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Project schedule assessment with a focus on different input weather data sources

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Abstract

During all planning stages of offshore projects, the assessment of the effects of adverse weather is essential. In order to address this problem, the WaTSS (Weather Time Series Scheduling) method and its application will be presented. The defined project schedule and the environmental data in form of weather time series are the input data.

Three different case studies were carried out using one project schedule and different input time series. Within the first case, differences in the project progress due to minor differences in model and measurement data are displayed. In the second case, the effects of variations or uncertainty in the input time series are studied. Within the third case, the method is applied for a number of spatial distributed locations in the North Sea.

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Keywords: WaTSS, COAST, project scheduling, weather dependencies

1. Introduction

Most offshore project schedules consist of a number of different tasks which have to be executed in a particular order and are subject to environmental restrictions. An example is the installation of a wind turbine foundation which consists of the following tasks: positioning the vessel, fixing the heavy lift vessel and lifting the foundation. Due to the different vessel sensitivities to sea states within the different tasks as well as the high number of tasks, project schedules tend to be complex. Hence the assessment of the mean project duration, weather down times, alternative vessel concepts or weather risks is difficult.

Considering [1], the expected downtime has to be calculated using statistical weather conditions. An often used method are weather window or persistence statistics [2]. These statistics define the relative available time for a given task in a given time period, like a distinct month. For the assessment of the duration of process parts or the whole installation process, the statistics for different tasks are combined. Due to possible correlations between the different

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statistical results and difficulties assessing extreme durations, the application of weather window statistics must be questioned at least for complex schedules.

The Fraunhofer Institute for Wind Energy and Energy System Technology (IWES) developed the Weather Time Series Scheduling (WaTSS) method implemented in the Comprehensive Offshore Analysis and Simulation Tool (COAST) software in order to solve this issue. By combining the project schedule with time series of the environmental variables, the offshore procedure is analyzed. Within this paper, we focus on the input time series environmental data and different analysis methods [3]. For all test cases, a project schedule for the installation of an offshore wind farm comprising about 1400 tasks was used.

2. WaTSS method and implementation

The project schedule data consist of a number of tasks that have to be executed in a particular order. Examples are the before mentioned foundation installation, nacelle replacements, offshore substation installation or the installation of a whole wind farm, comprising foundations, wind turbines, cables and substation. For each task within the project schedule, the duration is defined as well as one or more constraints if necessary. Typical constraints are wind speeds on distinct altitudes or wave height thresholds that must not be exceeded during the duration of the task. Also parallel installation processes can be considered in the project schedule.

The input weather data may comprise meteorological and oceanographic data as well as further parameters, like working shift or daylight. The data can cover measured and model data, whereas the latter normally brings a number of advantages; hindcast model data often exists for longer periods in time until some decades, exist for a number of spatial distributed grid points, are consistent and normally do not suffer from corrupt or missing data. Using measurement data, effort has to be taken for meeting the aforementioned possible problems.

Within the WaTSS method, the execution of the project schedule is simulated using weather time series data. Hence a task will be executed if the time series weather conditions obey the task's weather restrictions for the task duration. If the weather is not appropriate, the start of the task is delayed until a fitting weather window occurs. After the completion of the task, the process will be repeated for the successor, see figure 1. Applying the WaTSS method using a given project schedule and a well-defined starting time, results are the realization time for each task as well as the overall duration of the complete project. The overall duration consists of the net working time and the additional waiting time due to waiting for the required weather conditions.

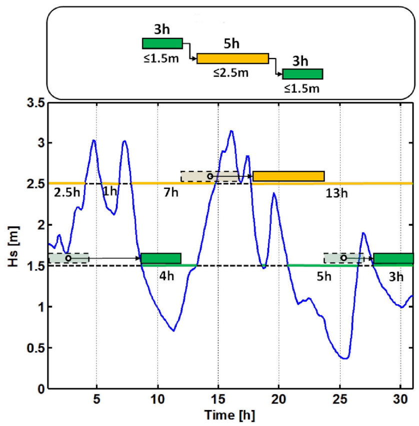

Fig. 1. Exemplary illustration of a project schedule with three tasks and restrictions. The WaTSS simulation using a significant wave height time series is illustrated.

