Database of Jason-2 Plasmaspheric Electron Content for Validation and Correction of IRI-Plas Model

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Outline

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Introduction-1

- To derive information on the vertical structure of the ionosphere and plasmasphere from TEC, one needs to apply a 3D ionospheric model. The IRI-Plas code available online at http://ftp.izmiran.ru/pub/izmiran/SPIM/ is a 3D interpolator of TEC for reconstruction of electron density distribution $Ne(\varphi, \lambda, h)$ profile at altitudes from 65 km to 20,200 km (GPS orbit).
- A unique data of the plasmaspheric electron content, pTEC, are measured through the plasmasphere over the Jason-2 orbit (1335 km) to the GPS orbit altitude (20,200 km) from GPS receiver placed onboard Jason-2 with a zenith looking antenna that can be used not only for precise orbit determination (POD), but can also provide new data on the plasma density distribution in the plasmasphere.

Introduction-2

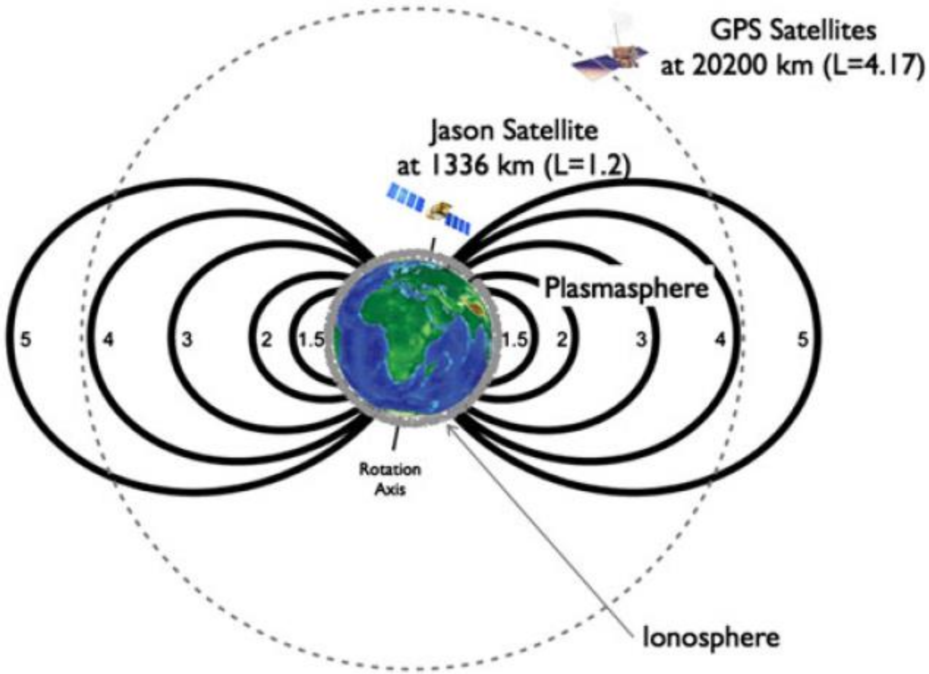


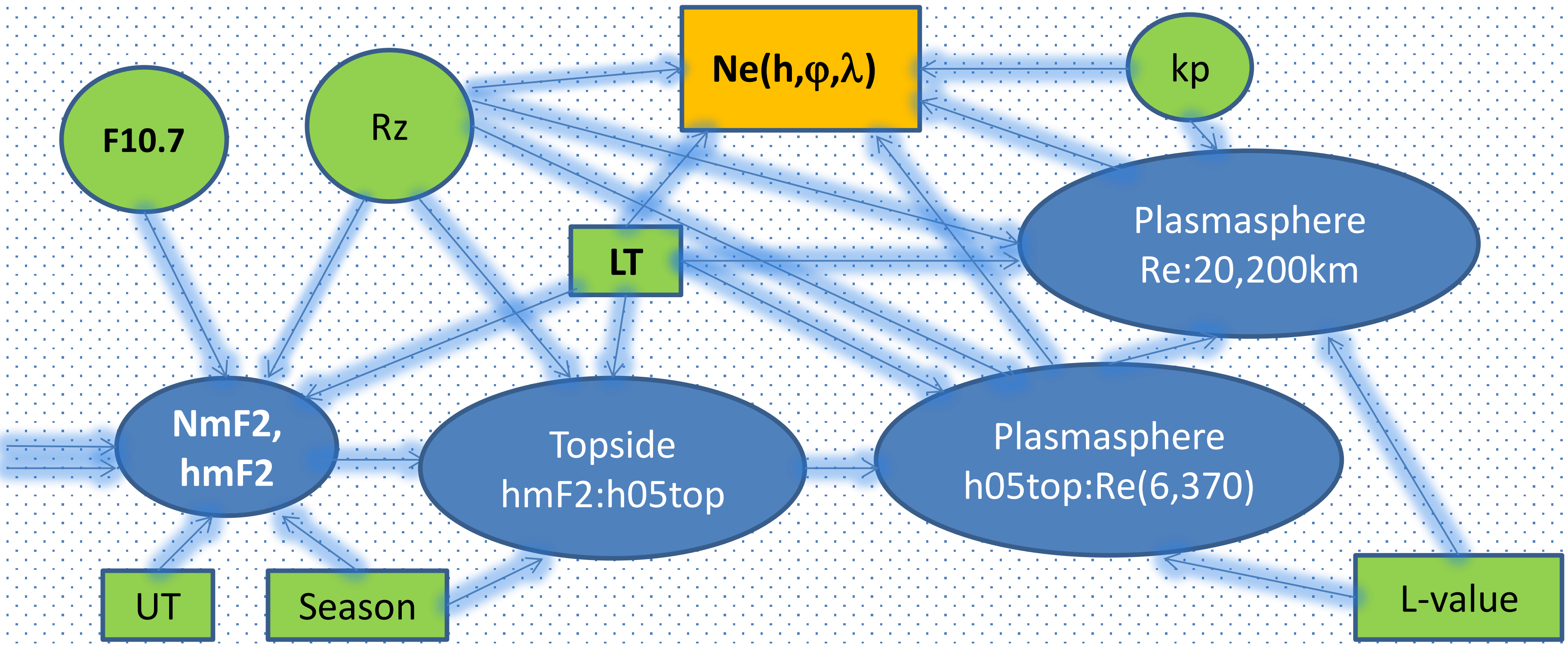
Figure 1 by *Jee et al. [JGR, Space Physics, 118, 1-12, 2013]* illustrates Jason-1 satellite measurements of the ionospheric ***iTEC*** from the satellite orbit (1336km) to ocean surface and also the plasmaspheric ***pTEC*** from the onboard GPS receiver to GPS satellite orbit (20200 km) simultaneously:

