SCINDA Scintillation System Network: Sites, Systems and Science Opportunities

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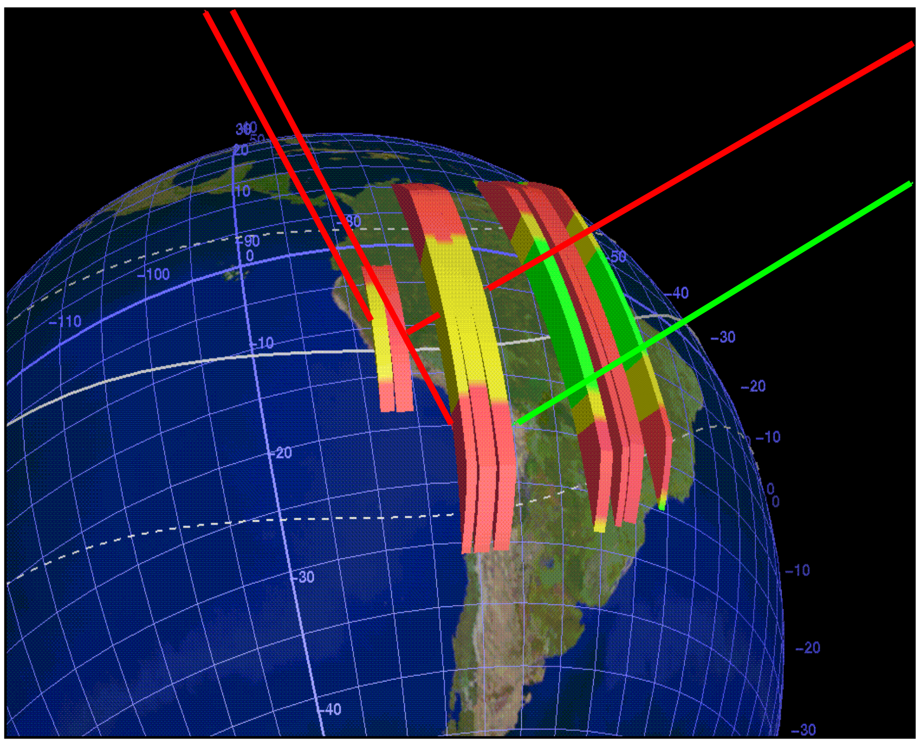
Outline

- 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

SCINTILLATION NETWORK DECISION AID (SCINDA)

