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SCINDA Scintillation System Network: Sites, Systems and Science Opportunities

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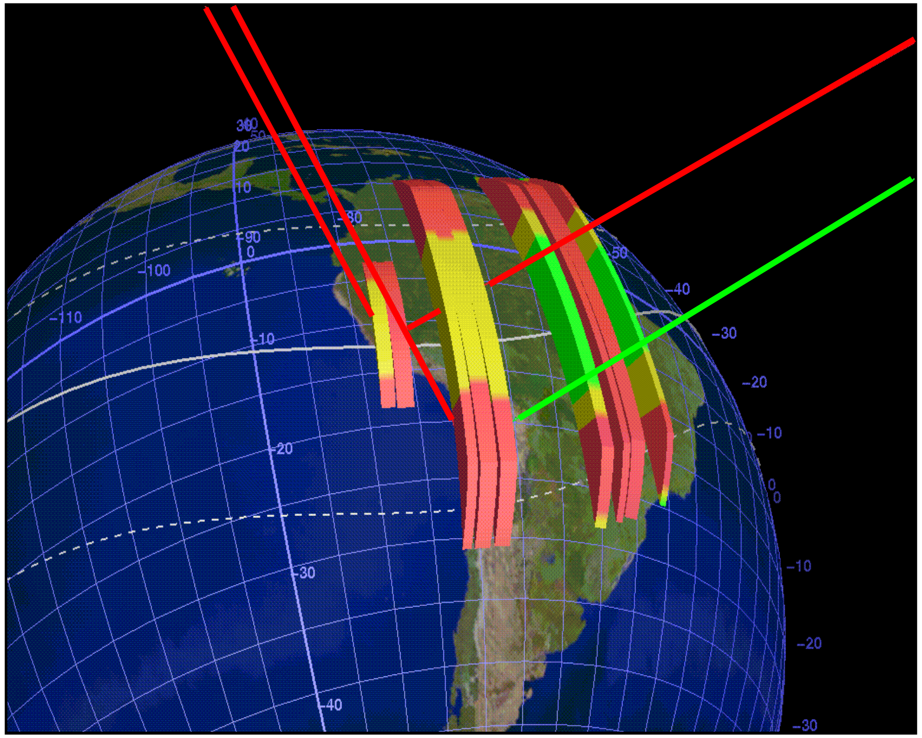
Outline

- 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)

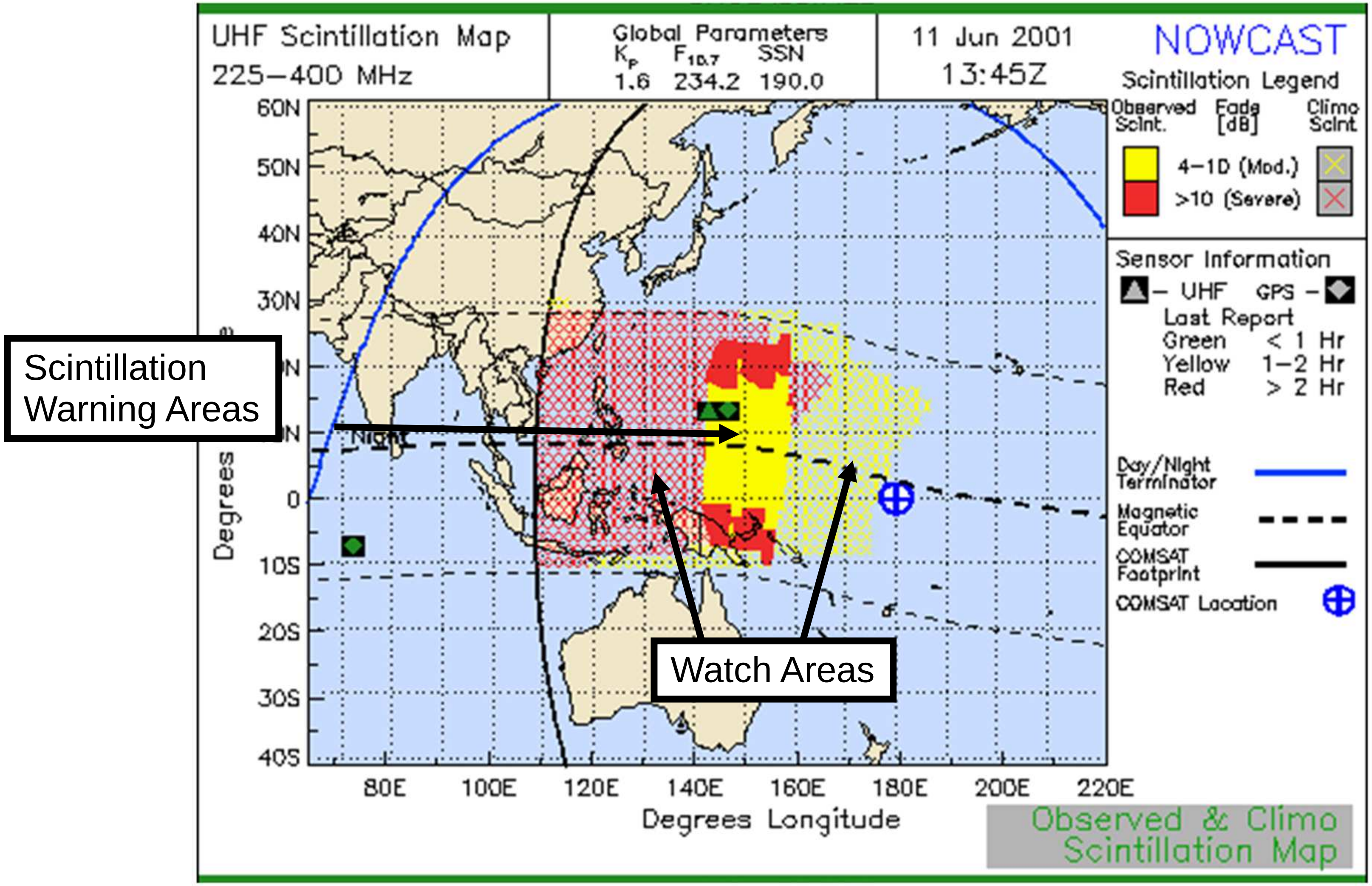
A *regional nowcasting system* to support research and users of space-based communication and navigation systems



