Spatial and Temporal Changes in Methane emission in INDIA during (2003-2015)

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ABSTRACT

One of the most potent greenhouse gases is methane, which is the most basic hydrocarbon in the paraffin series. With a GWP of roughly 28, this is the second most significant greenhouse gas. Since there is a lot of it in the Indian subcontinent, it is important to monitor and research this gas.

This study analyses satellite readings that were taken all over the world between 2003 and 2015 and are retrieved for the Indian region. This study made use of the satellite-based SCIAMACHY and TANSO-FTS equipment. Additionally, the work examines how a change in concentration levels depends on a region's location and climate by estimating the rate of change of methane levels through time and obtaining information on the change in concentration. According to this study, it is rising quickly over the Indo-Gangetic Plain, the Northeast, and certain coastal areas. The majority of the sources are man-made, such as fossil fuels and the energy industry, as well as natural sources like wetlands.

Both instruments indicate that methane content is rapidly rising in the area, depending on a number of variables and seasonal fluctuations. Methane emissions must be decreased otherwise it will be the main cause of the greenhouse effect.

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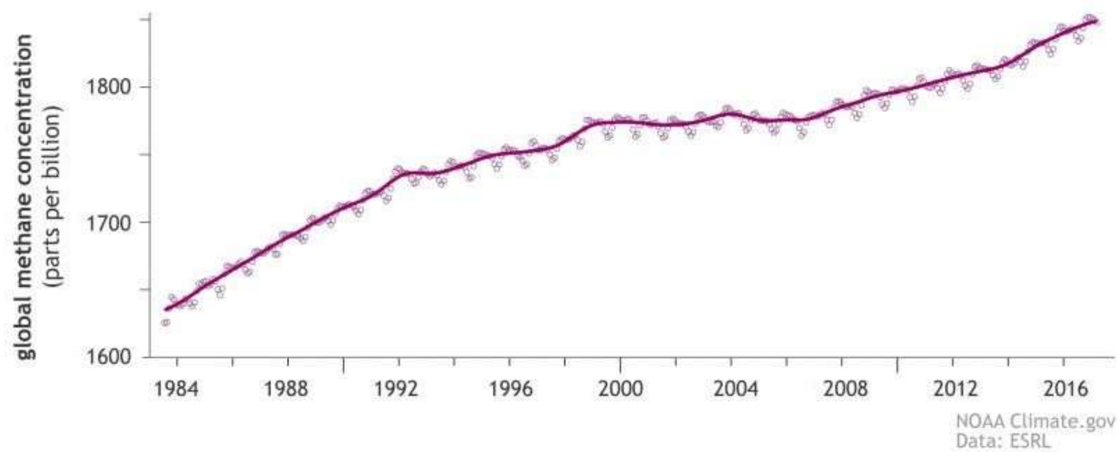
INTRODUCTION

Chemically speaking, methane has the formula CH4 (one carbon atom and four hydrogen atoms). It is natural gas's primary component. Methane is an appealing fuel due to its relative abundance on Earth, but its gaseous nature under normal circumstances makes its capture and storage difficult. Methane gas is a colorless, highly combustible substance that, when combined with air, can explode.

Methanogenesis, the mechanism that produces methane, takes place in anaerobic conditions where organic matter is undergoing decomposition. Rice is often grown in a saturated environment, which generates an anoxic environment and encourages the strictly anaerobic methanogenic bacteria to produce methane. Methanogens use organic compounds as electron donors for energy and the synthesis of cellular constituents.

Numerous chemical, radiative, and dynamical processes govern the Earth's climate. In this context, the interaction between chemistry and climate in the bottom 100 km is crucial (e.g. [SPARC, 2010]).



Monthly methane concentrations (small circles) since 1983, with the running average as a solid line. Image via NOAA/Climate.gov.

Figure 1: Change in methane level since 1983(Rebecca Lindsey, NOAA et al., 2017)

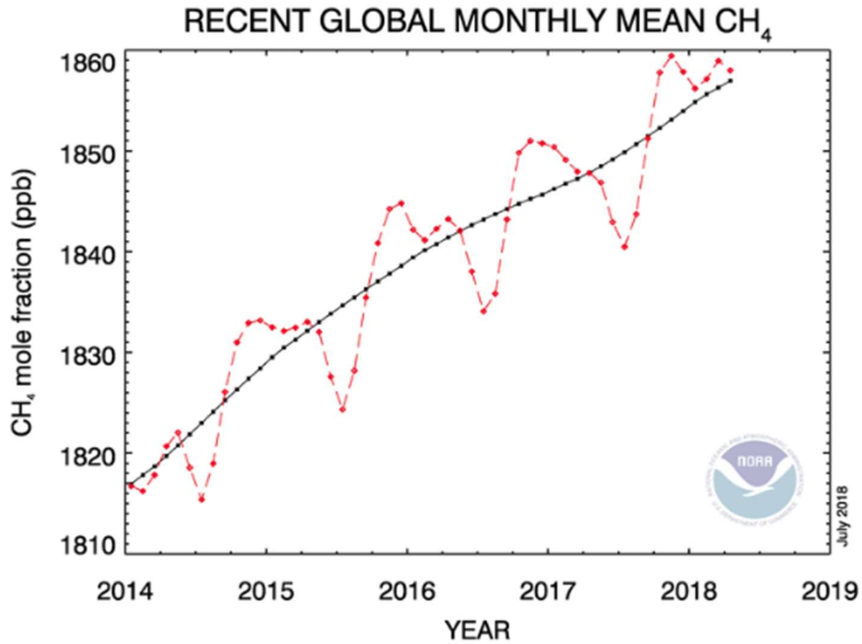


Figure 2: Trends in global methane since 2014 (NOAA et al., 2019).

