<u>Tropospheric Columnar Ozone Concentration Estimation using Satellite Data</u>

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Abstract

Ozone is found in two regions of the Earth’s atmosphere at ground level (up to 18km) and in the stratospheric region (18-50 km) of the upper atmosphere. The stratospheric columnar ozone (SCO) is generally referred as good ozone and protects the life from the Sun’s harmful ultraviolet rays reaching the ground level by absorbing. The depletion of strtospheric ozone is studied and it is due to colling of stratospheric temperature (Sujatha P et. al 2014: RSL). The tropospheric columnar ozone (TO) or the ground level ozone is also referred as bad ozone and not generated in the air directly, but created by photo chemical and chemical reactions between oxides of nitrogen (NO_x) and Volatile Organic Compounds (VOCs). The tropospheric ozone is generated by human activities largely due to incomplete combustion of fossil fuels, transportation and industrial emissions, etc. This is often referred to as a greenhouse gas formed with NOx, Carbon Monoxide (CO) and VOCs. These are also called Ozone Precursors. The TO is derived from Ozone Monitoring Instrument and Microwave Limb Sounder (MLS) based on Tropospheric Ozone Residual Techinque (TOR)

Key words: Total Columnar Ozone (TCO), Stratospheric Columnar Ozone (SCO), Tropospheric Columnar Ozone (TO), Ozone Precursors

Introduction

Most of the Ozone in the atmosphere is in the stratosphere of the atmosphere, with about 10% in the lower troposphere. Ozone is formed due to photo chemical and chemical reactions involved in presence of Sun’s UV radiation. In the study of recent decades, investigation of transport of Ozone and its precursors in the upper troposphere has accelerated due to the progression in satellite estimations and model activities. Upper troposphere is the area where radiative driving, long-range contamination transport, and the transport of air into/from the stratosphere play important role (Mahlman 1997). Midy et al 2012 showed variation of TCO in the recent past, after and during landfall of tropical cyclone when it passes through an additional tropical district. During tropical cyclones, there is a change in TCO mixing ratios budget. Numerous researches completed on tropical cyclones and their effect in transporting contamination, such as Ozone and CO (Fadnavis et al., 2010, Midya et al., 2012). The mechanism for lifting gases out of the Planetary Boundary Layer (PBL) into the free troposphere is important in understanding the local and global air pollution problems and climate issues (Dickerson et al.2007). Fadnavis et al., 2010 showed the role of cyclone in transporting pollutants into the upper troposphere from lower troposphere. This study also reported vertical exchange of Ozone from lower stratosphere to upper troposphere.

The estimation of total columnar atmospheric ozone concentration using satellite sensors from Ozone monitoring instrument (OMI), Microwave Limb Sounder (MLS) and Total Ozone Monitoring Spectrometer (TOMS) were used to estimate tropospheric (TO), Stratospheric columnar Ozone (SCO) concentrations. Using multiple satellite sources from 2007-2013 over a period of 7 years on a daily basis atmospheric columnar ozone concentrations were used to derive TO and SCO over the Indian region.

Data and Methodology

- TCO (0.25°*0.25°): Ozone Monitoring Instrument (OMI) is a nadir-scanning instrument that detects back-scattered solar radiance to measure column ozone. OMI pixels have a nadir resolution of 13 km *24 km (Levelt et al., 2006). The OMI is one of the four Aura satellite sensors gives daily global estimations of four imperative U.S Environmental Protection Agency's criteria pollutants, for example Ozone, Nitrogen-dioxide, Sulfur-dioxide and Aerosols from biomass burning and industrial emissions.
- Vertical Profiles of Ozone: The Aura Microwave Limb Sounder (MLS) instrument measures vertical profiles of mesospheric, stratospheric, and upper tropospheric temperature, ozone and other constituents from limb scans. In this study, we utilized the MLS standard product for ozone derived from radiances measured by the 240 GHz radiometer (Froidevaux et al., 2008; Jiang et al., 2007; Livesey et al., 2008).