- 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

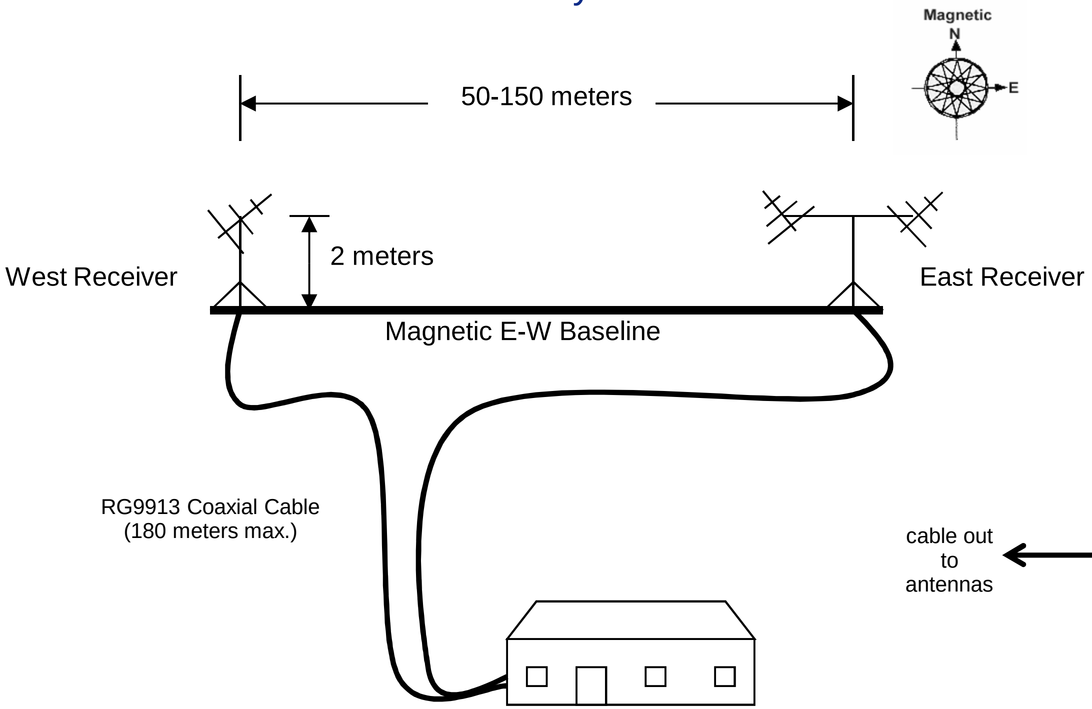
VHF Antenna

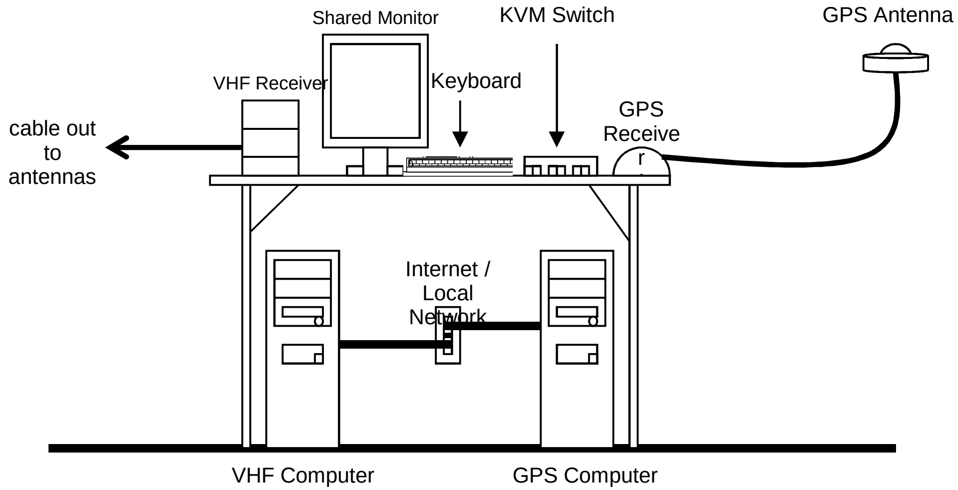
GPS Receiver

GPS Antenna

Typical Hardware Configuration

Antenna Layout





Receivers Set-Up

Background and Motivation

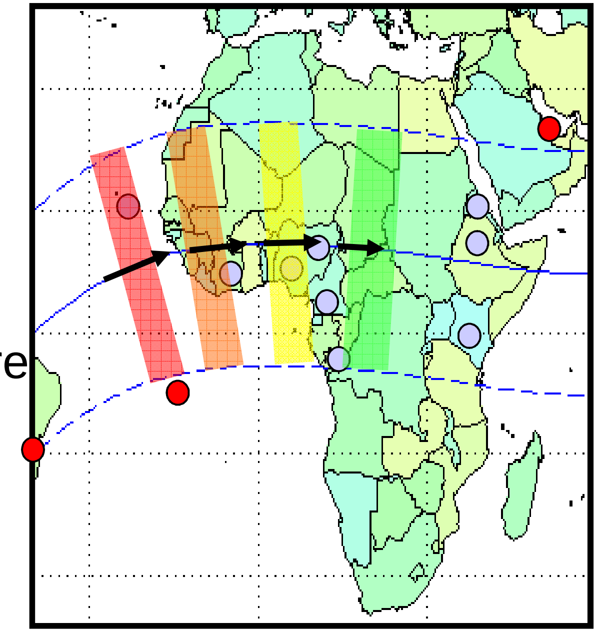
- Beginning in the mid-to-late-90's AFWA and AFRL supported the development of a research-grade scintillation monitoring network to support both research and operations.
- As the network grew, the desire to increase longitudinal coverage resulted in establishing sites in disadvantaged locations posing 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
- > 80% 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
