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PHENOLOGY OBSERVED BY SENTINEL-2 AND DIGITAL CAMERAS: OPTIONS AND CHALLENGES

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ROTHAMSTED RESEARCH

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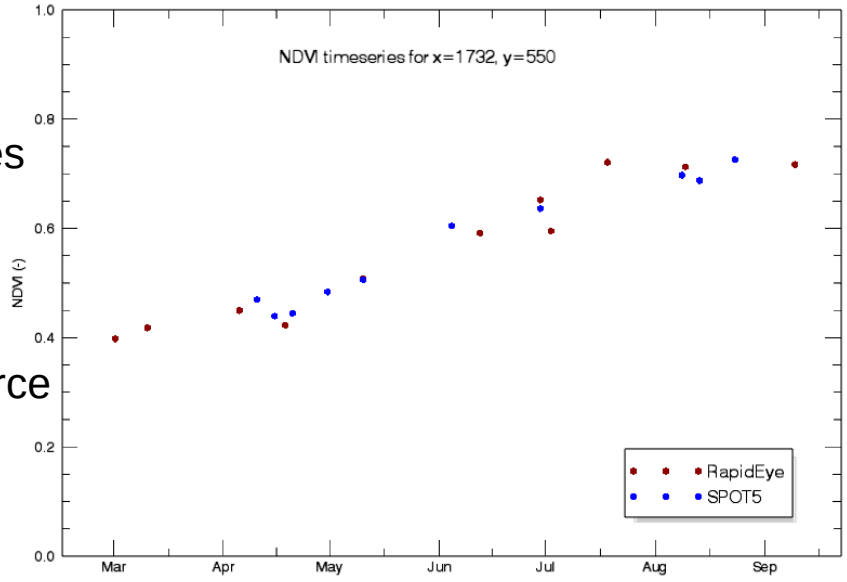
NDVI SERIES

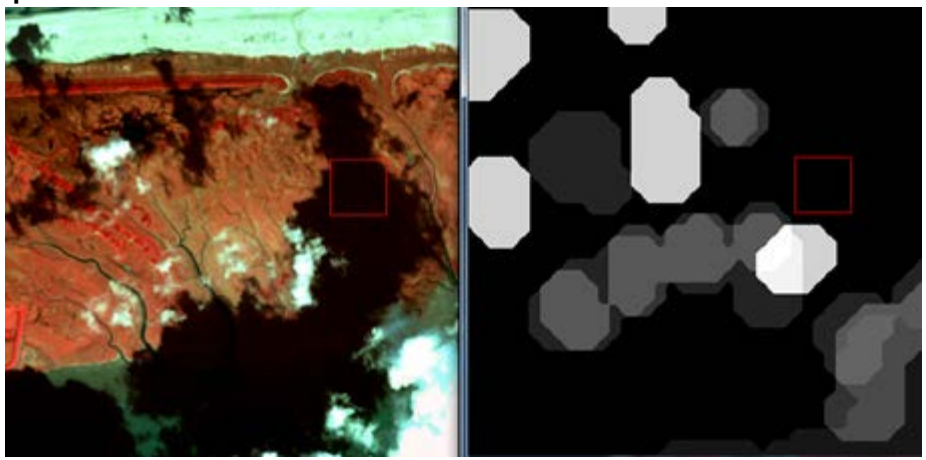
- Phenology: need for frequent observations *before, during, and after* key phenological phases
  - Phase 1: combine RapidEye and SPOT5 (*March – September*)
  - Not possible to model senescence phase, only green-up

- Step1: NDVI calculation
  - Input: atmospherically-corrected images
  - Quick intercalibration red/NIR bands
    - Use ± same date image
    - Not an issue when using single source

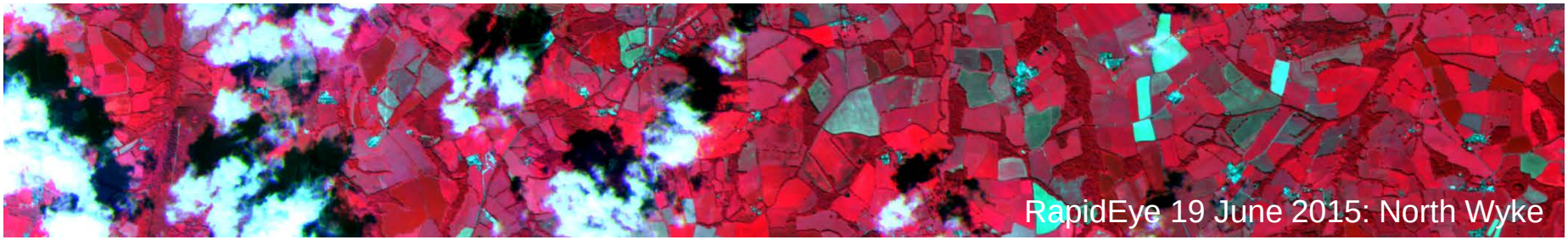


CLOUD MASKING

- SPOT5: multi-temporal cloud detection at 100m resolution
  - much time between cloud-free acquisitions
  - small clouds missed
- Now use CESBIO's mask
  - Accuracy not always great…
  - cloud shadow update (CESBIO)



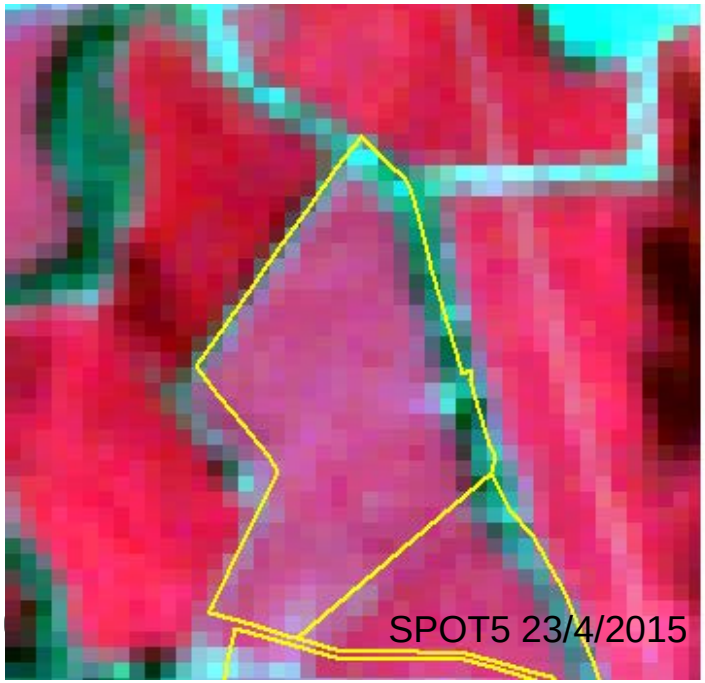
- RapidEye:
  - To increase confidence in NDVI-values over time (and maximally use available data): manual digitization

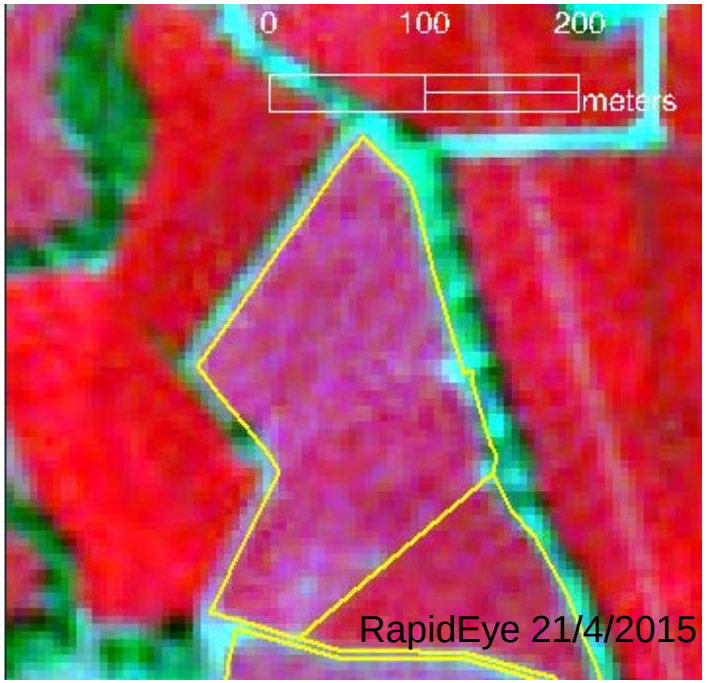


GEOMETRIC ACCURACY

- SPOT-5 are perfectly aligned between them
- RapidEye has some small shifts
  - different observation angles
  - no correction applied
- Offset S5 & RE: manual shift (max. 15 m in single direction)

