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Precise determination of the geoid in Iran using the Stokes - Helmert scheme

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The theory of Stokes-Helmert scheme was developed by Peter Vanicek and Zdenec Martinec in 1994 for the precise determination of geoidal height. In this scheme, the Earth gravity field is first reduced to the so called Helmert gravity field by condensing both the topographic and the atmospheric masses above the geoid as a surface material layer with known surface density onto the geoid. As a result of codensation, the geoid as an equipotential surface is uplifted to a new position where it is called the co-geoid. The co-geoid is determined as a solution to the Geodetic Boundary Value Problem (GBVP) in the Helmert space. In this determination, two different kinds of data are used. The purely satellite-derived geo-potential coefficients, already reduced to the Helmert space are used to determine the long wavelengths part up to harmonic degree and order 20 of the co-geoid (spheroid of degree 20). The terrestrial and local gravity anomalies are used into the generalized Stokes integral employing spheroidal Stokes kernel to determine the remaining short wavelengths part, the residual co-geoid. Because of the shortages of gravity measurements across the world, the kernel is modified in a way to minimize the contribution of lacking far zones gravity data, beyond the spherical distance of 6° from a computation point. The ellipsoidal degree of approximation is employed throughout the computation of both parts. Finally the co-geoid is transformed to the geoid in the real Earth space by precisely accounting for the indirect effect (uplift). For the determination of geoid in Iran, the Stokes-Helmert scheme was employed. The long wave lengths part of co-geoid, in the Helmert space, is determined using the EIGEN-1S geo-potential model for its minimal commission error. For transformation of the geo-potential coefficients to the Helmert space, a harmonic squared-topographical model derived from the harmonic topographical model TUG87 was used. The residual co-geoid was determined using local gravity data. The data was

in the form of absolute value of point gravities supplied partly by the international BGI and partly by the National Cartographic Center (NCC) of Iran. Even in total, the data do not cover the whole region (Iran) of computation satisfactorily, i.e., the gravity points were scarce. For this, the region of interest was first divided into 256 areas each one restricted by latitudes and meridians intervals of size $1^\circ \times 1^\circ$. The point gravities sited into each area were transformed into point Complete Bouguer anomalies, using their known orthometric heights. The point anomalies were then (multiquadric) modeled. The model was used to predict the anomalies over grid points of $1' \times 1'$ spacing in the area. The point values were averaged into mean complete Bouguer anomalies representing $5' \times 5'$ cells. The mean anomalies were transformed into corresponding (surface) Helmert mean free air anomalies at the topographical height. For this transformation, $5' \times 5'$ mean orthometric heights of topography are needed. These heights were estimated using high resolution DTMs, e.g., NIMA $30'' \times 30''$, RS $3'' \times 3''$ and NCC $1'' \times 1''$. Then the surface anomalies were continued down ward to the co-geoid level using inverse Poisson transformation. The generalized Stokes integral with a modified spheroidal Stokes kernel was used to compute the residual co-geoid, given the Helmert gravity anomalies on the co-geoid reduced already for the long wavelengths part derived from the EIGEN-1S geo-potential model. The sum of spheroid and residual parts yielded the full spectrum of the co-geoid in the Helmert space. The so-derived co-geoid was finally transformed to the geoid in Iran. As external evidence, a profile of geoid was compared to the GPS solution at some points into the national height network. The comparison showed a good relative accuracy but a shift between two Stokes-Helmert and GPS geoid profiles. As it was tested, the origin of the shift was not from the scale of the geo-potential model used. In a test of gravity data, the Helmert gravity anomalies computed at 50 selected points distributed evenly across the country were compared against almost similar (free air) anomalies extracted from the combined geo-potential model EGM96 at the same points. A considerable positive correlation was discovered. The positive correlation is partly due to the comparison of two naturally different types of Helmert vs. free-air data, partly due to the full spectrum Helmert vs. truncated EGM96-derived anomalies. But the remaining large part of the correlation is due to the insufficient gravity data in the region, which led to employing undesirable prediction method for the densification of data.