Wake model evaluation metrics

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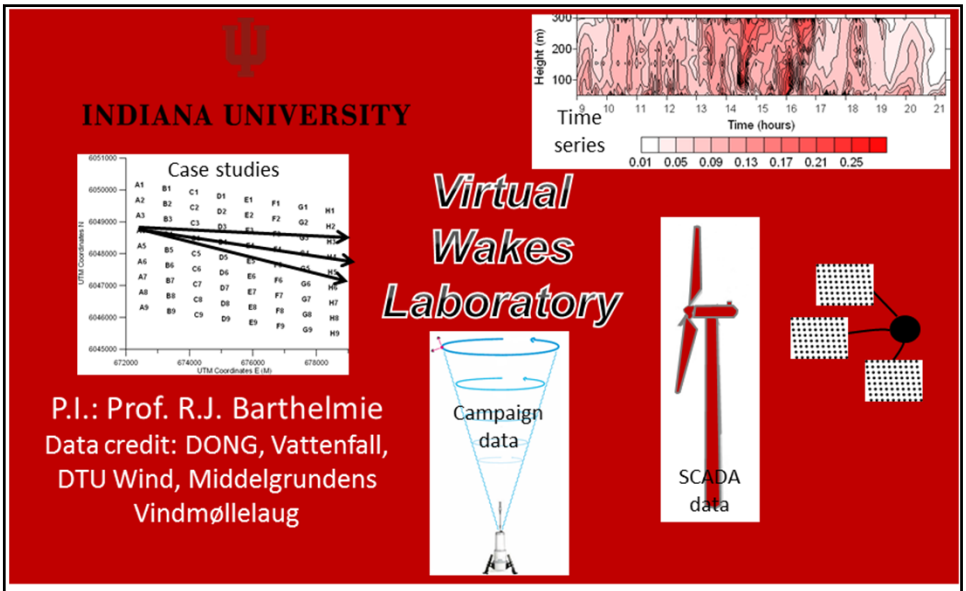

- Open access source for wake data
- http://mypage.iu.edu/~rbarthel/Welcome.pdf

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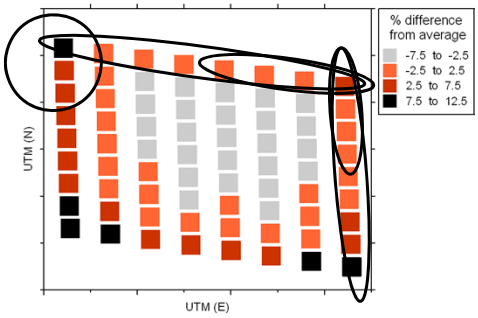
Models vs measurements

1. What is the freestream condition?
   Wind, turbulence intensity profiles, turbine power and thrust coefficients
2. How does the freestream change?
   With time i.e. averaging period, frontal passages
   In space, gradients over the wind farm area
3. What are the measurement errors?
   Direction/yaw angle, distance to met mast
4. What are the model assumptions?
   Variability, turbulence intensity, stability, roughness, grid size/spacing



Barthelmie et al. AWEA 2012

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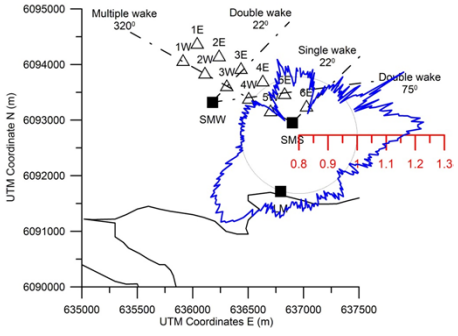
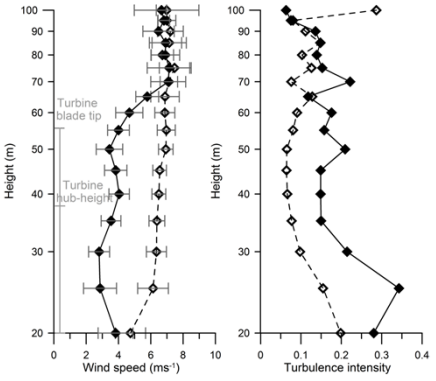
Model evaluation

- What is the goal comparing models with measurements?
- Which variables should agree, and to what level of precision and accuracy?
- What can the model simulate?





