



VERIFYING COSMIC GPS OCCULTATION INVERSION PROFILES WITH THE ALTAIR RADAR

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Overview



- FORMOSAT-3 / COSMIC produces ~1000-2000 *ionospheric* profiles per day
- Ionospheric profiles derive from Abel inversion—assumes spherical symmetry
- How does spherical symmetry assumption affect profiles in equatorial ionosphere? Challenges:
 - Horizontal gradients (e.g., equatorial anomaly)
 - Ionospheric “bubbles” (equatorial spread-*F*)
- We used ALTAIR VHF / UHF incoherent scatter radar (ISR) to study three (3) occultations in Sep 2007
- Main result: even “modest” departures from spherical symmetry affected profiles, particularly bottomside



Experiment Summary

Period: 05-26 Sep 2007



ALTAIR (Kwajalein Atoll)

- Six (6) useful occultations in ALTAIR field of view predicted
- Three (3) occultations with ALTAIR data and COSMIC profile
 - 11 Sep 2007 (quiet, some E_s)
 - 06 Sep 2007 (uplift toward E)
 - 16 Sep 2007 (spread- F)
- Other instruments available: Digisonde, All-sky imager, VHF scintillation, Tri-band beacon receiver, GPS receiver



- Powerful UHF/VHF radar
- Coherent scatter scans ($\perp \mathbf{B}$)
- Various ISR scans



Occultation Geometry

Sets Stage for Abel Inversion Errors



Total Electron Content (TEC) for Bottomside Profile Reconstruction Is Weighted by Distant *F*-peaks along Line of Sight (LOS)

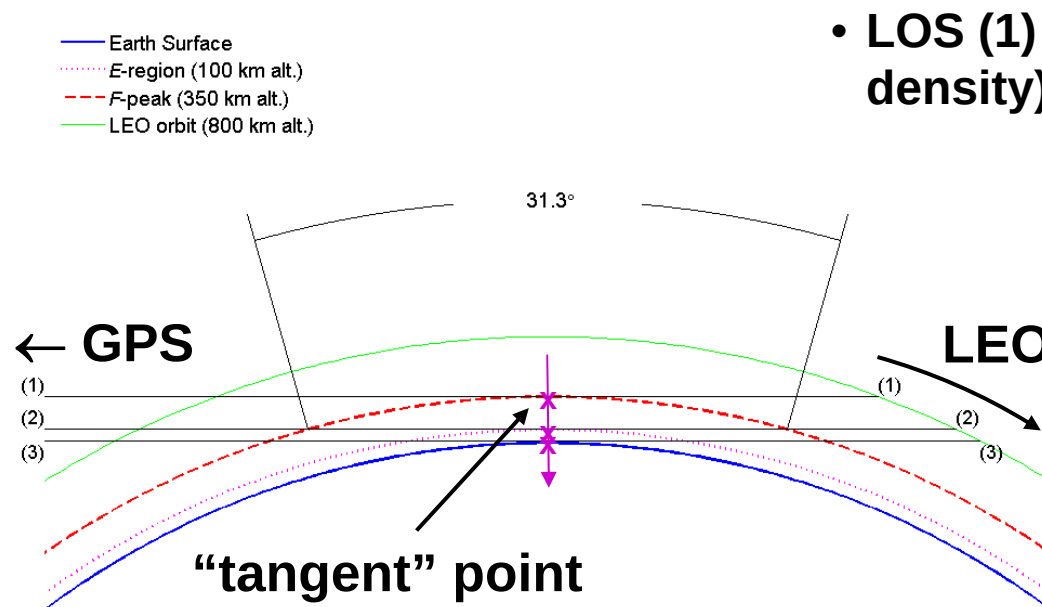


Figure to Scale

- LOS (1) samples *F* peak (bulk of electron density) $\sim 16^\circ$ away from LOS (2)
- LOS (2), at *E* region altitude, includes *F* peaks 31° apart (~ 3300 km @ R_E)
- GPS occultation also rarely forward or aft of LEO $\Rightarrow$ "lateral smearing"
- Note: Abel inversion depends on $d\text{TEC}/dr$, not TEC alone