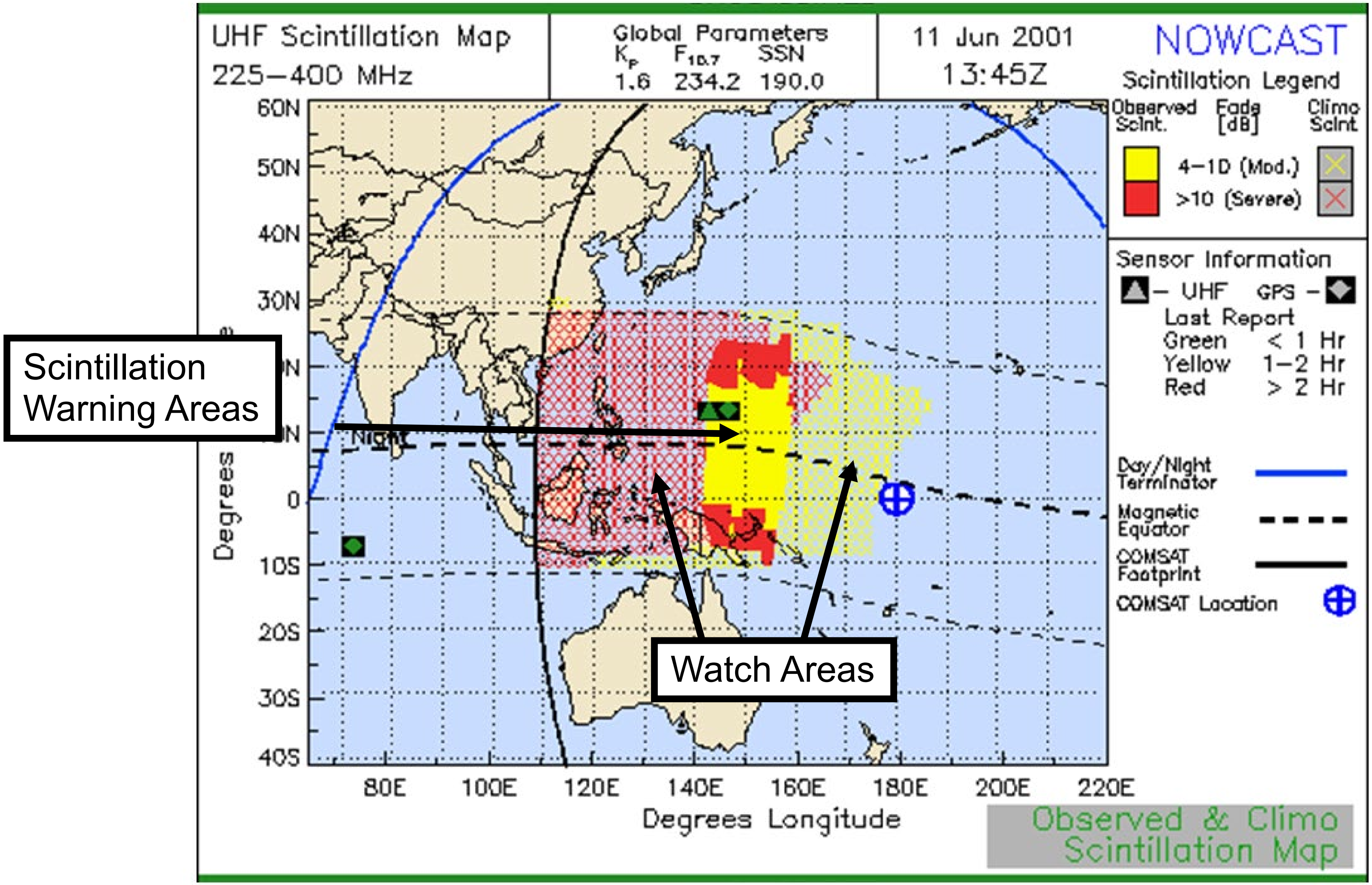
A *regional nowcasting system* to support research and users of space-based communication and navigation systems



