Monitoring the phenological stages of winter wheat and grain maize in France with Sentinel-2

Martin CLAVERIE [1], *Catherine CAUCHARD* [2], *Marc ZRIBI* [2], *Wassim BEN AOUN* [1], *Marijn VAN DER VELDE* [1], Raphaël D'ANDRIMONT [1], *Maurits VANDENBERG* [1]

[1] Joint Research Centre (JRC), Food Security Unit

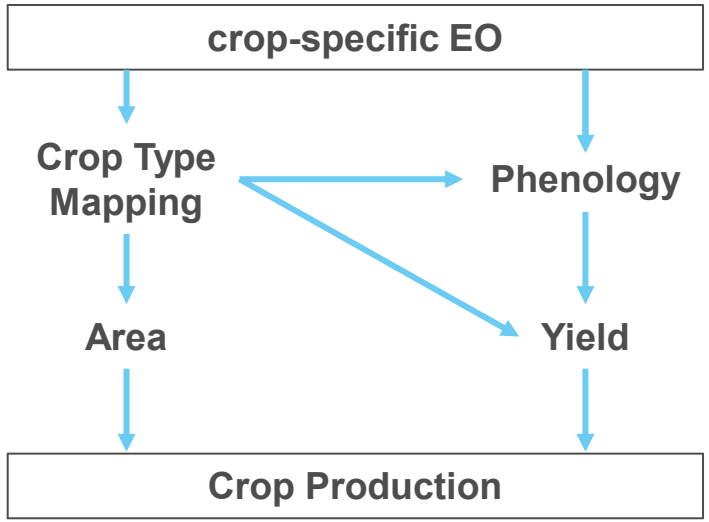
[2] FranceAgriMer

Living Planet Symposium 2022, Bonn

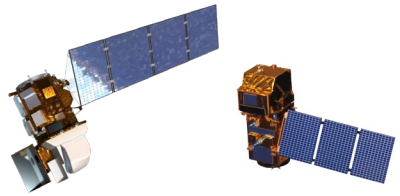
European Commission

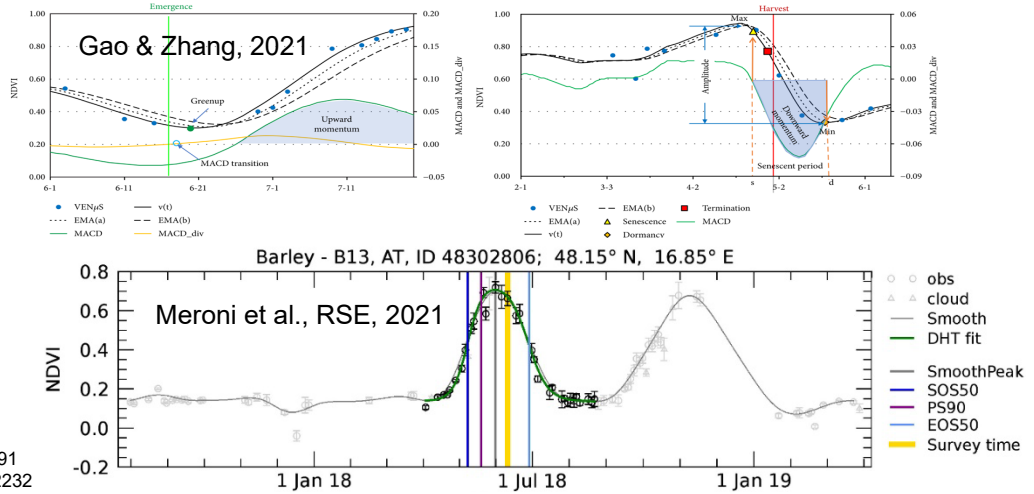
Retrieve detailed crop phenology from Earth Observation is challenging

How can **crop-specific Earth Observation** data contribute to improve **crop production monitoring**?



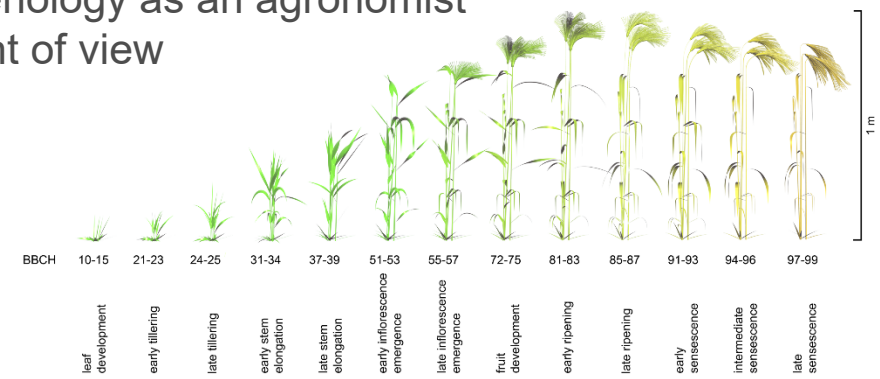
Phenology with EO point of view



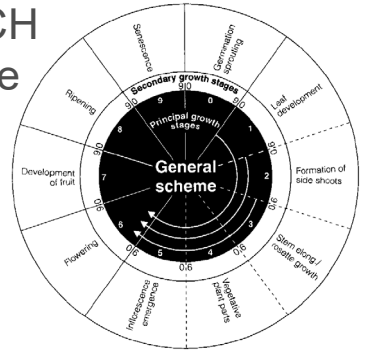


Gao & Zhang, *JRS*, 2021. https://doi.org/10.34133/2021/8379391
Meroni et al., RSE, 2022. https://doi.org/10.1016/j.rse.2020.112232

Phenology as an agronomist point of view



BBCH scale

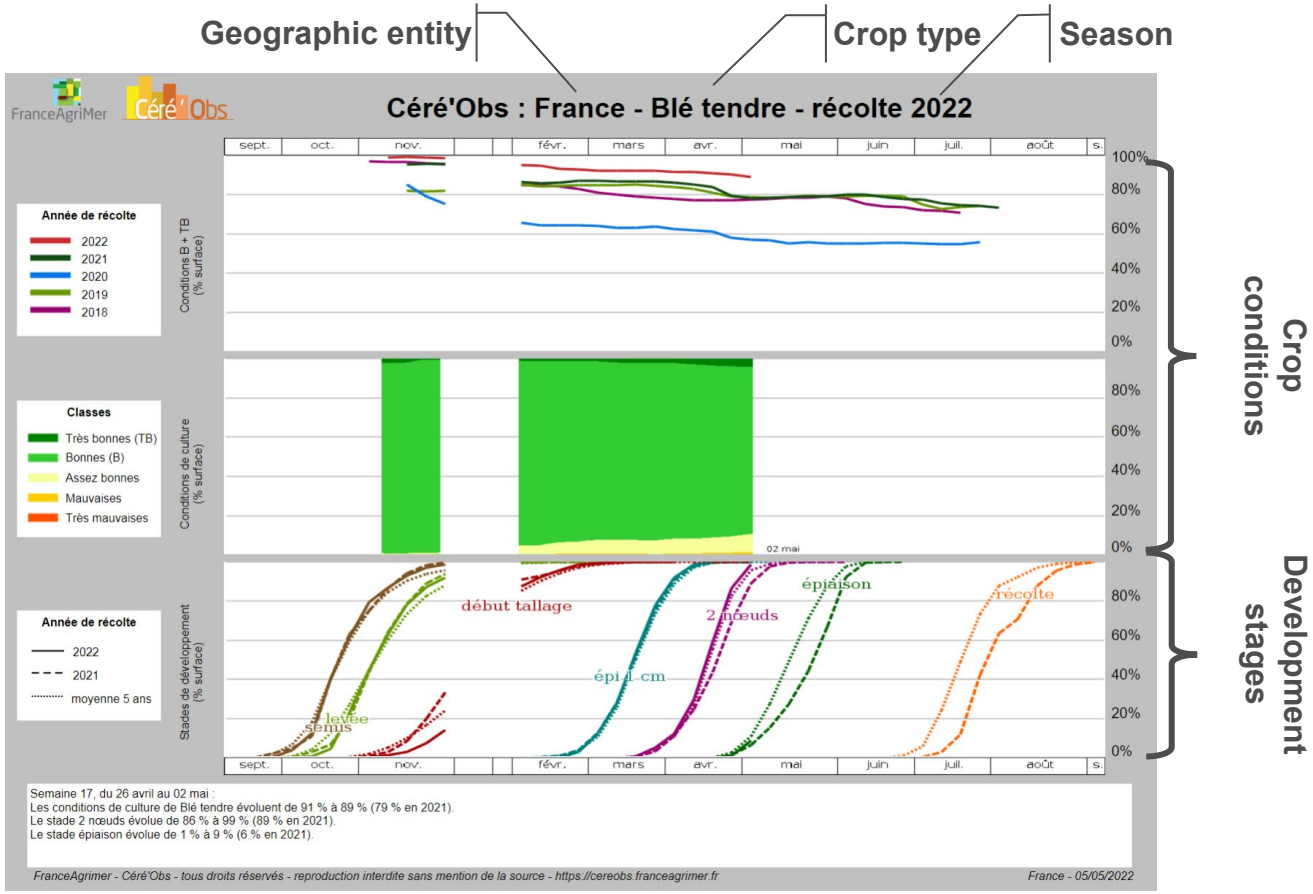


BBCH derives from **B**iologische **B**undesanstalt Bundessortenamt and **CH**emical industry

