Ionosphere Results of FORMOSAT-3/COSMIC

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GPS Scientific Application Research Center

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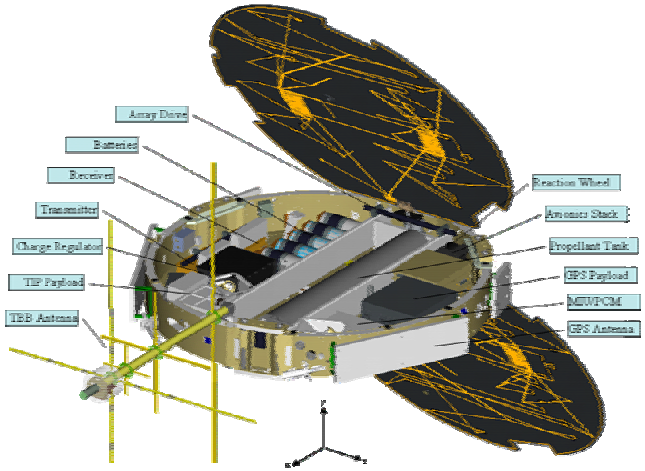

- Ionospheric scintillation
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  - F3/C S4 index max in the F-region
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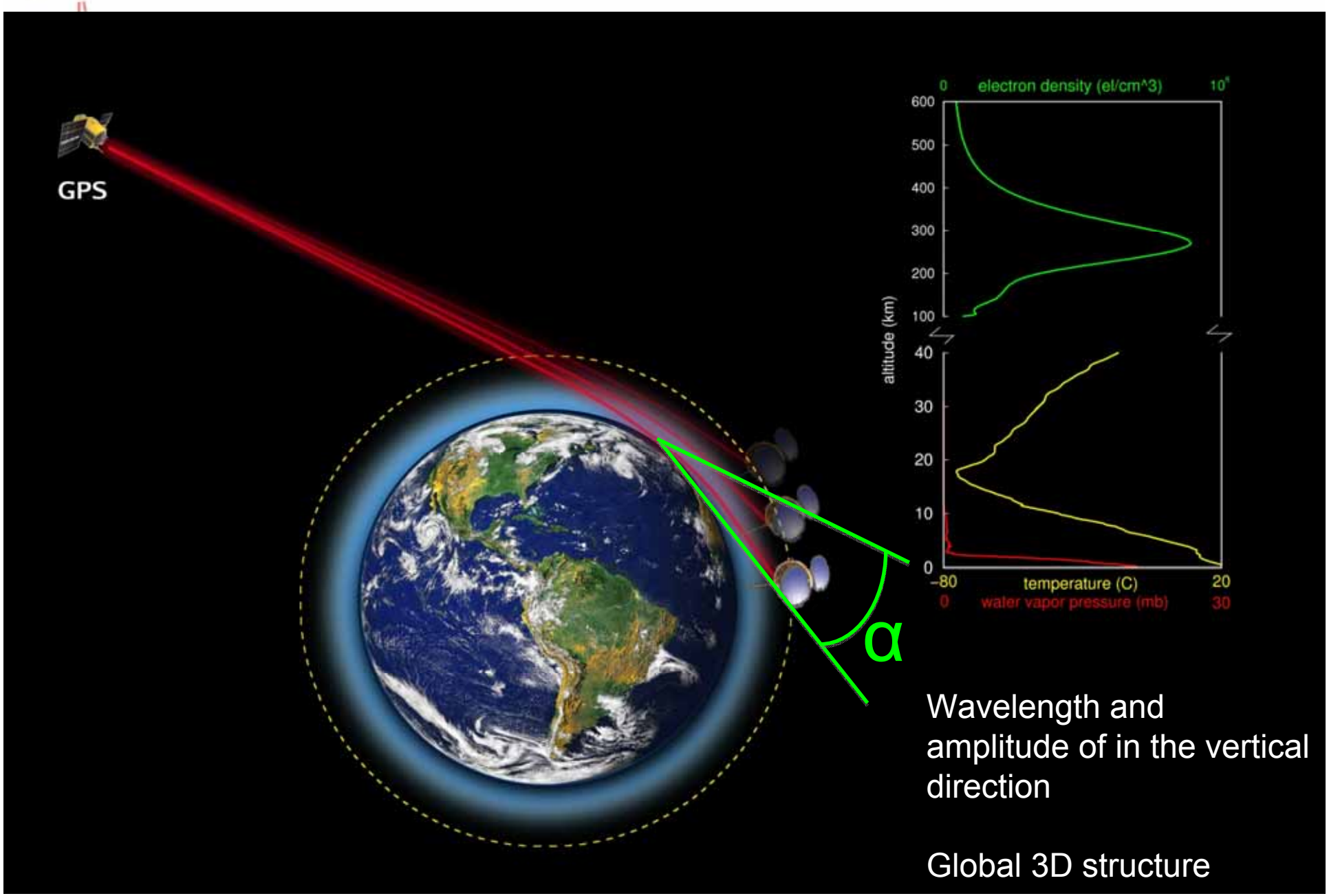
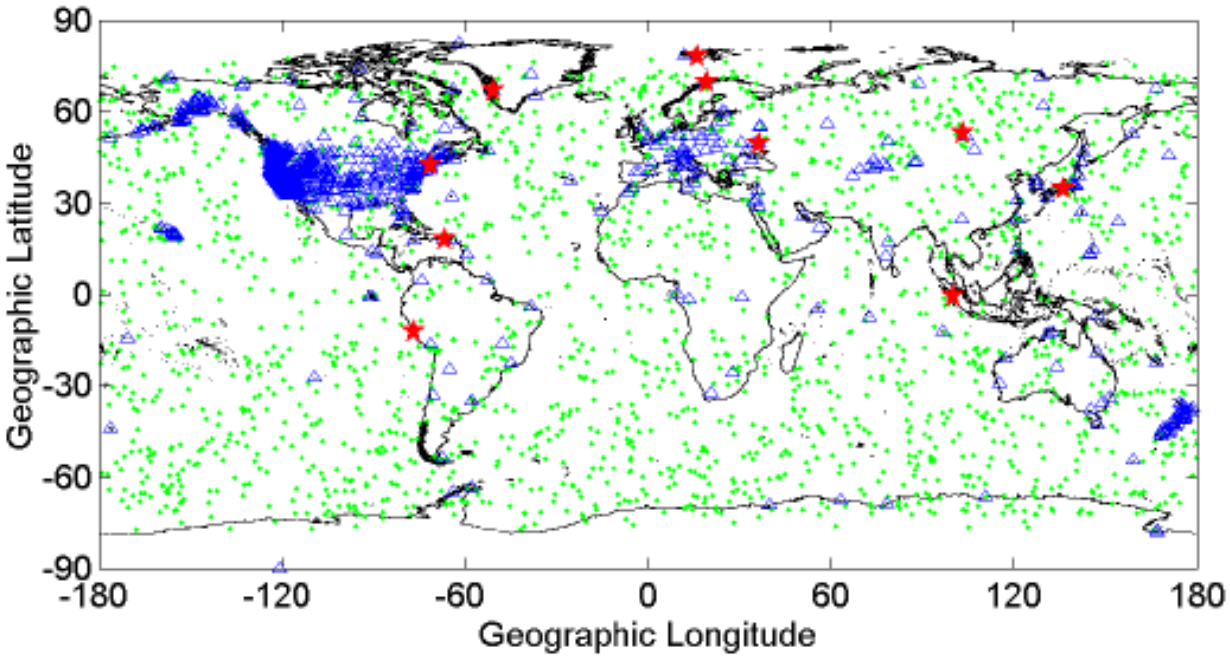
GPS Radio Occultation



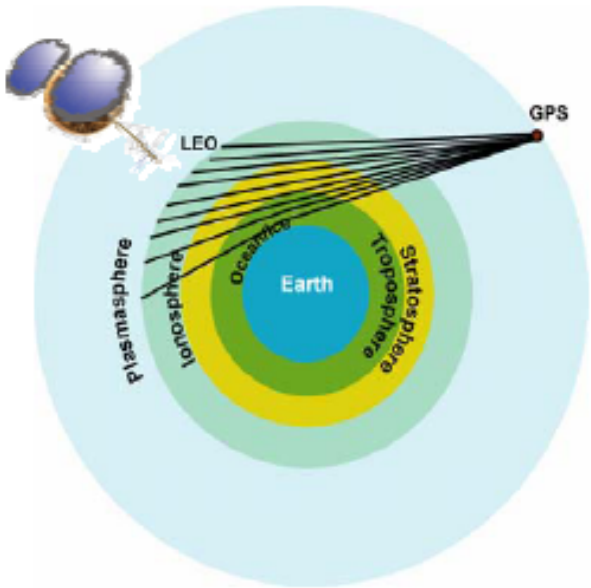
Wavelength and amplitude of in the vertical direction

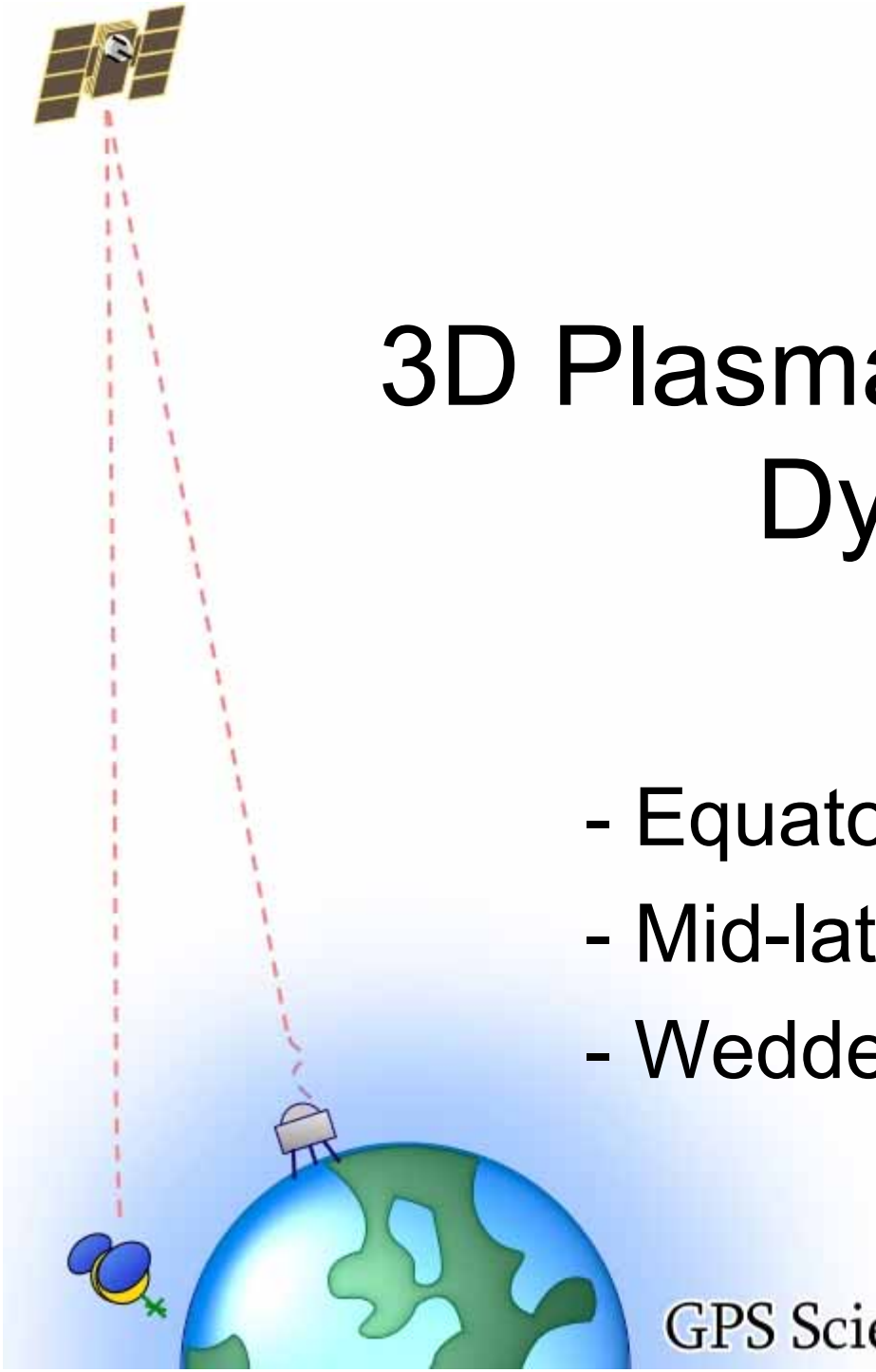
Global 3D structure

Distribution of occultation events observed by FORMOSAT-3



GOX

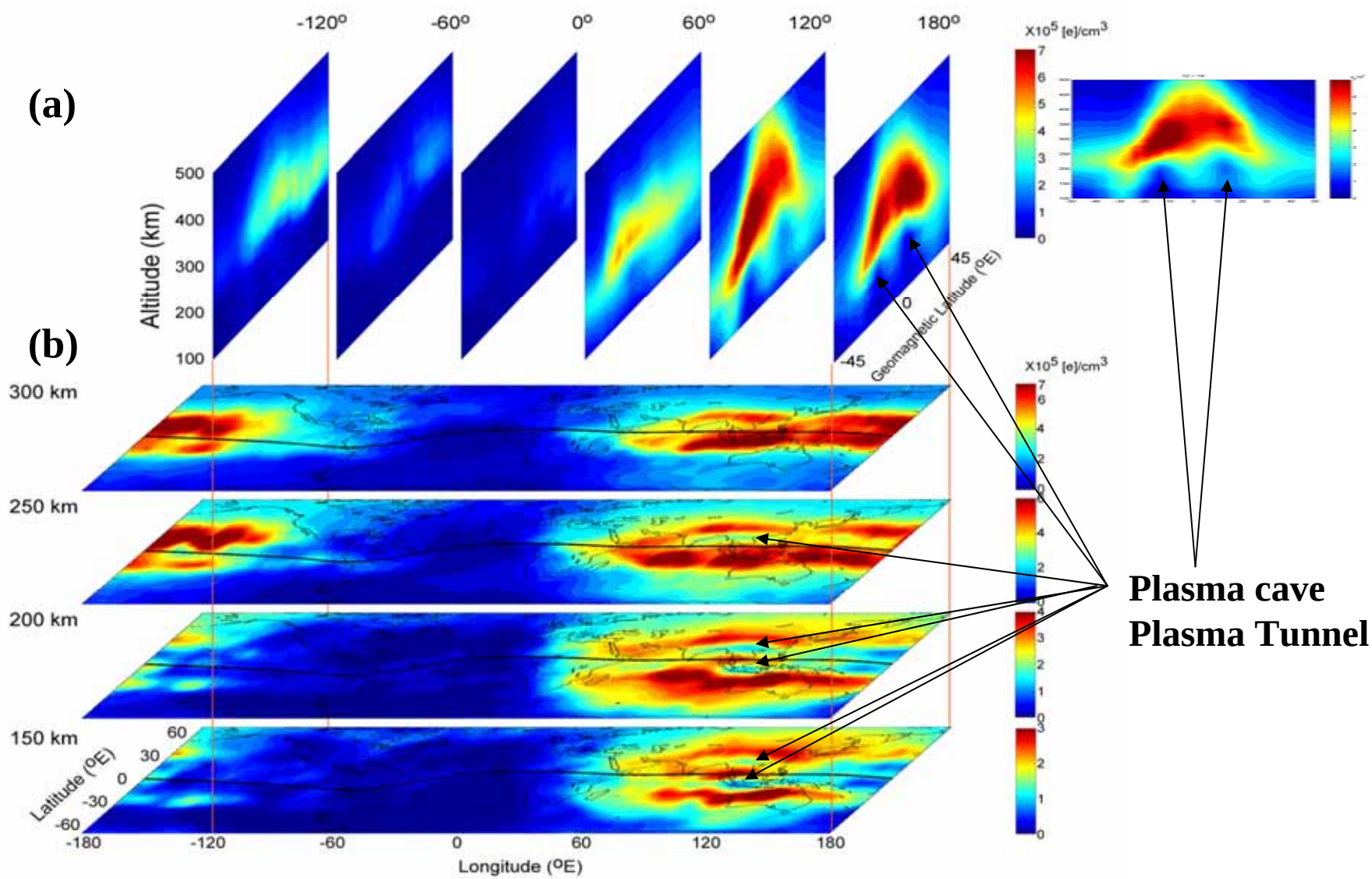




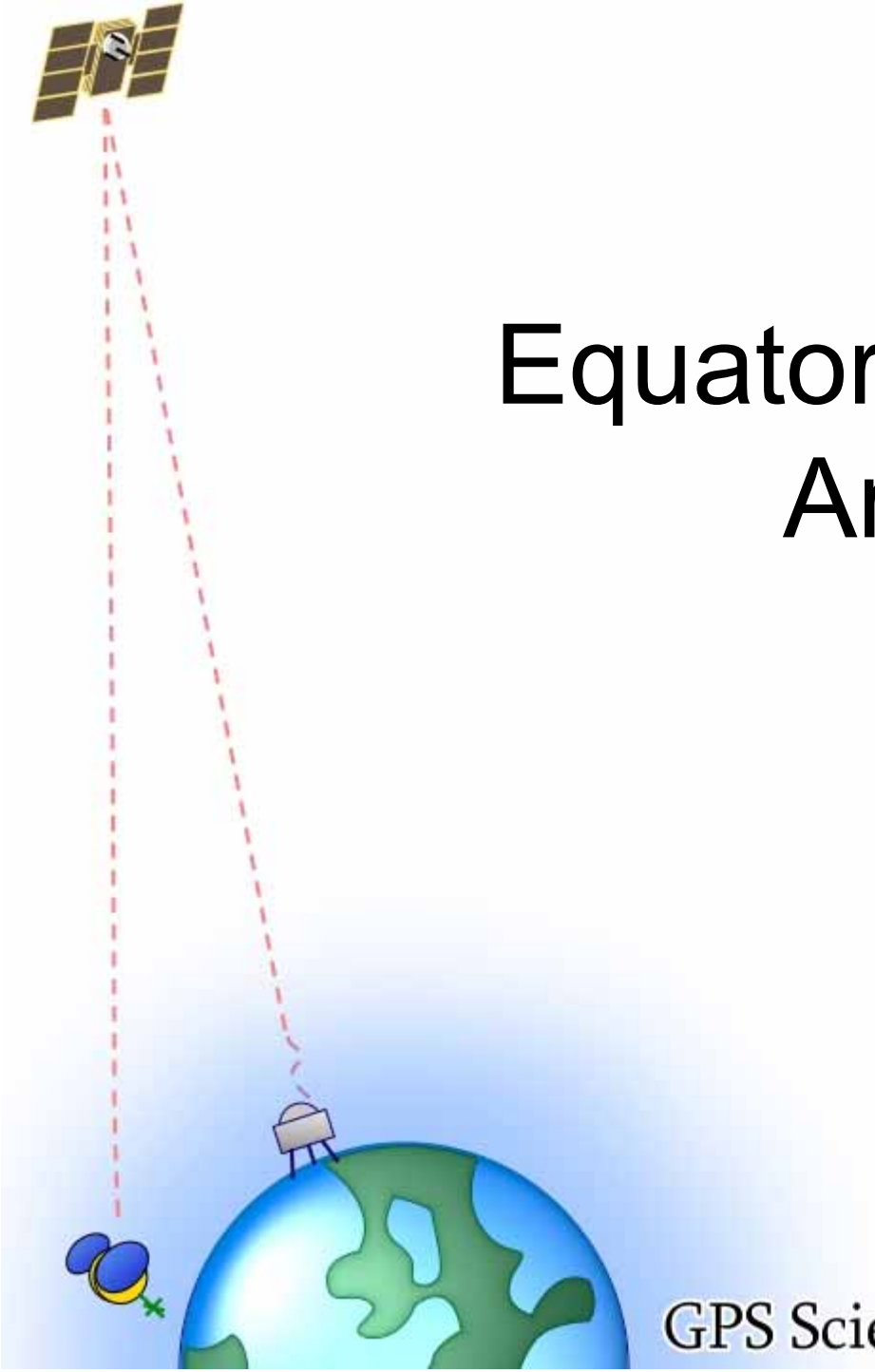
3D Plasma Structure and Dynamics

- Equatorial Ionization Anomaly
- Mid-latitude Trough
- Weddell Sea Anomaly

3D Ionospheric plasma Structure



Liu et al. (JGR 2010)



