Variation of GPS-TEC in Hainan and comparisons with IRI TEC

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Outline

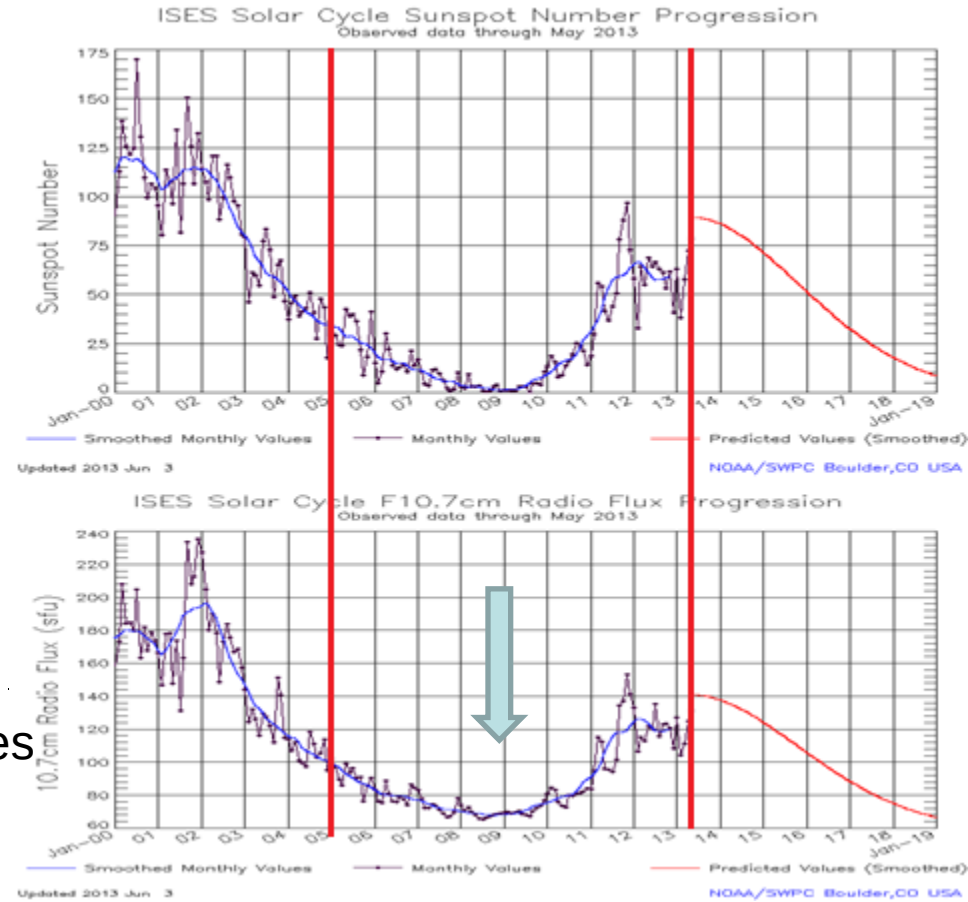
- **Introduction**
- **Data used**
- **Results**
  - **Variation of GPS-TEC**
  - **Comparison between GPS and IRI TEC**
  - **Comparison between GPS and Ionogram-derived TEC**
- **Summary**

1. Introduction

- TEC is a key ionospheric parameter that describe the major impact of the ionosphere on the propagation of radio waves, which is crucial for terrestrial and Earth-space communications including navigation satellite systems such as GPS, GLONASS and GALILEO systems.
- The main source of TEC is from the ground dual frequency GPS receivers all over the world. It is globally distributed, continuously available and low cost which are not comparable by other ground instruments.
- Another source of TEC is derived from the routine ionogram observation (Reinisch and Huang , 2001), which is the so-called ionogram derived TEC or ITEC. It can prolongate the time series of TEC forwardly and also is an important assistance for the current GPS-TEC.
- In this study, using the data from Hainan Ionospheric Observatory (19.4^0N, 109.0^0E), variation of GPS-TEC and its comparison with IRI 2012 predictions for different topside ionosphere options are investigated. And they are also compared with the ionogram-derived TEC.

2. Data used

- Location: Hainan, China (geo:109.1^{o}E,19.5^{o} N; Geomag: 178.95^{0} E，8.1^{0} N)
- Period: 2005 – 2012
- Time interval: 15 minutes



GPS TEC data: daily quarter-hourly values of the GPS-derived vertical Total Electron Content

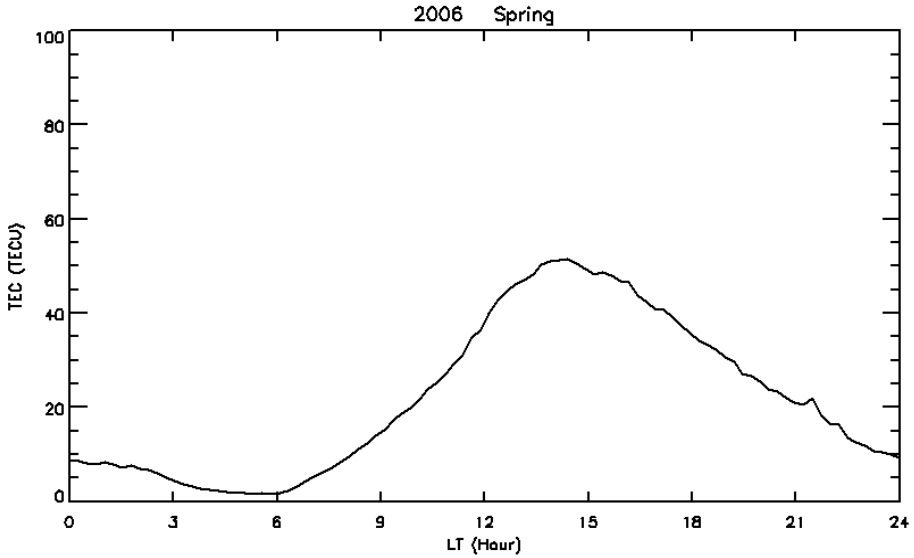
IRI TEC data: monthly quarter-hourly median values of the vertical TEC are calculated using IRI-2012 for different topside ionosphere options.

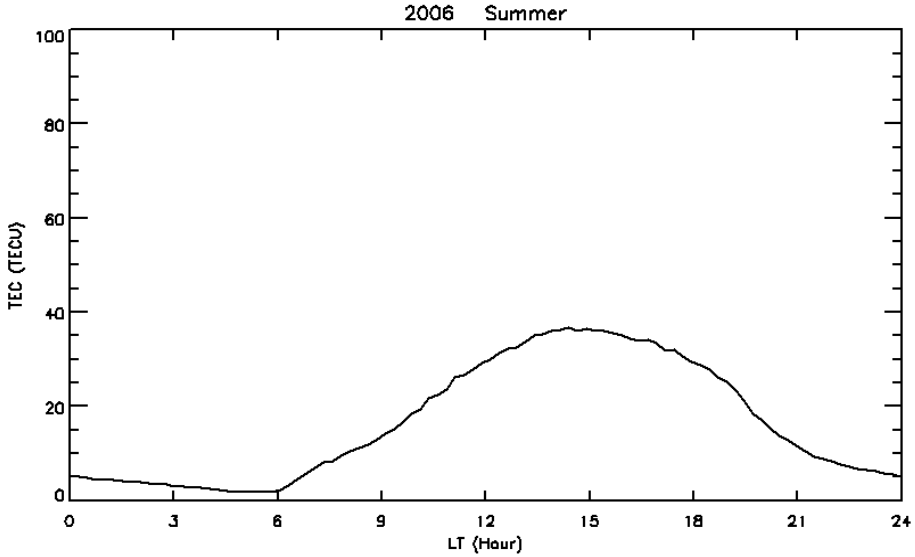
ITEC data: daily quarter-hourly values of the Ionogram-derived vertical Total Electron Content with NHPC program. All the ionograms used were manually edited before ITEC data are calculated.