European Commission

Céré'Obs reports provide weekly development stage information at *département* level

- Published by FranceAgriMer, a French public institute
- **Weekly** reports from February to November
- **Expert**-based information
- Regional level (*département* = NUTS-3)
- Information provided:
  - **Crop condition** notations
  - **Crop development stages**
- Five crop covered:
  - **Winter soft wheat**
  - Durum wheat
  - Winter barley
  - Spring barley
  - **Grain maize**



https://cereobs.franceagrimer.fr

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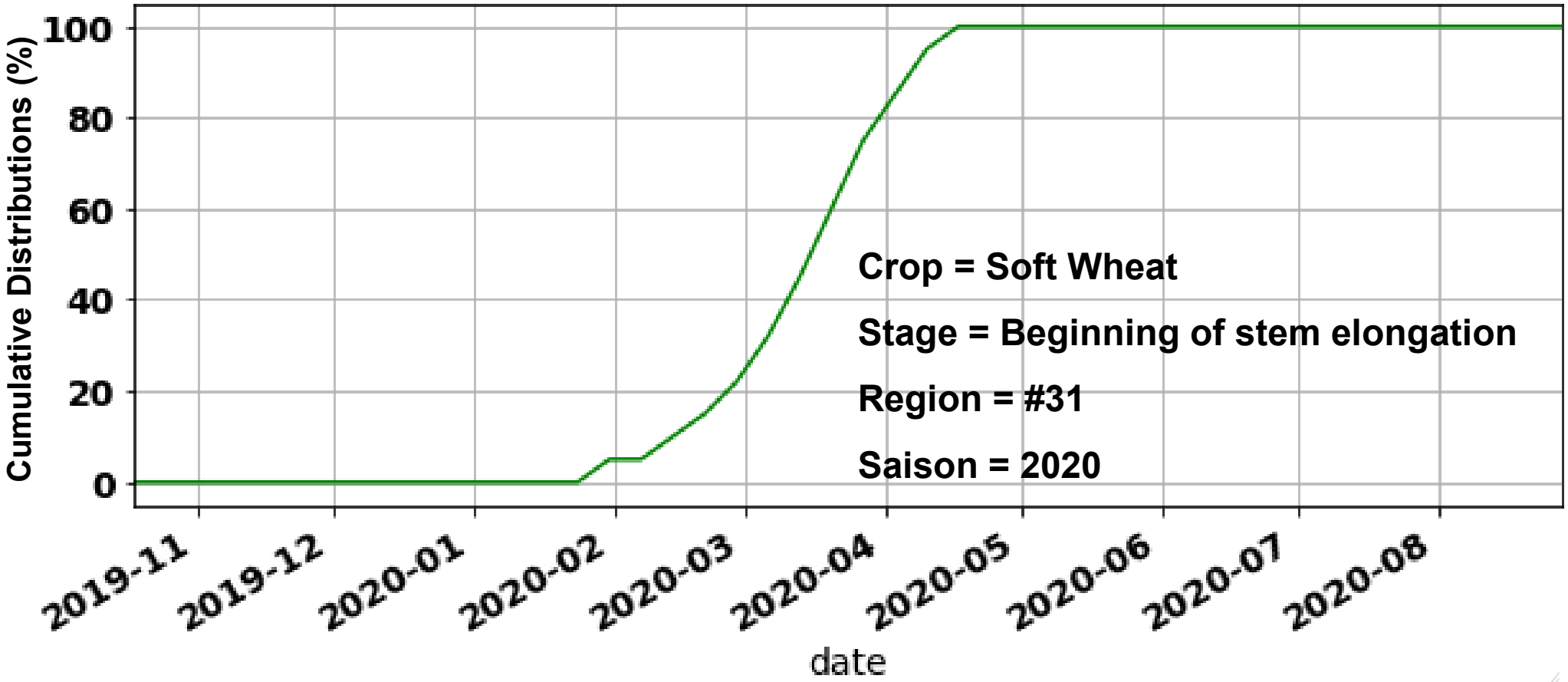
Experts provide cumulative distributions of specific development stage for each crop



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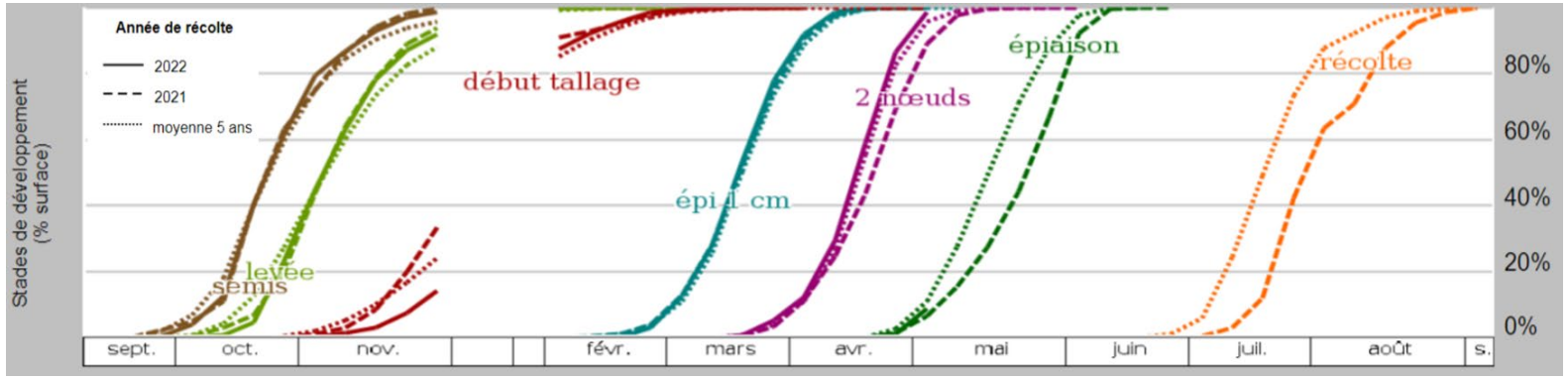
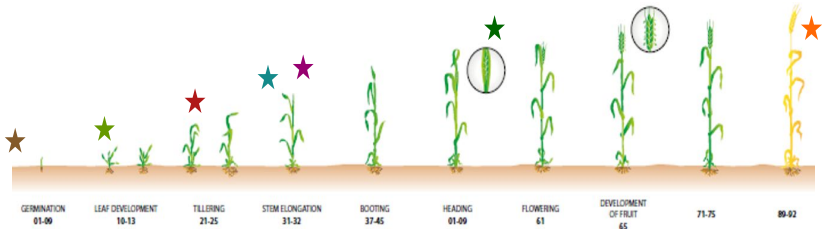
For each region, 7 stages of Soft Wheat and 6 stages for Grain Maize are monitored weekly

