The effect of ionospheric irregularities on RO signals derived from COSMIC

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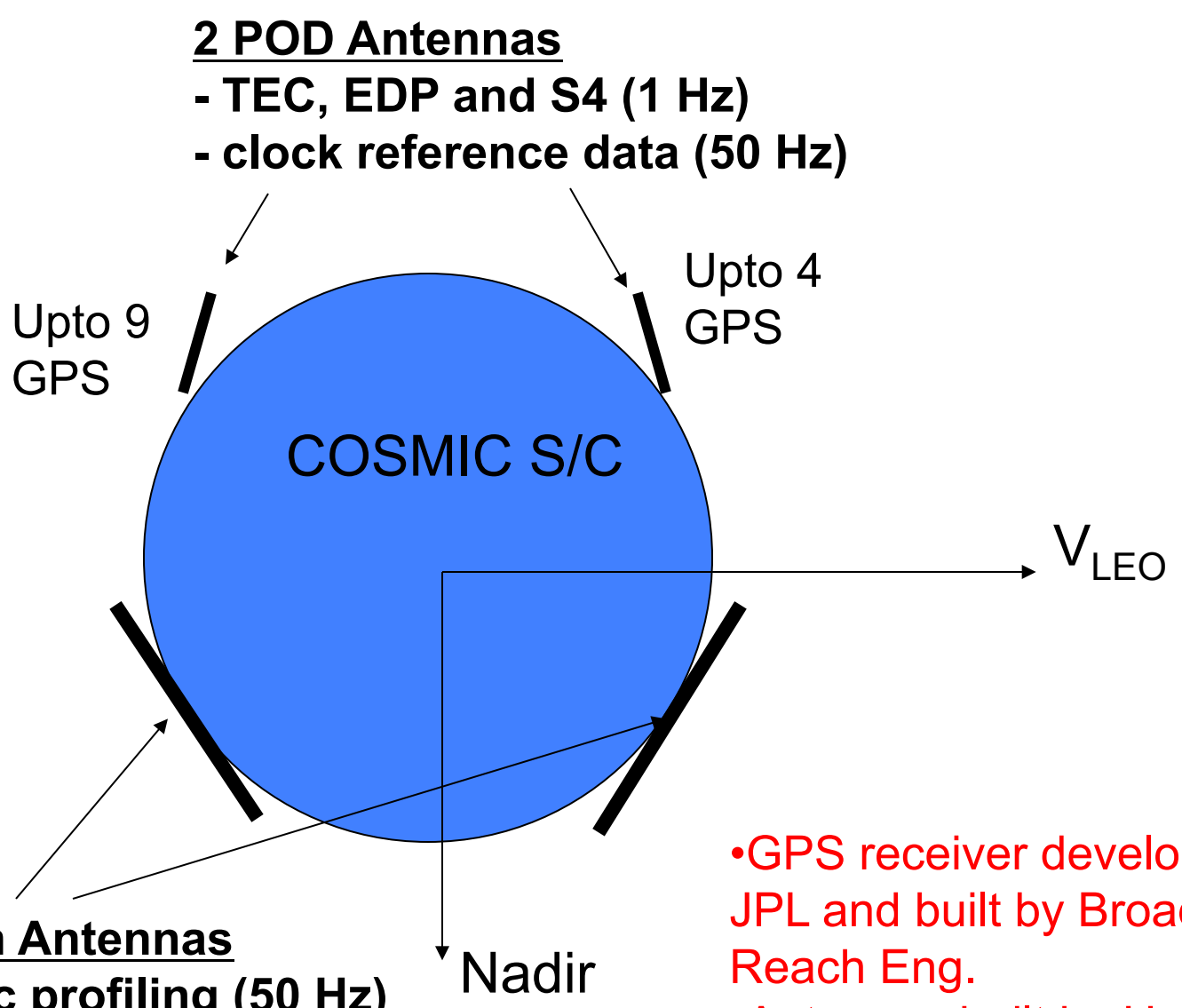
Outline

- **Motivation:**
  - COSMIC has accumulated >4M ionospheric scintillation profiles in CDAAC
  - On the one hand, the RO data could be used to derive ionospheric irregularity information (sporadic E, spread F)
  - On the other hand, the ionospheric irregularity will degrade the RO data quality (cycle slip, fluctuations in electron densities and bending angles)
- **Main Content:**
  - Correlation analysis between irregularities, cycle slip of RO signal, and atmospheric bending angle residual
  - **COSMIC observations during 2007-2011 are used**

COSMIC Satellites

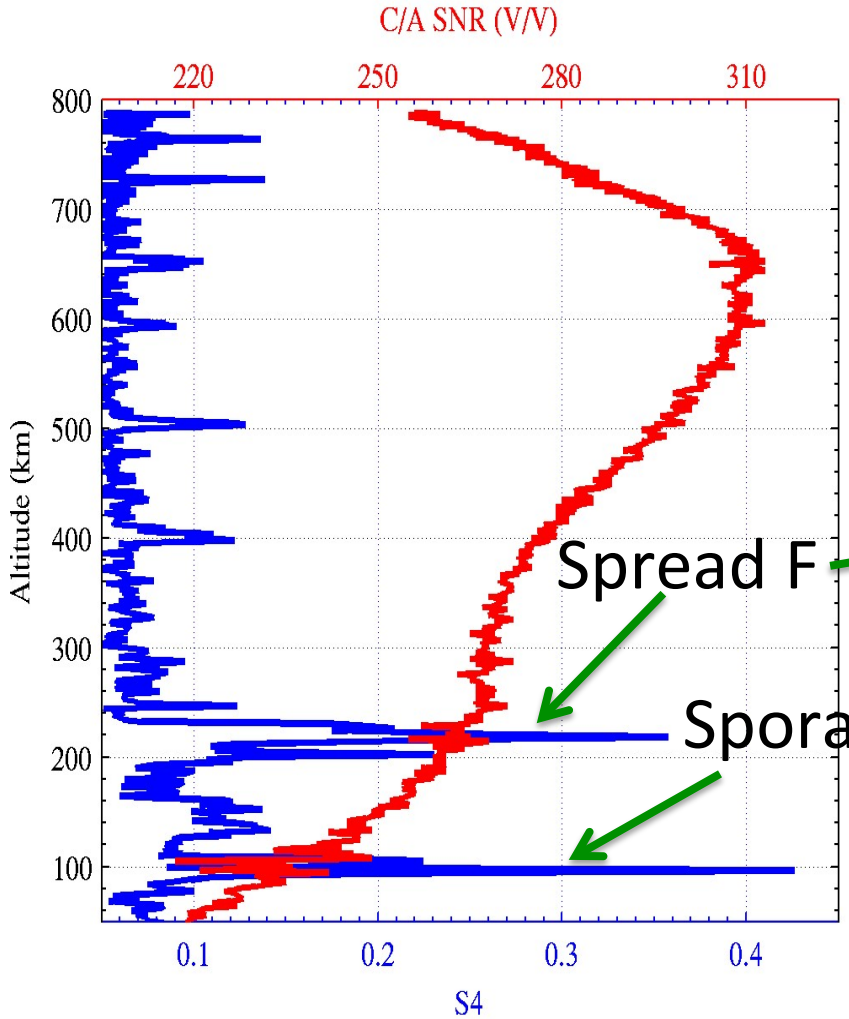


- GPS receiver developed by JPL and built by Broad Reach Eng.
- Antennas built by Haigh-Farr

