Chapter –7

Summary and Conclusions

7.1 Summary and conclusions

Some aspects of stratosphere-troposphere interactions like biennial timescale interaction over near equatorial region, the interannual to synoptic timescale stratosphere-troposphere ozone exchanges caused by longwaves are studied using NCEP/NCAR reanalysis data, high-resolution radiosonde data, satellite measured global total ozone data, etc and the results are discussed in this thesis. Major outcomes of the study are presented as follows.

The biennial timescale interactions between lower stratosphere and troposphere over Thumba is analyzed using high-resolution radiosonde data. Signals of oscillation with periods ranging from 20-32 months were found in the tropospheric temperature over this near-equatorial Indian station. The phase of the TBO in temperature did not vary with height from surface to the level of tropopause and was associated with the intensity of the Indian monsoon rainfall. A QBO signal is seen in temperature in the lower stratosphere. Examination of the phase of the biennial mode in temperature in lower stratosphere and troposphere showed decadal change in the phase coherence between 1971-81 and 1982-92 periods. Marked differences in amplitudes of QBO and TBO were also noticed between these dacades. During the first decade the downward propagating phase of QBO was disturbed in the 18-23 km altitude.

These results and the correlations suggested not an association between TBO and QBO, but rather a lack of association between the two phenomena. The results suggest that TBO and QBO are two different phenomena with nearly biennial periodicity. Strong relation exists between TBO in temperature over Thumba and Indian summer monsoon activity.

During strong Indian monsoons the temperature TBO is in positive phase. Of the 4 weak Indian monsoons except in 1979 TBO is in negative phase. The results suggest that the observed biennial variability in the tropospheric temperature over Thumba may be due to the monsoon-ocean-atmosphere interactions taking place over Indian Ocean region in biennial time scales.

Interannual timescale meridional stratosphere-troposphere exchanges caused by the newly documented Asia Pacific Wave (APW) were analyzed using ozone as tracer of atmospheric motion. Analysis of the NCEP/NCAR reanalysis wind data showed the presence of a stationary Rossby wave in the lower stratosphere during May. This wave is seen prominently below 70 hPa level, confined between 10°N and 50°N latitudes and has a zonal wave number of 6 or 7. It is an extension into the stratosphere of the Asia Pacific Wave of the troposphere documented by Joseph and Srinivasan (1999). This wave shows a phase shift of 20° longitudes between deficient and excess ISMR years. This shift is due to the shift in the longitudinal position of the convective heat sources associated with the ITCZ.

Since the APW is present between 70 hPa and 500 hPa levels, it couples the lower stratosphere and troposphere directly. Since the maximum amplitude of the APW is in tropopause break region, the APW is able to transport ozone rich extratropical lower stratospheric air into tropical upper troposphere and ozone poor upper tropospheric air into the extratropical lower stratosphere effectively through the tropopause break region, which in turn can affect the total ozone distribution. Analysis of the global total ozone measurements by the TOMS instrument onboard Nimbus-7 satellite showed the signatures of the APW. Since the phase of APW changes through 20° longitudes between extreme Indian summer monsoon years, the APW affects the total ozone distribution over large areas of the globe on interannual timescales. Analysis of the NCEP/NCAR data during the summer monsoon season and the following autumn season showed the presence of APW and its signature on global total ozone distribution during these seasons. The amplitude of the total ozone anomalies caused by APW is about 5-10% from climatology. Counter-part of the APW is also seen in Southern Hemisphere. During May and the following summer monsoon months, solar radiation is maximum in the Northern Hemisphere, and the negative anomalies in ozone thus pose health hazards due to increased UV-B radiation.

Synoptic timescale meridional stratosphere-troposphere exchanges caused by subtropical upper tropospheric long waves over Asia were studied using global total ozone measurements from TOMS. One such long wave is seen as Upper Tropospheric Trough (UTT) in zonal westerly winds during winter season in the tropical Asia and another one as Upper Tropospheric Blocking High and Trough (UTBHT) pattern in summer over Asia. The characteristics of these two waves are studied using NCEP/NCAR reanalysis data. These waves occasionally develop large amplitudes when the associated north-south wave troughs span across the break region between the tropical and extra-tropical tropopauses. Exchanges of ozone poor air mass from the tropical upper troposphere to the extratropical lower stratosphere and ozone rich air mass from the extratropical lower stratosphere to the tropical upper troposphere *via* the tropopause break region occurs associated with these large amplitude waves, due to the presence of steep meridional ozone gradients around these levels. Since these waves are present around the tropopause level, these wave troughs and ridges deflect the tropopause. A trough in upper troposphere lowers the tropopause, thereby enhancing the stratospheric column and hence the total ozone column. On the other hand, ridge decreases the stratospheric column and hence the total ozone column.

Analysis of the global total ozone data from Nimbus-7 TOMS shows the signatures of the total ozone anomalies generated by these waves. Values of TOA from long climatology reached upto ± 25-35 % during the UTT conditions over south Asia. The summer time UTBHT situation persists for a few days to a few weeks and creates negative and positive TOA over Asia. Positive TOA generated by UTBHT reaches values of the order of 100 DU and negative TOA upto –140 DU depending upon the strengths of the blocking highs and troughs. The negative TOA reached even 50% less than the long-term mean in some areas during these episodes and created a sort of *mini ozone hole* like situation. The negative TOA anomalies associated with the UTBHT is expected to increase the amount of ground level UV-B radiation in Asia over large areas in summer season.

7.2 Scope for future studies

The meridional transport of ozone between extratropical lower stratosphere and tropical upper troposphere by APW, UTT and UTBHT can be studied and quantified using the ozonesonde vertical profiles and potential vorticity maps around tropopause levels. Since the global ozonesonde data can be obtained easily from the archives of World Ozone and Ultraviolet Radiation Data Centre, Canada and the potential vorticity data from NCEP/NCAR reanalysis data sets, detailed study about the vertical structure of the meridional transport can be made. Effect of the interannual timescale total ozone anomalies caused by APW on the long-term trend in total ozone over a region can be estimated for the realistic computation of the trend. This research work can be extended to study the influence of decadal scale epochal nature in Indian summer monsoon activity on the APW generated total ozone anomalies around the globe and the trend estimates in total ozone. Total ozone anomalies generated by the counter-part of the APW in Southern Hemisphere during austral summer can be studied using TOMS data. Based on these observational evidences, modeling studies can be initiated about the stratosphere-troposphere exchange processes for a better understanding on stratosphere-troposphere interactions.