CEDAR Support from the CCMC: Model Challenges and Metrics

Barbara A Emery and Ja Soon Shim

7th CCMC Workshop

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Annapolis, MD

http://ccmc.gsfc.nasa.gov/challenges/GEM-CEDAR/

6 CEDAR (Coupling, Energetics and Dynamics of Atmospheric Regions)Models at the CCMC

IRI (International Reference Ionosphere, free source)

5 Models with Runs on Request (RoR) for <Jan12, Jan12-Mar14

1) TIE-GCM (Thermosphere-Ionosphere-Electrodynamics General Circulation Model, free source) RoR=67+91=156

2) CTIP/e (Coupled Thermosphere-Ionosphere Plasmasphere) RoR=153+61=214

3) SAMI2/3-HWM93 (Still Another Model Ionosphere, SAMI2 is free source) RoR=87+66=153

4) USU-GAIM (USU-IFM background) RoR=102+47=149

5) GITM (U MI Global Ionosphere Thermosphere Model) RoR=0+21=21

History

- First CEDAR CCMC Challenge Workshop in June 2009 at CEDAR Workshop in Santa Fe, NM and continue 2010, 2011, 2012, 2013
- CEDAR-GEM CCMC Challenge Workshops begin at the mini-GEM Workshop in December 2011 in San Francisco, CA, and continue 2012, 2013
- CEDAR-GEM CCMC Challenge Workshops begin on the Monday before Space Weather Week in Boulder, CO in April 2013 and continue 2014.

http://ccmc.gsfc.nasa.gov/challenges/GEM-CEDAR/

2009 Summary Periods

- CEDAR Climatology 'year': March 1, 2008 to March 31, 2009 (07060-08091) prompted in part by the International Space Science Institute (ISSI) in Bern, Switzerland
  - 3 moderate storms: 07091 , 07142, 08059
  - 3 quiet periods: 07079, 07190, 07341
- GEM Storm Event Studies
  - 6 UT 29 Oct 2003 to 6 UT 30 Oct 2003 (03302-03303 'Halloween Storm')
  - 12 UT 14 Dec 2006 to 0 UT 16 Dec or 24 UT 17 Dec 2006 (06348-06349 'AGU Storm')
  - 0 UT 31 Aug 2001 to 0 UT 01 Sep or 24 UT Aug 2001 (01243)
  - 10 UT 31 Aug 2005 to 12 UT 01 Sep 2005 (05243-05244)

Storms (GEM) vs Climatology (CEDAR)

- GEM models are in the magnetosphere or in high-latitudes. Geomagnetic storms rely on the source input of the solar wind and IMF, where radiation is a minor secondary input.
- CEDAR ionospheric and thermospheric models have 3 source inputs:
  - EUV radiation globally
  - Solar wind and IMF at high-latitudes
  - Tides especially at low latitudes, gravity waves and planetary waves (e.g. Sudden Stratospheric Warmings) from below which can be seen especially in solar minimum periods.

2009 Summary Data for ETI Challenge

Limited to 1-D time-series data for a single station or satellite track.

- Electrodynamic as Viz from Jicamarca ISR, JULIA, and estimates using ground-based equatorial daytime ground magnetometers (Dave Anderson/Koki Chau) (Equatorial electrodynamics tied to high-latitudes through under and over-shielding.)
- Thermosphere
  - Neutral density at 400 km from CHAMP and satellite drag (Bruce Bowman) (~35% differences in data sources or analyses)
  - Exospheric neutral temperature from GUVI/TIMED (Bob Meier)
  - Neutral Winds from FPI 630 nm
- Ionosphere:
  - Ne as vertical TEC from ground-based madrigal (~35% differences with other TEC sources) and COSMIC; NmF2 and hmF2 from ISRs and COSMIC; and electron density at 400 km from CHAMP
  - Te and Ti from ISRs

