CEDAR Support from the CCMC: The Model Challenges

Barbara A Emery

CCMC Workshop

January 16-20, 2012

Key Largo, FL

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

- IRI (International Reference Ionosphere, also free source in the community)

- TIE-GCM (Thermosphere-Ionosphere-Electrodynamics General Circulation Model, 67 RoR, also free source)

- CTIP/e (Coupled Thermosphere-Ionosphere Plasmasphere, 153 RoR)

- SAMI2/3-HWM93 (87 RoR, SAMI2 free source)

- USU-GAIM (USU-IFM background, 102 RoR)

History

- First CEDAR CCMC Challenge Workshop in June 2009 at CEDAR Workshop in Santa Fe, NM

- Second CEDAR CCMC Challenge Workshop in June 2010 at CEDAR Workshop in Boulder, CO

- Third CEDAR CCMC Challenge Workshop joint with GEM in June 2011 in Santa Fe, NM along with first climatology workshop

- Fourth CEDAR CCMC Challenge Workshop at the mini-GEM Workshop in December 2011 in San Francisco, CA

Key Players

- Masha Kuznetsova and Ja Soon Shim of CCMC
- Barbara Emery of HAO/NCAR for workshop coordinator, data coordinator, etc
- Many others in the CEDAR community as modelers, data providers, interested participants.

First Workshop at CEDAR June 2009

- http://cedarweb.hao.ucar.edu/wiki/index.php/2009_Workshop:CEDAR_ETI_Challenge
- **2009 Workshop:CEDAR ETI Challenge**
- **CEDAR Electrodynamics Thermosphere Ionosphere Modeling Challenge**
- **Anasazi South, 1930-2130, 29 June 2009, Santa Fe, NM**
- **Conveners**
- Maria Kuznetsova
  Barbara Emery
  Jan Sojka
  Aaron Ridley
  John Holt
  Jiuhou Lei
- Focus on climatology from: The International Space Science Institute in Bern, Switzerland, was the host of an ionospheric modeling challenge in 2008 based on the year-long incoherent scatter radar (ISR) runs of EISCAT, Svalbard, and Poker Flat (PFISR) from March 2007 to March 2008.

2009 Summary Periods

- CEDAR Climatology 'year': March 1, 2008 to March 31, 2009 (07060-08091)
  - 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)

2009 Summary Data for ETI Challenge

- 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)
  - Exospheric neutral temperature from GUVI/TIMED (Bob Meier)
  - Neutral Winds from FPI 630 nm
- Ionosphere:
  - Ne as vertical TEC from ground-based madrigal and COSMIC; NmF2 and hmF2 from ISRs and COSMIC; and electron density at 400 km from CHAMP
  - Te and Ti from ISRs

  http://ccmc.gsfc.nasa.gov/support/CETI2010/events_studies.php
  Limited to 1-dimensional time-series data for a single station or satellite track.

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.

Why is Climatology Important?

- Solar minimum conditions have least EUV, so we can see the largest effects of other sources.

- If we cannot get quiet conditions right, we don't have the right physics in the model.

- Magnetic storms can be 'fitted' by changing the Joule heat factor, the convection model, or other things in the model.

- Also of interest is the variability ('weather') seen in quiet conditions which can be quite large and is suspected to be from lower boundary sources.

DE3 non-migrating tide (4 peaks at 20LT) at the equatorial anomaly peaks
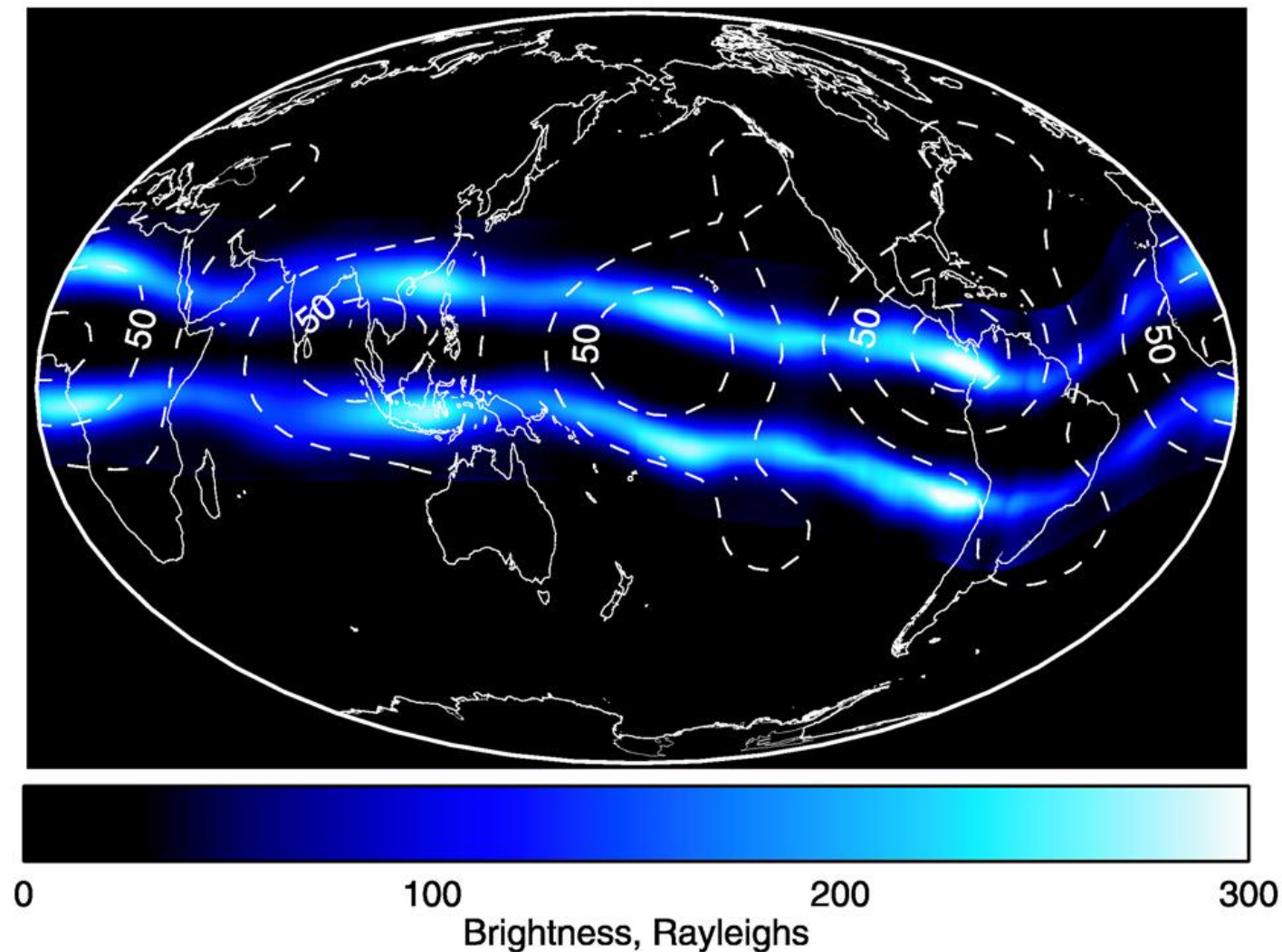
Sources from Below

WACCM (Whole Atmosphere Community Climate Model) variability in the meridional wind with constant solar radiation and no high-latitude forcing at 46S in summer.

V, Dec. Lon. 0, Lat. 46S
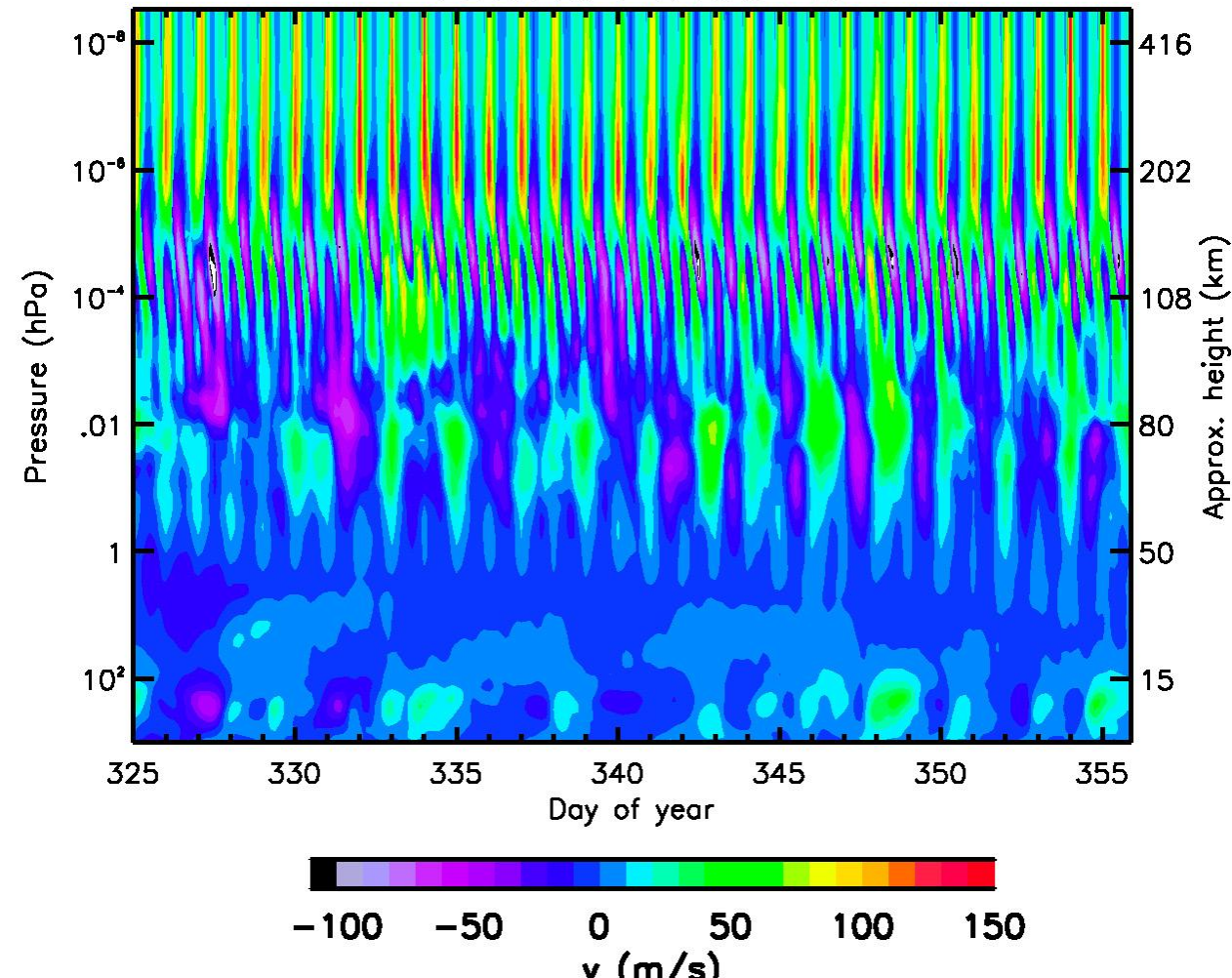
*Thermosphere day-night diurnal tides but strong variability from thunderstorms.
•Semi-diurnal tides

•Variability in mesosphere and propagating tides amplified
•Tides ~50km

•Lower stratosphere effects of thunderstorms below.

