# Mesoscale Modelling Benchmarking Exercise: Initial Results

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# Mesoscale Modelling Benchmarking Exercise: Initial Results

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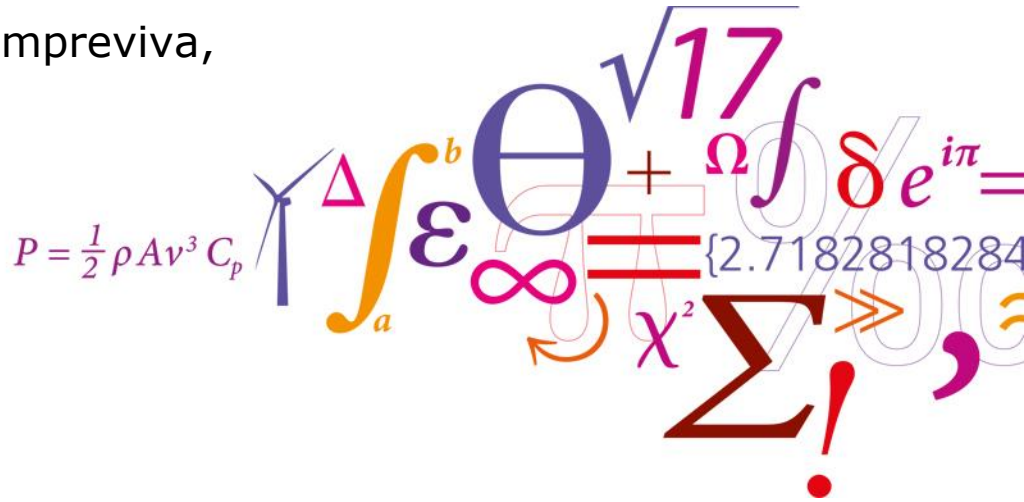



DTU Wind Energy
Department of Wind Energy

# Motivation and objectives

- There are many sources of mesoscale model output
  - Are there general rules in how to select the best mesoscale model output for various applications?
  - What magnitude of errors in wind speed and direction can be expected in a highly observed and relatively simple region?

- Provide guidance in setting up simulations

- Provide guidance in the magnitude of the errors that can be expected from 'raw' mesoscale model output

# Outline

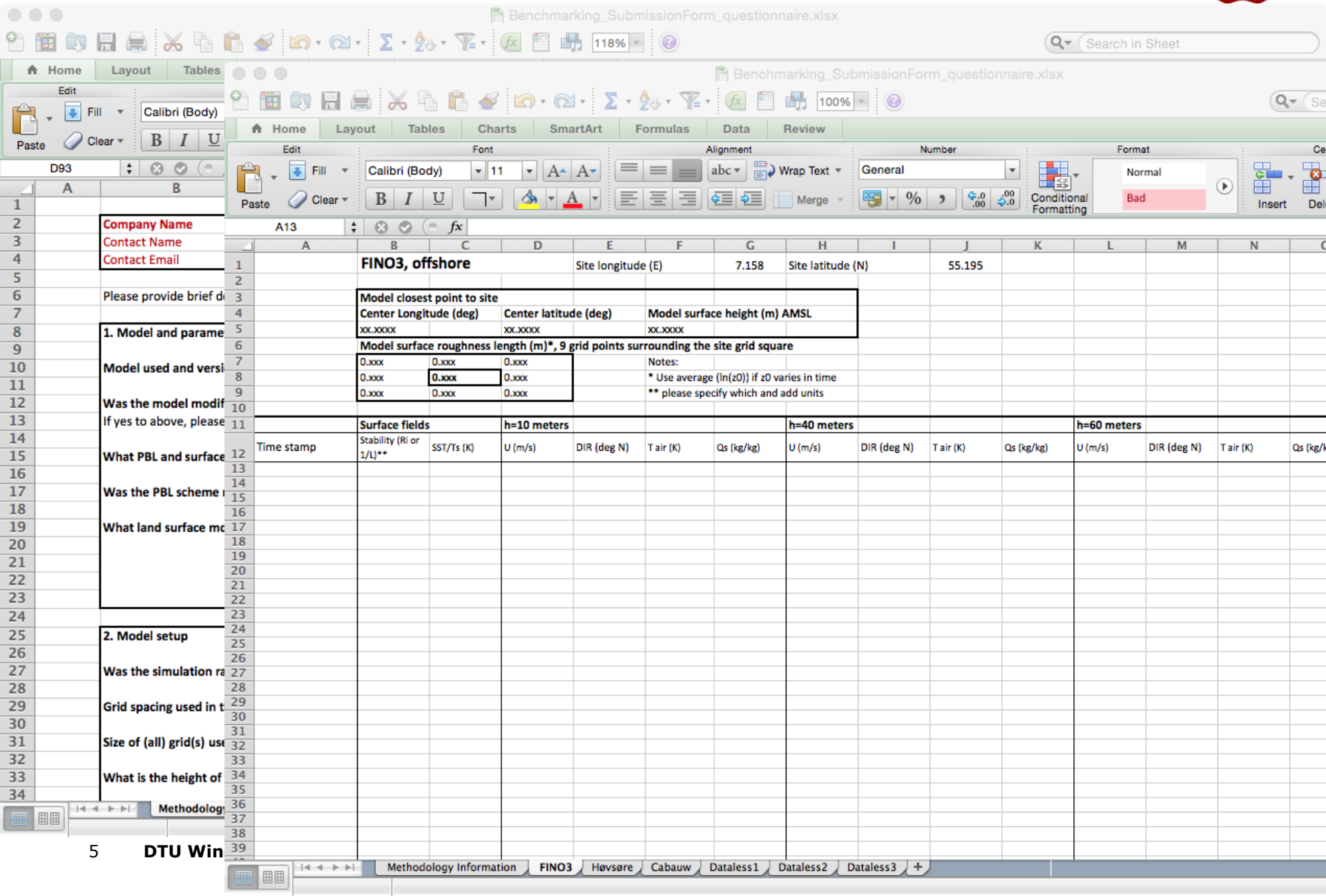
- Rules of the exercise
- Brief summary of submissions
- Basic statistics
  - wind speed
  - wind direction
  - wind profiles
- The effect of resolution
- Comparison of models and sites
- Conclusions and future analysis
- A request

# Rules of the Exercise


- **Many thanks to EWEA for handling the data submission!!**

- Provide time series of raw mesoscale model output for 6 sites in Northern Europe:
  - Fino3, DE – offshore
  - Høvsøre, DK – coastal land
  - Cabauw, NL – land
  - 3 dataless sites: offshore, coastal (water based) and land
- Each entry: Hourly data, year 2011, wind speed and direction, temperatures and humidity, surface fluxes
- Several vertical levels (10-200 meters AGL)
- Many other metadata requested; examples:
  - model name and version
  - horizontal and vertical resolution
  - forcing, surface roughness, etc

# Time series submission



Benchmarking_SubmissionForm_questionnaire.xlsx

| | A | B |
|---|---|---|
| 2 | | Company Name |
| 3 | | Contact Name |
| 4 | | Contact Email |
| 6 | | Please provide brief d |
| 8 | | 1. Model and parame |
| 10 | | Model used and versi |
| 12 | | Was the model modif |
| 13 | | If yes to above, please |
| 15 | | What PBL and surface |
| 17 | | Was the PBL scheme |
| 19 | | What land surface mo |
| 25 | | 2. Model setup |
| 27 | | Was the simulation ra |
| 29 | | Grid spacing used in t |
| 31 | | Size of (all) grid(s) use |
| 33 | | What is the height of |

