Towards GDGPS High Accuracy Service (GDGPS HAS)

Attila Komjathy, Group Supervisor
Larry Romans, GDGPS Chief Technologist

Jet Propulsion Laboratory
California Institute of Technology

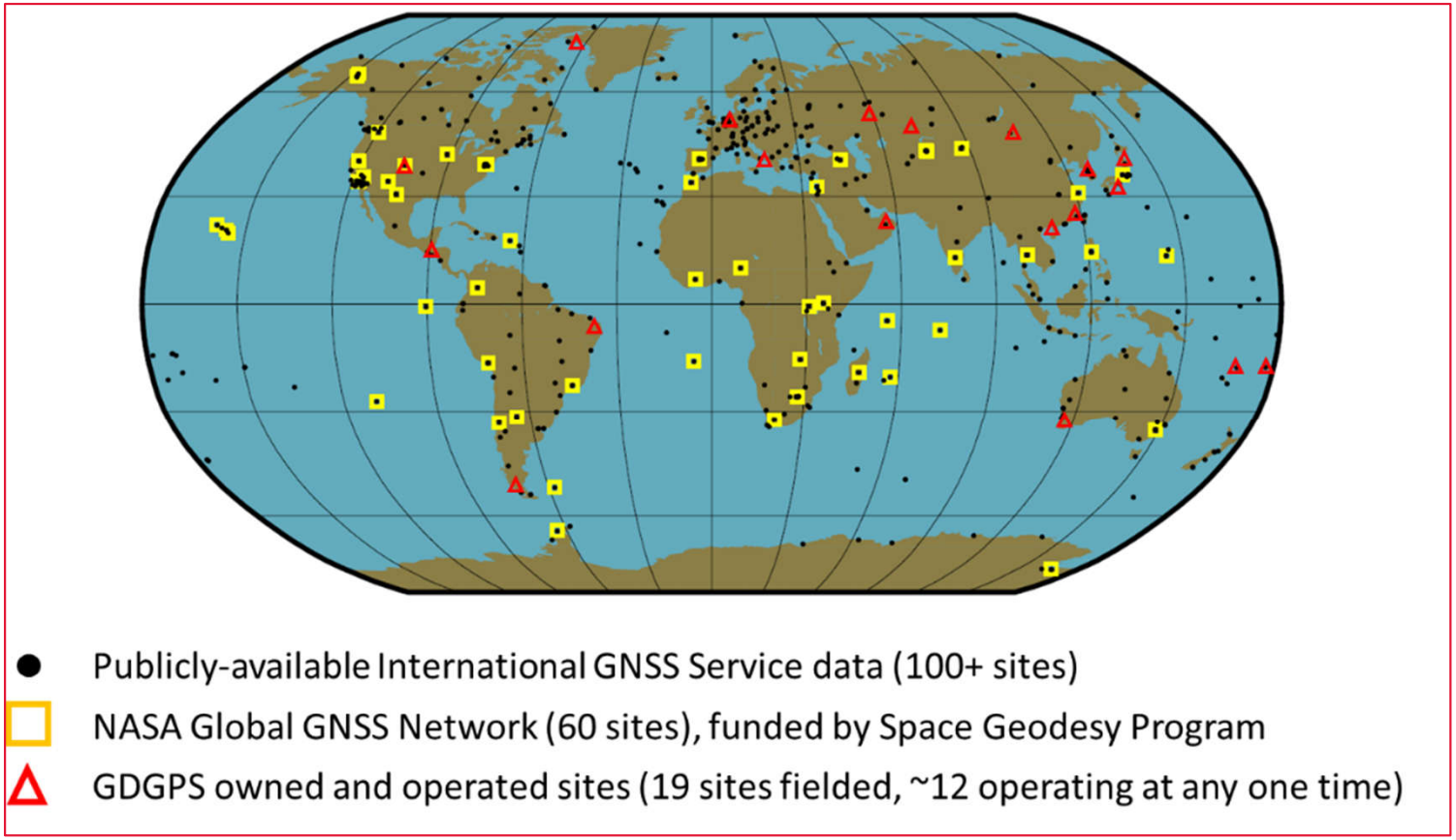
Outline

- Current GDGPS status and JPL activities
  - Network, GOCs and capabilities
- Towards GDGPS High Accuracy Service (HAS)
  - Galileo HAS vs GDGPS HAS
  - Real-Time orbits, clocks and UREs
  - Representative Real-Time PPP accuracy using RTGx
- Other upcoming NASA products for public distribution
- Summary

