Improving the temporal allocation of ammonia agricultural emissions using fertilization days predicted with in-situ and remote sensed phenology information

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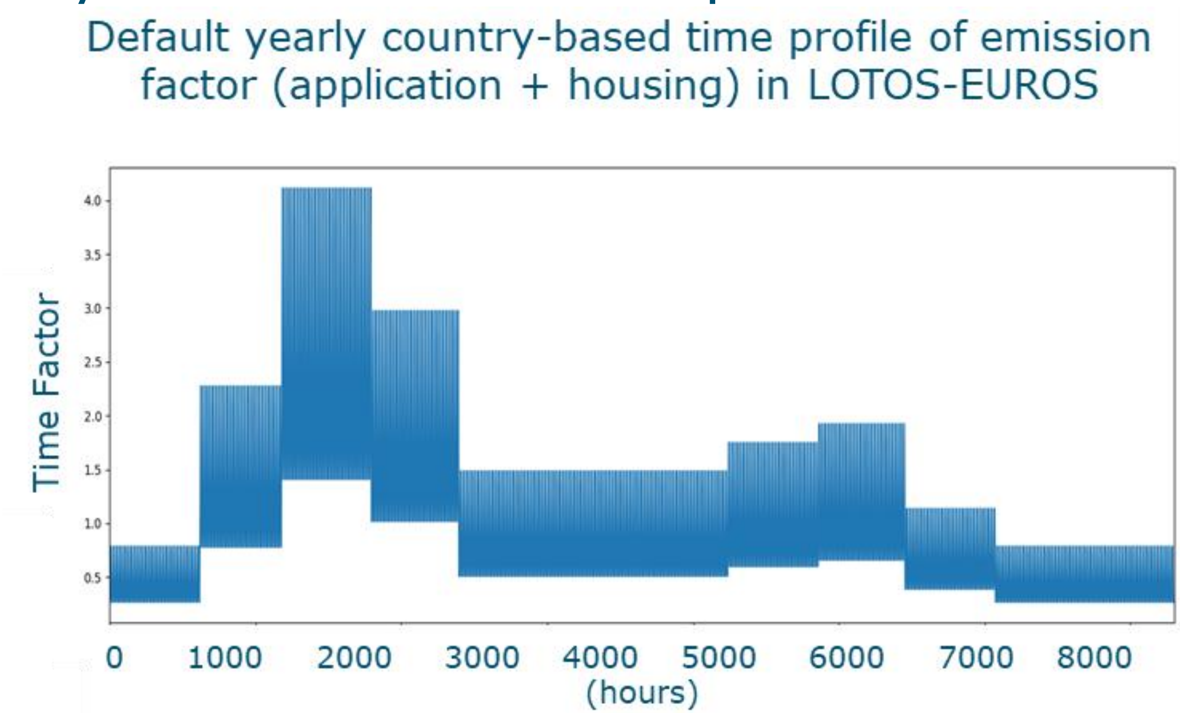
Background

- Ammonia plays a key role in nitrogen deposition and particulate matter formation and has severe side effects on ecosystems and human health
- There are large uncertainties in ammonia budgets. More accurate distribution of ammonia emission and deposition is needed for policy purposes
- The dominant source of ammonia emission is agriculture. In the Netherlands, it contributes to more than 90% of the total emission
    - Livestock housing
    - Manure storage
    - Manure and mineral fertilizer application

Problems and Objectives

- The temporal details of ammonia emission in the current air quality models are oversimplified



- Temporal variability
  - Livestock housing types
  - When fertilization occurs on crop fields

Methodology overview

- Temporalization of ammonia emission from manure and fertilizer application
- Update on fertilization day predictions
  - Model development
  - Validation
- Validation of the new ammonia emission time profile by comparing modeled surface concentrations with in-situ measurements

Temporalization of ammonia emissions from fertilization

- $E_{x,y}(t) = \epsilon_{x,y} e^{0.0223T(t)} e^{0.0419W(t)} \frac{1}{\sigma\sqrt{2\pi}} e^{\left(\frac{(t-\mu)^2}{-2\sigma^2}\right)}$

  - $E_{x,y}(t)$: emission strength at the time step t at a given location
  - $\epsilon_{x,y}$: annual total emission (kg/ha) at a location
  - T(t) and W(t): air temperature (Celsius) and wind speed (m/s) for the applied time step (t)
  - μ: fertilization day
  - σ: standard deviation to represent spread and uncertainty in the application activities and emission timing.

Gyldenkærne et al (2005): A dynamical ammonia emission parameterization for use in air pollution models

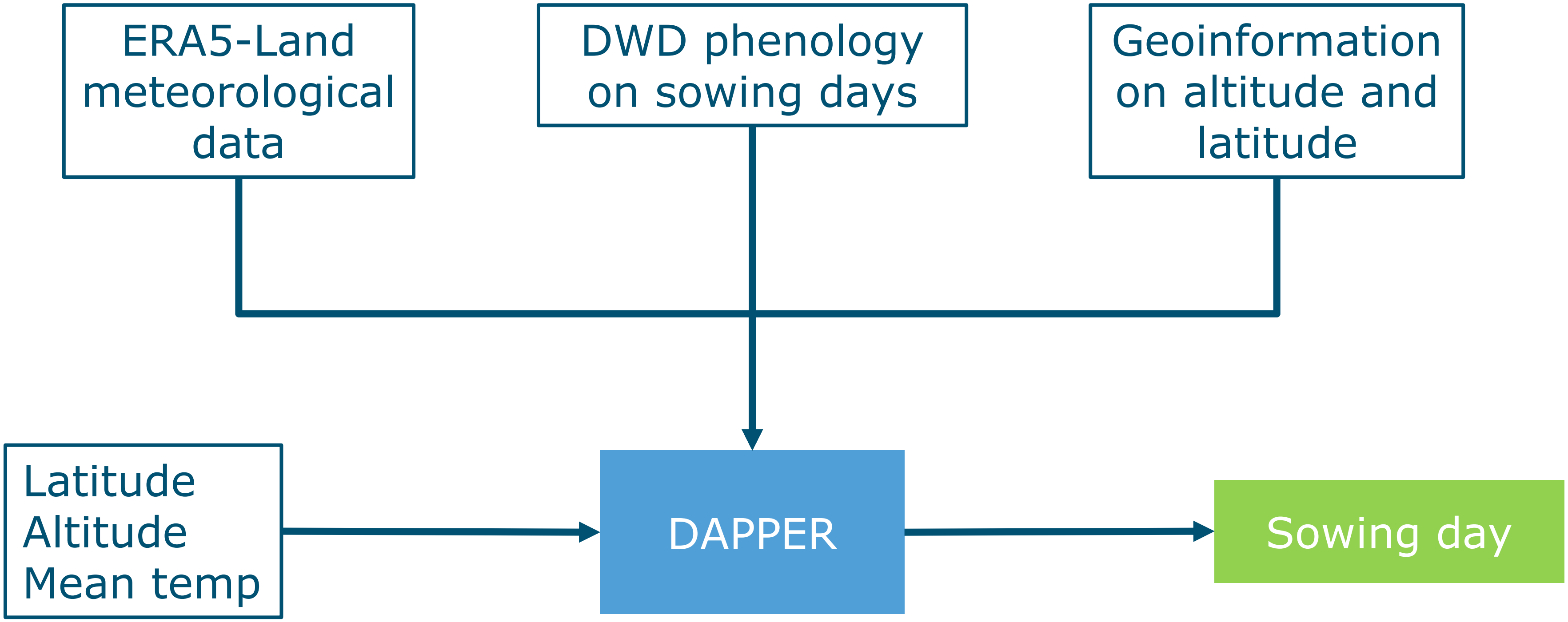
Fertilization day prediction

There is available dataset on reference sowing Tsum for several crops ......But...... Low resolution, constant between years

