Evaluation of IRI-2012 by comparison with JASON-1 TEC and incoherent scatter radar observations during the 2008-2009 solar minimum period

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Introduction

- The International Reference Ionosphere (IRI) is the most widely used standard model for the ionospheric specification.

➢ It is an empirical model based on the extensive database obtained from satellites and ground-based observations.

- The 2008-2009 solar minimum period was unusual in terms of solar EUV level and its duration.

✓ The level of solar EUV was extremely low and the duration of low solar activity was longer than previous minimum periods.

➢ It should be difficult to expect for the data-driven model like the IRI to reasonably well reproduce the ionospheric parameters during this period.

- ***Lühr and Xiong*** [2010] compared the electron density of IRI-2007 with in-situ measurements of the satellite CHAMP and GRACE. They found that the IRI averagely overestimated the electron density at 400-500 km altitude by as high as 50 % and 60 % for 2008 and 2009, respectively.

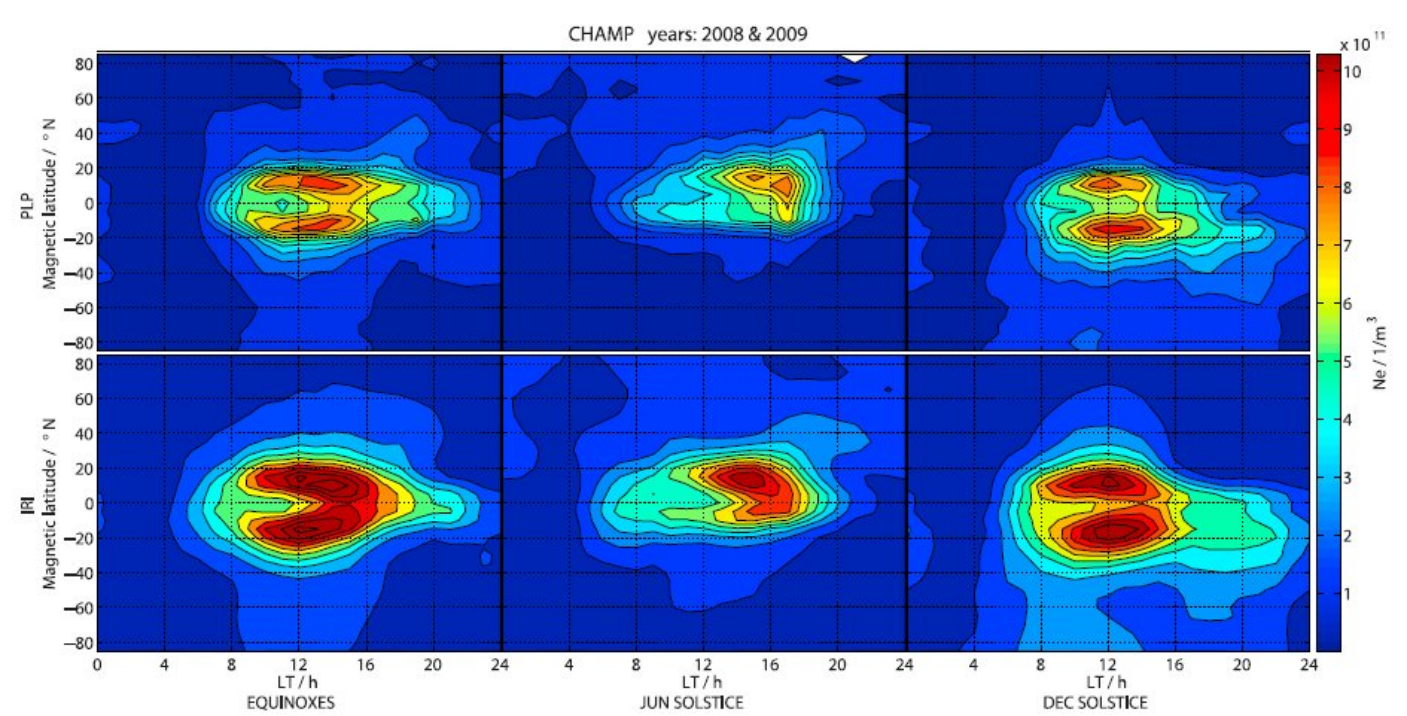


Figure 3. Distribution of electron density versus magnetic latitude and local time (averages over all longitudes) separately for the three Lloyd seasons. (top) CHAMP observations of the years 2008 and 2009, and (bottom) collocated IRI *Ne* predictions.

