Interannual and seasonal variation of energy, water and carbon exchanges on a transition zone of tundra and forest in Northeastern Siberia

Shin Miyazaki[1,2], Shunsuke Tei[1,3], Ivan Bragin[4], Rikie Suzuki[2], Shinya Takano[3],
Ryo Shingubara[3], Tomoki Morozumi[3], Atsuko Sugimoto[3] and Trofim Maximov[5]
[1]*National Institute of Polar Research, Japan,* [2]*Japan Agency for Marine-Earth Science and Technology, Japan,*
[3]*Hokkaido University, Japan,* [4]*FarEast Geological Institute, FE RAS,Russia,*
[5]*Institute for Biological Problems of Cryolithozone SD RAS, Russia*

1. Introduction

In Arctic, temperature has increased almost twice the global average rate in the past 100 years. We aim to clarify the land-atmosphere interaction on a transition zone of tundra and forest in northeastern Siberia, where the climate change effect might be remarkable. We have started the energy, water and carbon fluxes observation as well as hydro-meteorological observation in northeastern Siberia, Sakha Republic, Russia in June 2013. This study aims to investigate the interannual and seasonal variation of energy and carbon budget at the boundary between taiga and tundra in northeastern Siberia.

2. Material and methods

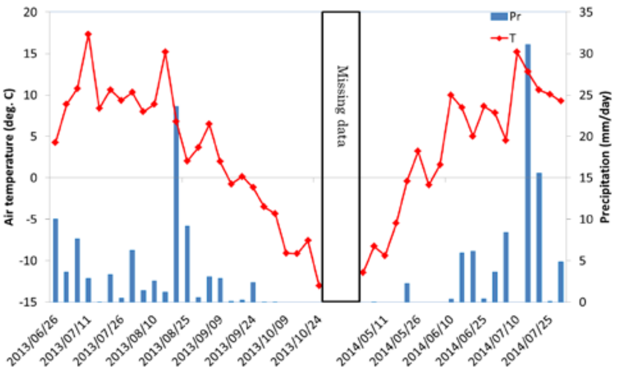
Our observation site is located at Kodack site (70.564 N, 148.267E, altitude 7m) about 100km south from East Siberian Sea in Arctic Ocean near Chokurdakh city in the North-Eastern Siberia, Sakha Republic, Russia. The Kodack site is forest tundra in the floodplain situated on a transition zone of tundra and forest along the Indigirka river basin (drainage area: 324,244km^2) which flow to the East Siberian Sea (Iwahana et al., 2014). The annual air temperature and precipitation are -13.4 deg. C and 200mm respectively (1979-2008, Baseline Meteorological Data in Siberia (BMDS) Ver.5.0, Yabuki et al., 2011). The surface is covered by snow except July and August and the maximum snow depth is 40cm in April. In this region, the permafrost exits and the active layer depth ranges from 25cm to 40cm (van der Molen et al., 2007). The topography at the site consists of higher mounds and lower wet lands, where the difference of the height is about 50cm. At the higher mound, the shrubs and larches (less than 3m height) are dominant, while the sedges, mosses, lichens, and dwarf shrubs are prevailing at the lower wet land (Iwahana et al., 2014). The meteorological and flux observation has been carried out over the dry mound area.

The air temperature, relative humidity, wind speed and direction, air pressure, precipitation were observed at 1.5m height. The incoming and outgoing shortwave and longwave radiation were observed by 4-compnent radiometer at 1.37m height. The soil heat flux was observed by heat flux plate at 0.05m depth. The soil temperature was observed by platinum sensor at depths of 0.025, 0.05, 0.225, 0.425, and 0.625 m. The soil moisture was observed by capacitance sensor at surface, and frequency domain reflectometry sensor at depths of 0.035, 0.145, 0.335, and 0.535 m. The energy and carbon fluxes were calculated by the eddy covariance method from the observed values of the sonic anemo-thermometer and infrared gas analyzer at 2.55m height. We stopped the observation on 27 October 2013 to avoid the out of order of instruments due to too cold environments in winter as well as no electricity by solar panels during polar night. We restarted our observation on 26 April 2014.

