Analysis of Siberian CH_4 flux during 1994-2010: preliminary results for 2006-2010

Heon-Sook Kim* (kim.heon.sook@nies.go.jp),
Shamil Maksyutov, Tazu Saeki, Dmitry Belikov,
Toshinobu Machida

National Institute for Environmental Studies, Tsukuba, Japan

1. Introduction: Recent increase of atmospheric CH_4

- Atmospheric methane (CH4) has risen dramatically since pre-industrial times, and the rate of increase has slowed since the early 1990s, decreasing to near zero during 1999-2006 with large year-to-year variations. The growth rate of atmospheric CH4 has been increasing again after the unexplained steady state: +13.7 ppb/yr at polar northern latitudes in 2007 (Dlugokencky et al. GRL 2009)

- The cause of a large CH4 increase in 2007 is still uncertain, but wetland CH4 emissions enhanced by high temperatures in northern regions and by greater than average precipitation in the tropics are potential contributors (Dlugokencky et al. GRL 2009; Bloom et al. Nature 2010).

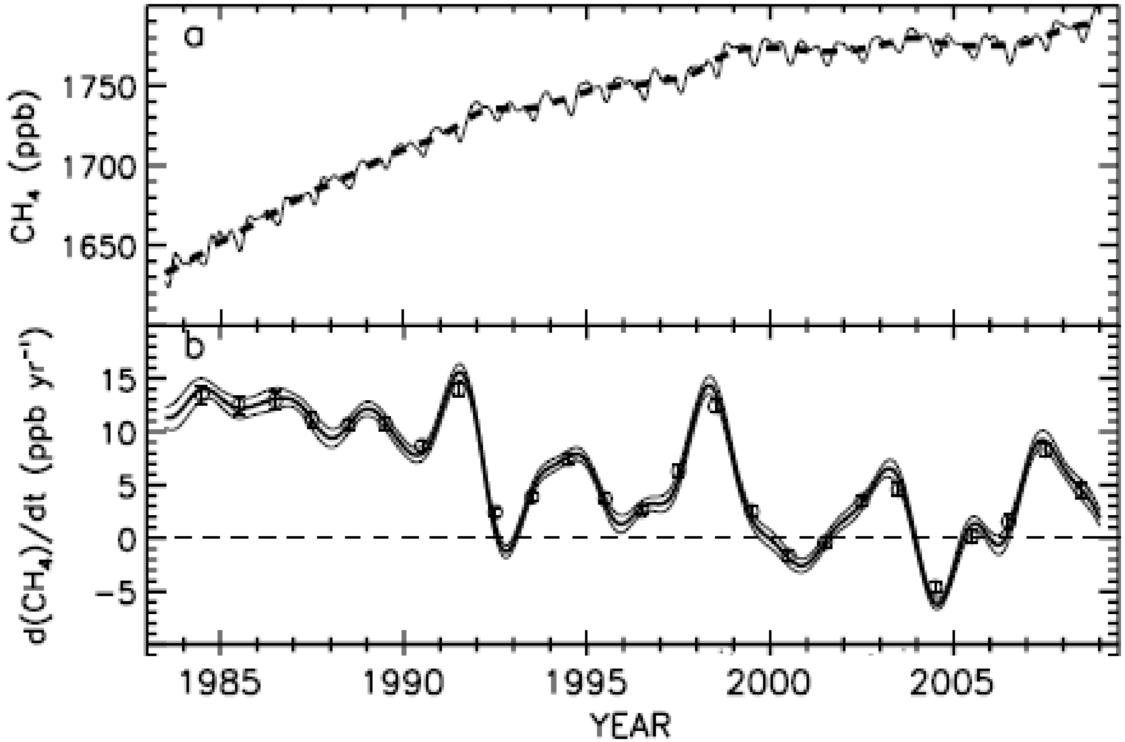


Figure 1. (a) Globally averaged CH4 (ppb) (solid line; dashed line is a deseasonalized trend curve fitted to the global averages). (b) Instantaneous growth rate for globally averaged atmospheric CH4 (solid line; dashed lines are ±1δ). The growth rate is the time-derivative of the dashed line in Figure 1a. Circles are annual increases, calculated from the trend line in Figure 1a as the increase from January 1 in one year to January 1 in the next. [taken from Dlugokencky et al. GRL 2009]

1. Introduction: Siberia

- A vast Siberian forest area and the world's largest Siberian wetland area play a significant role in the global carbon cycle as a large carbon sink and a major natural CH_4 source .