In contrast, tropospheric inversion has several mitigating factors that make spherical symmetry assumption more tenable

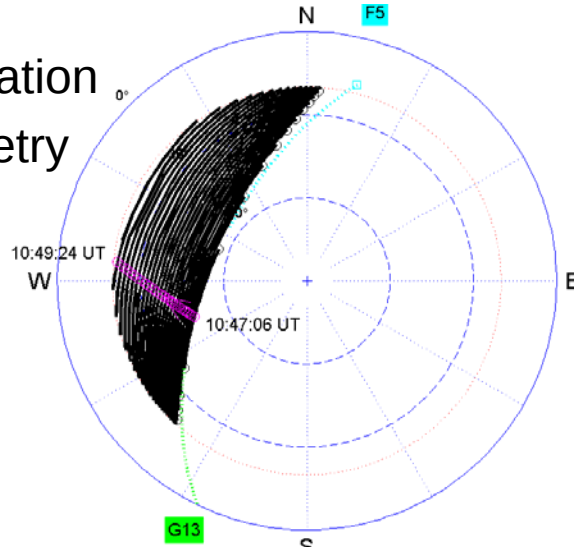


11 Sep 2007 Case

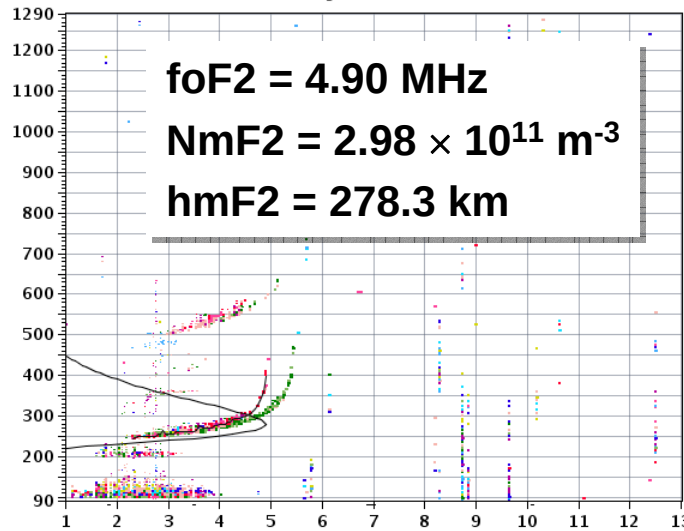
Smooth Ionosphere (with Sporadic-E)



Occultation
Geometry



(km)

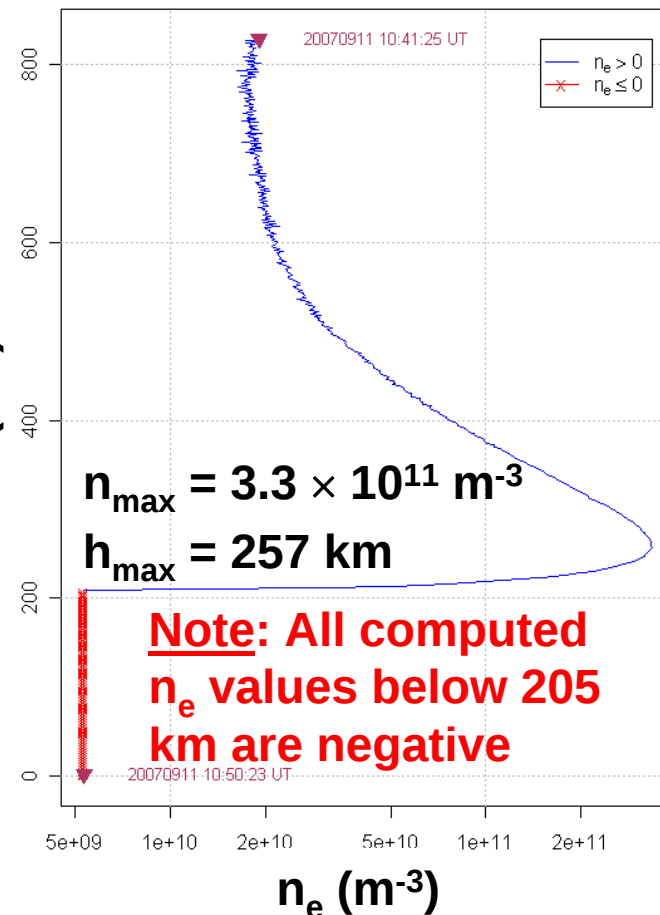


Digisonde Trace (with Sporadic-E)

