Examining the optimal depth of the condensed topographic masses for precise geoid determination based on the Stokes-Helmert scheme – A case study in Colorado

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In gravimetric geoid determination based on the Stokes-Helmert scheme, the topographic masses outside the geoid are condensed to an infinitely thin layer and stored on or below the geoid. Heck (2003) generalized the Stokes-Helmert scheme, and showed theoretically that the deeper the condensed topographic masses, the smoother the gravitational field becomes, while the larger the indirect effects becomes. The smooth gravity field alleviates the error in downward continuation process, while the large indirect effect leads to an unstable result of the geoid computation. Therefore, it is necessary to store the condensed topographic masses at the optimal depth for precise geoid computation. In this study, we examine the optimal depth of the condensed topographic masses for precise geoid determination based on the Stokes-Helmert scheme, as a case study in Colorado, USA. The basic methodology for geoid computation is the remove-compute-restore technique with the UNB Stokes-Helmert Scheme (Vaníček and Martinec, 1994; Huang and Véronneau, 2013). The evaluation of the computed geoid is performed by comparing with 222 GNSS/leveling geoid height data (Westrum et al., 2021). Consequently, the computed geoid heights are consistent with the GNSS/leveling geoid heights with a standard deviation of 2.38 cm when the condensation depth is set to 0 km, 2.20 cm when the depth is 25 km, 2.14 cm when the depth is 50 km, 2.37 cm when the depth is 75 km, and 3.16 cm when the depth is 100 km. In summary, the condensation depth of 50 km shows the best consistency with the GNSS/leveling geoid heights in the case of Colorado. In the most of the current studies using the Stokes-Helmert scheme, Helmert's second condensation method, which condense the topographic masses onto the geoid, is widely used. However, as demonstrated in this study, storing the condensed topographic masses below the geoid could produce more precise result of the geoid computation.