Webcam based phenology in the Western Alps

E. Cremonese

Aosta Valley Environmental Protection Agency
ARPA VdA

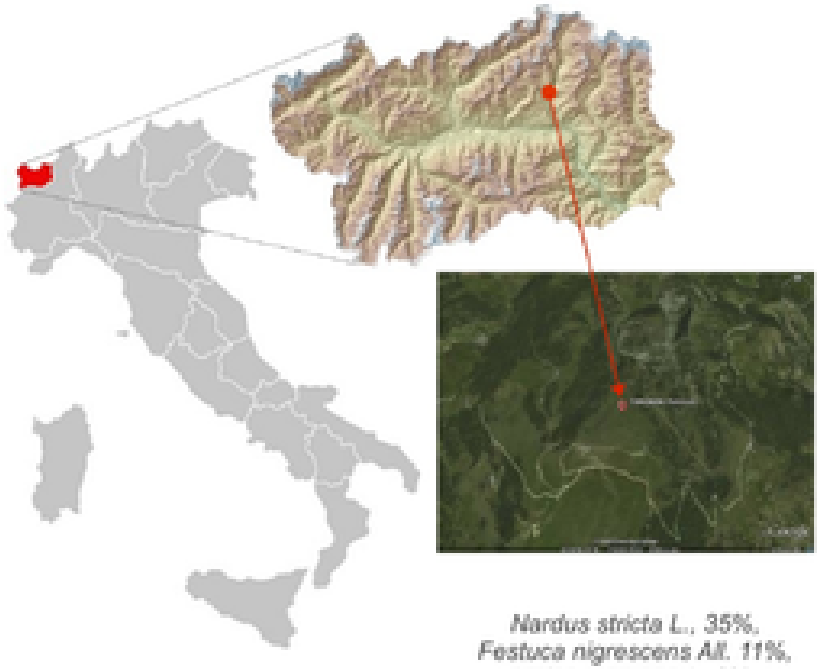
Bordeaux, 8 September 2014 - PhenoWebcam workshop

Sites

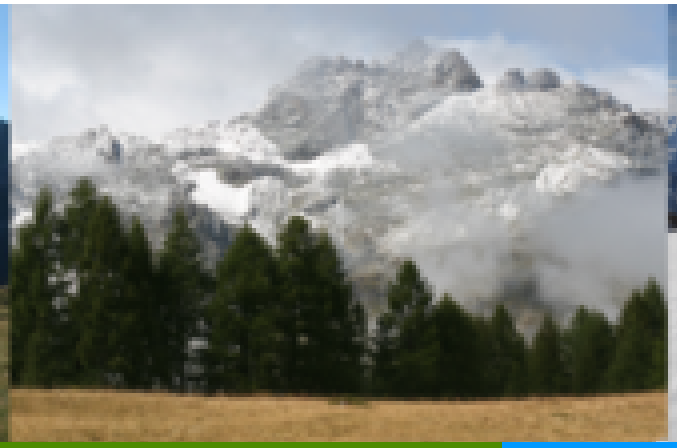
- alpine grassland - Tellinod
- larch forest - Tronchaney
- pinot gris vineyard - Winecam

Grassland: 1/3

- Tellinod (Torgnon - Aosta Valley)
- sub-alpine unmanaged grassland (2160 m asl)
- EC tower-phenology-radiometric vegetation indexes
- data since 2009

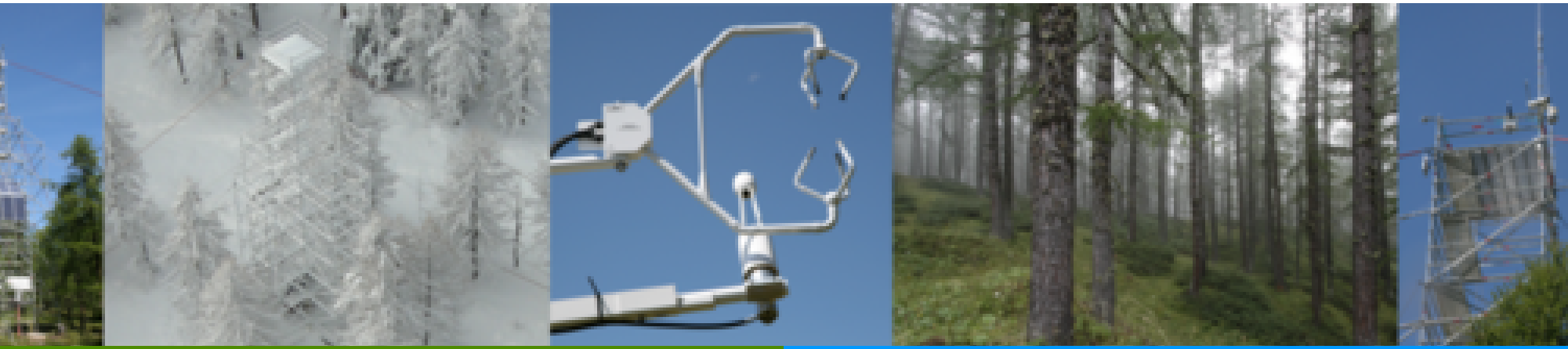


Nardus stricta L., 35%,
Festuca nigrescens All. 11%,
Arnica montana L. 8%,
Carex sempervirens Vill. 5%,
Trifolium alpinum L. 4%

Larch forest: 2/3

- Tronchaney (Torgnon - Aosta Valley)
- Larch (*L. decidua*) forest (2100 m asl)
- EC tower-phenology-radiometric vegetation indexes
- data since 2010

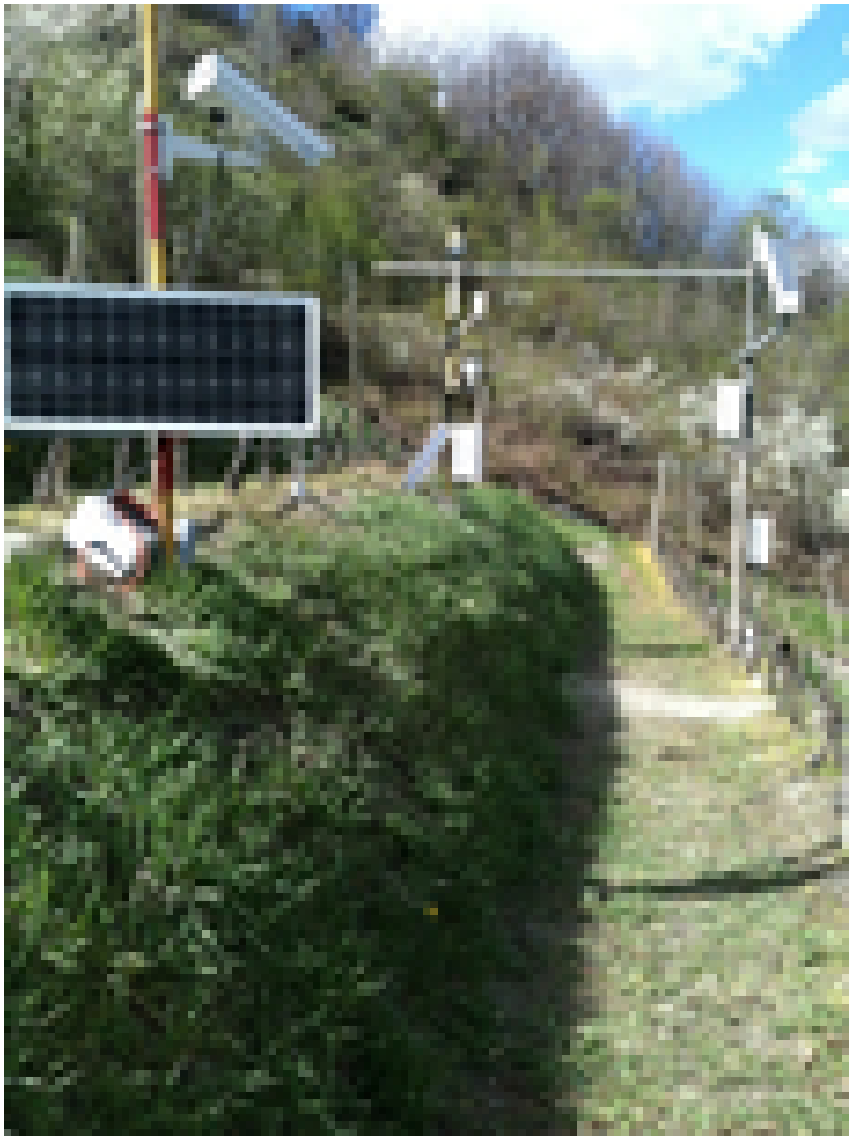


objectives

- **long term monitoring** of ecosystem processes phenology
- **phenology** - **carbon and water fluxes**
- understand the role of climate drivers with a special focus on **snow**

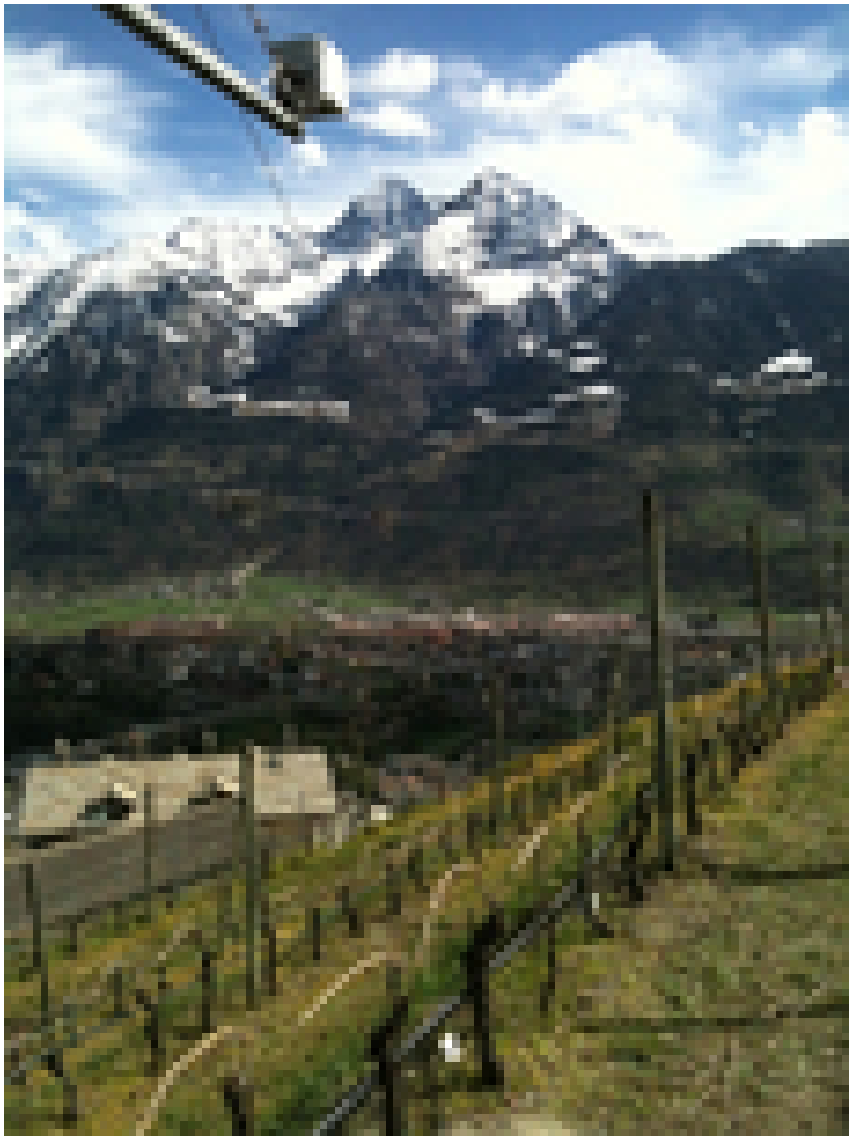
Vineyard: 3/3

- Vineyard (Aosta - Aosta Valley)
- Pinot gris (600 m asl)
- phenology-radiometric vegetation indexes (16 bands Cropscan)-field measures
- just started Apr 2014



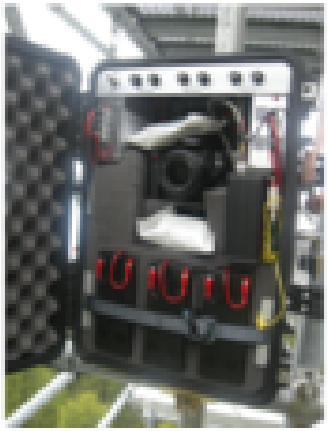
Vineyard: 3/3

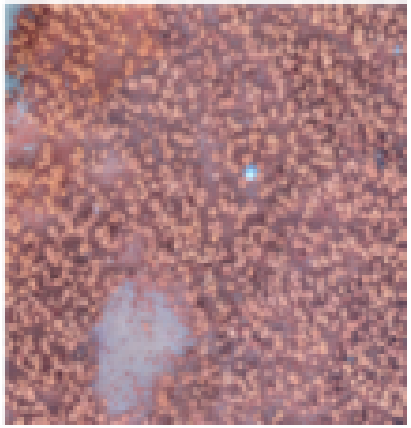
- Vineyard (Aosta - Aosta Valley)
- Pinot gris (600 m asl)
- phenology-radiometric vegetation indexes (16 bands Cropscan)-field measures
- just started Apr 2014
- obj: use webcam and radiometric indexes to infer canopy status and detect stresses



camera type overview

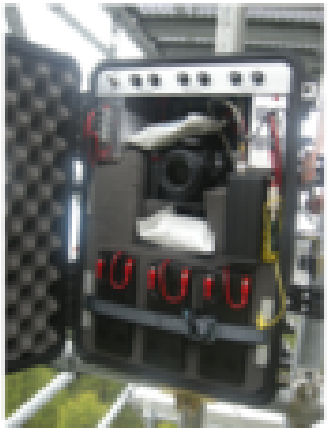
- campbell cameras logged to dataloggers (CC640, CC5MPX)
- "homemade" systems with Nikon D5000 and microcontroller (12MPx)
- "homemade" raspberry camera with microcontroller (5MPx)
- infrared cameras (NIR-R-G, Tetracam)

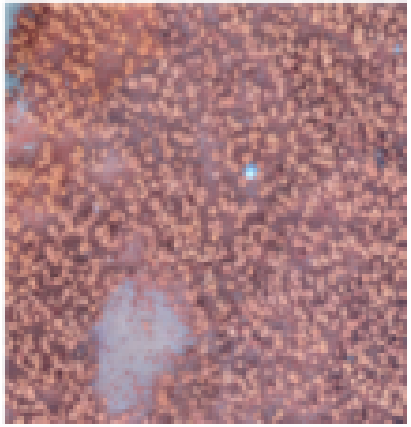





some issues ...

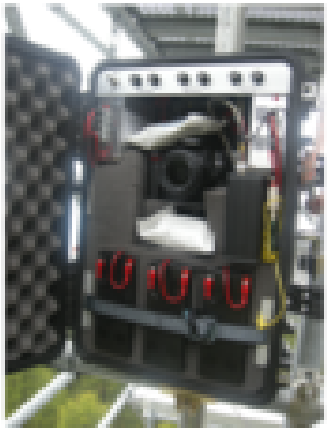
- spatial and radiometric resolution (i.e. camera quality)
- camera settings (exposure - white balance - raw vs. jpeg)
- camera control (computer vs. microcontroller vs. datalogger)
- communication (data transfer vs. manual download)

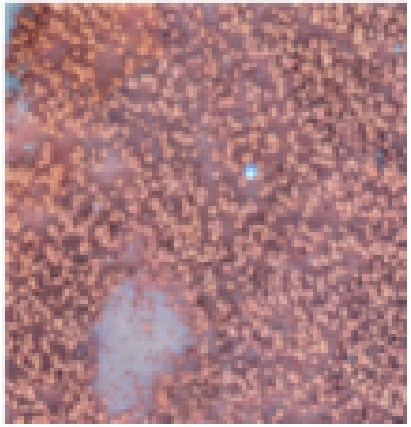





some issues ...

