2016/05/21 @ 北海道大学

# 北ユーラシア陸域水循環変化とその影響

# Hydrological cycle change in Northern Eurasia and its influence on terrestrial environment

Contents

> Influence of Arctic climate change on warming near-surface permafrost in eastern Siberia
> Permafrost / boreal forest degradation under wet climate by satellite remote sensing
> Conclusions


飯島　慈裕 (Yoshihiro Iijima)

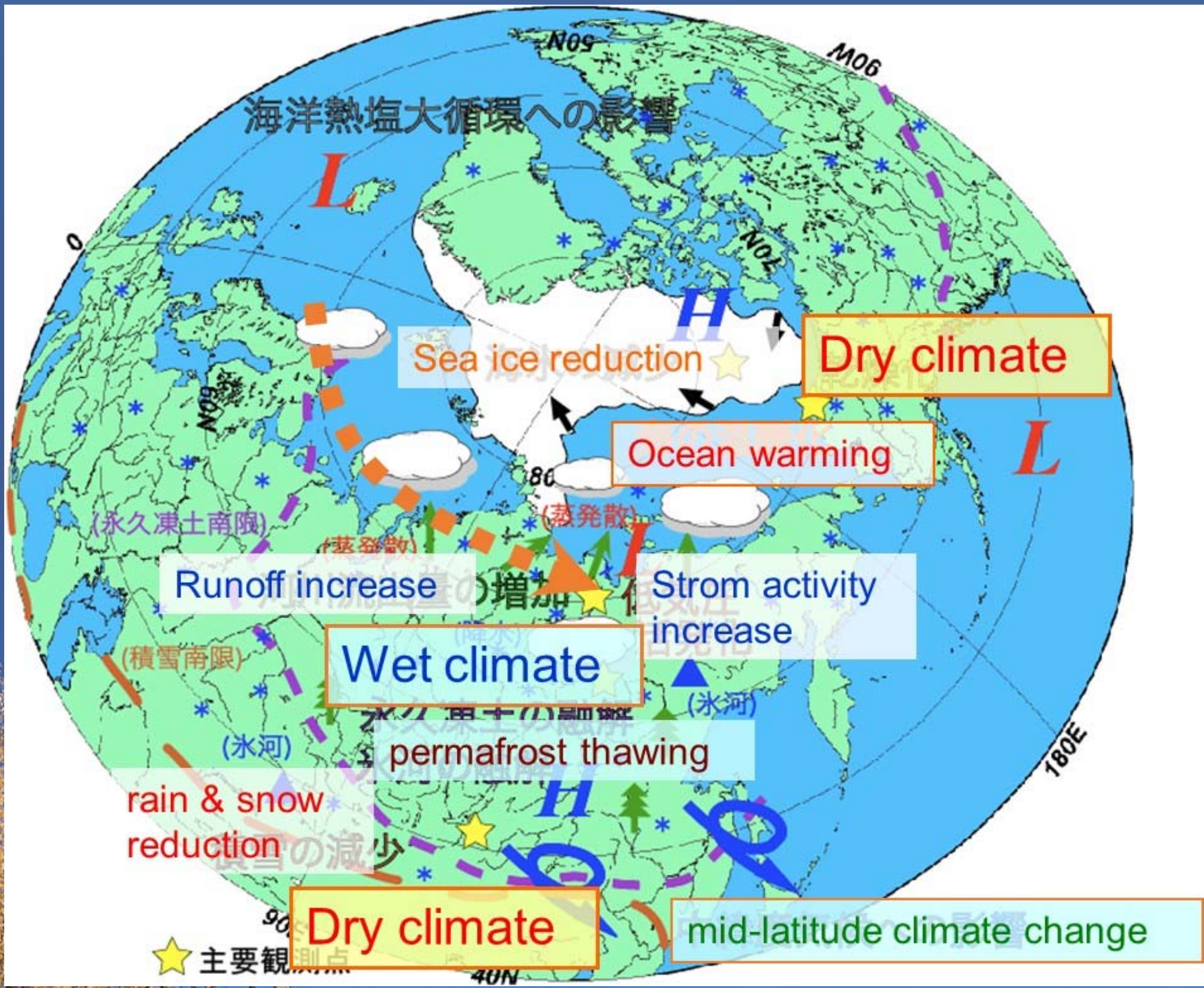
三重大学生物資源学研究科

(Graduate School of Bioresources, Mie University)

# Arctic climate change affects permafrost environment in eastern Siberia

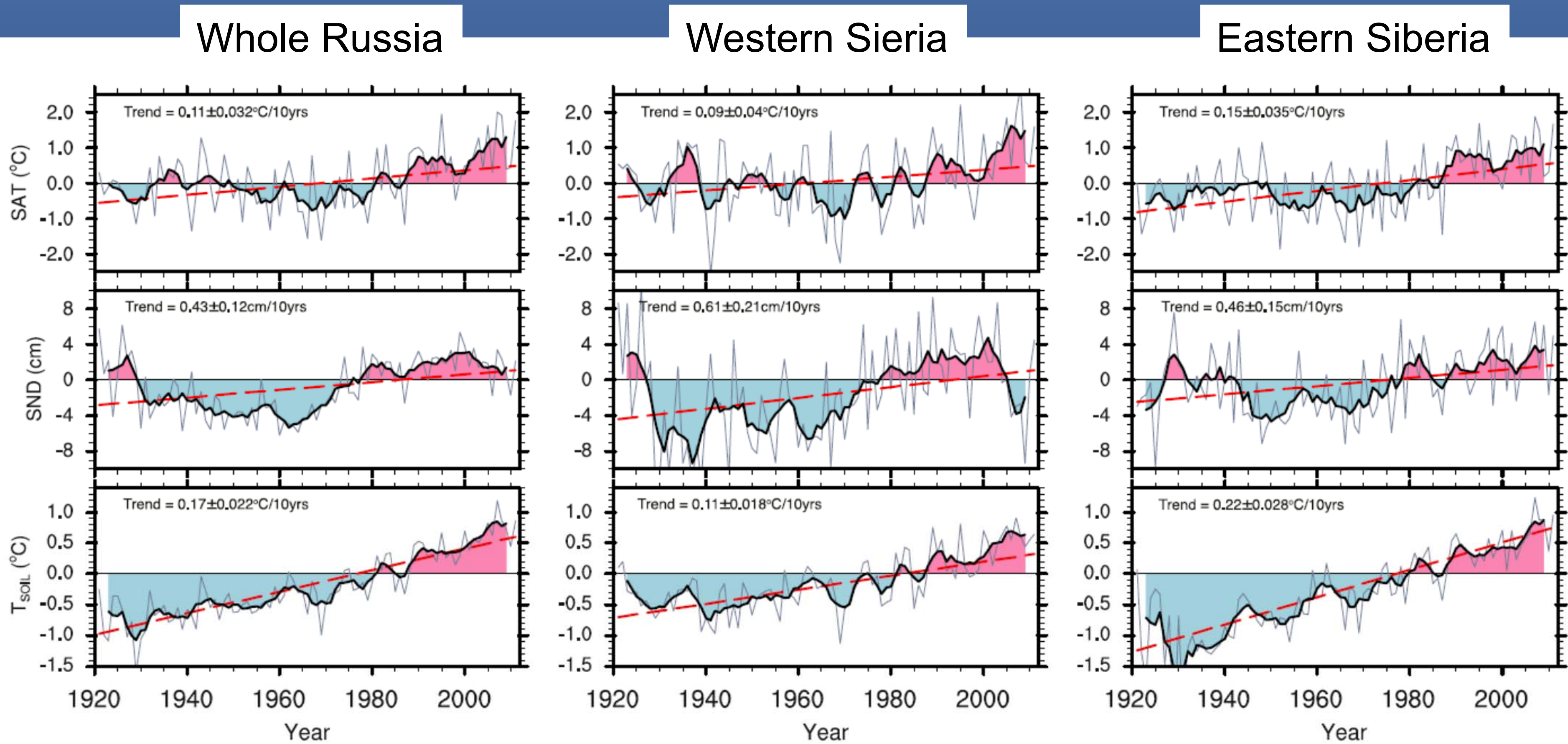
= increasing rainfall in late summer enhances warming permafrost

= permafrost eco-hydrological change in humidifying eastern Eurasia




Schematic of Arctic-subarctic climate pattern during 2000s.

