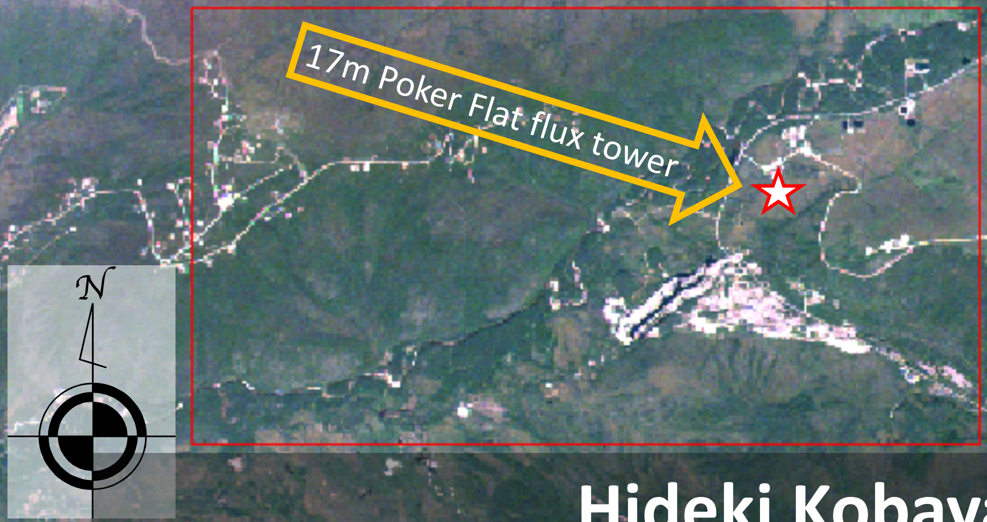
Seasonal changes of spectral reflectance in Alaskan boreal forests



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Japan Agency for Marine-Earth Science and Technology (JAMSTEC)

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Rikie Suzuki

Warming in boreal and arctic region

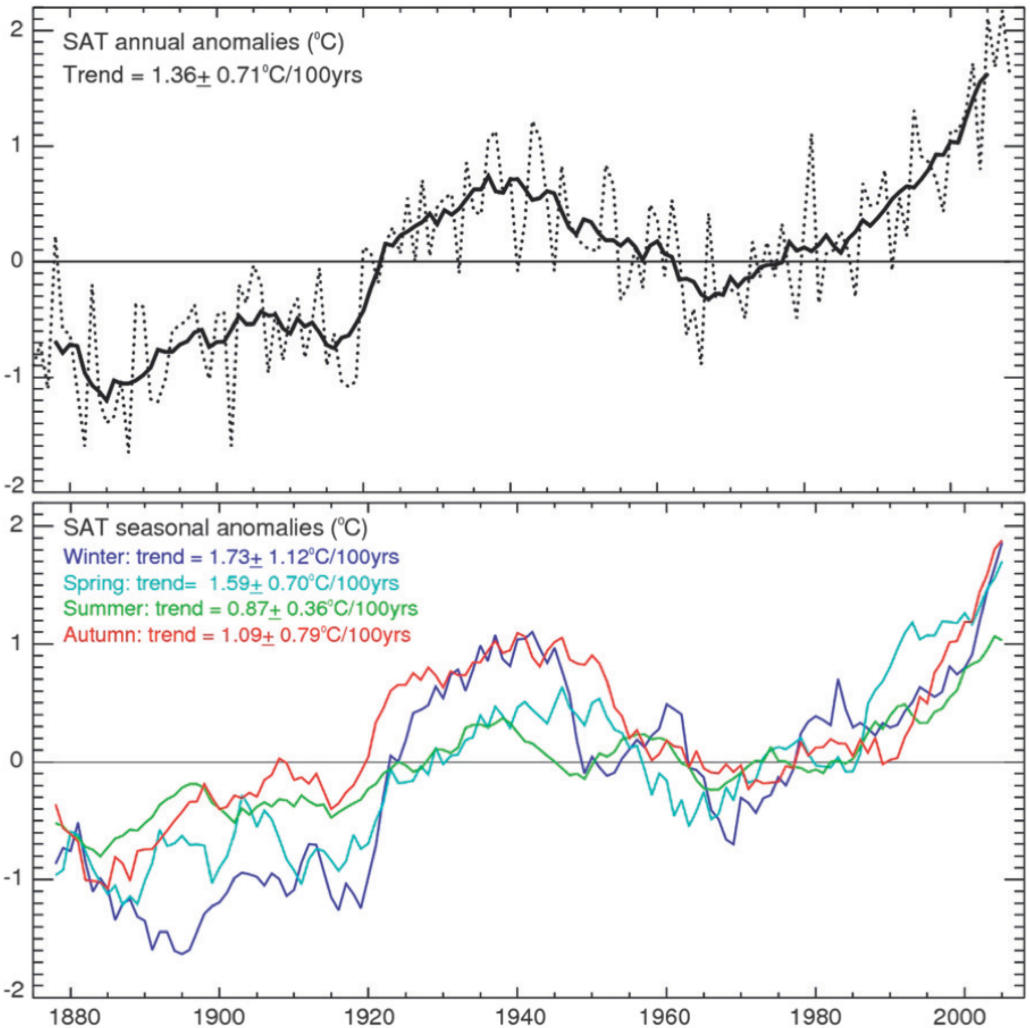


FIG. 2. Composite time series of the (top) annual and (bottom) seasonal surface air temperature (SAT) anomalies (°C) for the region poleward of 59°N. Dotted lines show unsmoothed values; solid lines 7-yr running means. In the legend, trends are for 1900–2008.

Bekryaev et al. (2010)

During 1875–2008

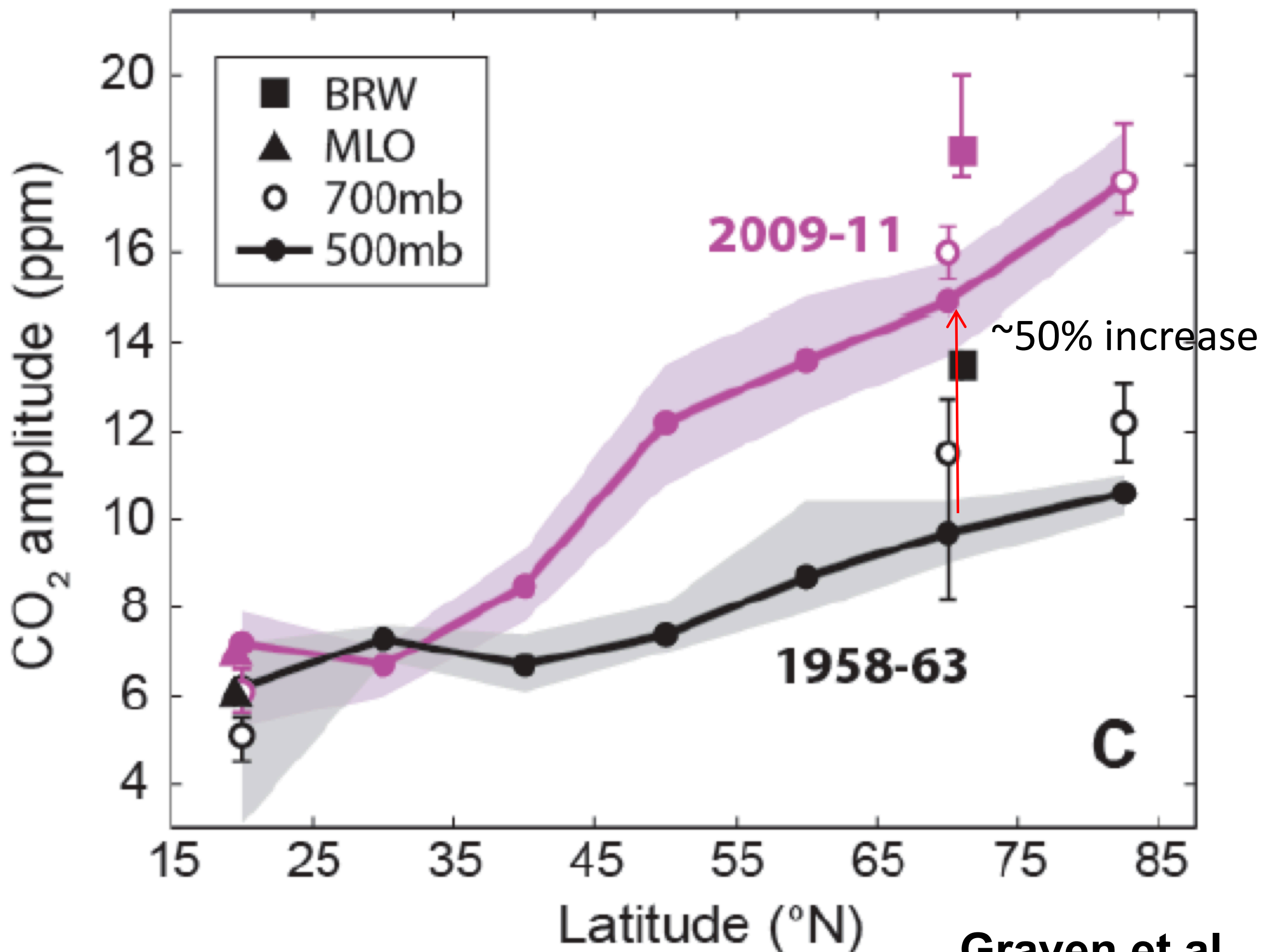
- temp. increase in N.H. mean 0.79℃ Century^{-1}
- temp. increase higher than 59° N 1.36℃ Century^{-1}

During 1999–2008

- temp. increase higher than 59° N 1.35℃ decade^{-1}

How does this warming trend influence the terrestrial biosphere in N. High Lat.?

