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Modeling Center

# Climatology Assessment of Ionosphere/Thermosphere Models in Low Solar Flux Conditions for the CCMC CEDAR Challenge

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*CEDAR, SOLA-06, 26 June 2012, Santa Fe, NM*

# CCMC Electrodynamic-Ionosphere-Thermosphere Challenge

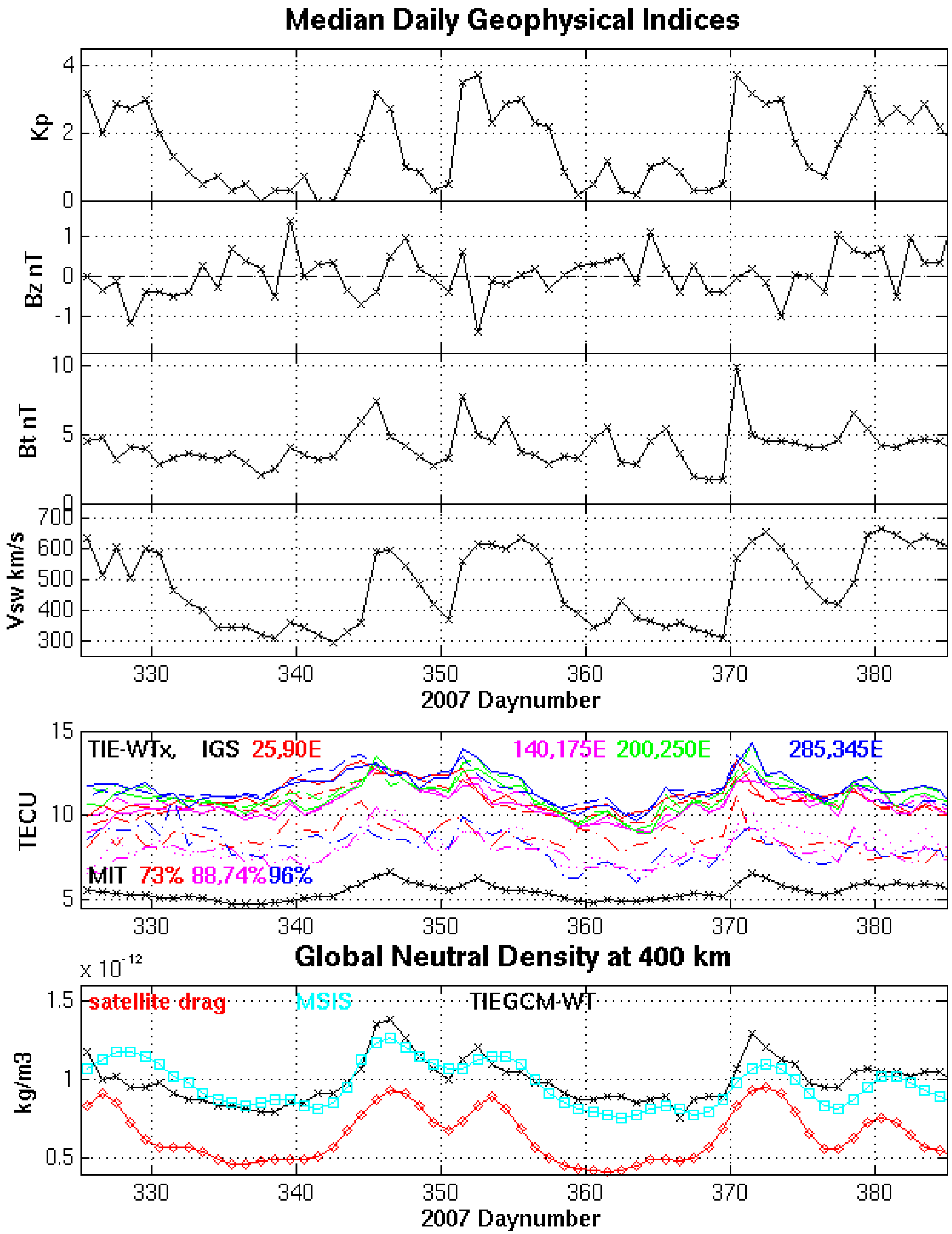
.The CEDAR Electrodynamics-Thermosphere Ionosphere (ETI) Climatology Challenge selected several GEM storms and the year of ISR observations (March 2007 – March 2008) for climatology at the first CEDAR ETI Challenge Workshop in the summer of 2009.

. We examine solar minimum December solstice (07355) for +/-30 days.

. Data sets: MIT, JPL, and IGS GPS TEC, USU COSMIC NmF2 and hmF2, NRL satellite drag daily global neutral density at 400 km, CHAMP neutral density at 400 km, Jicamarca ion drifts (mags, JULIA, ISR)

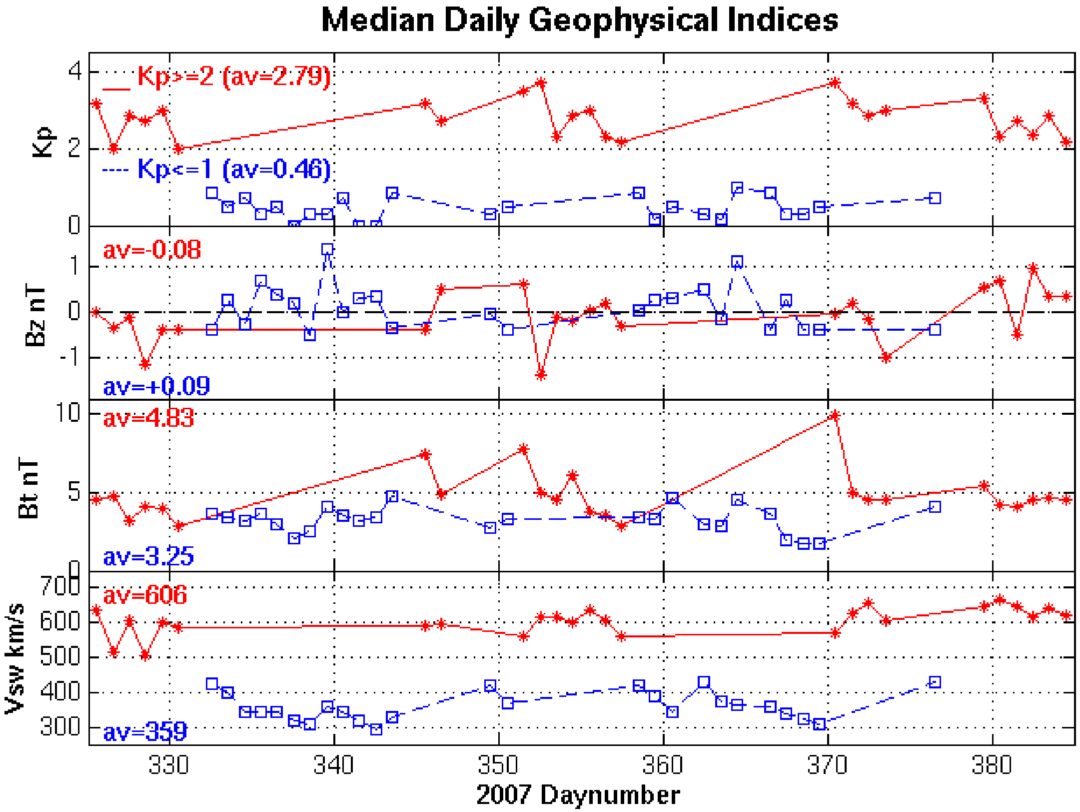
. Models: CCMC runs of IRI2007, SAMI3_HWM93, USU_IFM, CTIPe, TIEGCM (Heelis Kp), USU_GAIM, and runs of TIEGCM (Weimer 2005 and TIMED lbs), TIME-GCM (AMIE), and SAMI3 (MSIS tweaked).

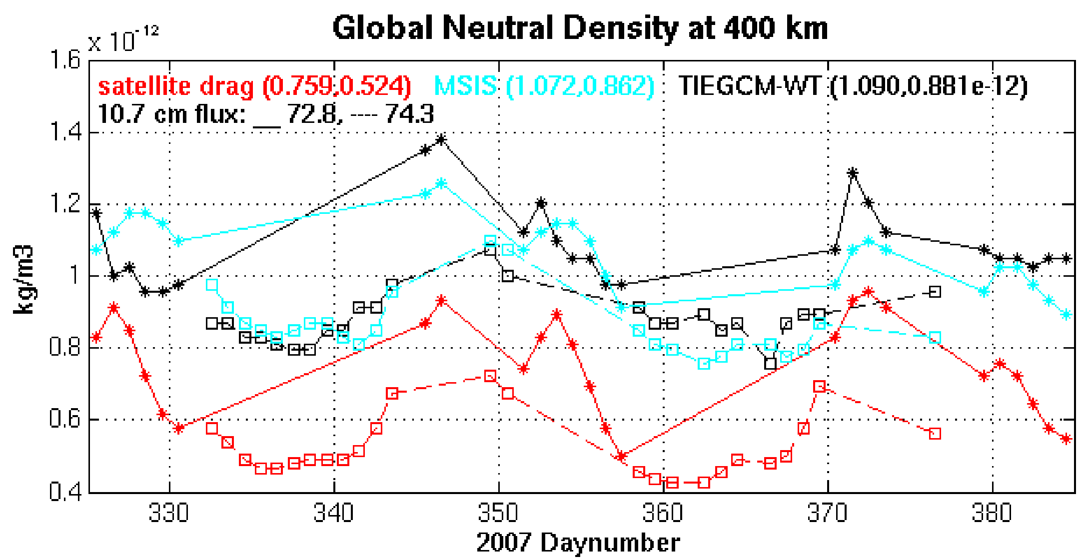
# Solar Wind and Global TEC and Neutral Density at 400 km




The conditions from 07325-08020 were dominated by 5 periods of High Speed Streams (HSS) in the solar wind velocity (Vsw) and low solar wind. Kp values were usually >2 for the HSS and <1 for the low Vsw. The HSS prompted high global TEC and neutral densities at 400 km in satellite drag data (red) from Emmert [2009, JGR], MSIS (cyan) and TIEGCM Weimer05 with TIMED lower boundaries.

