Accuracy of load assessments based on modelled turbulence
The German example

PO.253

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Abstract

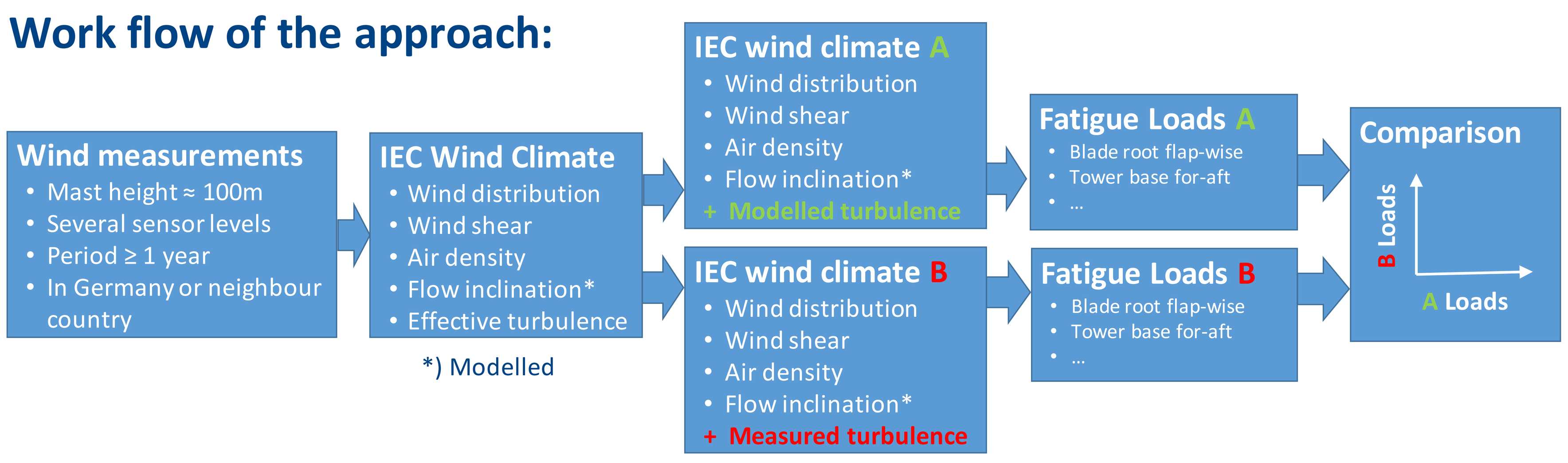
This work studies the accuracy of wind turbine fatigue load assessments based on modelled ambient turbulence intensity (TI) for typical German sites.

The results are important as wind measurements are not commonly installed when developing a wind farm in Germany or Denmark. The wind model is calibrated with production of neighbouring wind farms, but modelled TI is used directly in site suitability assessments according to e.g. IEC61400-1 [1].

Approach

Fatigue loads are estimated using the measured wind climate for 23 masts in non-complex terrain. Results are compared to load estimates based on the same wind climate, but with the measured TI replaced by modelled TI.

Work flow of the approach:



Turbulence Models and Data

TI is calculated using two different micro scale models: WEng and WAsP-CFD.

Additional assumptions are needed as these models predict mean TI, but [1] requires the 90th percentile ($TI_{mean}+1.28\cdot TI_{\sigma}$). Two assumptions are studied:

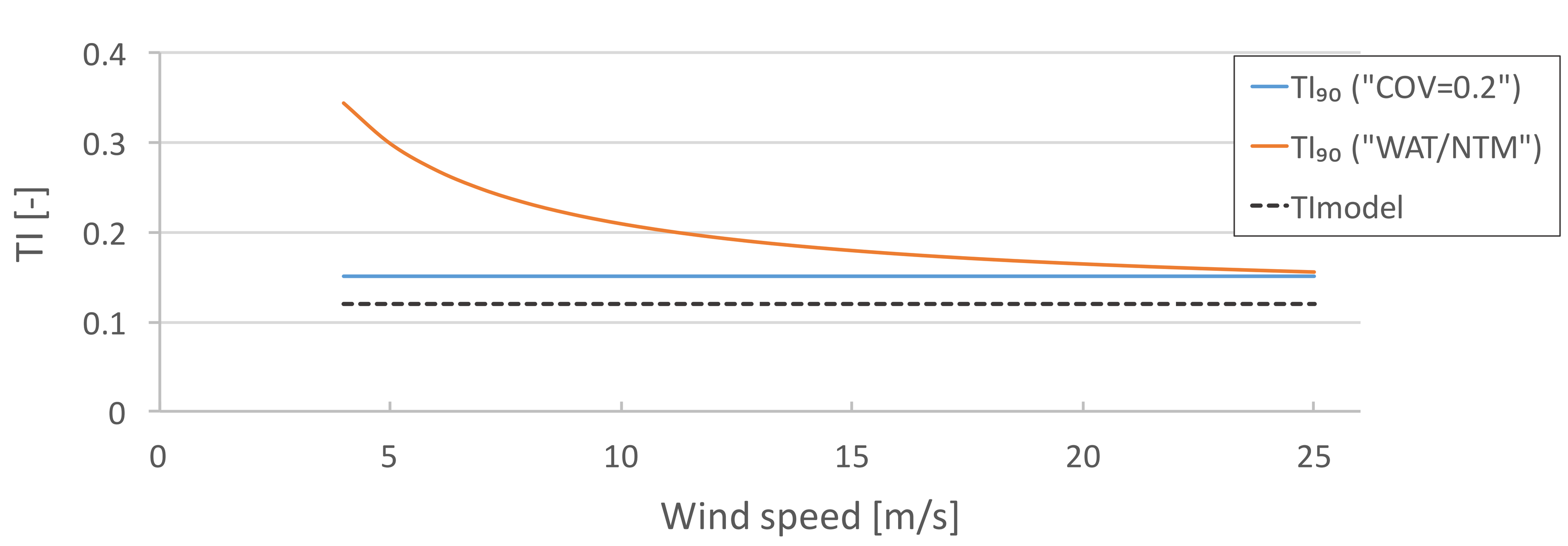
(1) "COV=0.2" proposed in windPRO (2) "WAT/NTM" proposed in WAT

Model assumptions in (1) and (2):

(1) $TI_{mean} = TI_{model}$ and $TI_{\sigma} = 0.2 TI_{model}$ "COV=0.2" [3]

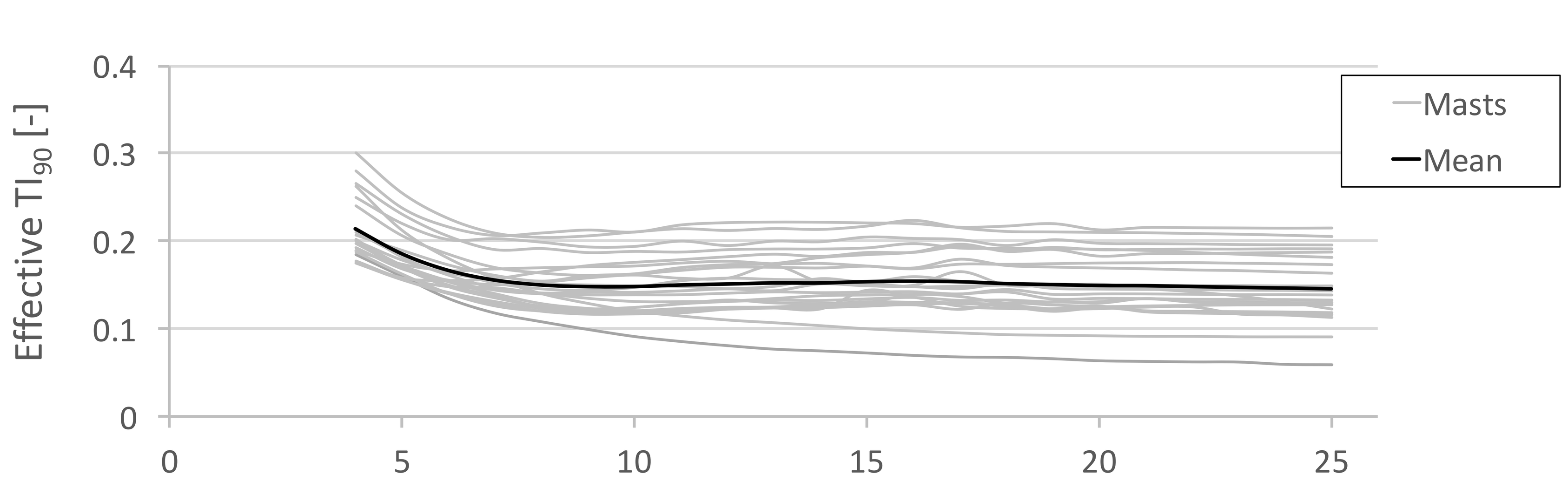
(2) $TI_{mean} = \frac{5+u}{u} TI_{model}$ and $TI_{\sigma} = \frac{1.92}{u} TI_{model}$ "WAT/NTM" [4]

Example of (1) and (2) for TI_{model}=0.12:



Note: the very high values of TI_{90} at low wind speeds of "WAT/NTM".

