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In-depth Validation Key to Acceptance of Mesoscale Results

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Introduction

- Not always wind measurement on-site available
- Particularly offshore, high costs (5-10 mEUR)
- Alternative: mesoscale model w offsite measurements.
- How can we best apply mesoscale model data within a bankable wind resource assessment?

Agenda

1. Benefits and limitations of mesoscale model data

2. Validation of models using nearby measurements

3. Recommended use in wind resource assessment

Mesoscale models:DIY

- WRF and other models are publicly-available
- So are input weather models (MERRA, ERA-Interim, NCEP)
- So you can perform your own mesoscale modelling

- Advantages:
  - Full flexibility
  - Can test the impact of different inputs: reanalysis data, terrain models and parametrisation (e.g. stability)
  - Can tune model to match measurements
- Disadvantages
  - Computer- and time-intensive calculations
  - Complex
  - Number of validations limited to your own available data
  - Limited transparency for third-party review

Mesoscale models: commercial

- There are also many commercial providers of mesoscale model data

- Advantages:
  - Experienced teams dedicated to understanding the models
  - Available quickly (often pre-calculated)
  - Validated against a larger database of measurements
  - Well-documented for third-party review

- Disadvantages
  - Limited possibility to tune model based on your input measurement campaigns

Mesoscale models: Sample assignment

- But how to choose between available commercial models?
- Comparing 6 mesoscale models from market leaders:

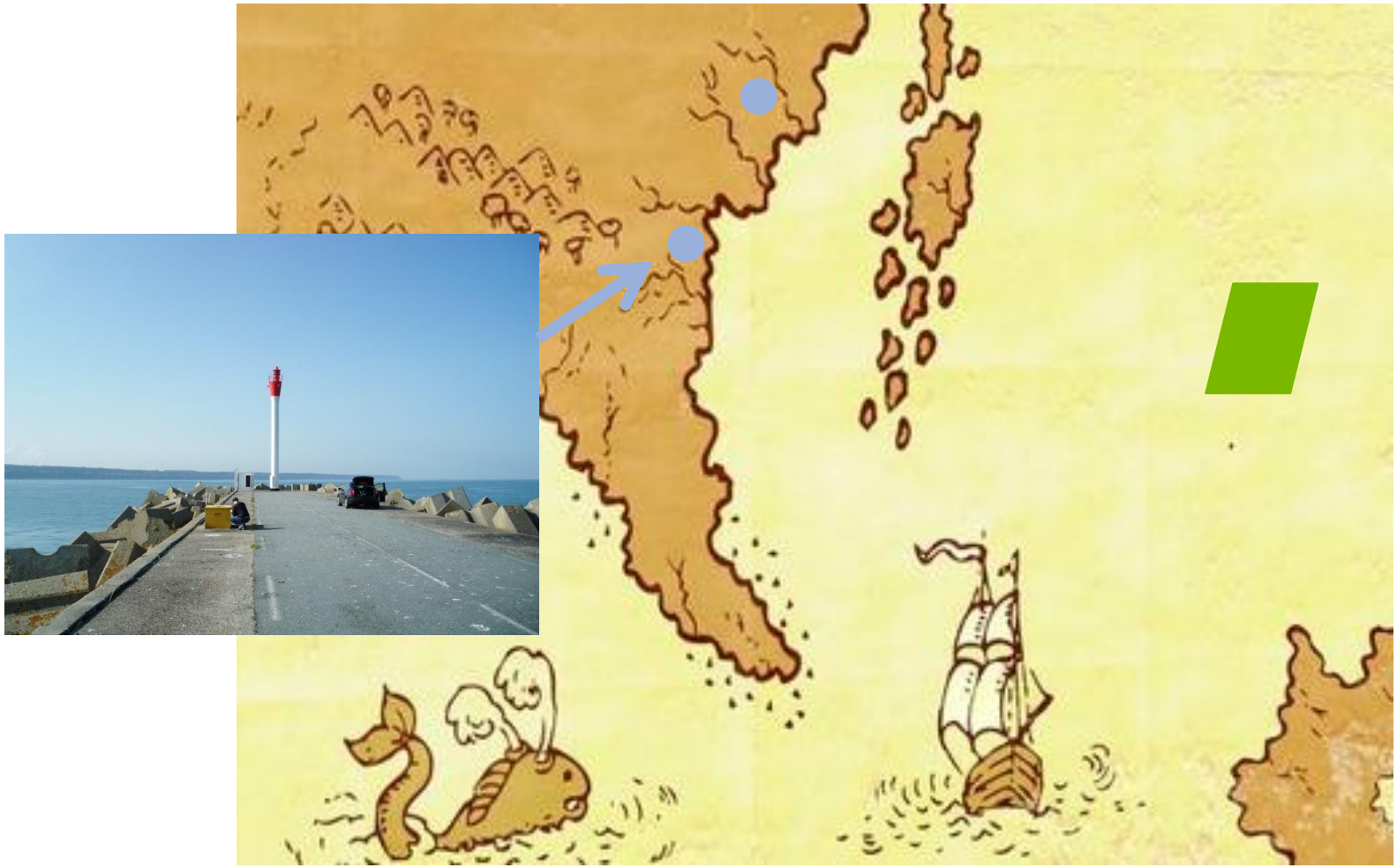
	1	2	3	4	5	6
State-of-the-art flow models	✓	✓	✓	✓	✓	✓
Robust input data (NCEP/NCAR, MERRA or ERA-Interim)	✓	✓	✓	✓	✓	✓
Long-term time series 15+ years	✓	✓	✓	✓	✓	✓
Hourly time resolution	✓	✓	✓	✓	✓	✓
Model grid resolution <= 3 km	✓	✓	✓	✓	✓	✓
Extensive internal validations	✓	✓	✓	✓	✓	✓

