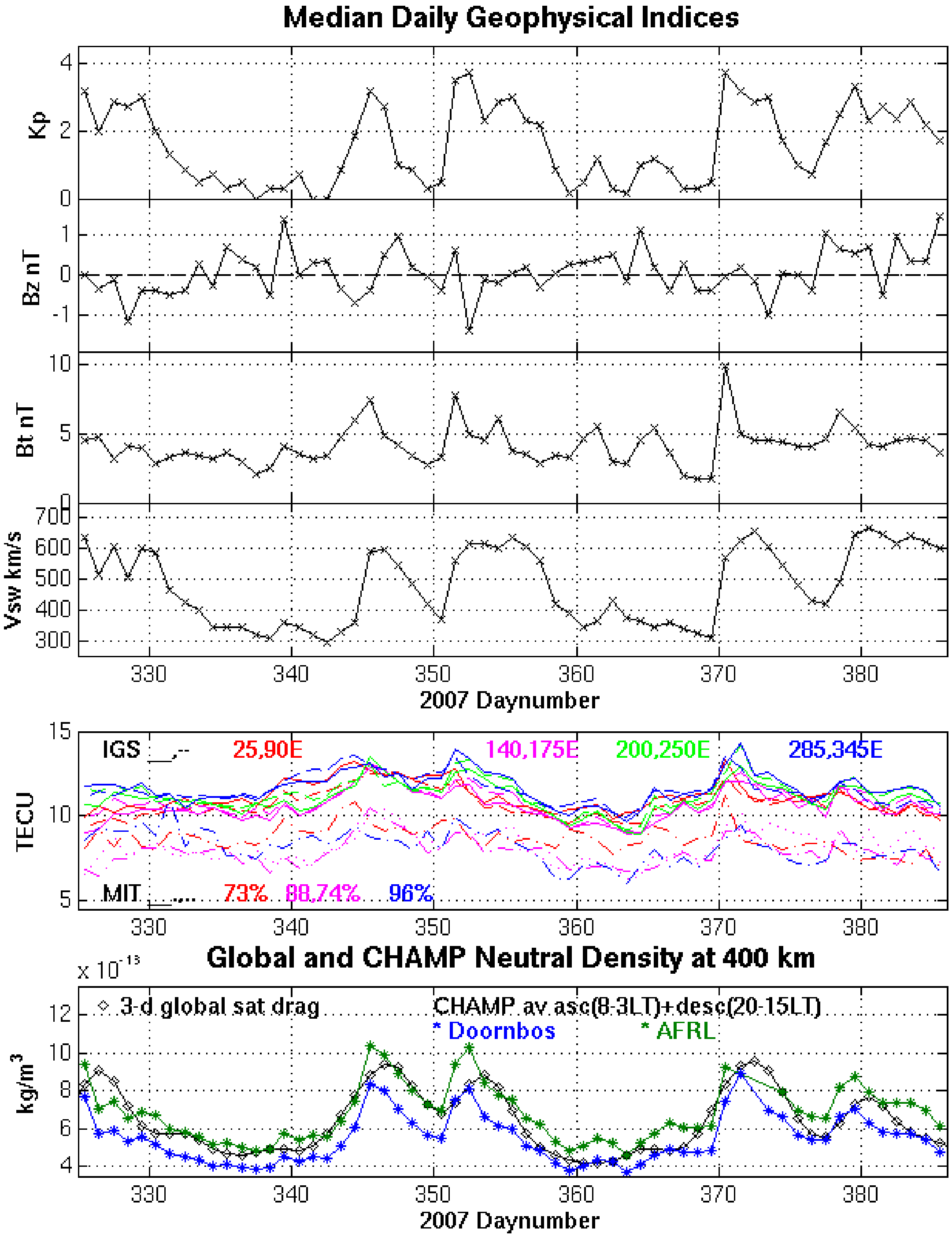
Community Coordinated Modeling Center

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

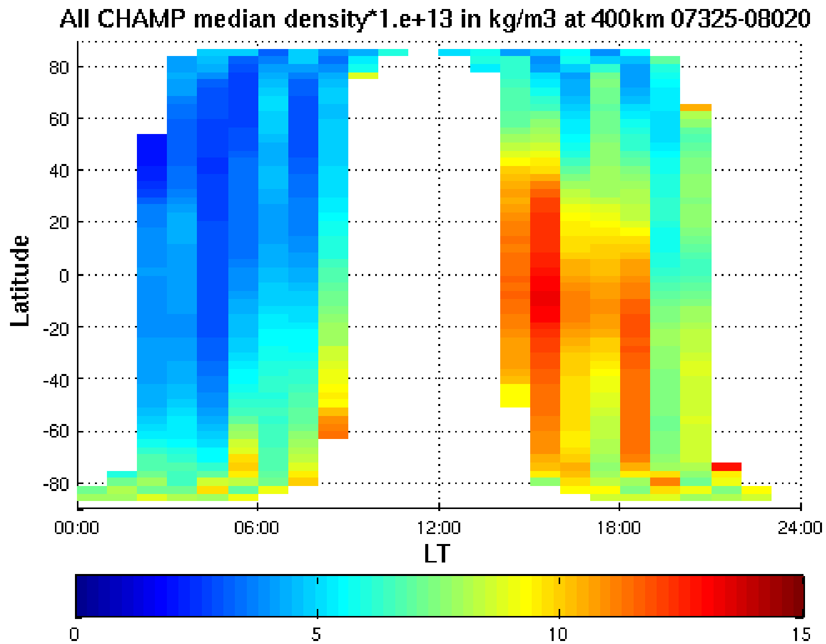
BA Emery, JS Shim, D Anderson, D Bilitza, J Chau, G Crowley, M Codrescu, AJ Coster, E Doornbos, JT Emmert, M Fedrizzi, M Förster, TJ Fuller-Rowell, LP Goncharenko , Kathrin Häusler, J Huba, L Lomidze, H Lühr, AJ Mannucci, S McDonald, R Pfaff, X Pi, B Prokhorov, J Retterer, P Roddy, L Scherliess, R Stoneback, Y-J Su, E Sutton, D Weimer, Q Wu

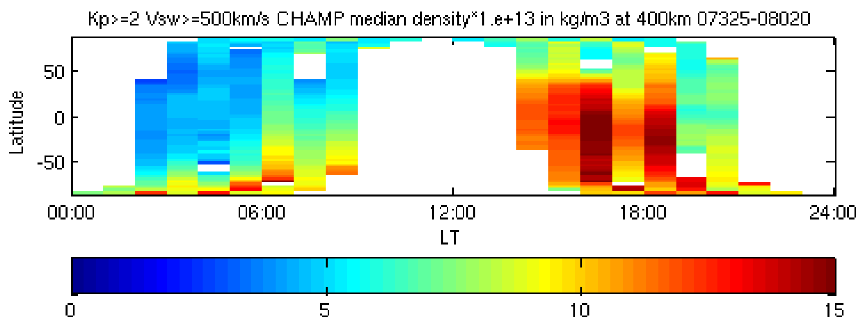
AGU Mini-GEM, 2 December 2012, San Francisco, CA

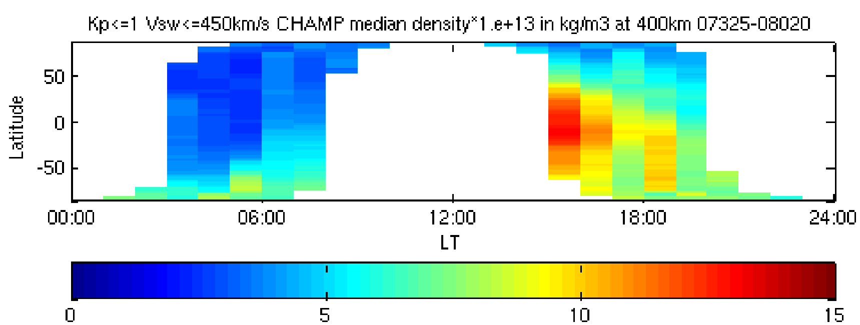


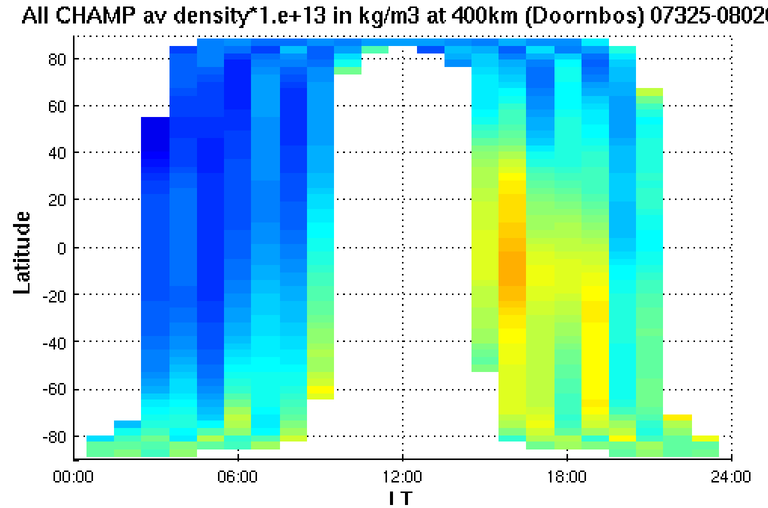
Solar Wind and Global TEC and Neutral Density at 400 km

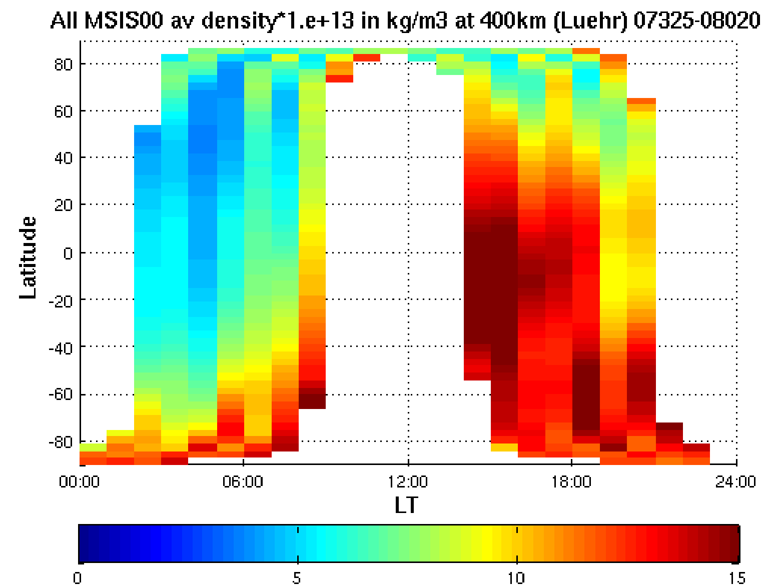
The conditions from 07325-08020 included 5 periods of High Speed Streams (HSS) in the solar wind velocity (Vsw). Kp values were usually >=2 for the HSS and <=1 for slow Vsw. The HSS prompted high daily TEC along 8 longitudes and high 400 km neutral densities in satellite drag data from Emmert [2009, JGR] and in two calibrations of the CHAMP satellite at 2 LTs.





