Study on Wind Resources at Mid-Altitude

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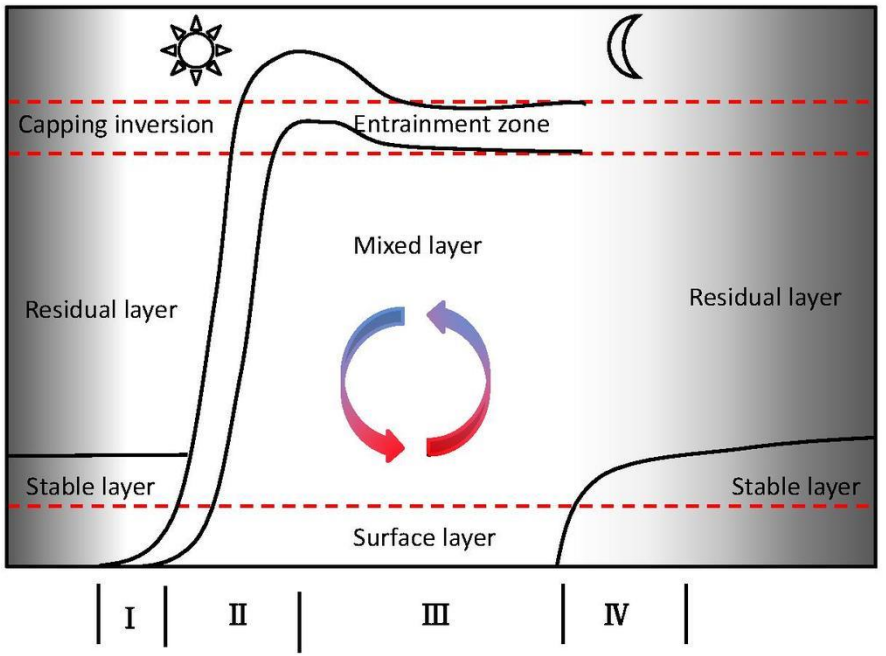
Meteorology at mid-altitudes

- wind speed increases with height between altitudes of
  200 m and 1 000 m
- no significant change in wind speed at altitudes between
  1 000 m and 4 000 m
- wind speed increases again at heights over
  4 000 m

➢ the range between 200 m and 1 000 m is at present the most useful for AWE systems



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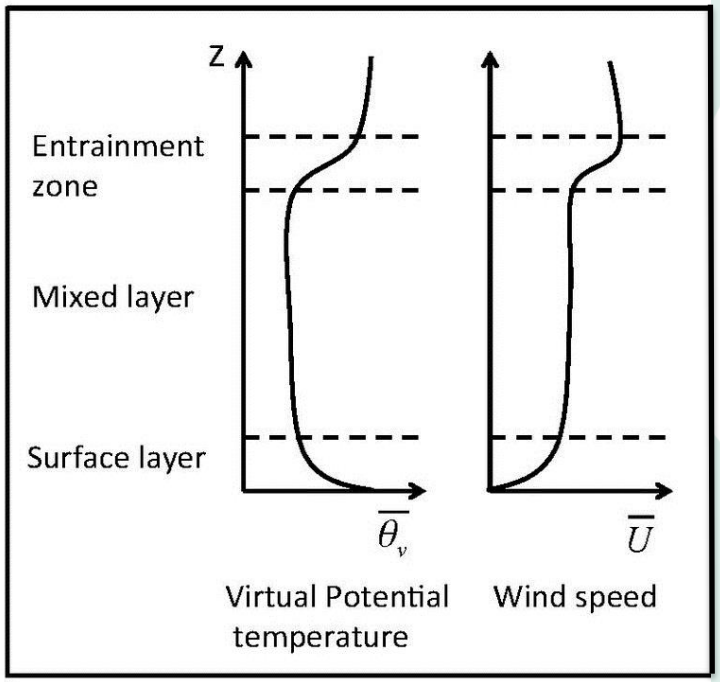

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Selected studies

Archer/Caldeira (2009): Global Assessment of High-Altitude Wind Power. *Energies, 2, 307-319.*