- 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



Typical SCINDA Sensor Suite

VHF Receiver

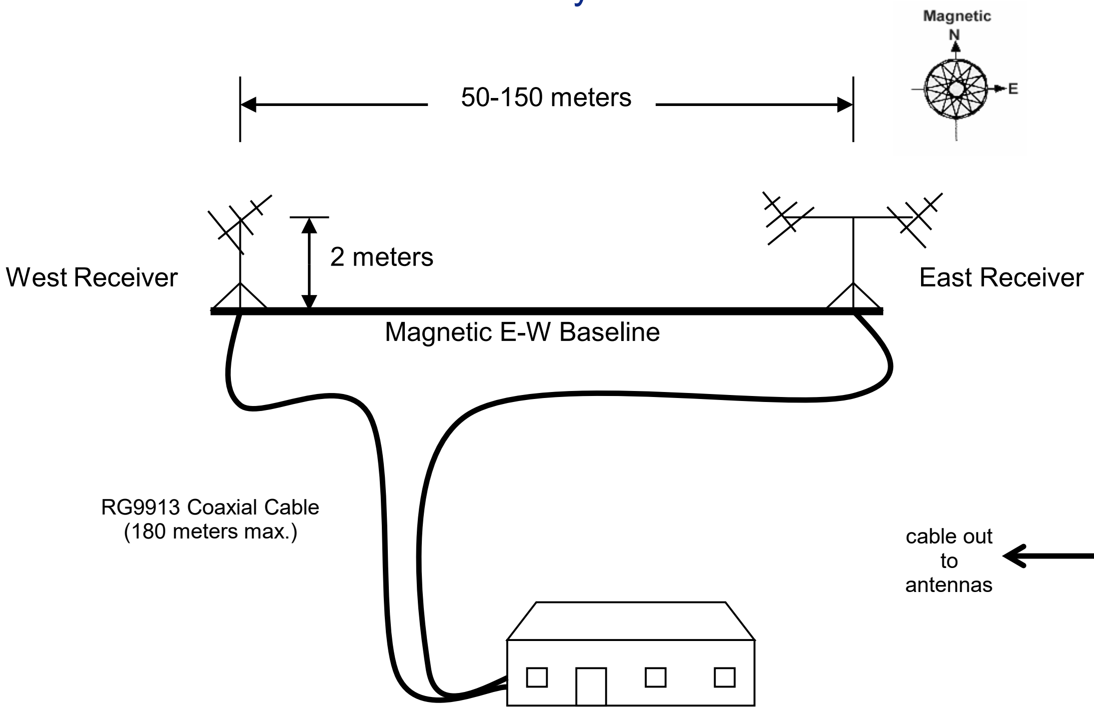
VHF Antenna

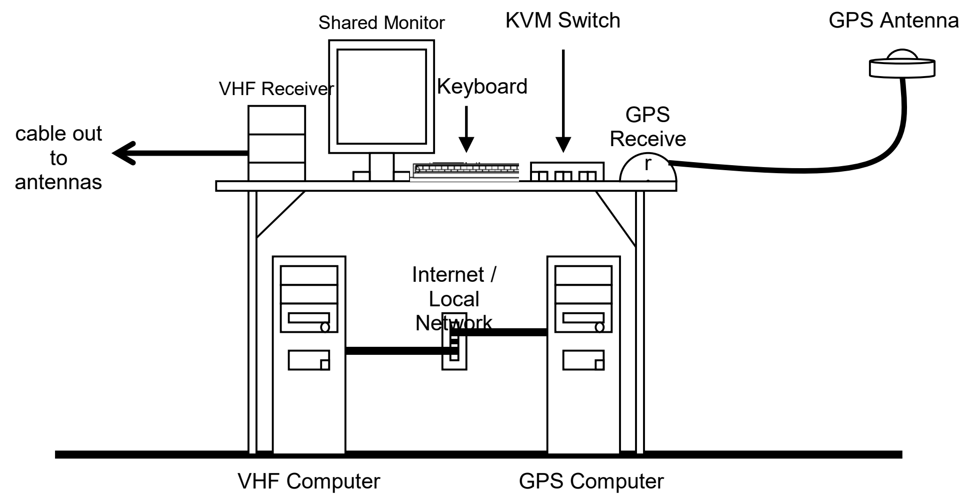
GPS Receiver

GPS Antenna

Typical Hardware Configuration

Antenna Layout





Receivers Set-Up

Background and Motivation

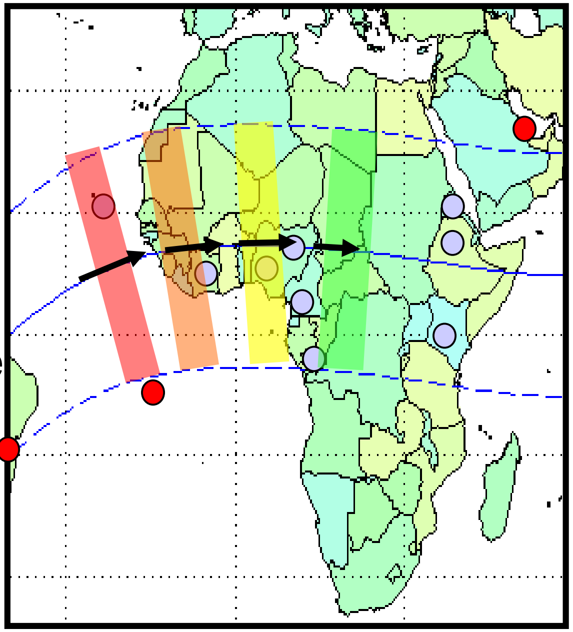
- Beginning in the mid-to-late-90's AFWA and AFRL supported the development of a research-grade scintillation monitoring network to support both research and operations.
- As the network grew, the desire to increase longitudinal coverage resulted in establishing sites in disadvantaged locations posing 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

