Erosion safemode control demonstration

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Publication date:
2021

Document Version
Publisher's PDF, also known as Version of record

Erosion safe mode control demonstration

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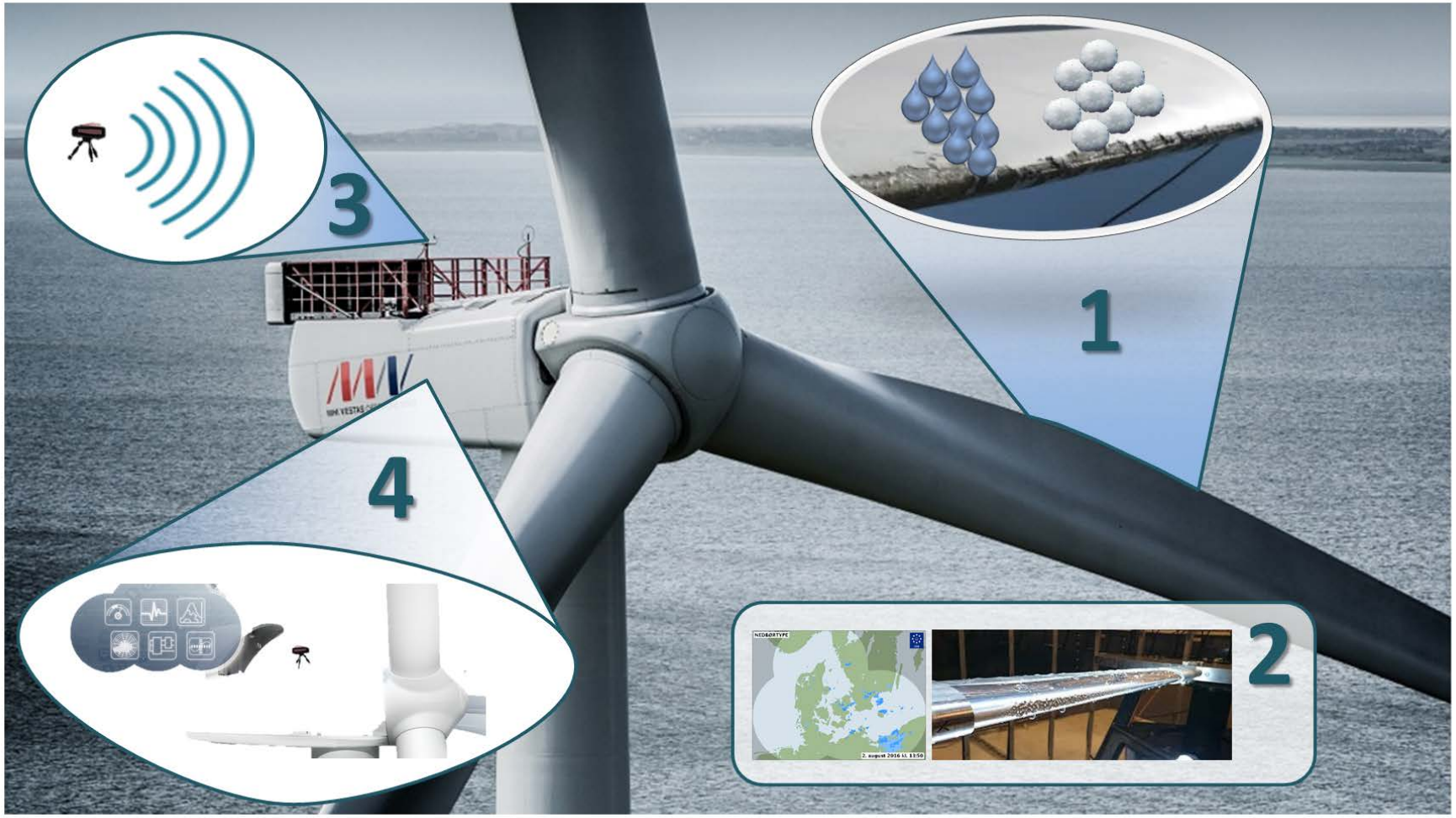
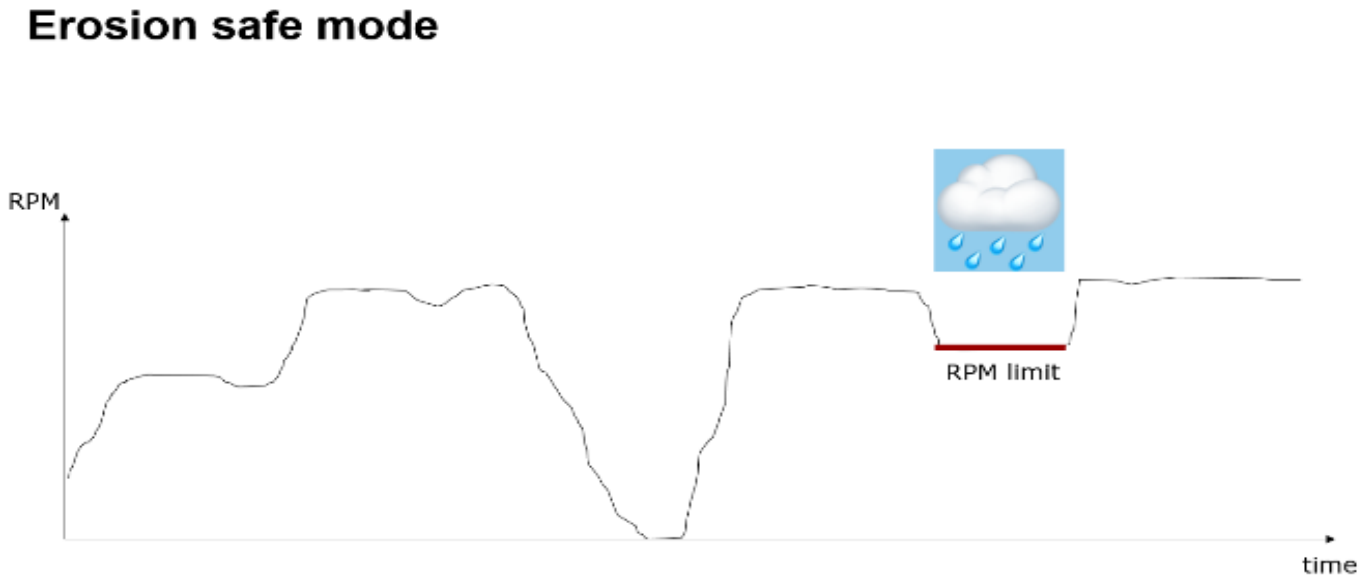
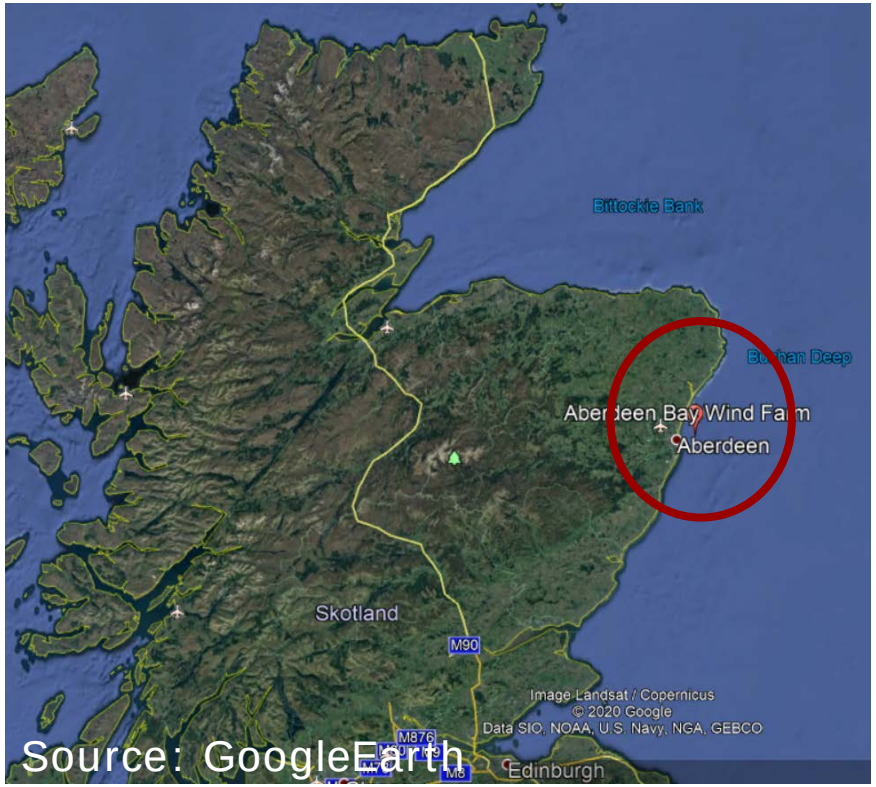
EERA SP4 Aerodynamics Loads & Control, Blade Erosion Workshop
14 December 2021 online, organizer CENER


