



# OFFWIND

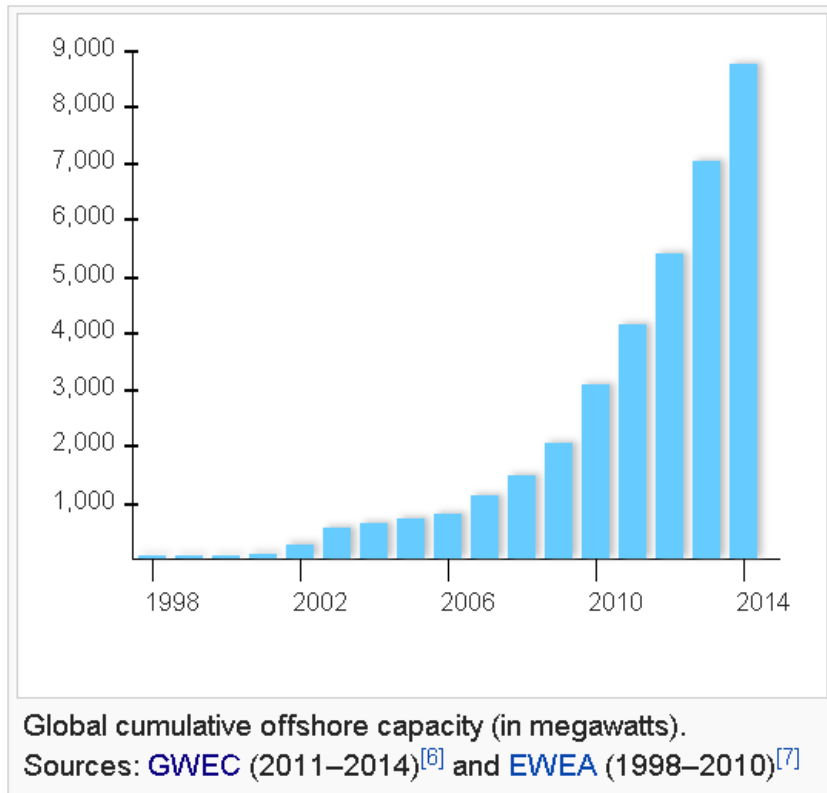
A tool for planning and prediction of  
offshore wind farms

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Presenter: Robert Szasz

Final seminar for Sustainable Energy Systems 2050, 21-22  
October, Oslo

# Background – Offshore wind farms

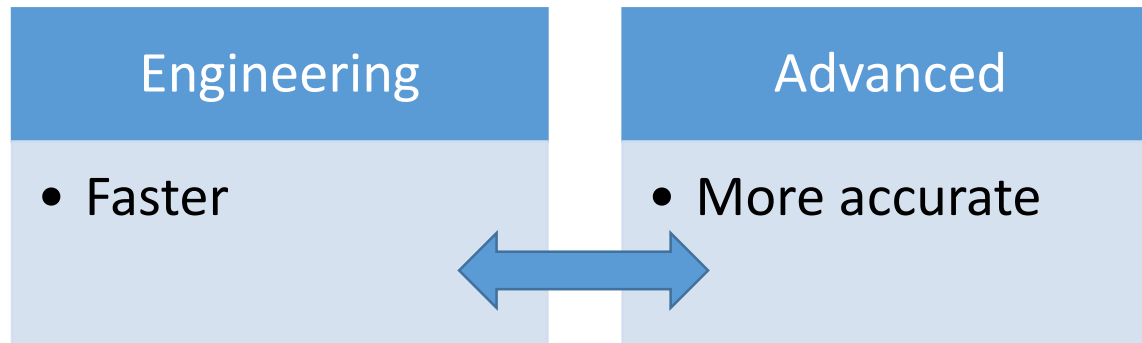


- Why?
  - Larger wind potential
  - More space
  - Less disturbance
- Why not?
  - Challenging environment
  - Difficult maintenance
- Optimization needed!

