Linkage between net ecosystem exchange of CO_2 and H_2O over boreal forest at eastern Siberia

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To improve our understanding of water and carbon exchange over eastern Siberia boreal forest, three observations at larch and pine dominated forest in the southern part of Lena basin are compared. These fluxes above the forest canopy observed with eddy covariance method showed following results;
(1) Pine forest has larger water use efficiency due to less evapotranspiration compared to adjoining larch forest.
(2) Larch-willow forest has larger water use efficiency due to more CO_2 uptake compared to larch-birch forest.
(3) Increase of humidity deficit and decrease of cloud caused decrease of ecosystem water use efficiency. Larch-willow forest, which has most biomass, has most sensitivity.
(4) Continuous rain less period less than 2weeks did not have clear effect on water use efficiency, since both of evapotranspiration and CO_2 uptake declined.

1. H_2O and CO_2 fluxes between forest and atmosphere in the eastern Siberia

Role of forest ecosystem and permafrost soil in the water and carbon exchange at eastern Siberia

Response to drying environment in summer
* Small inter-annual variation of evapotranspiration due to water supply from permafrost (Ohta et al., 2010; Sugimoto et al. 2002)
* Humidity deficit strongly regulates canopy conductance and CO_2 uptake (Kelliher et al 1997; Dolman et al., 2004)
* Soil water deficit caused decline of evapotranspiration but did not affect clearly CO_2 uptake (Kelliher et al., 1997)
* Contribution of ET and CO_2 fluxes from floor vegetation (Iida et al., 2007; Ito, 2012)

This study focused on difference in species composition.

2. Study sites

SP-P(2008July) SP-L(2008July) EG(2009July)

Table1 Meteorological condition and stand characteristics

	SpasskayaPad SP	Elgeeii EG
Annual mean air temperature (℃)*	-8.7	-8.8
Annual sum precipitation (mm)*	230	290
Plant area index	(L)0.8-1.4 (P) 1.1	1.2-2.1
Age of larch trees	180	150
Stand density (ha^{-1})**	(L)1800, 2428***, (P) 1490	2600
Density of basal area at BH (m^{2}ha^{-1})**	(L) 24, 28***, (P) 22***	35
Soil type	solodic	podzolic

* Baseline Meteorological data in Siberia (Suzuki et al. 2007)
** tree height>1m
*** measured in 1998

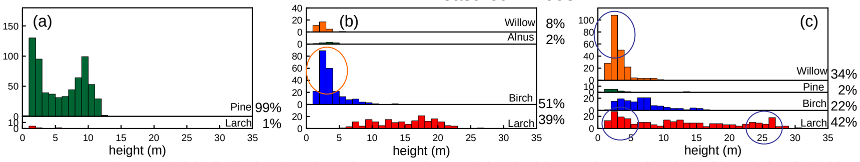

Fig.1 Tree height distribution of each species at SpasskayaPad pine site (a), Spasskaya Pad larch site (b), and Elgeeii site (c)

SP-P: Pine dominated forest
SP-L: Mature larch forest mixed with birch
EG: Mature and young larch forest mixed with willow and birch

3. Field observations

Table2 Measurement items

Tower top	turbulent flux (eddy covariance) precipitation, radiation, wind speed air temperature/humidity,	
Middle	air temperature/humidity	
Floor	radiation, wind speed air temperature/humidity	
Ground	ground temperature, heat flux, soil water content	

water vapor flux
=evapotranspiration (ET)

CO_2 flux (Fc)
= net ecosystem exchange
= -photosynthesis uptake (A) + ecosystem respiration (R)

3. Seasonal variation of evapotranspiration and CO_2 fluxes

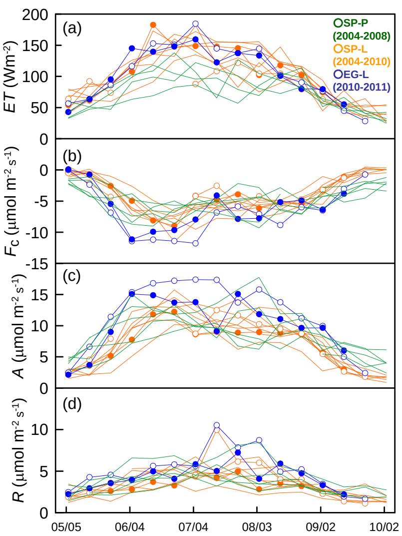

Fig. 2 10days mean of midday (10:00-14:00) evapotranspiration (a), net ecosystem CO_2 exchange (b), gross primary production (photosynthesis uptake) (c), ecosystem respiration (d).
orange: SP-L(2004-2011), green: SP-P (2004-2008), blue: EG (2010 and 2011). Solid and open circles is 2010 and 2011 data, respectively.