- ***Bilitza et al.*** [2012] further investigated *Lühr's* study by using ionosonde and C/NOFS satellite data at low and mid-latitude. Their results showed that NmF2 generally agree with measurements from ionosode but the IRI overestimated the topside ionosphere as in *Lühr's* study.

◆Research purpose

- Most of previous studies evaluated the IRI in the equatorial region. In order to **evaluate the IRI-2012 during the 2008-2009 solar minimum period on a global scale**, we utilize the **JASON-1 TEC data for the global ionosphere**.

- The results of the evaluation for the global ionosphere are further investigated by using the measurements of the **electron density profiles obtained from the incoherent scatter radars at middle and high latitudes**.

Data

◆JASON-1 satellite

- The TEC from JASON-1 satellite provides a direct measurement of the ionospheric TEC almost every second in a vertical column extending from ocean surface to the satellite orbit at about 1336 km altitude.

✓ In this study, we use 18 second averaged TEC data.

◆Incoherent scatter radars (ISRs)

	Millstone Hill	EISCAT TromsØ UHF	EISCAT Svalbard Radar (ESR)
location	42.6°N, 288.5°E	69.6°N, 19.2°E	78.2°N, 16.0°E
Time resolution	8 second	1 minute	1 minute

◆IRI-2012

- We use the standard version of the IRI-2012. The standard version adopts the URSI option for f_0F_2 and NeQuick topside model.

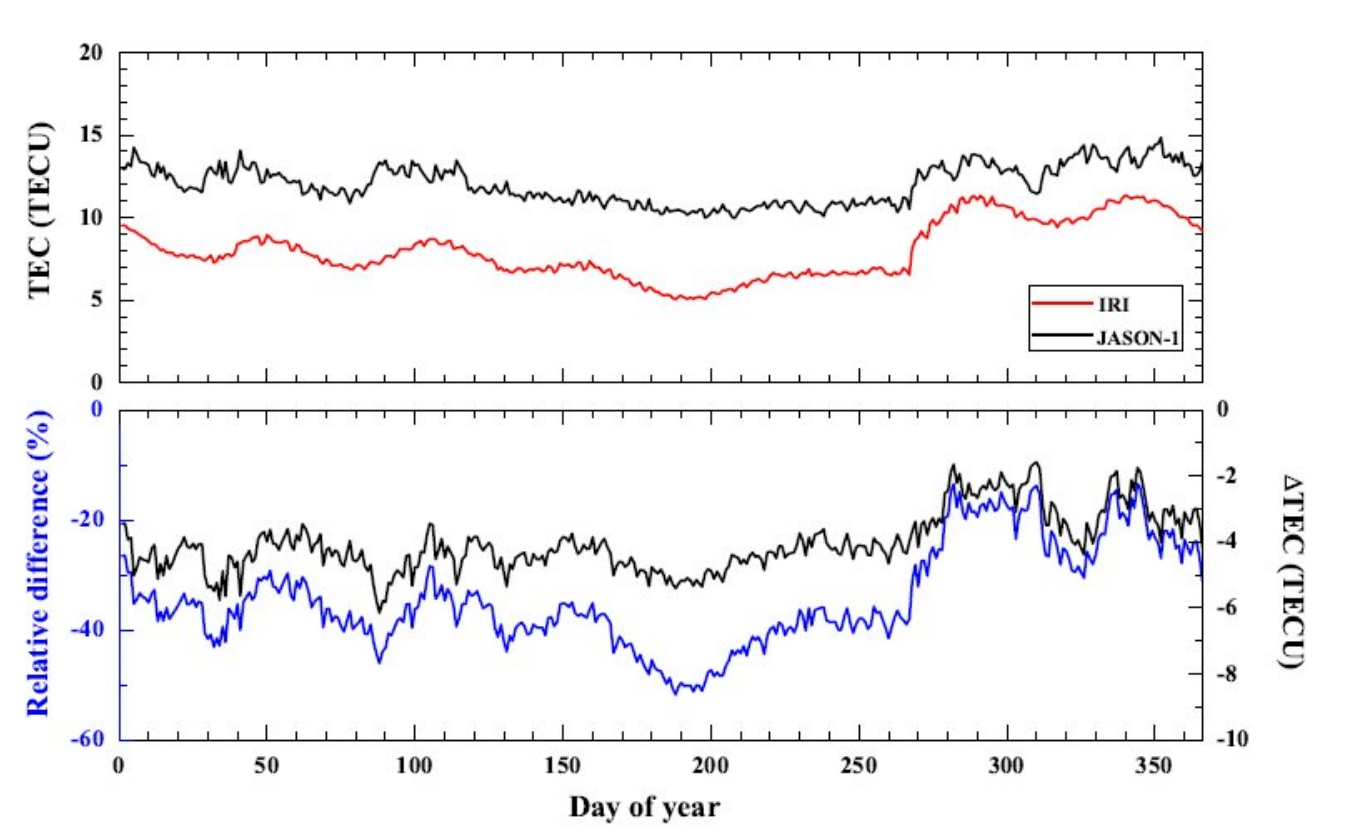
➢ The IRI TEC is calculated at time of day, day of year, and location of our 18 seconds averaged JASON-1 TEC data along the satellite orbit.