- Moreover the high Siberian Arctic land areas containing thick permafrost layers with carbon rich soils could release high CO_2 and CH_4 emissions thawing under a warmer climate: annual net CH_4 flux from Russian permafrost regions of 6-8 Tg/yr, of which 2.2-3.3 Tg/yr from West Siberia (Anisimov, ERL 2007)

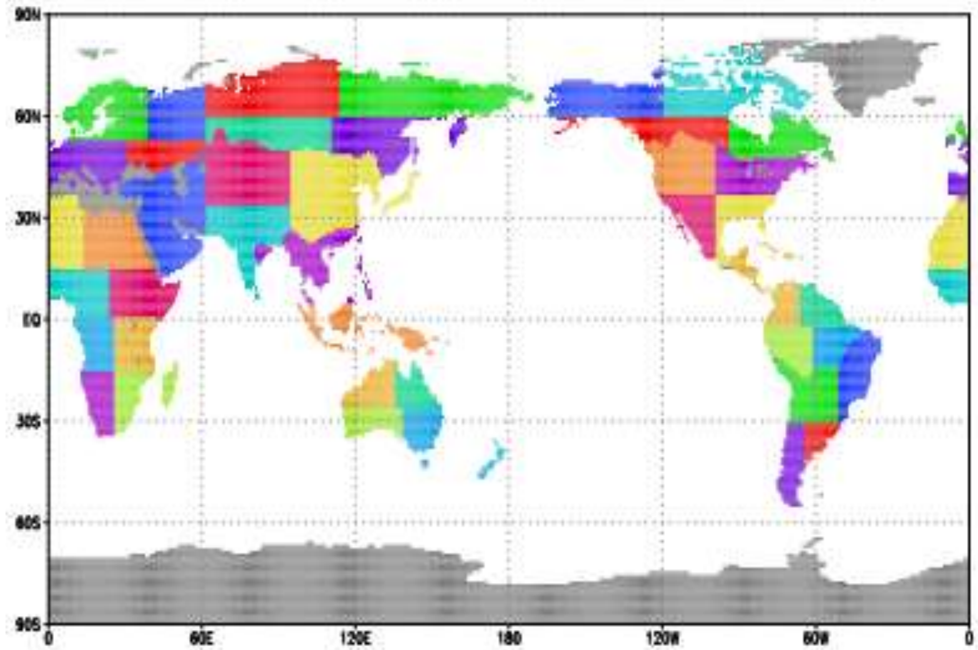
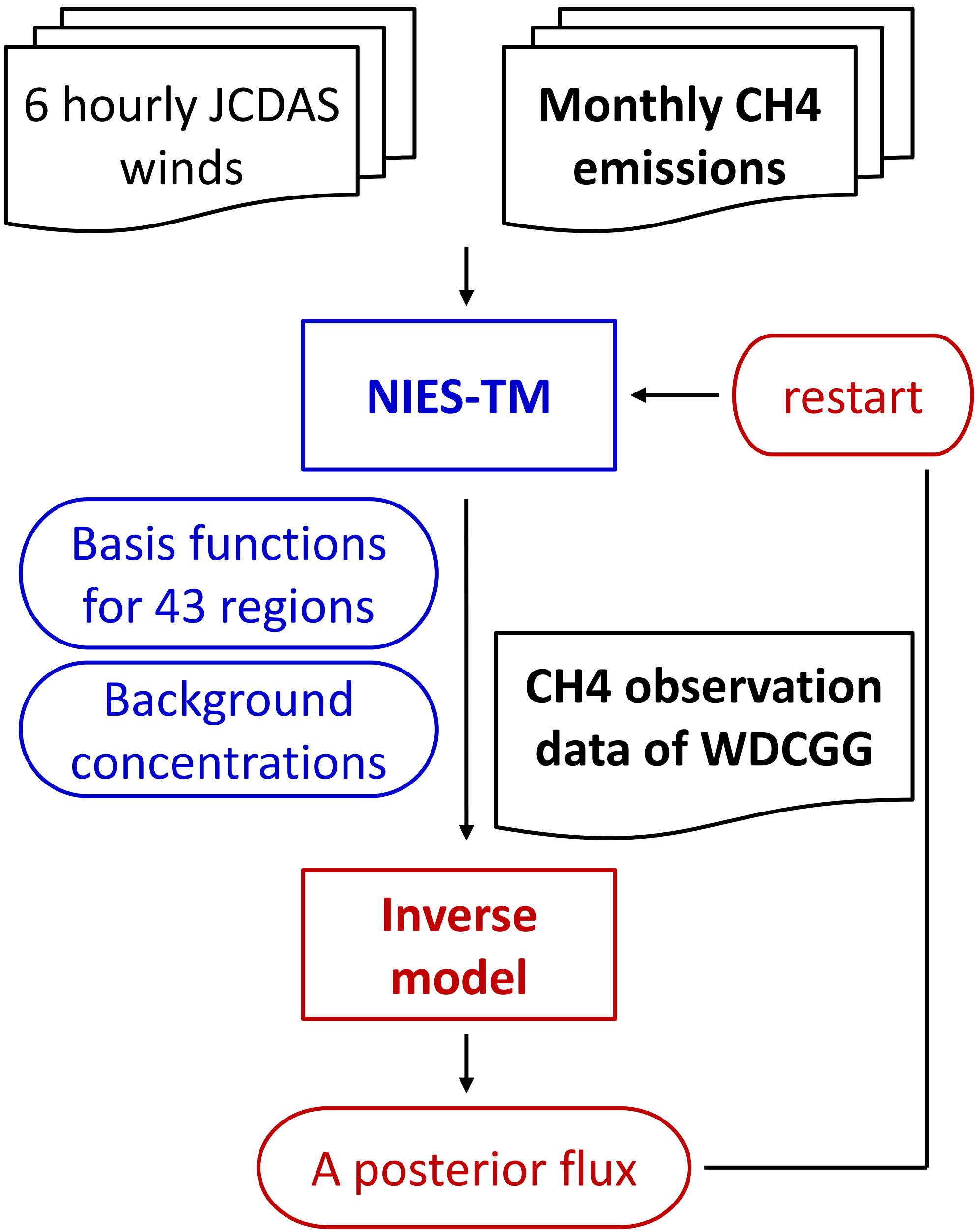