TEC = iTEC + pTEC

The present study is focused on a comparison of the pTEC predictions provided by the IRI-Plas model with a unique data base of the plasmasphere electron content, pTEC, using GPS measurements onboard the Jason-2 satellite at the altitudes from 1335 km (Jason-2 orbit) to 20,200 km (GPS orbit) for 24 hours of local time during four seasons at the solar minimum (2009) and solar maximum (2014).

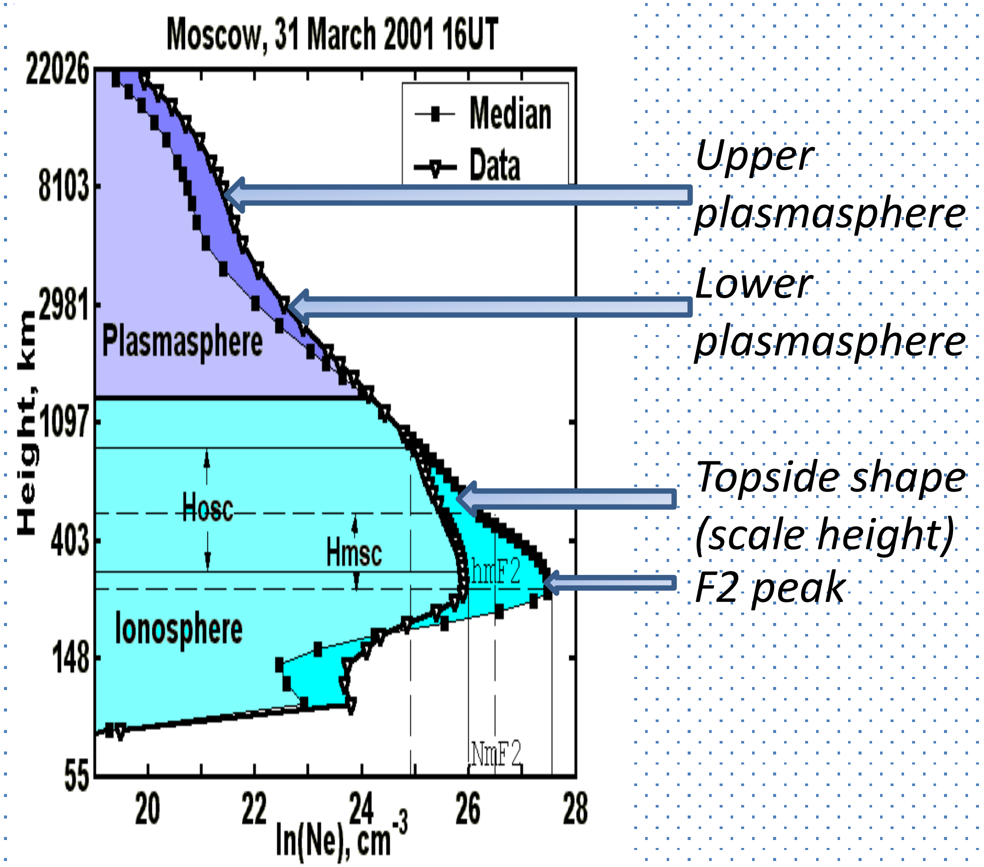
IRI-Plas pTEC model dependence on outer input and inside IRI-Plas parameters

$$pTEC(\varphi,\lambda) = \int_{h05top}^{20,200} Ne(h,\varphi,\lambda)\,dh$$



The example of IRI-Plas electron density profile adjusted to GPS-TEC observations

Structure of electron density Ne(h) profile through the ionosphere and plasmasphere (median ITU-R F2 peak prediction and instantaneous F2 peak adjusted to TECgps values feeding the IRI-Plas code)



TEC model comparison with GPS-TEC measurements at solar maximum (top panel) and solar minimum (bottom panel):

