Geophysical Research Abstracts
Vol. 16, EGU2014-1597, 2014
EGU General Assembly 2014

Gravity field modeling with spherical radial basis functions: A closed-loop simulation applying regularization

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The global gravity field is usually represented in spherical harmonics. Radial basis functions form an alternative mathematical representation of the global gravity field, provided that the basis function is chosen such that it is identical to spherical harmonics. Shannon low-pass spherical radial basis function sets all coefficients above a chosen spherical harmonic degree to zero, thereby forming a radial basis function that is equivalent to spherical harmonics in the global case.

Radial basis functions are versatile in that their approximation characteristics and spatial distribution can be adjusted, making it possible to use them for all kinds of data sets and for combining different types of observations. The radial basis function values decrease with the distance from their origin and, consequently, they are deemed suitable for regional gravity field modeling. However, the radial basis function parameters need to be chosen carefully in order to obtain a correct signal representation with convincing quality. Since radial basis functions can be related to spherical harmonics, a transformation between the respective coefficients is possible, making existing spectral analysis techniques for spherical harmonics applicable for radial basis functions.

To verify their theoretical equivalence in the global case numerically, a closed-loop simulation is set up. A “true” synthetic disturbing potential field is computed with spherical harmonic synthesis from the global geopotential model EGM2008. The synthetic observations are both analyzed and synthesized with Shannon low-pass radial basis function. Several cases are tested with varying observation height, noise and grid type. Ultimately, the “true” field and the synthesized field are compared.

In the analysis step, radial basis function coefficients are estimated by least-squares adjustment. Already in the ideal noise-free case, this linear inverse problem is ill-conditioned. Consequently, Tikhonov regularization with prior information is applied to the radial basis function analysis. Furthermore, the L-curve approach for choosing an optimal regularization parameter is applied. The necessity of choosing the regularization parameter correctly, as well as the benefits of correctly applied regularization, is demonstrated.