WINDSCANNER:
- a Facility for Wind and Turbulence Measurements around large Wind Turbines

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In Nordic Conf. on:
Global Challenges - Regional Opportunities:
How can Research Infrastructure and eScience support Nordic competitiveness?
Topic: Climate, Energy and Environment
Stockholm 12-13 Nov. 2008

We propose a new Energy Research Infrastructure

"Windscanner"

- within a joint Nordic/European mobile and distributed experimental RI facility with the aim:

1. to measure the entire 3-D wind and turbulence fields over complex terrain for optimal wind turbine siting

2. to determine optimal inter-WT spacing for minimizing the effects of wakes

3. to provide real-time upwind wind data for improved and pro-active turbine control during operation at turbulent and problematic (complex terrain) sites - for optimal energy production per unit and per array

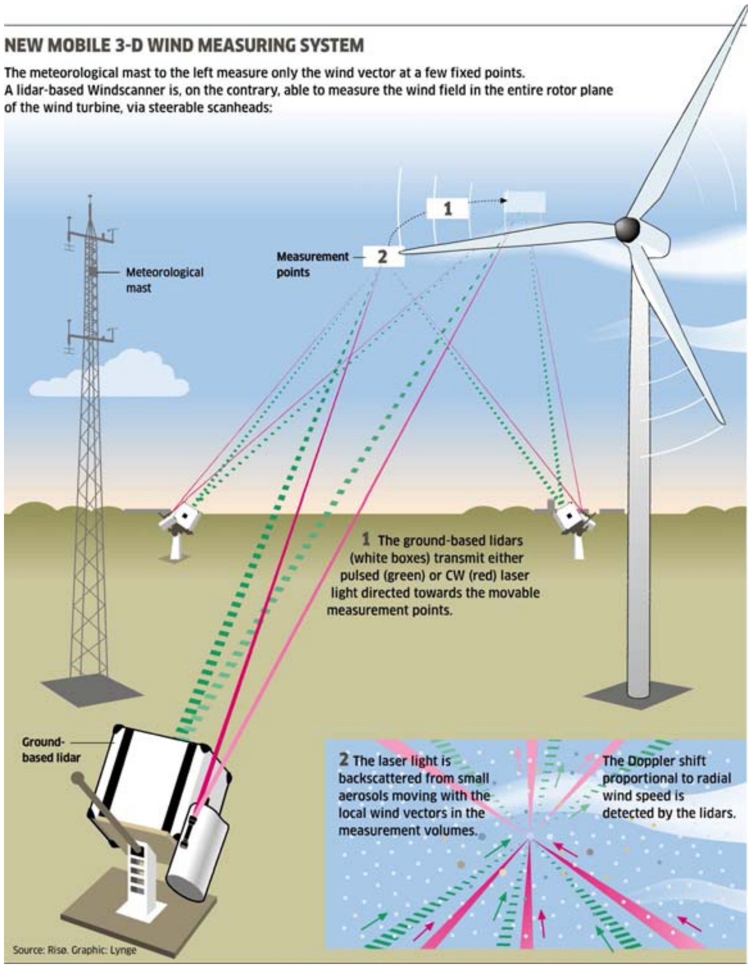
4. To establish methodologies for bettering wind turbine's longevity and uptime availability

