Evaluation of methane emission over West Siberia

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➢ Recent increase of atmospheric CH_4

- Methane (CH_4) is one of the important greenhouse gases and plays an important role in atmospheric chemistry. Its contribution to the current greenhouse effect is about 22% (Lelieveld et al., 1998)

- Atmospheric methane (CH_4) 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 CH_4 has been increasing again after the unexplained steady state.

- A growth rate increase of atmospheric CH_4 in 2007 was 7.3 ppb yr^{-1} in NH and 9.2 ppb yr^{-1} in SH with very large increase of 13.7 ppb yr^{-1} at polar northern latitudes (Dlugokencky et all., 2009). The large increase of CH_4 at polar northern latitudes was coincident with high temperature observed in 2007, which led increase of CH_4 emission from wetlands. It is one of the main contributors to the large increase at polar northern latitudes.

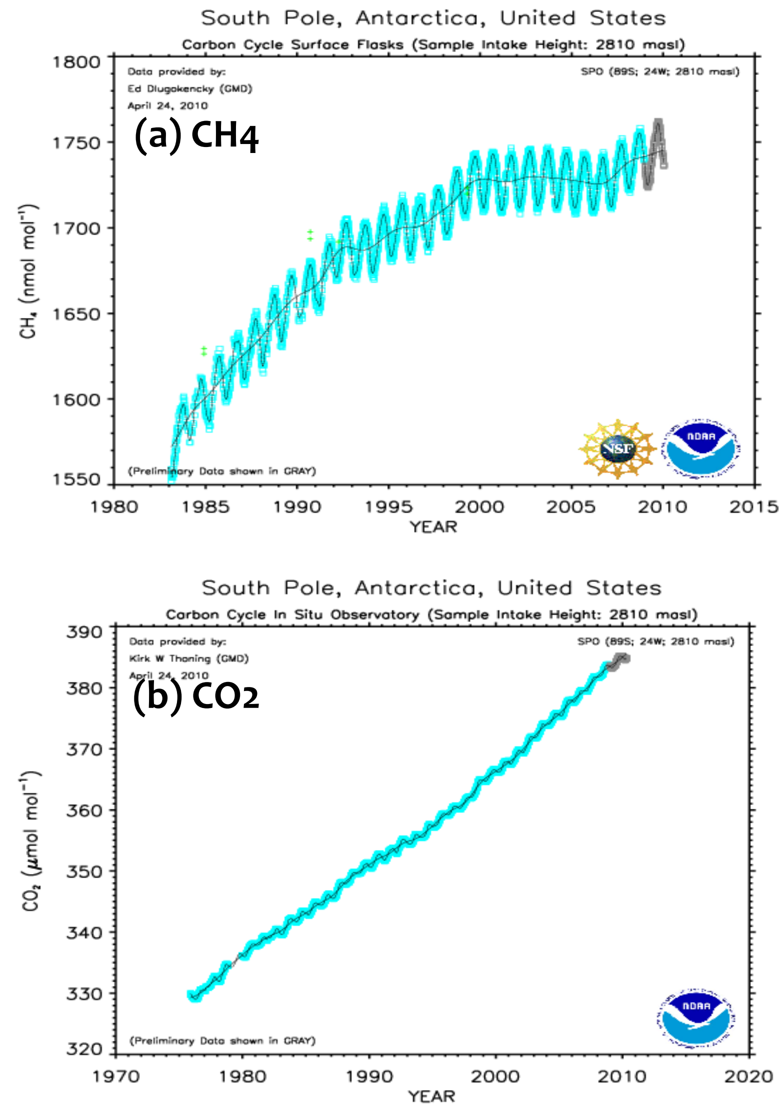


Figure 1. Trends of atmospheric CH_4 (a) and CO_2 (b) at South Pole, Antarctica (NOAA/ESRL)

➢ Wetland emission of CH_4

- Wetland emission which is the large single source of CH4 constitutes 20% to 40% of the total CH4 sources with very large standard deviation (IPCC, 2007). The wetland emission magnitude depends highly on soil temperature and water table (for example, Water et al., 2001), and its variation plays a large role in the year-to-year variation of CH4 budget (Bouquet et al., 2006).

- Matthews and Fung (1987) developed a global data base of natural wetlands, consisting of the spatial distribution of wetland sites, together with data on vegetation, soil, and fractional inundation. The global wetland area is estimated to 5300 Mha, of which about one half lies between 50-70N and is occupied mainly by forested and non-forested bogs.

