Estimation of leading edge erosion risk on wind turbines, repair prediction and mitigration strategy

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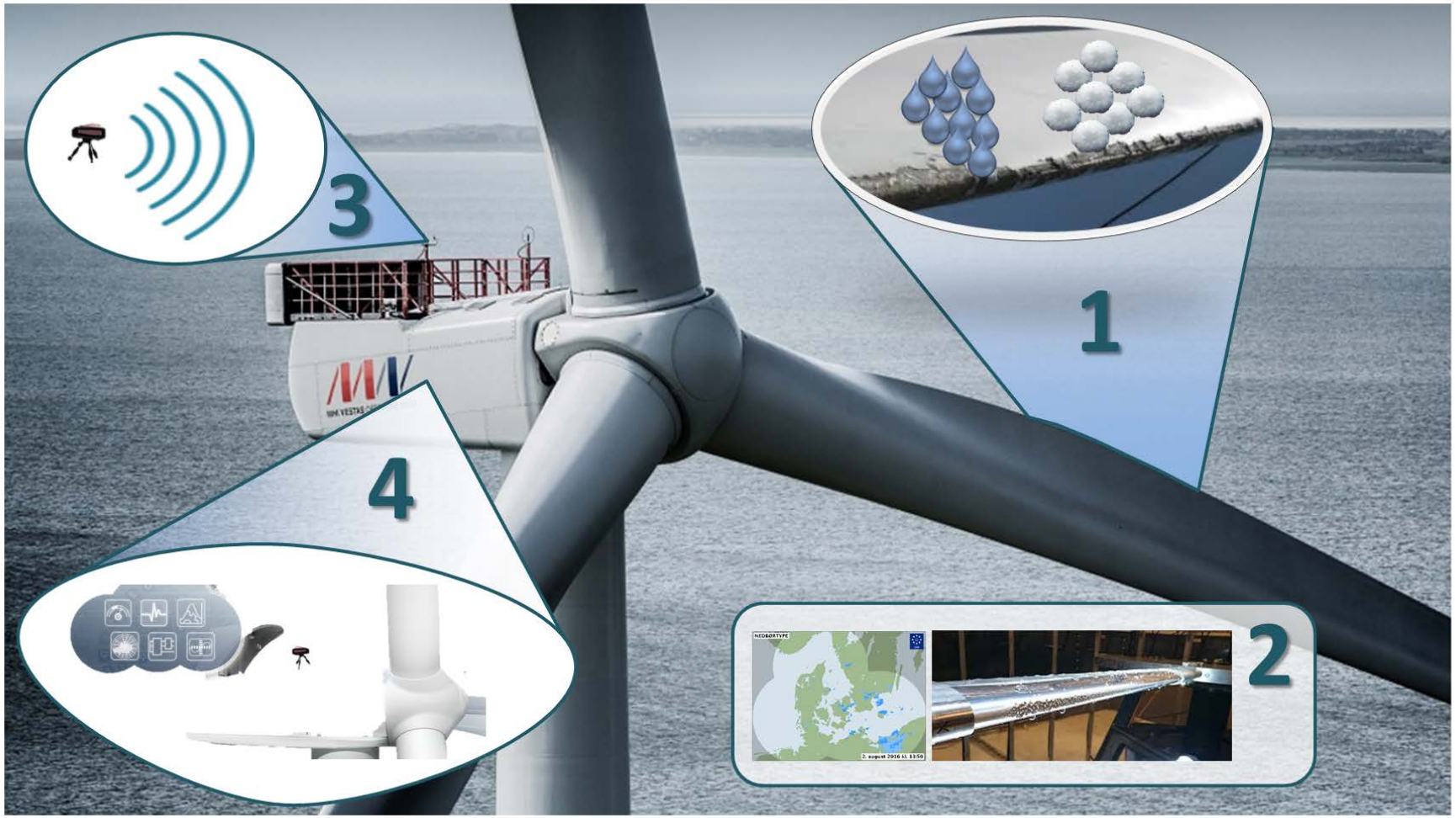
EERA DeepWind conference, 19-21 January 2022

Content

- Introduction
- Mitigation strategy using turbine control based on nowcasting of rain
- Long-term monitoring to estimate blade lifetime and repair need
- Conclusions

