
DTU

Project "EROSION": Concept and main results

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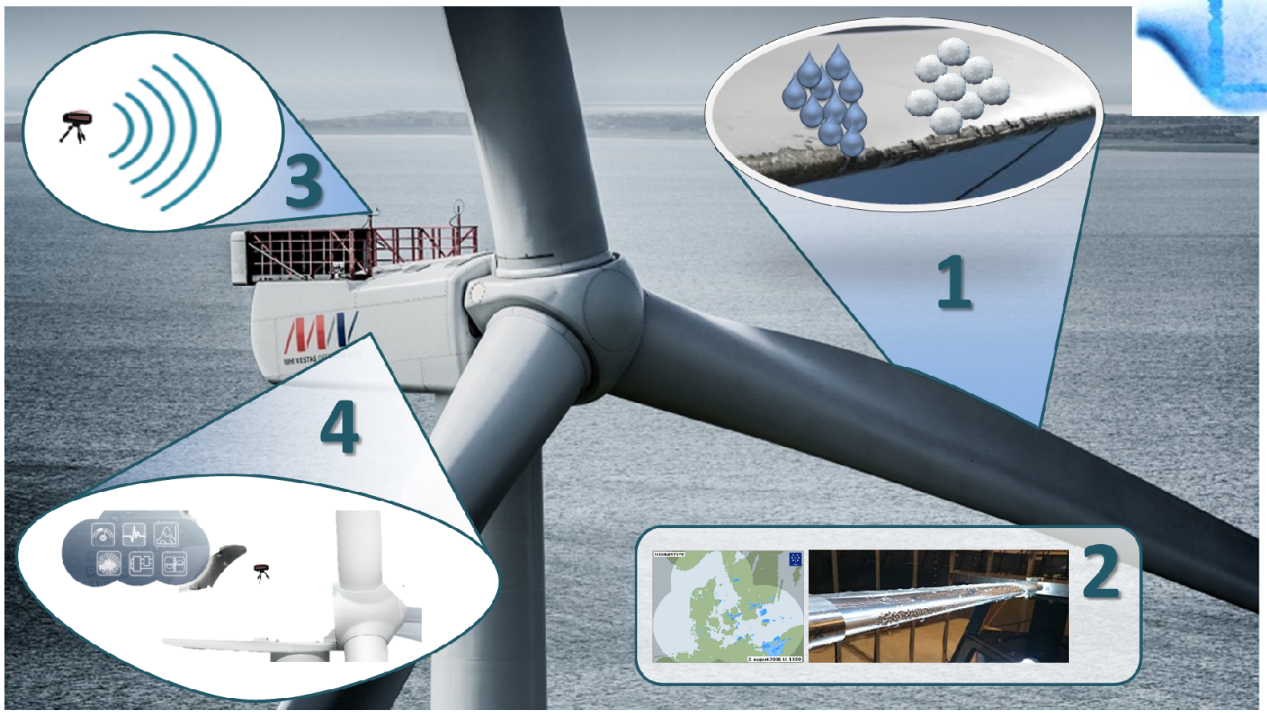
International Symposium on

Leading Edge Erosion of Wind Turbine Blades

Outline

- Motivation
- Working hypothesis
- Rain erosion climate
- Erosion-safe operation
- Disdrometers, lessons learnt
- Conclusions
- Perspective



