OFFWIND

A tool for planning and prediction of offshore wind farms

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Presenter: Robert Szasz

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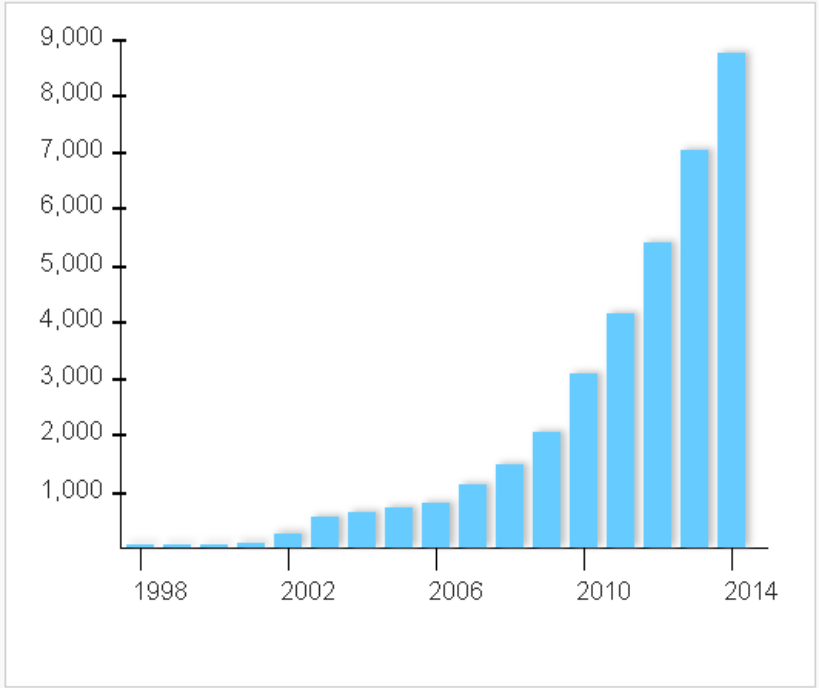
Background – Offshore wind farms



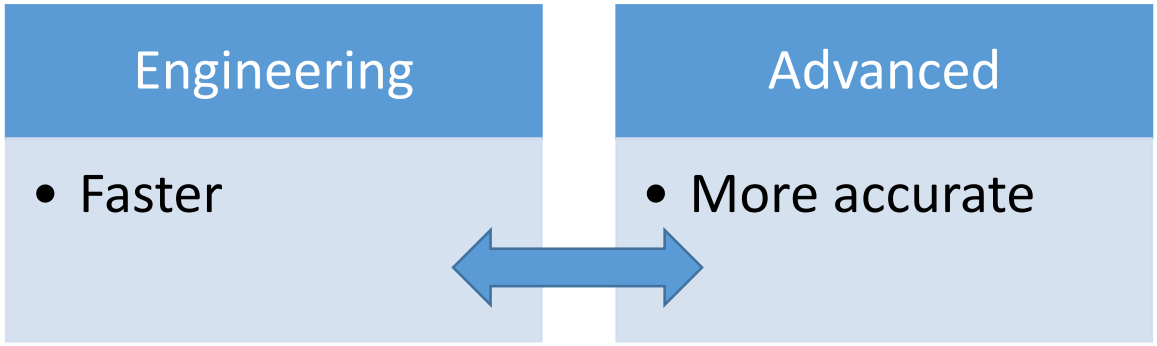
Global cumulative offshore capacity (in megawatts).
Sources: GWEC (2011–2014)[6] and EWEA (1998–2010)[7]

[https://en.wikipedia.org/wiki/Offshore_wind_power]

- Why?
  - Larger wind potential
  - More space
  - Less disturbance
- Why not?
  - Challenging environment
  - Difficult maintenance
- Optimization needed!