Publications from First Workshops

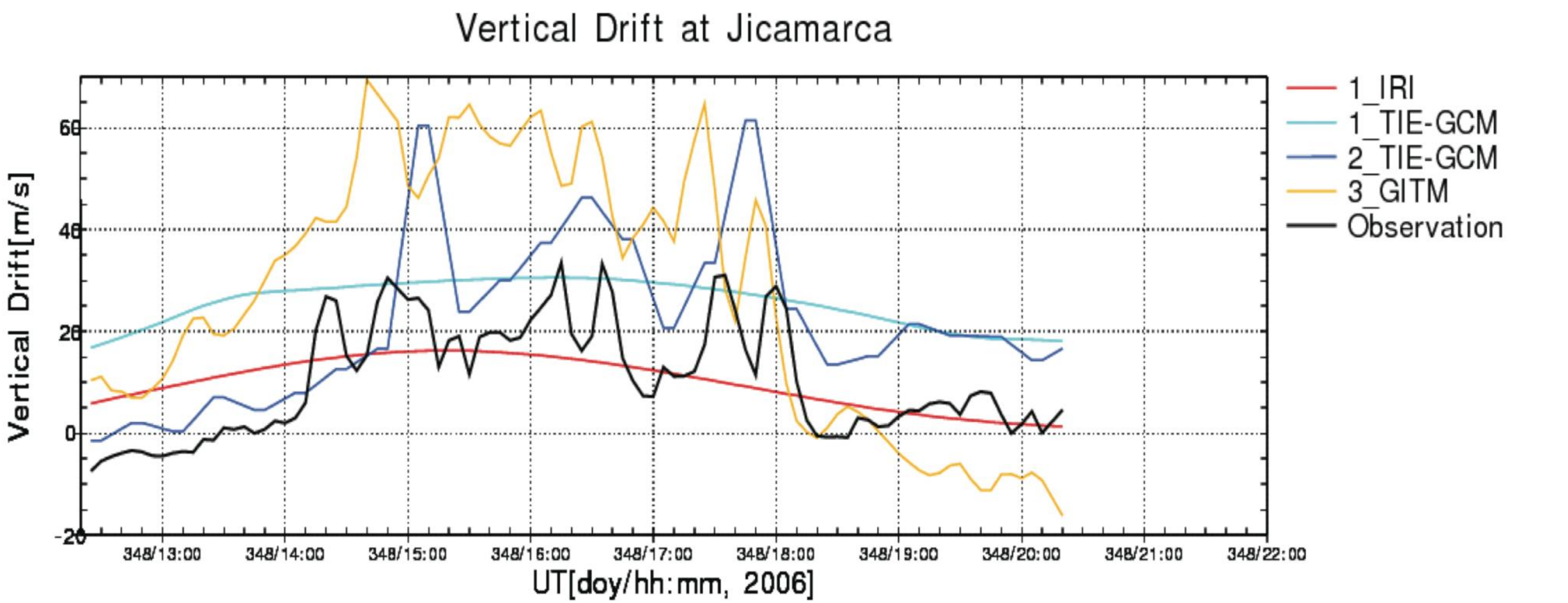
J. S. Shim et al. [2011 and 2012], "CEDAR Electrodynamics Thermosphere Ionosphere (ETI) Challenge for systematic assessment of ionosphere/thermosphere models:

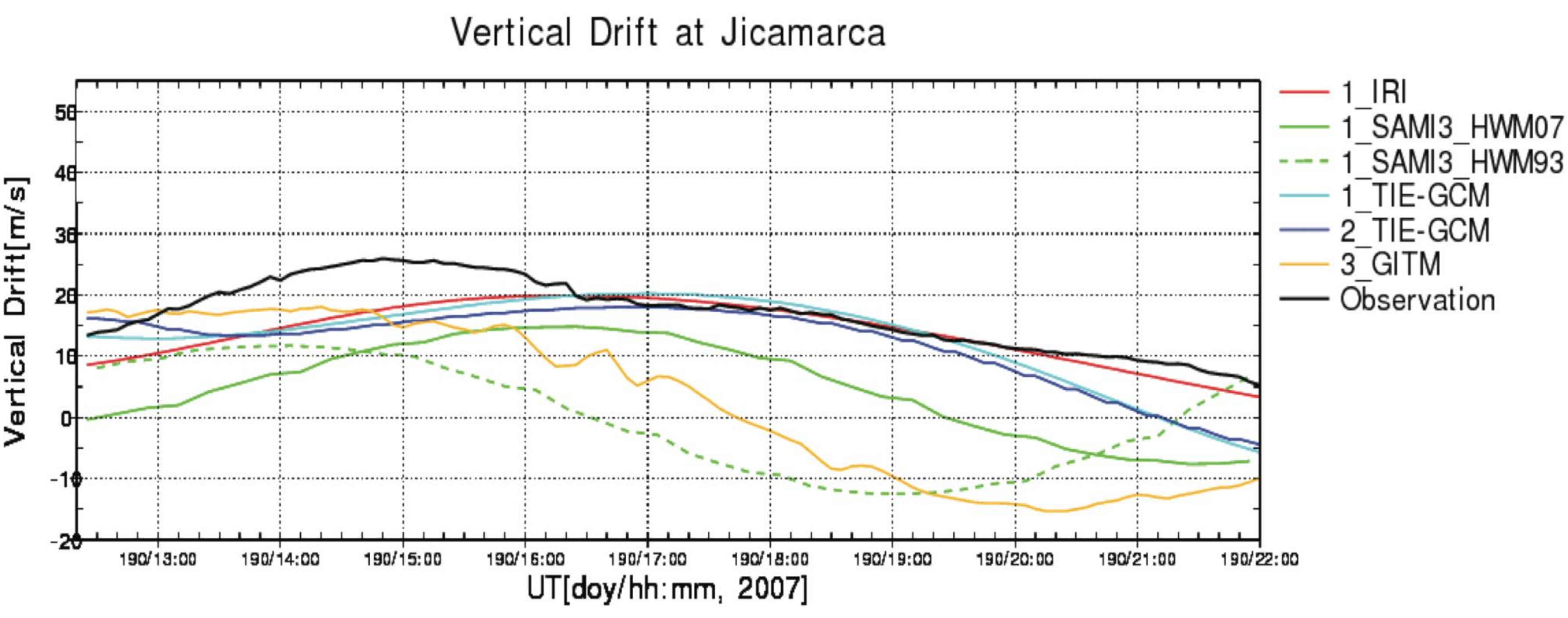
1) NmF2, hmF2, and vertical drift using ground-based observations", Space Weather, vol 9, S12003, doi:10.1029/2011SW000727

2) Electron density, Neutral density, NmF2, and hmF2 Using Space Based Observations", Space Weather, vol 10 issue 10, doi10.1029/2012SW000851.

