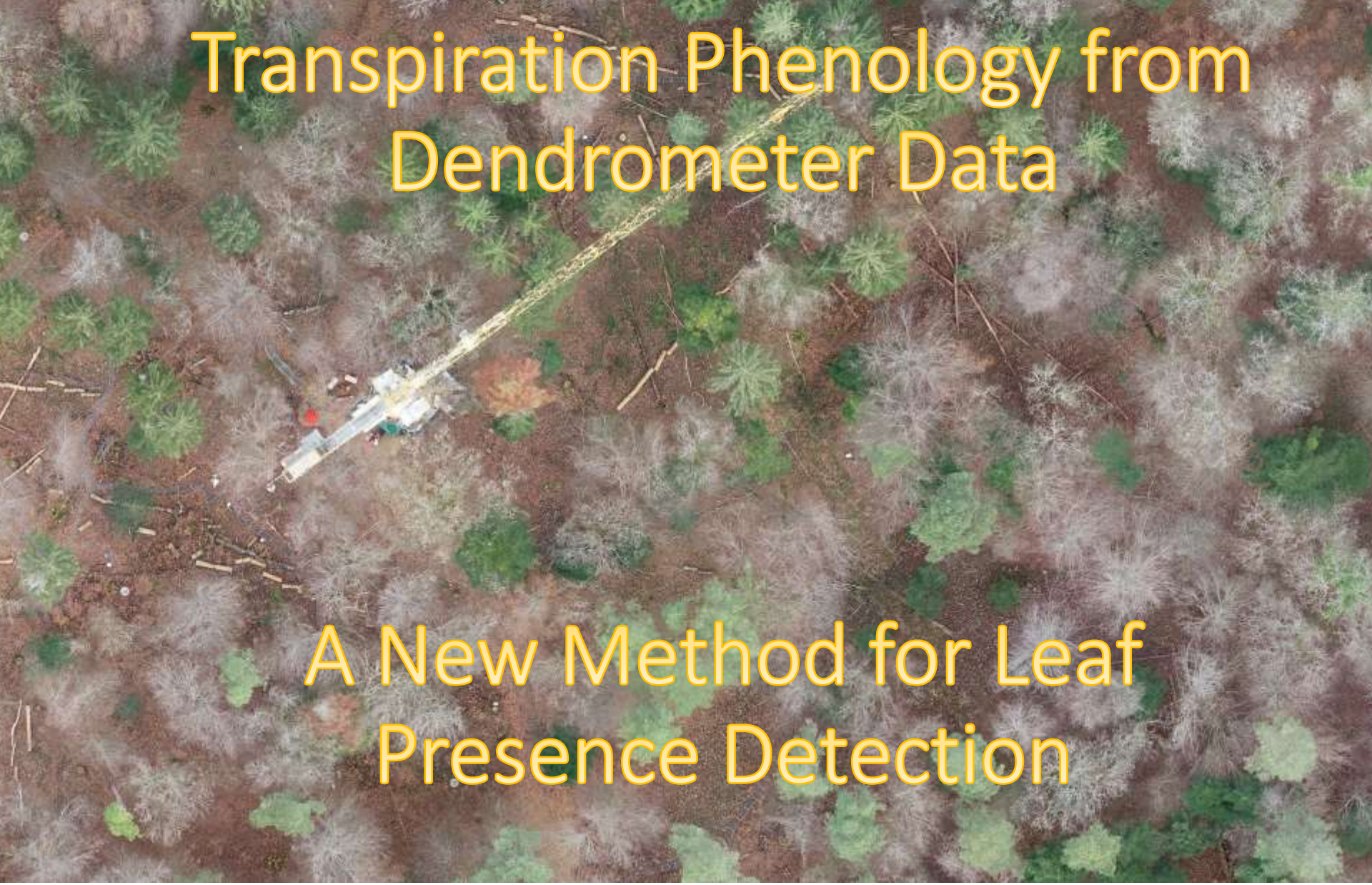
Transpiration Phenology from Dendrometer Data



