whiffle

Ørsted

Bridging scales

Explicit forest representation for wind resource modelling

Ardjan Sturm, Andrew Davidson, Pim van Dorp

The problem

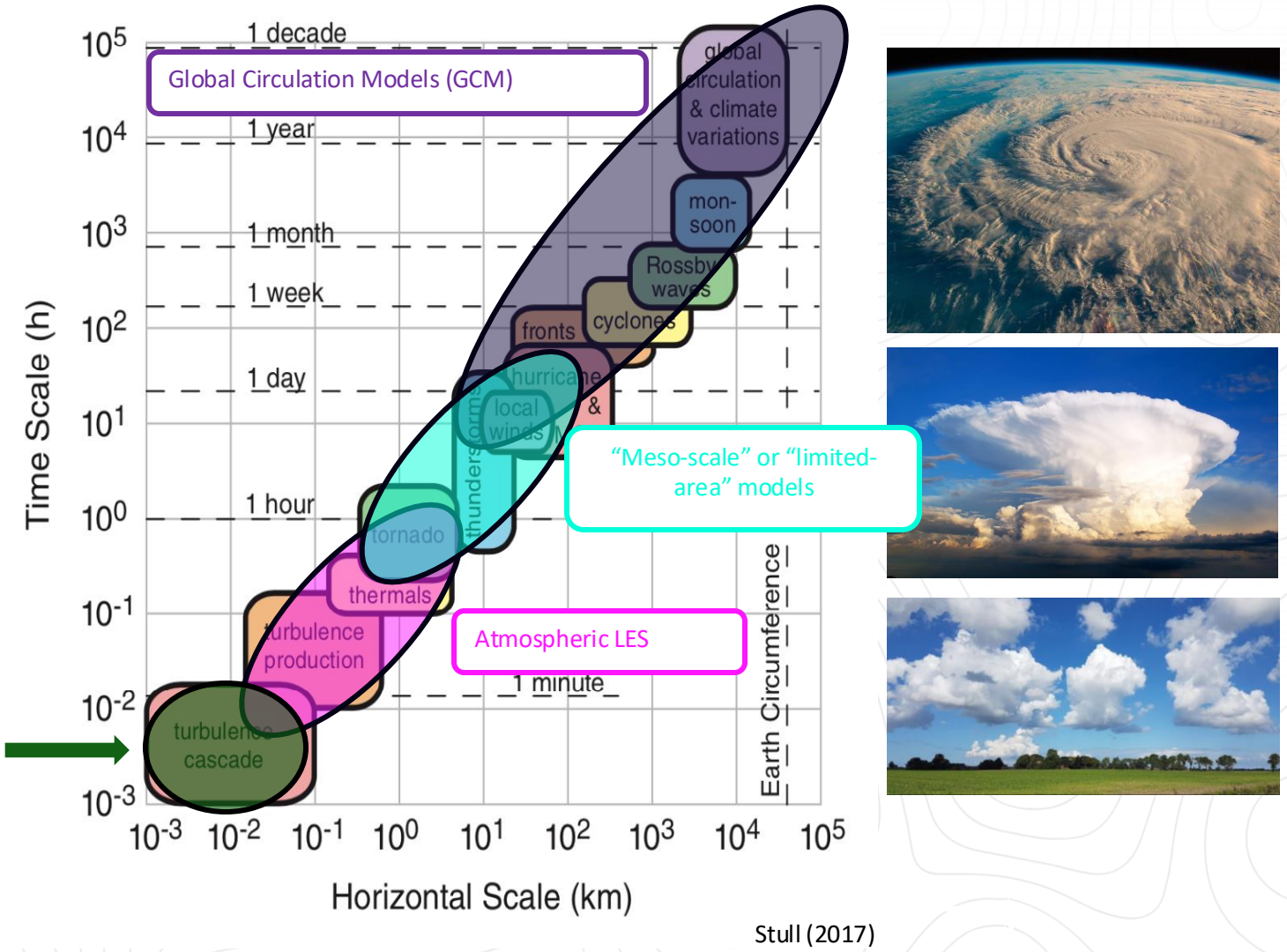
- Onshore wind is moving into remote, complex, forested terrain
- Forests and terrain create heterogeneous, nonlinear, scale-dependent flow. **Hard to model!**
- Poor pre-construction modeling directly affects siting, AEP, and project margins

Accuracy, Representativity, and Cost — we need all three

Rehling et al. 2023

Why It is Hard

- High accuracy airborne laser scanning data is only regionally available
- Trees vary on the scales of meters
- Modeling the atmosphere at those resolutions is costly



