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The International Reference Ionosphere and NeQuick – Improving the Representation of the Real-Time Ionosphere

Comparison of Sporadic E Occurrences using COSMIC and Ionosonde data in Thailand region

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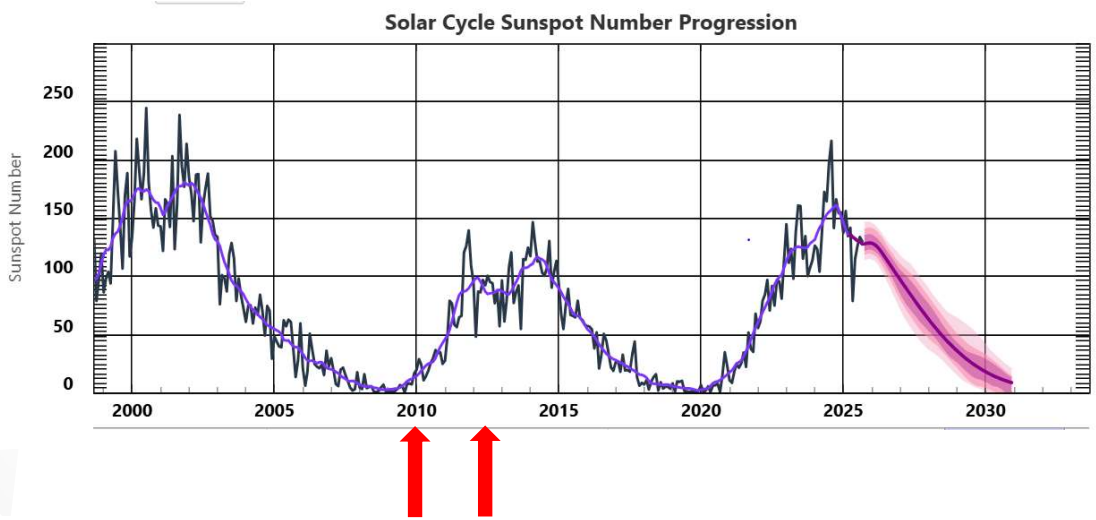
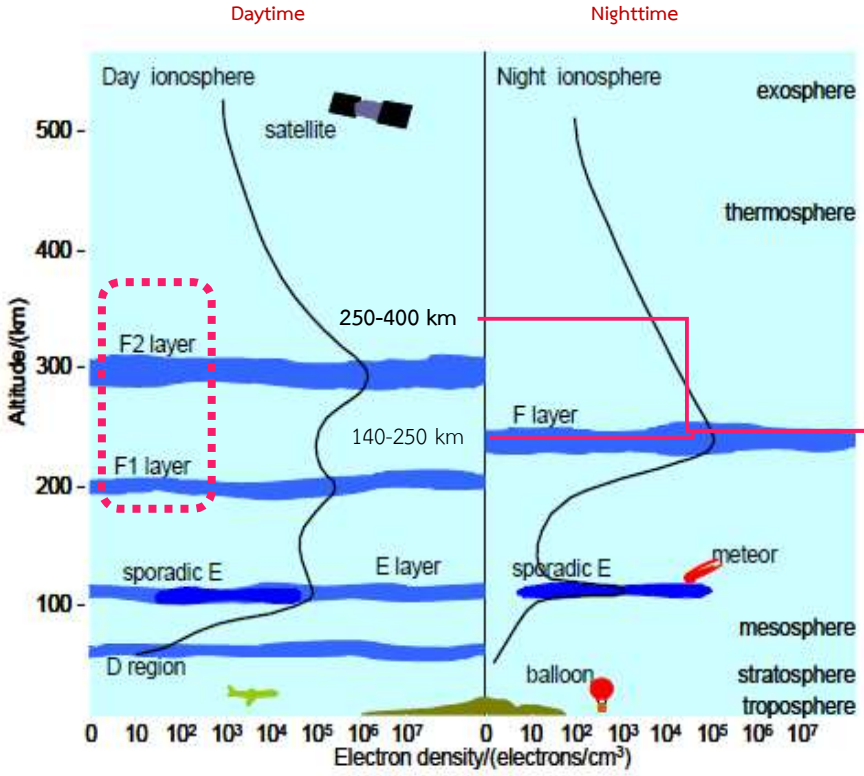
Objectives

- Perform the data analysis of the Sporadic E occurrences using SNR profiles from the COSMIC-1 in 2010 (LSA) and 2012 (HSA)
- Compare the results with ionogram-based results



Ionosphere and Its Layers



- Divided into 3 layers: D, E, F
- **The F2 layer** is the uppermost layer of the ionosphere (HF comm.)

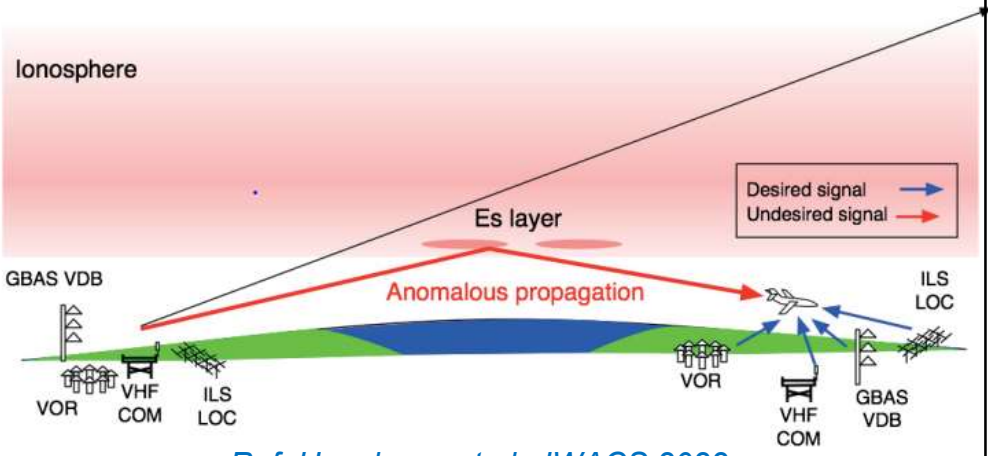
F layer:140-400 km

E layer : 90-140 km

D layer : 50-90 km

Ionospheric Sporadic E (Es) Layer

- A thin metallic ion layer in the E layer at 90-130 km
- Very thin with 0.1–10 km thick, horizontal spread more than 1,000 km (Qiu, Yu, et al., 2021; Tsai et al., 2018)
- Indicator for atmosphere-ionosphere coupling (Whitehead, 1961, 1989)
- F-region irregularities are highly correlated to Es layer [Liu et al., 2020; Otsuka et al., 2008; Yokoyama et al., 2004, 2010]



