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EERA DeepWind'2017

LIDAR capability to model robust rotor equivalent wind speed

by

Jørgen R. Krokstad (Fugro/NTNU)
Vegar Neshaug (Fugro)
Birgitte Furevik (NMI)
Knut Helge Midtbø (NMI)
Teresa Valkonen (NMI)

The Seawatch Wind LiDAR Buoy – status - 2017

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- Integrate wind and metocean measurements
- Many operational projects in Europa – Netherland, UK and Poland
- Wind profiling capability up to 300m
- May utilize wind profiles «above» hub heights
- IEC 61400-12, CD-2 will allow wind measurements to be based on LiDAR only
- Current profiling capability down to 1000m
- Directional wave measurements
- Measurement of a wide range of met-ocean parameters
- Flexible energy system
- A fraction of the cost of a traditional offshore met-mast

Motivation for looking at REWS (Rotor Equivalent Wind Speed)

- May utilize data above hub height – metmast always truncated

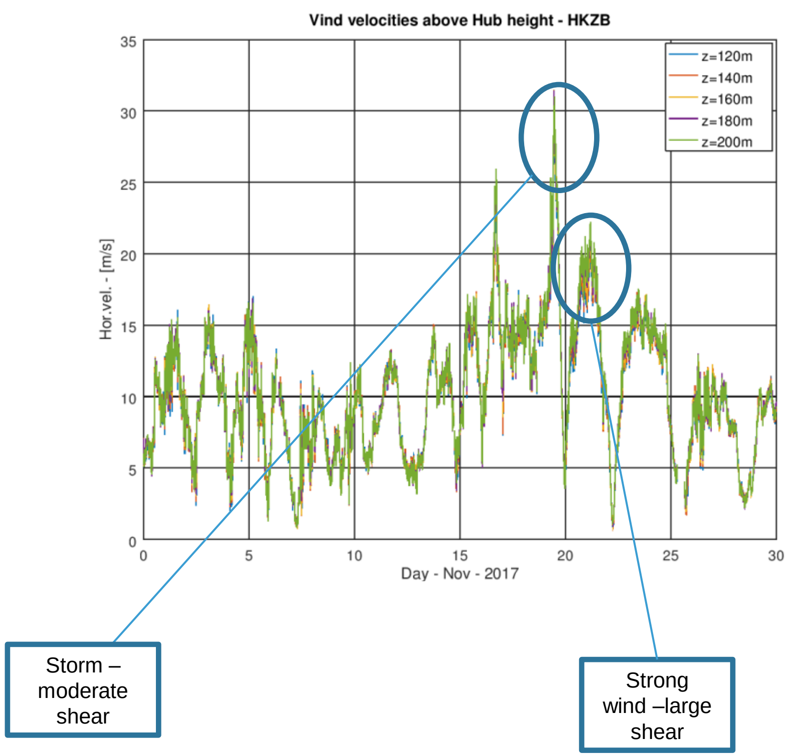
- Improved accuracy of Power estimates

  U_{hub} versus U_{eq}

- More important for large rotor diameter turbines (D=150-180 meter) than standard (D=110–150 meter)

- Reduced uncertainty in AEP (annual energy production) estimates

- Prepare for ratification of IEC-61400-12 CD2



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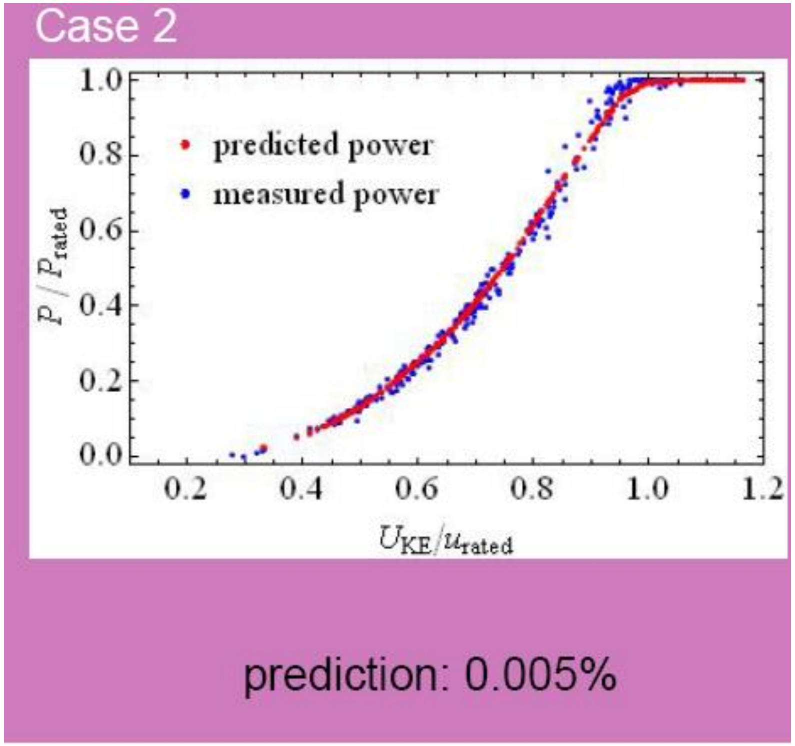
New requirements using REWS

- Wind Resource Assessment is sensitive to small % changes in AEP (annual energy production)
- IEC – 61400-12 – CD2 is not publically available but used as a reference for measurement campaigns – consequence?
- IEC - 61400-12 – CD2 is a drive from metmast based to LiDAR based power curve and AEP estimation
- Ref: Wagner et al – *Rotor equivalent wind speed for power curve measurements – comparative exercise for IEA Wind Annex 32*



