EUROPEAN AVIATION SAFETY AGENCY
AGENCE EUROPÉENNE DE LA SÉCURITÉ AÉRIENNE
EUROPÄISCHE AGENTUR FÜR FLUGSICHERHEIT

Issues and mitigations: Satellite Navigation Systems

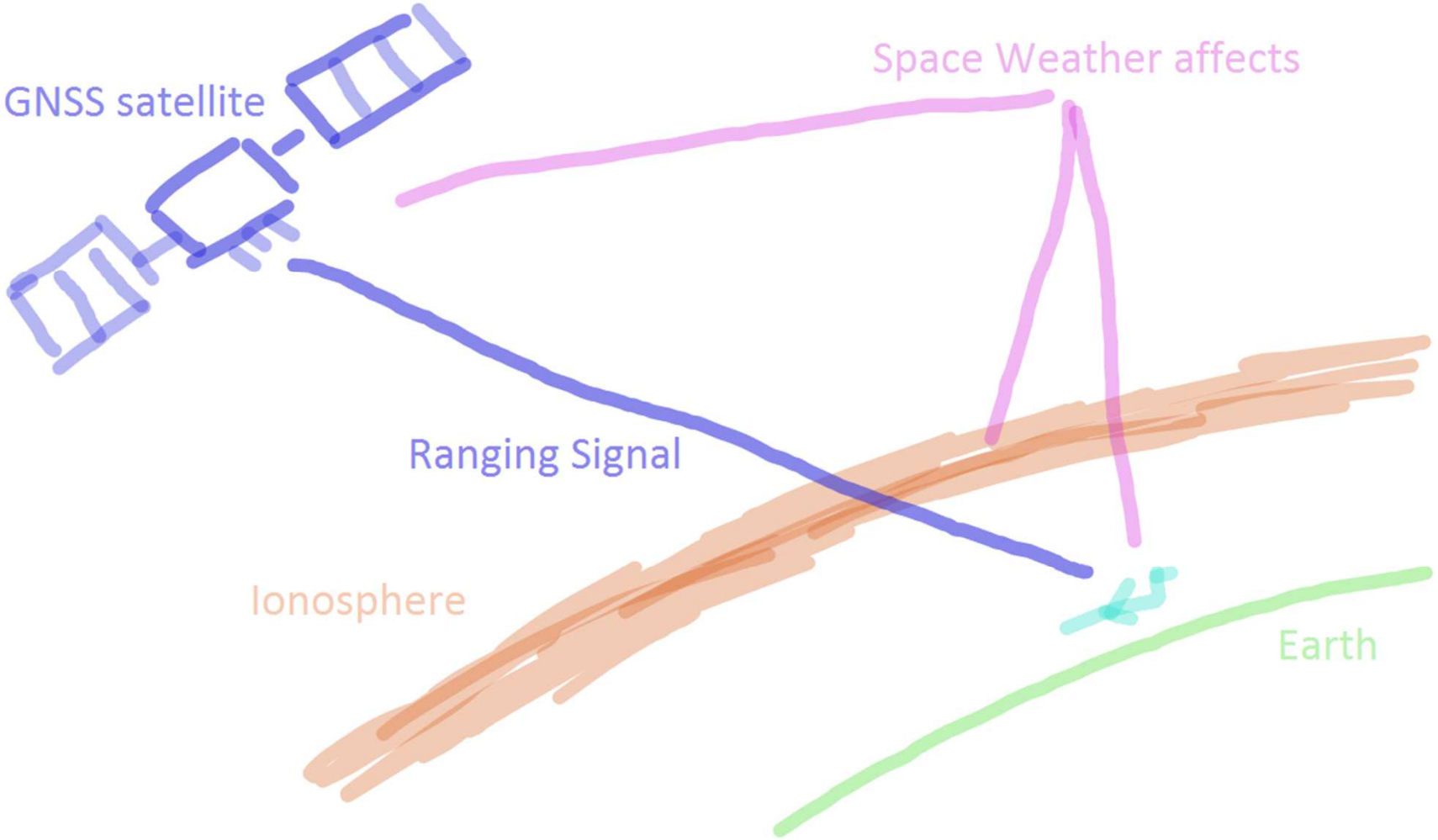
Dr. Hans L. Trautenberg
Senior ATM/ANS Expert
20.03.2013

Your safety is our mission.
easa.europa.eu

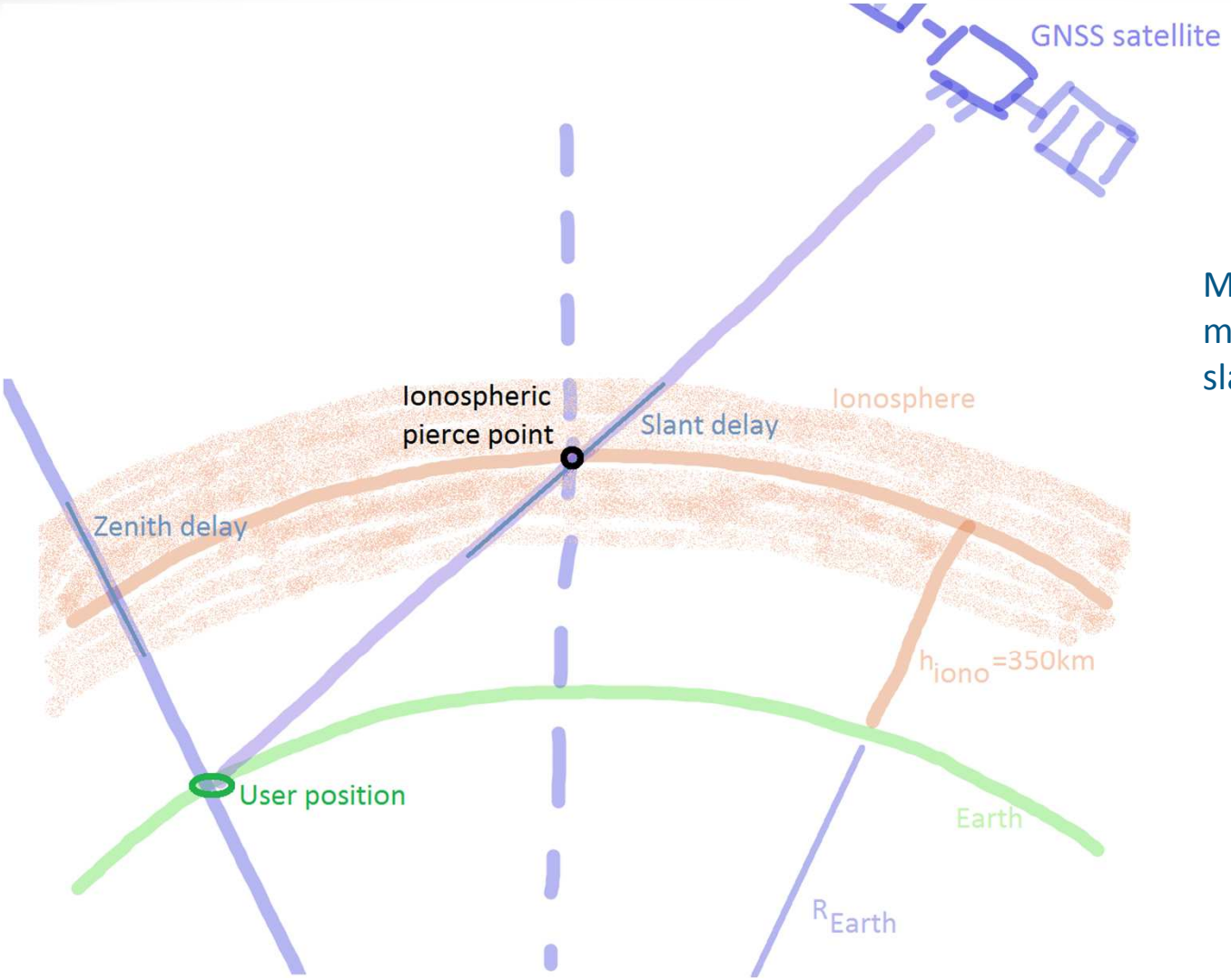
Content

- Space Weather and GNSS
- Single Frequency Iono Delay
- SBAS and Ionospheric Storms
- LAAS and Ionospheric Storms
- Scintillations
- Conclusion