Goals

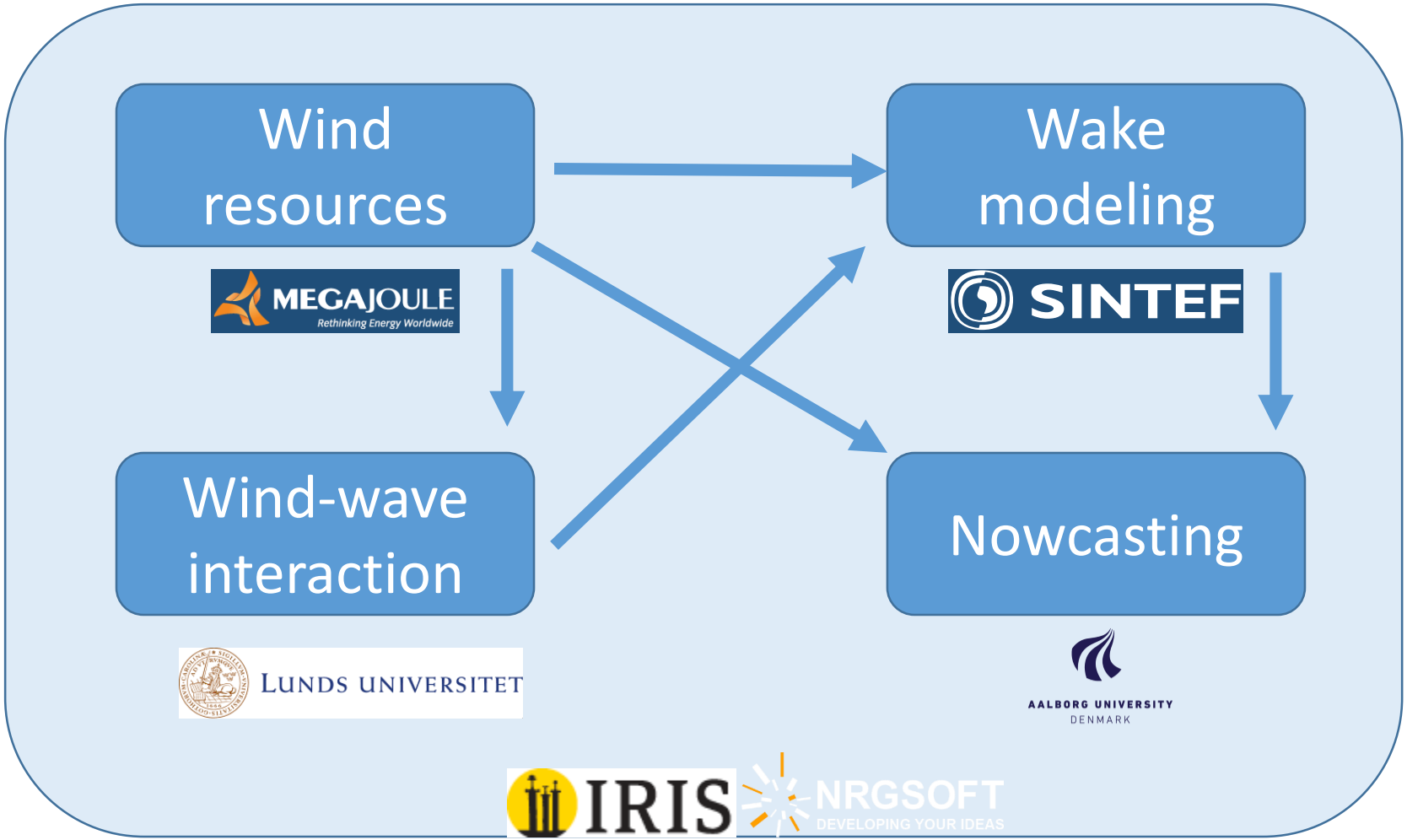
- Develop prediction tools for offshore wind energy applications.
  - Assist the various steps of the offshore wind farm planning process
  - 2 sets of tools



Partners

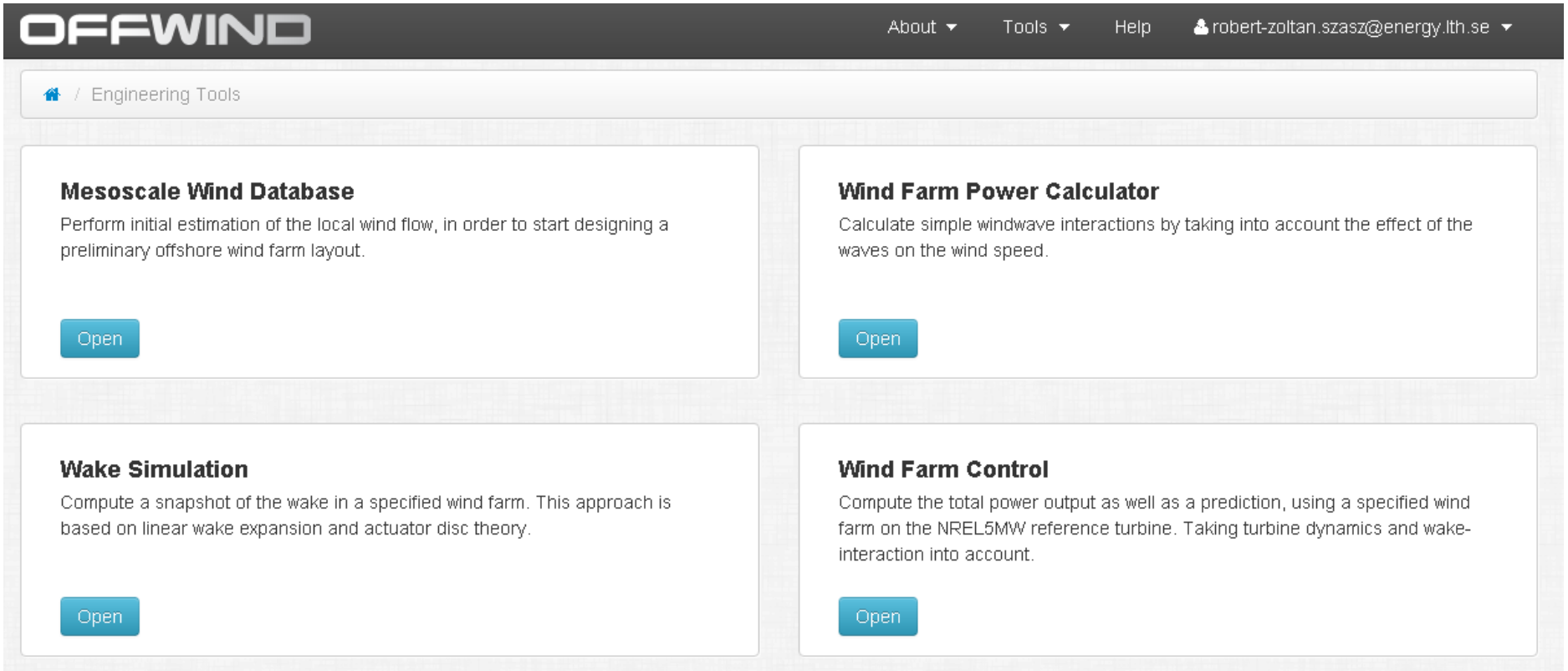
Partner	Country	Website
IRIS	Norway	www.iris.no
SINTEF	Norway	www.sintef.no
Lund University	Sweden	www.lu.se
Aalborg University	Denmark	www.en.aau.dk
Megajoule	Portugal	www.megajoule.pt
Norskvind	Norway	www.vindenergi.no
Vattenfall	Denmark	www.vattenfall.com
FuE-Zentrum FH Kiel GmbH	Germany	www.fh-kiel-gmbh.de
NREL (associated member)	USA	www.nrel.gov
NRG Soft Ltd.	Russia	www.nrg-soft.com

