IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

SEASONAL CYCLE AND ANNUAL VARIABILITY OF TROPOSPHERIC CO_2 BASED ON GOSAT AND OCO-2 SATELLITE OBSERVATION

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Abstract: In this paper, Satellite (GOSAT, OCO-2) and in situ observation are used to estimate CO_2 concentration over Indian region. The two different satellite are different temporal and spatial resolutions .The CO_2 atmospheric with OCO-2 and GOSAT satellite observation over four different regions in the Indian land region. The analysis has good comparison and time series analysis shows us good coherent with atmospheric surface CO_2 with satellite and in-situ observation .In the analysis observed seasonal and inter annual variation over four regions of box: North India(Box A) , South India(Box B) and North east India(Box C) and south west region(Box D). Over India region the CO_2 maximum is in month of May and minimum in August/September .Both satellite observation shows seasonal and annual variation .The mainly effect of seasonal and inter-annual increase depends on terrestrial biosphere.

Index Terms - GEOS-Chem, Carbon Dioxide, Greenhouse Gas, Seasonal Cycle, GOSAT, OCO-2.

I. Introduction

Atmospheric carbon dioxide (CO_2) is the most important element in the carbon cycle and it is a major greenhouse gas that has a significant role in global warming. The greenhouse gases are can trap thermal radiation or heat of the earth emit to space. CO_2 concentrations have been increasing continuously since pre-industrial times, from 280 parts per million by volume (ppmv) to 413 parts per million by volume, primarily due to the increase in anthropogenic emissions like fossil fuel burning, deforestation etc. Globally among the highest CO_2 emitting countries, China is leading with (~9.8 Gt CO_2 yr^{-1}) and followed by USA (~5.3 Gt CO_2 yr^{-1}), then India with ~2.5 Gt CO_2 yr^{-1} in 2017 (e.g., Le Quere et al. 2018).

Our understanding of the chemistry of the global troposphere has advanced significantly over the past twenty years. A quantitative understanding of the atmospheric carbon budget is very important for developing climate mitigation policies. Global studies have been carried out to understand Atmospheric CO_2 variability using different approaches using in-situ measurements, Satellite data and various modelling techniques. Many studies have used atmospheric transport models with in situ CO_2 observations to surface fluxes of CO_2 (Baker et al., 2006a; Peters et al., 2007; ; Schuh et al., 2010; Feng et al., 2017; Basu et al., 2013; Deng et al., 2014; Lau-vaux et al., 2016) at various spatiotemporal scales. High spatial temporal resolution of transport model to improve and understanding the source and sink for the greenhouse gases (Yoshida et al.2011.). Major developments in the Atmospheric chemical transport modelling over the past decades has been helpful in overcoming the limitations of satellite and in-situ measurements in understanding the troposphere chemistry in a coupled manner(Land-Atmosphere-Ocean).source process is where CO_2 is released into atmospheric from animal and planet decay ,deforestation and the burning of fossil fuel (Coal or Gas).sink is remove CO_2 from atmospheric such as vegetation and trees take up CO_2 for photosynthesis process. Ma et al developed a downscaled method for CO_2 using OCO2 column dataset.

In this paper we analysis the spatial and temporal variation of atmospheric CO_2 with GOSAT and OCO-2 satellite and different insitu measurements. Due to insitu observation data available over Indian region after 2012 onwards, by using satellite retrievals data of CO_2 column average user to showing variability of regional scale and source and sink are estimate. In the evaluation of model performance through four different sensitivity experiments, most commonly used statistical tools such as correlation coefficient (r), root mean square error (RMSE), standard deviation, bias are applied to the entire time series spanning from 2013-2019.

