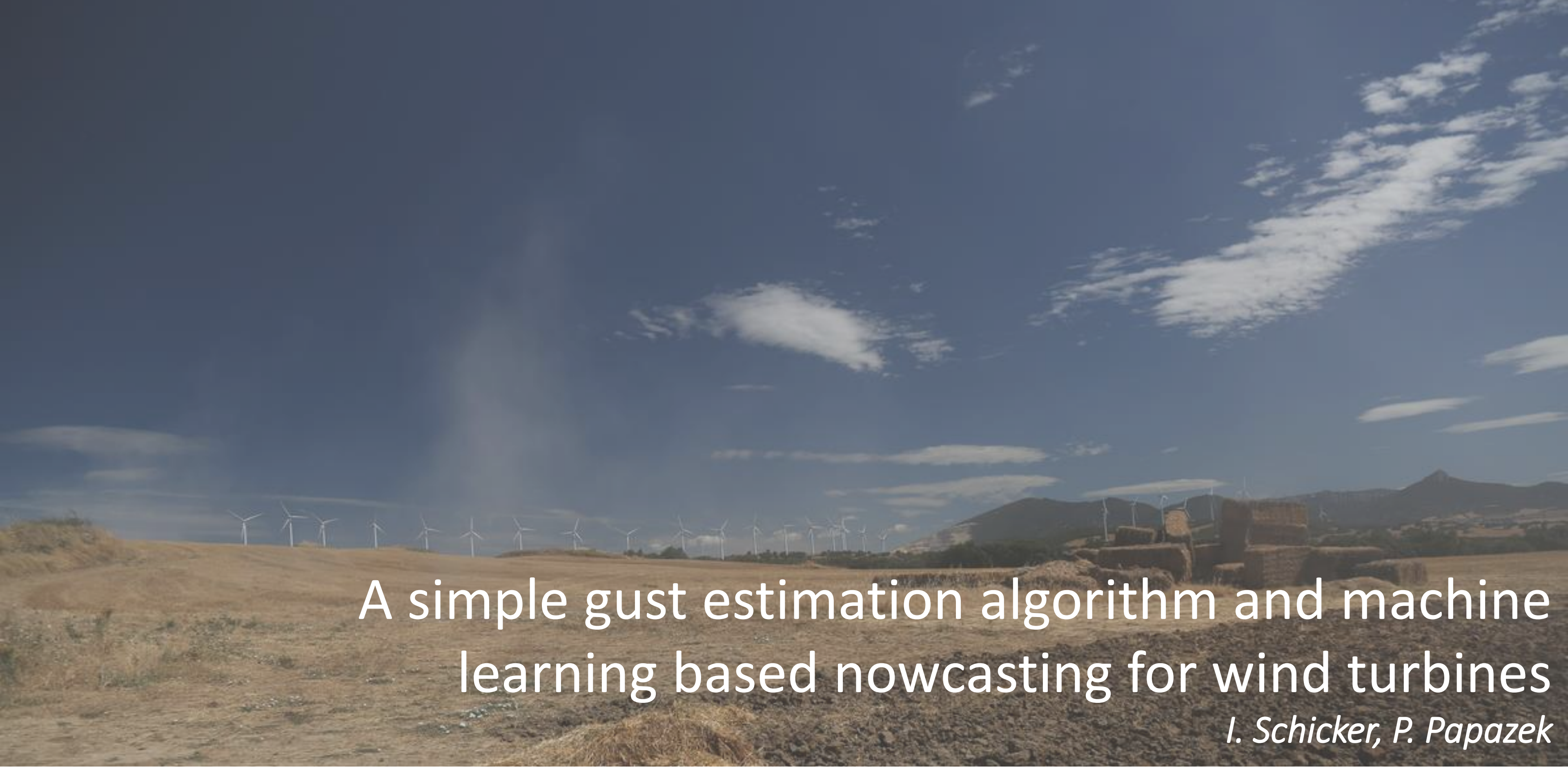

A simple gust estimation algorithm and machine learning based nowcasting for wind turbines

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Introduction

Gusts:

- can cause damage to building, infrastructure, (wild) life, nature
- important for wind energy production, wind turbines, power lines, aviation, air-pollution dispersion, siting of turbines and turbine construction (turbulence, return time of extremes, etc.) and turbine management, Ski resorts / alpine skiing, ski jumping, biathlon, etc.
- provide important information on turbulence conditions at specific sites as turbulence is seldomly reported

Aims

- **Develop a (super) simple gust estimation algorithm usable for hub height / wind turbines**
- **(Ultra) Short frequency nowcasting of gusts for turbines and surface sites**
- **Use machine learning and data mining**