www.rain-erosion.dk

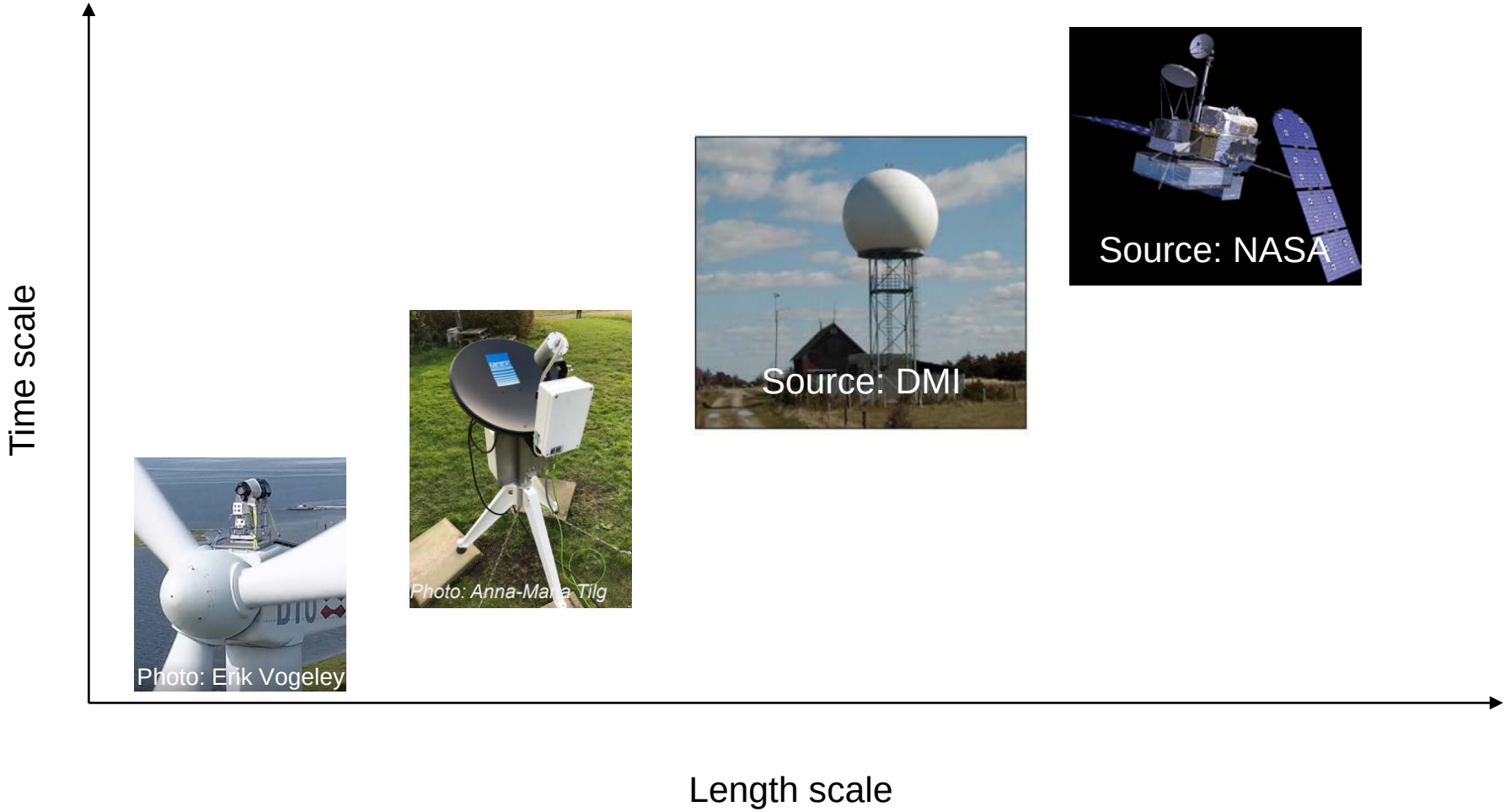


Erosion safe mode operation

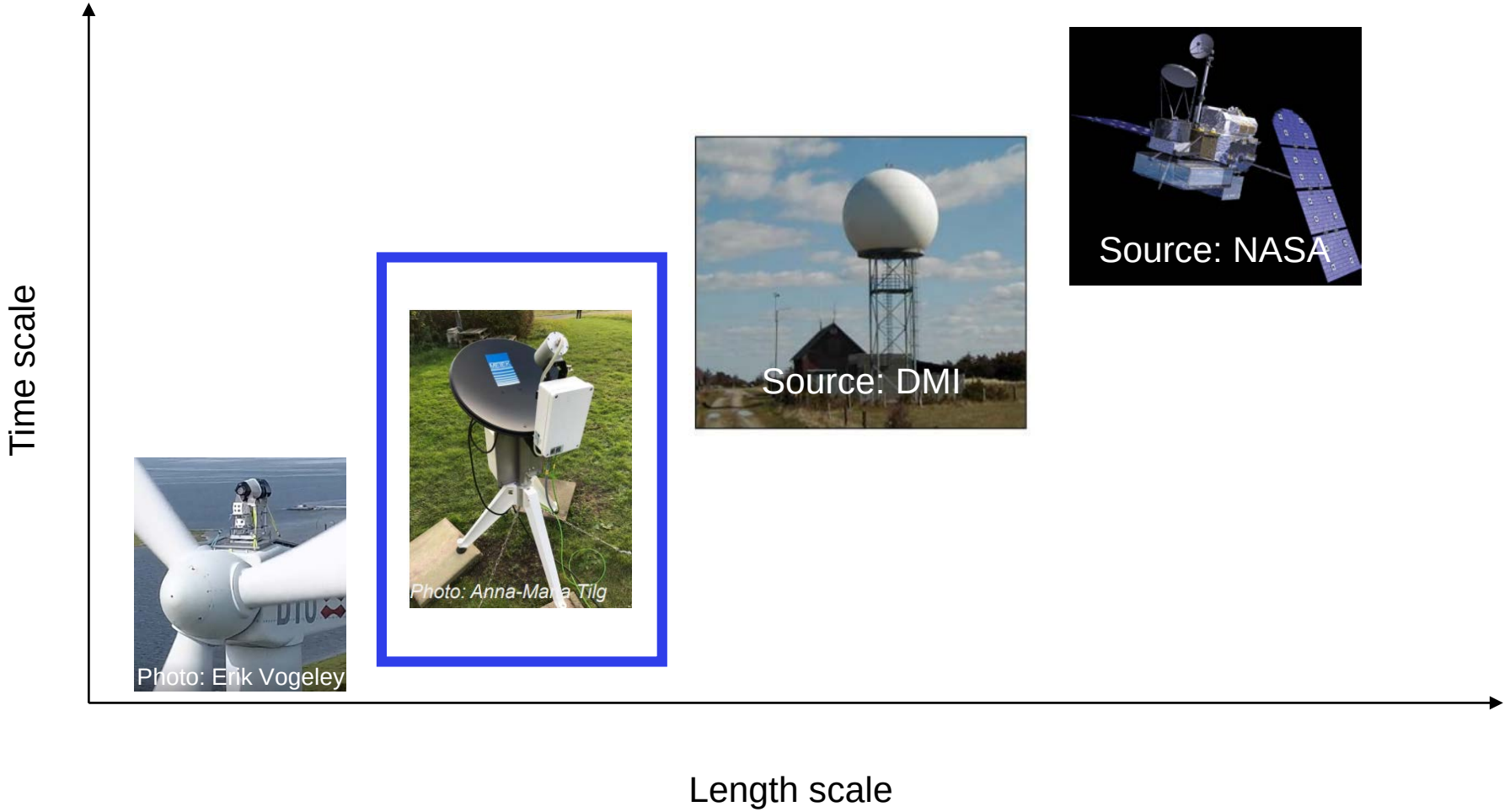
Rounds per minute
(blade tip speed)

Courtesy: Jakob Ilsted Bech

Technologies for nowcasting rain



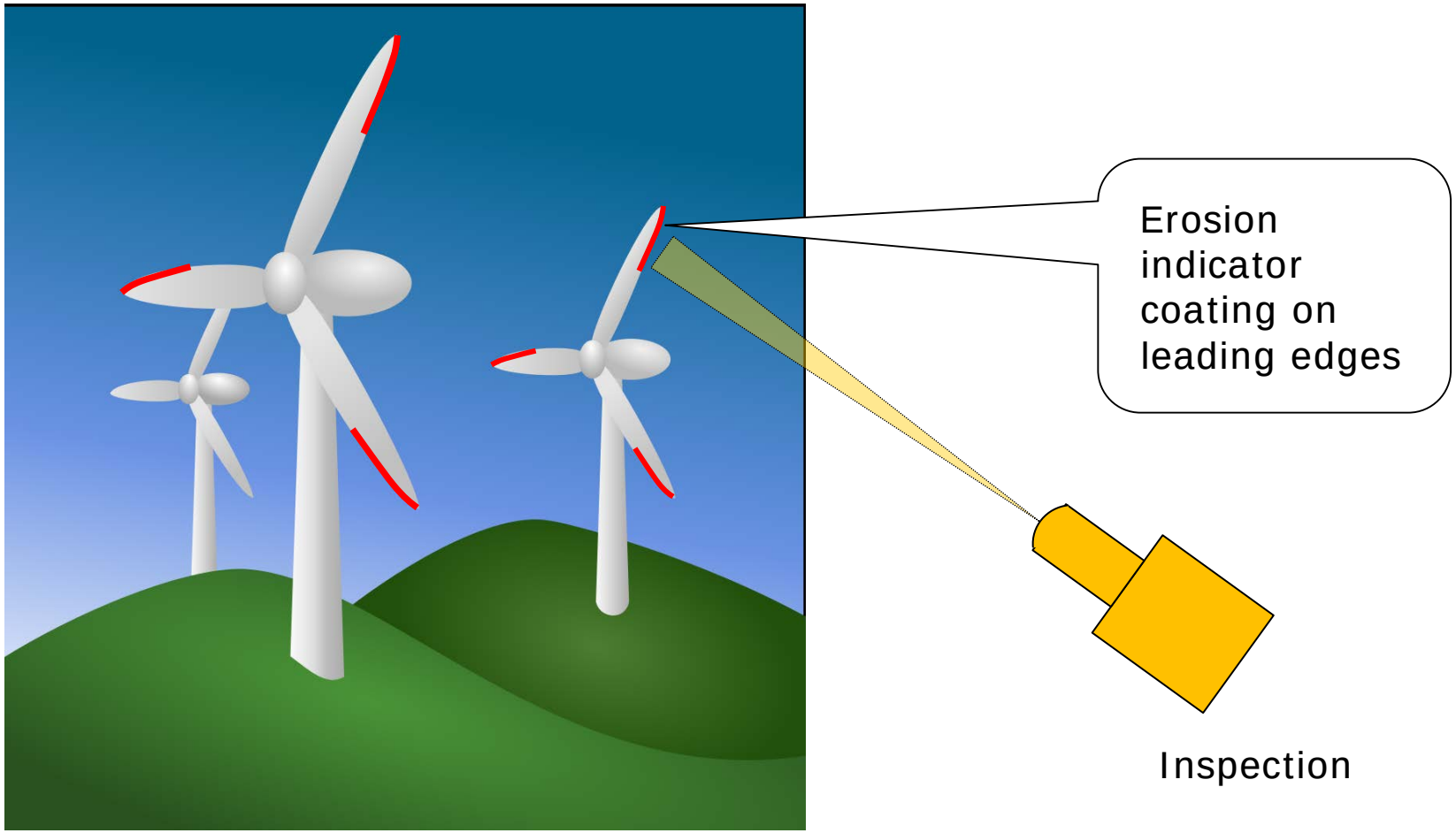
Technologies for nowcasting rain



Technical implementation

Micro Rain Radar
at the nacelle

Technical implementation



A priori knowledge

VN-curve of the indicator coating.