COSMIC scintillation index (S4) profile

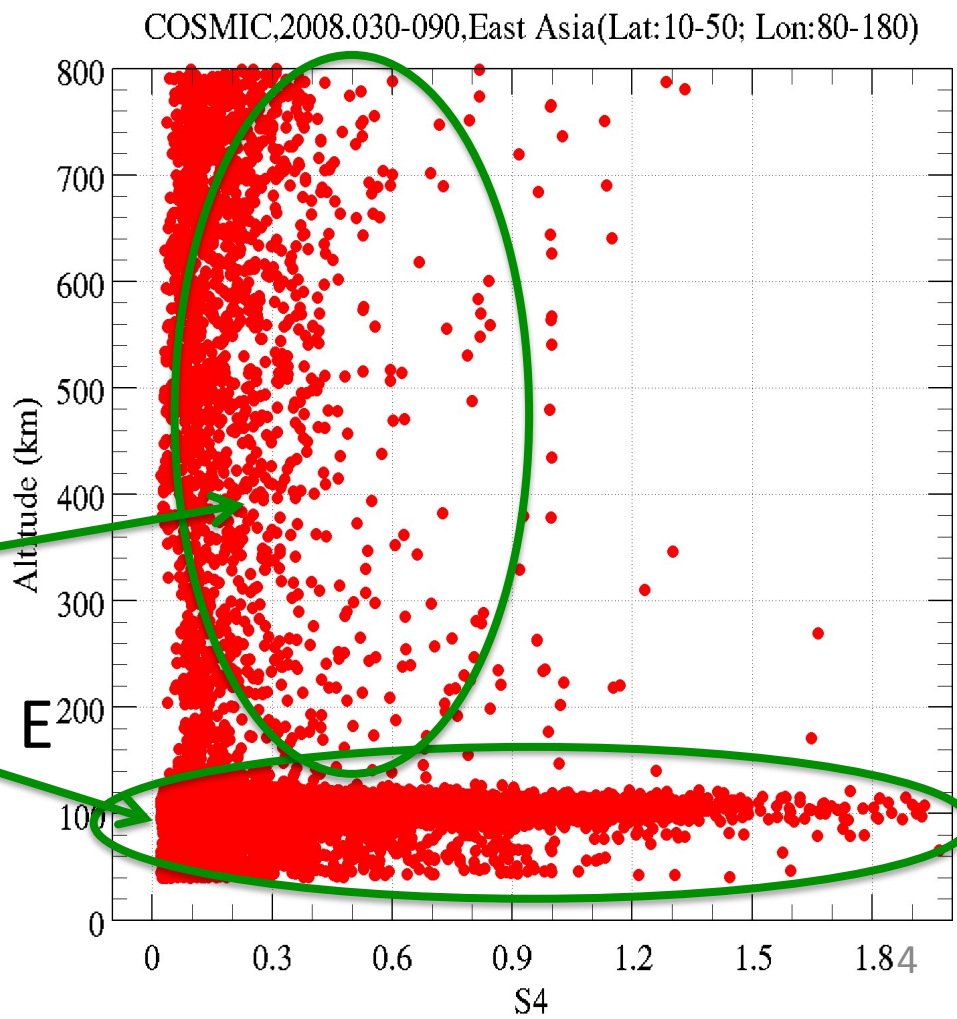
L1 SNR , S4

COSMIC S4 maximum, 2 months



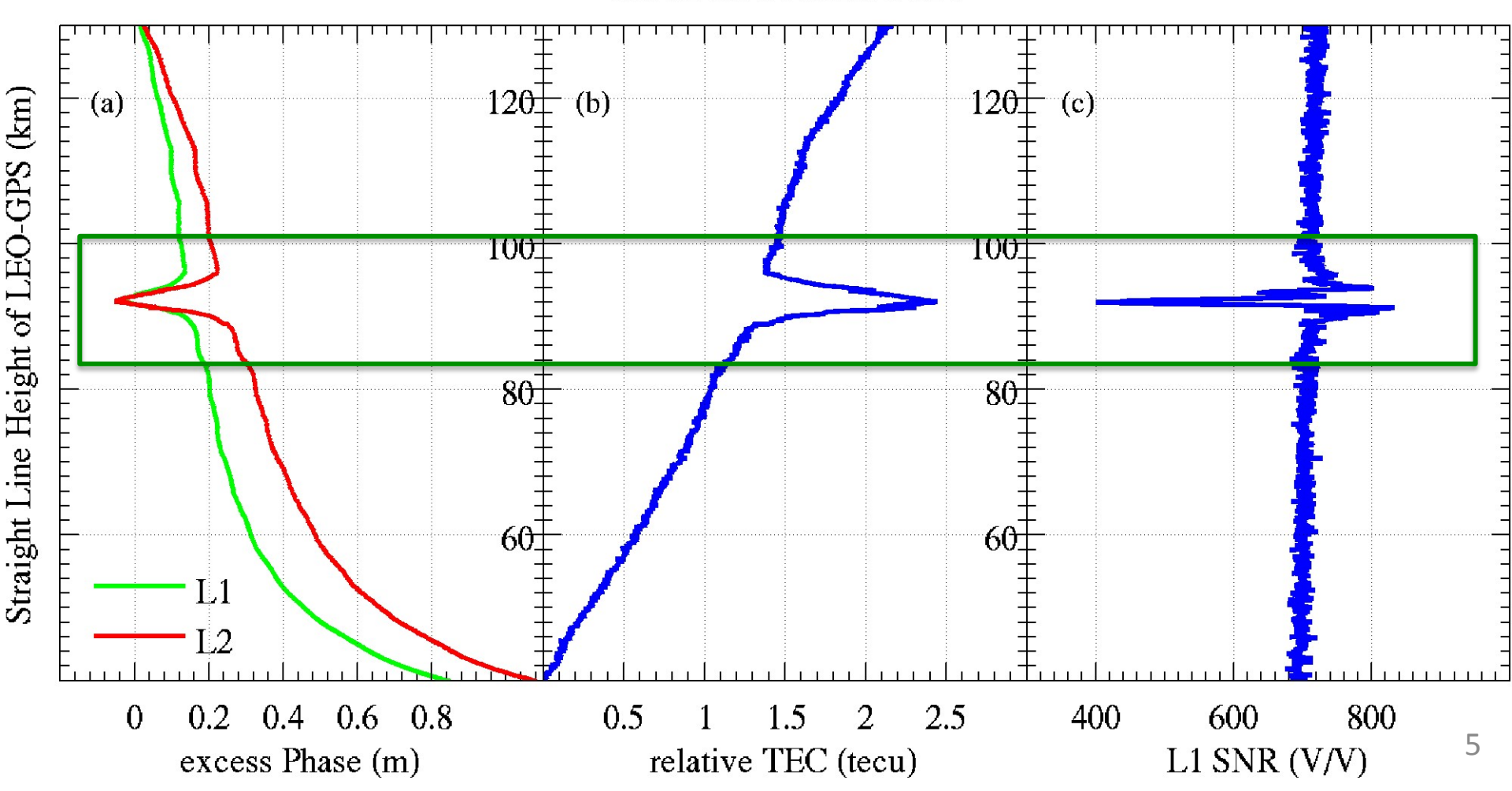
Spread F

Sporadic E