Space Weather and GNSS

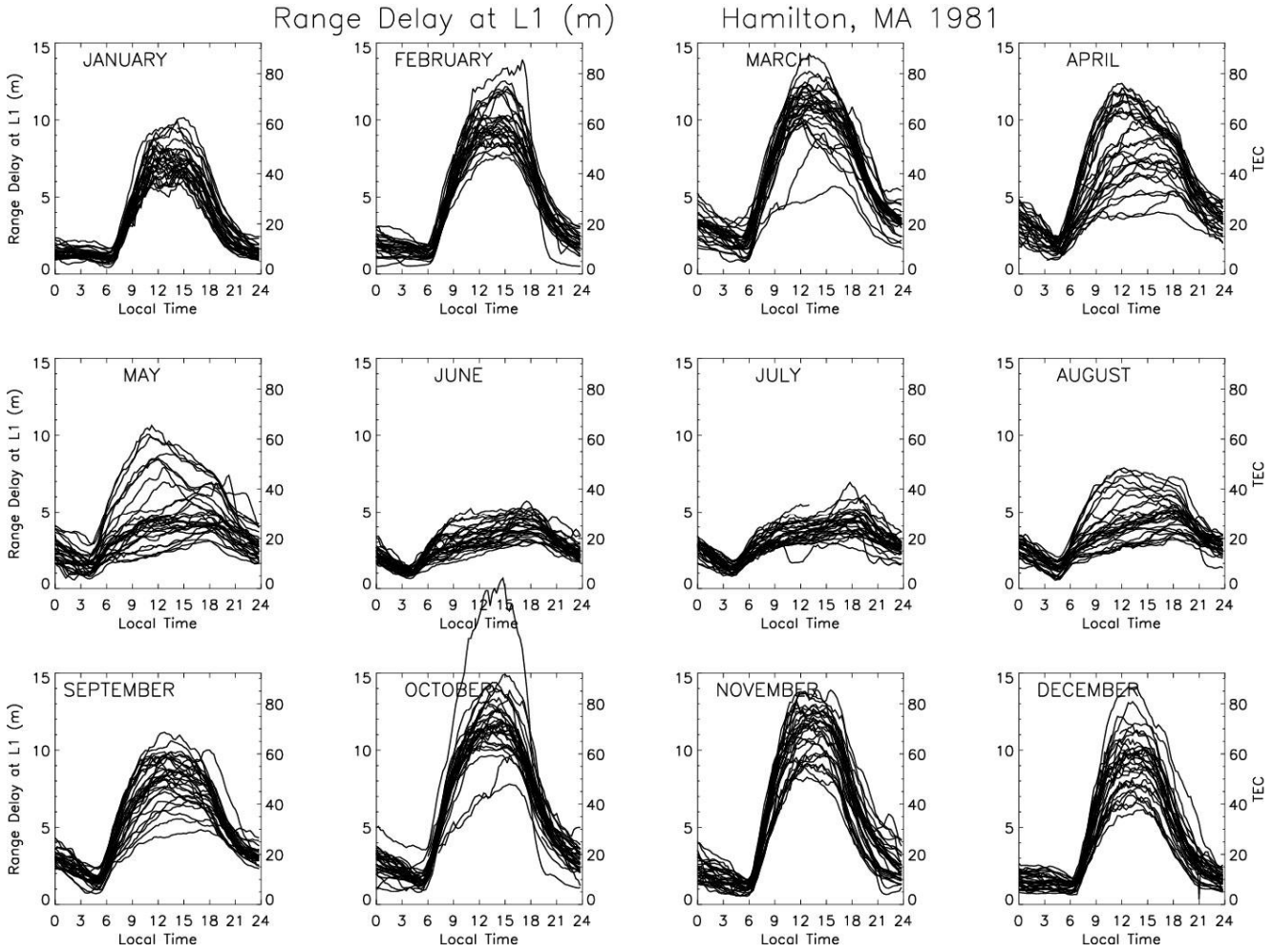


Single Frequency Iono Delay



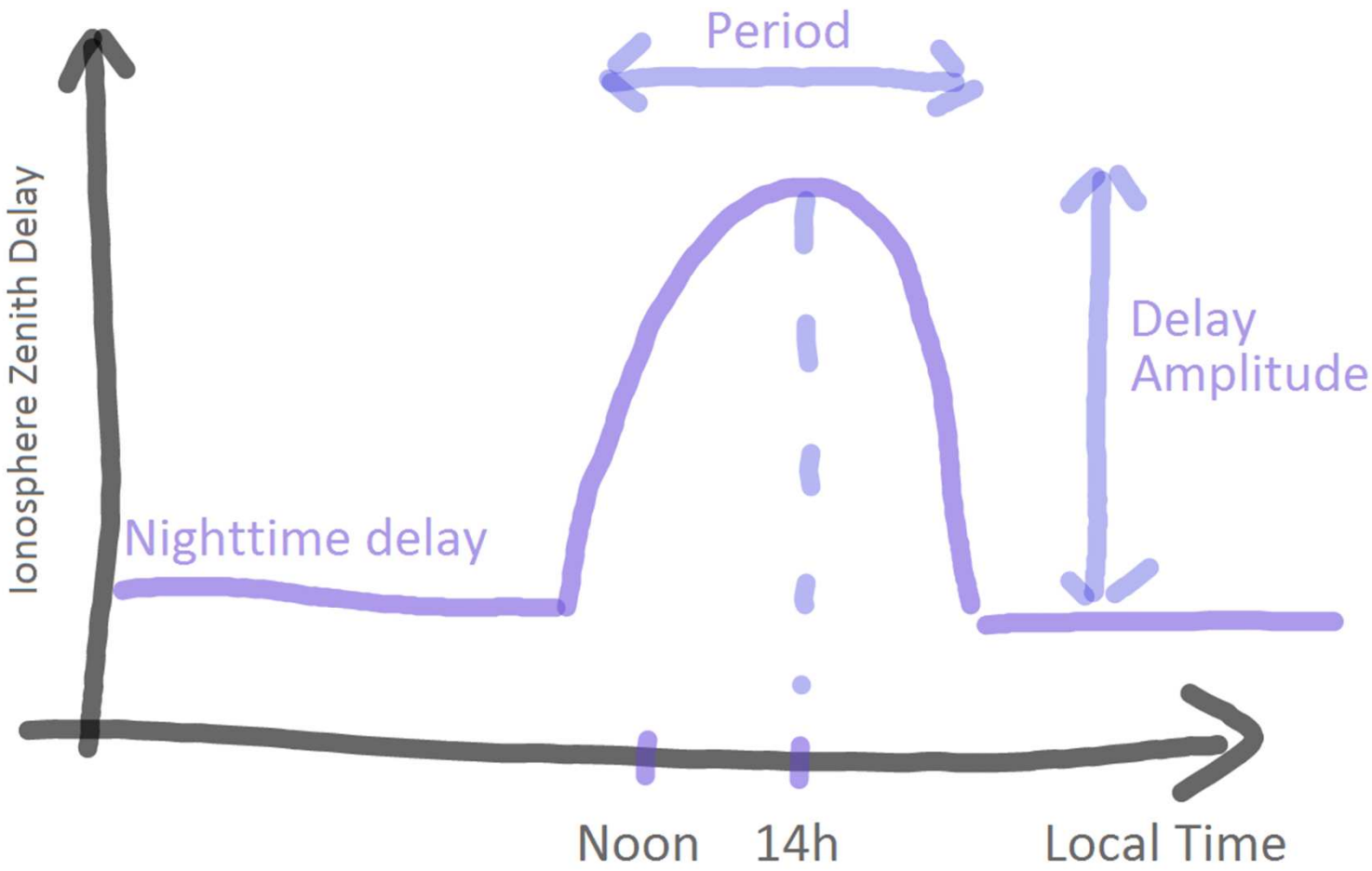
Map the Zenith delay via a mapping function to the slant delay.

