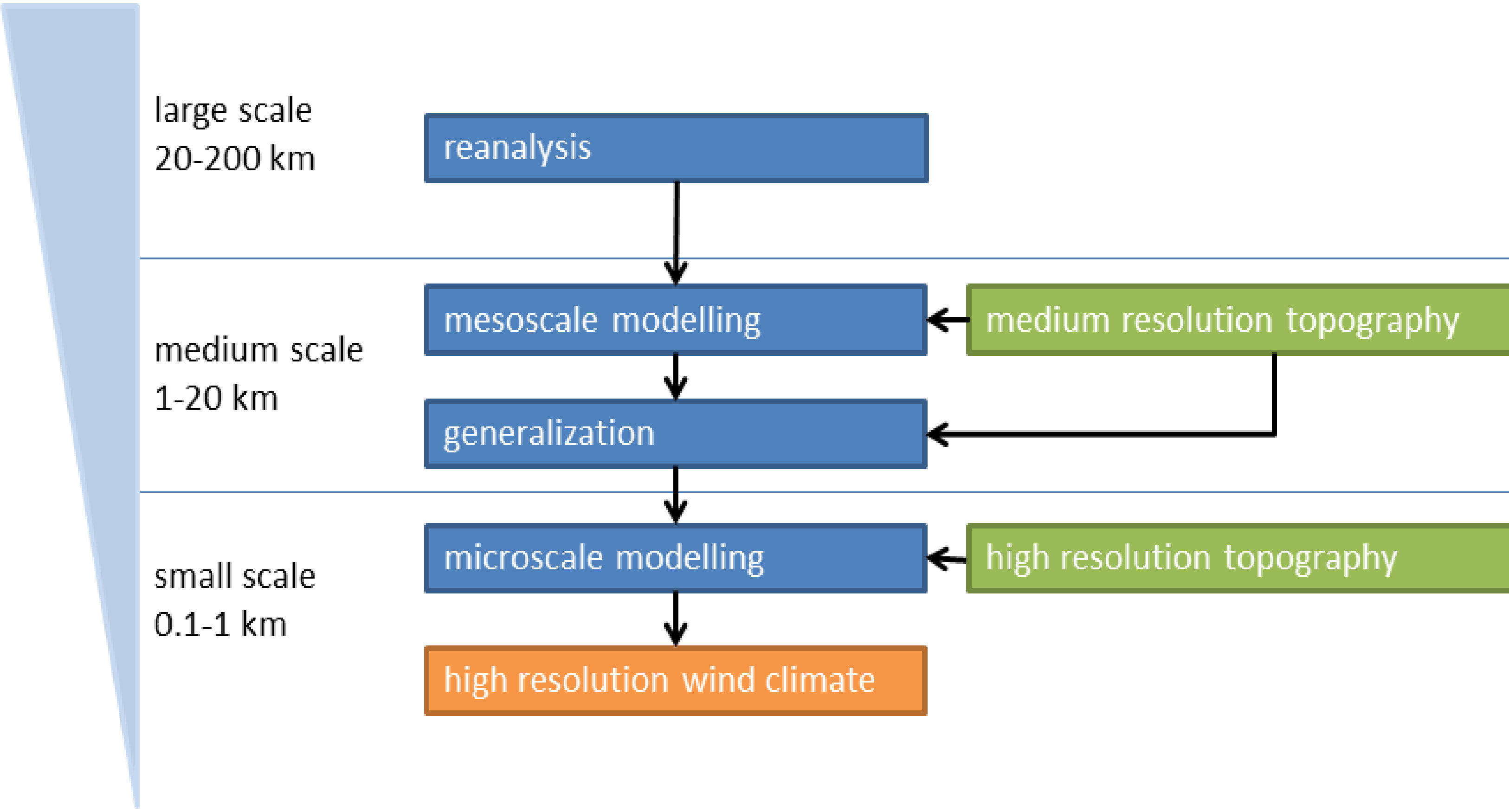
DTU

Rogier Floors & colleagues from DTU

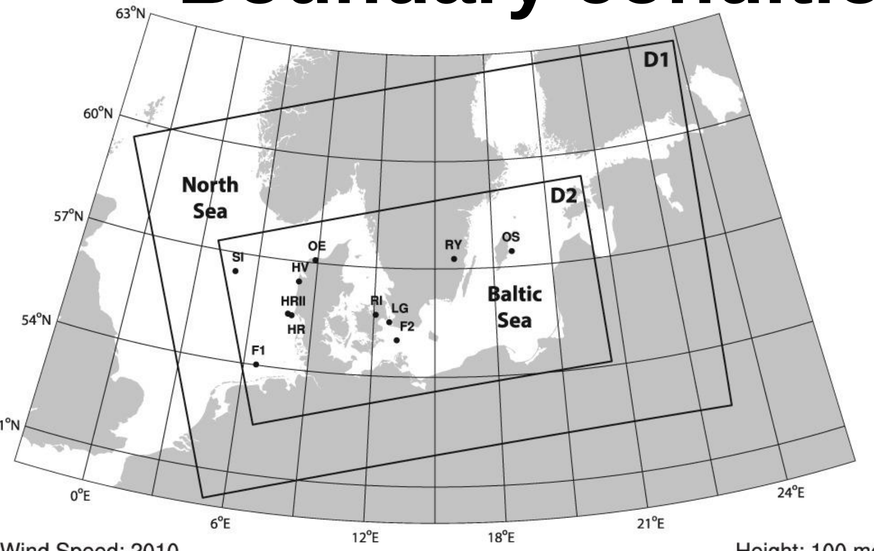
# Current usage and future applications of reanalysis data

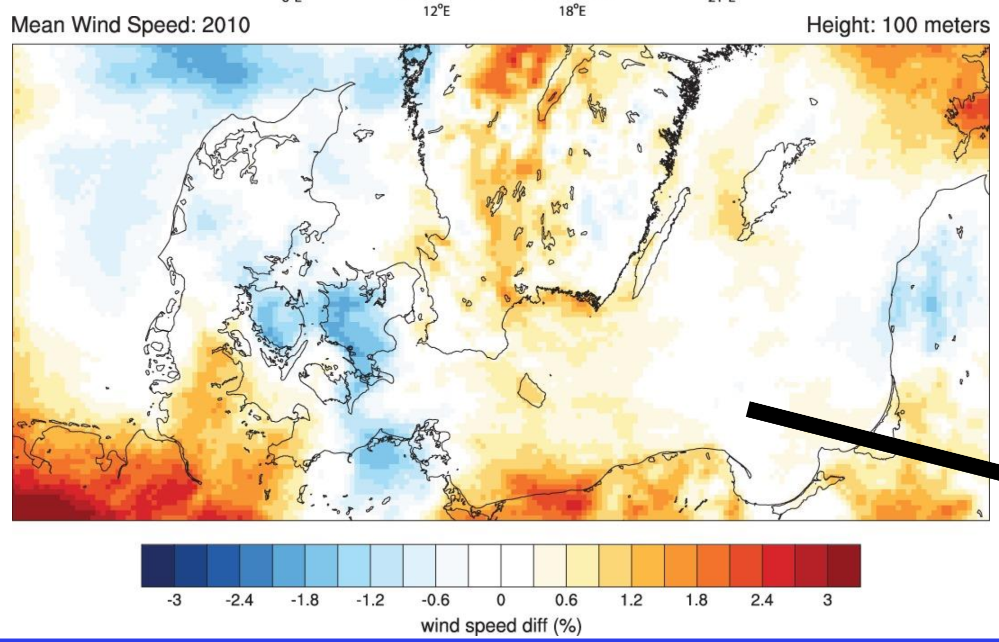
# The importance of reanalysis for wind energy