Increase in atm. CO_2 amplitude may be caused by the enhancement of plant activity



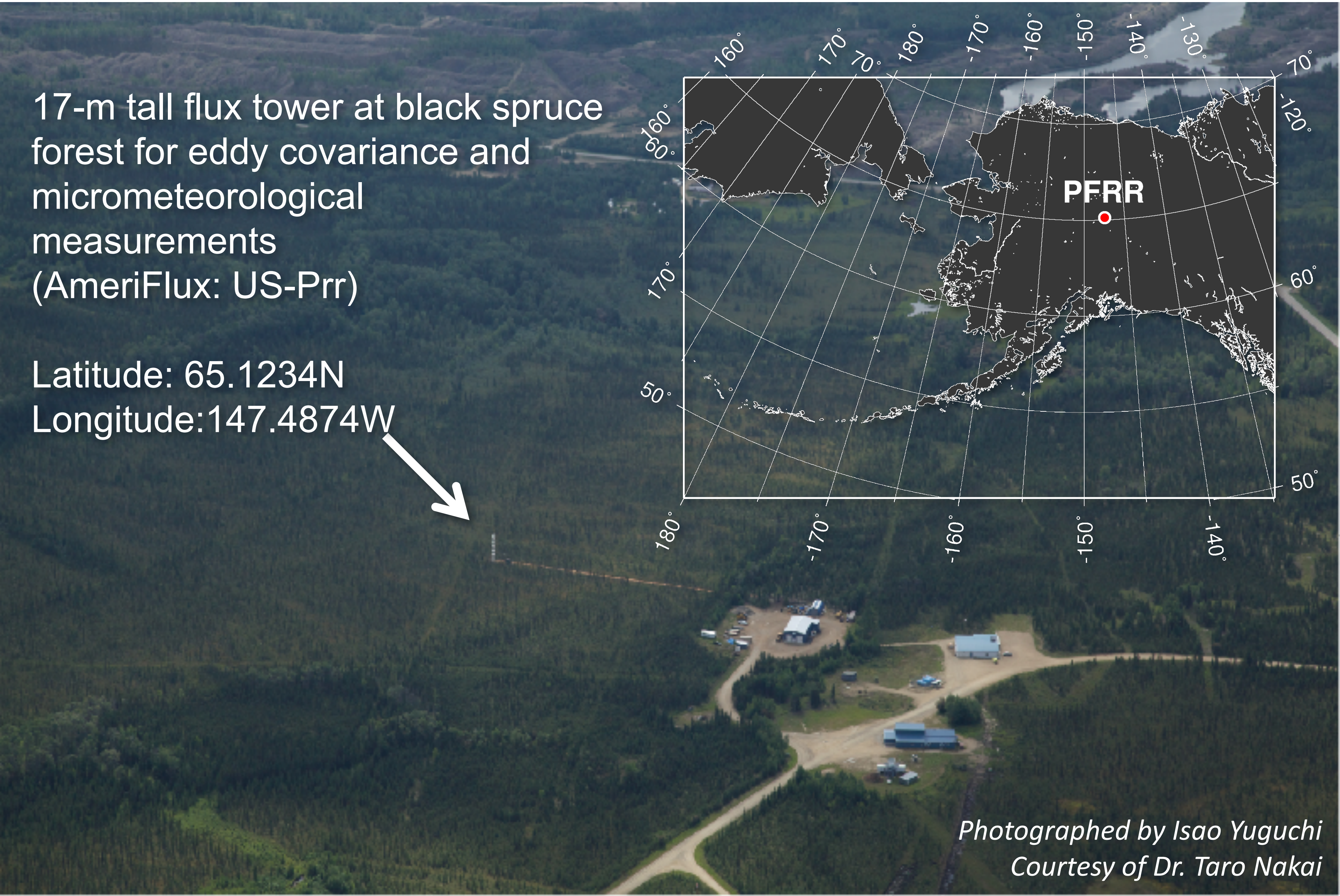
Graven et al., 2013

Seasonality in boreal ENF

- Plant phenology (GL, SOS, EOS) is one of the key information for terrestrial carbon sources and sinks
- For ENF, needle's color does change when looking visually but affect a little to NDVI
- In Interior Alaska, sporadic tree stands in black spruce forests are one of the most abundant landscape
- Understory plants changes seasonally

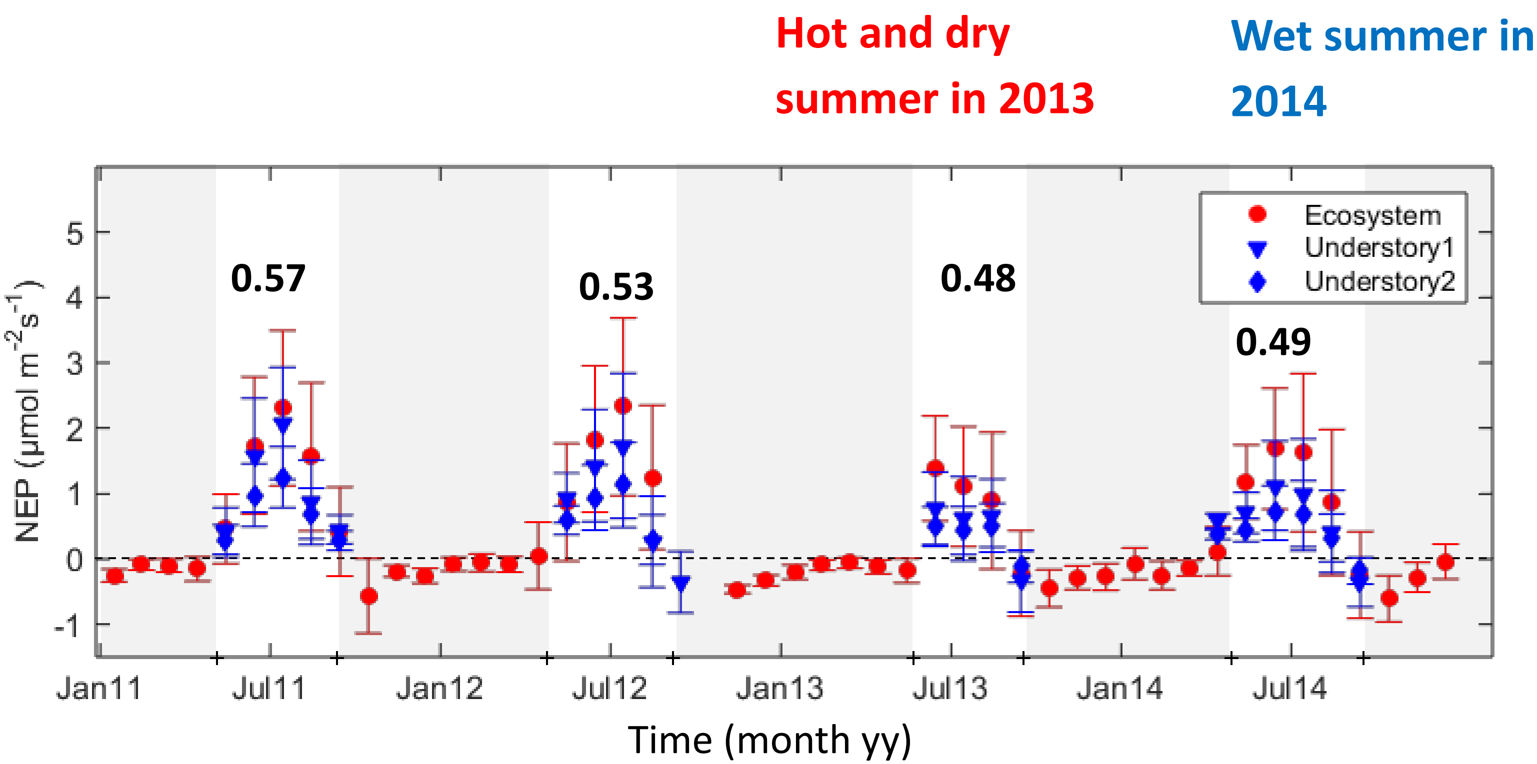

Black spruce forest at Poker Flat site
(Ameriflux: US-Prr)
“Understory” is mostly covered with moss,
lichen, grass, and dwarf shrubs
Tree cover 15~20 %
2014.09.12

Poker Flat Research Range, University of Alaska



Photographed by Isao Yuguchi
Courtesy of Dr. Taro Nakai

Understory CO2 flux (NEP) account for 48 to 57% of total NEP in an open black spruce forest

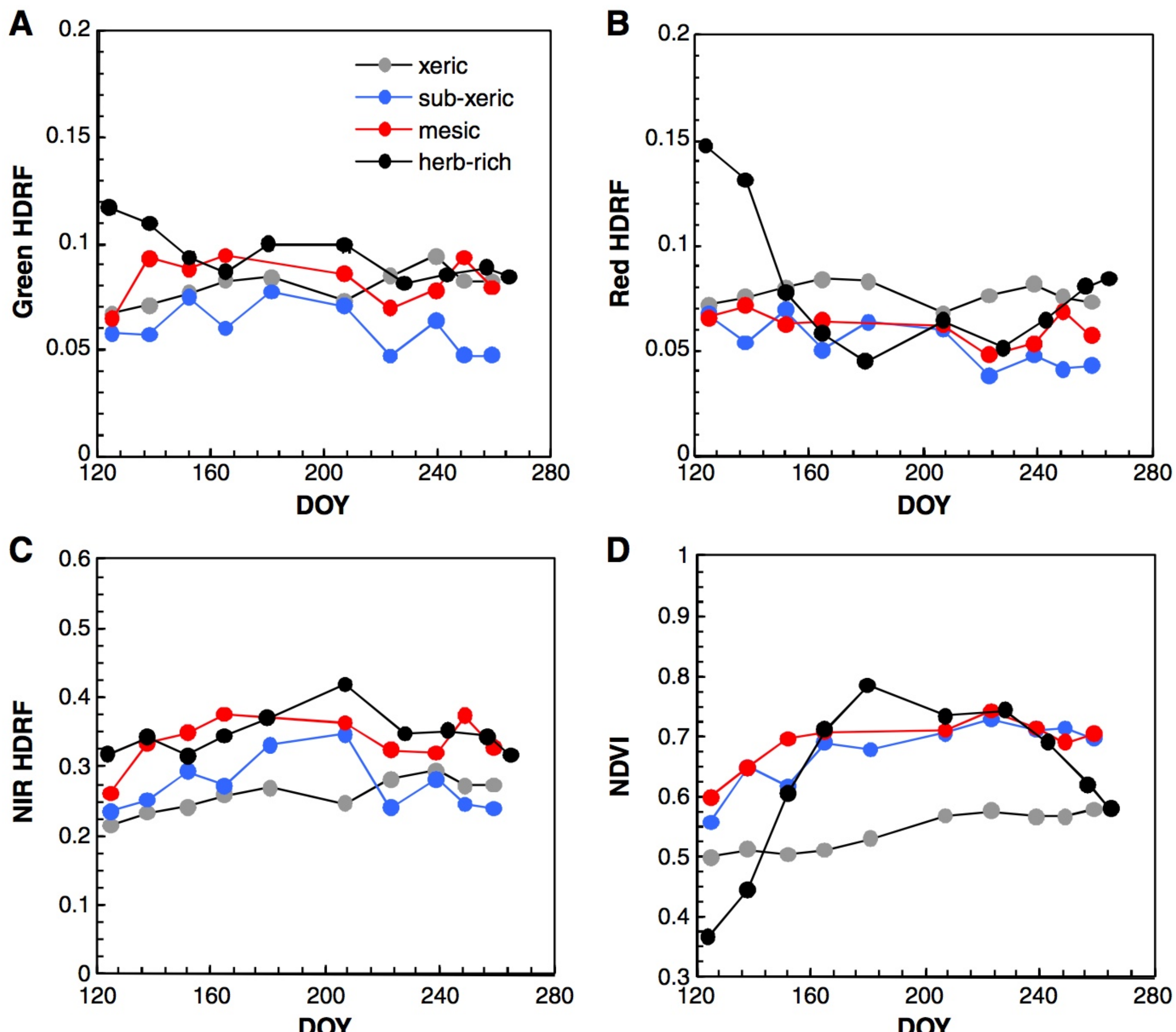


Ecosystem and understory NEP. Numbers indicate the understory contribution for each non-snow covered season. Shadows indicate the periods when the snow was present.

