Wind Power Meteorology

A general overview and an introduction to the next two sessions

Dr. Gregor Giebel
Senior Scientist
Risø National Laboratory for Sustainable Energy, DTU
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Acknowledgements

Slides copied and pasted from (amongst others)

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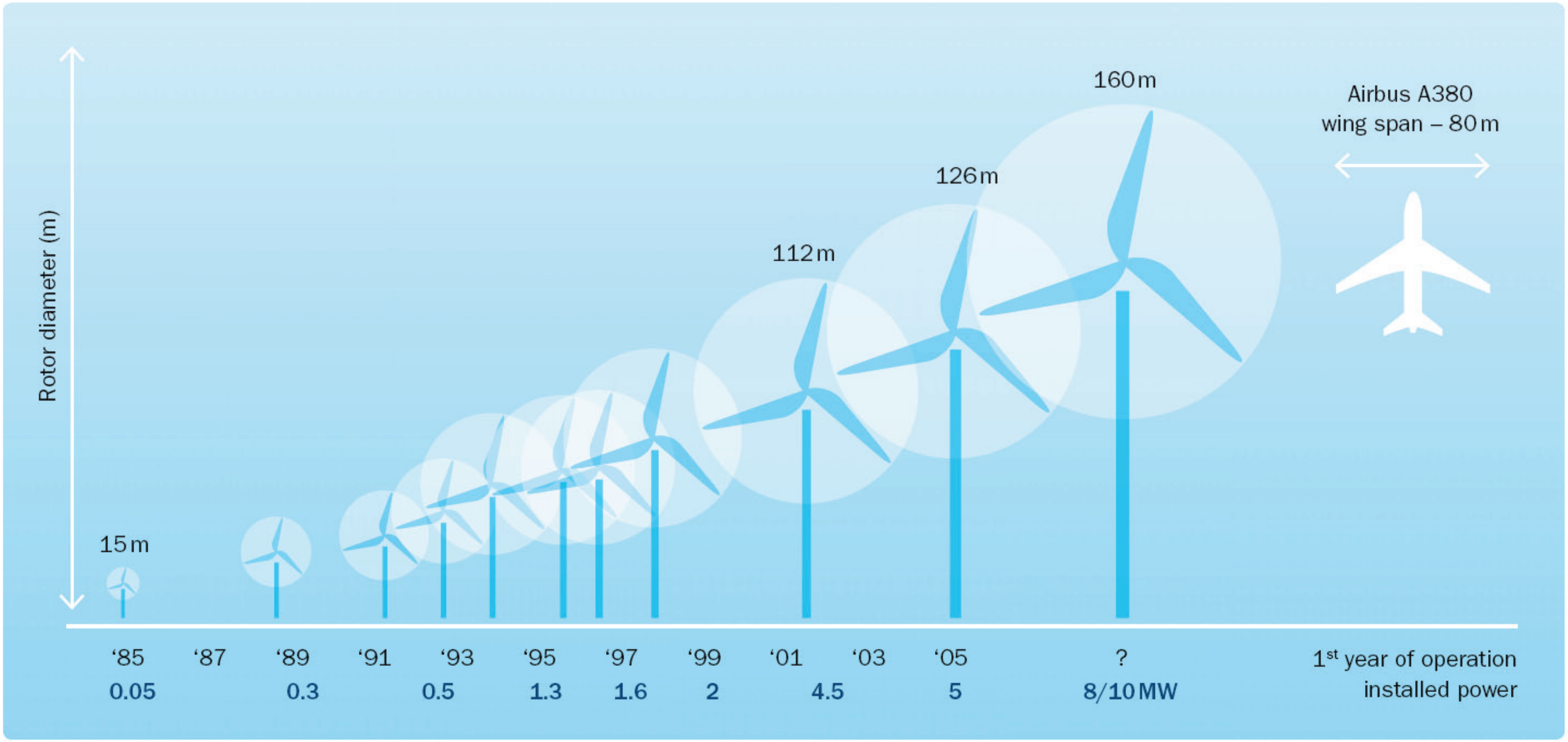
- EU (ANEMOS, ANEMOS.plus, SafeWind, POW'WOW, TradeWind, …)
- Energinet.dk PSO (Ensemble, Unmanned Aerial Sensors, MesoScale, Radar@Sea, …)
- Other sources, including commercial clients

