Use of cameras to track phenology of trees, experiences from Monimet project

Mikko Peltoniemi, Mika Aurela, Kristin Böttcher, Pasi Kolari, John Loehr, Cemal Melih Tanis, Maiju Linkosalmi, Ali Nadir Arslan et al.

EU Life+ MONIMET(LIFE12 ENV/FI/000409) Final Stakeholder Workshop on "Climate Change Indicators and Vulnerability of Boreal Zone Ecosystems"

Why to monitor phenology?

- There is a motivation to monitor seasonal changes of ecosystems, climate change, no-analogue future

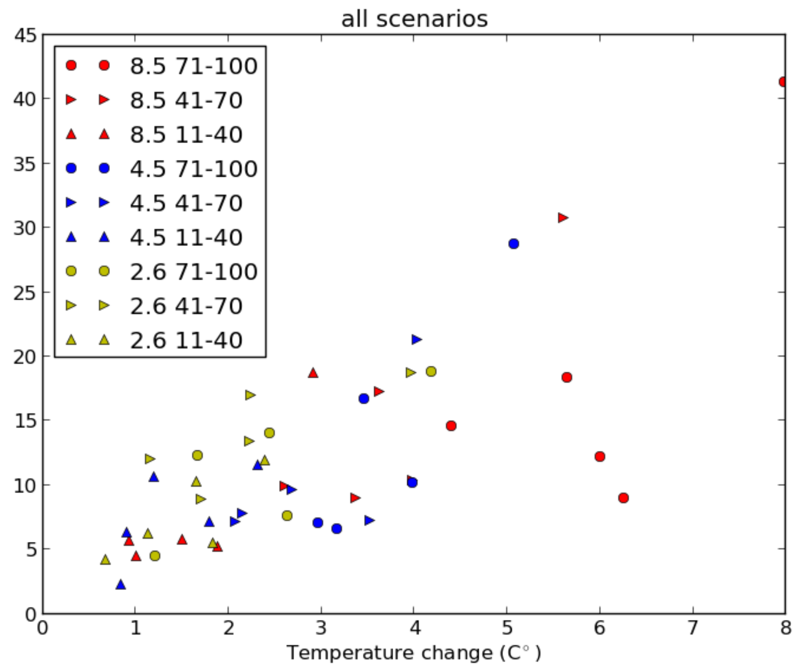


Fig. Climate change projections for this century by 5 climate models, RCP 2.6, 4.5, 8.5. Fig. T. Markkanen

- Models poorly predict phenology in general (Basler et al., 2016)

Why to use cameras for phenological monitoring

- Optical EO is frequently interfered by clouds

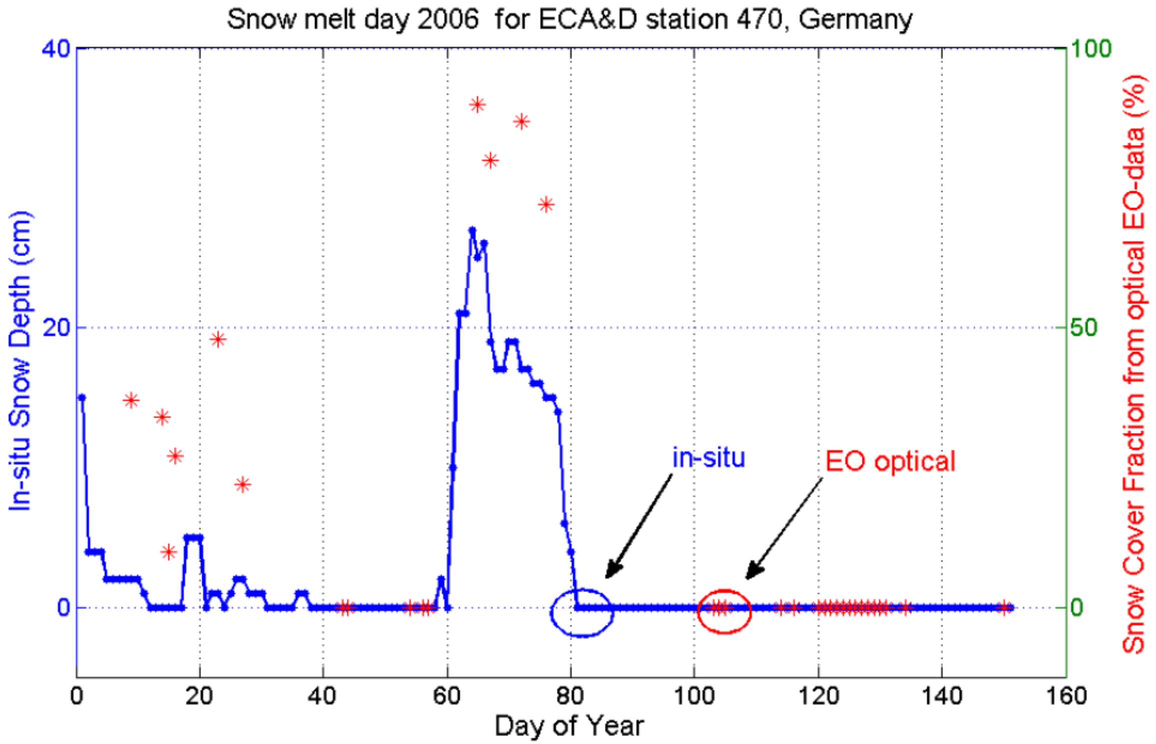


Fig. EO vs. in-sity observation of snow. Fig by S. Metsämäki

Why to use cameras for phenological monitoring

- Validation data needed
- Existing monitoring is field based and costly, cameras are multi-use
- Cameras are affordable and wide network could be established
- Cameras can observe distinctive phenological color changes