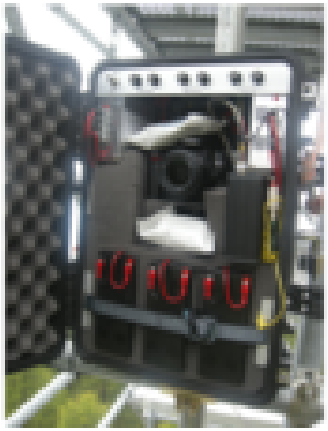
- spatial and radiometric resolution (i.e. camera quality)
- camera settings (exposure - white balance - raw vs. jpeg)
- camera control (computer vs. microcontroller vs. datalogger)
- communication (data transfer vs. manual download)

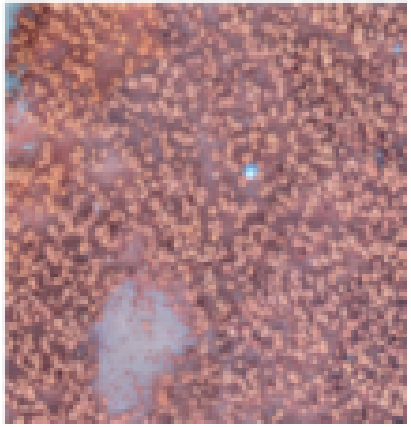





some issues ...

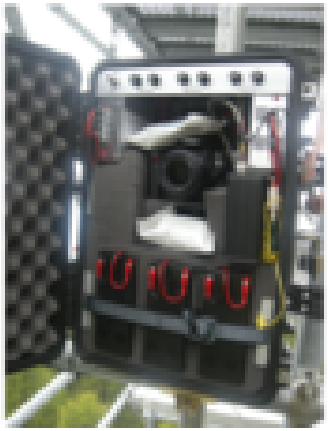
- spatial and radiometric resolution (i.e. camera quality)
- camera settings (exposure - white balance - raw vs. jpeg)
- camera control (computer vs. microcontroller vs. datalogger)
- communication (data transfer vs. manual download)

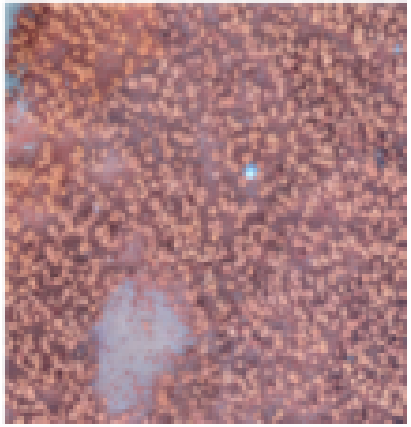





some issues ...

- spatial and radiometric resolution (i.e. camera quality)
- camera settings (exposure - white balance - raw vs. jpeg)
- camera control (computer vs. microcontroller vs. datalogger)
- communication (data transfer vs. manual download)

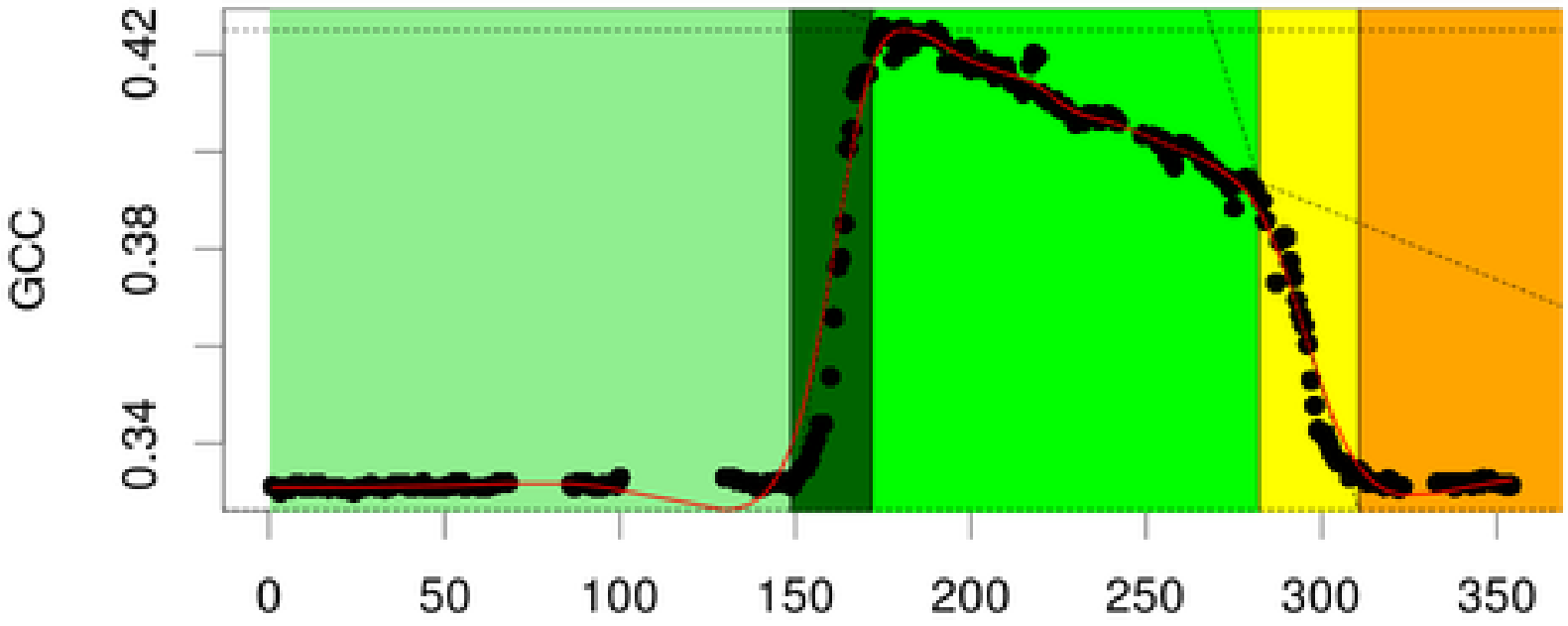


some results: larch forest

- larch forest phenological cycle

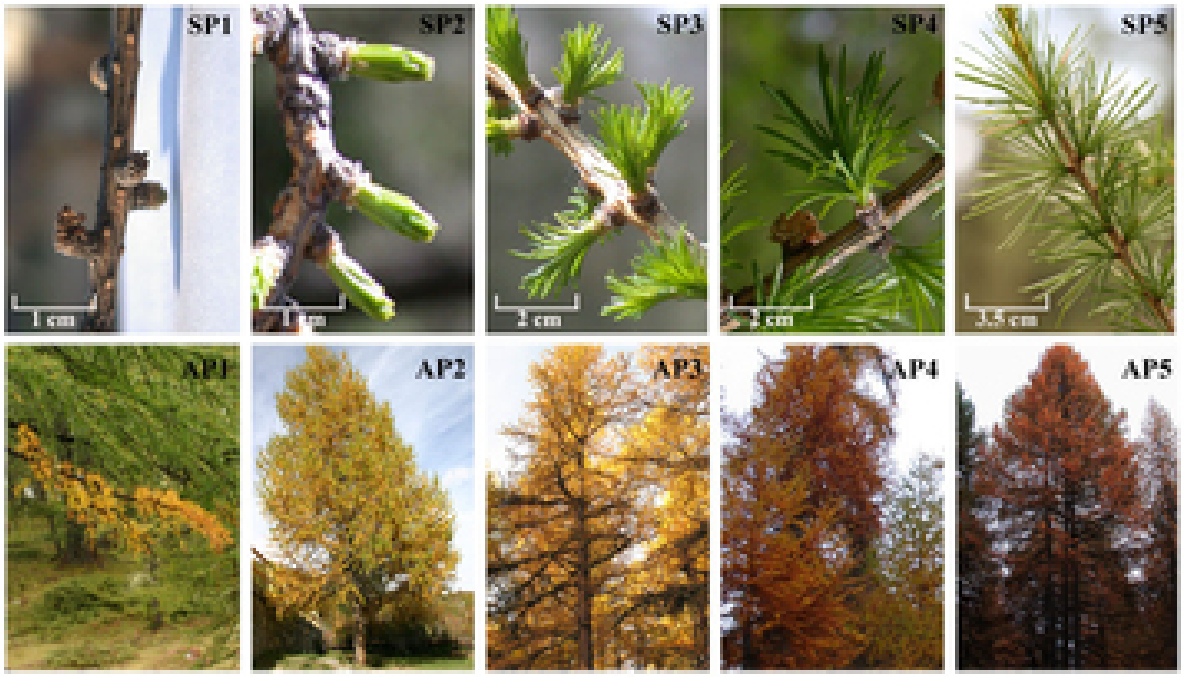
some results: larch forest

- Green Index (GCC) and phenophase extraction



some results: larch forest

- comparison with field observations



Spring Phases (SP)

SP1 = unexpanded buds
SP2 = budburst [B_{GS}], needles length < 1cm
SP3 = needles elongation, length: 1-3 cm
SP4 = needles unfolding, length > 3 cm
SP5 = needles fully expanded

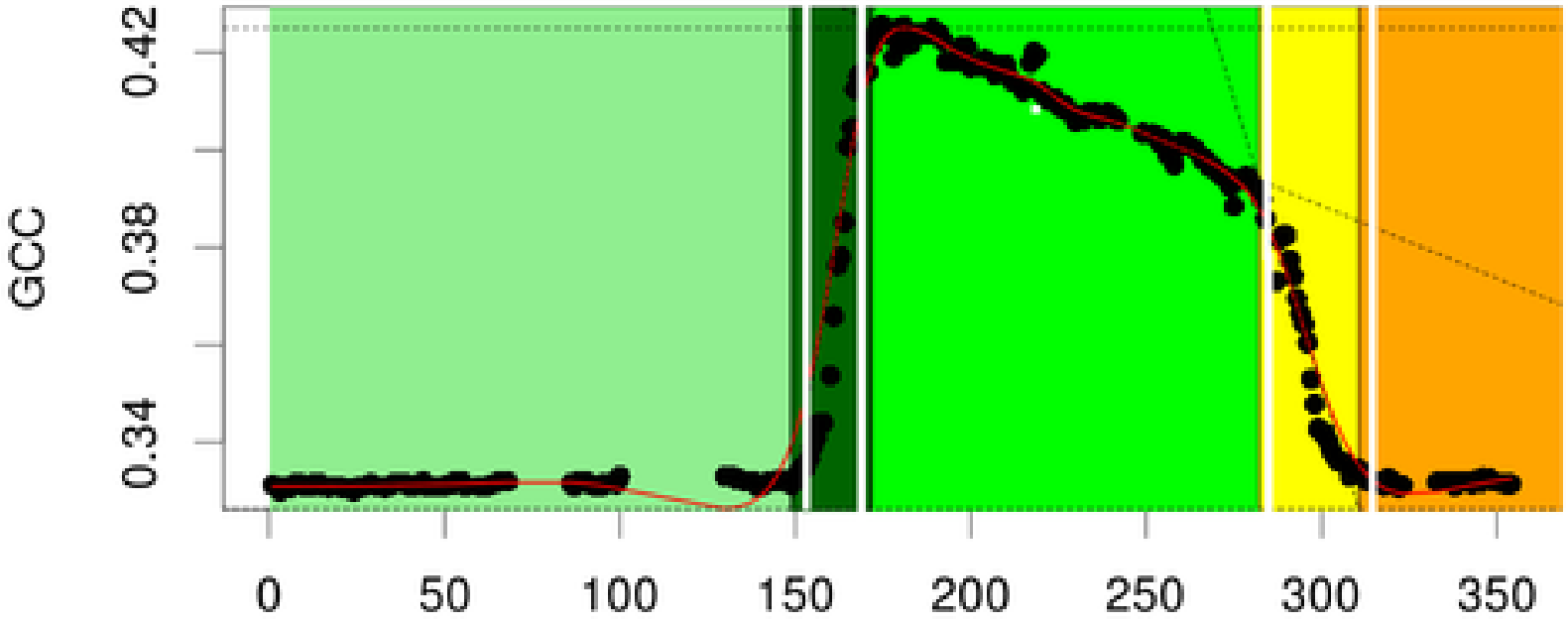
Autumn Phases (AP)

AP1 = yellow spot decolouration
AP2 = green to yellow
AP3 = yellow [E_{GS}]
AP4 = yellow to red
AP5 = red

AP2-AP5: decolouration spread on the whole crown

some results: larch forest

- comparison with field observations



some results: larch forest

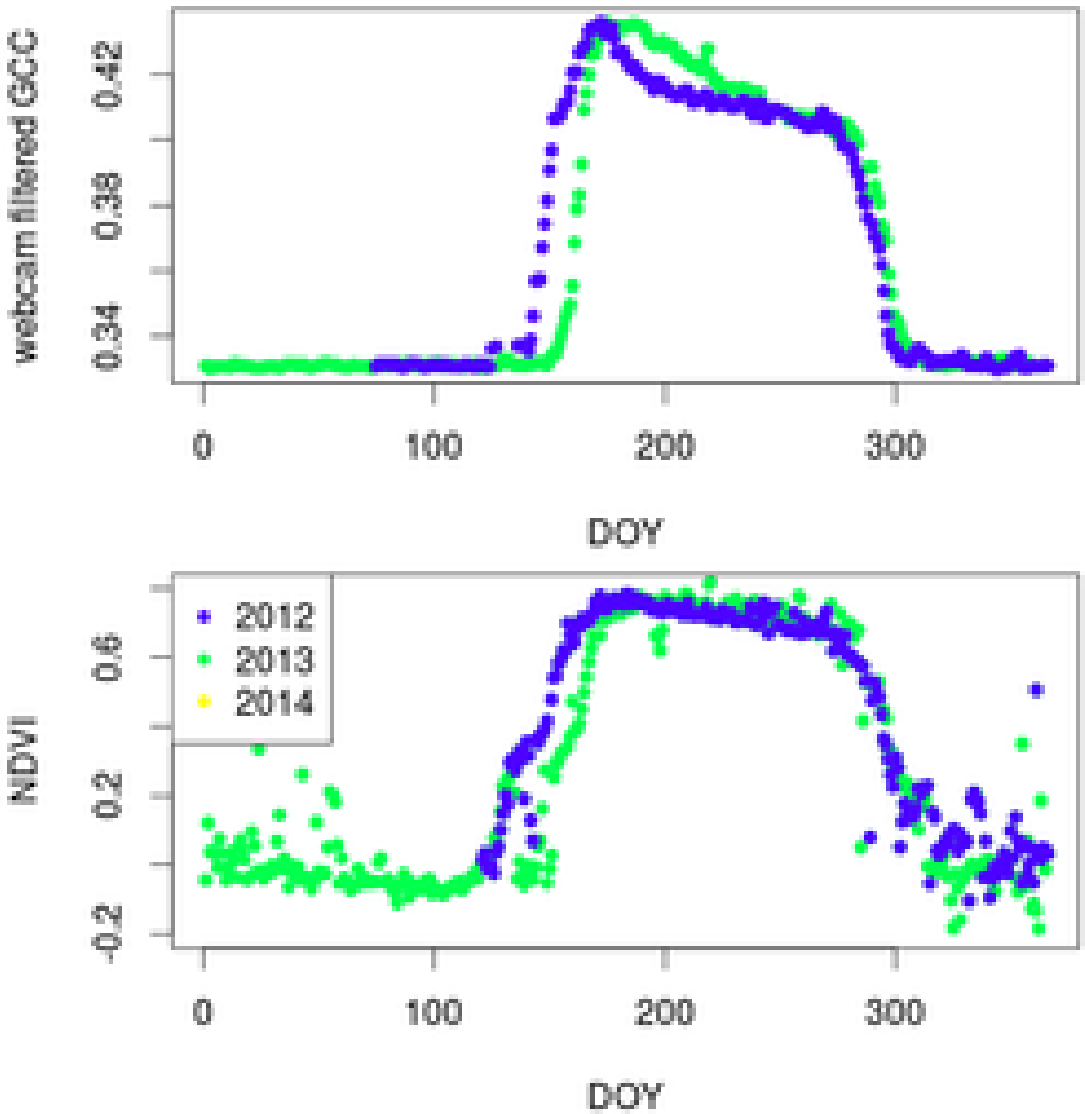
- Tracking IAV: webcam GCC *vs.* ground based NDVI *vs.* carbon fluxes (EC)