- Agreement with AFRL granting BC rights to operate and maintain sites is in process

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

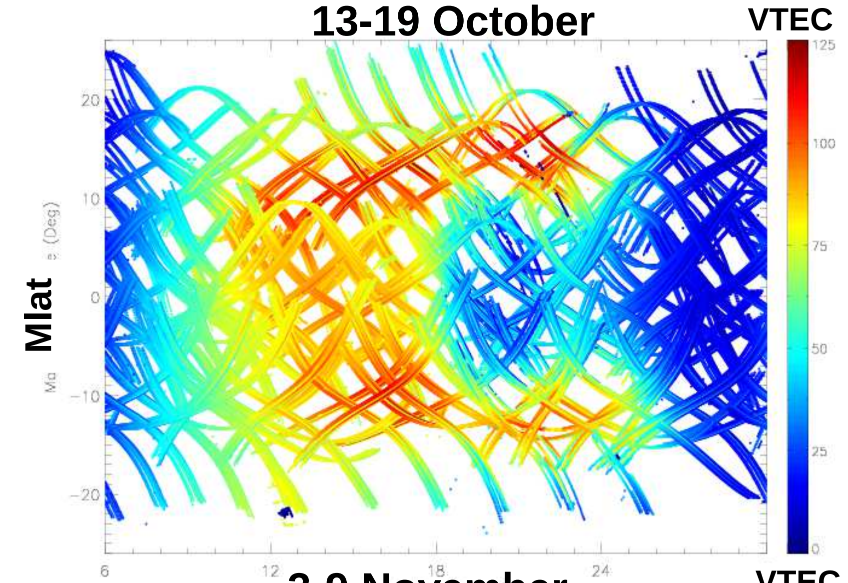


Benefits of Routine Data Collection Across Multiple Sites

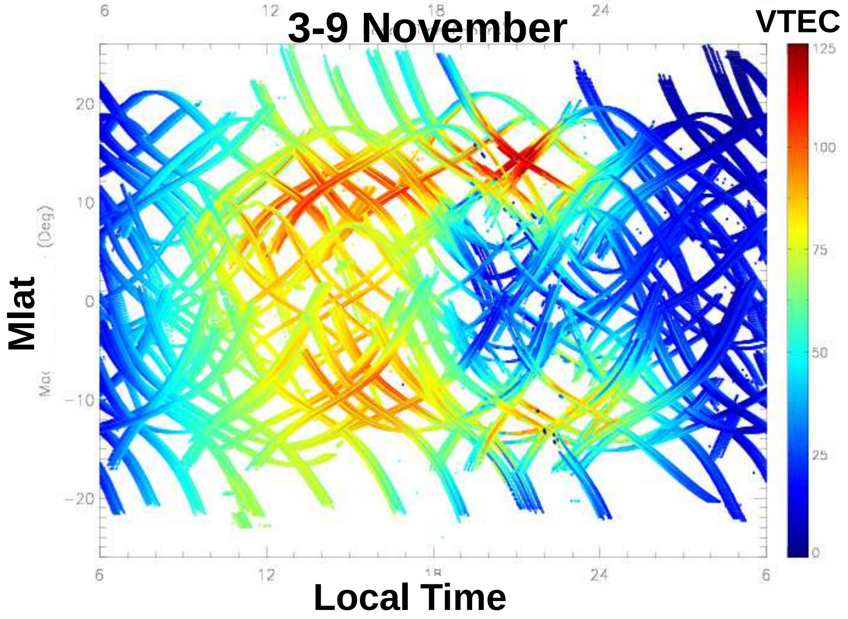
- Establish global baseline of climatology *and* variations from climatology (no two solar cycles are the same it seems)
- Explore spatio-temporal correlation scales and variability (both meridional and longitudinal)
- Assess system(s) performance/improvements under range of conditions; improves insight 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)
- AND…support for SATCOM users who might be impacted by scintillation