Figure 2. Location of the 42 land regions used in this study.

In this study, we estimate monthly CH_4 fluxes for 43 regions (42 lands and ocean) including 4 regions over Siberia during 2006-2010 using a fixed-lag Kalman smoother and investigate the year-to-year variation of Siberian CH_4 flux to understand climate-induced changes in Siberian CH_4 flux and the significance of Siberia on year-to-year variation of global CH_4 budget.

2. Method and data: CH_4 inverse modeling



- **Interannually varying CH4 emissions** from

(1) wetlands and rice paddies of VISIT (Ito and Inatomi, Biogeosci 2011)

(2) biomass burning of GFED v3.1 (van der Werf et al. ACP 2010)

(3) soil sinks of VISIT

(4) anthropogenic sources of EDGAR v4.2 with no seasonal variation

(5) termites of GISS (Fung et al. JGR 1991) with no interannual/seasonal variation

- **NIES transport model** (Belikov et al. GMD 2011) including photochemical loss applied in Transcom-CH4 (Patra et al. ACP 2011)

- **Inverse model** to estimate 43 regional CH4 fluxes during 2005-2010 including 1 yr spin-up

$$J = (z - Hs)^T R^{-1} (z - Hs) + (s - s_p)^T Q^{-1} (s - s_p)$$

z : difference between obs. and model

H : basis function s_p: a prior flux

s : source strength to be estimated

v : model-data mismatch error

R : data error covariance Q : flux covariance

2. Method and data: Observation data

- Atmospheric CH4 of WDCGG at 82 sites

- Siberian CH4 data (NIES):