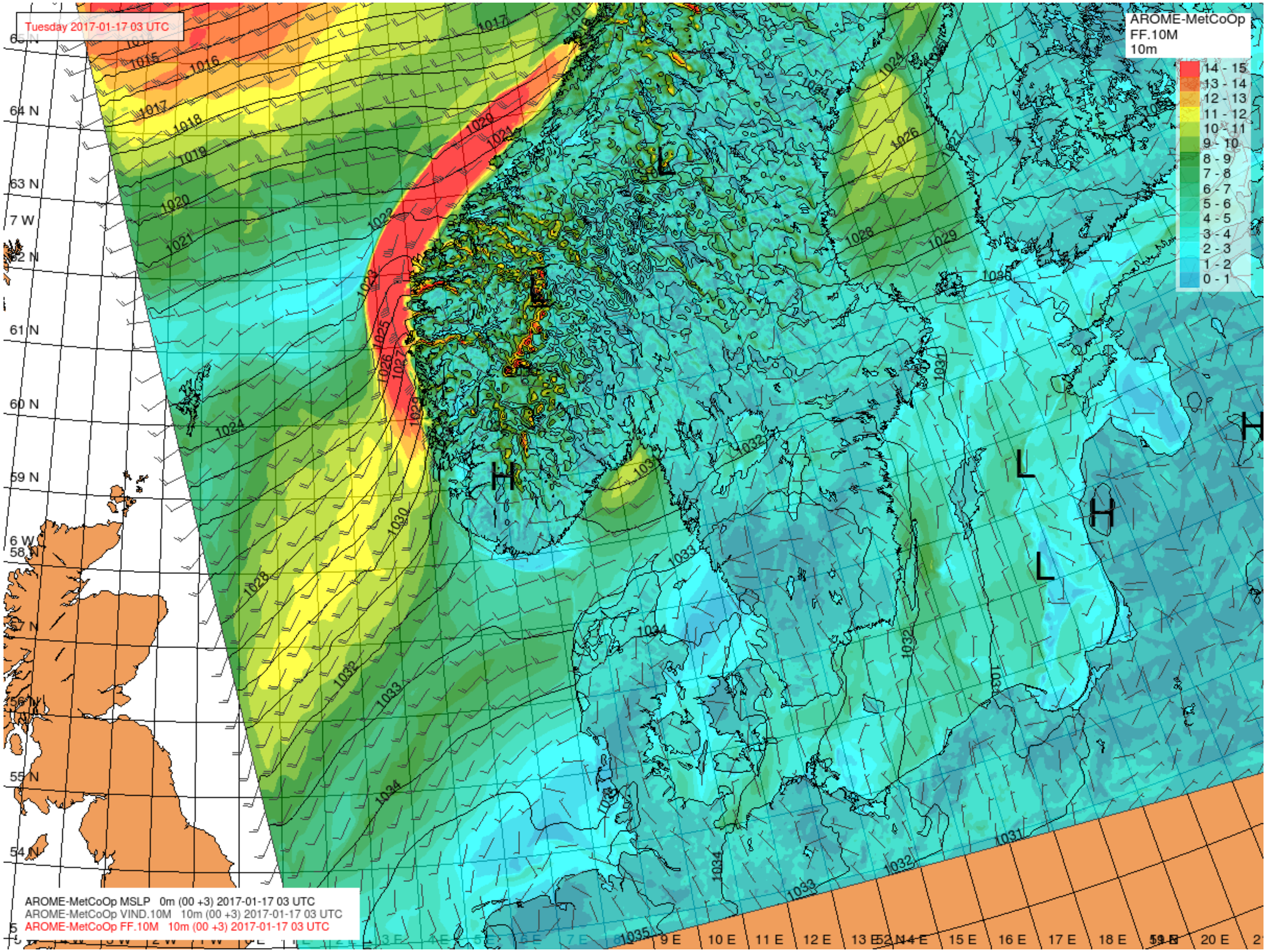
Improved AEP estimation by using REWS compared with measured power

DTU – Risø – Rozenn Wagner

Causes of wind shear in the coastal zone and offshore

- Surface friction
- Stability effects, internal boundary layers
- Convection, rain cells
- Atmospheric fronts
- Low level jets