Tasks/Organization



Results

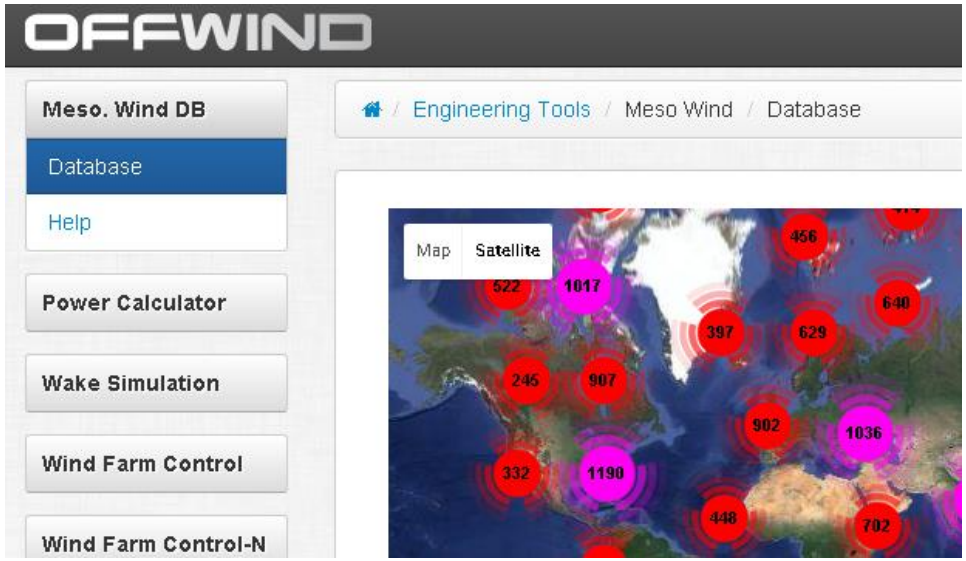
- Web-based toolset: www.offwind.eu

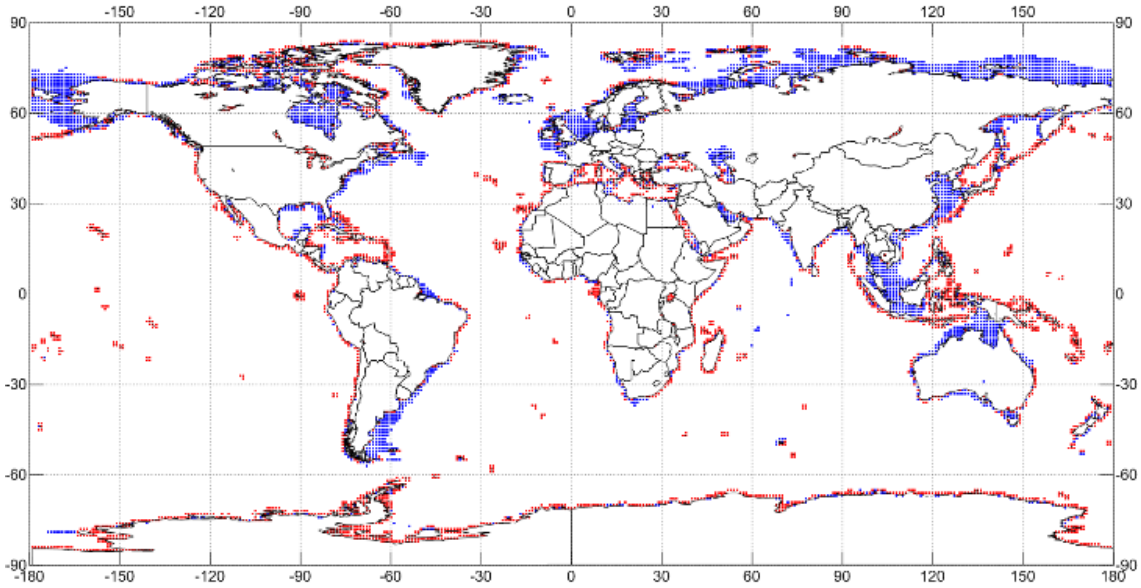


Wind resource assessment

- Objective:
  - Integrate local climatology
  - Provide prevalent wind direction, velocity characteristics
- Methodology
  - Simplified approach
    - Use existing databases to estimate local climatology
  - Advanced approach
    - Detailed simulation of local weather using WRF
    - Extract boundary conditions for each wind sector
    - Subsequent CFD to include wake effects

Sample results





- Based on 5 worldwide databases
