Press Releases

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Methane Emission Level and Trend by Region May Need to be Revised ~New simulations suggest overestimation in East Asia and tropical regions~

A joint research team led by Dr. Prabir K Patra at Department of Environmental Geochemical Cycle Research, the Japan Agency for Marine-Earth Science and Technology (JAMSTEC: Asahiko Taira, President) studied methane (CH_4)[*1] emissions from 53 regions of global land for the period of 2002-2012, using an atmospheric chemistry-transport model (ACTM)[*2] developed by JAMSTEC for simulation of atmospheric CH_4. As a result, it demonstrated that CH_4 emission level has very likely been overestimated in East Asia and tropical regions. It also suggested that CH_4 emission increase in tropics is due to an increase in livestock population. The work was carried out in collaboration with researchers from Center for Global Environmental Research at the National Institute for Environmental Studies (Akimasa Sumi, President).

Methane is the second most prevalent greenhouse gas[*3] after carbon dioxide (CO_2) since it traps heat in the atmosphere by absorbing the Earth's outgoing infrared radiation. While CO_2 resides more than 100 years in the atmosphere after being released, CH_4 stays shorter, only 10 years. On the other hand, CH_4 absorbs heat about 28 times more efficiently than CO_2. It also reacts with other chemical substances in the air, affecting reduction or growth of one another in a coupled manner (as shown in figure 1). Thus an accurate estimation of CH_4 emissions is essential for formulating effective emission mitigation policies to reduce its impact on global climate and environmental changes.

To estimate CH_4 emissions, the research team developed a global inverse modeling system with the JAMSTEC's ACTM, which allows elaborate simulations of CH_4 transport processes and chemical reactions in the air. The simulation results suggest that it is necessary to review factors of CH_4 emission increase in East Asia, which is thought to be coal burning mainly in China. In addition, it would be effective to improve farming practices to reduce CH_4 emissions. These new findings are expected to contribute in formulating better policies for global warming countermeasures by emission control.

This study has been carried out as part of Grant-in-Aid for Scientific Research (A) (Research Number: 22241008), the Environment Research and Technology Development Fund (Research Number: 2-1401) by Ministry of the Environment, and the Japan Society for the Promotion of Science and Arctic Climate Change Research,

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Title: Regional methane emission estimation based on observed atmospheric concentrations (2002–2012)

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*1 Methane (CH_4): Methane, a colorless and odorless gas, is the most abundant hydrocarbon in the Earth's atmosphere. It is the second most prevalent anthropogenically produced greenhouse gas after carbon dioxide (CO_2), having large impacts on global warming. About 20% of the total greenhouse effect is attributed to methane. Methane has large number of sources and sinks in the Earth's environment (figure 1), and its concentration growth rate has varied wildly in the recent decades (figure 2). Since CH_4 also participates actively in air pollution chemistry, reduction of CH_4 emissions offers potential co-benefits for improving Earth's future environment.

*2 Atmospheric Chemistry Transport Model (ACTM): It is an atmospheric chemical transport model (ACTM) based on the CCSR/NIES/FRCGC atmospheric general circulation model (AGCM) developed by JAMSTEC. It is a numerical model to calculate distribution and time evolution of chemical species in the atmosphere using large-scale super computers. It is also used for evaluating impacts of emission control of chemical substances on future atmospheric environment and climate (figure 3).

*3 Greenhouse gas : A gas in atmosphere absorbs infrared radiation emitted from the Earth's surface. By sending it back to the Earth's surface, it traps heat in the atmosphere.

Reference: Concentrations, lifetime and global warming potentials (GWPs) of main greenhouse gases, quoted from Table 8.2 & Table 8A of the IPCC Fifth Assessment Report.
GWP is a measure of heat trapping efficiency by a greenhouse gas in the atmosphere, relative to CO_2 on per molecule basis.

Name	Chemical formula	Concentration in 2005 (ppb)	Lifetime (year)	GWP for 100 years
Carbon Dioxide	CO_2	379,000	-	1

Methane	CH_4	1,774	12.4*	28
Nitrous oxide	N_2O	319	121	265
Freon 11	CCl_3F	0.251	45	4,660
Freon 12	CCl_2F_2	0.538	100	10,200
HCFC-22	$CHCl_2F$	0.169	11.9	1,760
Sulfur hexafluoride	SF_6	0.006	3200	23,500
Methyl chloroform	CH_3CCl_3	0.025	5	160

* In this study, methane lifetime has been estimated to be 10 years (calculated based on atmospheric mass).

