National Aeronautics and Space Administration

Postdoc Research

JPL's Proposed GDGPS-Based High Accuracy Service for GPS

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Background

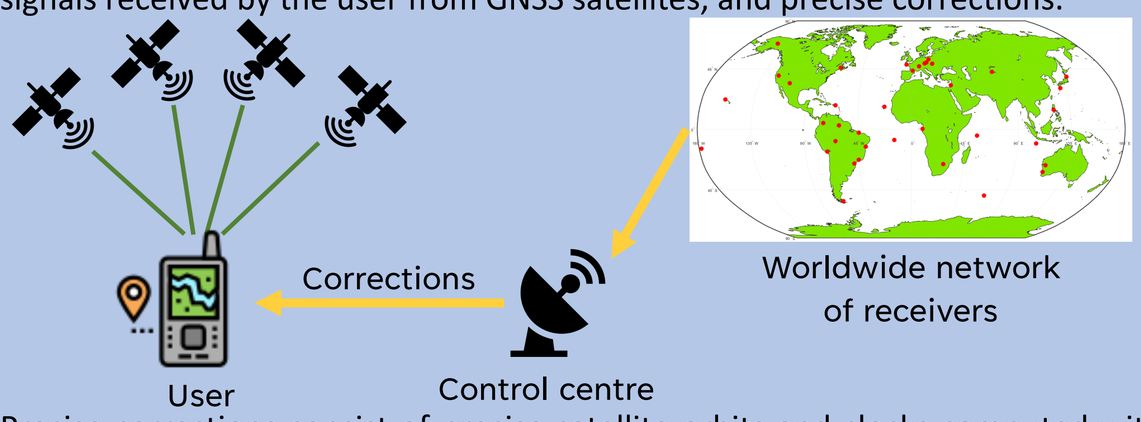
GNSS constellations

The field of Global Navigation Satellite Systems (GNSS) has been subject to many advances in recent years. Advances include:

- Move from a **GPS-only**, to a landscape involving **Europe's Galileo**, **Russia's GLONASS**, **China's BeiDou** (and regional actors such as Japan's QZSS and India's NavIC)
- **New modernized signals**, with some constellations broadcasting on as many as five frequencies, as opposed to the traditional two frequencies (L1 and L2)
- New services, including:
  - Precise Point Positioning service, such as: **Galileo's High Accuracy Service (HAS)** and **BeiDou's PPP-B2b**, allowing **standalone precise user positioning**.
  - Authentication service, such as: Galileo's Open Service Navigation Message Authentication (OSNMA).

Precise Point Positioning (PPP)

- PPP is a technique that allows for centimeter-level positioning using satellite signals received by the user from GNSS satellites, and precise corrections.



- Precise corrections consist of precise satellite orbits and clocks computed with data from a global network of ground stations → **user reaches cm-level positioning in ~10 minutes**
- Faster convergence requires the estimation and provision of code and phase hardware delays, allowing **user cm-positioning in < 5 minutes**

GDGPS HAS

- For many years, JPL has been at the forefront of GNSS augmentation with the **Global Differential GPS (GDGPS)** technology
- GDGPS includes, but not limited to, ~200 global ground stations, three independent operation centers, real-time processing software, and multiple products generated routinely (https://www.gdgps.net/)

Objectives

Broad objective

- With the maturation of other constellations' PPP services, **GPS is lagging behind** with no such service being supported or provided by the constellation
- JPL's GDGPS group with its expertise and resources is **best placed** to provide such service for GPS
- Generating the precise corrections to allow for PPP requires **minimal effort** using the GDGPS technology

Research objectives / contributions

- **Analyze and validate** the corrections generated by GDGPS to be used as GPS HAS
- **Evaluate** GDGPS HAS performance
- **Compare** GDGPS HAS performance to Galileo HAS

Approach and results

Approach

- Use of independent PPP engine from York University, Canada for user processing
- Random selection of 50 global GNSS stations, used for user processing - black dots on the map
- Stations' data processed over one week, in independent three-hour chunks using:
  - **Galileo HAS corrections**: retrieved through Internet-based Distribution (IDD), generated based on the red stations on the map
  - **GDGPS HAS corrections**: streamed through Internet, generated based on the orange stations on the map
- User processing performed in simulated real-time