Unusually Smooth Ionosphere
Yields Good Quality Profile

C005.2007.254.10.49.G13
Inverted (@ CDAAC): 15-DEC-07 11:01

h (km)



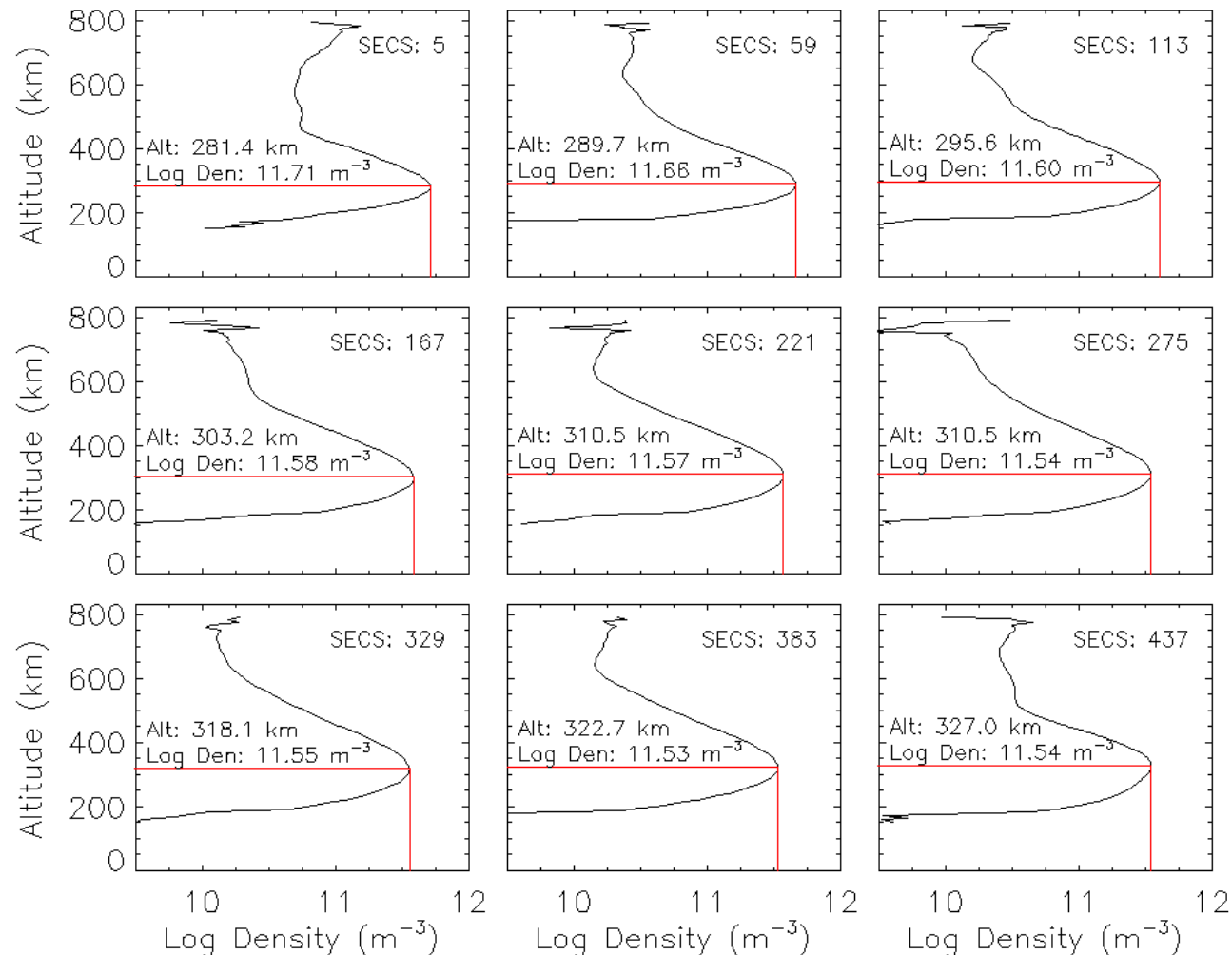


11 Sep 2007 Case

ALTAIR Scan Shows Smooth Ionosphere



