PNT Challenges: Space Weather and a Whole Lot More

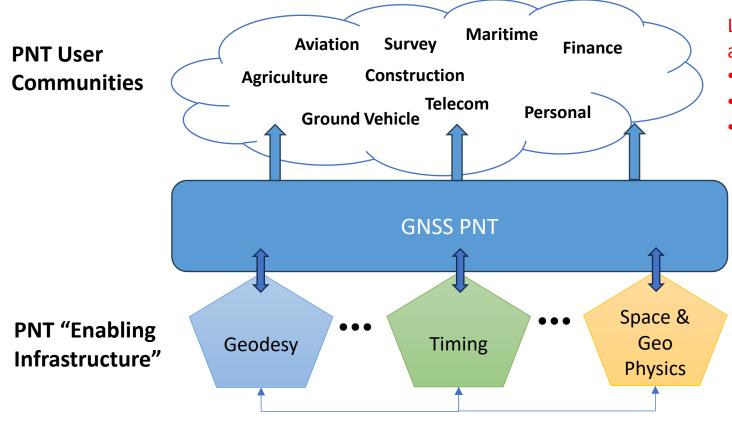
Dr. Gary A. McGraw PNT Consultant President, US Institute of Navigation

NAS Space Weather Roundtable February 5, 2025

Disclaimer:

The views expressed in this presentation are solely those of the presenter and do not necessarily reflect the positions of the Institute of Navigation Executive Committee, Council, or Staff.

BLUF: GPS/GNSS is Critically Threatened



Lack of user understanding & acknowledgement of GNSS vulnerabilities:

- Jamming, Spoofing,
- Cyber
- Space weather

PNT policy dispersed across USG:

- GPS OCX delays, slow L5 deployment
- Lack of modernized complementary PNT systems
- Aging S&T infrastructure
- Often no clear USG "owner", funding sources
- Dependent on ad hoc collaboration with international partners
- Shortage of trained personnel

There is a need for collaboration to advocate for PNT and enabling infrastructure

ION PNT Advocacy Initiative

1.

2.

