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Towards temporally and spatially varying extreme hydraulic loads

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In compliance with the Dutch Water Act the strength of the Dutch primary water defences must be assessed periodically for the required level of protection against hydraulic loads with return periods of up to 10,000 years. In the determination of the hydraulic loads, typically only one instant during a storm is considered, e.g. the instant at which the maximum water level is achieved in the region of the dike section of interest. For the determination of the required water defence crest level this is an appropriate approach, since the maximum wave overtopping rate is typically obtained at the maximum water level. For failure mechanisms other than overtopping, the instant of the maximum water level does not necessarily lead to the critical load on the water defence. Furthermore, failure mechanisms such as dune retreat and erosion of revetments typically depend on the temporal, and therefore also spatial, variation of the storm. In order to produce temporally and spatially varying hydraulic loads, numerical models (e.g. wave model) should be driven by wind fields evolving in time and space and provided with fields of other relevant variables (in the case of the wave model: offshore wave conditions, water levels and eventually currents) associated with extreme wind speeds.

Given the complexity of the problem, two leading experts in extreme value theory, Prof. Laurens de Haan and Prof. Richard L. Smith, were asked for advice on how to approach the estimation of time and space evolving multivariate extremes. Each expert independently derived a semi-parametric method, referred to as the method de Haan and the method Smith, based on the theory of max-stable processes. Roughly speaking, both methods use time series of the variables of interest (e.g. wind speed, significant wave height) over a grid of locations in order to lift (transform, translate) observed extreme events into yet unobserved and even more extreme events. The 'lifted events' provide descriptions of what happens in time and space within a future extreme event with a very small probability of occurrence.

These two methods have been implemented and applied to determine preliminary time and space evolving wind fields with associated return periods of up to 10,000 years. Furthermore, these 'lifted' wind fields have been used to force hydrodynamic models in a pilot study, in which a prototype probabilistic model was used for computing failure probabilities using temporally and spatially varying hydraulic loads. The results of the pilot study indicate that it is feasible to account for temporally and spatially varying hydraulic loads in the determination of failure probabilities. Given that the accuracy of the failure probability estimates strongly depend on the quality of the input extreme wind fields, the latter need to be thoroughly assessed.

At the conference the statistical methods to extrapolate the storm wind fields will be described and an assessment of the lifted wind fields (although, not yet in terms of the underlying physics) is to be presented.