- Peregon et al. (2008) produced a high resolution wetland type map over West Siberia using field survey data and satellite image, based on wetland type map in Romanova (1976) . The wetland area is estimated to 68.5 Mha which is about 27% of West Siberia.

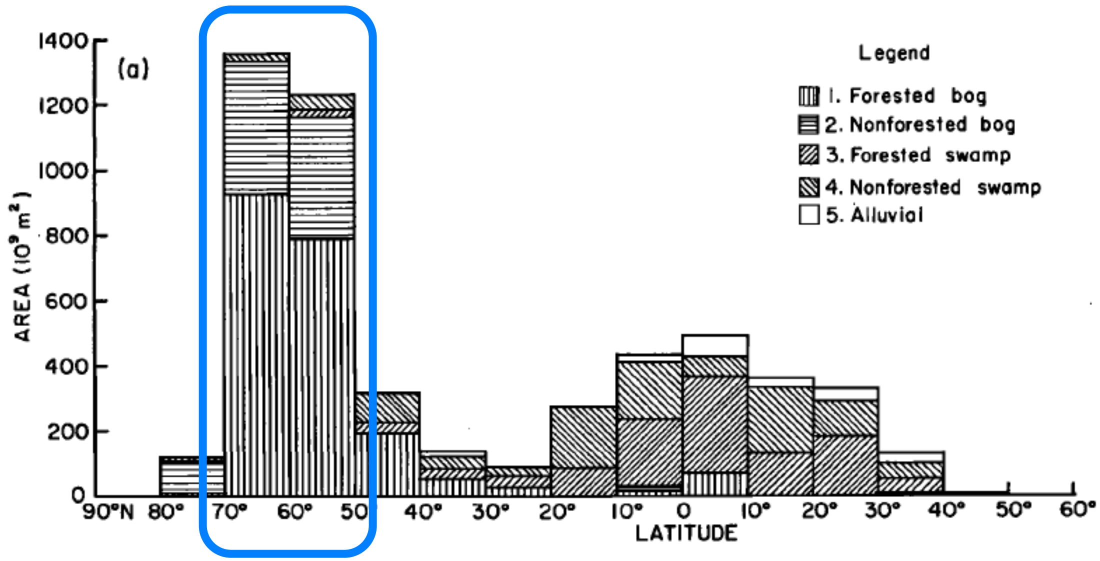
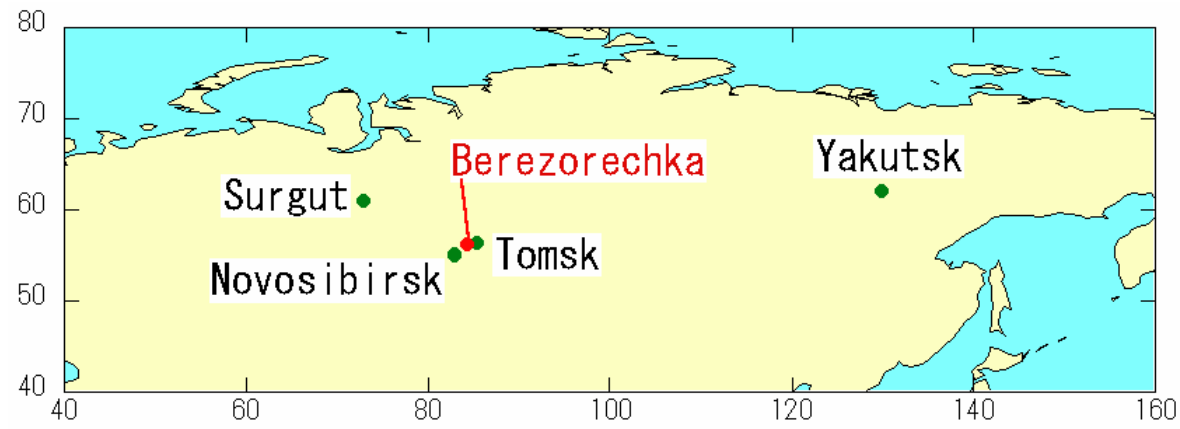


Figure 2. Latitudinal distribution of wetland areas (taken from Matthews and Fung, 1987)

Airborne observation over West Siberia

- Airborne air sampling is performed once a month over West Siberia under good weather. It was started in 1993 and 1997 at Surgut and Novosibirsk, respectively. The air sampling is performed at 8 levels from 0.5 km up to 7 km.