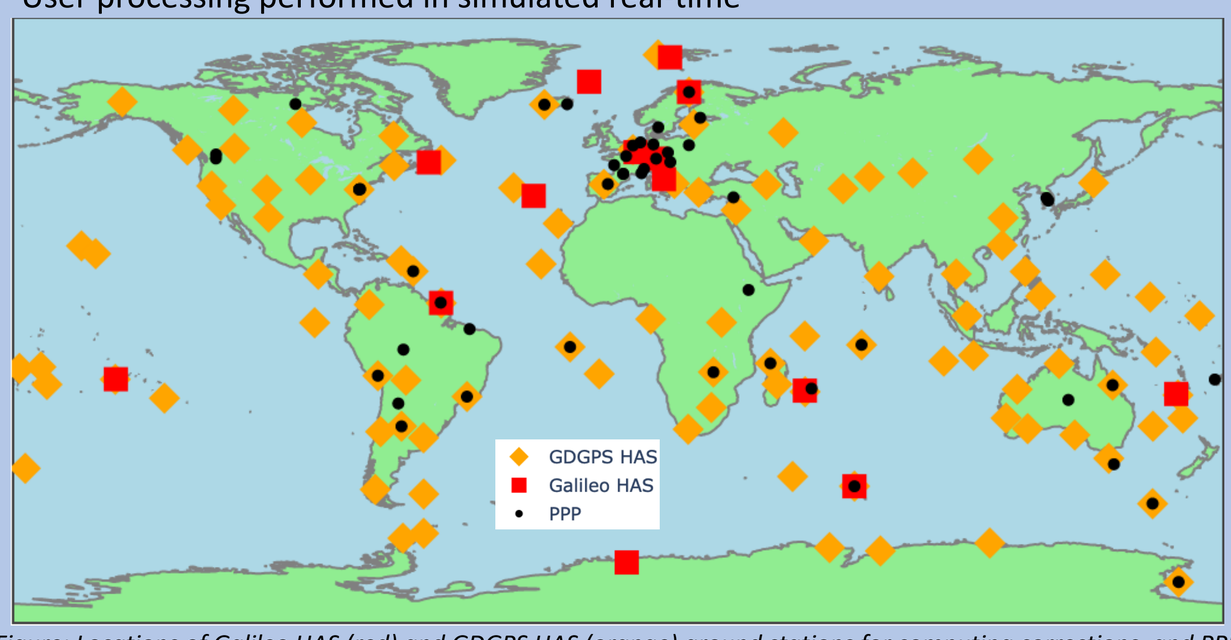


Figure: Locations of Galileo HAS (red) and GDGPS HAS (orange) ground stations for computing corrections, and PPP stations for this analysis (black)

Results

- For each set of corrections, process 1) GPS separately **(G)**, 2) Galileo separately **(E)**, and 3) GPS and Galileo together **(GE)**
- Compute root mean square error (rms) for each dataset; plot cumulative distribution based on 2,700 datasets for each constellation and correction combination

➢ GDGPS can provide **better performance** compared to Galileo HAS – ~60% of GDGPS HAS results have sub-decimeter horizontal error, compared to ~20% for Galileo HAS

➢ Comparable quality of GPS and Galileo corrections with GDGPS HAS

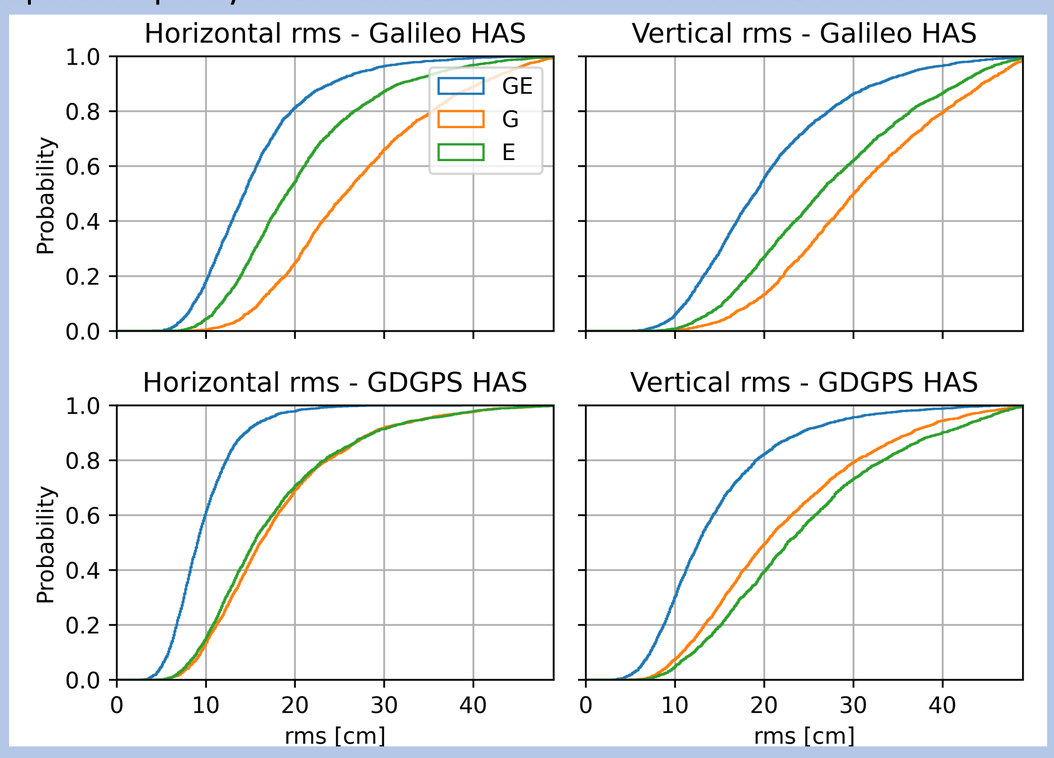


Figure: Cumulative distribution of position errors per correction and constellation combination

Significance and future work

- GDGPS can provide **highly accurate satellite clock and orbit** corrections
- GDGPS HAS would allow for **GPS-enabled standalone precise point positioning**
- Many applications would benefit from **free resilient precise positioning**, including police, security and rescue services; traffic decongestion, lane navigation; autonomous driving, UAV, agriculture, GIS collection, etc

➢ Satellite hardware biases yet to be analyzed and validated

➢ Ambiguity resolution possibility to be assessed

➢ Government partner to support the broadcast of corrections over Internet

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Relevant publications:

- Naciri, Nacer, et al. "Assessment of Galileo High Accuracy Service (HAS) test signals and preliminary positioning performance." GPS solutions 27.2 (2023): 73.
- Komjathy, Attila, et al. "Towards a GPS High Accuracy Service (GPS HAS) Based on GDGPS" 26th PNT Advisory Board Meeting, May 2022.

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