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Analysis of seasonal variability of methane over global land area

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Abstract: In this study, we determine the global emission concentration of methane using SCIAMACHY data. We analyzed land and sea area to investigate the nine-year changes in methane concentrations from 2003 to 2011. Moreover, by subtracting the concentration of methane from land and sea, we can found the methane emission concentration of land. As a result, it is cleared that a big amount of CH4 emission concentration was found not only in the Northern Hemisphere paddy fields but also in the Southern Hemisphere broadleaf evergreen areas (Central Africa and South America). And we also found that the global land CH4 growth rate is 3-5ppb/year during 9 years.

Keywords: CH4, emission concentration, Greenhouse gases, SCIMACHY, Sources, NDVI.

1 INTRODUCTION

A greenhouse gas is a gas in atmosphere that absorbs and emits radiation within the thermal infrared range. This process is the original cause of the greenhouse effect. The primary greenhouse gases in the Earth's atmosphere are water vapor, carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), and ozone (O3). Which from four of the principal greenhouses gases are human activities results (CO2, CH4, N2O, and the halocarbons). These gases increase concentrations of the long-lived greenhouse gases (LLGHGs). Greenhouse gases affect the temperature of the Earth. Since the beginning of the Industrial Revolution, the burning of fossil fuels have contributed to the increase in carbon dioxide in the atmosphere from 280ppm to 390ppm, despite the uptake of a large portion of the emissions through various natural "sinks" involved in the carbon cycle. In the past few years, many workers have noted that the combined effect on climate of the increase in the concentrations of a large number of trace gases could rival or even exceed the increasing concentration of carbon dioxide. Atmospheric CH4 is the second most important anthropogenic greenhouse gas after CO2. CH4's mixing ratio has increased by a factor of 2.5 compared to preindustrial levels and reached almost 1,800 ppb today. The direct radiative forcing of anthropogenic CH4 is 0.48W/m2 that is almost one third that of anthropogenic CO2 (1.66W/m2) [1][2]. CH4 emissions are separated into anthropogenic and natural sources. According to Lelieveld et al. (1998) and IPCC (2001), natural sources amount is only one-third of the total CH4 emission budget, which the most important natural source is wetland. Anthropogenic sources account for the other two-thirds of the total CH4 emission budget, with the most important being energy consumption (coal mining and combustion, oil- and gas-related emissions), domestic ruminants and waste treatment, rice paddies, biomass burning, landfills and waste water. A study from Nisbet et al. (2009) suggests that the emission of methane from plants under normal conditions is due to the transport of water containing dissolved methane from the soil to the atmosphere through transpiration. Transpiration could help to explain the satellite-observed methane enhancement over the tropical regions of South America and some of the published ground-based measurements (Carmo 2005, Miller 2007). Recent studies have proposed that there is an additional significant CH4 source that could radically impact the current CH4 budget estimates. Keppler et al. (2006) suggested that living plants with CH4 emissions (aerobic) 10–40% of the total annual source, may be a major CH4 source on a global scale. Wang et al (2008) have confirmed that some plant species emit methane under aerobic condition in the Inner Mongolia steppe. After a decade of near stable concentrations, the growth rate of atmospheric methane has started to increase again.

Recently SCIAMACHY (launch 2002) and GOSAT (launch 2009) enabled precise measurements of atmospheric CH4 from space. Unfortunately the global source strength of CH4 remains uncertain. In this study, we will focus on CH4 sources of global area using these satellite data, vegetation map and MODIS NDVI to investigate the characteristics of this CH4 sources