Using a multiplicity of different starting dates, the WaTSS analysis provides a distribution of project durations which is the basis for the statistical analysis, e.g. in terms of mean values or percentiles. For finding optimal or avoiding unfavorable project starting periods, the starting time is systematically shifted by a fixed number of days. This method is called *constant interval simulation*. A result for the later used project schedule is depicted in figure

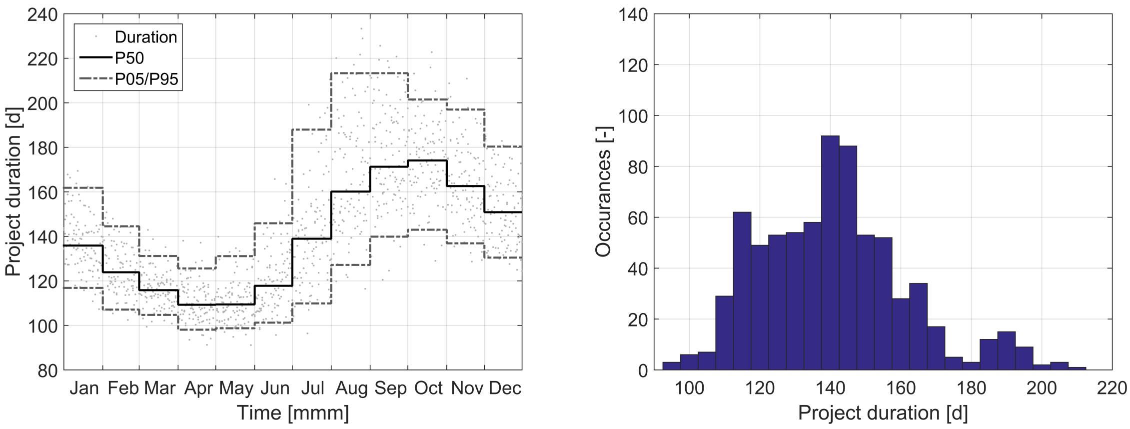

Fig. 2. Results of a constant interval analysisbased on coastDat hindcast data. Every dot represents the project duration for a given start date. These were used to calculate the different percentiles (P50, P05, P95) of the durations for each starting months (left). Distribution of project durations for a project starting period within the month July (right).

2, left plot. Every dot represents one simulated project duration for a given starting date. The distribution of project durations are arranged for their starting month, compare figure 2, right plot. This is the base for the calculation of the percentiles for each month.

The *yearly simulation method* is used if the starting date is set, and further detailed statistical information is needed. Figure 2 (right) shows a distribution of project durations for a given starting time in July. E.g. unfavorable durations based on the weather input data can be displayed. For a project start in July, the 50^{th} percentile corresponds to a project duration of approx. 140 days, including 54 days of accumulated waiting due to bad weather. For the 95^{th} percentile, the project duration is about 188 days, including 102 days waiting time.

The time series data should at least cover a number of years. This assures a representative ensemble of different environmental conditions, and thus, an ensemble of project durations. Also standard analysis should be conducted to verify the input data, for example by comparing model data to local measurement time series.

3. Simulations

3.1. Input data

The here studied showcase represents an exemplary wind farm installation comprising 20 individual wind turbines. The project schedule covers tasks for the foundation installation, the cable installation, the tower and wind turbine installation. The complete project schedule consists of approx. 1400 single tasks. The net installation duration is about 86 days without considering any delays due to adverse weather. The single task duration covers periods from 3 hours to 30 hours, while the restriction thresholds are varying from 1.5 m to 2.5 m for the significant wave height H_s and from 12 ms^{-1} to 20 ms^{-1} for the wind speed at 10 m altitude.

