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STUDY OF SURFACE CH4 FLUX EMISSION FROM GOSAT SATELLITE DATA OVER SELECTED AGRO-ECOSYSTEMS IN INDIA

Sneha Thakur[1,2*] and Hitesh Solanki[1]

[1]Department of Environmental Sciences, University School of Science, Gujarat University, Ahmedabad, India
[2]Crop Inventory and Agro-ecosystem Division,Space Applications Centre, ISRO,Ahmedabad, India
*Corresponding author: snehathakur410@gmail.com

ABSTRACT

The present study was carried out to characterize and quantify the seasonal behaviour of surface CH4 emissions from L4A product over two selected irrigated agro-ecosystems in India over sub-humid region of Indo-Gangetic Plain (IGP) and semi-arid region of Gujarat Plain and Hills Region (GPHR). Satellite data of Greenhouse Gases Observing SATllite (GOSAT) with L4A data product has been used with a cluster of contiguous grids of 3 x 3 within the Region of Interest (ROI) representing agricultural land uses spread over trans, upper, middle and lower part of IGP for analysis. The seasonal behaviour was studied for three agricultural years of June 2009 to May 2012 through time series plots of monthly means of each ROI. The annual CH4 emission from agricultural region using GOSAT data was found to be about 8-9 Mt CH4 which was about three times higher than reported over rice system in India using sparse ground samplings. The IGP showed the highest annual mean (88.11 mg CH4 $d^{-1}m^{-2}$) of surface emission in Lower Gangetic Plain Region (LGPR) and the lowest annual mean (7.01 mg CH4 $d^{-1}m^{-2}$) in Trans-Gangetic Plain Region (TGPR). These sub-humid irrigated agricultural regions with rice-wheat rotation showed substantially higher emissions than those in semi-arid irrigated agriculture (10.38 mg CH4 $d^{-1}m^{-2}$ to 11.32 mg CH4 $d^{-1}m^{-2}$) in GPHR. In IGP for an agricultural growing year (June 2009 to May 2010), the mean of CH4 emissions for kharif (June to October) season showed higher emission flux with 51.04 mg CH4 $d^{-1}m^{-2}$ than in rabi (November to April) Season (14.31 mg CH4 $d^{-1}m^{-2}$), but coefficient of variation was found to be more in rabi season (77.8%) than in kharif (39.3%) season. In GPHR region for same year, the annual mean of CH4 emissions for kharif and rabi season were 14.26 mgCH4 $d^{-1}m^{-2}$ and 7.03 mg CH4 $d^{-1}m^{-2}$, respectively but the coefficient of variation (CV) during kharif are more (30.37%) than in rabi (29.29%).

Keywords: *Methane, Kharif, Rabi, GOSAT*

INTRODUCTION

Climate change can be defined as "any long-term substantial deviation from present climate because of variation in weather and climate elements". Excess Green House Effect is an important influential factor for climate change. Green House Gases (GHG) in the earth's atmosphere are transparent to sun's shortwave radiation flux and prevent longwave radiation flux to escape thus maintains earth's temperature favourable for us to live in. Both natural and anthropogenic forcingslead to gradual built-up of GHG. Among different GHGs the Global warming Potential (GWP) ofCO_2 and CH_4 are 1 and 56 respectively for 20 years. Among anthropogenic factors, agricultural activity in terms of intensification or expansion of irrigated area play significant role for enhanced methanogenesis. Till date in India, periodic CH4 measurements from sparse agricultural sites were used for upscaling and to compute country's emission potential using fixed emission coefficients sampled over few sites. Extrapolation to larger area always leads to uncertainties in the regional estimations. Therefore, GHG flux emissions need to be studied with other co-existing energy andwater fluxes to study the interactions among them and to find out modelling mechanism to reduce this uncertainty. Moreover, the impact of expansion irrigated agriculture on surface GHG emissions have not been studied over India.