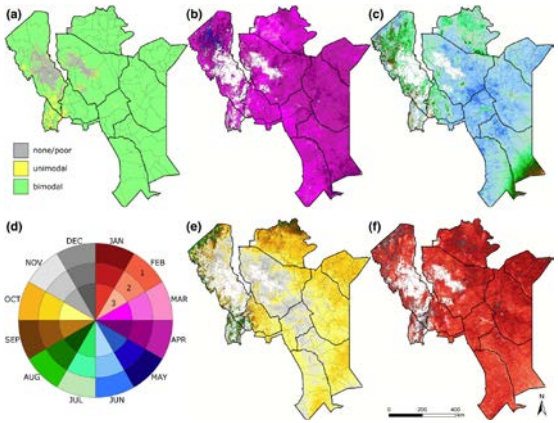
Pecketsford field – North Wyke

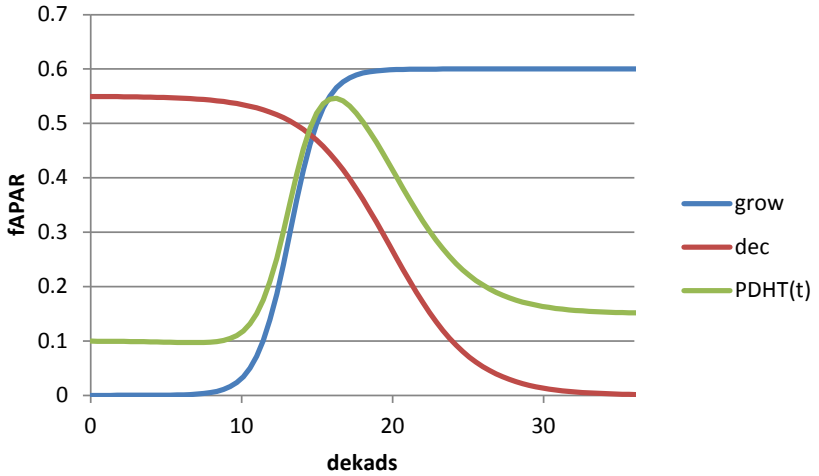




FUNCTION FITTING (1)

- Goal “reconstruct” per pixel real vegetation timeline from irregularly-spaced observations
- Hyperbolic tangent model (single)
  - Double models combining green-up/senescence
    - Meroni et al (2014) and Vrieling et al (2016)





- For 2015 only applied to single season green-up

Meroni et al. (2014): IJRS 35, 2472-2492.
Vrieling et al. (2016): RSE 174, 44-55.

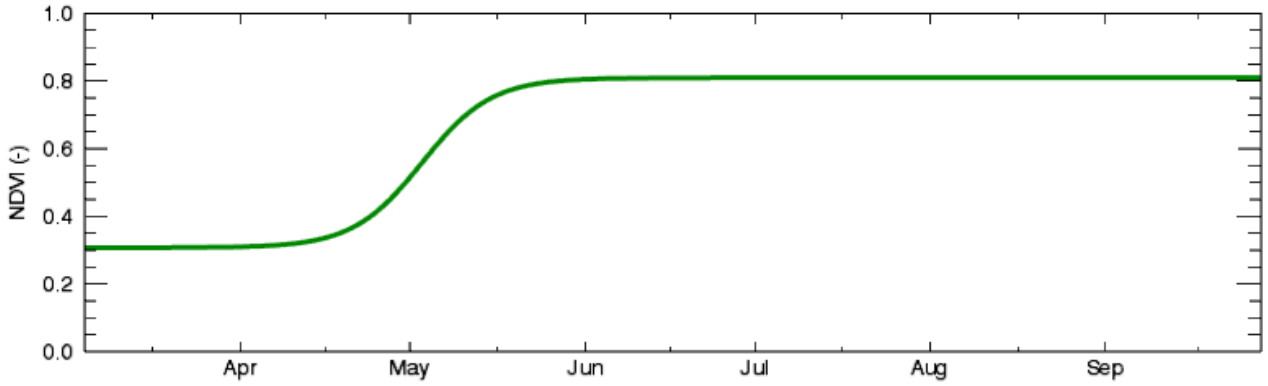
FUNCTION FITTING (2)

Constraints:

- a_0 → lowest limit = 0.5 * minNDVI
- a_1 → upper limit = 1.25 * (max – min)

- Model: $NDVI(t) = a_0 + a_1 \frac{\{\tanh[(t-a_2)*a_3]+1\}}{2}$

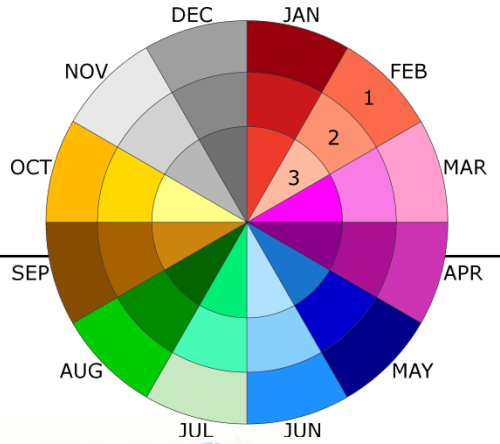
- We apply the model to NDVI data from 1 March to 31 August
- Assess 4 parameters using a least-squares method
  - Single fit vs future iterative fitting…
- Requirements/assumptions:
  - Baseline is included (i.e. first images show the “low” NDVI level before onset)
  - Little senescence yet in that period (although effect not so strong)
  - Several good-quality observations between “low” and “high” NDVI.



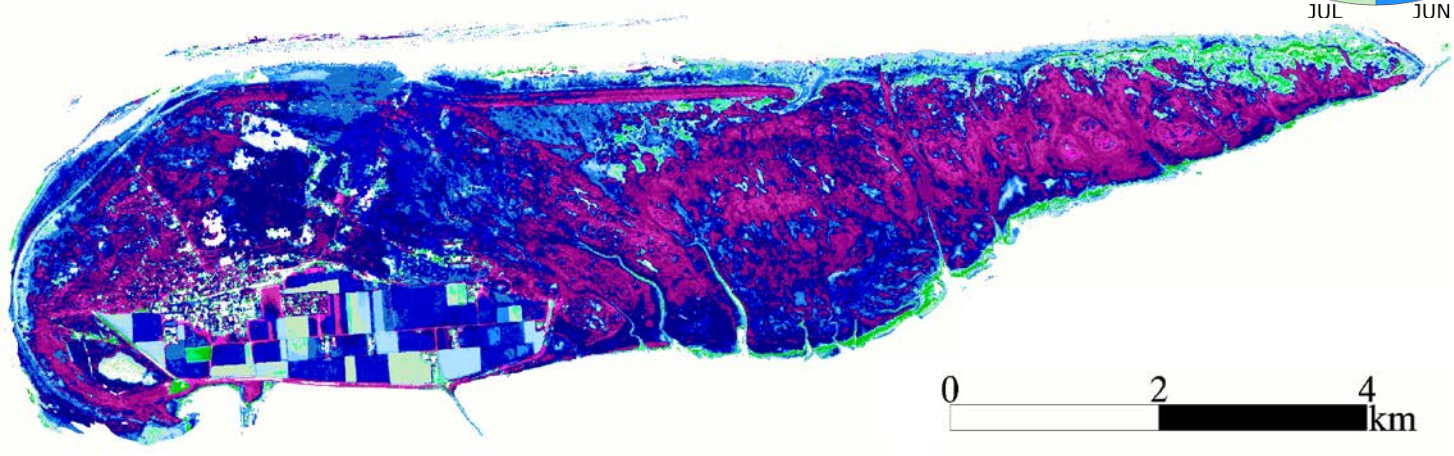
PHENOLOGICAL PARAMETERS

- We could directly use parameters of the model, but…
  - Retrieval may not be stable and extrapolate much beyond green-up period
- Commonly-used: thresholds
  - *maxNDVI: the maximum NDVI value, i.e. the fitted value for 31 August*
  - *AMP: the difference between the fitted NDVI value for 31 August and 1 March.*
  - *SOS : the DOY when the fitted function reaches **20% of AMP***
  - *PS: the DOY when the fitted function reaches **90% of AMP***
  - *LG: PS minus SOS*

