Gannon Storm Scintillation Observations via the NOAA Data Collection System

Theodore Beach[1], Daniel Gillies[2], William Dronen[3], Keith Groves[1], Brett Betsill[4], Matt Taylor[4], Nai-Yu Wang[2], Alan Hoskinson[1]

(1) Institute for Scientific Research, Boston College, Newton, MA, USA (theodore.beach@bc.edu)
(2) NOAA National Environmental Satellite, Data, and Information Service (NESDIS), Greenbelt, MD, USA, https://www.nesdis.noaa.gov/
(3) NOAA NESDIS, Suitland, MD, USA, https://www.nesdis.noaa.gov/
(4) Microcom Design, Inc., Cockeysville, MD, USA, https://www.microcomenviro.com/

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Overview

- The May 2024 Gannon storm caused rare mid-latitude scintillation
  - Some L-band (1.6 GHz) scintillation was detected in North America
  - More sensitive UHF (~400 MHz) measurements are available from NOAA data collection platform (DCP) transmissions, part of the GOES Data Collection System (DCS)
- Tradeoffs in using DCP measurements for scintillation monitoring
  - Pros: more sensitive UHF band than GNSS, extensive geographic coverage (western hemisphere), downlink signal is relatively straightforward to obtain
  - Cons: short transmissions (3–20 s), infrequent retransmissions from a given site (~1/hr typ)
- Initial work shows promise of the DCP signal technique
  - Demonstrated that bent-pipe analog transponder can faithfully reproduce variations
  - Studied statistics of short-time scintillation records
  - Identified some probable scintillation occurrence in Gannon Storm data

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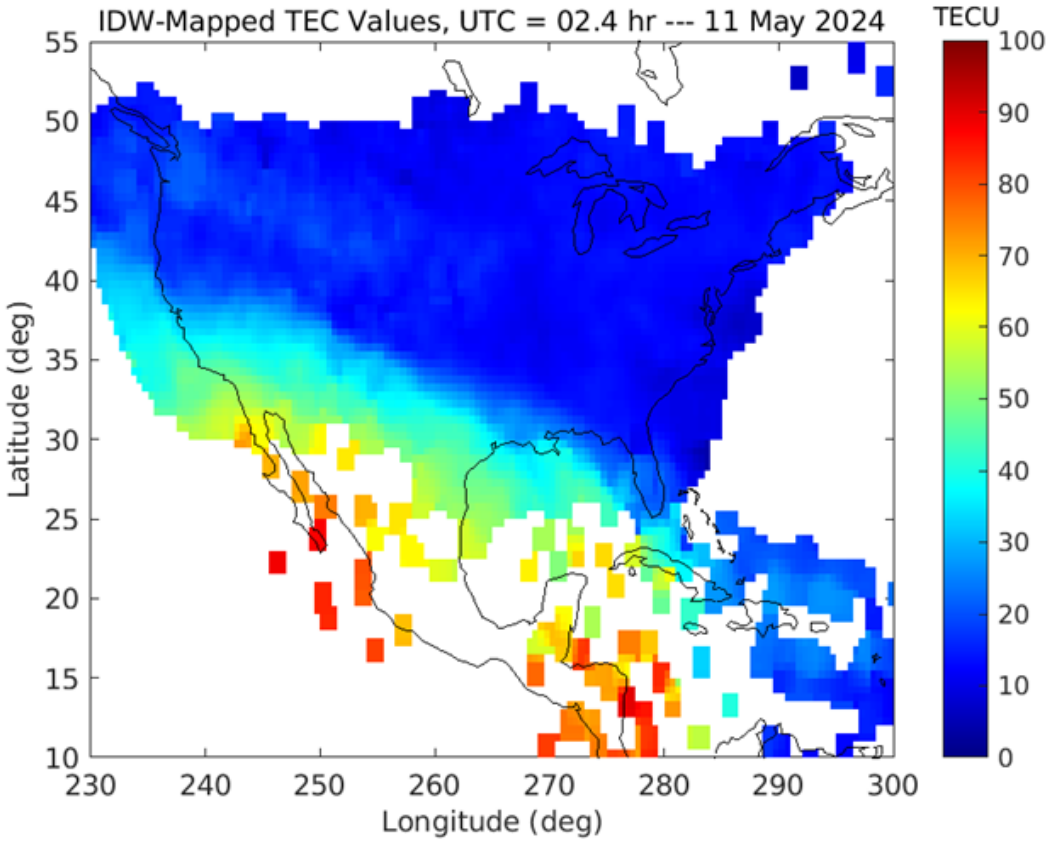
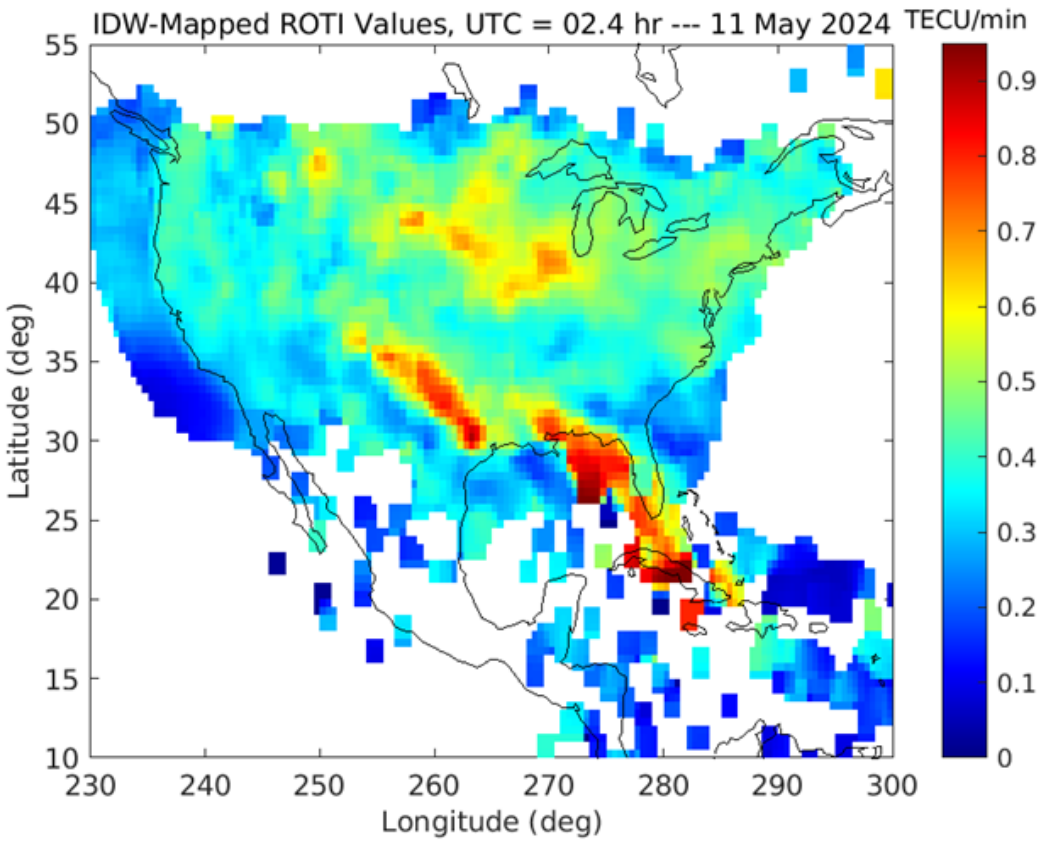
Storm Context