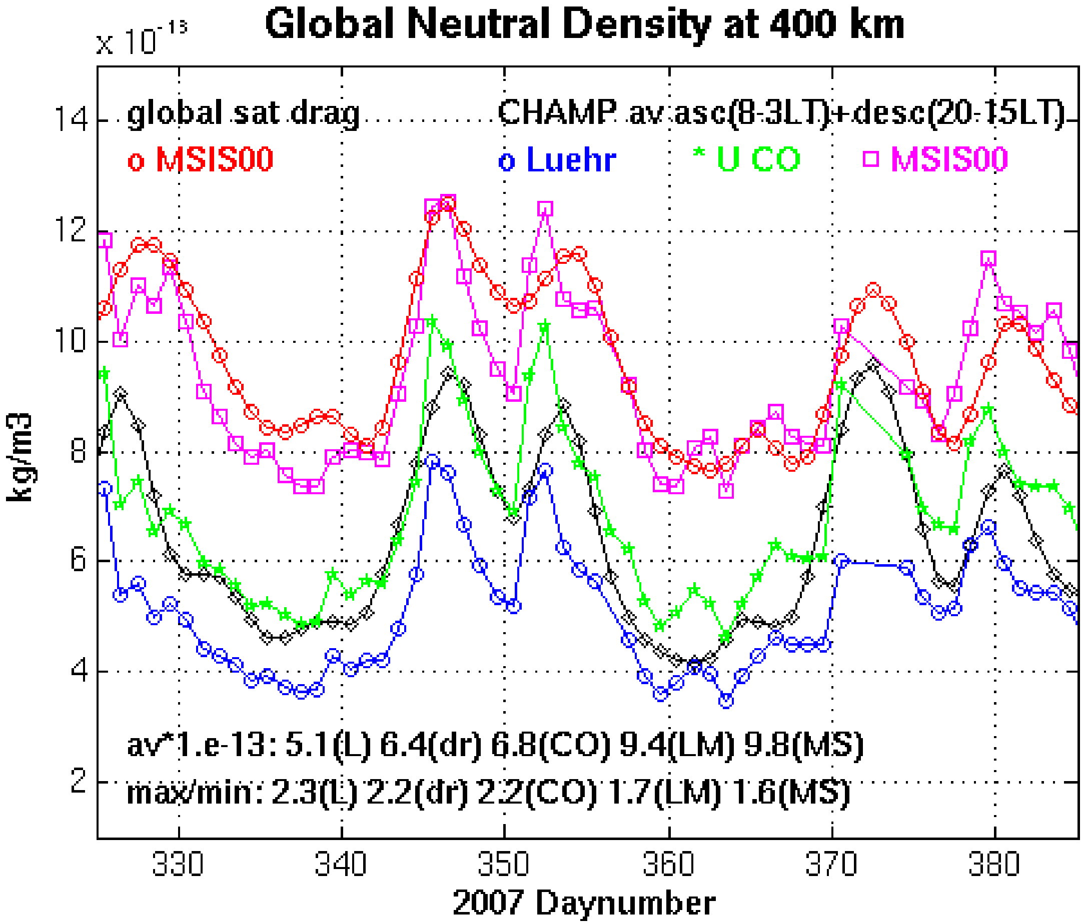
# Separating HSS and Slow Speed Wind




Choosing Kp>=2 and Vsw>=500km/s and Kp<=1 and Vsw<=450km/s results in 25 days each of HSS (red) and slow speed wind (blue) conditions. Averages from daily values are: 10.7 cm flux 72.8, 74.3; Kp 2.79, 0.46; Bz nT -0.08, +0.09; Vsw km/s 606, 359. Neutral densities at 400 km are higher for HSS (*) than for slow Vsw (squares).

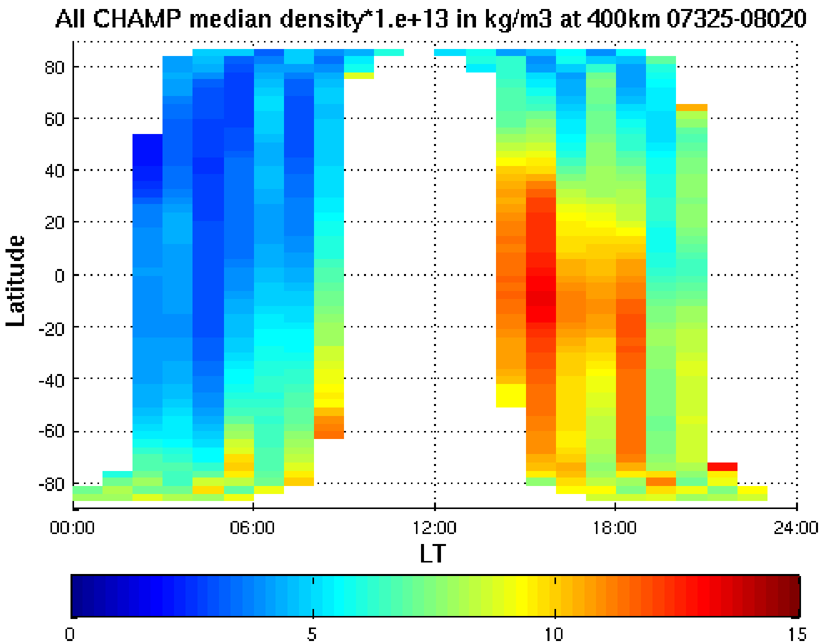
# Global or 24h-av CHAMP neutral Densities at 400 km

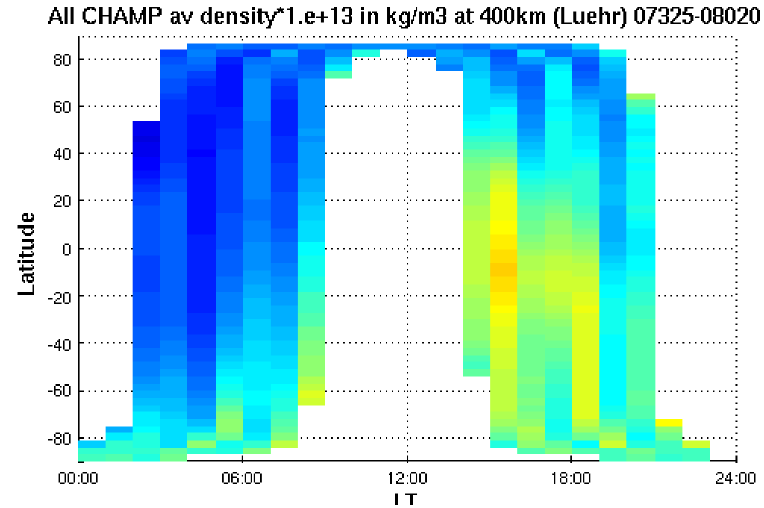


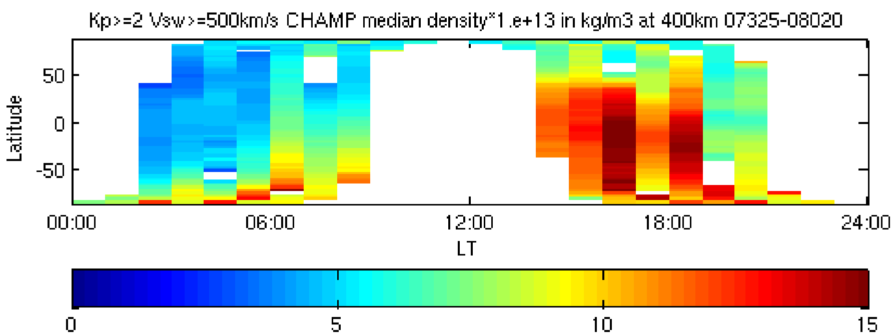

There are pronounced peaks at the times of the High-Speed solar wind Streams (HSS).

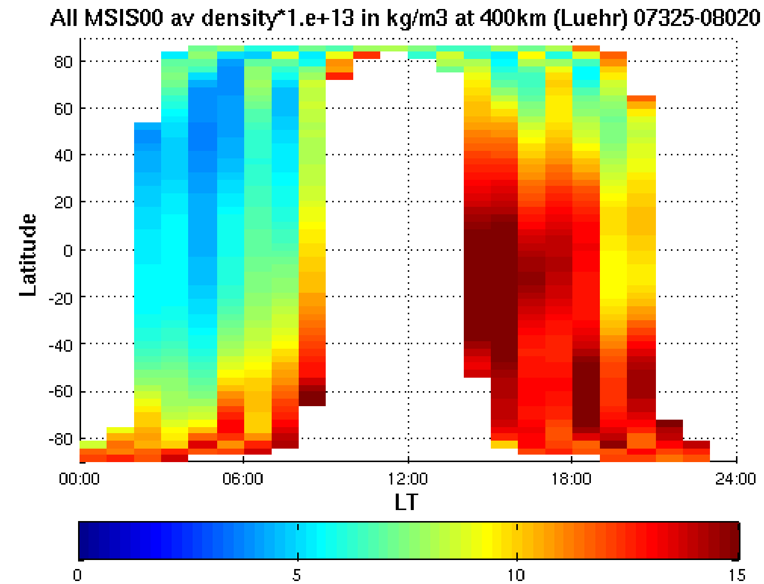
The CHAMP densities gradually increase in time because the LT slips from 8 and 20 LT towards 3 and 15 LT where the extra density at 15 LT outweighs the lesser density at 3 LT.

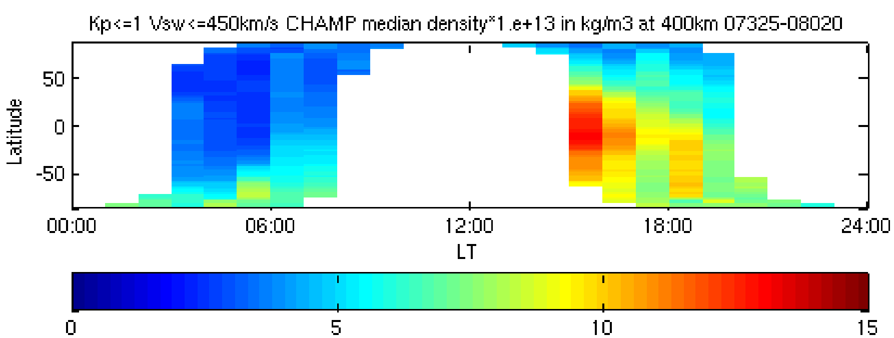
There are 2 of 4 versions of CHAMP data here: (1) from H. Lühr (PI for CHAMP) and (2) from E. Sutton (U CO, now at AFRL). Lühr 400 km densities are lowest in these 61 days, where the global satellite drag densities are 25% larger, the U CO densities are 33% larger, and the MSIS00 densities at CHAMP are 84% higher. The U CO densities agree best with the satellite drag estimates from John Emmert of NRL.