[[https://en.wikipedia.org/wiki/Offshore\\_wind\\_power](https://en.wikipedia.org/wiki/Offshore_wind_power)]

# Goals

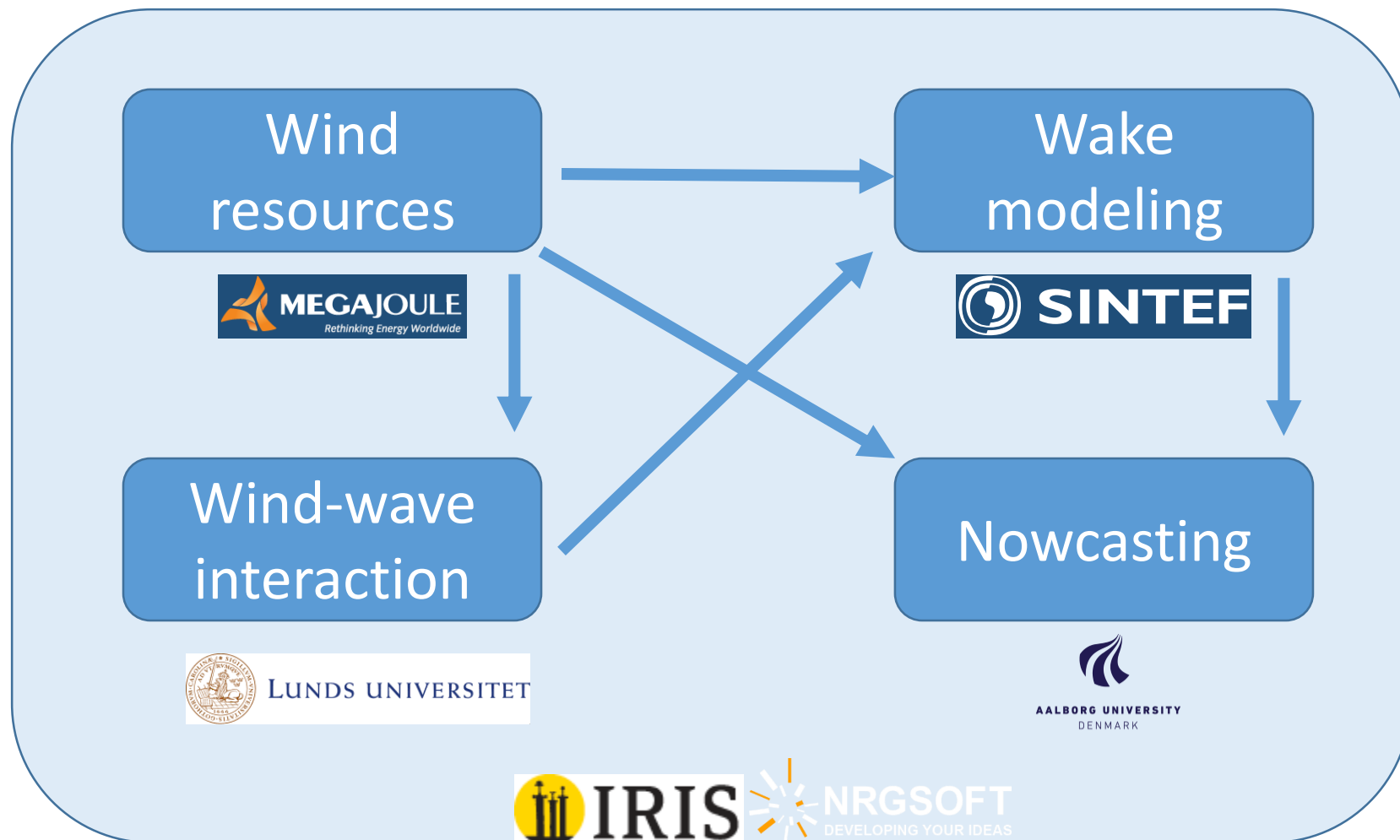
- Develop prediction tools for offshore wind energy applications.
  - Assist the various steps of the offshore wind farm planning process
  - 2 sets of tools



# Partners

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

# Tasks/Organization



# Results

- Web-based toolset: [www.offwind.eu](http://www.offwind.eu)

The screenshot shows the OFFWIND web-based toolset interface. The header features the OFFWIND logo on the left and navigation links for 'About', 'Tools', and 'Help' on the right, along with a user profile icon and email address 'robert-zoltan.szasz@energy.lth.se'. Below the header is a breadcrumb trail: 'Home / Engineering Tools'. The main content area is divided into four tool cards, each with a title, a brief description, and an 'Open' button:

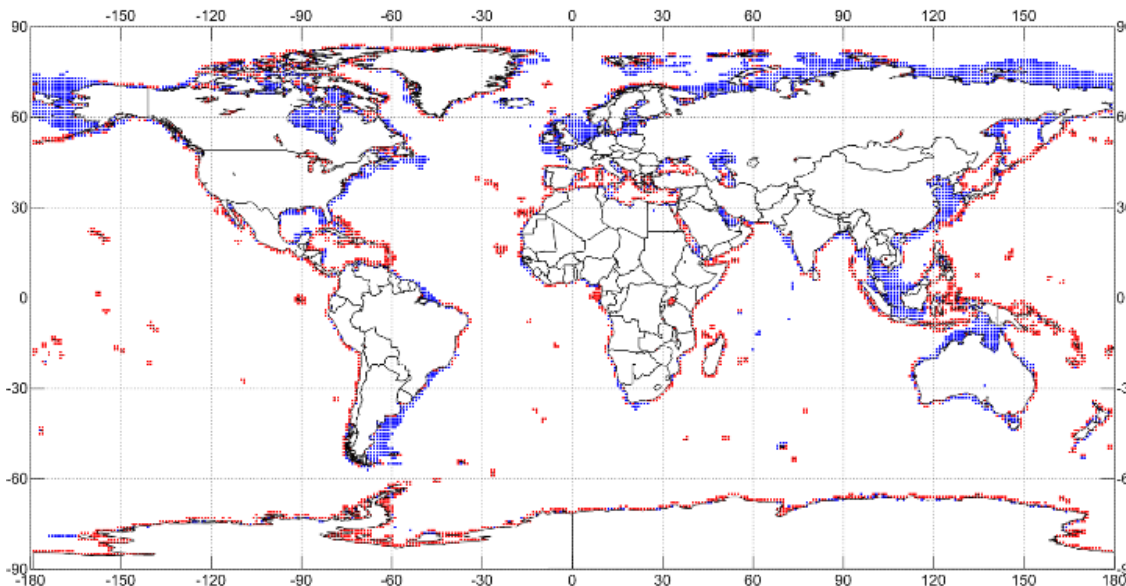
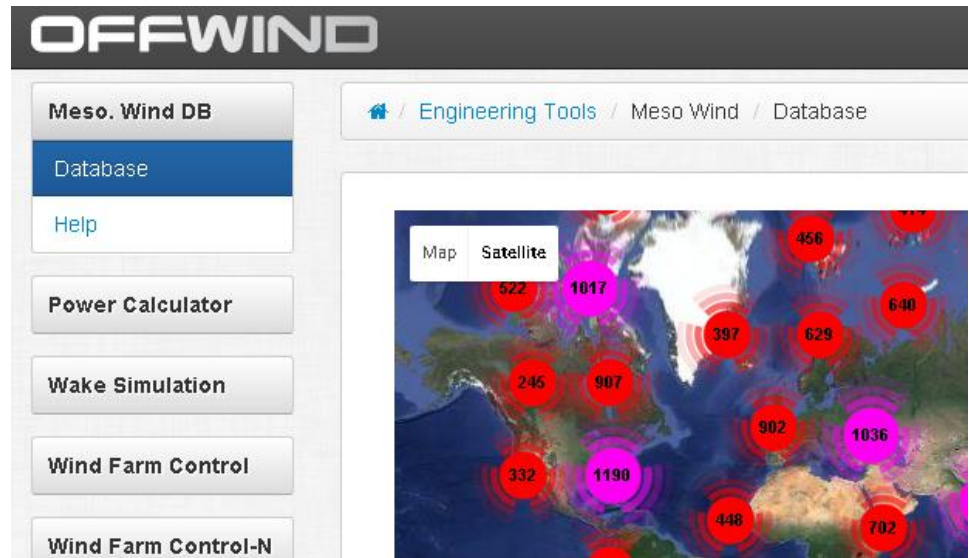
- Mesoscale Wind Database**: Perform initial estimation of the local wind flow, in order to start designing a preliminary offshore wind farm layout.
- Wind Farm Power Calculator**: Calculate simple windwave interactions by taking into account the effect of the waves on the wind speed.
- Wake Simulation**: Compute a snapshot of the wake in a specified wind farm. This approach is based on linear wake expansion and actuator disc theory.
- Wind Farm Control**: Compute the total power output as well as a prediction, using a specified wind farm on the NREL5MW reference turbine. Taking turbine dynamics and wake-interaction into account.

