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Wind Resource Assessment

Multiple Measurement Positions

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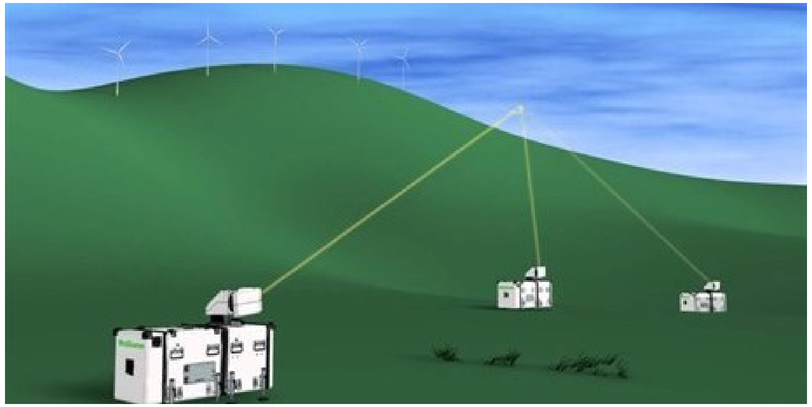
Vestas. EMD emd.dk res powering change Innovation Fund Denmark

Why?

Purpose of RECAST:

Credible Wind Resource Predictions using Scanning Lidars

RECAST
Reduced Assessment Time



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 uncerteinty” further improve resource assessments?

Outline

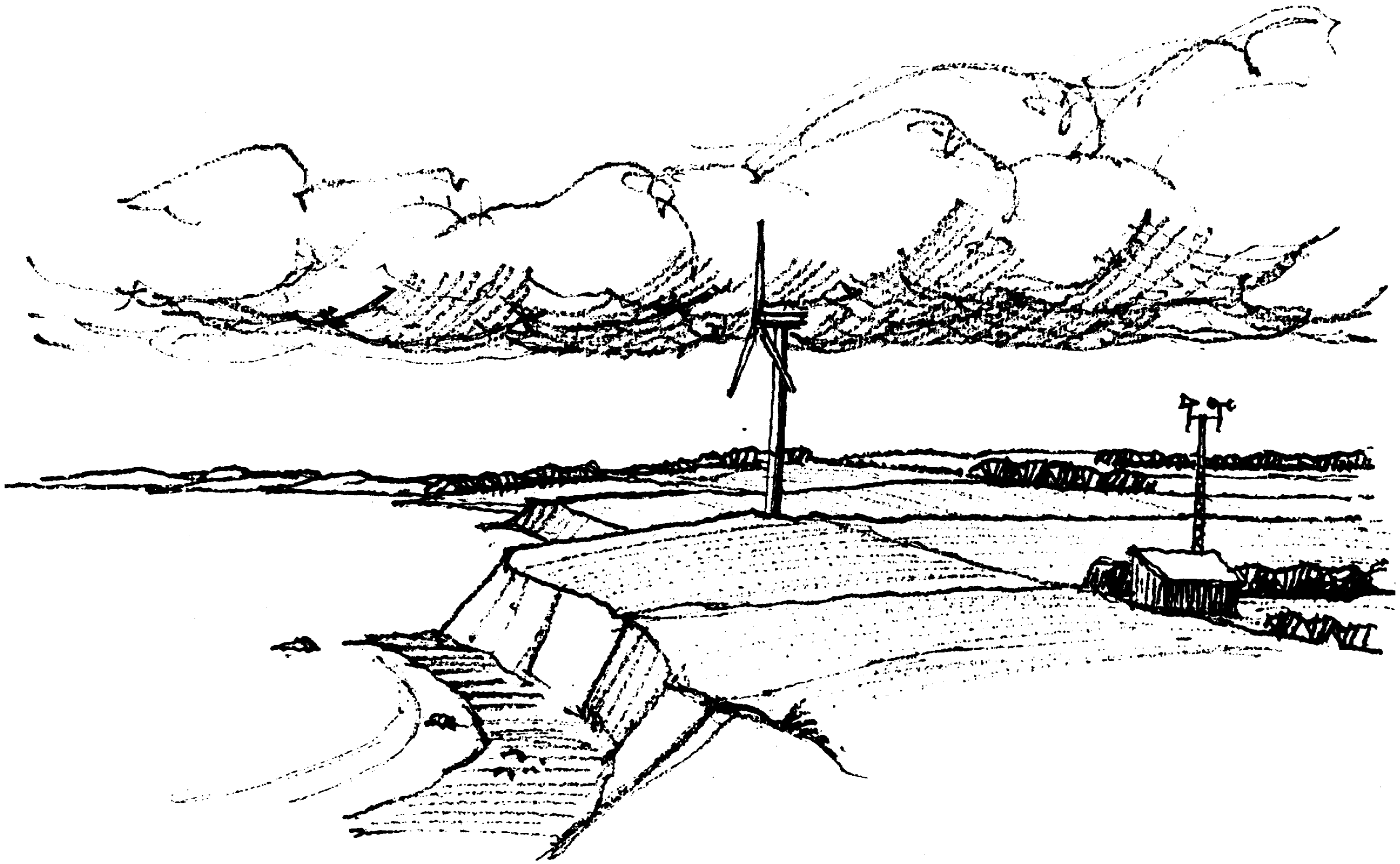
1. Spatial Extrapolation of Wind Resources