Ikawa et al, 2015, Agr. For. Met., 214-215, 80-90

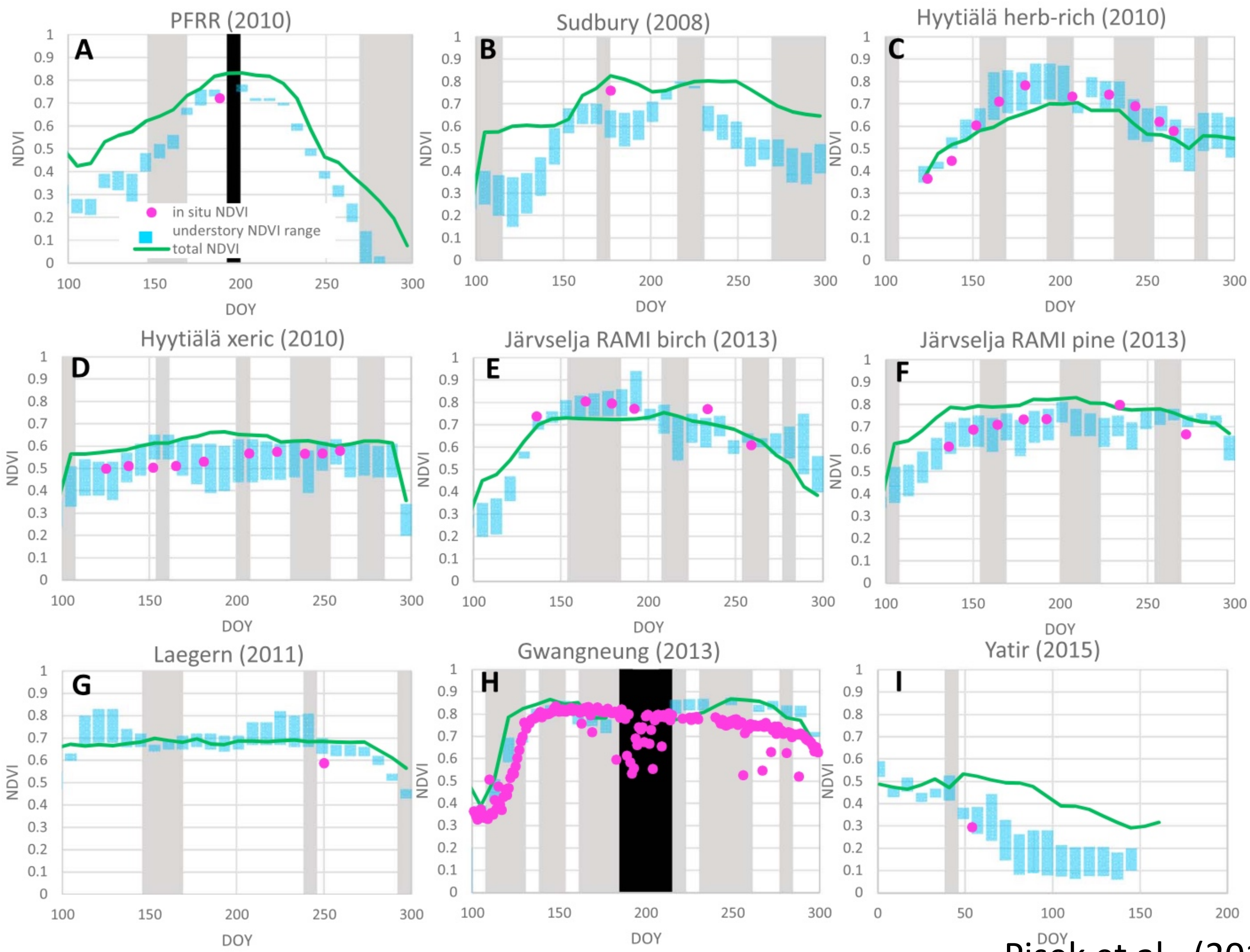
Seasonal change in reflectance

Hyytiälä in Finland



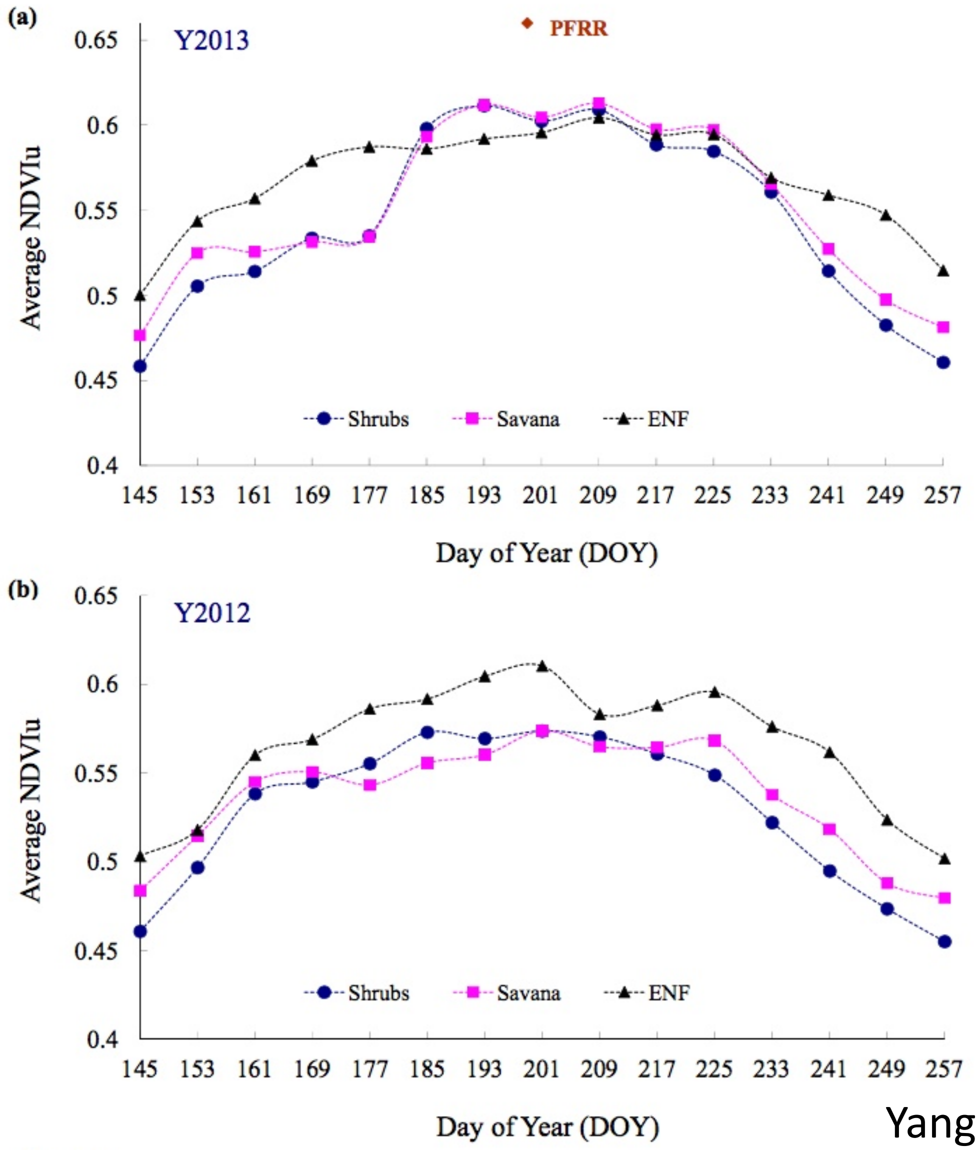
Rautiainen et al., 2011

NDVI seasonality of understory vegetation



Pisek et al., (2016) JGR

NDVI seasonality of understory vegetation



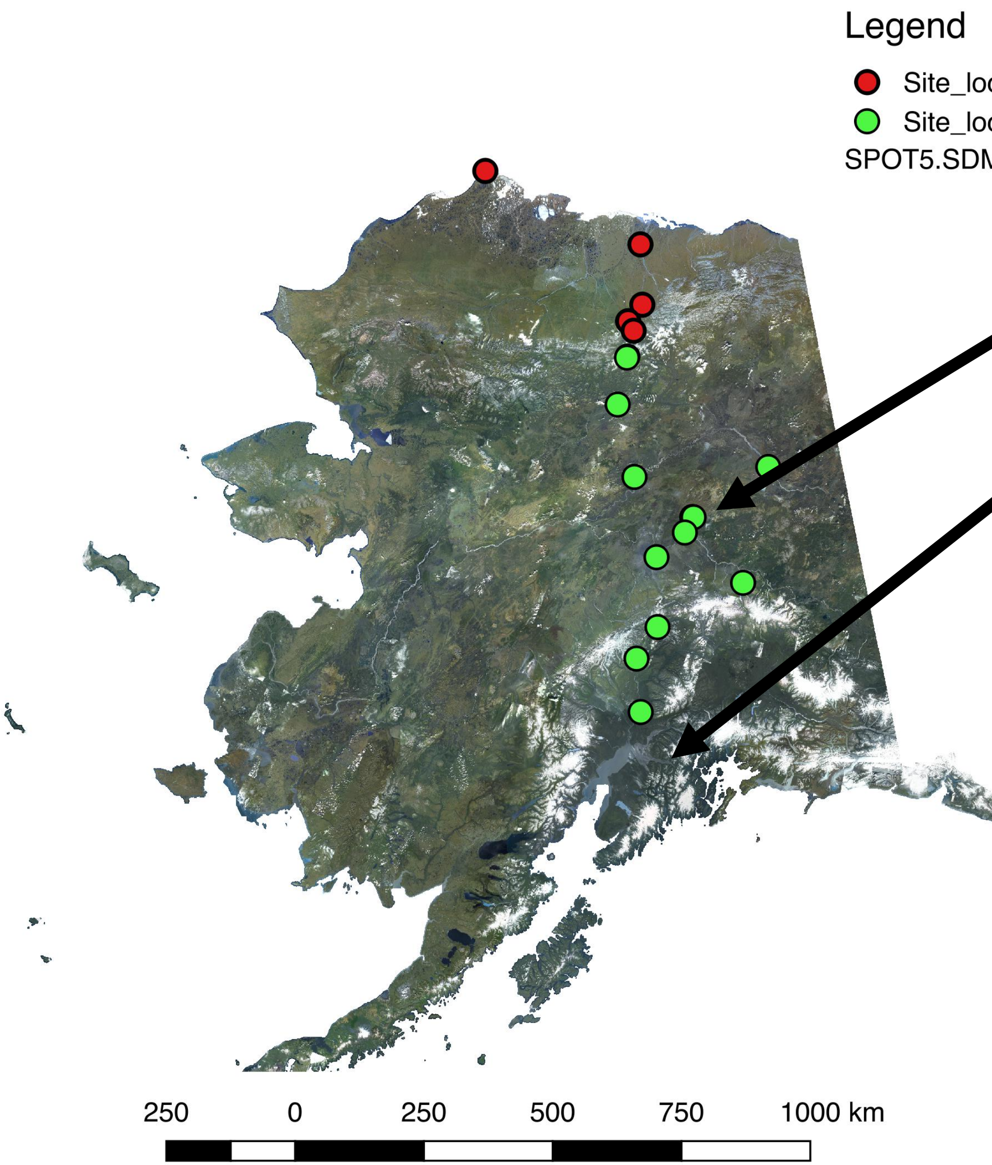
