Investigation of E-region Electron Density and Conductivity using COSMIC-1 Measurements

Cornelius Csar Jude H. Salinas[1,2], Dong L. Wu[2], Nimalan Swarnalingam[2,3], Daniel Emmons[4], Liying Qian[5], Yosuke Yamazaki[6] and Jorge Chau[6]

[1]Goddard Earth Sciences and Technology II, University of Maryland, Baltimore County, Baltimore, Maryland, USA
[2]NASA Goddard Space Flight Center, Greenbelt, Maryland, USA
[3]Department of Physics, The Catholic University of America, Washington DC, USA
[4]Department of Engineering Physics, Air Force Institute of Technology, Wright-Patterson Air Force Base, Dayton, Ohio, USA
[5]National Center for Atmospheric Research High Altitude Observatory, Boulder, Colorado, USA
[6]Leibniz Institute of Atmospheric Physics, Kühlungsborn, Germany

Email: cornelius.c.salinas@nasa.gov

I. E-region Prompt Radio Occultation Based Electron Density (E-PROBED) Model v01.00
[https://github.com/ccjsalinasNASA/EPROBED_v01.00; Salinas et al, 2024]

(1) WHAT DOES E-PROBED SIMULATE?

E-PROBED models the seasonal and solar dependencies of COSMIC-1 E-region Ne's latitude-local time-altitude profile.
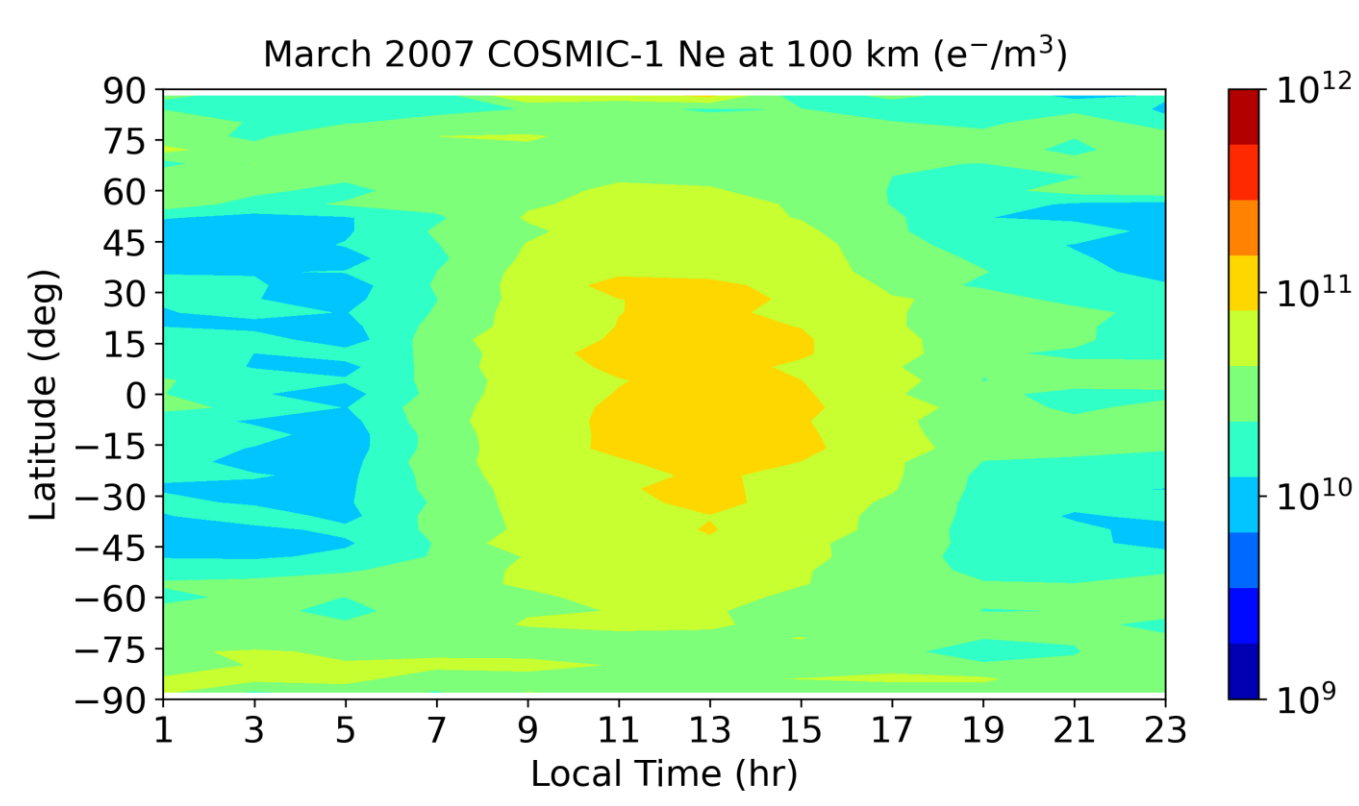
Fixed grid:
4-degree latitude by 3-hourly local time bin.
1 km vertical resolution.

(2) E-PROBED DEVELOPMENT

All variabilities are split into two components: a Solar Zenith Angle-dependent component (SZA component) and a non-SZA component. Both begin with the same step. Fit vertical profiles over each latitude-local time bin with the Chapman Function:

$$N_E(z) = N_{mE}e^{\left\{\frac{1}{2}\left(1-z'-g(\chi)e^{-z'}\right)\right\}} \text{ where } z' = \frac{z-H_{mE}}{H}$$