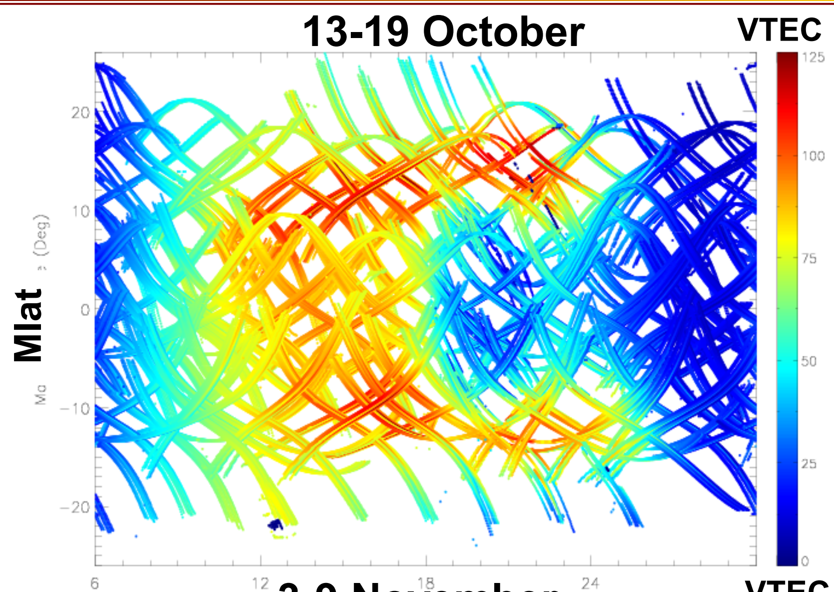


Benefits of Routine Data Collection Across Multiple Sites

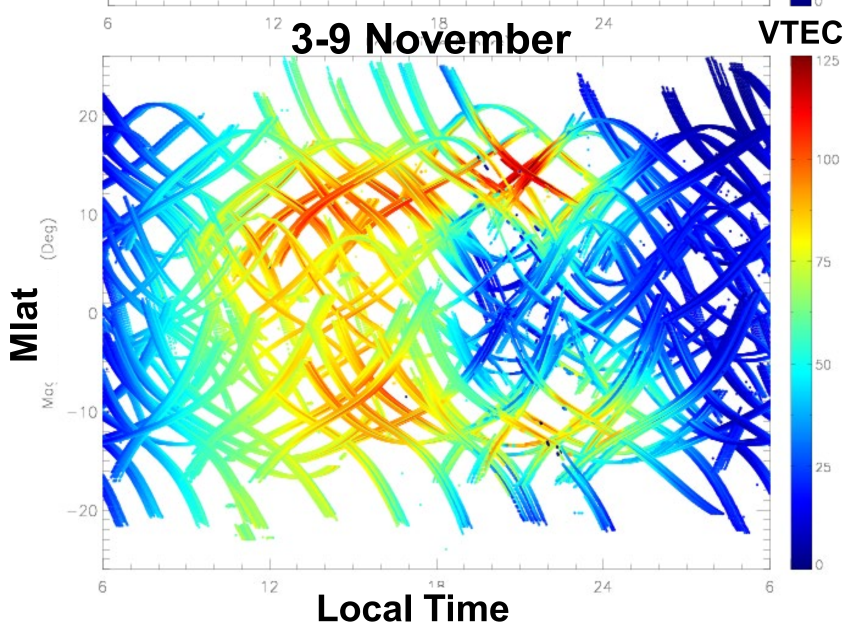
- Establish global baseline of climatology *and* variations from climatology (no two solar cycles are the same it seems)
- Explore spatio-temporal correlation scales and variability (both meridional and longitudinal)
- Assess system(s) performance/improvements under range of conditions; improves insight 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)