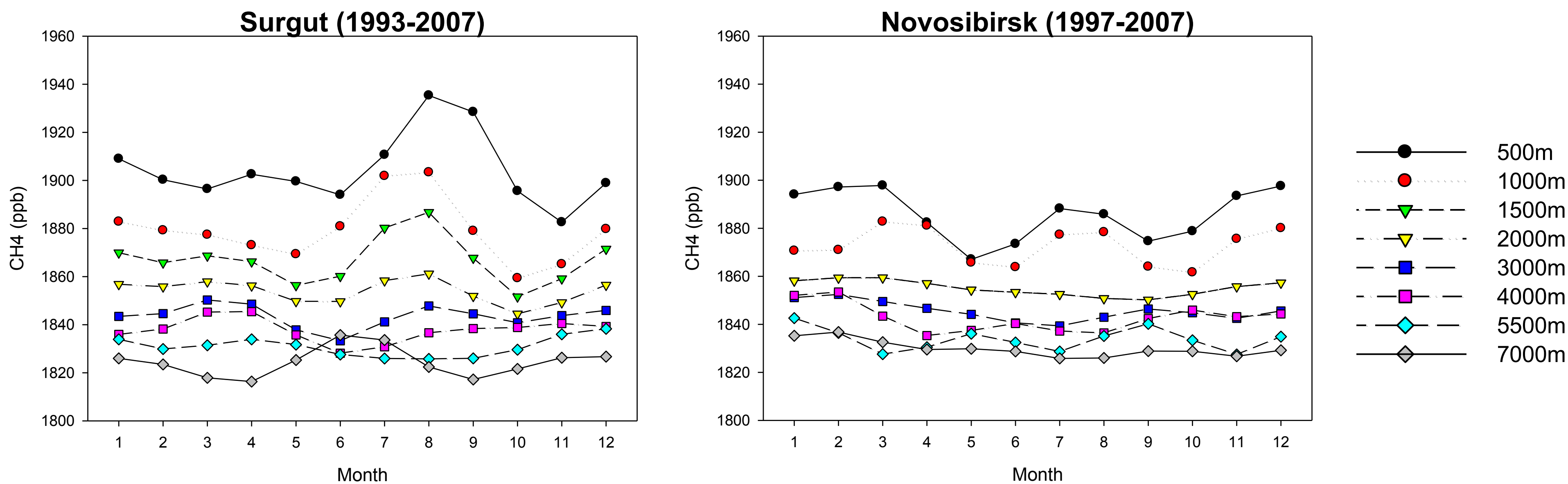


Figure 3. Seasonal variation of observed CH4 at Surgut (61.0N, 73.0E) and Novosibirsk (55.0N, 82.5E) from 0.5 km up to 7.0 km.

Regional CH_4 inverse modeling

NIES transport model
(Maksyutov and Inoue, 2000)
2.5 deg ×2.5 deg at 15 layers
12 hourly NCEP wind
monthly CHASER OH (Sudo et al., 2002)
↓
monthly mean CH4 concentrations for 11 regions and two emission groups

CH4 observations
Weekly observations (GLOBALVIEW) and monthly aircraft observations (NIES)
↓
monthly mean CH4 concentrations at 63 sites with minimum data uncertainty of 5 ppb

EDGAR and GISS inventories
CH4 emissions of energy sources and animals from EDGAR and soils, termites, rice paddies, wetlands and biomass burning from GISS
↓
a prior flux magnitudes from Patra et al. (2009) with flux uncertainty of 20%

Cyclo-Inverse model
minimize the mismatch between observed and modeled CH4 (based on TC3-CO2 inversion)

$$J = (x - TF)^T C_x^{-1} (x - TF)) + (F - F_0)^T C_{F0}^{-1} (F - F_0)$$

[x, observation; T, transport matrix, F_0 and F, prior and posterior fluxes; C, covariance]
↓
monthly CH4 fluxes for 11 regions and two emission groups

- **Chemical destruction of CH4 by OH radicals** is simulated using monthly mean OH fields with interannual variation predicted by CHASER (chemical atmospheric general circulation model). **The mean tropospheric CH4 lifetime derived by the chemical reaction is 9.7 years, very close to the recommended values of 9.6 years in IPCC 3rd report (2001).**