The NOAA report states that the aforementioned two numbers increased until 2000, when the average global concentration stabilised at 1,750 parts per billion (ppb). The rise in air levels that started in 2007 is still going strong today. "Stabilization" refers to the period from 2000 to 2007, and "renewed growth" refers to the increase from 2007 to the current level. Conflicting theories have been offered for both stabilisation and fresh growth. As many of these assessments have seen the time of renewed rise as unusual, it is argued that current stability may be a new steady state for atmospheric methane.

It is currently at a level of above 1870 ppbv. One of the key elements in determining the changes in the region's radiative balance is atmospheric methane. Monitoring atmospheric methane is therefore important for determining climate change. It is possible to find natural methane underwater and in the ocean. When it reaches the surface and atmosphere, it is referred to as atmospheric methane (Khalil et al., 1999). Because of industrialisation and modifications in agricultural practises since 1750, the amount of methane in the atmosphere has increased by around 150%. It makes up 20% of all long-lived and globally mixed greenhouse gases' combined radiative forcing (NOAA et al., 2017).

DATA and METHODS

SCIAMACHY-

In the current study, data were recovered utilising measurements of CH_4 in the Near Infrared channel 6 (1631-1671 nm) and Weighted Function Modified-Differential Optical Absorption Spectroscopy (WFM-DOAS v2.0.2) approach (Buchwitz et al., 2006). The computer algorithm finds that XCH_4

$$XCH_4 = (VCH_4/VCO_2) \times CO_2\ mf$$

The absolute column's extracted CH_4 and CO_2 from SCIAMACHY are designated as VCH_4 and VCO_2 (measured in molecules/cm2). The assimilated CO_2 column-averaged mixing ratio of the carbon tracker is denoted by CO_2 mf (peters et al., 2007). The simultaneously obtained CO_2 is employed as a stand-in for the air column, assuming a constant mixing ratio. The measurement's relative accuracy decreased from its initial value of around 1.7% to 4% after November 2005. (2012) Schneising et al. In this study, the XCH_4 for the Indian region (0°-40° N and 60°-100° E) for each month from 2003 to 2009 is taken from the worldwide data collection. The spatial resolution of the data is 0.5° 0.5°.

GOSAT-

For GOSAT CH_4 recovery, they used the CO_2 proxy approach [Frankenberg et al., 2011]. Although less so than CH_4, CO_2 has a history of varying in the atmosphere. We can use the CO_2 absorption band, which is spectrally close to that of CH_4, to eliminate common spectrum artefacts brought on by aerosol scattering and instrumental effects [Butz et al., 2010]. Retrievals of CH_4 and CO_2 are carried out sequentially on channels that measure 1.65 mm and 1.61 mm, respectively. The volume mixing ratio (VMR) of CH_4 must be calculated by multiplying the XCH_4/XCO_2 ratio by a model XCO_2. The XCH_4 obtained for the Indian region (0°-40° N and 60°-100° E) for each month between 2009 and 2015 is used in this investigation. We developed spatial plots using these datasets and looked for regional and seasonal patterns.

RESULTS & DISCUSSIONS

Atmospheric methane is one of the critical constituents in determining the Changes in the radiative balance of the region. Therefore, monitoring Atmospheric Methane is significant in tracking climate change through many different activities.