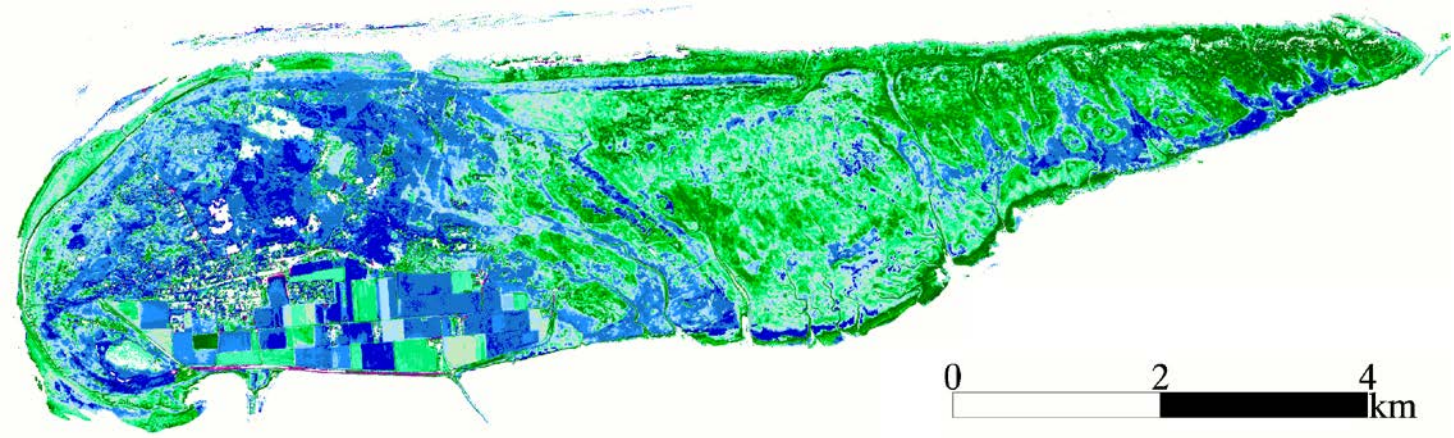
RESULTS: SCHIERMONNIKOOG

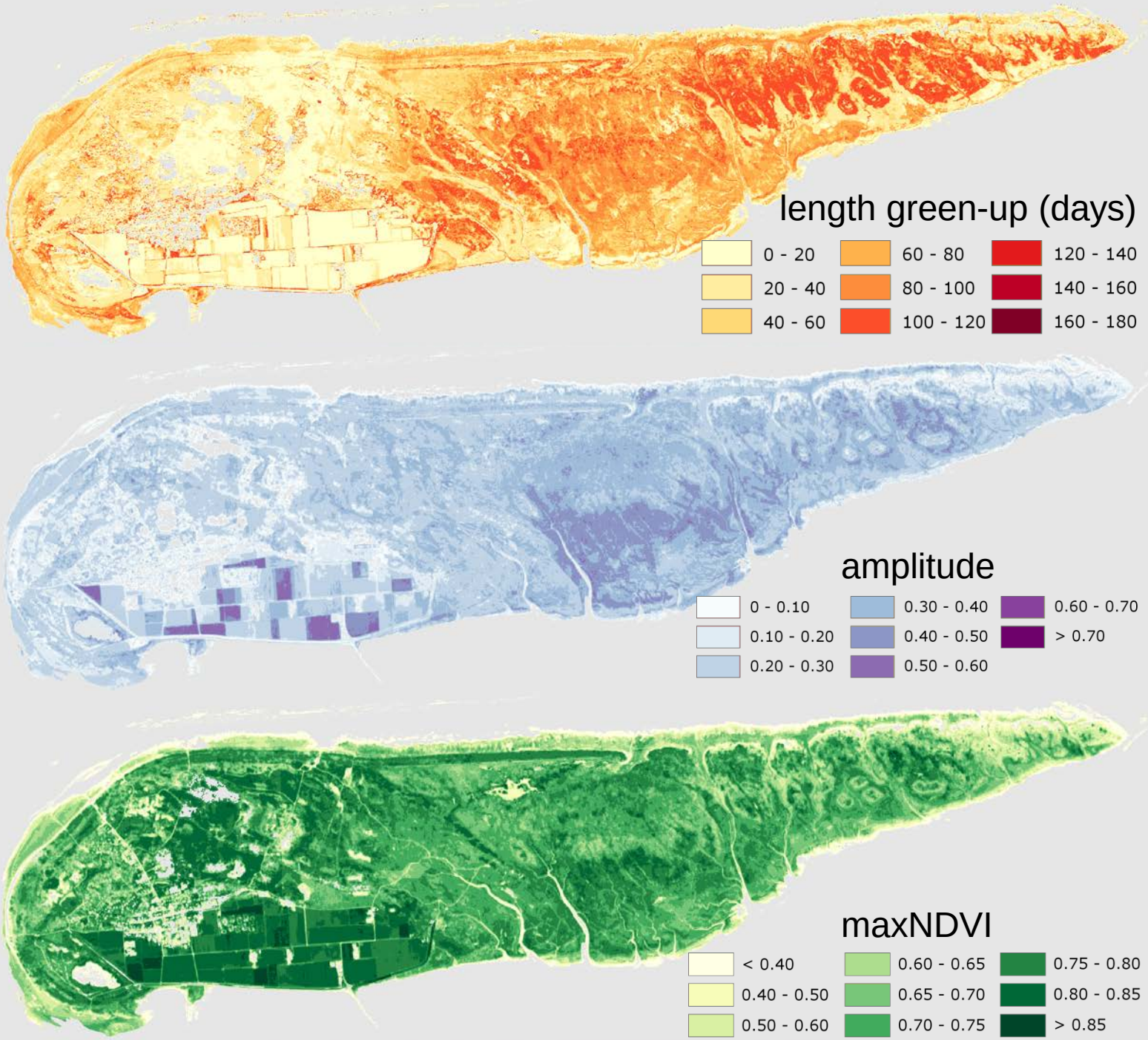


start of season

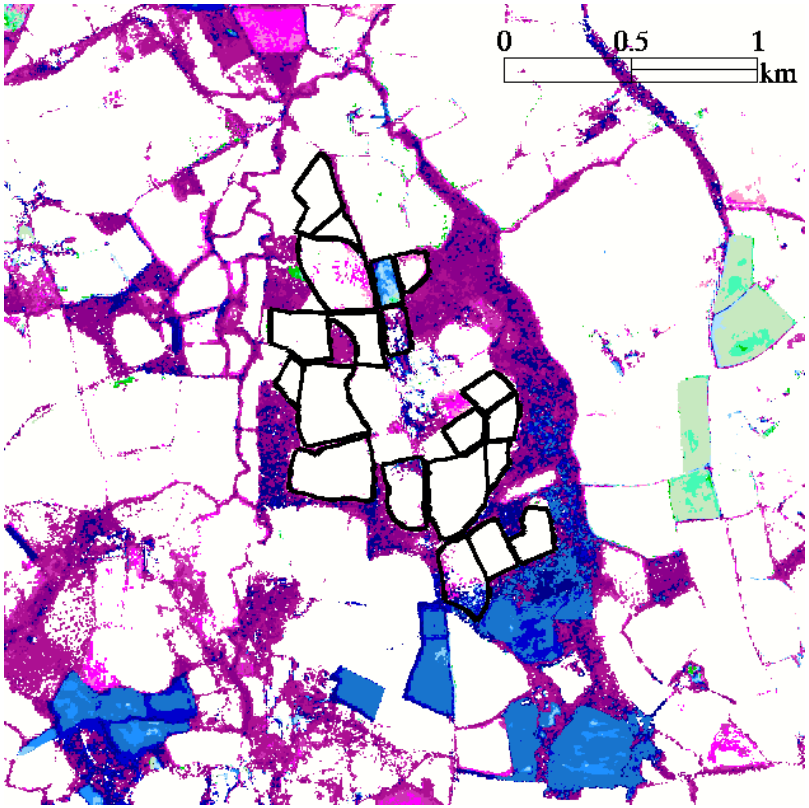


peak season

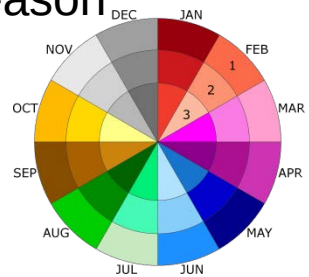


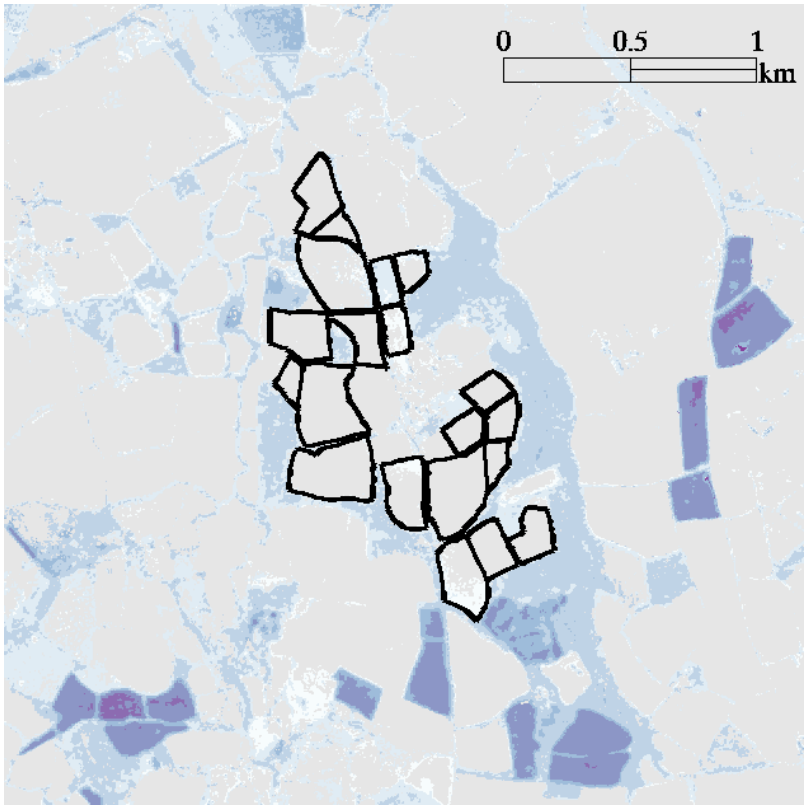

length green-up (days)
0 - 20
20 - 40
40 - 60
60 - 80
80 - 100
100 - 120
120 - 140
140 - 160
160 - 180
amplitude
0 - 0.10
0.10 - 0.20
0.20 - 0.30
0.30 - 0.40
0.40 - 0.50
