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Combining historical eyewitness accounts on tsunami-induced waves and numerical simulations for getting insights in uncertainty of source parameters

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Recent tsunami events including the 2004 Indian Ocean tsunami and the 2011 Tohoku tsunami have caused many casualties and damages to structures. Advances in numerical simulation of tsunami–induced wave processes have tremendously improved forecast, hazard and risk assessment and design of early warning for tsunamis. Among the major challenges, several studies have underlined uncertainties in earthquake slip distributions and rupture processes as major contributor on tsunami wave height and inundation extent. Constraining these uncertainties can be performed by taking advantage of observations either on tsunami waves (using network of water level gauge) or on inundation characteristics (using field evidence and eyewitness accounts). Despite these successful applications, combining tsunami observations and simulations still faces several limitations when the problem is addressed for past tsunamis events like 1755 Lisbon.
1) While recent inversion studies can benefit from current modern networks (e.g., tide gauges, sea bottom pressure gauges, GPS-mounted buoys), the number of tide gauges can be very scarce and testimonies on tsunami observations can be limited, incomplete and imprecise for past tsunamis events. These observations often restrict to eyewitness accounts on wave heights (e.g., maximum reached wave height at the coast) instead of the full observed waveforms;
2) Tsunami phenomena involve a large span of spatial scales (from ocean basin scales to local coastal wave interactions), which can make the modelling very demanding: the computation time cost of tsunami simulation can be very prohibitive; often reaching several hours. This often limits the number of allowable long-running simulations for performing the inversion, especially when the problem is addressed from a Bayesian inference perspective.
The objective of the present study is to overcome both afore-described difficulties in the view to combine historical observations on past tsunami-induced waves and numerical simulations. In order to learn the uncertainty information on source parameters, we treat the problem within the Bayesian setting, which enables to incorporate in a flexible manner the different uncertainty sources. We propose to rely on an emerging technique called Approximate Bayesian Computation ABC, which has been developed to estimate the posterior distribution in modelling scenarios where the likelihood function is either unknown or cannot be explicitly defined. To overcome the computational issue, we combine ABC with statistical emulators (aka meta-model). We apply the proposed approach on the case study of Ligurian (North West of Italy) tsunami (1887) and discuss the results with a special attention paid to the impact of the observational error.