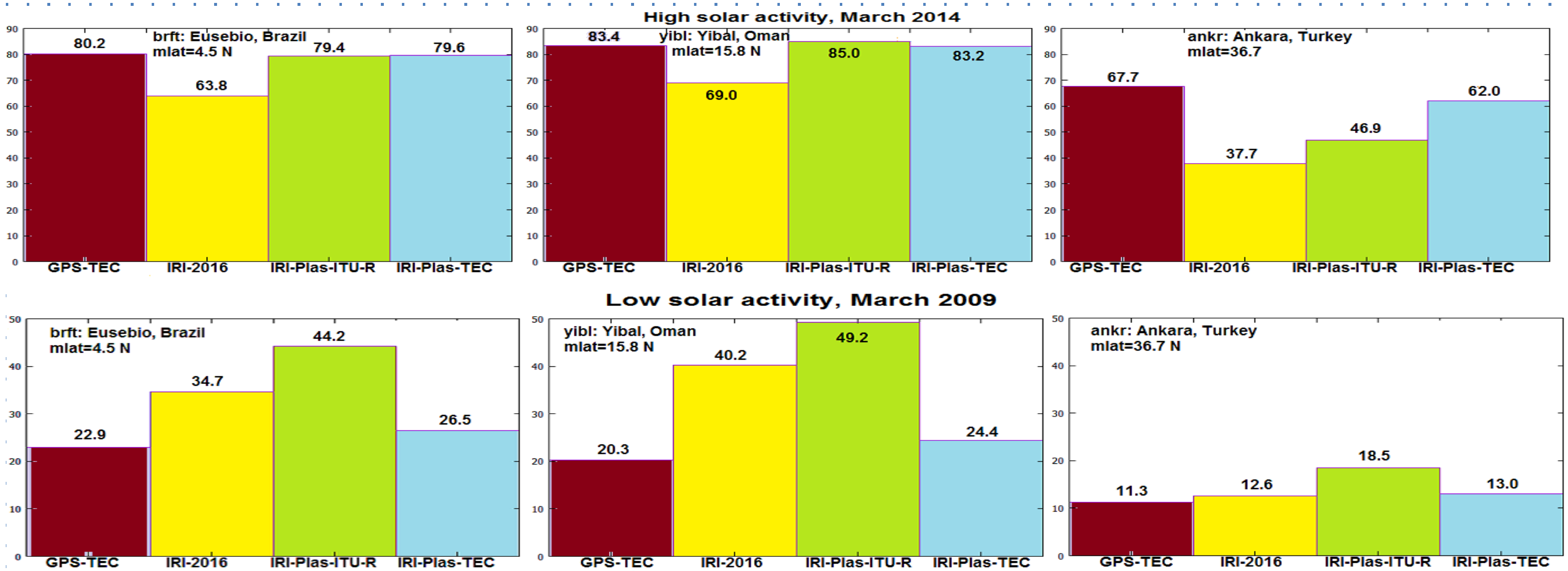
(1) The vertical GPS-TEC measurements at (0:20,200 km)

(2) IRI-2012 TEC prediction (80:2,000km)

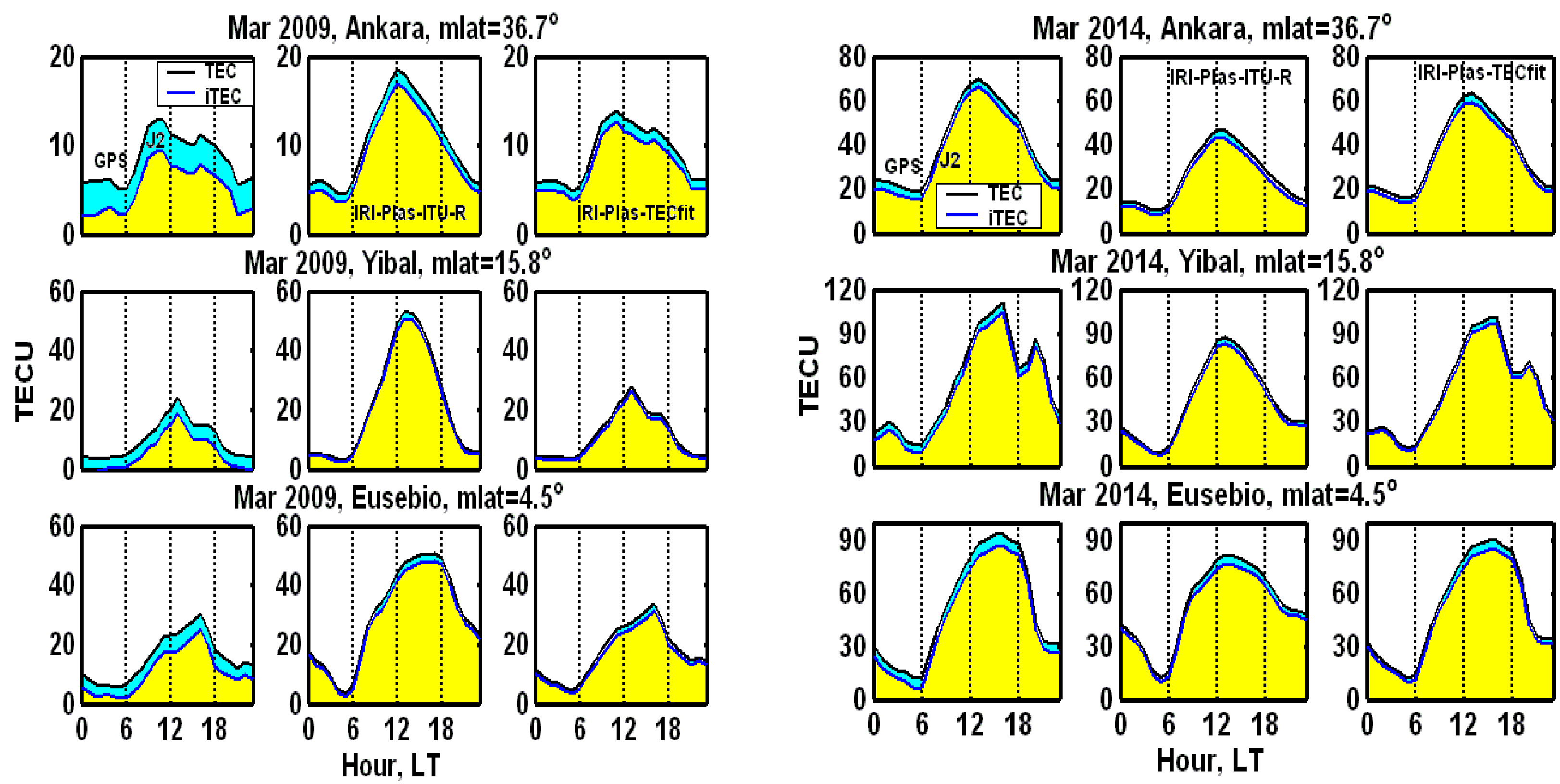
(3) IRI-Plas-ITU-R TEC predictions (80:20,200 km)

