Presentation and validation of a simulation environment for floating lidar systems

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Abstract. In recent years, floating lidar systems (FLS) have developed into a fully-fledged and accepted measuring instrument for determining and surveying wind conditions in the offshore sector. FLS are currently primarily used for wind resource assessment purposes before the construction phase of an offshore wind farm. That is why a precise knowledge of the measurement accuracy or uncertainty of the FLS for different wind and wave conditions is very important. The lack of knowledge could be mitigated with a simulation tool for FLS of different types and for variable wind and wave conditions. Within this paper we present an approach for such a simulation framework for FLS and the process for validating this simulation environment using data from an offshore measurement campaign. The data used for the validation include data from one FLS and two reference measurement systems (measuring mast and fixed lidar).

1. Introduction

Floating lidar systems (FLS) have been successfully brought to the offshore market in recent years [1], [2]. Nevertheless, this technology is still new compared to standard wind measurement techniques such as offshore met masts or the widely accepted onshore application of lidar systems. In order to get to full commercial acceptance, it is essential and current recommended practice [3] to run various trial campaigns with a duration of several months at different locations and different wind and wave climates, respectively. It is important for manufacturers and operators of FLS to gain a decent knowledge of the system behaviour and measurement uncertainties for the different met-ocean conditions. This is very relevant in order to reach maturity stage 3 (commercial stage) of FLS [4]. However, this is very time consuming and generally associated with high costs throughout the trial campaigns. Additionally, with every new deployment of an FLS in an unknown area with no reference measurement system, there is the problem of a certain unknown measurement uncertainty due to the different wind and wave conditions compared to previous measurement or trial campaigns. The same applies if the buoy type has been constructively changed and/or a lidar device of a different design is used. In both cases this is due to the different motion behaviour of the buoy caused by the wind and wave conditions which in turn results in a changed measurement behaviour of the lidar system (if these movements are not compensated).

In order to be able to predict these occurring measurement uncertainties, there are two possibilities. The first possibility is to use already acquired test data in which the test procedure, including the prevailing environmental conditions and buoy type, comes close to or corresponds to the planned measurement campaign. The other possibility is to simulate the planned measurement campaign with a suitable simulation model, including as many relevant environmental parameters as possible. Therefore,
within the publicly funded MALIBU project such a simulation environment for FLS has been developed. This modular simulation environment allows the user to simulate different buoys and lidar systems for different wind and wave conditions with a limited computational effort. Within this paper we present (1) a workflow for the simulation of a FLS including the coupled simulation of the buoy motions and the simulation of the lidar device, (2) the calculation of the horizontal wind speed based on a model based wind field reconstruction method and (3) a comparison of the simulation model against real measurements from a met mast, a fixed lidar and a floating lidar system. We show different case studies with wind and wave information of different fidelity levels and assess the accuracy of the horizontal wind speed measurement depending on the quality of the input data.

The paper is structured as follows: First in section 2 an overview over the simulation framework and the underlying simulation model is given. Section 3 describes the measurement campaign and the measurement data that is used for the validation process, followed by section 4 where the validation process is being explained in detail. The results of this validation process which are the result of a comparison of simulations with measurement results is being shown in section 5. Finally, in section 6 a conclusion of the validation results and an outlook on the next steps is being given.

2. The floating lidar system simulation model (framework)

In [5] a simplified tool for floating buoy simulations has been presented. This tool has been combined with a flexible simulation model for lidar measurements under the influence of motion [6]. The main goal of this approach was to develop a simplified but reliable simulation framework for FLS. The model should allow the simulation of the horizontal wind speed measurement of a FLS as well as the estimation of sensitivities to certain met-ocean conditions for a FLS at a specific offshore location for the wind and wave conditions that are expected at this location. The simplified simulation environment shall also allow fast parameter studies to simulate a large number of sea states and wind conditions with reasonable computational effort and include a possibility to test different buoy configurations for optimization purposes. The structure of the complete simulation framework is being shown in Figure 1.

