Global Distribution of L-Band Ionospheric Scintillation

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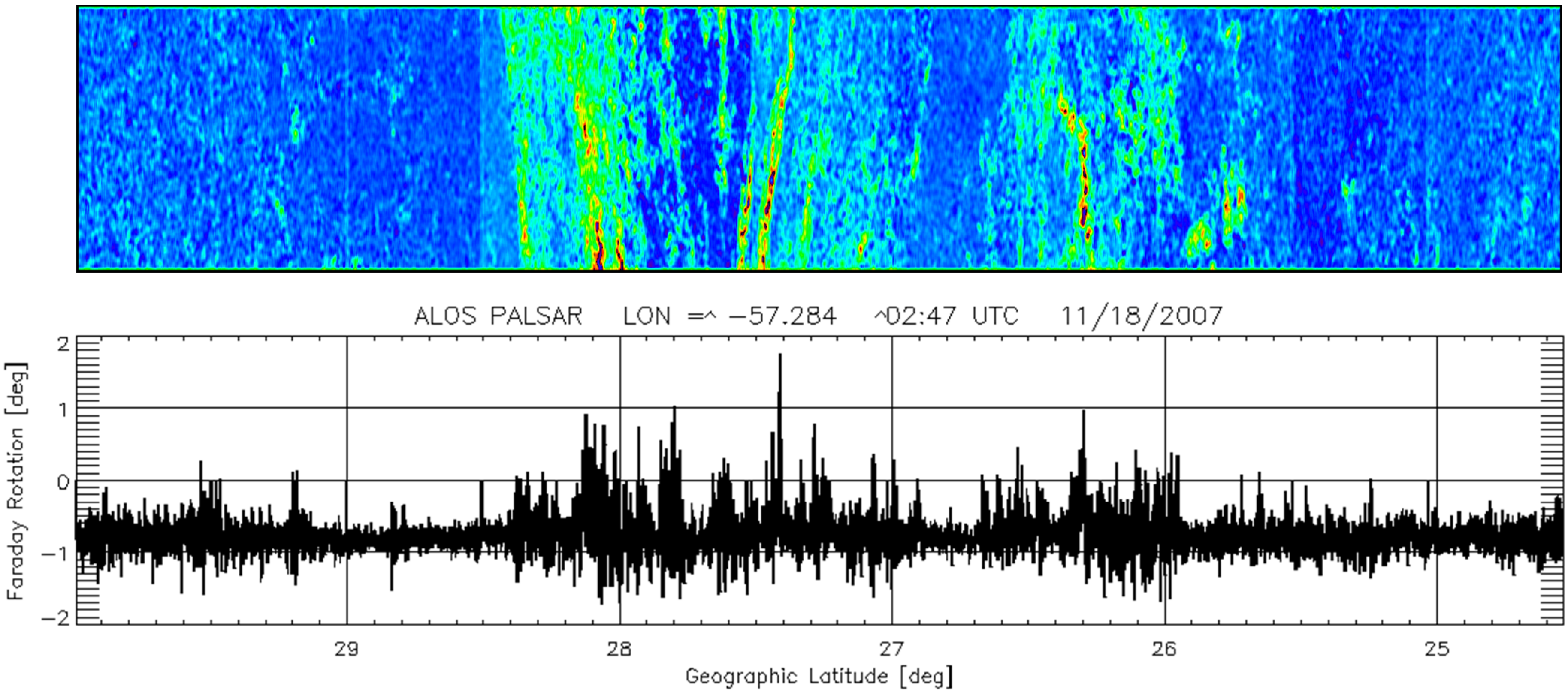
Outline

- **Motivation of the study**
  - To characterize ionospheric scintillation using GPS data made with GPS radio occultation receivers onboard six COSMIC satellites
  - To provide statistics of global ionospheric scintillation to support spaceborne remote sensing radar mission planning and data analyses
- **Statistical Analysis**
  - COSMIC 1-sec S_4 measurements (amplitude scintillation)
  - Global measurements made from all COSMIC satellites in 12 months
  - LAT, LON, LT, and ALT distribution; F and E regions
- **Summary**

Plasma Bubbles and Scintillation Effects Captured in PolSAR Images



Polarimetric observations made using ALOS PALSAR reveal

- random fluctuations of polarization (Faraday rotation)
- depletion of Faraday rotation (or TEC)

[Pi et al., 2011, JGR]

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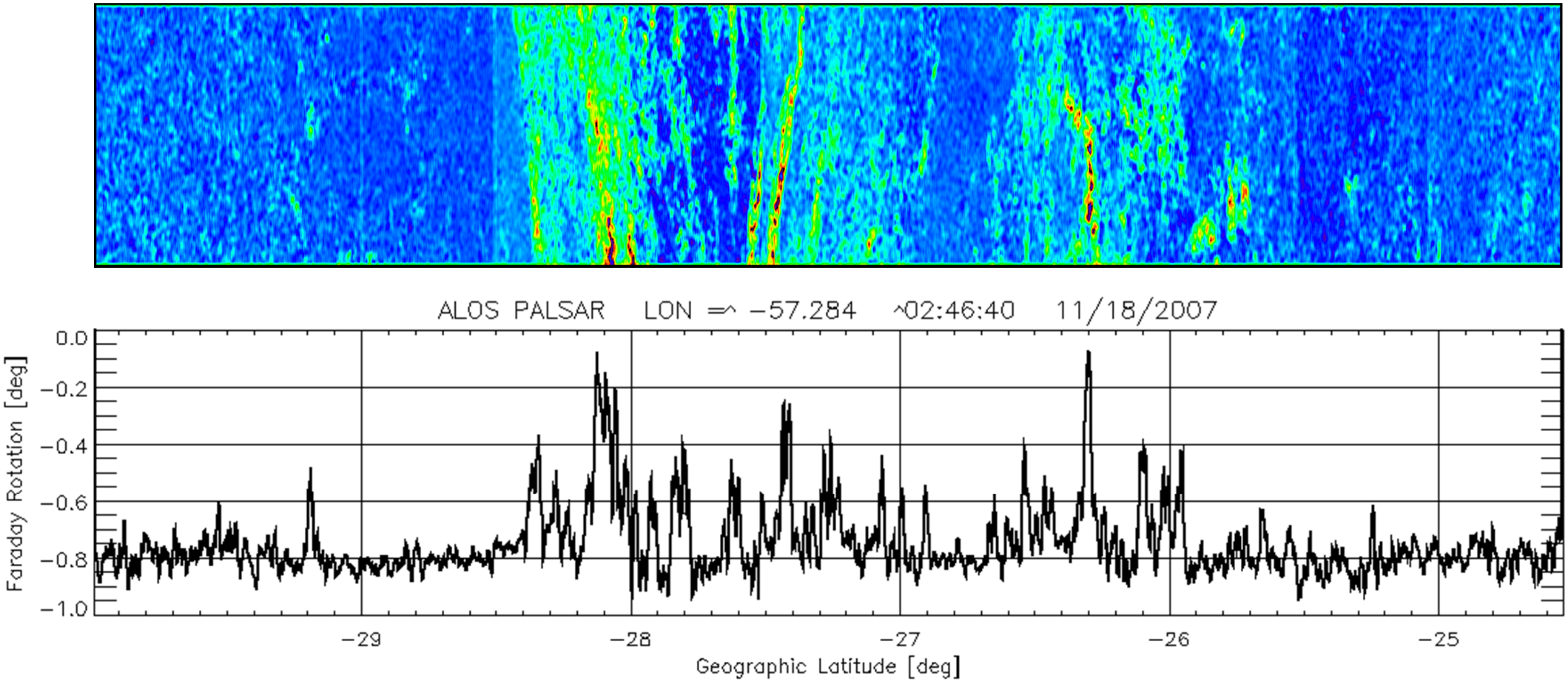

