GPS Occultation Studies of the Lower Ionosphere: Current Investigations and Future Roles for C/NOFS & COSMIC Sensors

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Outline

Ongoing GPS RO Ionospheric Investigations

- Scintillation
  - Global equatorial distribution
  - Tropospheric/Ionospheric coupling
  - Mid-latitude scintillation occurrence
- E-region Studies
  - Single profile extraction techniques
  - Validation with ISR
  - E-F region coupling

Future Roles for C/NOFS & COSMIC GPS receivers

- Brief CORISS (C/NOFS) instrument overview
- Goals of C/NOFS study
- Possible future equatorial Studies
- Collaboration with COSMIC satellites
  - Study examples

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Satellite GPS Occultation Ionospheric Data Sources

- CHAMP
  - ~400 km
  - 88° inclination
- SAC-C
  - ~700 km
  - 98° inclination – sun synchronous
- PICO Sat/IOX
  - ~800 km
  - 75° inclination
- IOX is the only instrument with ionospheric mission focus
  - Provides majority of assimilated ionospheric occultation data
  - Up to 500 occultations a day

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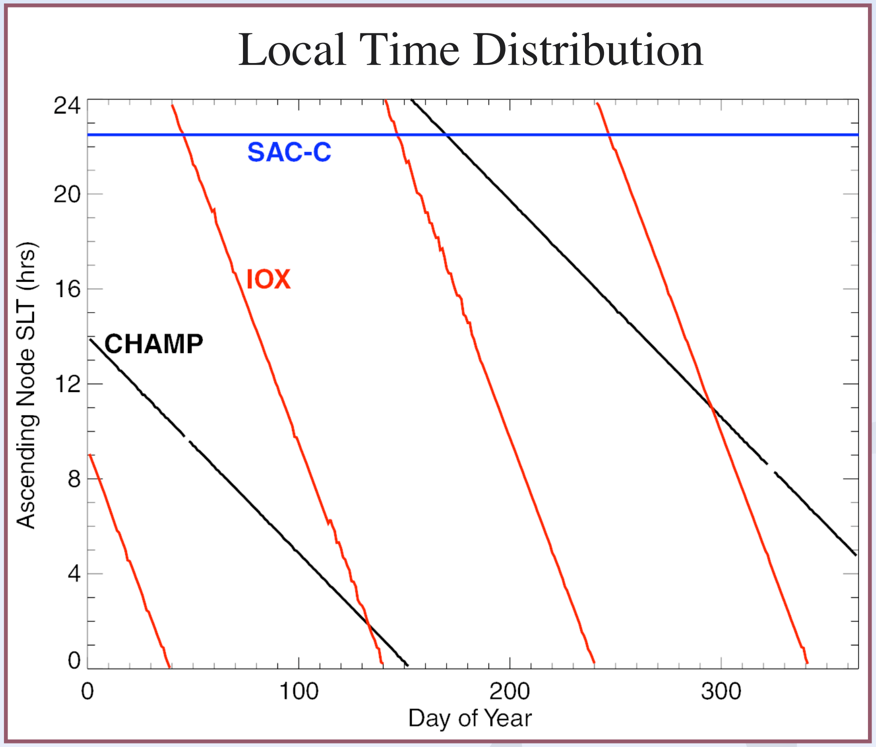
2002 Scintillation Occurrence

- PICOSat/IOX orbit precesses 360° in ~100 days - full local time coverage in ~50 days
- CHAMP orbit precesses 360° in ~260 days - full local time coverage in ~130 days
- Analysis limited to ray path tangent point altitudes above 200km.
- Rate of descent of the ray path tangent point:
  - IOX and SAC-C - from ~300 m/sec to ~2.5 km/sec
  - CHAMP - from ~150 m/sec to ~2 km/sec
- Equivalent to minimum scale sizes of the irregularities sampled by the GPS occultation receivers for 1-sec observations



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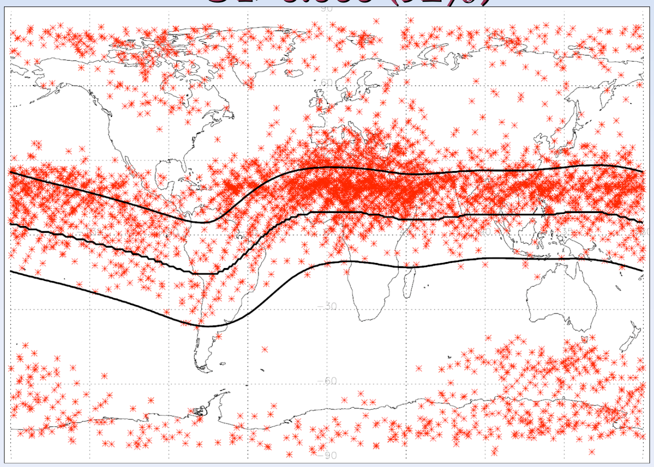
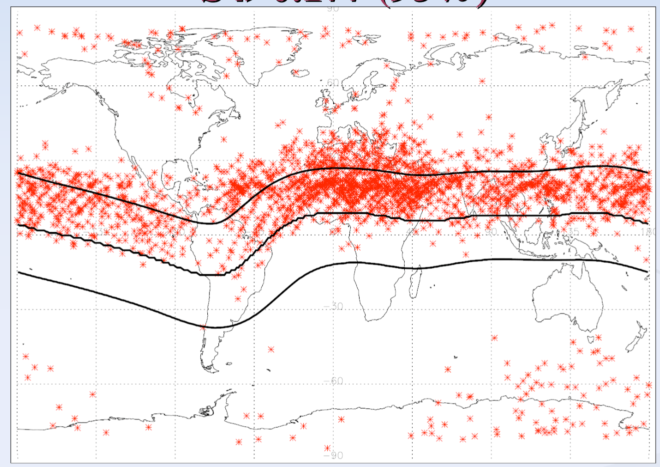
Global Distributions of SAC-C Occultations with differing S4 levels