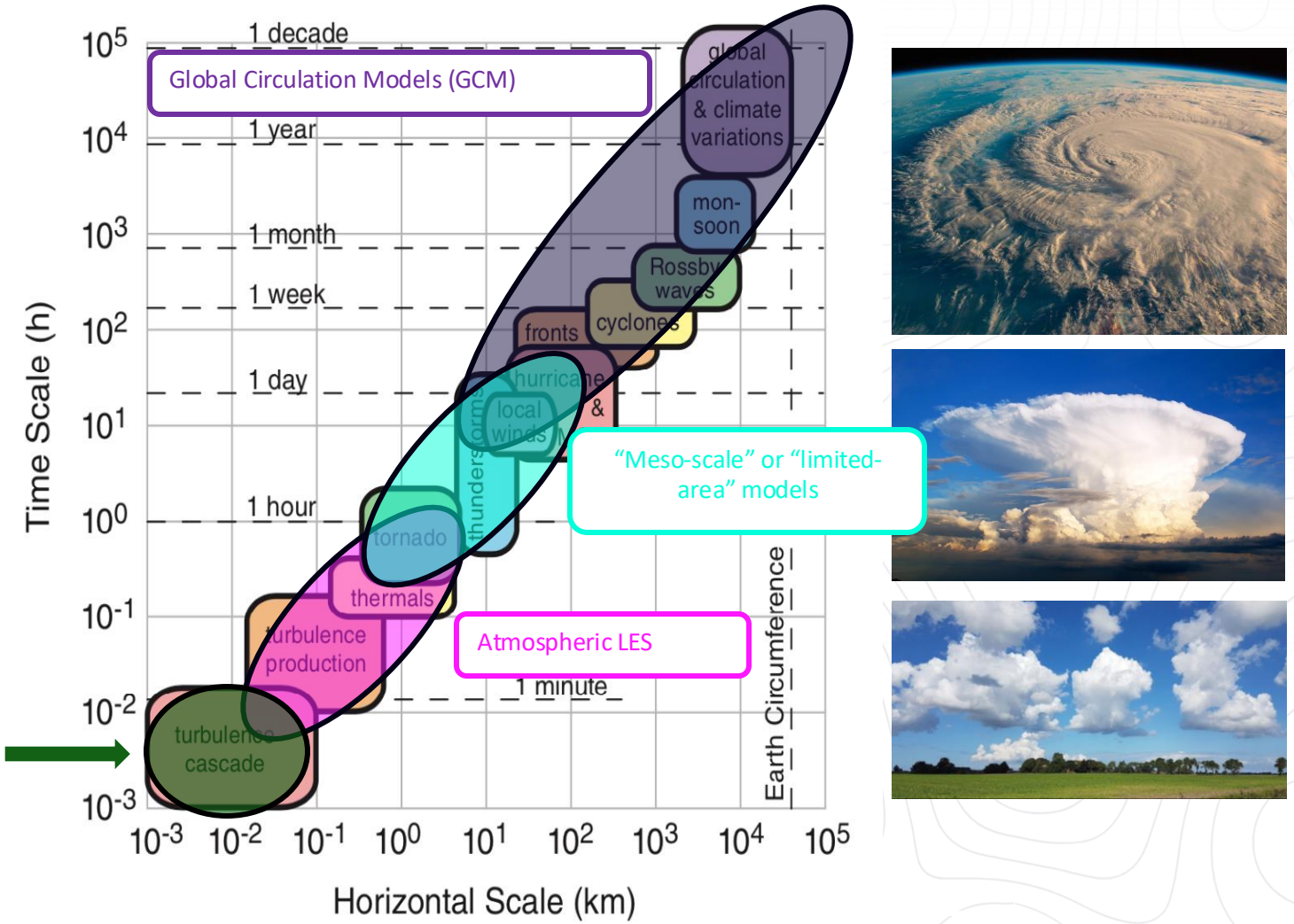
Stull (2017)

Why It is Hard

- High accuracy airborne laser scanning data is only regionally available
- Trees vary on the scales of meters
- Modeling the atmosphere at those resolutions is costly

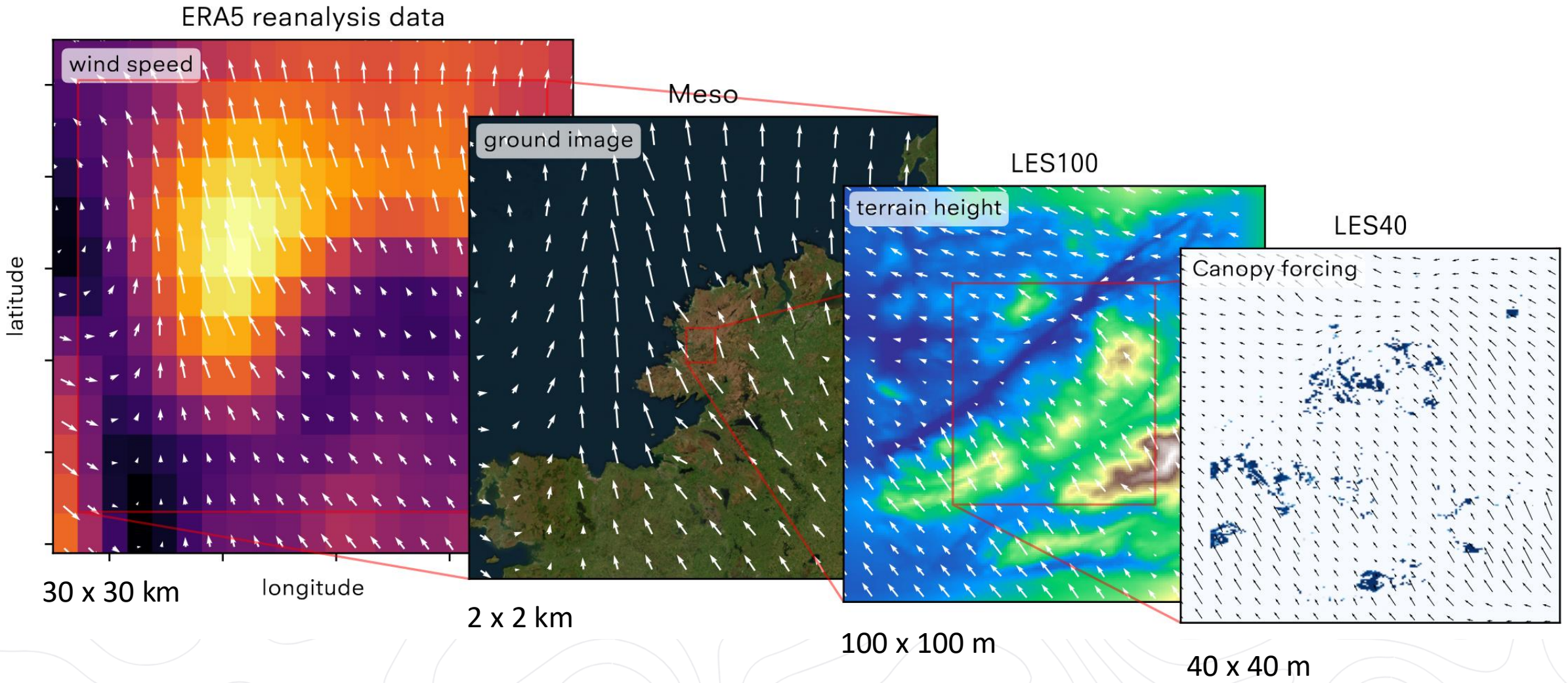
- **Whiffle LES**:
  - Real-weather LES including advanced relevant physics
  - GPU-resident LES: turnaround in hours
  - Ultra-high resolution

