IACS Workshop 2019, Valladolid-Spain, 10-11 April

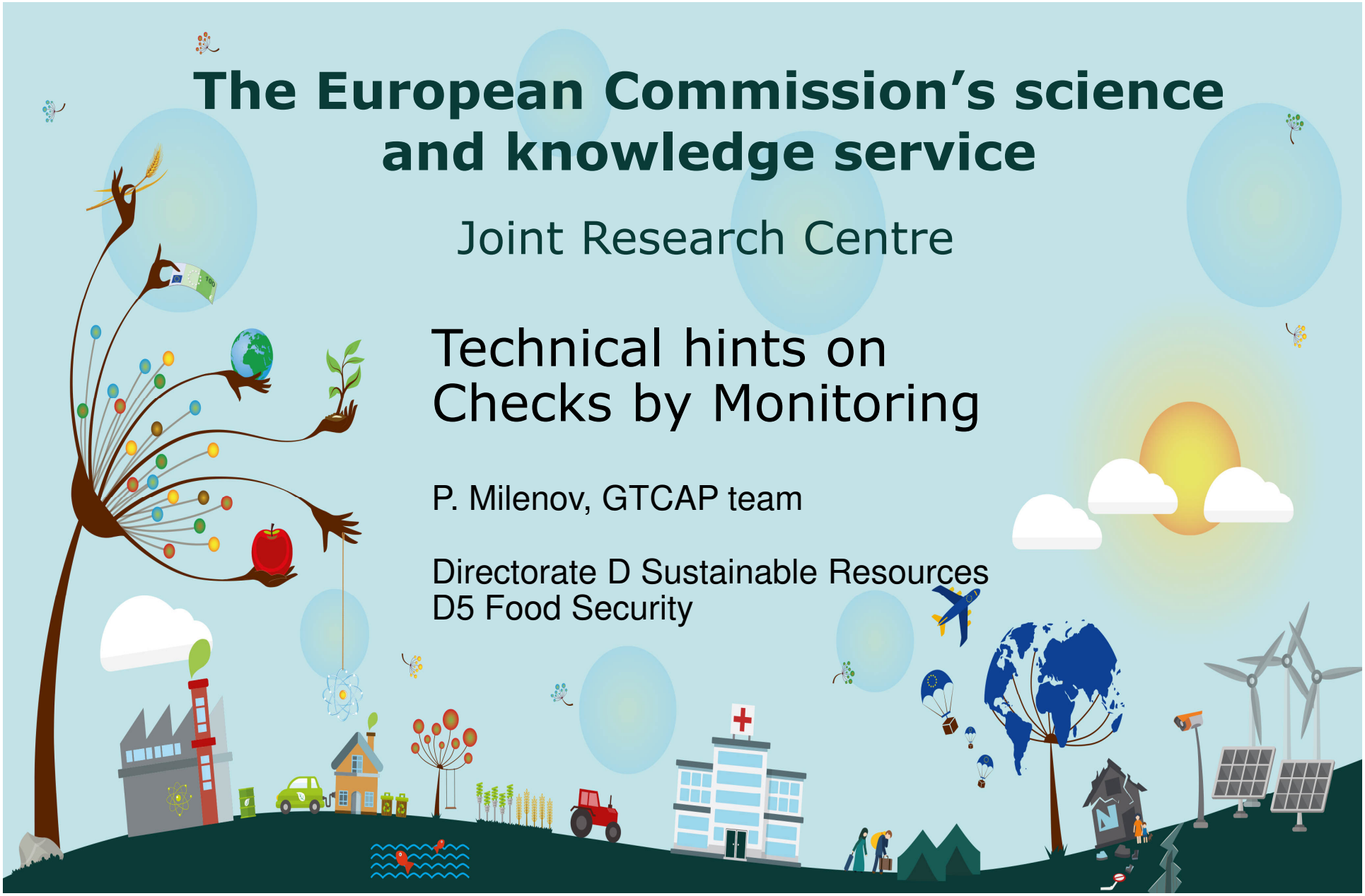
The European Commission's science and knowledge service

Joint Research Centre

Technical hints on Checks by Monitoring

P. Milenov, GTCAP team

Directorate D Sustainable Resources
D5 Food Security



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What kind of hints?

- Automated marker detection though phenology
- Monitoring of small parcels – extended study
- Others
  - FOI tracking through spatial markers
  - Testing measurements using a smartphone with a dual-frequency GNSS receiver

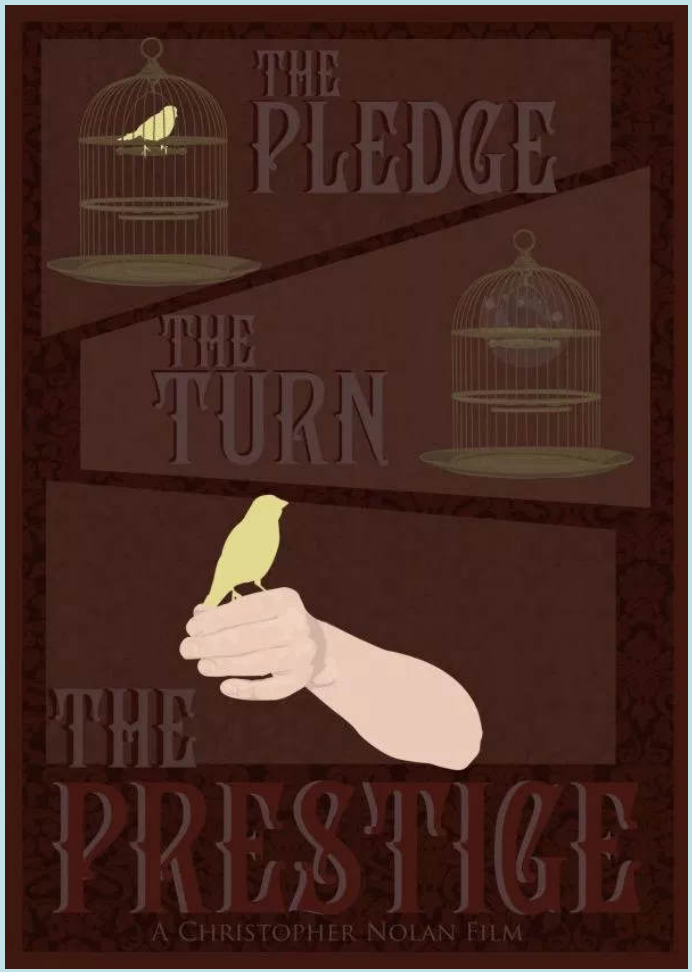
Automated marker detection

The Prestige (movie): labutacadearni.wordpress.com

3 stages of the magic trick

- The Pledge
- The Turn
- The Prestige

The Prestige (movie): Nikola Tesla's machine, Funnyjunk



Poster design:
Adam Rabalais

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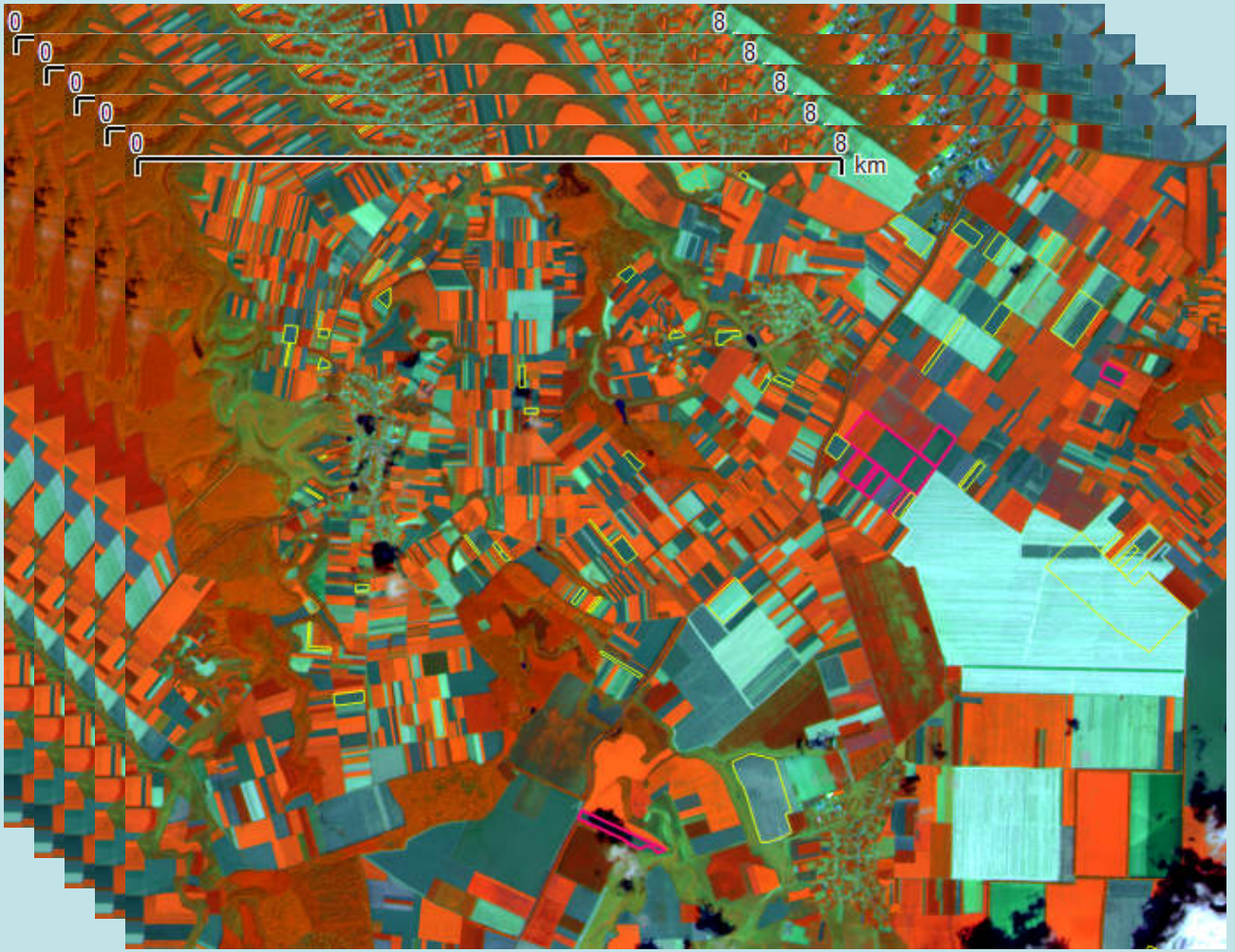
The Pledge