# 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

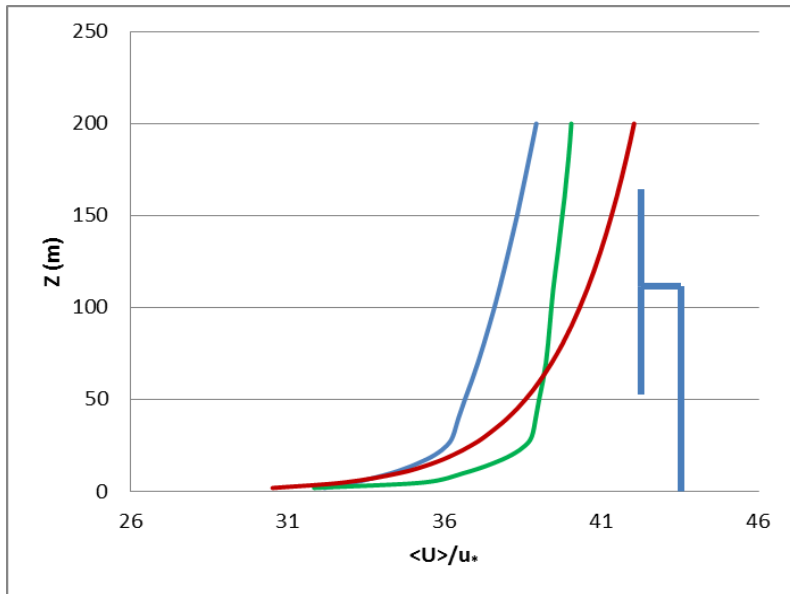
# Sample results



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



# Wind-wave interaction



- Objective:

- How are the waves changing the Atmospheric Boundary Layer (ABL)?
  - Wave age, direction

- Improve existing models

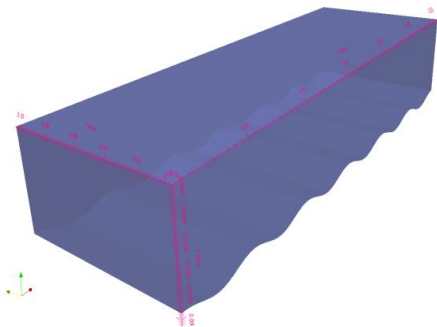
- Methodology

- Simplified approach:

- Algebraic correlations (waves = rough surface)

- Advanced approach

- Computational Fluid Dynamics (CFD)

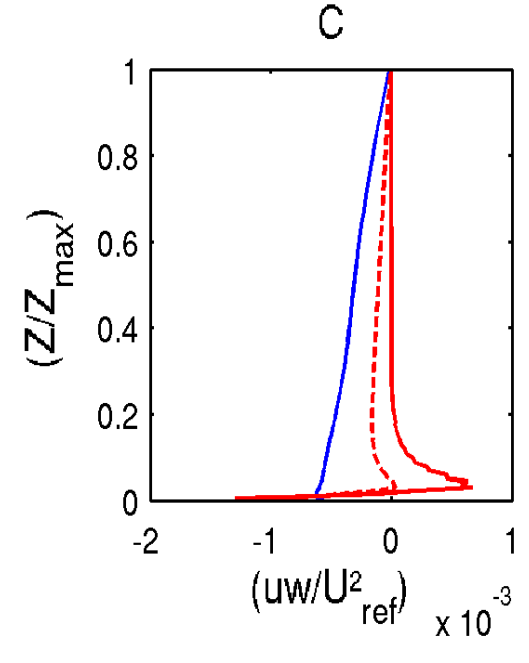
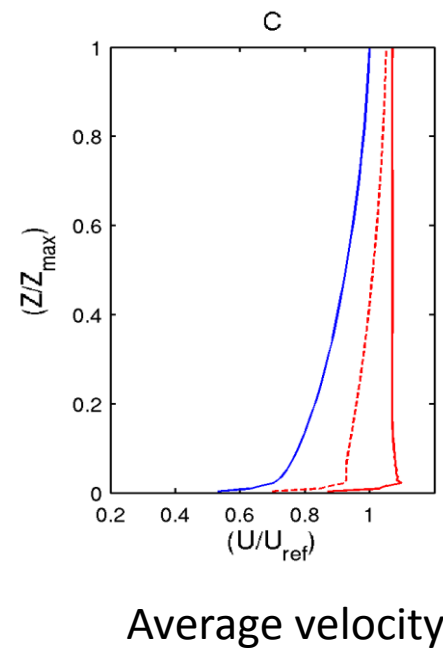
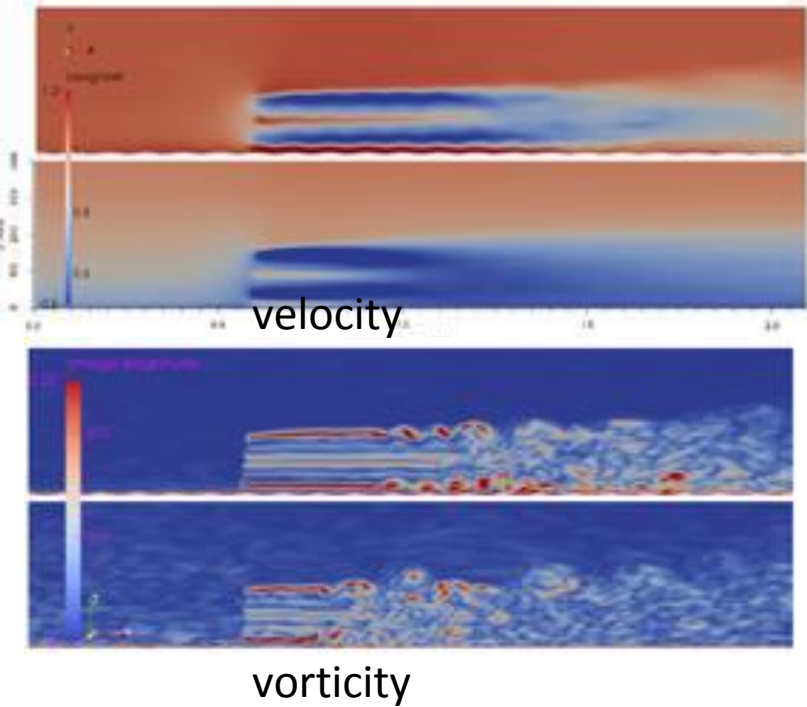


