Analysis of atmospheric methane from Siberian tower observation using chemistry transport model

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Atmospheric methane (CH_4) is a strong greenhouse gas and short-lived climate forcer (SLCF), which is present naturally in the Earth's atmosphere, but the amount in the atmosphere has been dramatically increased due to anthropogenic sources especially after industrialization in the 18th century. Such coexistence of both natural and anthropogenic sources at the present make it difficult to quantitatively understand CH_4 cycles on the globe. For example, CH_4 concentration was increasing in 1990s, became stable in 2000s, and began to increase again from 2007, but discussions on what caused the inter-decadal variations remain intriguing. On the other hand, it is well known that wetlands are the largest natural source of CH_4. Wetlands in Arctic regions have been recently receiving remarkable attention, because high-latitude regions are more sensitive to global warming than low-latitudes, possibly enhancing CH_4 emissions there. West Siberian wetlands alone are estimated to contribute 2% at a maximum to the global CH_4 budget.

In order to monitor atmospheric CH_4 variability, continuous measurements of CH_4 concentration from an expanded network of towers (JR-STATION: Japan–Russia Siberian Tall Tower Inland Observation Network; Sasakawa et al., 2010) have been conducted mainly in West Siberia since 2004. A previous study on the measurements has revealed that CH_4 concentration has large diurnal and seasonal variability, which are driven by seasonally varying wetlands and fossil fuel emissions as well as by significant diurnal and seasonal variations of planetary boundary layer height (PBLH). Chemistry transport model can be a useful tool to understand atmospheric CH_4 variations, but model simulation for the JR-STATION seems to be slightly challenging, since the stations are significantly affected by local sources and PBLH variability (Sasakawa et al., 2010), which in some cases need higher horizontal and vertical resolutions of the model to simulate.

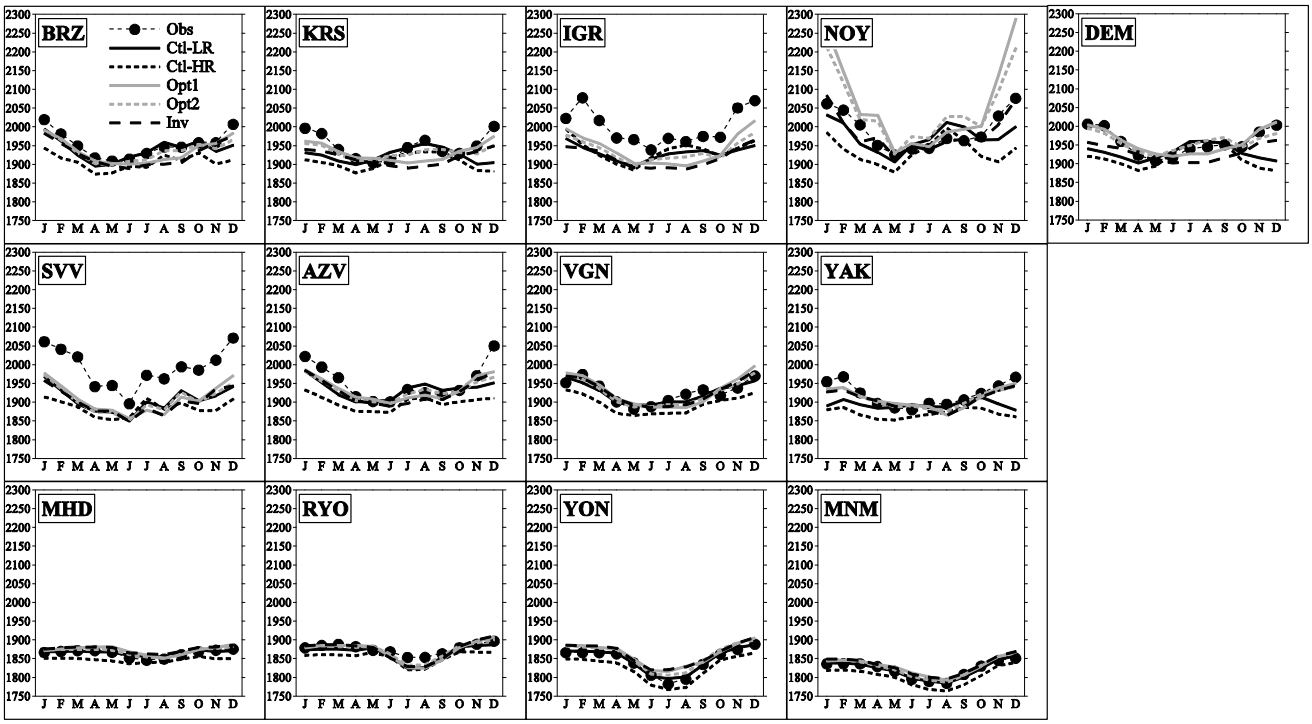

Figure 1. Monthly mean CH_4 of JR-STATION observation (obs) and the ACTM simulations for the period 2004-2013. 9 stations in the upper rows and others represent the results for the JR-STATION and for coastal stations, respectively. Model results are obtained as follows; Ctl-LR&HR: simulated by normal (LR) and high (HR) resolution ACTM with emissions by Patra et al (2011), Opt1&2: emissions by two different types of source balance optimization, Inv: emissions estimated by regional inversion (Patra et al., 2016).

In this study, we compare results simulated by the CCSR/NIES/FRCGC Atmospheric General Circulation Model based Chemistry Transport Model (ACTM; Patra et al., 2009; 2011) with several types of CH_4 emission inventories including the estimations by a process-based biogeochemical model (Ito and Inatomi, 2012) and by atmospheric inversions (Patra et al., 2016), and try to understand the driving factors for observed atmospheric CH_4 variations. Diurnal cycles are generally reproduced by ACTM, but, in summer, when the amplitudes are maximized by enhanced wetland emission and by large planetary boundary layer variability driven by large diurnal temperature change, disagreement for the amplitude and maximum timing between model and observation are found especially at stations located near wetlands (BRZ, KRS, IGR, NOY, and DEM). Seasonal cycles are compared using monthly means of daytime data (Fig.1). General tendency of observation of minimum in summer and maximum in winter is reproduced by model. However, wetland emission signals in summer at stations in wetter areas (KRS, NOY, and DEN) are missed by model cases of Opt1 and Inv. Also local anthropogenic emissions are underestimated at stations, less affected by the wetland emissions (IGR and SVV).

References

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