# Estimation of $CH_4$ emission of wetland from thawing permafrost in northern countries

SUDESURIGUGE, Wataru Takeuchi

Department of Civil Engineering, the University of Tokyo, Japan
Institute of Industrial Science, University of Tokyo, Japan
6-1, Komaba 4-chome, Meguro, Tokyo, JAPAN 153-8505
Tel: +81 080-4624-0622
E-mail: sorgog@iis.u-tokyo.ac.jp

**KEY WORDS:** permafrost, wetland, $CH_4$ emission, LST, VEG, SWE

**Abstract:** The parameters about wetland $CH_4$ emission include the land surface temperature (LST), snow water evaporation (SWE) and vegetation (VEG). Research will use MODIS and NOAA AVHRR data to get LST and VEG data and use AMSR-E and SSMI data to know the SWE of study area. In this paper, combing with reference paper estimate the $CH_4$ emission in growing season, using derivation model and then find out relationship among the methane emission with LST, SWE and VEG of study area in recent nine years. According extrapolated results, the methane emission could have a linear relationship with LST and VEG. And for the SWE parameters still could not find an appropriate model to describe the methane flux because of the data shortage.

## 1 INTRODUCTION

### 1.1 BACKGROUND OF THIS RESEARCH

Wetland is the main source of atmospheric methane. The increasing emission of atmospheric methane has brought great influence to global climate change and it has great necessary to estimate wetland methane emission accurately. The research of methane emission in a recent estimate and published literature suggests that about 66% of the total global $CH_4$ emissions from natural wetlands come from northern (>N40°) regions.

Permafrost regions are the main distribution area of the wetlands around the globe at the same time. More than 50% of world's wetlands distributed (Matthews and Fung, 1987) in northern higher latitude area where Siberia, Canada, and Qinghai-Tibet Plateau. From the second report of the IPCC (Stendal and Christensen), by the end of the 21st century, global warming will cause most of the active layer depth increased by 30% -40% of the northern hemisphere and it will lead many influences to wetland provide greater anaerobic environment so that increased $CH_4$ emissions.

In many scientific results, according to the wetland $CH_4$ emission seasonal distribution mode, in vegetation growing period will appear a peak value. In addition, after the end of growing season, the active layer of permafrost will accumulate a large number of $CH_4$ and released from soil results from physical compression in early winter. So that compare with growing season there will probably have a similar emission of $CH_4$.

### 1.2 OBJECTIVE OF THIS RESEARCH

The objective of this research is estimate the methane flux in RespublikaSakha of Russia based on models which related the land surface temperature (LST), normal difference vegetation index (NDVI) and snow water evaporation (SWE).

## 2 METHODOLOGY

### 2.1 DATA USED IN THIS STUDY

Figure 1 shows a process of $CH_4$ emission estimation using which affected parameters. There are three kinds of data used in this study including, (a) Normalized Difference Vegetation Index (NDVI), (b) Land Surface Temperature (LST) and (c) Snow Water Evaporation (SWE).