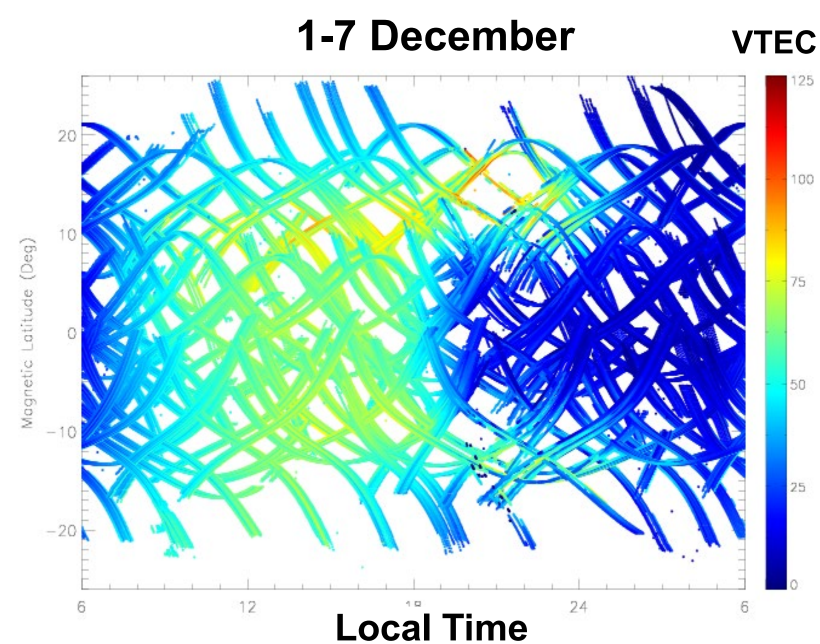
Meridional Structure & Evolution: COPEX

TEC Central Brazil Oct-Nov 2002



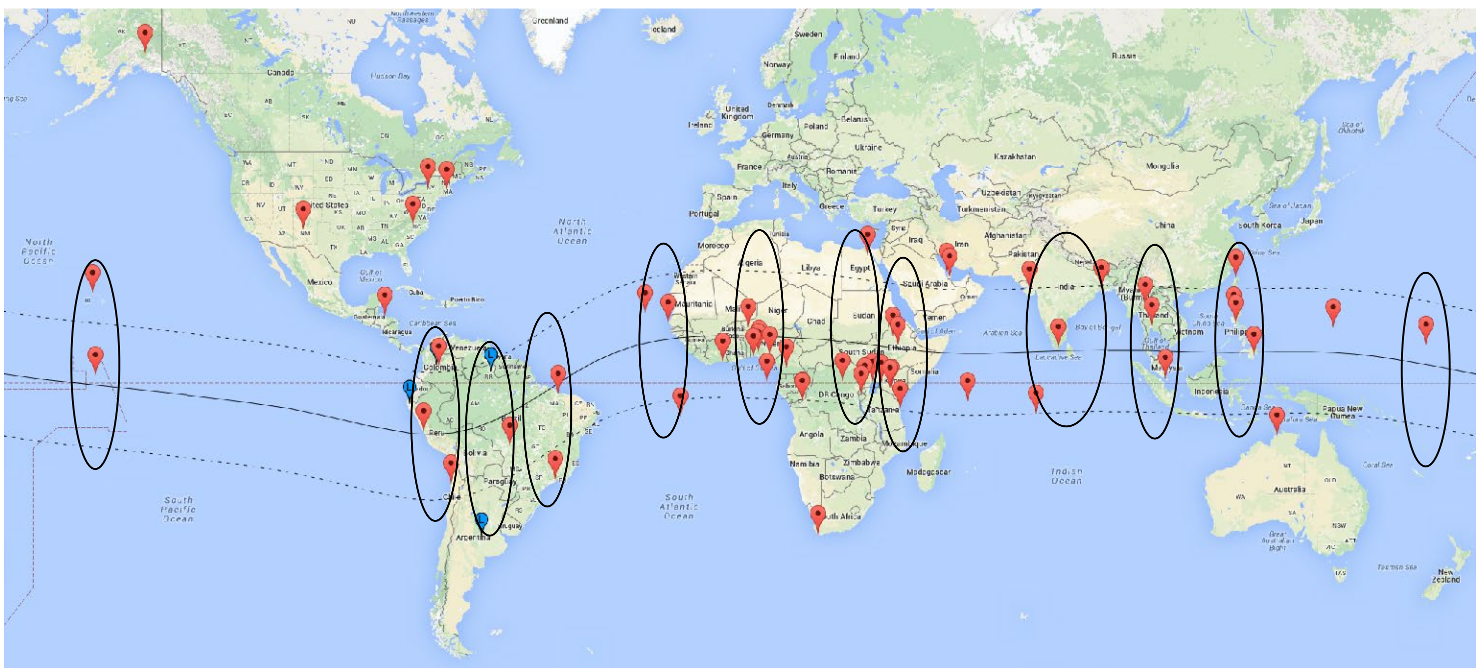
- Combined data from three (3) stations reveals dramatic low latitude density structure and variation
- Asymmetric anomaly structure driven by inter-hemispheric neutral wind
- Scintillation characteristics symmetric



