

ANOMALOUS WIND EVENTS OVER THE BELGIAN NORTH SEA AT HEIGHTS RELEVANT TO WIND ENERGY.

G. Glabeke^{1,2}, S. Buckingham¹, T. De Mulder² & J. van Beeck¹

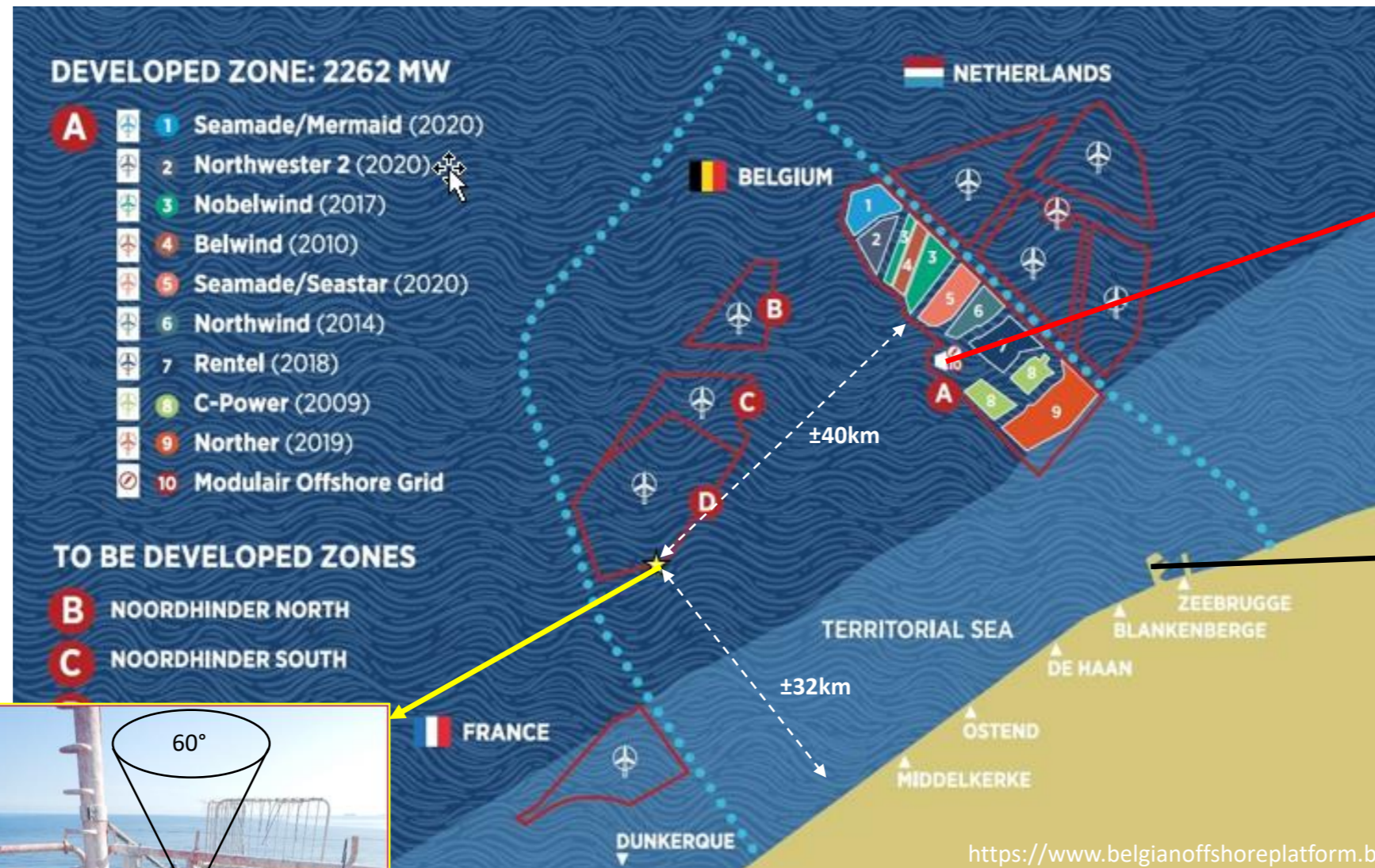
¹ Environmental and Applied Fluid Dynamics Department, von Karman Institute for Fluid Dynamics, Belgium

² Faculty of Engineering and Architecture - Department of Civil engineering, UGent, Belgium

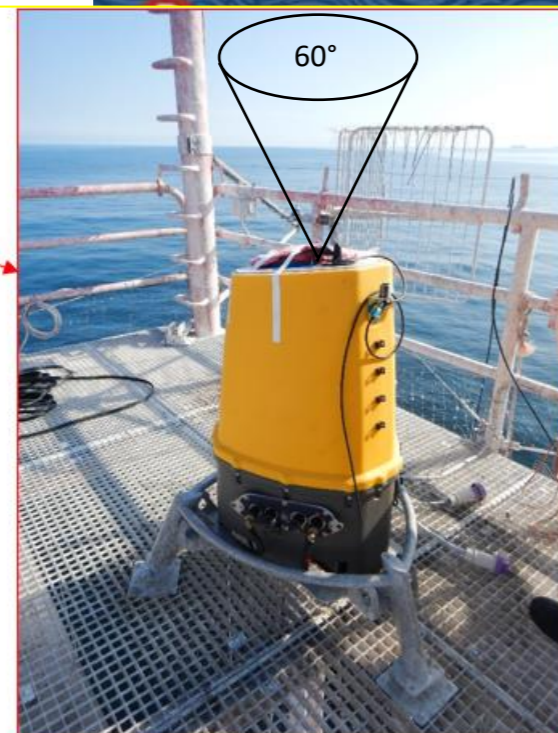
May 25, 2023 - Wind Energy Science Conference 2023 - Glasgow

MEASUREMENT LOCATIONS

Precipitation characterization on OSY MOG



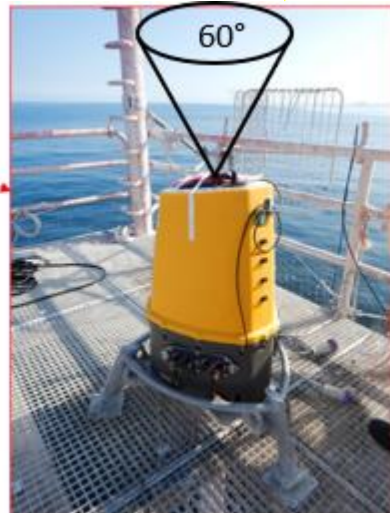
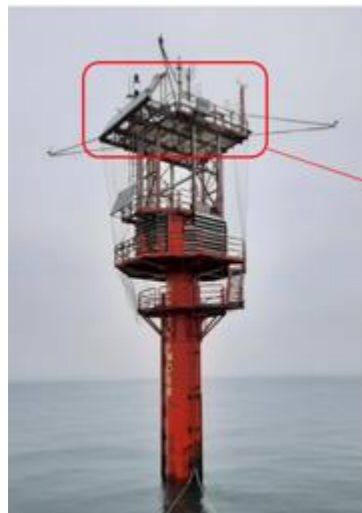
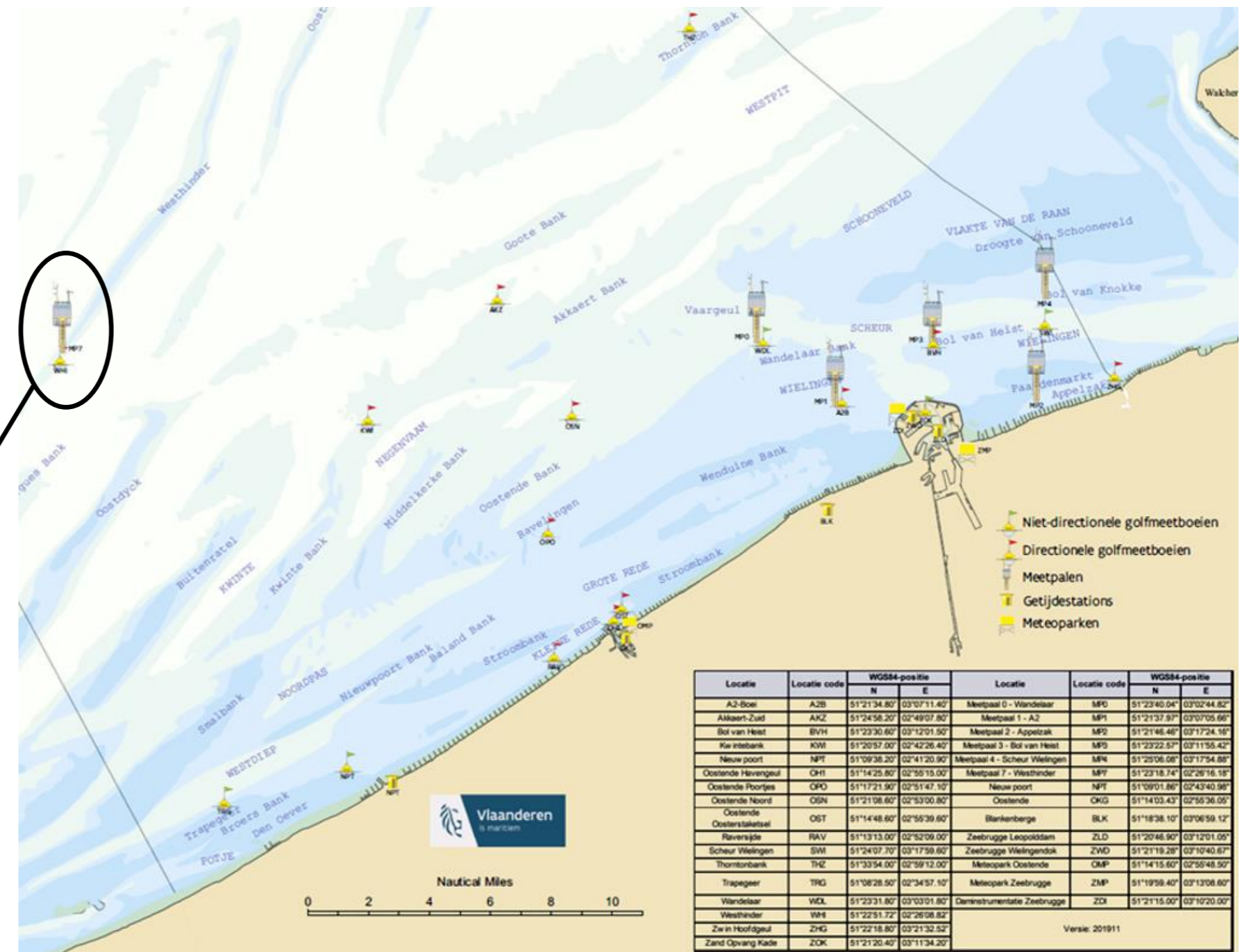
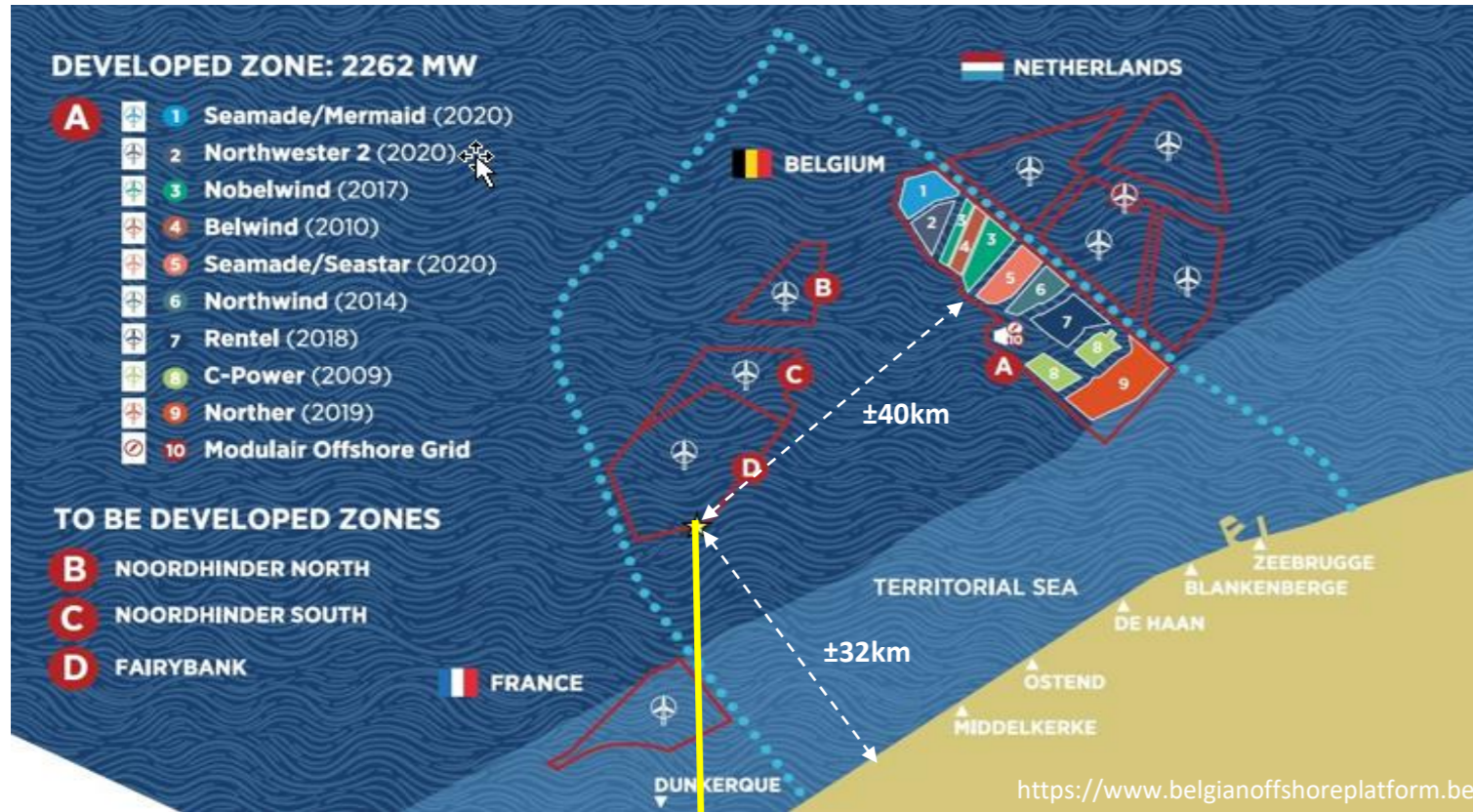
Vertical wind profiler (ZX300M) at Port of Zeebrugge