(4) IRI-Plas-TEC assimilation (80:20,200 km)

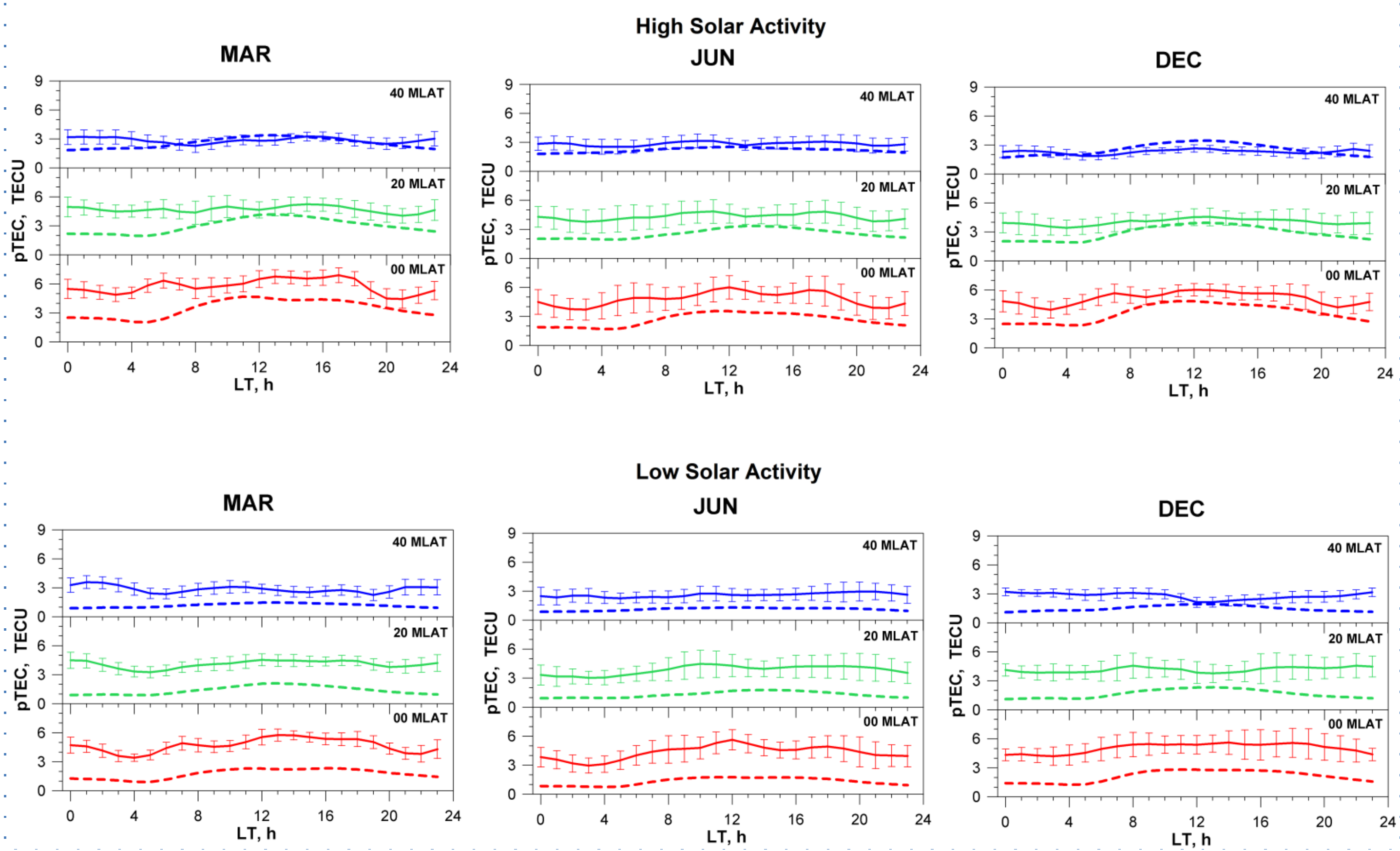
Local noon near geomagnetic equator (left), EIA crest (middle) and mid-latitude (right)



Diurnal variation of GPS-TEC including Jason-2 pTEC (1st col); IRI-Plas-ITU-R predictions (2nd col); IRI-Plas-TEC assimilation (3rd col). Equinox, solar minimum (left) and maximum (right) at *mid-latitude, EIA-peak and magnetic equator*. pTEC (blue) data - model comparisons are shown in the next slide.