Equatorial Ionization Anomaly

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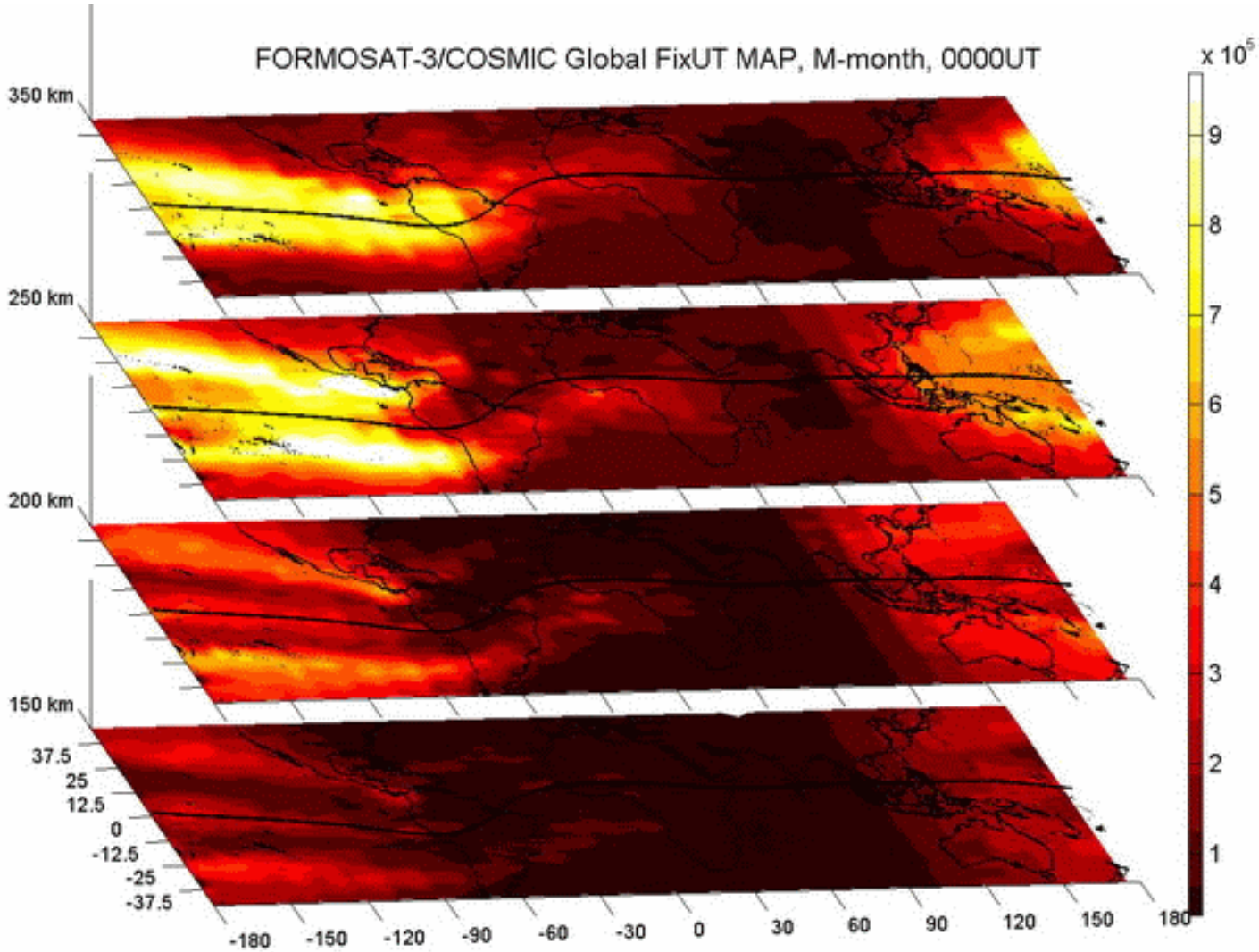
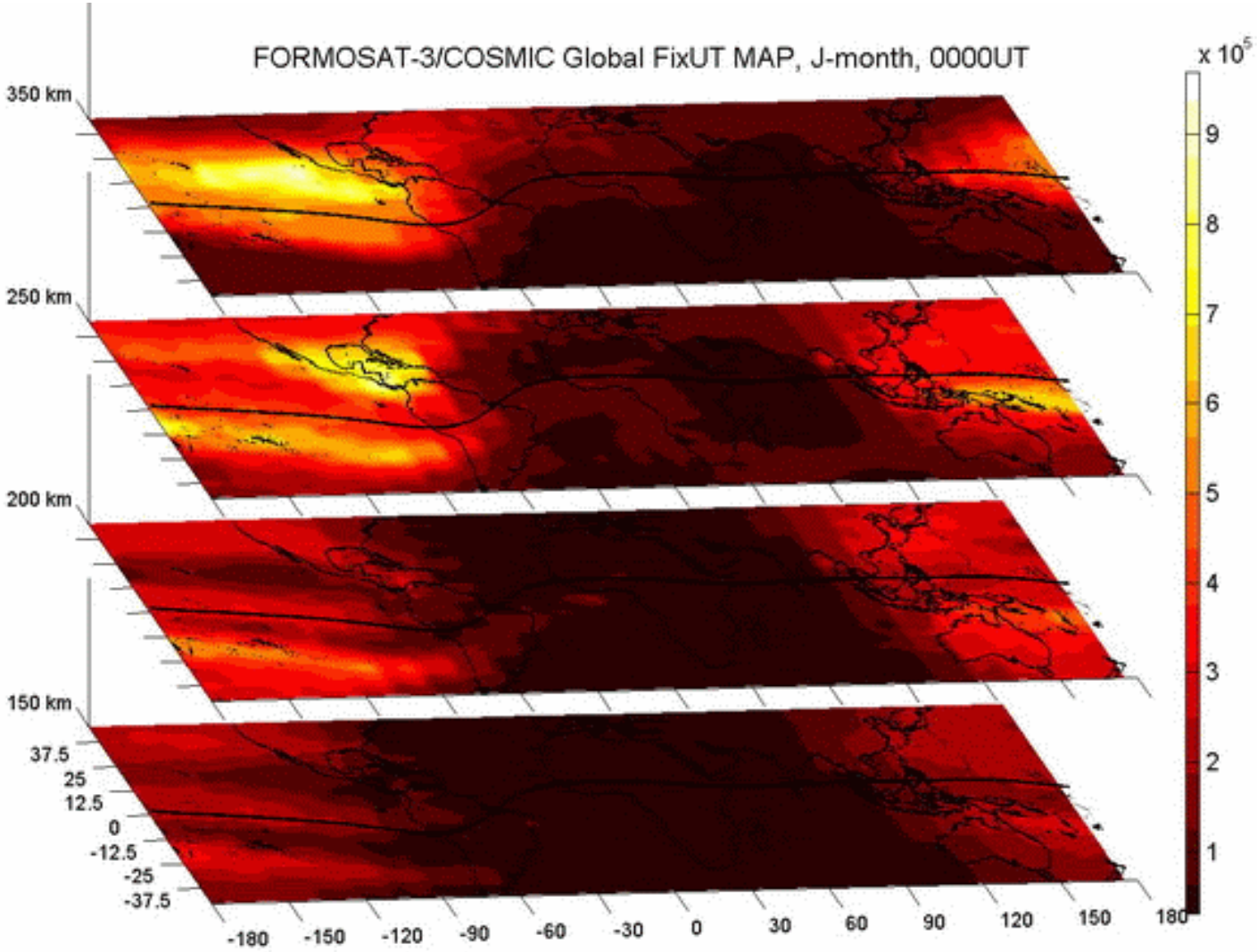
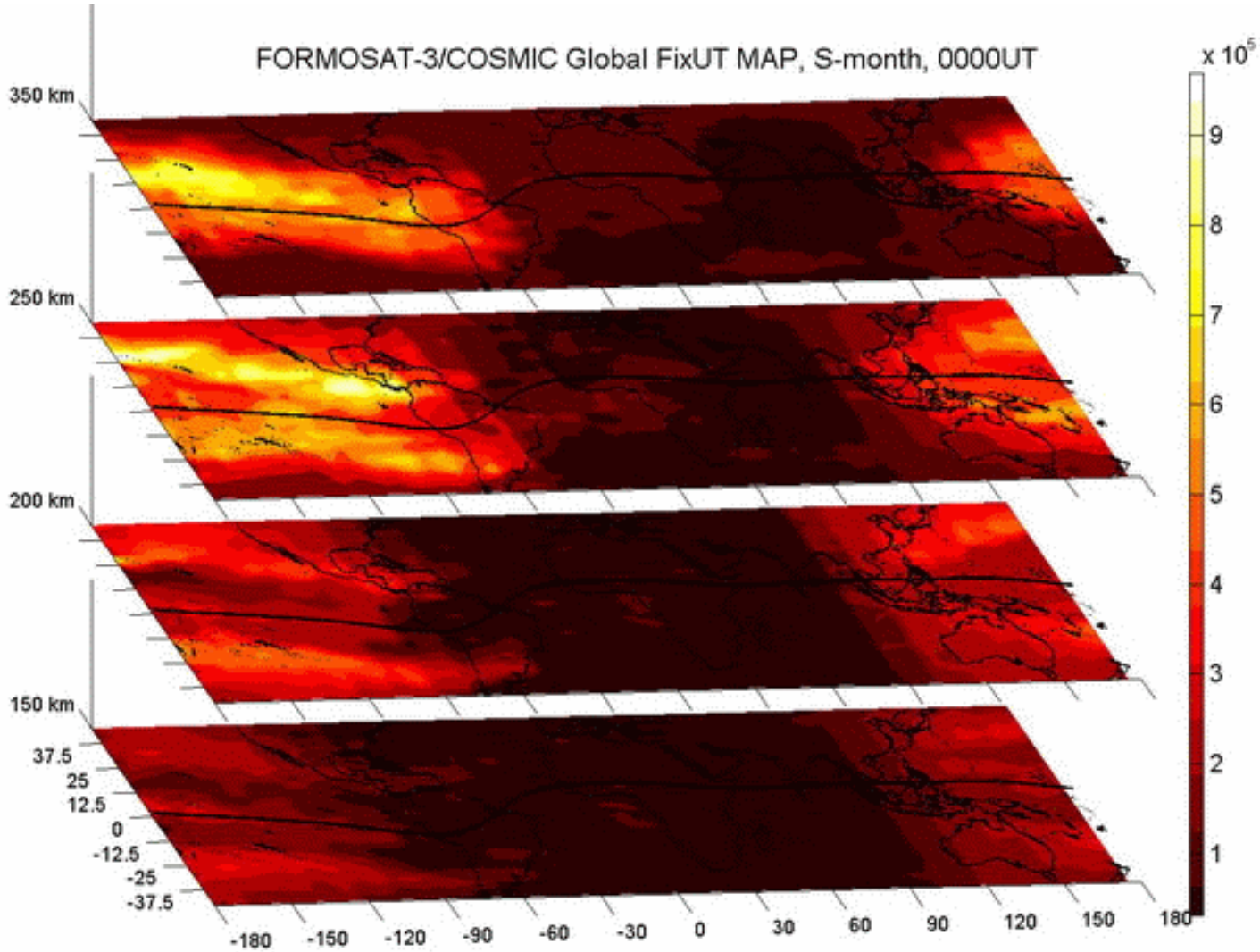
2007 M-month


FORMOSAT-3/COSMIC Global FixUT MAP, M-month, 0000UT
x 10^5
350 km
250 km
200 km
150 km
37.5
25
12.5
0
-12.5
-25
-37.5
-180
-150
-120
-90
-60
-30
0
30
60
90
120
150
180
9
8
7
6
5
4
3
2
1

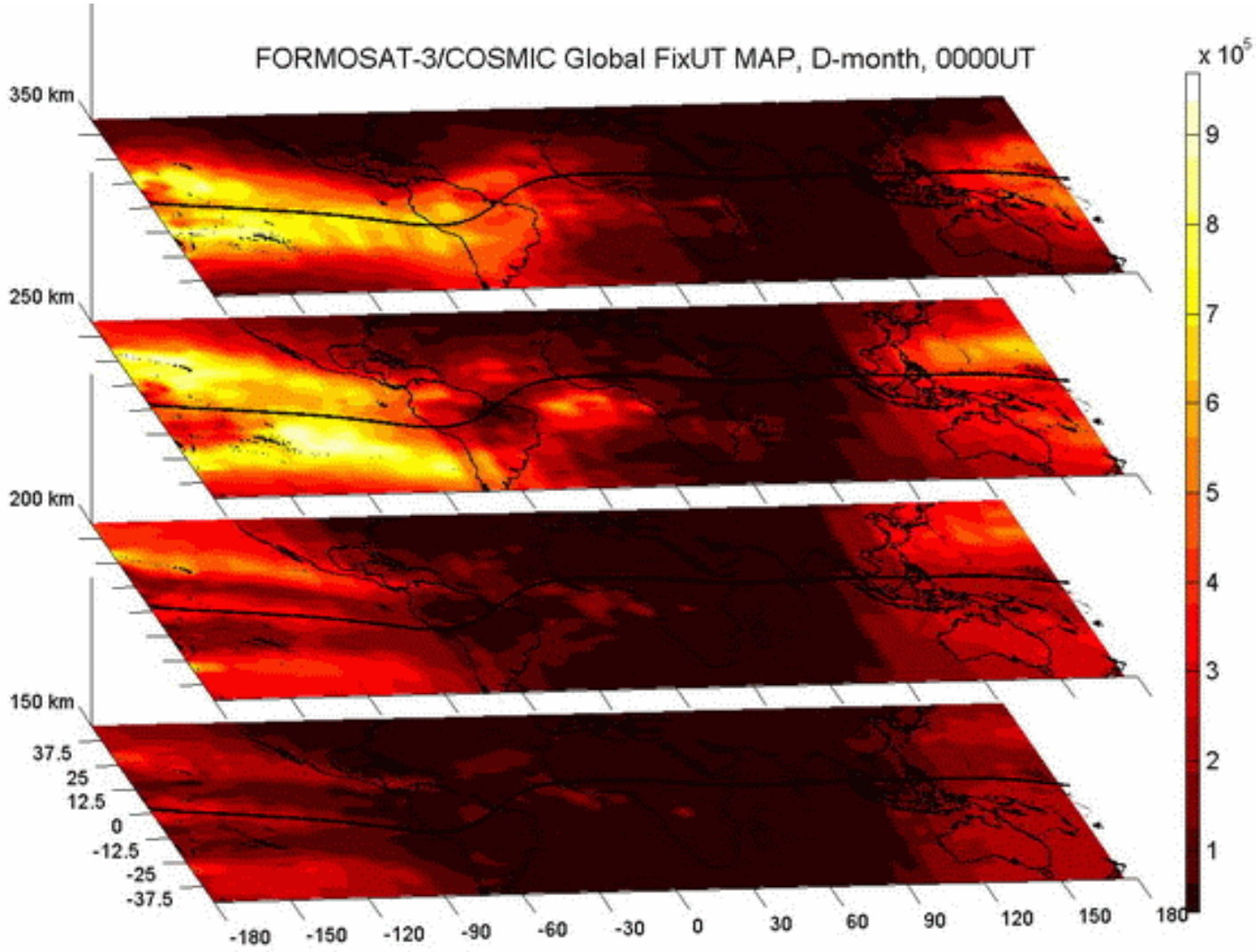
2007 J-month


FORMOSAT-3/COSMIC Global FixUT MAP, J-month, 0000UT
x 10^5
350 km
250 km
200 km
150 km
37.5
25
12.5
0
-12.5
-25
-37.5
-180
-150
-120
-90
-60
-30
0
30
60
90
120
150
180
9
8
7
6
5
4
3
2
1

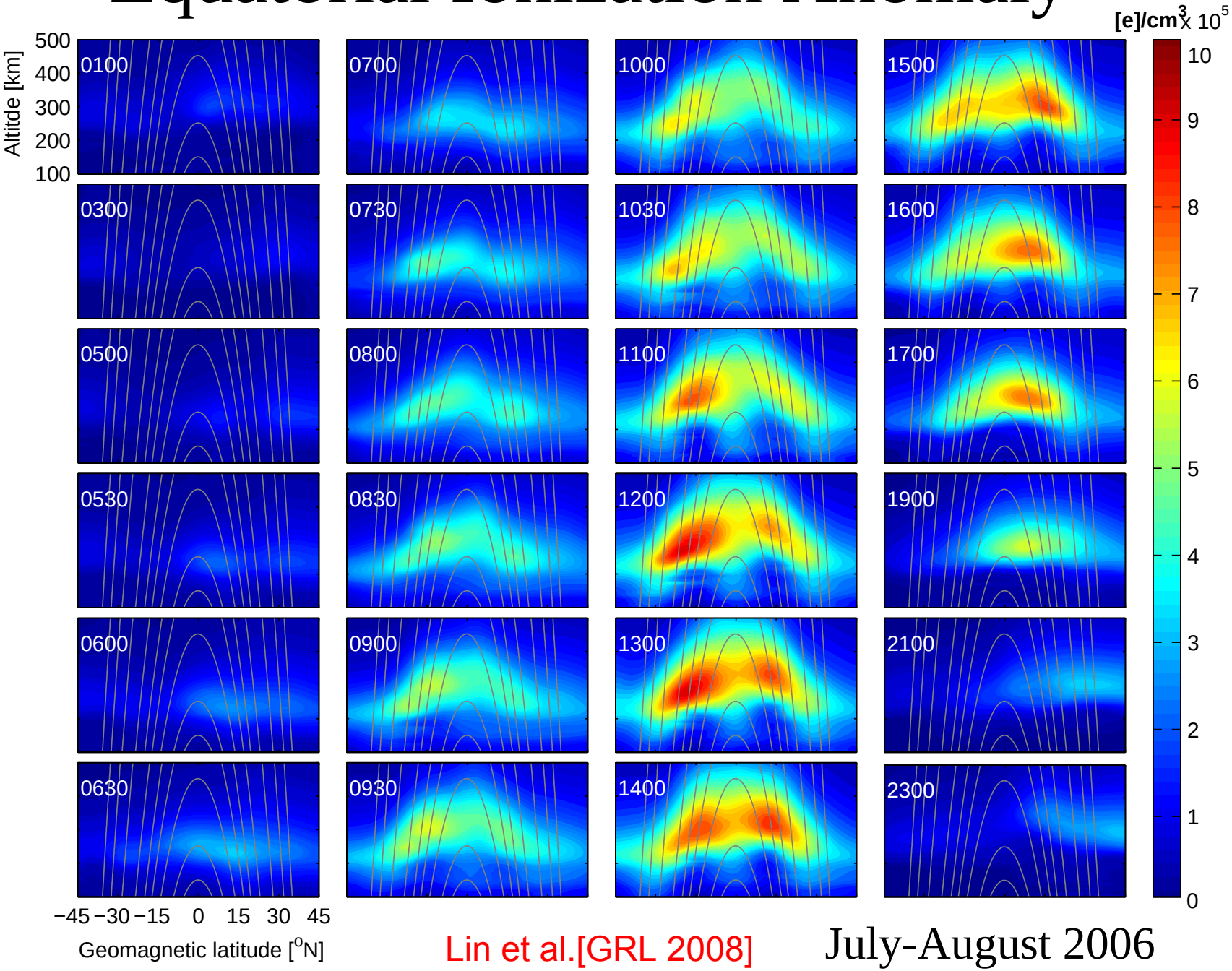
2007 S-month


FORMOSAT-3/COSMIC Global FixUT MAP, S-month, 0000UT
x 10^5
350 km
250 km
200 km
150 km
37.5
25
12.5
0
-12.5
-25
-37.5
-180
-150
-120
-90
-60
-30
0
30
60
90
120
150
180
9
8
7
6
5
4
3
2
1

2007 D-month


FORMOSAT-3/COSMIC Global FixUT MAP, D-month, 0000UT
x 10^5
350 km
250 km
200 km
150 km
37.5
25
12.5
0
-12.5
-25
-37.5
-180
-150
-120
-90
-60
-30
0
30
60
90
120
150
180
9
8
7
6
5
4
3
2
1

Equatorial Ionization Anomaly

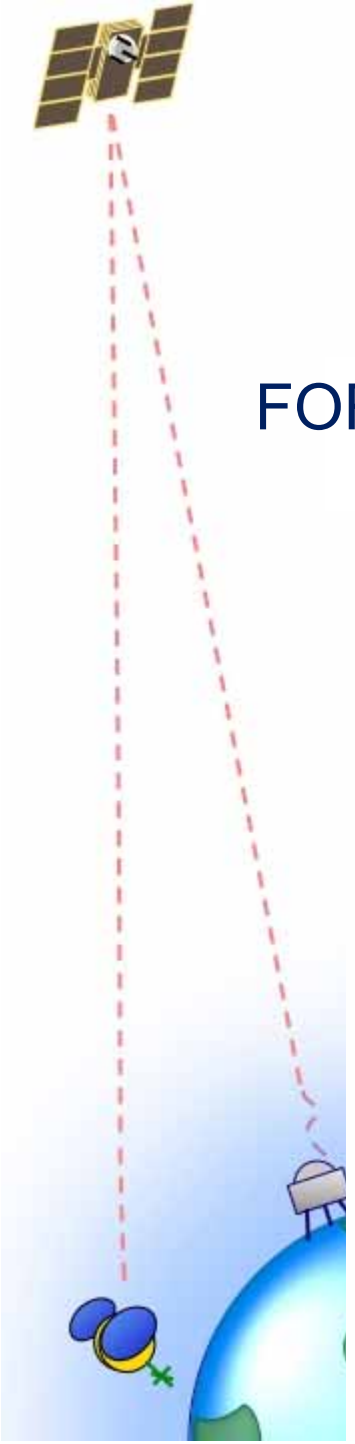


Lin et al.[GRL 2008]

July-August 2006

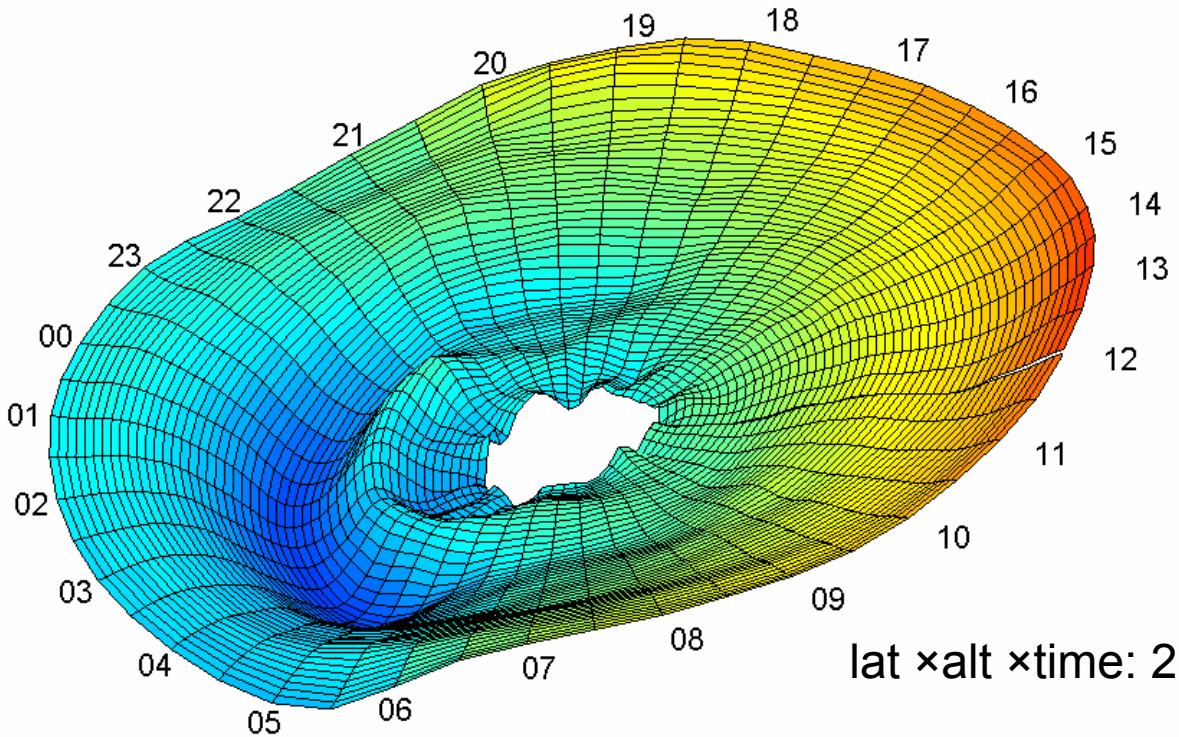
Remark 1

- Results suggest that in addition to the asymmetric neutral composition effect, interactions between the summer-to-winter (transequatorial) neutral winds and strength of the equatorial plasma fountain effect play important roles in producing asymmetric development of the EIA crests as imaged by the F3/C.



