



Universal benchmarks for wind turbine wake and wind farm models

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Abstract

We propose a benchmarking framework for wind turbine wakes and wind farm modeling. This represents an extension of the work within IEA Annex 23 to improve wind farm modeling techniques but includes onshore and offshore wind farms. The purpose is to gain insight into the benefits and drawbacks of a set of modeling assumptions for a wide range of applications. Much of this new task will involve benchmarking models of wind farms against other models and actual wind farm data. As such, participation by industrial partners willing to share wind farm data will be of utmost importance.

Objectives

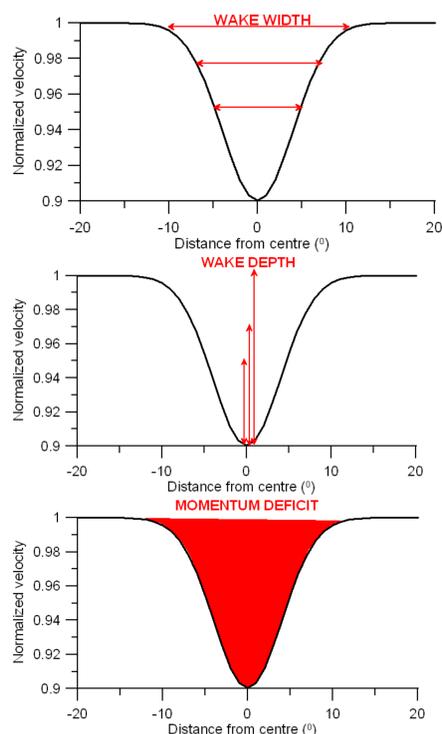
- To provide a universal set of benchmarks for wake model evaluation
- To evaluate current wind farm model performance
- To increase the availability and scope of detailed validation data

Methods

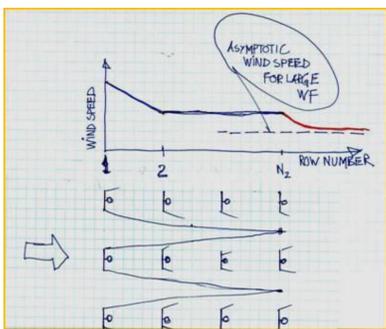
Types of wake data

- 1. Full scale wind farms**
Most "realistic"
Data sparse – temporally and spatially
Proprietary restrictions
- 2. Wind Tunnel Testing**
Realistic?
Atmospheric conditions
Scaling issues
- 3. Large Scale Simulation**
Most likely Large Eddy Simulation
Realistic?
- 4. Turbulence Models**
Boundary conditions
Large amounts of data
- 5. Analytical Approaches**
Self-similarity theory
"Infinite" wind farm
Can serve to bound the problem
- 6. All of the Above**
Will all data collapse on single curve(s)?
Correct normalization parameters

Benchmarks for single wakes



Benchmarks for multiple wakes



- Mean velocity deficit
- Turbulence Intensity Profile
- Asymptomatic behavior
 - Vertical momentum flux = power extracted
 - How many rows ?
- Total Farm Wake
 - Several farm length scales downstream
 - Recovery distance
 - Multiple farm interactions

Exercise variables

Inputs

- Mean Wind Speed
- Mean Wind Direction
- Turbine Spacing
- Turbine Operation – C_T /blade pitch/RPM
- Number of upstream turbines
- Atmospheric stability – day/night
- Turbine size/hub height
- Roughness – offshore/onshore – freestream turbulence
- Averaging time and/or RMS velocity and direction

Output

- Power deficit /momentum deficit – integrated quantity
- Mean velocity loss in wake – wake depth
- Wake width
- Turbulence intensity
- Change in vertical profiles in addition to horizontal
- All as a function of downstream distance



The Virtual Wakes Laboratory

- Contains wind farm data that has been made available by companies like DONG, Vattenfall and Middelgrunden's Wind Turbine Cooperative
- Currently available data:
 - 1) Data from the ship mounted sodar at Vindeby
 - 2) Time series of all available 30 min data from the Vindeby wind farm from 1993-2002
 - 3) Case studies from Horns Rev
 - 4) Time series of power and yaw data from Middelgrunden

Access

1. Is free and open to all <https://oncourse.iu.edu/portal>
2. Make yourself an Indiana University guest account at: <https://itaccounts.iu.edu/>
3. Send rbarthel@indiana.edu an email to be added as a data user
4. Use the data and please remember to acknowledge the data source and the Virtual Wakes Lab

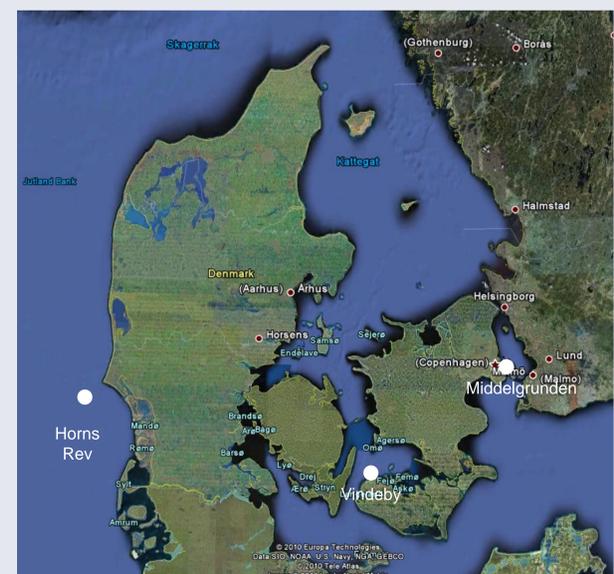


Image from Google Earth showing the locations of the wind farms for which data are available in the Virtual Wakes Laboratory

Conclusions

- The Virtual Wakes Laboratory provides a starting point for wake model evaluation
- A more formal wake model evaluation benchmarking is needed – likely in the framework of the IEA
- More wind farm data are needed from different environments
- Discussion is needed to decide the data type and format for the evaluation and the benchmarking criteria
- Next step is an open meeting to outline the wake model benchmarking exercise

References

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