Vertical wind profiler (ZX300M) on top deck (±21 m a.s.l.) of Westhinder survey platform:

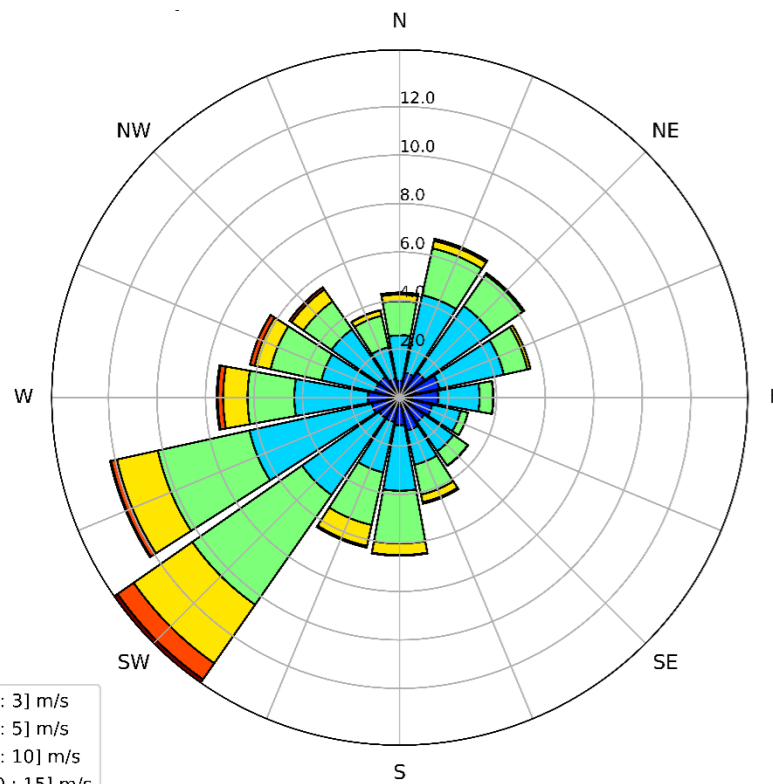
- Measurements at 10, 20, 38, 55, 80, 100, 125, 150, 200, 250 & 300 meters above Lidar
- 10min averaged dataset from 04/08/2021 9h00 until 18/07/2022 4h20 → 50075 datapoints (data availability > 99%)
- After filtering: 79% of data remains

MEASUREMENT LOCATIONS

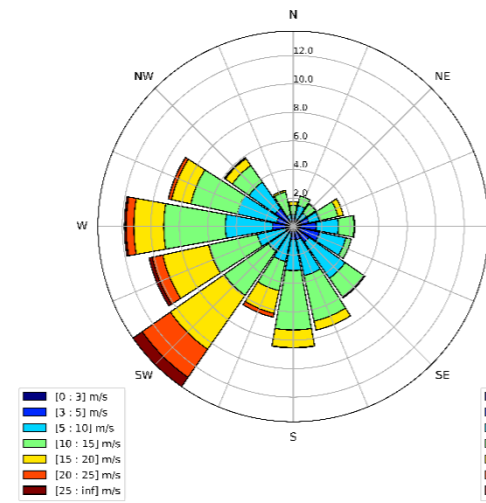


<https://meetnetvlaamsebanken.be/map>

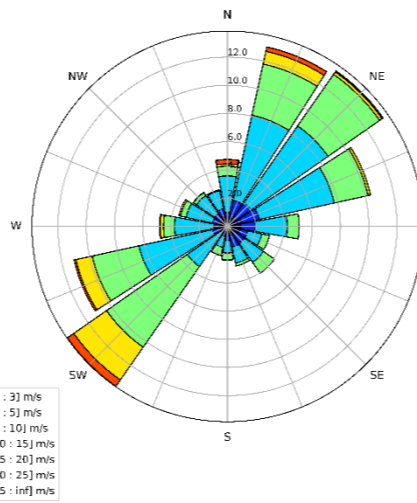
WESTHINDER WIND RESOURCE AT HUB HEIGHT



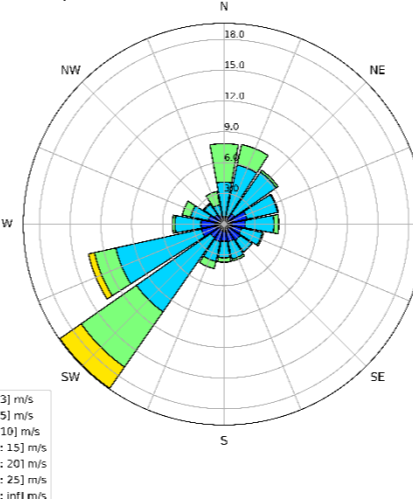
Winter:



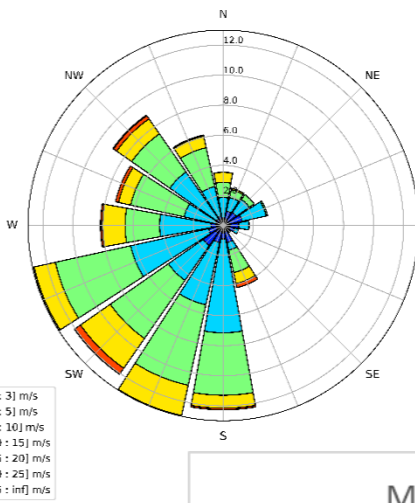
Spring:



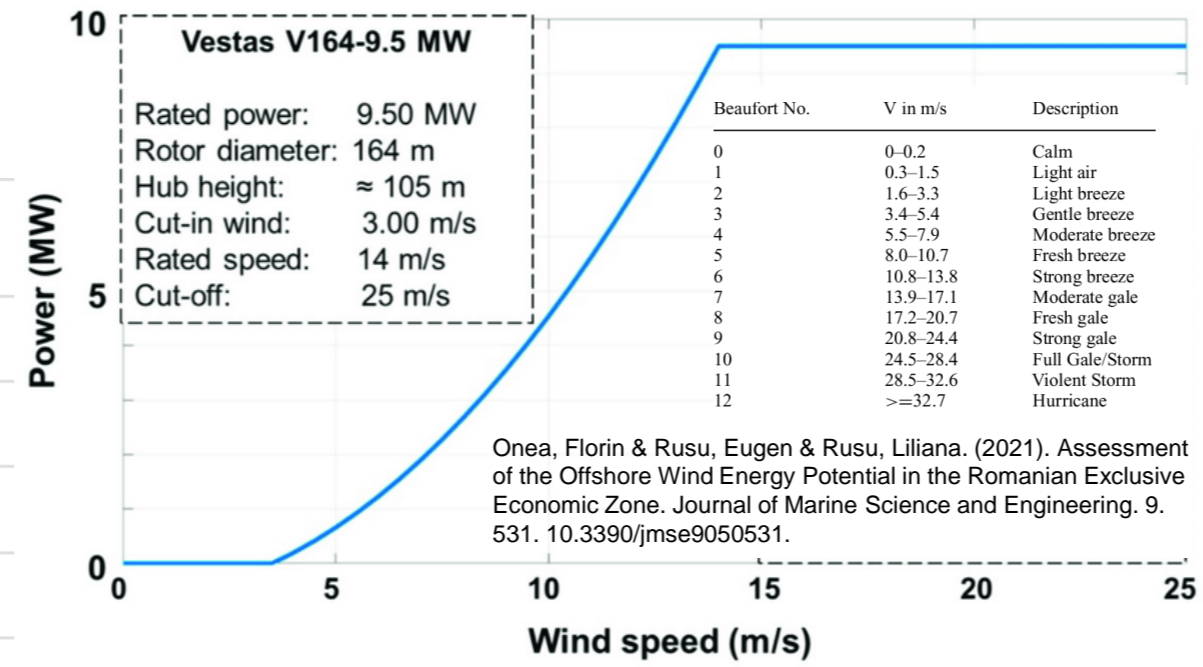
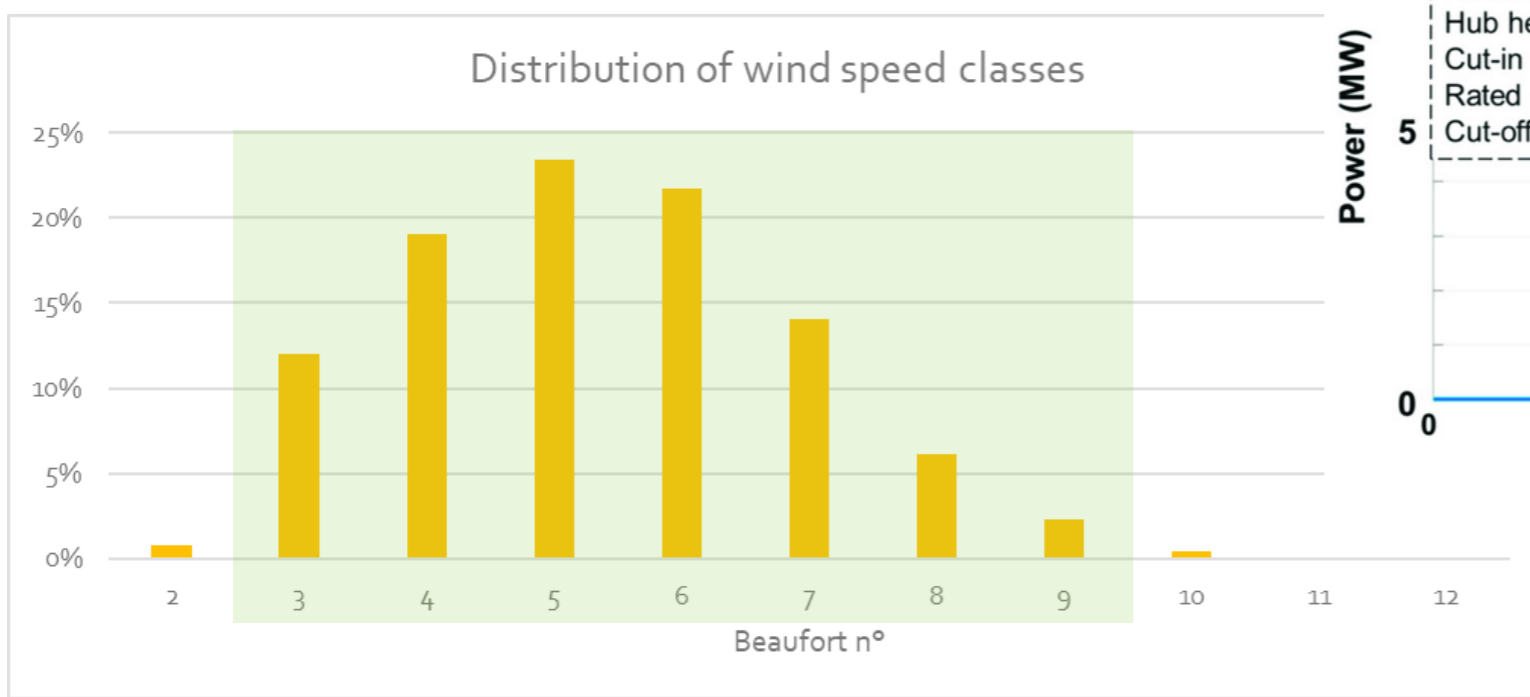
Summer:



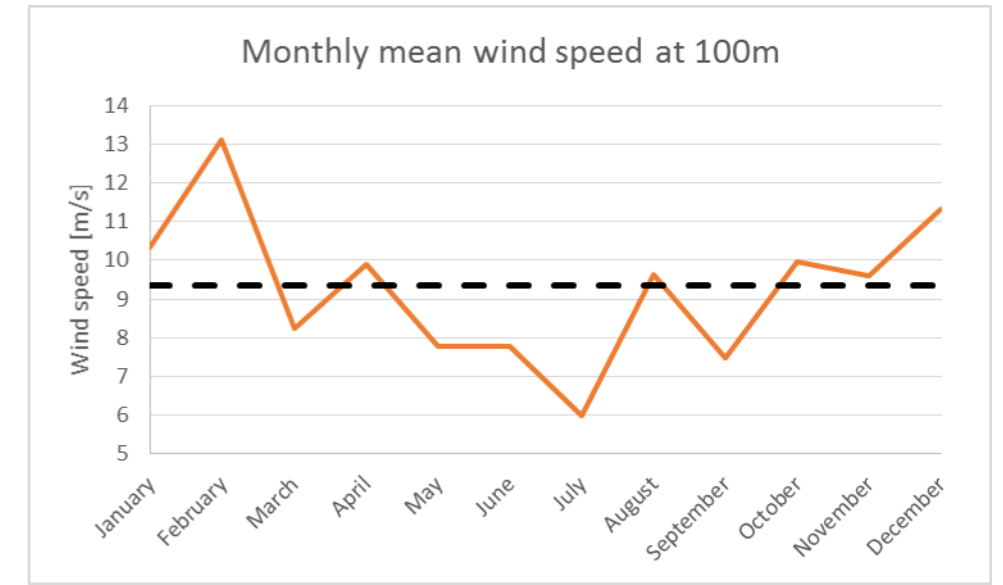
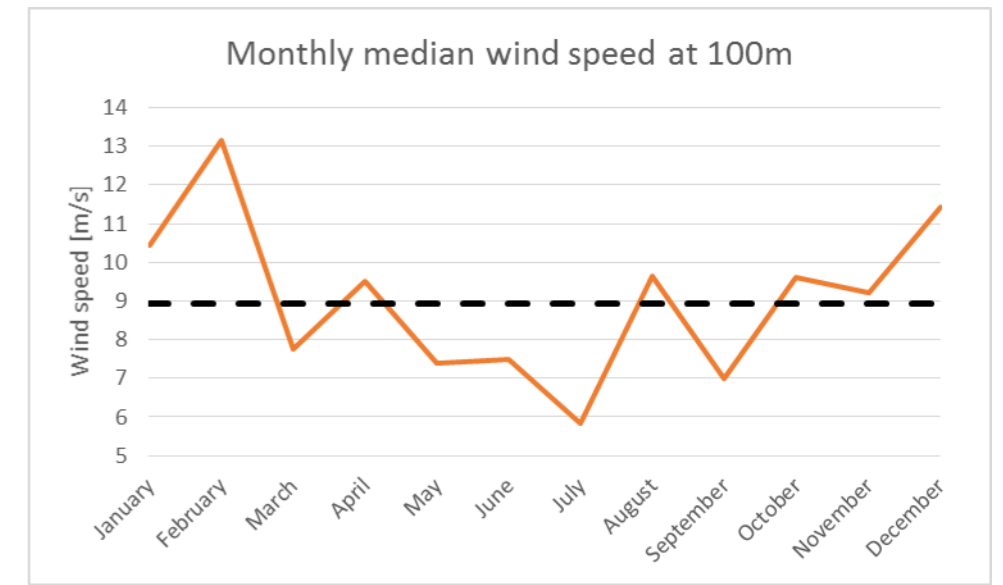
Autumn:



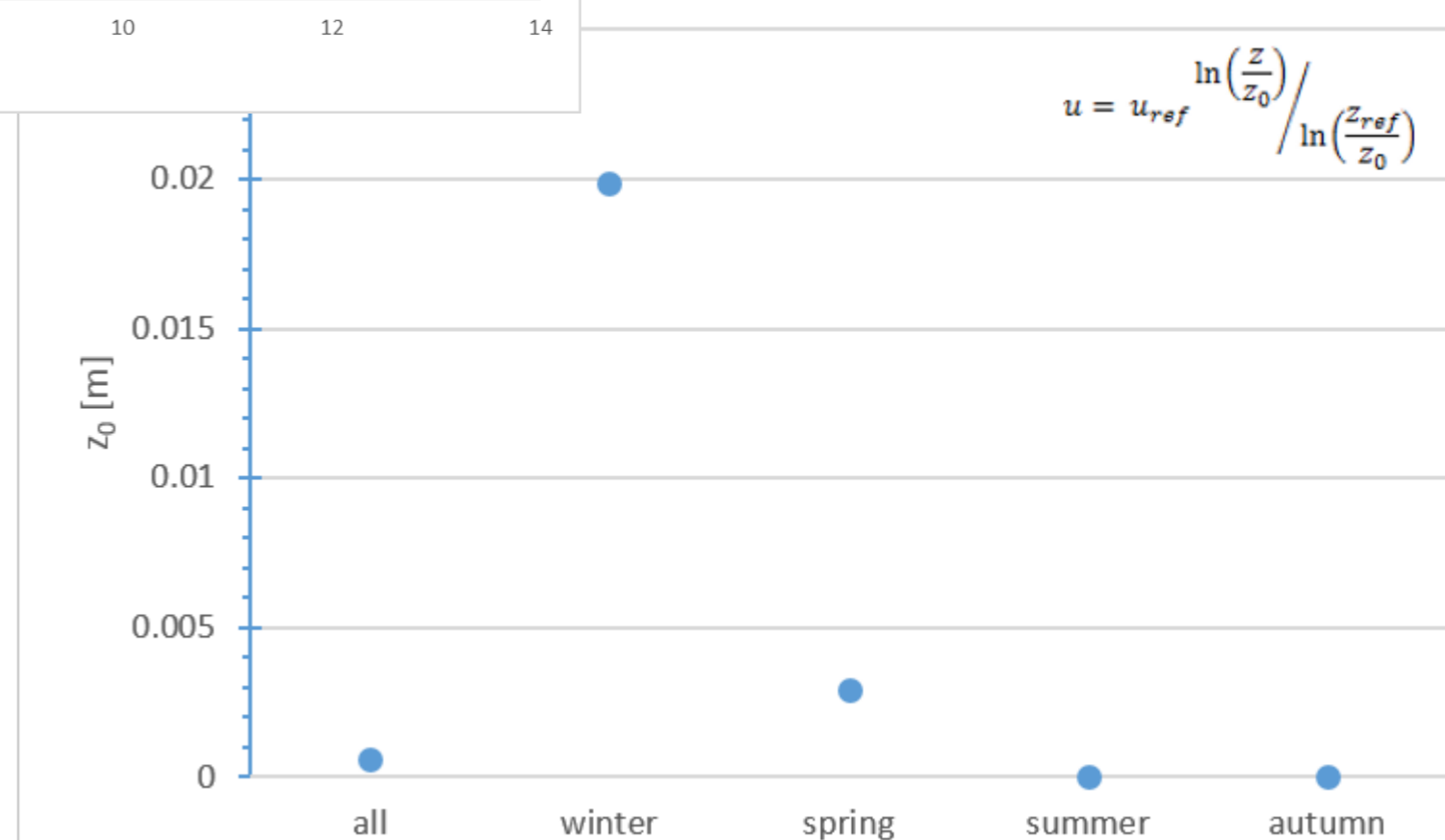
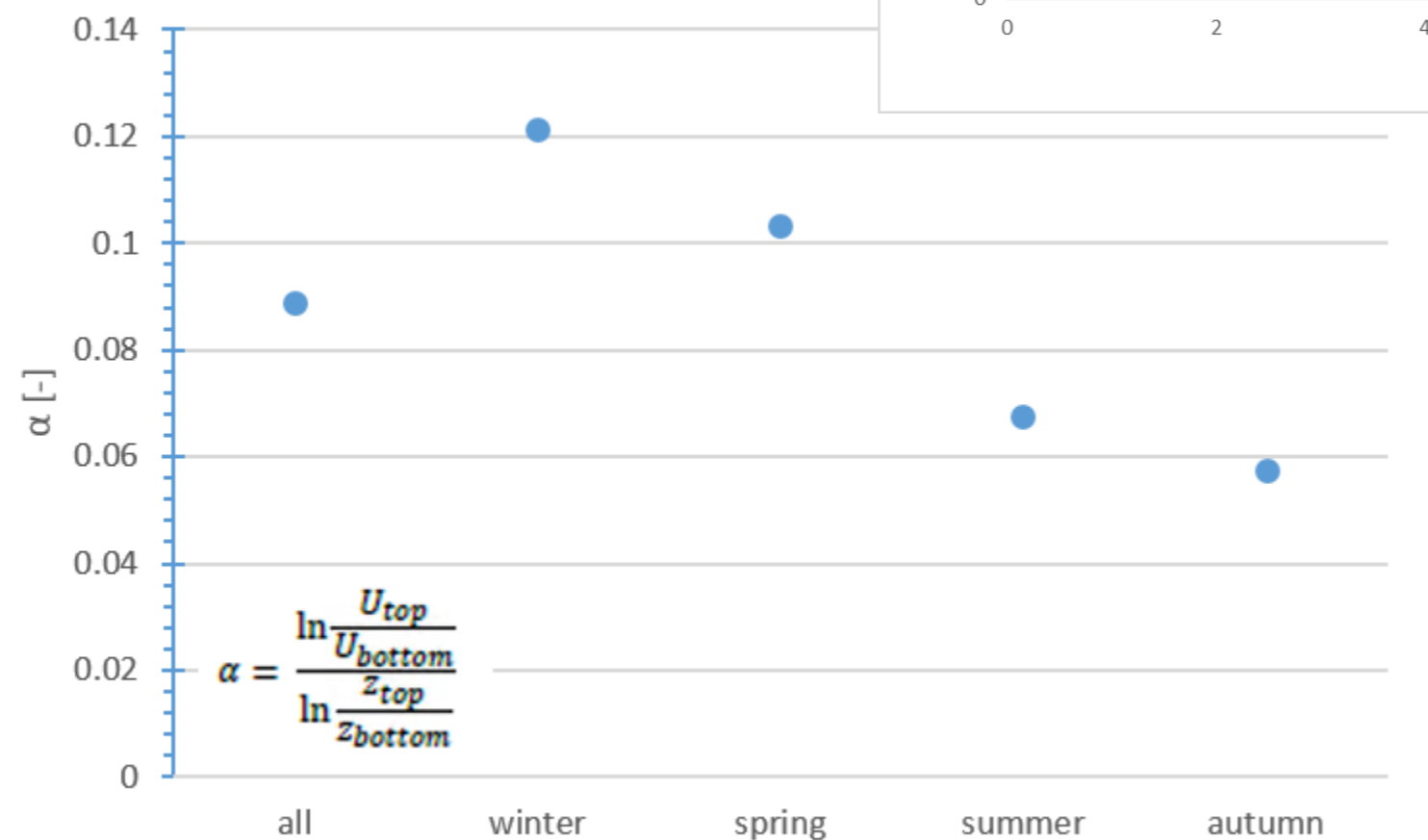
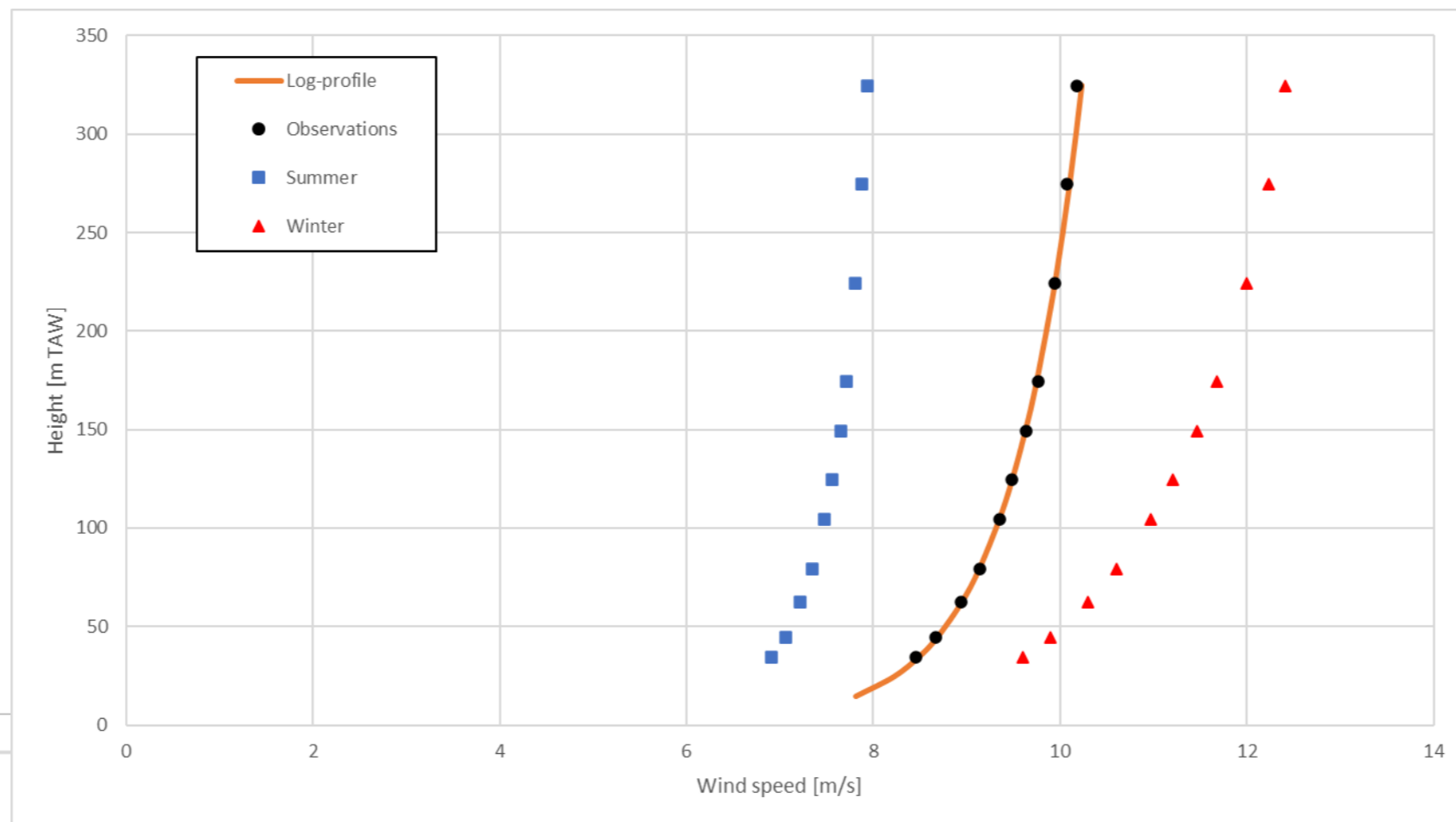
- [0 : 3] m/s
- [3 : 5] m/s
- [5 : 10] m/s
- [10 : 15] m/s
- [15 : 20] m/s
- [20 : 25] m/s
- [25 : inf] m/s



Onea, Florin & Rusu, Eugen & Rusu, Liliana. (2021). Assessment of the Offshore Wind Energy Potential in the Romanian Exclusive Economic Zone. Journal of Marine Science and Engineering. 9. 531. 10.3390/jmse9050531.