(1) aircraft measurements (▲) at Surgut, Novosibirsk, Yakutsk

(2) tower measurements (+) at Demyanskoe, Igrim, Karasevoe, Noyabrsk

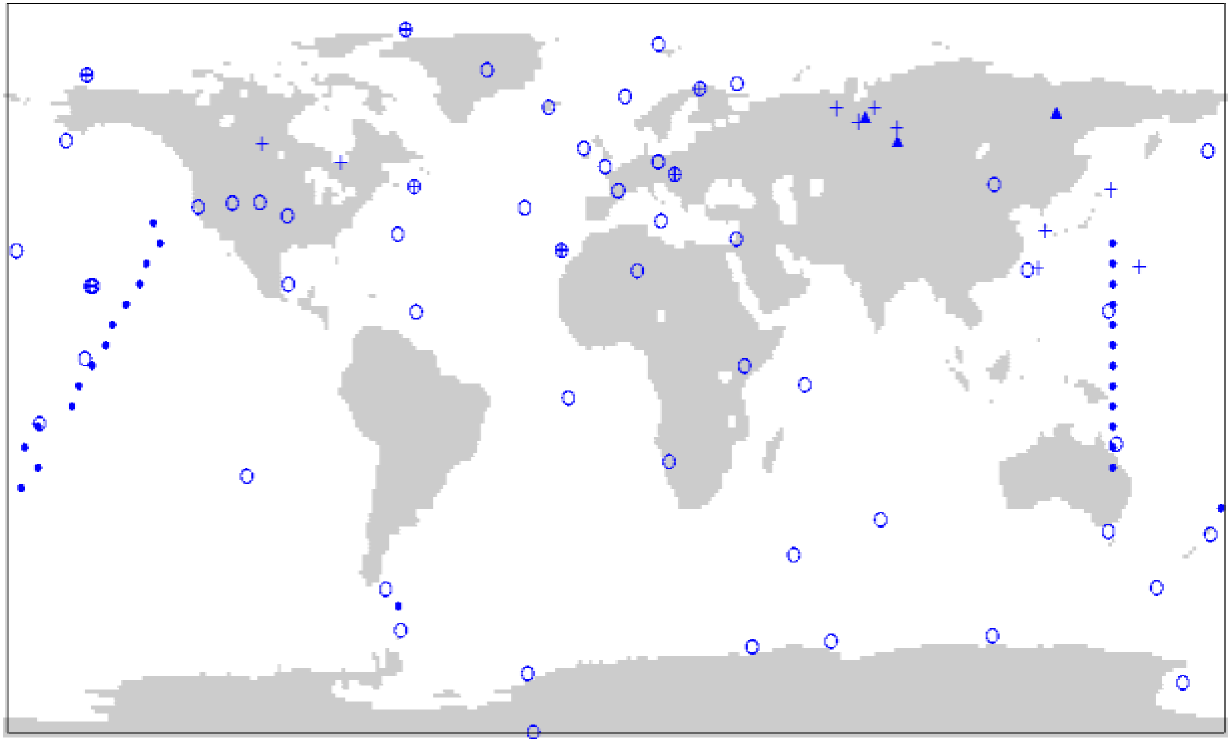


Figure 3. Location of measurements sites used in this study.

+ – continuous measurement sites

O – flask sampling measurement sites

• – mobile measurement sites

▲ – aircraft measurement sites

- Data selection

(1) data records longer than 70% of the simulation period

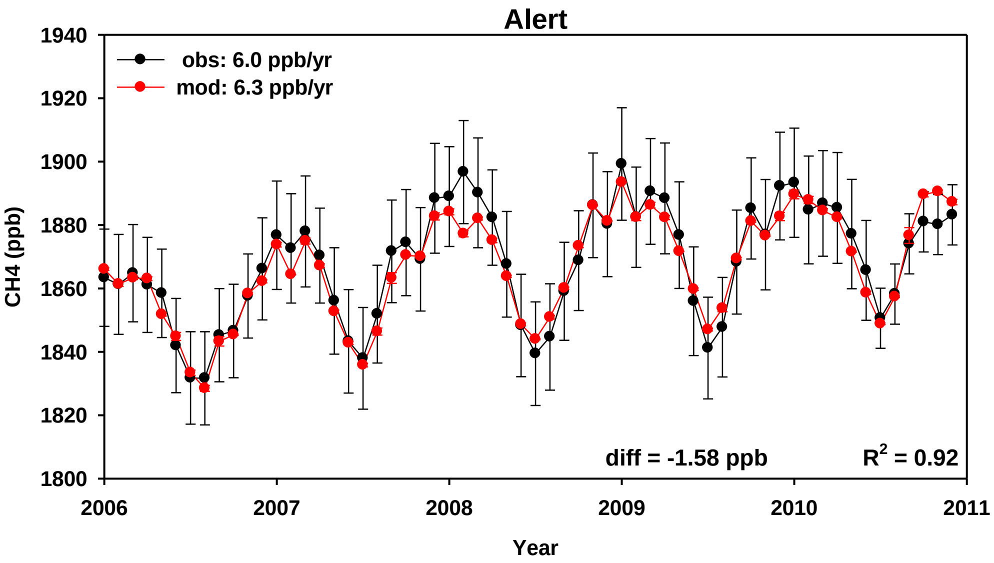
(2) all flask sampling data

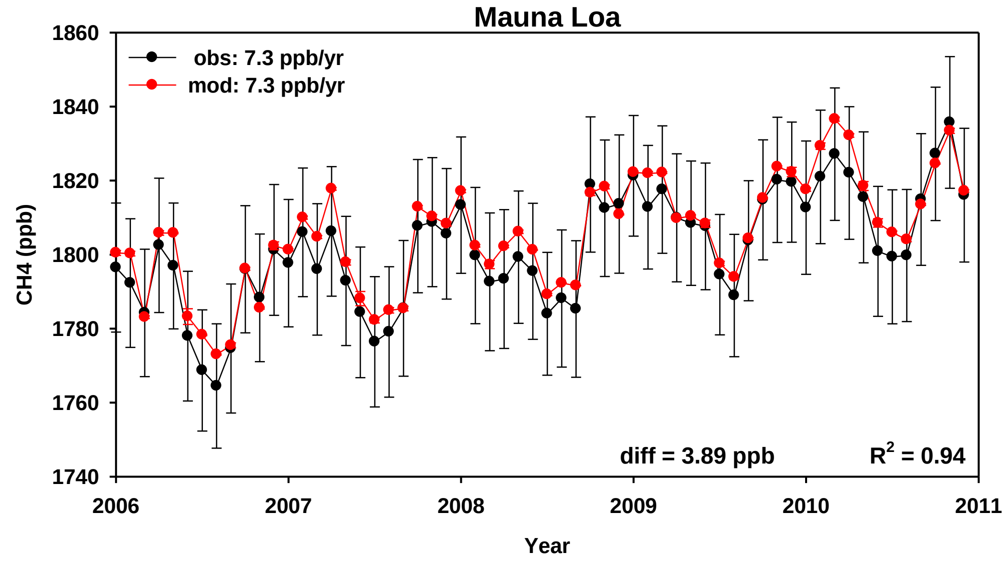
(3) 6 hourly continuous data during daytime for inland sites and nighttime for mountainous sites