2. Extrapolation Uncertainty

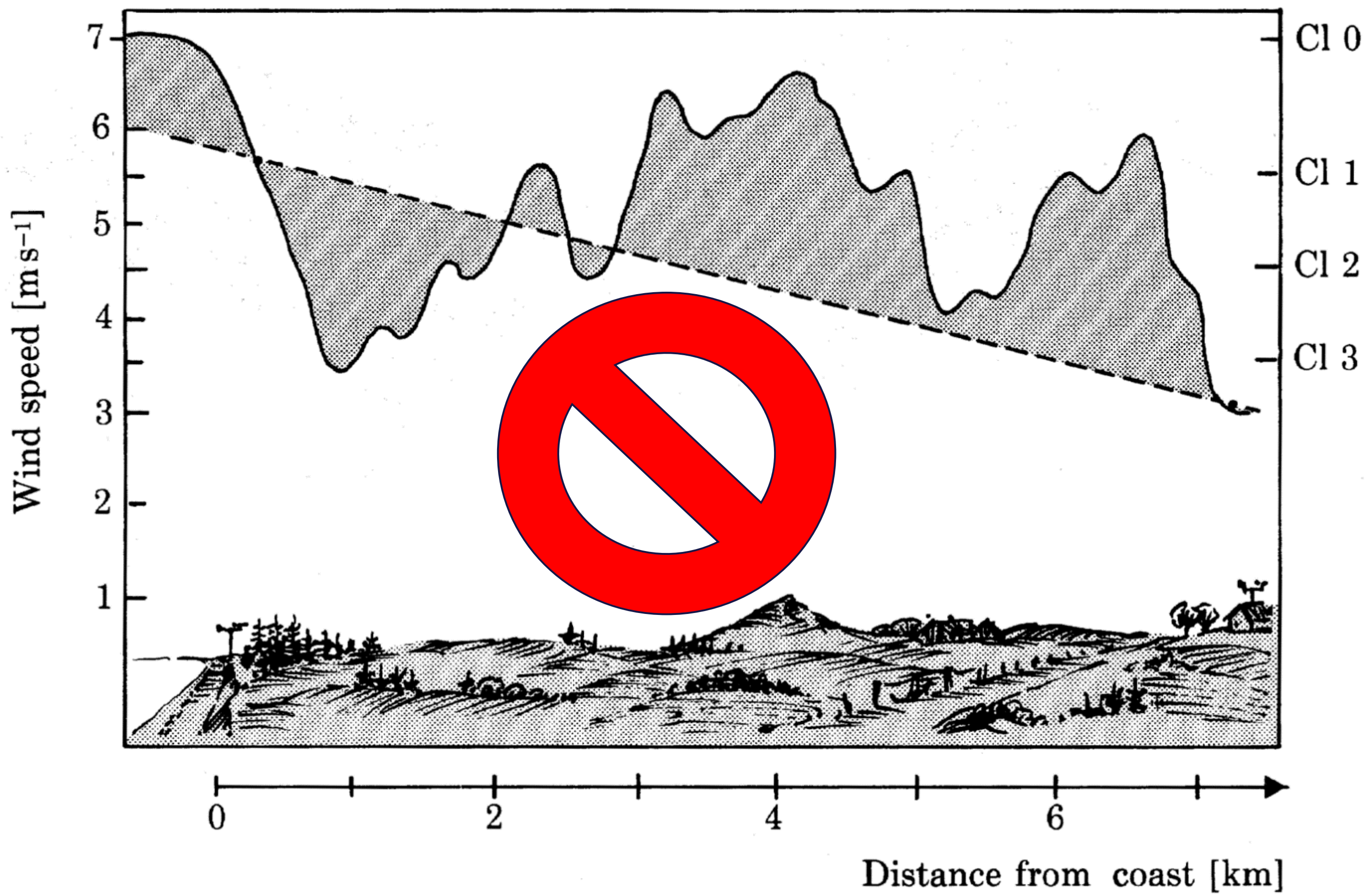
3. Multi-point Validation

4. Conclusions

The classic problem



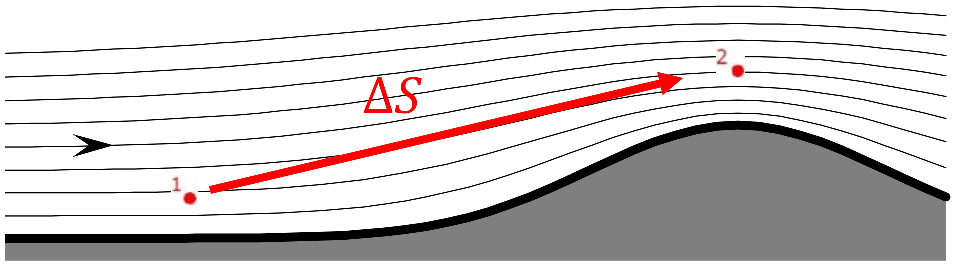
Linear Interpolation



Model extrapolation: single-point measurement

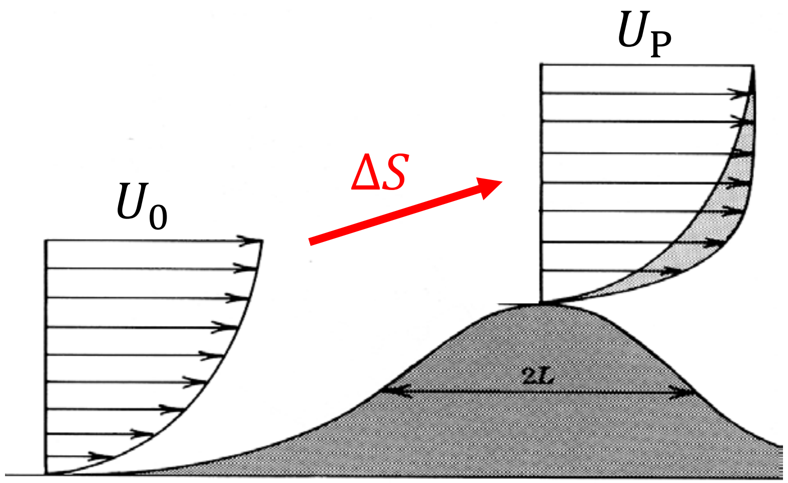
1. The model estimates the relative speedup:

$$\Delta S = \frac{U_2}{U_1}$$