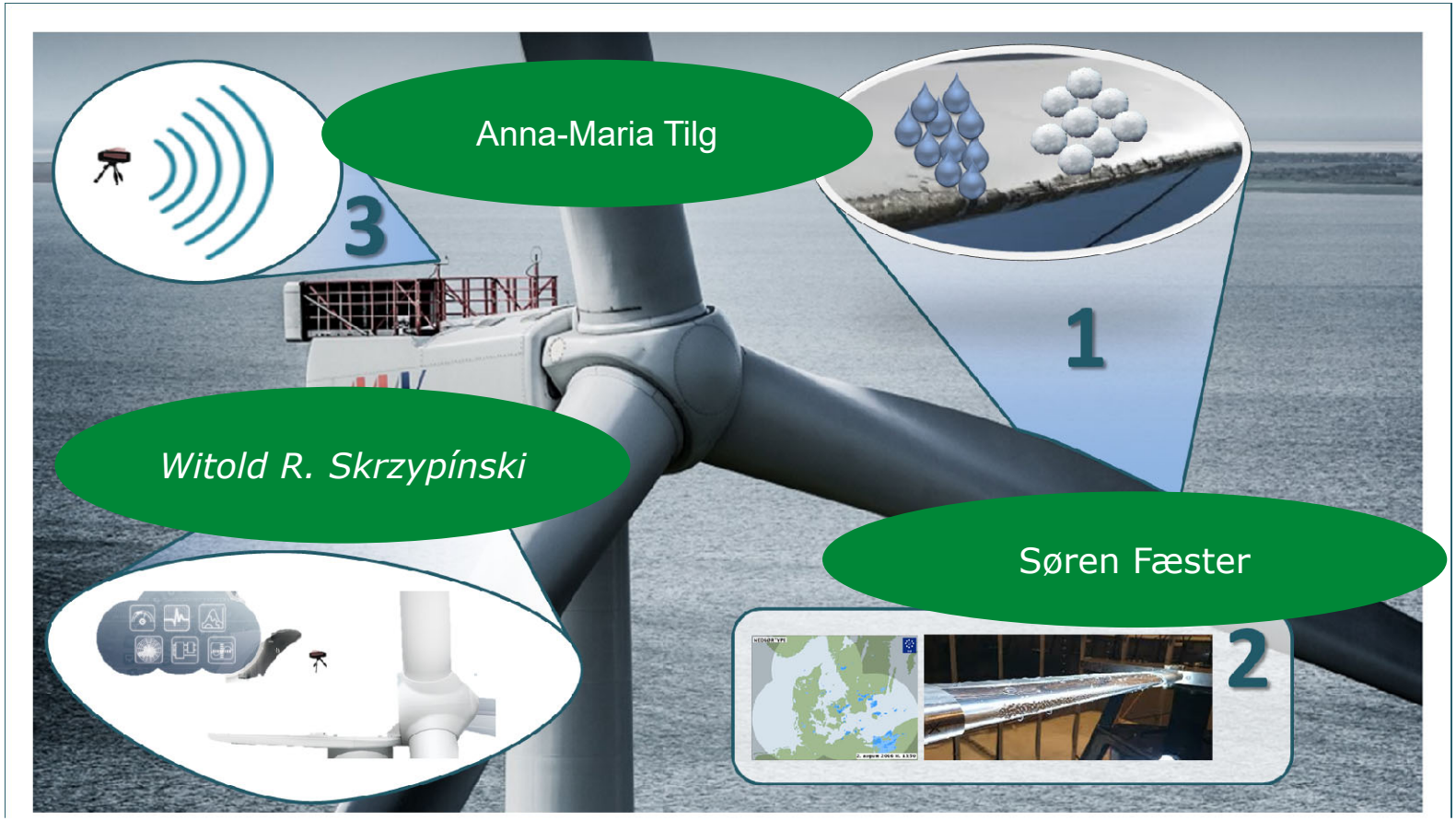
1. **Research hypothesis**: Erosion damage is mainly generated during heavy precipitation (big drops of rain or hail), which occurs in a very little fraction of the turbines operation time. By reducing the tip speed of the blades in these few hours a significant extension of the leading edge lifetime can be obtained with negligible loss of production.

2. **Methodology:** Define rain and hail erosion classes to quantify leading edge blade in-field and in lab testing. Correlations between rain intensity, droplet size, impact speed, materials properties, etc. will be established.