Ionospheric Zonal Averages, 2008

Work by A. G. Burns, et al.

Winter NH
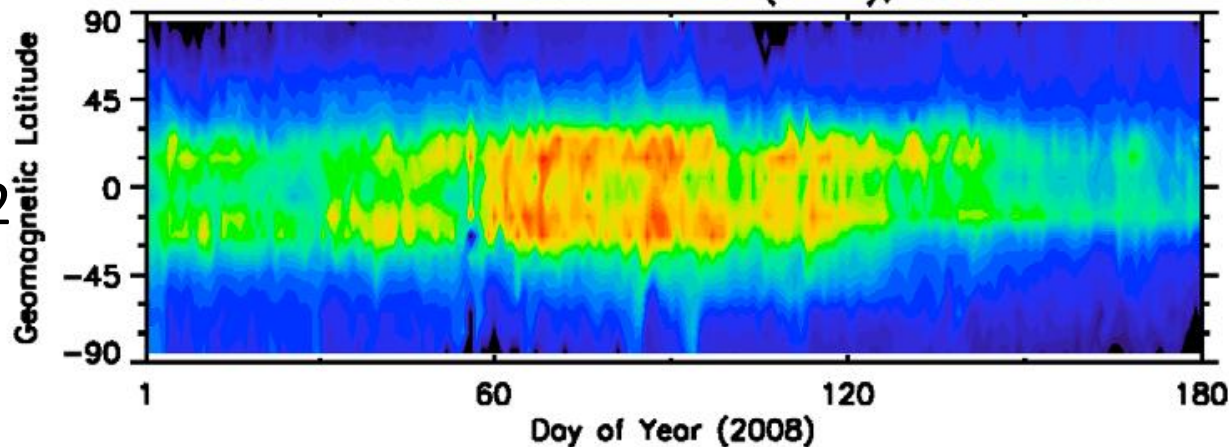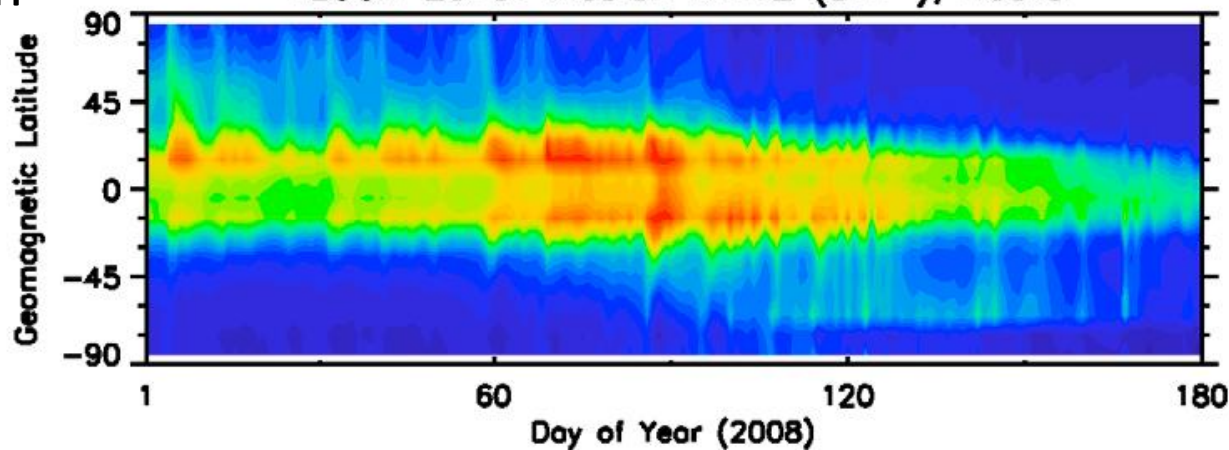
Summer NH

NH winter
anomaly
where NmF2
winter>
summer is
actually
Jan>Jun from
annual
composition
changes
where O/N2
is decreased
in June.

Summer SH

Winter SH

Mapping the Weddell Sea Anomaly – NmF2 night>day

17-18 Local Time

18-19 Local Time

19-20 Local Time

20-21 Local Time

N_mF_2 (10^6 cm^{-3})
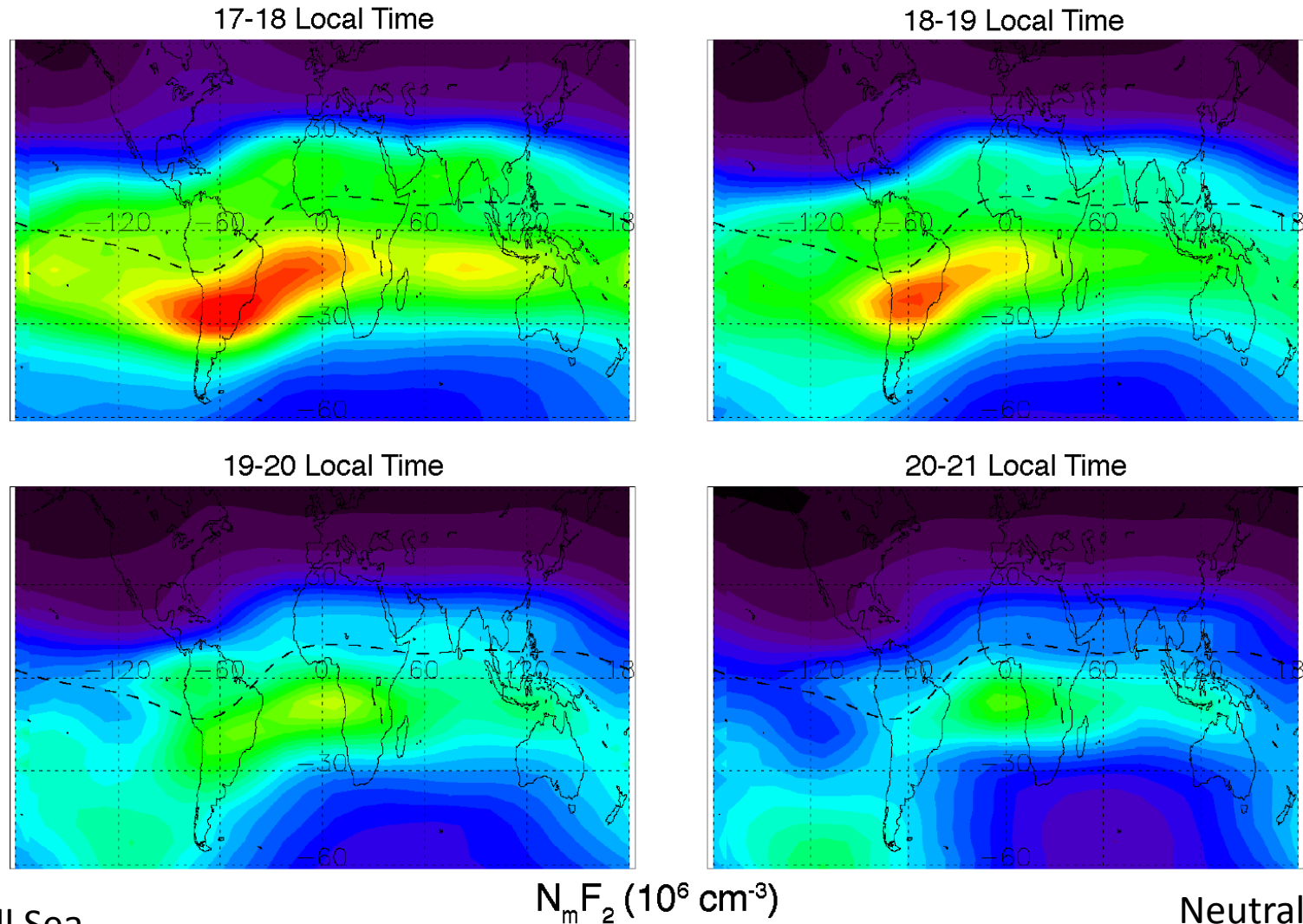
Weddell Sea
75S and 55mlat

Neutral wind or
conjugate hem at
terminator

Burns, A. G., Z. Zeng, W. Wang, J. Lei, S. C. Solomon, A. D. Richmond, T. L. Killeen, and Y.-H. Kuo, The behavior of the F2 peak ionosphere over the South Pacific at dusk during quiet summer conditions from COSMIC data, *J. Geophys. Res.*, *113*, A12305, doi:10.1029/2008JA013308 , 2008.

