Long term analysis of semi submersible offset

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Problem

In design of mooring lines the 100 year and 10 000 year responses are not defined in terms annual exceedance probabilities. Instead, the characteristic response are taken as the most probable largest response during a storm with prescribed design conditions. For example, the 100 year response of a moored semi-submersible are taken as the most probable largest response in a storm with 100-year waves and wind. It may be of interest to find the level of conservatism for this characteristic response, and this would again require a full long term analysis.

Therefor a long term analyses have been carried out to determine the 100 year and 10 000 year offsets of a semi submersible using the Peak Over Threshold (POT) method and the All Sea State approach. The results from the long term analyses will be compared to characteristic responses from design conditions.

Procedure

To obtain the full long term distribution of the maximum response, the short term distribution must be established for all possible environmental conditions. Then the long term distribution is calculated by merging the short term variability with the probability of occurrence of the short term incident as outlined by the equations below, [1].

POT:

$$F_X(x) = \int_{\tilde{X}} F_{X|\tilde{X}}(x|\tilde{x}) f_{\tilde{X}}(\tilde{x}) d\tilde{x}$$

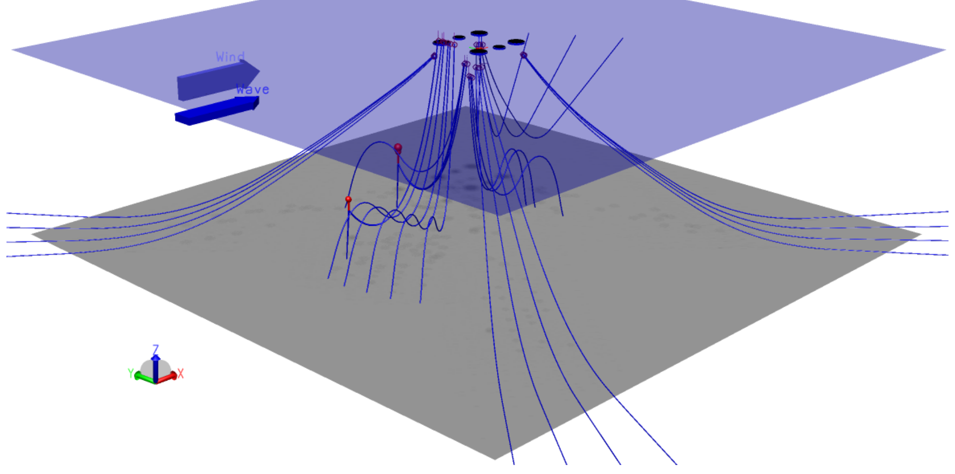
All sea state:

$$F_X(x) = \iiint_{H_s,T_p,W} F(x|h,t,w) f(h,t,w) dhdtdw$$

q-probability responses are calculated using IFORM.

Structural model

The structure is a typical spread-moored production semi submersible that comprise of ring pontoon with six columns that supports the topside, and it is symmetric about the x-axis. SIMO is used for time domain simulations. A picture of the model as it appears in SIMO is given below:



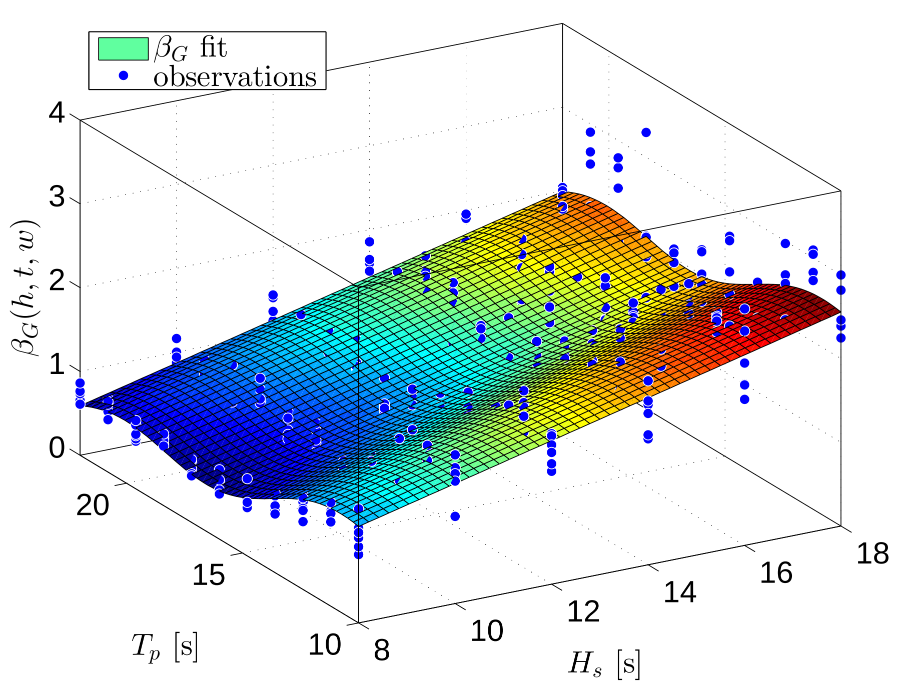
The semi submersible is located at Haltenbanken area.

