IPID4all Doctorate Research Exchange with Carl von Ossietzky Universität Oldenburg
Feedback report

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High Altitude Wind Simulation

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Introduction

Airborne wind energy systems (AWES) are a novel renewable energy source which make use of high altitude winds unreachable to conventional wind turbines. Many different concepts are currently under investigation by various companies and universities worldwide. The high altitude wind resource however is still not thoroughly investigated and high resolution data is hard to find. Reliable energy yield and cost predictions, scalability estimates as well as the development of sophisticated automated control systems can be improved with this information. One of the groups that will benefit from this research is the international, interdisciplinary Airborne Wind Energy System Modelling, Control and Optimisation (AWESCO) research network funded by European Union - Horizon 2020 project, of which the Institute for Integrated Energy Systems at the University of Victoria (IESVic) is an associated partner. The research conducted at Fraunhofer Institute for Wind Energy and Energy System Technology (IWES) and the University of Oldenburg combined Light Detection And Ranging (LiDAR) measurements, mesoscale reanalysis using the Weather Research & Forecasting Model (WRF) and high resolution Large Eddy Simulations (LES) using PArallelized Large-Eddy Simulation Model (PALM).

Research Undertaken

The three months research exchange program was subdivided into a stay at Fraunhofer IWES in Bremerhaven and a stay at the wind energy meteorology research group at the University of Oldenburg. This was possible due to their joint research collaboration ForWind where these groups collaborate with the University of Hannover, Bremen and the German Aerospace Centre (DLR).

I spent the first month at Fraunhofer IWES filtering and evaluating the data from a one year measurement campaign that was conducted in northern Germany as part of the OnKites II project. The two measurement locations were Emden, close to the ocean and Pritzwalk, further inland. A pulsed Galion G4000 Doppler LiDAR by SgurrEnergy, a mobile system which allows the measurement of wind speeds up to 4000 meters away from the device, was used. LiDAR measurement devices detect the backscatter of emitted laser light from small particles or aerosols carried by the wind. It is possible to assess their velocity in beam direction from the occurring frequency shift. Furthermore their location can be inferred from the delay between emission of the laser beam and the reception of the backscatter. By combining multiple inclined measurements the velocity of these particles and therefore the wind velocity can be determined.

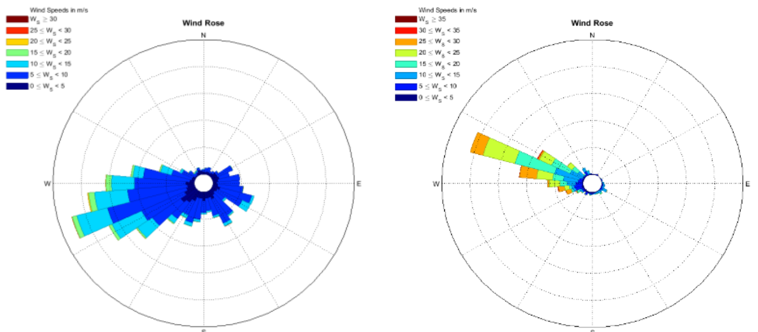

Figure 1 Wind roses for Pritzwalk at 92 m (left) and 993 m (right)

As is industry standard, the 10 minute average was calculated and evaluated. The measurements showed that the average wind speed aloft was higher than below and that the wind direction on average changes clockwise with altitude (see Figure 1).

Diverse diurnal variations were recorded and evaluated according to their speed and direction. Exemplarily Figure 2 shows the availability in the upper plot over a whole day, up to an altitude of 1000 m. Red symbolizes good data availability and blue stands for a lack of data. Centre and bottom show the 10 minute average horizontal wind speed and the corresponding wind direction at various elevations. This day in particular depicts the typical diurnal cycle with a stable stratification during night and an unstable stratification during daytime (illustrated by the converging velocities from around 11 am to 4pm).