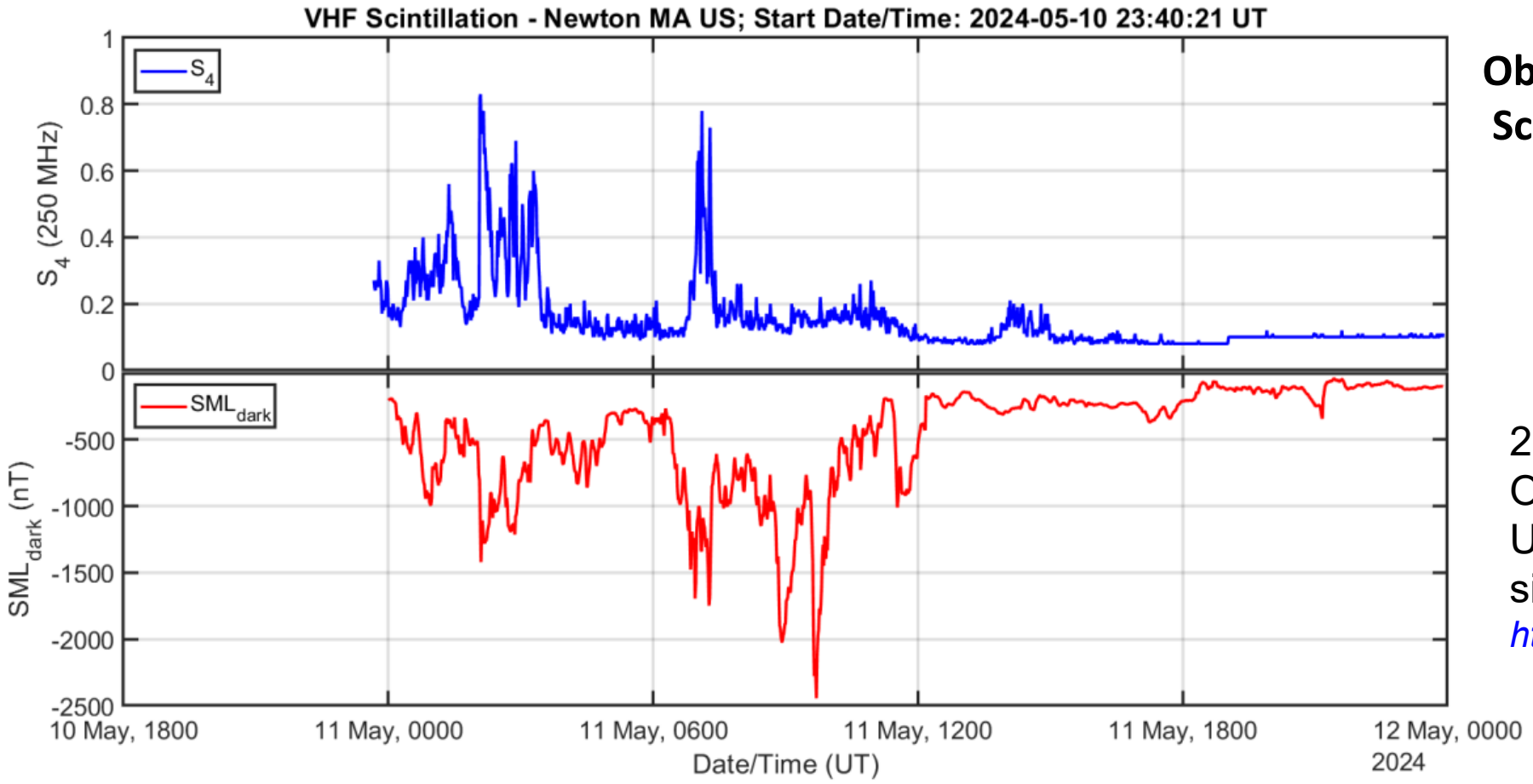
Storm Environment (Traditional GNSS TEC)

Weighted Madrigal TEC (Left) and Derived ROTI (Right) – 11 May 2024, 0226 UT





Mid-Latitude VHF Scintillation (250 MHz)