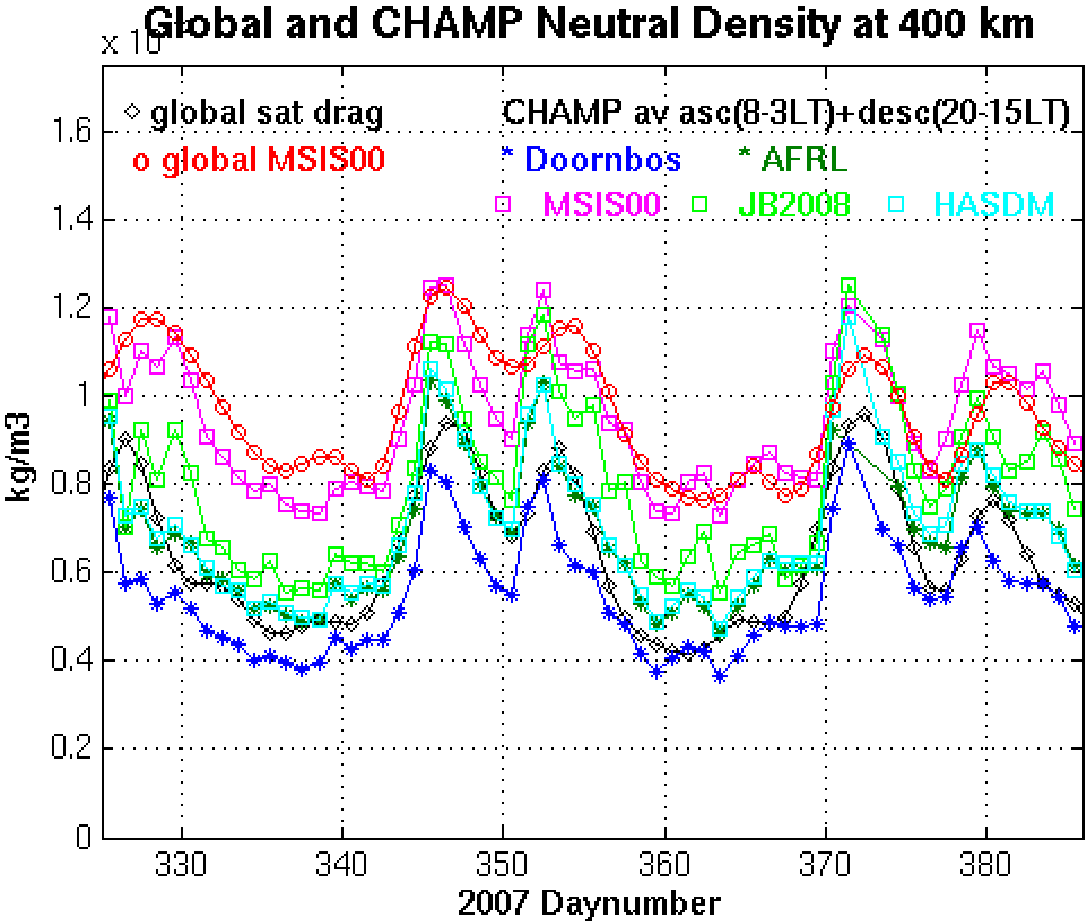






Doornbos CHAMP densities are lower than AFRL (on left) and MSIS are higher than both. Kp>=2 densities are larger than Kp<=1.

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

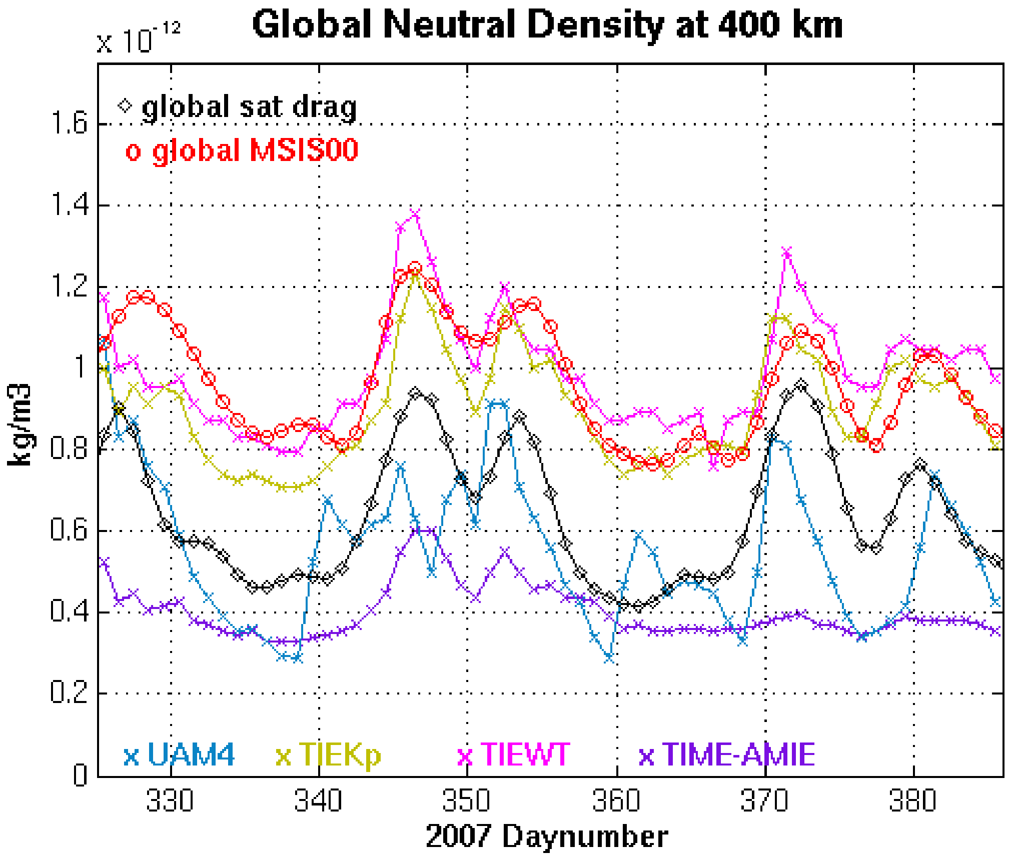


There are pronounced peaks at the times of the High-Speed solar wind Streams (HSS).

The densities from 2 LTs along the CHAMP orbit gradually increase in time as shown comparing MSIS00 in magenta squares to the global MSIS00 in red circles. This is because the LT slips from 8 and 20 LT towards 3 and 15 LT where the high density at 15 LT dominates.

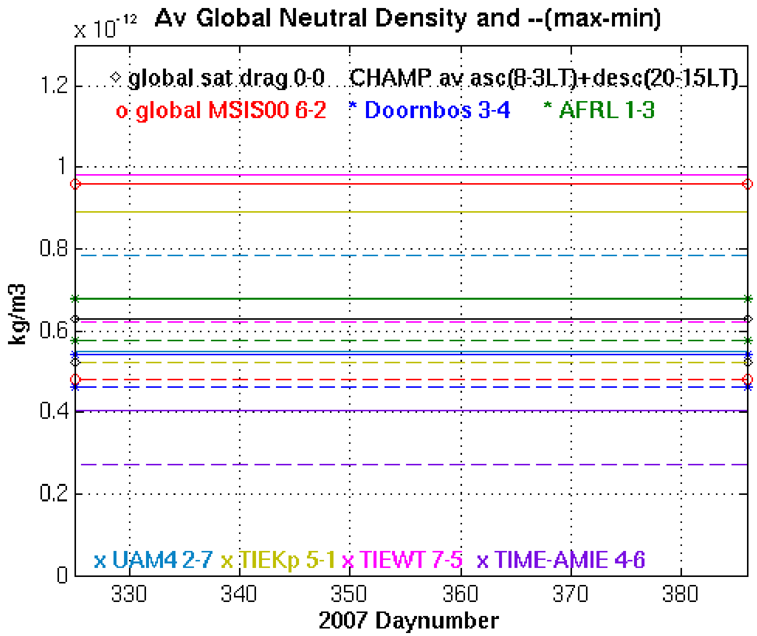
There are two versions of CHAMP data: (1) from E. Doornbos (official URL for CHAMP, missing day 372, blue stars) and (2) from E. Sutton (AFRL, missing days 371-373, different calibration, dark green stars similar to HASDM). Three empirical models are compared along the CHAMP orbit: (1) MSIS00, (2) JB2008, and (3) HASDM, where the MSIS00 model is also shown as a 3-d average of the global density to compare with the Emmert satellite drag estimates.

Comparing with Global Models



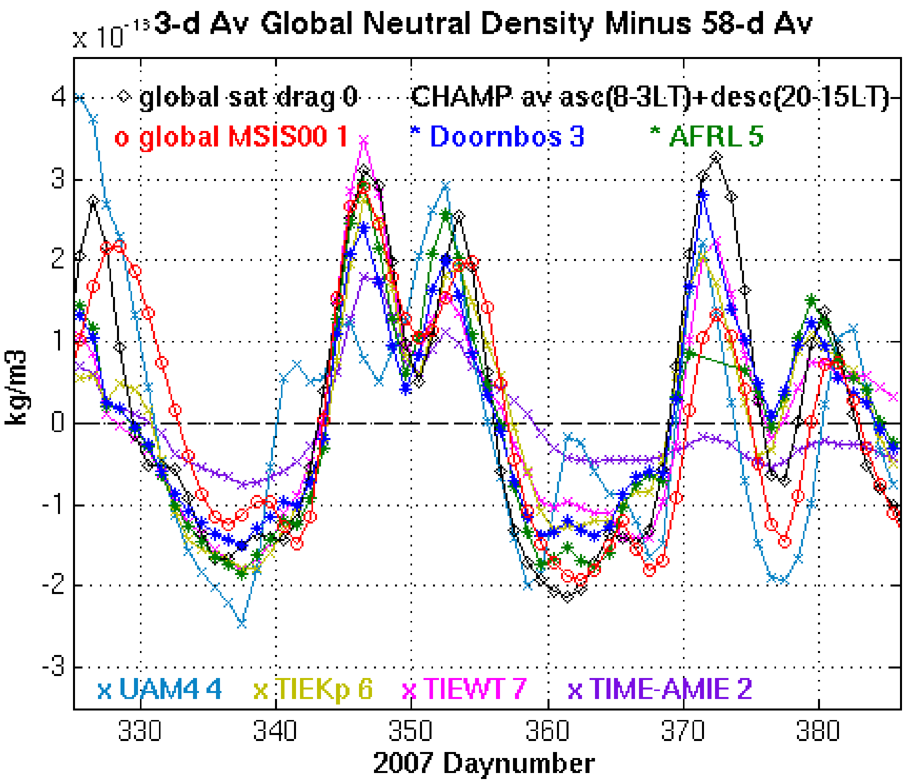
The sliding 3-day satellite drag observations at 400 km are compared with sliding 3-day empirical model MSIS00 estimates and daily global neutral densities from four theoretical models.