Validation with nearby wind measurements

> Some results from recent studies…

Validation with nearby wind measurements

> Coastal wind measurements

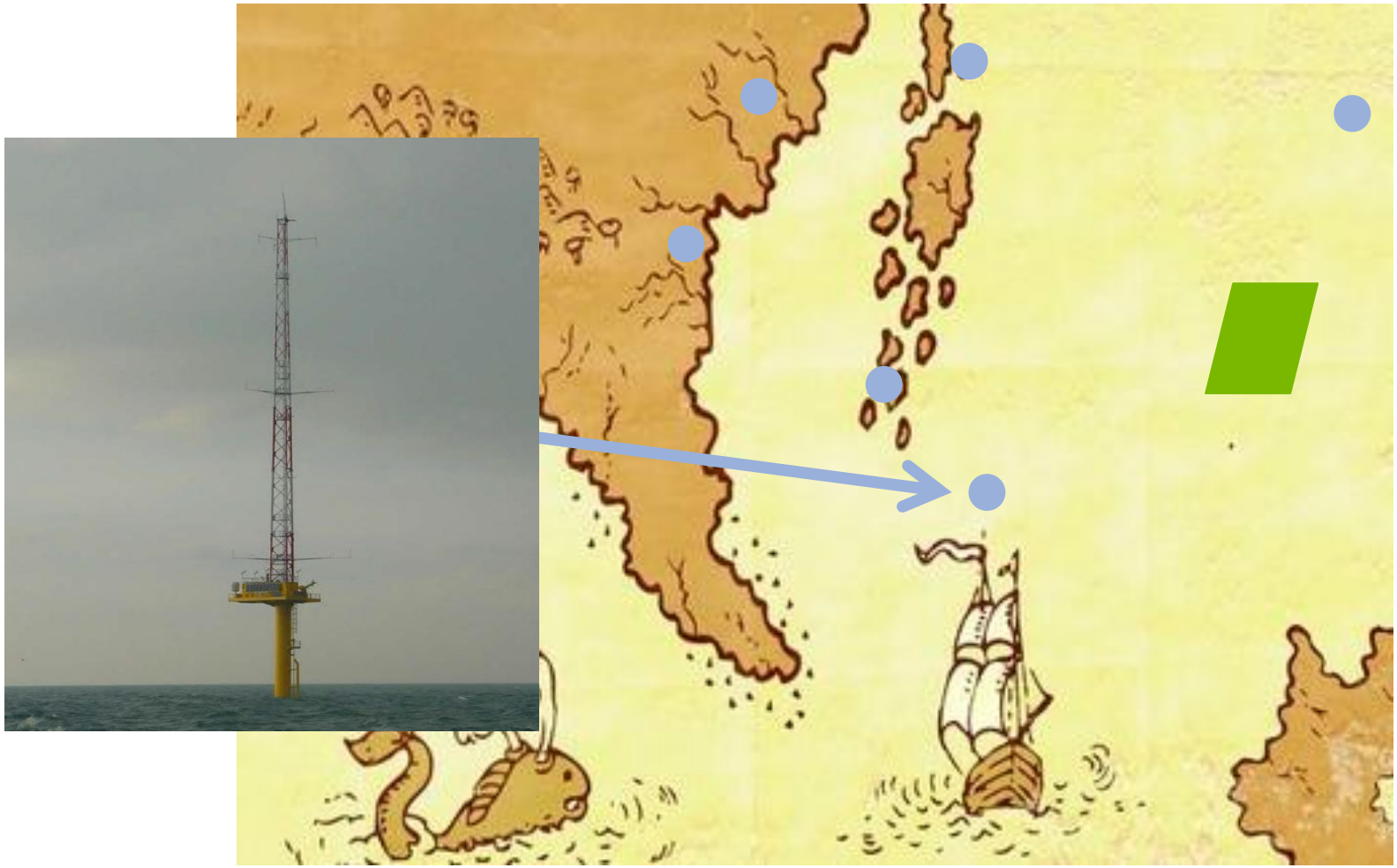


Validation with nearby wind measurements

