



# Processing of sonic anemometer measurements for offshore wind turbine applications

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# Motivation

How should the processing of sonic anemometer measurements be tailored to offshore wind turbine applications?

- This work defines such a processing procedure for offshore measurements at FINO1





# The measurements



- FINO1
- Sonic anemometers at 40, 60 and 80 m
  - Wind speed (m/s)
  - Sonic temperature (K)
- June 2015 – September 2016
- Other measurements
  - Direction from wind vanes
  - Precipitation

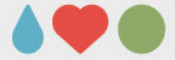




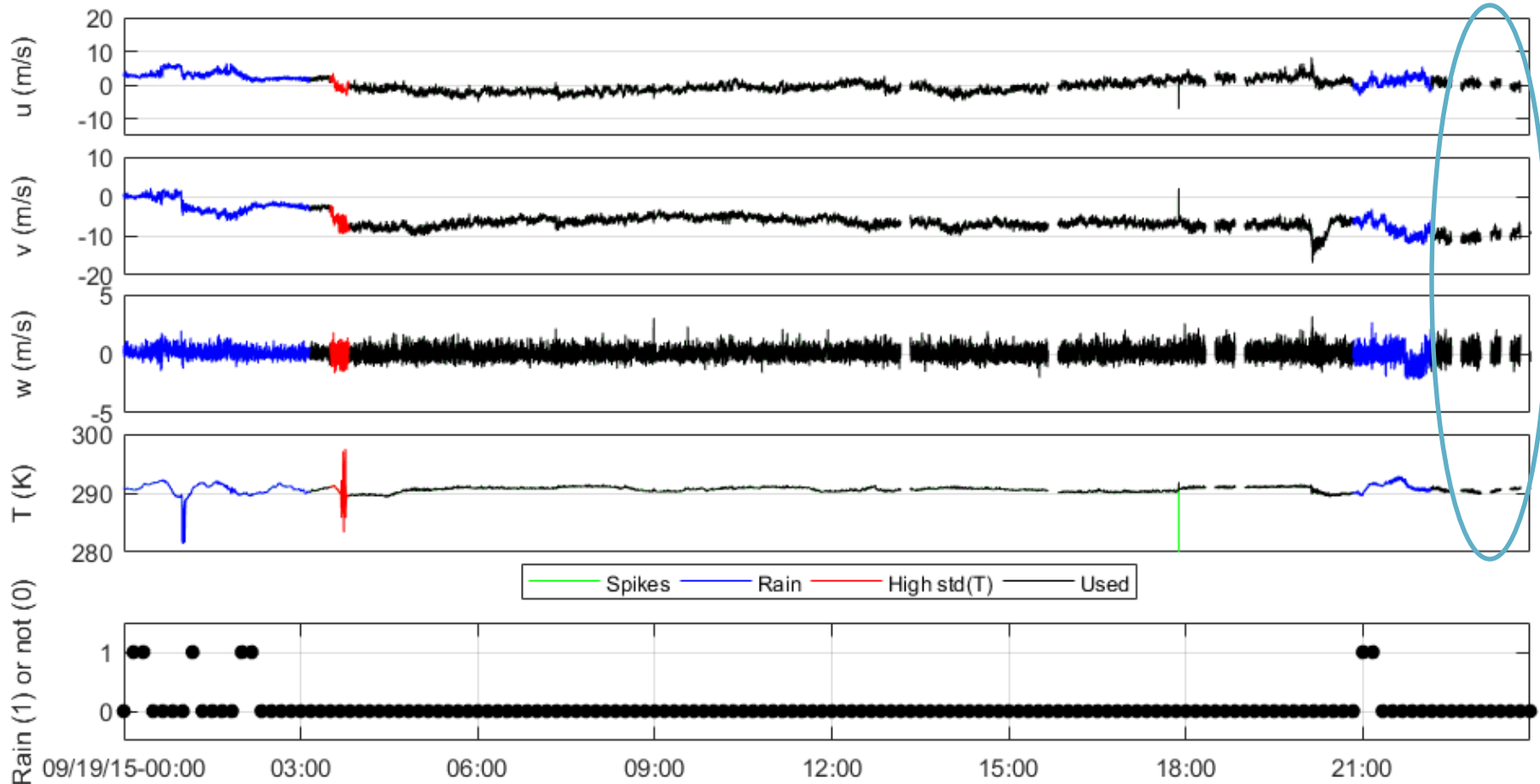
# The processing procedure

Assessing data gaps and removing corrupted raw data files





# The processing procedure

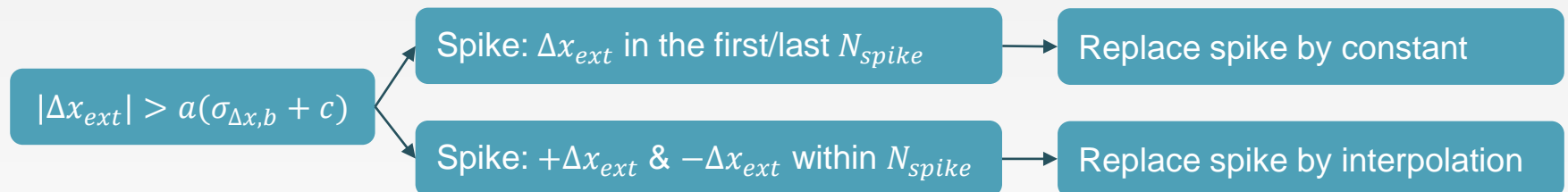




# The processing procedure

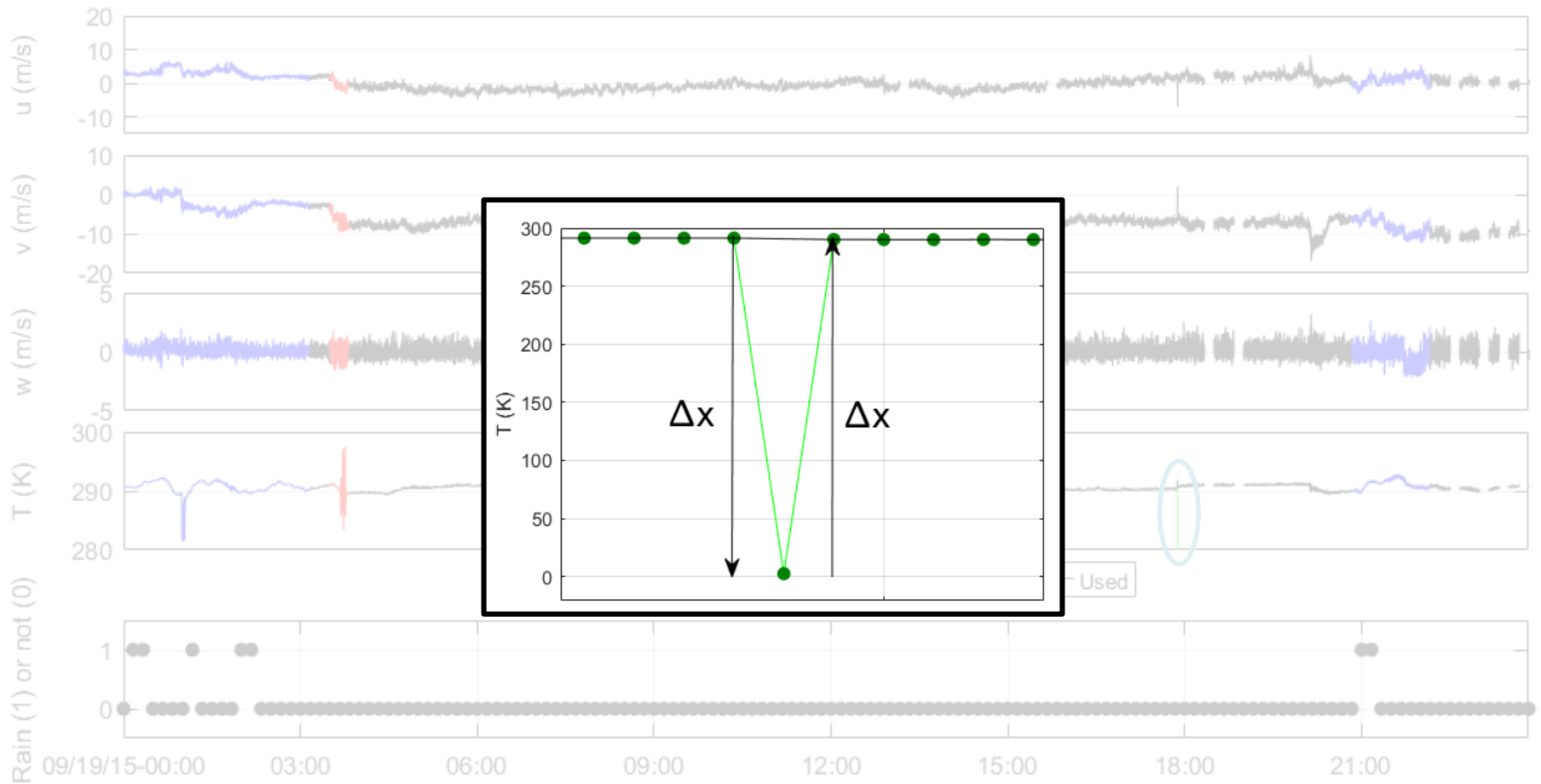
Assessing data gaps and removing corrupted raw data files