2.Data and methods

2.1 Satellite observation (GOSAT , OCO-2)

GOSAT was launched on 23 January 2009 by the Japanese Aerospace Exploration agency (JAXA). It operates in the SWIR (shortwave infrared) at 0.76, 1.6, 2.0-micrometer sensitivity to the near surface. GOSAT has two types of instruments, TANSO-FTS and TANSO-CIA. TANSO-FTS(thermal and near infrared sensor for carbon observation- Fourier transform spectrometer) ha four bands, one is thermal IR channel from 5.5 to 14.3 micrometer remain three are spectral channels with 0.27/cm ,resolution at 0.76,1.6,2.0 micrometre ,in this bands not only CO_2 retrieval and also CH_4, H_2O and O_2 .CO_2 absorption is high in near 1.6 µm and 2 µm bands near the lower troposphere .In this study CO_2 concentration near surface layer monthly using for period of 2013 and 2019 with 2.5^0 x 2.5^0 Spatial resolution form JAXA(Yokota et al., 2009; Yoshida et al., 2011; https://data.gosat.nies.go.jp) . We used the GOSAT FTS SWIR L4B daily of 2009 to 2017 with grid resolution of 2.5^0 x2.5^0 .(Level 3 data product available is monthly average of 2009 to 2018 for over a grid 2.5^0 x2.5^0 . The data were missing for the period June, December months in 2014 and January, September months 2015 in GOSAT FTS SWIR Level 3) .The details of the products and processing methods are described in https://data.gosat.nies.go.jp. GEOS-CHEM data were projected into grids of GOSAT observations both for horizontal and vertical levels.

Orbiting Carbon Observatory -2(OCO-2) launched by American environmental science on 2 July 2014 (crisp et al 2017),-2 replacement for the orbiting Carbon Observatory, in 2009 OCO fist launch failed to reach orbit. This OCO-2 second successful high precision observing satellite after GOSAT.OCO-2 is three band spectrometer which are measured two spectral band for column measurements of carbon dioxide (weak band 1.61 microns, strong band 2.06 microns) and one spectral band measurement column of Oxygen(A band 0.76 microns).in this paper we used OCO-2 X CO_2 version 9r algorithm use for retrieval Odell et al 2012.The OCO-2 XCO_2 retrieval and temporal resolution 16 days so we use monthly mean composite of Xco2 for atmospheric surface , and retrieval co2 used to comparison to Model from the seasonal and interannual variations.

2.4 Computation of seasonal cycles

The dominant oscillating signals of wind vectors with annual and semi-annual periodicity were found in the Fast Fourier Transformation (FFT) analysis. Time-series of the surface wind velocity A(t) are fitted with annual and semi-annual harmonics based on least square methods for calculation of the seasonal contributions PS (t) in the time series at each pixel level as they were the most prominent signals (Nayak et al. 2013). The time series $A(t)$ can be expressed as

$$A(t) = A_0 + A_a cos(w_a t + \Phi_a) + A_{as} cos(w_{as} t + \Phi_{as}) + e(A) \qquad (1)$$

Where the stationary component A_0 represents the climatological mean, (A_a , A_{as}) and (Φ_a, Φ_{as}) correspond to the amplitude and phase angles of annual and semi-annual harmonics, respectively, e represents the residual term and white noise. The non-seasonal time series is the residual of mean seasonal cycle from the original time-series data of surface wind velocity. It is important to note that this procedure can remove only the mean component of the seasonal variability. Hence nonseasonal contribution is composed of intra-seasonal variability and inter-annual variability. The changes in seasonal cycles during the study period contribute to inter-annual variability, while changes occurring within a seasonal time scale are called intra-seasonal variability.