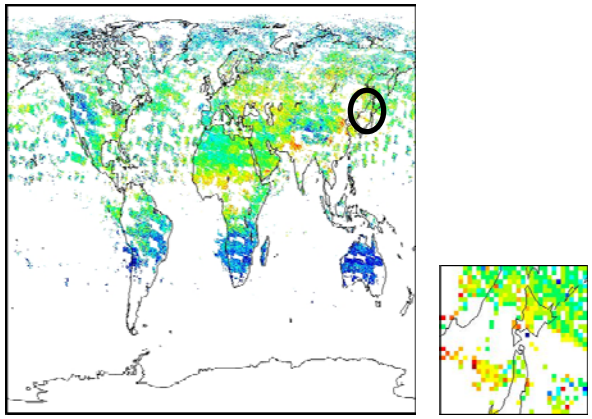
2 DATA

The World Data Centre for Greenhouse Gases (WDCGG) is one of the WDCs under the Global Atmosphere Watch (GAW) program. It serves to gather, archive and provide data on greenhouse gases (CO2, CH4, CFCs, N2O, surface ozone, etc.) and related gases (CO, NOx, SO2, VOC, etc.) in the atmosphere and ocean, as observed under GAW and other programs. Vegetation Index (VI) have trended to estimate a large number of vegetation properties such as LAI, biomass, chlorophyll concentration in leaves. The enhanced vegetation index(EVI) is an `optimized` index designed to enhance the vegetation signal with improved sensitivity in high biomass region and improved vegetation monitoring and reduction in atmosphere influences. Global Land Cover by National Mapping Organization (GLCNMO) has twenty land cover classes using 16-day composite MODIS data of 2003.The SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY (SCIAMACHY) instrument (Burrows 1995) is a part of the atmospheric chemistry payload of the European Space Agencies (ESA) environmental satellite ENVISAT, launched in March 2002. SCIAMACHY is the first satellite instrument that measures near-infrared spectra in the 1–2.4μm spectral range from space at high spectral resolution. The SCIAMACHY near-infrared spectra contain atmospherically interesting molecules such as CH4, CO2, CO, and H2O, of which the bulk resides in the troposphere. Retrieval algorithms applied to this wavelength range include the Iterative Maximum A Posteriori-DOAS (IMAP-DOAS) algorithm (Frankerberg 2005). The Greenhouse Gases Observing Satellite (GOSAT) instrument was launched in January 2009 with the aim of measuring the column amounts of CO2 and CH4. GOSAT has a CO2 target to achieve 4 ppm accuracy for a three month regional average using a combination of short-wavelength infrared (SWIR), and infrared (IR) channels (Kuze 2009).

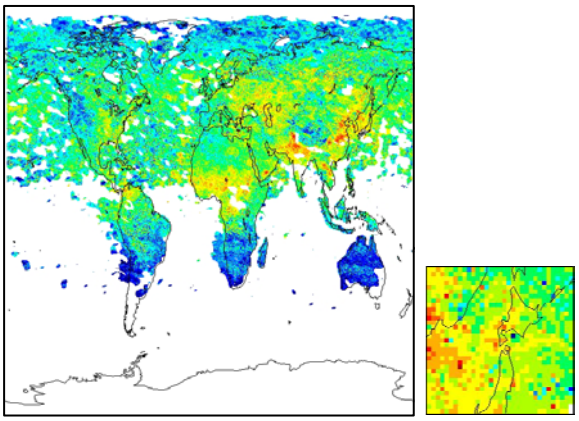
3 ANALYSIS AND RESULT

3.1 Data Process

Frankenberg's method was used to reduce cloud effect from SCIAMACHY data. By using a cloud free pixel data, a 15-day composite data was made to understand the CH4 source and its circulation. In addition, this data was spatially and temporally interpolated. As a result, the data was made up in 24 scenes per year during a period from 2003 to 2011. After removing the clouds, GOSAT data was distributed as a monthly data. Cloud free GOSAT data is valid because of the use of Thermal And Near infrared Sensor for carbon Observation-Cloud and Aerosol Imager (TANSO-CAI). GOSAT can only provide us four years of data, which is not sufficient, so we use it as SCIAMACHY data supplement (Fig. 1).



a) Cloud free image



b) Interpolated image

Fig. 1. Cloud Free and Interpolation CH_4 concentration SCIMACHY

3.2 Change in methane concentration on land

Figure 2 shows the concentration of CH_4 by terrestrial latitude band for nine years. CH_4 concentration in the Northern Hemisphere mid-latitude regions is higher than other regions. It increased approximately by 20ppb from 2003 (1750ppb) until 2011(1780ppb).Mainly in September, the high concentration areas are distributed on the paddy fields of Asia. It shows that in the rice harvest period, CH_4 concentration raised up to 1780ppb max. CH_4 concentration in the high latitudes of the north hemisphere is 1680ppb, near the equator is 1740ppb and in the south hemisphere is lower than 1670ppb. After 2007 every year, from January to February, it becomes clear that the CH_4 concentration was

increasing near the equator. There were no concentration changes of CH_4 from 2003 to 2006 but from 2007 to 2011 we understand that it was increasing.