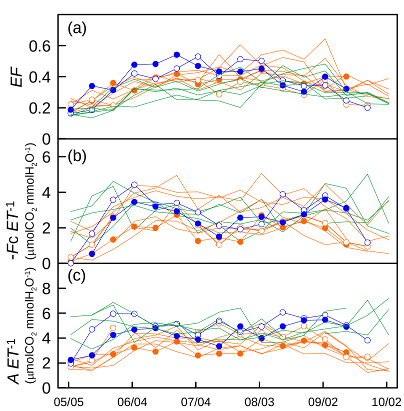

Fig. 3 10days mean of midday evaporative fraction [latent heat/(latent +sensible heat)] (a), ecosystem water use efficiency of net CO_2 uptake [-Fc/ET] (b), that of photosynthesis CO_2 uptake [A/ET] (c). Legend is same to Fig.2.

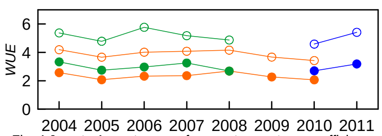

Fig. 4 June to August mean of ecosystem water use efficiency. Open and close circles indicate -Fc/ET and A/ET, respectively. Legend is same to Fig2.

Time lag in increase of photosynthesis uptake A and respiration R toward summer resulted in remarkable maximum in net CO_2 uptake Fc during June, which was remarkable at EG.
In some years, ET and A declined during summer in which continuous rainless period.
Water use efficiency (Fc/ET, A/ET) decreased during midsummer.

Deciduous larch (SP-L) Evergreen pine (SP-P)
* SP-P can uptake CO_2 similar to SP-L with less water loss (Smaller EF and larger WUE)
* Longer period of CO_2 uptake at SP-P

Mature larch (SP-L) Developing larch (EG)
* EG can uptake CO_2 more than SP-L with similar water loss (Larger WUE)
* Longer period of CO_2 uptake at EG

4. Response to environmental variability

4.1 Atmospheric humidity deficit: difference in conductance response

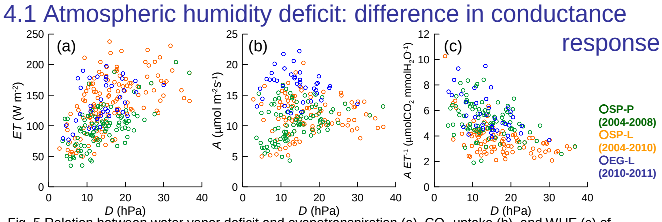

Fig. 5 Relation between water vapor deficit and evapotranspiration (a), CO_2 uptake (b), and WUE (c) of midday (10:00-14:00) mean.

Increase humidity deficit → increase evaporative demand → increase evaporation
→ decline in conductance→ limited CO_2 uptake and ET (unclear)
⇒decrease WUE

4.2 Cloudiness: difference in canopy light use

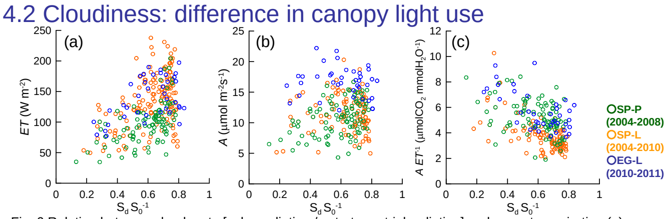

Fig. 6 Relation between cloudy rate [solar radiation / extraterrestrial radiation] and evapotranspiration (a), CO_2 uptake (b), and WUE (c) of midday (10:00-14:00) mean.

Cloudless day → increase evapotranspiration (all sites)
→ increase CO_2 uptake at SP (sparse canopy) but limited at EG (dense canopy)
⇒decrease WUE more rapidly at EG

4.3 drought length: difference in surface water availability

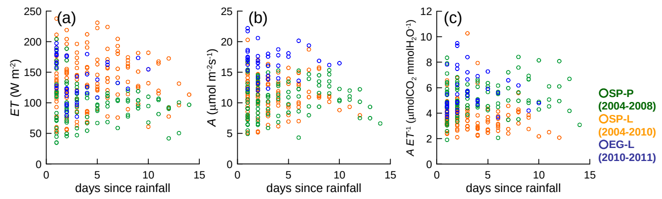

Fig. 7 Relation between days since last rainfall and evapotranspiration (a), CO_2 uptake (b), and WUE (c) of midday (10:00-14:00) mean.

Drought length longer than 1week → decrease ET and CO_2 uptake → unaffected WUE at SP-P
→ decrease CO_2 uptake → decreased WUE at SP-L
(EG did not experiment drought period longer than 10days)

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