- To reduce database size to currently feasible offshore locations:
  - within 1^{o} from coast
  - Max 200 m depth

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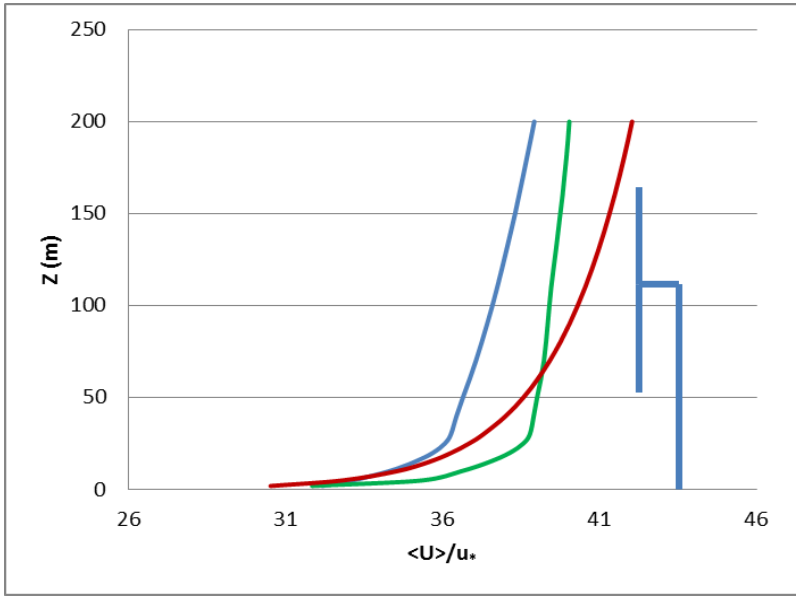
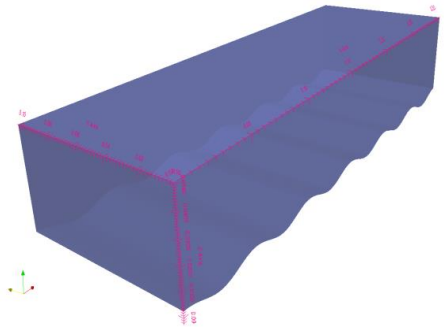
Wind-wave interaction





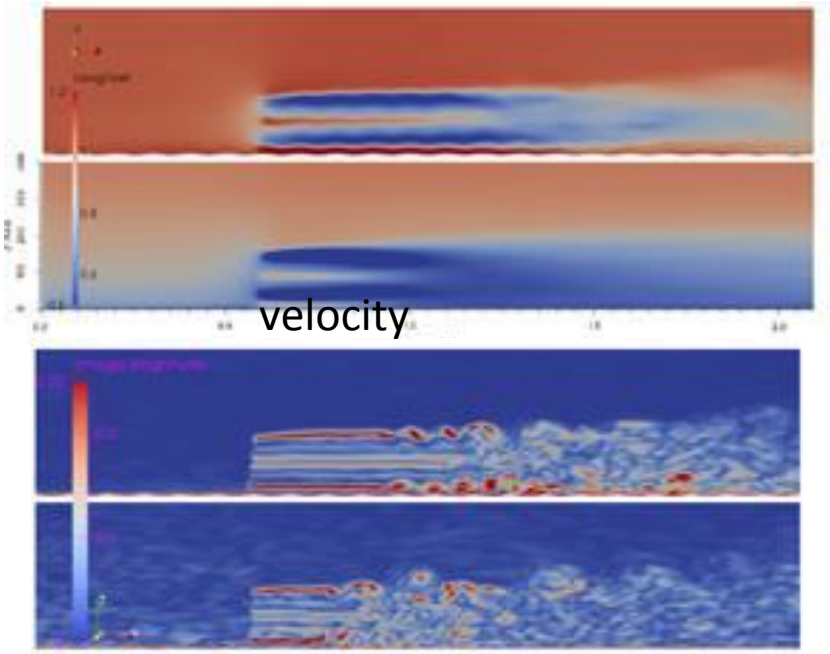
- Objective:
  - How are the waves changing the Atmospheric Boundary Layer (ABL)?
    - Wave age, direction
  - Improve existing models
- Methodology
  - Simplified approach:
    - Algebraic correlations (waves = rough surface)
  - Advanced approach
    - Computational Fluid Dynamics (CFD)