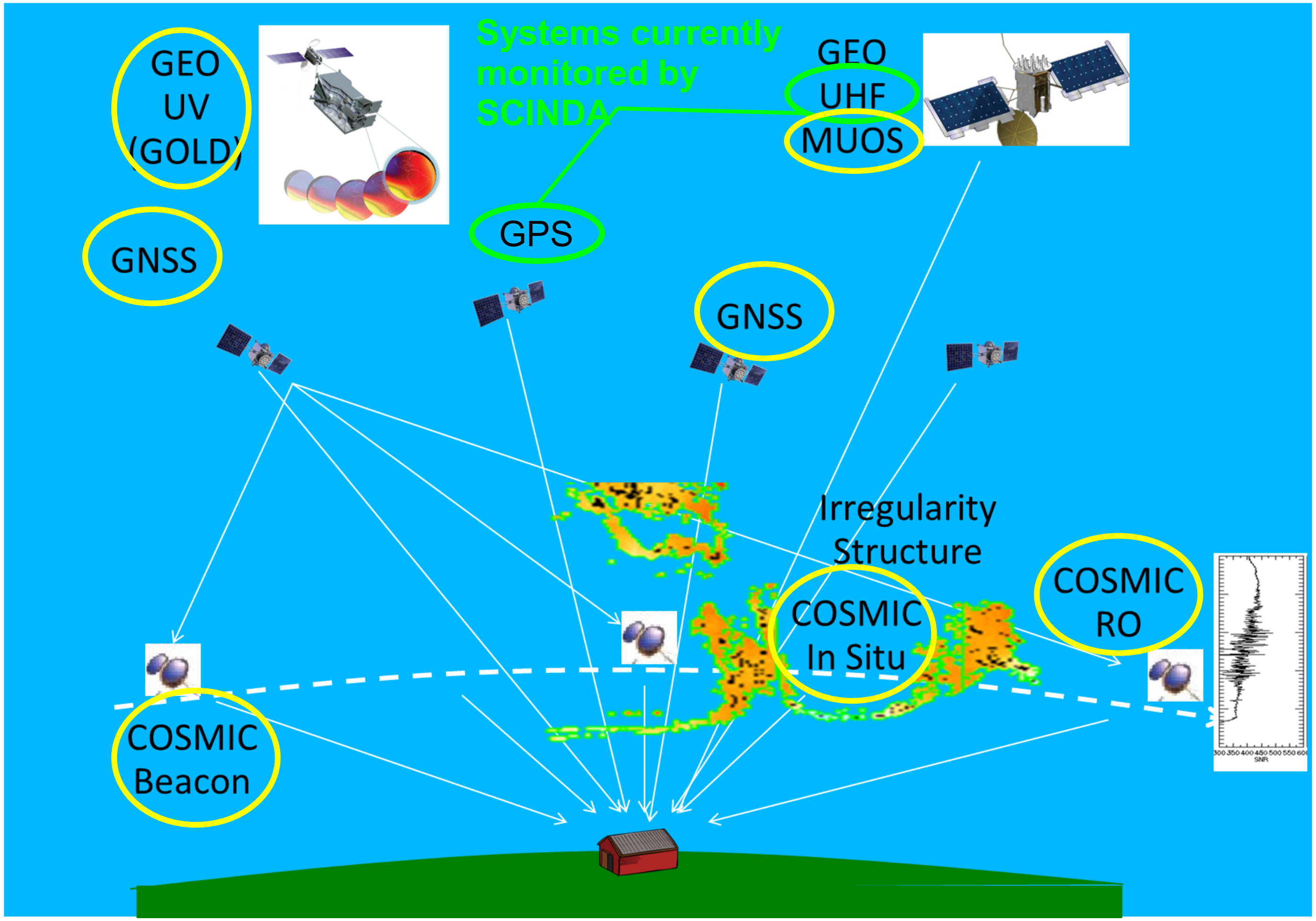


Combined Station Performance

- 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)



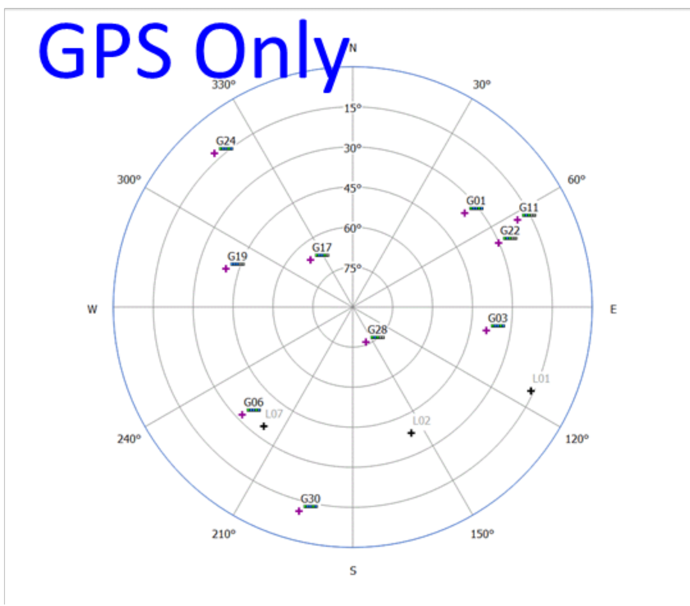