Trees



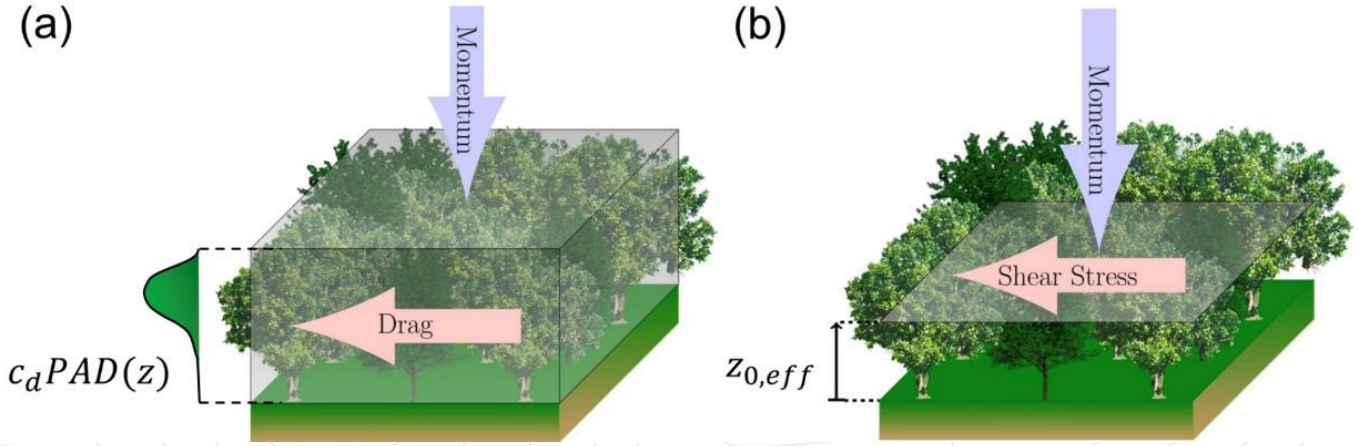
Stull (2017)

Nested LES: Resolving Forests Where It Matters

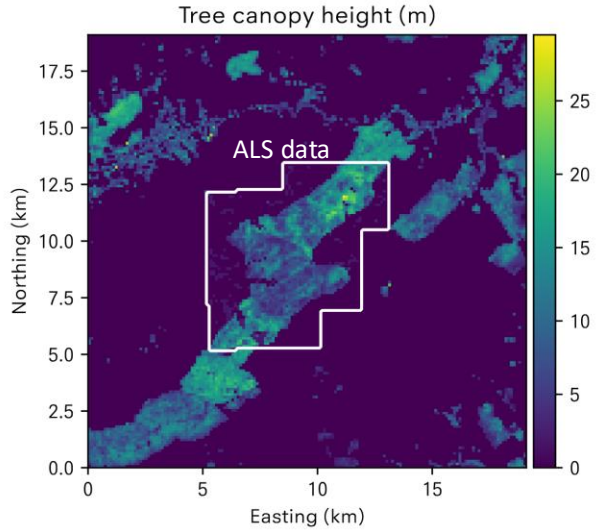


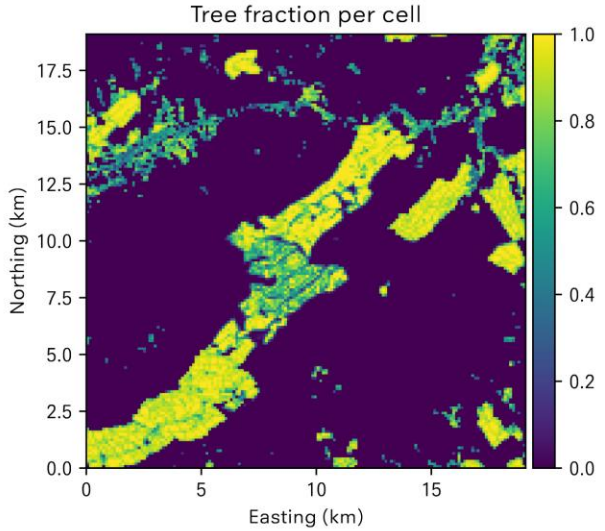
Blending scales

- Model high accuracy, high resolution data as drag force on grid in high-resolution LES with 10m vertical spacing
- Represent unresolved trees in LES and Meso with a surface stress and height displacement
- Blend high-accuracy, but regional, airborne laser based data with global 1m canopy height dataset (Tolan et al 2013)