MET Norway weather forecast model AROME 2.5km x 2.5km grid spacing



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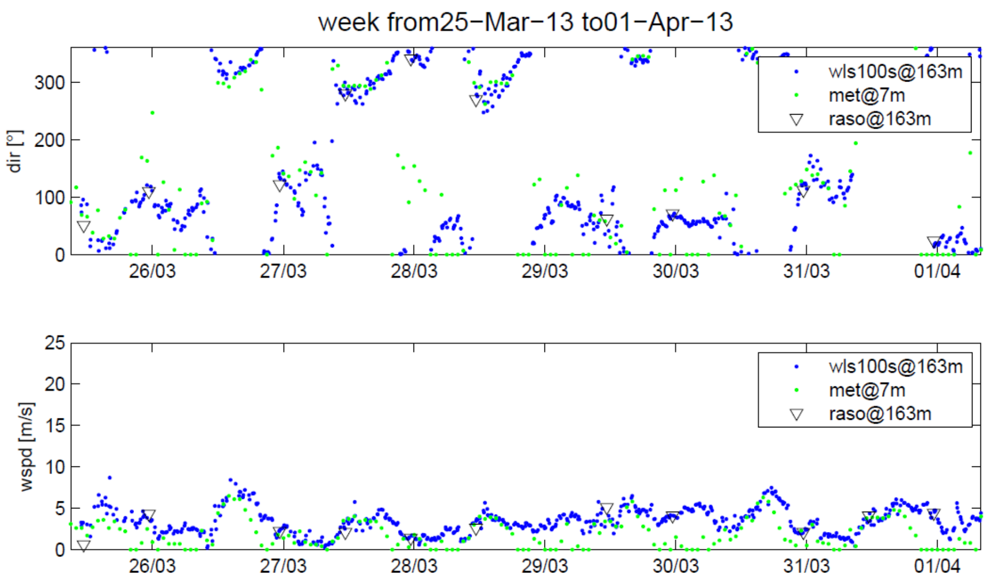
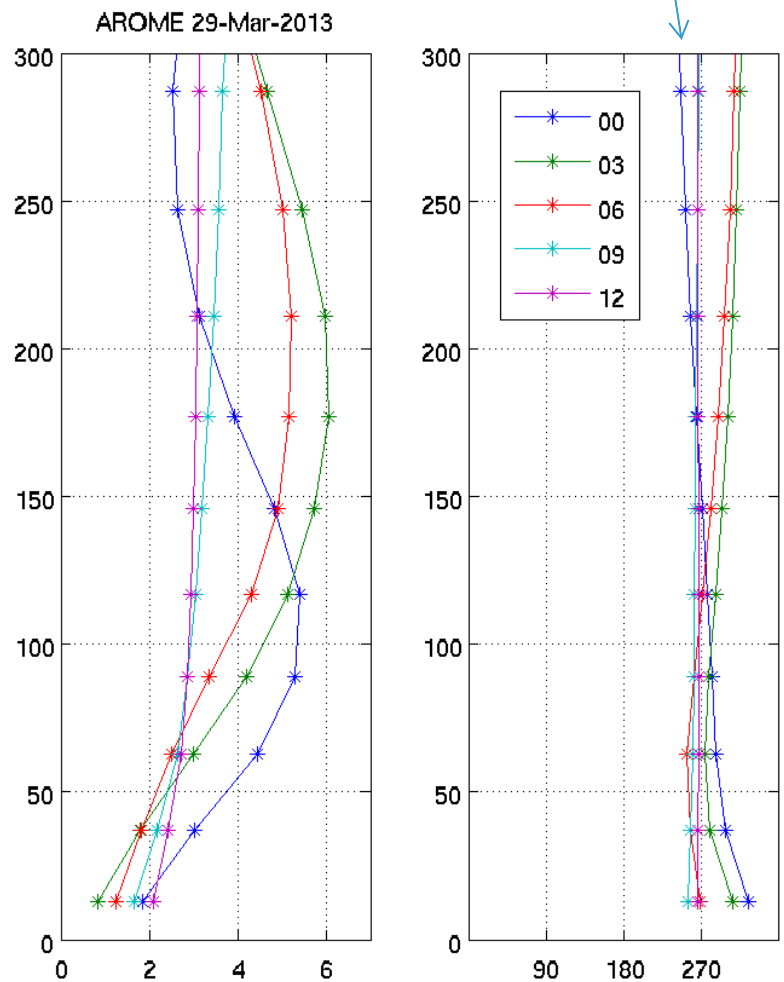
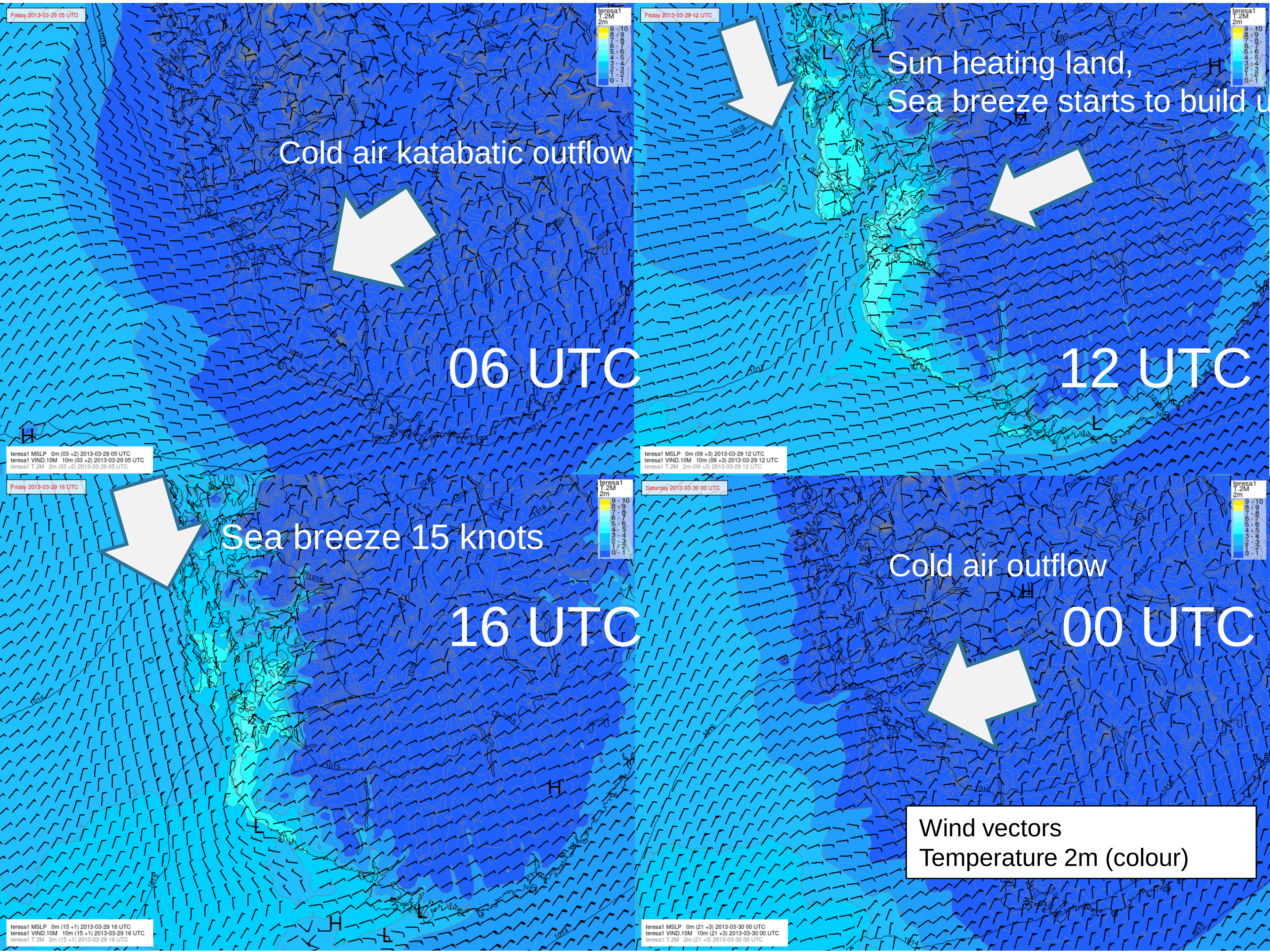
Hours (UTC)