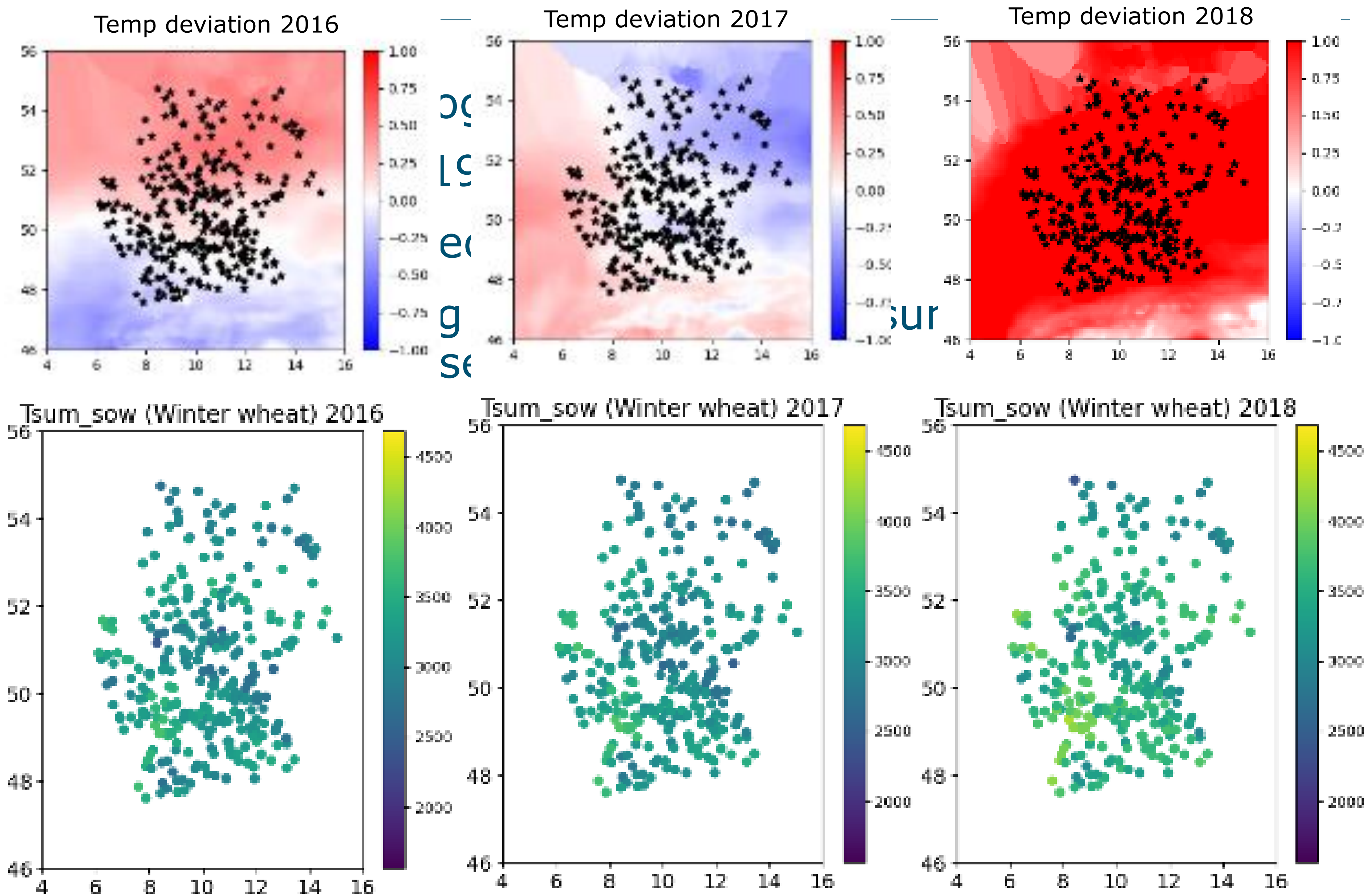
- Thermal sum approach
- $\tau_t = \sum_{k=t_0}^{t} \max((\theta_k - \theta_b), 0)$
  - τ_t: thermal time (in Celsius) over time t (day)
  - θ_k: daily mean air temperature at 2 meters
  - θ_b: base temperature (0 degree Celsius)
  - t_0: starting time of calculation 1 January
- Once the reference thermal sum for sowing (τ_{ref}) is exceeded, sowing is assumed to occur.

Fertilization day vs sowing day	Slurry app.	Solid manure app.	Fertilizer 1st app. (20%)	Fertilizer 2nd app. (80%)
Spring crops	5 days prior to sowing	5 days prior to sowing	5 days prior to sowing	after 20 % of the growing season has elapsed
Winter crops	start of the growing season	5 days prior to sowing	start of the growing season	