Sogachev, A 2020

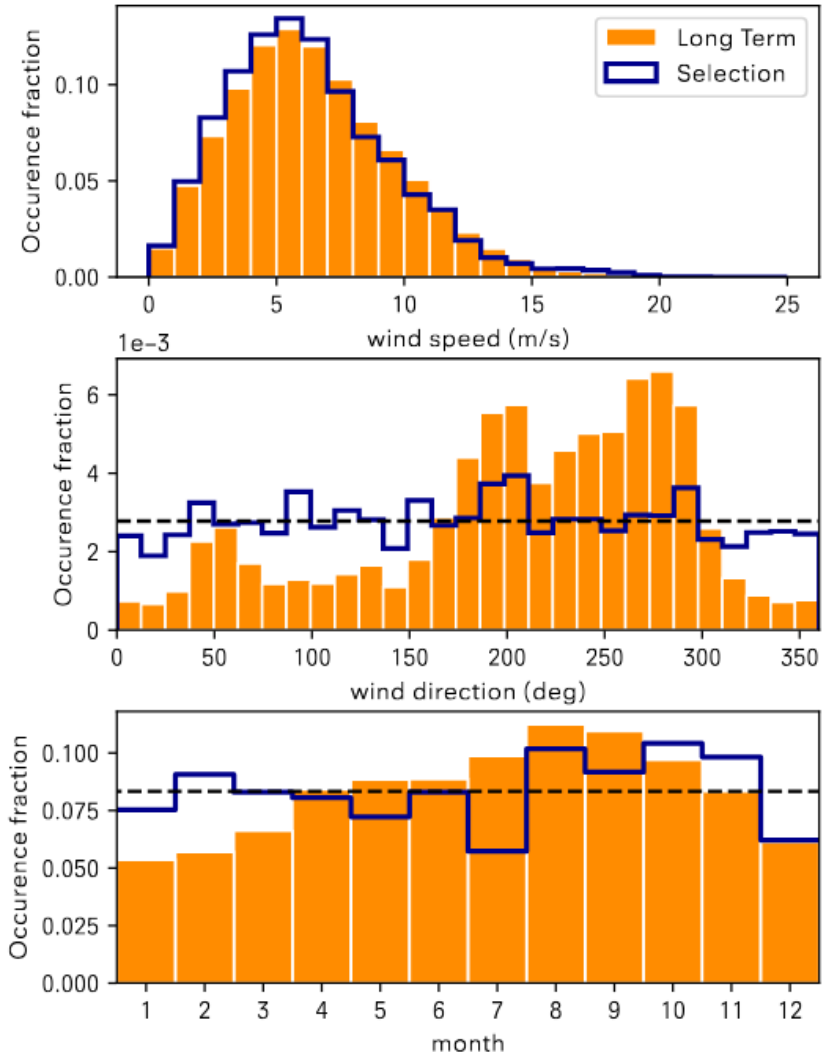




Observation-driven weather selection

- Run physical consistent weather, but preselect days on observations to ensure:
  - Long term representative wind speed distribution
  - Uniform wind direction
  - No seasonal bias

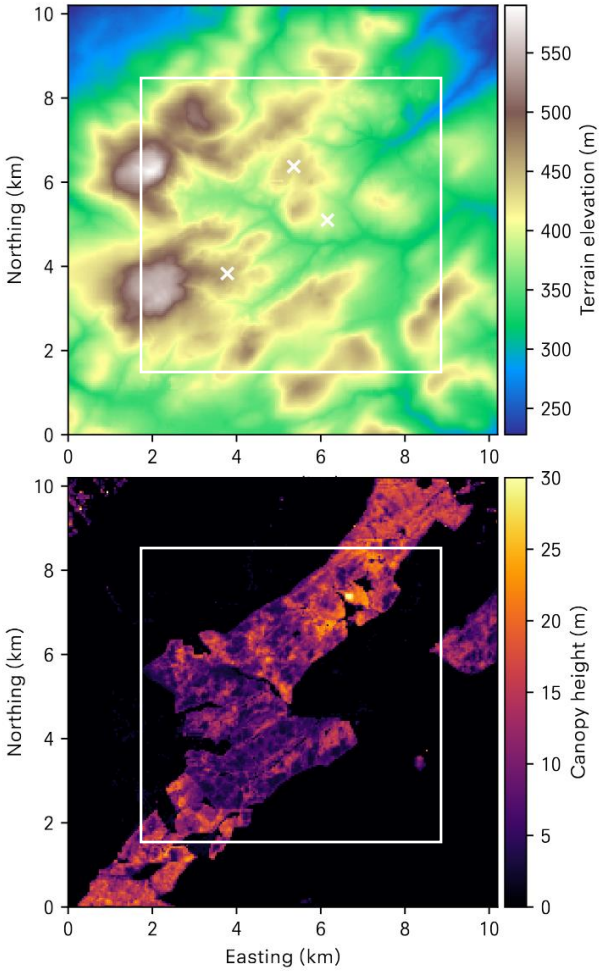
- Advantages:
  - Cost-saving, no full year necessary
  - Already long-term representative in seasonality and wind speed
  - High statistics in all wind sectors