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Data and pre-processing

- standard meteorological observation sites
- SCADA turbine data

pre-processing needed

Pre-processing SCADA data

- No recorded gusts → need to calculate gusts
- Different equations/definitions available from literature (selection):

Wieringa (1973) and Harper et al. (2010):

$$u_{t,T} = u_T + k\sigma_u$$

standard deviation wind speed

mean wind speed (averaged over T)

constant of proportionality

gust (time t, duration T)

→ Simple but missing e.g. convective parts

Cvitan (2004, based on CENELEC/TC 11 (SEC) 40):

$$u_{t,T} = k_g u_T$$ with:

$$k_g = 1 + \frac{2.28}{ln\left(\frac{z}{z_0}\right)}$$

height above ground

gust factor

Roughness length

Wieringa J. 1973. Gust factors over open water and built-up country. *Boundary-Layer Meteorol.* **3**: 424–441.
Cvitan, L., 2003: Determining wind gusts using mean hourly speed. Geofizika, 20, 63–74.

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Data and pre-processing

We have SCADA data measured:
- temperature
- power
- wind speed
- wind direction

Often don't know exact location and/or surroundings!
→ Need to keep it simple!

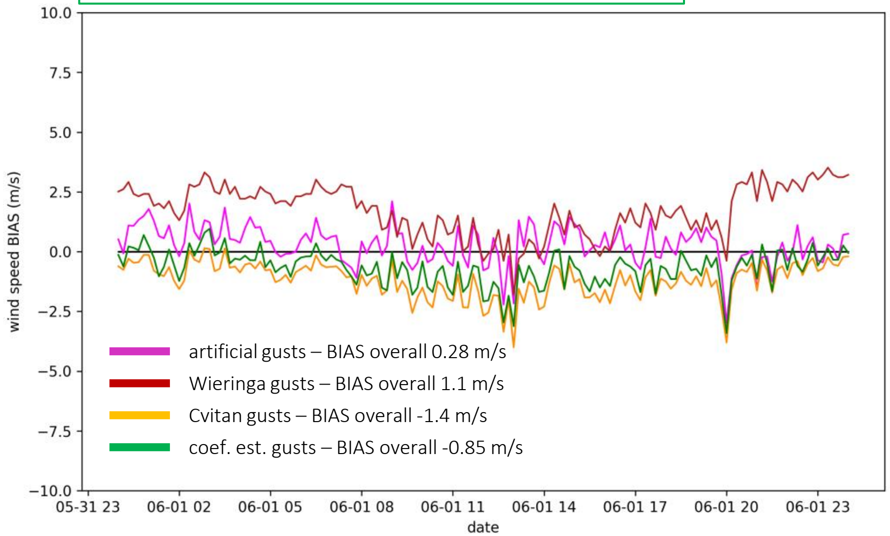
Developed simple, artificial gust estimation algorithm:

$$u_{t,T} = u_T\big(k - (\propto u_T)\big) + \varepsilon\beta$$

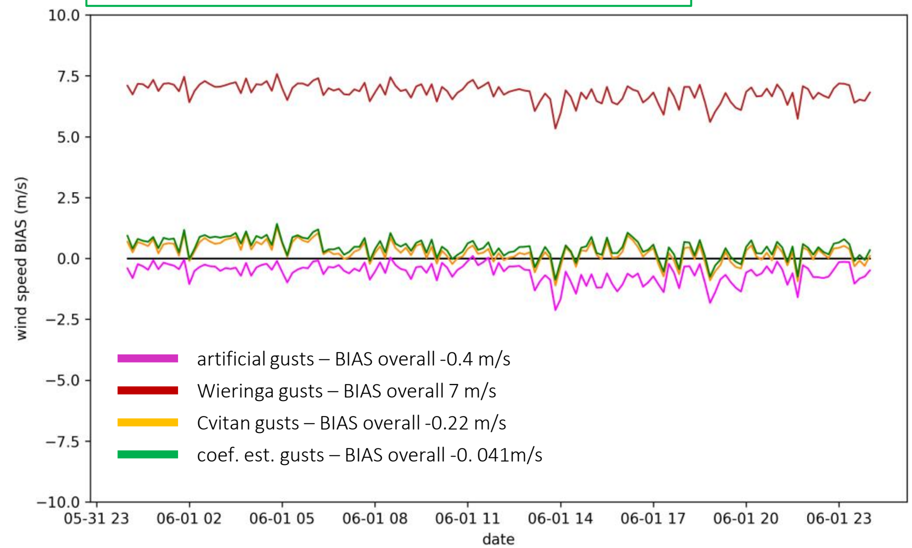
- k: scaling factor
- $\propto$: Scaling factor
- ε: gaussian (white) noise
- β: scaling factor Noise Depending on if hub height or surface measurement