some results: larch forest

- Tracking IAV: webcam GCC *vs.* ground based NDVI

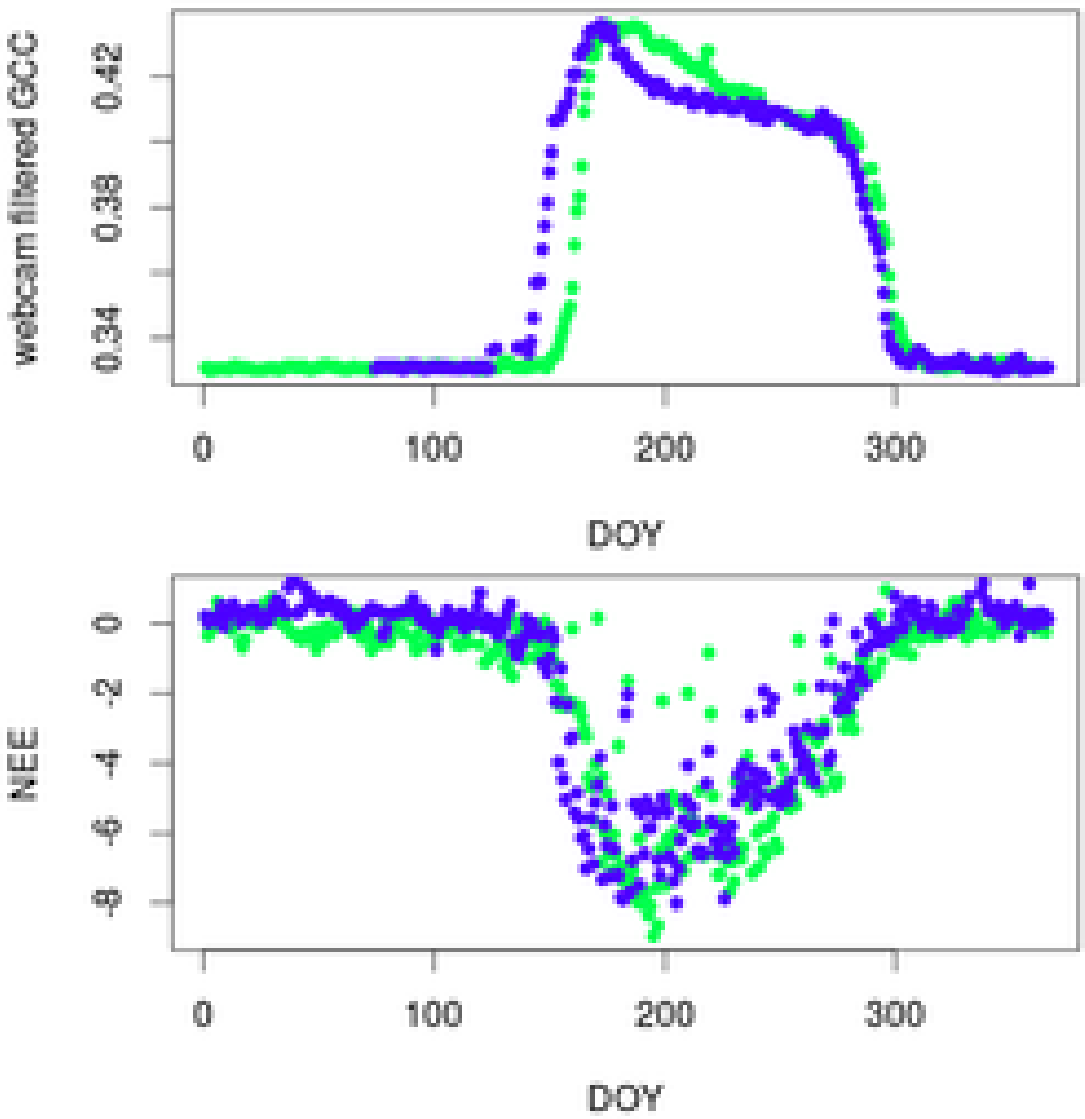
some results: larch forest

- Tracking IAV: webcam GCC *vs.* ground based NDVI



some results: larch forest

- Tracking IAV: webcam GCC *vs.* carbon fluxes (NEE)

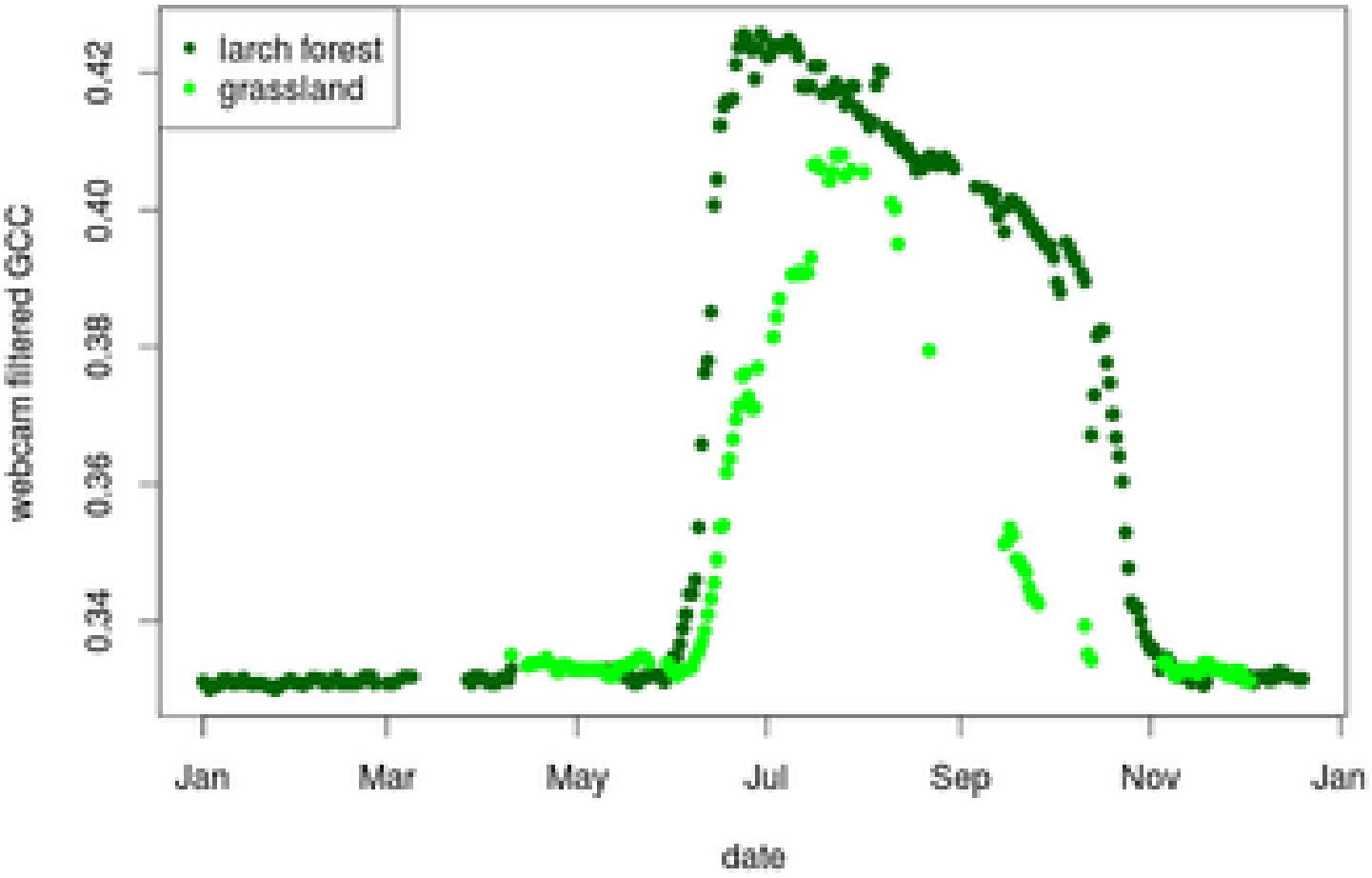


some results: grassland

- grassland phenological cycle

some results: grassland

- GCC seasonal course

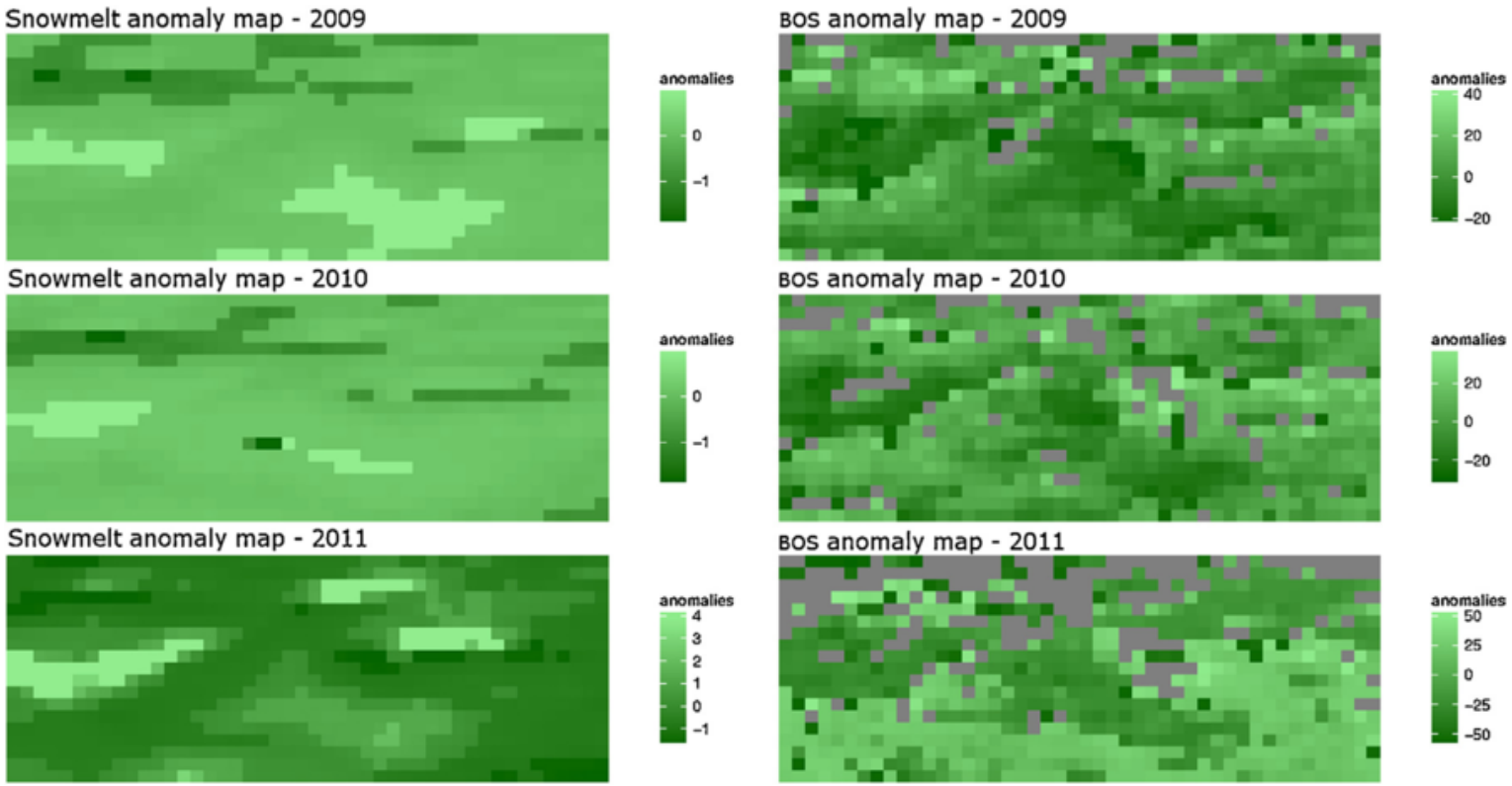


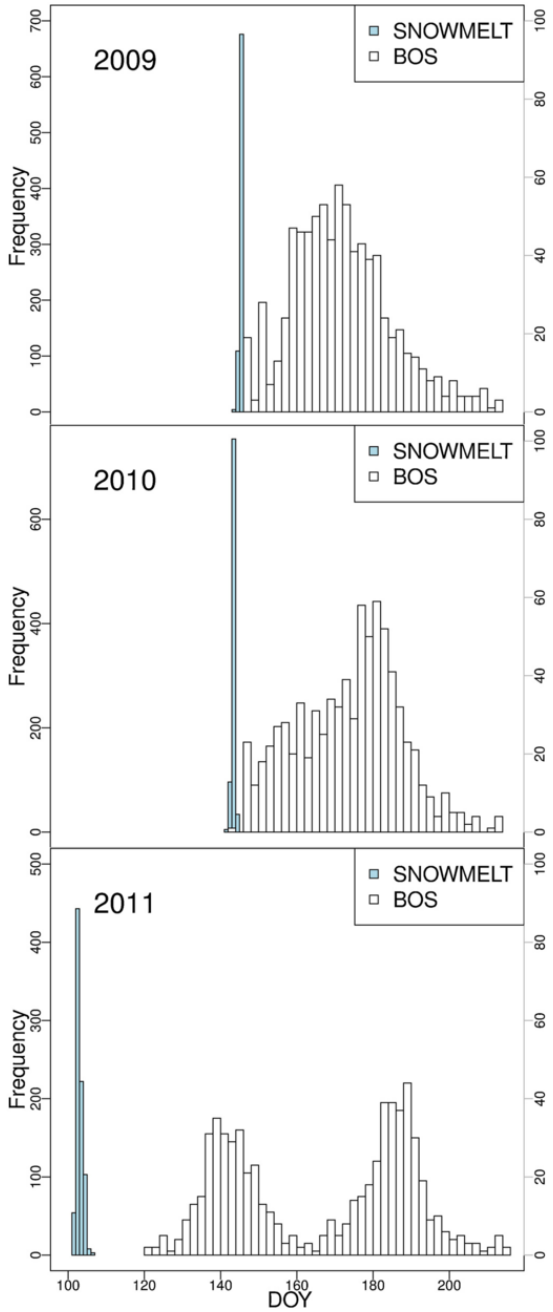
some results: grassland

- grid based analysis (Julitta et al, 2014)

some results: grassland

- grid based analysis (Julitta et al, 2014)