Four models are compared: (1) Upper Atmosphere Model (UAM) version 4 using MSIS00 temperatures as an empirical constraint and driven by IMF-dependent FACs from Papitashvili et al. [2002], (2) Thermosphere-Ionosphere-Electrodynamics General Circulation Model (TIEGCM) version 1.93 using Heelis [1982] convection driven by Kp, (3) TIEGCM using Weimer [2005] convection driven by IMF and lower boundary winds and temperatures driven by TIMED satellite SABER and TIDI observations, (4) Thermosphere-Ionosphere-Mesosphere-Electrodynamics General Circulation Model (TIMEGCM) driven by AMIE convection using observational inputs.



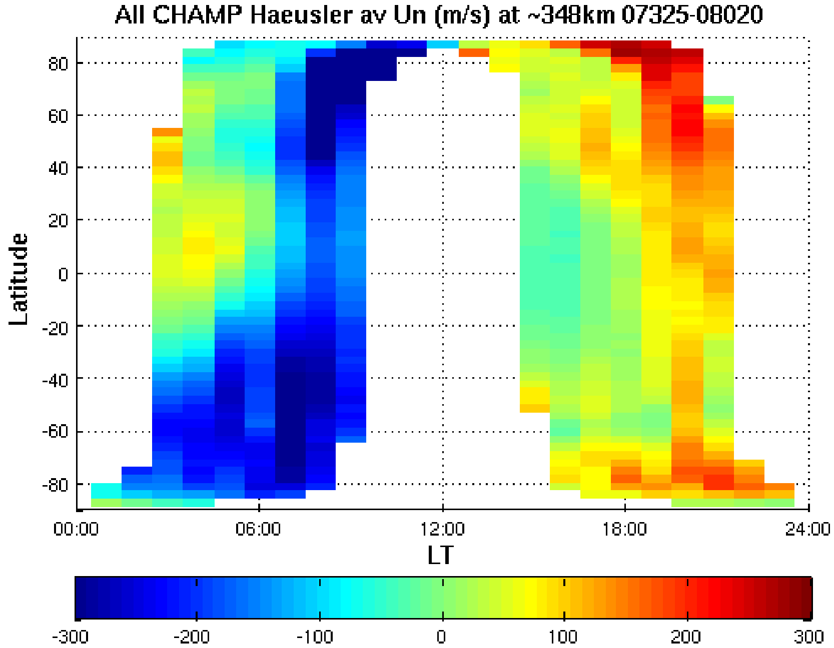
Metrics for Comparison

Because of the 26% increase in the baseline from Doornbos to AFRL CHAMP observations in 58-day averages (solid lines left figure), the first metric used is (1) the **baseline.** The other two metrics are (2) max-min (or the range), and (3) the root mean square rms from the satellite drag observations minus the 58-d averages.

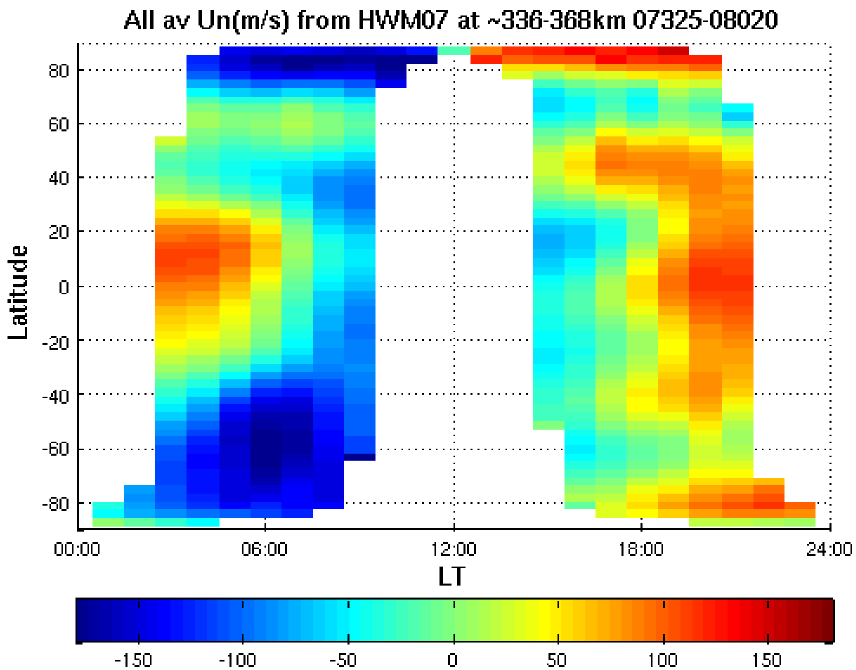


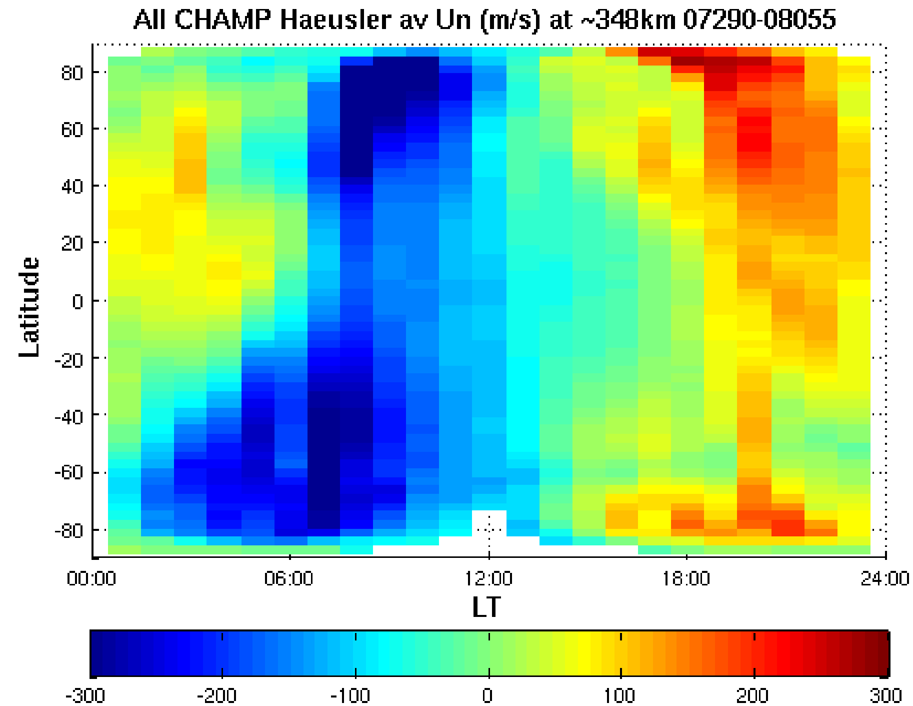
CHAMP obs and models were averaged over 3 days. The top figure gives two rankings from 0-8, where the first number is for the baseline, and the second is for the range. The bottom figure shows the sliding 3-day curves minus their 58-day averages (excluding the HSS peak at 371-373 to be able to compare with AFRL). Adding the 3 rankings together gives the best over-all comparisons to the satellite drag data as: (1a,b) AFRL obs and MSIS00, (3) Doornbos obs, (4a,b) TIEKp and TIME-AMIE, (6) UAM4, and (7) TIEWT.

CHAMP Zonal Neutral Winds

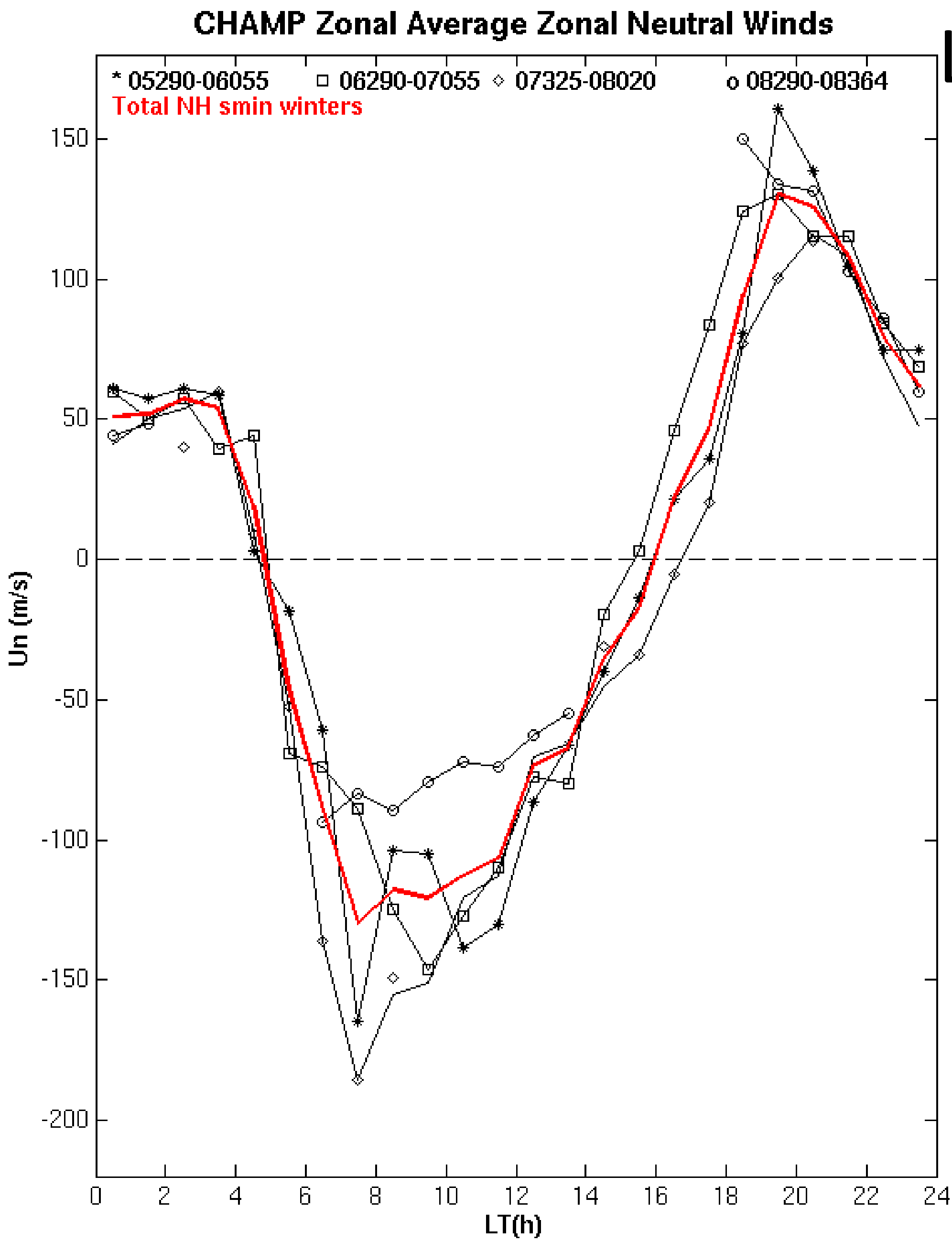


The CHAMP satellite measures the cross-track neutral winds (~Un), which in legacy outputs, are good from 2001-2008. Here are the plots of the observed Un and those from HWM07 for 07325-08020, and CHAMP Un expanded 131 days to cover all local times.