3
1
4
2

Erosion-safe mode operation



Aberdeen Bay Wind Farm



Source: GoogleEarth


Source: Vattenfall

Aberdeen Bay Wind Farm

- Wind turbine V164 at 8.8 MW
- Hub-height 120 m
- Wind farm 11 turbines
- Distance to shore 3 km

Erosion-safe mode demonstration campaign

Erosion safe operation

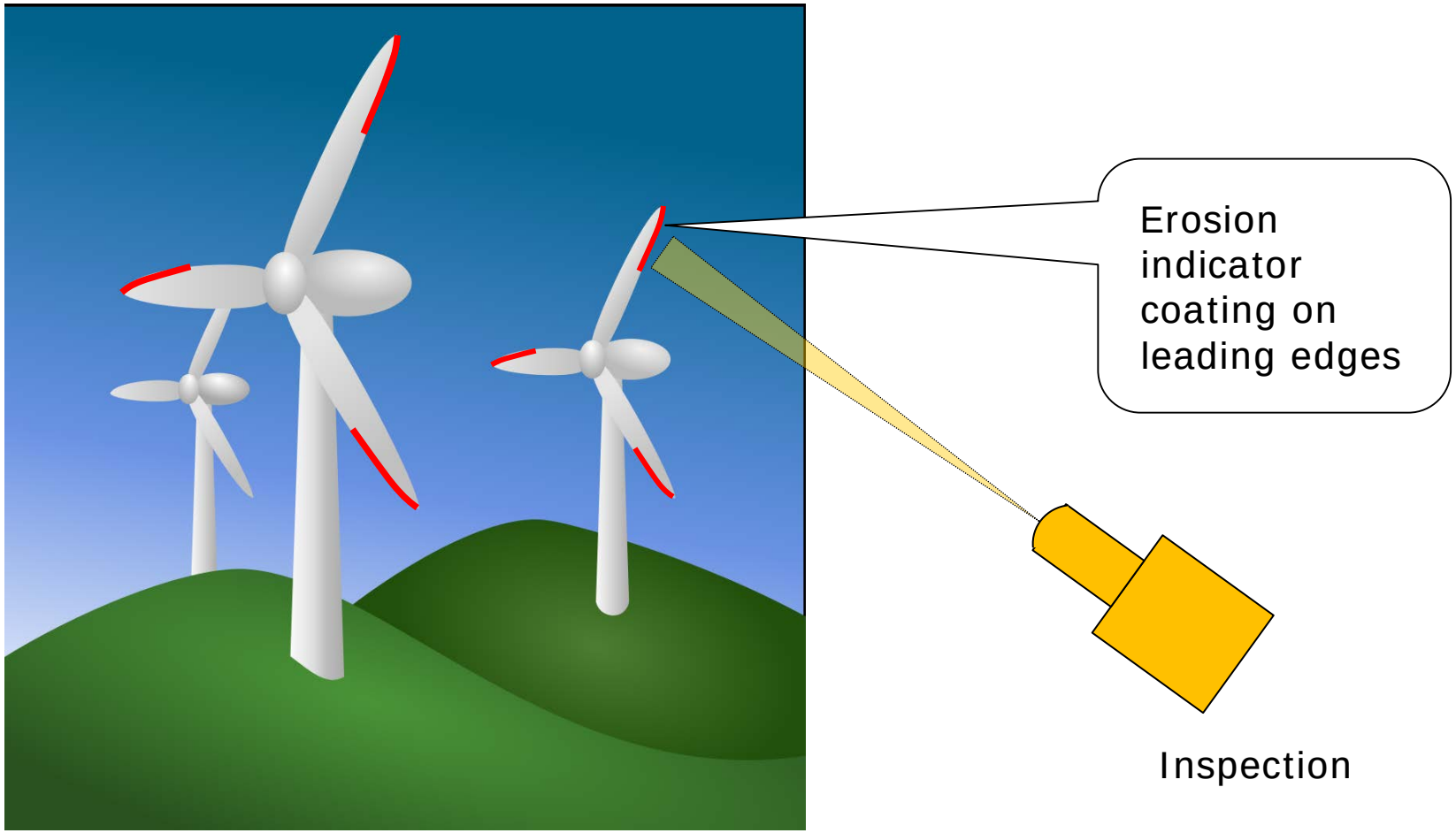
Standard operation

Aim is to compare:

- Erosion rate
- Cost model (profit)

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

Technical implementation



A priori knowledge

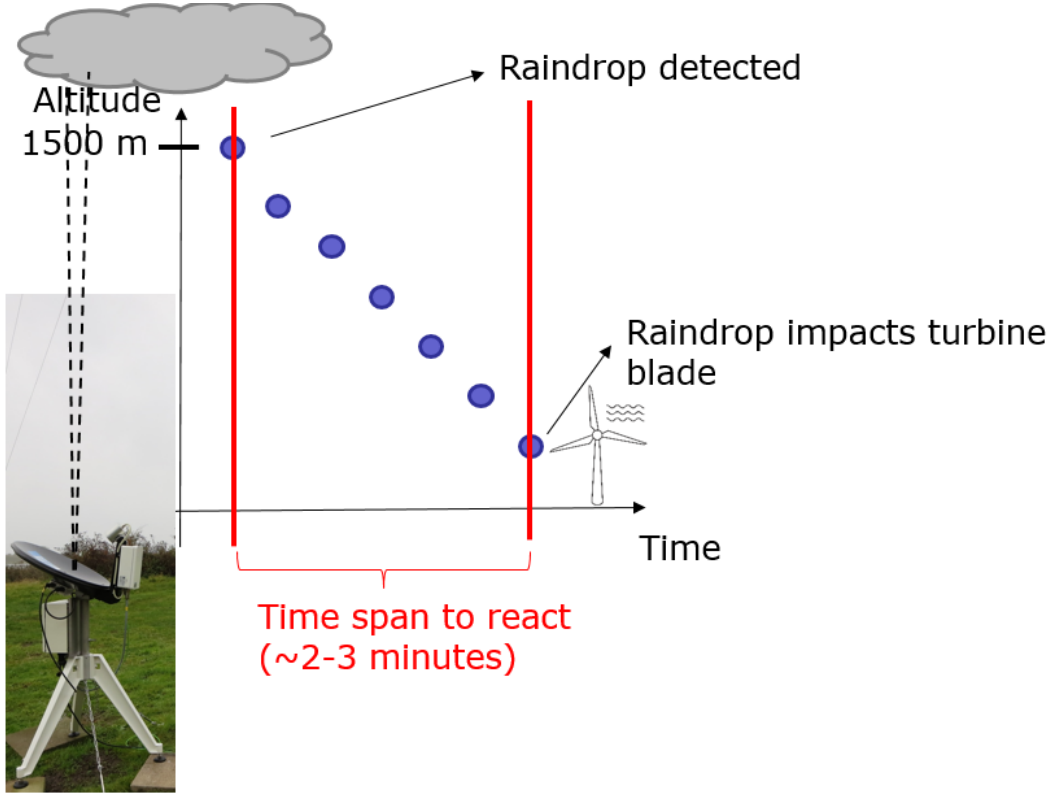
VN-curve of the indicator coating.

Testing is done in Rain Erosion Tester (RET).