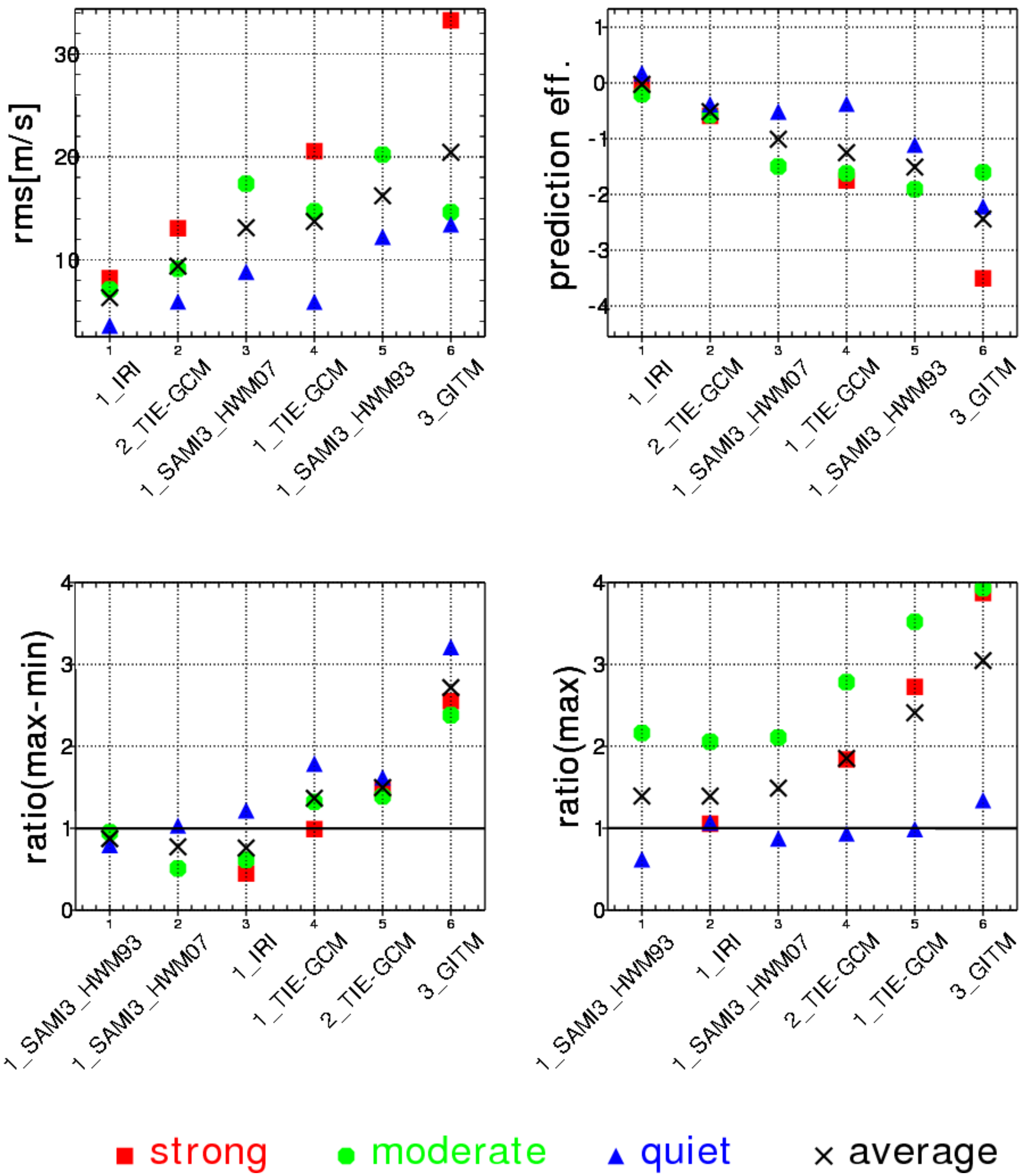
Key Points

- First-time metric studies for various ionosphere/thermosphere models
- Model performance strongly depends on the type of metrics used
- Model performance varies with latitude and geomagnetic activity level


Vertical Drift at Jicamarca
Vertical Drift[m/s]
UT[doy/hh:mm, 2006]
1_IRI
1_TIE-GCM
2_TIE-GCM
3_GITM
Observation


Vertical Drift at Jicamarca
Vertical Drift[m/s]
UT[doy/hh:mm, 2007]
1_IRI
1_SAMI3_HWM07
1_SAMI3_HWM93
1_TIE-GCM
2_TIE-GCM
3_GITM
Observation

Vertical Drift at Jicamarca



$$RMS = \sqrt{\frac{\Sigma(x_{obs} - x_{mod})^2}{N}}$$

$$PE = 1 - \frac{RMS_{mod}}{RMS_{ref}} = 1 - \frac{\sqrt{\Sigma(x_{obs} - x_{mod})^2 / N}}{\sqrt{\Sigma(x_{obs} - < x_{obs} >)^2 / N}}$$

