Variations of the Topside Ionospheric and Plasmaspheric Electron Content Derived from the COSMIC podTEC Observations and Comparison with the IZMIRAN_Plas Model Results

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Introduction

- The total electron content (TEC) is one of the most important parameters which is required by many users for different modern usage purposes such as ionospheric range error correction required by geodetic community.
- TEC is contributed by both the ionosphere and the plasmasphere. Although Ne(h) in the plasmasphere is much smaller than that in the ionosphere, the altitude range of the plasmasphere is much larger than that of the ionosphere. Therefore the contribution of the plasmasphere to TEC could not be ignored.
- Extension of the IRI model to the plasmasphere is one of the goals of the IRI community. The IZMIRAN_Plas (=IRI_Plas) model is one of the candidate models for this extension. Validation study on this model using observational data is very important.
- Here we present our preliminary study results on the variations of the topside ionospheric and plasmaspheric electron content derived from the upward-looking TEC measurements by receivers on board the COSMIC LEO satellites to GPS signals and compare with the IZMIRAN_Plas model results.

Source Data Used

- **podTEC dataset archived in the COSMIC Data Analysis and Archive Center (CDAAC, http://cosmic-io.cosmic.ucar.edu/cdaac/index.html) for the years 2008 and 2012 are used for the present study.**
- **podTEC is the upward-looking TEC measurement of the COSMIC low Earth orbit (LEO) satellite's precise orbit determination (pod) antenna to the GPS signals.**
- **Data are divided into four groups according to the following four defined seasons:**

March Equinox:	**--March, April.**
June Solstice :	**--May, June, July, Aug.**
September Equinox :	**--Sep., Oct.**
December Solstice :	**--Jan. , Feb., Nov., Dec.**

Method to Derive TPEC from podTEC

$$TPEC = podTEC \times f(\varepsilon)$$

$$f(\varepsilon) = \frac{\sin \varepsilon + \sqrt{(R_{ppt} / R_{orb})^2 - (\cos \varepsilon)^2}}{1 + R_{ppt} / R_{orb}}$$

$$R_{ppt} = R_e + H_{ppt}$$

$$R_{orb} = R_e + H_{orb}$$

Foelsche and Kirchengast, GRL, 2002

Yue et al., Space Weather, 2011

TPEC—Topside ionospheric and Plasmaspheric Electron Content (for the present study，altitude range: ~800-20200km);

podTEC—Upward looking TEC measurement of the COSMIC Low Earth Orbit satellite's precise orbit determination antenna to GPS signals;

ε—elevation angle of the LEO-GPS ray path;

R_e—Earth Radius;

H_{ppt}—altitude of the pierce point of the LEO-GPS ray path in the plasmasphere;

H_{orb}—altitude of the COSMIC LEO satellite (~800km)