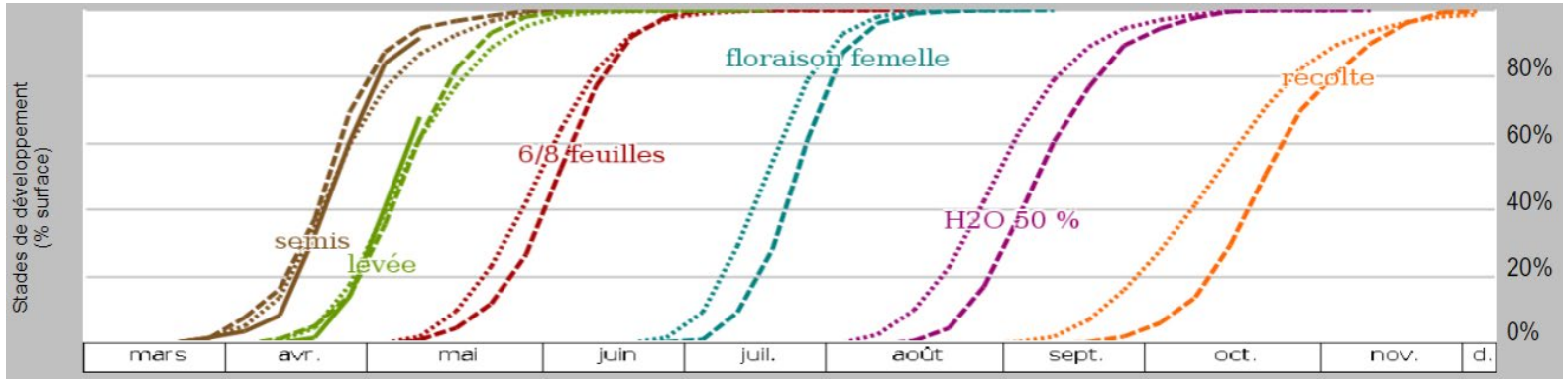
Soft Wheat

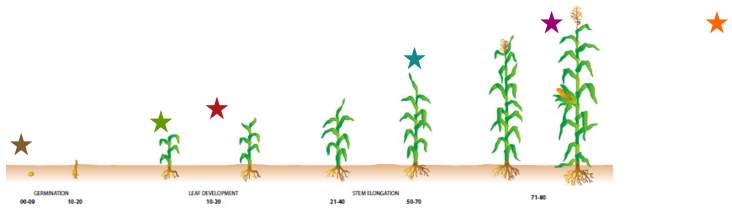




	Code	BBCH	BBCH name EN	Céré'Obs FR
Soft Wheat	S1	00	Dry seed	Semis
	S2	10	Emergence	levée
	S3	21	Beginning of tillering	début tallage
	S4	30	Beginning of stem elongation	épi 1 cm
	S5	32	Node 2	2 nœuds
	S6	55	Middle of heading	épiaison
	S7	99	harvest	Récolte

Grain Maize

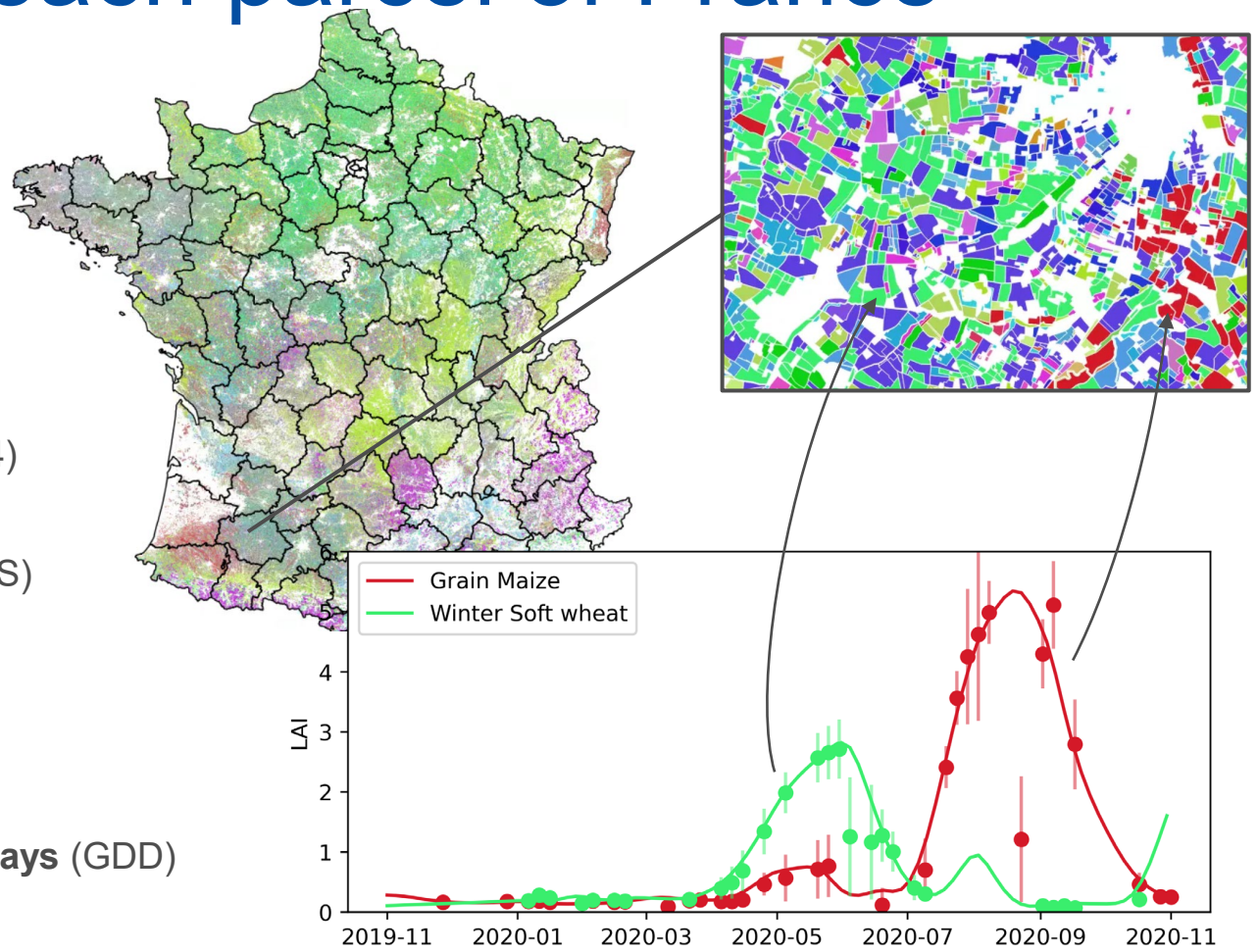




	Code	BBCH	BBCH name EN	Céré'Obs FR
Grain Maize	S1	00	Dry seed	Semis
	S2	10	Emergence	levée
	S3	16	6 leaves unfolded	6-8 feuilles visibles
	S4	65	Full flowering	floraison femelle
	S5	87	Hard dough	humidité du grain autour de 50 %
	S6	99	harvest	Récolte

High quality biophysical variables derived from Earth Observation for each parcel of France

- Agriculture **parcels** over France
  - Parcel geometries and crop types from 2015 to 2020
  - 7.5M parcels per year
- **Optical Remote Sensing** data preprocessing
  - **Sentinel-2** ESA Level 2A (Sen2Cor v2.x)
  - **Landsat-8** from Harmonized Landsat Sentinel-2 (v1.4)
  - Biophysical variables (**LAI** & **FAPAR**) computation
  - Red (clouds) and NIR (cloud shadows) time series (TS) **outliers detection** using Hampel filter
  - **Whittaker smoothing** with 4 days interpolation
- **Weather** data
  - ERA5 (grid=25km)
  - 2m daily temperature to compute **Growing Degree Days** (GDD)



BDAP

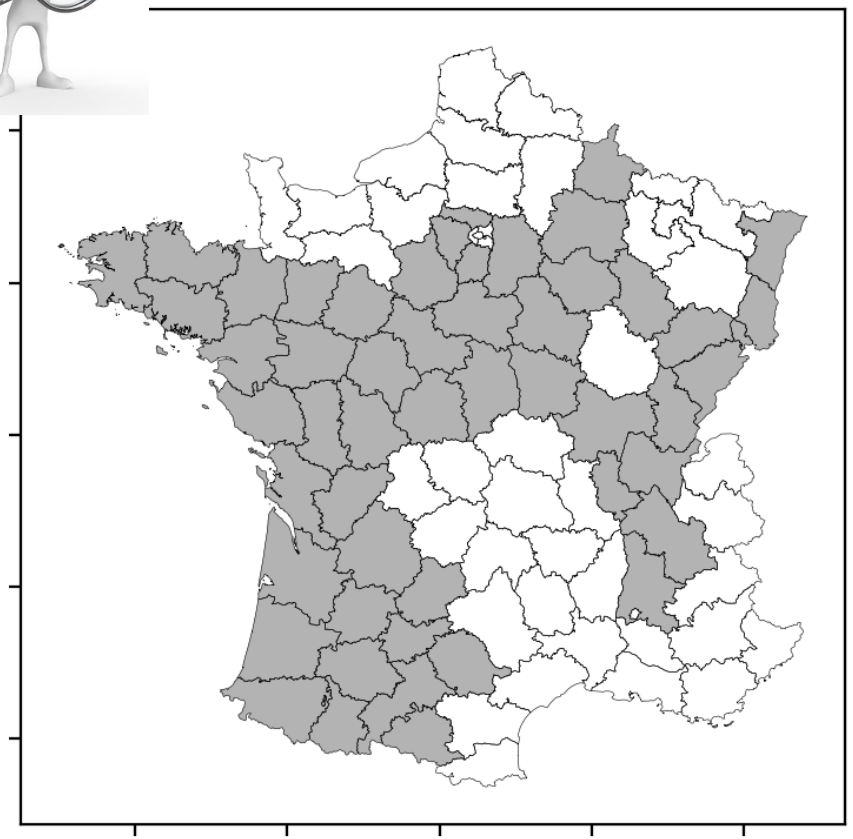
PostGIS

European Commission

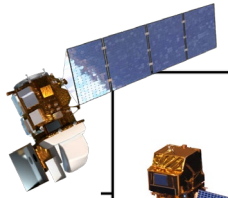
From regional expert-based phenology to parcel Earth observation-based phenology