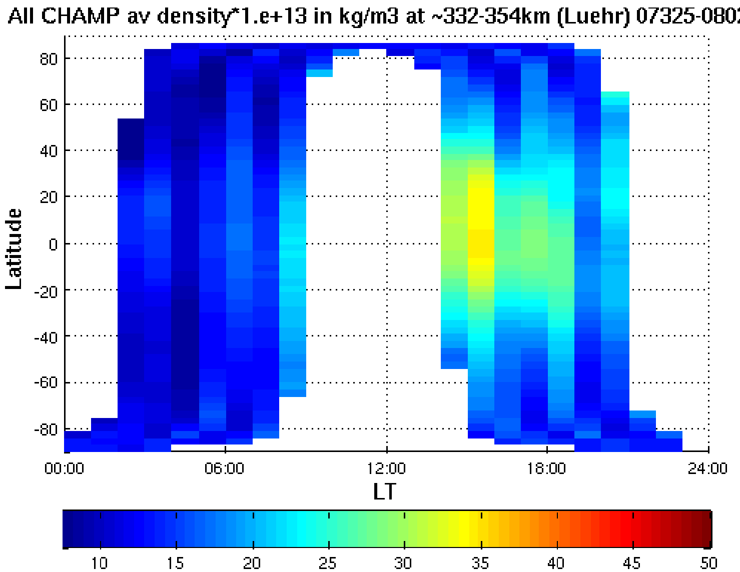



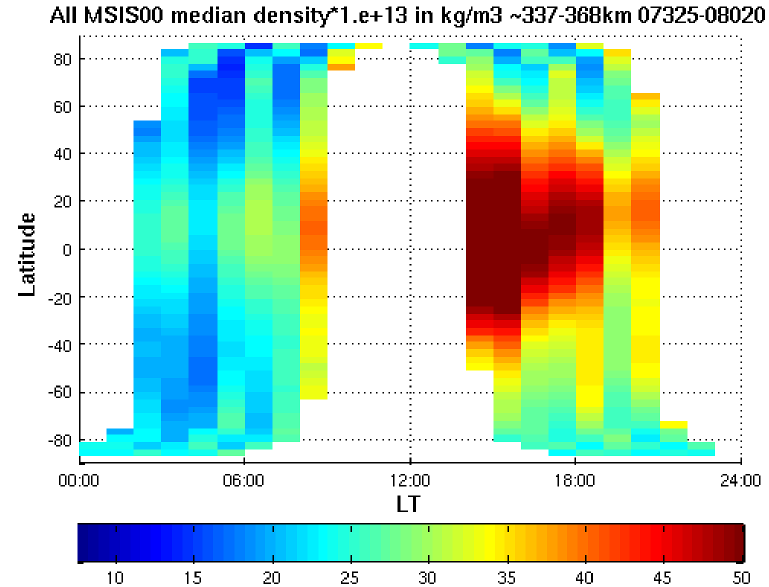



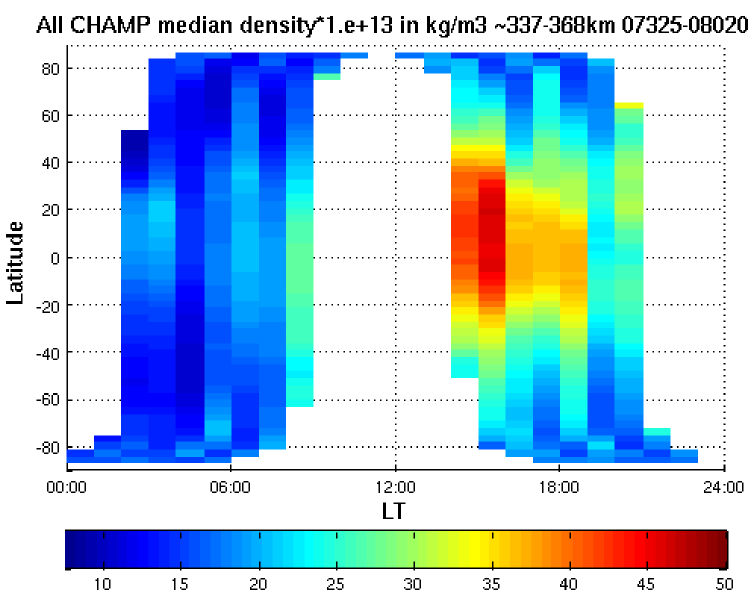

Lühr CHAMP densities are lower than U CO and MSIS. Kp>=2 densities are larger than Kp<=1.

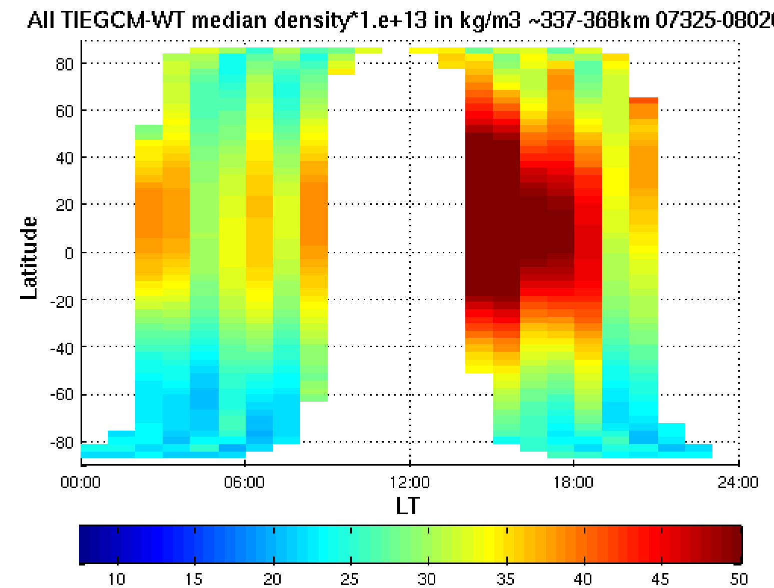
# CHAMP altitudes are higher for U CO (~337-368km) than for Lühr (~332-354km)




MSIS densities similar for both alt ranges.

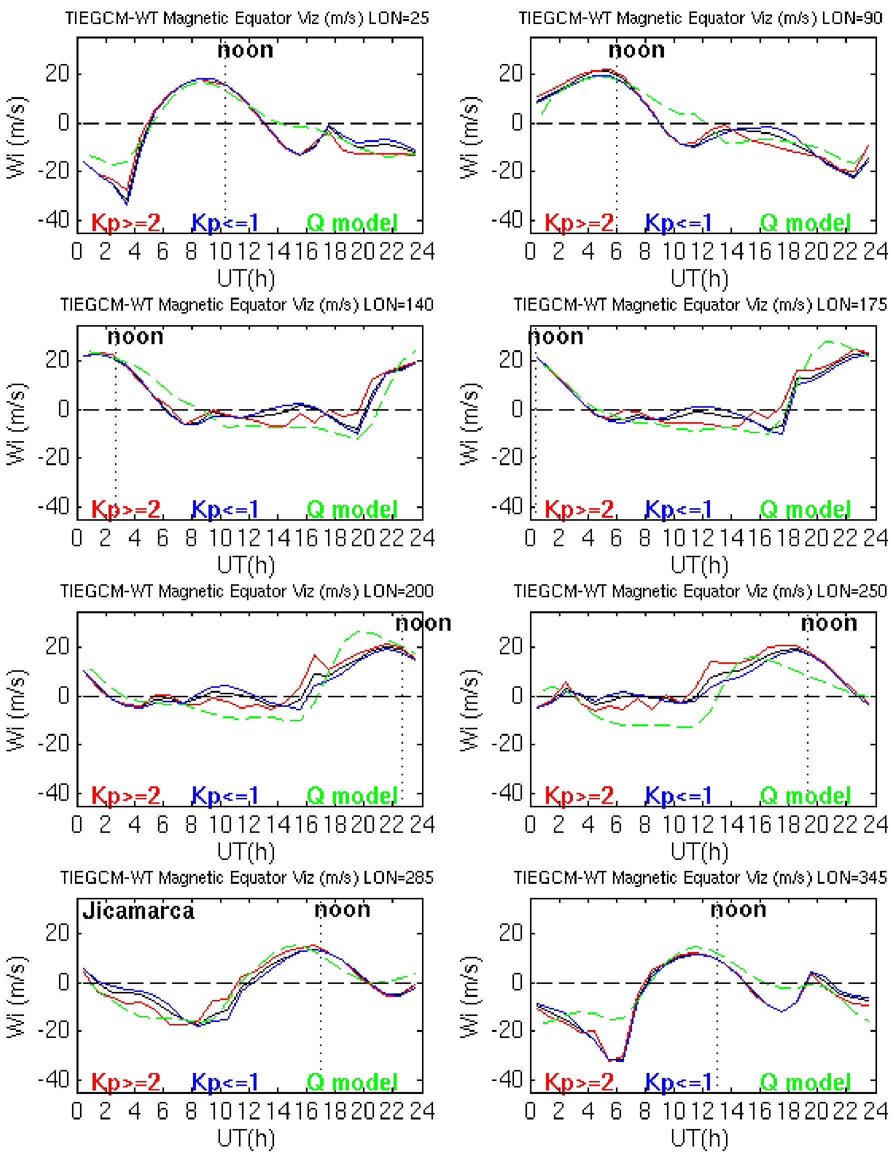



TIE-WT ~2x hi 2-8LT in quiet periods.

Empirical model of the equatorial vertical drift
(Scherliess and Fejer, JGR, 104, 6829-6842, 1999.

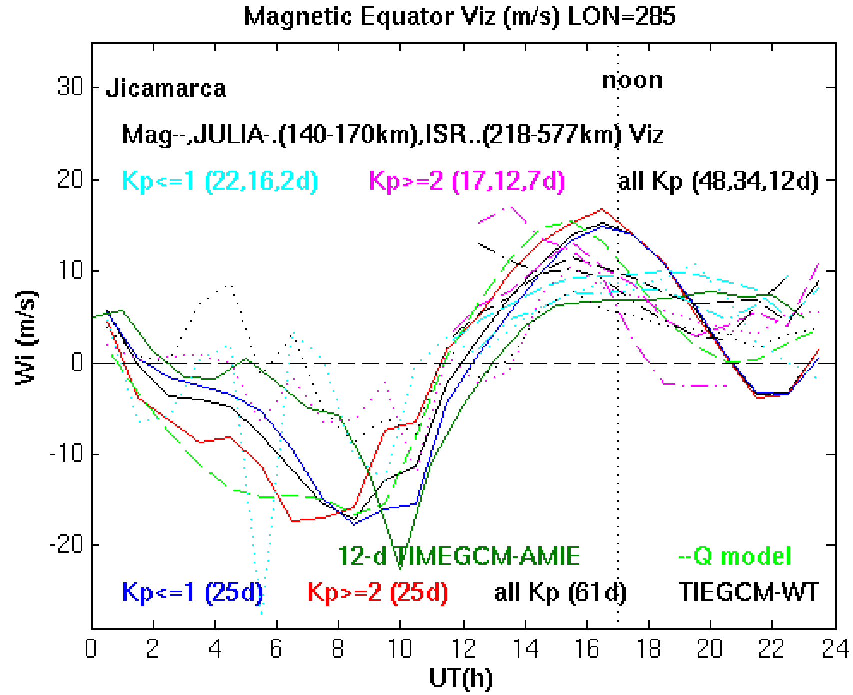
# Drifts around the magnetic equator

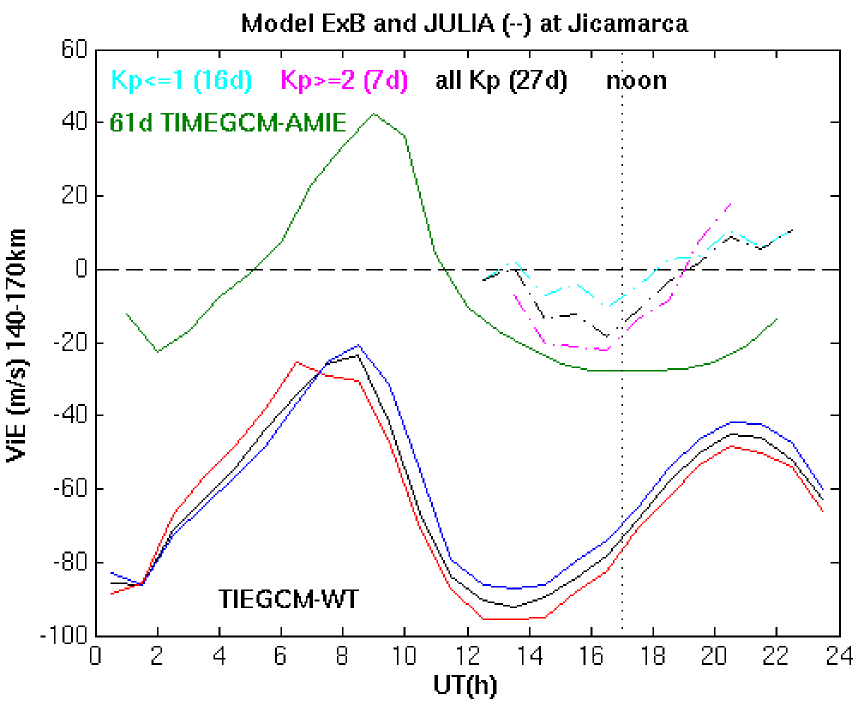


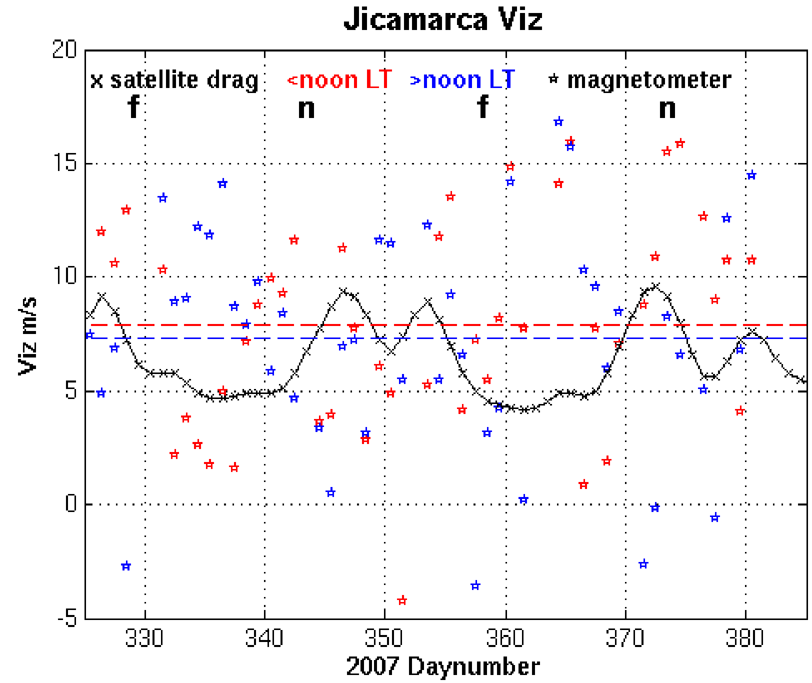

Can calculate the median vertical ion drift from the models and compare it to the quiet-time model as a function of LT and longitude at the magnetic equator.