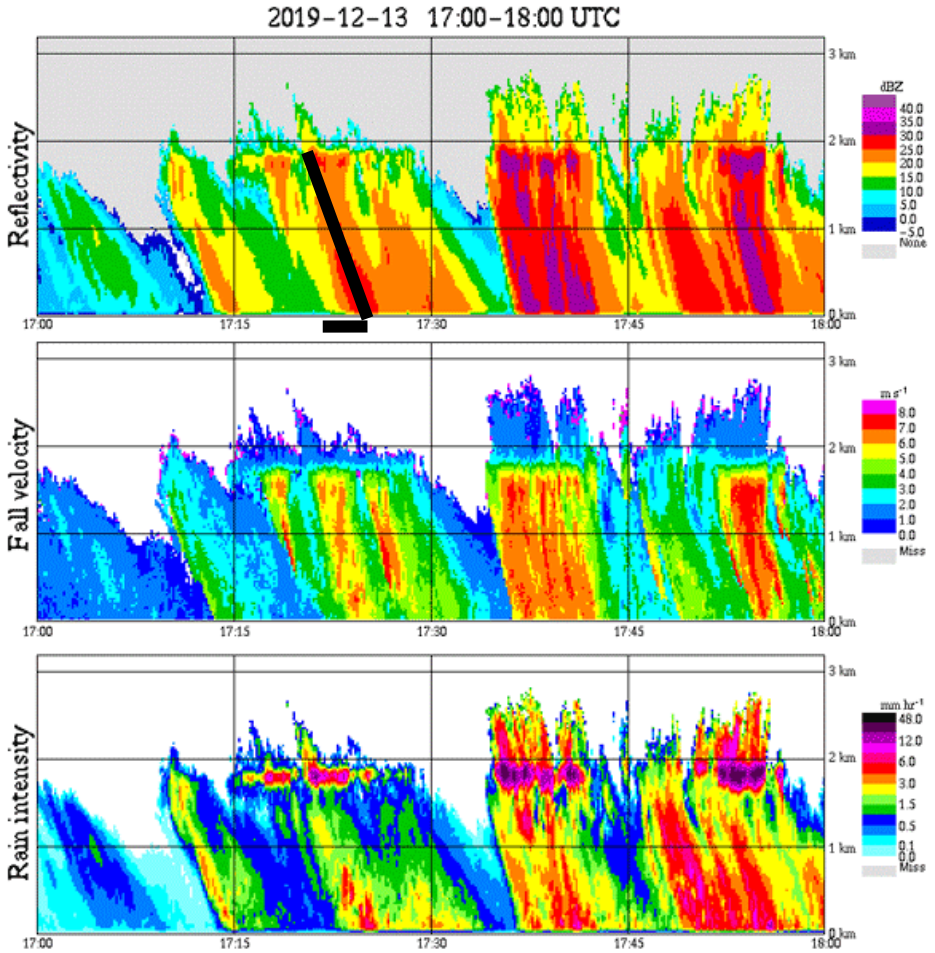
Technical implementation

Micro Rain Radar
at the nacelle

Micro Rain Radar



Source: Anna-Maria Tilg



Tilg et *al.* 2020, *Wind Energy Science*

A priori knowledge

Expected rain and wind at site

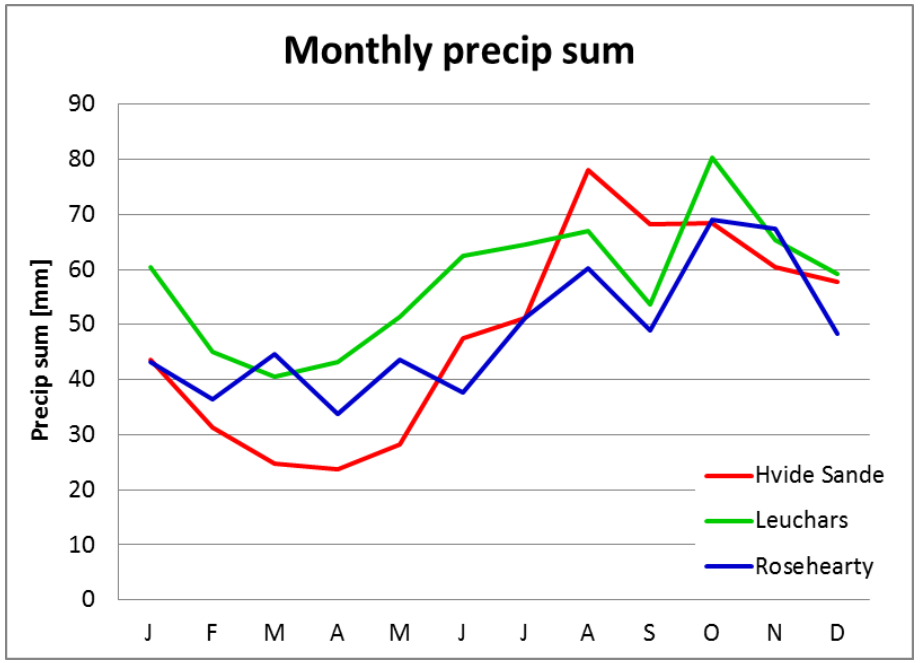
No data is available on site

Initial analysis comparing precipitation at Danish and Scottish sites

Numerical model (ERA5)