Expert-based phenology

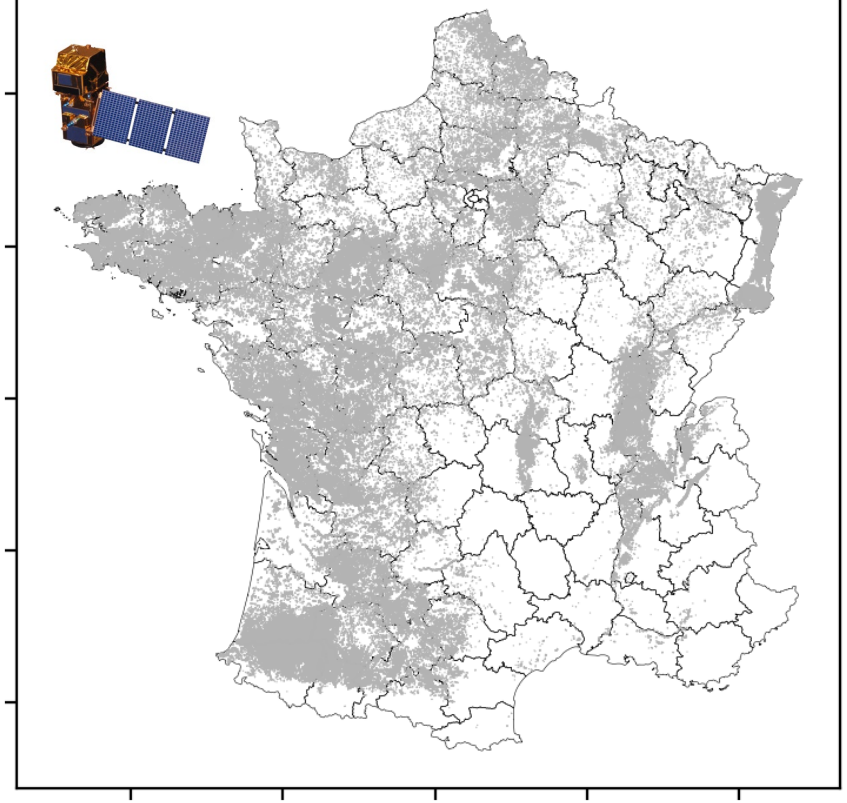
2020-04-01



Earth Observation-based phenology



2020-04-01



	Code	BBCH	name EN
Grain Maize	S1	00	Dry seed
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	S3	16	6 leaves unfolded
	S4	65	Full flowering
	S5	87	Hard dough
	S6	99	harvest

450k+ parcels plotted

Grain Maize 2020 time course

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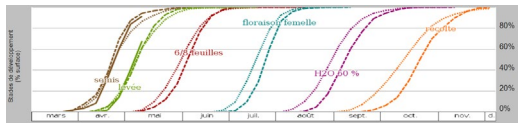
Calibrate a method to identify the crop stages at parcel level combining Earth Observation and the expert data



Expert data distribution

Parcel time series (GDD, LAI, FAPAR, …)

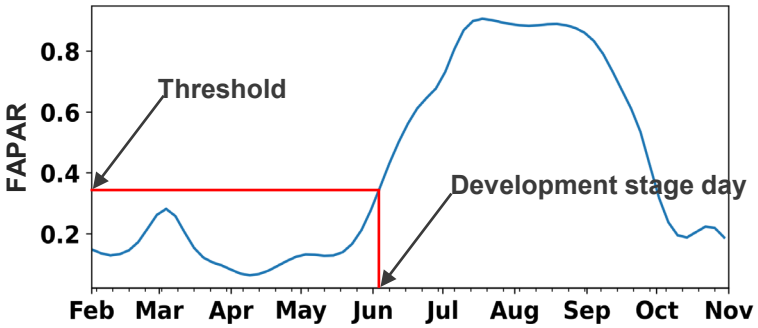
Parcel-level development stage day

Threshold

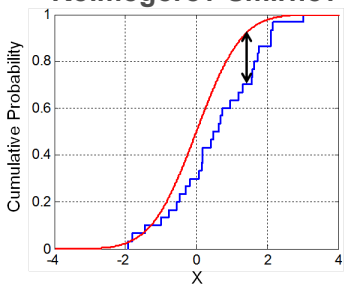
optimization

Region-level development stage distribution

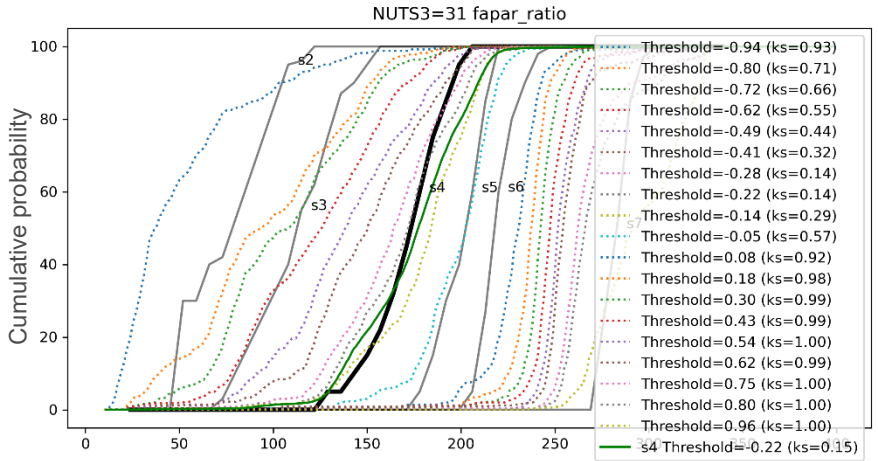
Kolmogorov-Smirnov

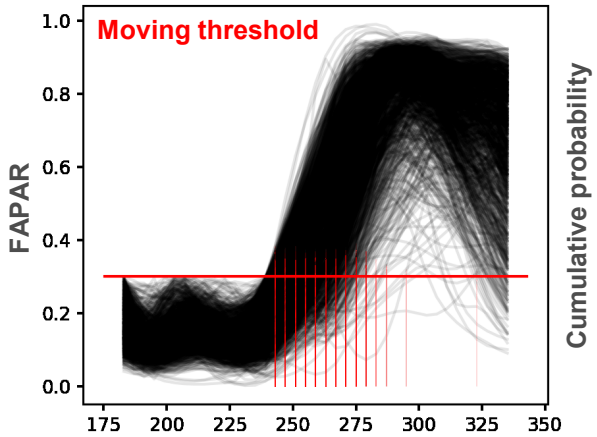


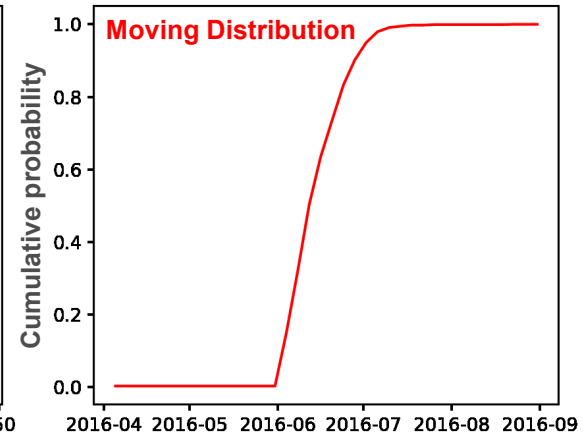
Kolmogorov-Smirnov



https://en.wikipedia.org/wiki/Kolmogorov-Smirnov_test







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The implementation of the Method

Expert data

2 crops: Grain Maize & Soft Wheat

5 years: 2016-2020

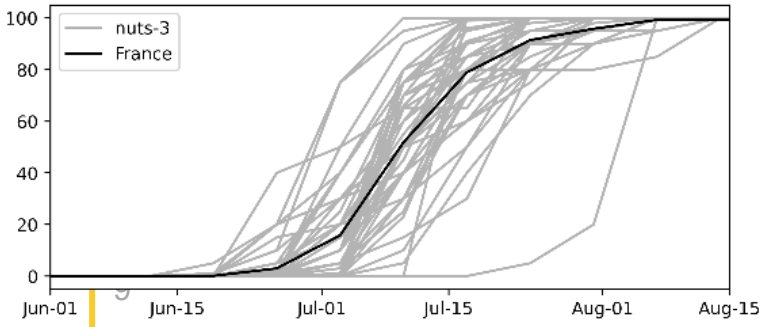
5 to 6 development stages: from emergence to harvest