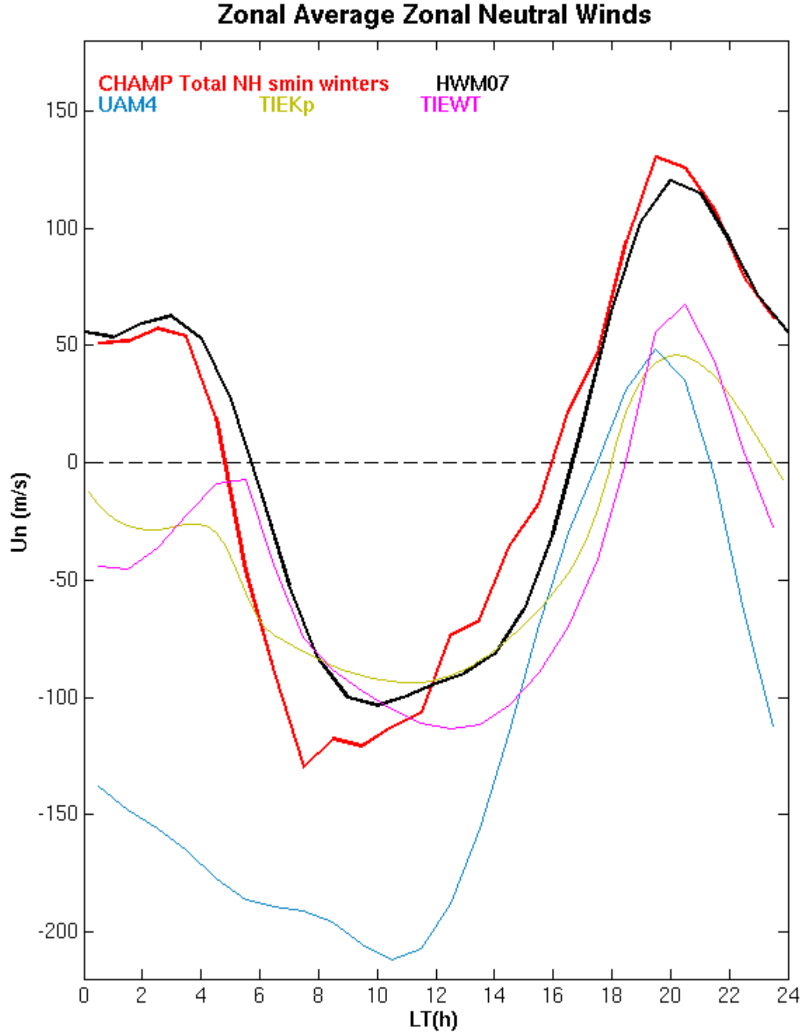
Low-latitude CHAMP Un

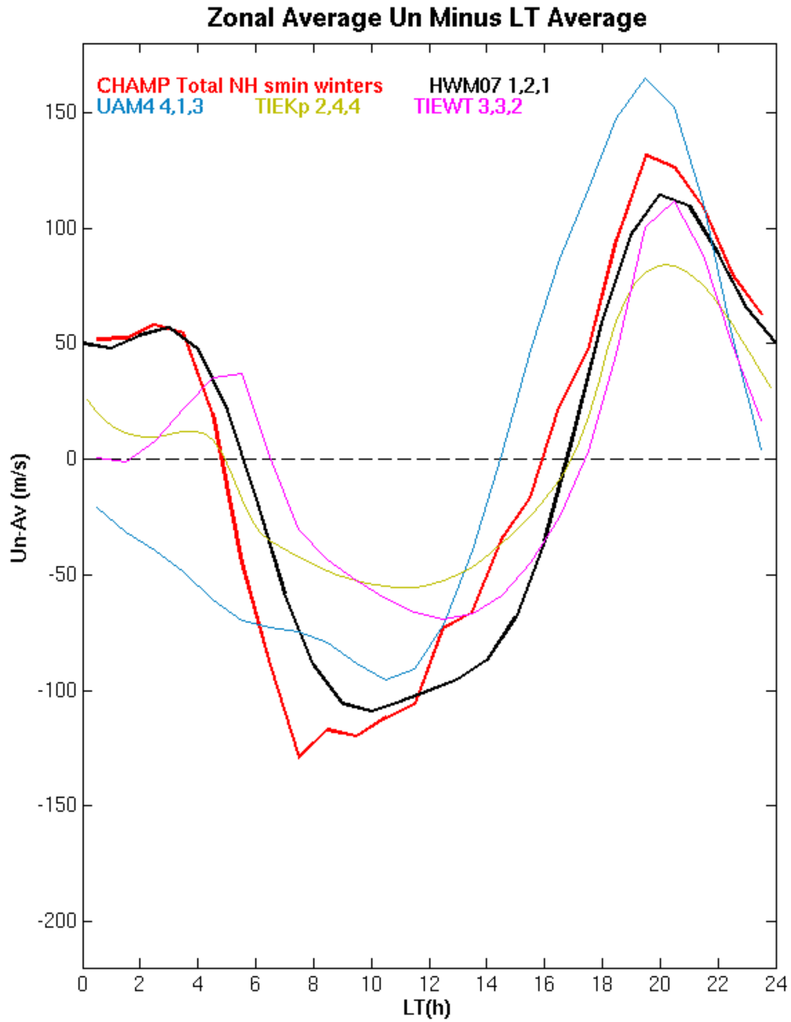


CHAMP Un were averaged from 2005 to 2008 from day numbers 290-365 and 1-55, with average winter 10.7 cm solar fluxes ~67-80 for +/-13.1 degrees around the geographic equator to be similar to the Communication/Navigation Outage Forecast System (C/NOFS) satellite observations which started in 2008.

Low-Latitude Un Metrics

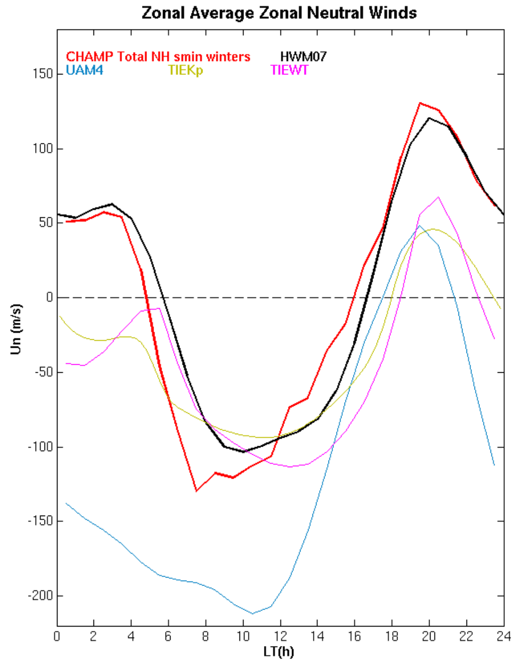
The ranking for the metrics of baseline, range and Un-Av RMS are listed after each model where: (1) HWM07, (2a,b) UAM4 and TIEWT, (4) TIEKp



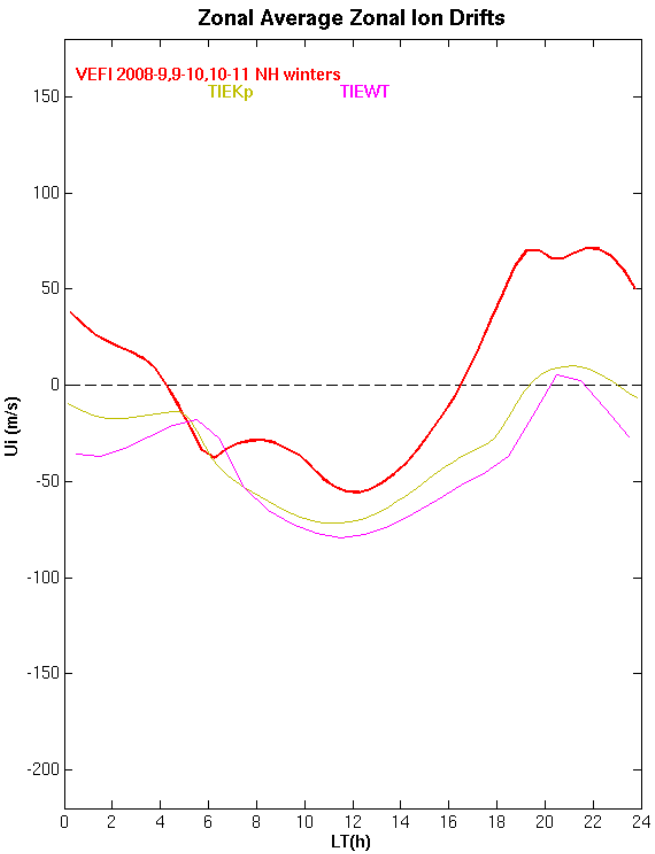


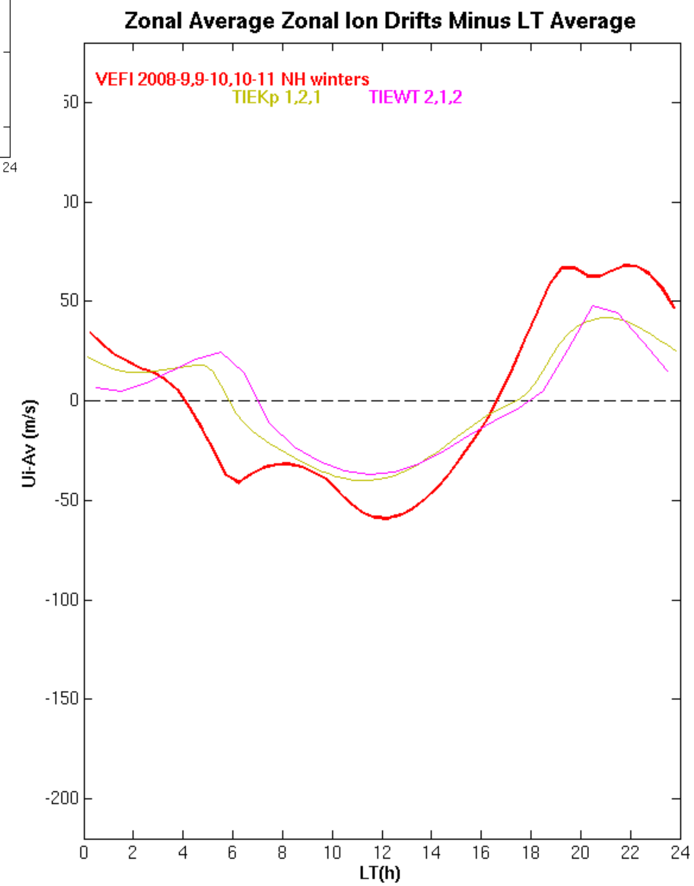
Low-Latitude Ui Metrics

Same scale as Un since Ui is mostly due to Un.