A New Method for Leaf Presence Detection

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WSL

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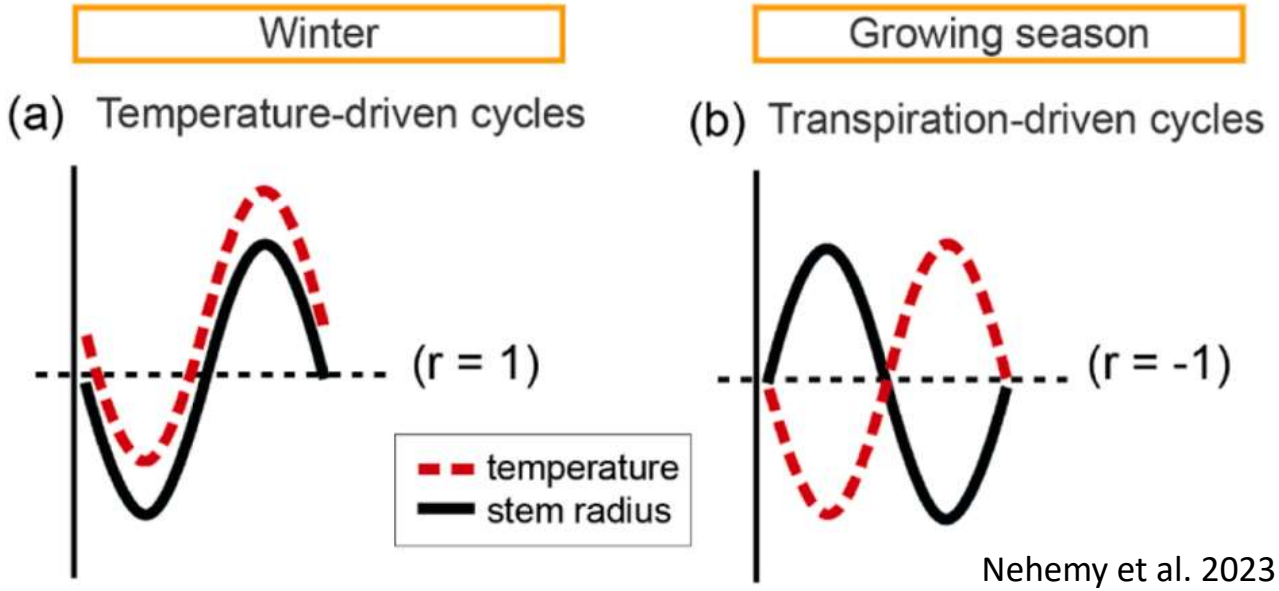
Dendrometer Capabilities

Seasonal signals are key to understanding carbon and water cycles, productivity, and climate change impacts.

Current Monitoring Gaps: Existing canopy phenology methods lack continuous, automated tree-level precision across larger areas.

- Growth
