Global Environment Research Account for National Institutes

Long-term analysis of greenhouse gases (CO_2, CH_4) observed with a tower observation network in Siberia. （Abstract of the Final Report）

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1. Introduction

Siberia includes many types of ground surfaces of source/sink for greenhouse gases. For example, the Siberian taiga is the largest in the world, and the largest wetland region exists in the West Siberia. Recently, many researchers have focused on the permafrost in the northeastern Siberia due to its vulnerability to global warming. However, Siberia was one of the blank regions for greenhouse gas observation in the world. To overcome this problem and to capture spatial and temporal variation in greenhouse gases, NIES began the Siberian tower network JR–STATION (Japan-Russia Siberian Tall Tower Inland Observation Network)[1)] to observe regional and short-term variations of greenhouse gases (CO_2 and CH_4) in 2001.

2. Research Objective

We have conducted continuous measurements of CO_2 and CH_4 using JR–STATION to reveal the spatial and long-term temporal variation of these greenhouse gases in the continental interior. We also plan to estimate the distribution of the flux of various types of the surface (taiga, steppe, wetland, etc.) and reduce the uncertainty to clarify the behavior of the greenhouse gases.

3. Method

The network of towers (JR–STATION) consists of eight towers located in West Siberia and one tower in Yakutsk in East Siberia (Fig. 1). Atmospheric air was delivered via a decabon tube by a diaphragm pump into the freight container with insulators to reduce temperature variation and dried with (1) adiabatic expansion in a glass water trap, (2) a semi-permeable membrane dryer, and (3) magnesium perchlorate. The dehumidified air was then introduced into a non-dispersive infrared analyzer (model LI-820, LI-COR, USA) and a CH_4 semiconductor sensor[2)] at a constant flow rate of 35 cm^3 min^{-1} using a mass flow controller. Three standard gases were prepared from pure CO_2 and CH_4 diluted with purified air, and their concentrations were determined against the NIES 09 CO_2 scale[3)] and NIES 94 CH_4 scale[4)].

We estimated CO_2 flux with (JR experiment) and without (CNTL experiment) JR-STATION data included in an inverted analysis[5)]. We also estimated CH_4 flux with JR-STATION data in different prior or observation condition (S1, S2, and S3)[6)].

4. Results and Discussion

Figure 2 shows temporal variation in CO_2 concentration and its daytime mean observed from 2002 to 2016. Daytime means exhibit clear seasonal cycle with minimum in summer and maximum in

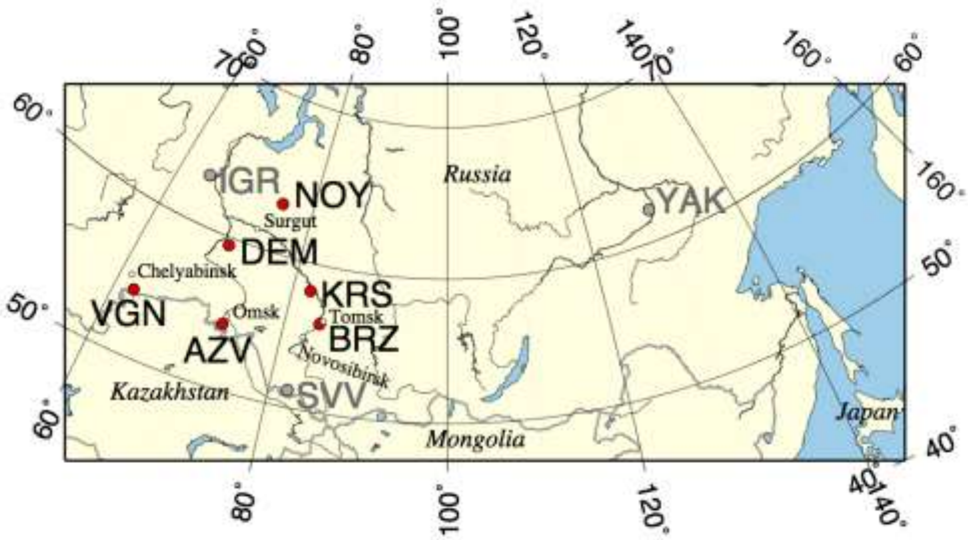

Figure 1. Location of JR–STATION (closed circle). Open circles indicate major cities.