Wind wave interaction

Method	Friction velocity m/s	Roughness height m	Hub height velocity m/s	Output power MW	Power differences %
Charnock[8]	0.21994	5.92e-05	7.88495	1.57868	0
Toba[18]	0.25734	3.76e-04	8.03542	1.67079	5.8
Sugimori[19]	0.26888	6.00e-04	8.08187	1.69994	7.7
Smith[20]	0.26073	4.34e0-4	8.04907	1.67932	6.4
Johnson[21]	0.26706	5.59e-04	8.07455	1.69532	7.4
Drennan[22]	0.25491	3.39e-04	8.02567	1.66472	5.4

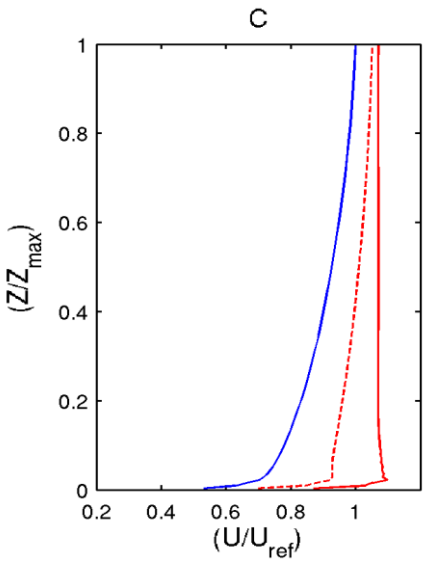
- Engineering model results
  - Relatively wide scatter of predicted power

Wind wave interactions

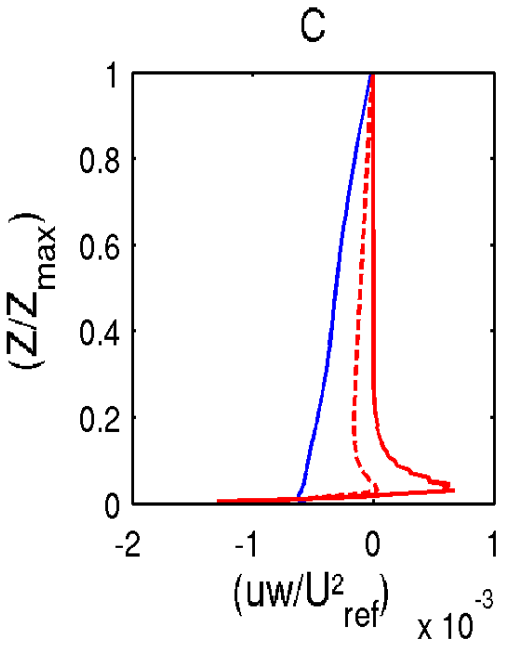


velocity

vorticity



Average velocity



Turbulent stress

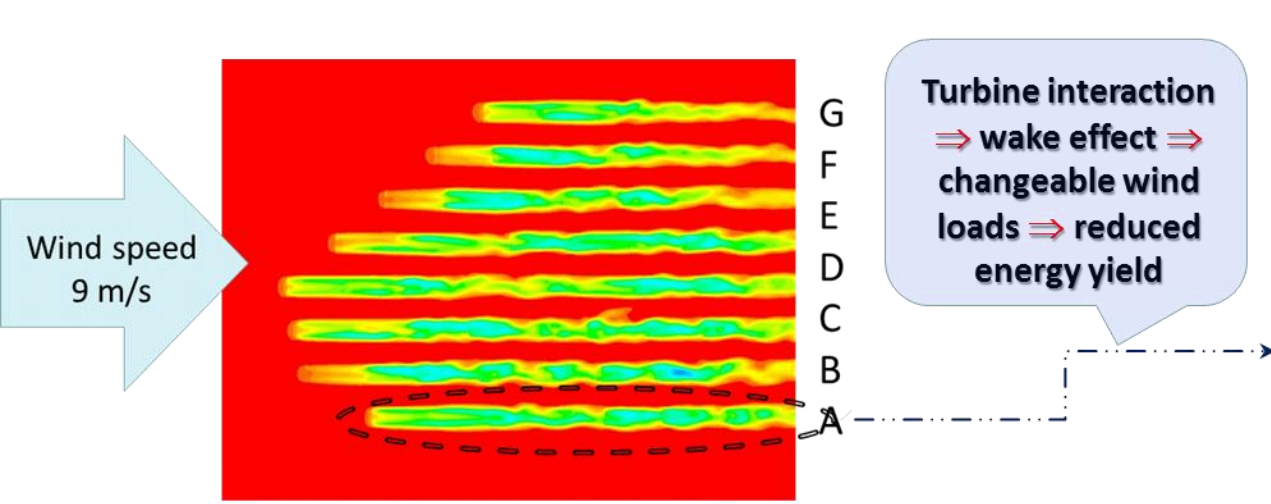
Same driving pressure, with/without swell