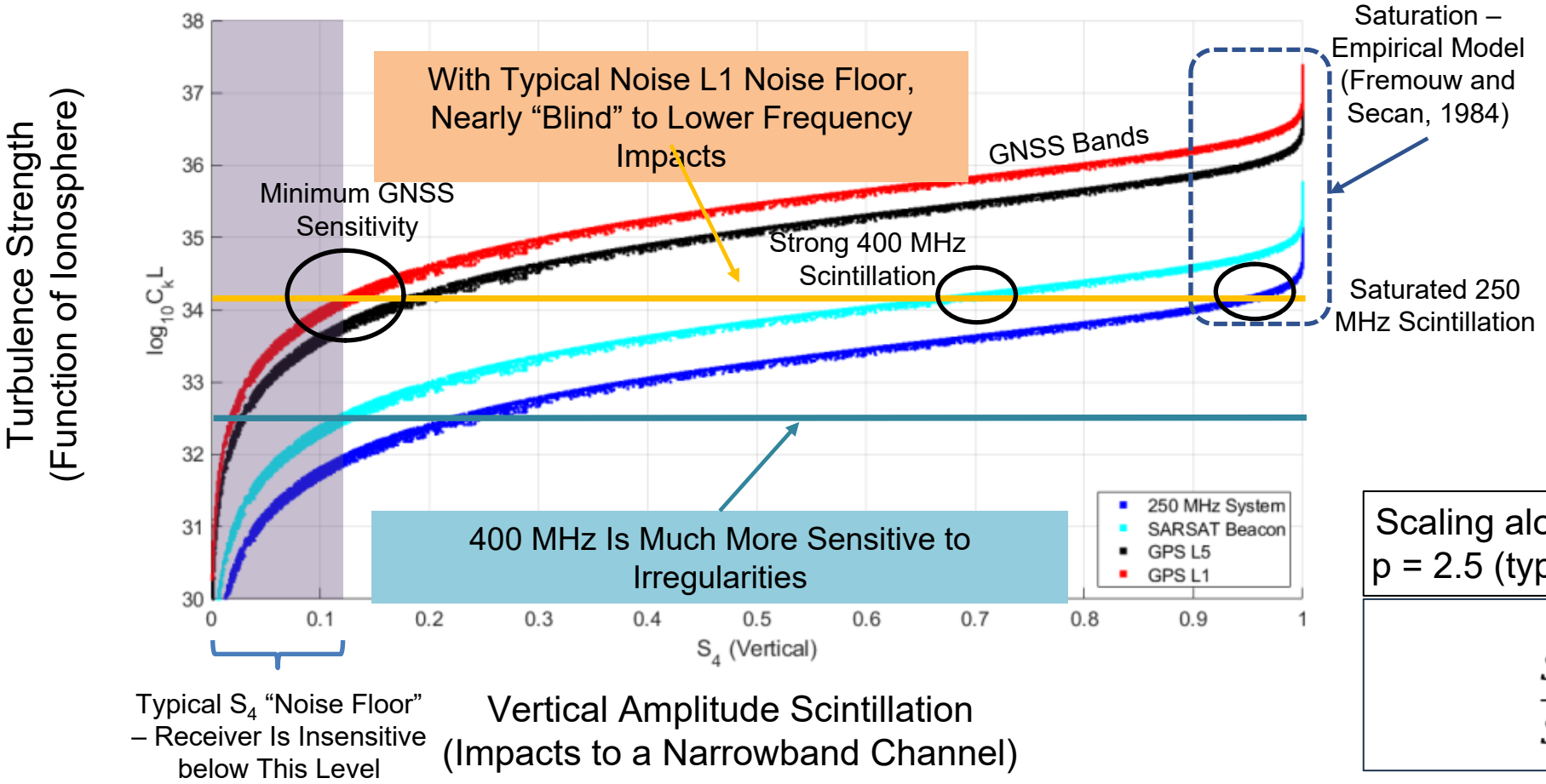
Observed Mid-Latitude VHF Scintillation (10 May 2024)

$$S_4^2 = \frac{\langle I^2 \rangle - \langle I \rangle^2}{\langle I \rangle^2}$$

250-MHz S4 (Top) Observed at Newton MA, US with SuperMAG dark side SML (Bottom) *https://supermag.jhuapl.edu/*

Frequency-Dependent S_4 Sensitivity (Equatorial)

By the Time S_4 Registers at GPS L1, Lower Bands Are Already Strongly Impacted



Frequencies Plotted

- GPS L1 – 1.57542 GHz
- GPS L5 – 1.17645 GHz
- SARSAT – 406 MHz
- 250 MHz

Scaling along same line of sight (LOS)
p = 2.5 (typ) for equatorial irregularities

$$\frac{S_{4w1}{}^2}{S_{4w0}{}^2} = \left(\frac{\lambda_1}{\lambda_0}\right)^{p/2+3/2}$$