# Wind wave interaction

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

- Engineering model results
  - Relatively wide scatter of predicted power

# Wind wave interactions



Same driving pressure, with/without swell

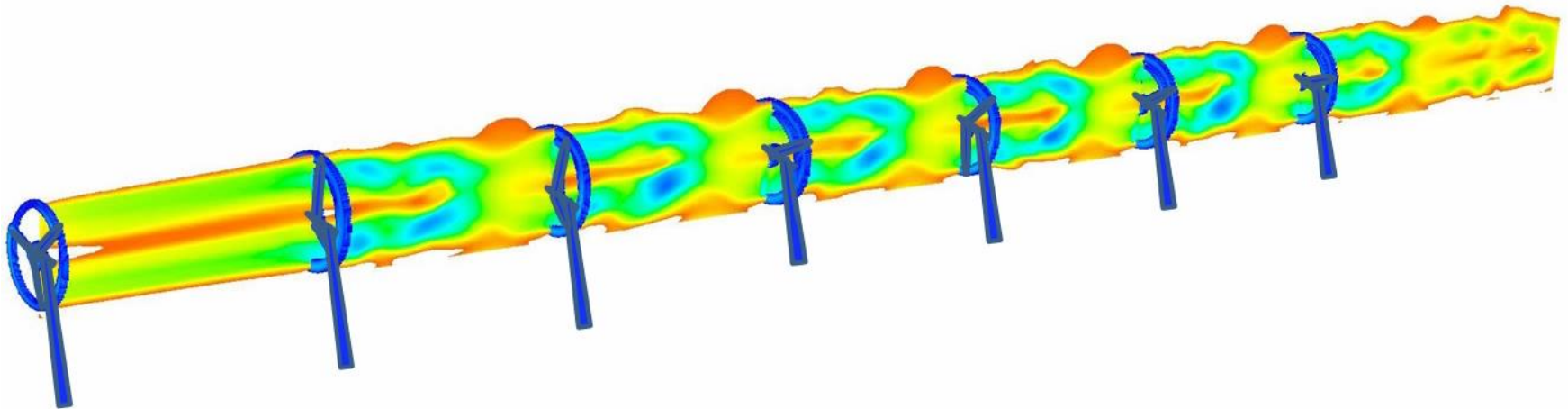
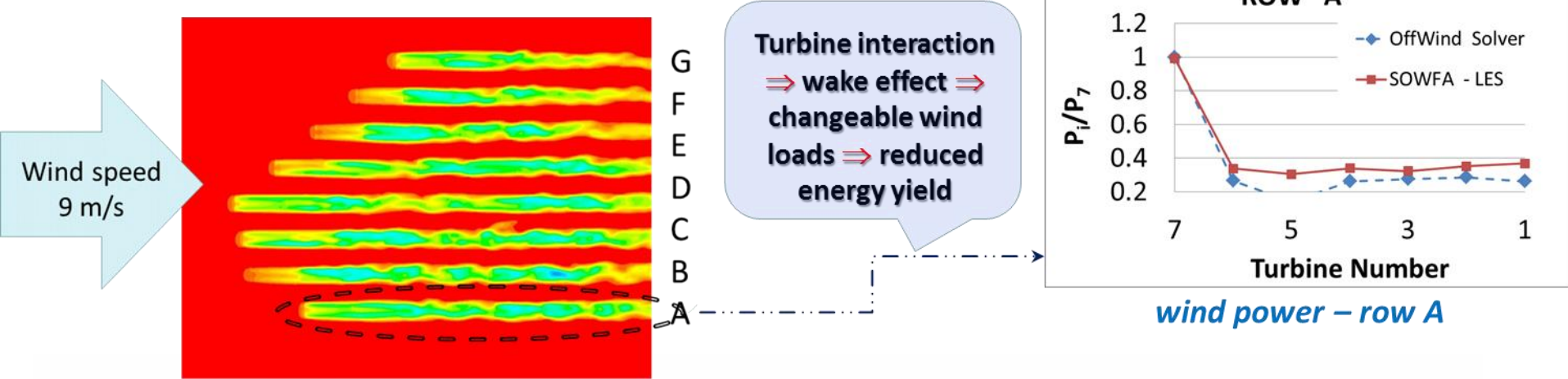
Turbulent stress