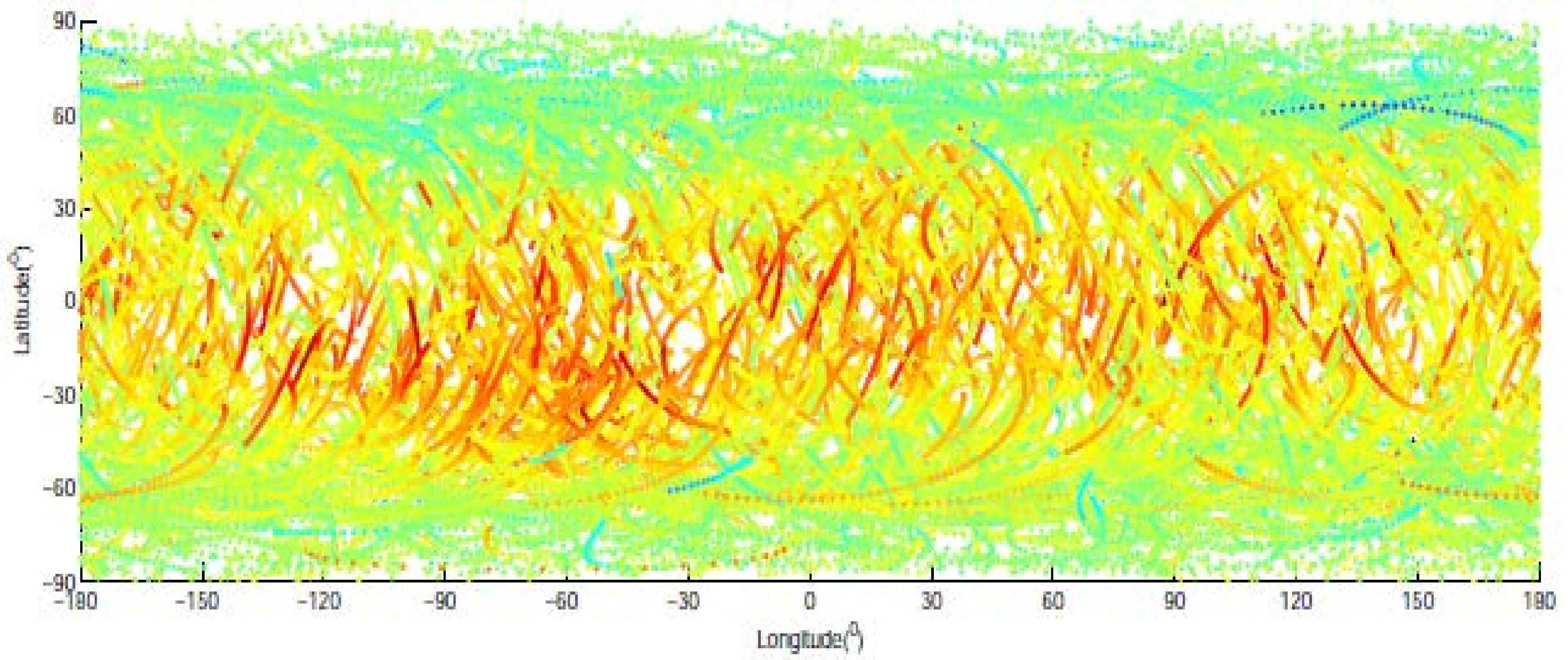

Fig.1 An example showing the global distribution of the *TPEC* derived from the podTEC measurement on board the COSMIC LEO satellites to GPS signals for the whole day of January 27, 2008.

IZMIRAN-Plas (=IRI-Plas) Model

- **Recently, the International Standardization Organization (ISO) recommended the IRI model for the specification of the ionosphere plasma densities and temperatures and listed several plasmasphere models for extending IRI to plasmaspheric altitudes [Gulyaeva and Bilitza, 2012]. The IZMIRAN_Plas has been proposed as one of candidate model for the plasmasphere extension of the IRI model.**

- **IZMIRAN_Plas = IRI2001 + Plasmasphere Model developed by the Institute of Terrestrial Magnetism, Ionosphere and Radiowaves Propagation, Russian Academy of Sciences**

- **It is an empirical model based on whistler and satellite observations. It presents global vertical analytical profiles of electron density smoothly linked with the IRI (Version 2001) electron density profile at altitude of one basis scale height above the F2 peak and extended towards the plasmapause up to 36000km.**

Gulyaeva, T., Bilitza, D., 2012. Towards ISO Standard Earth Ionosphere and Plasmasphere Model, in New Developments in the Standard Model, pp. 1-48. Editor: Ryan J. Larsen., ISBN: 978-1-61209-989-7, ©Nova Science Publishers, Inc.