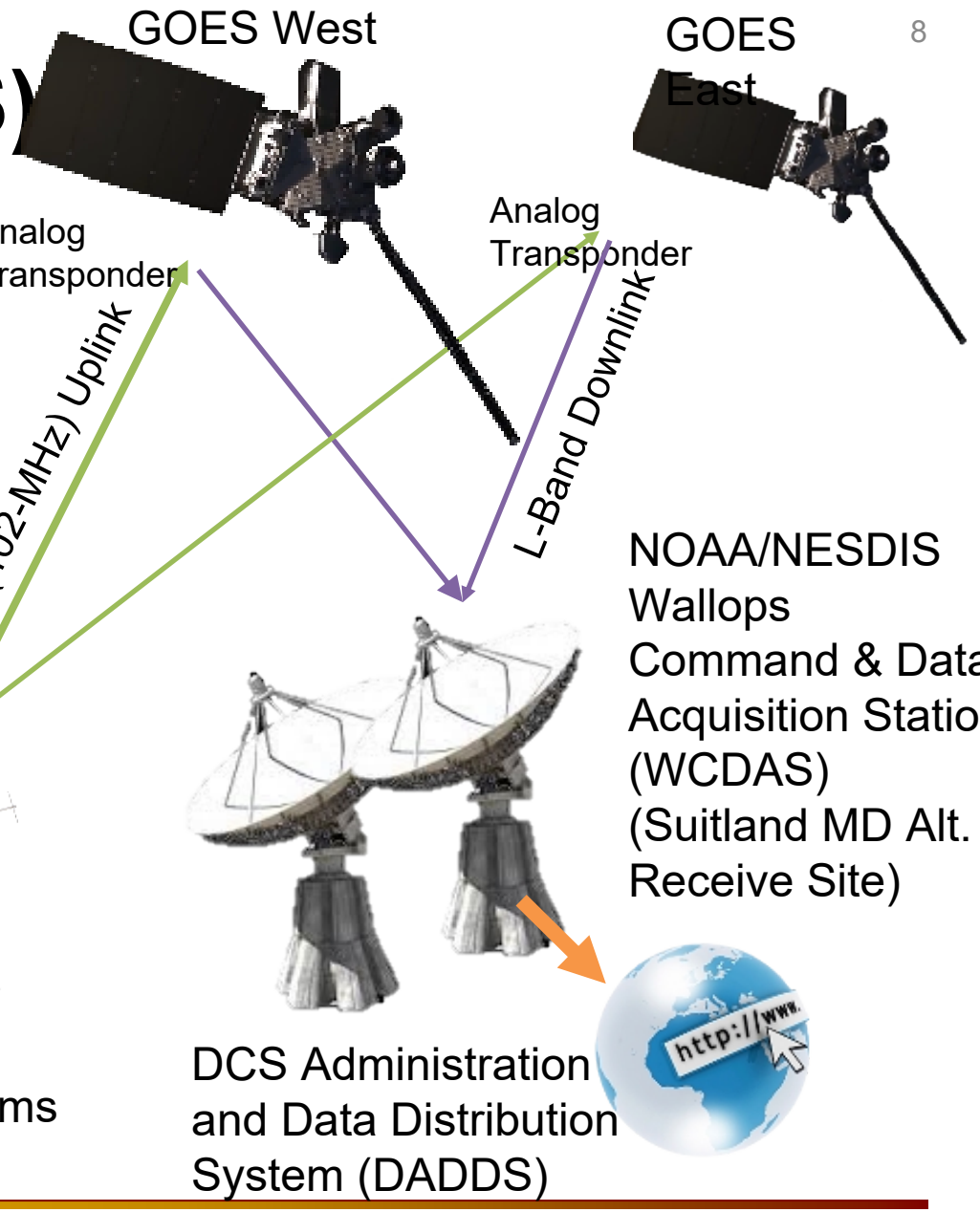
DCS Background

Data Collection System (DCS)

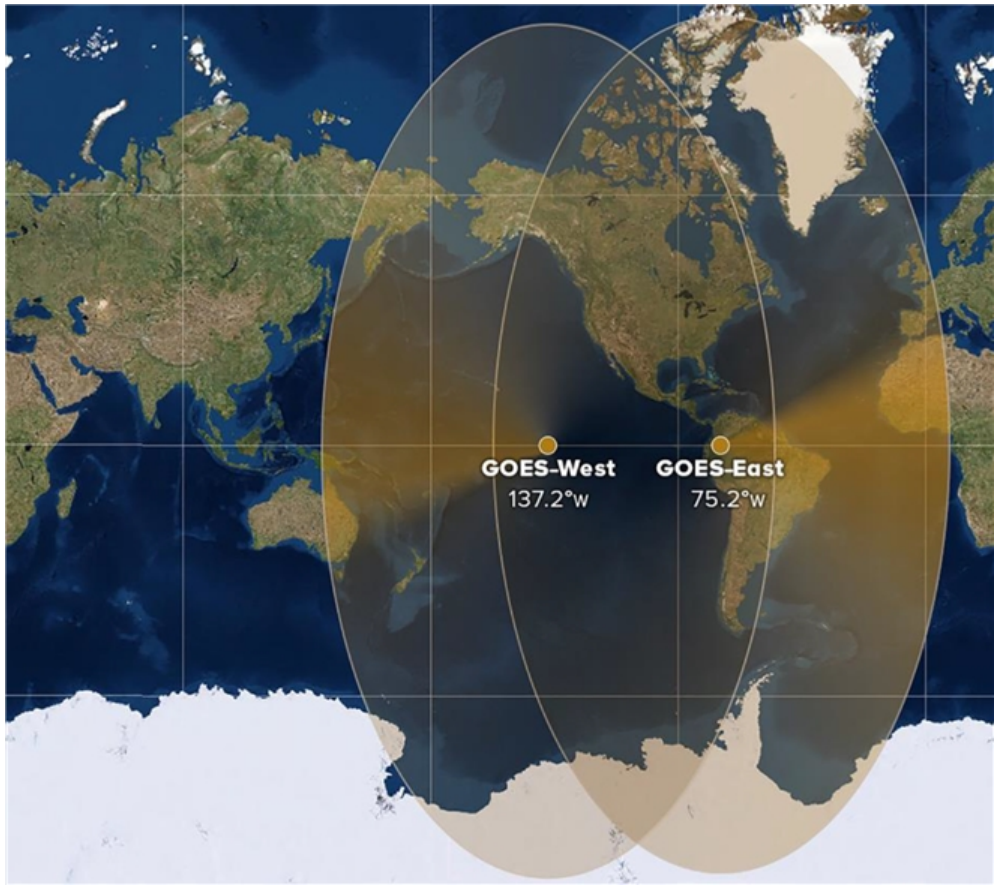
Satellites (Domestic):	GOES East & West (Current) GeoXO East & West (Future)
Data Collection Platforms:	32,000+ active 43,000+ registered

Function	Frequency (MHz)
DCP Uplink (Data)	401.7 – 402.4
Bent-Pipe Downlink	1679.7 – 1680.4

DCS = Environmental data relay system for western hemisphere platforms (carries ~1 million