Winter wheat

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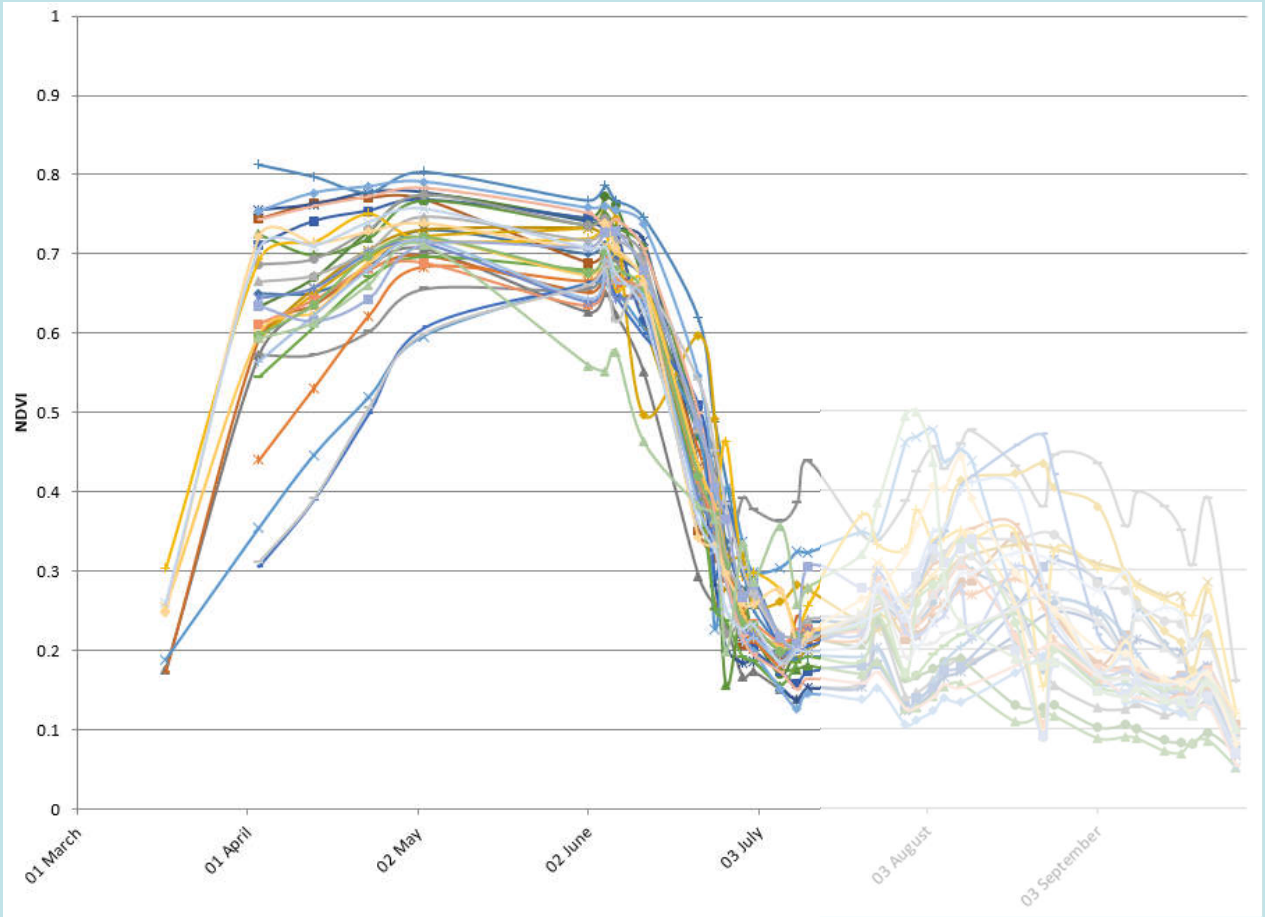
The Turn



Winter wheat

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The Prestige

Observable Event	Signal	Threshold (sd/dt)	Days of the year
Bare soil	NDVI	< 0.2	213 (Y-1) - 90 (Y)
Crop presence	NDVI	> 0.5	135-170
vegetation removal	NDVI	> 0.5 - < 0.2	171 - 212

Winter Wheat/
Ploughing
Seeding
Harvesting

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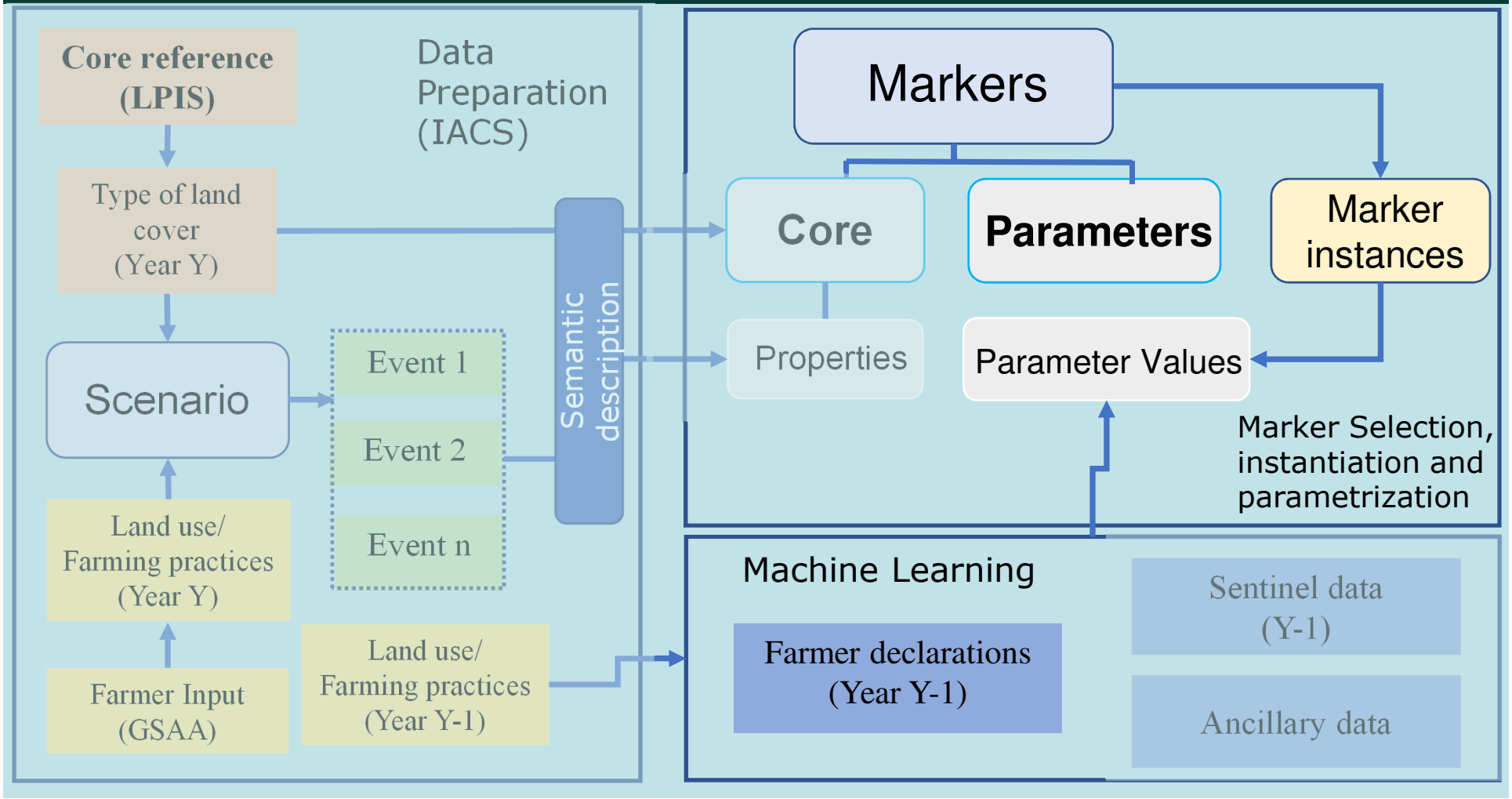
Magic explained: Marker Parametrization Workflow



