How Data and Modelling Can Improve Wind Farm Planning and Operation

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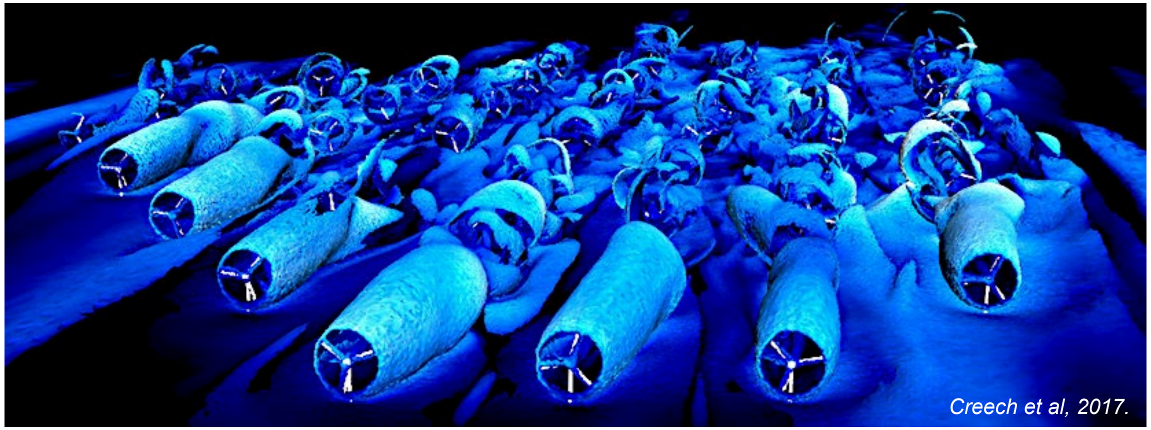
Advanced Wind Farm Modelling

What are advanced wind farm models?

- Origins in academic research
- Computational fluid dynamics modelling air flow in wind farms, turbine response
- Turbine sub-models for blades, structure, pitch control, drivetrain and generator

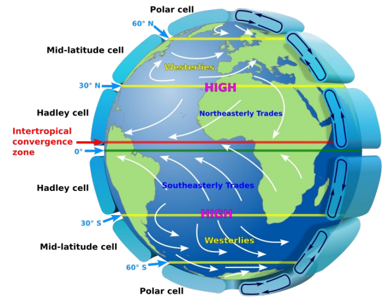

Creech et al, 2017.

Applications (why do should we use them?):

- More accurate than highly-parameterised commercial models
- Economic assessments (deep array effects, array layout optimisation, inter-farm interactions)
- Environmental impacts (atmospheric, ocean, marine wildlife, …)

Sources of Data

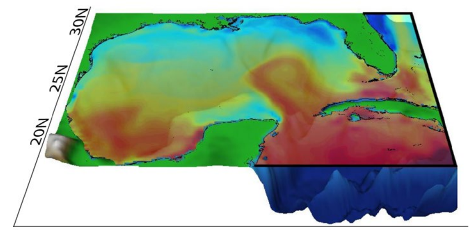
Wind farm operators



Atmospheric circulation models

Met masts

Regional ocean models



CFD wind farm model

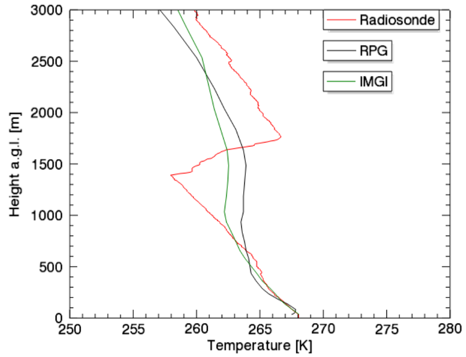
LIDAR

Online databases (eg. MERRA-2)

What Data Do These Models Need?

Metocean measurements:

- Wind speed, direction time-series at 10m ref. height
- Temperature and humidity from met mast
- Sea state

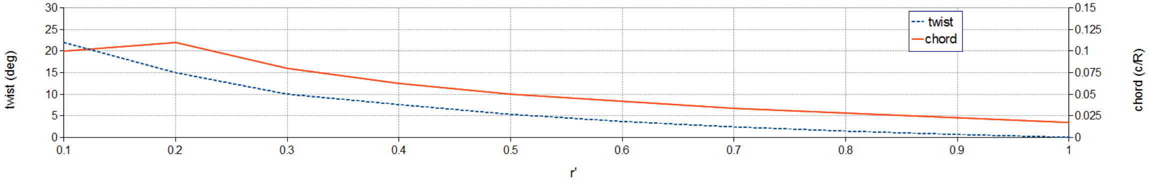


Atmospheric and oceanographic models:

- Temperature and humidity temperature profiles
- Wind speed and direction profiles (wind shear)
- Current data, sea surface temperature

Turbines:

- Specifications (rated power, TSR, hub height, rotor diameter)
- Blade design (blade length, aerofoil, twist, chord length)
- Generator and drivetrain specs



Formats:

- CSV, STL, NetCDF, XML

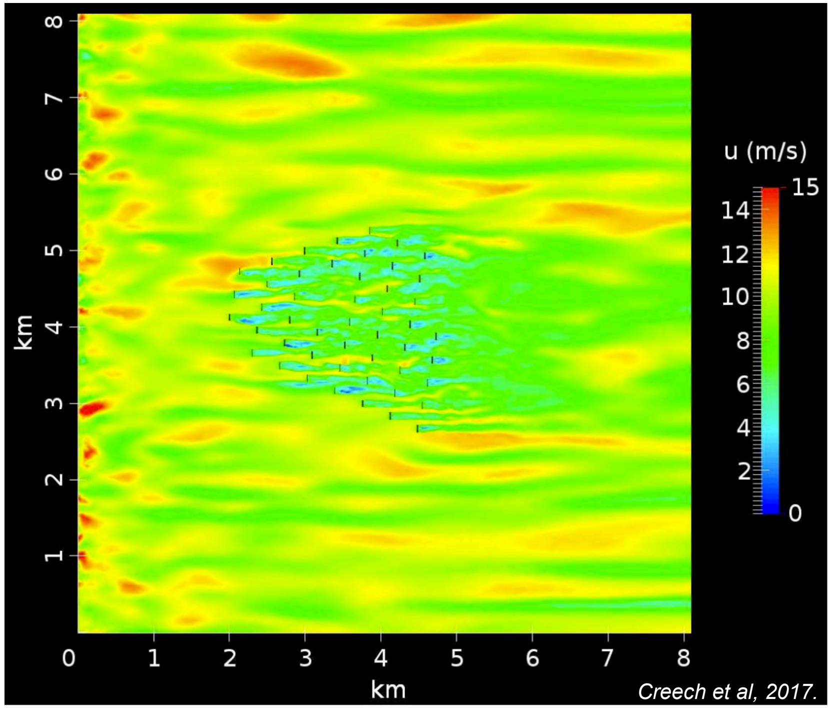
Results Data

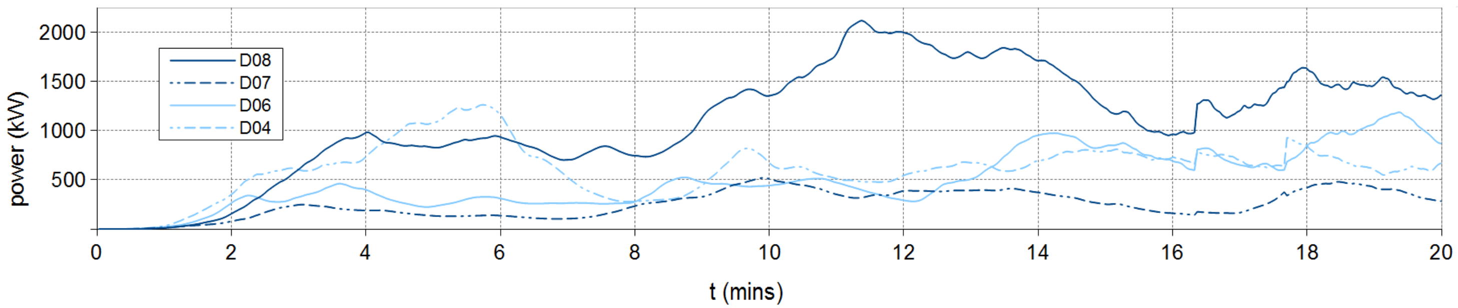
CFD results:

- Wind speeds at all locations within and surrounding the wind farm
- Pressures
- Especially wakes behind turbines and the whole wind farm wake
- Turbulence created by turbines

Turbines:

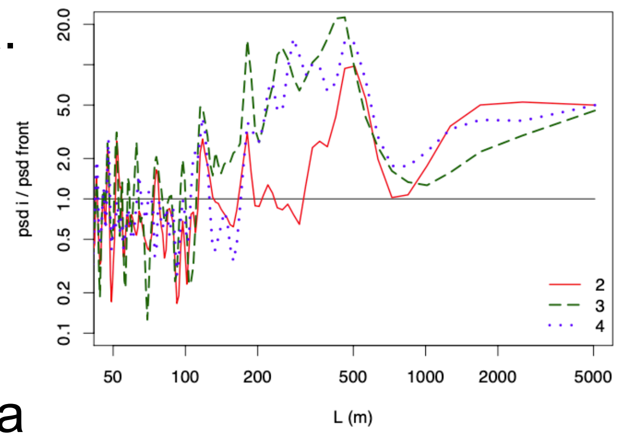
- Lift and drag forces on turbine blades
- Virtual SCADA diagnostics:
  - Power output, shaft RPM and torque
  - Blade pitch, mean AoA





What Does This Mean?

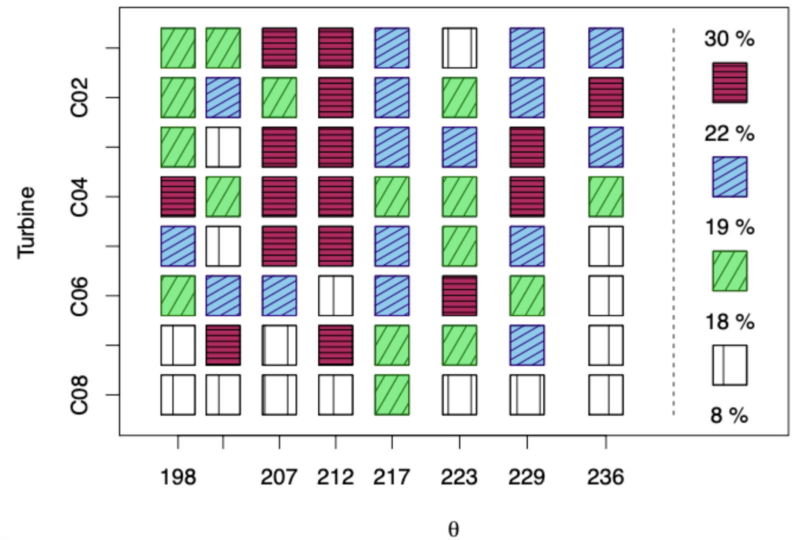
A single CFD simulation produces a very large amount of data with a large amount of useful information embedded in the data.



Opportunity: information can be extracted for extremely valuable planning and operational decision making

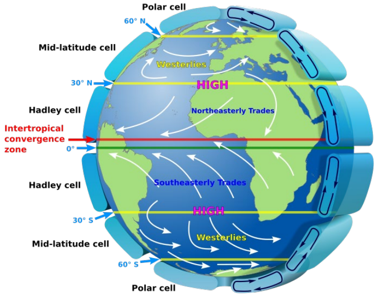
Analysis: effective analysis methods to extract data

- Spectral techniques useful for turbulence statistics and equipment vibration
- Statistical techniques for optimising layout
- Agent-based modelling (birds, fish)
- AI and machine learning



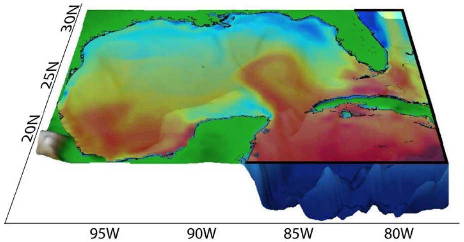
Applications of Model Data

Regulatory: environmental



Environmental: atmospheric impacts

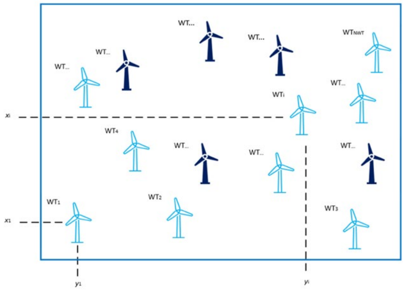
Regional ocean impacts



Operations: maintenance

CFD wind farm model

Planning: economic assessment



AI / Machine Learning

Conclusions

Practical experience

- Data comes in a variety of formats – simpler, open formats are better
- Availability of flexible tools to process input data is key: open-source is often better (Python, R, Paraview, …)
- Developing new techniques time-consuming
- Multiple data sources not an issue, if well documented and maintained
- Information Management Systems are useful sources, but can become subject to 'bit-rot'

Challenges for the future

- Information Management Systems: what to do with terabytes of data? (AI?)
- *Integration*: getting data in useful format for other disciplines and regulatory bodies

Acknowledgements

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