Update on GPS HAS Based on GDGPS: A Comparison with Galileo HAS

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Objective

- Highlight JPL's advanced technical contributions to improve GPS performance through High Accuracy Service (HAS) and associated applications using GDGPS

Potential GPS HAS with GDGPS vs GAL HAS

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Potential GPS HAS Features

- GDGPS is **fully capable** of providing global high-accuracy corrections for a potential GPS HAS
- **Global network** of GDGPS monitoring-stations available (100+ stations globally)
- **Two** geographically separated GDGPS Operations Centers (GOCs) with independent processing and distribution, highly tested redundant and robust architecture
- Meets and exceeds **accuracy requirements** set for GAL HAS Phase 2 (horizontal 20 cm (95%) and vertical 40 cm (95%))
- **Latency** including internet distribution consistently measured approximately 6 sec

Differences with Galileo HAS

- **Ground-based distribution of solution**, over internet and other land lines (available for GAL HAS)
- **No Signal-in-Space** (SIS) for GPS HAS available in present or planned GPS architecture

GDGPS Contribution to a High Accuracy Service (HAS)

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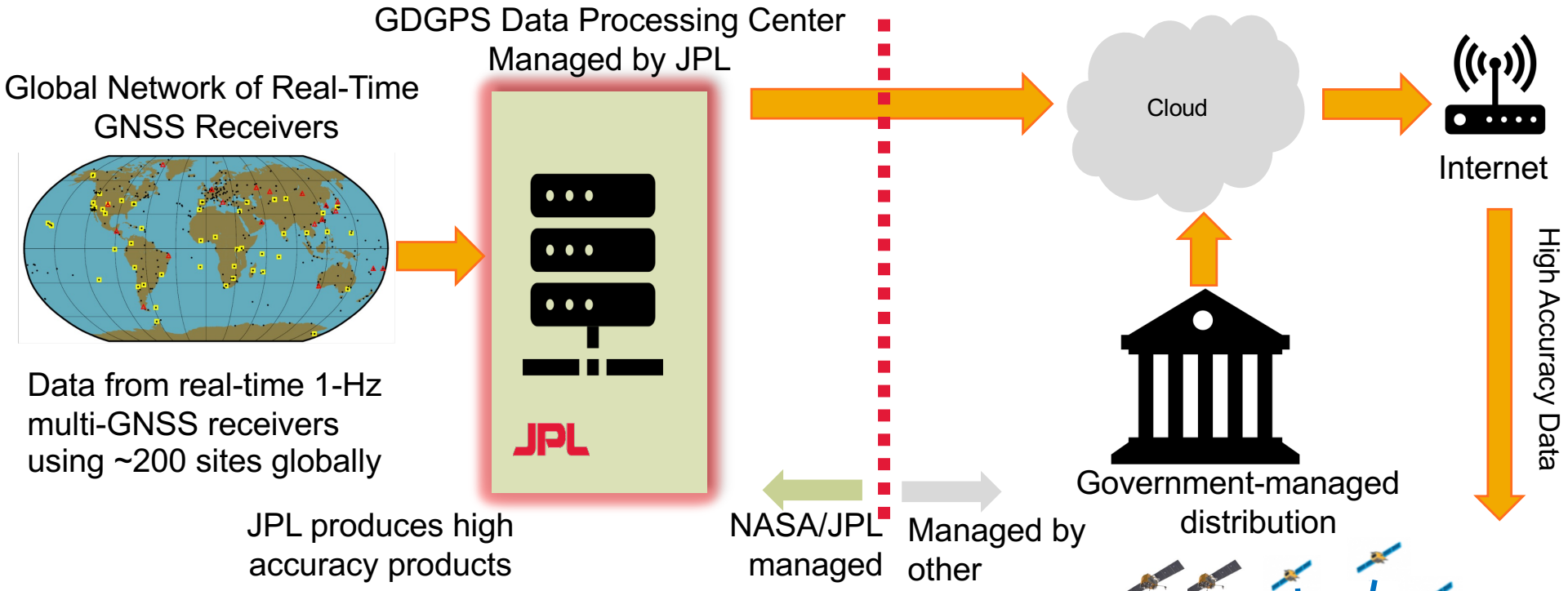
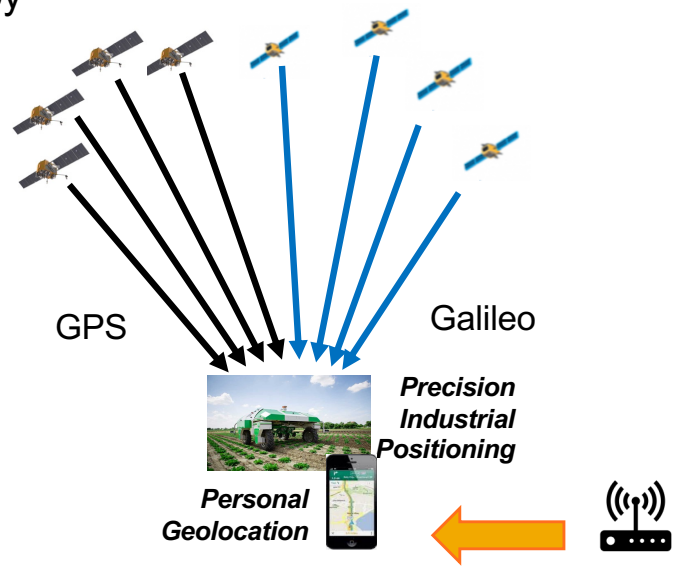
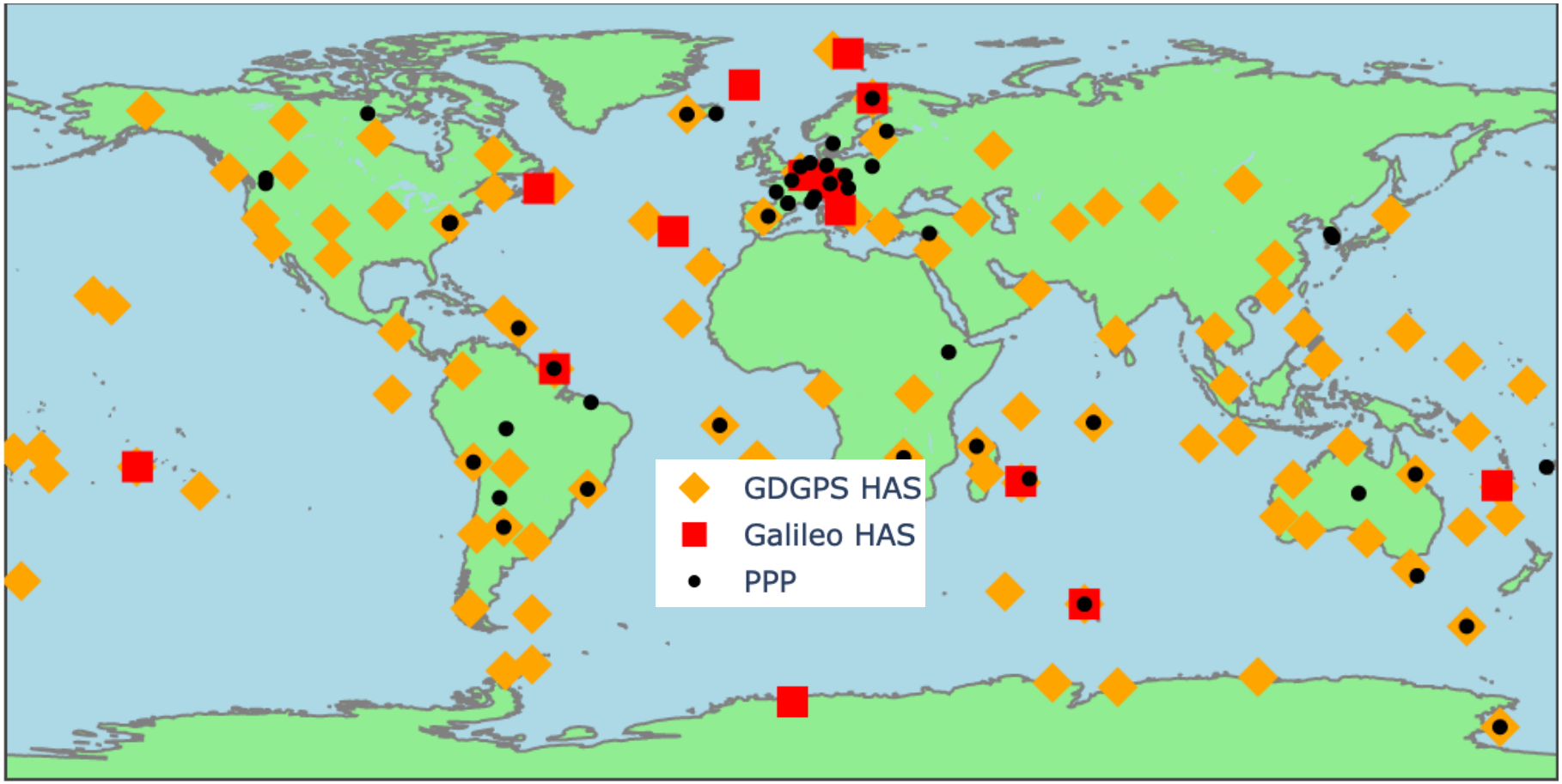