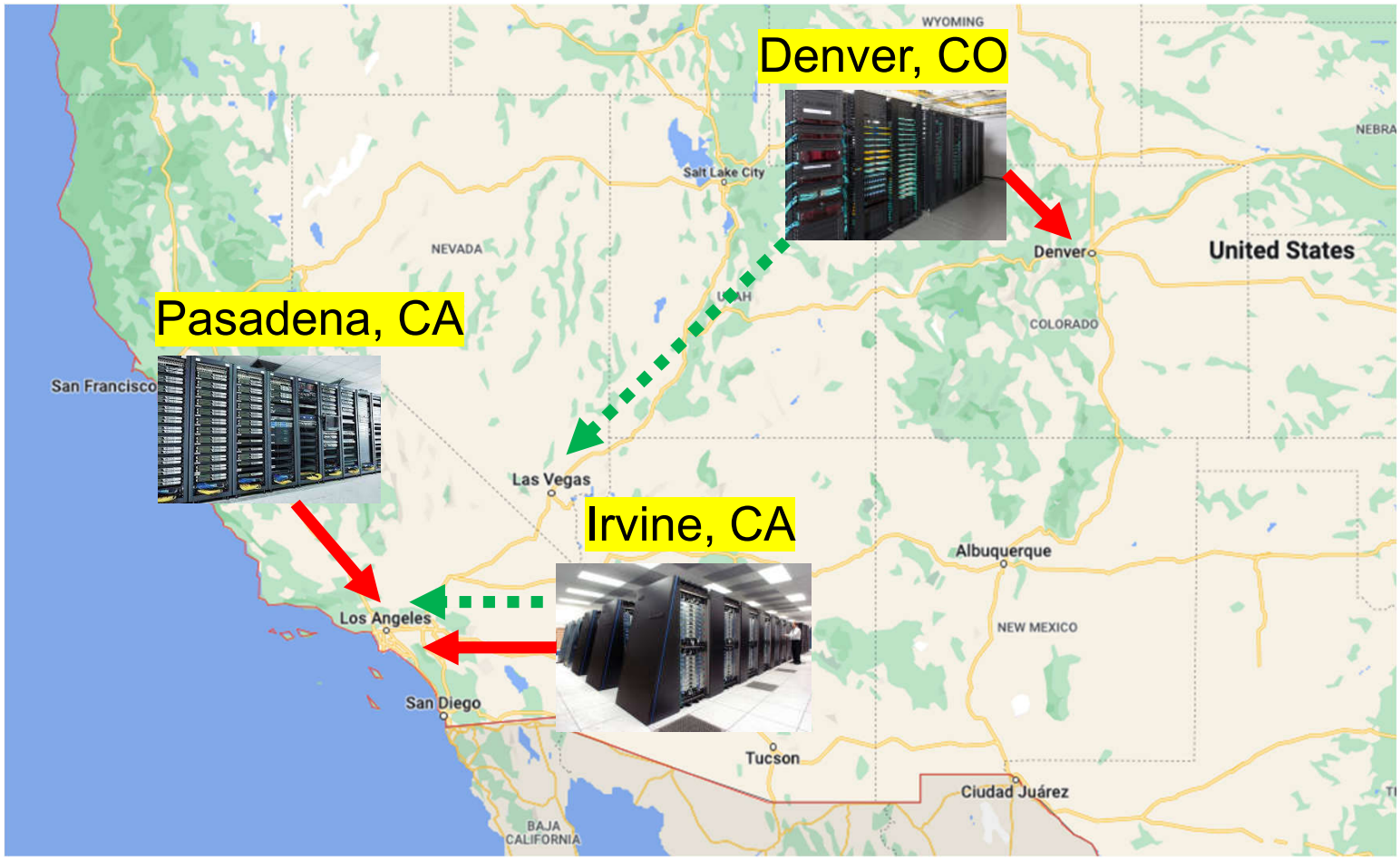
Network of GDGPS-Processed GNSS Receivers