Yang et al., Remote Sens. 2014

Objectives

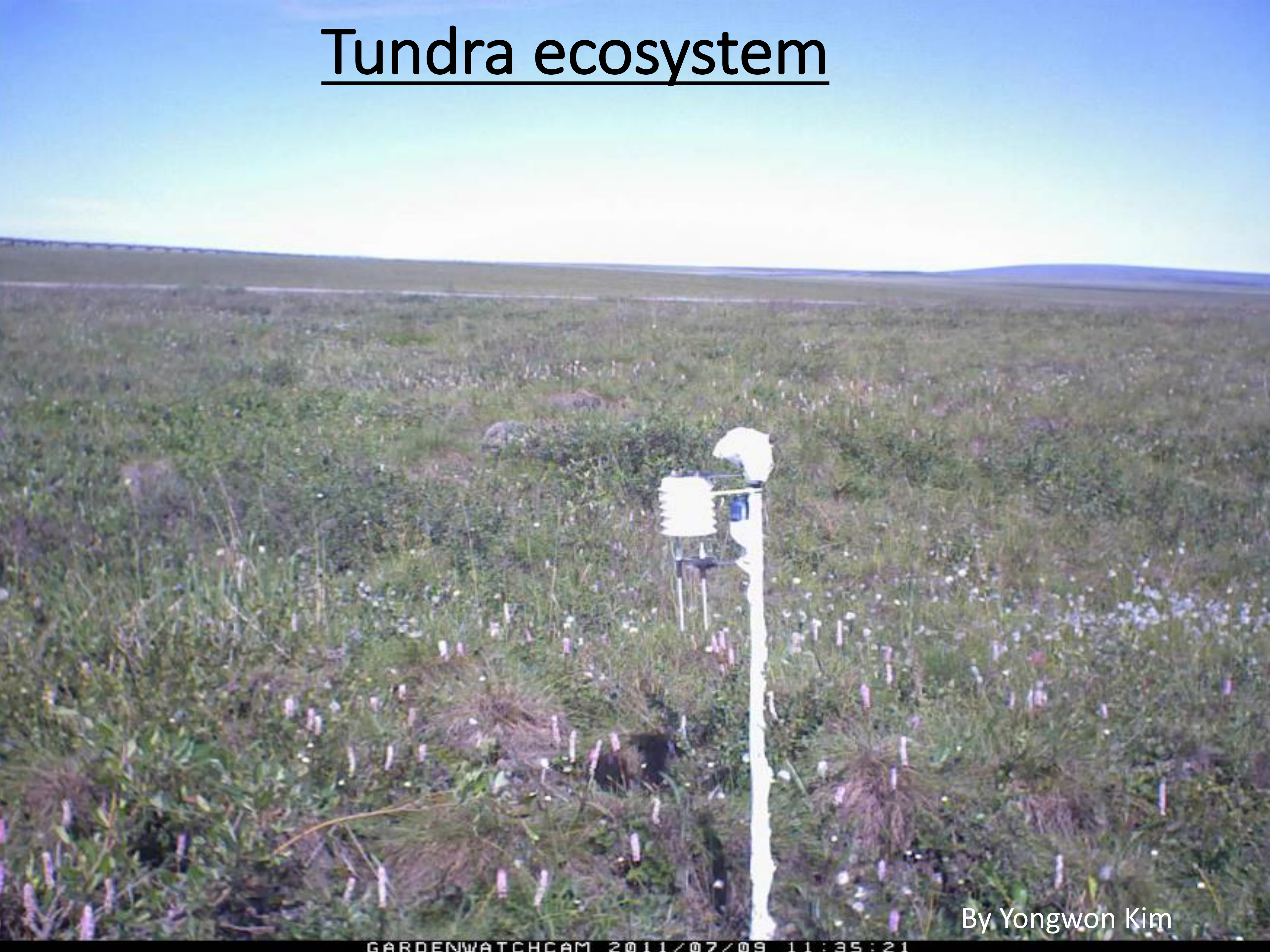
- To quantify the phenological timings of understory vegetation along the Alaskan highway (61 to 71-deg)

- To perform the RT simulation to understand the seasonality of open black spruce forest
  - Based on the forest census in Poker Flat Research Range (UAF)