3. Results

Fig. 1 shows the time series of 5-day air temperature (Ta) and precipitation (Pr) in 2013 and 2014. The Ta dropped below 0 deg. C in late September 2013 and then the Ta exceeded 0 deg. C in late May 2014. The Pr in July 2013 (20 mm) was about half of August in 2013 (40 mm) while Pr in July 2014 (60 mm) was three times of the Pr in July 2013. The time series of 5-day soil temperature (Tg) is shown in Fig. 2. The Tg at the depths of 0.025, 0.05, 0.225 and 0.425m exceeded 0 deg. C in late May, early June, mid-June and mid-July in 2014, respectively. The Tg at the depth of 0.625m has never exceeded 0 deg. C while the Tg at other depths exceeded 0 deg. C in summer. Fig. 3 (a) and (b) show the time series of 5-day soil water content (Wg) at dry mound and wetland, respectively. The Wg at the depth of 0.145m (Wg_0.145) shows clear contrast between the dry mound (about 60% except winter) and wetland (less than 10% except summer). In 2014, the Wg_0.145 on dry mound increased to about 20% in mid-July reflected large amount of Pr in mid-July. The Wg at the depth of 0.335m was about 50% both on dry mound and the wetland except early summer and autumn. The Wg at the depth of 0.535 kept about 4 % both on dry mound and wetland, which was caused by frozen soil for all year round. The sensor for soil water content can measure the liquid phase water only as it shows the quite low value same as dry soil due to low dielectric content when the soil was frozen. The time series of 5-day energy and carbon budget in Fig. 4 (a) and (b), respectively. As the start of observation in 2013 was late June, the latent heat flux (LE) and the sensible heat flux (H) was almost same value. The rapid increase and higher value of the H was dominant from late May to mid-June than the LE in 2014. The net radiation (Rn) was negative value from early October 2013 to late May 2014 when the albedo was higher than 0.4 that meant the surface was covered by the snow. The start of rapid increasing of LE coincided with the timing of shifting from the positive (carbon source) to the negative value (carbon sink) of net ecosystem exchange (NEE) in late May 2014 when the snow and surface soil were melted. It suggests that the start of photosynthesis is closely related to the hydro-meteorological condition of ground surface.

Table 1 summarizes the monthly values in July in 2013 and 2014 to clarify the inter-annual variation of hydro-meteorological variables at Kodack site. As the Pr in 2014 (60.1mm) was three times of the Pr in 2013 (20.1mm), the incident solar radiation (Rs_d) in 2014 (179.0 W/m^2) was smaller than the Rs_d (203.1 W/m^2) in 2013. The Wg at the depth of 0.145m on dry mound (Wg_dry_0.145) in 2014 (15.7%) was quite higher than the Wg_dry_0.145 in 2013 (5.9%) due to much precipitation in 2014. The Tg at the depth of 0.025m in 2014 (10.4 deg. C) was higher than Tg_0.025 in 2013 (6.4 deg. C). The LE and H was almost same in both 2013 and 2014. The NEE in 2014 (-1.9 gC/m^2/day) was lower (higher carbon sink) than NEE in 2013 (-1.5 gC/m^2/day), which the Rs_d in 2014 was lower than the Rs_d in 2013 due to more precipitation in 2014 than the Pr in 2013. Further analysis using the data after August 2014 will be presented.