54 regions + 1 national

5 Phenology-Driving Variables

1. GDD = Growing Degree Day
2. LAI = Leaf Area Index
3. FAPAR = Fraction of Absorbed Photosynthetically Active Radiation
4. LAI_RATIO = (LAI - min{LAI}) / max{LAI}
5. FAPAR_RATIO = (FAPAR - min{FAPAR}) / max{FAPAR}

Grain Maize – S4 = BBCH30



4153 optimization processes and Thresholds computed

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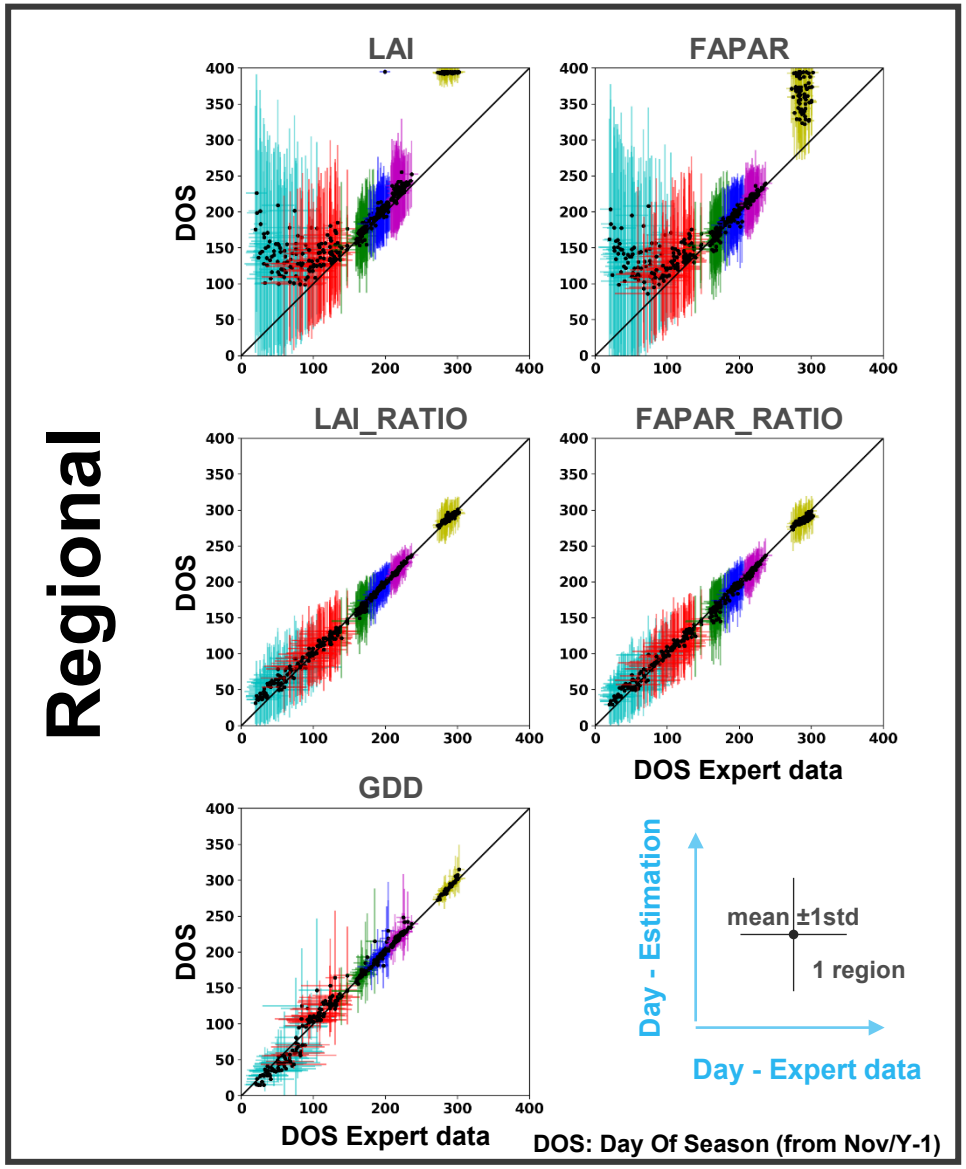
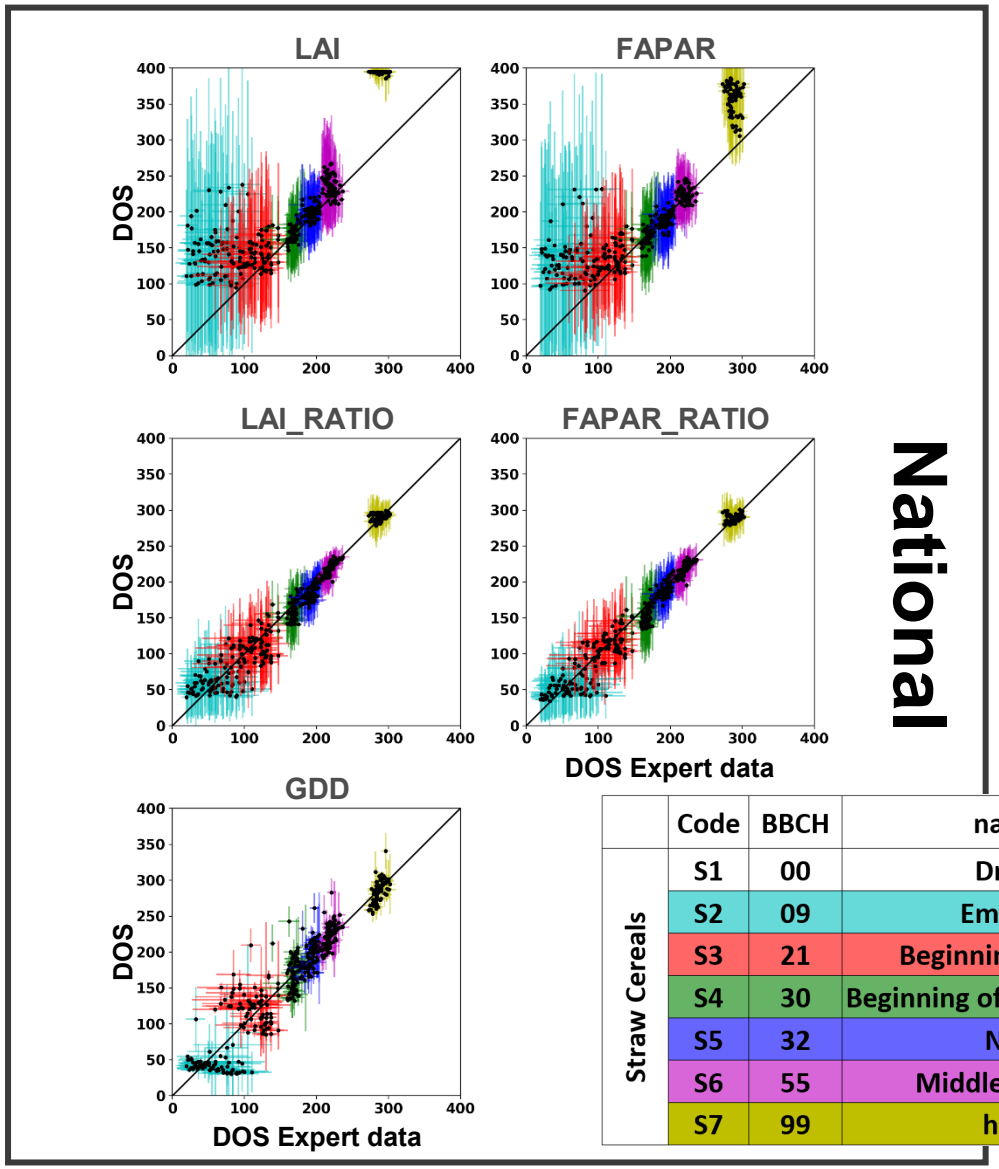
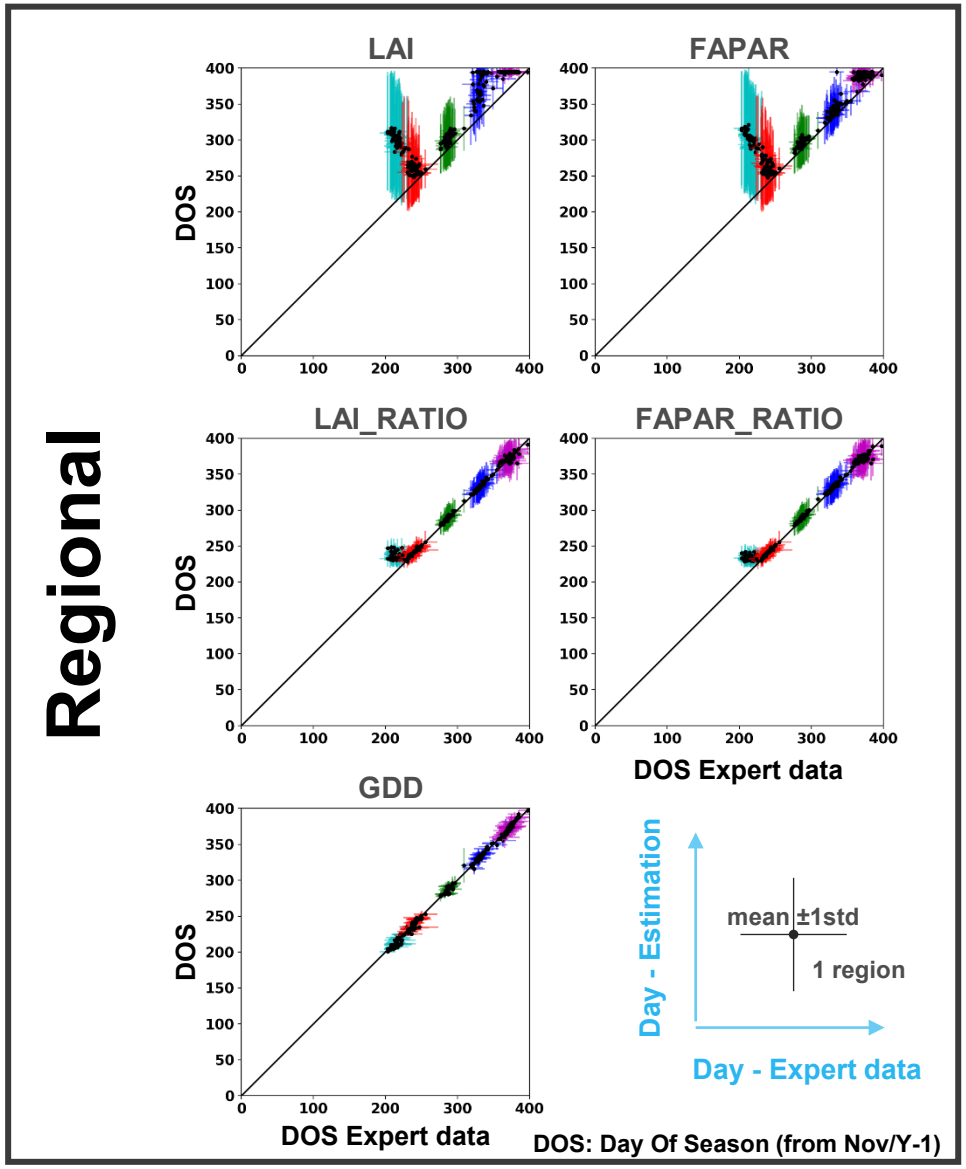
How well are matching the estimates for Soft Wheat?