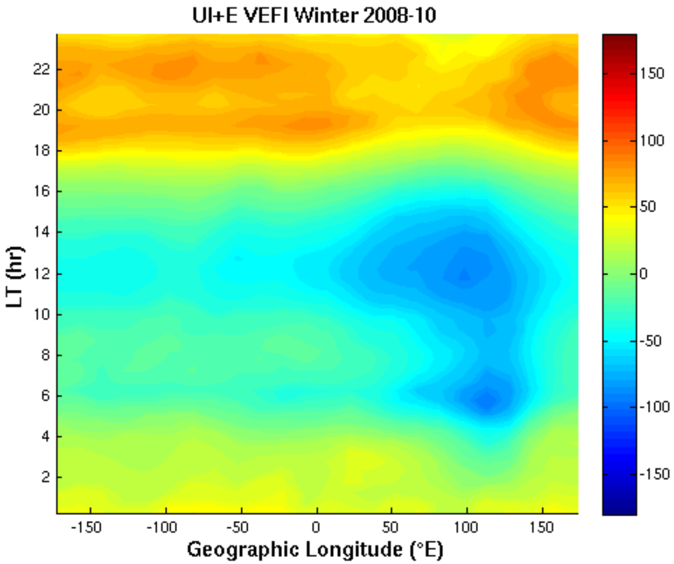


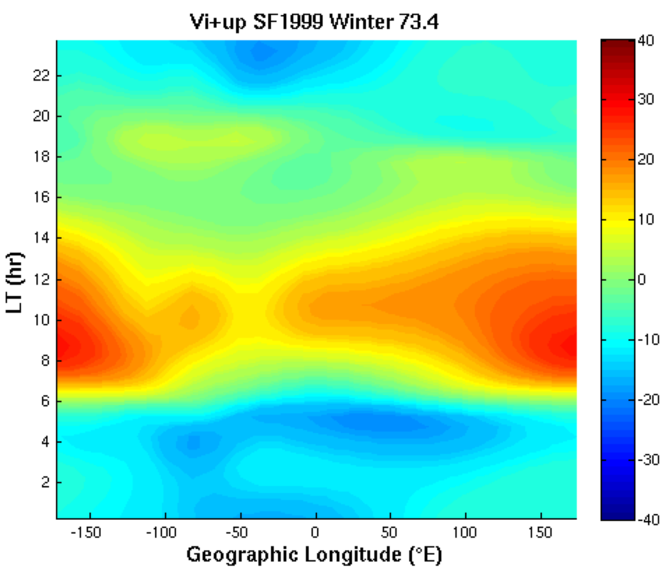
The ranking for the metrics of baseline, range and Ui-Av RMS are listed after each model where: (1) TIEKp and (2) TIEWT





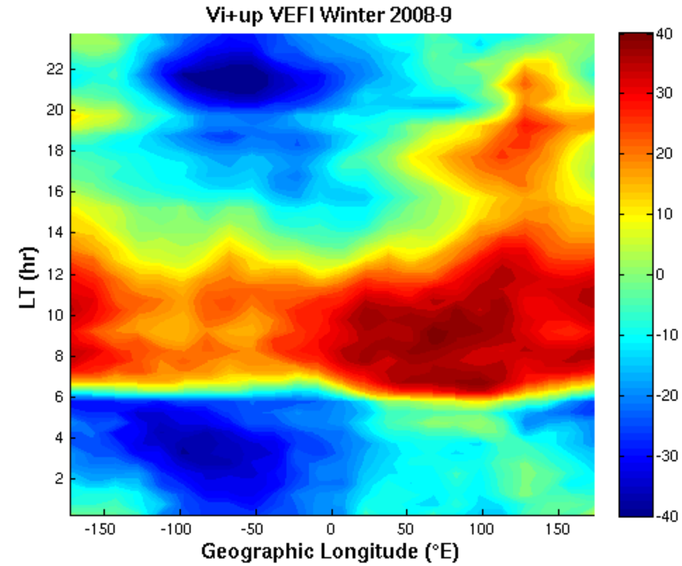
Low Latitude Ion Drifts from C/NOFS

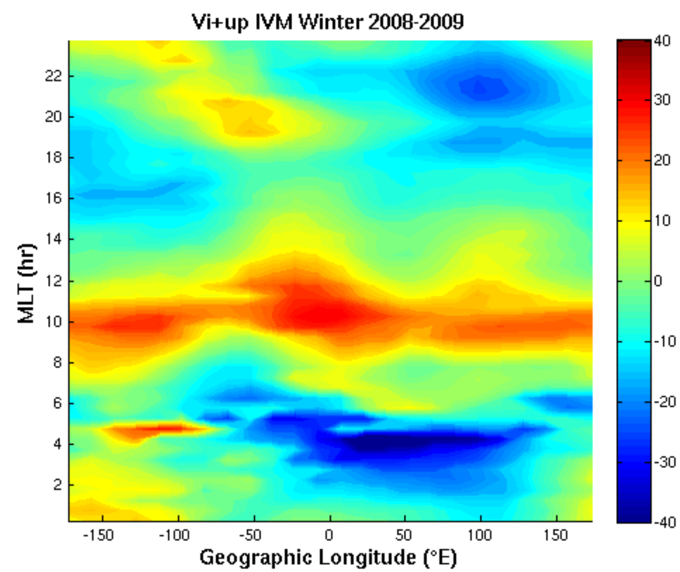




Scherliess and Fejer [1999] low-latitude model Viz.

The Vector Electric Field Instrument (VEFI) and IVM both measure the eastward (Ui) and upward (meridional to B or Viz) ion drifts, but IVM Ui are in the RAM direction and so are difficult to observe. The Viz from VEFI is larger than from IVM, and previous work by Su et al [2012] shows the Ne observations are best matched using IVM Viz.