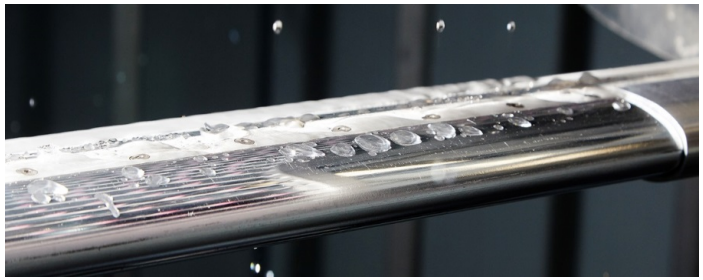
3. **Measurement Device:** Low-cost prototype for precipitation measurement on site and real time warning device enabling modern control of wind turbines.

4. **Erosion safe mode:** A safe mode control based on the erosion classes to control the wind turbine, reducing the tip speed under severe conditions – preventing aerodynamic degradation and reducing maintenance costs.

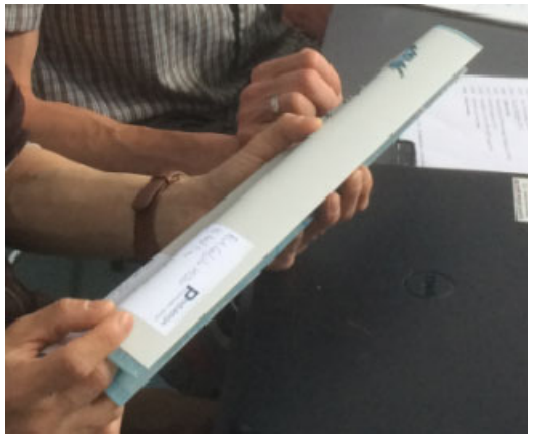
Detailed presentations



Rain erosion testing



Rain Erosion Tester by R&D Test systems



Example of specimen

Test matrix

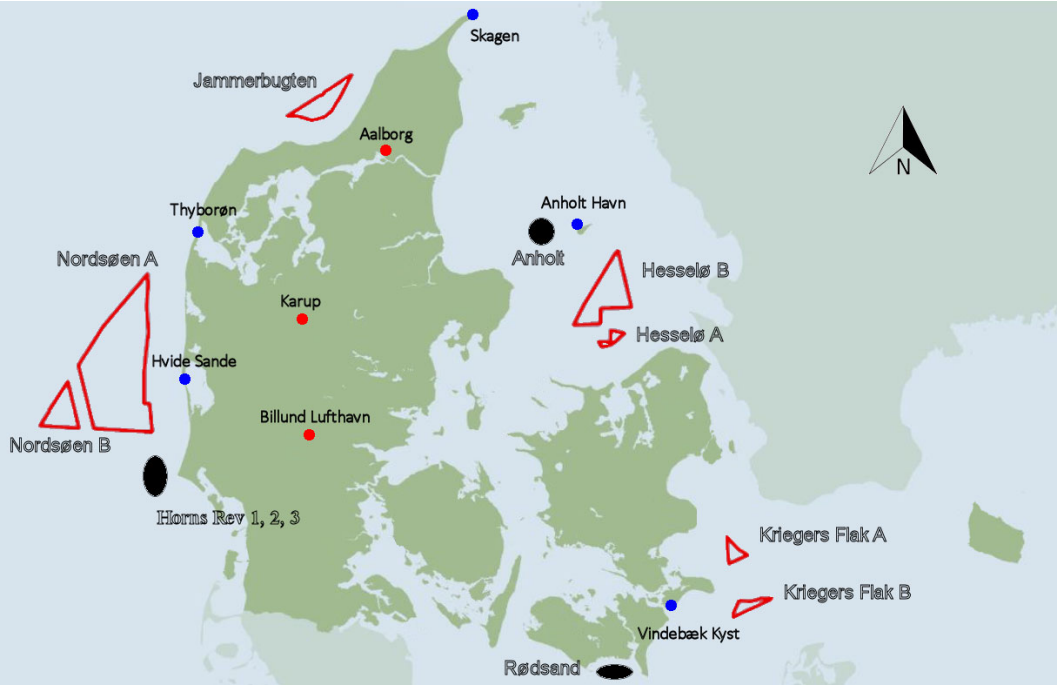

EROSION test campaign
Leading edge configurations
"conventional coating"
LEP
Filler
Layer thicknesses
Test parameters
Speed
v1, v2, v3, v4, v5
droplet size
d1, d2, d3
sequence
sq1
sq2
sq3
Characterisation
Pre test
X CT
US
Post test
X CT
US
SEM
Light Microscopy
Failure modes
surface cracks
debonding of layers
crushing of filler
sub surface cracks