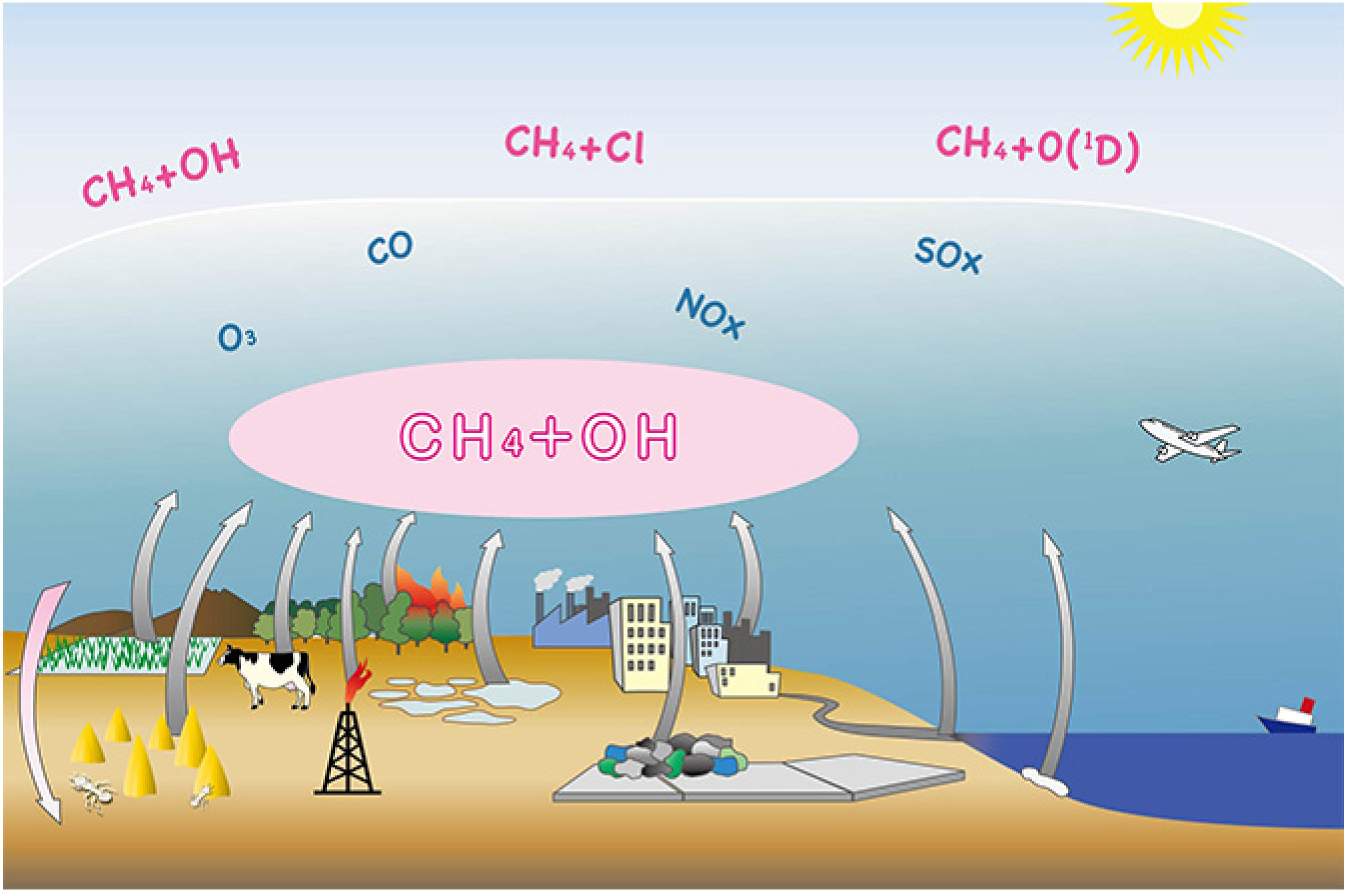

Figure 1: Diagram showing major sources and sinks of CH_4 playing a significant role in the Earth's environment including greenhouse effects, tropospheric air pollutions and stratospheric chemistry. Major emission processes of CH_4 includes fossil fuel burning, industrial activities, ruminants (enteric fermentation), manure and waste management, wetlands, tundra, bogs, peat/forest/savanna burning, termites, hydrates, coastal ocean and fjords, etc. Almost 90% of methane destruction currently occurs in the troposphere due to reactions with hydroxyl radical (OH), and the rest with chlorine (Cl) and excited oxygen atoms ($O(^1D)$) after penetrating to the stratosphere. OH acts also as a removal process of many pollutants in the troposphere with reactions. These chemical substances increase or decrease by affecting one another.

