Estimating offshore wind farm insta installation performance with satellite data

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Abstract.

- Offshore wind maturing, installations are a massive challenge
- Little public data on offshore wind farm installation performance available
- Offshore Wind Farm Installation massively influenced by weather limits
- Combining Automatic Identification System (AIS), ERA5 and public wind farm data allows to assess performance of offshore wind farm installation as a function of metocean data, location, wind turbine type and installation vessel

1 Introduction

With 5,795 offshore wind turbines operational in Europe alone (June 2022), offshore wind has become a major source of electricity in several countries, and more than 20 years of installing offshore wind farms has led to a significant amount of learning in the industry. While a great deal of scientific literature is available on wind turbine design and operations, the body of literature dealing with offshore wind farm installations is comparatively small, even though installing wind turbines offshore imposes a complex and thus scientifically interesting problem.

The installation of an offshore wind farm is by no means an easy undertaking: metocean conditions must be within narrow limits to allow save operations. Specialized equipment, vessels, and crews are required. The continuously increasing size of turbines, as well as increasing water depths, and new locations where little experience is available, add to the risks associated with installations. Unforeseen downtimes are costly and put additional strain on already difficult operations.

In this study, we investigate how metocean conditions correlate with offshore wind farm installation times. We compile a statistical overview of offshore wind farm installations: from satellite data, we extract correlations between turbine size, wind

Table 1. AIS vessel data used in this study.

MMSI	Name	Data time range
218389000	Thor	2010 - 2021
218657000	Vole au Vent	2013 - 2021
219019002	Sea Challenger	2013 - 2021
229044000	Brave Tern	2012 - 2021
229080000	Bold Tern	2013 - 2021
235090598	Blue Tern	2015 - 2021
245179000	Aeolus	2010 - 2021
245924000	MPI Adventure	2010 - 2021
246777000	MPI Resolution	2010 - 2021

farm locations, installation vessels and installation duration with metocean conditions during the installation process. Finally, we extract the observed metocean limits for turbine sizes, manufacturers, vessels, and locations

2 Material and Methods

2.1 Vessel tracks

2.1.1 Data acquisition and pre-processing

To reliably extract installation times for as many offshore wind farms as possible, we acquired hourly *Automatic Identification System* (AIS) vessel data from a data broker. The AIS data includes 9 offshore wind installation vessels over a period of 11 years (see Table 1).

Each AIS vessel record includes latitude, longitude, speed, heading, course and a timestamp for a given vessel.

2.1.2 Clustering vessel tracks to extract wind farms

To extract installation times per turbine per offshore wind farm, we preselected vessel records where the speed of the vessel was 0 and further removed records where the vessel was close to shore or in port. The vessel records were then automatically clustered using the DBSCAN algorithm as implemented in the scikit-learn python package.

2.1.3 Clustering wind farms to extract single turbines

To yield vessel records corresponding to single turbine installations, each wind farm cluster was clustered again with the DBSCAN algorithm, yielding vessel records corresponding to individual turbines. Only turbine locations where at least two vessel records were available were kept for further analysis. Installation times per turbine were then calculated by assuming, that the first available AIS vessel record corresponds to the beginning of turbine installation activities and the last AIS record marks the end of installation activities.

2.2 Wind farms

These clusters were then cross-referenced with the locations of offshore wind farms to select vessel records within a given radius of a known wind farm.

2.3 Metocean data

Based on the time stamps of the AIS records per turbine, ERA5 metocean data was requested for the wind farm location. ERA5 data includes wind speed and wind direction at several altitudes, wave direction, wave period and significant wave height. For each wind farm, metadata such as wind turbine model, rated power and foundation type were collected, and all data was combined into a SQLite database. The database will be made available to the public once analysis has been completed.