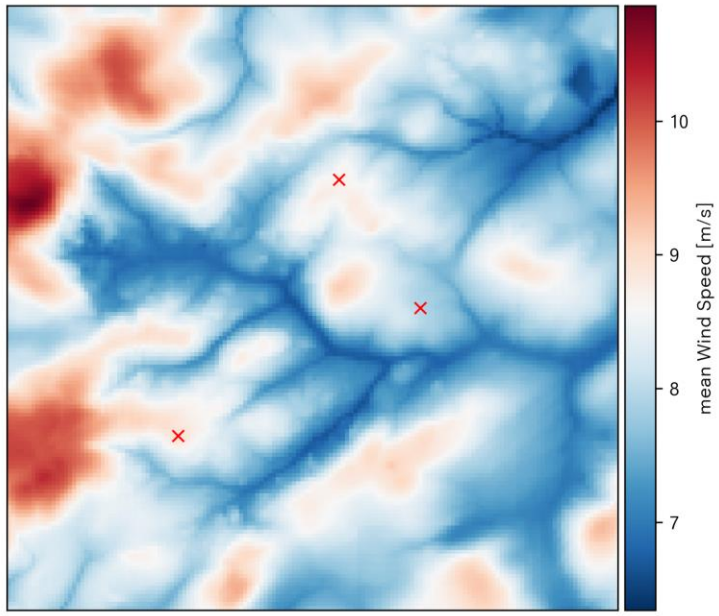
Validation sites

- Test method on 3 complex sites
  - 400m+ elevation difference
  - Highly heterogeneous forestry
  - Multiple met masts at a few km apart to look at cross-prediction
  - All sites have regional ALS data