Identify sporadic E from RO signal

- Additional phase delay, enhanced electron density
- SNR oscillation

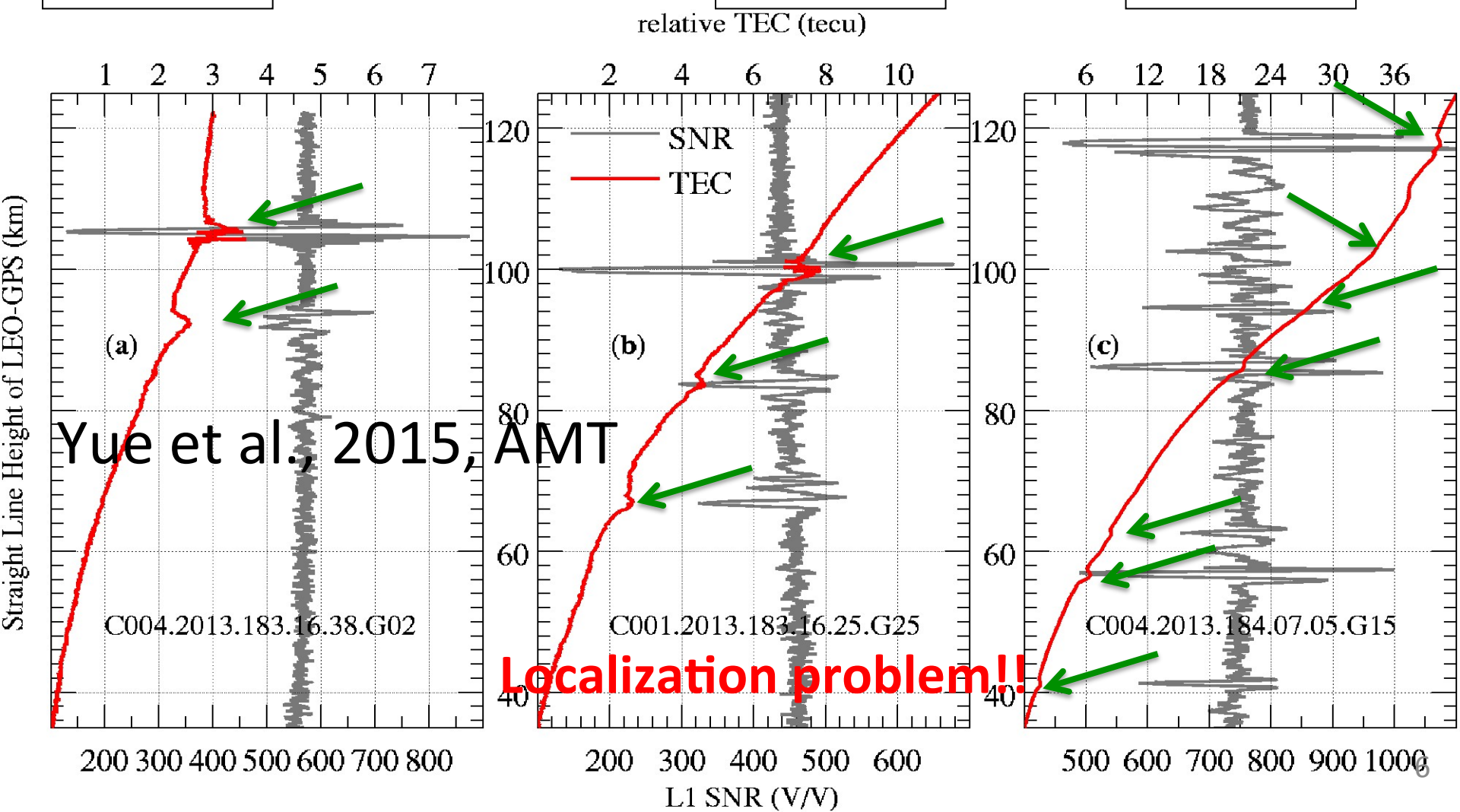


complex sporadic E layers by COSMIC