Pre-pass / Pre-occultation UHF ISR Scan along COSMIC F5 Track (SW → NNE) Shows Little Profile Variation



Peak density:
 $\sim 3.8 \times 10^{11} \text{ m}^{-3}$

Peak altitude:
280 km at SW to
327 km at NNE

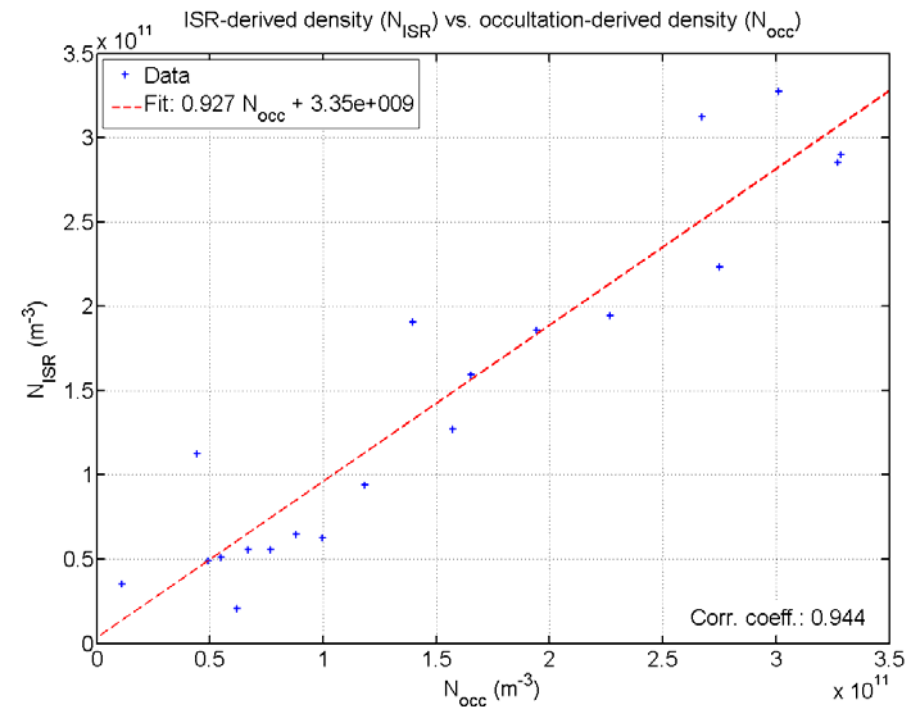
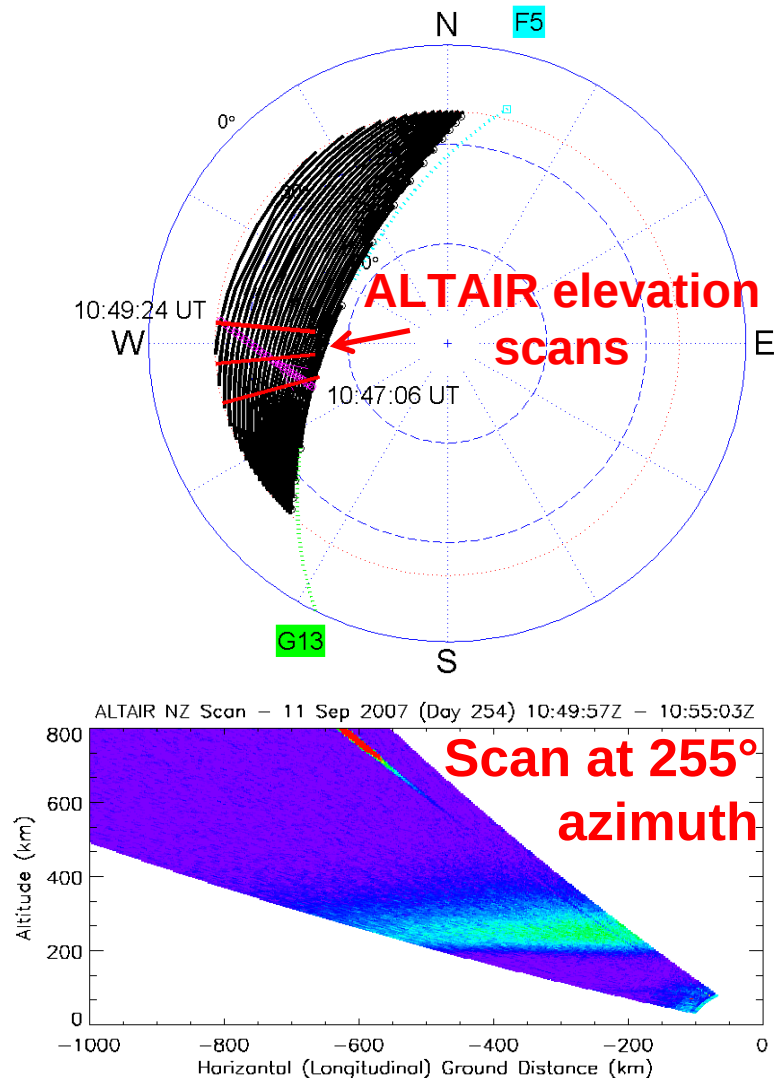