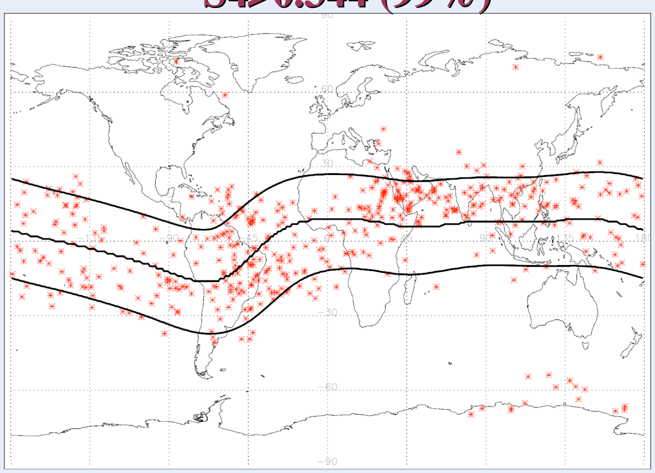
S4>0.066 (92%)



S4>0.177 (95%)



S4>0.344 (99%)



- Most scintillation shown occurs within +/-25 deg. mlat.
- Increase in occurrence over Africa for the 92/95% S4.
- Highest S4 levels occur in equatorial region.
- 82% in northern hemisphere
  - Driven by magnetic field configuration and occultation geometry.

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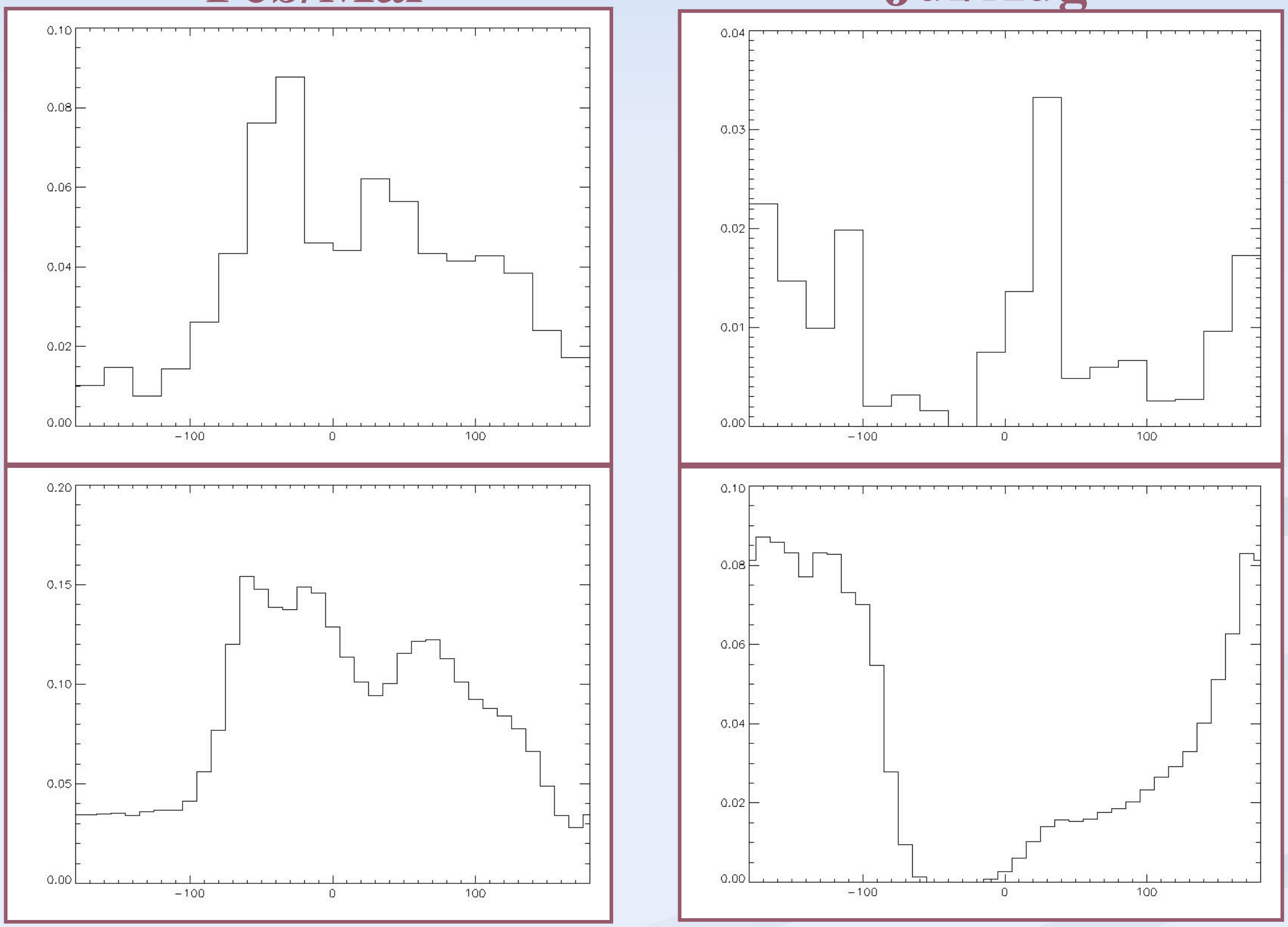
Climatological Scintillation Model Comparison

Feb/Mar | Jul/Aug

Occurrence Probability



IOX

WBMOD

Geographic Longitude (deg)