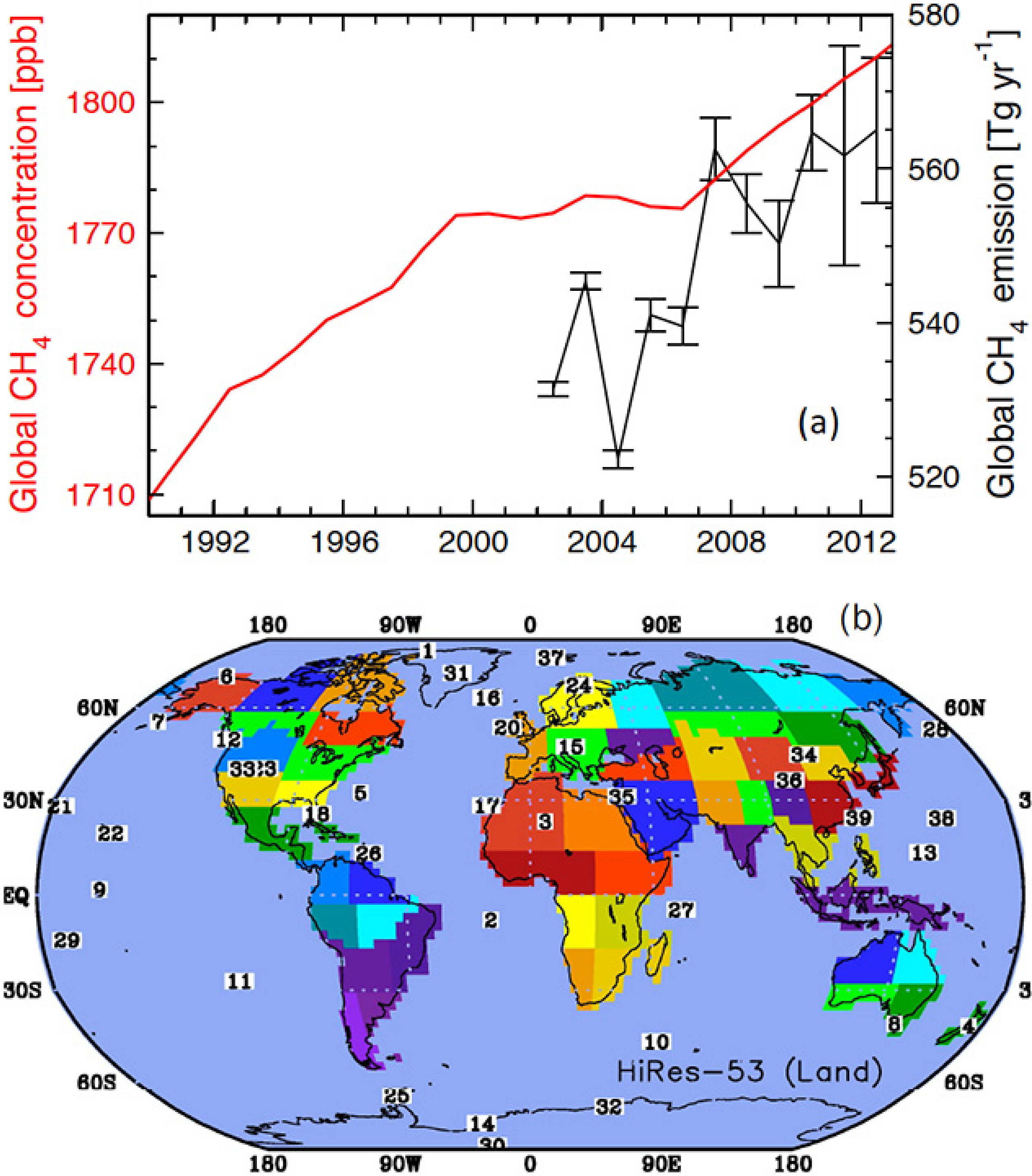

Figure 2: (a) Avearge of CH_4 concentrations during the period of 1990- 2012 (shown by red line) and total CH_4 emissions during the period of 2002-2012(shown by black line), and (b) Locations of 39 measurement sites for atmospheric CH_4 and regional partitions in the inversion model calculation as adopted in this study.

Currently, CH_4 concentrations are measured at more than 100 land-based observation statioins and also using commercial/research aircarft or ship.

In this study, CH_4 measurement sites were chosen from those by the National Oceanic and Atmospheric Administration (NOAA; 37 sites) and Japan Meteorological Agency (JMA; 2 sites) under the condition that they were being away from major CH_4 emission hotspots, and had small numer of missing data during the analysis period (2002-2012).