- GDGPS uses and supports NASA-owned JPL-operated GNSS receivers (GGN)
- Network also augmented by a smaller set of GDGPS-operated sites
- Publicly available IGS streaming data supplementing the global network

The available global tracking network undergoes continual review and upgrading.



Plan to Transition GOCs to JPL Data Centers

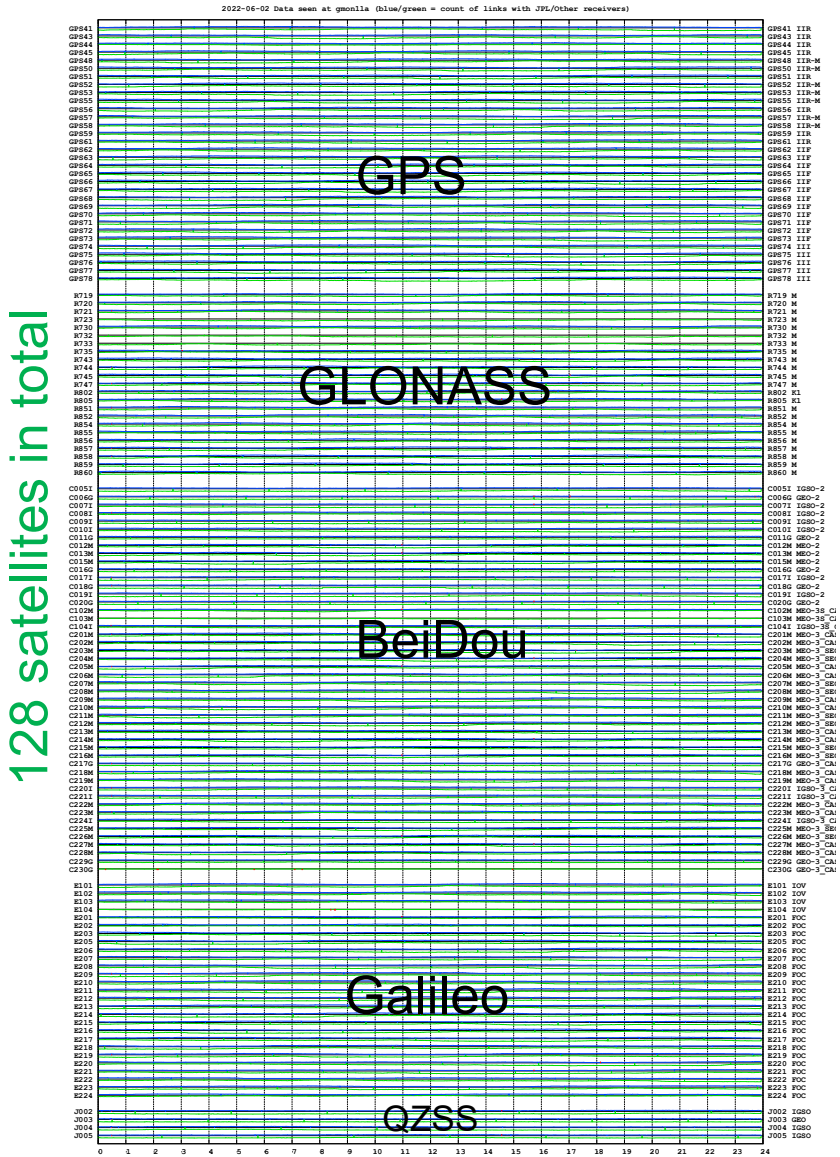


- Operational data processing is carried out in three independent GDGPS Operations Centers (GOCs) with separate ISPs, providing operational robustness
- We are exploring ways to transition to two JPL Data Centers located in Las Vegas and at JPL in order to comply with NASA data security requirements (FISMA)