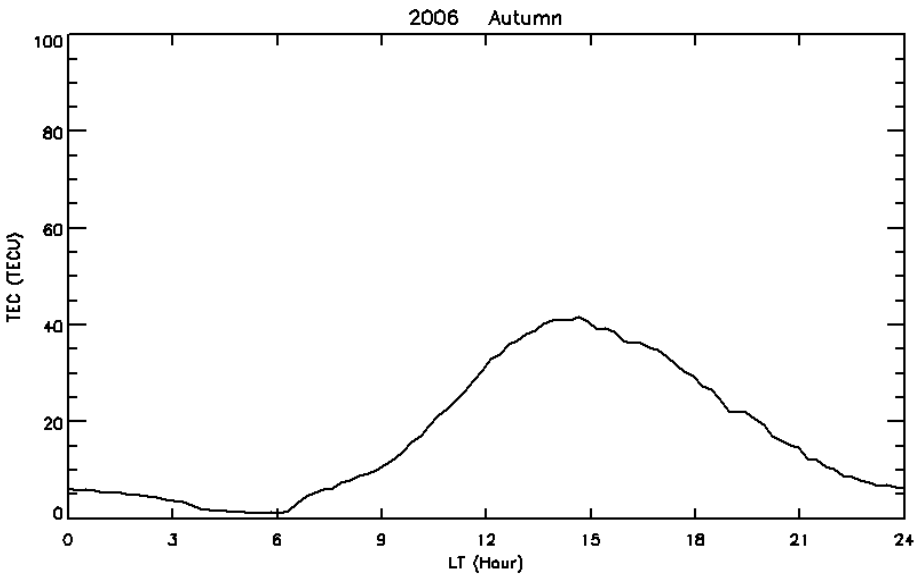
3. Results

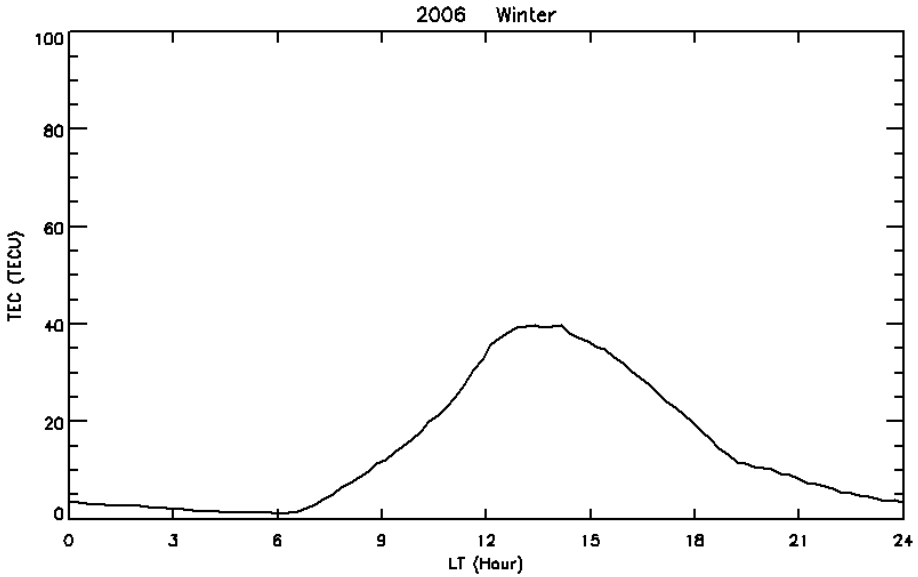
3.1 Variation of GPS-TEC

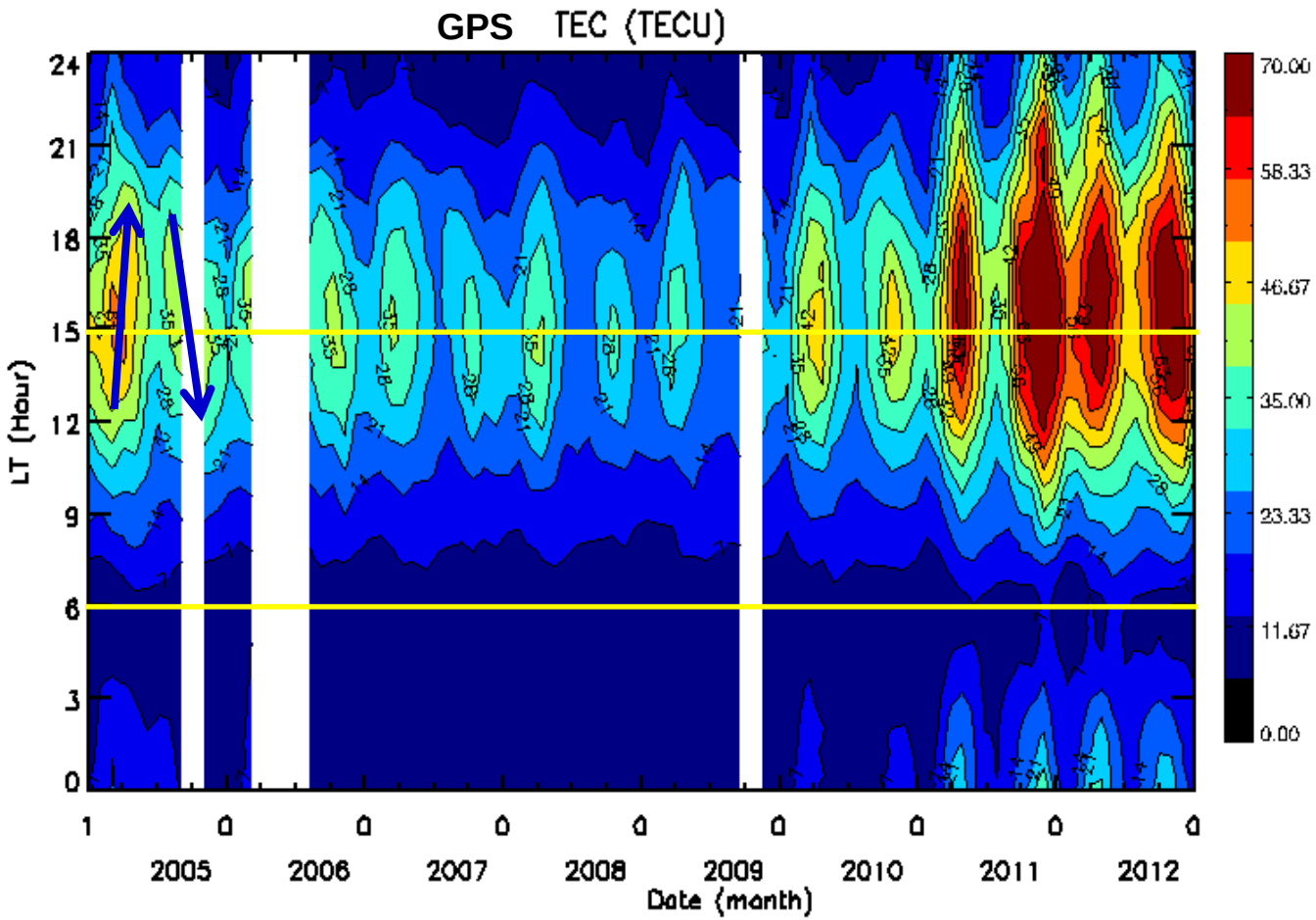
a. Diurnal, Monthly, seasonal and yearly variation





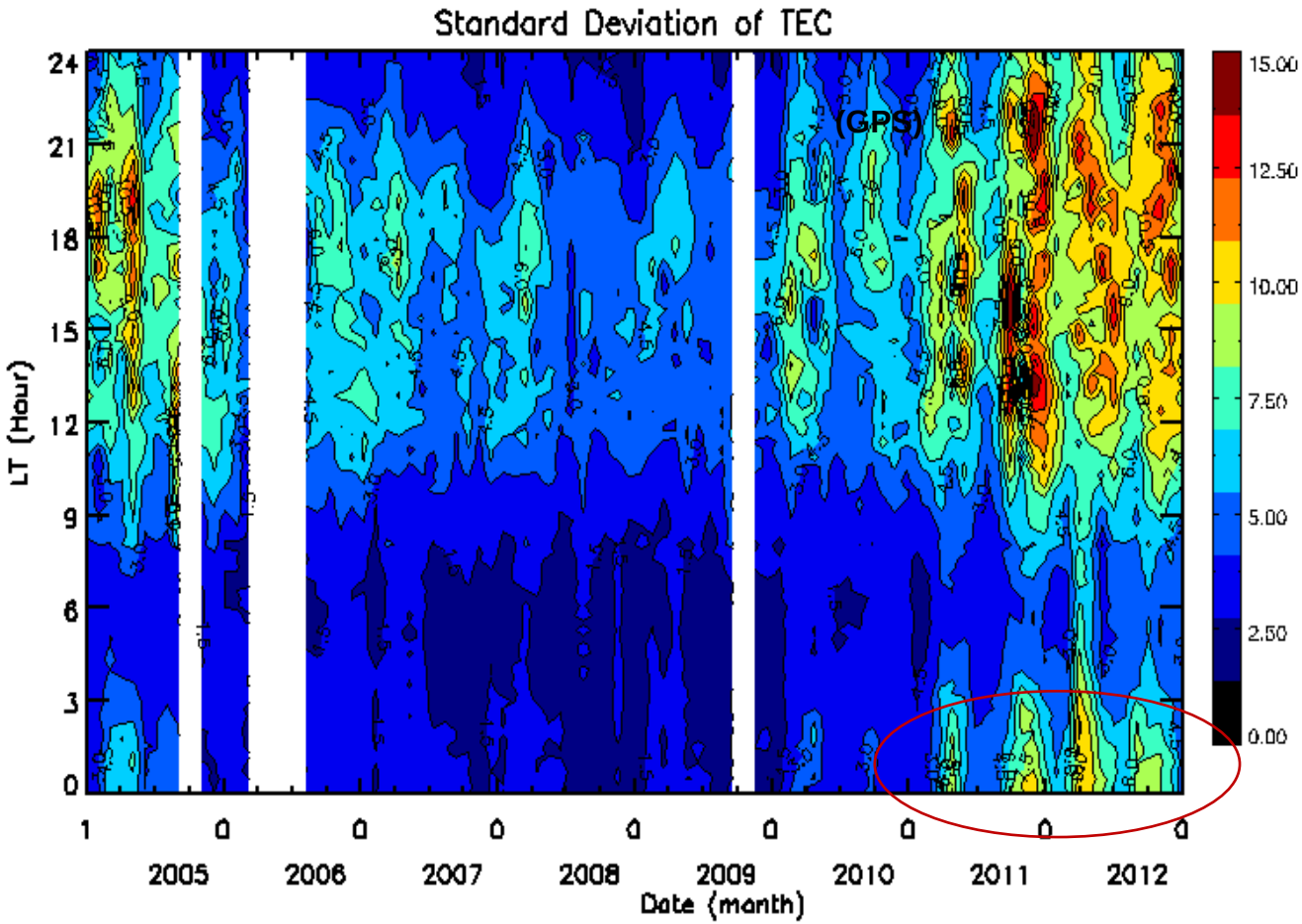






1. Diurnal, seasonal and solar cycle variation.
2. Peak values in equinox, but stronger in spring (2005-2009) and in autumn (2010-2012); then in winter.
3. The daily peak values of GPS-TEC occur at about 15 o'clock(LT): seasonal variation (spring: later with date and autumn: earlier with date)
4. Minimum: about 0600 LT