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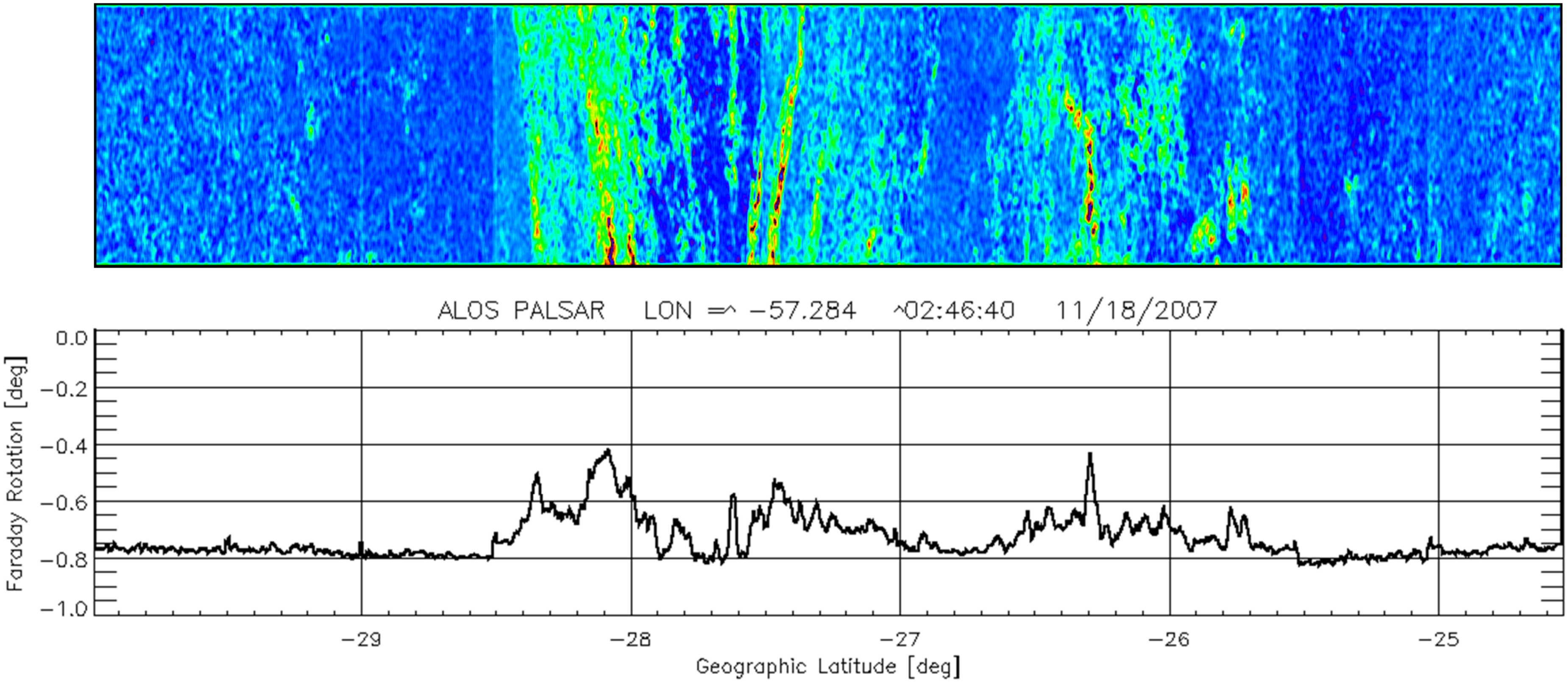

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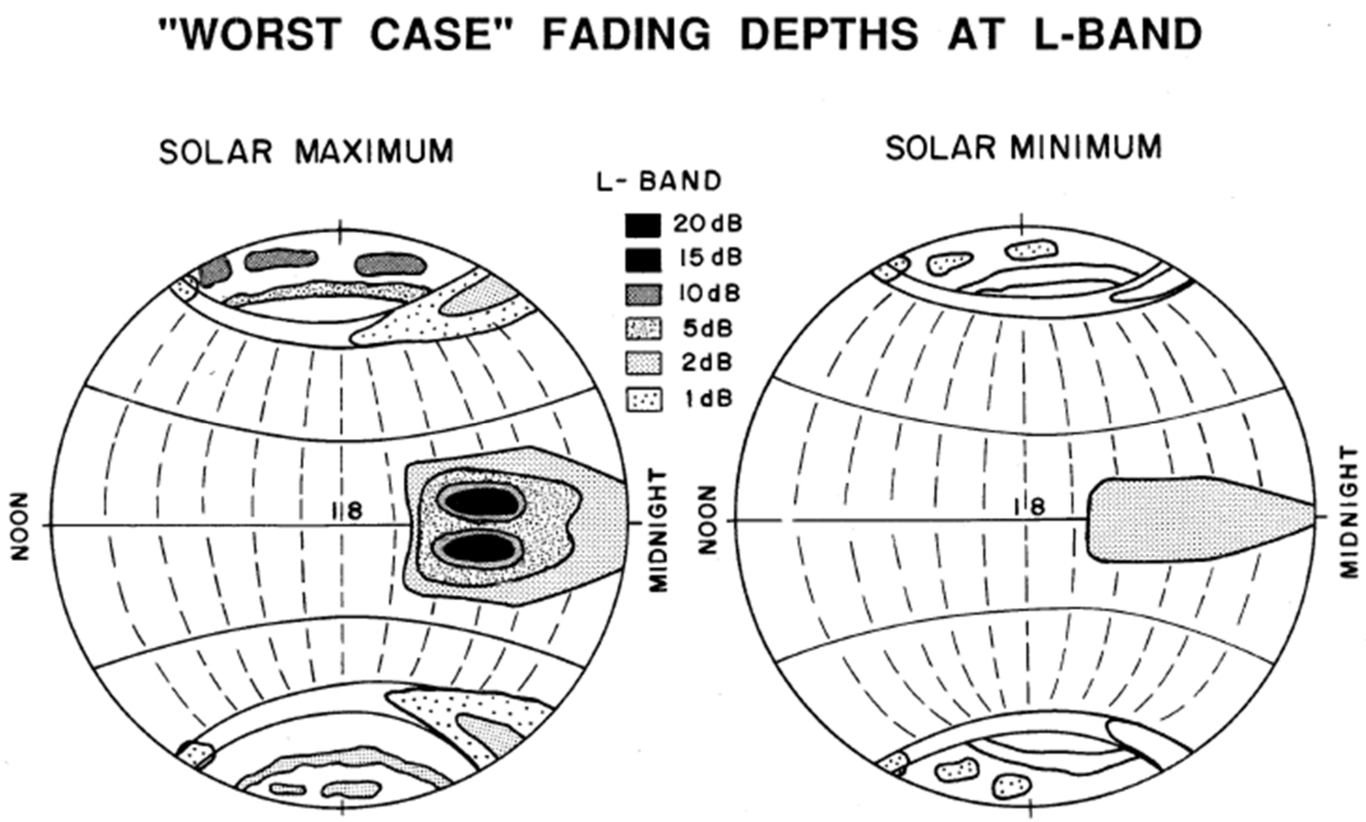
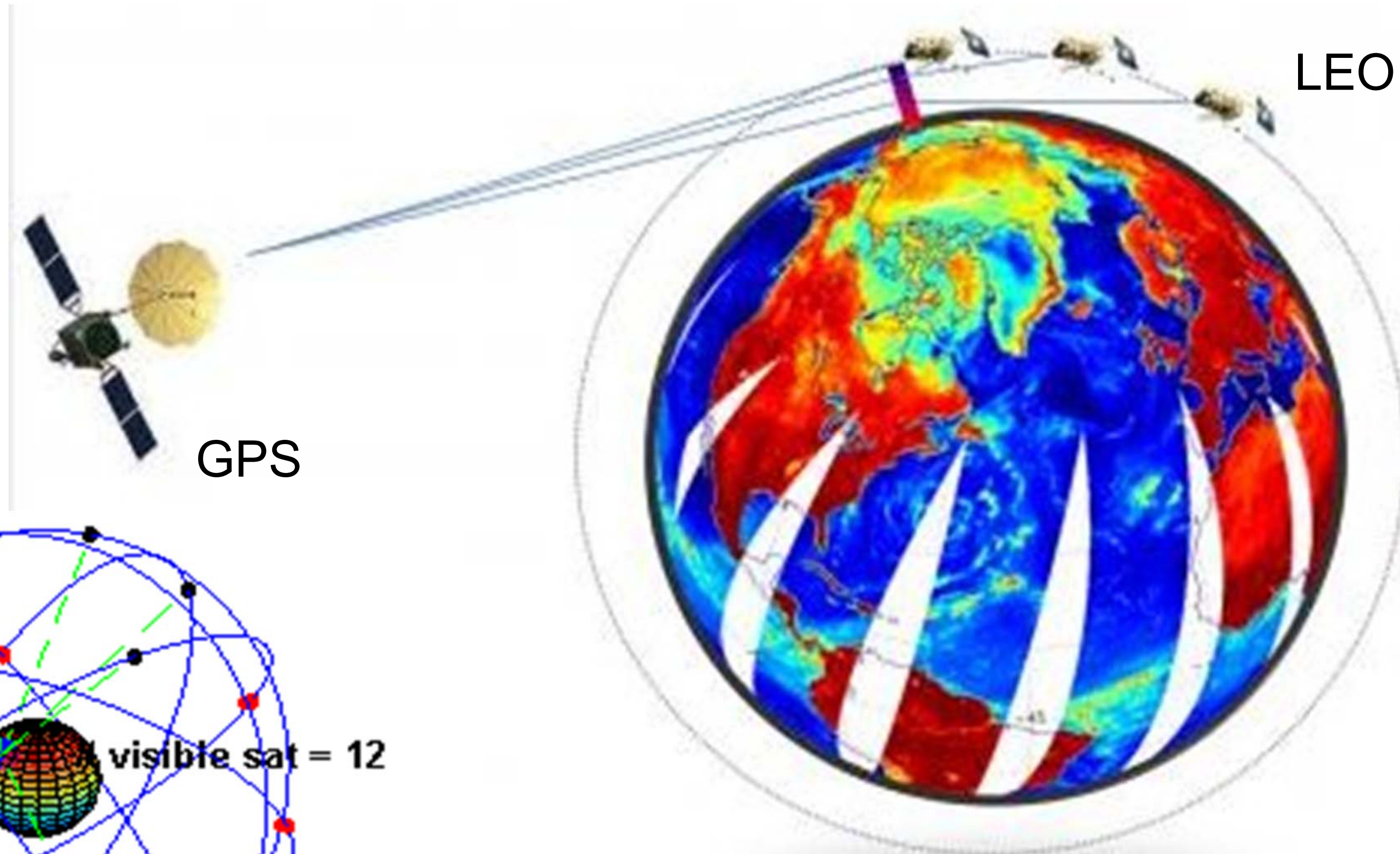
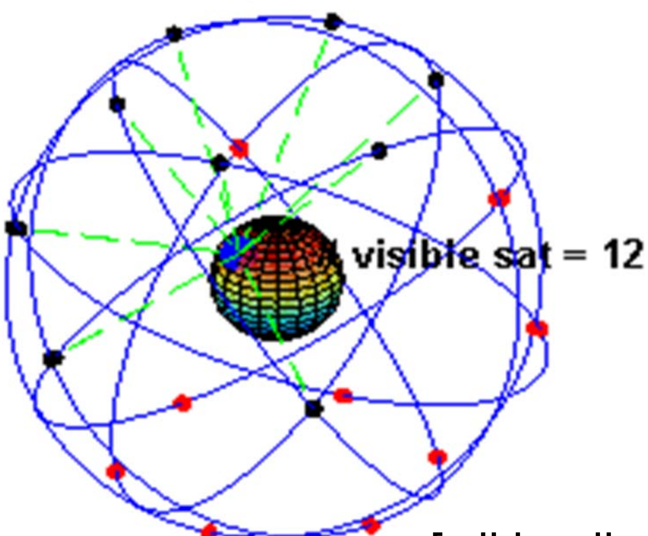
Scintillation LT & LAT Distribution from Ground-Based Measurements