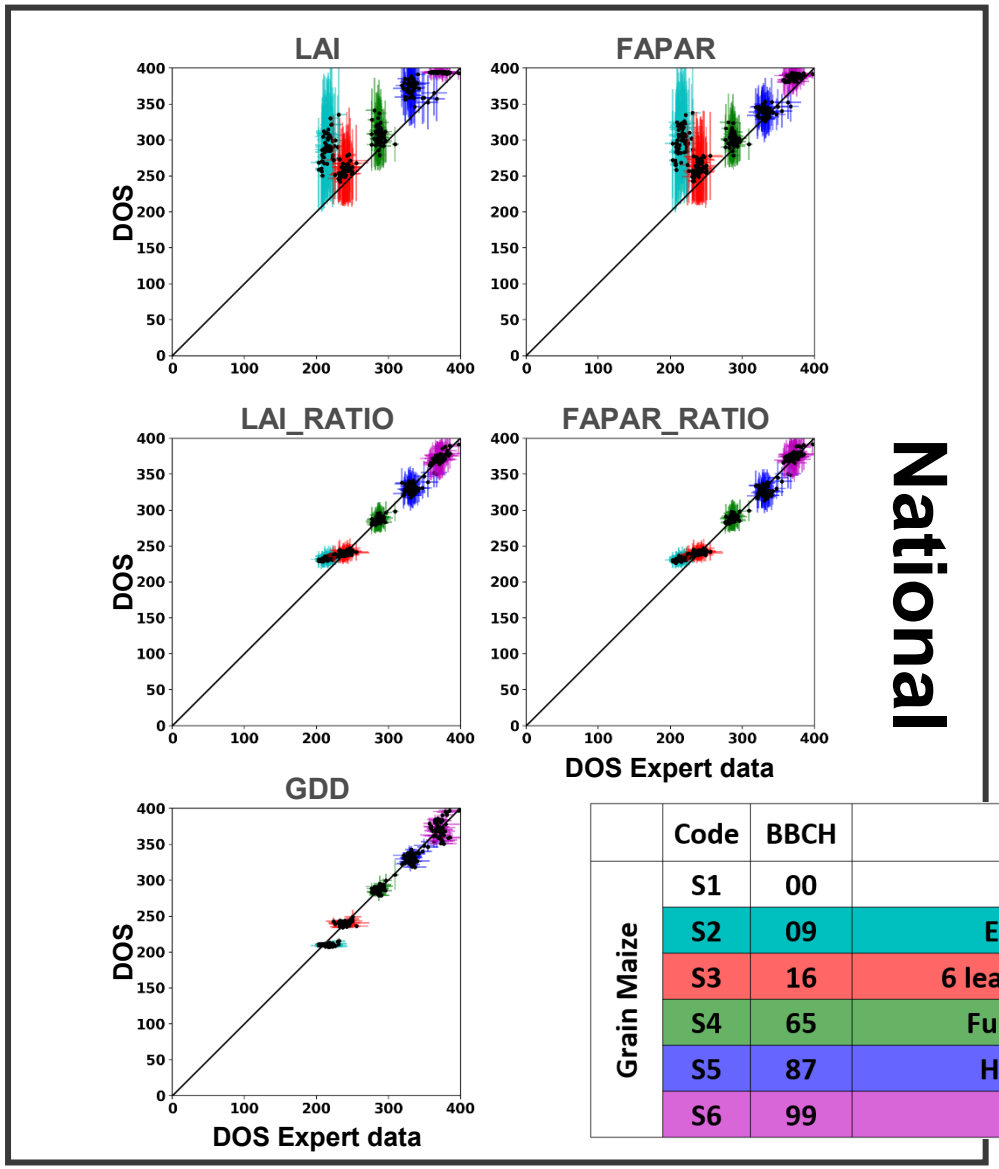




	Code	BBCH	name EN
Straw Cereals	S1	00	Dry seed
	S2	09	Emergence
	S3	21	Beginning of tillering
	S4	30	Beginning of stem elongation
	S5	32	Node 2
	S6	55	Middle of heading
	S7	99	harvest

How well are matching the estimates for Grain Maize?





	Code	BBCH	name EN
Grain Maize	S1	00	Dry seed
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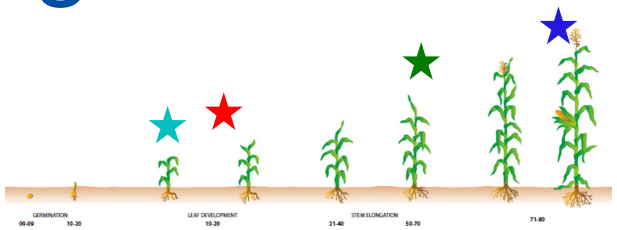
	S4	65	Full flowering
	S5	87	Hard dough
	S6	99	harvest