- investigation of NCEP/DOE model data, spatial resolution 2.5°
- ➢ constant energy density between 500 m and 2 000 m
- ➢ energy maximum between 8 000 m and 10 000 m

Batchvarova, Gryning et al. (2014): Measurements modeling of the wind profile up to 600 meters at a flat coastal site. *32nd NATO/SPS International Technical Meeting on Air Pollution Modelling and its Application, Utrecht, Netherlands, 07-11 May 2012.*

- comparison of LiDAR data with WRF model data
- Weibull-Parameter up to 600 m
- ➢ underestimation of wind speed by the model

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Selected studies

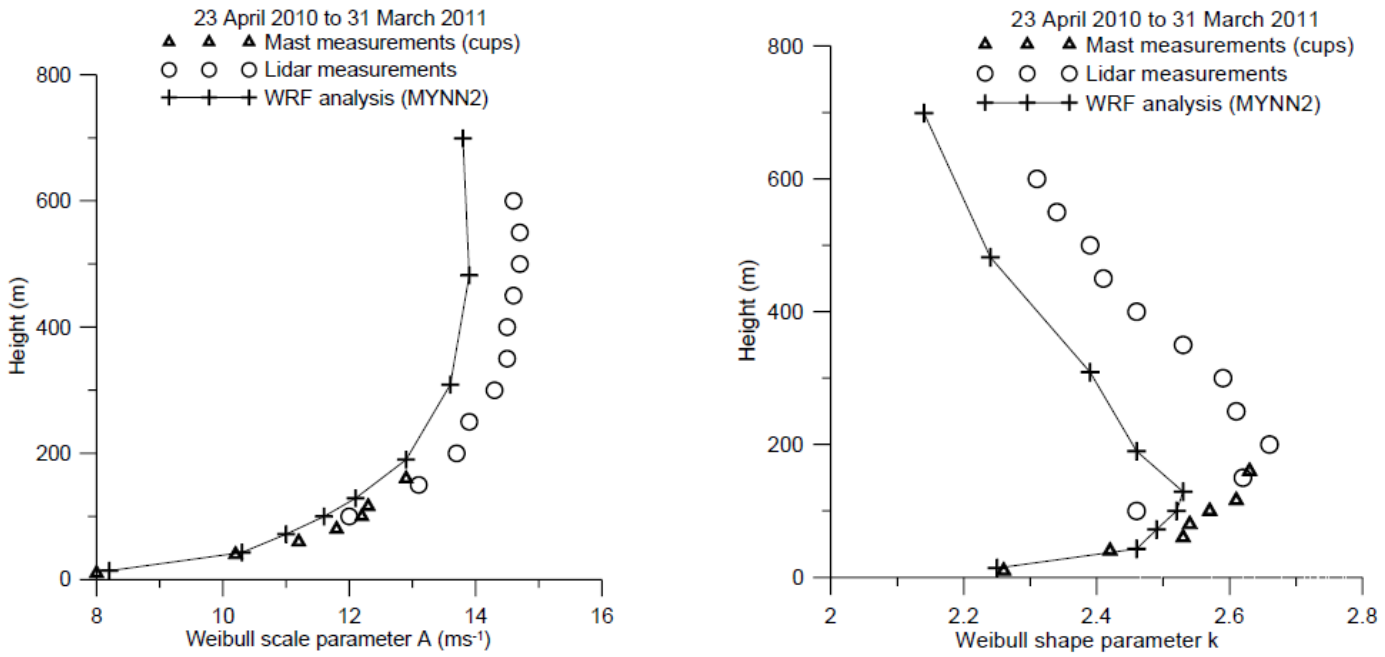

Fig. 3. Profiles of the scale (A, left panel) and shape (k, right panel) parameter in the Weibull distribution.

from Batchvarova, Gryning et al. (2014): Measurements modeling of the wind profile up to 600 meters at a flat coastal site. *32nd NATO/SPS International Technical Meeting on Air Pollution Modelling and its Application, Utrecht, Netherlands, 07-11 May 2012.*