Mid-latitude Trough

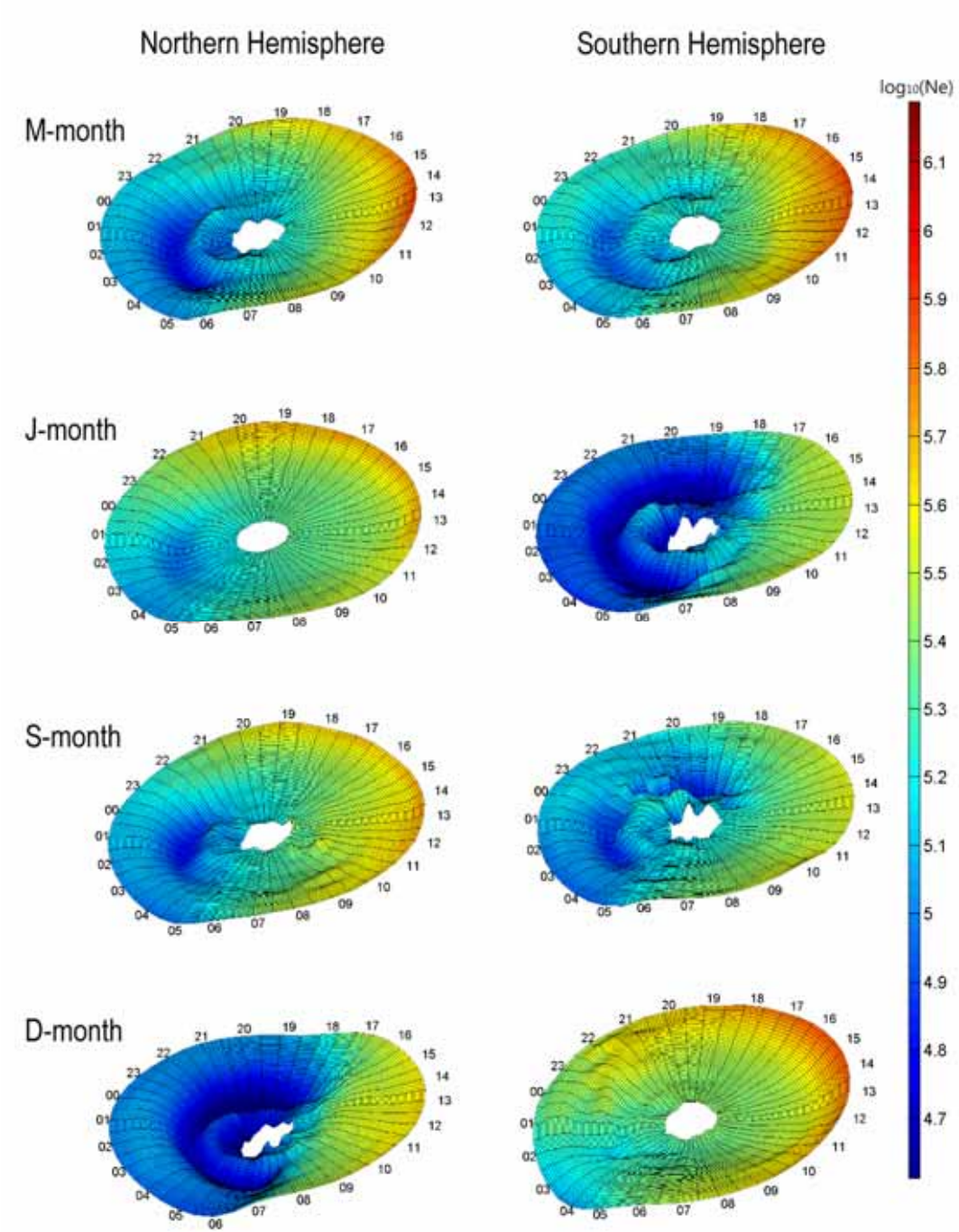
FORMOSAT-3/COSMIC NmF2 Persudo-3D structure
Northern Hemisphere, M-month



lat ×alt ×time: 2°×2km ×0.5hr

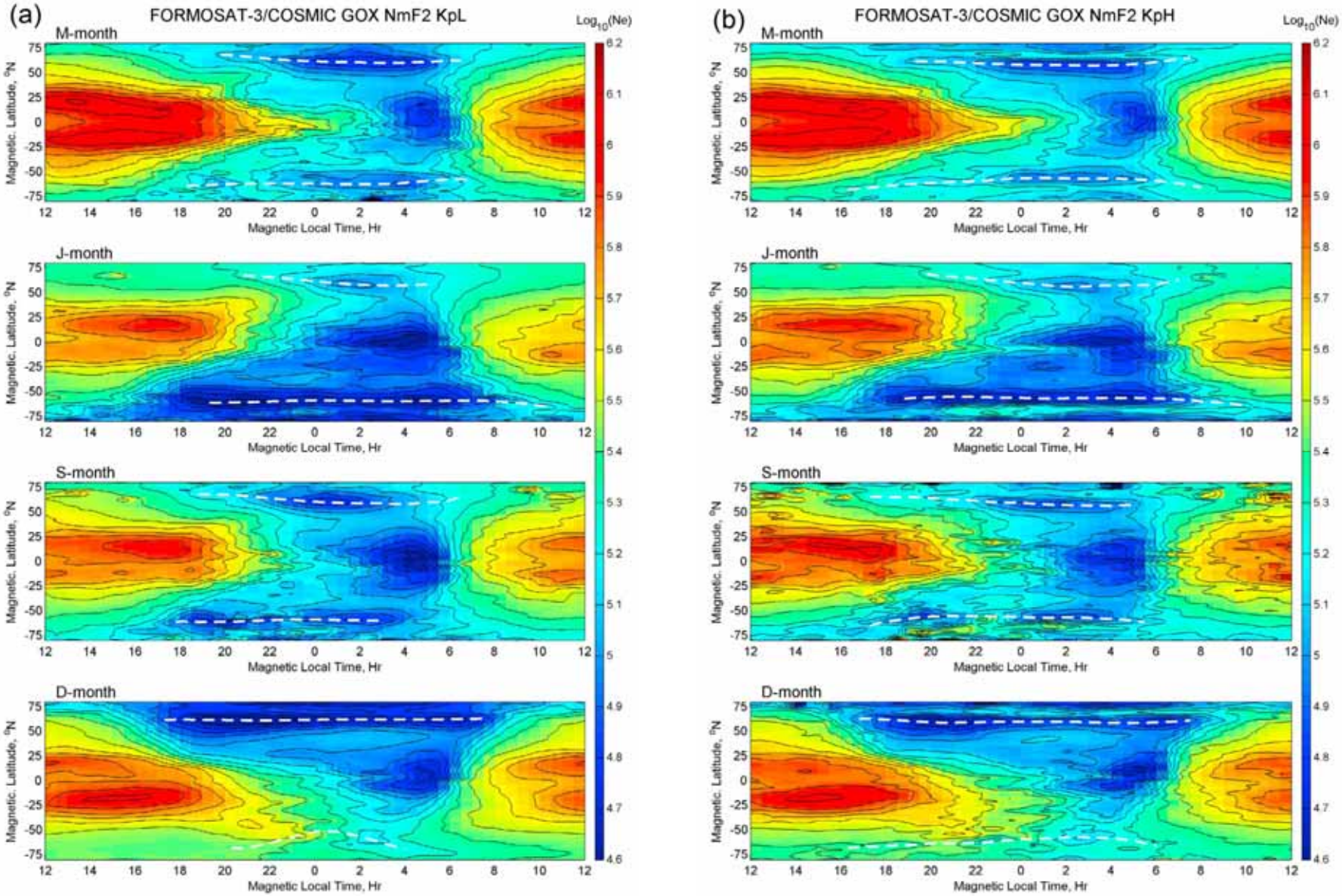
Center

Seasonal Variation

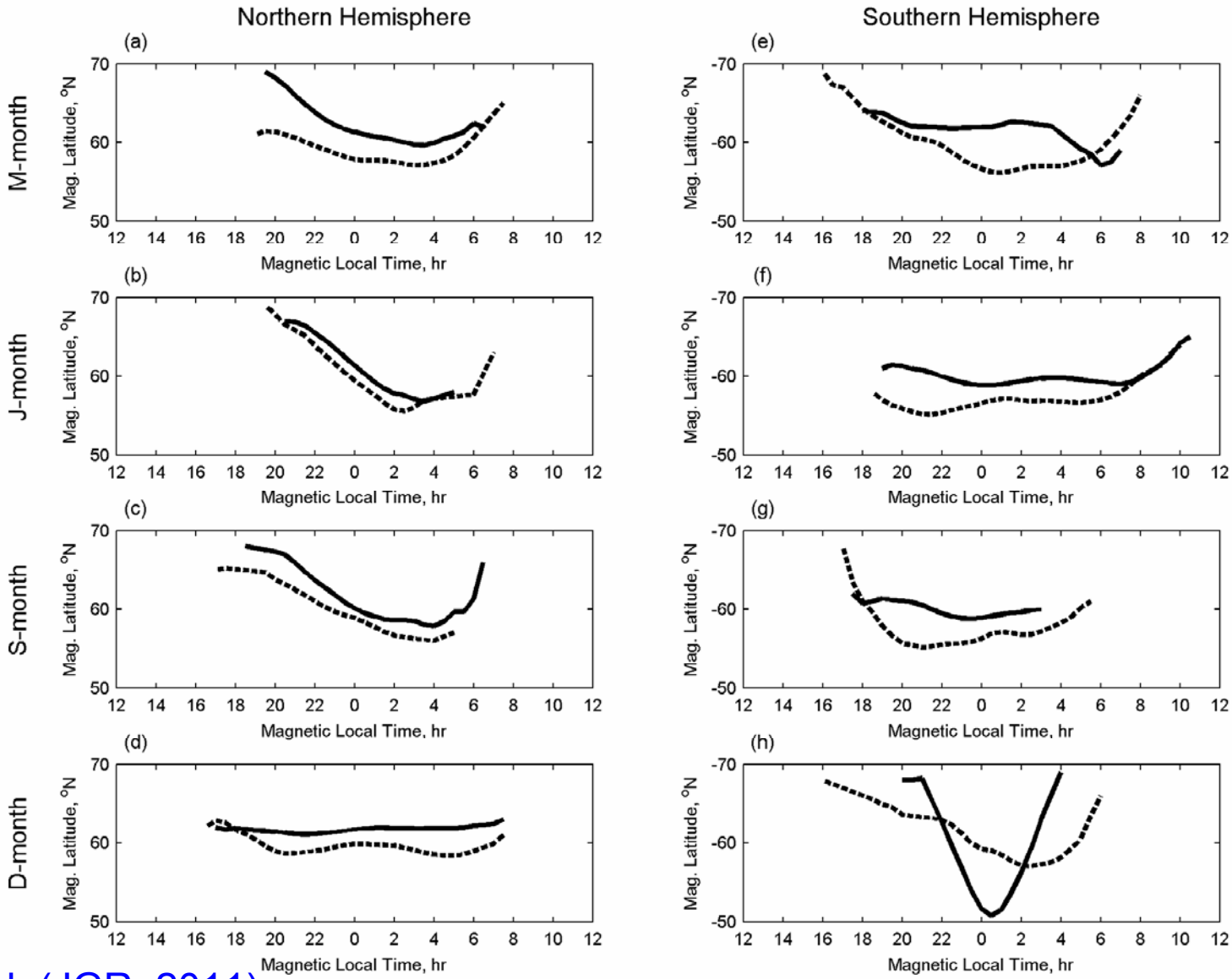


Lee et al. (JGR, 2011)

The seasonal averaged pseudo 3□D images of the F2 peak density map (log10 (Ne), cm^{-3}) from February 2008 to January 2009 in magnetic polar coordinates for the March equinox, June solstice, September equinox, and December solstice. The inner and outer perimeters are 80° and 30° in magnetic latitude. The left and right columns are results in the Northern and Southern hemispheres, respectively. The color and vertical change refer to the electron density, and the numbers around each plot give the geomagnetic local time.

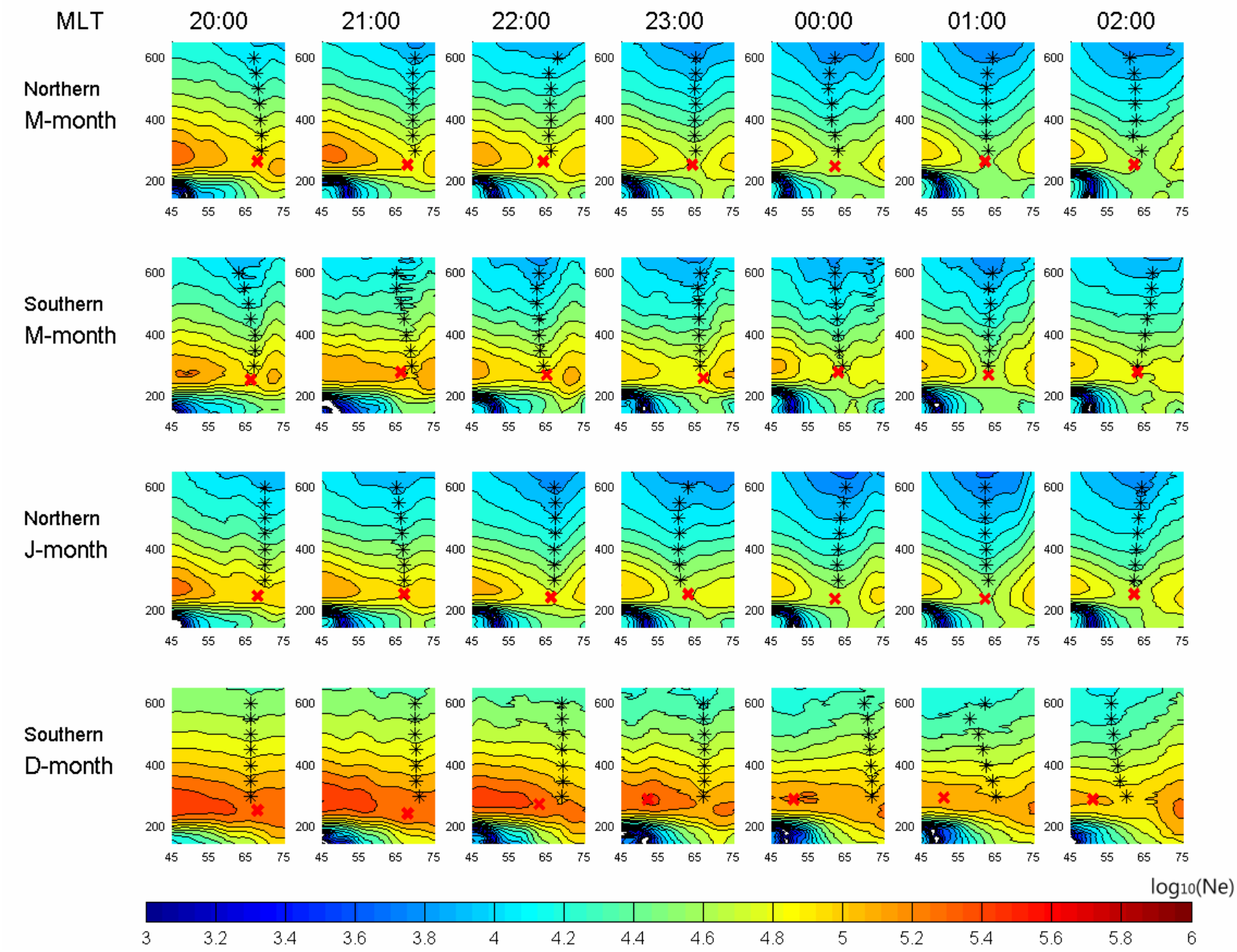


The NmF2 on MLAT versus MLT maps in various seasons under (a) lower (Kp = 0–2) and (b) higher (Kp = 2+–5+) geomagnetic activity conditions. The dashed lines denote the trough minimum position. The contour lines begin with 3.0 (log10 Ne in electron/cm3) and are incremented linearly in a step of 0.1–7.0. Lee et al. (JGR, 2011)



Lee et al. (JGR, 2011)

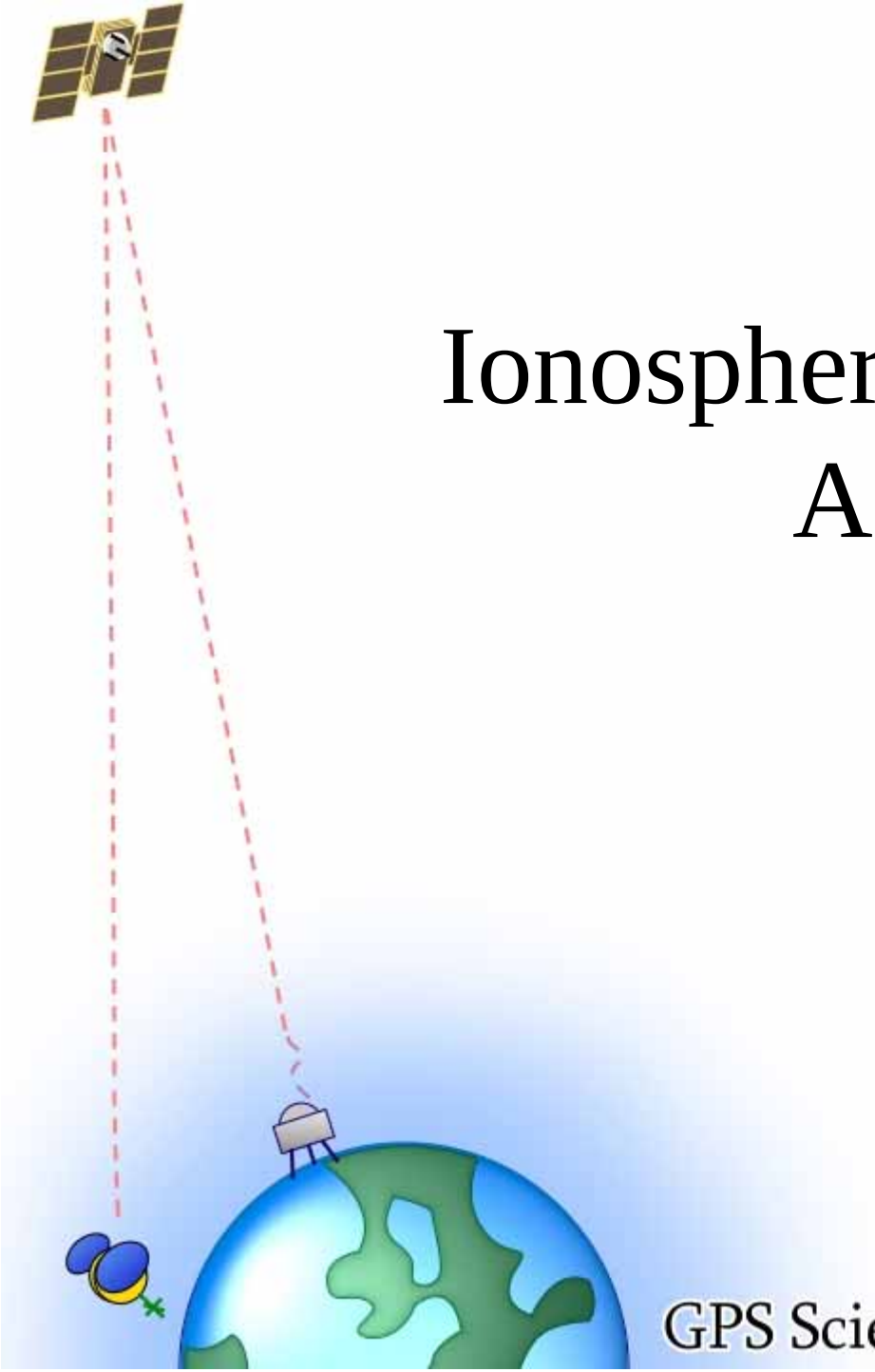
The magnetic local time variations of the trough minimum positions extracted from Figure 2. Results for the (left) Northern Hemisphere and (right) Southern Hemisphere for the M, J, S, and D month" from top to bottom. The solid lines indicate the lower geomagnetic activity conditions, and the dashed lines indicate higher geomagnetic activity conditions.