Spike detection and removal





# The processing procedure





# The processing procedure

Assessing data gaps and removing corrupted raw data files

Spike detection and removal

Disregarding measurements close to precipitation events

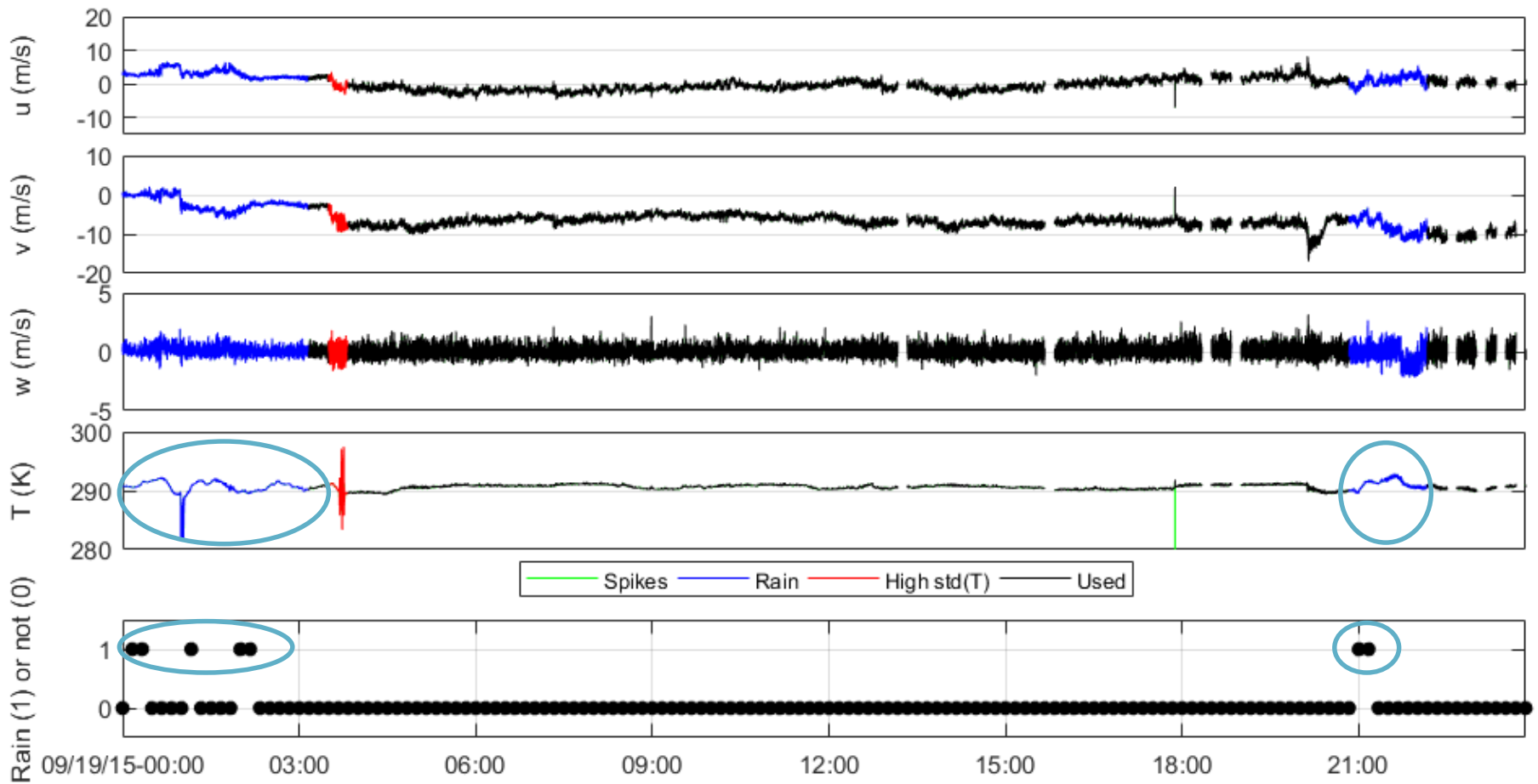
- Rain / no rain
- Removing 10 minutes before and 50 minutes after precipitation event







# The processing procedure





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Disregarding measurements close to precipitation events

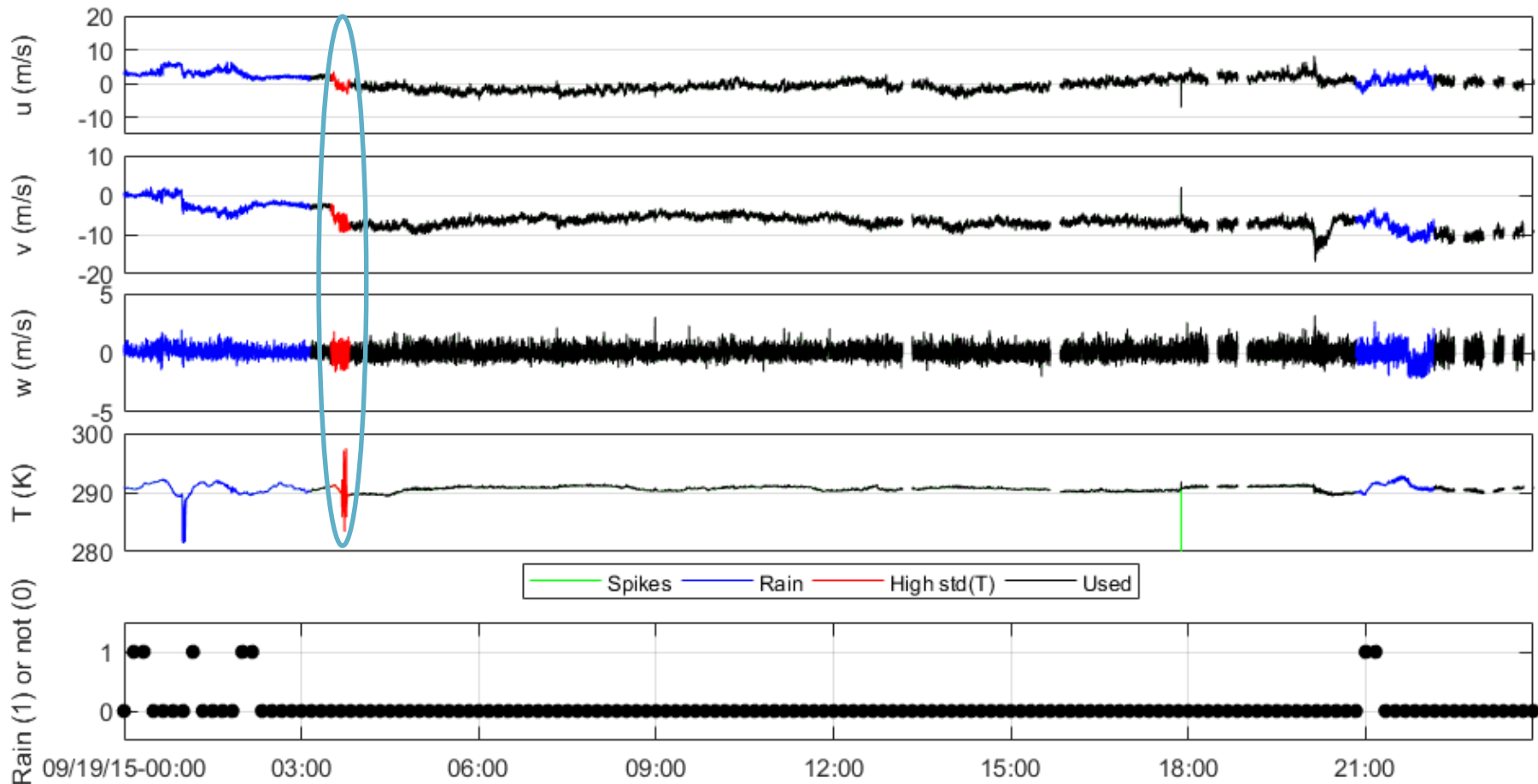
Disregarding measurements influenced by other disturbances