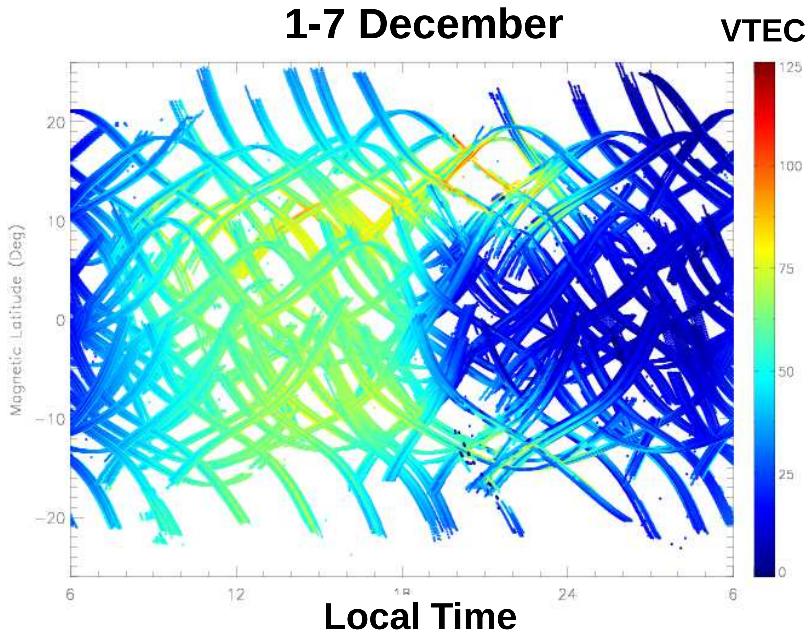
Meridional Structure & Evolution: COPEX

TEC Central Brazil Oct-Nov 2002



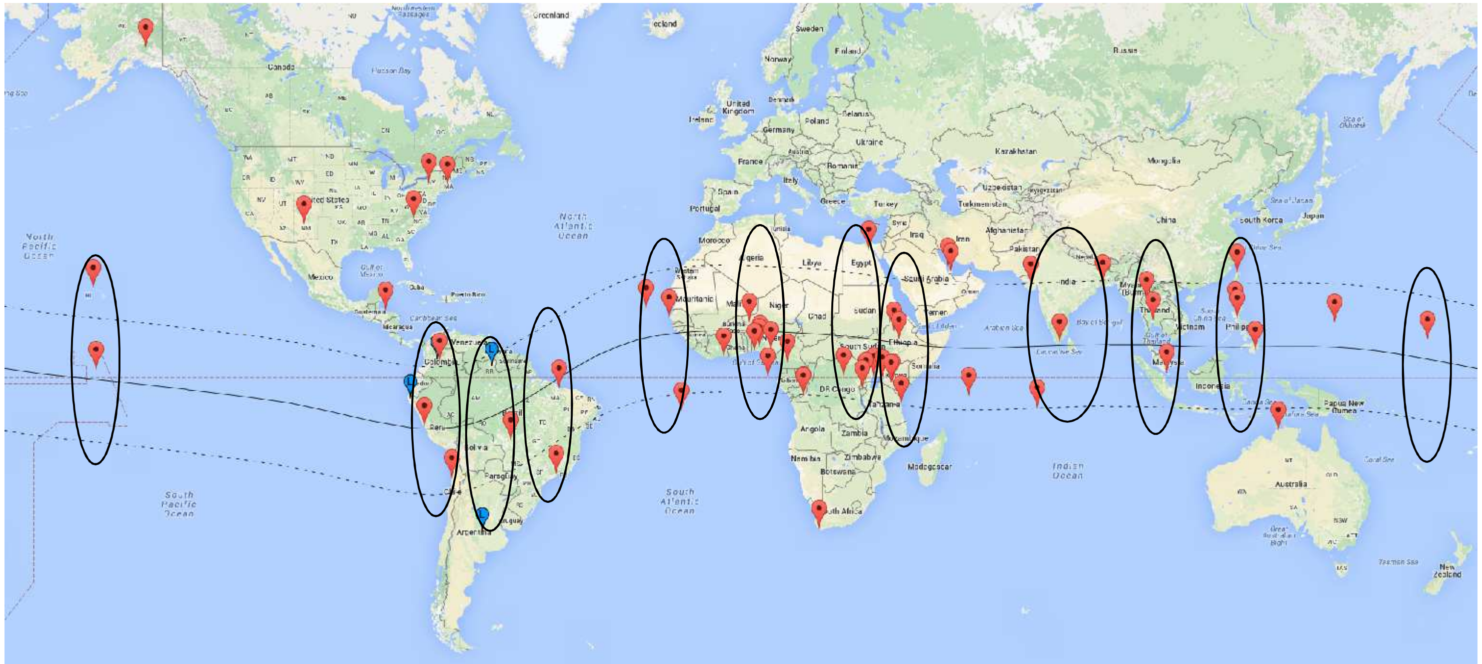
- Combined data from three (3) stations reveals dramatic low latitude density structure and variation
- Asymmetric anomaly structure driven by inter-hemispheric neutral wind
- Scintillation characteristics symmetric





