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Height System Unification in North America

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GOCE has contributed important gravity information towards the definition and realization of the new North American height reference system. In addition to the new gravimetric geoid models based on GOCE, offsets of the classical levelling-based vertical datums in North America, namely CGVD28 in Canada and NAVD88 in the USA and Mexico, can be computed with respect to a global equipotential surface defined by means of a GOCE-based geoid. Although the two datums will eventually be replaced by a common and continent-wide vertical datum (and in fact the new Canadian height datum established in 2013 is already geoid based), their connection and unification is of great interest to the scientific and user communities.

This study investigates the practical implementation of the geodetic boundary value problem (GBVP) approach as a rigorous method for unifying classical levelling-based vertical datums. The so-called indirect bias term, the effect of the GOCE geoid omission error, the effect of the systematic levelling datum errors and distortions, and the effect of the data errors on the datum unification are of great importance for the practical implementation of this approach. These factors are investigated numerically using the GNSS-levelling and tide gauge (TG) stations in Canada, the USA, Alaska, and Mexico. The results show that the indirect bias term can be omitted if a GOCE-based global geopotential model is used in geoid computation. This is significant because the omission of the indirect bias term simplifies the geoid computations as well as the linear system of equations for the estimation of datum offsets. Because of the existing systematic levelling errors and distortions in the Canadian and US levelling networks, the datum offsets are investigated in eight smaller regions along Canadian and US coastal areas instead of over the whole North American land mass. The effect of the omission error on the datum offsets decreases significantly in areas with good coverage and distribution of GNSS-levelling and TG stations, but in general it should be taken into account by use of gravity and topography data. Results using GNSS-levelling stations in the US coastal regions show that the mean datum offset can be estimated with a 1 cm error if the GOCE geoid omission error is taken into account using the local gravity and topography information. In the Canadian Atlantic and Pacific regions, the datum offsets can be estimated with 2.3 and 3.5 cm uncertainty using GNSS-levelling stations. Using the very limited number of TG stations, the datum offset error can reach one decimetre in the Pacific regions. With the available GNSS-levelling stations in Alaska and Mexico, the datum offsets can be estimated with less than 3 cm error. These results clearly illustrate the importance of the aforementioned four factors in when implementing the GBVP approach for the unification of vertical datums.