Commencial wind turbine size development



Source: TPWind

Wind

Wind conditions
Turbine design
Off shore

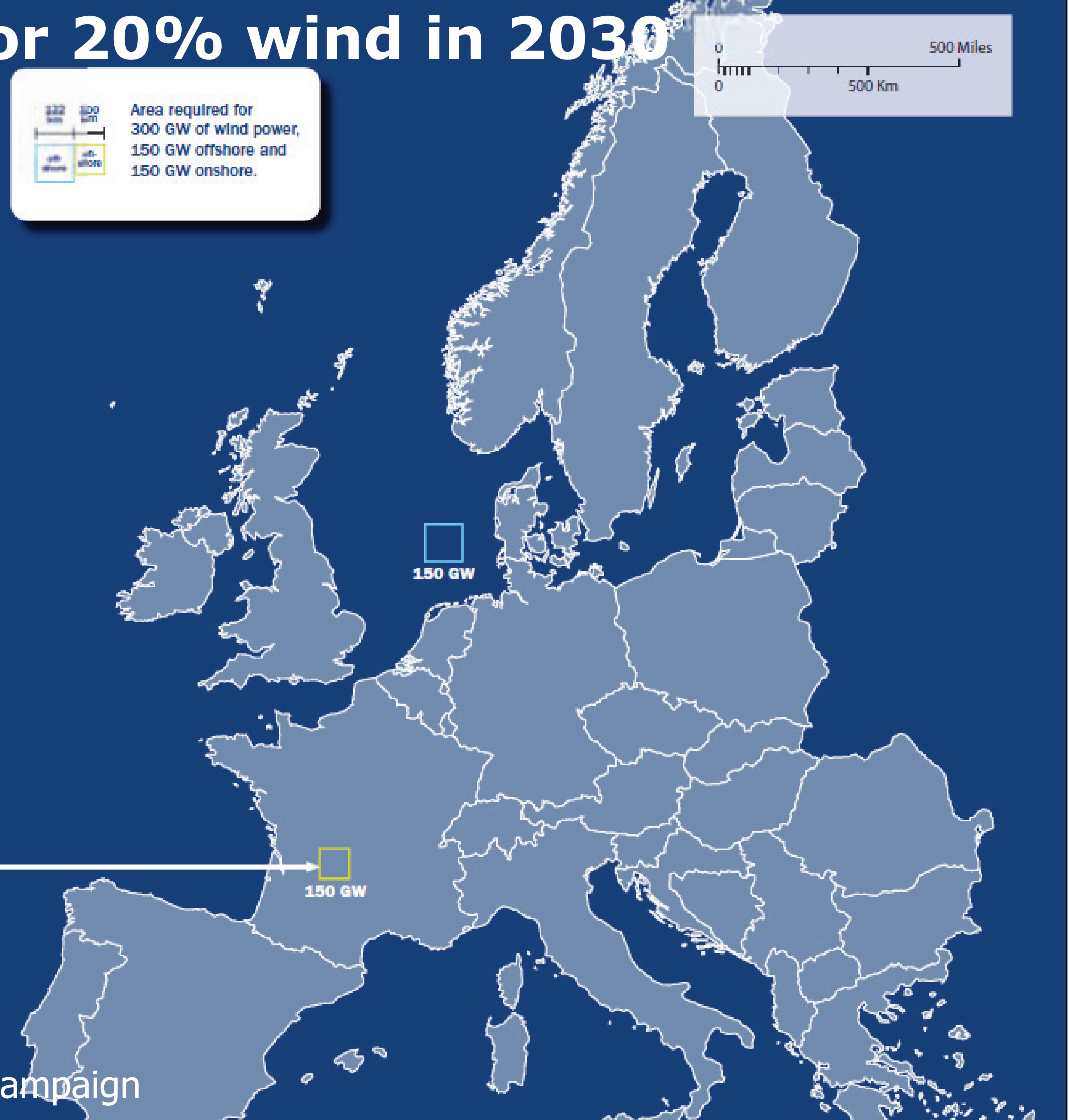
Middelgrunden 20X2 MW

Area used for 20% wind in 2030

300GW = 965TWh

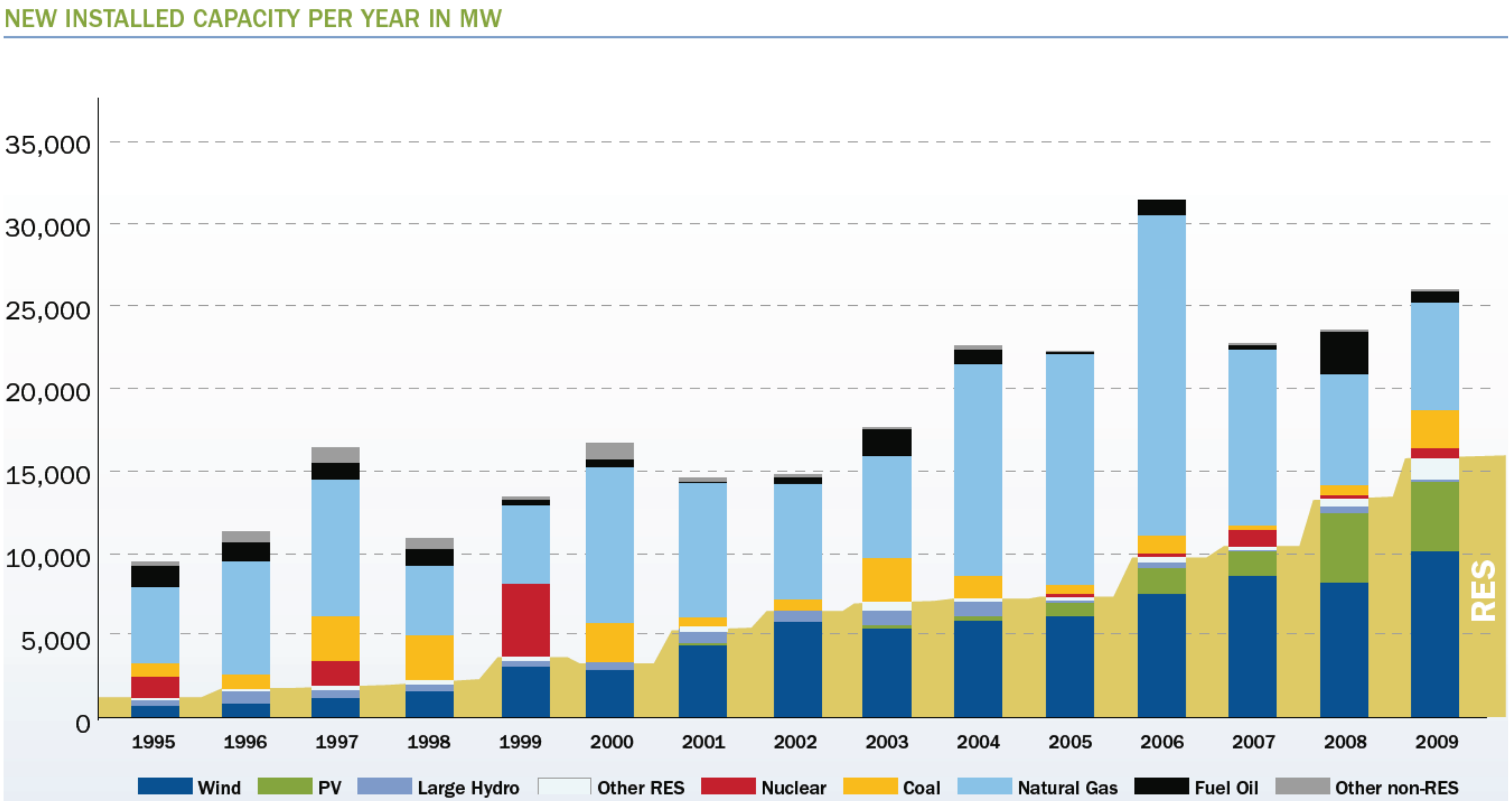
100x100km onshore

122x122km offshore



Source: EWEA no fuel campaign

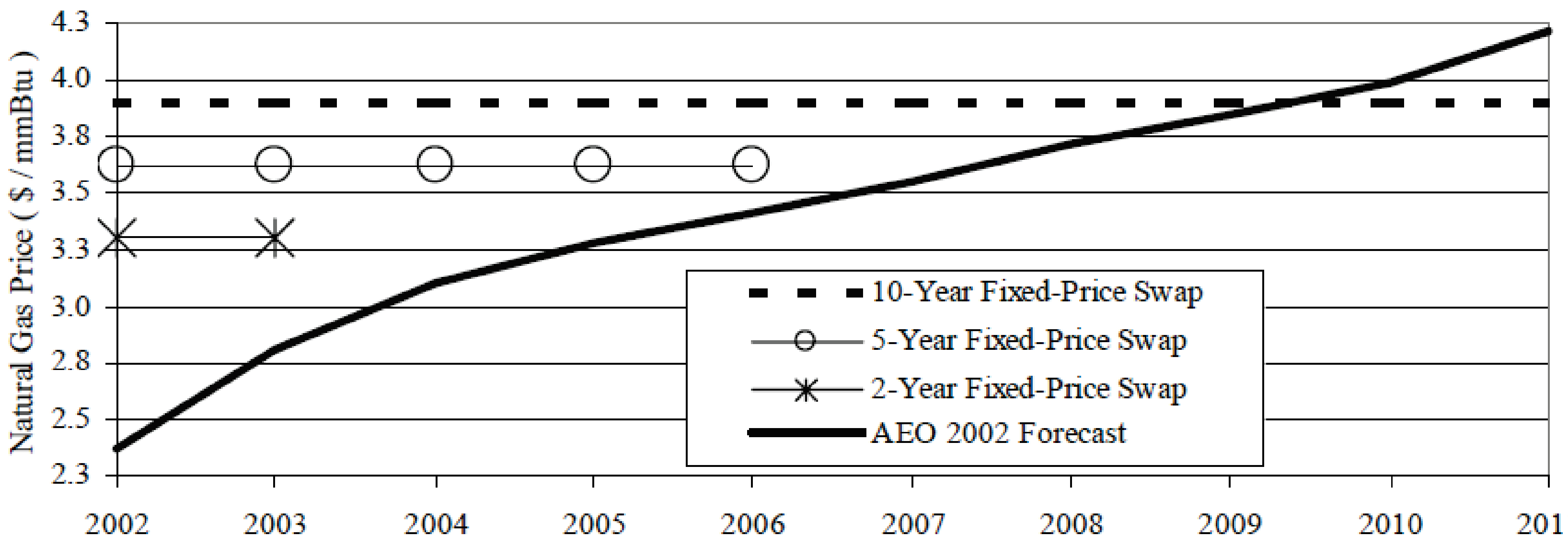
Wind power share of new installed capacity (source: EWEA)



This means that RES already represent over 50% of new capacity

Wind power as hedging against high fossil fuel prices

- Bolinger / Wiser showed in 2002 (AWEA) that wind power has a hedging value against high gas prices.



Source: Enron (2001) and EIA (1997-2001)

- Result: *"We conclude that it costs approximately 0.5US¢/kWh to hedge away natural gas price risk over a 10-year period using financial swaps."*

Source: Bolinger and Wiser: *Quantifying the value that wind power provides as hedge against volatile natural gas prices.* Paper on the AWEA 2002,

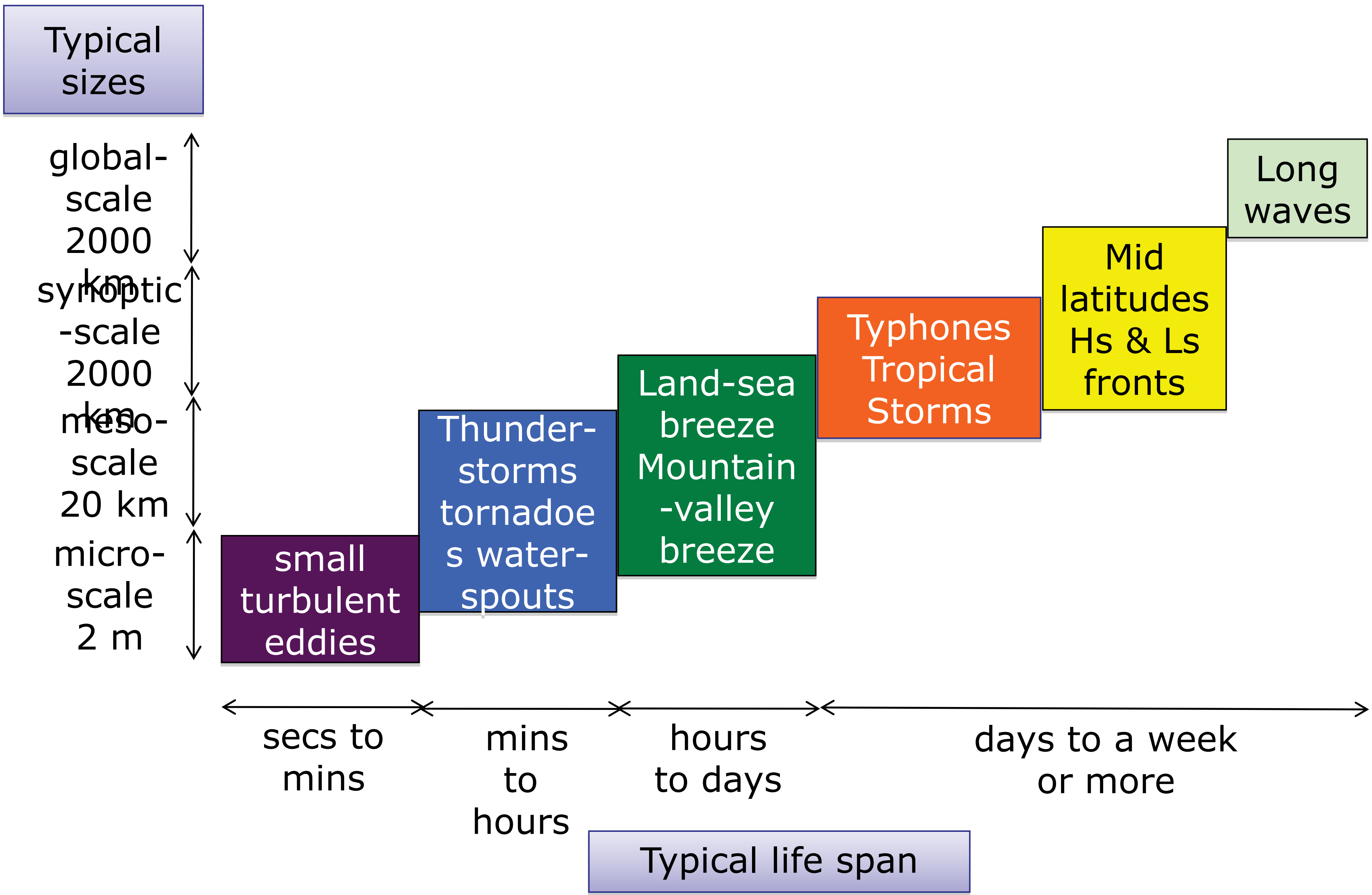
Wind Power Meteorology - Timescales

Chronologically in the life of a wind farm:

- Siting: where is the best wind resource for the next 20 years?
  - Often done with simple linear flow models (e.g. WAsP)
  - Only rarely takes climate change effects into account
  - Includes wind farm layout (wakes, micro-scale effects)
- Siting: which IEC class of turbine do I need?
  - Effects of extreme winds / shear / turbulence / mean wind speed

- Grid integration: short-term forecasts
  - Market time scale: next-day
  - Scheduling of conventional generation: 8-12 hours
  - Uses Numerical Weather Prediction plus power conversion
- Turbine control: seconds
  - Pitching of blades to optimise aerodynamics and alleviate loads
  - Only really possible with forward looking lidar

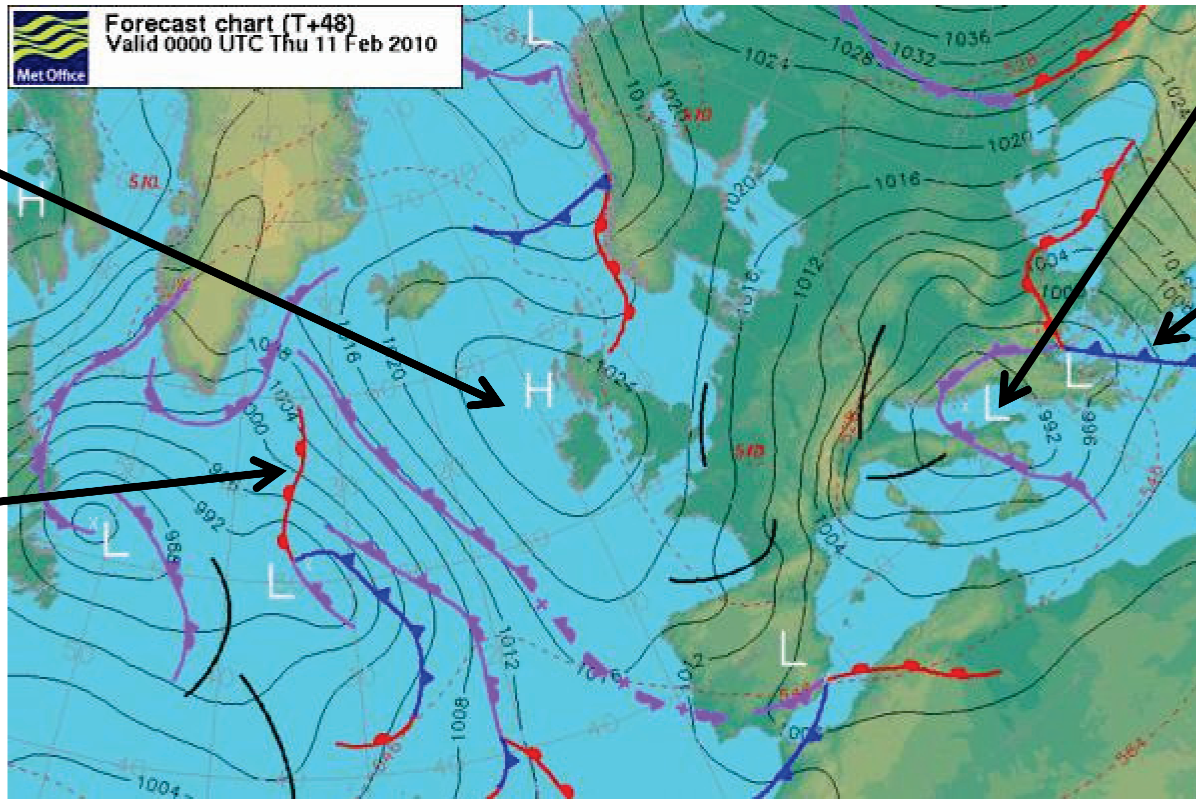
Time and space scale of atmospheric motion