b. Monthly standard deviation

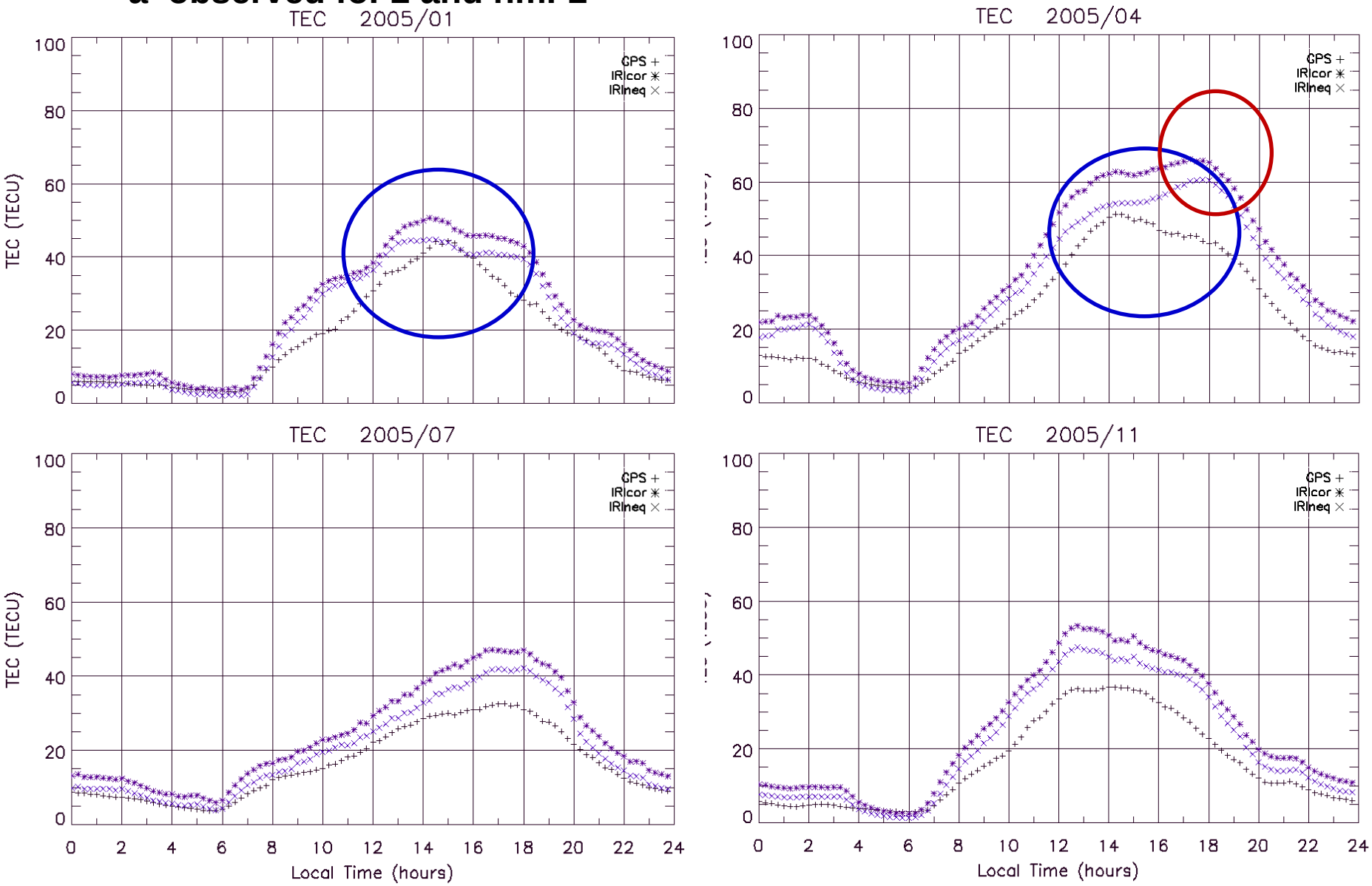


1. Diurnal: generally, there are small standard deviations at night time and bigger ones at daytime(11-20LT, especially in the evening).
2. Seasonal: Bigger values in equinox, then winter, small in summer.
3. Solar cycle

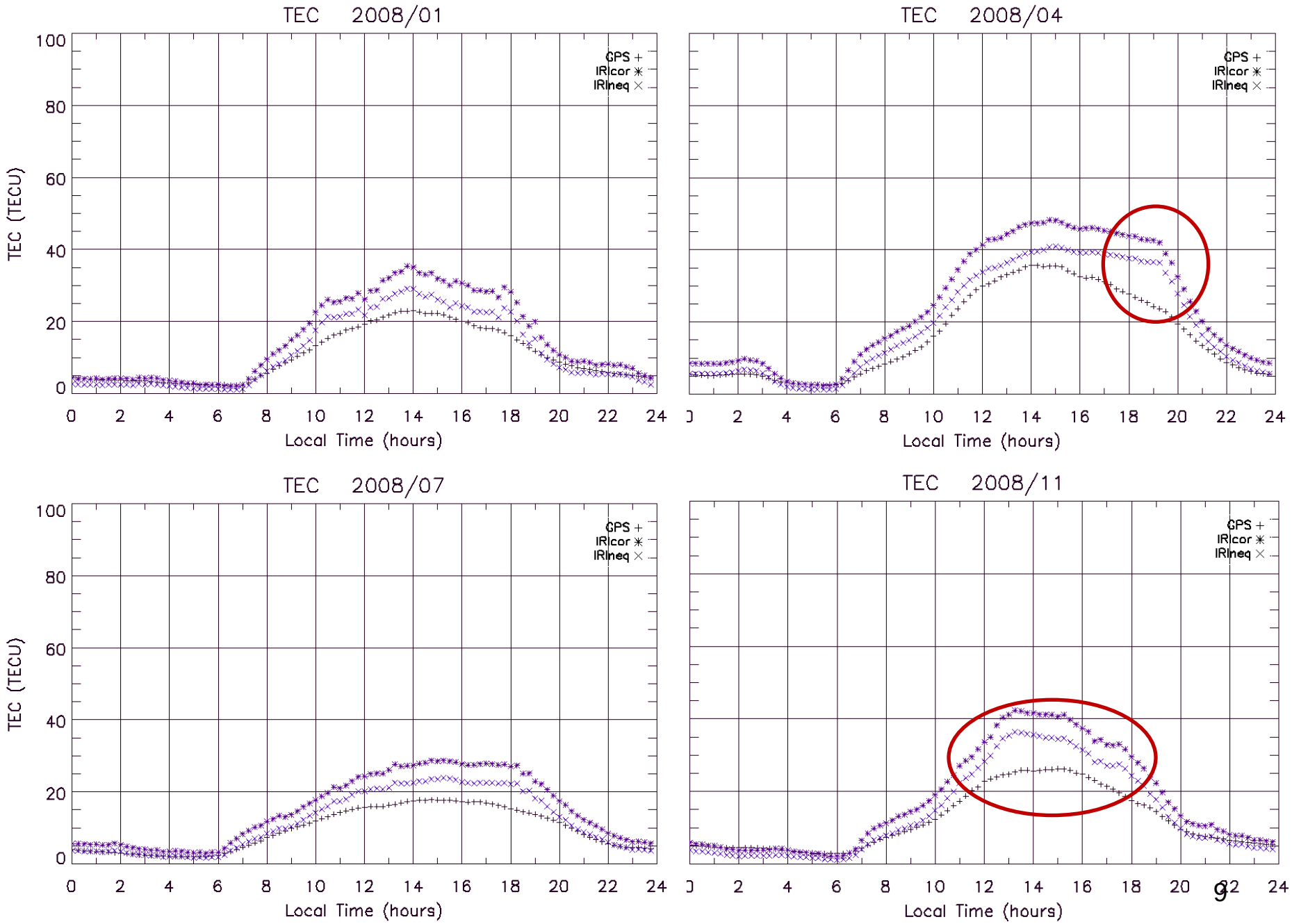
decreasing and increasing with solar activity level; there is also strong day-to-day variation at night in solar max.

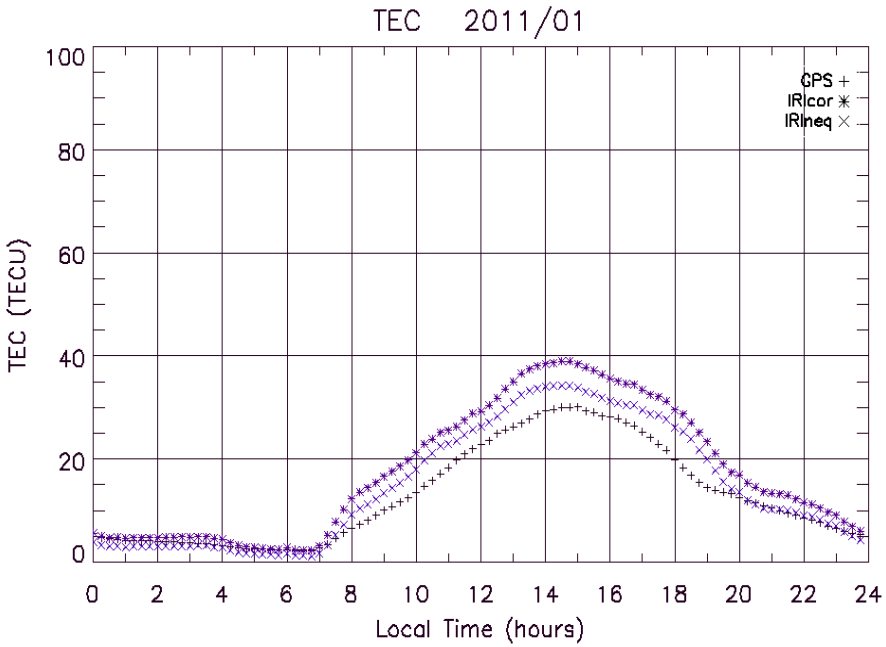
3.2. Comparison between GPS-TEC and IRI TEC data

