

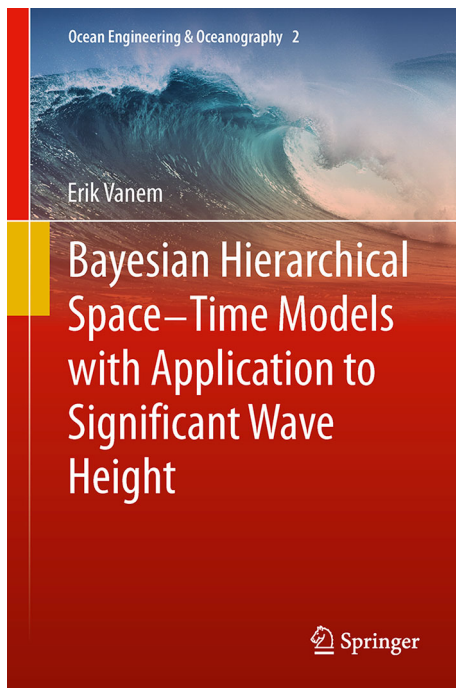
Erik Vanem: Bayesian hierarchical space-time models with application to significant wave height

Springer, Heidelberg (2013), Ocean Engineering & Oceanography, Vol. 2

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Published online: 11 June 2015

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Bayesian inference spent centuries outside the mainstream of statistical theory. Statisticians have traditionally been uneasy about the subjective estimates of prior probabilities necessary in Bayesian analysis. But in recent years, the success of Bayesian analysis in solving practical problems has rapidly increased its popularity. The development of efficient algo-

rithms for estimating the necessary integrals has been crucial in these applications.

The core of this book is the development of a space-time model for significant wave heights. The data come from a wave hindcast for the area of the North Atlantic between Iceland and the United Kingdom. Spatial dependence of the data is modeled using a Markov random field. The time evolution is modeled as a Markov chain. Because the main motivation of the study is to determine long-term trends in the data, linear and quadratic terms are explicitly included in the temporal model. Most of the priors are specified as simple Gaussian distributions. The integrals necessary for the Bayesian update are calculated using Markov Chain Monte Carlo techniques. These techniques are explained in a detailed Appendix. Other Appendices describe extreme value modeling, Markov random fields, and sampling from a multi-normal distribution. These Appendices are the most useful part of the book. But it would have been helpful to novices to more fully describe the path from the probability integrals to Bayesian simulations.

The book begins with a literature review of 215 references. The review is broad but not deep. Most of the references are described in a sentence or two, and the connections between references are not clear. For example, forecasts of significant wave height are mixed up with statistics of individual waves in a section on short-term models.

Many variations of the model were run. As is generally true, changing the prior distributions had very little effect on the results. The basic model sums the time-independent, space-time, seasonal, and secular time components. Taking a log transform of the data leads to a multiplicative model. The author was unable to find a convincing argument to prefer one model over the others. But almost all of the models show an increasing trend of significant wave height over the 42 years of hindcast data. The modeled increase in monthly maximum wave heights is about 70 cm. The author is reluc-

Communicated by Umesh A. Korde.

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tant to extrapolate the fitted trends to the future. For future projections, the model is extended with a regression term on atmospheric CO₂ levels. Even for the optimistic B1 future CO₂ scenario, the model predicts an increase of 1.9 m in monthly maximum significant wave heights by the end of this century.

A similar model was applied to the hindcast wind speeds over the same area. Surprisingly, the long-term trend of wind speeds over the whole area is slightly negative. There is a positive trend for the area north of Iceland, but it is less than 1 m/sec. Explaining the increase in wave heights will require a careful study of the physics in the hindcast model.

The wave model was also run for several other ocean areas. Almost all of them showed increases in wave height over the hindcast period. This contrasts with some previous studies which showed increases in some areas and decreases in others.

The author frankly admits that the studies reported in this book do not increase our certainty about what future wave

heights will be. An advantage of the Bayesian method is that it provides probabilistic bounds for uncertainties in the estimates. Other than that, it is hard for me to see how the estimates of long-term trends in this book improve on results from simple regression models. The greatest uncertainties lie outside the statistical model. A stochastic relationship between rising CO₂ levels and wave height does not prove a causal mechanism. And the 40 years of hindcast may not be long enough to detect climate cycles. Indeed, the quadratic model for monthly maxima shows a decreasing trend in the last decade or so of the hindcast data.

Despite my reservations about the usefulness of the climate projections, I believe the models are carefully constructed and executed. They should serve as a useful guide to anyone who wishes to experiment with similar techniques and I recommend this book to researchers interested in exploring time series data by Bayesian methods.