![Figure 1. Flowchart of the simulation framework for floating lidar systems](image)

This simulation framework consists of several modules that are interconnected. The two main components of this framework are, first, a module for simulating the buoy motions for different wind and wave conditions and, second, a module for simulating the lidar measurement for different buoy motions i.e. motion states of the lidar system and wind conditions. The two main components of this framework are first a reduced hydrodynamic buoy model [5] that enables the simulation of the buoy for different wave climates (in the following this will be denoted as SLOW model which stands for simplified low-order model) and a model for simulating measurements with a moving lidar system.
including a wind field reconstruction algorithm [6]. Both models are coupled in such a way that the wave-dependent motion data serve as input data for the lidar simulation. Both models have been independently validated in previous studies. [5], [7].

The SLOW model is structured as follows. Based on the given geometrical parameters of the buoy, the platform CAD model is set up and the structural properties are calculated. Subsequently, the panel code Ansys AQWA is used to calculate the hydrodynamic coefficients, serving as input to a coupled simplified model. The time-domain simulation is then carried out by the FLS numerical model for each selected load case and the platform dynamic indicator is calculated. Based on this approach generic time series for the estimated buoy motion for the different sea states are derived. With these wave dependent buoy movements, the dynamic lidar simulation is then being carried out and both models are coupled. However, the simulation environment also allows the simulation of the FLS using real measured motion time series or other generic wave time series such as sinusoidal motion patterns.

With the help of the lidar simulation model [7], different VAD lidar devices with their respective wind field reconstruction methods can be simulated. Here, ideal conditions are assumed. Turbulent or non-turbulent wind fields with a constant shear as well as the above-mentioned motion time series serve as input data for the lidar simulation. The various possible adjustable simulation parameters are shown in Figure 2. The highlighted parameters are being used in this validation study (see also section 4.1).

![Figure 2. Graphical representation of the possible simulation parameters of the dynamic lidar simulation model, parameters in blue and black are being used in this study](image)

The execution of a simulation comparable to a trial of an FLS requires a certain amount of preparation. Measurement data or data from mesoscale models must be prepared. Likewise, the buoy or its structure and properties must be designed. Subsequently, the behaviour of the buoy can be simulated for the expected environmental conditions, in this case significant wave heights and wave periods. Finally, the actual simulation of the FLS can then be performed with the prepared wind fields. However, many of the preparatory modelling steps only need to be performed once, if the buoys structure is not changing. Considering the necessary preparation time and the subsequent execution, a FLS simulation, corresponding to the semi-annual measurement campaign explained in section 3, can be carried out with this approach within a few days, or within a few hours if a computer cluster is used.

3. Measurement data for the Validation case

In order to validate the developed simulation environment, data from a six-month offshore measurement campaign from an FLS are used. The Fraunhofer IWES Wind LiDAR Buoy [8] was used in this measurement campaign. This type of buoy can be equipped both with a Leosphere WindCube V2 or a ZX 300 Lidar and has been used in numerous research projects and commercial measurement campaigns over the past years. In this measurement campaign a buoy with a Leosphere WindCube V2 Lidar has been deployed. Here the lidar device is located approx. 2 m above the waterline in a metal housing to
protect the lidar e.g. from splash water (see Figure 3a). The buoy is anchored with a single mooring line to keep its position. The movements in all six degrees of freedom (pitch, roll, yaw, surge, sway, heave) of the buoy, and thereby also of the lidar, are recorded with an inertial measurement unit (IMU) and a GPS with high temporal resolution. During this measurement campaign the buoy was deployed in a distance of approx. 360 m southwest (230°) of the FINO3 offshore platform in the German North Sea. The water depth here is approx. 23 m. The FINO3 offshore platform is equipped with a large amount of wind measurement equipment up to a height of H=106 m above sea level. Furthermore, there were also measurement devices to measure the wave conditions such as significant wave height and wave period. The relevant data sets have been downloaded from the FINO-Datenbank which is operated by the German institute Bundesamt für Seeschifffahrt und Hydrographie (BSH). In addition, another Leosphere WindCube V2 lidar device was operating on the platform of the FINO3 met mast during the measurement period. Measurement data of this device could be obtained via DNV-GL.

