S2–P1

SOIL MOISTURE AND PERMAFROST CONDITIONS AT NEWLY ESTABLISHED YAKUTSK–VILYUY TRANSECT

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Soil moisture and temperature near the land surface had abruptly increased since 2004 in continuous permafrost region in the central Lena river basin (Iijima et al., 2010). According to gravity changes in this region detected by GRACE satellite (Velicogna et al., 2012), terrestrial water storage had an increasing trend in the basin of Siberian rivers, with the largest increase noted in the central Lena River basin. Increasing in water storage under wet climate forces the active layer to retain soil moisture. The hydrological processes likely lead to further enhancement of permafrost degradation and changes in forest ecosystems. The center of action in the water storage increase was detected in the Vilyuy river basin, where the frozen ice content and alas formation are small due to sandy loam deposits on river terrace. In July and September 2012, we established new soil temperature and moisture observation stations from Yakutsk to Chernoshevsky along Vilyuy River basin (Fig. 1). Each station set boreholes for soil temperature and frost tube (4.0m depth) and an access tube for soil moisture (2.0m). The pit survey of heat and water properties within active layer during the installation, high soil moisture still remained at the deeper part of the active layer at most of the site, and moreover saturated water layer (talik) was formed at Tangnary stations. These results showed that soil water and heat changes were perennially carried over in this area after wet years.

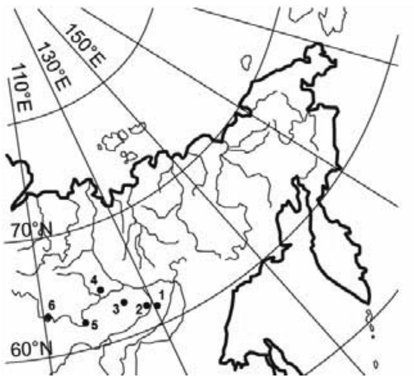

Figure 1 New soil moisture and temperature stations.
1: Yukechi, 2: Spasskayapad & Neleger, 3: Ort-sort & Tangnary, 4: Khoro, 5: Suntar, 6: Chernoshevsky

Iijima et al. (2010) Permafrost and Periglacial Processes, 21, 30–41.
Velicogna et al. (2012) Geophysical Research Letters, 39, L09403.

S2–P2

ECOHYDROLOGY IN ALASKA'S BOREAL FOREST: INTERPRETING MEASUREMENTS OF WATER VAPOR ISOTOPES FROM AIRCRAFT AND SATELLITE SENSORS

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Water vapor isotopes such as Deuterium and ^{18}O can be useful tracers for the movement of water through the environment. In the Far North, we are interested in changes to the hydrologic system and the role of ecosystems. In particular, we postulate that the amount of moisture recycled between the atmosphere and the land surface during summer, may change with a warmer climate and we are interested in observing these patterns under differing conditions. Ecosystems play a critical role in conveying moisture from the subsurface to the atmosphere. Members of our research team integrated and then flew a Picarro laser spectroscopy instrument in an aircraft to measure water vapor over the boreal forest during 2010-2012. We also collaborated to calibrate the Tropospheric Emissions Spectrometer onboard the Aura satellite for Interior Alaska. Patterns of variability in these datasets and their physical drivers will be the subject of this presentation.

S2–P3

RECONSTRUCTION OF PAST 100 YEARS SOIL MOISTURE IN EASTERN SIBERIA BY USING DELTA-13C OF LARCH TREE RINGS

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Climate in eastern Siberian Taiga forest has experienced significant changes during the past few decades. Changes in hydrothermal conditions contribute to some change in surface soil moisture, which is an important control on the interactions among the hydrosphere, biosphere and atmosphere. Soil moisture records in eastern Siberia are sparsely available and not lengthy (less than 20-year period). Therefore, long records of soil moisture or some other hydrological variables are necessary to place the current moisture variability for this climatically sensitive region in a long term context. Thus, we tried to reconstruct past soil moisture water equivalent (SWE) from delta-^{13}C of tree ring.