Methodology

Benchmarking_SubmissionForm_questionnaire.xlsx

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | FINO3, offshore | | | Site longitude (E) | | 7.158 | Site latitude (N) | | 55.195 | | | | |
| 3 | | Model closest point to site | | | | | | | | | | | | |
| 4 | | Center Longitude (deg) | | Center latitude (deg) | | Model surface height (m) AMSL | | | | | | | | |
| 5 | | xx.xxxx | | xx.xxxx | | xx.xxxx | | | | | | | | |
| 6 | | Model surface roughness length (m)*, 9 grid points surrounding the site grid square | | | | | | | | | | | | |
| 7 | | 0.xxx | 0.xxx | 0.xxx | | Notes: | | | | | | | | |
| 8 | | 0.xxx | 0.xxx | 0.xxx | | * Use average (ln(z0)) if z0 varies in time | | | | | | | | |
| 9 | | 0.xxx | 0.xxx | 0.xxx | | ** please specify which and add units | | | | | | | | |
| 11 | | | Surface fields | | h=10 meters | | | | h=40 meters | | | | h=60 meters | | |
| 12 | Time stamp | Stability (Ri or 1/L)** | SST/Ts (K) | U (m/s) | DIR (deg N) | T air (K) | Qs (kg/kg) | U (m/s) | DIR (deg N) | T air (K) | Qs (kg/kg) | U (m/s) | DIR (deg N) | T air (K) | Qs (kg/k |

Methodology Information | FINO3 | Høvsøre | Cabauw | Dataless1 | Dataless2 | Dataless3

# Data received

21 files containing time series were received by the deadline of 1 April 2015

**Participants:**

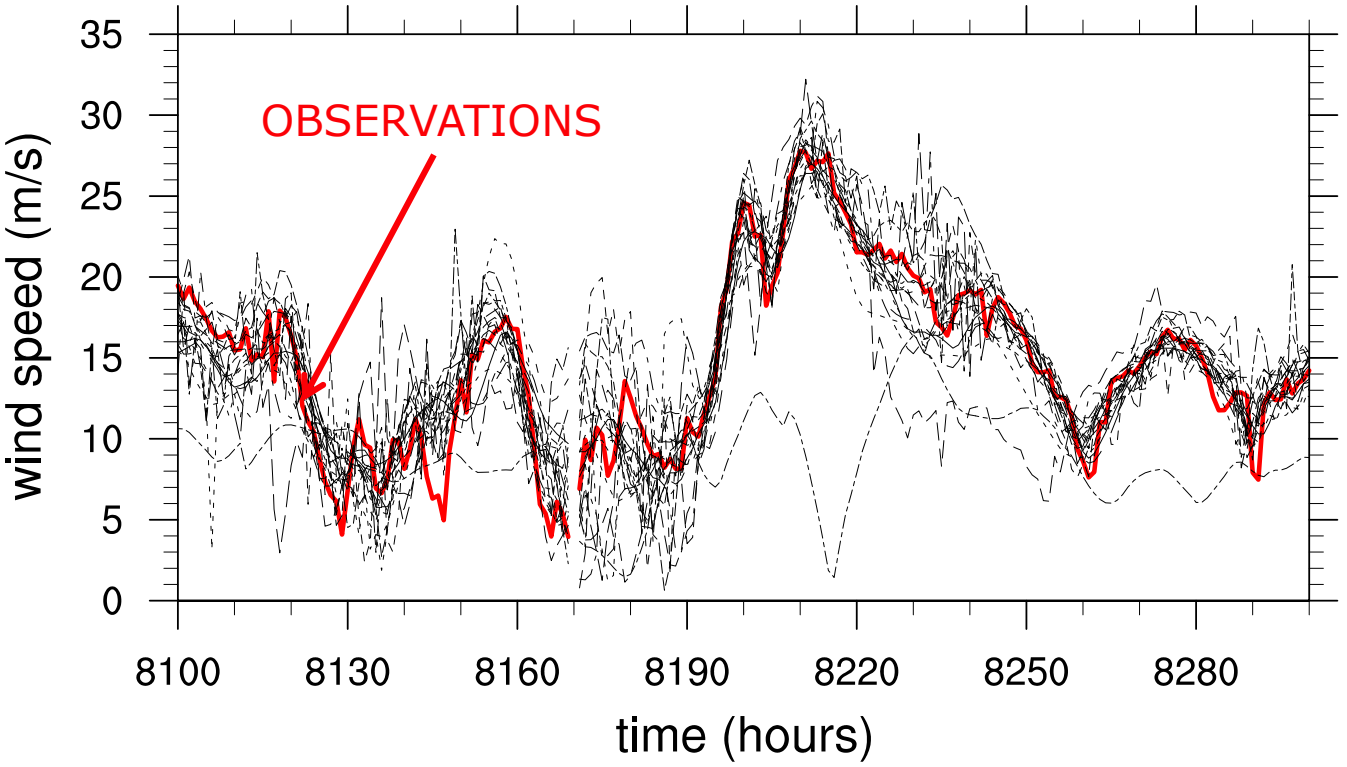
- 3E, BE
- Anemos GmbH, DE
- CENER, ES
- CIEMAT, ES
- DEWI, DE
- DTU Wind Energy, DK
- DX Wind Technologies (Beijing) Co., Ltd.
- EMD International, DK
- ISAC-CNR, IT
- KNMI, NL
- Met Office, UK
- Noveltis, FR
- Statoil ASA, NO
- University Oldenburg, DE
- Vortex, ES

# Good sample of existing models and methodologies

- Models:
  - Harmonie 37h1.1
  - HIRLAM, v6.4.2
  - Met Office v8.4
  - MM5
  - RAMS 6.0
  - SKIRON 6.9
  - WRF v3.0.1
  - WRF v3.1
  - WRF v3.2.1
  - WRF v3.3.1
  - WRF v3.4
  - WRF v3.5.1
  - WRF v3.6
  - WRF v3.6.1

- Model resolutions:
  - 2 km x 2 km, to
  - 20 x 20 km
- Simulation and spin-up length:
  - min: 9 h with 3 h spin-up
  - max: 100 days
  - most 30-36 h with 3-12 h spin-up
- Forcing data:
  - ERA Interim (most)
  - CFSR
  - MERRA
  - GFS/FNL (NCEP oper. analysis)
  - ECMWF oper. analysis
- Planetary boundary layer schemes:
  - YSU (1$^{st}$ order)
  - MYJ (2$^{nd}$ order)
  - MYNM (1.5 and 2.5 order)
  - ACM2

# Wind speed at FINO3 - 90 m AGL




- Most model results cluster close to observations, but lots of variations
- Some obvious outliers
- How do we quantify their similarity and/or their ability to predict the observed wind climate at the site?

# Standard statistics: bias, correlation and variance ratio

A few statistical quantities

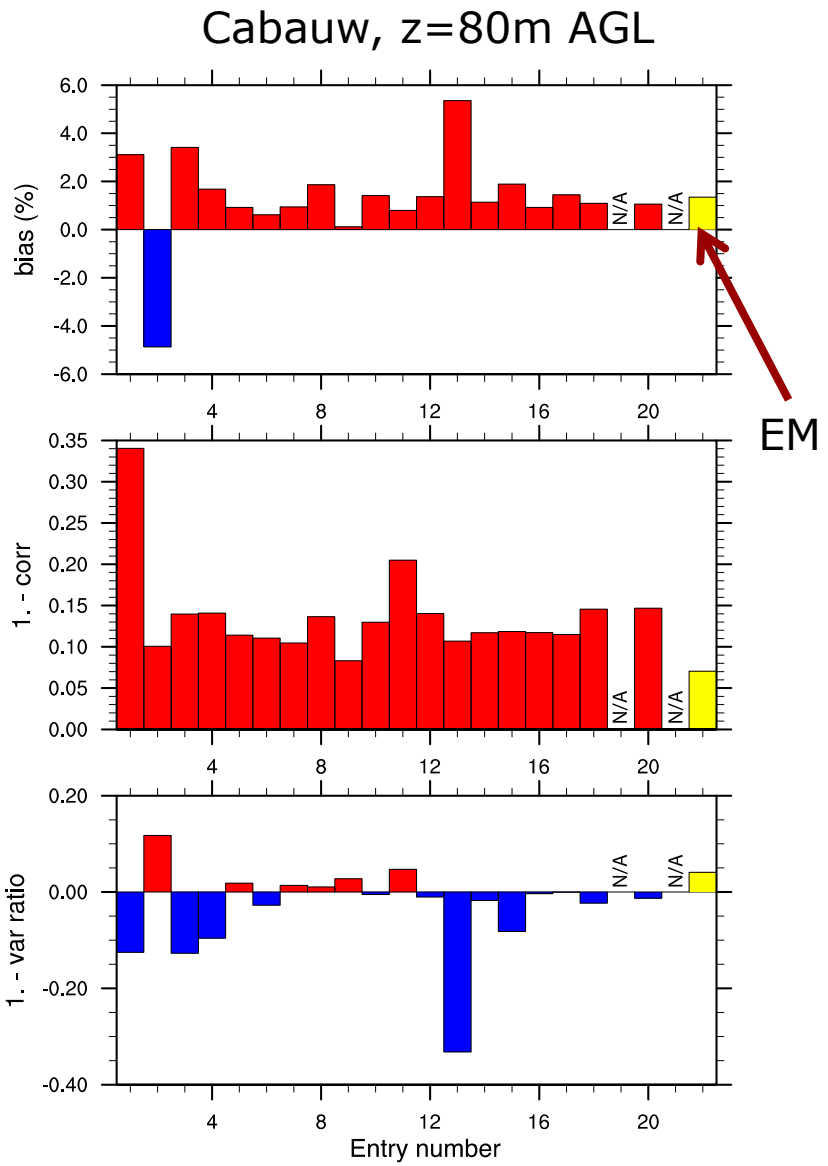
$$\mathrm{BIAS} = \frac{1}{N}\sum(U_M - U_O)$$