Results for TIEGCM Weimer TIMED lower boundary are fairly good.  Usually active period (Kp~3-) larger magnitudes.

# Jicamarca Viz and Vi(+E) Drifts



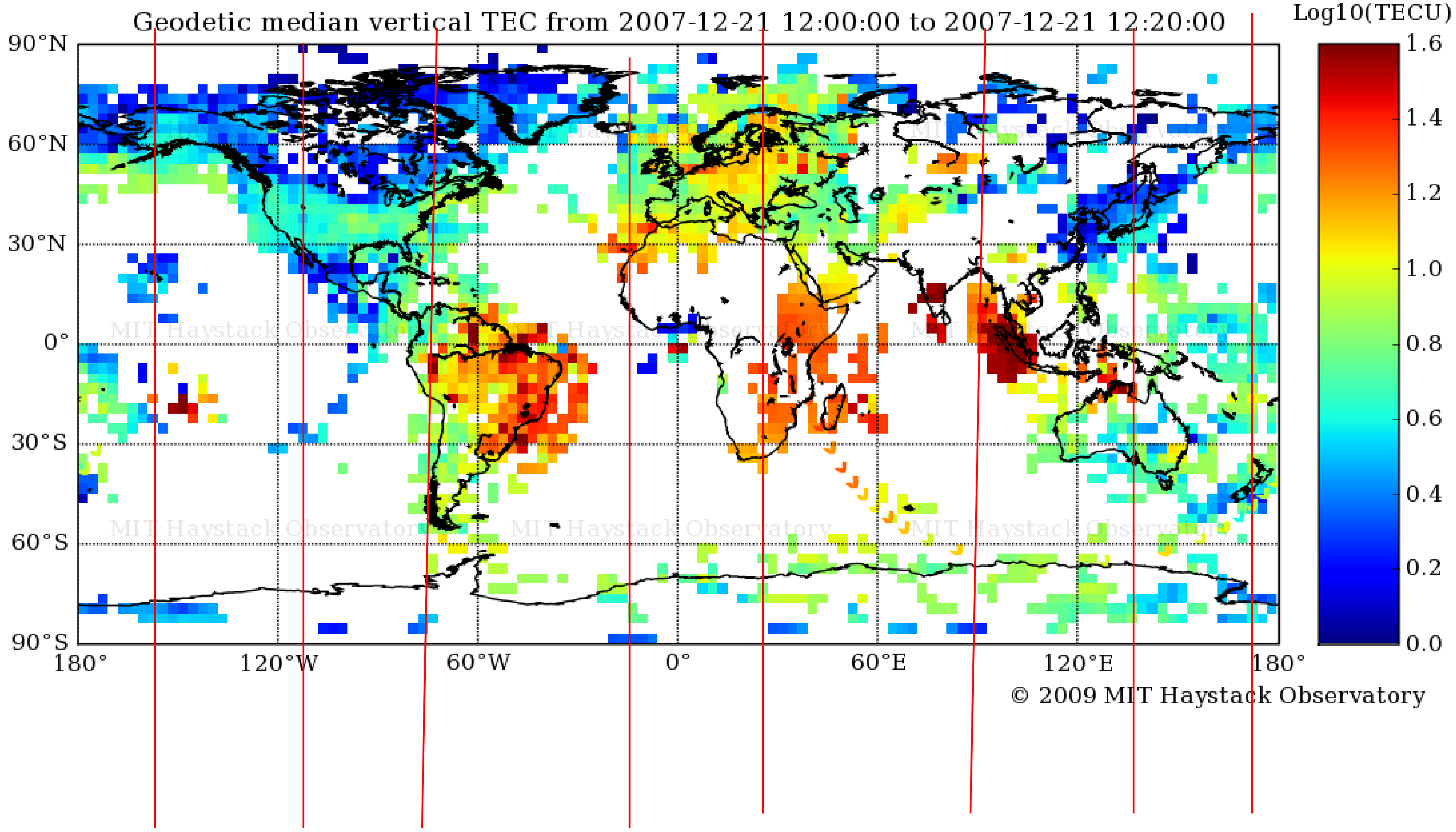



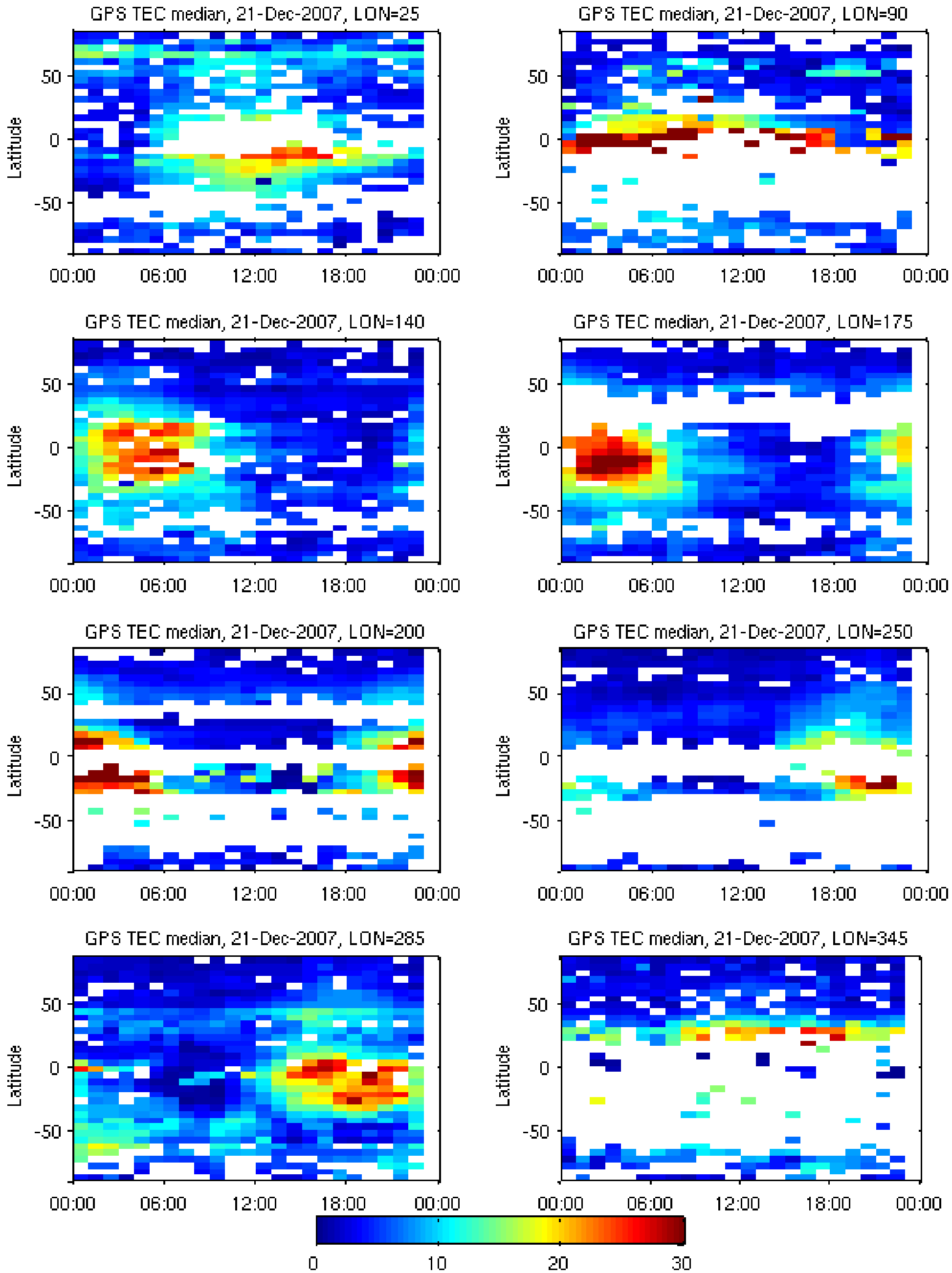

Daytime obs show Kp~3- Viz drifts are larger in magnitude before noon, and smaller after noon.

Dec lunar semi-diurnal tide expects full and new moon +2m/s pre-noon.

# Choose 8 Longitude Slices from GPS TEC




5 deg lat and 5 deg lon bins for 20 min in December solstice 07355. Longitudes chosen: 25E, 90E, 140E , 175E, 200E (160W), 250E (110W), 285E (75W), 345E (15W).