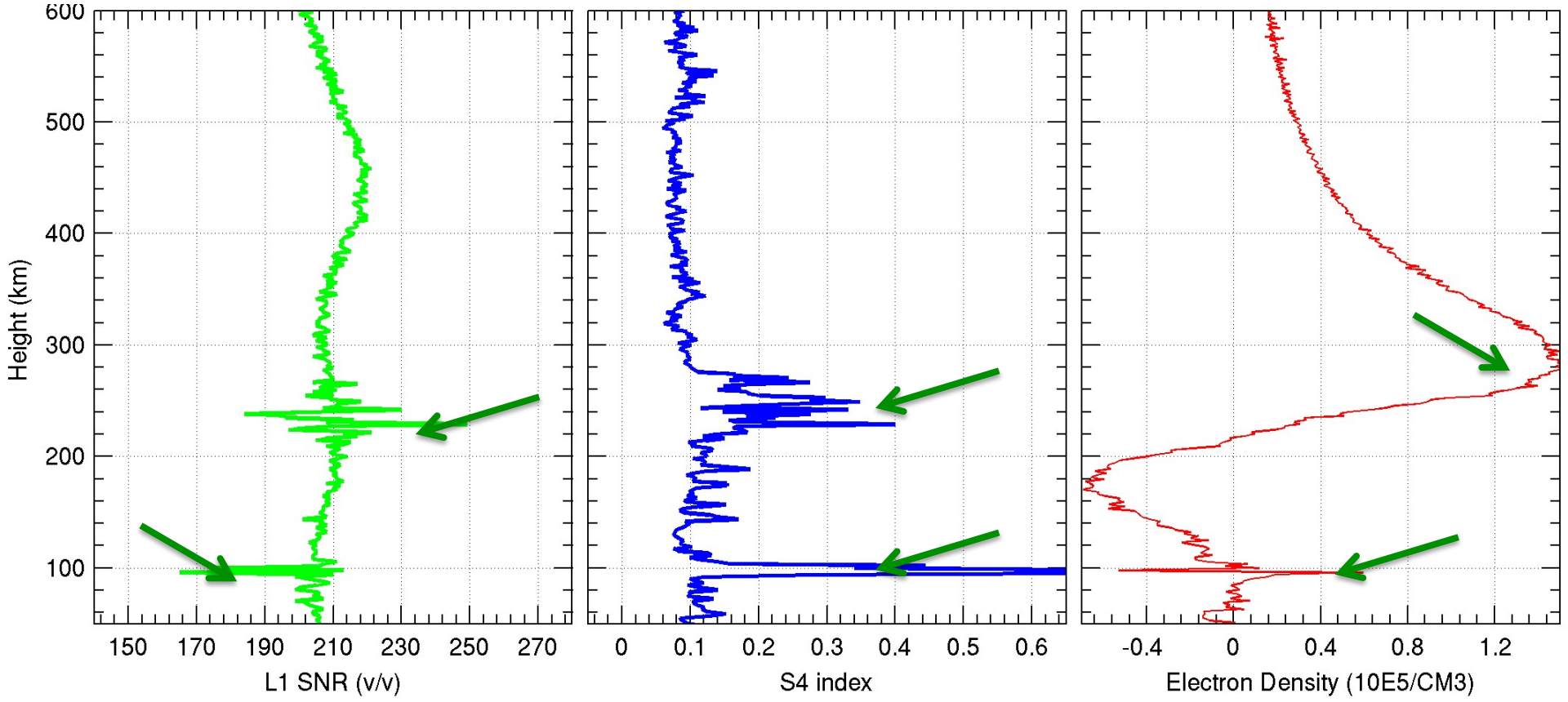
2 layers

3 layers

7 layers

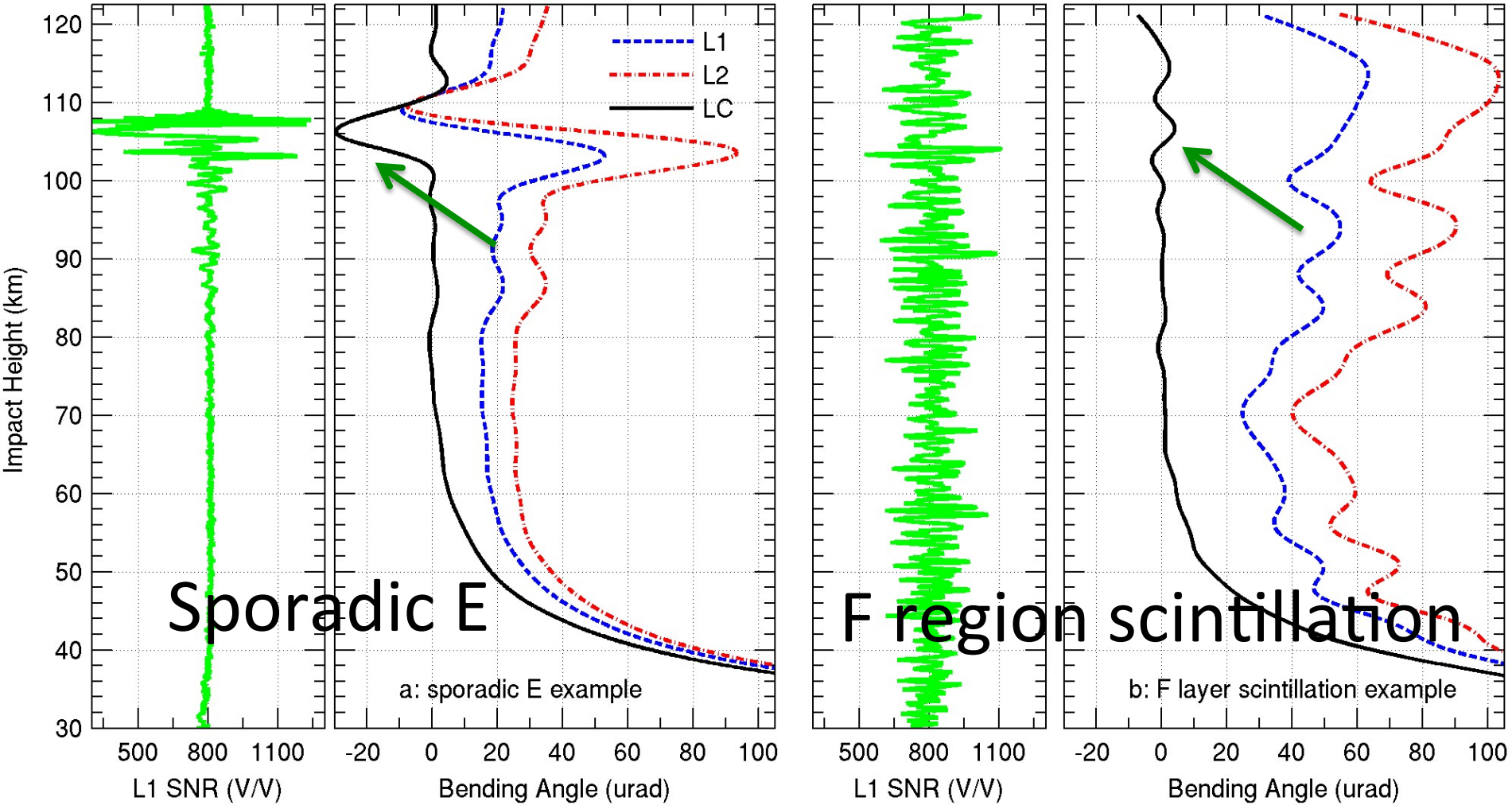


Example: effect of irregularity on EDP



L1 SNR(V/V) S4 Index Electron Density(1E5/CM3)