Ref. Hosokawa et al., IWACS 2022

Effects of Es:

- GNSS cycle slips [Yue et al, 2016]
- Anomalous VHF signals [Hosokawa et al. 2022; Sakai et al. 2019, 2020; Chartier et al. 2022]

Introduction (2)

- Equatorial Es layers (during geomagnetic storms)
  - prompt penetration electric fields (PPEFs) [Moro et al., 2017, 2022]
  - disturbance dynamo electric fields (DDEFs) [Resende et al., 2013, 2020, 2024]
- Es layer can be observed using ionosondes, satellite data among others
  - Ionosondes [Haldoupis et al., 2006; Merriman et al., 2021; Oikonomou et al., 2014, Wichaipanich et al., 2022]
  - GNSS RO signals [D. L. Wu et al., 2005; Arras et al., 2008; Chu et al., 2014; Z. Liu, Fang, et al., 2021; Tsai et al., 2018; Resende et al. 2018; Yu et al., 2019, 2022; Bergsson, 2022; J.A.Ellis et al., 2025]
- Recently, there is a strong interest to develop global Es model using COSMIC data.
- Validation with ground-based data is crucial

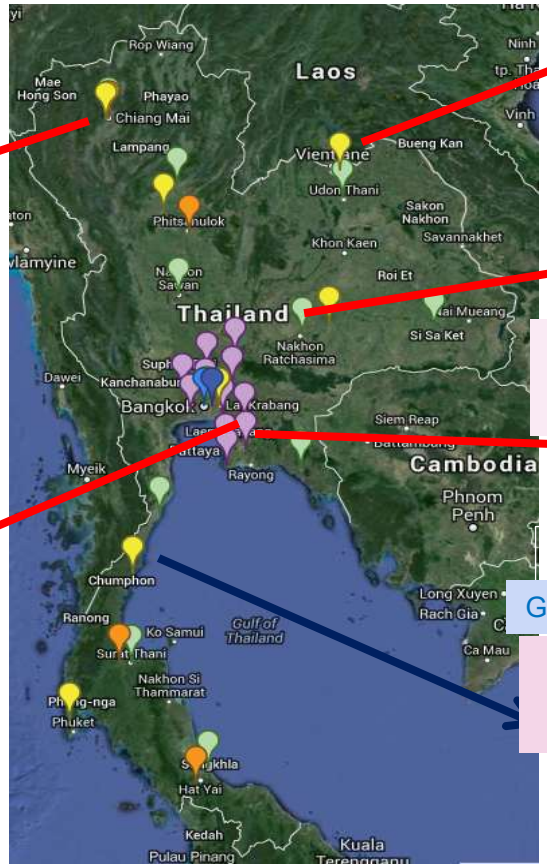
Research Facilities

Ionosonde
GNSS receiver
Beacon receiver

Chiangmai (CHM)

Bangkok (STFD)

GNSS receiver



Vientiene (Laos)

GNSS receiver

Nakhon Ratchasima (NKR)

GNSS receiver

Bangkok (KMITL)

GNSS receiver
Beacon receiver

Phenom Penh

GNSS receiver

Chumphon (CPN)

Ionosonde
GNSS receiver
Beacon receiver
VHF radar

COE in GNSS & Sapce Weather, KMITL *IRI /NeQuick Workshop 2025*

Chumphon Observatory

Lat: 10.794463, **Long**: 99.322922, **Magn. Lat.** 3 deg.

Located on Chumphon campus, King Mongkut's Institute of Technology Ladkrabang

Ionosonde

VHF radar station

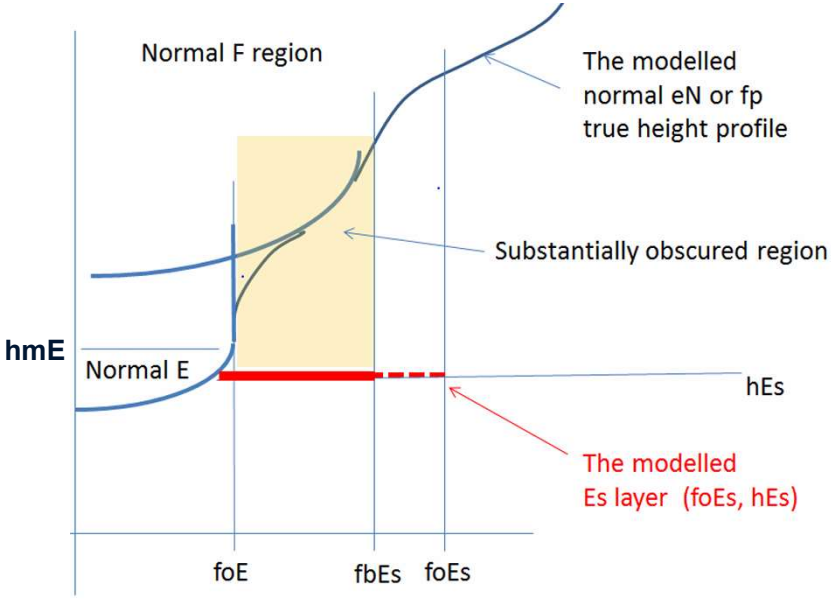
Magnetometer

Optical Sky Imager

GNSS receiver

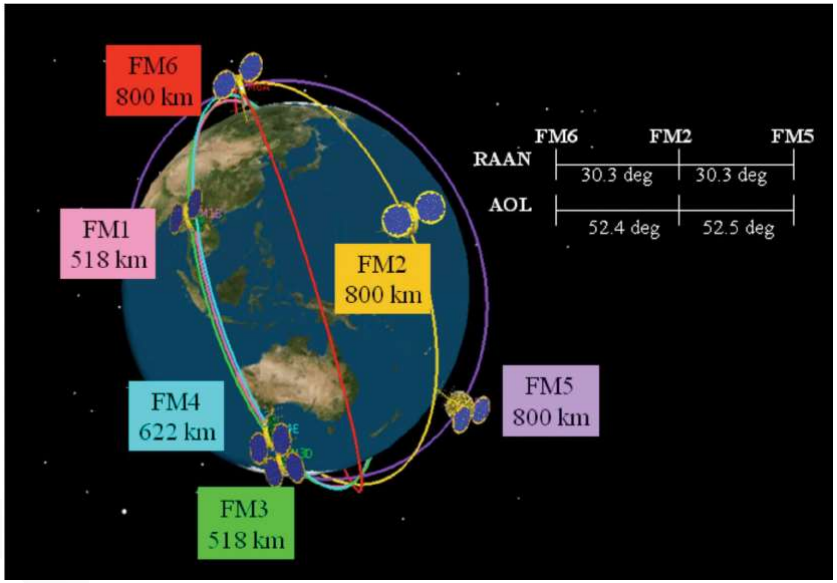
Ionosonde and Ionograms

Item	Description
Operating frequency	2 MHz - 30 MHz
Transmitter power	20 W (peak)
Antenna	30 m antenna tower
Range	900 km
Chip rate	0.5 ms