NORCOWE Lidar measurements at Sola airport showing diurnal variation in wind speed and direction (*Lidar measurement campaign field report*, Kumer, 2014)





AROME model 3-hr profiles


Cold air katabatic outflow
06 UTC
Sun heating land,
Sea breeze starts to build u
12 UTC
Sea breeze 15 knots
16 UTC
Cold air outflow
00 UTC
Wind vectors
Temperature 2m (colour)

REWS principles for calculation

$$A_i = \int_{z_i}^{z_{i+1}} c(z)dz$$

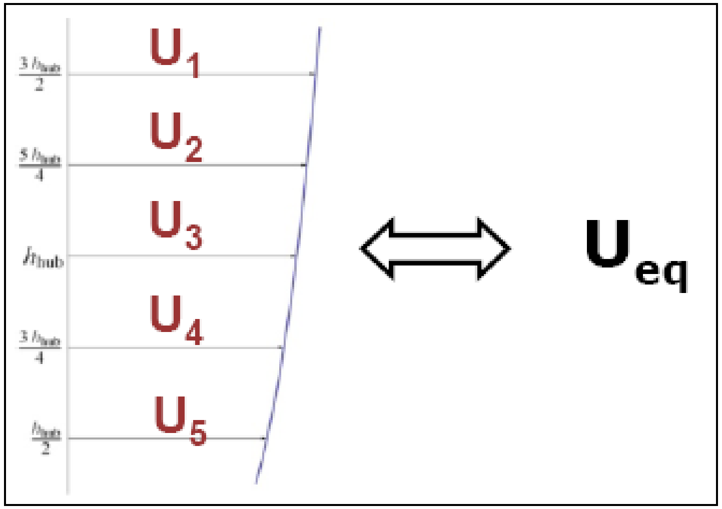
$$c(z) = 2\sqrt{R^2 - (z-H)^2}$$

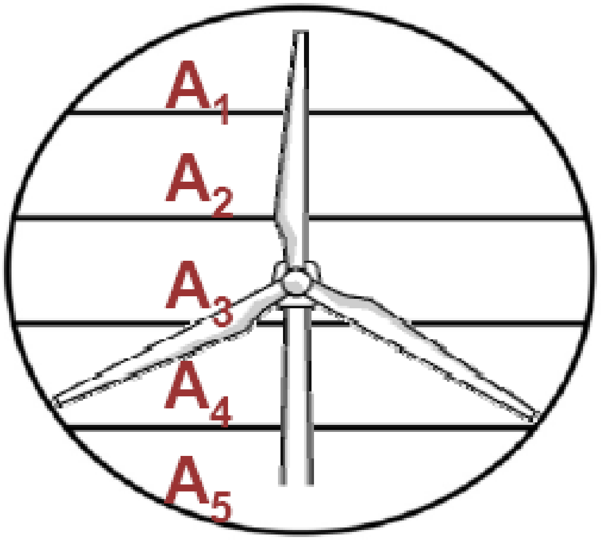
Where H is hub height – R is rotor radius