Testing is done in Rain Erosion Tester (RET).

Erosion-safe mode demonstration campaign

Erosion safe operation

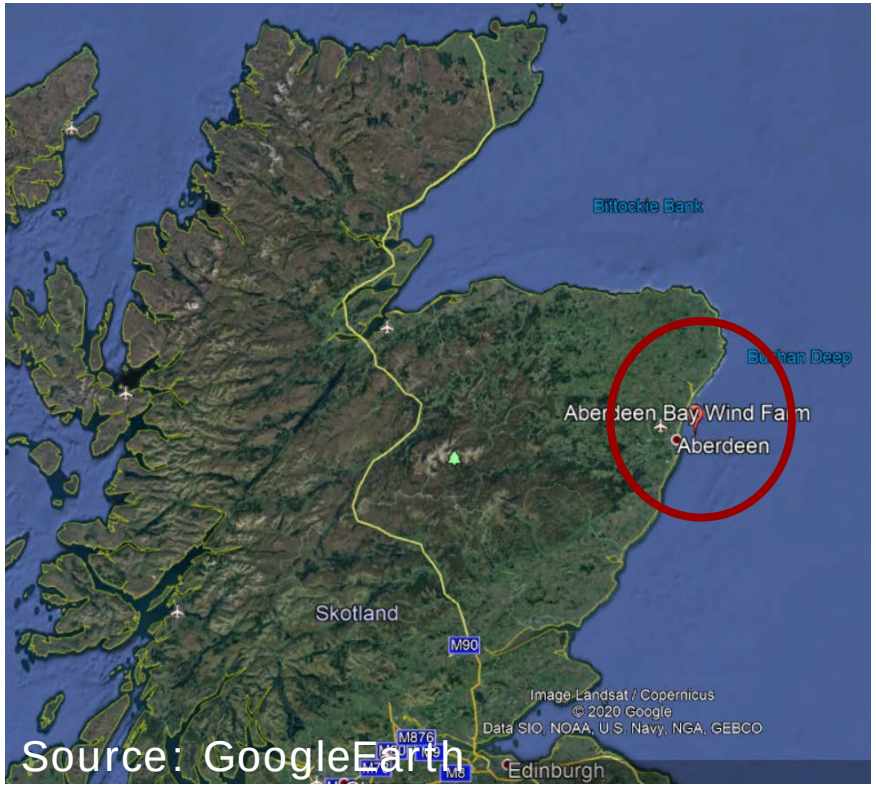
Standard operation

Aim is to compare:

- Erosion rate
- Cost model (profit)