[Basu, 2003]

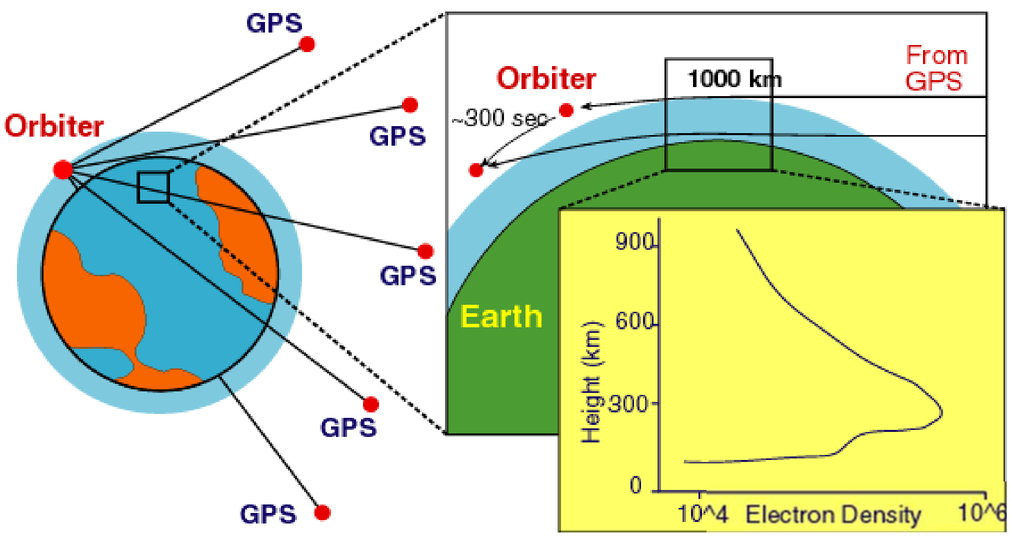
GPS Radio Occultation Tracking





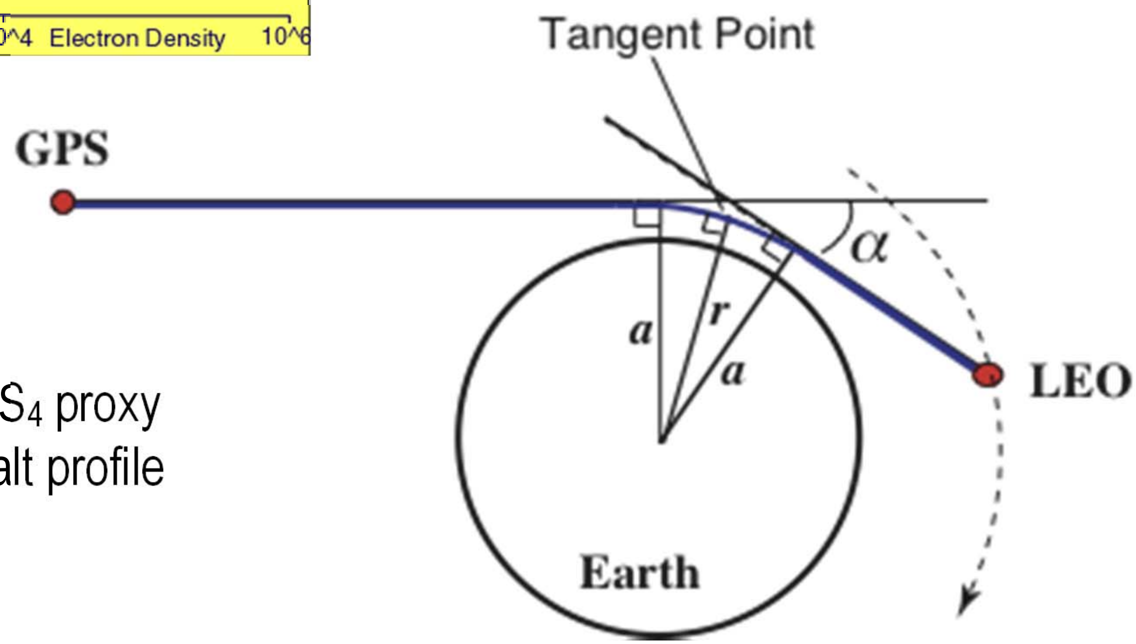
[wikipedia.com]

Ionospheric Measurements from GPS Radio Occultations



Density Profiles

- Time sequence of dual-frequency GPS phase and pseudorange measurements to derive TEC along the signal path
- Abel inversion → electron and neutral density profile



Scintillation

- 50-Hz L1 C/A SNR data
- 1-sec amplitude scintillation S_4 proxy
- Time sequence of S_4 → S_4 alt profile
- $S_{4,max}$ for the profile