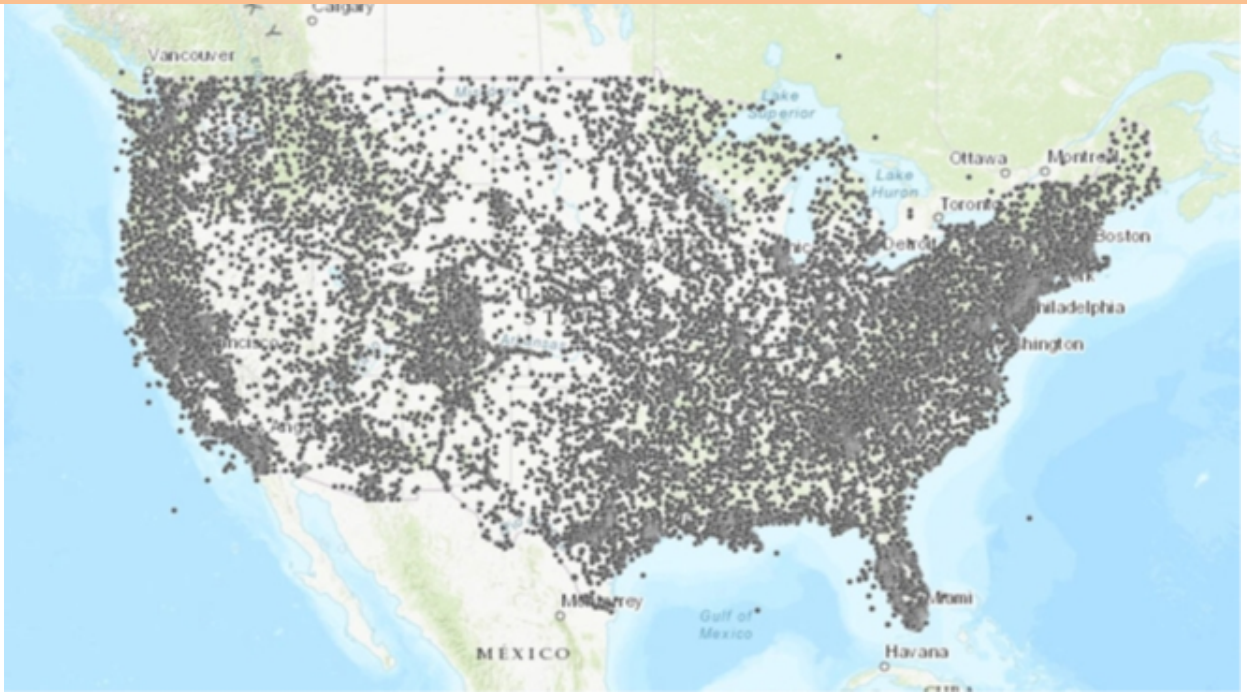


Coverage and Contiguous US Transmitters



GOES-E/W DCS Ground Coverage Areas

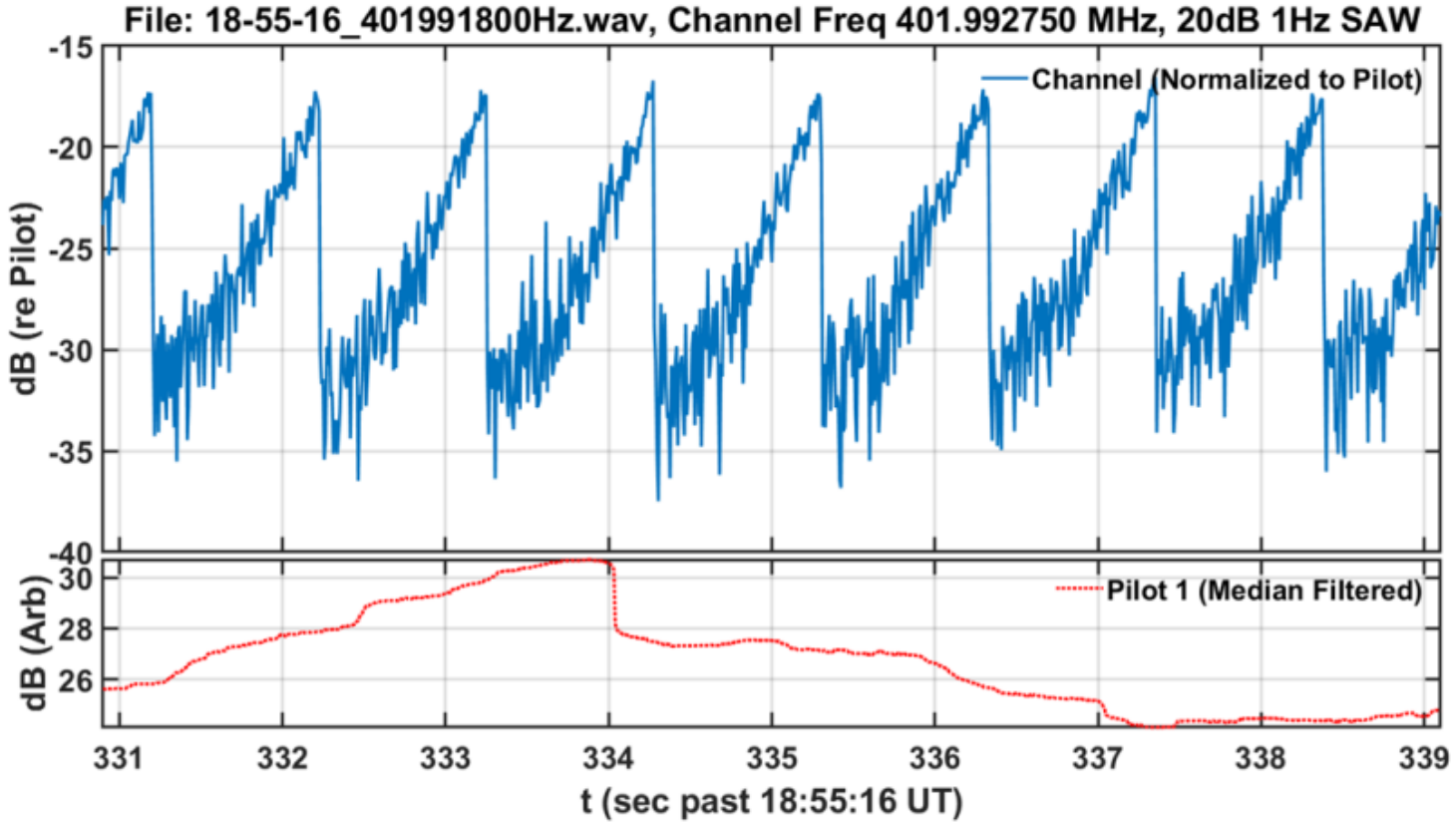
Extensive DCP Coverage May Help Compensate for Low Transmission Cadence



CONUS DCP Transmitter Distribution

Transponder Response Verification

Team Tested Artificial Signal Modulation with Transmissions from Microcom (Maryland, US) in June 2024



Reproduced 20 dB, 1 Hz Sawtooth Wave Broadcast from Microcom to GOES-16 (Top); ALC Effects on Pilot Channel Amplitude (Bottom)

Achieved test goals:

- **Verified that transponder frequency response appears adequate**
- **Demonstrated Automatic Level Control (ALC) Compensation**

Tested Cases with and Without DCP Modulation, Plus Other Waveform Patterns & Frequencies