Rain erosion climate

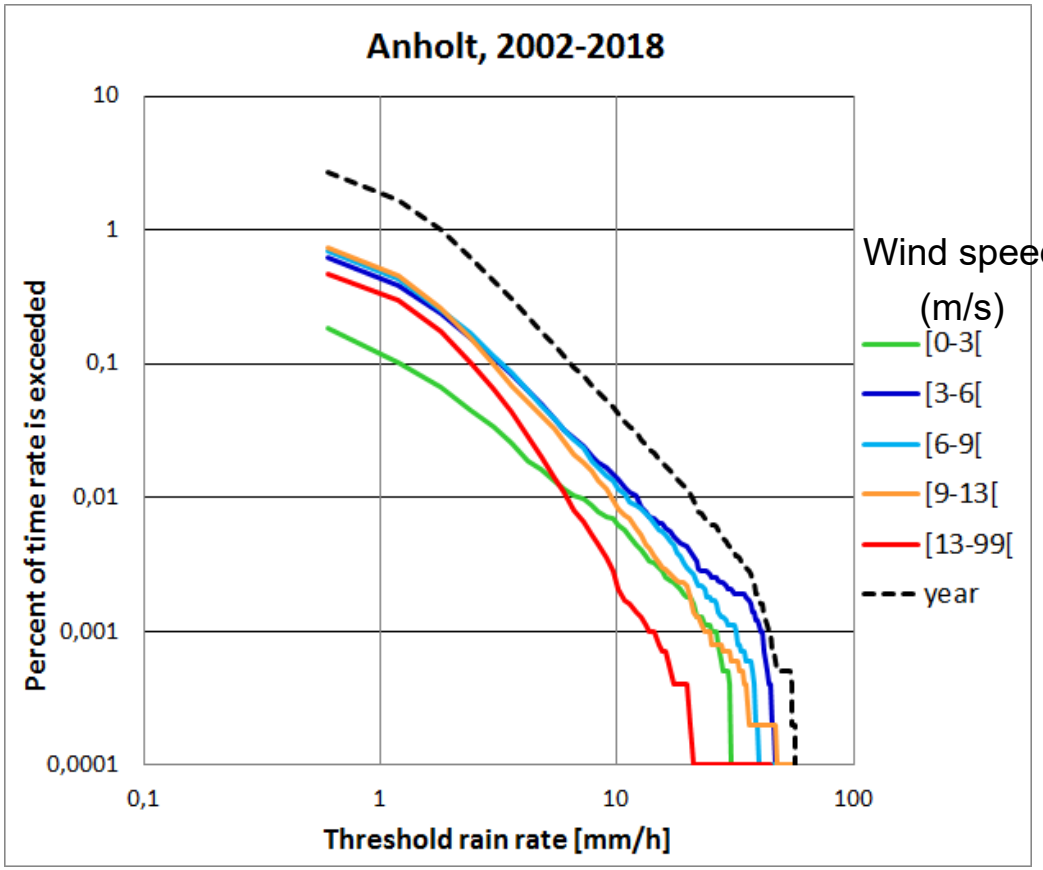
Eight meteorological stations

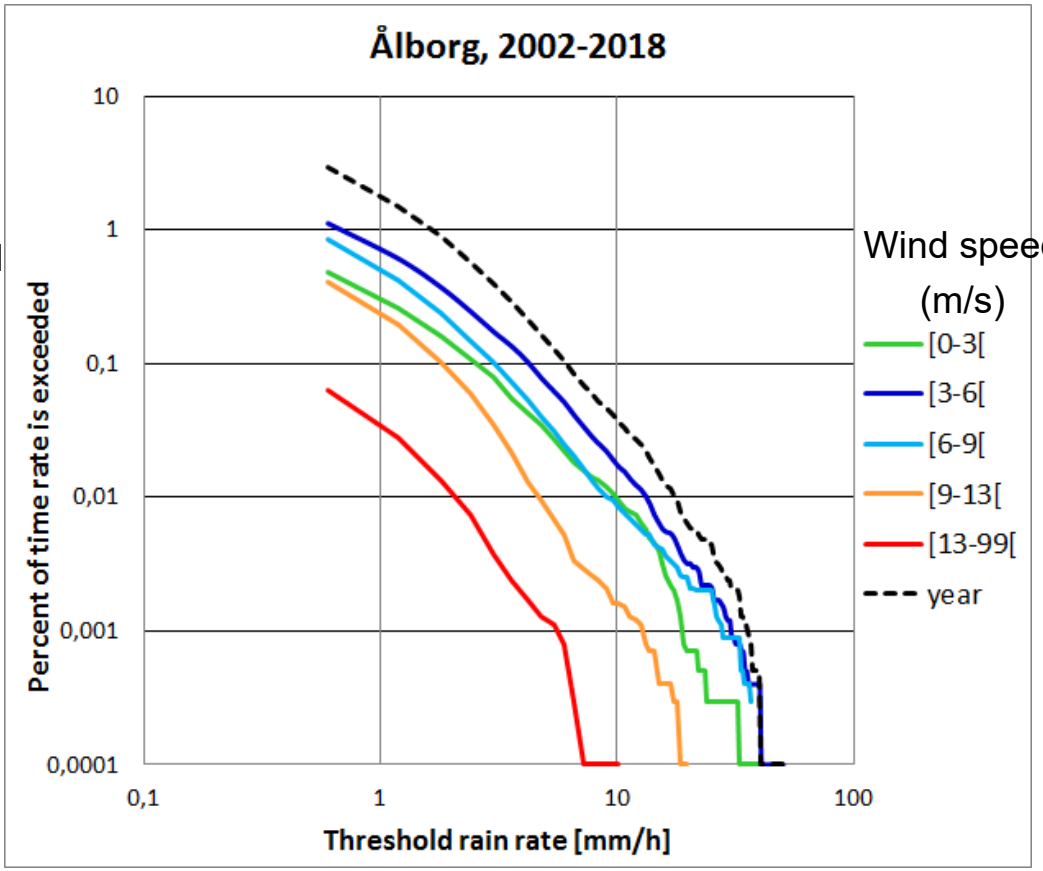
Five coastal and three inland

16 years of 10-minute observations of rain rate and wind speed from Danish Meteorological Institute



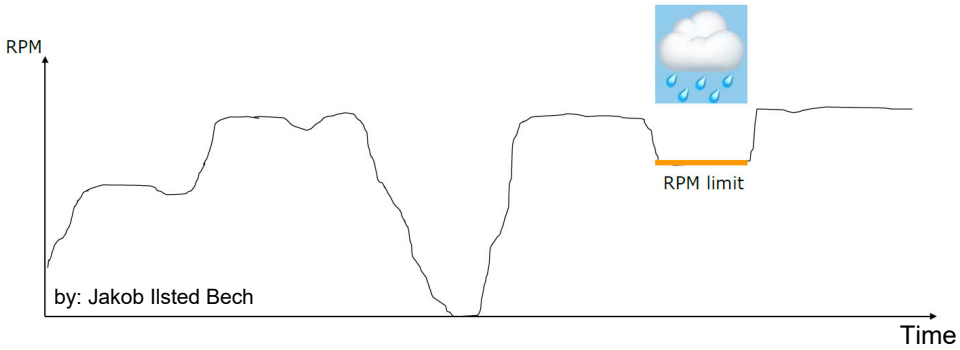
The average yearly variation of percentage of time of exceedance of rain intensities at wind speed bins