Synoptic scale meteorology

High pressure system

Warm front



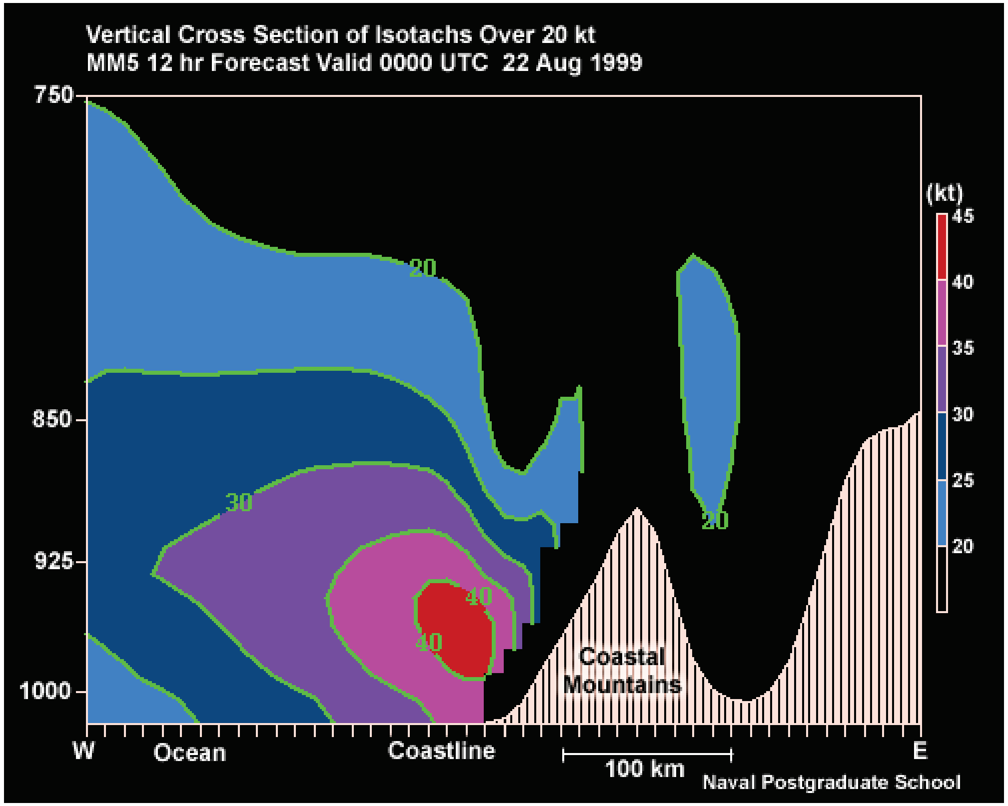
Low pressure system

Cold front

(http://www.metoffice.gov.uk/weather/uk/surface_pressure.html#view)

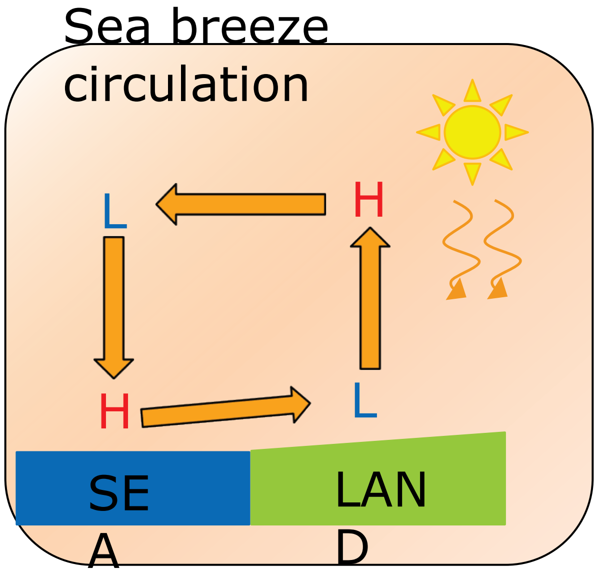
Mesoscale Meteorology

Coastal low level jets



Thunderstorm

Picture from http://www.news2.dk/pdf/20060224X008.pdf



Micro scales

There are always unresolved processes that cannot be represented by a numerical model.

These features are approximated through Parametrization!

Turbulent stress seen on the sea surface scales 1-500 m

Dust devils scale 25-50 m

Importance of resolution

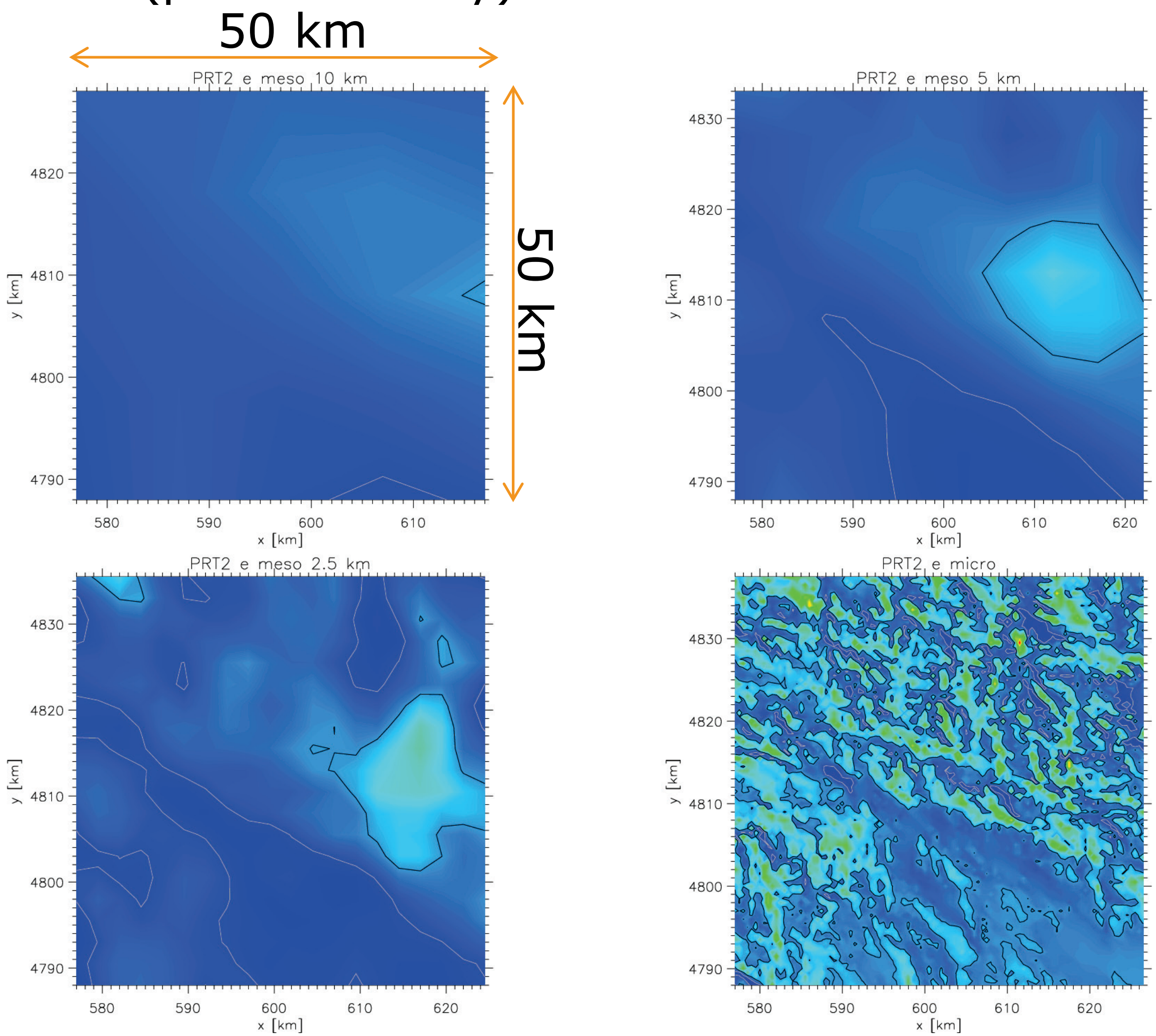
Wind resource (power density) calculated at different resolutions

10 km

324 W/m²
378 W/m²

5 km

328 W/m²
378 W/m²



2.5 km

323 W/m²
378 W/m²

0.1 km

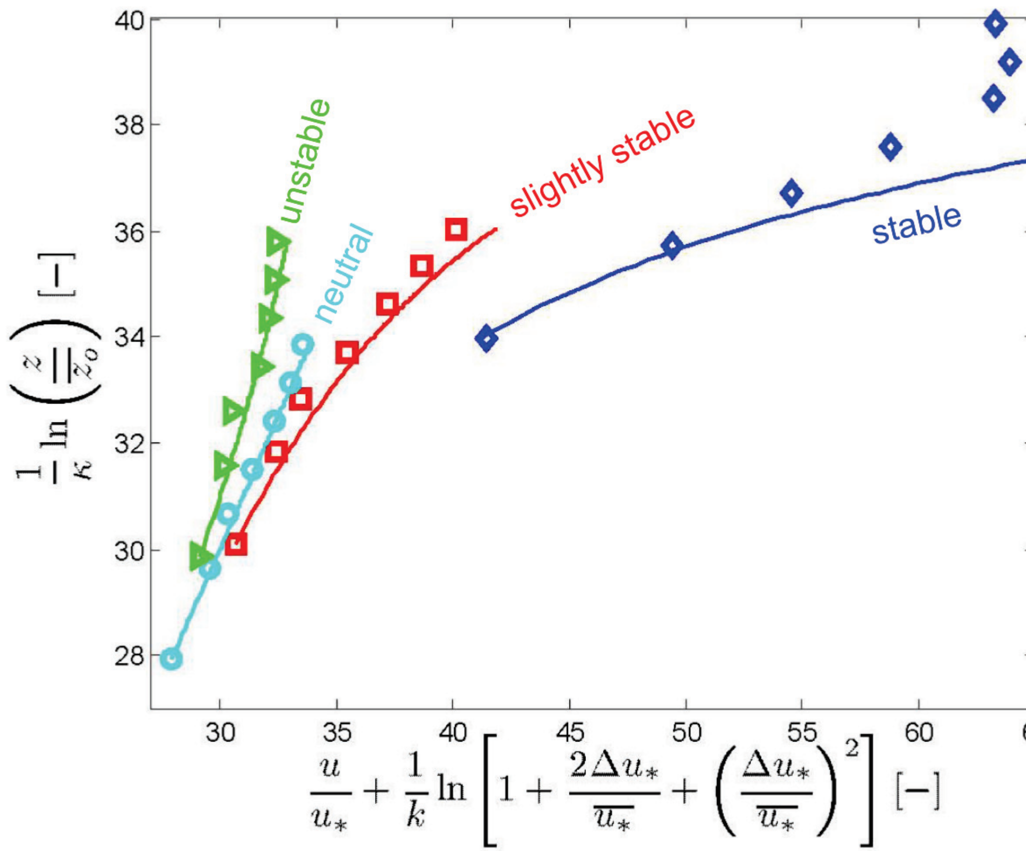
505 W/m²
641 W/m²

mean power density of total area   mean power density for windiest 50% of area

M2, platform and measured profiles

Wind profile measurements were combined:

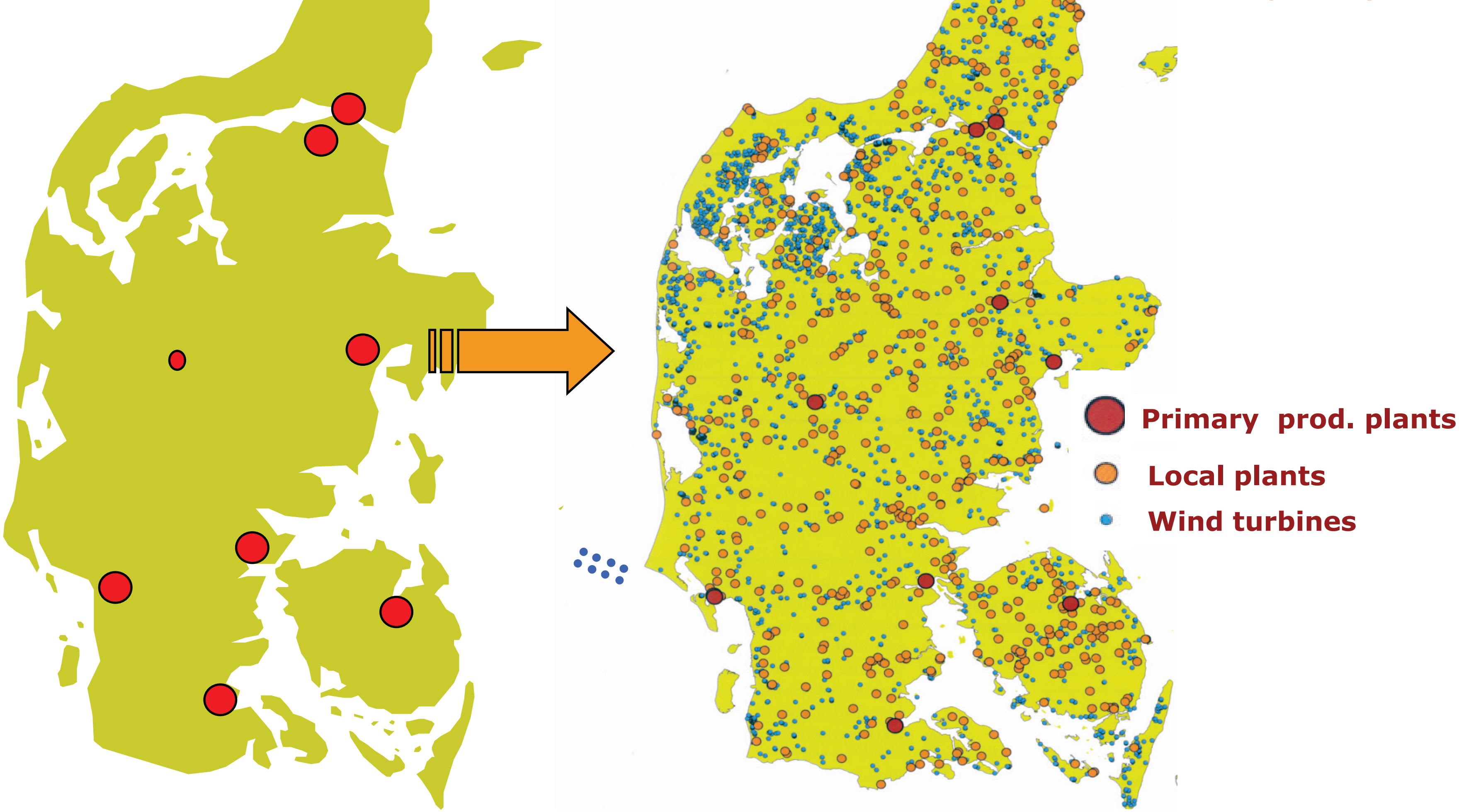
1) from a 60 meter mast and
2) wind profiling Lidar (60 to 160 m) installed on a platform