The Dynamic Agricultural Practices PrEdictoR (DAPPER): Overview

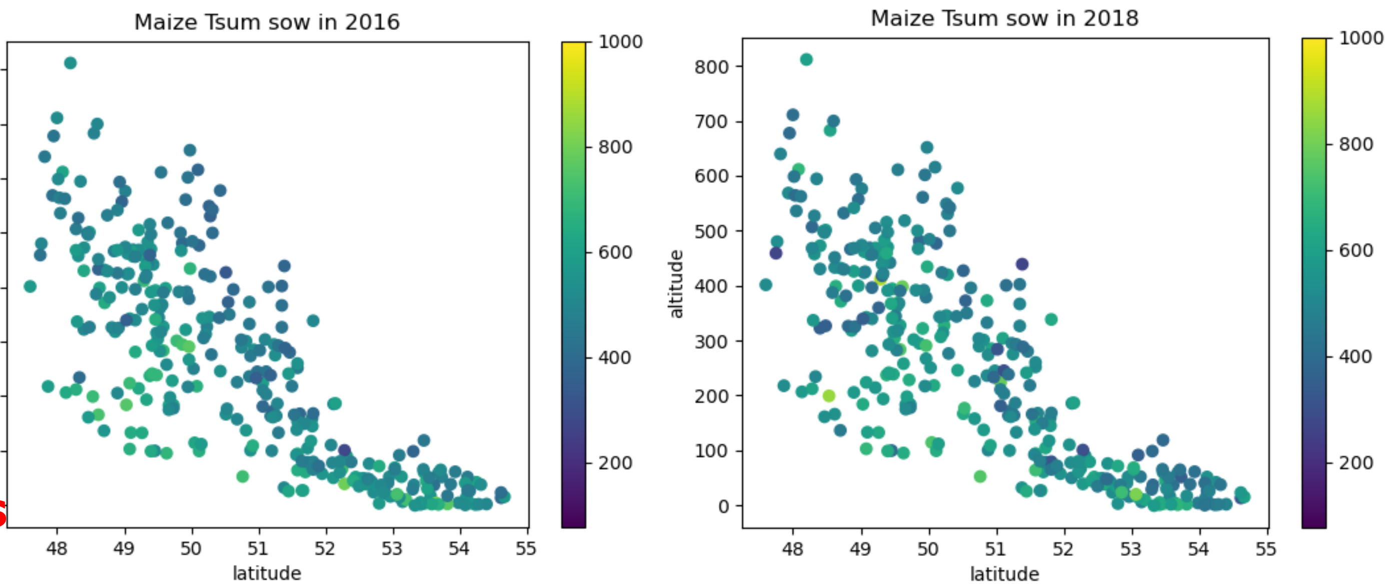


Sowing Tsum vs Mean temperature



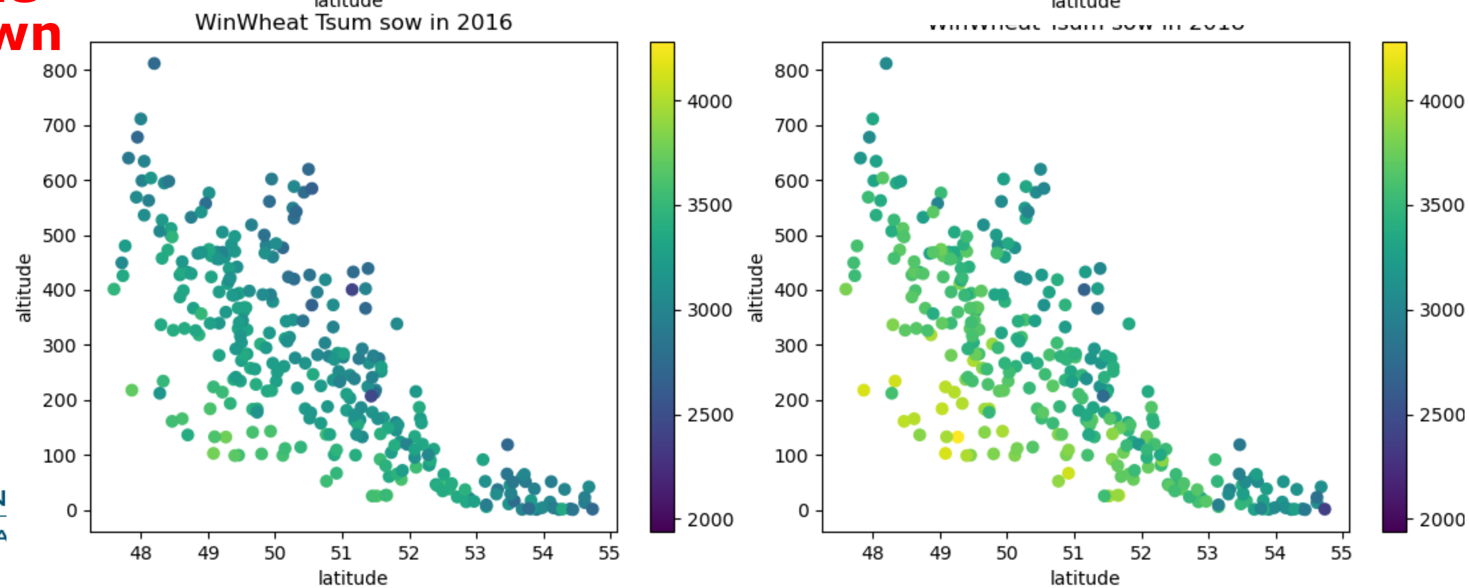
DAPPER: Latitude and altitude

- Maize



Impact of temperature is less obvious on maize because it is sown early in a year

- WinWheat



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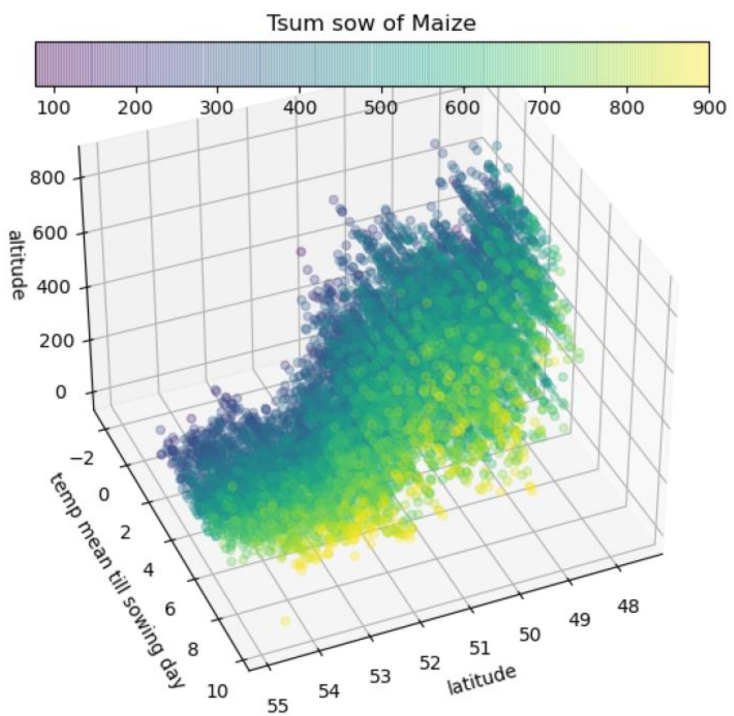
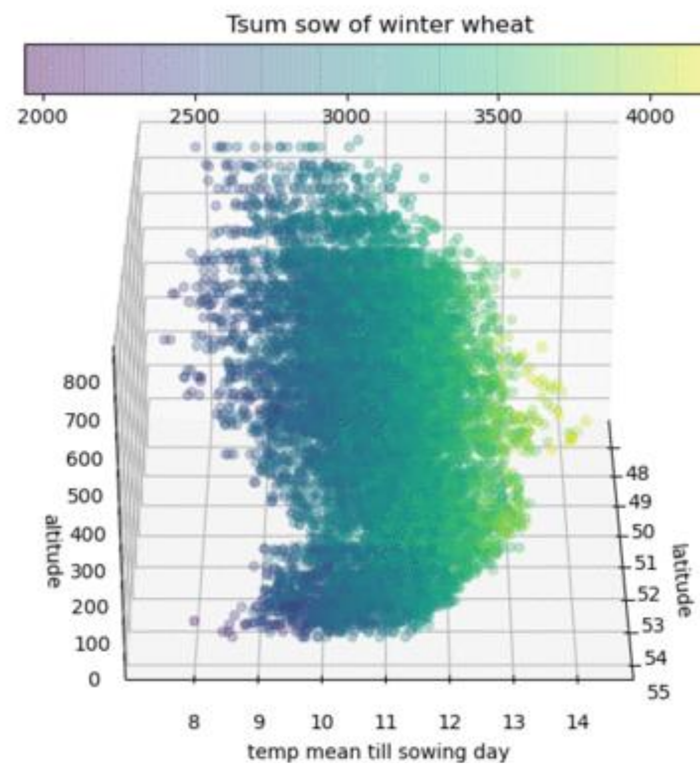
DAPPER: Machine learning

