Geophysical Research Abstracts
Vol. 20, EGU2018-6074, 2018
EGU General Assembly 2018

A high order and large-time stable scheme for very low-frequency Earth's free oscillations by spectral-element method and infinite-element projection

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Obtaining the synthetic spectral of Earth's free oscillations at very low-frequencies is difficult but of great significant in computational seismology. The obstacles are attributed to two major elements. First of all, gravity must be taken into consideration, which is usually neglected in conventional Earth's free oscillations models. The traditional way is adopting Cowling approximation to avoid the calculation of the geopotential perturbation, but it is not acceptable for the realistic Earth. When gravity is included, it leads to great difficulties to both analytical and numerical solutions because it breaks the intrinsical spectral structure of the free oscillations over large time. Therefore, constructing a large-time stable and high-precision time scheme is essential and critical. While it becomes extremely difficult due to the spectral splitting, especially in very low-frequency oscillation problems. The difficulty also comes from the infinite boundary of the gravity, which cannot be handled by the regular spectral-element method. In this work, we employ an infinite-element projection to map the infinite boundary to a finite domain. And we replace the commonly used New-Mark scheme with symplectic Nyström scheme. Symplectic Nyström scheme has 4th order accuracy larger than the 2nd order of New-Mark scheme. Most importantly, it can preserve the symplectic structures and therefore keep numerical scheme stable for large-time calculation even with very small time step. Finally, we verify our method in a 2.5 dimension problem and analyze the splitting of normal mode splitting caused by Earth's self-rotation.