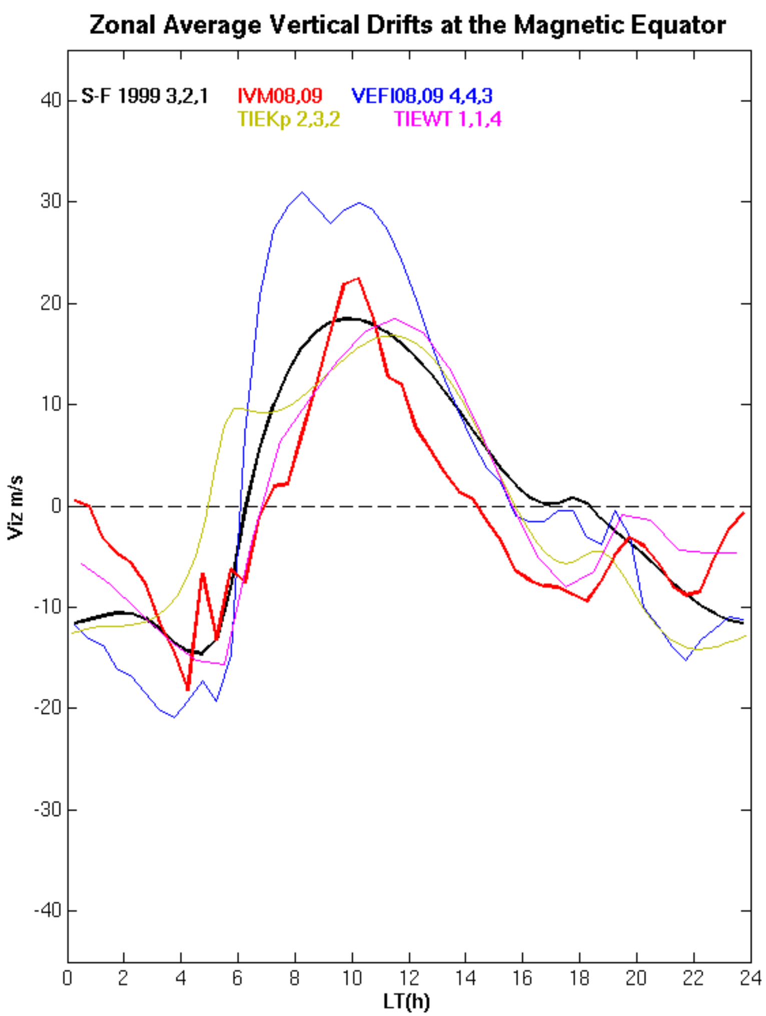


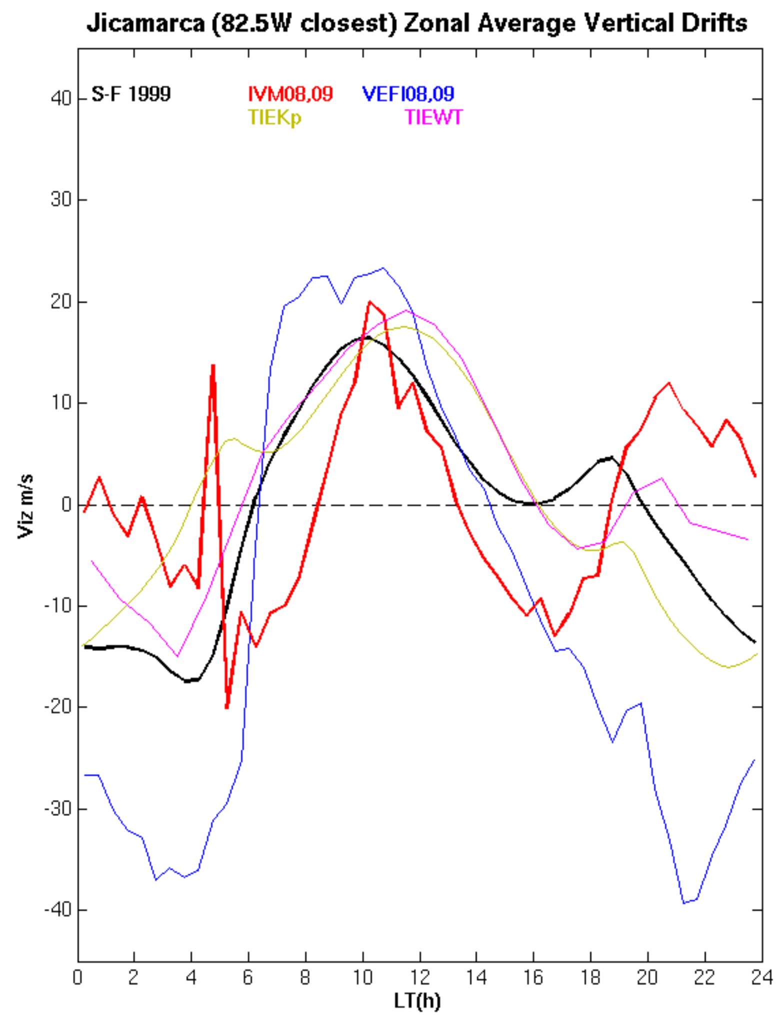


Low-Latitude Viz Metrics

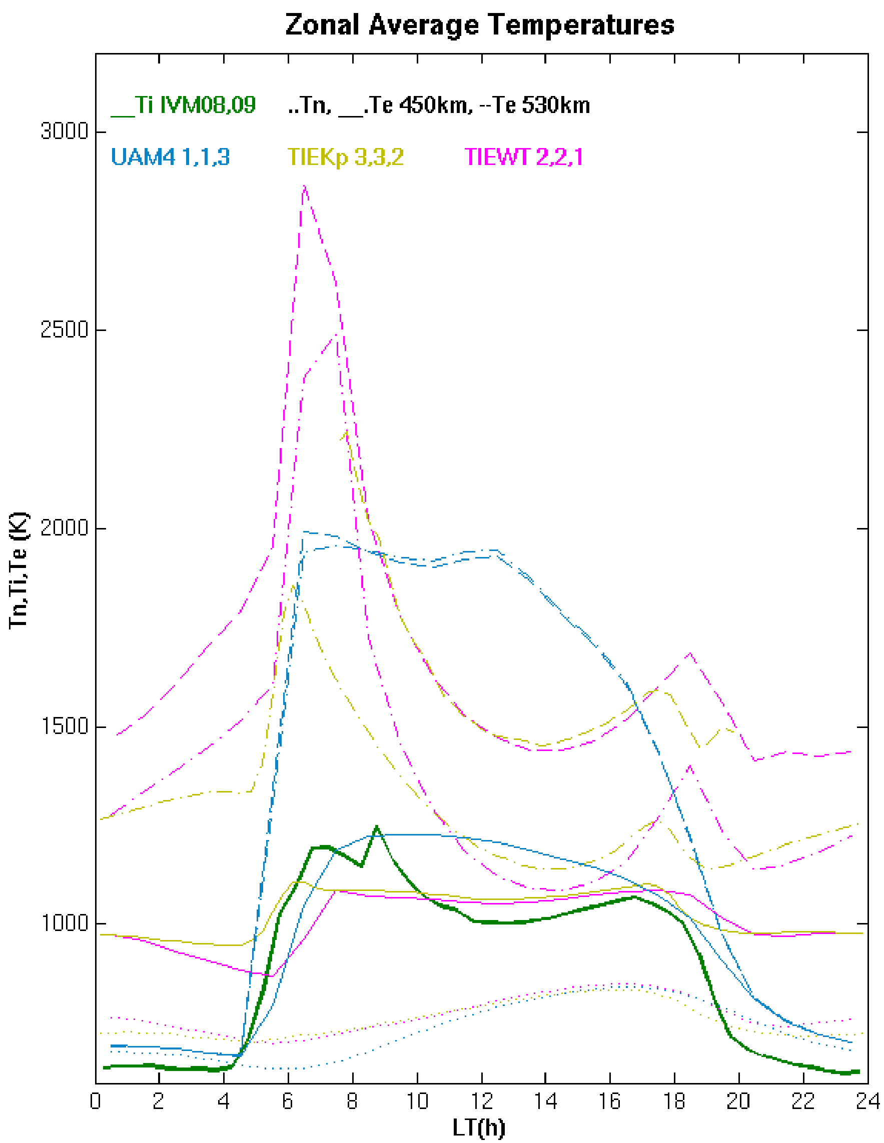
The ranking for the metrics of baseline (close to zero), range and Viz-Av RMS are listed after each model where: (1a,b) SF 1999 and TIEWT, (3) TIEKp and (4) VEFI Viz obs.

Jicamarca at the magnetic equator and 76W has a stronger pre-reversal enhancement after sunset.





Low-Latitude Temperatures

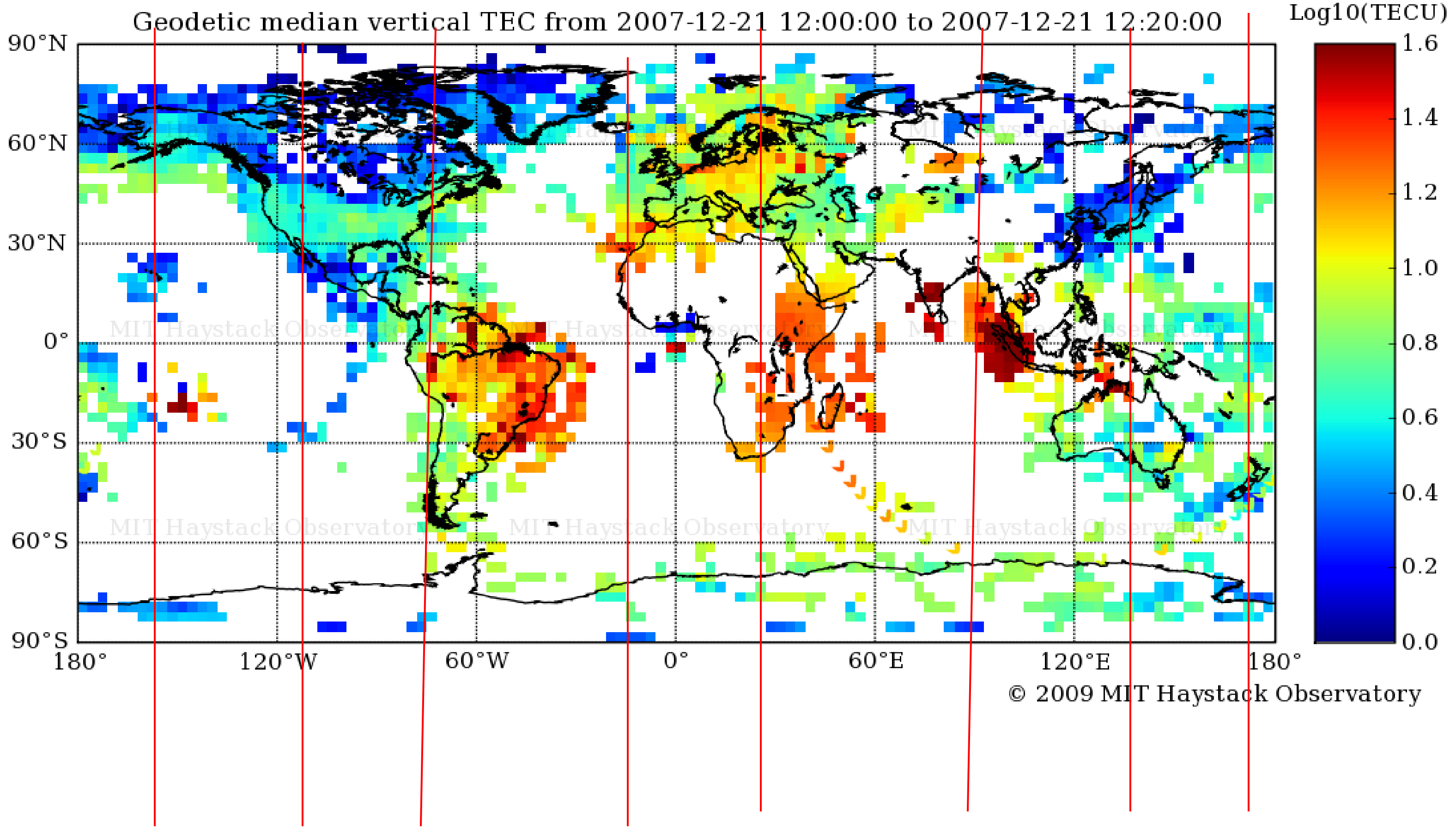


IVM measures the [O+] ion temperature from 400-550km. Clearly the UAM4 models does best for the day-night range where Ti from the TIEGCMs are too large because Te are too large at night from incoming heat fluxes.

Observations of Te from the Planar Langmuir Probe (PLP) on C/NOFS will help determine the appropriate heat flux at night for the TIEGCM.

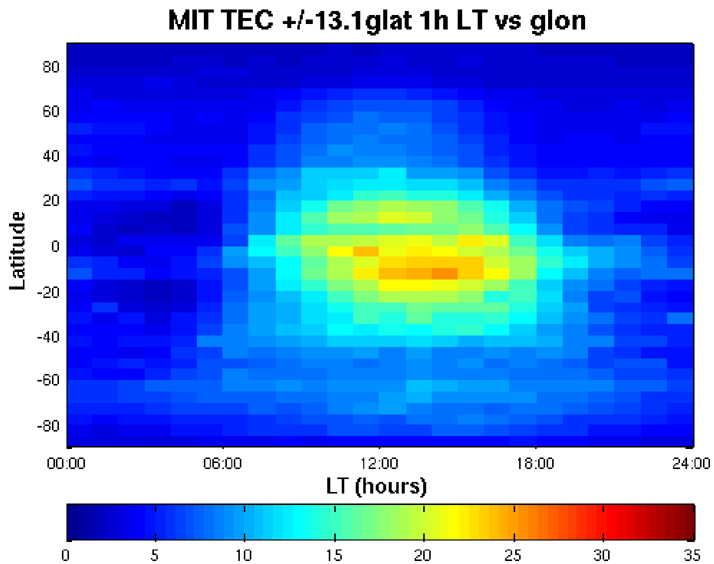
The ranking for the metrics of baseline, range and Ti-Av RMS are listed after each model where: (1a,b) UAM4 and TIEWT, (3) TIEKp.

