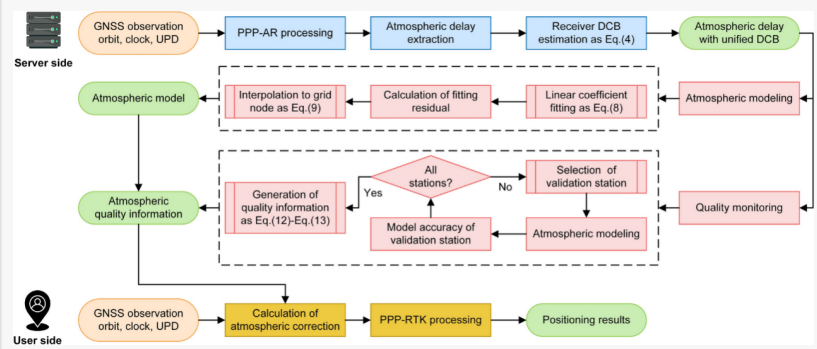
Cross-validation method enhances atmospheric corrections in satellite positioning

GA, UNITED STATES, October 7, 2025 /EINPresswire.com/ -- Accurate positioning is vital for applications ranging from autonomous vehicles to precision agriculture, yet atmospheric disturbances often compromise Global Navigation Satellite System (GNSS) performance. This study introduces a novel method that applies leave-one-out cross-validation to monitor the quality of atmospheric corrections in Precise Point Positioning–Real-Time Kinematic (PPP-RTK) services. By using each station sequentially as a validation point, the method produces real-time quality information without requiring extra monitoring stations or historical datasets. Experiments in both large-scale European and small-scale Hong Kong networks show that this approach can capture centimeter-level variations in atmospheric conditions and improve positioning accuracy by more than 20%, even under strong solar activity.



Design of quality monitoring for grid-base atmospheric corrections.

Precise Point Positioning (PPP) has become indispensable in delivering high-precision Global Navigation Satellite System (GNSS) results, but its relatively long convergence time limits real-time applications. To address this, Precise Point Positioning–Real-Time Kinematic (PPP-RTK) leverages atmospheric corrections to accelerate ambiguity resolution. However, the accuracy of these corrections is highly sensitive to factors like satellite elevation, solar activity, and station spacing, leading to errors that range from centimeters to decimeters. Traditional solutions either rely on empirical models built from historical data or require dense monitoring networks, both of which limit adaptability. Due to these challenges, there is a pressing need to develop robust, real-time quality monitoring methods for atmospheric corrections.

Researchers from Wuhan University and Universitat Politècnica de Catalunya have unveiled a new strategy to enhance GNSS PPP-RTK performance. Published on September 22, 2025 in Satellite Navigation, the study presents a leave-one-out cross-validation technique to evaluate and improve atmospheric correction accuracy. By systematically designating each station as a

validation point, the method produces dynamic quality information that is broadcast alongside corrections. This innovative approach provides users with self-monitoring atmospheric data, significantly improving positioning stability and reliability, particularly under variable or disturbed atmospheric conditions.

The new approach fundamentally rethinks how atmospheric corrections are validated. Instead of relying on external monitoring stations or static models, the leave-one-out cross-validation technique internally rotates each reference station as a "test case" while others generate correction data. The resulting discrepancies reveal the true quality of atmospheric corrections, which are then compiled into a comprehensive quality map. This information is transmitted directly to users, allowing them to assess reliability in real time.

Experiments were conducted in two distinct networks: a 21-station European system in mid-latitudes, generally stable, and a 19-station Hong Kong network in low latitudes, prone to ionospheric disturbances. Results showed that tropospheric corrections maintained stability within 2 cm, while ionospheric variations ranged from 2 to 15 cm depending on solar activity. Importantly, the method consistently provided reliable envelopes of error estimates, with more than 90% of quality values accurately reflecting real deviations. In PPP-RTK positioning trials, the method improved accuracy by 6–29% in Europe and 9–20% in Hong Kong, while also achieving faster convergence. Even during geomagnetic storms, improvements of up to 40% were recorded. These findings underscore the method's robustness across scales and atmospheric conditions.

"Our work demonstrates that GNSS services can become more resilient by embedding self-monitoring capabilities," said Prof. Xingxing Li, corresponding author of the study. "The leave-one-out cross-validation approach eliminates the dependence on additional monitoring stations or empirical historical models, offering flexibility across diverse networks. Most importantly, the method ensures that users receive not just corrections, but also a measure of their reliability. This is critical for safety-sensitive applications like autonomous driving and disaster response, where accuracy under unpredictable atmospheric conditions cannot be compromised."

The ability to broadcast real-time quality information alongside atmospheric corrections marks a significant step toward more trustworthy GNSS positioning. By ensuring centimeter-level accuracy across different regions and atmospheric conditions, the method has immediate potential in fields requiring dependable navigation, such as intelligent transportation systems, precision farming, and surveying. Moreover, during periods of high solar activity or geomagnetic storms, the approach can maintain stability and reduce positioning errors, safeguarding operations that rely on continuous precision. Looking forward, integrating this method into global augmentation services could accelerate the adoption of GNSS-based solutions for both civilian and industrial applications.

References
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