Global Mean Density at 400 km during 1996 and 2008

>EUV   >EUV

14
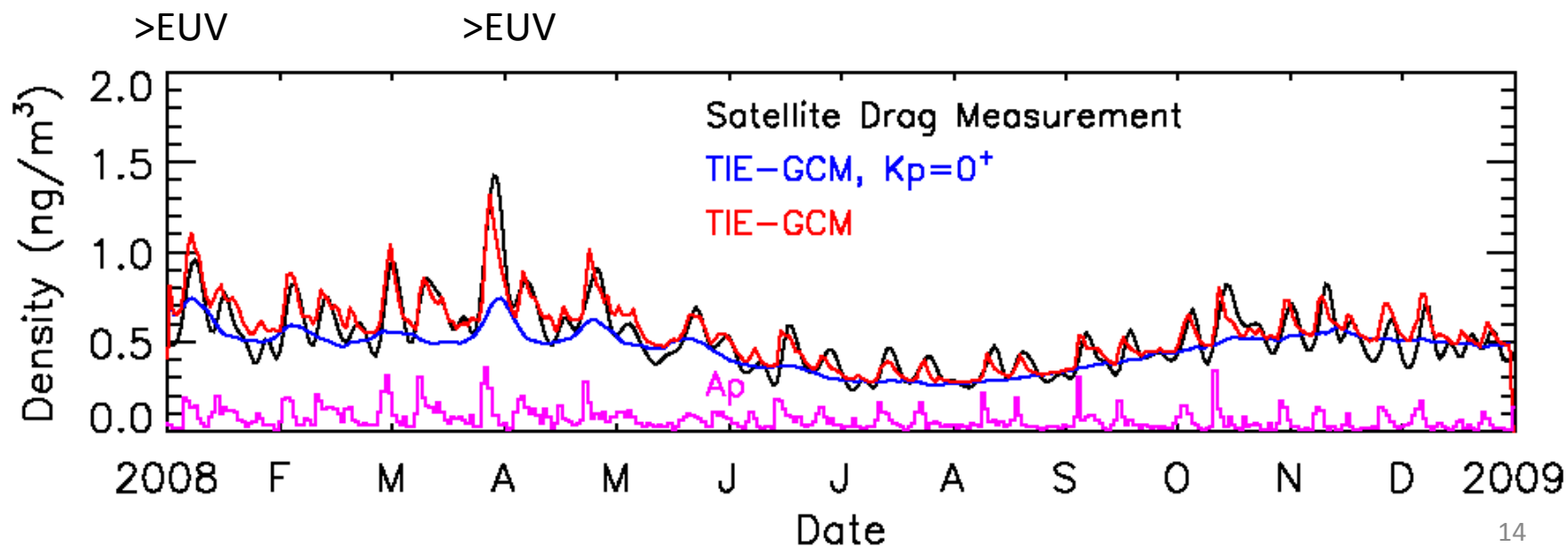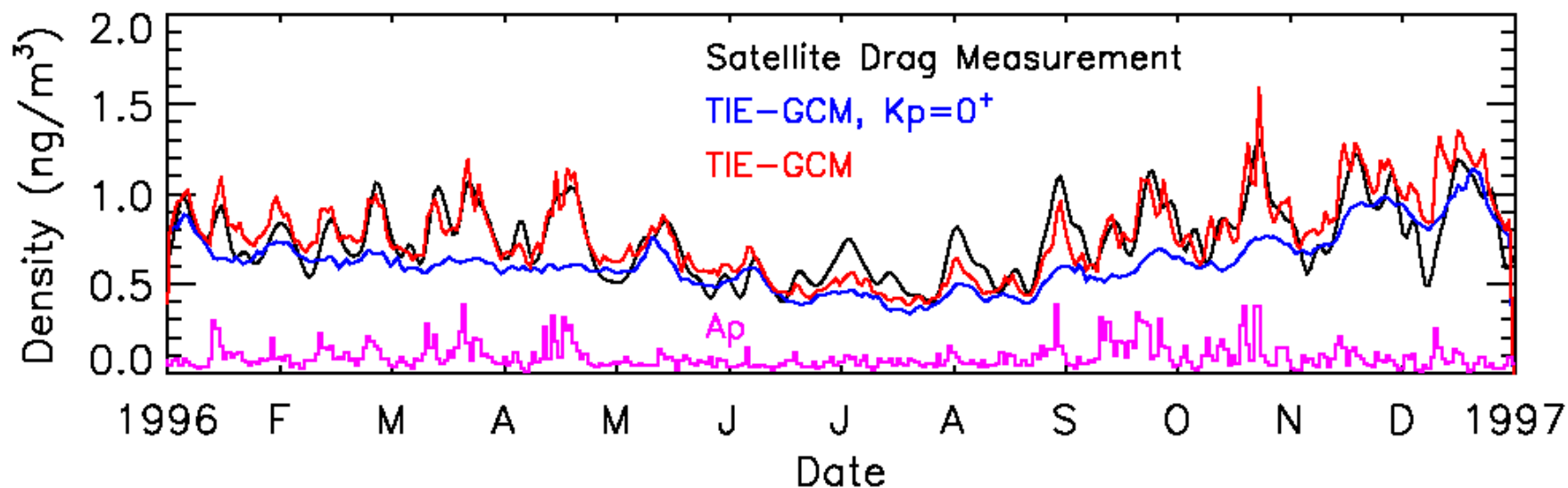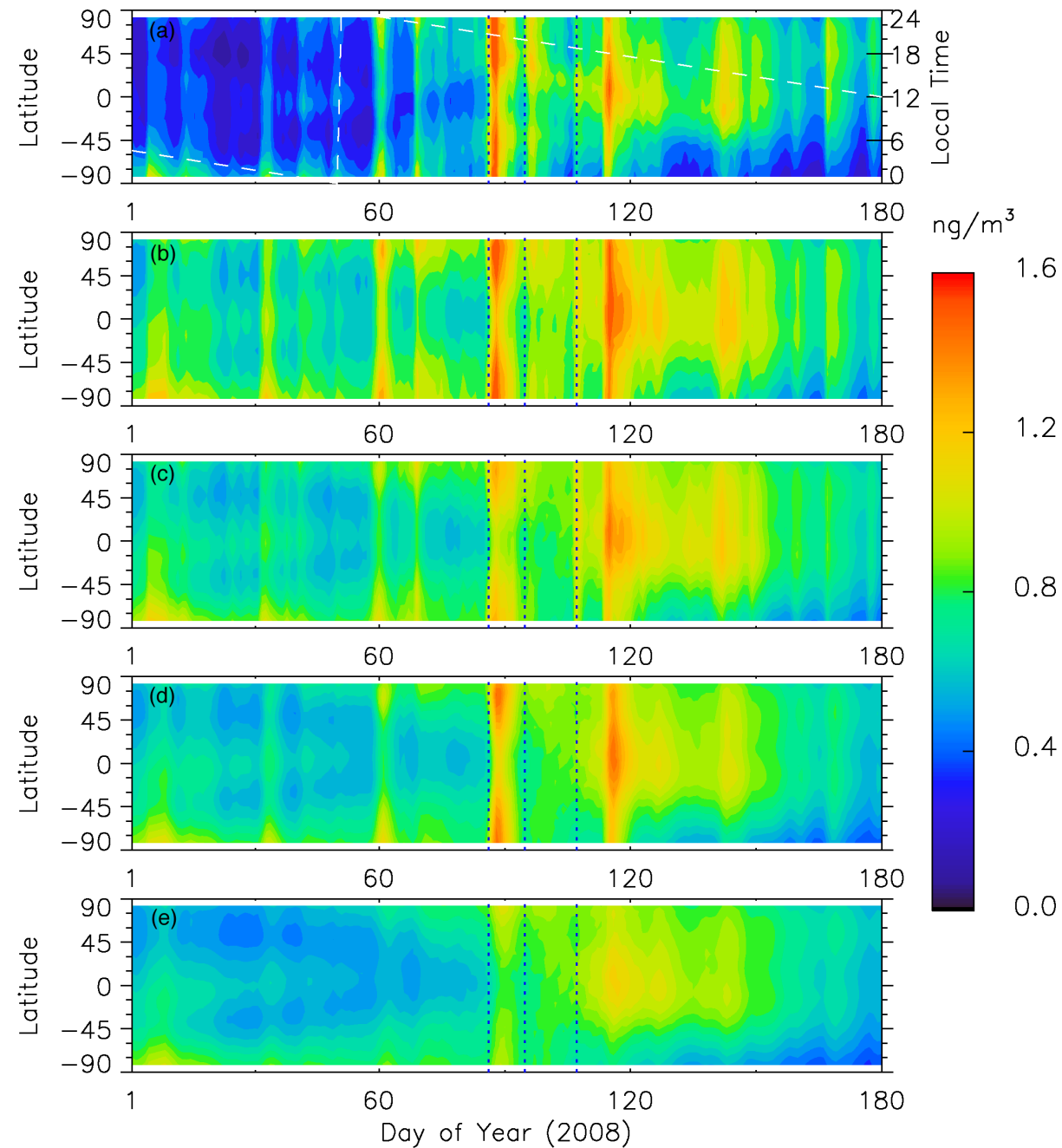
CHAMP

TIEGCM Weimer 2005

High-Speed
Streams and
Neutral Density
at 400 km

Second Workshop at CEDAR June 2010

- http://cedarweb.hao.ucar.edu/wiki/index.php/2010_Workshop:CEDAR_ETI_Challenge
- **2010 Workshop:CEDAR ETI Challenge**
- **CEDAR Electrodynamics Thermosphere Ionosphere (ETI) Challenge**
- **1030-1230, 25 June 2010, Boulder, CO**
- **Conveners**

      - Maria Kuznetsova

      - JaSoon Shim

      - Barbara Emery

      - Aaron Ridley

      - Jiuhou Lei

Metrics, Year Run, TEC 2-D Data?

- **Selected 2010 Discussion Topics were:**

- What metric(s) should be used for model comparisons? What formula(e) should be used for skill score calculations? Should there be any type of threshold-based/utility metrics especially for storm modeling?

- Should modelers and the CCMC run the entire climatology 'year' (13-months from March 2007 through March 2008) for all models and make all model output available for the entire year? If so, what parameters?

- How do we utilize global TEC data? Should we pick a few representative stations/points or utilize the entire 2D grid? Should we accept submission of 2D timelines? How do we visualize the comparison for 2D timelines?

First Publication

CEDAR Electrodynamics Thermosphere Ionosphere (ETI) Challenge for systematic assessment of ionosphere/thermosphere models: NmF2, hmF2, and vertical drift using ground-based observations

By J. S. Shim et al.