$$u_{eq} = \left(\sum_{i=1}^{n} u_i^3 \frac{A_i}{A}\right)^{\frac{1}{3}}$$

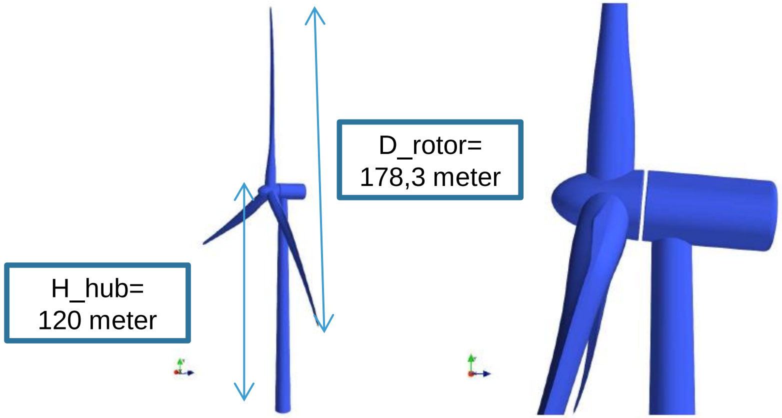
$$AEP = N_h \sum_{i=1}^{N} [F(u_i) - \ F(u_{i-1})] \left(\frac{P_{i-1} + P_i}{2}\right)$$

$$F(u) = 1 - e^{-\frac{\pi}{4}\left(\frac{u}{u_{ave}}\right)^2}$$



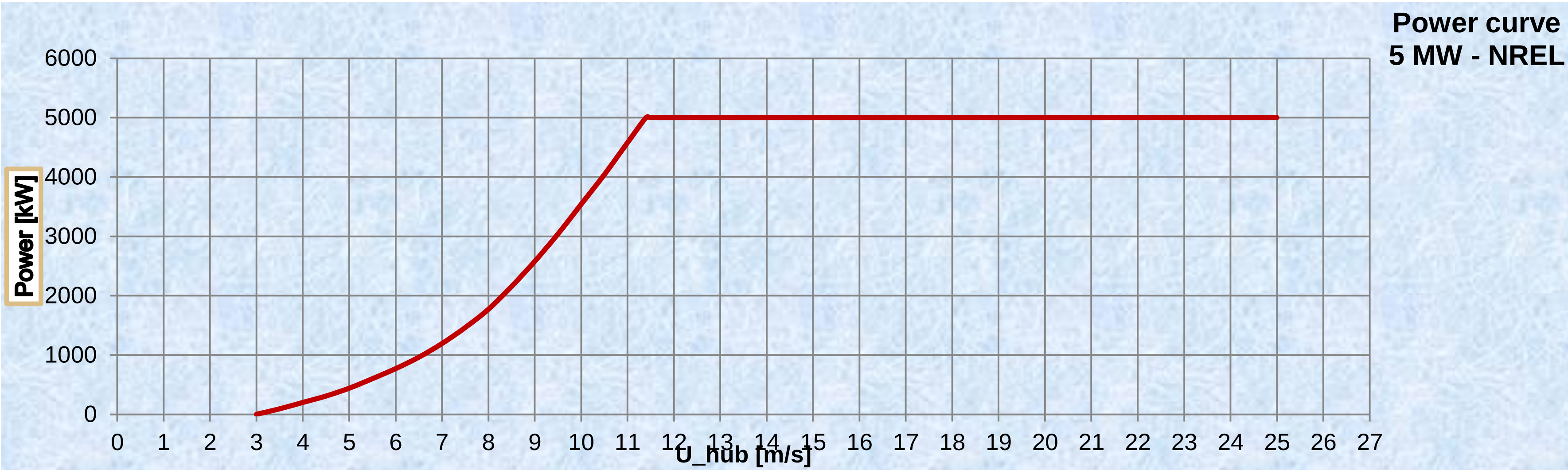


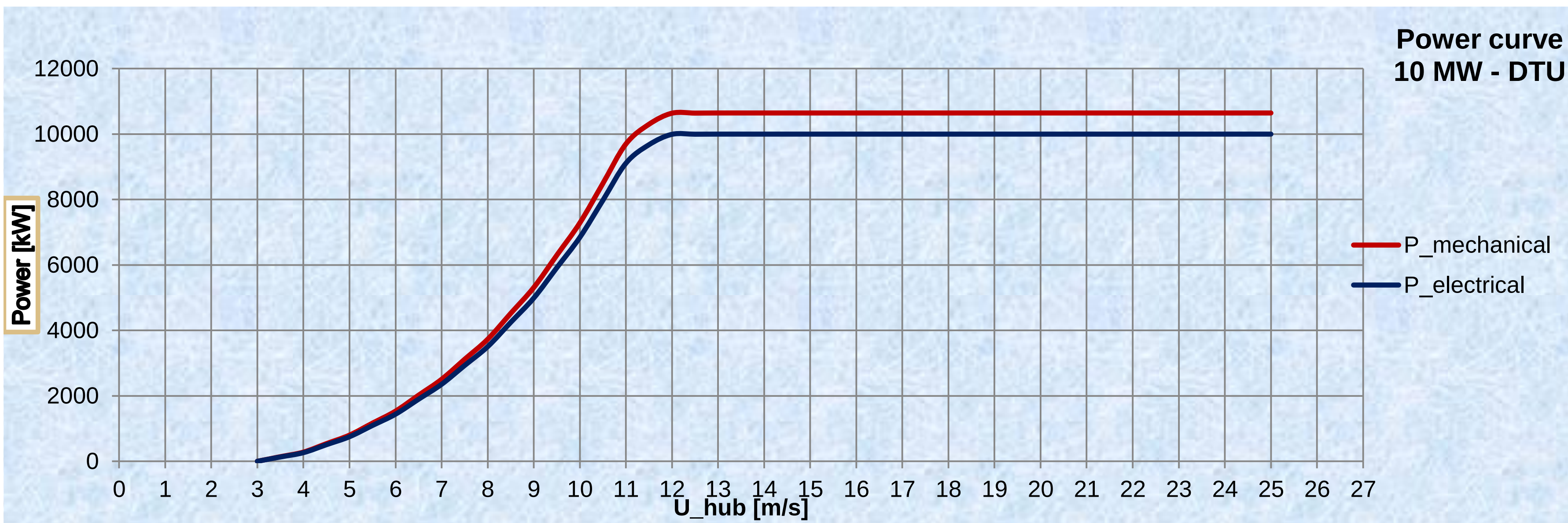
NREL – 5 MW turbine , DTU – 10 MW turbine