1. JPL collects GNSS data and generates high accuracy products
2. JPL passes products to distribution infrastructure, managed by government partner
3. Users receive and apply high precision products to increase performance across multiple sectors



Stations Used for Comparing PPP Performance Using GDGPS HAS and Galileo HAS

- Over 2700 independent overlapping 3-hour Galileo HAS and GDGPS HAS datasets used to compute combined GPS+GAL solutions at 50 stations
- 7-days' worth of GDGPS HAS and Galileo HAS data analyzed



50 stations used globally to compare HAS performances

Galileo and GDGPS HAS Horizontal and Vertical Error Comparisons

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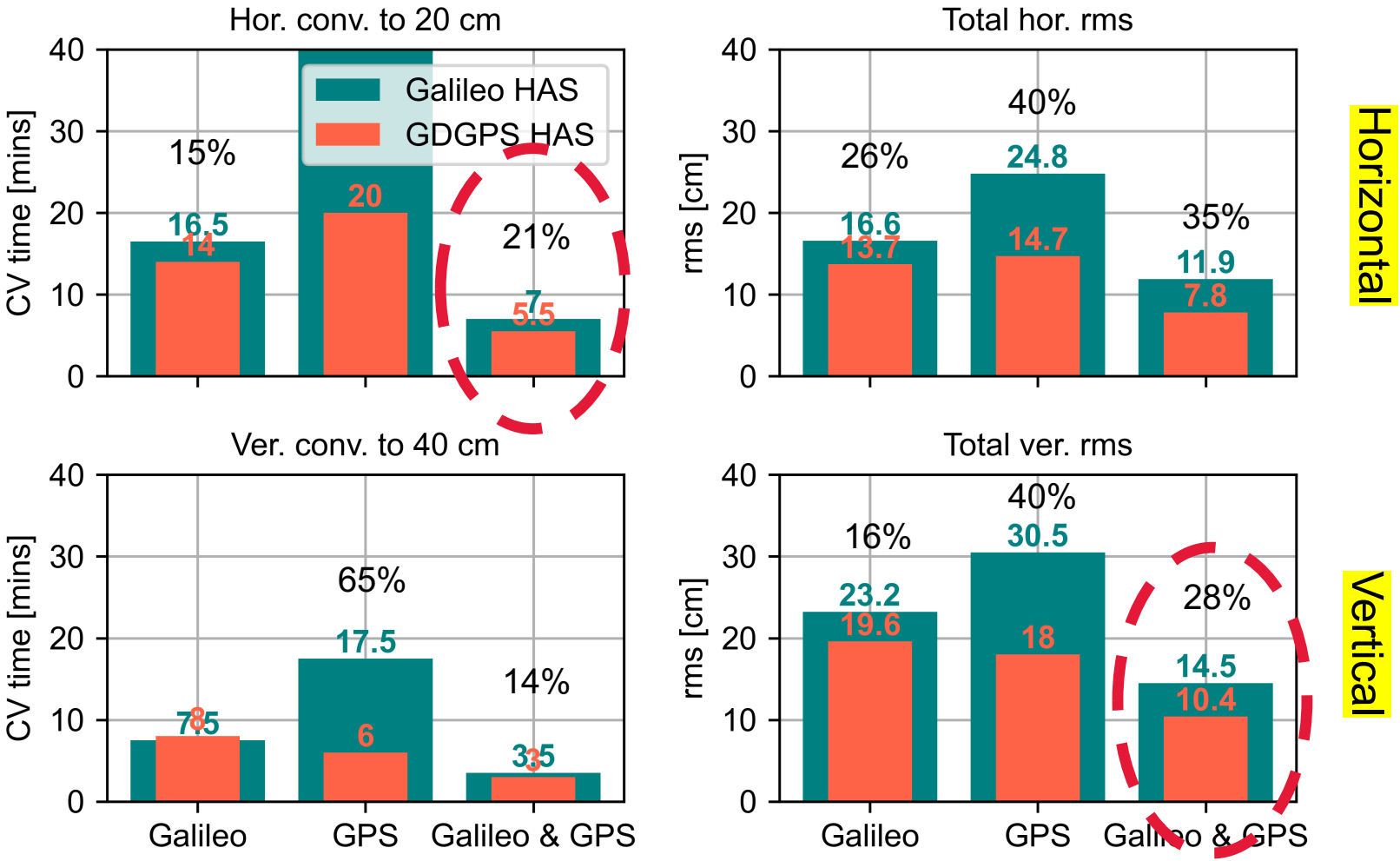
- Real-time PPP solutions computed using York University's PPP engine (GNSS Lab at York University, Canada)



20 cm convergence is achieved in 5.5 min using GDGPS GPS+GAL HAS

10.4 cm vertical RMS achieved using GDGPS GPS+GAL HAS

Average RMS Errors for All Stations Investigated

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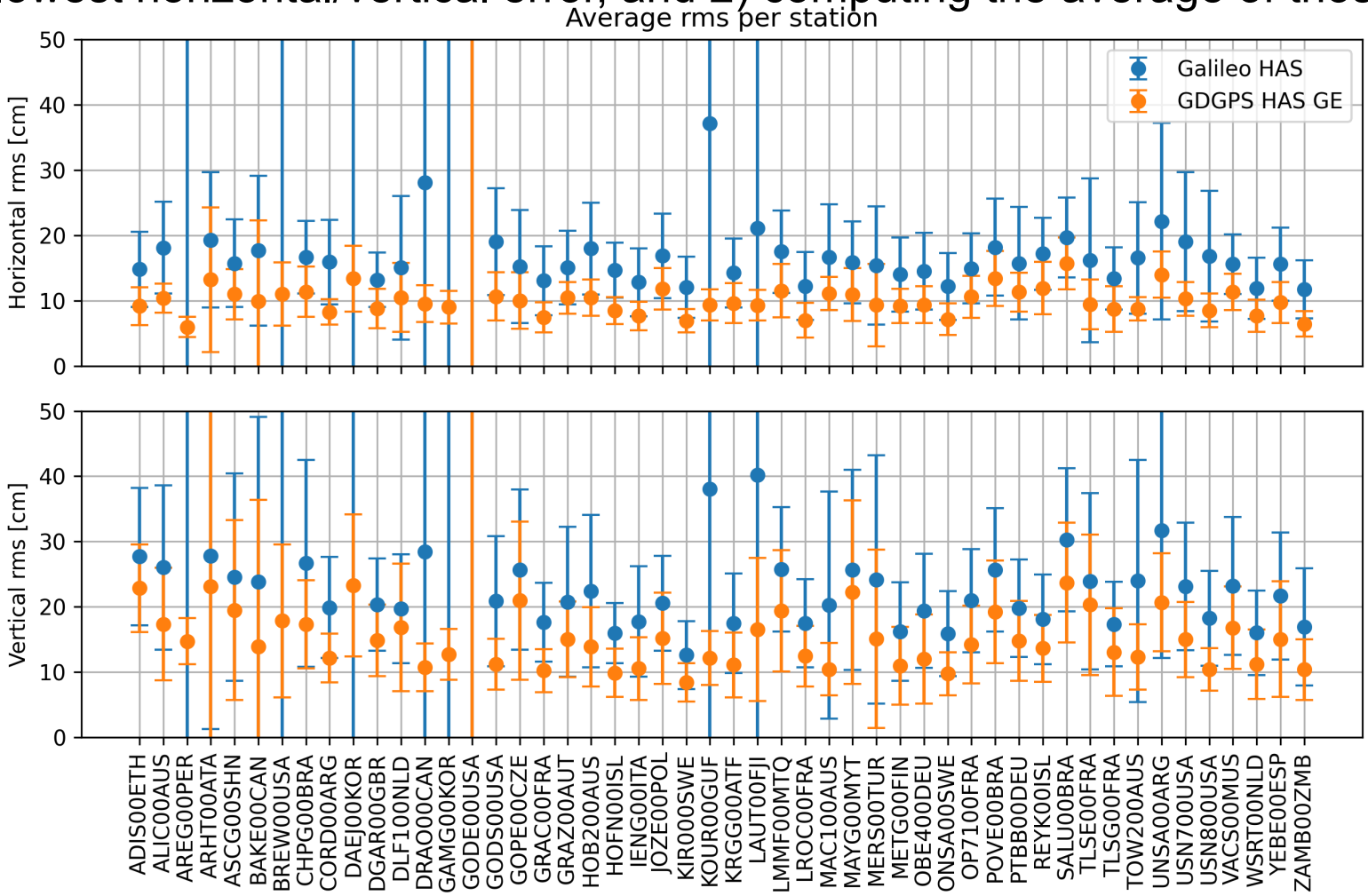
- Computed at each epoch by 1) taking the 95% datasets (out of ~2,700) with the lowest horizontal/vertical error, and 2) computing the average of those.