DCS Observations of Scintillation

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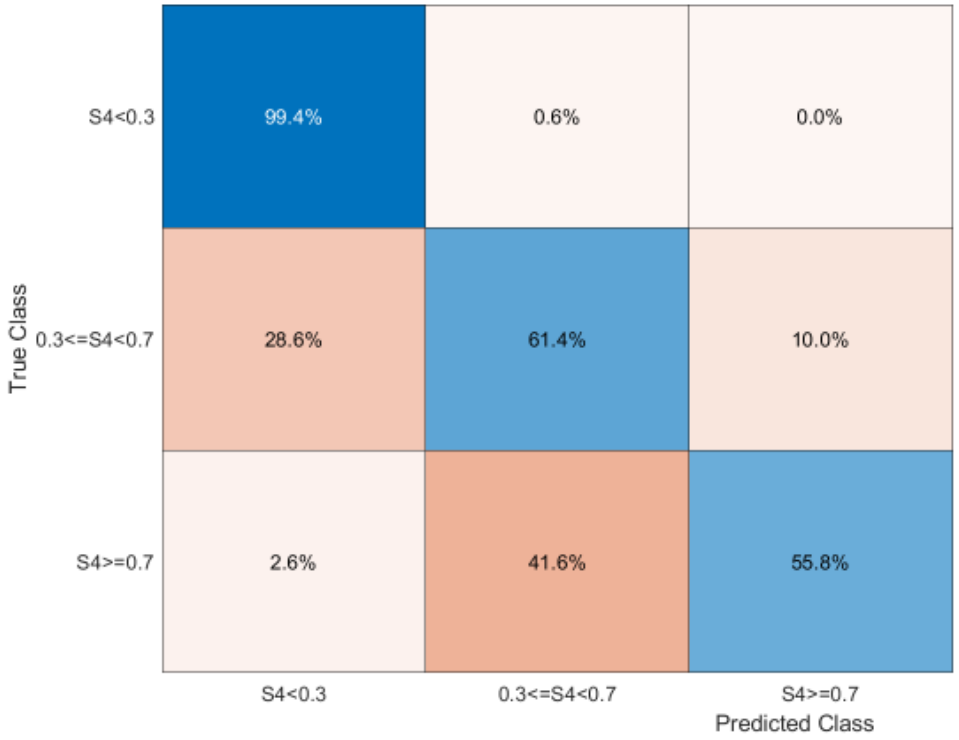
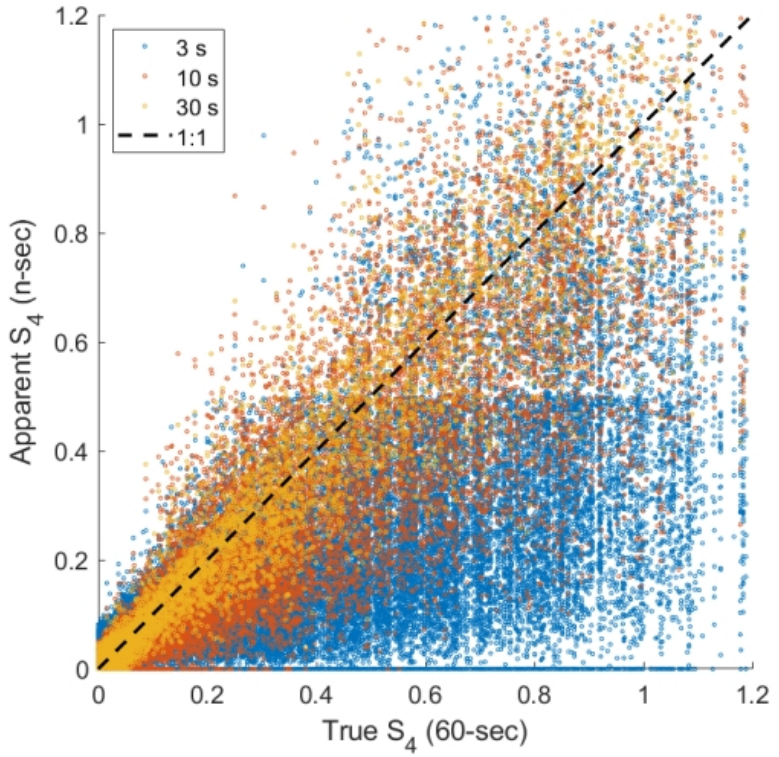
Effects of Short Transmissions

