Storm peak validation and analysis of uncertainty in estimates of extreme sea states

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Introduction
All sites where estimates of extreme conditions are needed for engineering design, man-made structures such as ERAs-Interim (Dee et al. 2011) and CFSR (Chen et al. 2013) are often the best available sources of information on past wave conditions. Published validations often focus on quintile based measures, whereas extreme conditions are estimated from distinct storm peaks. Storm peaks are often underestimated by numerical models (Cavaleri, 2009). A peak based validation method is used and shows that model accuracy at storm peaks differs from that of the overall population. A storm peak-focused calibration method is tested, and the remaining uncertainty in model predictions of storm peaks is propagated through the estimation of extreme conditions.

Validation at storm peaks for extremes analysis
In estimating extreme conditions, a Peaks Over Threshold approach is adopted, in which a time series is reduced to a set of independent peak values of Hs. The exceedance curve shown below shows the different distributions of the whole population and independent storm peaks at the Coruña buoy. By matching pairs of observed and modelled peaks, we can generate error statistics specific to the storm peaks. Errors at storm peaks are often different to errors in the wider population.

The example shown is CFSR at the Coruña buoy. The wider population is shown in grey (with depth of grey indicating density of points), and matched peaks are coloured. Here, there is a high bias in the wider population, not present in the peaks. For most models at most buoys, the storm peaks are biased lower than the population above the 99th percentile, biased lower again than the population as a whole.

Calibration of storm peaks
If there is a consistent relationship between modelled and observed storm peaks, then we may be able to correct the model data and achieve more accurate estimates of extreme conditions. As buoys with long records are generally not located near locations of interest, we are looking for a calibration method with relatively simple mappable coefficients.

Uncertainty in extremes
If we assume that model errors at storm peaks are normally distributed, then we can use error statistics from the validation and combine Monte Carlo sampling of model error with Bayesian estimation of extreme value distributions to generate estimates of extreme conditions that include both the uncertainty due to input conditions and estimated uncertainty due to sampling of the distribution.

Here we use a simplified one-directional version of the Minguez (2011) scheme, where Hs(peak) = a * Hs(population) and coefficients a and b are found through an iterative process minimising bias in storm peaks. Estimated calibration coefficients are geographically consistent (open ocean vs marginal sea, offshore vs nearshore).

Conclusions and further work
A peaks-based validation is needed to assess the accuracy of modelled datasets for use in estimation of extreme conditions. Uncertainty in extreme conditions can be estimated, including the effect of uncertainty in input conditions, using combined Monte Carlo techniques and Bayesian statistical approaches.

Validation of uncertainty estimates requires collation of validations of multiple datasets at many buoys - this is on-going.

The increase in median estimate of extreme conditions due to uncertainty in the input was not expected and may yet be identified as an artefact of the analysis. If so, it may be interpreted as a contribution to the estimate due to the lack of skill of the estimator.

The confidence intervals/credible limits of the extremes estimates seem wider than our perception of the uncertainty. It is likely that work is needed on both the statistical analysis and our appreciation of what it is saying.

Further work will include building into analysis the uncertainty in buoy data (e.g. as analysed by Bitner-Gregersen and Magnusson (2014)) and extending analysis to higher resolution datasets such as NORA10 (Aarnes et al. 2012), and forecast models.

References