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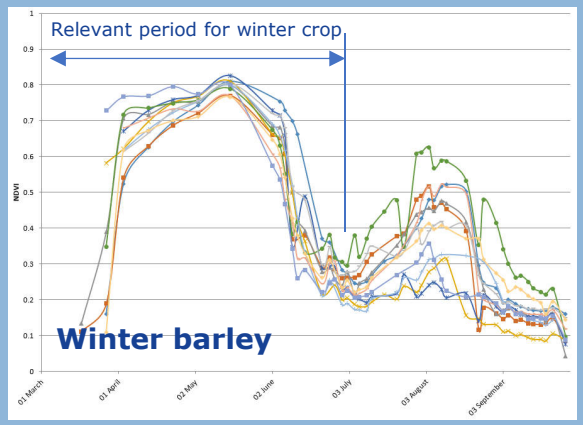
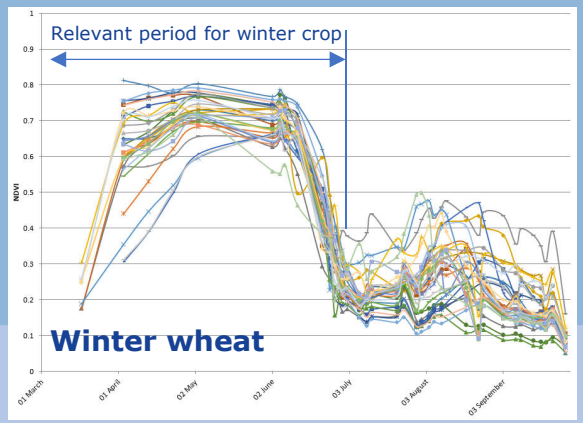
The two parts of the "Tesla machine"

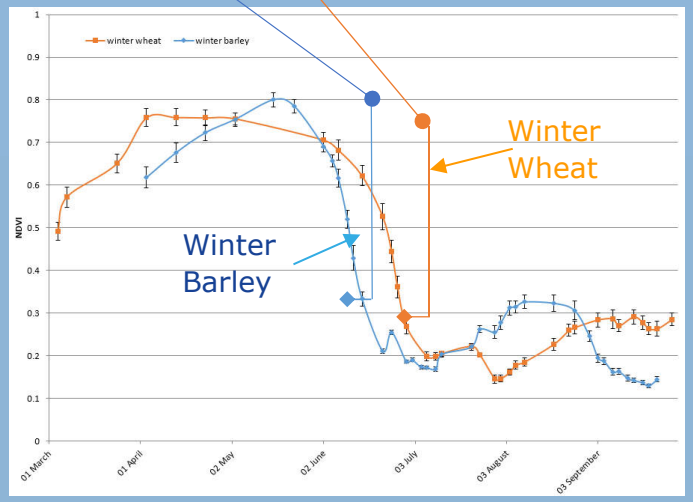
Machine learning (TensorFlow) to find the right crops + Data reduction (JEODPP) to extract NDVI time series





Curve fitting to derive the key phenological indicators (candidate markers)

End of Season (EOS) → distinction marker



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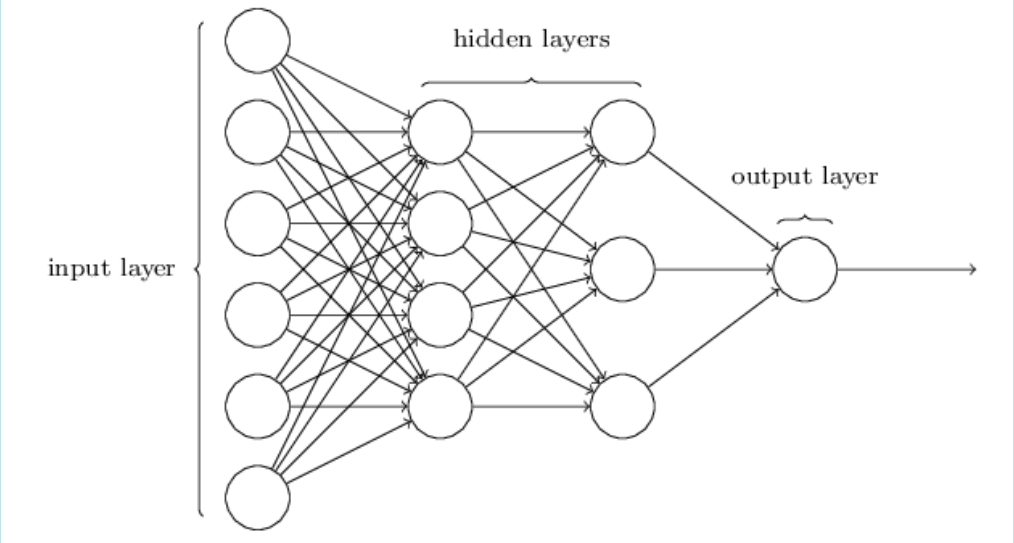
Basics of Machine Learning

Consistent training set

Neural network design



Minimization of the cost function

$$C(w,b) \equiv \frac{1}{2n} \sum_x \|y(x) - a\|^2.$$

Michael A. Nielsen, "Neural Networks and Deep Learning", Determination Press, 2015

Concept of Curve Fitting

- Parametric Double Hyperbolic Tangent (PDHT) model to simulate a single growing season

$$f_{\mathrm{PDHT}}(t) = a_0 + a_1\{\tanh[(t - a_2)a_3] + 1\}/2 + a_4\{\tanh[(t - a_5)a_6] + 1\}/2 - a_4$$

- Phenology indicators of growing season characteristics

SOS	(Start of season) Timing of the start of the growth phase	The growth phase is deemed to start whenever the value of the modelled time series exceeds the initial base value a_0 (asymptotic model value before the growth phase) plus 20% of the amplitude a_1.
EOS	(End of season) Timing of the end of the decay phase	The decay phase is deemed to end whenever the value of the modelled time series drops below the final base value (asymptotic model value after the decay phase) plus 20% of the amplitude a_4.
LGS	Length of the growing season	The length of the period between the SOS and EOS.

After M. Merroni et.al., 2014. "A phenology-based method to derive biomass production anomalies for food security monitoring in the Horn of Africa". International Journal of Remote Sensing, DOI: 10.1080/01431161.2014.883090

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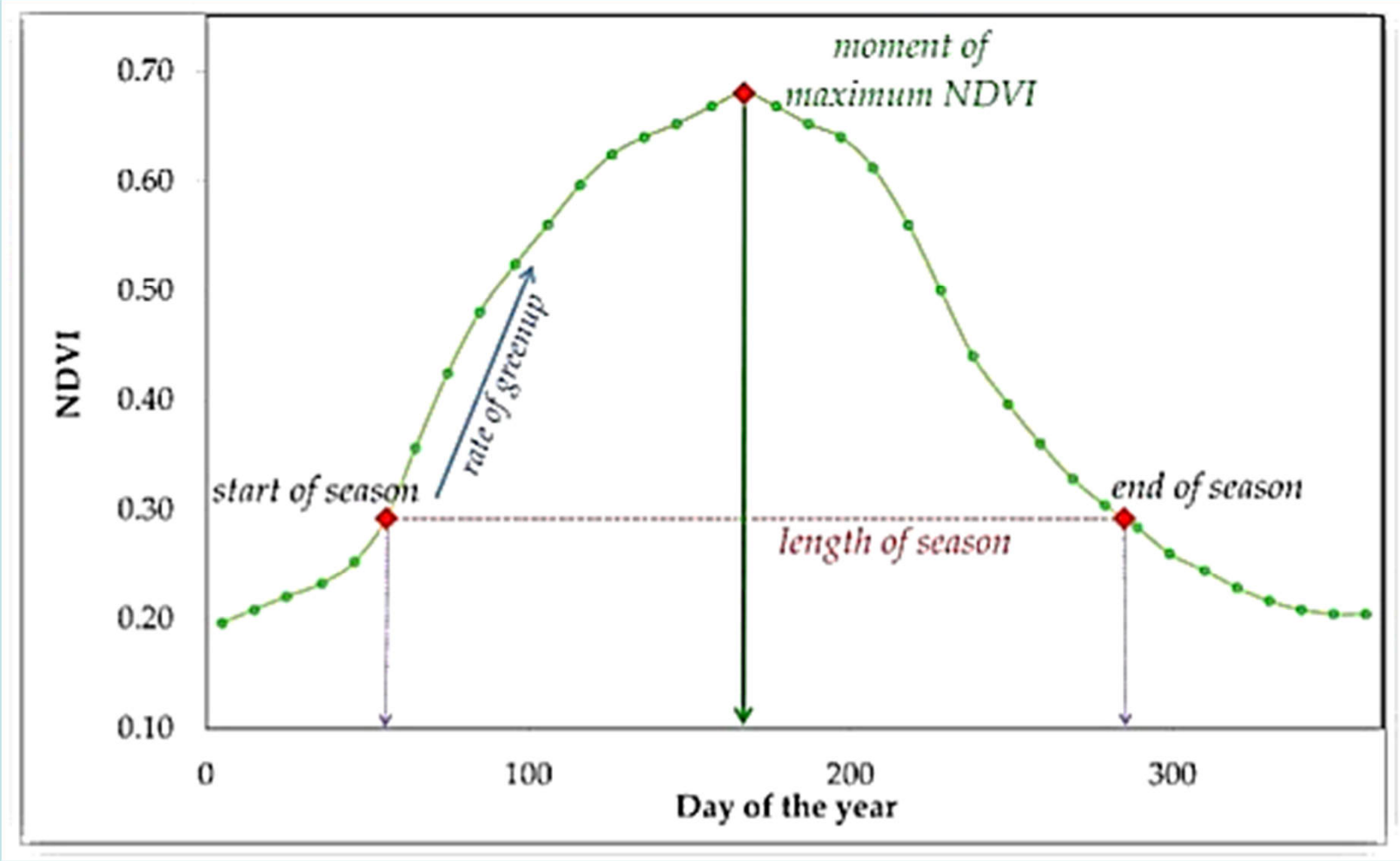
Phenological analysis



