Radio Occultation Observations of Ionospheric Scintillation

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Overview

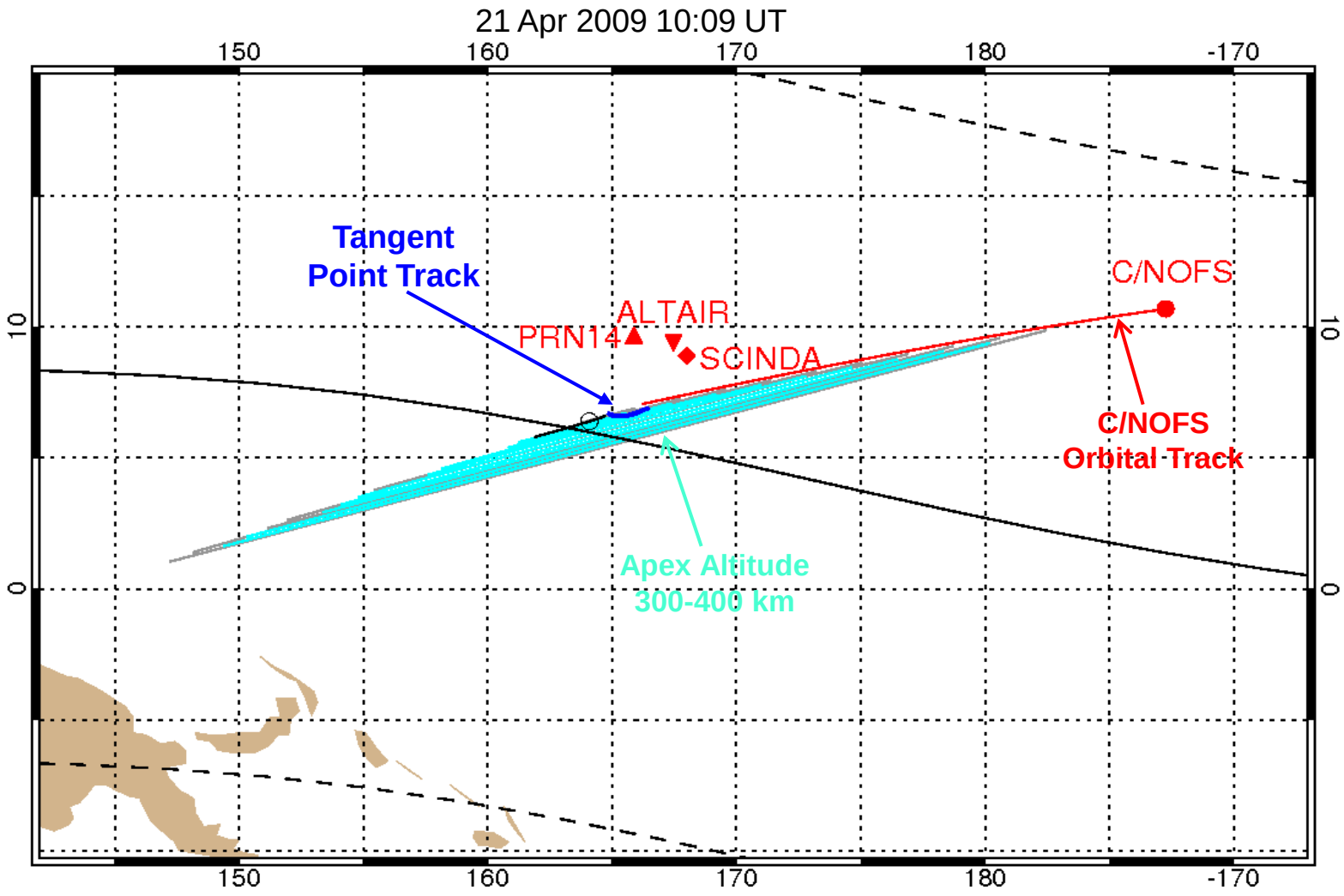
- CORISS (on C/NOFS) update
- Spectral/theoretical analysis of a scintillation event observed by CORISS & ground-based instrumentation
- The future: COSMIC-2 as the ideal platform for RO scintillation studies
- Comments on joint RO observations of scintillation & ionospheric profiles

CORISS Instrument on C/NOFS: Status

- C/NOFS launch: April 2008
- C/NOFS orbit: 13° inclination, 410×860 km elliptical (initial)
  - *Altitude is now 405×780 km due to atmospheric drag induced delay*
- AF is now planning to keep operating C/NOFS satellite in FY13+
  - *C/NOFS re-entry projected to be sometime in 2015*
- CORISS obtains L1 high rate (50 Hz) data throughout occultations at ionospheric tangent altitudes (100-800 km) on the nightside of the C/NOFS orbit for scintillation studies

- CORISS improvements planned for tropospheric data collection
  - *Adjust sensor operating mode to provide nightside as well as dayside tropospheric profile data*
  - *Evaluate the possibility of a software upload to enable open loop data collection (may not be possible due to microprocessor limitations)*