- Fog, frost, sea spray or larger aerosol particles





# The processing procedure





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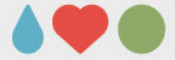
Spike detection and removal

Disregarding measurements close to precipitation events

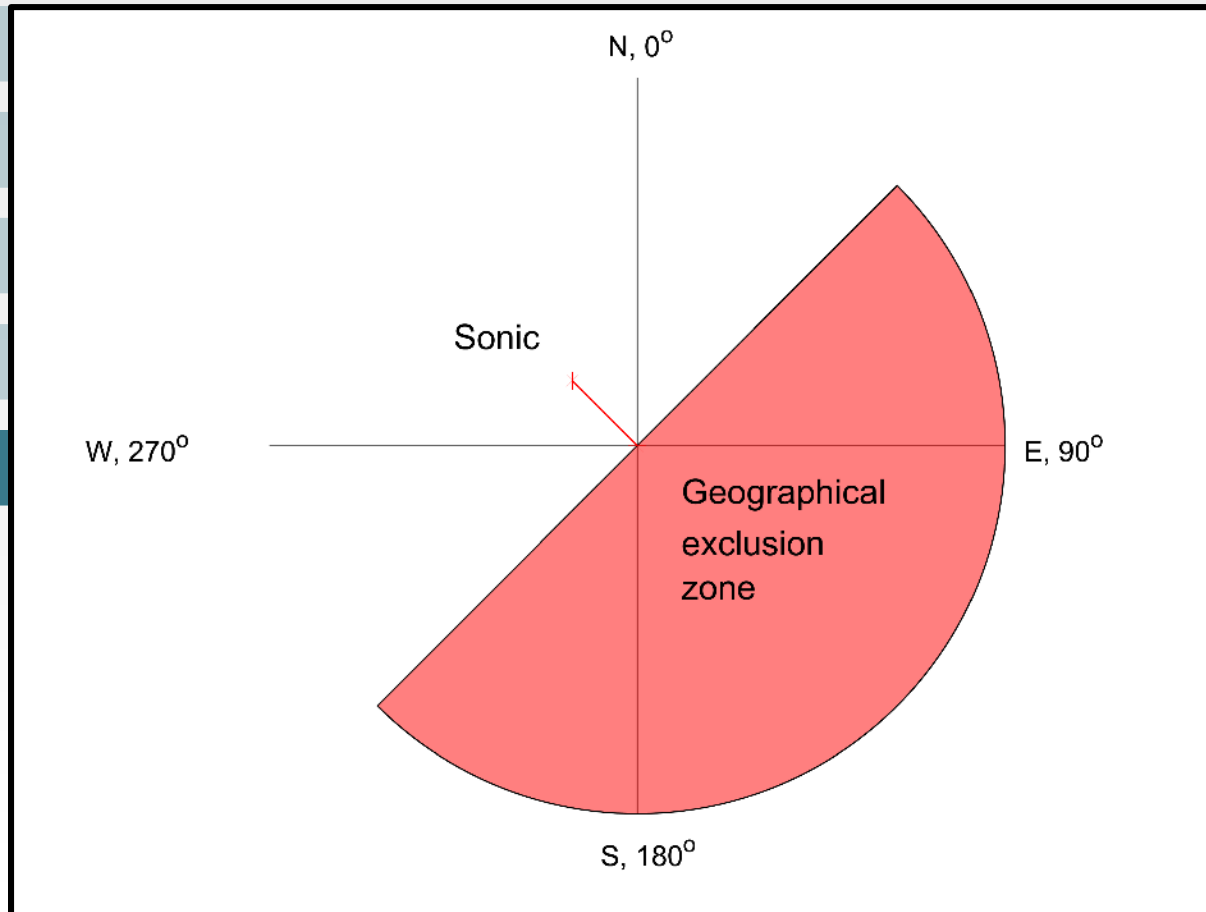
Disregarding measurements influenced by other disturbances