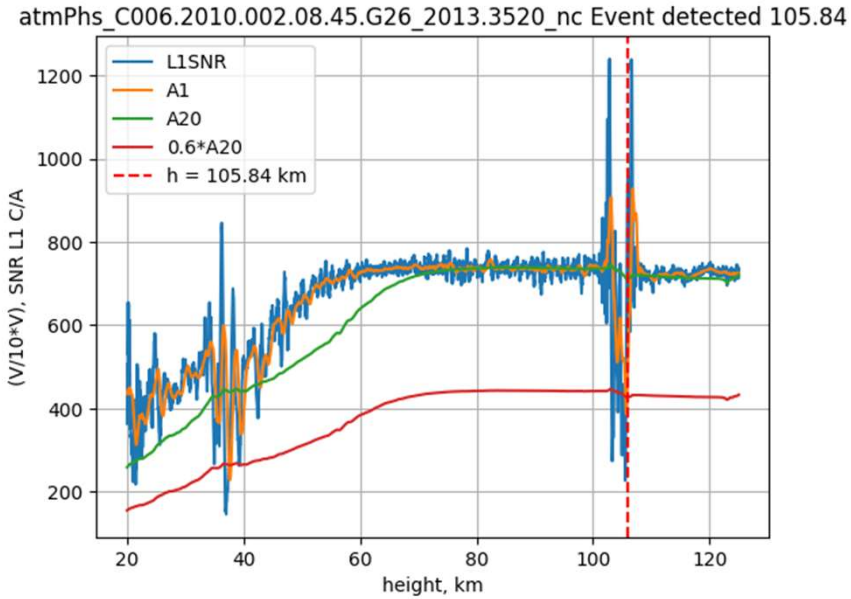
[bert S. Gardiner-Garden , A Description of a New Model of Sporadic E for JORN, 2017]

COSMIC I and SNR profiles



Operational 2006-2020
6 LEO satellites, polar orbits

SNR Profile (Example)



[Y.A.Liu et al., IEEE Trans. Geoscience and Remote Sensing, 45(11):3813 – 3826]

[C. A. Resende et al. Annales Geophysicae, 2018]
[B. Bergsson and S. Syndergaard, S. Journal of Geophysical Research Space Physics, 2022]

COSMIC I: Levels of Data

- Level1a – Raw RO data
- **Level1b** – Processed RO data (Atmosphere profiles)
- Level 2 – high-level processed data (TEC, electron density etc)

Data access:

https://data.cosmic.ucar.edu/gnss-ro/cosmic1/repro2013/

Data from the level 1b

scnLv1_C006.2010.002.23.59.0027.G26.01_2021.0390_nc	15 Sept 2022
ionPrf_C006.2010.021.23.43.G18_2021.0390_nc	13 Mar 2021
ionPhs_C006.2010.021.23.47.G17_2021.0390_nc	13 Mar 2021
ionPhs_C006.2010.021.23.43.G18_2021.0390_nc	13 Mar 2021
atmPrf_C006.2010.021.23.53.G23_2021.0390_nc	28 Dec 2021

Data Structure of COSMIC-1 Data

	time	occheight	caL1Snr	xLeo	yLeo	zLeo	xGps	yGps	zGps	file_id
0	NaN	44.048405	360.0	-1989.449479	4539.632591	-5179.843299	-10708.484191	11079.589181	21867.409324	C0012010
1	1.000000	46.874756	466.0	-1994.433236	4542.684513	-5175.206476	-10711.683637	11077.515165	21866.904403	C0012010
2	2.000000	49.696804	328.0	-1999.414839	4545.731531	-5170.564051	-10714.882860	11075.440918	21866.399028	C0012010
3	3.000000	52.514549	406.0	-2004.394284	4548.773642	-5165.916030	-10718.081860	11073.366440	21865.893196	C0012010
4	4.000000	55.327984	408.0	-2009.371565	4551.810842	-5161.262417	-10721.280637	11071.291732	21865.386910	C0012010
...	...	...	...	...	...	...	...	...	...	...

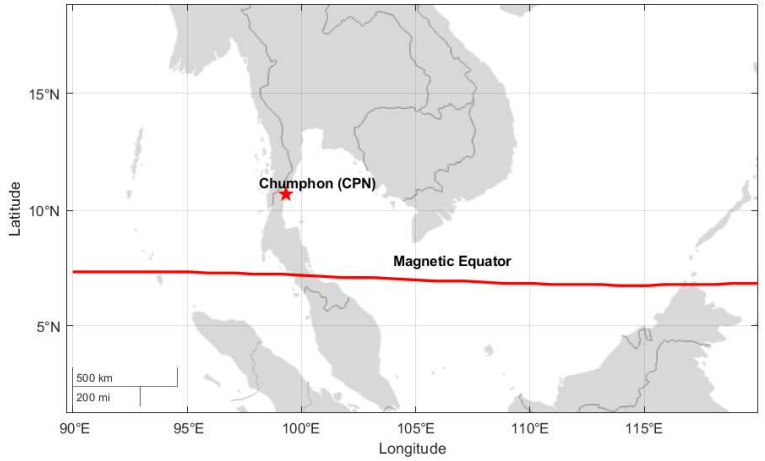
- ⇨ Time — time of one RO session (seconds)
- ⇨ Occheight — altitude of the RO perigee point (km)
- ⇨ xLeo, yLeo, zLeo — coordinates of LEO (COSMIC) (ECI, km)
- ⇨ XGPS, yGPS, zGPS — coordinates of GPS (ECI, km)
- ⇨ caL1Snr — SNR for L1 C/A signal

Analysis Procedures

- Extract the latitude and longitude of the RO point
- Select Southeast Asia area