- Results in very complex flow fields with steep velocity gradients

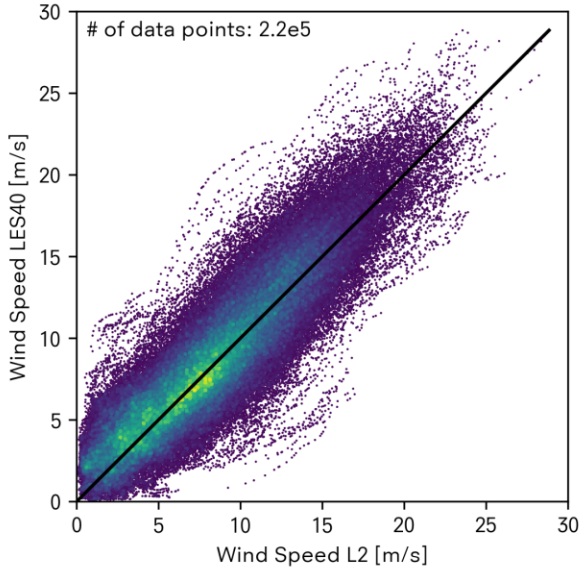


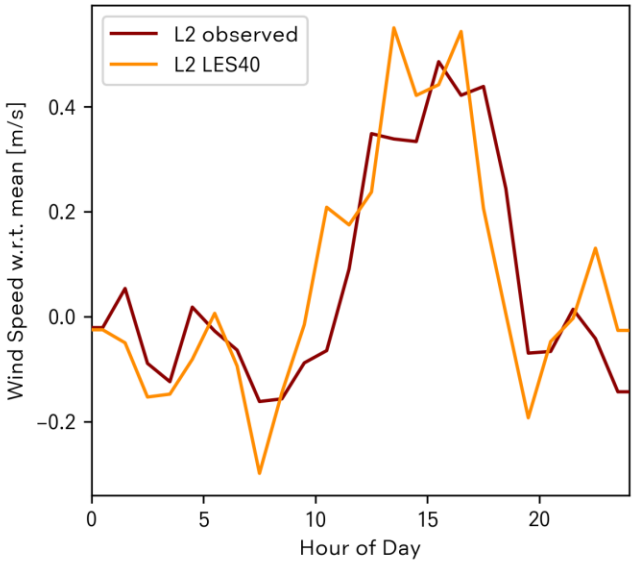
Flow field

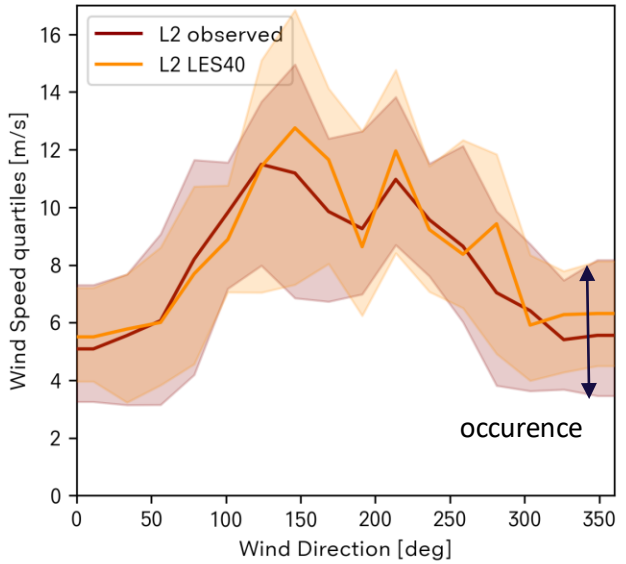


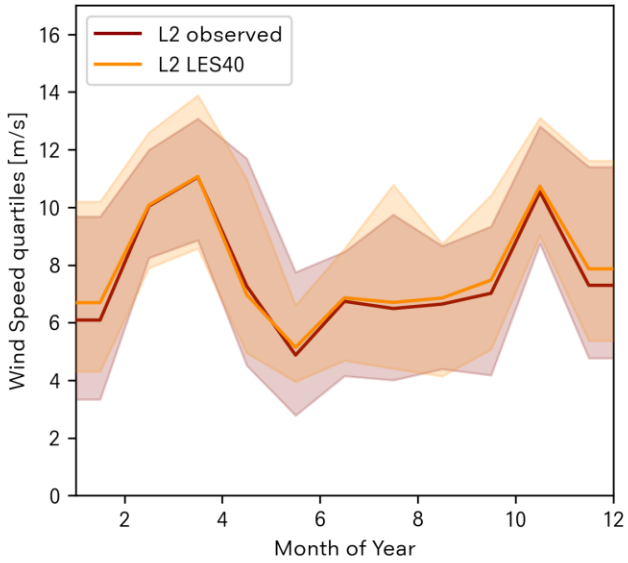
Validation results (per met mast)

- Many physical trends with local time, wind direction, seasonality etc. are captured naturally in the time series:
  - Wind speed



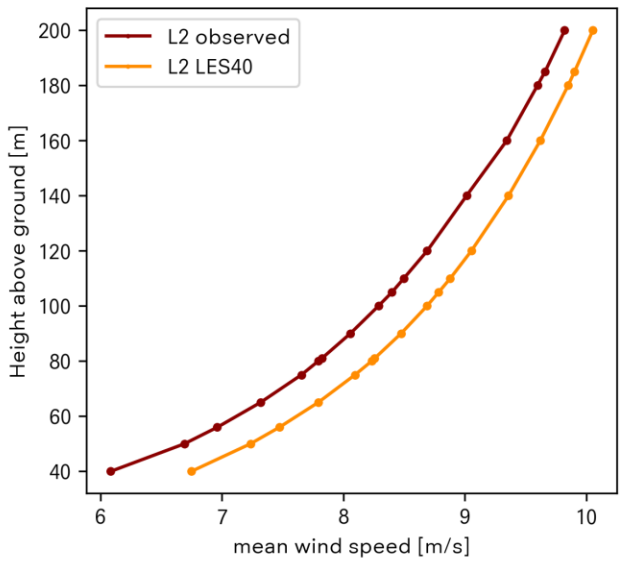


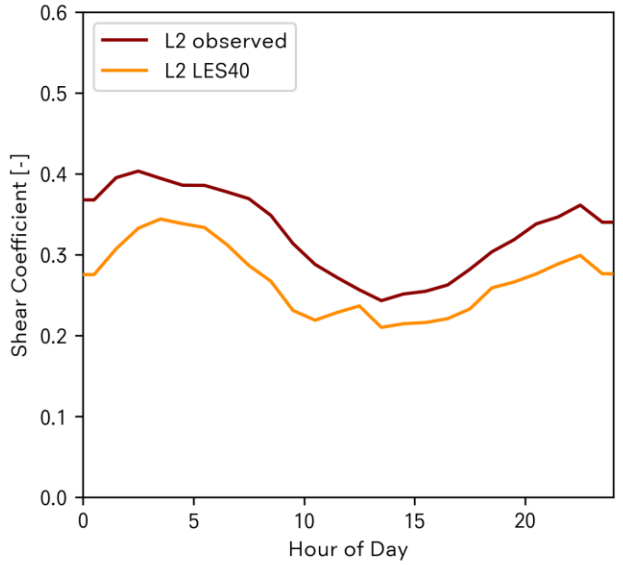


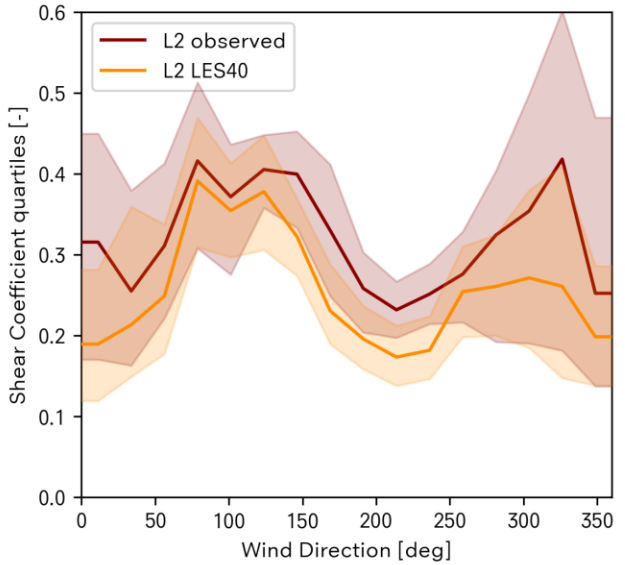


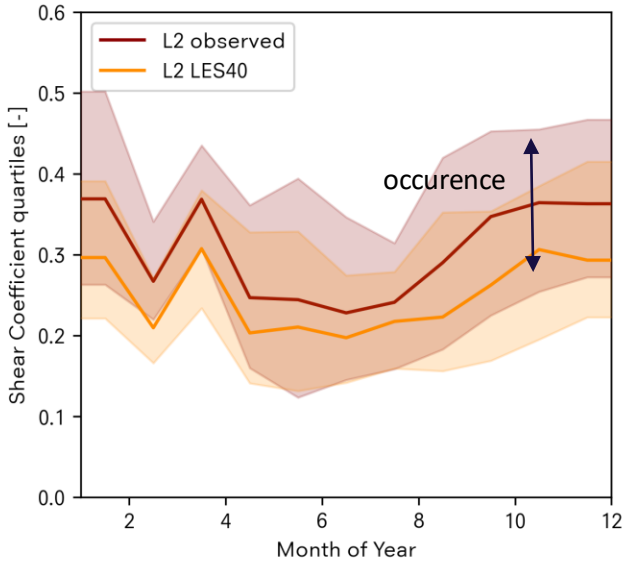
Validation results (per met mast)

