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MODELING OF THE EARTH'S GRAVITY FIELD USING THE NEW GLOBAL EARTH MODEL (NEWGEM)

YEONG E. KIM

Department of Physics, Purdue University, West Lafayette, IN 47907

W. Danny Braswell

Nichols Research Corporation, 4040 South Memorial Parkway, Huntsville, AL 35802

Traditionally, the global gravity field has been described by representations based on the spherical harmonic (SH) expansion of the geopotential (Heiskanen and Moritz, 1967). The SH expansion coefficients have been determined by fitting the Earth's gravity data as measured by many different methods including the use of artificial satellites. As gravity data has accumulated with increasingly better accuracies, more of the higher order SH expansion coefficients have been determined (Lerch et al., 1985; Reigber et al., 1985; Rapp, 1987, references therein; Marsh, 1988). The SH representation is useful for describing the gravity field exterior to the earth but is theoretically invalid on the Earth's surface and in the Earth's interior (Heiskanen and Moritz, 1967). Further, the smaller-scale detailed structure of the mass distribution is not reflected in SH representations.

It is well known that there is not a unique distribution of mass which gives rise to a given gravitational potential. Because of this nonuniqueness, other geophysical data such as topographic information and seismic observations must be combined with the gravity data to constrain the possible solutions to those which are geophysically meaningful.

Since some knowledge of the mass distribution in the interior of the Earth is emerging from seismic studies (Dziewonski and Anderson, 1981; Dziewonski and Woodhouse, 1987, references therein) and rather detailed knowledge of the earth's crust and surface is increasingly available in many places, it is desirable to introduce a new physical representation of the mass distribution for the entire Earth which can be refined to accommodate new and more accurate data as it becomes available and which can describe many different component properties and processes of the entire Earth system on both global and regional bases. A new global Earth model (NEWGEM) (Kim, 1987 and 1988a) has been recently proposed to provide a unified description of the Earth's gravity field inside, on, and outside the Earth's surface using (1) the Earth's mass density profile as deduced from seismic studies, (2) elevation and bathymetric information, and (3) local and global gravity data. Using NEWGEM, it is possible to determine the constraints on the mass distribution of the Earth imposed by gravity, topography, and seismic data.

Density distributions in NEWGEM will be fine-tuned by requiring reasonable agreement between the NEWGEM gravity field and local gravity data such as the absolute gravity data of the United States (Peter, Moore, and Beruff, 1986). The NEWGEM gravity field will also be constrained to agree with SH expansion models at high altitudes.

NEWGEM is useful in investigating a variety of geophysical phenomena. It is currently being utilized to develop a geophysical interpretation of Kaula's rule (Kaula, 1968; Lambeck, 1976; Kaula, 1977; Cook, 1980). In this investigation, the zeroth order NEWGEM is being used to numerically integrate spherical harmonic expansion coefficients and simultaneously determine the contribution of each layer in the model to a given coefficient. The numerically determined SH expansion coefficients are also being used to test the validity of SH expansions at the surface of the earth by comparing the resulting SH expansion gravity model with exact calculations of the gravity at the Earth's surface.

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As the zeroth-order approximation for NEWGEM, the ellipsoidal layer (EL) model (Kim and Klepacki, 1987; Kim, 1987) is used. In the EL model the Earth is assumed to consist of n ellipsoidal layers plus a core ellipsoid, with layer densities inferred from the Preliminary Reference Earth Model (PREM) (Dziewonski and Anderson, 1981). EL models have previously been investigated in ellipsoidal coordinates (Moritz, 1968; and references therein) and also in spherical coordinates (Jeffreys, 1976; Moritz, 1973; references therein). The EL model in NEWGEM utilizes cartesian coordinates since analytic solutions for the gravitational potential outside and inside an ellipsoidal layer of uniform density are available in that coordinate system (Kim and Klepacki, 1987; Kim, 1987 and 1988a).

As the first-order correction for NEWGEM, three-dimensional global variations of the mass density profile for the Earth's crust (oceans and continents) and also mass irregularities due to isostasy and the Earth's large -scale interior heterogeneity as observed from seismic data (Dziewonski and Woodhouse, 1987; references therein) are considered. These global corrections are being implemented by dividing the Earth's interior into many small spherical shell segments, each with it's own density. The corrections necessitated by the earth's varying topography are being included using the 5 minute by 5 minute worldwide elevation and bathymetric data base, ETOPO5, available from the National Geophysical Data Center. The total contribution to the gravitational acceleration (both magnitude and direction) at a location can be computed by summing the contributions of each cell. These global corrections will be added to the gravity field of the EL model. The resulting total gravity field will be compared to the International Gravity Standardization Net (IGSN) 1971 (Morelli et al., 1971) and also to the gravity field deduced form ground-based tracking of artificial satellites, GEM-T1 (Marsh et al., 1988).

Recently, the first order global corrections for lateral density variations have been estimated and shown to provide a consistent explanation of signature (attractive or repulsive) and magnitude of apparent anomalies observed in borehole and seafloor gravity measurements carried out as precision tests of Newton's gravitational law (Kim, 1988b).

Higher order corrections to NEWGEM can obtained by calculating the local and/or regional corrections with an additional subdivision of spherical shell segments in the local and /or regional volumes (limited area and depth) without disturbing the zeroth and first order description of the entire Earth system exterior to the local and or regional volumes under consideration. This is one of the advantages of NEWGEM, its capacity to be improved and upgraded indefinitely on local, regional, or global scales as more accurate data (local, regional and/or global) becomes available. This allows the investigation of local and/or regional gravity piecewise but yet as an integral part of the entire Earth system.

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Gravity Field Measuring Techniques

Moderators: Christopher Jekeli
Klaus-Peter Schwaz