EGU21-14164
https://doi.org/10.5194/egusphere-egu21-14164
EGU General Assembly 2021

A kinematic formalism for tracking ice-ocean mass exchange on the Earth's surface and estimating sea-level change

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Polar ice sheets are important components of the Earth System. As the geometries of land, ocean, and ice sheets evolve, they must be consistently captured within the lexicon of geodesy. Understanding the interplay between the processes such as ice-sheet dynamics, solid-Earth deformation, and sea-level adjustment requires both geodetically consistent and mass conserving descriptions of evolving land and ocean domains, grounded ice sheets and floating ice shelves, and their respective interfaces. Here we present mathematical descriptions of a generic level set that can be used to track both the grounding lines and coastlines, in light of ice-ocean mass exchange and complex feedbacks from the solid Earth and sea level. We next present a unified method to accurately compute the sea-level contribution of evolving ice sheets based on the change in ice thickness, bedrock elevation and mean sea level caused by any geophysical processes. Our formalism can be applied to arbitrary geometries and at all time scales. While it can be used for applications with modeling, observations and the combination of two, it is best suited for Earth System models, comprising ice sheets, solid Earth and sea level, that seek to conserve mass.