2. The observation is extrapolated:

$$U_P \pm \sigma_E = U_O \times \Delta S$$

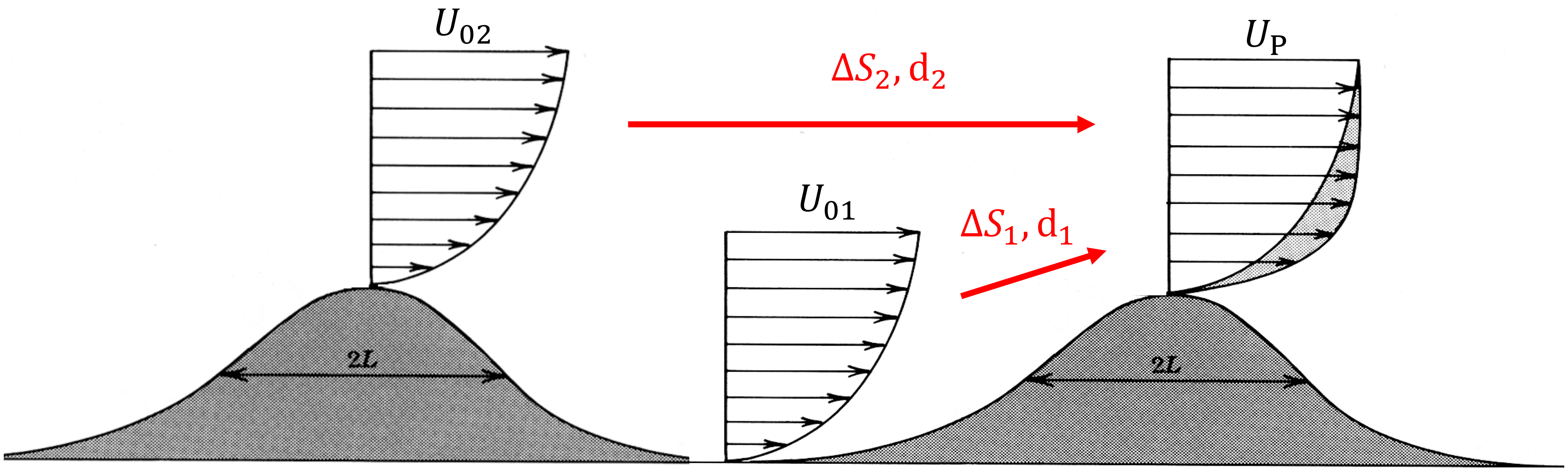


Model extrapolation: multi-point measurements

- To minimize error, weights should be proportional $w_i \propto \sigma_{E_i}^2 \longrightarrow \sigma_E^2 = \frac{1}{\sum_i 1/\sigma_{E_i}^2}$
- Inverse-distance is the industry-standard, $w_i = \frac{1}{d_i^2}$