Average and 1-sigma error bars of RMS for horizontal and vertical components for individual stations investigated

GDGPS HAS vs GAL HAS Error Distribution

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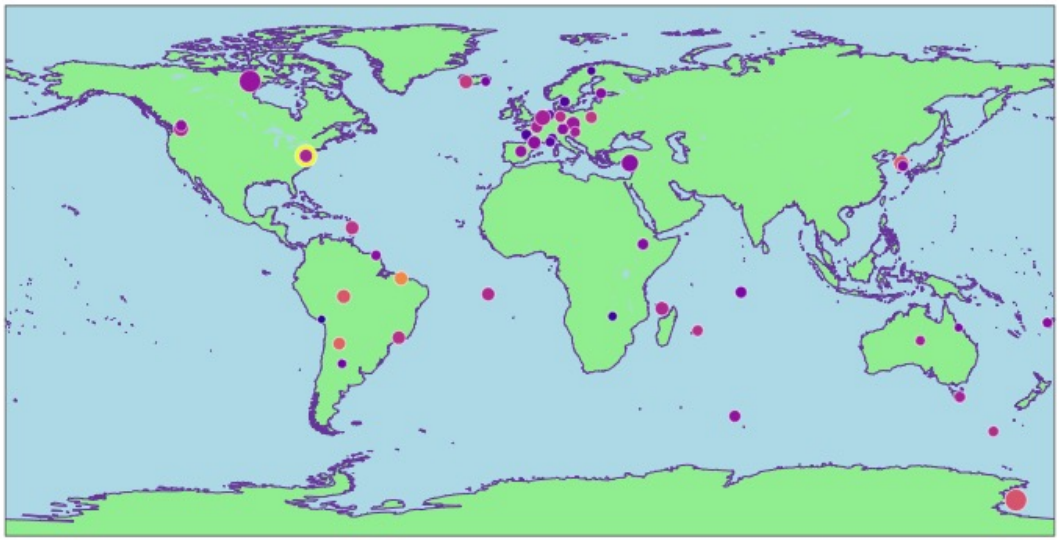
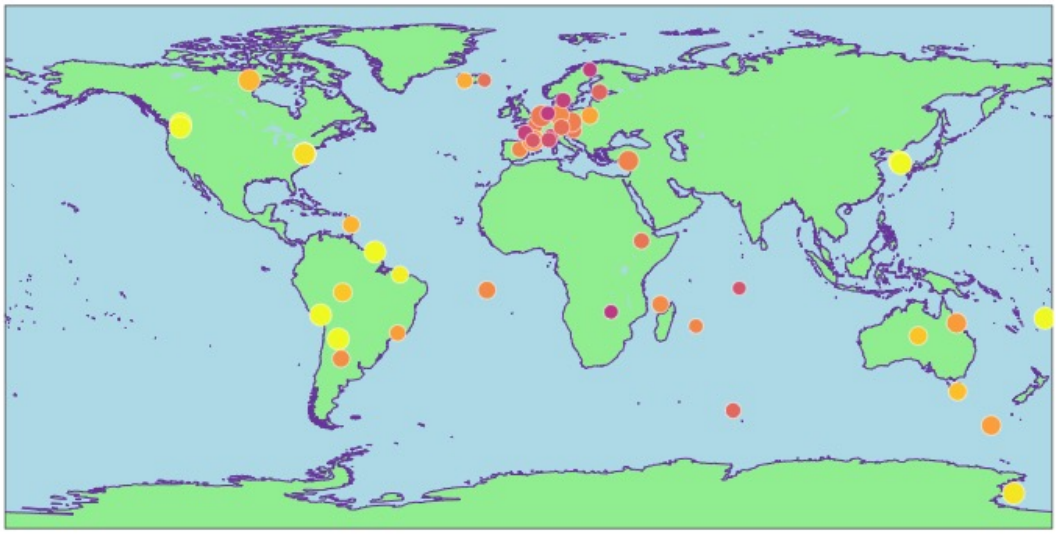
Average GPS HAS RMS Error



Average Galileo HAS RMS Error



- The sizes of the dots are based on the standard deviations of the rms
- Horizontal component only shown
- All solutions are GPS+Galileo