- Advanced model results

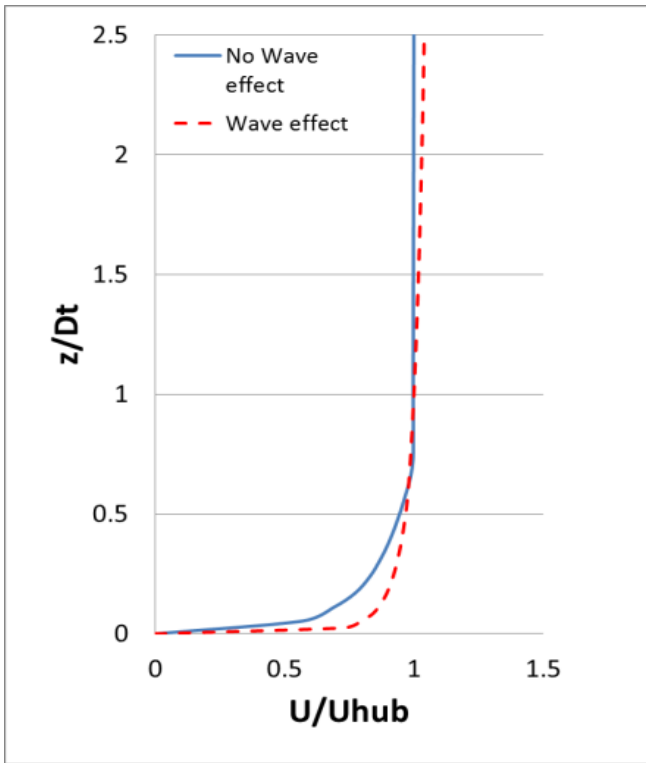
# Wind farm wake interaction

- 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

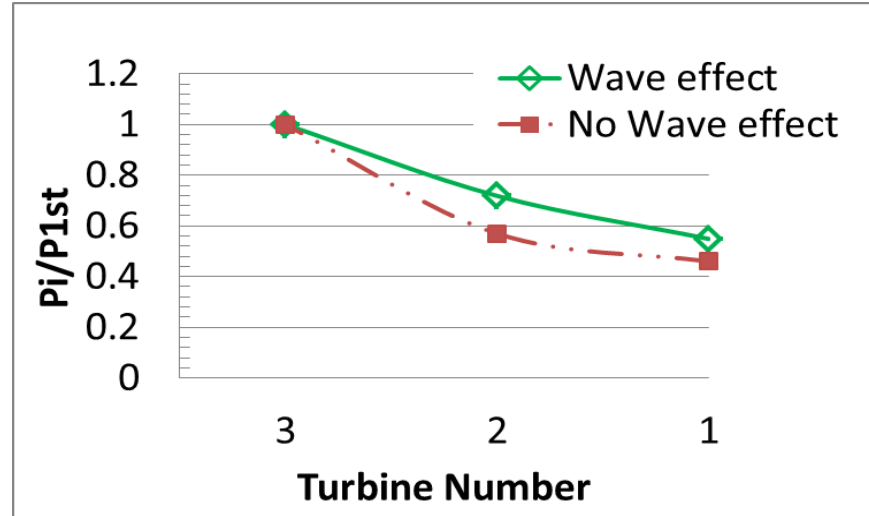
# Validation - Lillgrund



# Wind-wave + Wake Modelling



MABL vertical profiles



Wave effect on the power production

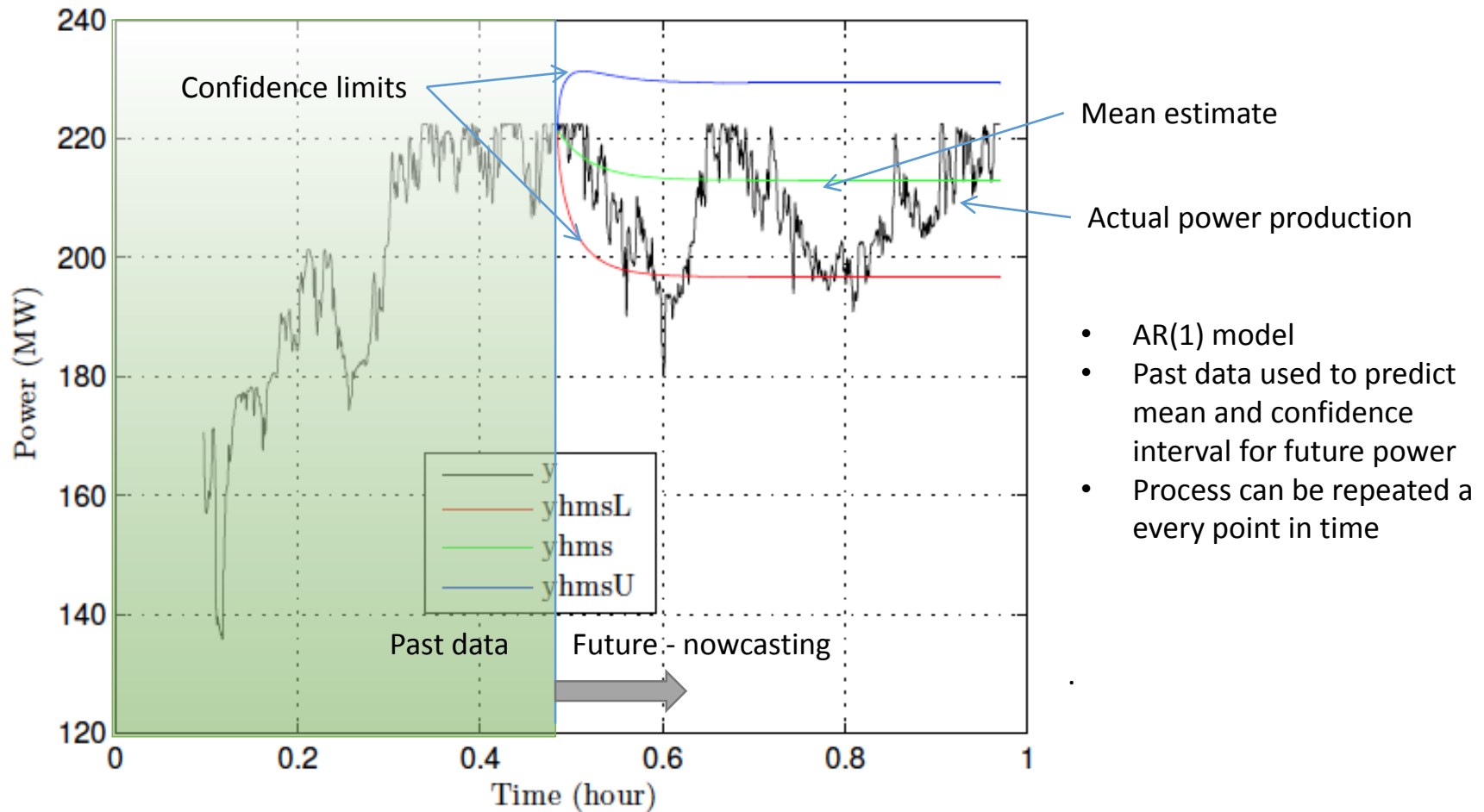
# Nowcasting of available farm power based on data driven modeling

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
<b>Persistence*</b>	Wind speed at time t+k will be the same at time t	Is used as a benchmark.	N/A
<b>Statistical*</b>	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
<b>Physical</b>	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