$$\rho = \frac{\sum(U_O - \overline{U}_O)(U_M - \overline{U}_M)}{\sigma_O\,\sigma_M}$$

$$\mathrm{VAR\ ratio} = \frac{\sigma(U_M)}{\sigma(U_O)}$$

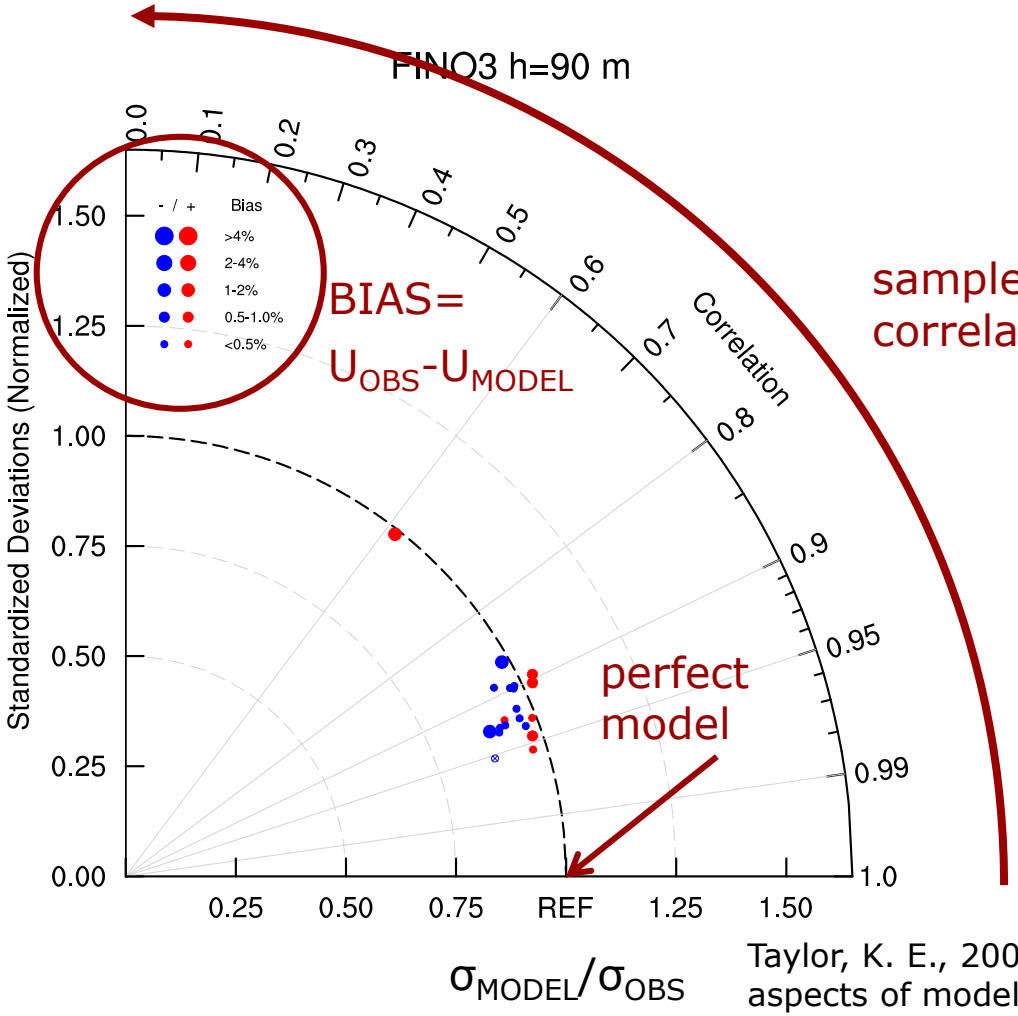
$$\mathrm{EM} = \frac{1}{M}\sum_{n=1}^{n=M} U_n(\mathrm{time}, \mathrm{height})$$

Most of the following plots are without submission number, please come to poster session to see how your model compares



# Taylor diagrams

Combined view of bias, correlation and variance
Used often in climate model intercomparison

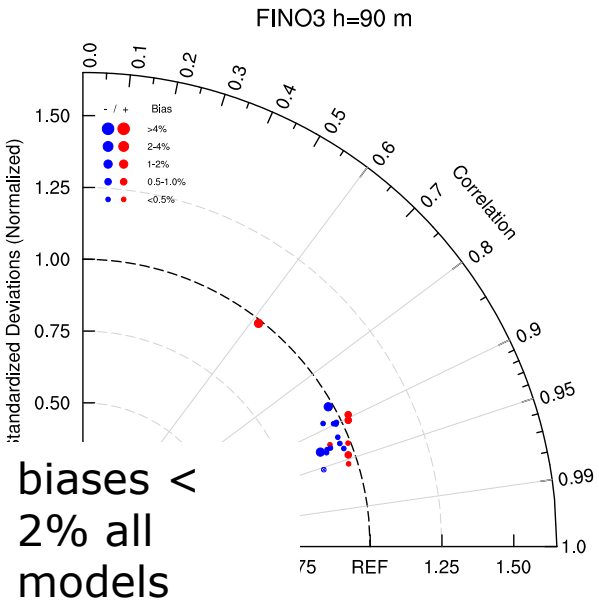



Taylor, K. E., 2001: Summarizing multiple aspects of model performance in a single diagram, JGR Atmospheres.