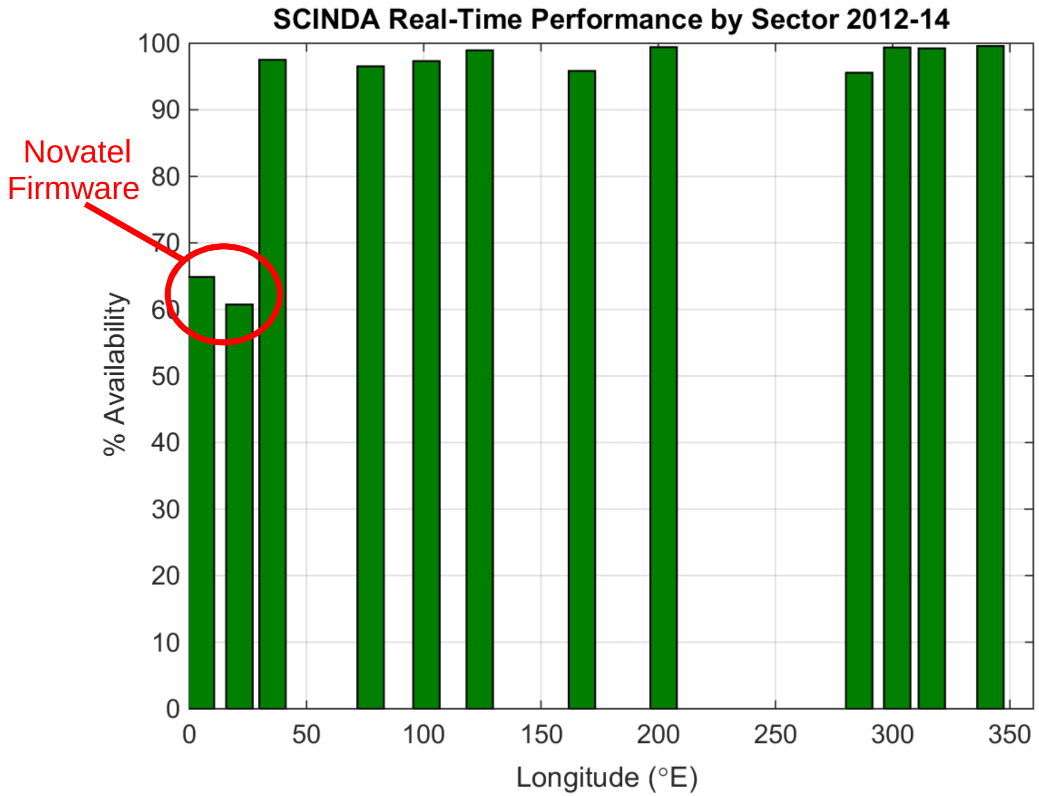
Combined Station Performance

- 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)



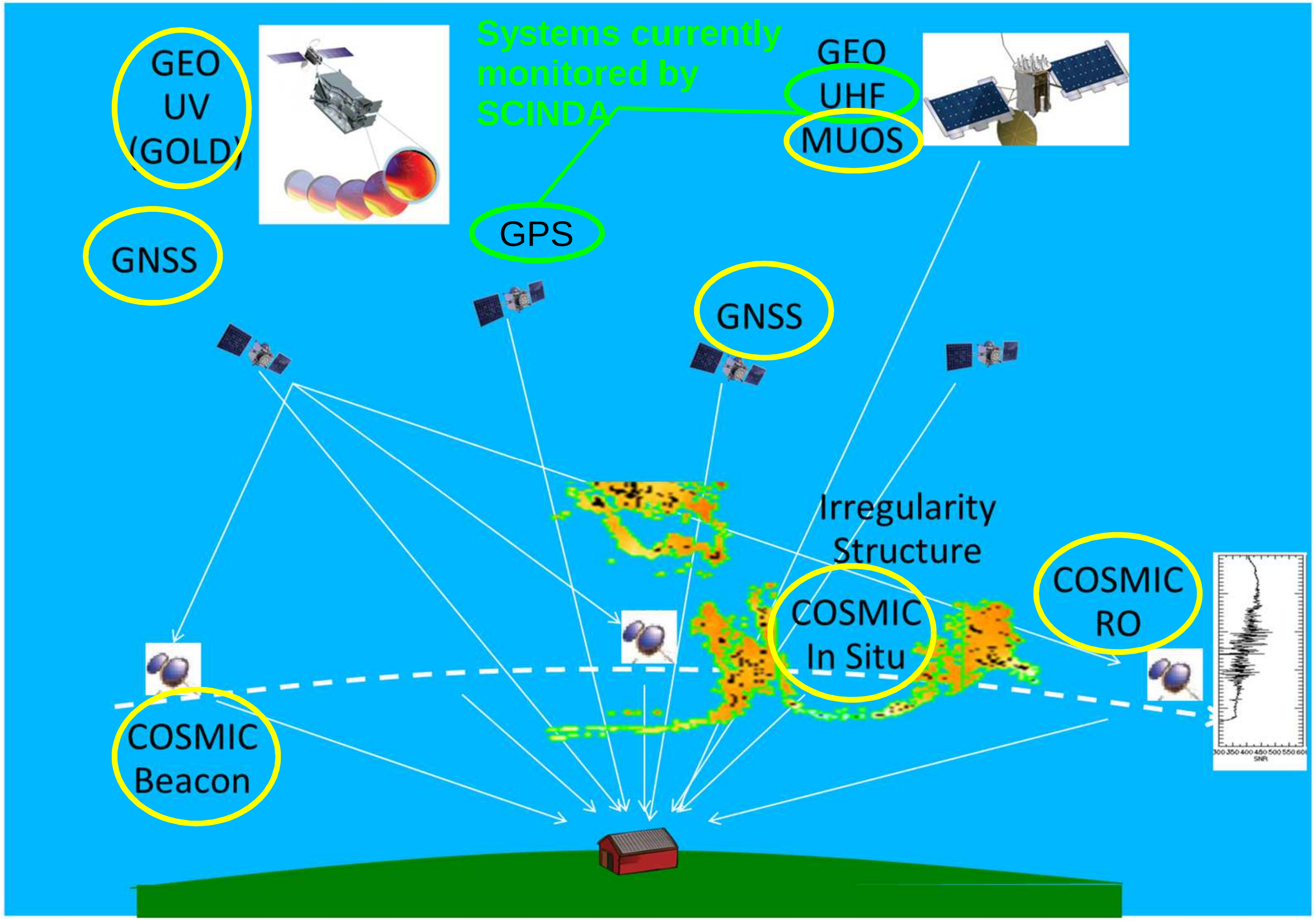
Real-Time Data Availability for 2012-2014