Table 1 Data resource information

Mission	**Period**	**Parameter**	**Resolution**	**Source**
Aura/OMI	2007-2013	TCO	25km spatial	Giovanni
Aura/MLS	2007-2013	Temperature,O_3 profiles	3km vertical	Mirodor
COSMIC1-DVAR	2007-2013	Temperature	0.1km vertical	CDAAC
Ozonesonde	2007-2012	O_3 profiles	~7.5m vertical	SHADOZ

Tropospheric Ozone Residual (TOR) technique to derive TO

(*Ziemke et al., 2006 and Schoeberl et al., 2007)*

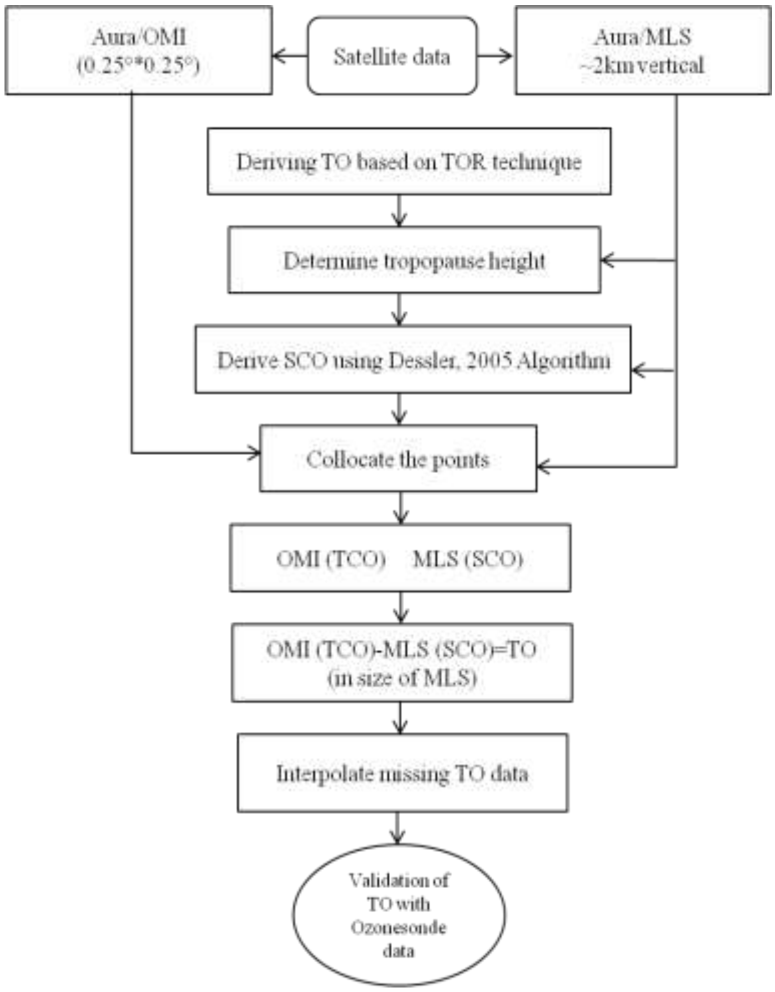


Figure 1 Methodology for deriving TO from Aura/OMI & MLS satellite data

TO is derived using tropospheric ozone residual (TOR) method introduced by Ziemke et al. 2006 and Schoeberl et al. 2007 shown in figure 1. The TOR is residual of total columnar ozone and stratospheric columnar ozone with the spatial resolution of Aura/MLS. Tropopause height is essential parameter before calculating the SCO since its behaviour is different at equator and poles. The altitude of lowest temperature in the vertical profile (i.e. Tropopause Height (TH)) is considered as a bottom level of tropopause (Jain et al. 2011; Sujatha et al. 2014). The height of the tropopause is determined using multi satellite data summarized in table 1. The tropical tropopause height has shown in figure 2 for further implementation of deriving TO over the Indian region.

Setting up tropopause height: The altitude of lowest temperature in the vertical profile (i.e. cold point tropopause (CPT)) has been taken as the level of tropopause (Jain et al., 2011).

Tropopause height is required to estimate SCO using MLS data. We have ascertained the tropopause height using available ozonesonde data in the region of 6 years fortnightly146 soundings were used. The Radio Occultation data as well as microwave limb sounding of 6 years have been used to ascertain the average tropopause height in the Indian region. (Fig.2). The SCO is calculated as followed by Dessler, 2005 equation (1);

Step 1: Total Columnar Ozone direct from Aura/OMI

Step 2: Stratospheric Columnar Ozone from Aura/MLS is computed using following method

To compute SCO3, we need to know vertical profiles of Ozone from surface to mesosphere. i.e., 1000hpa to 0.01hpa. According to Algorithm and Theoretical Basis Document (ATBD) of Aura/MLS, we considered valid data fields from 215hpa to 0.01hpa and hence for tropical region of India, we used 100hpa to 1hpa covering 37 atmospheric pressure levels to derive SCO.