COSMIC 1-Sec S_4 Proxy for Amplitude Scintillation Measurements

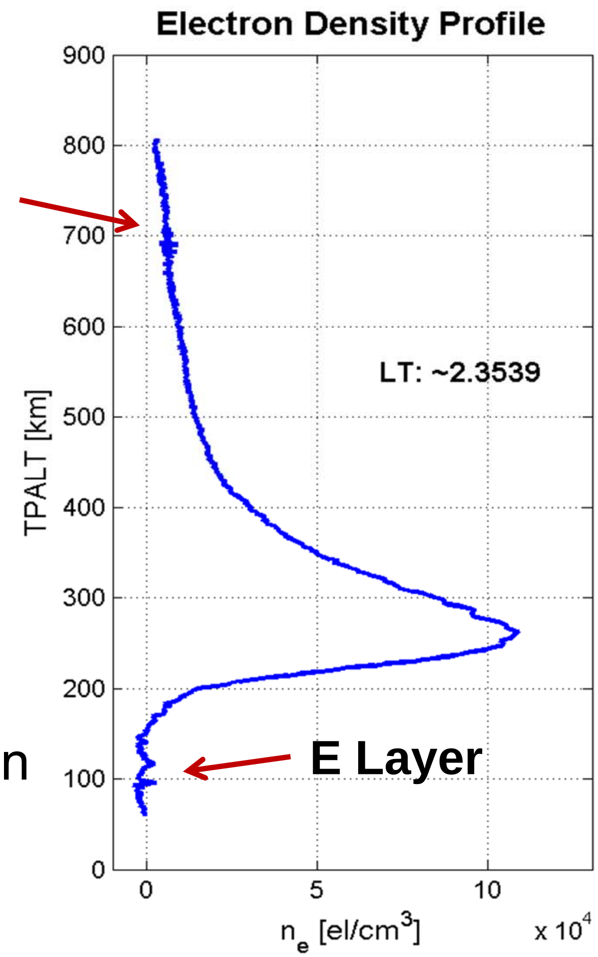
$$S_4 = \frac{\sqrt{\langle (I - \overline{\langle I \rangle})^2 \rangle}}{\overline{\langle I \rangle}}$$

$$I = SNR^2$$

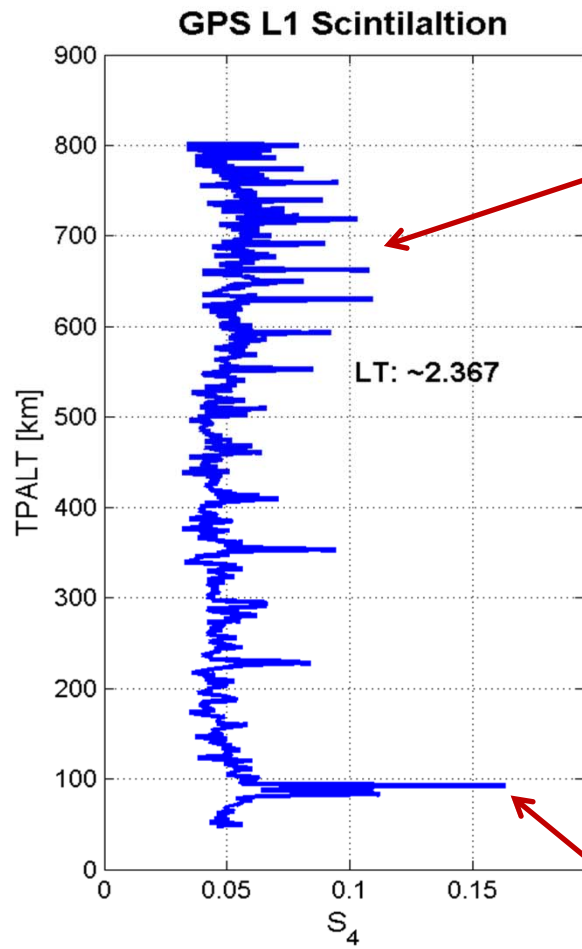
- 1-second S_4 index proxy, $\overline{\langle I \rangle}$ is the low-pass filtered intensity, and the filtering is performed on $\langle I \rangle$. The average is approximately derived from the *SNR* data.
- *SNR*: L1-C/A signal to noise ratio, sampled at 50 Hz
- No phase scintillation measurements (which require higher standard and more expensive oscillator as well as more CPU, storage, and power)

Measured S4 Index and Retrieved Ne Profile

F-region topside Irregularities ?



