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Numerical modeling of the thermal state of Earth after the Moon-forming impact event

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Planetary collisions play an important role in the compositional and thermal evolution of planetary systems and such collisions are caracteristics of the final stage of planetary formation. The Moon-forming impact event is thought to (re)set the conditions for the subsequent thermochemical evolution of Earth and Moon. Large parts of proto-Earth are thought to melt as a consequence of the impact [e.g.1] and the extent of melting affects the evolution of the Earth's interior and atmosphere. It is then critical to address the initial conditions of the proto-Earth and the volume and shape of a possible magma ocean after the impact. Previously, the Moon-forming giant impact was modeled with mesh-free so-called smoothed particle hydrodynamics (SPH [1, 2, 3]). In this study, we, in contrast, carried out numerical simulations of the Moon-forming impact event considering different impact scenarios with the three-dimensional (3D) iSALE code [4, 5], that tends to be more accurate in the description of thermodynamics and shock waves than SPH simulations. We also compare simulation results from our iSALE code with SPH models for benchmarking ([1]) because SPH uses self-gravity, whereas iSALE uses central gravity. We vary the impact angle (15° to 90°) and impact velocities (12 to 20 km/s). In order to quantify the volume of impact-induced melt, we use the so-called peak-shock pressure approach ('Tracer method') that has been used in several modeling studies [6,7] and is described in more detail by [8].

The benchmark study shows a good agreement of the two different numerical approaches with respect to pressure evolution. However the production of a magma ocean show some differences that need to be further explored, with notably the effects of considering central gravity instead of self-gravity into iSALE 3D simulations.

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