**Figure 3.** (a) Fraunhofer IWES Wind LiDAR Buoy (©IWES), (b) Positions of FINO3 Reference Met Mast and the Fraunhofer IWES Wind LiDAR Buoy (© IWES), (c) Aerial view of the test setup (© DNV-GL)

The entire measurement period extended from November 27th, 2016 to June 17th, 2017. A total of 203 days of raw data with each 144 10-min time series were available. The data availability for all systems, i.e. the period in which all systems were in operation at the same time, was approx. 97 %. Figure 4 shows the ranges for the measured horizontal wind speed $v_{\text{hor, 100m}}$, wind direction $v_{\text{dir, 100m}}$, turbulence intensity $TI_{100m}$ and the vertical shear exponent $\alpha_{40m,100m}$ as well as for significant wave height $H_{s}$ and wave period $T_p$, which occurred during the measurement period. With the help of these parameters, the TurbSim wind fields and the generic motion time series of the buoy were generated.

**Figure 4.** Overview of the distribution of the main input parameters for wind field and motion time series generation and the relevant parameters of data filtering within of this measurement campaign.
4. FLS simulation and validation

4.1. FLS Simulation procedure

In order to validate the developed FLS simulation model and to compare it with the measured data, it is necessary to simulate operating conditions within the simulation environment that are as similar as possible to those that occurred during the real measurement campaign. Due to the fact that the exact wind field and motions cannot be reproduced in the simulation environment, statistical approximations are being used. This concerns, on the one hand, the reproduction of the wind conditions that occurred during the measurement campaign as well as the replication of the motion states of the buoy as input values for the simulation of the FLS. And secondly, the most accurate possible modelling of the measurement setup related to the location and type of the reference measuring systems.

With respect to the input wind fields, the following procedure was followed. Data from the cup anemometer at a height of $H = 100 \text{ m}$ of the FINO3 met mast were used. The mean horizontal wind speed $\bar{v}_{\text{hor,FINO3,cup}}$ could be used directly whereas the turbulence intensity $T1_{\text{FINO3,cup}}$ was calculated for each 10-minute time series. In addition, the shear exponent $\alpha_{\text{FINO3,40m,100m}}$ was calculated for each time series in relation to the wind measurement at $H = 40 \text{ m}$ height. These parameters were then used to generate synthetic TurbSim wind fields with a temporal resolution of $t = 0.25 \text{ s}$ and a mesh size of $200 \text{ m} \times 140 \text{ m}$ with a grid resolution of $41 \times 29$. In the simulation only the period between $t_{\text{Start}} = 30 \text{ s}$ to $t_{\text{End}} = 630 \text{ s}$ will be used to ensure that the simulated lidar measurement is always performed within the wind field volume for each simulation case.

Two approaches were taken for the simulation of the buoy movement. In the first one, measured motion data (with a temporal resolution of $f = 5 \text{ Hz}$) of the pitch, roll and heave motions are considered as input signals for the buoy and lidar simulation (in the following this is denoted by the index $t_{\text{REAL}}$). In the second approach, the buoy motions are generated using the hydrodynamic simulation module already described, based on measured significant wave heights $H_s$ and wave periods $T_p$ (this is denoted with the index $t_{\text{SLOW}}$).

With these two main input signals the simulations are carried out for every 10-min series analogous to the recorded measurements within the half year measurement period. Results from these simulations will be denoted in the following with the index $t_{\text{Mov}}$. In parallel, as a reference, simulations were performed for the same simulation parameters excluding the movement of the system. These simulation results will be denoted in the following with the index $t_{\text{Ref}}$. For a better overview, the horizontal wind speeds used in this work are explained again in Table 1 with their respective indices.

Table 1. Measured and simulated horizontal wind speeds $v_{\text{hor}}$ for a height of $H = 100 \text{ m}$

| $V_{\text{hor,FINO3,cup}}$ | Measured hor. wind speed at FINO3 with a cup anemometer |
|--------------------------|--------------------------------------------------------|
| $V_{\text{hor,FINO3,lidar}}$ | Measured hor. wind speed at FINO3 with a WindCube V2 |
| $V_{\text{hor,FLS}}$ | Measured hor. wind speed with the Fraunhofer Wind LiDAR Buoy |
| $V_{\text{hor,Ref}}$ | Simulated hor. wind speed for a fixed lidar system |
| $V_{\text{hor,REAL,Mov}}$ | Simulated hor. wind speed for REAL motions for a moving lidar system |
| $V_{\text{hor,SLOW,Mov}}$ | Simulated hor. wind speed for SLOW motions for a moving lidar system |