Within the following case studies, the location of the FINO1 meteorological (met.) mast was chosen. The reason is the availability of both FINO1 measurement data and Helmholtz-Zentrum Geesthacht (HZG) coastDat hindcast data for this location [4]. CoastDat contains met-ocean data for the North Sea and Baltic Sea. It covers a time period of nearly 50 years, beginning in 1958. The data has a temporal resolution of one hour. The spatial resolution of the model grid points is approximately 7 km in the area of FINO1. For the third case study, additional coastDat hindcast data covering the southern part of the North Sea was used.

3.2. Case study 1: measurement vs. model data

Within the first case study, both measurement and model data for the location FINO1 in the North Sea were used. Due to a period of approx. two years of existing data from both sources comprising a number of longer gaps in the measurement data, the comparison of statistical results is difficult. Instead, the series were compared in a first step. Figure 3 (left) shows a plot displaying both time series. The data seems to agree well.

In figure 3 (right), the temporal progress of the project schedules first 440 tasks is plotted for both data sources. For both simulations, the starting day is 10-08-2008. The x-axis shows the duration since project start, while the y-axis identifies the started task. It is apparent, that the progress differs by 2 days after the first 12 days of execution, and temporally reaches up to five days in between day 18 and day 30. Even if in this case both simulations converge around task 400, slight difference in the input data can have considerable effects. Hence, the input data must be studied carefully and verified, respectively. Furthermore a sensitivity analysis should be performed for assessing the deviations due to uncertainties within the input information.

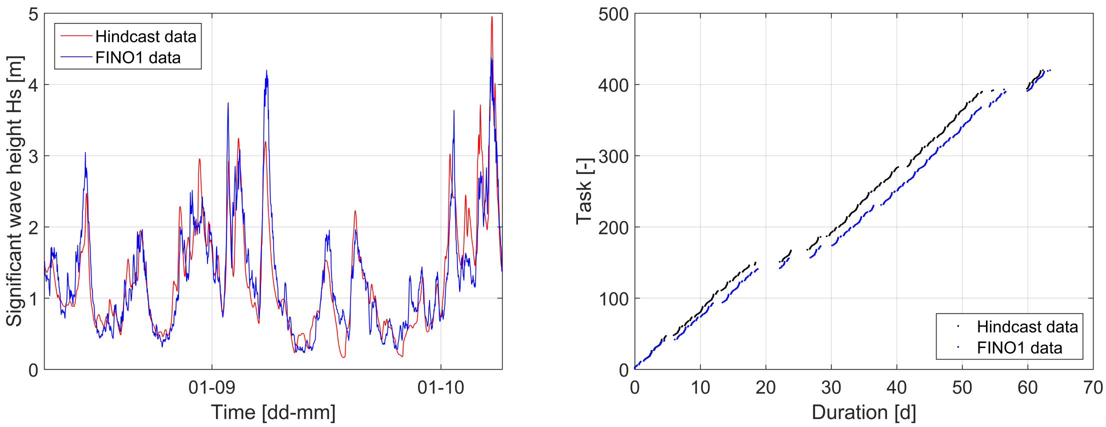

Fig. 3. Comparison of hindcast model data and measurement data for the locations of FINO1 (left). Project progress diagram displaying the task start time after the project start. Here the same start date, but different model and measurement time series are used (right).

3.3. Case study 2: Effects of variations in the input weather data

The result of the previous case study pointed out differences in the project progress even if input data sources seem to be similar. Deviations between data sources, e.g. measurement and model data, are often described in terms of the measures Bias and Root Mean Squared Errors (RMSE). In order to simulate these deviations and to assess the robustness of the WaTSS method results, the FINO1 significant wave height model data time series H_s was selected and modified systematically. This comprehends both an additional time-independent *offset* and random noise rand(t):

$$H_{\mathrm{s}}^{\mathrm{modified}}(t) = H_{\mathrm{s}}(t) + \mathit{offset} + \mathrm{rand}(t) \qquad (1)$$

The *offset* was set to values in the range of −1.0 m to 1.0 m. The random noise rand(t) is uniformly distributed in an interval from -max_{rand} to max_{rand} with values for max_{rand} from 0.0 m to 1.0 m.