E Layer



Weak Scintillation (?) or noisy data

Nighttime

Max S4

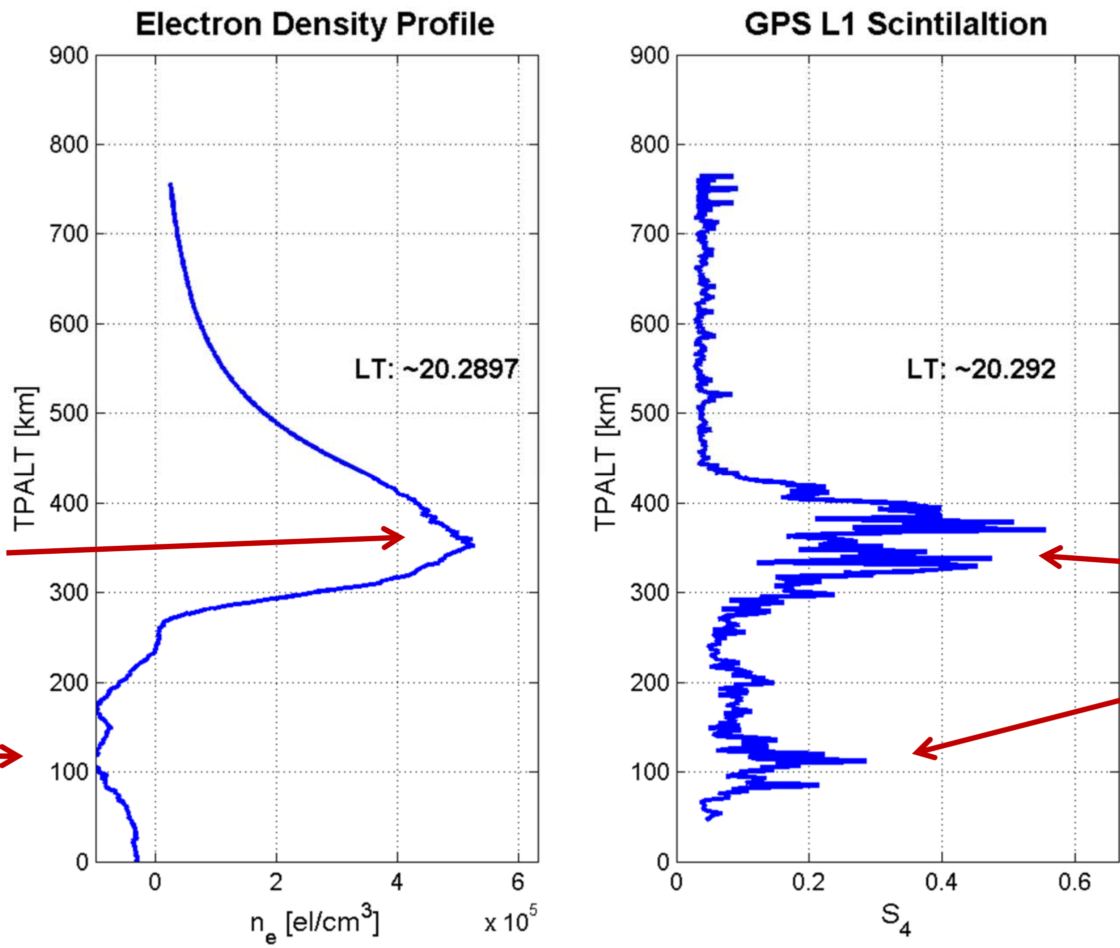
Duration:
$\tau \approx$ 9.7 min

TP range:
$\Delta\theta \sim$ 10.7°
$\Delta\phi \sim$ 4.7°

- **LEO: CSM02**
- **GPS: PRN11**

- **LAT: –42.519°**
- **LON: 168.043°**

F- and E-Region Irregularities/Scintillations



Evening

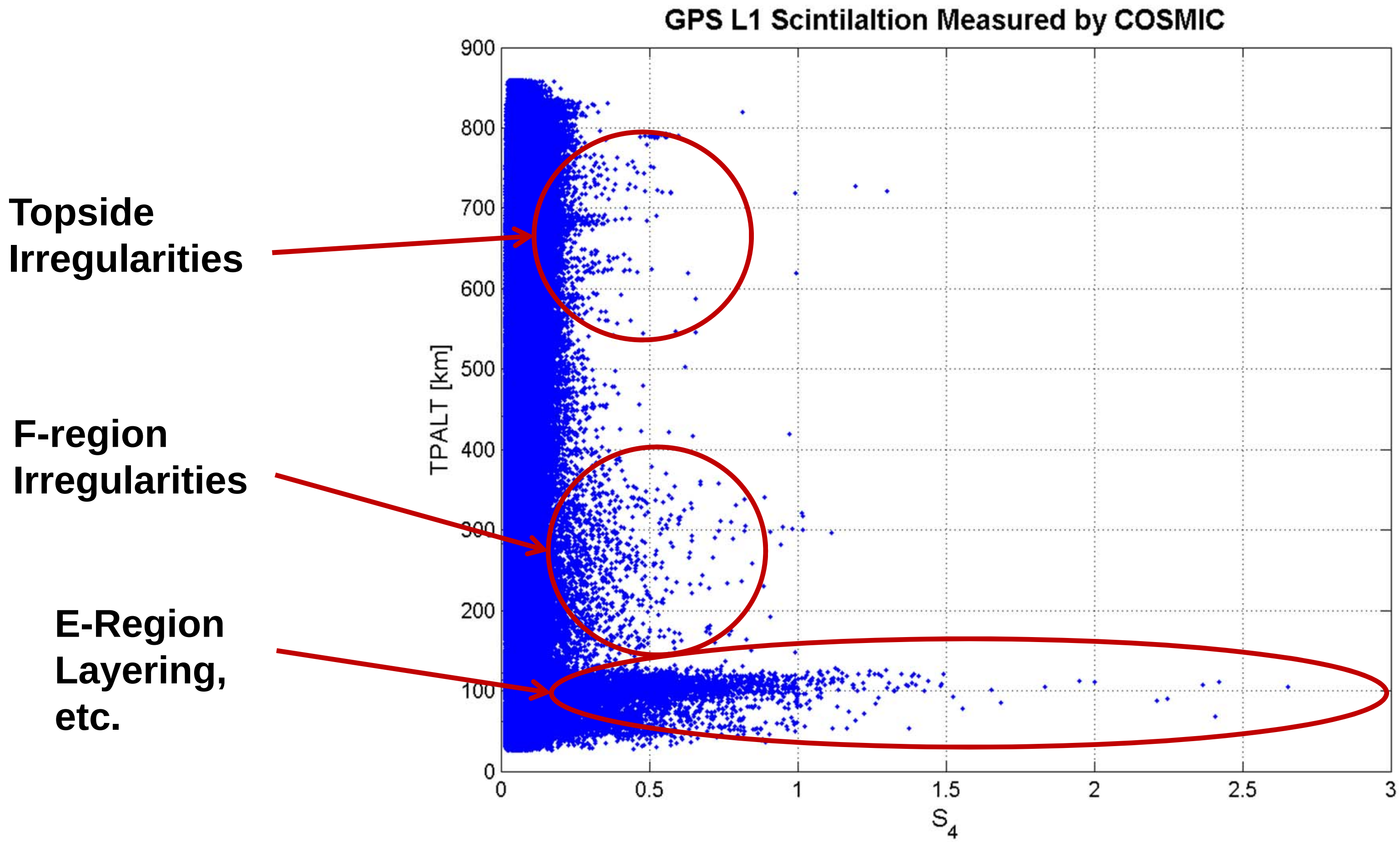
F-Region Irregularities

E Layer

F-Region and E-Region Scintillation

- **LEO: CSM04**
- **GPS: PRN19**
- **LAT: –4.086°**
- **LON: 37.336°**

Ionospheric Scintillation Associated with Various Inhomogeneities

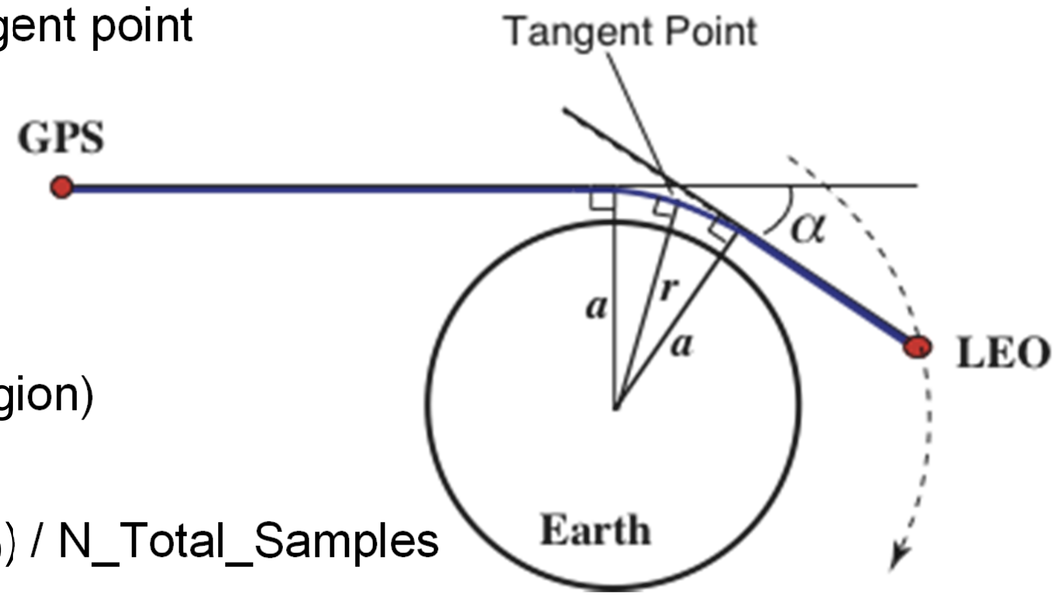


- LEO's: CSM01-06
- GPS's: All

- 2009.274 (one day in Oct)
- Global, all time

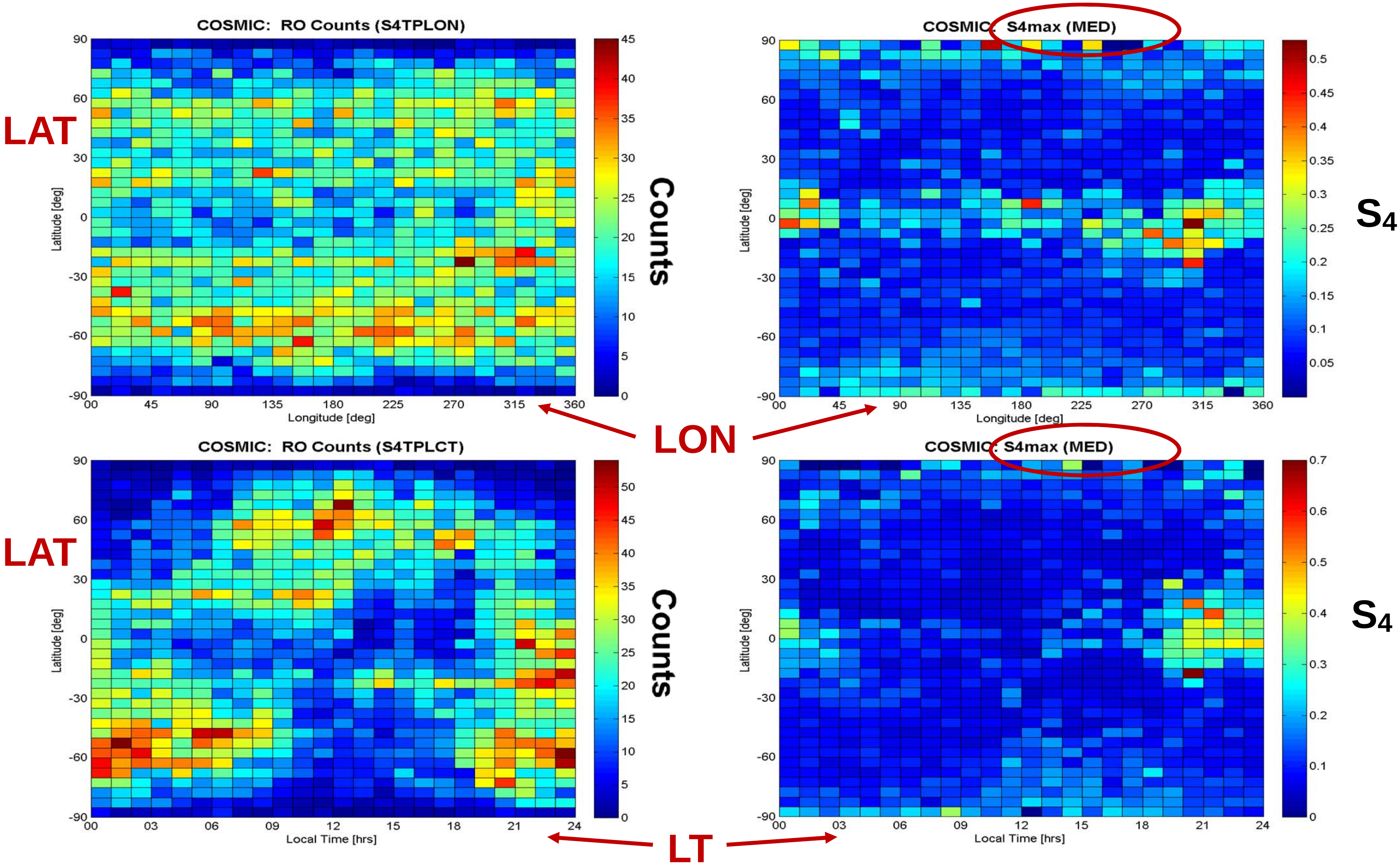
Data Presentation

- **$S_{4,max}$ and its corresponding tangent point altitude (TPALT)**
  - Radio occultation links: elevation angle ≤ 0°
  - Tangent point: the point along the radio link where the distance to the center of the Earth is closest
  - Maximum S_4 in an occultation profile
  - TPALT: altitude of the tangent point
- **Data binning**
- **Median($S_{4,max}$)**
- **ALT range**
  - 150 – 600 km (F region)
  - 80 – 150 km (D and E region)
- **Occurrence Rate**
  - N_Events($S_{4,max}$ >= $S_{4,max0}$) / N_Total_Samples