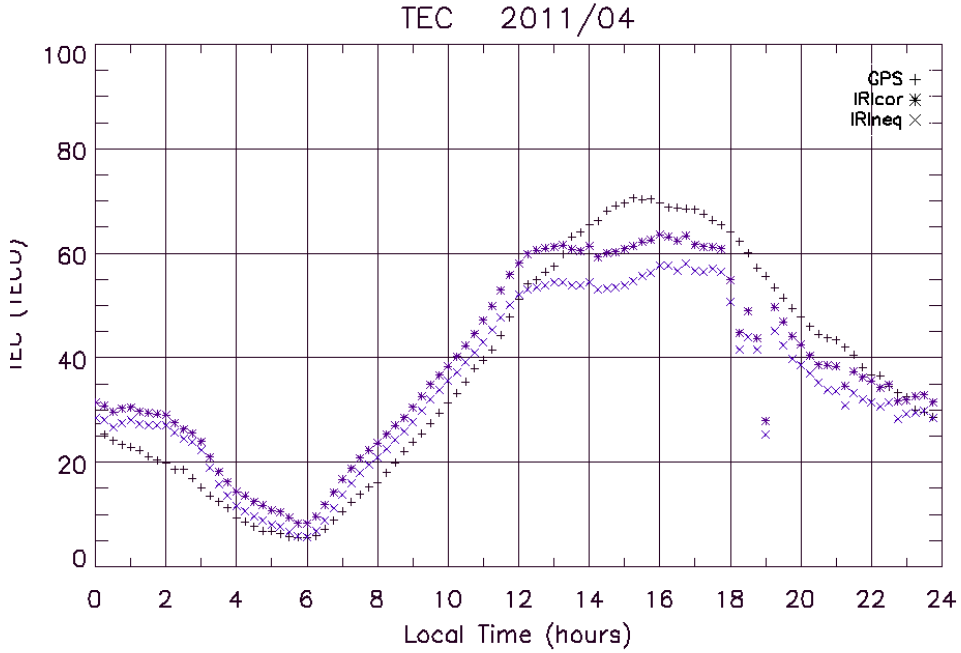
a observed foF2 and hmF2

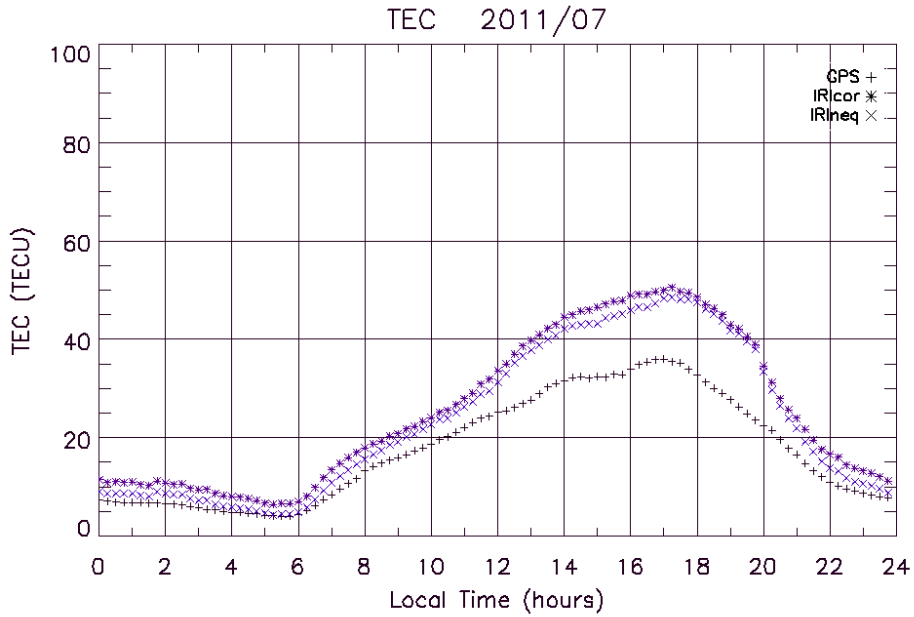


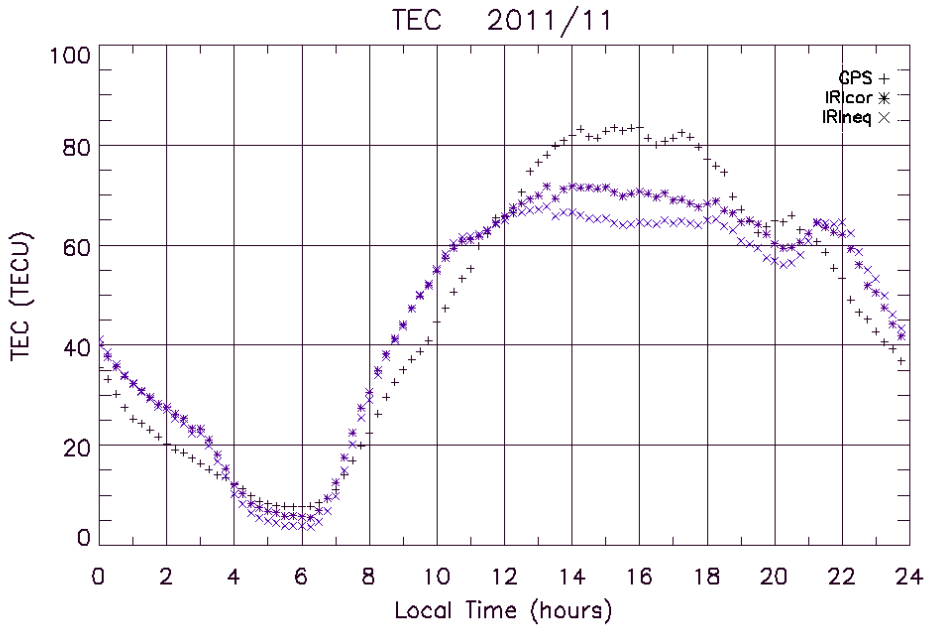
Diurnal variation of GPS TEC and IRI TEC in different months in 2005


TEC 2008/01
TEC 2008/04
TEC 2008/07
TEC 2008/11
GPS +
IRIcor ✳
IRIneq ×
TEC (TECU)
Local Time (hours)
0
20
40
60
80
100
0 2 4 6 8 10 12 14 16 18 20 22 24


TEC 2011/01
GPS +
IRIcor ✳
IRIneq ×
TEC (TECU)
Local Time (hours)
0
20
40
60
80
100
0 2 4 6 8 10 12 14 16 18 20 22 24


TEC 2011/04
GPS +
IRIcor ✳
IRIneq ×
Local Time (hours)
0
20
40
60
80
100
0 2 4 6 8 10 12 14 16 18 20 22 24


TEC 2011/07
GPS +
IRIcor ✳
IRIneq ×
TEC (TECU)
Local Time (hours)
0
20
40
60
80
100
0 2 4 6 8 10 12 14 16 18 20 22 24

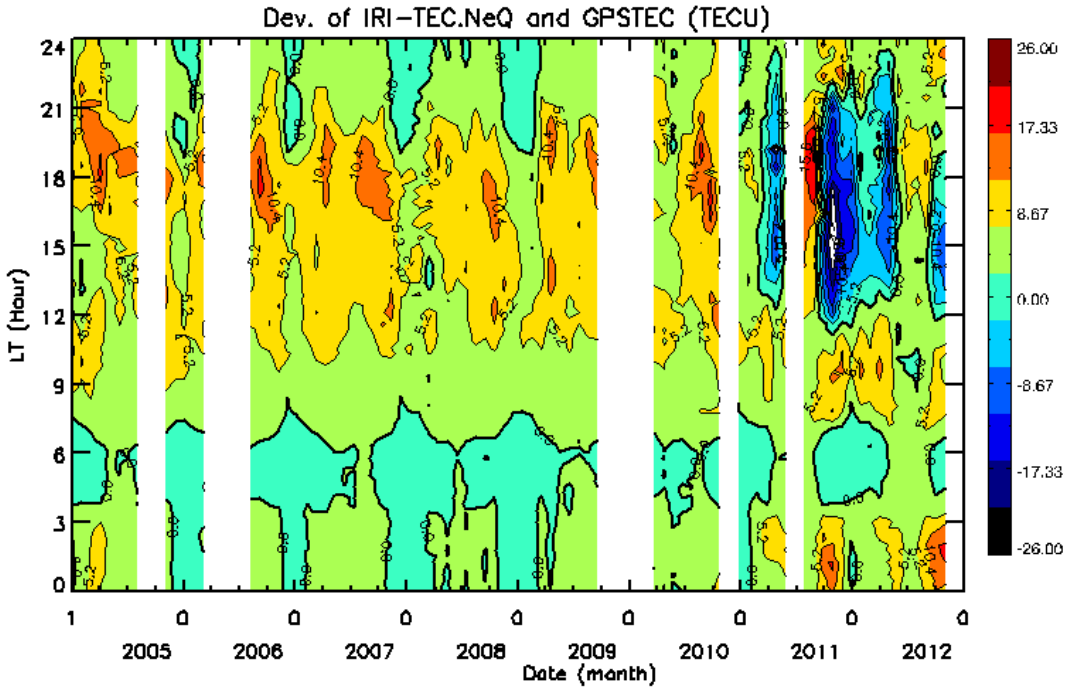

TEC 2011/11
GPS +
IRIcor ✳
IRIneq ×
TEC (TECU)
Local Time (hours)
0
20
40
60
80
100
0 2 4 6 8 10 12 14 16 18 20 22 24

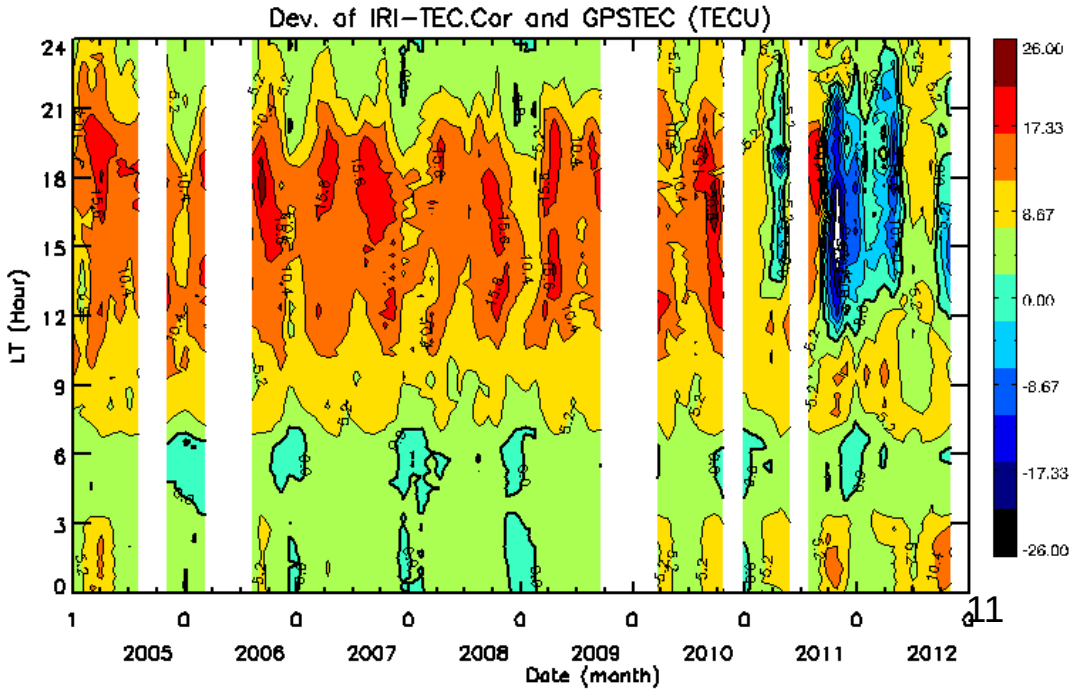
1. Generally, the TEC predictions of IRI 2012 overestimate greatly the TEC values during daytime (especially at about 1800LT) for both Corrected and NeQuick topside ionosphere options. Good agreement in the nighttime (IRI2012 predictions with NeQuick option slightly underestimate TEC at nighttime in winter and around sunrise in equinox.)

2. The TEC predictions of IRI 2012 with NeQuick topside ionosphere option are relatively good agreement with GPS TEC.

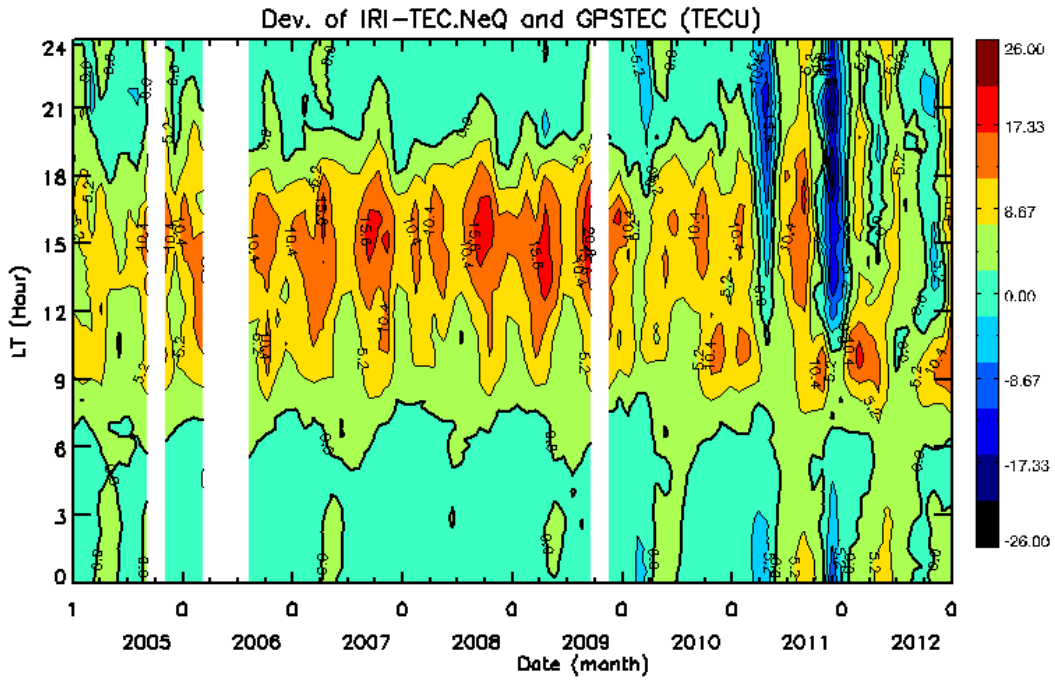
3. Bigger deviations between GPS TEC and IRI TEC in the equinox, then summer. It is notable that there is another TEC peak around sunset in spring for IRI predictions.

