The Next Generation of Earthquakes, Tsunamis and Volcanoes Simulations: Accounting for Real-Earth Elastic Complexities

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The recent advancements of space technology have provided us with extraordinary opportunities to observe and study Earth processes with unprecedented data precision and spatial coverage. The surface displacements associated with momentary earthquake ruptures, tsunami genesis and restless volcanoes can be well captured by InSAR, GPS, and other remote sensing data, thanks to multiple satellite missions launched around the globe. The commonly-used approaches to interpret these displacement signatures, and evaluate fault-slip and magmatic behaviors rely heavily on the analytical solutions of a homogeneous crust. While such models are very computationally efficient, they often oversimplify the interior complexities of the crust. Research efforts of multidisciplinary geoscientists continue to reveal the rich rock and structural complexity beneath the Earth surface. A new generation of simulation, leveraging the powerful capabilities of 3D finite element models, is revolutionizing the current capacity of accounting for these complexities with a vastly-boosted computational speed. These techniques are designed to seamlessly unify interdisciplinary data (e.g. geodetic observations, seismic tomography models, relocated seismicity, geophysical imaging data, geothermal data, topography/bathymetry, field measurements, drill-core logging, and petrophysical experiments) into a single physical domain for understanding elastic or semi-elastic earth behaviors. Keeping abreast with the rapid developments of geoinformatics and high-performance computing, this advanced numerical strategy serves to be incorporated into existing early geohazard warning systems with near-real-time inverse/forward results. The improved modeling accuracy for tsunami and aftershock hazard, from a probabilistic perspective, helps us quantitatively address fundamental questions related to regional tectonics, volcanology, and geodynamics.

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