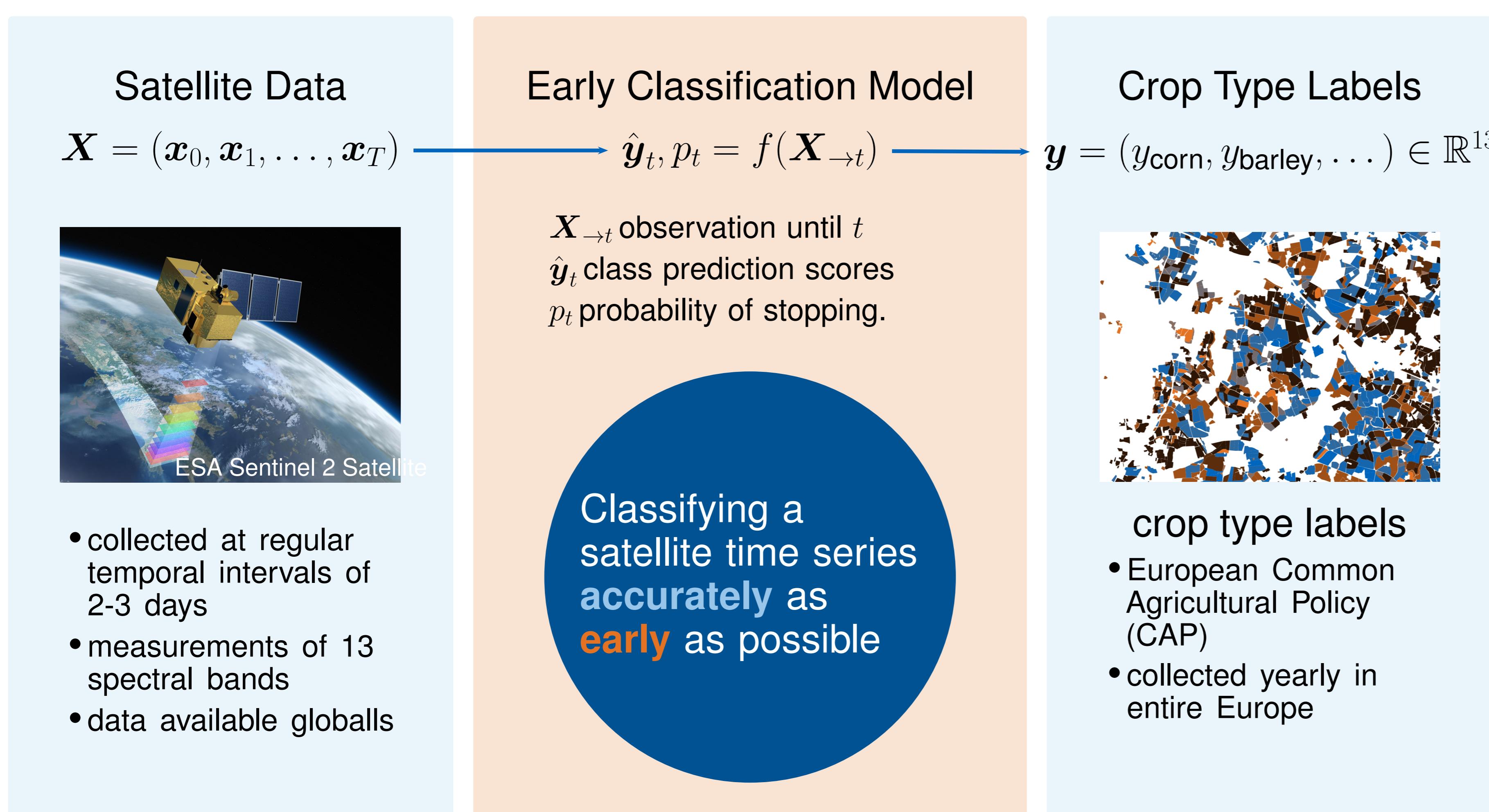


# Early Classification for Agricultural Monitoring from Satellite Time Series

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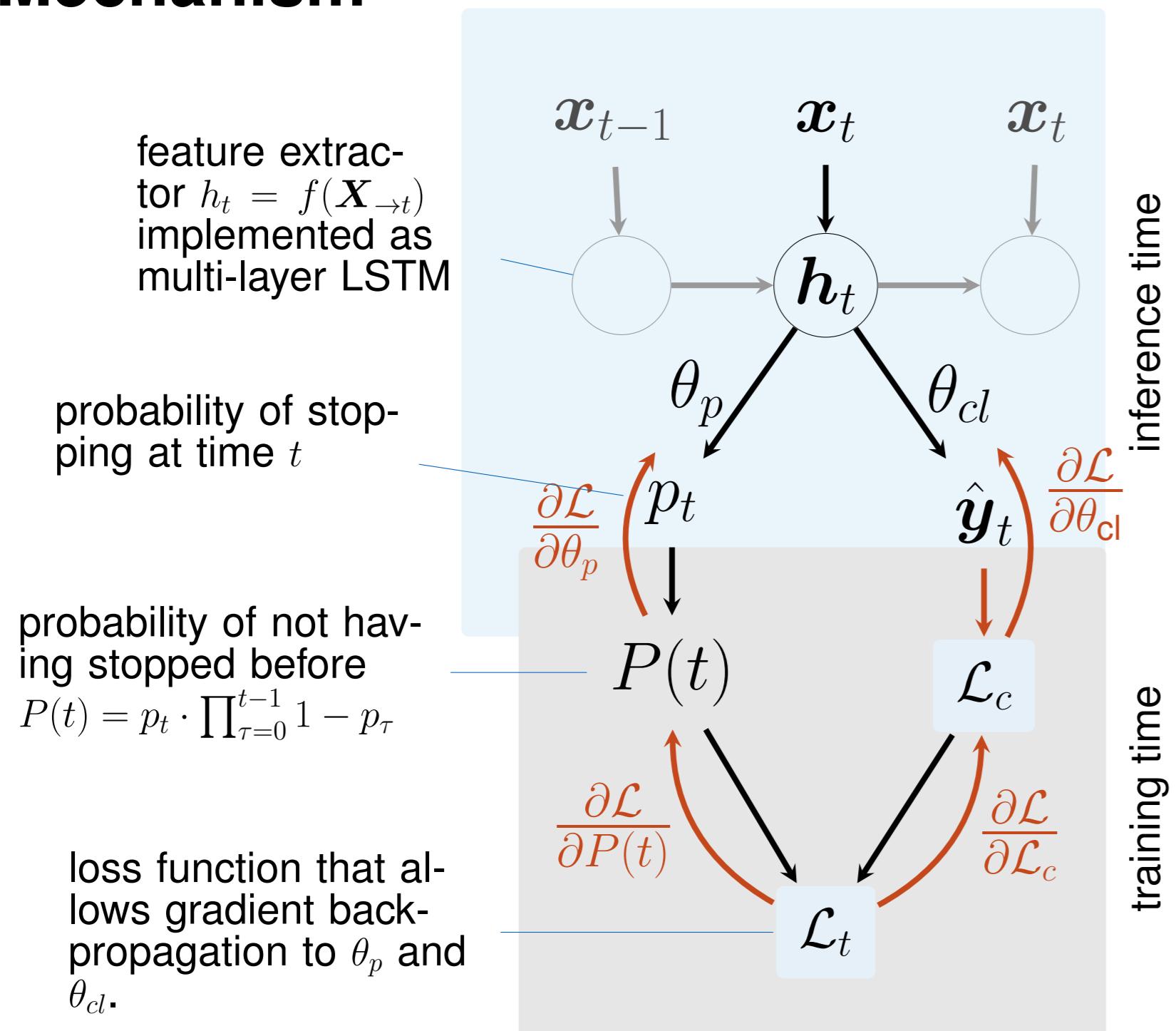
## Objective



## Method

Based on previous work (Rußwurm et al., 2019) applied to crop type mapping from remote sensing data.

### Mechanism



Rußwurm, M., Lefèvre, S., County, N., Emonet, R., Körner, M., and Tavenard, R. End-to-end learning for early classification of time series. arXiv preprint arXiv:1901.10681, 2019.