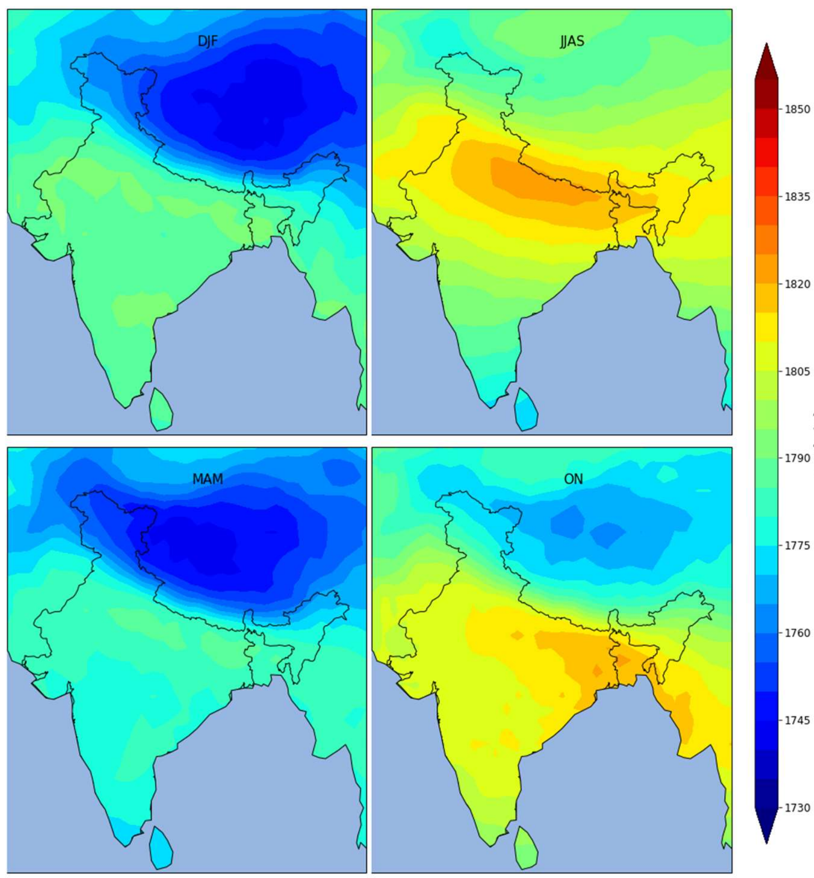


Figure 3: The Seasonal average methane concentration over India, as analyzed from SCIAMACHY data for the period 2003-2012

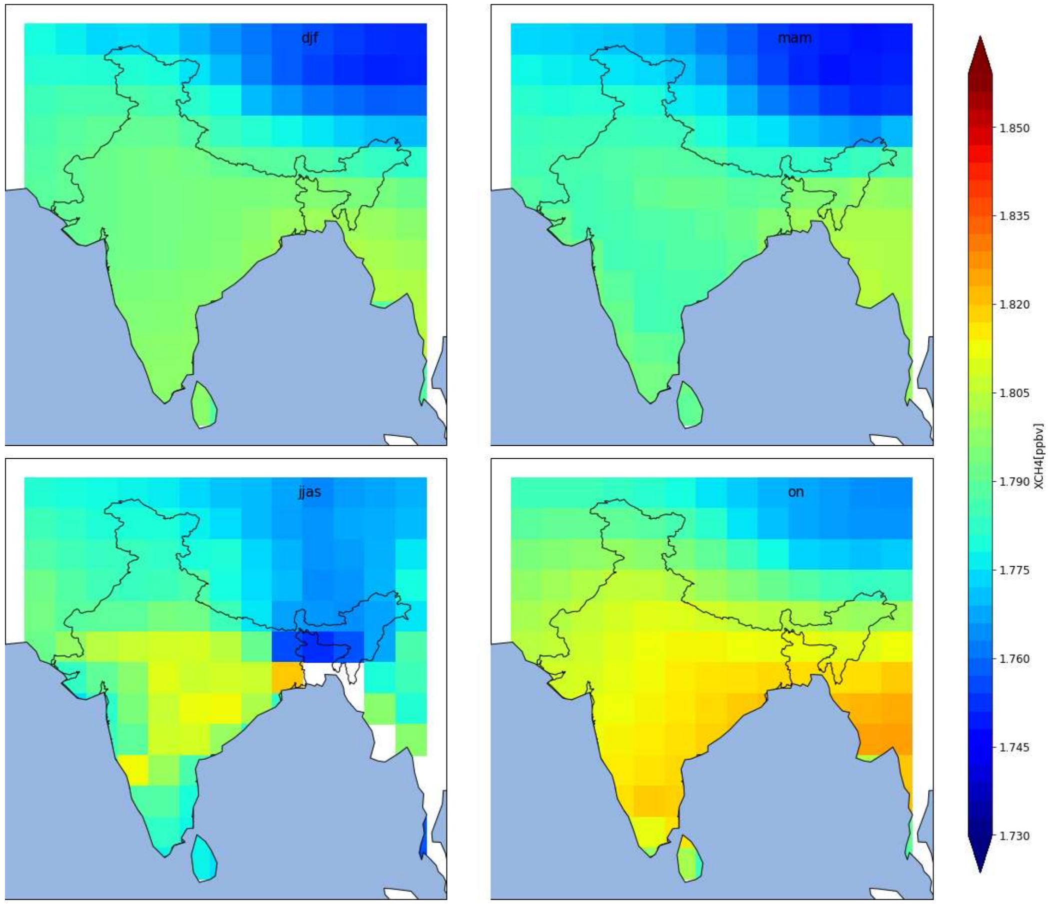


Figure 4: The Seasonal average methane concentration over India, as analyzed from GOSAT data for the period 2009-2015

According to data from SCIAMACHY and GOSAT, the aforementioned statistics represent India's seasonal average methane graph. According to the aforementioned figures, emission is primarily dispersed throughout India. The Indo Gangetic Plain, the Northeast, and the coastal region of Andhra Pradesh, Orissa, and West Bengal are still the key hotspot zones. The large animal population, increased rice farming, and deep water rice, which releases more methane than ordinary rice production, are the main causes. It is predominantly grown in the coastal regions and the Brahmaputra valley. Wetlands, factories, and coal mining all contribute significantly to the atmosphere's methane emissions, which cannot be ignored. Biogenic emissions, primarily from agriculture and waste management, are increasing due to the rapid growth in methane concentrations in both India and the world. The chart shows that, during the kharif season, higher methane concentrations were found in Uttar Pradesh, West Bengal, and Odisha than in Maharashtra, Karnataka, and the Himalayan wooded region (Jammu and Kashmir). Due to the planting of rice during the northeast monsoon season, Tamil Nadu's concentration throughout the winter season was higher than the Indian average.