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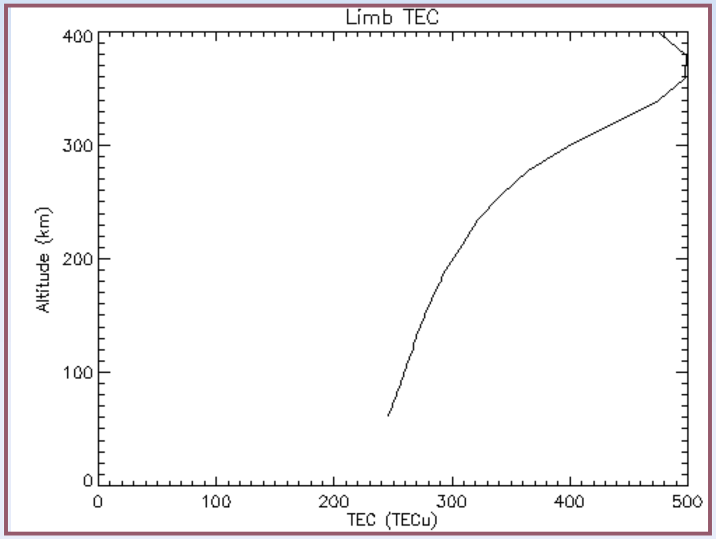
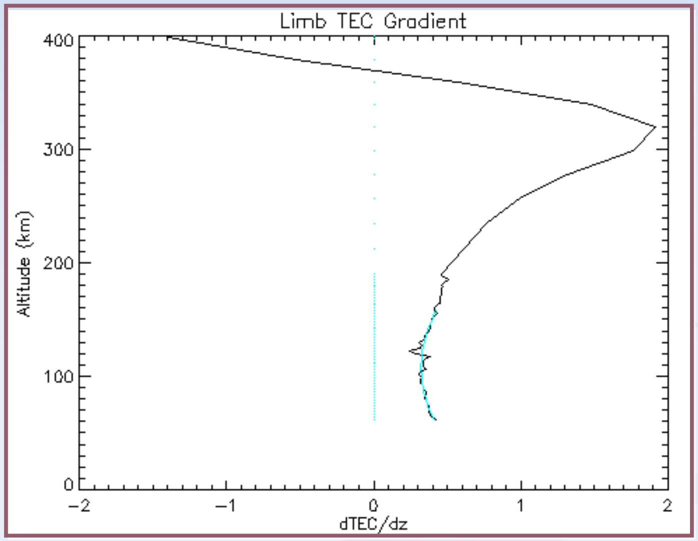
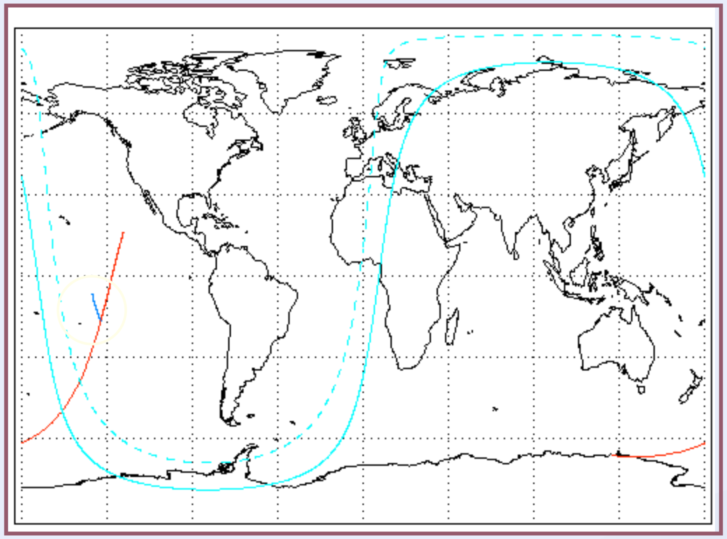
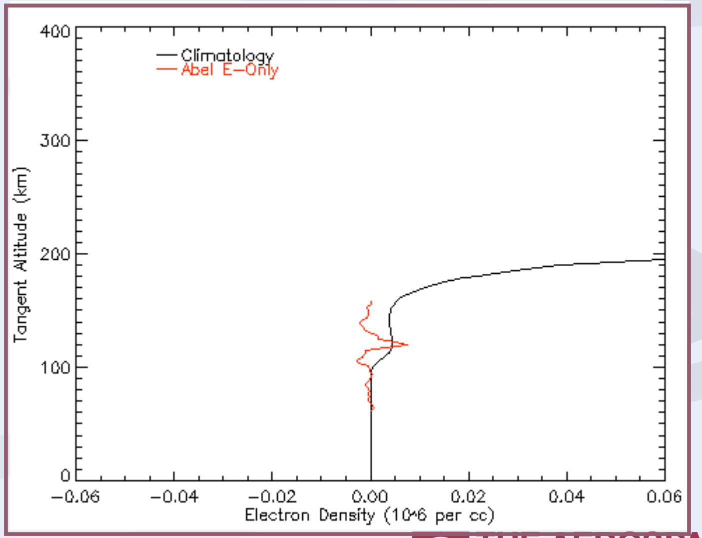
Extraction of E-region Profiles

PRN23 22-Oct-03 05:18 UT (19:51 LT)









