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A concept for the estimation of high-degree gravity field models in a high performance computing environment

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The estimation of the global Earth's gravity field parametrized as a finite spherical harmonic series is computationally demanding. The computational effort depends on the one hand on the maximal resolution of the spherical harmonic expansion (i.e. the number of parameters to be estimated) and on the other hand on the number of observations (which might be several millions). All global high-resolution Earth's gravity field models currently available (above degree and order 360) were computed introducing approximations. These approximations significantly reduce the numerical complexity. For example, the prerequisites for the orthogonality of the spherical harmonic base functions, leading to a block diagonal system of normal equations, are often artificially introduced by working with equally distributed data along parallels with constant accuracy. In addition, these methods do not allow for a complex modeling of the observation errors, or the inclusion of redundant observations. The gravity fields are then derived from the block-diagonal normal equations.
Within this contribution a concept for the rigorous estimation of high-degree gravity models above degree and order 2000 is presented. Iterative solvers implemented in a high performance computing environment using several thousands compute cores are used to derive the rigorous least-squares solution from millions of observations for more than 4 000 000 unknown parameters. A flexible design was implemented to process an arbitrary number of observation groups. For each of these observation groups a variance component can be estimated to derive a data adaptive weighting factor of each of these observation groups. For this reason a Monte Carlo based variance component estimation is integrated into the iterative solver. The combined solution is derived in a weighted joint estimation from all observation groups which might be preprocessed normal equations (e.g. from the dedicated gravity field missions like CHAMP, GRACE or GOCE) or observations like data sets of point-wise measured terrestrial gravity field information. The concept of the implemented solver is demonstrated. A small scale closed loop simulation serves as proof of concept.