Scintillation Specification Opportunities

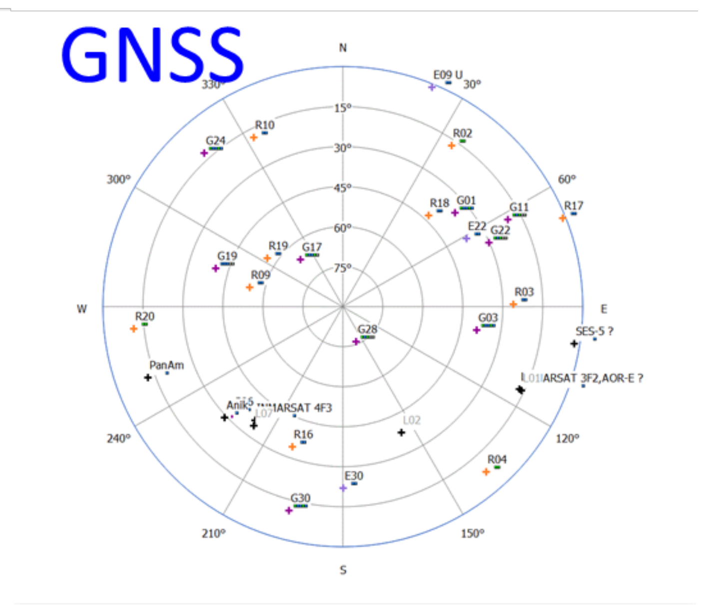


Potential scintillation observing opportunities in the near future: increase capability by more than 100%!