- The plot to the right shows the data availability averaged for three years, 2012-2014 (30 min latency)
- Availability exceeds 90% nearly everywhere and approaches 100% in several sectors
- The reduced values in the west-central Africa sectors (0° and 25° E long) were largely caused by a network-wide firmware glitch in the Novatel receivers
  - Availability in those two sectors was only 21% and 31% in 2013.



The data supporting this plot is available in more detail, sector-by-sector, in the back-up slides

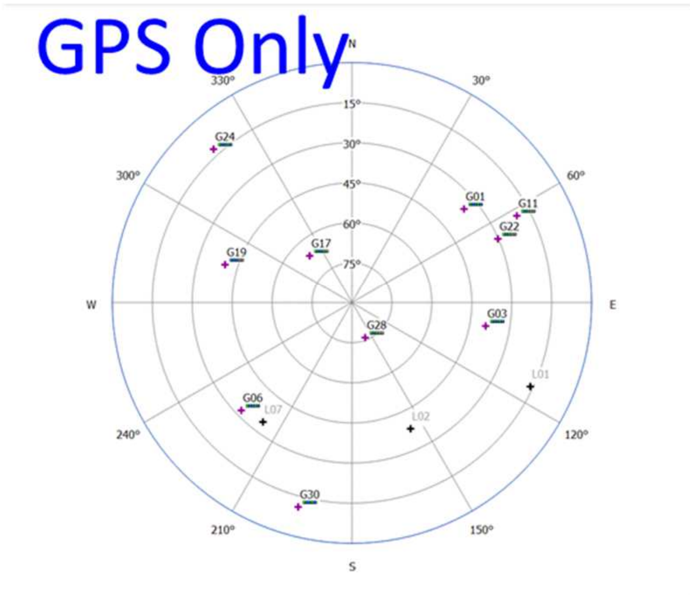
Scintillation Specification Opportunities

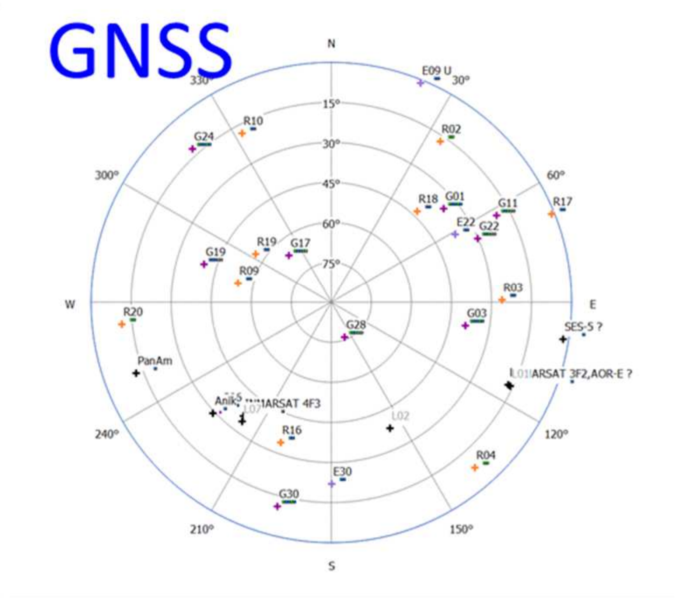


Potential scintillation observing opportunities in the near future: increase capability by more than 100%!