Galileo HAS RMS error seems larger in the Asian Sector due to lack of coverage

GDGPS-Based Real-Time Detection of M7.6 Earthquake on Dec 2, 2023

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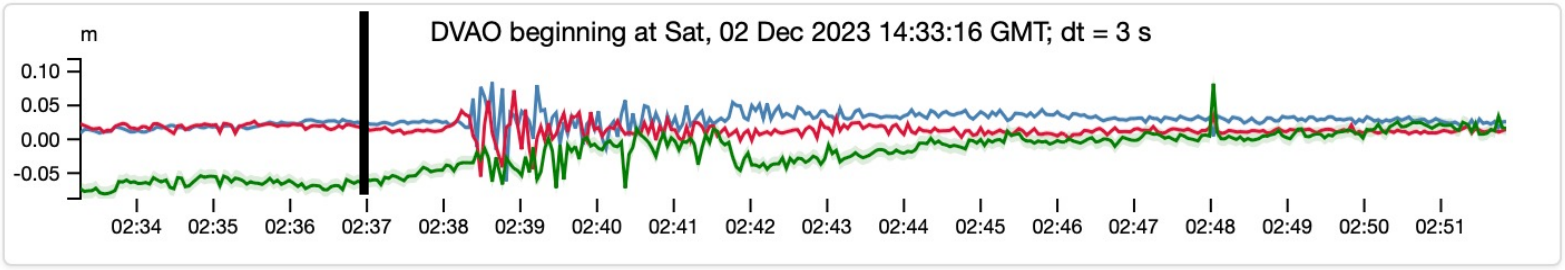
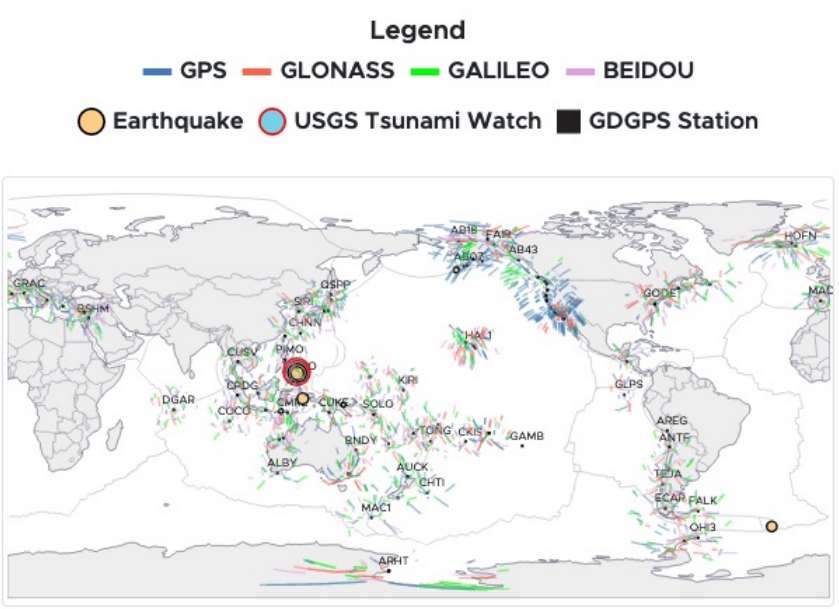
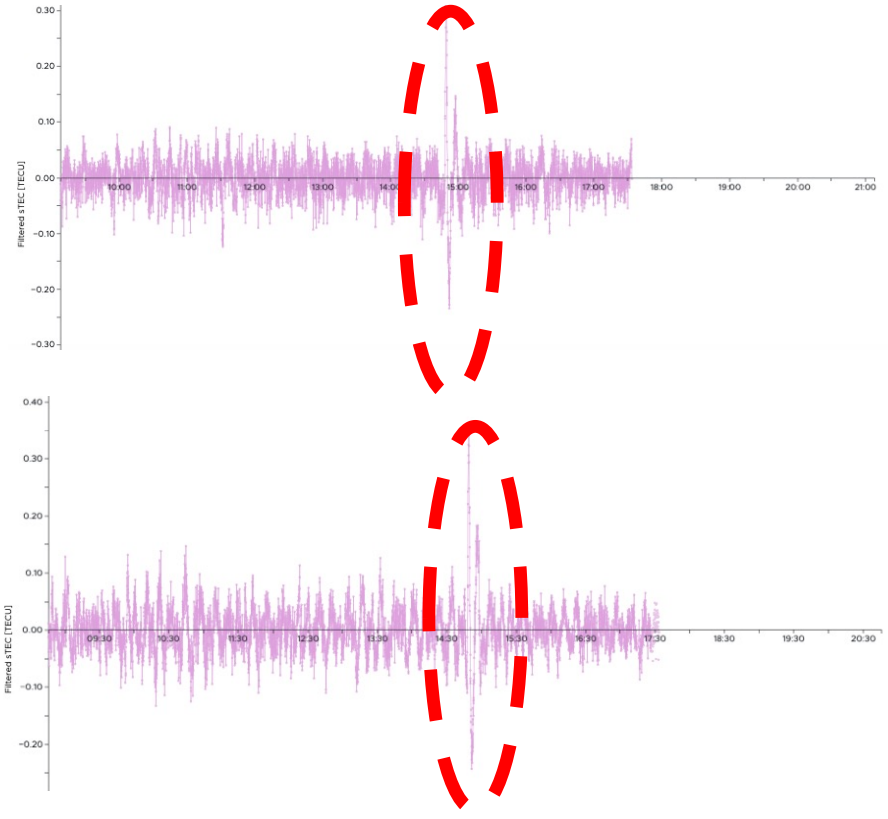
Mindanao, Philippines



