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Improved direct atmospheric correction in gravimetric geoid computations

ABSTRACT

Prior to the Stokes integration, the effect of atmospheric masses on the gravity anomaly Δg must be removed. A theory for the atmospheric gravity effect is the well-known International Association of Geodesy (IAG) approach in connection with Stokes's integral formula. Another strategy is the use of the spherical harmonic representation of the topography. This presentation will use a new formula to improve the previous procedures by accounting for local contributions and a more detailed treatment of topography. The new formula uses a combination of the local contributions of the atmospheric effect, computed from a detailed Digital Terrain Model (DTM) and a set of spherical harmonics, which accounts for the global contributions. The new formula has been computed over Iran. A comparison of the new and old formulas shows significant differences.

INTRODUCTION

Geoid determination by Stokes's well-known formula requires that there are no masses outside the geoid. Consequently, the effect of atmospheric masses must be removed or reduced, which corresponds to the so-called direct effect on gravity anomaly. Stokes's formula applied to the corrected gravity anomalies results to the co-geoid. The restoration of the atmospheric masses corresponds to the indirect effect, i.e. the correction from the co-geoid to the geoid. Ecker and Mittermayer (1969) derived a formula for the direct atmospheric effect on the gravity, which later named the IAG approach. This method is described in Moritz (1980). Sjöberg and Nahavandchi (2000) investigated the direct and indirect atmospheric gravity and geoid effects with a more detailed treatment of Earth's topography than is made in the IAG approach. They derived a formula for the direct atmospheric gravity and geoid effects using a spherical harmonic representation of the topography. This presentation uses new formulas for the direct atmospheric gravity and geoid effects by combination of the local contributions and a set of spherical harmonic coefficients of topography (Nahavandchi 2002). These formulas were tested numerically over Iran with a maximum elevation of 5671 m. The height coefficients H_{nm} are determined using a 30' x 30' DTM which is generated using the Geophysical Exploration Technology (GETECH) 5' x 5' DTM (GETECH, 1995). This 30' x 30' DTM is averaged using area weighting. Since the interest is in continental elevation coefficients and we are trying to evaluate the effect of the masses above the geoid, the heights below sea level are all set to zero. The spherical harmonic coefficients of topographic heights are computed to degree and order 360. Parameter definitions are as follows: $G= 6.673 \times 10^{-11} m^3 kg^{-1} s^{-2}$ and $\rho^0 = 1.23$ kg / m^3, R=6371 km, and γ= 981 Gal. To compute the local contributions in the new formula, a 1 x 1 km DTM is used. It means that the local contributions are computed from the heights of computation points (derived from 1 x 1 km DTM) and the global contributions are derived from the spherical harmonic representation of topographical heights at the computation point.

CONCLUSIONS:

The atmospheric effect is a first-order effect of elevations and its direct effect on the geoid reaches to a few decimeters. The direct atmospheric effect in gravimetric geoid determination is composed of both local effects and long-wavelength contributions. The new formula treats the Earth as a sphere with the radius R and a variable topography H on top of sphere, while IAG approach assumes a spherical Earth with Radius R and a spherical layering of the atmosphere, neglecting an ellipsoidal layering. The topography is more or less ignored. The new formula includes both short- and long-wavelength constituents.

References:

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Figure 1 shows the presentation of topography in the test area, which includes the whole of Iran. Maximum elevation reaches to 5671 m over a mountainous area in the northeast of Tehran, Damavand. This presentation of topography is computed from a 1 x 1 km Digital Terrain Model (DTM) over Iran.