- Tree Water Deficit
- Water Potential
- Stomatal responses
- Seasonality of events

Theory of Daily Stem Radius Changes



Nehemy et al. 2023

Radius changes mirror temperature
- expands with warmth
- contracts with cold

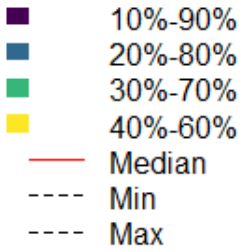
Radius changes driven by transpiration
- shrinks in day with water loss
- expands at night

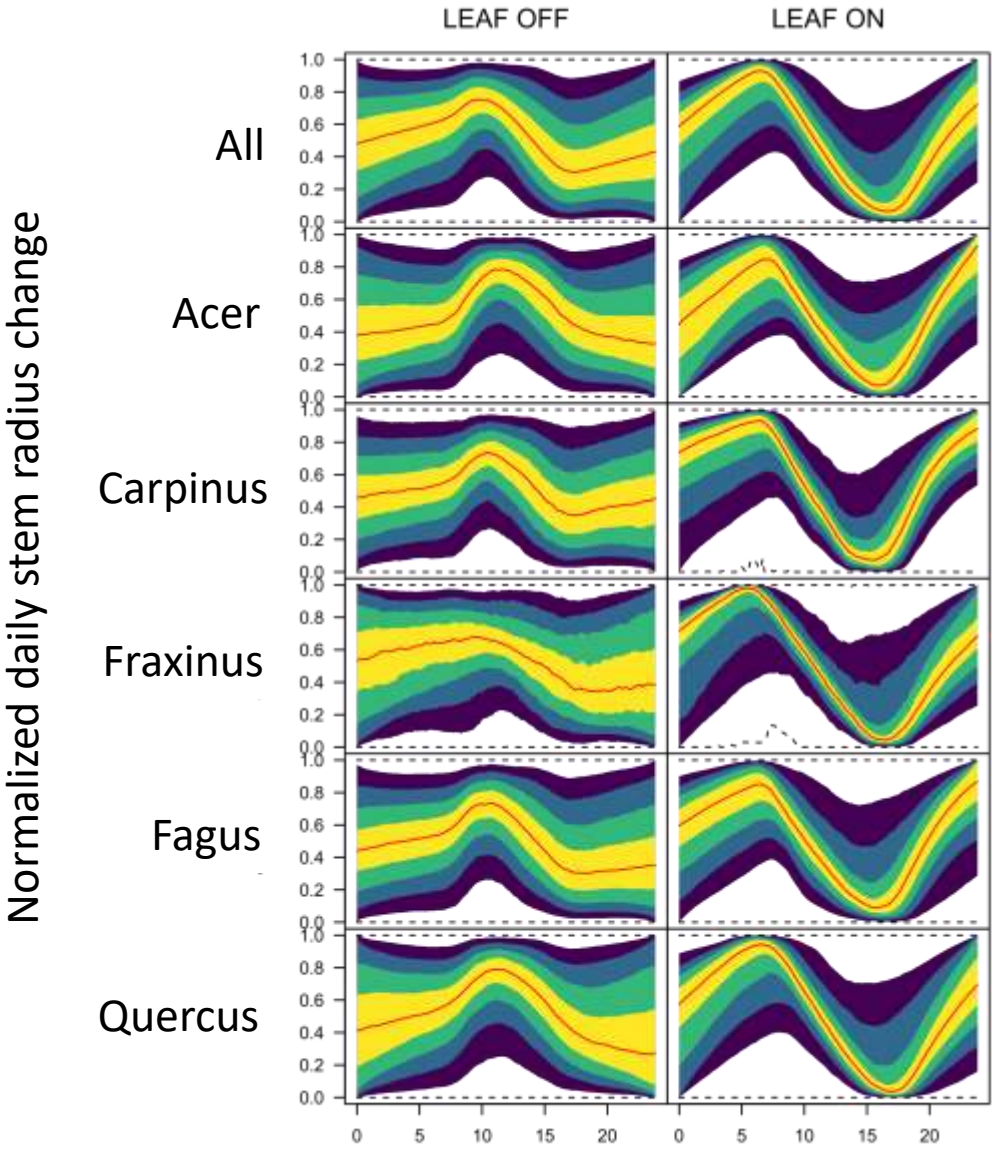
Previous implementations
Stem-Temp model (Nehemy et al. 2023)
Phase change (TreeNetProc)