3. Results and Discussion

3.1 Time series analysis of Model simulation and satellite observation

Seasonal cycle, spatial and temporal cycle is Comparison of model CO_2 with satellite observation for Time series analysis. The Fig 1 show the temporal variations of OCO-2 observation and GOSAT for four different region over Indian land region for the period 2013-2019,.The temporal characteristics of atmospheric CO_2 concentration is strong seasonal variation observed and rising trend over Indian land region , The four region are box A represented cropland dominance Indo Gangagetic plain and this area away from the marina environment .box B is southern peninsular region and evergreen trees. Box C is grassland dominance of Rajasthan and Thar Desert. Box D is evergreen forest region .In the fig 2 shows us four red box of A,B,C and D of Indian region .The CO_2 concentration lower tropospheric columnar mean is batter agreement with GOSAT and OCO-2 observation .Yoshida et all described the SWIR band of the GOSAT surface layer CO_2 concentration is more sensitive. The all data set shows a similar range of CO_2 between 390 to 415 ppmv, linear growth rate 2.25 ppmv yr^{-1}.

In the Figure 1 observed the GOSAT has a bias of 3 ppm compared with OCO-2 observation because This is probably due to their different observing sensitivities and retrieval algorithms. The temporal and seasonal variation in atmospheric CO_2 concentration includes intense increasing trends over four different regions over India. The interannual oscillation observed in the atmospheric CO_2 in the year 2017 and 2019 and the minimum observed in 2015, and 2016 .low and Simmonds 1996 explained interannual variability and latitudinal gradient occurs mainly in CO_2 surface changes.GOSAT and OCO-2 satellites some region data not present because of clouds. . The average XCO2 concentration of India was the lowest as 393 ppm from September to October and then drastically increased to 416 ppm from November to February for 2014 to 2019 period. The biases between OCO-2 and GOSAT was found at the minimum in April, followed by July, October, and January.

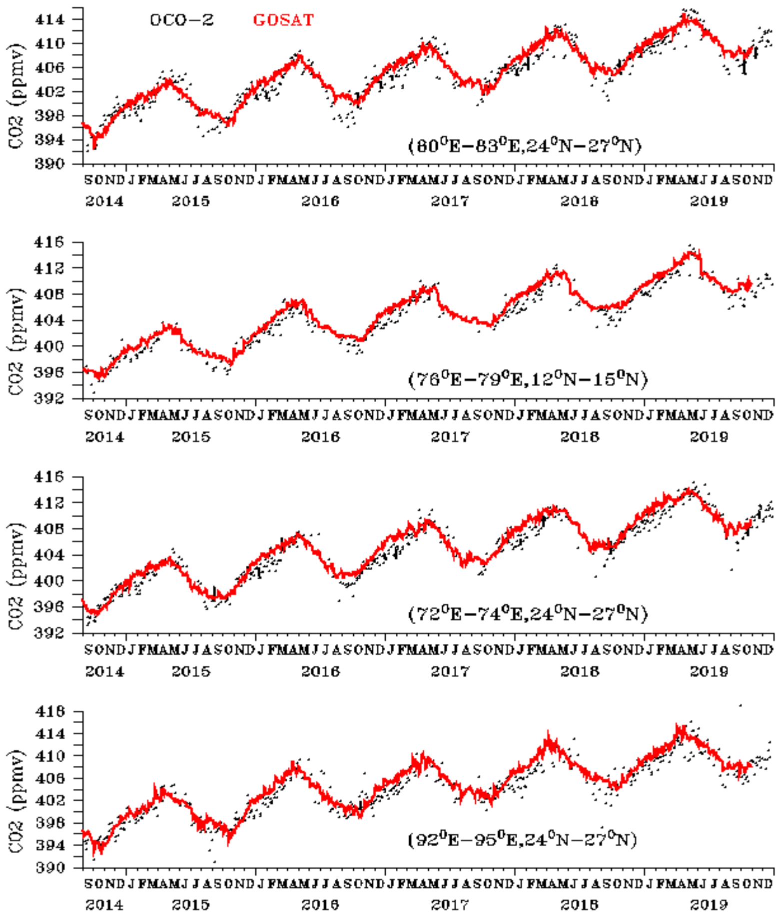

Figure 1 shows time-series analysis of GOSAT and OCO-2 satellite observation with four different location show in figure 2 four Box A,B,C and D .