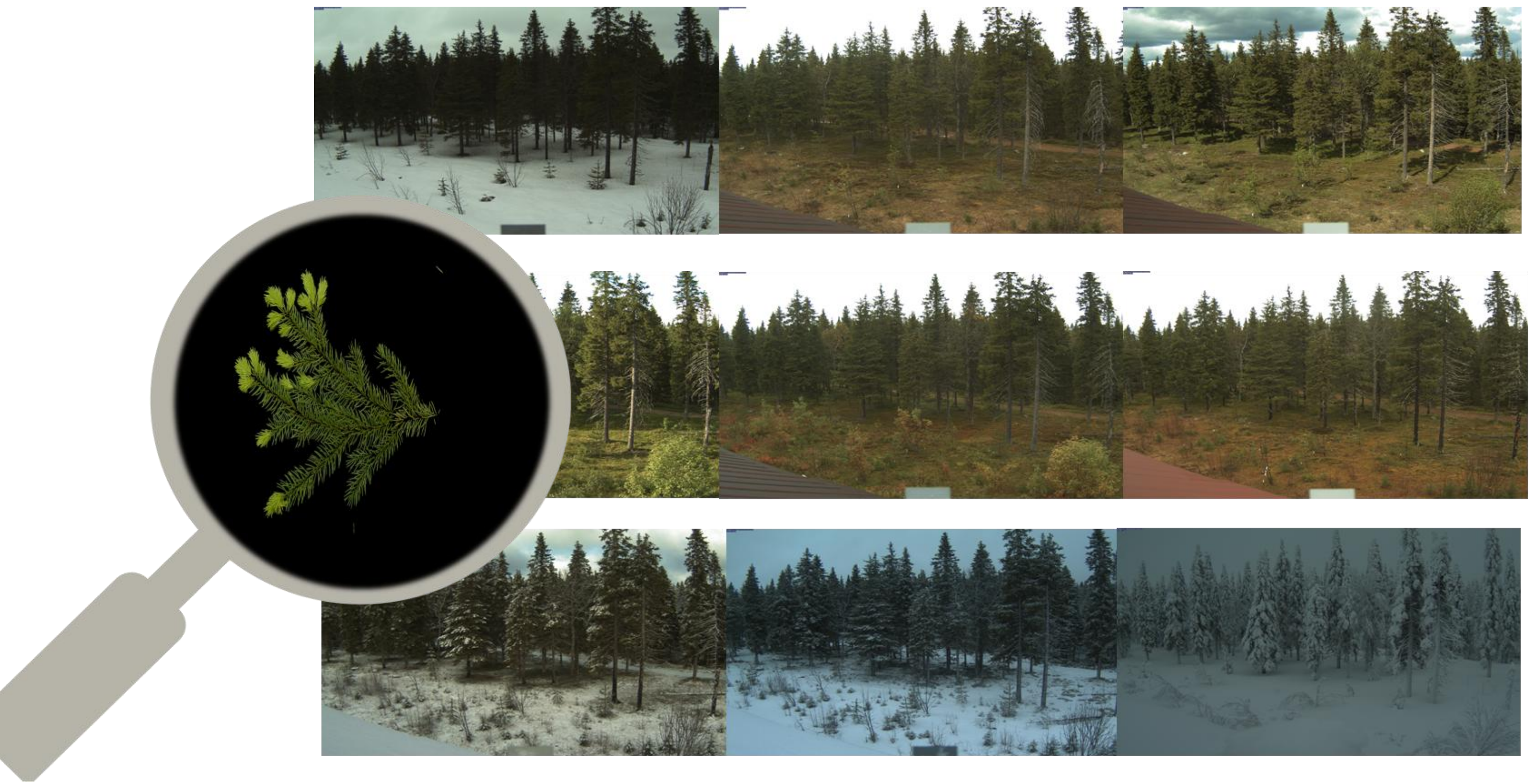


Fig. Paljakka, central Finland

Simple principle

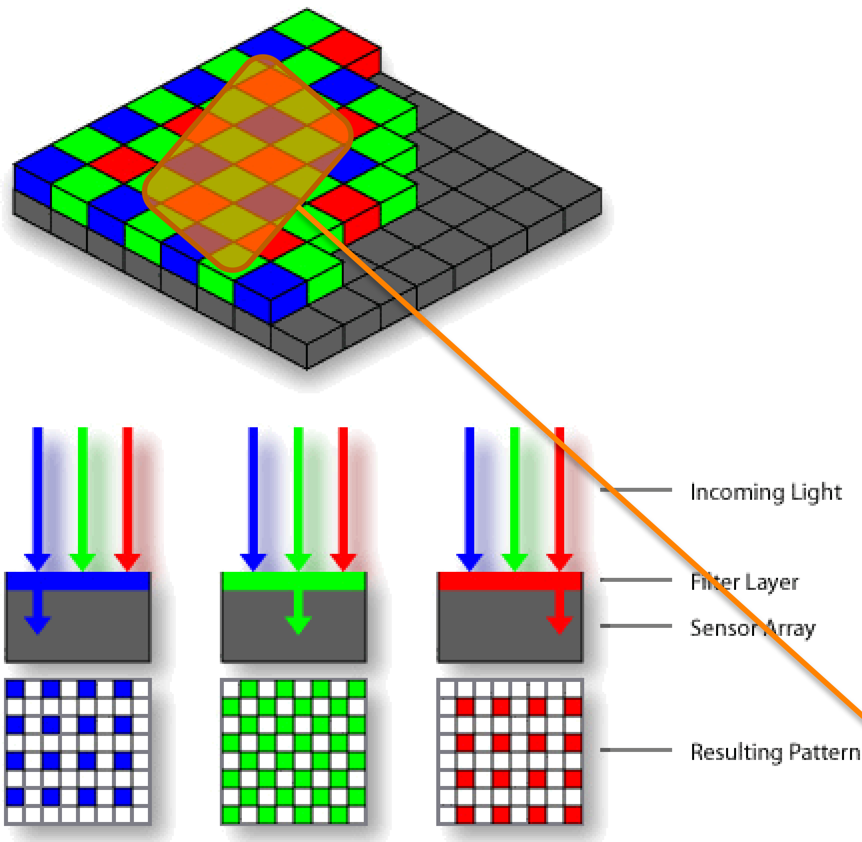


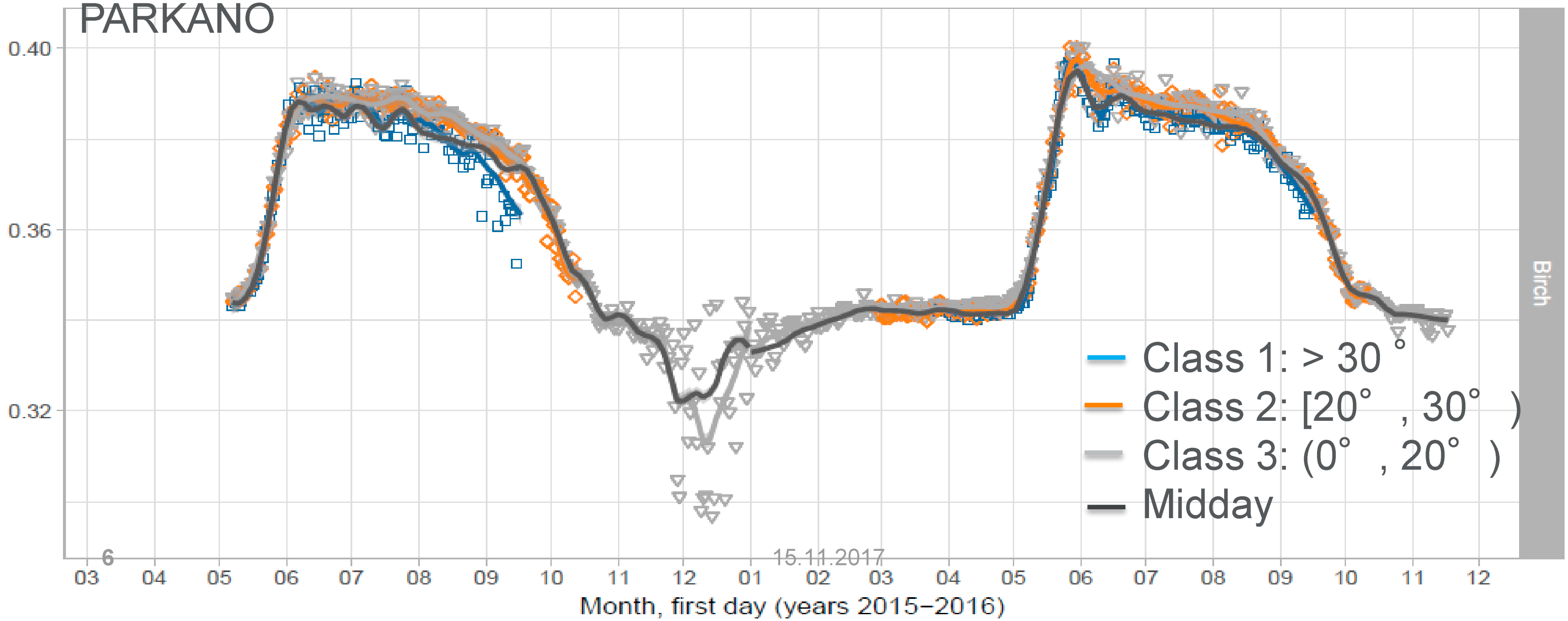
Fig. Wikipedia

- Very high resolution and quality/price (thanks to consumer markets)
- Color analyses can by constrained to sub-regions of images:
  - Snow
  - Birch
  - Spruce,
  - Etc.

e.g. GCC = G / (R+G+B),
Where R, G, B in [0, 254]
'green chromatic coordinate'

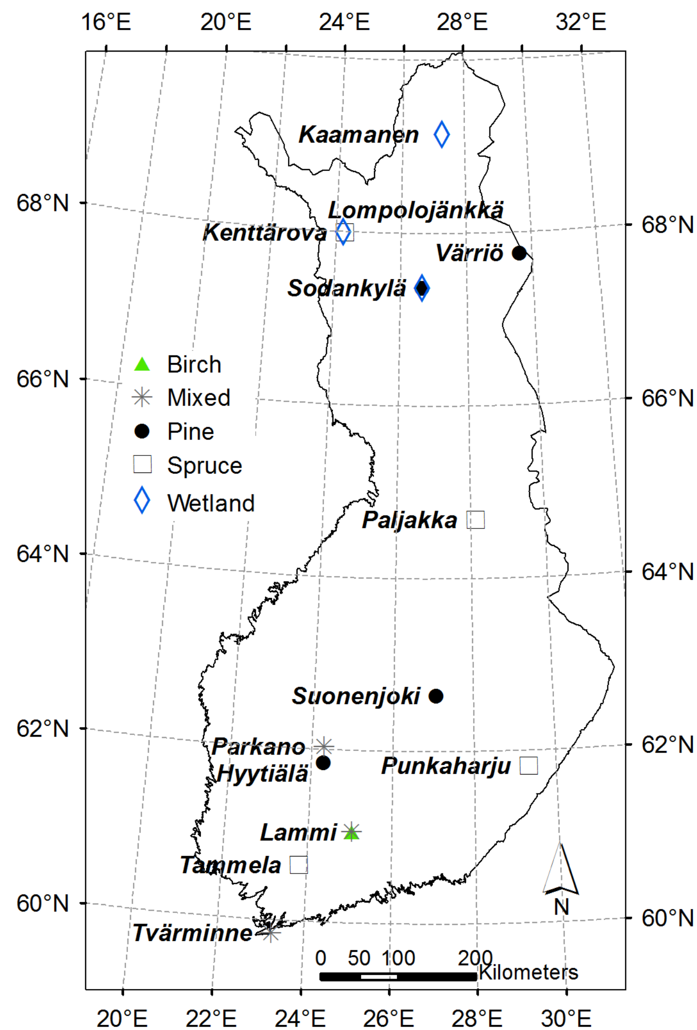
Green fraction (GCC) is fairly robust to illumination changes