Long-term averages (masts)

Case studies (sodar)

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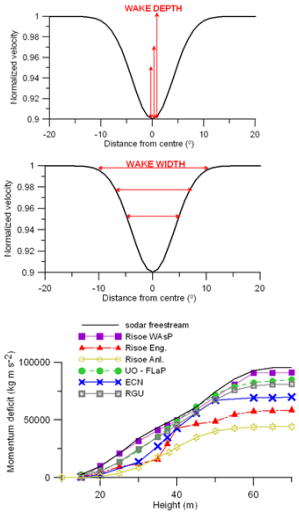
Possible evaluation metrics



- Quantities:
  - Turbine power output
  - Wake width
  - Wake depth
  - Power production by turbine, row/column and by wind farm
  - Momentum losses through the wind speed profile
  - Wind speed/turbulence intensity at hub-height
- Approaches:
  - Mean (statistics), case studies and dynamic cases
- Criteria:
  - RMSE
  - Bias

Barthelmie et al.. Journal of Atmospheric and Oceanic Technology 2006

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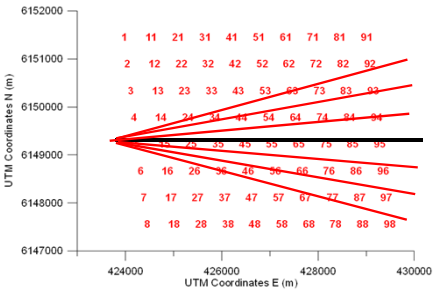
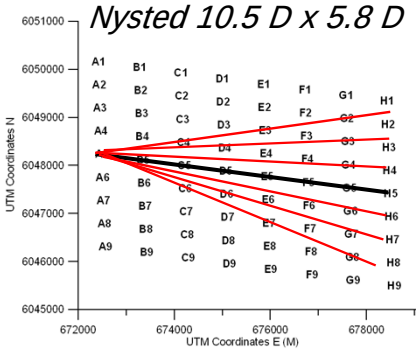
Model vs Observations: Example

1. Exact flow down the row (ER=270^0 at Horns Rev, ER=278^0 at Nysted)
2. $\pm 5^0$, $\pm 10^0$ and $\pm 15^0$

Horns Rev 7 D x 7 D



Nysted 10.5 D x 5.8 D



Barthelmie et al. Journal of Atmospheric and Oceanic Technology, 2010

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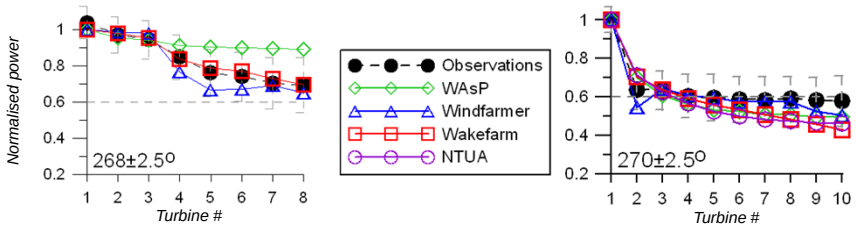
Models vs observations: Power

- What is the goal?
- The model simulates *** that agrees with measurements?
- What is a successful outcome?



RMSE ~ 0.06-0.15

Barthelmie et al. Journal of Atmospheric and Oceanic Technology, 2010

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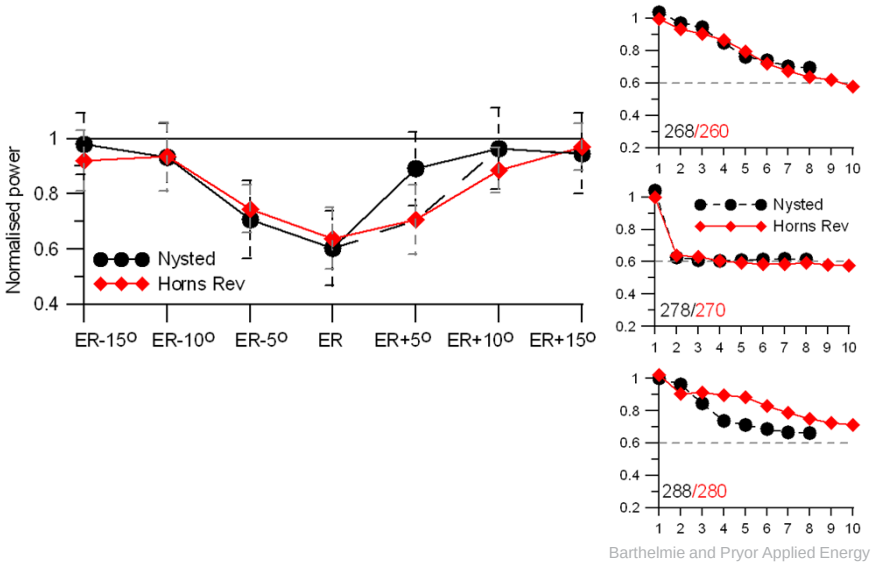
Model vs Observations: Wake width