➢ Regional CH_4 inverse modeling

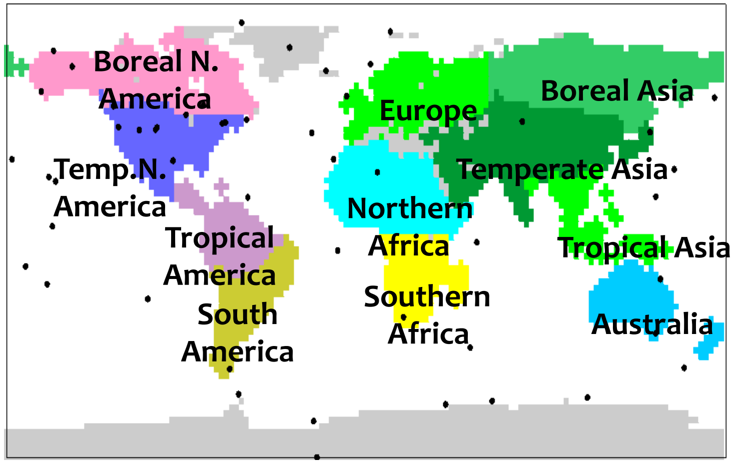
- ***NIES transport model (NIES99)***

1) Simulation period: 6 years using climatological data

$$resp(m,e) = \sum_{y=1}^{6} c(m,e,y) + c(m,e,6)\sum_{y=7}^{\infty} \exp\left(-\frac{b(y-6)}{\tau}\right)$$

b; constant
τ; lifetime of CH4

2) 264 response functions (12 mon.×11 reg.×2cat)
3) Input data i) monthly OH fields from CHASER (Sudo et al., 2002)
ii) CH4 flux magnitude from Patra et al. (2009)
iii) 12 hourly NCEP data



- ***Prior flux magnitude from Patra et al. (2009)***

Flux	prior	
Anthropogenic process[1]	280.9	from EDGAR
Soils	-25.1	
Termites	20.2	natural sources from GISS
Wetlands[2]	153.0	
Rice agriculture	39.2	
Biomass burning	59.8	
Total	528.0	

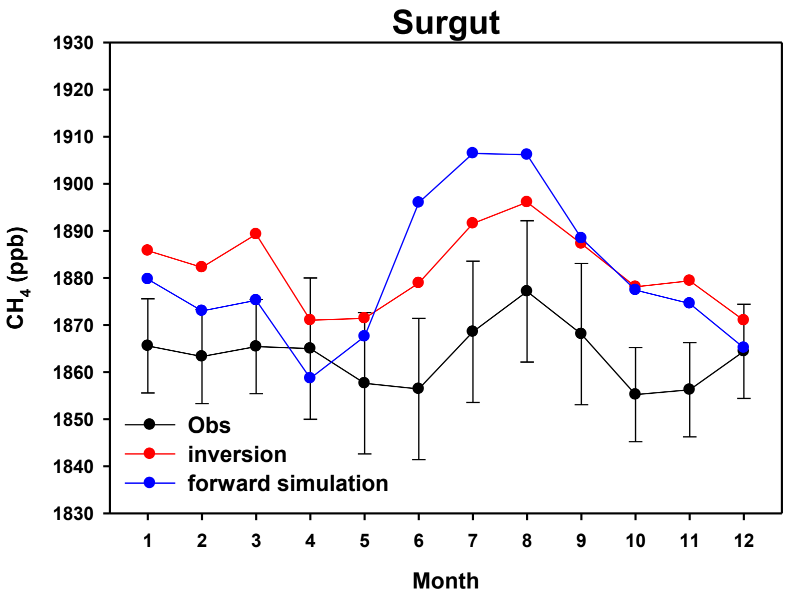
unit; Tg CH_4 yr^{-1}

[1] Includes animal flux
[2] swamp, bogs, tundra

- ***CH4 observation data***

1) Surface-level CH4:
57 sites in GLOBALVIEW
2) Partial-column CH4 up to 4 km:
4 sites in GLOBALVIEW and 2 sites in NIES