Previously methane emissions were evaluated theoretically using eco-physiological, micro metrological and biogeochemical theories [1]. Irrigated agricultural system contributes to GHG emissions significantly [5]. The surface energy balance regime is also altered by different irrigation regimes. More Irrigation leads to more loss of water through evapotranspiration thus leading to built-up of water vapour in the atmosphere [2]. Higher soil wetness and decrease in LandSurface Temperature (LST) seem to modulate CH_4 and CO_2 emissions to a larger extent depending on different solar radiation regimes [6]. For peat lands CO_2 is sequestered by partial decompositionbut releases more CH_4 than any other ecosystem [3]. Excess use of nitrogenous fertilizers under sufficient moisture regime leads to higher emissions of N_2O from soil [4]. Till now, GHG emissioncoefficients are generated based on certain qualitative indicators

involving crop types, water regime etc. Flux-based emission coefficients using boundary layer techniques have been least attempted [7]. Methane concentration in short wave infrared (SWIR) are unique as they provide dense and continuous data. We have used this data using GOSAT to observe methane flux over selected contrarily agro-ecosystems of India. Observation were mainlyfocused on regional variability and seasonal variability for a temporal period of June 2009 to May2012.
Study Area

Indo-Gangetic-Plains:-

Indo-Gangetic-Plains of India comprises of four agro-climatic regions/zones of India, namely Lower Gangetic Plains, Middle Gangetic Plains, Upper Gangetic Plains and Trans Gangetic Plains;stretching from Haryana to West Bengal covering an area of about 3.75lakh sq km. As the name defines all these plains are along the river Ganga consisting soil rich in alluvium content. Rice andwheat are grown dominantly with other crops like maize, sugarcane, and cotton.

