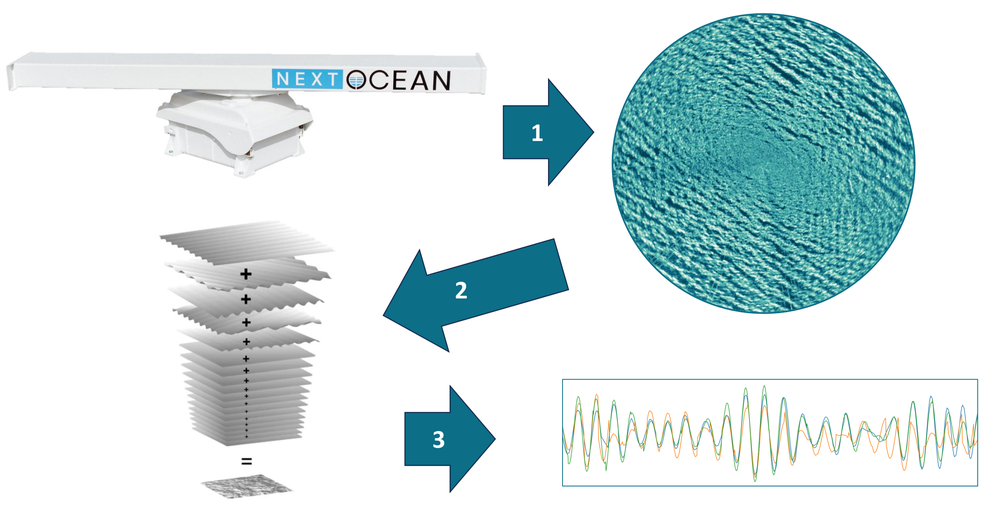
Real time prediction of extreme waves and motion response onboard offshore vessels and its effect on safety and operability

What can we gain?

Waves are an important factor for the operability of offshore operations. Operating limits for critical operations are usually expressed in statistical properties of the waves (e.g. significant wave height) or the motion response (e.g. significant heave motion, velocity or acceleration). These limits take a safety margin into account to ensure a sufficiently low probability of encountering a critical extreme value of the wave or the motion response, which is typically much higher than its statistical limit. A crucial underlying assumption to this classical approach to operability is that we don't know when an extreme (wave/vessel motion) will be occurring, meaning we cannot anticipate on its occurrence. The Vessel Motion Radar, which uses an ordinary commercial off the shelf X-band radar system to monitor the waves surrounding the vessel changes this paradigm entirely. This system provides real time information about the (extreme) waves and motions upcoming in the next minutes, enabling crew to temporarily cease or postpone operation in case of an upcoming extreme event. This means critical steps can still be executed safely even in conditions classified unworkable based on statistical properties alone.

Vessel Motion Prediction Technology

Step 1: The x-band radar scans the surface. By means of Bragg Scatter reflections a digital map of the sea surface is derived. This is a continuous process. Step 2: The Next Ocean Proprietary software decomposes the sea surface into its underlying wave components, all with their own amplitude, frequency, direction and phase. Step 3: Using linear wave theory and the wave to vessel motion transfer functions (also known as Response Amplitude Operators, or RAO) a prediction is made for the motions of the vessel, up to 180 seconds ahead of time. All 6 degrees of freedom (DOF).



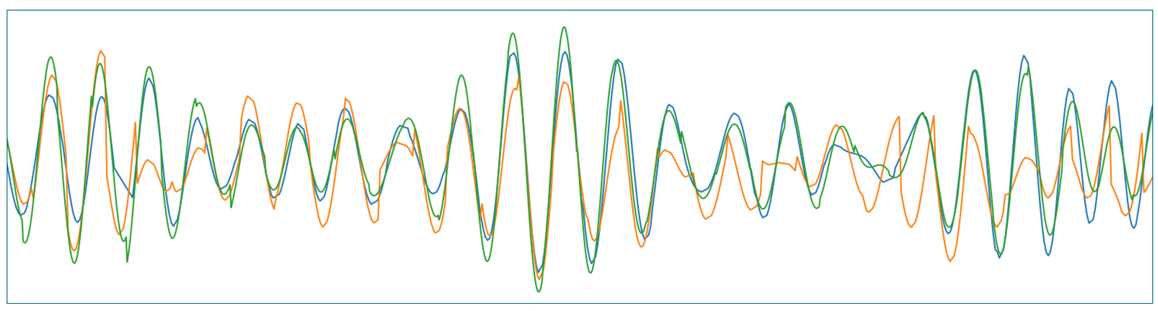
Scheme displaying the different steps to get from conventional X-band radar data to 120 seconds ahead of time predicted semi submersible rig heave motions.