June/July, the starting point, and August/September, a significant hotspot of methane release, are when variations over India begin. SPU & SPL are higher than usual during October/November, while they are lower during the monsoon season. It is believed that the seasonality in destruction is more significant than the seasonality of methane source strengths in determining seasonal atmospheric methane levels because the rate of destruction of atmospheric methane by the hydroxyl radical is substantially lower in winter than in summer (Khalil et al., 1993). In the Himalayan region, when ice forms over the land surface, it has a higher methane retention capacity and stores more methane than it did previously. Ice contributes to the wintertime near-surface methane buildup beneath the ice. Methane stocks at depth (25 to 75 cm) were lowest in the middle of the summer and highest in the early winter (Khalil et al., 1993).

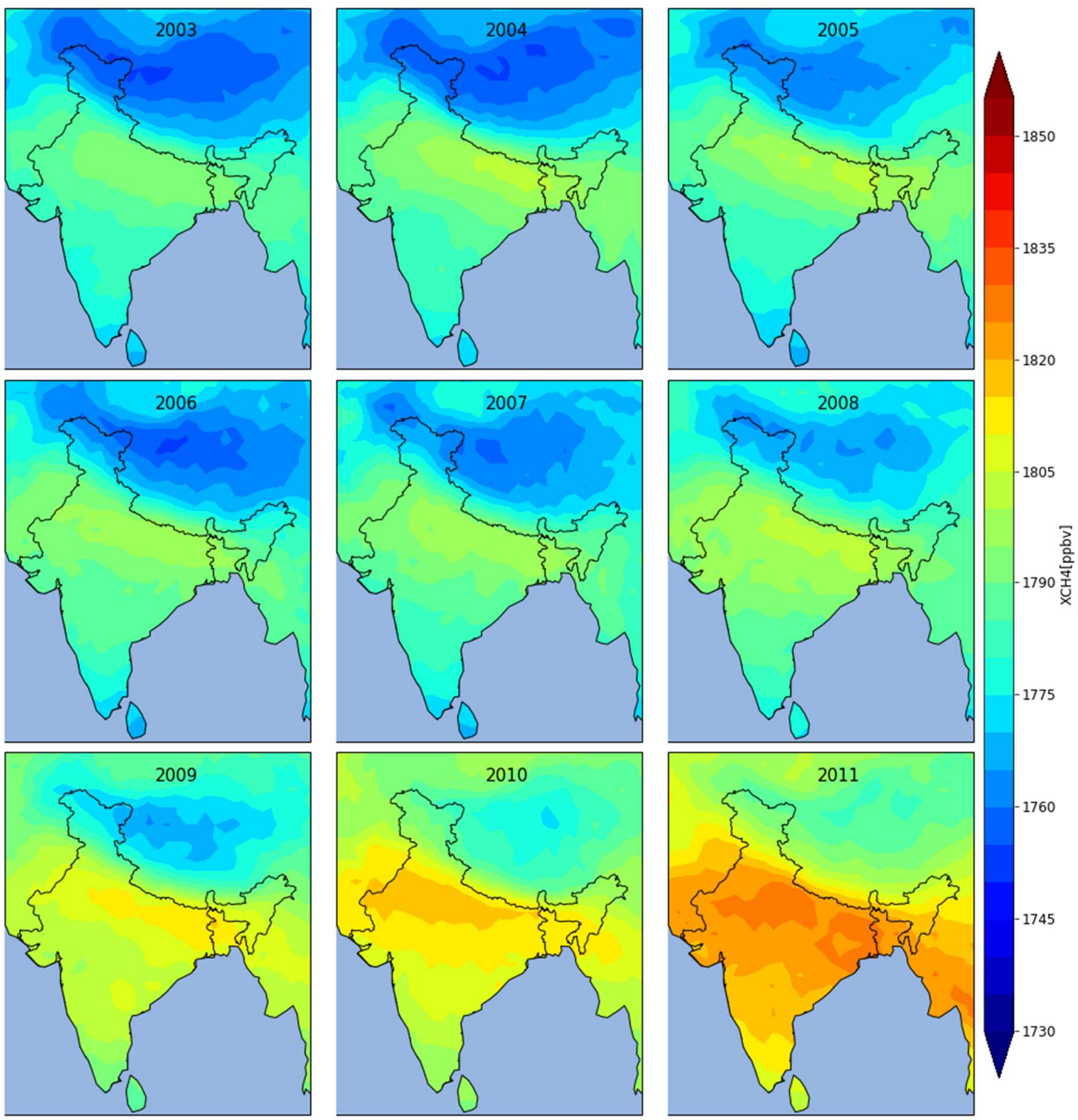


Figure 5: The inter-annual average methane concentration over India, as analyzed from SCIAMACHY data for the period 2003-2012.