E-PROBED architecture is centered on modeling the seasonal and solar-dependencies of 3-parameters: N_{mE}, H_{mE} and H.
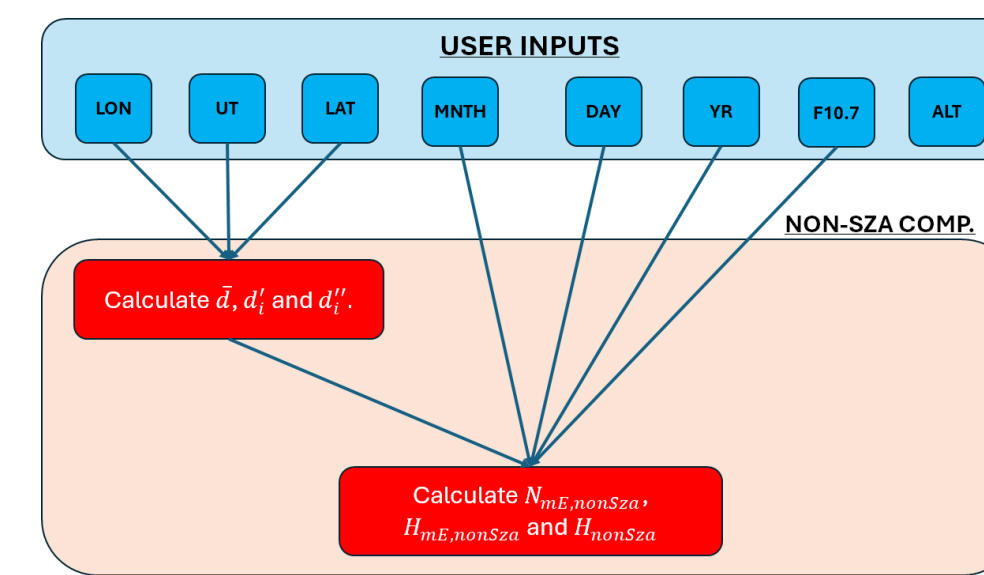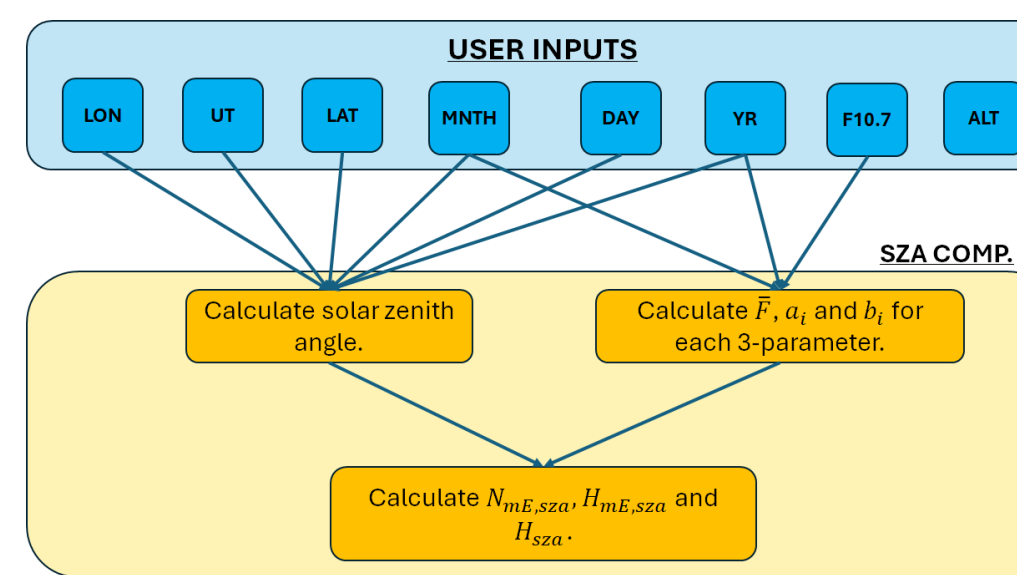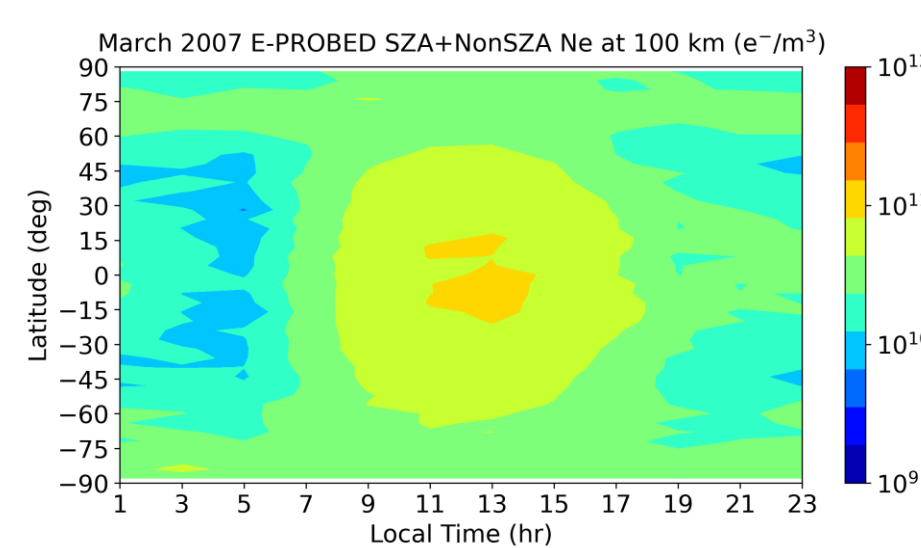