Development from the 1980s

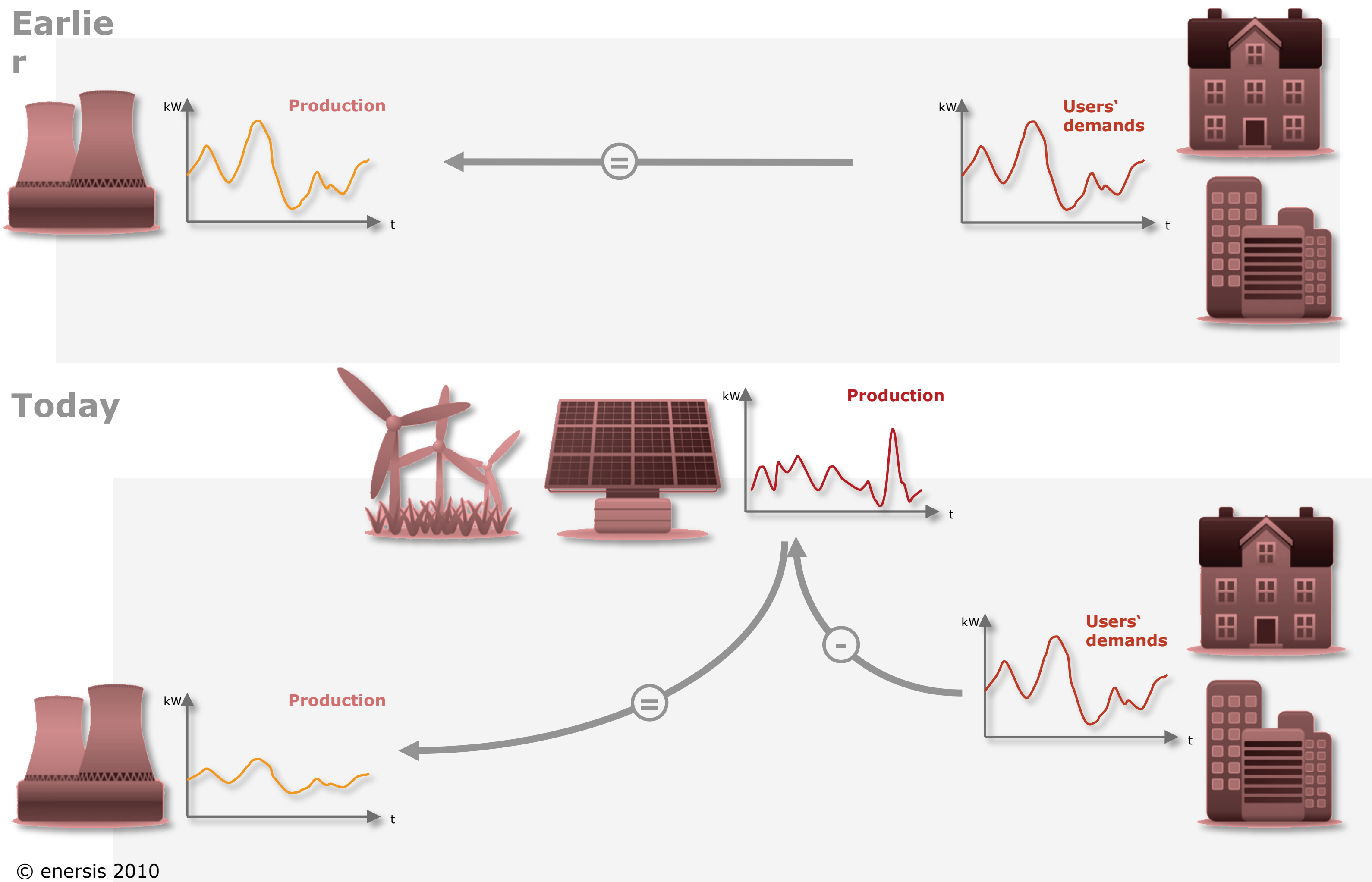
Primary Production Capacity

Local Production Capacity

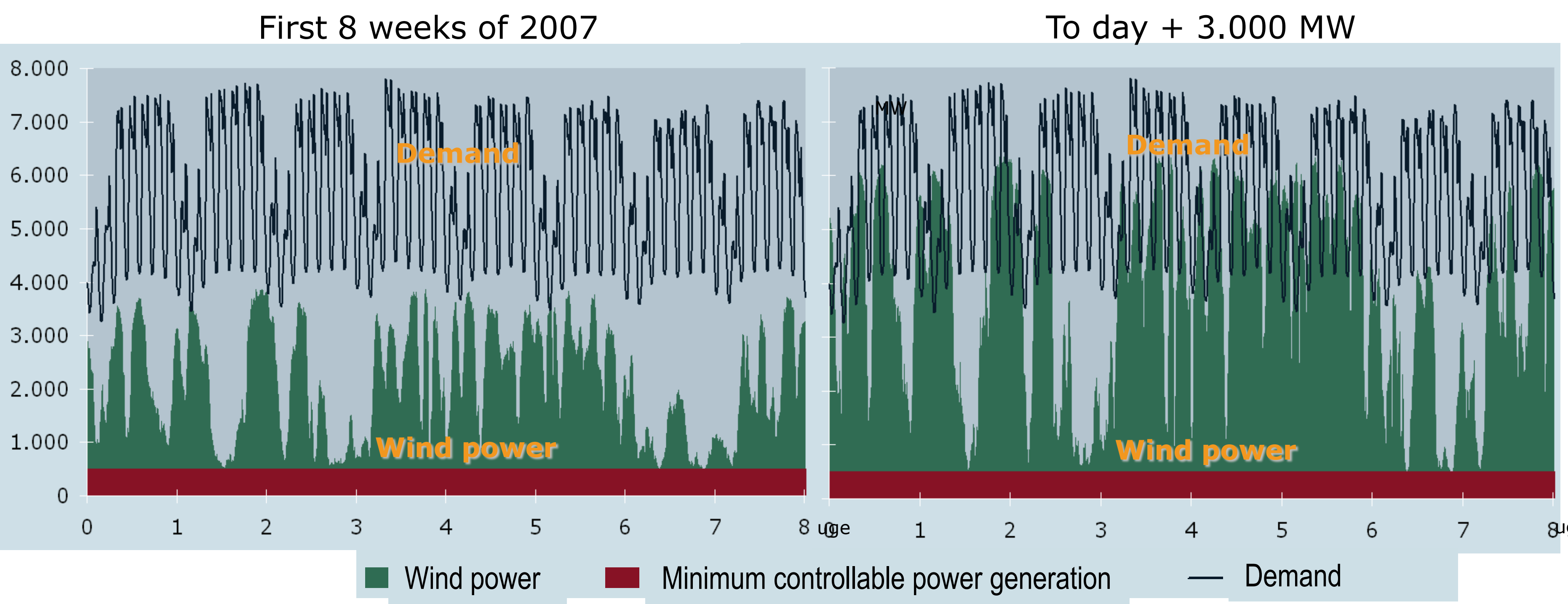


Source: EcoGrid.dk (Energinet.c

Decentralized energy production: consequences

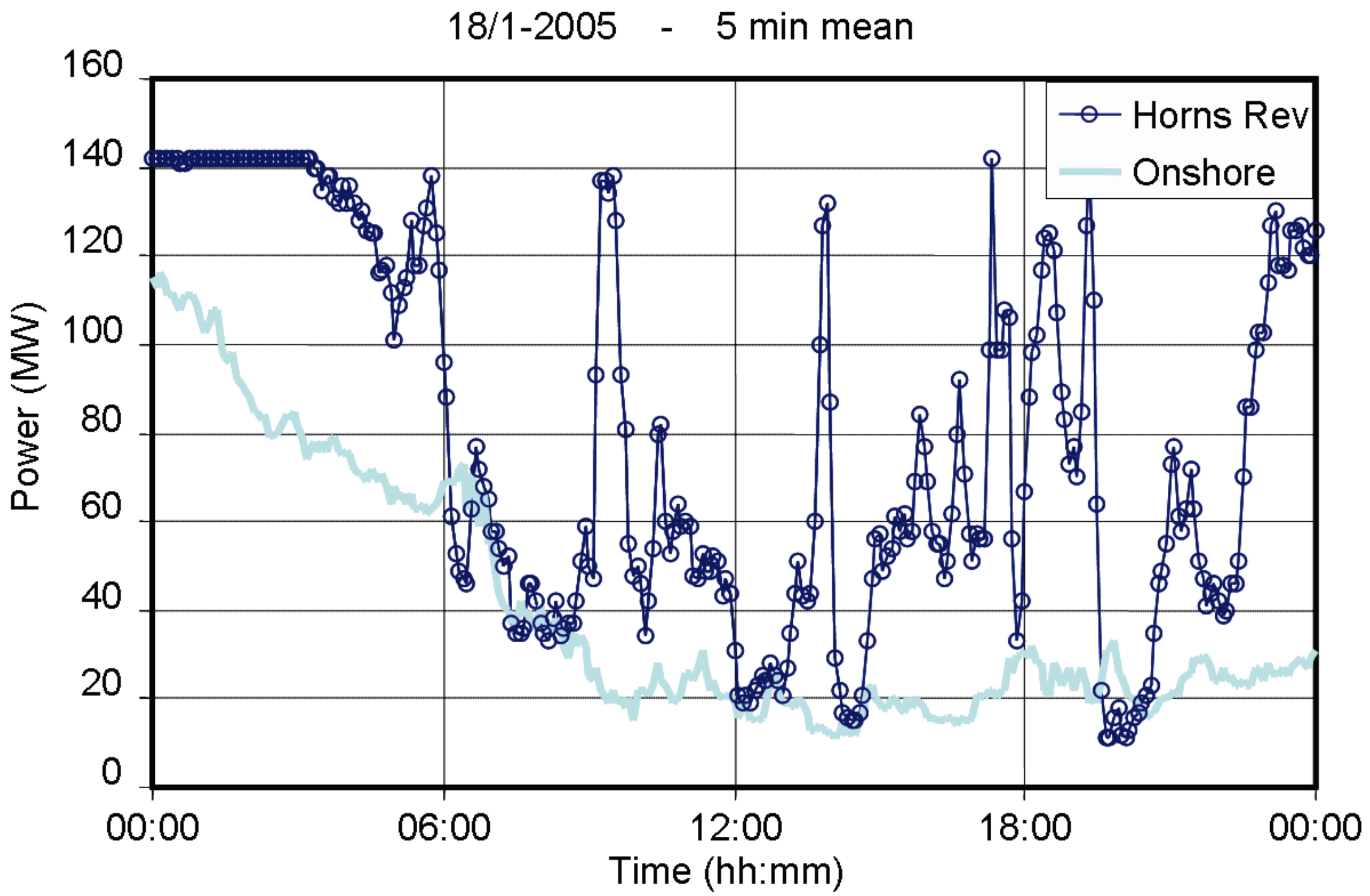


Integration of fluctuating renewable energy ressources

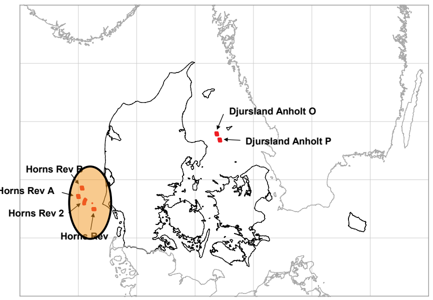


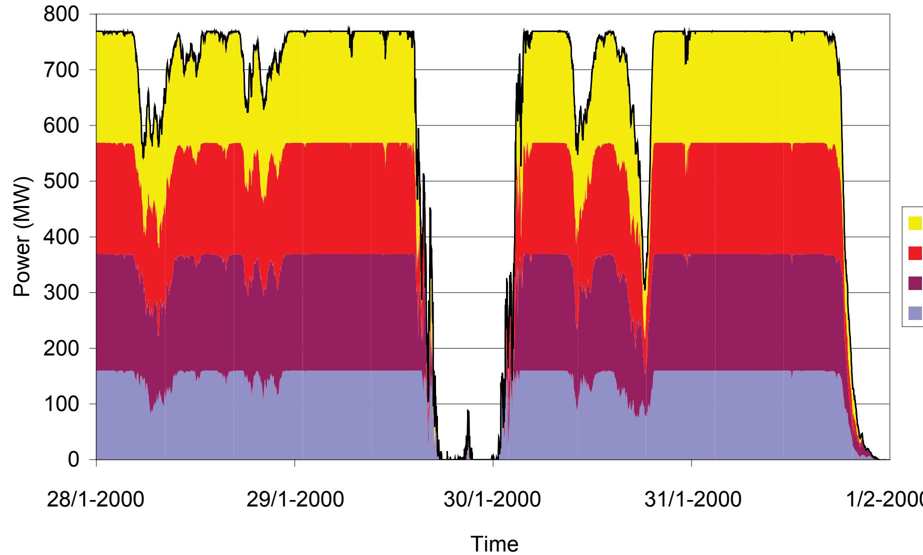
So far (left), wind power alone doesn't really reach 100% of power in th
At 50% penetration,

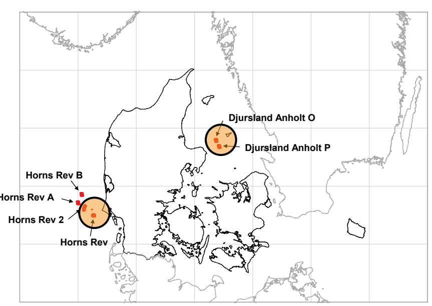
Geographical spreading

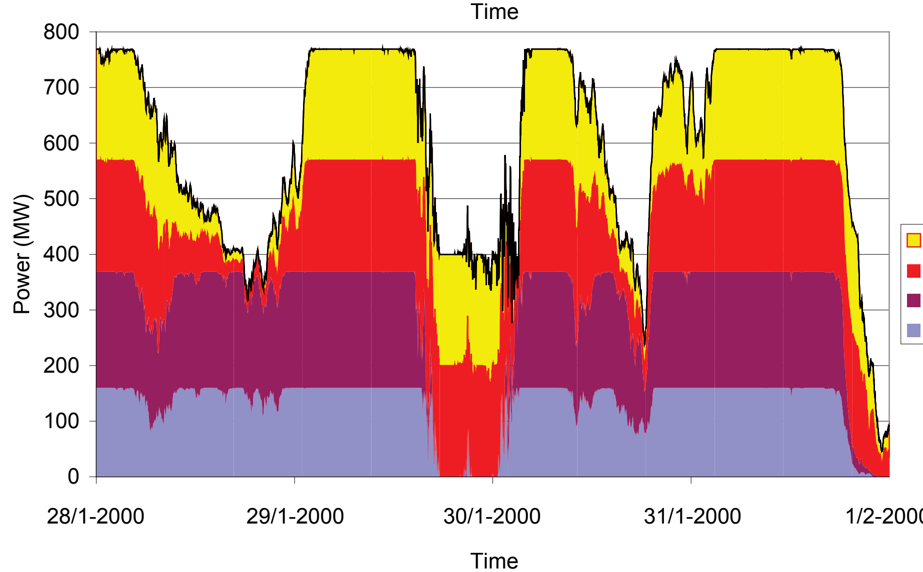


Power fluctuations – the 2 cases



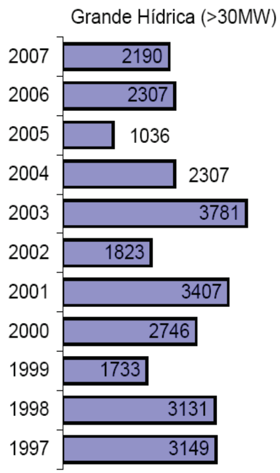


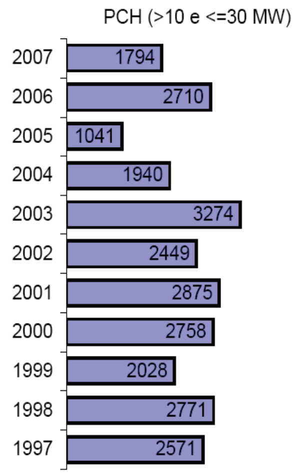


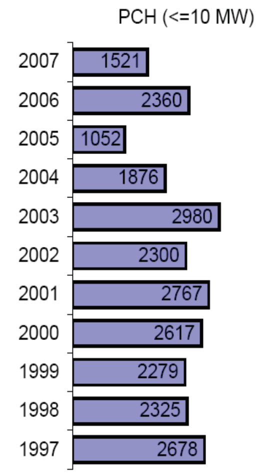


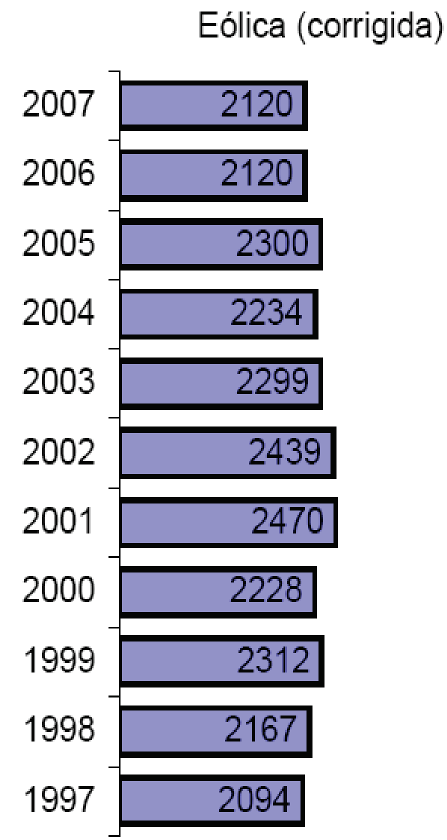
Annual Energy – Wind vs Hydro

- It has a better Energy guarantee (lower variation) than Hydro (h/year)