Key Points

- First-time metric studies for various ionosphere/thermosphere models

- Model performance strongly depends on the type of metrics used

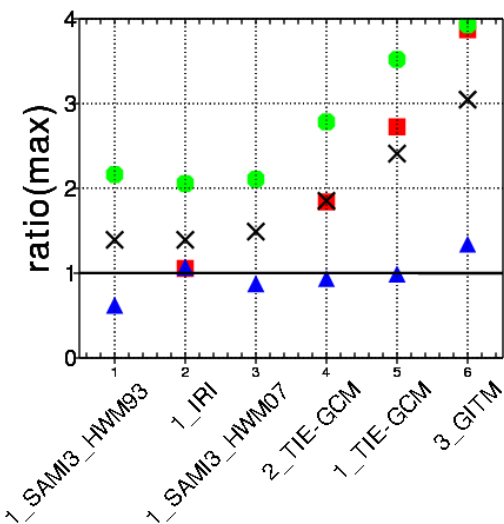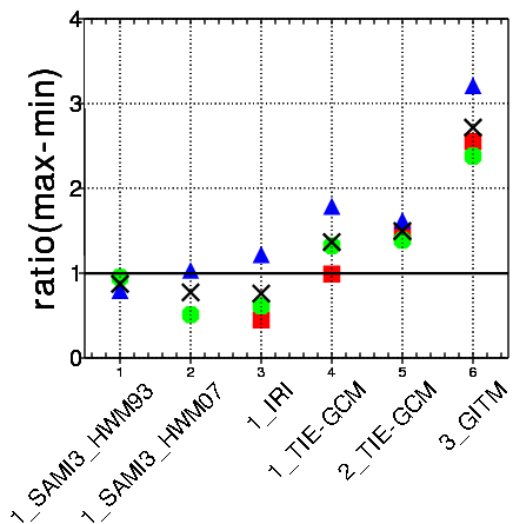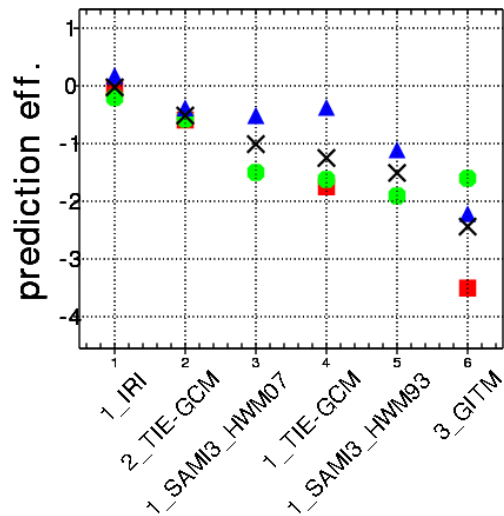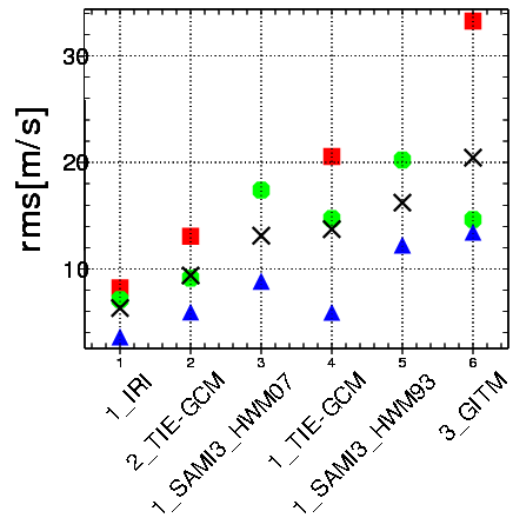- Model performance varies with latitude and geomagnetic activity level
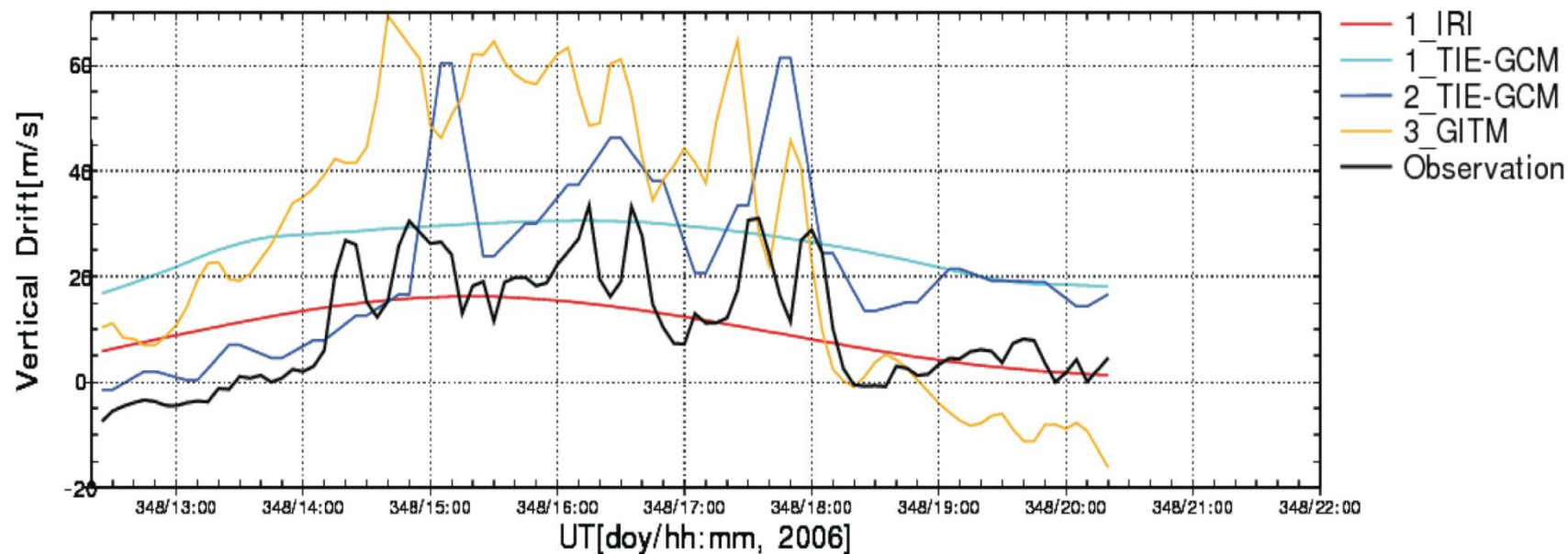
Vertical Drift at Jicamarca
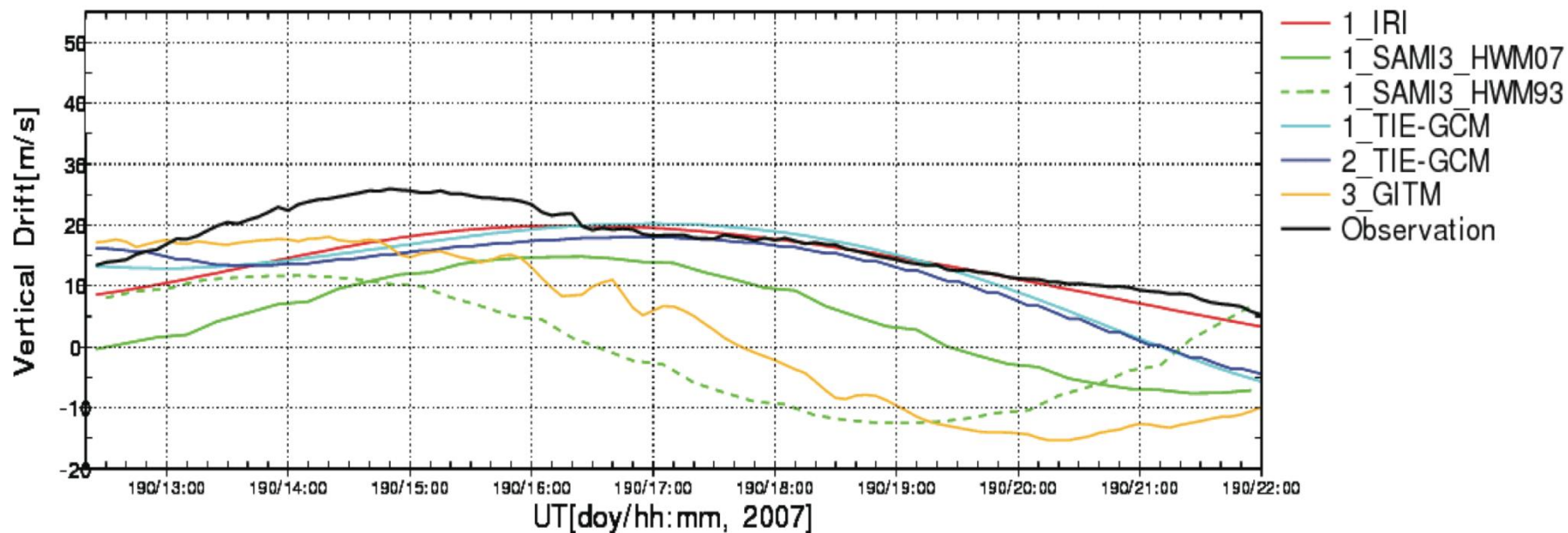
Vertical Drift at Jicamarca

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

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

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

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

■ strong   ● moderate   ▲ quiet   × average

Third Workshop at CEDAR-GEM June 2011

- http://cedarweb.hao.ucar.edu/wiki/index.php/2011_Workshop:CEDAR_ETI_Challenge

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

- 2011 Workshop: ModelingChallenge

- Three 2-hour Sessions (up from one 2-hour session)

  - Review of Challenge Results for 5 events: 06348-349, 01243, 05243-244 (3 GEM storms from before) and 2 big By IMF Poynting flux events: 05135, 05190-192

  - Poynting flux, Dst Challenge (GEM), auroral boundary, 2-dimensional TEC and COSMIC NmF2/hmF2 – chose 8 longitude slices to get a GLOBAL view for two 2011 Fall AGU posters (Dec06, climatology)

    - Conveners: M Kuznetsova and JS Shim

  - Climatology Projects (CEDAR IT and GEM Ring Current, Radiation Belts, and the Plasmasheet)

    - Conveners: BA Emery (CEDAR) and T. Guild (GEM)