After A. Vrieling et.al., 2015. EARLY ASSESSMENT OF FORAGE AVAILABILITY FOR AN ASSET PROTECTION INSURANCE SCHEME, ADRAS workshop – Nairobi, Kenya

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Parametrization using phenological modelling

Objective of the test

Understand if winter crops, having similar NDVI profiles, could be separated using phenological data

Evaluate if automatically retrieved phenological indicators (SOS, LGS, EOS) can be used as markers in CbM

Method

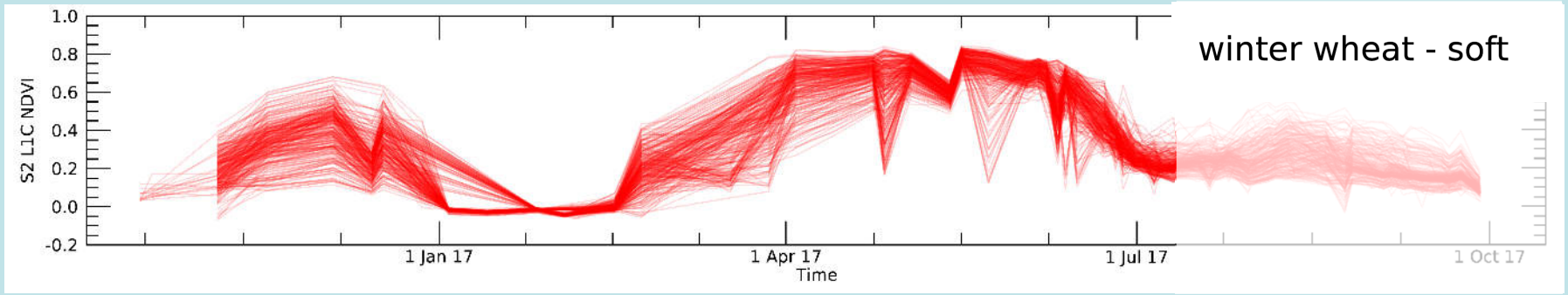
Run the pheno-algorithm (PDHT curve fitting) on 2017 Sentinel-2 L1C data and declaration data with confirmed crops

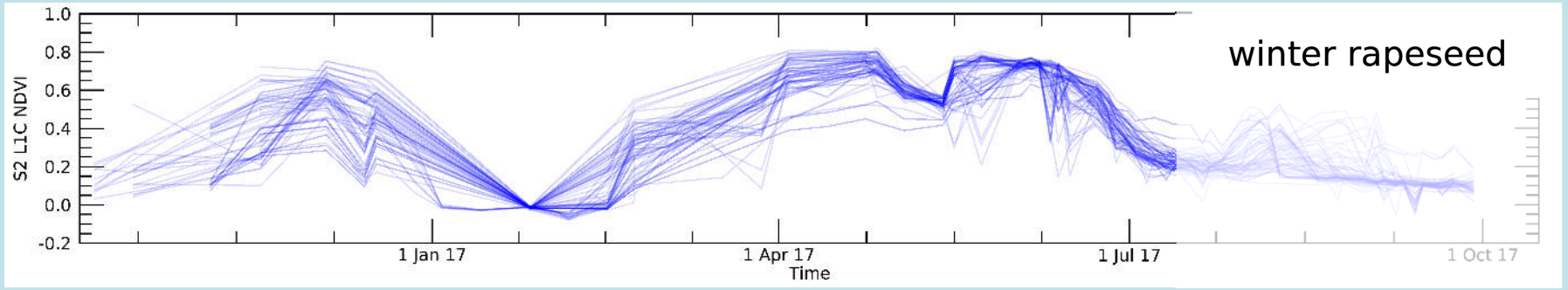
Input data and issues

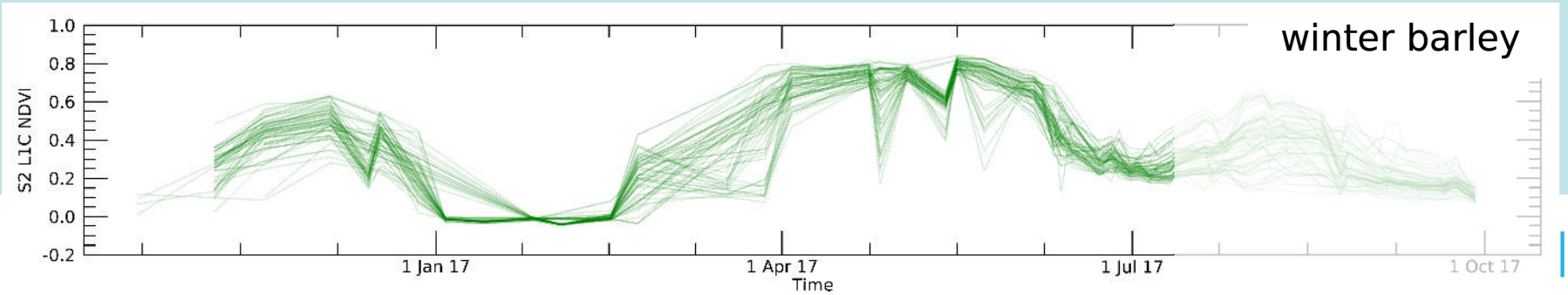
- Unbalanced data sample (279 wheat, 64 barley, 69 rapeseed)
- Possible poor cloud screening and no atmospheric correction
- Very few S2 observations during green-up phase (snow in Jan-Feb)