Results

1. Latitudinal, Diurnal and Seasonal Variations of TPEC

Latitudinal, Diurnal and Seasonal Variations of TPEC

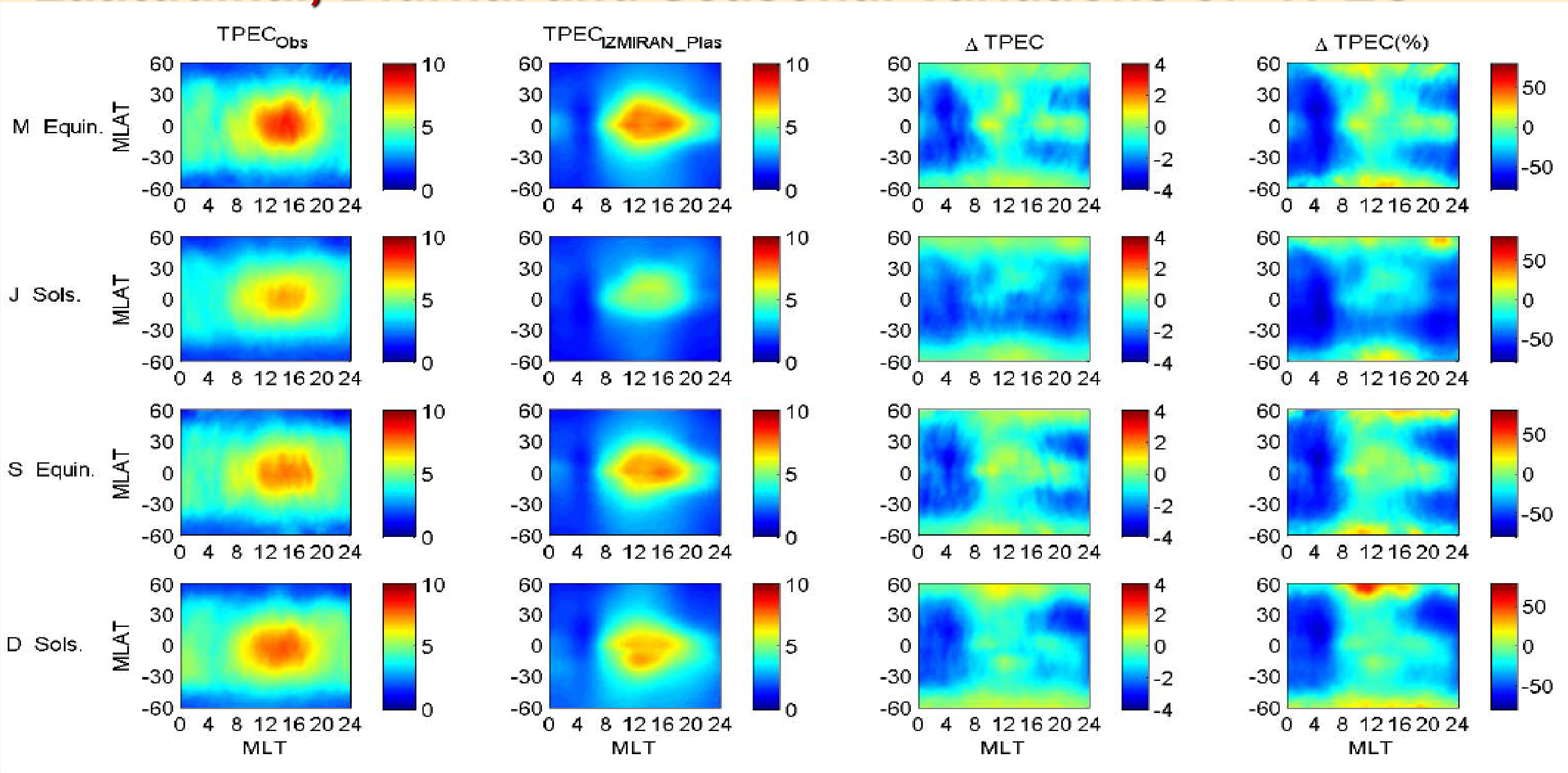

Fig.2 Observed TPEC variations and comparison with IZMIRAN_Plas result for the year 2008

For the year 2008:

- ➔ **The observed TPEC is mainly confined to a region of $\pm 45^0$ of the magnetic equator of the Earth; TPEC has maximum value around 12-16MLT and minimum value around 4-5 MLT； TPEC has lowest value in the June Solstice season.**
- ➔ **IZMIRAN_Plas model captured the seasonal variation tendency, however, it generally underestimate the observed TPEC values, particularly in the low-latitude region during nighttime hours.**