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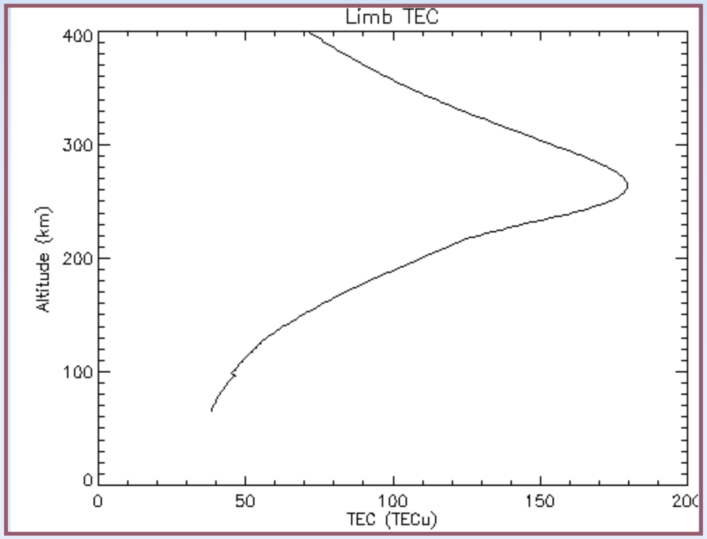
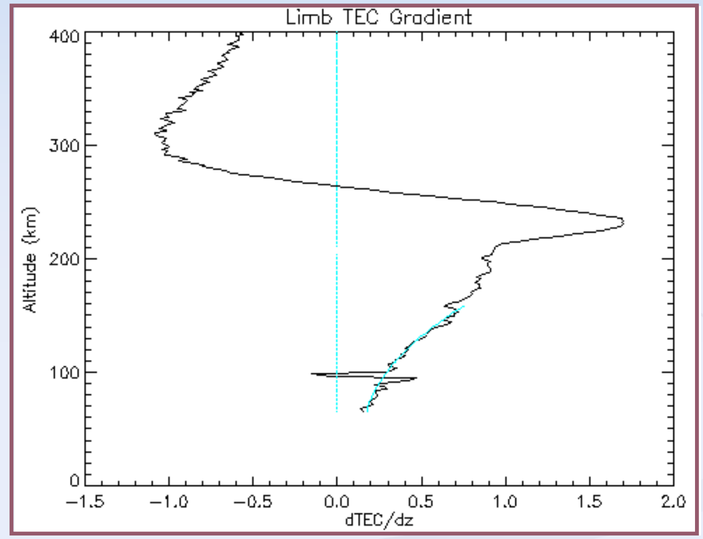
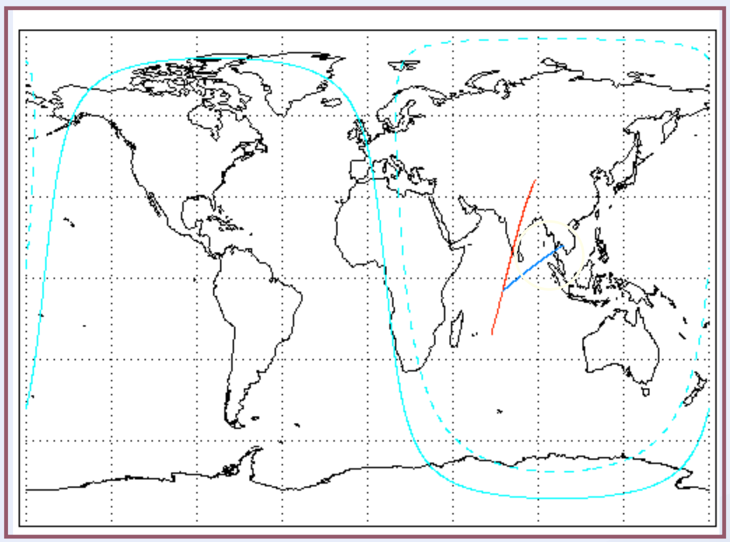
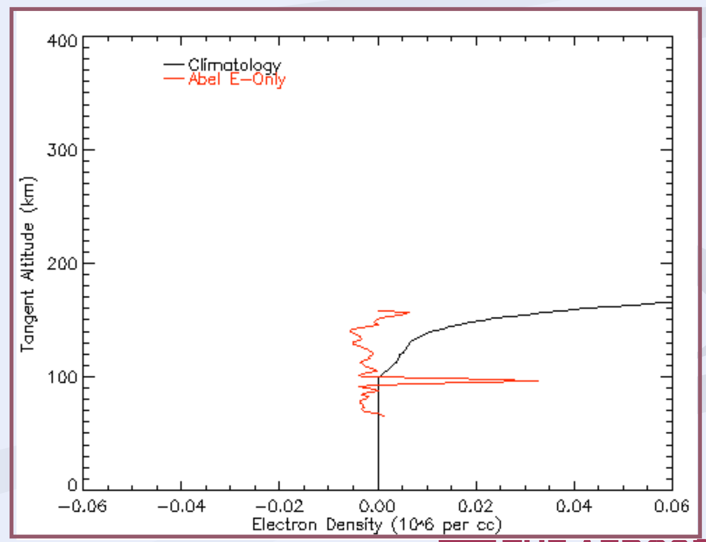
Extraction of E-region Profiles

PRN28 15-Oct-03 17:17 UT (23:57 LT)