Zenith Delay during a Solar Max



Powell, J. D., and Walter, Todd, Space Weather: Its Effect on GNSS, DGPS, SBAS, and Flight Inspection
Presented June 2010 at the International Flight Inspection Symposium (IFIS), Beijing, China

GPS Iono Zenith Delay Model



SBAS Iono Model

Appendix A
Page A-30

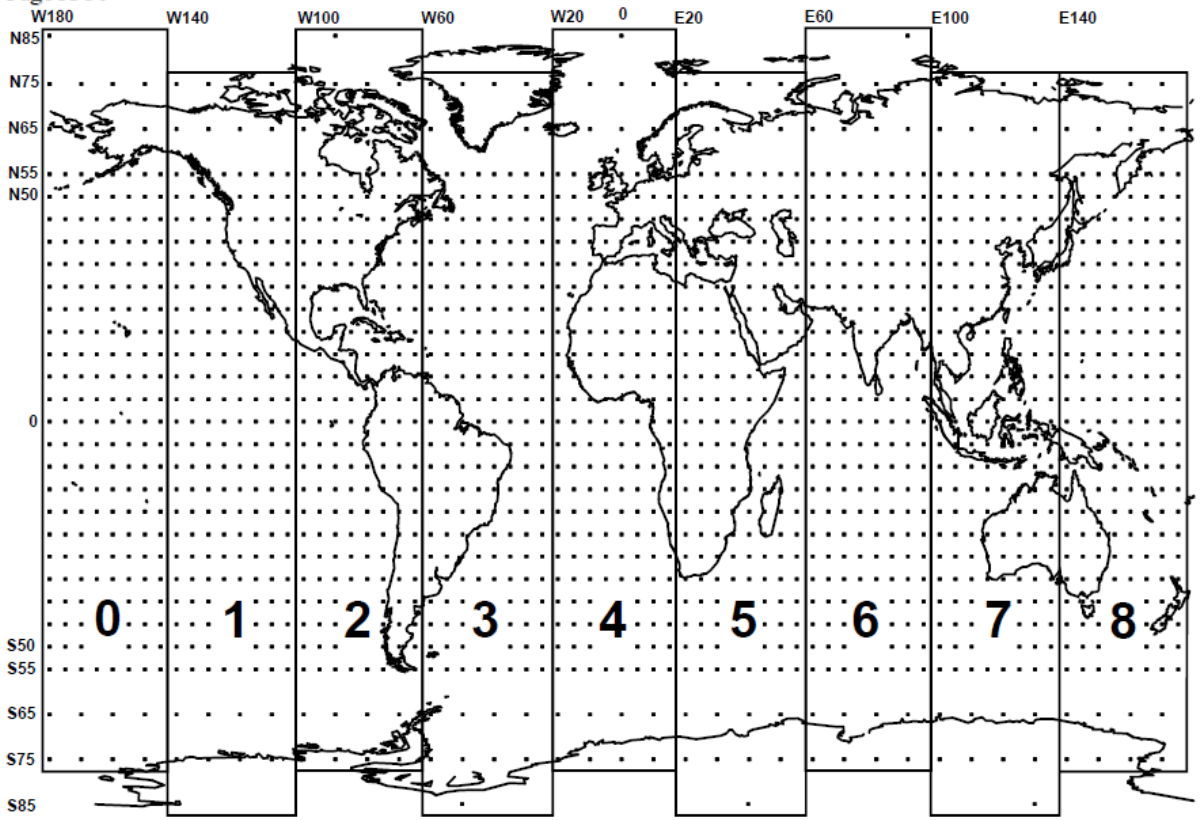
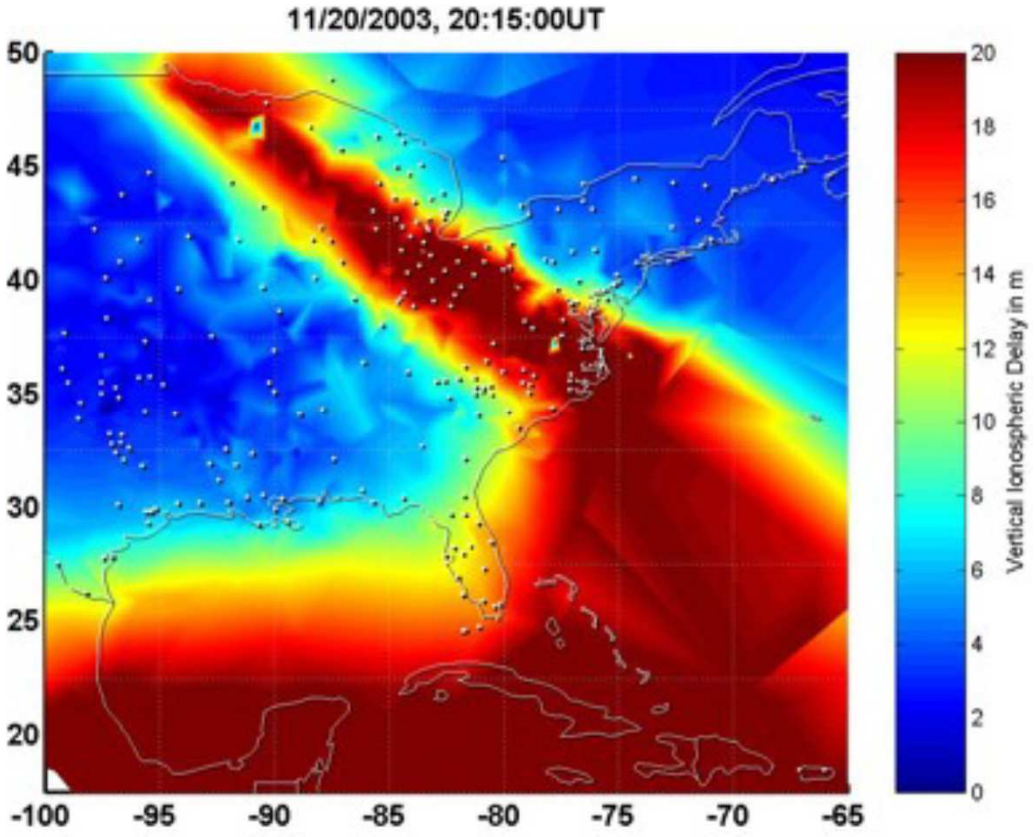