Latitudinal, Diurnal and Seasonal Variations of TPEC

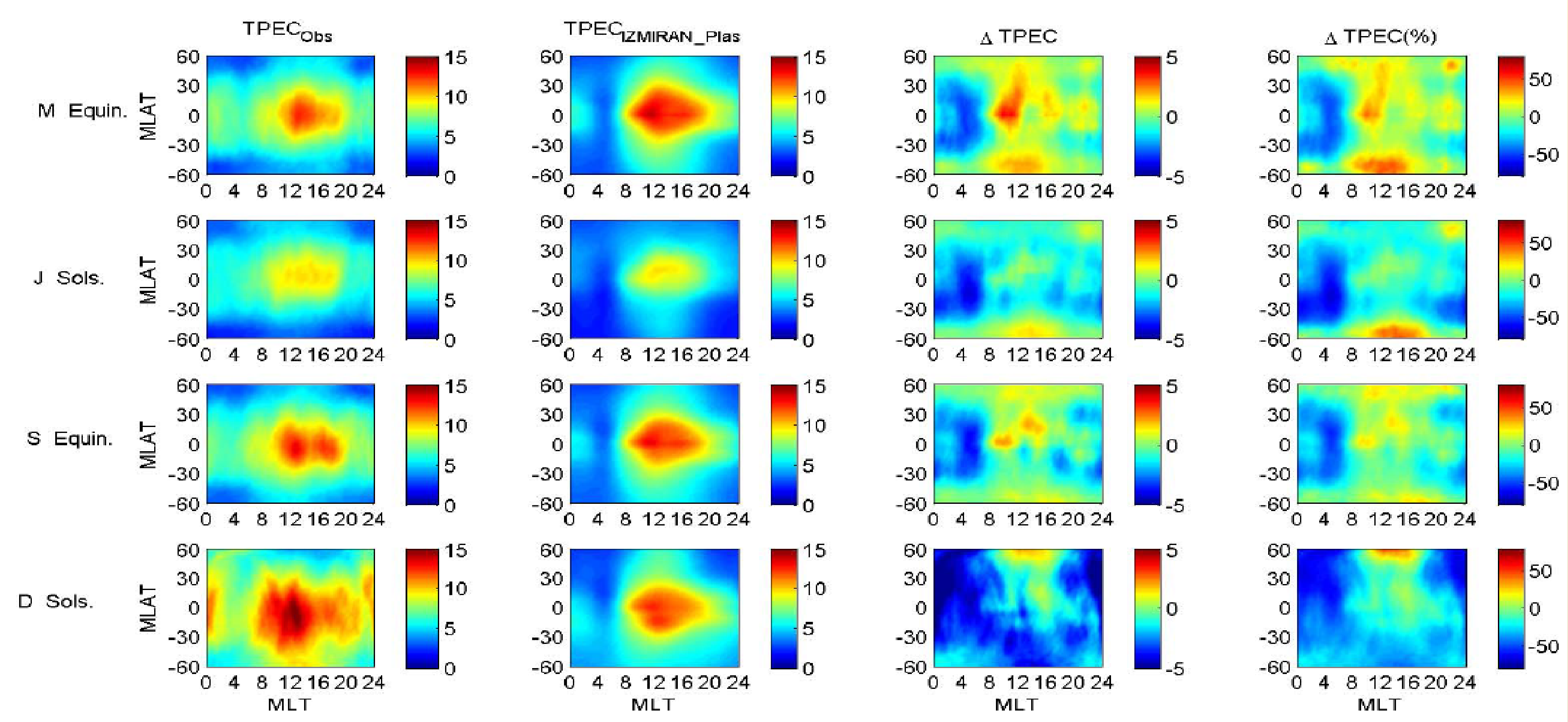

Fig.3 Observed TPEC variations and comparison with IZMIRAN_Plas results for the year 2012

For the year 2012:

- ➔ **TPECobs shows a strong annual variation with highest value in D-Solstice season. IZMIRAN_Plas model doesn't capture this annual variation of TPECobs;**
- ➔ **During nighttime hours, IZMIRAN_Plas generally underestimates TPECobs values, particularly in the low-latitude region ;**
- ➔ **For the day-time hours, IZMIRAN_Plas produces reasonably well the TPECobs value for the J Solstice and S Equinoctial seasons;However, it overestimates the TPECobs value in the M Equinoctial and underestimates the TPECobs value in the D Solstice season.**