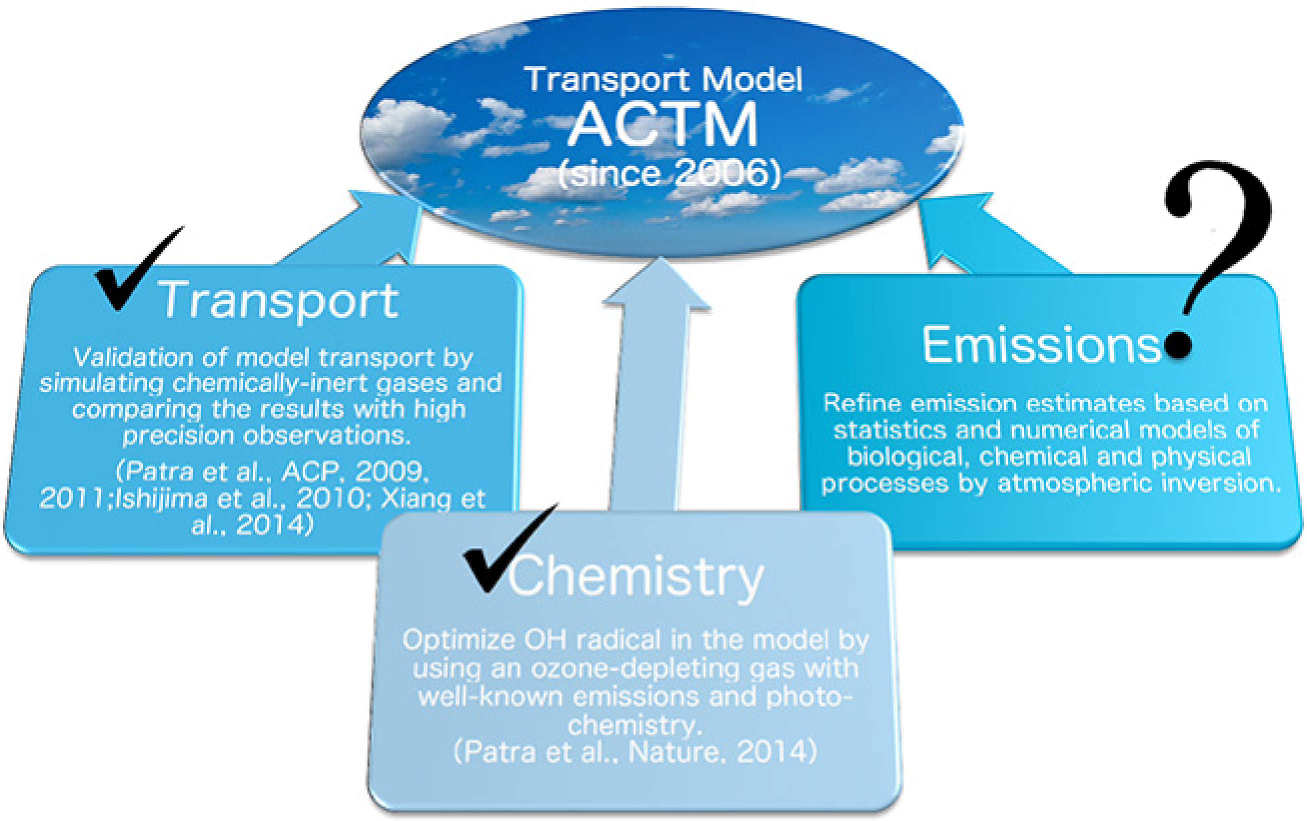

Figure 3: Methane modeling is complicated due to a large number of source/sink processes on the Earth's surface and three main loss mechanisms in the atmosphere.
To successfully simulate variations of metahne concentarions in the atmosphere, it is necessary to incorporate three modeling components into the ACTM; surface emissions, constitutent transport and photo-chemical loss.