# Longterm trend in Siberia



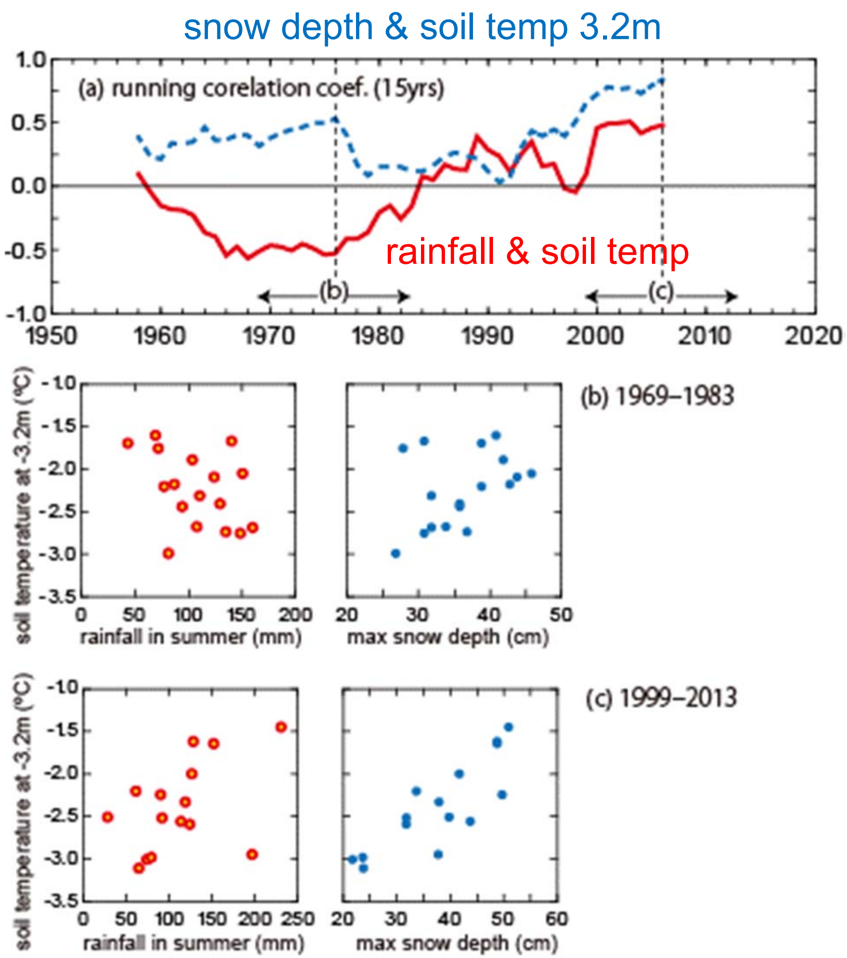

High air temperature + increasing snow
→ warming surface permafrost

Park et al. (2014 ERL)

# Relationship between soil temp. and snow, rainfall in summer (Yakutsk)


Less cooling in winter

Much heat conduction
& capacity in summer




Snow:
continuously positive

Rainfall:
negative to positive

1960-80s:
Only snow has positive effects on soil temperature

1990-2000s:
Both positive effects on soil temperature

Iijima et al. (2016 IJC)

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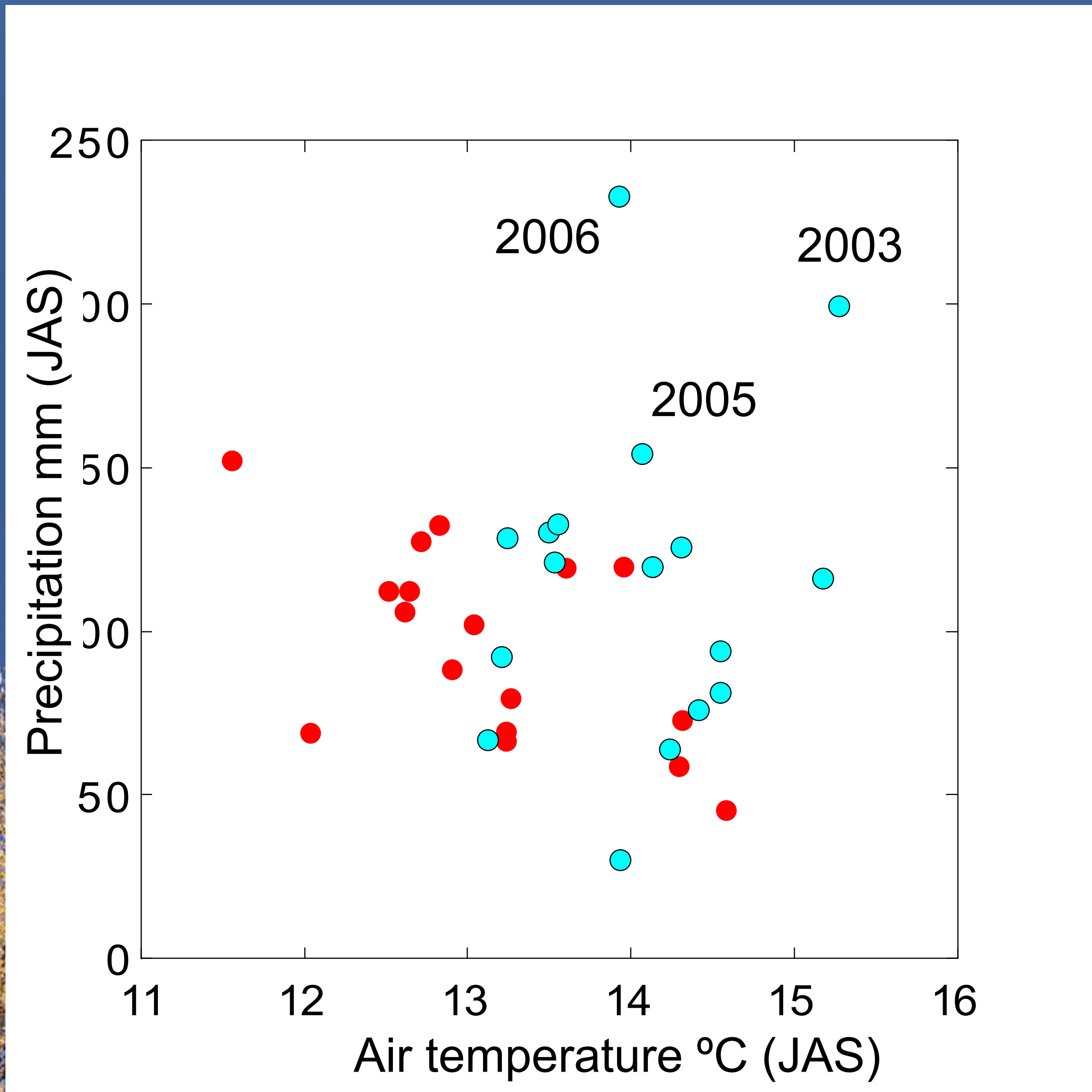
# Warm & rainy summer during the last decade (Yakutsk)




●1998-2013
Positive correlation
= warm summer with high prec.

●1979-1997
Negative correlation
= cool summer with high prec.

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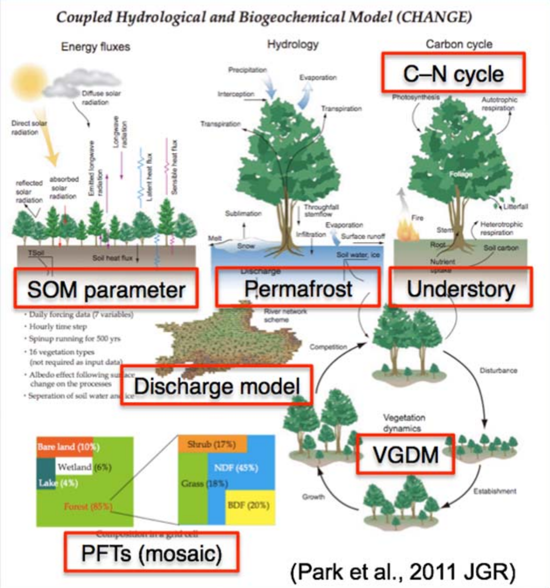
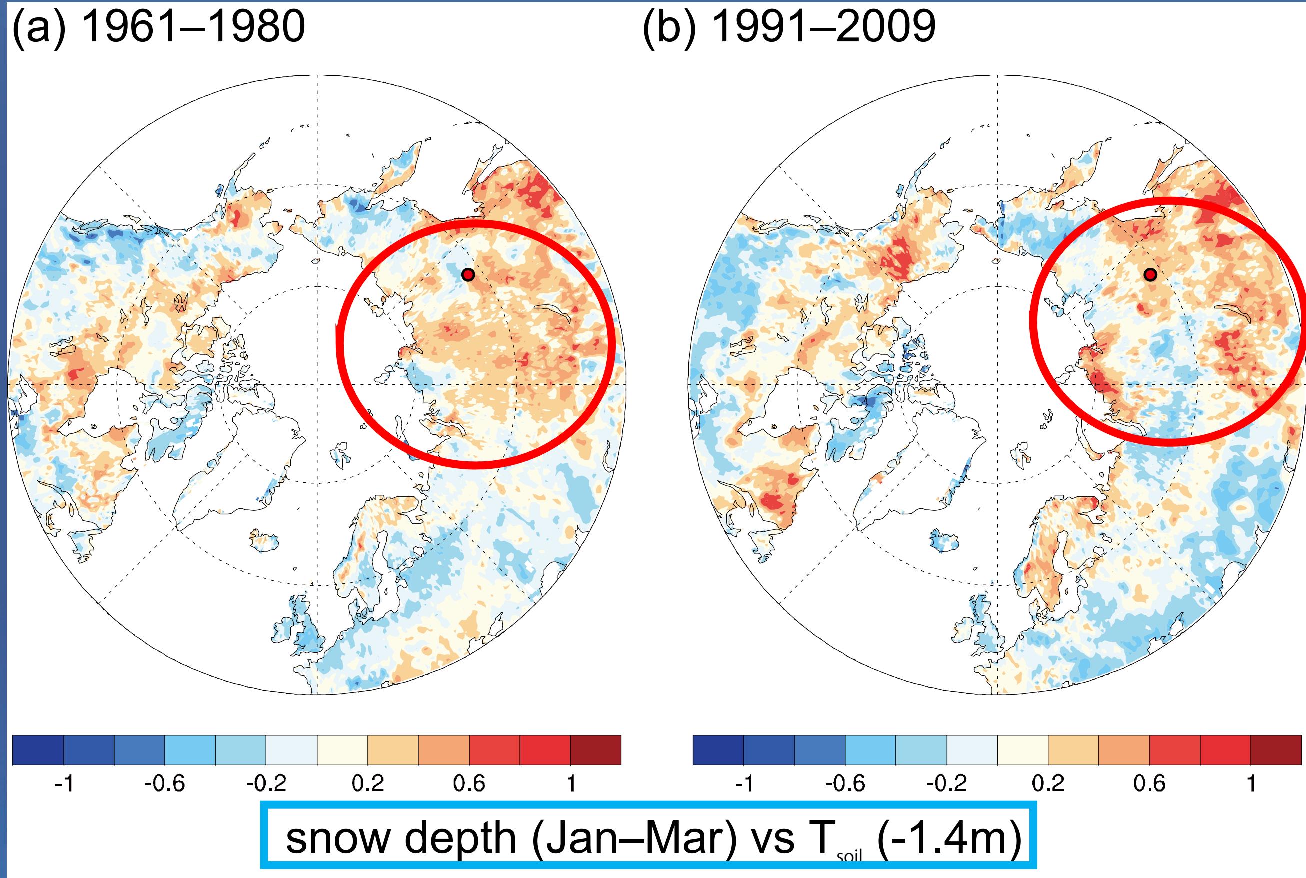
## Relationship between soil temperature and snow depth (generally positive)

