COSMIC-2 for Specification of the Global Scintillation Environment

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AFRL C/NOFS Satellite Instruments

**GPS Receiver**
- C/NOFS Occultation Receiver for Ionospheric Sensing and Specification (CORISS)
- Developed by Aerospace (P. Straus, PI)
- Measures: Remote sensing of LoS TEC

**Electric Field Instrument**
- Vector Electric Field Instrument (VEFI)
- Developed by NASA/GSFC (R. Pfaff, PI)
- Measures: Vector AC and DC electric as well as magnetic fields
- Includes lightning detector

**Planar Langmuir Probe (PLP)**
- Developed by AFRL/RVBX (P. Roddy, PI)
- Measures: Ion Density, Ion Density Variations, Electron Temperature

**Ion Velocity Meter (IVM)**
- Developed by Univ. of Texas at Dallas (R. Heelis, PI)
- Measures: Vector Ion Velocity, Ion Density, Ion Temperature

**Neutral Wind Meter (NWM)**
- Developed by Univ. of Texas at Dallas (G. Earle, PI)
- Measures: Vector Neutral Wind Velocity

**RF Beacon**
- Coherent EM Radio Tomography (CERTO)
- Developed by NRL (P. Bernhardt, PI)
- Measures: Remote sensing of RF scintillations and LoS TEC
COSMIC-2

Ion Velocity Meter (IVM)
Gridded electrostatic analyzers for \textit{in-situ} ion density, temperature, & 3D drifts (E-Fields)

RF Beacon
3-Frequency Beacon (plus Channel Probe) for ground-based measurement of scintillation and total electron content (TEC)

TriG GNSS RO Sensor
Fore & Aft looking RO sensors capable of tracking GPS & GLONASS at high-rates for space-based ionospheric scintillation measurements

Goal: To develop a fully coupled system to take advantage of Space/Ground-based data from COSMIC-2 to improve the global characterization of scintillation.
Scintillation Outage Maps

- Current state-of-the-art analogous to terrestrial weather products
  - **Warning** = Direct Ground-Based Data Observations
  - **Watch** = Data-Driven Climatology
- Use available information from COSMIC-2 to supplement current limitations of ground-based system
Enhanced Coverage with Space-Based Observations

Primary Objective:
Ground-based sensors provide first-hand knowledge of the local scintillation environment but coverage is limited due to geographical considerations.

Can we fill in the gaps providing global coverage with COSMIC-2?
Enhanced Coverage with Space-Based Observations

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*Can we fill in the gaps providing global coverage with COSMIC-2?*
COSMIC-2 RO Coverage

Global Occultation Coverage for two different hour periods with COSMIC-2 including GPS & GLONASS

**COSMIC-2**
- 6 satellites
- Multi-GNSS capabilities
- Fore & Aft sensors

*Significant expansion of coverage with many overlapping events which can help to identify scintillating and ALL CLEAR regions*
• Accurately geolocating the scintillating regions is a complex task due to...
✓ The long slant paths over which the RO events are observed
✓ Multiple pierce points through the F-Region ionosphere
✓ Potential for interaction with multiple turbulent structures
✓ Varying propagation geometry with respect to B
**In-Situ** Density Observations

- Example from the PLP sensor on C/NOFS
- In-Situ density observations can be used to map out irregularity regions
- Must pay attention to the satellite ephemeris

- Data can be used in conjunction with a phase screen model to estimate scintillation impacts on ground users
- Or as a supplement to RO for geolocation
Improved RO Geolocation with *In-Situ* Densities

- **Case Study:**
  - Scintillation detected on RO event over S. Am.
  - Scatterer at any location along RO path (red)
  - Tangent Point (gray) maps to longitude of ANC
  - Test using **IPE Technique**
  - Comparison with *in-situ* densities from PLP sensor pinpoint scatterer at > 10° to the west

> 1,000 km error in geolocation with use of Tangent Point alone to discriminate irregularity location
RF Beacon Measurements

- Sample data from C/NOFS overflight
- Relative phase difference between $f$ provides TEC
- Amplitude fluctuations map scintillation structures
RF Beacon Measurements

SCINDA RADAR MAP
Current Product

Improved Product

Beacon Data From 1038 UT Overflight

SCINDA SPECIFICATION MAP

Kwajalein
Evening of 23 Apr 2009 (Day 113)
RF Beacon Measurements

- **COSMIC-2 RF Beacon**
  - Significant expansion of spatial coverage over fixed-link ground-site locations
  - Improved forecasting capabilities for specification products and “custody” of propagated structures with ~15 minute revisit rate
  - Can be incorporated into a coupled-model to aid space-based RO technique

- Activation of 5 MHz Channel Probe will be important diagnostic for impacts on Next-Gen SATCOM systems with wideband channels
Summary / Questions

- Plan to develop set of coupled algorithms to take advantage of all available data sets for real-time ionospheric specification
  - Full constellation Multi-GNSS RO
  - Ground-Based observations (SCINDA/ISTO)
  - *In-situ* densities
  - Other (UV imager, etc)

COSMIC-2 will play a significant role in making this a reality!
**In-Situ Density Observations**

Day 148, 28 May 2010 15:46:59 UT orbit 11464

- Example from the PLP sensor on C/NOFS
- *In-situ* density structure can be used to map out irregularity regions
- Must pay attention to the satellite ephemeris