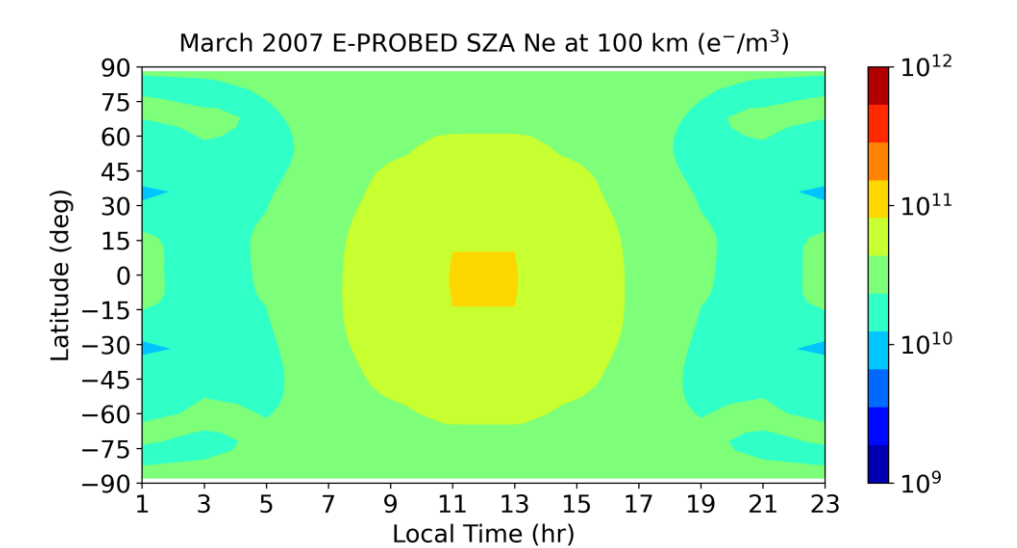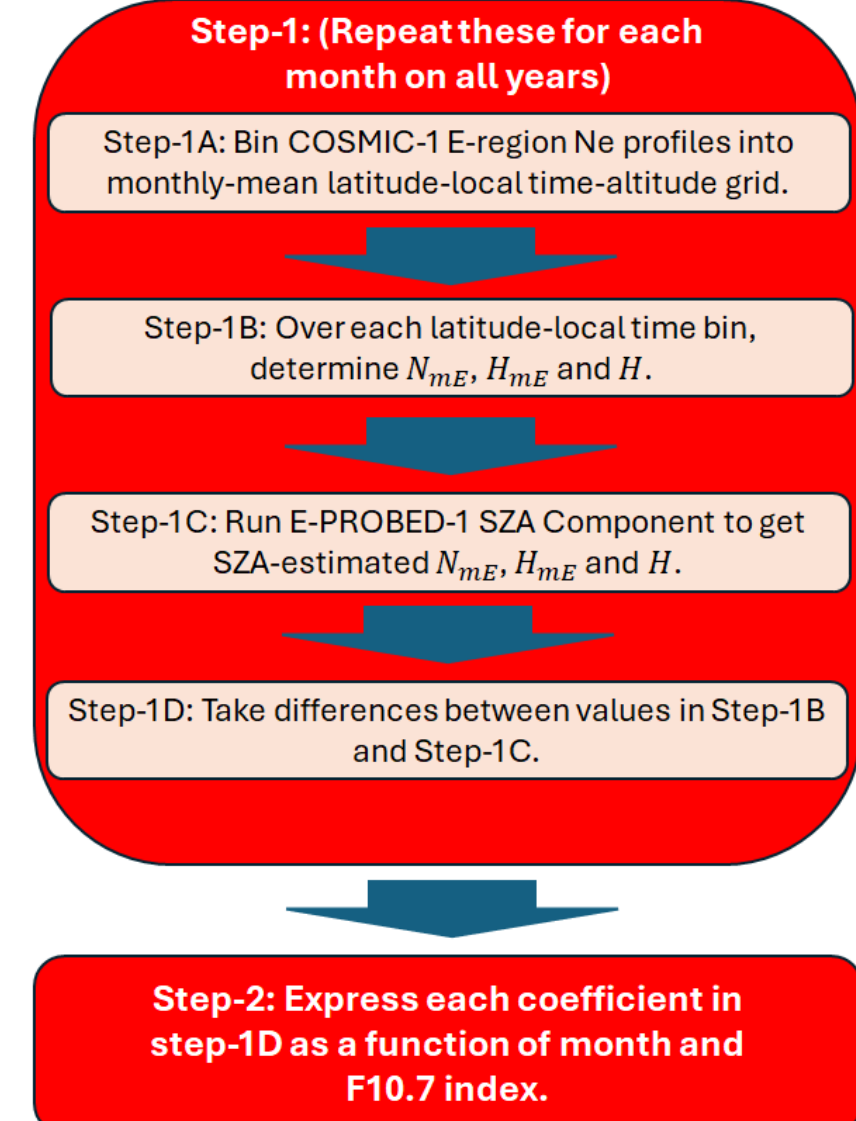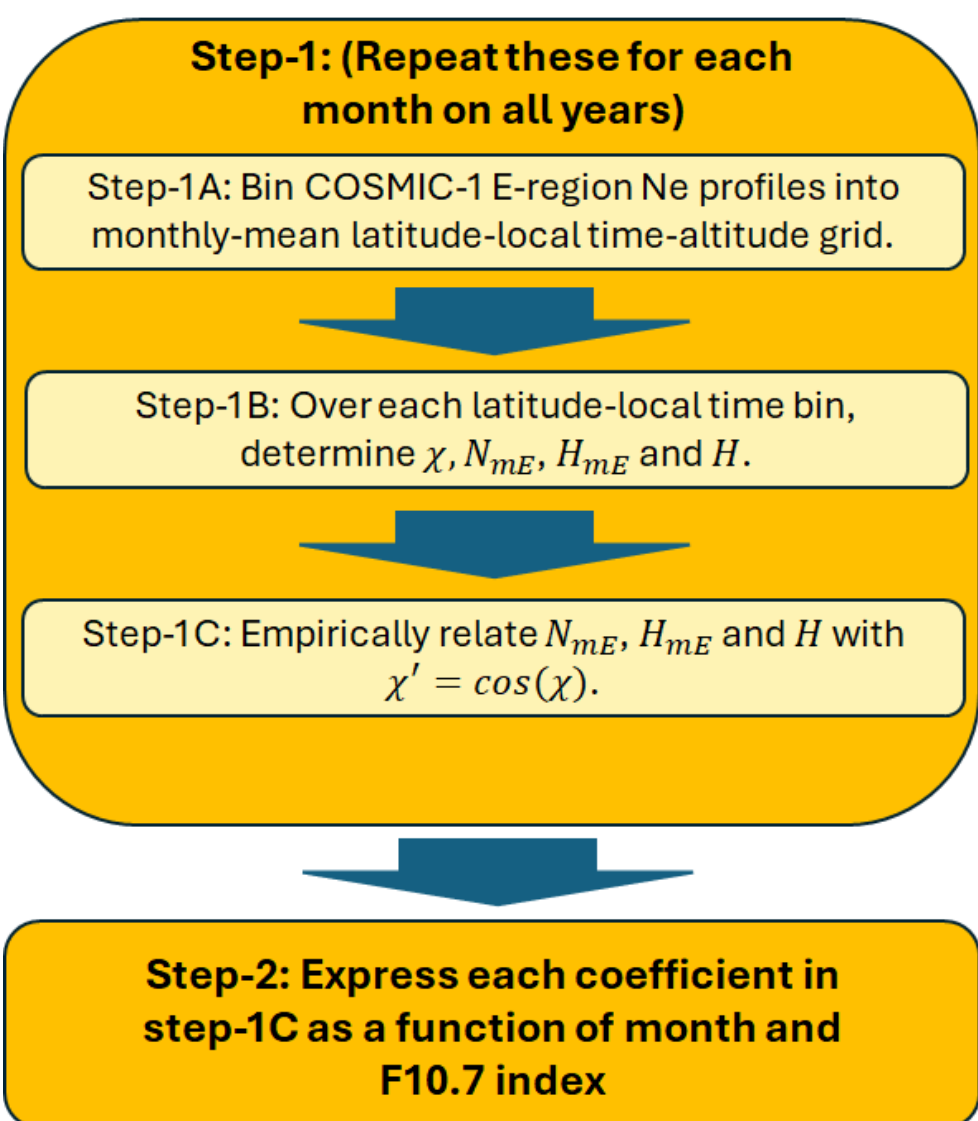
What is the empirical relationship between the 3-parameters and SZA for the date that the user needs?