Choose 8 Longitude Slices from GPS TEC

Geodetic median vertical TEC from 2007-12-21 12:00:00 to 2007-12-21 12:20:00
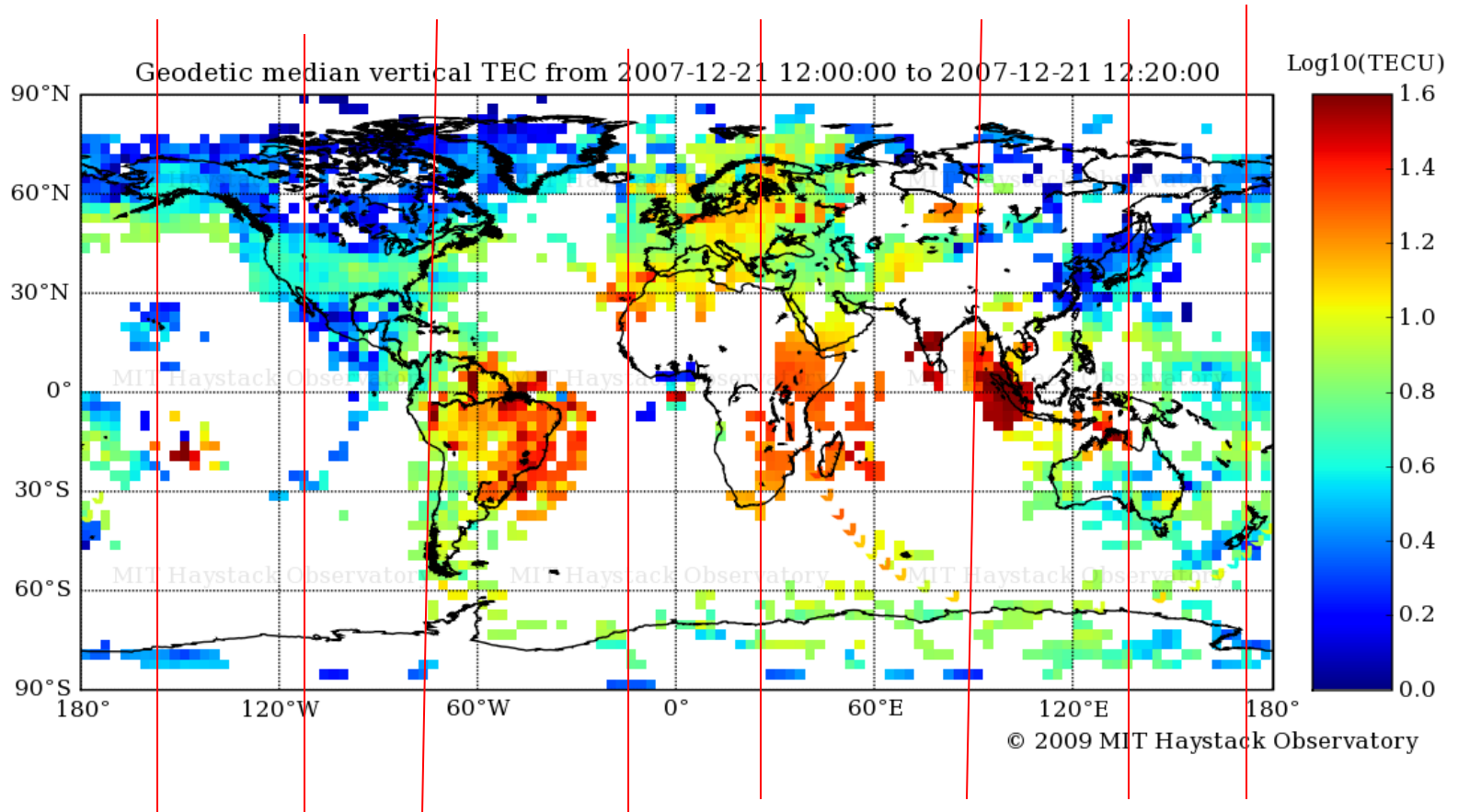
5 deg lat and 5 deg lon bins for December solstice 07355. Longitudes chosen: 25E, 90E, 140E , 175E, 200E (160W), 250E (110W), 285E (75W), 345E (15W).

Fourth Workshop at mini-GEM before Fall AGU December 2011

- http://ccmc.gsfc.nasa.gov/challenges/GEM-CEDAR/
- GGCM Metrics & Validation Focus Group (12:00 pm - 2:00 pm) including auroral oval boundaries
- CEDAR-GEM Modeling Challenge (2:30 pm - 4:30 pm)
  - Poynting Flux/Joule Heating metrics study
  - Role of drivers on ionosphere model results
  - Global TEC/NMF2/HMF2 metrics study Dec06
  - Climatology study (Nov 21 2007 to Jan 20 2008)

Fall AGU 2011 Climatology Study for the Ionosphere-Thermosphere (14 authors)

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

. This first Climatology Challenge centers on GPS Total Electron Content (TEC) around the solar minimum December solstice (07355) for +/-30 days to avoid a sudden stratospheric warming (SSW) January 22-23, 2008.

. Data sets: MIT GPS TEC, USU COSMIC NmF2 and hmF2, NRL satellite drag daily global neutral density at 400 km.

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

. Model runs: IRI, CTIPE, TIEGCM (Heelis Kp, double resolution Weimer 2005 with TIMED lower boundary)

. Added 10 more participants to this study at AGU.

Solar Wind and Global Neutral Density at 400 km

Median Daily Geophysical Indices

Global Neutral Density at 400 km

satellite drag   MSIS   TIEGCM-WT

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.
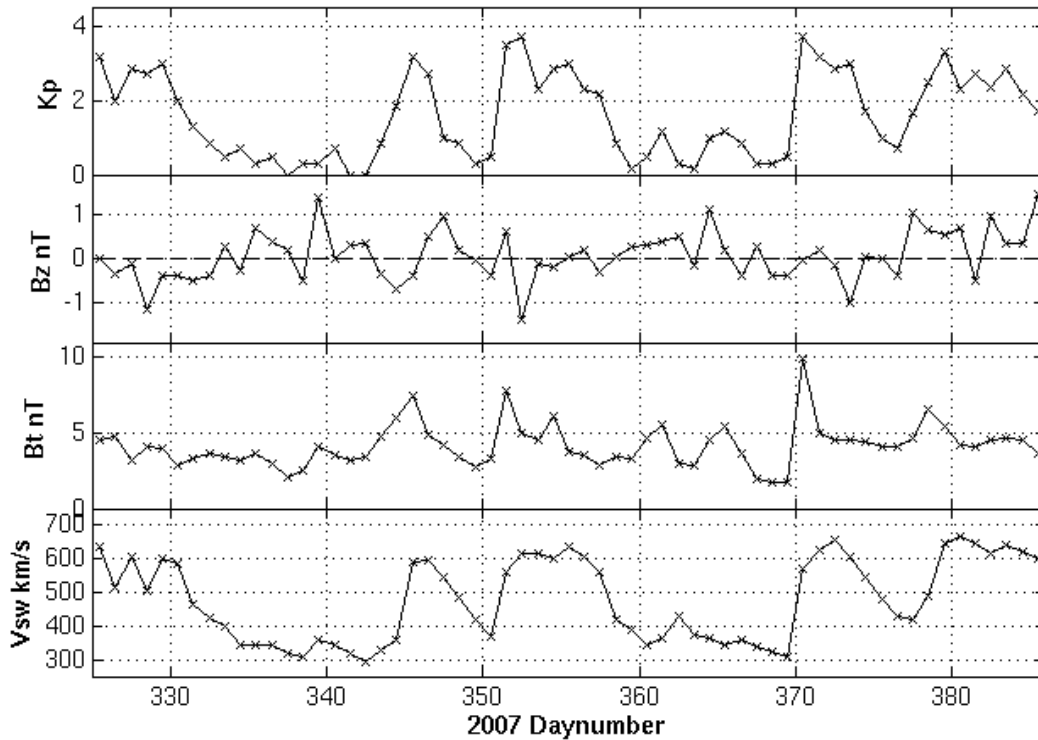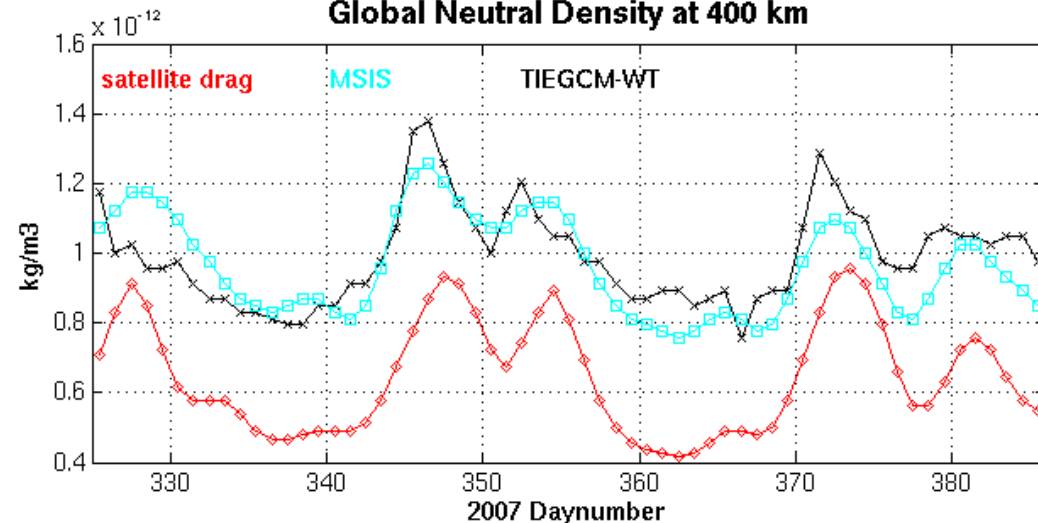
Separating HSS and Slow Speed Wind