  Latitude: **0 – 20 deg.**

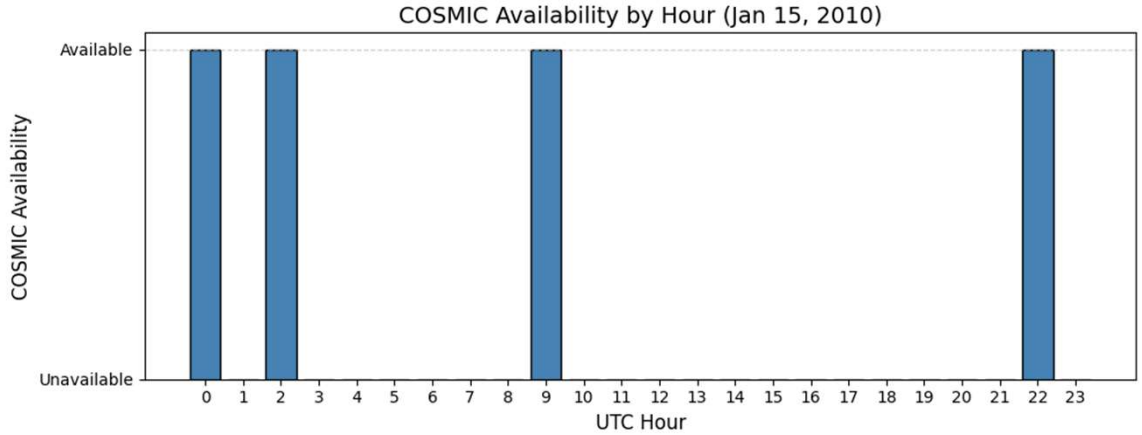
  Longitude: 90 – 120 deg.
- Remove missing rows



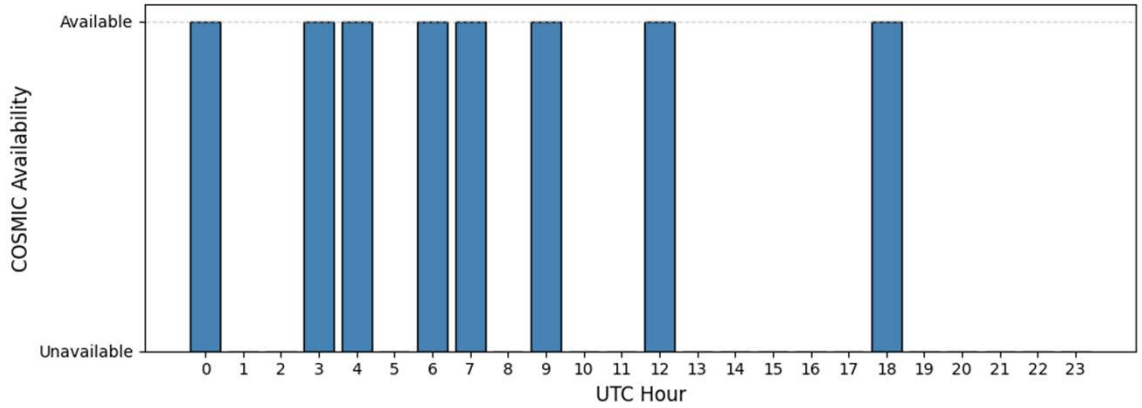
	time	occheight	caL1Snr	xLeo	yLeo	zLeo	xGps	yGps	zGps	file_id	Latitude	Longitude
67	0.999999	28.720579	279.0	-5150.929661	4784.988581	1291.075072	-3963.153361	-17819.318045	18999.263196	C0012010	10.466930	137.109257
68	1.999999	31.313385	288.0	-5151.583077	4782.382181	1298.062923	-3959.588133	-17818.612666	19000.691781	C0012010	10.524214	137.128447
69	2.999999	33.902760	296.0	-5152.230865	4779.770557	1305.049352	-3956.022819	-17817.906898	19002.119953	C0012010	10.581497	137.147645
70	3.999999	36.488701	294.0	-5152.873023	4777.153710	1312.034352	-3952.457418	-17817.200742	19003.547711	C0012010	10.638779	137.166849
71	4.999999	39.071201	297.0	-5153.509552	4774.531644	1319.017915	-3948.891931	-17816.494198	19004.975054	C0012010	10.696060	137.186060