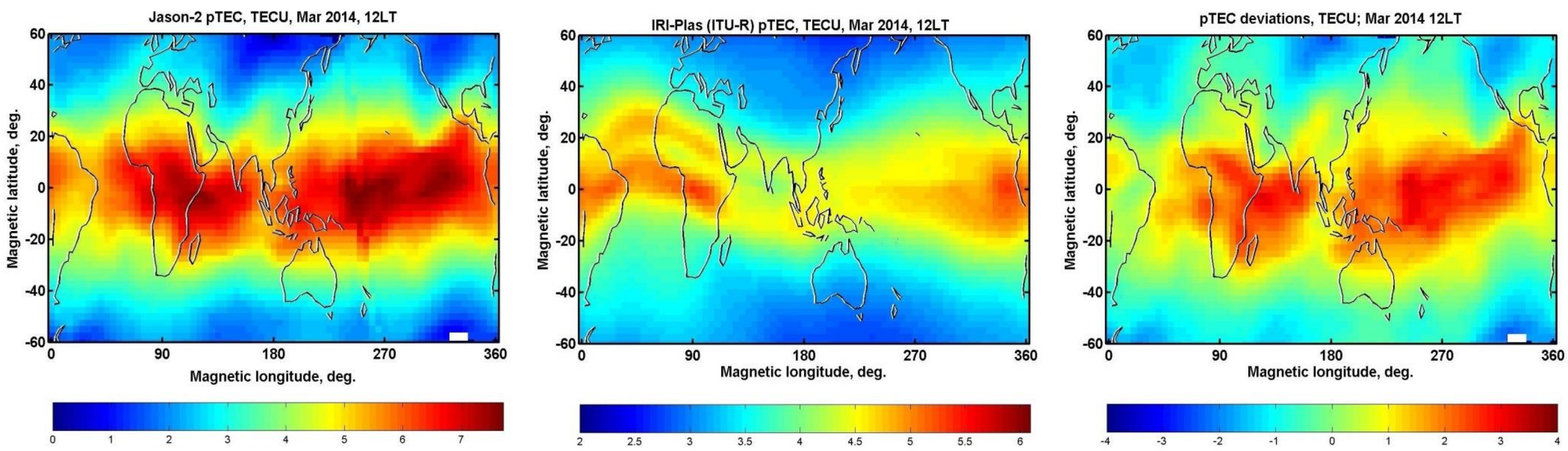
Model pTEC results (dashed lines) underestimate Jason2 pTEC data (solid lines) for 3 seasons and 2 levels of solar activity at three magnetic latitudes: 40°N (*mid-latitude*), 20°N (*EIA crest*) and 0° (*magnetic equator*)



