Using a Langevin model for the simulation of environmental conditions in an offshore wind farm

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Introduction

- The **optimization** of operations and maintenance (**O&M**) is a focus of current research.
- Many simulation models/optimizations rely on **artificially generated weather** time series to test different strategies.
- We present a **novel approach** to modeling both the significant wave height and wind speed based on measurements from the site.
- We use a stochastic process called **Langevin process**. First, equations are fitted to the available data, which are then used to generate the artificial weather.

Data

- **ECMWF:** re-analysis, 6 hour resolution, Dogger Bank WF, 37 years
- **Fino 1:** measurements, 30min/10min means, Alpha Ventus, 6 years

Langevin Process

- Deterministic contribution
$$F = D^{(1)}$$
- Stochastic contribution
$$G = \sqrt{D^{(2)}}\Gamma_t$$
- The stochastic contribution makes it easy to include uncertainty.

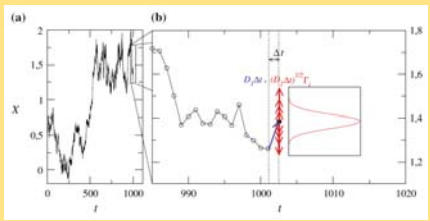


Fig: Example of a Langevin process, from Reinke et al.

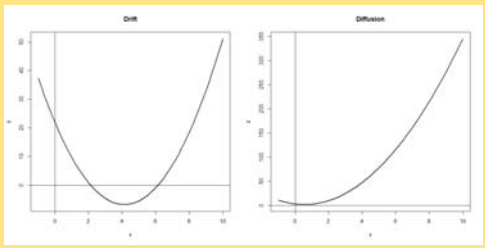


Fig: This example shows the drift and diffusion function for the simulation of the wave heights for a selected winter month used in the Fino 1 simulation.

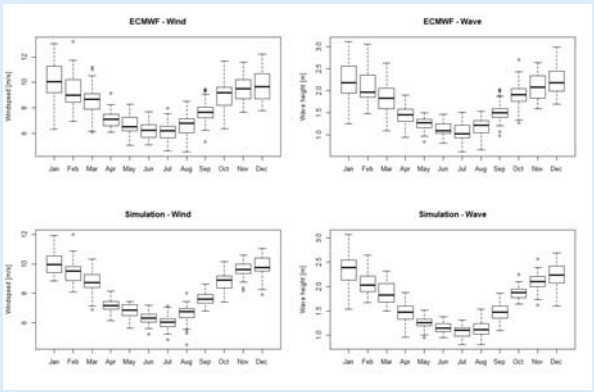


Fig: The monthly means of significant wave height and wind speed, both for the original data and the simulation based on it. The model was fitted to the re-analysis data from the ECMWF.

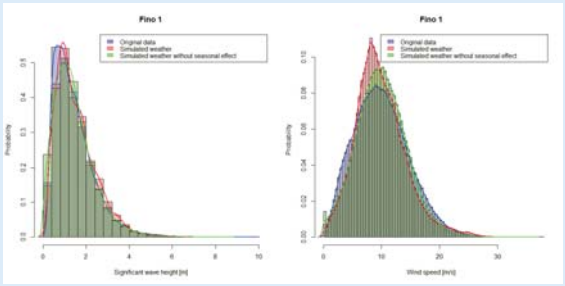


Fig: The distribution of wave heights and wind speeds over 6 years. Shown is the data, simulation and simulation without the seasonal effect.

Wave height	Mean	SD
Data	1.44	0.93
Simulation	1.51	0.92
Simulation without seasonal effect	1.44	0.93

Wind speed	Mean	SD
Data	9.99	4.66
Simulation	9.83	4.38
Simulation without seasonal effect	10.03	4.34

Table: Statistics of the Fino 1 data and the simulations that are based on the data. For the simulation without seasonal effect, one system of equations was fitted for the whole year. In the seasonal simulation, each month was estimated separately.

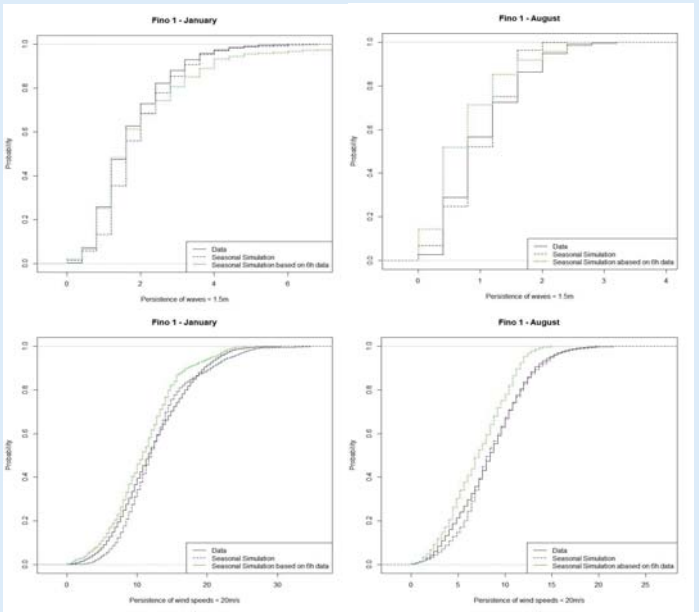
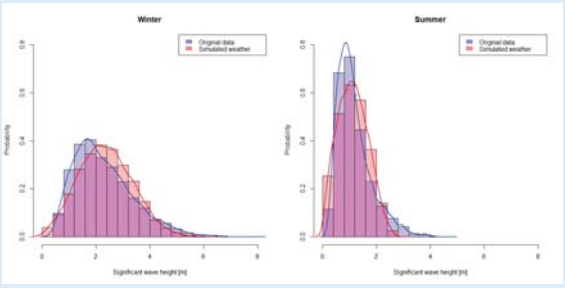


Fig: Persistence of wave heights under 1.5m and wind speeds under 20m/s for two different month for the Fino simulation.

Fig: The distribution of wave heights during a winter month and a summer month. Shown is the data and simulation based on the re-analysis data.



Conclusions and Future work

- The analysis shows that the Langevin process is an adequate alternative to other weather simulation models.
- The properties of the waves (distribution and persistence) are represented very well.
- Higher sampling frequency in the data improves the model.
- Multidimensional Langevin process might capture the correlation between wave heights and wind speeds is another topic for further research.

Selected References

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