Disregarding measurements from the geographical exclusion zone



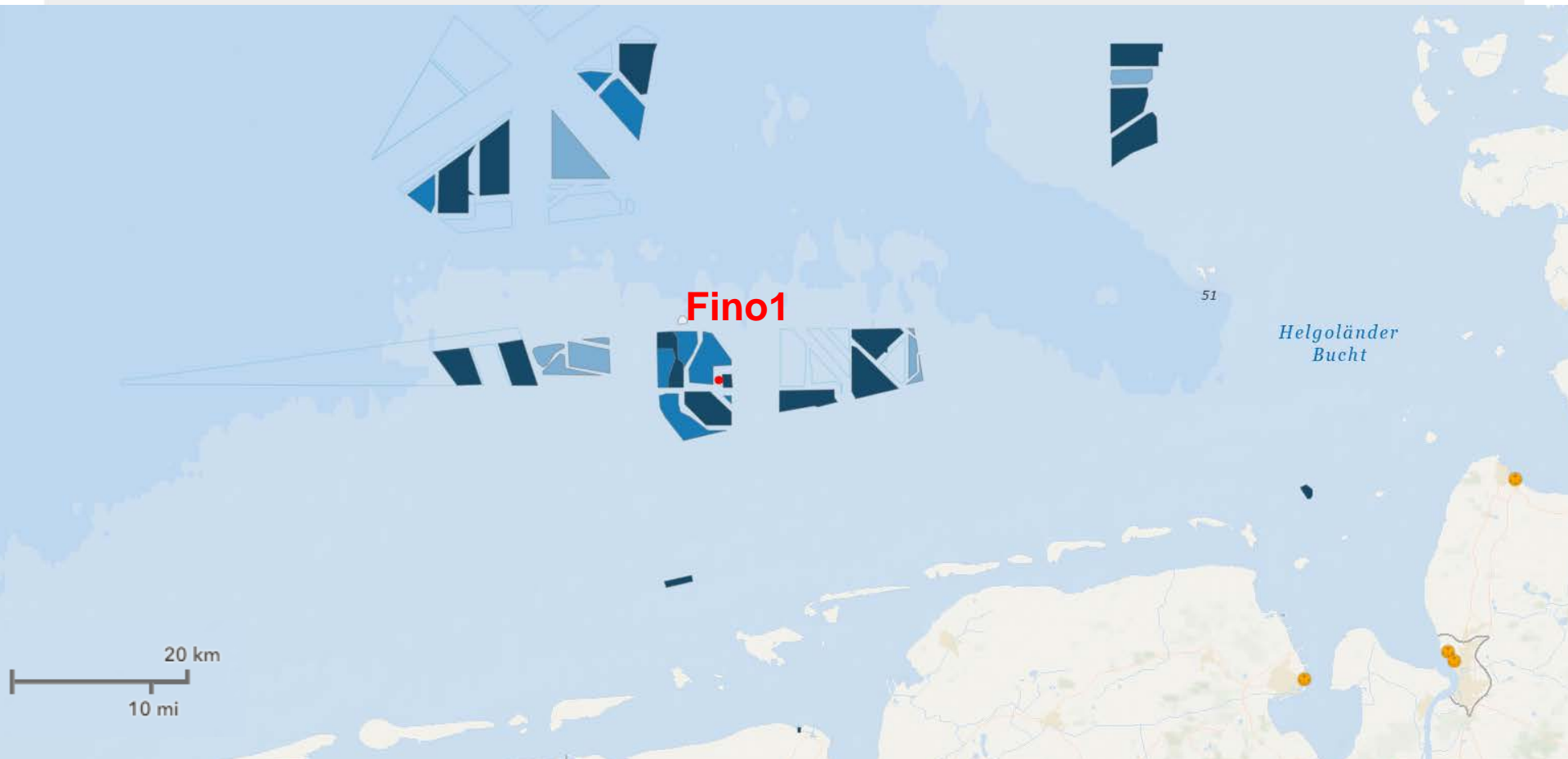


# The processing procedure





# The processing procedure





# The processing procedure

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Spike detection and removal

Disregarding measurements close to precipitation events

Disregarding measurements influenced by other disturbances

Disregarding measurements from the geographical exclusion zone

Rotation to mean flow direction

- Double rotation





# The processing procedure

Assessing data gaps and removing corrupted raw data files

Spike detection and removal

Disregarding measurements close to precipitation events

Disregarding measurements influenced by other disturbances

Disregarding measurements from the geographical exclusion zone

Rotation to mean flow direction

Organizing in 30-minute periods







# Stationarity assessment

1. Step: Linear trend test

$$\frac{\Delta U}{\bar{U}} \leq \frac{0.2 * \Delta t(\text{min})}{60 \text{ min}}$$