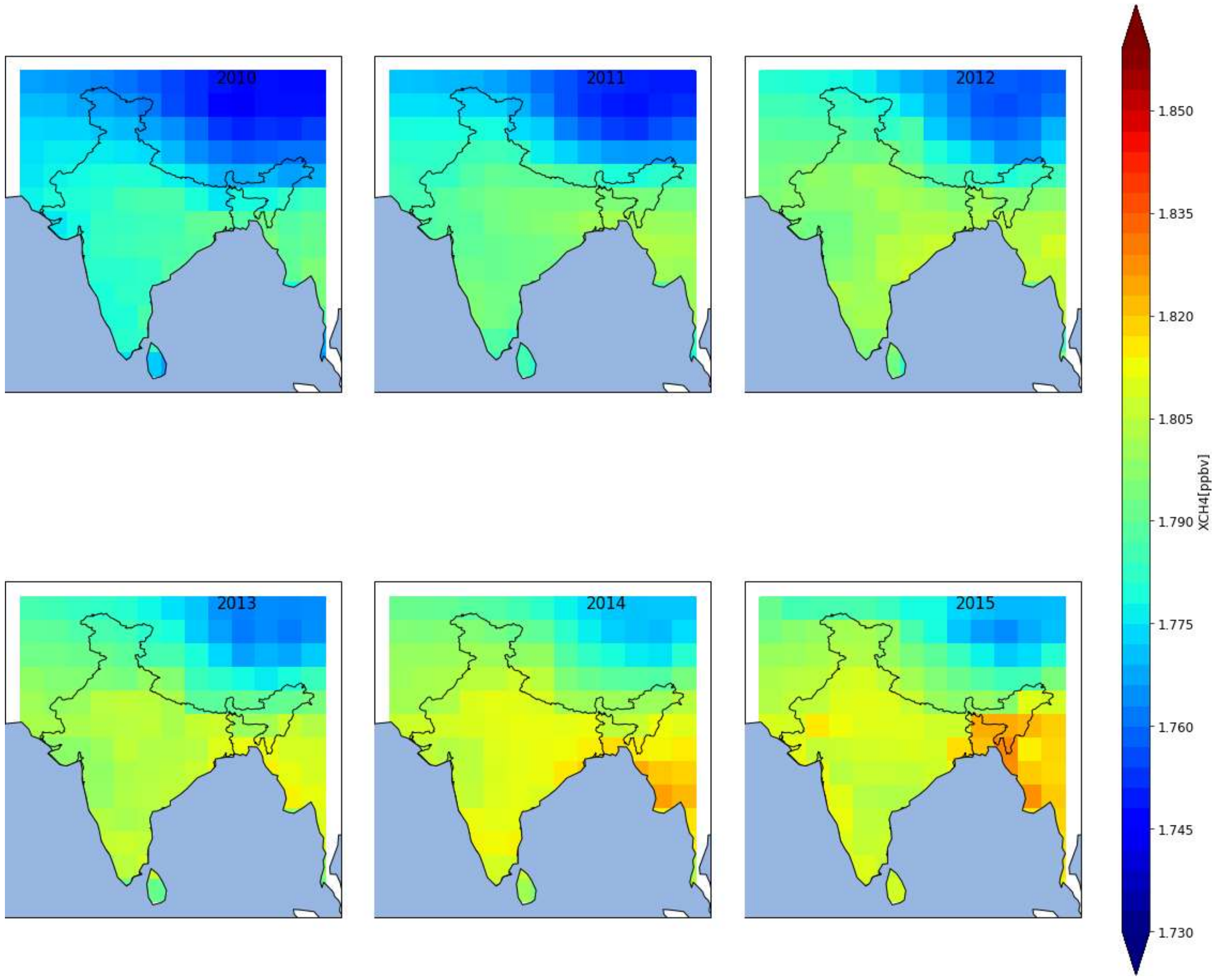


Figure 6: The inter-annual average methane concentration over India, as analyzed from GOSAT data for the period 2009-2015.

Methane levels climbed gradually between 2000 and 2007 according to the analysis of the aforementioned inter-annual methane concentration graphs. But starting in 2008, atmospheric levels started rising once more, and they are still rising now. The surge from 2008 to the present is referred to as "renewed growth," and the period from 2000 to 2008 is known as the "stabilisation." Additionally, methane levels rose quickly in certain regions of India between 2010 and 2015. The two main regions where the methane hotspot may be seen are the Northeast and the Indo-Gangetic Plain region.

61% of the methane emissions in this area are caused by agricultural activities. During this time, the column density of methane ranges between 1740 and 1890 ppb, and this variation is influenced by wetland emissions and the burning of biomass. Less than 2% of national emissions are made up by wetland areas and termites. Additionally, the permitted flooding of the rice field reduced the annual emission of methane to 0.12–0.13 Tg while the continuous flooding of the rice produced net annual emissions of 1.07–1.10 Tg.

In 2010, agriculture was responsible for 50 billion tonnes of CO_2 equivalent in GH emissions. In 2018, there were 1.002 billion head of cattle in the world. In 2018, India, Brazil, and China all had the highest inventories of cattle worldwide. About 63% of the cattle on earth are in India, Brazil, and China (Rob Cook et al., 2019).