For the latitude-local time bin that the user needs, what is the "correction" needed for the 3-parameters that the SZA component calculated?
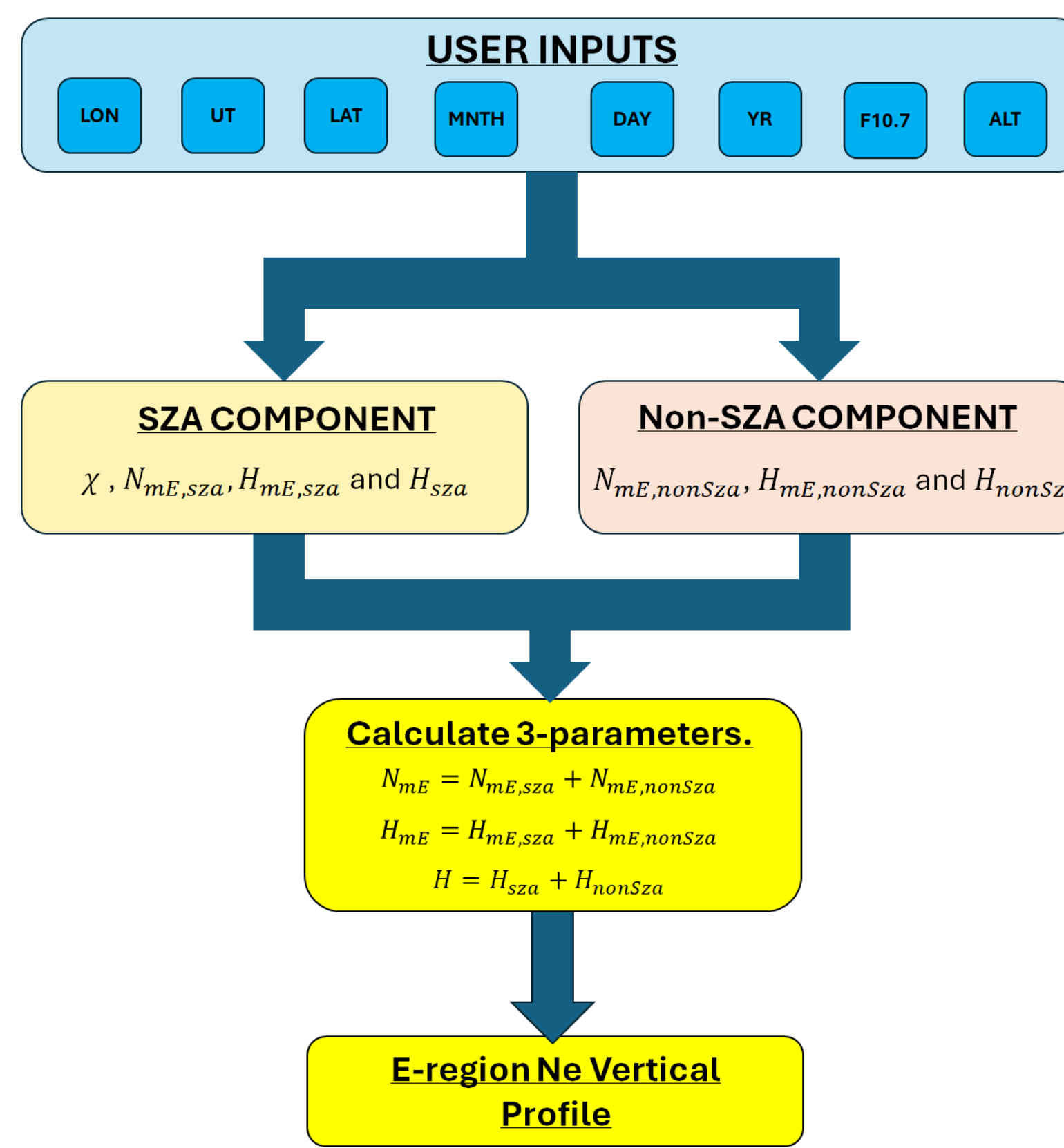
(3) COMPLETE E-PROBED ARCHITECTURE

