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Padding of Terrestrial Gravity Data to Improve Stokes-Helmert Geoid Computation

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The Stokes-Helmert method is a well-known method of geoid computation that has been implemented in the University of New Brunswick's SHGeo software and is used around the world. The SHGeo implementation applies Stokes's integration in spatial form to gravity anomalies in the Helmert space, after continuing them down to the geoid. A spherical harmonic model of the global gravity field is used to generate and remove reference Helmert anomalies before Stokes's integration is done, and also to generate and add the reference Helmert spheroid after Stokes's integration. The same model is used to evaluate, in spectral form, the far-zone contribution in Stokes's integration. The boundaries of the near zone for Stokes's integration depend on the degree/order of this reference field, so the choice of optimal integration cap size and degree of reference field is critical and can change the result significantly.

Larger cap sizes also require larger buffers of data surrounding the computation area to accurately capture all wavelengths, and because of convergence of the meridians, the width of this buffer must be larger in longitude degrees than in latitude degrees. Terrestrial gravity data from these buffer regions are often unavailable, as neighboring countries may not wish to share their gravity data, or it may be unreliable. This data deficiency problem may be addressed either by increasing the degree of reference field and thus decreasing the integration cap size or by padding the regions outside the geoid computation area by data from global gravity field models and retaining the preferred larger integration cap. The latter approach is to be advocated, as it avoids misplaced over-reliance on the accuracy of the higher degrees of existing global models.

While testing the Stokes-Helmert technique in the Auvergne (France) area with limits of -1° $< \lambda <$7° and 43° $< \varphi <$49°, we have computed the geoid in the region (1.5° $< \lambda <$4.5°, 44.5° $< \varphi <$47.5°), with a reference field of degree 90 (considered reasonable for "satellite only" global fields) and Stokes's integration near-zone radius of 2°. In this case, additional 2°52' buffer in the longitude direction, and 2° in the latitude direction, was required, exceeding the coverage of the available terrestrial gravity data. A solution was attempted both by (a) increasing the reference field degree/order to 170, and correspondingly decreasing the Stokes's near zone radius to 1.05°, such that only a 1.5° wide buffer was required in both directions and no padding was necessary; and (b) padding the area using values from the EGM2008 global gravity field taken to degree/order 2190. The RMS differences between the computed geoid, and geoid-ellipsoid separations at 75 GPS/levelling test points, were of the order of 5.2 cm for the first method; for the second method, the RMS was only 3.7 cm.

The results confirm that it is preferable to use padding in the outlying regions from a global model to shrinking the integration cap and raising the degree of reference field as the accuracy of higher orders in the global models degenerates. Clearly, there is a lot of information in the terrestrial data that can be used to improve the geoid obtained from the global models, if these data are used judiciously.