Lee et al. (JGR, 2011)

Remark 2

- Results show that the mid-latitude trough extends from dusk to dawn in all four seasons and is most pronounced in the winter hemisphere.
- The troughs in the two hemispheres are asymmetric, where the trough in the Northern Hemisphere is more evident and stronger than that in the Southern Hemisphere during the equinoctial seasons.
- The mid-latitude trough moves equatorward during higher geomagnetic activity conditions.
- The data set of GPS radio occultation by F3/C is useful to probe the global 3□D electron density structures.



Ionospheric Weddell Sea Anomaly

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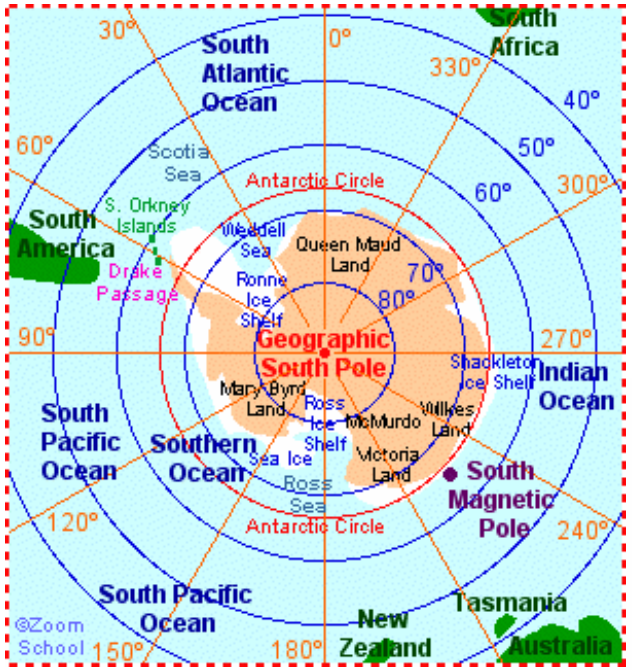
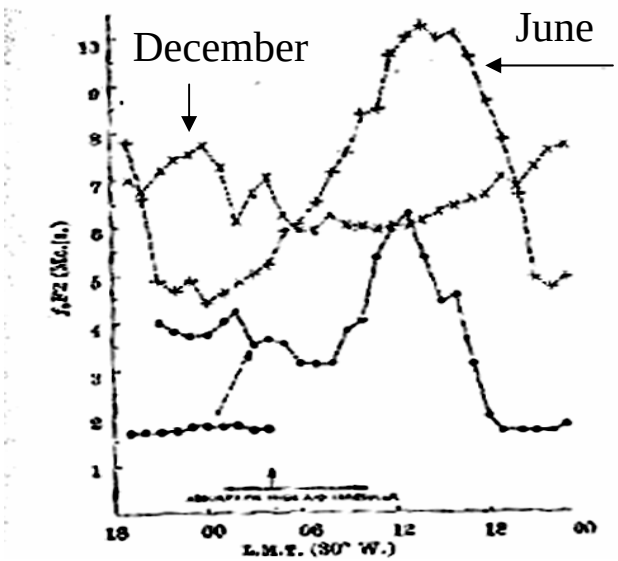
The Ionospheric Weddell Sea Anomaly

1. Stronger nighttime Ne than that during daytime

2. Discovered 50 years ahead of renewed observation by COSMIC

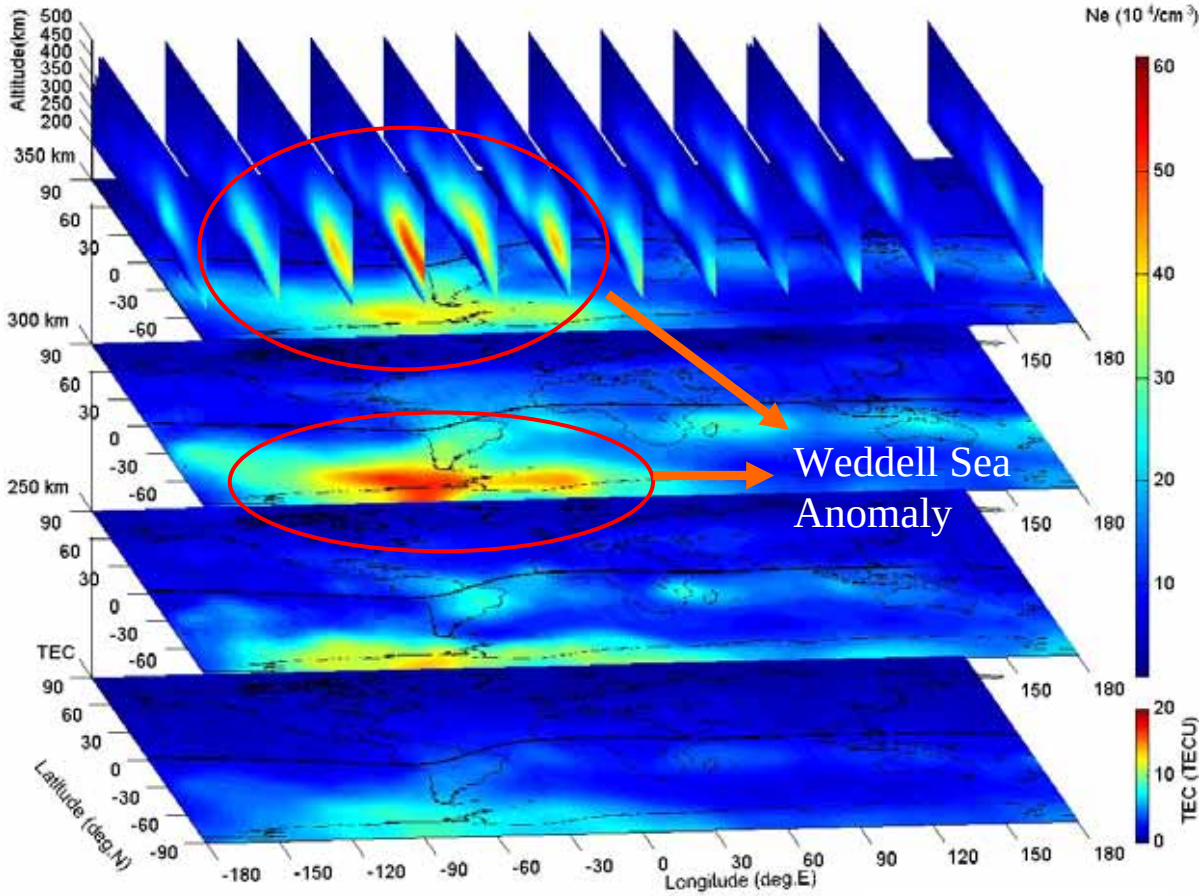
3. First glance of its vertical structure by COSMIC!





Ionosonde Observation

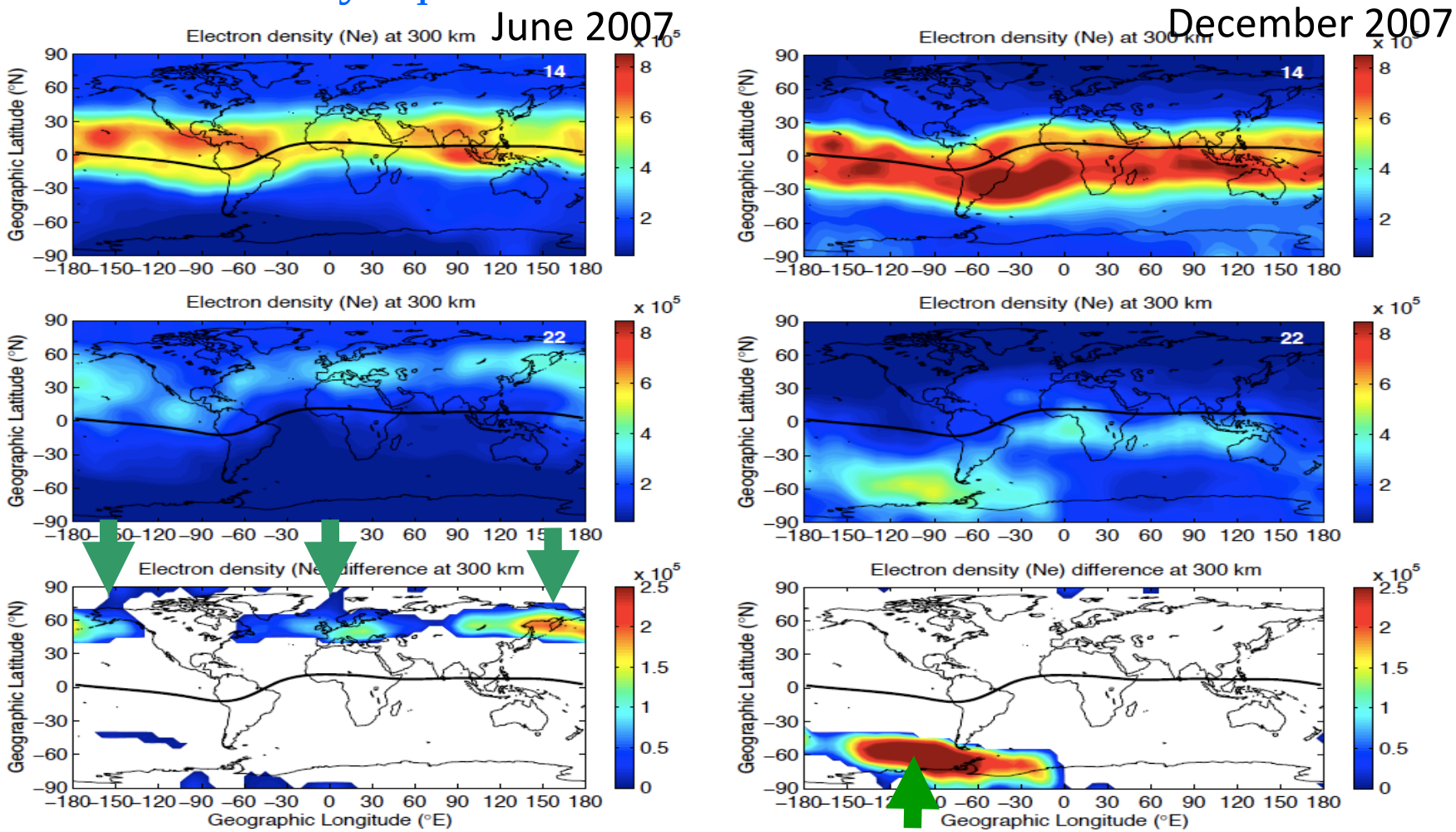
(Bellchambers and Piggott, 1958)



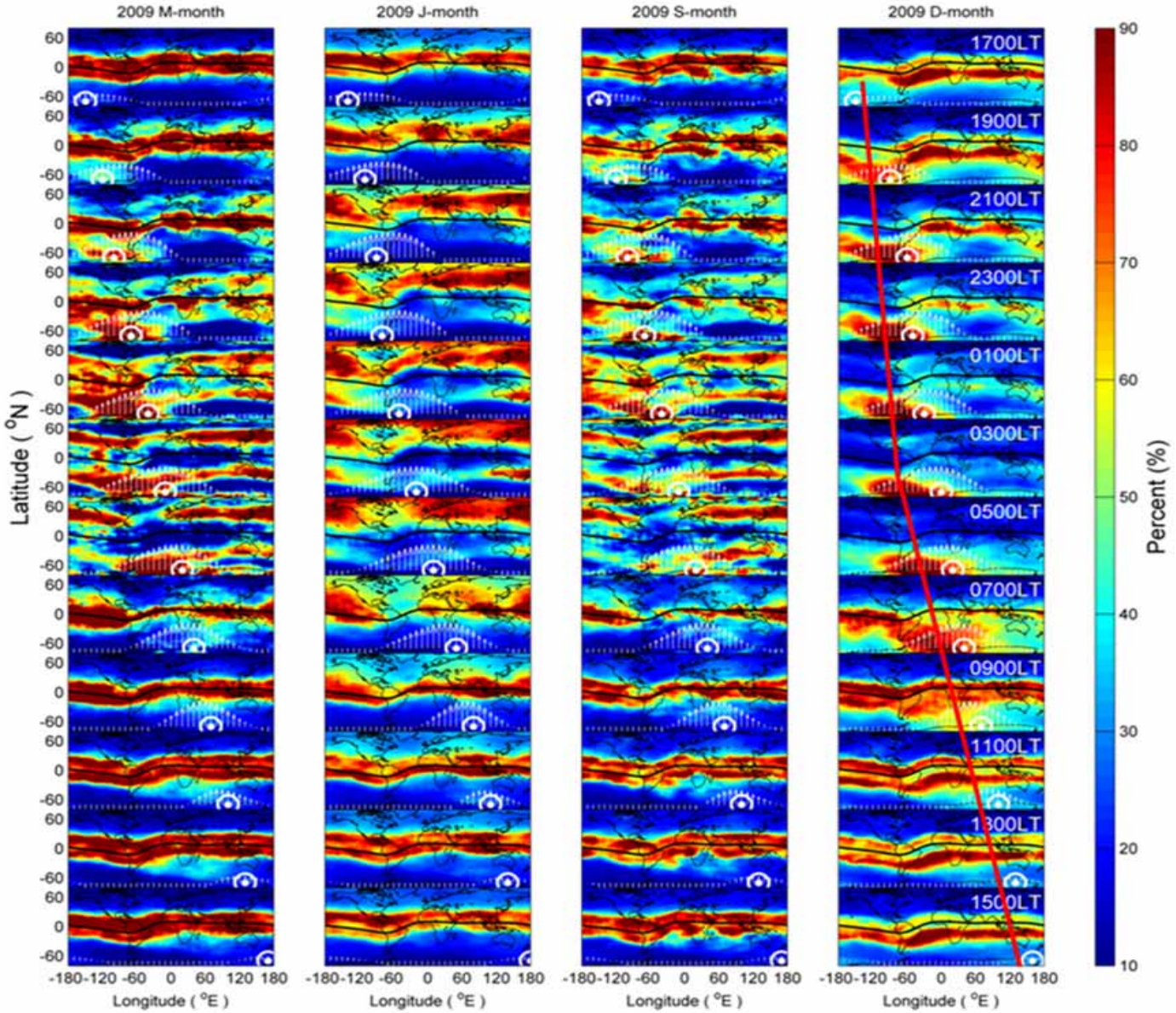
Lin et al., 2009

Not only occurred in the Southern hemisphere but also in the North
- Categorized as the Mid-latitude Summer Nighttime Anomaly (MSNA)

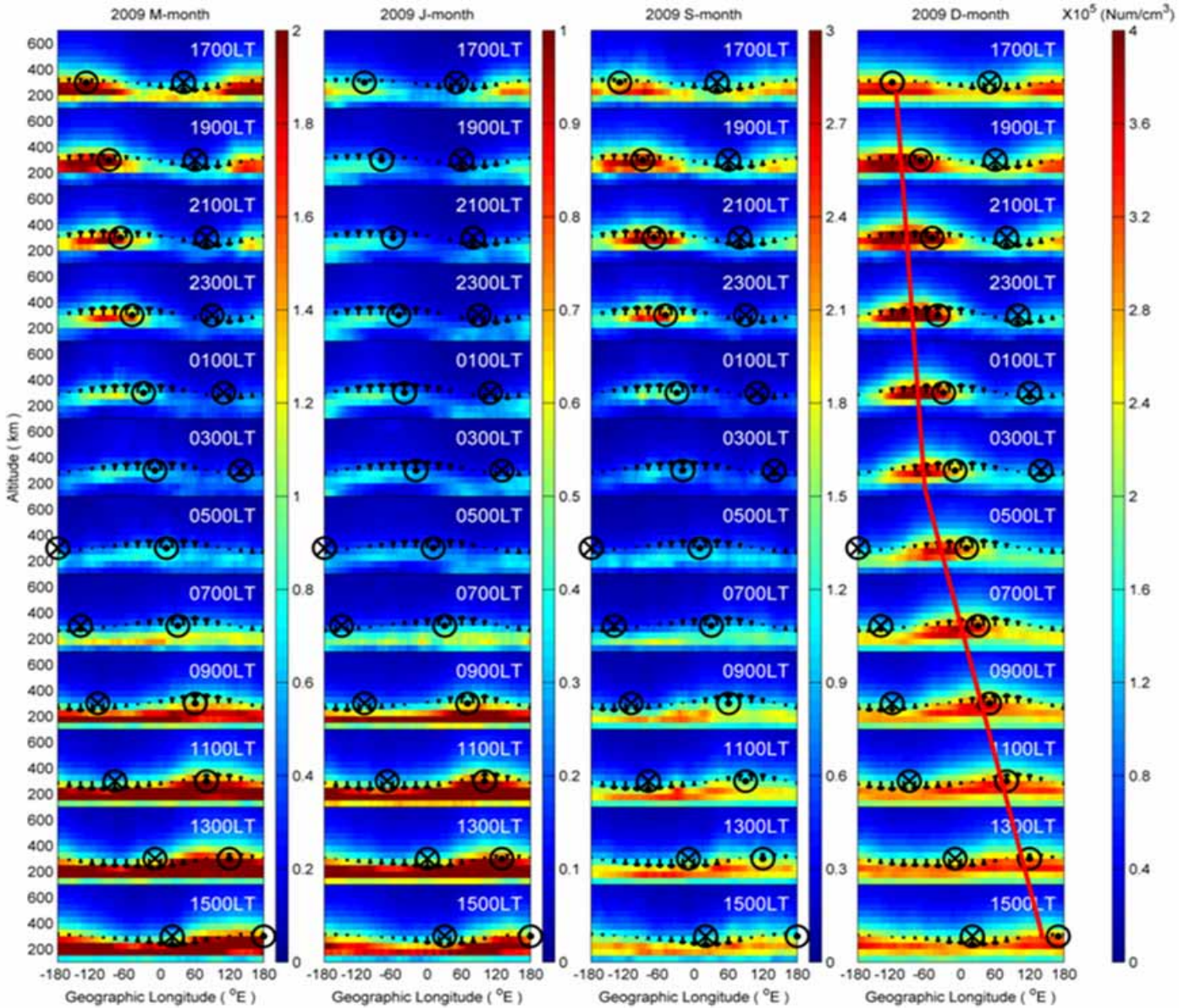
Ne(2200LT) > Ne(1400LT)
- driven by equatorward meridional neutral wind