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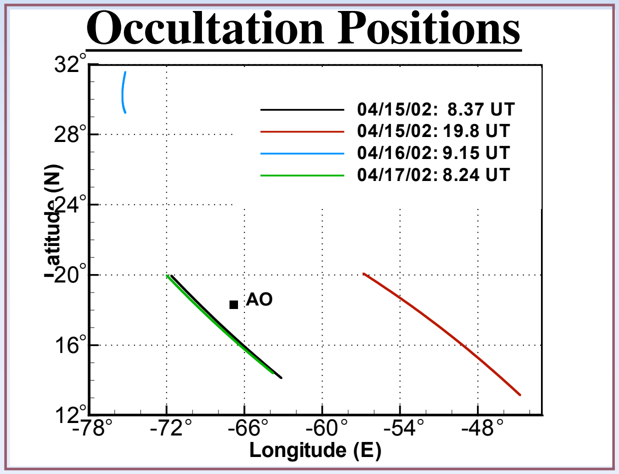
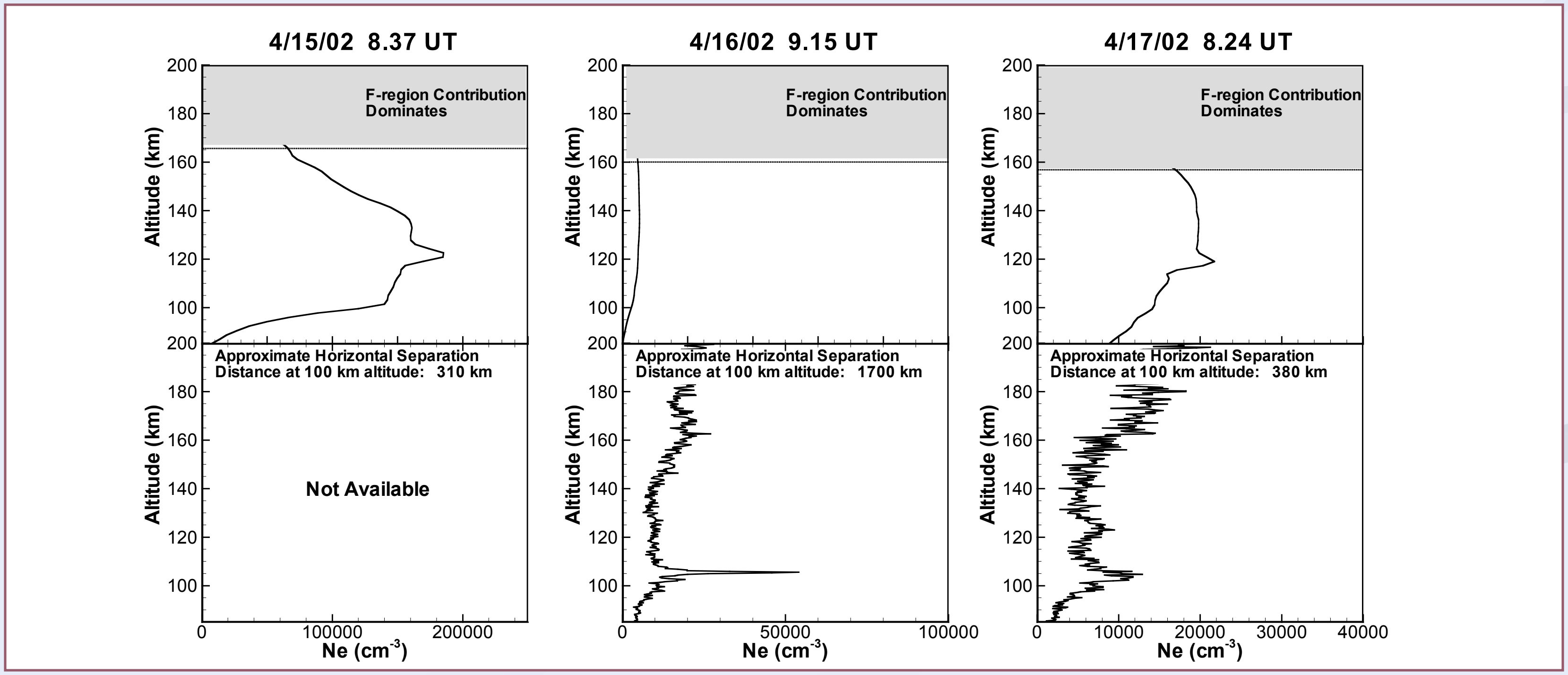
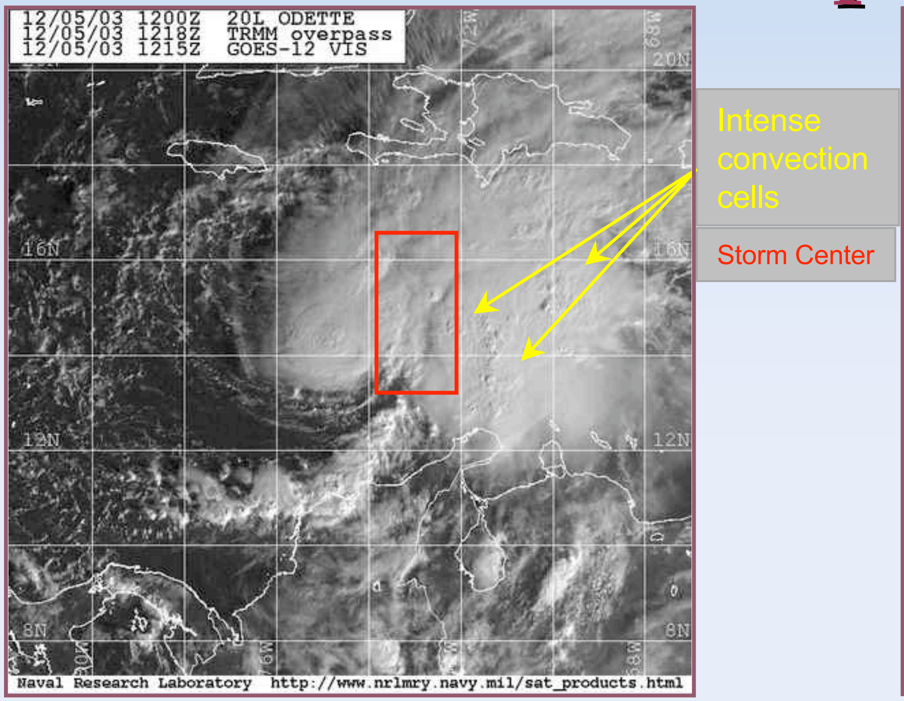
GPS Occultation and ISR data Comparison