Larch trees (Larix cajanderi) collected in Yakutsk (62°N, 129°E) were used for the analyses of tree ring width and its carbon isotope ratio. The samples were crossdated with ITRDB's (International Tree-Ring Data Bank) ring-width records in eastern Siberia. SWE in late growing season (7/15-8/31) for the past 100 years was reconstructed form the delta-^{13}C of larch tree ring.

Reconstructed SWE was compared with various factors such as temperature in the growing season of June–July–August (JJA), annual precipitation (from previous August to current July), and calculated results of past SWE from a one-dimensional land surface model and Palmer Drought Severity Index (PDSI) for July; Form these comparisons, reconstructed SWE appear to be reasonable. Tree ring-width index and δ^{13}C were negatively correlated in most periods. However, positive or less negative correlations were detected in the 1920s and 1970s, corresponding to periods in which relatively low air temperature was observed and the estimated SWE was larger than that expected from annual precipitation. These results indicate that tree-ring δ^{13}C has been mostly controlled by stomatal conductance (g) in this region, but has at times been affected by photosynthetic rate (A) during cool periods. A comparison between δ^{13}C and the width of tree-ring chronologies enabled reliable evaluation of the reconstructed SWE. Reconstructed SWE showed significant variation in the past 100 years. Severe droughts have repeatedly occurred in this region, and very high soil moisture observed in 2006–2007 marked the extreme.

S2–P4

INVESTIGATION OF ENERGY BALANCE ABOVE A LARCH FOREST IN CENTRAL YAKUTIA

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The components of energy balance were measured above the canopy of a coniferous forest dominated by *Larix cajanderi* over growing season in 2010 and 2011. Sensible and latent heat fluxes were measured by eddy covariance system.

The fluxes reached maximum values in midsummer (end of June and beginning of July) with magnitudes of about 400 / 280 W/m^2 in 2010 and 200 / 150 W/m^2 in 2011 for sensible / latent flux respectively.

Seasonal variability of the Bowen ratio was similar both years and on average made 1.3-1.4. Diurnally the Bowen ratio is above zero between 07:00 AM and 08:00 PM. The evaporative fraction was calculated from the Bowen ratio that had two peaks in diurnal range at 06:00 AM and 08:00 PM.

Latent heat flux was of dome-like shape and showed maximum in June/July (156.8/153.8 W/m^2 in 2010 and 87.1/101.9 W/m^2 in 2011). This difference between two years is a result of higher amount of precipitation in 2010. The seasonal sum of precipitation in 2010 was 154.7 mm compared to 123.8 mm in 2011. In midsummer the potential evapotranspiration rate in 2010 was 1.5 times higher than in 2011, because of warm summer with enough amount of available water in the ecosystem.

S2–P5

SOIL WATER CHANGE IN EASTERN SIBERIAN TAIGA FORESTS SIMULATED BY A ONE-DIMENSIONAL LAND-SURFACE MODEL

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Soil water and temperature is simulated in some eastern Siberian taiga forests by a one-dimensional land-surface model. The model is composed of three submodels; vegetation, snow cover, and soil. It can calculate profiles of soil water/temperature as well as snow cover, and water/energy fluxes above and within forest, if meteorological data over the forest are given as input. The data used in this study are Baseline Meteorological Data in Siberia (BMDS) Version 5. In Yakutsk, the simulation period is 1966 - 2008. The simulated column soil water indicates variation with about ten year's period; it corresponds with reconstructed soil moisture based on delta 13C of tree rings. The influence of soil water initial condition on the simulation disappears about eight years later. Significant rising of soil water and temperature is observed after 2004 around Yakutsk. The model also calculated soil water/temperature rising, however the drastic change cannot be simulated. It is suggested that precipitation in early winter (snow depth) affects the temperature rising. The results for Kirensk, Chokurdah and Ust'-Maja will be presented in the symposium.

S2–P6

FINE ROOT BIOMASS OF BLACK SPRUCE AT STANDS WITH DIFFERENT DEPTHS OF PERMAFROST TABLE

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Background: Fine roots (root < 2 mm in diameter) are a key component of forest carbon dynamics. Fine roots are a major pathway of belowground carbon flux of black spruce stands (Fig. 1), which dominate areas underlain with permafrost in interior Alaska (1). However, effects of permafrost conditions on fine roots are not well understood. In this study, we examined fine root biomass in two black spruce stands with different depths to permafrost table.