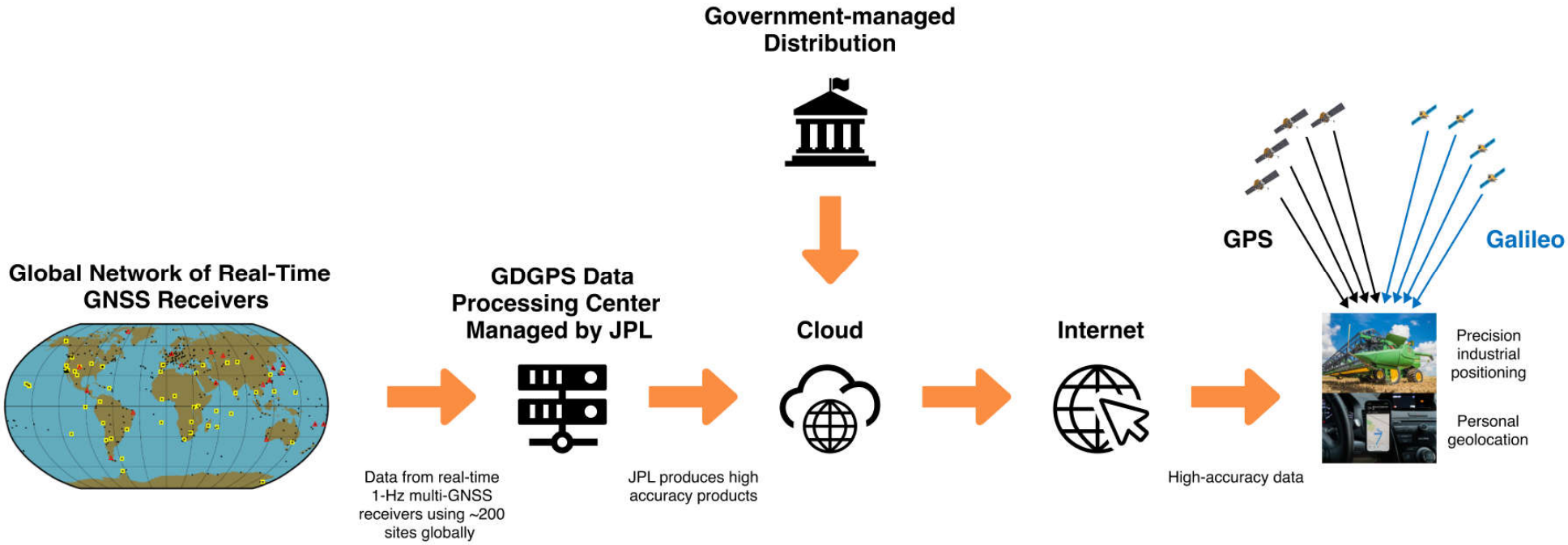
Current Real-Time GDGPS Monitoring Capabilities

- GPS LNAV Integrity Monitor
- GPS L2C CNAV Integrity Monitor
- GPS L5 CNAV Integrity Monitor
- Galileo Integrity Monitor
- GLONASS Integrity Monitor
- BeiDou Integrity Monitor
- QZSS Integrity Monitor
- GNSS Corrections Monitor
- Filter Status Monitor
- RTCM PPP Monitor
- Flex Power Monitor
- GUARDIAN

We monitor 128 satellites in real time including the accuracy and integrity of our GNSS clock and orbit corrections intended as public product for FY23



Towards GDGPS High Accuracy Service (HAS)



- Spoke with PNT Advisory Board and received strong support for GDGPS-HAS
- Real-time GDGPS HAS is synergistic with existing GDGPS capabilities delivered to government customers including NASA and US Air Force/US Space Force
- Still seeking government partner for co-support GDGPS-HAS with NASA

GDGPS HAS vs Galileo HAS (1)