- Regional wind climate vital for identifying areas with the best wind resources
- Even high-resolution regional reanalysis may miss features present on microscale (extreme winds, rain erosion etc).
- Apart from long-term wind resource, the temporal aspects are important for grid integration (e.g. CorRES)
- Resolving microscale features and in situ validation against measurements are crucial



# Boundary conditions for mesoscale models




ERA-I – CFSR (%)

Geosci. Model Dev., 13, 5053–5078, 2020
https://doi.org/10.5194/gmd-13-5053-2020

Geoscientific Model Development
Open Access
EGU

**The making of the New European Wind Atlas – Part 1: Model sensitivity**

**Andrea N. Hahmann[1], Tija Sīle[2], Björn Witha[3,4], Neil N. Davis[1], Martin Dörenkämper[5], Yasemin Ezber[6], Elena García-Bustamante[7], J. Fidel González-Rouco[8,9], Jorge Navarro[7], Bjarke T. Olsen[1], and Stefan Söderberg[10,11]**

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[2]Institute of Numerical Modelling, Department of Physics, University of Latvia, Riga, Latvia
[3]ForWind, Carl von Ossietzky University Oldenburg, Oldenburg, Germany
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[9]Institute of Geoscie
[10]WeatherTech, Upps
[11]Renewable Energy

**Correspondence:** A

Received: 8 Decembe
Revised: 27 August 2

**Abstract.** This is the
creation of the New
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formed the basis for c
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**Journal of Geophysical Research: Atmospheres**

**RESEARCH ARTICLE**
10.1002/2017JD027504

**Evaluating Mesoscale Simulations of the Coastal Flow Using Lidar Measurements**

**Key Points:**
- The sensitivity of simulated win from the WRF model to varying boundary layer schemes, boun conditions, and horizontal reso is studied
- The flow in a transect across th is evaluated using lidar measure for the first time
- The modeling choices that hav be made to simulate the flow i coastal zone during a 3 month are described

**Supporting Information:**
- Supporting Information S1

INTERNATIONAL JOURNAL OF CLIMATOLOGY
*Int. J. Climatol.* 35: 3422–3439 (2015)
Published online 5 December 2014 in Wiley Online Library
(wileyonlinelibrary.com) DOI: 10.1002/joc.4217

RMetS
Royal Meteorological Society

**Wind climate estimation using WRF model output: method and model sensitivities over the sea**

BAM
Ar

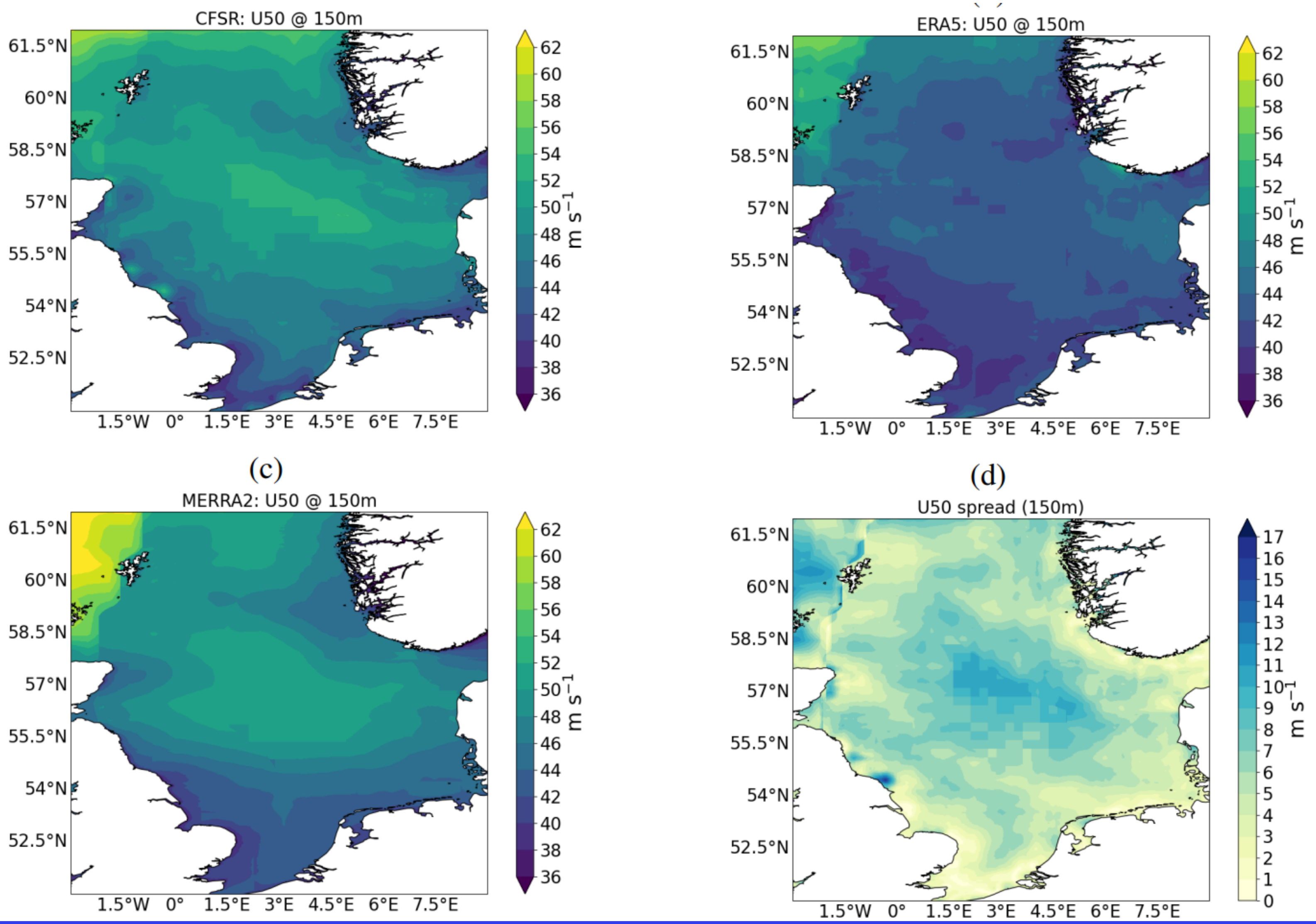
## The Global Wind Atlas

A High-Resolution Dataset of Climatologies and Associated Web-Based Application

Neil N. Davis, Jake Badger, Andrea N. Hahmann, Brian O. Hansen, Niels G. Mortensen, Mark Kelly, Xiaoli G. Larsén, Bjarke T. Olsen, Rogier Floors, Gil Lizcano, Pau Casso, Oriol Lacave, Albert Bosch, Ides Bauwens, Oliver James Knight, Albertine Potter van Loon, Rachel Fox, Tigran Parvanyan, Søren Bo Krohn Hansen, Duncan Heathfield, Marko Onninen, and Ray Drummond