Study site: This study was conducted in two black spruce stands in interior Alaska, which are located at different slope positions on the same north-facing slope. The depth to the permafrost table (summer in 2010) was 113 cm at the upper slope site compared to 67 cm on the lower slope site. Aboveground biomass of black spruce in the lower slope site (1.9 kg m^{-2}) was 33% of that in the upper slope site (5.6 kg m^{-2}).

Results and Discussion: Fine root/aboveground biomass ratio was larger in the lower slope site (0.46) than in upper slope site (0.22). Biomass of very fine roots (< 0.5 mm in diameter) was not significantly different between the two sites, whereas that of fine roots with larger diameter (0.5-2.0 mm) was significantly smaller in the lower slope site than in upper slope site (Fig. 2). These results suggest that in sites with shallow permafrost table, black spruce allocates more biomass into fine roots, especially to those with smaller diameter, likely to facilitate efficient acquisition of limited belowground resources.

Fig. 1. Fine roots of black spruce

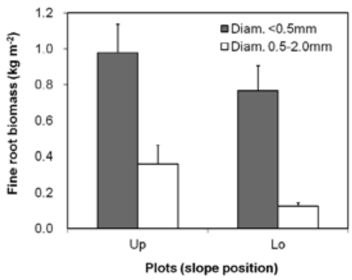

Fig. 2. Fine root biomass of black spruce on different slope positions

(1) Ruess et al. (2003) Ecol Monogr 73: 643-662

S2–P7

ENERGY AND CARBON EXCHANGES OVER THE LARCH FORESTS ON THE PERMAFROST IN MONGOLIA

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To clarify the heat, water carbon exchange process and dynamics by comprehensive approach, we've carried out the long term monitoring of the energy and carbon balances, the hydroclimatic, the phonological camera monitoring and sap flow measurement at the 25-m height tower and larch forest around the tower in the Udleg (48 15'43.7" N, 106 50'56.6"E, altitude: 1264m) in permafrost area of northern Mongolia since 2010. According to the image analysis of in situ camera and PAR albedo data, we clarified the seasonal variation of surface condition and phenology of larch forest. From January to March, November and December, there was continuous snow cover. In late May the leaf of larch emerged and attained the mature growth in July, and then the leaf senescence occurred in mid September. The soil moisture at 10 cm depth was less than 10% before April, then it gradually increase in May to 20% in August, after that it decreases to less than 10% from October. The temporal variation of soil moisture matched to temporal variation of rainfall. The soil temperature below 3m was about -0.2 degree C in all year round that suggests that there is the permafrost. In late May the latent heat flux start to increase with soil moisture and become dominant component of energy fluxes from mid June to early September when the carbon uptake was active. From mid September to early June, the sensible heat flux was dominant component of energy fluxes when the surface was carbon source. We found that the close relationship between phenology (leaf emergence, growth and senescence) of larch trees with hydro-climate condition (soil moisture and snow cover) and energy/carbon budget. We investigated the effect of the hydro-meteorological conditions on energy and carbon budget.

S2–P8

FEATURES OF SOIL CO_2 EFFLUX IN TAIGA LARCH FORESTS OF CENTRAL AND SOUTH-EASTERN YAKUTIA

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Long-term monitoring studies of soil CO_2 efflux was carried out during 2 seasons (April – October) in 2010 and 2011 at two sites: “Spasskya Pad” site in Central Yakutia with low-productive light taiga and “Elgeeii” site in South-Eastern Yakutia in larch forest with higher biomass, both sites with dominance of 150-180 years old *Larix cajanderi* trees, using automated semi-open chamber systems with simultaneous measurements of environmental parameters.

There are no big differences in environmental conditions between the sites during the growing season except twice higher soil water content in the south-eastern site while summer-time precipitation in Central Yakutia was 10-20% less. Average air and soil temperatures are almost same at both sites, fluctuating a little depending on year.