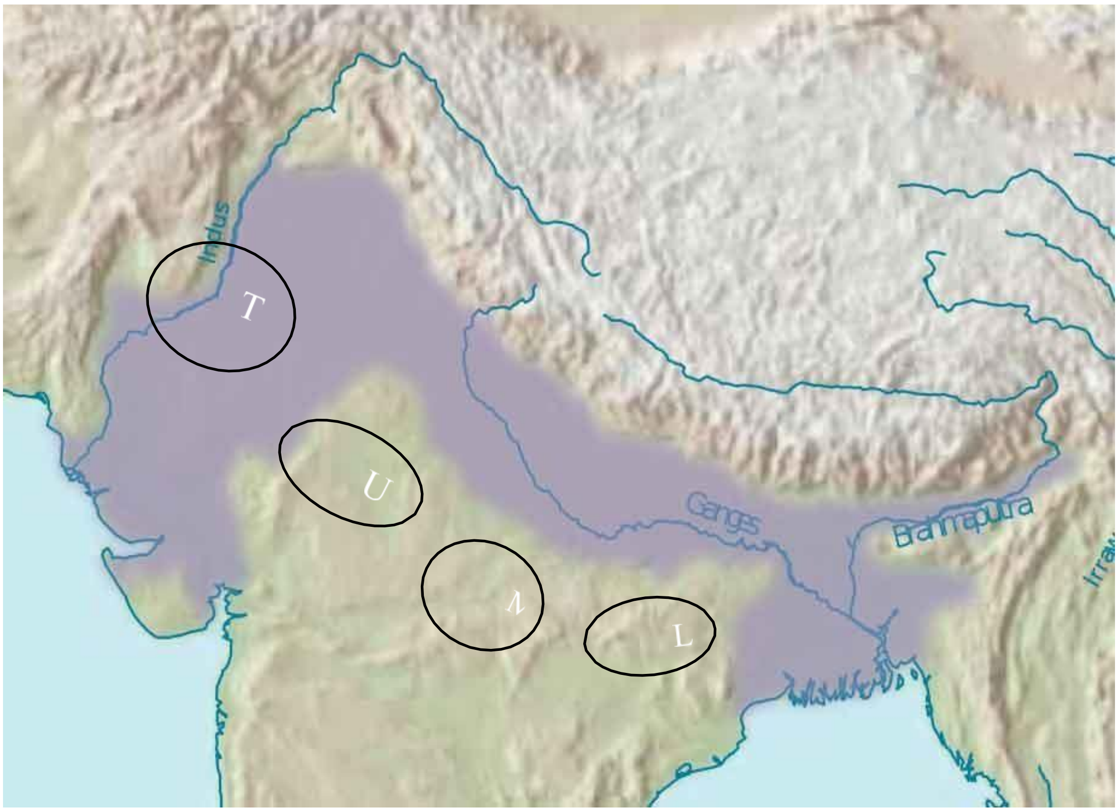


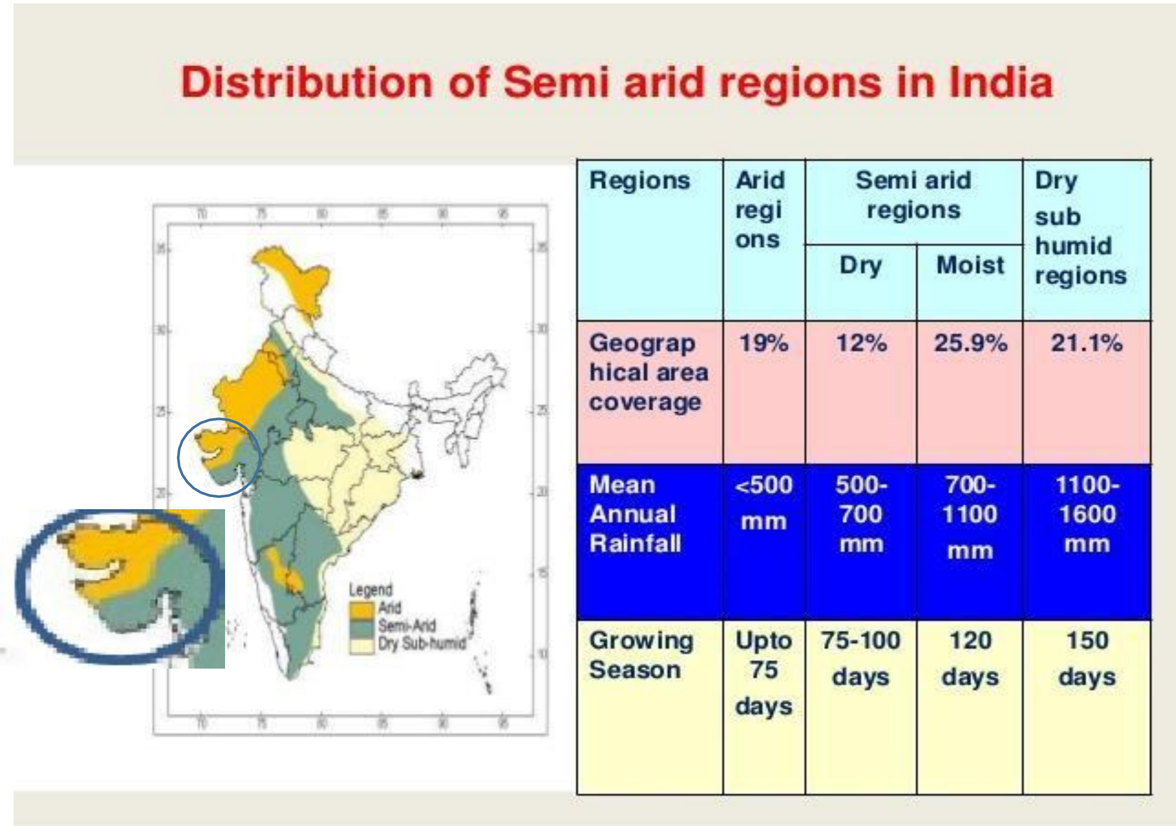
Fig1: Selected regions if Indo Gangetic Plains
Gujarat Plains and Hills Region:-

Gujarat (20° 1' and 24°7' N latitude and 68°4' and 74°4' E longitude) makes 6% of India's geographic area. About 20% land of Gujarat is drought prone. In this study we have considered three region of Gujarat that are; North Gujarat, Saurashtra and Southern Hills of Gujarat as RegionOf Interest (ROI) for our area of study. North Gujarat's land productivity is low with an average rainfall of 340to 735mm per annum. Most of the land is a waste land and few agricultural patches are practiced for groundnut. Overall decreased agricultural practice is observed in this region. Sub-agroclimatic zone Saurashtra is a semi-arid zone towards north and coastal patch having sub-humidregion towards south with coastal alluvium medium black soil. Average rainfall observed is around537 to 850mm annually. Whereas for southern hills of Gujarat annual rainfall is above 850 and less than 1000mm annually, thus irrigation practice is also observed.

Both the regions selected are apt for studying contradictive variations in terms of geographical distribution and agricultural pattern with respect to GHG Methane emission Fluxes. Over and above till date in India, CH_4 measurements are taken from sparse agricultural sites for upscaling, and its extrapolation is done for whole country which shown large uncertainties in regional estimation.