➢ Seasonal variation of West Siberian CH4



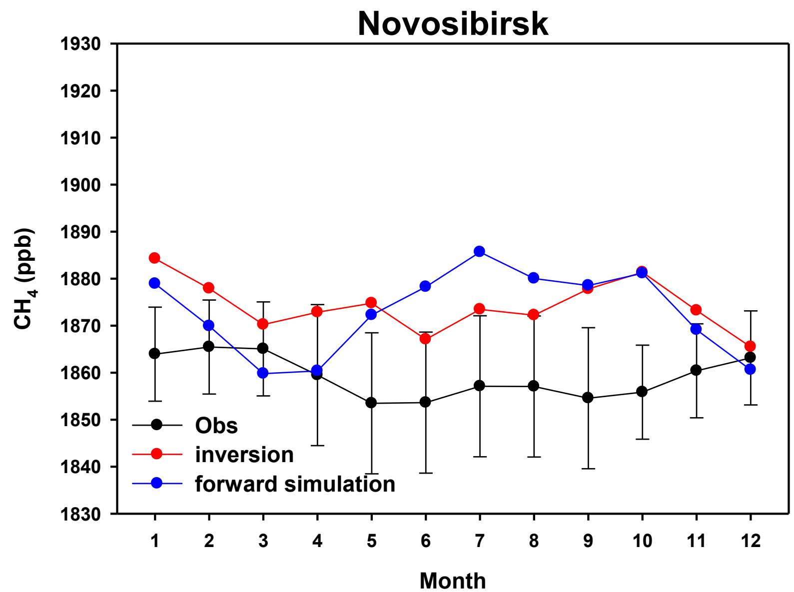
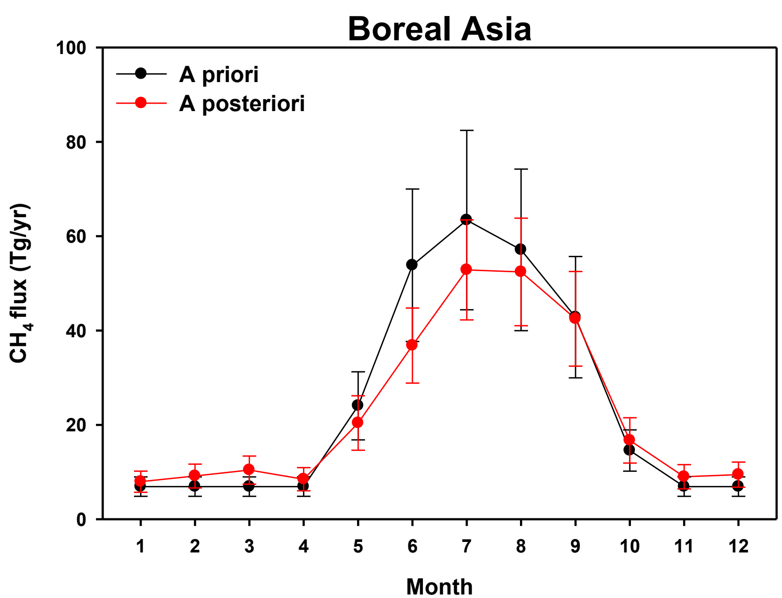
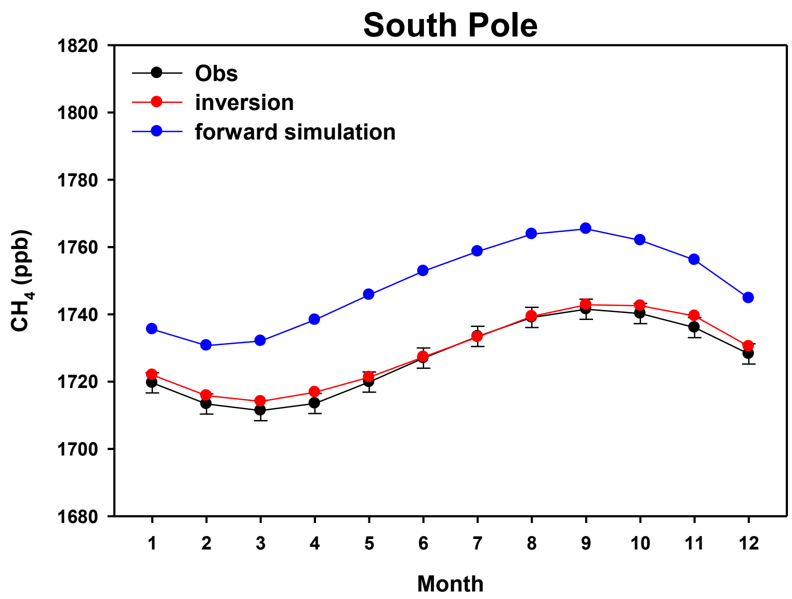


