

Method for yaw misalignment detection based on satellite imagery and numerical weather models

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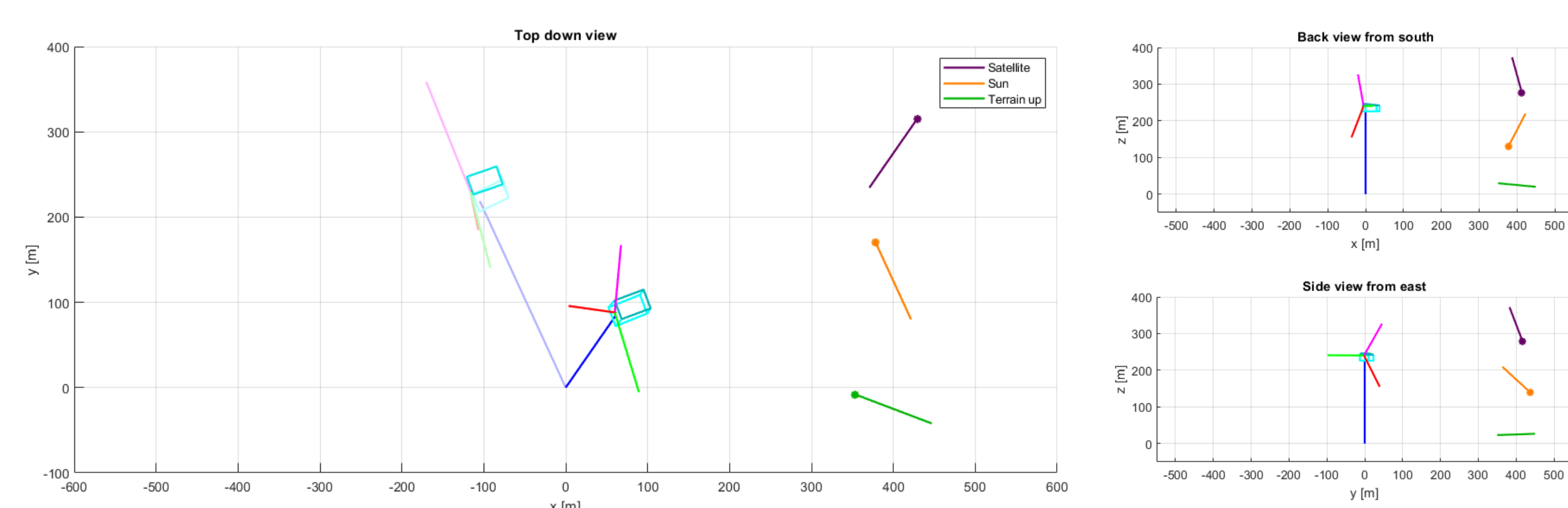
A new recipe to determine yaw misalignment reliably using standard 10 min SCADA data, and no external sensors.

We recently presented [1] a sensor-free method to assess yaw misalignment, with validations showing a 2.5° accuracy:

Yaw misalignment = Nacelle direction (from SCADA + satellite) – Wind direction (from numerical weather models + wake calibration)

This poster provides a more detailed breakdown of the method, with a focus on the use of satellite imagery (steps 1 - 3).