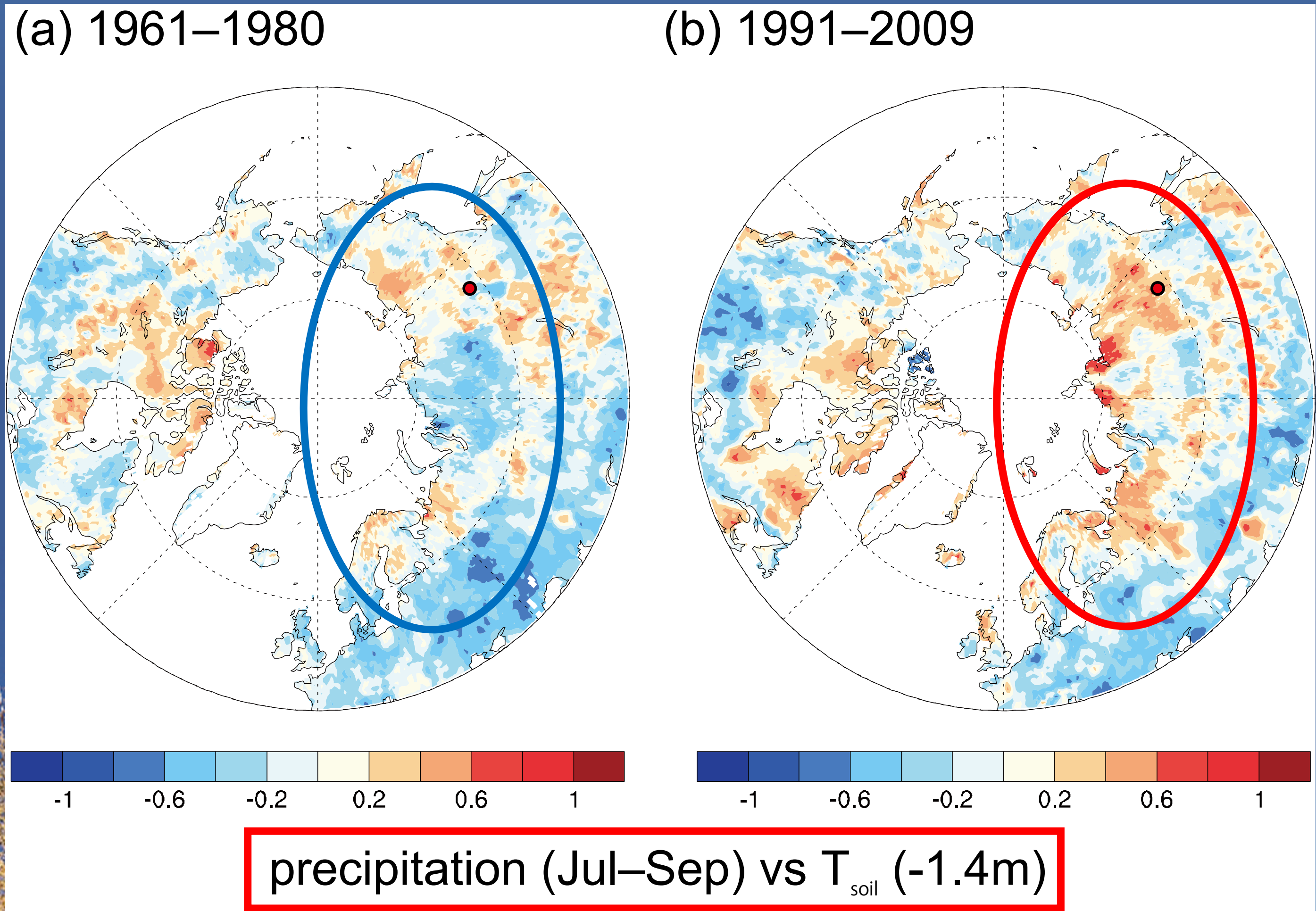



Description of CHANGE model




Soil temp. is simulated by land surface model (CHANGE: Park et al. 2012)

## Relationship between soil temperature and precipitation in summer




Soil temp. is simulated by land surface model (CHANGE: Park et al. 2012)

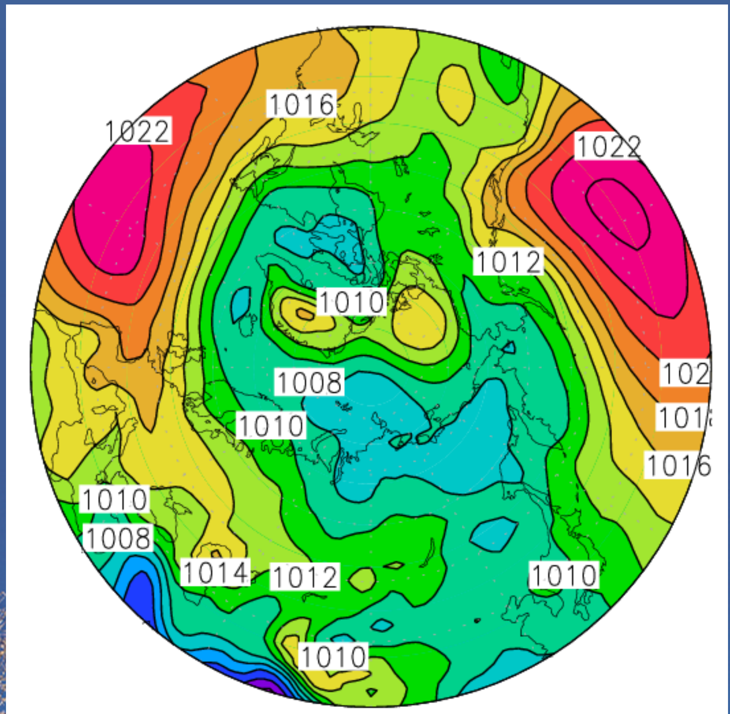
Before 1980s: negative or insignificant relationship

After 1990s: Change to positive relationship

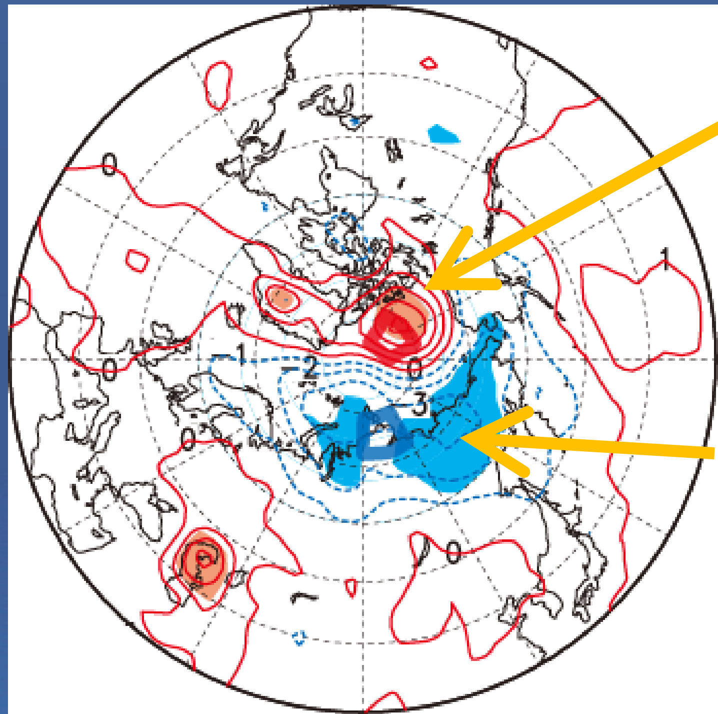
In permafrost zone In northern Eurasia

## Sea Level Pressure in late summer (Jul, Aug, Sep) during 2004-2008

(a) average




(b) anomaly



anticyclone

cyclone

by NCEP2 Reanalysis

Anticyclone:
North American side
Cyclone:
Siberian Side

Arctic dipole mode
= CL index (Inoue & Kikuchi 2007, JMSJ)