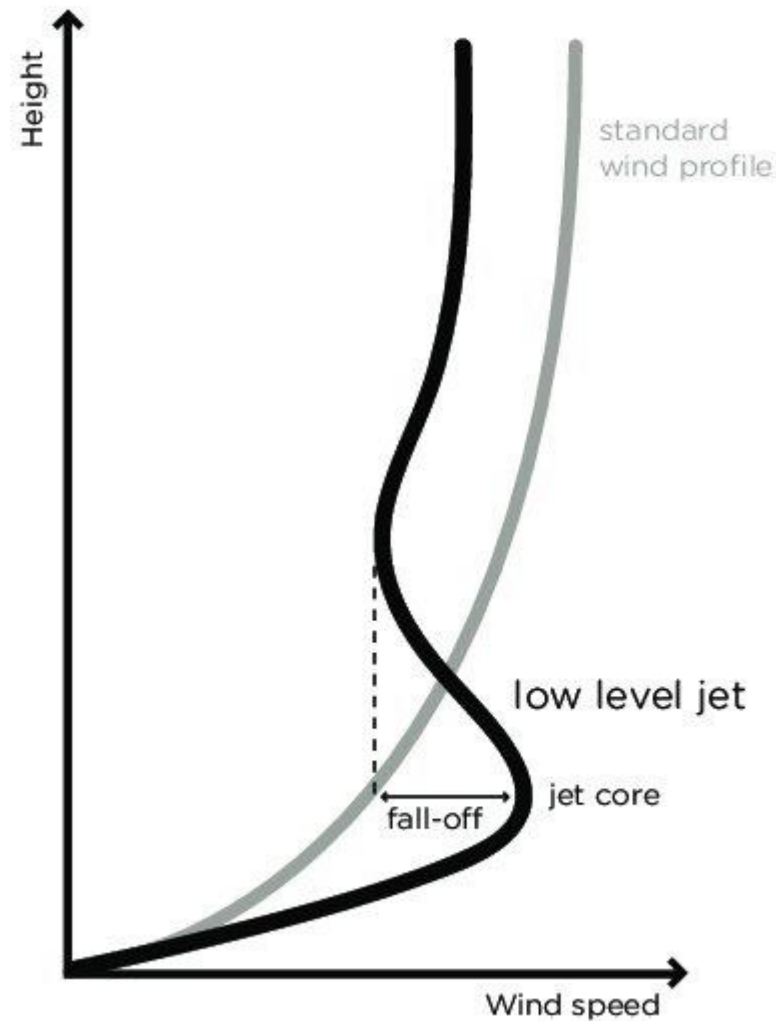


WESTHINDER WIND RESOURCE AT HUB HEIGHT

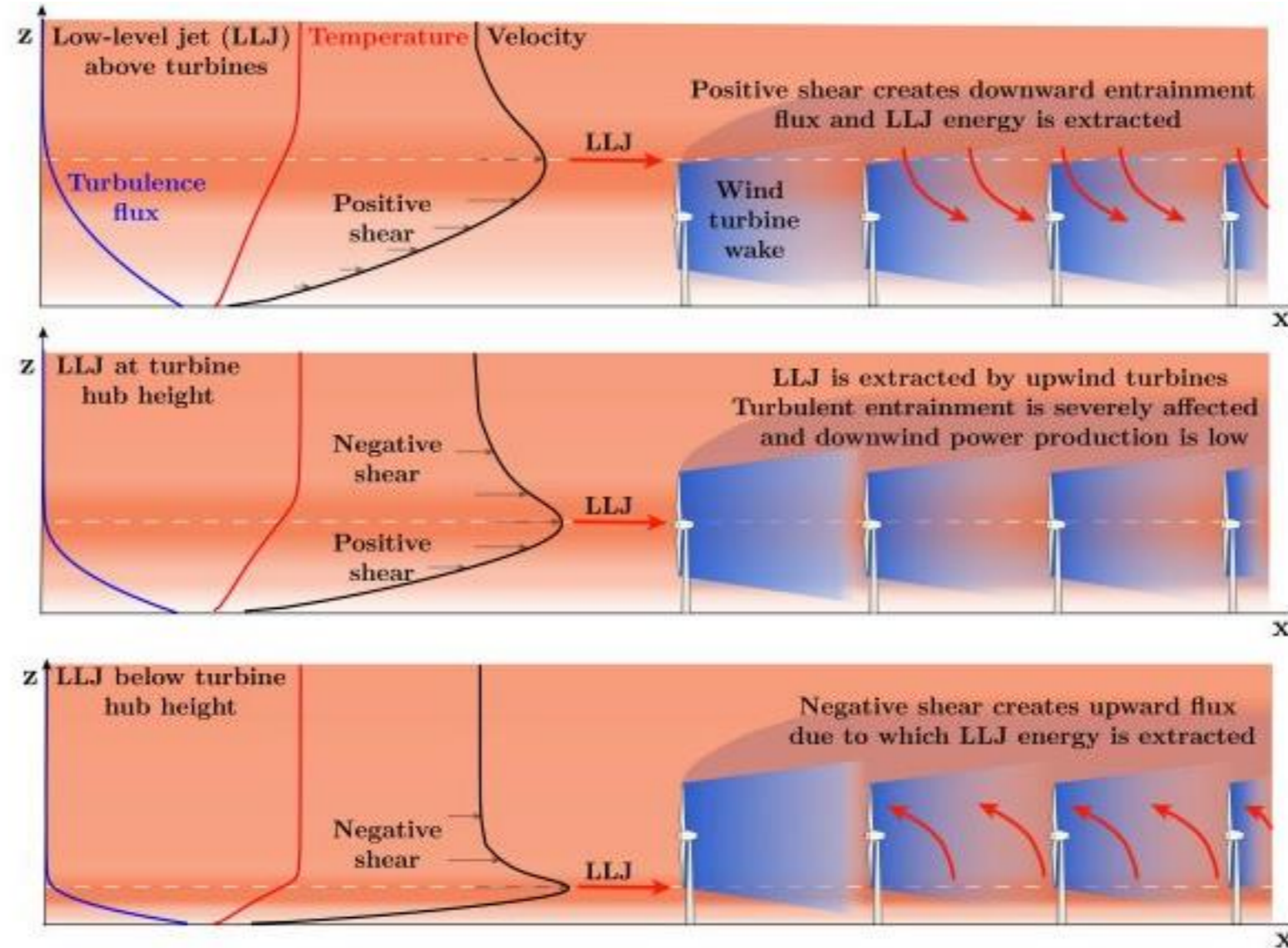


WESTHINDER ANOMALOUS WIND EVENTS

Low-Level Jets (LLJ)



Effect of low-level jet height on wind farm performance:

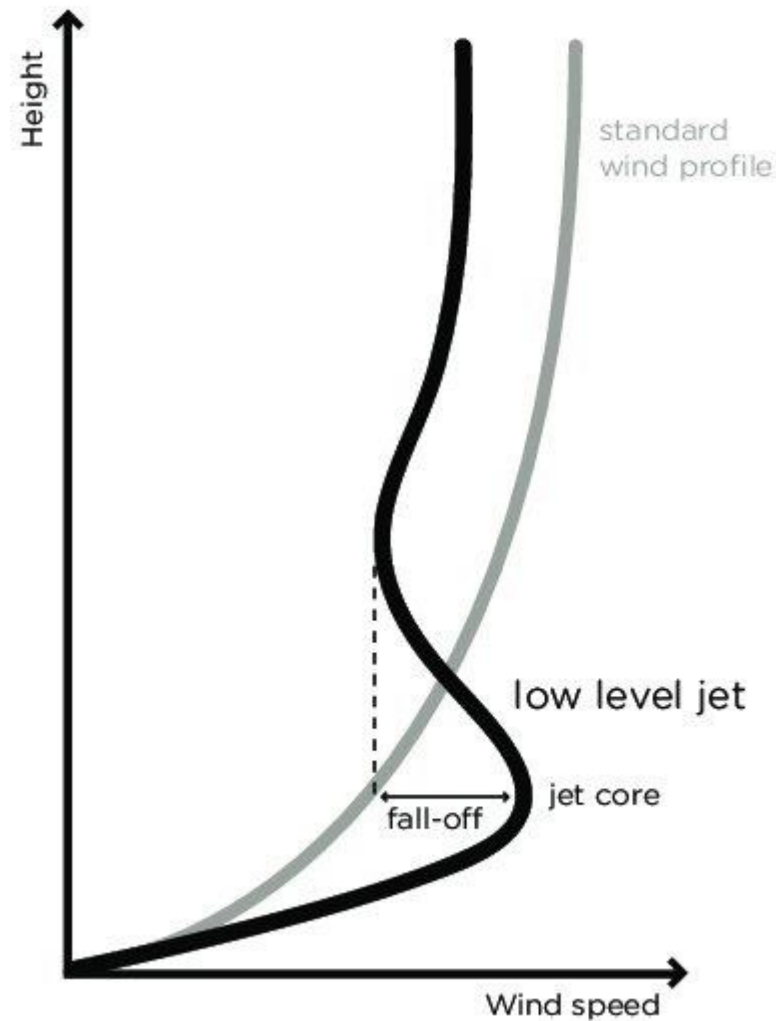


Hallgren, Christoffer & Arnqvist, Johan & Ivanell, S. & Körnich, Heiner & Vakkari, Ville & Sahlée, Erik. (2020). Looking for an Offshore Low-Level Jet Champion Among Recent Reanalyses: A Tight Race Over the Baltic Sea. *Energies*. 13. 3670. 10.3390/en13143670.

Nagarada Gade, Srinidhi & Stevens, Richard. (2021). Effect of low-level jet height on wind farm performance. *Journal of Renewable and Sustainable Energy*. 13. 10.1063/5.0026232.

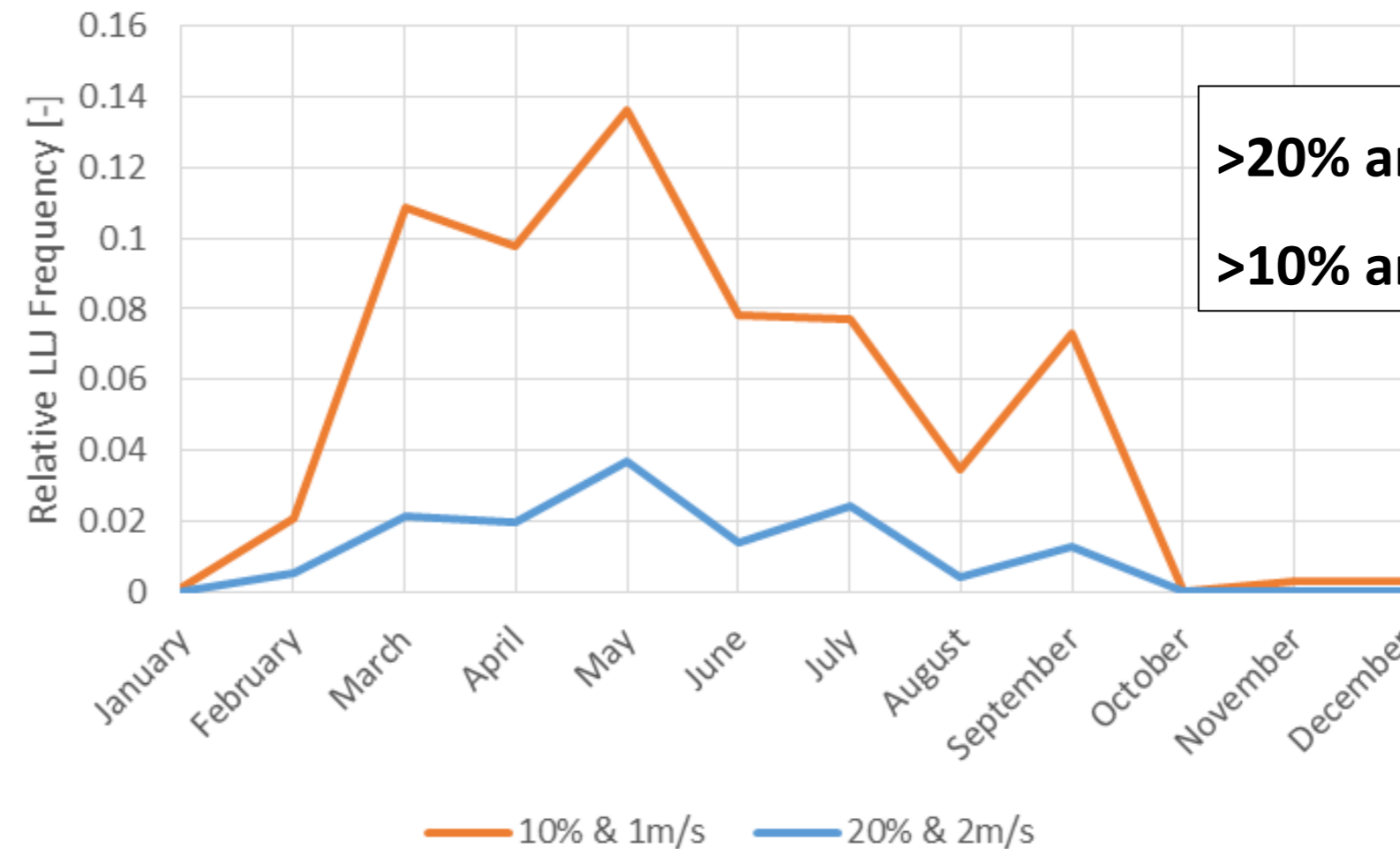
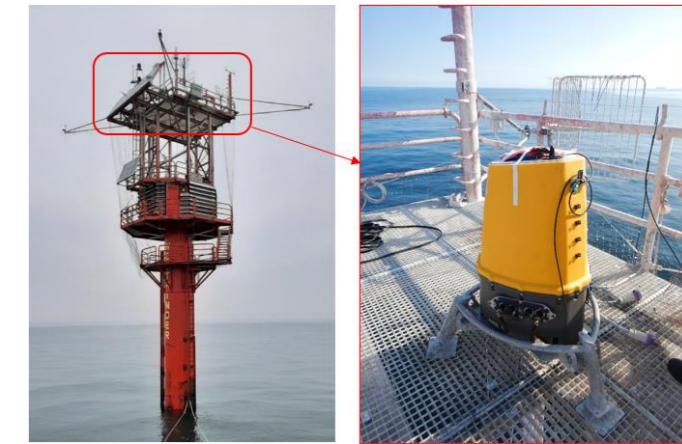
WESTHINDER ANOMALOUS WIND EVENTS