3 Results and Discussion

Table 2. Overview of detected wind farms and number of extracted wind turbines per wind farm

Wind Farm Name	Number of Turbines	Rated Turbine Power	Wind Farm Capacity	Number of Extracted Wind Turbines
Luchterduinen	43	3.00	129.00	4
Westermost Rough	35	6.00	210.00	32
Arkona	60	6.42	385.00	49
East Anglia One	102	7.00	714.00	11
Dudgeon	67	6.00	402.00	61
Gode Wind I & II	97	6.00	582.00	61
Hornsea	174	7.00	1218.00	100
Borssele I/II	94	8.00	752.00	55
Humber Gateway	73	3.00	219.00	83
Northwind	72	3.00	216.00	52
Deutsche Bucht	31	8.40	260.40	14
Veja Mate	67	6.00	402.00	19
Galloper	56	6.30	352.80	11
Global Tech I	80	5.00	400.00	22
Butendiek	80	3.60	288.00	76
Moray East	100	9.50	950.00	68
Borkum Riffgrund 2	56	8.00	448.00	48
Borkum Riffgat	30	3.77	113.25	20
Merkur	66	6.00	396.00	59
Trianel Borkum 2	32	6.33	202.56	9
Gemini	150	4.00	600.00	29
Albatros	16	7.00	112.00	11
Nobelwind	50	3.30	165.00	41
Kriegers Flak	72	8.00	576.00	72
Wikinger	70	5.00	350.00	64
Yunlin	80	8.00	640.00	11
Horns Rev 3	49	8.30	406.70	46
Sandbank	72	4.00	288.00	73
Teesside	27	2.30	62.10	25
Rampion	116	3.45	400.20	41
BARD Offshore I	80	5.00	400.00	15
Northwester 2	23	9.50	218.50	41
EnBW Baltic II (MP)	39	3.60	140.40	42