# Taylor diagrams

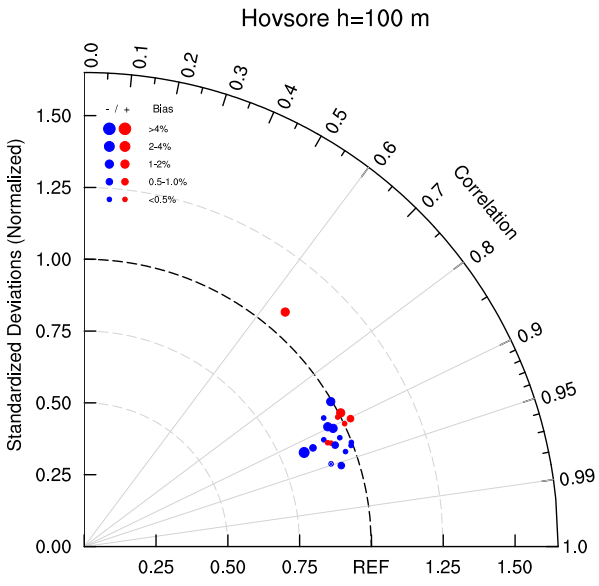
Wind speed, All sites – 80-100 m

offshore

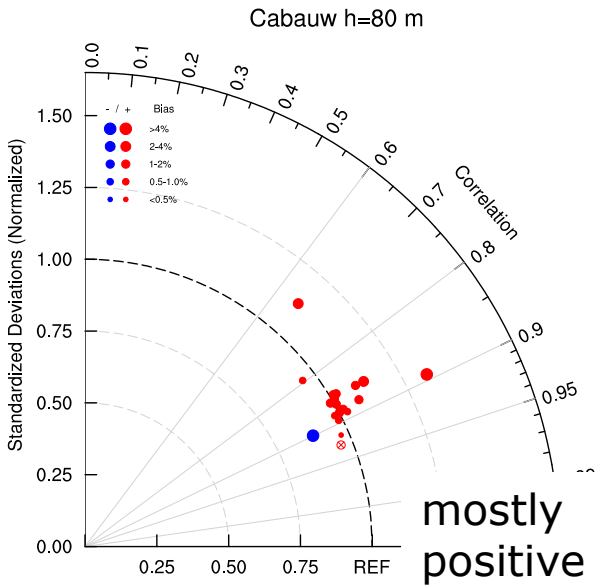



biases < 2% all models

coastal




land




mostly positive biases

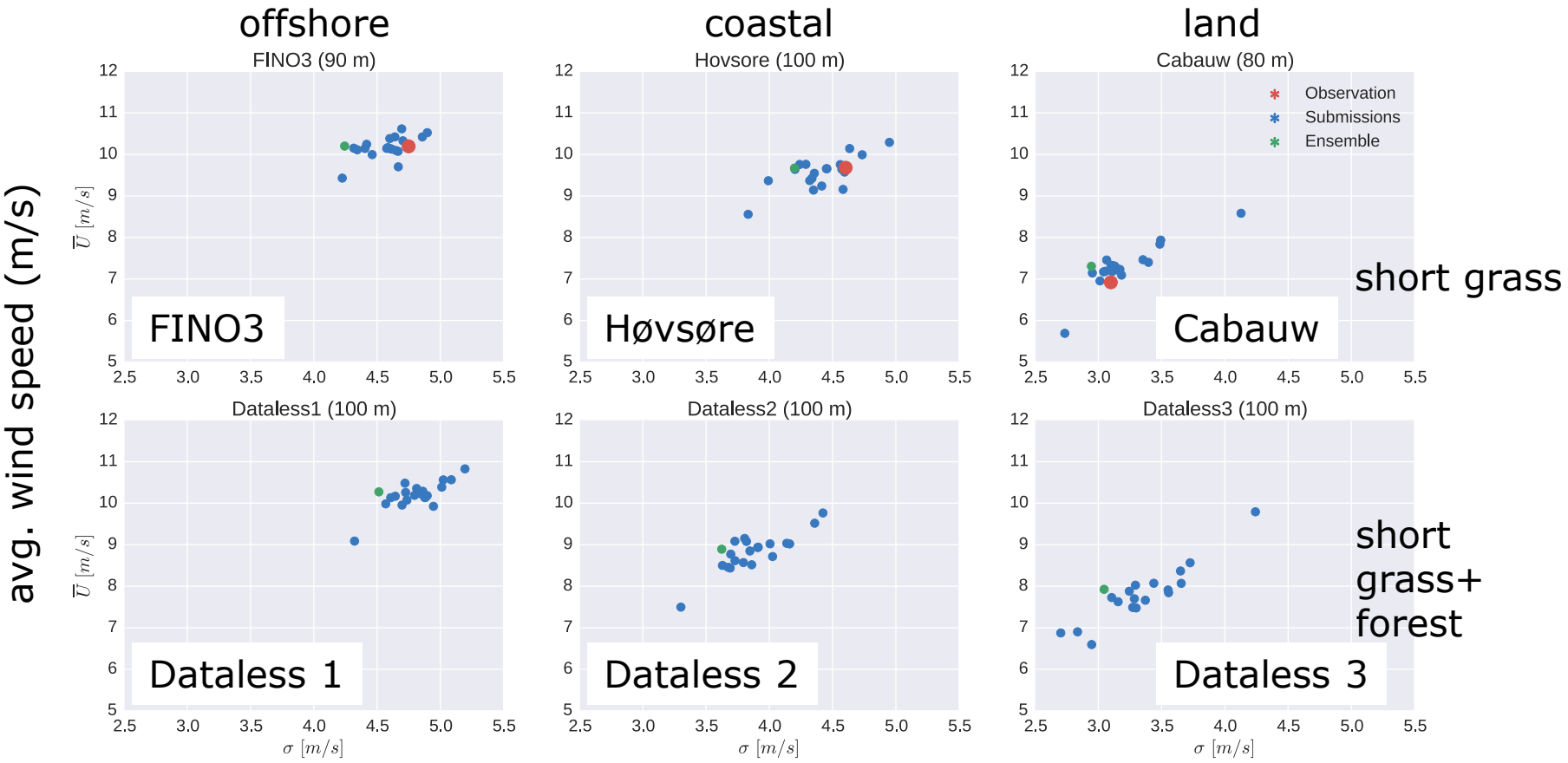
Low biases

Low spread among models

higher biases, lower correlations

larger spread among models

# Spread between sites with data and without

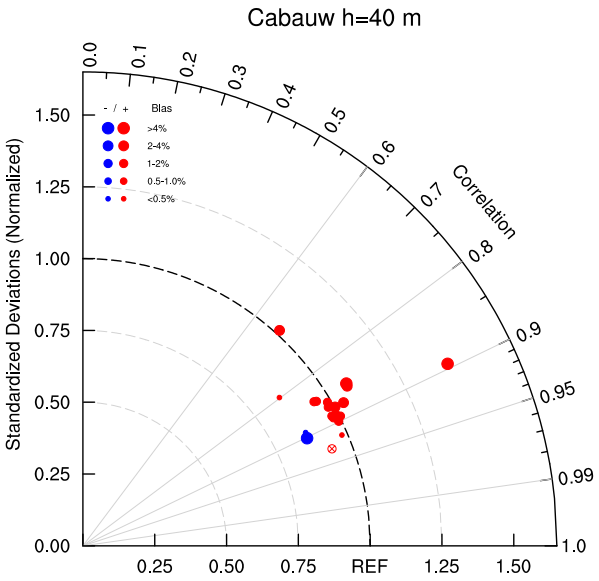