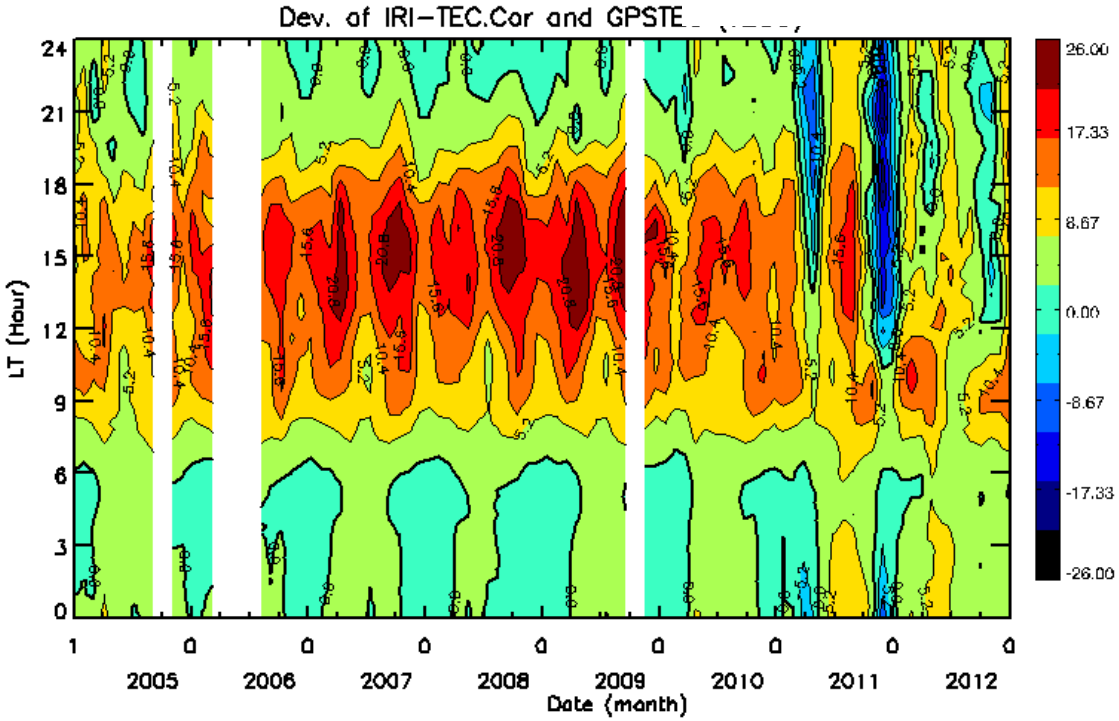
4. Deviations of ITEC vs GPS TEC: near the same for NeQuick option; but decrease in daytime from 2005 to 2008 for Corr. option.





b model foF2 and hmF2

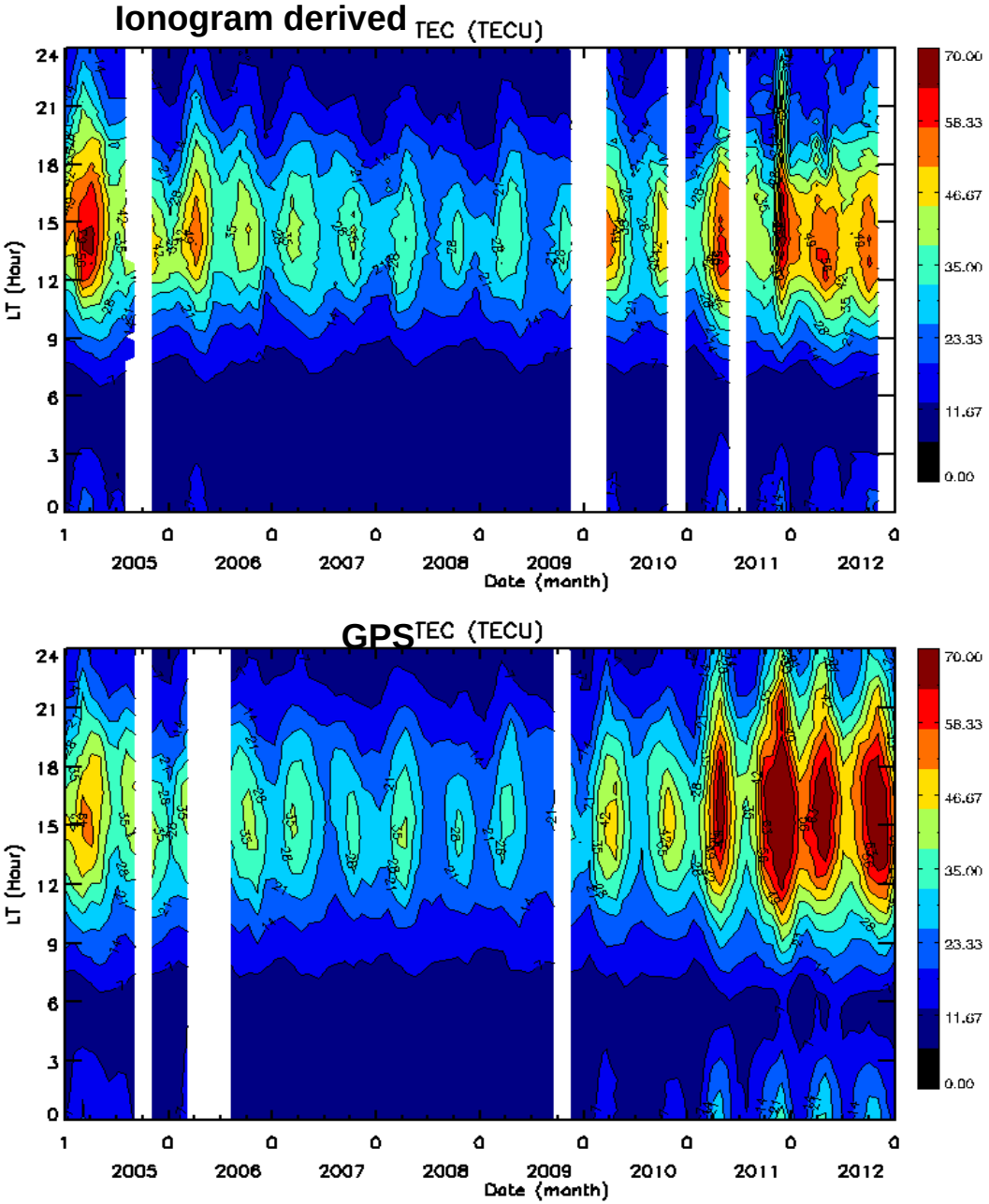




3.3 Comparison between GPS-TEC and ITEC data

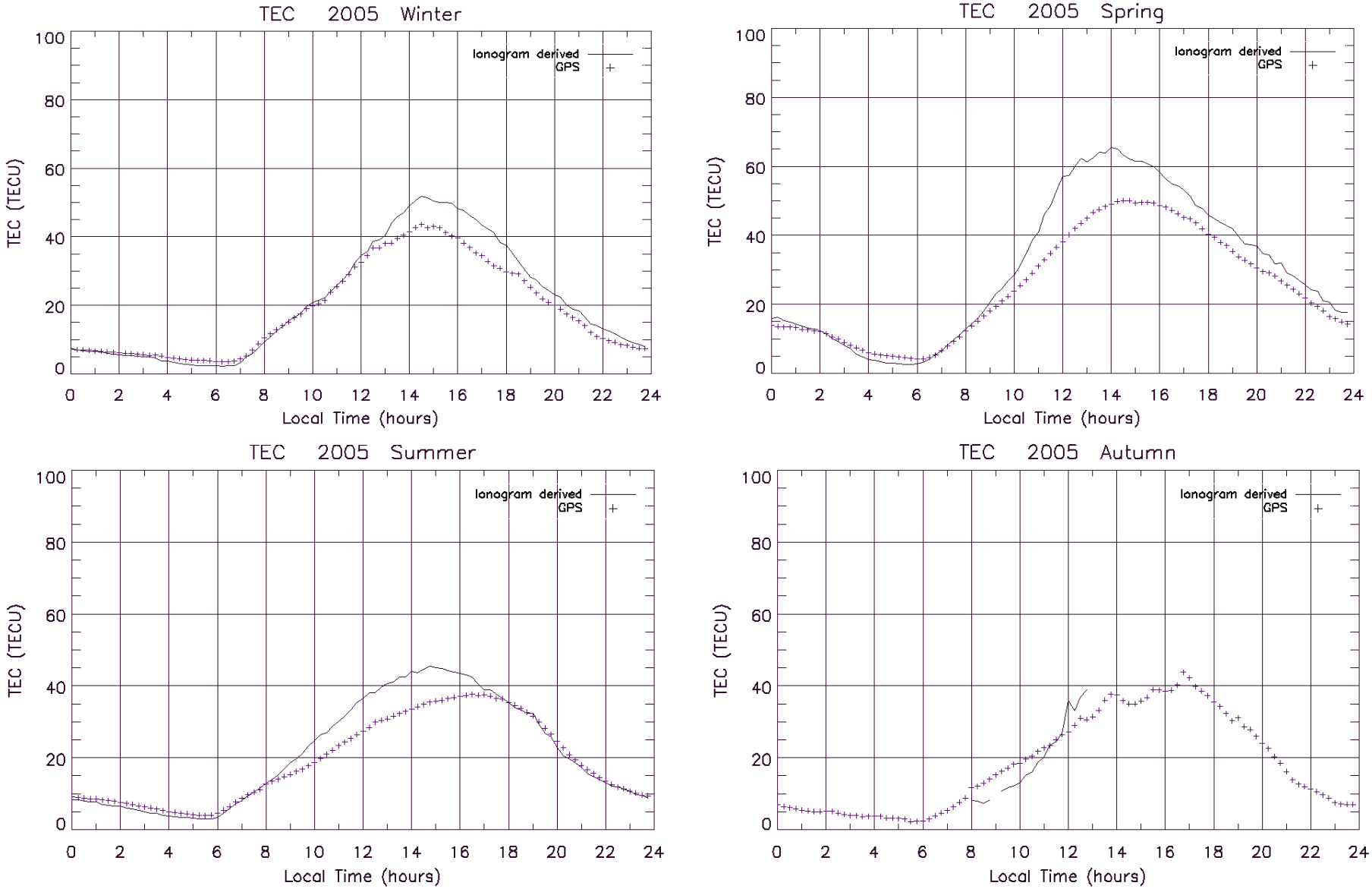
a. Monthly mean values

1. Similar diurnal, seasonal and solar cycle variation for GPS TEC and ITEC.
2. The daily peak values of GPS TEC occur at about 15 o'clock(LT), but a little earlier for the ITEC.
3. ITEC have higher peak values than GPS TEC during 2005-2010, but it is opposite in 2011 and 2012.