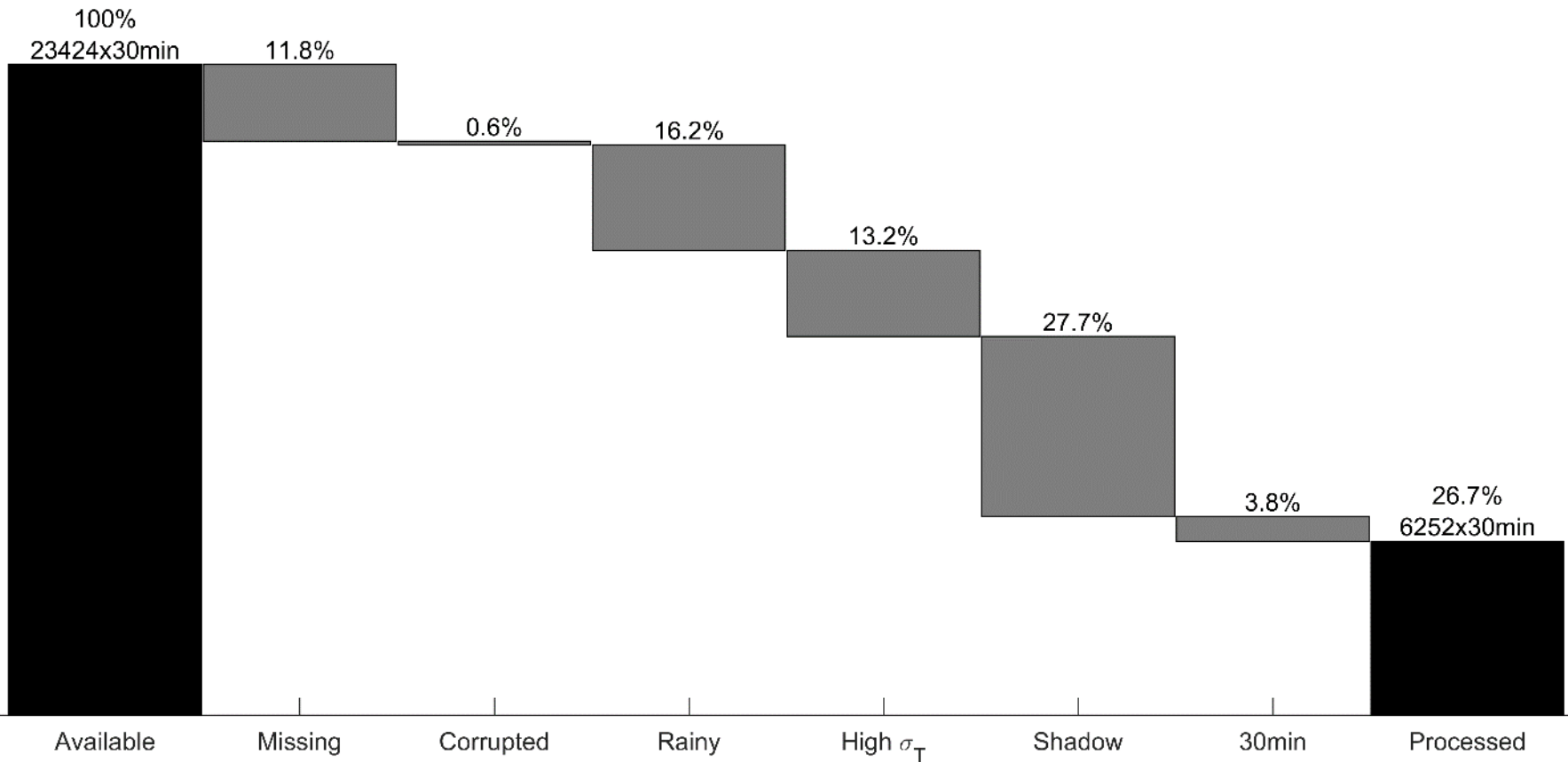
2. Step: Moving mean and moving standard deviation test

$$\max \left( \frac{|\overline{U_{60min}} - U_{10min}|}{\overline{U_{60min}}} \right) \leq 0.4 \quad \& \quad \max \left( \frac{|\overline{\sigma_{U,10min}} - \sigma_{U,10min}|}{\overline{\sigma_{U,10min}}} \right) \leq 0.4$$



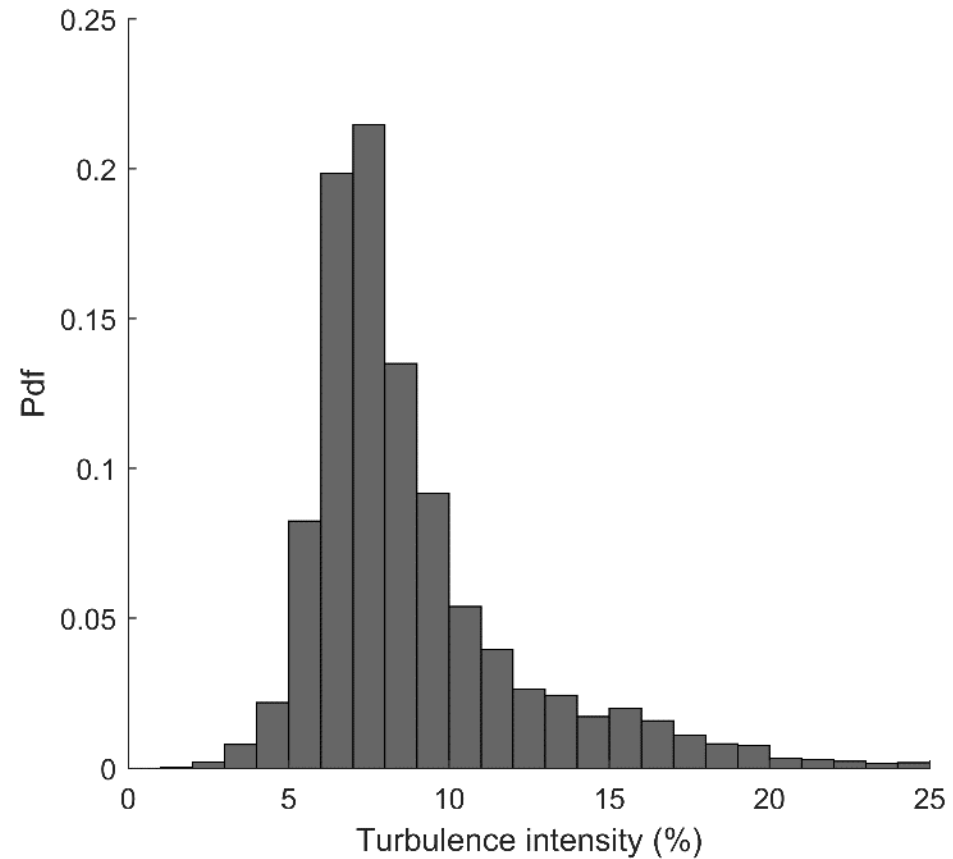
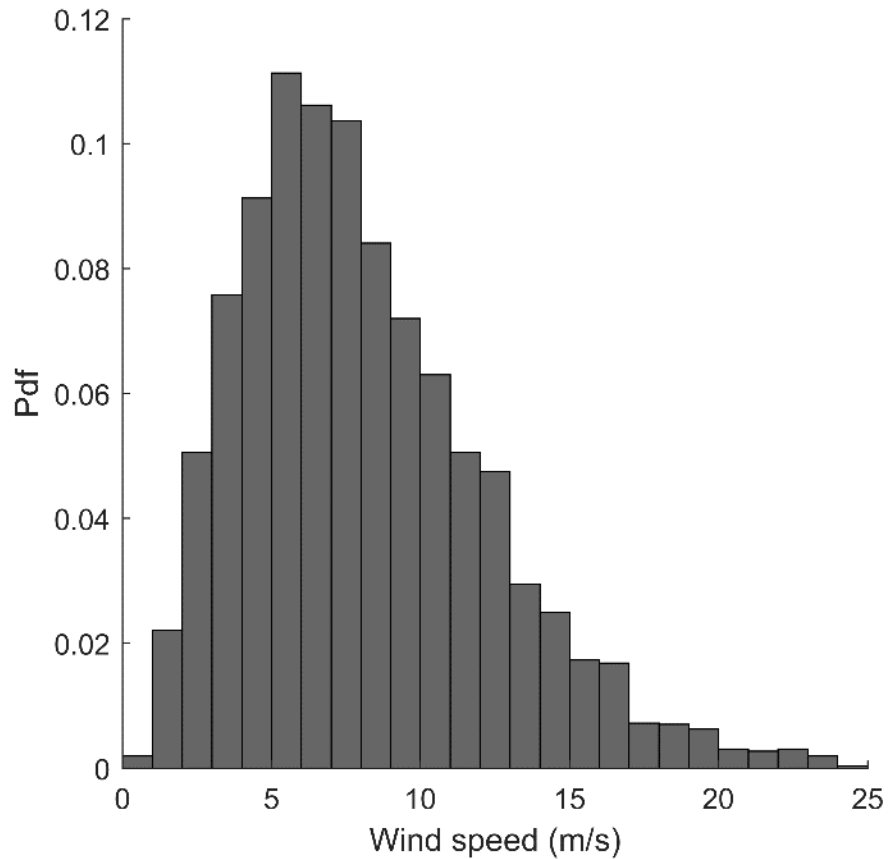