Bech *et al.* 2018 *Wind Energy Science*

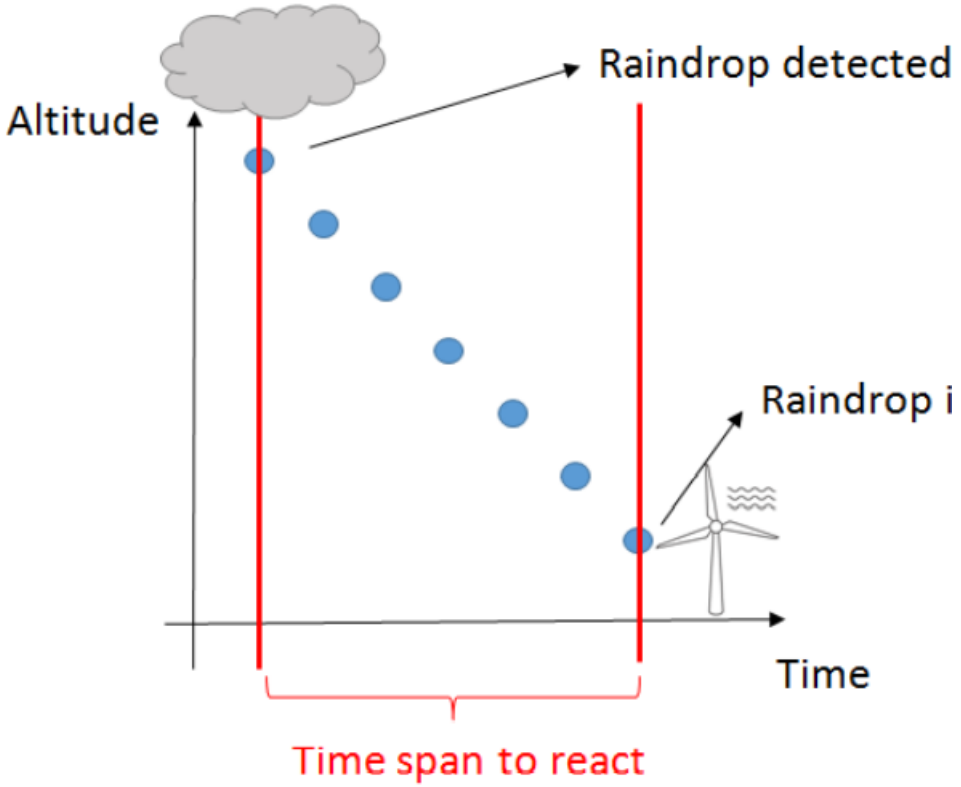
Aberdeen Bay Wind Farm

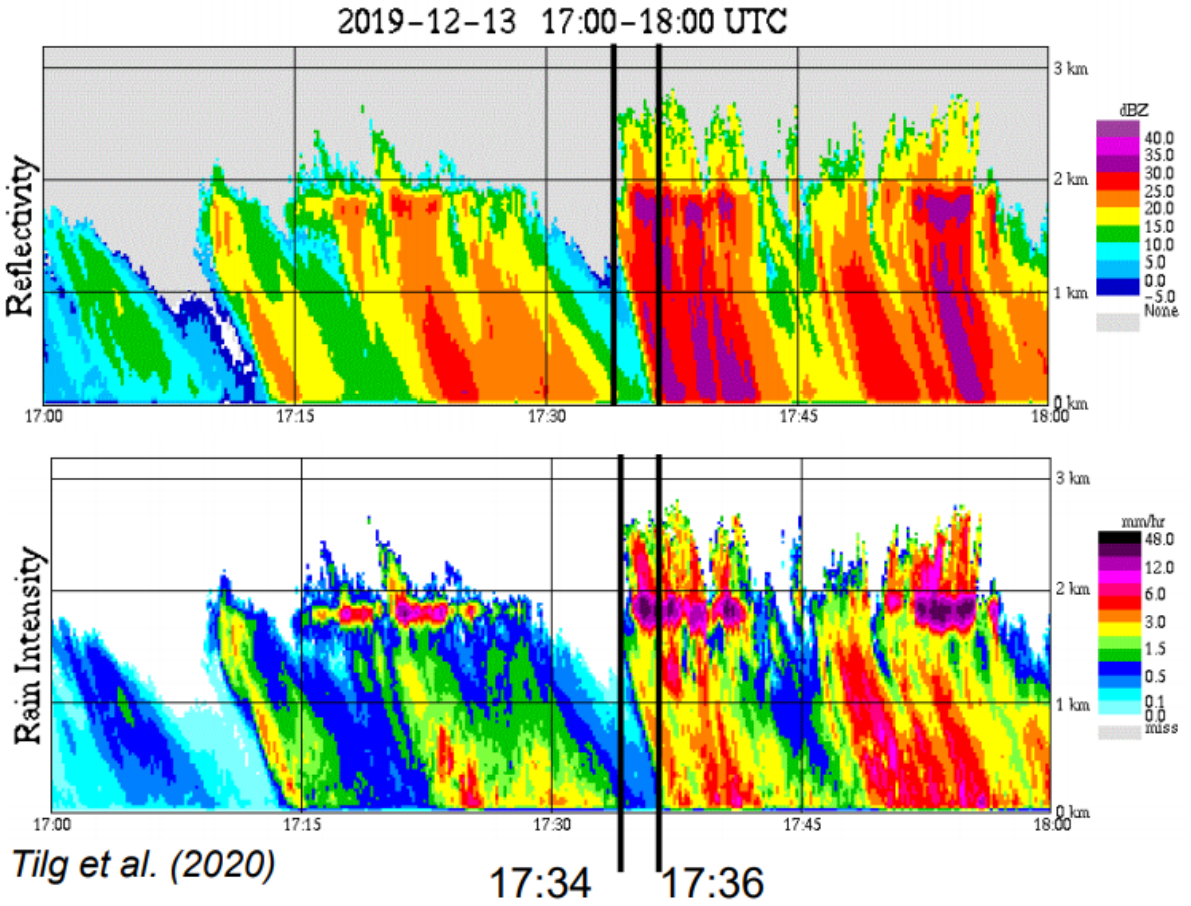


Source: GoogleEarth

Source: Vattenfall

Micro Rain Radar from METEK





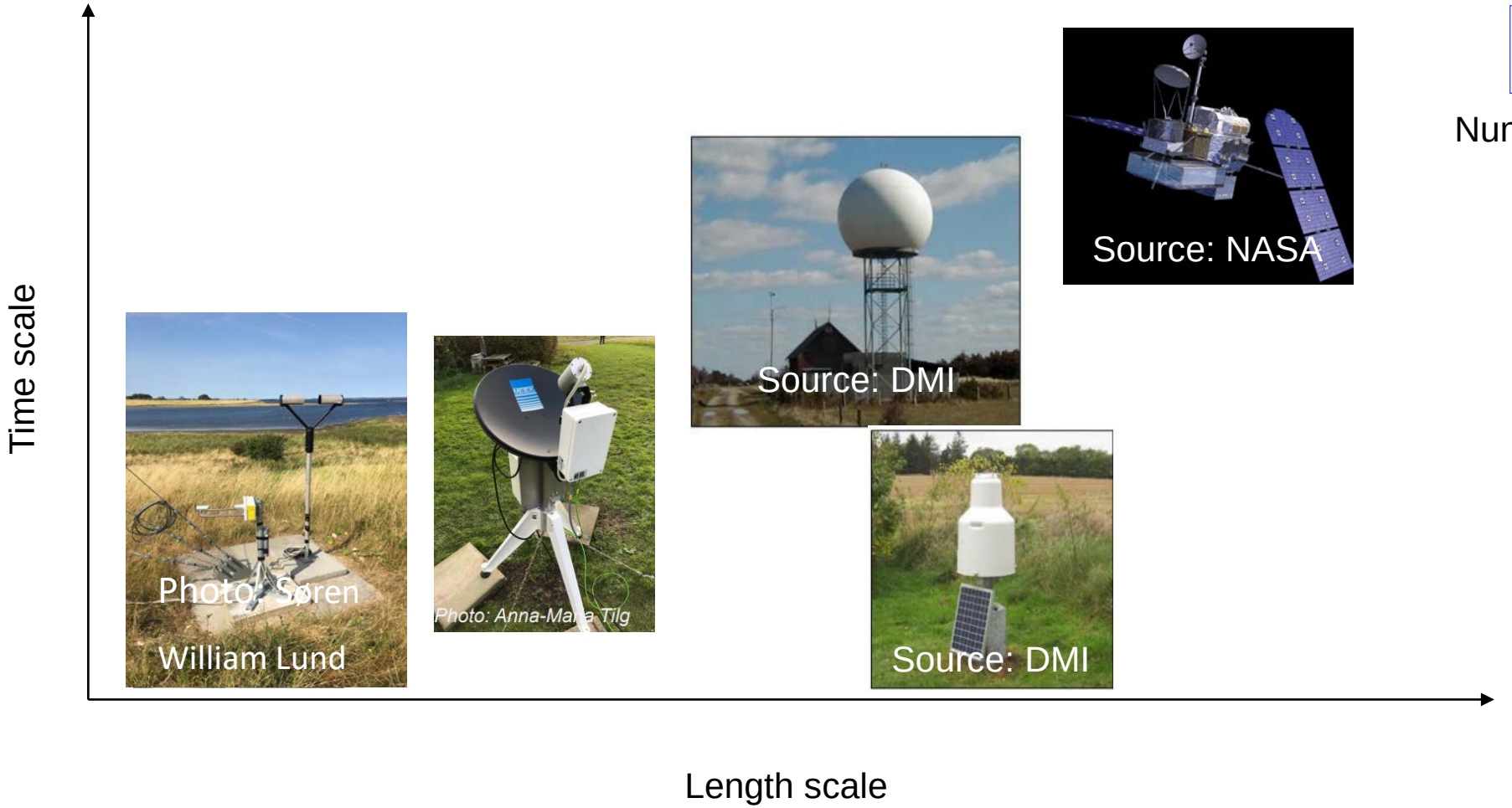
Tilg *et al.* 2021

Challenges

- To install Micro Rain Radar
- To paint the blades
- To monitor regularly
- *To make the control settings without knowing the rain and winds well*

- The exciting part is to overcome all the challenges and demonstrate erosion safe mode

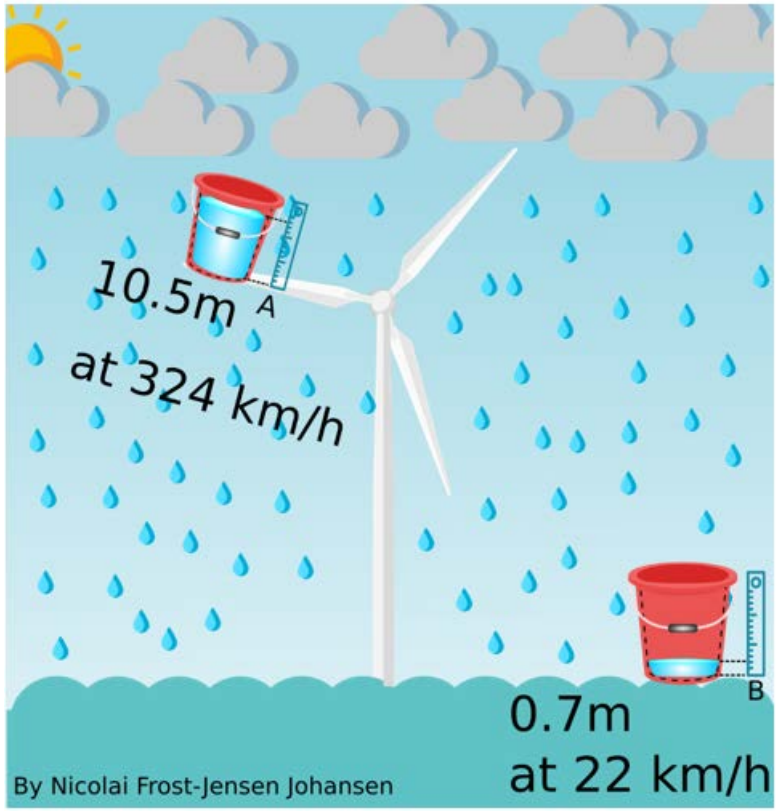
Long-term rain monitoring for leading edge erosion



NWP

Numerical Weather Prediction (model)

Rain ‘magnified’



Annual rain amount at 0.7 m

Tip speed of the blades at 90 m/s

Assume the turbine is at rated speed.