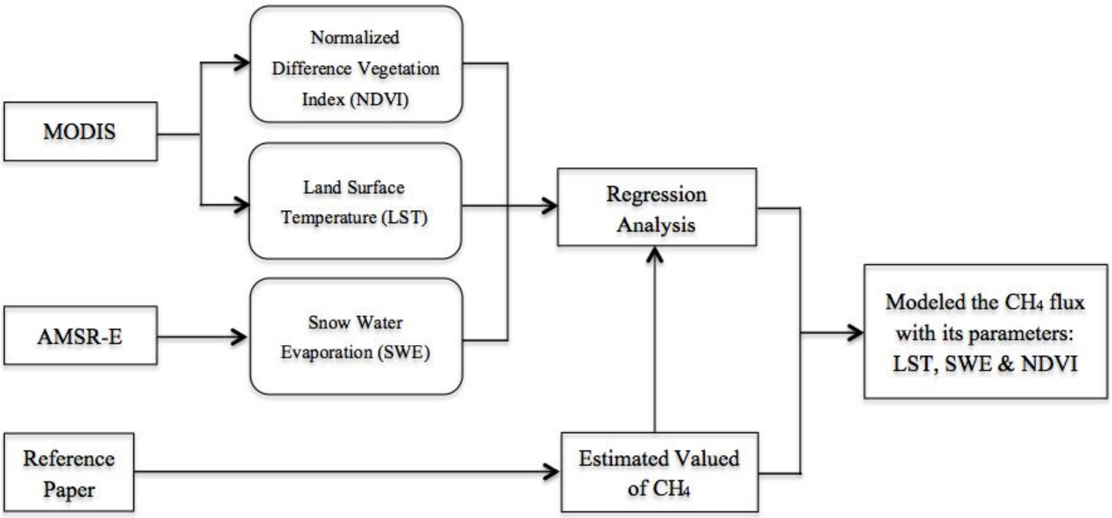



**Figure 1.** Flowchart of framework of $CH_4$ emission estimation using NDVI, LST and SWE

### 2.2 STUDY SITE

The study site is located in Lena River Delta (72°~73.8°N, 122°~129.5°E) of eastern Siberia at a point 72.37°N, 126.50°E (Fig.2), named RespublikaSakha. Lena Delta Wildlife Reserve is in the far north of eastern Siberia, Russia. It has a total land area of 61,000 km$^2$, making it the largest protected area in Russia. The delta itself has a size of about 30,000 km$^2$, making it one of the largest of the world (Hubberten et al., 2006).

In this study, collecting interrelation data from 2003 to 2011for estimate the $CH_4$ flux. The detail will be showed in next part.

## 3 RESULTS AND DISCUSSIONS

### 3.1 METHANE ESTIMATION MODEL

Equation (1) shows an estimation of methane emission as a function of NDVI. Equation (2) has a same theory as (1) and with LST function. The $y_{CH_4}$ represents methane emission (mg/m$^2$/year).

$$F(NDVI): y_{CH_4} = 0.1505 \times NDVI + 33.371 \qquad (1)$$

$$F(LST): y_{CH_4} = 0.4181 \times LST + 37.102 \qquad (2)$$

$$F(SNOW): y_{CH_4} = Average\ of\ CH_4(2003) \qquad (3)$$

Figure 3 shows the comparison of *F(NDVI), F(LST)* and *F(SNOW)* as methane emission. Overall, a modeled methane emission all shows very good time-series of behaviors along with that of in-situ measurement.

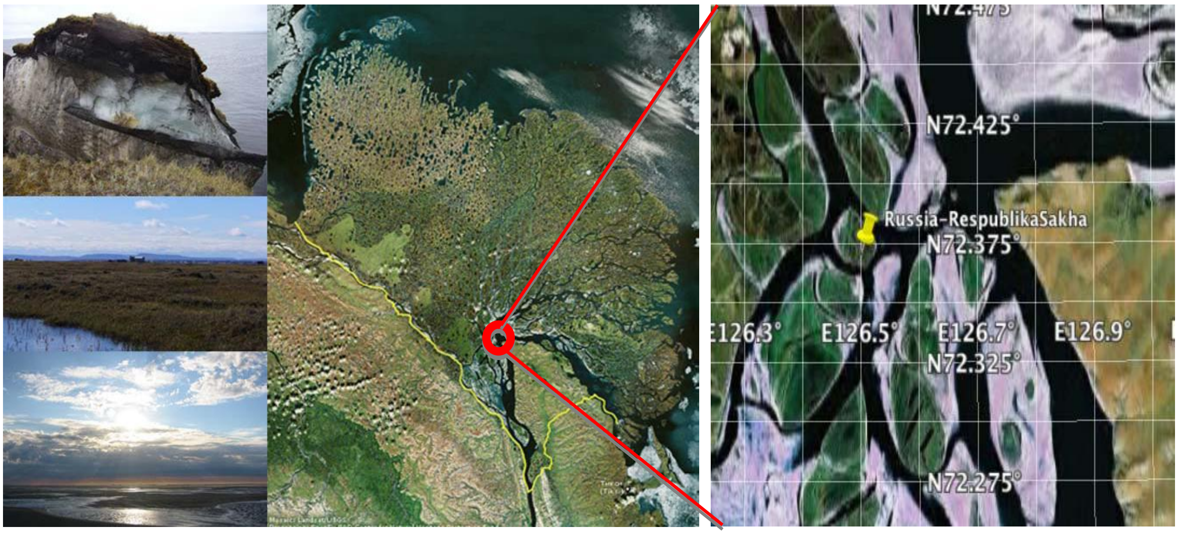
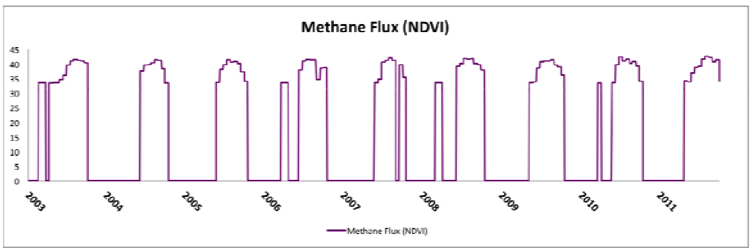