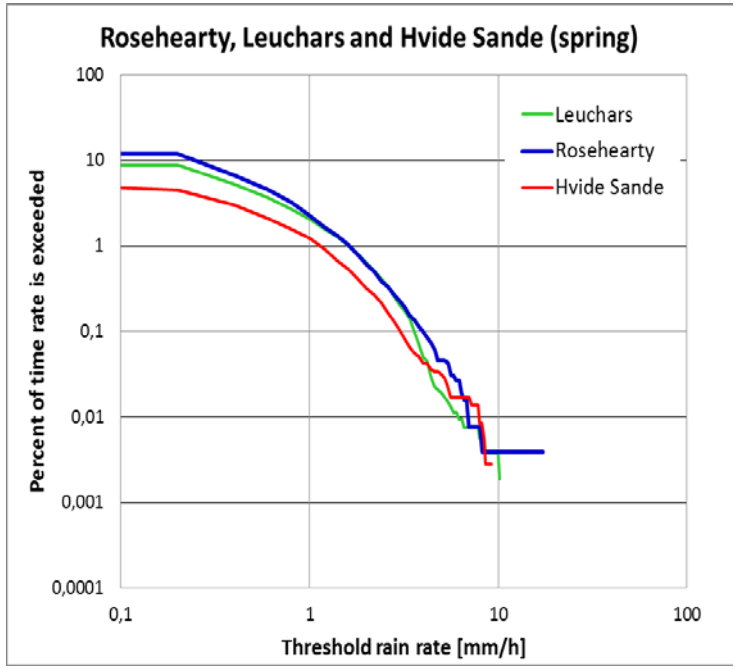
Precipitation observations

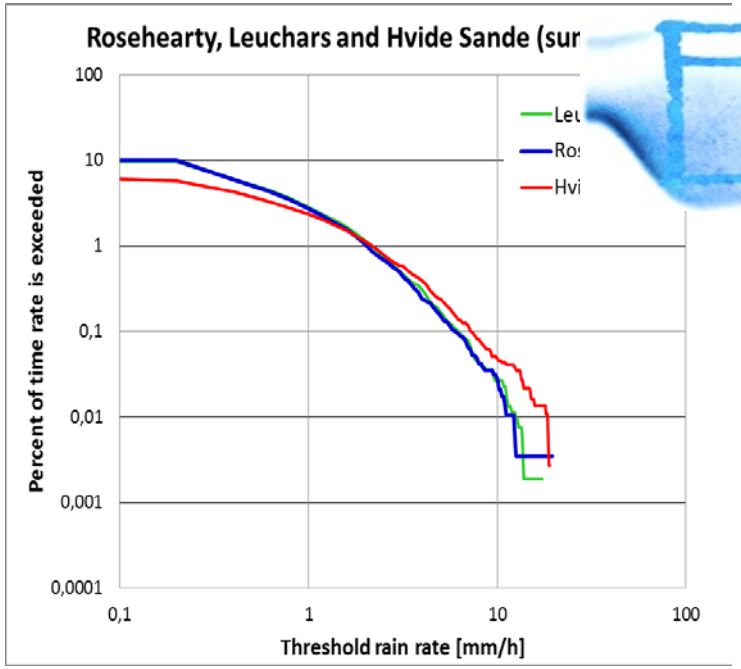
Courtesy: Google Earth



Courtesy; Flemming Vejen, DMI

Data from CEDA and DMI


Rosehearty, Leuchars and Hvide Sande (spring)
Percent of time rate is exceeded
100
10
1
0,1
0,01
0,001
0,0001
0,1
1
10
100
Threshold rain rate [mm/h]
Leuchars
Rosehearty
Hvide Sande


Rosehearty, Leuchars and Hvide Sande (sur
Percent of time rate is exceeded