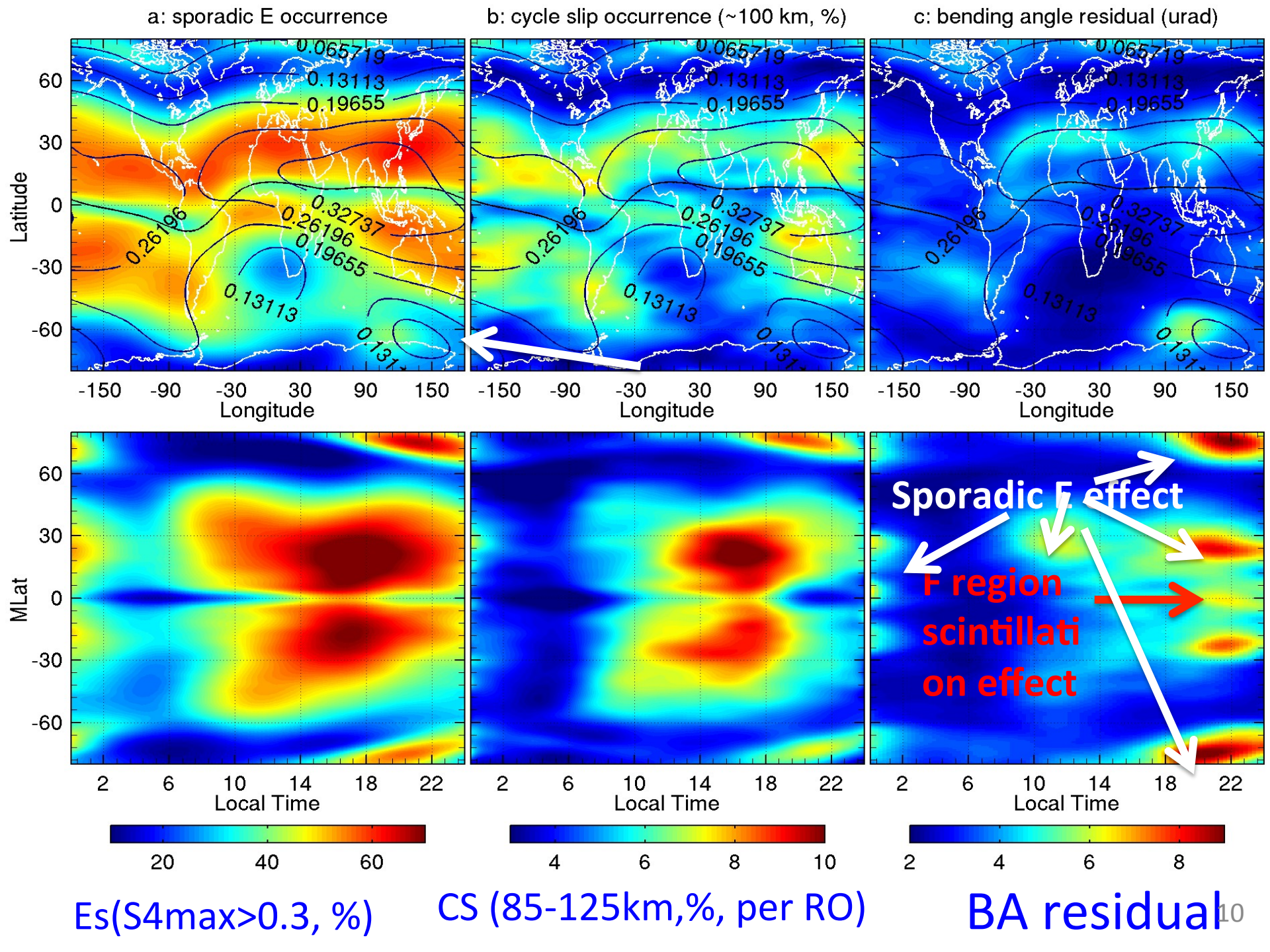
Example: effect of irregularity on BA



L1 SNR Bending Angle(urad) L1 SNR Bending Angle

Definition

- **Irregularity (%, percent):**
  - S4 > 0.3 (implies moderate to strong scintillation) occurrence ratio in percent
- **Cycle Slip (CS, %, percent per Occultation):**
  - Detection based on 1-Hz L1 carrier phase data
  - Blewitt 1990 method: wide lane phase combination
  - A threshold of 6 cycles is used to avoid potential influence by the phase oscillations due to ionospheric activity
- **Bending Angle (BA, micro radiance) residual:**
  - Standard deviation of the difference between COSMIC BA and NCAR climatology BA between 60 and 80 km


a: sporadic E occurrence
b: cycle slip occurrence (~100 km, %)
c: bending angle residual (urad)
Latitude
Longitude
MLat
Local Time
0.065719
0.13113
0.19655
0.26196
0.32737
Sporadic E effect
F region scintillation effect
Es(S4max>0.3, %)
CS (85-125km,%, per RO)
BA residual

Northern Summer (5-8)

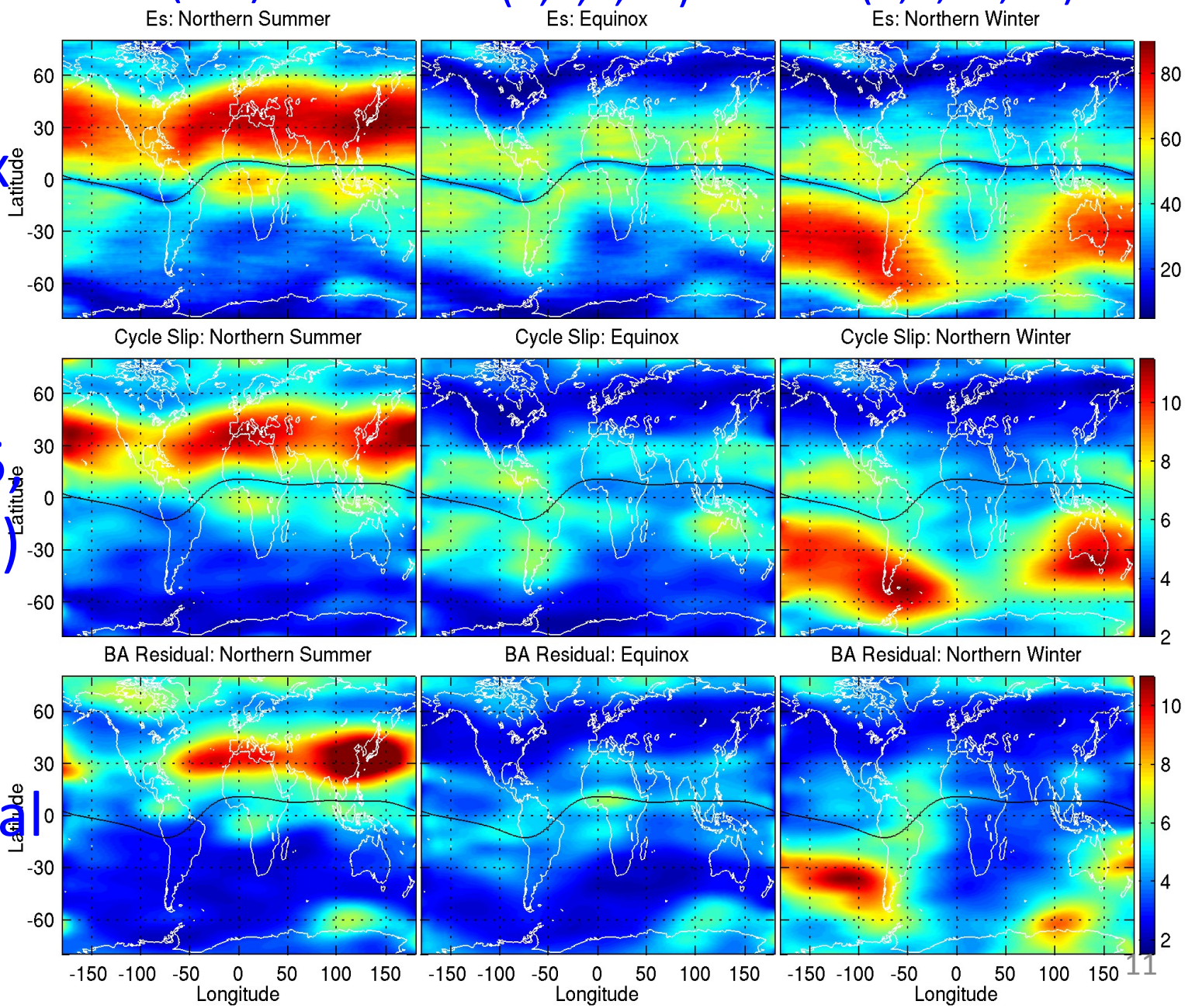
Equinox (3,4,9,10)