New Capabilities

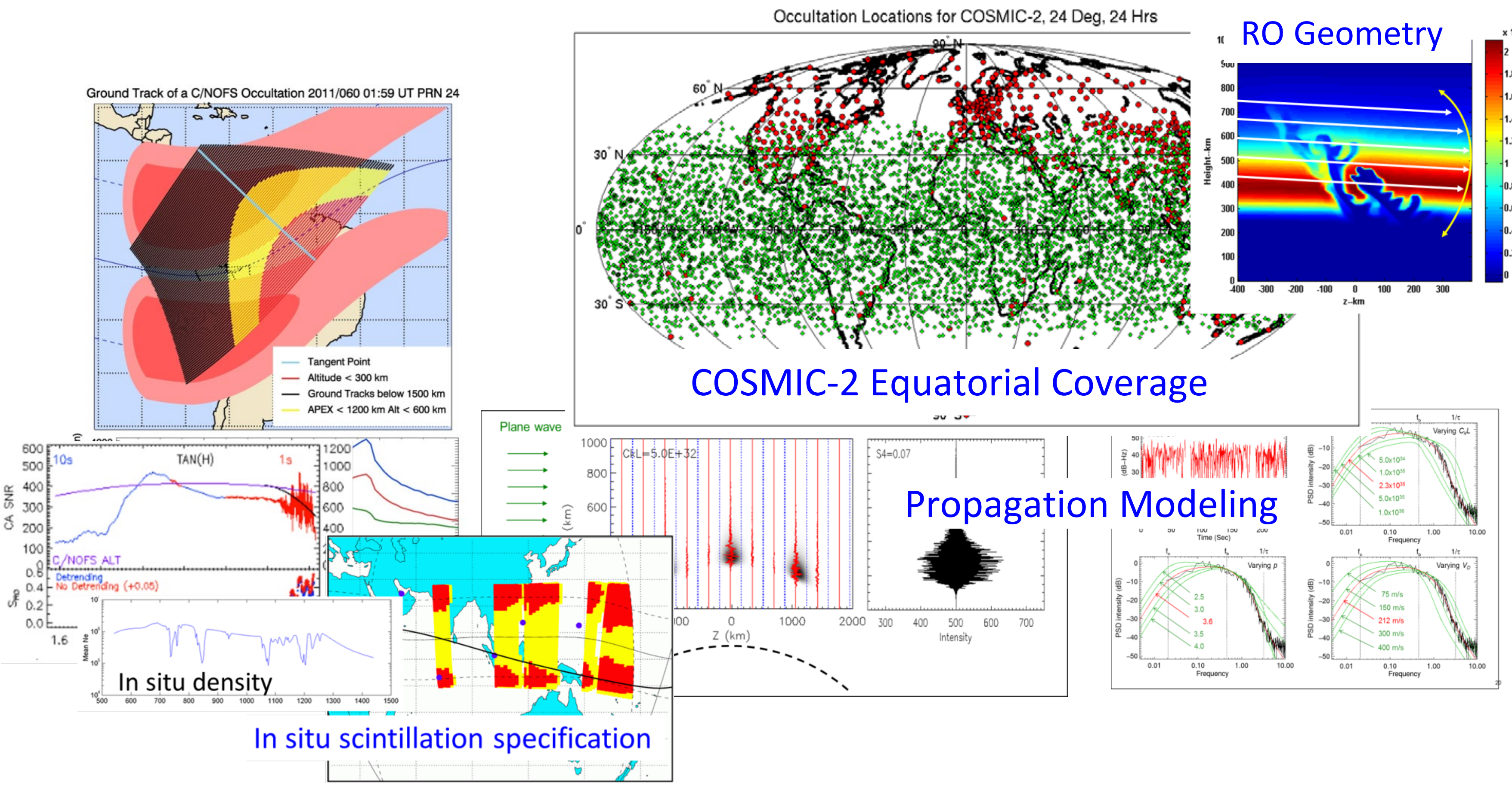
- Migration from Global Position System to Global Navigation Satellite Systems (GPS → GNSS)
- Effectively doubles the number of measurement points from a single location greatly improving resolution within the field-of-view





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.