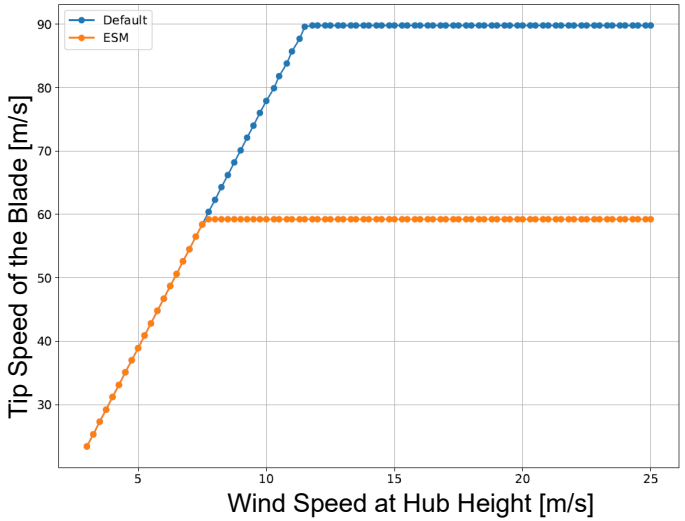


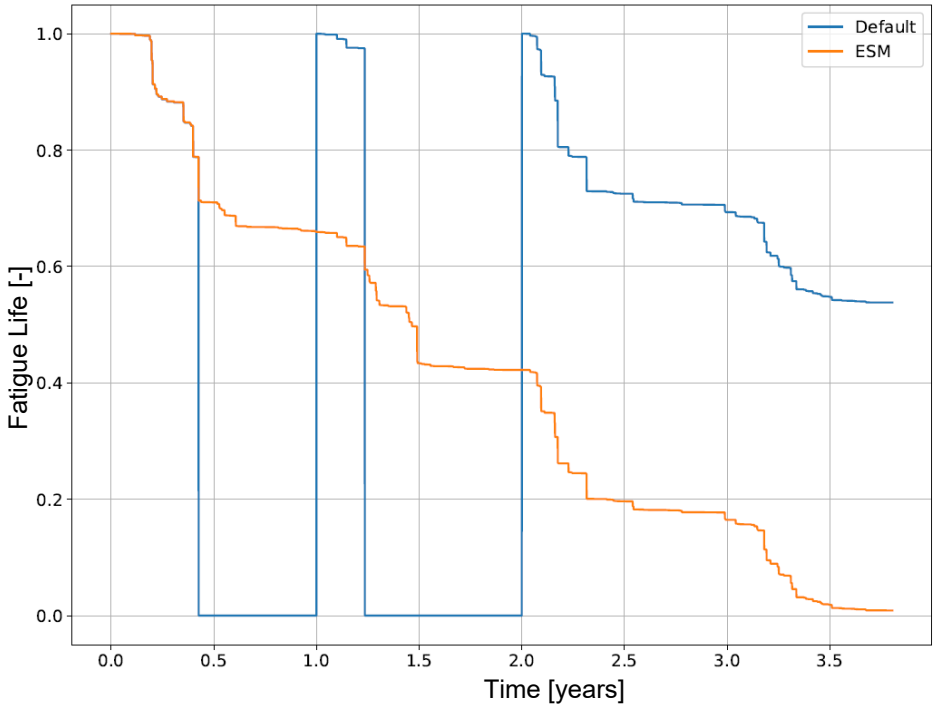


Erosion-safe operation

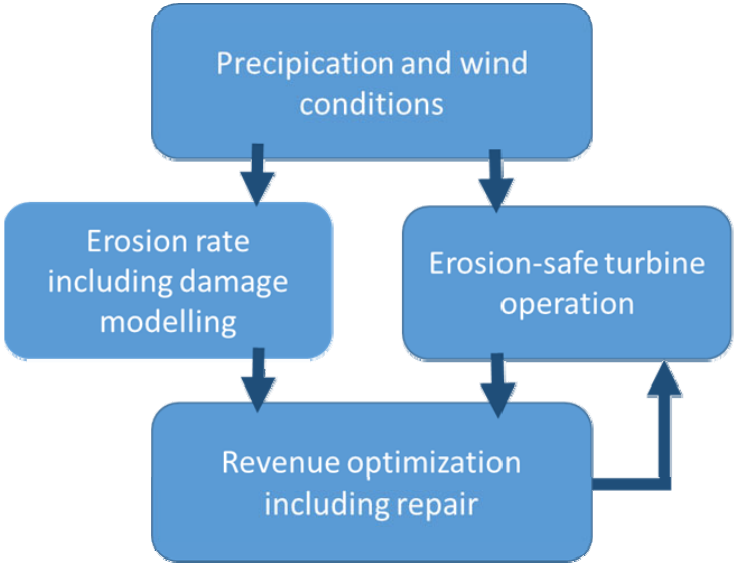
Erosion safe control







Flow chart for cost analysis of leading edge erosion



Expected life

	Coastal stations					Inland stations		
Station	Anholt	Hvide Sande	Skagen	Thyborøn	Vindebæk	Aalborg	Billund	Karup
Life (years)	2.9	3.0	3.6	3.5	3.1	13.6	3.1	11.8

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Life (years)	2.9	3.0	3.6	3.5	3.1	13.6	3.1	11.8