Methane is released into the atmosphere as a result of coal mining, oil and natural gas transportation, and storage, as well as venting and flaring of coal. Methane is transported and redistributed over the south Asian monsoon zone primarily through convection and advection. Methane emissions into the atmosphere are also a result of this. The likelihood of severe, abrupt, and irreversible impacts on people and ecosystems will increase as greenhouse gas emissions continue to rise and produce long-lasting changes in all aspects of the climate system. For natural and human systems, climate change will amplify already present dangers and generate new ones. Climate change risks can be reduced and managed through a combination of adaptation and mitigation techniques. The rate of sea level rise will vary depending on the region. More than 95% of the ocean area would likely experience sea level rise by the end of this century, according to predictions. It is predicted that sea levels will rise by about 30% relative to the global average along about 70% of the world's coastlines (Indian Govt. report, 2015).

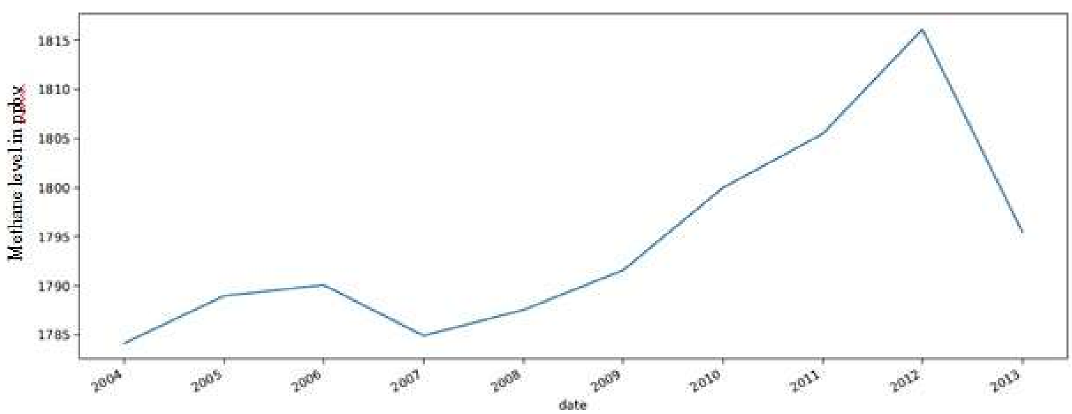


Figure 7- Methane Annual Average trend over Indian Gangetic Plain region as per SCIAMACHY data 2003-2012.

Methane over the Indian subcontinent varied regionally between 1740 and 1840 ppbv between 2003 and 2009, according to the SCIAMACHY research, with notable regional variances. The Northern / IGP regions recorded the greatest methane values throughout the monsoon and post-monsoon seasons (1770-1850 ppbv). There are both biological and non-biological sources of methane in the atmosphere. Livestock, rice farming, and wetlands are the main biogenic sources, whereas burning biomass and extracting fossil fuels are non-biogenic sources. Only burning biomass, wetland emissions, and agricultural activity are influenced by the seasons. Over the course of a year, emissions from other sources remain more or less constant; the majority of Indian emissions come from anthropogenic sources. In wetlands, termites make up a very minor portion—less than 2% of national emissions—and are most certainly a major factor in the recent, sharp increase in the amounts of methane in the atmosphere both globally and in India.

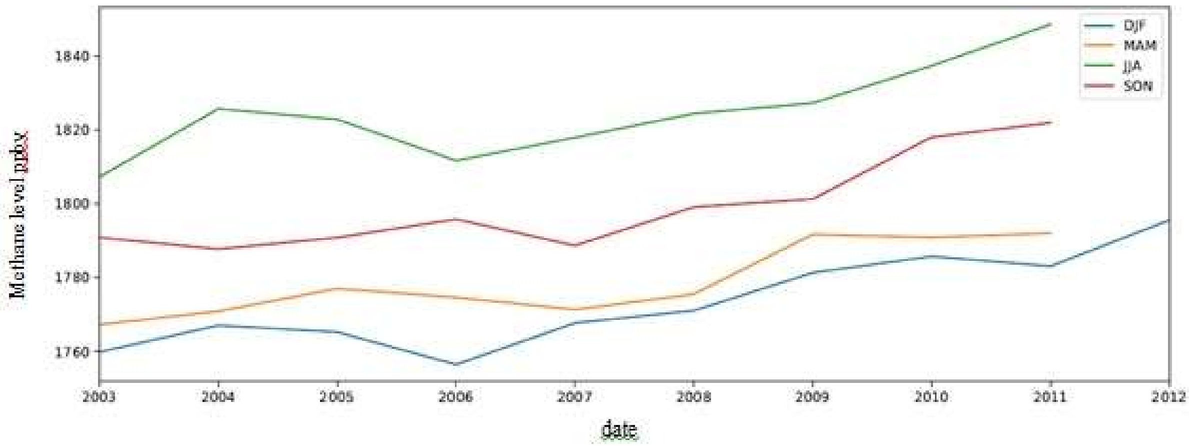


Figure 8- Methane Seasonal Average trend over Indian Gangetic Plain region as per SCIAMACHY data 2003-2012.