- Seasonal signal of distinctive enough not to be confounded by solar angle effects on illumination spectral distribution
- …expect when it is very dark
- It seems possible to adjust algorithms to extract meaningful phenological variables



Camera network

- 15 sites
- Each site has 1-3 cameras
  - Mixed landscape/canopy
  - Crown
  - Understorey
- Sites vary in species composition / ecosystem type



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Open Access Earth System Science Data Discussions

Webcam network and image database for studies of phenological changes of vegetation and snow cover in Finland, image time series from 2014-2016

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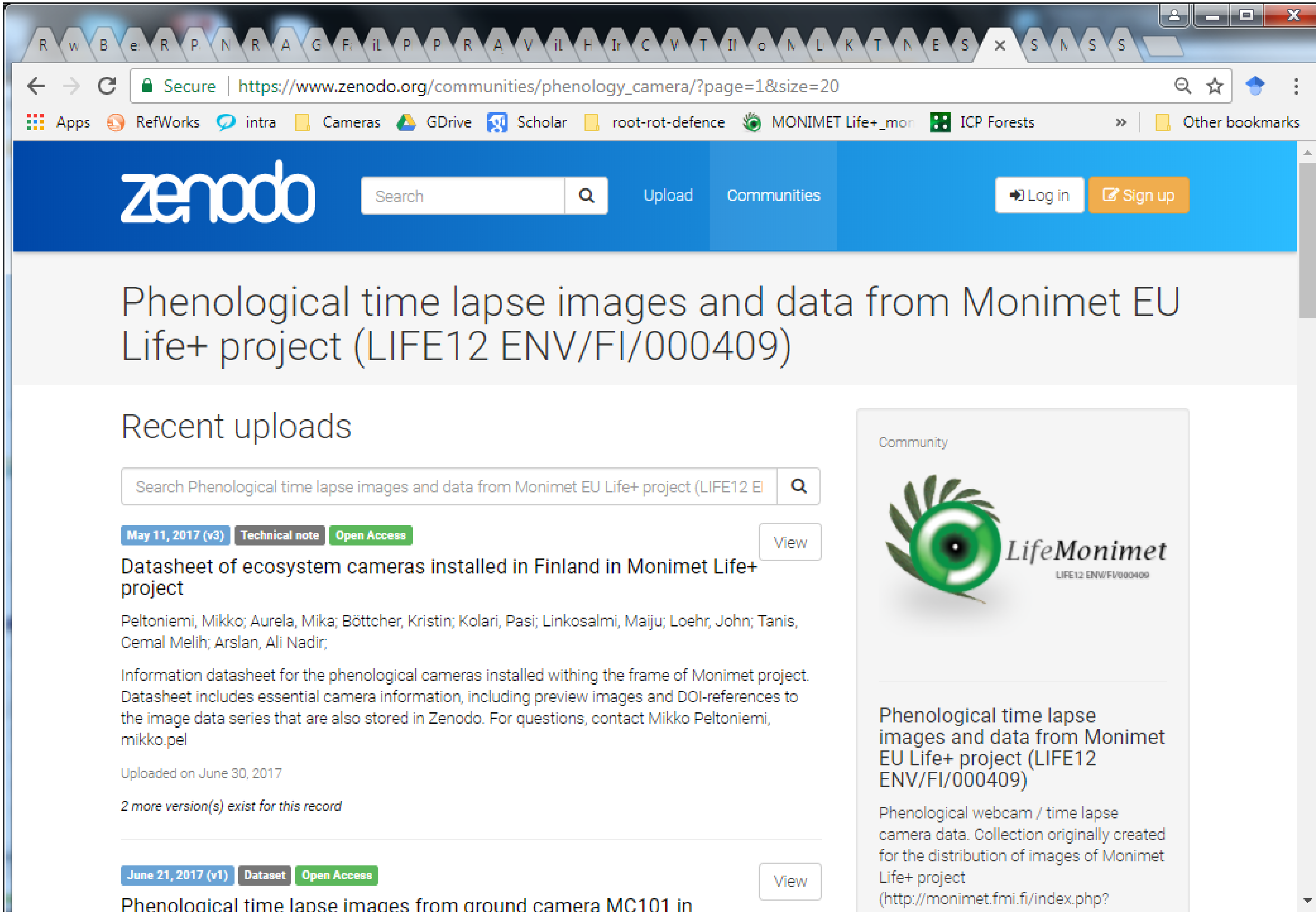
Open science data: Monimet image repository



Example: use of networked cameras in assessing birch ’colour’ phenology

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Networked web-cameras monitor congruent seasonal development of birches with phenological field observations

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Birches are appear frequently (sometimes coincidentally) in the camera views.

Question: Can cameras provide consistent information about birch phenology across latitudinal gradient of Finland?

Aim: To compare automatically derived phenological colour based transition dates from cameras to

- Visually extracted phenogical transition dates (by an expert observer)
- Phenological field observations from independent network

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Camera sites with birch appearances

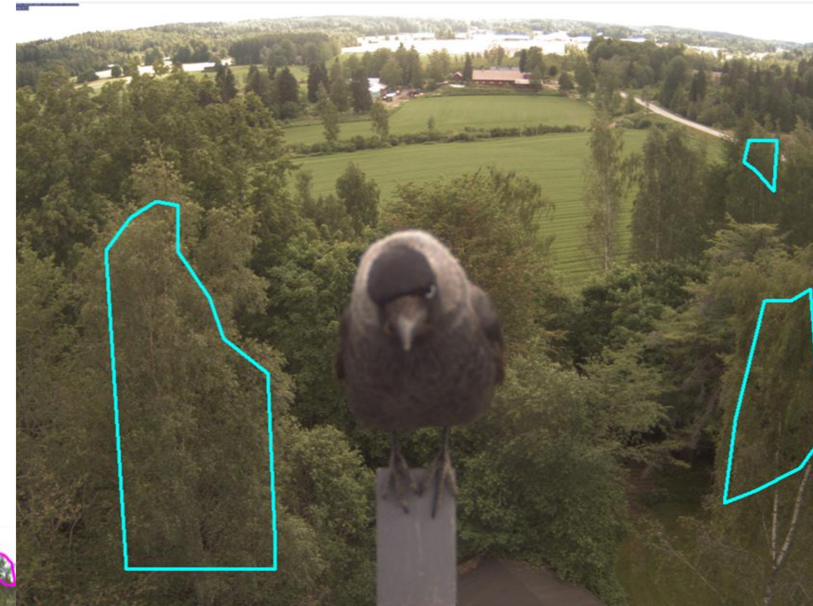
- Birch targets varied in quality i.e. proximity and size of the image region and background
- Camera positions (and to some extent the view directions) varied
- 1-6 trees were selected per image view.

Table 1 Subset of camera sites used in this study. For all camera sites and camera views suppl. 1. Coordinates are in decimal degrees WGS84.

No.	Site	Lat.	Lon.	Camera view / dominant species	Betula species analysed from image time series	Spring periods in data******	Autumn period in data******
1	Hyytiälä (crown)	61.85	24.30	Forest canopy / P. sylvestris	B. pendula	2014-2016	2014-2016
2	Kaamanen****	69.14	27.27	Wetland / Sphagnum spp.	B. pubescens	2015-2016	2015 – (2016)
3	Kenttärova (canopy)	67.99	24.24	Forest canopy / P. abies	B. pubescens	2015-2016	2015-2016
4	Lammi (landscape)	61.05	25.04	Mixed landscape / B. pendula	B. pendula	2016	2016
5	Lompolojänkkä	69.80	24.21	Wetland / grasses	B. pubescens	2015	2015
6	Paljakka	64.68	64.68	Mixed landscape / P. abies	B. pubescens	2016	2015
7	Parkano**	62.03	23.04	Mixed landscape / B. pendula	B. pendula	2016	2015-2016
8	Sodankylä, wetland*	67.37	26.65	Wetland / Sphagnum spp.	B. pubescens	2014-2015	2014-2016
9	Suonenjoki***	62.64	27.05	Forest crown level / P. sylvestris	B. pendula	2016	2015-2016
10	Tammela (canopy)	60.65	23.81	Forest canopy / P. abies	B. pendula	2014-2016	2014-2016
11	Tvärminne	59.84	23.25	Mixed landscape / P. sylvestris	B. pendula	2016	2016
12	Värriö (crown)	67.75	29.61	Forest crown level / P. abies	B. pubescens	2015-2016	2016
	N site-years					20	21

Examples of birch targets

Värriö



Lammi

Sodankylä

Paljakka

Validation data for automatically extracted GCC and RCC

1. Expert observations from image time series
   - **Budburst first visual distinctive day of increased greenness**
   - Leaves yellow 90%