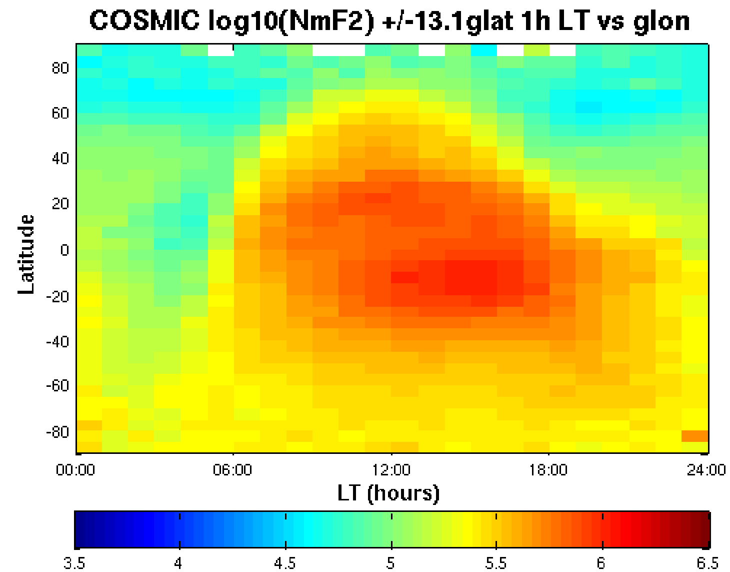
Choose 8 Longitude Slices from GPS TEC

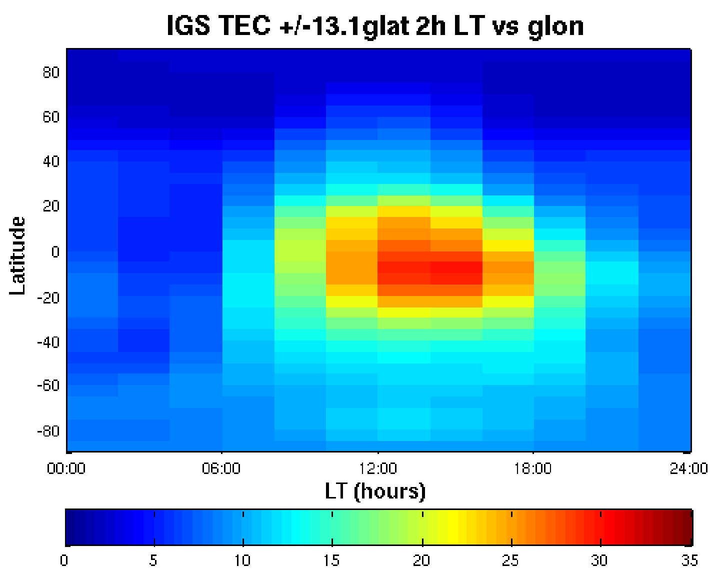


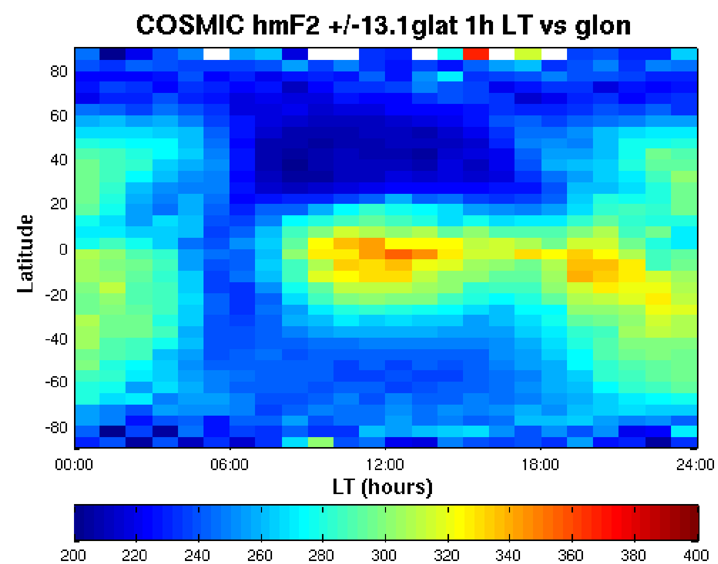
5 deg lat and 5 deg lon bins for 20 min in December solstice 07355. Longitudes chosen: 25E, 90E, 140E , 175E, 200E (160W), 250E (110W), 285E (75W), 345E (15W).

61-d Averages over medians from 8 glons

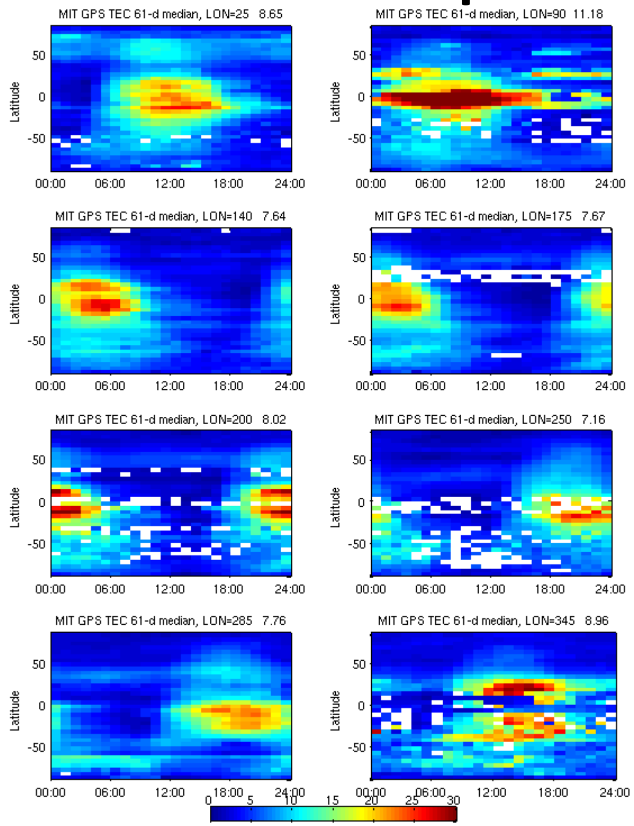


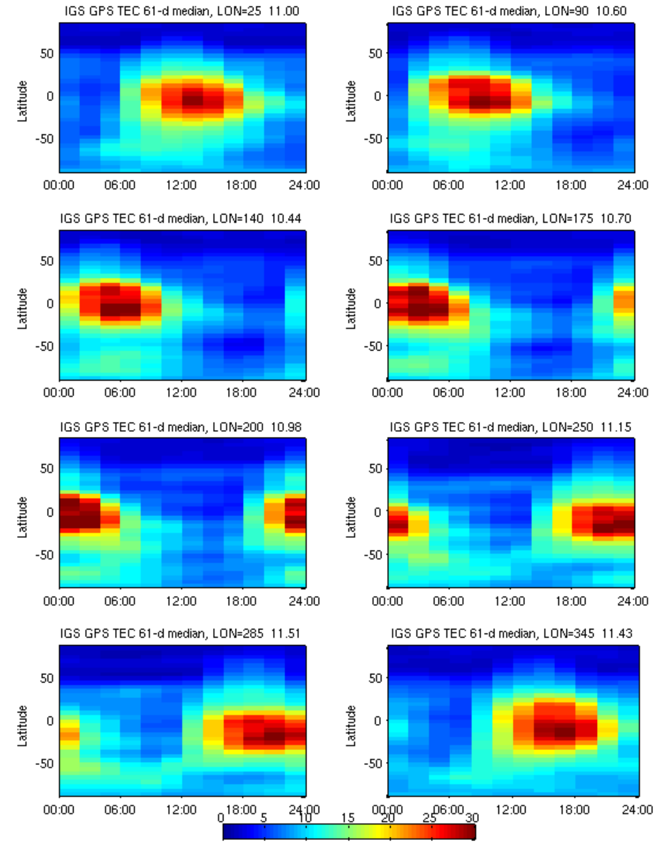






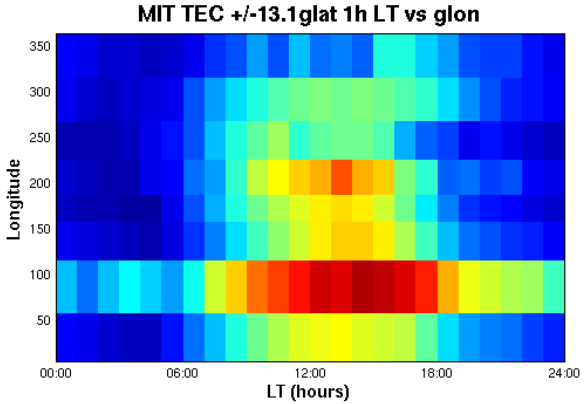
Previous Comparison of MIT and IGS TEC

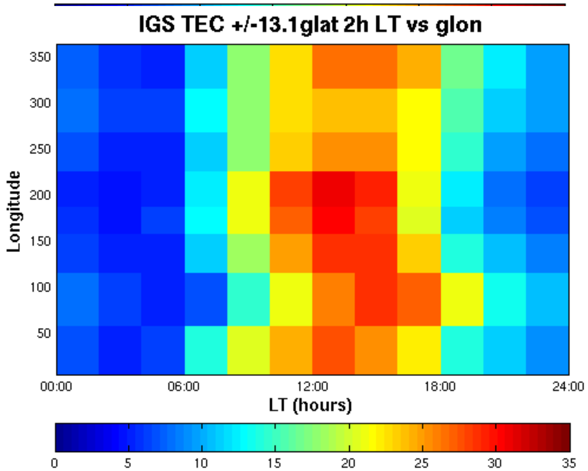


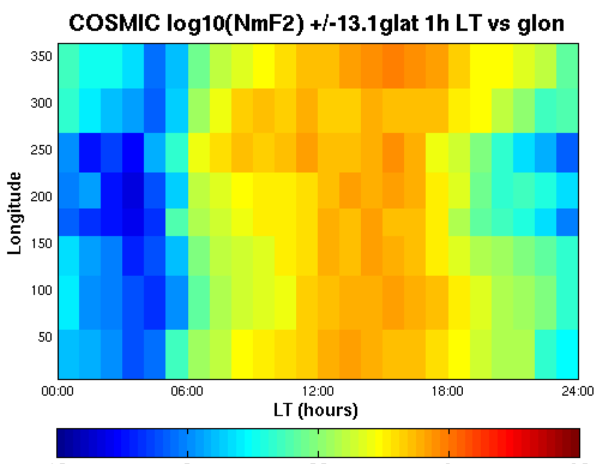


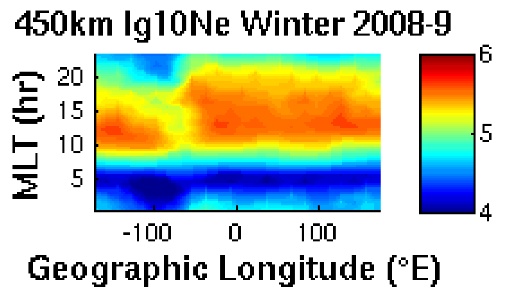
IGS higher anomaly peaks, lower TEC winter NH pole and higher TEC summer SH pole. All models lower than both obs except for SAMI3. Previous summaries of MIT TEC: TIME-AMIE, TIEKp, TIEWT, IRI07, CTIPe, SAMI3 and IGS TEC: SAMI3, CTIPe, IRI07, TIEKp, TIEWT, TIME-AMIE. These reversed order since the baseline was not removed in the metric of the mean percentage error.

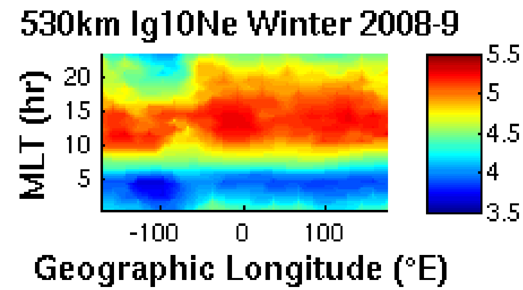
Average +/-13.1glat for LT vs Longitude and compare to C/NOFS PLP Ne with 3 peaks from DE2 waves from the lower atmosphere. The PLP Ne minimum at -80 (or +280E) shows in all but MIT TEC, but PLP peaks ~ 120E, 210E and 340E are best seen in hmF2.