Annual precipiation (mm)	556	647	625	794	591	723	1012	868

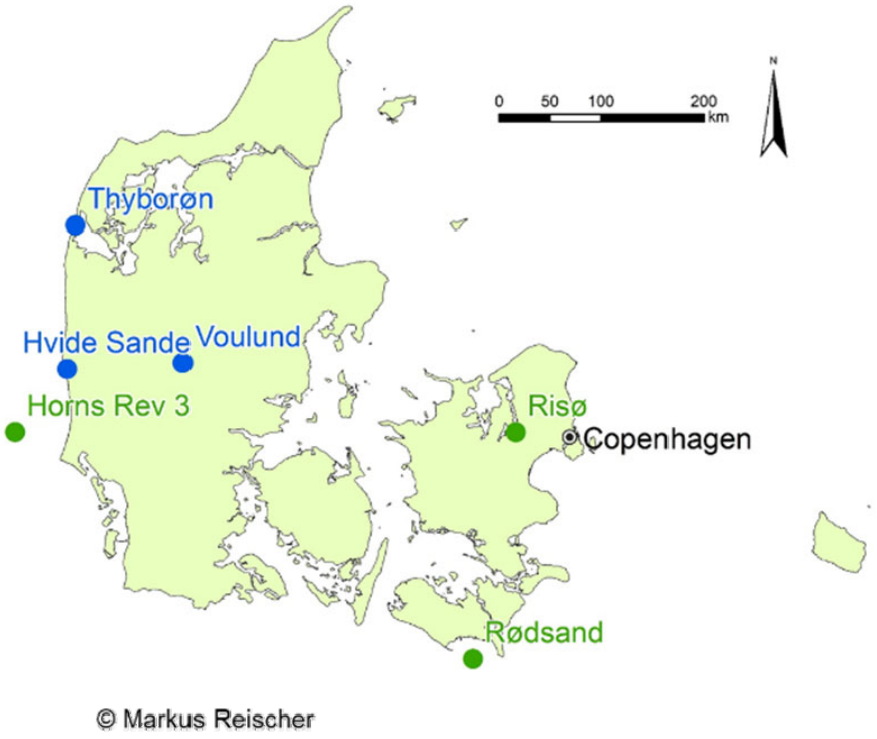
Increase in profit from erosion safe mode control

	Coastal stations					Inland stations		
Station	Anholt	Hvide Sande	Skagen	Thyborøn	Vindebæk	Aalborg	Billund	Karup
Increase in profit (%)	2.5	2.3	1.9	1.6	3.1	0.9	3.0	0.9

Hasager *et al.* Assessment of the rain and wind climate with focus on wind turbine blade leading edge erosion rate and expected lifetime in Danish Seas. *Renewable Energy 2020*