➢ The IRI electron density profile is hourly calculated at the day and location for each ISR.

Comparison of IRI and JASON-1 TECs

◆ Daily global mean TEC

- For the global mean ionosphere, daily mean TECs calculated from the IRI and JASON data are compared with each other during the two-year period.



✓**The IRI-2012 underestimates the TEC by about 34%.**

◆Global TEC map

- For the global ionosphere, we compare the global TEC maps between IRI and JASON-1TECs.

- **Data analysis for the global TEC map**

➢We bin the IRI and JASON-1 TEC data in MLAT versus MLT frames.

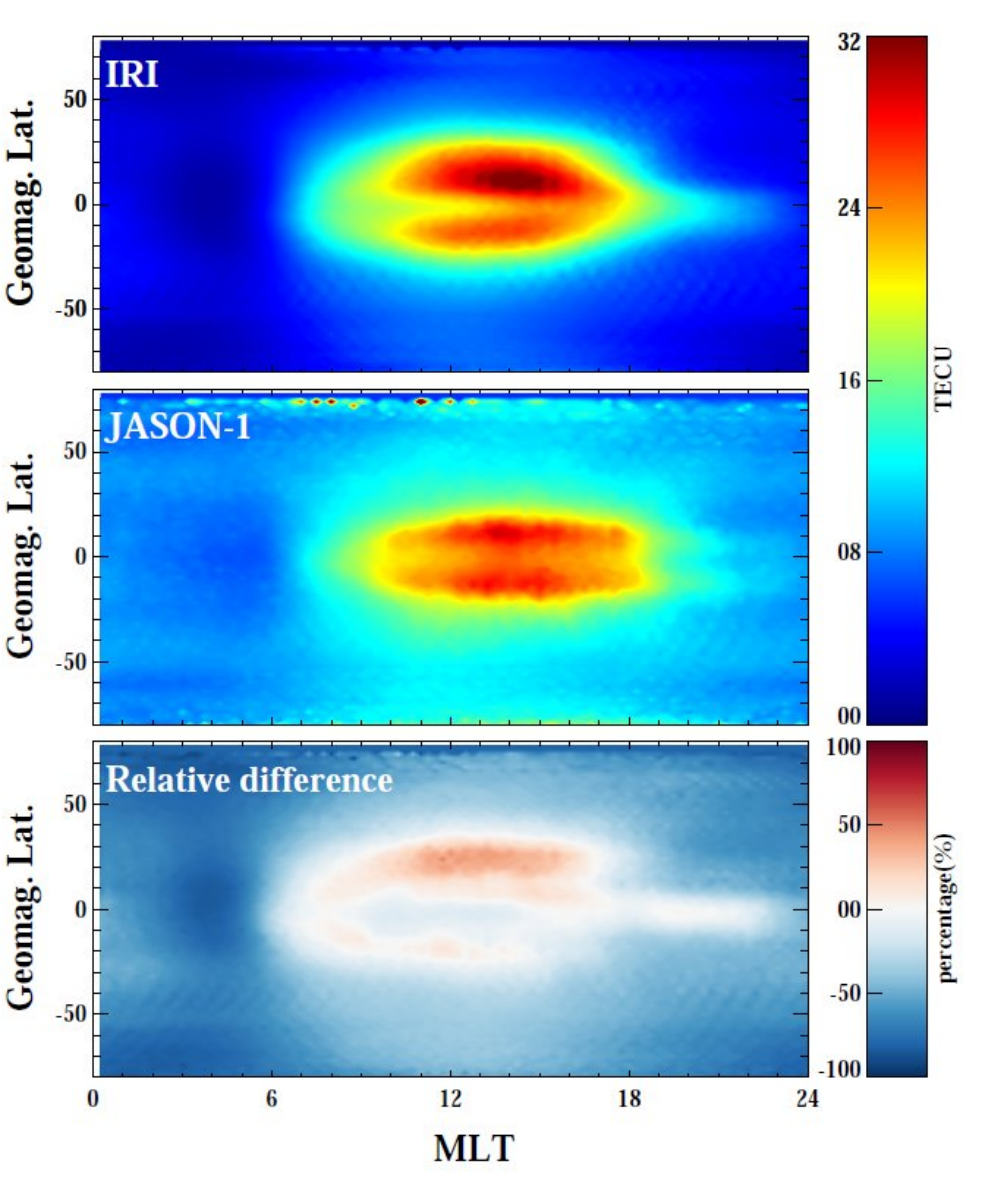
➢The binning resolution for MLAT and MLT is 2° X 15min.