Low-Level Jets (LLJ)



Characterization based on:

- Absolute fall-off → detection of higher speed LLJ
 - Relative fall-off → detection of lower speed LLJ
- Combination of both (>20% and 2m/s)¹



>20% and 2m/s: 1.2% LLJ occurrences
 >10% and 1m/s: 5.4% LLJ occurrences

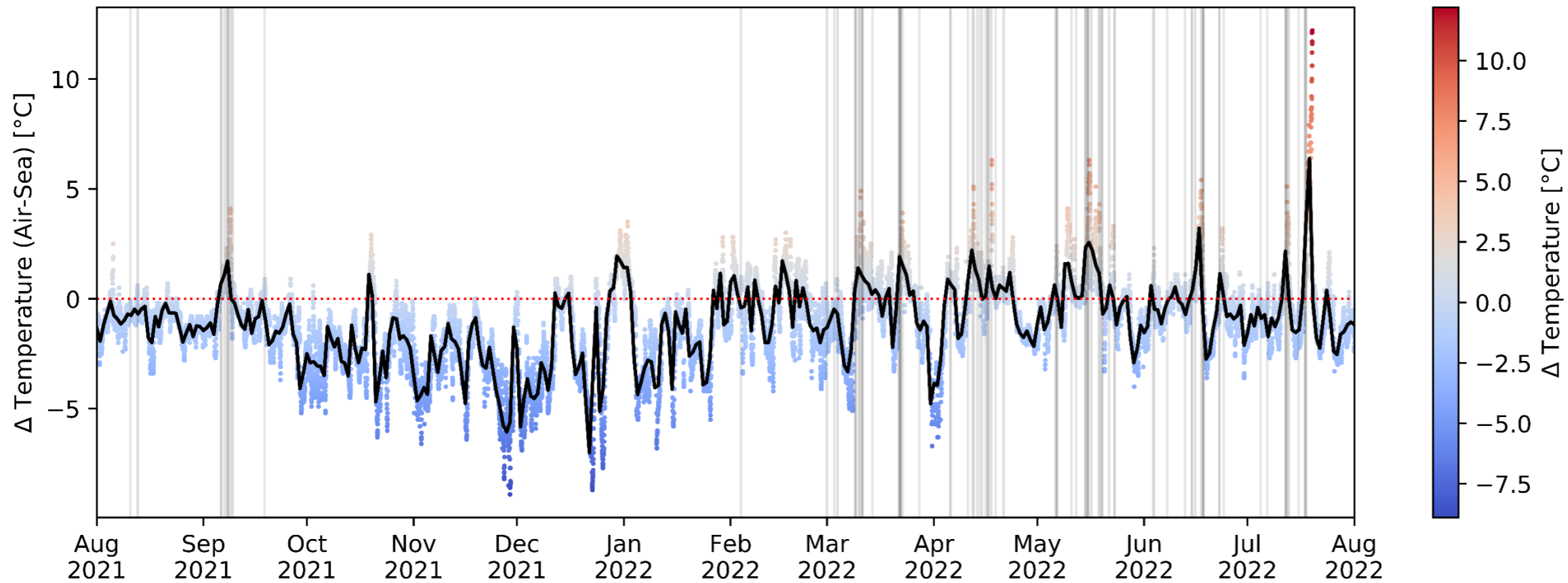
Hallgren, Christoffer & Arnqvist, Johan & Ivanell, S. & Körnich, Heiner & Vakkari, Ville & Sahlée, Erik. (2020). Looking for an Offshore Low-Level Jet Champion Among Recent Reanalyses: A Tight Race Over the Baltic Sea. *Energies*. 13. 3670. 10.3390/en13143670.

[1] Aird, Jeanie & Barthelmie, R. & Shepherd, Tristan & Pryor, Sara. (2022). Occurrence of Low-Level Jets over the Eastern U.S. Coastal Zone at Heights Relevant to Wind Energy. *Energies*. 15. 445. 10.3390/en15020445.

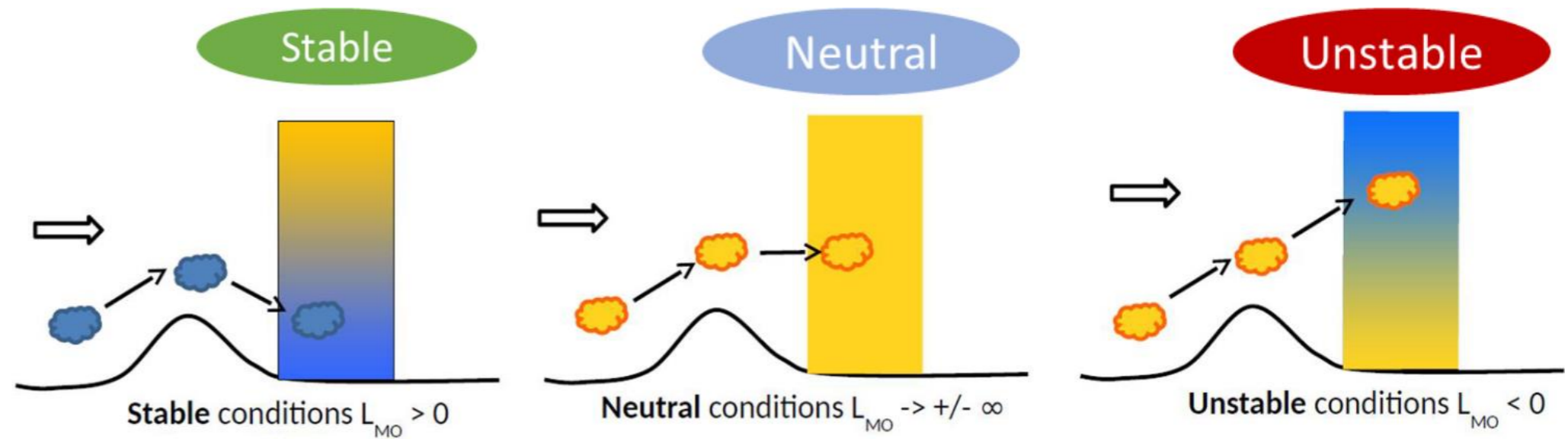
WESTHINDER ANOMALOUS WIND EVENTS

Low-Level Jets (LLJ)

Characterization based on absolute and relative fall-off (>20% and 2m/s)



LLJ formation in atmospheric stable conditions
 → air hotter than sea water

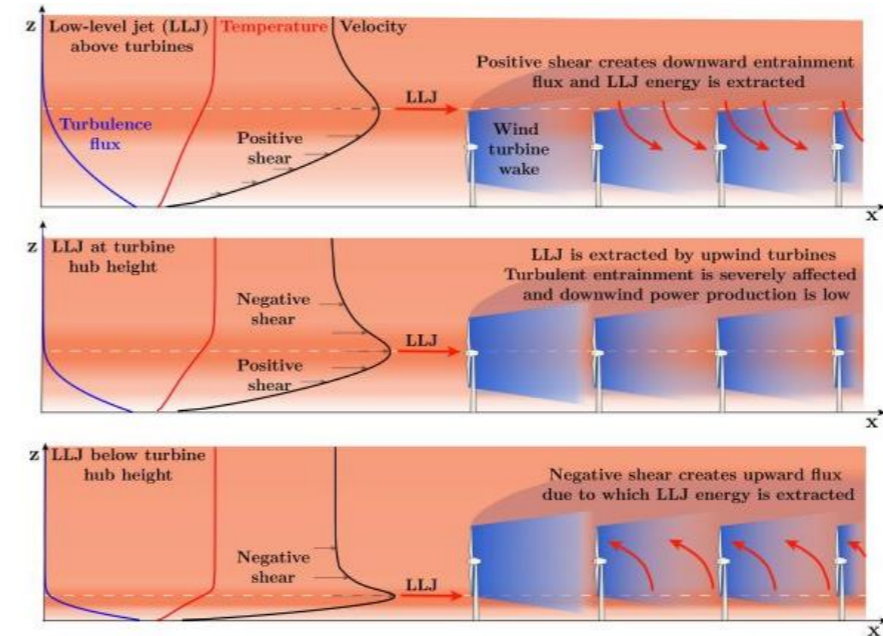
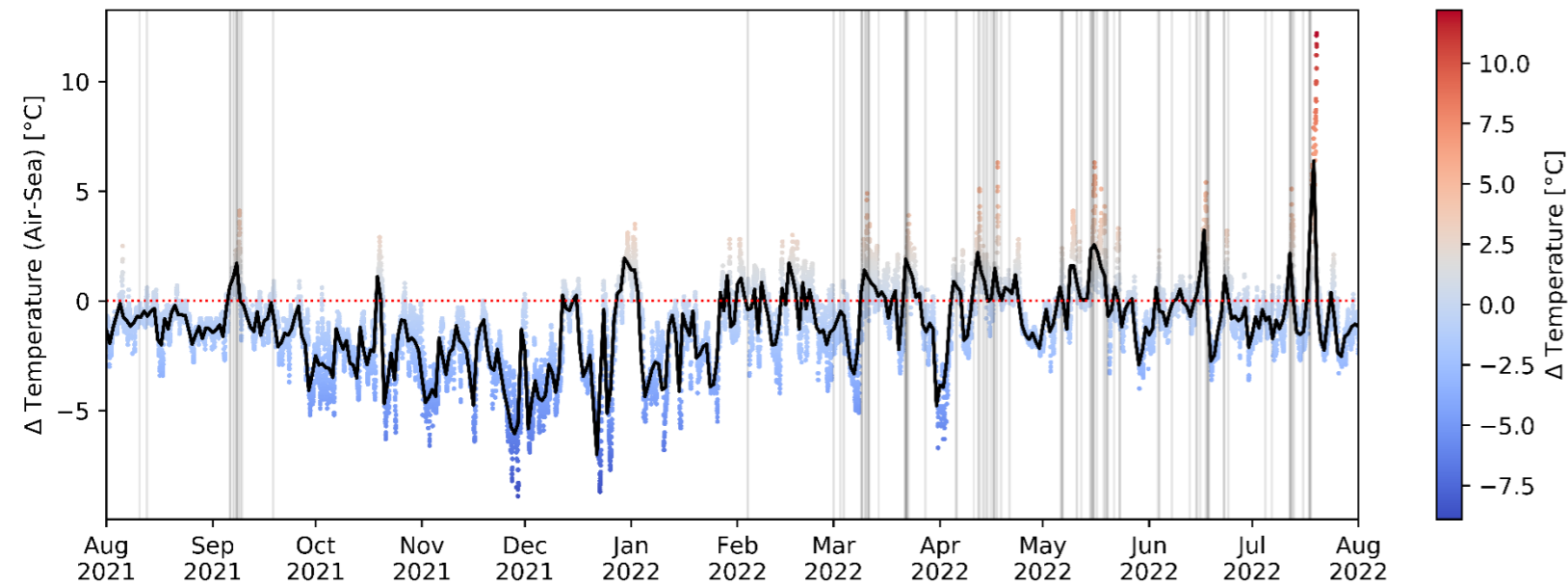