COSMIC I availability

January 15, 2010

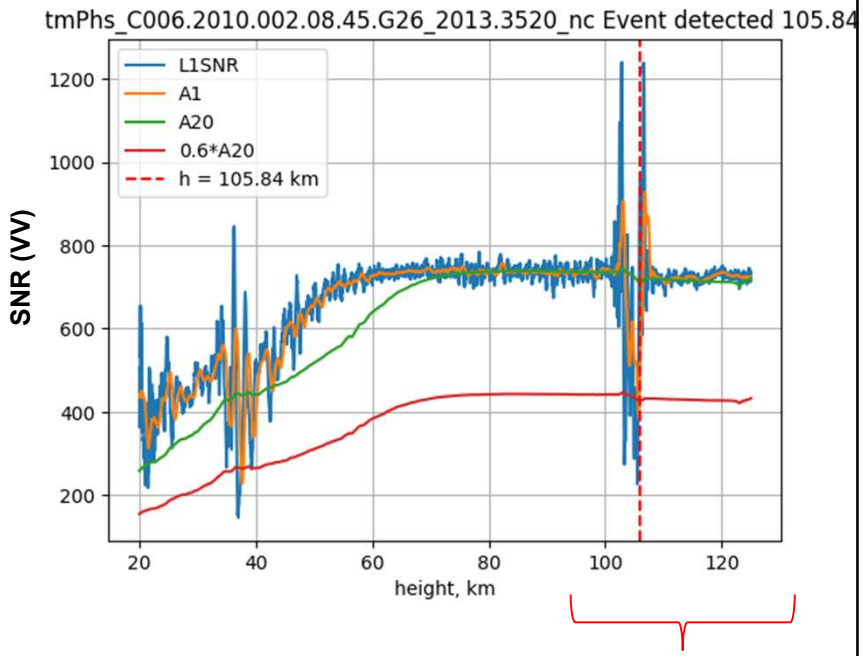


January 19, 2010



Methodology: U-shape algorithm

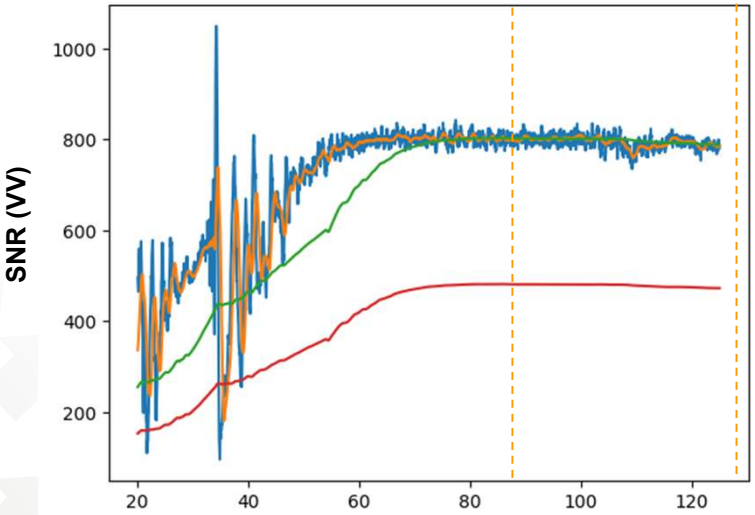
- U-shape algorithm requires to compute two running means with the different window sizes from the L1 C/A SNR measurements
- A1 - running mean (window size = 1 km)
- A20 - running mean (window size = 20 km)
- A1 < 0.6*A20 (for the altitudes 90-120 km) is the criteria for the Sporadic E detection



[L. C. A. Resende, et al. *Annales Geophysicae*, 2018]
[Bergsson, B., & Syndergaard, S. *Journal of Geophysical Research Space Physics*, 2022]

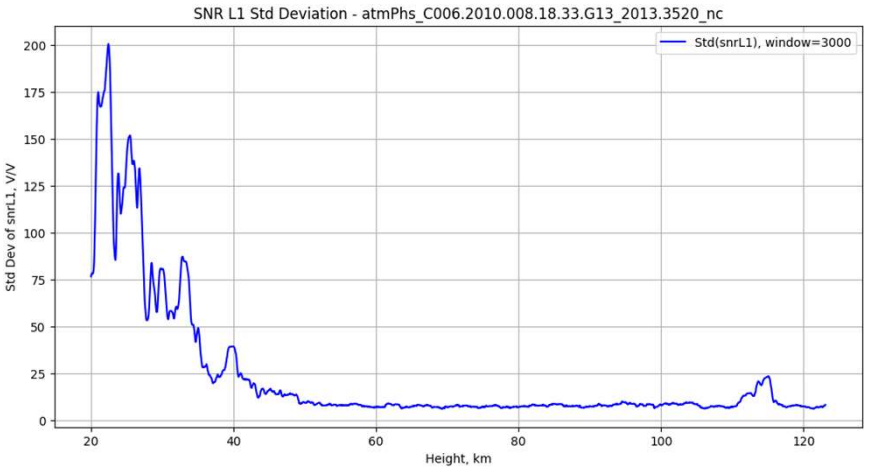
SNR Profile examples: No Sporadic E Detected

NO Sporadic E



90-130 km

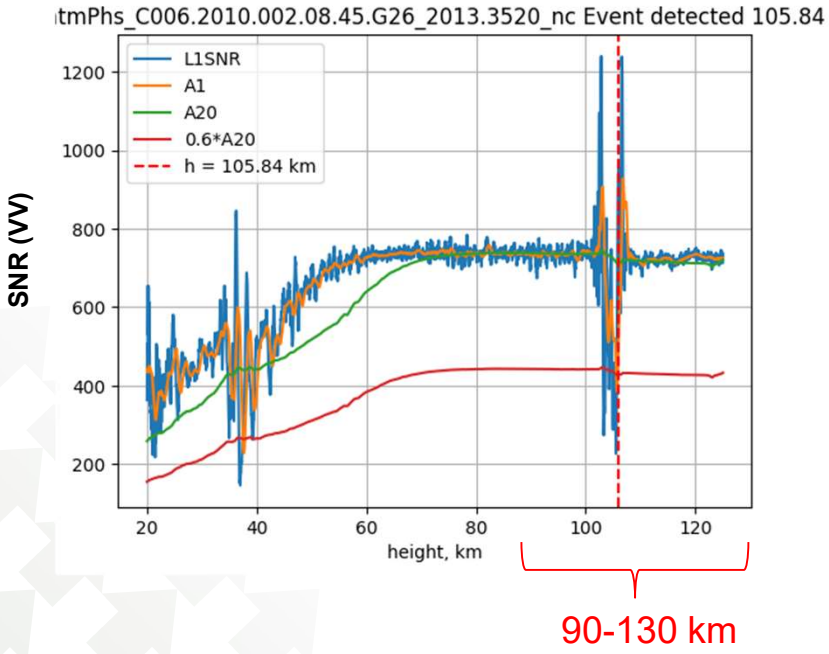
Standard deviation of SNR (No Sporadic E detected)



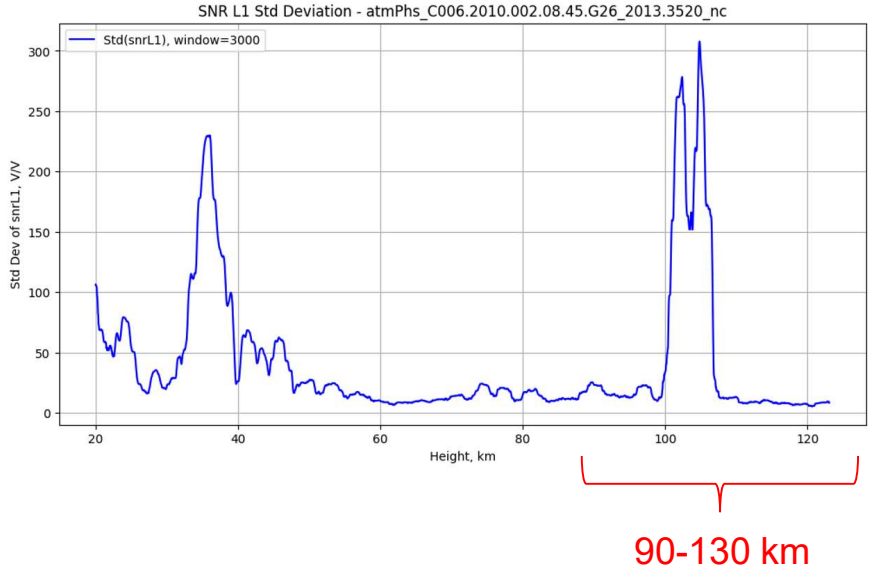
90-130 km

SNR profile examples: Sporadic E

Detected Sporadic E



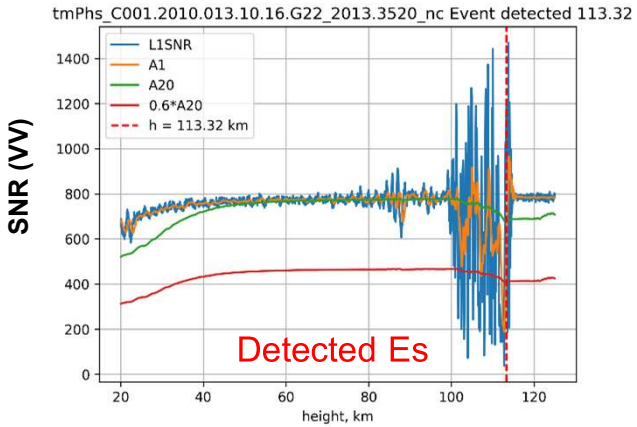
Standard deviation of SNR (Sporadic E detected)

