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Modelling the Effect of Climate Change on the Ocean Wave Climate Around the World

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ABSTRACT

This paper analyses the trends and the future projections of significant wave height in several ocean areas at different parts of the world. It uses a stochastic Bayesian hierarchical space-time model, with a regression component with atmospheric levels of CO2 as covariates in order to estimate the expected long-term trends and make future projections towards the year 2100. The model was initially developed for an area in the North Atlantic ocean, and has been found to perform reasonably well there, and it is now investigated how the model performs for other ocean areas. 11 new ocean areas have been analysed with the model, and this paper presents the results pertaining to the estimated long-term trends and future projections of monthly maximum significant wave height for each of the 12 ocean areas..

KEY WORDS: Ocean wave climate, climate change, significant wave height, atmosphere-ocean modelling, ocean environment, trends and projections of wave climate.

INTRODUCTION

The ocean wave climate is obviously important to maritime safety, as well as many other areas of society. Ships and other marine and coastal structures are designed in order to withstand normal and extreme environmental loads imposed by the forces of wind and waves at sea. However, the potential impact of climate change on the ocean wave climate is often neglected, and it is also a lack of knowledge on how the future ocean wave climate will change as a result of climate change.

Recently, a Bayesian hierarchical space-time model was developed to investigate long-term trends and make future projections of the ocean wave climate for an area in the North Atlantic ocean. Results from the initial model are reported in Vanem et al. (2012a), results from a revised model with a logarithmic transformation of the data are reported in Vanem et al. (2012b) and results from an extended model with a regression component on atmospheric levels of CO_2 are reported in Vanem et al. (2012c). Furthermore, it is demonstrated in Vanem and Bitner-Gregersen (2012) how estimated trends and future projections can be taken into account in calculations of ship structural loads and responses and it was suggested that these trends are not negligible. However, all previous results pertain to a specific area in the North Atlantic ocean, and in this paper, it will be investigated how the model performs on 11 alternative areas of the world's oceans. Hence, estimated long-term trends and future projections towards the year 2100, obtained by the Bayesian hierarchical space-time model, will be presented for the following ocean areas:

1. North Atlantic	5. North West Pacific	9. Tasmanian Sea
2. North East Pacific	6. Indian Ocean	10. Mediterranean Sea
3. Gulf od Mexico	7. South Pacific Ocean	11. Equatorial Pacific
4. South Atlantic	8. Mid Atlantic Ocean	12. Western Australia

It is believed that this will give an indication of how the climate change will influence the wave climate of the world's oceans, even though all future projections are inevitably uncertain.

DATA AND AREA DESCRIPTIONS

Two types of data are essentially needed, i.e. data for significant wave height, which is the main parameter of interest, and for atmospheric levels of CO_2, which are used in the regression component. For the CO_2 data, both historic data are needed for model fitting, and future projections of CO_2 are needed for future projections of the wave climate. In this study, corrected monthly maximum significant wave height data from ERA-40 and monthly average CO_2 data from Mauna Loa Observatory have been used, covering the period from 1958 – 2002. For future projections of CO_2, two emission scenarios proposed by the IPCC have been assumed, i.e. the A2 and B1 scenarios. Further descriptions of these data sets can be found in Vanem et al. (2012c; 2012d).

The spatial resolution of the significant wave height data is 1.5º x 1.5º. Hence, a grid of this resolution covers each area under consideration. The various ocean areas that have been considered, with corresponding coordinates and sizes, are summarized in table 1.

THE STOCHASTIC MODEL

In order to model significant wave height in space and time, a Bayesian hierarchical space-time model, motivated by the models of Wikle et al. (1998); Wikle (2003); Natvig and Tvete (2007), has been constructed.