CORISS/ALTAIR Geometry for Scintillation Event



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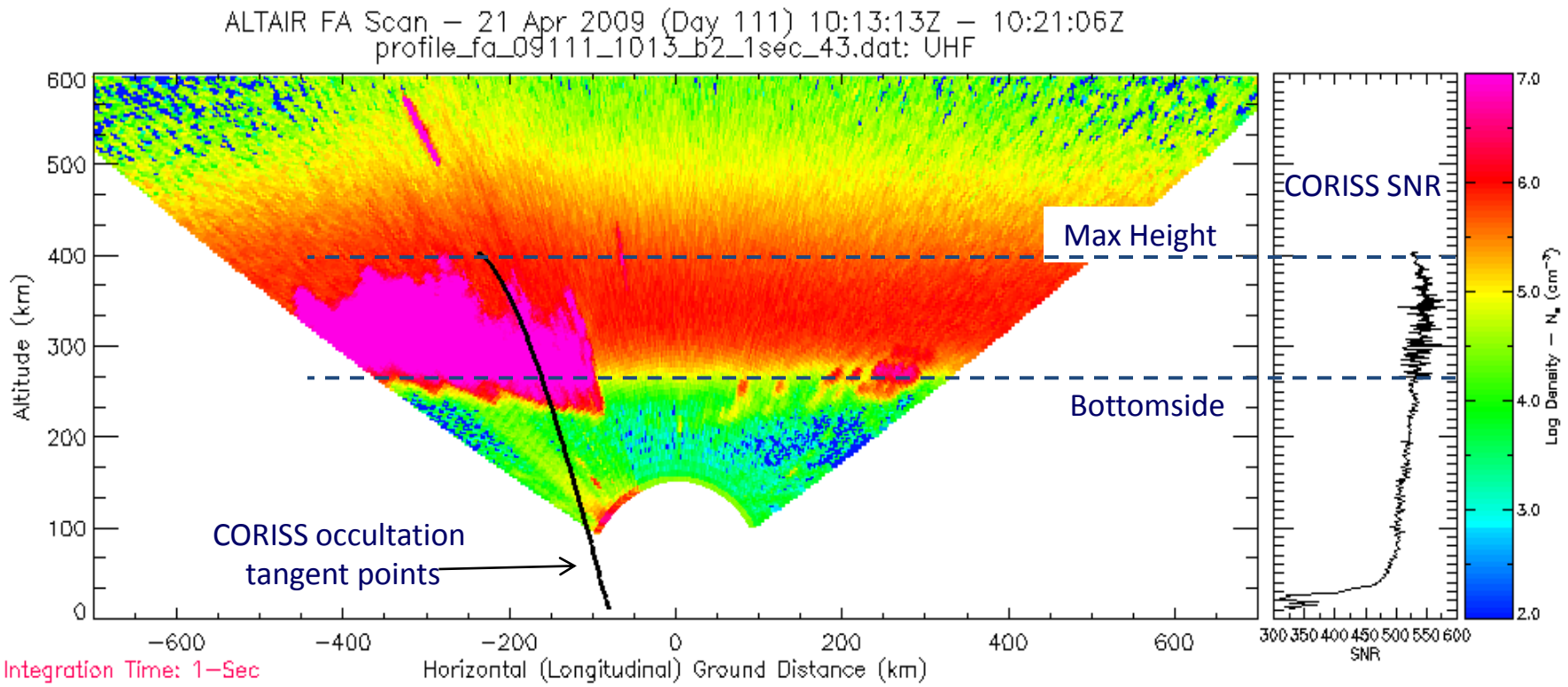
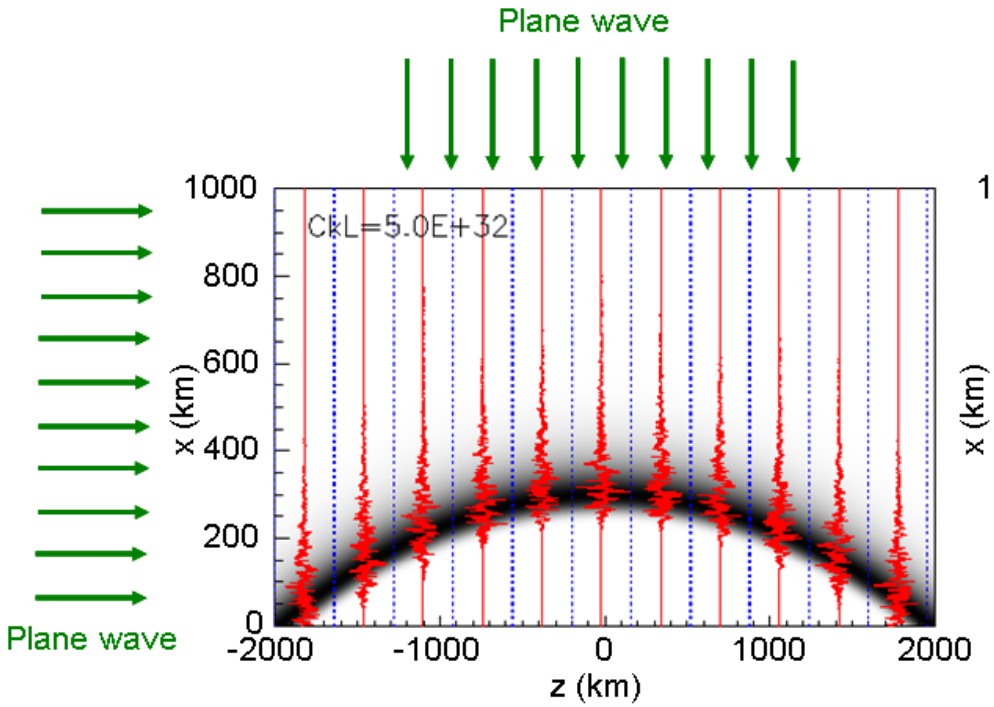
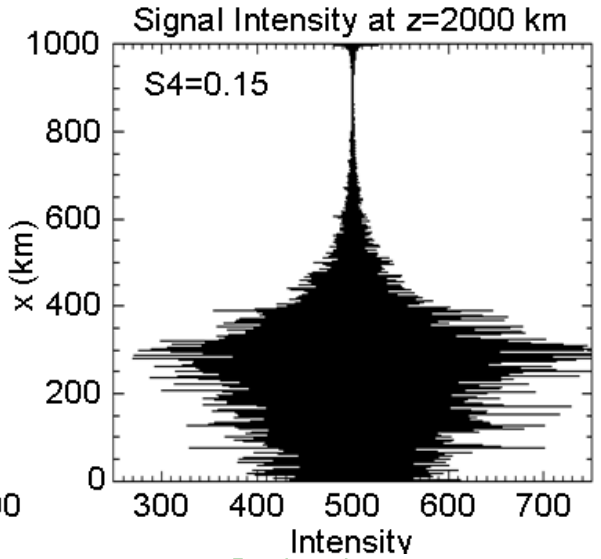
Coherent Returns from ALTAIR & CORISS SNR

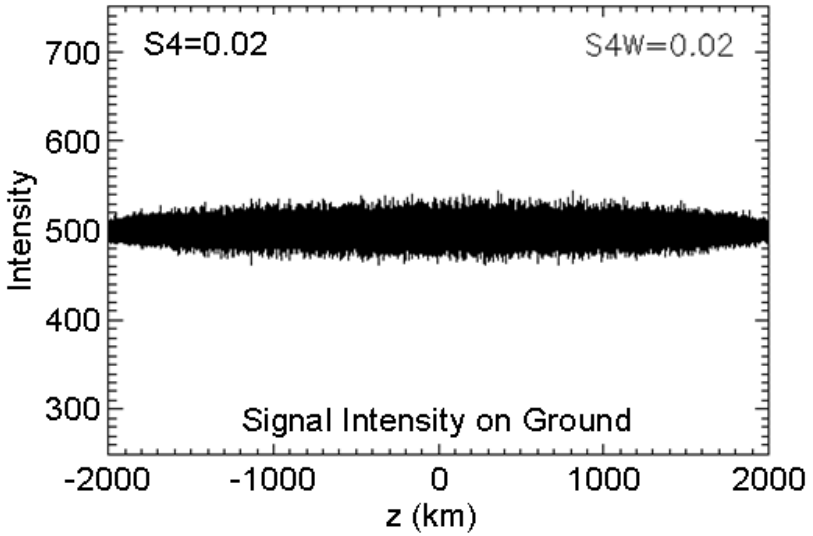


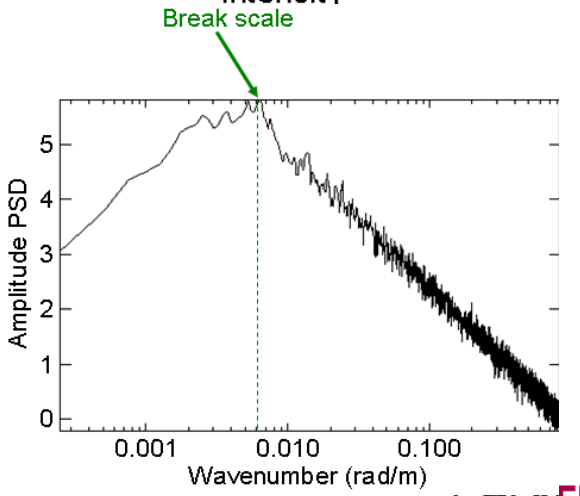
- ALTAIR indicates location of small-scale (40cm) irregularities relative to the CORISS tangent point track
- CORISS detects ionospheric irregularities only within F region, while high sensitivity of ALTAIR reveals structure at slightly lower altitudes
- Mean scattering location is slightly westward of the CORISS tangent point track.