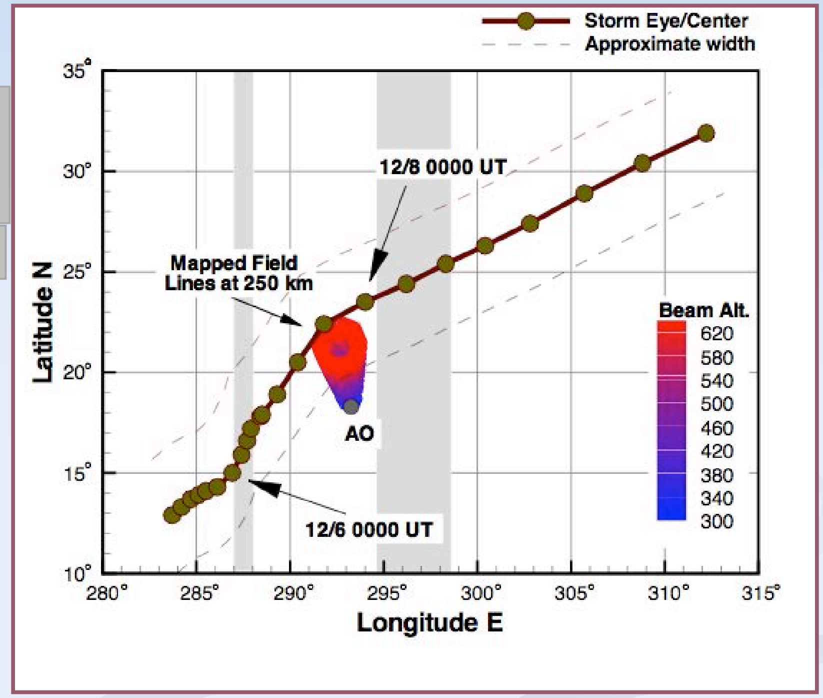


- Sporadic E layers (Es) can exist over large horizontal distances.
- Es observed in occultations profiles within a few degrees of Arecibo Observatory.
- GPS profiles show the presence of Es at higher altitudes.



Mid-latitude Ionospheric Scintillation





Storm Facts:

- Approximate Lifetime: Dec. 4-9
- Minimum pressure: 993 mb
- Maximum surface winds: 55 kt
- Unusual Caribbean/Dec. formation
- Most intense convection located on leading edge (east) of storm.

Data Sources:

- ISR: Arecibo Observatory (AO)
- Ionosonde: Ramey and AO
- Microbarometric Data
- GPS Radio Occultation Data
  - CHAMP satellite; orbit ~ 400 km
  - Ionospheric data
  - Tropospheric data

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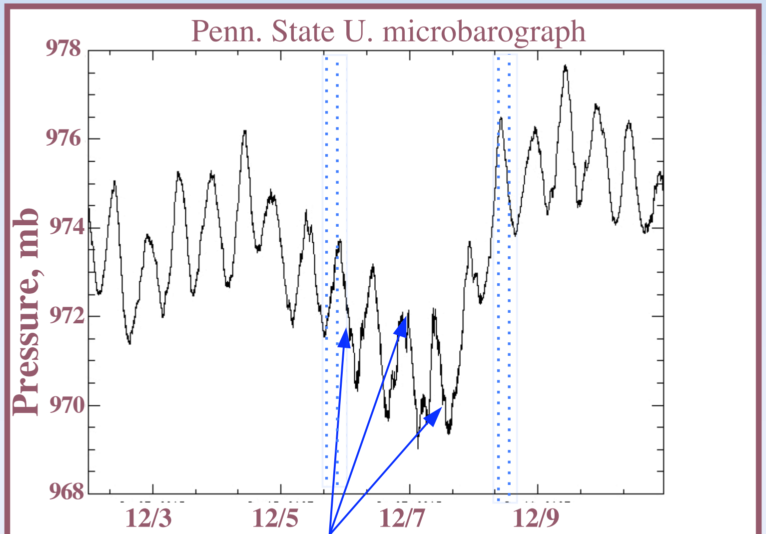
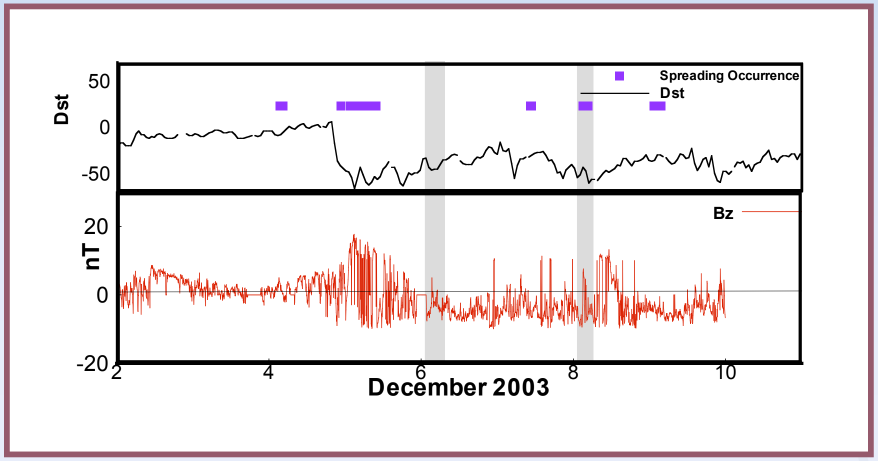
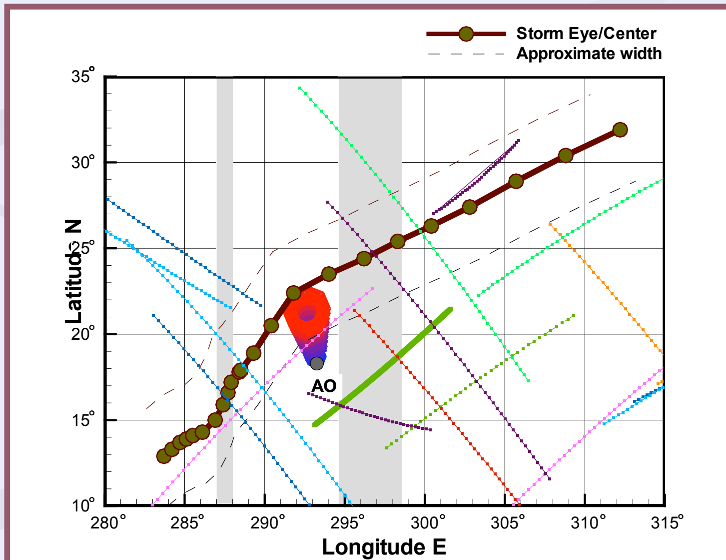
Surface & Geomagnetic Conditions