Summary

Rain data are ‘magnified’ by turbines so good accuracy is required!

Hasager *et al.* 2021, in Book chapter

Disdrometer data from DTU

https://www.rain-erosion.dk/publication

Data from seven disdrometers, Open Access

- Risø - on the ground next to the tall met mast
- Risø - on the top of the tall met mast
- Risø - on the ground next to the V52 met mast
- Rødsand - offshore wind farm
- Horns Rev 3 - offshore wind farm
- Hvide Sande - DMI station
- Thyborøn - DMI station
- Voulund - DMI station

Parsivel² disdrometer

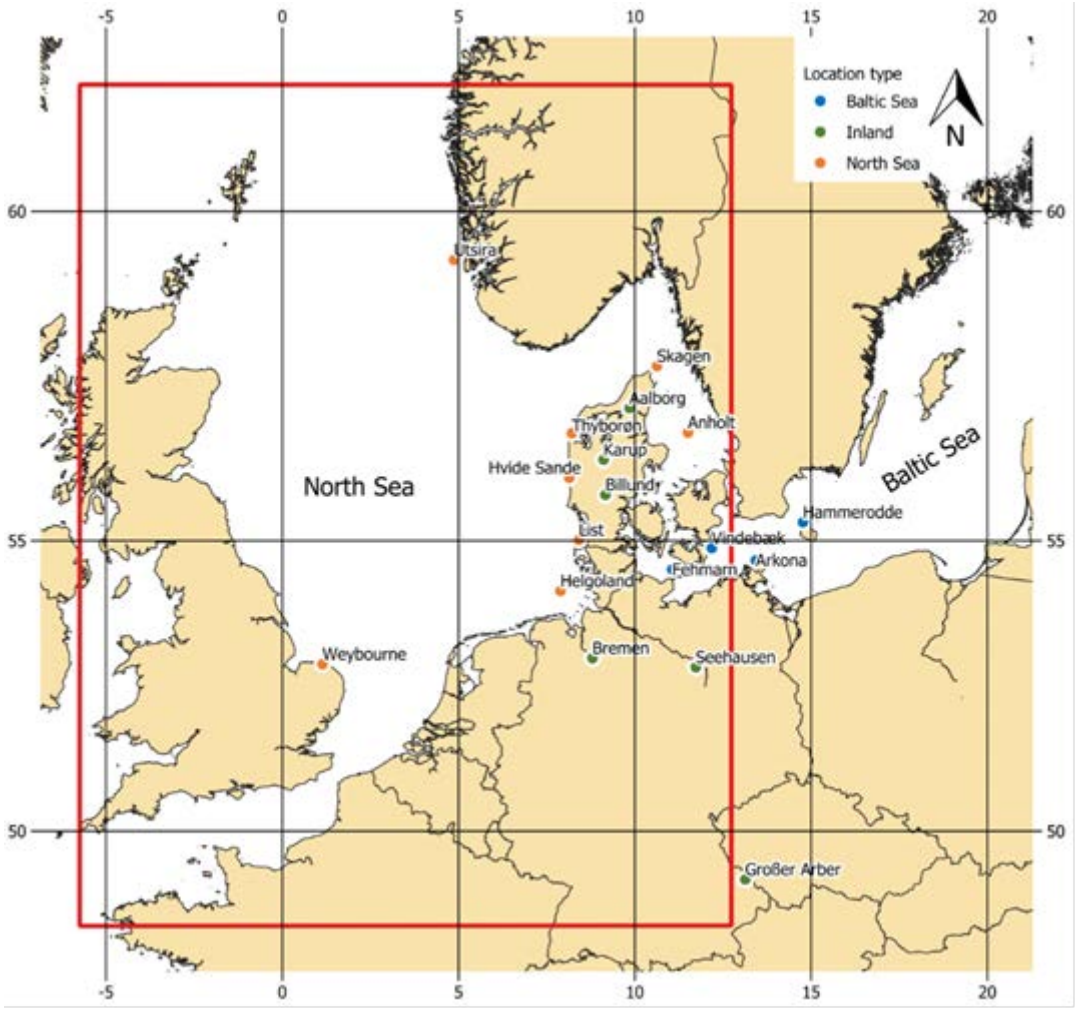
- Tilg and Hasager, 2021, DOI links to raw and Quality Controlled data

Wind and rain data

Location	Number of years
Aalborg	16.9
Anholt	17.9
Arkona	28.2
Billund	16.4
Bremen	28.2
Fehmarn	23.6
Grosser Arber	21.9
Hammerodde	18.3
Helgoland	23.0
Hvide Sande	18.0
Karup	16.9
List	24.1
Seehausen	28.2
Skagen	18.0
Thyborøn	18.0
Utsira	3.3
Vindebæk	13.6
Weybourne	2.6

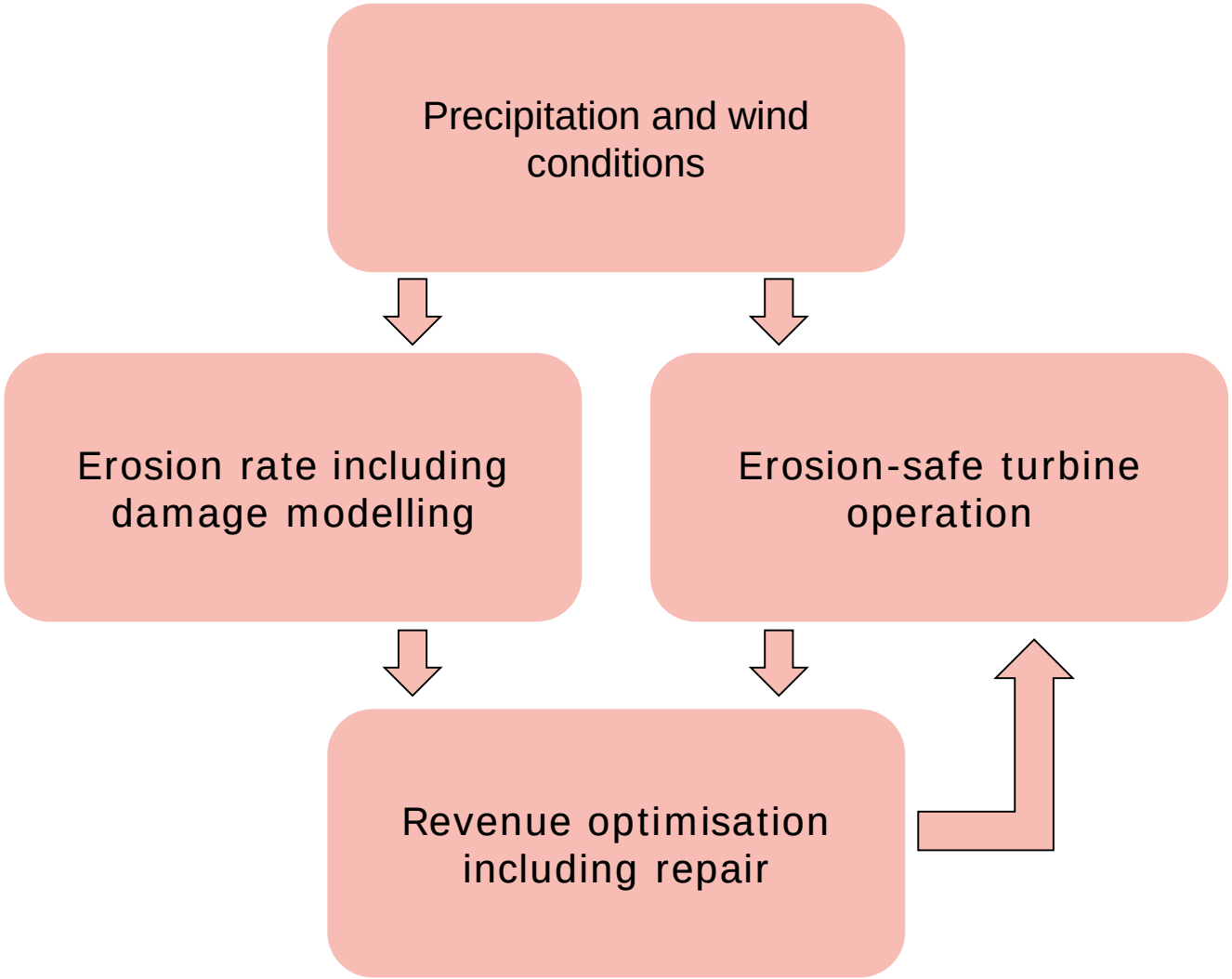
10-minute wind speed
10-minute rain rate
Quality control