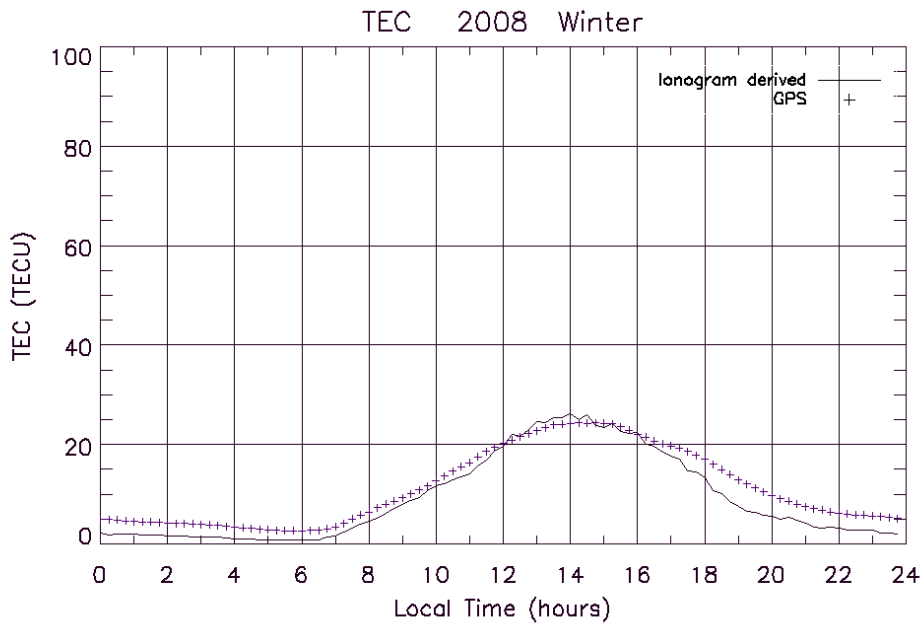


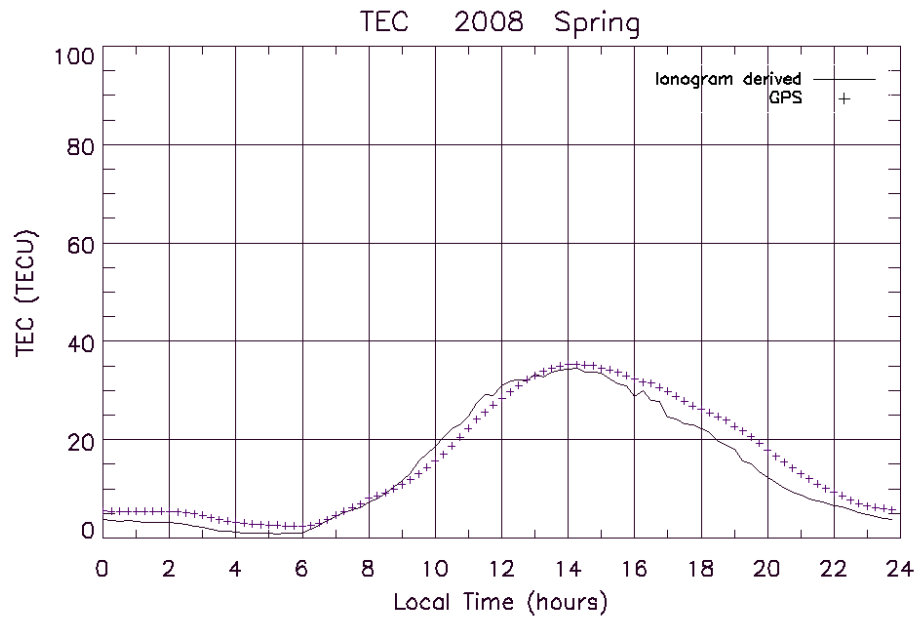
Diurnal and seasonal variation of ITEC and GPS TEC at Hainan. (upper panel: ITEC; lower panel: GPS TEC)

3.3b Seasonal variation

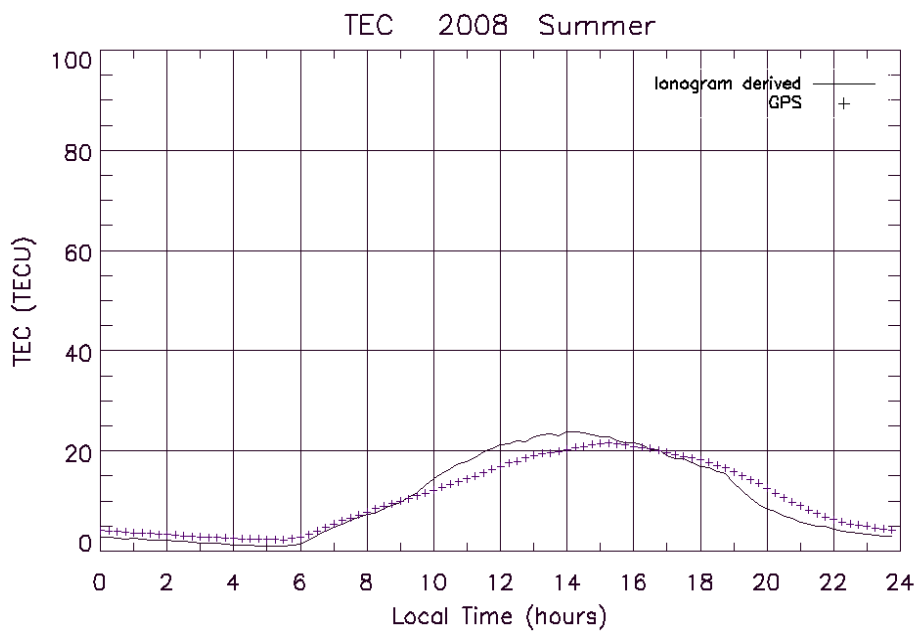


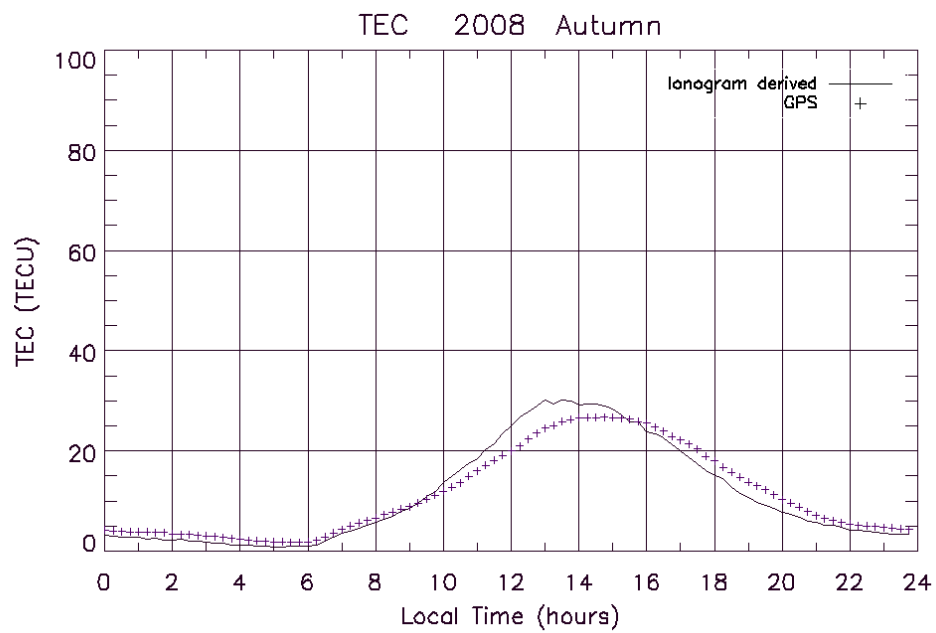
Diurnal variation of ITEC and GPS TEC in different seasons in 2005



