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Second-order ionospheric term in High Precision GPS modeling: Impact and Simple Procedure implementation

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This work is focused on simple procedures to apply the second order ionospheric correction term on GPS measurements (I2), as far as its impact on different geodetic estimates, in particular on receiver coordinates. A new and easy way of computing the I2 effect will be presented, that differs in two aspects with respect to previous works. Firstly, the STEC is computed using the geometry-free pseudorange instead of using the TEC values from a GIM, or any GIM software in general. And, secondly, an accurate model has been used to calculate the geomagnetic field. In this way, improvements up to 60% can be achieved in the I2 term computation.

Using differential positioning techniques, it will be shown that the deviations of the receiver positions are driven by the differential (among receivers) I2 effect, instead of their absolute values. These deviations can reach up to several millimeters, one order of magnitude larger than the typical daily effect. This is due to that the subdaily variation of the I2 effect (driven for the large electron content variation in terms of Local Time) is greater than the day-to-day variation. But, in these regional solutions, the most affected parameters by the I2 effect would be the satellite clocks, which variations would be adapted to this effect.

In global geodetic computations, a new method has been used that allows understanding how I2 affects the parameter estimations. Following this procedure, the conclusion

of the differential positioning study was confirmed, i.e. that the I2 effect is adjusted mainly by the satellite-dependent parameters (orbits and clocks), while the effect on the receiver coordinates is clearly small because they are only affected by the differential or relative value of the I2 effect (i.e. compared to the values of the other receivers of the network).

It has also been shown that the most affected parameter is the satellite clock, which can show deviations greater than 1 cm. These deviations depend on the latitude and local time of the satellite position, achieving the largest values at local daytime, positive in the Southern Hemisphere and negative in the Northern Hemisphere. This effect is comparable with the accuracy of the Final IGS products.

Satellite positions are affected by a global southward (along the Z-axis) displacement of the orbits of several millimeters. The amount of this displacement is related to the ionization degree of the ionosphere, that determines the values of the I2 effect. This result agrees with the geocenter displacement in the z-component found by other authors. Among these global displacements of the orbits, there is still a sub-daily part of the deviations of the satellite positions mainly in the latitudinal component. This effect can reach up to several millimeters and depends on the latitude and on the local time. Taking into account the IGS orbits accuracy this effect could affect to this accuracy.

The I2 impact on receiver positions is usually smaller than 1 mm (for the period studied in this work). The most significant displacement on the receiver positions occurs, as was also noted by previous authors, in the North-South direction. But in discordance with these authors' results, a latitudinal dependence on the sign of this displacement has been found. Indeed, high latitude receivers would be shifted northwards while the low latitude ones would be moved southwards. This agrees with the idea that the receiver position is affected by the differential I2 effect. In this way, receivers with large values of the I2 effect are shifted southward, while those with small values are shifted northward. Moreover, it has been found that such latitudinal dependence is modulated by the ionization degree of the Ionosphere, providing the corresponding model.

Finally, the authors of this work think that this effect should be taken into account in routinely geodetic computations because: (1) the contribution of the I2 effect is not negligible (several centimeters in range), (2), the algorithms presented in this work are easy to implement (they don't require the previous computation of a GIM or associated software). And (3) the I2 effect on satellites clocks and orbits is significant and should be taken into account to improve its accuracy.