All time series are > 13 years
(except at two stations)



Hasager *et al.* 2021 *Energies*

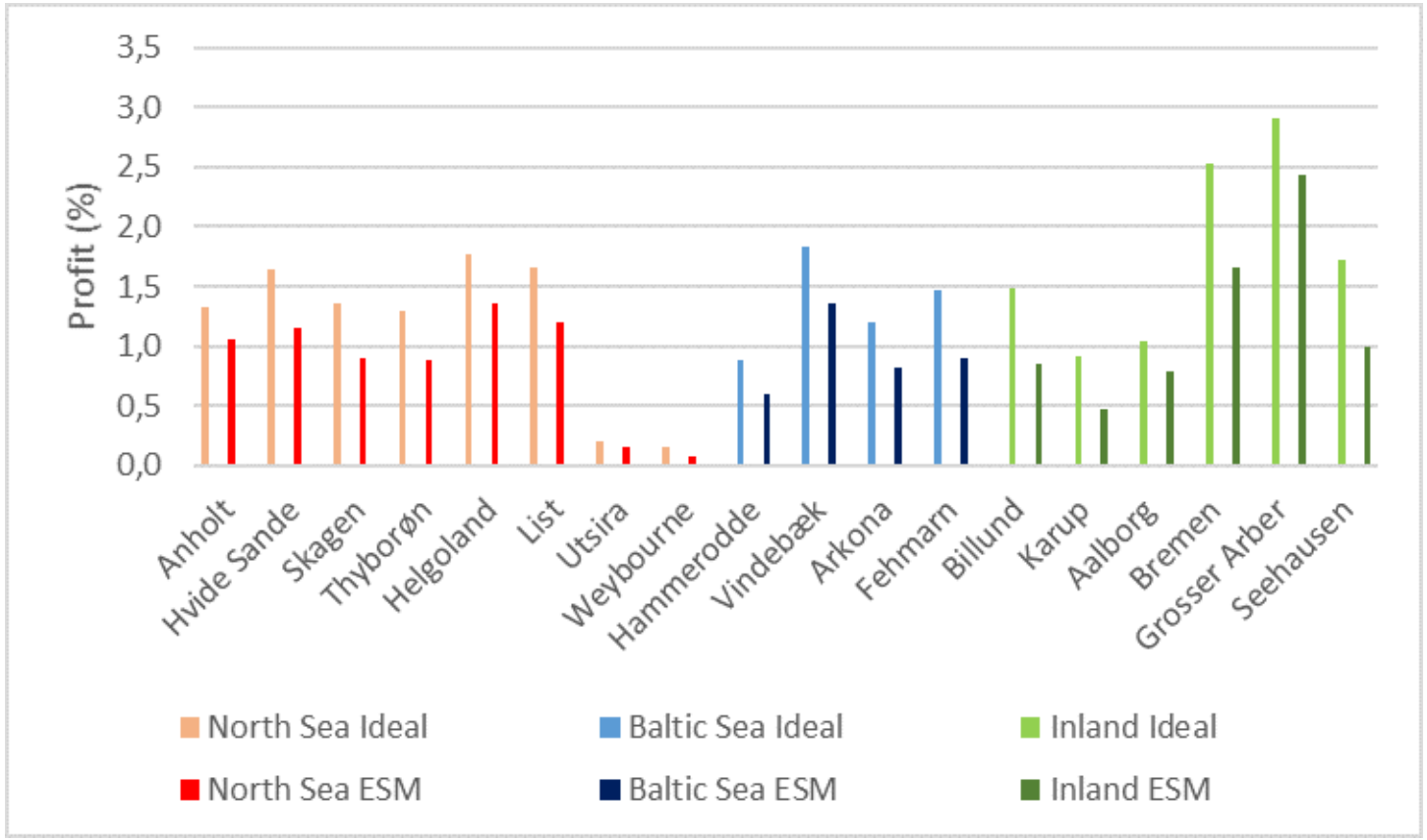
Erosion-safe mode



Hasager *et al.* 2020 *Renewable Energy*

Profit for ideal blades and for erosion-safe mode

Assume cost of electricity at Euro 0.05 per kWh, 20k Euro each repair and six days downtime for repair



