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ORIGINAL ARTICLE

Multifrequency algorithms for precise point positioning: MAP3

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Abstract We present the new MAP3 algorithms to perform static precise point positioning (PPP) from multifrequency and multisystem GNSS observations. MAP3 represents a two-step strategy in which the least squares theory is applied twice to estimate smoothed pseudo-distances, initial phase ambiguities, and slant ionospheric delay first, and the absolute receiver position and its clock offset in a second adjustment. Unlike the classic PPP technique, in our new approach, the ionospheric-free linear combination is not used. The combination of signals from different satellite systems is accomplished by taking into account the receiver inter-system bias. MAP3 has been implemented in MATLAB and integrated within a complete PPP software developed on site and named PCube. We test the MAP3 performance numerically and contrast it with other external PPP programs. In general, MAP3 positioning accuracy with low-noise GPS dual-frequency observations is about 2.5 cm in 2-h observation periods, 1 cm in 10 h, and 7 mm after 1 day. This means an improvement in the accuracy in short observation periods of at least 7 mm with respect to the other PPP programs. The MAP3 convergence time is also analyzed and some results obtained from real triple-frequency GPS and GIOVE observations are presented.

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Introduction

Precise point positioning (PPP) has become widely studied due to its great operational flexibility and its capability to reach decimeter-level accuracy in kinematic positioning and centimeter-level accuracy in static mode (Bisnath and Gao 2007). Millimeter-level accuracy in static positioning can also be achieved with 1-day observation periods (Kouba and Héroux 2001). The classic PPP strategy is based on the ionospheric-free linear combination of dual-frequency observations to remove the slant ionospheric delay, which increases the observations noise about three times. In addition, an initialization period of several minutes is required until the PPP solution reaches a high accuracy.

In recent years, a number of free PPP online services have become available, such as APPS (apps.gdgps.net), GAPS (gaps.gge.unb.ca), CSRS–PPP (www.geod.nrcan.gc.ca), and magicGNSS (magicgnss.gmv.com). APPS was the first PPP online service processing GPS dual-frequency observations and used the JPL precise satellite products. GAPS only supports GPS data while the other two programs perform static and kinematic PPP from GPS and GLONASS observations using precise products provided by the international GNSS service (IGS). Additionally, the Bernese software version 5.0 (Dach et al. 2007) also processes GPS data in a preliminary PPP mode.

Soon more than 100 modernized satellites belonging to GPS, GLONASS, Beidou, and Galileo will become operational and transmit open access signals in at least three different frequencies simultaneously. Currently, three GPS

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