4.2. Validation procedure

The primary goal of this work is to validate the described simulation environment. The main objective is to show that with the help of this simulation environment it is possible to reproduce the behaviour and the measurement of a FLS as well as the measurement uncertainties compared to reference measurement systems. Therefore, a number of test cases were defined within the scope of this work, which can be used to perform this validation analysis. For each of the test cases listed in Table 2, an unmoved reference system is compared with a moving system.
Table 2. Summary of the different test cases that have been analysed

| Test case | Moving system | Reference System |
|-----------|---------------|-----------------|
| 1: FLS/Mast | Fraunhofer IWES Wind LiDAR Buoy | FINO3 cup anemometer |
| 2: FLS/Lidar | Fraunhofer IWES Wind LiDAR Buoy | FINO3 Lidar WindCube V2 |
| 3: Lidar_Moving/REAL/Lidar_Ref | Simulated moving Lidar (REAL motions) | Simulated Fixed Lidar |
| 4: Lidar_Moving/SLOW/Lidar_Ref | Simulated moving Lidar (SLOW motions) | Simulated Fixed Lidar |

For all of these test cases a variety of statistical parameters are calculated for the individual 10-min mean values and for the binned value ranges of the horizontal wind speed. The following statistical parameters are used to analyse the goodness of the simulation results in comparison to the measurement results. These are calculated for each of the test cases of the measurements and the simulations listed in Table 2. The first of these parameters is the difference of the horizontal wind speeds (1), which is defined as the difference between the measured or simulated horizontal wind speed \( v_{\text{hor, Mov}} \) and the according horizontal wind speed \( v_{\text{hor, Ref}} \) of the reference system.

\[
v_{\text{hor, Diff}} = v_{\text{hor, Mov}} - v_{\text{hor, Ref}}
\]

The second parameter is the ratio of horizontal wind speeds of the moving to the stationary system \( v_{\text{hor, rel}} \) (2).

\[
v_{\text{hor, rel}} = \frac{v_{\text{hor, Mov}}}{v_{\text{hor, Ref}}}
\]

Additionally, we evaluate the simulation model with the following goodness-of-fit measures: \( MAE \) (3) which is the mean absolute error), \( RMSE \) (4), which is the square root of the square of the horizontal wind speed differences divided by the number of data points \( n \) and \( R^2 \) (5) the coefficient of determination \( R^2 \) which defines how well the data fits to the model. In our case, how well the data from the moving lidar fits to the reference lidar.

\[
MAE = \frac{\sum_{i=1}^{n}|v_{\text{hor, Mov},i} - v_{\text{hor, Ref},i}|}{n}
\]

\[
RMSE = \sqrt{\frac{\sum_{i=1}^{n}(v_{\text{hor, Mov},i} - v_{\text{hor, Ref},i})^2}{n}}
\]

\[
R^2 = 1 - \frac{\sum_{i=1}^{n}(v_{\text{hor, Ref},i} - v_{\text{hor, Mov},i})^2}{\sum_{i=1}^{n}(v_{\text{hor, Ref},i} - \bar{v}_{\text{hor, Ref}})^2}
\]

4.3. Restrictions of the validation

Due to the structure of the simulation environment and the parametrization of the same, there are still some limitations regarding the modelling of all environmental parameters or the exact reproduction of the reference measurement. These will be briefly explained below. Possible effects of these limitations will be explained in more detail when discussing the validation results in section 5.

A distinction must be made between limitations of the simulation models and the modeling of the experimental setup or the measurement layout. In its current state, the lidar simulation assumes that the lidar device works the same for all wind speeds or wind conditions. This means that e.g. measurement uncertainties of a real lidar device regarding different measurement inaccuracies at different wind speeds are not included. Real lidar devices show e.g. different measurement accuracies for very low wind speeds due to back-scatter effects. Likewise, the signal-to-noise ratio is also dependent on aerosol density. These effects are not modelled. In the current setup of the simulation environment, the simulated
reference lidar is also located at the same position as the simulated FLS. This differs from the measurement setup since the FLS is located there at a certain distance from the reference measurement systems. By not considering these, the above conditions logically lead to lower measurement uncertainties within the simulation. However, the magnitude of these measurement uncertainties is still unclear and will be subject of further studies.