Not a large difference, but more spread in more complex sites

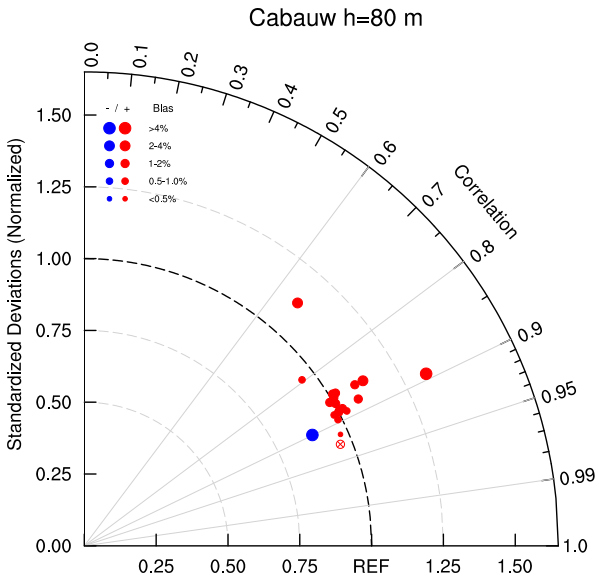
# Taylor diagrams

wind speed for different heights at Cabauw

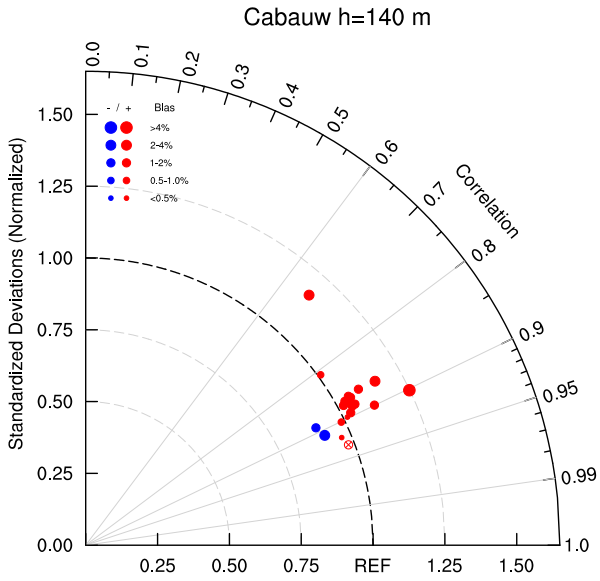
h=40 m




h=80 m



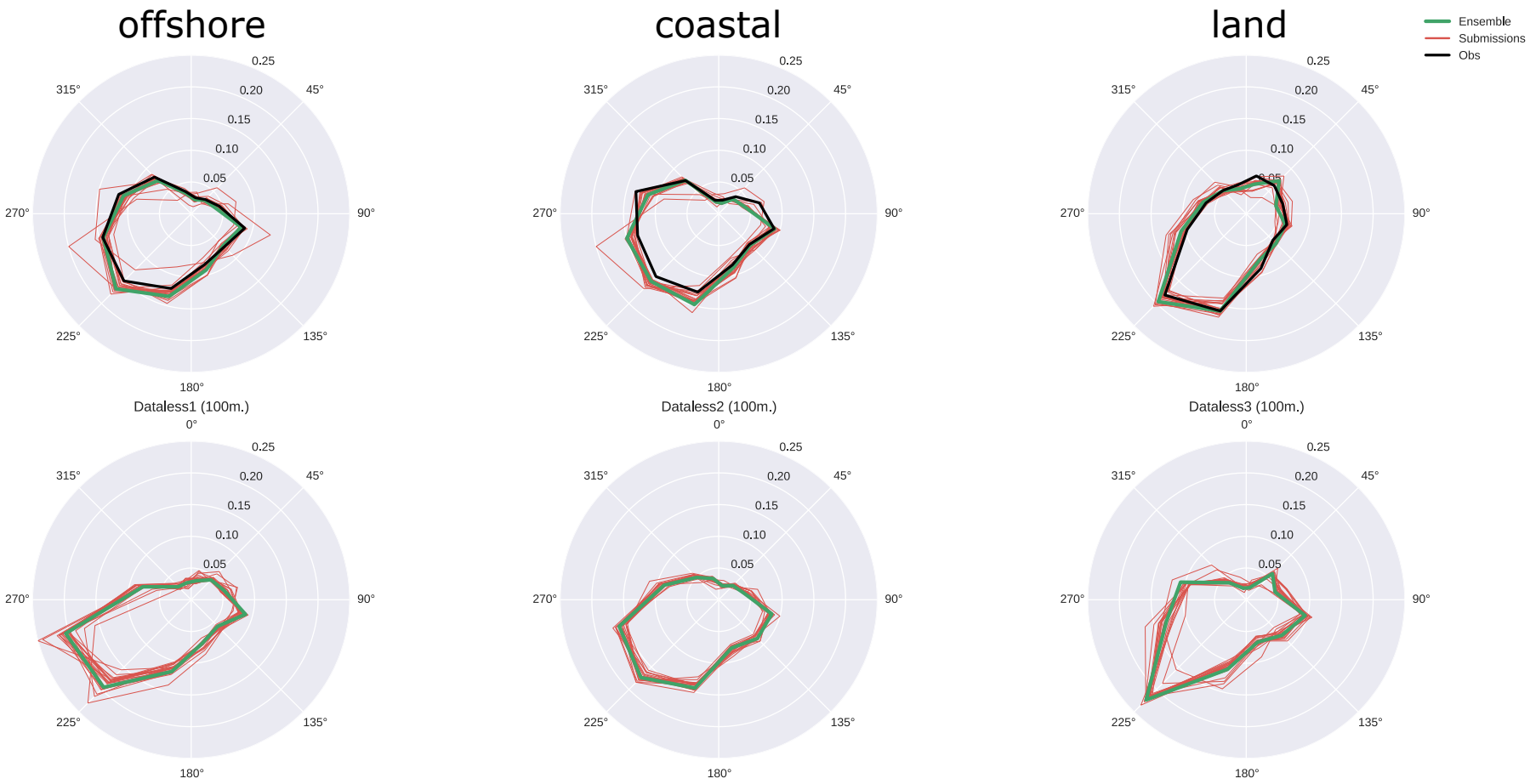

h=140 m




Not a large difference in the patterns with height.
But smaller biases at 140 m than at 40 m. More on this later