2009
2010
2011
SNOWMELT
BOS
Frequency
DOY

some results: grassland

- grid based analysis (Julitta et al, 2014)
- phenological models optimisation (Migliavacca et al, 2012)
- *Light use efficiency* (LUE) models (Rossini et al, 2012, 2013)
- grassland phenology observation methods (Filippa et al, in prep)

some results: grassland

- grid based analysis (Julitta et al, 2014)
- phenological models optimisation (Migliavacca et al, 2012)
- *Light use efficiency* (LUE) models (Rossini et al, 2012, 2013)
- grassland phenology observation methods (Filippa et al, in prep)

some results: grassland

- grid based analysis (Julitta et al, 2014)
- phenological models optimisation (Migliavacca et al, 2012)
- *Light use efficiency* (LUE) models (Rossini et al, 2012, 2013)
- grassland phenology observation methods (Filippa et al, in prep)

some results: grassland

- grid based analysis (Julitta et al, 2014)
- phenological models optimisation (Migliavacca et al, 2012)
- *Light use efficiency* (LUE) models (Rossini et al, 2012, 2013)
- grassland phenology observation methods (Filippa et al, in prep)

some results: vineyard

- vineyard phenological cycle

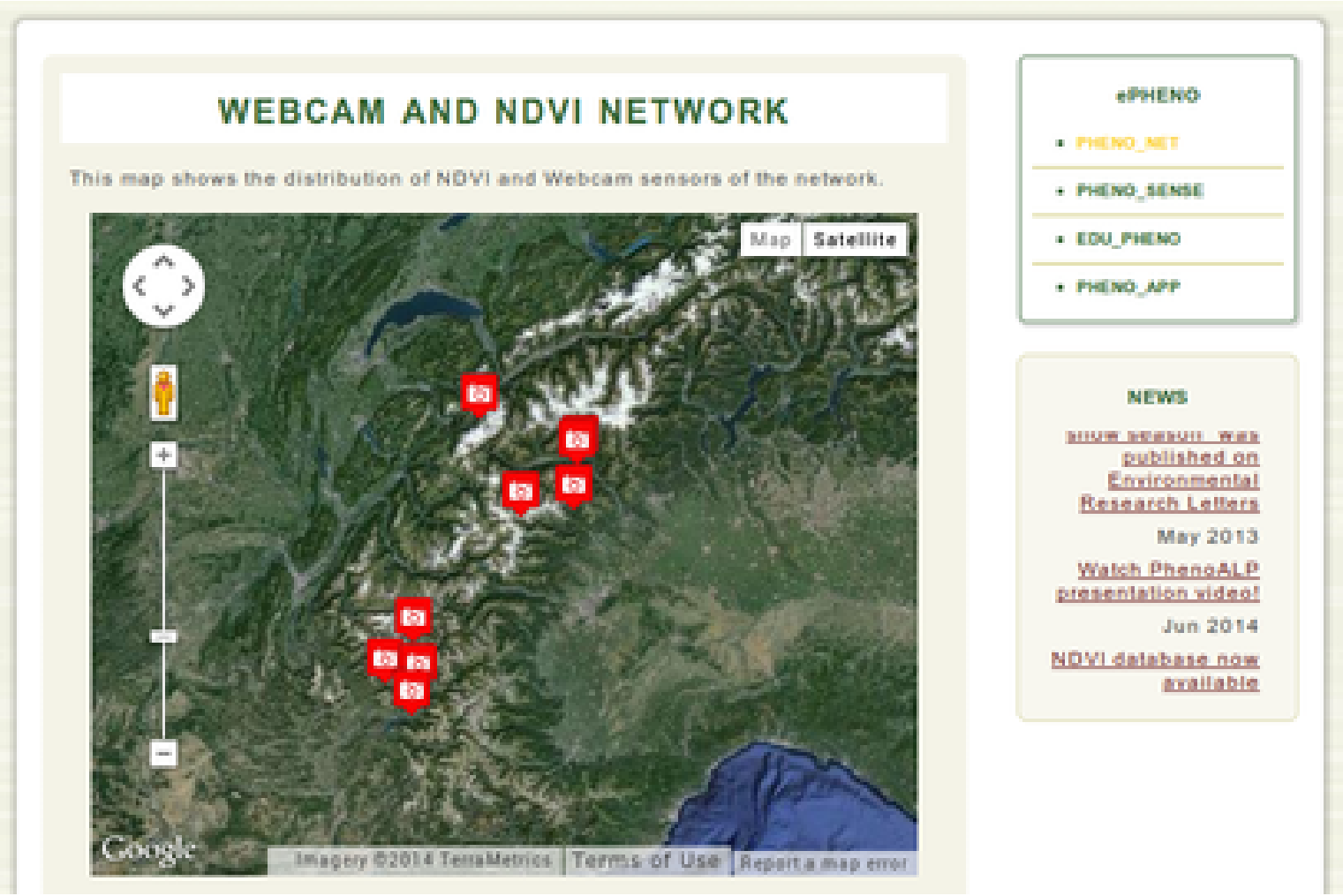
North Western Alps phenological network

North Western Alps phenological network

- started in 2008
- Italy-France cooperation project (Interreg Alcotra)
  - PhenoAlp (2008-2011) www.phenoalp.eu
  - e-Pheno (2012-2014) www.epheno.eu
- Italy - Aosta Valley (ARPA, Parco Naturale Mont Avic, Parco Nazionale Gran Paradiso)
- France - (CREA, Parc National des Ecrins, LECA Grenoble, Parc des Bauges)
- **field observations, sensor based observations (NDVI, webcam), schools engagement**

North Western Alps phenological network

- Webcam and NDVI sensors (10 sites: 5IT, 5FR)



North Western Alps phenological network

- Webcam and NDVI sensors (10 sites: 5IT, 5FR)
- most sites installed in 2012-2013
- ecosystems: grasslands (1800-2400 m asl) and subalpine ($<$ 2000 m asl) larch forests
- common protocols and set-up but different cameras
- storing and processing strategy under discussion

North Western Alps phenological network

- Webcam and NDVI sensors (10 sites: 5IT, 5FR)
- most sites installed in 2012-2013
- ecosystems: grasslands (1800-2400 m asl) and subalpine ($<$ 2000 m asl) larch forests
- common protocols and set-up but different cameras
- storing and processing strategy under discussion

North Western Alps phenological network

- Webcam and NDVI sensors (10 sites: 5IT, 5FR)
- most sites installed in 2012-2013
- ecosystems: grasslands (1800-2400 m asl) and subalpine ($<$ 2000 m asl) larch forests
- common protocols and set-up but different cameras
- storing and processing strategy under discussion

North Western Alps phenological network

- Webcam and NDVI sensors (10 sites: 5IT, 5FR)
- most sites installed in 2012-2013
- ecosystems: grasslands (1800-2400 m asl) and subalpine ($<$ 2000 m asl) larch forests
- common protocols and set-up but different cameras
- storing and processing strategy under discussion

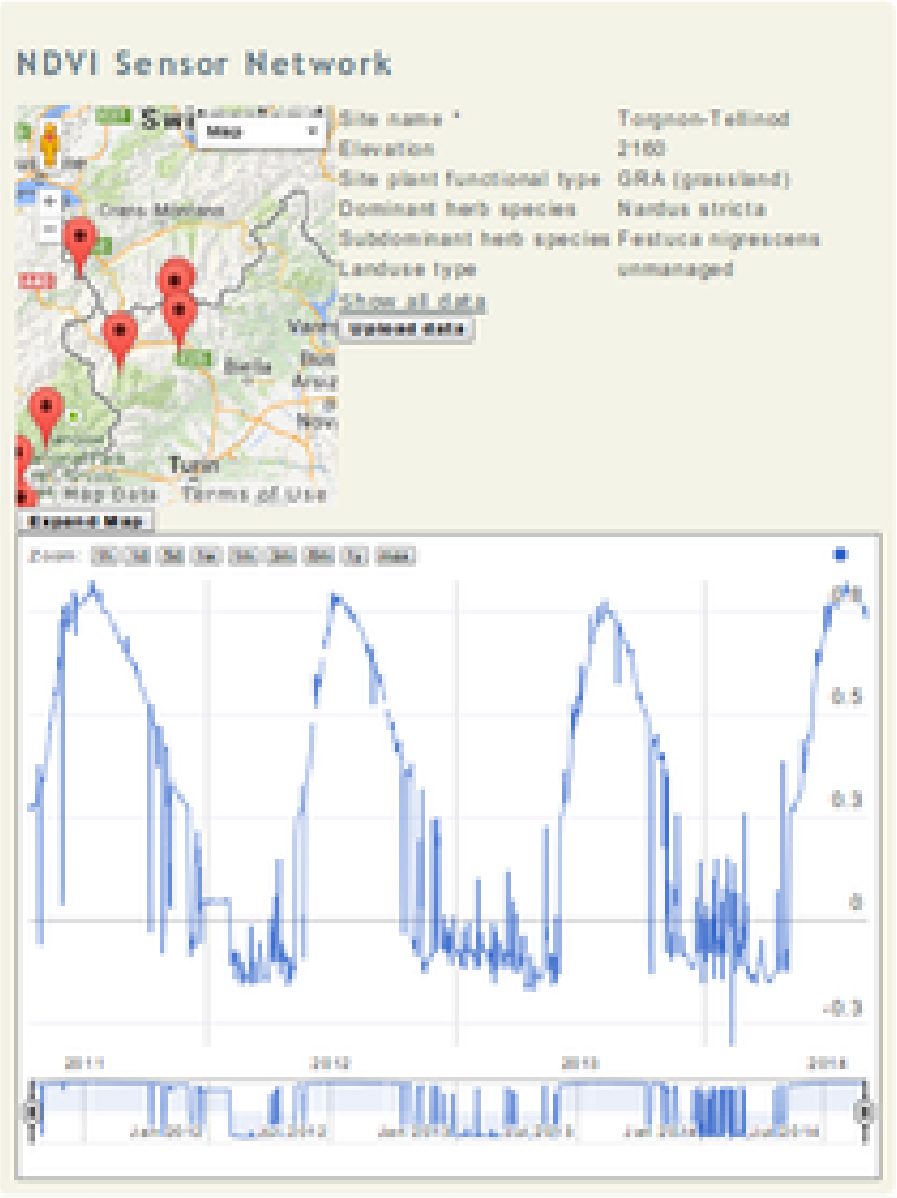
North Western Alps phenological network

- Webcam and NDVI sensors (10 sites: 5IT, 5FR)
- most sites installed in 2012-2013
- ecosystems: grasslands (1800-2400 m asl) and subalpine ($<$ 2000 m asl) larch forests
- common protocols and set-up but different cameras
- storing and processing strategy under discussion

NDVI database

- NDVI database (12 sites: 5IT, 7FR) but other 6 from LECA ready to be included

NDVI database



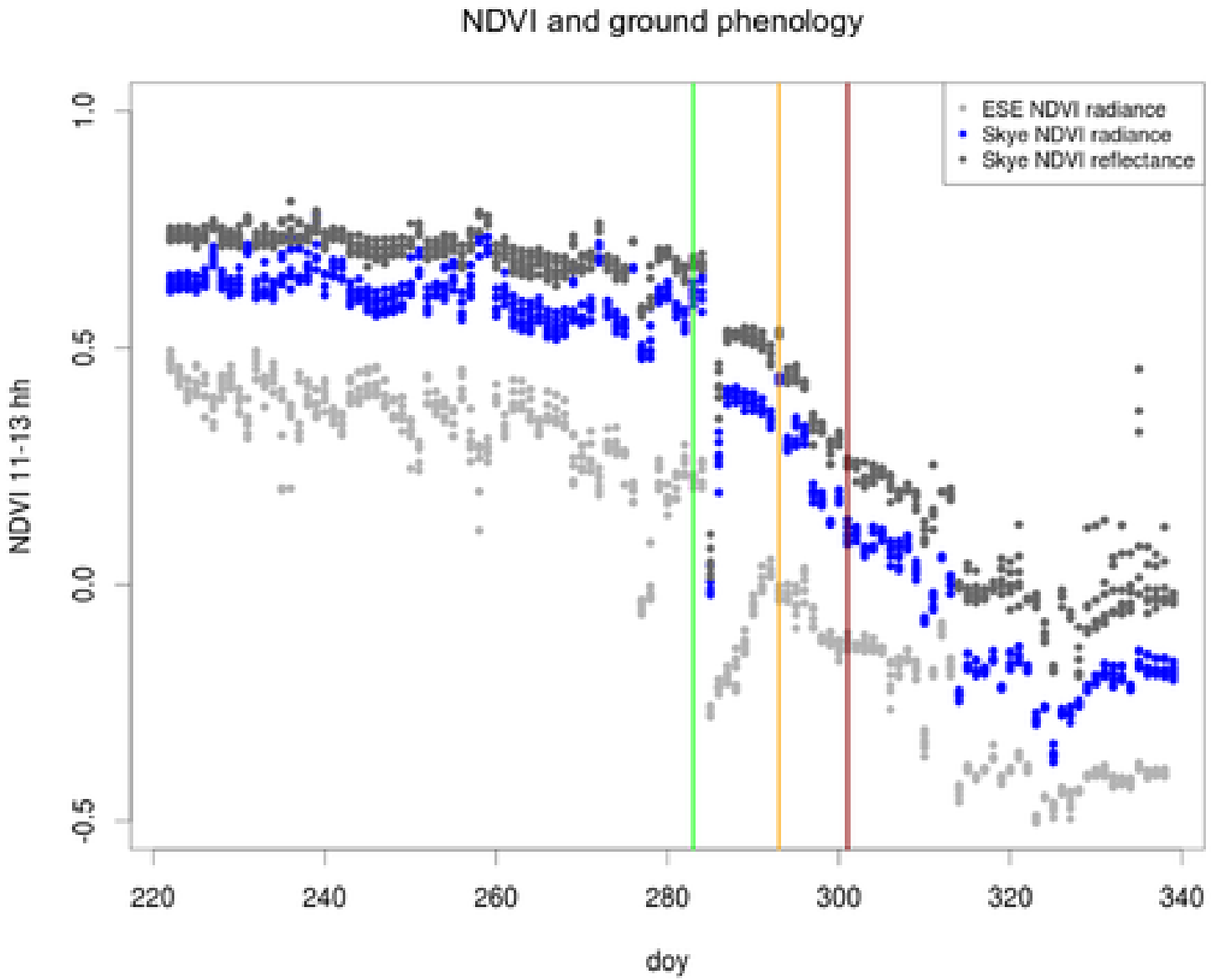
NDVI sensors comparison

- similar installation protocols but different sensors (Skye and ESE-LECA-Paris)