- Besides latitude and altitude, mean temperature from day 1 to the mean sowing day from 2003-2019 was introduced, as an indicator of how warm that year is
- Range: Latitude (47.6~54.9), Altitude (-1.7~811.7), Mean temp (7.4~14.4)

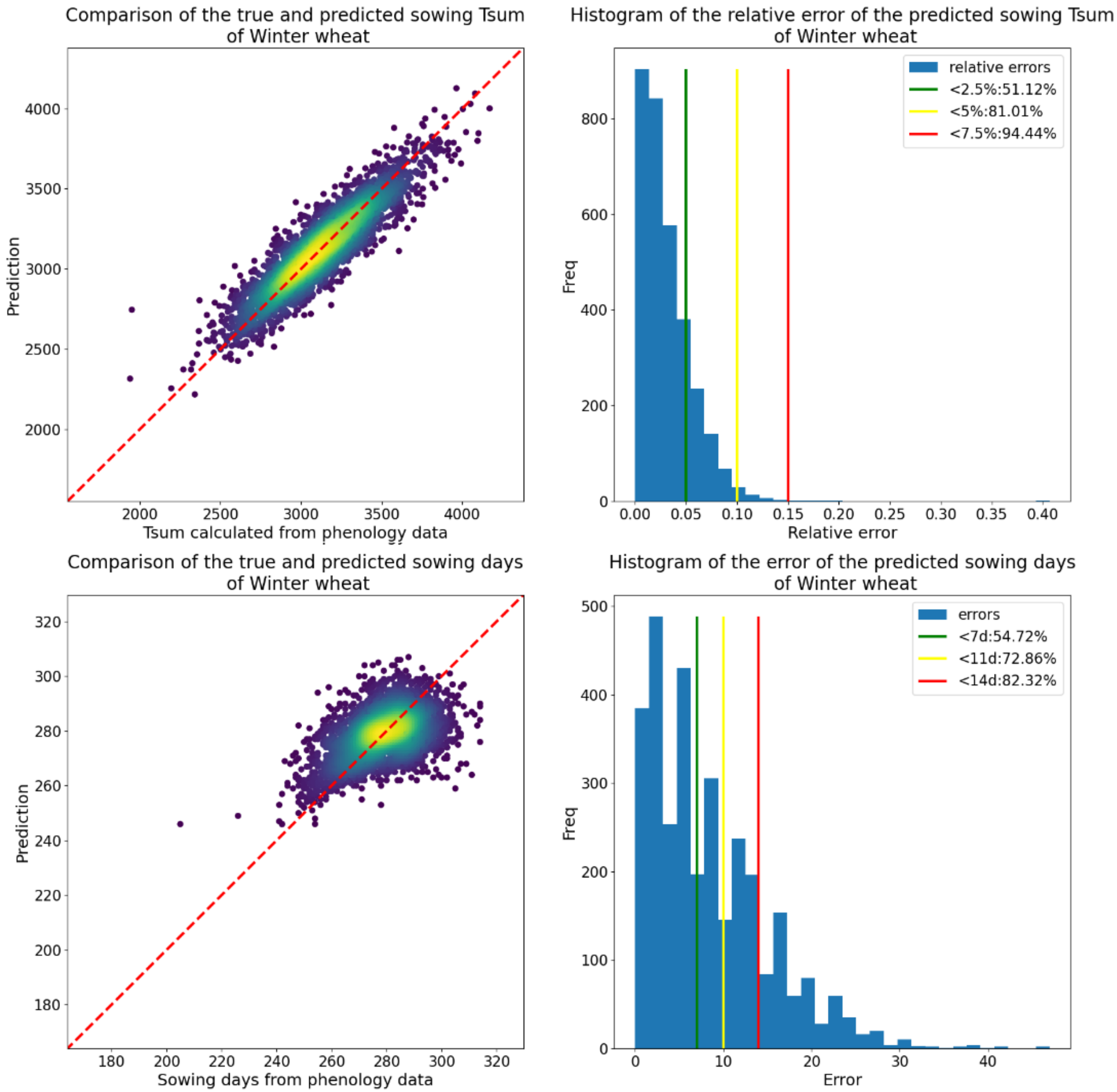




Random forest: 75% as training set, the rest 25% as test set