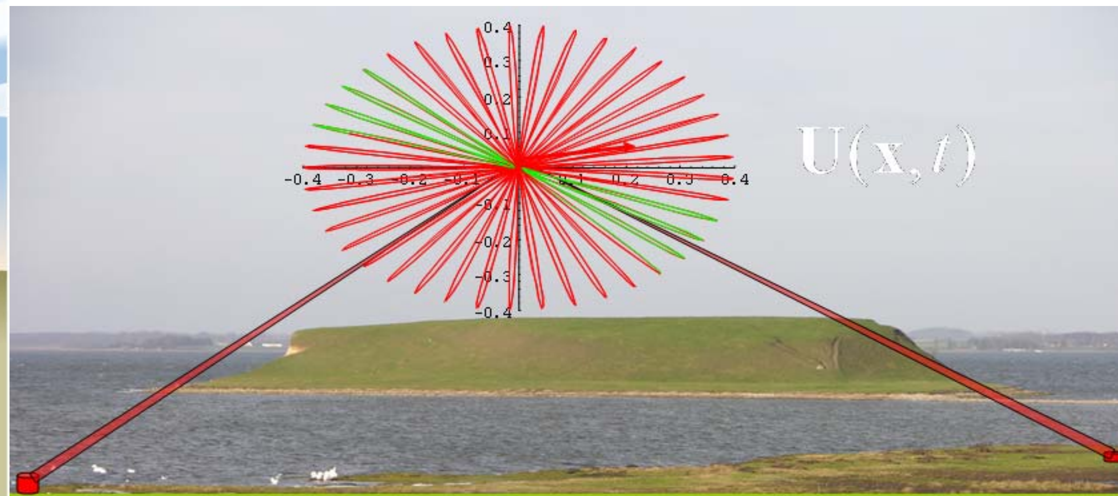
Background:

- In year 2008 wind power contributes ~20 % to the average Danish electricity consumption
- Today DK is leading worldwide regarding research and development of wind power technology
- Danish Government wish to maintain the lead Internationally on the wind power market
- By year 2020 EU's goal is to cover ~20% of the Unions electricity consumption via sustainable resources including wind power
- The wind energy industry need new and detailed knowledge of wind and turbulence around the huge WT's of today and the future (cf. EU's TP Wind 2010-2030)

We see this renewable energy RI "Windscanner" as an important new research facility to secure and to better the effective energy production from today's and tomorrows huge WT's and to improve their efficacy and longevity.

The RI WINDSCANNER methodology is based on 3-dimensional scanning with wind lidars to determine the instantaneous turbulence fields:

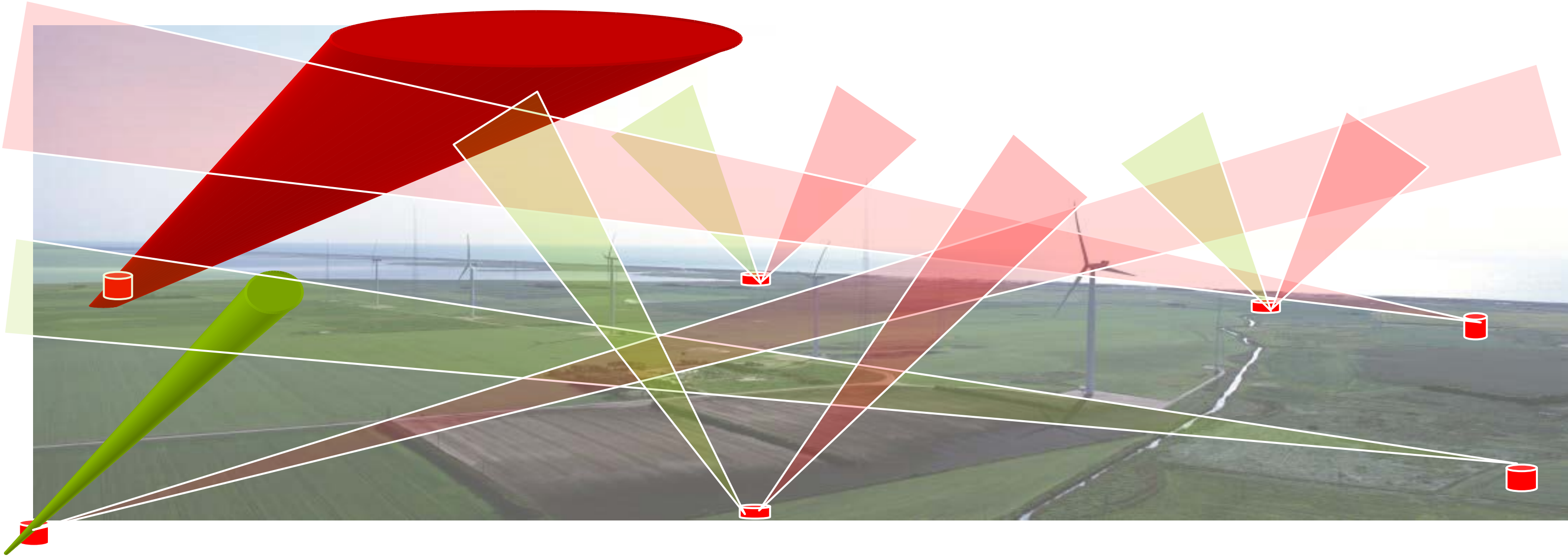


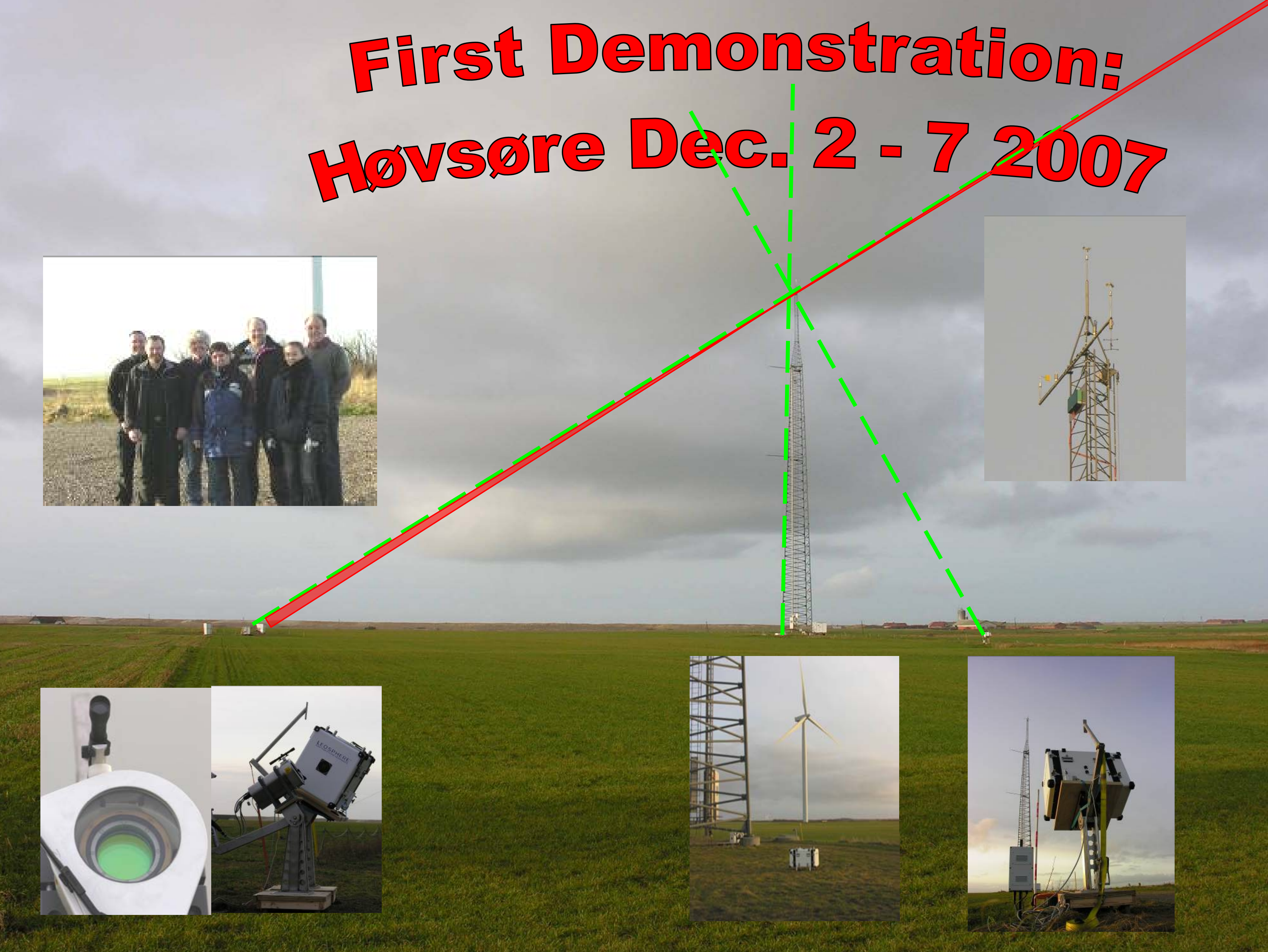


Full Scale Laser Wind Scanner

Since 2005 wind lidar technology has enabled replacement of tall (>100m) met masts

