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Real-time crustal deformation monitoring using single frequency precise point positioning with fixed ionospheric estimates

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Real-time high precise crustal deformations are significant for early earthquake warning, which can be obtained by precise point positioning (PPP) technique. To obtain crustal deformations with high spatial resolution, a denser GPS network is needed. Single frequency (SF) GPS receiver is preferable to increase the density of network due to its cost effectiveness. One crucial issue in SF PPP is the treatment of ionospheric delay which can be eliminated by combining observations on different frequencies. Typically, there are three main strategies to mitigate the ionospheric effect: employing the existing ionospheric models, combining the pseudorange and carrier-phase observations, and modeling the ionospheric delay with a polynomial. However, the positioning accuracy at dm level is not sufficient for high precise applications. Some researchers use dual-frequency (DF) observations to produce high precise epoch-differenced ionospheric delays, which then are applied to correct ionospheric effect in SF PPP. The drawback, however, is that only float PPP solutions can be obtained. In this study, the precise un-differenced ionospheric delays are derived from carrier-phase observations with PPP fixed and float ambiguities from the nearest dual-frequency reference stations, referred as to fixed and float ionospheric estimates, respectively. Then, they are interpolated at user stations to mitigate the ionospheric effect in SF PPP. The GPS data are collected at 18 stations with dual-frequency observations from Hong Kong CORS. Some of the stations are regarded as the user stations, of which only single frequency observations are used. A short baseline configure is used to evaluate the accuracy of the ionospheric delay estimates. The differences of the fixed ionospheric estimates between two close stations show their excellent agreement, while the inter-satellite biases are about 1–3 TECU for the float ones, which means the accuracy of the fixed ionospheric estimates is better than that of the float ones. The validation results show that SF PPP using precise ionospheric delays estimated based on DF reference stations outperforms the GRAPHIC (Group and Phase Ionosphere Calibration) approach and the approach estimating ionospheric delays. Compared to SF PPP using float ionospheric estimates delay, the convergence time can be improved by nearly 20% when using fixed ionospheric estimates, and they show comparable accuracy at cm level after convergence. It is noteworthy that the fixed ionospheric estimates include the UPDs (uncalibrated phase delays), therefore fix SF PPP solutions can be obtained. This study indicates the feasibility of SF PPP for large destructive earthquake monitoring.