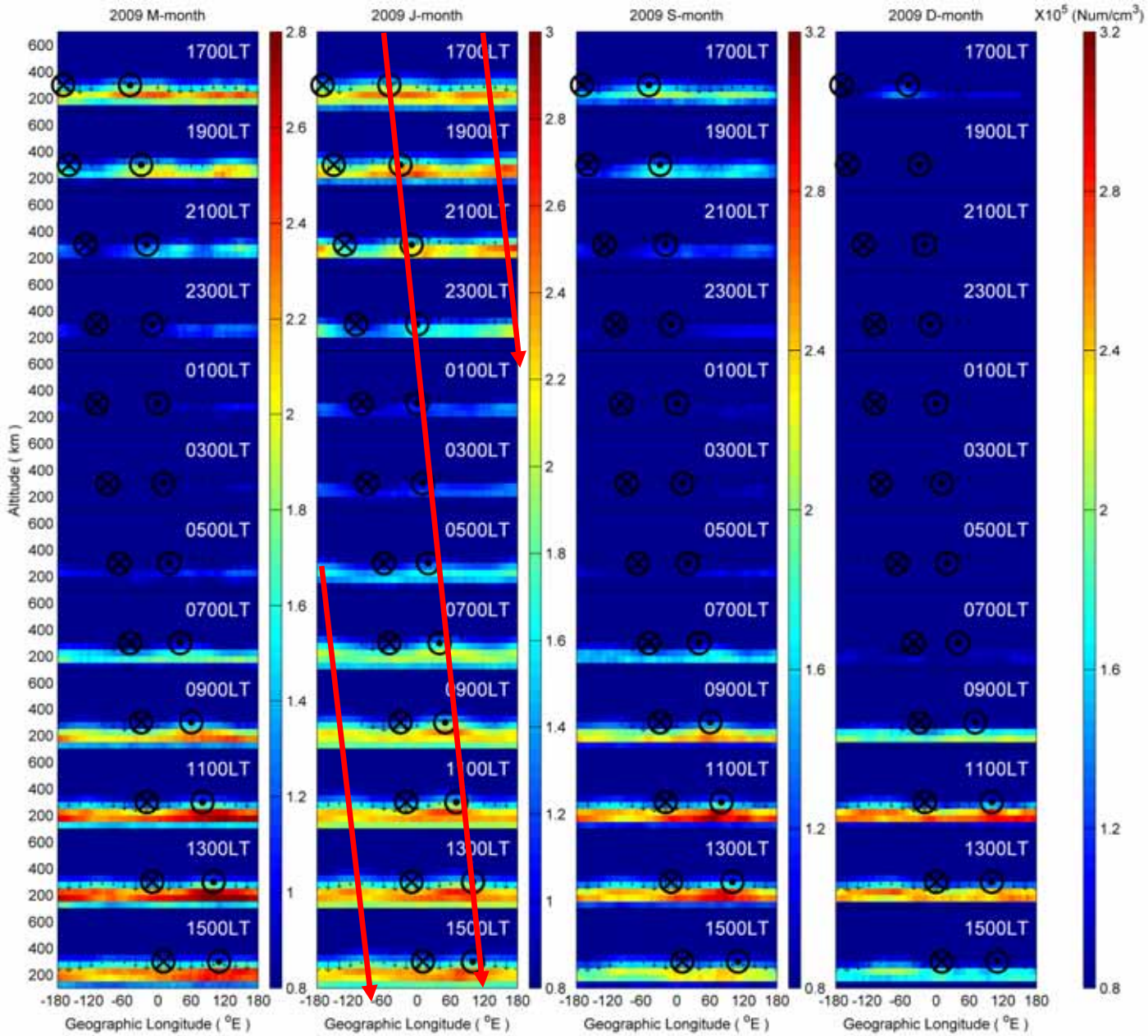
Lin et al., 2010



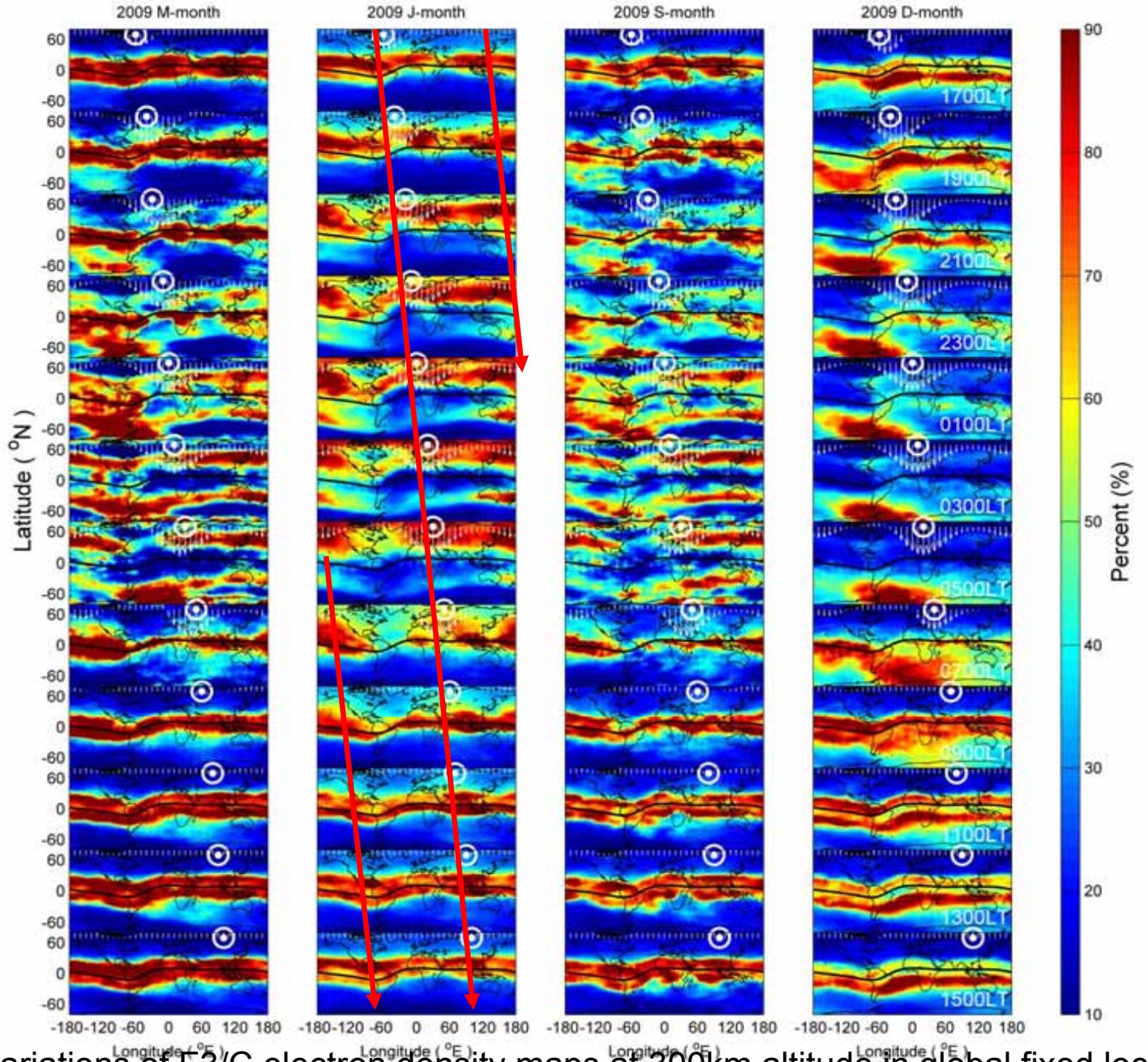
Diurnal variations of F3/C electron density maps at 300km altitude in global constant local time in four months. White arrows and dots are the maximum magnetic meridional plasma flow $U_M(300)$ and vertical plasma flow $W_M(300)$ at -75°N. From left to right are M-, J-, S- ,and D-month, respectively. The color bar denotes 10% to 90% of N(300).



Altitude variations of the electron density within -40° to -80° N latitude in global constant local time in four months. Black dots/circles and arrows are the equatoward/poleward plasma flow ($U_M(300)$/ $U_m(300)$) and vertical plasma flow W(300), respectively. The two eastward phase shifting speeds 167 and 296m/s are computed by averaging in every each 4-hour.



Altitude variations of the electron density within 30° to 60°N latitude in global fixed local time in four months. Black dots/circles and arrows are the equatoward/poleward plasma flow ($U_M(300)$/ $U_m(300)$) and vertical plasma flow W(300), respectively



Diurnal variations of F3/C electron density maps at 300km altitude in global fixed local time in four months. White arrows and dots are the maximum magnetic meridional plasma flow $U_M(300)$ and vertical plasma flow $W_M(300)$ at 55°N.

Remark 3

- It is found that the multiple-speeds in the eastward phase shift are about of 167 and 296m/s for the MEDA peaks (WSA feature) in the southern hemisphere, while the peaked double MEDAs (MSNA feature) with speeds yield 91 and 121m/s in the northern hemisphere.
- The simultaneous eastward phase shifts in the electron density and the plasma flows suggest that the neutral winds are essential.

Ionospheric Scintillation

S. Basu et al. / Journal of Atmospheric and Solar-Terrestrial Physics 64 (2002) 1745–1754 1747

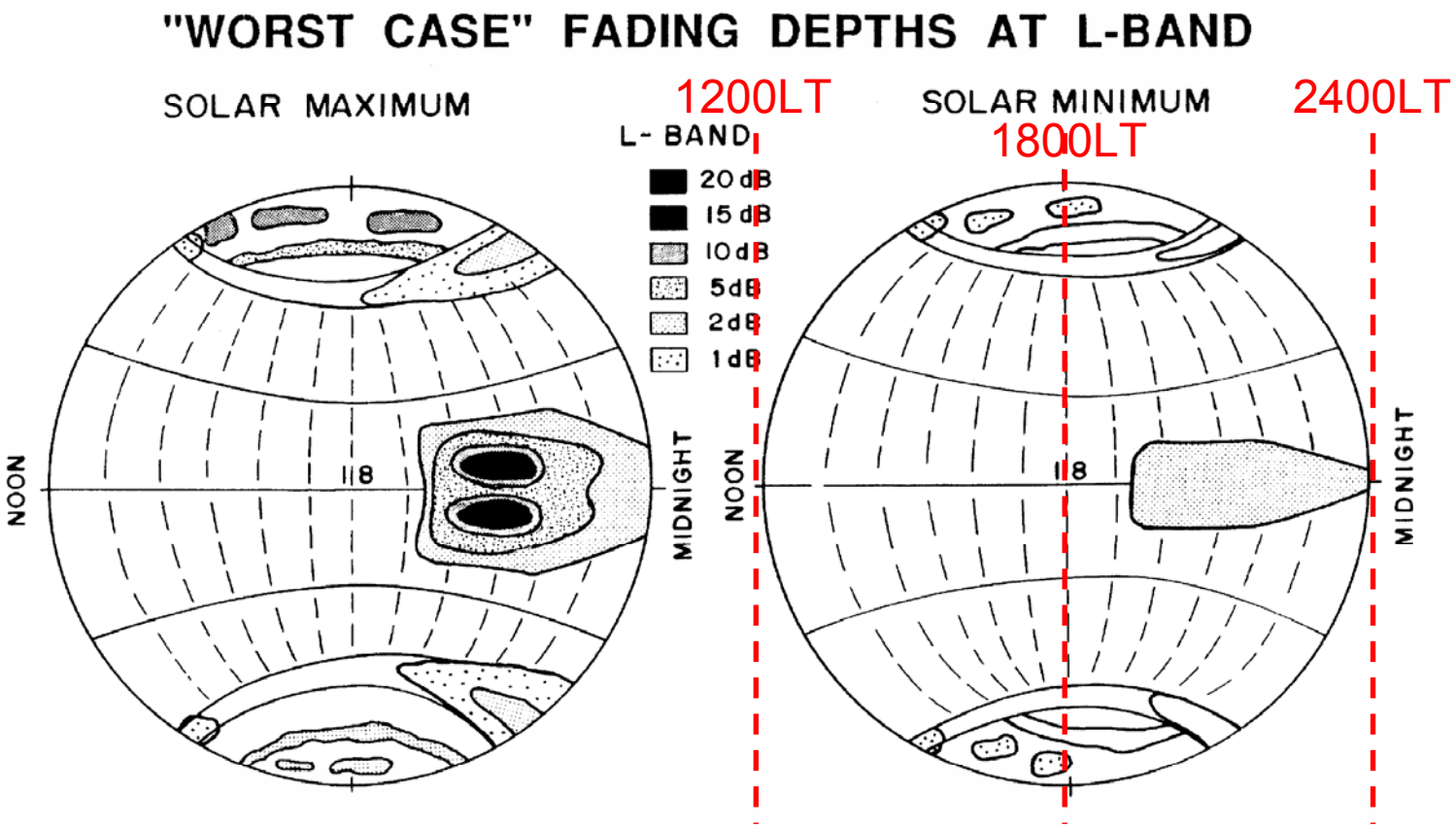
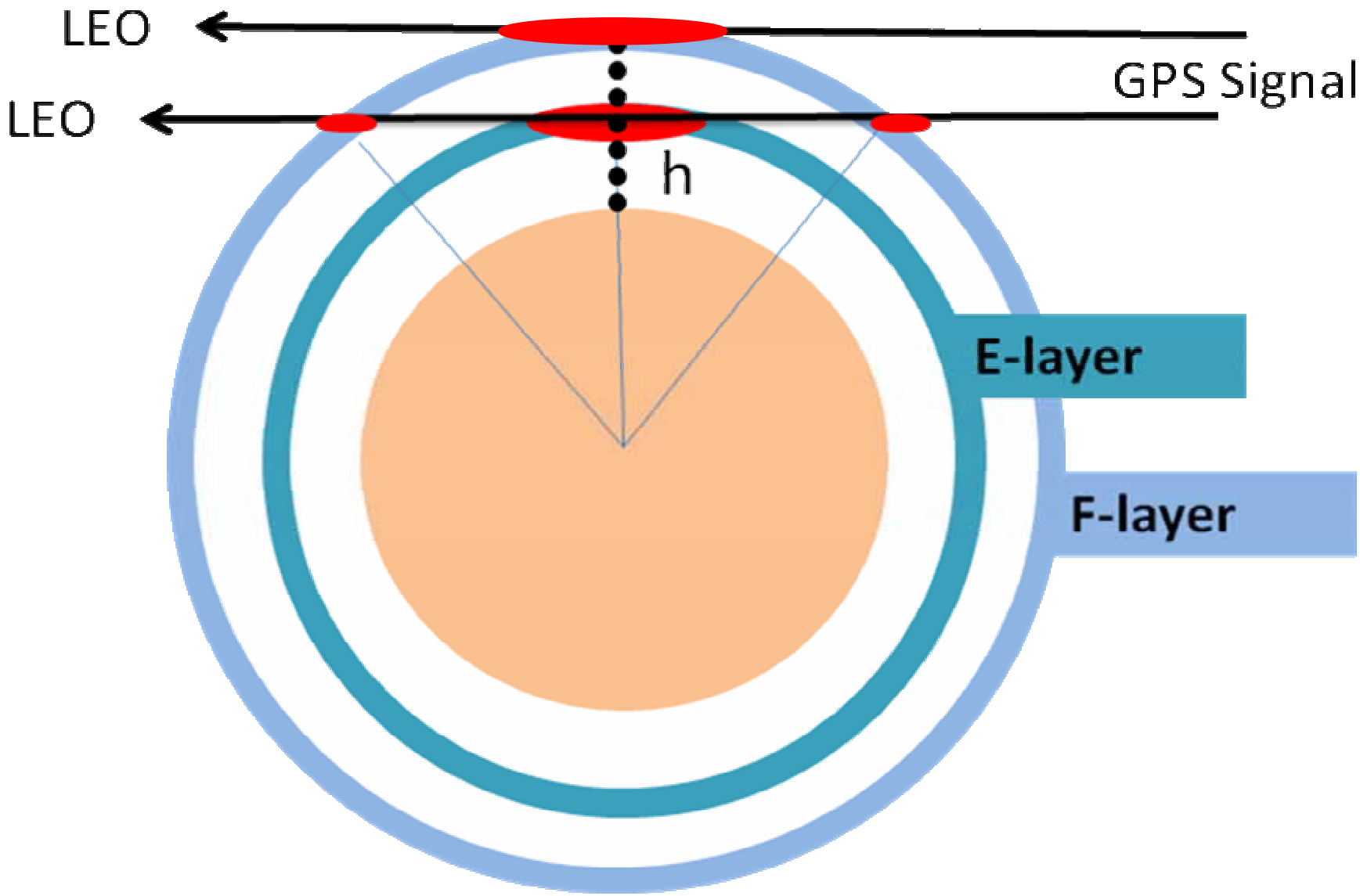


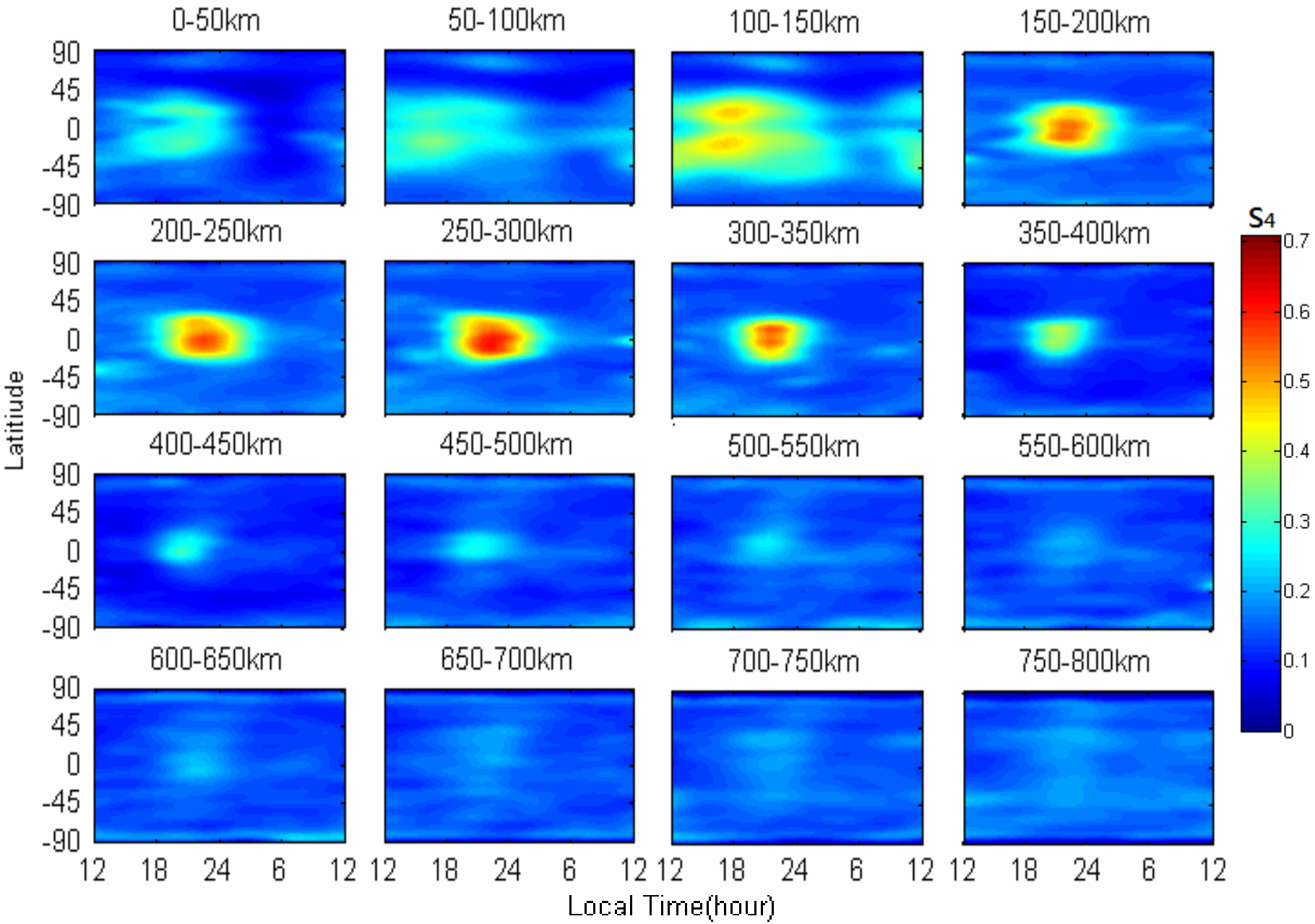
Fig. 1. Schematic of the global morphology of scintillations at L-band frequencies during the solar maximum (left panel) and solar minimum (right panel) conditions. Reproduced from S. Basu and K.M. Groves, Specification and forecasting of outages on satellite communication and navigation systems, Space Weather, Geophysical Monograph 125, 424–430, 2001. Published 2001 by the American Geophysical Union. Reproduced/modified by permission of American Geophysical Union.

Basu et al. [JASTP 2002]