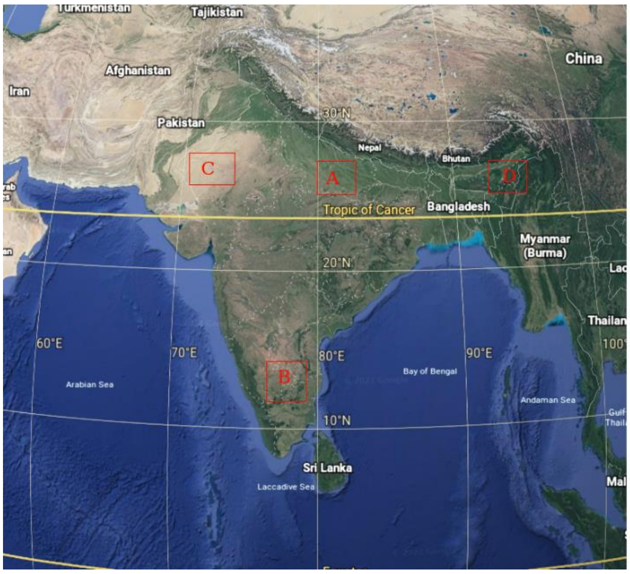

Figure 2 shows us the study region shows the four different location over Indian region ,box A Indogenatic region box B southern peninsular region ,box C Desert region ,Box D is green forest region. The map is created from http://www.google.com/maps.

3.2 Seasonal Variability of atmospheric CO_2

Figure 3 and 4 show seasonal variations of CO_2 derived from the GOSAT for the period of 2012 to 2019 and OCO-2 for the period from September 2014 to August 2019 for four seasons based on the three months; winter (December January February or DJF), spring (March April May or MAM), summer (June July August or JJA) and autumn (September October November or SON). The seasonal cycle has significant effects on CO_2 concentration. The higher CO_2 concentrations have been observed in winter and spring while the lower ones occurred in summer and autumn. The weak photosynthesis, microorganism activity, and heating measures are the major causes of the increased CO_2 concentrations in winter and the spring; while CO_2 uptake from vegetation in summer removes CO_2 from the atmosphere and decreases the CO_2 concentrations. Over the Indian region, the co2 concentration is high in April month in Indoganatic region. Although much of the data between June to August for the eastern coast is lost due to the monsoon, but CO_2 is comparatively lower in this region. In GOSAT and OCO-2 observation minimum CO2 concentration in August/September and maximum concentration was observed in May .

The highest in April and the lowest in August. It starts increasing in the fall, continues to increase in the winter, and reaches the maximum value in spring. In these regions, the heating systems are used in winter and spring which consume larger amounts of fossil energy, such as natural gas, oil, and coal, and thus produce a large amount of CO_2 which is discharged into the atmosphere. During this period, the strong respiration and the weak photosynthesis also contribute significantly to increasing the CO_2 concentration in the atmosphere. The CO_2 concentration decreases from May to August. During this period, the temperature, precipitation, and lightning are beneficial to vegetation growth which enhances the photosynthesis process