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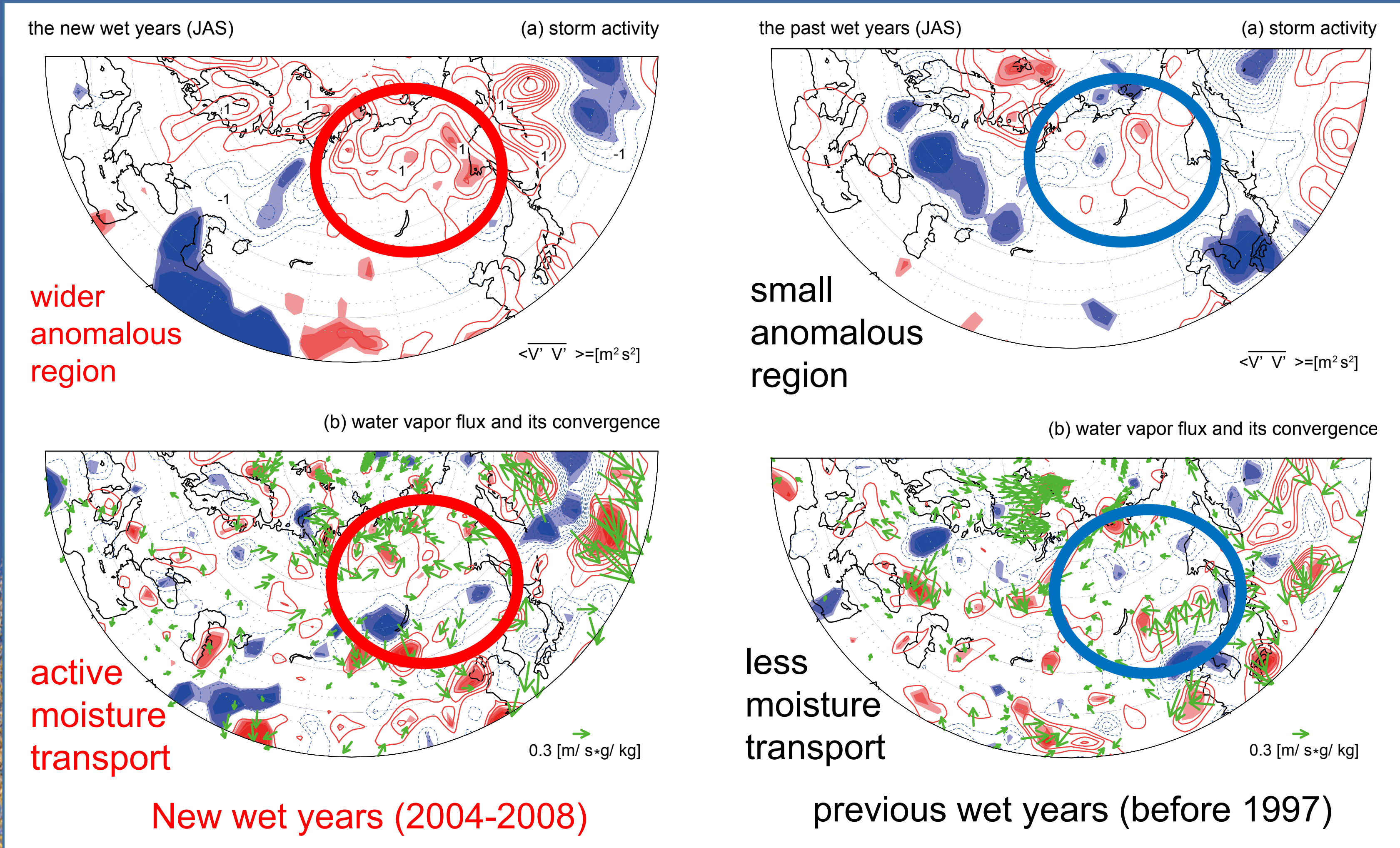
# Transient storm activity in previous and new wet years

stationary(monthly)

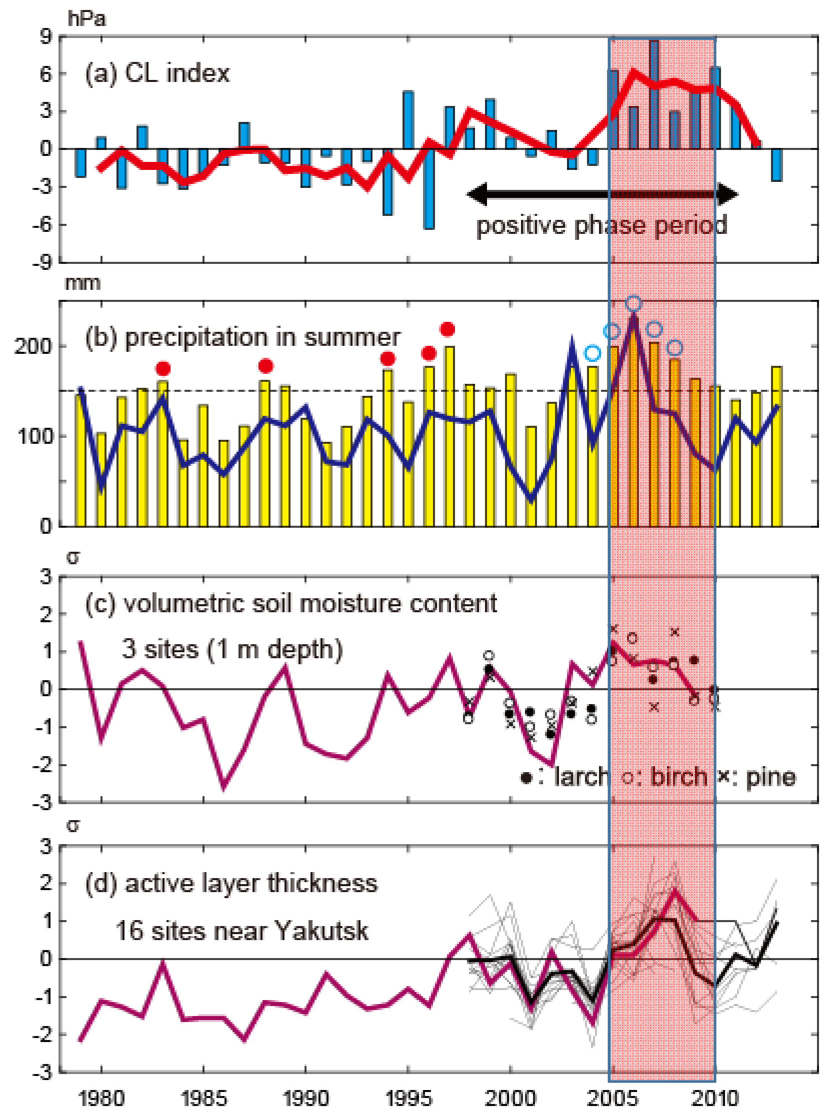
$$<\overline{v\,v}>=<\bar{v}\,\bar{v}>+<\overline{v'\,v'}>$$

transient (<5day)




Iijima et al. (2016 IJC)

# Interannual variations in eastern Sibreia (1979 to 2013)




(c), (d) simulated by CHANGE model

CL index (Inoue & Kikuchi 2007)
+ Dipole intensity:
Siberian Cyclone Enhancement

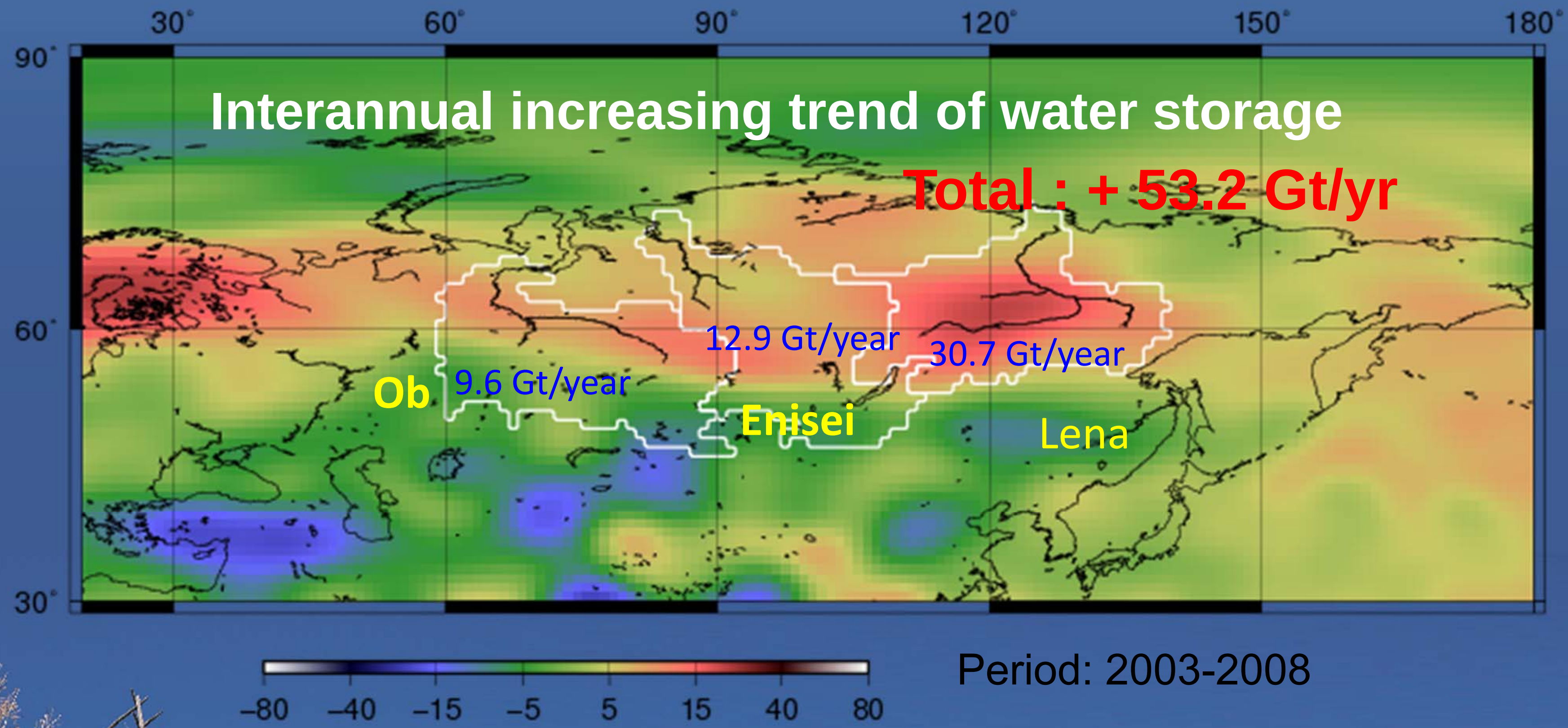
Rainfall amount in eastern Siberia
consecutive anomalous rainfall from 2004 to 2008