Median Daily Geophysical Indices

Global Neutral Density at 400 km

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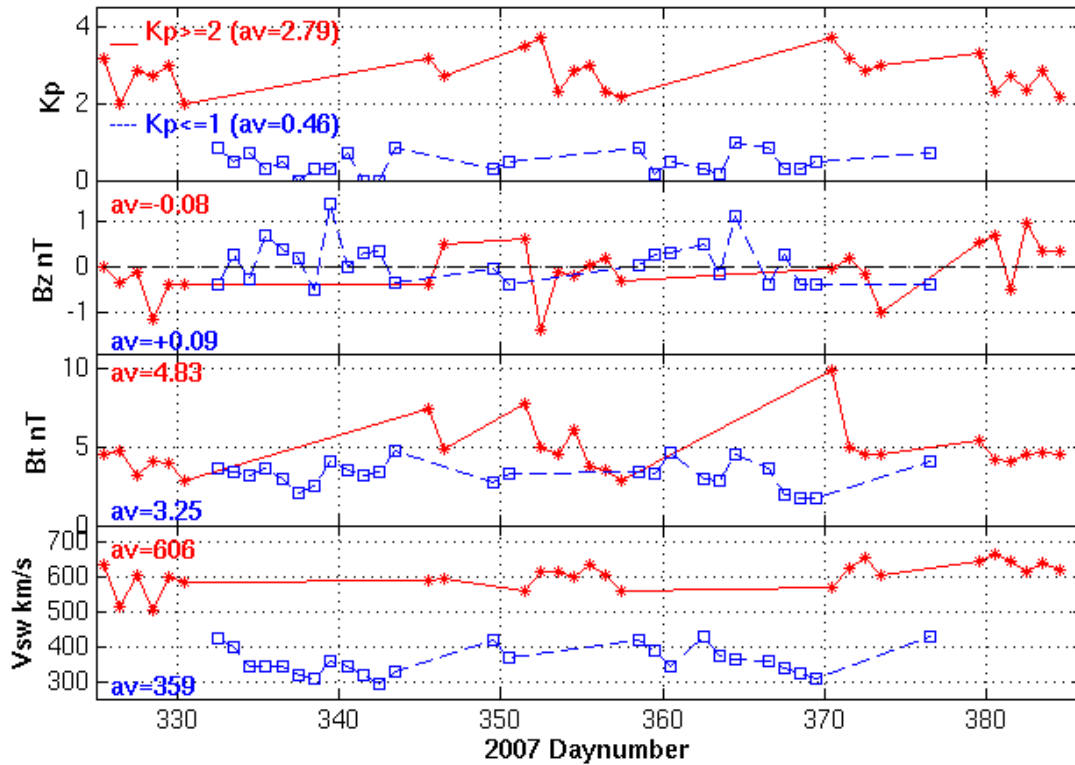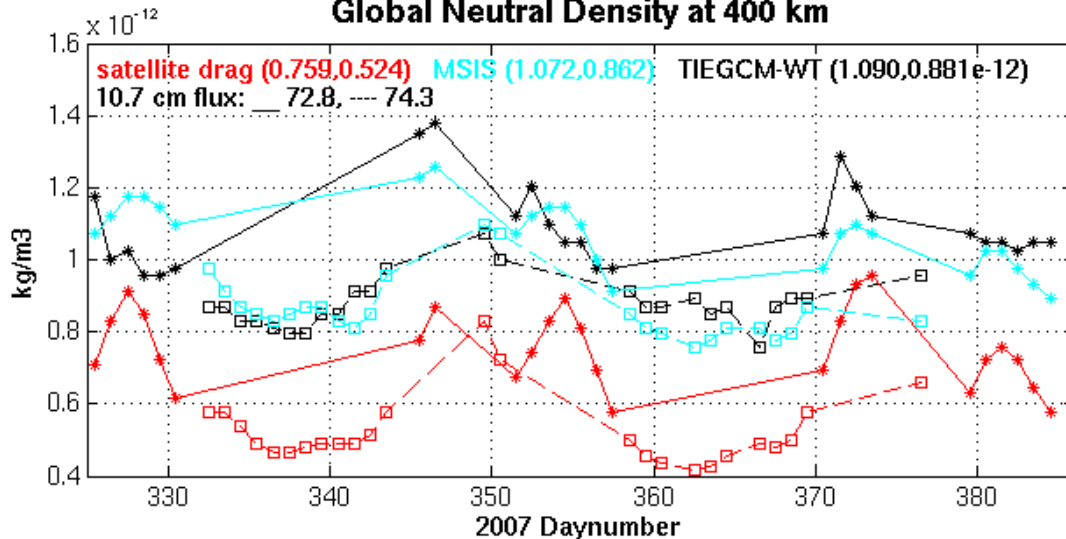
Hourly coverage of the 8 longitude slices for 21 December 2007 from MIT GPS TEC analysis.

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

Can see daily low latitude maxima.
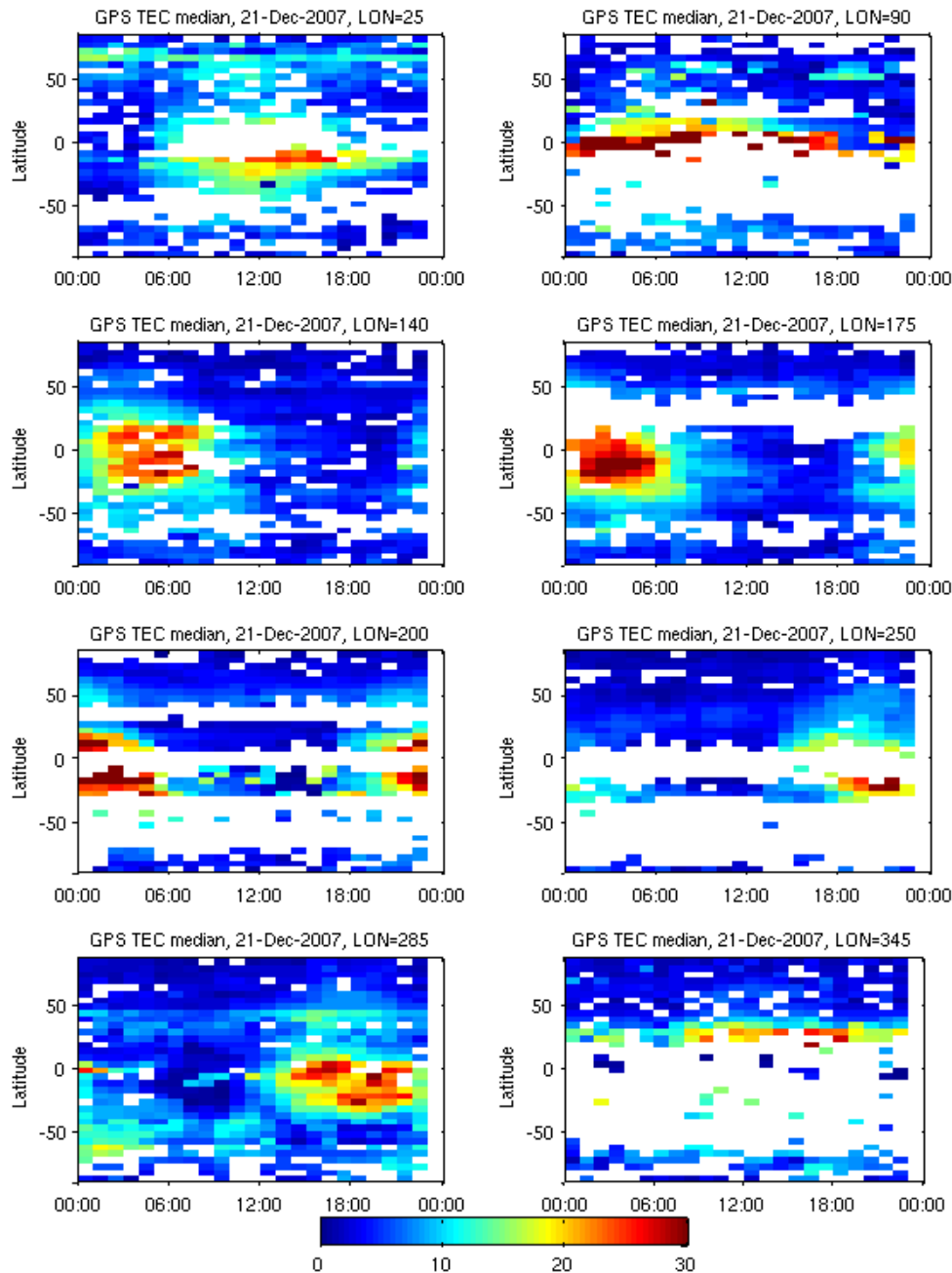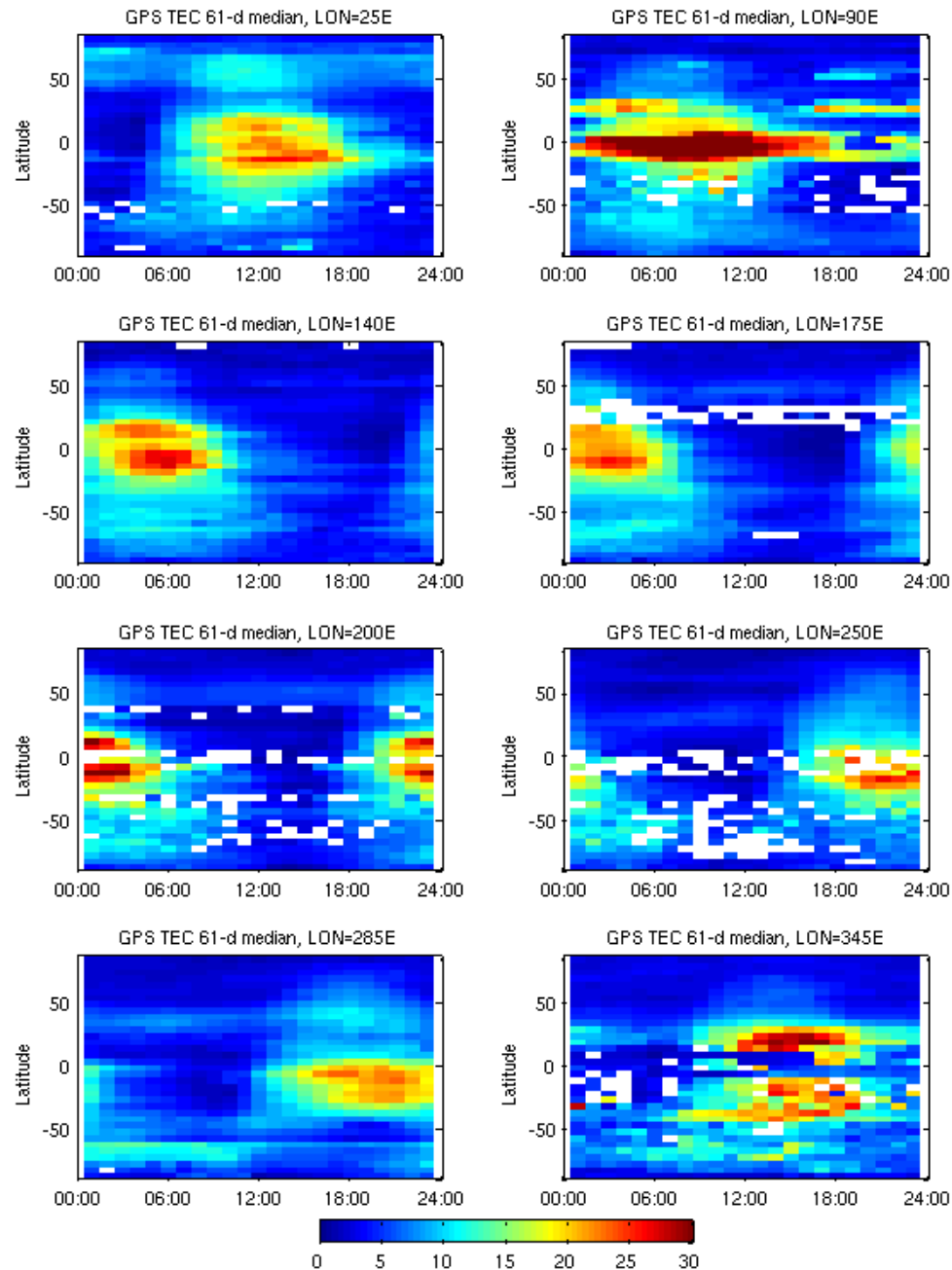
-Climatology medians for 61 days from MIT GPS TEC from 07325 (21 Nov) to 08020 (20 Jan).