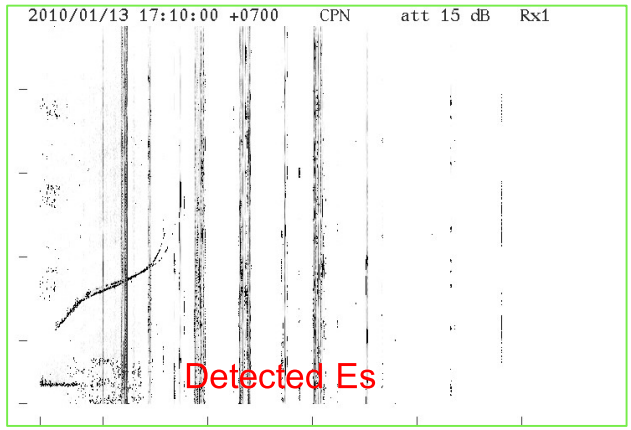


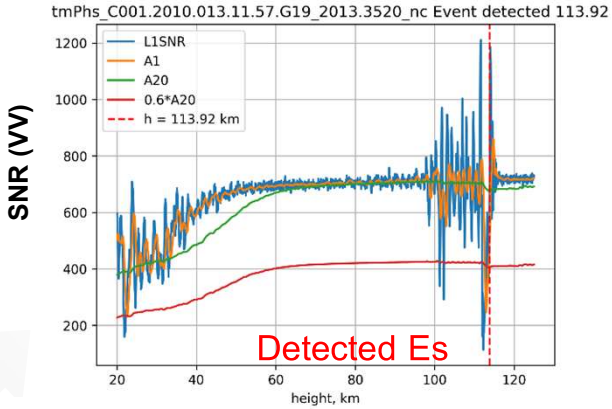
COSMIC I (SNR) vs. Ionogram

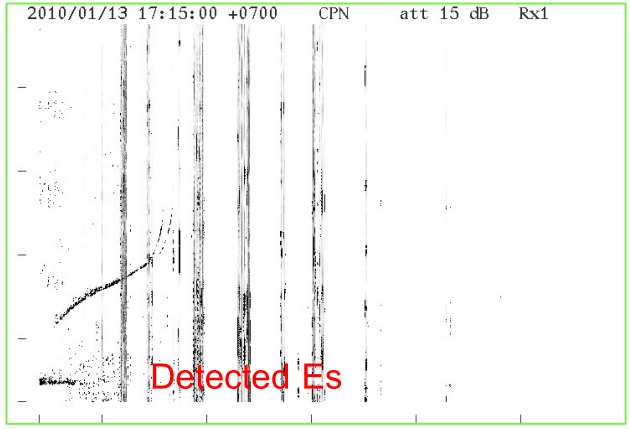
January 13, 2010

(both COSMIC 1 SNR, Ionograms)