Simulation of Scintillation in a Limb Viewing Geometry









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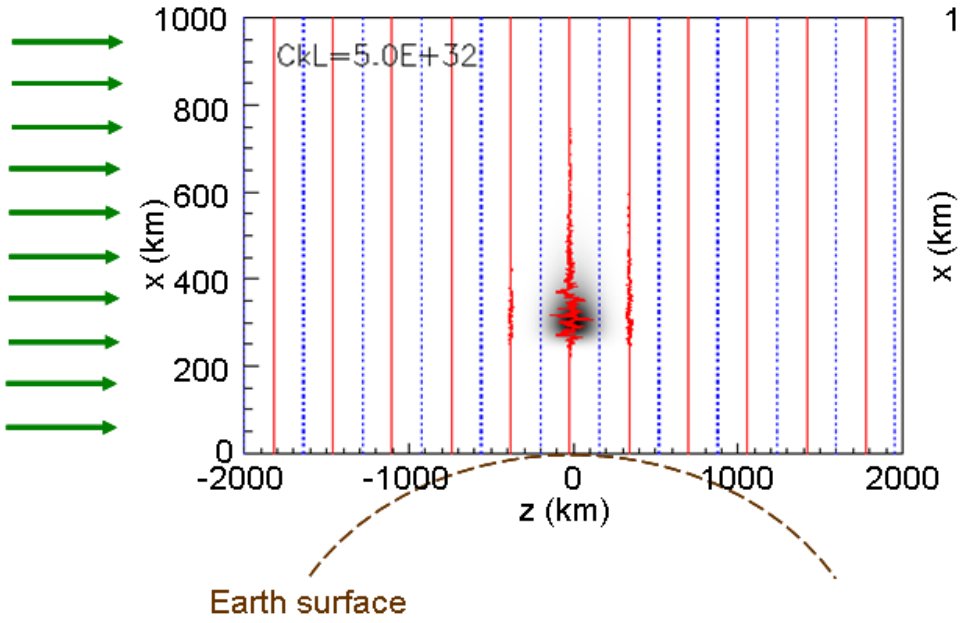
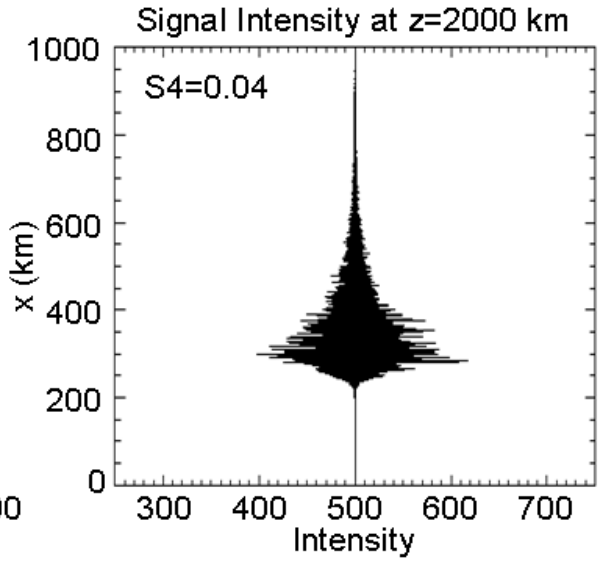
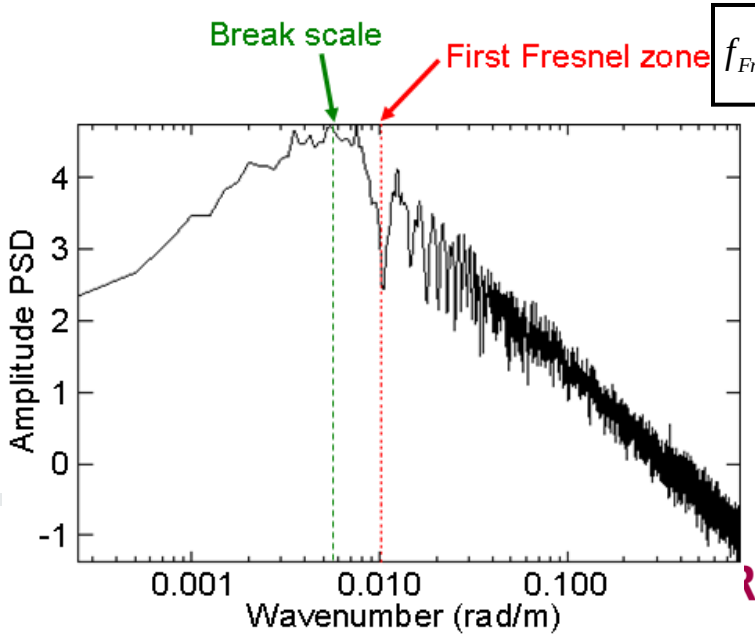
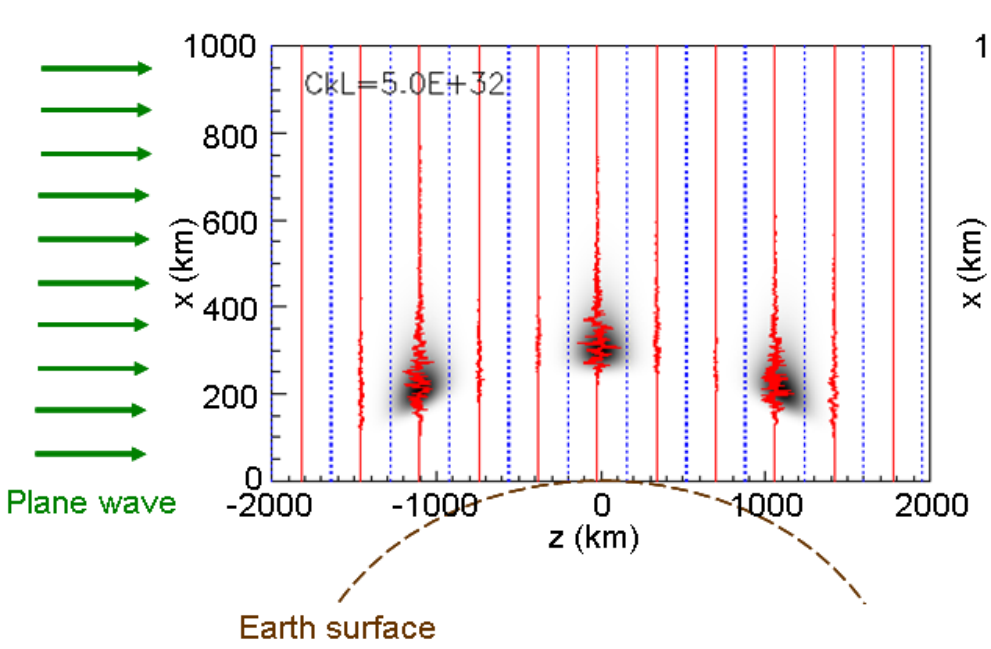
Single Bubble Simulation