# Wind direction distributions

Wind roses (80-100 m) for all 6 sites




Good agreement between most models and observations

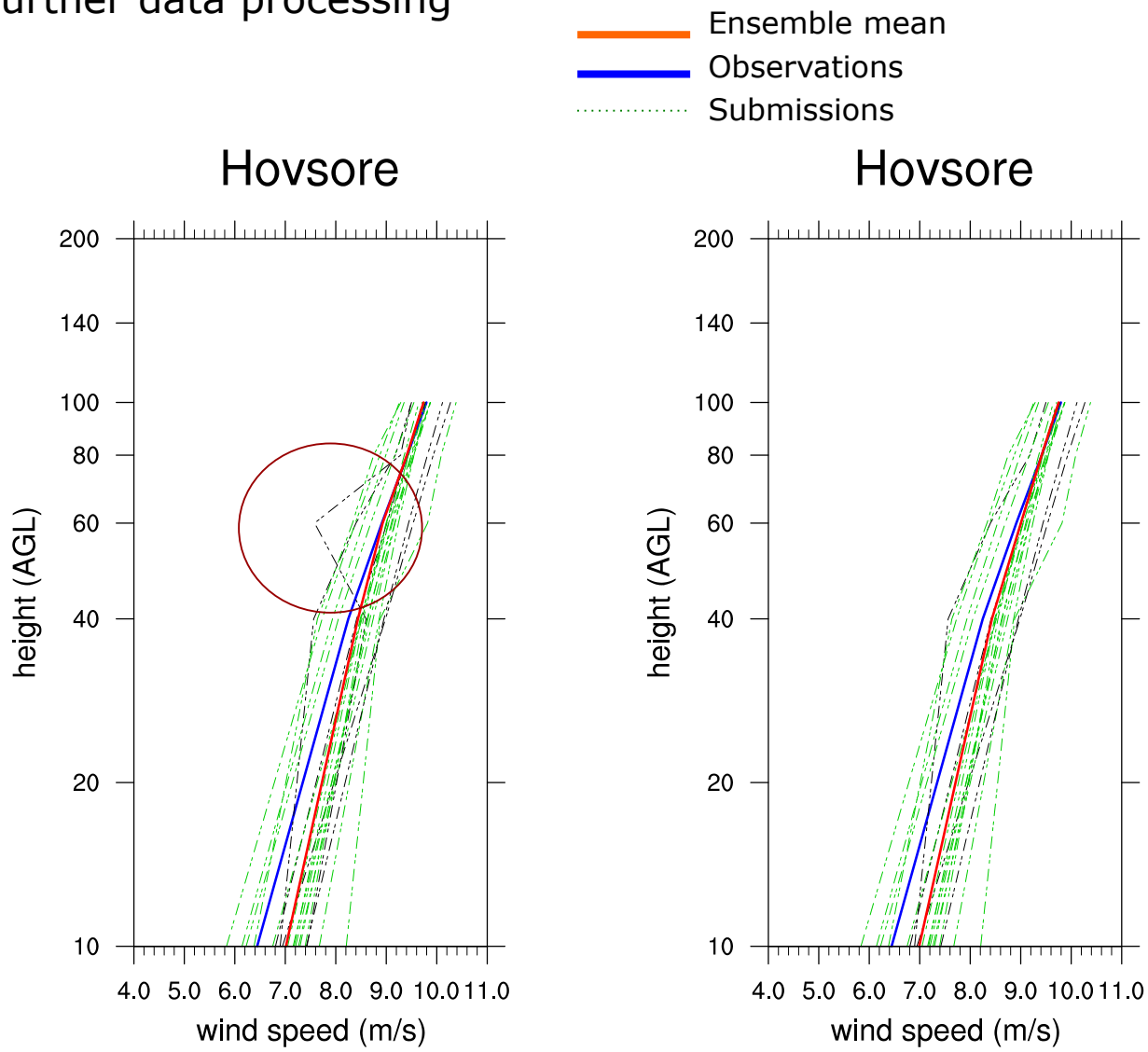
Ensemble mean

Observations

Submissions

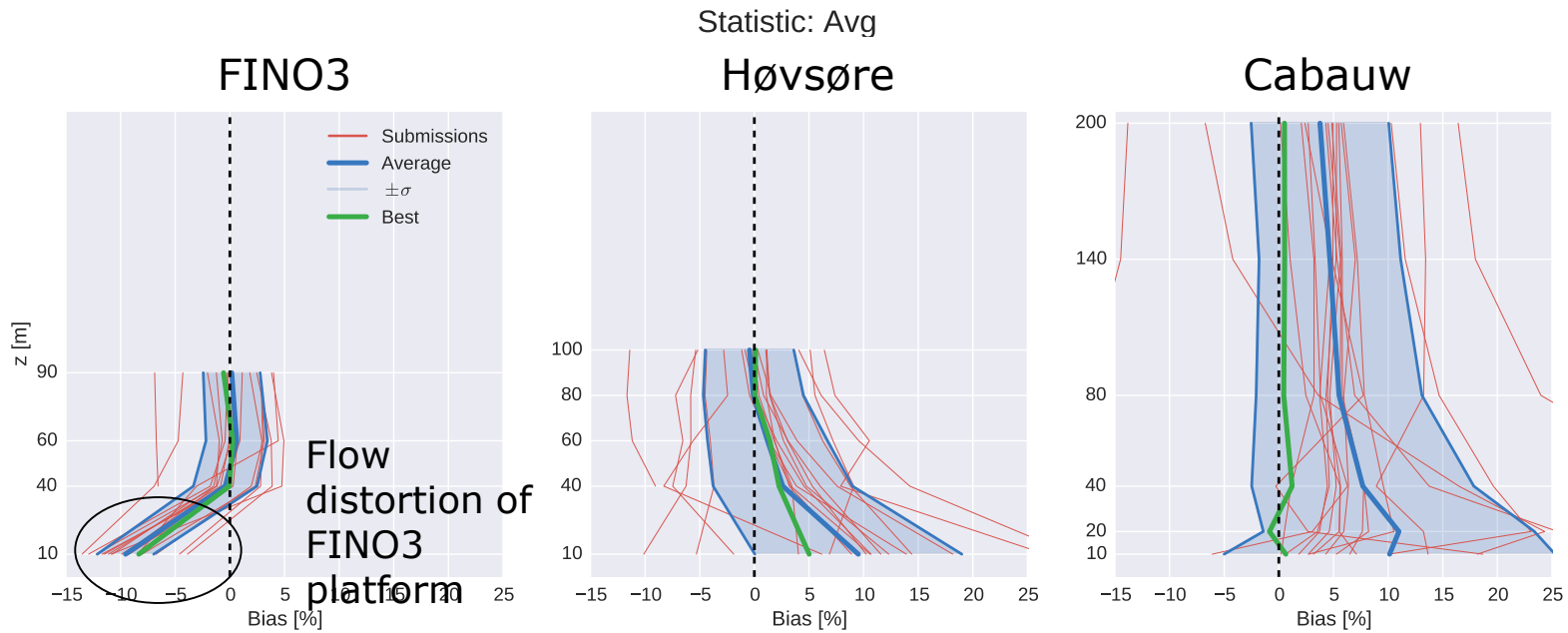
# Comparison of wind profiles

Need for further data processing



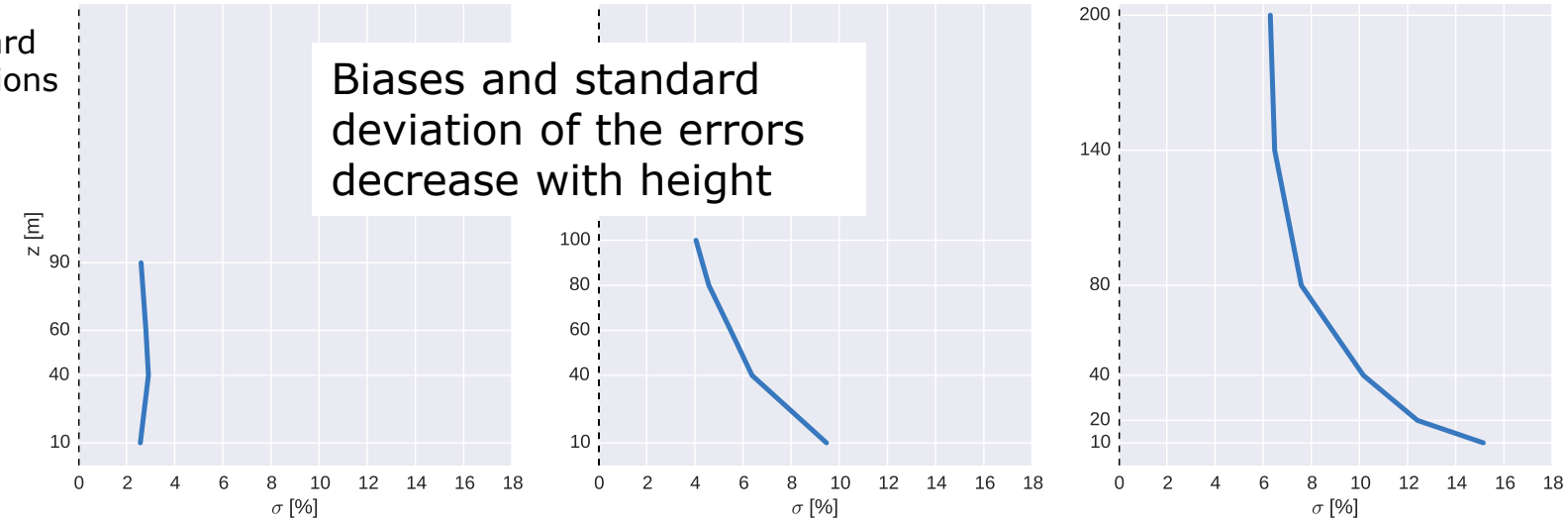
# Effect of height

Bias of wind speed as a function of height, all models, 3 sites



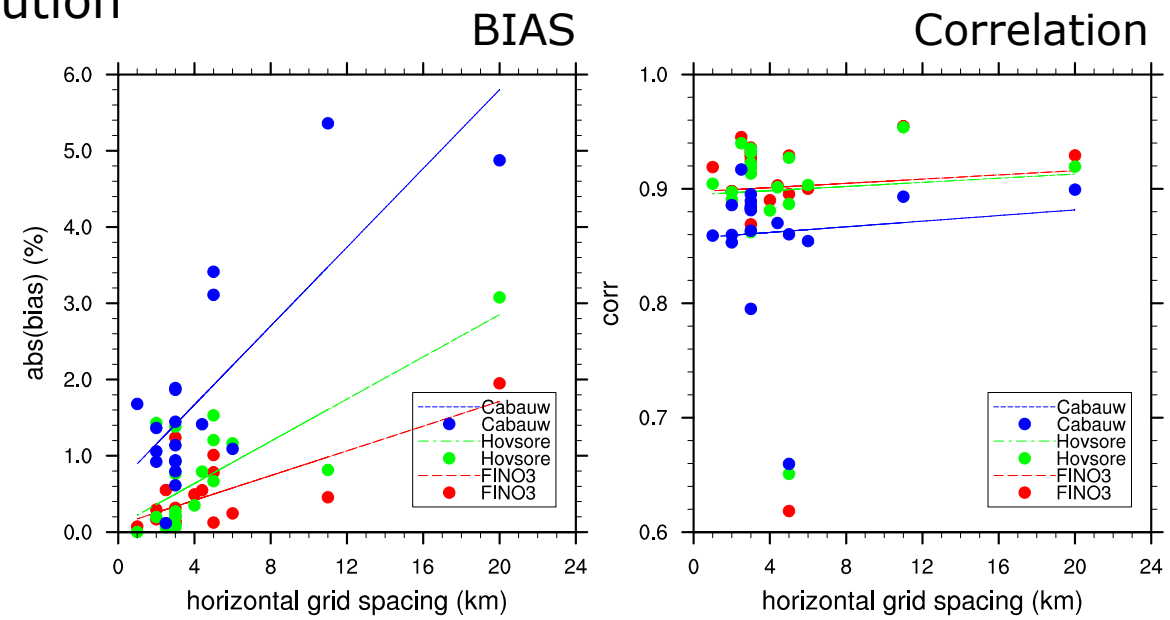

standard deviations of the errors

Biases and standard deviation of the errors decrease with height

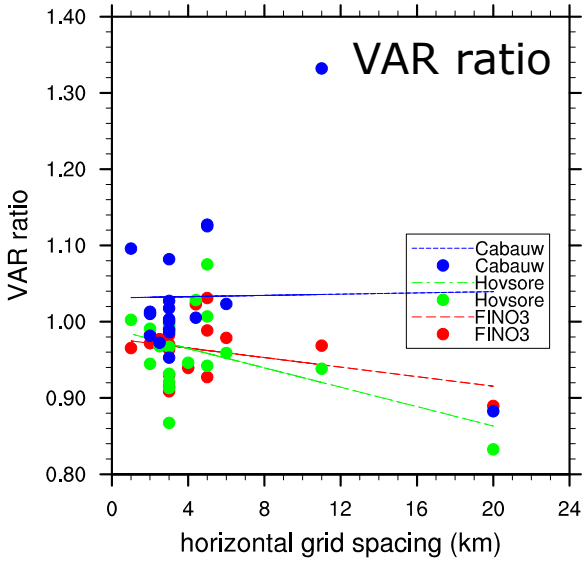