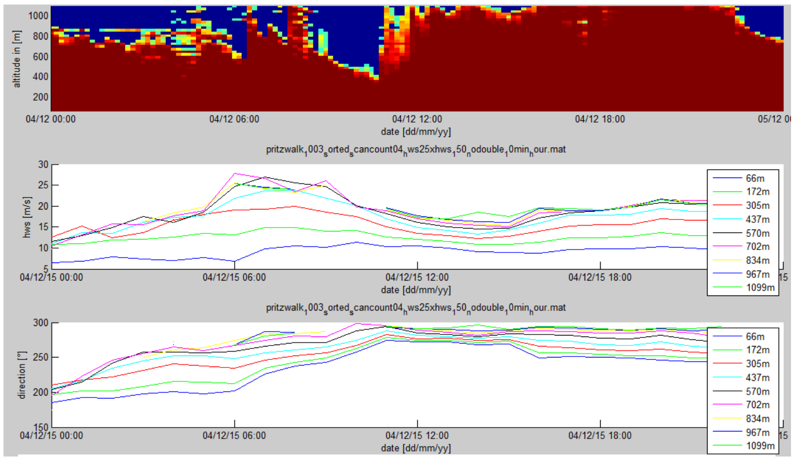

Figure 2 Diurnal cycle 4th Dec 2015 at Pritzwalk

A major problem of high altitude wind measurements is that the data availability diminishes with altitude. One reason is that the number of backscattering particles decreases with altitude up to the atmospheric boundary layer height, above which the particle density drops significantly. Additionally other effects such as low hanging clouds, fog, rain or switch off periods further reduce the overall availability.

Turbulence plays a significant role in the control of airborne wind energy systems. These high frequency fluctuations however are filtered out by averaging the measurements over the above mentioned 10 minute period. This and the low data availability aloft motivated the computational simulation of high altitude winds using a mesoscale weather model as well as a more detailed investigation of turbulence using large eddy simulations (LES). My goal is to use these calculations to fill the measurement gabs with reasonable data. Such simulations were performed in collaboration with the EnMet research group at the University of Oldenburg using WRF and PALM.

The flow chart in Figure 3 visualizes the two simulation subcategories that we performed. First the whole measurement period was simulated as a mesoscale reanalysis using WRF, once with the previously described LiDAR measurements implemented and once without. Its results function as boundary and initial conditions for the subsequent LES simulations. Further simulations need to be run and results investigated.

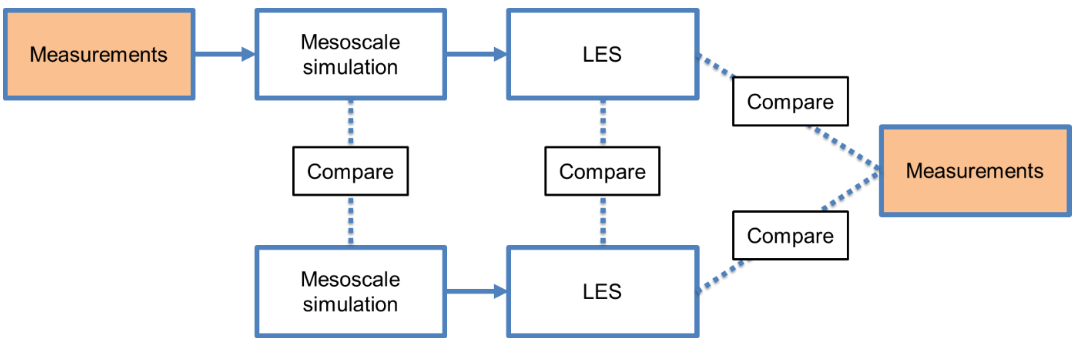

Figure 3 Flow chart of the two branched simulation sequence

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Personal Experience

The IPID4all research exchange program not only allowed me to further my research, but also connected me to very knowledgeable meteorologists and physicists. It gave me a new perspective on wind energy, which I as an engineer, didn't have before.

I want to thank Dr. Ilona Bastigkeit for the help in organising the exchange to Fraunhofer IWES in Bremerhaven and her support in evaluating the LiDAR measurements. It was great to return to Fraunhofer IWES where I wrote my Diploma thesis in 2015. This allowed me to see what became of my previous research project, catch up with former colleagues and friends.

The great support by researchers and staff at the energy meteorology research group at the University of Oldenburg, especially Dr. Gerald Steinfeld, Dr. Martin Dörenkämper, Lukas Vollmer, Hauke Wurps, Sonja Krüger, Wilke Trei and the rest of the EnMet wind group, helped me succeed in running the simulations. Their friendly, open and approachable manner made the few days I spend at Oldenburg very productive and enjoyable. Especially our discussions during coffee breaks were very helpful and amusing. We are still in contact in matters of ongoing simulations and we hope to publish our findings in a joint paper soon.

Conclusions

In summary the exchange to Fraunhofer IWES and the University of Oldenburg was a great success. I learned a lot by working with meteorology experts on the evaluation of LiDAR measurements their implementation into numerical weather reanalysis and LES. I believe that the two complementing data sets from measurements and simulations will be of interest to AWESCO as well as the whole airborne wind energy community and will function as the basis for my further research.

Outlook

- Co-author for the OnKites II report at Fraunhofer IWES
- Publication of measurement results with Dr. Ilona Bastigkeit
- Complementing presentation at the AWEC conference 2017 in Octobers 2017 with Dr. Ilona Bastigkeit
- Publication of simulation results and implementation of measurements into WRF / PALM with Dr. Gerald Steinfeld and Dr. Martin Dörenkämper

DAAD

Federal Ministry of Education and Research