FIGURE A-14 PREDEFINED GLOBAL IGP GRID (BANDS 9 AND 10 ARE NOT SHOWN)

- For each gridpoint disseminate the zenith delay in the range form 0 to 63.750 m
- Update the information when necessary
- Use a mapping function to compute the slant delay

Iono Storms

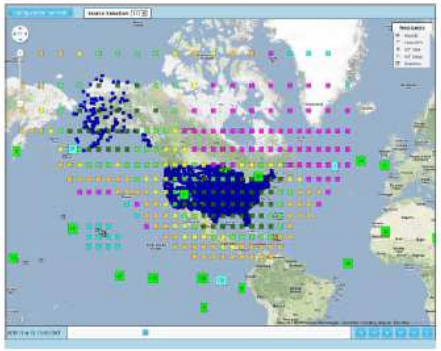


- Lee, Jiyun, Jung, Sungwook, Bang, Eugene, Pullen, Sam, and Enge, Per
Long Term Monitoring of Ionospheric Anomalies to Support the Local Area Augmentation System
Presented September 2010 at the ION Institute of Navigation Global Navigation Satellite Systems Conference, Portland, OR

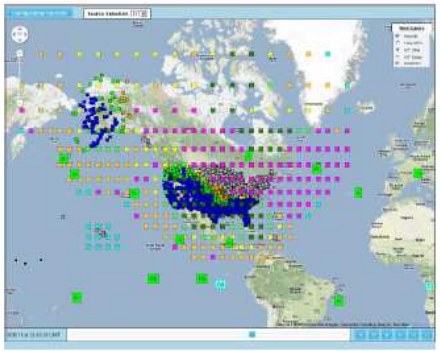
WAAS and a IONO Storm

15:51:30: Grid Points over Canada switch to storm state

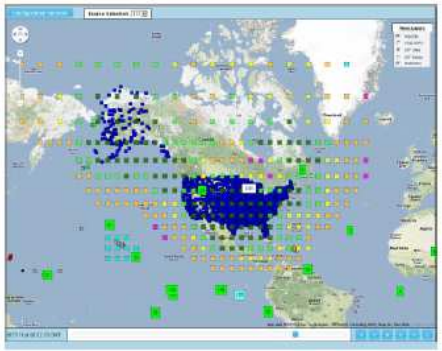
16:46:15: WAAS stops providing LPV 200 service in Alaska



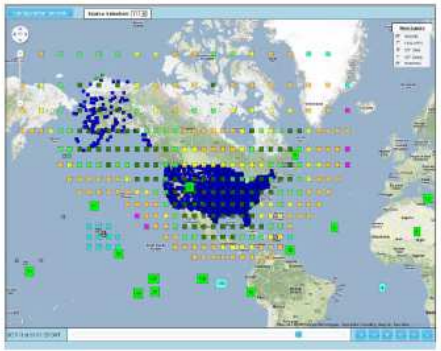
18:13:45: First airports in CONUS lose LPV 200 service (North central CONUS)



23:00:01: Storm continues



9/27/2011 00:52:15: All airports in CONUS support LPV-200



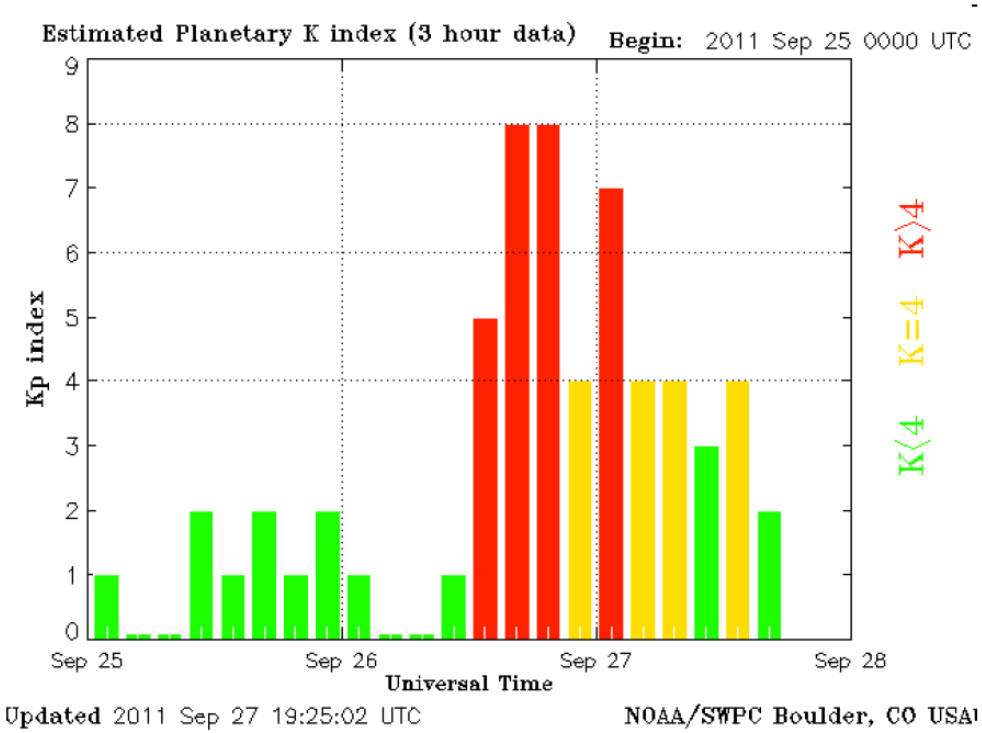
9/27/2011 01:01:29: Last grid point no longer in storm state