5. Results of the validation analysis for the FLS simulation framework

In the following section we present different approaches to the validation of the described FLS simulation framework and some main results of this process. We focus here on results for a measuring height of $H = 100$ m. In the following analysis we only consider filtered data in order to exclude as many uncertainty parameters as possible which cannot be modelled in the simulation environment. The following filter criteria were applied to the measurement data:

(i) due to adjacent wind farms and met mast wake effects we only consider data from a wind direction of $220^\circ < \nu_{\text{dir}} < 280^\circ$

(ii) we only consider data for horizontal wind speeds between $v_{\text{hor}} = 2$ m/s and $v_{\text{hor}} = 25$ m/s

(iii) data from the lidar systems of the FLS and the stationary lidar have been filtered for CNR and a minimum data availability of 95% is required per 10-min time interval

After data filtering $n = 7553$ 10-min intervals remain for further data analysis, which is approximately 25% of the total available raw data. In addition, it must be mentioned that no data was processed in any way to compensate e.g. movements of the buoy as this would possibly be done for commercial use.

5.1. Visual Analysis in the time domain

The first step in evaluating the simulation results is to compare the 10-min average horizontal wind speed values with the measured values via a visual inspection in the time domain. For this purpose, measured values of the horizontal wind speed $v_{\text{hor}}$ of the met mast, the fixed lidar and the FLS were compared to simulation results of the reference lidar and the moving lidar in the time domain. Figure 5 shows two 2-hour time intervals with measured values and the corresponding simulation results for different wind and wave conditions.

![Figure 5](image-url) Measurement and simulation results (performed with REAL buoy motions) for 12 10-min time intervals for (left) low wave conditions ($H_s = 0.98$ m, $T_p = 5.75$ s) on Jan. 23, 2017, (right) harsh wave conditions ($H_s = 3.83$ m, $T_p = 8.96$ s) on Dec. 24, 2016
When looking at the time domain diagrams, the following conclusions can be drawn. It can be seen that in both cases considered, i.e. for low wave conditions as well as for rather strong wave conditions, the simulation with a fixed and a moving lidar system is able to depict the general course of the horizontal wind speeds. Furthermore, when looking at the interval for weak wave conditions it can be seen that the simulation of the buoy can represent the overestimation of the wind speed similar to the measurement with the FLS. This is different for the interval for strong wave conditions and high horizontal wind speeds. Here we see a slight underestimation of the wind speeds within the simulation and also larger differences in the reconstructed wind speeds. However, at least in the first step, it can be assumed by the visual analysis in the time domain that the simulation does not contain any big errors. At the same time, however, minor deviations for certain time steps are also discernible. To assess these discrepancies, we subsequently perform a detailed statistical analysis.

5.2. Statistical analysis

Hereinafter we consider the scatter of the simulation results in comparison with the measurements. For this purpose, in Figure 6 we contrast the moving system or the recorded horizontal wind speeds with those of the non-moving system, respectively. On the left side of Figure 6 we compare the simulation with the conditions between the met mast and the FLS (Test case 1). On the right side, we make the same comparison for the reference lidar and the FLS (Test case 2). In both cases, the simulation was performed for REAL buoy motions (Test case 3). A single variant regression analogous to [4] was performed for all test cases. For the measured data the regression fit is marked with a green line, for the simulation data with a red line. In both scatter plots, a smaller scatter range with a very high coefficient of determination of $R^2_{\text{case3}} = 0.999$ can be seen for the simulation results than for the measured data where we have $R^2_{\text{case1}} = 0.995$ and $R^2_{\text{case2}} = 0.991$ respectively. In addition, in contrast to the measurement, there is a slight overestimation of the reconstructed horizontal wind speeds for the moving system with a slope of the fitting line of $m_{\text{case3}} = 1.007$. In the case of the measurement, when comparing the FLS to the cup measurement at the met mast we can see an underestimation of the measured horizontal wind speed with a slope of $m_{\text{case1}} = 0.990$. This changes for the comparison of the FLS with the stationary lidar at the mast where we have a slope of $m_{\text{case2}} = 1.004$ which fits very well to our simulation.

![Figure 6. Comparison of measurements with simulations with scatter plots (left) between Test case 1 and Test case 3 and (right) Test case 2 and Test case 3](image-url)

Table 3 shows the statistical goodness of fit measures again in detail for the filtered data for the different test cases. Here we include also the statistical results for the simulation with SLOW motions (Test case 4). In the simulations it is noticeable that in both cases (for REAL and SLOW motions) we have better values for all goodness of fit measures than it is the case with the measurements. MAE and
RMSE are lower whereas $R^2$ is closer to 1 for the simulations. This is mainly due to the smaller scattering range and the smaller deviations in horizontal wind speed of the moving system in relation to the simulated reference system, as was already evident in Figure 6.

