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Leveraging Sentinel-1 SAR and AI for High-Resolution Crop Phenology Monitoring

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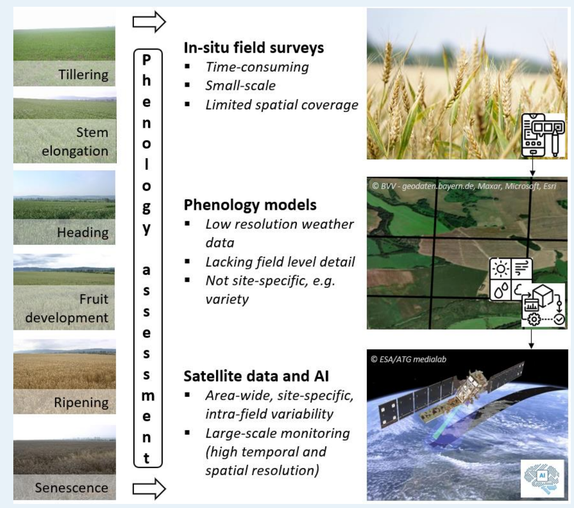
Motivation

- Sustainable agriculture: crop phenology monitoring is crucial, e.g. for optimal timing of fertilization and pesticide applications as well as for crop yield estimations.
- Common practice to collect data on crop growth stage (figure right): (1) in-situ field surveys and (2) ontogenesis models → area-wide detailed analyses of individual fields or site-specific assessments are not feasible.

GeoProg project objectives

Improvement of forecast models and decision support systems (DSS) by integrating high-resolution Earth observation (EO) data and AI-optimized methods.

Poster: Use case crop phenology | Optimize SIMONTO phenology model by EO and AI



Data

Satellite data

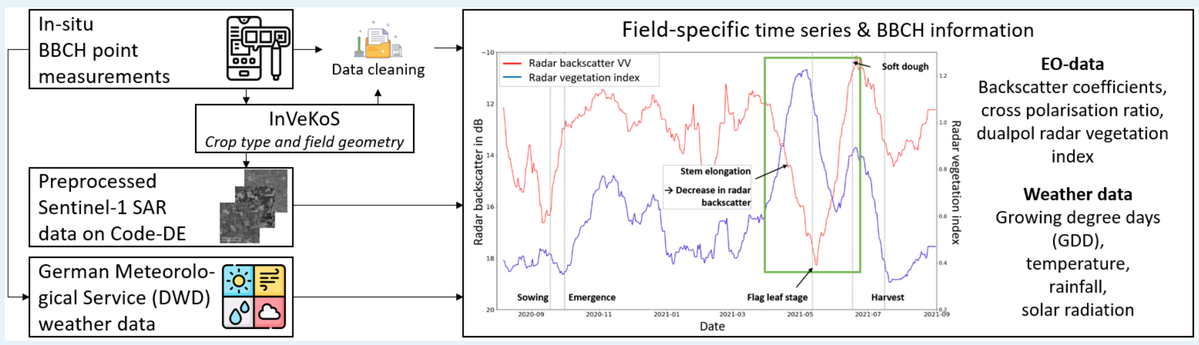
- Sentinel-1 SAR data on Code-DE
- All weather capability
- Sensitive to crop geometry, e.g. stem elongation, flag leaf & ear development

Phenological in-situ data

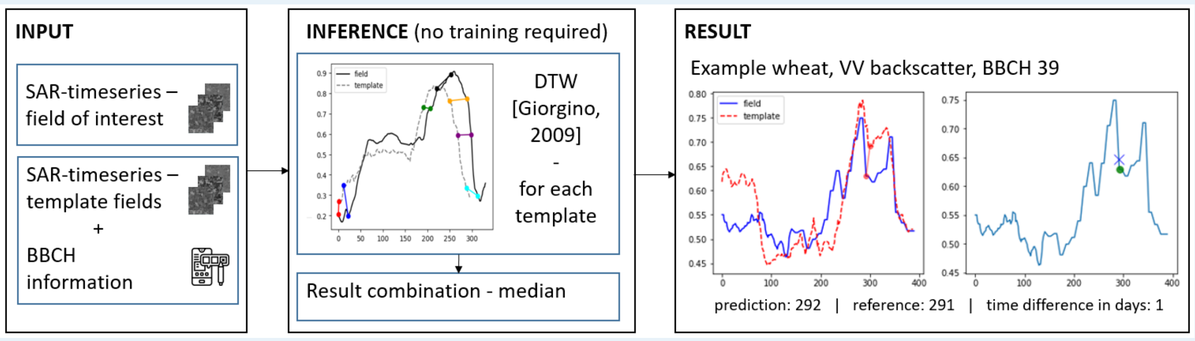
- Germany-wide field observations: standardized BBCH scale
- Oilseed rape, wheat and barley
- Sources: ISIP e.V., plant protection services of the German federal states (PIAF data), Vereinigte Hagel