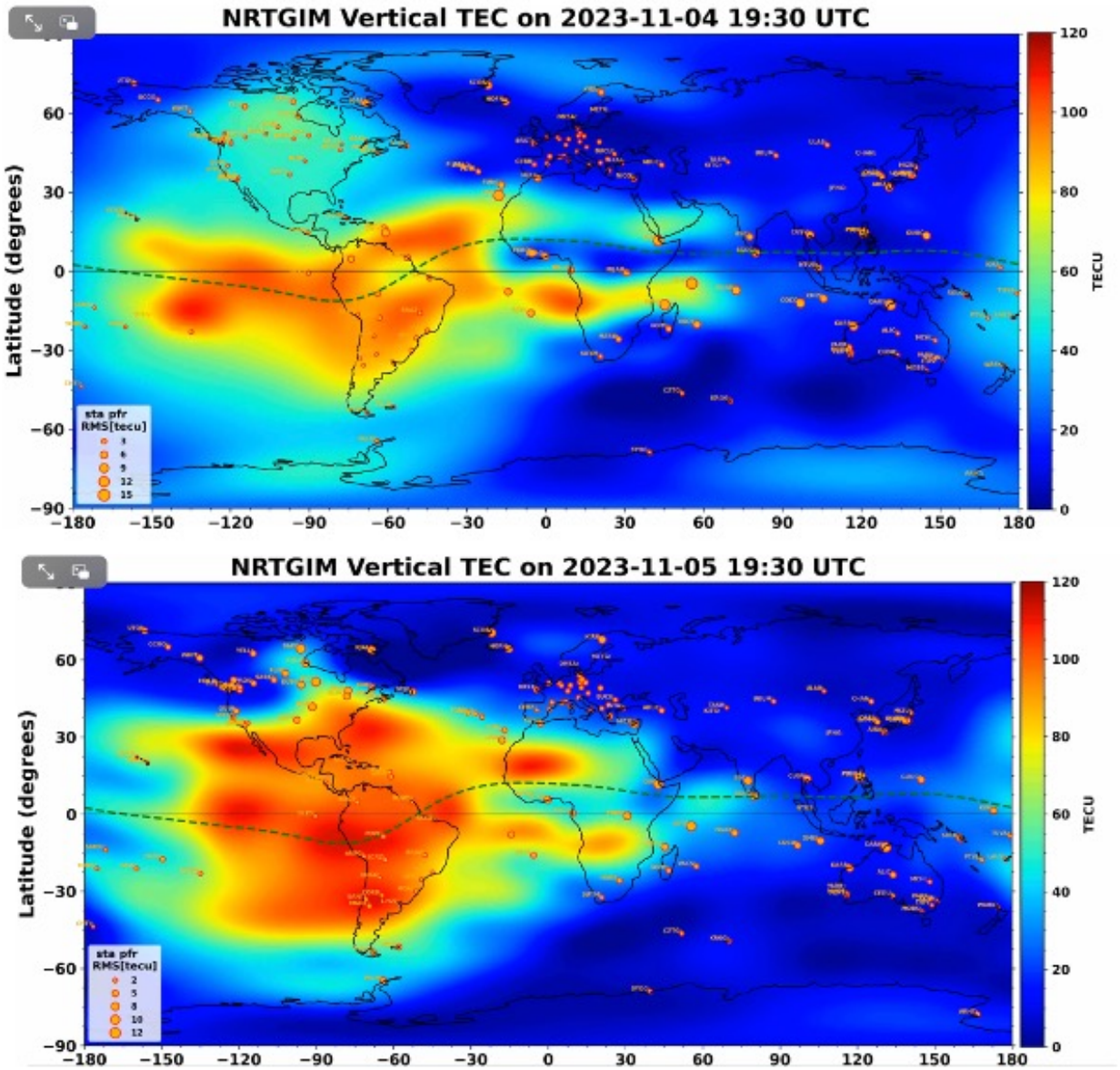
GUARDIAN





Real-time detection of earthquake last weekend based on PPP-AR using GDGPS

NRT Monitoring of Geomagnetic Storm on Nov 5, 2023



- Near-Real-Time monitoring of ionospheric disturbances including geomagnetic and solar disturbances

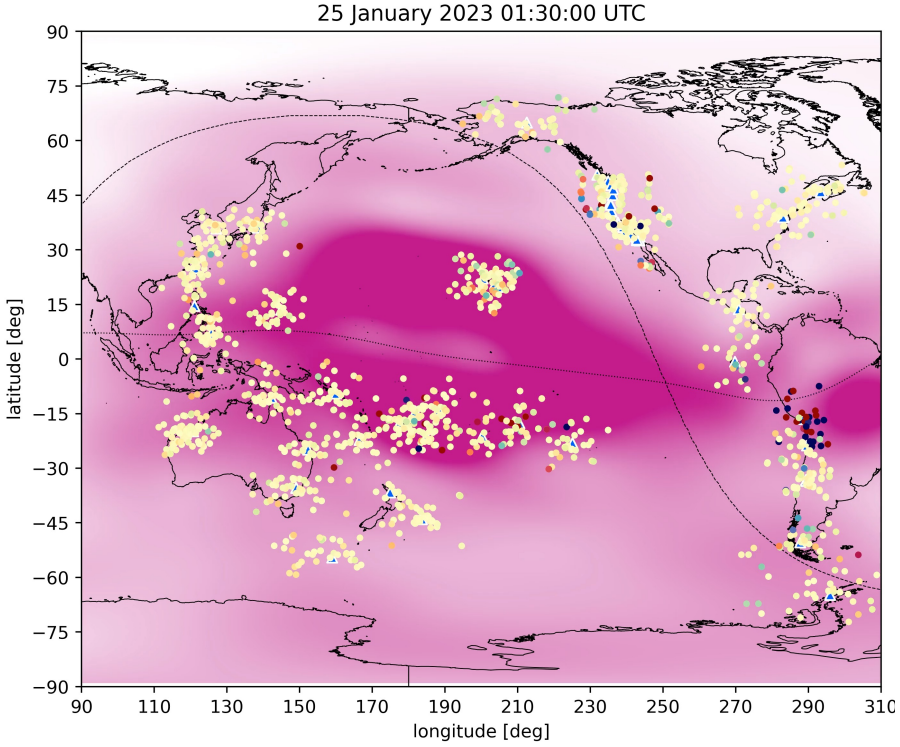
- GDGPS features additional science capabilities