- Data rejection in inverse modeling:

data with larger mismatch between observation and model than 60 ppb

3. Results: Comparison of CH_4 concentrations (ppb)





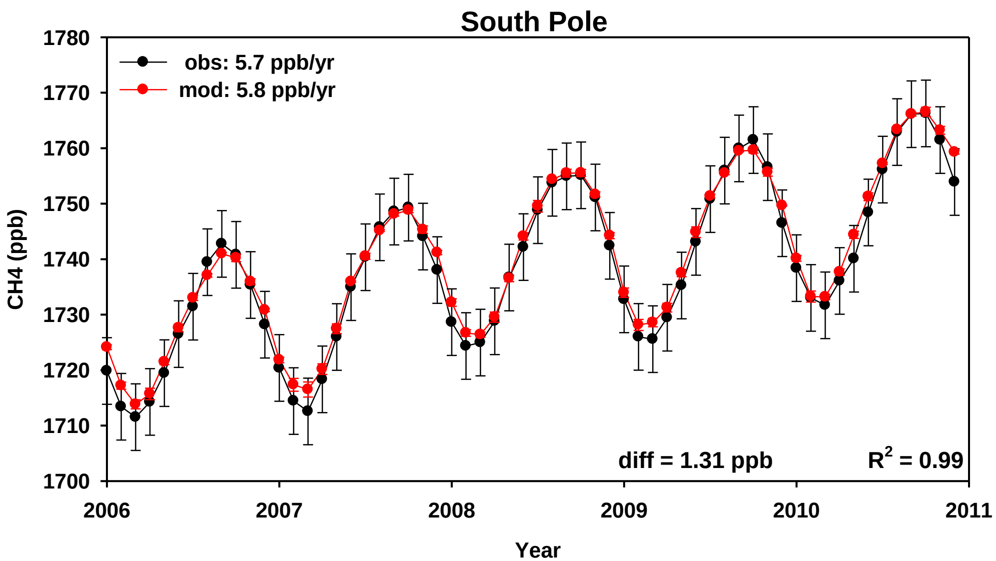


Figure 4. Time series of CH4 (ppb) of **observation** and **model** at Alert, Mauna Loa, and South Pole.

Table 1. Chi-square, defined as $\chi^2 = \frac{1}{n}\sum_{i=1}^{n}\frac{(Mod-Obs)^2}{cdat^2}$ for different data and flux uncertainties.

Data unc.*	Flux unc.	Chi-square	n
0.7	30%	1.67	55521
0.7	50%	1.59	55541
0.7	70%	1.55	55534
1	30%	0.85	55494
1	50%	0.80	55530
1	70%	0.78	55538
1.3	30%	0.52	55462
1.3	50%	0.49	55516
1.3	70%	0.47	55528