DAPPER: Machine learning validation

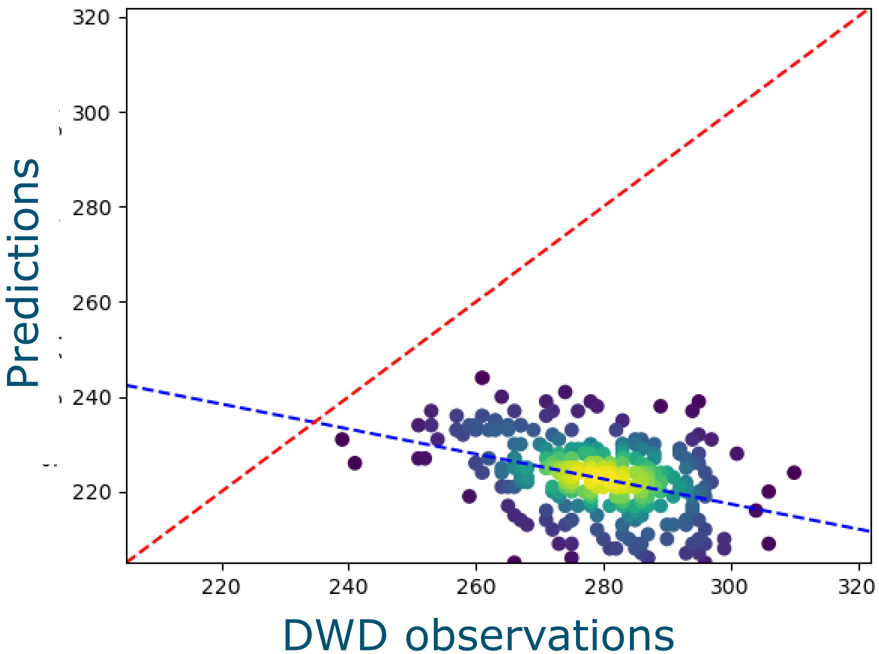
Winter wheat



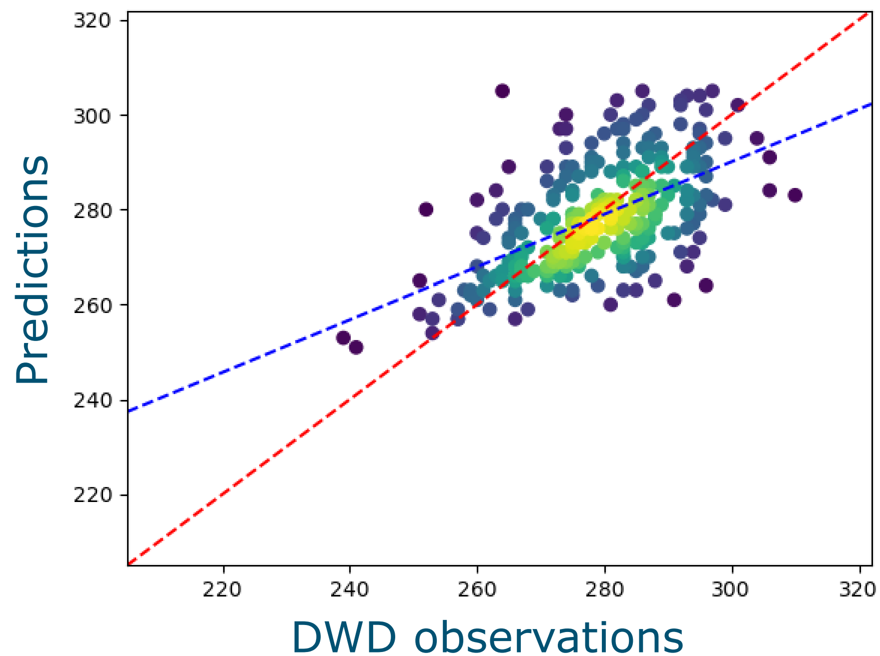
DAPPER: Predict sowing day in 2020

Winter wheat

Predictions using the available reference Tsum database

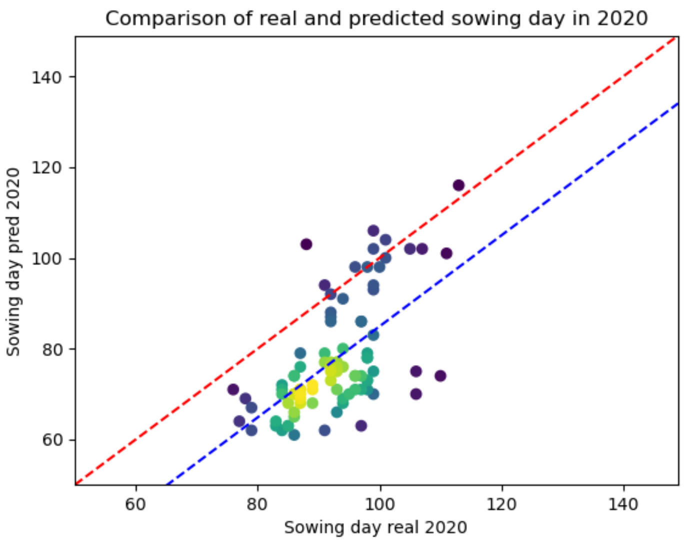


New predictions