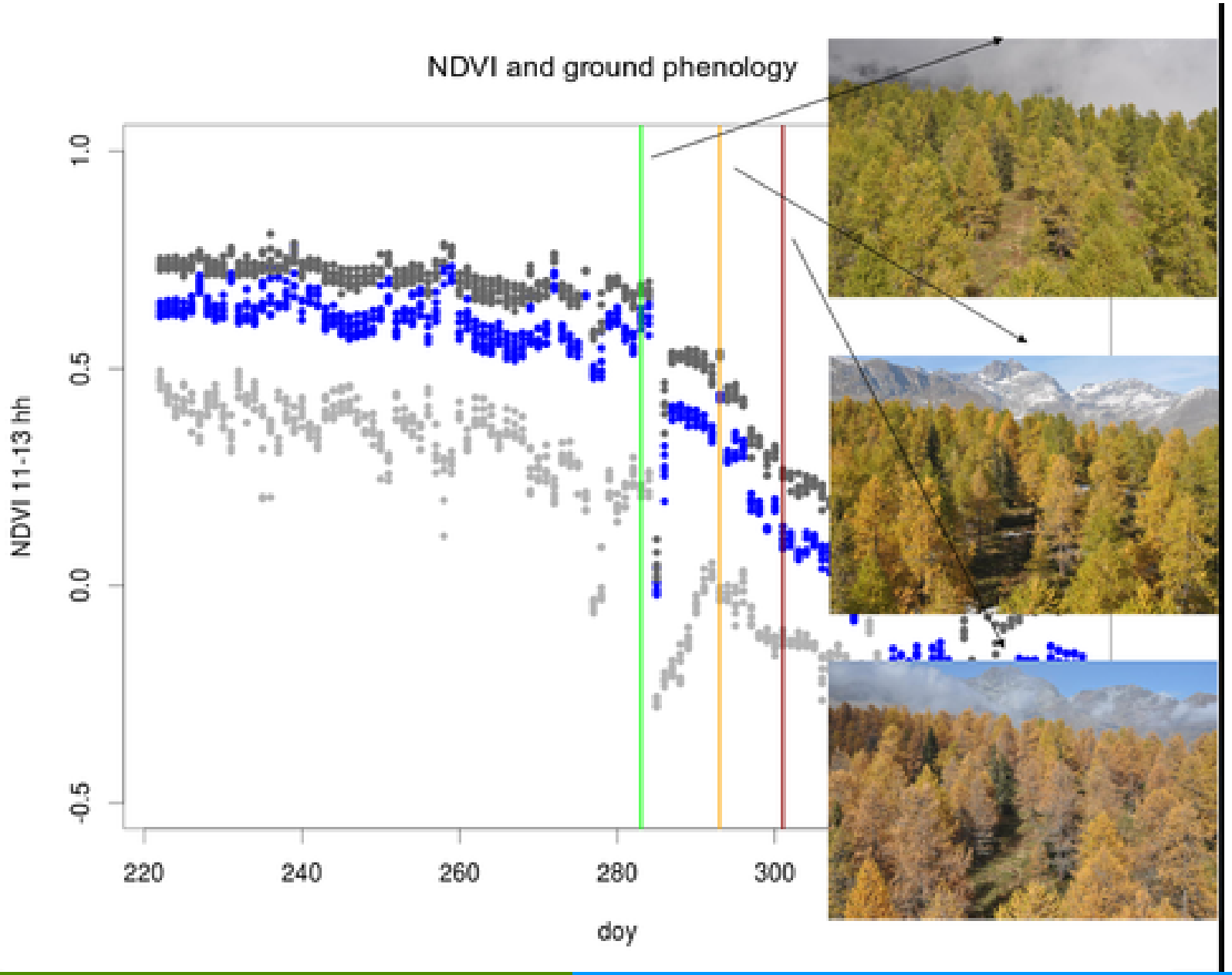
NDVI sensors comparison

- similar installation protocols but different sensors (Skye and ESE-LECA-Paris)

NDVI sensors comparison



NDVI sensors comparison



NDVI database

- NDVI database (12 sites: 5IT, 7FR) but other 6 from LECA ready to be included
- similar installation protocols but different sensors (Skye and ESE-LECA-Paris)
- most sites installed in 2010-2011
- ecosystems: grasslands (1800-2400 m asl) and subalpine ($<$ 2000 m asl) larch forests
- storing and processing strategy defined (e-pheno database)

NDVI database

- NDVI database (12 sites: 5IT, 7FR) but other 6 from LECA ready to be included
- similar installation protocols but different sensors (Skye and ESE-LECA-Paris)
- most sites installed in 2010-2011
- ecosystems: grasslands (1800-2400 m asl) and subalpine ($<$ 2000 m asl) larch forests
- storing and processing strategy defined (e-pheno database)

NDVI database

- NDVI database (12 sites: 5IT, 7FR) but other 6 from LECA ready to be included
- similar installation protocols but different sensors (Skye and ESE-LECA-Paris)
- most sites installed in 2010-2011
- ecosystems: grasslands (1800-2400 m asl) and subalpine ($<$ 2000 m asl) larch forests
- storing and processing strategy defined (e-pheno database)

NDVI database

- NDVI database (12 sites: 5IT, 7FR) but other 6 from LECA ready to be included
- similar installation protocols but different sensors (Skye and ESE-LECA-Paris)
- most sites installed in 2010-2011
- ecosystems: grasslands (1800-2400 m asl) and subalpine ($<$ 2000 m asl) larch forests
- storing and processing strategy defined (e-pheno database)

Image Processing package

Image Processing package

- R package for ROI definition, VIs computation, filtering, fitting, phenophase extraction and uncertainty estimation
- collaborative effort with Mirco's and Andrew's groups
- developed and tested on phenocam (phenocam.sr.unh.edu/webcam/) dataset: deciduous and evergreen forest, grassland and cropland
- v0 released soon (1 month)

Image Processing package

- R package for ROI definition, VIs computation, filtering, fitting, phenophase extraction and uncertainty estimation
- collaborative effort with Mirco's and Andrew's groups
- developed and tested on phenocam (phenocam.sr.unh.edu/webcam/) dataset: deciduous and evergreen forest, grassland and cropland
- v0 released soon (1 month)

Image Processing package

- R package for ROI definition, VIs computation, filtering, fitting, phenophase extraction and uncertainty estimation
- collaborative effort with Mirco's and Andrew's groups
- developed and tested on phenocam (phenocam.sr.unh.edu/webcam/) dataset: deciduous and evergreen forest, grassland and cropland
- v0 released soon (1 month)

Image Processing package

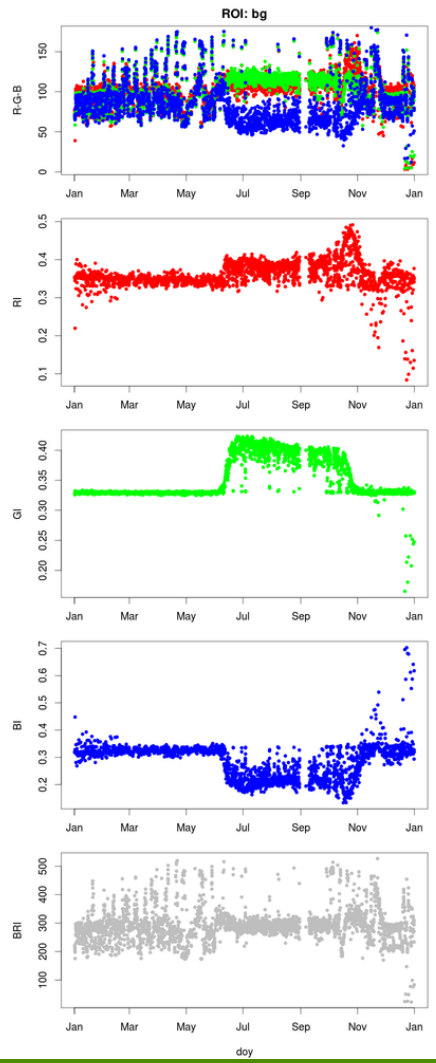
- R package for ROI definition, VIs computation, filtering, fitting, phenophase extraction and uncertainty estimation
- collaborative effort with Mirco's and Andrew's groups
- developed and tested on phenocam (phenocam.sr.unh.edu/webcam/) dataset: deciduous and evergreen forest, grassland and cropland
- v0 released soon (1 month)

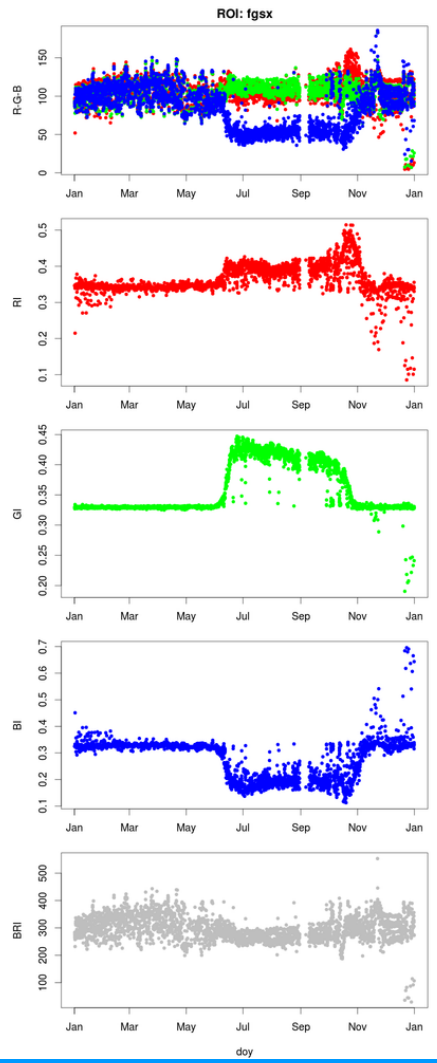
ROI (Region of Interest) definition

- User can define ROIs on a reference image clicking on ROIs vertexes

VI's computation

- VI's (GCC, BCC, RCC, GEI, BRI, HSV, ...) are computed as mean ROI values for each image





VI's filtering

- most recently published filtering approaches are implemented: max (Sonnentag 2012), spline and MAD (Migliavacca 2011), clouds (Julitta 2014)
- filters can be applied in a default sequence or according to user's needs
- daily aggregation

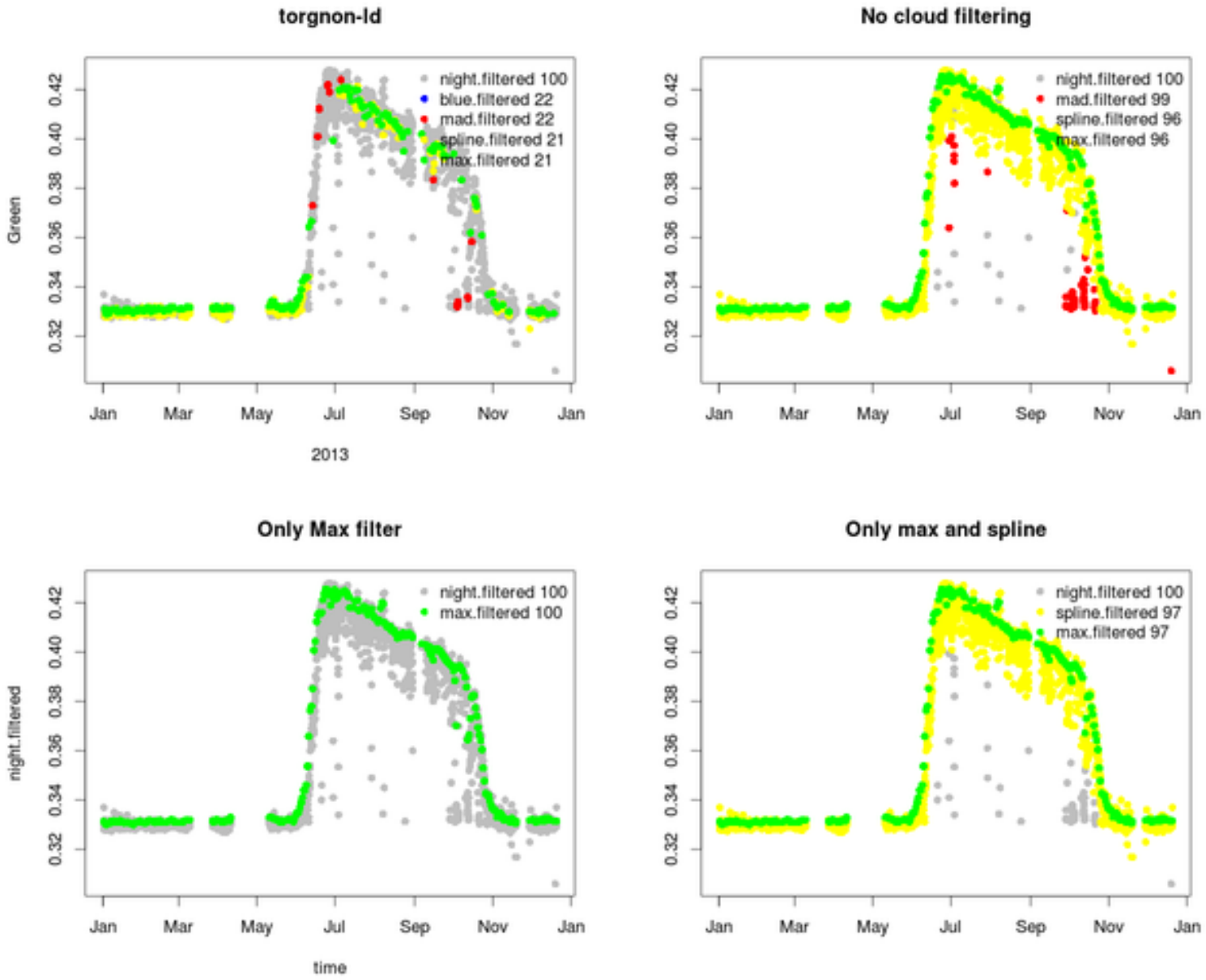
VI's filtering

- most recently published filtering approaches are implemented: max (Sonnentag 2012), spline and MAD (Migliavacca 2011), clouds (Julitta 2014)
- filters can be applied in a default sequence or according to user's needs
- daily aggregation

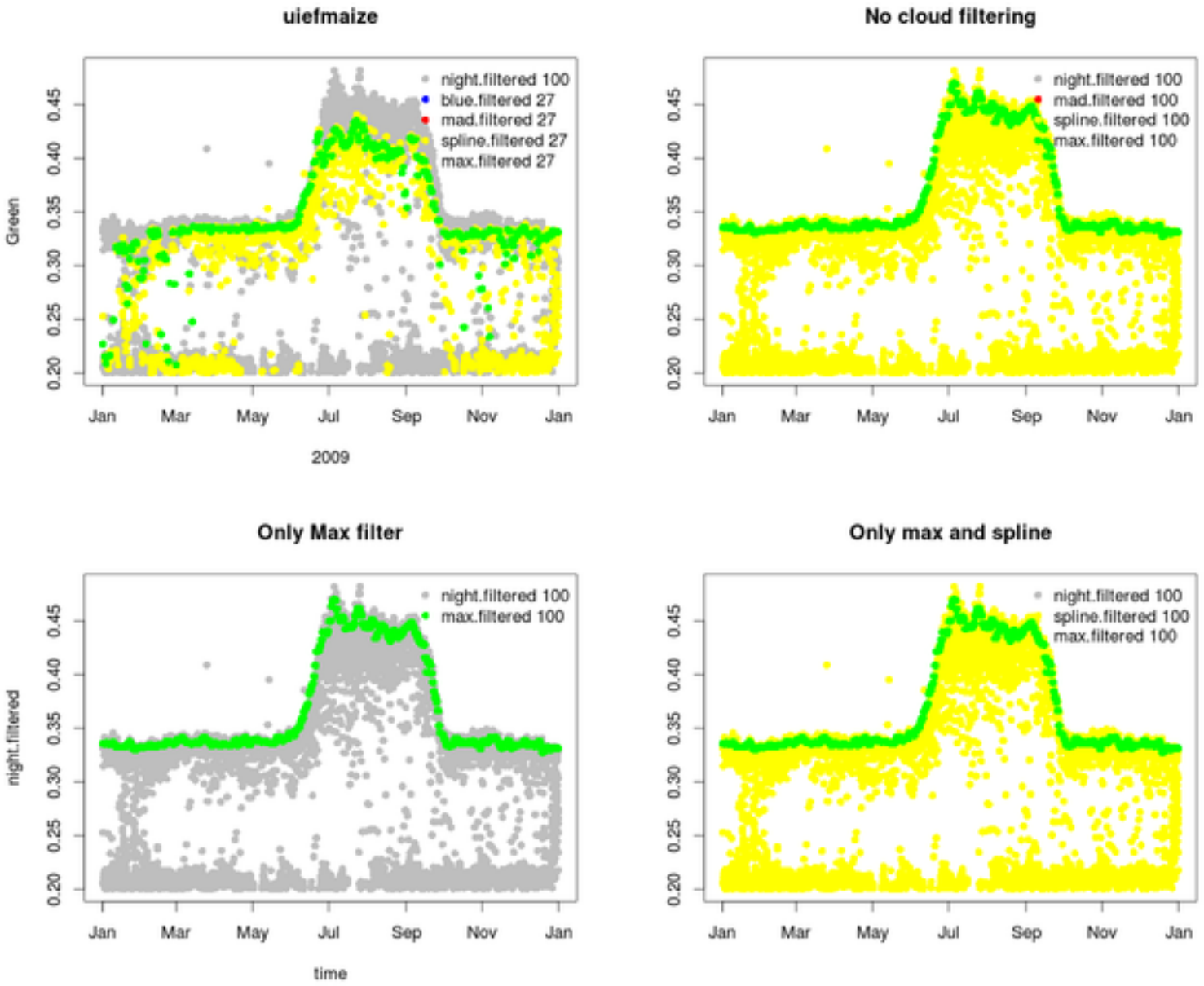
VI's filtering

- most recently published filtering approaches are implemented: max (Sonnentag 2012), spline and MAD (Migliavacca 2011), clouds (Julitta 2014)
- filters can be applied in a default sequence or according to user's needs
- daily aggregation