Calibration results at regional level



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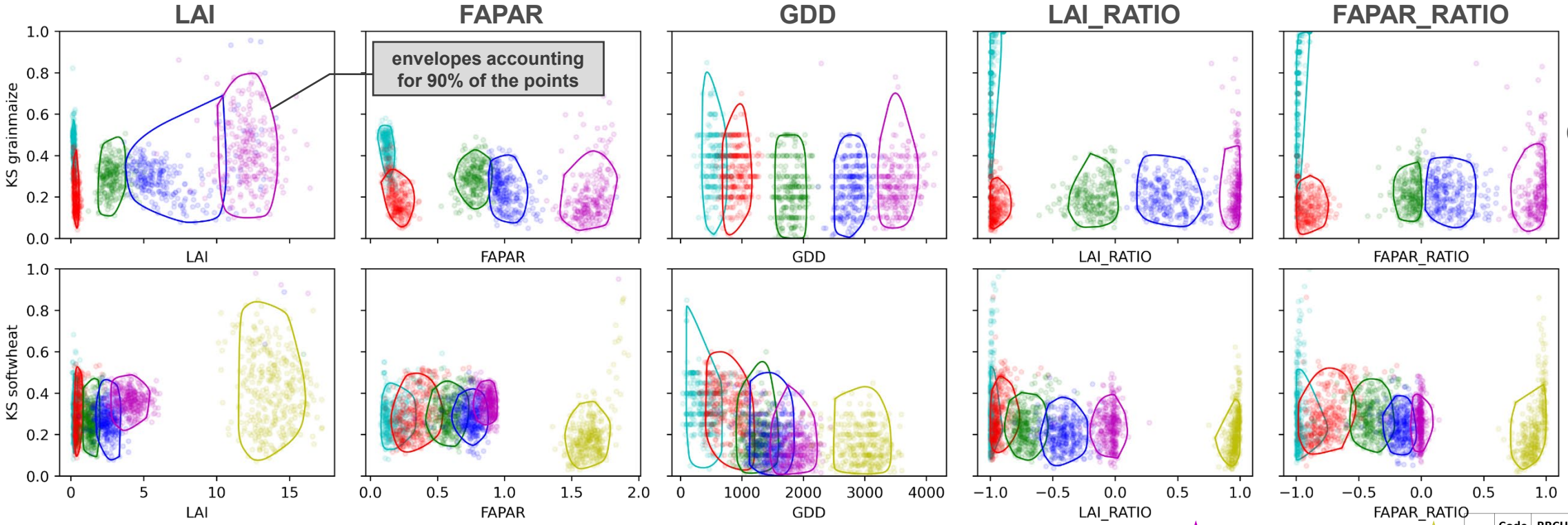

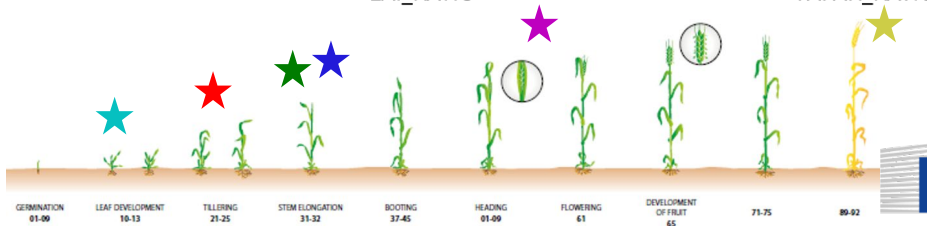

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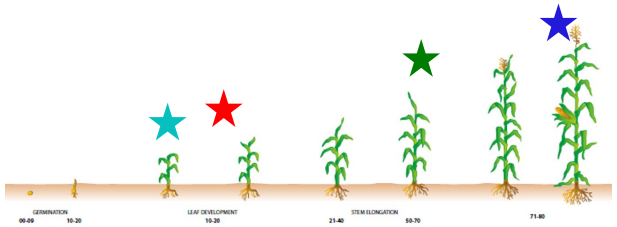
	S7	99	harvest

Calibration results at national level



	Code	BBCH	name EN
Grain Maize	S1	00	Dry seed
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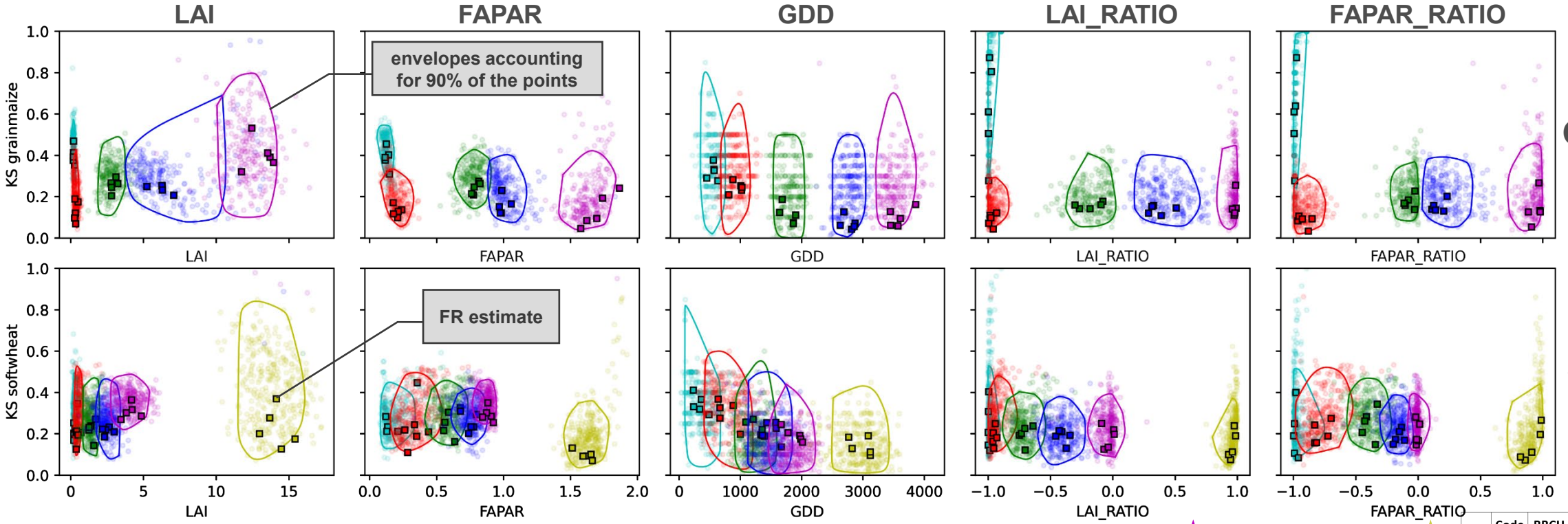

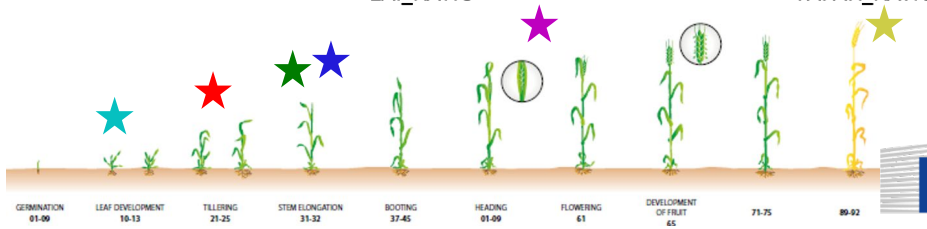

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	S5	32	Node 2
	S6	55	Middle of heading
	S7	99	harvest