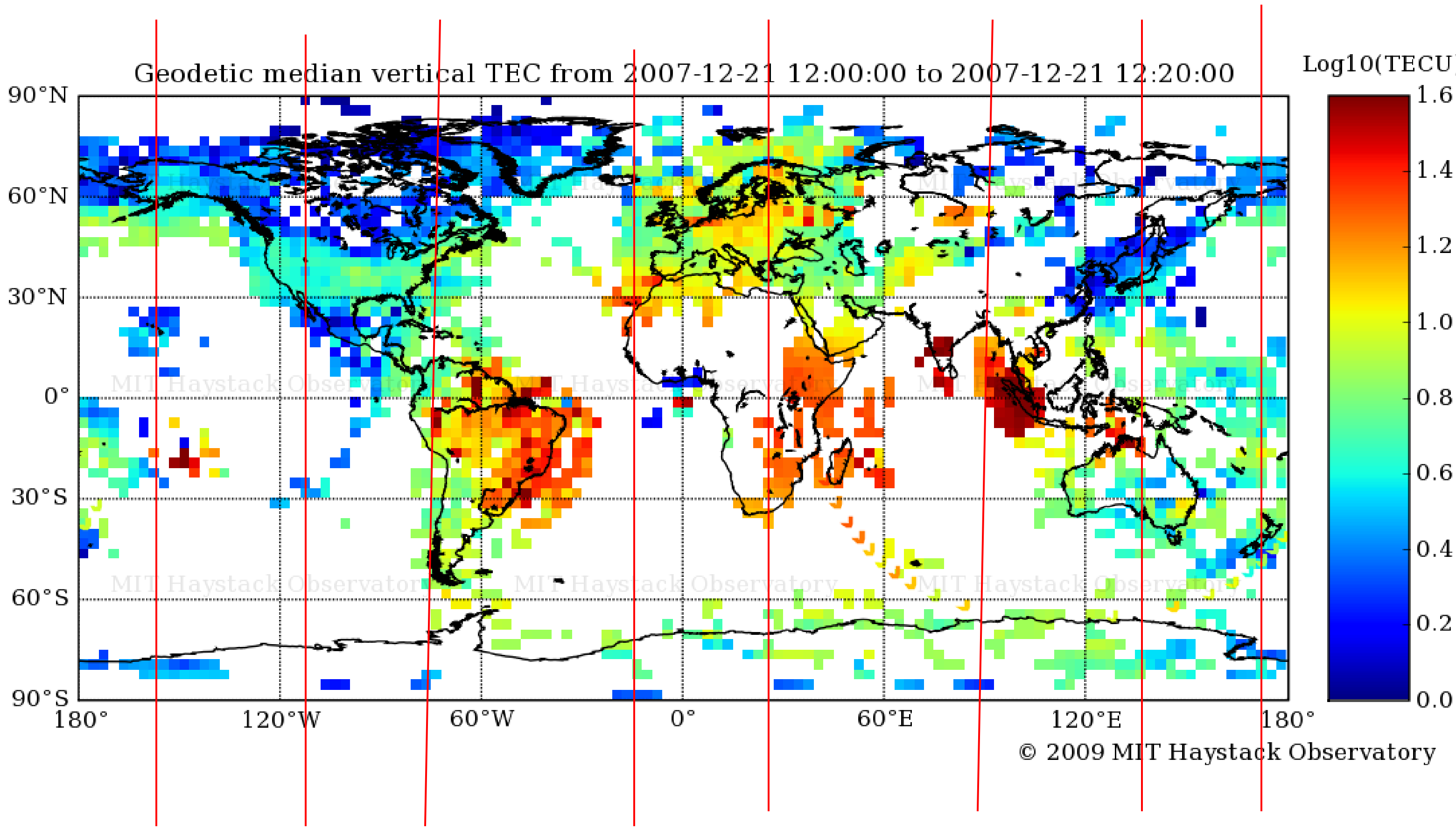
$$ratio(max - min) = \frac{(x_{mod})_{max} - (x_{mod})_{min}}{(x_{obs})_{max} - (x_{obs})_{min}}$$