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Threshold rain rate [mm/h]
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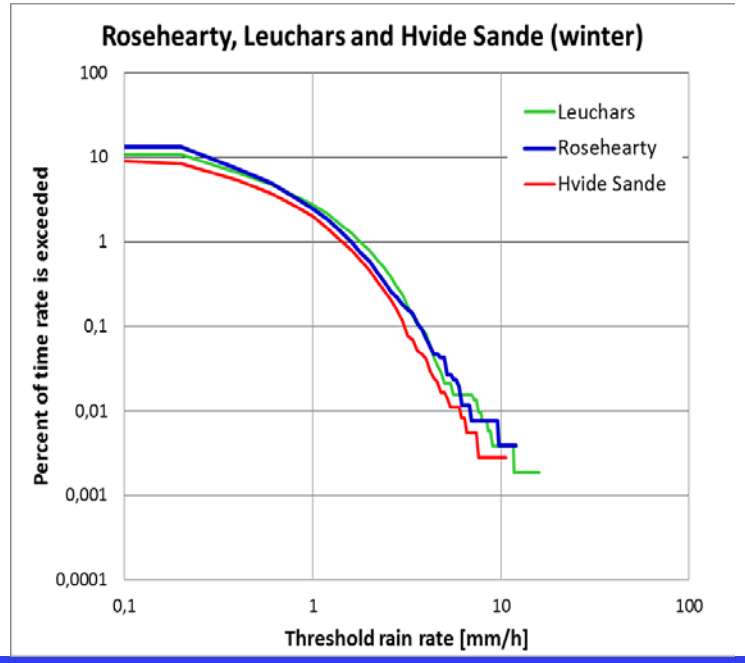
Rosehearty, Leuchars and Hvide Sande (winter)
Percent of time rate is exceeded
100
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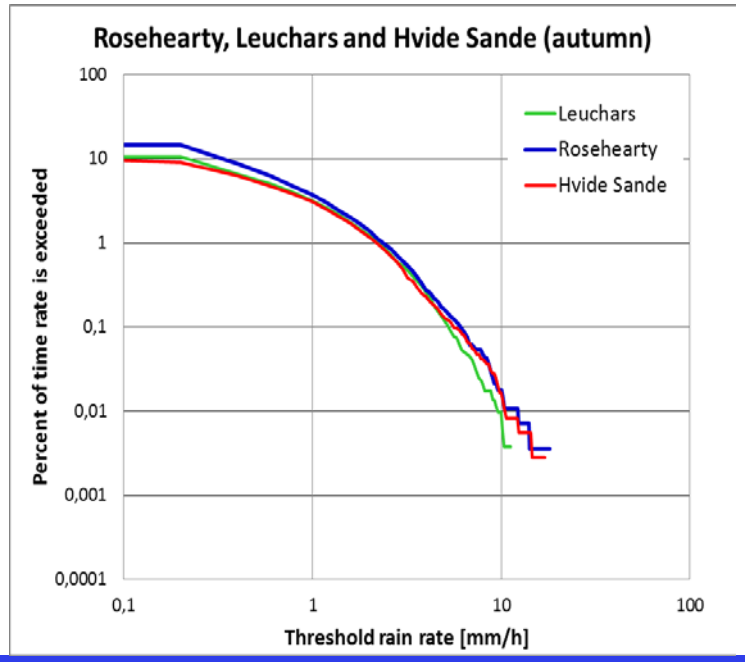
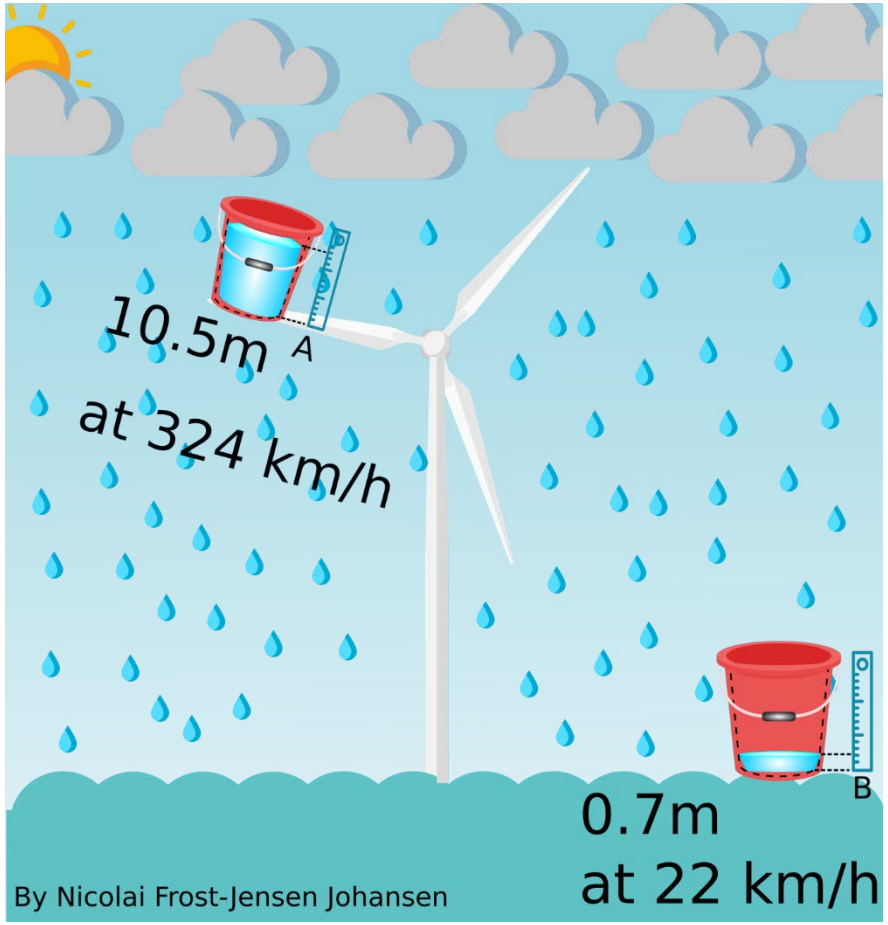
10
100
Threshold rain rate [mm/h]
Leuchars
Rosehearty
Hvide Sande


