBO years have different patterns of vertical structure of zonal winds over India and equator giving a hint for stratosphere-troposphere interaction during the TBO period over Indian region.

Objectives of the study

To find the association between stratospheric QBO and tropospheric biennial oscillation over monsoon area.

Data and methodology

QBO-TBO interaction is analyzed by studying the vertical structure of both zonal wind and temperature over Indian summer monsoon region (10N-30N 65E-95E). Zonal wind and temperature data sets are obtained from European Center for Medium Range Weather Forecast (ECMWF) zonal wind and is for 23 vertical levels from 1000 hPa to 1 hPa for the period 1960-2002. NCEP/NCAR horizontal wind data for the period 1950-2006 has also been used. Indian summer monsoon rainfall (ISMR) data, which is the area averaged June to September rainfall of 306 stations well distributed over India, has been taken from Parthasarathy et al. (1994) and updated for making it to period 1960-2002 in order to define TBO years.

A year is defined as strong (weak) TBO year if the ISMR index is relatively higher (lesser) than previous and the next year .

In order to obtain the QBO frequency only for the study the data sets are filtered into biennial scale by using a band pass Butterworth filter developed by Murakami (1979).

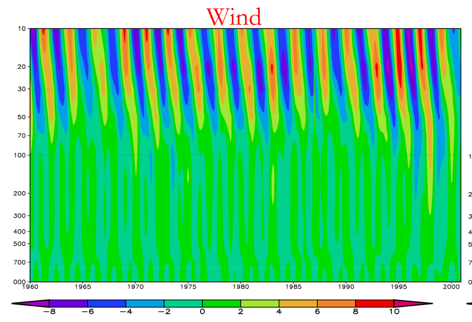
Time series analysis is made to understand propagation of anomalies. Strong minus weak TBO composite is made to study TBO cycle of wind and temperature in all the three areas considered.

Results and Discussion

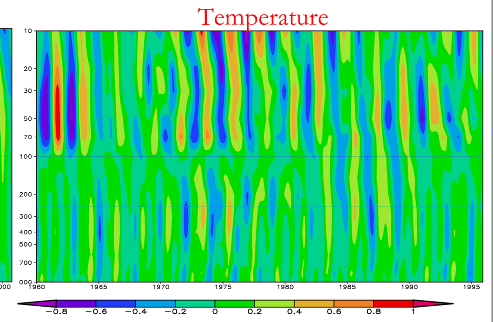
In our analysis of QBO and TBO years, almost all the strong TBO years are associated with strong westerly phase of QBO and negative TBO years with easterly phase of QBO.

Time series of zonal wind and Temperature over Indian Monsoon region in QBO scale

Wind



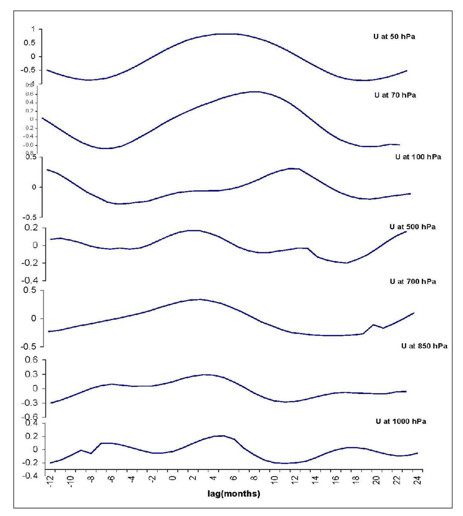
Temperature



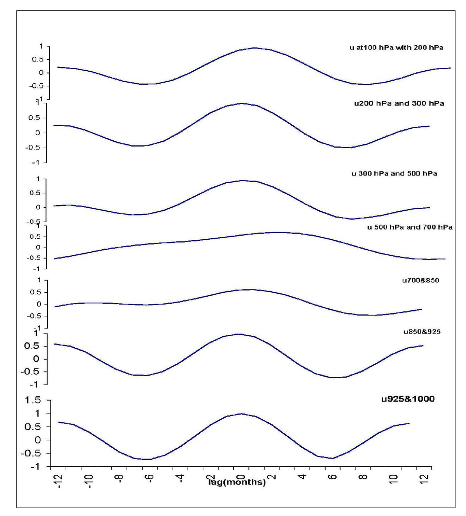
Downward propagation from lower stratosphere to tropopause and weakens and extends to troposphere. After 1980's propagation extends more to tropopause

Temperature anomalies have maximum at 30-70 hPa level and propagates downward and weakens at tropopause level. Another maximum is seen between 500 and 300 hPa.