Northern Winter (1,2,11,12)

Es(s4max >0.3,%)

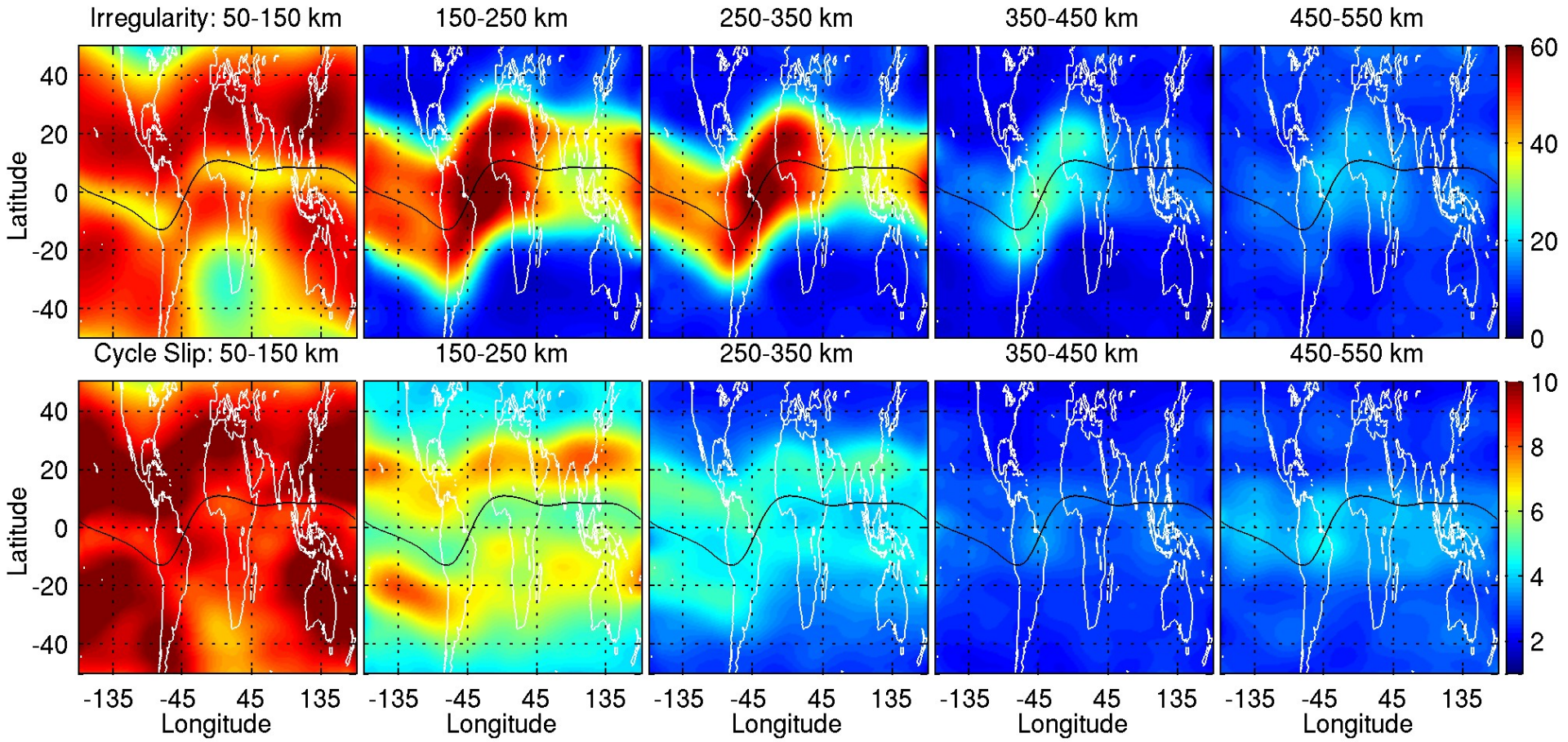
CS(85-125 % per RO)

BA residual (urad)



Altitude distribution: irregularity(top,s4max>0.3,%) and CS (bottom,per RO)

50-150(km) 150-250 250-350 350-450 450-550



Longitude-Latitude map

Altitude distribution: irregularity(top,s4max>0.3,%) and CS (bottom,per RO)