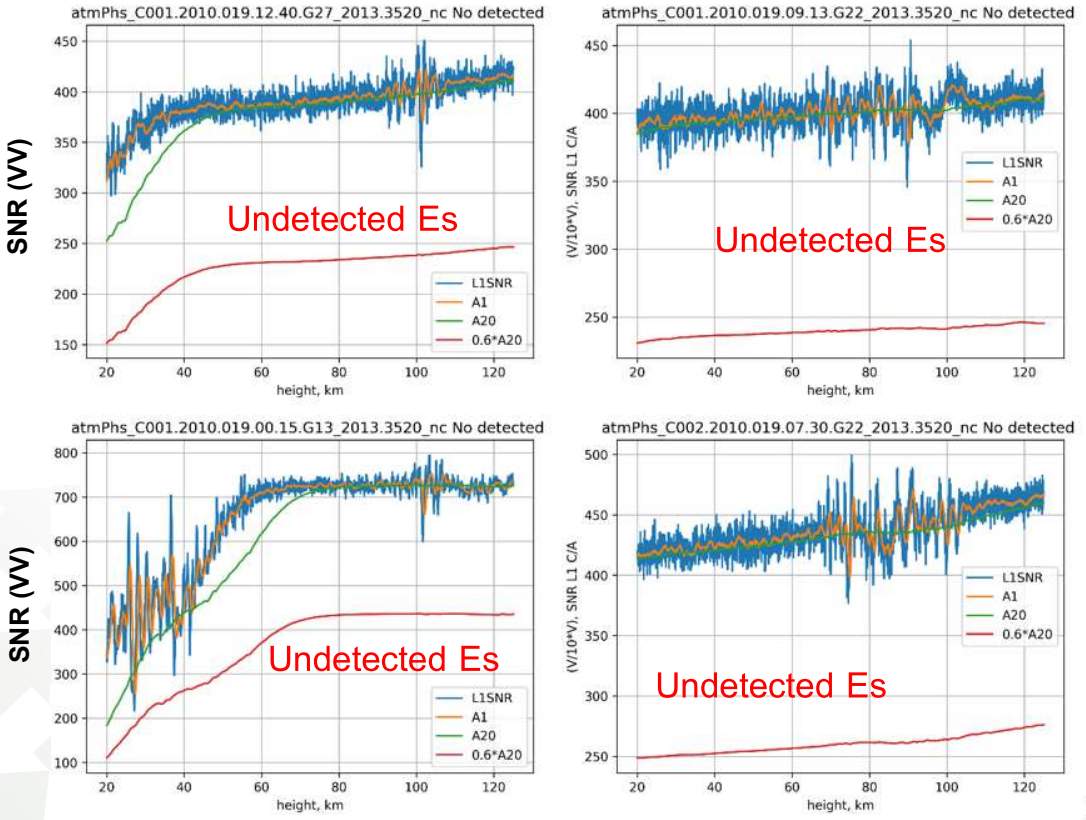


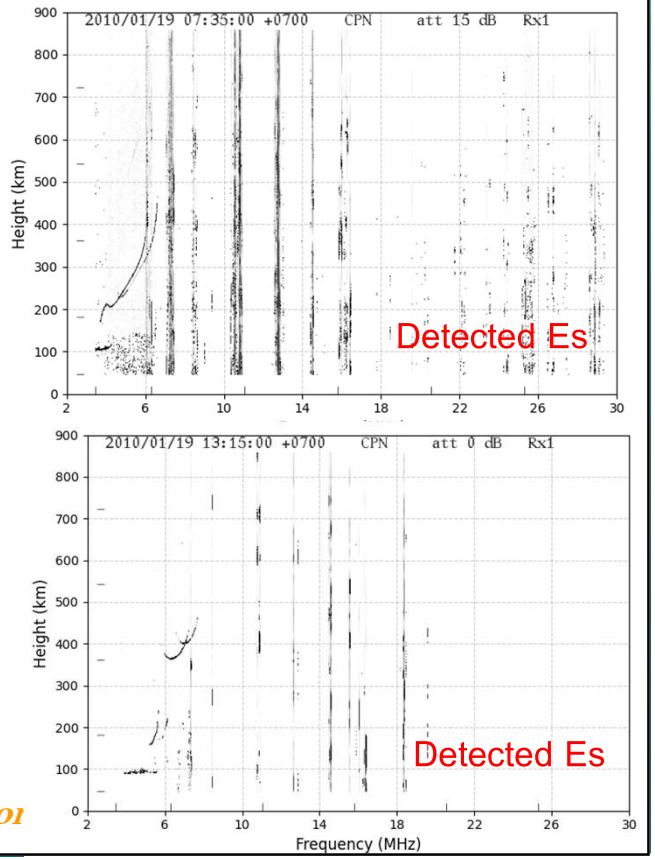


COSMIC I (SNR) vs. Ionogram

January 19, 2010

Duration is 5 hours 40 minutes (started at UTC 07:35. The end time is 13:15)





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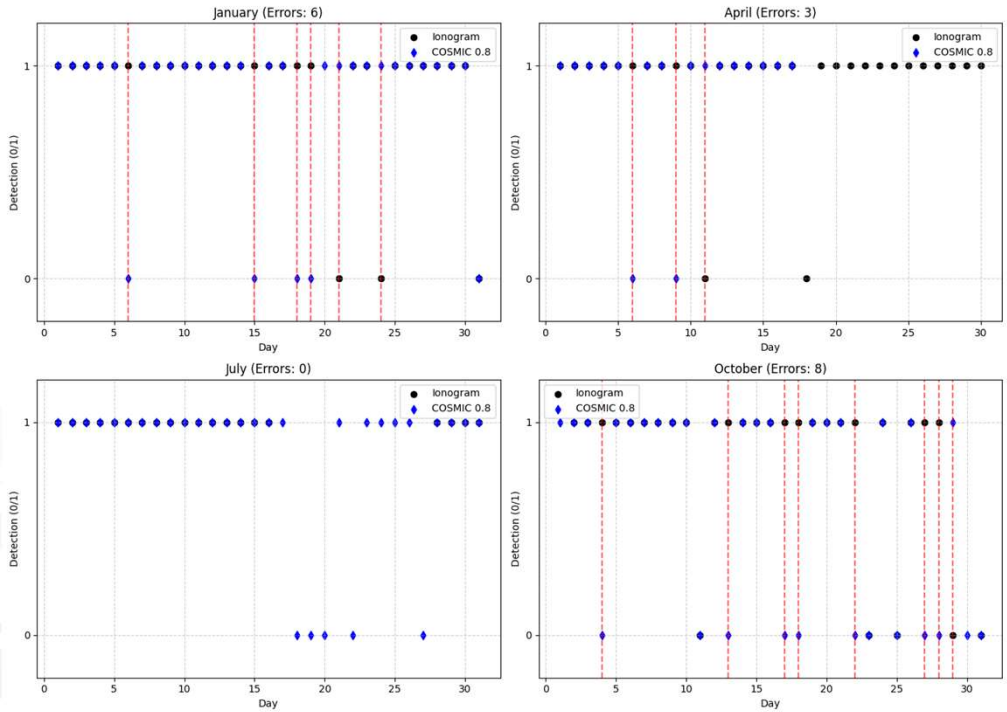
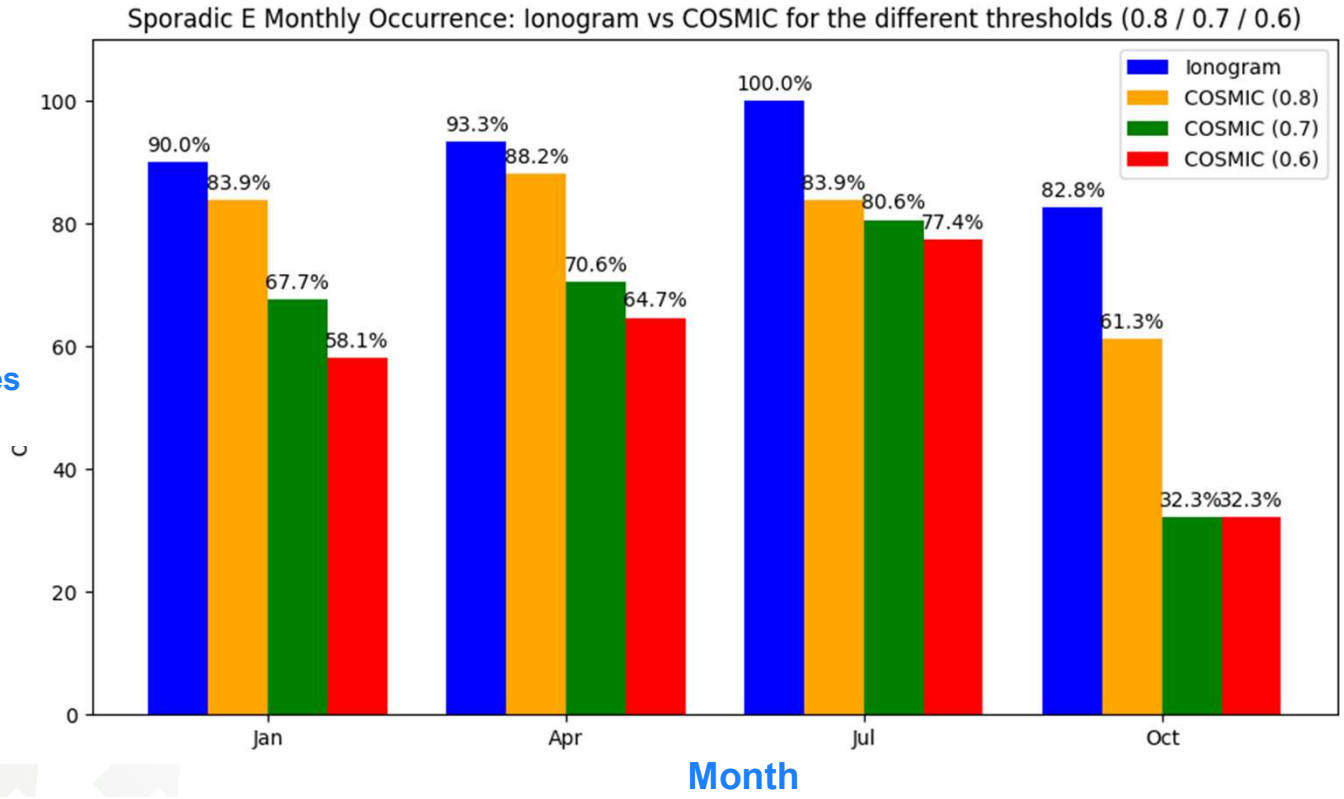
Sporadic E detection - 2010