- Advanced model results

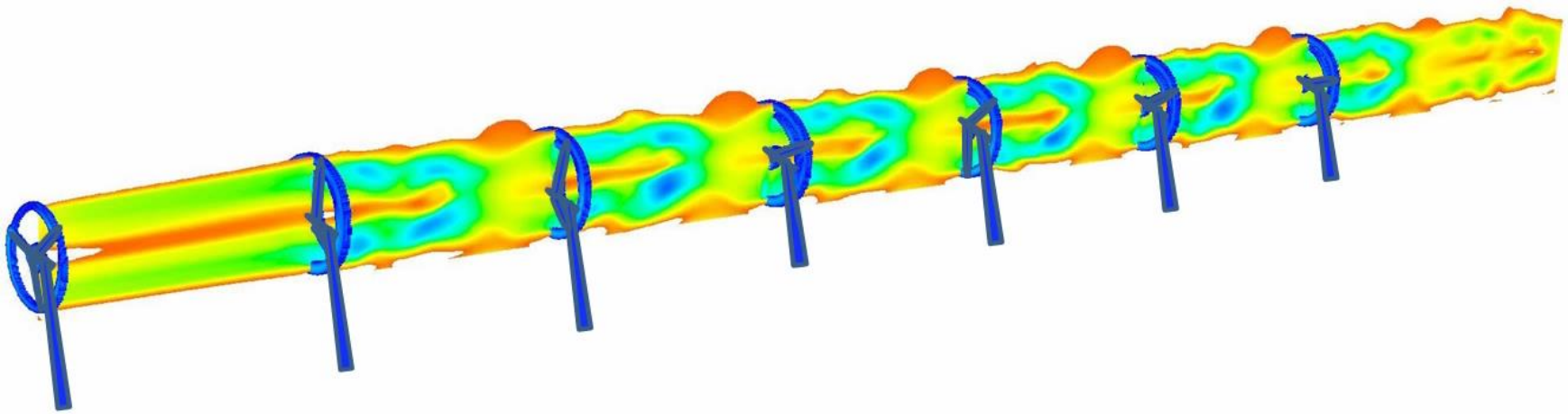
Wind farm wake interaction

- Developed Offshore Wind Farm Assessment Tool
  - Simple (wake models) and advanced (CFD)
  - Provide not only power production of a wind farm but also detailed flow field around the wind turbines useful for blade loading calculation.
  - Validated against existing wind farm
- The tool has been used for understanding
  - Effect of wind direction on power production
  - Effect of wind wave interaction on the power production