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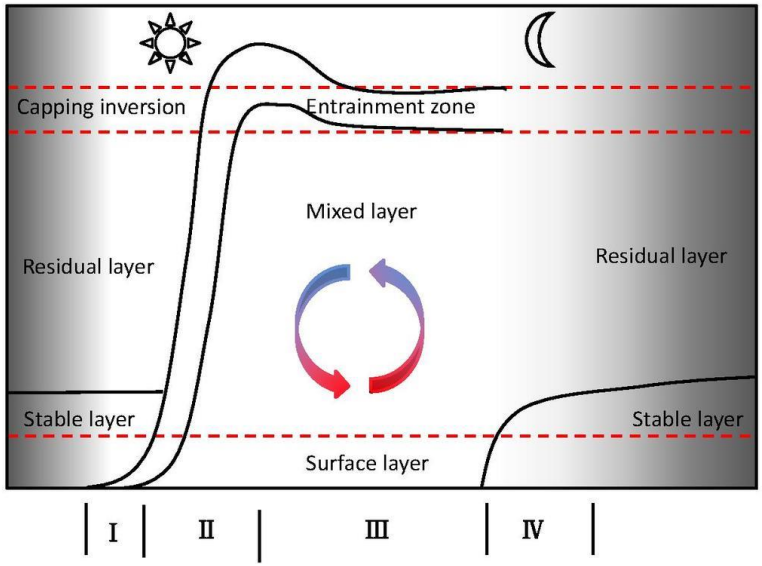
Motivation

- studies are based on model data of the wind speed with low resolution in time and space
- inaccurate and not convenient for kite-based systems



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Onkites - Study on the Potentiality of Kite-based Wind Energy Systems (finished 2013, funded by BMWi)

Investigation of

- offshore site
- coastal site
- onshore site

Existent data

- model data COSMO-EU, heights 300 m, 1 000 m
- sounding data at selected sites
- model data NCEP/DOE, heights 200 m, 850 m, 1 564 m

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Selected results

- several measurement campaigns were carried out
- real-time series of the wind speed were collected in Pritzwalk, Insel Poel and Datzetal
- measurements with WindCube V2
  - pulsed LiDAR system
  - up to 12 different heights
  - up to 250 m altitude