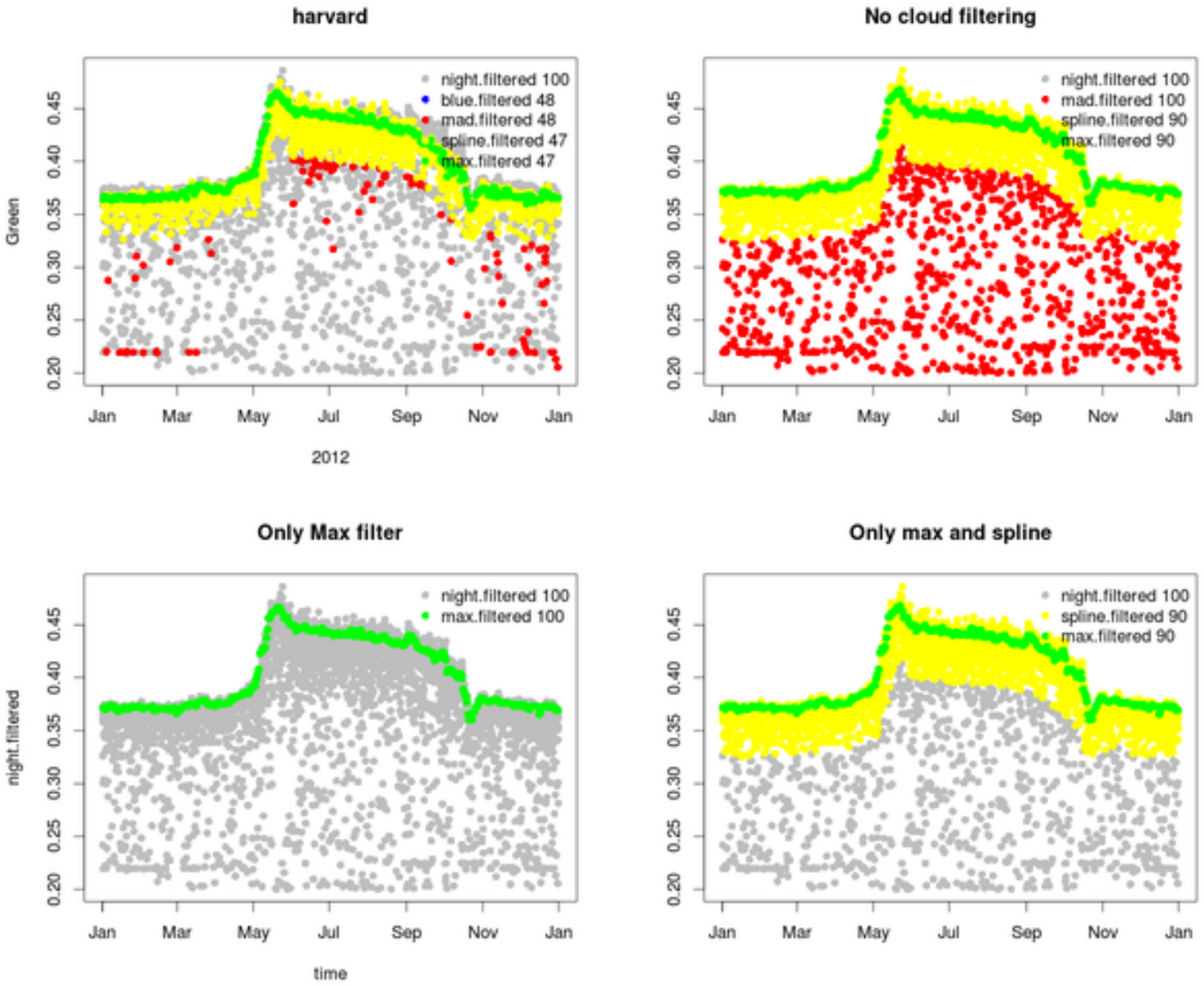
VI's filtering



VI's filtering



VI's filtering



fitting - phenophase extraction - uncertainty

- filtered timeseries fitting:
  - spline
  - double logistic functions with different formulation (Elmore et al 2012, Beck et al 2006, Klosterman et al 2014, Gu et al 2009)
- phenophases (i.e start of season, end of season, ...) extraction:
  - fixed thresholds (e.g. half peak)
  - derivative approaches (inflection points of fitting functions)
  - breakpoint analysis
- phenophase uncertainty estimation (residual bootstrap)

fitting - phenophase extraction - uncertainty

- filtered timeseries fitting:
  - spline
  - double logistic functions with different formulation (Elmore et al 2012, Beck et al 2006, Klosterman et al 2014, Gu et al 2009)
- phenophases (i.e start of season, end of season, ...) extraction:
  - fixed thresholds (e.g. half peak)
  - derivative approaches (inflection points of fitting functions)
  - breakpoint analysis
- phenophase uncertainty estimation (residual bootstrap)

fitting - phenophase extraction - uncertainty

- filtered timeseries fitting:
  - spline
  - double logistic functions with different formulation (Elmore et al 2012, Beck et al 2006, Klosterman et al 2014, Gu et al 2009)
- phenophases (i.e start of season, end of season, ...) extraction:
  - fixed thresholds (e.g. half peak)
  - derivative approaches (inflection points of fitting functions)
  - breakpoint analysis
- phenophase uncertainty estimation (residual bootstrap)

fitting - phenophase extraction - uncertainty

- filtered timeseries fitting:
  - spline
  - double logistic functions with different formulation (Elmore et al 2012, Beck et al 2006, Klosterman et al 2014, Gu et al 2009)
- phenophases (i.e start of season, end of season, ...) extraction:
  - fixed thresholds (e.g. half peak)
  - derivative approaches (inflection points of fitting functions)
  - breakpoint analysis
- phenophase uncertainty estimation (residual bootstrap)

fitting - phenophase extraction - uncertainty

- filtered timeseries fitting:
  - spline
  - double logistic functions with different formulation (Elmore et al 2012, Beck et al 2006, Klosterman et al 2014, Gu et al 2009)
- phenophases (i.e start of season, end of season, ...) extraction:
  - fixed thresholds (e.g. half peak)
  - derivative approaches (inflection points of fitting functions)
  - breakpoint analysis
- phenophase uncertainty estimation (residual bootstrap)

fitting - phenophase extraction - uncertainty

- filtered timeseries fitting:
  - spline
  - double logistic functions with different formulation (Elmore et al 2012, Beck et al 2006, Klosterman et al 2014, Gu et al 2009)
- phenophases (i.e start of season, end of season, ...) extraction:
  - fixed thresholds (e.g. half peak)
  - derivative approaches (inflection points of fitting functions)
  - breakpoint analysis
- phenophase uncertainty estimation (residual bootstrap)

fitting - phenophase extraction - uncertainty

- filtered timeseries fitting:
  - spline
  - double logistic functions with different formulation (Elmore et al 2012, Beck et al 2006, Klosterman et al 2014, Gu et al 2009)
- phenophases (i.e start of season, end of season, ...) extraction:
  - fixed thresholds (e.g. half peak)
  - derivative approaches (inflection points of fitting functions)
  - breakpoint analysis
- phenophase uncertainty estimation (residual bootstrap)

fitting - phenophase extraction - uncertainty

- filtered timeseries fitting:
  - spline
  - double logistic functions with different formulation (Elmore et al 2012, Beck et al 2006, Klosterman et al 2014, Gu et al 2009)
- phenophases (i.e start of season, end of season, ...) extraction:
  - fixed thresholds (e.g. half peak)
  - derivative approaches (inflection points of fitting functions)
  - breakpoint analysis
- phenophase uncertainty estimation (residual bootstrap)