Disdrometers, lessons learnt

Disdrometer network



Parsivel2 at Risø

Disdrometers at Risø Campus

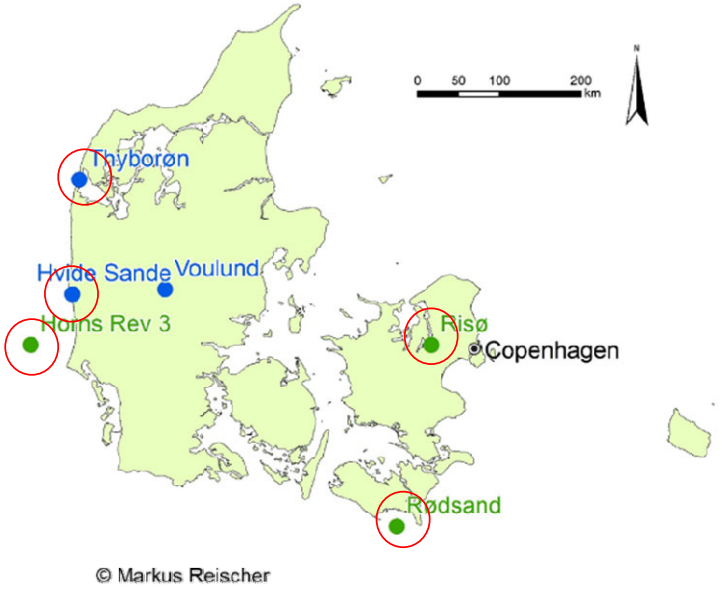
123 m tall meteorological mast

Disdrometers: lessons learnt

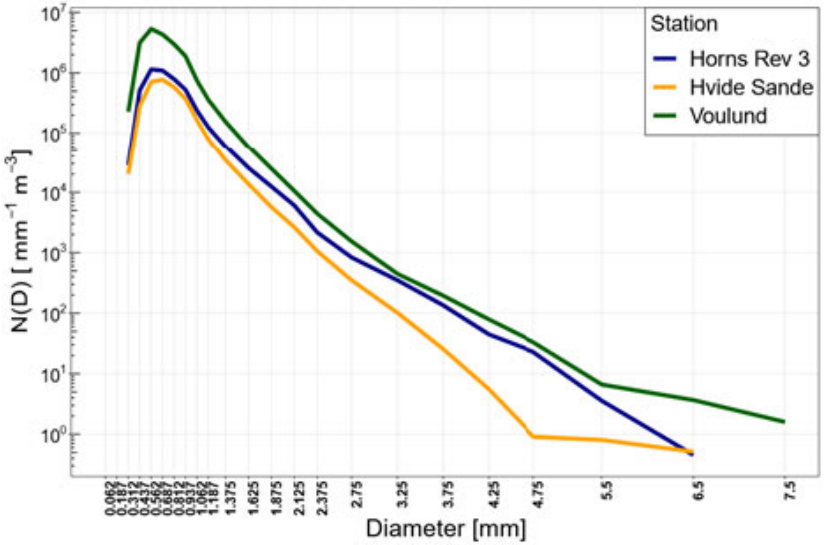
We re-install 5 out of 7.

The disdrometers failed at sites:

- 2 offshore
- 2 coastal
- 1 at top of Risø mast



Disdrometer data from offshore, coastal and inland sites



The mean drop size diameter and the concentration of drops at the stations Horns Rev 3, Hvide Sande and Voulund in Denmark for the time period mid-February to mid-June 2019.

Mishnaevsky *et al.* in review.

Conclusions

- We have calculated the rain erosion climate in Denmark
  - We will analyse for sites outside Denmark
- We have calculated the potential benefit of erosion safe control
  - We are planning a trial at Aberdeen Bay
- We have been challenged with Parsivel2 disdrometers
  - We look for alternatives for installation at turbines

Acknowledgements

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www.rain-erosion.dk

Innovation Fund Denmark