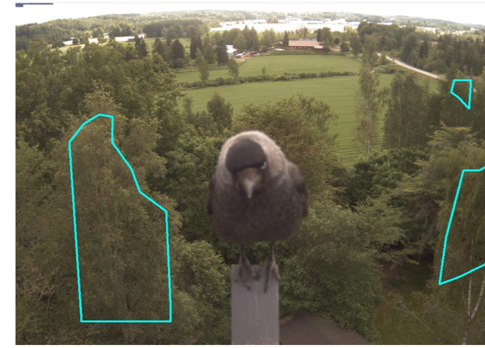
2. Phenological field observations

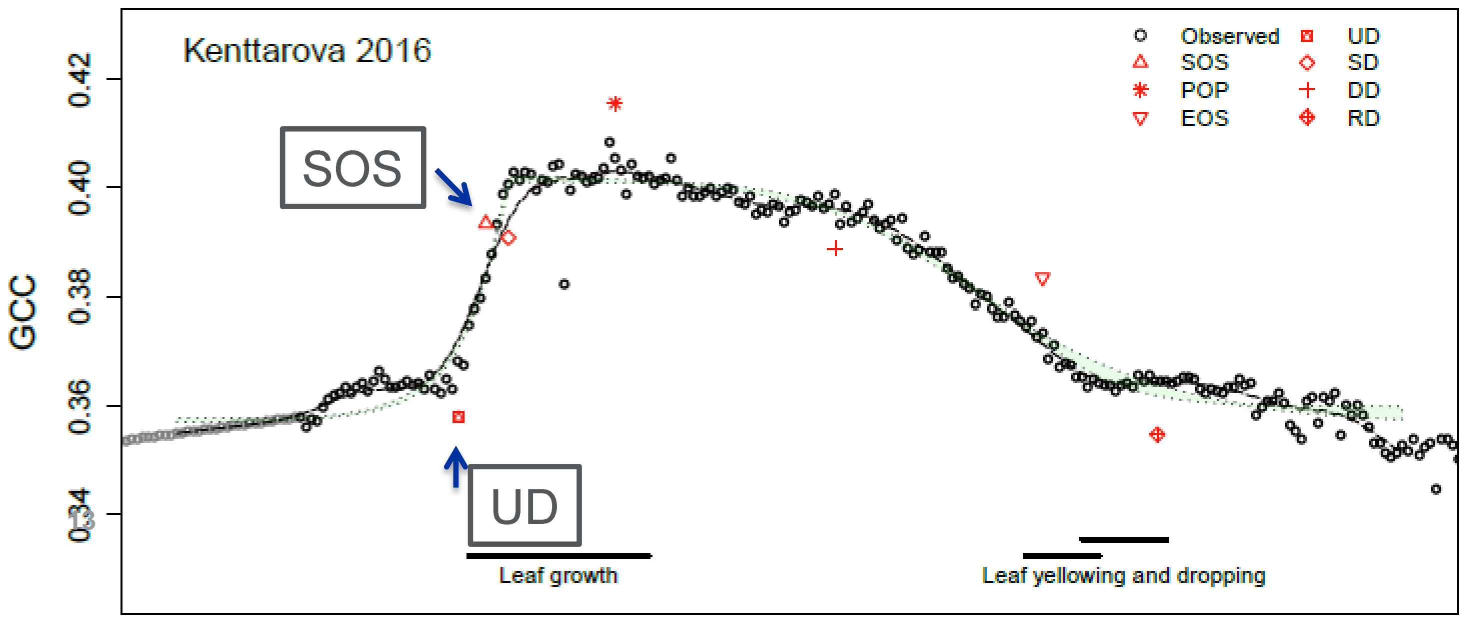
- **Budburst (50% of leaves in canopy emerged from the bud; not unfolded.)**
- Leaves grown
- Leaves yellow 50% (field)

Table 2 Phenological field observation sites used in the study.

id	Site	Latitude (km)	Longitude (km)	Species
a	Aulanko	6770646	3362992	B. pubescens
b	Joensuu	6947385	3640484	B. pubescens & B. pendula
c	Kannus	7095903	3347506	B. pubescens & B. pendula
d	Kevo	7741981	3500493	B. pubescens
e	Kolari	7477368	3363867	B. pubescens & B. pendula
f	Lapinjarvi	6723257	3454559	B. pubescens & B. pendula
g	Muddusjarvi	7664782	3504620	B. pubescens
h	Muhos	7191320	3453011	B. pubescens & B. pendula
i	Oulanka	7364042	3604009	B. pubescens & B. pendula
j	Parkano	6886577	3292924	B. pubescens & B. pendula
k	Preitila	6711819	3267026	B. pubescens & B. pendula
l	Punkaharju	6857897	3622866	B. pubescens & B. pendula
m	Ruotsinkyla	6696441	3389043	B. pubescens & B. pendula
n	Solbole	6664868	3279528	B. pubescens & B. pendula
o	Suonenjoki	6948061	3503091	B. pendula
p	Varrio	7520286	3610573	B. pubescens & B. pendula
q	Vesijako	6810866	3395763	B. pubescens & B. pendula