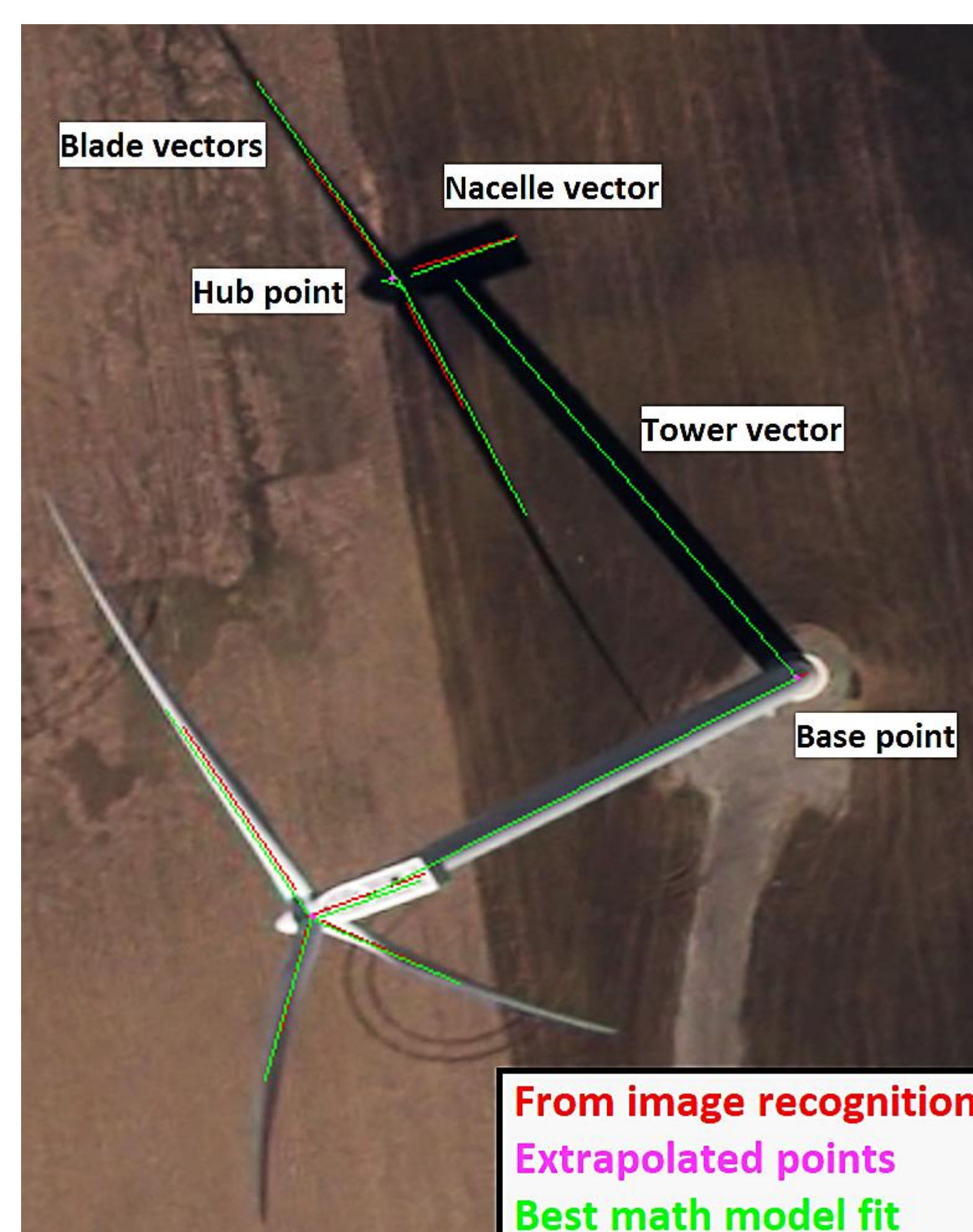
1. Create a 3D turbine and terrain specific model to predict ground-shadow geometry for any sun and satellite position