- Many physical trends with local time, wind direction, seasonality etc. are captured naturally in the time series:
  - Wind speed
  - Shear



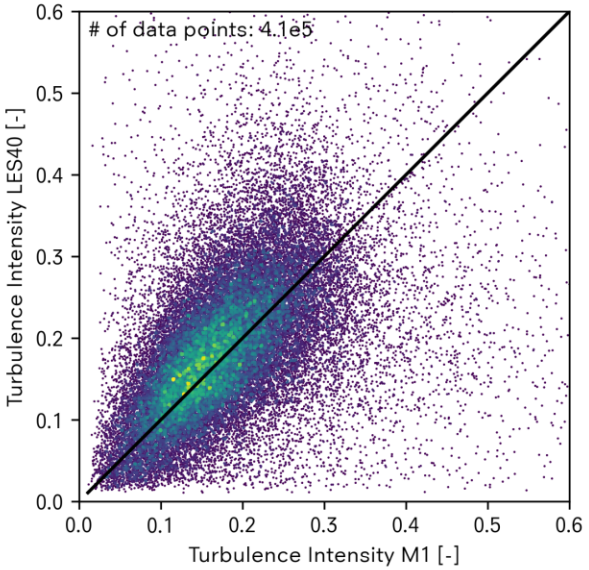


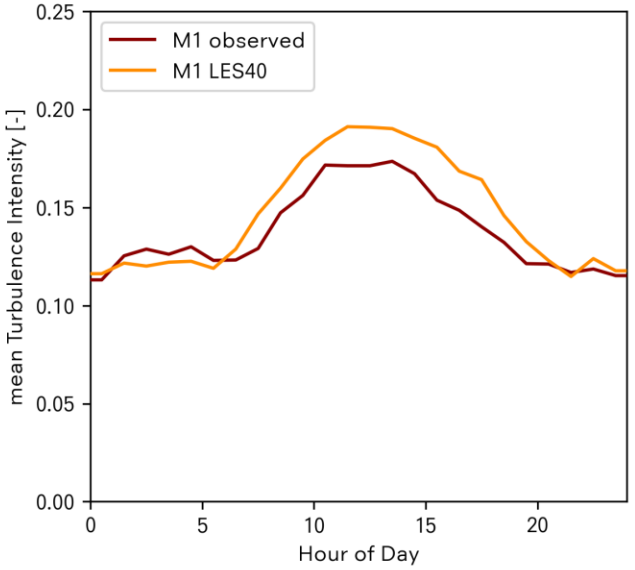


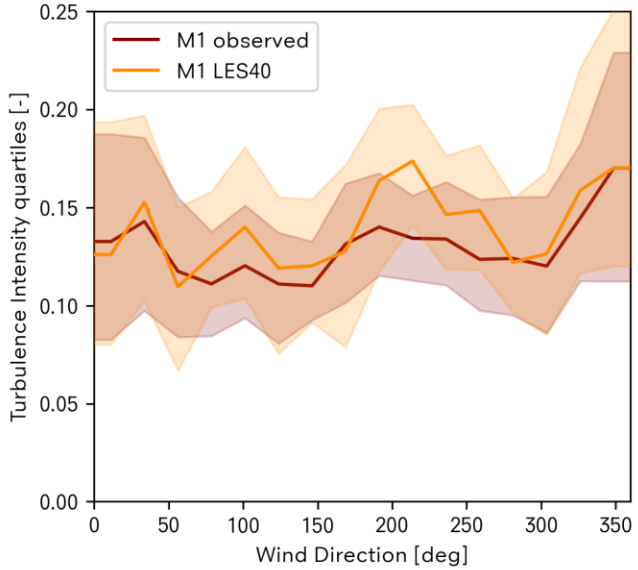


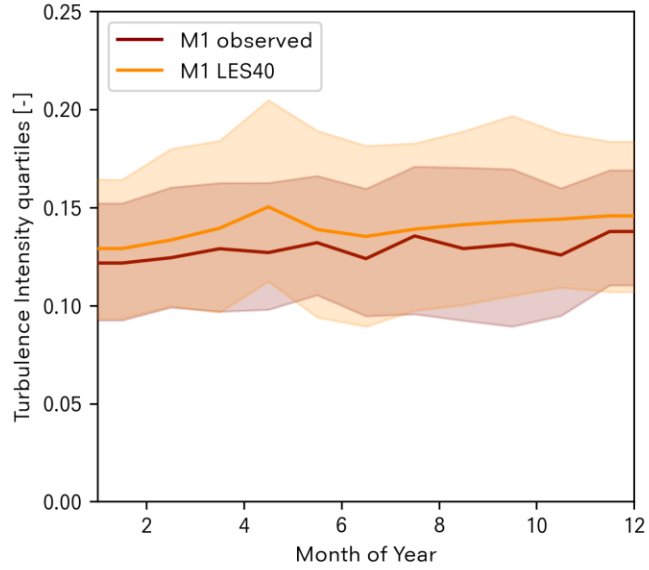
Validation results (per met mast)