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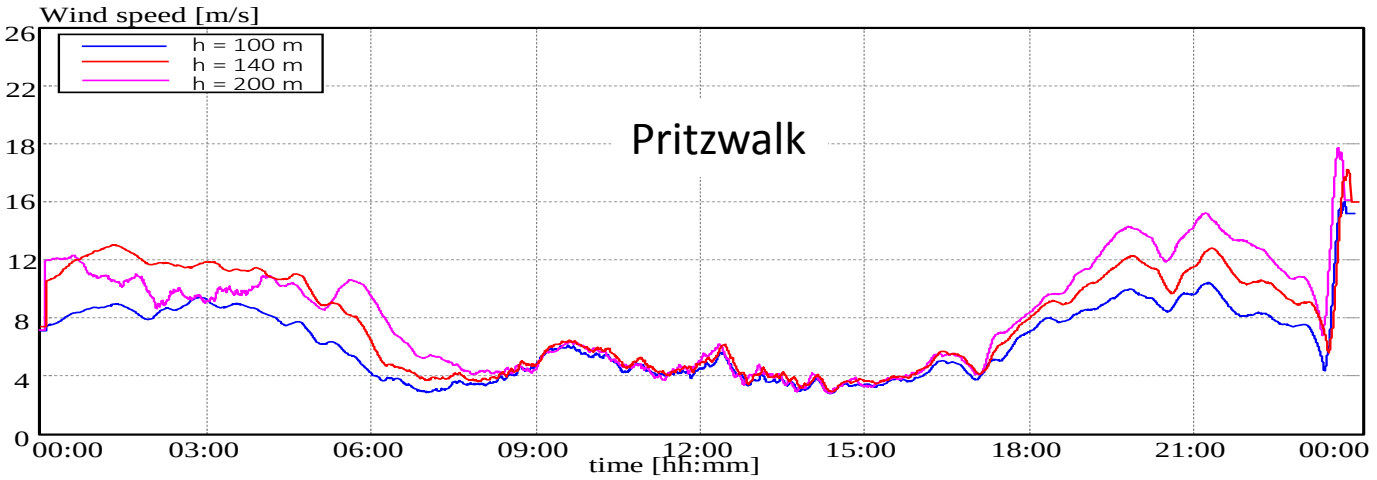
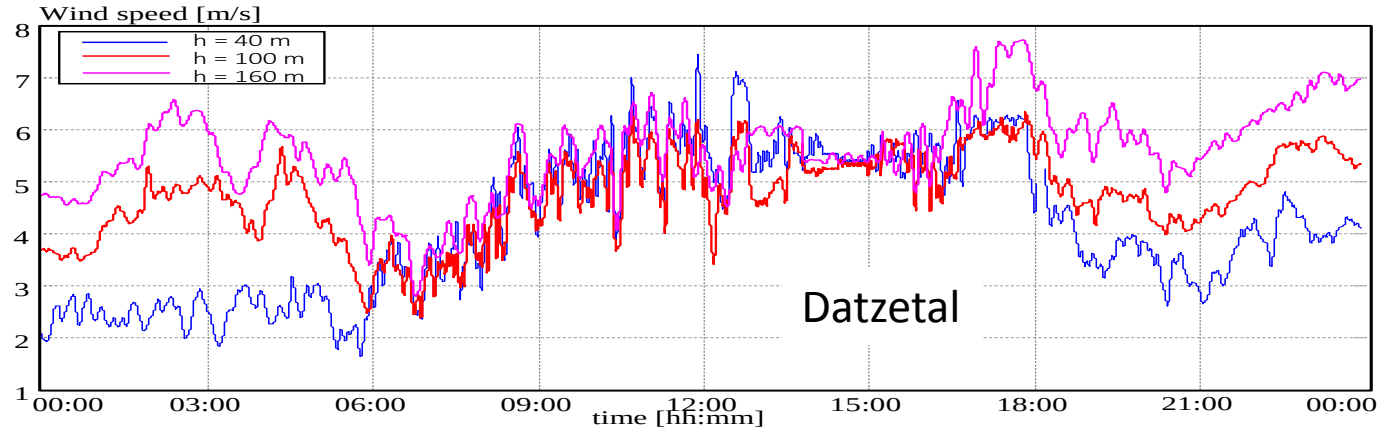
Results of LiDAR measurements