- Reduces dynamic turbulence
- Low vertical mixing
- Light winds on cold surfaces
- Nights with clear sky
- Turbulence due to shear
- Moderate to strong wind
- Little surface heating or cooling
- Thermally-enhanced turbulence
- High vertical mixing
- Light wind on warm surface
- Sunny day with fair weather

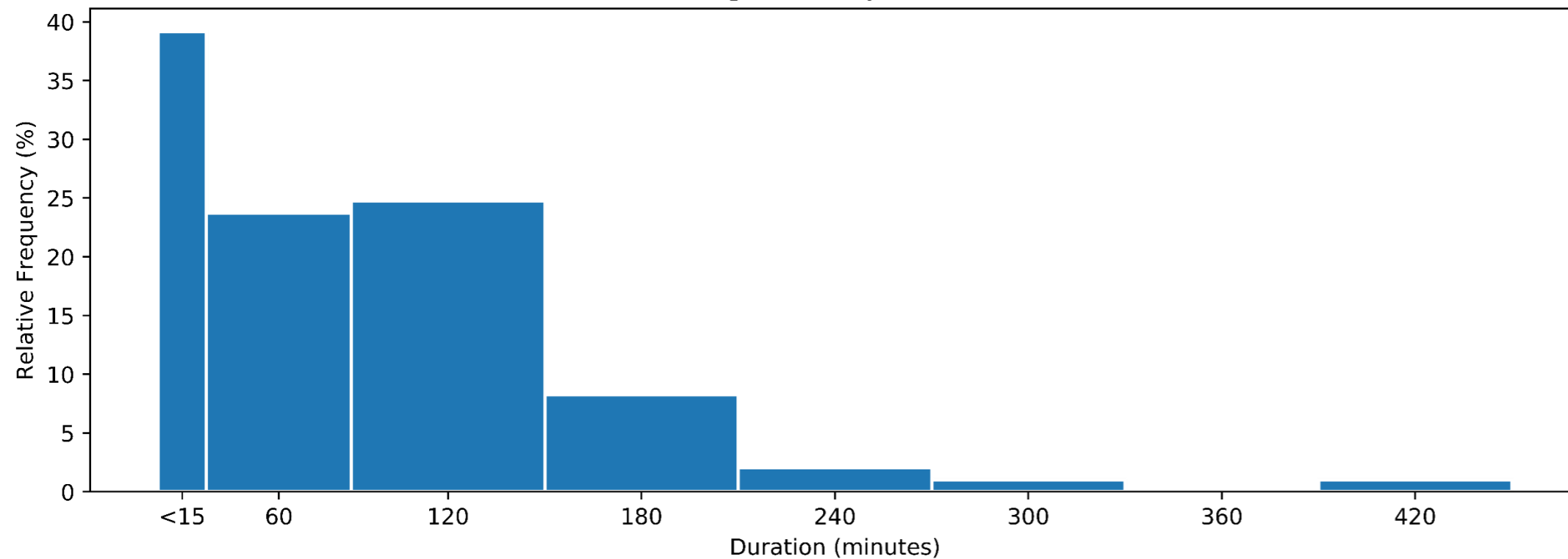
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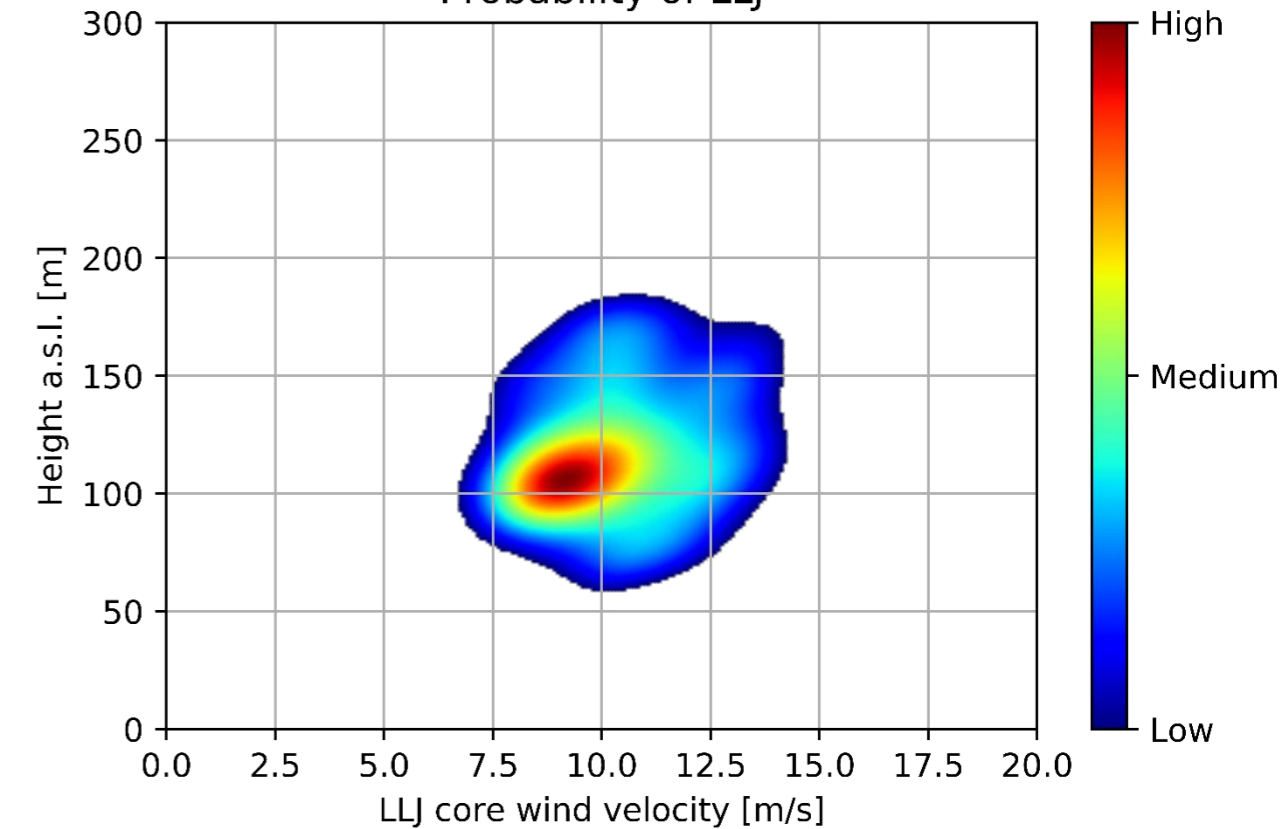
Characterization based on absolute and relative fall-off (>20% and 2m/s)