The Plegde: NDVI time series as input data

average NDVI values of Sentinel 2 level 1C, per parcel, 10.2016-11.2017

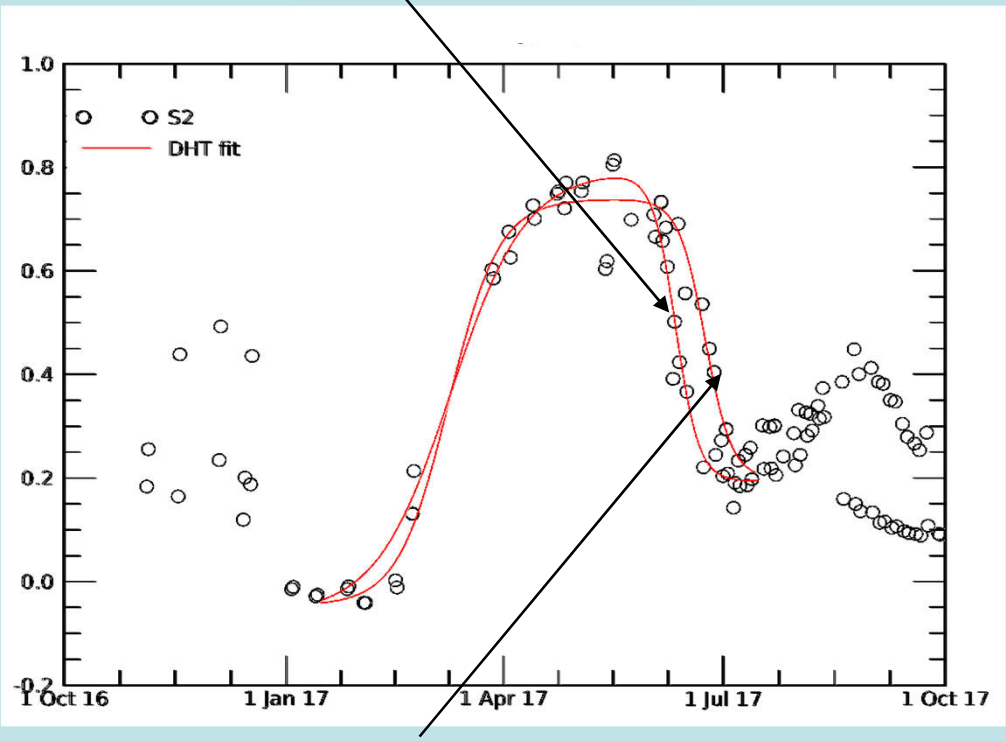






The Turn: Winter crop fitted curves

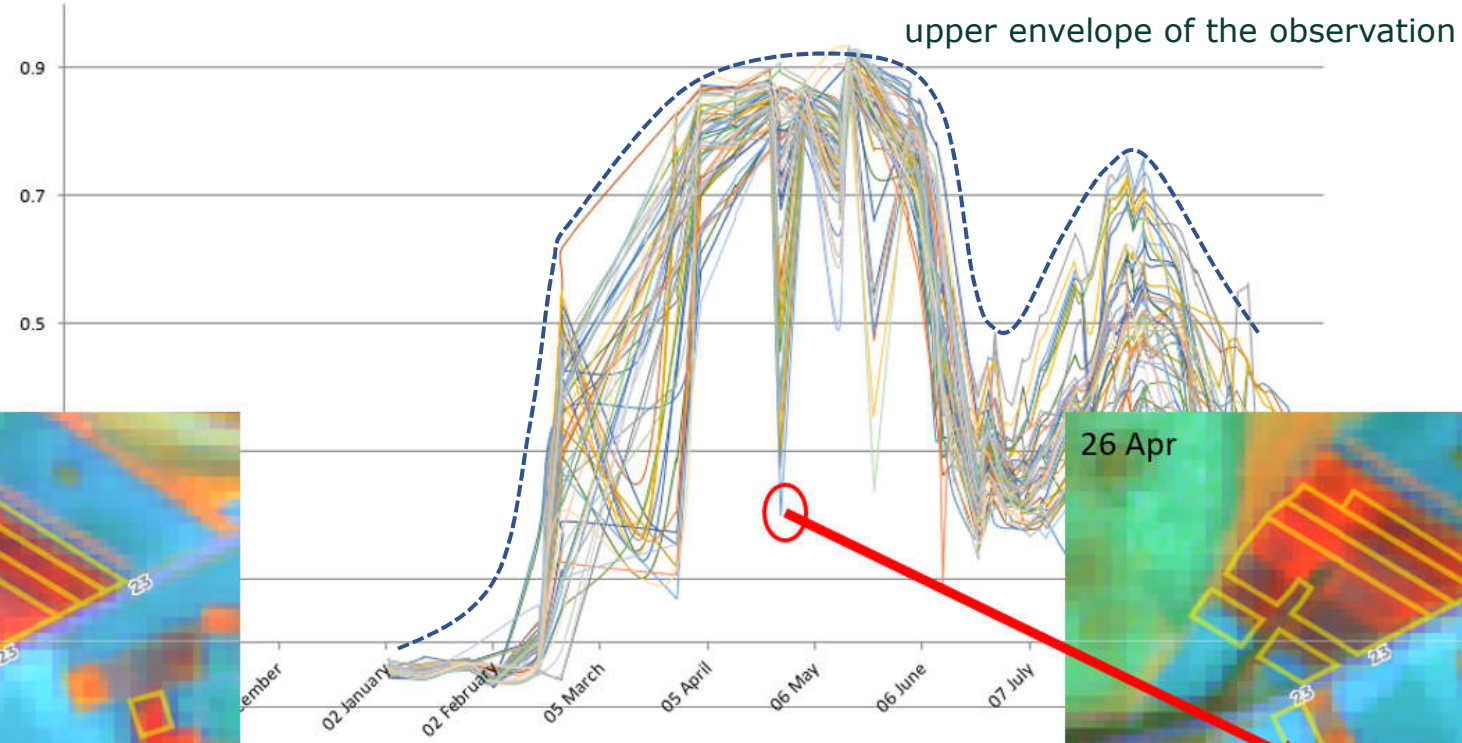
Winter barley

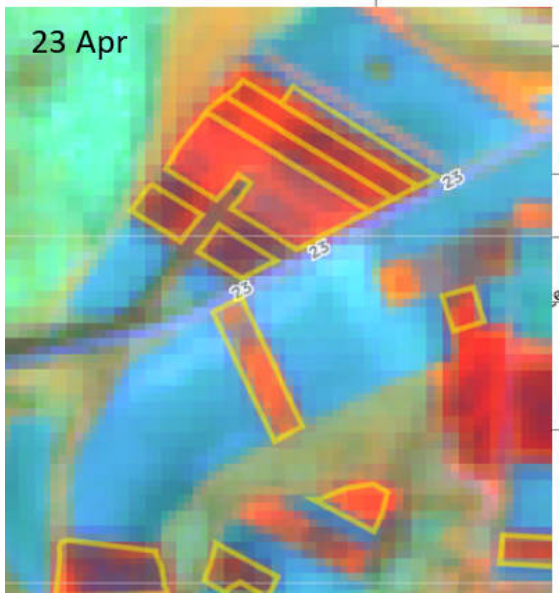


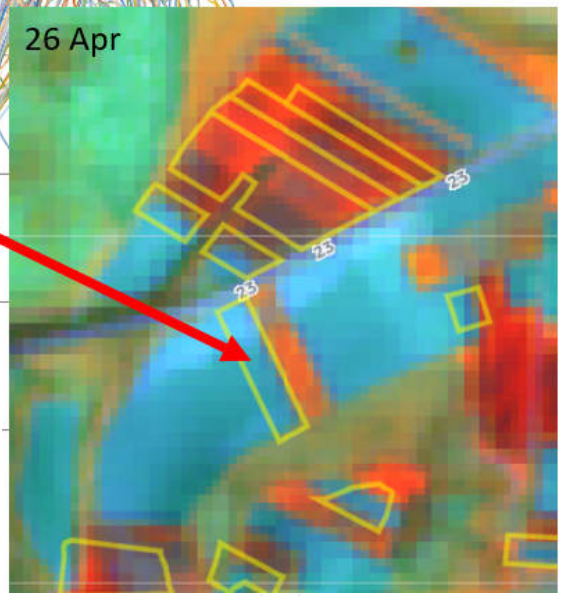
Winter wheat

The Turn: NDVI Drop due to S2 geometric shift

Winter barley







No adverse effect on pheno-algorithm, as it fits to the upper envelope of the observation

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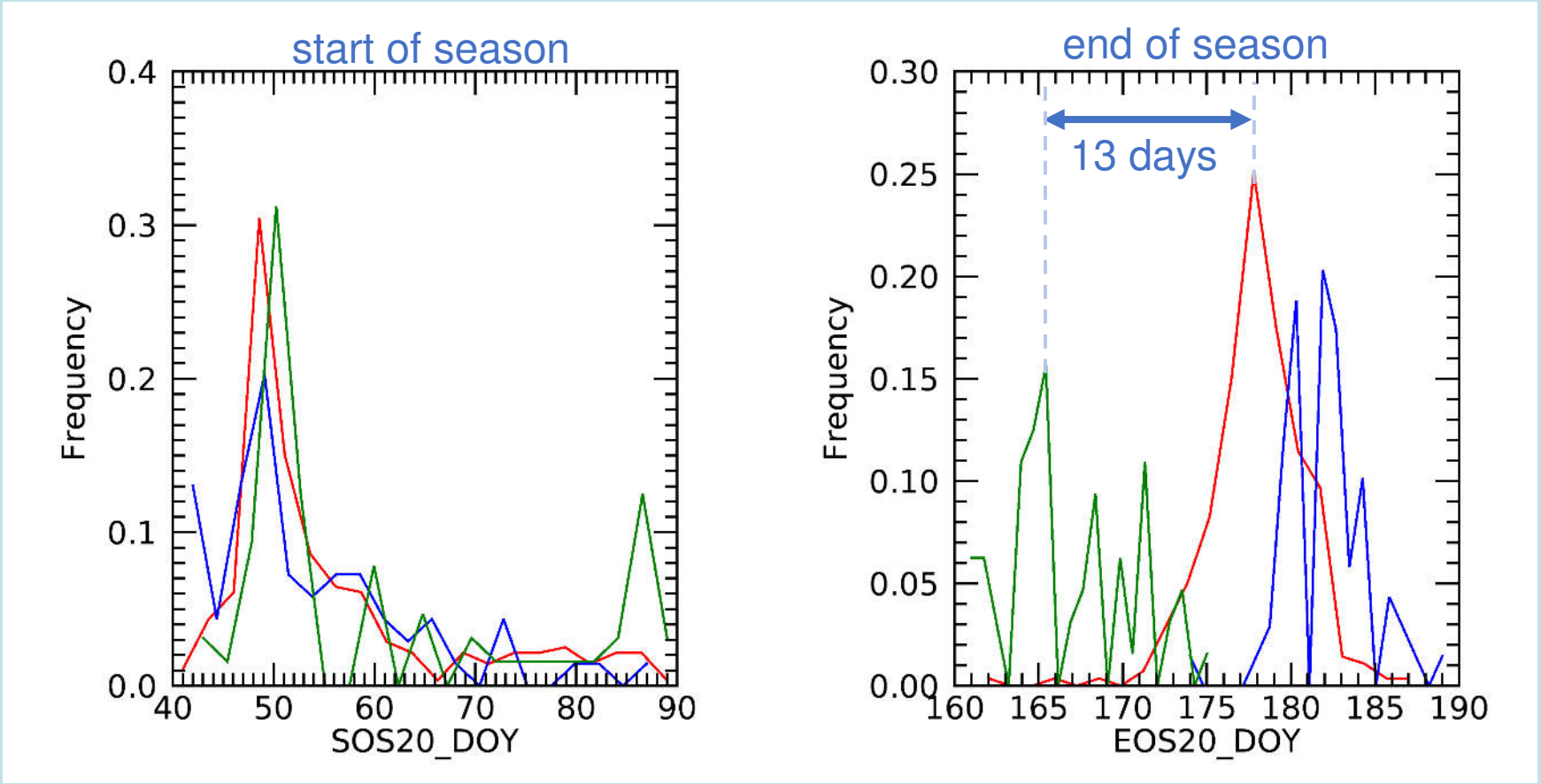
The Prestige: Preliminary results 1/2