Simple gust estimation - evaluation

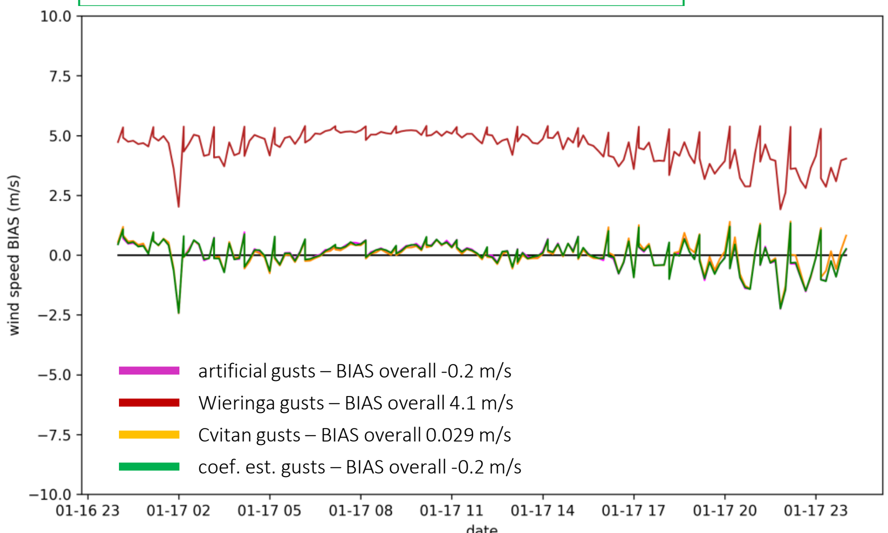
observation site bias to measured gust



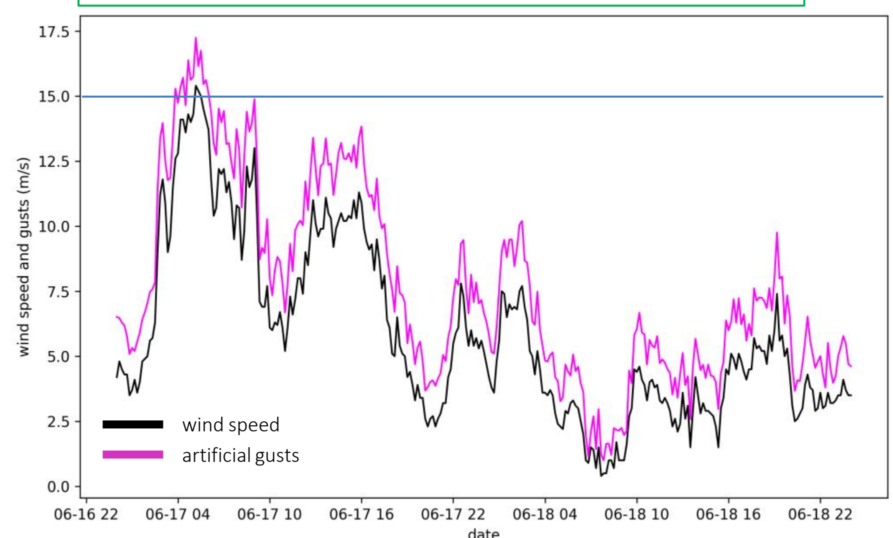
FINO 1 - 102m bias to measured gust



WFIP2 physics site 12, 80 m tower



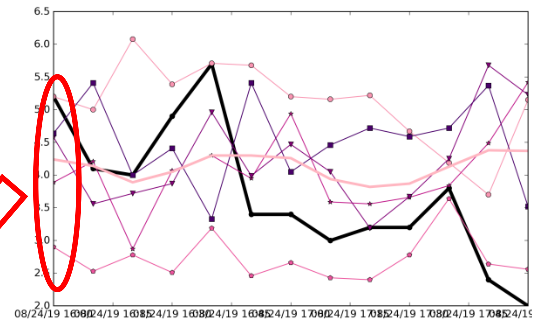
Example artificial gust wind turbine (E101)



Short frequency nowcasting methodology

Nowcasting model
NONAME ZAMG – next +1 to +3 hours

Data
Observations only
(changes in future when AROME-RUC available)



Perturbing observations for ensemble

Feature selection
(LASSO, XGBoost, Random Forest)

Ensemble nowcasting methods (single/multiple selections possible):

- Multilinear regression
- SVR (grid searched)
- **Random Forest**
- XGBoost
- **FF ANN**
- Complex NN
- **Monte Carlo**
- Stochastic Noise Forecast
- **LightGBM**
- Gradient Boosting
- .....