-The winter (NH) anomaly expects daytime midlatitude NmF2 to be higher than summer (SH) as for 25E and 285E, but usually TEC is larger in the summer (SH) daytime midlatitudes.

-Low latitude night TEC and winter pole TEC lowest.

-Weddell Sea anomaly (~60-70S,~250-345E) shows night TEC larger than day.

-Possible bias problems with Indonesia (~0N, 90E) and Scandinavia (~ 70N,25E).
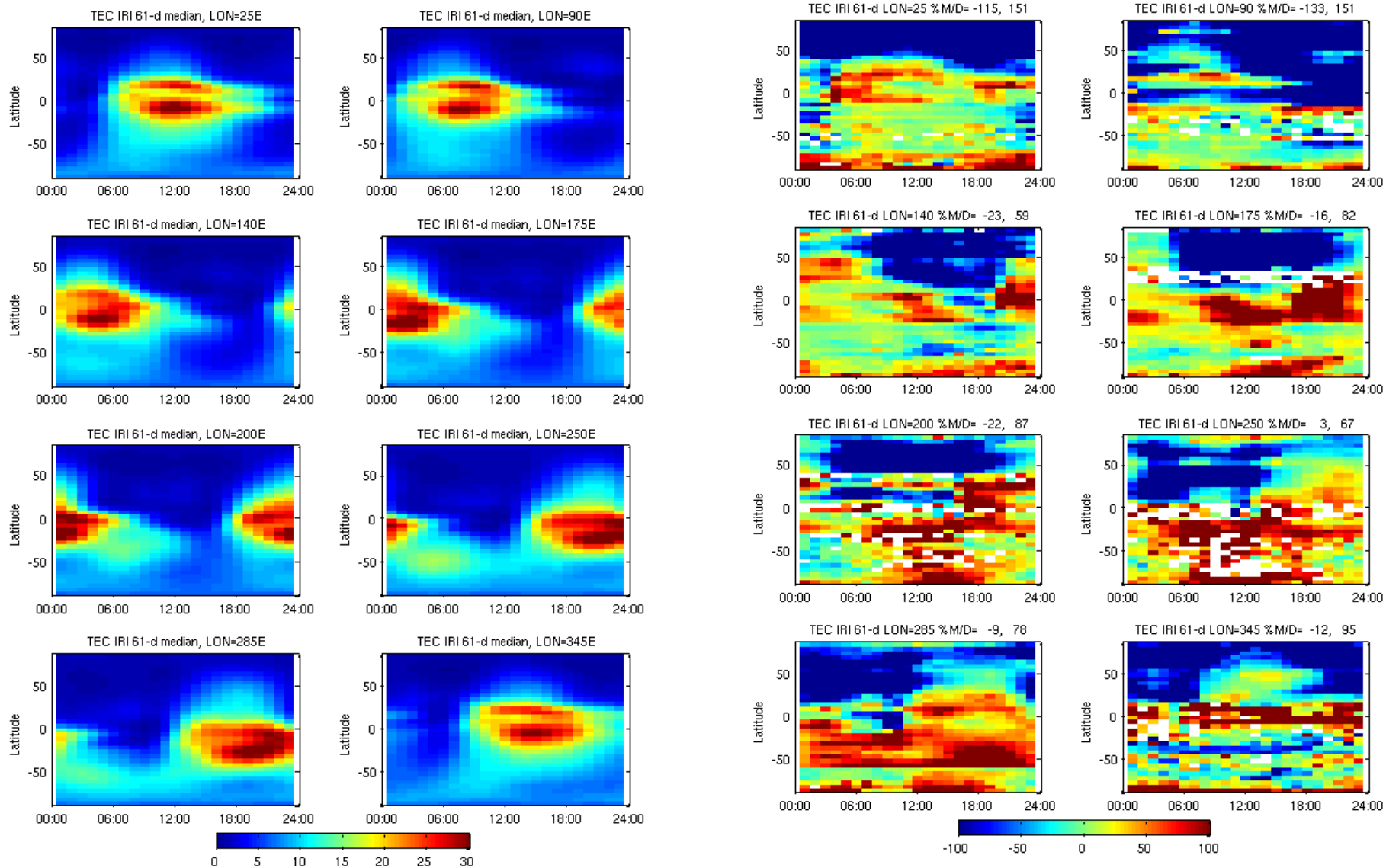
IRI model TEC and %model/data shows IRI overestimates morning day and summer night TEC and underestimates winter night TEC. %M/D for average model/data, and for absolute ratio average (New Metric!) Compare with average of 8 longitudes.

Summary of TEC Climatology
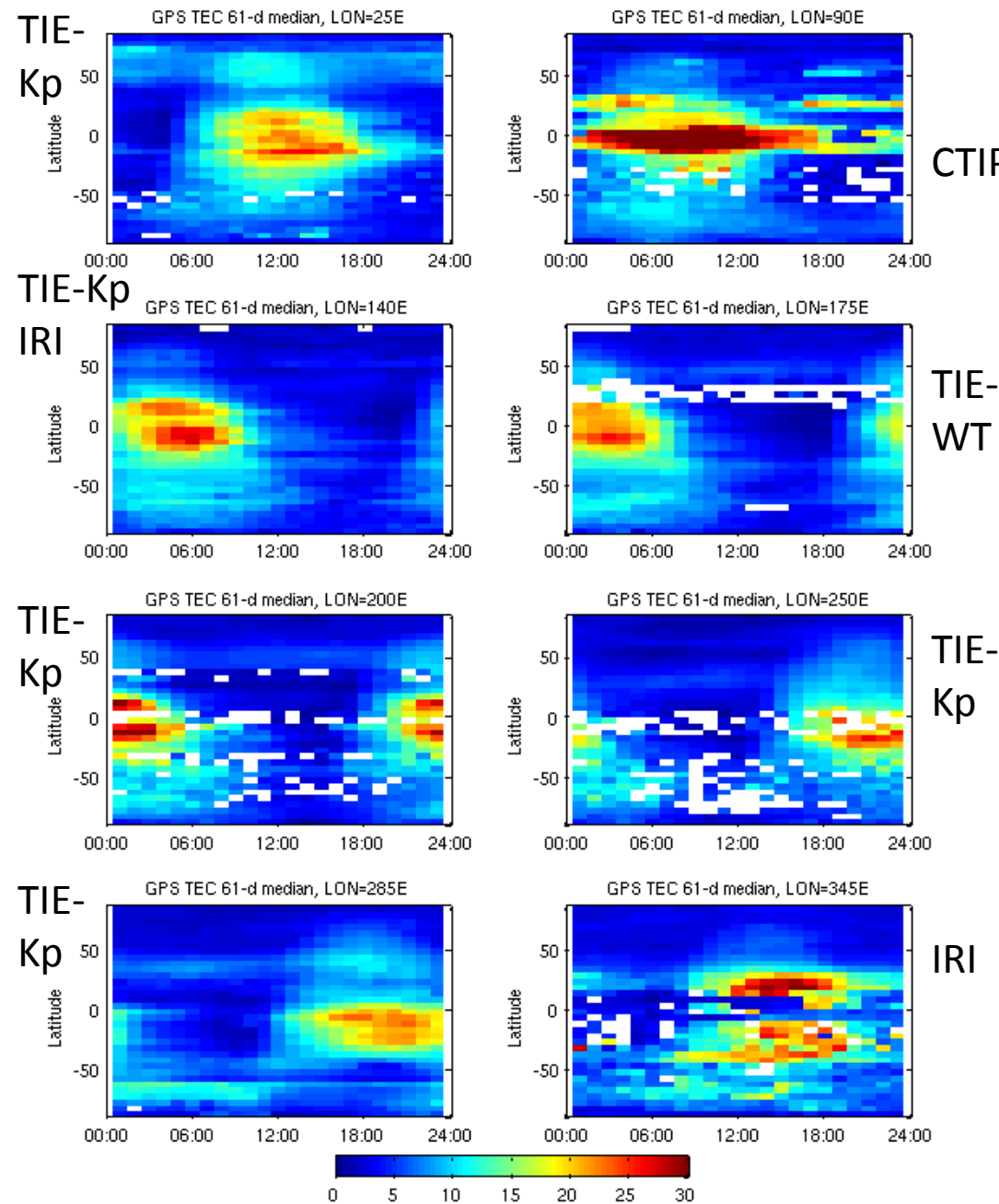
1) All models show different regions of overestimation and underestimation of the 'real' GPS TEC.

2) All models did best for at least 1 lon (IRI 1-2 lons, TIE-Kp 4-5 lons)