	Phase 1 Initial Service	Phase 2 Full Service	GPS HAS Using GDGPS
Coverage	EU+ →	Global	Global
Orbit corrections	Y	Y	Y
Clock corrections	Y	Y	Y
Code biases	Y	Y	Y
Phase biases	Y	Y	Y
Galileo corrected signals	E1, E5a, E5b, E5, E6	E1, E5a, E5b, E5, E6	E1,E5a,E5b (++)
GPS corrected signals	L1, L2C	L1, L2C, L5	L1W, L2W, L5Q (++)
Signal Quality indicator	N	Y	TBA
Horizontal accuracy requirement 95%	> 20 cm	20 cm	< 10 cm
Vertical accuracy requirement 95%	> 40 cm	40 cm	< 20 cm
Convergence time requirement Global, no ionosphere (Service Level 1)	> 300 s	300 s	TBA
EU, ionosphere corrections (Service Level 2)	N/A →	100 s	300 sec
Ground channel	Y	Y	Y
Ground reference stations	14 (GSS)	To be defined	100+
Max. sat. downlinks (448 bps)	20	To be defined	N
Authentication	N	Y	Possible
Phase Start	2022 →	2024+	Unplanned

++ supporting different signals at the same frequency via code biases

Fernandez-Hernandez et al., 2022

GDGPS HAS vs GAL HAS (2)

Potential GDGPS HAS Features

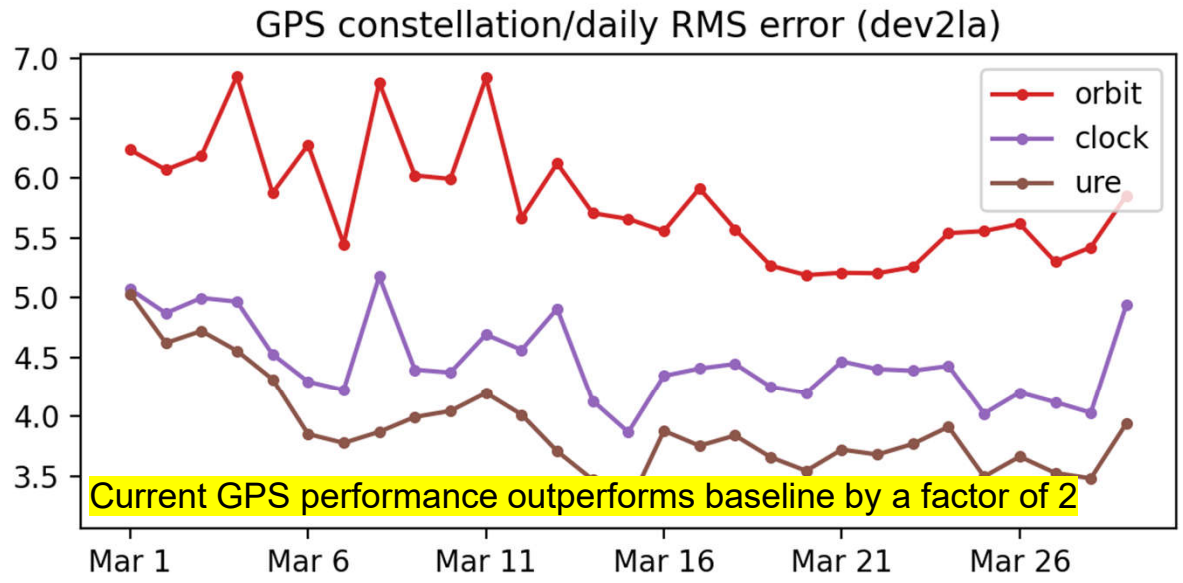
- **Global network** of GDGPS monitoring-stations available (100+ stations globally)
- **Three independent** GDGPS Operations Centers (GOCs). They are:
  - geographically separated,
  - redundant power supplies, and various ancillary devices,
  - computational redundancy, spares, and backup capabilities bring resiliency
- GDGPS is **technologically fully capable** of providing global high-accuracy corrections for a potential GPS HAS. A history of innovation and reliable service.
- 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 (vs 20 uplink stations for GAL HAS)
- **No Signal-in-Space** (SIS) planned for GPS
- **PPP convergence times** not systematically established yet