Results

2. Longitudinal Dependence of TPEC's Seasonal Variations

Longitudinal Dependence of TPEC's Seasonal Variations

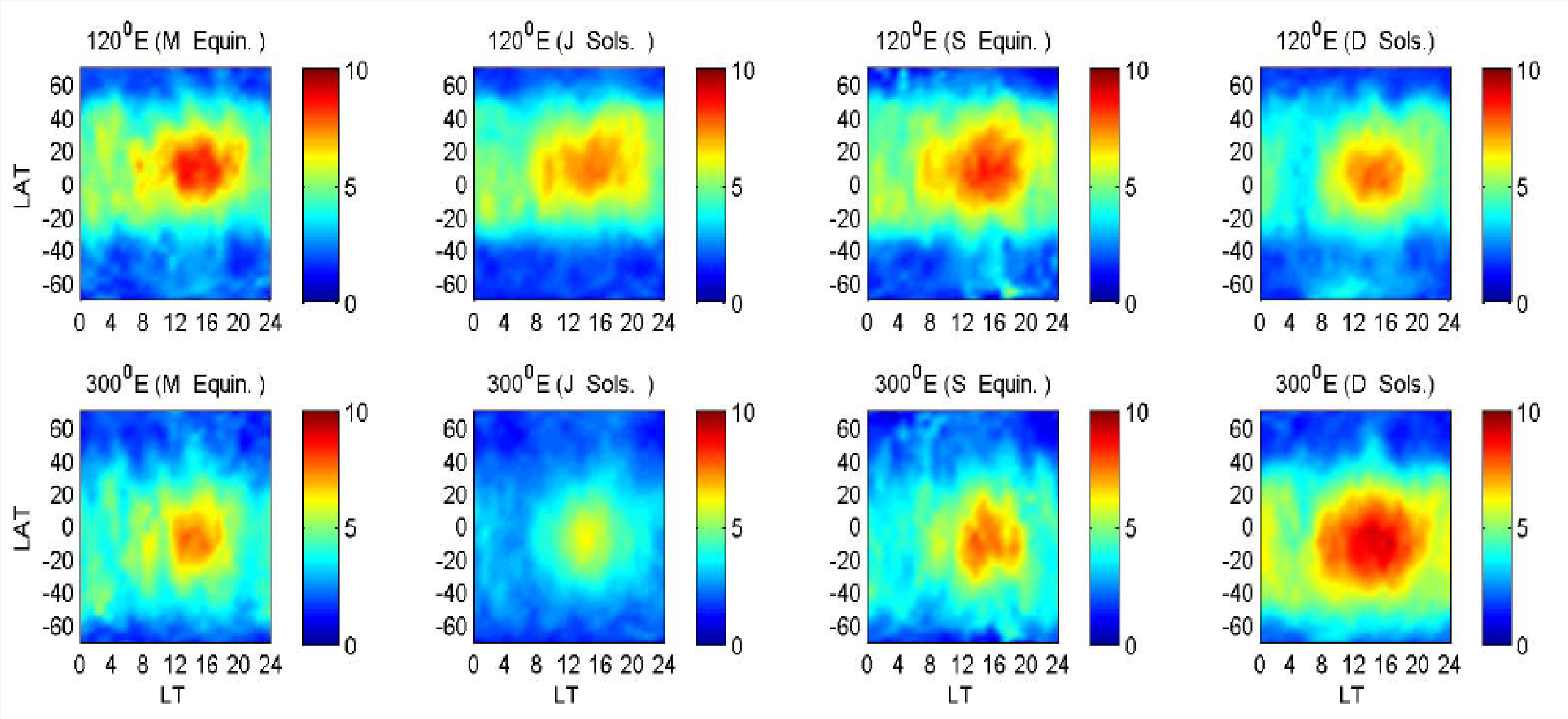

Fig. 4 The seasonal variations of the observed TPEC at 120^0E (upper) and 300^0E (bottom) for the year 2008.

- ➔ **120^0E: Week Semi-annual Variation**
- ➔ **300^0E: Strong Annual Variation**

Longitudinal Dependence of $TPEC_{OBS}$ Seasonal Variations

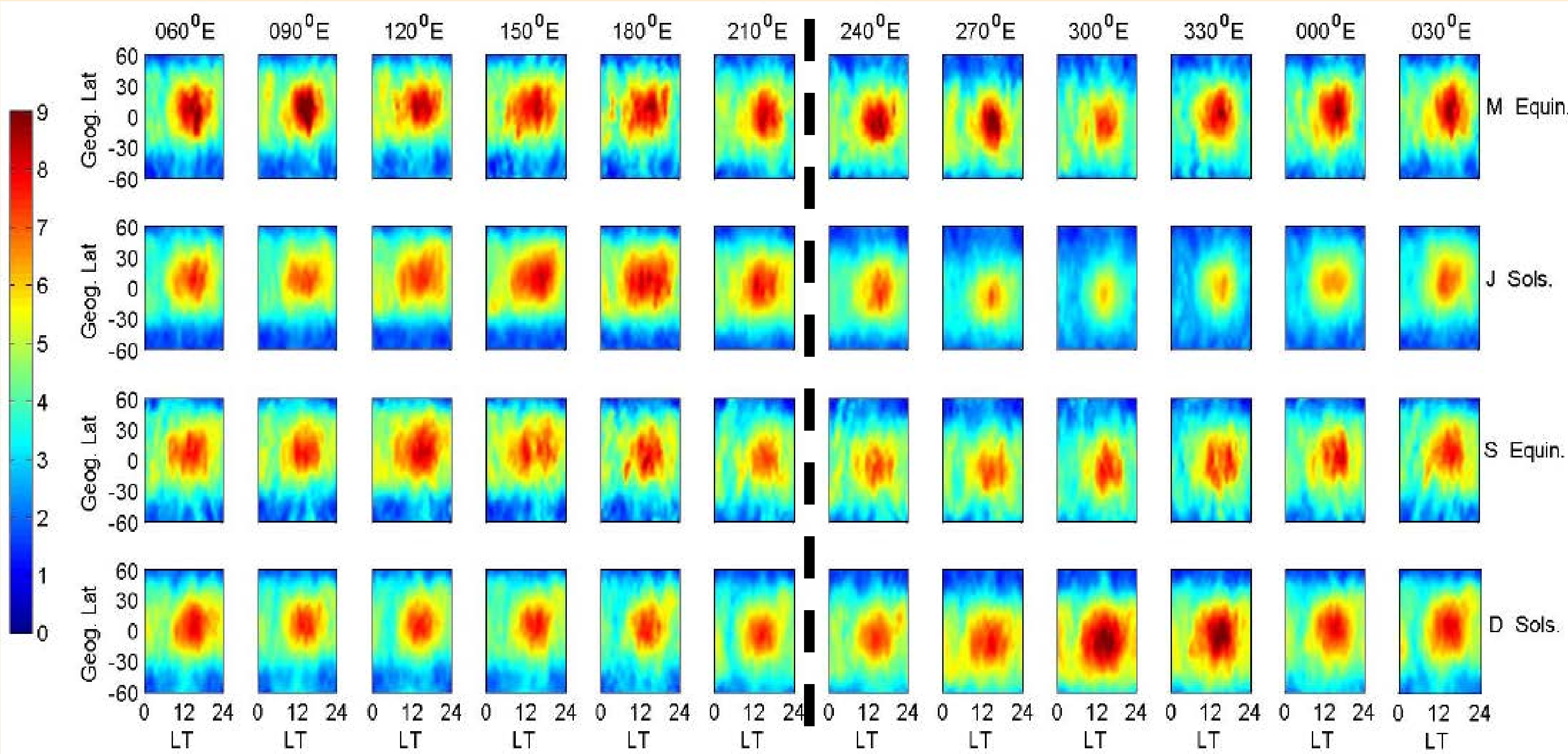

Fig.5 Seasonal variation of the observed TPEC at different longitudes for 2008.