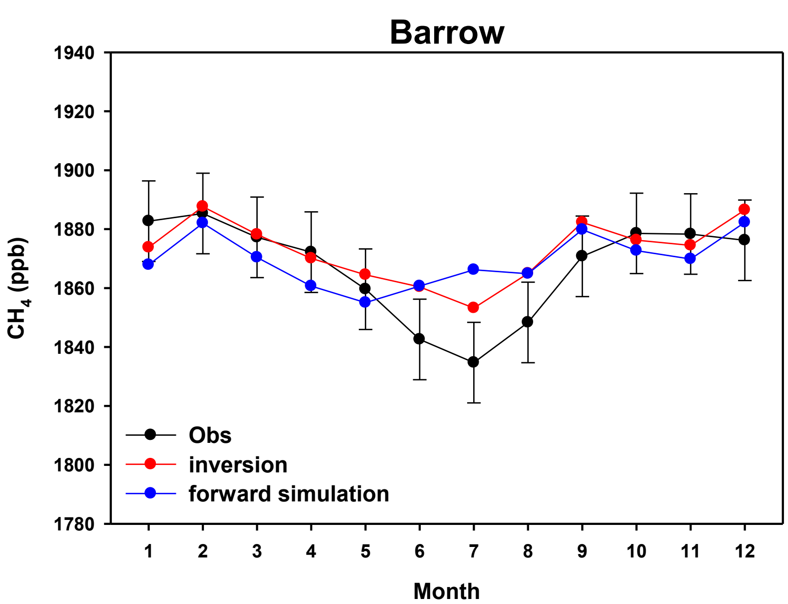
Figure 4. Seasonal variation of CH4 concentration (ppb) at Surgut and Novosibirsk and CH4 flux in Boreal Asia.



- In the observed CH4 at Surgut, a seasonal amplitude of 4.6 ppb is calculated by the difference between the average of Jun-Sep and the average of Oct-Mar. Comparing to observation, the overestimated seasonal amplitude of 25.7 ppb in forward simulation is decreased to 6.9 ppb in inversion. The seasonal amplitude in inversion close to the observation is also shown at Novosibirsk, but negative values of seasonal amplitudes except for forward simulation.

North-south gradient of CH_4 fluxes





Aggregated regional CH4 fluxes (Tg yr^{-1})

	A priori	A posteriori
North	252.37	285.10
Tropics	175.79	162.29
South	86.76	64.72
Global	514.91	512.11

- Large CH4 emission from biomass burning of 59.8 Tg yr^{-1} in Fung et al. (1991) is used as a priori in this study as compared with recent biomass burning of 20.1 Tg yr^{-1} in Randerson et al. (2007). The overestimated CH4 concentrations of the Tropical and Southern regions in forward simulation is constrained by observations, leading decreased tropical and southern fluxes and increased northern flux.

Figure 5. Seasonal variation of observed and modeled CH4 (ppb)

➢ Wetland CH4 flux database over West Siberia

- Glagolev et al. (2010) produced a high resolution wetland CH4 flux over West Siberia though an emission model with fractional wetland topology map in Peregon et al. (2008), using field observation in 7 natural zones of tundra, forest tundra, northern-, middle-, southern taiga, subtaiga and forested steppe.