Windscanners in operation measuring the wind and turbulence properties around the huge Wind Turbine's at the Danish test site for large wind turbine’s at Høvsøre, Denmark

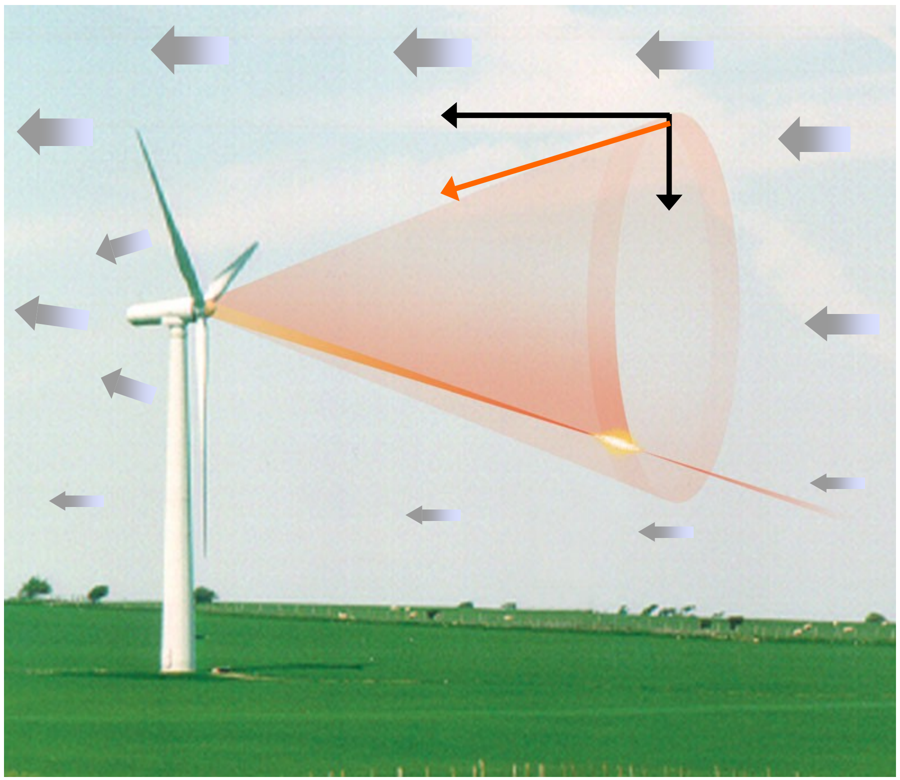


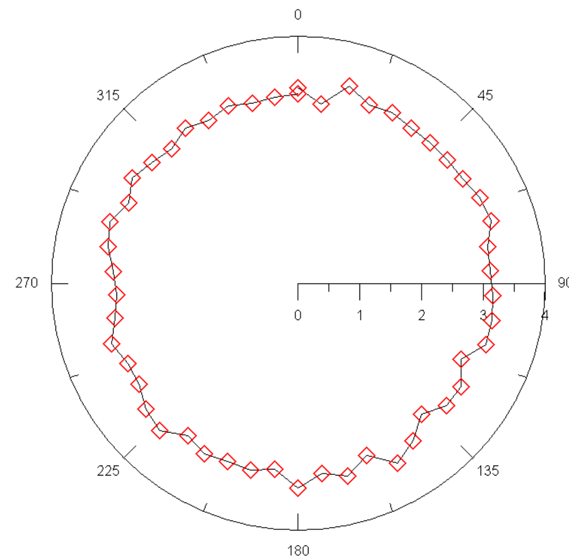

First Demonstration:
Høvsøre Dec. 2 - 7 2007
LEOSPHERE

(1)

VISION

Pro-active wind turbine control from upwind measurements by lidars integrated in the nacelle… :





(2)

VISION:

Full scale off and on shore measurements on WT arrays & wakes

e.g. as here at Horns reef

RI Windscanner

will provide the wind energy society with the detailed 3-D wind and turbulence information requested by atmospheric science researchers and industry for the fulfillment of the EU 2010-2030 TP wind platform.