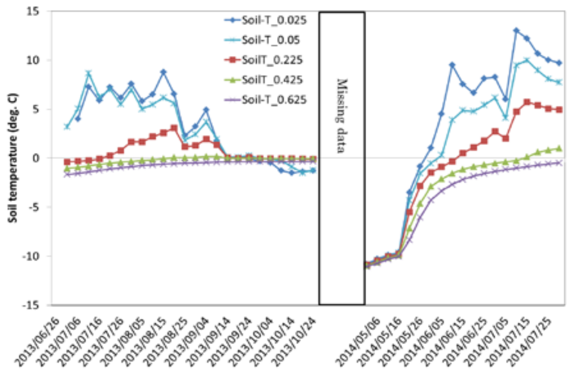
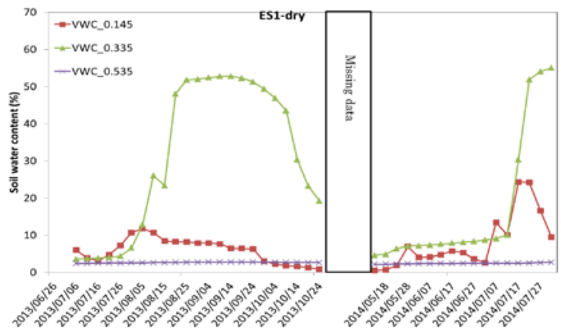


Fig.1: Time serises of 5-day air temperature and precipitation **Fig.2: Time series of 5-day soil temperature**



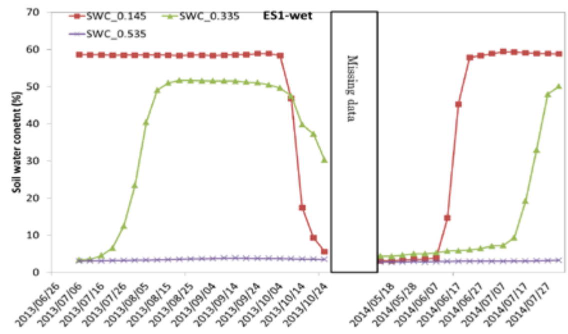
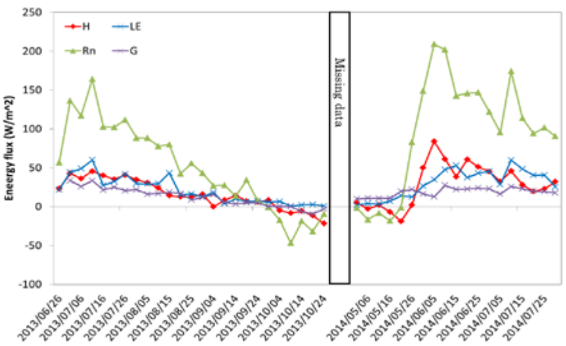


Fig.3: Time series of 5-day soil water content at (a) dry mound and (b) wetland



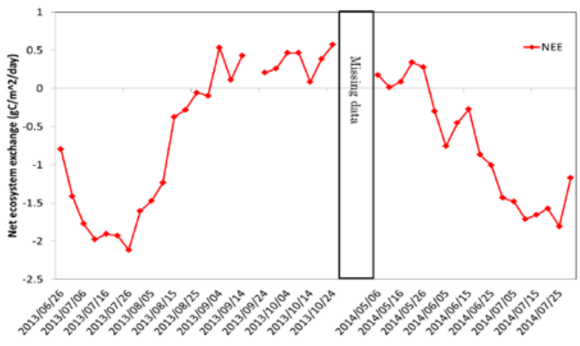


Fig.4: Time series of 5-day (a) energy and (b) carbon budget

Table1: Monthly hydrometeorological varaiables at Kodack site.

	T_air (deg.C)	Pr (mm/m.)	Rs_d (W/m^2)	Rn (W/m^2)	H (W/m^2)	LE (W/m^2)	NEE (gC/m^2/d)	Tg_0.025 (deg. C)	Wg_dry_ 0.145 (%)	Wg_wet_ 0.145 (%)
July 2013	**11.2**	**20.6**	**203.1**	**115.6**	**38.8**	**40.6**	**-1.9**	**6.4**	**5.9**	**58.5**
July 2014	**10.6**	**60.1**	**179.0**	**110.9**	**29.6**	**40.7**	**-1.5**	**10.4**	**15.7**	**59.0**

References

Iwahana et al. (2014), Polar Sci., 8, 96-113.

Parmentier et al. (2010), J. Geophy. Res., 116, G04013.

van der Molen et al. (2007), Biogeosceince, 4, 985-1003.

Yabuki et al. (2011), JAMSTEC, Yokosuka, Japan, distributed by CrDAP, Digital media.