Soil moisture within active layer at various forest type in Yakutsk
Anomalous high water contents

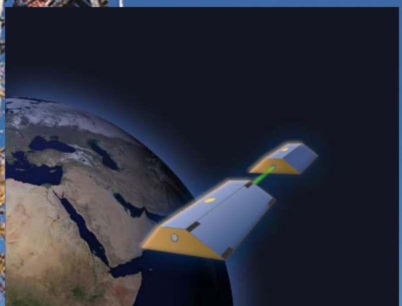
Active layer thickness at various borehole sites in Yakutsk
Anomalous deeper thawing

Iijima et al. (2016 IJC)

# Terrestrial water storage detected by GRACE




Period: 2003-2008

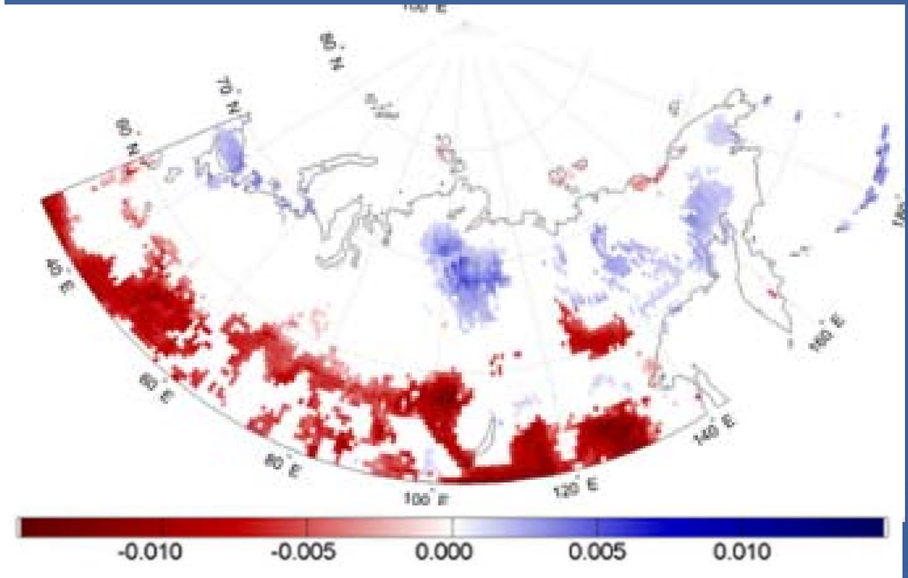


High terrestrial water storage trends
in central Yakutsk region

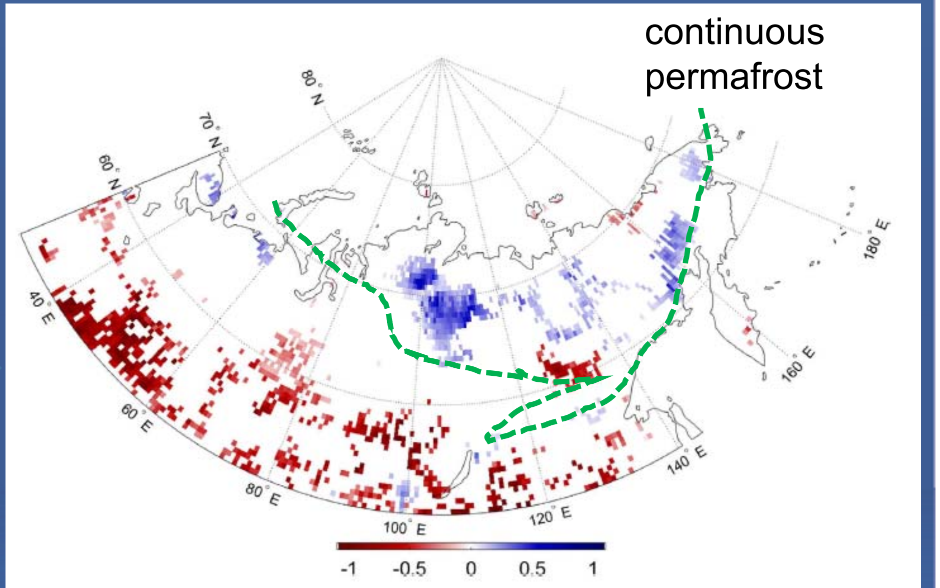
Ogawa et a. (2011, *Geophys. J. Int.*)

# Regional difference in surface-atmosphere moisture interaction in permafrost zone

Evapotranspiration




Precipitation




Long-term trend (1979-2012) of evaporative fraction (EF) in morning in July

Changes in Probability (%) of afternoon precipitation as a function of surface EF in July

$$EF = \frac{LH}{LH + SH}$$

Using hourly reanalysis data (MERRA)

Ford and Frauenfeld (2016, Sci Rep)

# Extensive degradation in permafrost environment

Cumulus over Siberia
（by Mr. Kobayashi JAL pilot）

Extensive boreal forest mortality

Erosion after deeply thawing active layer

Abnormal runoff in mid-winter

**Main cause is ….**

**“Wet climate conditions”**

## Large scale phenomena of forest degradation

upper left：colored larch forest
upper right：damaged leaf

lower right：water logged forest floor

(7 Aug. 2007)

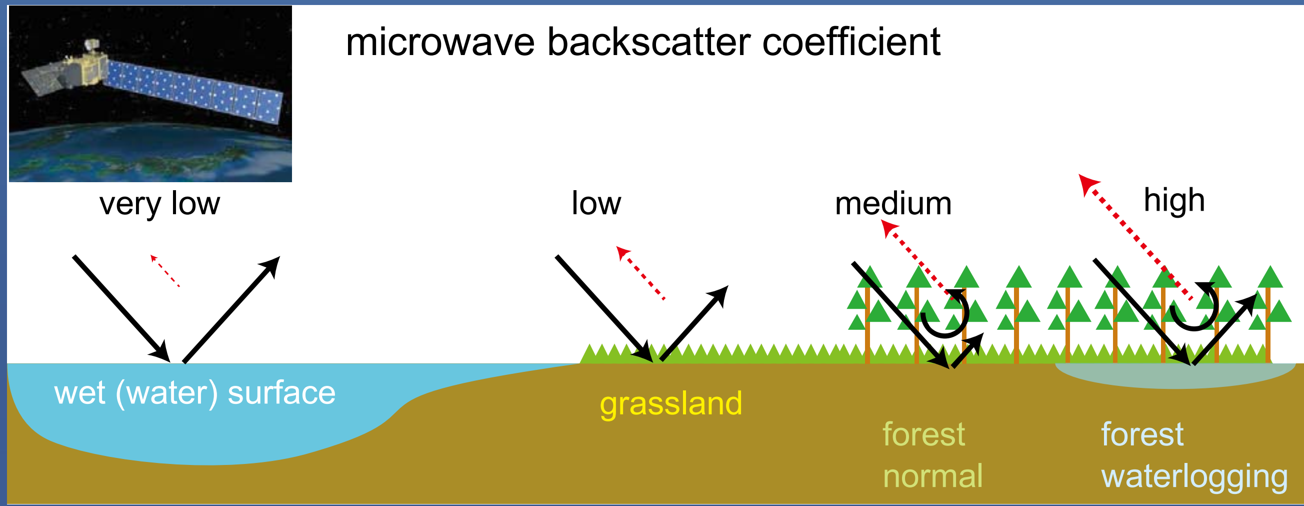
# Method: Satellite data analyses

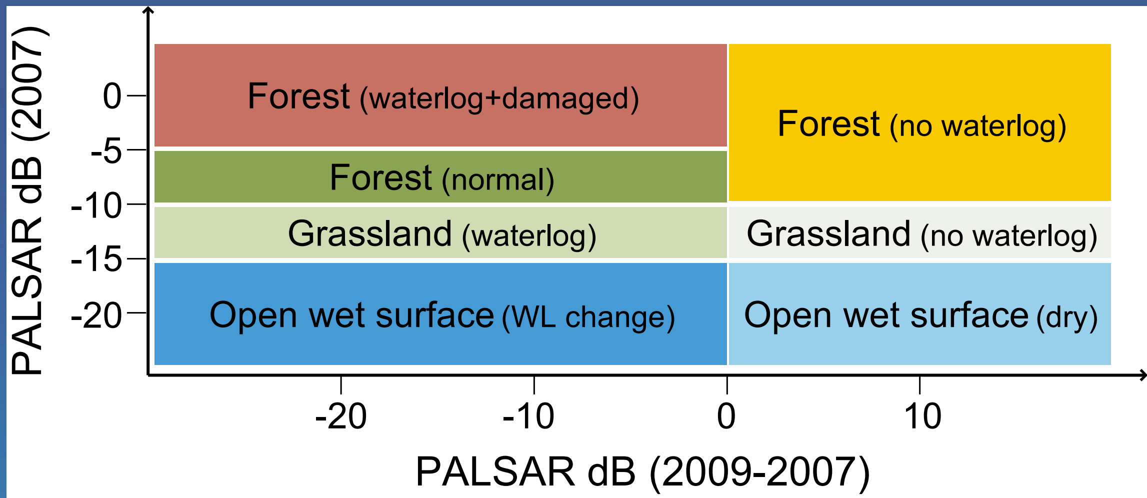
ALOS-PALSAR images

2007 (high precipitation year)
2009 (after degradation)

