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The relation between degree-2160 spectral models of Earth's gravitational and topographic potential: a guide on global correlation measures and their dependency on approximation effects

Abstract:
Comparisons between high-degree models of the Earth's topographic and gravitational potential may give insight into the quality and resolution of the source data sets, provide feedback on the modelling techniques and help to better understand the gravity field composition. Degree correlations (cross-correlation coefficients) or reduction rates (quantifying the amount of topographic signal contained in the gravitational potential) are indicators used in a number of contemporary studies. However, depending on the modelling techniques and underlying levels of approximation, the correlation at high degrees may vary significantly, as do the conclusions drawn. The present paper addresses this problem by attempting to provide a guide on global correlation measures with particular emphasis on approximation effects and variants of topographic potential modelling. We investigate and discuss the impact of different effects (e.g., truncation of series expansions of the topographic potential, mass compression, ellipsoidal versus spherical approximation, ellipsoidal harmonic coefficient versus spherical harmonic coefficient (SHC) representation) on correlation measures. Our study demonstrates that the correlation coefficients are realistic only when the model's harmonic coefficients of a given degree are largely independent of the coefficients of other degrees, permitting degree-wise evaluations. This is the case, e.g., when both...
models are represented in terms of SHCs and spherical approximation (i.e. spherical arrangement of field-generating masses). Alternatively, a representation in ellipsoidal harmonics can be combined with ellipsoidal approximation. The usual ellipsoidal approximation level (i.e. ellipsoidal mass arrangement) is shown to bias correlation coefficients when SHCs are used. Importantly, gravity models from the International Centre for Global Earth Models (ICGEM) are inherently based on this approximation level. A transformation is presented that enables a transformation of ICGEM geopotential models from ellipsoidal to spherical approximation. The transformation is applied to generate a spherical transform of EGM2008 (sphEGM2008) that can meaningfully be correlated degree-wise with the topographic potential. We exploit this new technique and compare a number of models of topographic potential constituents (e.g., potential implied by land topography, ocean water masses) based on the Earth2014 global relief model and a mass-layer forward modelling technique with sphEGM2008. Different to previous findings, our results show very significant short-scale correlation between Earth's gravitational potential and the potential generated by Earth's land topography (correlation +0.92, and 60(%) of EGM2008 signals are delivered through the forward modelling). Our tests reveal that the potential generated by Earth's oceans water masses is largely unrelated to the geopotential at short scales, suggesting that altimetry-derived gravity and/or bathymetric data sets are significantly underpowered at 5 arc-min scales. We further decompose the topographic potential into the Bouguer shell and terrain correction and show that they are responsible for about 20 and 25(%) of EGM2008 short-scale signals, respectively. As a general conclusion, the paper shows the importance of using compatible models in topographic/gravitational potential comparisons and recommends the use of SHCs together with spherical approximation or EHCs with ellipsoidal approximation in order to avoid biases in the correlation measures.