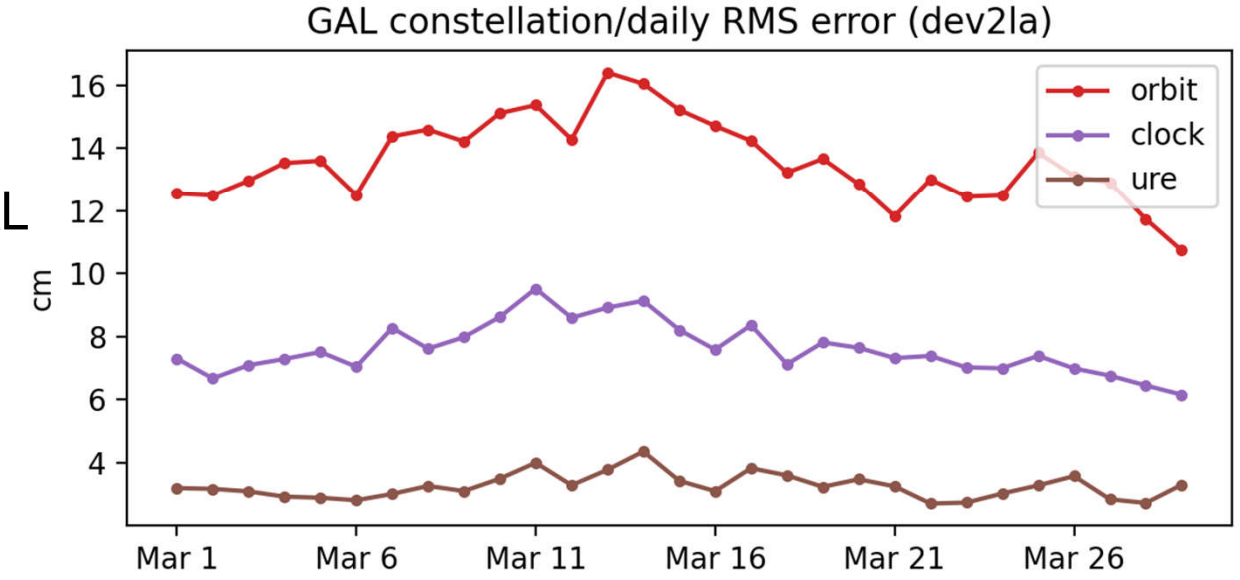
Real-Time Orbits, Clock and UREs for March 2022

GPS



Current GPS performance outperforms baseline by a factor of 2

GAL



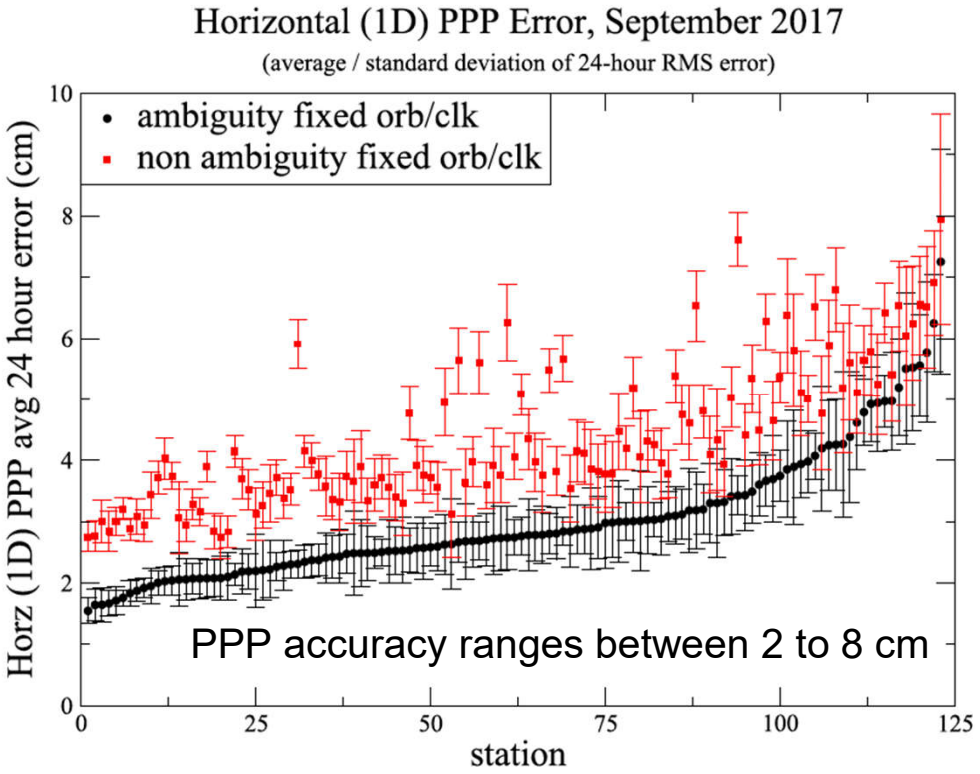
Current GAL performance appears within the baseline requirement