0.50 - 0.60
0.60 - 0.70
> 0.70
maxNDVI
< 0.40
0.40 - 0.50
0.50 - 0.60
0.60 - 0.65
0.65 - 0.70
0.70 - 0.75
0.75 - 0.80
0.80 - 0.85
> 0.85

RESULTS: NORTH WYKE

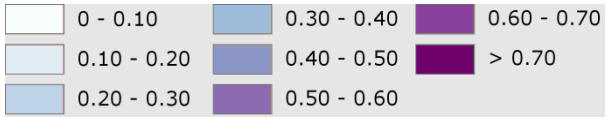


start of season





amplitude



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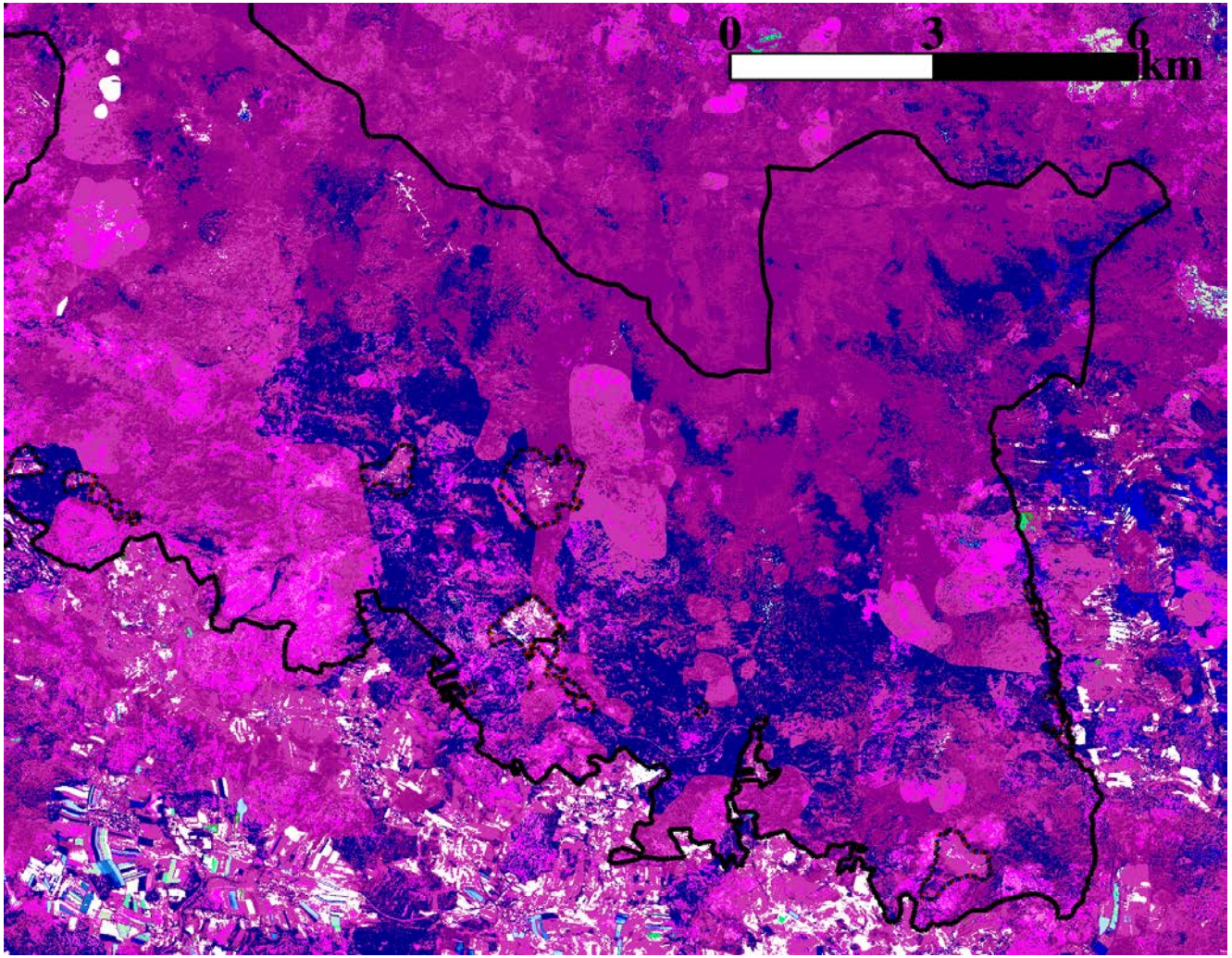
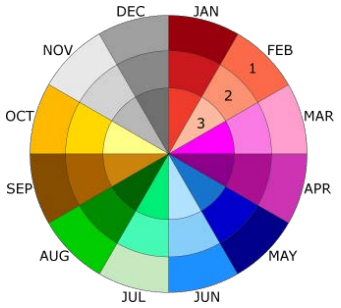
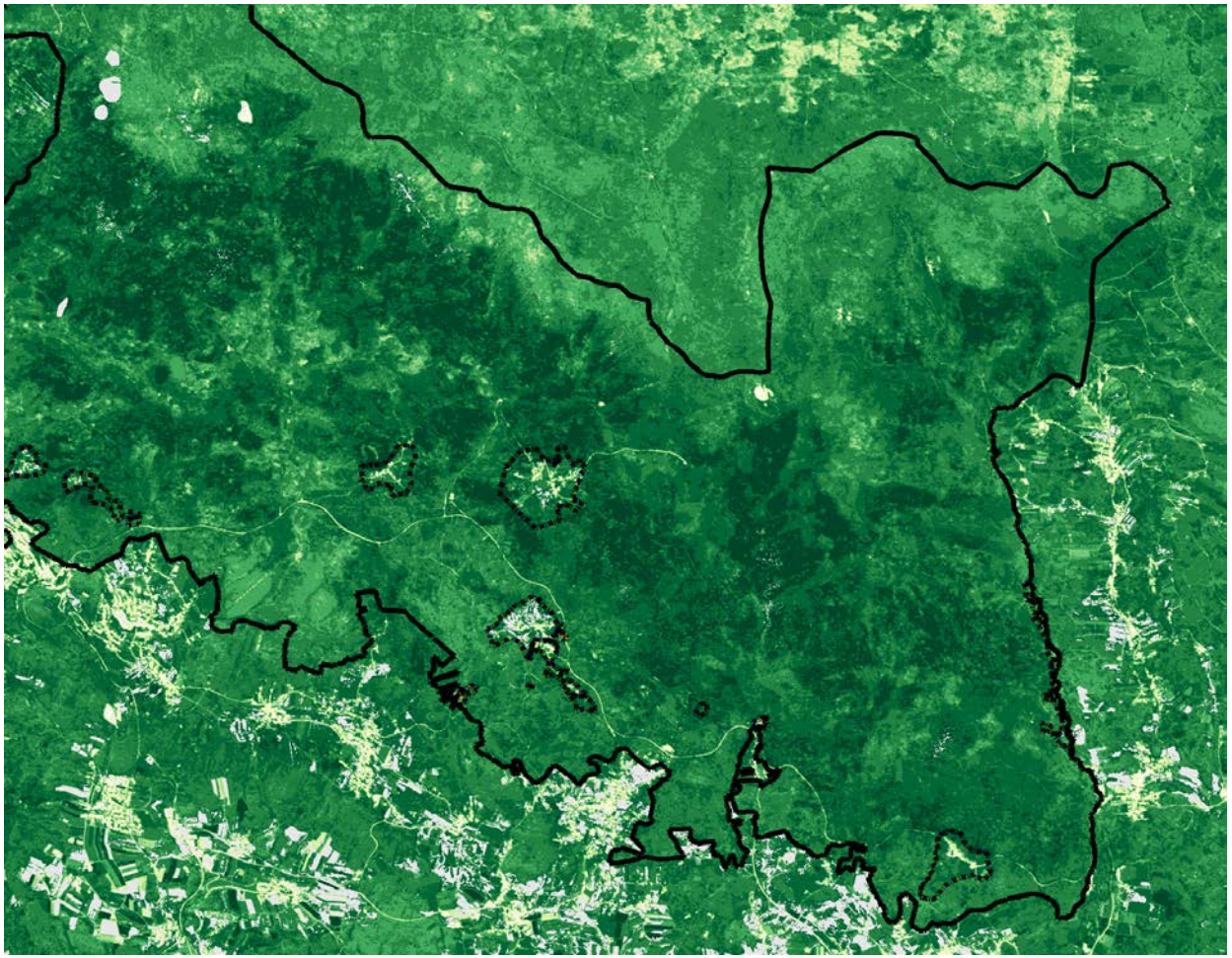
RESULTS BAVARIA (1): SOS