$$ratio(max) = \frac{(x_{mod})_{max}}{(x_{obs})_{max}}$$

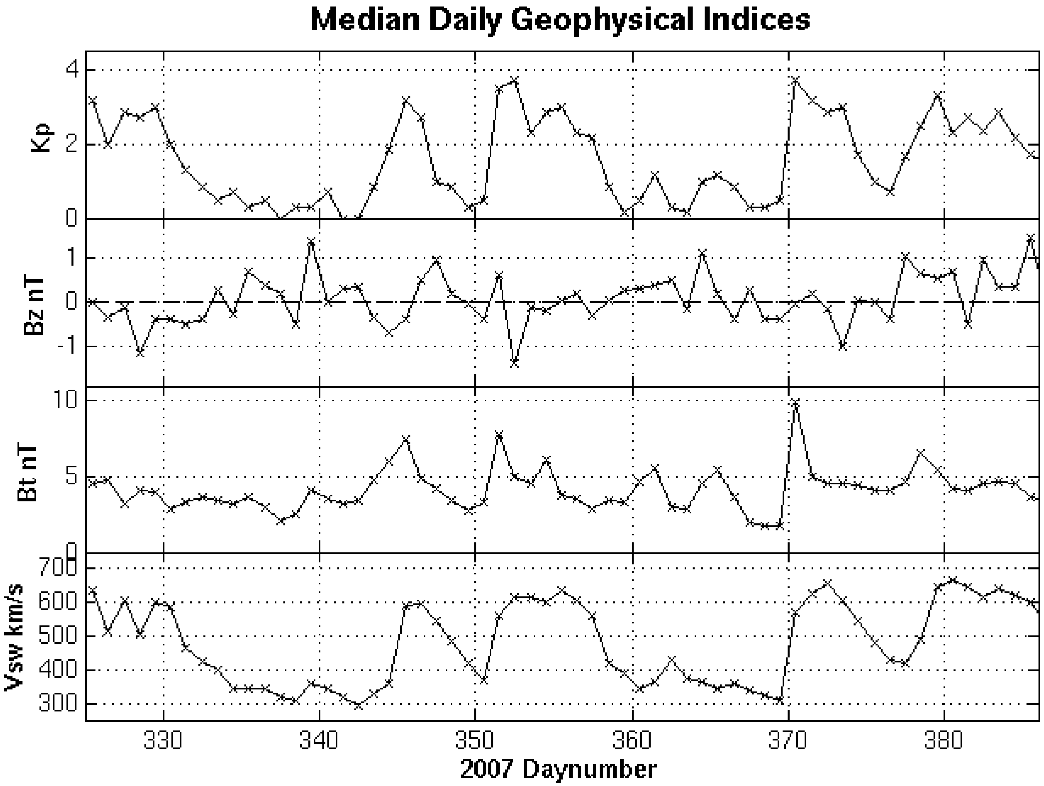
Expanding to 2-D Data

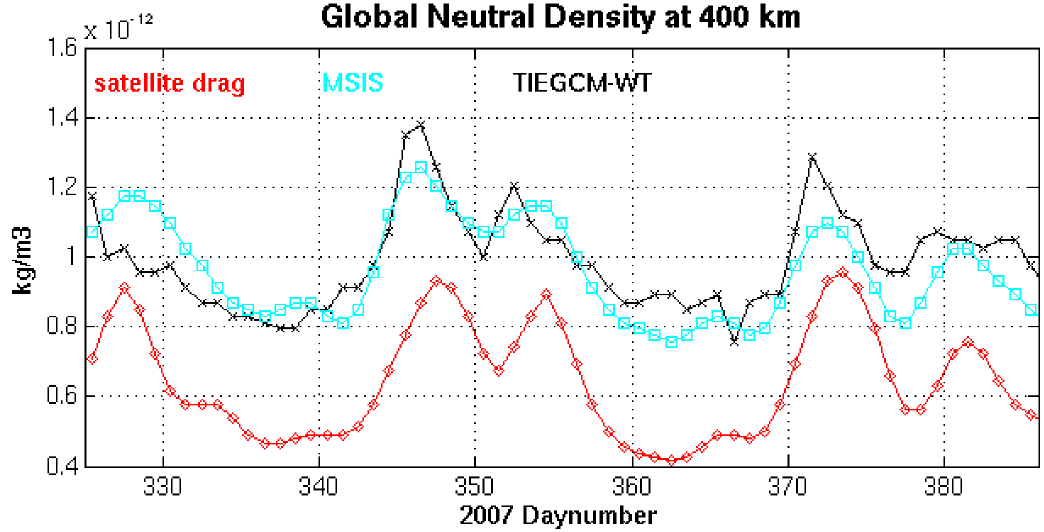
- Global 2-dimensional TEC and COSMIC Nmf2/hmf2 data was discussed in 2010.
- In 2011, 8 longitudes were picked for the December 2006 storm and the climatology study.
  - mini-GEM in December 2011 presented the first climatology study and TEC comparisons for the climatology and Dec06 studies.