L-band (waver length 23cm)
Back scatter coefficient

To detect
- open water body,
- biomass change,
- waterlogged forest



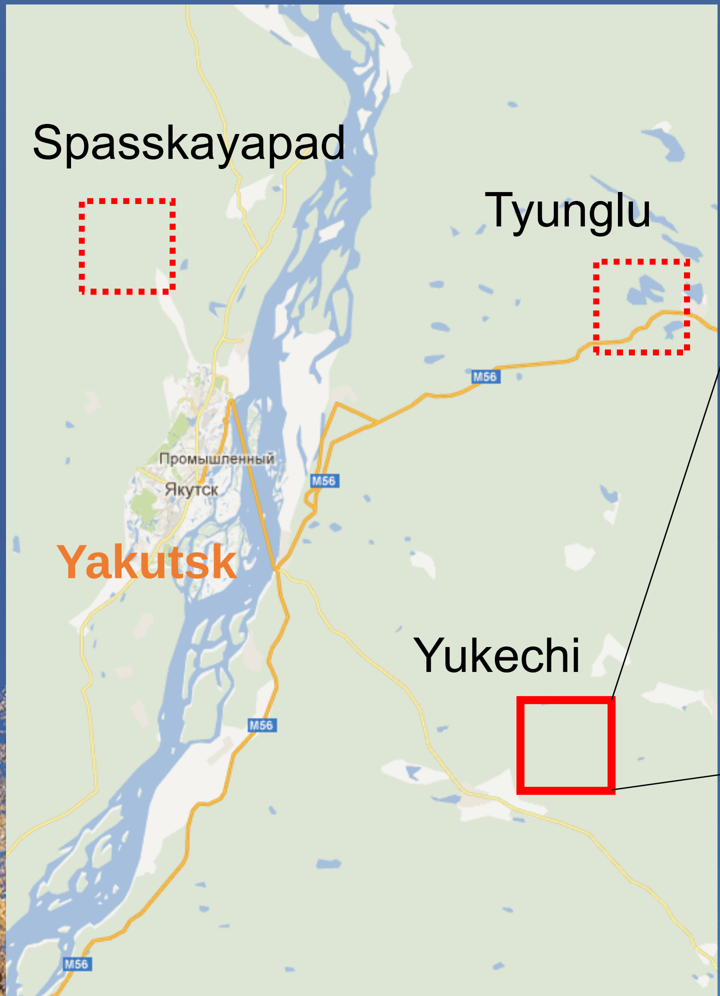



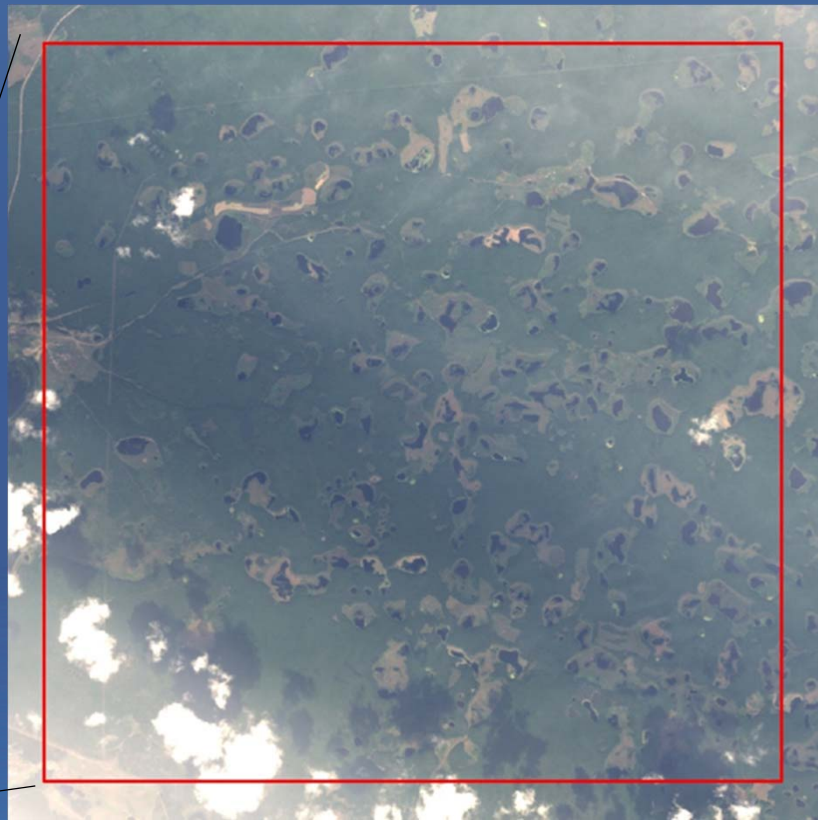

Determine look up table based on Supervised Classification

Iijima et al. (in prep.)

# Results: study area (central Yakutia): Yukechi

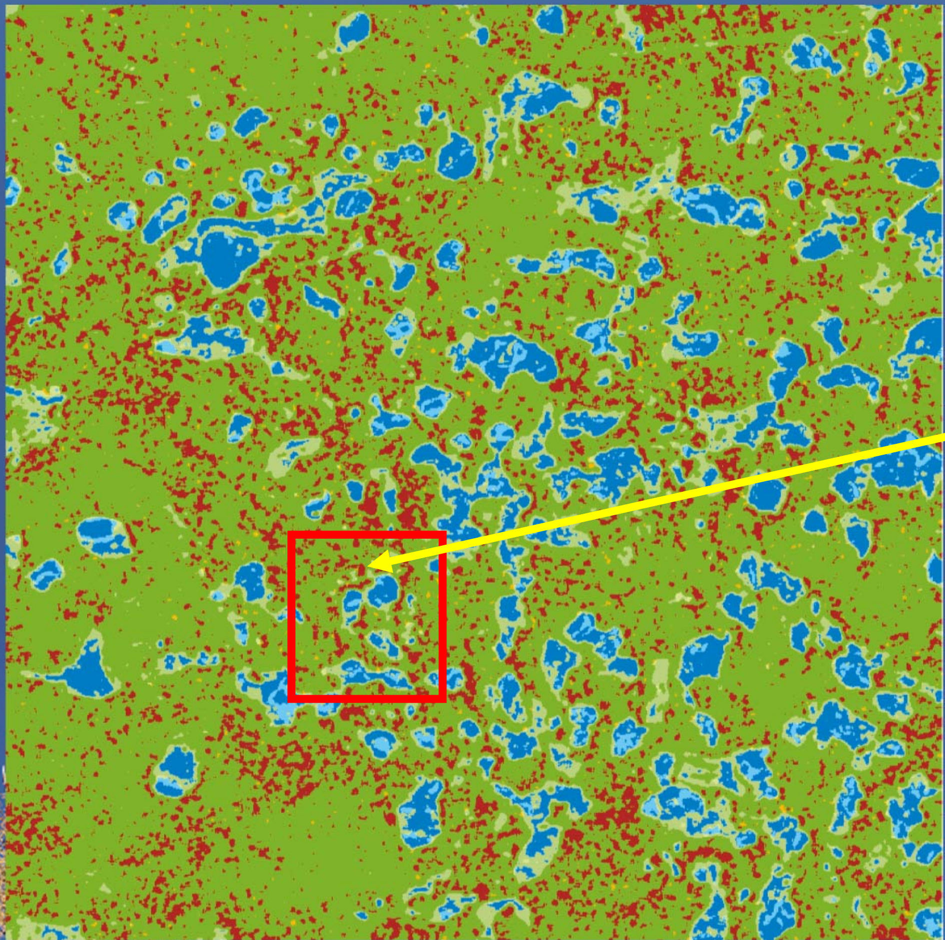
Study area：10km × 10km



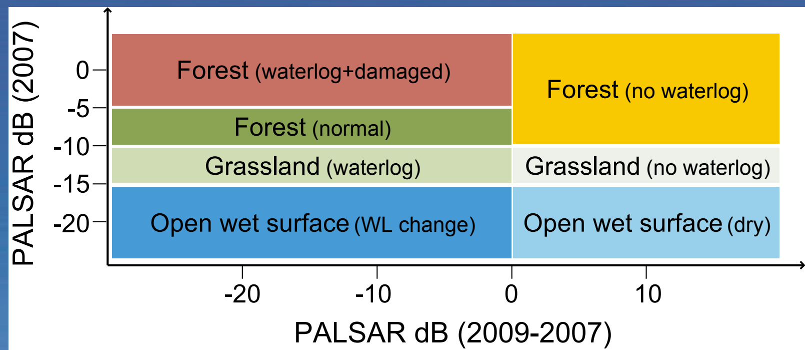



| | Spasskaya | Tyunglu | Yukechi | MODE | resolution |
|---|---|---|---|---|---|
| 2007 | Aug | Sep | Sep | FBD | 10m |
| 2009 | Aug | Sep | Sep | FBD | 10m |

# Water induced degradation map at Yukechi (high density of thermokarst lakes)



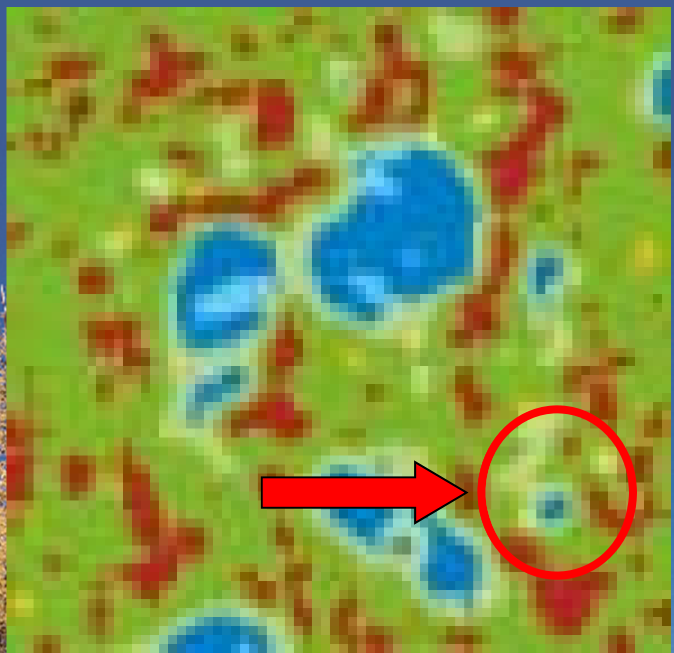
Expanding thermokarst lake
and waterlogged (damaged) trees in 2009




Iijima et al. (in prep.)