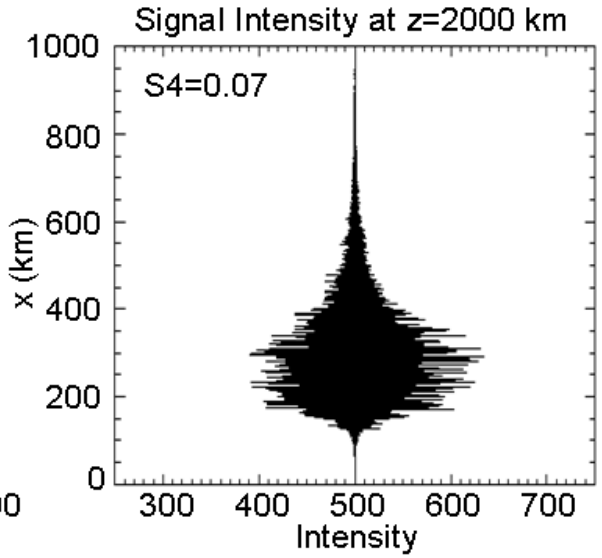


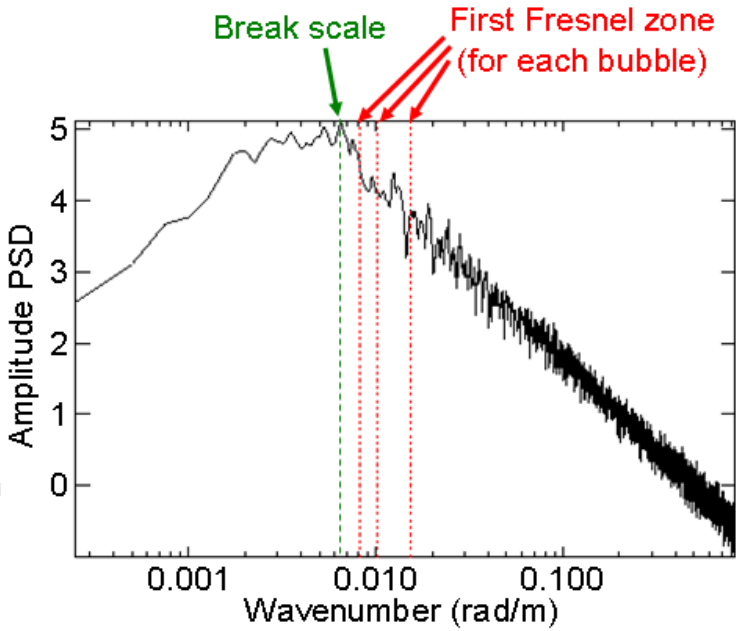




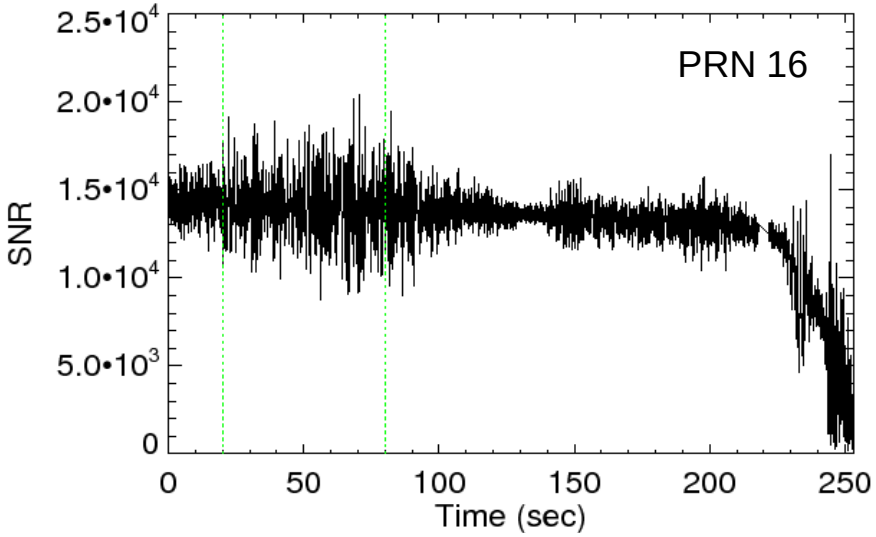
Multi-Bubble Simulation







CORISS Observations & Simulation

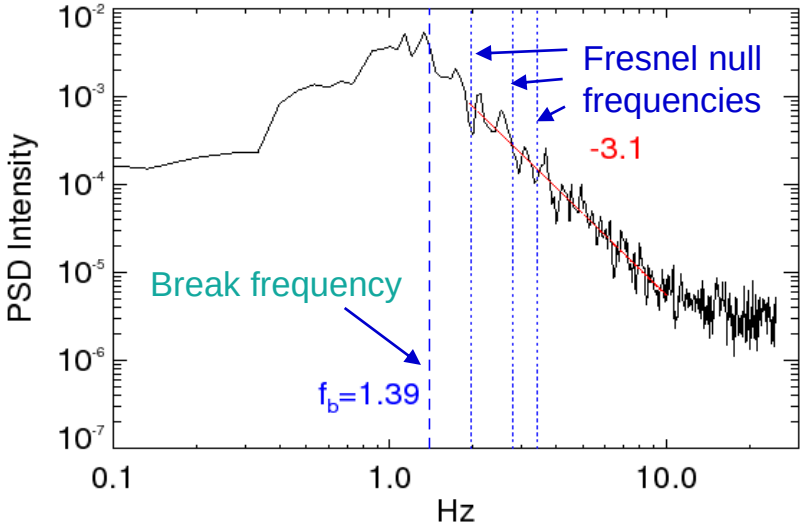


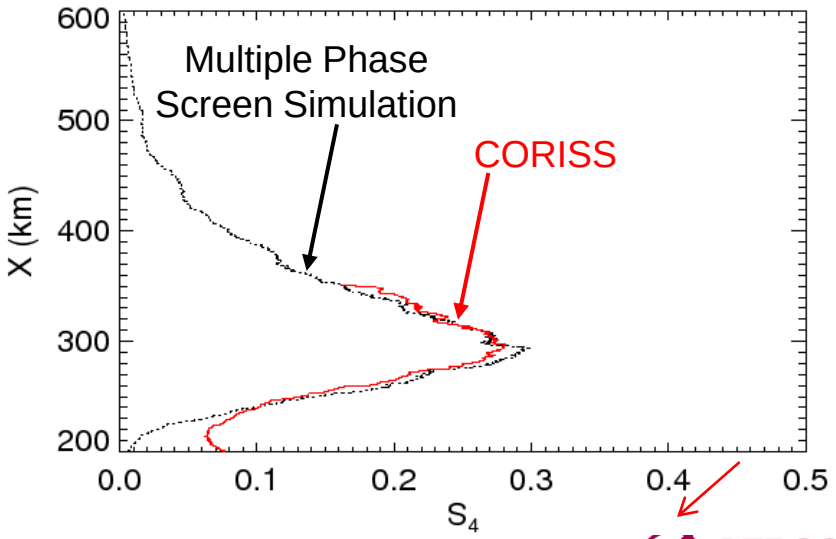
- Assume weak scattering: $d_s = \frac{1}{2\lambda}\left(\frac{V_{scan}}{f_b}\right)^2$
- Given propagation orthogonal to B, then

$$V_{scan} = V_{\perp}^{C/NOFS} + \frac{d_s}{d}\left[V_{\perp}^{GPS} - V_{\perp}^{C/NOFS}\right]$$

