Geophysical Research Abstracts
Vol. 18, EGU2016-12650, 2016
EGU General Assembly 2016

High-resolution combined global gravity field modelling: Solving large kite systems using distributed computational algorithms

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One of the major obstacles in modern global gravity field modelling is the seamless combination of lower degree inhomogeneous gravity field observations (e.g. data from satellite missions) with (very) high degree homogeneous information (e.g. gridded and reduced gravity anomalies, beyond d/o 1000). Actual approaches mostly combine such data only on the basis of the coefficients, meaning that previously for both observation classes (resp. models) a spherical harmonic analysis is done independently, solving dense normal equations (NEQ) for the inhomogeneous model and block-diagonal NEQs for the homogeneous. Obviously those methods are unable to identify or eliminate effects as spectral leakage due to band limitations of the models and non-orthogonality of the spherical harmonic base functions.

To antagonize such problems a combination of both models on NEQ-basis is desirable. Theoretically this can be achieved using NEQ-stacking. Because of the higher maximum degree of the homogeneous model a reordering of the coefficient is needed which leads inevitably to the destruction of the block diagonal structure of the appropriate NEQ-matrix and therefore also to the destruction of simple sparsity. Hence, a special coefficient ordering is needed to create some new favorable sparsity pattern leading to a later efficient computational solving method. Such pattern can be found in the so called kite-structure (Bosch, 1993), achieving when applying the kite-ordering to the stacked NEQ-matrix.

In a first step it is shown what is needed to attain the kite-(NEQ)system, how to solve it efficiently and also how to calculate the appropriate variance information from it. Further, because of the massive computational workload when operating on large kite-systems (theoretically possible up to about max. d/o 100.000), the main emphasis is put on to the presentation of special distributed algorithms which may solve those systems parallel on an indeterminate number of processes and are therefore suitable for the application on supercomputers (such as SuperMUC). Finally, (if time or space) some in-detail problems are shown that occur when dealing with high degree spherical harmonic base functions (mostly due to instabilities of Legendre polynomials), introducing also an appropriate solution for each.