Locations of time-lapse camera

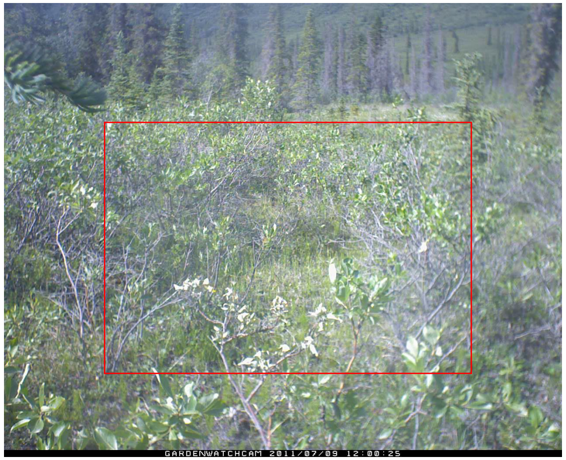


Tundra ecosystem



Understory conditions in July 9th, 2011

T-A



T-B

T-C

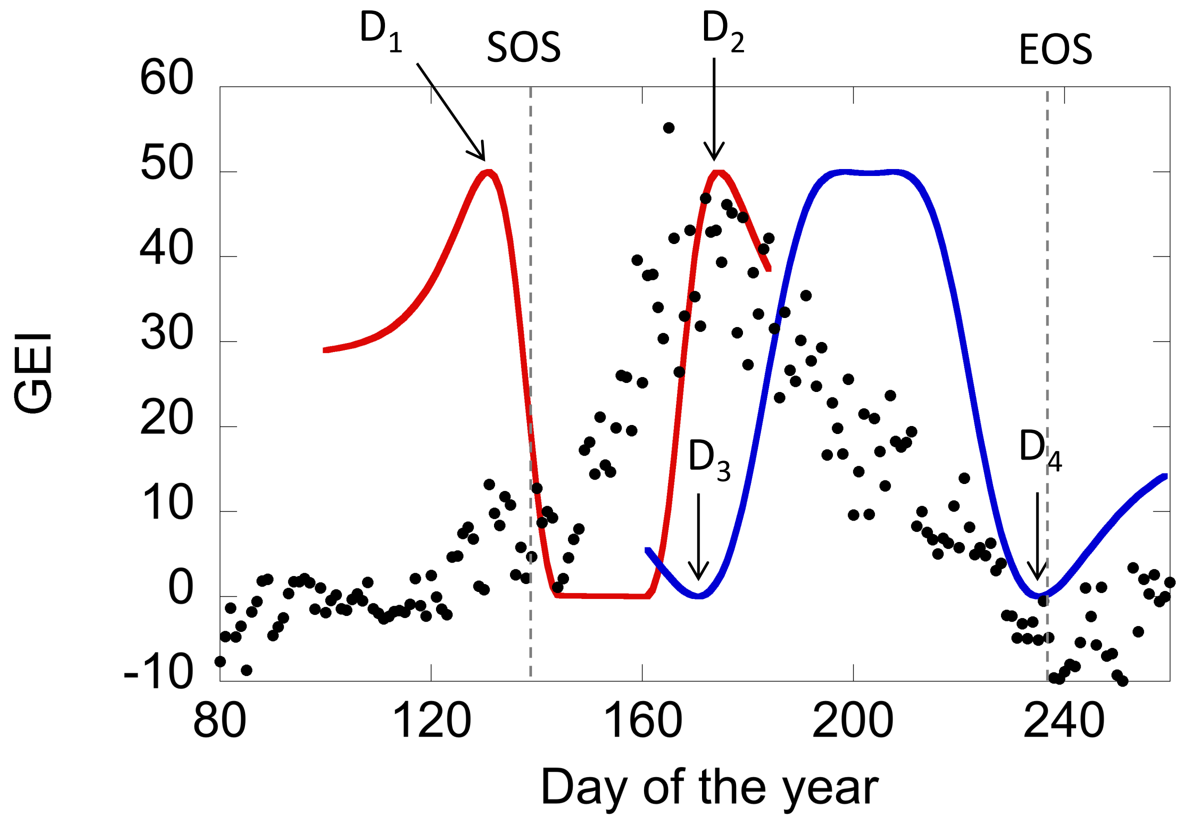
T-E

T-F

T-H

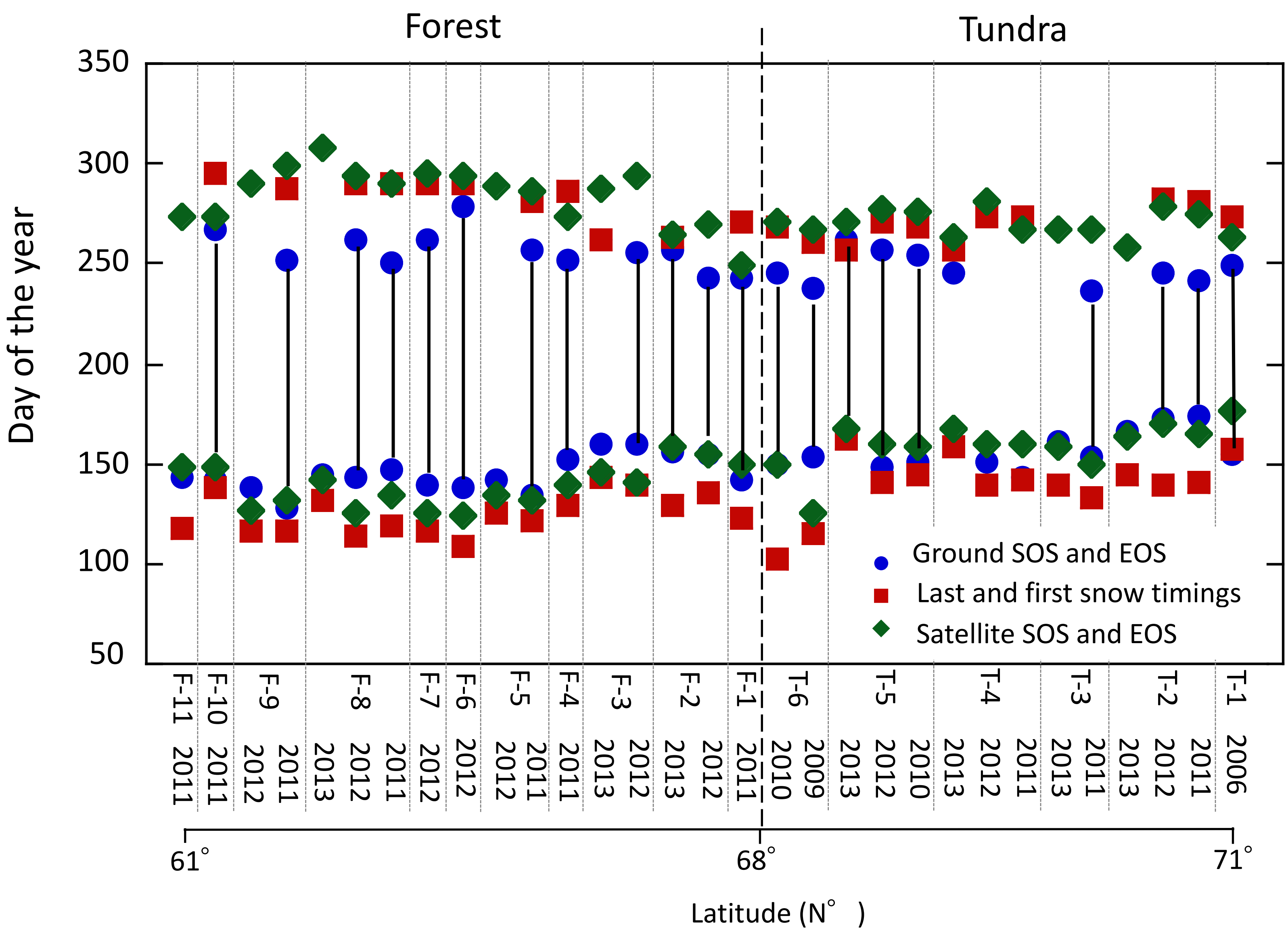
Dr. Sugiura (U of Toyama)

Determination of spring (SOS) and autumn (EOS) dates from camera and satellite data



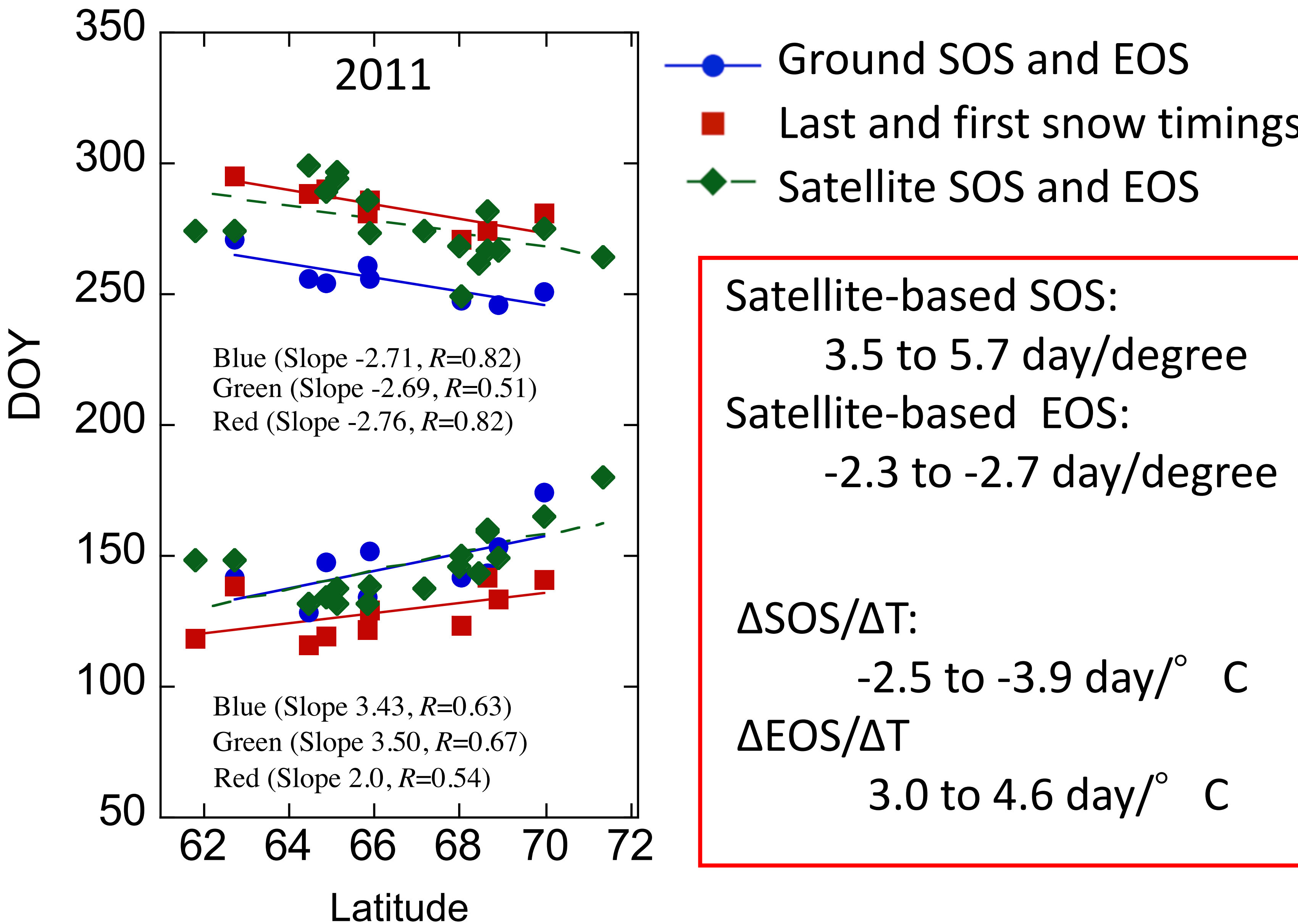
- MODIS phenology algorithm (Zhang et al., 2003) was applied for both camera index (GEI) and MODIS and SPOT-VGT VI data sets
- For satellite data, NDVI-threshold (White et al., 1997) and NDWI methods (Delbart et al., 2004) were also applied

Results



Forest
Tundra
Day of the year
350
300
250
200
150
100
50
Ground SOS and EOS
Last and first snow timings
Satellite SOS and EOS
F-11 2011
F-10 2011
F-9 2012 2011
2013
F-8 2012 2011
F-7 2012
F-6 2012
F-5 2012 2011
F-4 2011
F-3 2013 2012
F-2 2013 2012
F-1 2011
T-6 2010 2009
T-5 2013 2012 2010
T-4 2013 2012 2011
T-3 2013 2011
T-2 2013 2012 2011
T-1 2006
61°
68°
71°
Latitude (N°)