https://journals.ametsoc.org/view/journals/bams/104/8/BAMS-D-21-0075.1.xml
https://gmd.copernicus.org/articles/13/5053/2020/gmd-13-5053-2020.html
https://rmets.onlinelibrary.wiley.com/doi/full/10.1002/joc.4217
https://agupubs.onlinelibrary.wiley.com/doi/10.1002/2017JD027504

# 50-year extreme winds from reanalysis




Received: 14 February 2022 | Revised: 12 June 2022 | Accepted: 4 July 2022

DOI: 10.1002/we.2771

RESEARCH ARTICLE

WILEY

## The Global Atlas for Siting Parameters project: Extreme wind, turbulence, and turbine classes

Xiaoli Guo Larsén[1] | Neil Davis[1] | Ásta Hannesdóttir[1] | Mark Kelly[1] | Lasse Svenningsen[2] | René Slot[2] | Marc Imberger[1] | Bjarke Tobias Olsen[1] | Rogier Floors[1]

[1]Wind Energy Department, Technical University of Denmark, Risø Campus, Roskilde, Denmark

[2]EMD International A/S, Aalborg, Denmark

Correspondence
Xiaoli Guo Larsén, Frederiksborgvej

**Summary**

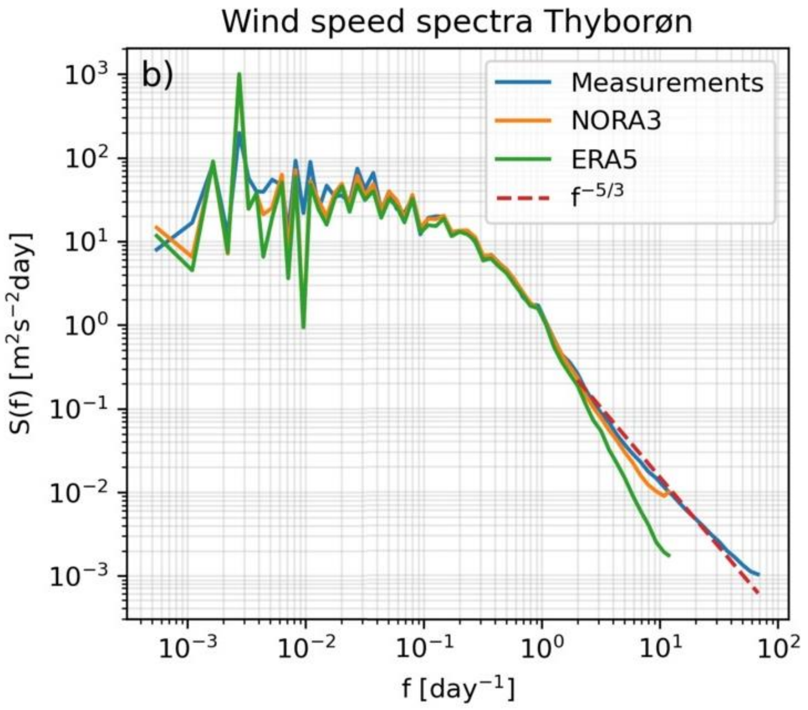
The Global Atlas for Siting Parameters project compiles a suite of models into a complex modeling system, uses up-to-date global datasets, and creates global atlases of siting parameters at a spatial resolution of 275 m. These parameters include the

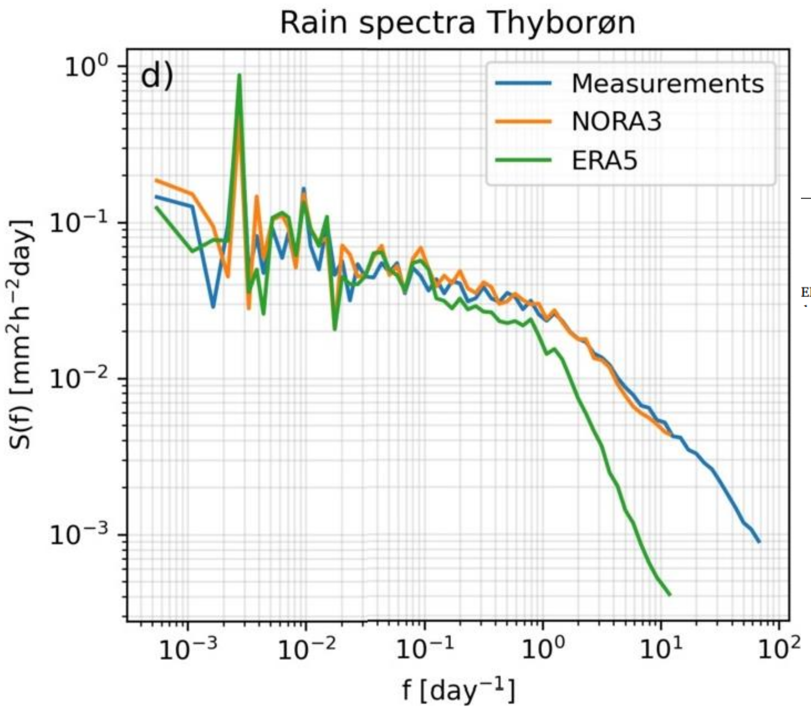
https://backend.orbit.dtu.dk/ws/portalfiles/portal/358197290/GASPOC_U50_Offshore_FullReport.pdf