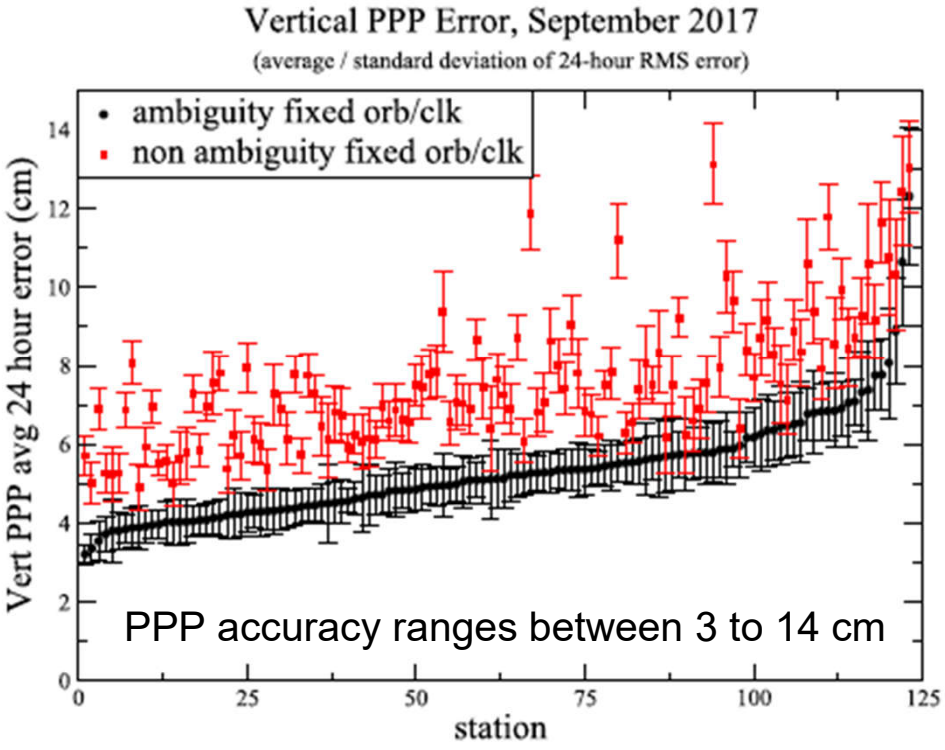
GDGPS Baseline Requirements

Attribute	GPS	Galileo
Orbit Errors (3D RMS)	< 0.15 m	< 0.15 m
Clock Error (RMS)	< 0.1 m	< 0.1 m
User Range Error (RMS)	< 0.08 m	< 0.08 m

- Low cadence orbit filter at every 60 sec
- High cadence clock filter at every second
- Compared to high precision GipsyX rapid product