Specifically, RI Windscanner will provide the **users** of the RI with detailed information on:

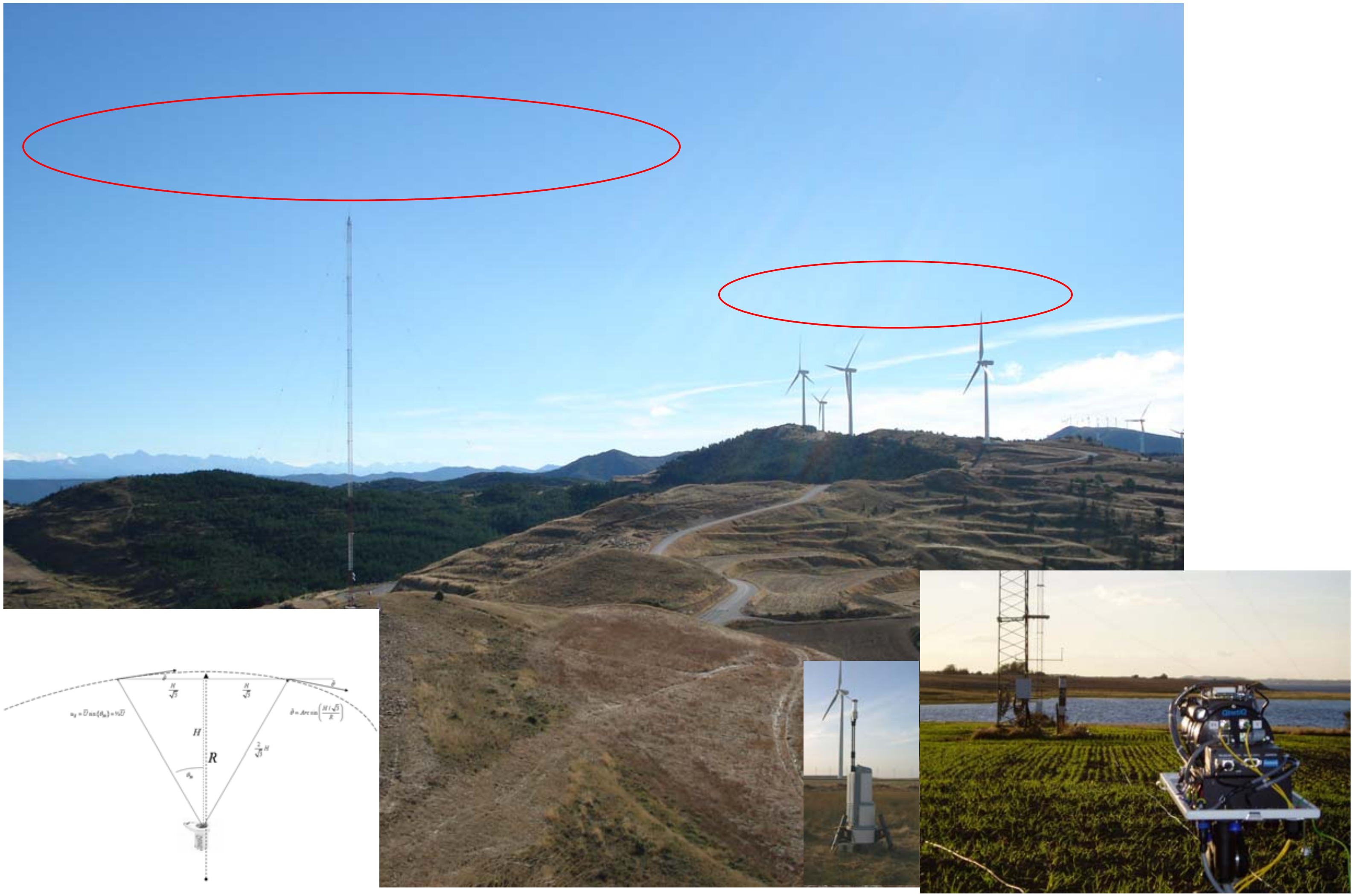
1. Secure siting of WT's' and improving the energy efficacy.
2. Wind condition over the entire rotor plane - at all heights.
3. Detailed wind and turbulence data: i) in front, ii) during the passage, and iii) from the wakes behind the wind turbines - on and offshore.
4. Gusts and wind shear at problematic sites in complex terrain

RI Windscanner provide detailed measurements of wind and turbulence in 3-D space and time and at heights up to 200- 300 m aloft.