$$U_{Pi} \pm \sigma_{E_i} = U_{\mathrm{Oi}} \times \Delta S_i$$

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



Model extrapolation: multi-point measurements

- To minimize error, weights should be proportional $w_i \propto \sigma_{E_i}^2$
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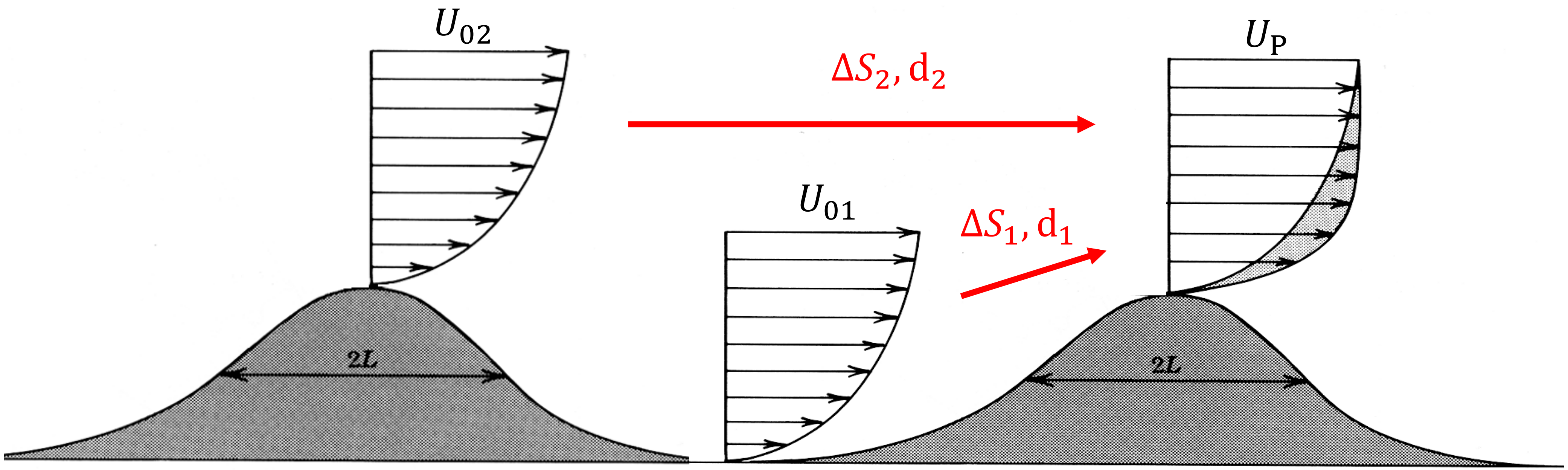
Is extrapolation distance the best measure of model error?



