ExWaCli : Extreme waves and climate change: Accounting for uncertainties in design of marine structures

A project funded by RCN

Background

Marine safety is a main concern of shipping, offshore industry and Classification. The importance of including the state-of-the-art knowledge on meteorological and oceanographic conditions in standards have been discussed increasingly by industry and academia in the last decades in several international forums. Climate changes in met-ocean conditions are presently not included in classification societies rules and offshore standards. To be able to design for climate change time-dependent statistical descriptions need to be adopted. Statistical extreme value analysis, as currently used in the met-ocean community, has to be upgraded to take into account the non-stationary character of current climate, in terms of both climate change trends and natural variability cycles. These changes need to be incorporated in the risk based approach used currently in design as proposed by Bitner-Gregersen and Eide (2010) and Bitner-Gregersen et al. (2013). The latter identified some shortcomings of previous publications addressing the topic, including:

- Only a limited number of the factors that influence future projections of wave conditions has been investigated
- Focus has been on mean values and not on the extremes that are used in shipping, offshore and coastal design
- The studies carried out so far have not been conducted with viewpoint of a designer and have not been placed in the context of structural reliability, loads and responses procedures.

Challenges

The main challenges in ExWaCli are

- Selecting the right blend of GCM/ESMs and number of combinations of model ensembles and scenarios to achieve necessary and sufficient data for estimating uncertainties
- Little information on the performance of many GCMs/ESMs
- Decide the statistical treatment of the large amount of data for extraction of trends and uncertainties in extremes

Objectives and structure

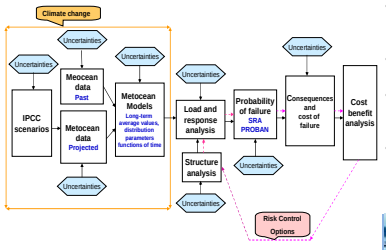
The overall objectives

- To understand how climate change will impact wave conditions in the northern areas in the 21st century and to specify uncertainties associated with the predicted changes.
- To suggest an integrated approach that handles the uncertainties associated with climate change projections and to take this into account in current design and operation procedures for marine structures.
- To provide recommendations for design and operations of marine structures.

WP1 Scenarios and approaches a → WP2 Data production → WP3 Statistics → WP4 Structural reliability analysis → WP5 Recommended practices

WP0 Project management

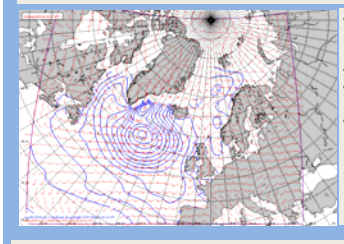
Risk based approach and climate change



The goal of ExWaCli is to answer two questions:

- Is it likely that marine structures will experience higher environmental loads;
- What does this mean for the design of marine structures?
- How to account for the changing environmental loads and responses?
- Will Classification Societies' Rules and Offshore Standards need to be updated?

Area



- The North Sea, the Norwegian/Greenland Seas and the Barents Sea
- The northeastern North Atlantic
- The Arctic Ocean between 90°E and 20°W
- The Kara Sea

Data

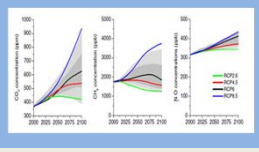
GCM/ESM

Choose model from CMIP5, considering

- Number of ensemble members
- No or few restrictions on use
- Resolution in time and space
- Validation/evaluation/performance, include sea ice

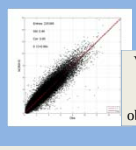
Scenarios

RCP4.5; RCP8.5



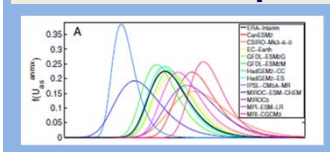
Regional model

WAM50 (met.no)

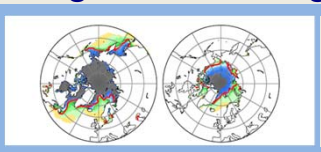


Validation NORA10 versus observations

Status – examples showing challenges in selecting «right» climate models



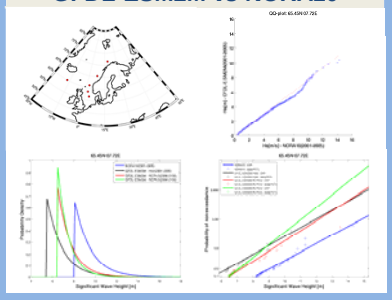
Performance wind northern North sea
(de Winter et al.(2013)



Performance sea ice (IPCC WG1AR5).
The maps show the number of models that simulate at least 15% of the cell area covered by sea ice. The heavy red lines indicate observations

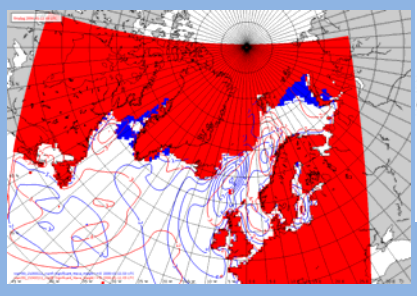
Example– future projection of the ocean wave climate using GFDL-ESM2M and WAM50

GFDL-ESM2M vs NORA10



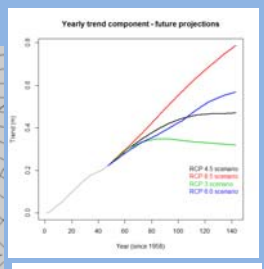
Exponential distributions of significant wave height 2001 – 2005 (NORA10, blue, GFDL-ESM2M, black) and 2096-2100 with GFDL-ESM2M using RCP4.5 (Red) and RCP8.5 (green) based on POT-data above the 99-percentile

WAM50 – RCP8.5 and RCP4.5



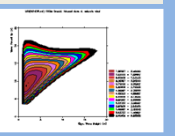
Wave conditions at 2100 11. januar kl 03 UTC using GFDL-ESM2M and WAM50. Blue RCP4.5; red RCP8.5
Lines: Significant wave height
Solid: Land and sea ice

Example– Bayesian Model



Projected cumulative increase in significant wave height for the blue area through the 21st century for the four representative concentration pathways (RCPs) used in IPCC AR5. Based om NORA10 data 1958 – 2005 (black curve)

Joint (Hs, Tp) Model



NORA10 data
1958 – 2009
North Atlantic

References

- Bitner-Gregersen, E.M. and Eide, L.I. (2010). Climate Change and Effect on Marine Structure Design. DNVRI Position Paper No.1
- Bitner-Gregersen, E.M., L.I.Eide, T. Hørte and R. Skjong (2013). Ship and Offshore Structure Design in a Climate Change Perspective. Springer Briefs in Climate Studies Springer –Verlag GmbH Berlin Heidelberg
- De Winter, R.C., A.Sterl and B.G. Ruessink, (2013). Wind extremes in the North Sea basin under climate change: An ensemble study of 12 CMIP5 GCMs. *J. Geophys. Res.: Atmospheres*, Vol. 118, 1-12, doi: 10.1002/jgrd.50147

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