# Complete data set



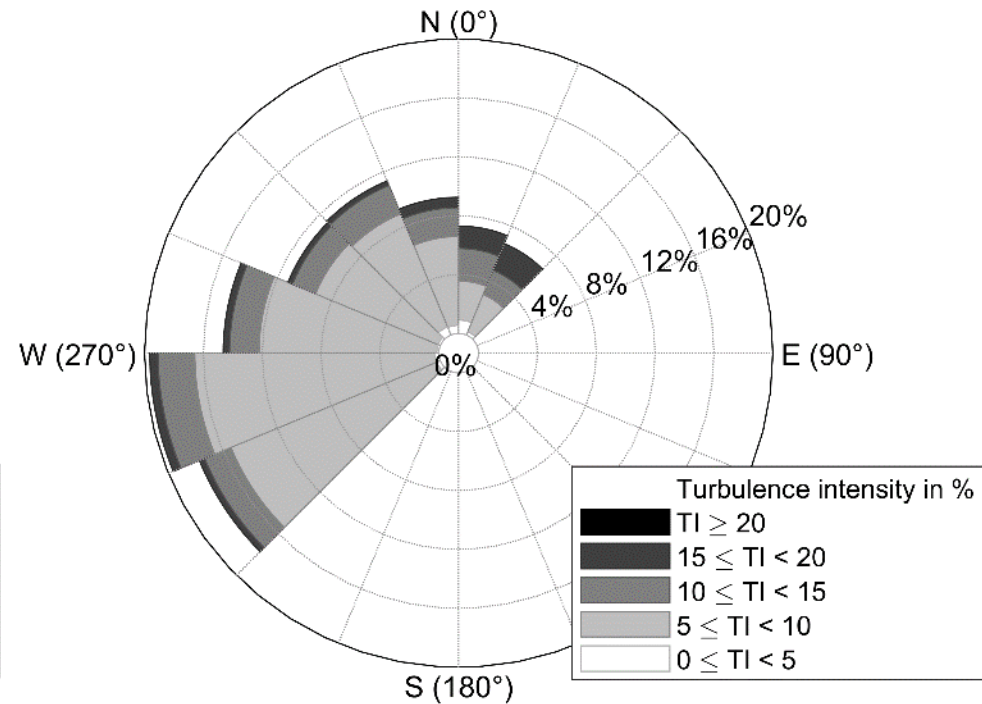
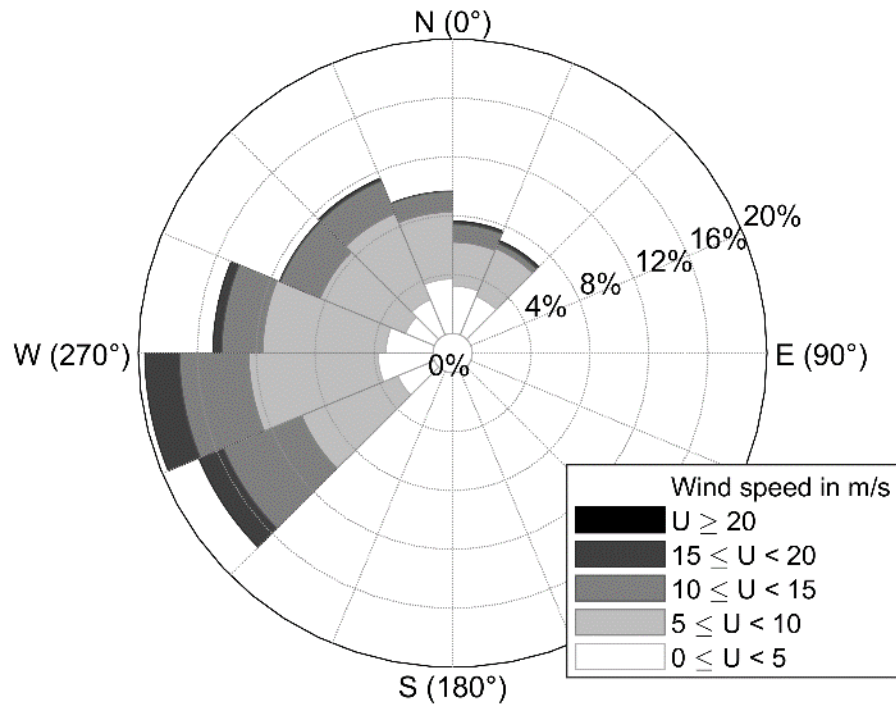