https://sideshow.jpl.nasa.gov/pub/usrs/rfm/nrtgim/

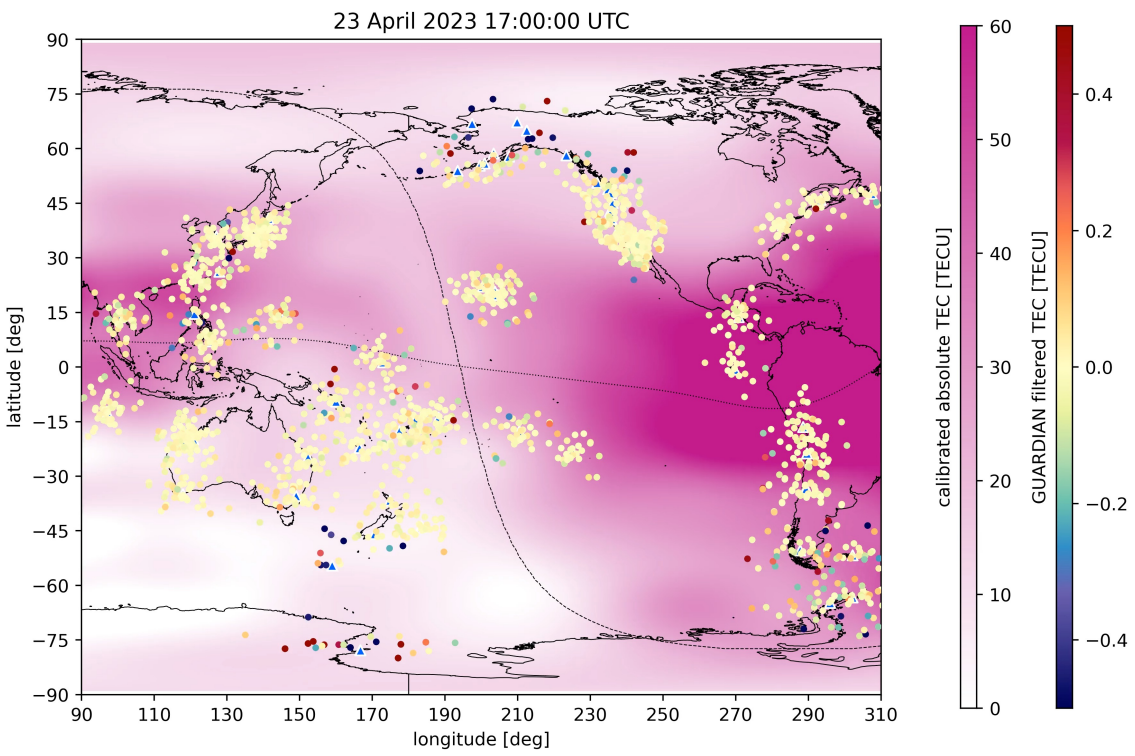
GDGPS Monitoring Ionospheric Perturbations Using Combined NRT and Real-Time GDGPS Data

Space Weather Activity

Low Solar Activity (Kp 0.0)



High Solar Activity (Kp 5.7 to 8.4)



Real-time monitoring of ionospheric disturbances using a combination of high-resolution multi-shell GIM mapping and real-time GDGPS-based TEC measurements

Global Landscape: Galileo HAS and PPP-B2b Are Operational

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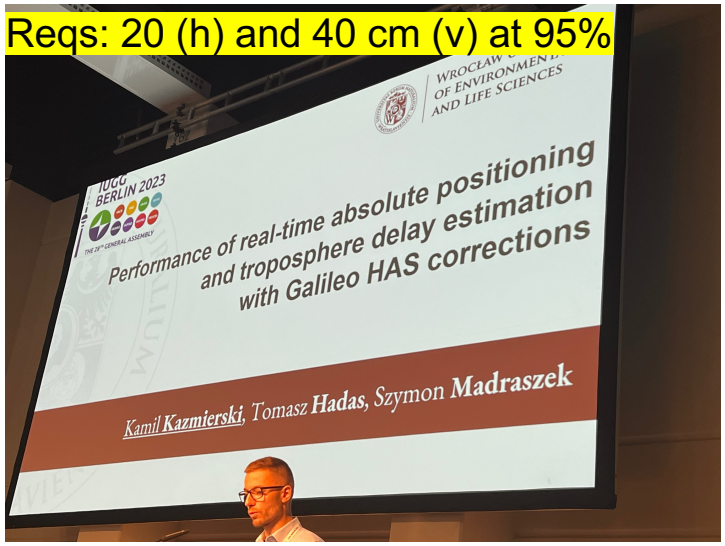
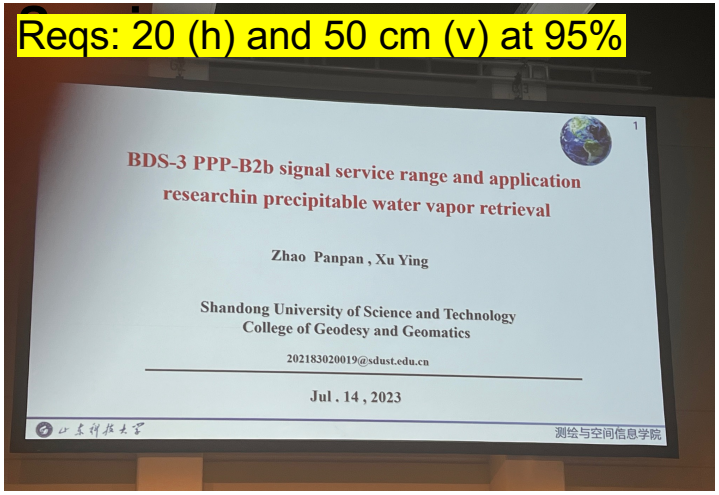
1) Galileo High Accuracy Service