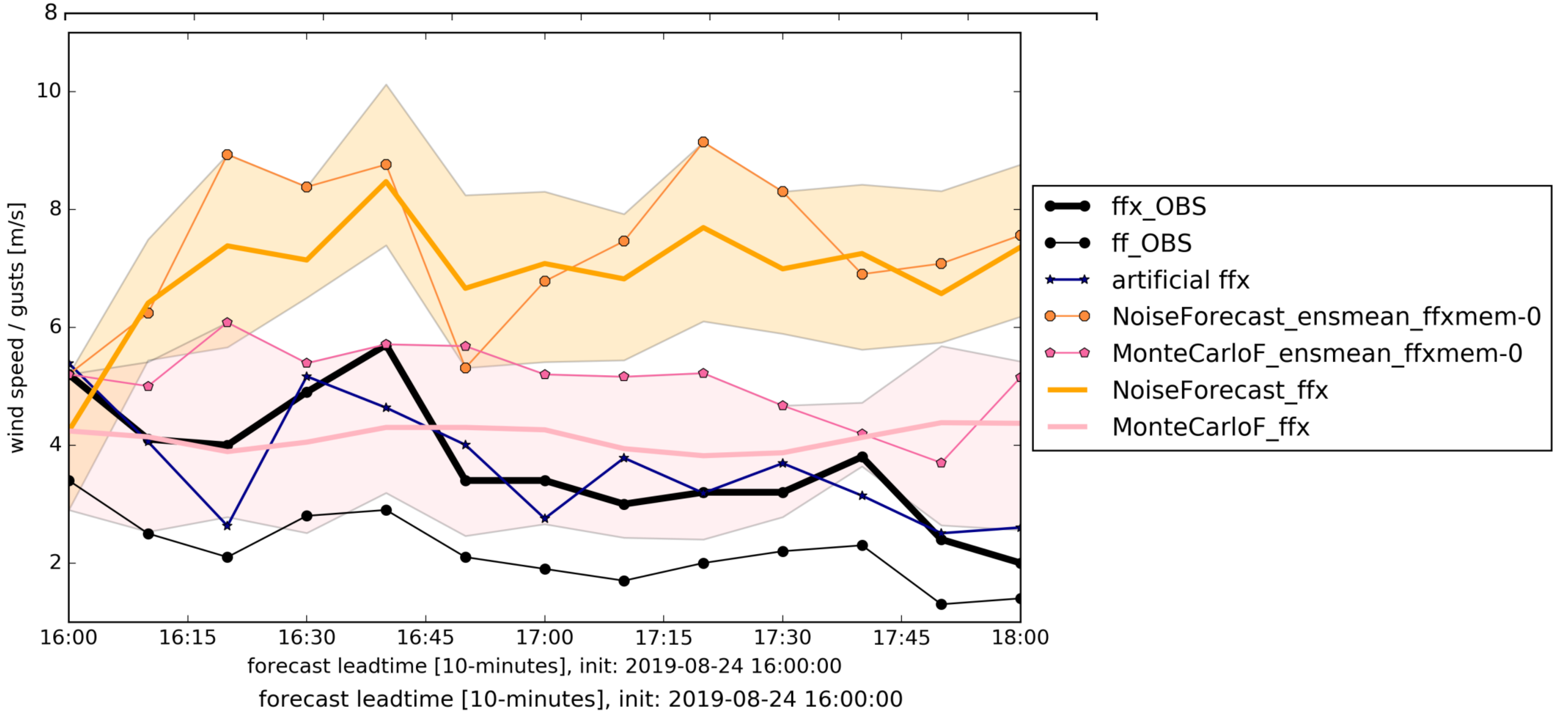
Forecasts: up to 3 hours, 5 – 15-min. frequency

Schicker, I., Papazek, P., Kann, A., and Y. Wang, 2017: Short-range wind speed predictions for complex terrain using an interval-artificial neural network, Energy Procedia, 125, pp. 199-206, https://doi.org/10.1016/j.egypro.2017.08.182
Schicker, I. et al., 2020: Short-frequency ensemble predictions for wind speed and gusts for wind turbines using machine learning, tbs

Result 10 m site – use cases short frequency nowcasting

meteorological observation site Wien Hohe Warte, forecast of 24.08.2019, init at 16 UTC

artificial gusts used in training&forcast, measured plotted



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Conclusions

- Artificial/synthetic gust algorithm in general good. Adjustments still needed. Usable for wind turbine applications
- Nowcasting: need to be really careful with input data, feature selecting and training length. Especially for a feed forward neural network.
- Reliable high-frequency ensemble nowcasts using the new algorithm. However, some methods need hyperparameter tuning.
- Spread of ensemble approach using perturbed observations still too small for some of the methods (e.g. FFNN)