The main environmental factor, affecting soil CO_2 flux, was soil temperature at both sites. At the same time, precipitation (and, accordingly, soil moisture) plays an important role on seasonal scale as well. Maximum soil respiration during season in “Elgeeii” was observed in mid July (10.3 μmol CO_2 m^{-2} s^{-1}), but in “Spasskaya Pad” it was discovered in early August (4.7 μmol CO_2 m^{-2} s^{-1}). Calculated accumulated soil carbon efflux in the south-eastern site was more than twice higher than in Central Yakutia (8.64 t C ha^{-1} and 4.34 t C ha^{-1} respectively). The main reason of this difference most probably is a higher soil biota activity (including roots) at the south-eastern site. Increasing of precipitation amount and soil temperature in high latitudes along with global climate changes will cause escalating of soil biological activity and dramatic fluctuations in soil carbon pools, CO_2 emission included, and finally will lead to soil degradation with abrupt changes in carbon exchange processes in northern forest ecosystems.

S2–P9

Permafrost carbon and climate feedbacks enhance Arctic ecohydrological processes

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Permafrost is considered vulnerable to increasing temperatures. Air temperatures over the Arctic have indeed increased considerably over the last century. Most climate models project that the warming will continue, enhancing permafrost degradation. The degradation of permafrost has the potential to initiate numerous feedbacks, predominantly positive, in the Arctic climatic, hydrological, and biogeochemical processes. For instance, the Arctic terrestrial evapotranspiration during summer season tends to exceed precipitation of the period. The imbalance of water budget may be offset by permafrost thaw and its associated hydrologic impacts. However, we do not have enough knowledge for a definitive explanation of the role of permafrost to the ecohydrological processes. The purpose of this study is to assess influences of permafrost dynamics (i.e. active layer thickness, ALT) on ecohydrological processes (i.e. evapotranspiration (ET) and net primary production (NPP)).

A land surface model CHANGE, including hydrological and biogeochemical processes, was applied to the pan-Arctic terrestrial region over the period 1901-2010. For exploring the influence of ALT on ecohydrological processes, two-way simulation experiments were conducted: (1) the hydrothermal effect of permafrost carbon vertical profile is determined (control experiment) and (2) a uniform rise of air temperature by 3℃ is applied to 1971–2010 based on experiment (1) (warming experiment). We assessed the influence of ALT variability on ET and NPP through the comparison between the two experiments.

In the control experiment, the ALT increased during the study period. The increase was significant in the southern discontinuous permafrost regions, primarily in North America rather than Eurasia. The increase of ALT resulted in increases in ET and NPP due to the alleviation of water stress. When air temperature was increased by 3℃, both ET and NPP increased by 10–40% compared to the control experiment. Higher ET driven by increased temperature should result in drier soil. However, the increased NPP associated with temperature increase resulted in an increase of soil organic matter, which increased its soil water-holding capacity and limited soil warming due to its insulation effect. These effects of permafrost carbon tended to keep summertime ET and NPP relatively high.

S2–P10

APPLICATION OF STABLE ISOTOPE RATIOS OF C AND N TO CARBON ASSIMILATION AND NITROGEN UTILIZATION OF LARCH IN ARCTIC ECOSYSTEM OF EASTERN SIBERIA

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North Eastern Eurasia is covered by permafrost which is the largest and the deepest in the world, and in arctic region, larch dominated tree line ecosystem, taiga-tundra boundary ecosystem, exists on it. It is expected that larch growth in arctic ecosystem is greatly affected by global warming due to sensitivity of moisture condition and possible availability of N. It is necessary to investigate the related controlling factors on C assimilation and N utilization of larch. Observations were conducted at different sites with different tree density and topography near Chokurdakh (70°37'N,147°53'E), Sakha, Russia, in July from 2008 to 2011. Diurnal photosynthetic rate, C and N contents in needle and stem and related stable isotope ratios were observed for larch.

Photosynthetic rate linearly increased with Photosynthetically Available Radiation (PAR). The needle mass was positively correlated with needle nitrogen, needle area, and needle $\delta^{13}C$. Among the sites, nitrogen content of needles increased with needle $\delta^{13}C$. At the sites where the topography level is higher and the soil condition is dry, larger needle mass and larger sizes of trees were found than the sites with wetter condition. Nitrogen content of needle in the year was positively correlated with needle $\delta^{13}C$ in the following year, although the year to year variation in needle nitrogen content was small at wetter sites.