10 MW – scaled from 5 MW NREL

Power curves – 5 MW NREL , 10 MW DTU





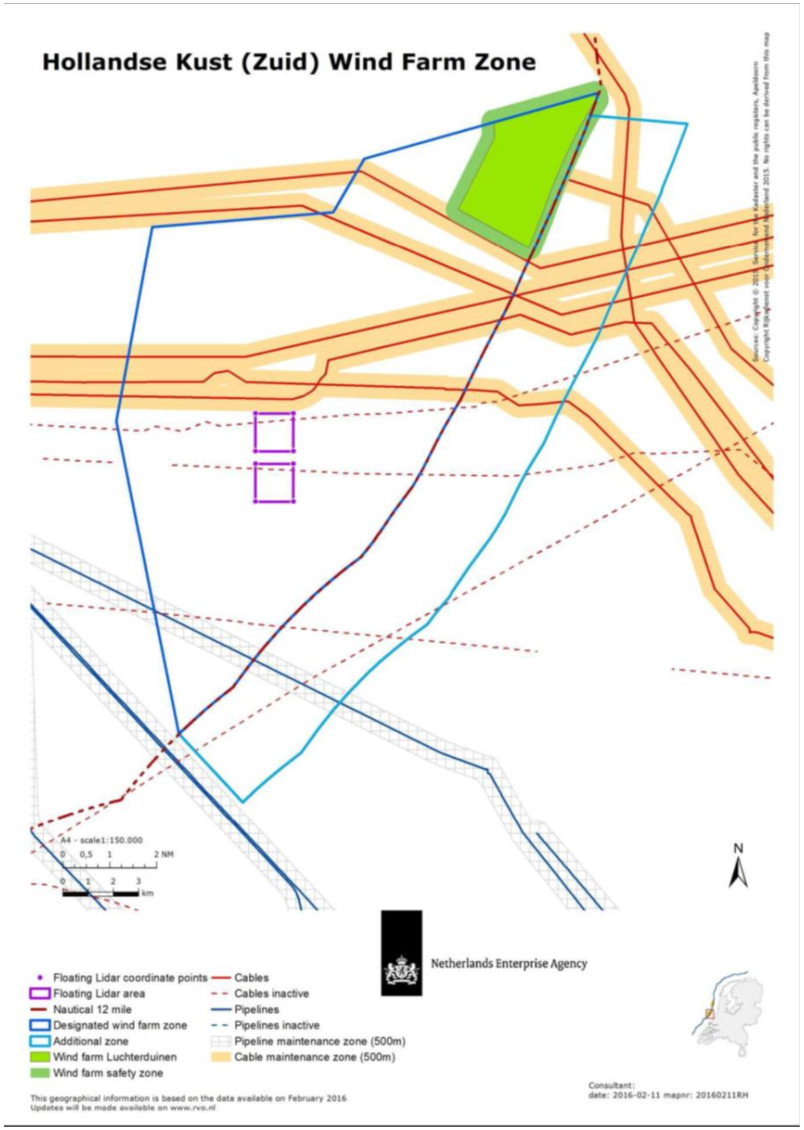
2 SW Wind Lidar buoys deployed June 2016

Parameters:

- Mooring at 23 m water depth
- Wave height, period and direction
- Current profile (22 m) and water temperature
- Wind speed and direction
- Wind speed and direction profile
- Air pressure
- Air humidity and temperature
- Water level (tide)