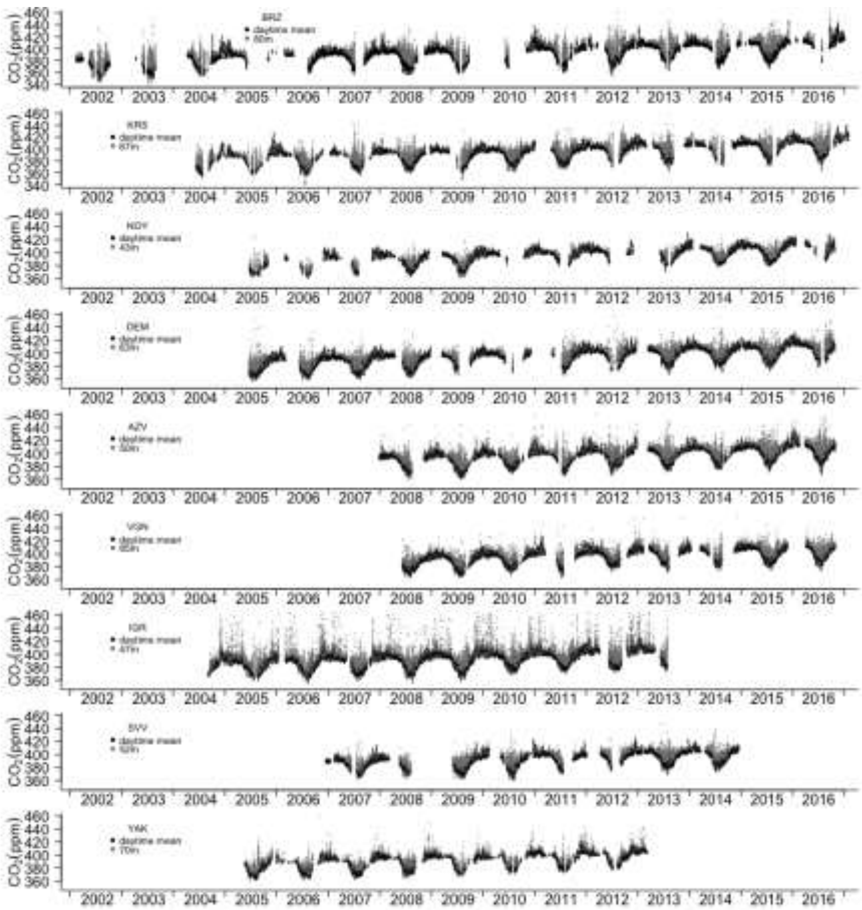

Figure 2. Temporal variation in CO_2 mixing ratio (ppmv) observed from high inlet at JR-STATION (Gray circle). Black circle indicates its daytime mean (13:00-17:00 LST).

winter. The strong summer minimum occurred by CO_2 assimilation due to photosynthesis by taiga vegetation. The concentration during summer sometimes exceeded those during winter, which was mainly observed during nighttime. This suggests that CO_2 emitted by respiration of land biospherewas accumulated in the lower atmosphere due to weak vertical mixing during nighttime.

Background CH_4 data showed regrowth in global CH_4 concentration since 2007[7)]. On the other hand, it is difficult to detect the long-term trend from all CH_4 data observed by JR-STATION due to large deviation in CH_4 concentration particularly during winter and summer[1) 8)]. Figure 3 shows temporal variation in CH_4 concentration and its daytime mean observed from 2004 to 2016. High CH_4 concentrations were observed at almost all tower sites except for the southern sites.