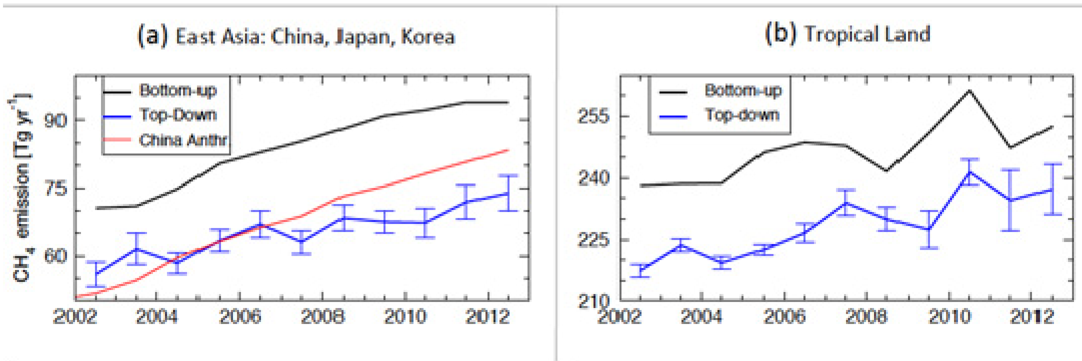

Figure 4: a) Estimated CH_4 emissions in East Asian countries (China, Japan and Korea); and; b) Countries in the Tropical belt during the period of 2002-2012. The black line shows botton-up estimation and the blue line is for top-down calculation methods. The red line in panel a) indicates estimation of anthropogenic CH_4 emissions from China (increase mainly due to the coal sectors). On the other hand, large inter-annual variations in both top-down and bottom-up estimations for tropical land are caused by emissions due to biomass burning and wetlands, which are affected by climate variations, and is under scanner how the emission would evolve under climate change scenarios.

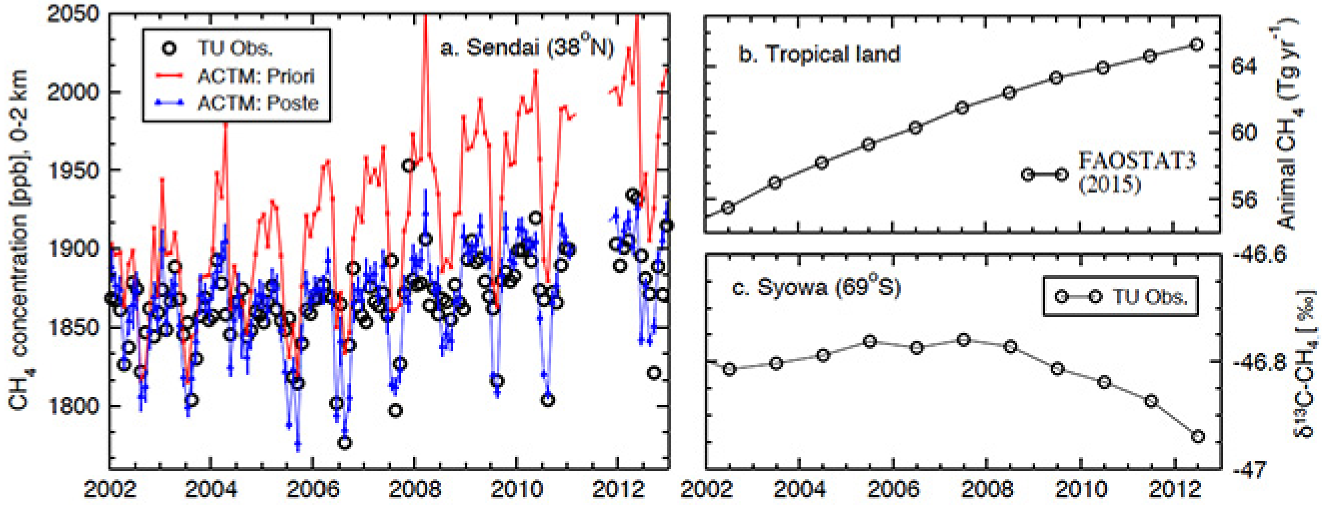

Figure 5: Left) Comparison of CH_4 concentrations over Sendai between an altitude of 0 and 2km using aircraft measurements by Tohoku University (Umezawa et al., 2014) and ACTM simulation using a priori and a posteriori CH_4 emissions. Sendai is located on the leeward side where the signal of CH_4 emission from China is captured. These data, therefore, help validate top-down (posteriori) estimation of CH_4 emissions in East Asia. In fact, it is clear that the ACTM simulation using bottom-up emissions (priori; red line) overestimates CH_4 concentrations observed over Sendai (as shown by the black dots). On the oher hand, simulations using top-down emissions (shown by the blue line) match with the observation data quite closely.
Right) b) Trends in CH_4 emissions from animal enteric fermentation over the tropical land as per the statistics of the Food and Agriculture Organization (FAOSTAT, 2015) of the United Nations; and (c) carbon isotopic ratio of CH_4 as measured at Showa Station in Antarctic coast. Decrease of carbon (^{14}C) isotope ratio of CH_4 is suggested to be a result of CH_4 emission increase from enteric fermentation in ruminant animals.
The FAO mentions that "cows hold the greatest promise for greenhouse gase emission reduction by improving their feeds and feeding techniques."

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