Choose 8 Longitude Slices from GPS TEC



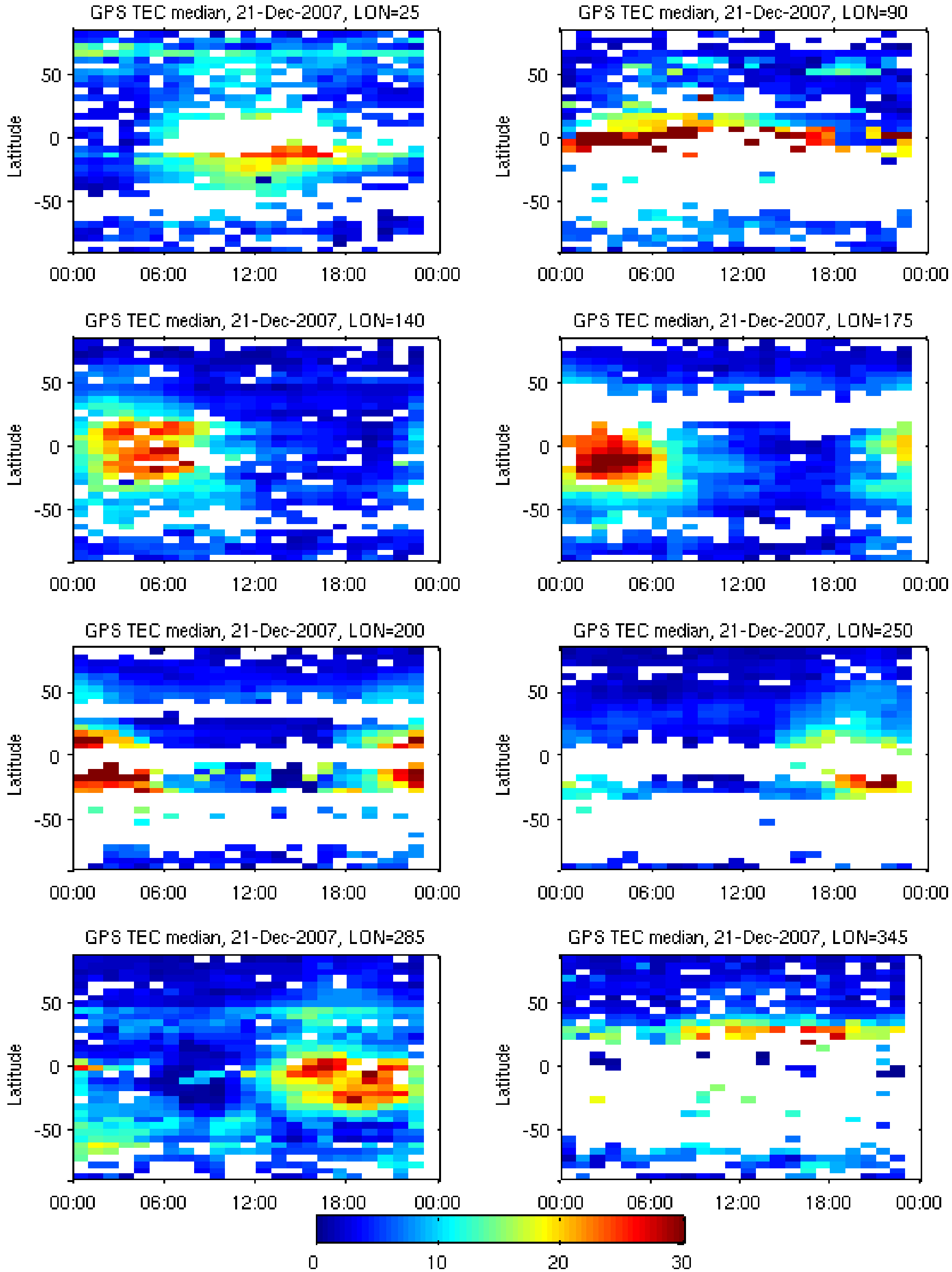
5 deg lat and 5 deg lon bins for December solstice 07355. Longitudes chosen: 25E, 90E, 140E , 175E, 200E (160W), 250E (110W), 285E (75W), 345E (15W).





Solar Wind and Global 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 neutral densities at 400 km in satellite drag data (red) from Emmert [2009, JGR], MSIS (cyan) and TIEGCM Weimer05 with TIMED lower boundaries.