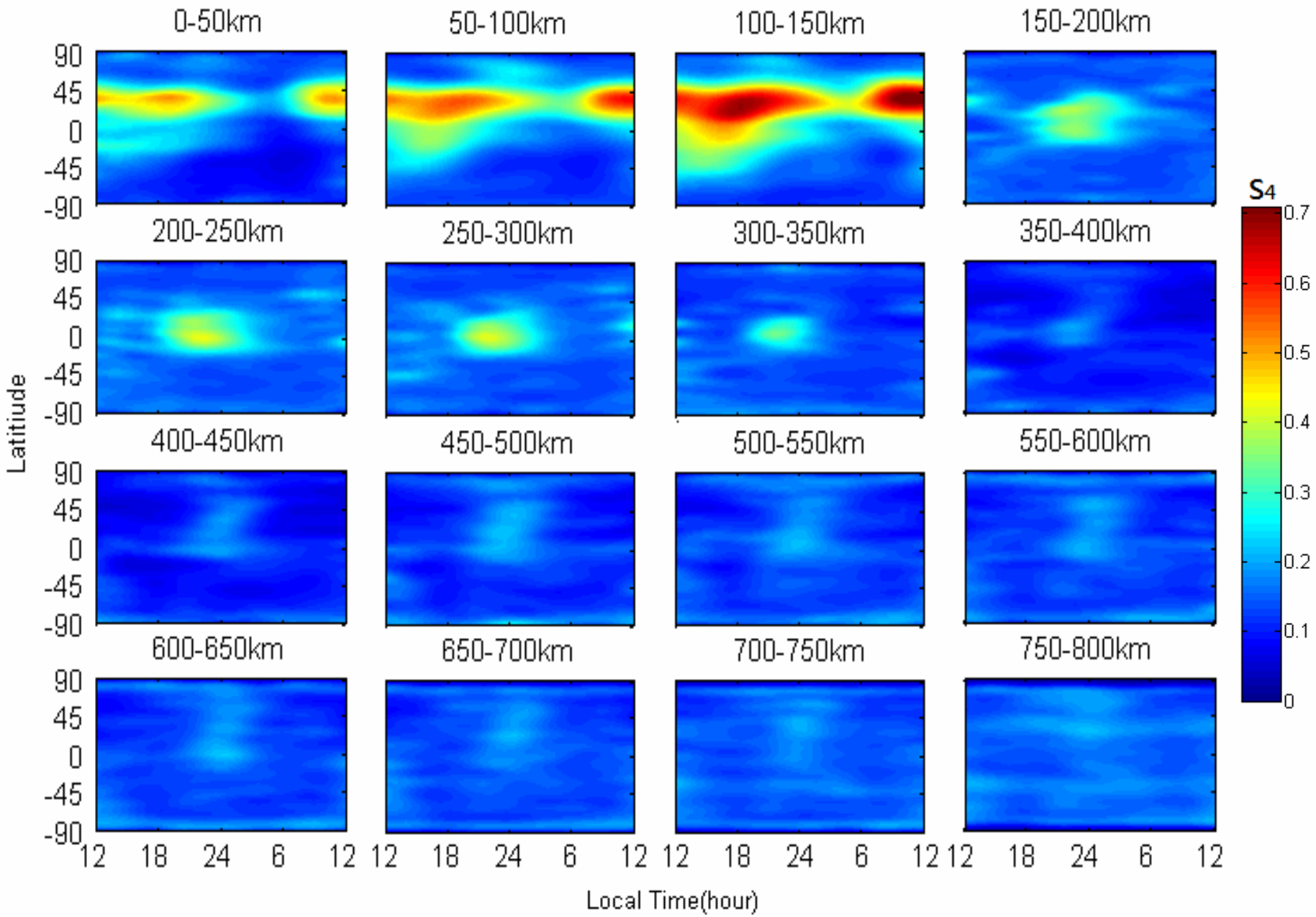
F3/C S4 index sounding



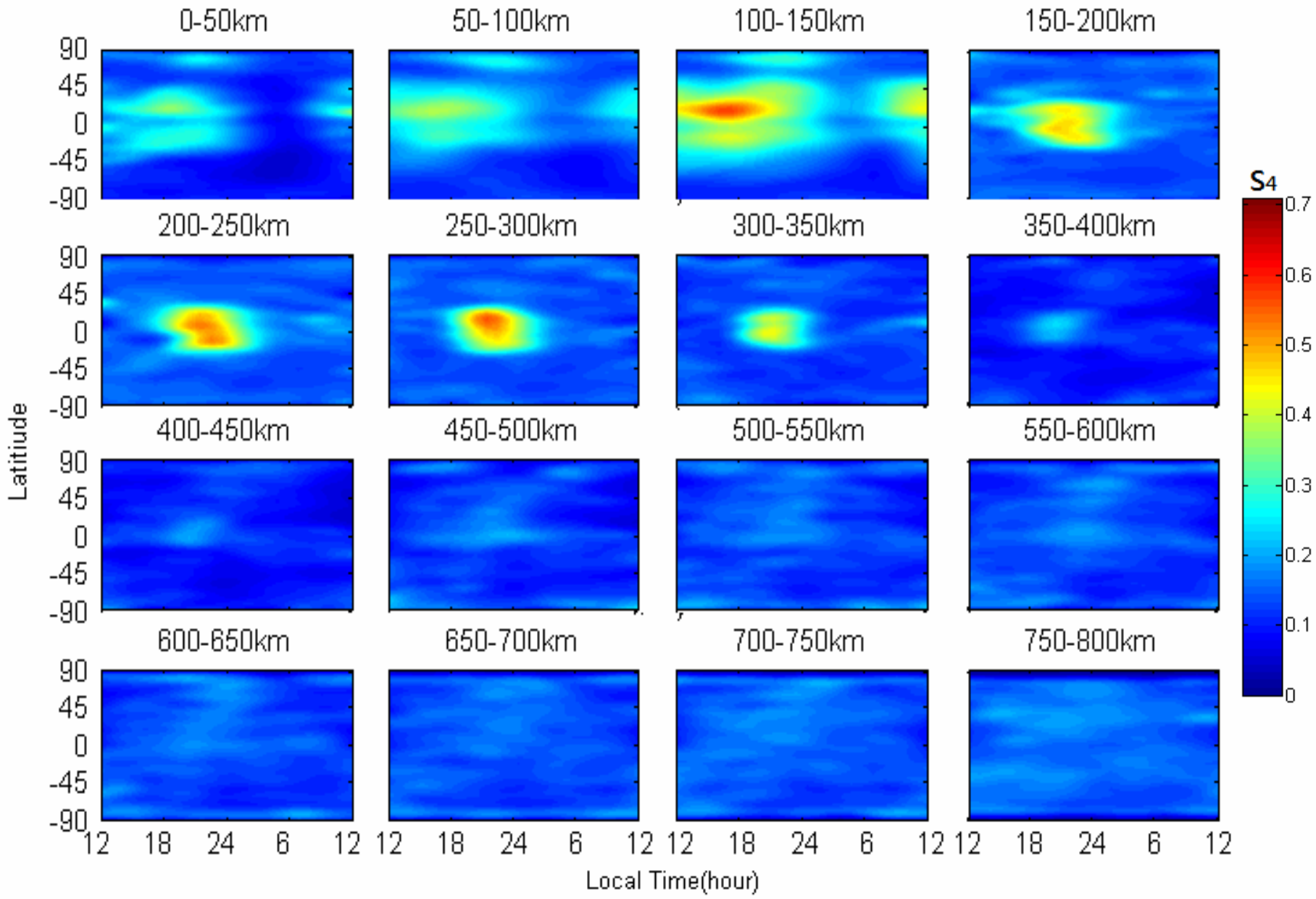
M-month


0-50km
50-100km
100-150km
150-200km
200-250km
250-300km
300-350km
350-400km
400-450km
450-500km
500-550km
550-600km
600-650km
650-700km
700-750km
750-800km
90
45
0
-45
-90
Latitiude
12 18 24 6 12
Local Time(hour)
S4
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

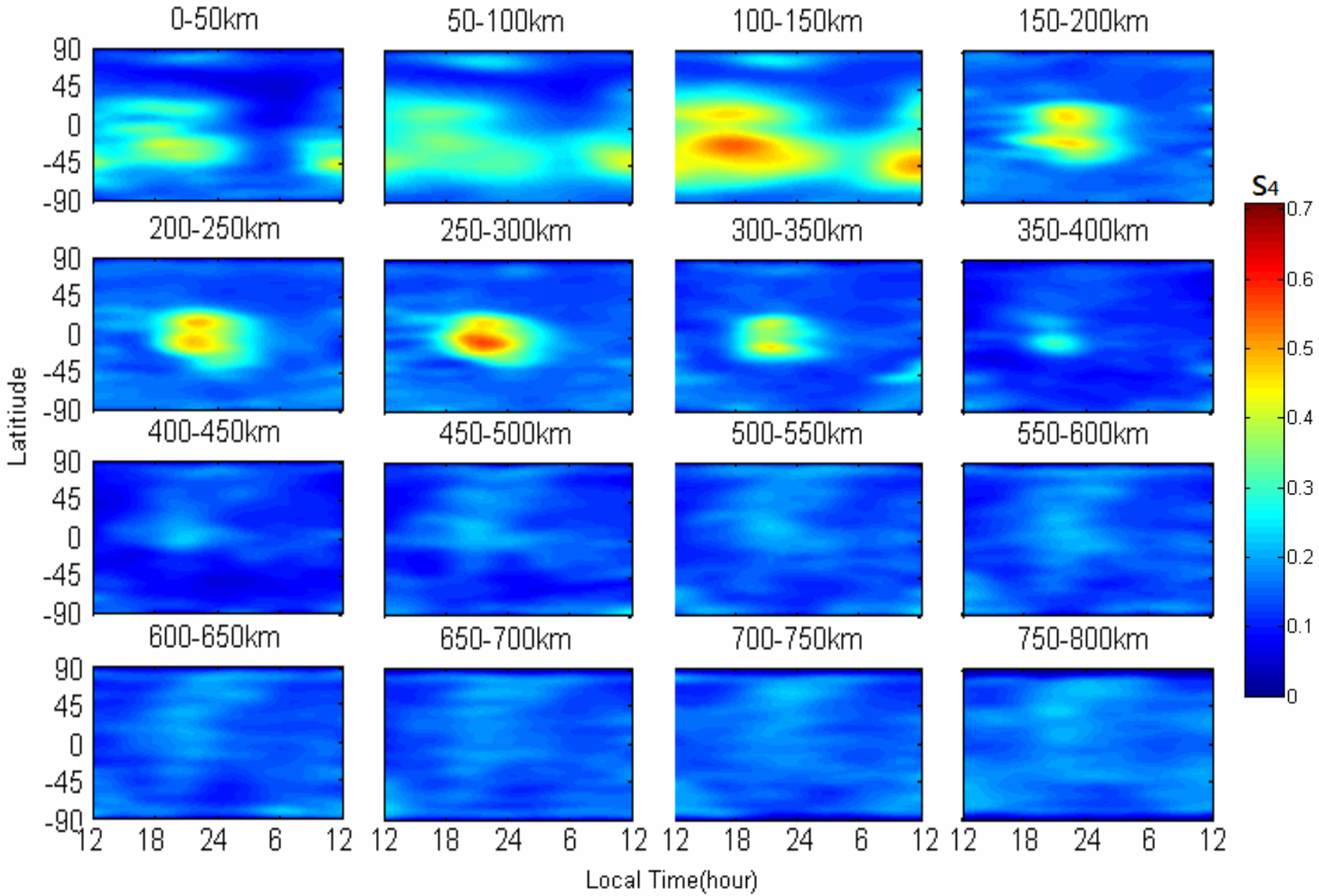
J-month


0-50km
50-100km
100-150km
150-200km
200-250km
250-300km
300-350km
350-400km
400-450km
450-500km
500-550km
550-600km
600-650km
650-700km
700-750km
750-800km
90
45
0
-45
-90
Latitiude
12 18 24 6 12
Local Time(hour)
S4
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

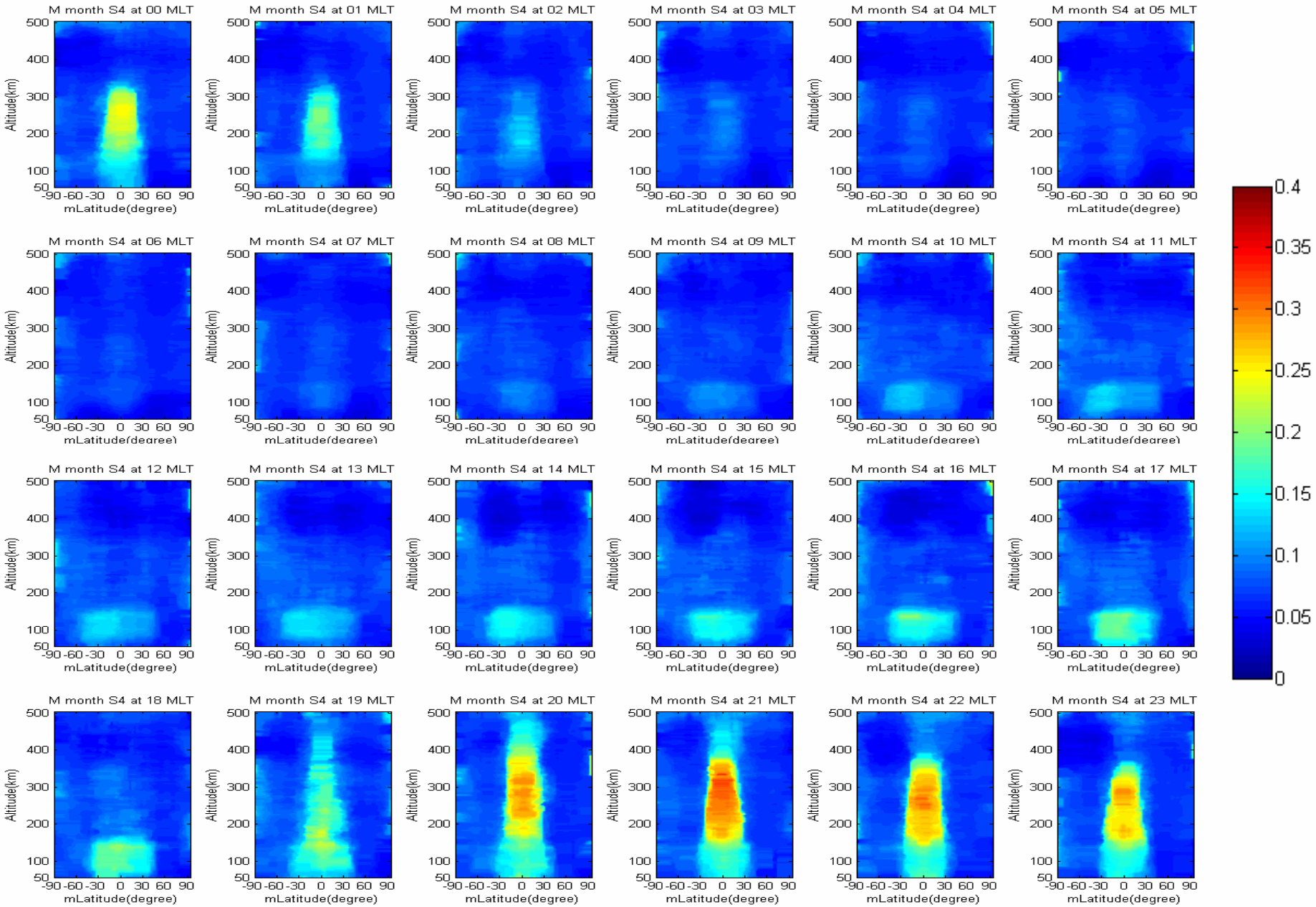
S-month


0-50km
50-100km
100-150km
150-200km
200-250km
250-300km
300-350km
350-400km
400-450km
450-500km
500-550km
550-600km
600-650km
650-700km
700-750km
750-800km
90
45
0
-45
-90
Latitiude
12 18 24 6 12
Local Time(hour)
S4
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

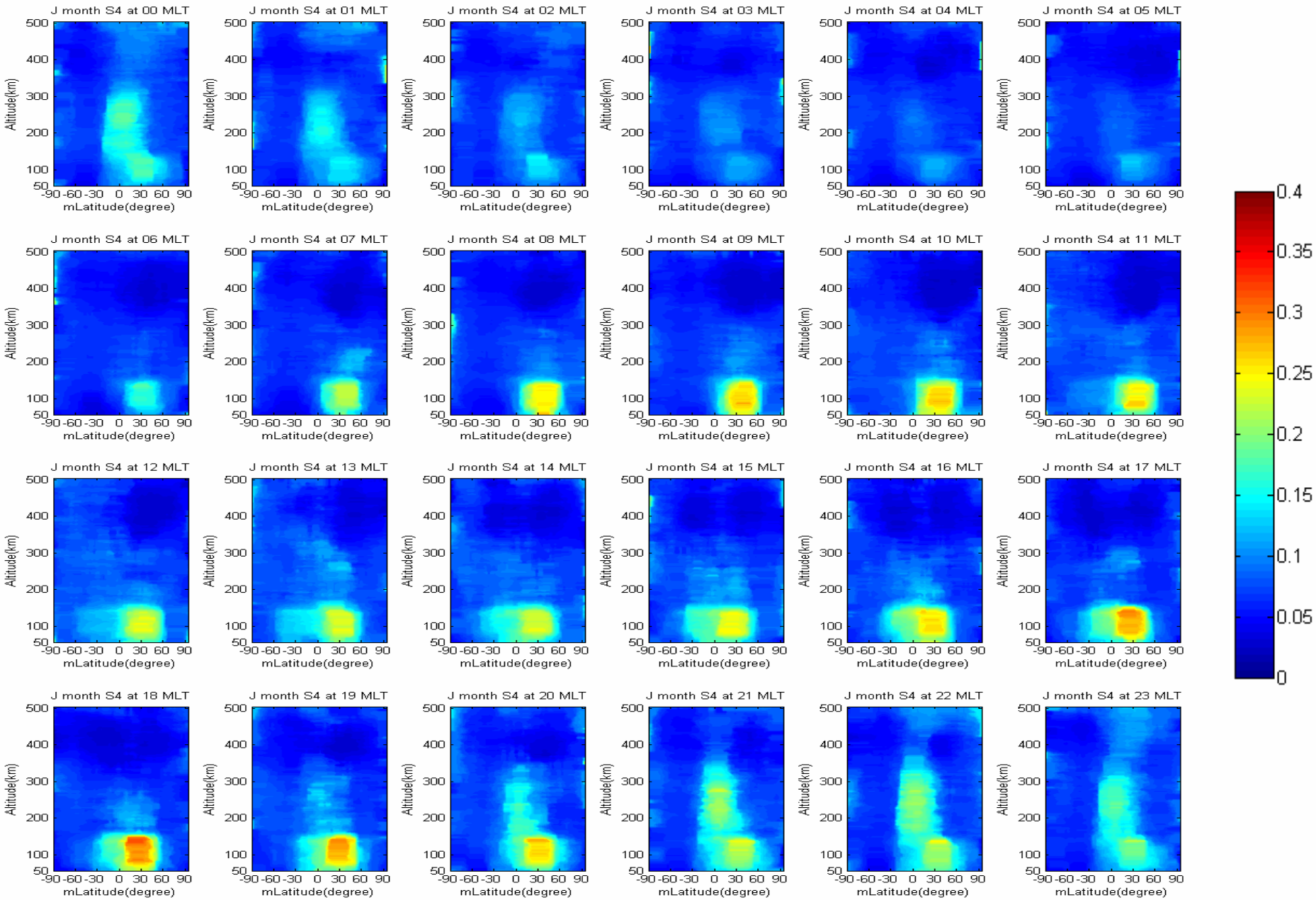
D-month


0-50km
50-100km
100-150km
150-200km
200-250km
250-300km
300-350km
350-400km
400-450km
450-500km
500-550km
550-600km
600-650km
650-700km
700-750km
750-800km
90
45
0
-45
-90
Latitiude
12
18
24
6
12
Local Time(hour)
S4
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

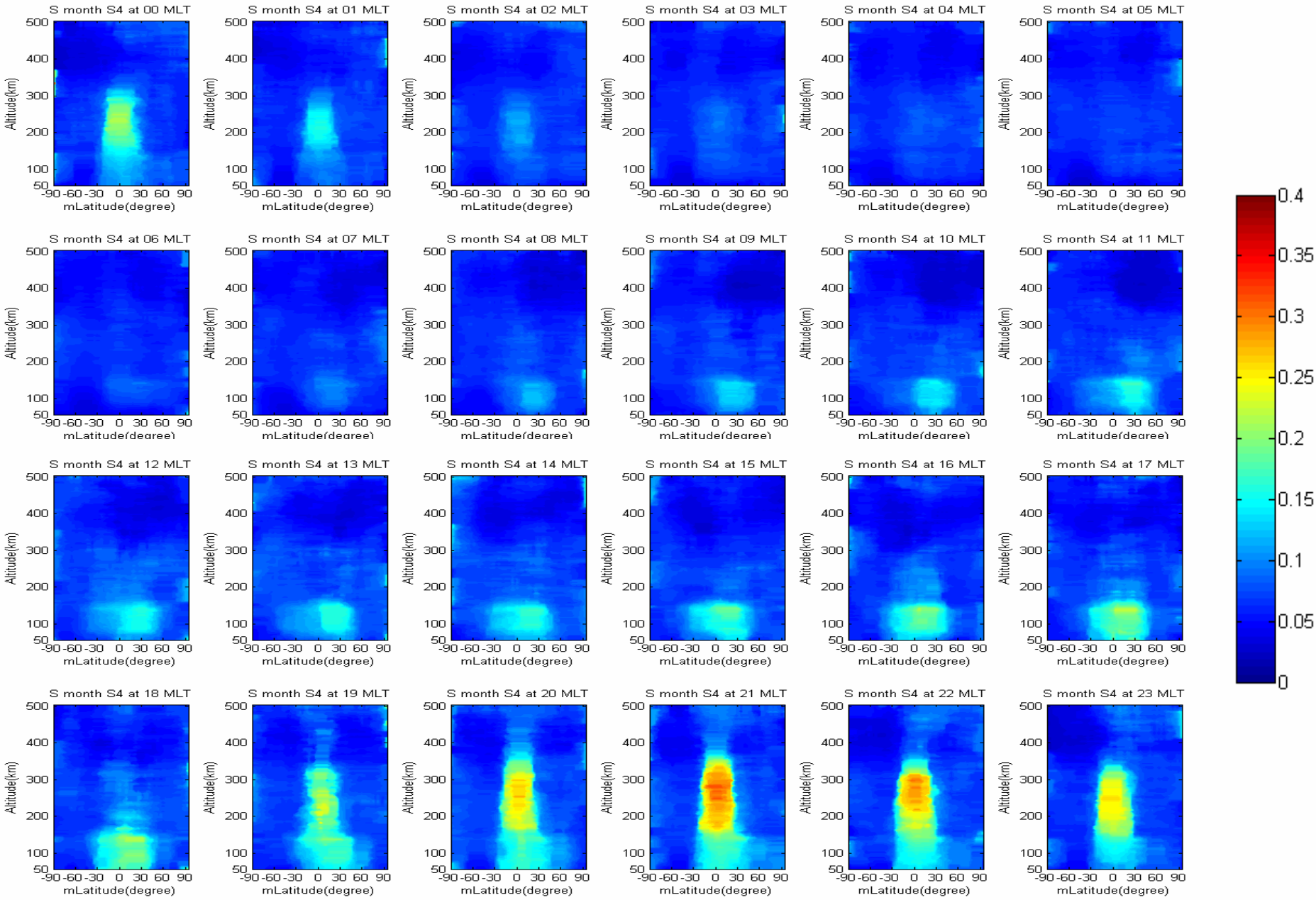
Diurnal Variations of the S4 Max Alt vs. Mlat in M-month