SZA COMPONENT: χ, $N_{mE,sza}$, $H_{mE,sza}$ and H_{sza}

Non-SZA COMPONENT: $N_{mE,nonSza}$, $H_{mE,nonSza}$ and H_{nonSza}

Calculate 3-parameters.
$$N_{mE} = N_{mE,sza} + N_{mE,nonSza}$$
$$H_{mE} = H_{mE,sza} + H_{mE,nonSza}$$
$$H = H_{sza} + H_{nonSza}$$

E-region Ne Vertical Profile

	PHOTO	NON-PHOTO	TRANSPORT	PROTON CHEM	SPORADIC E	EEP OR AURORA	LOWER ATMOSPHERE
LON	SZA	BOTH	BOTH	NO	NO	NON-SZA	NO
UT	SZA	BOTH	BOTH	NO	NO	NON-SZA	NO
LAT	SZA	BOTH	BOTH	NO	NO	NON-SZA	NO
MNTH	SZA	BOTH	BOTH	NO	NO	NON-SZA	NO
DAY	SZA	NO	NO	NO	NO	NO	NO
YR	SZA	BOTH	BOTH	NO	NO	NO	NO
F10.7	SZA	BOTH	BOTH	NO	NO	NO	NO

This table shows which E-PROBED-1 component accounts for specific physical drivers of E-region Ne's latitude-local time variabilities.
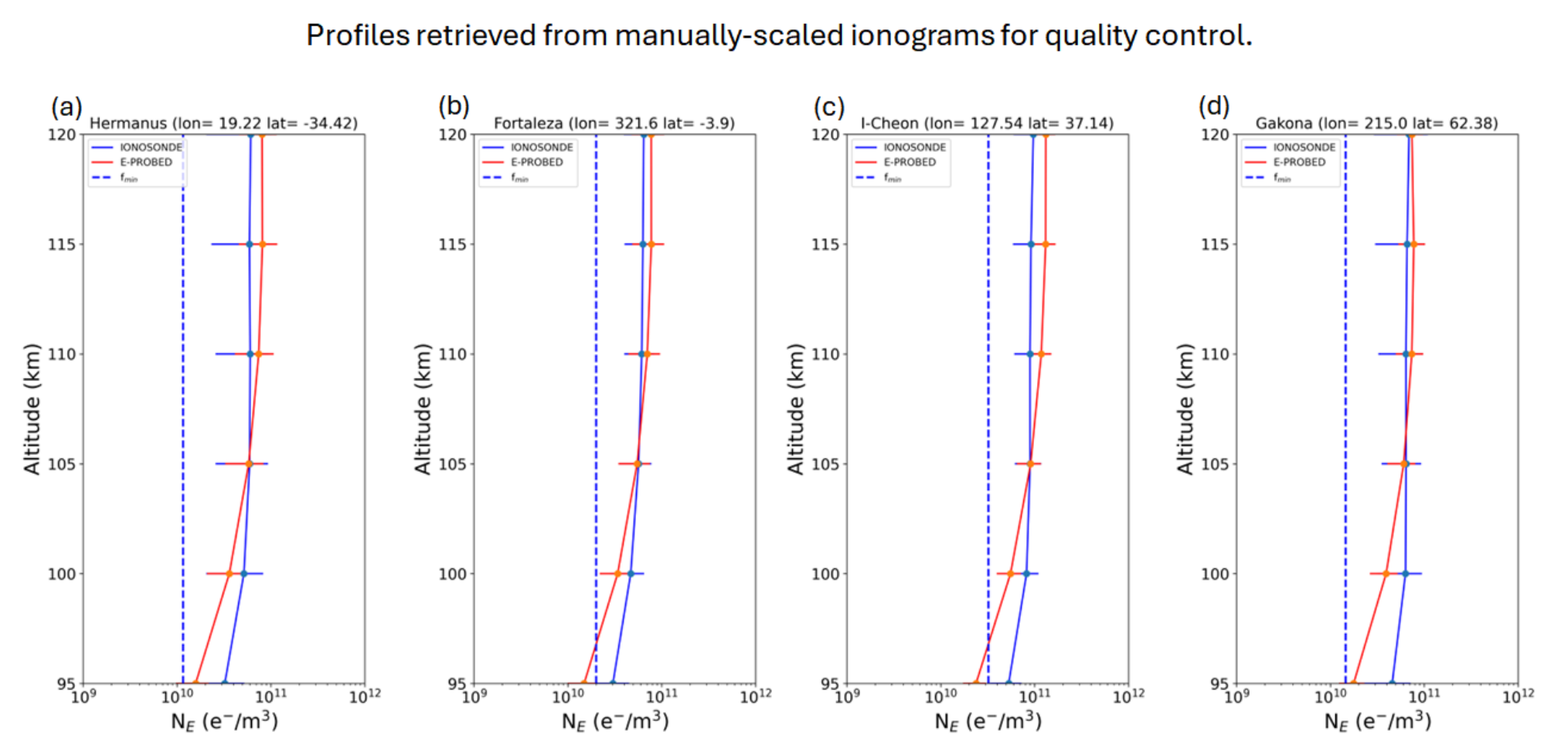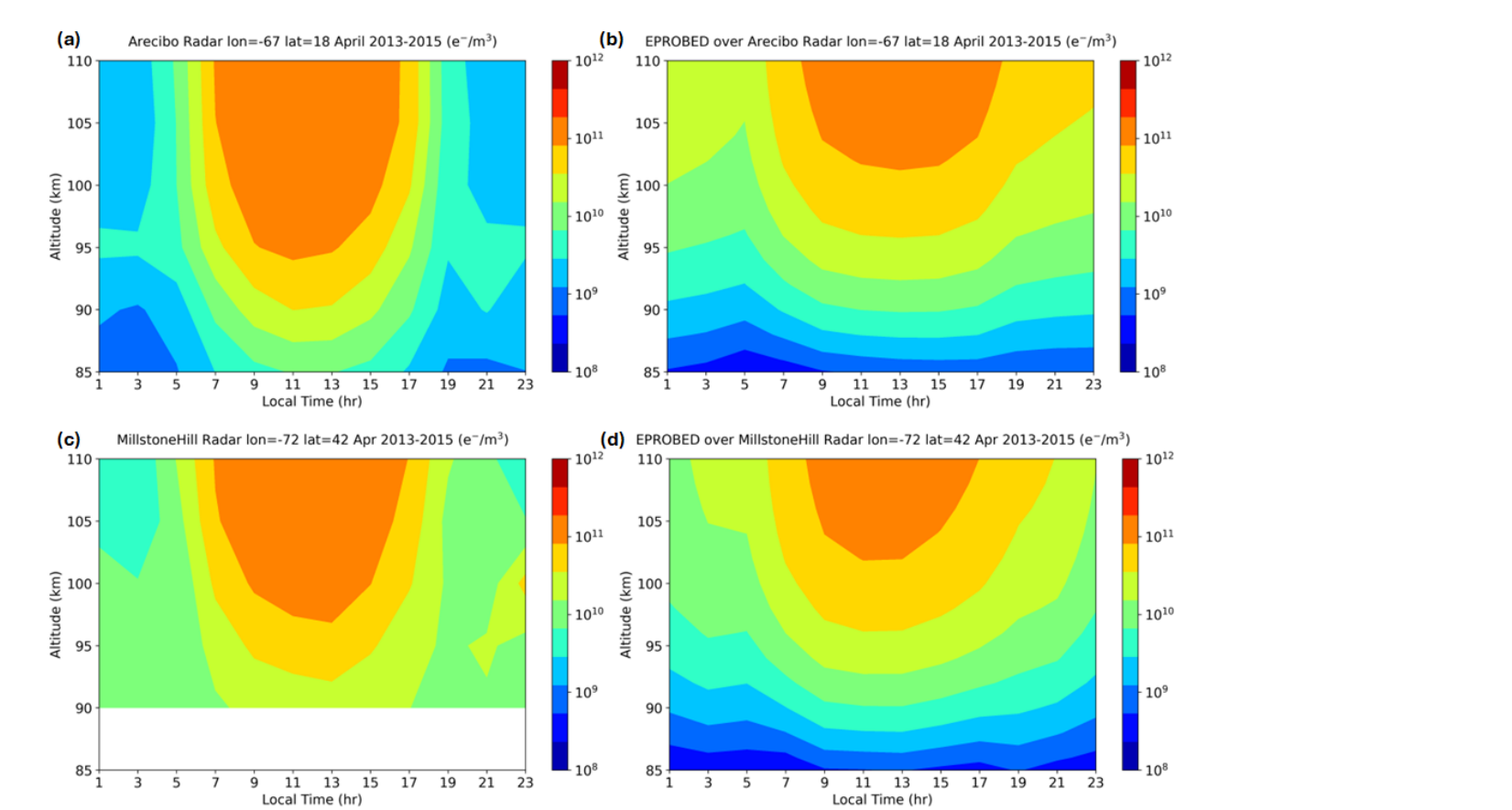
(4) MODEL PERFORMANCE
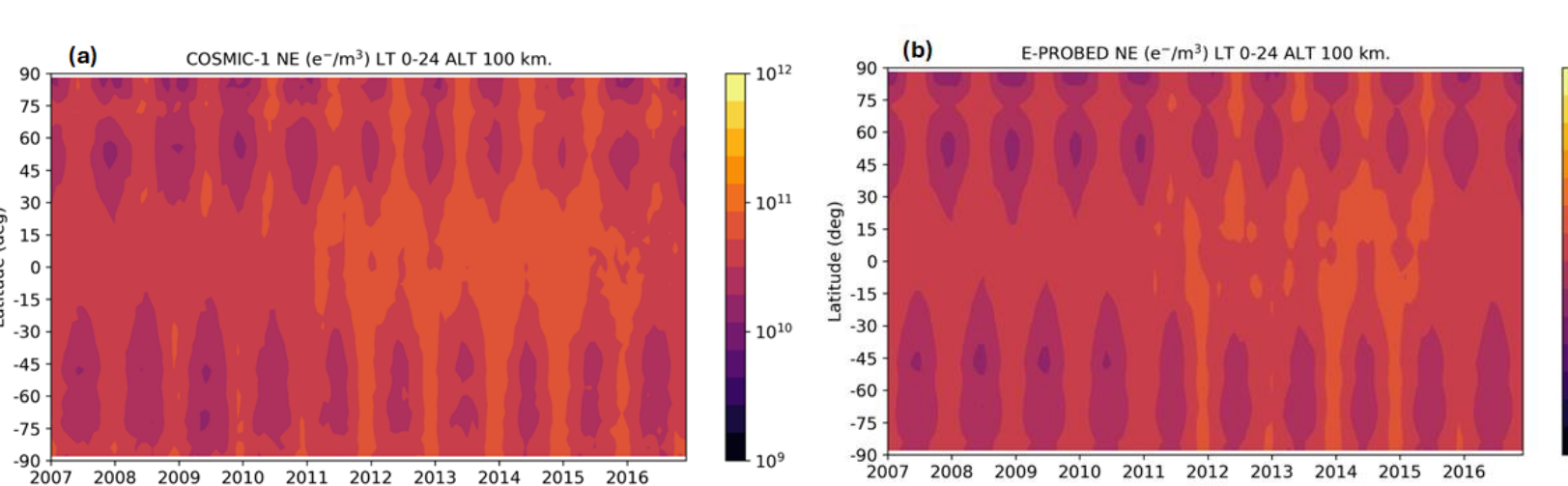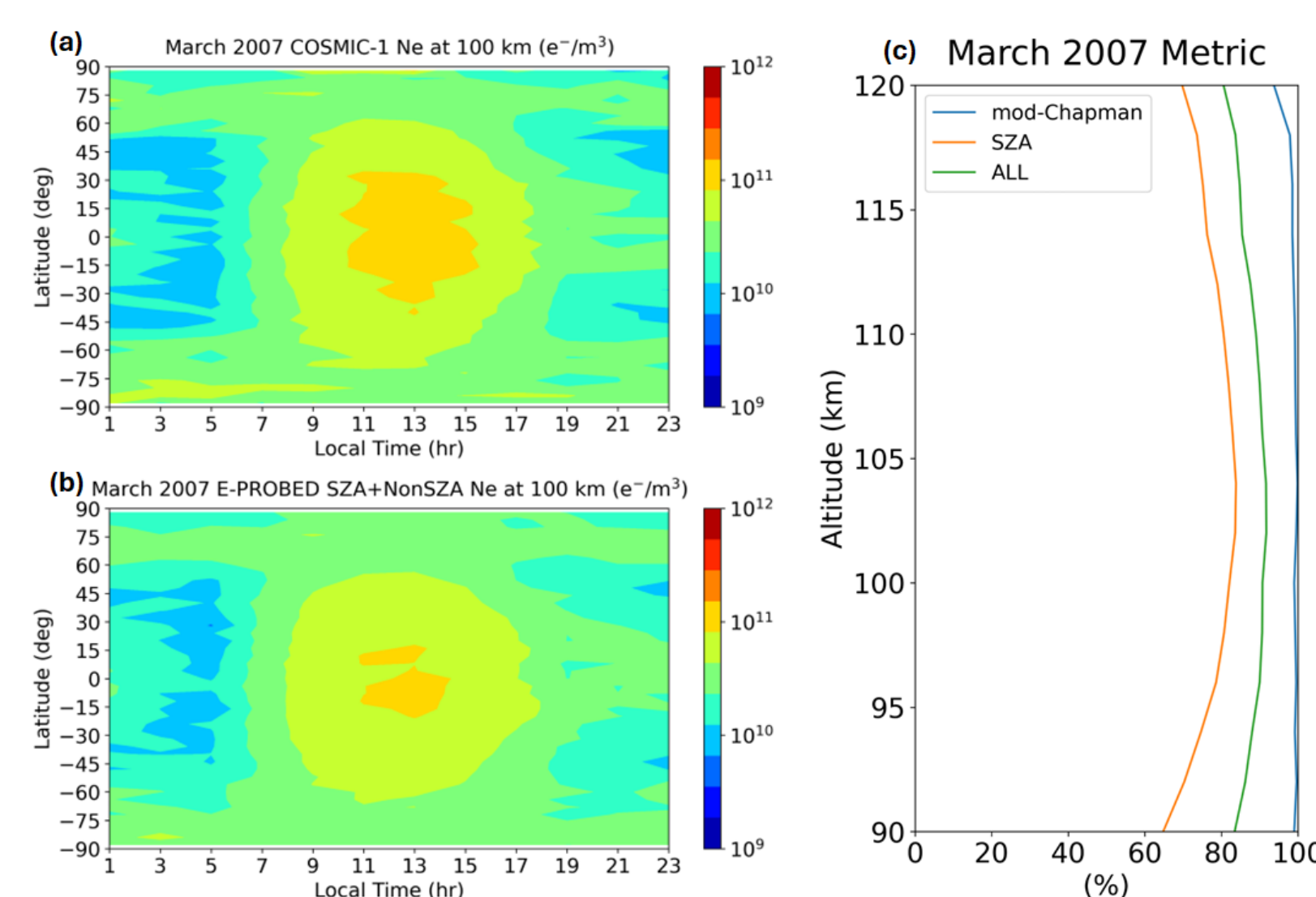
E-PROBED models ~80% of the observed seasonal and interannual variabilities of E-region Ne's latitude-local time profile.