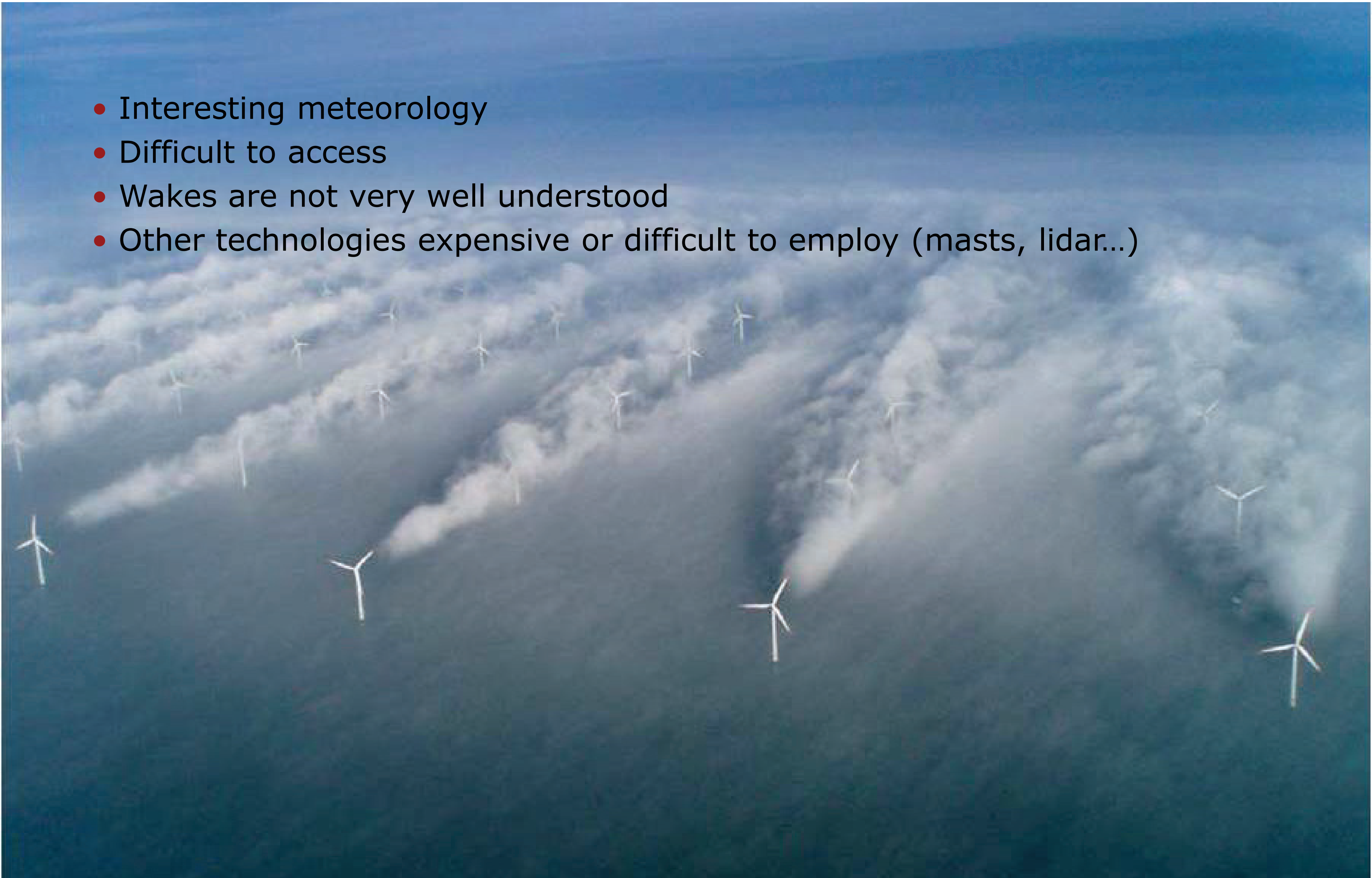




Source: Presentation by Rui Pestana, REN (Portuguese TSO) on the 2nd Workshop on Best Practice in the Use of Short-term Forecasting, Madrid, 28 Ma

Offshore example: Horns Rev

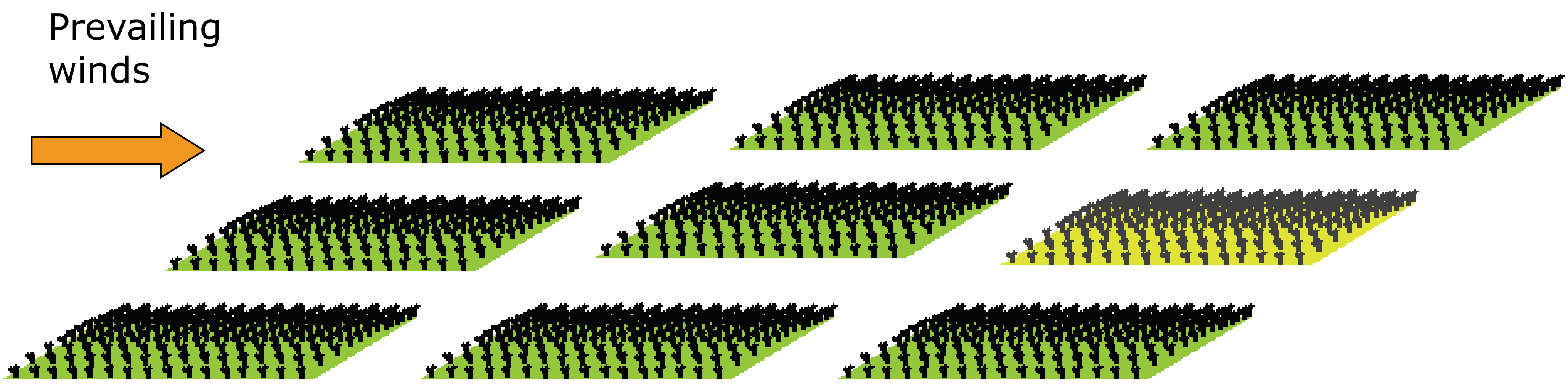
- Interesting meteorology
- Difficult to access
- Wakes are not very well understood
- Other technologies expensive or difficult to employ (masts, lidar…)

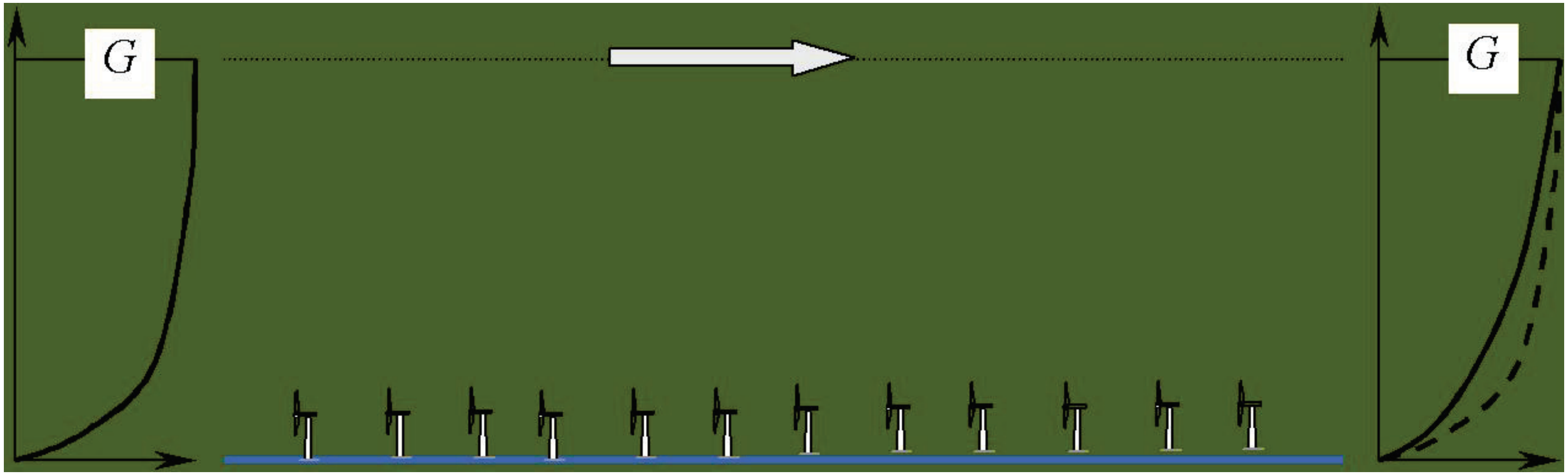


Huge offshore wind farms will change the local climate – how to model?

Offshore wind farms in operation, construction and planning

Flow in large-scale wind farms





Aggregation
Microscale to mesoscale
PhD Joakim Refslund Nielsen

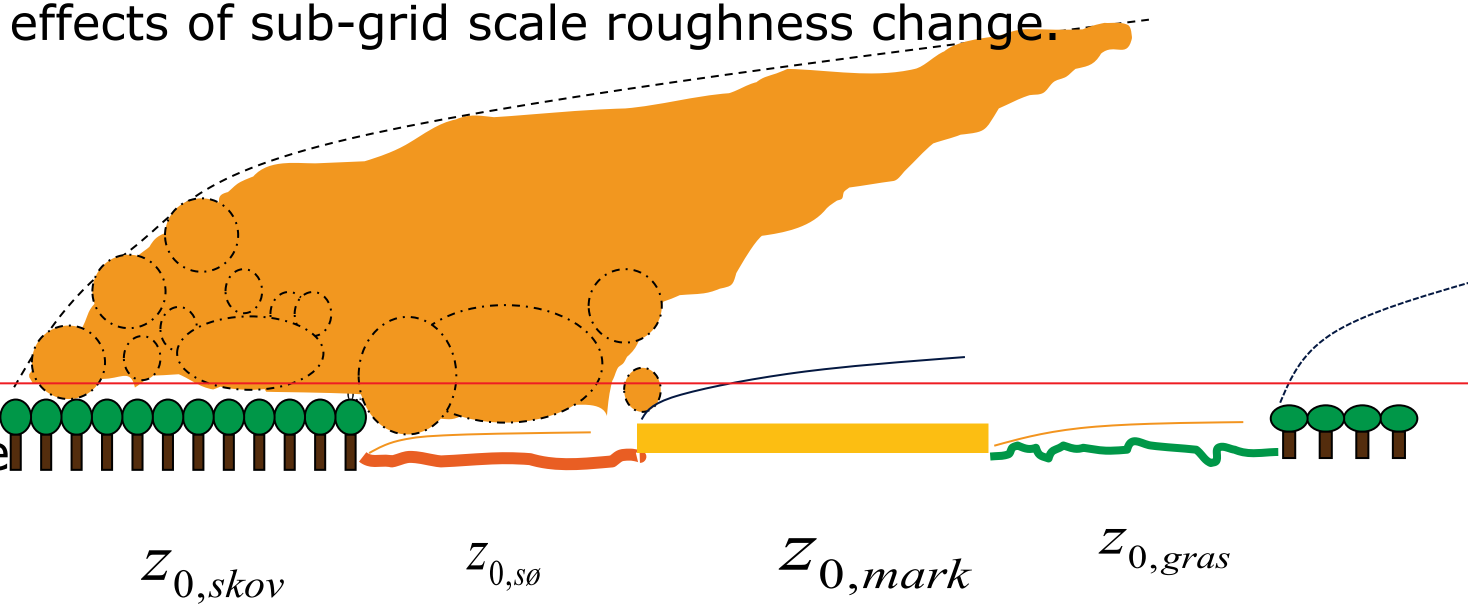
Micro-scale flow effects

1. Internal boundary layers
2. Edge effects

How can these be upscaled into parameterizations within mesoscale models
A number of microscale models will be employed to
aggregate the effects of sub-grid scale roughness change.