Wind observations

Wind speed and direction, turbulence intensity, inflow angle and wind shear/veer



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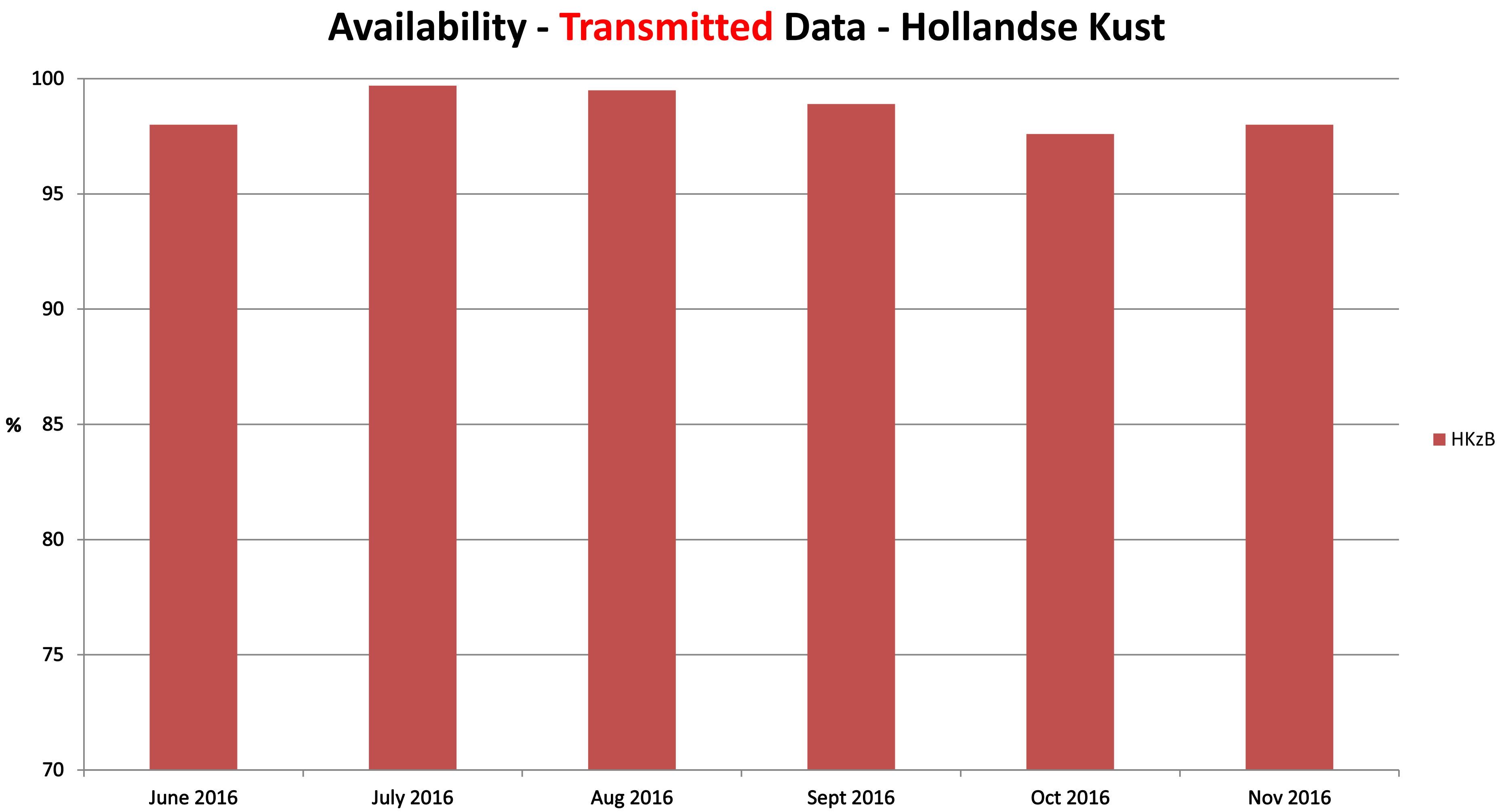
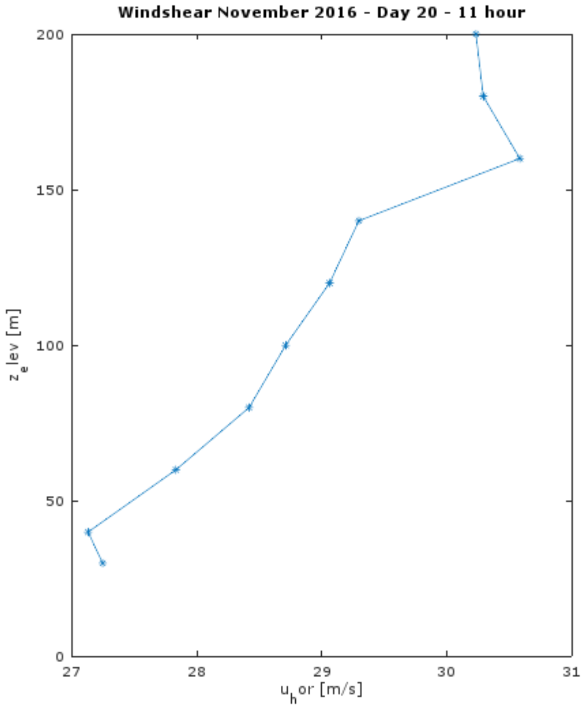
Environmental conditions experienced at Hollandse Kust Wind Farm Zone

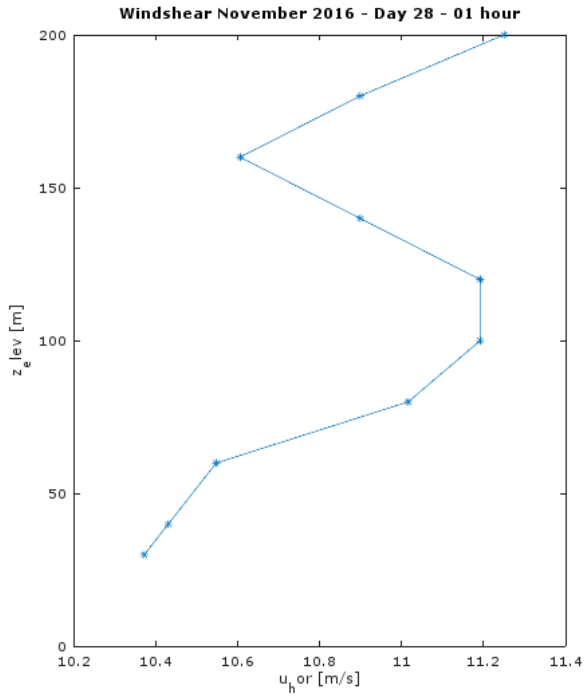
Parameter		Value	
Highest Significant Wave height	m	5.20	20^{th} Nov2016
Max wave height	m	7.74	20^{th} Nov 2016
Highest 10 min Average Wind speed (30 m)	m/s	29.1	20^{th} Nov 2016
Highest 10 min Average Wind speed (200 m)	m/s	33.7	20^{th} Nov 2016