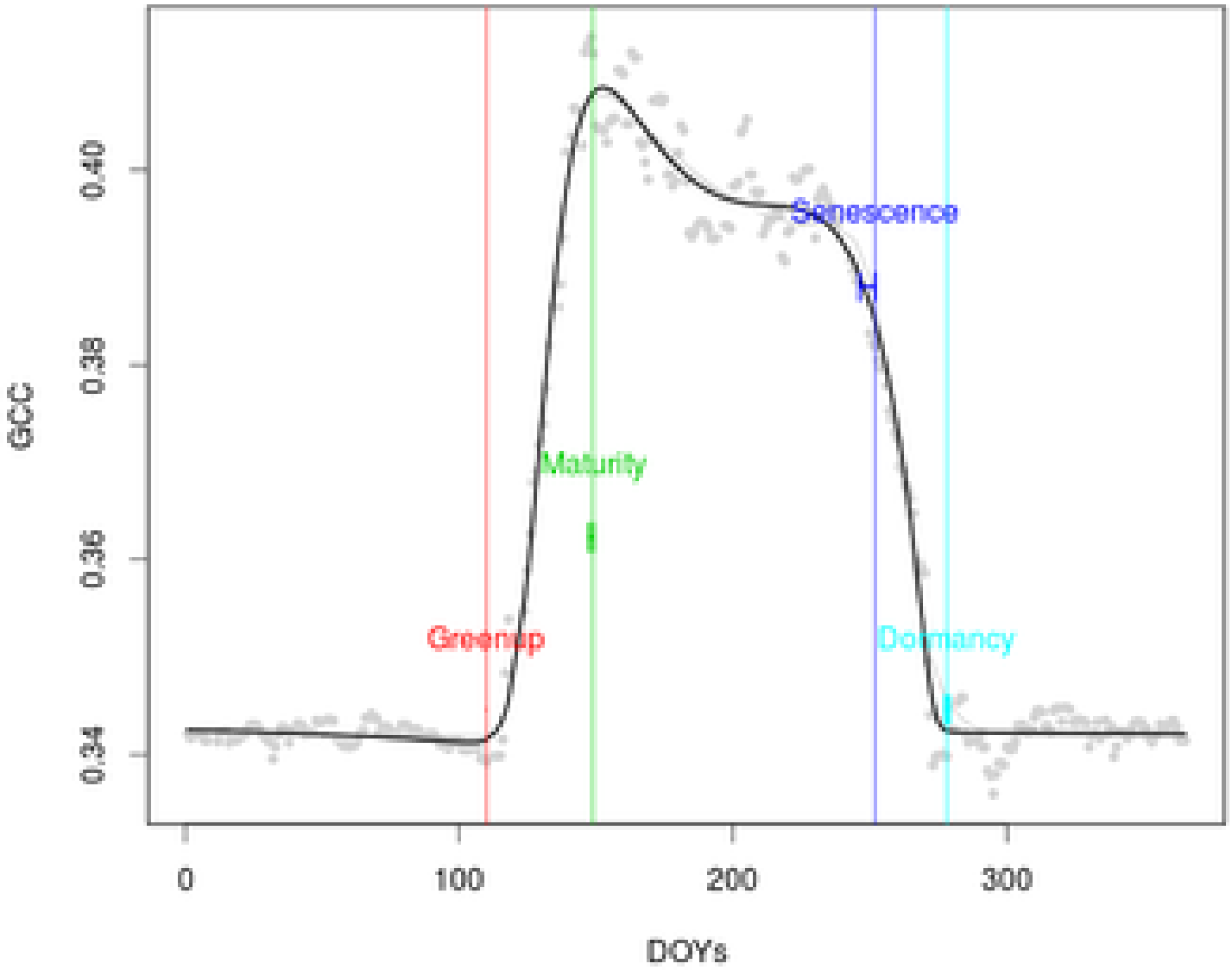


Figure: Bartlett filtered data - Klosterman et al 2014 fitting and phenophases

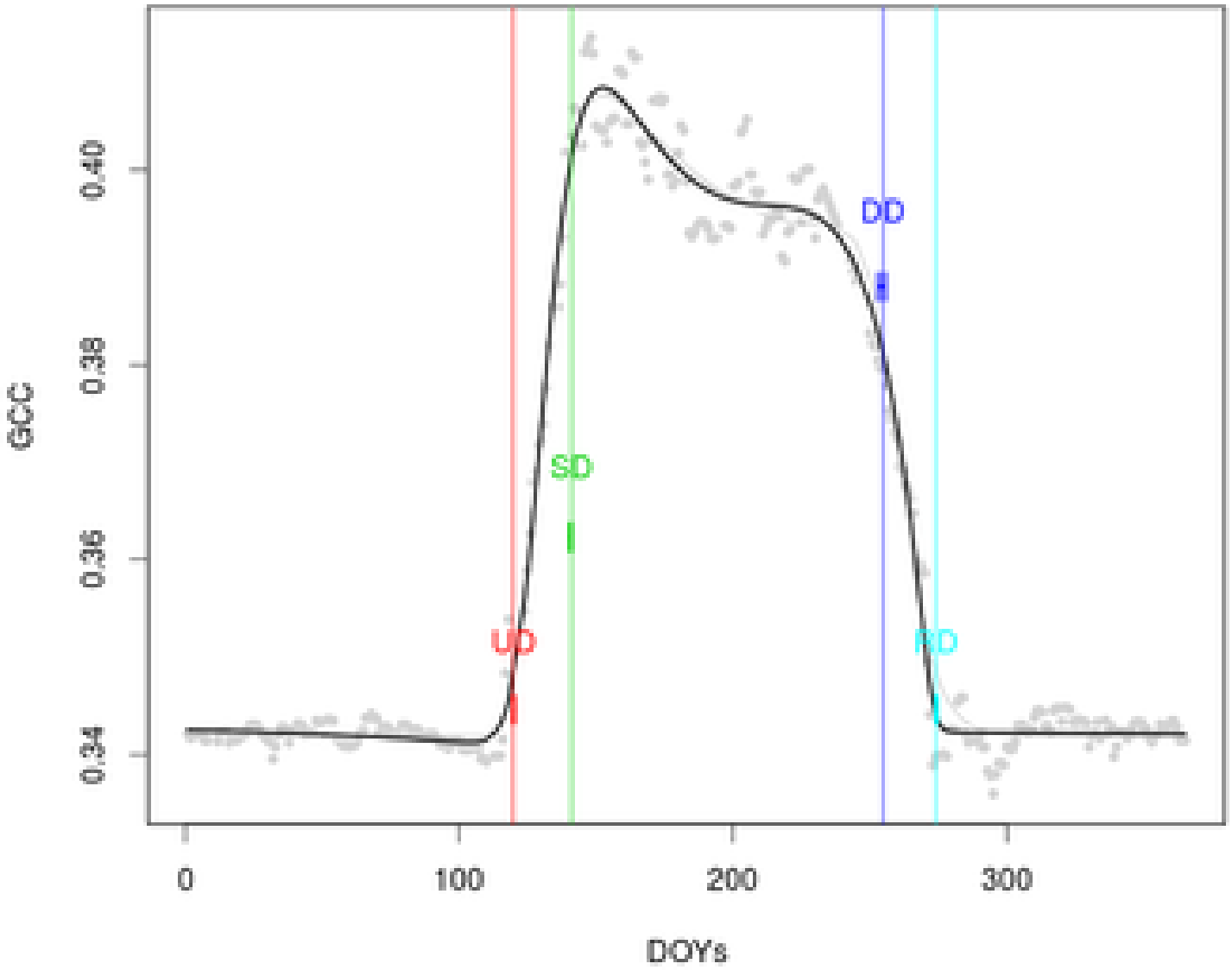
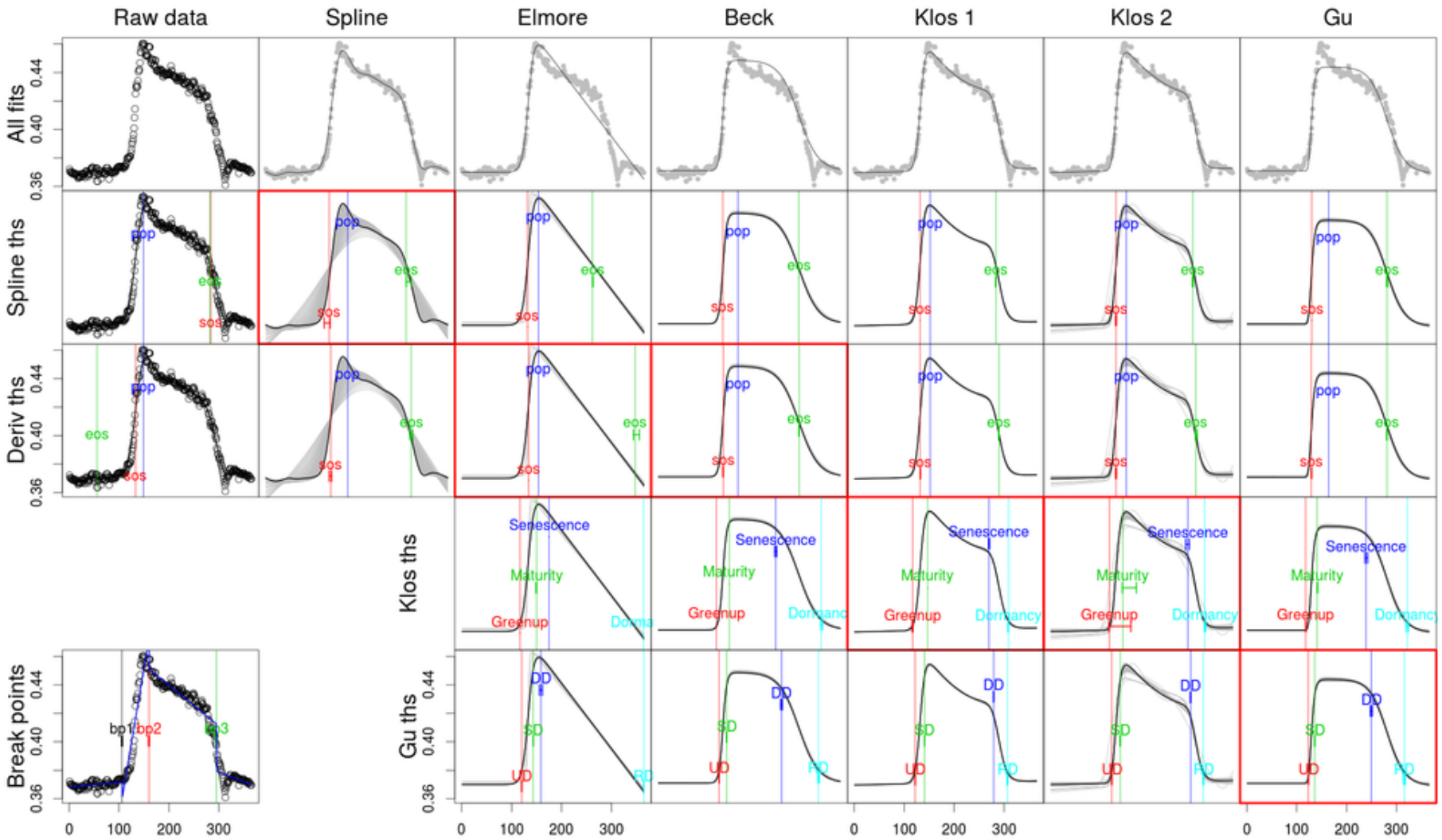
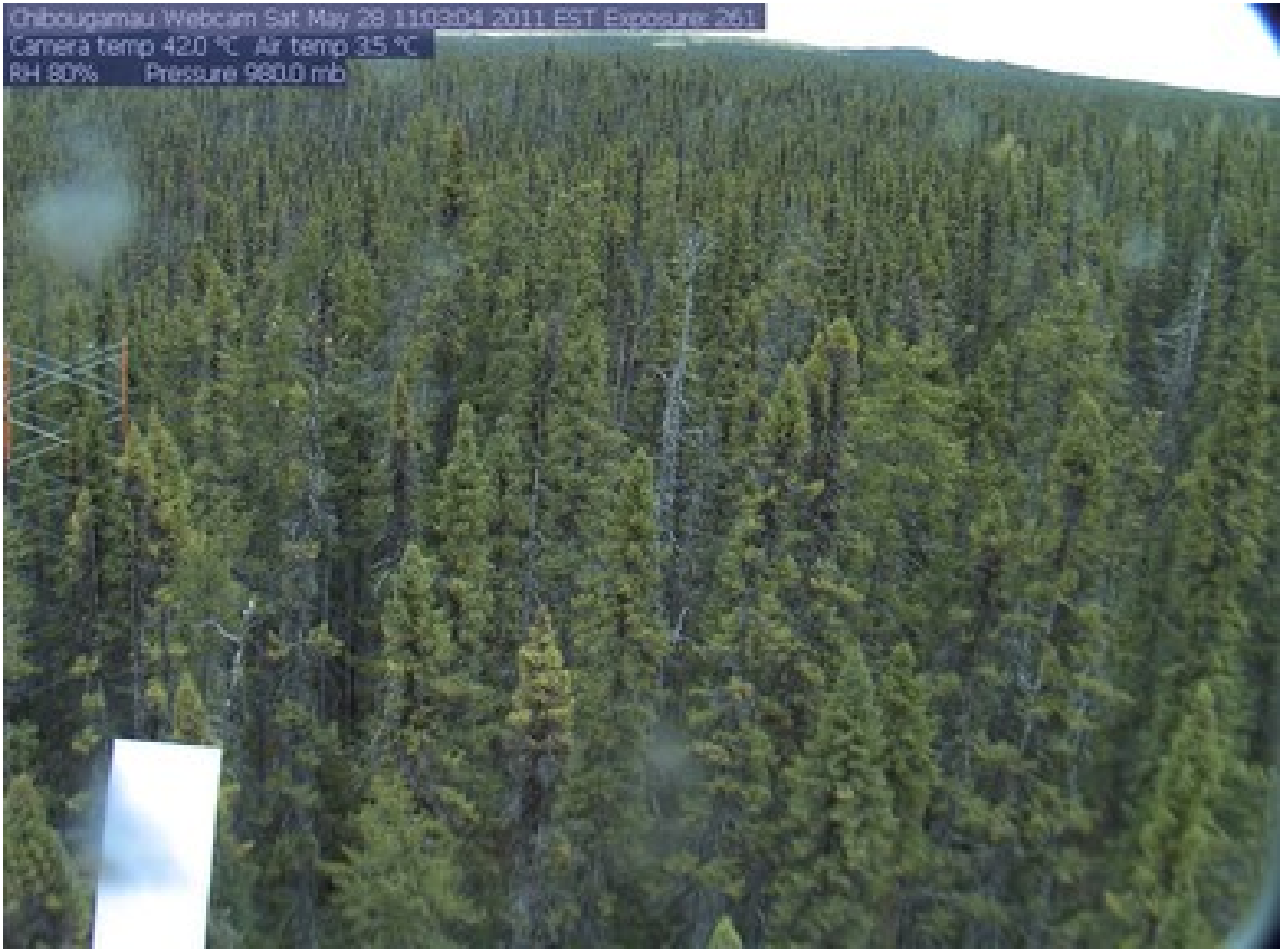


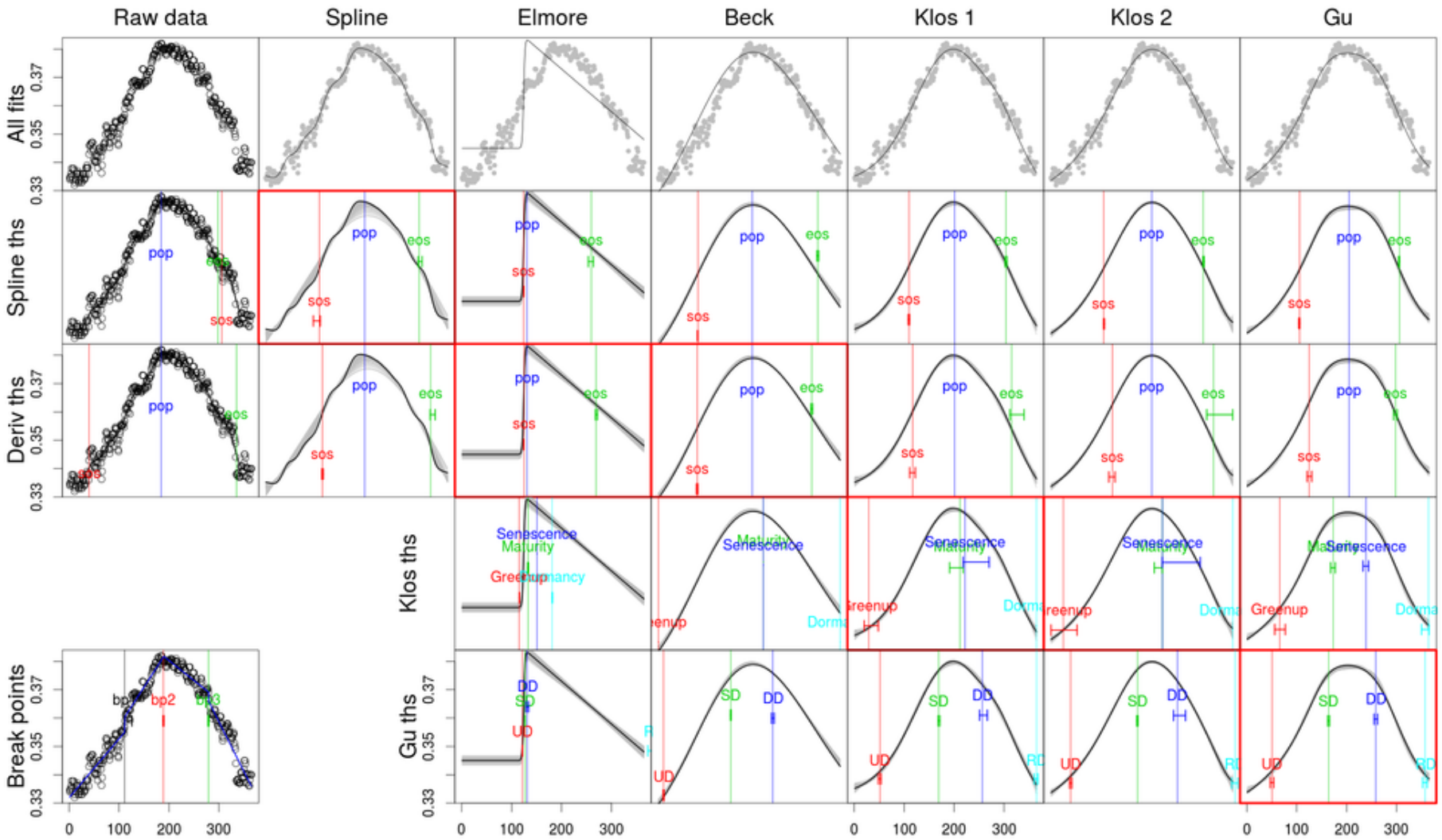
Figure: Bartlett filtered data - Klosterman et al 2014 - Gu et al 2009 phenophases

Deciduous forest - Harvard Forest

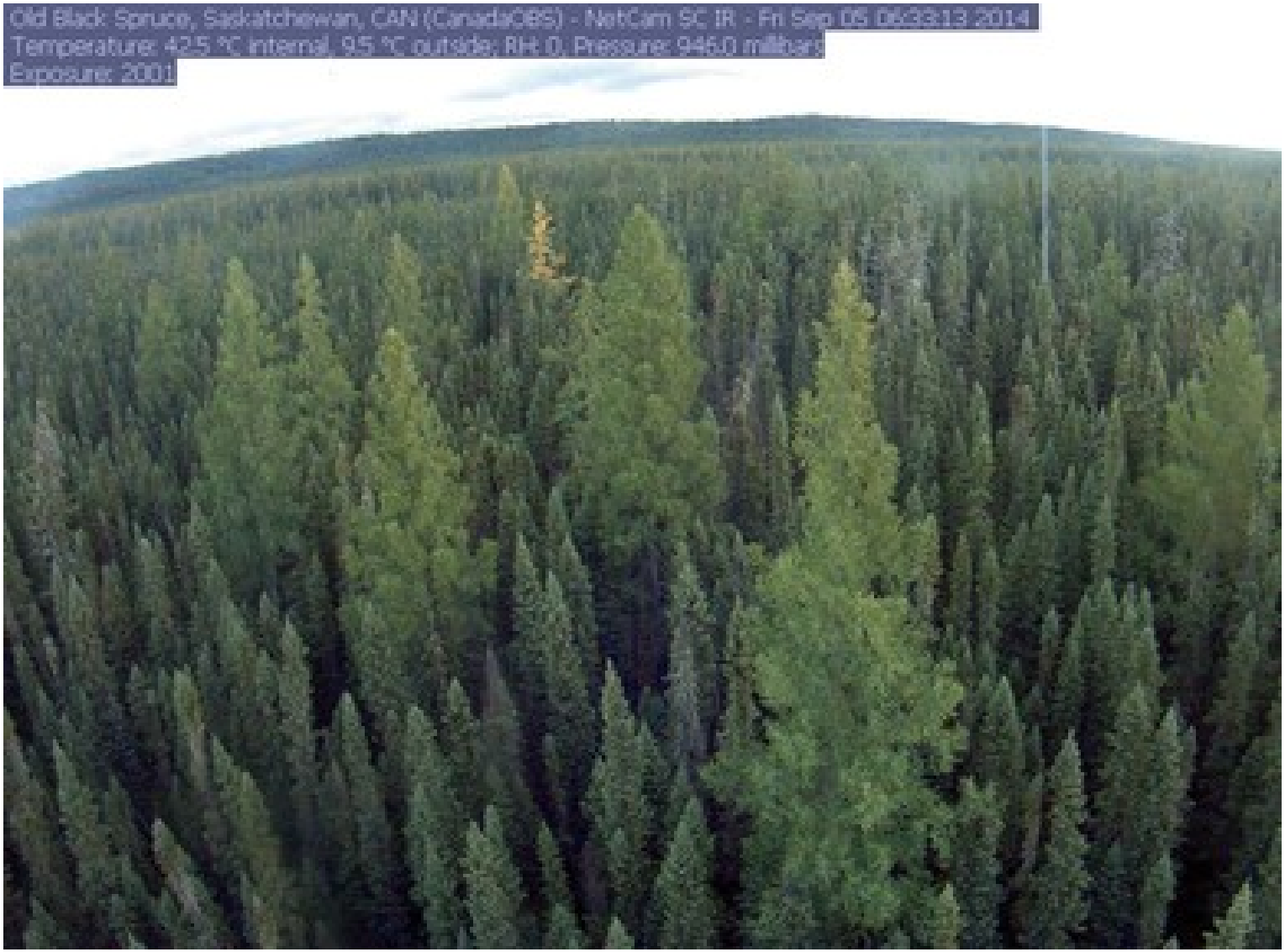

Raw data
Spline
Elmore
Beck
Klos 1
Klos 2
Gu
All fits
Spline ths
Deriv ths
Klos ths
Gu ths
Break points
pop
eos
sos
H
Senescence
Maturity
Greenup
Dormancy
DD
SD
UD
PD
bp1
bp2
bp3
0.36
0.40
0.44
0
100
200
300

