

The tropopause height analysis in equatorial region through the GPS-RO

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Abstract. This study was performed to analyze the variation level of tropopause height in vertical resolution using radio occultation (RO) data from GRACE database due to the high spatial resolution of radio occultation data. The analysis was conducted for data collected in the year of 2016 and latitudinal variation of study in a range of 30° S to 30° N for an equatorial region with an interval of 5°. The CPT and LRT technique is used in this analysis to identify the tropopause height due to well performance in the previous study. The analysis shows that the tropopause height location varies in the latitude of an equatorial region with the highest level reach up to 19.1 km and the lowest is 16.4km over the year of 2016. Therefore, from the analysis that shows the correlation of highest tropopause layer at near of equatorial plane for northern hemisphere while lower tropopause layer at southern hemisphere.

1 Introduction

The tropopause height is one of the significant key elements in climate change research due to the correlation between global warming phenomena and the variation of tropopause height level. Known, that the Tropopause is the boundary layer between the troposphere and the stratosphere and the transmission of water vapor and other trace constituents to the tropical tropopause affects their concentration and distribution in the stratosphere [1, 2]. Therefore, the minor changes in water vapor can drive significant changes in the climate below by modifying the global radiation budget [3, 4]. The location of tropopause in atmosphere layer was varying due to the global temperature variation related to human activities. Hence, the large vertical temperature gradients for above and below tropopause layer act as a strong constraint on the tropopause height variability that can cause such phenomenon like El Nino [5]. There are various ways to define the tropopause from the previous research study. It can be defined based on the chemical composition of the atmosphere make use of the fact that the tropopause is associated with sharp gradients in trace gases [6]. While the tropopause also can be defined based on critical values of isentropic potential vorticity (PV) and variation thereof [7].

There are various methods and definition used to identify the variation of tropopause in the recent study. Cold Point Tropopause (CPT) and Lapse Rate Tropopause (LRT) used by World

Meteorological Organization (WMO) to measure the tropopause height [8]. The CPT defined as the coldest point of temperature due to the convection activity where the temperature varies with height. It also referred to the cross-tropopause flux of water vapor in the tropics and affected by radiative heating of the stratosphere [9, 10]. The transport of water vapor from troposphere to stratosphere layer is a great extent controlled by the temperature at CPT [3]. While the LRT called thermal tropopause from global distributed vertical profiles, which the tropopause height is the lowest level that the lapse rate is less than 2K/km for a depth of at least 2km [8, 9]. This method was not suitable to use for a subtropical and polar region that presence double tropopause [9]. Besides using the temperature as an indicator of tropopause location, the bending angle from an occultation data also can use to determine the tropopause height by using covariance transform method [10].

The data used in the research study of tropopause variation also play an important role in order to get an accurate determination method. Radiosonde data has been used by researchers so many years ago in atmospheric studies. However, this type of data has a weaknesses and limitation which is it have a low vertical resolution of data and also limited radiosonde observations over small populated area such as deserts, north and south poles, seas and oceans and et cetera. The radio occultation (RO) from GPS LEO satellite has recently been used as a remote sensing technique for measuring the earth atmosphere

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[11-13]. GPS-RO data provided active limb sounding measurements of the Earth's atmosphere with a high vertical resolution [9] and also have a global distribution for both southern and northern hemisphere. The data varies vertically with altitude from lower level 0.1–40 km which is up to stratosphere layer. Long term stability enables data from different missions to be combined without inter-calibration [10]. This RO data provided the atmospheric profile such as refractivity, bending angle, pressure, temperature and also the atmospheric density.

Therefore, the understanding of the tropopause trending is very important in climate change study especially to understand the tropical cyclone activity in future study.

2 Methods

The GRACE Radio Occultation (RO) data will use in this analysis that was provided by Postdam from the GRACE mission. This mission that was launched in 2002 operated by the German Satellite Operation Centre and still maintaining providing the outstanding real time data even though it has operated more than 10 years. In this analysis, the data collected from the year of 2016 to see the variation of tropopause height for the equatorial region for both northern and southern hemisphere with the latitude of -30° to $+30^\circ$. The latitude divided by 6 zones with 5° interval. The measurement of tropopause height was using the existing CPT and LRT techniques.

The tropopause height was determined from the LRT definition that the lapse rate is calculated as follow [14] ;

$$\Gamma(P) = -\frac{dT}{dz} = -\frac{dT}{dp} \times \frac{dp}{dz} \quad (1)$$

where T is temperature, P is pressure, z is height and k are R/c_p , with R, is a gas constant for dry air while c_p is the specific heat capacity of air at

constant pressure [14]. Then the level of $\Gamma_{i+1/2}$ determining based on the half level of pressure as shown by equation (2) below ;

$$P_{i+1/2}^k = \frac{P_i^k + P_{i+1}^k}{2} \quad (2)$$

which, k varies from i to $i+1$, so that the half level of lapse rate can be calculated based on equation (3) below ;

$$T_{i+1/2} = \frac{(T_{i+1} - T_i)}{(P_{i+1}^k - P_i^k)} \times \left(\frac{P_i^k + P_{i+1}^k}{T_i + T_{i+1}} \right) \times \left(\frac{kg}{R} \right) \quad (3)$$

The lapse rate determination was linearly interpolated from the lowest level to the highest

that meet the condition of that the deep layer will remain below the critical lapse rate, $T_{TP} = 2K/km$.