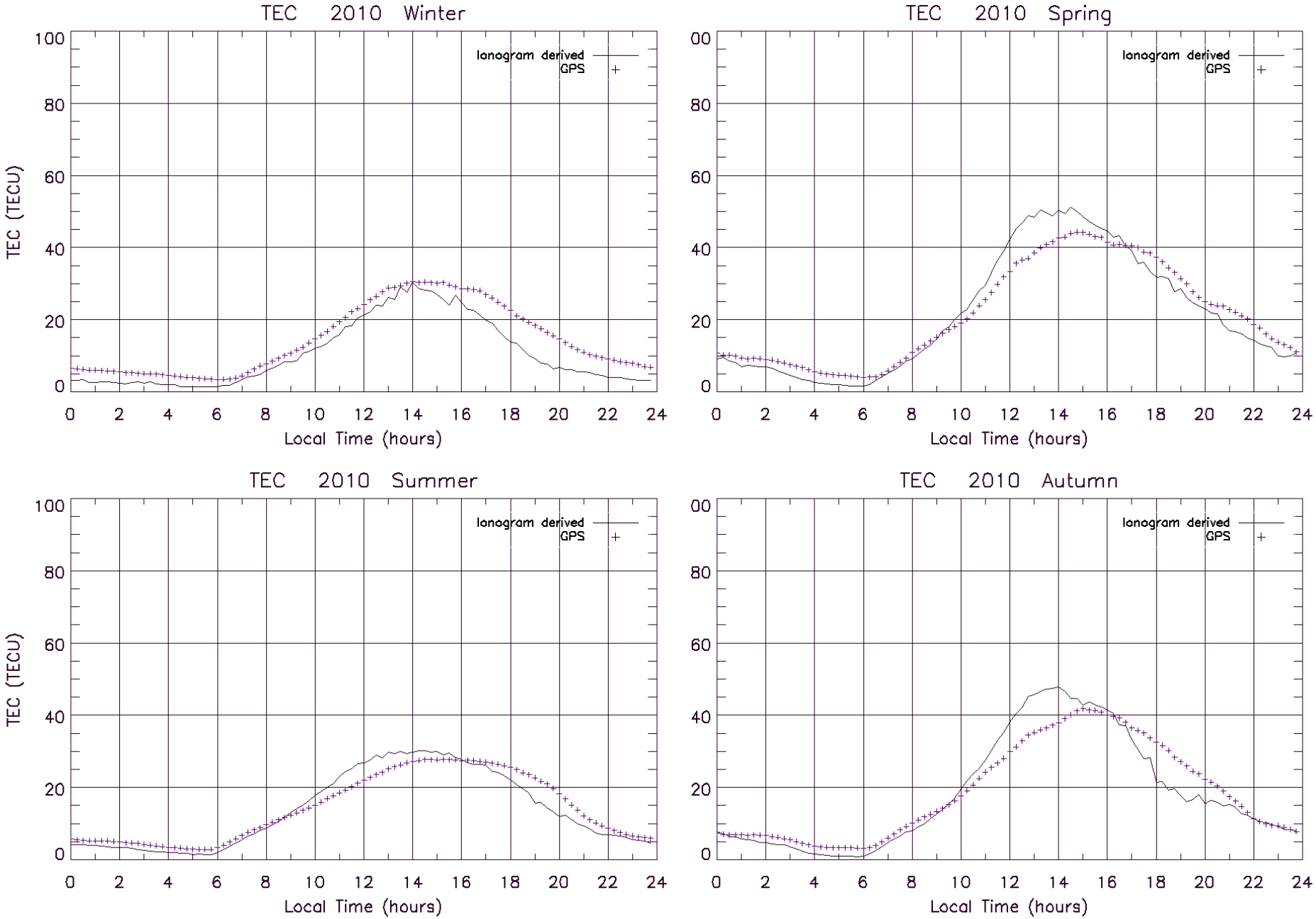


Peak time: Chang?

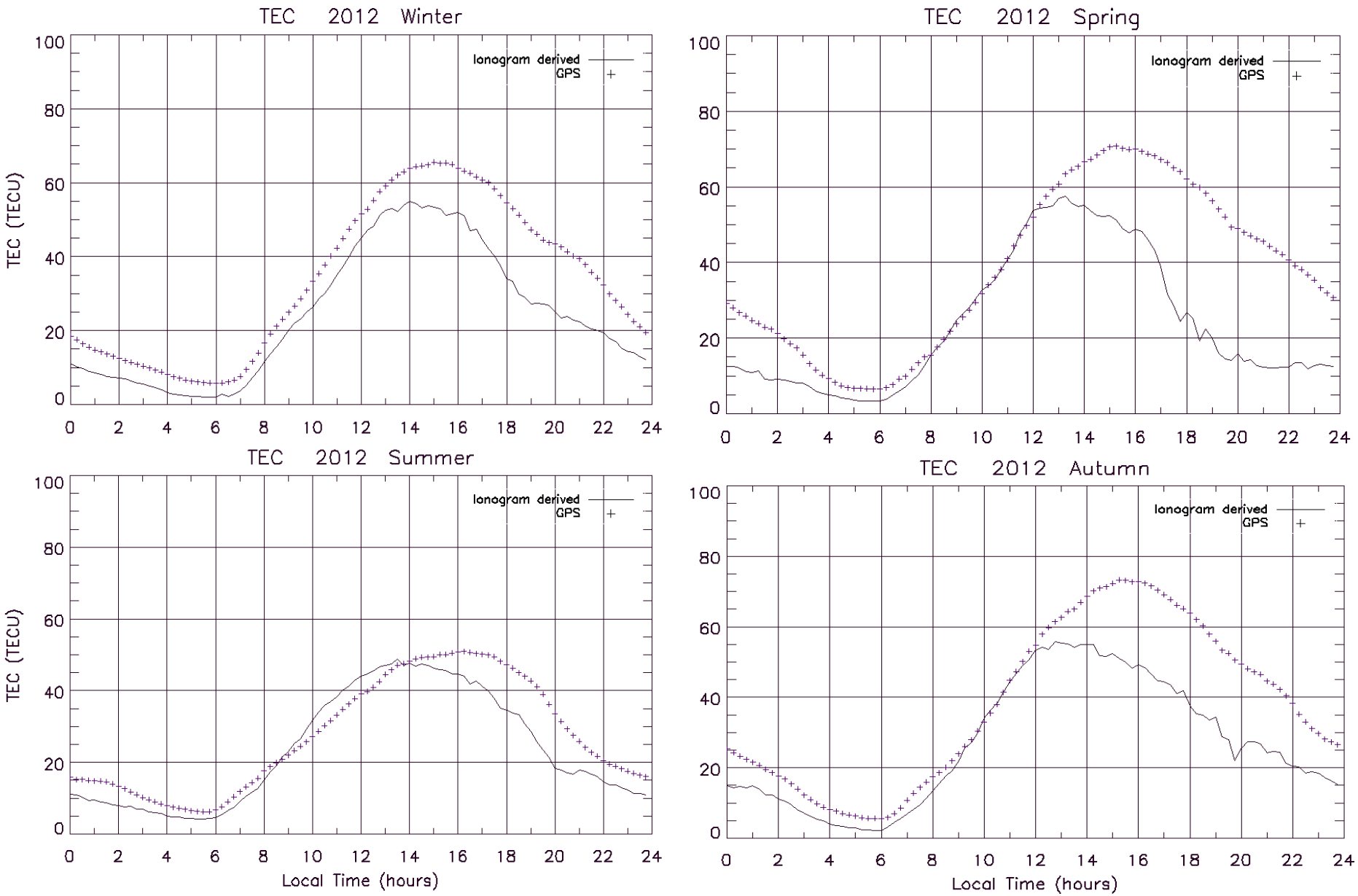




Diurnal variation of ITEC and GPS TEC in different seasons in 2008

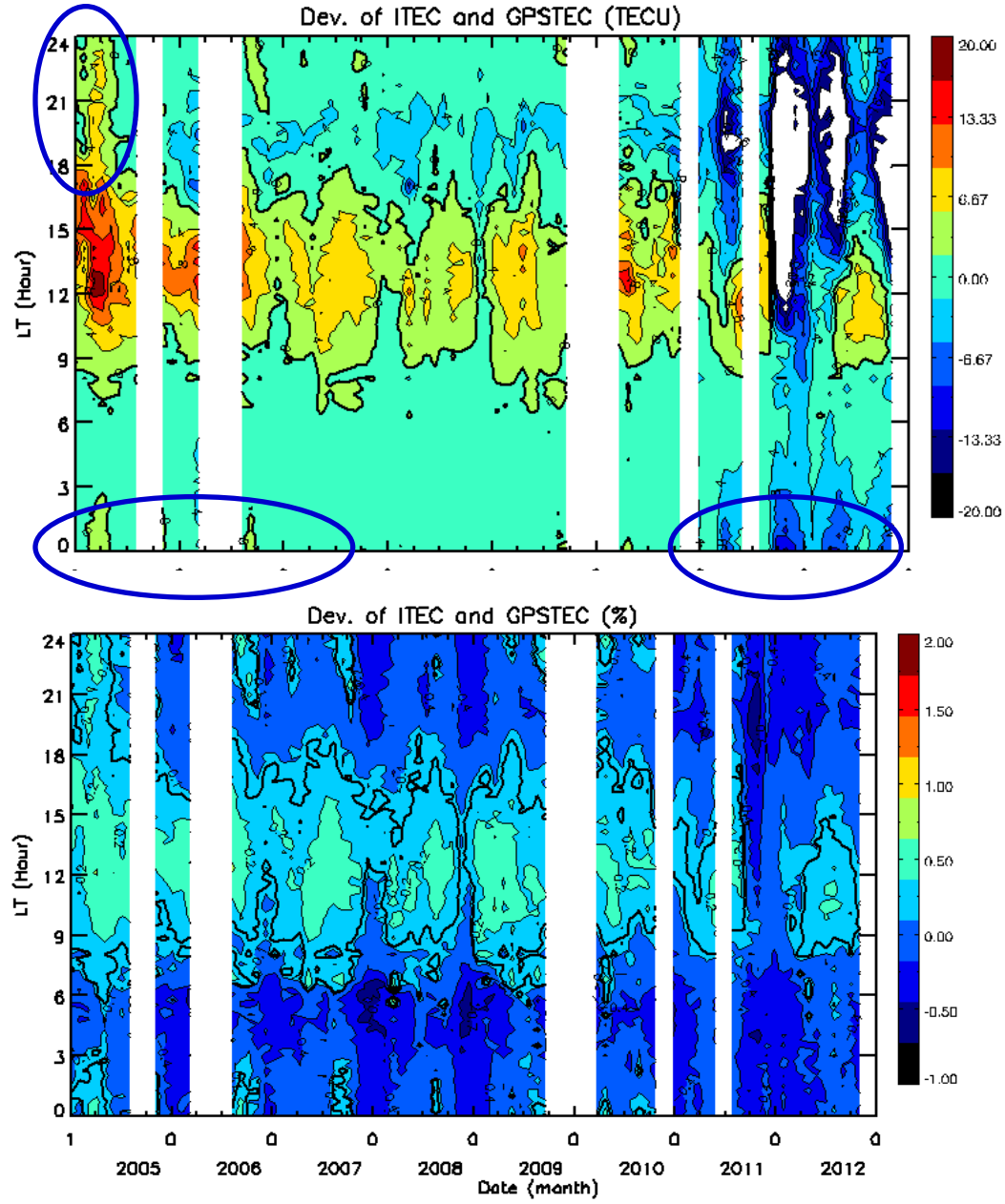


Diurnal variation of ITEC and GPS TEC in different seasons in 2010


TEC 2012 Winter
TEC 2012 Spring
TEC 2012 Summer
TEC 2012 Autumn
Ionogram derived
GPS
TEC (TECU)
Local Time (hours)
0
20
40
60
80
100
0
2
4
6
8
10
12
14
16
18
20
22
24

