Stratospheric Variability: Before and After mid-1970's Climate Shift

K. Mohanakumar, Prasanth A. Pillai and Nithin Viswambharan
Department of Atmospheric Sciences,
Cochin University of Science and Technology, Cochin –682 016, Kerala, India
Email: *kmkcusat@gmail.com, kmk@cusat.ac.in*

Introduction

According to recent reports from the Intergovernmental Panel on Climate Change (IPCC) most of the observed increase in globally averaged temperatures since the mid-20th century is *likely* due to the observed increase in anthropogenic greenhouse gas concentrations. It is suggested that human activities have exerted a substantial net warming influence on climate since 1750.

Observational evidences indicate that the solar radiation reaching the Earth's surface decreased significantly (termed as *global dimming*) over Northern Hemispheric mid-latitude land areas from late 1950's to late 1980's (Ohring et al, 2008). Since then increase in solar radiation (labeled as *global brightening)* have been observed in many places in Europe and North America, but not in India and China. Since the energy output from the Sun varies, the so-called global dimming and brightening have profound effect the Earth's environment.

Earth's climate underwent a major shift in the mid-1970s, as global temperatures began a warming trend that continues at present. The largest changes were centered in and near the Pacific Ocean. According to a new set of climate simulations, increased emissions from fossil fuel burning set the stage for the climate shift in the 1960s, but natural variations delayed it until the 1970s (Mohanakumar 2008).

Temperature measurements in the stratosphere show a long-term cooling trend in the last few decades. This cooling trend is speculated partly due to the decrease in stratospheric ozone and the increase in carbon dioxide, which radiates heat away from the stratosphere, thereby cooling. The cooling trend is found to have different trends before and after mid-1970's. Most importantly, the decrease in stratospheric ozone commences during this period. The present study concentrated on the abrupt changes found in many parameters in the stratosphere including ozone during the mid-1970's and its possible link with the climate shift reported in oceanic parameters during the same period.

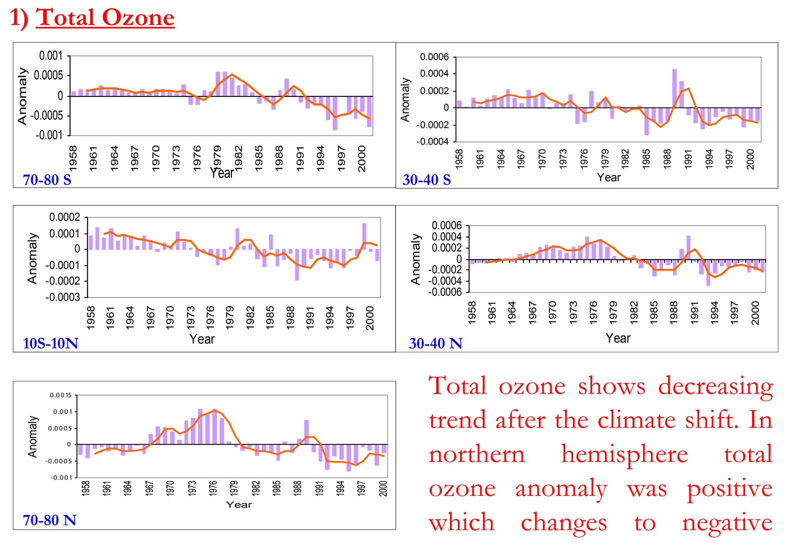
Data and Analysis

NCEP/NCAR reanalysis (Kalnay et al 1996) data sets of zonal and meridional wind, air temperature, shortwave and longwave radiation, Sea level pressure, from 1950-2007 time period are used for the study. The wind and temperature data sets are taken only for lower stratospheric region like 10 hPa, 20 hPa, 50 hPa and 70 hPa and also for tropopause level, 100 hPa. NCEP SST data sets and total ozone data sets from ECMWF (1959-2001) are also used. Anomalies after removing annual cycle are calculated for all these parameters and time series is plotted for global average, equatorial belt, (10^0N-10^0S), mid latitudes (30^0-40^0) and high latitudes (70^0-80^0) for both the hemispheres are calculated and time series is plotted.

Uncertainty in the change in global atmospheric and ocean parameters is due to several factors, such as modern scientific observational techniques, dense observational network, high resolution in spatial and temporal data availability, minimizing observational errors, etc. Even considering these factors, the global temperatures have increased substantially in the last three decades.

