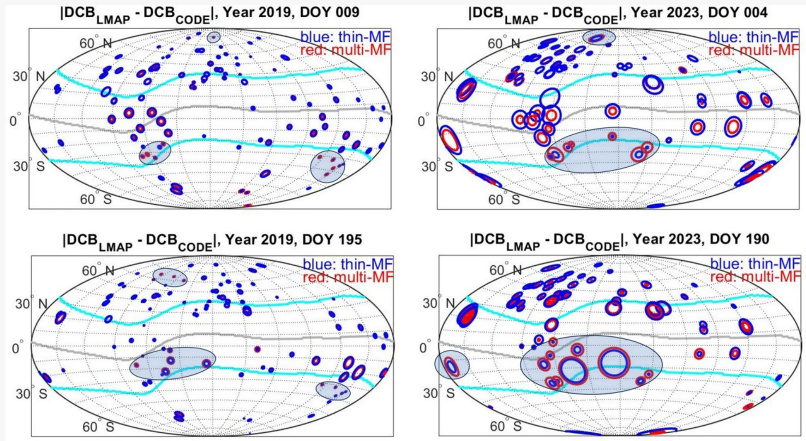
A multi-layer view of the ionosphere sharpens GNSS accuracy

GA, UNITED STATES, December 31, 2025 /EINPresswire.com/ -- Accurate estimation of the ionosphere is essential for reliable Global Navigation Satellite System (GNSS) positioning, timing, and space weather applications. A key challenge lies in converting slant ionospheric measurements into their vertical components without introducing systematic errors. This study presents a multi-layer ionosphere mapping approach that moves beyond the widely used single-layer assumption. By representing the ionosphere as a vertically structured system rather than a thin shell, the method reduces sensitivity to poorly constrained ionospheric effective heights. The results demonstrate that the multi-layer strategy consistently improves accuracies in receiver bias estimation and global ionosphere mapping, particularly under disturbed ionospheric conditions, offering a more robust foundation for next-generation GNSS data processing and satellite-based navigation services.



Global distribution of receiver DCB differences (absolute values) between CODE and our computation on 9th Jan & 14th July 2019 (left panel) and 4th Jan &10th Jul 2023 (right panel).

Global Navigation Satellite System (GNSS)-based ionospheric modeling relies on mapping functions to transform slant Total Electron Content into vertical values. Most operational systems still use a single-layer ionosphere model with a fixed effective height, despite the ionosphere's strong spatial, temporal, and solar-driven variability. This simplification can introduce significant mapping errors, especially at low latitudes and during periods of high solar or geomagnetic activity. Such errors directly affect differential code bias estimation and the quality of global ionosphere maps. Although previous studies have attempted to refine effective heights or introduce directional corrections, fundamental limitations remain. Based on these challenges, there is a clear need to develop and systematically evaluate more physically representative ionosphere mapping strategies.

In a study published (DOI: 10.1186/s43020-025-00182-9) in Satellite Navigation in 2025, researchers from the German Aerospace Center (DLR), the Shanghai Astronomical Observatory of the Chinese Academy of Sciences, the University of Warmia and Mazury in Olsztyn, and the European Space Agency investigated a multi-layer ionosphere mapping function for GNSS applications. Using both ground-based GNSS observations and data from multiple low Earth orbit (LEO) satellite missions, the team assessed how the new mapping strategy affects differential code bias estimation and global ionosphere map reconstruction under quiet and disturbed ionospheric conditions.

The researchers modeled the ionosphere as a series of thin layers whose vertical structure follows established electron density profiles, allowing slant GNSS signals to intersect multiple ionospheric regions rather than a single fixed shell. This approach reduces dependence on an assumed effective ionospheric height, a major source of uncertainty in traditional mapping functions. The team implemented the method using a stand-alone configuration and compared its performance against the conventional single-layer model.

Across multiple test periods in 2019 and 2023, covering both low and high solar activity, the multi-layer mapping function consistently improved GNSS ground receiver differential code bias estimates. Mean receiver bias deviations were reduced by approximately 0.14–0.27 ns during low solar activity and by up to 0.78 ns during high solar activity, with improvements observed for more than two-thirds of GNSS stations worldwide. In contrast, satellite bias estimates showed little sensitivity to the choice of mapping function.

The benefits extended to global ionosphere maps, where the multi-layer approach reduced mean TEC biases by up to several TEC units compared with international reference products, particularly in low-latitude regions where ionospheric electrodynamics are more influential. When applied to LEO satellite data, the method enabled consistent bias estimation across missions with different orbital heights, demonstrating its flexibility for multi-satellite GNSS applications.

The authors emphasize that improving ionospheric mapping is not merely a technical refinement but a prerequisite for reliable GNSS services. By reducing systematic mapping errors, the multi-layer approach strengthens the physical consistency of ionospheric models, especially under challenging space weather conditions. The study highlights that receiver bias estimation and global ionosphere products benefit most from the new strategy, suggesting that operational GNSS analysis centers could achieve measurable accuracy gains without requiring additional observations, but by rethinking how existing data are interpreted.

More accurate ionospheric modeling has direct implications for satellite navigation, precise positioning, space weather monitoring, and Earth observation missions. The multi-layer mapping function offers a pathway to improve GNSS-based services in equatorial and low-latitude regions, where current models struggle most. Its successful application to both ground-based and LEO satellite data also supports future multi-mission ionospheric monitoring frameworks. As GNSS increasingly underpins critical infrastructure, autonomous systems, and scientific research, adopting more realistic ionosphere representations could enhance resilience against solar disturbances and contribute to more reliable global navigation and positioning capabilities.

DOI
10.1186/s43020-025-00182-9

Original Source URL
https://doi.org/10.1186/s43020-025-00182-9

Funding information
The work is partly funded by the LMAP (LEO Ionospheric Mapping Assessment and Derivation For Precise PVT Applications) project under the ESA Contract No. 4000142821/23/NL/MGu/my.

Lucy Wang
BioDesign Research
email us here

This press release can be viewed online at: https://www.einpresswire.com/article/879396058

EIN Presswire's priority is source transparency. We do not allow opaque clients, and our editors try to be careful about weeding out false and misleading content. As a user, if you see something we have missed, please do bring it to our attention. Your help is welcome. EIN Presswire, Everyone's Internet News Presswire™, tries to define some of the boundaries that are reasonable in today's world. Please see our Editorial Guidelines for more information.
© 1995-2025 Newsmatics Inc. All Right Reserved.