New Capabilities

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

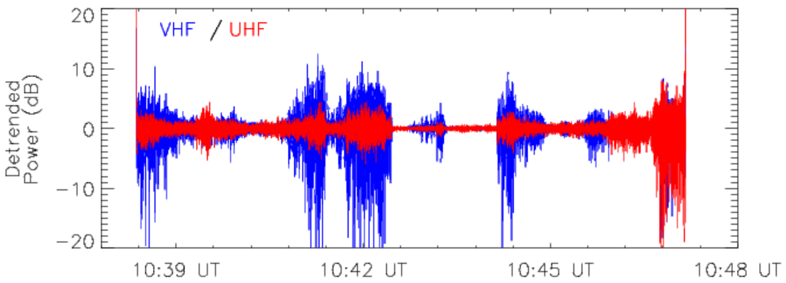


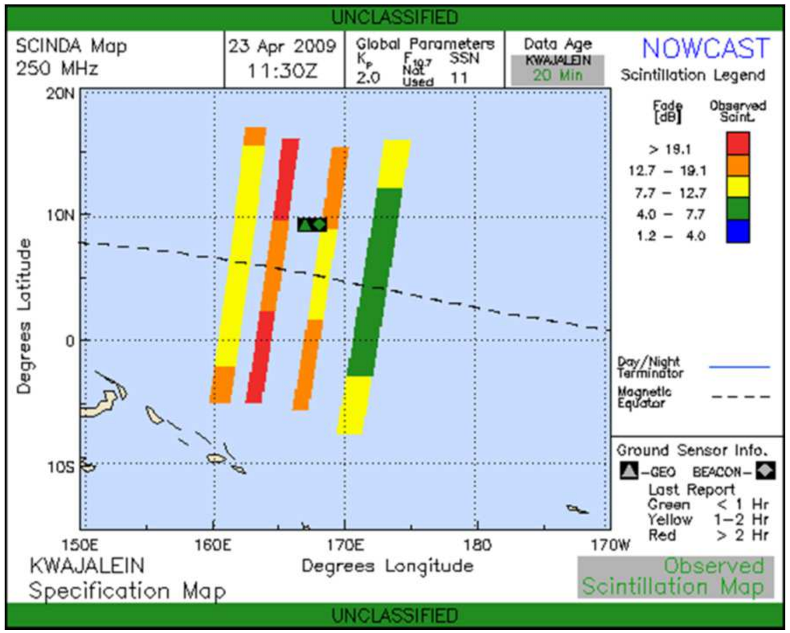


RF Beacon Integration

- Tri-frequency RF beacons to be flown on six COSMIC-2 satellites in LEO orbit (~525 km altitude, 24° inclination)
- LEO beacon observations provide a spatial snapshot of irregularity structures that is difficult to infer from GEO and GNSS observations
- RF Beacon receivers can readily be fielded at ancillary sites