Real Data

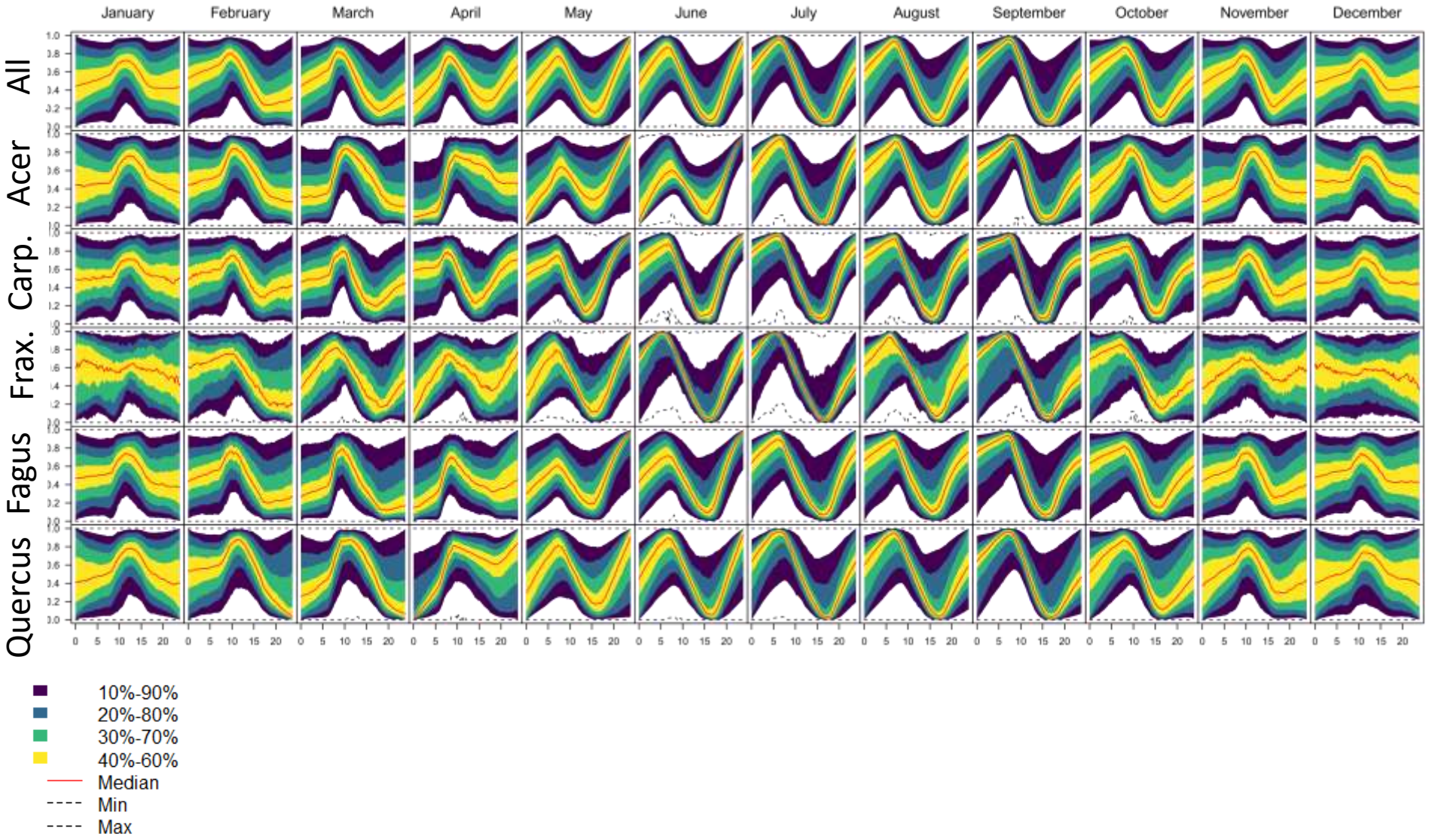
Swiss Canopy Crane II
Hölstein, Switzerland

