Estimation of effects of astronomic tides and ocean tidal loading on leveling

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Three-dimensional positioning on earth is realized with a cm level of precision by space geodetic techniques such as GPS and the success of the dedicated gravity satellite missions has enabled geoid determination at unprecedented accuracy, which necessitates the high quality of orthometric height determination because the vertical datums link them together.

Sprit leveling is mostly applied to precise height determination on earth by measuring height differences along the topography with reference to the equi-geopotential surfaces In geodesy the orthometric height is defined as the vertical distance to the geoid. Due to topographic undulations and heterogeneity in geologic structures underground, the equi-geopotential surfaces (the geoid is one of them) are not generally parallel to each other. It is, therefore, necessary to correct observed height differences for non-uniform distribution of gravity if we try to precisely determine the orthometric heights of stations by leveling from a distant benchmark. The Geographical Survey Institute introduced in their computation of the so-called Helmert height a correction to this effect on leveling by using a grid model of gravity anomalies created on the Japanese Islands.

On the other hand, the astronomic tidal forces by the Moon, Sun and other solar planets deform the shape of the equi-geopotential surfaces and the crust and dislocate the oceanic masses. In this case, the deformations of the qui-geopotential surfaces and of the crust are different each other and their differences depend on location (mostly on latitude) and time. Moreover, ocean tides load and deform the crust substantially near the coasts, making the tide-induced effects on leveling more complicated.

The astronomic correction on leveling is estimated as small as 0.1 mm/km at most, but it may accumulate significantly along the long distances especially in the north-south direction. It is reported that the maximum accumulated astronomic correction reaches at 7 cm along the leveling route from San Diego, California to Spokane, Washington in the west coast of U.S.A., whose latitudinal extent is almost the same as that of Japanese major islands. Accordingly, it is possible to have a substantial amount of astronomic tidal effects on leveled heights along the nation-wide leveling routes of Japan.

Theoretical models of astronomic tides on the Earth and its elastic response are well established and high quality models of ocean tide loading and related crustal deformation are also developed from satellite altimetry. We can evaluate the effects of astronomic tides and ocean tide loading on leveling by using those models. This study tries to estimate these effects on first-order leveling data in Japan and experimental results are given for a continuous line of leveling routes extended in the north-south direction in Hokkaido.