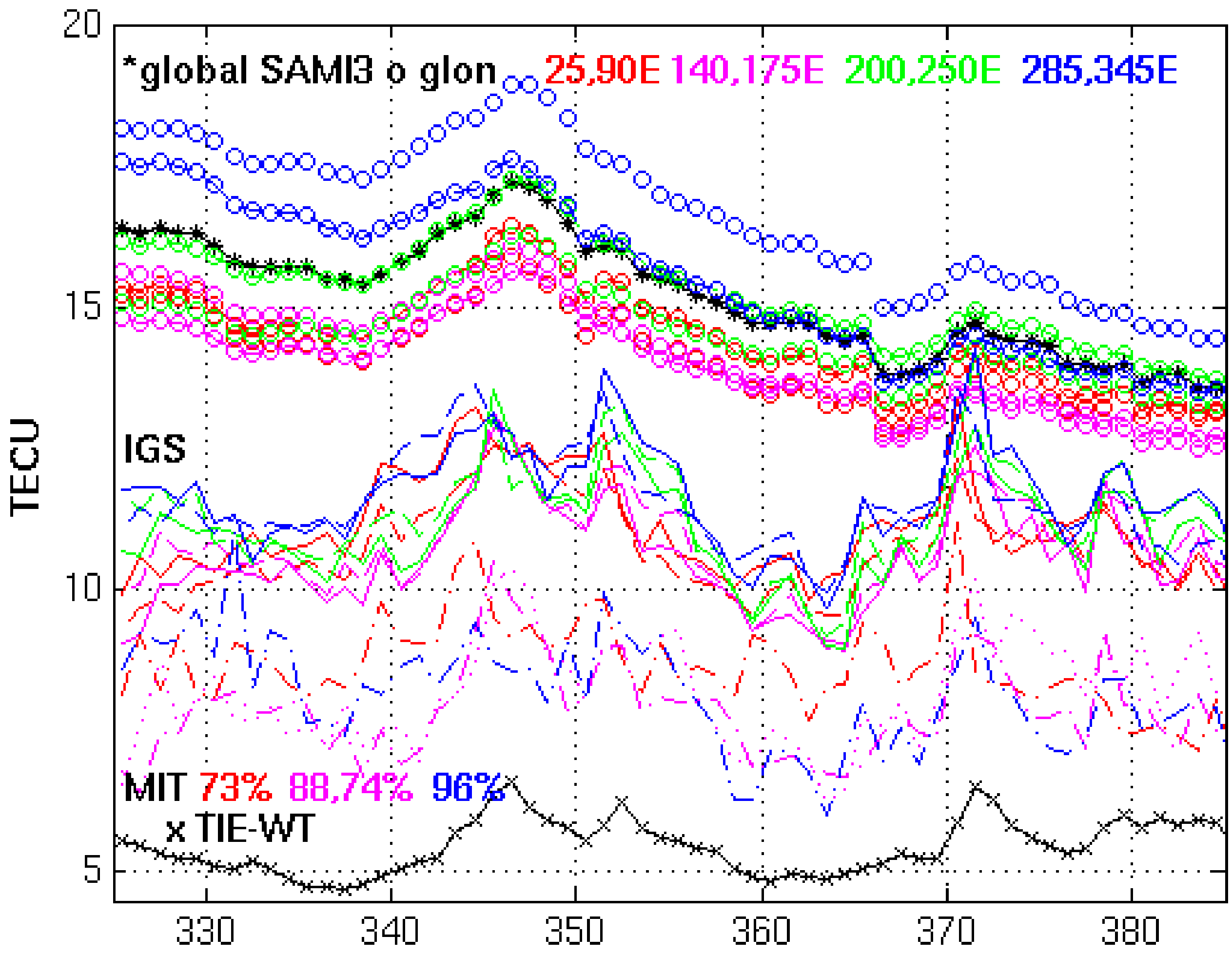



Hourly coverage of the 8 longitude slices for 21 December 2007 from MIT GPS TEC analysis.

Minimum number of bins 446 (52%) for 345E, maximum 727 (84%) for 140E for 24h*36lat = 864 bins.

Can see daily low latitude maxima.

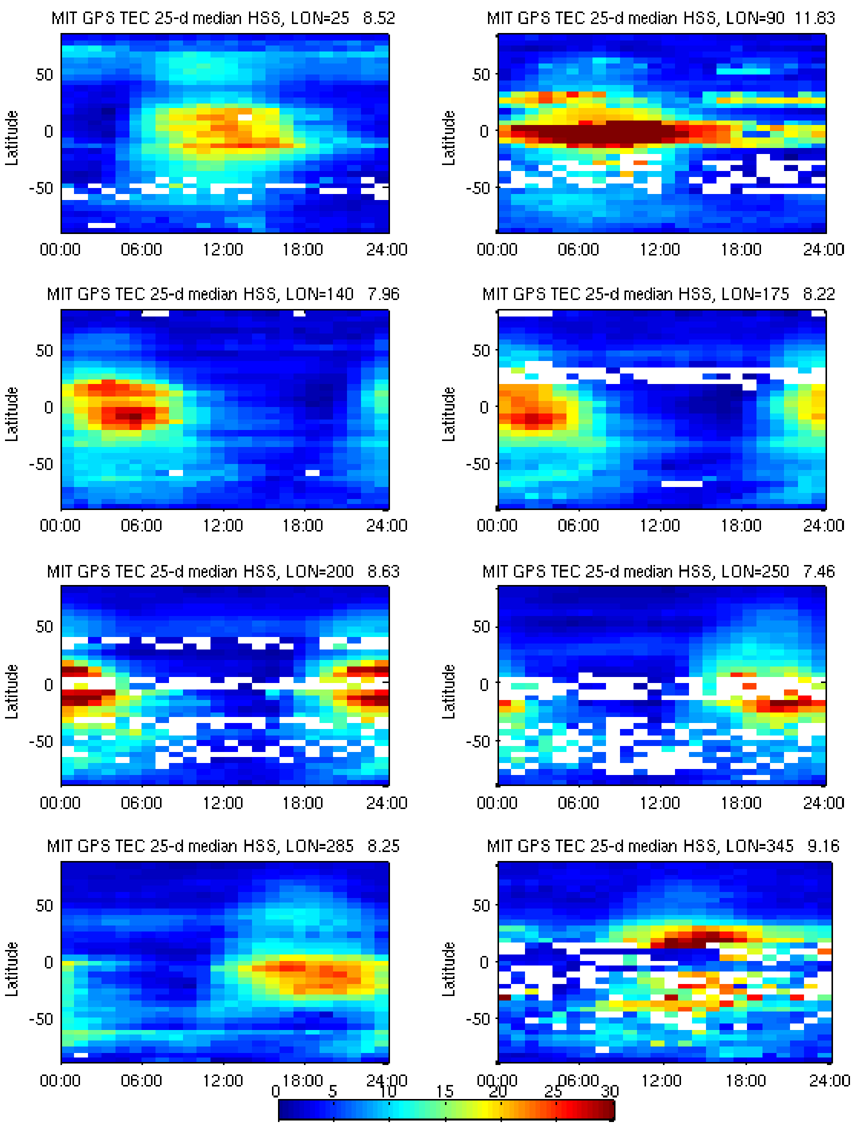
# Daily TEC (global and glon-24h)

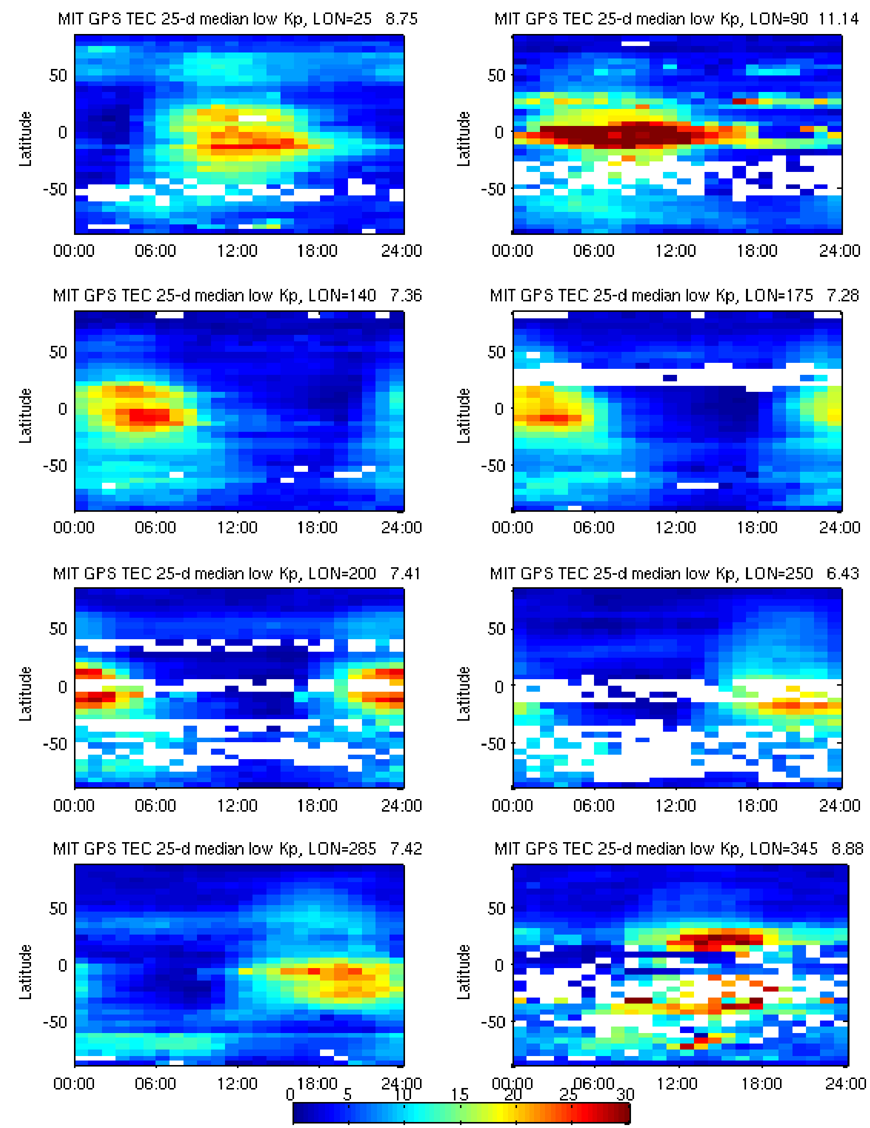


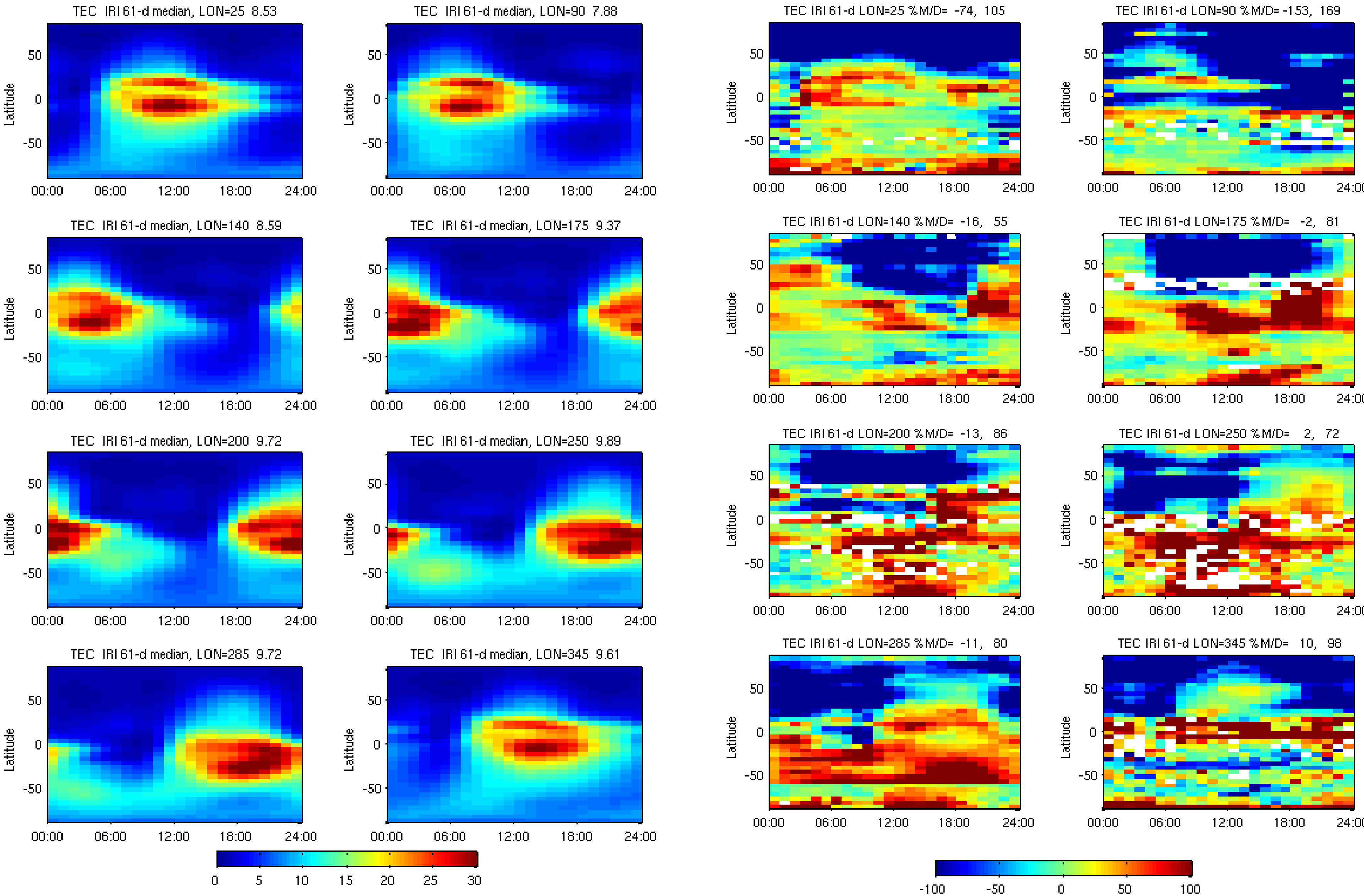

See peaks in the area-weighted global and daily glon TEC in the GPS data and the models.