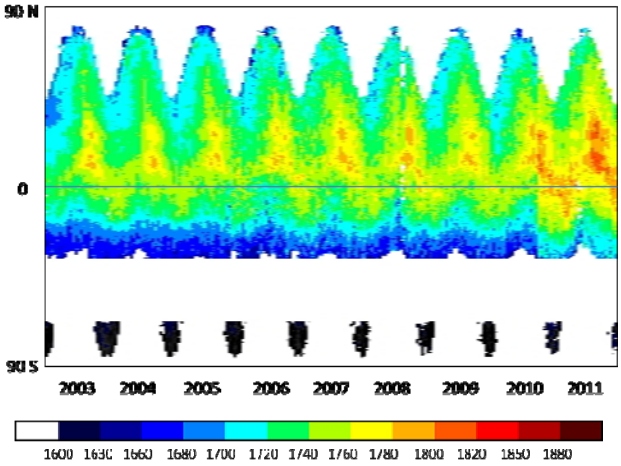


Fig. 2. Land methane concentration in time series from 2003 to 2011

3.3 CH4 emission concentration

CH4 emission concentration is defined as the emission of land CH4 concentration. Time series changes in the CH4 concentration of land can be relatively compared. it is difficult to compare the CH4 emission concentration because of the different background concentration of CH4. Therefore, we can assume that a very small amount of CH4 is emitted from the sea surface, that CH4 concentration of the sea is used as a same latitude background. The difference of CH4 concentration between land and sea is equal to the CH4 emission concentration of land at the same latitude (Fig. 3). As a result, it is cleared that a big emission concentration of CH4 was found not only in the Northern Hemisphere paddy fields but also in the Southern Hemisphere broadleaf evergreen areas (Central Africa and South America)(Fig. 4).

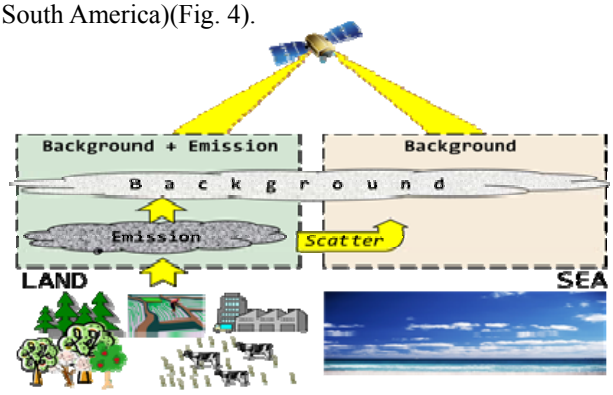
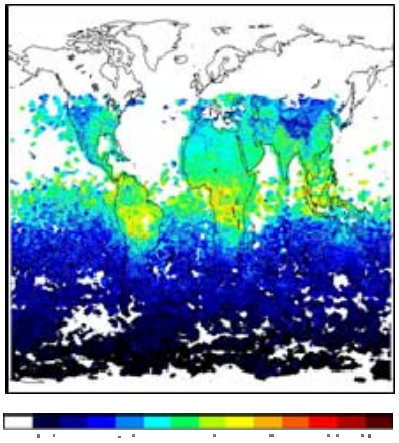
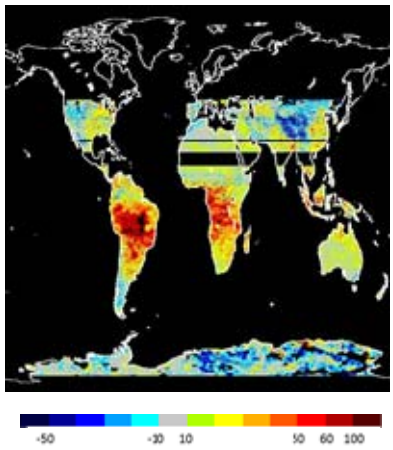