The graph up above demonstrates that summertime is when methane concentrations are at their highest. In India, there are two seasons for agricultural activity: Kharif (May to October) and Rabi (November to April) (November to April). Methane emissions peak during the wet season, from June to September, when the majority of rice is cultivated. The greatest Methane emission from the vegetative stage of rice production during Kharif is the likely cause of the high value of Methane over IGP during monsoon. Agricultural practises determine the seasonal variance of methane over the Indian region (100 ppbv). Additionally significant contributors to emissions across the IGP and CI regions include wetlands and biomass fires. Maximum biomass burning is seen in the IGP region in terms of fire count.

Based on statistics from the livestock population in 2012, it is projected that India's yearly emissions of methane from livestock total 15.3Tg CH_4. The estimated amounts of methane emissions from enteric fermentation and manure management are 14.20 Tg and 1.16 Tg, respectively. More than 90% of emissions are a result of intestinal fermentation, according to analysis. The largest CH_4 emission is recorded in Uttar Pradesh (2746 Gg yr-1), followed by Rajasthan (1528 Gg yr-1), and Madhya Pradesh among the 28 states and 7 Union Territories (UTs) (1310 Gg yr-1). Figure shows that the annual livestock CH_4 emissions in Uttar Pradesh, Rajasthan, Madhya Pradesh, Gujarat, Andhra Pradesh, and Bihar are larger than 1000 Gg. The two main emission regions of India are the western and Indo-Gangetic plains. In contrast, all eight of the northeastern states' contributions to CH_4 emissions are lower than those from other regions of the nation (Shilpi et al., 2018).

Seasonal changes

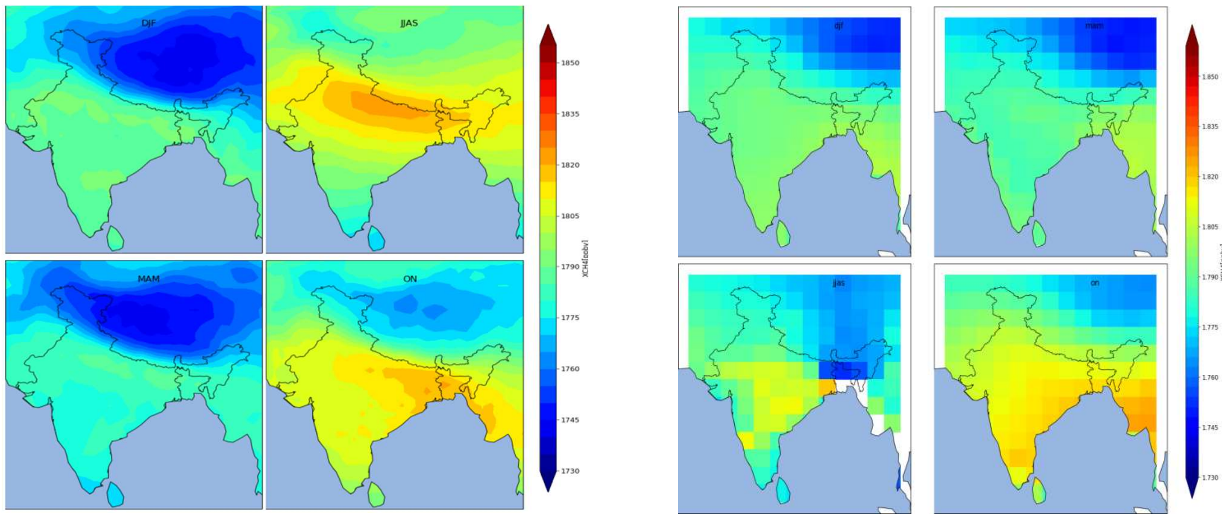


Figure 9: The Seasonal average methane concentration over India, as analyzed from SCIAMACHY data (2003-2011) and GOSAT data (2009-2015).

According to data from GOSAT and SCIAMACHY, the figures above represent the seasonal average methane graph for India. The graph above demonstrates how emissions are primarily dispersed throughout India. The Indo Gangetic Plain, the Northeast, and the coastal region of Andhra Pradesh, Orissa, and West Bengal are still the key hotspot zones. The large livestock population, increased rice farming, and deep water rice, which releases more methane than regular rice farming, are the main causes. It is predominantly grown in the coastal regions and the Brahmaputra valley. Wetlands, businesses, and coal mining are additional sources of fresh water that contribute methane to the atmosphere. Methane concentrations have recently increased rapidly in both India and the world atmosphere, increasing biogenic emissions, primarily from waste management and agriculture. When compared to Maharashtra, Karnataka, and the Himalayan forested region, Uttar Pradesh, West Bengal, and Odisha had greater methane concentrations during the Kharif season (Jammu and Kashmir). Due mostly to the production of rice during the northeast monsoon season, it can be seen that the Tamil Nadu region exhibits higher emission concentration levels during the winter than the Indian average concentration. June/July is when variations over India begin, and August/September is when they reach their peak in terms of methane emission. SPU & SPL are higher than usual during October/November, while they are lower during the monsoon season.

It is believed that the seasonality in destruction is more significant than the seasonality of methane source strengths in determining seasonal atmospheric methane levels because the rate of destruction of atmospheric methane by the hydroxyl radical is substantially lower in winter than in summer (Khalil et al., 1993). In the Himalayan region, the ice forms over the land surface, where it has a higher methane retention capacity and accumulates more methane than in the earlier stage. Ice contributes to the wintertime near-surface methane buildup beneath the ice. Methane stocks at depth (25 to 75 cm) were lowest in the middle of the summer and highest in the early winter (Khalil et al., 1993).