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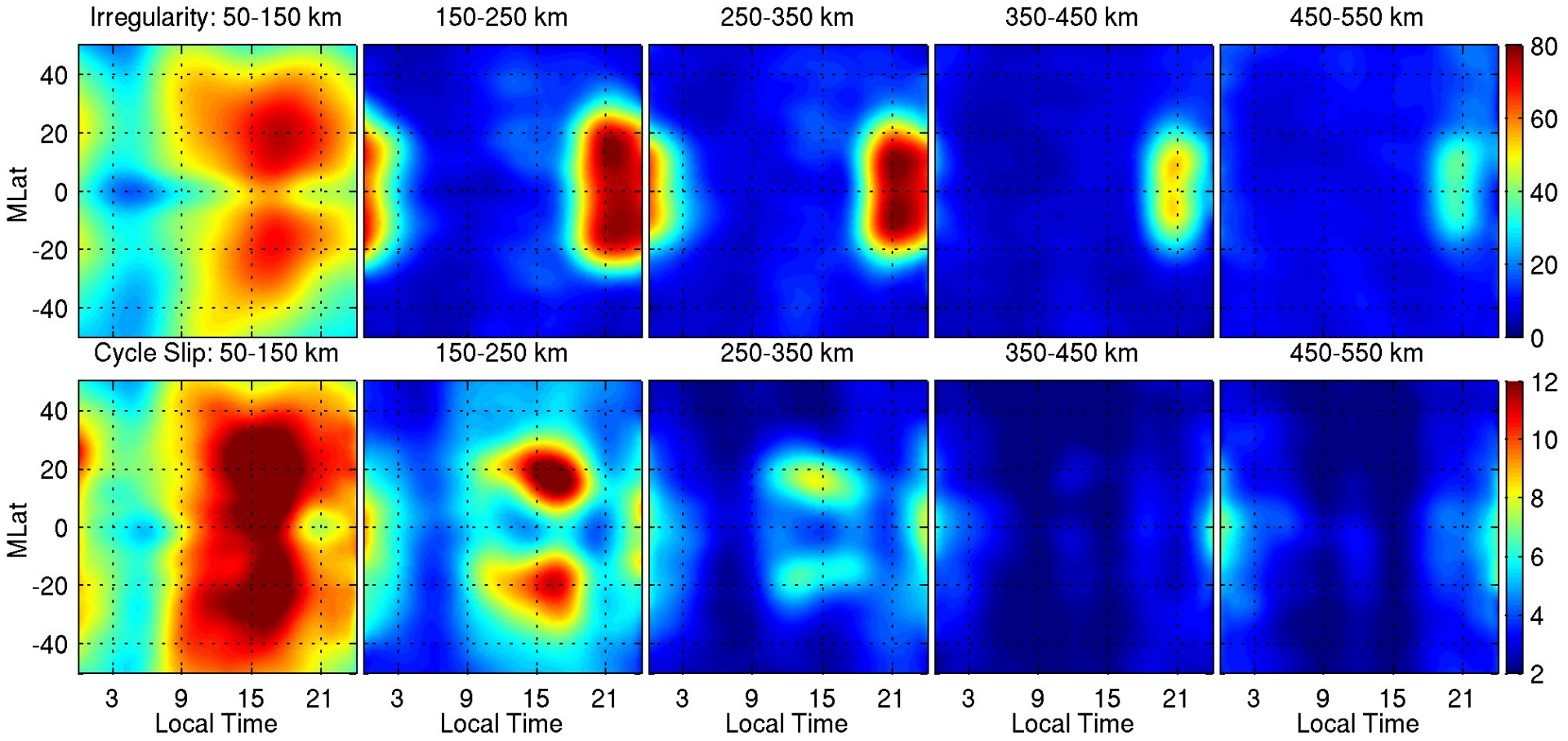
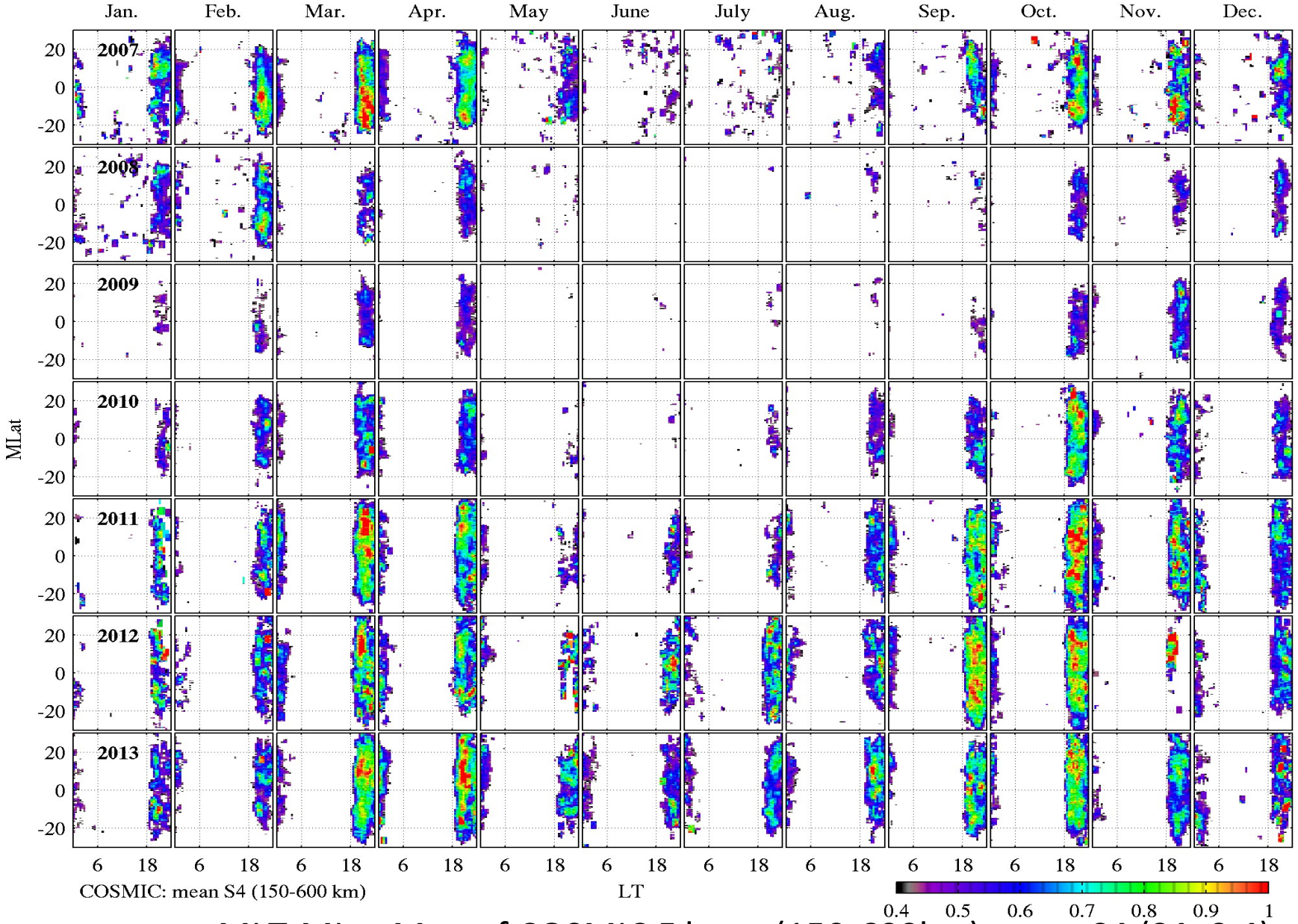