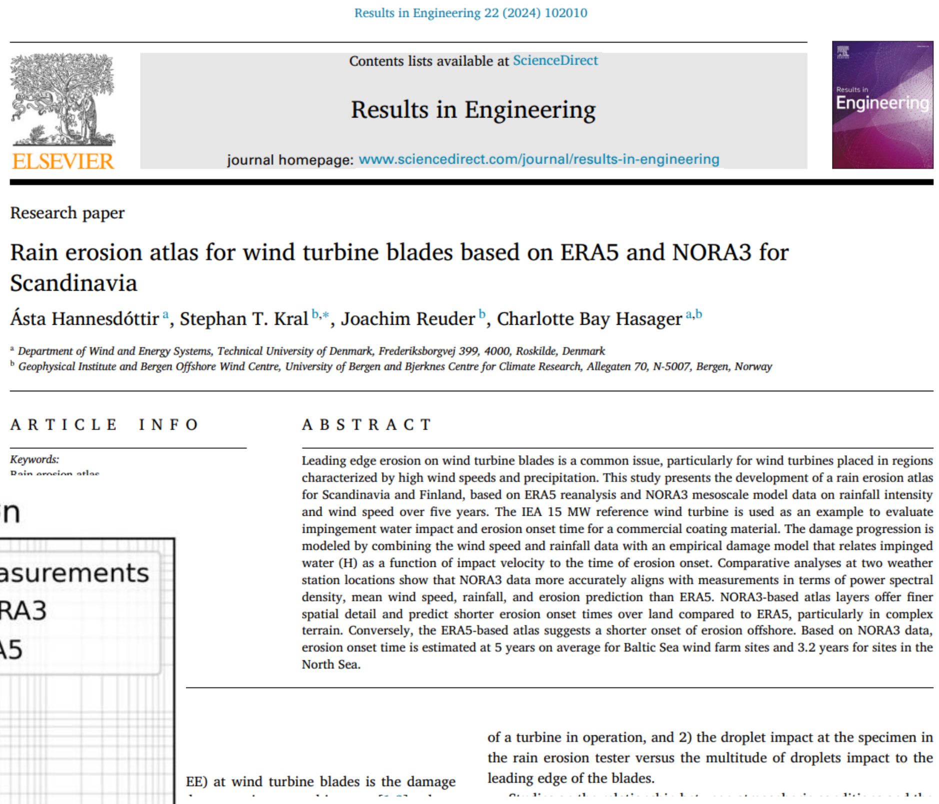
https://onlinelibrary.wiley.com/doi/epdf/10.1002/we.2771

# Rain erosion

- Leading edge erosion on wind turbine blades is a common issue, particularly for wind turbines placed in regions characterized by high wind speeds and precipitation.




Results in Engineering 22 (2024) 102010

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journal homepage: www.sciencedirect.com/journal/results-in-engineering


Research paper

Rain erosion atlas for wind turbine blades based on ERA5 and NORA3 for Scandinavia


Ásta Hannesdóttir [a], Stephan T. Kral [b,*], Joachim Reuder [b], Charlotte Bay Hasager [a,b]

[a] Department of Wind and Energy Systems, Technical University of Denmark, Frederiksborgvej 399, 4000, Roskilde, Denmark
[b] Geophysical Institute and Bergen Offshore Wind Centre, University of Bergen and Bjerknes Centre for Climate Research, Allegaten 70, N-5007, Bergen, Norway


ARTICLE INFO


Keywords:



ABSTRACT

Leading edge erosion on wind turbine blades is a common issue, particularly for wind turbines placed in regions characterized by high wind speeds and precipitation. This study presents the development of a rain erosion atlas for Scandinavia and Finland, based on ERA5 reanalysis and NORA3 mesoscale model data on rainfall intensity and wind speed over five years. The IEA 15 MW reference wind turbine is used as an example to evaluate impingement water impact and erosion onset time for a commercial coating material. The damage progression is modeled by combining the wind speed and rainfall data with an empirical damage model that relates impinged water (H) as a function of impact velocity to the time of erosion onset. Comparative analyses at two weather station locations show that NORA3 data more accurately aligns with measurements in terms of power spectral density, mean wind speed, rainfall, and erosion prediction than ERA5. NORA3-based atlas layers offer finer spatial detail and predict shorter erosion onset times over land compared to ERA5, particularly in complex terrain. Conversely, the ERA5-based atlas suggests a shorter onset of erosion offshore. Based on NORA3 data, erosion onset time is estimated at 5 years on average for Baltic Sea wind farm sites and 3.2 years for sites in the North Sea.


EE) at wind turbine blades is the damage

of a turbine in operation, and 2) the droplet impact at the specimen in the rain erosion tester versus the multitude of droplets impact to the leading edge of the blades.

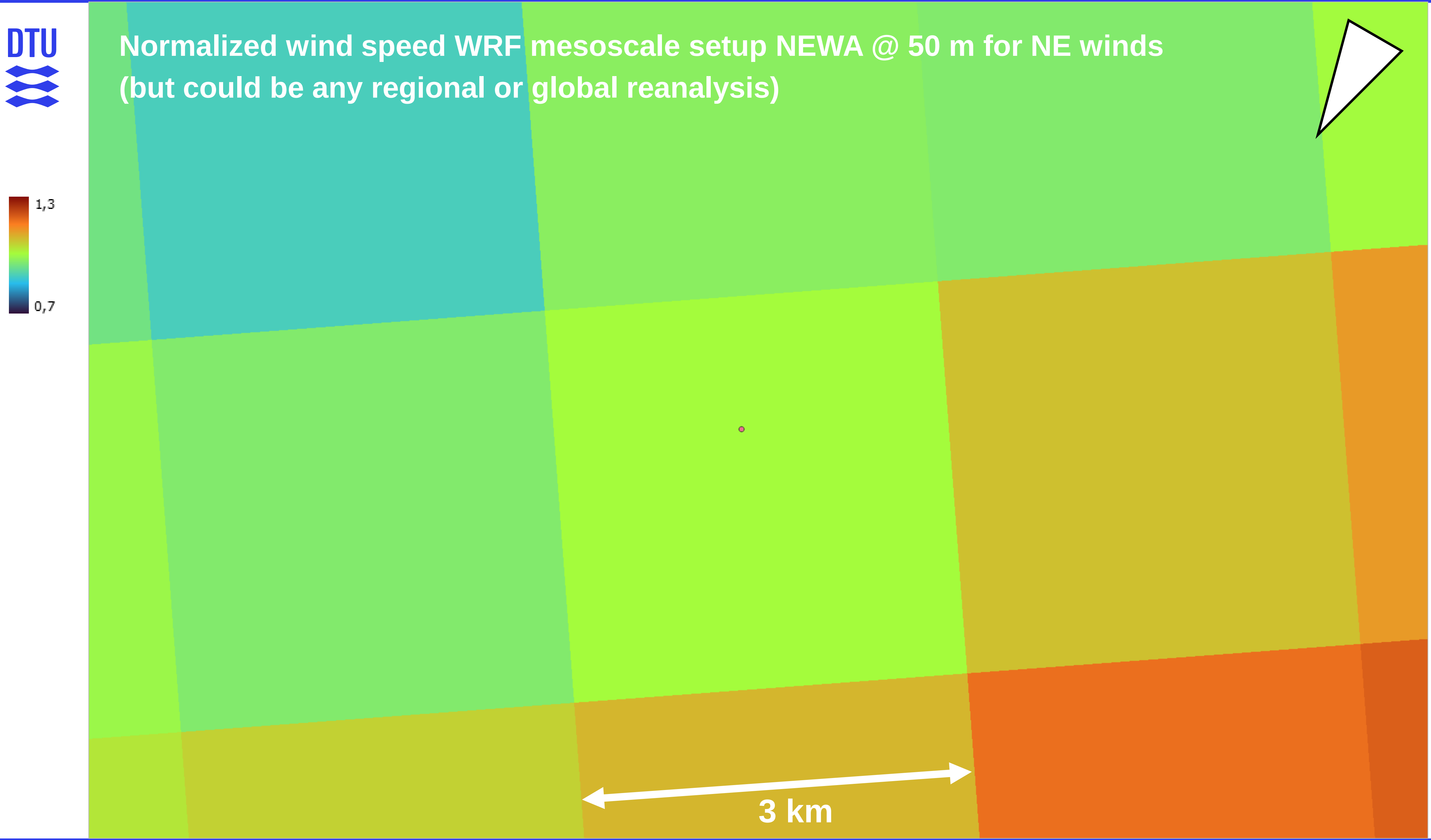
https://www.sciencedirect.com/science/article/pii/S2590123024002639