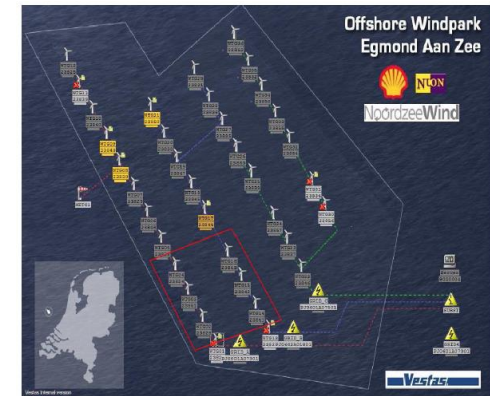
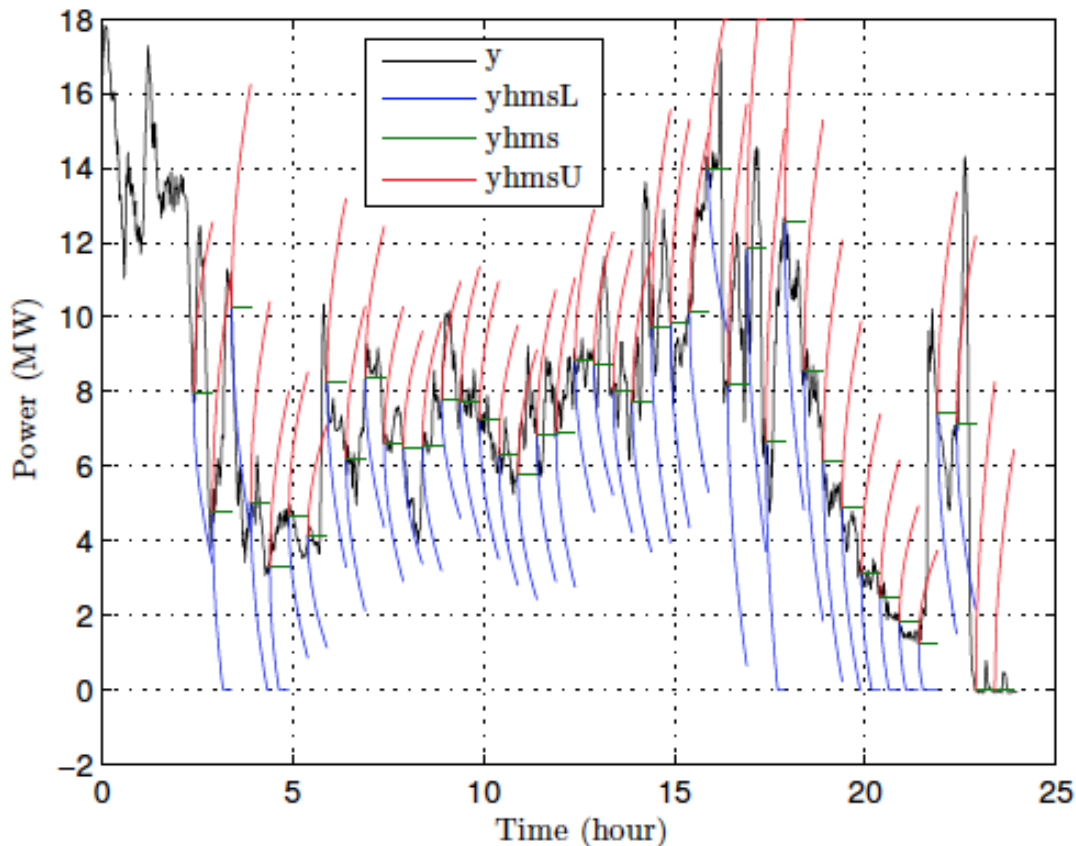
\* Addressed in OFFWIND

# Example – OFFWIND simulated data





# 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](http://www.offwind.eu)

**OFFWIND** About Tools Help robert-zoltan.szasz@energy.lth.se

## What is Offwind?

Offwind - is a set of prediction tools for offshore wind energy generation. It is being actively developed by Offwind group which consists of several partners from different countries in Europe.

### Welcome to Offwind!

**Offwind** - is a set of prediction tools for offshore wind energy generation. It is being developed by Offwind group which consists of several partners from different countries in Europe.

[Read more...](#)

#### Engineering Tools

Run a number of tools which will help you to make quick calculations and estimations.

#### Advanced Tools

Utilize a power of CFD simulations based on OpenFOAM standard solvers. The simulations are being run at Offwind's backend servers. ⓘ

#### Wind Farms & Turbines

Here you will find some predefined models for popular windfarms and turbines. They can be used in your own cases. ⓘ

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