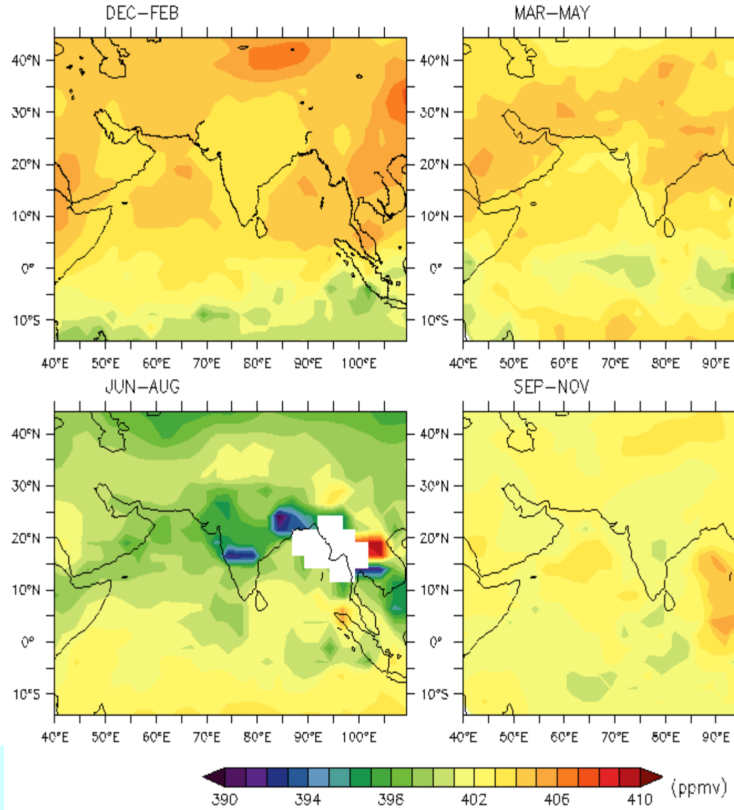

Figure 3 shows us the seasonal variability of the GOSAT satellite retrieved CO_2 over Indian region

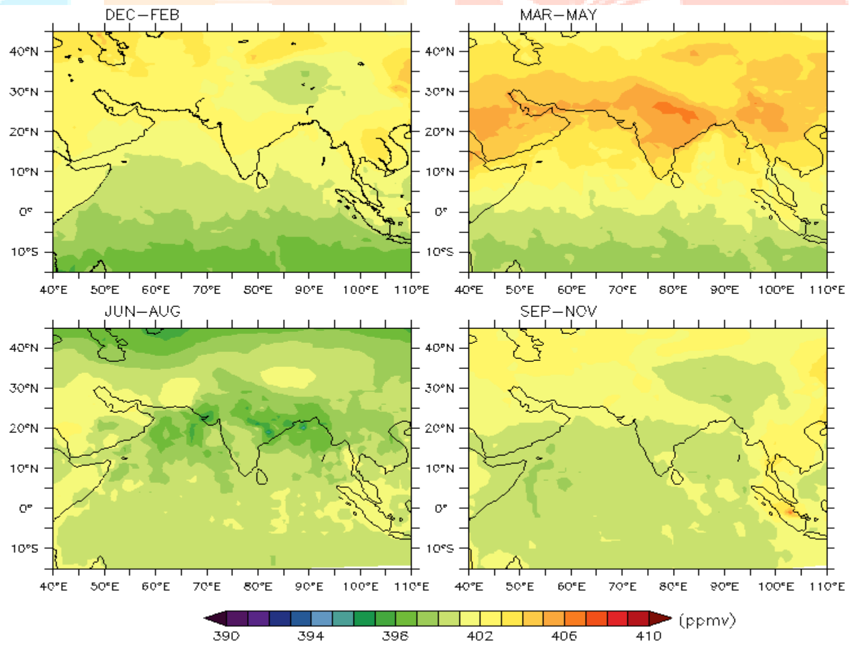

Figure 4 shows us the seasonal variability of OCO-2 retrieved CO_2 over the Indian region

Considering the column-averaged values over the Indian land boundary, the variation of CO2 over India is studied by masking other regions. Fig. 5 presents the harmonic analysis of the OCO-2 and GOSAT data over India. The fist panel shows us the climatology mean of GOSAT and OCO-2 observation. The CO2 concentration is high in the Indian land region. The Semiannual amplitude high amplitude observed in high latitude, lower amplitude is observed in at equatorial region similar pattern observed in OCO-2 observation. But in Indian region more amplitude observed. In Winter(DJF), the OCO-2 XCO2 values were significantly higher than those of GOSAT in the ocean of the southern tropic and lower than those of GOSAT . In summer

(JJA), the OCO-2 XCO2 values were significantly higher than those of GOSAT in the high latitudes of the northern tropics.