Distributed Wind scanners are envisioned to provide such measurements

On shore	Germany, Denmark, Spain, Sweden, Finland, ...
Off shore	Denmark, Norway, Sweden, Finland, U.K, ...
Complex terrain	Spain, Norway, Sweden, Portugal, ...

RI Windscanner
Secure wind resource estimation in particular in complex terrain



Windscanner - ESFRI – RI Centre for Wind Energy and Turbulence Research

States having accepted to become partners and to participate in a preparatory FP7 pre-study phase:

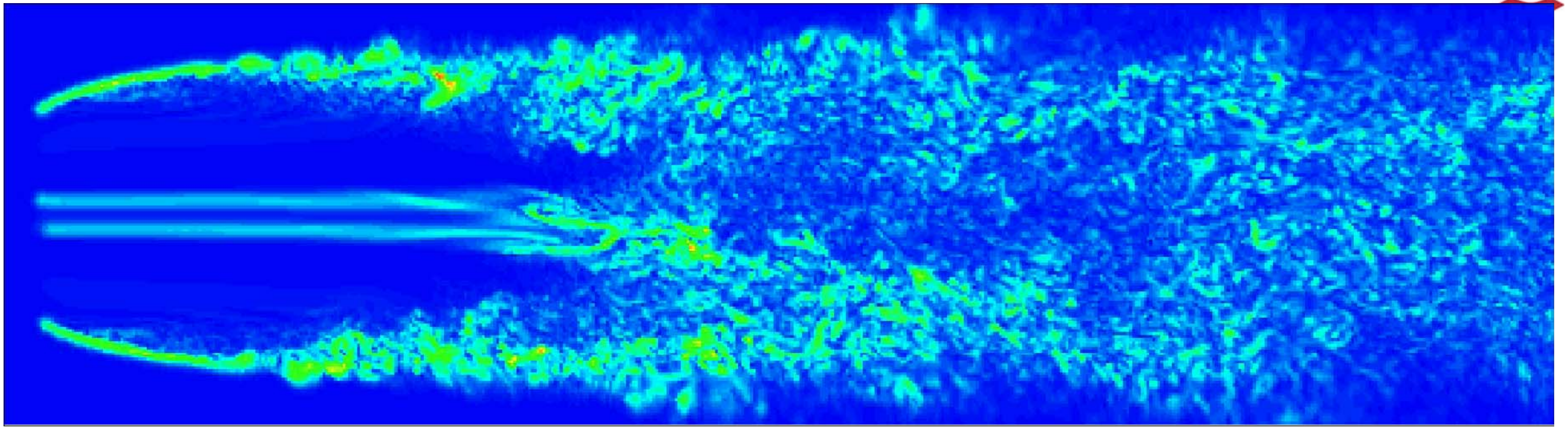
- 1. Spain: CENER (inland mountain wind turbine test station)
- 2. Holland: ECN (research scale wind farm)
- 3. Greece: CRES (coastal complex terrain)
- 4. Germany: University of Stuttgart (inland, low wind speed sites)
- 5. Denmark: DONG Energy (full scale offshore wind parks)
- 6. Denmark: Risø DTU (flat terrain wind turbine test station)

RI Windscanner has furthermore contact to other existing RI’s:

- 7. Germany: FINO platforms (offshore research platforms)
- 8. U.K.: Myres Hill (highlands test station)
- 9. Germany: DLR (lidar technology)

RI Windscanner will become “public accessible” Worldwide to scientists and to industry (WT manufactures).