✓**The binning in MLT results in longitudinally averaged TEC values.**

➢We also use three seasonal bins:

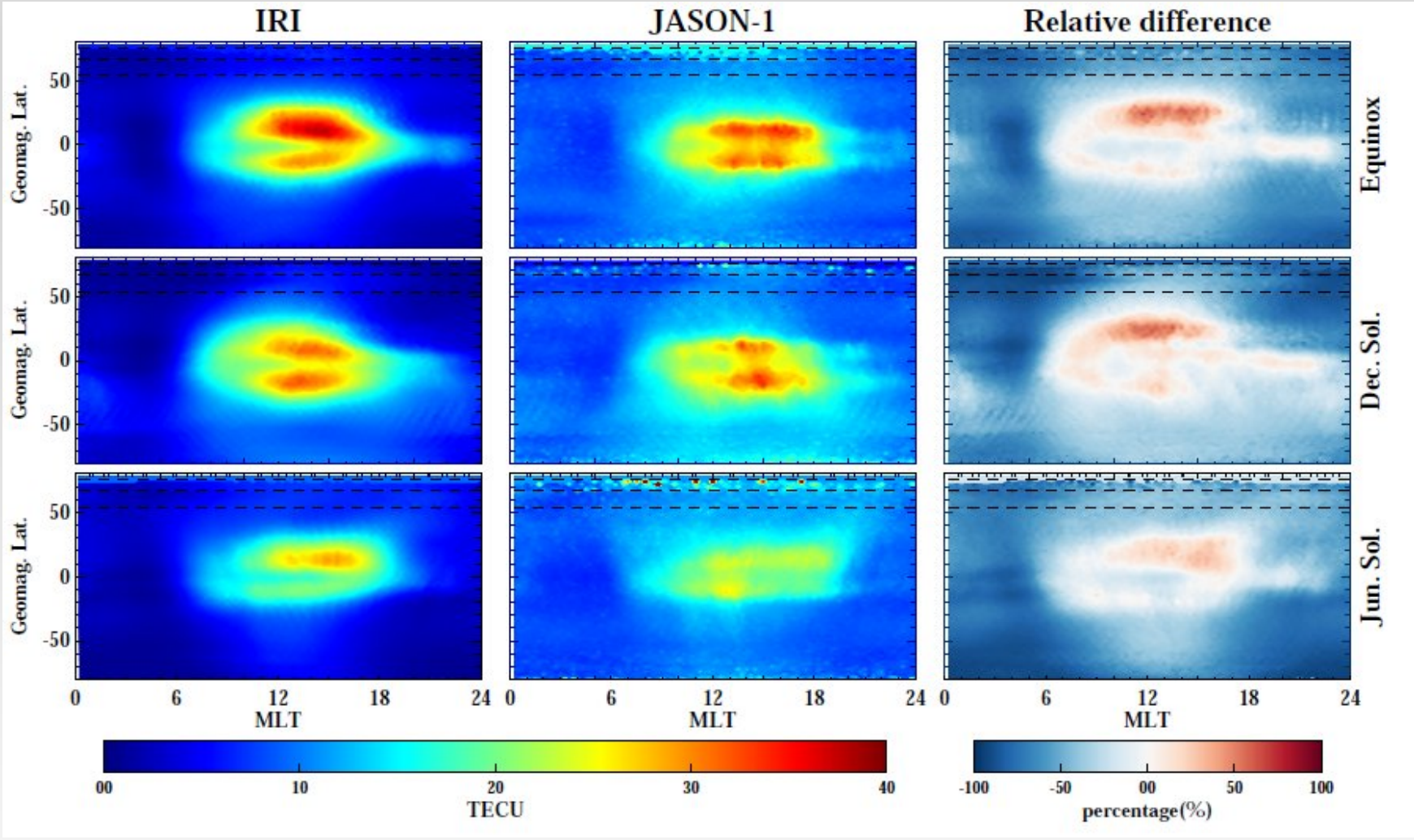
	Equinox	December solstice	June solstice
Day of year	50-110	1-50 and 295-366	111-233