## Application

### Agriculture

#### Early Crop Detection

- early assessment of cultivated crops
- basis for early crop yield estimation

#### Extraction of Crop Phenology

- extraction of vegetation specific events
- monitoring time of classification
- regional or temporal variations

#### Generalization

- end-to-end trainable
- no region-specific expert knowledge
- applicable globally

### Loss function

composite loss function

$$\mathcal{L}(\mathbf{x}, \mathbf{y}) = \sum_{t=0}^T P(t; \delta_{\rightarrow t}) \mathcal{L}_t(\mathbf{X}_{\rightarrow t}, \mathbf{y})$$

A Loss function including accuracy and earliness

$$\mathcal{L}_t(\mathbf{X}_{\rightarrow t}, \mathbf{y}) = \alpha \mathcal{L}_c(\mathbf{X}_{\rightarrow t}, \mathbf{y}) - (1 - \alpha) \mathcal{R}_e(t, \hat{\mathbf{y}}_t^+)$$

$$\mathcal{L}_c = -\log(\hat{\mathbf{y}}_t^+)$$

cross entropy loss for accurate classifications

$$\mathcal{R}_e(t, \hat{\mathbf{y}}_t^+) = \hat{\mathbf{y}}_t^+ (1 - \frac{t}{T})$$

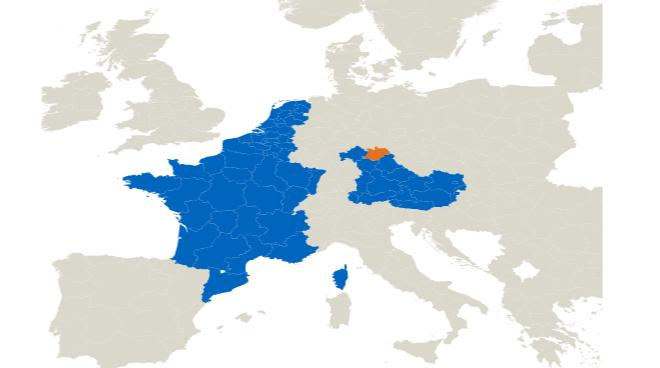
reduces loss for earlier classifications  $1 - \frac{t}{T}$  if the correct class  $\hat{\mathbf{y}}_t^+$  has been predicted

## Dataset and Area of Interest

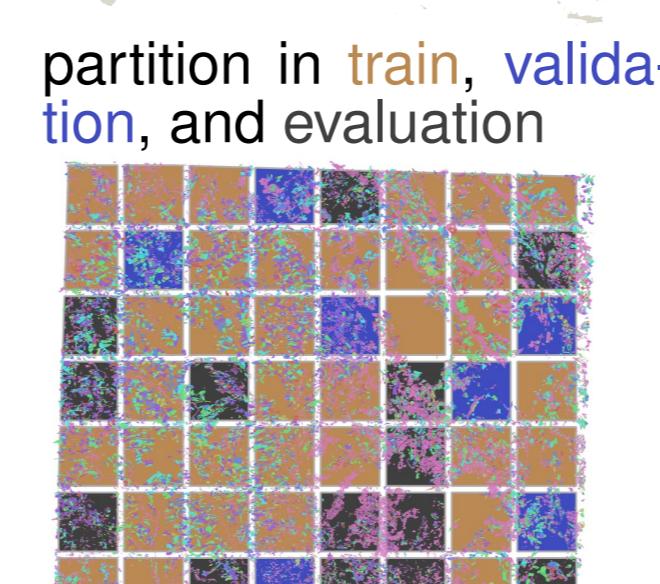
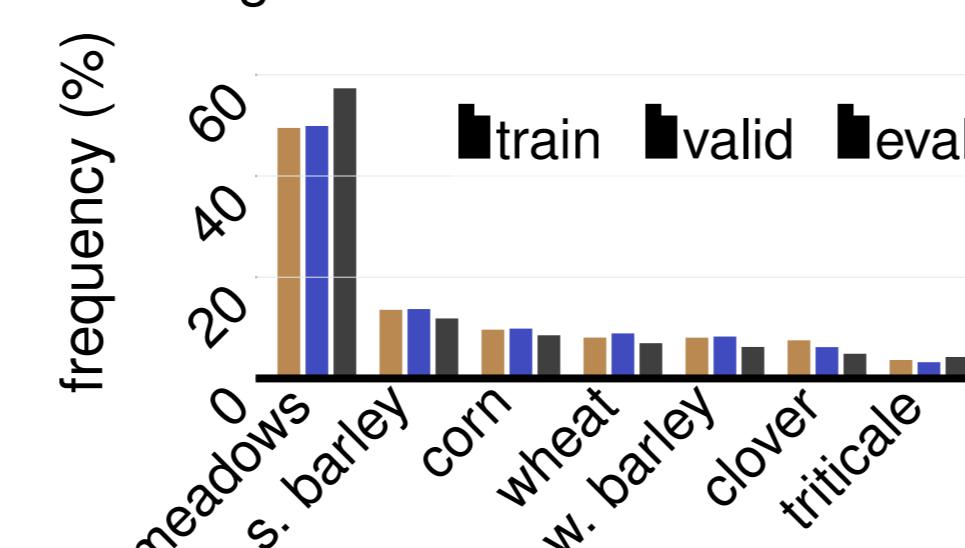
Hollfeld region Bavaria