- TreeNet SuperSite
- Established 2018
- Currently 76 Trees





Real data is more ambiguous



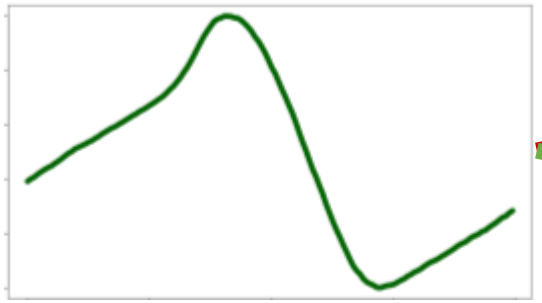
ML Classification Method & Feature Extraction

Direct Approach: Predict directly for time series

- Only one transition per year not enough training data

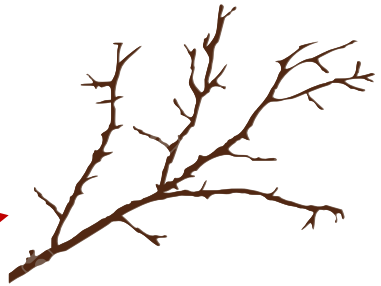
Indirect approach: Predict leaf presence from daily cycle (features)

- Binary Classification
- Enhanced method of previous phase detection approach



Daily cycle

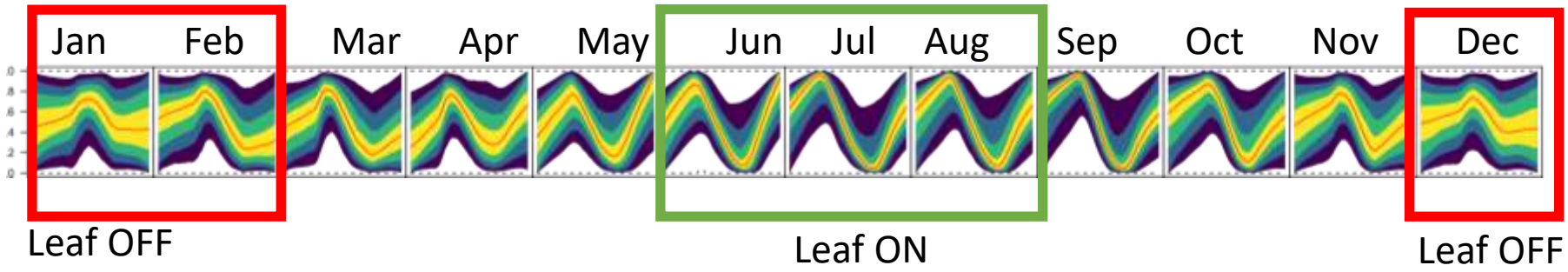
Binary Classification



Leaf off

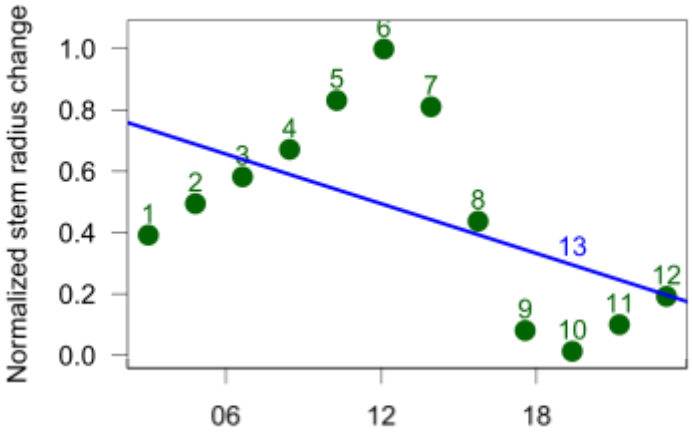
Leaf on

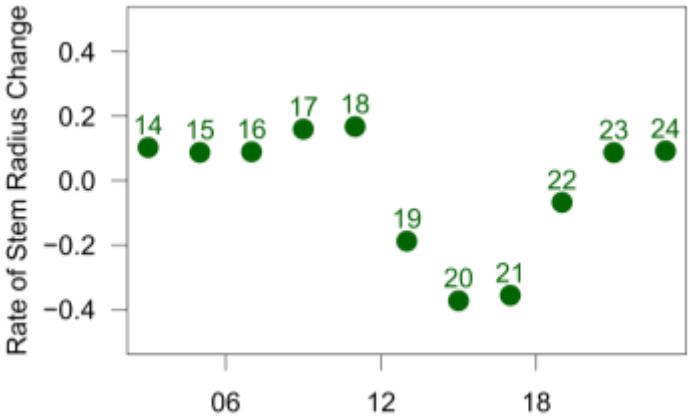
ML Classification Method & Feature Extraction



Day Cycles:	27’450 Training
	11’765 Testing
	5’676 Validation
Model:	XGBoost

Species	5
Trees	58
Features (initial)	42





- Normalized means
- Rates
- Species
- Period
- FFT decomp.

ML Model Accuracy & Time Series Conversion

Training

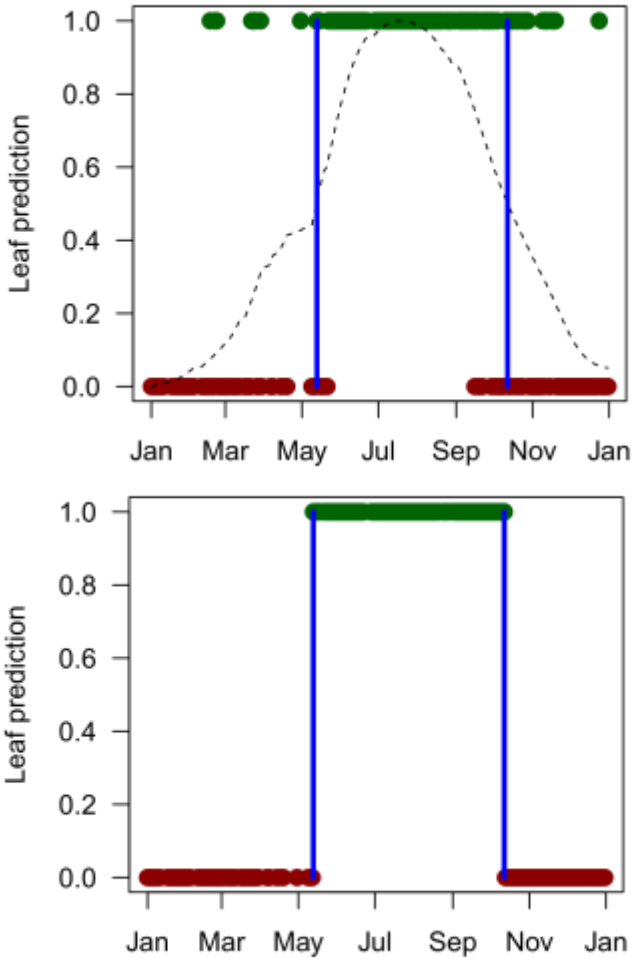
10-fold CV	Accuracy	F1
Mean	0.927	0.929
SD	0.005	0.004