WAAS Reaction to Iono Activity on September 26, 2011
September 27, 2011

Federal Aviation Administration

KP Index

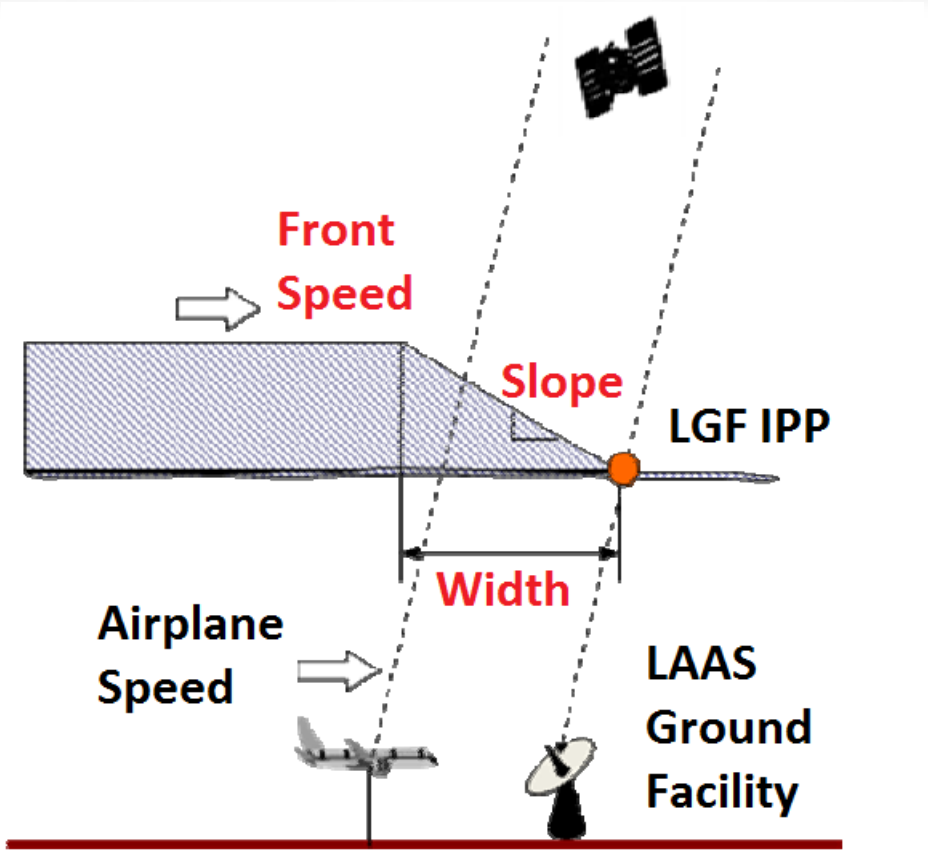
KP Index for September 25 - 28 2011



WAAS Reaction to Iono Activity on September 26, 2011
September 27, 2011

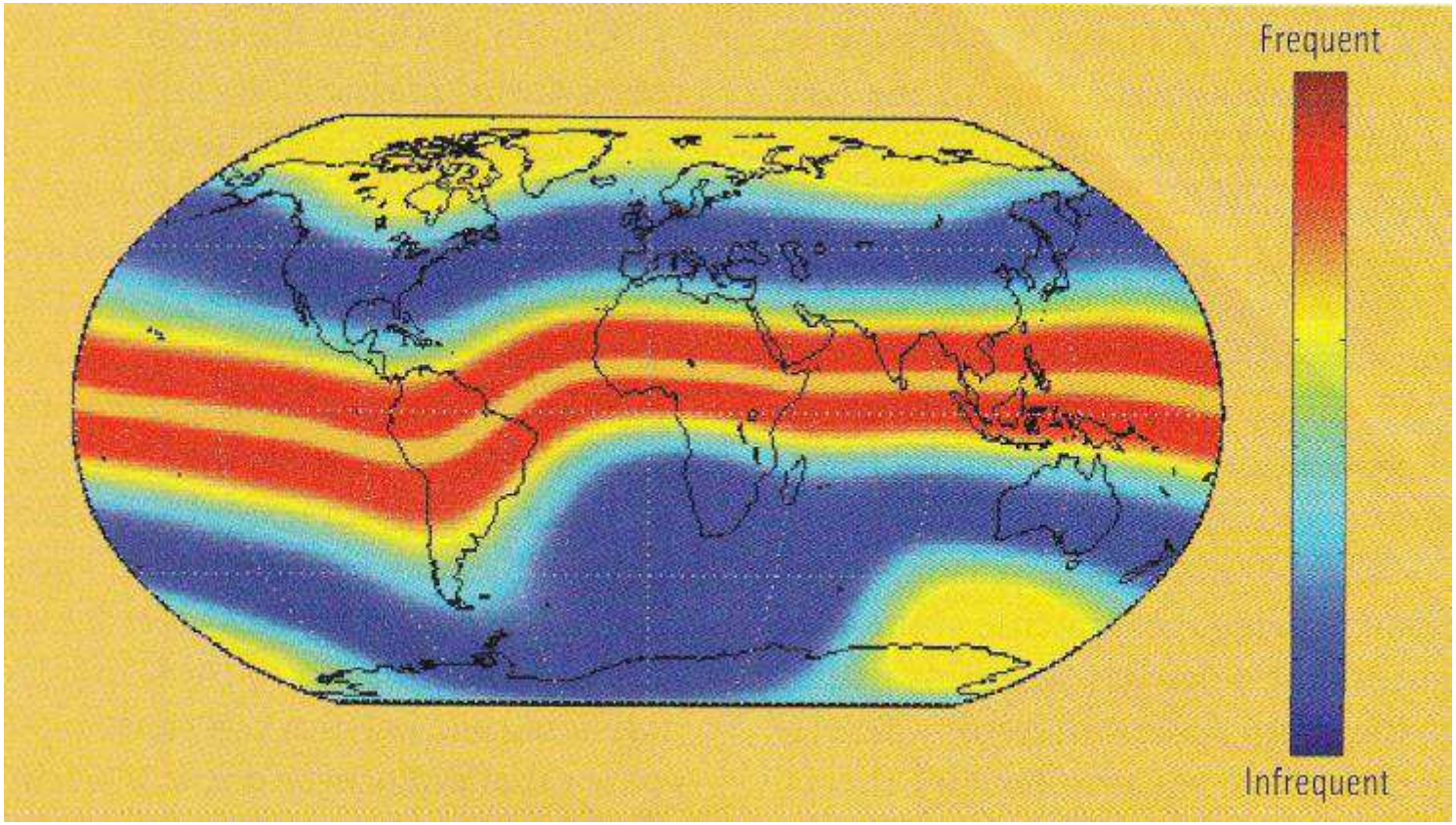
Federal Aviation Administration

Iono Storms and LAAS



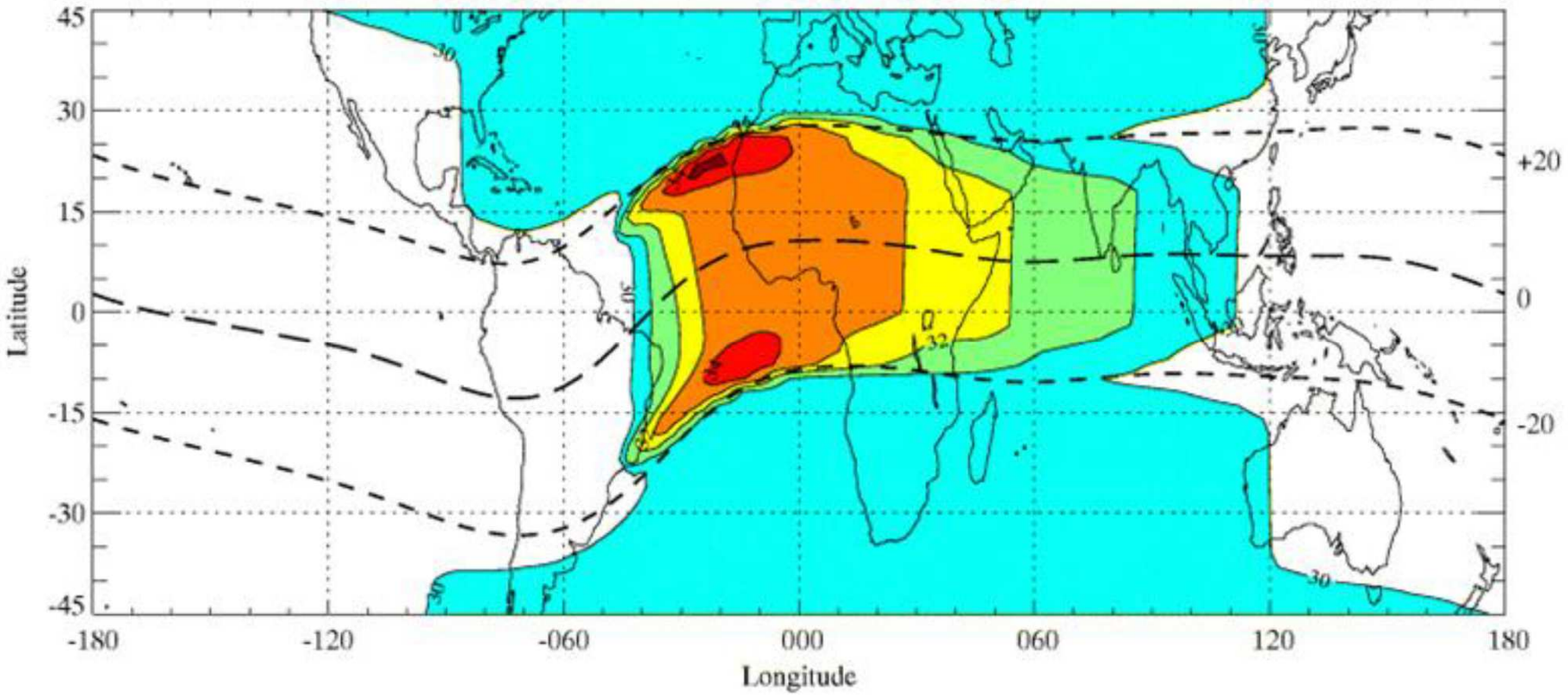
Lee, Jiyun, Jung, Sungwook, Bang, Eugene, Pullen, Sam, and Enge, Per
Long Term Monitoring of Ionospheric Anomalies to Support the Local Area Augmentation System
Presented September 2010 at the ION Institute of Navigation Global Navigation Satellite Systems Conference, Portland, OR