- 49k field parcels
- 6 main crop types
- covering 40km by 30 km
- central Germany

regions with labels and location of dataset.



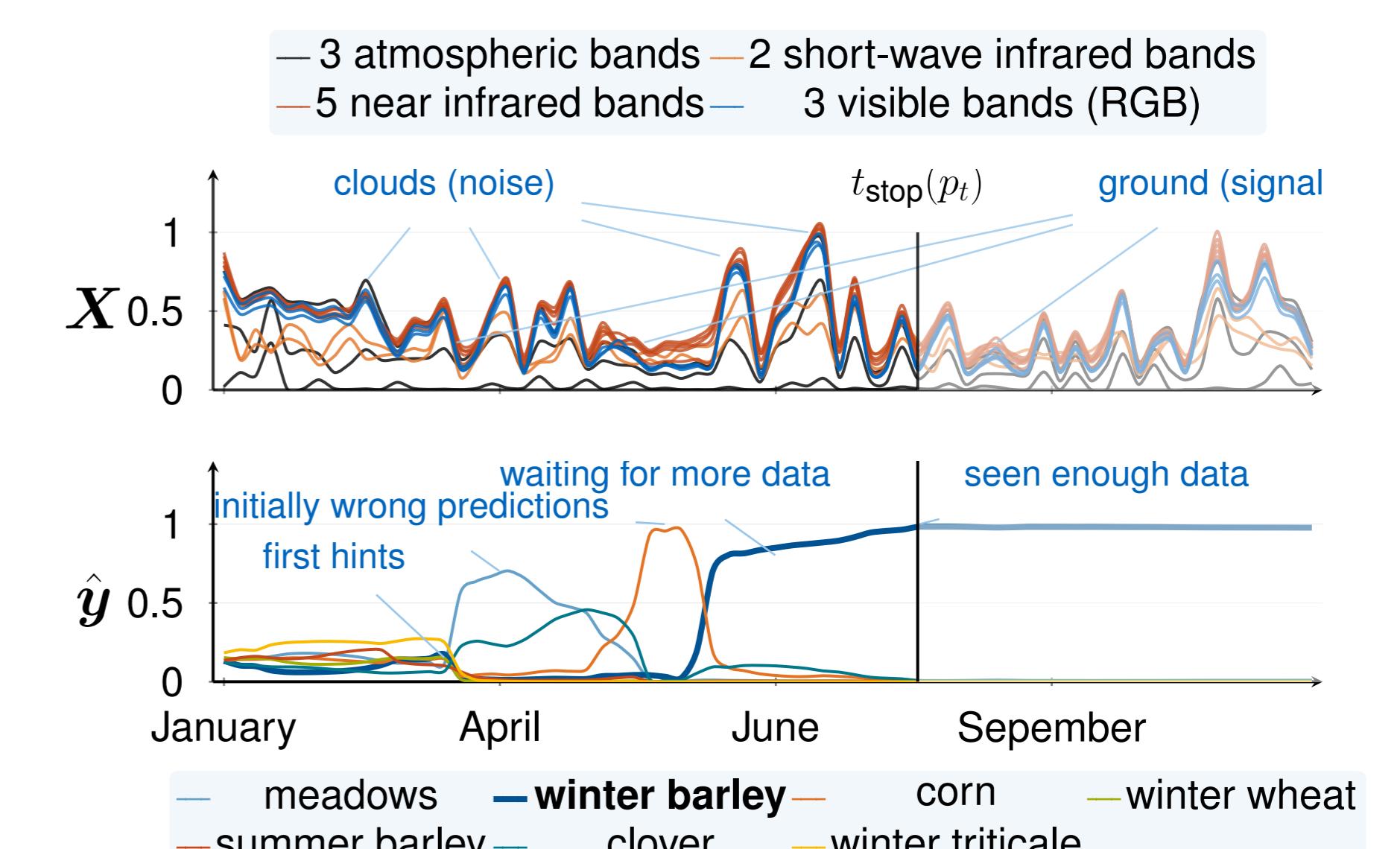
Challenge: Class imbalance