Fig. 3. CH_4 emission concentration



a) CH4 concentration

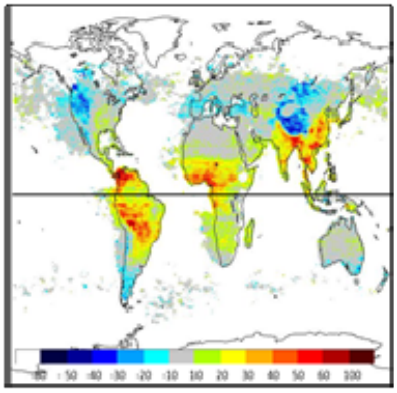


b) CH4 emission concentration

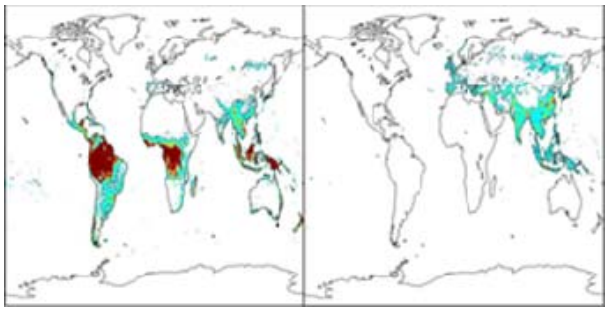
Fig. 4. CH4 concentration (a) and CH_4 emission concentration (b) in January 2004

3.4 Relation between CH4 emission concentration ar ea and Landcover type

We understood that CH4 emission concentration increased in the Southern Hemisphere from 2007. Figure 6 shows CH4 average emission in 2009 and the vegetation map that was used to determine the geographical features of the CH4 emission concentration areas. From that we understood that there are a lot of broadleaf evergreen areas near the equator of the southern hemisphere, which emits 50-80ppb/year of methane (b). CH4 emission concentration areas of the northern hemisphere are consistent with the distribution of paddy fields which emits 80ppb/year (c). And because of the clouds in Northern hemisphere high latitude areas, we don't dispose of enough data to extract information about CH4 emission concentration on wetland areas.



a) CH_4 average emission concentration



b) Broadleaf Evergreen c) Paddy field

Fig. 5. The comparison of the CH_4 emission concentration and Land Cover Type by MODIS

3.5 The growth rate of CH4 concentration

We investigated the CH4 concentration's growth rate during 9 years of its data that reduces a seasonal change effect. As a result, in almost of land, there was a trend of 3-5 ppb/year, but especially, in Brazil, China and Indonesia we noticed that it increased to more than 6ppb/year (Figure 7). According to the WMO-GAW, the average growth rate is 2.2ppb/year during 10 years until 2009. From 2003 to 2006 there was no CH4 growth, but announced that from 2006 it has been increasing by about 6ppb/year. This means that there is no big difference from our results.

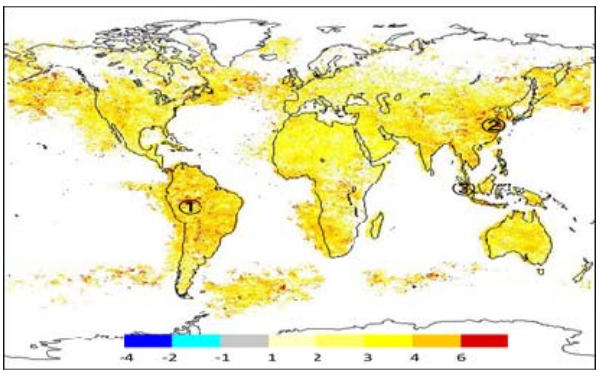


Fig. 6. CH_4 growth rate during 9years

4 CONCLUSION

In this study, we examined separately the changes in methane concentration in land and sea areas using a time series SCIMACHY. Paddy field in Southeast Asia showed the highest among the CH4 concentration areas by 1780ppb. According to the MODIS NDVI comparison, the CH4 concentration increases by the paddy growth. And in the harvest time, the CH4 concentration raises its maximum. Methane concentration in the sea becomes higher gradually during 9 years. It reaches its maximum at the mid-latitude of the northern hemisphere, but becomes lower as it goes to the polar regions. Assuming that CH4 does not emit in the sea, the increase in CH4 concentration of sea areas is caused by the flowing CH4 emitted in land. The difference of land and sea methane concentration is the emission of land CH4 concentration. According to the land CH4 emission concentration, the high CH4 emission concentration areas are not only in paddy fields (80ppb/year) but also broadleaf evergreen areas in South America and Central Africa(50- 80ppb/year).

Finally, we removed the seasonal variation of CH_4 concentration from land during 9 years to investigate the CH_4 growth rate. As a result, in most of land areas, the growth rate of CH_4 concentration is 3-5ppb/year, but in some areas in Brazil, Indonesia and China is more than 6ppb/year. Next, it is necessary to search the cause of this growth rate increasing in these 3 areas.

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