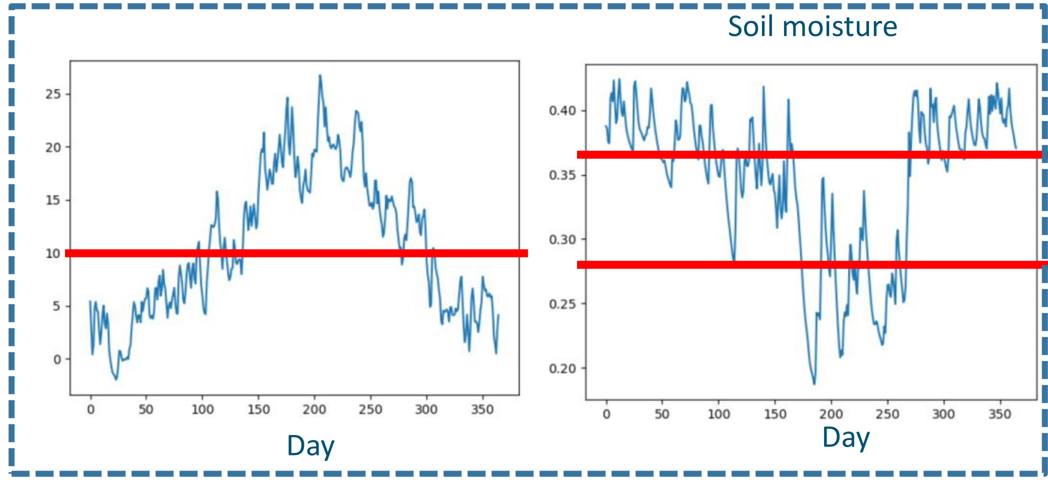


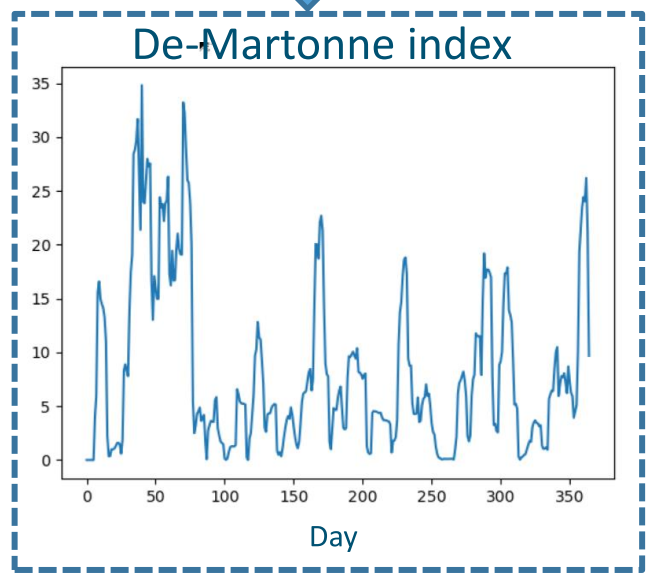
DAPPER: Add other constraints

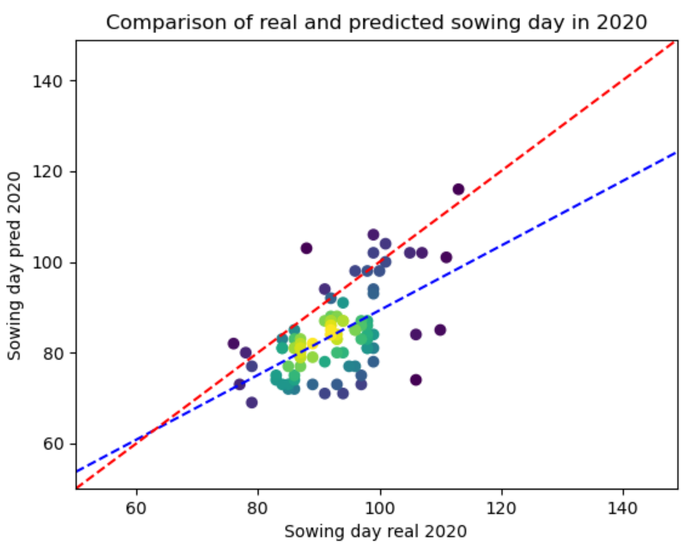
Sugar beet



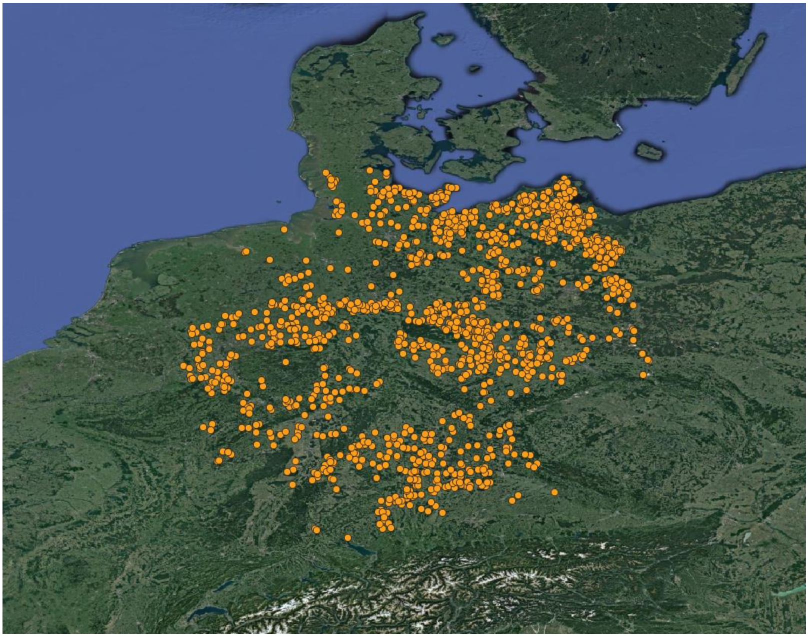
Soil constraint







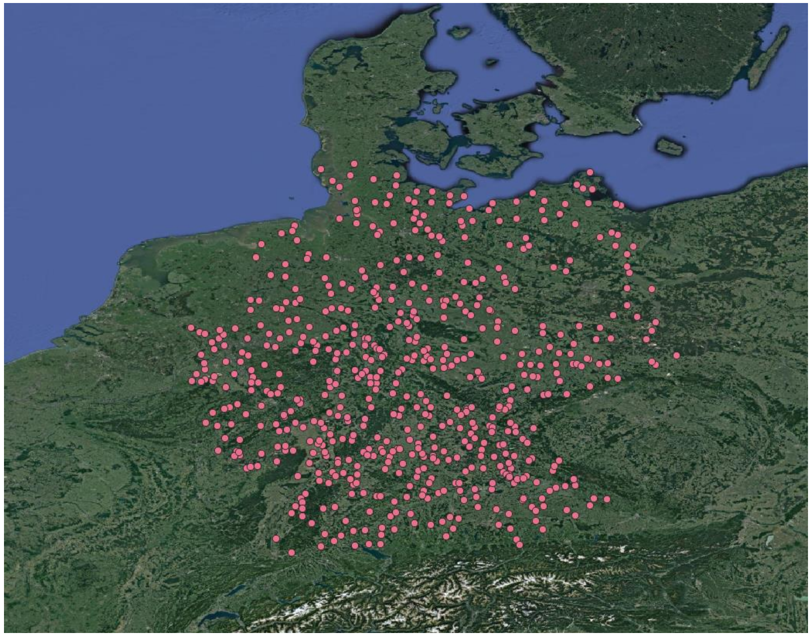
DAPPER: Expanding training set



LUCAS in-situ land use