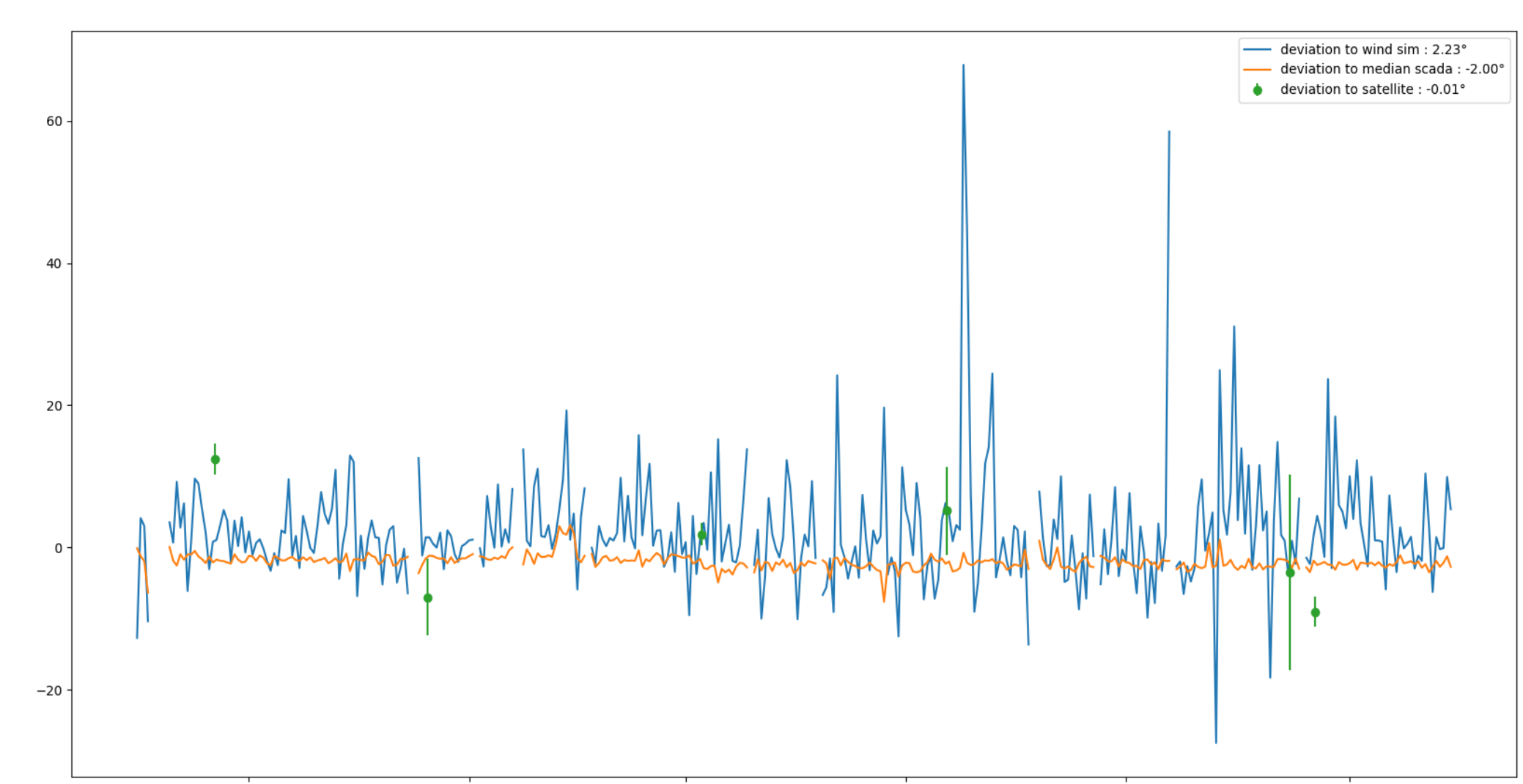
- The model includes nacelle, blades, and tower, parameterized by rotor diameter, hub-height, tilt and cone angles
- Projections account for sun and satellite positions, terrain slope, nacelle direction and rotor position

2. Determine nacelle direction by minimizing the error between predicted and observed turbine features in satellite imagery

- Use image recognition to automatically identify turbine features (nacelle, tower, blades) in high-res satellite images
- Use the 3D model (step 1) to predict features positions under the given viewing geometry
- Find the nacelle direction that minimizes the error between predicted (green) and observed features (red)