Validation

Extensive research was done together with DNV to quantify the effect of Motion Prediction Technology on safety and workability of offshore operations. The findings are based on field data collected by Next Ocean Motion Prediction Radar systems operational onboard several vessels in challenging wave conditions.

Method

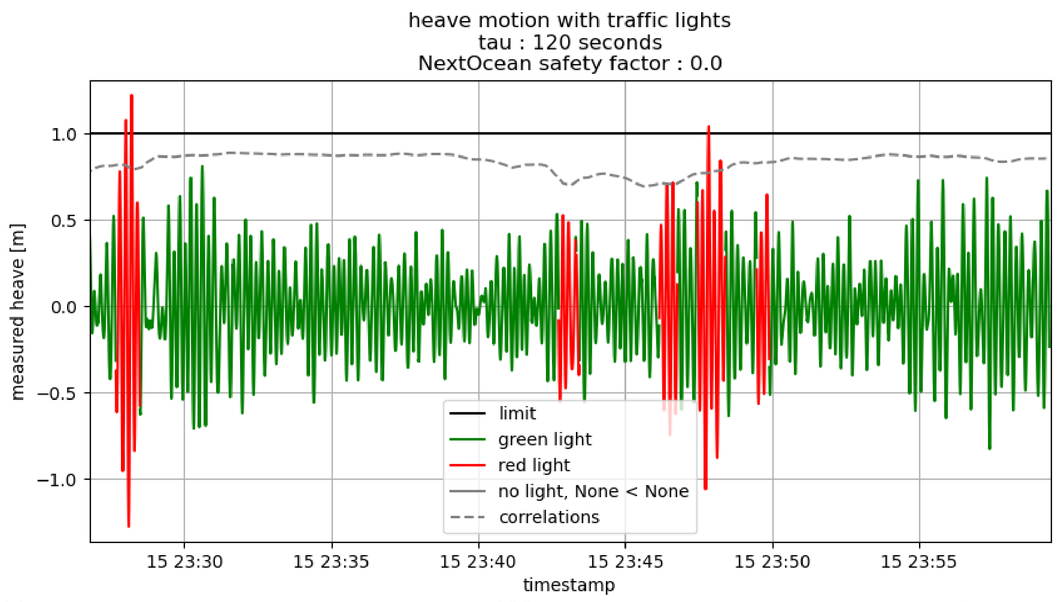
Both predicted motions and measured motions are collected onboard these vessels over the course of several months. This study compares the vessel motion as predicted 120 seconds ahead of time against the measured motions.



Measured heave motion overlayed with heave motions predicted 120 seconds ahead of time.

As operational limit an arbitrary limit of 1-meter single heave amplitude is considered. This is a limit typical for operations like lifting equipment, gangway transfers, ROV splash and recovery, landing of the BOP stack, or whilst temporarily hanging off the drill string in the slips to make or break a pipe or casing connection during drilling/running/tripping operations.

According to industry standard a 1/1000 oscillations probability ('3-hour maximum') of crossing the set motion limit is deemed acceptable. The acquired operational data is filtered and divided in two categories before analysis: all hours where the limit crossing probability was close to but lower than 1/1000, and all hours where the limit crossing probability was between 1/1000 and 1/100. Each of these hours is scanned for true positives, true negatives, false positives and false negatives, see graph below.



Measured heave motion colored based on the 120 seconds ahead of time predicted under limit or over limit states (green, red respectively). The limit of 1m single amplitude is displayed by a black solid line, the correlation between the predicted and measured heave motion is shown in a dashed line. It can be seen in the figure that when the correlations drop slightly between 23:40 and 23:50, the system tends to indicate more false positives. Nevertheless, all three peaks that do cross the set limit (2 times around 23:27 and 1 time around 23:48) are correctly warned for, 2 minutes ahead of time.

Results & Conclusions

Processing several thousands of hours of operational data acquired onboard three different vessels showed that the Next Ocean Mortion Prediction system:

1. Reduces the chance of an unforeseen limit crossing more than 10-fold
2. Allows for operations maintaining the same or a lower chance of an unforeseen limit crossing in conditions up to 120% of the conventional statistical limits
3. Enables as much of 98% of the time between the 1/1000 and 1/100 limit crossing probability situations to be successfully reclaimed as workable time