

Towards Earth System Models with a Fully Integrated Solid Earth

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The solid Earth is a key component of the Earth system dominating its dynamic behavior as a planet. Nevertheless, Earth system models often include the solid Earth as a rigid body not impacting the dynamics of, for example, the climate system. For climate models, the solid Earth normally is represented as a rigid boundary condition. On the other hand, models of dynamic properties of the Earth such as changes in Earth rotation, gravity field, and shape often focus on particular aspects of the solid Earth and consider atmosphere and ocean as independent excitations. Over time, the accuracy of geodetic observations has reach a level where links between atmosphere, ocean and solid Earth dynamics may be significant and the current separate treatment of solid earth dynamics on the one side and atmosphere-ocean dynamics on the other side no longer is applicable.

A possible approach to fully integrated Earth system models is a modular system that accounts for all couplings between the individual modules. The internal physics of the modules also would have to account for all effects resulting from the couplings of any given module with all other modules. If the modules are chosen appropriately, a modular model would have several characteristics, including the frequencies of eigenmodes as emerging properties without the necessity of pre-defining these frequencies.

A simple modular system consisting of atmosphere, ocean, and a solid Earth with mantle and core is used to illustrate the approach. Since angular and linear momentum equations are not coupled, a separate deformation module is added to the system. The eigen frequencies are studied analytically as function of coupling parameters, and they are found to depend significantly on these parameters. The modular model is implemented in a numerical time-domain model. It is shown that the numerical model has the same eigen frequencies as the analytical model. Integration of the numerical model requires long start-up times to avoid impacts of the initial conditions and high temporal resolution to overcome dynamic instabilities.