DTU

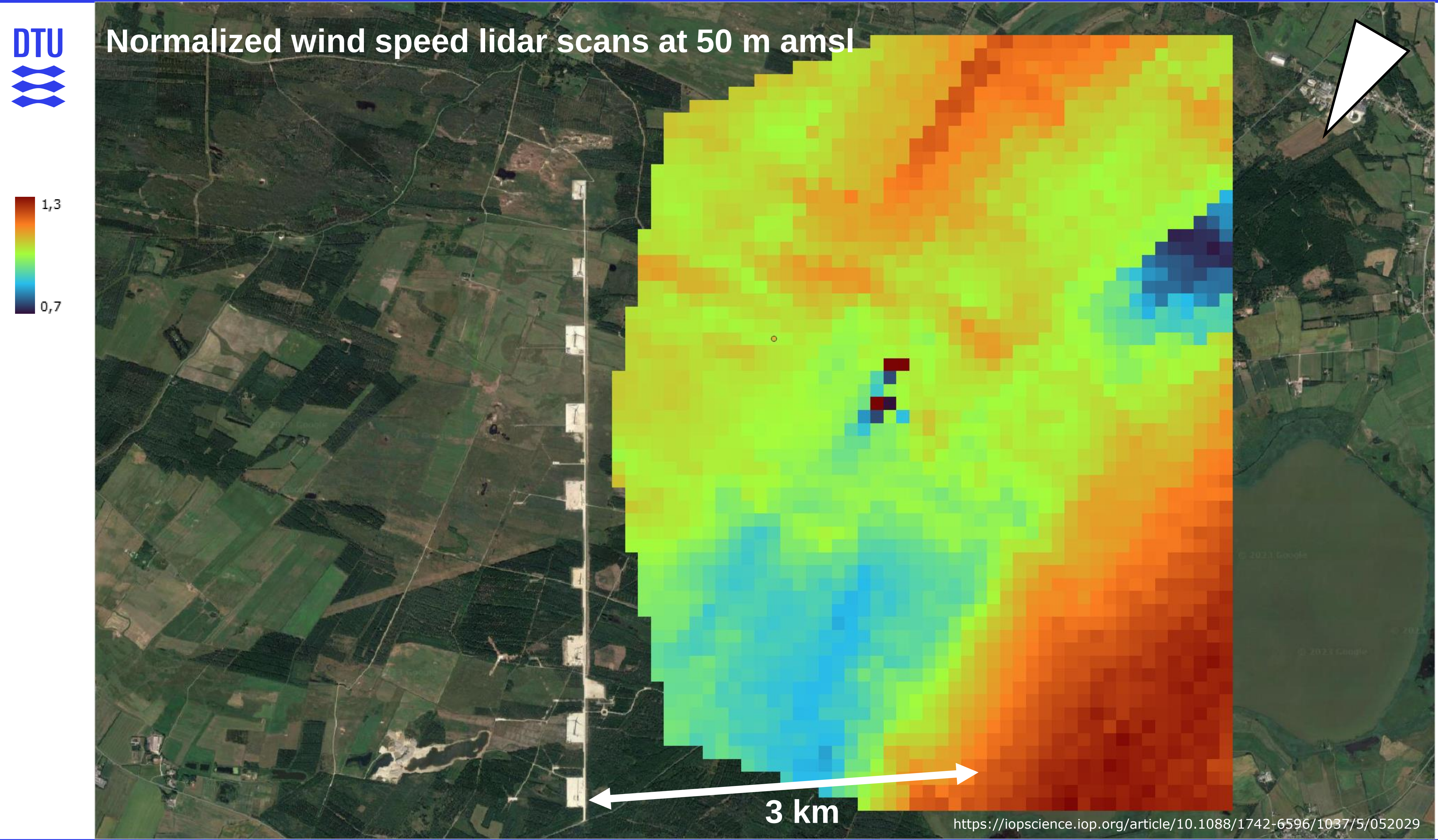
## Two meteorological masts

- Red dots equipped with cup and sonic anemometers

# Normalized wind speed WRF mesoscale setup NEWA @ 50 m for NE winds (but could be any regional or global reanalysis)

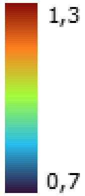


# Normalized wind speed lidar scans at 50 m amsl




https://iopscience.iop.org/article/10.1088/1742-6596/1037/5/052029

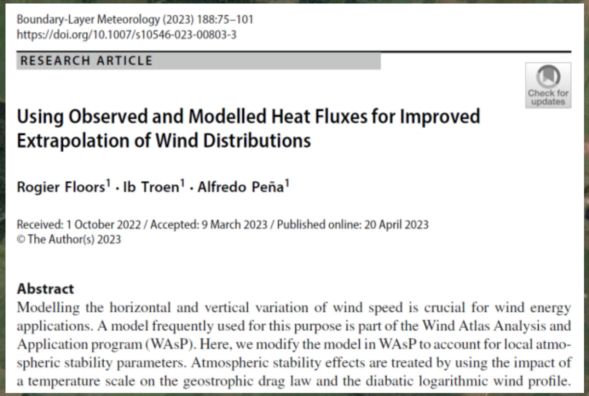
# Normalized wind speed WAsP at 50 m amsl




## WAsP microscale model:

- >1700 active users
- Uses ERA5 stability data for modelling

https://link.springer.com/article/10.1007/s10546-023-00803-3



Boundary-Layer Meteorology (2023) 188:75–101
https://doi.org/10.1007/s10546-023-00803-3

RESEARCH ARTICLE

Using Observed and Modelled Heat Fluxes for Improved Extrapolation of Wind Distributions