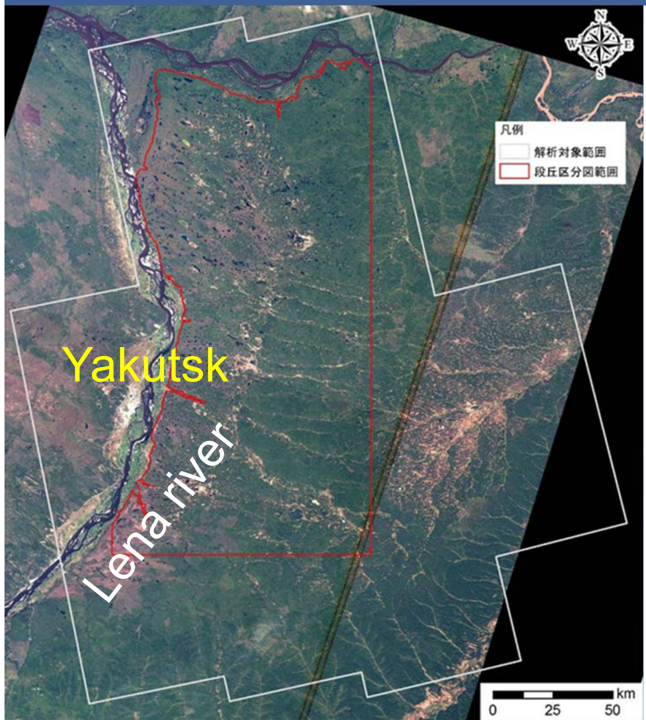
# Yukechi thermokarst lake expansion

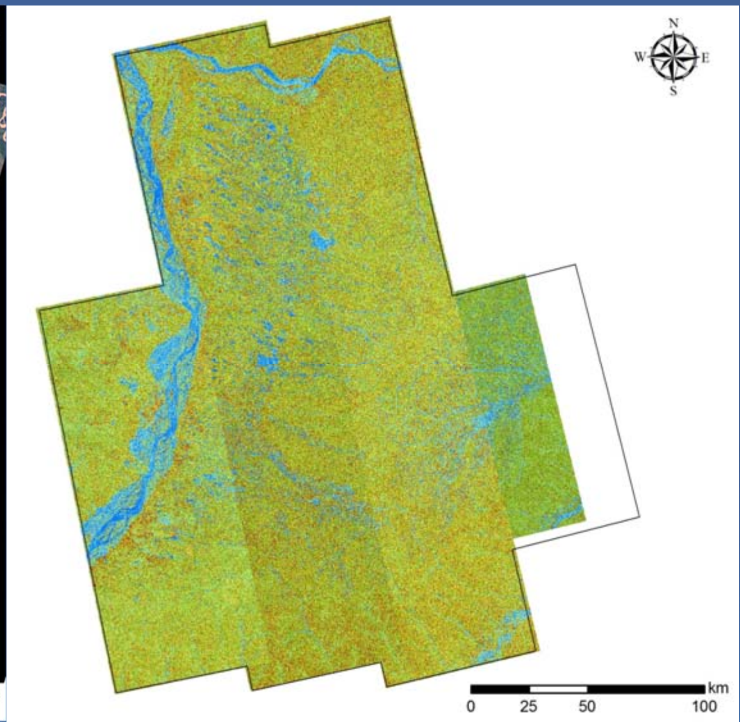


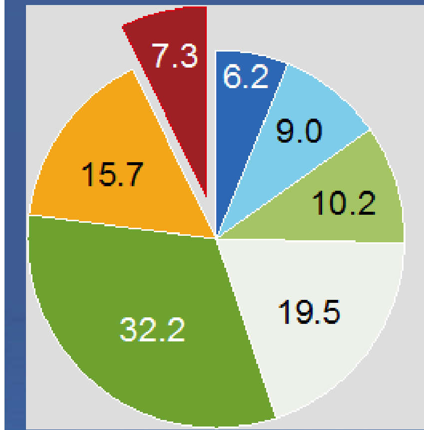
# Water induced degradation map in central Yakutia

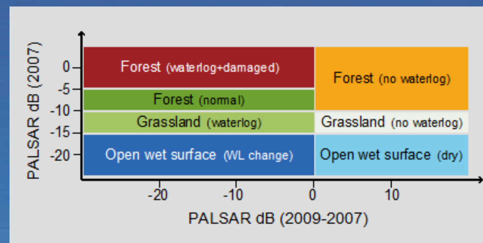
## Water induced degradation map (16 scenes)




Damaged boreal forest during wet climate years

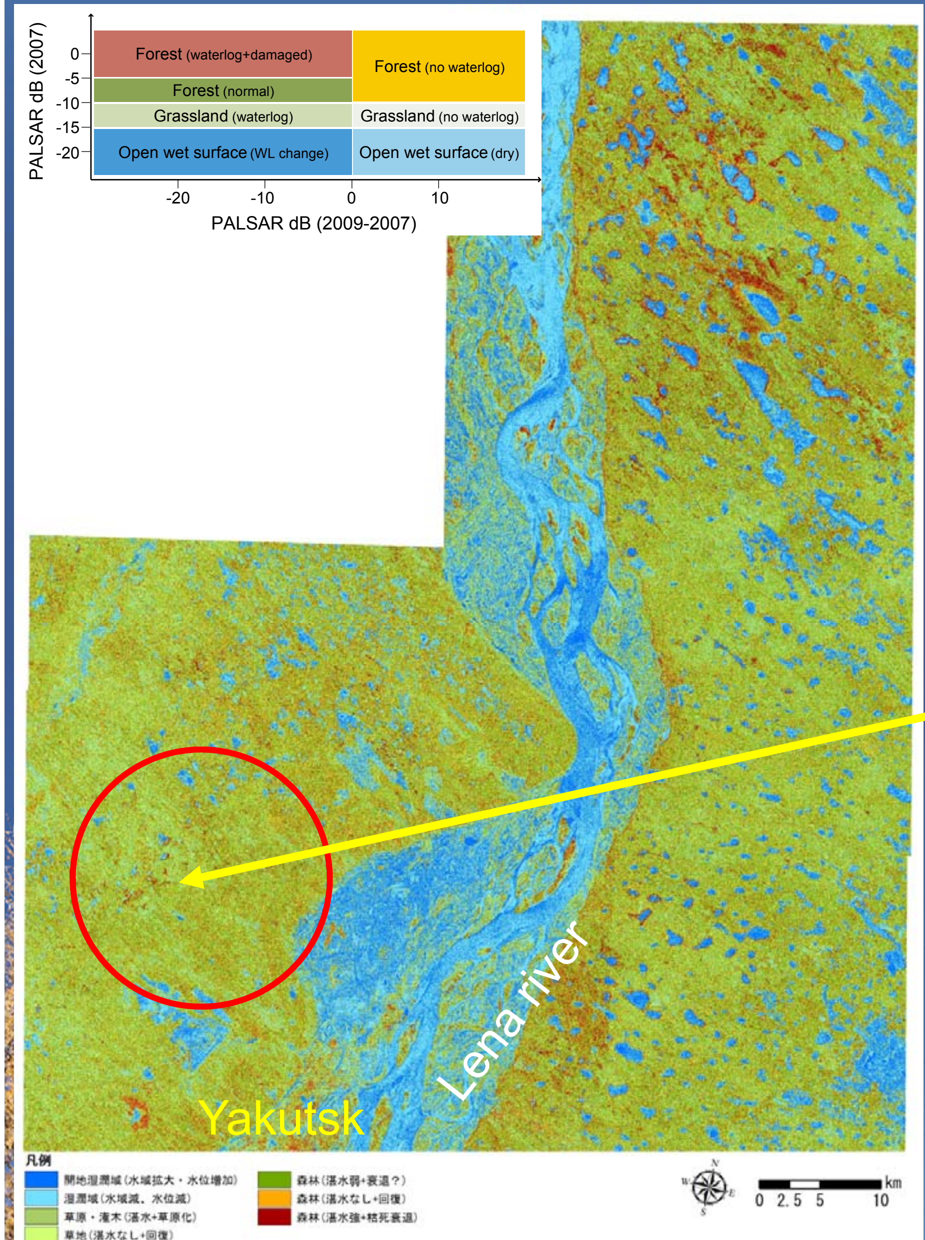


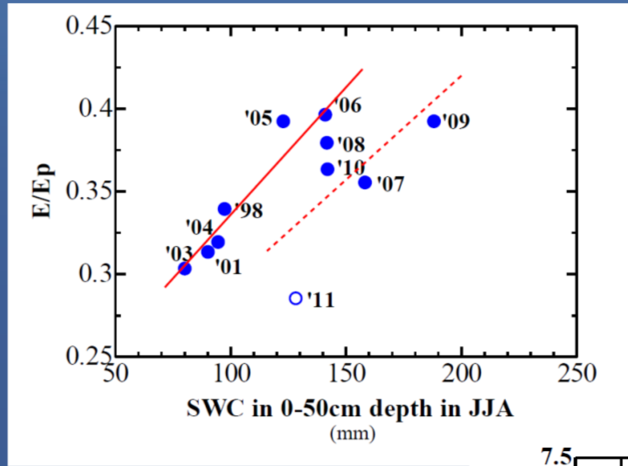



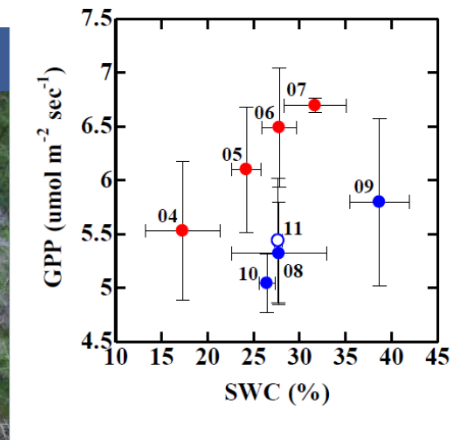

(ALOS-PALSAR : Aug 2007, Jul-Aug 2010)

Iijima et al. (in prep.)