Latitudinal gradient

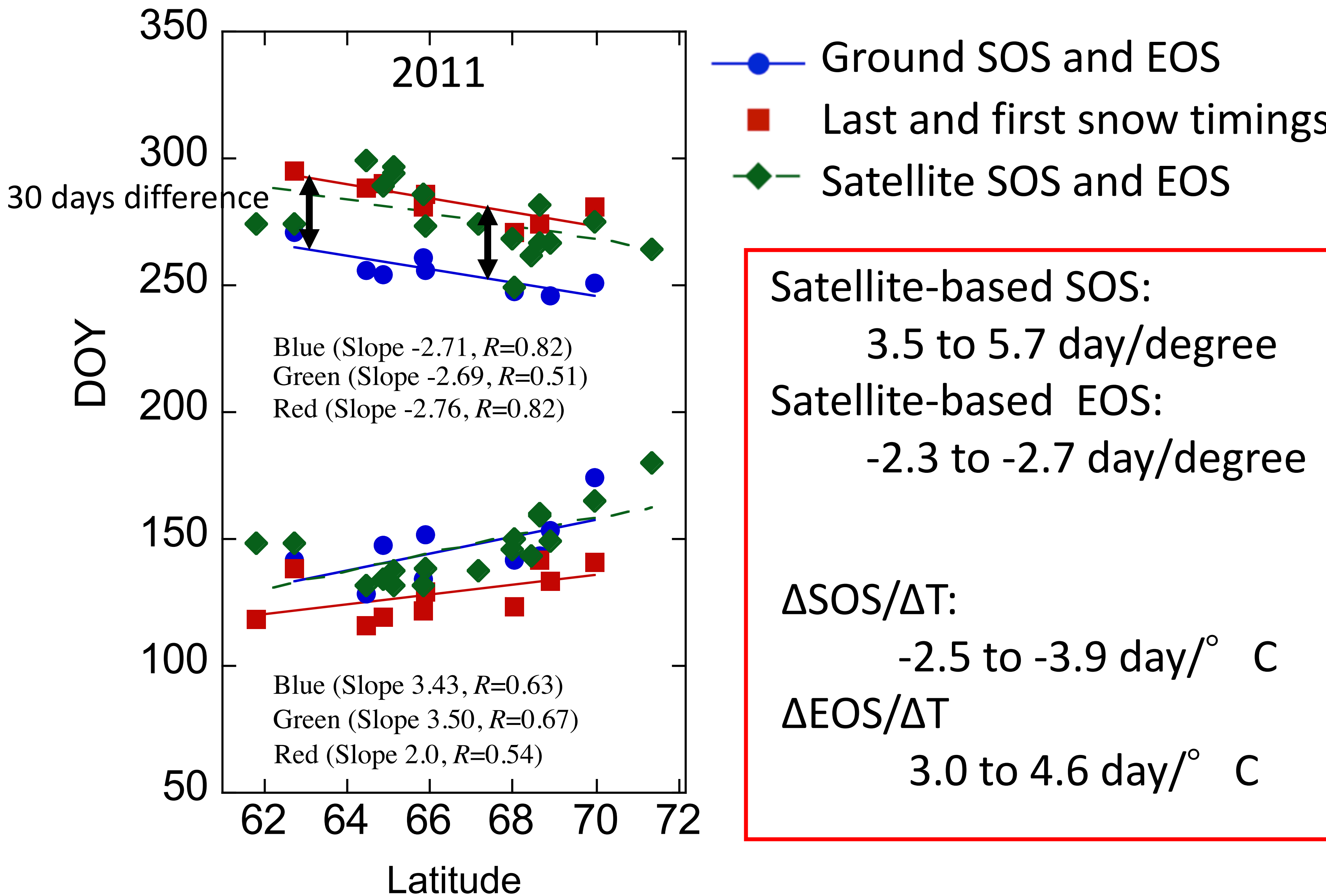


Satellite-based SOS:
3.5 to 5.7 day/degree
Satellite-based EOS:
-2.3 to -2.7 day/degree

ΔSOS/ΔT:
-2.5 to -3.9 day/° C
ΔEOS/ΔT
3.0 to 4.6 day/° C

Kobayashi et al., 2016 RSE

Latitudinal gradient



Satellite-based SOS:

3.5 to 5.7 day/degree

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-2.3 to -2.7 day/degree

ΔSOS/ΔT:

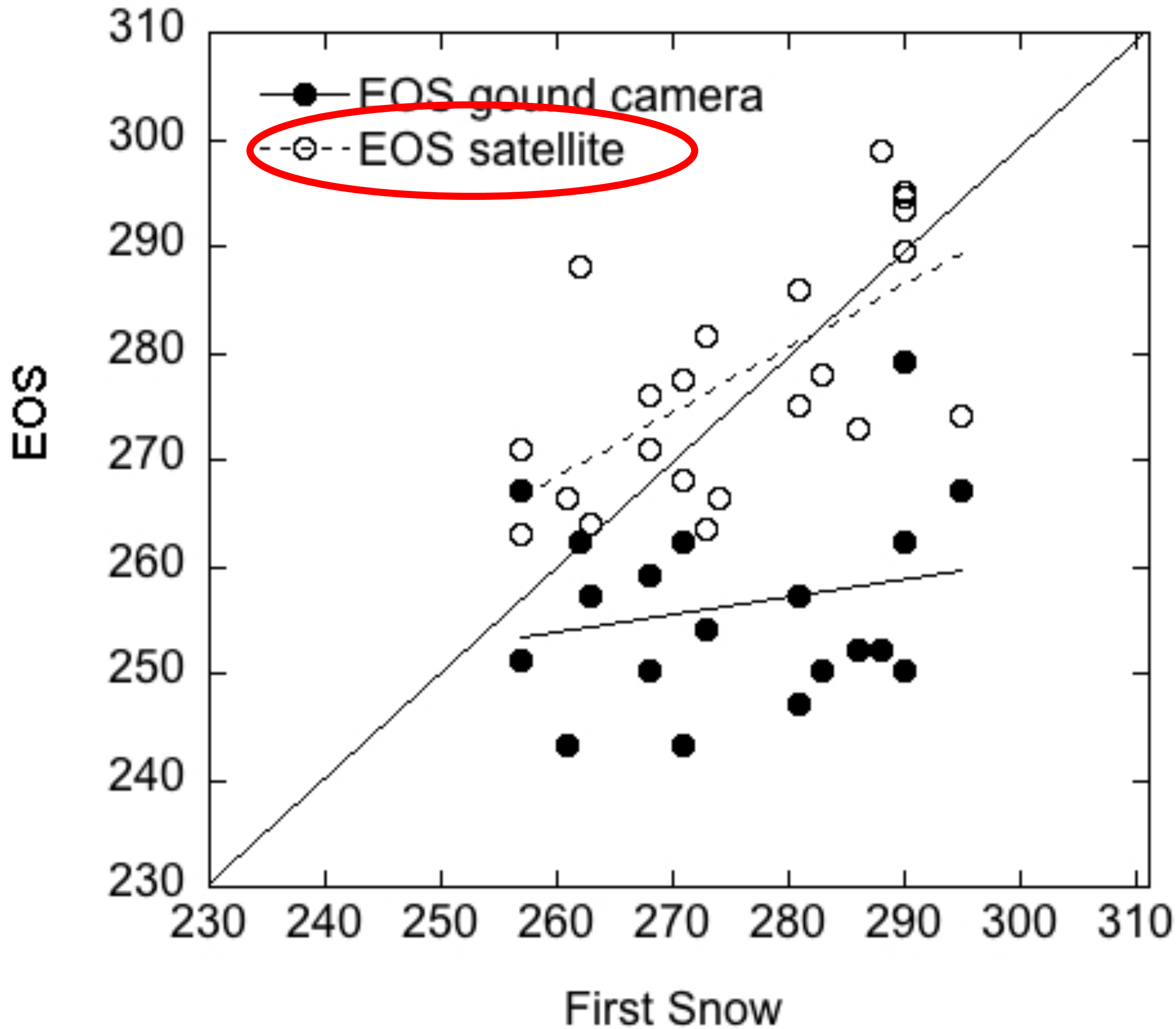
-2.5 to -3.9 day/° C

ΔEOS/ΔT

3.0 to 4.6 day/° C

Kobayashi et al., 2016 RSE

First snow and EOS timings



Kobayashi et al., 2016 RSE

- Canopy cover of Alaskan black spruce forests are sparse (PFRR 15-20%)
- Leaf colors of understory vegetation turn to brown from late August to September, but not detected by satellite

RT simulation

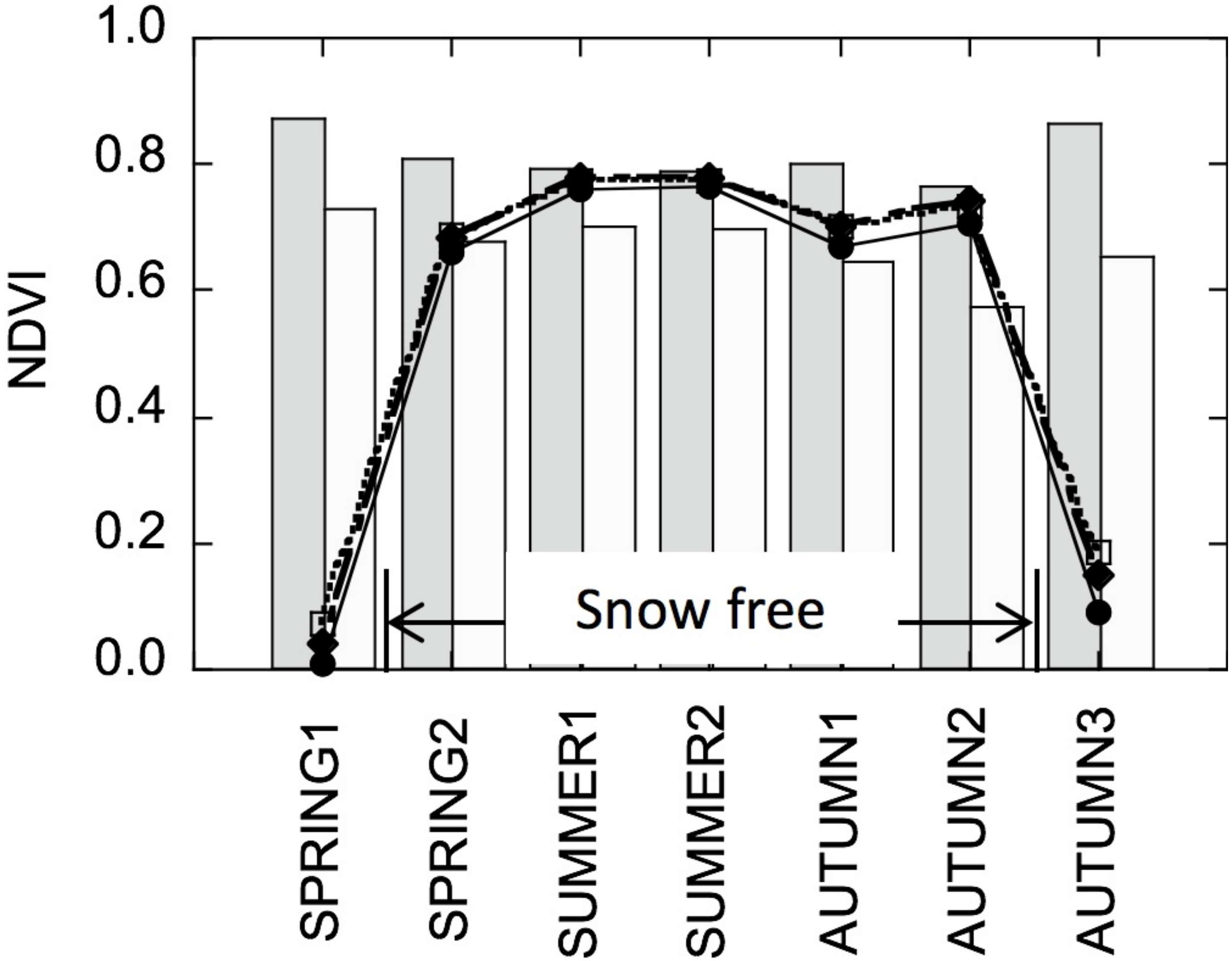
RT simulation for reflectance and VI

- Model
  - ✓ 3D Monte Carlo Ray-tracing model, FLiES (Kobayashi and Iwabuchi, 2008)
- Tree condition
  - ✓ 30m x 30m Census at PFRR (2010)
- Black spruce needle reflectance and transmittance
  - ✓ ORNL database
- Shoot clumping
  - ✓ Chen et al (1997)
- Understory seasonality