*scaling factor for data uncertainty

3. Results: Regional CH4 fluxes during 2006-2010

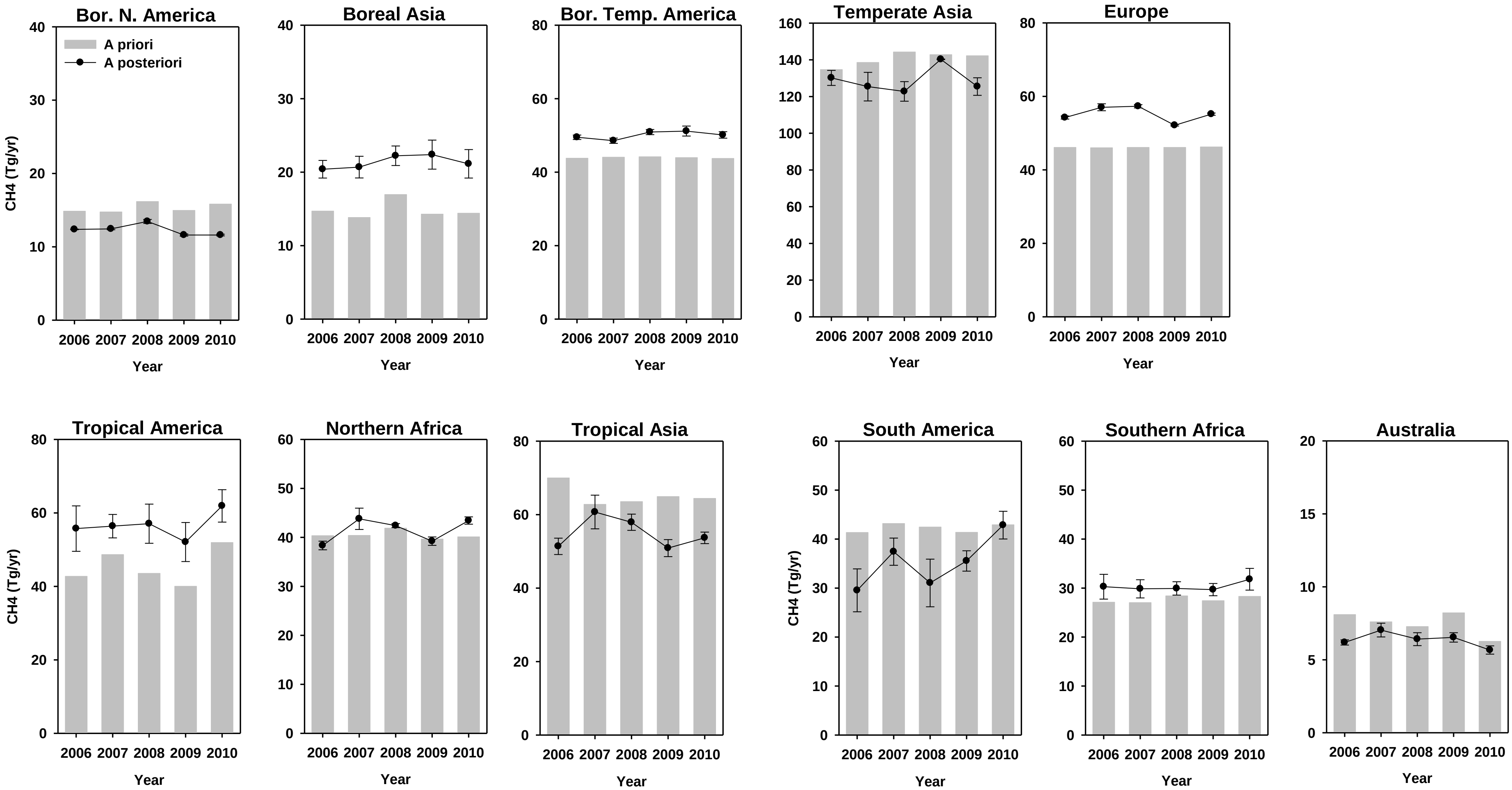


Figure 5. Recent variation of regional CH4 fluxes (Tg/yr) in 2006-2010. A posterior flux is the mean of nine inversion scenarios with different data and flux uncertainties. Error bars indicate the standard deviation for the a posterior flux.