- Many physical trends with local time, wind direction, seasonality etc. are captured naturally in the time series:
  - Wind speed
  - Shear
  - Turbulence intensity



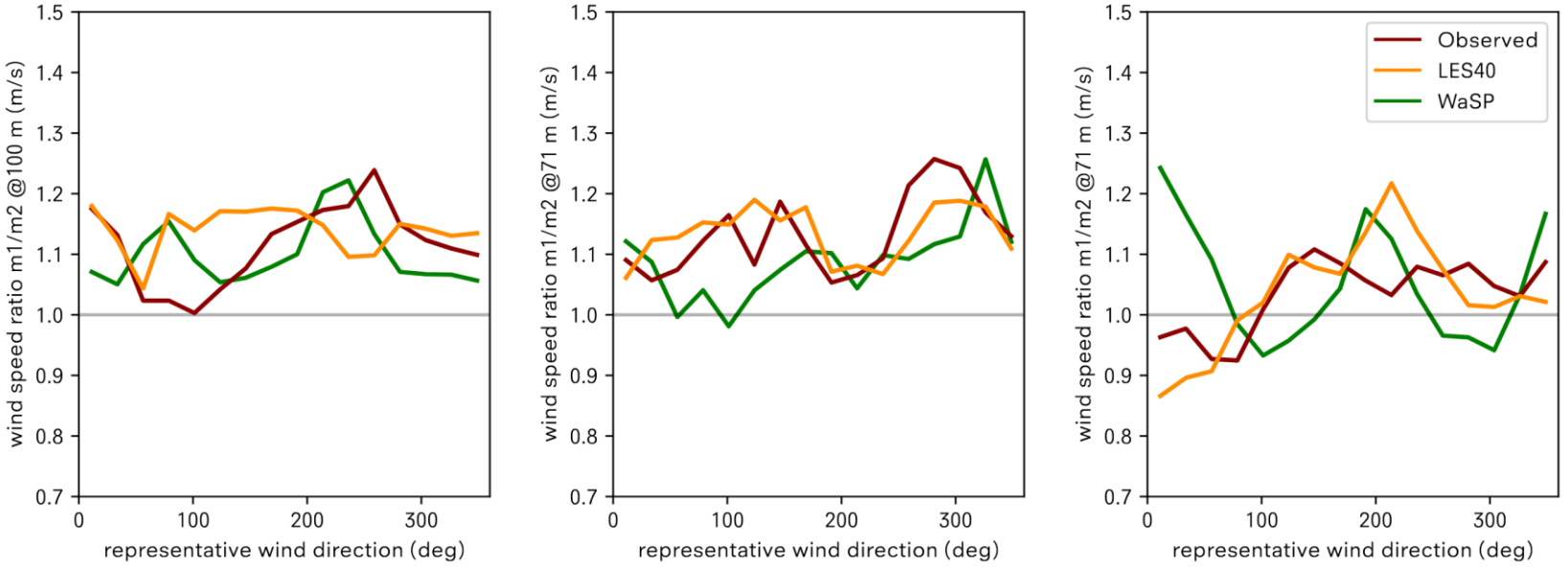


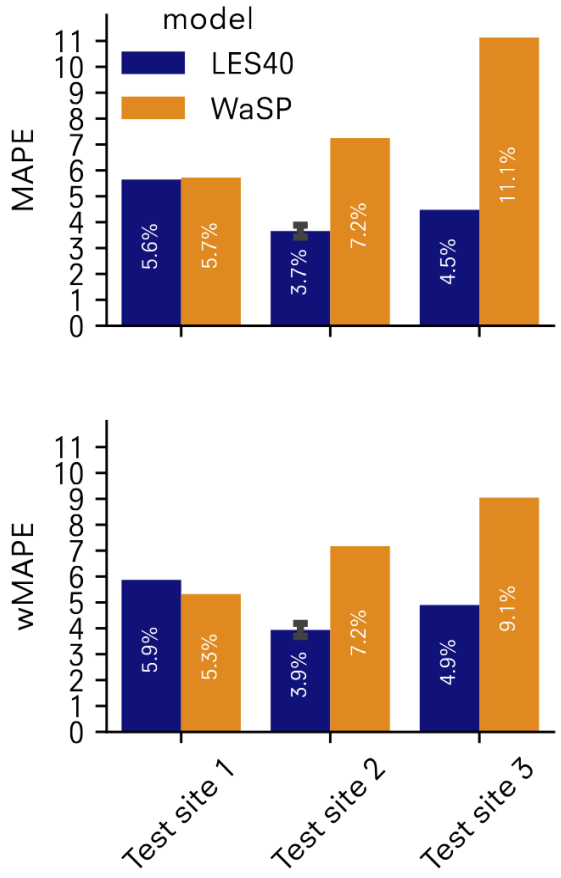




Validation results (cross-prediction)

- Statistical cross-prediction follows mostly similar trend with wind direction as in observations.





Summary

- A cost-effective method to model forests where they matter most:
  - Full physics representation of orography and forestry in the region of interest
  - Realistic input from real weather boundary conditions
  - Resolving diurnal cycles, stability, shear, sectorial trends, leads to reduced compensating errors
  - Robust turbulence predictions for loads / fatigue
  - High-confidence cross-prediction over complex sites