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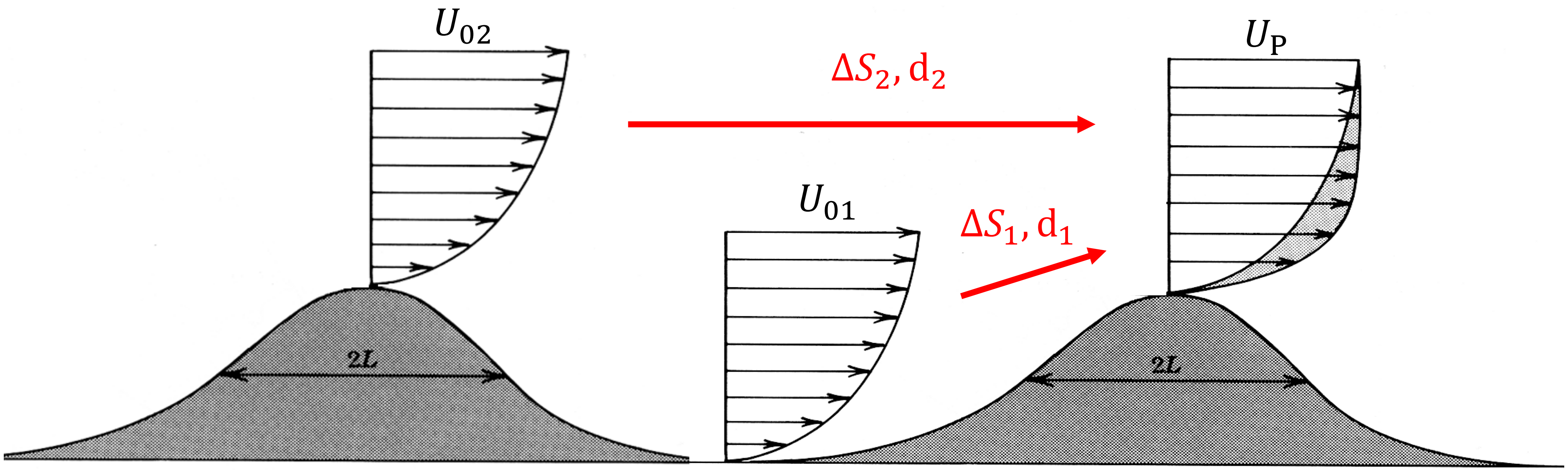
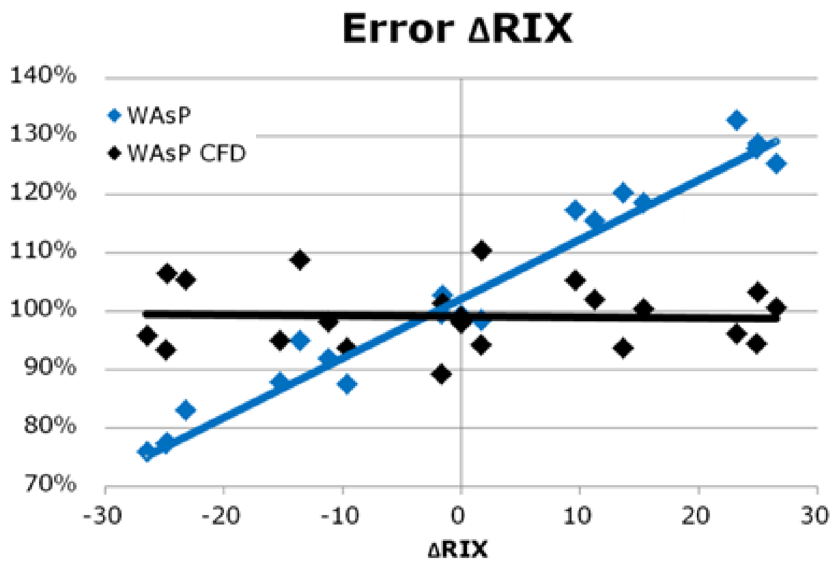
The similarity principle

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



Micro-scale model - spread and bias



Publication on delta RIX: *N.G. Mortensen and E.L. Petersen. “Influence of topographical input data on the accuracy of wind flow modeling in complex terrain”. European Wind Energy Conference, Dublin, Ireland, 1997*

All models have shortcomings. To reduce errors always keep the observation and prediction sites as “similar” as possible

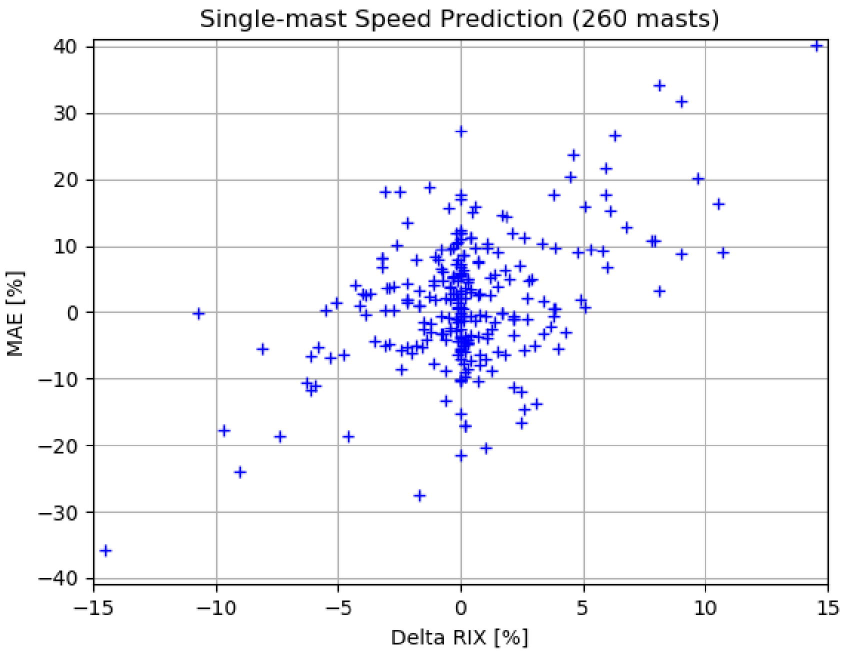
ΔRIX as “similarity” indicator:

- Indicates differences in steepness only
- WAsP specific indicator

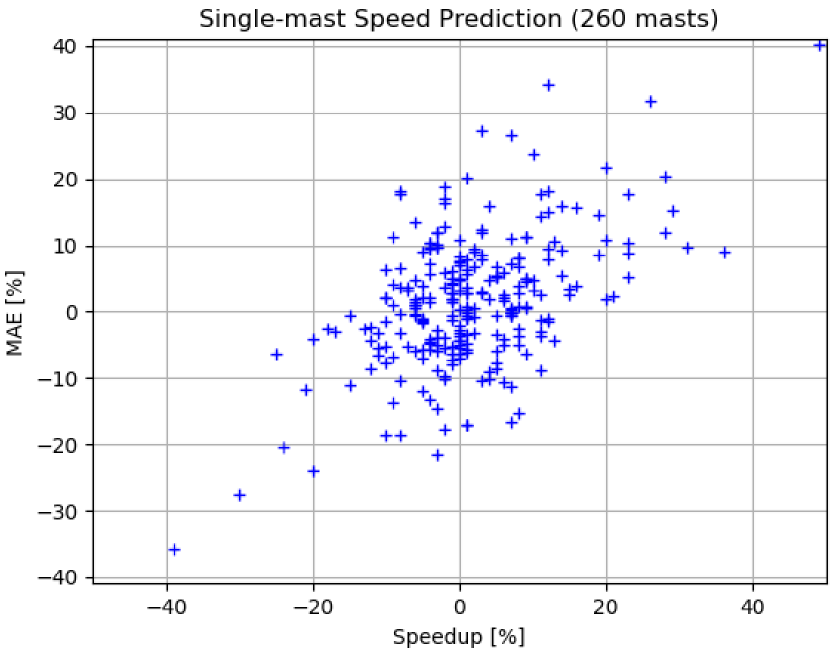
ΔS as “similarity” indicator:

- 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

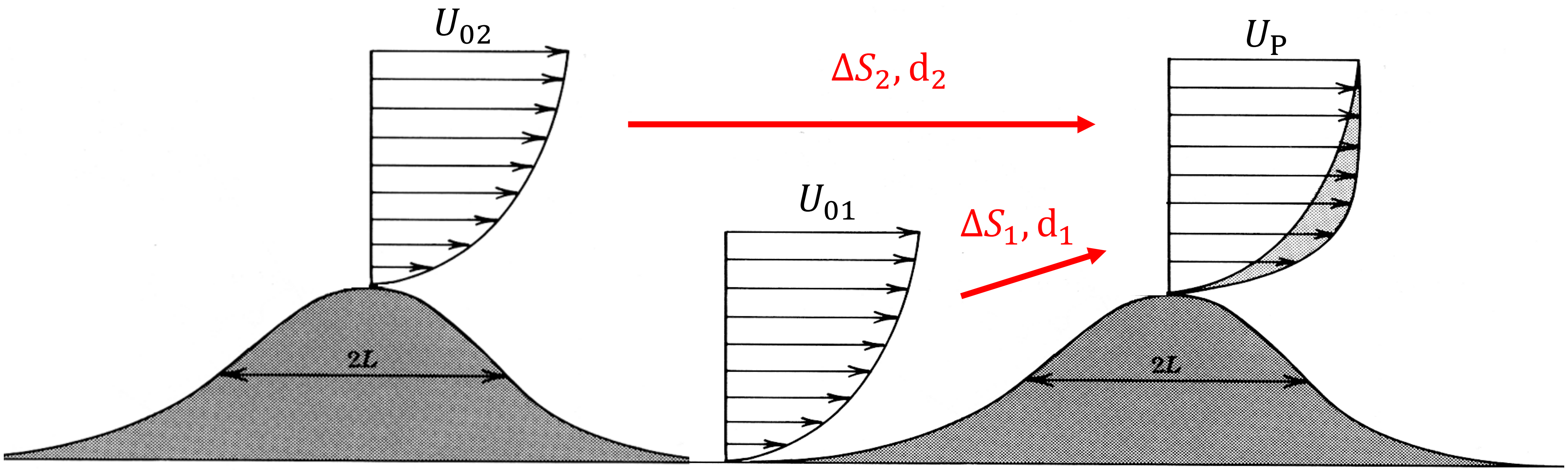
Extrapolation uncertainty

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

Clerc et al. "A Systematic Method for Quantifying Wind Flow Modelling Uncertainty in Wind Resource Assessment." Journal of Wind Engineering and Industrial Aerodynamics 111 (December): 85–94, 2012