different land use

different
roughness length



THE UPCOMING SESSIONS

The Wind Power Meteorology Session at EGU

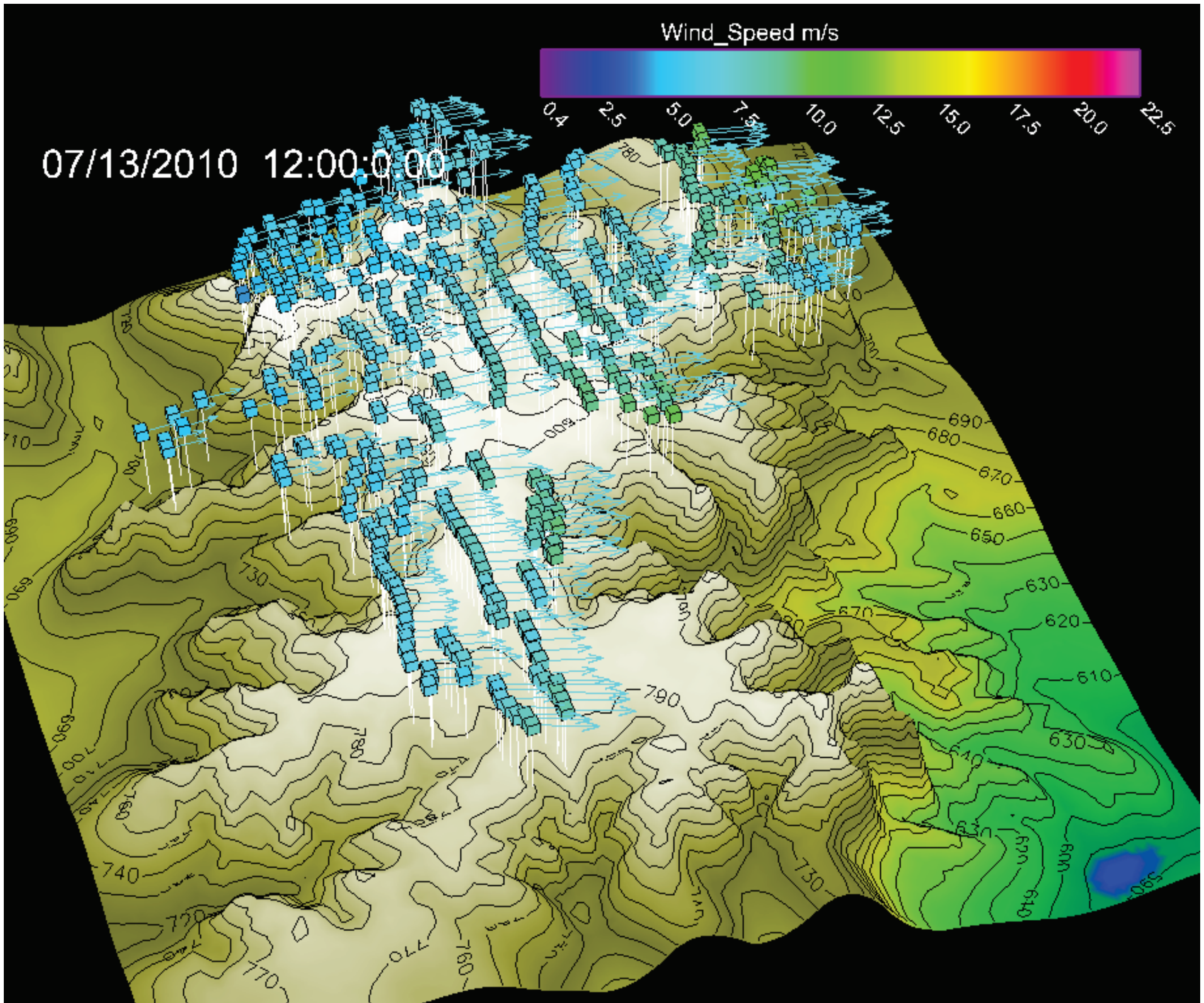
Convenors: Gregor Giebel, Risø DTU, Anna Maria Sempreviva, CNR-ISAC, and Somnath Baidya Roy, University of Illinois

40 Abstracts, 2 oral slots (this room from 1330-1700), poster session 1730-1900

Topics:
- Wind conditions (both resources and loads) on short and long time scales for wind power development.
- Wind conditions in complex terrain (mountains, forests and coastal).
- Forecasts of wind power for the next minutes or next days, in general and for extreme events.
- Wake effects, especially for large wind farms and offshore.
- Effects of large-scale integration.
- Local, regional and global impacts of wind farms.
- Dedicated wind measurement techniques (SODARS, LIDARS, UAVs etc.).

•A Large Onshore Wind Farm: Impact of Modest Topography versus Turbine Wakes

Bob Conzemius, *WindLogics Inc.*



Wind turbine data taken from SCADA system.

Coloring on shapes (cubes) denotes wind speed. Wind is faster on the upper right.

Arrows denote wind direction.

•A Large Onshore Wind Farm: Impact of Modest Topography versus Turbine Wakes

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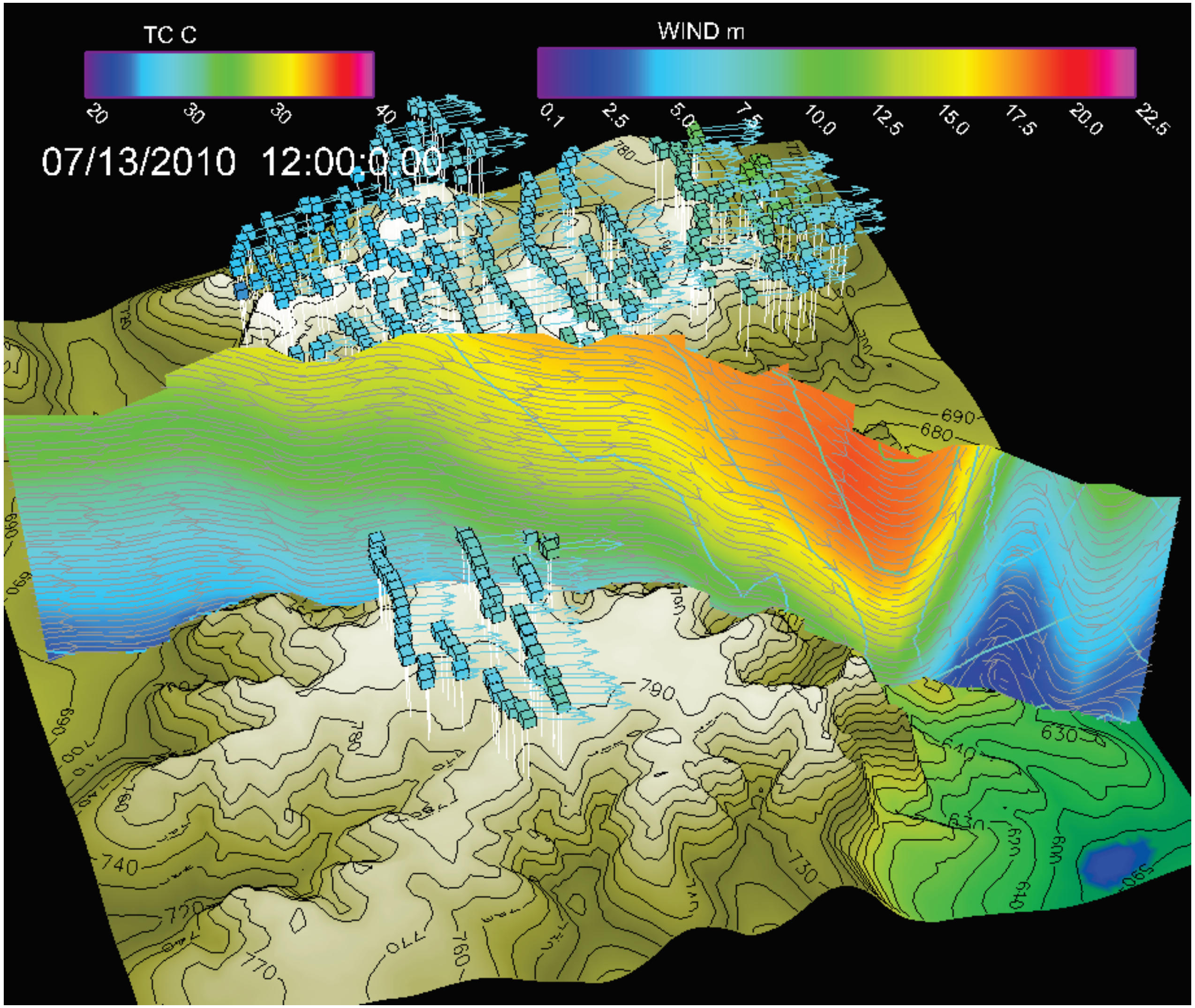


Wind turbine data compared to WRF model cross section.

Shading on cross-section is wind speed.

Colored cubes are wind speeds at turbine hub height.

Colored contour lines on cross section are temperature.

Arrows and streamlines denote

Autonomous Aerial Sensors for Wind Power Meteorology

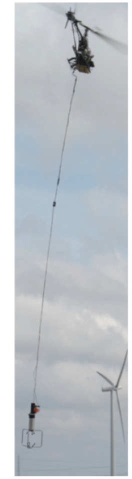
Gregor Giebel, Uwe Schmidt Paulsen, Joachim Reuder, Anders la Cour-Harbo, Carsten Thomsen, Jens Bange

Risø DTU
National Laboratory for Sustainable Energy

Project to investigate the applicability of Autonomous Aerial Vehicles with wind sensors for wind power meteorology

This poster describes a new approach for measurements in wind power meteorology using small unmanned flying platforms. During a week of flying a lighter-than-air vehicle, two small electrically powered aeroplanes and a larger helicopter at the Risø test station at Høvsøre [NEWS: due to legal reasons regarding overflight rights, we will fly at Nøjsomheds Odde], we will compare wind speed measurements with ~~fixed mast and~~ LIDAR measurements, investigate optimal flight patterns for each measurement task, and measure other interesting meteorological features like the air-sea boundary in the vicinity of the wind farm. In order to prepare the measurement campaign, a worksh[…]unities.

Flight Week at DONG Energy wind farm, Nøjsomheds Odde, ~~Danish National Test Station for Large Wind Turbines, Høvsøre~~, DK



5 met masts

5 large wind turbines

2 met masts of 167m

Lidars

Risø DTU:
Skydoc
Lighter-than-air platform
Equipped with GPS, sonic anemometer, and other met sensors. Data acquisition synchronised to 200 ns and 10 cm absolute accuracy from GPS signal.