Results

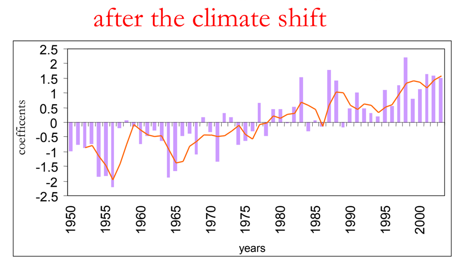
1) Total Ozone



Total ozone shows decreasing trend after the climate shift. In northern hemisphere total ozone anomaly was positive which changes to negative after the climate shift

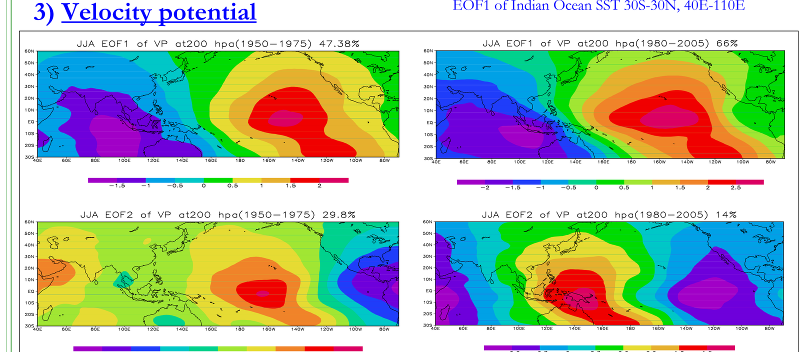
2) Sea surface temperature

Indian ocean SST shows a warming trend after climate shift.



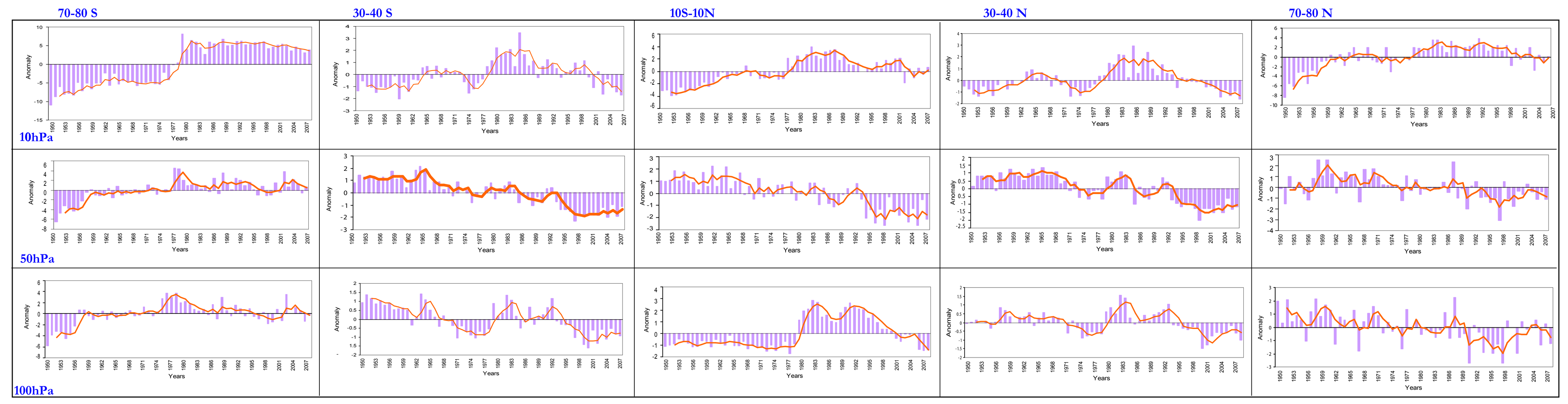
EOF1 of Indian Ocean SST 30S-30N, 40E-110E