High frequency variations indicative of intense convection activity.





- Significant geomagnetic storm 12/4-12/5 prior to first AO observing period.
- High frequency pressure variations increase with the approach of the tropical storm. Variations are likely indicative of active generation of gravity waves.
- Similar to Bauer [1957,1958], F-peak density and altitude vary with the near passage of Odette.
- Range spreading observed the night following closest approach of the storm.
- Preliminary GPS data show scintillation along storm path after passage of center.

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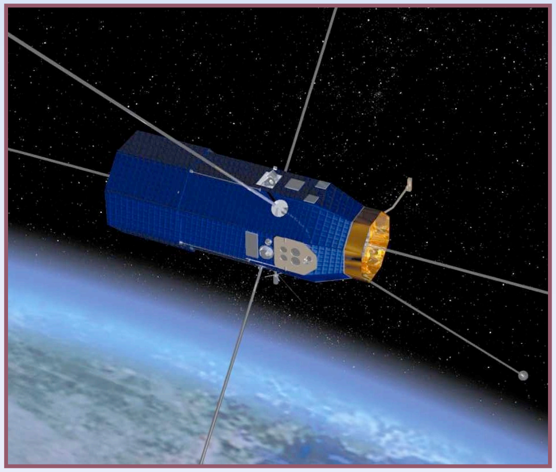
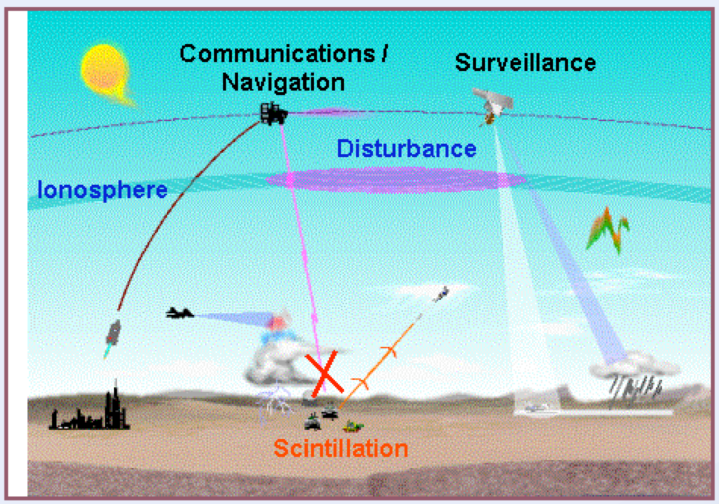
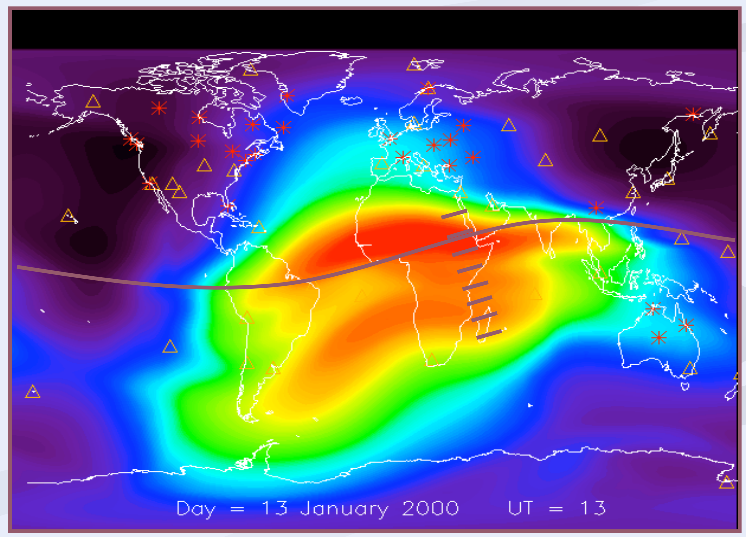
C/NOFS satellite & the CORISS Instrument



Artist rendition of C/NOFS satellite
http://www.te.plk.af.mil/stp/cnofs/cnofs.html

- First-ever system for continuous global scintillation forecasts of comm/nav outages.
- Ionospheric scintillation impacts all satellite data links <2.5GHz
- Developing data-driven, scientifically-based models for:
  - 1-3 hr scintillation warnings
  - 4+ hr scintillation forecasts