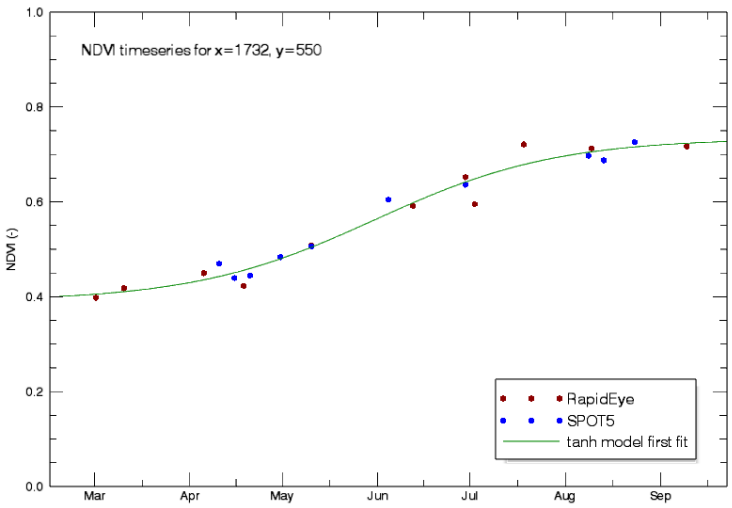


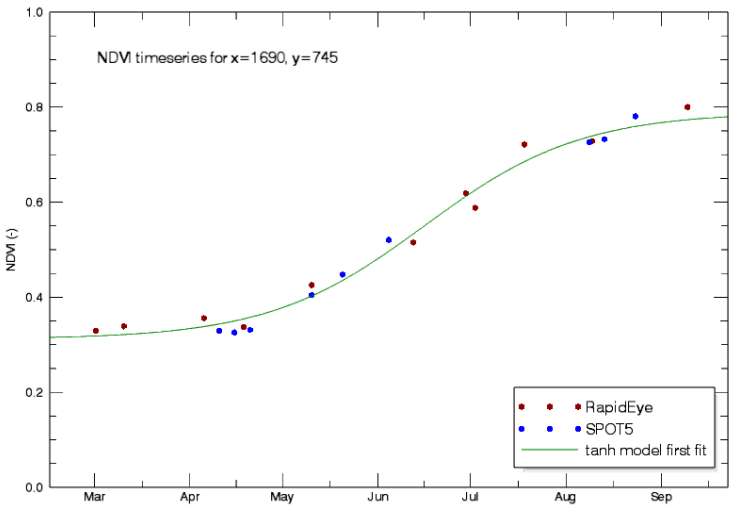


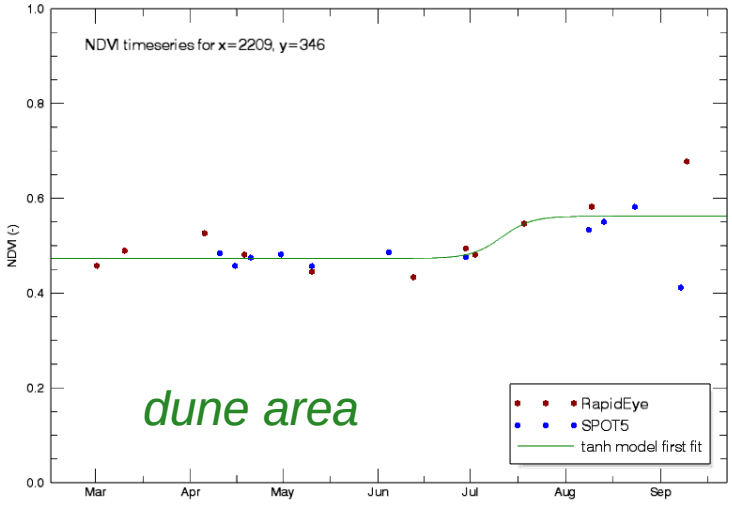
RESULTS BAVARIA (1): MAXNDVI

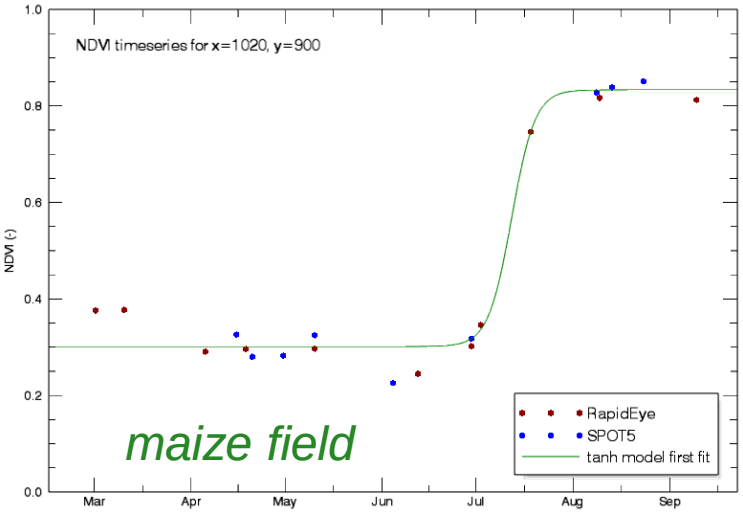


SAMPLE PROFILES: SCHIERMONNIKOOG

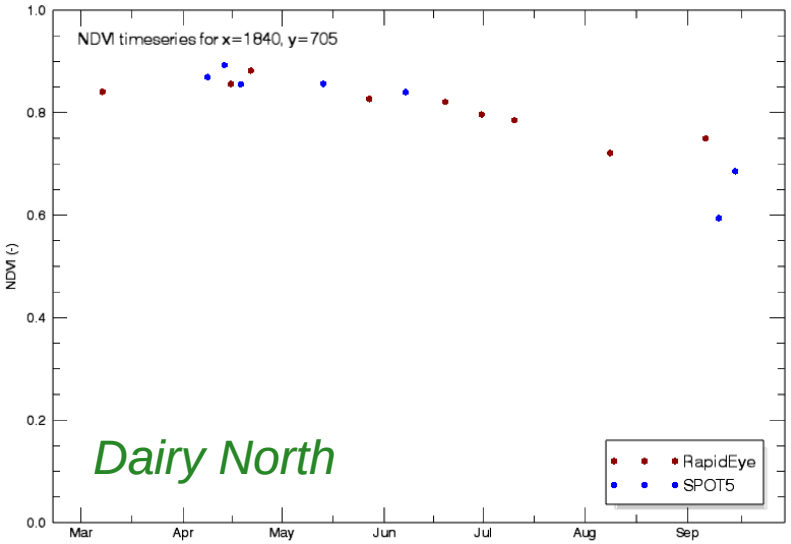


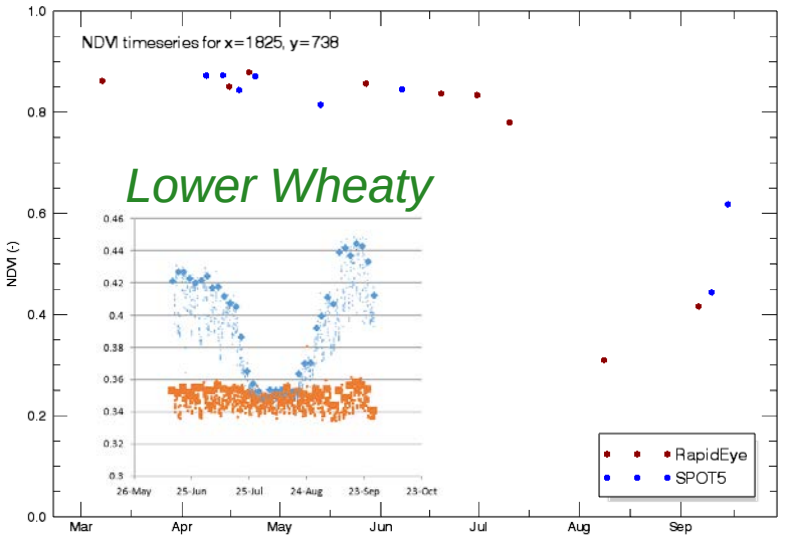


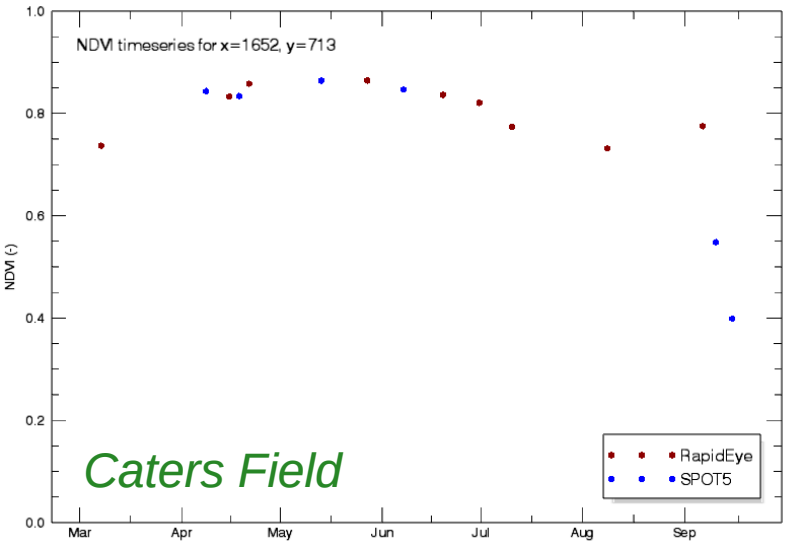


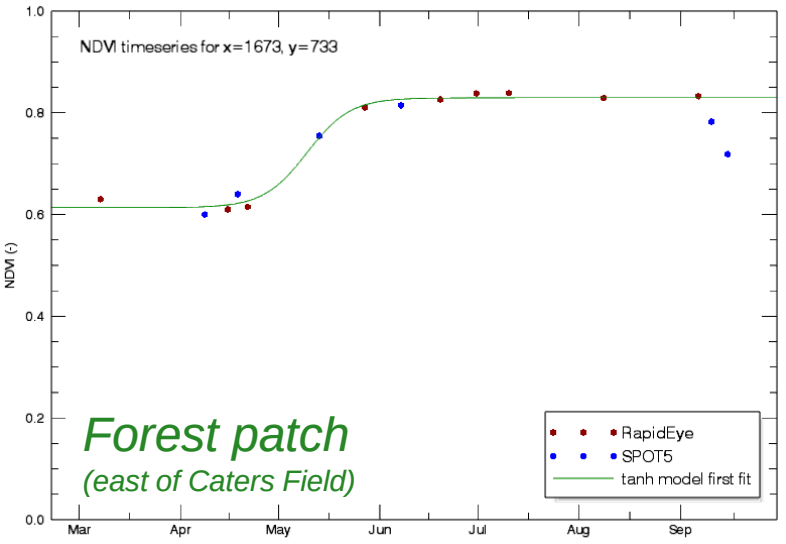


SAMPLE PROFILES: NORTH WYKE

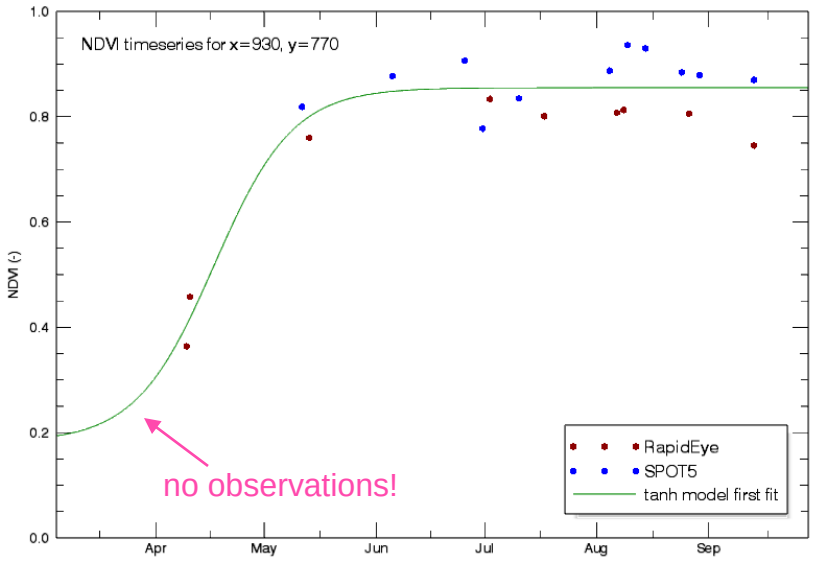


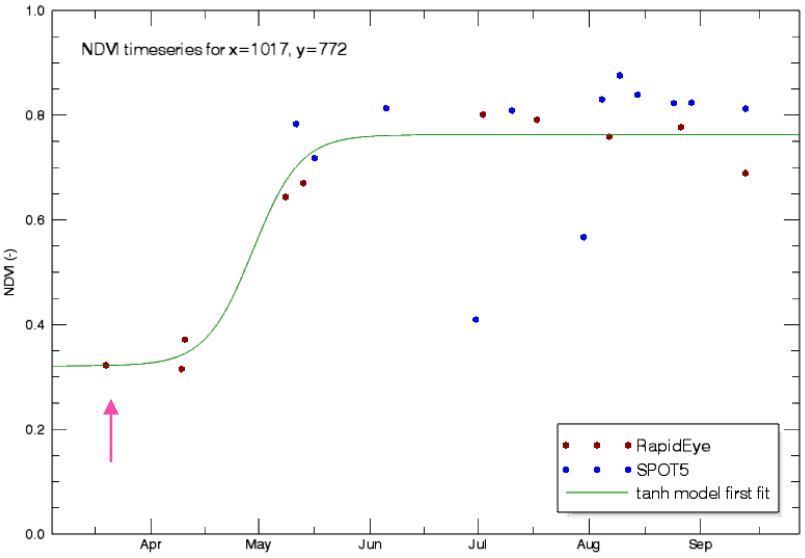


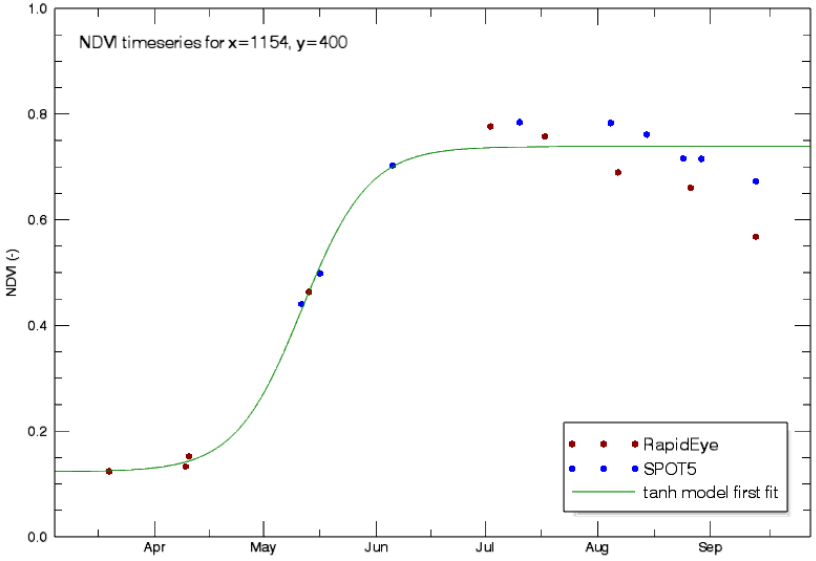


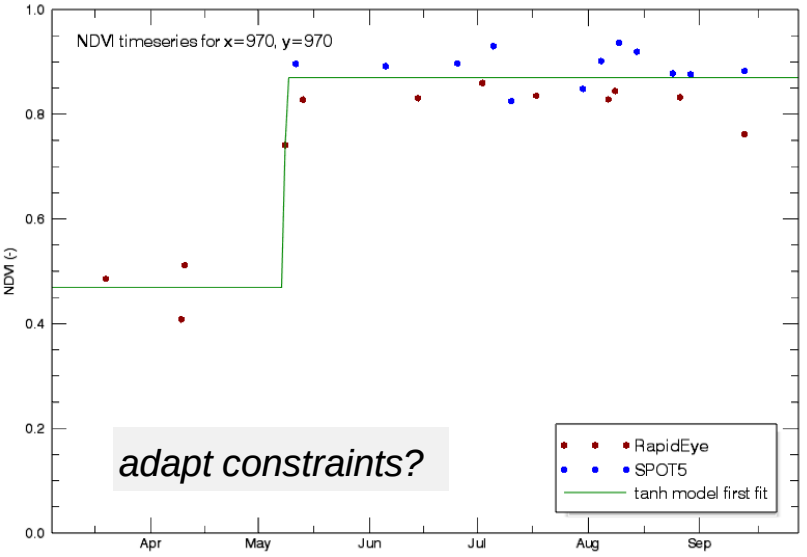


