Wind Resource Assessment

Multiple Measurement Positions

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Why?

Purpose of RECAST:
Credible Wind Resource Predictions using Scanning Lidars

Questions addressed in presentation:
Q1: Does Multi-point measurements improve resource assessments?
Q2: How do I select positions for measurement campaigns?
Q3: How can “inverse uncertainty” further improve resource assessments?
Outline

1. Spatial Extrapolation of Wind Resources
2. Extrapolation Uncertainty
3. Multi-point Validation
4. Conclusions
The classic problem
Linear Interpolation
Model extrapolation: single-point measurement

1. The model estimates the relative speedup:

\[ \Delta S = \frac{U_2}{U_1} \]

2. The observation is extrapolated:

\[ U_P \pm \sigma_E = U_0 \times \Delta S \]
Model extrapolation: multi-point measurements

- To minimize error, weights should be proportional to the inverse of the measurement variance: $w_i \propto \sigma_{E_i}^{-2}$
- Inverse-distance is the industry-standard, $w_i = \frac{1}{d_i^2}$

\[
\sigma_E^2 = \frac{1}{\sum_i 1/\sigma_{E_i}^2}
\]

\[
U_P \pm \sigma_E = \frac{\sum_i w_i U_{Pi}}{\sum_i w_i}
\]

\[
U_{Pi} \pm \sigma_{E_i} = U_{Oi} \times \Delta S_i
\]
Model extrapolation: multi-point measurements

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Is extrapolation distance the best measure of model error?
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The similarity principle

To minimize errors related to the spatial extrapolation, the predictor site and the predicted site should be as "similar" as possible regarding factors like regional wind climate, roughness, orography, obstacles, etc.

Landberg et al., European Wind Energy Conference and Exhibition Proceedings, 2003
All models have shortcomings. To reduce errors always keep the observation and prediction sites as “similar” as possible.

ΔRIX as “similarity” indicator:
- Indicates differences in steepness only
- WAsP specific indicator

ΔS as “similarity” indicator:
- Indicates micro-scale roughness-, orography-, obstacle- & height-differences
- Large ΔS = bias risk + high stakes
- Every micro-scale model calculates ΔS

Micro-scale model - spread and bias

The mean absolute error of 260 wind speed predictions using PyWAsP as function of delta RIX

The mean absolute error of 260 wind speed predictions using PyWAsP as function of speedup
Extrapolation uncertainty

\[ \sigma_E^2 = \sigma_d^2 + \sigma_{\Delta S}^2 = \left( \lambda \left( 1 - e^{-d/L} \right) \right)^2 + (A|\Delta S|)^2 \]

Hypothesis:
- \( \sigma_E^2 \) is a better measure of model error than distance and improves weighted ave. \( w_i = \frac{1}{\sigma_E^2} \)
- \( \sigma_E^2 \) indicates good measurement positions

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Multi-mast dataset

Multi-mast sites
25 sites with 2 masts
44 sites with 3+ masts

Number of possible predictions
260 single-mast predictions
210 multi-mast prediction
Multi-point Validation

Validation procedure:
1. Select masts with at least 2 neighbouring masts (260 > 210 masts)
2. Filter for DRIX < 7.5 (210 > 189 masts)
3. PyWAsP prediction with standard conditions – no individual site corrections
4. Weighted averages using:
   – Closest Mast (single mast)
   – Inverse distance (multiple masts)
   – Inverse uncertainty (multiple masts)
5. Compare with measurement and calculate mean absolute wind speed error (MAE)
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Conclusion

Q1: Does Multi-point measurements improve resource assessments?
“Yes, making weighted average of multiple measurements reduce prediction error”

Q2: How do I select positions for measurement campaigns?
“Extrapolation uncertainty will indicate good measurement positions and can be used by optimization algorithms. Using extrapolation distance can be problematic”

Q3: How can “inverse uncertainty” further improve resource assessments?
“Inverse uncertainty only improved results slightly. This is properly because the masts used had been well positioned by experienced site-engineers. For randomly placed positions, e.g. WRF simulation, the improvement is expected to be larger especially compared to linear interpolation”