PO031

Affordable, full-physics wind resource maps: how a smart selection of LES runs accurately captures horizontal heterogeneity and long-term statistics.

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Relevance

High-fidelity **Large Eddy Simulations** (LES) unlock detailed wind statistics and site heterogeneity in one go, eliminating costly multi-mast campaigns and overcoming the steady-state assumptions that limit linear flow and RANS models.

Methodology

We validate site heterogeneity by cross-predicting wind speeds between multiple met masts. Using a **full-physics approach** integrating high resolution terrain maps, soil properties, land use, and reanalysis weather data, we conducted nested LES runs across 16 multi-mast locations, testing 116 mast pairings.

A **smart pre-selection of 30 representative days** based on wind speed and wind direction enables highly cost-effective modeling. These modeled time series predict **diurnal trends**, capturing variations due to wind direction, wind speed, solar radiation, boundary layer height, detailed land-use characteristics, microscale topography, etc.

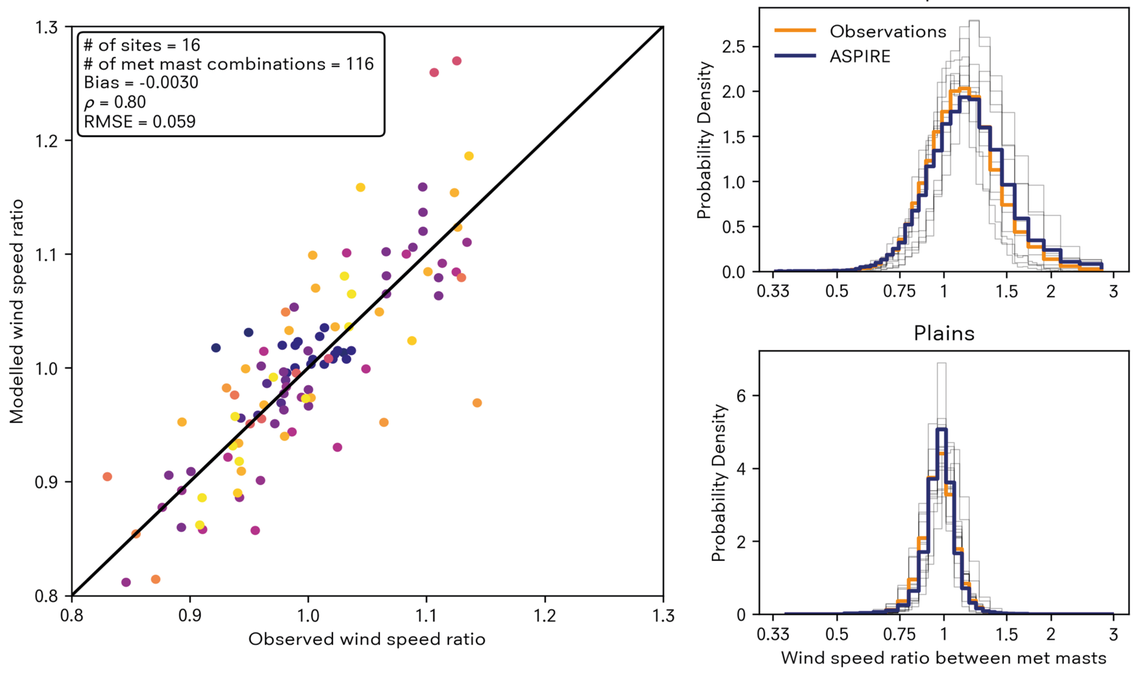

Fig. 1 Left: Cross-predicted wind speeds between met mast pairs from LES time series vs. observations. Each point represents a mast pairing, color-coded by site. **Right:** Normalized wind speed ratio distributions over time for two representative sites, one complex (top), one homogeneous (bottom). Colored lines show the average across all mast pairings per site, highlighting the model's ability to capture site-specific heterogeneity.

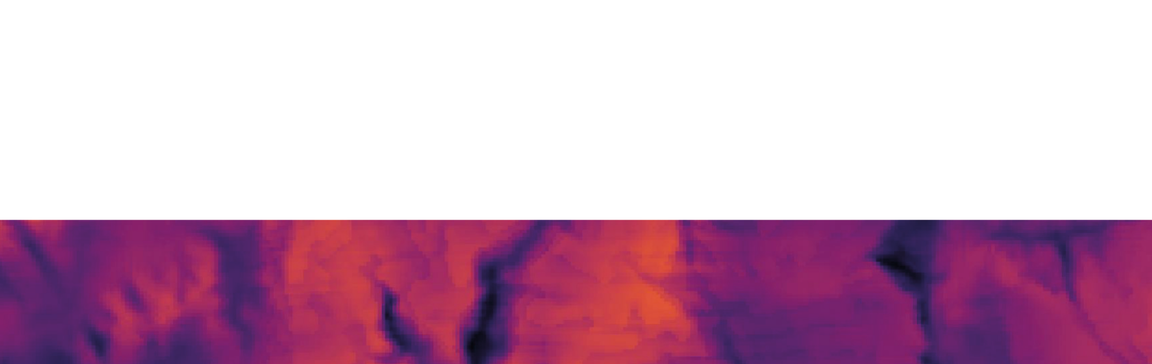

Fig. 2 Representative variation in wind speed ratio (speedup) between met masts as a function of wind direction (left) and time of day (right). Shaded regions indicate the interquartile range (25th - 75th percentile).

Results

Mean wind speed-up maps and **full statistical distributions of wind speed ratios** between met masts are accurately reproduced by our full-physics based LES model, confirming the robustness of the approach. The time series distribution of met mast cross-predictions, a measure of site heterogeneity, varies strongly between sites and is well captured by the simulations.

Smart day selection dramatically reduces computational cost, while **reliably capturing temporal trends and horizontal heterogeneity,** critical for long-term wind resource assessments. Daily and annual trends are caught accurately in a statistical representation of the full measurement campaign, without the need to understand each site-specific forcing. The 30-day selection is a pragmatic trade-off, enabling simulations across many sites. Postema (in prep.) shows that statistical uncertainty in wind resource metrics converges when using approximately 100 representative days.

Conclusions

LES-based full-physics modeling offers a **powerful, affordable alternative to extensive mast deployments**, improving accuracy in heterogeneous terrain and de-risking project development. LES time series can be used in all stages of project development, from micrositing and layout optimization to bankable production estimates.

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