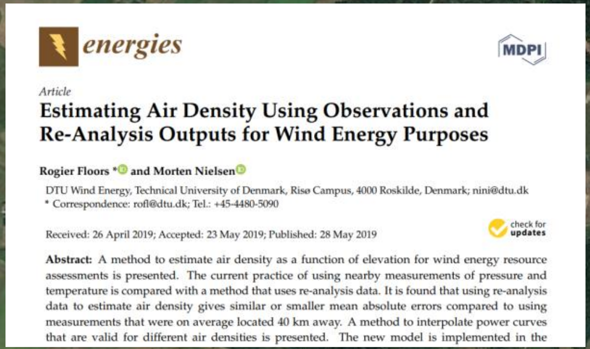
Rogier Floors[1] · Ib Troen[1] · Alfredo Peña[1]

Received: 1 October 2022 / Accepted: 9 March 2023 / Published online: 20 April 2023
© The Author(s) 2023

**Abstract**
Modelling the horizontal and vertical variation of wind speed is crucial for wind energy applications. A model frequently used for this purpose is part of the Wind Atlas Analysis and Application program (WAsP). Here, we modify the model in WAsP to account for local atmospheric stability parameters. Atmospheric stability effects are treated by using the impact of a temperature scale on the geostrophic drag law and the diabatic logarithmic wind profile.

- Uses ERA5 for air density model

https://www.mdpi.com/1996-1073/12/11/2038



energies MDPI

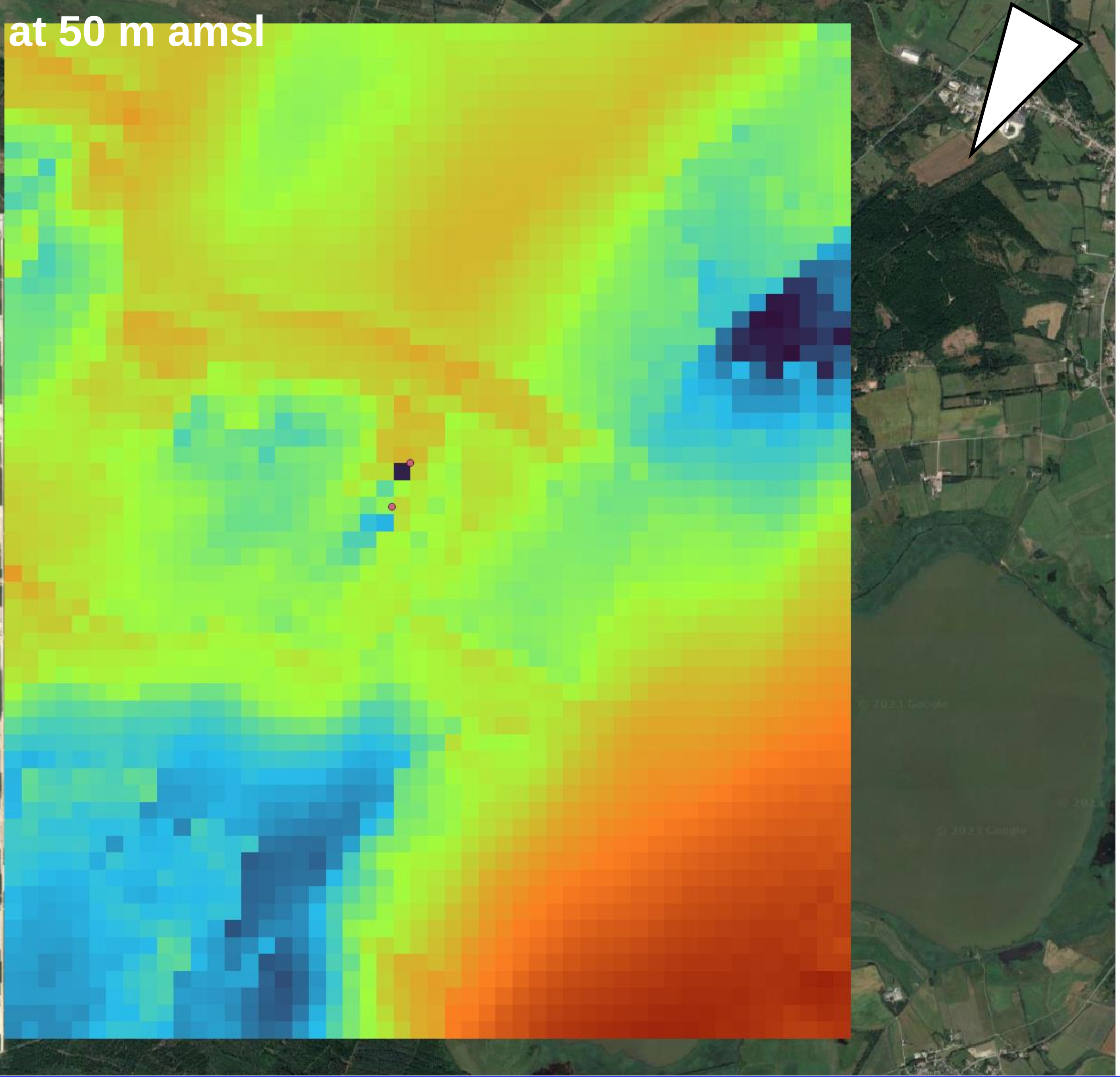
*Article*
**Estimating Air Density Using Observations and Re-Analysis Outputs for Wind Energy Purposes**

**Rogier Floors** * and **Morten Nielsen**

DTU Wind Energy, Technical University of Denmark, Risø Campus, 4000 Roskilde, Denmark; nini@dtu.dk
* Correspondence: rofl@dtu.dk; Tel.: +45-4480-5090

Received: 26 April 2019; Accepted: 23 May 2019; Published: 28 May 2019

**Abstract:** A method to estimate air density as a function of elevation for wind energy resource assessments is presented. The current practice of using nearby measurements of pressure and temperature is compared with a method that uses re-analysis data. It is found that using re-analysis data to estimate air density gives similar or smaller mean absolute errors compared to using measurements that were on average located 40 km away. A method to interpolate power curves that are valid for different air densities is presented. The new model is implemented in the



# Future applications

- Important for wind applications to have boundary scaling variables available (z0, U*, H, h)
- Important for wind applications to have wind speed and dir at some heights above surface
- Easy interface to download both in spatial and time slices (downloading a time series is currently often problematic).
- Portal for all regional reanalysis?