Uni Bergen:
SUMO
Small Unmanned Meteorological Observer
Up to 5 planes, 580g each, equipped with GPS, temperature, pressure and humidity sensors. Potential for very small Pitot tube.

Uni Tübingen:
M²AV
2-m plane with high-resolution pitot tubes and other met sensors. Electrically flying, flight system developed by Mavionics.

Aalborg University:
Helicopter
Equipped with laptop, GPS, sonic anemometer, and other met sensors. Total weight <25 kg.

Questions to answer from the project

Wakes

Flight patterns

Loads

Taylor's hypothesis

Air-sea boundary

Profiles

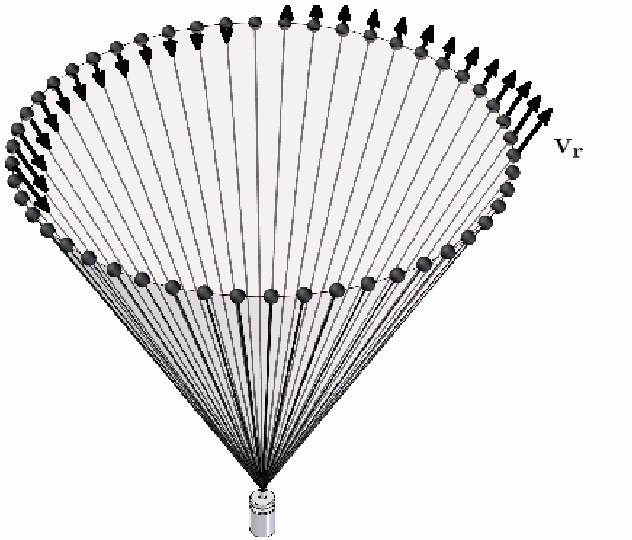
Accuracy?

Distance to turbines?

Flight envelope

Website: aerialwindsensors.risoe.dk

Can wind lidars measure turbulence?



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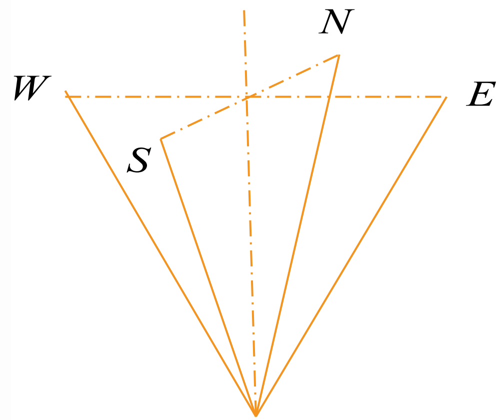
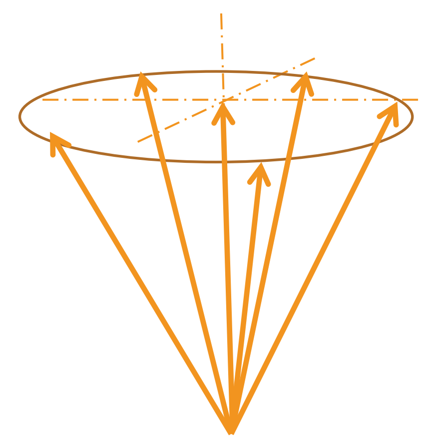


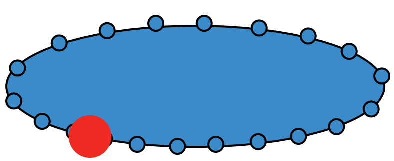
Windcube

Two approaches will be discussed !!!

6-beam method



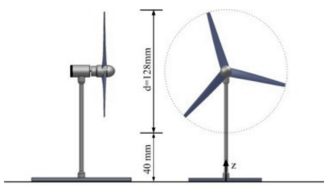
Conical scanning

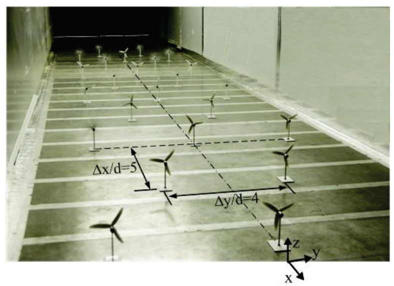


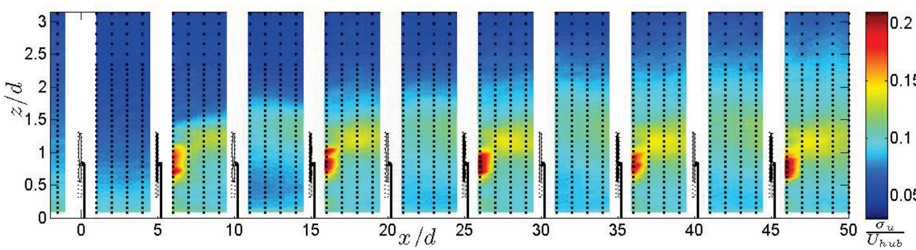
Presented by:
Ameya Sathe
Session ERE 1.2
13.45 – 14.00

Experimental and computational investigation of the turbulent interaction between the atmospheric boundary layer and large wind farms

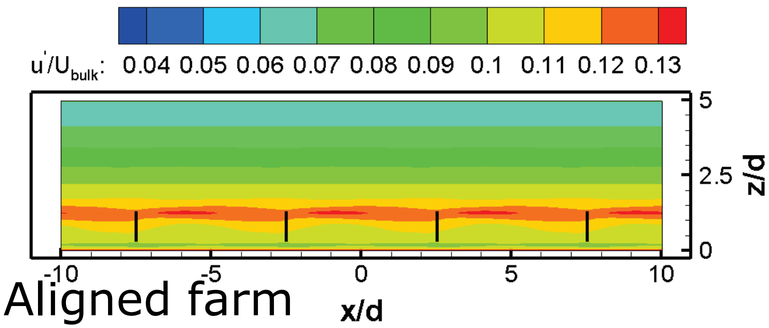
Leonardo P. Chamorro, X. Yang, S. Kang, R. Arndt, and F. Sotiropoulos



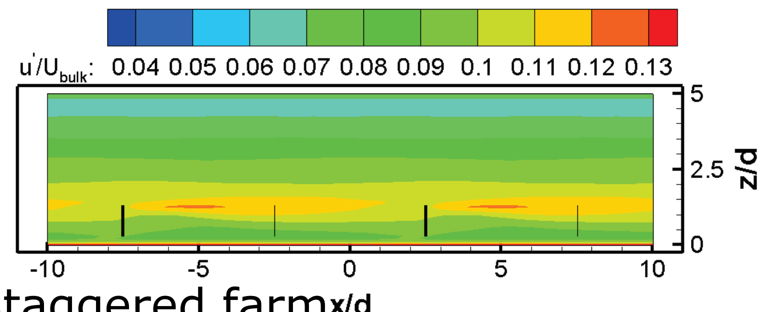




Staggered farm



Aligned farm



Staggered farm

Experiments | LES – actuator disk

- Wind tunnel experiments show that power and turbulence in a wind farm are highly affected by the turbine layout (e.g., aligned/staggered with same turbine density).
- LES using actuator disk model agrees with this observations.

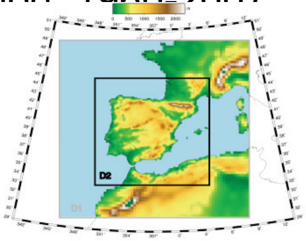
EOLMAP: A pseudoreal wind database for small wind turbines for the Iberian Peninsula

Raquel Lorente-Plazas , Juan Pedro Montávez (1), David Pozo-Vázquez , Juan José Gómez-Navarro , Juan Andrés Garcia-Valero , Pedro Jiménez-Guerrero , Pedro A. Jiménez , Sonia Jerez and J. Fidel Gonzalez-Rouco.

(1) Regional Atmospheric group, Department of Physics, Universidad de Murcia
(Contact: Juan Pedro Montavez Gómez: montavez@um.es)

Pseudoreal wind database

- MM5-Regional Climate Model
- Spatial resolution: 10 km
- Period: 1960-2007
- Are



ula

Obsevational data set

- More than 500 stations
- Period 1999-2007
- Temporal resolution:hourly
- Quality control as in Jimenez et al. (2001)

MM5 validation

- Model skill reproducing the observed wind has been analyzed
- Main conclusions:
  - MM5 overstimate wind module mainly in Mediterranean basin
  - Satisfactory reproduction of the main spatial an temporal modes of variation
  - Most errors are related to orography that the model resolution is unable to capture accurately.

You can see our website in:

http://meteo.inf.um.es/eolo/map.

Web tool

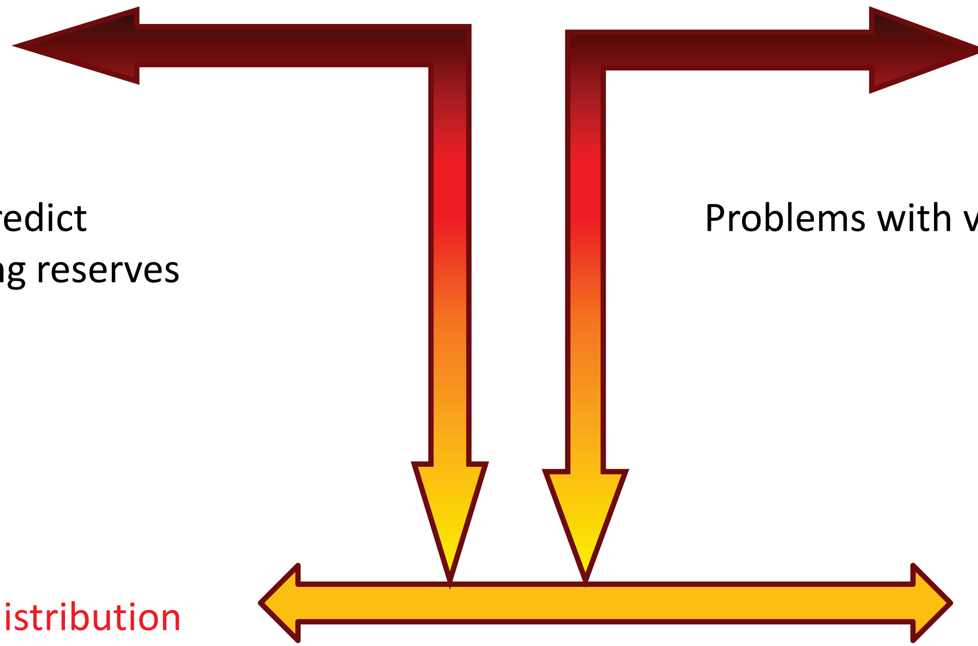
- Assessment of the potencial wind and energy production in a selected place
  - Intepolation MM5 wind components to selected place
  - Comparison with nearer observational stations
  - Calculation of energy produced by Small Wind Turbines

Risø DTU, Technical University of Denmark

Weather Intelligence for Renewable Energies WIRE

Wind Power
Challenging to predict
Design of spinning reserves

Solar Power
Problems with voltage regulation



Transmission & distribution
Grid management
Thermal rating - Outages

Load Forecasting
Users' demands

Renewable energy supply and outage Issues are heavily influenced by weather: intelligent weather integration is the key factor for efficient grid management.

Therefore: **COST Action WIRE – see wire1002.ch.**