# HSS (Kp>=2) and Slow Vsw (Kp<=1)

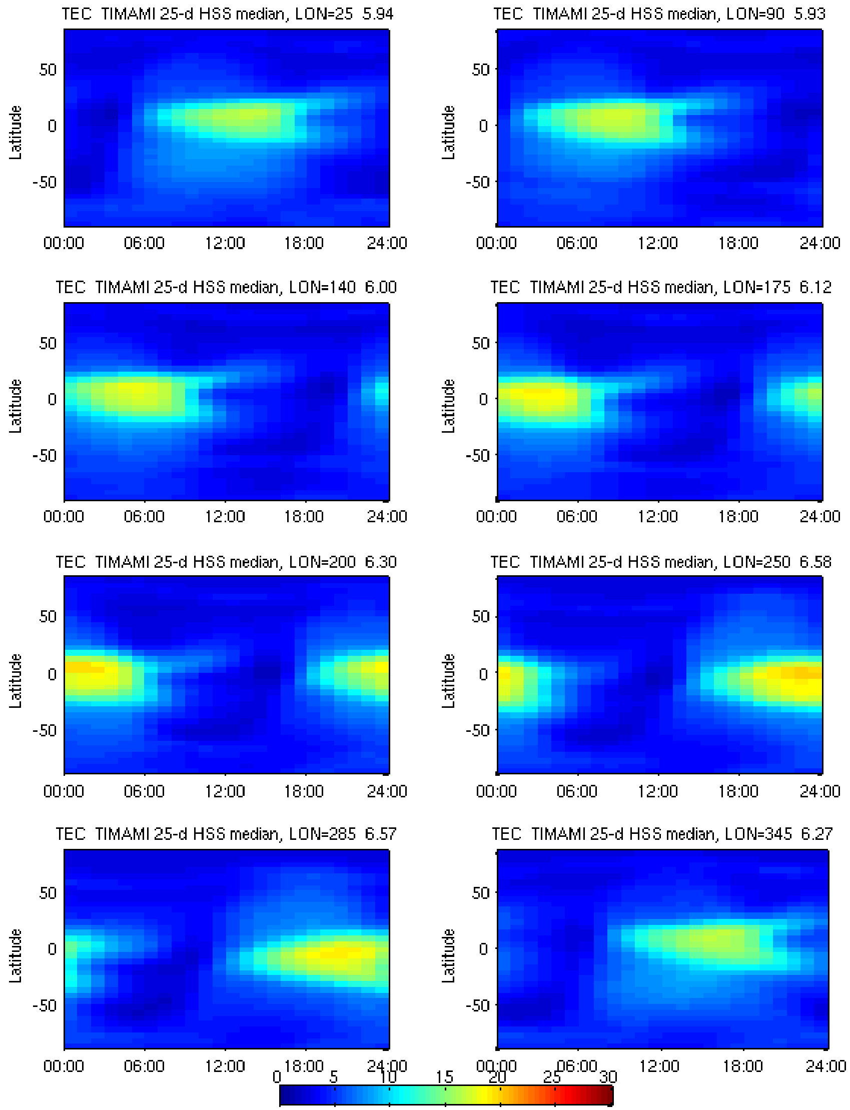
The TEC for moderate Kp>=2 (HSS) is slightly larger than for low Kp<=1 (slow Vsw)

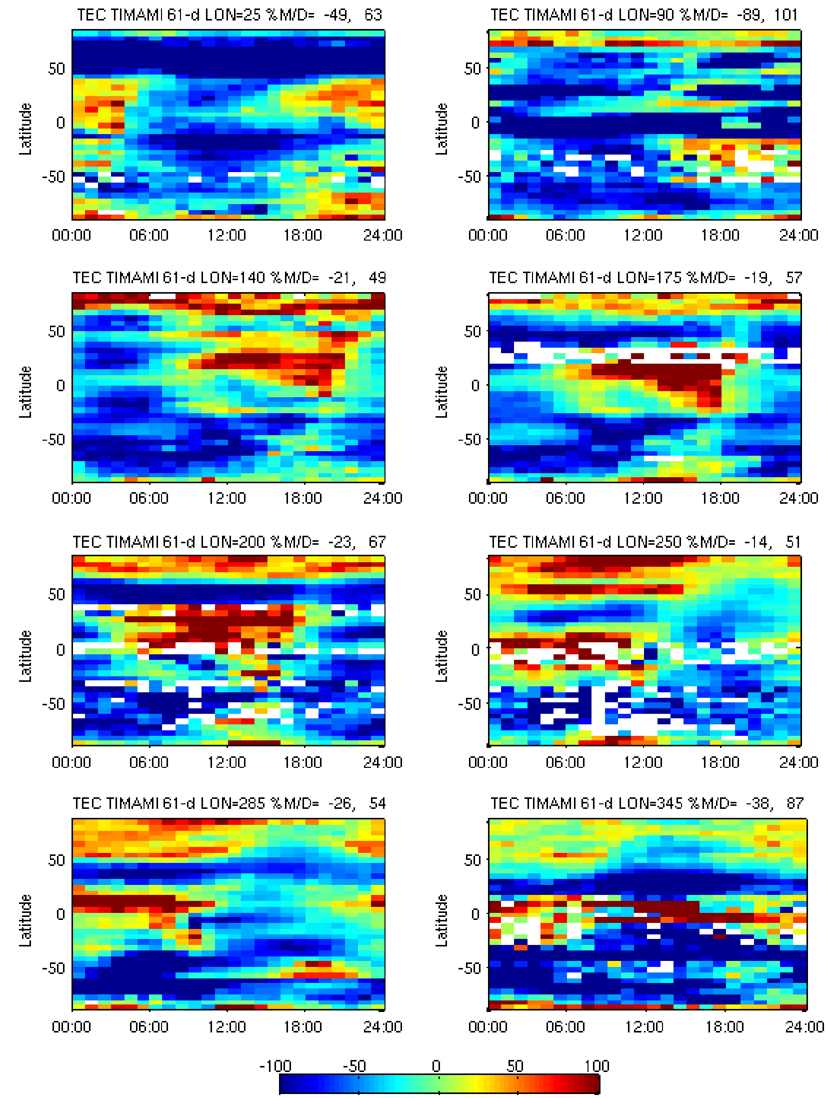


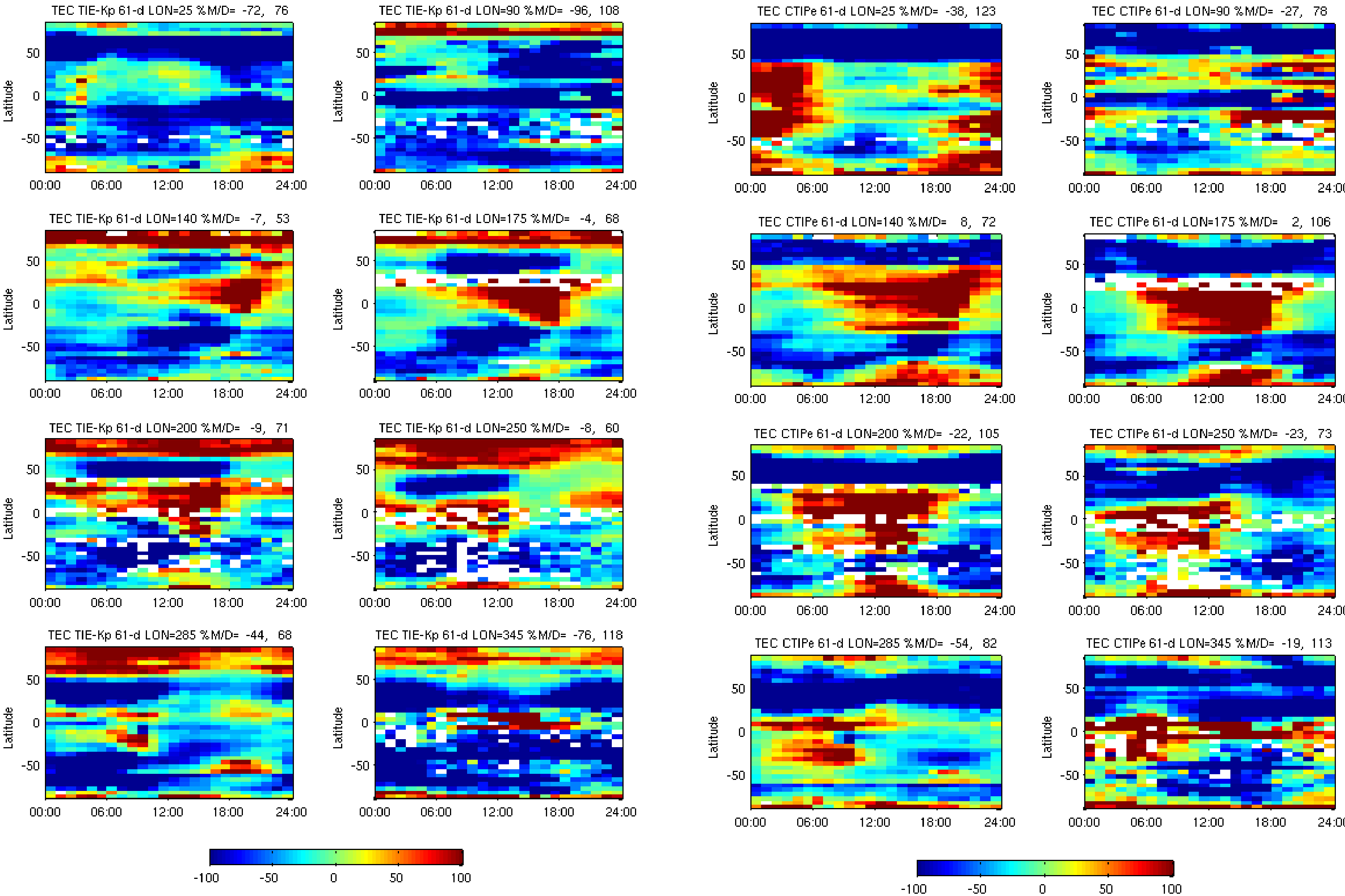



IRI model TEC and %model/data shows IRI overestimates morning day and summer night TEC and underestimates winter night TEC. If model(M)>dat (D), the mean percentage error (MPE)=100 % (M/D-1) . If D>M, MPE=-100%(D/M-1). List ave, |abs|