Rosehearty, Leuchars and Hvide Sande (autumn)
Percent of time rate is exceeded
100
10
1
0,1
0,01
0,001
0,0001
0,1
1
10
100
Threshold rain rate [mm/h]
Leuchars
Rosehearty
Hvide Sande

Rain ‘magnified’



Hasager *et al.* 2021, in Book chapter

Annual rain amount at 0.7 m

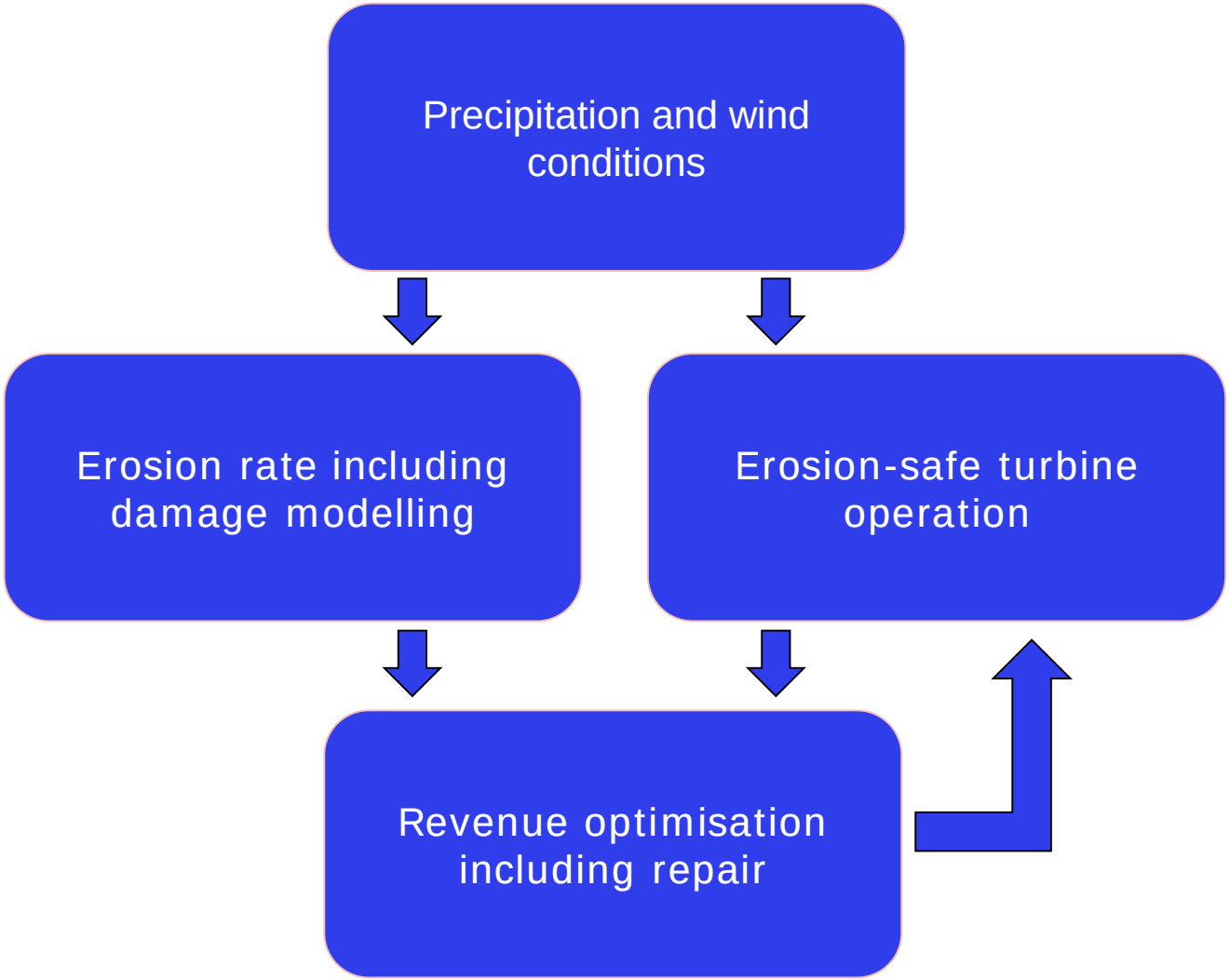
Tip speed of the blades at 90 m/s

Assume the turbine is at rated speed.