Transition date extraction

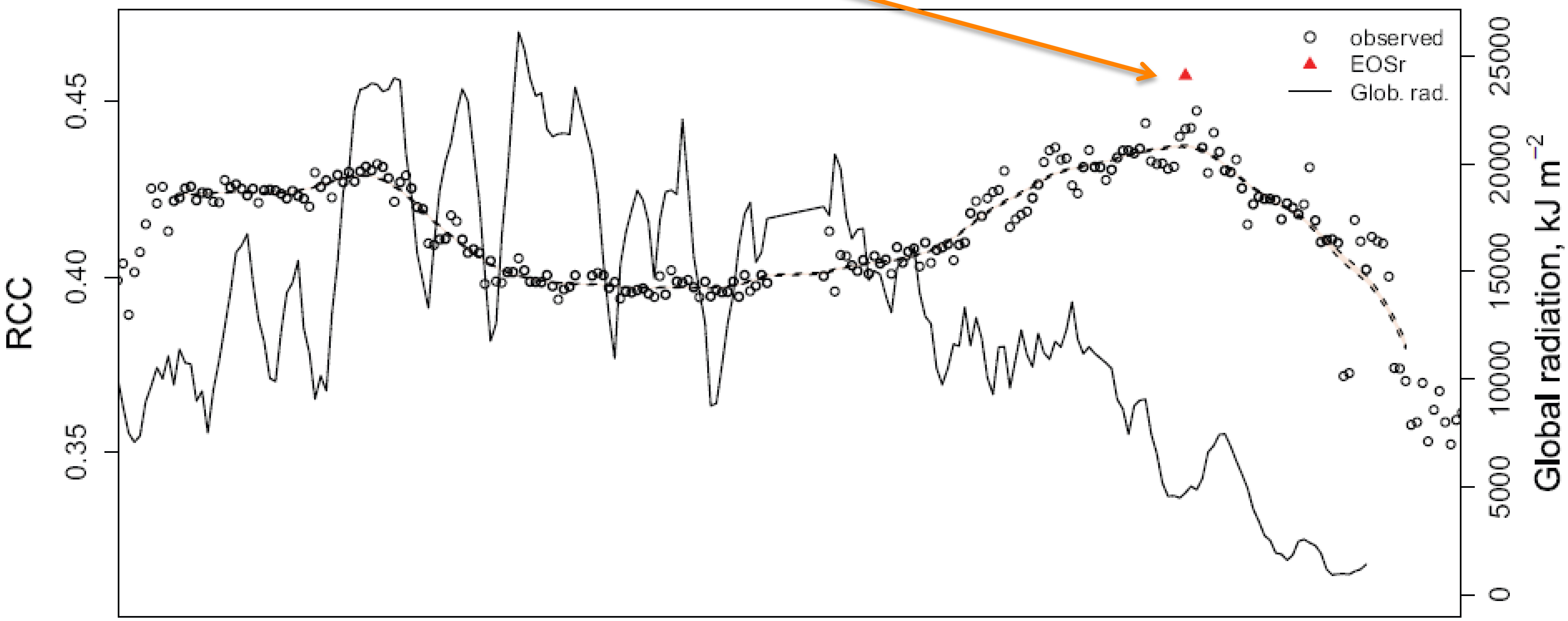


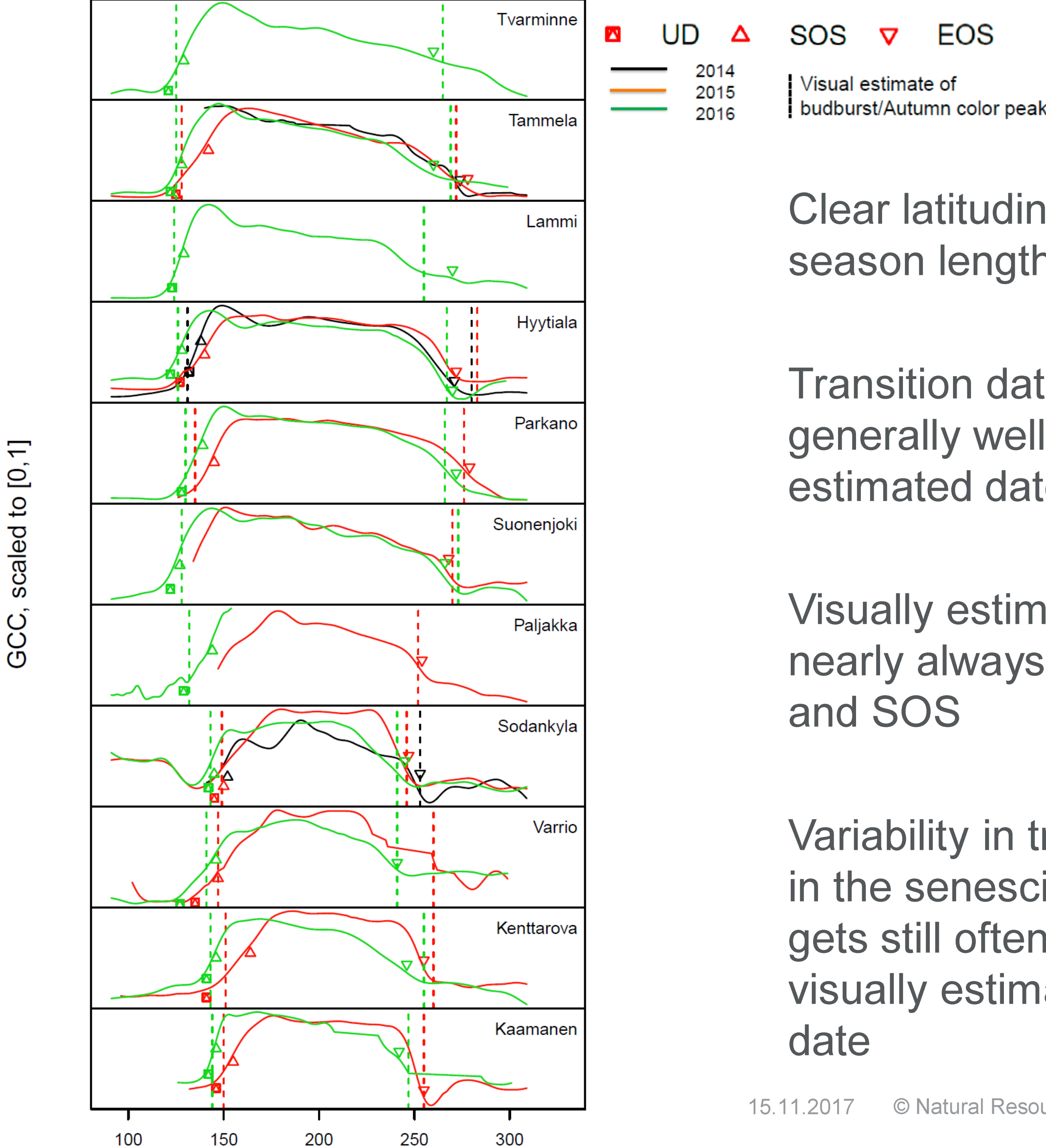


– SOS, Start of season
– Upturn date (UD), Stabilization date (SD), Downturn date (DD) and Recession date (RD)

End of season, EOSr

- Using RCC peak





Results

Clear latitudinal gradient in season length

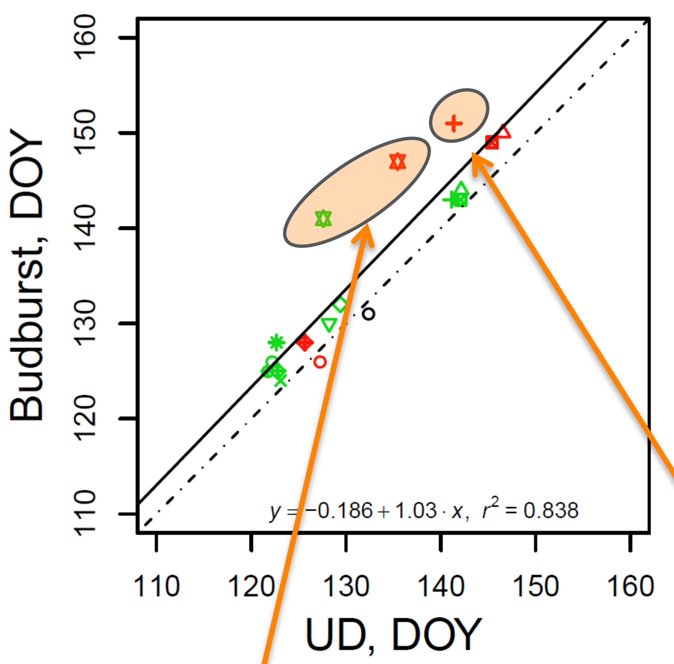
Transition dates compare generally well against visually estimated dates

Visually estimated season start nearly always in between UD and SOS

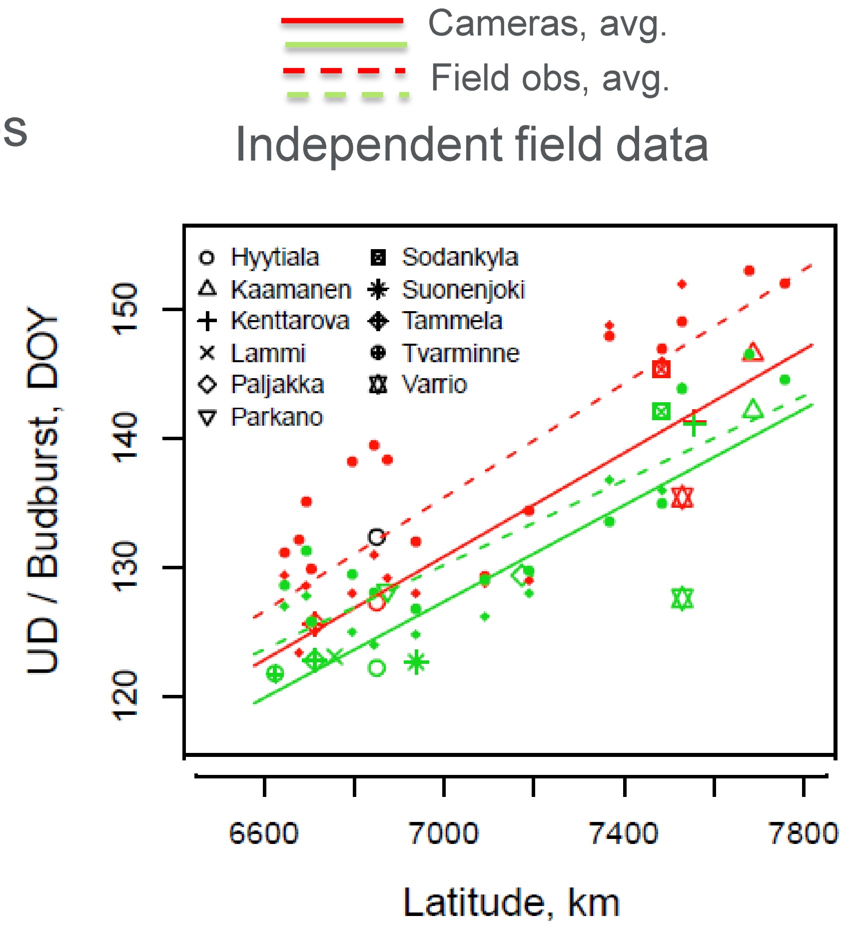
Variability in trends, especially in the senescing trail, but EOSr gets still often close to the visually estimated season end date