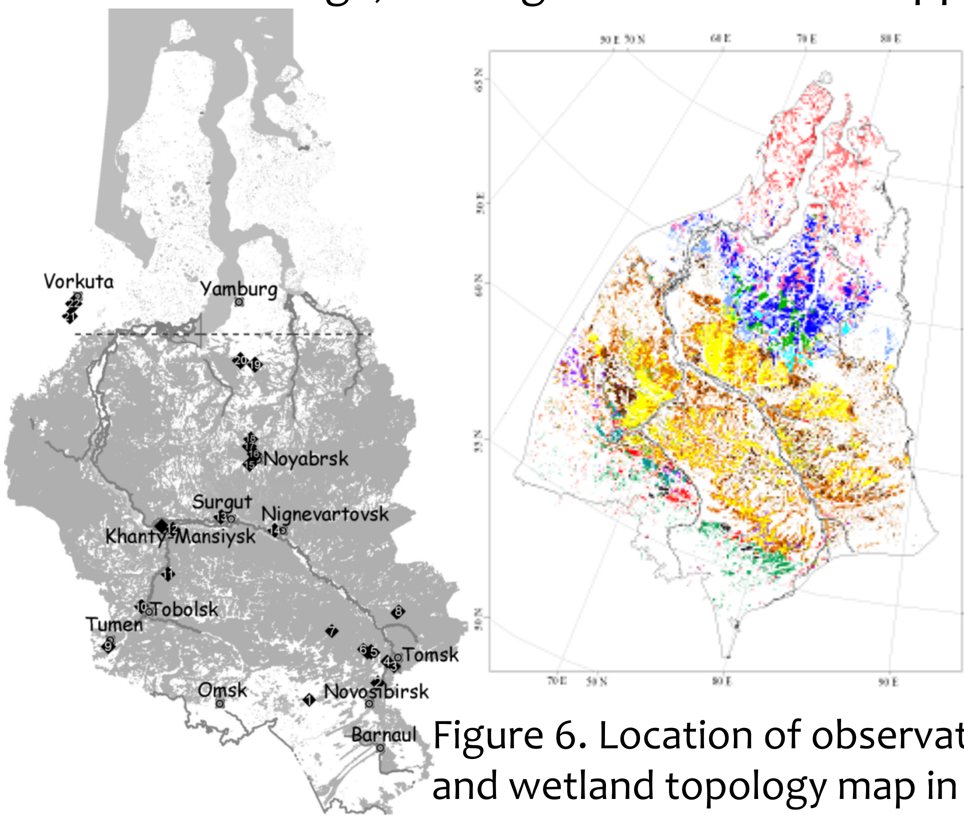


Figure 6. Location of observation and wetland topology map in West Siberia (taken from Paregon et al., 2008)

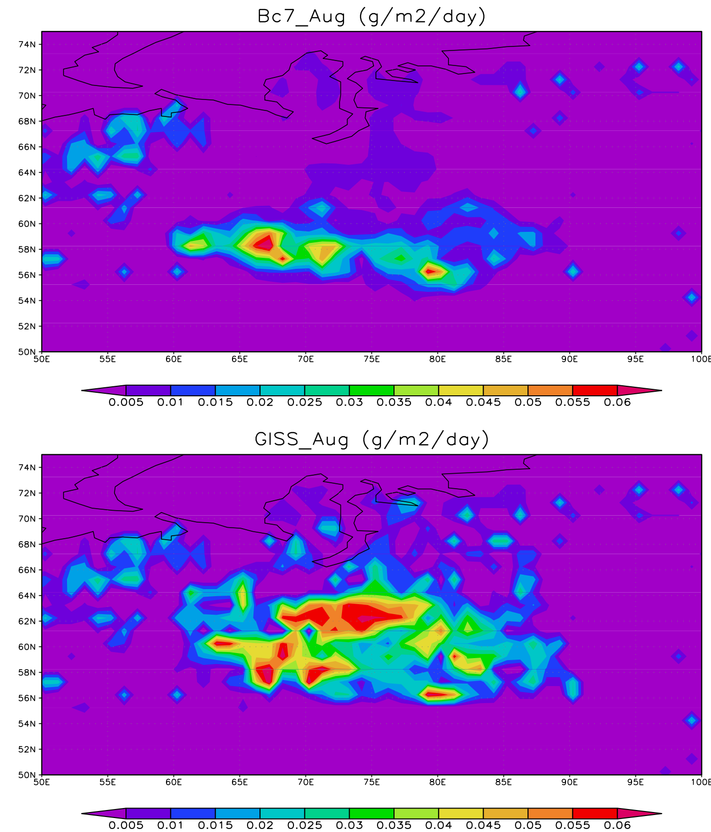


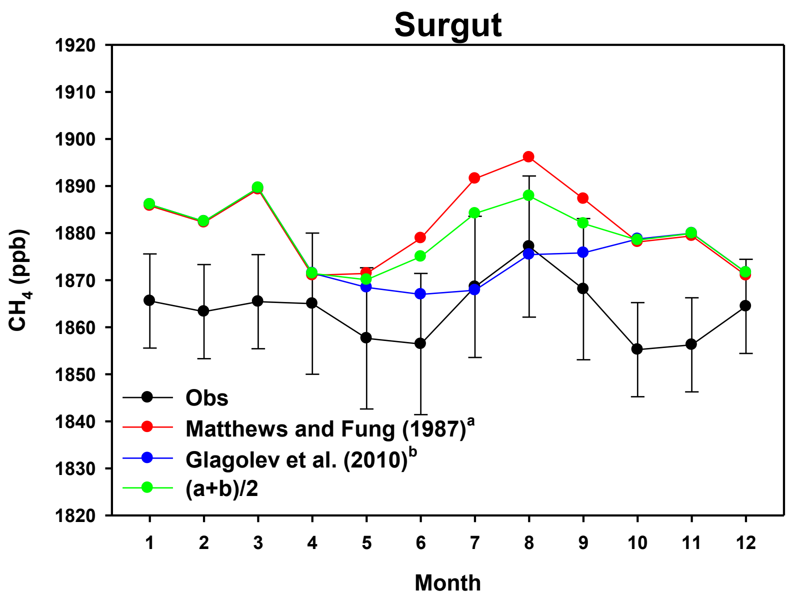
Figure 7. Comparison of bog emissions (g CH4 m^{-1} day^{-1}) between Glagolev et al. (2010) [Bc7] and Matthews and Fung (1987) [GISS] in August.

