CHARACTERISTICS AND VARIABILITY OF TOTAL OZONE CONCENTRATION OVER PETALING JAYA, MALAYSIA USING THE BREWER OZONE SPECTROPHOTOMETER

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INTRODUCTION

Ozone is an atmospheric trace gas formed from triatomic oxygen molecules by photochemical reactions. About 90 percent of the atmospheric ozone is found in the stratosphere which acts as a shield for UV radiation from the sun. However during certain times of the year UV light from the sun aids in the creation of ozone in the stratosphere. The concentration of the total column ozone (TCO) varies largely around the globe with higher concentrations towards the poles than the equator. Even though the production at the equator is higher, the Brewer-Dobson circulation transports it poleward and downward to the lower stratosphere of the high latitudes. Few studies have being carried out in the past to understand the characteristics and variability of TCO for locations close to the equator due to lack of good observational data. In this study, 13 years of daily TCO data for a station in Malaysia which is 3 degrees north of the equator is analyzed to understand its distribution, short and long-term variability. Comparison is also made with satellite estimates and its relationship to UVB radiation is carried out.

DATA & ANALYSIS

Data

Daily TCO and UVB data recorded at Petaling Jaya meteorological station, Malaysia (3.1^{0}N, 101.^{0}E) using the Brewer MKII Spectrophotometer. Period of data is from 1997 to 2009. Outliers are removed and missing values are replaced with interpolated values using the cubic spline or method of least square error. Satellite estimates of daily TCO is from the EP-TOMS satellite for the period 1997-2005. Stratospheric wind data is the monthly zonal wind over Singapore for the period 1997-2009.

Analysis

Statistical quantities including the frequency distribution are computed at the annual and seasonal time scale. Time series of the data is analyzed with the power spectrum computed for the daily TCO to determine the intra-seasonal oscillations (ISO). The interannual variability is compared with the stratospheric zonal wind QBO. Linear relationship between the observed TCO at the station with satellite estimates is determined. Finally the relationship between the observed UVB and TCO is studied.

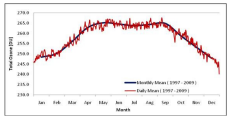
RESULTS

Annual Cycle

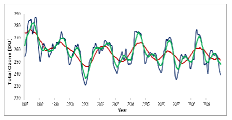
The annual cycle shows a clear seasonal pattern in TCO concentrations levels with significant inter-day variability. During boreal winter the TCO is at a minimum and gradually increases to reach its peak value of 265.2DU in May and there after remains almost steady with a slight decrease towards mid-summer in July. Second maximum peak occurs in September and there after it starts to gradually decrease, reaching its minimum value of 247.9DU in late December to early January. Peak TCO concentration in May and September coincides closely to the equinox and the intermonsoon season in Peninsular Malaysia, during which period the vertical shear is weak and winds are variable and light throughout the entire troposphere which reduces the horizontal transport of ozone.

At higher latitudes the maximum and minimum TCO occurs at different times of the year, due to variation in the poleward transport of ozone by the Brewer-Dobson Circulation. The TCO has a distinct annual cycle with two distinct regime, April to September and October to March.

From year to year there is significant interannual variation, with a 2 to 3 year quasi-periodic oscillation. In 1997 the TCO concentrations were abnormally high due to elevated ozone concentration in the lower troposphere as a consequence of widespread biomass burning across the region. The next 4 years the TCO showed a decreasing trend and thereafter there was no significant trend.

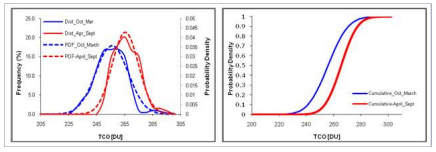


The annual variation of daily and monthly TCO (1997 - 2009).



Time series of monthly TCO. Green and red lines are filtered series using the 6 and 13 point running mean respectively.

Frequency distribution of daily TCO



Frequency distribution and PDF of daily TCO for the periods Apr-Sept and Oct-Mar (left panel); CDF of daily TCO for the periods Apr-Sept and Oct-Mar (right panel).

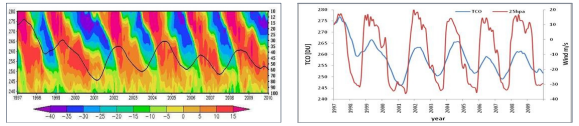
$$f(x) = \frac{1}{9.3\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-263.9}{9.3}\right)^2} \quad \text{- for April to September}$$

$$f(x) = \frac{1}{11.1\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-252.9}{11.1}\right)^2} \quad \text{- for October to March}$$

The frequency distribution of the daily TCO for the entire period is normally distributed. For the two different periods the frequency distribution are also normally distributed with distinct PDFs and CDFs. The probability of daily TCO concentrations exceeding any threshold value is always higher during the middle six months of the year compared to the October - March period.