Automated date extraction vs. visual data – correspondences of season starts

- Visual examination of time series



Independent field data



Falsely interpreted season start due to snow in Värriö

..and in Kenttärova

Lessons learned

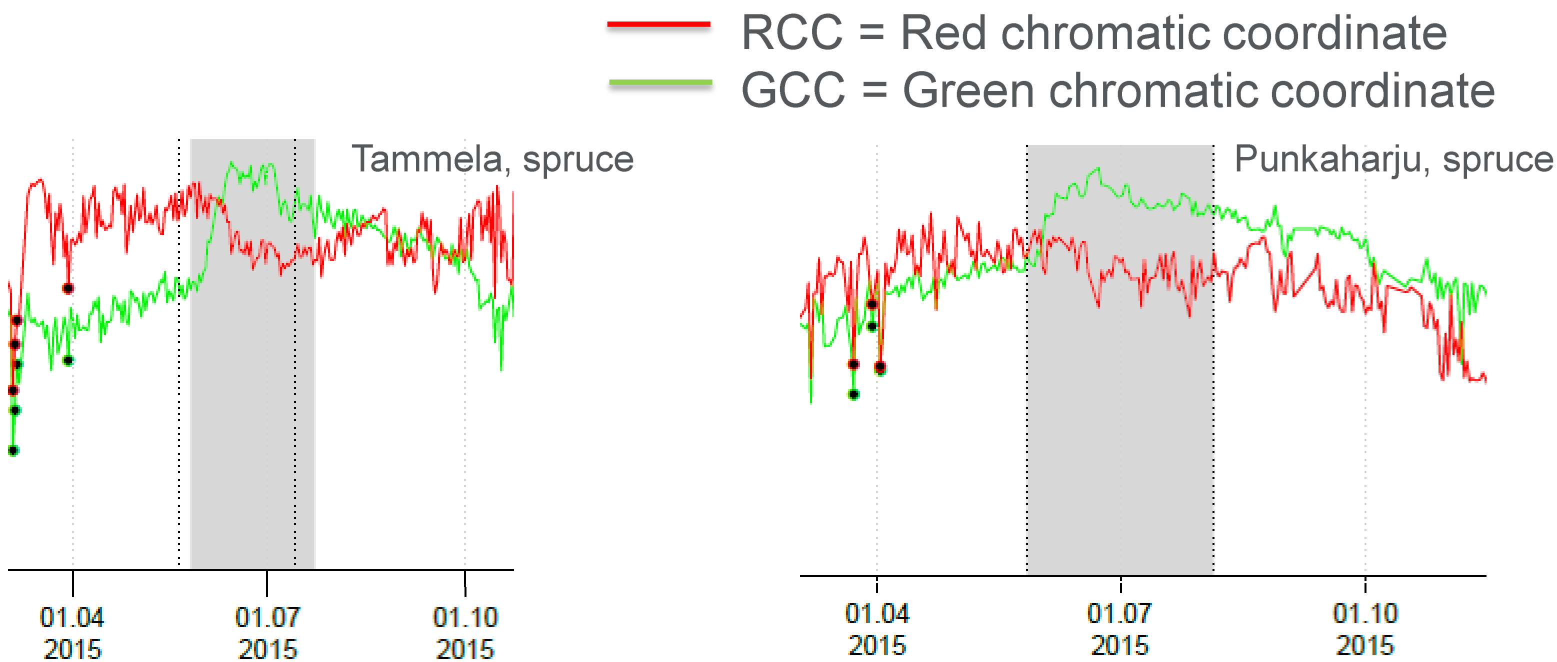
- We get season start and end automatically from cameras for birch
  - Estimates correspond to traditional field observations
  - Suitable for upscaling, and informing models of leaf growth / fall periods
- Some lessons learded:
  - Conifer background is OK
  - Snow melt can be falsely identified as spring green-up of birches as they occur with a narrow date margin (or even co-occur) in north
  - Red peak in the autumn best variable to estimate season end
  - Stable mounting of cameras important…

Conifers and GCC: Comparison with field data

- Four sites, two spruce and two pine sites
- Measured:
  - GCC and RCC with a camera
  - Chlorophyl fluorencence (or photosynthesis of needles)
  - Pigment ratios

Cameras and conifer phenology, early results

Spruce shoot growth start discernible



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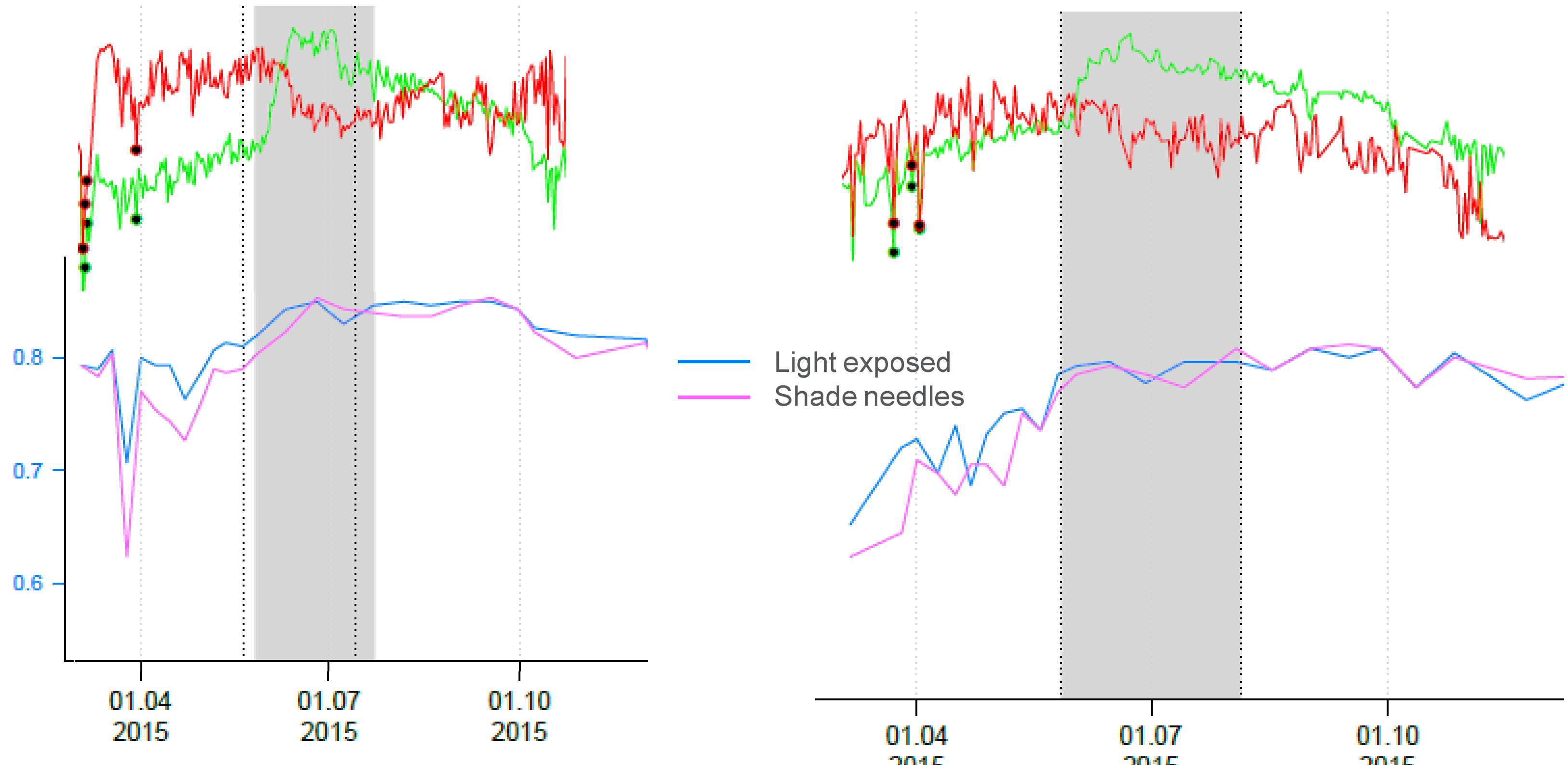
Cameras and conifer phenology, early results