Measured Effective turbulence (TI_{90}) for the 23 masts:



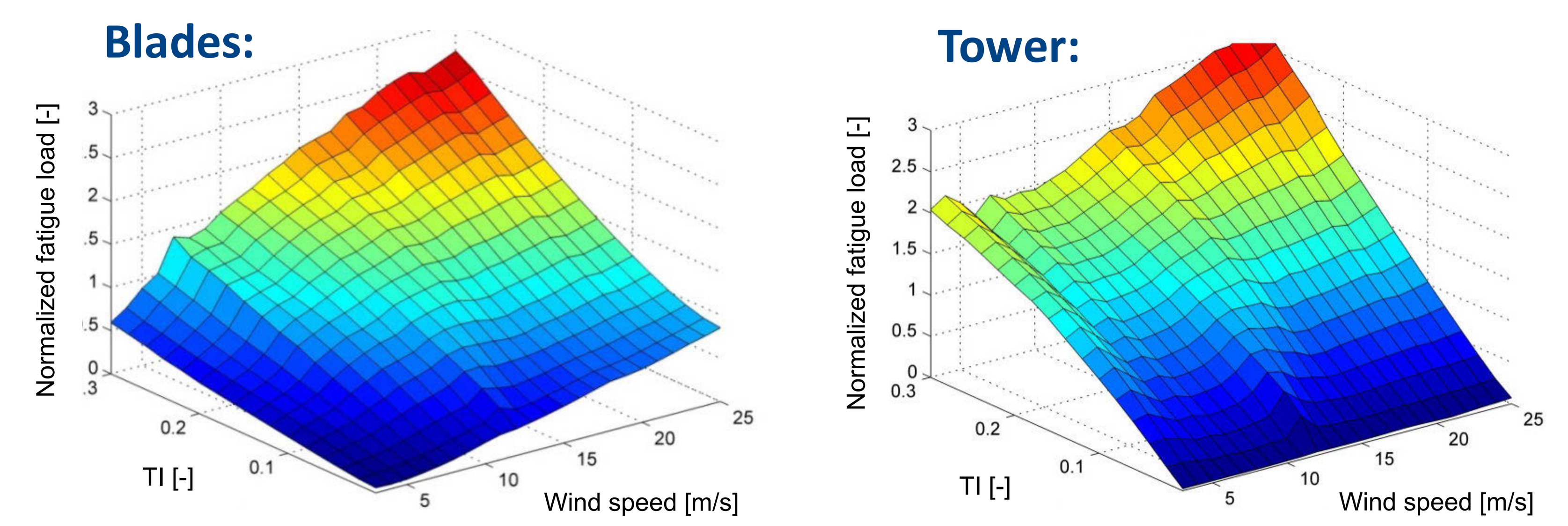
Note: the TI_{90} mast data are essentially constant from 6 m/s.

Fatigue Load Estimates

Fatigue loads are based on design load case 1.2 [1] and the NREL 5MW turbine. Focus is the key components most sensitive to turbulence: "blade" (blade root flap-wise bending) and "tower" (bottom for-aft bending).

The response surface method in [5] is used for efficient and accurate fatigue load estimation, with expected errors <1% for tower and blade cf. [5].

Fatigue load response to wind speed and TI:

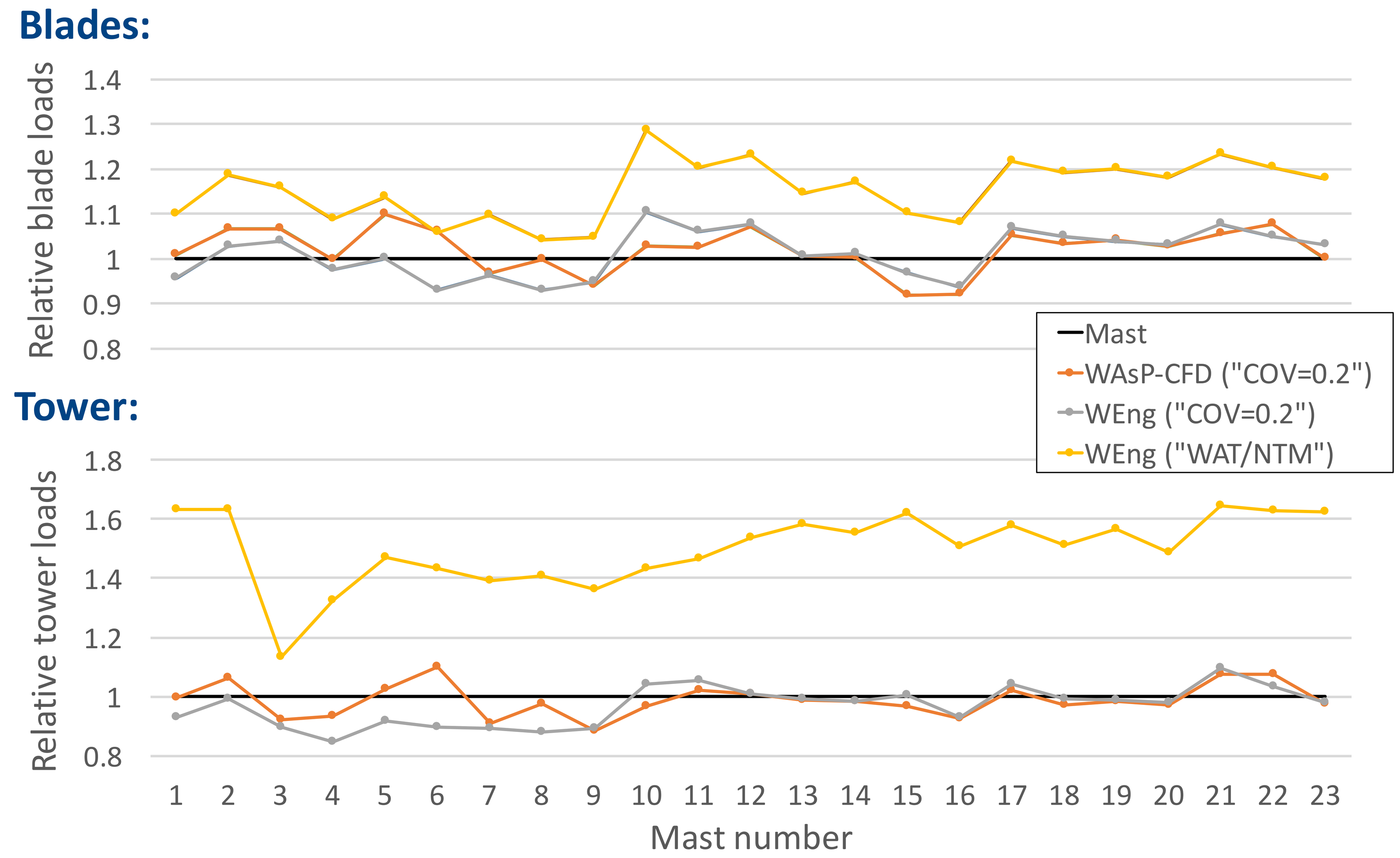


Results

The 23 masts included in this study show consistent and on average unbiased results for WAsP-CFD and WEng using the "COV=0.2" assumption.

Results for WEng+"WAT/NTM" show a significant positive bias, particularly for tower loads, which are more sensitive to high TI at low wind speeds.

Results normalized to loads using mast TI:



Results summary:

	WAsP-CFD ("COV=0.2")		WEng ("COV=0.2")		WEng ("WAT/NTM")	
	Mean bias	SD bias	Mean bias	SD bias	Mean bias	SD bias
Blades	2%	5%	-1%	5%	15%	6%
Tower	-1%	5%	-3%	6%	50%	12%

Conclusions

WEng and WAsP-CFD load results are comparably accurate using "COV=0.2".

Load assessments using "COV=0.2" are unbiased (mean bias < 2-3%).

Load assessments using "COV=0.2" are most accurate (SD bias ≈ 5-6%).

Load assessments for WEng with "WAT/NTM" have a significant positive bias.

References

1. IEC 61400-1 ed. 3, 2010, "Wind turbines - Part 1: Design requirements", IEC, Geneva.
2. Sørensen NN. 1995. General purpose flow solver applied to flow over hill. Risø-R-827(EN). Risø National Laboratory, Roskilde, Denmark, 154 pp.
3. windPRO 3.0 LOADS manual p.36 (http://help.emd.dk/knowledgebase/content/WindPRO3.0/05-UK_windPRO3.0-LOADS.pdf).
4. DTU WAT 4.1, Help/Introduction/Modelling with WAT/Ambient turbulence models/Method 1
5. Toft HS, Svenningsen L, Moser W, Sørensen JD, Thøgersen ML. 2016. Assessment of Wind Turbine Structural Integrity using Response Surface Methodology. Engineering Structures. 106(2016):471–483.