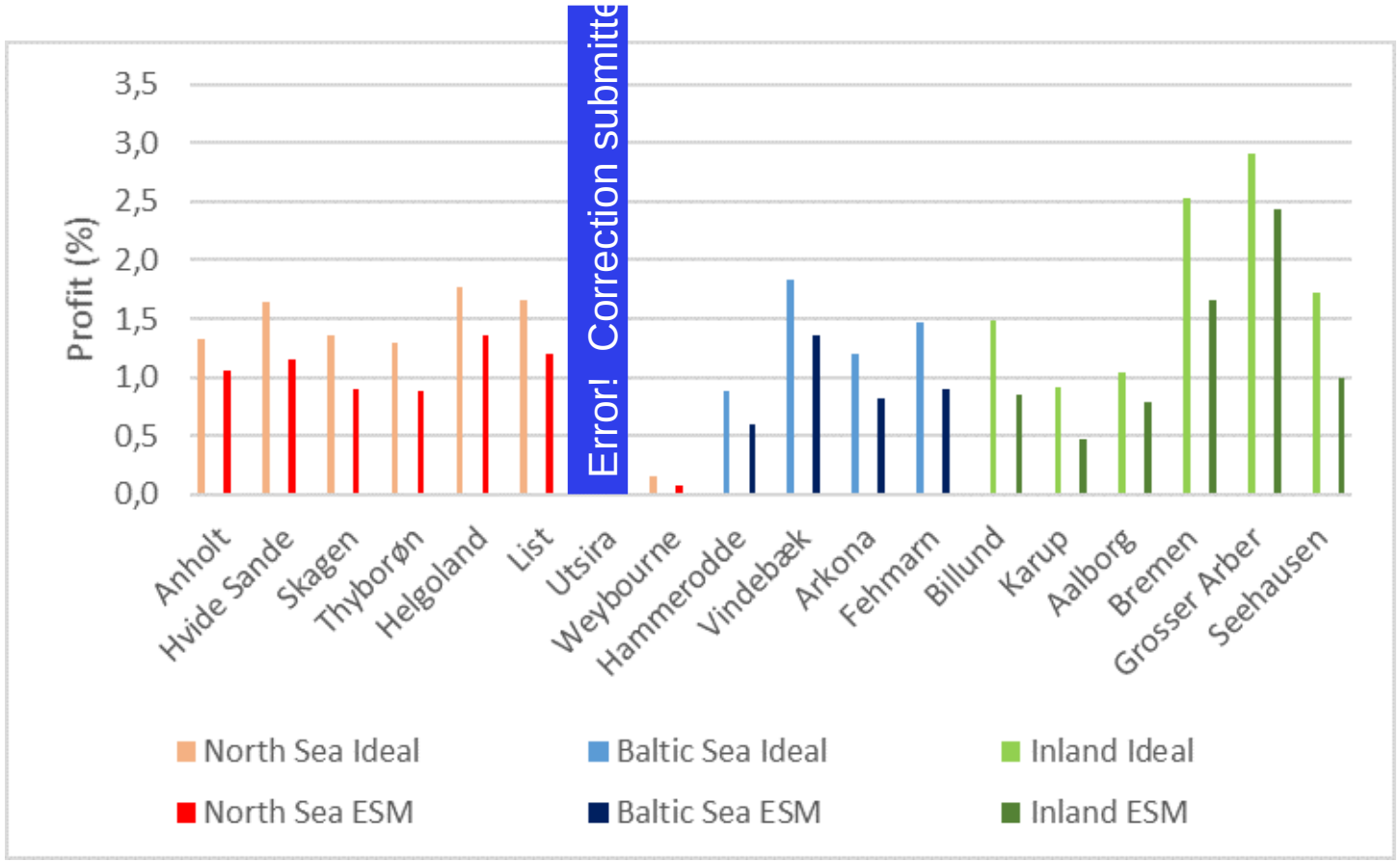
Hasager *et al.* 2021 *Energies*

Profit for ideal blades and for erosion-safe mode

Assume cost of electricity at Euro 0.05 per kWh, 20k Euro each repair and six days downtime for repair

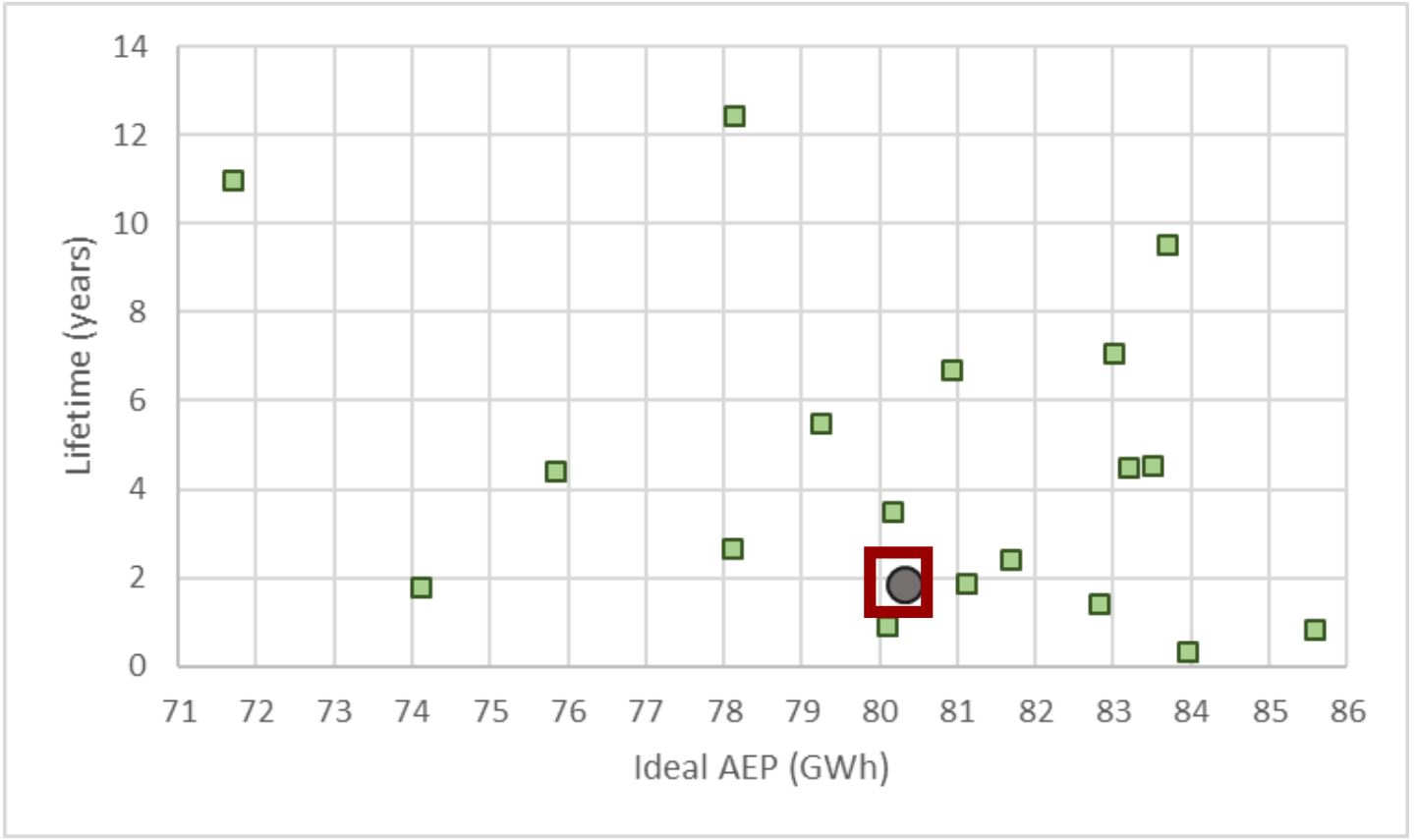
Average potential profit using erosion-safe mode is 70 %

The last 30 % can only be obtained with ideal blades



Hasager *et al.* 2021 *Energies*

Blade lifetime



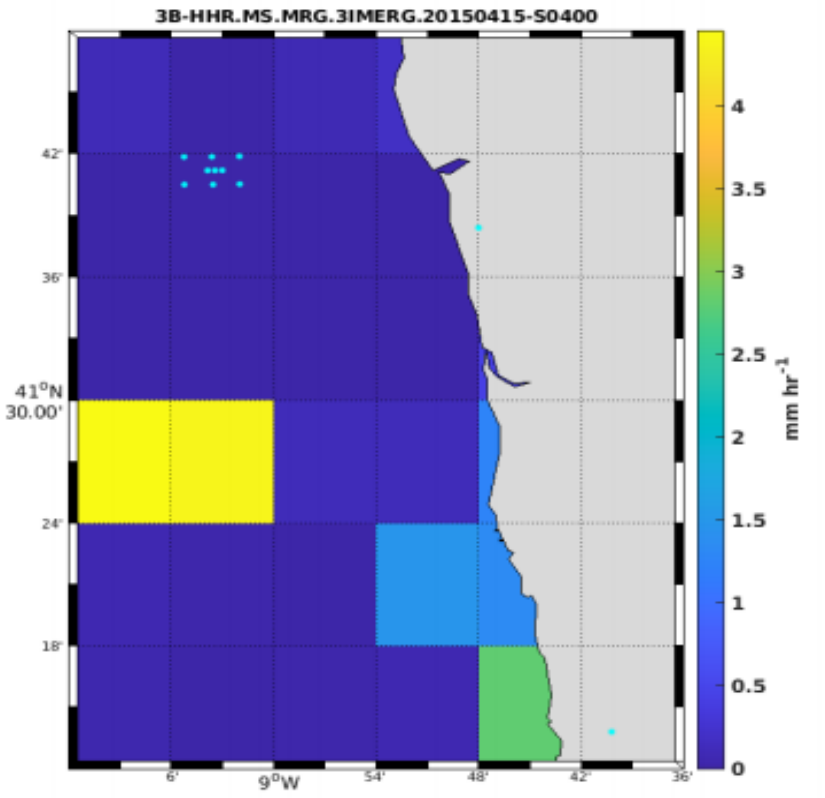
References is 18 year's data at Hvide Sande from 2002 to 2019