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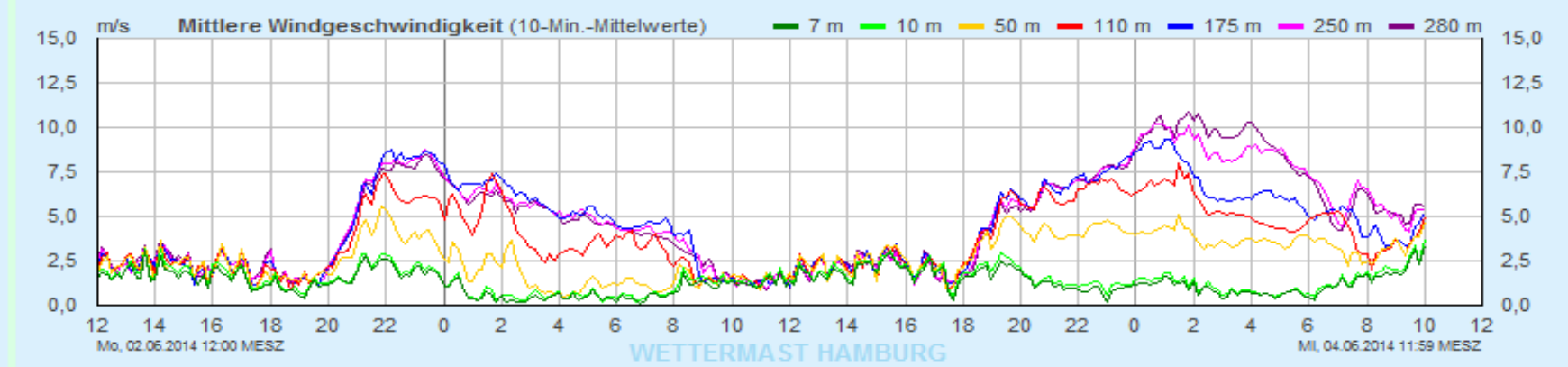
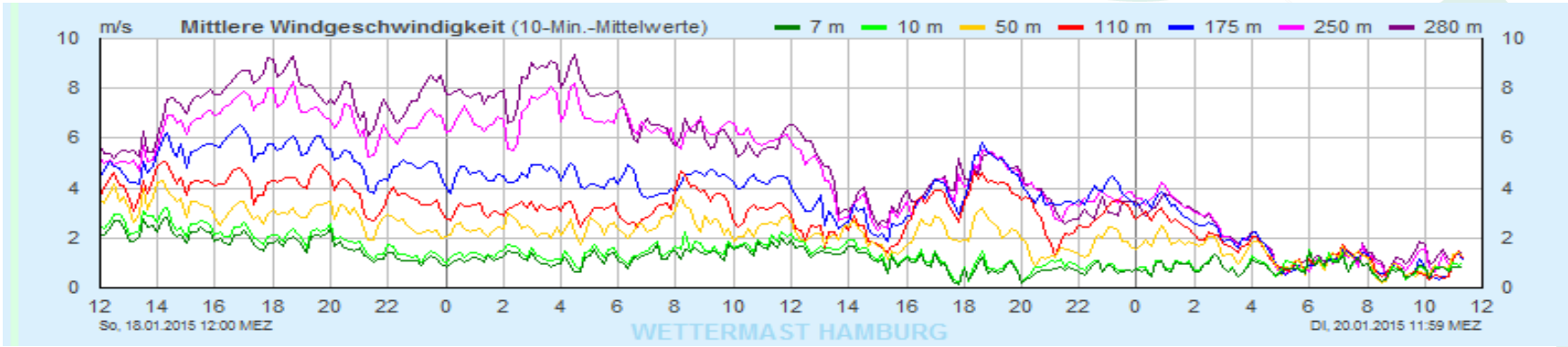
Example of wind data from weather mast in Hamburg





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Conclusions of Onkites

- only few data of the meteorological conditions in heights over 150 m
- comprehensive assessment of the potential of AWE systems is extremely difficult
- in the case of sunny and warm days, the wind is very turbulent with similar wind speeds at all layers up to 300 m
- Remark:
  - effect only in the time series with a resolution under minute/hour
  - in annual time series, where the wind data are daily averaged, the phenomenon remains hidden because of the long-time averaging range

➢ it is very important to know about the wind resources between 200 m and 1 000 m at one minute sampling times for AWE systems

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Onkites II (2014-2016, funded by BMWi)

- more accurate investigations of the wind properties of the upper winds at different thermal stratification
- development of a methodology for yield assessment
- two measurement campaigns
  - onshore site: Pritzwalk Sommersberg (with project partner EnerKite), start of measurement campaign in summer 2015
  - coastal site at North Sea (with project partner SkySails), start of measurement campaign beginning of 2016
- measurement campaigns: 6 months at each site