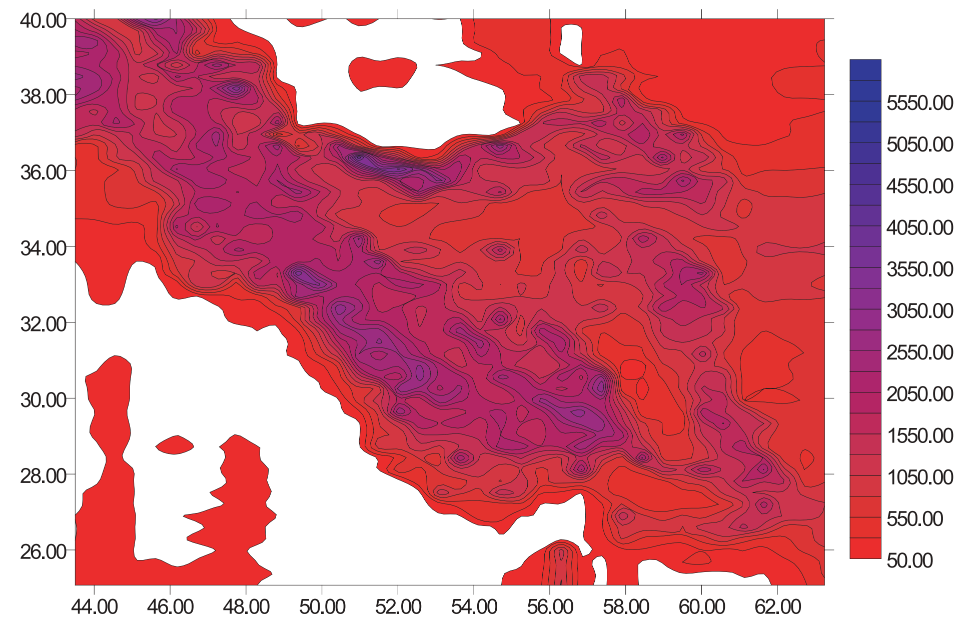

Fig. 1. Presentation of topography over Iran. Units in m.

Figure 2 shows the direct atmospheric effect on gravity computed from Sjöberg and Nahavandchi (2000) formula. This formula uses spherical harmonic representation of topography, which excludes the local contributions.To incorporate all significant contributions of both short and long-wavelength constituents, an expansion in spherical harmonics of height coefficients to very high degrees should be required, which is practically difficult and ruins the simplicity of this method. The direct atmospheric effect on gravity reaches to 0.195 mGal in the test area over Damavand mountainous region with a maximum elevation of 5671.

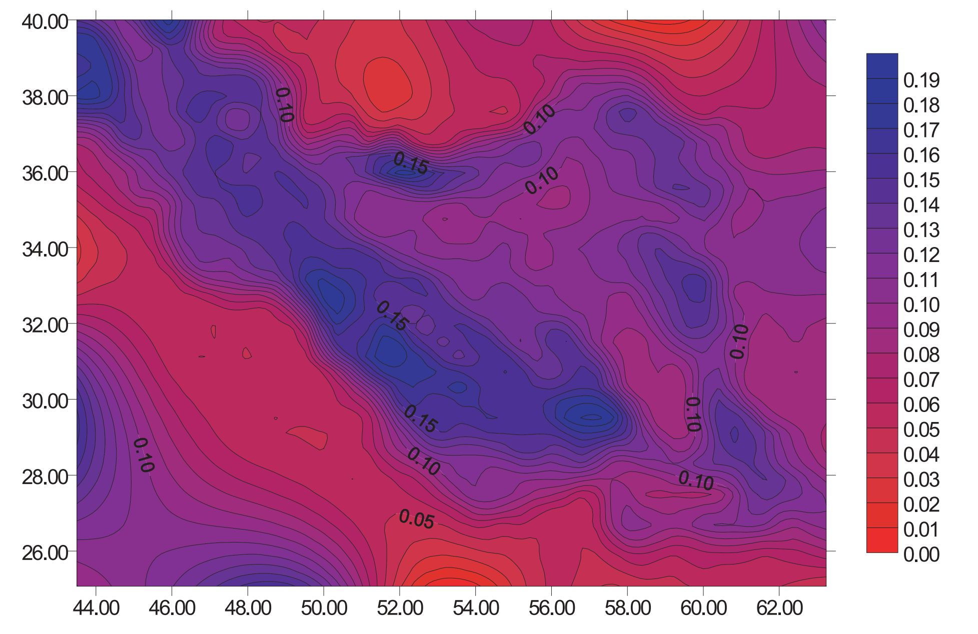

Fig. 2. The direct atmospheric gravity effect with the old formula. Units in mGal.

Figure 3 shows the direct atmospheric effect on gravity computed from the new formula (Nahavandchi 2002). This formula includes both long- and short-wavelength contributions. Spherical harmonic representation of topography is used to compute the long-wavelength contributions and a 1 x 1 km DTM is used to compute the local constituents. This effect reaches to 0.347 mGal over Damanad region. Inclusion of a dense DTM will present local irregularities in the formula, which are obvious in this figure too.