> Island wind measurements

Validation with nearby wind measurements

> Offshore wind measurements



Validation with nearby wind measurements

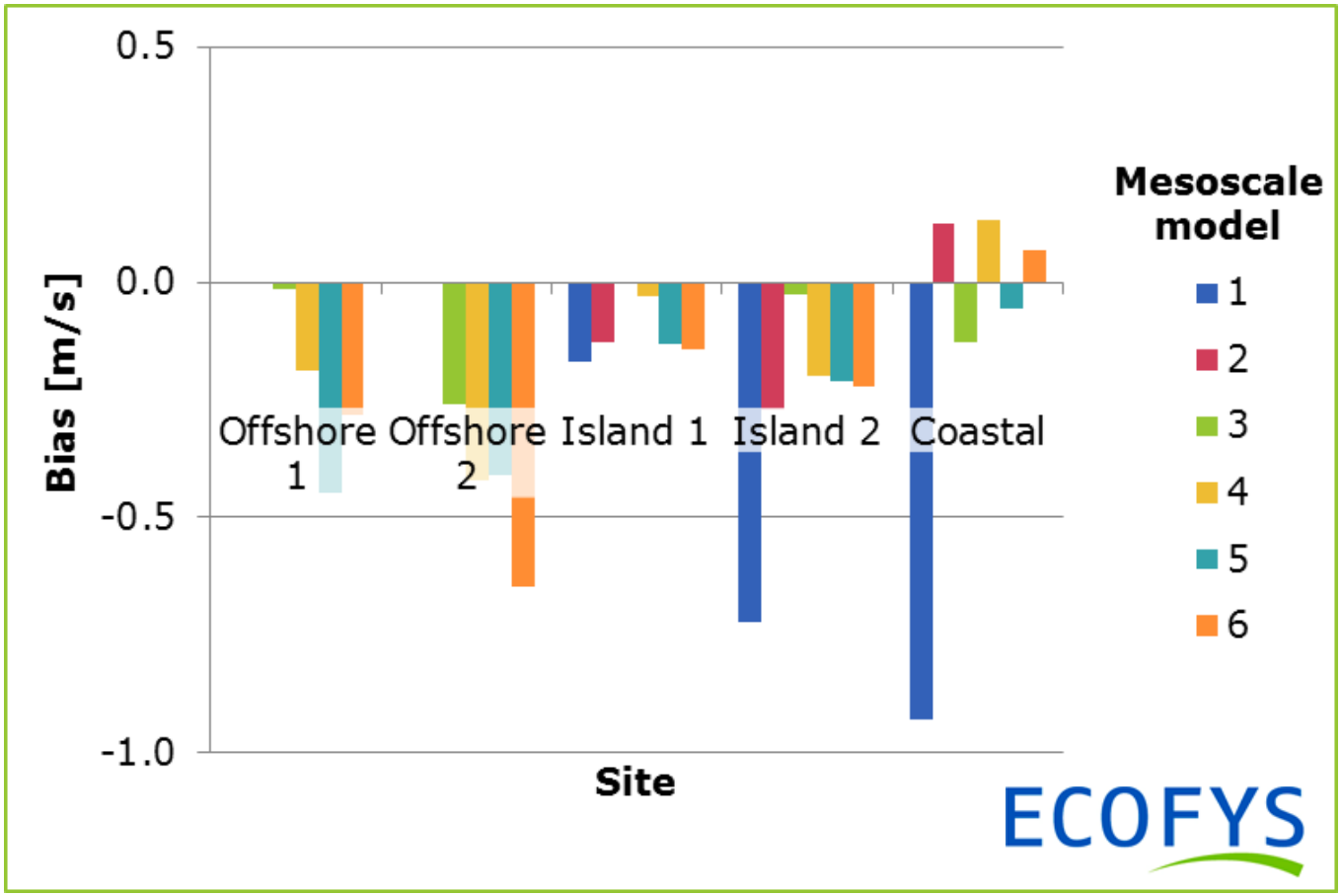
Statistical tests:

- Wind speed correlation coefficient (10-min)
- Wind speed correlation coefficient (daily)
- Bias (mean difference) in wind speed [m/s]
- Bias in wind speed [%]
- Bias in wind speed [m/s] (> 3 m/s)
- Bias in wind speed [m/s] (daily)
- Direction-wise bias [m/s]
- Normalised bias in wind speed
- Standard deviation of differences in wind speed [m/s]
- Mean absolute difference in wind speed [m/s]
- Mean absolute difference in wind speed [%]
- Mean absolute difference in wind speed [m/s] (> 3m/s)
- Mean absolute difference in wind speed [m/s] (daily)
- Normalised mean absolute difference in wind speed
- Root mean square difference in wind speed [m/s]
- Root mean square difference in wind speed [%]
- Direction-wise comparison of Weibull A
- Direction-wise comparison of Weibull k
- Kolmogorov–Smirnov test statistic
- Difference in energy yield with representative wind turbine [%]

Validation with nearby wind measurements

Statistical tests:

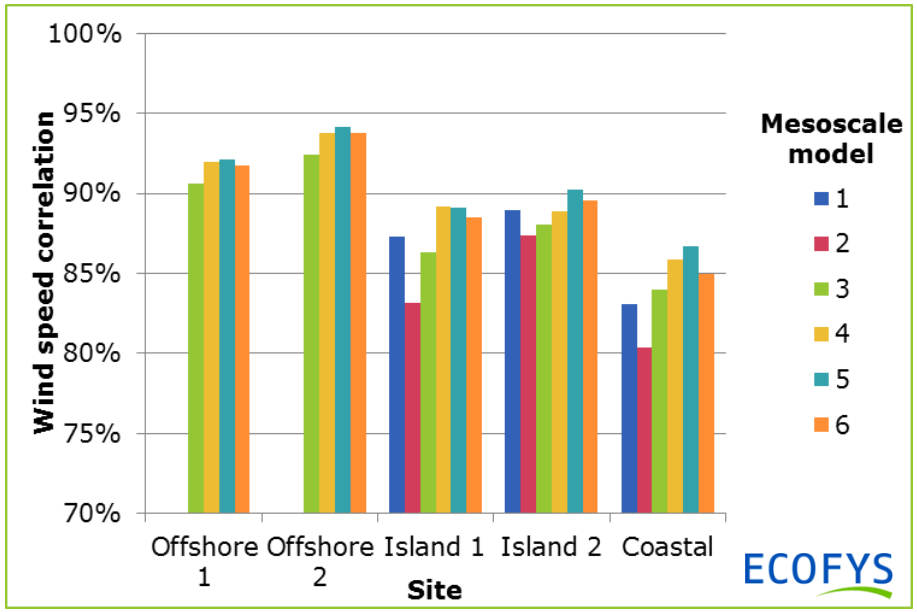
> Bias [m/s]