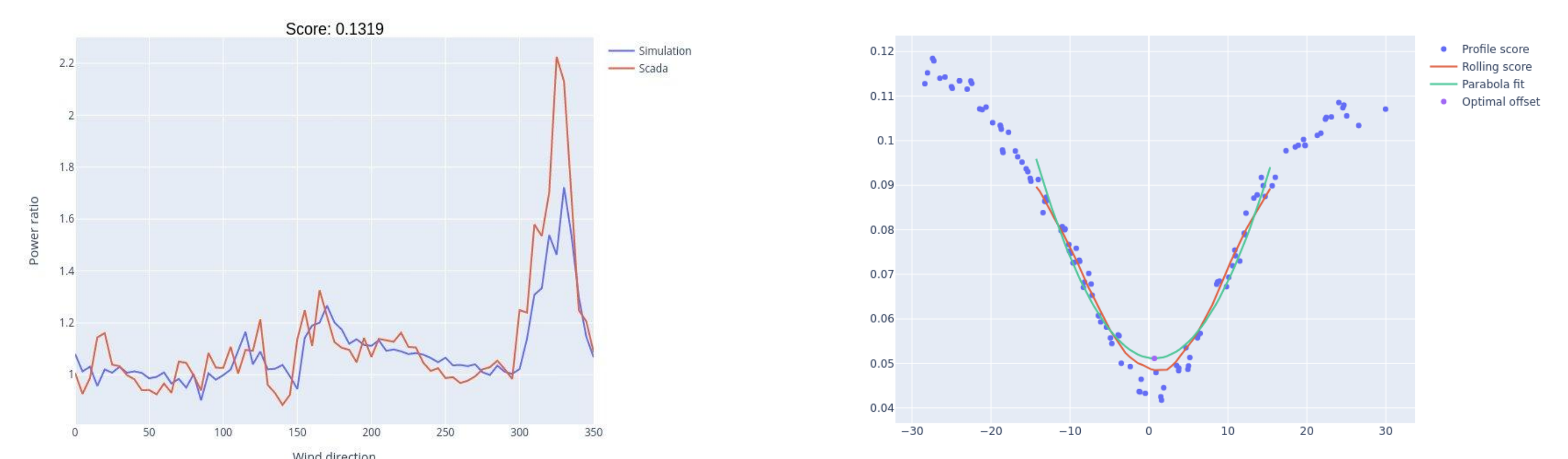


3. Correct SCADA nacelle direction timeseries using satellite observations



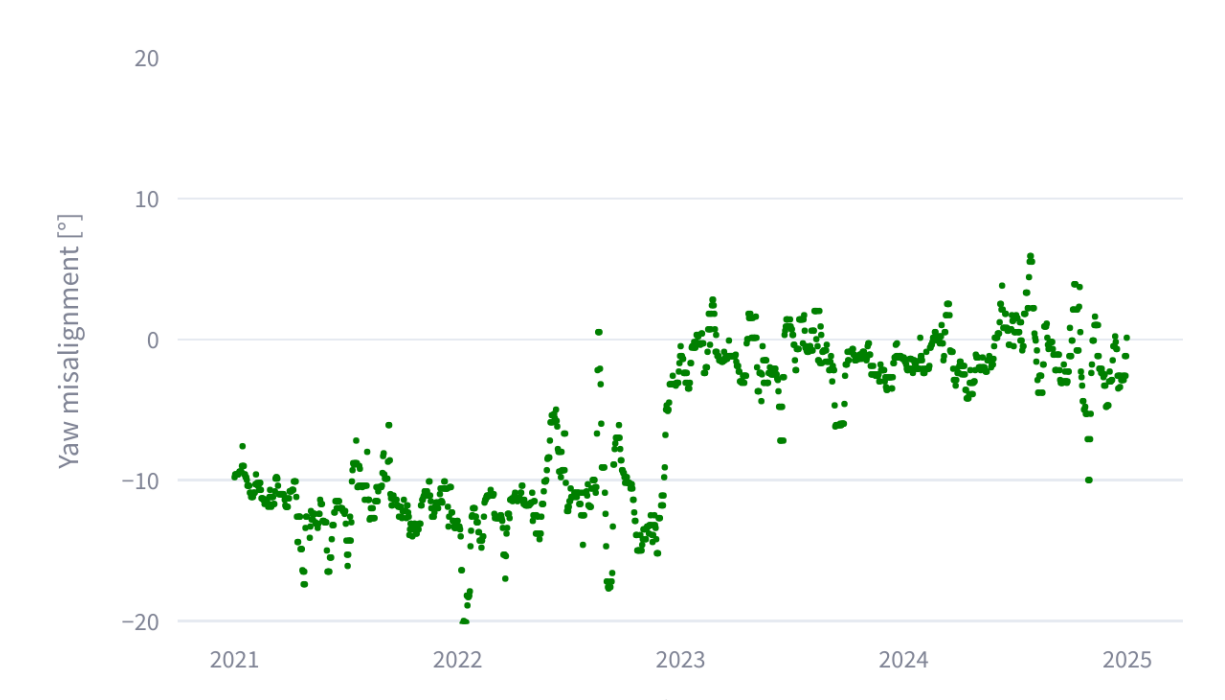
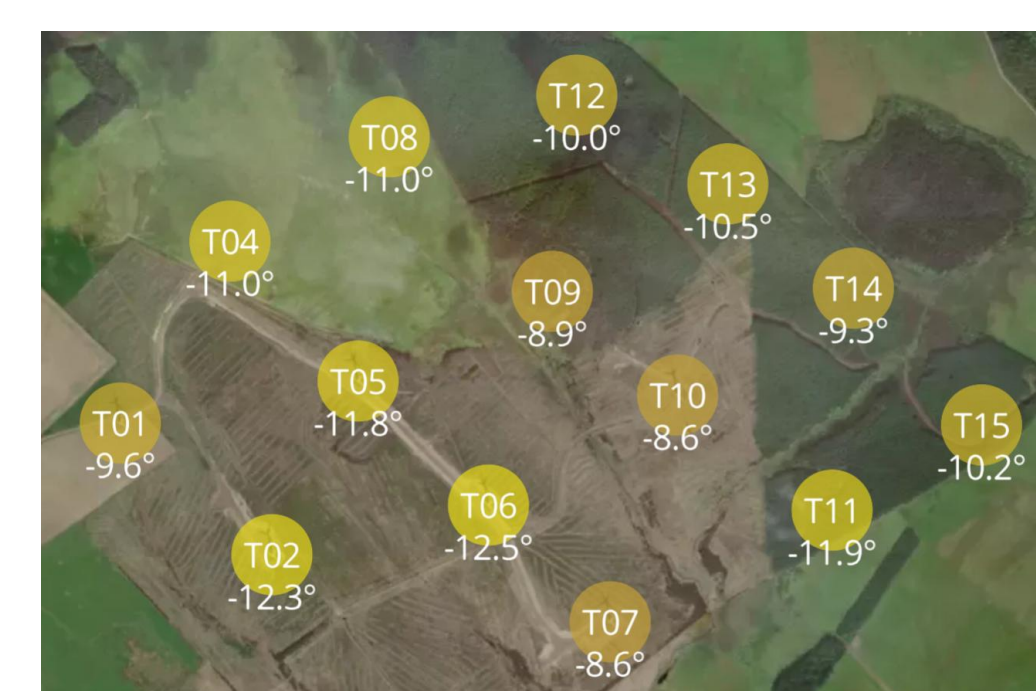
- Use the wind direction timeseries from the numerical weather model to derive first order corrections
- Use of one or more nacelle directions from satellite observations (step 2) to determine the remaining offsets

4. Calibrate the site-specific numerical weather wind direction predictions by comparing modelled vs actual wake patterns



- Score wake model fit to SCADA power ratios for each turbine pair and wind direction offset
- Select the offset that minimizes the score metric across pairs

5. Calculate yaw misalignment as the difference between the corrected nacelle direction (1-3) and wind direction timeseries (4)



- Average over time to obtain yaw misalignment per turbine
- Inspect turbine-level timeseries to detect misalignment events

[1] : S. Davoust, F. Delaunay (2025). Automated yaw misalignment detection based on satellite imagery and numerical weather models. WindEurope Annual conference 2025.