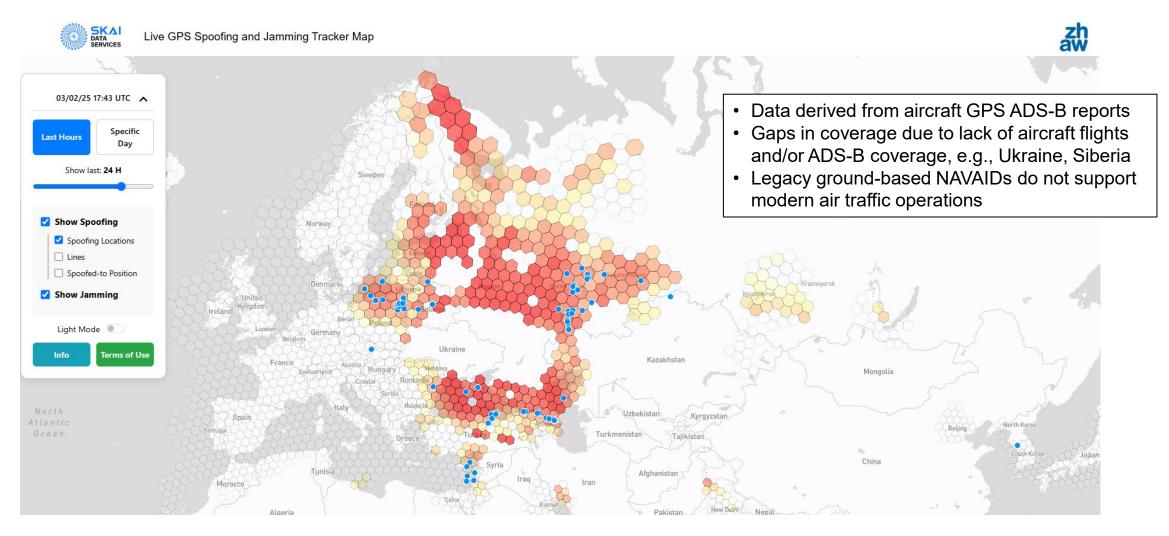


PNT Challenges: Overview

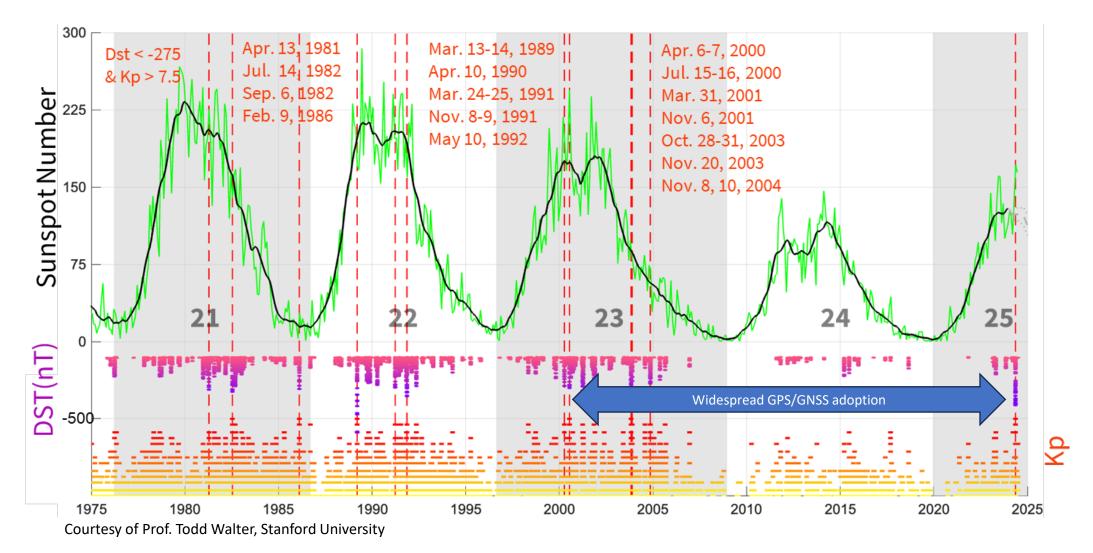
- GPS/GNSS PNT vital to national infrastructure, economy and public safety
- GNSS are vulnerable to:
 - Radio frequency interference: jamming & spoofing
 - Space weather
 - Underlying infrastructure is fragile
 - Complacency by governments and users
- Need to Protect, Toughen and Augment (PTA) GPS/GNSS
 - Complementary PNT sources are especially important to address space weather effects to GNSS
- Outreach, Education & Collaboration for PNT advocacy is needed

Topics for remainder of presentation

GNSS Jamming & Spoofing Now Widespread



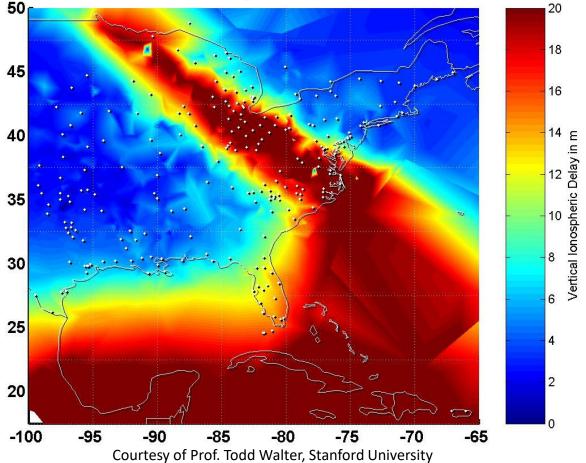
Recent Solar Cycles



Ionospheric Effects on GNSS Summary

Example Disturbed Ionosphere

11/20/2003, 20:15:00UT



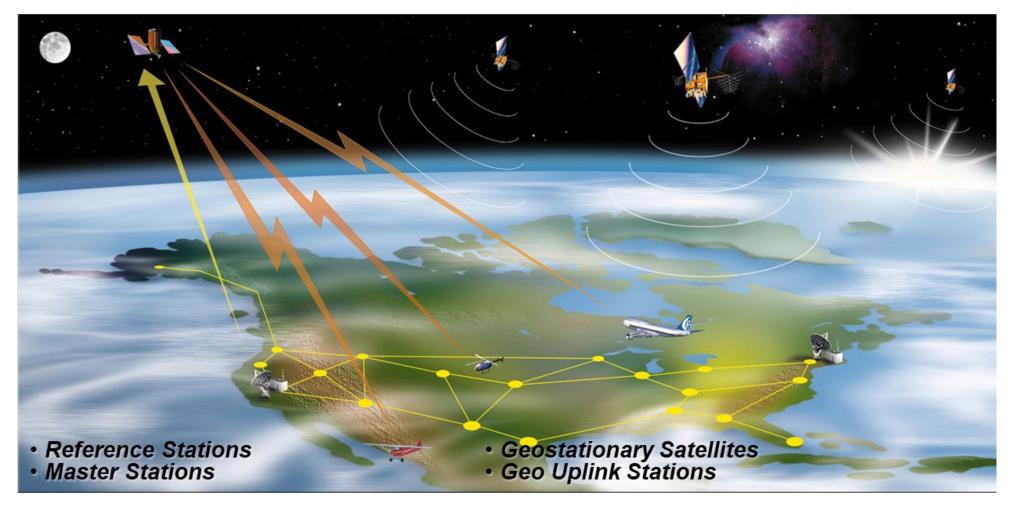
- Single frequency iono compensation models unreliable in disturbed conditions
- Spatial and temporal gradients affect augmentation systems
 - Local differential (e.g.: Ground Based Augmentation System-GBAS)
 - Regional differential (e.g.: Space Based Augmentation System-SBAS)
- Dual frequency GNSS much more robust but large gradients can still lead to ranging errors due to extreme refraction effects
- Scintillation can lead to loss of signal tracking – affecting continuity