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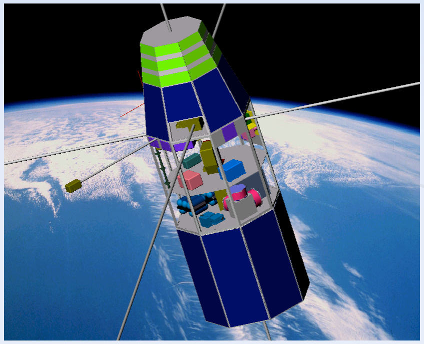
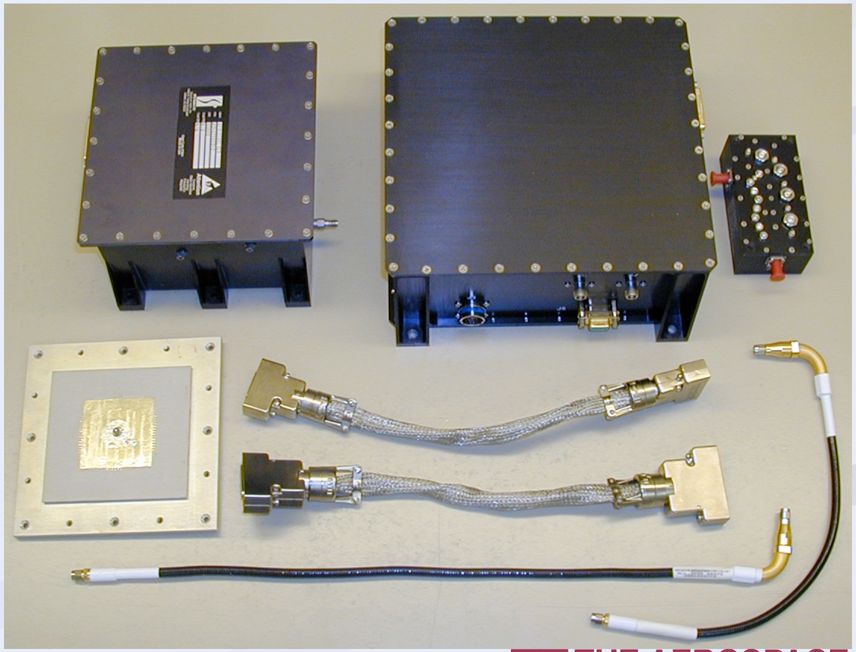
C/NOFS Occultation Receiver for Ionospheric Sensing and Specification (CORISS) Instrument

- GPS dual-frequency receiver.
- Measured Parameters:
  - Line-of-sight TEC
  - Vertical Ne profiles
  - On-board scintillation indices & spectra
    - → S4, σ_ϕ
  - Stratospheric temperature profile
  - High rate scintillation products
    - → S4, σ_ϕ





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CORISS Features

- CORISS is a Modified Version of the Jason/ICESat Receiver
  - RF front end adapted to C/NOFS RFI requirements
  - Single patch antenna on anti-velocity side of s/c
  - Receiver s/w updated by Aerospace to perform occultations & other special functions (Tom Meehan consulting)
    - On-board processing of scintillation parameters: S4, σ_ϕ, spectra
    - Two telemetry streams
      - TDRSS: near real time; low/medium rate data + scintillation parameters
      - SGLS: store-and-forward high volume; same as TDRSS + high rate (50 Hz) tropospheric occultations + high rate ionospheric occultations (L1 only w/ non-occulting reference satellite for phase scintillation)
        - Tropospheric data all the time
        - Ionospheric HR data about _ of orbit due to data rate restrictions (programmable – generally will be in the post-sunset sector)

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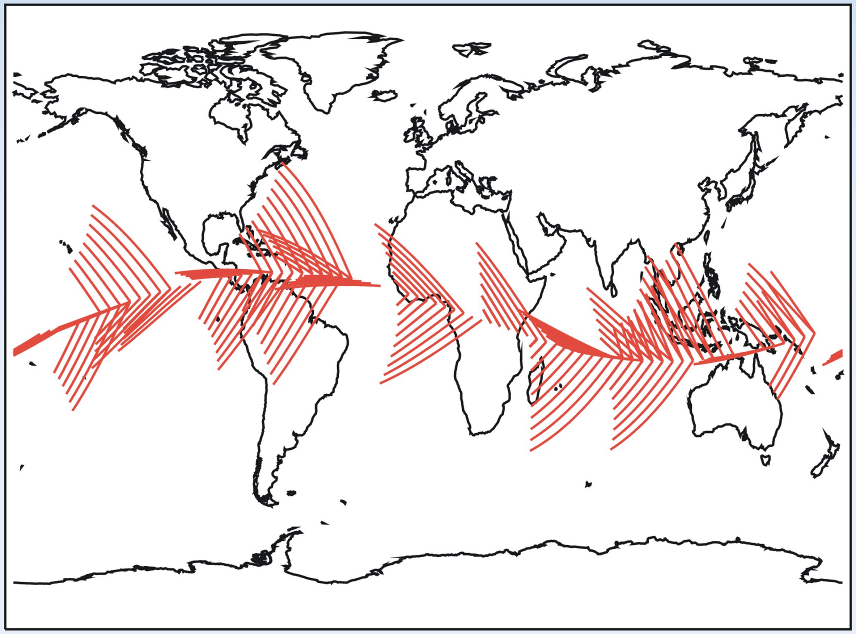
Future C/NOFS & COSMIC Studies



CORISS Occulting Lines of Sight

CORISS Studies:

- Nighttime E-F region coupling
- Scintillation triggering mechanisms
- Atmospheric gravity wave studies

CORISS/COSMIC Studies:

- Traveling ionospheric disturbances
- Mid-latitude scintillation studies
- Tropospheric/Ionospheric coupling via gravity waves

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Summary

- GPS occultation data is highly useful for ionospheric studies.
  - Provides global observations of the state of the ionosphere
  - On-going investigations include:
    - Scintillation studies (IOX, C/NOFS)
    - Lower E-region validation studies
    - Tropospheric/Ionospheric coupling via tropical storms
- Future ionospheric studies would greatly benefit from C/NOFS and COSMIC data and collaborative efforts.
  - Ionospheric specification related to scintillation.
  - TEC response to geomagnetic changes.

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