where *d* is C/NOFS-GPS distance

- Yields d_s ~ 630 km (t.p. is ~500 km)
- Determine irregularity strength, region size, spectral slope, & BG density profile from ALTAIR, SCINDA & CORISS measurements





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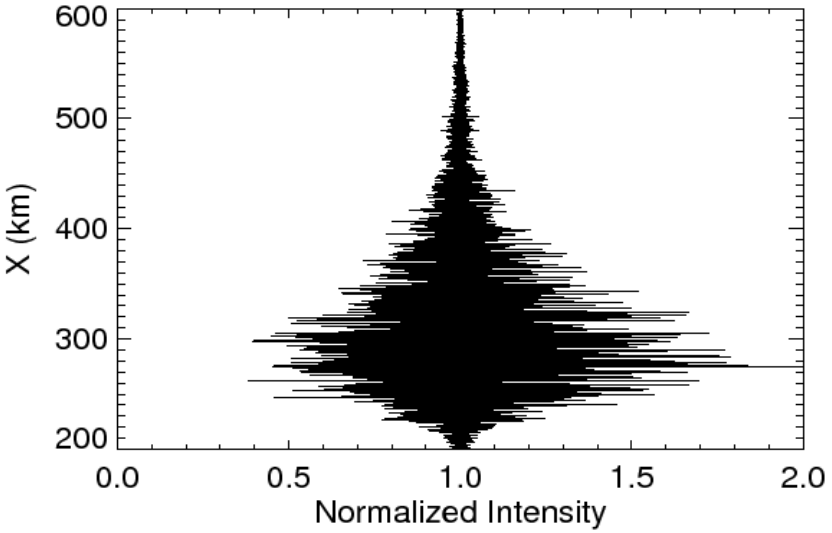
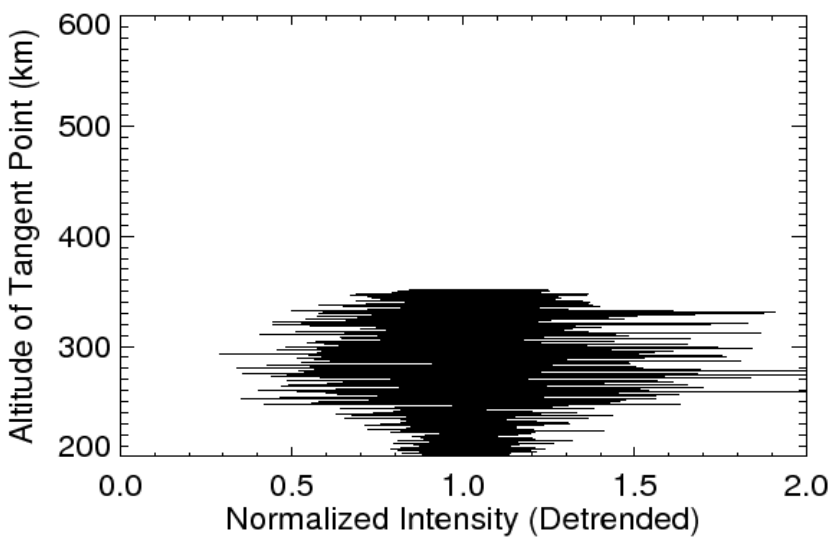
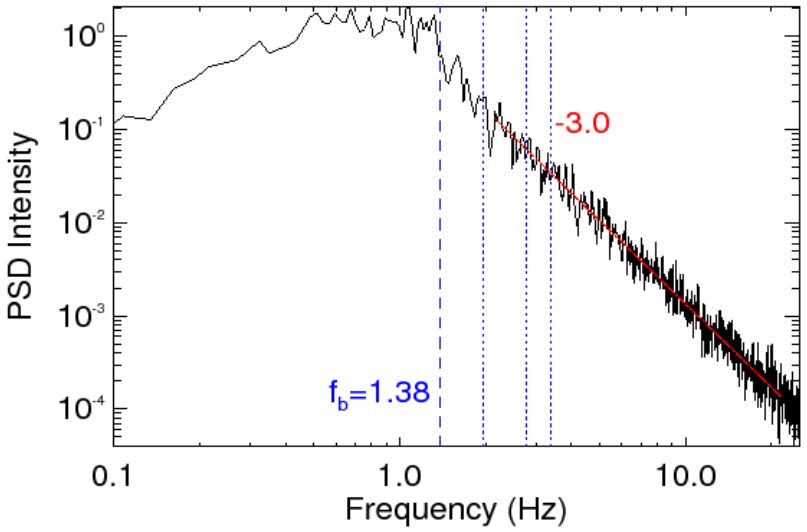
Multiple Phase Screen Simulation of CORISS Data