Ozone Vertical profiles in volume mixing ratio (vmr) to SCO in Dobson Units (DU) from Dessler algorithm (2005).

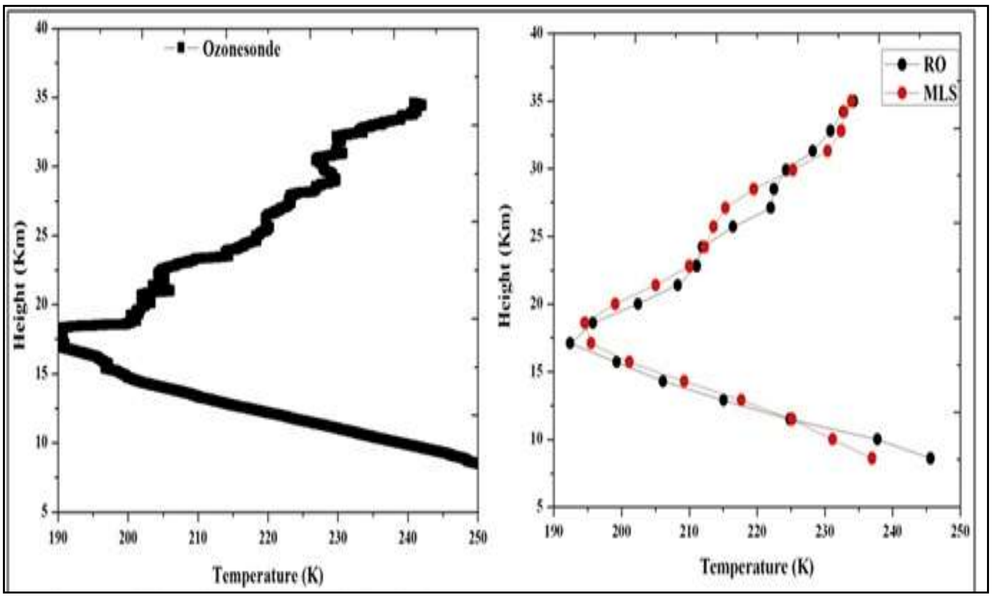


Figure 2 setting up tropopause height to derive TO

$$SCO\ (DU) = 10^7 * \left(\frac{RT_0}{g_0 p_0}\right) * \sum_{i=1}^{N-1} 0.5\big(vmr(i) + vmr(i+1)\big)(p_i - p_{i+1}) ------(1)$$

Where

P is pressure in hpa, SCO in DU and vmr is volume mixing ratio in ppm

$P_0 = 1.01325*10^5$ hpa

$R = kN_A/M_A = 287.3 JKg^{-1}K^{-1}$

k = Boltzmann constant = $1.38*10^{-23}$ $JK^{-1}molecule^{-1}$

N_A = Avogadro's number = $6.02*10^{23}$

M_A = mass of air = $28.94*10^{-23}Kg$

T_0 = 273.1K standard temperature

$g_0 = 9.88ms^{-2}$

From step 1 and step2 (equation 1);

$$TO = TCO\ (OMI) - SCO(MLS) - - - - - - -(2)$$

The MLS spatial observations are broad in resolution around 200-400 km. The MLS data has been uniformly distributed by interpolating to 100 km Spatial resolution. Accordingly OMI 25 km resolution has been resampled to 100 km. We followed the best possible interpolation method to get SCO observations close to OMI observations. In this method, we used nearest neighborhood to interpolate SCO data over Indian region.