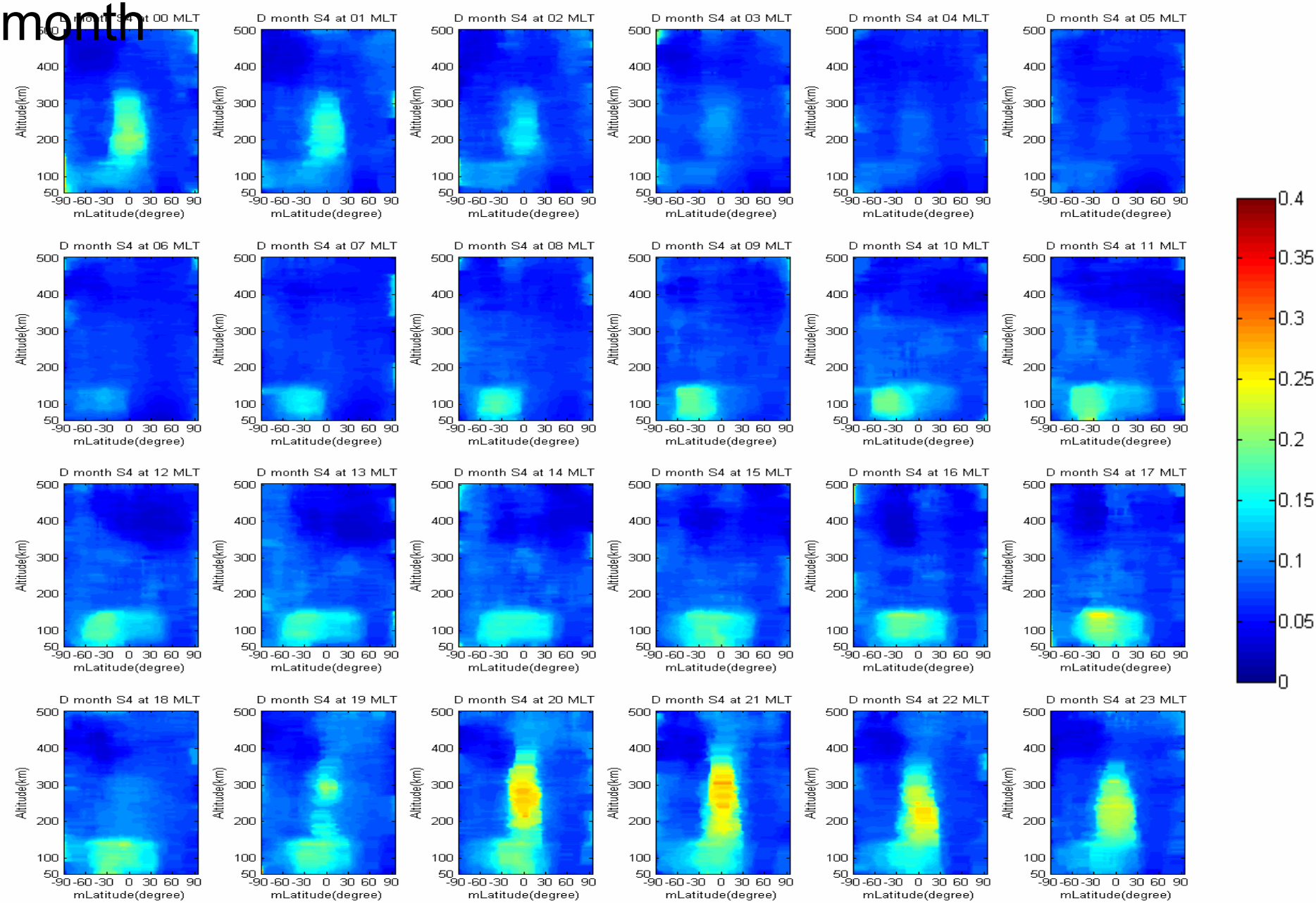
Diurnal Variations of the S4 Max Alt vs. Mlat in J-month

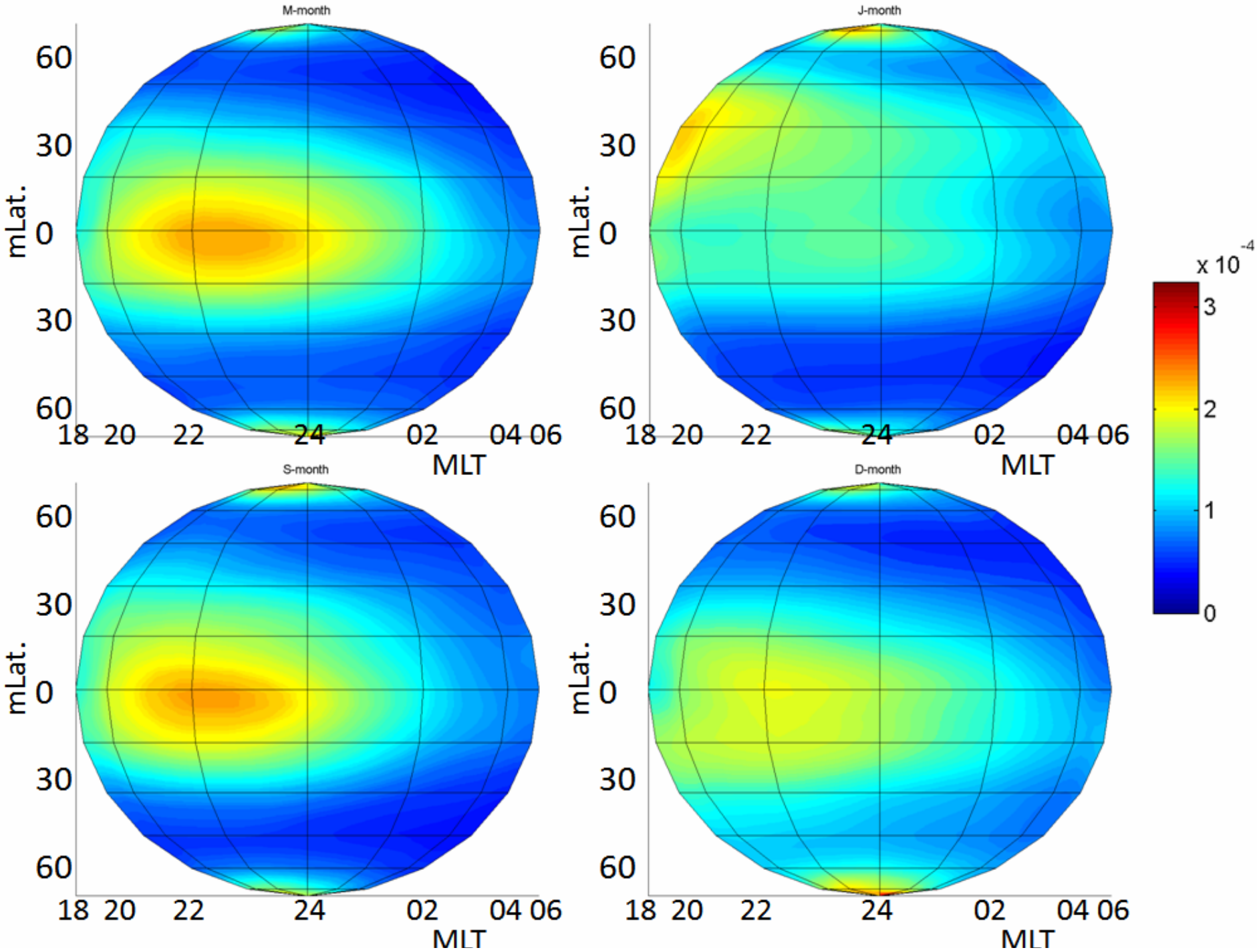


Diurnal Variations of the S4 Max Alt vs. Mlat in S-month

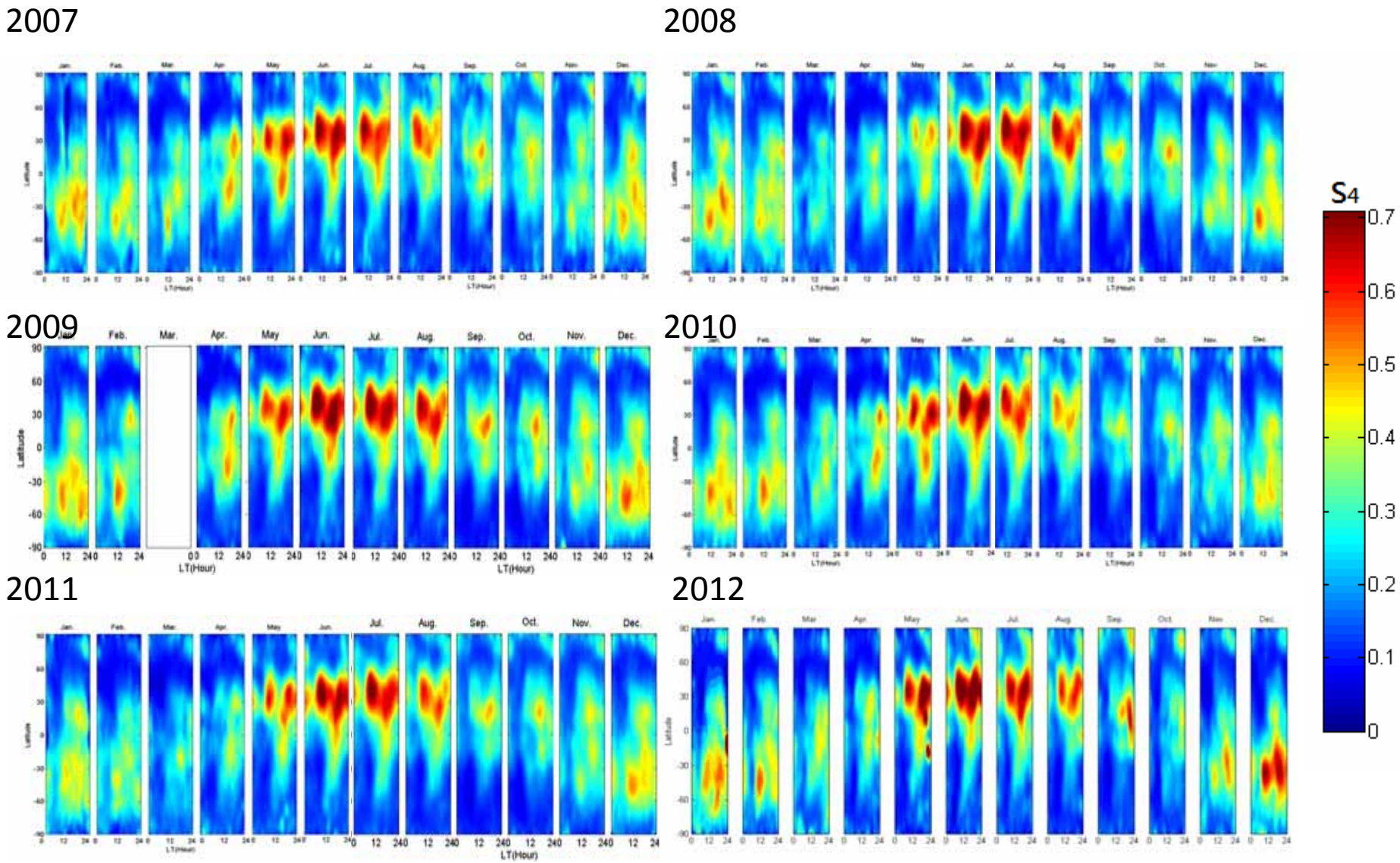


Diurnal Variations of the S4 Max Alt vs. Mlat in D-month

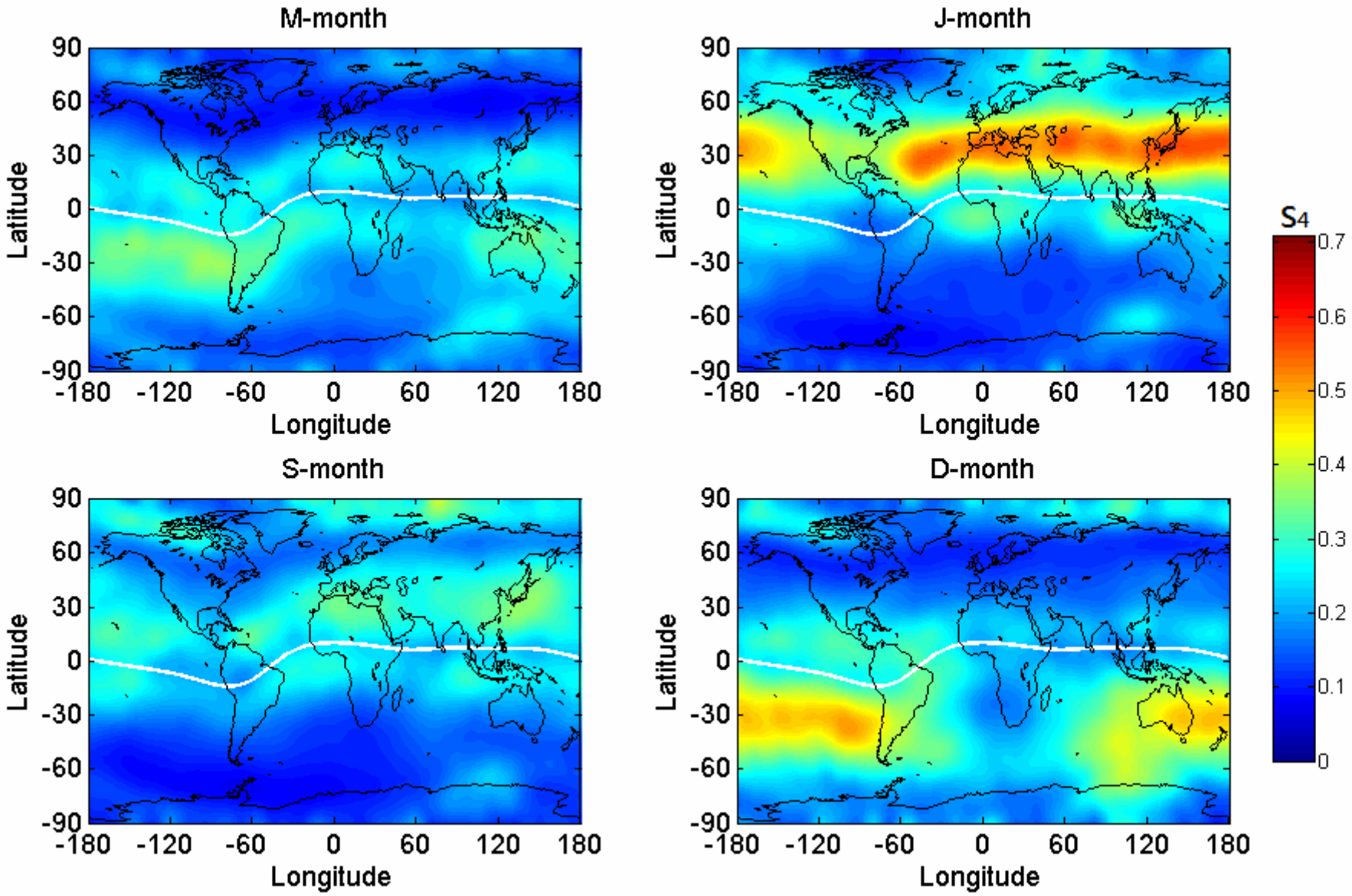



M-month
J-month
S-month
D-month
mLat.
60
30
0
30
60
18 20 22 24 02 04 06
MLT
x 10^-4
3
2
1
0