◆Global TEC map



- Overall, the IRI underestimates TEC except for the daytime low-latitude region around the equatorial anomaly.
- The equatorial anomaly in IRI does not agree with JASON TEC data:
  - Magnitude and location of the anomaly peaks
  - Symmetry around the magnetic equator
  - Equatorial anomaly in the evening

◆Seasonal variation of the TEC difference



- Overestimation of the equatorial anomaly in the northern hemisphere
- Larger underestimation of nighttime TEC in winter hemisphere than in summer hemisphere.

Comparison of IRI and ISRs electron density profiles

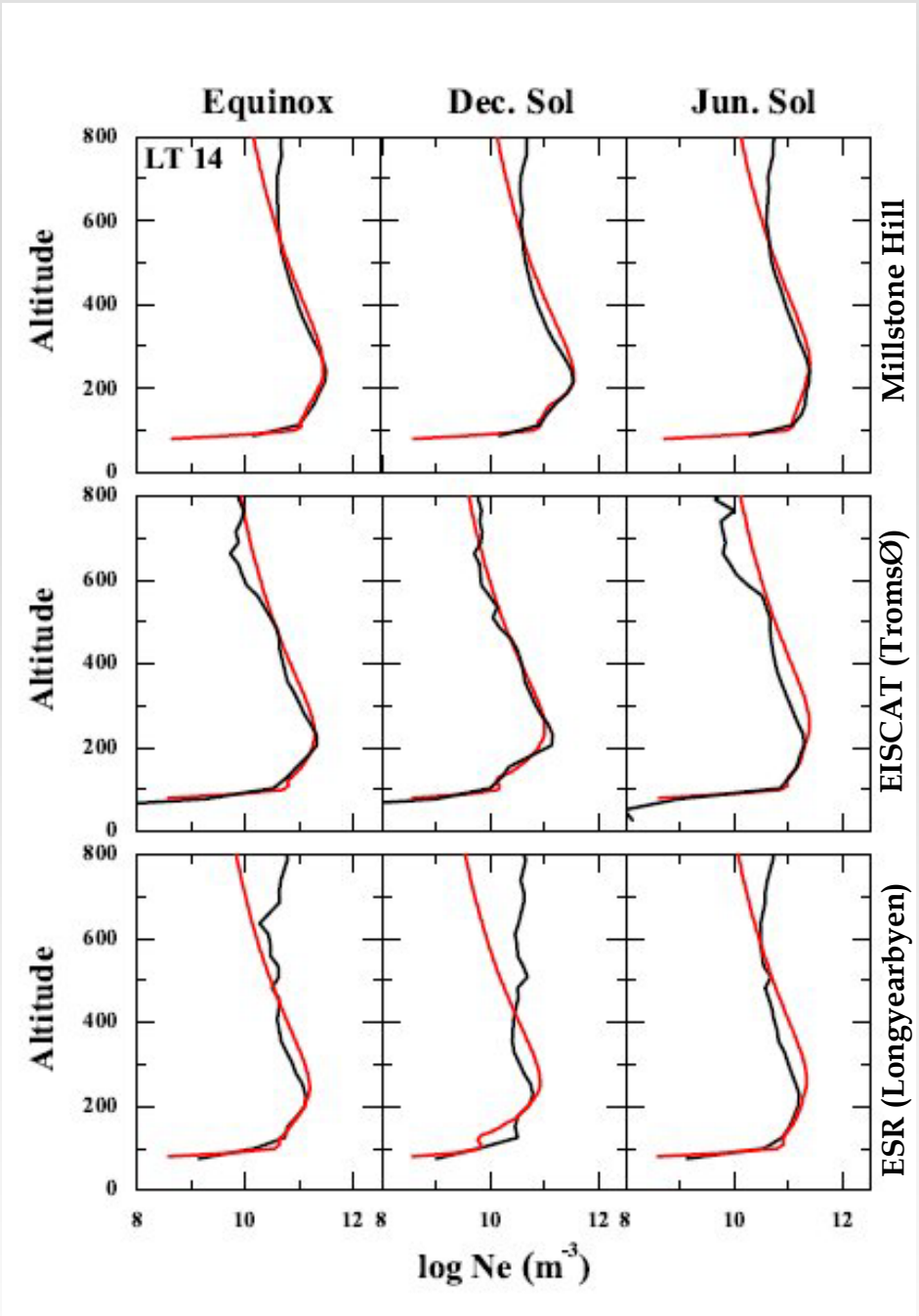
- Using the observations in the topside ionosphere, the previous studies showed that the IRI overestimates the ionosphere in the equatorial region during the last solar minimum period, which agrees with our result from TEC data.
- However, we find that the IRI overall underestimates the ionosphere except for the daytime equatorial region.
- Using the ISR observations, we further investigate the underestimation of IRI in the middle and high latitude regions.

➢ We compare the electron density profiles between IRI and ISRs at Millstone Hill, EISCAT, and ESR.