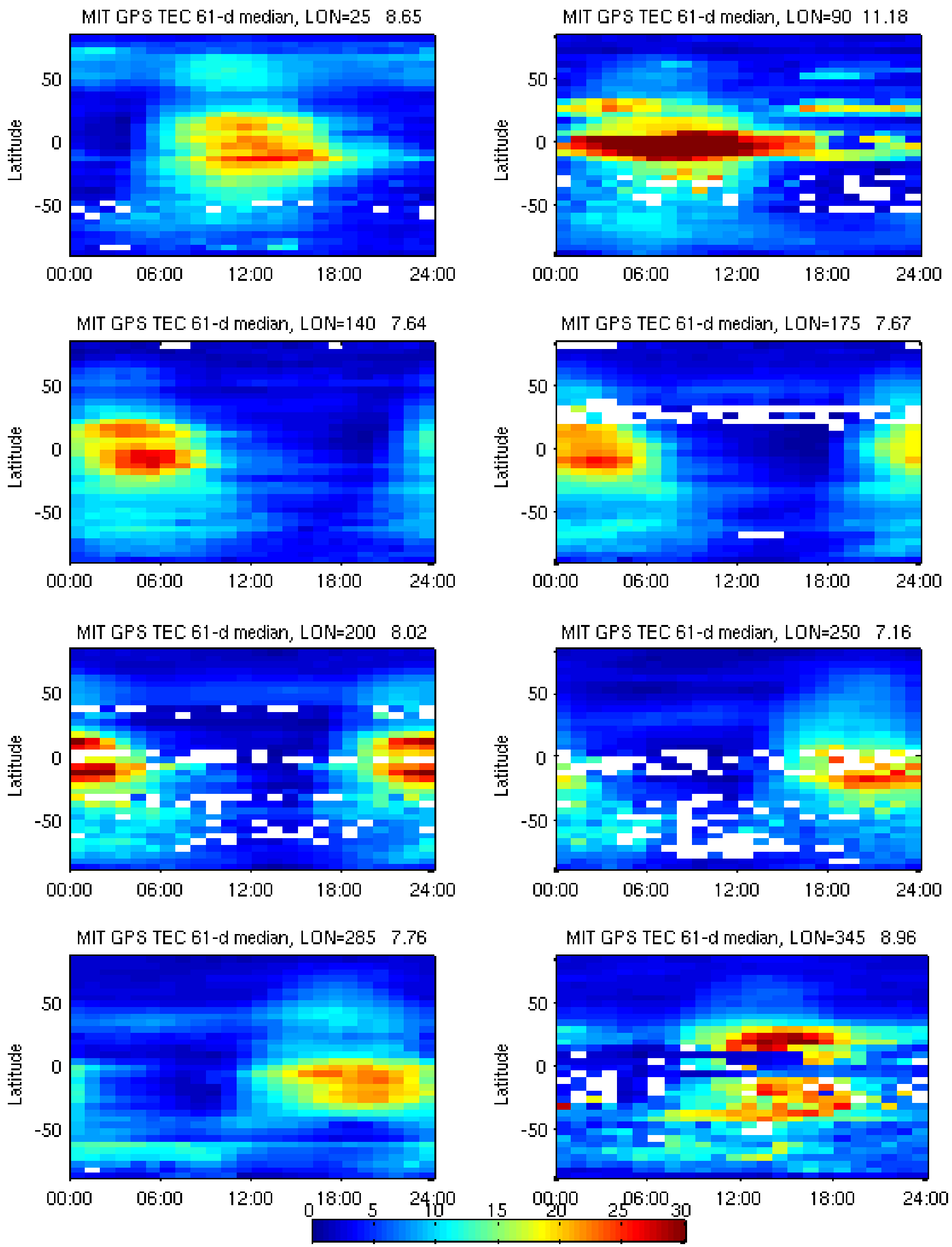




TIME-GCM with AMIE from ASTRA did best overall for TEC from MIT GPS analysis, but was high in the winter pole, low in the summer pole, and high in equatorial night.




The mean percent errors for the Kp TIEGCM and CTIPe are almost opposite for most errors except for a common overestimate at night in mid and low latitudes.

# Summary of MIT TEC Climatology

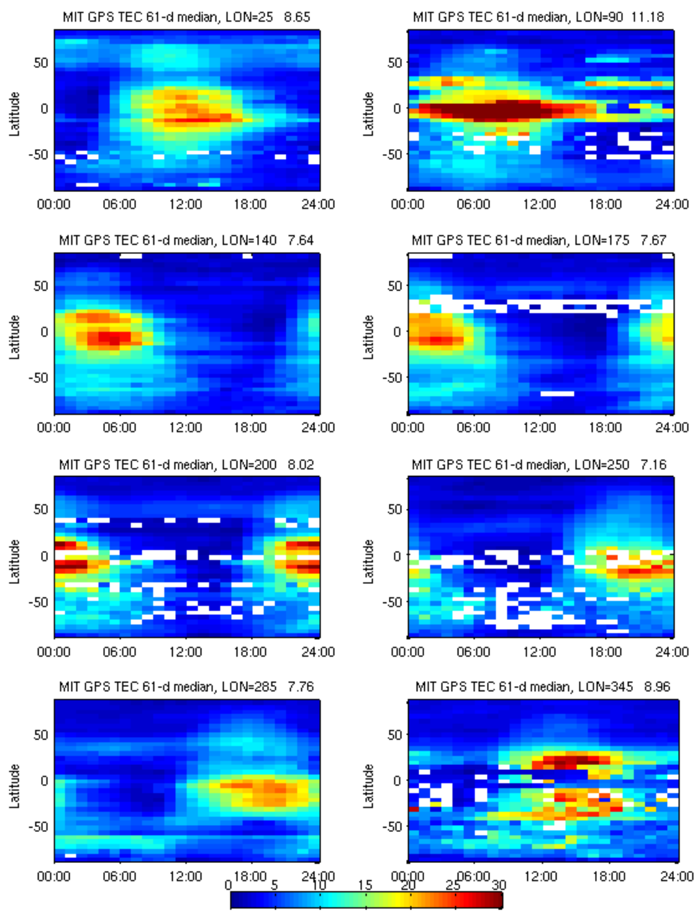


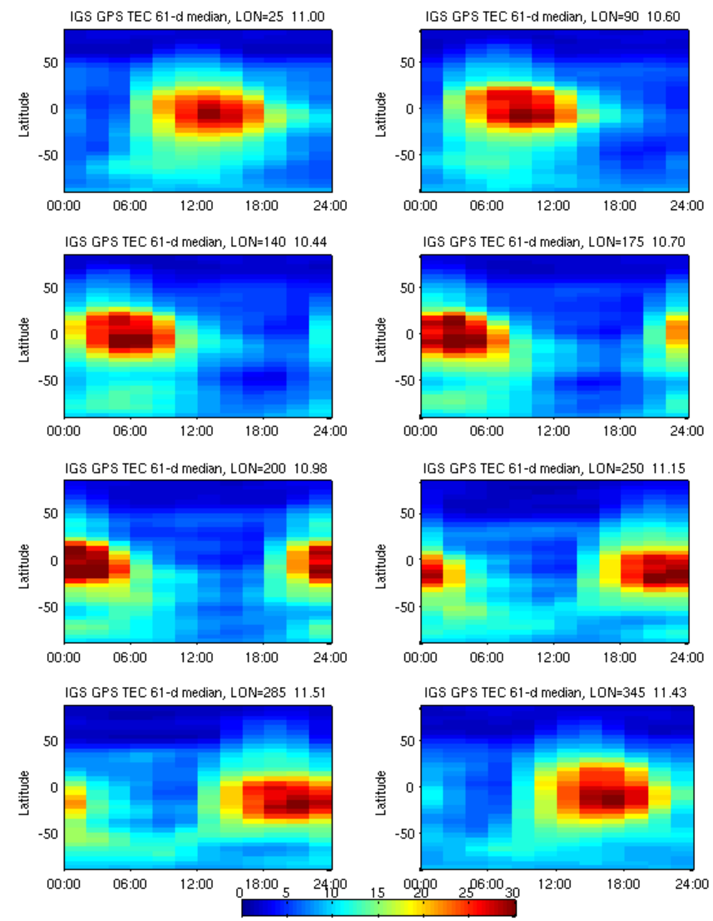

All models show different regions of overestimation and underestimation from the ‘real’ MIT GPS TEC.

Average absolute value percent deviations for 61 days total, or 25 days HSS or slow Vsw:

1) TIME-AMIE (lo) 66,66,71%
2) TIE-Kp (lo) 76,77,84%
3) TIE-WT (lo) 90,90,93%
4) IRI07 (lo) 93,99,104%
5) CTIPe (lo) 94,108,99%
6) SAMI3 (hi) 129,229,156%