# Effect of resolution

Wind speed BIAS, correlation and variance ratio as a function of horizontal resolution




- Strong relationship between BIAS and model resolution
  - Not reaching zero for land site
- Weak relationship between correlation and model resolution
- Weak relationship for VAR ratio for coastal and offshore

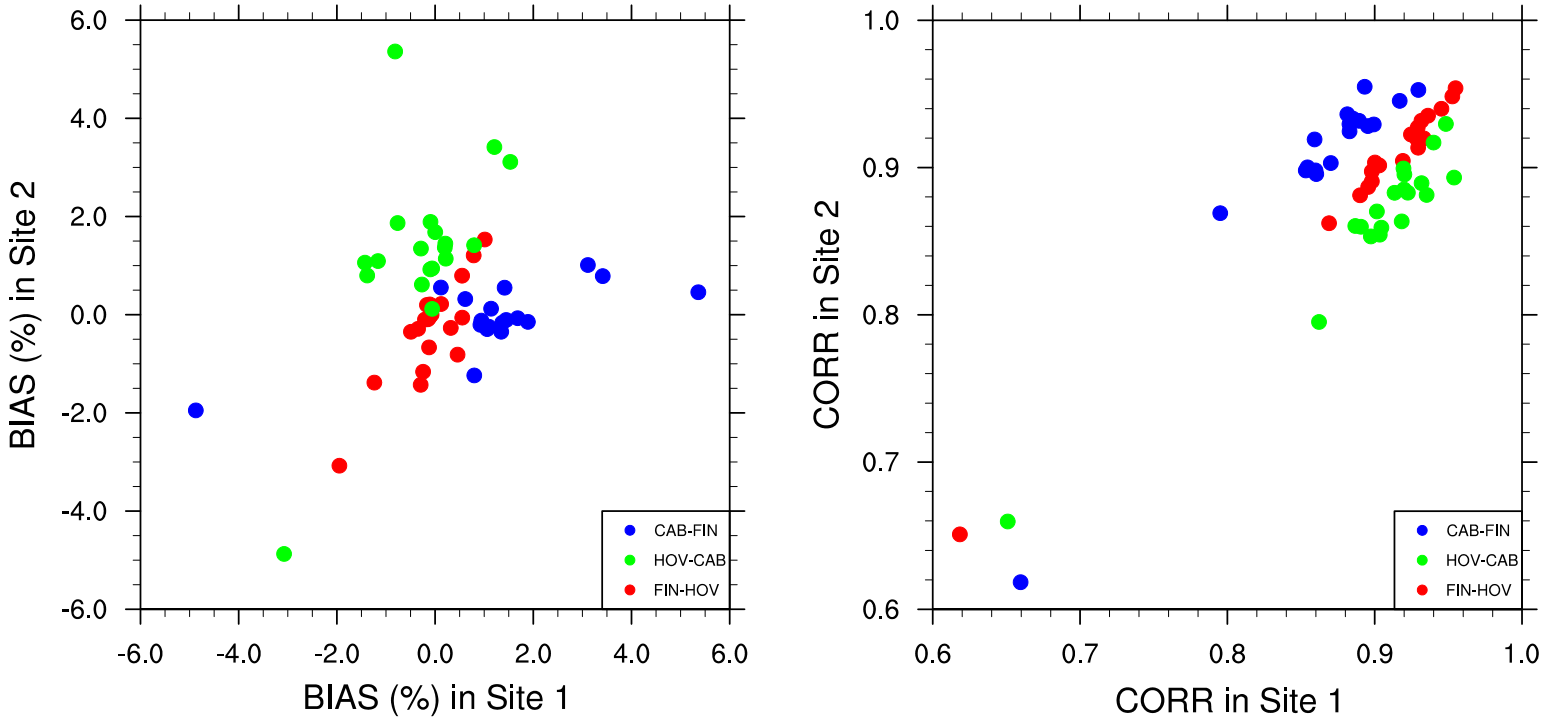



Wind speed

- FINO3 90 m
- Høvsøre 100 m
- Cabauw 80 m

# Comparison of models and sites

If one model is “the best” at site 1, is it also “the best” at site 2?

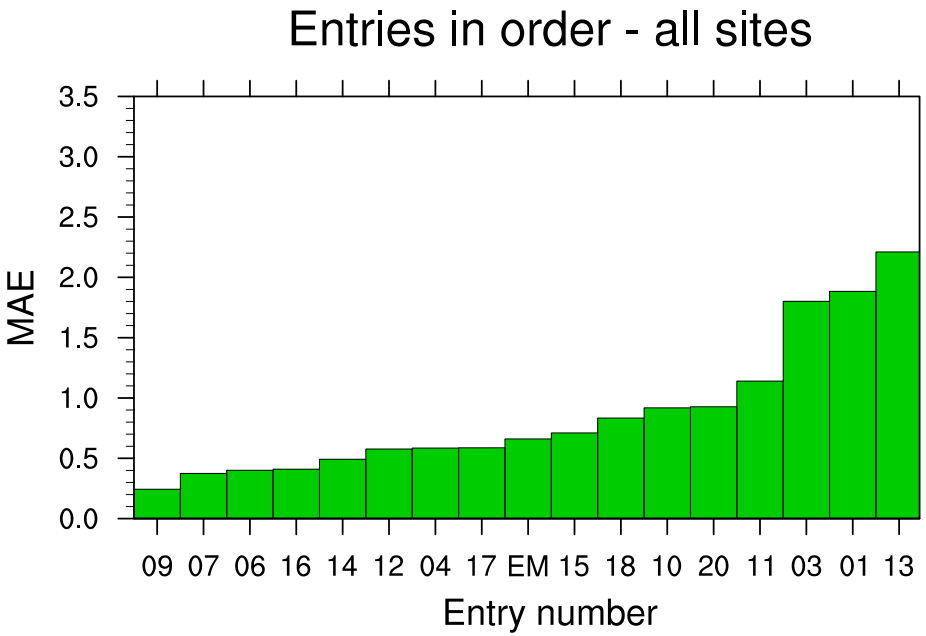



Statement is true for relationship between BIAS at FINO3 and at Høvsøre, also for Cabauw but not as clear