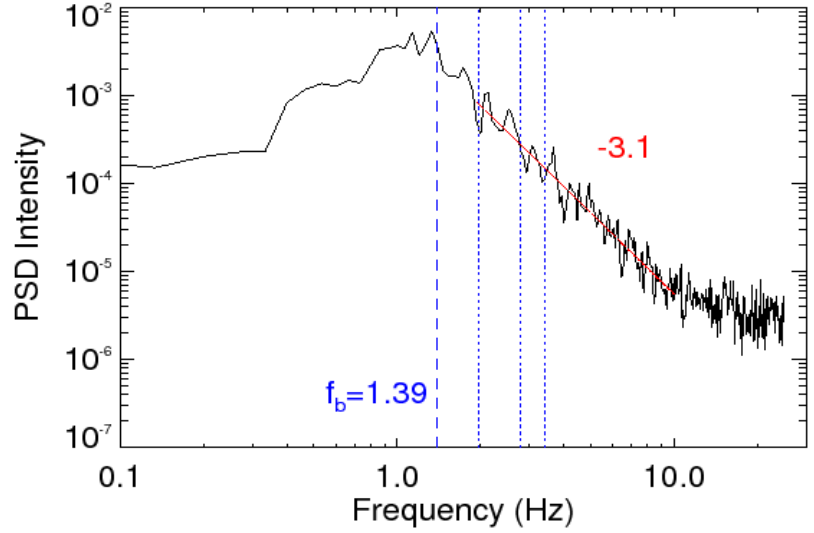
MPS Simulation



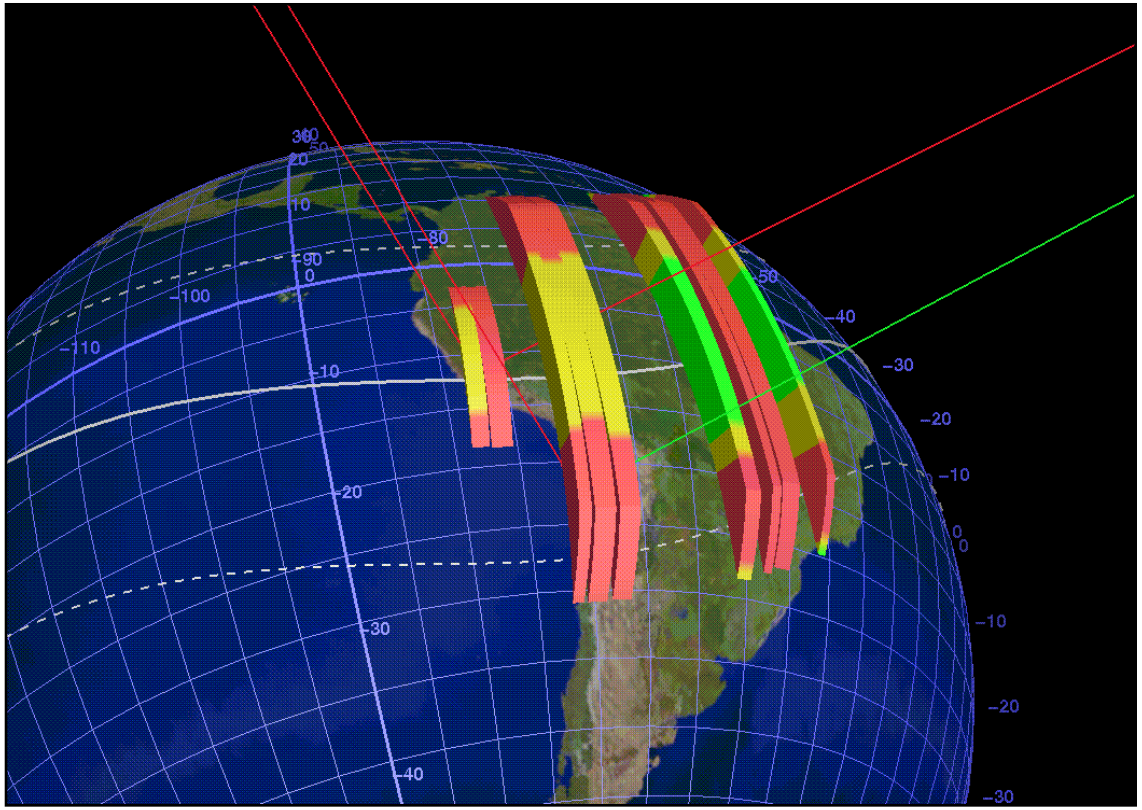
CORISS







Mapping of Instability Regions Along Magnetic Field Lines Aids in Scintillation Data Interpretation



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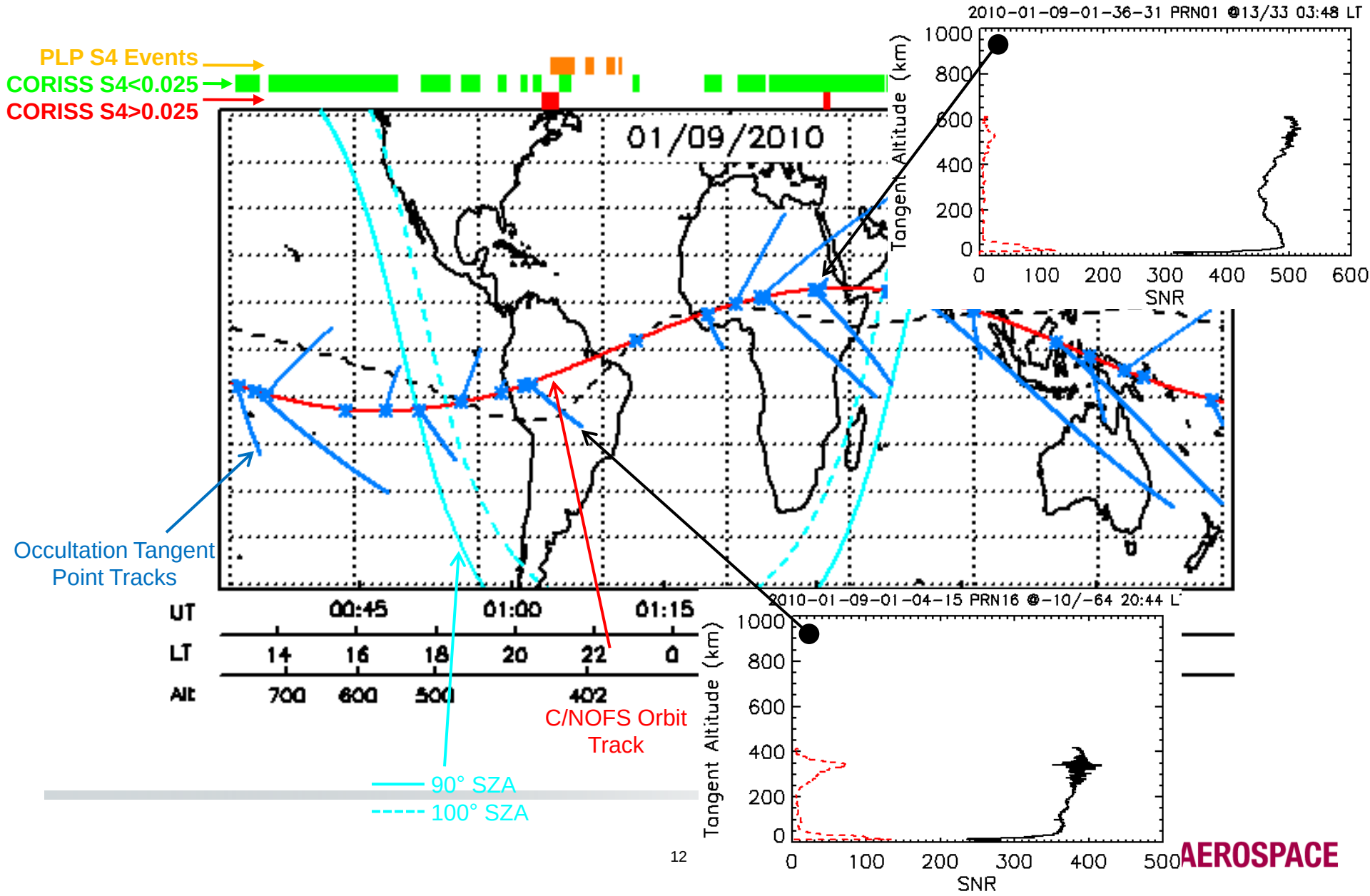
Low Latitude CORISS Scintillation Map