**Figure 2.** The study area where covered by permafrost wetland (referenced from google earth and image)

### 3.2 CHARACTERISTIC OF MODELED $CH_4$

Figure 3 shows the relationship among $CH_4$ with NDVI, LST and SWE respectively. Firstly, the methane flux with function of NDVI appears normal phenomenon as growing season. From early June (around the 161 days), the methane flux will gradually increased and the high vale will concentrate in June, July and August. Most of methane flux will released in this period. Secondly, this phenomenon also appears a perfect agreement in LST function plot. After temperature rose, the vegetation growing and cause methane flux happened and go up.

About methane flux of SWE function, used the mean value of reference paper in 2003 (Christian Wille et al., 2008) because of the data shortage. In this study the satellite data of SWE from AMSR-E provide the onset and offset date of snow so that it used as the duration in the plot.



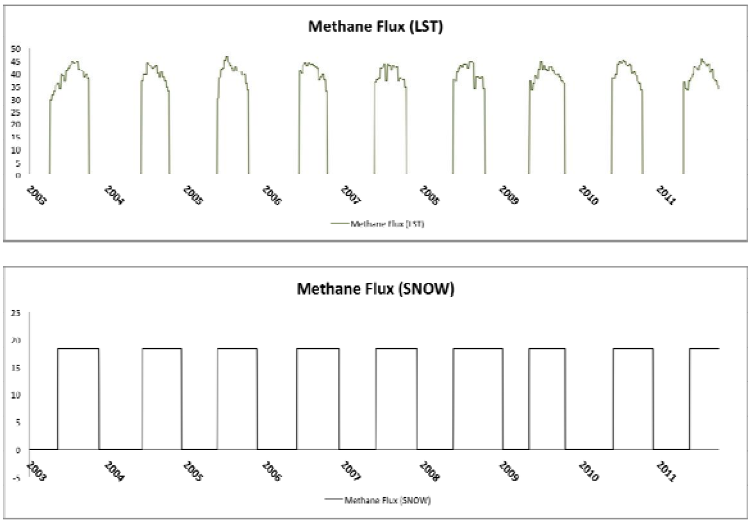



**Figure 3.** The modeled result of methane emission estimation

**Table 1.** Statistic value of $CH_4$ flux from 2003 to 2011

| Year | | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | Average (mg/m²/yr) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $CH_4$ (NDVI) | Flux (mg/m²/yr) | 2010.26 | 1975.08 | 1955.26 | 1990.8 | 2125.68 | 2101.83 | 1971.37 | 2257.08 | 2304.57 | 2076.91 |
| | Duration(day) | 208 | 128 | 144 | 160 | 128 | 160 | 160 | 157 | 161 | |
| $CH_4$ (LST) | Flux (mg/m²/yr) | 1345.68 | 949.93 | 1501.84 | 1054.15 | 833.16 | 998.95 | 1028.97 | 1097.90 | 1141.76 | 1105.81 |
| | Duration(day) | 176 | 128 | 144 | 128 | 144 | 144 | 160 | 141 | 161 | |
| $CH_4$ (SNOW) | Flux (mg/m²/d) | 18.28 | 18.28 | 18.28 | 18.28 | 18.28 | 18.28 | 18.28 | 18.28 | 18.28 | - |
| | Duration(day) | 188 | 178 | 180 | 192 | 186 | 220 | 169 | 185 | 134 | |
| $CH_4$ (*Reference value) | Flux (mg/m²/yr) | 1737 | - | - | 1458 | - | - | - | - | - | - |
| | Duration(day) | 95 | - | - | 70 | - | - | - | - | - | - |

*: Christian Wille, etc. 2008, Global Change Biology (2008) 14, 1395–1408;
Torsten Sachs, etc. 2010, Global Change Biology (2010) 16, 3096–3110.