Cross correlation of zonal wind at 20 hPa with lower levels

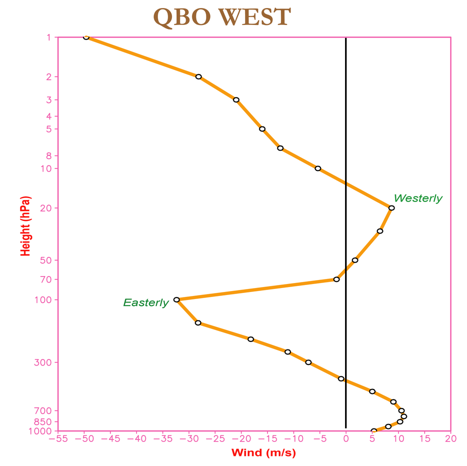


Cross correlation of zonal winds at adjacent levels



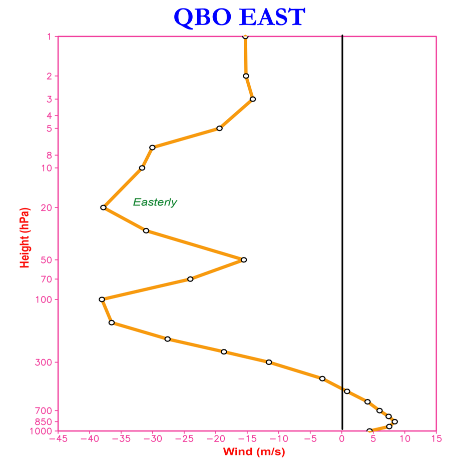
Relationship of QBO phase and Indian summer monsoon

QBO WEST



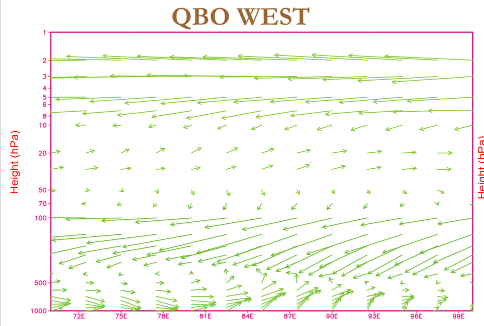
Strengthened low level jet and tropical easterly jet, indicating active monsoon

QBO EAST

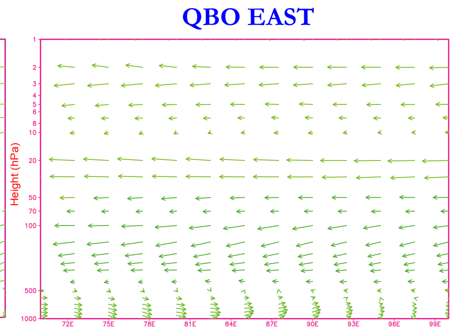


Weakened low level jet and tropical easterly jet indicating weak monsoon

QBO WEST

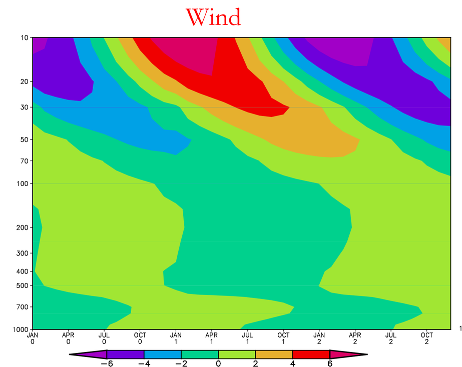


QBO EAST

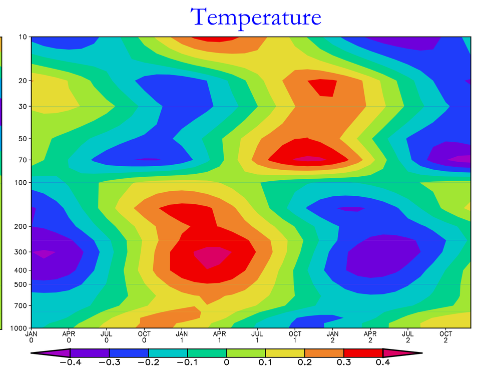


Zonal wind and SST during interannual variabilty of Indian summe rmonsoon assocaited with TBO