Scintillations



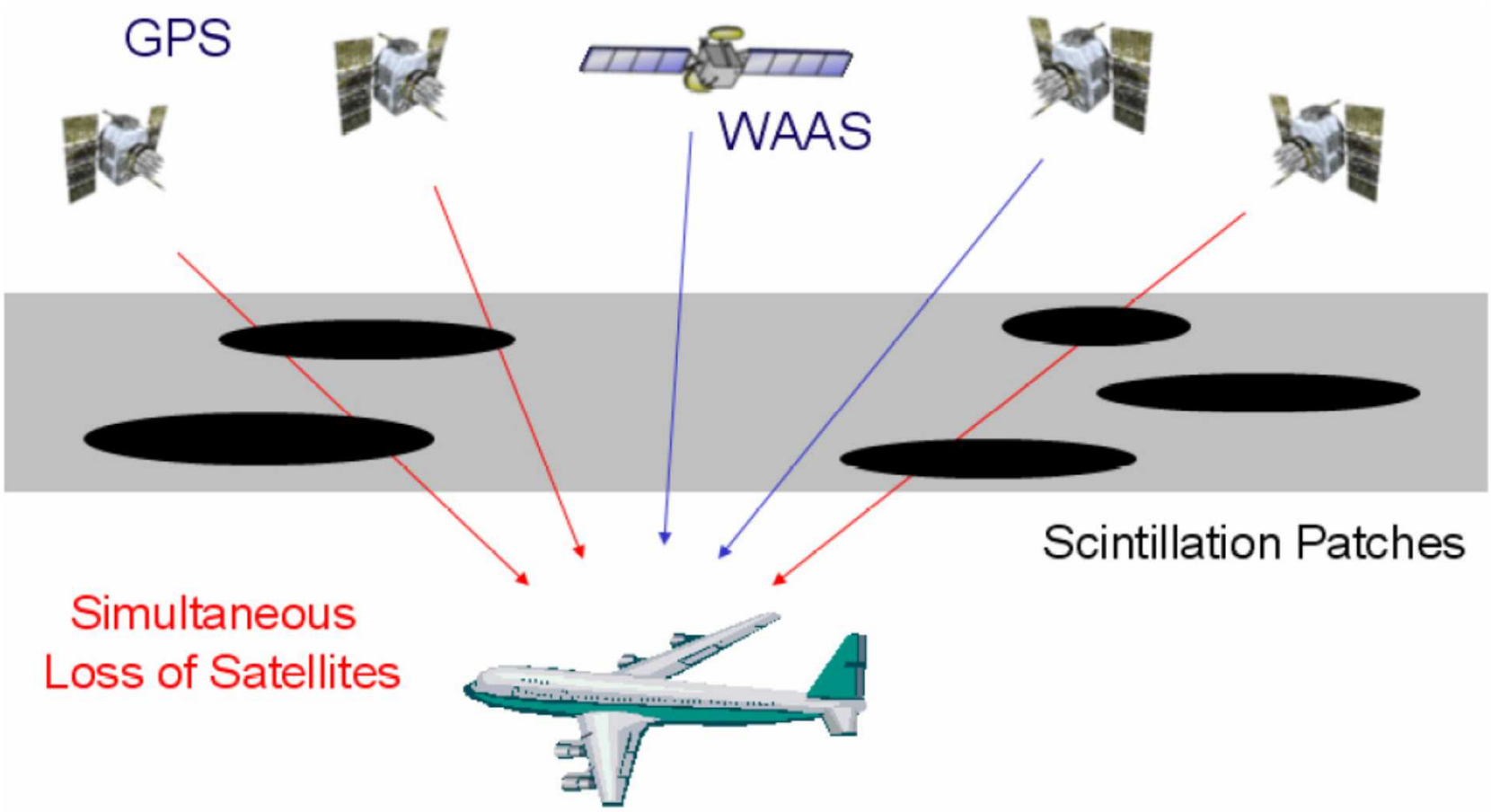
Powell, J. D., and Walter, Todd
Space Weather: Its Effect on GNSS, DGPS, SBAS, and Flight Inspection
Presented June 2010 at the International Flight Inspection Symposium (IFIS), Beijing, China

Scintillations



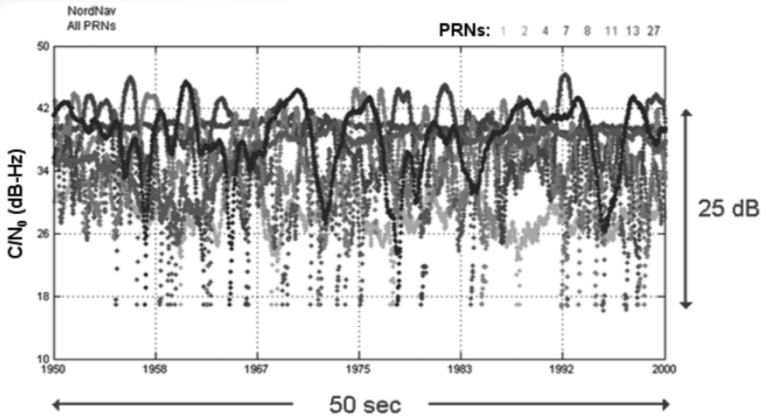
Powell, J. D., and Walter, Todd Space Weather: Its Effect on GNSS, DGPS, SBAS, and Flight Inspection
Presented June 2010 at the International Flight Inspection Symposium (IFIS), Beijing, China

Scintillation Threat



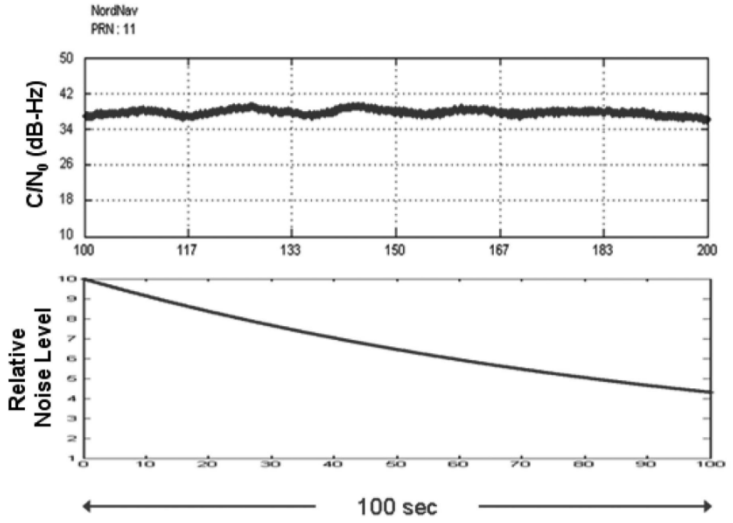
Lee, Jiyun, Jung, Sungwook, Bang, Eugene, Pullen, Sam, and Enge, Per
Long Term Monitoring of Ionospheric Anomalies to Support the Local Area Augmentation System
Presented September 2010 at the ION Institute of Navigation Global Navigation Satellite Systems Conference, Portland, OR