3. Results: Siberian CH4 fluxes during 2006-2010

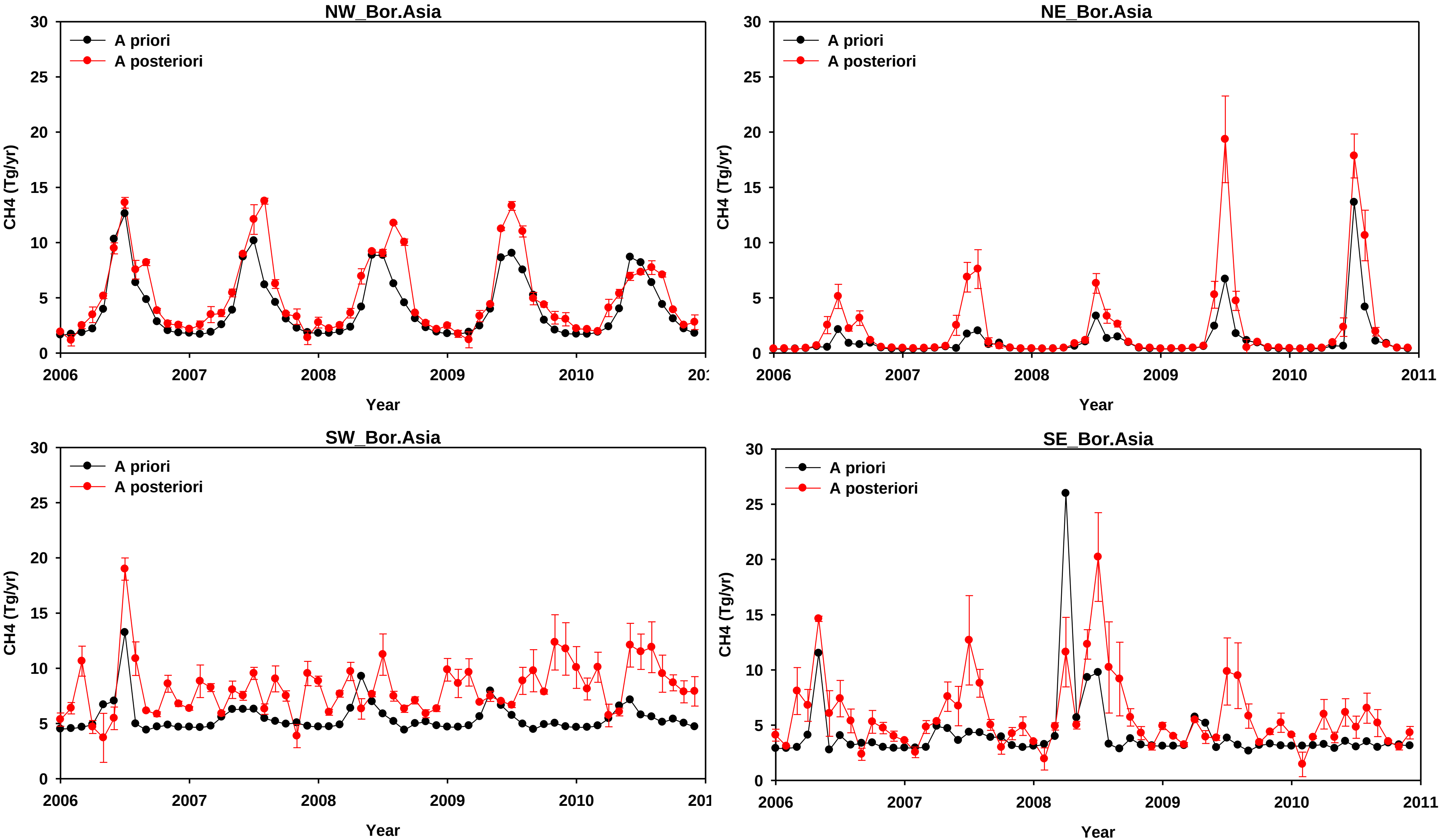
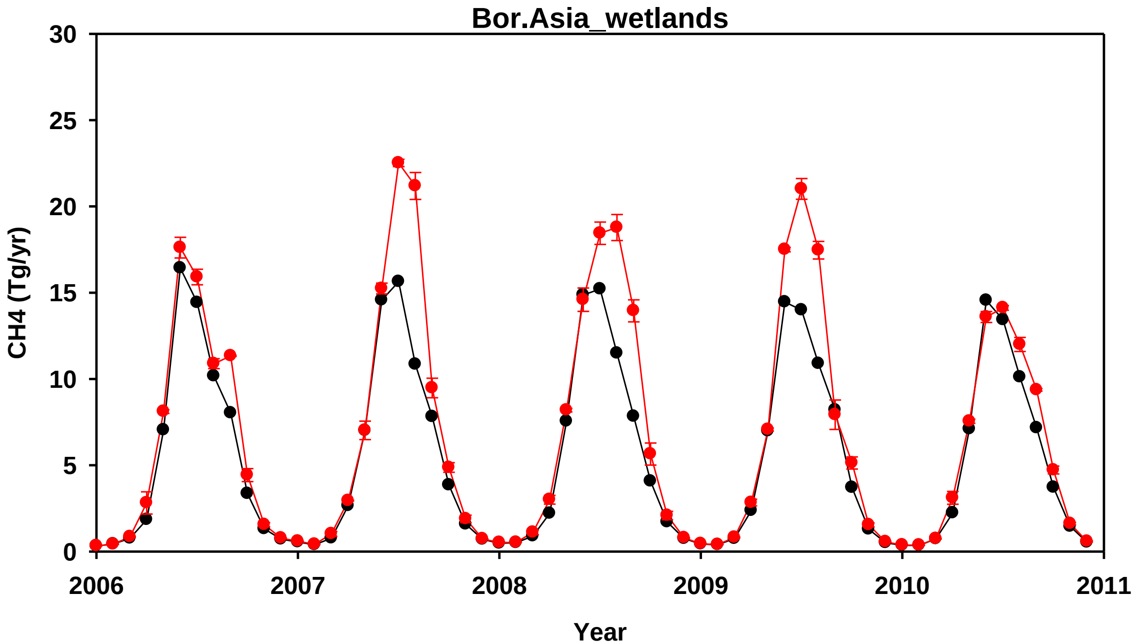


Figure 6. Recent variation of regional CH4 fluxes (Tg/yr) in 2006-2010. A posterior flux is the mean of nine inversion scenarios. Error bars indicate the standard deviation for the a posterior flux.