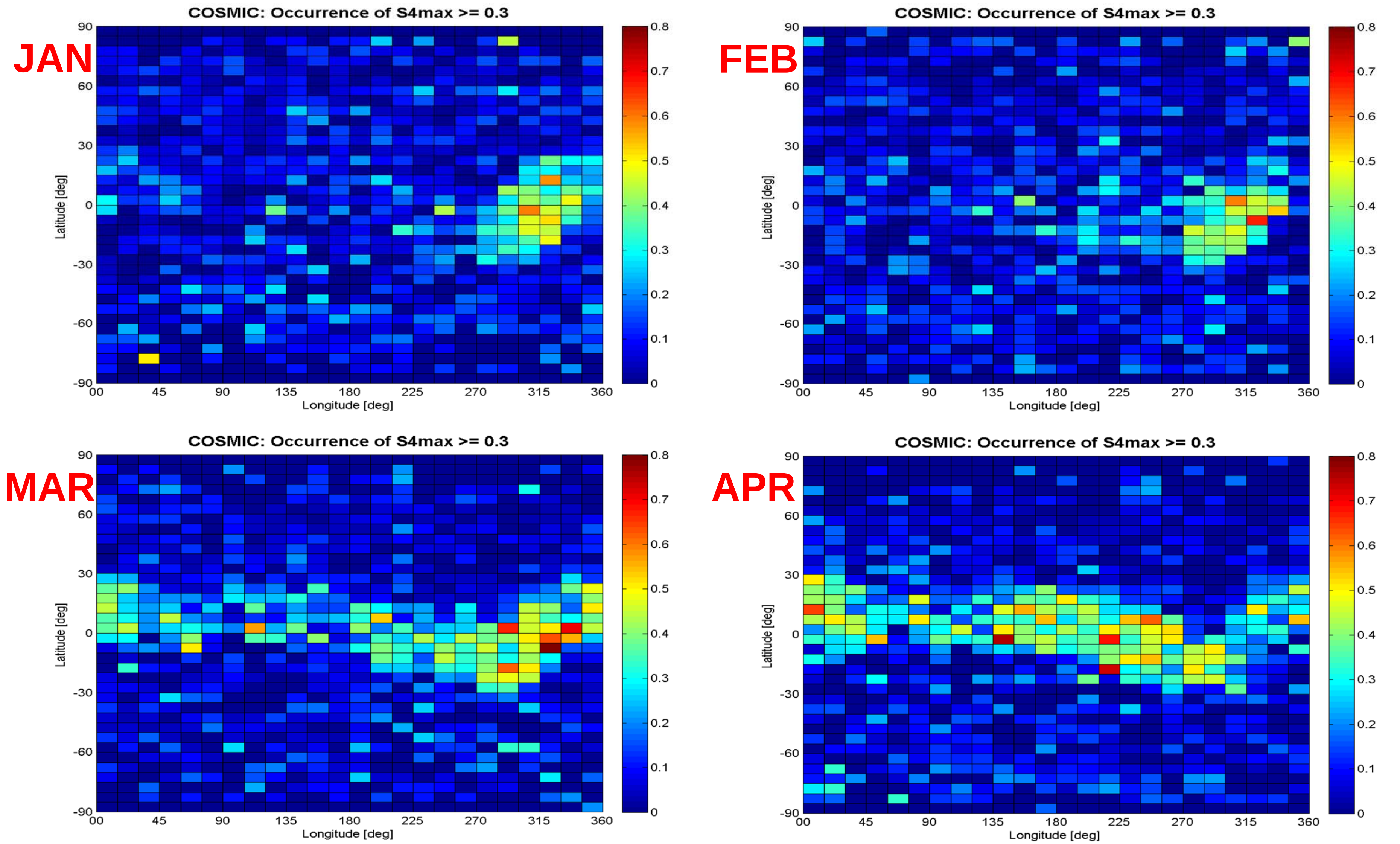


Global Distribution of Amplitude Scintillation

Altitude Range: 150~600 km October 2009



Scintillation Occurrence: (2009, LON, LAT)



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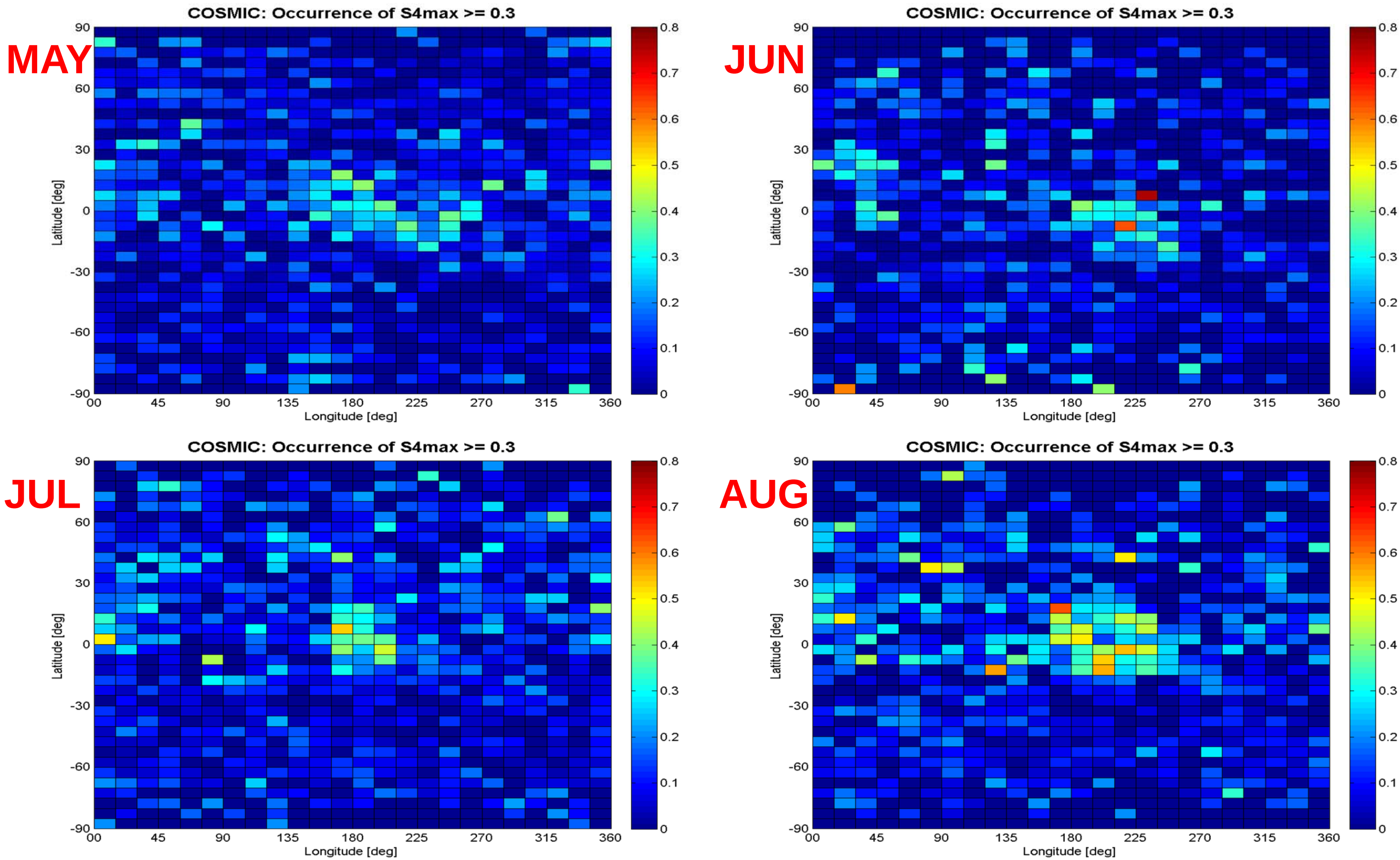