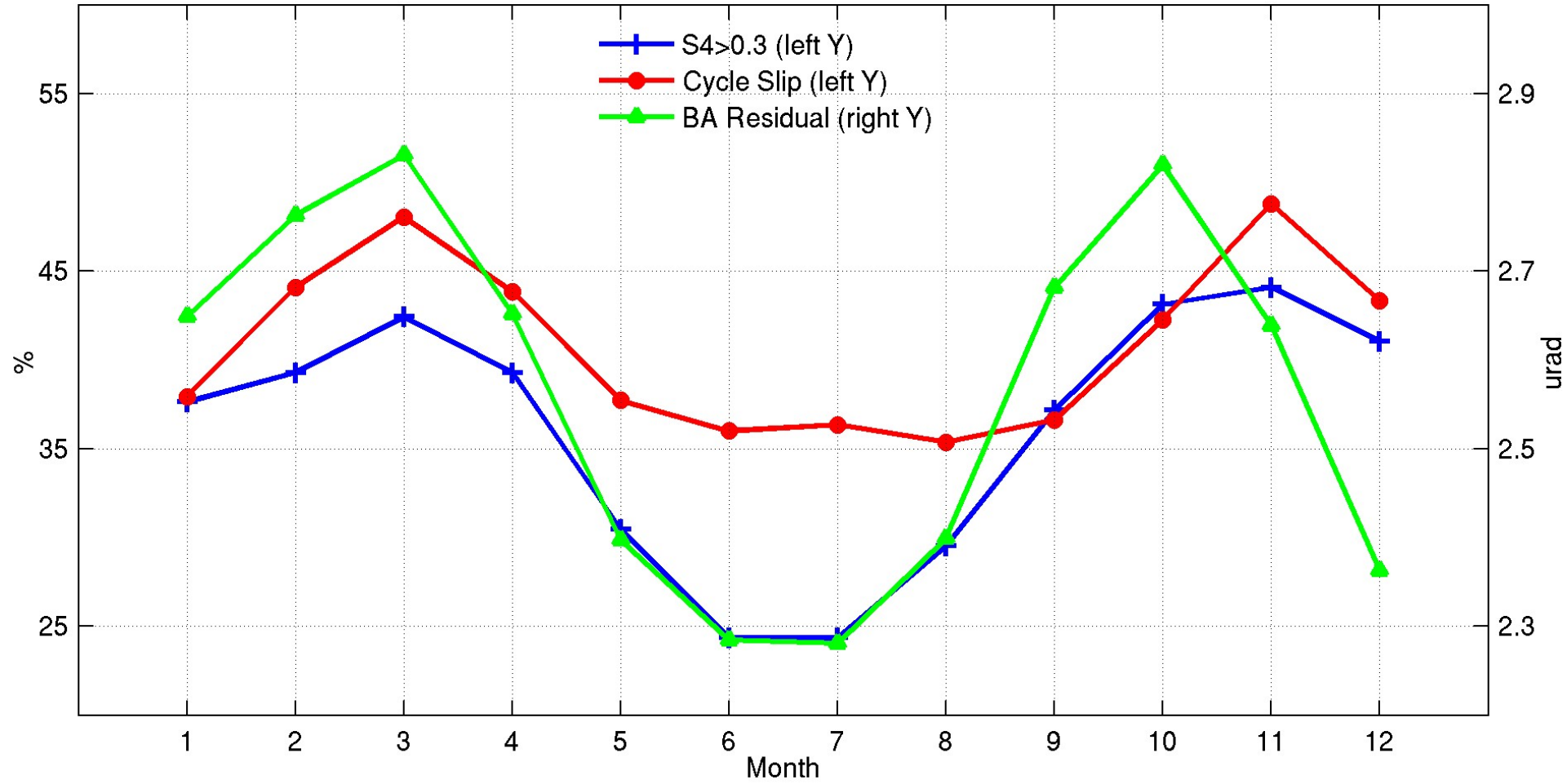
Local Time-Magnetic Latitude map

Left to Right: January-December; Top to Bottom: 2007-2013



MLT-MLat Map of COSMIC F layer (150-600km) mean S4 (S4>0.4)
[**seasonal and solar variation of equatorial F region irregularity**]

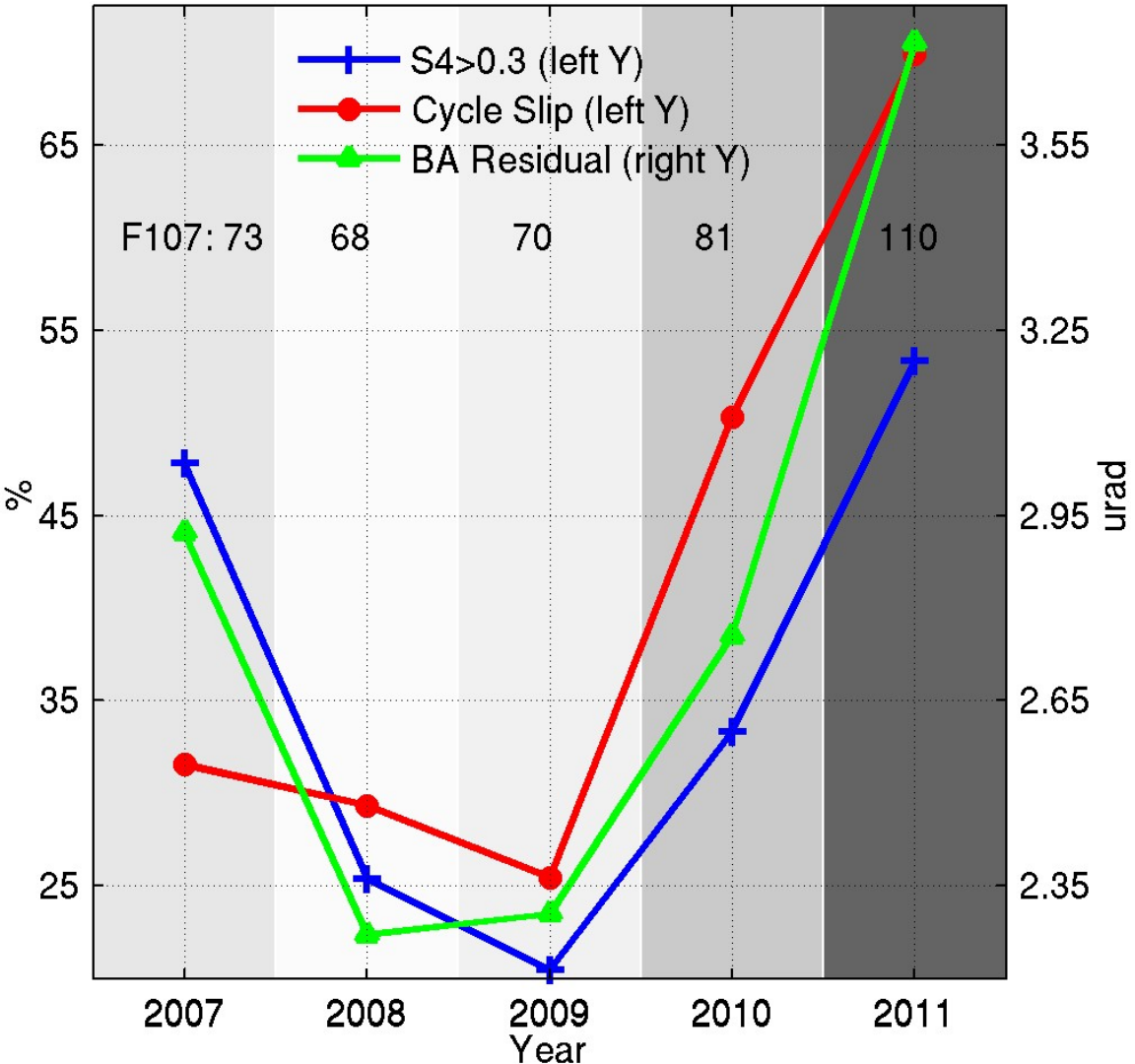
Seasonal variation (semi-annual variation dominated)



Equatorial F (150-600) region: within 8 degree of magnetic equator

Night time: 2100-0300 LT

Solar activity dependency



Equatorial F (150-600) region: within 8 degree of magnetic equator

Night time: 2100-0300 LT

Conclusions

- Strong correlation among ionospheric irregularity, RO signal cycle slip occurrence, and atmospheric bending angle residuals
- Cycle Slip is dominated by sporadic E, equatorial ionization anomaly, and equatorial F region scintillation
- Atmospheric bending angle residuals due to ionospheric irregularities have specific variations versus location, season, solar activity, and local time, which might influence the corresponding applications of RO data in NWP/climate especially in the upper stratosphere