Scintillation



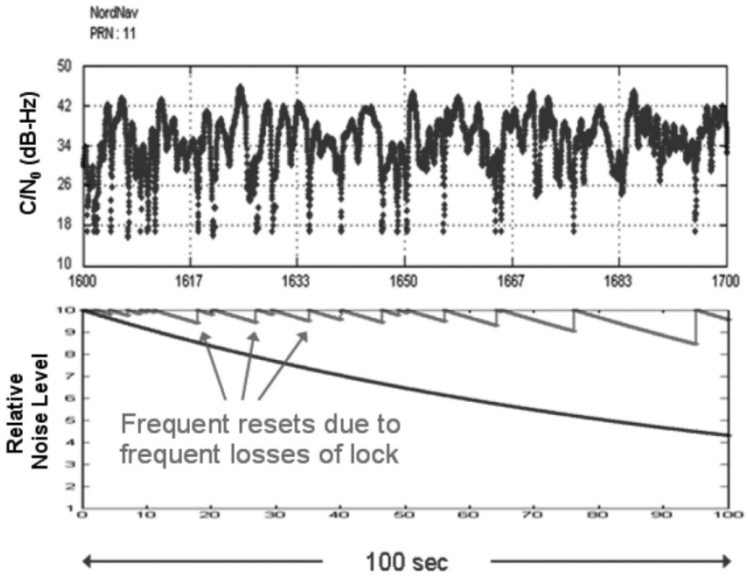
C/N_0 outputs of all satellites in view during strong scintillation. Different grey tones represent different satellites. Data collected at Ascension Island in 2001 and processed using NordNav commercial software receiver.

Decreasing code noise by Hatch filtering under nominal conditions without scintillation. Carrier tracking lock assumed to be established at 0 s. C/N_0 remains nearly constant over 100 s.



Seo, Jiwon, Walter, Todd, and Enge, Per, Availability Impact on GPS Aviation Due to Ionospheric Scintillation, IEEE Transactions on Aerospace and Electronic Systems, 2011

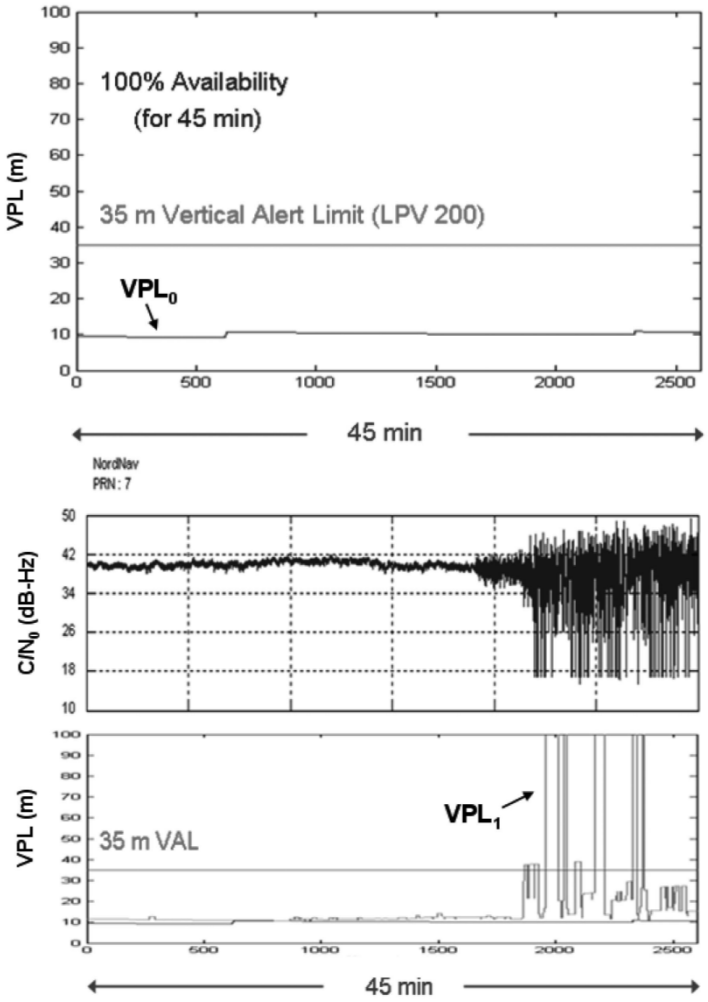
Scintillation



Frequent reset of Hatch filter and high code noise level during severe scintillation. Receiver is assumed to reestablish carrier lock promptly after loss of lock. More than 25 dB fading can occur during severe scintillation.

Seo, Jiwon, Walter, Todd, and Enge, Per, Availability Impact on GPS Aviation Due to Ionospheric Scintillation, IEEE Transactions on Aerospace and Electronic Systems, 2011

Scintillation



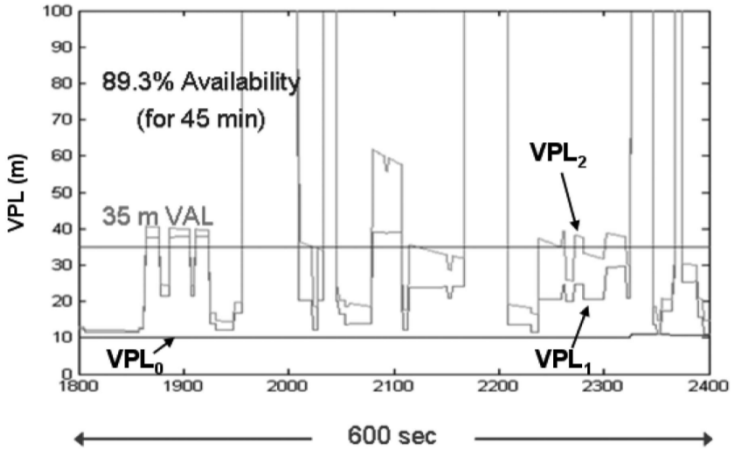
Simulated VPL without considering scintillation effects (labelled as VPL_0). Actual satellite geometry during the 45 min of severe scintillation at Ascension Island on 18 March 2001 was used for VPL calculation.

C/N_0 and VPL during severe scintillation period considering satellite outages only (labelled as VPL_1). Longest allowable reacquisition time limit under the WAAS MOPS (20 s) was always assumed for VPL calculation. Effect of shortened carrier smoothing time not yet considered.