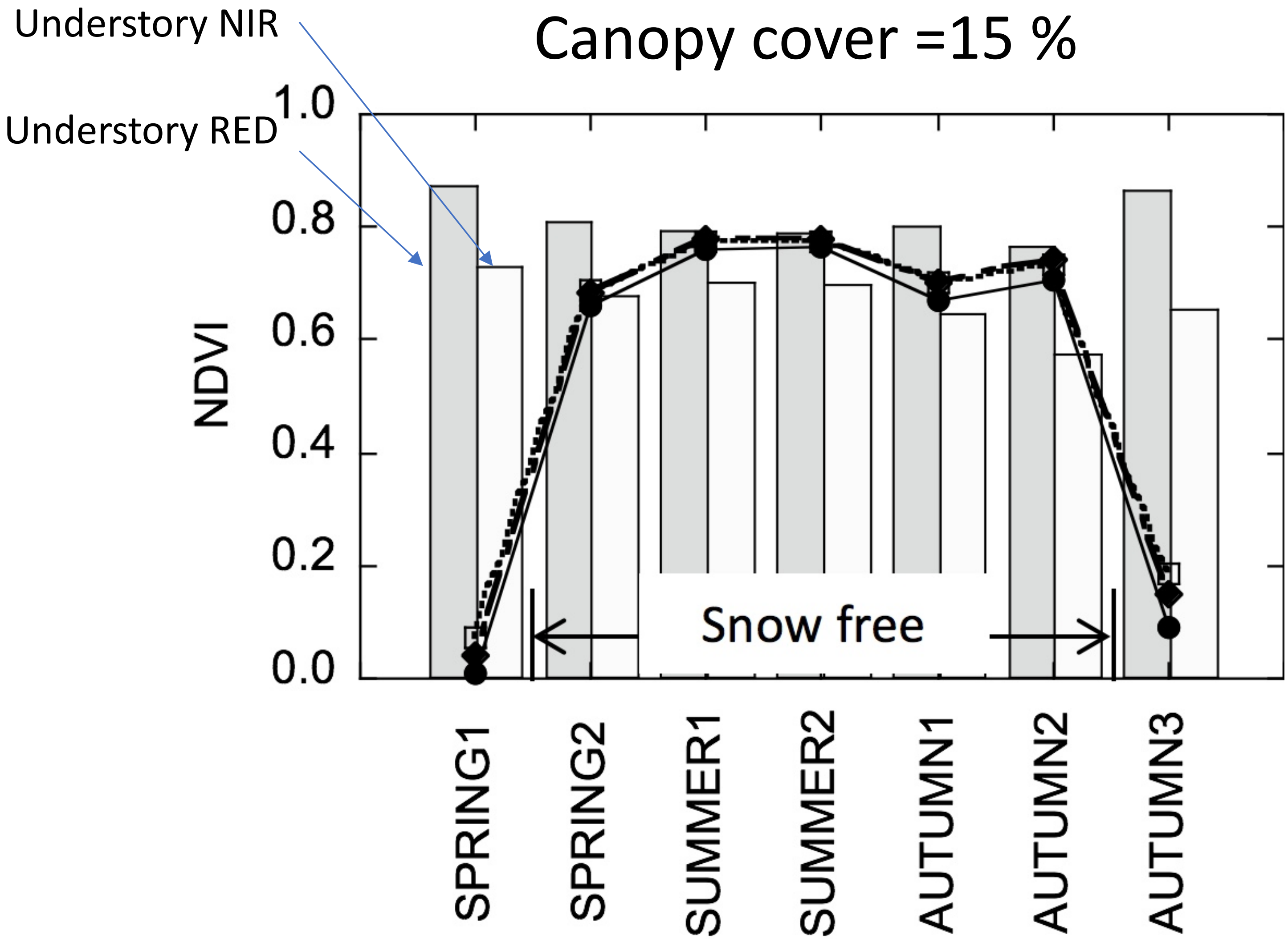
	DOY	SZA	Understory reflectance	
			Red	NIR
Spring-1 w/snow	140 (May 20th)	47.57°	0.561	0.466
Spring-2	140 (May 20th)	47.57°	0.0737	0.294
Summer-1	182 (Jul. 1st)	44.31°	0.0527	0.330
Summer-2	213 (Aug. 1st)	49.14°	0.0527	0.330
Autumn-1	244 (Sep. 1st)	58.62°	0.0737	0.294
Autumn-2	274 (Oct. 1st)	69.93°	0.0737	0.294
Autumn-3 w/snow	274 (Oct. 1st)	69.93°	0.561	0.466

Simulated seasonality

Canopy cover =15 %



Simulated seasonality



- Contributions of understory spectral signal decrease from spring to autumn
- In autumn, satellite views more greenery overstory than brown understory

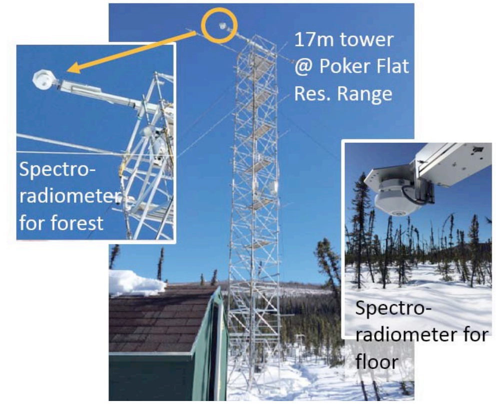
Summary

- Even in the extremely sparse tree stands like Alaskan black spruce forest (CC < 20%), detection of autumn phenological timings of understory vegetation is not straightforward

- RT simulation predicted that NDVI may increase in the early autumn because of satellite views more greenery overstory needles rather than brown understory
  - ✓This has not been confirmed from actual satellite data

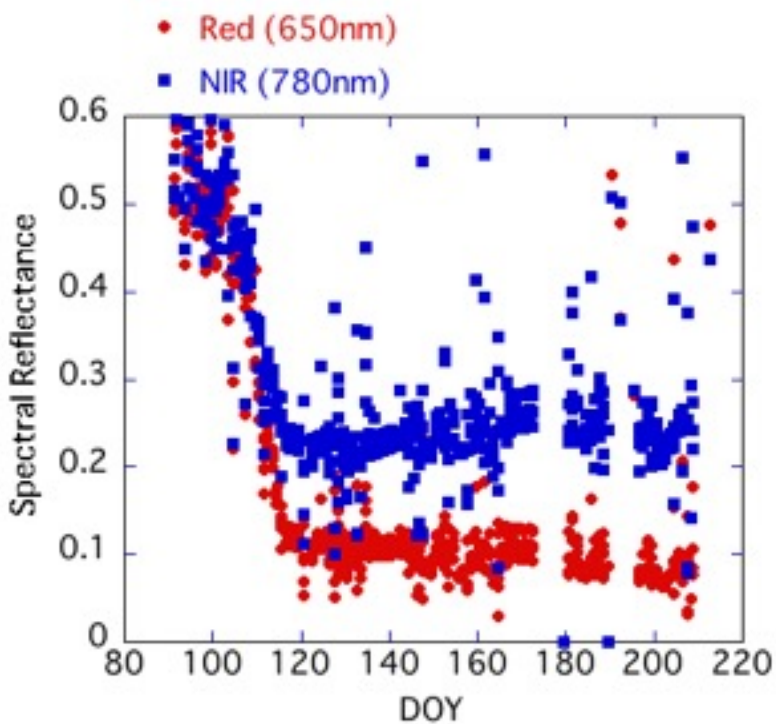
- Continuous observation in the remote boreal location help to understand the signature from satellites

Spectral reflectance at top of tower/forest floor at PFRR

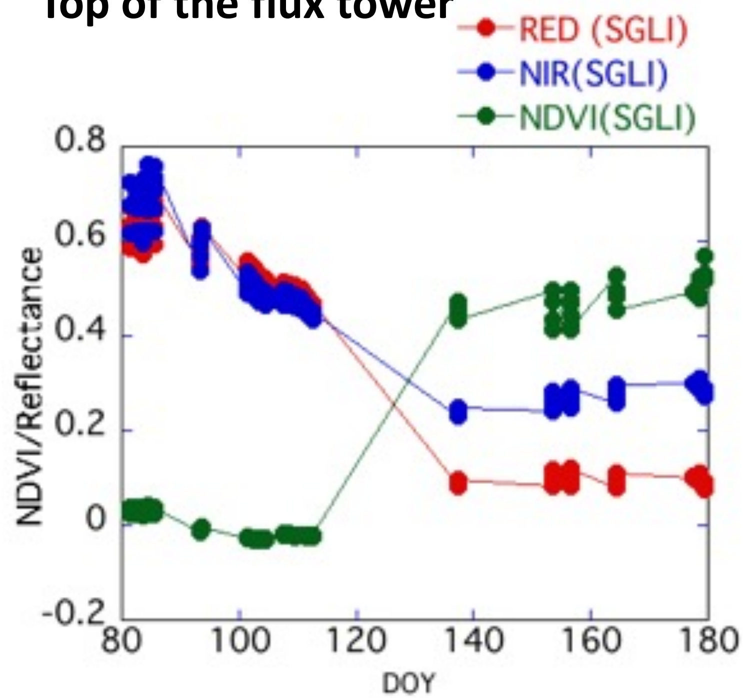


Spectral reflectance has been measured since March 2015 by two sensors: Top of the tower and black spruce forest floor.