Hypothesis:

- *σ_E^2 is a better measure of model error than distance and improves wighted ave.* $w_i = \frac{1}{\sigma_E^2}$
- *σ_E^2 indicates good measurement positions*



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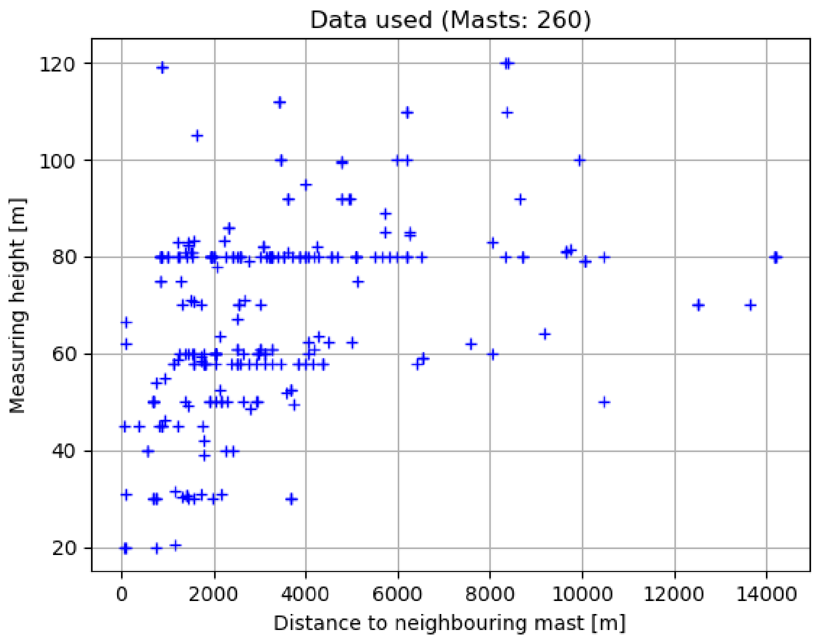
Multi-mast dataset