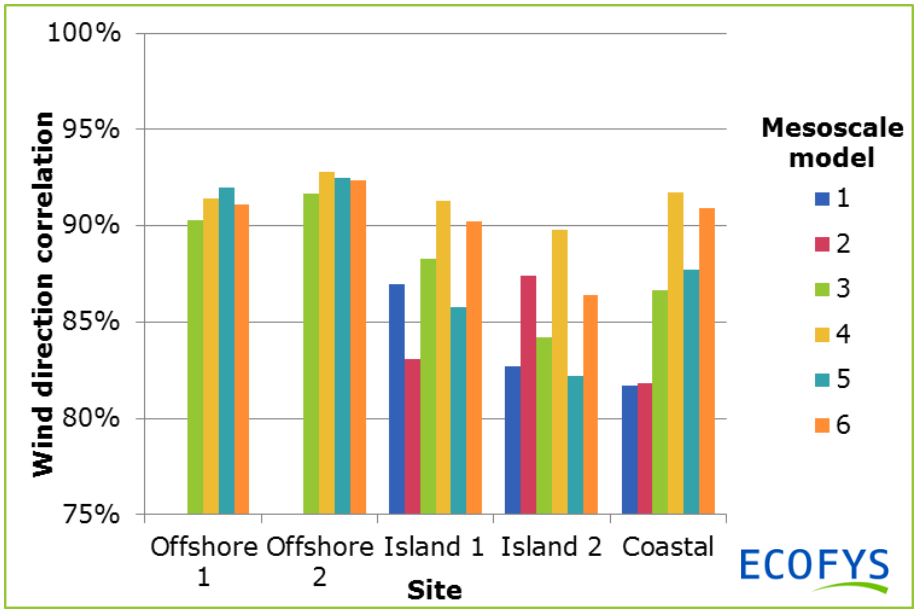


Validation with nearby wind measurements

Statistical tests:

- Wind speed correlation coefficient (10-minute)
- Wind direction correlation coefficient (10-minute)