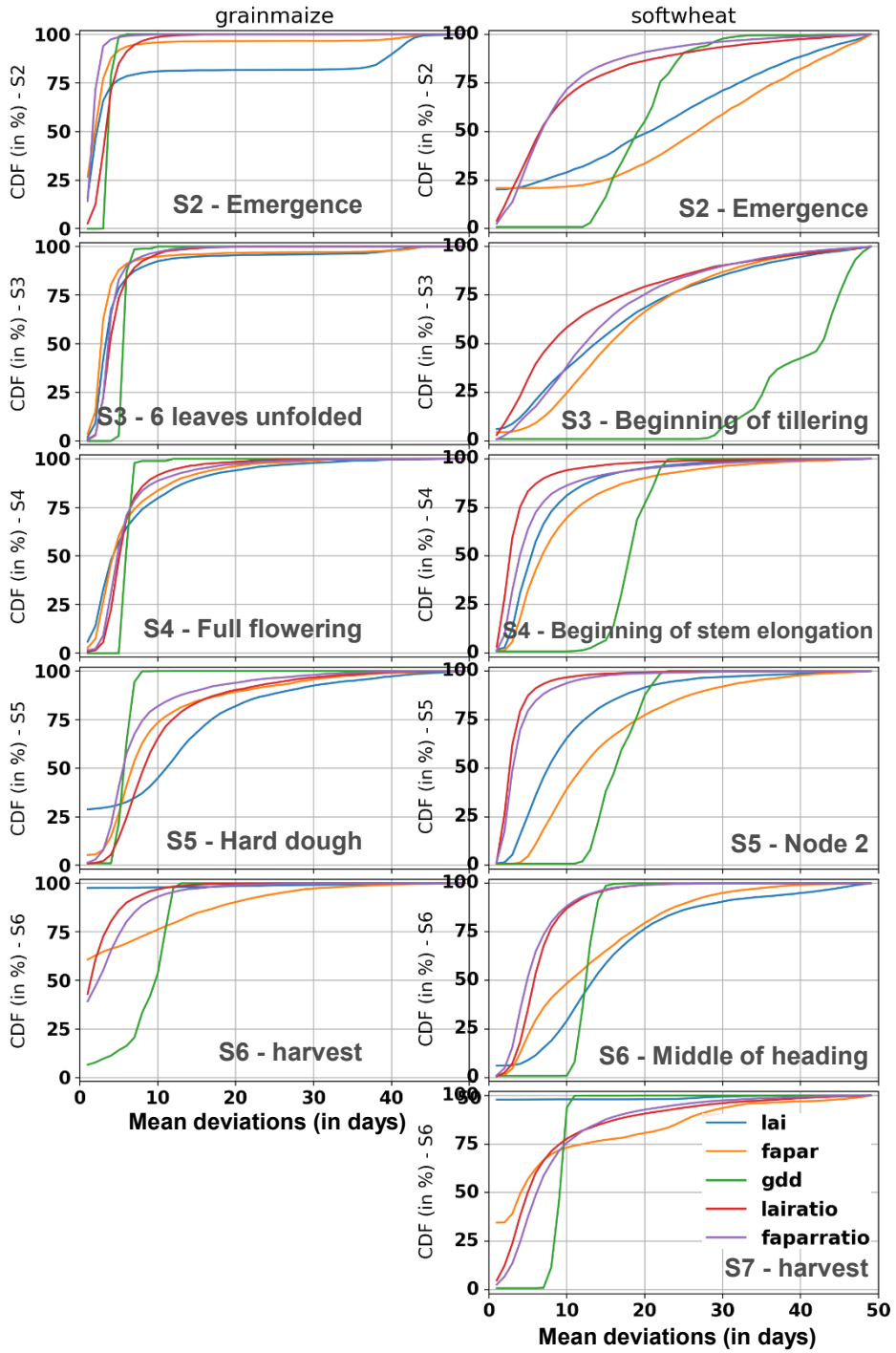
Temporal stability Analysis

- We computed the **mean deviations (in days)** using Thresholds from other years (Using only the national estimates) – similar to **leave-on-out**

- For **grain maize**, all variables are in line with a **mean deviation less than 10 days**

- For **soft wheat**
  - **Early stages** are more **difficult to capture**
  - **GDD is less stable** than other methods

- Overall, the LAI_**RATIO** and the FAPAR_**RATIO** demonstrated to be the **most robust** variables



From regional expert-based to parcel Earth observation-based phenology

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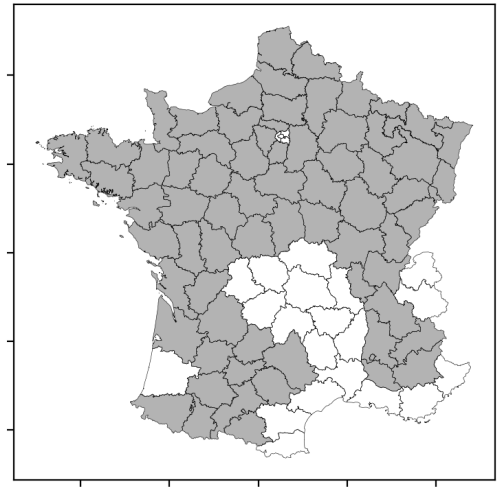
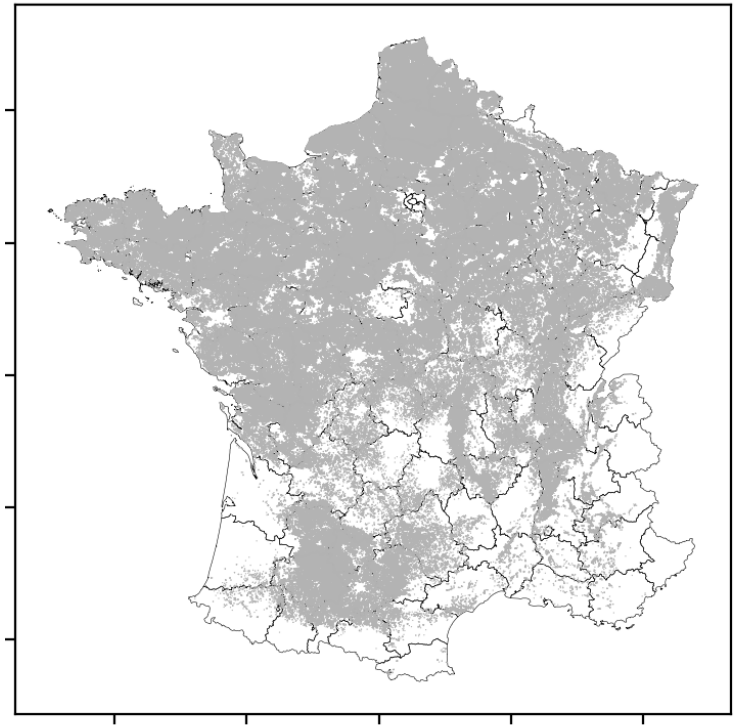
	S6	55	Middle of heading
	S7	99	harvest

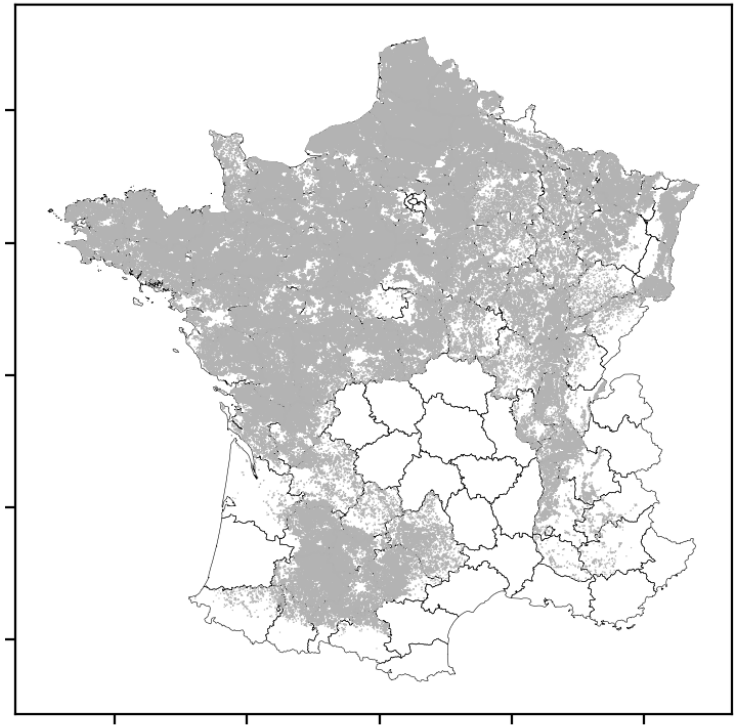
Expert data
2019-10-01



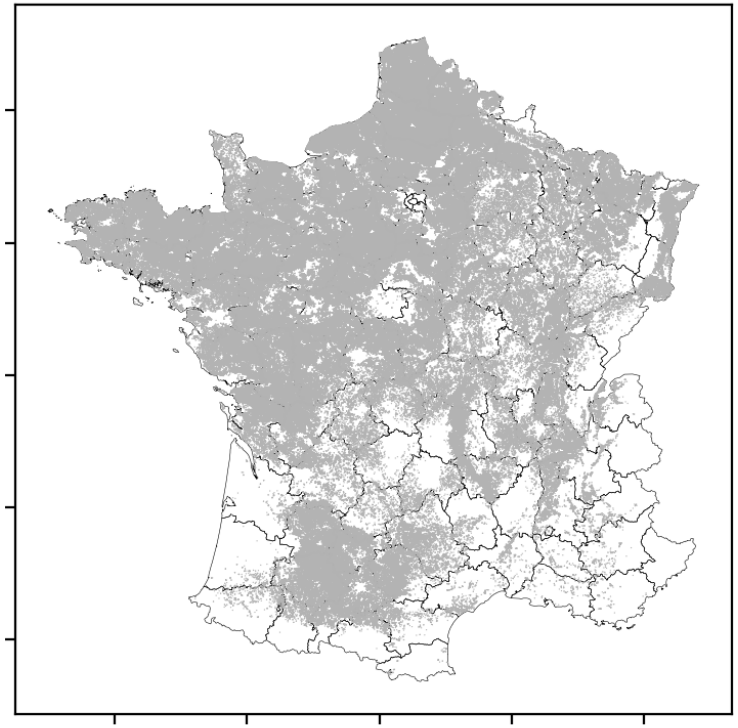
GDD estimates (single national Threshold)
2019-10-01



FAPAR_RATIO estimates (1 Threshold per region)
2019-10-01



FAPAR_RATIO estimates (single national Threshold)
2019-10-01



Conclusions

- The **GDD** variable remains a very simple and easy to use proxy for phenology but **not very robust** over time
- The **FAPAR_RATIO** and the **LAI_RATIO** displayed the best performances
- The **early stages** and **harvest** were difficult to capture and remains non stable
- Grain **Maize** modeling was **more robust**
- **Good** quality of the **smooth TS** is essential
- How **reproducible** are the methods? Can we apply the same methodology to same crop cultivated elsewhere?

Thank you

martin.claverie@ec.europa.eu