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Tsunami Generation due to Supershear Earthquakes: A Case Study

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The 28 September 2018 Mw 7.5 Sulawesi strike-slip earthquake generated an unexpected tsunami with devastating consequences. Since such strike-slip earthquakes are not expected to generate large tsunamis, the latter's origin remains much debated. A key notable feature of this earthquake is that it ruptured at supershear speed, i.e., with a rupture speed greater than the shear wave speed of the host medium. Dunham and Bhat (2008) showed that such supershear ruptures, in half-space, produce two shock fronts (or Mach fronts) corresponding to an exceedance of shear and Rayleigh wave speeds. The Rayleigh Mach front carries significant vertical velocity along its front. We couple the ground motion produced by such a supershear earthquake to a 1D non-linear shallow water wave equation that accounts for both the time-dependent bathymetric displacement as well its velocity. We use an extension of Fourier-based PDE solvers called the Fourier Continuation (FC) method to numerically solve the system. The FC method enables high-order convergence of Fourier series approximations of non-periodic functions by resolving the well-known Gibbs "ringing" effect. FC-based solvers offer limited numerical dispersion, high-order accuracy and mild CFL conditions—making them ideal to solve this system. Using the local bathymetric profile of Palu bay around the Pantoloan harbor tidal gauge, we have been able to clearly reproduce the observed tsunami with minimal tuning of parameters. We conclude that the Rayleigh Mach front, generated by a supershear earthquake combined with the Palu bay geometry, caused the tsunami.