2018 & Sentinel-2 NDVI

↓

Used to obtain NDVI time
series of a given crop



Any phenology data

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Sowing day

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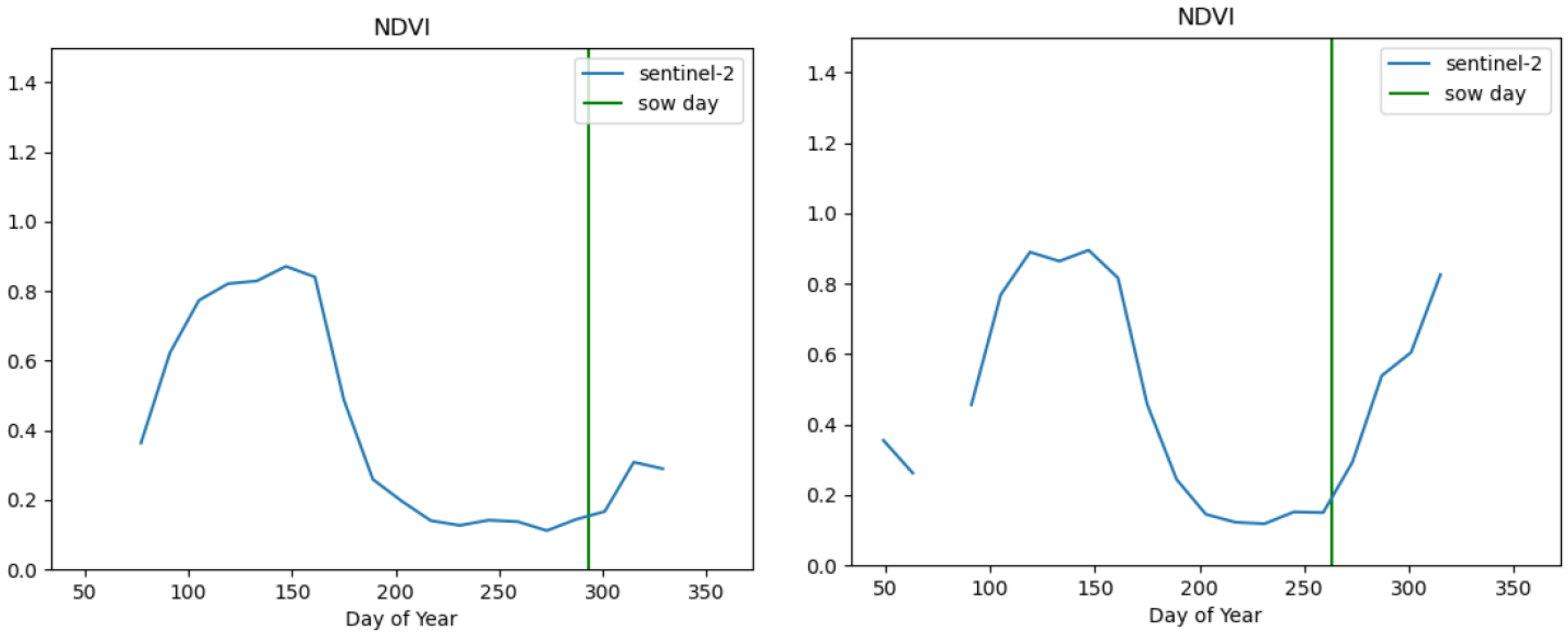
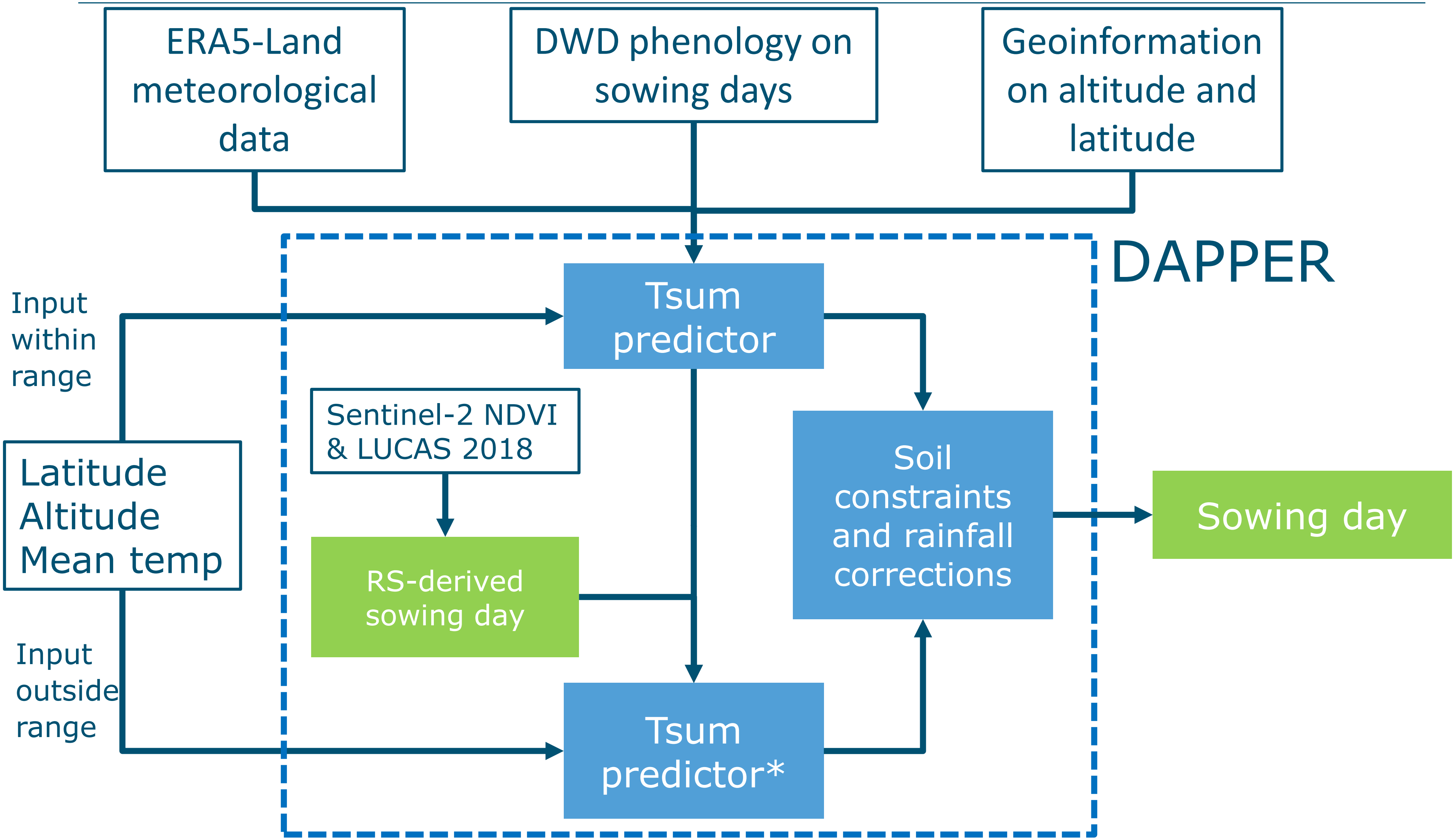
DAPPER: Expanding training set

