論文の内容の要旨

論文題目:　ESTIMATION OF METHANE EMISSION FROM NATURAL WETLANDS IN THE NORTHERN PERMAFROST REGION BY REMOTE SENSING AND BIO-GEOPHYSICAL MODELING
(リモートセンシングと生物・地球物理学的モデルを用いた永久凍土地帯からのメタン発生量の推定)

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Wetland is one of the main sources of atmospheric methane. The increasing emission of atmospheric methane has brought great influence to global climate change and it is necessary to estimate wetland methane emission accurately. The methane has 20 times stronger greenhouse effect compared with the same amount of carbon dioxide. From the fifth report of the IPCC, by the end of the 21st century, global warming will cause that most of the active layer depth will increase by 30% to 40% of the northern hemisphere and the changes in climate will be expected to produce changes in the energy balance at the ground active layer. The increased active layer depth will provide greater anaerobic environment and increase methane emissions. Methane emission from anaerobic soil is released to the atmosphere by three ways including diffusion, ebullition and plant-mediated transport. These biochemical processes are greatly effected by the water condition in soil. The methane emission depends on the water table depth and therefore the land surface water coverage was considered in this study. The study site covers the whole Siberian (41°N~83°N, 27°E~180°E) permafrost area. The north coast of study area belongs to arctic climate, and the southernmost part has cold winters and fairly warm summer for at least 4 months. Methane estimation methods are evaluated as the two kinds of values, emission and concentration. In this study, bio-geophysical models were derived based on in-situ measurements integrated with vegetation index and temperature data which were obtained from satellite measurements to cover huge areas.

Firstly, the wetland selected from ENVISAT MERIS global land-cover data. The MERIS global land cover data has 300m spatial resolution with in 22 land cover classes. As a source of methane emission, 5 of them used to represent wetland in this study.

Secondly, the land surface dynamics were investigated by AMSR-E data. Land surface water coverage (LSWC) and snow coverage were computed by normalized polarization index. LSWC and snow coverage in wetland area were mapped over wetland land cover map from 2003 to 2010 in daily basis. The result indicated that LSWC gradually increased 3.31% of area in 2010 through 8 years from 2003; snow coverage shrunk about 2.11% of area at the same time. The results implied that summer season (LSWC onset time) started earlier and the continuing period was longer in 2010 than that in 2003.

Thirdly, bio-geophysical models are derived from the in-situ measurement published by Wille's. The models are defined as the function of land surface temperature (LST) and normalized difference vegetation index (NDVI) by MODIS from 2001 to 2012. The models are composed of three types including CH4_lst, CH4_ndvi and CH4_Ndl. They are applied to the wetland map derived from MERIS global land-cover data. Through applied models on different land cover types, we found that shurbland and grassland area are identified as the biggest source of methane in permafrost area. Moreover, through applied models on all land cover, the results showed positive methane growth rate, 0.24% (CH4_lst), 4.74% (CH4_ndvi) and 0.36% (CH4_Ndl) in 2012 respectively compare with those of 2003. This result indicated that the methane emissions would increase according as increase of melting permafrost due to climate warming.

Fourthly, the column averaged methane concentration data of SCanning Imaging Absorption spectroMeter for Atmospheric CHartography (SCIAMACHY) were used to provide the seasonal variation of methane concentration from 2003 to 2010. From 2003 to 2010, around 13% of methane concentration growth rate over 8 years was observed by SCIAMACHY compared with the emission estimation mentioned above. The Pearson's correlations were carried out between SCIAMACHY concentration data and modeled methane emissions. The results showed that the models well represents seasonal dynamics of methane emissions over the years, however, some methane concentration anomalies were found in April and September. The Probable reasons for those anomalies were considered as sensor's degradation since 2005 and errors originated from lower tropopause height. The temperature anomaly were found in September when ground surface freeze quickly and pushed out amount of methane from the soil and in April when accumulated methane under the ground in previous year will released to the atmosphere along with ground melting.

Finally, the emission estimated derived from our models were compared with several inventory data and satellite observations including World Data Center of Greenhouse Gas (WDCGG), Emission Database for Global Atmospheric Research (EDGAR) and Greenhouse Gases Observing Satellite (GOSAT). WDCGG consist of measurement data and associated metadata of methane and the other related trace gas from various platforms. EDGAR is global anthropogenic emissions of greenhouse gases and air pollutants by country basis. GOSAT measures column averaged concentration of greenhouse gas since 2009. Its restriction is limited global coverage due to sampling pattern. In this study, one station (69.2N 35.1E) from WDCGG was used to do comparison analysis with methane estimation results and SCIAMACHY. Methane concentration of the satation indicated increasing tendency from 1999 to 2012, in which was consistant with the estimation results of this study. SCIAMACHY concentration at that point also indicated increasing tendency but showed much bigger fluctuation than in WDCGG.

Uncertainties and limitations still remain in estimation models, satellite data and in-situ measurements. They are dependent on climate parameters such as soil moisture, wind speed, atmospheric pressure, topography, atmospheric circulation and tropopause height. That's why the satellite data appear abnormal values sometimes. In order to let emission and concentration value comparable, the atmospheric transport model should be considered. It is important that doing more investigations and exploring the fusion of scientific techniques is necessary to remedy those limitations.