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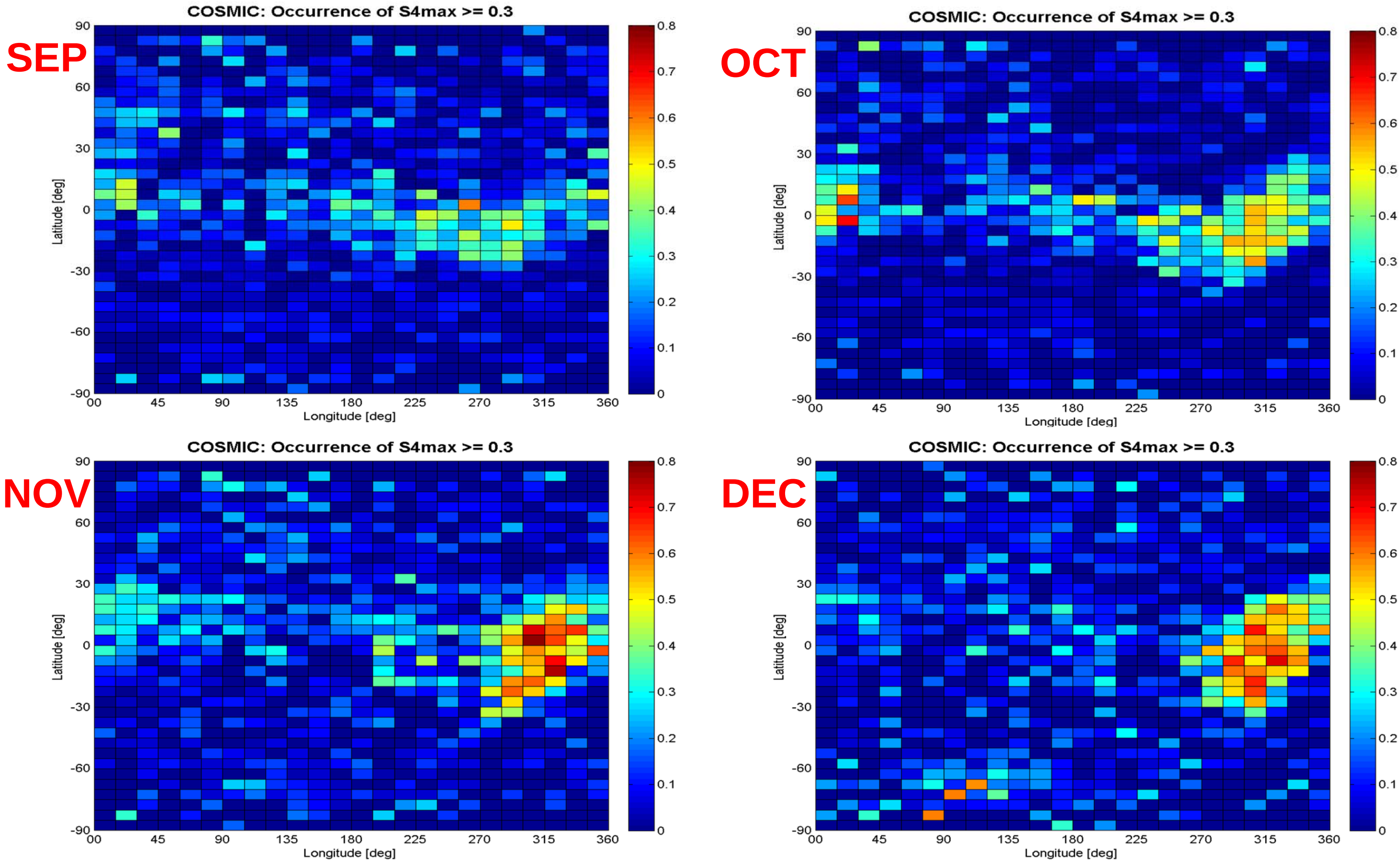
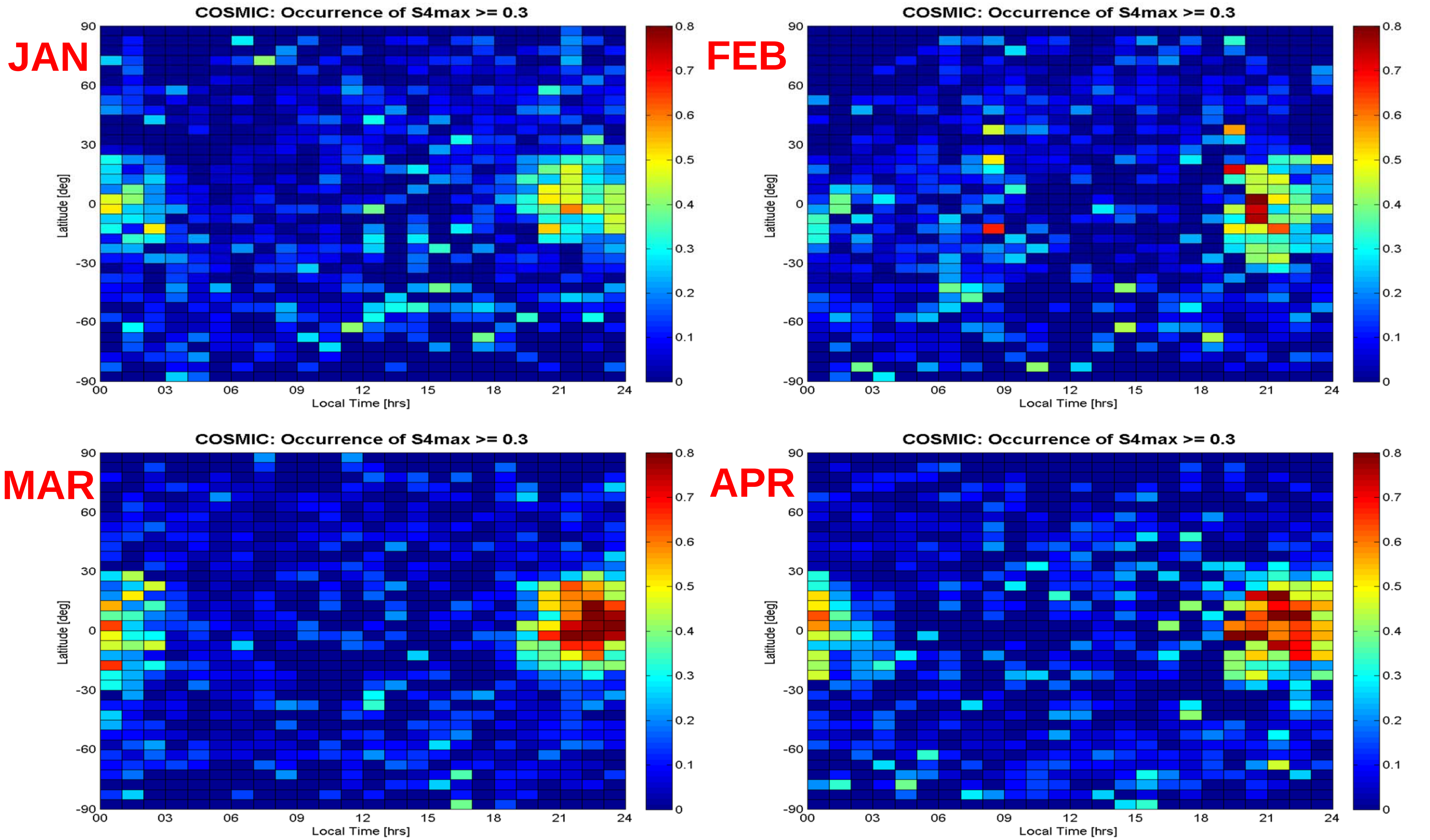


Scintillation Occurrence: (2009, LT, LAT)