Take

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

Erosion-safe mode



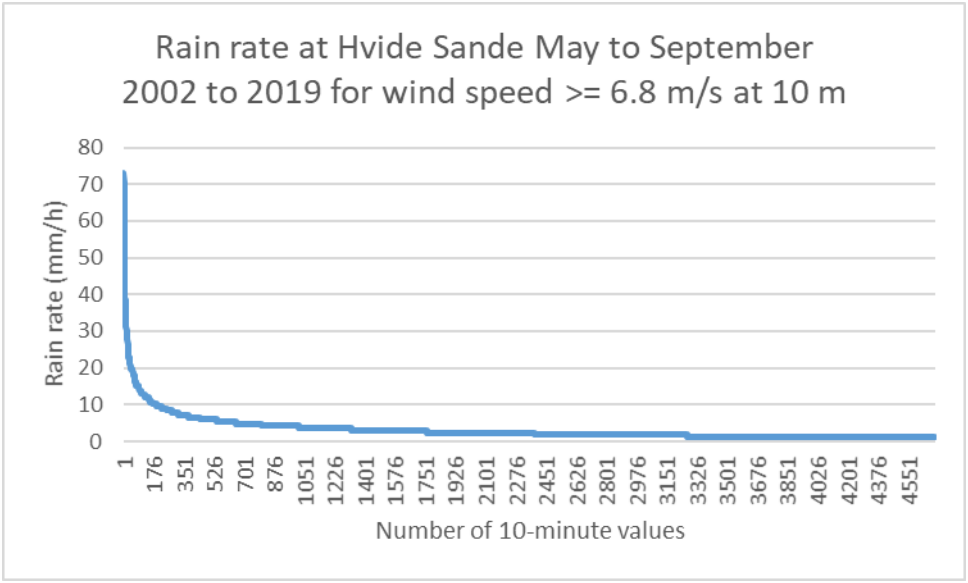
Hasager *et al.* 2020 *Renewable Energy*

Hvide Sande: How much time?

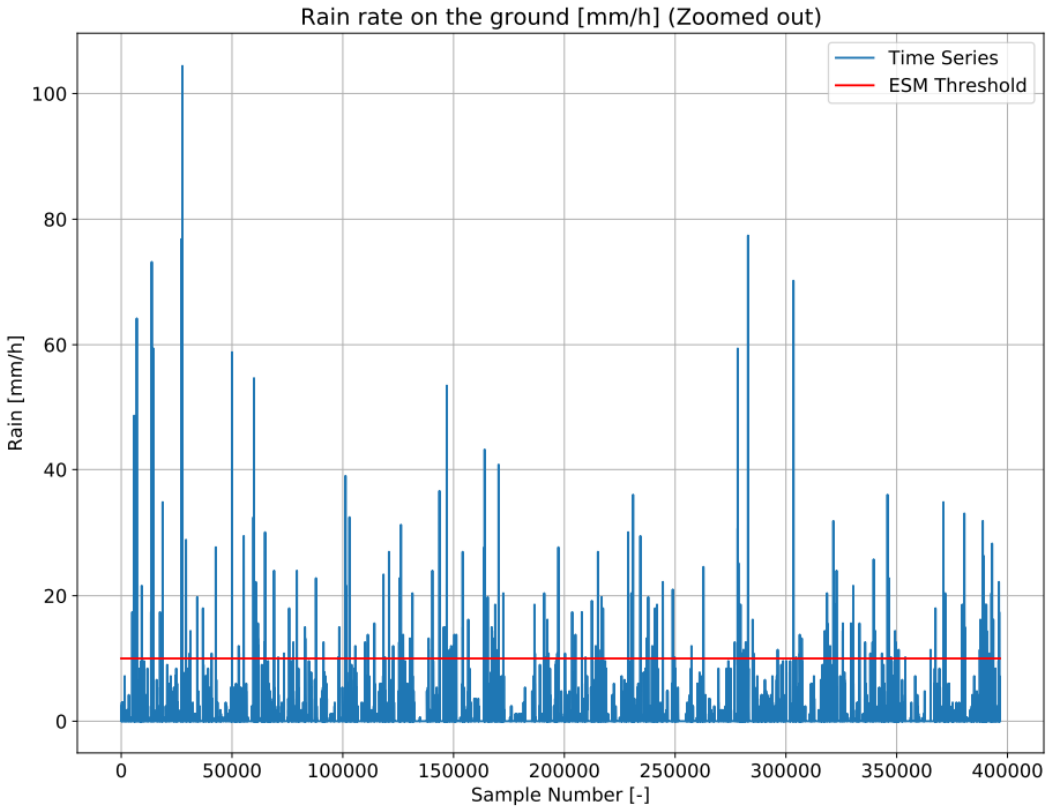
- In 18 years May to September 2002 to 2019 there are
  - 12.200 10-minute values with rain >= 0.6 mm/h
  - 8.296 10-minute values with rain >= 1.2 mm/h
  - 3.064 10-minute values with rain >= 3.0 mm/h
  - 377 10-minute values with rain >= 10.0 mm/h