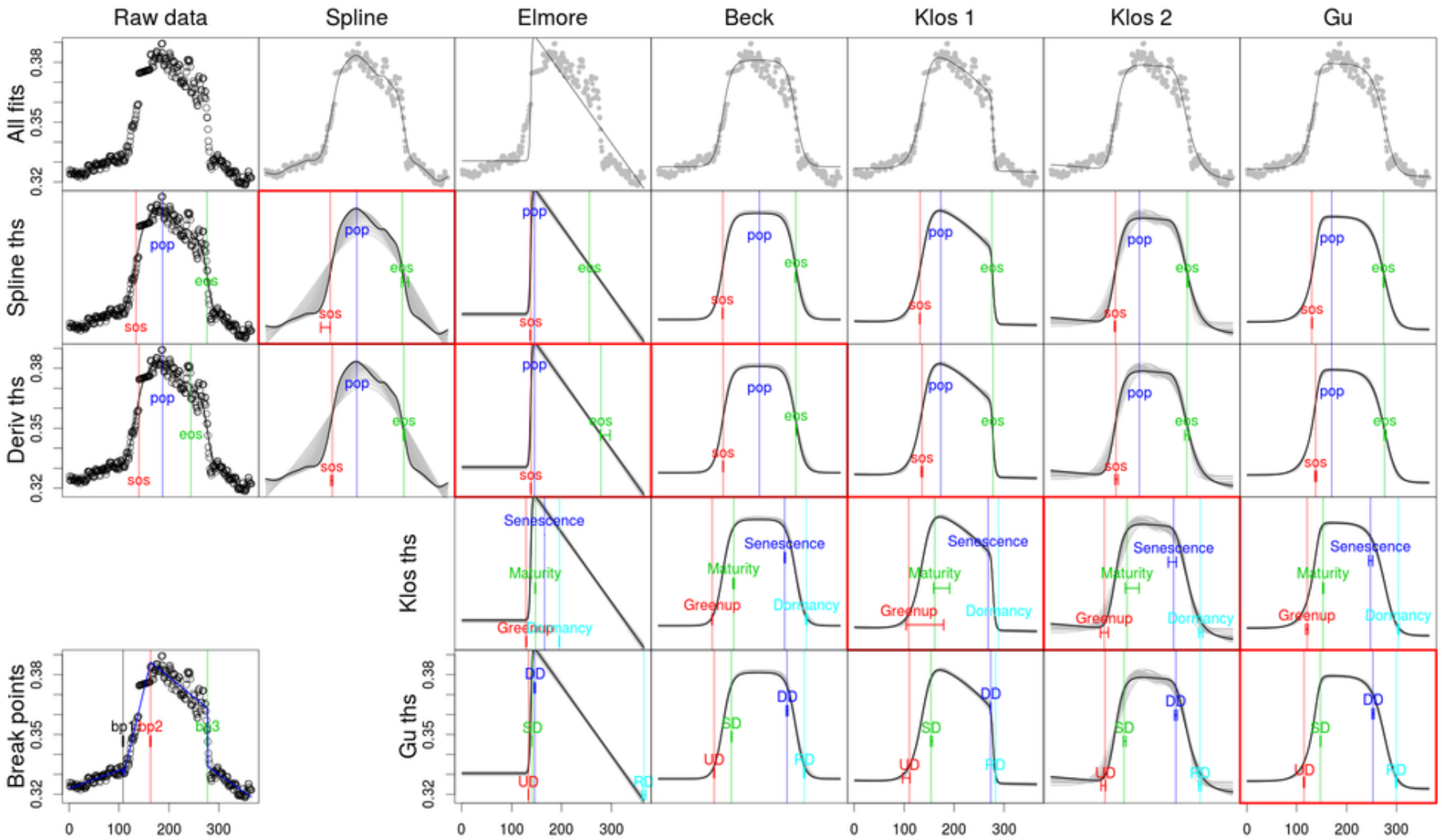
Evergreen forest - Chibougamu Forest



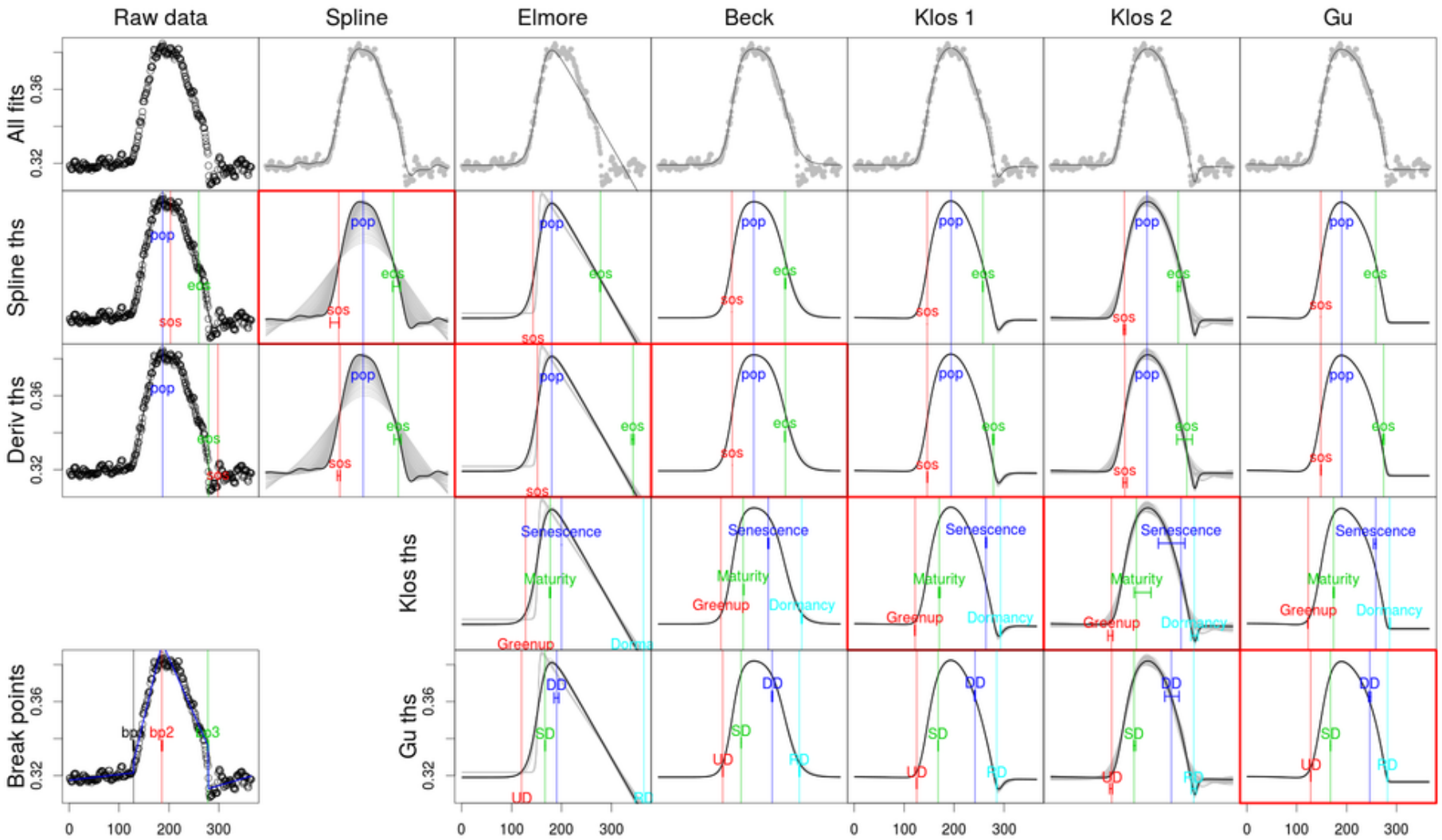

Raw data
Spline
Elmore
Beck
Klos 1
Klos 2
Gu
All fits
Spline ths
Deriv ths
Klos ths
Gu ths
Break points
pop
sos
eos
H
Senescence
Maturity
Greenup
Dormancy
DD
SD
UD
RD
bp1
bp2
bp3
0.33
0.35
0.37
0
100
200
300

Mixed forest - Canada OBS Forest

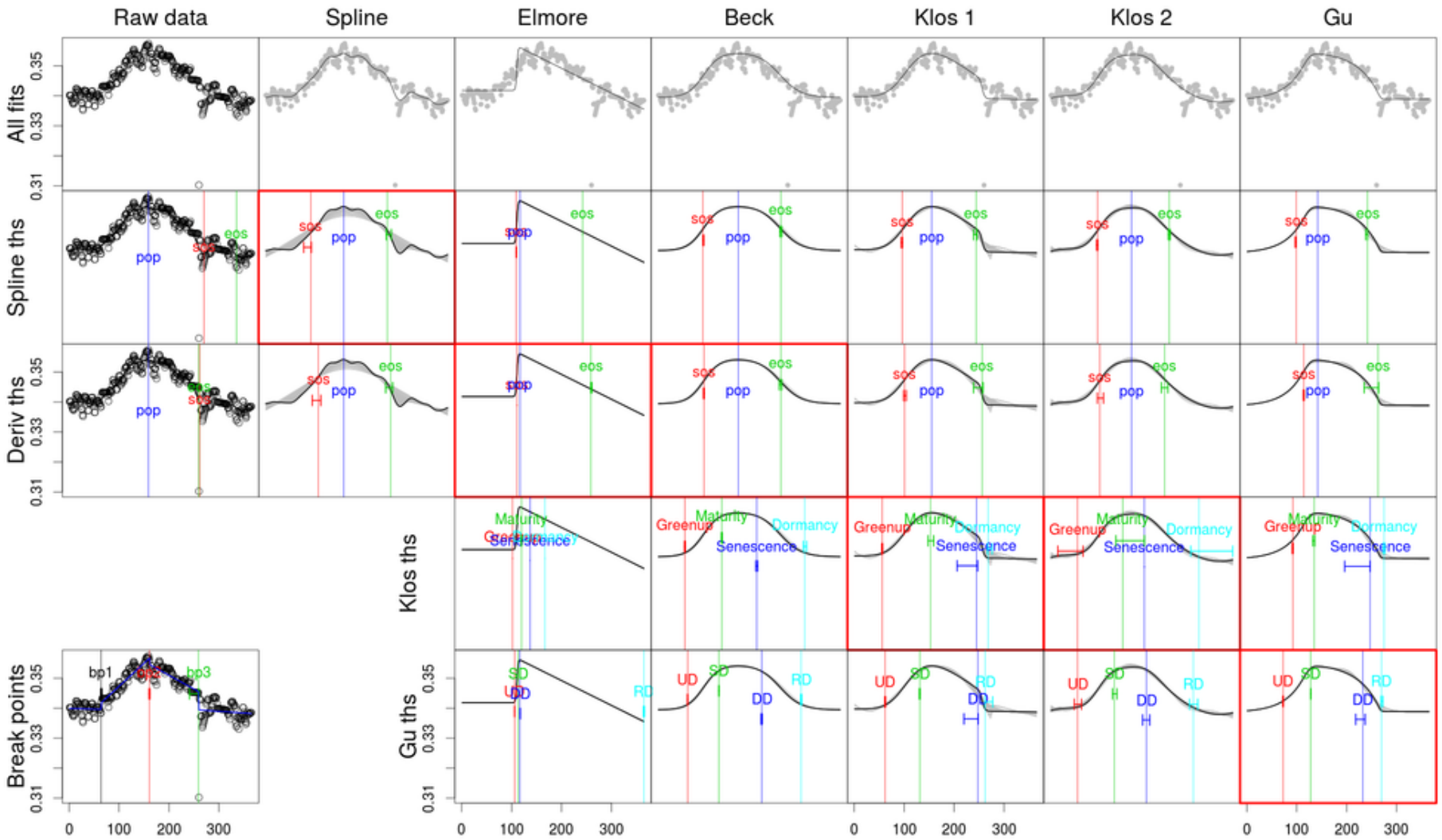



Raw data
Spline
Elmore
Beck
Klos 1
Klos 2
Gu
All fits
Spline ths
Deriv ths
Klos ths
Gu ths
Break points
sos
pop
eos
Senescence
Maturity
Greenup
Dormancy
DD
SD
UD
RD
bp1
bp2
bp3
0.32
0.35
0.38
0
100
200
300

Grassland - Lethbridge Grassland


Raw data
Spline
Elmore
Beck
Klos 1
Klos 2
Gu
All fits
Spline ths
Deriv ths
Klos ths
Gu ths
Break points
pop
eos
sos
Senescence
Maturity
Greenup
Dormancy
DD
SD
UD
RD
bp1
bp2
bp3
0.32
0.36
0
100
200
300

Shrubland - Burnssagebrush


Raw data
Spline
Elmore
Beck
Klos 1
Klos 2
Gu
All fits
Spline ths
Deriv ths
Klos ths
Gu ths
Break points
sos
pop
eos
Greenup
Maturity
Senescence
Dormancy
SD
UD
DD
RD
bp1
bp2
bp3
0.31
0.33
0.35
0
100
200
300

next steps

- release v0
- evaluate fittings performace and phenophase extraction on phenocam and european dataset
- future developments:
  - import external ROIs
  - ROIs change detection
  - include grid based analysis
  - improve uncertainty estimation
  - multipeack phenological cycle (drought, crops, ...)

next steps

- release v0
- evaluate fittings performace and phenophase extraction on phenocam and european dataset
- future developments:
  - import external ROIs
  - ROIs change detection
  - include grid based analysis
  - improve uncertainty estimation
  - multipeack phenological cycle (drought, crops, ...)

next steps

- release v0
- evaluate fittings performace and phenophase extraction on phenocam and european dataset
- future developments:
  - import external ROIs
  - ROIs change detection
  - include grid based analysis
  - improve uncertainty estimation
  - multipeack phenological cycle (drought, crops, ...)

next steps

- release v0
- evaluate fittings performace and phenophase extraction on phenocam and european dataset
- future developments:
  - import external ROIs
  - ROIs change detection
  - include grid based analysis
  - improve uncertainty estimation
  - multipeack phenological cycle (drought, crops, ...)

next steps

- release v0
- evaluate fittings performace and phenophase extraction on phenocam and european dataset
- future developments:
  - import external ROIs
  - ROIs change detection
  - include grid based analysis
  - improve uncertainty estimation
  - multipeack phenological cycle (drought, crops, ...)

next steps

- release v0
- evaluate fittings performace and phenophase extraction on phenocam and european dataset
- future developments:
  - import external ROIs
  - ROIs change detection
  - include grid based analysis
  - improve uncertainty estimation
  - multipeack phenological cycle (drought, crops, ...)

next steps

- release v0
- evaluate fittings performace and phenophase extraction on phenocam and european dataset
- future developments:
  - import external ROIs
  - ROIs change detection
  - include grid based analysis
  - improve uncertainty estimation
  - multipeack phenological cycle (drought, crops, ...)

next steps

- release v0
- evaluate fittings performace and phenophase extraction on phenocam and european dataset
- future developments:
  - import external ROIs
  - ROIs change detection
  - include grid based analysis
  - improve uncertainty estimation
  - multipeack phenological cycle (drought, crops, ...)

next steps

- release v0
- evaluate fittings performace and phenophase extraction on phenocam and european dataset
- future developments:
  - import external ROIs
  - ROIs change detection
  - include grid based analysis
  - improve uncertainty estimation
  - multipeack phenological cycle (drought, crops, ...)