Seo, Jiwon, Walter, Todd, and Enge, Per, Availability Impact on GPS Aviation Due to Ionospheric Scintillation, IEEE Transactions on Aerospace and Electronic Systems, 2011

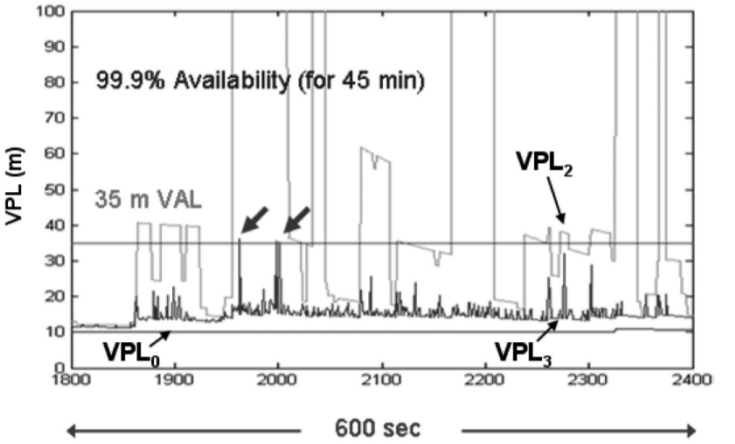
Scintillation

Impact of shortened carrier smoothing times due to frequent fades (600 s example from the 45 min data). VPL_1 curve considering satellite outages only, but VPL_2 curve considers effects from both satellite outages and shortened carrier smoothing times. Assumed reacquisition time 20 s.



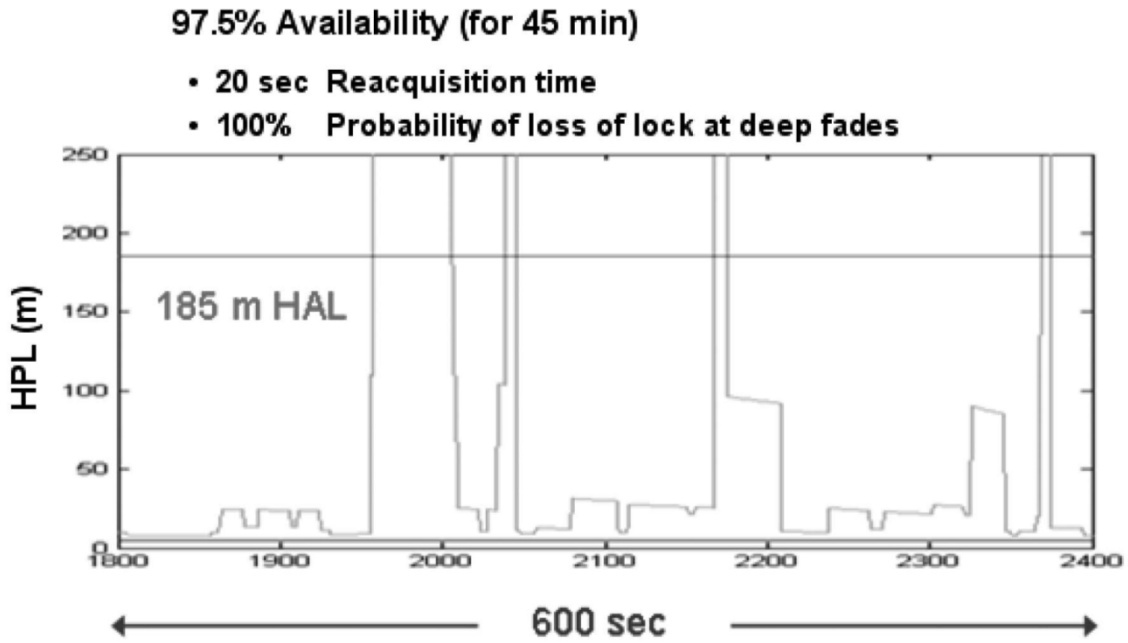
Availability benefit of shorter reacquisition time (1 s versus 20 s). VPL_2 curve assumes 20 s reacquisition time (WAAS MOPS limit) and VPL_3 curve assumes 1 s reacquisition time.

Figure shows clear availability benefit of shorter reacquisition time for receiver (600 s example from the 45 min data).



Seo, Jiwon, Walter, Todd, and Enge, Per, Availability Impact on GPS Aviation Due to Ionospheric Scintillation, IEEE Transactions on Aerospace and Electronic Systems, 2011

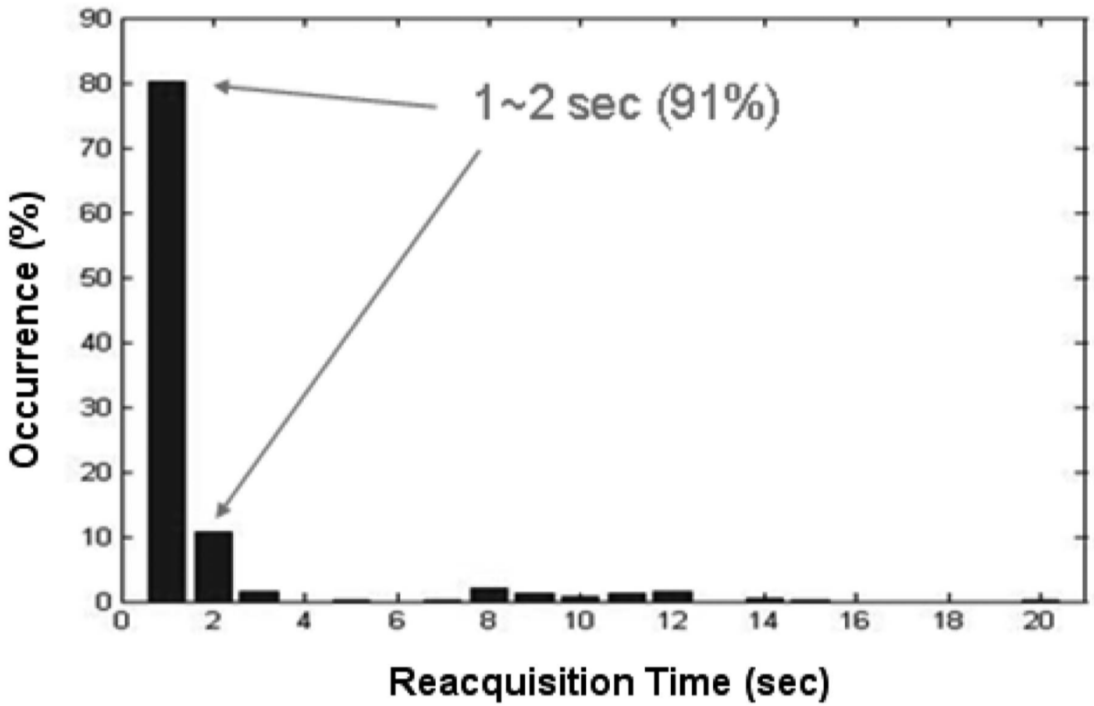
Scintillation



HPL during severe scintillation (600 s example from the 45 min data). Even with the most conservative assumptions about reacquisition time and probability of loss of lock, operational availability for RNP-0.1 during the 45 min is 97.5%.

Seo, Jiwon, Walter, Todd, and Enge, Per, Availability Impact on GPS Aviation Due to Ionospheric Scintillation, IEEE Transactions on Aerospace and Electronic Systems, 2011

Scintillation



Observed reacquisition times of a certified WAAS receiver during a 36-day campaign in Brazil during solar minimum.

Performance was much better than WAAS MOPS requirement (20 s limit).

Seo, Jiwon, Walter, Todd, and Enge, Per, Availability Impact on GPS Aviation Due to Ionospheric Scintillation, IEEE Transactions on Aerospace and Electronic Systems, 2011

Conclusion

- Space Weather affects GNSS
- Satellites might get lost
- Single Frequency Landing applications affected most
- En-route seems to be not so much a problem

EUROPEAN AVIATION SAFETY AGENCY
AGENCE EUROPÉENNE DE LA SÉCURITÉ AÉRIENNE
EUROPÄISCHE AGENTUR FÜR FLUGSICHERHEIT

Your safety is our mission.

easa.europa.eu