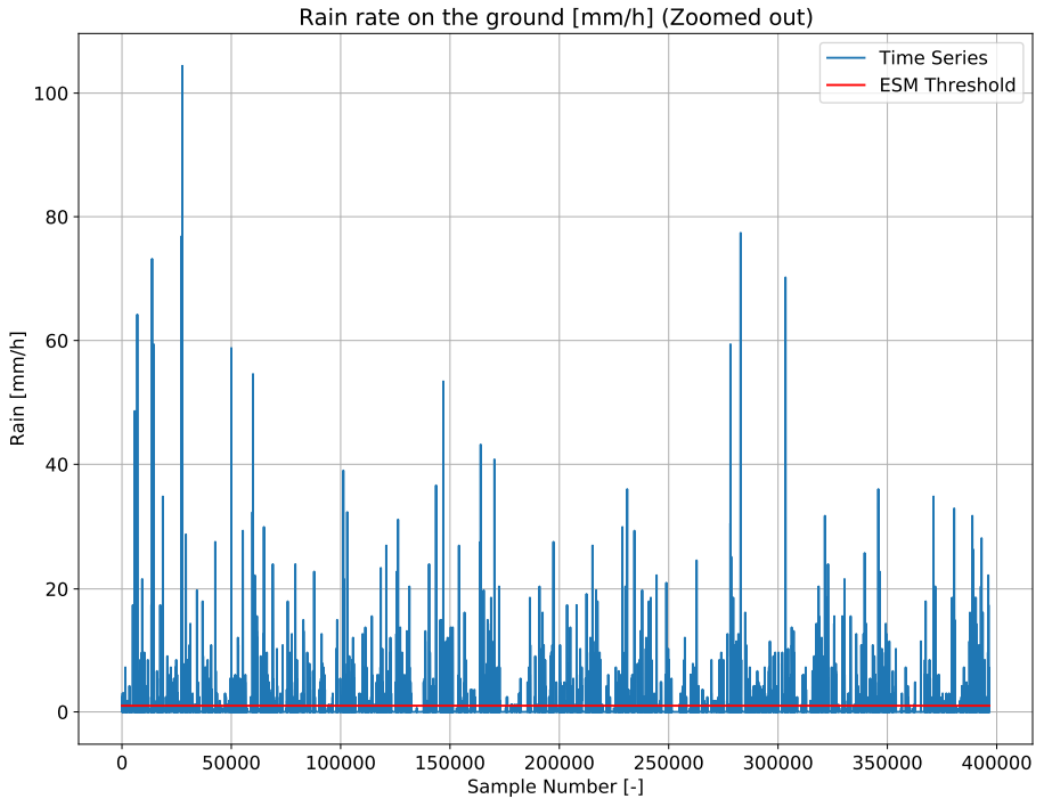
Using 1.2 mm/h as threshold gives in 5 months
460 10-minute values, i.e. 77 hours (3.2 days)

Out of these wind speed >= 6.8 m/s at 10 m
261 10-minute values, i.e. **43 hours (1.8 days)**



Rain rate for 18 years *only May to September!*





MRR PRO

- We can operate for rain rate >= 1 mm/h in 10 minute intervals
- We can alternatively operate for rain rate >= 1 mm/h in 1 or 2 minute intervals
- We can suggest to stop the turbine in case of hail

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

WP5 Peer-reviewed articles

Published

- Bech, J. I., Hasager, C.B., Bak, C. 2018 Extending the life of wind turbine blade leading edges by reducing the tip speed during extreme precipitation events. Wind Energy Science, 3, 729–748, https://doi.org/10.5194/wes-3-729-2018, 2018.
- Fæster, S. Johansen, N. F.-J., Mishnaevsky Jr., L., Kusano, Y., Bech, J.I. and Madsen, M. B. 2021 Rain erosion of wind turbine blades and the effect of air bubbles in the coatings *Wind Energy, DOI: 10.1002/we.2617*
- Hasager CB, Vejen F, Skrzypiński WR, Tilg A-M. Rain Erosion Load and Its Effect on Leading-Edge Lifetime and Potential of Erosion-Safe Mode at Wind Turbines in the North Sea and Baltic Sea. 2021 *Energies*, 14(7):1959. https://doi.org/10.3390/en14071959
- Hasager, C.B., Vejen, F., Bech, J. I., Skrzypiński, W. R., Tilg, A.-M. Nielsen, M. 2020 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*, 149, 91-102. https://doi.org/10.1016/j.renene.2019.12.043
- Mishnaevsky Jr, L.. et al. 2019 Micormechanisms of leading edge erosion of wind turbine blades:X-ray tomography analysis and computational studies, *Wind Energy* https://doi.org/10.1002/we.2441
- Mishnaevsky Jr., L., Hasager, C.B., Bak, C., Tilg, A.-M., Bech, J. I., Rad, S.D., Fæster, S. 2021 Rain erosion of wind turbine blades: Understanding, prevention and protection, *Renewable Energy*, 169, 953–969, https://doi.org/10.1016/j.renene.2021.01.044.
- Skrzypiński, W.R.; Bech, J.I.; Hasager, C.B.; Tilg, A.-M.; Bak, C. Optimization of the erosion-safe operation of the IEA Wind 15 MW Reference Wind Turbine. *J. Phys: Conf. Ser*. 2020, 1618, 052034
- Tilg, A.-M., Hasager, C. B., Kirtzel, H.-J., and Hummelshøj, P. 2020 Brief communication: Nowcasting of precipitation for leading edge erosion-safe mode, *Wind Energ. Sci.*, 5, 3, p. 977-981.https://doi.org/10.5194/wes-2020-4
- Tilg, A.-M., Vejen, F., Hasager, C. B., Nielsen, M. 2020 Rainfall kinetic energy in Denmark: relationship with drop size, wind speed and rain rate. *J. Hydrometeor*. https://doi.org/10.1175/JHM-D-19-0251.1
- Tilg, A.-M., Hagen, M., Vejen, F., Hasager, C. B. 2021 Variation of leading-edge-erosion relevant precipitation parameters with location and weather 2 type. *Meteorol. Z.,* Vol. 30, No. 3, 251–269, DOI 10.1127/metz/2021/1063
- Tilg, A.-M., Skrzypiński, W. R., Hannesdóttir, Á., Hasager, C.B. 2021 Effect of drop-size parameterization and rain amount on blade-lifetime calculations considering leading-edge erosion, *Wind Energy* (accepted)

Book chapter

- Hasager, C.B., Mishnaevsky, L., Bak, C., Bech, J.I., Fæster, S., Johansen, N. F.-J., 2021 How can we combat leading edge erosion at wind turbine blades? DOI: https://doi.org/10.11581/DTU.00000214 In: Jørgensen, B.H. et al. DTU International Energy Report 2021: Perspectives on Wind Energy.

Acknowledgements

- We acknowledge the funding support by the Innovation Fund Denmark
- grant 6154-00018B for the project EROSION.

www.rain-erosion.dk

Innovation Fund Denmark


DTU