Thank you

Rogier Floors <rofl@dtu.dk>

Jakob Mann, Charlotte Bay Hasager, Asta Hannesdottir, Bjarke Tobias Olsen, Shubham Nayak, Andrea Hahmann, Jake Badger

# Extra: Observing wind climates

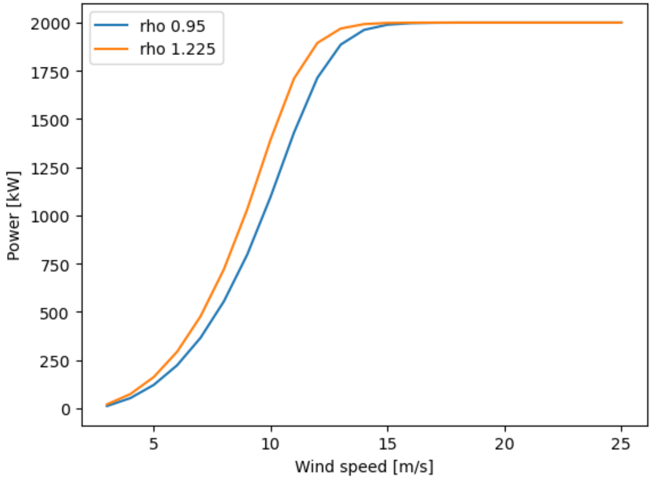
- Only mean wind speed is not enough! We want the distribution of wind speeds so that we can calculate power density per square meter of area covered by turbine

$$P = 0.5\rho \frac{1}{N}\sum_{t=0}^{N} U_t^3$$

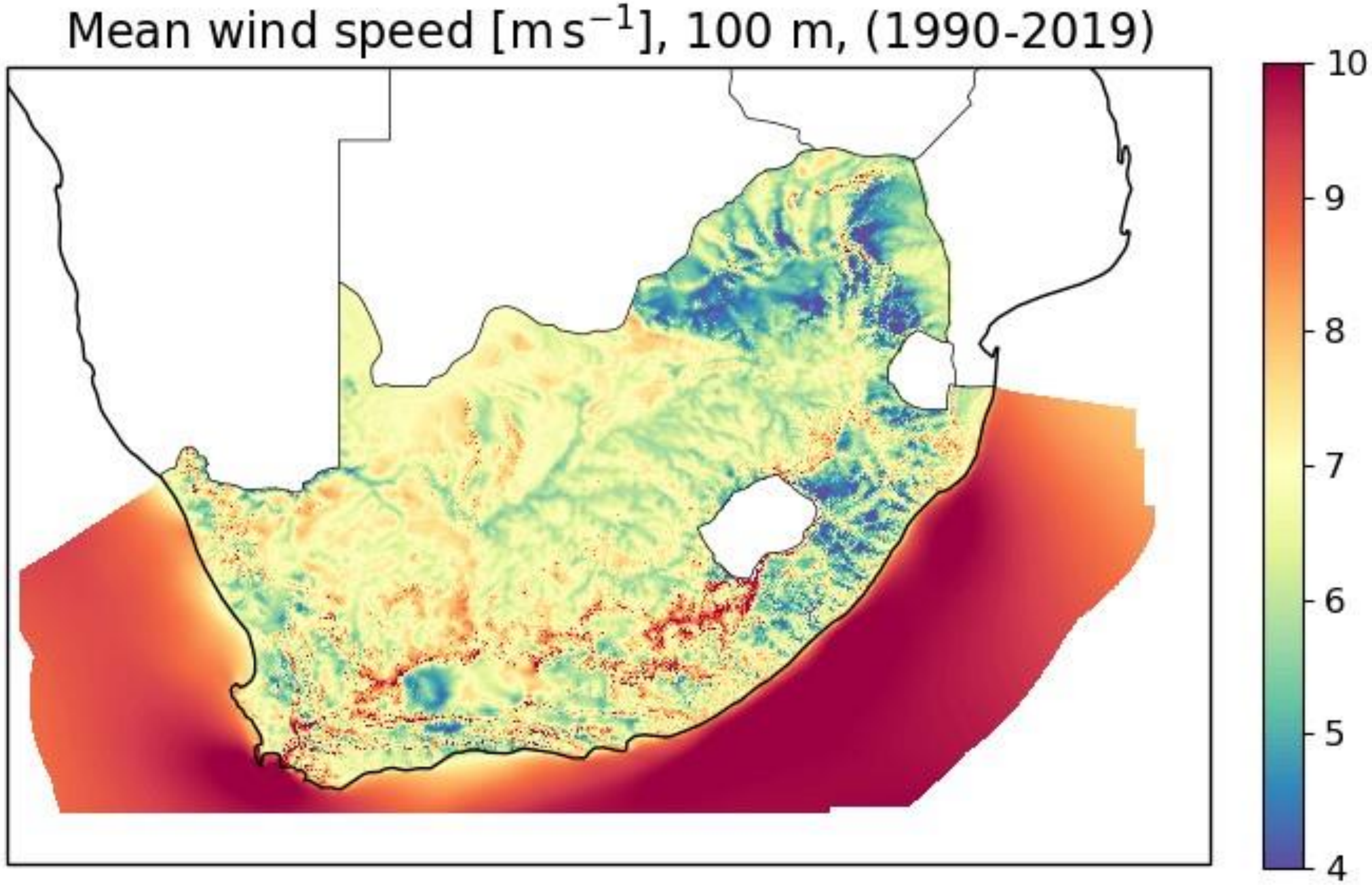
- Quite often things are simplified by fitting Weibull distributions

$$P_{\text{weibull}} = 0.5\rho \frac{1}{nsec}\sum_{s=1}^{nsec} A_s^3 \Gamma\left(1 + \frac{3}{k_s}\right)$$

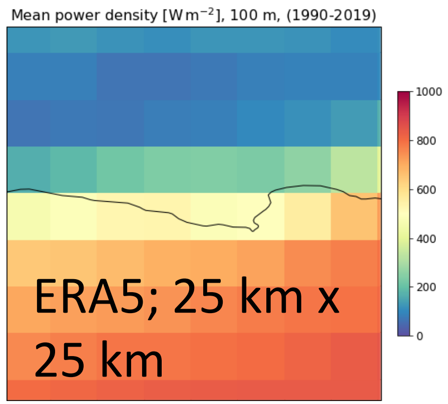
- Finally, a power curve is needed to calculate the actual power production



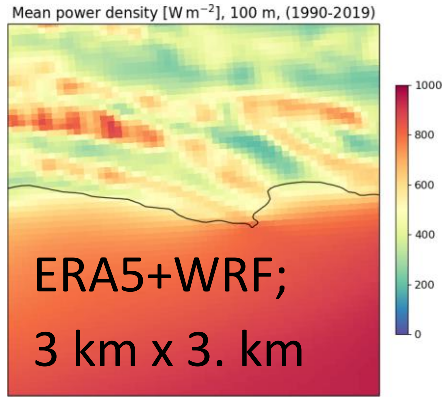
# Extra: WASA3



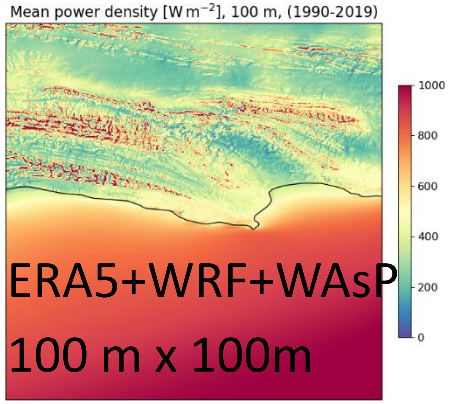
Mean wind speed [m s$^{-1}$], 100 m, (1990-2019)
10
9
8
7
6
5
4