3.3c Deviation between GPS-TEC and ITEC data

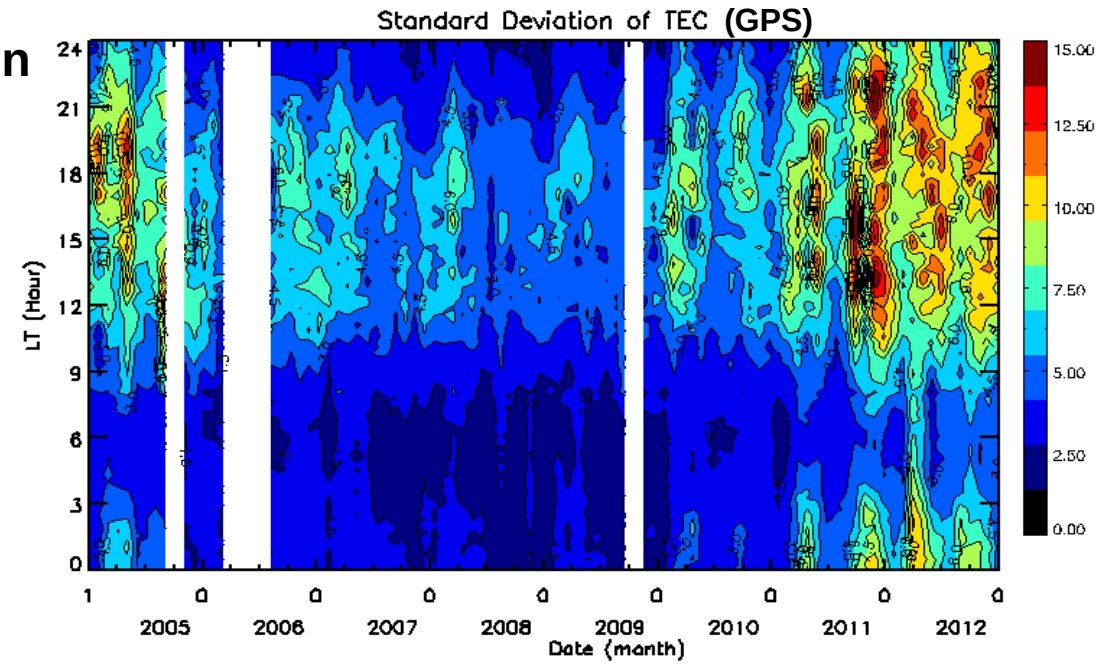
1. Generally, the values of ITEC are higher than that of GPS TEC from 0900 to 1800 LT and lower for the other periods.
2. It is notable that the daytime higher ITEC extend to the post midnight in the spring of 2005; higher ITEC near the midnight in the equinox(median solar activity).
3. The bigger deviation(ITEC >GPS-TEC) : the spring and summer (especially, spring in 2005) and then autumn; the smallest one is always in the winter and duration of strong deviation is also short.
4. The deviation decreases from 2005 to 2008, then increases, but ? in 2011 and 2012.
5. ITEC<GPS-TEC: low solar activity, evening, strong in winter, weak in summer

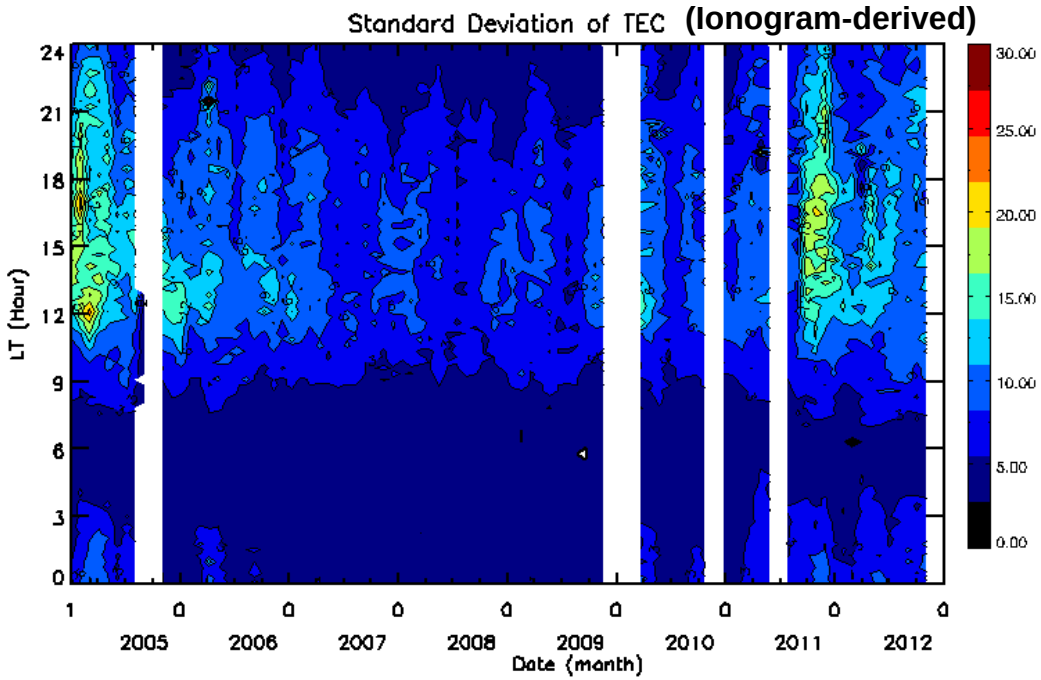


Diurnal and seasonal variation of deviation between ITEC and GPS TEC at Hainan. (upper panel: △TEC; lower panel: percent of △TEC for GPS TEC) Black thick line is zero.

3.3d Monthly standard deviation

1. Generally, there are small standard deviations at night time and bigger ones at daytime for both ITEC and GPS-TEC.
2. Bigger values in equinox, then winter for ITEC and GPSTEC.
3. Bigger values for ITEC

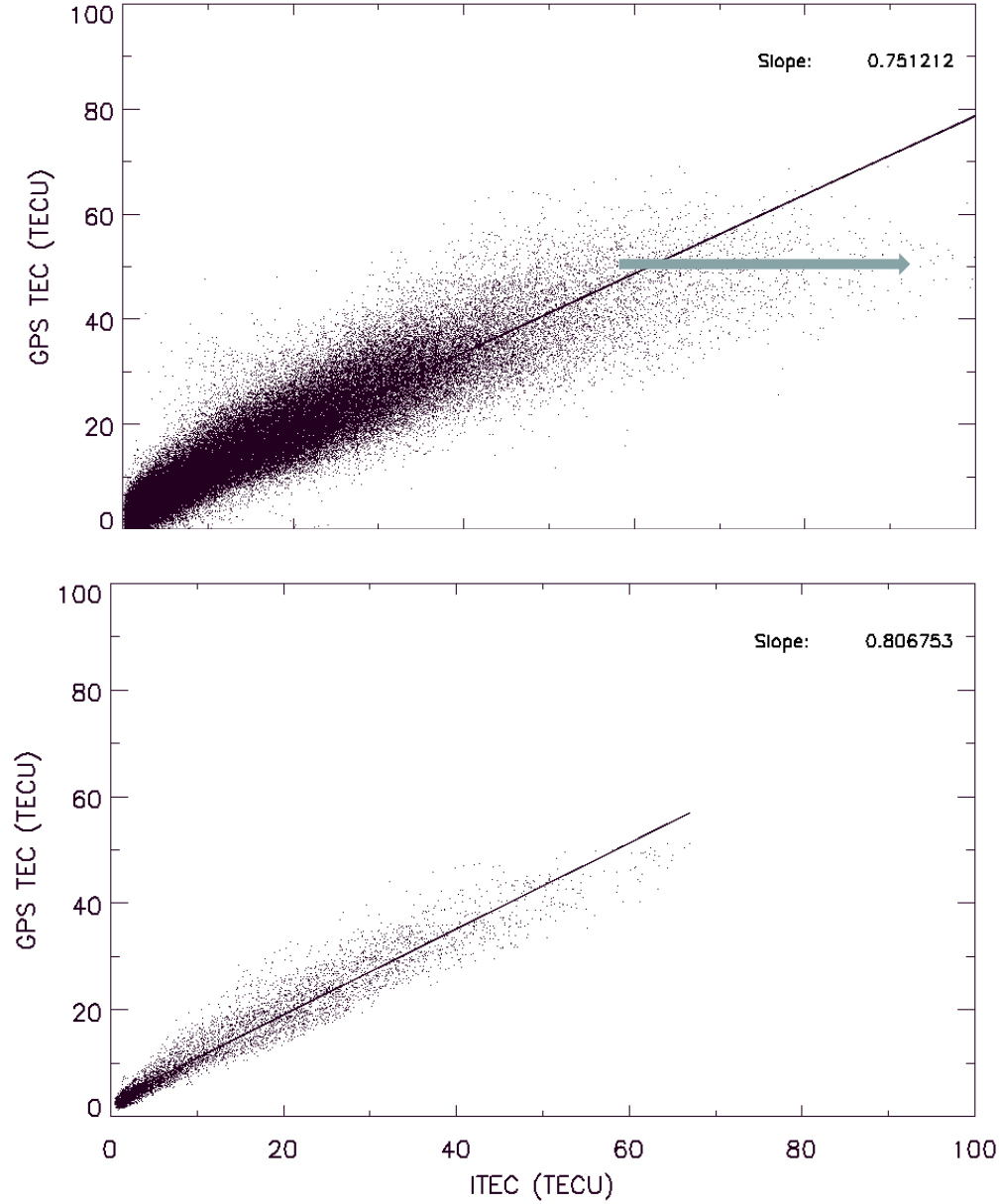




Diurnal and seasonal variation of standard deviation of ITEC and GPS TEC at Hainan.

3.3e Relation between GPS-TEC and ITEC data

1. Generally, there is good linear relationship (GPS-TEC=0.75 ITEC+const. for daily data; GPS-TEC=0.80 ITEC+const. for monthly median data).
2. It is notable that the GPS TEC seems to be saturated for the ITEC when ITEC/GPS TEC is more than 60/40 TECUs for the daily quarter-hourly data. For the monthly median data, very few data (ITEC) are more than 60 TECUs and the saturation phenomena is not clear.



Scatter plot of ITEC and GPS TEC at Hainan during 2005 - 2010. (upper panel: daily quarter-hourly data; lower panel: monthly mean data.)

4. Summary

① The total electron contents produced by all techniques (GPS-TEC, ITEC and TECiri) have similar variation trends and diurnal and seasonal variation; behavior of the total electron content can be reproduced well by IRI-2012;

② Generally the IRI predictions greatly overestimate TEC values in the daytime and there is small deviation at nighttime; the IRI predictions with NeQuick topside ionosphere option are better than the corr. one.

③ Deviations between TECiri and ITEC/GPSTEC have no obvious variation for NeQ. option with solar activity, but change for Cor. Option, except in 2011 and 2012.

④ There are systematically small differences between ITEC and GPS-TEC. Generally, ITEC reach daily peak earlier than GPS-TEC; ITEC is smaller/bigger than GPSTEC during nighttime/daytime; smaller differences in winter and bigger ones in other seasons.

⑤ there is good linear relationship between ITEC and GPS TEC; but it seems that GPS TEC is saturated when ITEC is more than 60 TECUs.

谢谢！

Thanks for your attentions!