Wind



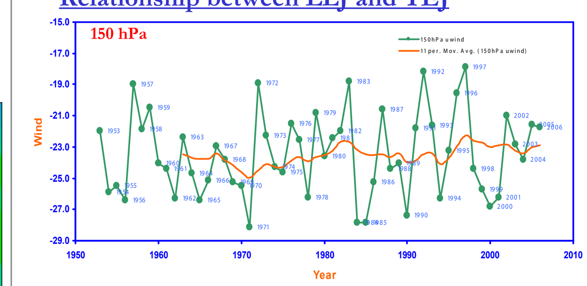
Temperature

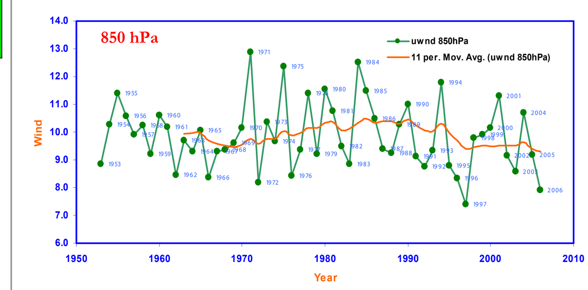


Instead of dissipating at the upper troposphere, the anomalies propagates downwards to troposphere. But the propagation speed varies at different levels. The westerly anomalies seen over the upper stratosphere during the weak monsoon propagates to lower level by the next strong monsoon and easterly anomalies from the stratosphere come to the upper troposphere. Easterly anomalies prevail in the bottom region during the weak monsoon. In the upper region westerlies are seen until the spring season before the positive phase of TBO and is replaced by easterlies and continue to the next spring. The transition layer slowly transits the upper region to the bottom region uniquely over the monsoon area, in about six months.

The lower levels have negative temperature anomalies in the previous year upto April month maximum cooling anomalies are seen over the troposphere region between 500 hPa to 200 hPa. But in the upper troposphere the negative anomalies are seen upto June of previous year. Positive anomalies are seen in the lower troposphere throughout this period. Anomalies reverse in the next year, which is a strong monsoon year. The profile has an upward propagating structure in the troposphere. But the maximum anomaly is seen in the 500 to 200 hPa region, as a source of heat before a strong monsoon and a sink before a weak monsoon with maximum anomaly during the spring season.

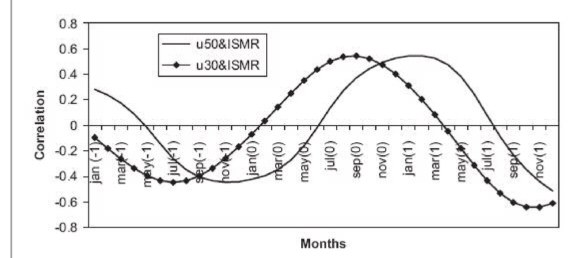
Relationship between LLJ and TEJ





Mean zonal winds during the active monsoon months (June, July and August) at 850 hPa level, representing the monsoon Low Level Jet (LLJ) and at 150 hPa level, indicating Tropical E asterly Jetstream, over 10 N latitude region are illustrated in Fig. Monsoon LLJ is found to be out-of-phase with the tropical easterly jetstream. There exists a strong anti-correlation between the zonal winds at 850 and 150 hPa levels over the monsoon region.