CONCLUSIONS

The agriculture sector is a source of greenhouse gas emissions, accounting for 18% of India's emissions in 2010, according to official data of the Indian government submitted to the United Framework Convention on Climate Change (UNFCCC). India produces 20% of the world's rice and has the greatest number of cattle. The study also found that methane emissions rose from June to September, then again from February to March, which is consistent with the timing of rice cultivation and the need for winter heating. Nearly half of methane emissions are caused by human activity, which accounts for more than 60% of all emissions.

Methane throughout the Indian subcontinent varied spatially and temporally between 1740 and 1890 ppbv between 2003 and 2009 (PR. Nair, 2015), with notable regional variations. Over the Indo-Gangetic plains, Thar Desert, and Central India, the monsoon and post-monsoon seasons saw the highest methane levels. With seasonal peaks in late October to early December and low values during the monsoon, southern peninsular regions have clearly unique seasonal behaviour (PR. Nair, 2015). The distribution of sources such as cattle population (with the highest correlation coefficient), rice farming, wetland, biomass burning, and oil and gas mining are all closely related to these geographical differences in methane levels. Methane oscillations in the boundary layer exhibit a stronger association with sources. Based on NDVI data, it was discovered that agricultural activities, particularly rice farming, are responsible for the seasonal change of methane over the Indian region (100 ppbv) (Kavitha & P R Nair, 2016). In the IGP and CI regions, emissions from wetlands and biomass burning are significant factors. Methane over India is predicted to have increased from 1795 1.4 ppbv between 2003 and 2015, excluding the seasonal increase. The findings showed that top-down inversions have projected worldwide methane emissions for the 2003–2015 decade at 558 million tonnes annually. About 60% of all global emissions are attributable to human activity. Methane levels over Thar are equivalent to those over IGP and CI, despite sources and emission inventory data showing low levels. Despite active sources, methane levels are low at SPL. Methane is reduced by the unusual weather patterns, heavy rainfall, and elevated water vapour content over the area. There are a few steps that can be performed to lower the nation's methane emissions.

Methane emissions can be decreased by employing better livestock rearing techniques, such as using the right feed types and raising animal production (Shilpi kumari, 2018). Methane levels may be decreased by reducing environmental risk through increased animal productivity, population stabilisation, and better feed and manure utilisation. Reduced red meat consumption will result in fewer cows, which will cut methane emissions (Erik, 2011).

Anaerobic "digesters" at farms with digesters use microorganisms to break down animal manure in a sizable container. Instead of releasing the generated biogas into the atmosphere, it can be collected and used to generate "free" electricity (Erik, 2011). Livestock can generate a significant amount of methane over the course of their natural digestion. Some feed additives can prevent the bacteria in the rumen from producing methane, which in turn lowers methane emissions (Rob Sudmeyer, 2018). Synthetic chemicals, natural supplements, other substances including tannins and seaweed, as well as fats and oils, can be used as methane-reducing feed additives and supplements. Landfills for municipal solid waste rank third in terms of anthropogenic methane emissions. Instead of letting these emissions escape into the atmosphere, it is possible to capture the carbon or methane they contain and utilise them as a source of clean energy (USA Gov., 2014). Methane from coal mines can be an important, reliable, and clean-burning energy source after safe recovery. Since unchecked methane emissions can result in fires and explosions, improving mine safety is one of the primary side advantages of reducing methane emissions from coal mines (USA Gov., 2014). Even though the garbage sector in India only contributes about 3% of all GHG emissions, this quantity can be significantly decreased. Based on analysis and modelling estimates, it can be concluded that further capturing and using methane, diverting wastewater from residential and commercial areas to the sewer, and diverting organic waste from landfills towards treatment options are some alternatives that can help reduce the peak of GHGs by 11.19% in 2021 and 29.89% in 2031. Through wastewater treatment units, industries like pulp and paper, beer, sugar, and dairy can trap methane and cut GHG emissions by a significant amount (Saurabh et al., 2018).

Over the Indian subcontinent, we conducted a thorough biassed analysis of two satellite-based sensors, SCIAMACHY and GOSAT-FTS. Numerous research are available for certain years, however the majority of them have a short time span. In order to assess the long-term series analysis in India, we have tried.

The analysis demonstrates that methane measurements were made accurately and produced a significant, satisfactory result. Methane levels are rising rapidly all across the world, but especially in Southeast Asia. These studies are crucial because global warming is becoming worse and methane is a key gas that needs to be decreased because it has a greater capacity to warm the planet than carbon dioxide. After 2010, there has been a sharp increase in methane content across the Indo Gangetic plain, Northeast India, and some coastal locations. The location of the land and the seasons have an impact on the methane emission. The main biogenic sources include livestock, rice farming, and wetlands, whereas non-biogenic sources include fossil fuel mining and biomass burning. Additionally, it has been noted that India's Eastern and Indo-Gangetic plains include the majority of its emission states. All eight of the northeastern states collectively provide fewer methane emissions than other regions of the nation. As a result, this study provides some important data for estimating methane levels in the Indian region in the future.

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