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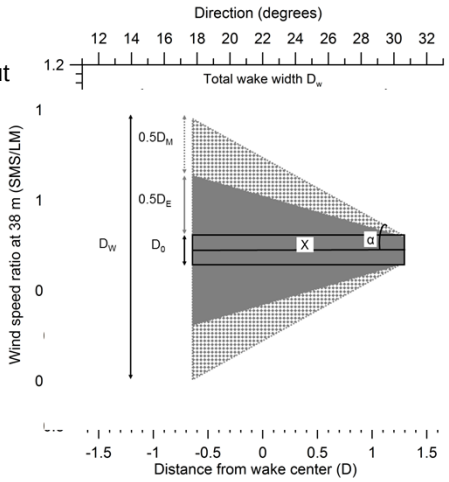
Components of wake width

- Should we use a more diagnostic approach?
- E.g. not comparing wake width but looking at the processes that contribute to it?

$$D_w = D_0 + D_E + D_W$$



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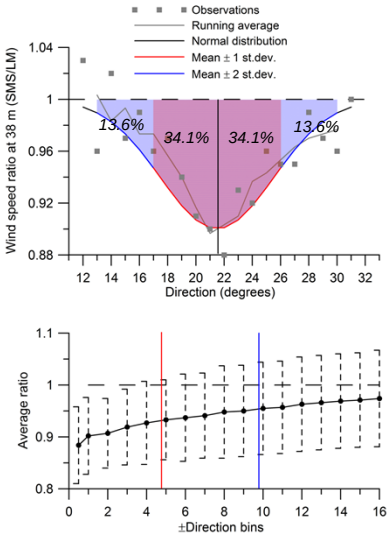
Defining wake width

- Should we try to define metrics in a more systematic way?
- The standard deviation is 'universal' descriptor
- Assuming a Gaussian Distribution and the mean direction:
  - ± 1 st.dev. of direction ~ 0.95 wake depth, ~68% of observations
  - ± 2 st.dev. of direction ~ 0.99 wake depth, ~95% of observations
- Wake depth is large if wake width considered is small (and vice versa)



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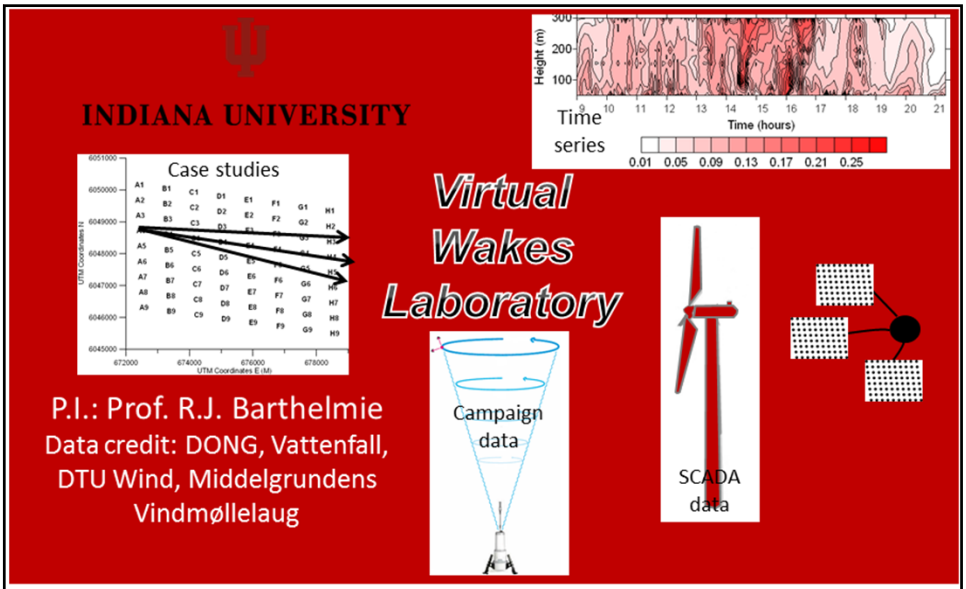
Summary

- Finding ‘a level playing field’ for models and measurements
- Proposal to move away from visual inspection and define a set of metrics that quantify model agreement with measurements
- Try to incorporate a more systematic approach to the evaluation (e.g. as used in short-term forecasting)
- Focus on more dynamic studies and process level experiments



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