Fig2: Selected regions of Gujarat Plains and Hills Regions

Data Used



Regions	Arid regions	Semi arid regions		Dry sub humid regions
		Dry	Moist	
Geographical area coverage	19%	12%	25.9%	21.1%
Mean Annual Rainfall	<500 mm	500-700 mm	700-1100 mm	1100-1600 mm
Growing Season	Upto 75 days	75-100 days	120 days	150 days

GOSAT:- Greenhouse gas Observing SATellite was launched on 23rd January 2009, providing satellite data from June 2009 to May 2012. Infrared light reflected and emitted from the earth's surface is observed by GOSAT. GOSAT is sun synchronized at an altitude of 666km with 3 daysrevisit time.
The atmospheric concentrations of CO_2 and CH_4 are generally available as L3 data product throughrigorous retrieval algorithm using observations in Short-Wave Infrared (SWIR) (1.56 to 1.72μm) band in Fourier Transform Spectrometer (FTS) payload at Greenhouse Gases

Observing SATellite(GOSAT). These products have been used along with NOAA's ObsPack-GLOBALVIEW DATAto produce CO_2 and CH_4 surface emission fluxes which are available as L4A Product at 1° x 1° grid resolution. This L4A processing level product is available in text format as well as in NetCDFformat for 64 location and 1° grids annually (consisting monthly data for each year), globally. Wehave used L4A, text format product for our analysis.

Table:1 GOSAT SPECIFICATIONS (FTS-Fourier Transform Spectrometer)

	Band 1	Band2	Band3	Band4
Spectral Coverage(µm)	0.758-0.775	1.56-1.72	1.92-2.08	5.56-14.3
Spectral Resolution (cm^{-1})	0.2	0.2	0.2	0.2
Revisit Time	3 Days			
Polarized light observation	Performed	Perform ed	Performed	Not Performed
TargetedGases	O_2	CO_2.CH_4	CO_2.H_2O	CO_2.CH_4
Angle of instantaneous field of view	15.8 mrad. (corresponding to 10.5 km when projected on theearth's surface)			
Time necessary for a singlescanning (sec)	4.0, 2.0, or 1.1 (depending on scanning mode being used)			

Methodology

This study has been done using GOSAT satellite data of L4A product. L4A product is obtained byestimating FTS SWIR Level 2 column-average mixing rations and ground-based observed data with the help of global atmospheric transport model.

Table 2: GOSAT Data Products Used

Prod uct Level	Sensor/band	Product designation	Description	Product ProvisionUnit	Data Format
L4A	FTS SWIR L2 CH_4 Column + ground-based observation	L4A global CH_4 flux	CH_4 flux per each 64 global region(monthly average)	Per year (64 regions)	Text

Monthly data was extracted from annual data for all the three years, these data were rasterize andresized to Land Use and Land Cover (LULC) of India. ROIs with grids of 3x3 over agricultural land use was studied by applying agricultural mask over Indo-Gangetic Plains (trans, upper, middleand lower) Region and Gujarat Plains and Hills Region. Statistic were computed by taking average,standard deviation and co-efficient of variation with respect to seasonal variability (kharif and rabi)for three agricultural years (June-2009 to May-2012).

RESULT AND DISCUSSIONS

Earth's climate is dynamic and due to human interventions, change in climate in recent time is ina scrutiny to mitigate its negative impacts. The gaseous compounds like CO_2 AND CH_4 are mainlyincreased due to anthropogenic activities. These activities also include agricultural practices, specially rice-paddy cultivation. India is one of the major rice cultivators. Rice fields are continuous flooded with water favouring anoxic conditions causing methanogenesis. A Methanogenic bacterium uses organic compounds as electron donors for energy and in turn reduces C to CH_4 as its product. In Indo-Gangetic Plains of India Rice-wheat cultivation is observed. This is due to higher soil moisture and rich alluvial soil availability. In contrarily this agro-climatic region of Gujarat Plains and Hills is of semi-arid type.