Results and validation

Table 2 SCO and TO derived from OMI & MLS satellites

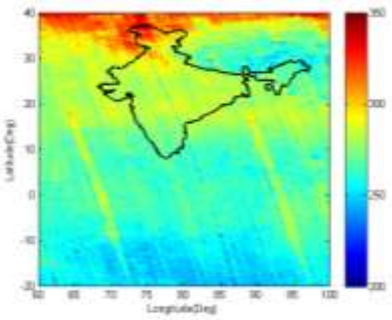
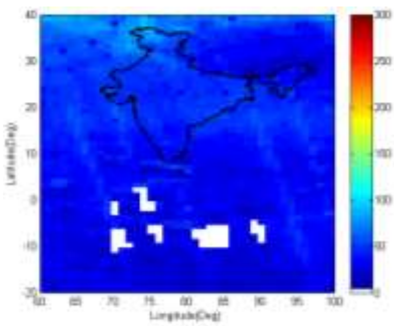
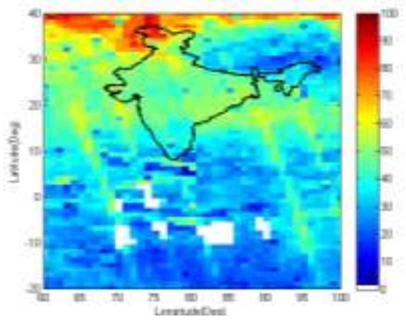
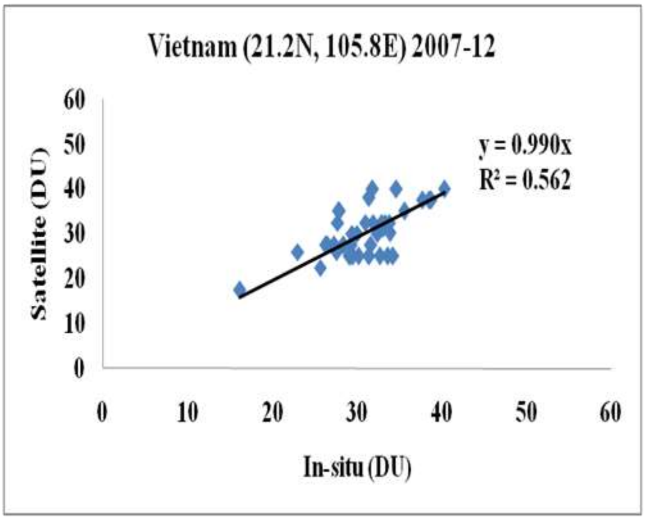
		
TCO (DU) TCO is extracted from Aura/OMI for May 2013.	SCO (DU) SCO is derived from MLS data using equation 1	TO (DU) TO is TCO (100 Km)- SCO (100 Km)

Fig 3: Scatter plot between derived TO and In-situ TO



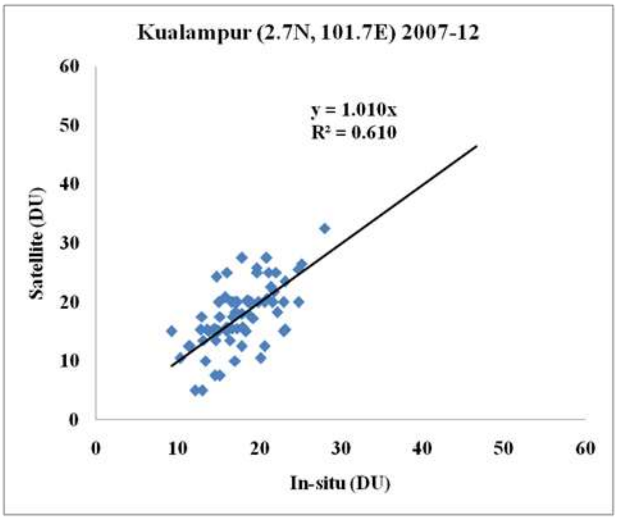


Table 3 Validation Statistics

Figure 3 shows the scatter plot between derived TO and in-situ TO for Vietnam and Kaulampur. The derived Tropospheric Columnar Ozone is compared using Ozonesonde data archived at Southern Hemisphere ADditional OZonesondes. Under the Indian Climatological zone, we considered Vietnam and Kualampur for validating derived TO from 2007 – 2012. In due course, SCO and TO will be compared using Ozonesonde data for Indian site for improving derived TO. The quality flag mean±1σ has applied for six years TO data w.r.t 6 years Ozonesonde fortnightly observations. We obtained good correlation coefficient for 2 stations shown in table 3.

Station (2007-12)	N Satellite	N In-situ	μ±1σ (DU)	N' (flag)	R^2	Bias (DU)	RMSD	SI
Vietnam (21.2N, 105.8E)	58	60	32.8±11.1	41	0.56	0.2	4.6	0.14
Kualampur (2.7N, 101.7E)	96	109	18.96±6.8	74	0.61	0.12	4.2	0.23

Table 3 Validation of derived TO against ozonesonde

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