Validation

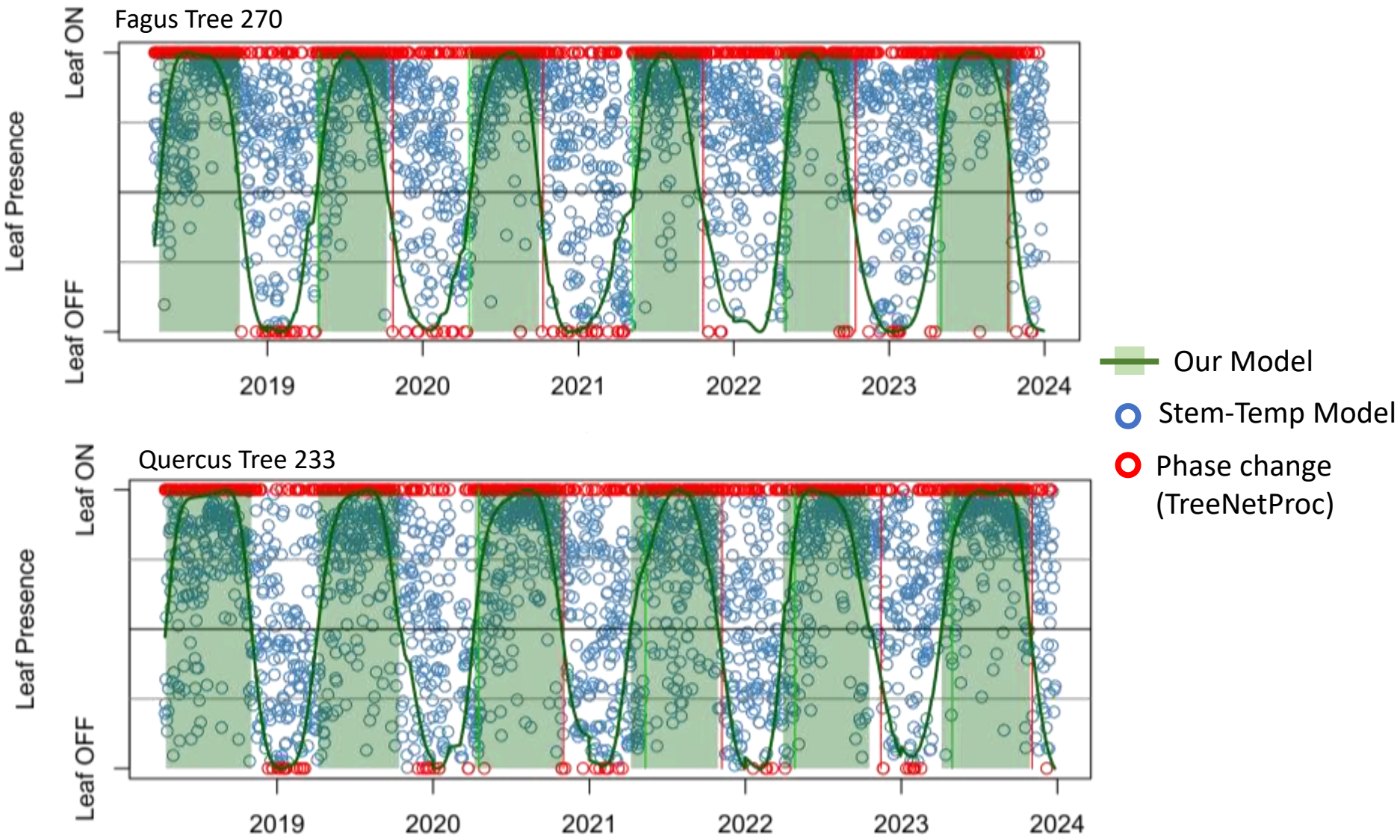
	Accuracy	F1
Overall	0.947	0.949
Acer	0.968	0.970
Fagus	0.916	0.923
Quercus	0.946	0.947