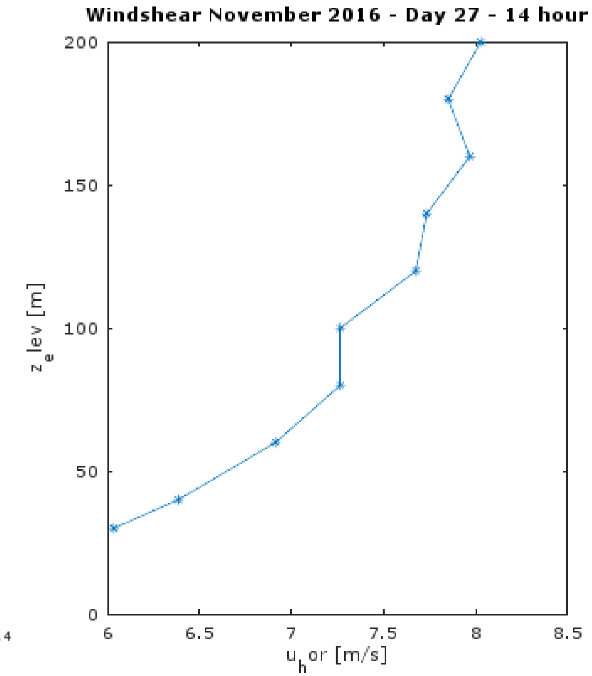
Hollandse Kust Wind Farm Zone, 2016 - *Ongoing*



Wind profiles – against ratio between (u_eq/u_hub)^3







Above cut-out

10 MW

(u_eq/u_hub)^3 = 1,005

5 MW

(u_eq/u_hub)^3 = 0,982

Close to rated

10 MW

(u_eq/u_hub)^3 = 1,066

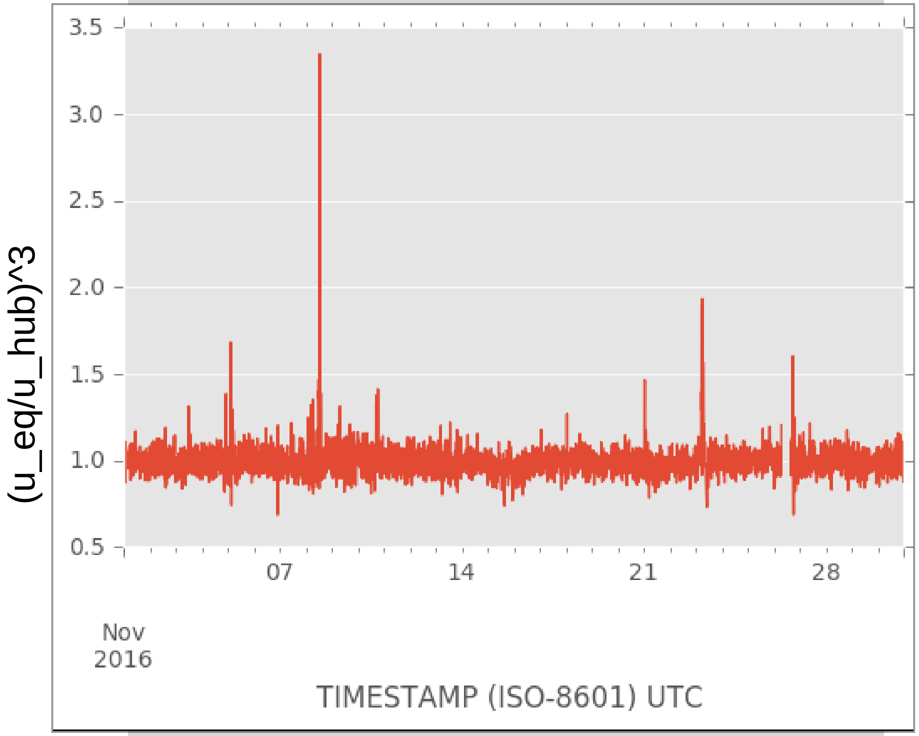
5 MW

(u_eq/u_hub)^3 = 1,013

Below rated

Ratio between energy production - AEP

- Average(u_eq/u_hub)^3 < 1 for the monthly dataset – 10 MW turbine
- Spikes due to sudden changes in heading of the profile
- AEP ratios calculated as follows



Turbine	Ratio P_rews/P_hub
5 MW	0,99
10 MW	0,98

Conclusions

- **Floating LiDAR** – the first choice for measuring offshore wind resource
- **Data** from the Hollandse Kust zuid is used – the data is publically available
- Different **shear profiles** are presented, Holland, and from the LiDAR based Sola airport project (near offshore conditions) in 2013
- A **weather front driven change** in wind share is shown
- **Rotor Equivalent Wind Speed is introduced** and applied for two «theoretical» turbines with medium and large rotor diameter's, NREL 5MW and DTU 10 MW.
- From prelimenary results – The ratio between hub height and equivalent wind speed - **larger than 1 for some speed ranges** and largest for 10 MW.
- **Small reduction effects in AEP** – reduced production with the use of REWS - but limited confidence in data basis for the conclusion.

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Thank you for your time

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