Chapter 5 Discussion and Conclusions

The raw data series of the zonal winds through out the troposphere and lower stratosphere show that the QBO signal persisting only in the lower stratosphere. While the annual pattern is generally seen in the lower troposphere from the 925-hPa level up to the 500-hPa level, the middle and upper troposphere do not have any distinct pattern. After the annual pattern and trend are removed, and a binomial band pass filter is used to further filter the data series, not only the QBO signal is further enhanced in the lower stratosphere, similar pattern can also be seen through out the whole troposphere. Even though the amplitude of this QBO-like pattern is much smaller in comparison to that of the actual QBO in the lower stratosphere, statistical methods indicate that this QBO-like pattern are statistically significant at the 90-95% confident level. The Pearson cross correlation functions between zonal winds at different levels show that the QBO-like oscillation starts at the lower troposphere near the surface of the earth, almost at the same time as QBO signal is generated in the 20-hPa level of the lower stratosphere.

The second analysis on the 500-hPa geopotential height, SST and tropopause height all indicate that each of these data series oscillate with a mean period of 26-30 months that lie within a broad spectral band with periods ranging from 23.2-33.8 months. The Pearson cross correlation functions point out that both the 500-hPa geopotential height and the tropopause height are exactly in phase. While the warm SST lags behind both the heights and the 925-hPa easterly wind by 2 and 4 months respectively, both heights also lag behind the 925-hPa easterly wind by 2 months.

Pearson cross correlation of the 925-hPa zonal wind over the western and central Pacific with respect to that over the Malaysian region indicates that low level tropospheric zonal wind over the western and central Pacific is almost in phase with that over the Malaysian region.

The above results could be interpreted as follow. Strong easterly at the surface of the earth pushes the warm SST from the equatorial central and eastern Pacific into the equatorial western Pacific and the South China Sea regions. The warming of the equatorial South China Sea and western Pacific then causes an increase in convective activity in the regions, thereby energy is transferred from the sea and ocean to the atmosphere, warming up the atmosphere and causing a bulge in the geopotential height. The convective activity generated such as thunderstorms could than transfer energy upward to the tropopause or higher at a tremendous rate. This could cause simultaneously the bulging of the tropopause height and the 500-hPa geopotential height. Both heights have their maximum bulges 2 months after the strongest easterly had occurred in the regions. As the sea and ocean response to changes slower than the atmosphere due to their larger inertia, they can retain energy much longer than the atmosphere. Thus the warming of the sea and ocean continues as the easterly weaken and the two heights decrease. The sea and ocean were observed to become warmest 4 months after the strongest easterly had occurred.

The energy that reaches the tropopause is then able to generate the westerly phase of the QBO at the 10 to 20-hPa levels by means of Kelvin waves (Holton and Lindzen, 1972). This explains why easterly phase at the surface of the earth and westerly phase of the QBO at the lower stratosphere occur almost simultaneously. While the westerly at the lower stratosphere propagates downwards, the easterly at the surface could also propagate upwards by means of internal gravity waves. This is possible because as we approach the equator, the pendulum day goes to infinity, and the energy in the long period waves can begin to propagate vertically as internal gravity waves (Lindzen, 1990). The easterly at the surface propagates upwards up to approximately the 300-hPa level, and from this level onwards, westerly replaces the easterly and continues to propagate upwards. This upwards propagating westerly from the surface and the downwards propagating westerly from the lower stratosphere meet at a level somewhere between the 100 and 200-hPa levels (referred to as the critical level of energy deposition). The energy accumulated due to convergence of wind at this level is then able to propagate upwards again by means of mixed Rossby-gravity waves (Holton and Lindzen, 1972) to generate the easterly phase of the QBO at the 10 to 20-hPa levels. By this time, at the surface, the wind has changed from easterly to westerly, which could cause warm SST to be pushed away from the equatorial South China Sea and western Pacific towards the equatorial central and eastern Pacific. Thus upwelling of cold water from underneath the equatorial South China Sea and eastern Pacific cools the SST, thereby reducing or even completely eliminating convective activity. As the atmosphere becomes more stable due to the cooling effect from below, both the 500-hPa geopotential height and the tropopause height are depressed. As a result, there will be no direct energy transfer from the surface to the tropopause as before. However, the westerly at the surface still could propagate upwards by means of internal gravity waves as such waves are produced in the neighbourhood of the equator with both easterly and westerly phase speed (Lindzen, 1990). This upwards-propagating surface wind converges with the downward propagating easterly at the 100 to 200-hPa levels to complete the cycle. The whole cycle is able to repeat by itself every 2-2½ years as energy is being pumped into the system through anomalous warm SST. The whole conceptual model can be summarised as in

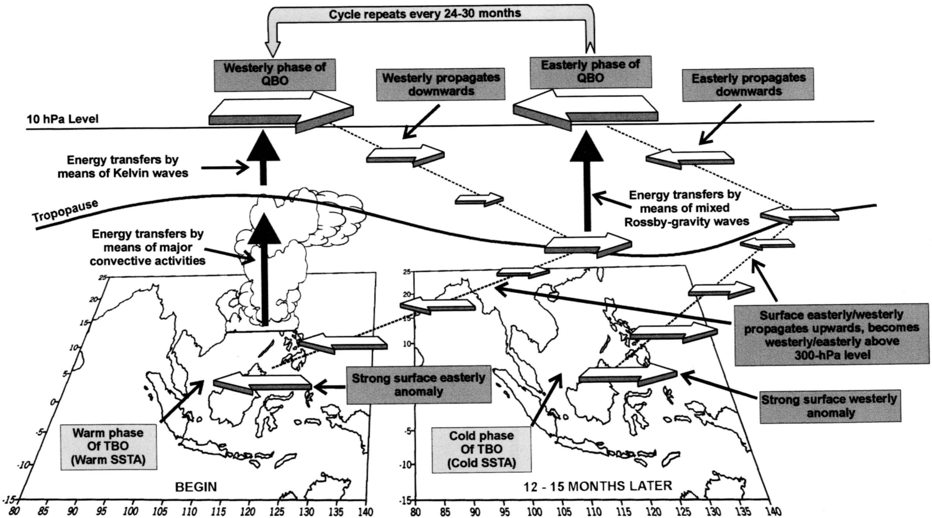

Figure 5.1 Conceptual model relating QBO and TBO over the Malaysian region.

Figure 5.1.

The above-mentioned conceptual model was constructed based on rely the statistical approach. Hence, further research works, in particularly those involving dynamics of the coupled atmosphere-ocean system in generating the QBO, are much needed in order to verify the model.

The tropospheric zonal winds, 500-hPa geopotential heights and tropopause heights over the Malaysian region were found to exhibit QBO-like variations that oscillate with mean periods in the range of 25-29 months. The SSTs of South China Sea and Sulu Sea surrounding Malaysia were also found to attain TBO pattern with similar period ranges. These results are in agreement to many other studies regarding QBO and TBO. The QBO is thermodynamically linked to the TBO through coupled ocean-atmosphere interaction. This relationship forms the basis in constructing the conceptual model linking the QBO and TBO.