Removing ‘species’ category only affected accuracy by - 0.1%

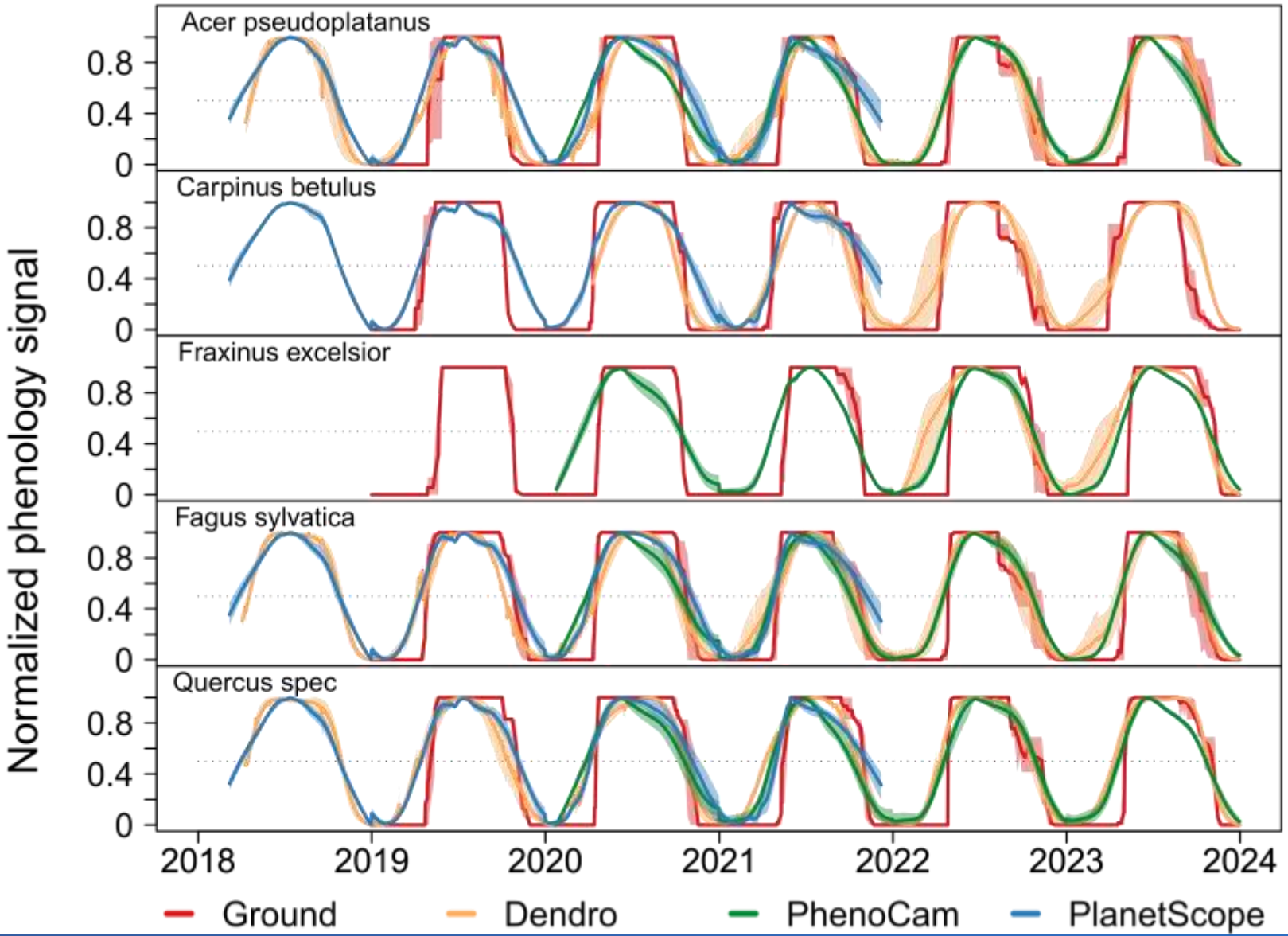
Generating time-series



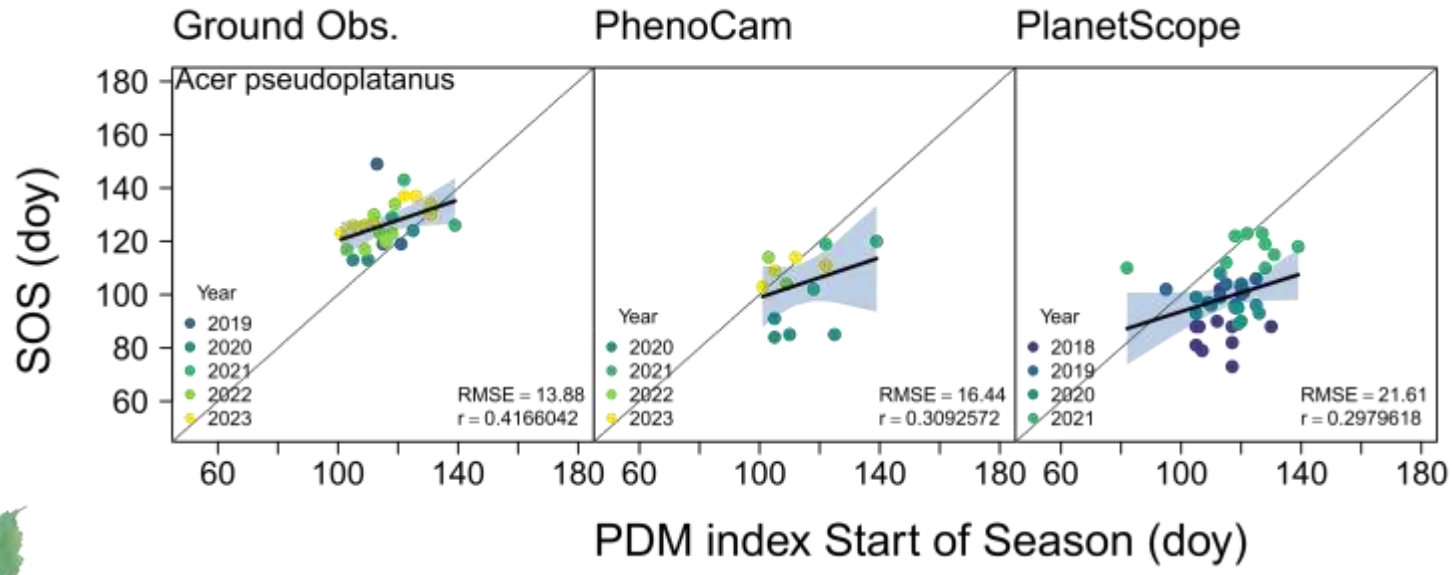
Comparison to Transpiration Phenology Metrics