2) PPP-B2b High Accuracy Service



3) German Federal Agency for Cartography and Geodesy (BKG) planning a global PPP service

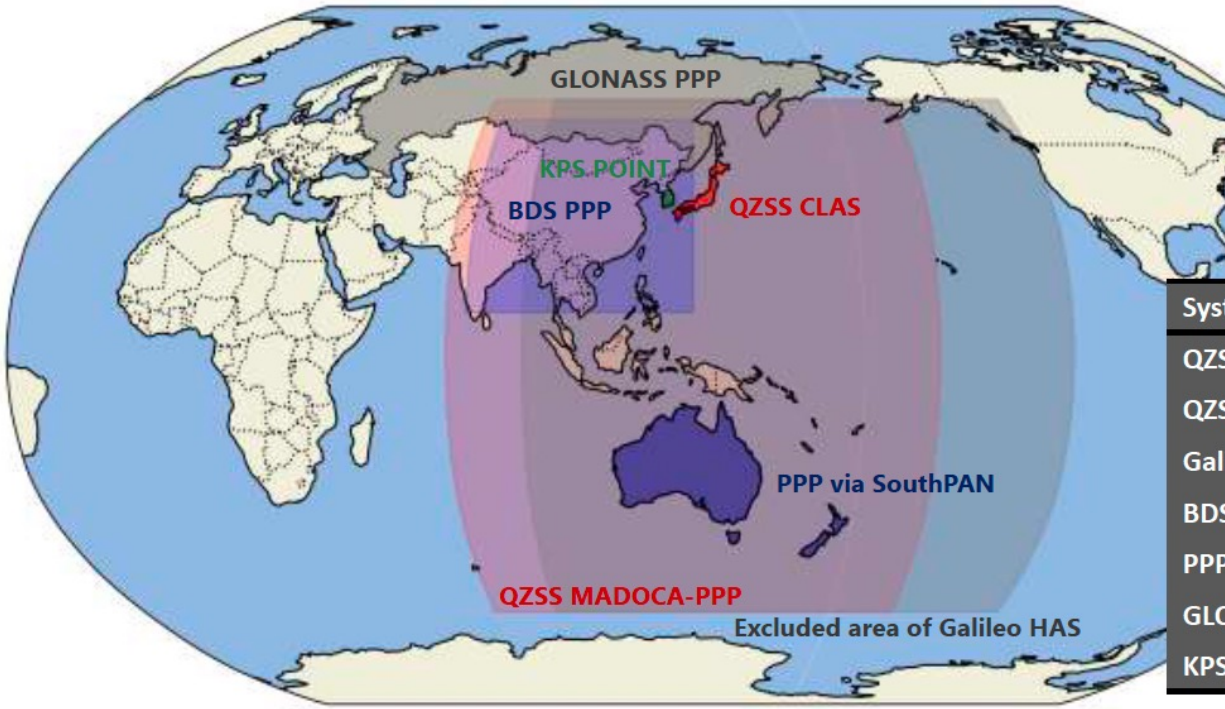
- Accuracy: <10 cm in 2D, <30 cm in height
- Distribution: mobile internet; via NTRIP
- Network: global RT-GNSS of IGS
- Timeline: development stage 2024-2025; Operational phase: beginning of 2026

Potential users and applications

- Police, security and rescue services; traffic decongestion, lane navigation; autonomous driving, UAV, agriculture, GIS collection, etc.

Galileo and BeiDou HAS systems in service now

Multiple High-Accuracy Services Available Internationally



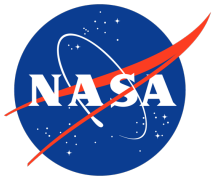
System	Service	Status
QZSS CLAS	PPP-RTK	Operational
QZSS MADOCA-PPP	PPP	Trial
Galileo HAS	PPP	Initial Service
BDS PPP	PPP	Operational
PPP Via SouthPAN	PPP	Early Service
GLONASS PPP	PPP	Modernization
KPS POINT	PPP-RTK	Development

Hirokawa, et al., 2023 at ION GNSS+ in Denver, CO

6 regional HAS and 1 global HAS service are operational or in development at this time

Conclusions

- GPS has been the premier satnav system to date
  - All consumer GNSS chips depend primarily on GPS
  - Competing systems coming on strong: European Galileo HAS and BeiDou PPP-B2b HAS are operational; Germany planning global PPP service
- A potential GPS HAS using GDGPS has unique and multiple advantages:
  - Global network of GDGPS-processed stations available (100+ stations)
  - Network designed for resiliency, robustness using multiple redundancies
  - GDGPS also provides global real-time monitoring capability of ionospheric disturbances
  - GDGPS is fully capable of providing GPS & Galileo HAS



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