- **60^0E-240^0E: Seasonal variations are weak**
- **240^0E-60^0E: Strong annual variation , TPEC(D Sslight ols.)>>TPEC(J Sols.)**

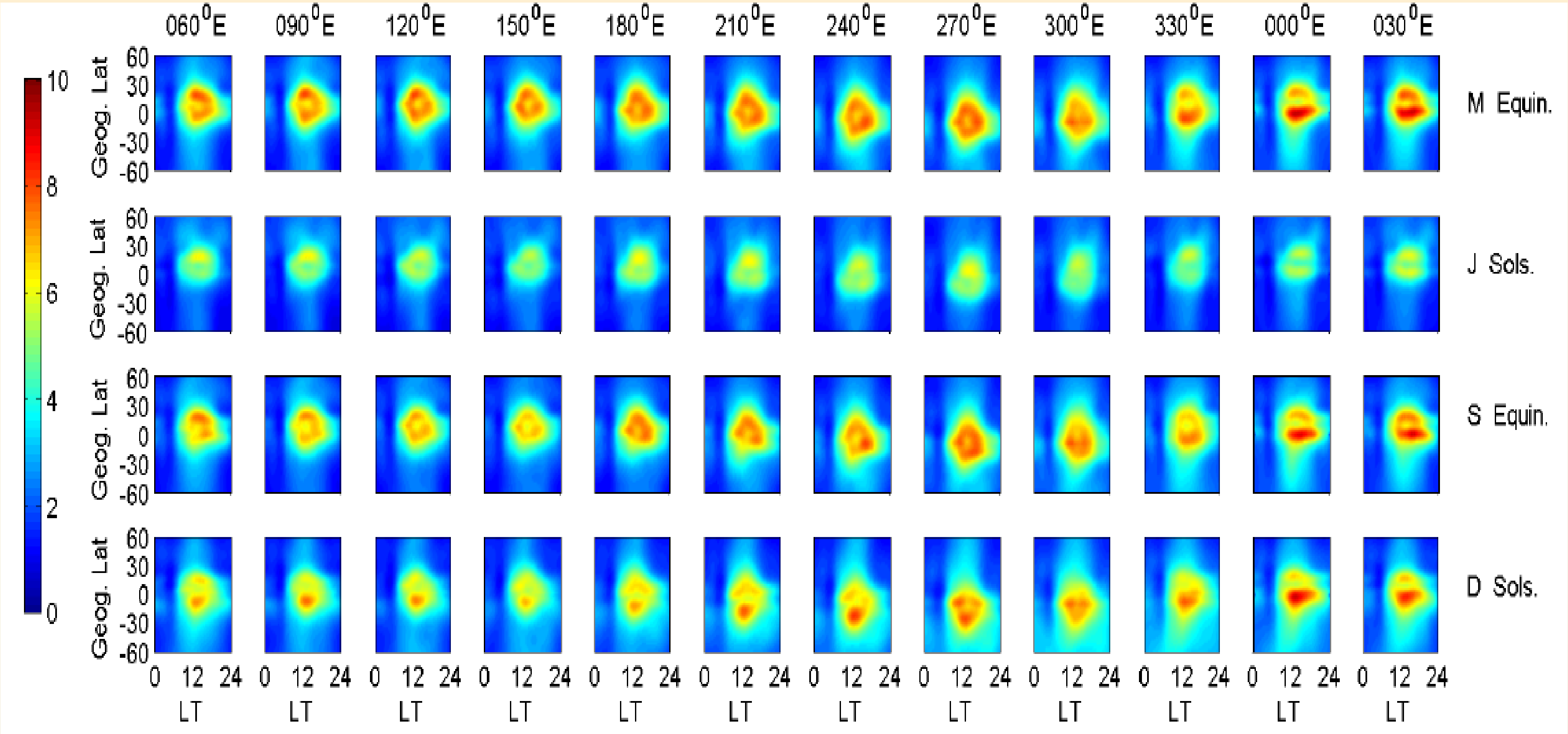

Fig.6 Seasonal variation of IZMIRAN_Plas Model produced TPEC at different longitudes for the year 2008.