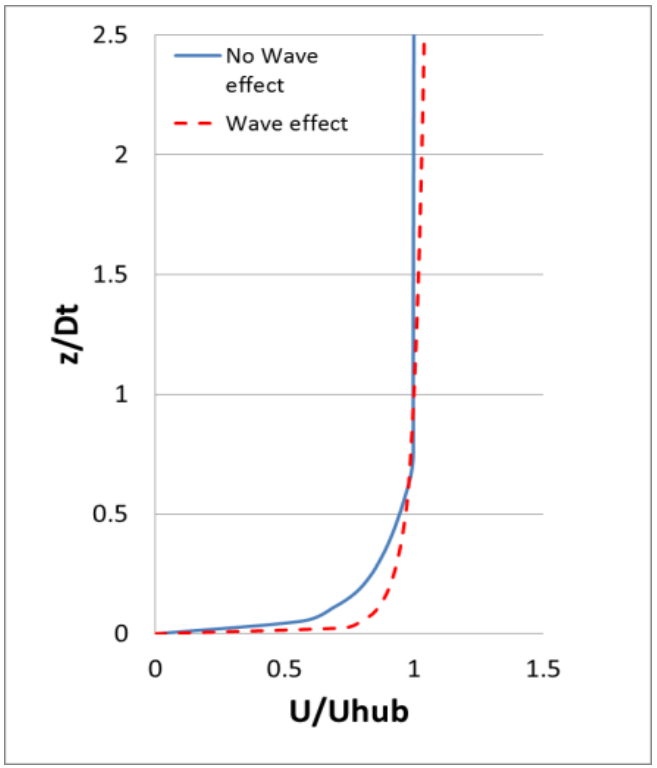
Validation - Lillgrund



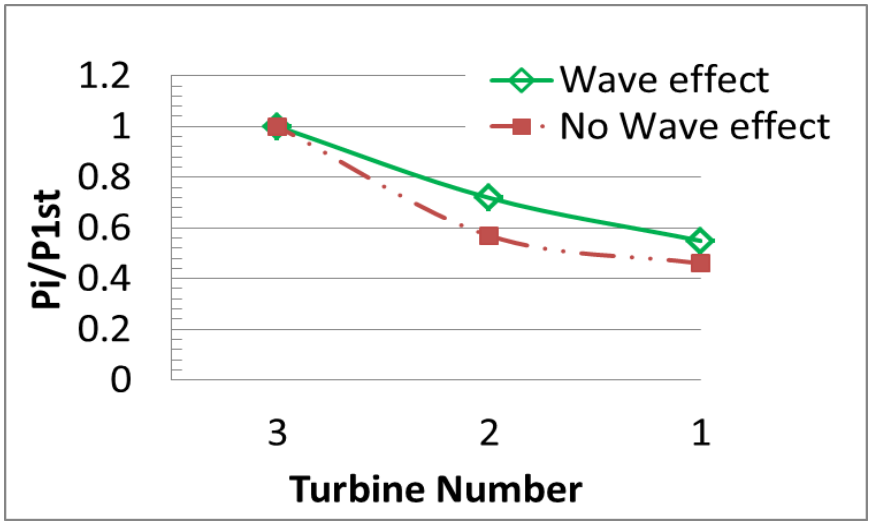
wind power – row A



Wind-wave + Wake Modelling



MABL vertical profiles



Wave effect on the power production

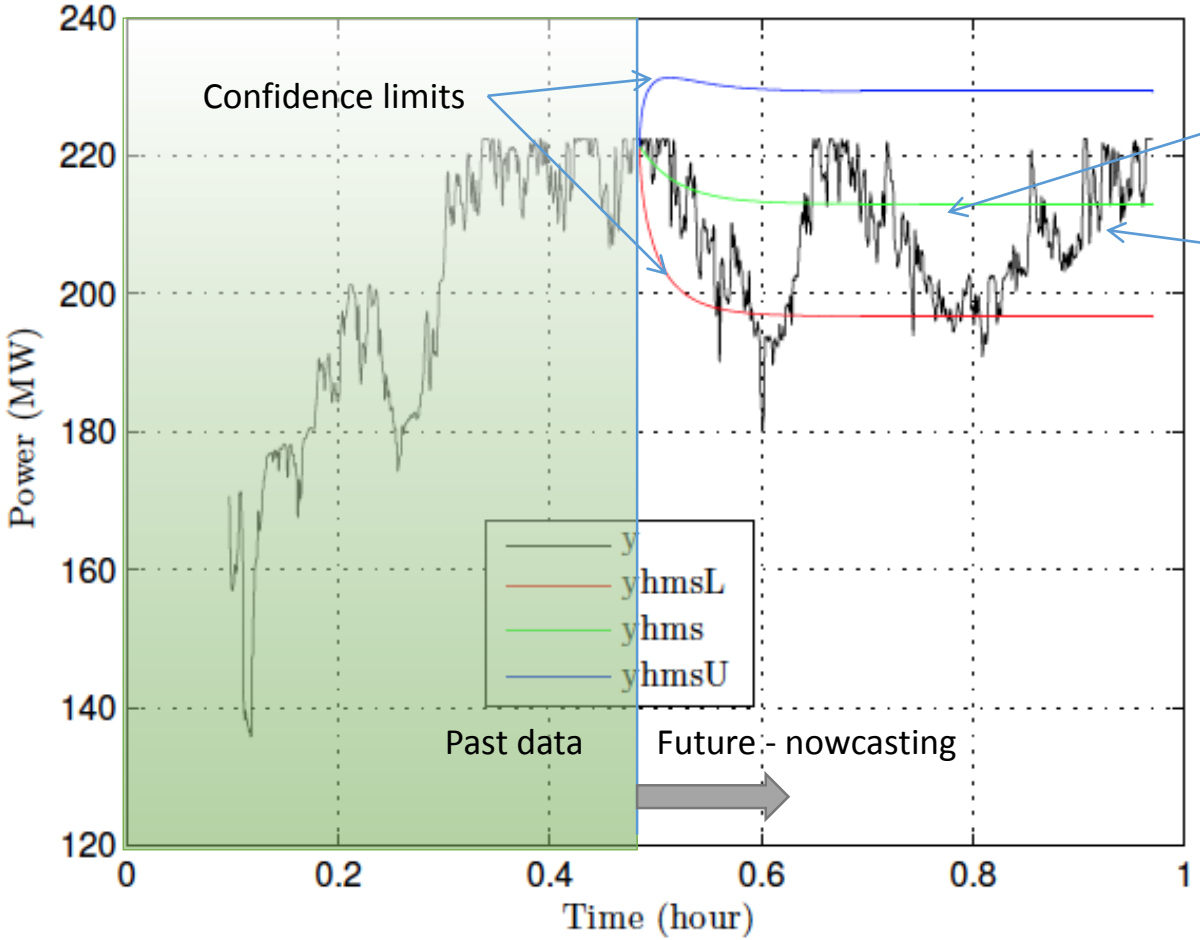
Nowcasting of available farm power based on data driven modeling

Very short -term	Short-term	Medium-term	Long-term
< 30 min	30 min – 6h	6h – 1 day	1 day – 1 week
Its main applications are in (control), electric market clearing or regulation actions	Economic dispatch planning or load increment/decrement decisions, curtailment	Generator on/off decisions, operational security in day- ahead market. What-if scenarios	Unit commitment, reserve requirements or maintenance scheduling