NDVI time series on winter wheat



LUCAS in-situ land use 2018 + Sentinel-2 NDVI time series → Sowing days

The Dynamic Agricultural Practices PrEdictoR (DAPPER): Updated overview



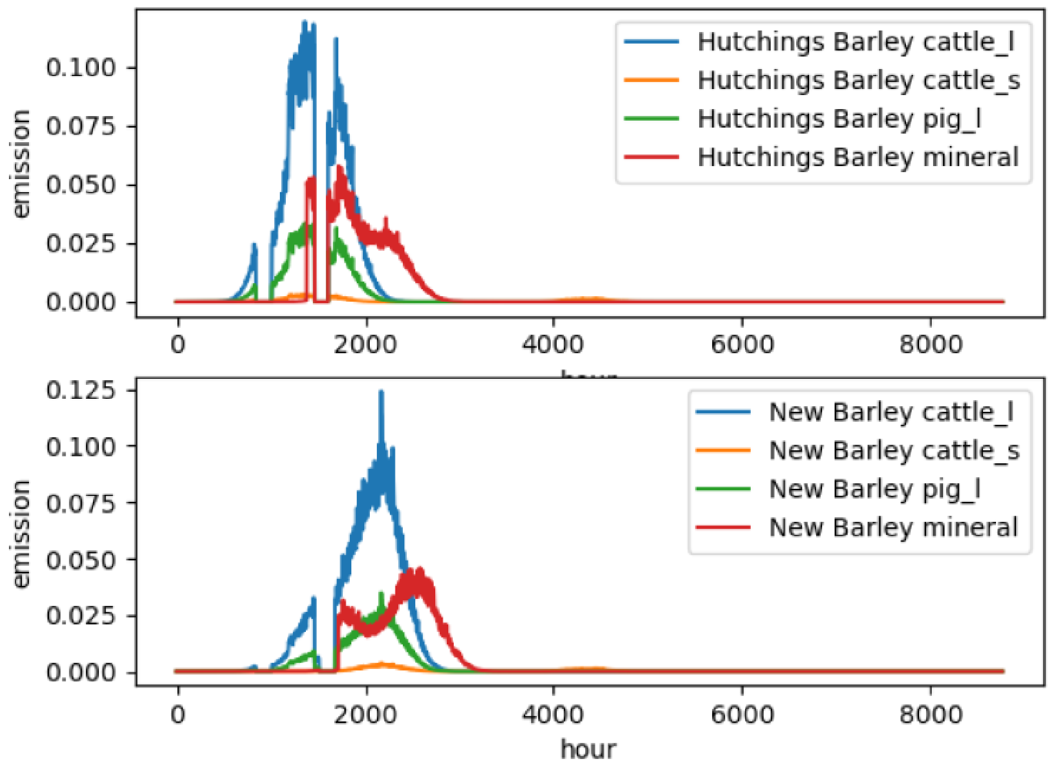
Sowing days impact on ammonia emission

- The Netherlands in 2017 as test case (more measurements)
- Used as input in the chemistry transport model LOTOS-EUROS to derive surface concentrations

Sowing day predictions at a Dutch location in 2017

Sowing day	Updated	Old
Maize	111	114
SpBarl	87	54
Sunflower	112	82
WinBarl	270	276
WinRape	234	211
WinWheat	286	272
SugBeet	99	81

Time series of ammonia emission from fertilization at a Dutch location



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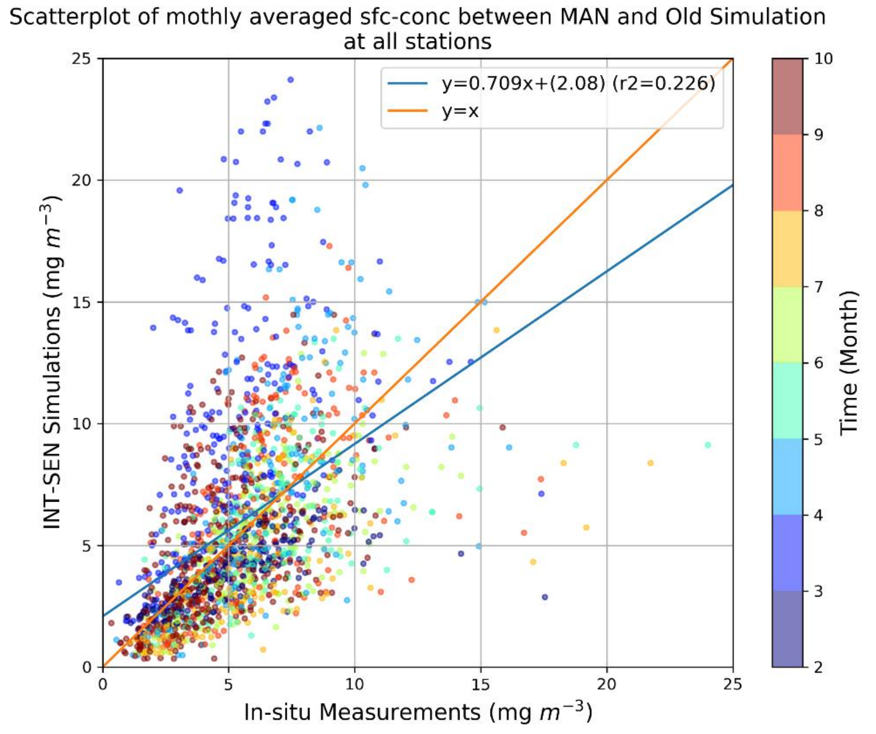
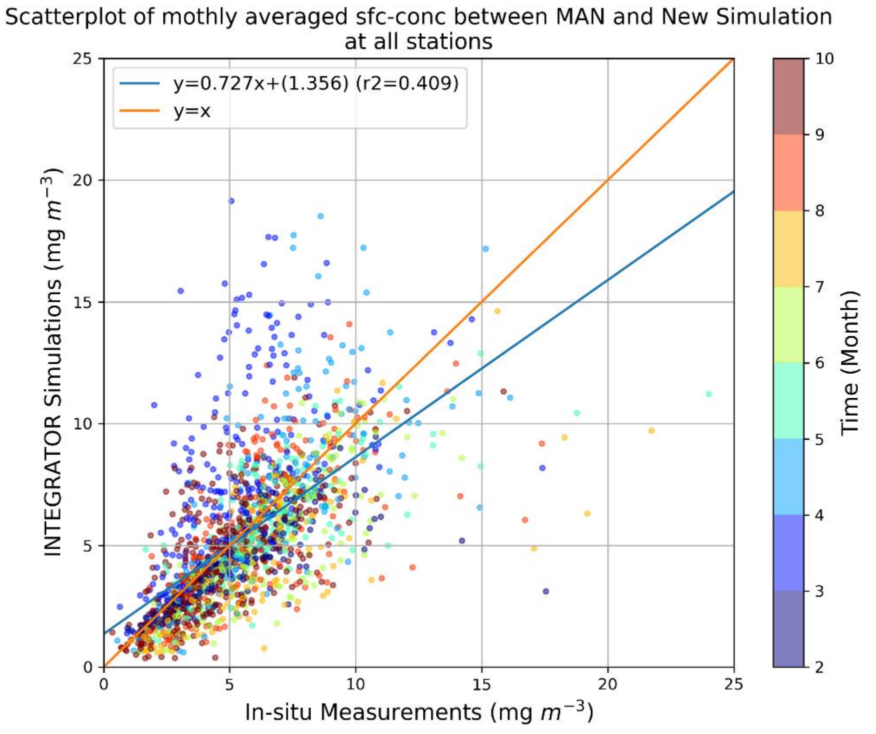
Ammonia surface concentration: comparison with in-situ measurements

- Measuring Ammonia in Nature (MAN)
- 280 locations in nature reserve areas
- Monthly temporal resolution

Measurements with higher temporal resolution in agricultural areas are needed!!!





Conclusion and Outlook

- The DAPPER model can efficiently and rapidly predict sowing day with mean temperature, latitude and altitude information.
- Soil property, precipitation and temperature data are important to refine the prediction of sowing days.
- Crop phenology derivation from Sentinel-2 satellite imagery is helpful to add more machine learning training database to ML database.
- The update/improvement in sowing day estimates has an large impact on the temporal distribution of ammonia emissions.
- In-situ measurements with higher temporal resolution in agricultural areas are needed to see the improvements in the temporal allocation of ammonia emissions.

Thank you!

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