SAMPLE PROFILES: BAVARIA









CONCLUSIONS IMAGE PROCESSING

- High-res phenology: still experimental, but promising…
- Need for frequent observation
  - Capture several images before/during/after green-up onset
  - Multiple satellite sensors? OK, but adds uncertainty (intercalibration…)
- Main issues:
  - Bavaria: few images at start (for lower latitudes) & cloudy
  - North Wyke: little variability for grassland between March-September
- Cloud mask vs frequency
  - low frequency of observation + inaccurate cloud mask = high uncertainty
- Model fitting
  - Possibility to iterate (to implement and test further) → improvement?
  - Full year(s) of data preferable: joint accounting for senescence (even if earlier)

TOWARDS SENTINEL-2 FOR PHENOLOGY

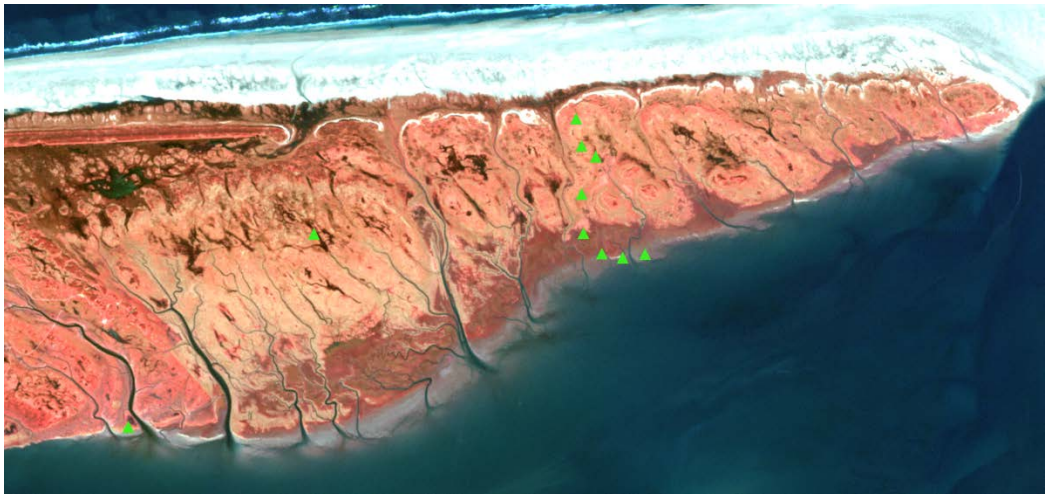
- Key issue for phenology:
  - Can we get sufficient cloud-free data points across relevant parts of the vegetation year? (e.g., rapid green-up in Bavaria)
  - Is cloud-masking in sen2cor effective? (NDVI certainty…)
  - Multi-year data will help, also to better understand “average” season behaviour (for natural systems; and remark valid towards future!)