These results show that solar radiation and nitrogen are important factors affecting C assimilation of larch, and nitrogen availability is possibly controlled by soil moisture and texture.

S2–P11

The effect of the feedback cycle between the soil organic carbon and the soil hydrologic and thermal dynamics

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Biogeochemical feedback processes between soil organic carbon (SOC) in high-latitude organic soils and climate change is of great concern for projecting future climate. More accurate models of the SOC stock and its dynamics in organic soil are of increasing importance. As a first step toward creating a soil model that accurately represents SOC dynamics, we have created the Physical and Biogeochemical Soil Dynamics Model (PB-SDM) that couples a land surface model with a SOC dynamics model to simulate the feedback cycle of SOC accumulation and thermal hydrological dynamics of high-latitude soils. The model successfully simulated soil temperatures for observed data from a boreal forest near Fairbanks, and 2000 year simulations indicated that the effect of the feedback cycle of SOC accumulation on soil thickness would result in significant differences in the amount of SOC.

DYNAMICS AND LARCH UPTAKE OF NITROGEN IN THE NORTH EASTERN SIBERIA TAIGA FOREST

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Nitrogen (N) is known to be one of the major limiting factors for plant growth in the northern hemisphere. CO_2 assimilation is directly related to nitrogen contents in the plant leaf as it is the major component of photosynthetic system.

We conducted the study on N dynamics at Spasskaya Pad Experimental forest station located near Yakutsk city, Russia in 2009-2011 years. Amount of N input with atmospheric deposition occurred to be very low. It was found that large amount of soil N was mineralized during vegetation season every year. Increase of inorganic N in the soil pool was closely related to soil temperatures accumulation during summer time. However, in the beginning of the next growing season the content of inorganic N in the soil pool was very low again. Amount of water extractable N in the soil was much lower than KCl extractable, which is related to existence of clay particles in the soil constitution.

The discrepancy between N mineralization by soil microorganisms and plant N demand timing led to specific mechanism of nutrient accumulation in larch trees. The recovery of N prior to needle senescence was very high. Also allocation of uptaken N varied during growing season. N that was uptaken in the beginning of growing season (June) was used for the growth of new organs, such as new shoots and needles, however N that was uptaken in the middle of growing season (from the mid-July) was stored in the tree perennial parts (branches, trunk and especially buds) to be used in the beginning of the next growing season. Therefore, needle N content was affected by the previous growing season environmental conditions.

Needle N content affected amount of needles in the litterfall with one year delay. Therefore, there was a positive relationship between N availability and amount of CO_2 assimilated by larch trees in the area of study.

S2–P13

Developing a methane emission model for Siberian river floodplains

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Methane contributes significantly to global warming. Methane emission is essentially the net result of a balance between CH_4 production by methanogenic bacteria in anaerobic soil zones, and CH_4 oxidation by methanotrophic bacteria in aerated soil zones and plants. Arctic and sub---arctic permafrost holds a large amount of climate vulnerable carbon. In particular river floodplains are carbon--- rich soils. River floodplains in this area are periodically or permanently submerged. The occurrence of flooding decreases soil oxygen availability, providing an ideal anaerobic environment for methane generation. The extension of flooded area links strongly to the amount of methane released to the atmosphere. Here we describe the coupling of a newly developed river flooding model, to be coupled with the Peatland---VU wetland methane emission model, in order to better explain spatial and temporal variations in methane emissions from northern permafrost.

S2–P14

METHANE AND ORGANIC MATTER IN PERMAFROST OBSERVED AT CHOKURDAKH (EASTERN SIBERIA)

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Methane is effective greenhouse gas (GHG), which is 20 times stronger than carbon dioxide. Being stored in permafrost areas and released as the result of the global warming, it accelerates the processes. Organic matter stored in the permafrost may also be converted to released by permafrost degradation, which in tern results emissions of GHG. We present the results of studying the ice core of permafrost area for the content of methane and organic matter, and it`s distribution depending on the sampling depth and type of landscape. Studies were carried out in the territory of Eastern Siberia, near the village of Chokurdakh (70N, 148E), Sakha republic. This place reflects the most wide spread type of landscape of the territory. We sampled the ice core obtained by drilling several boreholes down to 4.5 m. Obtained data shows that distribution of methane concentration is not linear at all depth and has some peaks, caused by processes of accumulation and storage of methane. The results can be used for calculation of methane flux after melting the ice core causing acceleration of the global warming.