3) 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%

COSMIC NmF2 and HmF2
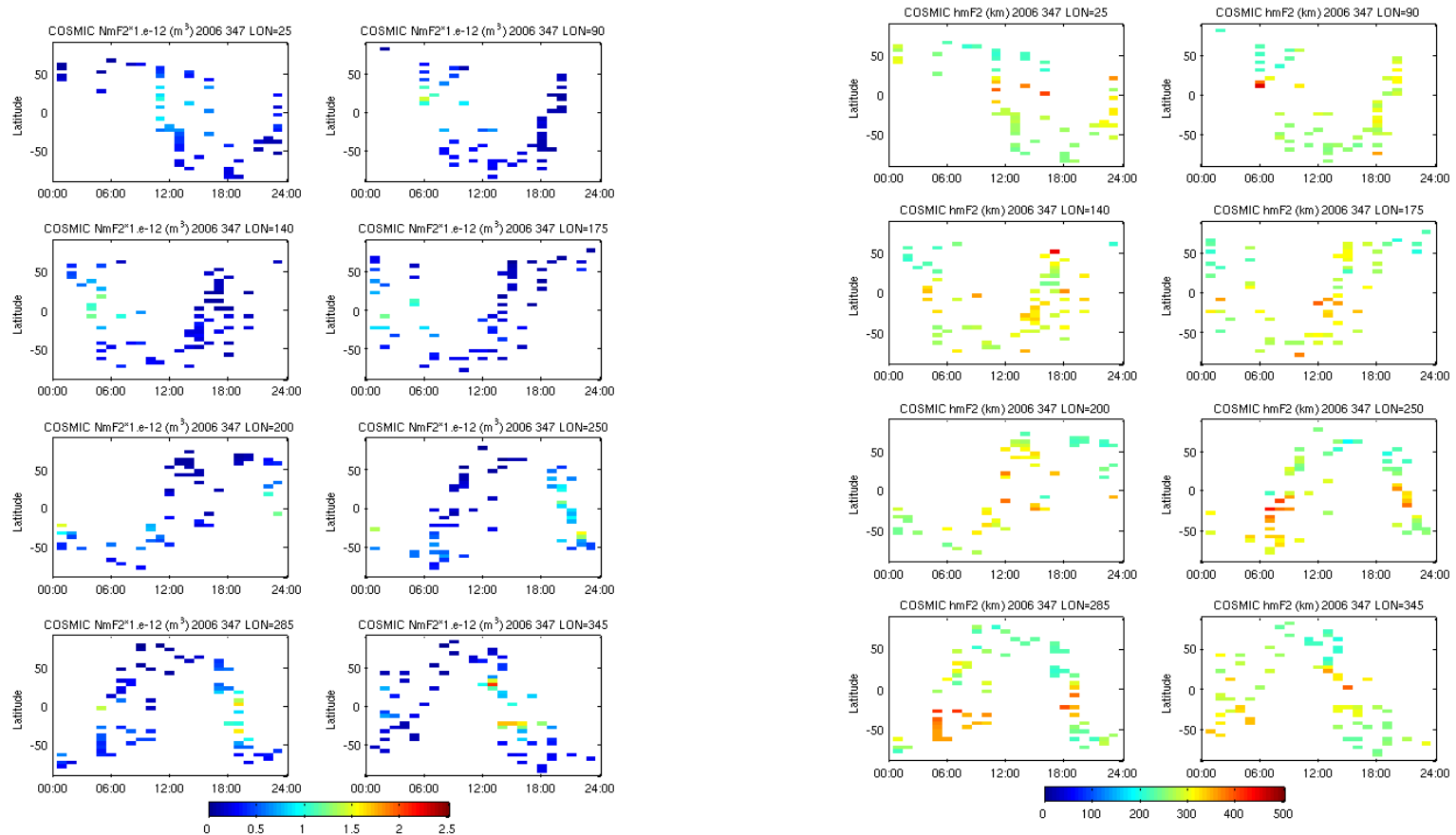
For 15 min averages of 5x5 glat/glon bins on Dec 13, 2006, a 24-h lon period has 96*36=3356 total bins. GPS TEC fills 34-79% of the bins, while COSMIC fills 1-2% (~60).

Summary of NmF2 Climatology

The regions of over- and under-estimates for NmF2 was sometimes the same as for TEC and often different.

1) IRI was the clear winner, with CTIPe doing next best.
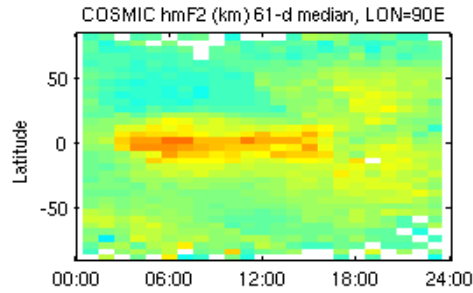2) Average absolute percent deviations (not area wtd): IRI 36%, CTIPE 61%, TIE-Kp 89%, TIE-WT 93%.
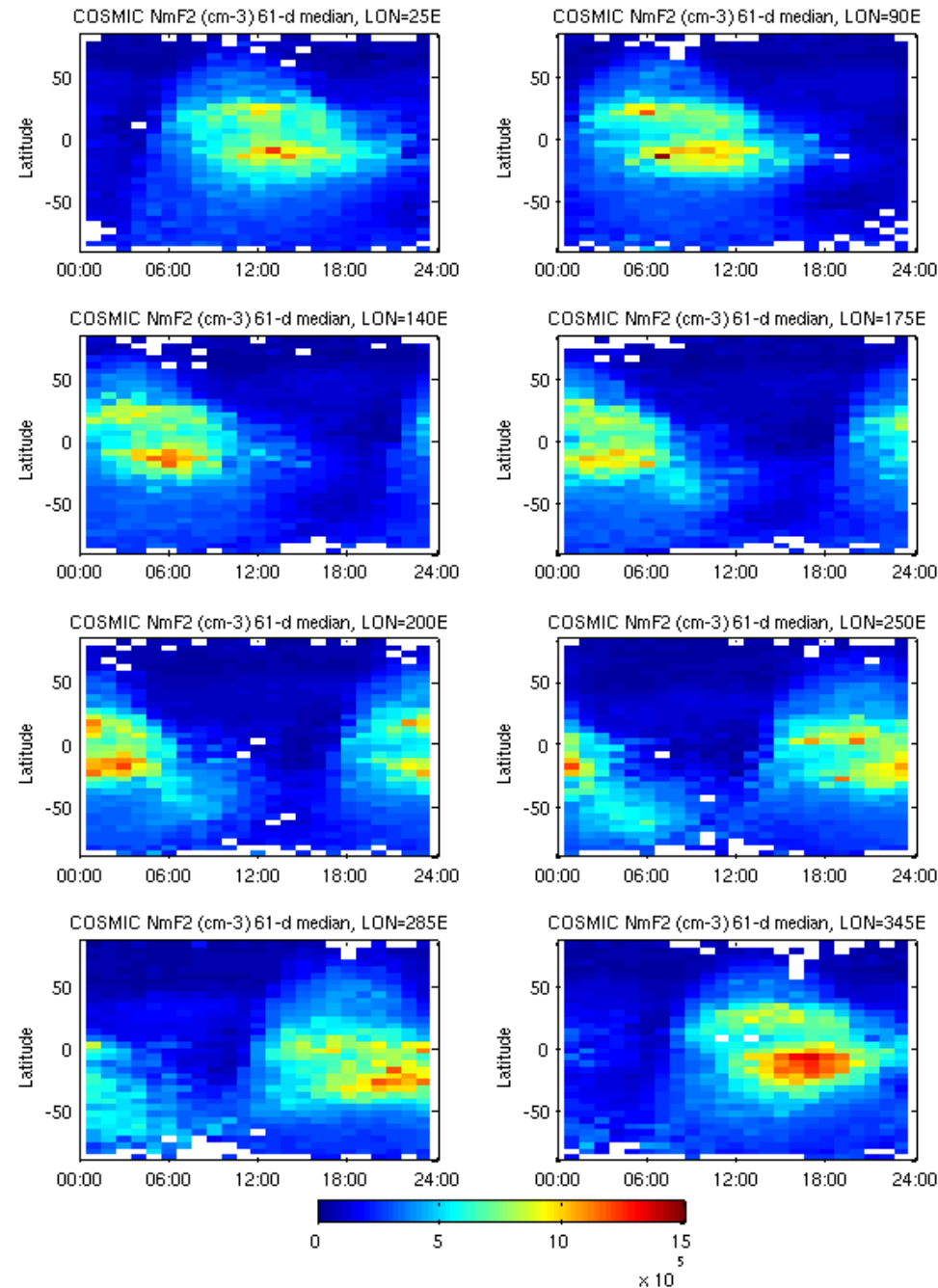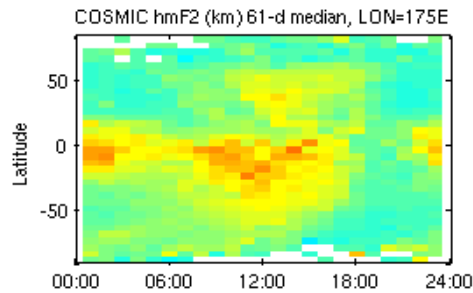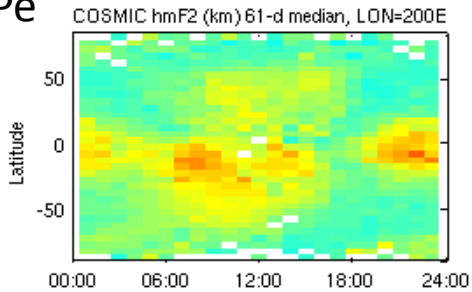
Summary of HmF2 Climatology
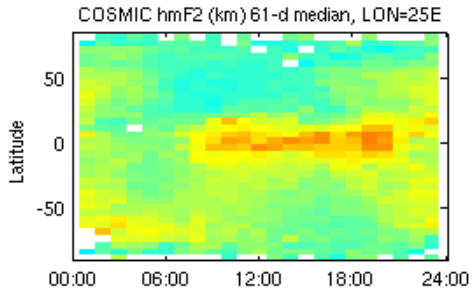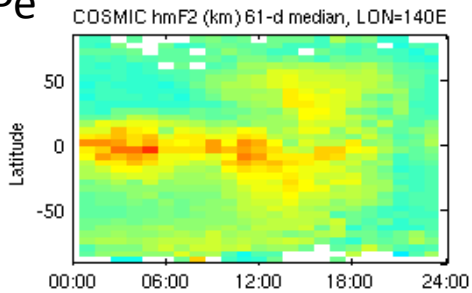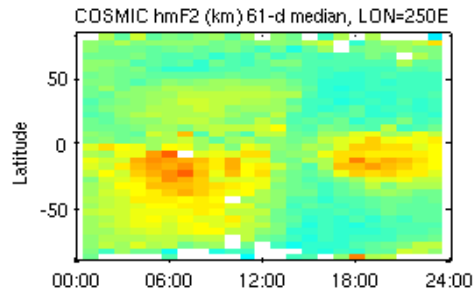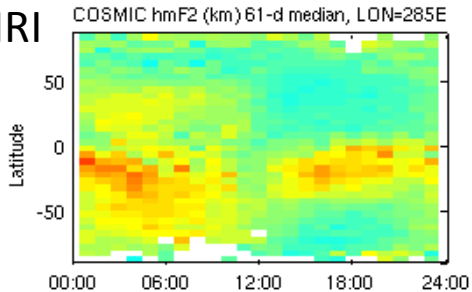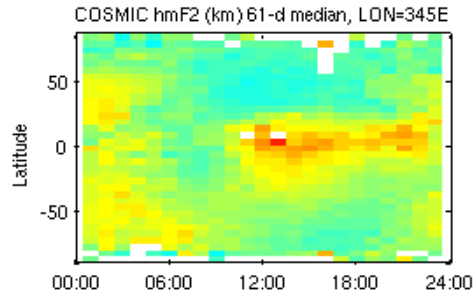

1) CTIPe and IRI were close, where CTIPe was best for 5 longitudes, while IRI was best for 3 longitudes

2) Average absolute model-data deviations in km were (not area wtd): IRI 25km, CTIPe 23km, TIE-Kp 35km, TIE-WT 38km

Summary

- We went from storms to climatology

- 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 make progress and add more models and parameters to compare against.

- Thank You to the CCMC from CEDAR!