- Chlrophyl fluorescense increase before shoot growth start as does the GCC



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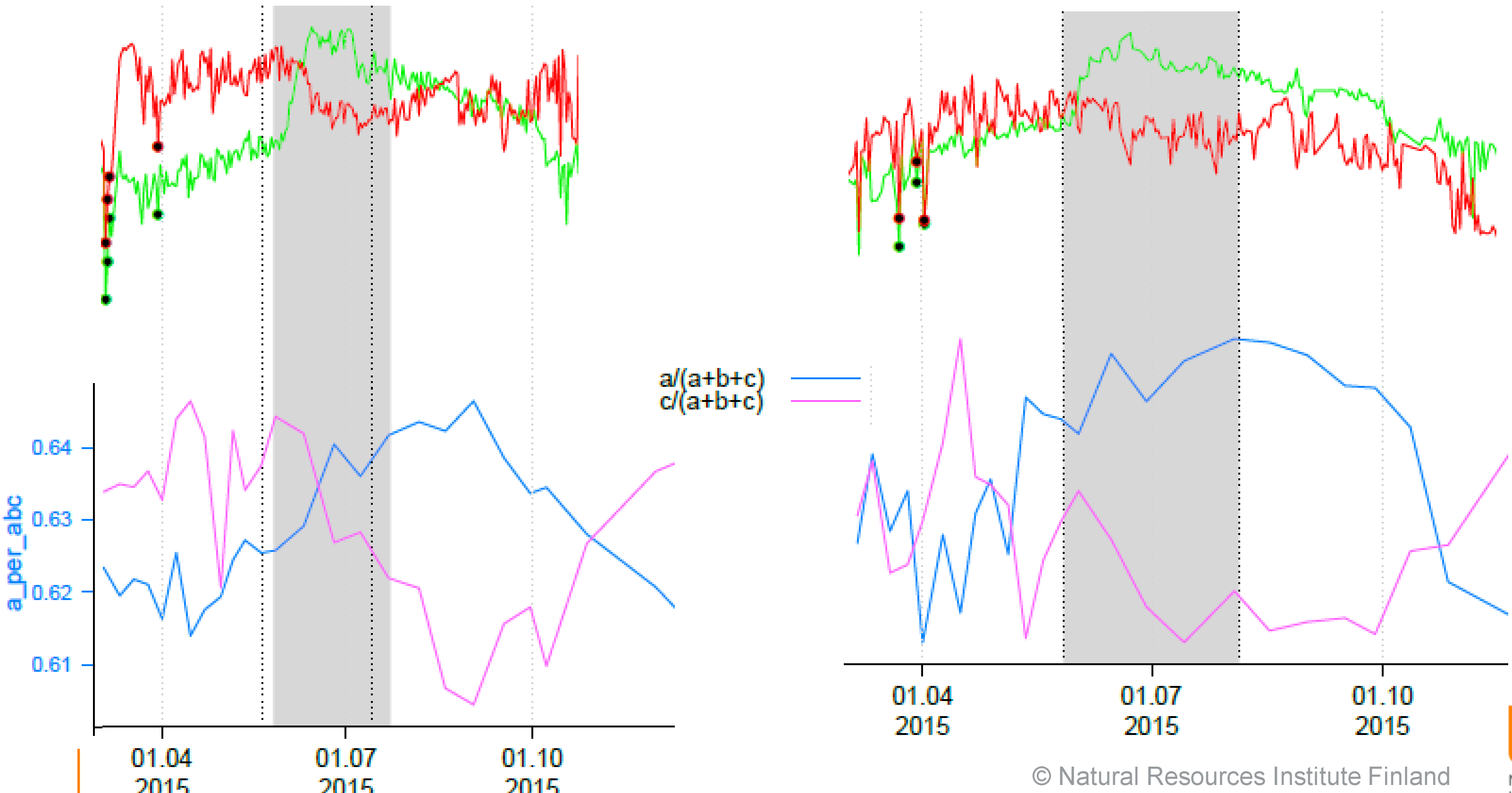
Cameras and spruce phenology, early results

Chl pigment changes not clearly associated with the increase of GCC but seem to time later



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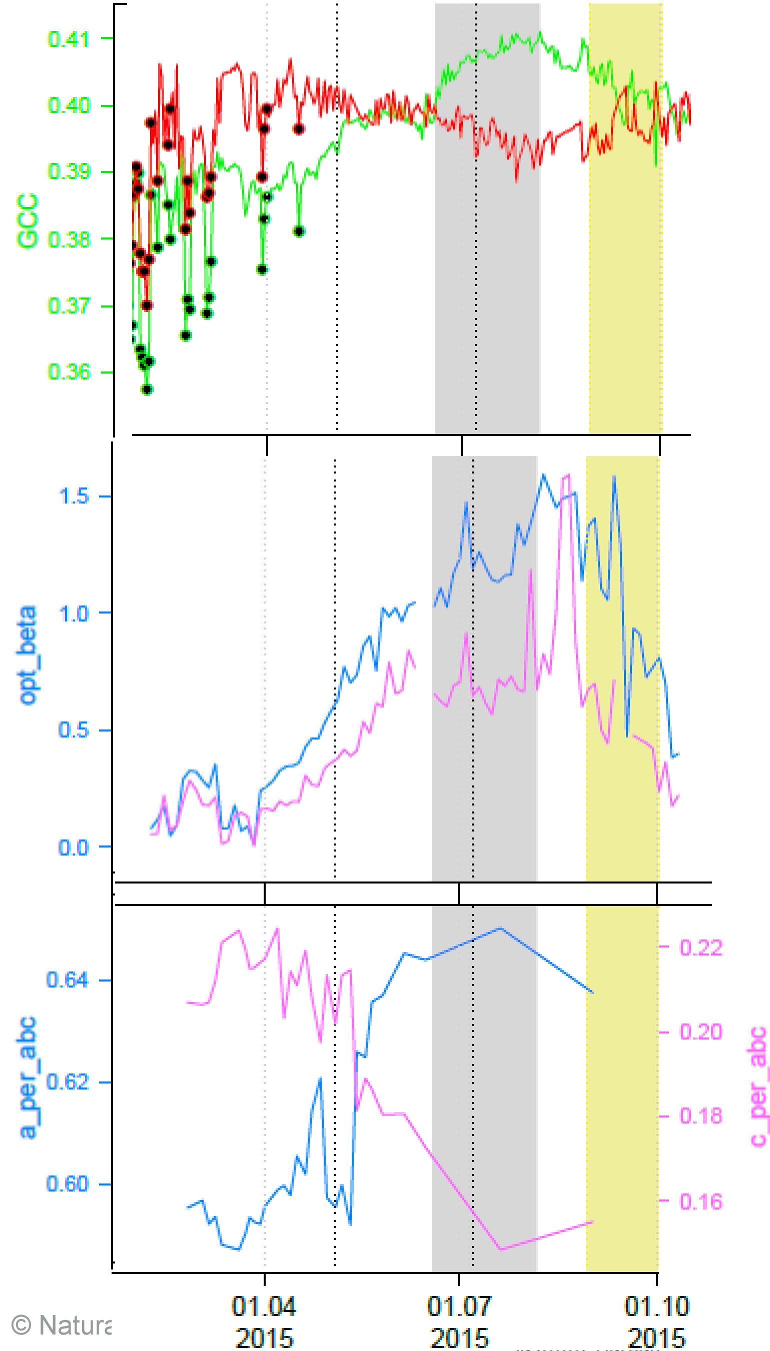
Pine

- Changes of GCC are also complicated by separation of phenophases:
  - Shoot growth phase flattens GCC increase during the spring
  - GCC increases again when needles emerge
  - GCC increase simulateous with photosynthetic parameter increase
- GCC decreases with season and more rapidly when older needle cohort turns yellow
  - Simultaneously with photosynthetic parameters decrease
- Pigment ratios changes parallel to GCC/RCC changes



Lessons learned

- There seems to be parallel changes of GCC and chlorophyl fluorescense
- Temporal correlation is more unclear with pigment ratio changes
- Statistical analyses of GCC changes
  - Time series are short to make statistical inferences
  - Phenophase shifts complicate analyses
- Strong a priori information seems important for automated analyses of conifer:
  - E.g. Model presenting changes in phenophases (e.g. Cassia, Schiestl-Aalto, 2015) would be useful for further analyses of data.

Thank you!

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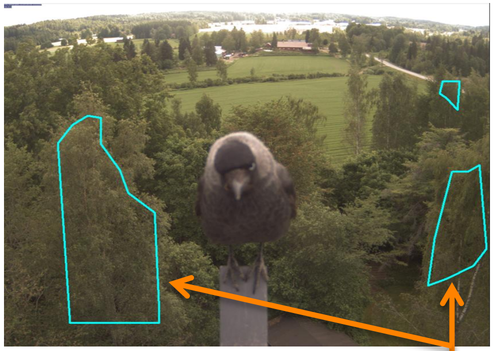
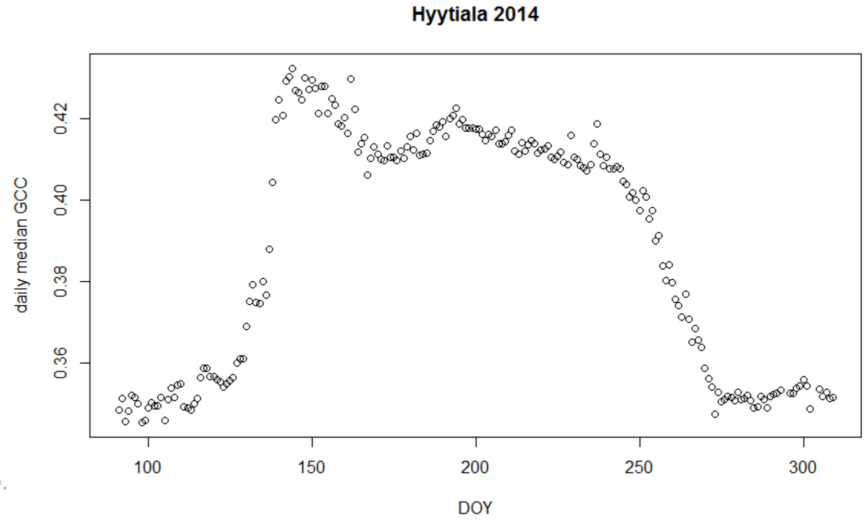
Image time series analyses