winter wheat - soft winter rapeseed winter barley



End of season (EOS20) somehow different in 2017
Start of season (SOS20) uninformative

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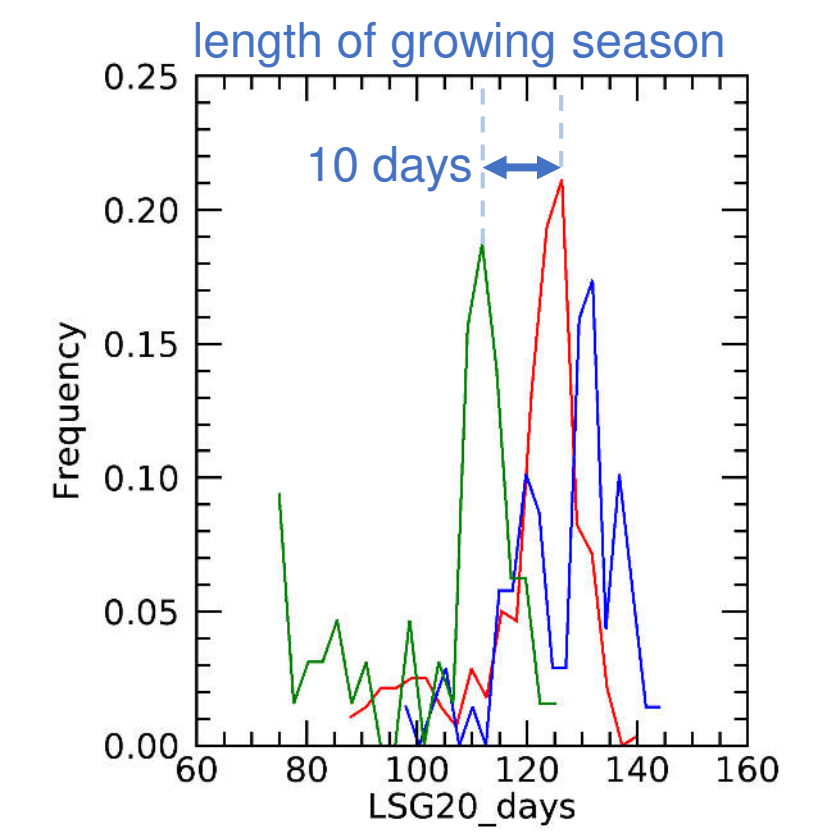
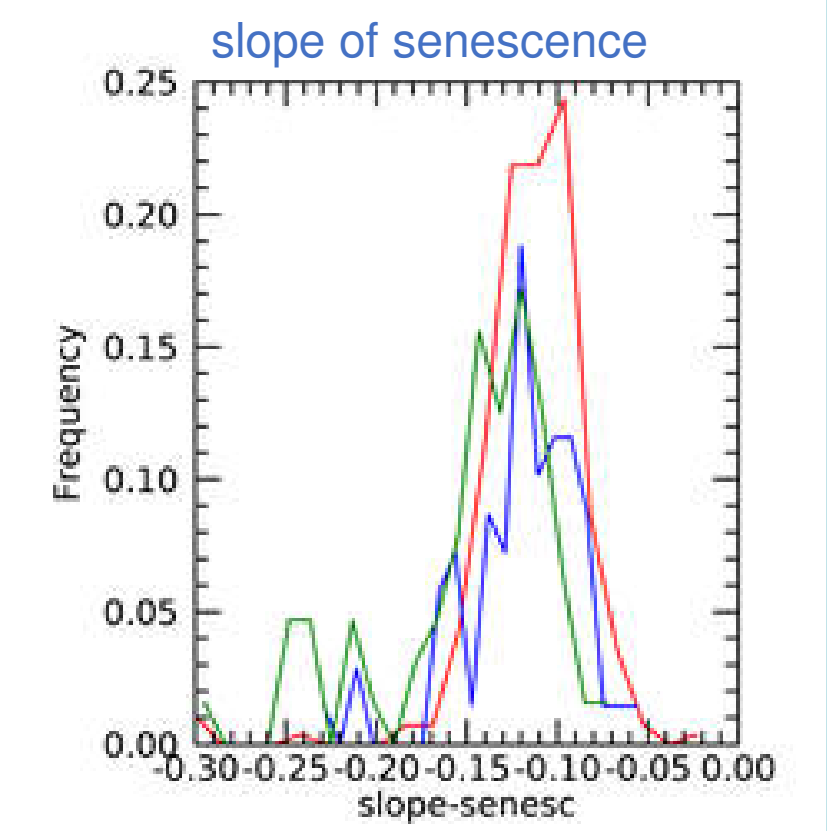
The Prestige: Preliminary results 2/2

Ready for the markers?

Well, not yet, but close…

winter wheat - soft winter rapeseed winter barley





Length of season (LSG20) different, but affected by poor SOS20
Senescence slope doesn't tell anything

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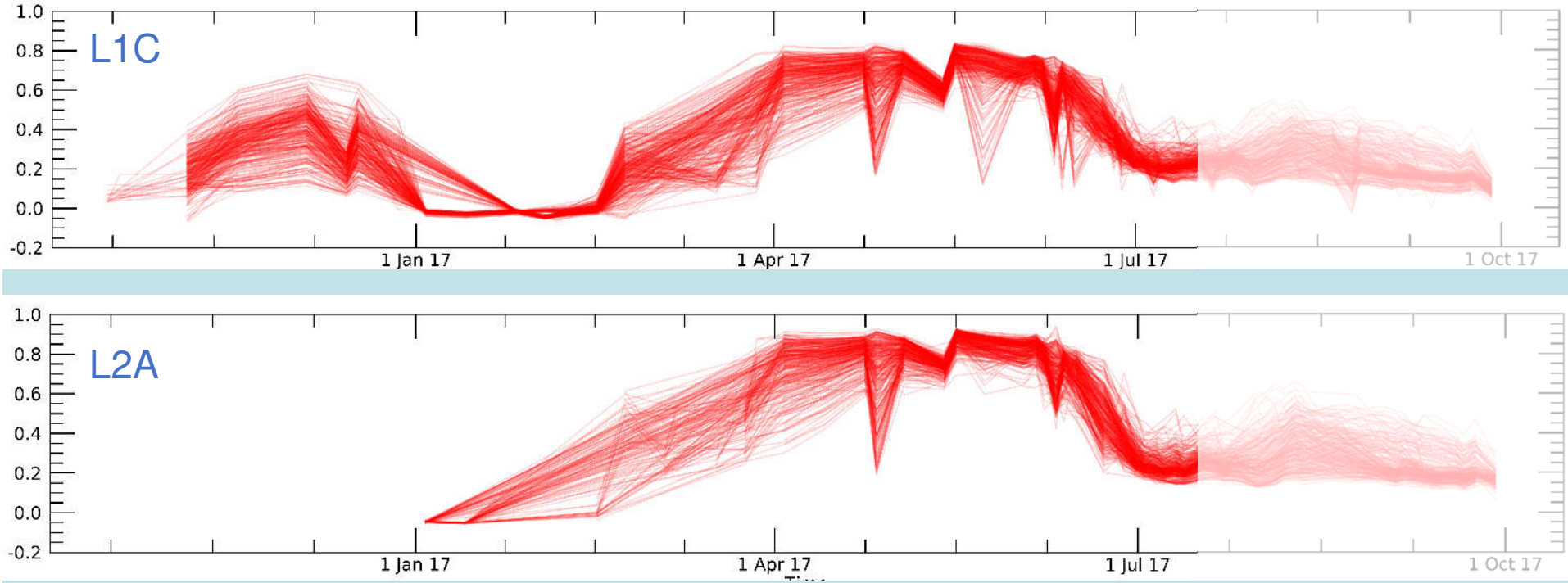
Dealing with atmosphere effects