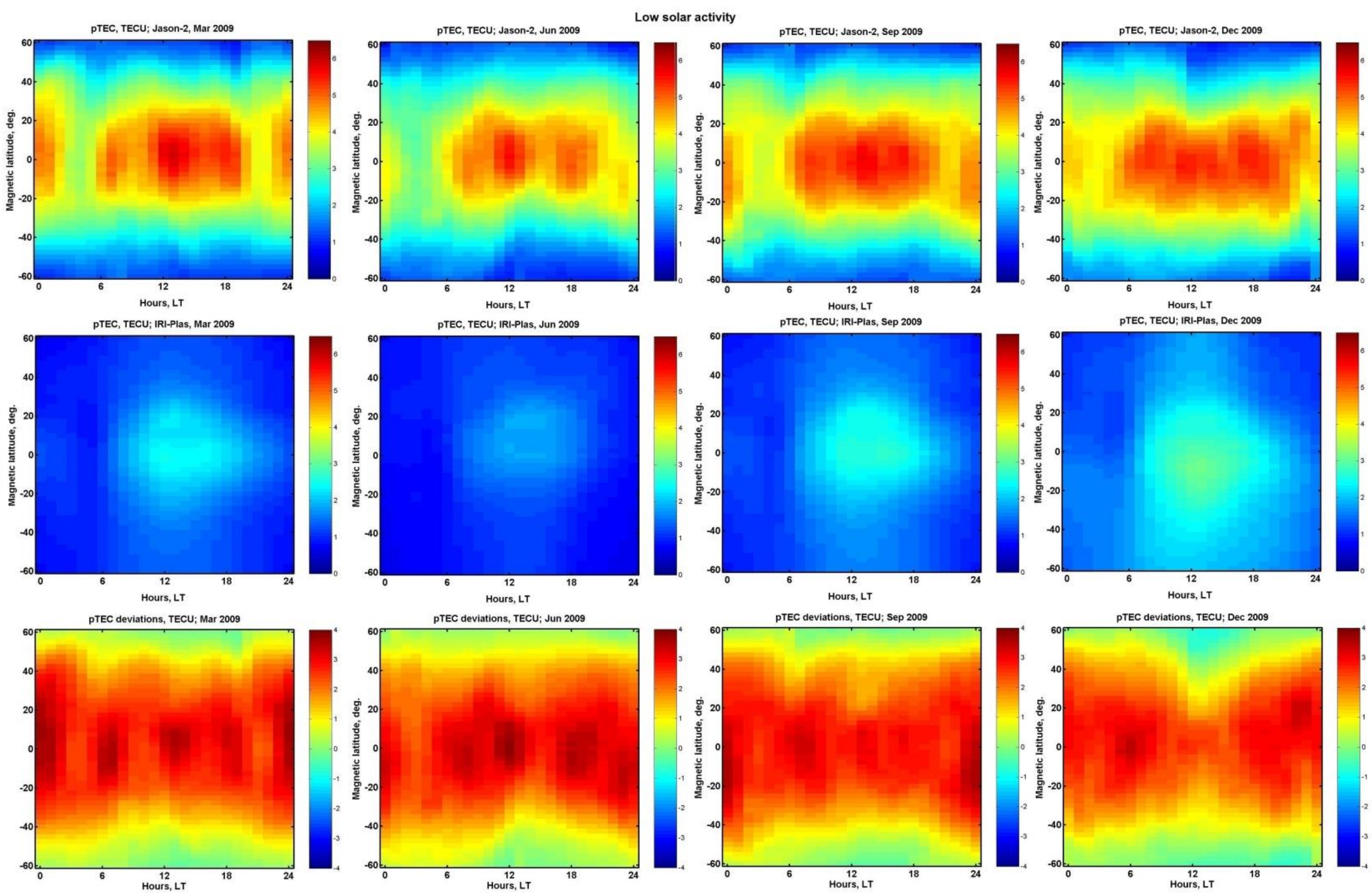
Jason-2 pTEC database

- The Jason-2 GPS POD measurements were processed to retrieve the topside pTEC values above the orbit altitudes of 1335 km. The details of the method for pTEC determination from LEO POD GPS measurements are described in [*Zakharenkova and Cherniak, 2015*].
- Slant pTEC values are scaled to estimate vertical pTEC using a geometric factor derived by assuming the plasma occupies a spherical thin shell at 1400 km.
- The elevation angle cut-off is selected as 40°.
- Global distribution of the POD TEC values is presented in the form of global pTEC maps that are made by projecting the pTEC values on the Earth from the ionosphere pierce point at the shell altitude.
- Along the satellite pass for each epoch we have pTEC values for several linked LEO-GPS simultaneously, that can be binned and averaged into map cells.
- The pTEC can be mainly obtained within 60°N-60°S geomagnetic latitudes range (plasmasphere location) due to the Jason-2 orbit inclination of 66°.

Maps (in magnetic latitude vs magnetic longitude frame) of plasmaspheric electron content, pTEC, measured by Jason-2 (left), produced with IRI-Plas-ITU-R model (middle) for equinox at high solar activity March 2014, 12h LT and their difference ΔpTEC = pTECobs-pTECmodel (right panel).



pTEC map in <Magnetic latitude – LT> frame for 4 seasons/months at LSA, 2009: Jason-2 (top), IRI-Plas (middle), data-model deviation ΔpTEC (lower panel)



pTEC map in <Magnetic latitude – LT> frame for 4 seasons/months at HSA, 2014: Jason-2 (top), IRI-Plas (middle), data-model deviation ΔpTEC (lower panel)