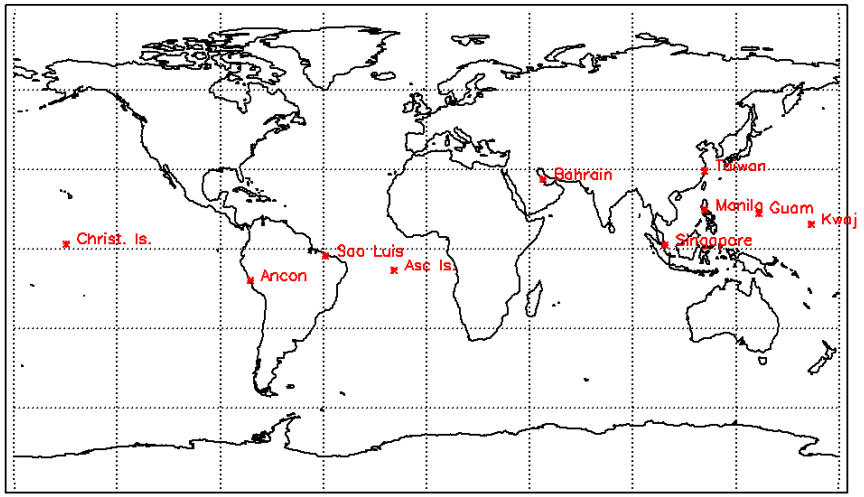
COSMIC-2 Instrumentation/Orbit is Ideal for Scintillation Studies

- VIDI in-situ sensor will measure plasma density fluctuations, enabling comparison of irregularity spectrum with RO observations of scintillation spectrum
  - *3D plasma drift (Electric Field) measurements also provide insight into instability onset*
  - *24°/520 km orbit enables these observations*
- RF Beacon will enable measurements of scintillation at UHF, L-band, and S-band frequencies (when over ground sites) enabling comprehensive comparisons of RO measurements with “ground truth” data at non-GNSS frequencies
  - *Can RO observations be used as a reliable proxy for frequencies above and below L-band?*
  - *Additional consideration: TriG may be able to provide independent L1/L2/L5 scintillation observations*

Summary of CORISS (L-Band)/SCINDA (UHF) Comparisons

April 2008-July 2009 Study Period

SCINDA Site	CORISS $S_{RO(1s)}$>0.05 & SCINDA S4>BG+0.1		CORISS $S_{RO(1s)}$<0.02 & SCINDA S4<BG+0.1	
	Δt = ±1 hour	Δt = ±2 hour	Δt = ±1 hour	Δt = ±2 hour
Ancon	72%	82%	93%	87%
Christmas Island	66%	77%	88%	81%
Kwajalein	77%	84%	93%	87%
Guam/Manila	49%	57%	95%	91%