- The longitudinal dependence feature of the observed *TPEC*'s seasonal variation is not captured well by the IZMIRAN_Plas model
- IZMIRAN_Plas model results tend to show a double-peak feature in the low-latitude region, which is not observed in the observational TPEC results

Longitudinal Dependence of $TPEC_{OBS}$ Seasonal Variations

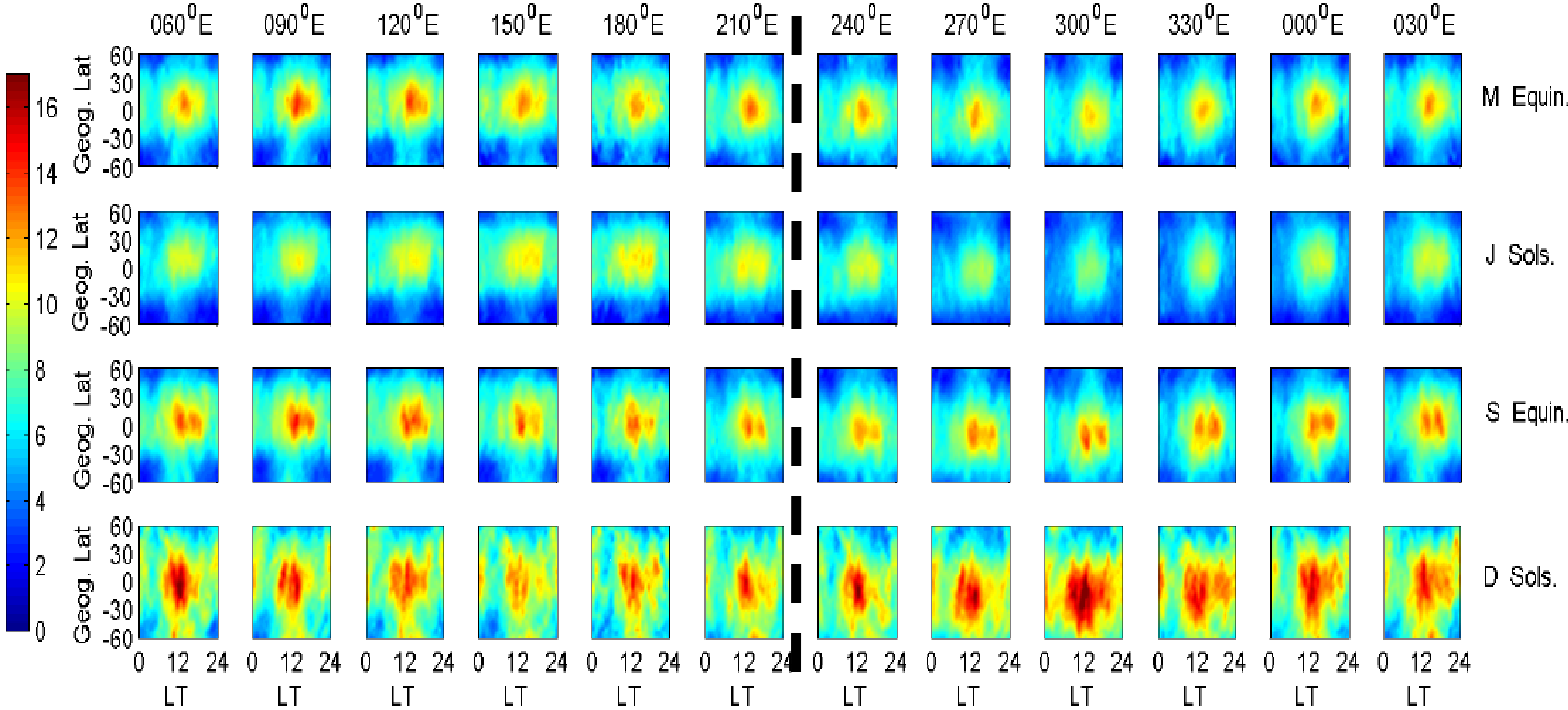

Fig.7 Seasonal variation of the observed TPEC at different longitudes for 2012.

- **240^0E-60^0E: Strong annual variation with TPEC(D Sols.)>>TPEC(J Sols.)**
- **60^0E-240^0E: Much weaker seasonal variations are observed for TPEC**