Wind Turbines of today and tomorrow extract energy from the wind…
….but generates also wakes, over land…(eScience):



…and off-shore (Middelgrunden @ Copenhagen…)

Time series analysis of continuous-wave coherent Doppler Lidar wind measurements

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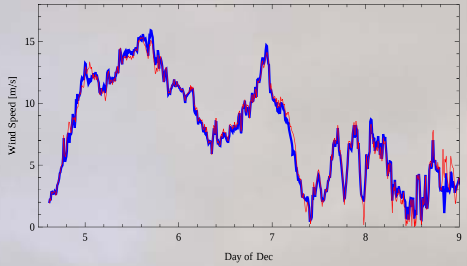

Figure 1. Time series of 10 minute averaged radial wind speed measured by a sonic anemometer (Red curve) and a focused cw coherent Doppler Lidar (Blue curve) at the Risø DTU operated test station for large wind turbines at Høvsøre in Western Denmark in December 2007.

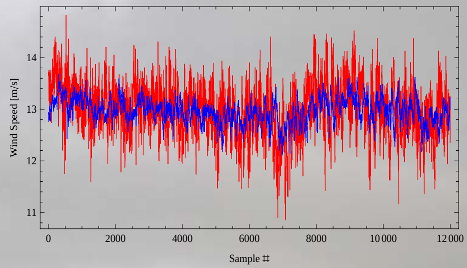

Figure 2. An example of wind time series measured by a sonic anemometer (Red curve) and a focused cw coherent Doppler Lidar (Blue curve). The data presented were sampled at 20 Hz for a period of 10 minutes in the morning of December 5th, 2007.

The influence of spatial volume averaging of a focused 1.55 μm continuous-wave coherent Doppler Lidar on observed wind turbulence measured in the atmospheric surface layer over homogeneous terrain is described and analyzed. Comparison of Lidar-measured turbulent spectra with spectra simultaneously obtained from a mast-mounted sonic anemometer at 78 meters height at the test station for large wind turbines at Høvsøre in Western Jutland, Denmark is presented.

The wind speed measured by a cw Lidar focused at a location x can generally be expressed by an integration along the laser beam of the wind field projected to the direction of the beam,

$$v(x)=\int_{-\infty}^{\infty}\varphi(s)\vec{n}\cdot\vec{u}(s\vec{n}+x)ds$$

where $\vec{n}$ is a unity vector along the beam and $\varphi(s)$ is the spatial volume averaging function which is described by the Lorentzian function

$$\varphi(s)=\frac{1}{\pi}\frac{\frac{1}{z_R}}{1+(s/z_R)^2},$$

which corresponds to the filter function,

$$L_{Lorentzian}(k_1)=\exp(-2z_R|k_1|),$$

in the frequency domain.

Sonic anemometer

Doppler Lidar

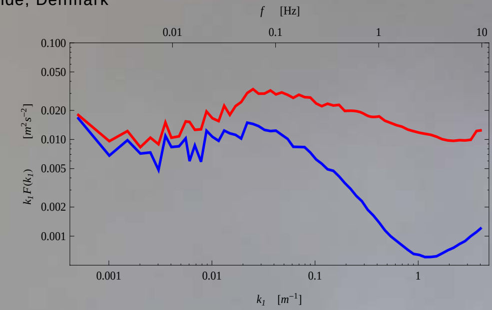

Figure 3. The Lidar-measured wind spectrum (Blue curve) and the corresponding projected sonic-measured wind spectrum (Red curve) from a measurement period of ~5 hours obtained in the morning of December 5th, 2007.

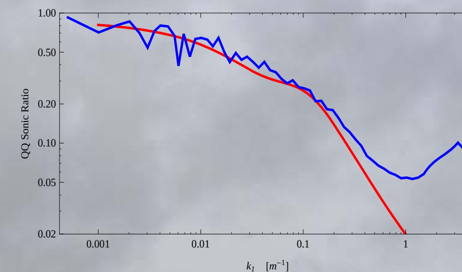

Figure 4. The predicted spectral transfer function, i.e., the ratio between the modeled Lidar spectrum and the sonic spectrum as a function of wave-number (Red curve) and the measured spectral transfer function, i.e., the ratio between the Lidar-measured and the sonic-measured power spectra (Blue curve) from the same measurement set as in figure 3.