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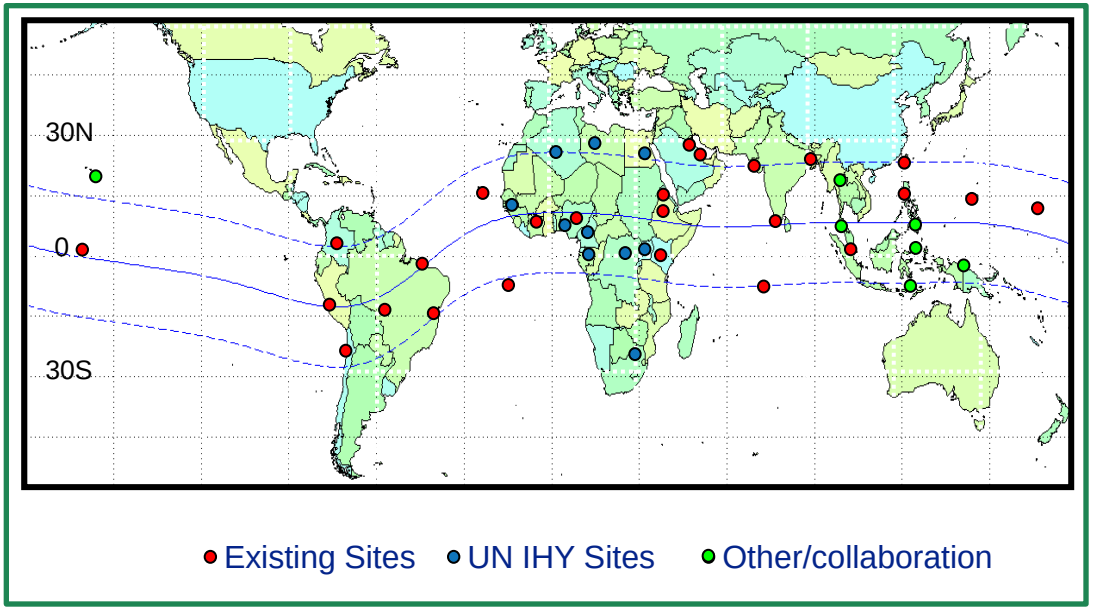
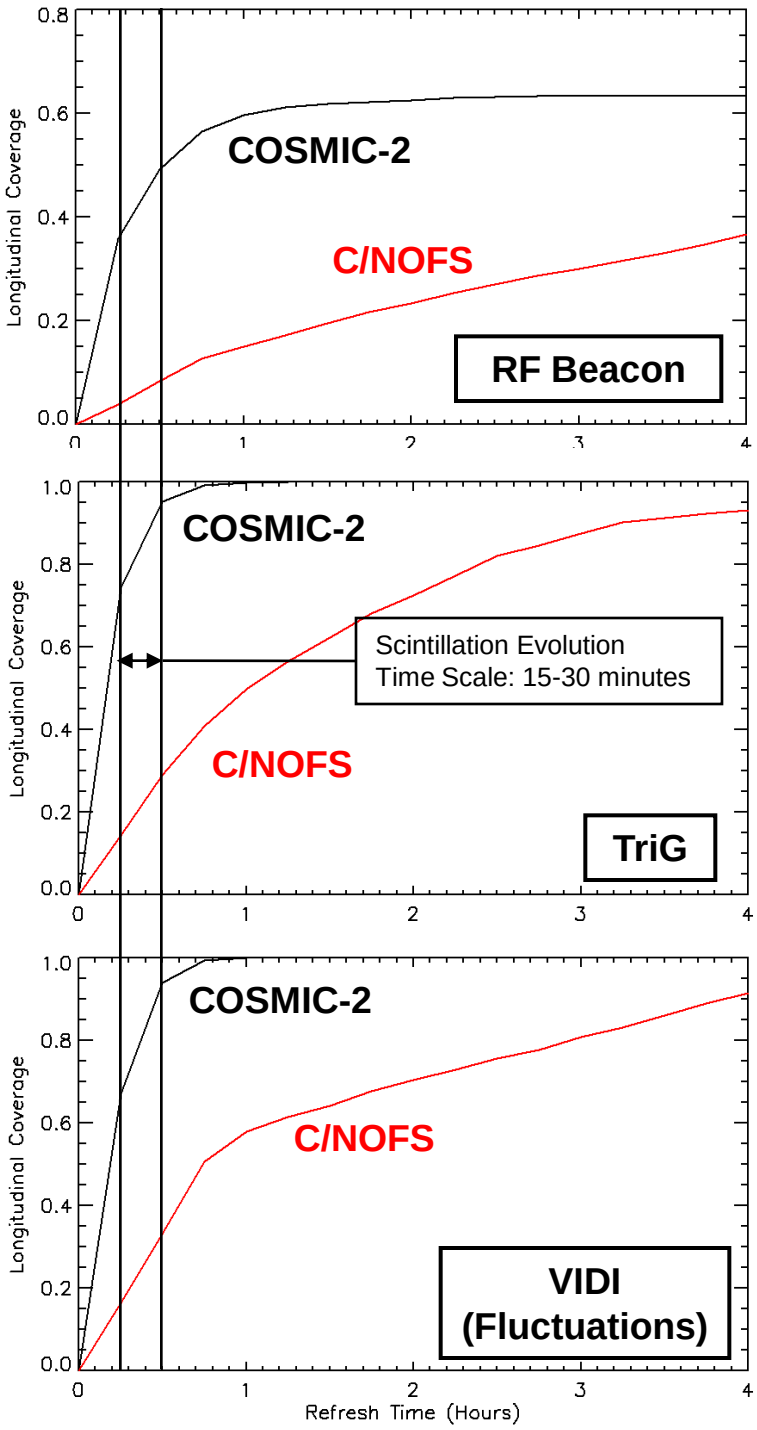
Scintillation Coverage vs. Refresh

SCINDA Ground Stations

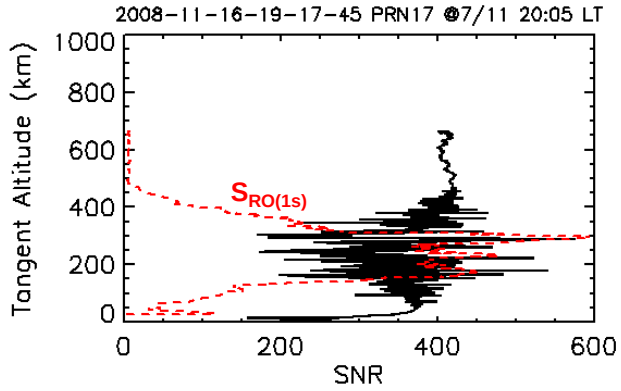


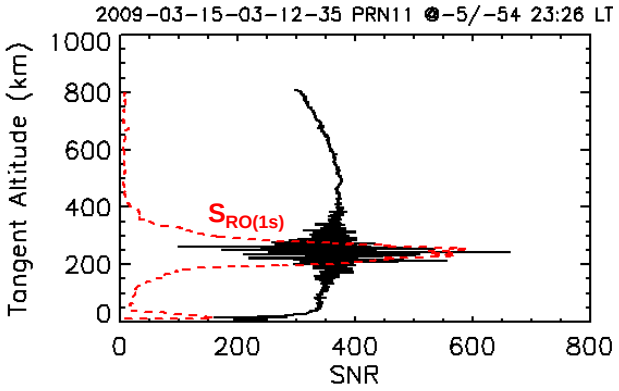
COSMIC-2 Will Completely Characterize the Equatorial Scintillation Environment

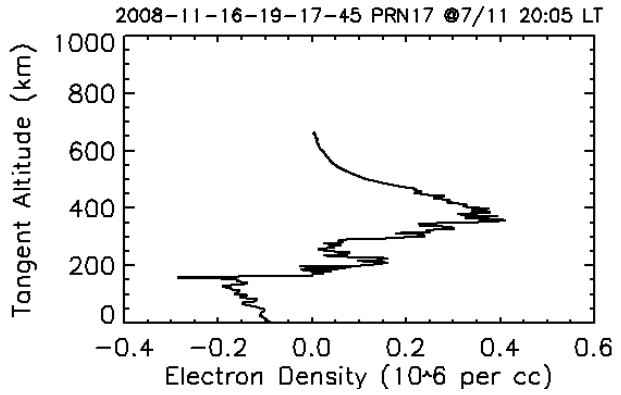


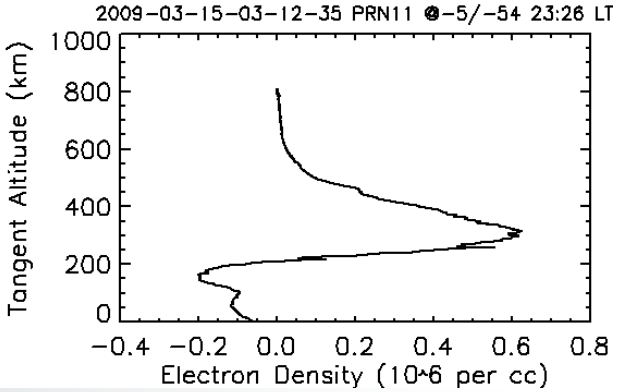
RO Scintillation & Ionospheric Profile Observations

- Irregularity regions that cause scintillation are embedded in plasma depletion regions ("bubbles") → major deviations from spherical symmetry
  - Might anticipate that Abel transformed profiles would be very poor – but this is not always the case
  - One also sometimes sees "ratty" EDPs, but no scintillation!









Summary

- RO studies of ionospheric scintillation are in their infancy (or maybe “early childhood”) and there is great potential for RO to be used for global scintillation specification
- The COSMIC-2 mission will enable RO to achieve this potential