Results for the 50th and 95th percentile for July are displayed in figure 4. Here the overall project waiting time difference to the reference waiting time for unmodified input weather is displayed. For this case major influence in the waiting time is the offset. A change in the significant wave height by 0.1 m increases the project duration by approx. 5 days for the 50th and 12 days for the 95th percentile, respectively. The results strongly depend on the project schedule, the location, the starting time within the year or the studied percentiles. Hence the project-specific uncertainty due to uncertainties within the time series data can be assessed.

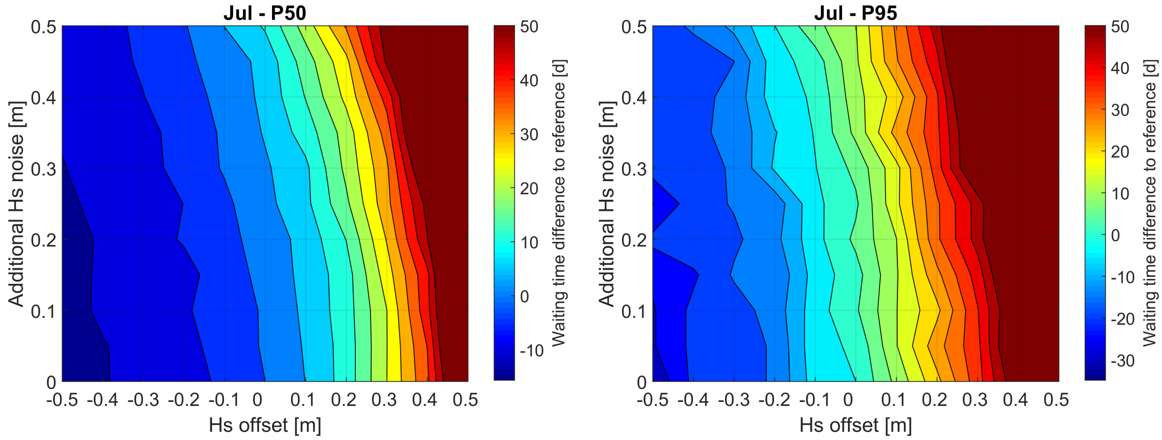

Fig. 4. Plot of additional waiting time for different time series modifications compared to original data in days. Results for the 50th percentile (left) and the 95th percentile (right) are displayed.

3.4. Case study 3: Spatial analysis

Within the third case study, an analysis for the southern part of the North Sea was undertaken. Hence the project schedule was simulated using time series data for 1596 different locations. Different distances and thus transfer times to the ports are not considered yet.

Results are displayed in figure 5 and figure 6 for the months May and July. These plots allow to compare the feasibility of project schedules for distinct areas by their additional waiting time. As an example, the 50th percentile for the locations FINO1 (May: 24 days; July: 54 days) and FINO3 (May: 32 days; July: 75 days) can be easily compared. The 95th percentile plot for July as starting month also indicates the strong increase of weather risk if the start date is shifted by two months.