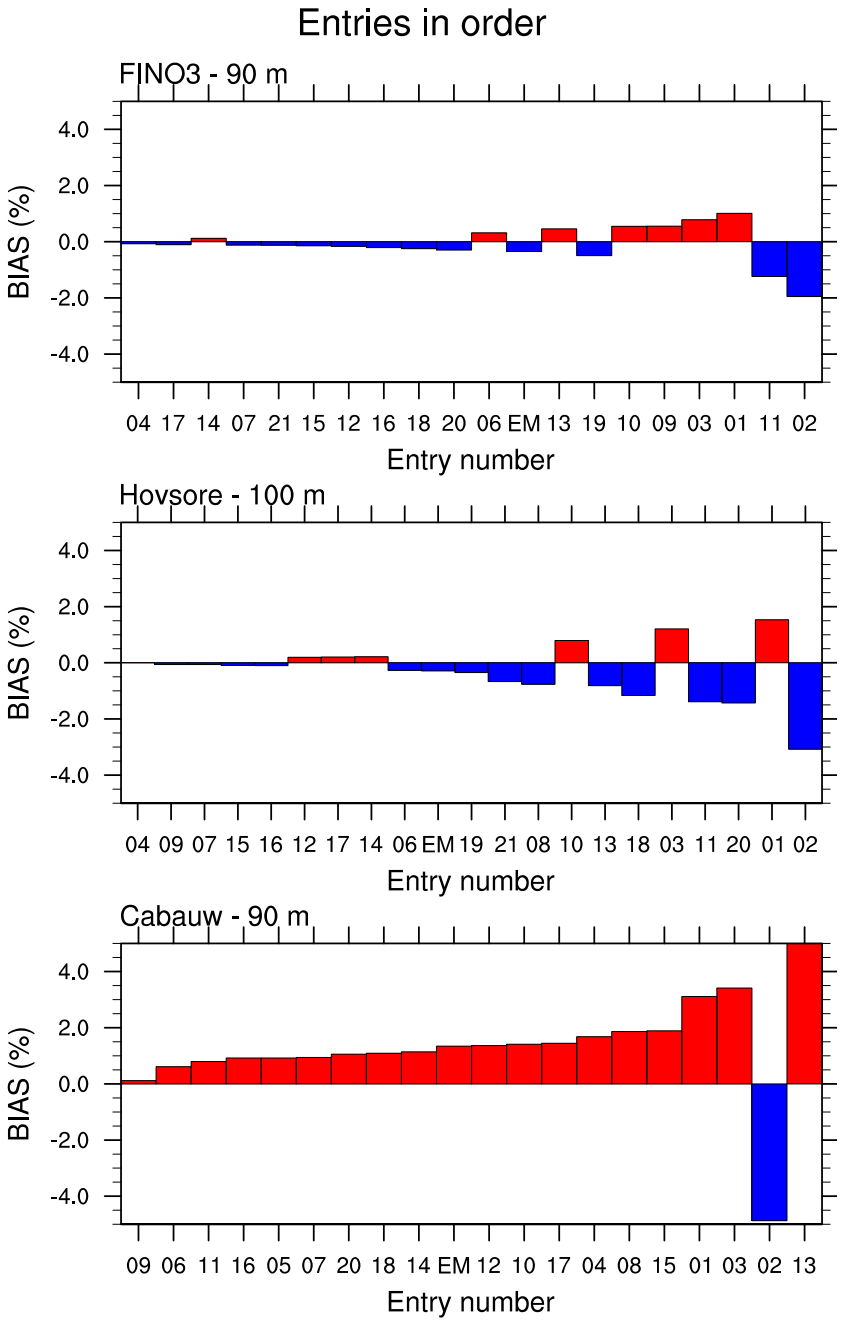
Statement is true for relationship between correlation at any two sites

# Comparison of models and sites

If one model is “the best” at site 1, is it also “the best” at site 2?




MAE = mean absolute error for all three sites

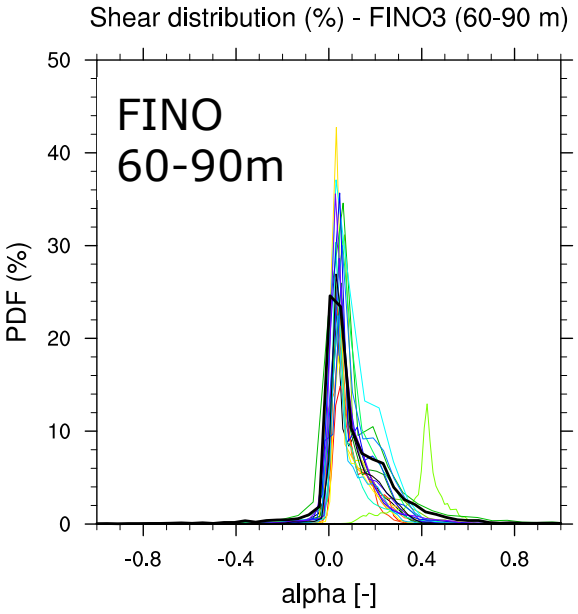


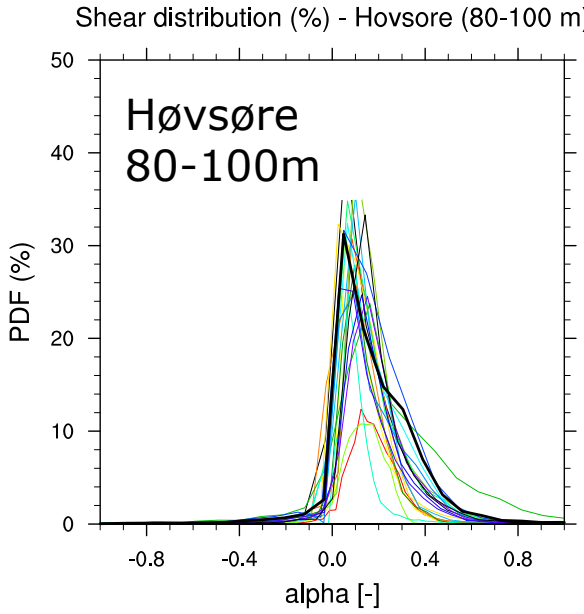
# And now, the not so good news…

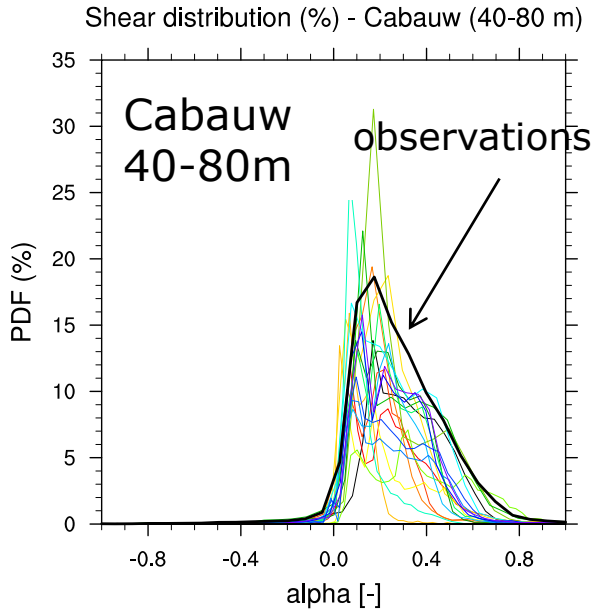
How accurate are the models at simulating other derived quantities?

One example, the wind shear exponent distribution,

$$u(z) = u_r \left( \frac{z}{z_r} \right)^{\alpha}, \quad \alpha = \frac{du}{dz} \frac{z}{u}.$$



# Summary and conclusions

- 21 entries from 15 participants, with various degrees of compliance with the instructions
  - data mostly good quality, but some problems with vertical interpolation
  - missing a lot of metadata
- Very small biases at all sites: <±2% offshore, <±3% at coastal site, and <±5% at land site (most overestimate wind speed) – misrepresentation of surface roughness?
- Biases and the standard deviation of the biases decrease with height
- Excellent representation of the wind rose at all sites
- Strong evidence that higher resolution reduces biases, but indications that higher resolution decreases correlation
- "Best" model a one site is not the best at all sites
- Skill of other derived quantities is not as good as that for mean wind speed and direction
- Very valuable knowledge for the New European Wind Atlas project

# Future work

- Missing statistics
  - Include time series from raw reanalysis data
  - Explore the relationships as a function of model and their parameterizations
  - Explore the relationships as a function of other parameters, e.g. surface roughness and stability
  - Quantify the directional statistics
  - Compute the wind speed spectra as a function of resolution and model
- Input time series into the annual energy production for a given site
- Other suggestions?

# A request

- If your company/research institute has not participated, please do. There is still time
  - Plan to make a more detailed presentation at EWEA 2015 in Paris
  - More robust results with more varied submissions and detailed metadata
- If you have made a submission, please consider revising your metadata. The more accurate it is, the more we can learn from the exercise
- Thanks to all that have participated!!!


Thanks for your attention!
Any questions?