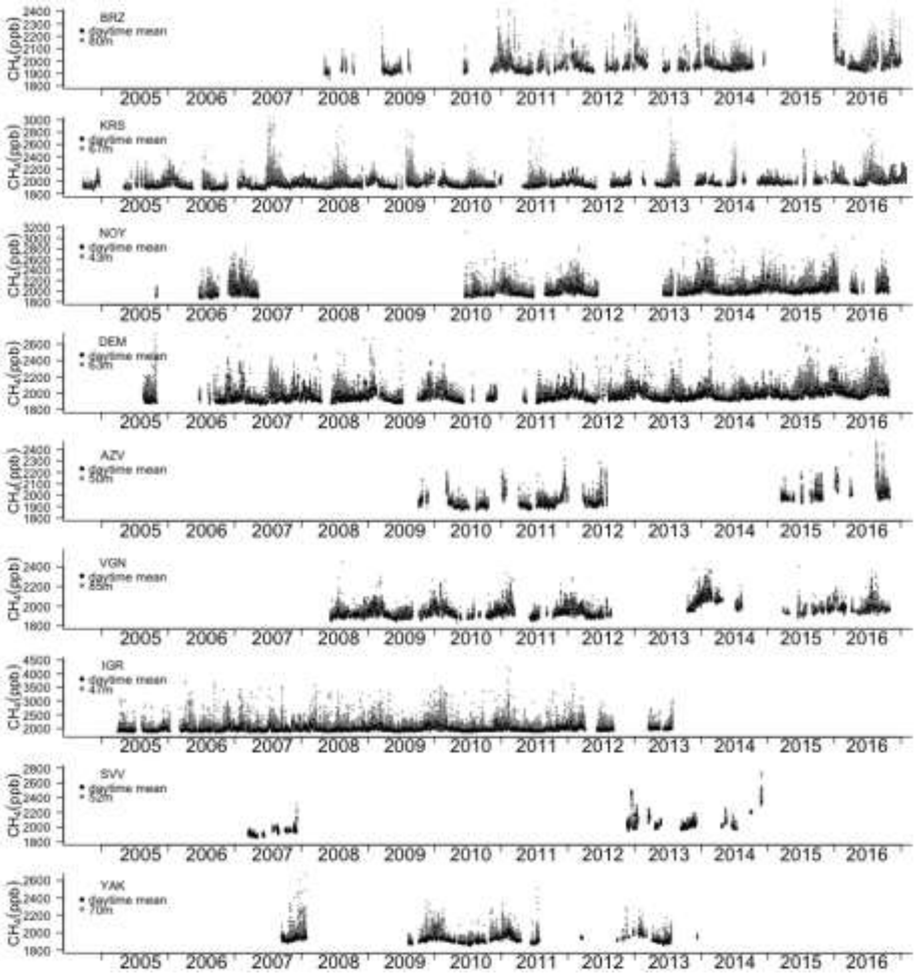

Figure 3. Temporal variation in CH_4 mixing ratio (ppbv) observed from high inlet at JR-STATION (Gray circle). Black circle indicates its daytime mean (13:00-17:00 LST).

The estimated CO_2 fluxes over Eurasian Boreal (EB) show greater annual uptake relative to the prior fluxes in both experiment (Fig. 4). The difference between the two experiments is large in the EB where JR-STATION observations are assimilated. The JR experiment exhibits a weaker surface CO_2 uptake in the EB than does the CNTL experiment except for 2003, whereas the JR experiment exhibits a greater surface CO_2 uptake in the other regions than the CNTL experiment (not shown). The trend of EB in the CNTL experiments is -0.06 Pg C yr^{-2}, whereas that in the JR experiment is 0.02 Pg C yr^{-2} due to the reduced uptake of CO_2 in the JR experiment since 2005.

In northern Eurasia, the year-to-year variability in the estimated CH_4 fluxes is considerable and is much larger than that in the prior fluxes (Fig. 5). The inter-annual variability in the WSL is similar to that of all of northern Eurasia ($R = 0.53$) and, in particular, the 2007 anomaly almost entirely originates in the WSL. The year 2007 was particularly warm in the WSL and wet. Therefore, it is likely that this anomaly is driven by increased CH_4 production by wetlands. We find an anomaly for the WSL in 2007 of +3.3 Tg of CH_4 (compared to the 2005-2013 annual mean). This finding further supports the hypothesis that the 2007 anomaly in the atmospheric growth rate was at least in part due to an increase in boreal wetland emissions as previously suggested[7)].

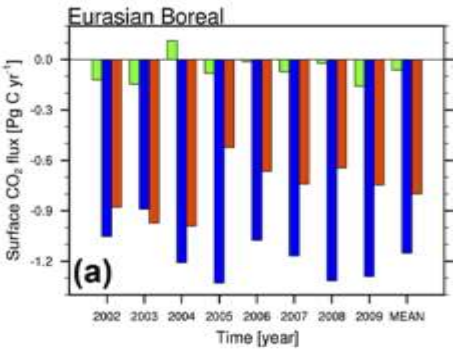

Figure 4. Annual and average biosphere CO_2 fluxes (Pg C yr^{-1}) from the prior (green bar), CNTL (blue bar), and JR (red bar) experiment aggregated over the (a) Eurasian boreal[5)]

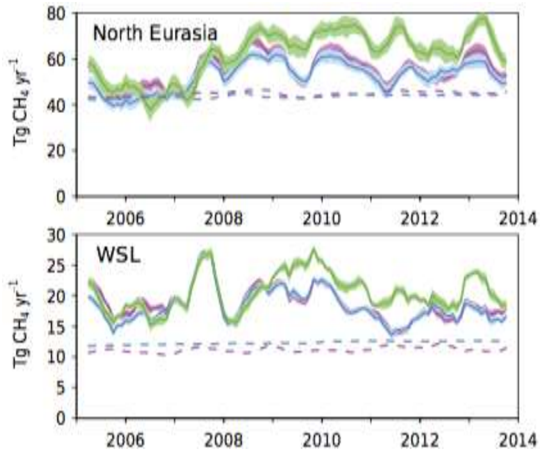

Figure 5. Inter-annual variability in CH_4 fluxes (Tg yr^{-1}) northern Eurasia, WSL (Western Siberian Lowlands)[6)]. The inter-annual variability was calculated by subtracting the mean seasonal cycle (resolved monthly) from the time series for each region and performing a running average on the residuals with a 6-month time window. The solid lines are the posterior fluxes from S1 (magenta), S2 (blue), and S3 (green); the dashed lines are the prior fluxes from S1 and S2. The shading indicates the posterior uncertainty

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