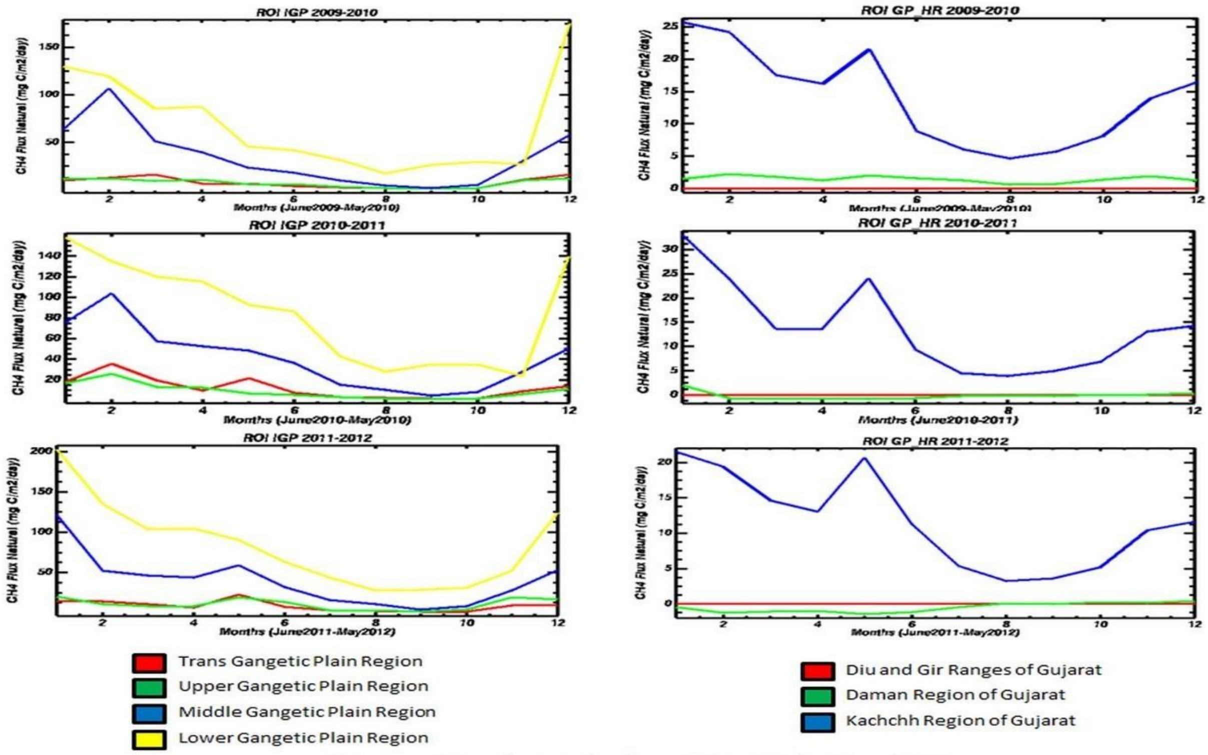


Fig4: Annual Mean for agricultural year 2009 to 2012 for IGP and GPHR

The annual CH4 emission from agricultural region using GOSAT data was found to be about 8-9 Mt CH4 which was about three times higher than reported over rice system in India using sparse ground samplings. The seasonal variability of CH4 emissions showed primary and secondary peaks. The IGP showed the highest annual mean (88.11 mg CH4 d-1m-2) of surface emission in Lower Gangetic Plain Region (LGPR) and the lowest annual mean (7.01 mg CH4 d-1m-2) in Trans-Gangetic Plain Region (TGPR). These sub-humid irrigated agricultural regions with rice-wheat rotation showed substantially higher emissions than those in semi-arid irrigated agriculture (10.38mg CH4 d-1m-2 to 11.32 mg CH4 d-1m-2) in GPHR. In IGP for an agricultural growing year (June2009 to May 2010), the mean of CH4 emissions for kharif (June to October) season showed higheremission flux with 51.04 mg CH4 d-1m-2 than in rabi (November to April) Season (14.31 mg CH4 d-1m-2), but coefficient of variation was found to be more in rabi season (77.8%) than in kharif (39.3%) season. In GPHR region for same year, the annual mean of CH4 emissions for kharif and rabi season were 14.26 mgCH4 d-1m-2 and 7.03 mg CH4 d-1m-2, respectively but the coefficient of variation (CV) during kharif are more (30.37%) than in rabi (29.29%). The cloud persistence and possibility of continuous higher soil moisture through rainfall and irrigation are more during kharif in IGP than in semi-arid GPHR. These could probably lead to contrasting behaviour of surface emission of methane fluxes.

CONCLUSION

We investigate the correspondence of GOSAT CH4 with five agro-climatic zones, grouped in twocontradictory climate ie Indo-gangetic Plains (TGPR, UGPR, MGPR, LGPR) and Gujarat Plains and Hills Region (GPHR) for three agricultural years (June 2009 to May 2012). Emissions variation in Kharif and Rabi were observed for India agricultural systems. After Processing our datasets, we observed Primary and secondary peaks on annual basis for CH4 emissions. The calculated CH4 emissions using GOSAT data was also found to be much more than the theoretically calculation by sparse ground sampling. Comparing two agro climatic regions, the annual mean of surface emissions from IGP is much higher to GPHR.
Seasonal variation for both regions showed higher emissions in Kharif than Rabi.

These variations are likely to express the dependency of CH_4 flux emissions for these regions is due to heterogeneity in the biotic and abiotic acclimatization.

CONFLICT OF INTEREST

Authors declare no conflict of interest

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