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Optimum weighting of GPS, GLONASS, Galileo, and BeiDou observations in real-time PPP

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A dynamic development of Global Navigational Satellite Systems (GNSS), namely GPS, GLONASS, Galileo, and BeiDou, constantly increases the number of operational spacecraft and the provided frequencies. There are plenty of differences between GNSS, which are caused by different satellite constructions and different on-board equipment employed, differences in the number and types of broadcasted frequencies and in sensitivity of those frequencies to ionospheric disturbances. Another significant feature is a different spacecraft distribution in the space for different GNSS constellations. Besides commonly used medium earth-orbit (MEO) satellites, geostationary satellites (GEO) and inclined geosynchronous orbit (IGSO) satellites are encountered in the BeiDou constellation. Moreover, each of mentioned GNSS uses an individual reference frame and time-scale. To overcome difficulties connected with the multi-GNSS integration, the International GNSS Service (IGS) established a multi-GNSS experiment (MGEX) to track, collate and analyze all available GNSS signals. Additionally, real-time users are able to use the streamed corrections provided by IGS Real-Time Service (IGS-RTS) which support GPS and GLONASS. Multi-GNSS users can employ corrections for all systems that are provided by Centre National d'Études Spatiales (CNES). Unfortunately, the quality of real-time products is not homogenous among systems and depends on many factors like the satellite constellation, Sun elevation angle above the orbital plane (β angle) or orbit type. The differences between the GNSS data quality are additionally caused by deficiencies in the satellite orbit models, especially for the newly established and modernized satellite blocks.

Many weighting approaches have been proposed for observation weighting of the same type, e.g. carrier-to-noise ratio and elevation-depending weight model. For weighting different types of observations, which is the case when processing multi-GNSS data, the rigorous Helmert variance component estimation method is widely used, but it requires post-processing of high redundant observations. For real-time multi-GNSS applications, both intra- and intersystem weights should be known in advance, which would optimize the processing of the observations' diversity. Thus, this work's goal is to develop and compare several observation weighting schemes that are suitable for real-time multi-GNSS PPP.

We will show the results from processing GPS, GLONASS, Galileo and BeiDou observations from 12 IGS worldwide distributed stations. Five different schemes of observation weighting are tested for two 7-day periods. The effectiveness of each weighting scheme is assessed on the basis of the formal errors of the obtained coordinates, coordinate repeatability, and on the basis of the solution convergence time. All results of multi-GNSS weighting schemes are compared to those based on GPS-only solutions. When using the same weights for all GNSS, the formal errors are reduced, but the station coordinate repeatability is worse than when using GPS-only solutions. However, when using a proper multi-GNSS weighting, the reduction of formal errors equals about 40%, whereas the GNSS coordinate repeatability is improved by 6%, the convergence time is reduced by about 40% and 47% for horizontal and vertical components, respectively. The results show that different weighting approaches may lead to diversified results and sometimes may even yield wrong results if improper or equal weights are used.