Multi-mast sites

25 sites with 2 masts

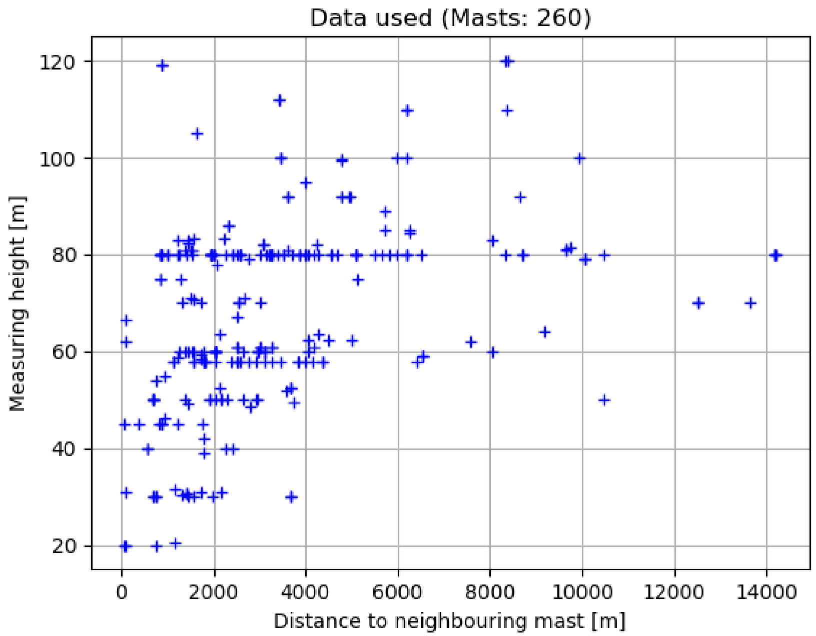
44 sites with 3+ masts

Number of possible predictions

260 single-mast predictions

210 multi-mast prediction

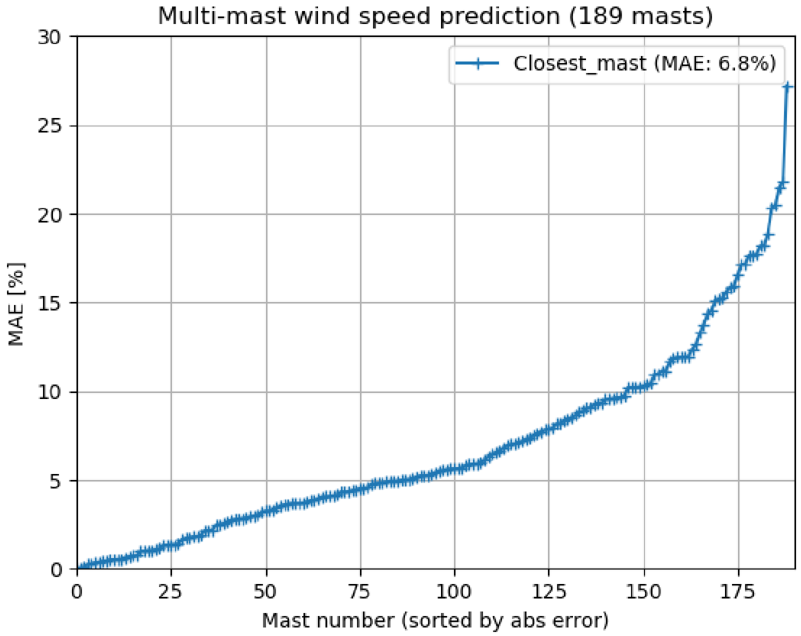
Multi-point Validation



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)

Multi-point Validation



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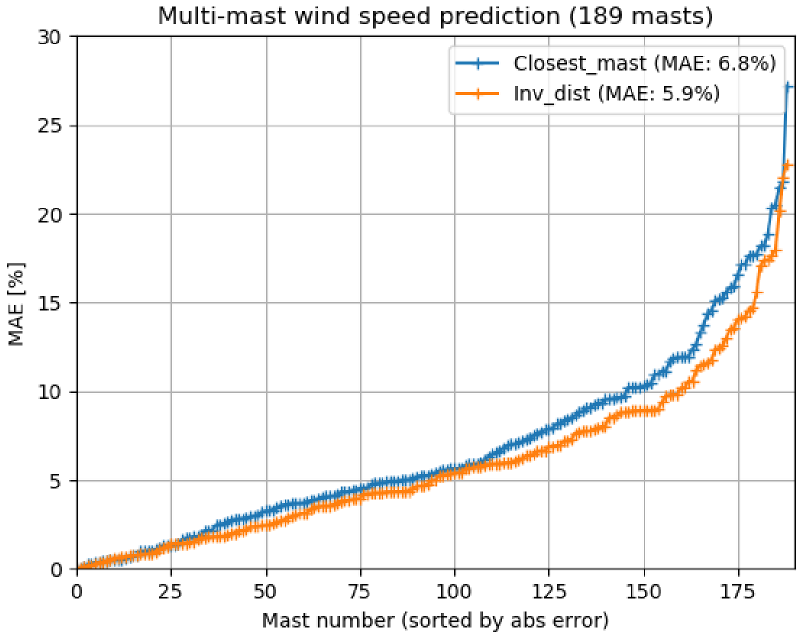

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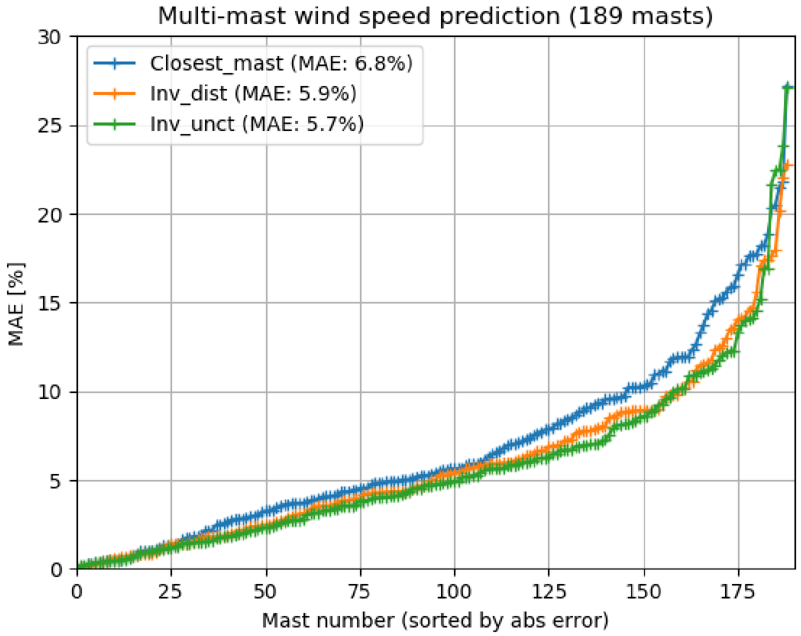

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Conclusion

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”

RECAS
Reduced Assessment Time