- **Data analysis for electron density profiles**

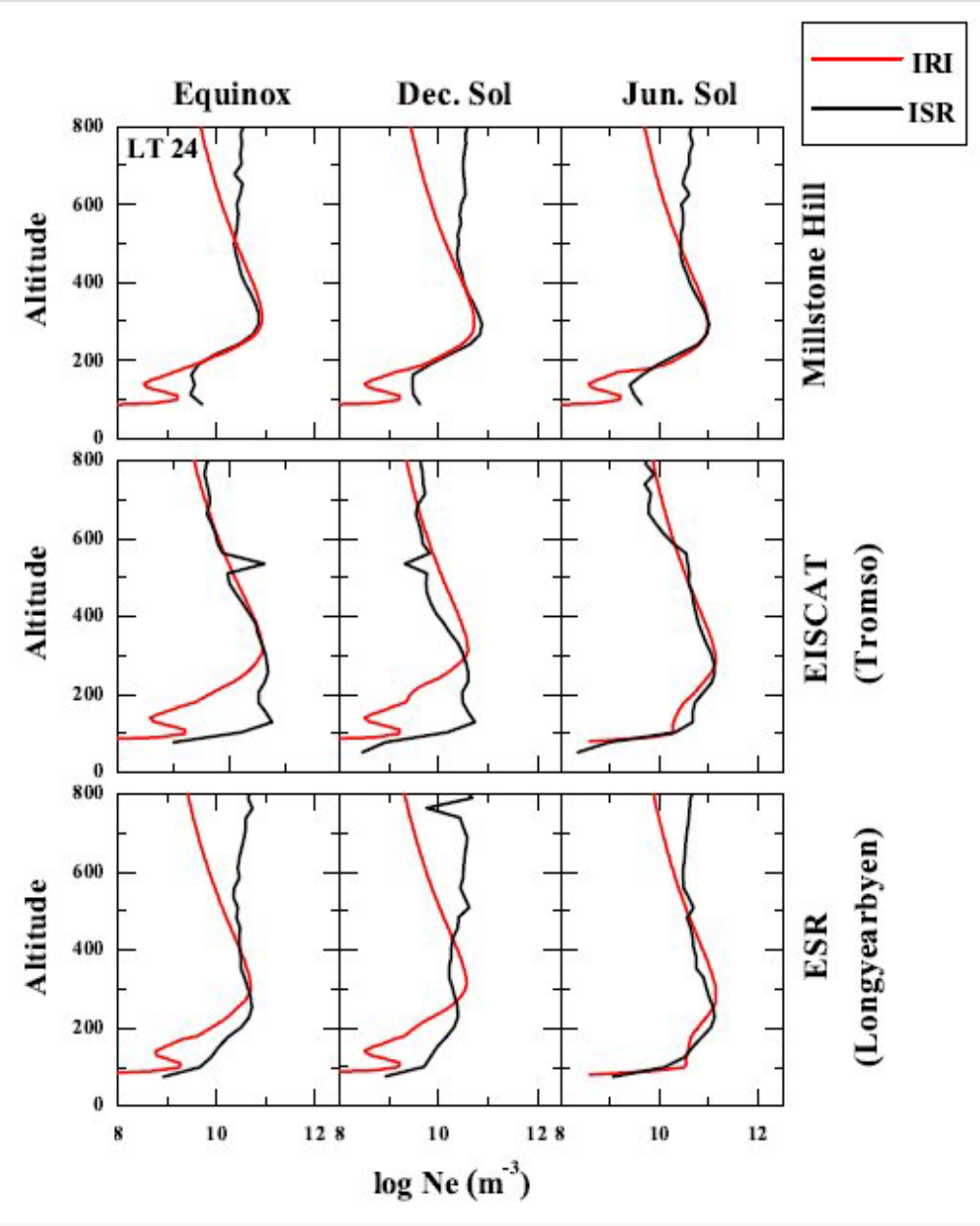
➢ We make the ISR data, which have the height variation of 25 km altitude because they show the irregular height variation.

➢ We bin the ISR data in season and local time with three seasons (equinox, December solstice, and June solstice) and 1 hour



◆<u>Daytime</u>

- There is good agreement between IRI and ISRs for NmF2 and hmF2 except for ESR during the daytime. This result coincide with the small differences in the daytime TECs.



◆Nighttime

- At Millstone Hill, NmF2 and hmF2 of IRI are nearly similar to observation. But IRI underestimates in the bottom and topside, which results in the slight underestimation in TEC.
- At EISCAT and ESR, the IRI electron density profiles are greatly deviated from the observations. In particular, the F-region peak altitude is very different from the mid-latitude ionosphere and the IRI seems not to be capable of estimating hmF2 in the high-latitude.
- The IRI largely underestimates the topside ionosphere.

➢ This result of the comparison of the density profiles well agrees with the large underestimation of IRI TEC in middle and high latitude nighttime ionosphere.

Conclusion

- **We have evaluated the IRI-2012 during the 2008-2009 solar minimum period.**

➢ The IRI underestimates the daily mean TEC by about 34%.

➢ The IRI overall underestimates global TEC except for the region around the equatorial anomaly only during the daytime, regardless of season.

➢ Larger underestimation of nighttime TEC in winter hemisphere than in summer hemisphere.

➢ During the daytime, there is near good agreement between IRI and ISRs for NmF2 and hmF2 at Millstone Hill and EISCAT.

➢ During the nighttime, the IRI largely underestimates electron density in topside. Its electron density profiles are also greatly deviated from observation in the high latitude.