11 Sep 2007 Case

Investigating Density near “Tangent” Points



Comparison Fairly Good between ISR and Occultation Density



Methodology

- Interpolate ISR density in vicinity of “tangent” points
- Plot vs. occultation profile at “tangent” point altitudes

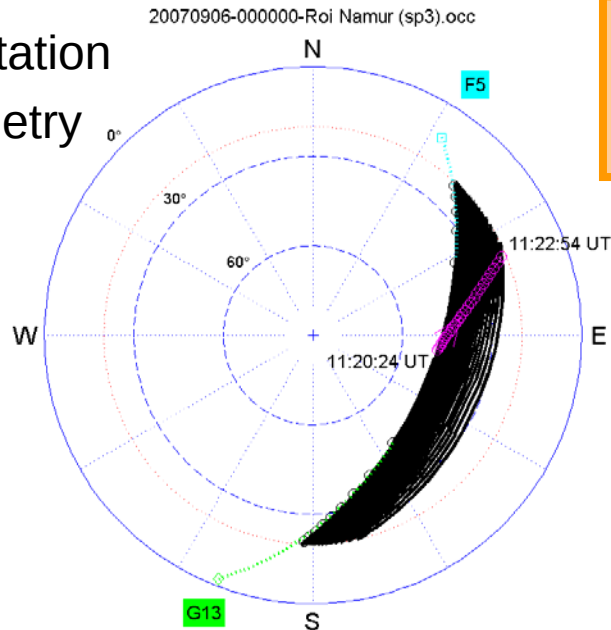


06 Sep 2007 Case

Uplift / Modest Disturbance toward East

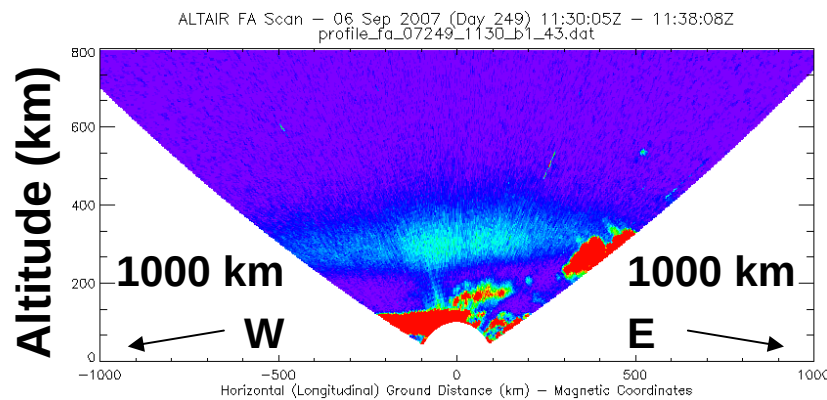


Occultation
Geometry

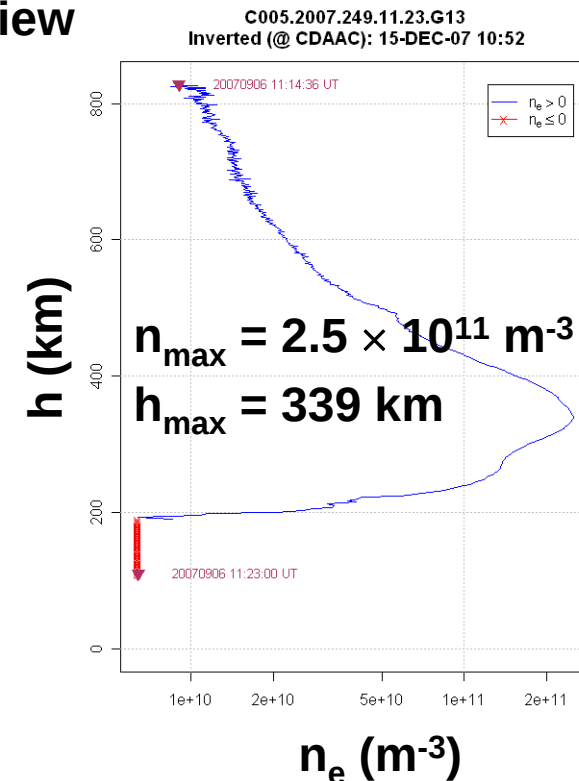


Uplift Broadens *F*-peak; Small Spread-*F* Plume Distorts Bottomside