Histogram of LLJ durations



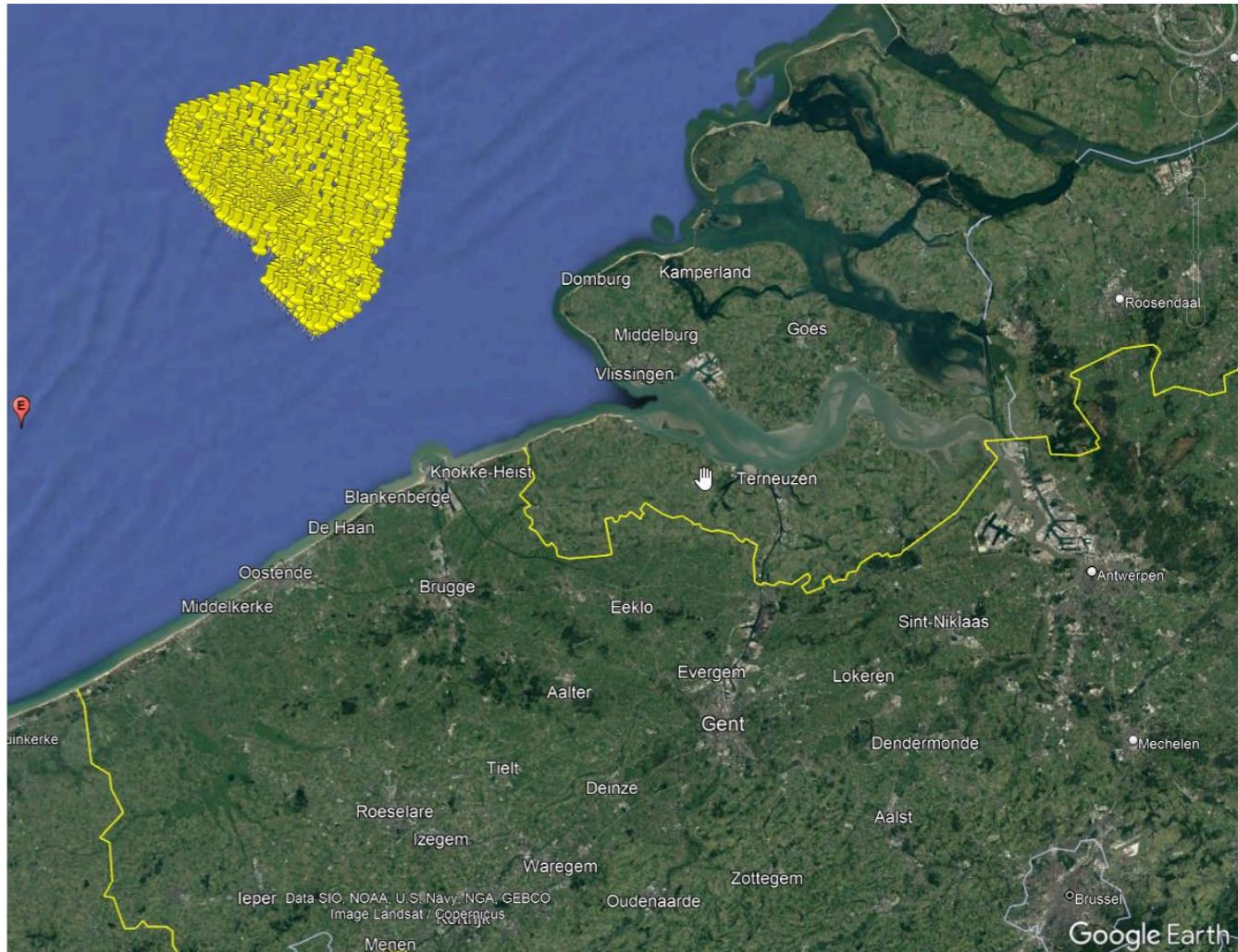
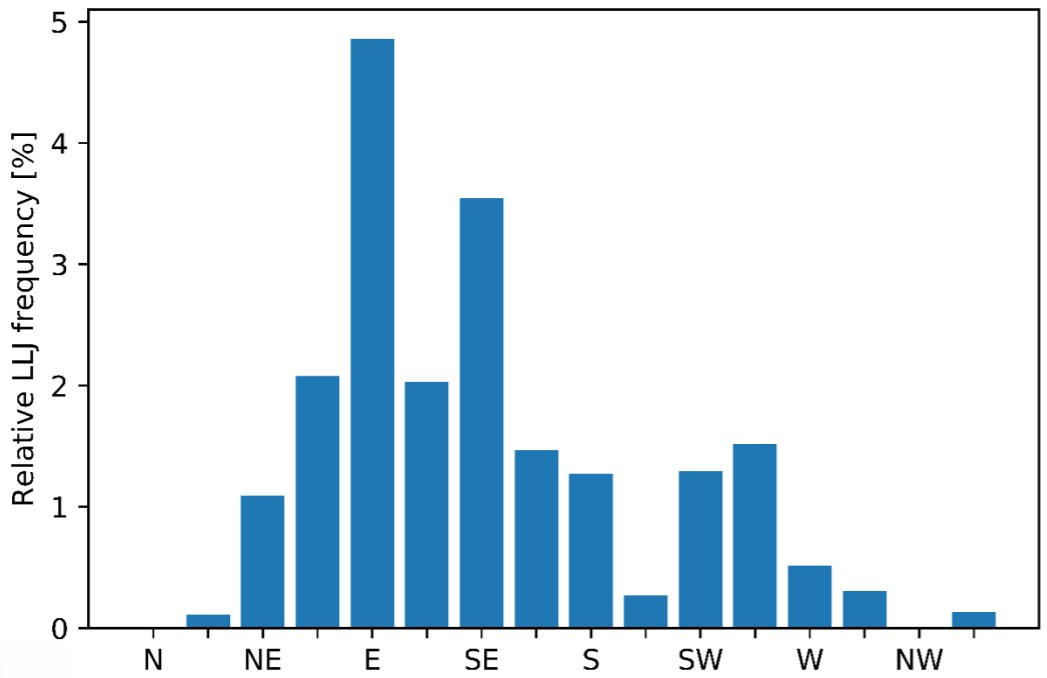
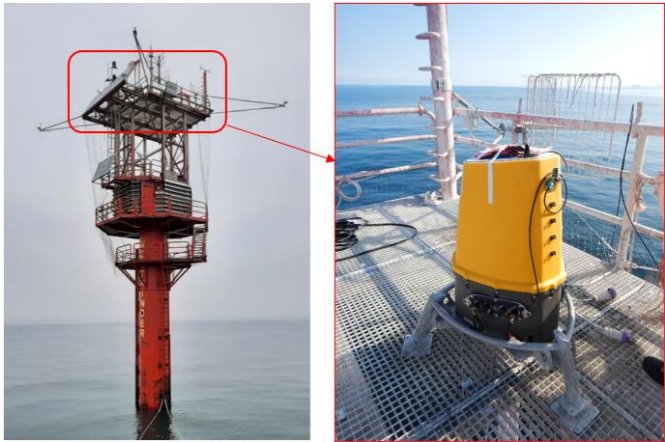
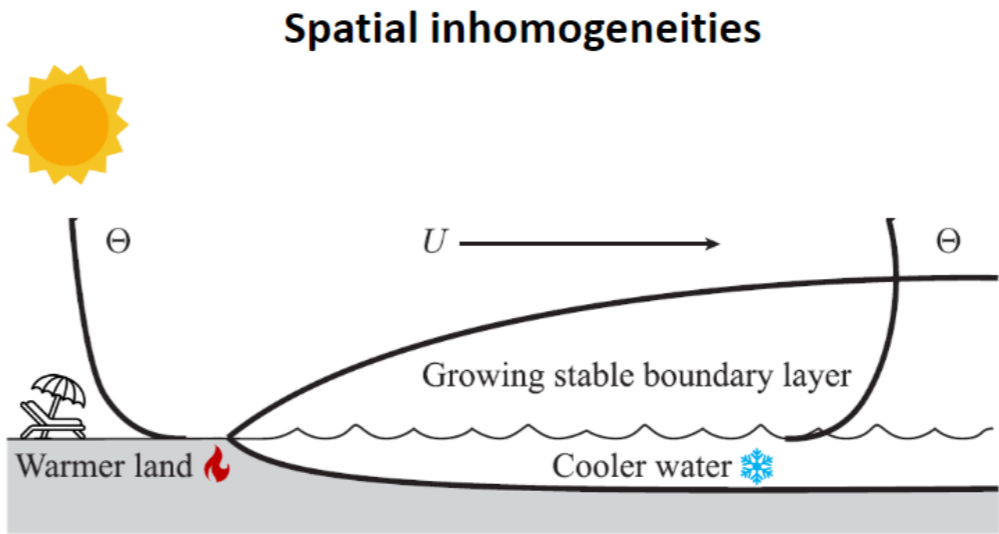
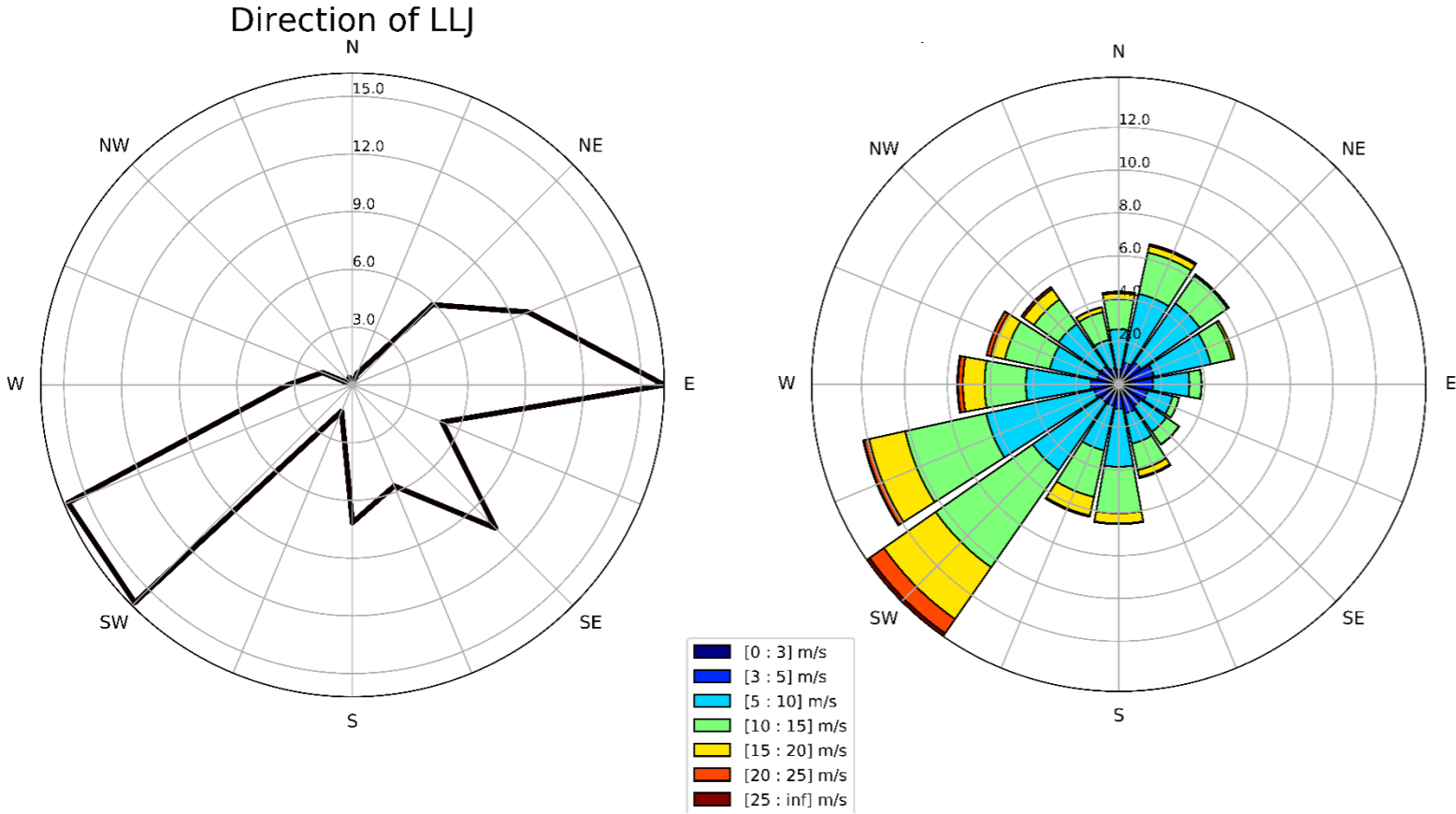
Probability of LLJ



WESTHINDER ANOMALOUS WIND EVENTS

Low-Level Jets (LLJ)

Characterization based on absolute and relative fall-off (>20% and 2m/s)





Detection of Extreme Weather Events (EWEs) in LiDAR data

- Extreme wind speeds (max. 150km/h during storm Eunice) and wind gusts (during storms : max .1.75)
- Rapid changes of wind speed and/or wind direction
- Low Level Jets (LLJ) : from March to September with jet core located around hub height
- High wind shear
- High veer
- High wind shear and high veer