Short Averaging Periods (< Fresnel Period) Typically Lead to S_4 Underestimation



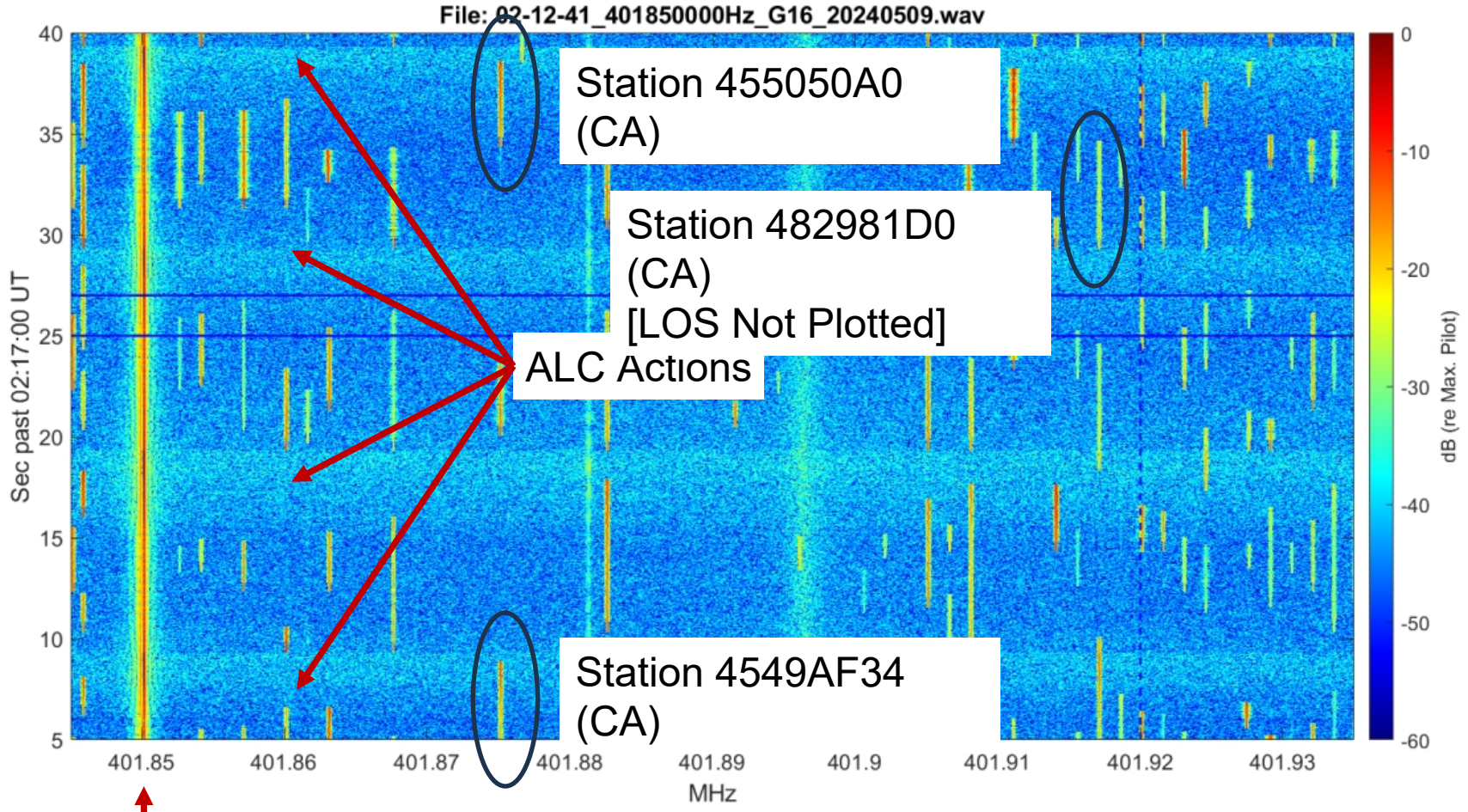


Data Derived from 50-Hz 1.6 GHz Equatorial Scintillation Time Series (Fixed Link) with Drift Timescales Scaled to 400 MHz Fresnel Scale (Simulated 25-Hz Sampling)

Sample Confusion Matrix Plot, Where Apparent Scintillation (Estimated from "Predicted Class" Is from a 15-sec S_4 Short Time Series) Vs. 60-second Value