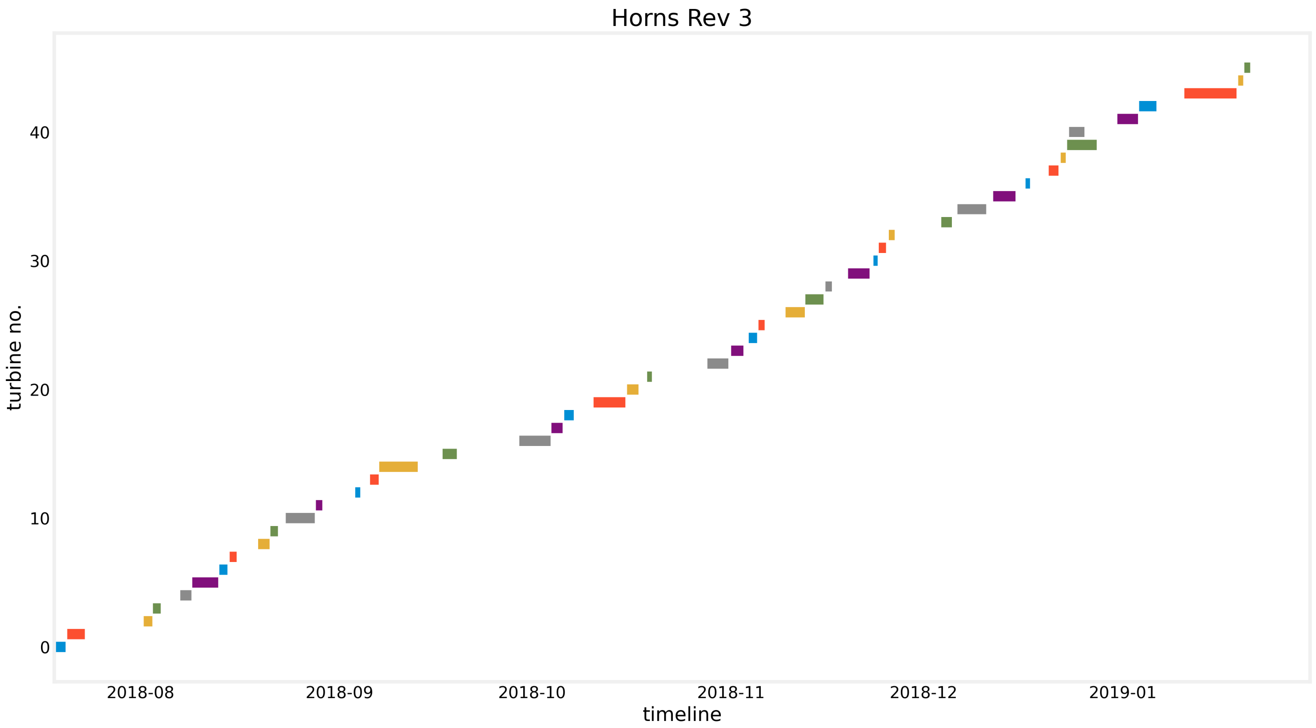

Figure 1. duration distribution

4 Conclusions

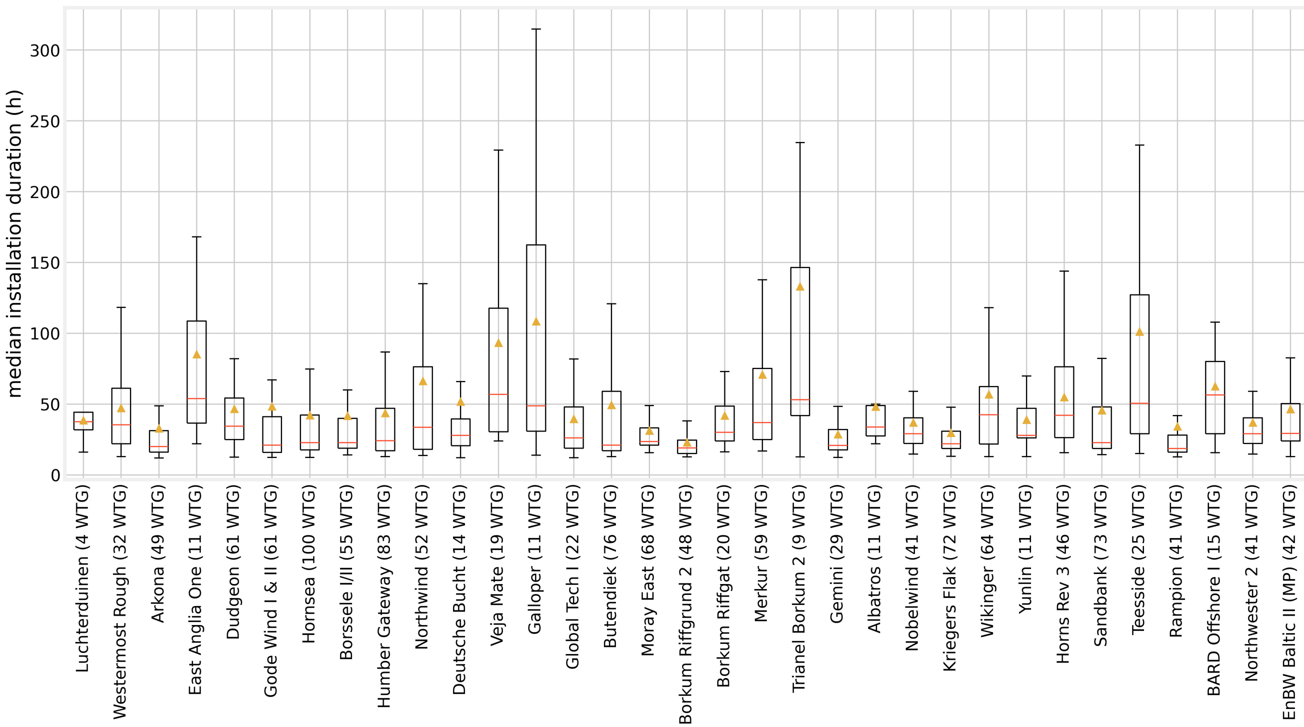

Figure 2. Overview of installation data

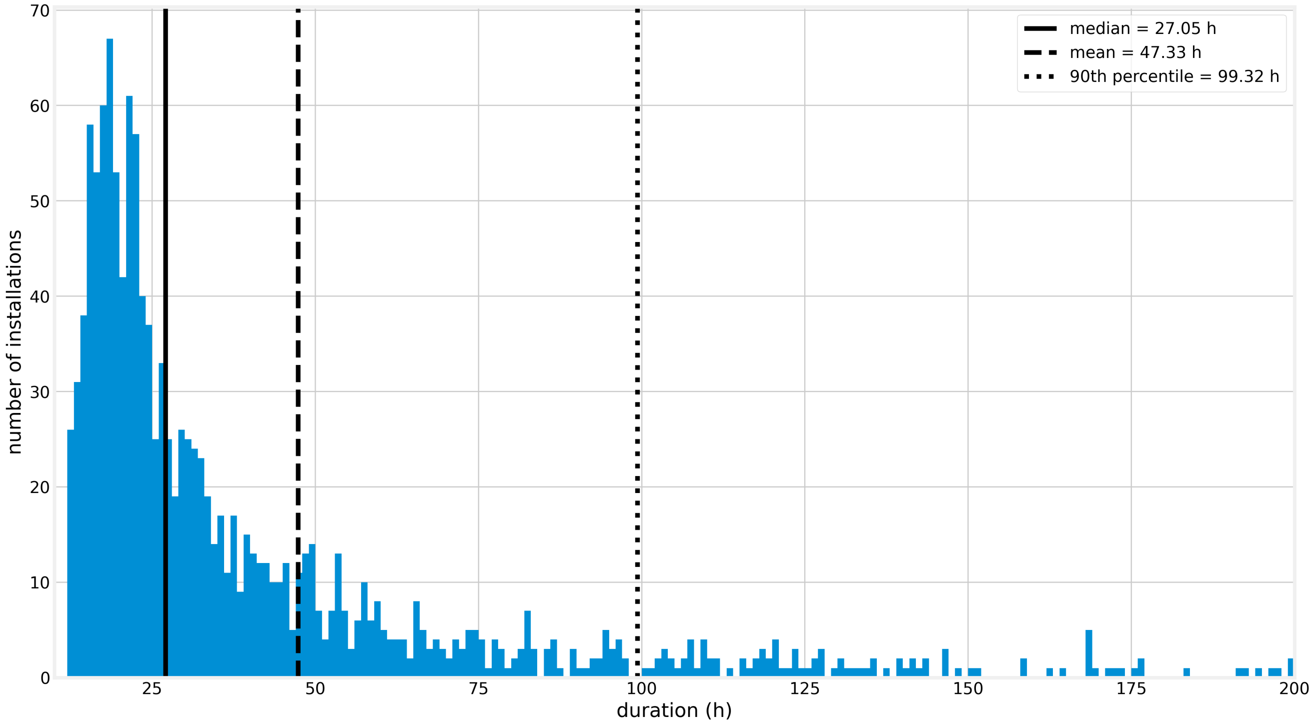

Figure 3. duration distribution