Representative Real-Time PPP Accuracy Using RTGx





Bertiger et al., 2020

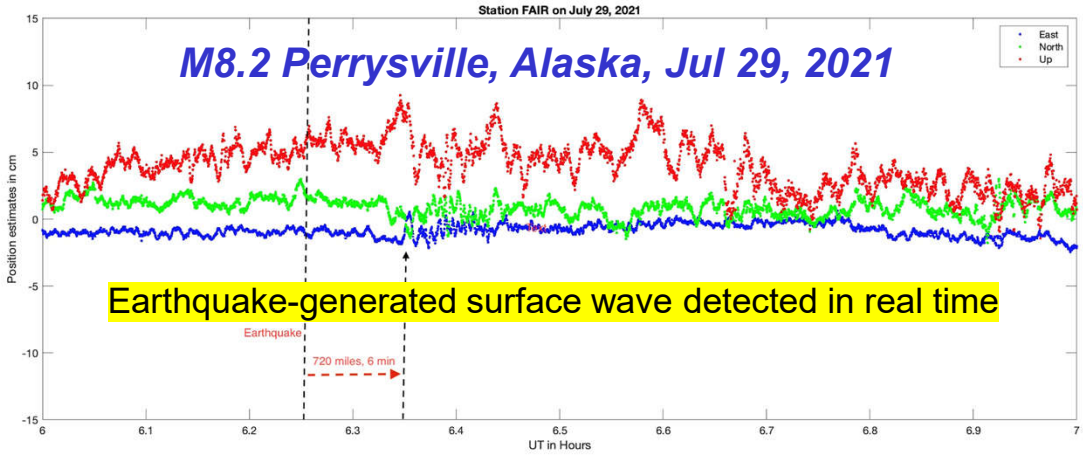
- Real-time positioning accuracy of real-time kinematic 5-min point-positioning of 125 GDGPS tracking sites with RTGx during September 2017

- Real-Time PPP accuracy for GAL HAS Phase 2 is 20 cm (95%) horizontal and 40 (95%) vertical.

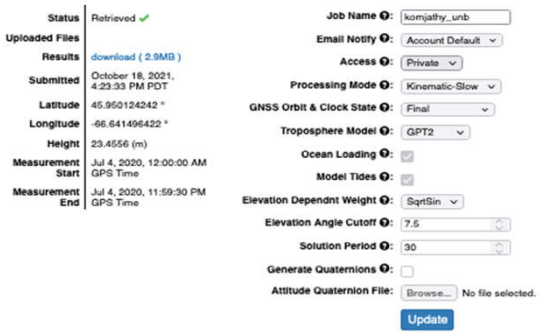
Other Upcoming NASA Products for Public Distribution

Products at higher maturity, but not yet ready for public distribution

- Multi-constellation (GPS+GAL+BDS +QZSS) real-time clock, orbit, range bias and phase-bias corrections for PPP-AR in RTCM SSR or IGS SSR formats.



- Real-time Great Alert System performing *PPP-AR* for hundreds of stations
- *GPS-based* Automated Point Positioning Service (APPS) for static and kinematic positioning



Currently under development

- Multi-constellation APPS for static and kinematic positioning
- GNSS-based Upper Atmospheric Realtime Disaster Information and Alert Network (GUARDIAN)
- Multi-constellation near Real-Time GIM (nrtGIM) maps and inter-frequency bias monitoring.

Summary

- Developing public products and working with commercial partners to test robustness of real-time public products
- Working towards GPS HAS: A potential GPS HAS using GDGPS has unique and multiple advantages
  - Global network of GDGPS-processed stations available (100+ stations)
  - Network is designed for resiliency and robustness using redundancies at all levels
  - Current real-time accuracy is shown to be in par or higher than Phase 2 GAL HAS performance anticipated by 2024
- Significant challenges for GPS HAS remain including no signal-in-space planned, no access to uplink stations for GPS
  - Distribution only possible via Internet
  - Still seeking government partner for co-support GDGPS-HAS with NASA
- GDGPS is technologically fully capable of providing high-accuracy corrections to GPS and Galileo if requested to support GPS HAS

Acknowledgements

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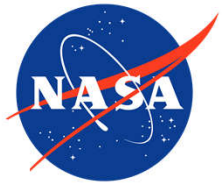

Jet Propulsion Laboratory
California Institute of Technology

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