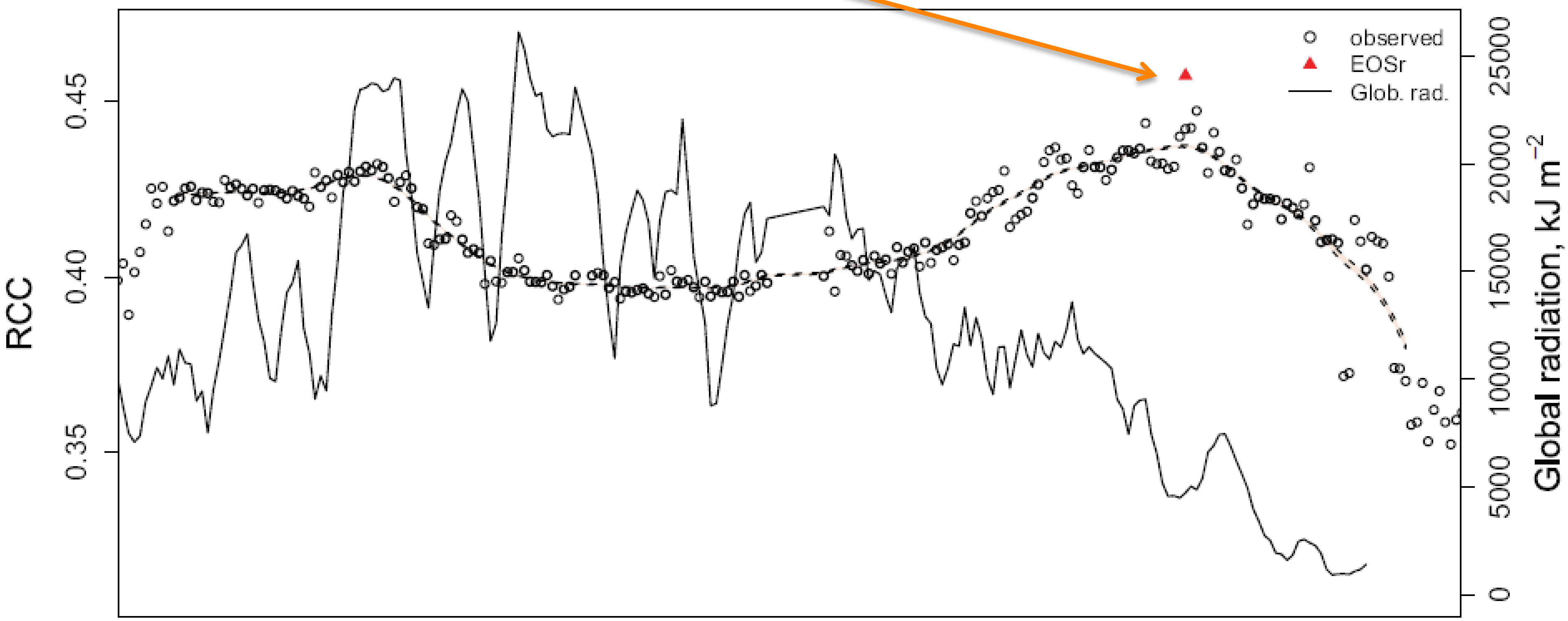
- Used images between 8:00-16:00 (half-hourly taken)
- For each image in the time series:
  - Extracted R, G, B [0, 255] channel information for each pixel in the target areas
  - Calculated GCC = G / (R+G+B), as an average over all pixels
  - Omitted pixels with poor exposure or overexposure, R, G, B in [30, 254]
- Calculated daily median GCC

from images of one day.



End of season, EOSr

- Using RCC peak



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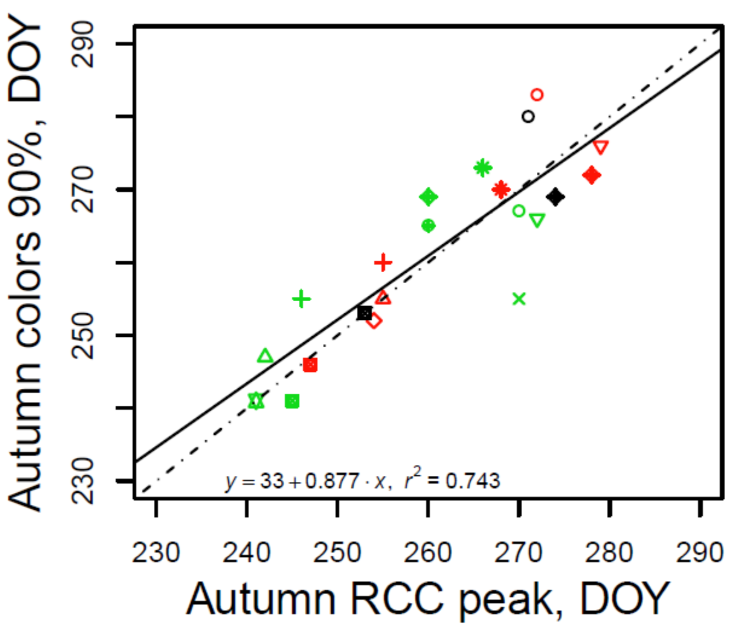
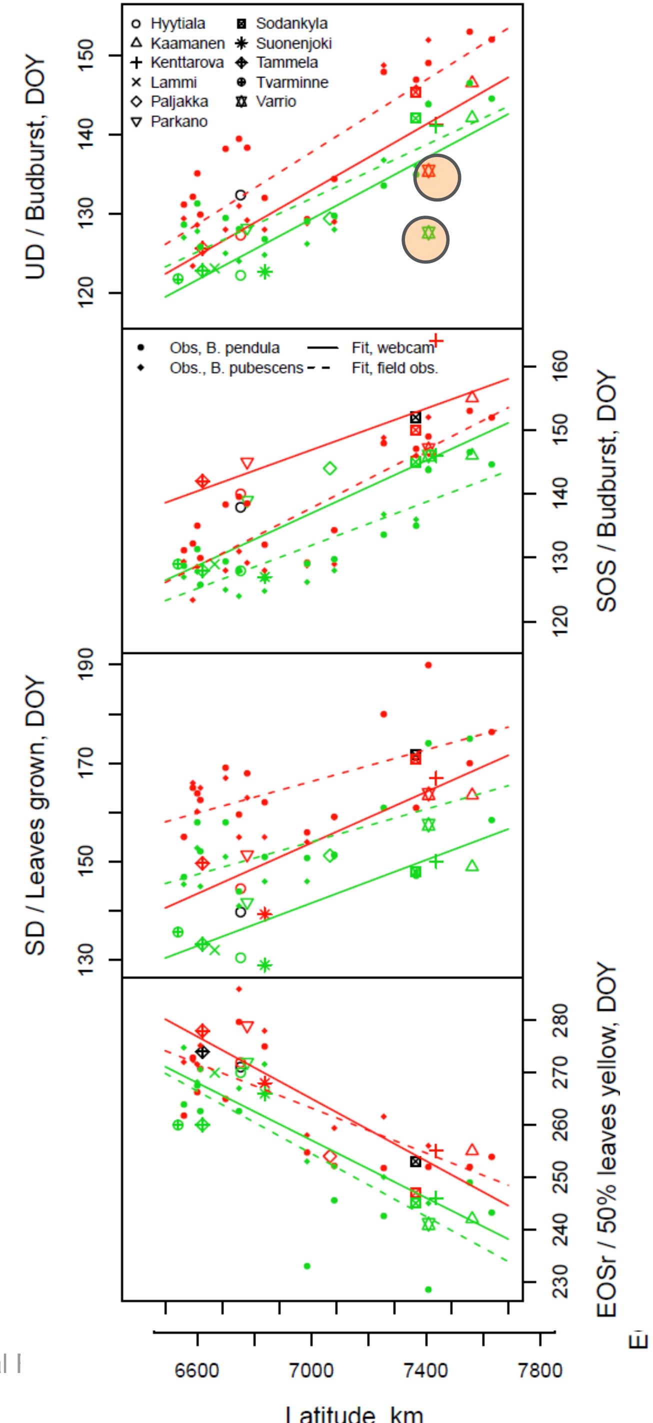
Cameras vs. phenological field observation network

- The best camera-based transition date estimate fall within variation of field measurements (UD, EOSr)
- UD tends to be slightly earlier while SOS slightly later than what is observed in the network

Visual





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Time series analyses

- Gapfilled, linear interpolation
- Smoothed GCC time series, two methods:
  - smoothing spline
    - + fits any curve
    - - may detect phenologically irrelevant temporal variation in GCC
  - Double logistic fit, modified by Gu et al (2009)
    - increasing, and decreasing parts, with stable period in between
    - + accounts for main seasonal trends
    - - may not fit all GCC time series

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