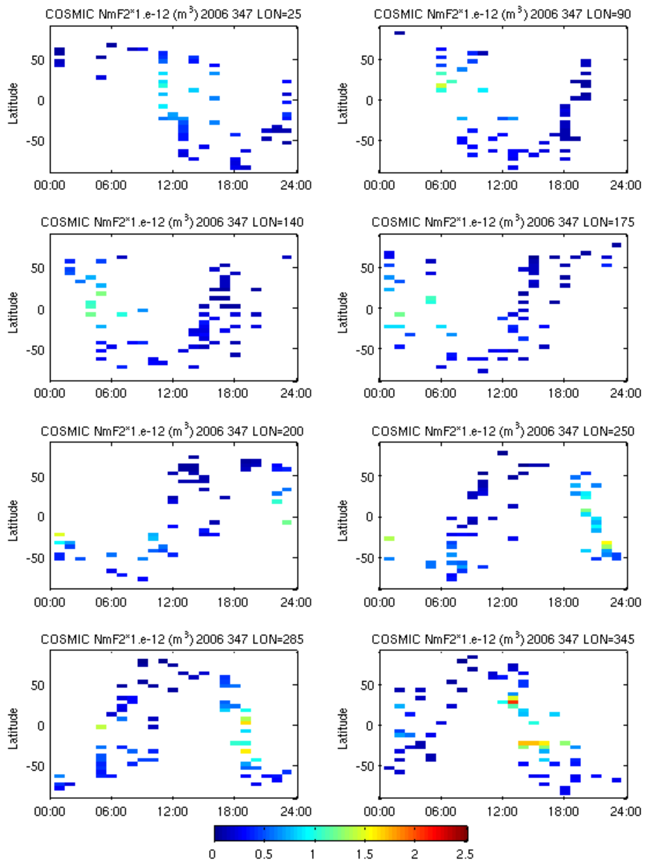
# Comparison of MIT and IGS TEC

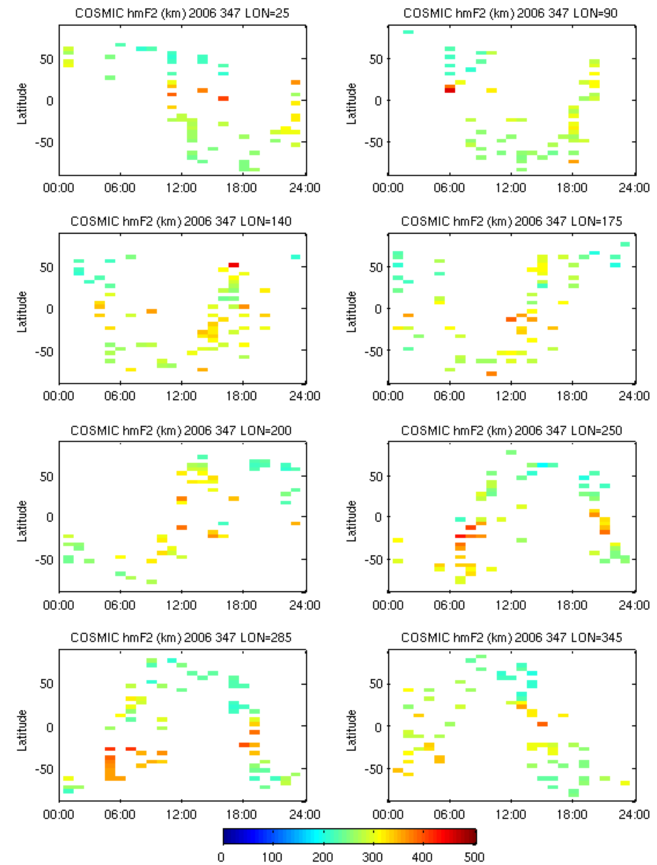


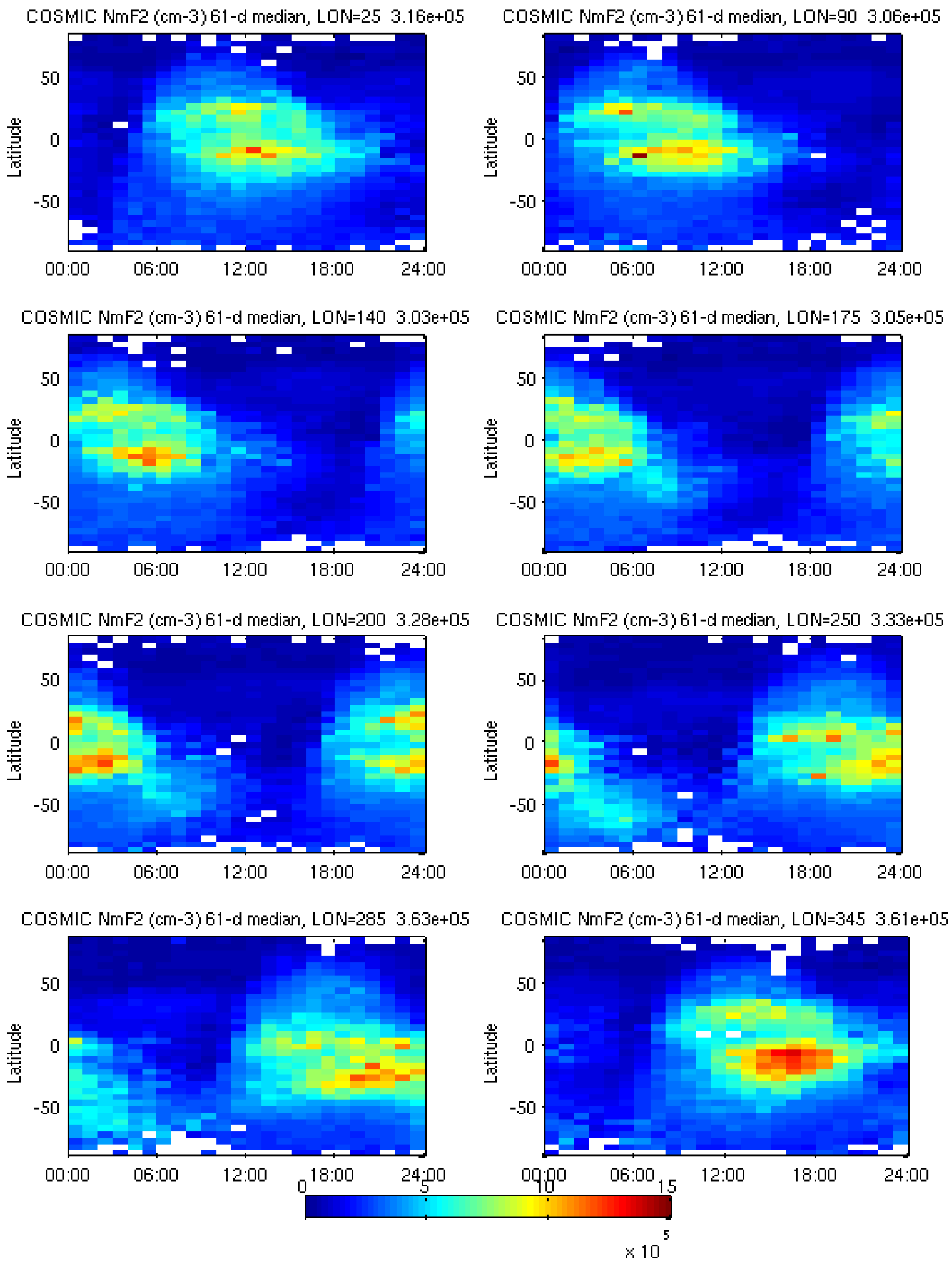

IGS higher anomaly peaks, lower TEC winter NH pole and higher TEC summer SH pole. **Summary of IGS TEC:** SAMI3 (hi) 36%, CTIPe (lo) 80%, IRI07 (lo) 88%, TIE-Kp (lo) 112%, TIE-WT (lo) 159%, TIME-AMIE (lo) 188%, a reversal in order of what is ‘best’.

# COSMIC NmF2 and HmF2



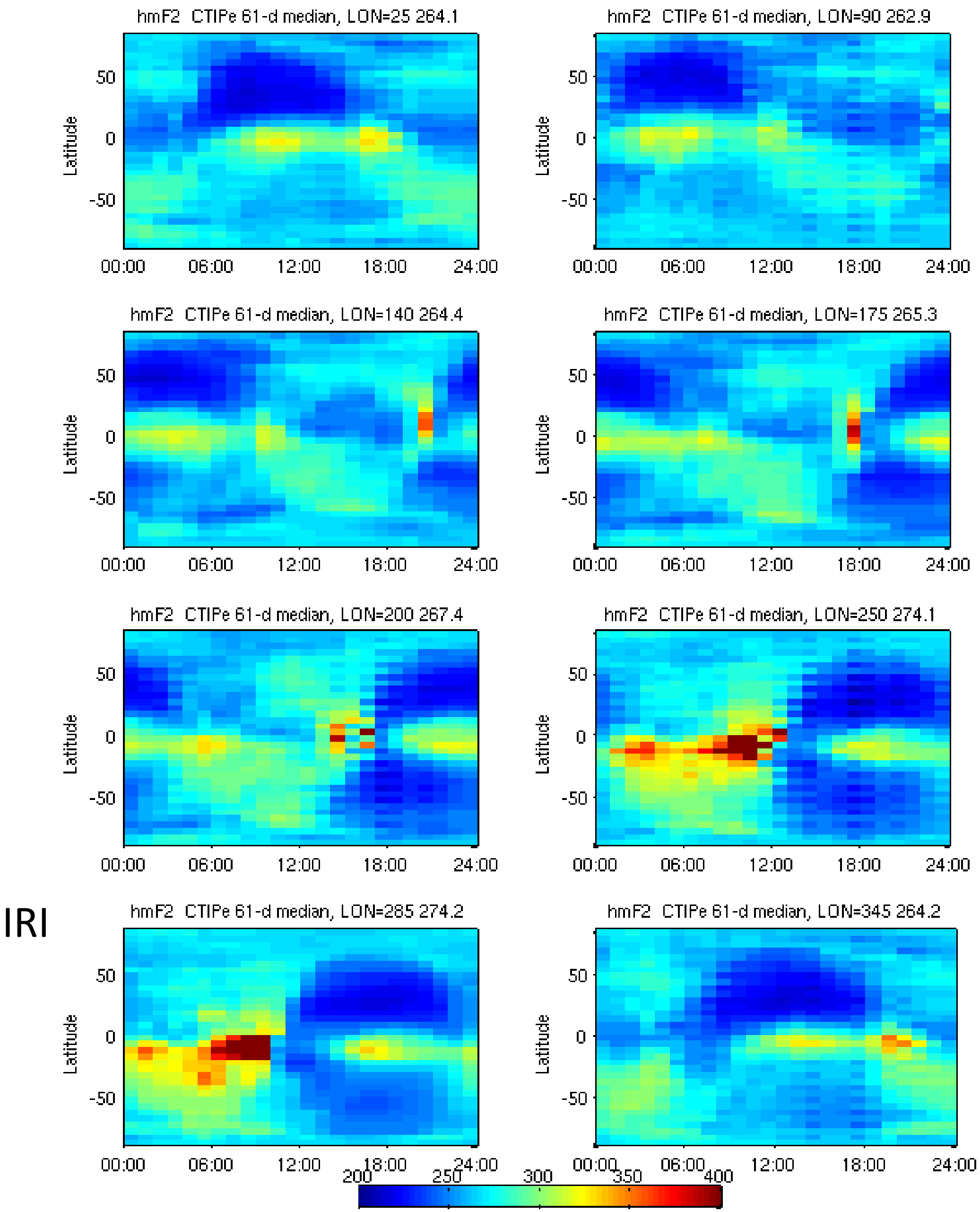




For 15 min averages of 5x5 glat/glon bins on Dec 13, 2006, a 24-h lon period has 96*36=3356 total bins. COSMIC fills 1-2% (~60) of the bins, but MIT GPS TEC fills 34-79% (~1140-2650) of the bins.




# Summary of COSMIC NmF2 Climatology

- The regions of over- and under- estimates for NmF2 was sometimes the same as for TEC and often different.
- IRI was the clear winner, with SAMI3 doing next best.
- Average absolute percent deviations: IRI07 (~lo) 37%, SAMI3 (hi) 53%, CTIPe (hi) 64%, TIE-Kp (hi) 73%, TIME-AMIE (hi) 80.9%, TIE-WT (lo) 81.2%.




# Summary of COSMIC HmF2 Climatology

CTIPe, SAMI3, and IRI07 were close, but TIME-AMIE did best for 7 of 8 longitudes, while IRI07 was best for 285E.

Average absolute model-data deviations in km were:

1) TIME-AMIE 18 km
2) SAMI3 21.7 km
3) IRI 22.1km
4) CTIPe 23km
5) TIE-Kp 36km
6) TIE-WT 38km

# Summary of the First CCMC Climatology Study

- model performance depends on
  - latitude
  - season
  - local time
  - *data set* (factors of ~35% in CHAMP and GPS TEC)
- none of models rank at the top for all data sets used
  - *IRI best for NmF2, near best for hmF2, and in middle for TEC from MIT and from IGS*
- establishes a baseline for new models and future versions
- *neutral densities and daily glon-24h TEC vary with Kp (and HSS or Vsw) in both data and models.*
- *Jicamarca vertical drifts show Kp~3- larger before noon and smaller after noon, but this is at least partially semi-diurnal lunar tides in Nov-Jan.*
- *More data sets and models are welcome for the future climatology CCMC Challenge at the 2012 mini-GEM at AGU.*

# Future Participants

*Michael.David@aggiemail.usu.edu for TDIM USU runs

*Andrzej Krankowsi (kand@uwm.edu.pl) for IGS TEC (>=1994 5deg glon+2.5deg glat at 15min, 1h, or 2h intervals)

*Aaron Ridley (ridley@umich.edu) for GITM runs

*ludger.scherliess@usu.edu for COSMIC NmF2/hmF2 for different Kp and GAIM runs

*Eric.Sutton@kirtland.af.mil for eddylb + Weimer05 TIEGCM runs

*elsayed.talaat@jhuapl.edu for TIEGCM + SABER

*Dan Weimer (dweimer@vt.edu) for runs of his Weimer+Jacchia+Bowman models for 400 km neutral density

*Michael Wiltberger (wiltbemj@ucar.edu) for CMIT-TIEGCM model

*Shunrong Zhang (shunrong@haystack.edu) for ISR model runs