3) Velocity potential



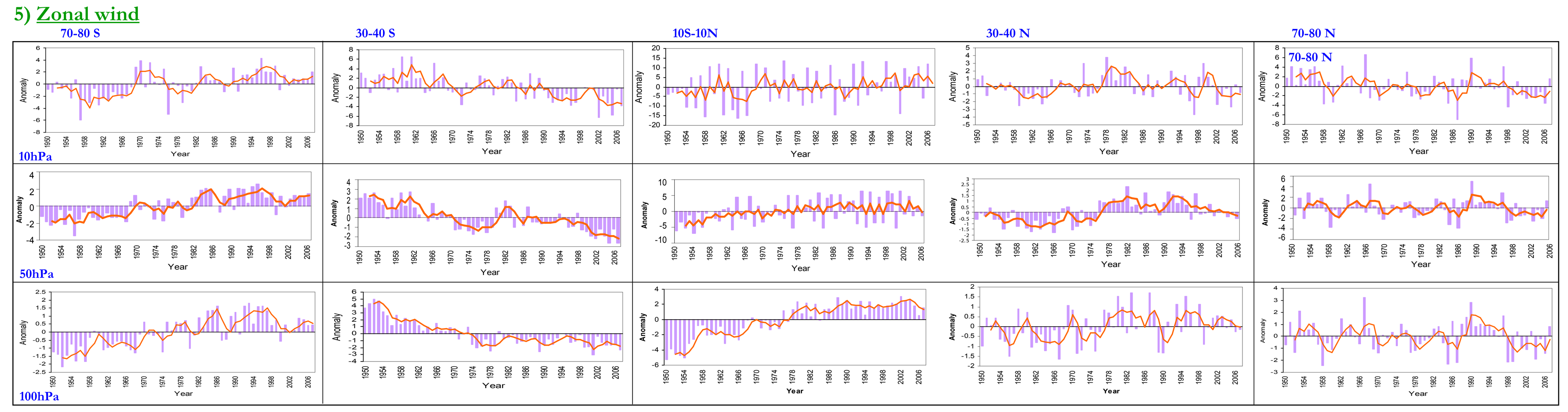
Variance of prominent mode (EOF) increased up to 20% and the position of the convergence and divergence centers shift their location after the climate shift

4) Stratospheric Temperature anomalies



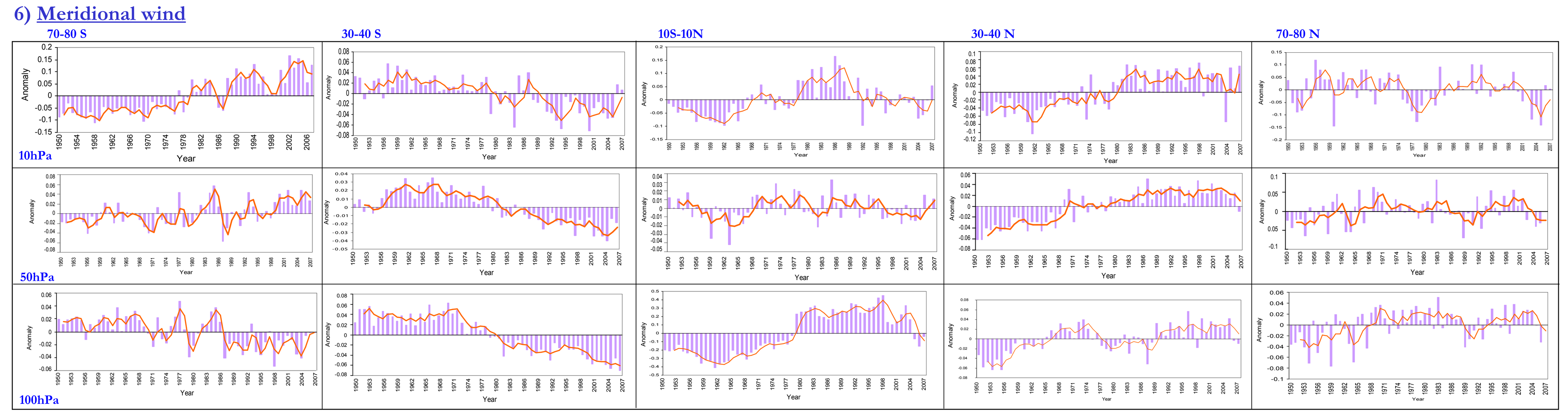
- The temperature anomaly in the Antarctic middle Stratosphere (10 and 20 hPa) abruptly changes from negative to positive after the shift.
- In Southern hemispheric mid latitudes the shift is evident at 10 and 20 hPa which persists upto late 1990's. Thereafter anomaly becomes negative. The temperature at 50 hPa level is found to be decreasing after the shift.
- Tropical stratosphere shows warming at 10 and 100 hPa but a cooling is noted at 50 hPa. The variability in temperature at 50 and 70 hPa is found to be out of phase to that at 100 and 10 hPa
- The northern hemispheric mid latitude lower and middle stratosphere shows cooling trend in late 1990's.
- The temperature in North polar region shows an increase after the shift at 10 hPa and cooling can be seen at lower levels.

5) Zonal wind



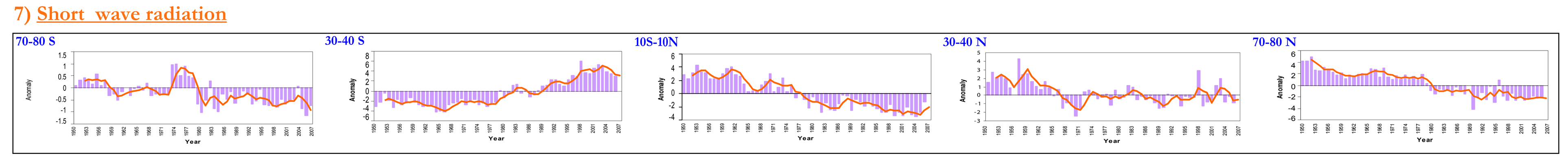
South polar zonal wind anomalies in the stratosphere changes from negative to positive after the climate shift. In the lower stratosphere over mid latitude the change can be seen slightly early. The influence of climate shift is found to be strong in the tropical lower stratosphere (100 hPa). In the upper levels the QBO has masked the effect of climate shift on zonal wind. In the northern mid latitude region the climate shift is evident at 50 hPa zonal wind.