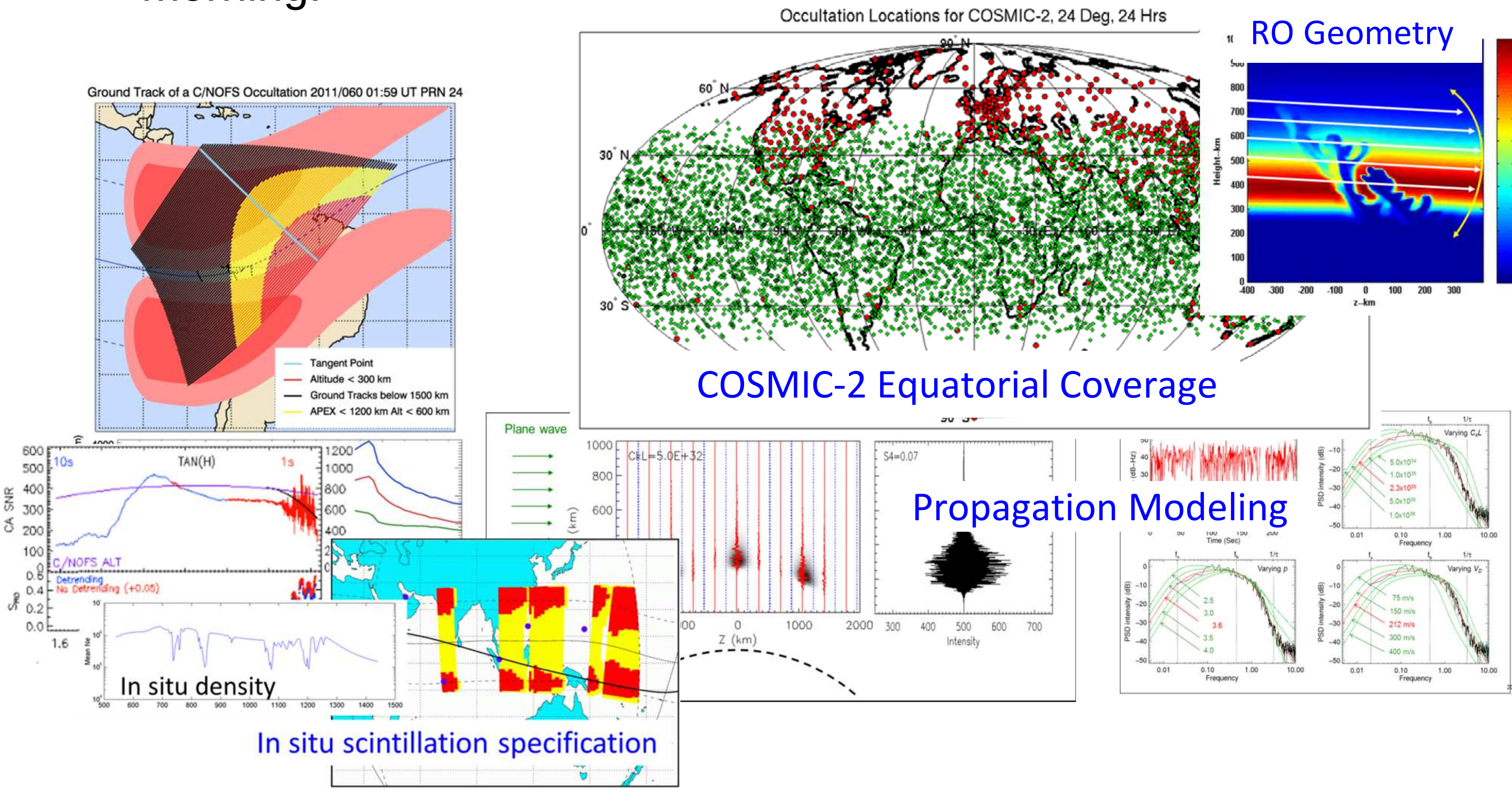
Mapping irregularities with RF Beacons





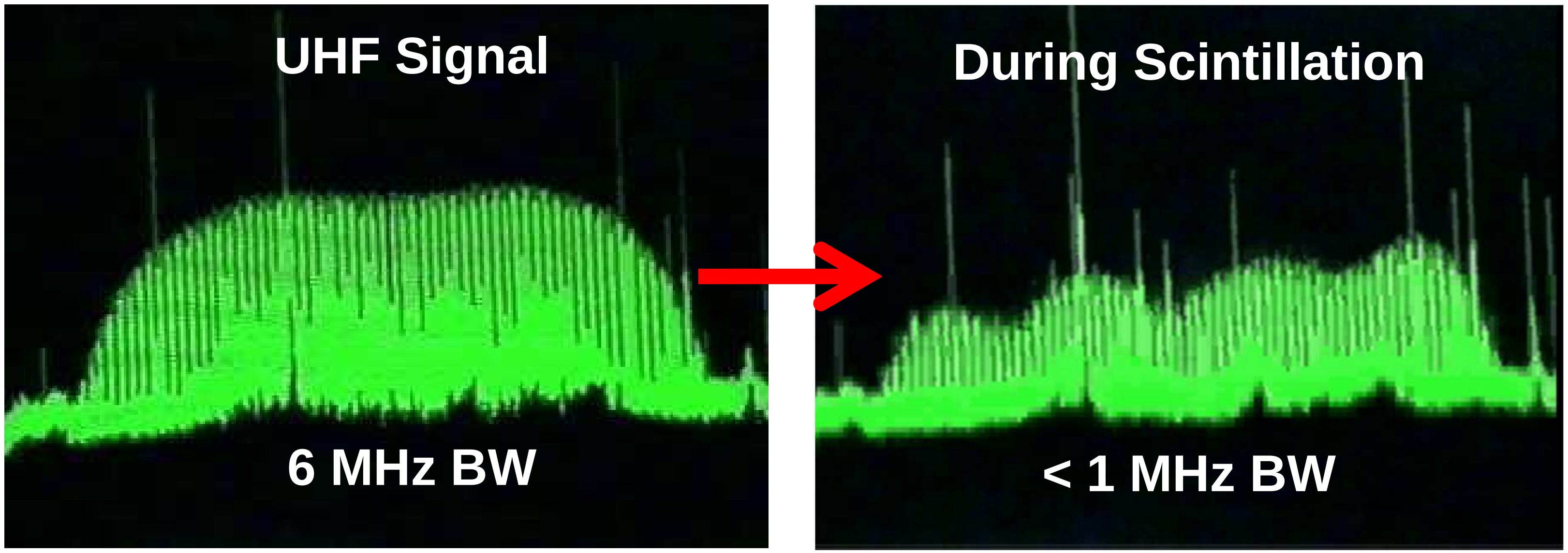
COSMIC-2 Radio Occultation & In Situ IVM Sensor

- Currently an on-going basic research effort supported by AFRL
- Early results are promising; tune in to the talk on Wednesday morning!



MUOS Next-Gen UHF SATCOM

- Wideband cell-phone type waveform from a space-based platform
- This is the next-Gen GEO UHF system for the USA
- Extremely interesting to monitor and uncover new features about the ionosphere: coherence bandwidth
- And the effects of scintillation on this system are unknown as well



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.
- They can be readily and affordably upgraded to include GNSS (2x ionospheric measurements) and RF beacon receivers for COSMIC-2

Way Ahead

- Optimistic that there will be future support for ground-based scintillation sensors, particularly at low latitudes – there is too much good going on!
  - Possible sponsors: US Air Force, NASA, NSF
- Site selection will depend on infrastructure, geophysical characteristics, local interest, commitment and support.
- GNSS will still be the primary sensor, but the sensor suite will be expanded at appropriate sites as well.
- Past performance is a strong indicator of future opportunities

More emphasis on training, education and data analysis planned in the next phase of SCINDA for better systems support and to expand the field of space science