SCINDA Scintillation System Network:
Sites, Systems and Science Opportunities

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Outline

- System, background and status of scintillation network
- Data applications and the benefits of routine collection
- SCINDA Performance
- Science—what are the opportunities and what will be the focus?
- Summary & Way Ahead
A **regional nowcasting system** to support research and users of space-based communication and navigation systems

- **Ground-based sensor network**
  - Passive UHF / L-band /GPS scintillation receivers
  - Measures scintillation intensity, eastward drift velocity, and TEC
  - Automated real-time data retrieval via internet

- **Data supports research and space weather users**
  - Understand on-set, evolution and dynamics of large-scale ionospheric disturbances
  - Empirical model provides simplified visualizations of scintillation regions in real-time
Data-Driven Scintillation Map

SCINDA User Product Example for SATCOM

Scintillation Warning Areas

Watch Areas
Typical SCINDA Sensor Suite

VHF Receiver

VHF Antenna

GPS Receiver

GPS Antenna
Typical Hardware Configuration

Antenna Layout

- West Receiver
- East Receiver
- Magnetic E-W Baseline
- 2 meters separation
- 50-150 meters separation
- RG9913 Coaxial Cable (180 meters max.)

Receivers Set-Up

- VHF Computer
- GPS Computer
- Shared Monitor
- KVM Switch
- GPS Antenna
- Internet / Local Network
- VHF Receiver
- GPS Receiver
- Cable out to antennas
Background and Motivation

• Beginning in the mid-to-late-90’s AFWA and AFRL supported the development of a research-grade scintillation monitoring network to support both research and operations.

• As the network grew, the desire to increase longitudinal coverage resulted in establishing sites in disadvantaged locations posing challenging infrastructure and support issues.

• Hardware costs for individual sites averaged less than $20K and annual operating costs were modest, but poor infrastructure often resulted in frequent data gaps.

• Based on realism and affordability, AFRL pursued a strategy to achieve resilience through redundancy.
  
  – Additional stations also reduce the probability of not detecting activity in a given sector, a real issue for sites at higher magnetic lat (> 15°)

• Individual site performance varies, but the objective was to provide good performance on a longitude-sector basis.
Status

• Network has been completely unfunded since June 2014

• ~50% of the sites still operating in some capacity, but numerous factors suggest degradation will accelerate soon
  – Hardware aging, lack of software support and perception of disinterest in system and project

• Data continues to stream to BC from most sites

• Existing GPS hardware obsolete, cannot be directly replaced or repaired
  – Superior replacement hardware & software already developed

• UHF system current but hardware & software mods may be required in the near future

• Currently demonstrating three new sites in S. America; successful demonstration may lead to support for new SCINDA sites in 2023 and beyond
SCINDA Data Uses

• Contribute to global morphology and climatology of scintillation
  – This takes sustained time and effort: solar cycles last a long time!
• Validation/comparisons with space-based sensors (e.g., C/NOFS)
• Investigate forecasting algorithms, particularly combined with other ground-based sensors (e.g., ionosonde, magnetometer)
• Document impacts on systems’ performance (e.g., GPS positioning)
  – Model system effects
• Ionospheric modeling and model validation
• Test turbulent medium propagation theory
• Sensor Networks:
  – Evolution of large-scale equatorial structures
  – Characterization of meridional gradients/structure
  – Conjugate phenomena
  – Storm-time behavior
Benefits of Routine Data Collection Across Multiple Sites

• Establish global baseline of climatology and variations from climatology (no two solar cycles are the same it seems)
• Explore spatio-temporal correlation scales and variability (both meridional and longitudinal)
• Assess system(s) performance/improvements under range of conditions; improves insight into new systems and expected effects through a solar cycle
• Capture anomalous events (radio bursts, CMEs, storms, ??)
• Motivate detailed analyses/dedicated collection campaigns to obtain new insights (i.e., science)
• The data have been used in countless applications, numerous publications and theses projects (> 350 journal and conference papers)
Meridional Structure & Evolution: COPEX
TEC Central Brazil Oct-Nov 2002

- Combined data from three (3) stations reveals dramatic low latitude density structure and variation
- Asymmetric anomaly structure driven by inter-hemispheric neutral wind
- Scintillation characteristics symmetric
Combined Station Performance

• By combining data from multiple sites in a sector within 15 degrees in longitude we find that the real-time data delivery at Boston College exceeds 90% for nearly all regions and times.

• The plot below shows the current SCINDA site map, a total of some 57 low-latitude sites (plus LISN sites in S. America, 3 shown)
Scintillation Specification Opportunities

Potential scintillation observing opportunities in the near future: increase capability by more than 100%!

- GEO UV (GOLD)
- GPS
- GEO UHF MUOS
- COSMIC In Situ
- COSMIC RO
- Irregularity Structure
- GNSS
- COSMIC Beacon
- Systems currently monitored by SCINDA

"GPS Systems currently monitored by SCINDA."
New Capabilities

- Migration from Global Position System to Global Navigation Satellite Systems (GPS → GNSS)

- Effectively doubles the number of measurement points from a single location greatly improving resolution within the field-of-view
COSMIC-2 Radio Occultation & In Situ IVM Sensor

- Currently an on-going basic research effort
- Early results are promising
Summary

• SCINDA and ISWI represent a somewhat unique union motivated by a common need to field space weather sensors—to users and build capacity in support of emerging interests in space science; mutual interests contributed to the success of both!

• The regional real-time performance of the legacy SCINDA network has been very good overall, though some individual sites have not performed well.

• The sites provide TEC useful to ionospheric modelers, as well as scintillation parameters.

• We hope to have sponsored support for additional stations in 2023-24 after a successful demonstration of new technology at three sites being performed in 2022.