- Large difference toward north of 60N
- Total West Siberia bog emission

  3.27 Tg CH_4 yr^{-1} in Bc7

  5.31 Tg CH_4 yr^{-1} in GISS

➢ Seasonal variation of West Siberian CH4



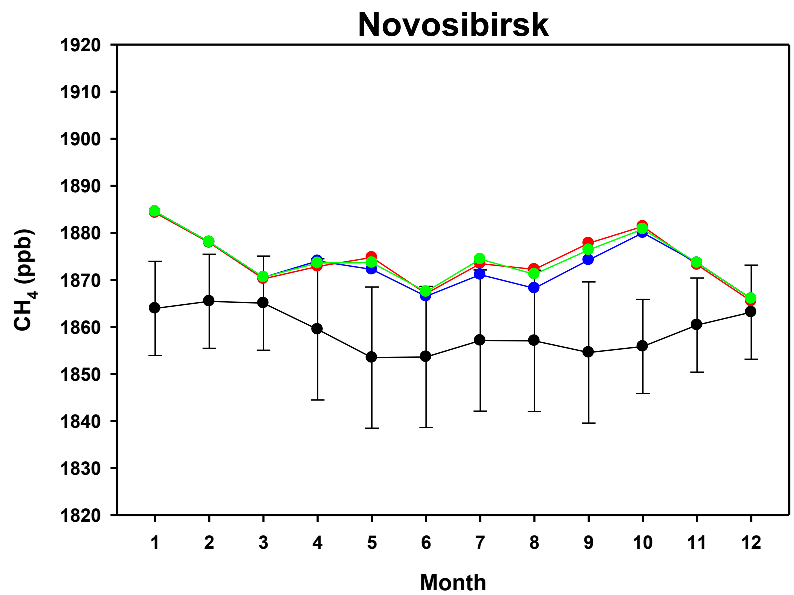
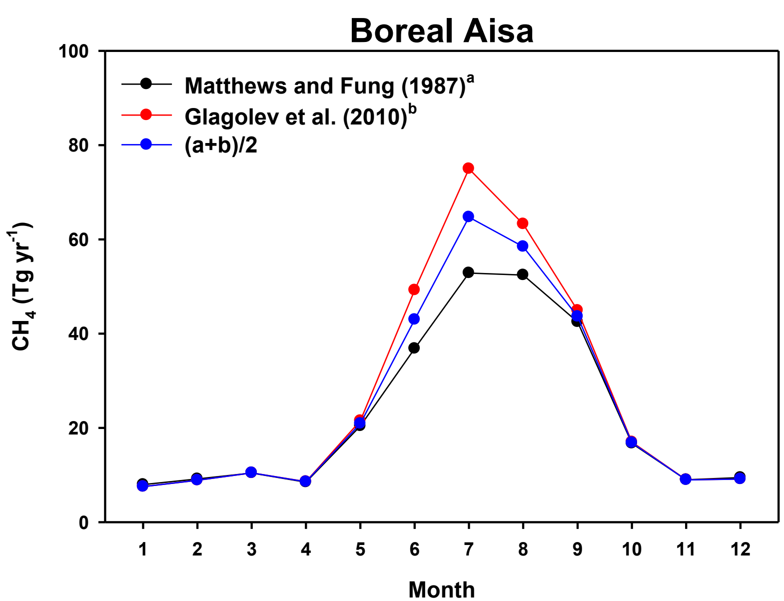


Figure 8. Seasonal variation of CH4 concentration (ppb) at Surgut and Novosibirsk and CH4 flux in Boreal Asia for three emissions.



- At Surgut, relatively large deviation of the inversed fluxes using different wetland emissions is shown in summer when wetland emission is active, whereas a little deviation of the inversed fluxes is shown at Novosibirsk.

- The observation constraint is not so robust over large CH4 source regions as compared with remote monitor sites.

Summary

1) Airborne CH_4 observations shows significance of big wetland sources in summer over West Siberia .

2) We estimated CH_4 fluxes through inverse modeling with the airborne observation data and compared the seasonal variation of the modeled CH_4 with observations over West Siberia.

3) These results suggest the sensitivity of a prior flux in flux estimates and the need for the emission model based on observation, accounting properly for spatial distribution and seasonality of CH_4 emission.