Threshold 0.8



By optimizing this threshold, we could get COSMIC I sporadic E to match Ionogram results

Monthly Es occurrences (2010)



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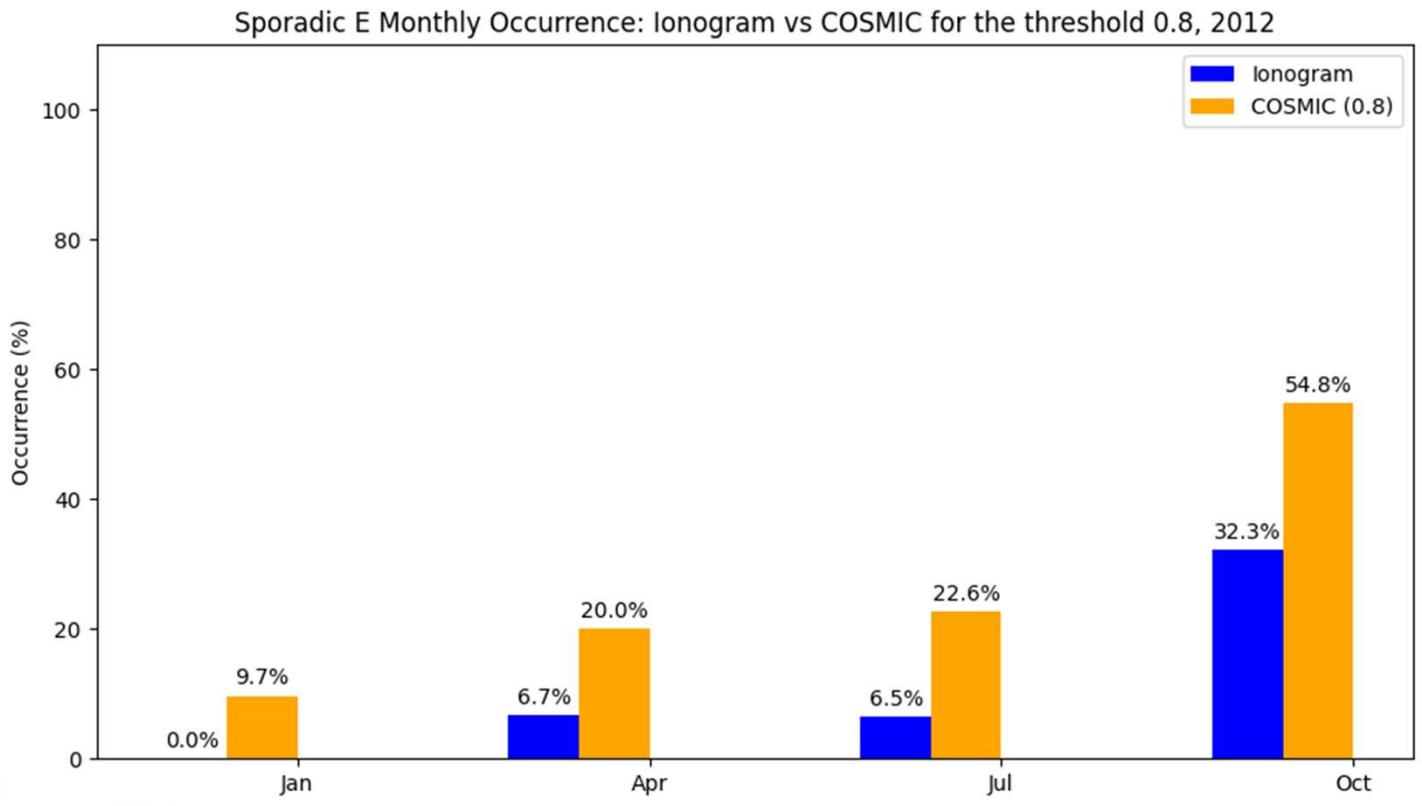
Monthly occurrence for 2012



Conclusions and Future Works

- Comparison between ionosonde E and COSMIC I Es during 2010 and 2012 show that
  - There are some discrepancies in percentages of Es occurrences
  - The reason could be that the coverage under study is large
  - We are currently analyzing COSMIC II data and ionogram data during 2020-2024 now, should have more results in the near future.
- Future works:
  - Wiggle the coverage radius
  - Extend the work to COSMIC II and more recent data in 2020-2024

The 8th AOSWA 2025 Workshop
(Asia-Oceania Space Weather Alliance Workshop)
November 10-12, 2025
Hainan, China

https://aoswa2025.casconf.cn/

Workshop Venue

Conference Venue: SHERATON HAIKOU HOTEL(https://haikousheraton.cn/)
Address: No.119 Binhai Avenue, Xiuying District, Haikou, Hainan, China
Sheraton Haikou Hotel is a beachfront hotel, about 10 minutes away from the heart of the city, 50 minutes drive to Meilan International Airport.

Thanks!

Homepage : https://sites.google.com/site/pornchaisupnithi/

GNSS and Space Weather Information Center:

Center of Excellence in GNSS and Space Weather:

http://iono-gnss.kmitl.ac.th

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