## Results

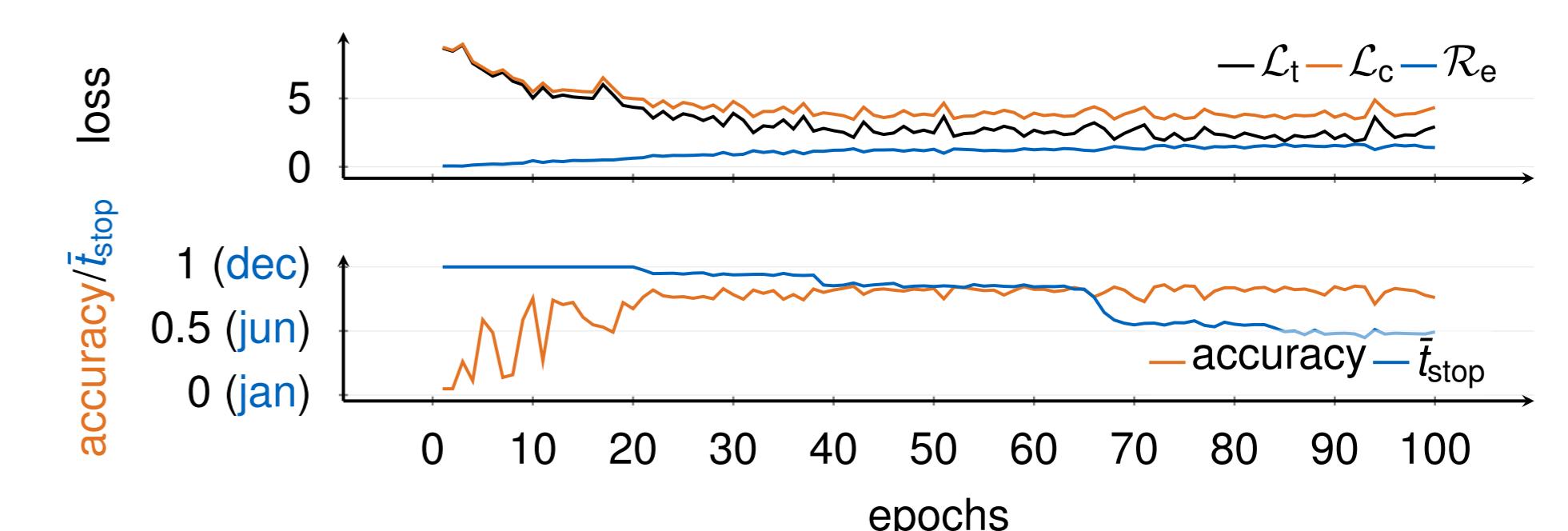
### Qualitative Example

Single example showing reflectance data  $\mathbf{X}$  and predictions  $\hat{\mathbf{y}}$  along with the stopping time  $t_{stop} \sim Ber(p_t)$ .