Mean power density [W m$^{-2}$], 100 m, (1990-2019)
1000
800
600
400
200
0
ERA5; 25 km x 25 km

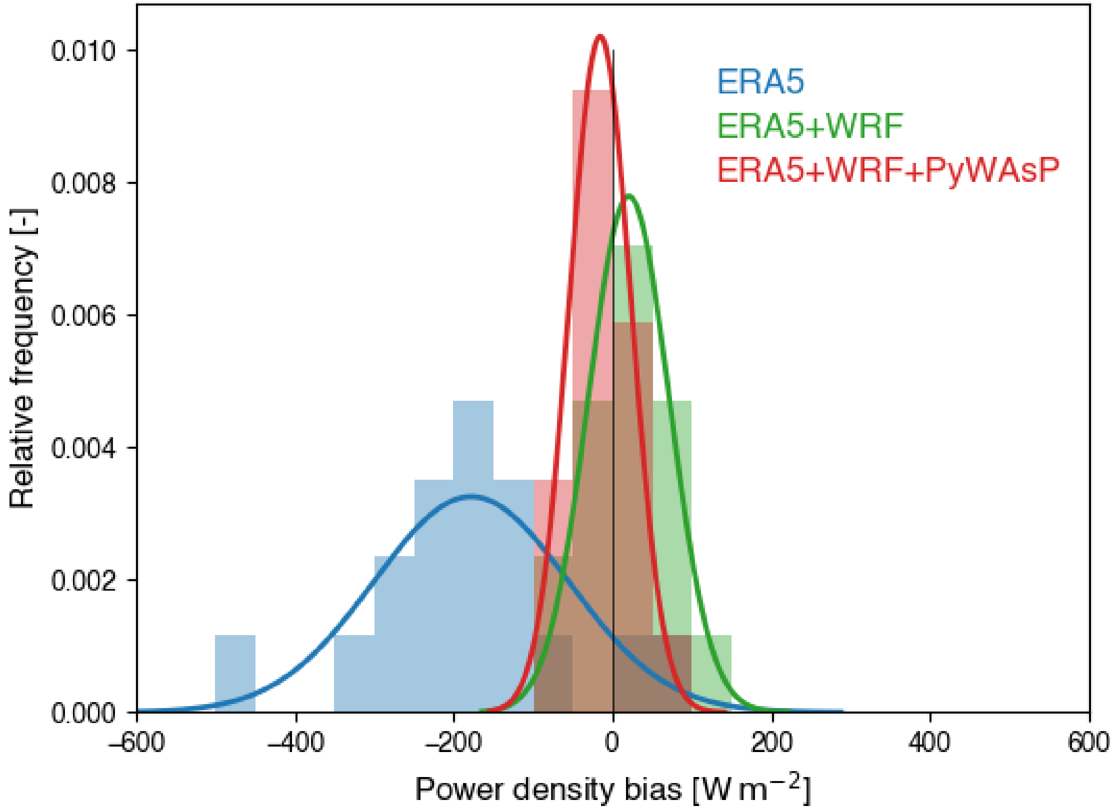



Mean power density [W m$^{-2}$], 100 m, (1990-2019)
1000
800
600
400
200
0
ERA5+WRF; 3 km x 3. km

Mean power density [W m$^{-2}$], 100 m, (1990-2019)
1000
800
600
400
200
0
ERA5+WRF+WAsP
100 m x 100m

# Extra: Validation of downscaling procedure

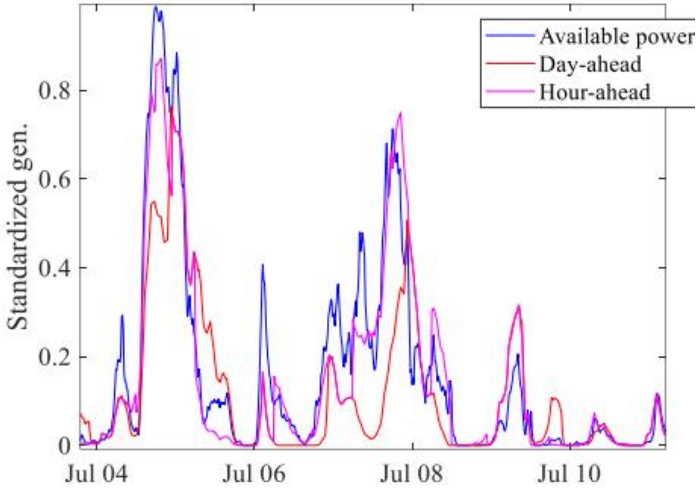


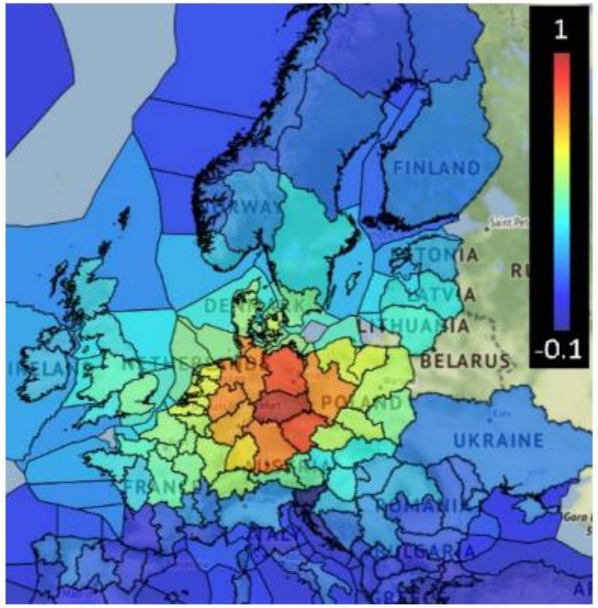

Overall (MAPE in wind speed)

- ERA5: 24.6 %
- ERA5 + WRF: 4.6 %
- ERA5 + WRF + PyWAsP: 3.5 %

# CorRES:
# What is it?

- Correlations in renewable energy sources (CorRES)
  - **Tool to simulate wind and solar generation time series**
  - Developed at DTU Wind
  - Based on ERA5 and global wind atlas
- **Used for power and energy system studies**
  - Large-scale runs (pan-European and beyond)
  - Can run 10000+ plants in one run
  - 35+ years on hourly (or higher) resolution
- **Used also in plant-level analyses**
  - E.g., revenue under variable electricity prices
  - Correlation between wind (and solar) generation and electricity price




Spatial correlations in wind generation looking from a German onshore region