Table 3. Statistical results for measured data and simulations

| Test case                  | Slope | MAE | RMSE | $R^2$ |
|----------------------------|-------|-----|------|-------|
| 1: FLS/Mast                | 0.990 | 0.253 | 0.340 | 0.995 |
| 2: FLS/Lidar               | 1.004 | 0.290 | 0.409 | 0.991 |
| 3: Lidar$_{mov,REAL}$/Lidar$_{Ref}$ | 1.007 | 0.103 | 0.143 | 0.999 |
| 4: Lidar$_{mov,SLOW}$/Lidar$_{Ref}$ | 1.024 | 0.250 | 0.308 | 0.998 |

Finally, we analyse in detail the previous findings with the help of probability density functions (PDF). We consider PDFs, similar to histograms, as a good method to provide a good representation of the statistical distribution of measurement uncertainties when comparing the measurements to the simulations. The mean value of the function here gives a good impression of the overestimation or underestimation of the analysed data comparisons. The width of the function is similar to the spread of the scatter. In this case, we compare, again, measurements with simulations for REAL buoy motions and simulations for generic SLOW buoy motions. In both comparisons it can be seen that the mean value is good approximated with only small deviations. The width of the PDF however, show larger differences between measurement and simulation results. Furthermore, it can be seen that the simulation using generic buoy motions based on the SLOW approach seem to slightly better reproduce the measured measurement uncertainties. However, the difference to the results from simulations with REAL buoy motions is evident. There are two possible reasons for this behaviour. Either the generic approach is better suited for the FLS simulation. Or there is a small error included in this approach which is responsible for the higher uncertainties. This has to be analysed in detail in further works.

Figure 7. Probability density function plots for all test cases outlined in Table 2 (left) showing the absolute wind speed differences and (right) showing the relative wind speed differences

In any case, it can be concluded from the findings so far that further analysis is needed to better understand the differences or the reasons for the deviating uncertainties between simulation and measurement when comparing a FLS with a reference system. Therefore, more modelling parameters should be added to the simulation in order to approximate the real measurement behaviour of an FLS more accurately. The first relevant model parameters for this analysis are the inclusion of (1) the surge and sway motions of the FLS, (2) the integration of an approach to model the distance of the measuring systems within the simulation model and (3) the simulation for different wind directions. Also different seasonal effects should be investigated. Effects inherent in lidar systems and the underlying wind field reconstruction such as backscatter or dependence on the signal to noise ratio are also possible to play a role.
6. Conclusion & Outlook
In this work, we have presented an approach as well as the implementation for a coupled simulation framework for FLS. Additionally, results of different validation steps for said FLS simulation framework were presented. It could be shown that with the help of the described simulation framework it is possible to carry out FLS studies for different wind and wave conditions analogous to real offshore trials in a short time. Furthermore, it could be shown that the simulation results for mean values of the horizontal wind speed correspond approximately to real measurement results. These aspects seem promising for the further development of the simulation framework. However, a closer look at the comparison of the measurement uncertainties still reveals deviations between the simulation and the measurement. This is particularly relevant because even small deviations of the measurement uncertainties of the horizontal wind speed have a big influence on later decision-making processes. A more precise investigation of the simulation results, especially with regard to these measurement uncertainties, is therefore to be aimed for. For this purpose, a series of parameter studies for these factors will be carried out.

Subsequently we plan to combine the FLS simulation framework with an uncertainty approach for FLS. Parameters like significant wave height or wave period are partially available or can be estimated for arbitrary offshore locations to assess the quality of future measurements. In those cases, the wave climate information will be taken from ECMWF’s ERA5 model data, which offers an extensive number of met-ocean parameters for different locations. On the other side, areas may be grouped to show similar measurement behaviours for FLS to specify areas which are represented by an existing validation or classification trial. The goal here is to provide a tool to forecast sensitivities and measurement uncertainties for different FLS designs at arbitrary offshore locations. Further works will include also the implementation of an optimization method for FLS.

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