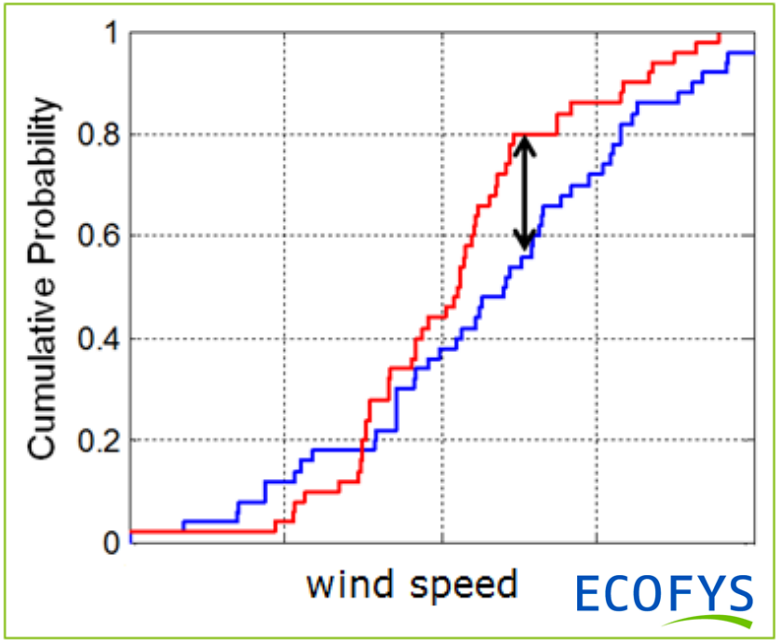


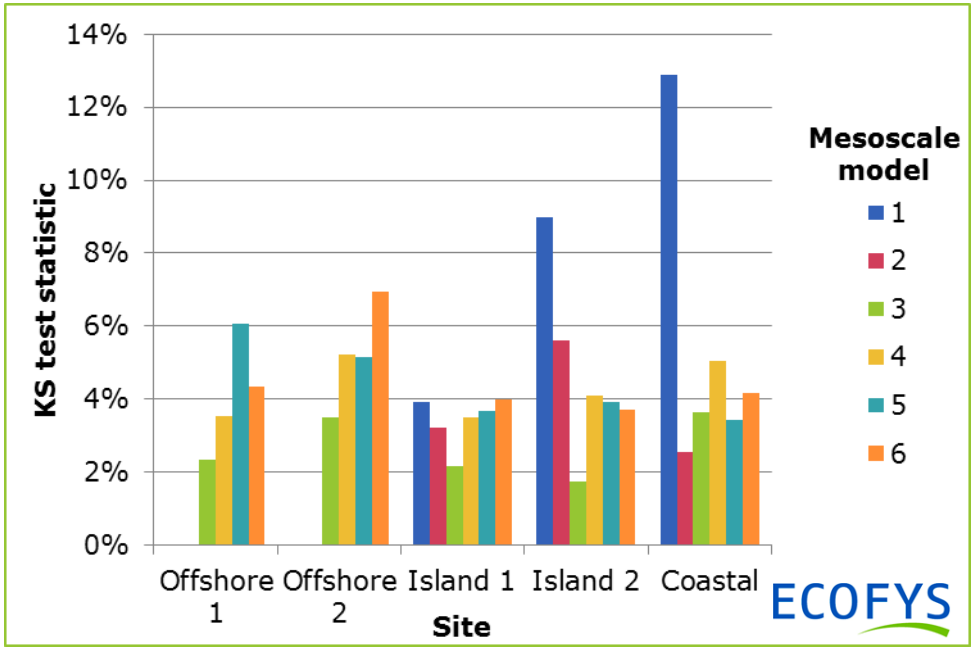


Validation with nearby wind measurements

Statistical tests:

> Kolmogorov–Smirnov test statistic





Validation with nearby wind measurements

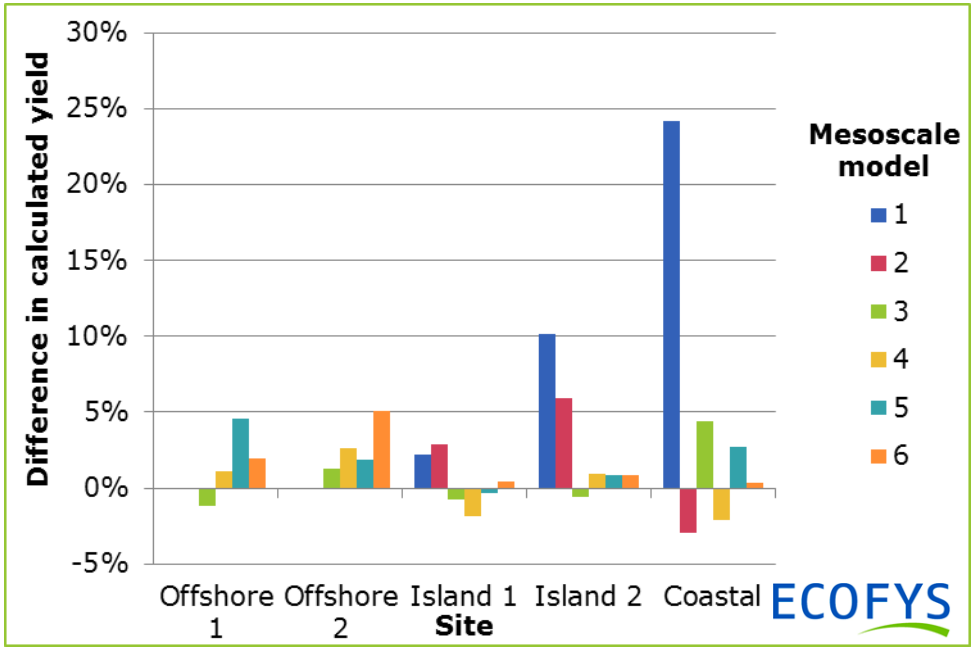
Statistical tests:

> Difference in energy yield for a representative wind turbine

> Calculate energy yield for time series of measured wind speed

> Compare to energy yield for time series of mesoscale wind speed

> Emphasises accuracy in critical wind speed range of 3-10 m/s



Recommended use in wind resource assessment

- Validation of multiple models helps with selection of the best-fit model for a specific site
- Need to validate against representative measurements

- Two possible uses for mesoscale data:
  1. Apply correction-factor (mean wind speed on-site / mean wind speed near measurement site) for wind climate based on nearest wind measurements

- Best if nearby measurements form a solid basis for the wind resource assessment
- Uncertainty in horizontal extrapolation can be quantified
- If the measurements are coastal (or island-based), then terrain-effects may dominate certain sectors

Recommended use in wind resource assessment

> Two possible uses for mesoscale data:

2. Direct use of on-site mesoscale wind speed data

> Best if wind measurements are significantly affected by coastal terrain
> Applies site-specific wind shear and wind rose
> Requires a thorough evaluation of bias (preferably from multiple validation sources)

> The best method depends on an assessment of the overall uncertainties. Which method will introduce the most uncertainty to the energy yield calculations?

Conclusions & Recommendations

- Mesoscale models (either commercial or own calculations) are a valuable tool for wind resource assessments
- A thorough validation against high-quality wind measurements needed to select the best model for the specific site
- The mesoscale data should be applied according to a method which minimizes overall uncertainty in the energy yield calculations (site dependent)

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