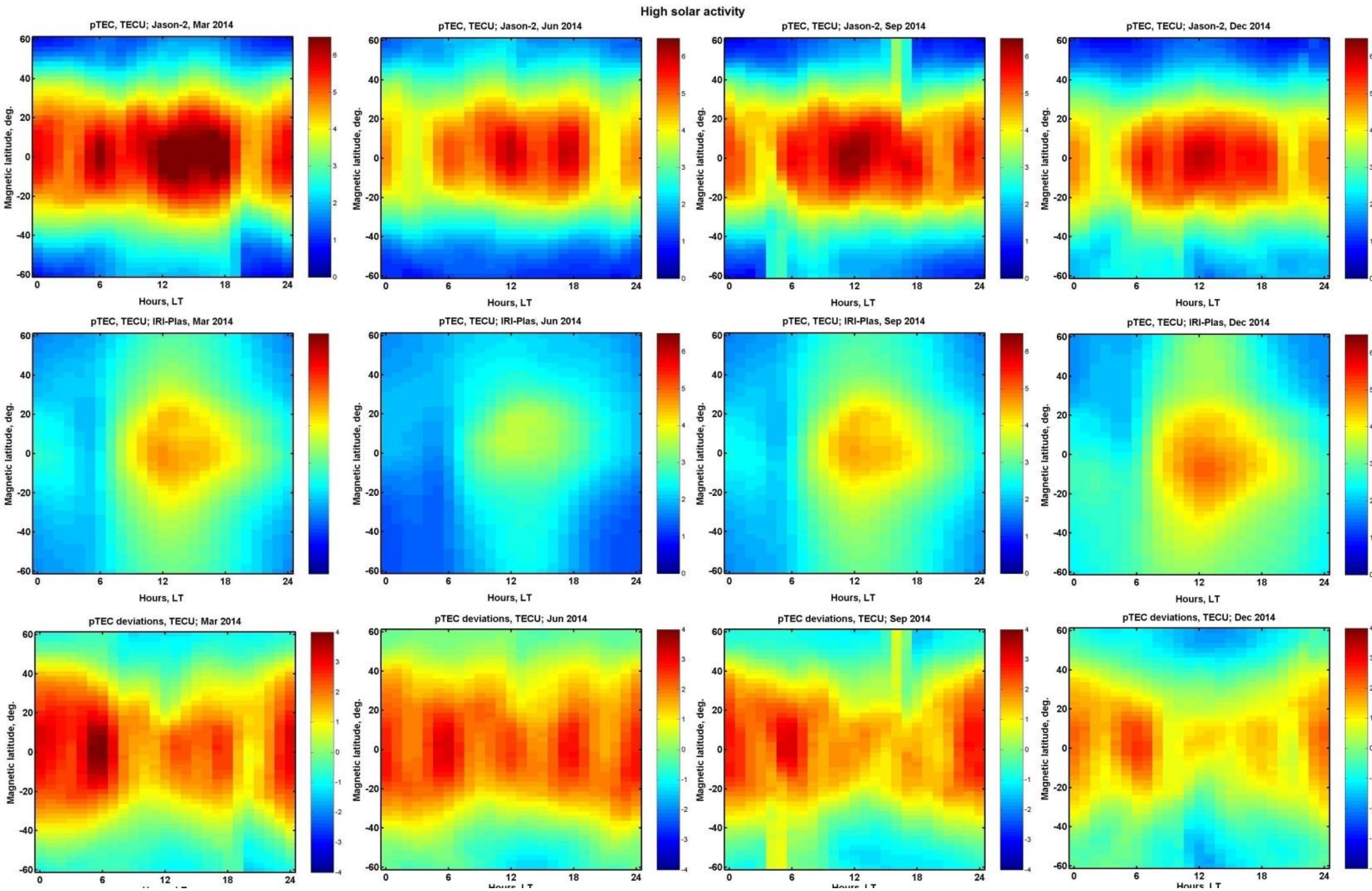


Table 1. The normalized root mean square error (NRMSE) between the 'true' pTEC data (*Xobs*) and those simulated with IRI-Plas model (*Xmodel*)

Year	2009				2014			
Month	03	06	09	12	03	06	09	12
NRMSE	.7106	.7853	.6778	.6244	.4754	.5394	.4614	.3953
n	99,127	98,087	98,597	98,407	98,738	98,732	94,476	98,220

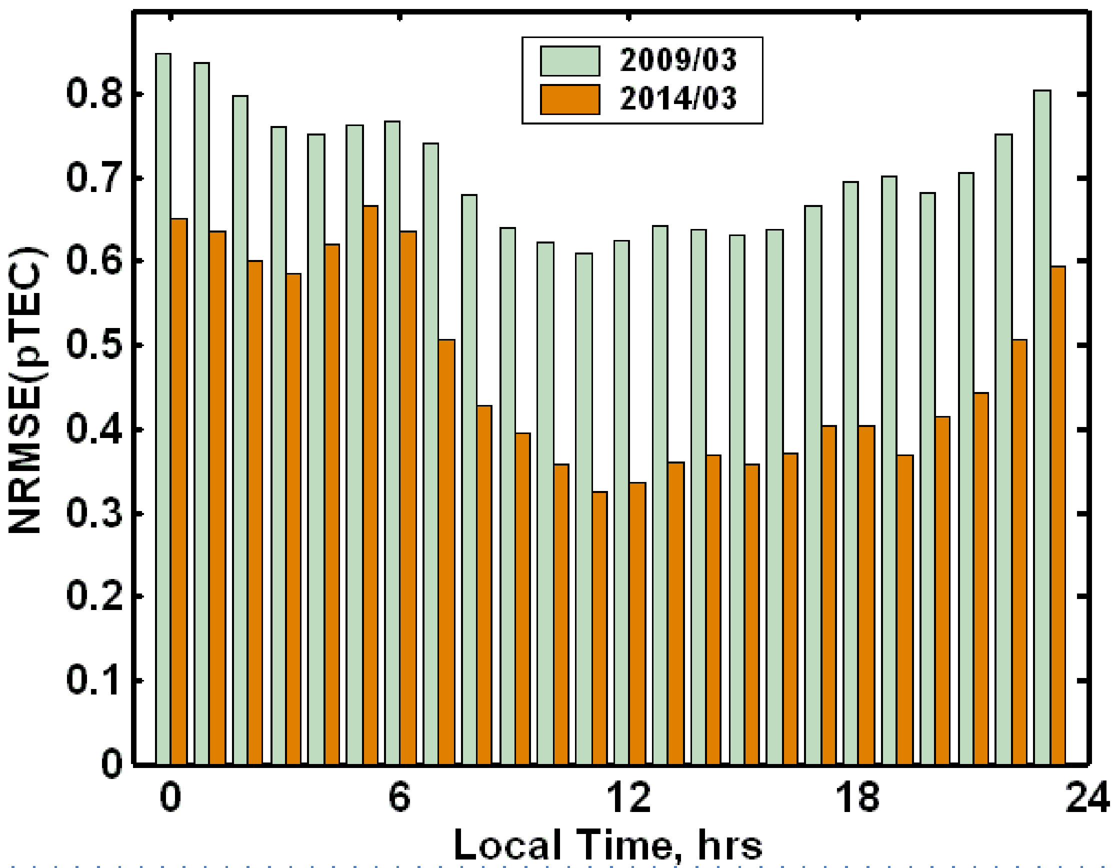
NRMSE presents RMSE normalized to the mean $\overline{Xobs}$ of the observed data for all cells *n* from all Local Time maps of pTEC:

$$NRMSE = \frac{RMSE}{\overline{Xobs}}$$

where

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(X_{obs,i} - X_{model})}{n}}$$

Local time NRMSE for low solar activity (March, 2009) exceeds NRMSE for high solar activity (March, 2014)



Global mean diurnal variation of pTEC and STD bars of Jason-2 data and IRI-Plas model results at four seasons for solar minimum (left) and solar maxiumum (right)