RESULTS

Interannual Variability (IAV) of TCO

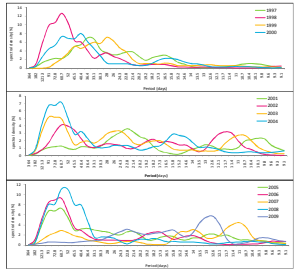


(Left) Hovmoller plot of monthly zonal wind component in the stratosphere between 100hPa and 10hPa over Singapore from 1997 to 2009. The solid line is the 13 month running mean filtered time series of the monthly TCO; (Right) Time series of monthly zonal wind at 25hPa over Singapore and filtered monthly TCO.

The IAV of TCO exhibits as strong QBO pattern that oscillates between 22 to 35 months cycle. The QBO of the TCO is nearly in phase with the stratospheric zonal wind QBO at 25 hPa over Singapore. The maximum in TCO coincides with the strongest westerly phase of the zonal wind and the minimum coincides with the strongest easterly phase of the zonal wind, except in 2004.

Intra-seasonal Oscillation

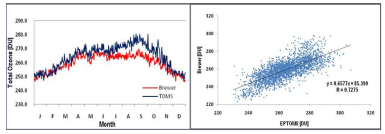
The daily TCO values show clear ISO, though for different years the dominant modes of oscillation have different periods. However most of the years have a single dominant mode of low frequency oscillation which is quasi-periodic in the 45 to 90 days time scale. The peak period is centered around 60 days. In 1997, 1999 and 2000 the daily TCO variations were dominated by ISO with peak periods centered at 36 days, 28 days and 40 days respectively. In 2001 and 2002 there were two dominant modes of oscillation. In 2001 the TCO had significant oscillation with periods centered at 23 and 10 days, whereas in 2002 the dominant modes had periods centered at 60 and 12 days. In 2003 however the daily TCO were influenced by oscillations in 3 different modes with periods centered at 80, 26 and 11 days. In 2007 and 2009 the ISO were influenced by oscillations at much higher frequencies, having periods centered at 11 and 13 days respectively.



Spectral density function of daily TCO concentration for the individual years from 1997 to 2009.

Comparison of observed daily TCO and satellite estimates

The seasonal cycle determined form the daily mean TCO values indicates EP-TOMS over estimates the TCO compared to the Brewer Measurement. Largest difference is observed between July and October.



Annual variation of daily TCO from Brewer and EPTOMS measurement (left panel) and scatter plot of daily TCO data from these two measurement (right panel).

Previous studies have shown that a well calibrated and maintained Brewer and Dobson instrument can agree within a 1% bias estimation.

A strong linear relationship exists between these two data with the satellite data accounting for 73% of the variance of the ground based measurement.

However on most occasions TOMS overestimates the TCO when compared to the Brewer data.

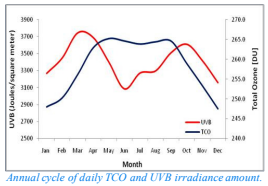
The Relationship between TCO and Ultraviolet Radiation

Monthly mean UVB radiation in Petaling Jaya shows a strong semi-annual cycle with minimum concentrations in June and December and maximum in March and October. Minimum in December occurs when the declination angle of sun is at its southern most latitude.

With steady increase in UVB in the first quarter of the year, the TCO concentrations correspondingly increases but reaches its maximum about 2 months later. From March to June, a combination of higher levels of ozone that absorbs the UVB and lesser radiation from the sun as it moves northward causes the UVB radiation levels to sharply reduce, reaching a minimum in June.

After summer solstice, as the sun moves closer to the equator the UVB radiation level slowly increases, but the higher levels of TCO which absorbs part of the UVB causes the increase to be more gradual and reaches its second maximum in October, which is lower than the first maximum in March.

After the autumnal equinox the TCO level starts to decline because of reduced production of ozone in the atmosphere due to reduced UVB from the sun and both quantities reach their minimum in December coinciding with the winter solstice.



Annual cycle of daily TCO and UVB irradiance amount.

CONCLUSIONS

The daily TCO concentrations at Petaling Jaya, Malaysia recorded from 1997 to 2009 shows distinct statistical properties. The data best fits the normal pdf. The temporal characteristics display an annual cycle with peak concentrations in May and September and minimum in late December or early January. This annual beat is strongly related to the UVB radiation from the sun, during part of the year the UVB aiding in the production of ozone and during peak TCO concentrations periods the ozone acting as a filter for the UVB. During the most intense EL Nino event in 1997 there was an elevation of ozone concentrations in the lower troposphere leading to higher TCO values. Within the annual cycle there is strong ISO that varies from year to year, but in most years a single dominant mode is found around the 45 to 90 day cycle, and some years having oscillations at higher frequencies. The IAV of the TCO has a single prominent mode on the time scale of the QBO. This oscillation is almost in phase with the stratospheric zonal wind QBO at 25 hPa over Singapore. Satellite estimates and ground based observed data are found to have strong correlation even though the satellite overestimates the TCO by about 3 percent particularly during the summer months.