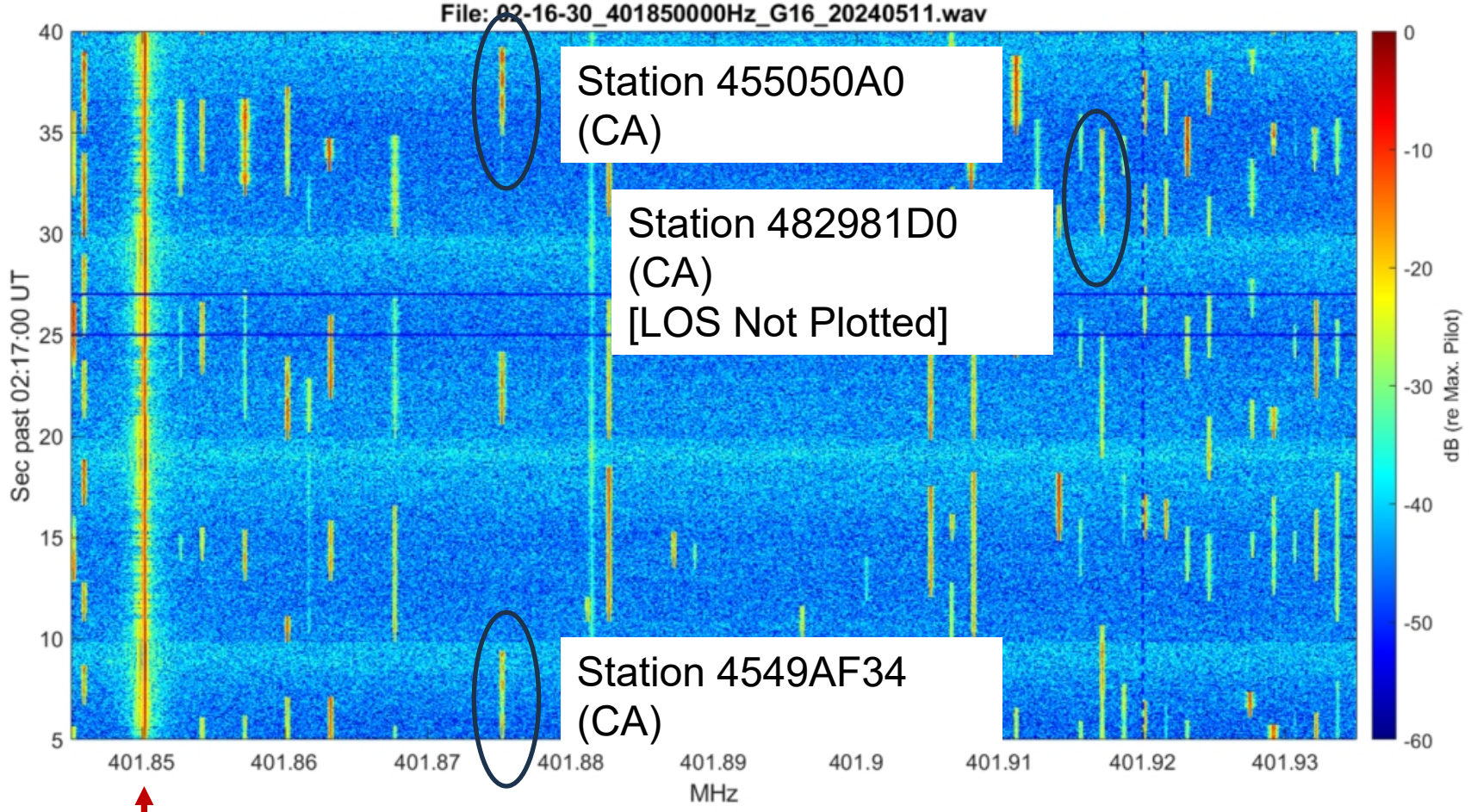
Pre-Storm Amplitude Monitoring

Pre-Storm, 09 May 2024; Will Examine Peak Scintillation Timeframe 2 Days Later



Storm-Time Amplitude Monitoring

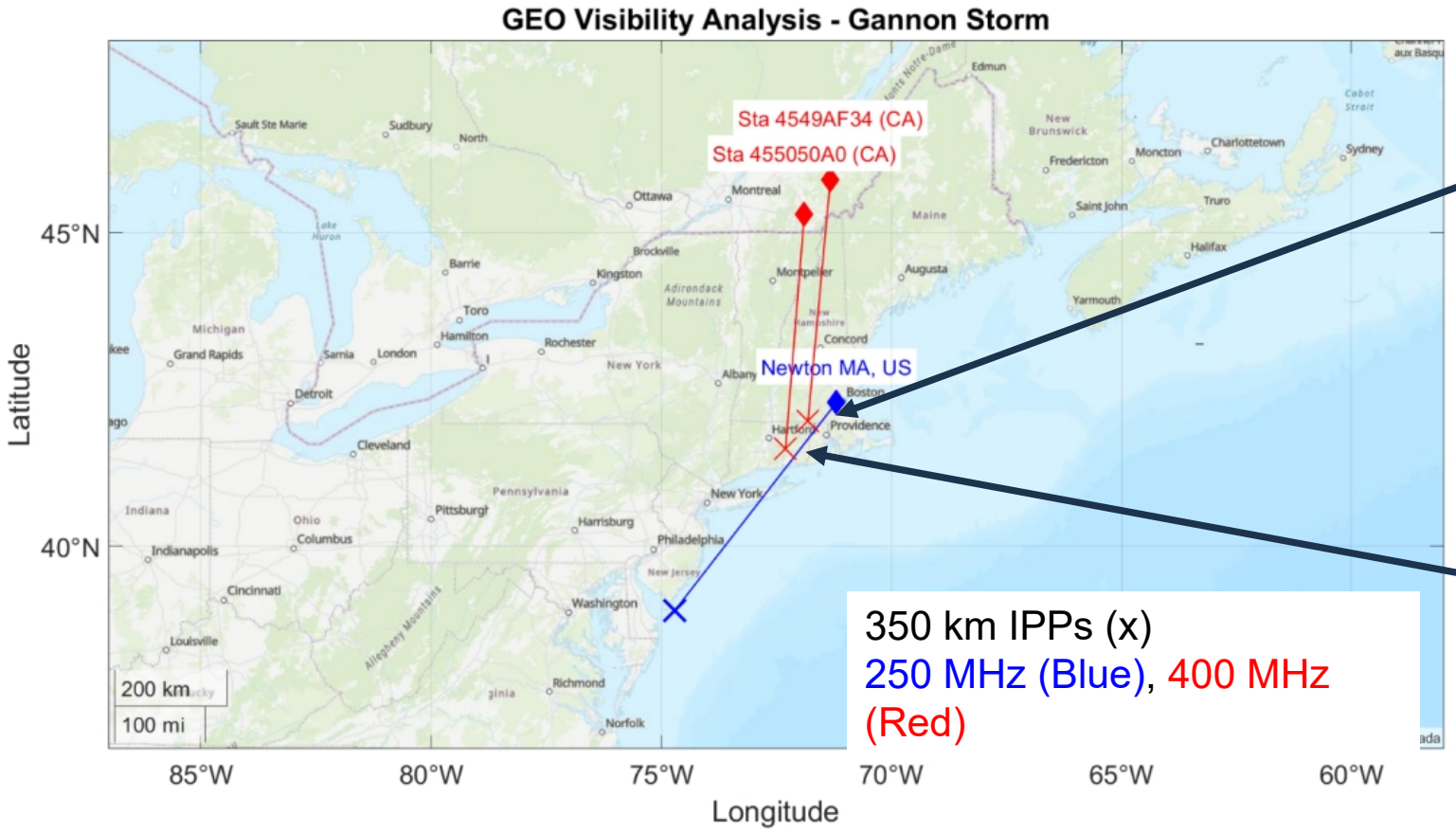
Storm Timeframe, 11 May 2024, Possible Scintillation Cases

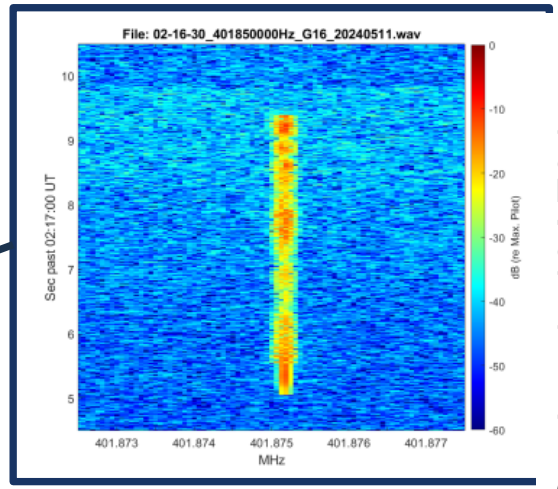


Pilot Tone
(Primary)

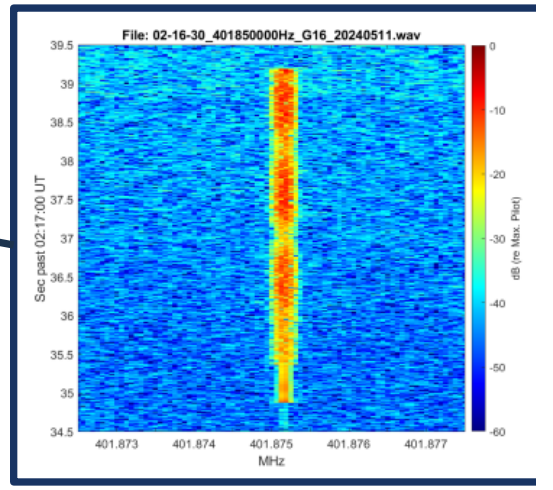
Mapped Amplitude Fluctuation Observations

Fluctuations Observed on Nearby Station IPPs Help Corroborate Fresnel Scale Irregularities as Likely Source





Station 4549AF34 (CA)



Station 455050A0 (CA)

Concluding Remarks

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Conclusions

DCS use is promising for scintillation monitoring with appropriate processing and data fusion

- DCP transmissions in DCS appear to be suitable for wide-area scintillation monitoring
- Analog transponder response seems capable of reproducing fluctuations (ALC can be compensated from pilot transmissions)
- Greatest challenges are short duration of most transmissions and the low duty cycle
- Combining the results of nearby sites may help fill in occurrence
- We present probable examples of mid-latitude scintillation from the Gannon storm

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