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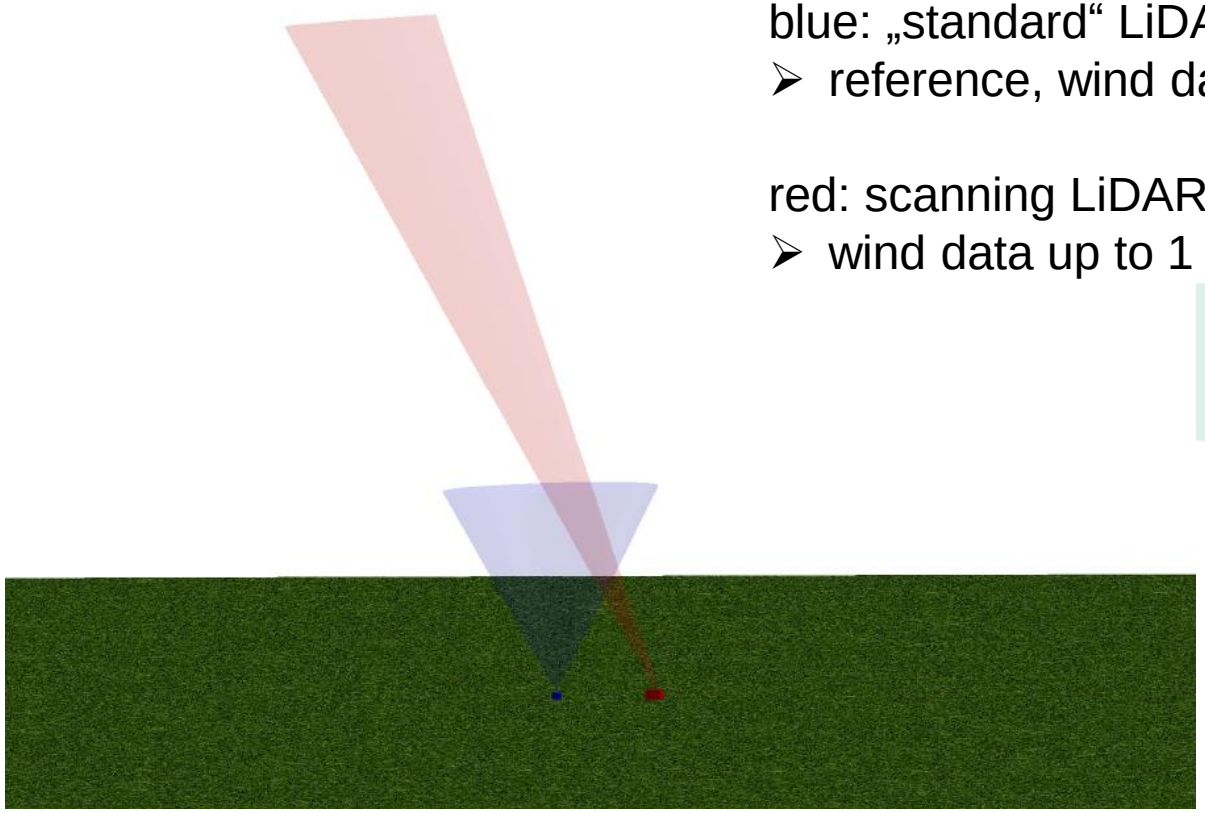
Planned measurement setup



blue: „standard“ LiDAR system (VAD scan)

- reference, wind data up to 200 m

red: scanning LiDAR system (ARC scan)

- wind data up to 1 000 m

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Future work

- development of a concept for determining power curves of AWE systems
  - comparative investigation of power curves for wind turbines and AWE systems
  - definition of power curves
  - requirements regarding to the measurement procedure for power curves
- measurement of the power curves of the AWE systems from the project partners

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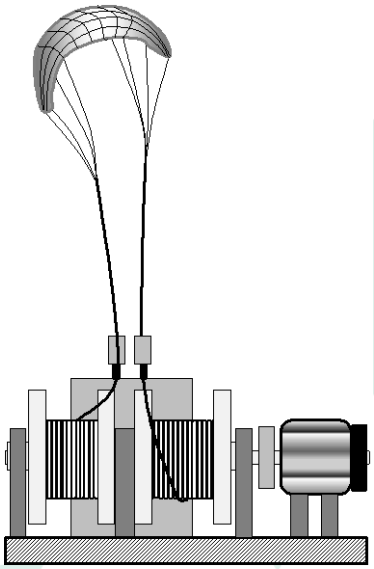
Summary



- comprehensive assessment of the potential of AWE systems is extremely difficult
- depends on diurnal variations

- ➢ it is very important to know about the wind resources between 200 m and 1 000 m at one minute sampling times for AWE systems
- ➢ measurements planned with scanning LiDAR system for yield assessment and determination of power curves for AWE systems

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THANK YOU FOR YOUR ATTENTION

Any questions?

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