(5) E-PROBED VALIDATION

a) Ionosonde Comparison

Profiles retrieved from manually-scaled ionograms for quality control.


b) Radar Comparison

- E-PROBED agrees well with day-time ionosonde E-region Ne profiles. E-PROBED overestimates radar night-time E-region Ne values.
- E-PROBED Ne vertical profile's slope is higher than radar Ne vertical profile during the day. This may be radar's vertical resolution is lower than E-PROBED.

c) Model Comparison

(i) Vertical Profile Comparison

(ii) Zonal-mean Daily-mean Profile Comparison

(iii) Map Comparison
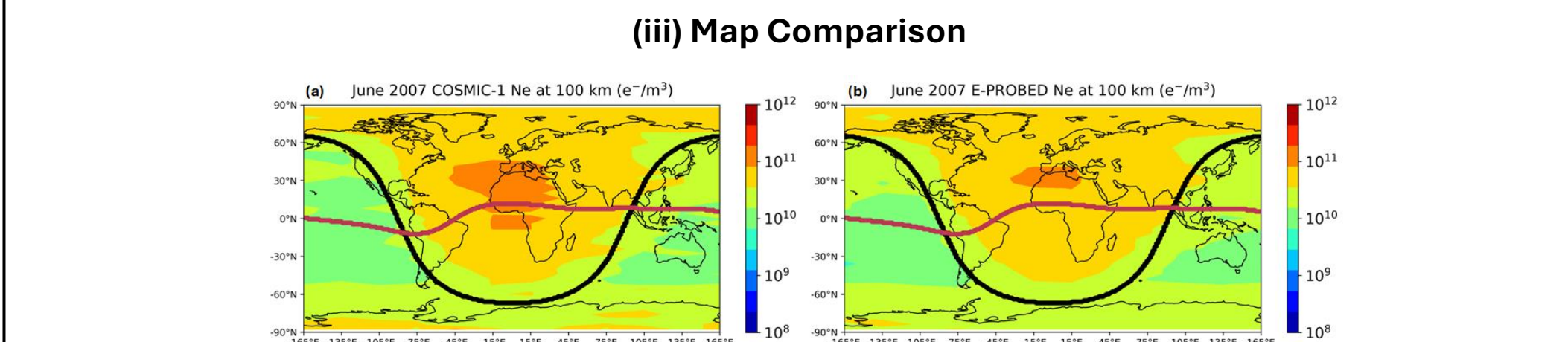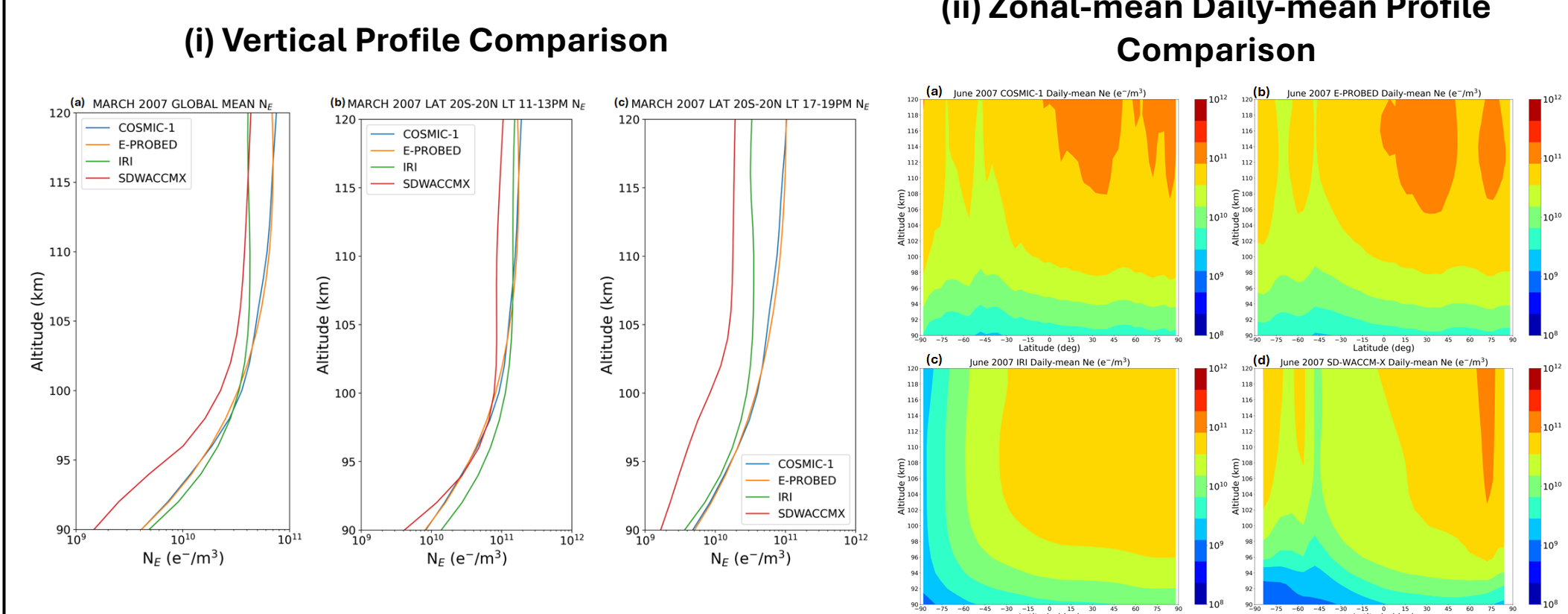
- E-PROBED and SD-WACCM-X show E-region Ne structures that cannot solely be explained by photoionization. IRI E-region Ne structures can solely be explained by photoionization.
- E-PROBED has the largest night-time E-region Ne values while IRI has lowest night-time E-region Ne.

II. E-PROBED APPLICATION: NASA LWS 2023 Funded Project on Ionospheric Conductivity (PI: Salinas)
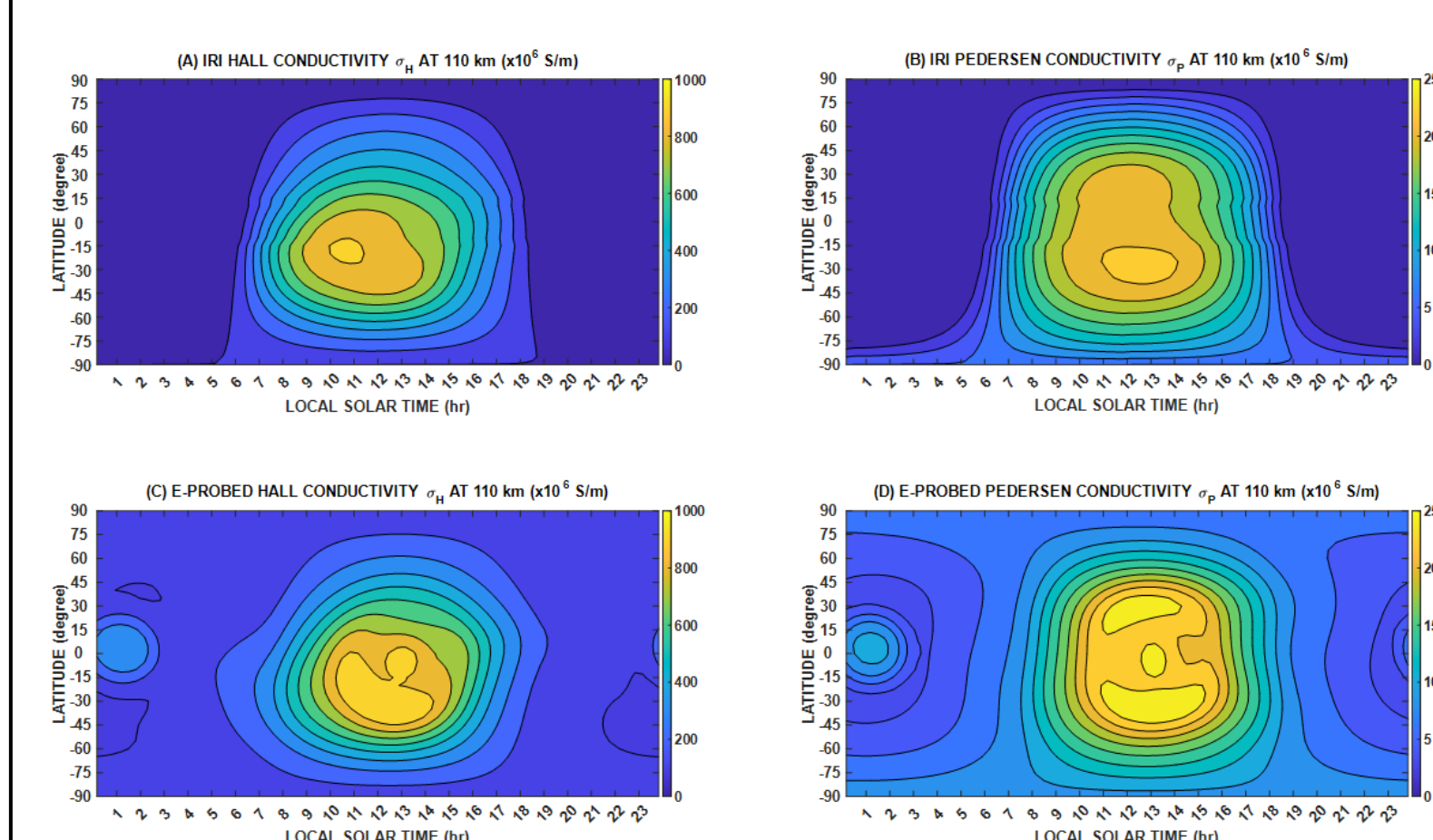

The collision and cyclotron frequency coefficients are calculated using outputs from NRLMSISE and IGRF. Ne profiles are from IRI and E-PROBED.