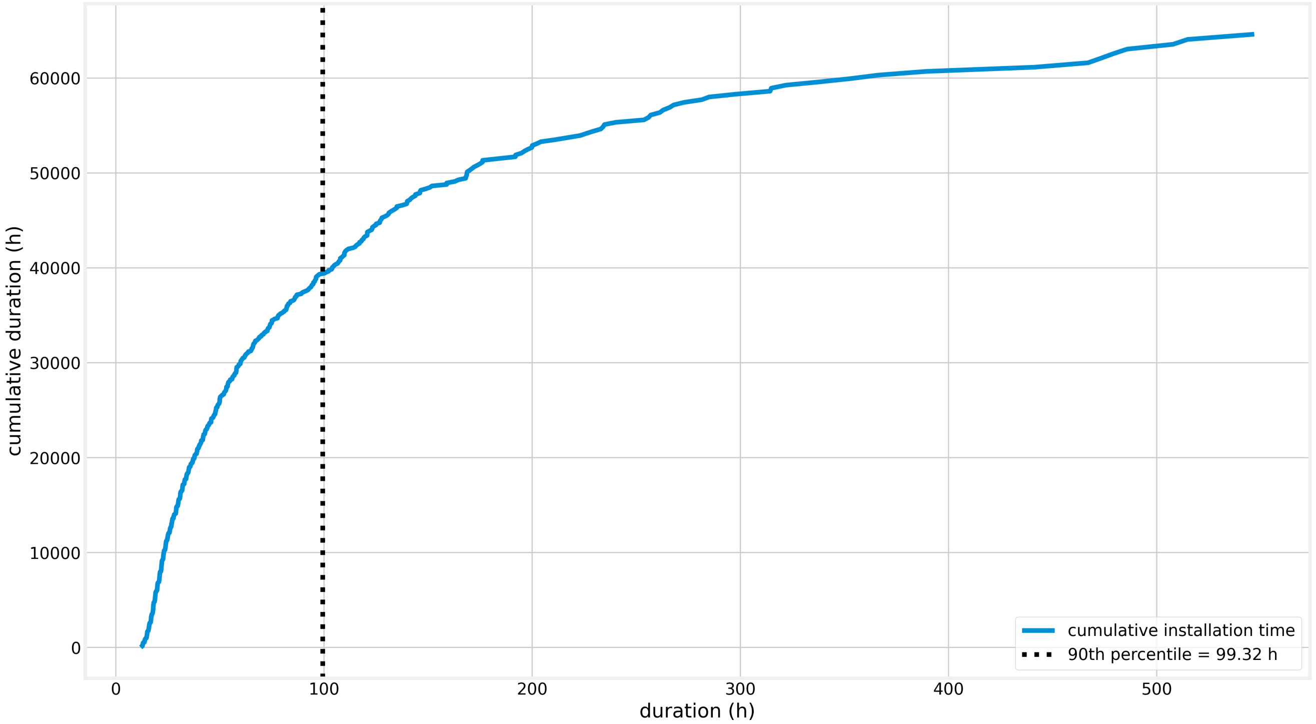

Figure 4. duration distribution

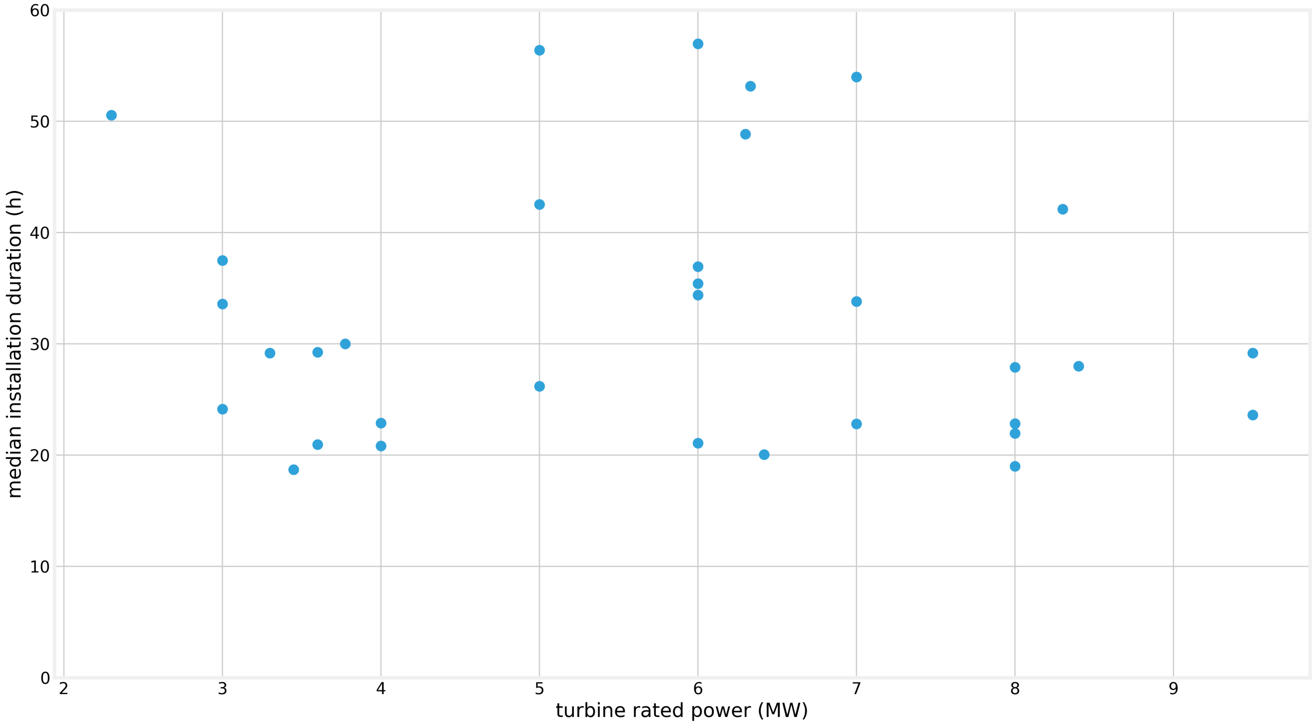

Figure 5. duration distribution

5 Conclusions

Code and data availability. All code related to the present publication is available on github under creative-commons licence: https://github.com/k323r/2022_WES_offshore-wind-installation

Sample availability. TEXT

Appendix A

A1

Author contributions. TEXT

Competing interests. TEXT

Disclaimer. TEXT

Acknowledgements. TEXT

References

REFERENCE 1

REFERENCE 2