Model		Comment	Time
Persistence*	Wind speed at time t+k will be the same at time t	Is used as a benchmark.	N/A
Statistical*	Tuning the parameters of a model, training it with historical measurement data	It includes time-series based models (ARMA, ARMAX, ARX, BJ …) and neural network based methods.	**< 6h**
Physical	Numerical model of the physical description of the phenomena. Numerical weather predictions models (NWP)	Wind speed is computed on a coarse grid at mesoscale then downscaled. Stable weather conditions generally give more accurate predictions.	**> 3 h**

* Addressed in OFFWIND

Example – OFFWIND simulated data



- AR(1) model
- Past data used to predict mean and confidence interval for future power
- Process can be repeated a every point in time

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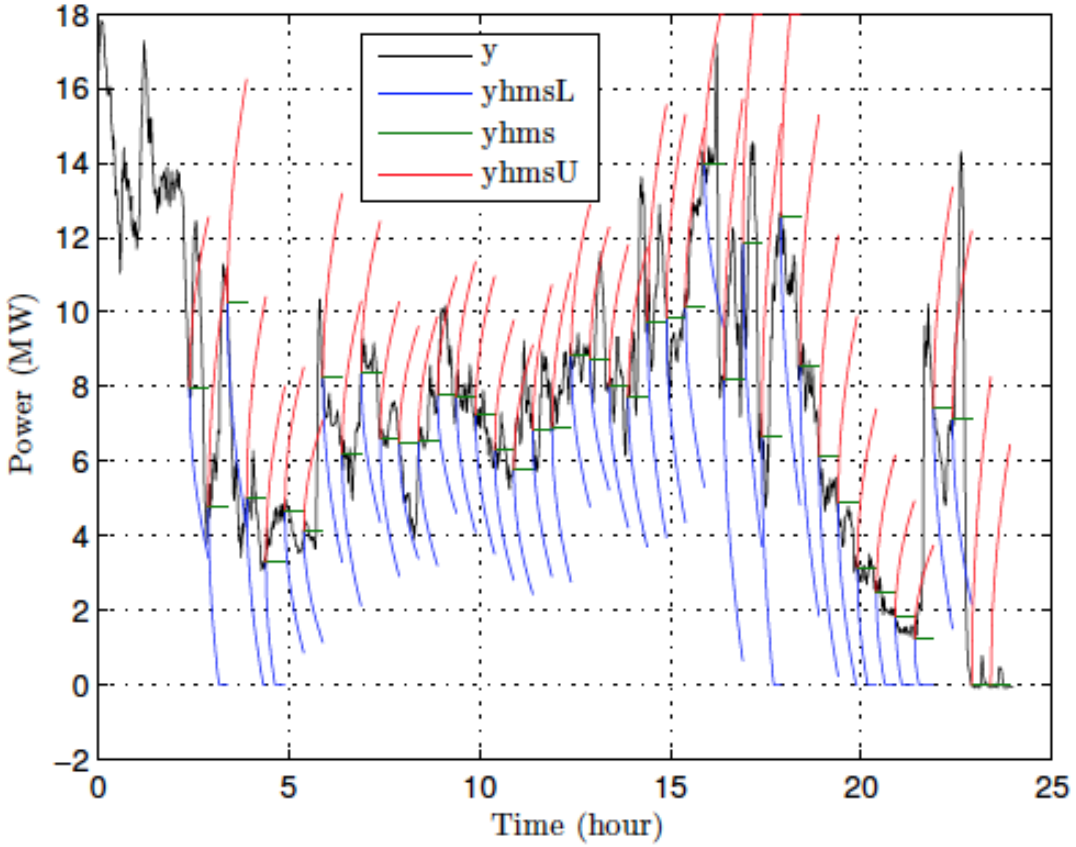
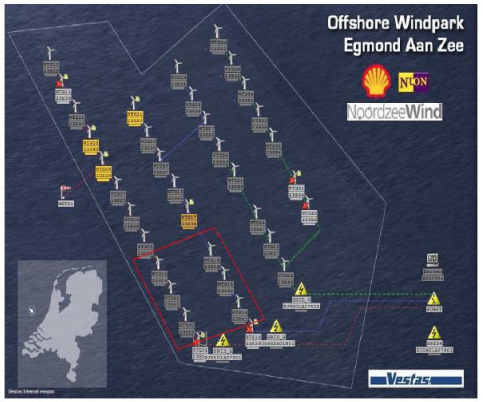
Example – experimental data, OWEZ wind farm





- Persistence model, predicting future power
- With confidence intervals (red and blue)
- Repeated nowcasting

Summary of main results

- Better understanding of
  - Wind-wave interactions
  - Wake dynamics
- Existing and improved models integrated into the Offwind toolkit for
  - Wind resource assessment
  - Wind wave interaction
  - Wake dynamics
  - Nowcasting

- Useful for:
  - Choice of suitable wind farm location
  - More accurate prediction of electricity production
  - Better control strategies of wind farms

Thank you! Questions?

- Contact: www.offwind.eu