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Evaluation of the imminence of a tsunami based on real-time seismic source parameter estimates – a Bayesian network approach

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Tsunami early warnings are based on co-seismic evidences being the earliest available information from a hazardous earthquake with the potential of causing a tsunami. Evaluations are generally done by applying rules derived from historic observation and making use of seismological expertise regarding regional tectonic contexts, faulting styles, occurrence frequency of large earthquakes and more. However, the co-seismic generation of a tsunami as well as the estimation of a potentially tsunamigenic event is prone to various uncertainties. As Bayesian networks (BNs) allow for integration and quantification of the uncertainties within the framework of probabilistic graphical models, we propose the usage of BNs for evaluating the imminence of a tsunami based on real-time seismic source parameter estimates. Earthquake parameter estimates (including uncertainties) are evaluated in real-time and the probabilities of tsunami threat levels are calculated and updated whenever new co-seismic evidence is available. The fast and efficient method gives an important additional information for the staff members at tsunami warning centers as it provides a probabilistic overview on the imminence of a tsunami for some particular costal region.

In our work, we have developed a preliminary BN tsunami warning system for the region of Sumatra by extracting knowledge from a set of formulas describing the physical process from earthquake rupture to sea-floor deformation to tsunami wave propagation and finally shoaling at the coast. The physical knowledge was transformed by ancestral sampling to a synthetic database and thereof BNs were learned for several sites of interest along the Sumatran coast and the fore-arc islands. To determine the conditional probability of the tsunami amplitude a set of seven co-seismic variables was defined: epicenter, centroid, magnitude, hypocentral depth, rupture direction, rupture length and width. We illustrate the advantages of this approach by case studies of recent tsunamigenic earhtquakes offshore Sumatra with particular focus on the probabilistically sound treatment of uncertainties relevant to tsunami early warning problem.