Methodology

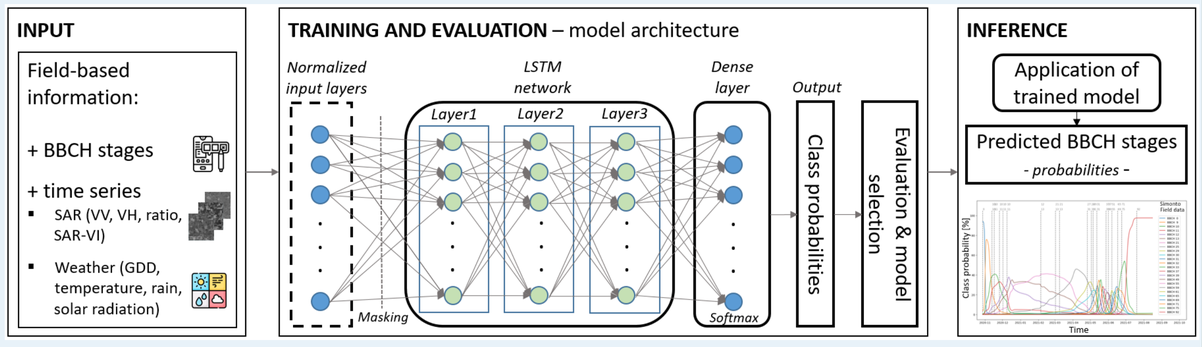
Input data preparation



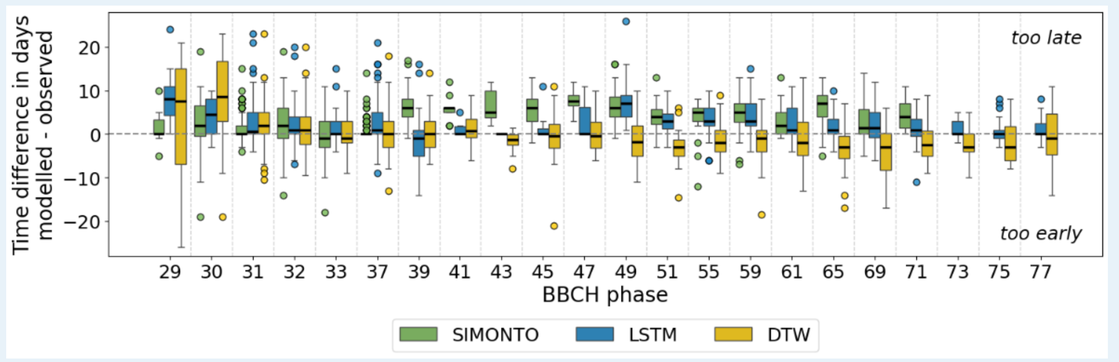
Method 1 – Dynamic time warping (DTW)



Method 2 – Long short-term memory model (LSTM)



Results

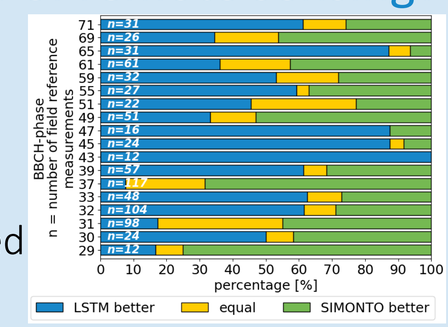


Modell results for cereals, > 10 fields for validation and > 50 for training per phase

- Preliminary results: S1 SAR data is promising tool – median absolute time difference between modelled and observed dates in days, n=793: SIMONTO: 2 | LSTM: 2 | DTW: 4
- Number of microstages: cereals LSTM 40; DTW 59 | oilseed rape LSTM 20; DTW 51 (missing stages due to limited in-situ data)
- Especially for late leaf development/tillering (winter months): insufficient results
- LSTM outperforms DTW, but less phases due to need of extensive training data; LSTM: near real-time, intra-season predictions
- Robustness / stability test: cross-validation, application to different seasons and data sources

Is it possible to improve current phenology models, in particular SIMONTO, by means of remote sensing?

- Improvement for individual phases
- Additional phases, EO whole season
  - SIMONTO cereals stops with BBCH 71
  - SIMONTO rape BBCH ranges: 55-75
- Comprehensive, spatially differentiated information for entire field / region



What's new or covered in very few EO studies only?

Intra-season | AI approach | daily BBCH microstages

Outlook

- Access to extensive training data: (1) Optimize model architecture (2) prediction of additional phases / crop types , (3) optimal parameter selection
- Integration of further data, e.g. optical data, soil moisture, terrain
- Integration in SIMONTO

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