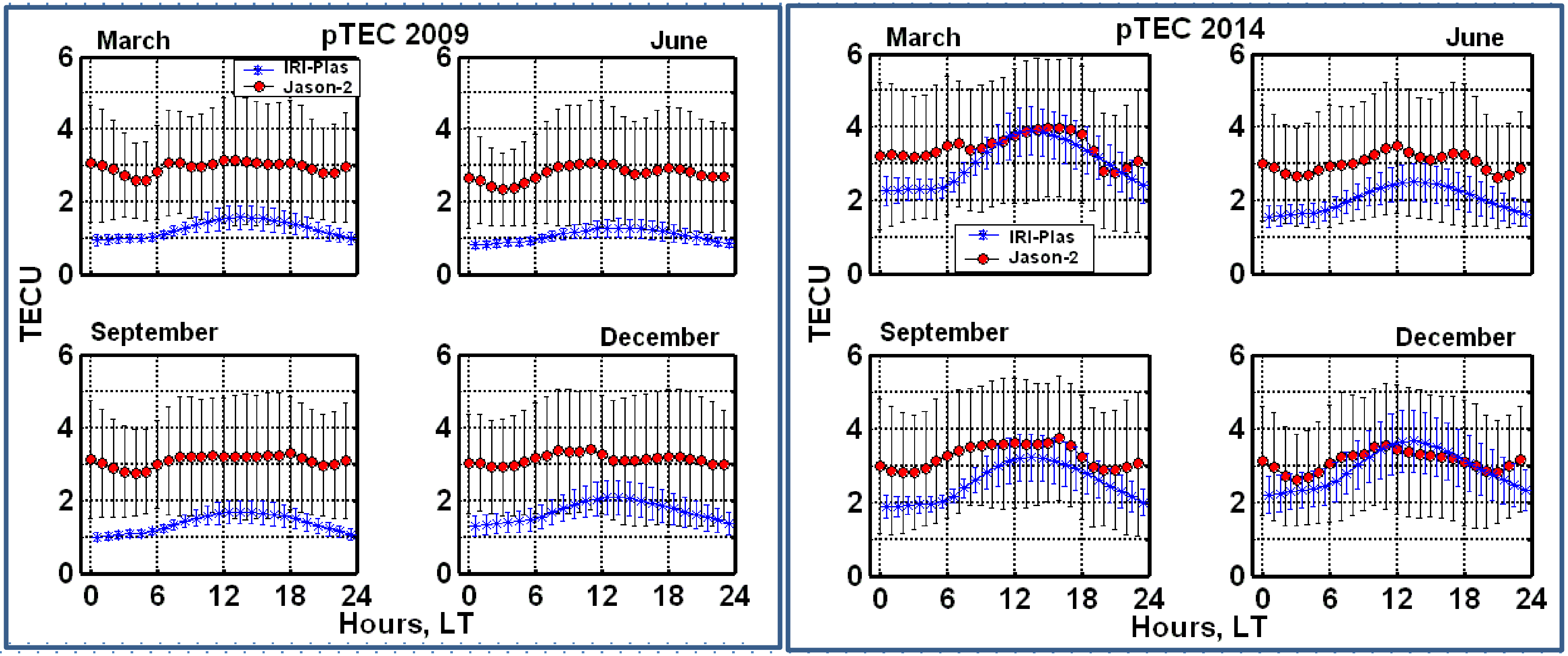


Table 2. pTEC mean and STD (TECU) from Jason-2 data and IRI-Plas model

	pTEC	std	pTEC	std	pTEC	std	pTEC	std
2009	Mar		Jun		Sep		Dec	
Jason-2	2.95	1.48	2.77	1.47	3.08	1.51	3.12	1.62
IRI-Plas	1.25	0.22	1.05	0.17	1.36	0.21	1.69	0.68
2014	Mar		Jun		Sep		Dec	
Jason-2	3.43	1.80	3.01	1.62	3.25	1.69	3.10	1.56
IRI-Plas	3.02	0.48	2.02	0.39	2.52	0.43	2.89	0.66

Summary and Conclusions

- Jason-2 pTEC maps show diurnal variation with denser plasmaspheric electron content at noon and towards geomagnetic equator at all seasons for low solar activity and high solar activity
- Jason-2 pTEC varies a little *with solar activity* from 3.0 TECU at *solar minimum* to 3.2 TECU at *solar maximum* while IRI-Plas pTEC is doubled from 1.3 at *solar minimum* to 2.6 TECU at *solar maximum*.
- pTEC results of IRI-Plas underestimate Jason-2 pTEC with the difference greatest at solar minimum and by night.
- The IRI-Plas pTEC model depends on the F2 peak, topside scale height of Ne(h) profile and numerous model driving parameters.
- The improvement of the *plasmasphere model* with Jason-2 pTEC measurements should include self-consistent model improvements of other IRI-Plas components such as NmF2 peak electron density and hmF2 and the topside scale height of electron density profile.

Acknowledgements

- The raw GPS measurements for the Jason-2 mission are provided through the NOAA CLASS Website
http://www.nsof.class.noaa.gov/saa/products/catSearch
- IRI-Plas model software is available at IZMIRAN web site
http://ftp.izmiran.ru/pub/izmiran/SPIM/
- The GPS-TEC data used for model-data comparison are provided by IONOLAB at
http://www.ionolab.org/
- The IRI-2016 model calculations are performed online at
http://omniweb.gsfc.nasa.gov/vitmo/iri2012_vitmo.html
- The authors are thankful to ICTP for the financial support for participation in the Beacon Satellite Symposium – 2016.

Thank you!