Note: Observed irregularities only slightly extend to topside within ALTAIR view



VHF $\perp$ **B** Scan (Coherent Scatter)
—Post-Occultation



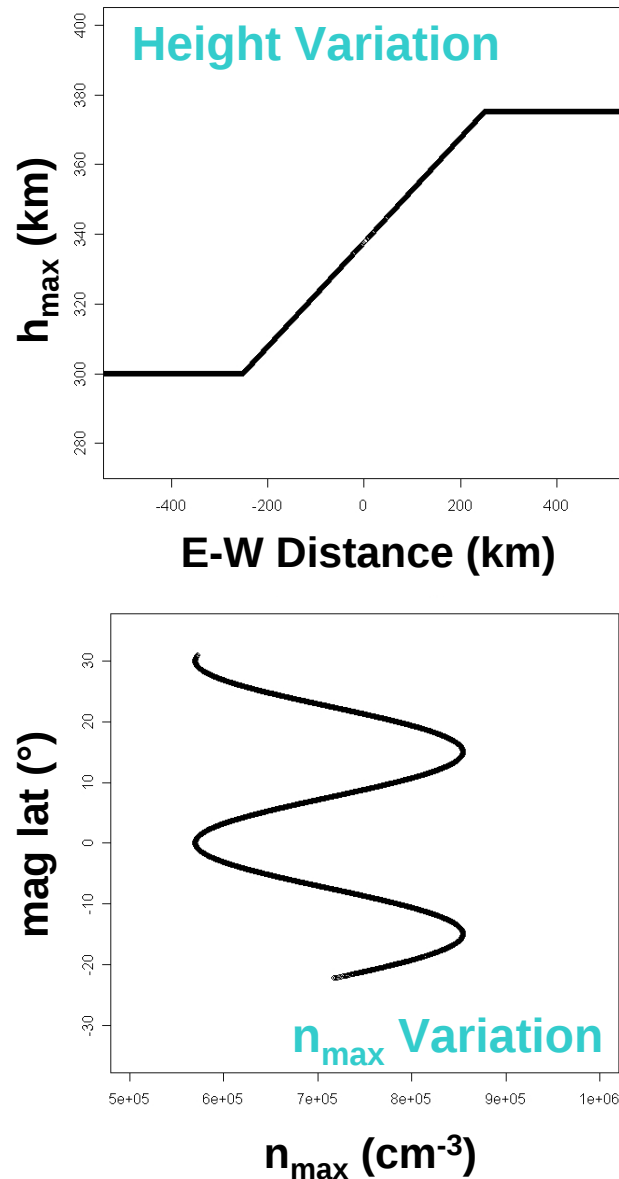


06 Sep 2007 Case

Abel Transform Modeling Shows Uplift Effect

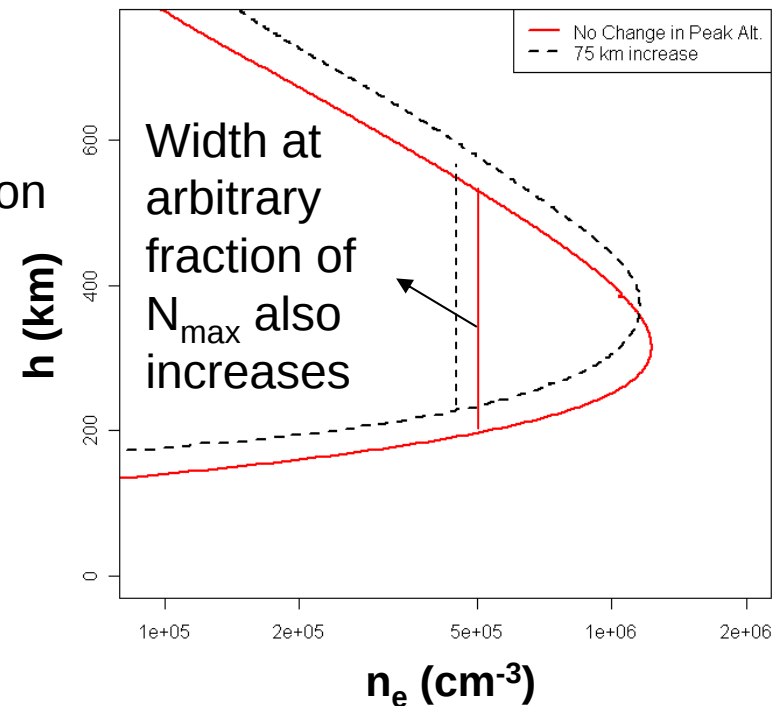


Ionospheric Modeling Parameters
Used in Occultation TEC Generation



An Uplift Broadens F -peak and Reduces $n_{\max}$ in Inversion

Abel
Inversion
 $\Rightarrow$



Goal was to reflect qualitative, not quantitative, results of 06 Sep 2007

