# Ionospheric corrections tailored to Galileo HAS: 2023 results and validation with single epoch navigation

C.C. Timote, José M. Juan, Jaume Sanz, Guillermo González-Casado, Adria Rovira-Garcia, Raul Orus-Perez, Ignacio Fernandez-Hernadez, Angela Aragón Angel and Yu Yin.
gAGE/UPC Research group of Astronomy and Geomatics. Technical University of Catalonia, Barcelona Tech, Spain; e-mail: cristhian.timote@upc.edu

The Galileo High Accuracy Positioning Service (HAS) is a new capability of the European Global Navigation Satellite System that will offer user positioning with decimeter-level accuracy, employing multiple constellations of the Global Navigation Satellite System (GNSS) and boasting ambiguity-fixing capabilities. Available since January 2023, Galileo HAS is the first-ever global precise point positioning (PPP) service, to be deployed in two service levels. Service Level 1 (SL1) comprises satellite orbit and clock corrections (i.e. non-dispersive effects), and dispersive effects such as inter-frequency code biases. Service Level 2 (SL2) incorporates ionospheric corrections for Fast-PPP navigation (at least over Europe).

Funded by the European Space Agency (ESA) under the ESA Real-Time Ionospheric Continental Caster (e-RTICC) project, gAGE/UPC has developed and deployed in real-time the IONO4HAS tool: a Central Processing Facility (CPF) to compute Galileo HAS SL2 corrections based on the Fast-PPP, encompassing precise clocks, zenith tropospheric delays, code and phase biases, and a two-layer ionospheric model. IONO4HAS tool's basic input are GNSS observations from a worldwide distributed network of permanent stations, collected in real-time using the Networked Transport of RTCM via Internet Protocol (NTRIP).

The routinely assessment of the ionospheric model is done in parallel using a novel real-time test that directly links the instantaneous (snapshot) position error with the error of the ionospheric corrections, a key point for a HAS. The test involved 15 GNSS receivers in Europe acting as user receivers at various latitudes, with distances to the nearest reference receivers ranging from tens to four hundred kilometers. In the position domain, the test results reveal that the 95th percentile of the instantaneous position error depends on the user-receiver distance, as expected, ranging in the horizontal and vertical components from 10 to 30 cm and from 20 to 50 cm, respectively, which are several times smaller than the corresponding errors obtained when using from other ionospheric models. These figures not only meet Galileo HAS SL2 requirements but outperform them by achieving instantaneous positioning. Moreover, formal errors of transmitted ionospheric corrections, typically at the decimeter level (1 sigma), play a key role in safeguarding users against erroneous positions by appropriately weighing their measurements in the navigation filter.

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