Parameters Used to Evaluate PNT Performance for Safety of Life Applications

- Accuracy: characterizes typical system behavior in the presence of nominal errors
- Integrity: characterizes risk that abnormal behavior affects the system
 - Integrity risk
 - Maximum tolerable error
 - Time to alert (TTA)
- **Continuity**: risk of losing the service unexpectedly
- Availability: fraction of time that one has the accuracy, integrity, and continuity required to perform the desired operation
- **Coverage**: Geographic area where PNT service is available

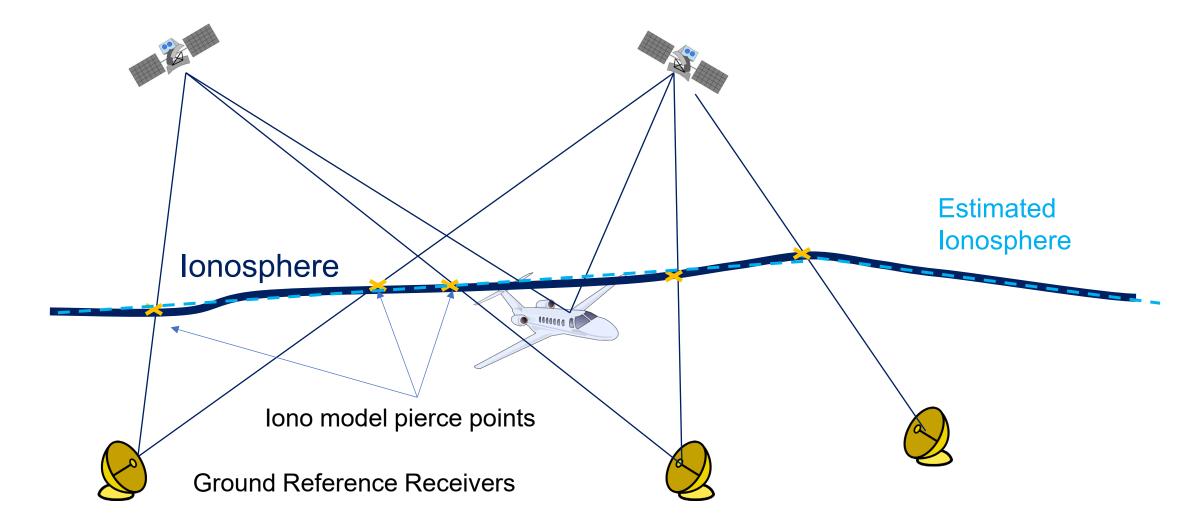
Space weather can impact all of these parameters for GNSS

Space Based Augmentation System (SBAS)