# Current situation of forest degradation in central Yakutia (2007⇒2015)




Evapotranspiration & Carbon balance changes in Spasskaya-pad forest

Ohta et al. (2015 AFM)

Aug. 2007 (ALOS)→ Aug. 2015 (ALOS2)

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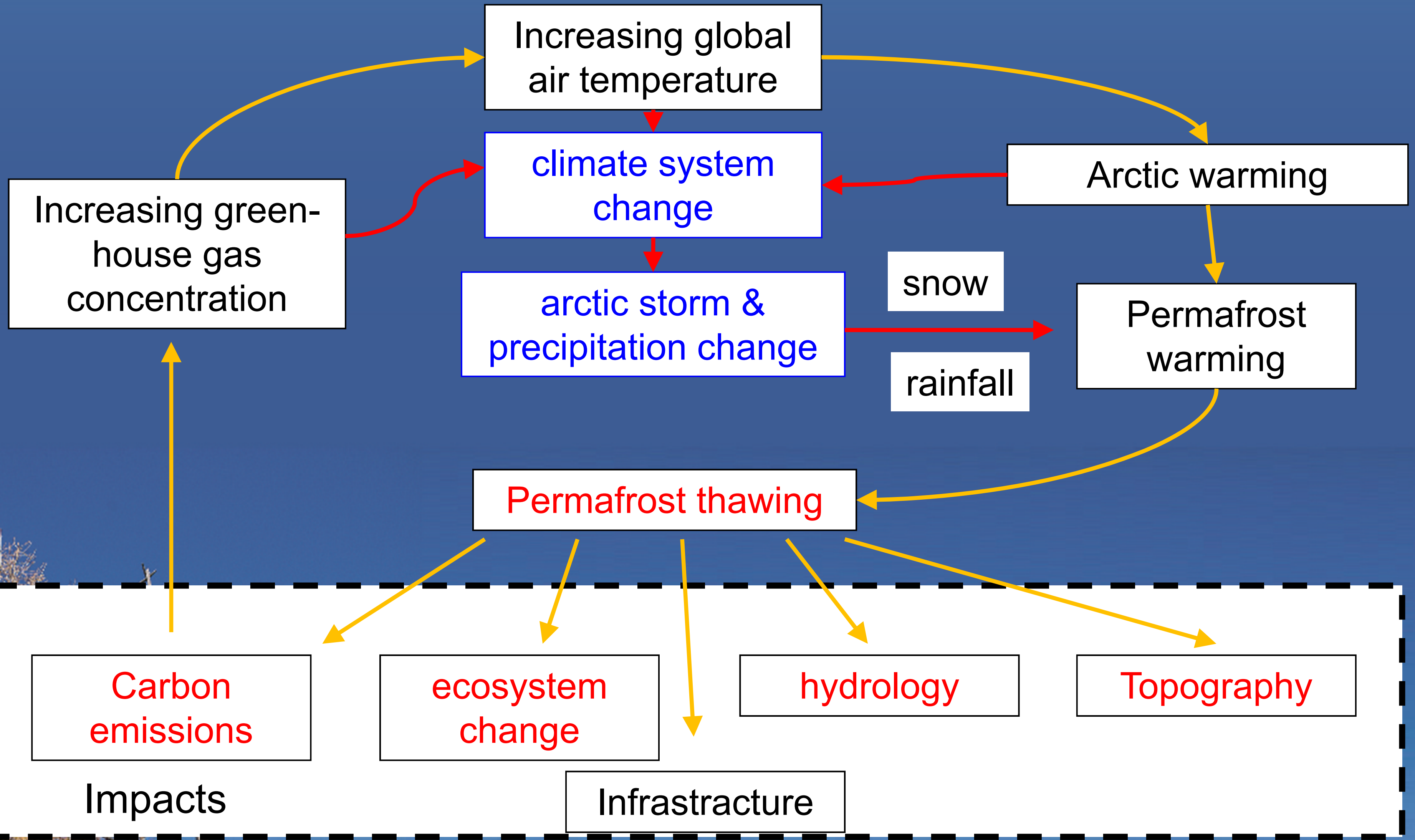
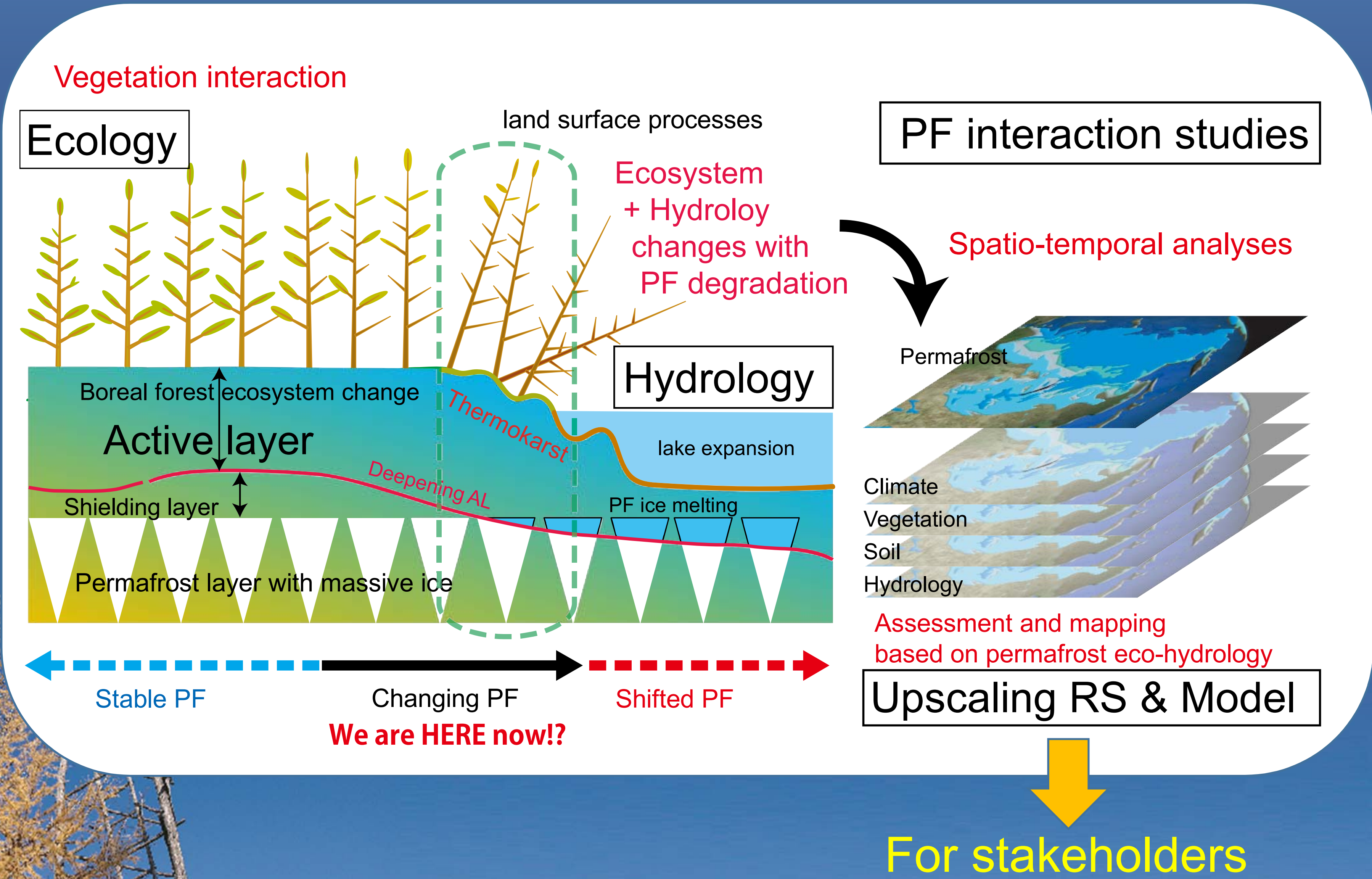
# Climate change & Permafrost feedback in eastern Siberia



# For future studies on permafrost degradation and its impact on hydro-climate



# CONCLUSIONS

- Soil temperature & moisture increased within active layer observed at many sites in eastern Siberia.
- This change was primarily due to wet climate conditions rather than atmospheric warming with abnormally large amounts of rainfall and snow fall from late summer to winter during the period enhancing storm activity
- Wet climate during the last decade (2004-) drove both forest mortality and permafrost degradation

## Implications

- Manifesting hydro-climatic impacts on permafrost environments !!
- Spatio-temporal variabilities (boreal to tundra) with trans-disciplinal approach will be the next international focus

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