Table 1 is statistic value of methane emission based on three kinds of parameters from 2003 to 2011. According NDVI function, methane flux in each year has an average of 2076.91 mg/m$^2$ in average 156 days. At LST function, it has 1105.81 mg/m$^2$/yr, half of NDVI function in average 147 days. This phenomenon could be explained in early winter the land surface temperature nearly zero and appears very stable condition and this condition could sustain around 1 month. At the same time, the vegetation almost died of old age and the soil become freezing. Result of this reason, there is a hypothesis that the methane flux still happened released from the soil because of physical mechanical effects in cold whether condition even there is no vegetation. Overall, all values have no big difference in recent nine years, express average.

Compare with reference value, the result of equation (1) was overestimated and from equation (2) was underestimated. This could be result from two reasons: (a) the simple linear regression analysis cannot express comprehensive effects of all parameters and (b) in reference paper it has some peak values which are abnormal because of specific factors influence the model. But it is the best probably model and results so far take advantage of NDVI and LST data we have without any field measurement.

## 4 CONCLUSIONS AND FUTURE WORKS

This research is estimate the methane emission in permafrost wetland area RespublikaSakha within three parameters respectively. The model used in this study was referred from a published paper (Christian Wille et al., 2008). The methane flux values from that paper were read and contrast with the data in hand and through confirm the usability. The more complicate model and analysis will be considered in future work. And another target is extends the research from specific point to region, find out more useable and enforceable expression.

In the past, people always focus on the vegetation growing season analyze the $CH_4$ emission of wetland. So the innovation of future work is not only estimate the $CH_4$ emission in growing season but also try to find out another peak value in early winter and get a quantitative result to describe wetland $CH_4$ emission and show the significant influence for change of global climate and $CH_4$ emission seasonal distribution mode.

## REFERENCES:

Elaine Matthews , Inez Fung (1987), Methane emission from natural wetlands: global distribution, area and environmental characteristics of sources. Global biogeochemical Cycles, 1(1): 61-86.

Christian Wille, Lars Kutzbach, Torsten Sachs, Dirk Wagner And Eva-Maria Pfeiffer, Methane emission from Siberian arctic polygonal tundra: eddy covariance measurements and modeling. Global Change Biology (2008) 14, 1395–1408.

Sun Xiaoxin, Song Changchun (2011), Effect of permafrost degradation on methane emission in wetlands: a review. Acta Ecologica Sinica, 31(18): 5379-5386.

Mikhail Mastepanov, Charlotte Sigsgaard, Edward J. Dlugokencky, Sander Houweling, Lena Strom, Mikkel P. Tamstorf, Torben R. Christensen (2008), Large tundra methane burst during onset of freezing. Nature, 146 (4).

Wataru Takeuchia, Masayuki Tamurab, Yoshifumi Yasuokaa (2003). Estimation of methane emission from west Siberian wetland by Scaling between NOAA_AVHRR and SPOT_HRV data. Remote Sensing of Environment 85, 21–29.

David M. Lawrence and Andrew G. Slater (2005). A projection of severe near-surface permafrost degradation during the 21st century. GEOPHYSICAL RESEARCH LETTERS, VOL. 32, L24401.

T J Bohn, D P Lettenmaier, K Sathulur, L C Bowling, E Podest, K C McDonald and T Friborg (2007). Methane emissions from western Siberian wetlands: heterogeneity and sensitivity to climate change. ENVIRONMENTAL RESEARCH LETTERS, 2, 045015.

Torsten Sachs, Christian Wille, Julia Boike and Lars Kutzbach (2007). Environmental controls on ecosystem-scale CH4 emission from polygonal tundra in the Lena River Delta, Siberia. OURNAL OF GEOPHYSICAL RESEARCH, VOL. 113, G00A03.

D. Wagner, S. Kobabe, E.-M. Pfeiffer and H.-W. Hubberten. Microbial Controls on Methane Fluxes from a Polygonal Tundra of the Lena Delta, Siberia. Permafrost and Periglac. Process., 14: 173–185 (2003).

Tomoko Nakano, Shunich Kuniyoshi, Masami Fukuda. Temporal variation in methane emission from tundra wetlands in a permafrost area, northeastern Siberia. Atmospheric Environment 34,1205-1213,2000.