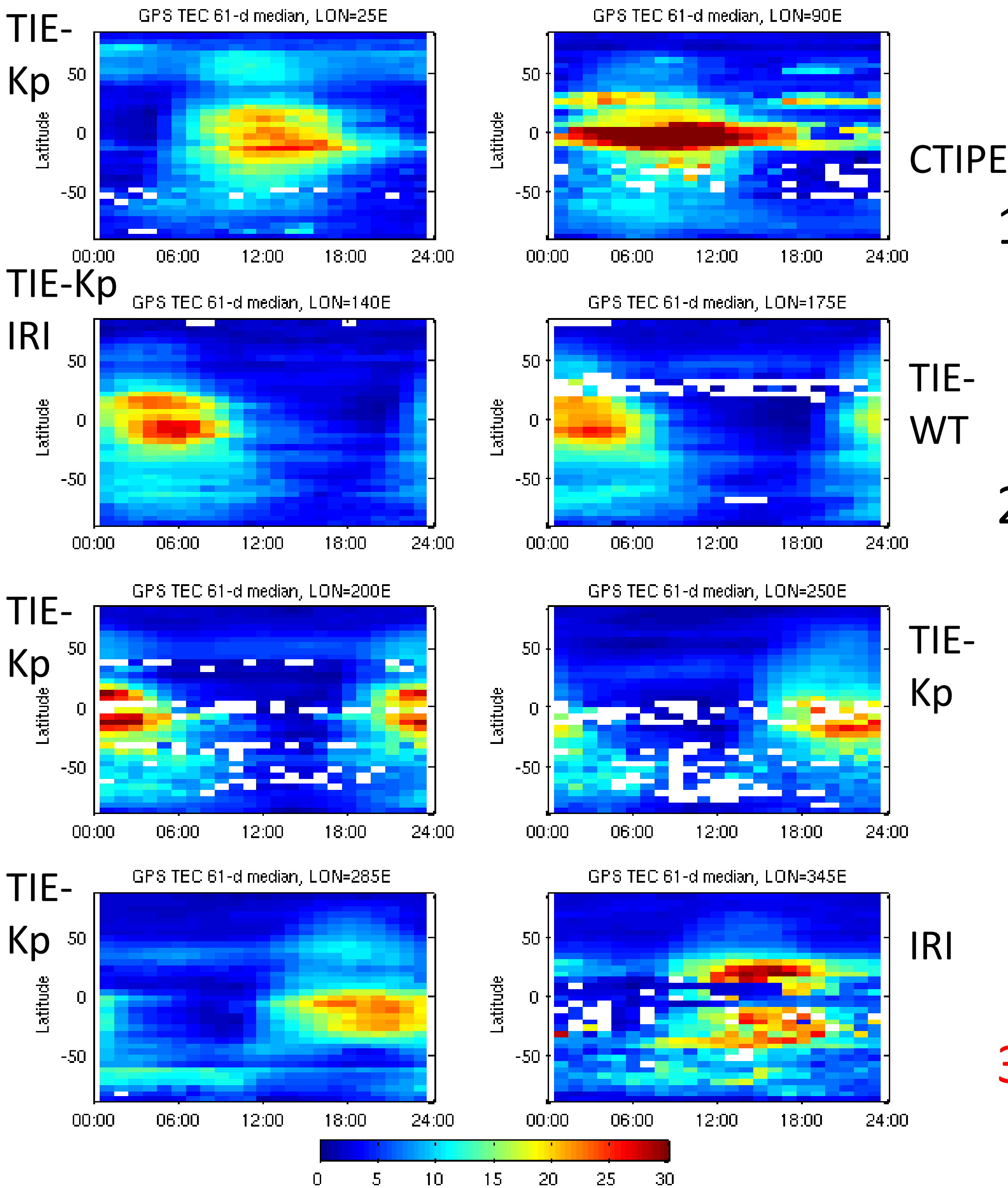


Hourly coverage of the 8 longitude slices for 21 December 2007 from MIT GPS TEC analysis.

Minimum number of bins 446 for 345E, maximum 727 for 140E.

Can see daily low latitude maxima.

Summary of TEC Climatology

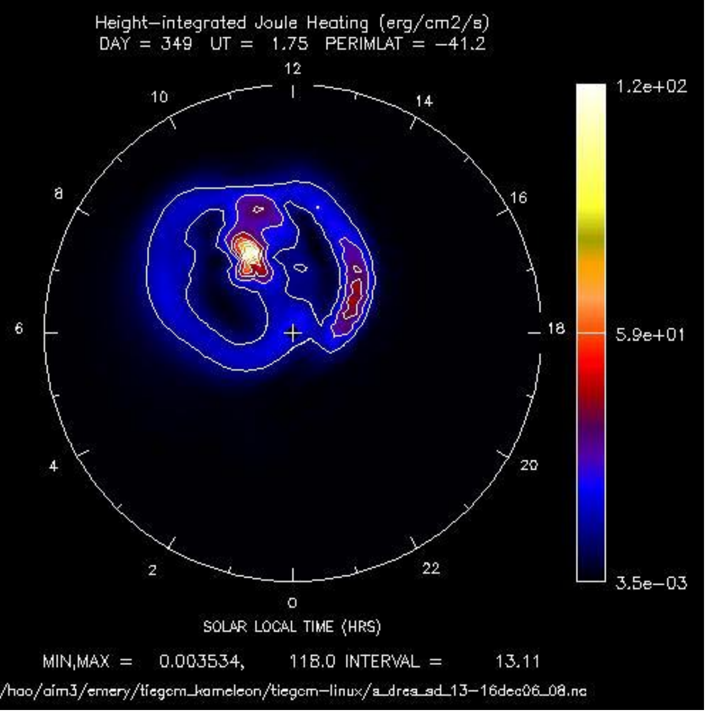


1) All models show different regions of overestimation and underestimation of the 'real' GPS TEC.
2) Average absolute value percent deviations for 61 days total, or 25 days of HSS or slow Vsw (not area wtd): IRI 96,99,104%; CTIPe 96,108,99%, TIE-Kp 77,77,84%, TIE-WT 90,90,93%
3) All models did best for at least 1 of 8 longitudes (IRI 1-2 lons, TIE-Kp 4-5 lons)

Different High-Latitude Driver Studies

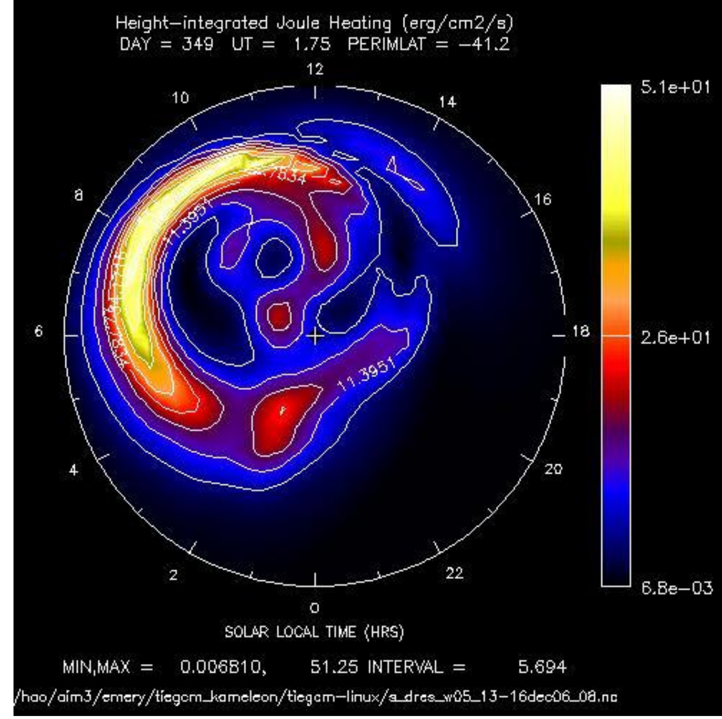
- First discussed at mini-GEM December 2011
- First results at CEDAR 2012 with further results at each successive meeting.
  - GITM (U MI suite of routines for U MI binary files) and
  - CCMC (CCMC suite of kameleon routines and libraries for .hdf files discussed by David Berrios)
    - Kameleon memory leak fixed in March 2014
- TIE-GCM has HAO/NCAR suite of routines for "AMIE-type" files (HAO binary, U MI binary, ASTRA ascii, SuperDARN ascii), kameleon .hdf files, and CMIT inputs (large code changes). All but CMIT inputs available in s/w release soon.