III. E-PROBED FUTURE IMPROVEMENTS
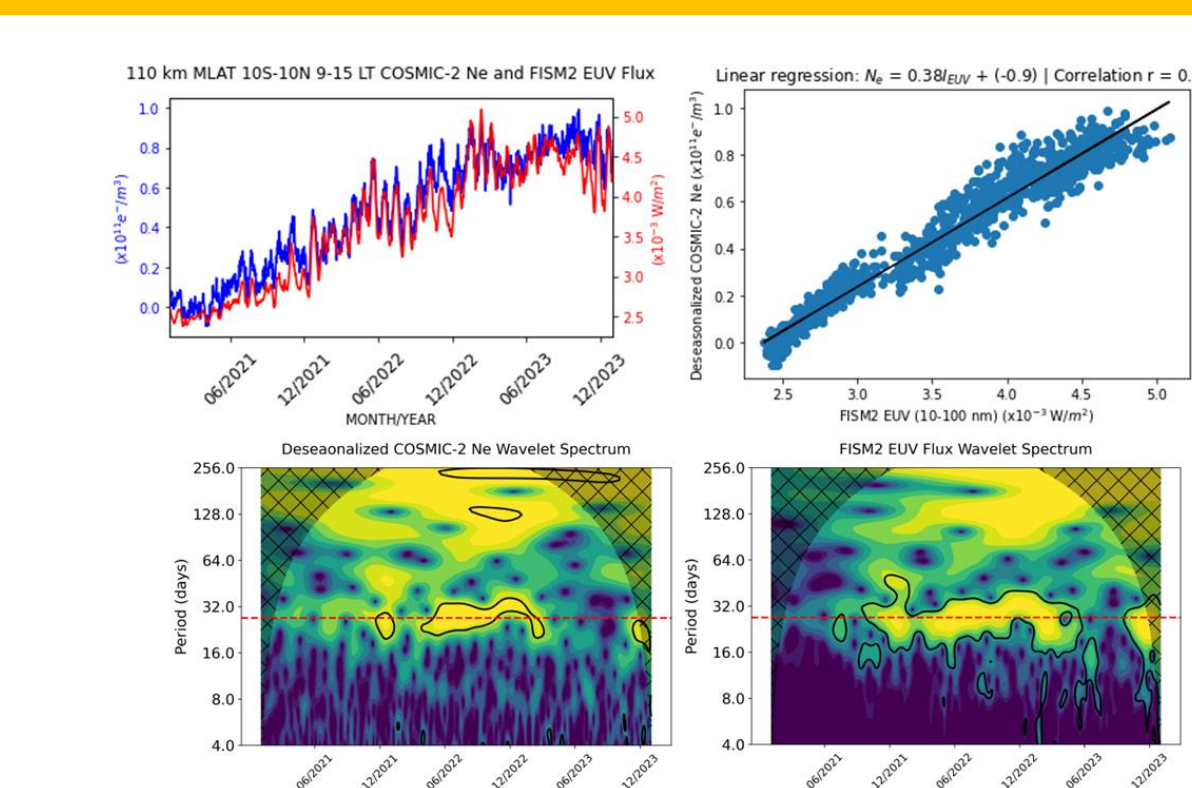
Next E-PROBED version shall include the day-to-day variability of E-region Ne's latitude local-time profile driven by solar and geomagnetic activity. Data from Spire and COSMIC-2 shall be used.
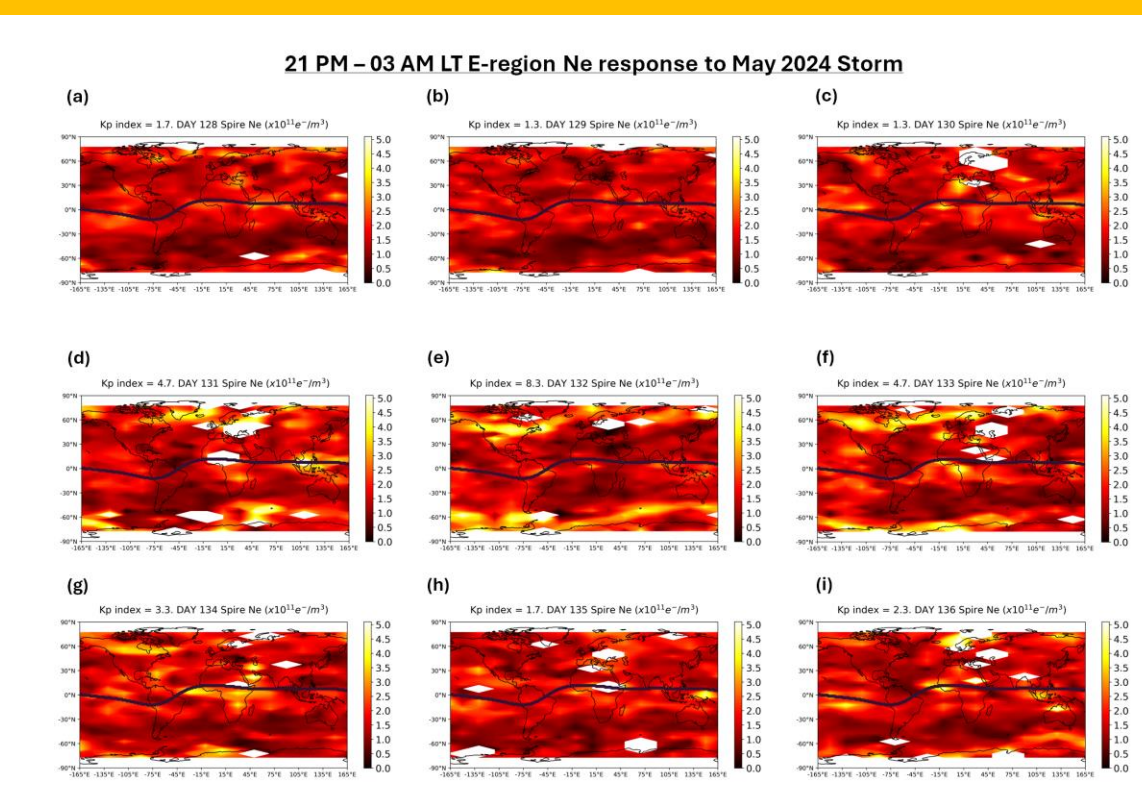
REFERENCES:
Salinas, C.C.J.H., Wu, D.L., Swarnalingam, N., Emmons, D. and Qian, L. (2024) Development of the Ionospheric E-region Prompt Radio Occultation Based Electron Density (E-PROBED) Model., *Space Weather*

Salinas C.C.J.H., Wu, D.L. and Emmons, D., Radio Occultation's First Measurements of Day-time Ionospheric E-region's Global Response to the Sun's Rotation, submitted.