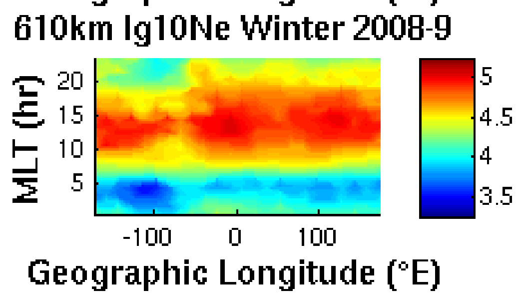


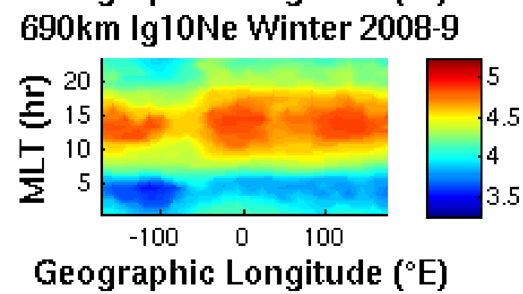


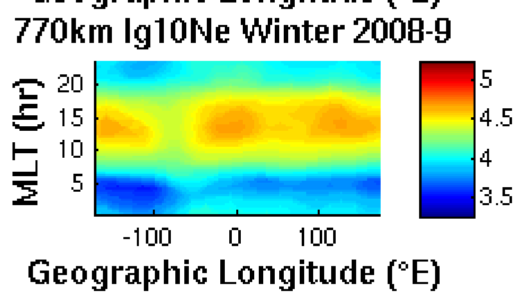


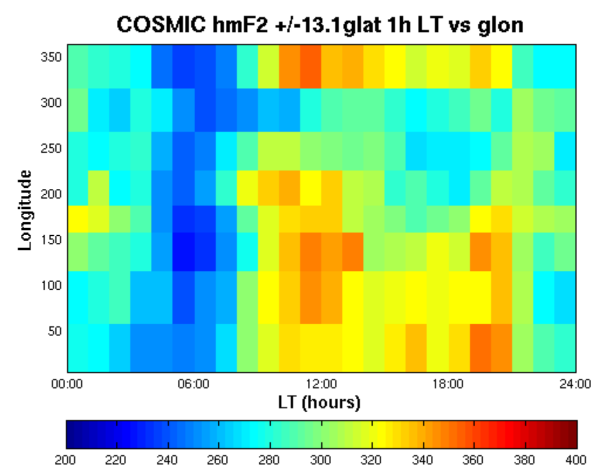




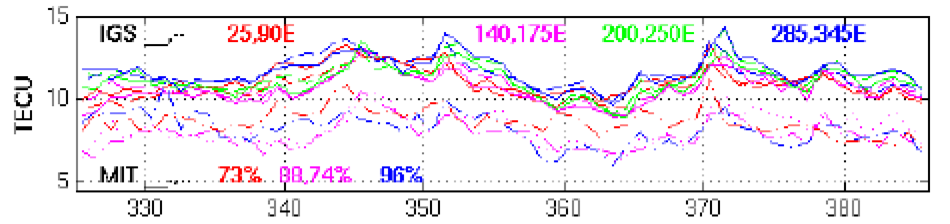


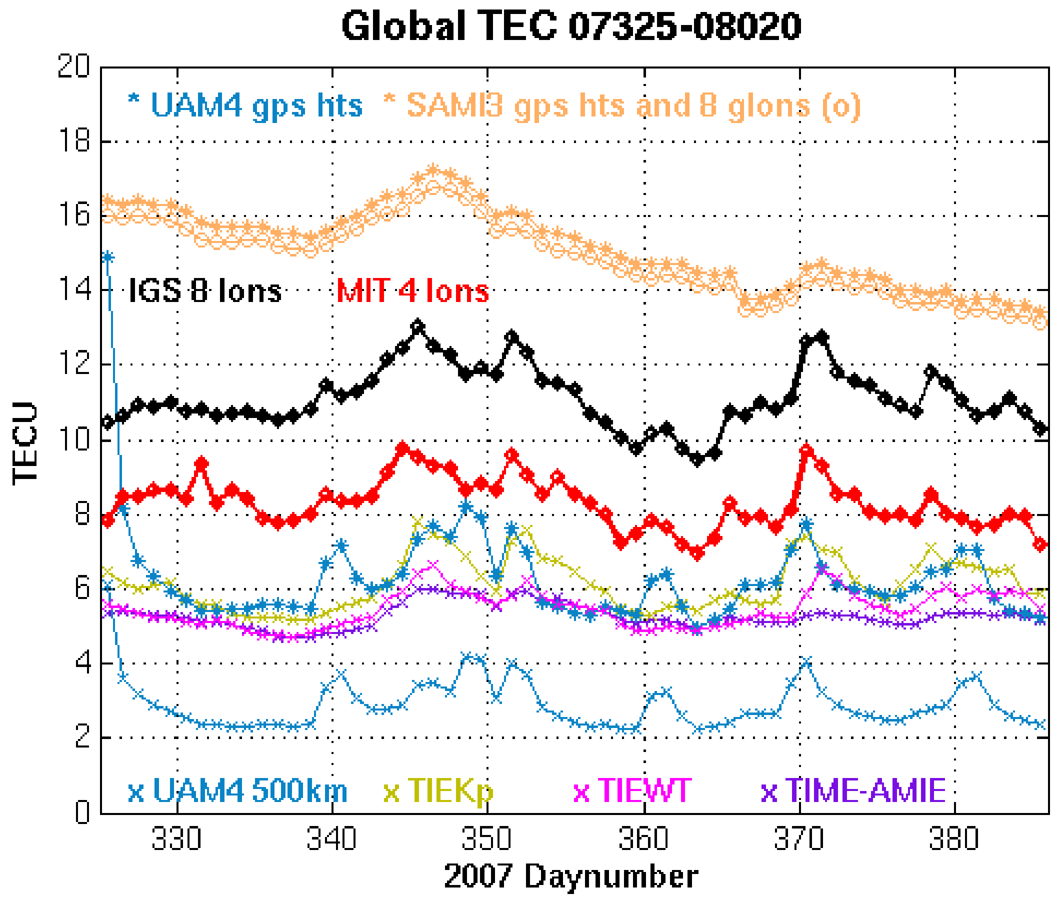






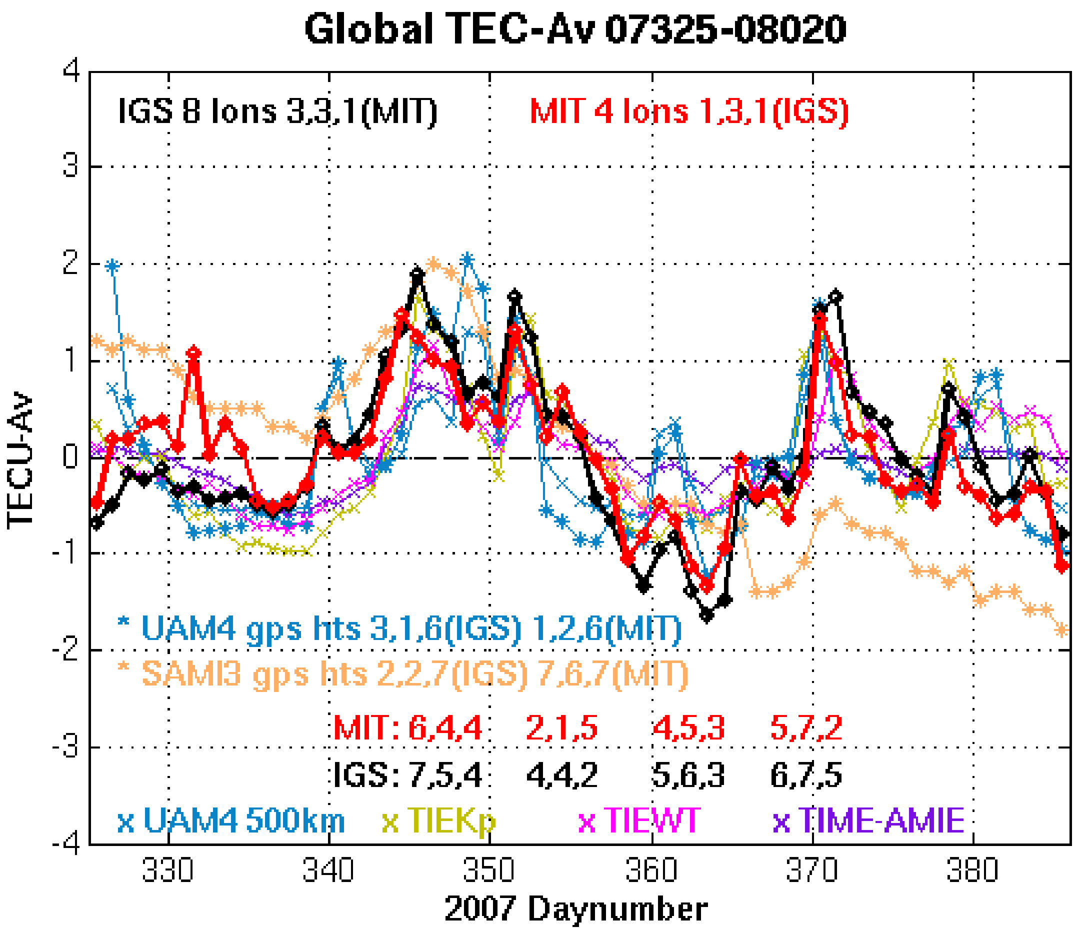
Global TEC





Average the 8 glons for IGS and the 4 'good' ones for MIT to get estimated global TEC from the data to compare with the models. There are obvious differences in TEC baselines, where the two UAM4 lines show approximately 3 TECU between 500 km and 20,100 km.

Global TEC Minus Averages



Using the metrics of baseline, range and RMS, the rankings for the 6 models and data are listed as before. For IGS, the total rankings are: (1) MIT obs, (2a,b) UAM4 gps and TIEKp, (4) SAMI3, (5) TIEWT, (6) UAM4 500km, (7) TIME-AMIE. For MIT, the total rankings are: (1) IGS obs, (2) TIEKp, (3) UAM4 gps, (4) TIEWT, (5a,b) TIME-AMIE and SAMI3, (7) UAM4 500 km. SAMI3 shows clearly a decrease in the magnitude over winter.

Summary of the Ongoing CCMC Climatology Study

- If there are baseline uncertainties, the metrics must compare values minus some average. The 3 metrics used were:
  - Baseline (ave over LT or 61-d becomes AV used in RMS)
  - Range (max-min)
  - Root-Mean Square (RMS) sqrt[sum(obs-AVob-mod+AVm)^2/N]
- Count 3 metrics as:
  - Sum of rankings (not as precise)
  - Sum of values (too much emphasis on unknown baseline)
  - Sum of values with relative baseline (|AVob-AVmod|/AVmod)
- Model rankings changed with parameter studied or with different versions of the same parameter.
- The winter solar minimum study can include other NH winter solar minimum data since many ionospheric and thermospheric quantities remain about the same.
  - Used later C/NOFS satellite observations at low latitudes (2008-2009 IVM and PLP or 2008-2010 VEFI)
  - Used expanded CHAMP observations (2005-2008)