S2–P15

CH_4 EMISSION FROM A TAIGA-TUNDRA ECOTONE OF EASTERN SIBERIA: PROCESS STUDY BY STABLE ISOTOPES

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The Arctic has a broad area of wetlands and it is one of the CH_4 sources to the atmosphere. Under the enhanced warming in the Arctic, increased soil temperature might strengthen the CH_4 emission, which could make a positive feedback to the climate. However, other conditions such as soil moisture or vegetation might be changed and affect the CH_4 emission as well. We observed CH_4 flux in summers of 2009 to 2012 by chamber method at each vegetation landscape of a taiga-tundra ecotone in Eastern Siberia, and aimed to clarify the processes of CH_4 production, oxidation, and transport to the atmosphere using stable isotopes. The observation sites were selected around Chokurdakh village (70.62N, 147.90E) in the lowland of Indigirka river basin: B site with isolated larch stands in tundra vegetation, K site where tree lines can be seen, and V site where forests exist partially. The observed flux was different among vegetation types. It was very small at tree mounds ((-0.15)-0.05 mgC m^{-2} h^{-1}), moderate at K graminoid wet area and K sphagnum wet area (not detected-2.2 mgC m^{-2} h^{-1}), and the largest at V graminoid wet area and B graminoid wet area (0.05-7.4 mgC m^{-2} h^{-1}). At wet areas, CH_4 flux was larger when the soil temperature was higher. CH_4 flux was correlated with CH_4 concentration in soil pore (at ca. 15 cm depth) while no significant correlation was found with that in surface water, except for the result observed at K graminoid wet area. Accordingly it can be thought that CH_4 was emitted from soil pore mainly through plant tissue not through surface water. On the other hand $d^{13}C$ of emitted CH_4 and soil pore CH_4 showed no correlation, indicating that $d^{13}C$-CH_4 changed during the emission process. While at V graminoid wet area and B graminoid wet area, where large CH_4 flux was observed, $d^{13}C$ of emitted CH_4 was much lower than that of soil pore CH_4, K sphagnum and K graminoid wet area, where CH_4 emission was moderate, had similar delta values. These results suggest a difference in the process of CH_4 emission.

S2–P16

Increased greenhouse gas emission from thaw ponds in Siberian arctic tundra on continuous permafrost

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Rising global temperatures threatens the stability of continuous permafrost environment, resulting in the release of previously frozen carbon, creating a positive climate feedback from terrestrial systems. The resulting permafrost degradation will impact on both a large scale, expansion of thaw lakes, and small-scale features, such as surficial pond formation and mass wasting.

The increased occurrence of thaw ponds and their impact on vegetation is been studied at the Kytalyk research station, located in Indigirka lowlands, Northeast Siberia. This area is located on the drained bed of an Early Holocene thaw lake. The area is characterised by the presence of low palsas (flat ice mounds), covered with mosses and Betula nana. The edges of these palsas are subject to frequent thawing, creating shallow ponds with decaying palsa vegetation.

Comparison, using high resolution satellite images from 1977 (American Keyhole project image) and 2010 (Geoeye), showed increased occurrence of thaw ponds over a 33 year period. Flux measurements from a selection of these ponds showed elevated emission of CO_2 and CH_4. Dead Betula nana produced fluxes of 106.84 mg $CO_2 m^{-2} hr^{-1}$ and 3.58 mg CH_4 m^{-2} hr^{-1} in the summer of 2011. However, a decrease of GHG fluxes occurs when Carex and Eriophorum (sedges) vegetation invades these ponds. The CH_4 m^{-2} hr^{-1} in 2010 and 3.9mgCH_4 emission from sedges is still high, 9.1 mg CH4 $m^2 hr^{-1}$ in 2011, but this is compensated by rapid CO_2 uptake. It is therefore likely that GHG emission from this type of shallow permafrost degradation is strongly influenced by ecosystem recovery rates.