winter wheat - soft

NDVI for Sentinel 2 L1C and L2A data



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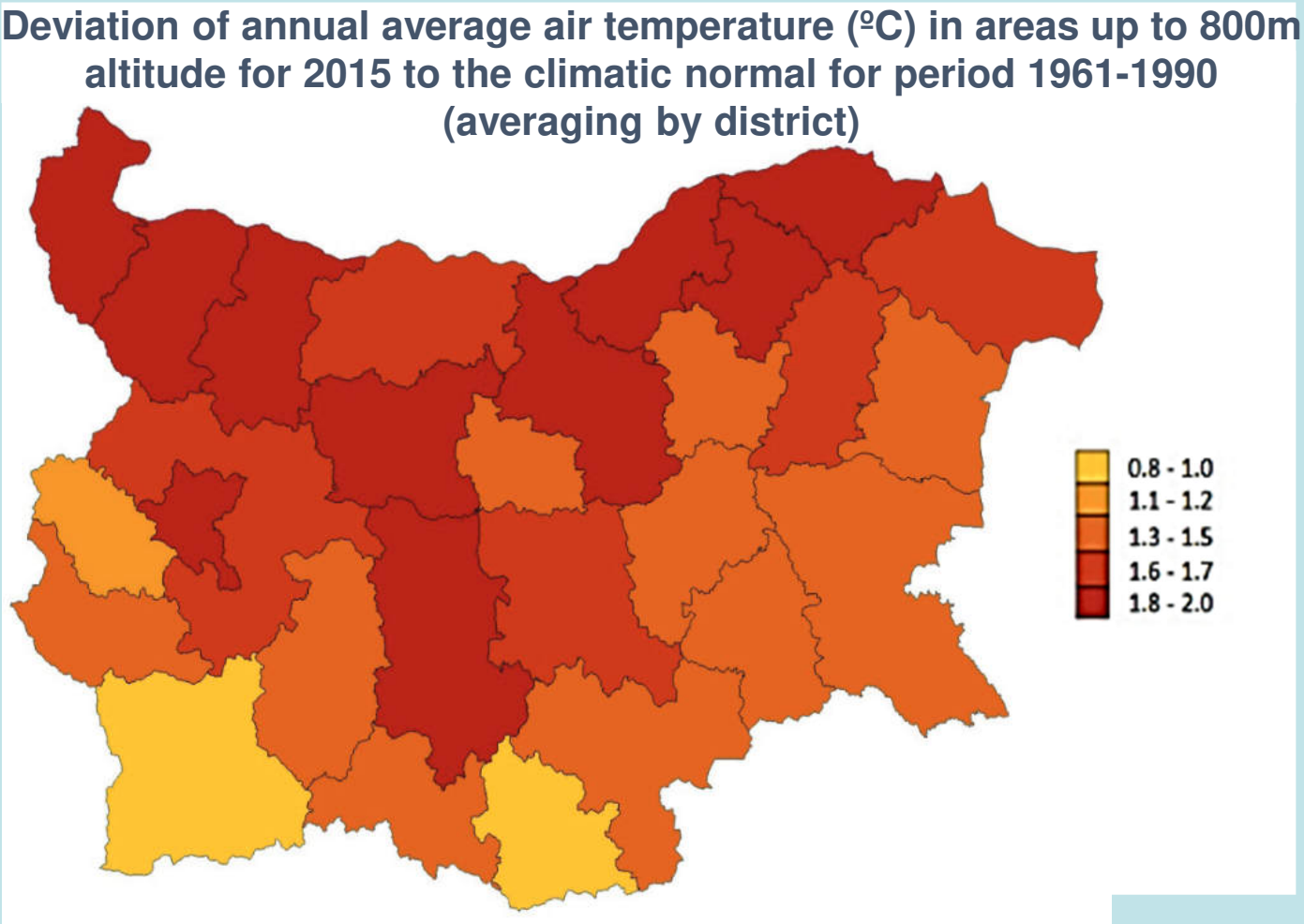
Dealing with weather variations



Source: T Marinova, K Malcheva, L Bocheva, L Trifonova, 2017: Climate profile of Bulgaria in the period 1988-2016 and brief climatic assessment of 2017. Bulgarian Journal of Meteorology & Hydrology: 22/3-4 (2017), 2-15.

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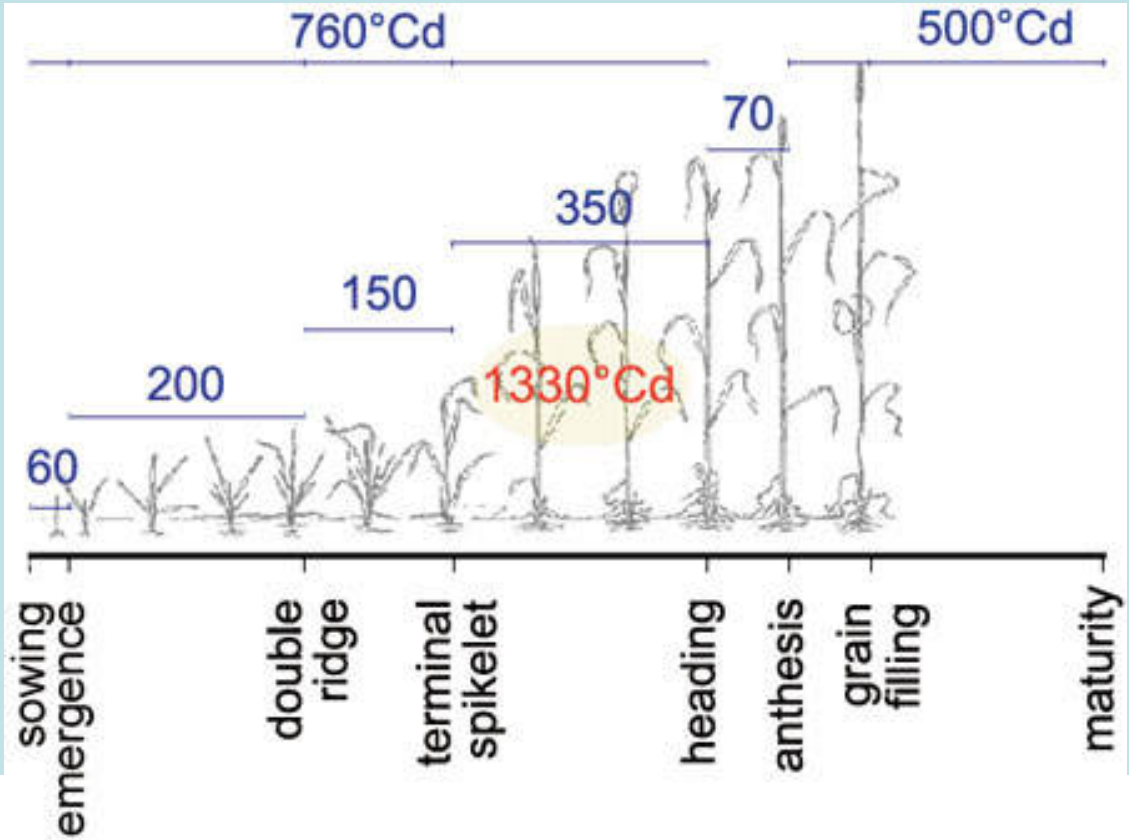
Thermal time

Thermal time - minimum accumulation of temperature required for a phenological phase to be completed [degree days (°Cd)]



Development of short duration wheat

Source: http://www.fao.org/3/X8234E/x8234e09.htm

First conclusions

- Phenological indicators are good promising candidates for markers
  - Marker parameters can be derived automatically
  - Values are normalized (relative to parameters of the model)
- End of season provides better crop discrimination than the start of season
  - However, EOS info comes only late (around 15 July)
- Sentinel Level 2A data preferred over L1C
  - Less noise, more truthful NDVI, better SOS estimation
- Thermal time could be better parameter than calendar time
  - Allows "calibration" of the marker parameters to the region/year-specific (weather) characteristics
  - 2017 EOS –> 2018 EOS (if expressed in °Cd ?)

End of the show? Not quite!