3. Results: West Siberian CH4 concentrations during 2006-2010



- Annual mean CH4 flux from wetlands: 6.7 Tg/yr during 2006-2010 -> higher flux in 2007-2008 (7.3 Tg/yr)

- Annual mean CH4 flux from biomass burning: 2.5 Tg/yr during 2006-2010 -> lower flux in 2007 (1.3 Tg/yr)

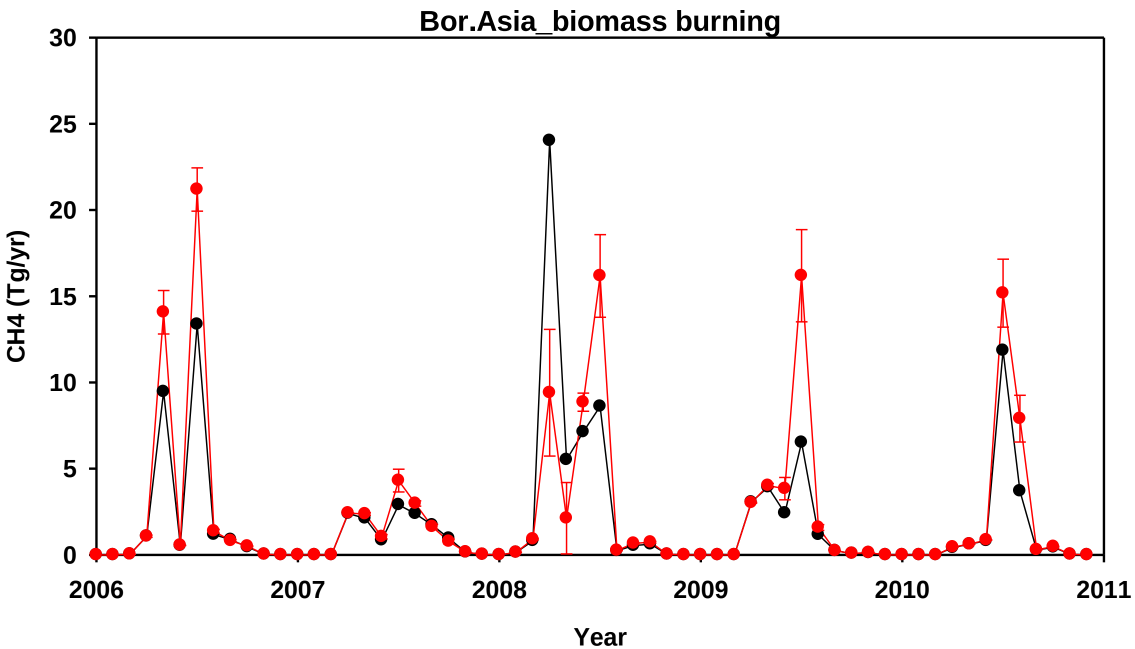


Figure 7. Recent variation of regional CH4 fluxes (Tg/yr) in 2006-2010. A posterior flux is the mean of nine inversion scenarios with different data and flux uncertainties. Error bars indicate the standard deviation for the a posterior flux.

4. Preliminary conclusions

- Regional CH_4 flux during 2006-2010 was estimated using flask sampling measurement and continuous measurement data with different data and flux uncertainties.

⇒ The standard deviation for inverse model-estimated fluxes with different inversion scenarios is very small as compared with the estimated flux uncertainties.

- Annual mean CH_4 flux of 21.4±1.6 Tg/yr is estimated over Boreal Asia during 2006-2010, which is 4.2% of the global total (510.9 Tg/yr).

- Higher CH_4 flux from wetlands during 2007-2008 is estimated in Boreal Asia, but lower CH_4 flux from biomass burning.

- A distinct seasonal variation of CH_4 flux is shown in northern west of Boreal Asia with large wetland area and it is not shown in other regions.

5. Acknowledgement

- We thank EDGAR v4.1, GISS/NASA, GFED v3.1, VISIT for emission inventories.
- We also thank Transcom-CH4 experiment for CH4 forward simulation setup.
- We also thank Dr. M. Sasakawa, Dr. Y. Terao, Dr. H. Mukai for providing CH4 observation data.
- All simulations in this study were calculated by GOSAT-RCF computer.