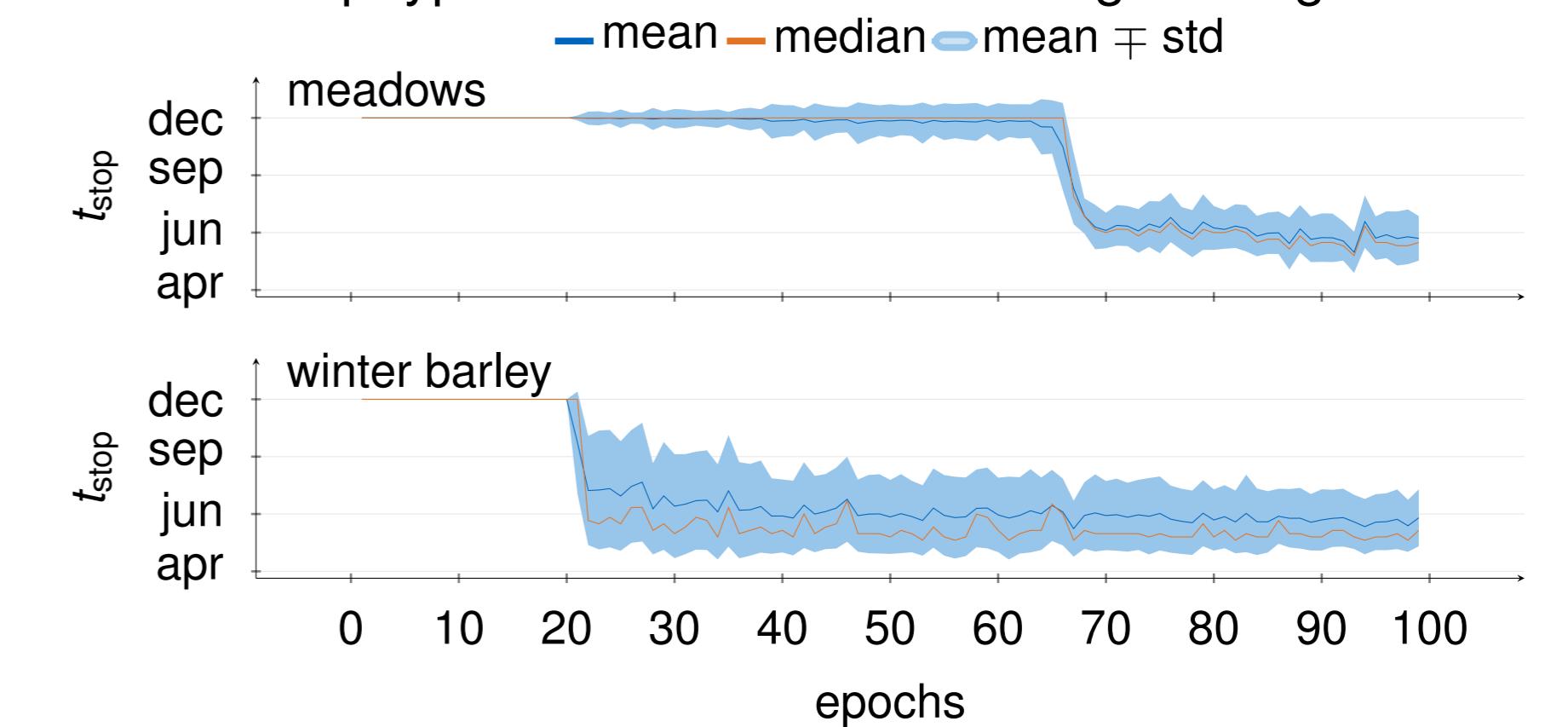
### Losses during Training

The combined loss  $\mathcal{L}_t$ , as well as earliness  $\mathcal{L}_e$  and accuracy  $\mathcal{R}_e$  losses during training.



### Stopping Condition Parameterization

Stopping times throughout the training grouped by crop category. The parameterization of early classification is learned for different crop types at different times during training.



### Balancing Earliness and Accuracy

Evaluating the effect of the trade-off parameter  $\alpha$  on the accuracy and earliness ( $t_{stop}$ ). Runs repeated three times to evaluated the stability of the results.

$\alpha$	accuracy	$\bar{t}_{stop}$	precision	recall	$f_1$	$\kappa$
.0	.25 ± .22	.10 ± .17	.19 ± .20	.25 ± .17	.16 ± .20	.12 ± .19
.2	.81 ± .03	.40 ± .02	.70 ± .01	.74 ± .01	.71 ± .01	.71 ± .04
.4	.80 ± .09	.47 ± .03	.71 ± .02	.74 ± .01	.71 ± .02	.71 ± .10
.6	.85 ± .02	.88 ± .07	.73 ± .04	.74 ± .03	.73 ± .03	.77 ± .03
.8	.84 ± .01	.93 ± .05	.72 ± .02	.75 ± .01	.73 ± .02	.76 ± .02
1.0	.83 ± .03	1.00 ± .00	.72 ± .03	.75 ± .01	.72 ± .03	.75 ± .04

### Extracting Vegetation Characteristics

Stopping time per crop category reveals characteristic variations in type of vegetation confirmed by date of harvest (▼) from local authorities.