- Data access/processing issues:
  - Possibility downloading per 100x100km tile?
    - high download/storage demand for temporal analyses
  - Sen2Cor: further testing needed

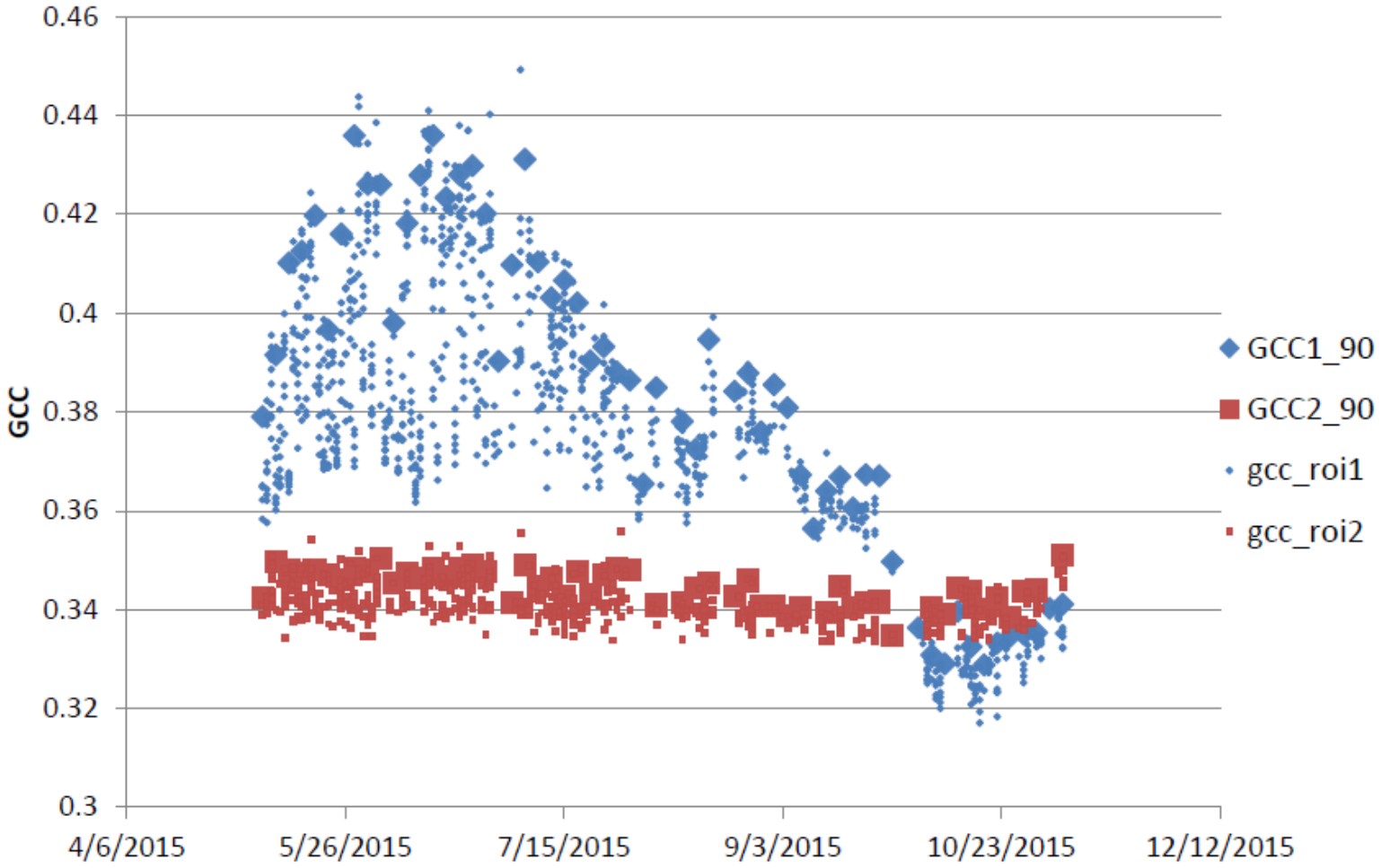
PHENOLOGICAL CAMERAS

- Cameras installed in May 2015 (a bit late to fully capture green-up):
  - Bavaria: 14 North Wyke: 5 Schiermonnikoog: 10
- to continue operations during 2016 (at least)
- 10 photos daily
- Overexposure issues: replacement cameras but unlikely to fully resolve → *solution = manual photo selection*
- Several useful time series were obtained
  - To be compared with NDVI series
  - However, green-up not fully captured due to late installation
- GCC = G / (R+G+B)
  - Filtering: take 90th percentile per 3 days

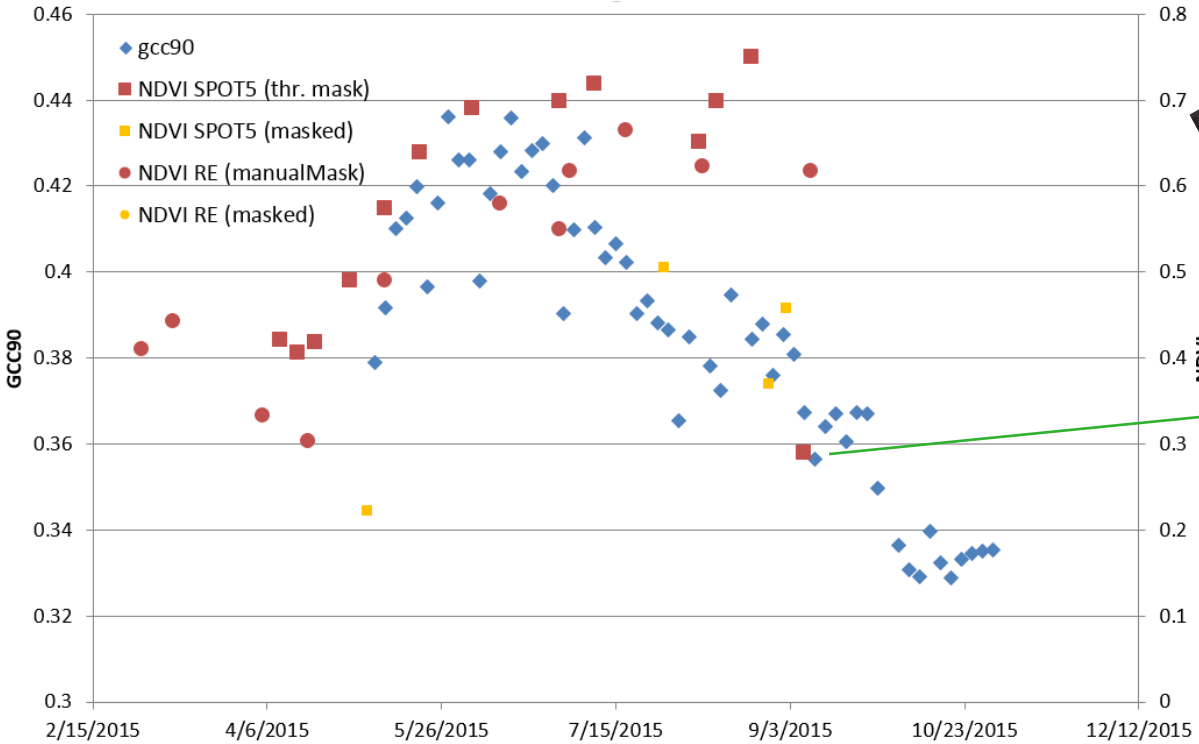
EXAMPLE: SCHIERMONNIKOOG

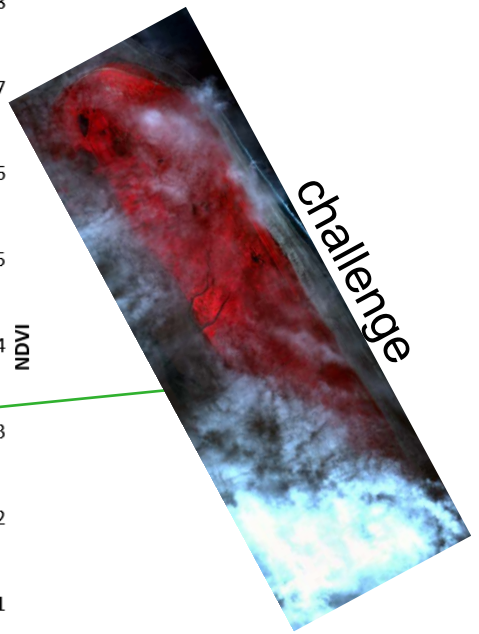


GCC EXAMPLE


0.46
0.44
0.42
0.4
0.38
0.36
0.34
0.32
0.3
GCC
4/6/2015
5/26/2015
7/15/2015
9/3/2015
10/23/2015
12/12/2015
GCC1_90
GCC2_90
gcc_roi1
gcc_roi2

FUTURE WORK: COMBINE CAMERA AND NDVI SERIES





- Validation of green-up
- Greenness nadir ≠ camera view…

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