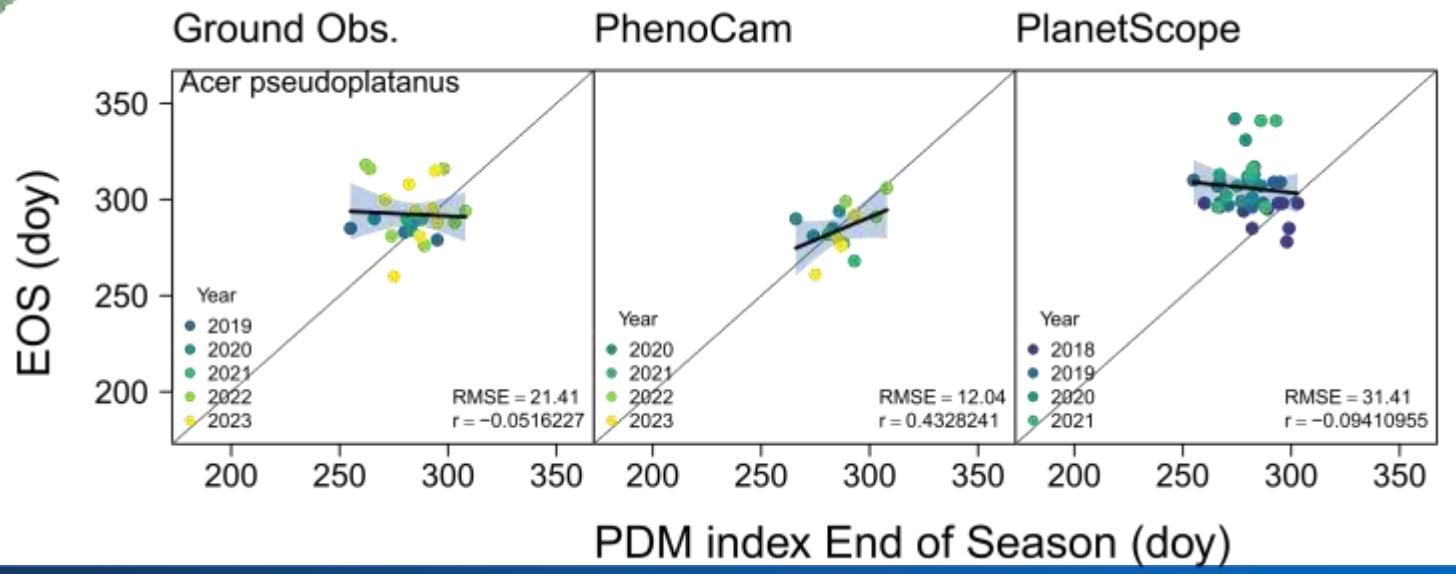


Comparison to Other Leaf Phenology Metrics



Comparison to Other Phenology Metrics





Sources of phenology observations

- Ground Observations
  - ⊕ Potentially very precise, individual trees
  - ⊖ Workload, temporal resolution, observer differences
- PhenoCam
  - ⊕ Automated, sub-daily resolution, individual trees
  - ⊖ Overlap with other trees, infrastructure
- Satellite remote sensing
  - ⊕ Automated, large spatial coverage, (individual trees)
  - ⊖ Understory, clouds
- Dendrometers (wood phenology)
  - ⊕ Automated, individual tree growth, tree water deficit
  - ⊕ Transpiration season as proxy for leaf phenology

Summary

- Daily Stem Patterns are known to be linked to transpiration cycles, but residual noise mask signals.
- ML model effectively classifies active vs. inactive seasons, serving as a proxy for leaf presence in broadleaf trees.
- ML model achieves > 90% accuracy for daily leaf presence estimation.
- Normalized daily variation makes it applicable across trees with different growth rates and max daily shrinkage (MDS).
- Transpiration Season: Closely aligns with, but differs slightly from, traditional leaf phenology methods.

Conclusions & Implications

- **Beyond Growth and TWD**: We can determine leaf presence from patterns of daily stem diameter variation
- **Enhanced Phenology**: Additional metric for insights into leaf cycles and “transpiration periods.”
- **Validated with other Data**: Matches roughly with PhenoCam, PlanetScope, and field observations.
- **Refined Fall Detection**: Captures fall transitions in physiology, offering a refined view of season length
- **Cost-Effective Tool**: A versatile, all-in-one sensor for forest monitoring.

Acknowledgements

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