MS-700, 2015 All data in 12:00-13:00
Top of the flux tower



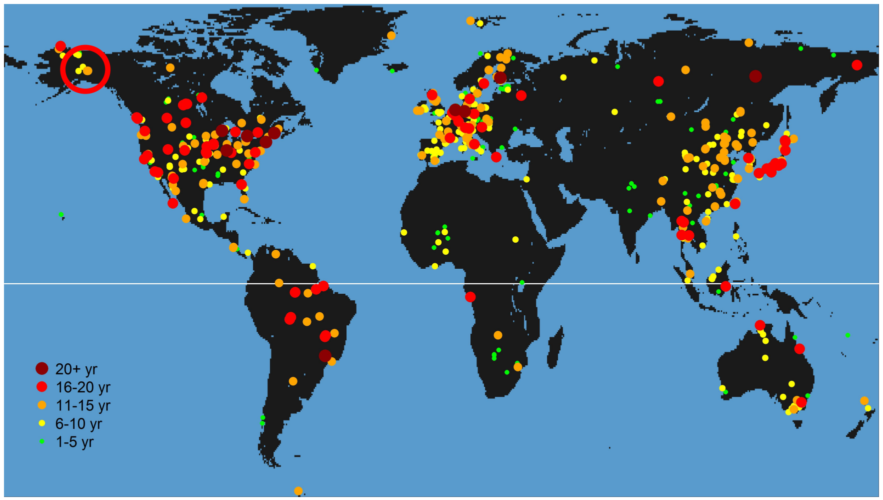
MS-700, 2017 Clear sky: 12:00-13:00
Top of the flux tower



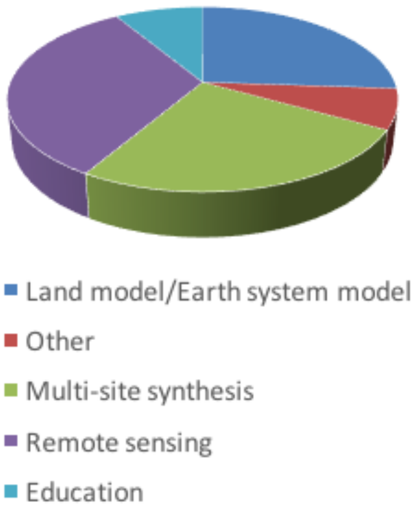
US-Prr flux data available from AmeriFlux & FLUXNET2015

Total # download = 316 (As of June 17th, 2017)

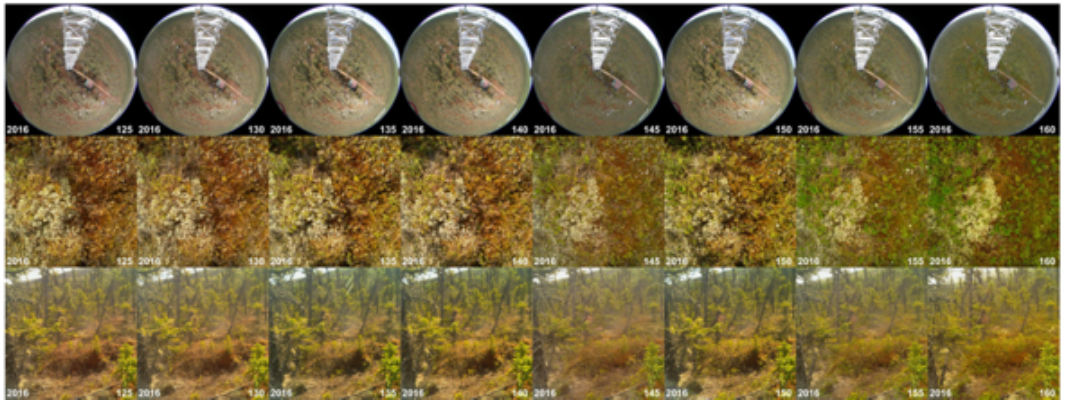
FLUXNET2015



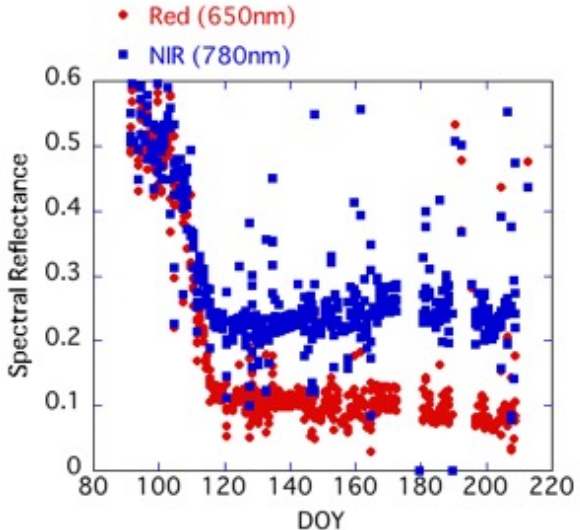
How to use



Time lapse camera data

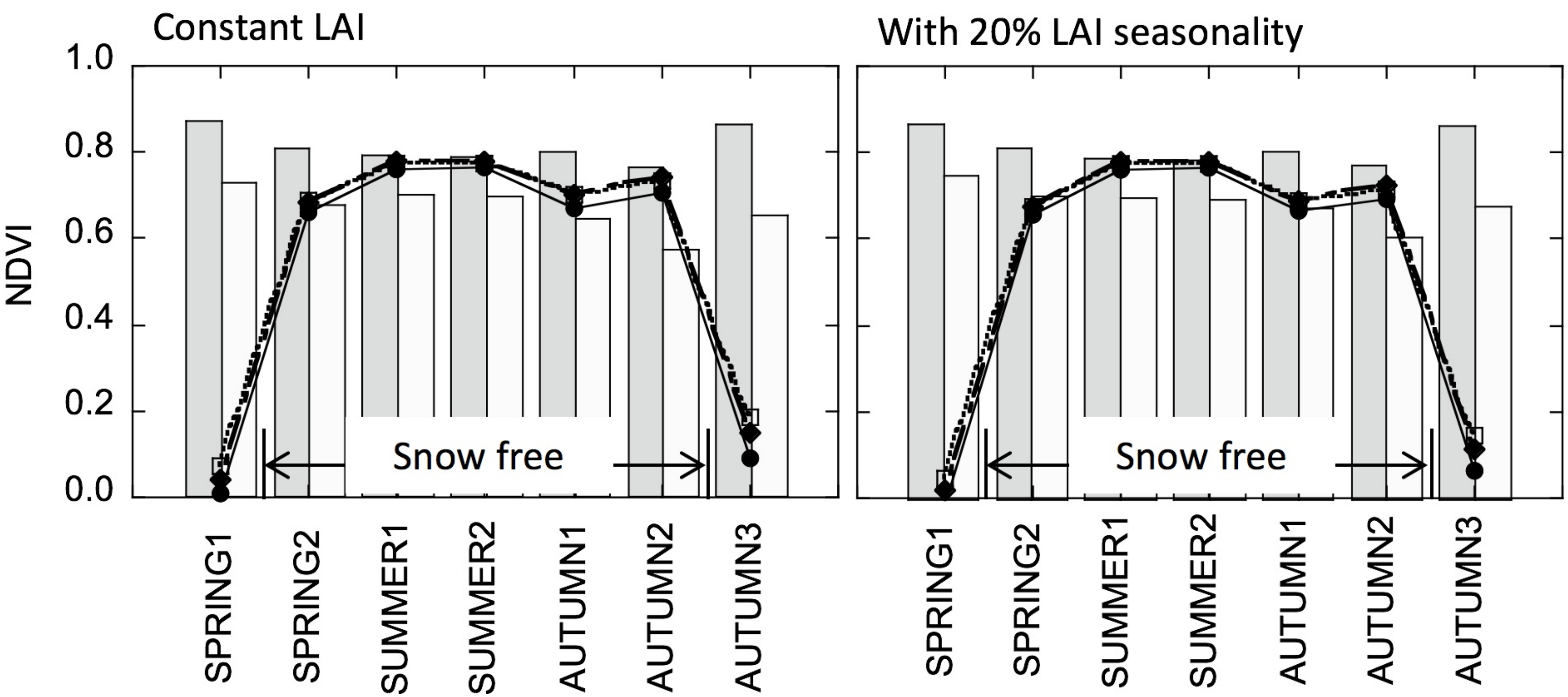


Spectral reflectance



Simulated seasonality

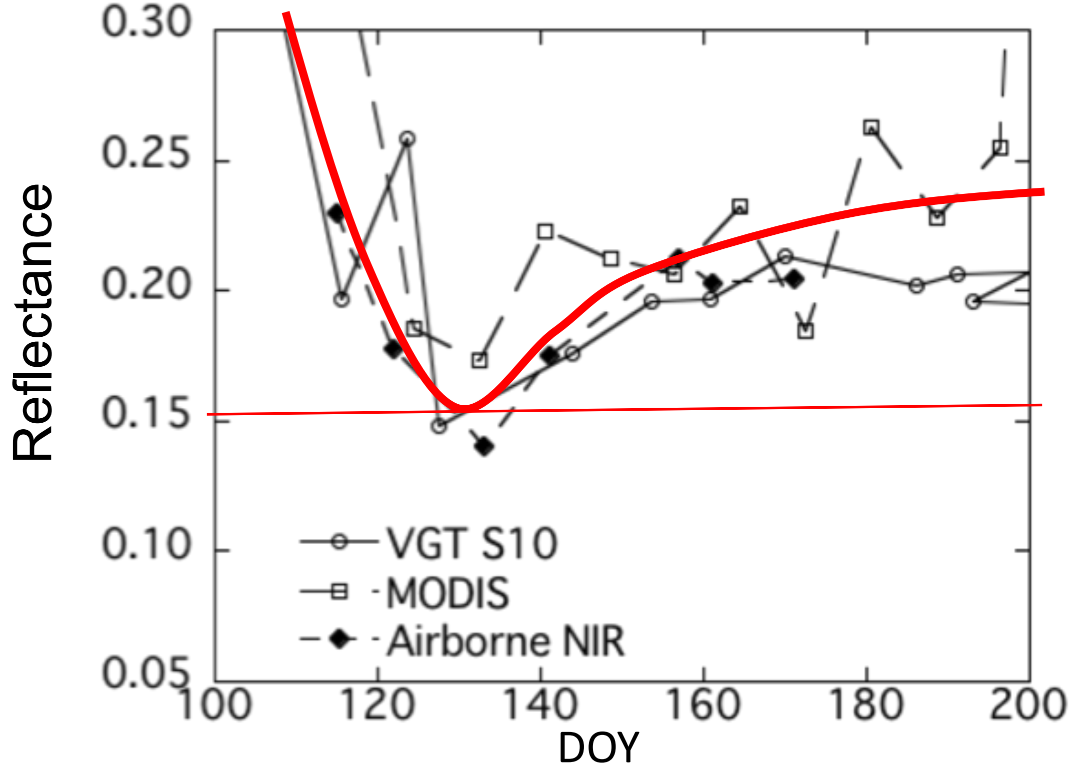
Canopy cover =15 %



Seasonal change in reflectance

NIR reflectance in East Siberian larch forest

Suzuki, et al., RSE (2011)



Kobayashi, et al., RSE (2007)