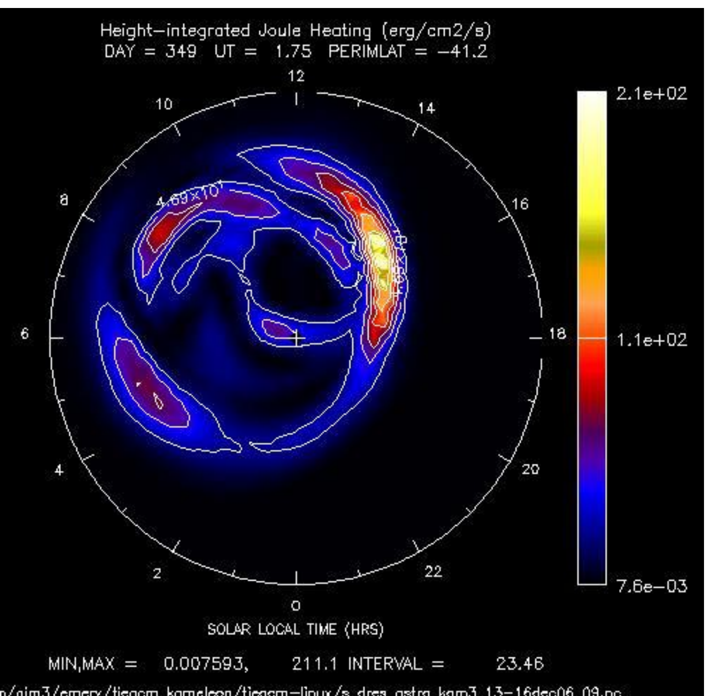
SH Joule Heat QJ



SuperDARN CP=57kV
HP~136GW(Kp)

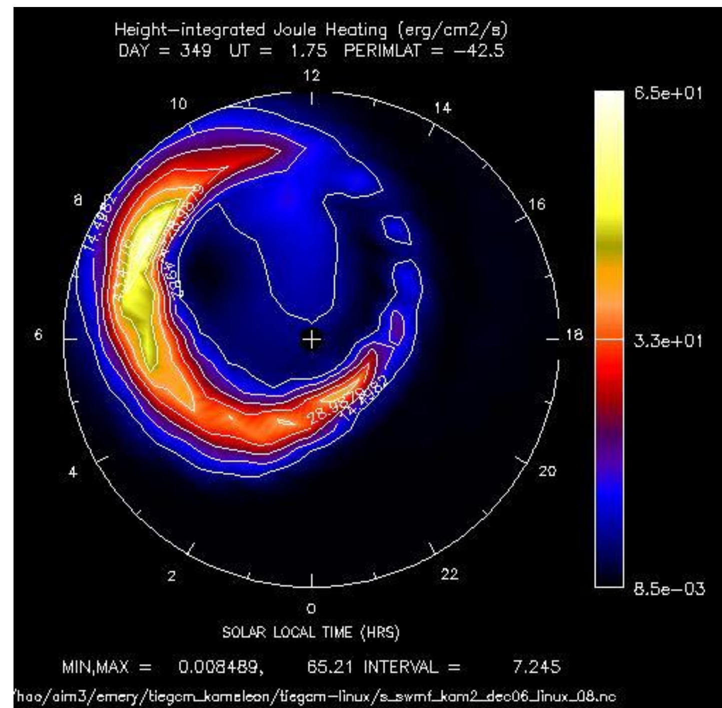
Weimer05 CP=181kV
HP~176GW(V,Bz)





SWMF CP=100kV
HP=115GW

ASTRA AMIE (SD+mags)
CP=186kV
HP=130GW



Peak QJ heating on AM or PM side or near cusp

How to quantify storm impact on the ionosphere and thermosphere

by Tim Fuller-Rowell at pre-SWW 2013 and CEDAR 2013

- Process 1: Quantifying the storm energy input.
  - NO cooling IR radiation measured by SABER (∝ NO and T)
  - Rate of temperature/density response and recovery
  - Presented first at mini GEM December 2013
- Process 3: Build-up of plasma and structure at mid-latitudes
  - Validate TEC from GPS maps; in-situ from satellites; points with ionosondes
  - Some work on this for CCMC CEDAR-GEM at SWW April 2014
- Process 6: Onset/timing/evolution of neutral composition change
  - Response and recovery of O/N2 (e.g. TIMED/GUVI)
  - Movement of boundaries in O/N2 (e.g. TIMED/GUVI)
  - Nothing done on this yet

Summary

- We include climatology as well as storms
- We went from single time-lines to near global comparisons with TEC and NmF2/hmF2
- We need various metrics for various latitude and activity regimes and various parameters
- We continue to add more models and parameters
- Tools exist (CCMC kameleon, U MI "AMIE" s/w, HAO/NCAR s/w) to help with various driver inputs
- Helpful resources like the integrated Space Weather Analysis (iSWA) system (displayed at 2012 CEDAR) at http://iswa.gsfc.nasa.gov/iswa/iSWA.html
- Tim Fuller-Rowell has suggested validations for the most important storm impacts.
- Thanks to the CCMC, modelers and data providers!