S4 max in the E-region during 2007-2011

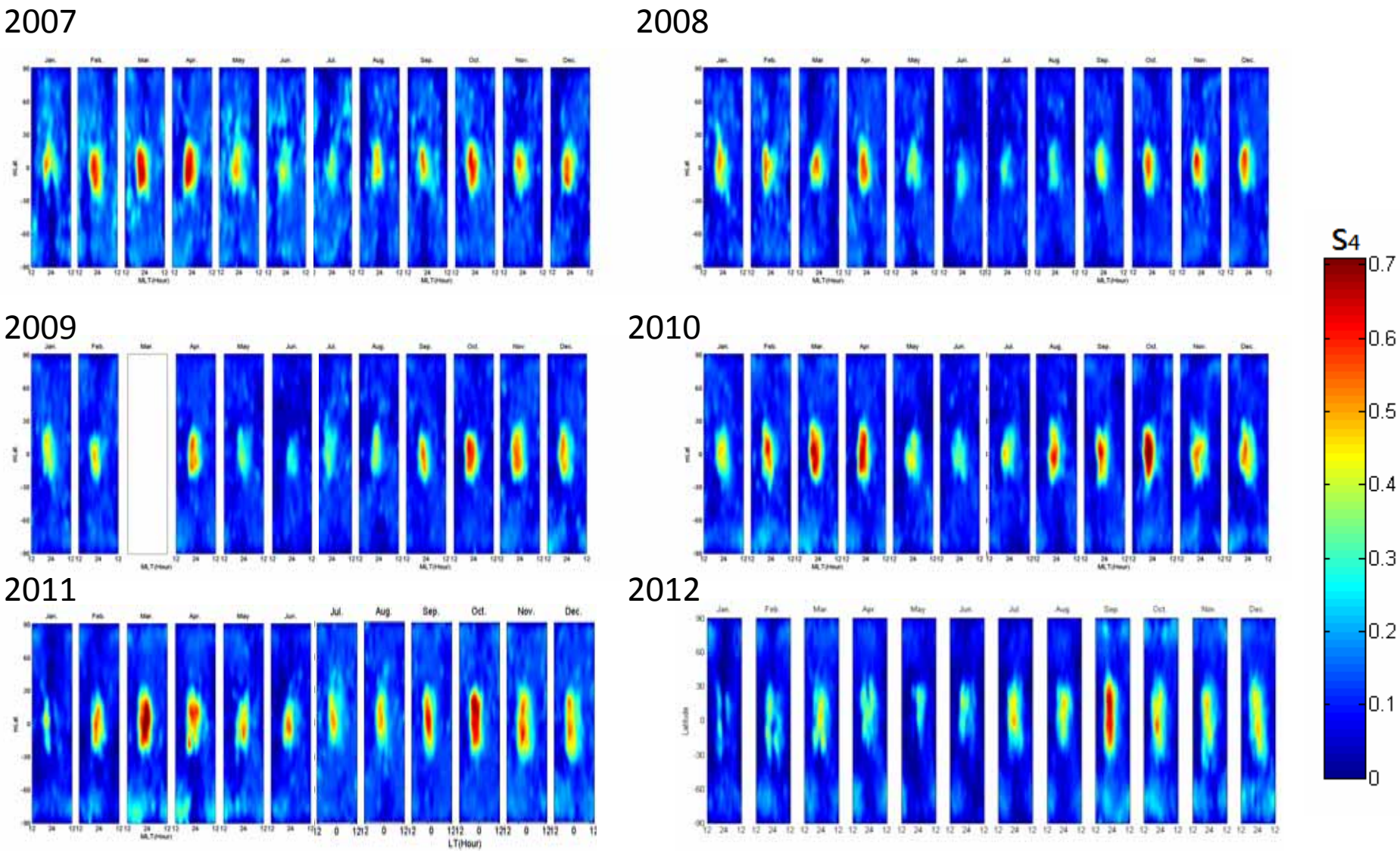


Global Distribution of E-region S4 max

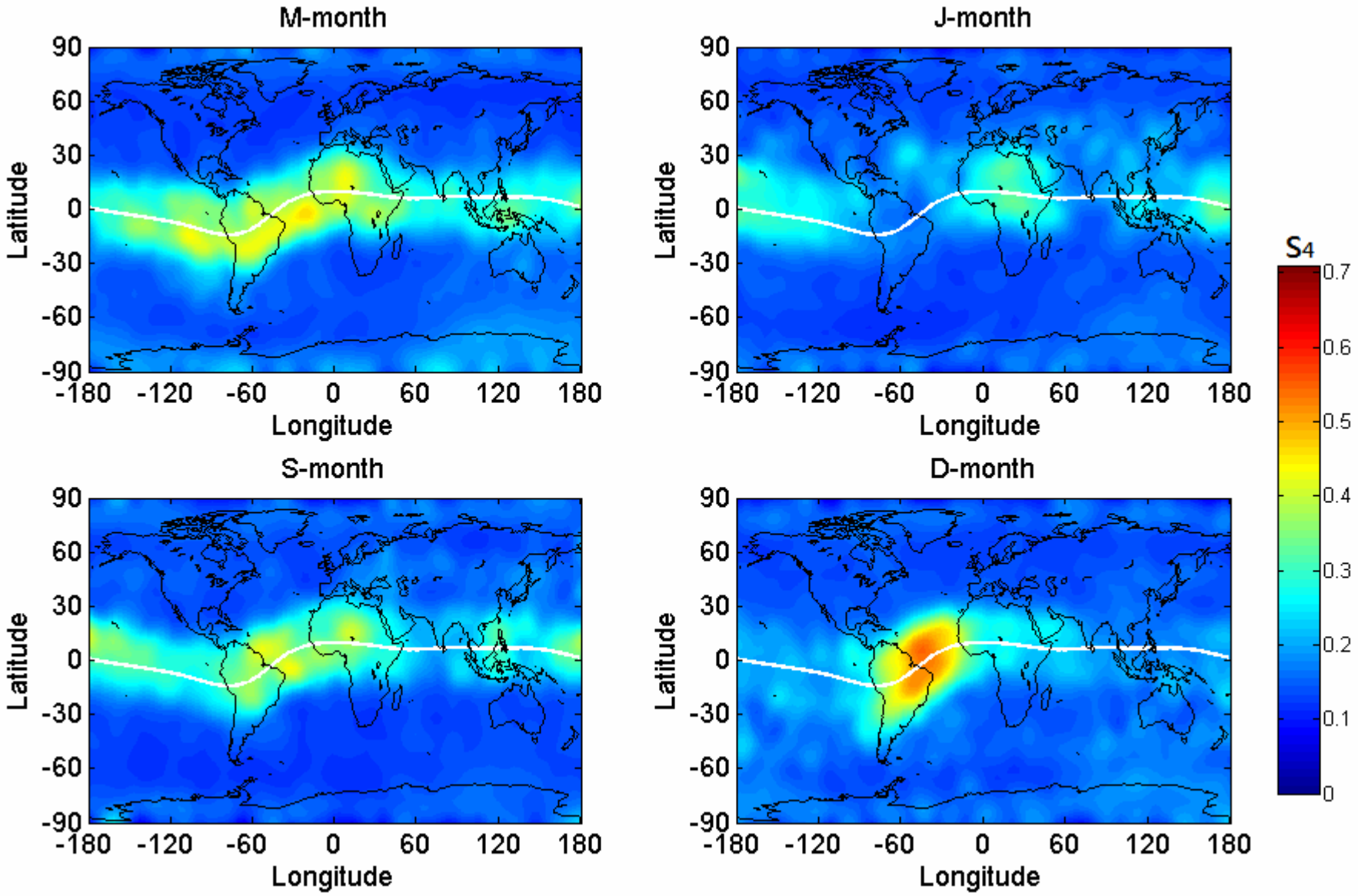


F3/C S4 max in the F-region

S4 max in the F-region during 2007-2012



Global Distribution of F-region S4 max



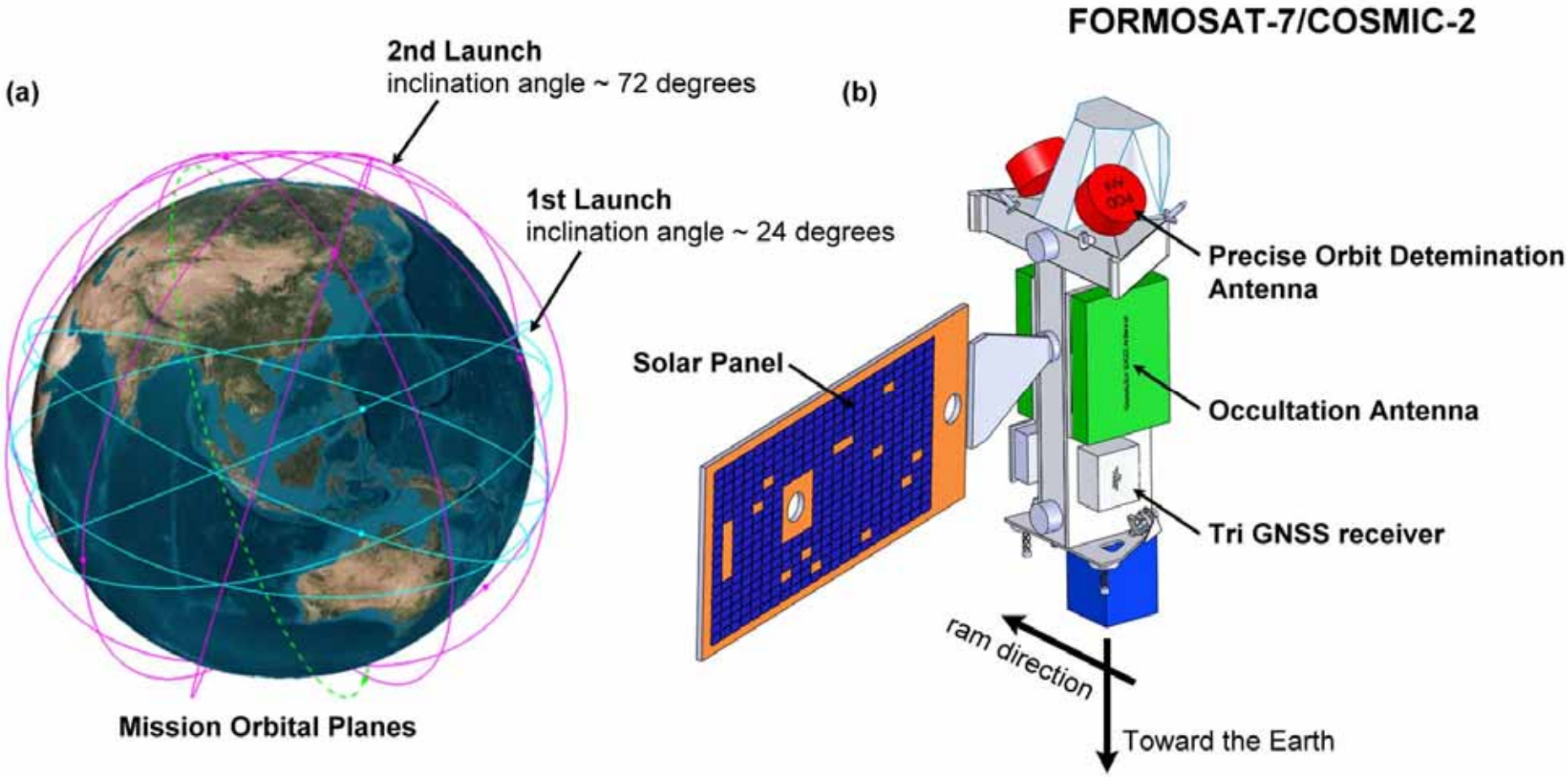
Remark 4

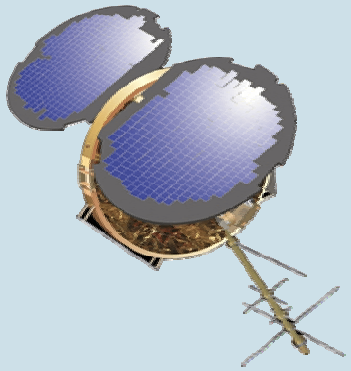
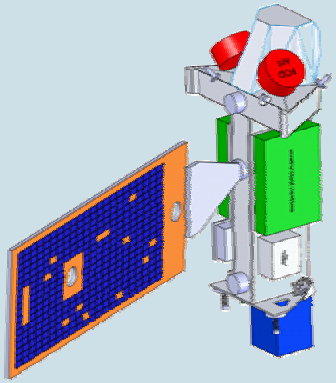
- The most prominent signatures of the F3/C S4 max in the E- (F-)region are in middle (equatorial-low) latitudes of the Summer J-month (equinox) months.
- The F3/C S4 max in the E-region is mainly contributed by the Es (sporadic-E) layer. Neutral wind is essential!
- The F3/C S4 max in the F-region lies between 20N and 20S and expends to higher latitudes in the equinox and D months. E×B plasma fountain is essential!
- The F3/C S4 max in the F-region yields the greatest value in the American sector. Geomagnetic control!

Conclusion

- F3/C observations show that the neutral wind is very essential.
- The F3/C RO provides global 3-D plasma and S4 index observations.

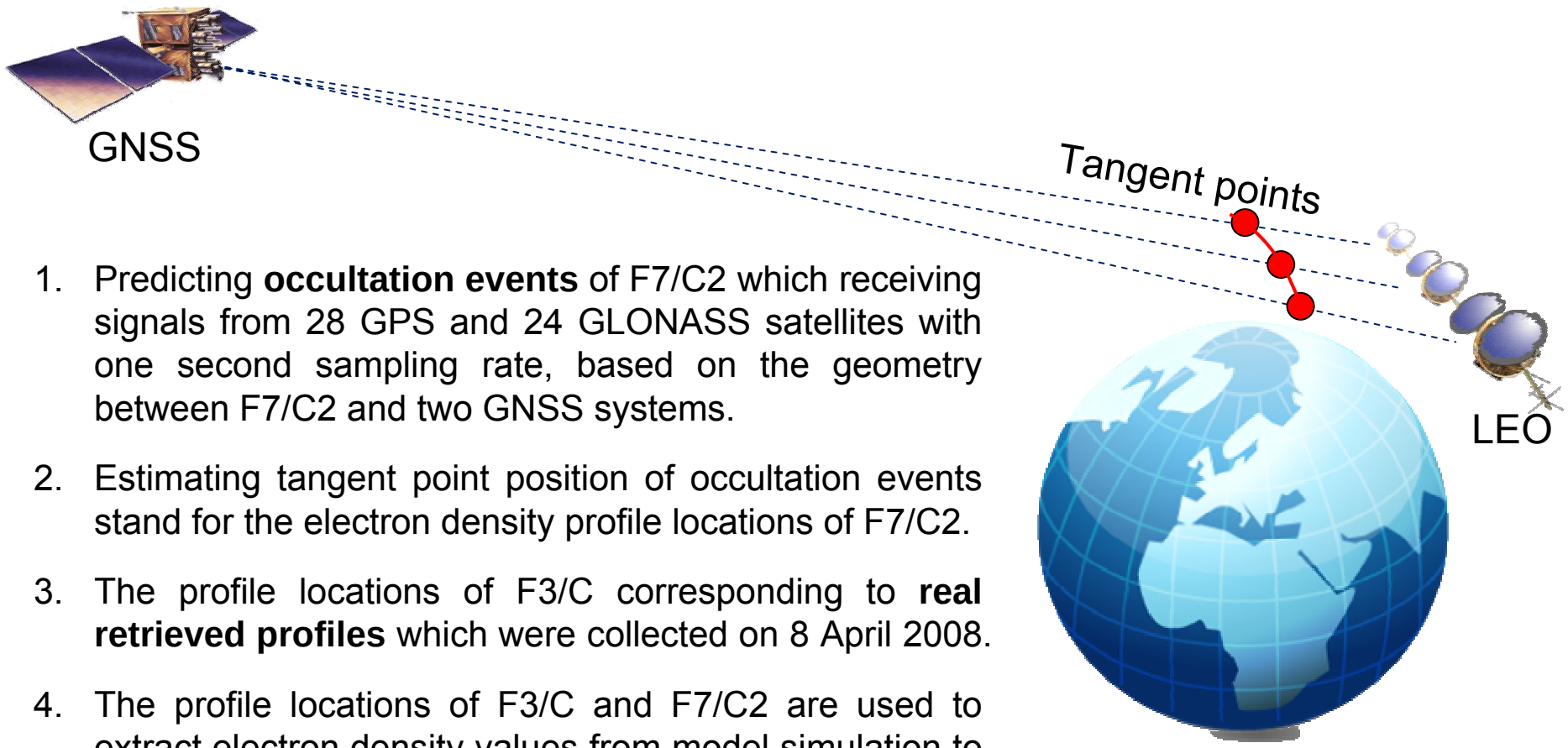
FORMOSAT-7/COSMIC-2 Mission Description



	FORMOSAT-3/COSMIC	FORMOSAT-7/COSMIC-2	
Exterior Design			
Sequence		1st Launch	2nd Launch
Constellation	6	6	6
Mission Orbit Altitude	800 km	520-550 km	720-750 km
Inclination Angle	72°	24-28.5°	72°
Mission Payload	GOX	TriG	
RO Signals	GPS	GPS, GLONASS, Galileo	
Launch Schedule	Launched in 2006	2016	2018

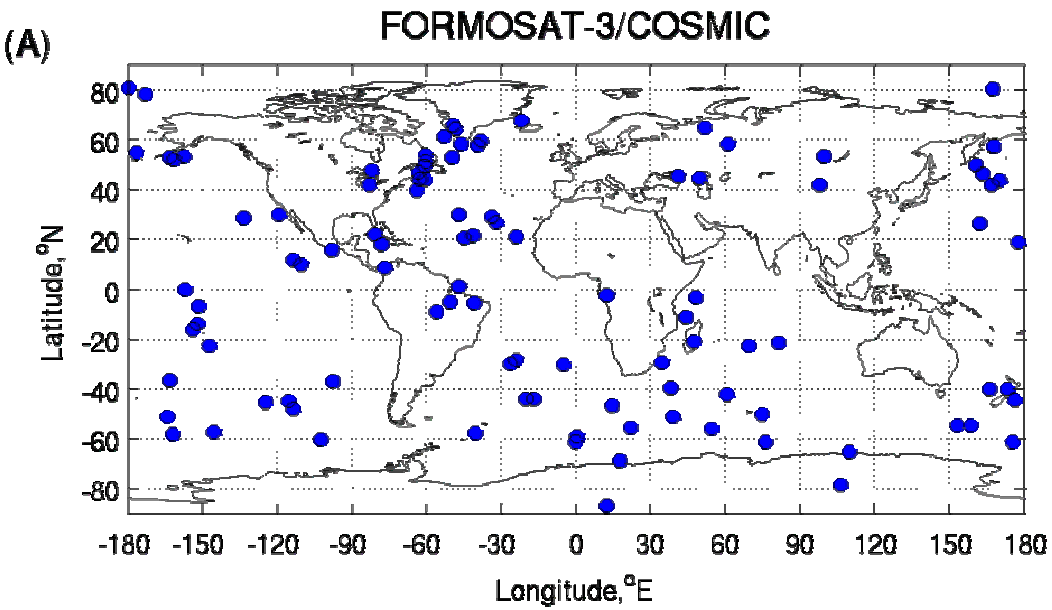
- Descriptions are provided by NSPO (http://www.nspo.org.tw).
- F7/C2 is illustrated by Surrey Satellite Technology LTD.

Observing System Simulation



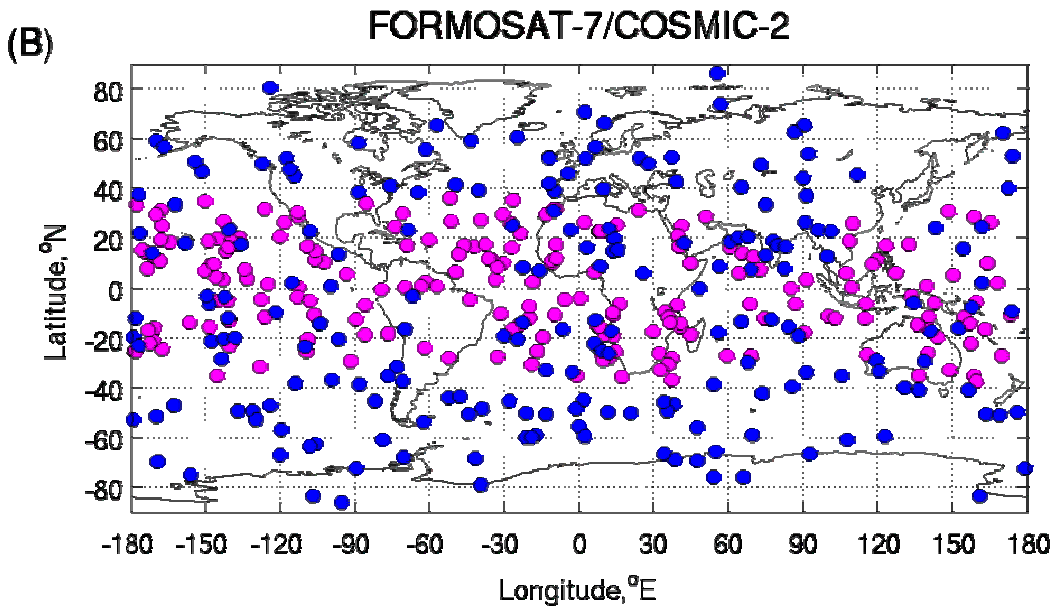
1. Predicting **occultation events** of F7/C2 which receiving signals from 28 GPS and 24 GLONASS satellites with one second sampling rate, based on the geometry between F7/C2 and two GNSS systems.
2. Estimating tangent point position of occultation events stand for the electron density profile locations of F7/C2.
3. The profile locations of F3/C corresponding to **real retrieved profiles** which were collected on 8 April 2008.
4. The profile locations of F3/C and F7/C2 are used to extract electron density values from model simulation to serve as synthetic observations.

Notices: number of occultation events ≠ number of profiles



With 6 satellites + GPS, 60 minutes

About 80-100 profiles per hour

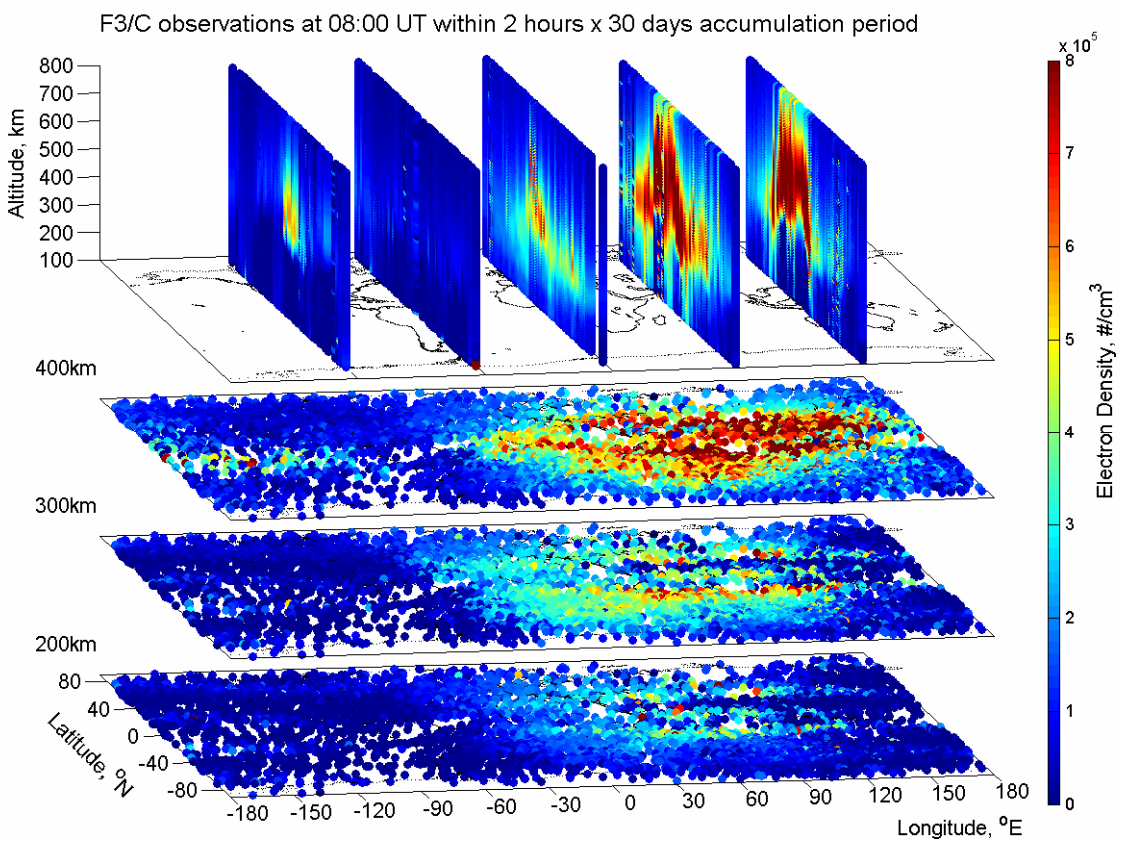


With 12 satellites + GPS, 60 minutes

About 400 profiles per hour

What is future impact of F7/C2 on ionospheric research?

Ionospheric Monitoring



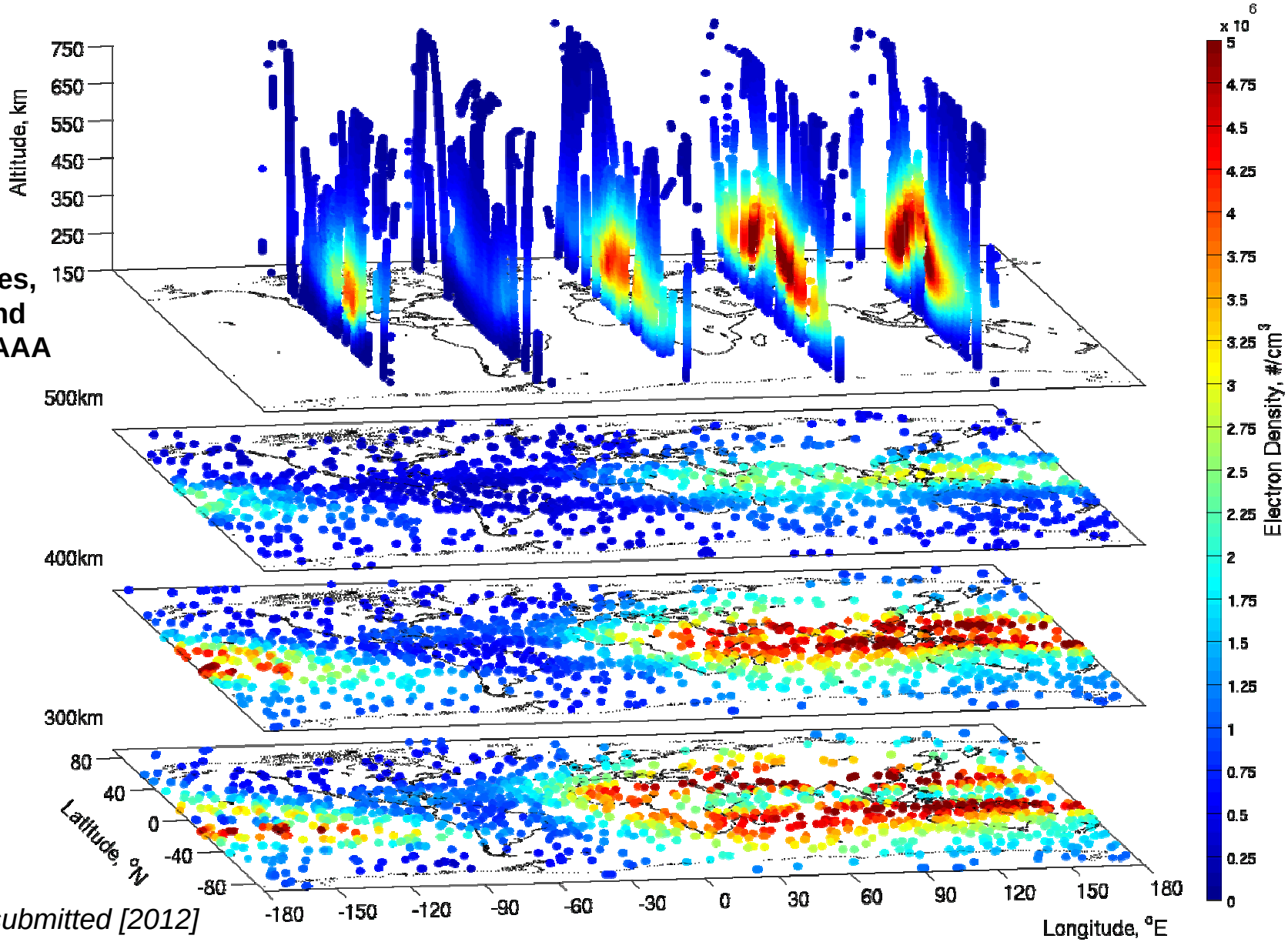
Latitudinal slices are at -120°, -60°, 0° 60° and 120° longitude with a interval of ±2.5°.

- Solar activity variations
- Seasonal variations
- Monthly variations
- Tidal effects
- Diurnal variations
- Semi-diurnal variations
- Disturbed period effects
- Other temporal variations
- Irregularities

Could it be advanced by F7/C2 ?

Simulated F7/C2 observations at 08:00 UT within 1 hour x 1 day accumulation period

12 satellites,
28 GPS and
24 GLONAAA



Lee et al. submitted [2012]


FORMOSAT-7
Thank you!!!
NSPO
20
Years In Space