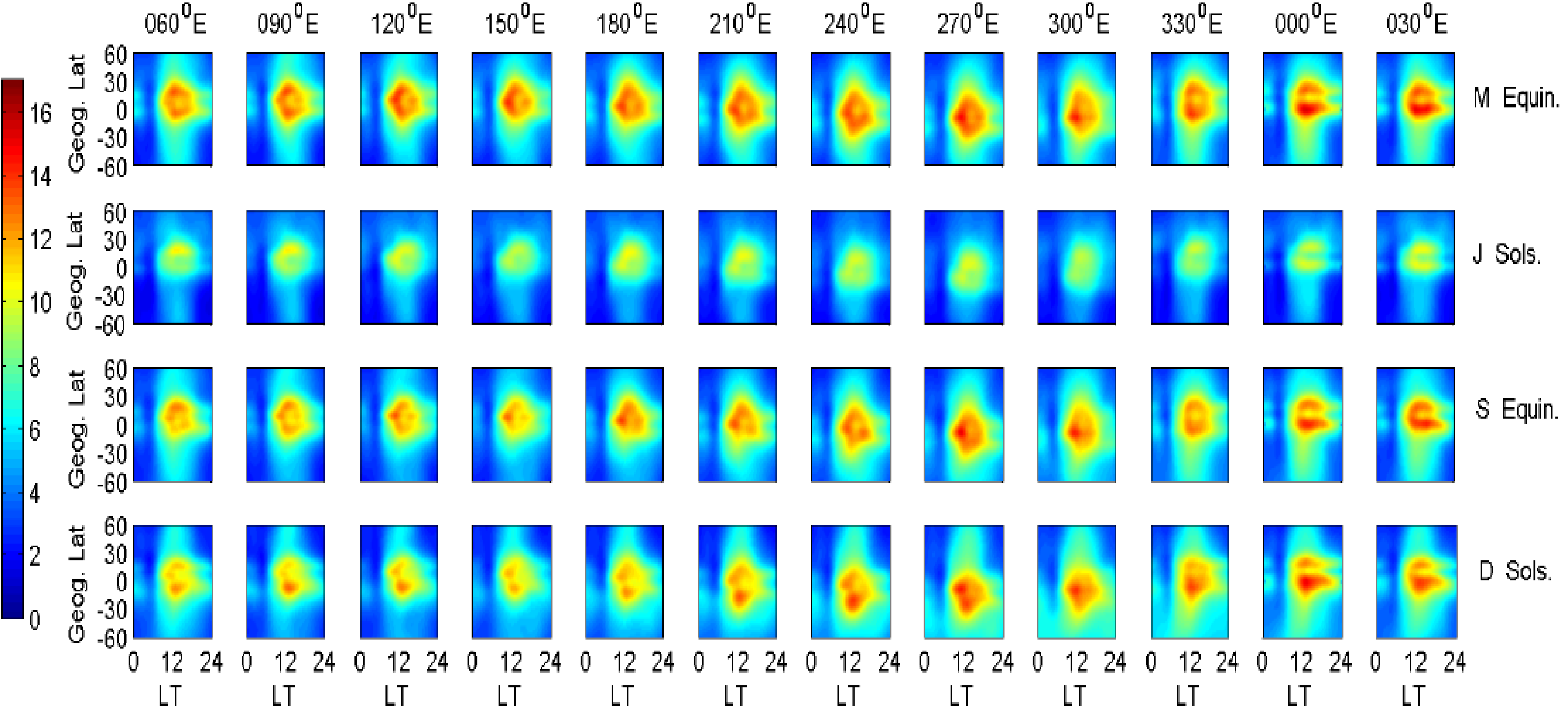

Fig.8 Seasonal variation of IZMIRAN_Plas Model produced TPEC at different longitudes for the year 2012.

- The longitudinal dependence feature of the observed *TPEC*'s seasonal variation is not captured well by the IZMIRAN_Plas model
- IZMIRAN_Plas model results tend to show a double-peak feature in the low-latitude region, which is not observed in the observational TPEC results

Summary and Conclusions

Our study showed that:

1) **The distribution of the observed TPEC is mainly confined to a region of $\pm 45^0$ of the magnetic equator of the Earth;**
2) **TPEC shows a well-defined diurnal variation pattern with higher values during daytime hours than during nighttime hours. TPEC reaches its peak value hours around 12-16MLT, whereas it reaches its minimum value around 4-5 MLT.**
3) **TPEC has a lowest value in the June Solstice season compared with other seasons.**
4) **Except for the day-time hours in the M Equinoctial season of the year 2012 when it overestimates the observed TPEC values, the IZMIRAN_Plas model results generally underestimate the observed TPEC values, in particular at nighttime hours.**

Summary and Conclusions

5) **The seasonal variations of the observed TPEC shows a longitudinal dependence: for the 240-60^{0}E longitudinal sector, TPEC shows a strong annual variation with lowest value in the June solstice and highest value in the D. solstice months; In contrast, very weak seasonal variations are observed for TPEC at 60-240^{0}E longitudinal sector.**

6) **The longitudinal dependence feature of the observed TPEC's seasonal variations is not captured well by the IZMIRAN_Plas model result. Moreover, the IZMIRAN_Plas model results tend to show double peaks in the low-latitude region, a feature not appearing in the observational results.**

Thank you !