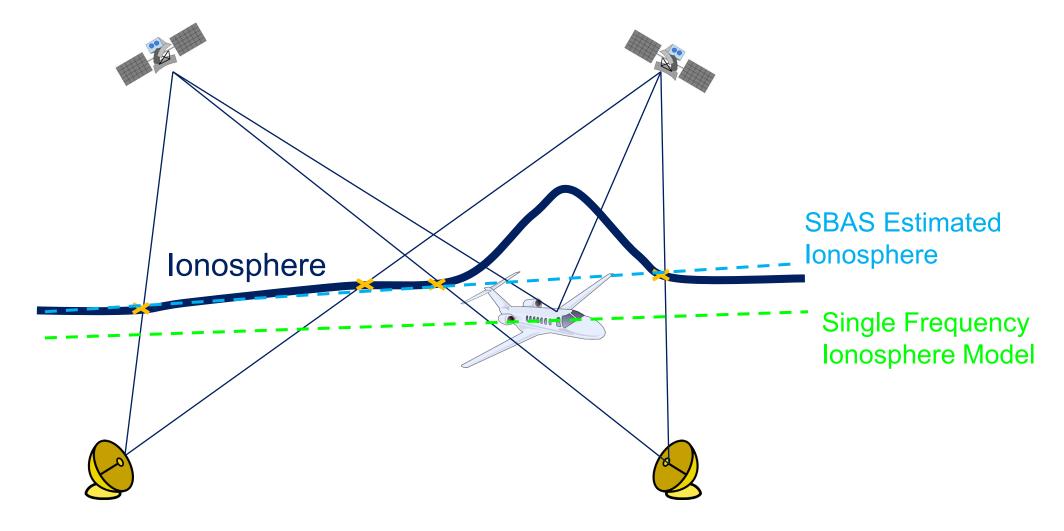


Courtesy of FAA

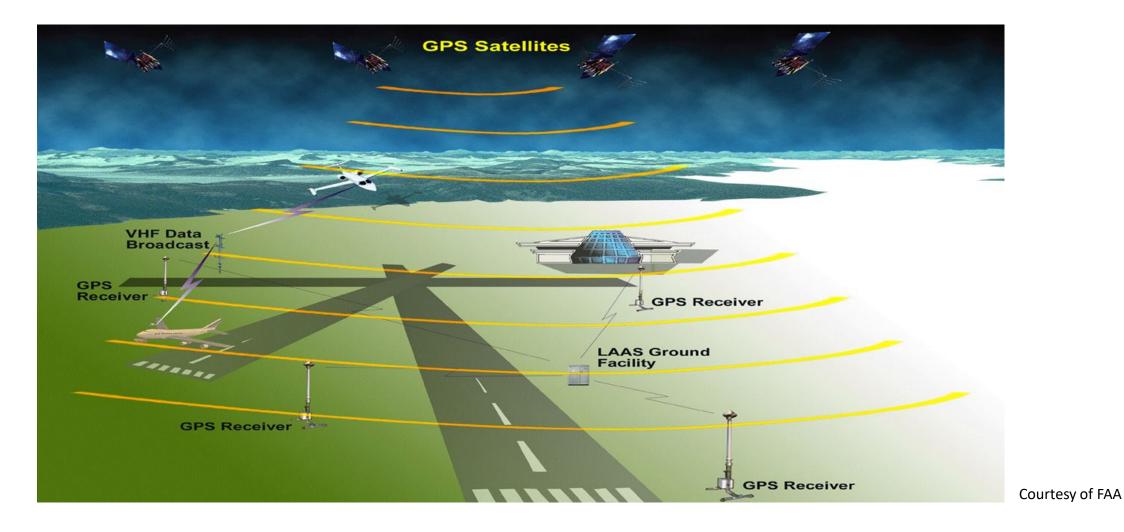
SBAS Models Ionospheric Delay on a Continental Scale



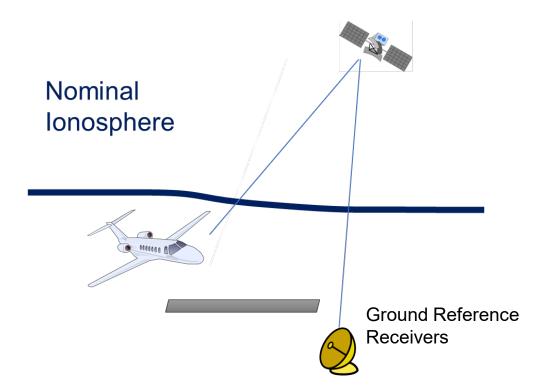
Disturbed Ionosphere Affects SBAS & Standalone Single Frequency Users



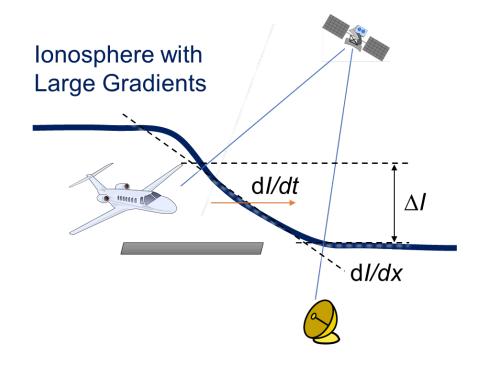
Ground Based Augmentation System (GBAS)



Local DGNSS Ionospheric Effects



• Air-ground ionosphere error approximately cancels for GBAS



- Air-ground ionosphere error, ∆I, is large and challenging to reliably detect
- Spatial & temporal gradients induce errors in single frequency carrier-smoothed code filters
- Coverage area for high accuracy & integrity shrinks

High-level PNT Recommendations for Aviation

Toughen GNSS

- Signal processing to detect & exclude spoofing
- CRPAs + digital beamforming antenna signal processing for Anti-Jam / Anti-Spoof

Toughen

Modernize Terrestrial Complementary PNT

- Develop and deploy new CPNT sources
- Improve spectrum efficiency & compatibility
- Improve coverage
- Enable support of RNP operations

Augment

Improve Aircraft PNT Integrations

- Robust GNSS monitoring with CPNT & inertial
- Eliminate use of unmonitored GNSS PNT for aircraft functions
- Have an independent aircraft time source

PTA Implementation Protect

Improve Air Traffic Services

- Bring in real-time RFI information
- Provide operators and aircrews with better preflight & real-time RFI & space Wx situational awareness