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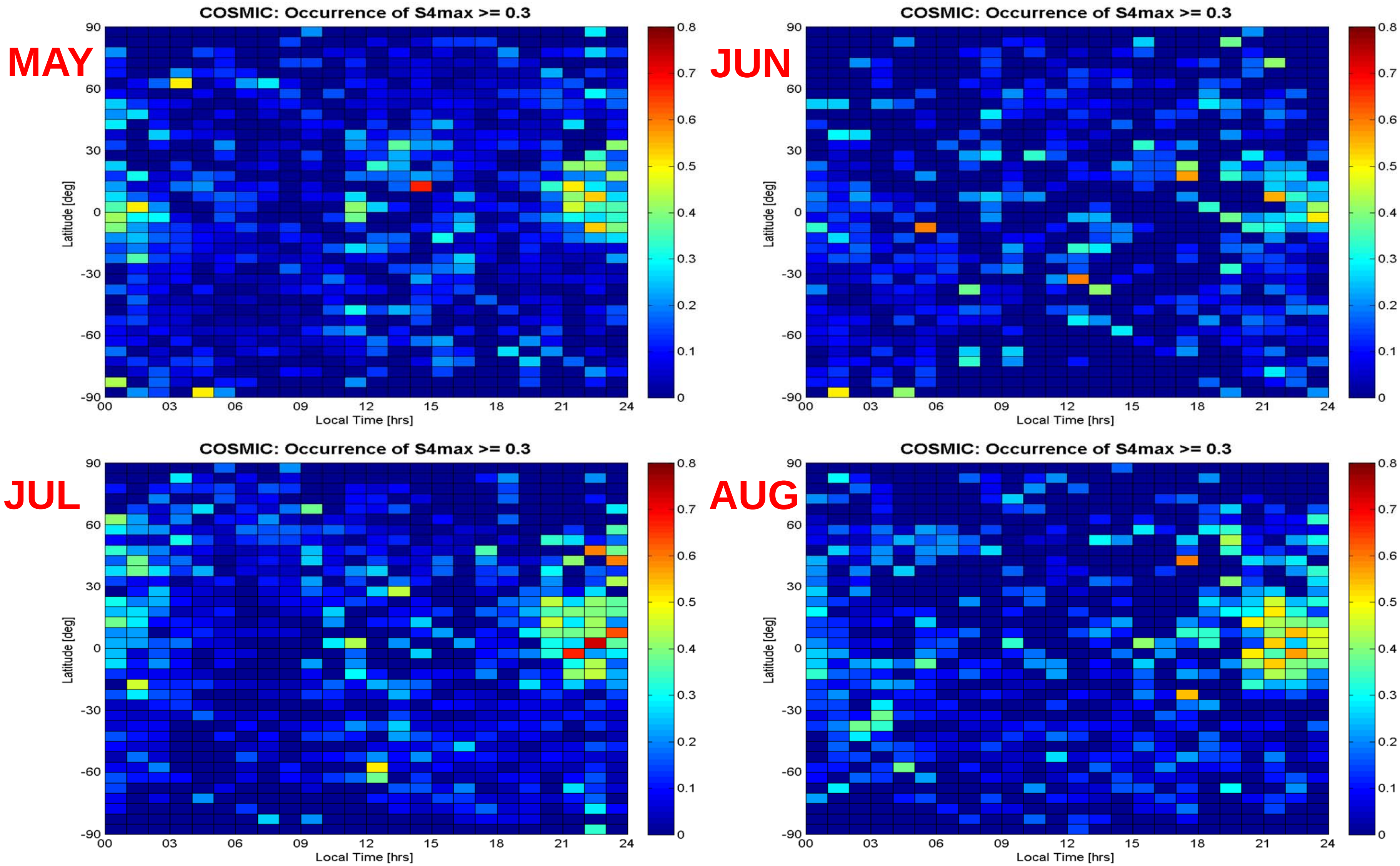
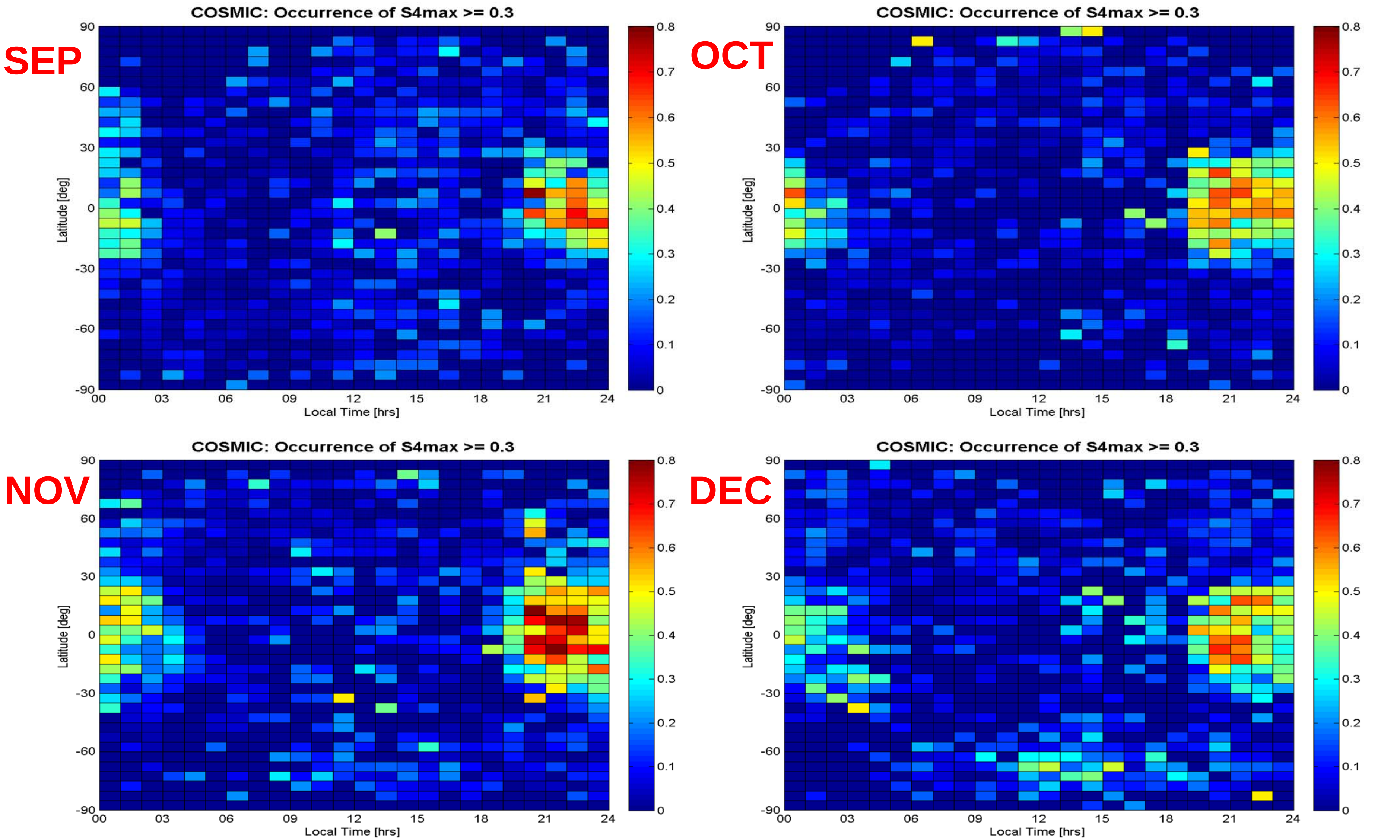


Scintillation Occurrence: (2009, LT, LAT)



Summary

- **Amplitude scintillation measured using GPS radio occultation signals must be characterized according to altitude regions (F and E regions) where different ionospheric phenomena occur**
  - ➢ F-region ionospheric irregularities, which also cause scintillation in ground-based GPS observations
  - ➢ E-region density changes or layering in a narrow altitude range, which usually do not cause scintillation in ground-based GPS or spaceborne observations

Summary (Cont.)

- **The results of the L-band amplitude scintillation analysis**
  - ➢ Distinguished local time, longitudinal, and seasonal variations at low latitudes
    - – Equinox months: extending to most longitudes
    - – May through August: Pacific regions
    - – Dec through Feb: America longitudes
    - – Nighttime phenomenon: after sunset, through 3 or 4 AM
  - ➢ Insignificant amplitude scintillation in high latitude/Auroral regions
    - – Dec 2009: an exception; daytime scintillation is observed in the southern hemisphere
  - ➢ Note (based on previous studies using ground-based GPS data):
    - – Phase scintillation cannot be ignored at high latitudes, which is not analyzed here
    - – Phase scintillation is usually as strong as amplitude at low latitudes, and stronger than amplitude scintillation at high latitudes

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