Hasager *et al.* 2021 *Energies*

Global Precipitation Mission (GPM) satellite

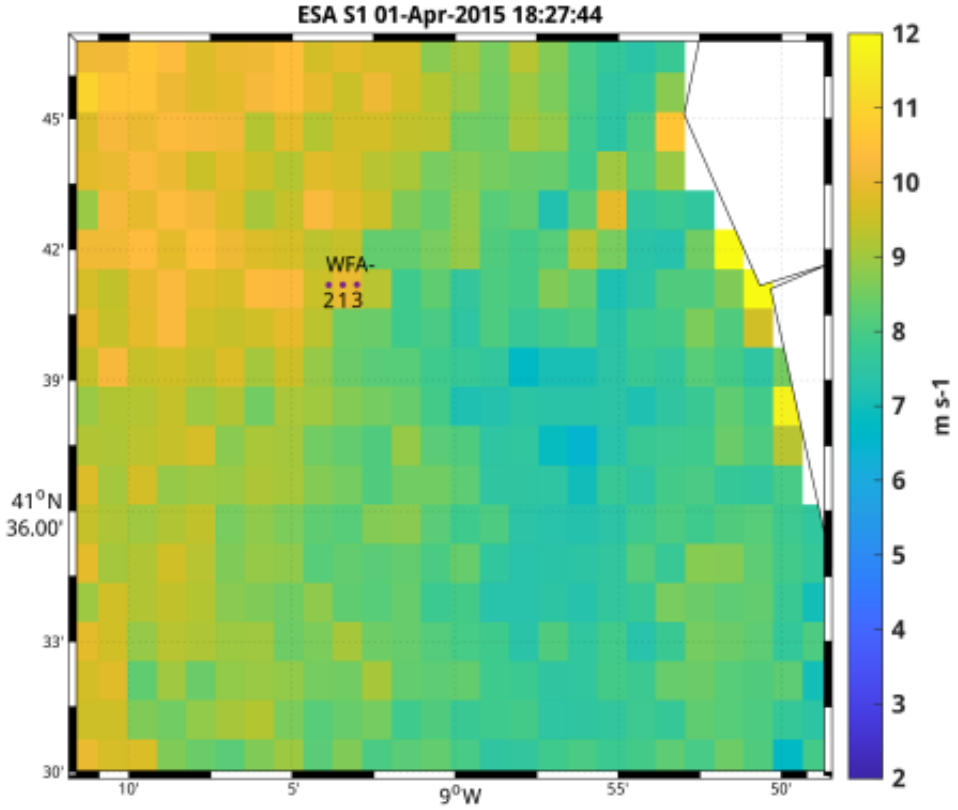
- Global coverage
- Grid resolution 25 km
- Data every 30 minutes

Global Precipitation Mission (GMP) and erosion



Rain intensity

Integrated Multi-satellitE Retrievals for GPM (IMERG)

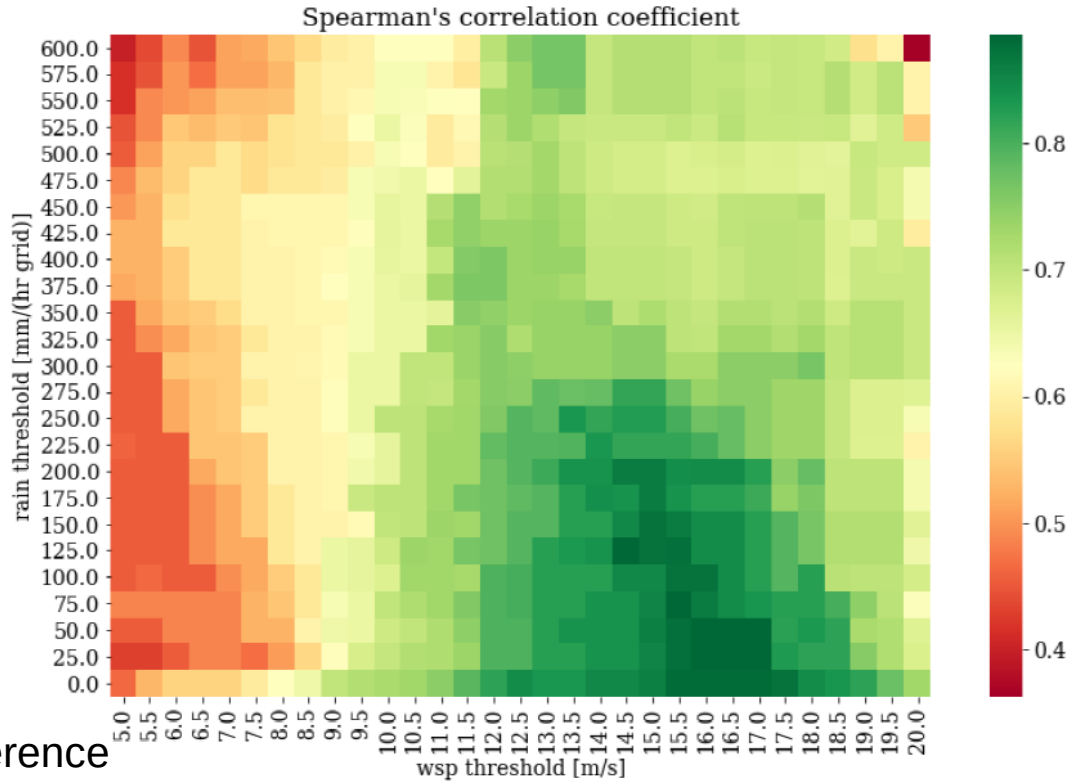


Ocean surface winds

SAR winds from Sentinel-1 from DTU

Artificial Intelligence correlation: Blade erosion vs. Numerical Weather Prediction

Representing weather in stratified format



- Correlation between damage progression and number of hours above threshold
- High correlation for high wind speeds in combination with rain
- Mesoscale weather model does not consider wake effects, blockage, etc.

WESC 2021 Conference

Madsen *et al.* 2021

Conclusions

– Nowcasting for erosion safe mode operation demonstration is in progress
  • Eventually wind farm control strategy is necessary

– Meteorological instrument technologies to be further developed and tested

– Long-term rain erosion risk mapping need further validation, e.g. using novel rain erosion test results (Bech et al. 2022, submitted) and meteorological data analysis including satellite data

– Repair recommendation based on meteorological data and blade erosion data using AI is established

Acknowledgements

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- EUDP grant 64021-0003 for the IEA Wind Task 46 Erosion of wind turbine blades (2021-2025).

Position:

- Professor II, Charlotte Hasager at University of Bergen (2020-2023).

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