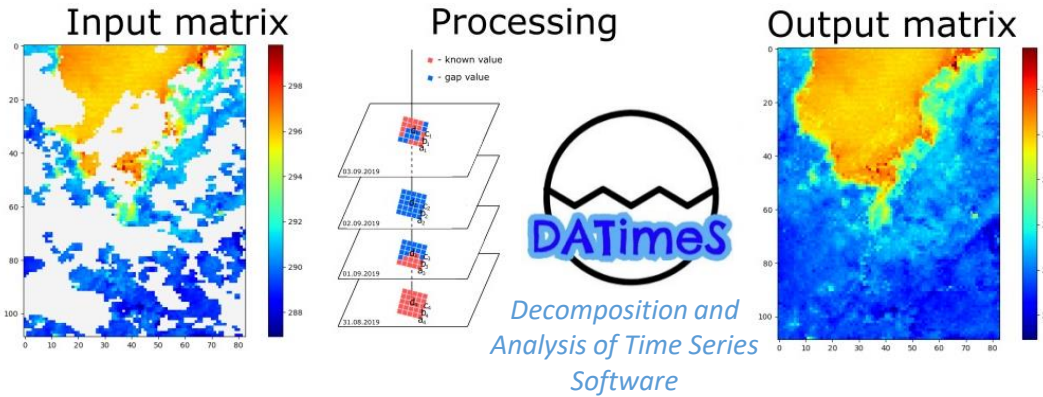


## Image Time series Gap-Filling



## Machine Learning Algorithms

Bagtree	KRR	RF1	SKRRrbf
Ares	LWP	RF2	TREE
ELM	LSLR	SKRRlin	WGPR
Boost	MSVR	RVM	VHGPR
KNRR	NNIPL	RLR	
<b>GPR</b>	RKS	SSGPR	

GPR: non-parametric fitting in a Bayesian framework providing uncertainty along with mean estimates

## Gaussian Process Regression

Various kernel functions with associated hyperparameters: **Exponential (SE)**, Matern3/2, Matern5/2 and Rational Quadratic (RQ), among others. For SE:

$$k(t_i, t_j) = \sigma_f^2 \exp\left(-\frac{1}{2l^2} (t_i - t_j)^2\right) + \sigma_n^2 \delta_{ij}$$

Length-scale  $l$

Signal variance  $\sigma_f^2$

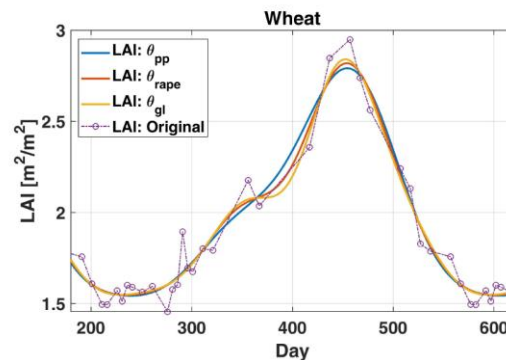
Noise variance  $\sigma_n^2$

## Methodology

- Crop type selection.** Wheat, corn, barley, sunflower, rape, pea, alfalfa, peat, potato.
- Hyperparameters optimization approaches**
  - Per-pixel ( $\theta_{pp}$ )
  - Hyperparameter crop type average ( $\theta_{crop}$ )
  - Hyperparameter global average ( $\theta_{gl}$ )
- Time series (TS) prediction.** LAI-reconstructed TS computed with different GPR hyperparameters
- Statistical analysis for performance comparison.** Performance of GPR models evaluated in terms of reconstruction (original vs. interpolated LAI TS) and processing time.
- Phenological metrics extraction.** Analysis of different GPR parametrizations on phenological indicator estimation.

Table 1. Variation in percentage of retrieved LAI using  $\theta_{crop}$  and  $\theta_{gl}$  wrt  $\theta_{pp}$

Crop Type	Per-Pixel Hyperpar.	Averaged Hyperparameters									
		Wheat	Corn	Barley	Sunflower	Rape	Pea	Alfalfa	Beet	Potato	Global
Wheat	6.269	6.721	6.006	6.165	6.698	6.571	5.138	6.425	6.298	5.335	6.166
Corn	5.817	7.334	6.223	6.445	7.134	7.066	5.408	6.762	6.631	5.554	6.432
Barley	5.763	7.150	6.098	6.308	7.043	6.904	5.250	6.663	6.493	5.396	6.309
Sunflower	9.284	12.717	10.948	11.278	12.165	12.283	9.493	11.691	11.562	9.850	11.251
Rape	6.905	8.049	6.779	7.111	7.843	7.830	5.288	7.474	7.356	5.504	7.085
Pea	5.809	10.845	8.908	9.252	10.252	10.357	7.422	9.730	9.560	7.765	9.234
Alfalfa	8.714	11.136	9.626	9.935	10.792	10.810	8.098	10.352	10.202	8.517	9.920
Beet	7.436	8.881	7.601	7.857	8.618	8.585	6.537	8.217	8.074	6.749	7.844
Potato	4.628	7.952	5.863	6.197	7.380	7.389	4.895	6.752	6.521	5.035	6.190



Crop Type	No. of Pixels	Time (m)		
		$\theta_{pp}$	$\{\theta_{pc}, \theta_{gl}\}$	Ratio
Wheat	62,482	104.136	1.145	90.95
Corn	36,065	60.108	0.661	90.93
Barley	44,154	73.590	0.809	9.96
Sunflower	29,463	49.105	0.540	90.94
Rape	23,467	39.111	0.430	90.96
Pea	14,726	24.543	0.269	91.24
Alfalfa	21,683	36.138	0.397	91.03
Beet	16,466	27.443	0.301	91.17
Potato	14,337	23.895	0.262	91.20
Total	262,843	438.069	4.814	-

Table 2. Processing time (minutes)

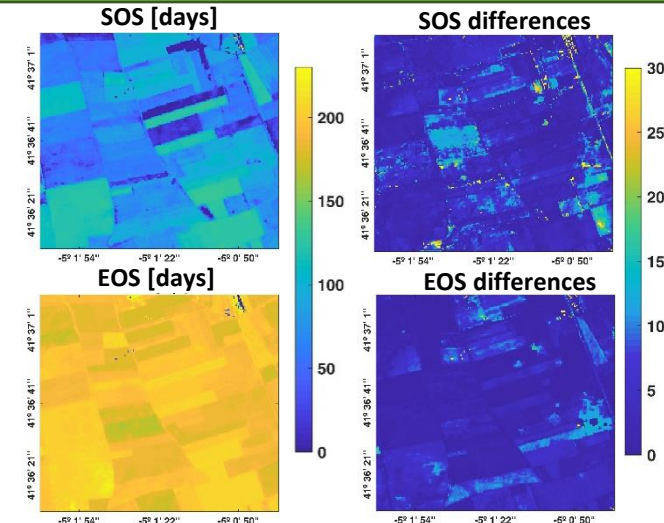


Figure. Phenological indicator maps estimated by  $\theta_{gl}$  (left) and difference wrt  $\theta_{pp}$  results (right)

Table 3. Mean absolute Deviation w.r.t. per-pixel approach

	$\theta$	SOS	EOS
Crop Mean		2.76 ± 4.9	3.47 ± 3.6
Global Mean		4.60 ± 8.5	4.99 ± 6.0