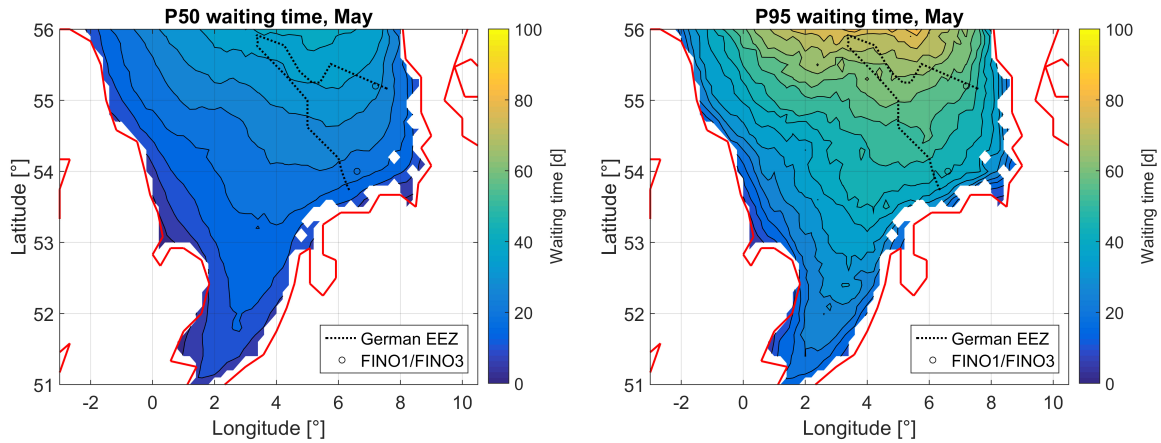

Fig. 5. Presentation of spatial project waiting time analysis in days for the southern part of the North Sea for project starting month May. Results for the 50th percentile (left) and the 95th percentile (right) are displayed.

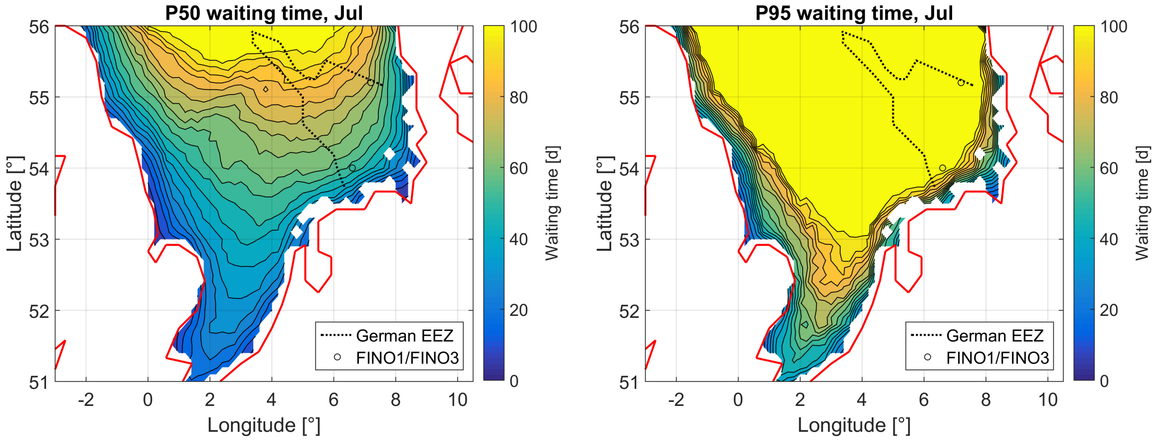

Fig. 6. Presentation of spatial project waiting time analysis in days for the southern part of the North Sea for project starting month July. Results for the 50th percentile (left) and the 95th percentile (right) are displayed.

4. Results and outlook

This paper is focused on weather input data used in the WaTSS simulation. Results are:

- Results of the project schedule analysis can vary considerably for similar weather input sources. Hence the input data must be studied and used with care.
- Assessment of uncertainty in the project duration results can be performed by systematically varying the weather input data. The uncertainty depends on the project schedule, input weather data and the project starting time.
- Using spatial distributed hindcast data allows to assess project duration for different locations. Hence the feasibility of a project schedule or strategy can be studied for different areas.

Future studies will cover the topics of differnet input project plans. Different offshore logistic concepts will be analyzed, e.g. the impact of different installation strategies, comprising different vessels with various weather limitations. Another issue is the consideration of different base ports for various offshore sites with its effects on the transfer time and the estimated project duration.

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