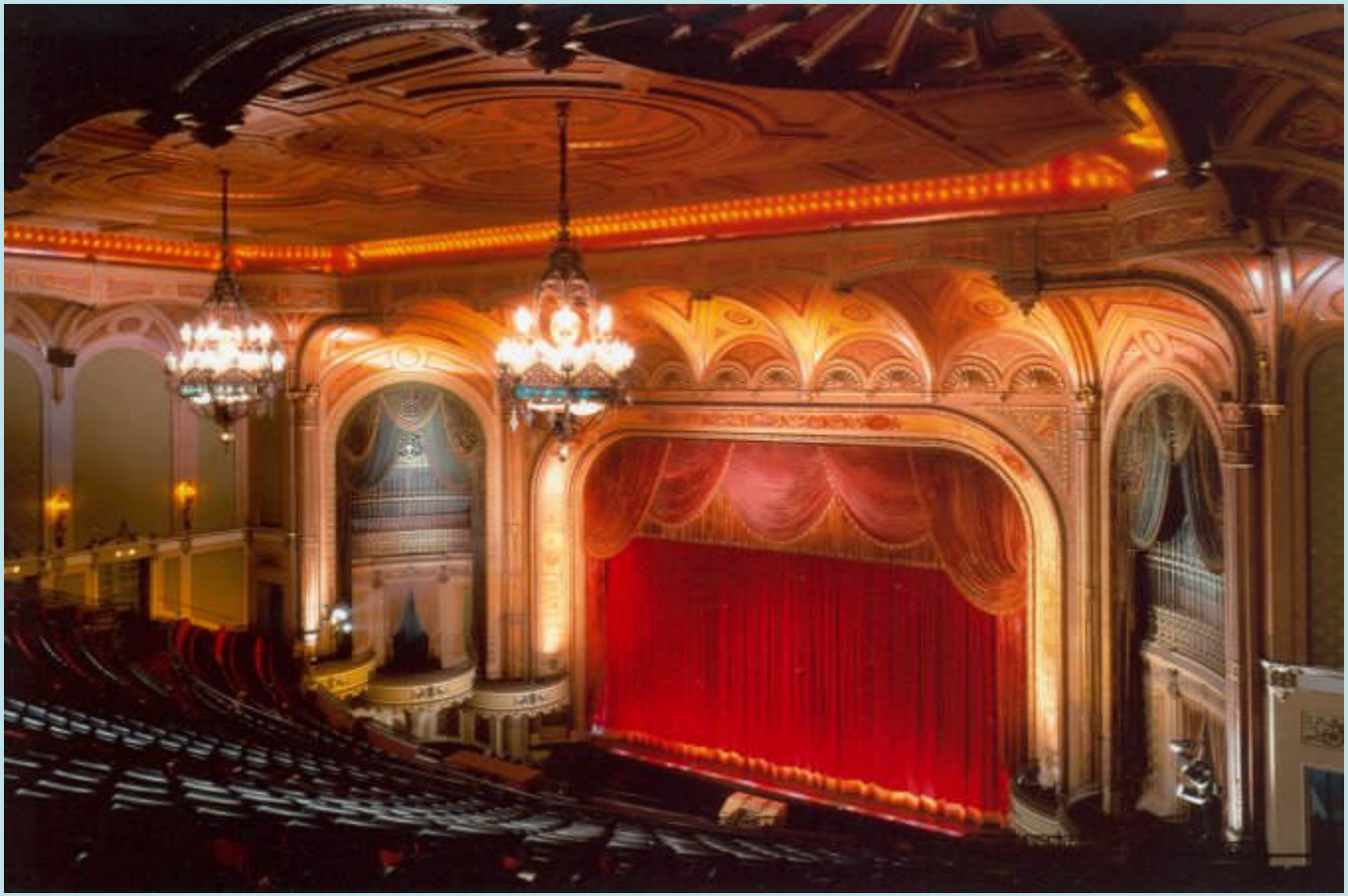


Photo courtesy of Berger/Conser Photography

Monitoring of small parcels - update

- Study extended to approx. 1000 parcels
- Results confirm that ~10% of small parcels (< 0.5 ha) require data other than Sentinel-2
- Confirmation of the Sentinel-2 limit parameters (8 pure pixels) is pending (reporting in pipeline).

Findings

- Geolocation performance of S2B has not been yet stabilized, some noise observed
- Crops of adjacent parcels have an influence on NDVI time series
- Permanent grassland – worst performance
- **S2 exceeded the expectations, in 92% of cases able to correctly identify required markers**

Lessons learnt

Hints based on the case study results

Sentinel-2 starts to have a difficulty compared to an HHR sensor when:

- Parcel contains less than 8 full pixels

and

- Percentage of S2 pixels lost after application of 5m negative buffer is higher than 60%

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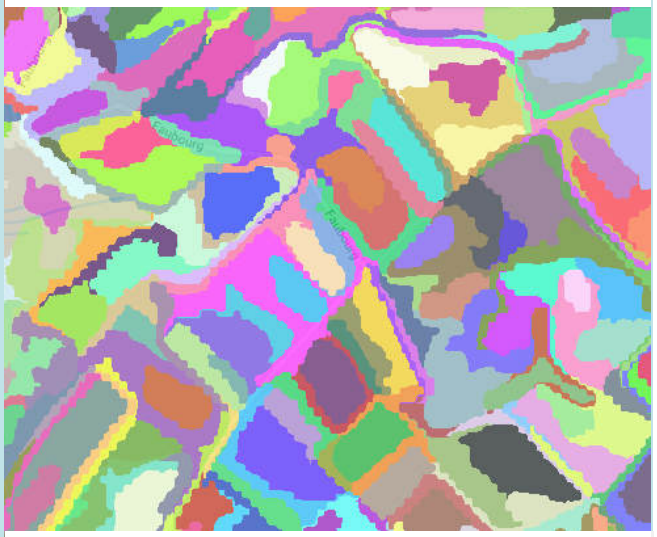
Other ongoing and planned activities

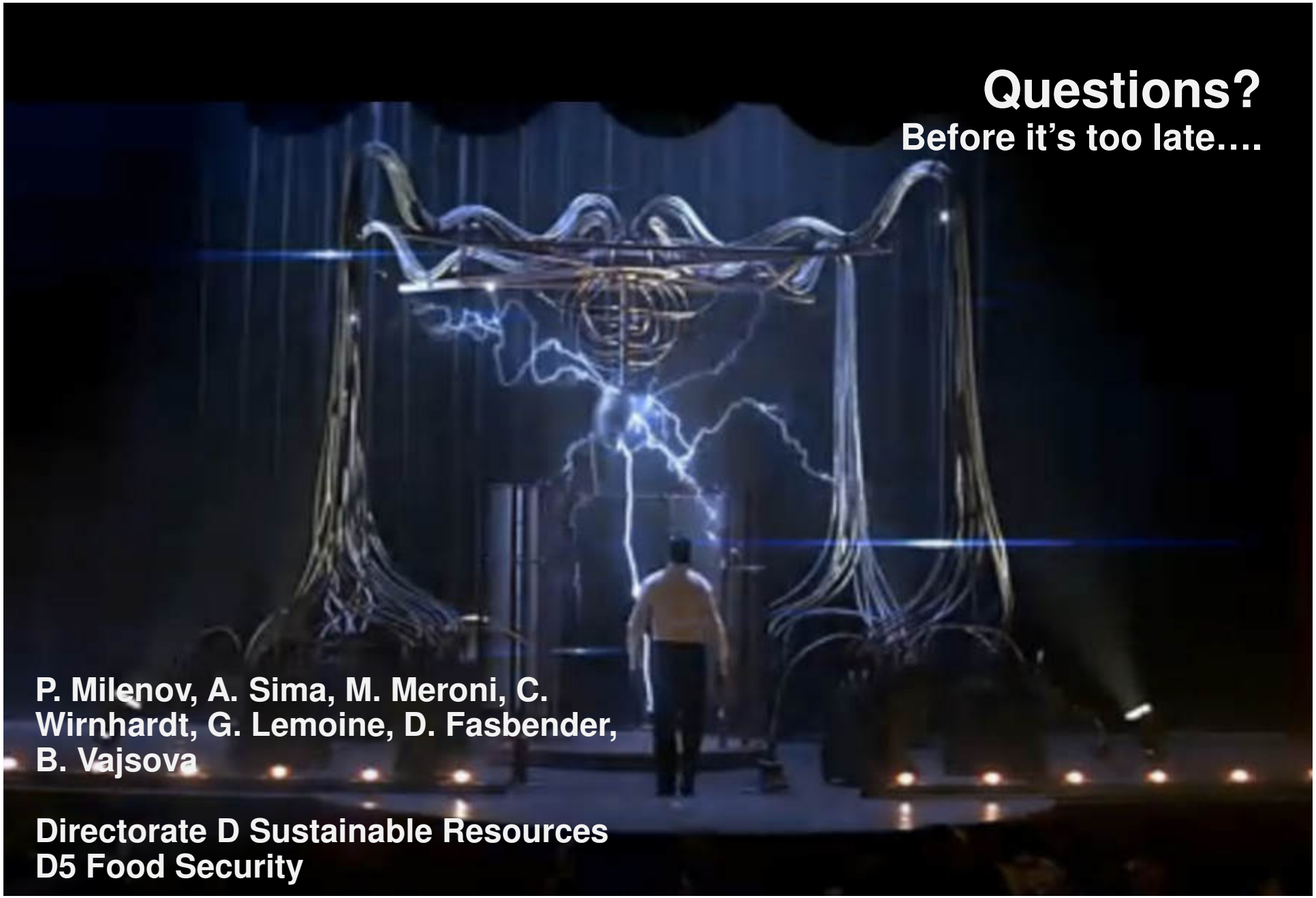
- Exploring potentials of the “spatial markers” for FOI tracking
- Evaluation of a smartphone with a dual-frequency GNSS chipset for point, line and area measurements
- Use of temporal synthesis (composites) of signal to overcome gaps and noise

Multi-temporal image segmentation



Composite of NDVI from 3 different dates

Source: Google Earth Engine



The Prestige (movie): reelworldtheology.com

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