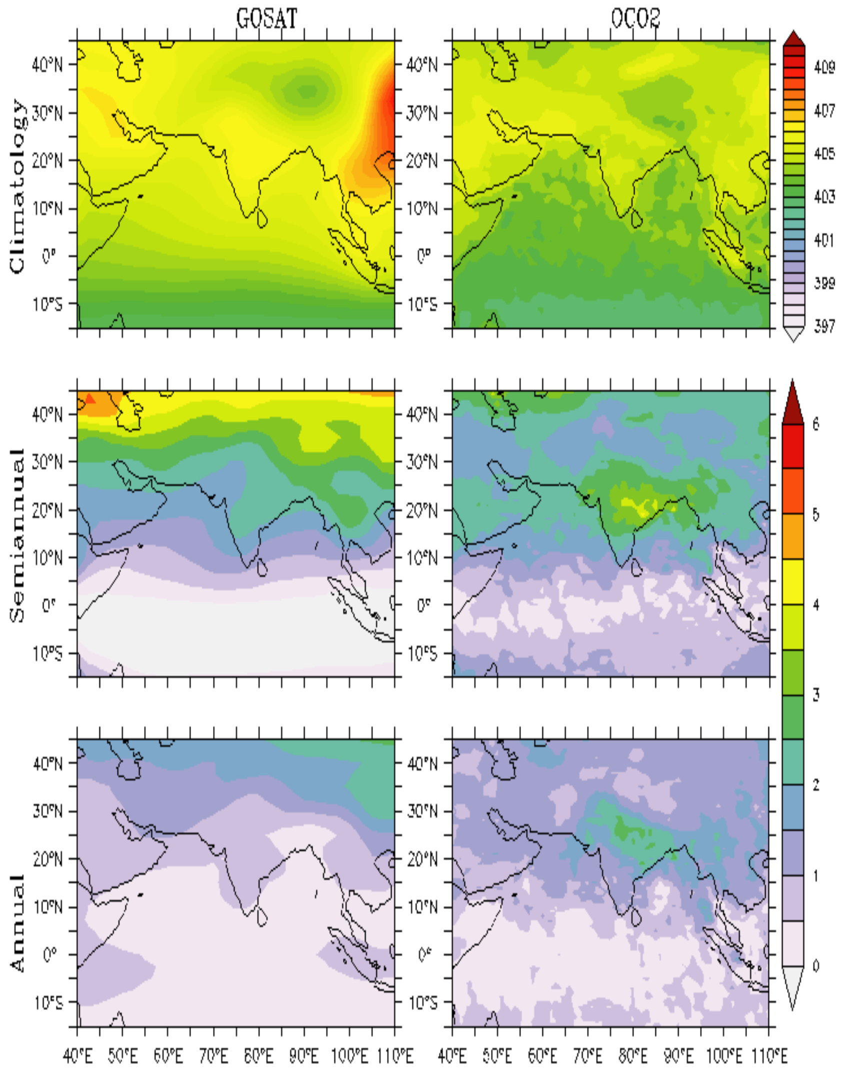

Figure 5 shows us Harmonic analysis of GOSAT and OCO-2 from the period sep 2014 -2019.

4. Summary and Conclusion

The seasonal dynamics and interannual variability of surface layer atmosphere CO2 in Four different region in Indian land region. They show good agreement between them and exhibit distinct seasonal cycles and inter-annual variability across four different regions. Over India the CO2 maximum is in May and minimum in August/September. The mean climatology exhibits a strong latitudinal gradient with a high concentration in the north and decreases towards the southern tropical Indian Ocean. The interannual variation of the terrestrial flues has main crucial parameter in the surface CO2 concentration .The terrestrial biosphere fluxes in Indian region has been main impact and understanding of the interannual variation of atmospheric CO2 and understating effect of uncertainty in fluxes.

ACKNOWLEDGEMENT: We are very thankful to GOSAT team JAXA, and OCO-2 for providing the data for this study.

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