# Overview of the data set



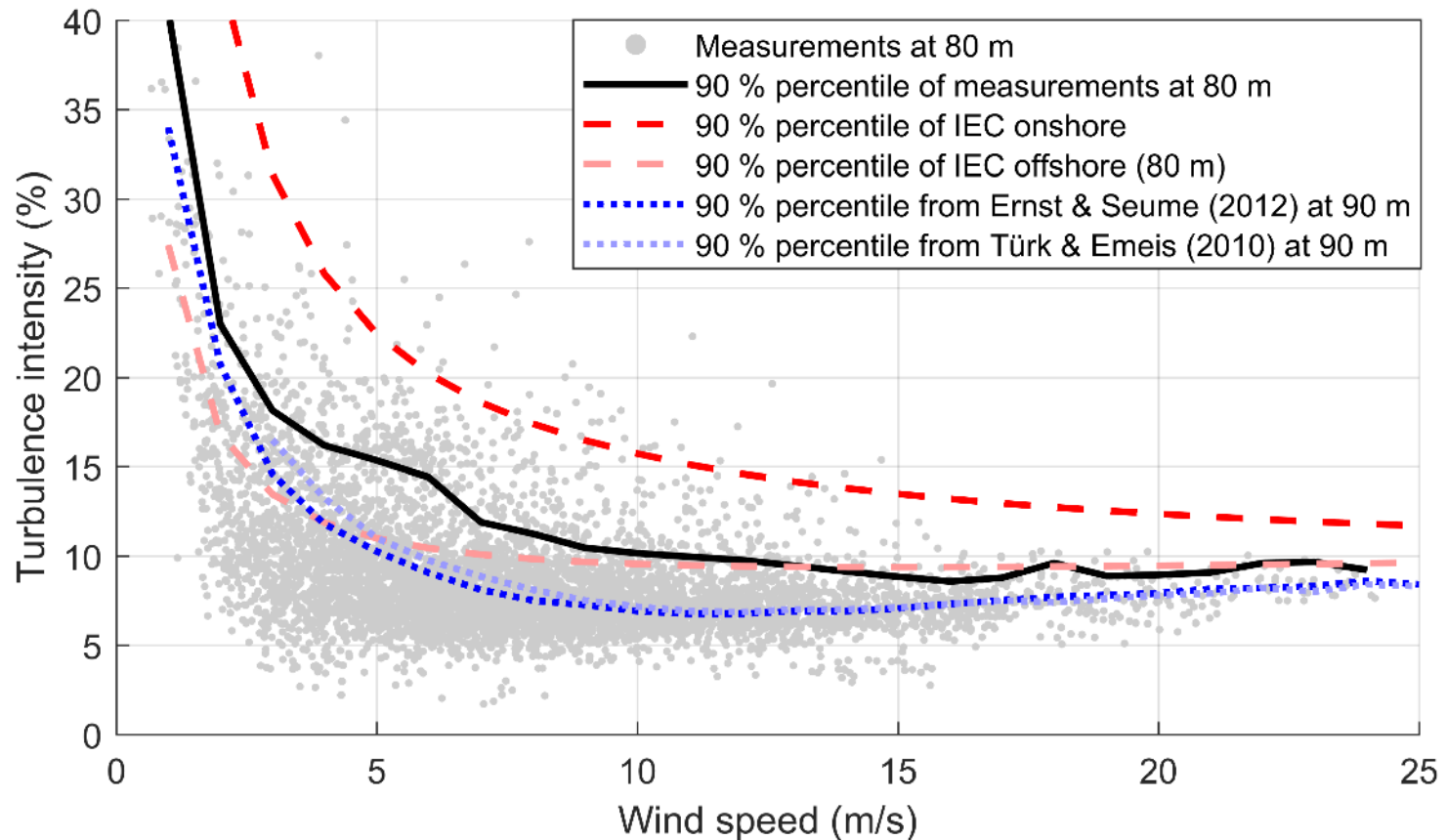


# Overview of the data set





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# Limitations of the data set

- Reduced data availability
- Biased towards situations without precipitation

Season	Availability after the processing procedure (%)
Summer 15	12
Autumn 15	24
Winter 15/16	23
Spring 16	28
Summer+Sept. 16	42

- Not able to retrieve proper wind or temperature profiles





# Other reflections

## Conservative approach

### Further use:

- Relation between parameters
- Frequency domain
- Validation of standards
- Simulations of dynamic response





# Conclusions

A thorough processing procedure of sonic anemometer measurements for offshore wind turbine applications is presented







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The processing procedure concludes in a data set with a great variety in offshore conditions





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The processing procedure concludes in a data set with a great variety in offshore conditions

Together with a stationarity assessment, the data set is prepared for numerous applications



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