6) Meridional wind



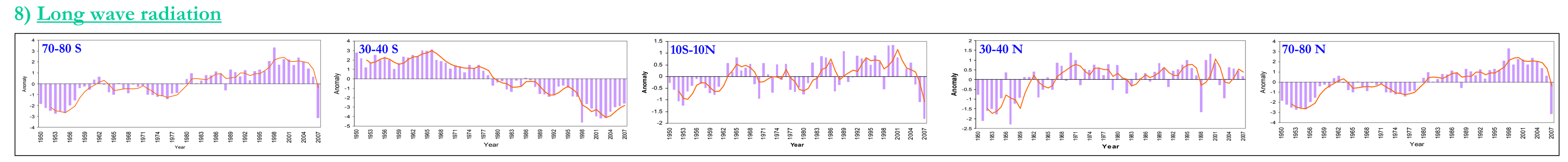
The meridional wind in the stratosphere shows distinct variability with climate shift. In south polar middle stratosphere the northerly anomaly changes to southerly after climate shift. The reverse is true in the lower stratosphere. The lower and middle stratosphere in mid latitude shows a clear variability from positive anomaly to negative anomaly before and after the shift. In the tropical lower stratosphere the effect of climate shift is predominant. At higher levels the effect of shift on meridional wind is generally weak. Meridional wind anomaly changes from northerly to southerly in the mid latitude middle stratosphere. In the north polar region the meridional wind variability is not regular.

7) Short wave radiation



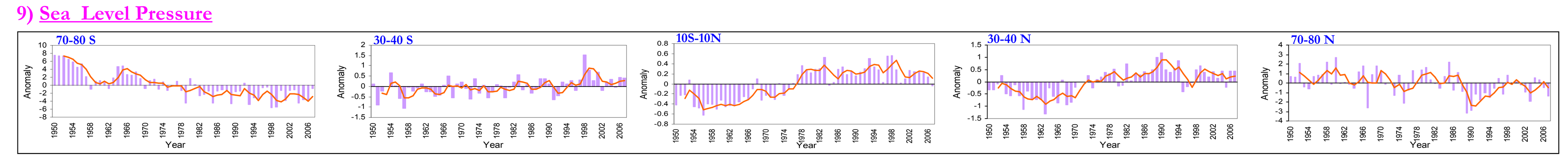
Net shortwave radiation anomaly changes from positive to negative in equatorial and polar regions whereas the anomaly changes from negative to positive in southern mid latitudes.

8) Long wave radiation



Except the southern hemispheric midlatitudes, the Net Longwave radiation anomaly changes from negative to positive before and after the climate shift.

9) Sea Level Pressure



In polar regions Sea level pressure changes from positive to negative before and after the shift. In equatorial and mid latitude regions the anomaly changes from negative to positive. In the equatorial region the climate shift is well defined in the Sea level pressure over the equatorial region

Conclusion

Temperature and wind in the lower and middle stratosphere, short wave and longwave radiation, Total Ozone, Sea level pressure and Sea Surface Temperature all shows a distinct change after the 1970's climate shift. The magnitude and direction of variation varies with latitude and altitude. The effect of climate shift is more pronounced in southern hemisphere. The changes at 50 hPa is found to be opposite to that at 100 and 10 hPa. Another noticeable feature is that the walker circulation shifts its position after 1975. All these observational evidences indicate that the 1970's climate shift is not limited to the oceanic region, but extends up to the stratosphere.

References

Climate Change Science (October 2001), Hadley Centre, U.K. Met Office (www.metoffice.com/research/hadleycentre/pubs/B2001/global.pdf)

Intergovernmental Panel on Climate Change (IPCC), Scientific Report: Climate Change, 2007

Mohanakumar K (2008) Stratosphere Troposphere Interactions: An Introduction, Springer, Heidelberg

Ohring G et al (2008) Global dimming and brightening, EOS Trans. AGU, 89(23) 212.

Wild M et al (2007) Impact of global dimming and brightening on global warming, Geophys Res Lette., 34, L04702, doi:10.1029/2006GL028031