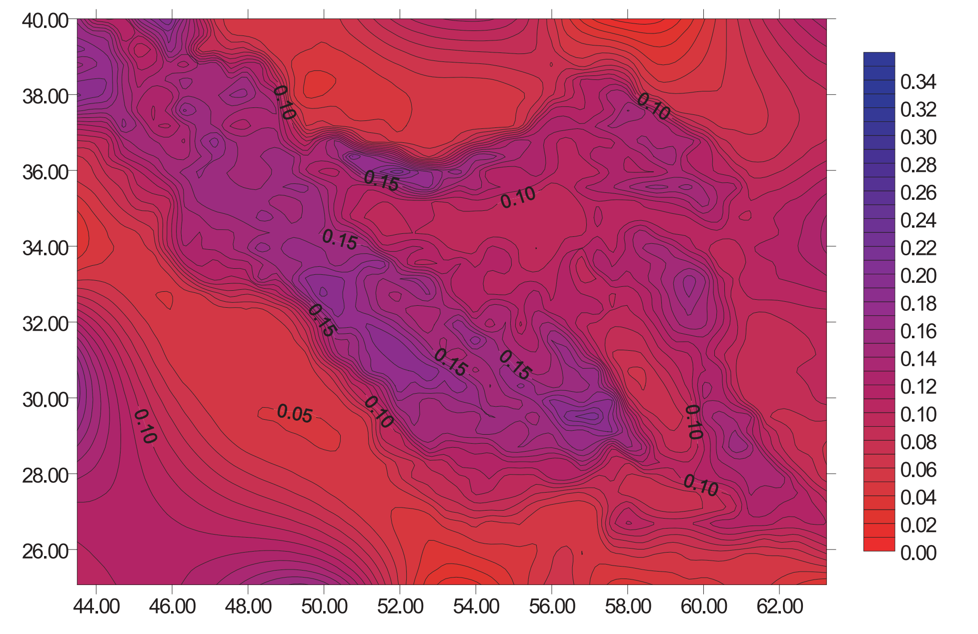

Fig. 3. The direct atmospheric gravity effect with the new formula. Units in mGal.

Figure 4 depicts the differences between two old and new formulas. This figure shows the local constituents neglected in the old formula. The reason for differences is the better treatment of Earth's topography with the new formula for the direct atmospheric effect. The differences on gravity anomaly reach to 0.176 mGal, which is significant in geoid computations. On the geoid, the differences reach to 18 cm.

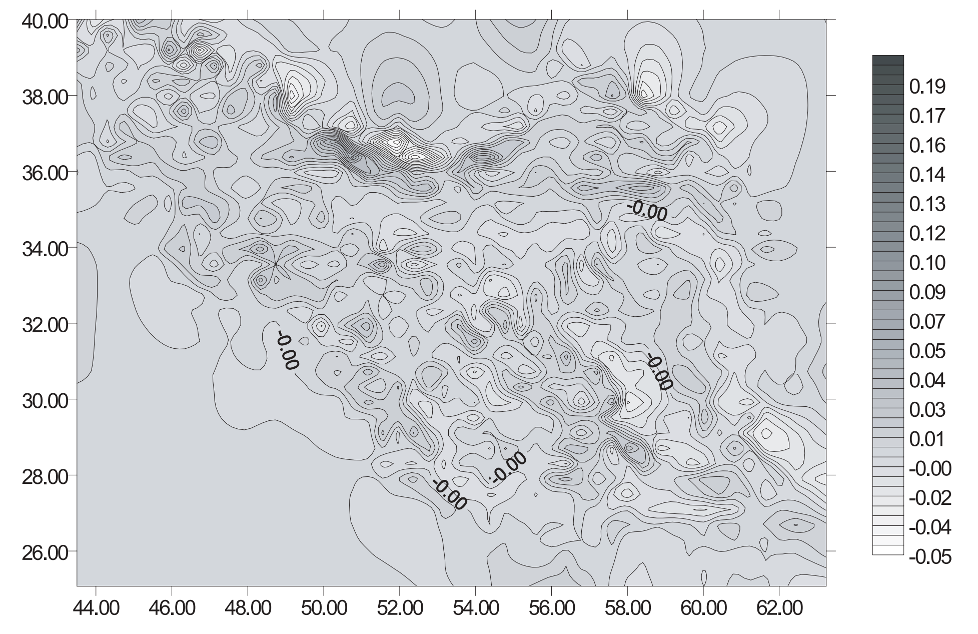

Fig. 4. The differences on direct atmospheric gravity effect between the old and new formulas. Units in mGal.