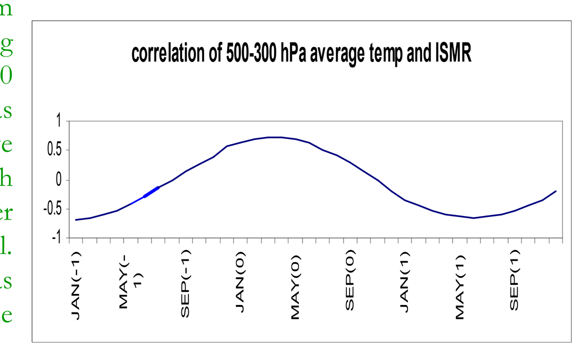
Predictability of monsoon from zonal wind and temperature



Lag-lead correlation of ISMR with zonal wind at 50hpa and zonal wind at 30 hpa (marked line).

50 hPa wind has strong negative correlation in the winter season before the strong monsoon. But 30 hPa correlates well with almost an year ahead of strong monsoon

Anomalous maximum temperature in spring season between 500 and 200 hPa has significant positive correlation w ith forthcoming summer monsoon rainfall. Thus it acts as additional source (sink) for monsoon



Major findings

Over Indian monsoon region, stratospheric winds propagates downwards to troposphere and it has three well defined regions.

An additional source (sink) region is found in the middle troposphere over Indian monsoon region attaining strength a season before monsoon, which is very crucial season for Indian monsoon.

The presence of Low Level westerly Jetstream (LLJ) at 1.5 km and strong Tropical Easterly Jetstream (TEJ) around 14 km produces a strong vertical shear in the troposphere. TEJ and LLJ are anti-correlated

During the period of the westerly phases of the QBO in the lower stratosphere produces opposite shear zone in the upper troposphere/lower stratosphere region. On the other hand in the easterly phase of the QBO, the shear zone in the UT/LS region is generally weak

It has been noted that during the westerly phases of the QBO, the Indian summer monsoon is quite active and during the easterly phase the monsoon is found to be generally weak or moderate.

In the TBO cycle, strong monsoon years are associated with westerly anomalies in the lower stratosphere and easterly anomalies in the upper troposphere. Reverse is true during the year of weak monsoon.

The zonal wind anomalies exhibit a dipole structure in the troposphere, which changes alternately with the strength of the monsoon.

Middle troposphere over the monsoon region seems to be modulating the QBO-TBO interaction.

Lower stratospheric westerly anomalies during winter indicates an active monsoon in the next summer, and easterlies indicates a weak monsoon in biennial scale.

Lower stratosphere wind and midtroposphere temperature have good predictability for Indian summer monsoon

References

Brier, G.W., 1978. Quasi-biennial oscillation and feedback processes in the atmosphere–ocean–earth system. Monthly Weather Review 106, 938–946.

Holton, J.R., Lindzen, R.S., 1972. An updated theory for the quasi-biennial cycle of tropical stratosphere. Journal of Atmospheric Sciences 37, 2200–2208.

Meehl, G.A., Arblaster, J.M., 2002. The tropospheric biennial oscillation and Asian–Australian monsoon rainfall. Journal of Climate 15, 722–744.

Mohanakumar K. (2008), Stratosphere Troposphere Interaction-An Introduction, Springer, Heidelberg

Mohanakumar K and Pillai P. A. 2008. Stratosphere–troposphere interaction associated with biennial oscillation of Indian summer monsoon. Journal of Atmospheric and Solar-Terrestrial Physics 70, 764–773

Murakami, M., 1978. Large-scale aspects of deep convective activity over the GATE data. Monthly Weather Review 106,1505–1508.

Nicholls, N., 1978. Air–sea interaction and the quasi-biennial oscillation. Monthly Weather Review 106, 1505–1508.

Parthasarathy, B., Munot, A.A., Kothwalae, D.R., 1994. All India monthly and seasonal rainfall series-1871–1993. Theoretical and Applied Climatology 49, 217–224.

Ropelewski, C.F., Halpert, M.S., Wang, X., 1992. Observed tropospheric biennial variability and its relationship to Southern Oscillation. Journal of Climate 5, 594–614.

Sathiyamoorthy, V., Mohanakumar, K., 2000. Characteristics of troposphere biennial oscillation and its possible association with stratospheric QBO. Geophysical Research Letter 7, 669–672.