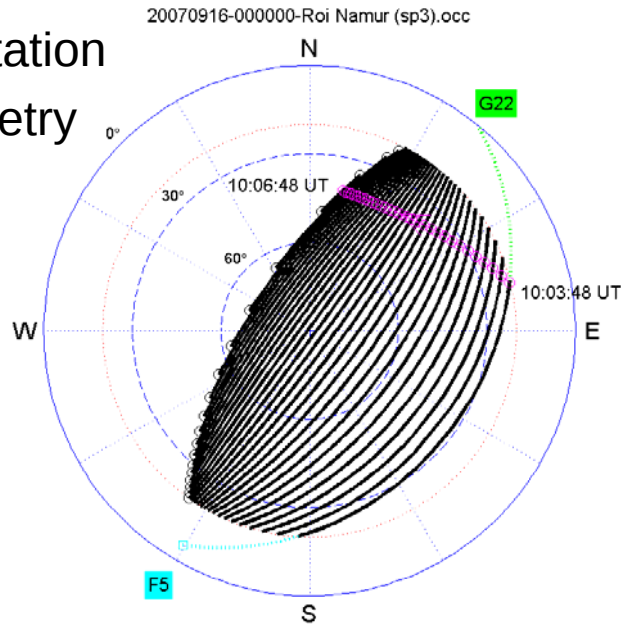


16 Sep 2007 Case

Disturbed Ionosphere

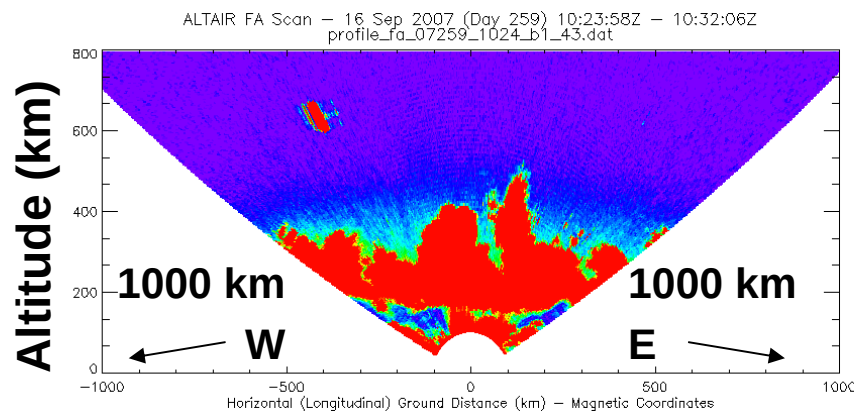


Occultation
Geometry

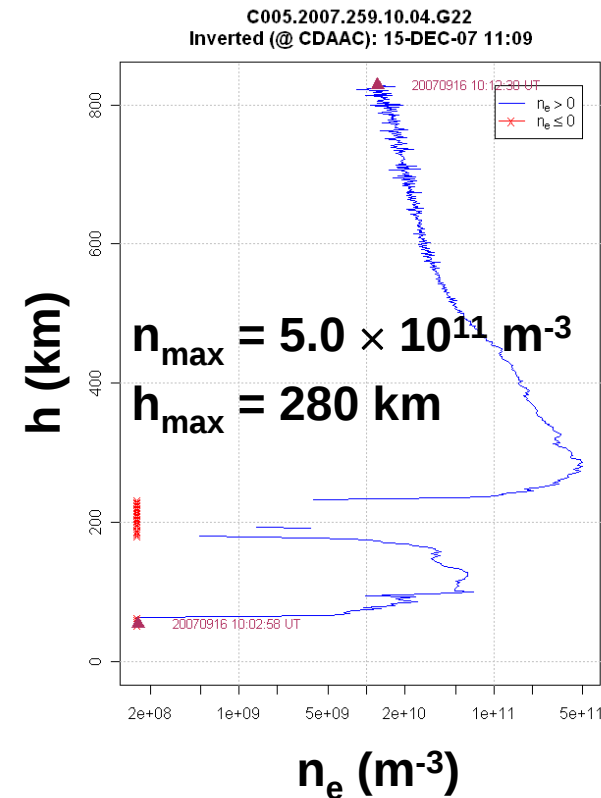


Disturbed Ionosphere Yields
Profile Shape Distortions

**Note: Corresponding ground-based
scintillation levels are low (250-MHz
 $S_4 \leq 0.8$; no GPS scintillation)**



VHF $\perp \mathbf{B}$ Scan—Post-Occultation





Concluding Remarks



- **Even low-altitude depletions with modest ground scintillation levels produce observable impacts in inversion**
 - Occultation link itself apparently not disturbed in 06 Sep 2007 case (no cycle slips; will investigate scnRaw, scnLv1)
 - Moderate uplifts also impact profile
- **Recommend *NOT* using Abel-inversion ionospheric profiles in equatorial and near-equatorial studies**
 - Discrepancies exist even in least-disturbed, most homogeneous case, despite rough quantitative agreement with ISR
 - Modeling, coupled with measurements, a useful tool to understand effects
 - What is the most useful single profile in an inhomogeneous ionosphere?