Furthermore, the LRT technique was not suitable to use for identifying the tropopause when the double tropopause present especially in the tropical region. In this case, the CPT is an ideal technique to determine the tropopause location.

3 Analysis

GRACE-RO data with a high vertical resolution from 0–40km covered troposphere and stratosphere layer. Therefore, the latitude was divided by two hemisphere which is northern hemisphere and southern hemisphere. Tropical region latitude varies from $30^\circ S$ – $30^\circ N$ from the equatorial plane. The RO spatial distribution data over the year of 2016 has analyzed for equatorial zone latitude with an interval of 5° . Hence, the temperature gradient distribution data than divided into latitude zonal with mean temperature calculation. There is 12 mean temperature zone was identified which is Zone 1 to Zone 6 (Northern Hemisphere): 0° – $5^\circ N$, 5° – $10^\circ N$, 10° – $15^\circ N$, 15° – $20^\circ N$, 20° – $25^\circ N$ and 25° – $30^\circ N$, while Zone 7 to Zone 12 (Southern Hemisphere): 0° – $5^\circ S$, 5° – $10^\circ S$, 10° – $15^\circ S$, 15° – $20^\circ S$, 20° – $25^\circ S$ and 25° – $30^\circ S$. Figure 1 below shows that, the tropopause height varies with the highest level of 19.1 km at 5° of northern hemisphere on July 2016 while the lowest level is at 16.4 km for 5° southern hemispheres in August 2016.

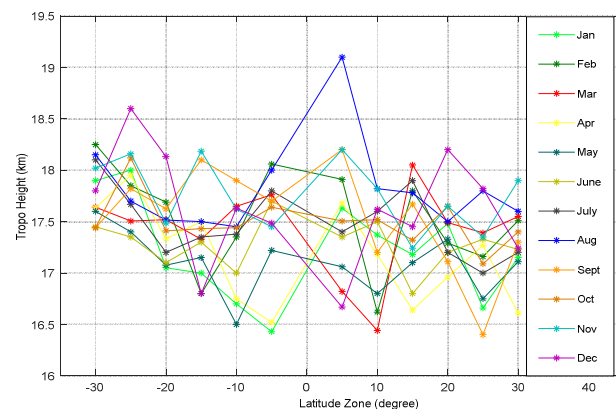


Fig.1. Tropopause height variation over equatorial zone.

This variation of tropopause height over both hemispheres shows the air convection activity. The highest level of tropopause height at the nearest equatorial plane at 5° in the northern hemisphere shows that this area was exposed to the heat by sun radiation and also contributed by human activity that causes the greenhouse effect. In fact, the higher water vapour concentration occurred in the northern hemisphere compared to

the south due to the larger proportion of land area than the ocean.

The tropopause level at 5° in the southern hemisphere which is near to equatorial plane has the lowest tropopause distance is because the location of data taken by GPS-RO is at the unpopulated area or an ocean with lower water vapor concentration in this area. Otherwise, the other result shows the symmetrical value between both hemispheres which is near to 16.5 km height at $\pm 10^\circ$ zone.

The Figure 2 shows the monthly temperature distribution over the equatorial region in the year of 2016. The temperature distribution below 8-10 km height shows inconsistent value. The temperatures reduce consistently from 10km to tropopause layer at around 16–18 km height. Furthermore, there is no double tropopause found over the equatorial region so it easier to identify the tropopause using the LRT techniques.

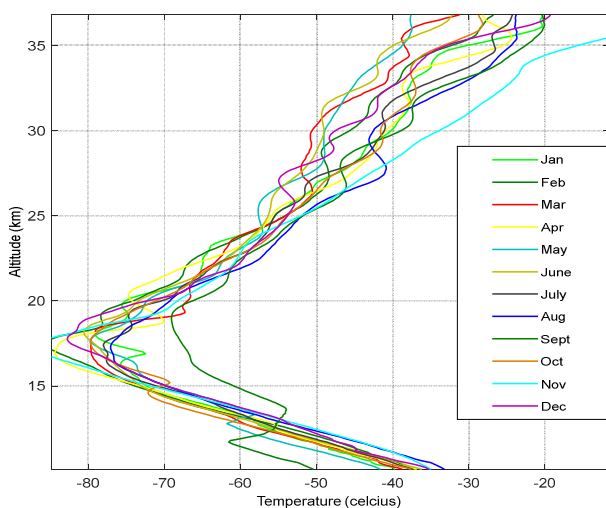


Fig. 2. Monthly temperature distribution over the year of 2012.

4 Conclusion

The analysis of RO data collected from GRACE mission shows that the highest level of tropopause occurs in the equatorial plane of 0° – 5° latitude. The increasing level of tropopause will indicate the increment volume of water vapor contained in troposphere layer due to the warming of earth surface which also contributed by human activities. However, the analysis conducted in this study is focusing on average temperature value that varied according to the latitude variation.

This analysis study was conducted for the year of 2016 data only. Even though the analysis shows the increasing of tropopause level compared to the previous study, however, the better understanding of tropopause trend can be found for a long period of data observation. The trend of the

increment value of tropopause layer can be an indication for climate change study.

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