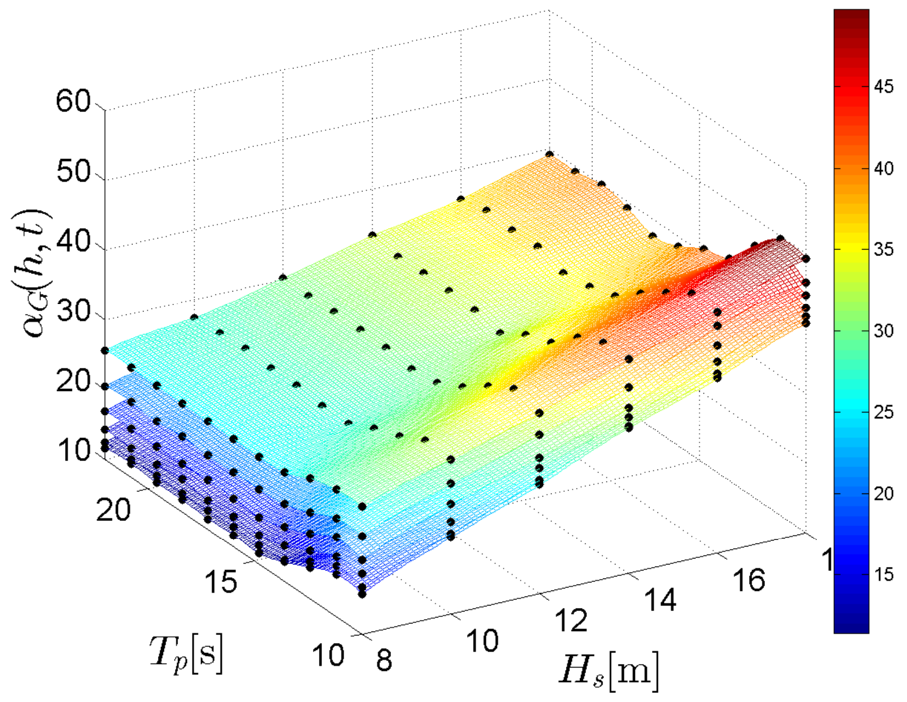
References

[1] Haver, S. Prediction of Characteristic Response for Design Purposes, 2011-09-02.

Response surfaces

In long term analysis the challenge is usually to establish the short term variability of the response, i.e. $F_{X|H_s,T_p,W}(x|h,t,w)$ and $F_{X|\tilde{X}}(x|\tilde{x})$. A cost efficient approach is to perform a number of 3-hour simulations of all possible combinations of significant wave height (H_s), spectral peak period (T_p) and wind speed (W) with reasonable resolution covering the actual sample space. The Gumbel distribution was selected for the 3-hour maximum response of a given combination of H_s, T_p and W and the Gumbel parameters, α_G and β_G, were estimated using method of moments. This was done for some combinations of sea states and continuous functions were fitted to the Gumbel parameters. The analysis of each sea state in the all sea states approach and for each storm step in the POT method are then carried out using these response surfaces. The response surfaces of the Gumbel parameters are visualized in the Figures below. Please notice that the lower layer of $\alpha_G(h,t)$ in the Figure to the right corresponds to $W = 5m/s$, increasing with a $6m/s$ increment to $W = 35m/s$ for the top layer. $\beta_G(h,t,w)$ is assumed to be independent of W and is therefor displayed as one surface for a set of H_s and T_p combinations.





Results

The calculated long term offsets of the semi submersible is listed in the Table below together with characteristic responses obtained from design conditions.

	100 year [m]	10 000 year [m]
POT	34.9	44.0
All sea state	36.7	52.1
Design condition	37.9	47.7

The design conditions for the 100 year response is defined as the most probable largest response in a storm with 100 year wind ($W = 33.6m/s$) and waves ($H_s = 17.2m$ and $T_p = 18.6s$). Similarly, the design condition for the 10 000 year response is taken as the most probable largest response in a storm with 100 year wind and 10 000 year waves ($H_s = 22.0m$ and $T_p = 21.0s$).

The All sea state approach neglects correlation between successive sea states, and is therefor expected to yield conservative predictions of extreme weather conditions and responses compared to the POT method. This is in line with the results summarized in the Table. In the POT method, correlation between adjacent sea states is avoided by establishing a sample of independent storms where each storm is modeled as a sequence of stationary sea states.

Conclusion

1. The design conditions in mooring analysis seem to be conservative for the 100 year and 10 000 year responses compared to the POT method. However, the design condition yield a non-conservative estimate of the 10 000 year response compared to the All sea state approach.

2. As expected, the POT method is less conservative than the All sea state approach.

3. The POT method shall -in theory- give more accurate predictions of extreme responses, and can in the future be used to design more cost efficient platforms without compromising the safety aspect.