CEDAR Electrodynamics Thermosphere Ionosphere (ETI) Challenge for Systematic Assessment of Ionospheric Model

Community Coordinated Modeling Center

http://ccmc.gsfc.nasa.gov

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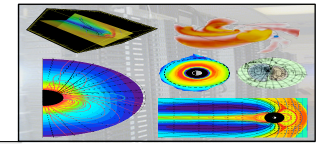


Abstract

The CEDAR Electrodynamics Thermosphere Ionosphere (ETI) Challenge was initiated at the CEDAR workshop in 2009 in order to help evaluate the current state of space physics modeling capability and to address differences between various modeling approaches. The CEDAR ETI challenge will track model improvements over time and facilitate interactions between research and operation communities. The Community Coordinated Modeling Center (CCMC) at the Goddard Space Flight Center is supporting the challenge using their experience with the GEM community and the metric tools available at CCMC. For the challenge, several geomagnetic storm events and the March 2007 to March 2008 timeframe, which is the first half of the International Polar Year (IPY) from March 2007 to March 2009, are selected to compare between model output and observations. Model output and observational data used for the challenge will be permanently posted as a resource for the space science communities to use. In this presentation, the preliminary results of the challenge will be discussed.

Model Performance Metric

Metrics based on RMS

- Model Skill Score : $\left(1 - \dfrac{\text{Model Score}}{\text{Reference Model Score}}\right)$

  Model Score against the observation : $\sqrt{\dfrac{\sum (x_{obs} - x_{mod})^2}{N}}$

  Reference Model : IRI-2007, NRLMSISe00

  1 : perfect model,
  > 0 : better than reference model,
  < 0 : worse than reference model

- Prediction efficiency : $1 - \dfrac{\langle (x_{obs} - x_{mod})^2 \rangle}{\sigma_{obs}^2}$

  1 : perfect model
  0 : model predicts the signal equally well to a model that uses the mean value of the signal as a predictor

Metrics based on Ratio

- Ratio of the difference between maximum and minimum values during an event:

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

- Ratio of the maximum values :

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

1 : perfect model
> 1 : over estimate,
< 1 : under estimate

* The closer the value is to 1 the better is the model.

Model Submission

- Vertical Drift : SAMI3, TIE-GCM, IRI
- Electron density : TIE-GCM, CTIPe, USU-GAIM, IFM, IRI
- Neutral density : TIE-GCM, CTIPe, NRLMSISe00, GITM, JB2008
- NmF2 and hmF2 : TIE-GCM, CTIPe, USU-GAIM, IFM, IRI, GITM

Model Setting ID	Model/Version	Resolution (lat x lon x alt)	Submitted by
1_SAMI3_HWM07	SAMI3 with the neutral wind model HWM07,	120 × 90 ×160 (90km < alt< 20,000 km)	J. Huba, NRL
1_SAMI3_HWM93	SAMI3 with the neutral wind model HWM93	120 × 90 ×160 (90km < alt< 20,000 km)	J. Huba, NRL
1_TIE-GCM	TIE-GCM1.92 driven by Heelis electric potential model	36× 72 ×29 (~ 90km < alt< 500 km)	CCMC
2_TIE-GCM	TIE-GCM1.93 driven by Weimer electric potential model with dynamic critical co-latitudes and constant eddy diffusion coefficient	36× 72 ×29 (~ 90km < alt< 500 km)	B. Emery, NCAR
3_TIE-GCM	TIE-GCM1.93 driven by Weimer electric potential model with dynamic critical co-latitude and seasonally variable eddy diffusion coefficient	36× 72 ×29 (~ 90km < alt< 500 km)	B. Emery, NCAR
4_TIE-GCM	TIE-GCM1.93 driven by Heelis electric potential model	36× 72 ×29 (~ 90km < alt< 500 km)	CCMC
1_CTIPE	CTIPe driven by Weimer electric potential model	91× 20 ×15 (~ 90km < alt< 500 km)	CCMC
1_USU-IFM	IFM driven by F10.7, Kp and empirical inputs for the thermosphere parameters	60× 49 ×73 (90km < alt< 1,600 km)	CCMC
1_USU-GAIM	USU-GAIM23 with GPS TEC observations from up to 400 ground stations	44× 24 ×83 (90km < alt< 1,400 km)	CCMC
1_IRI	IRI-2007, empirical model	(50km < alt< 2,000 km)	CCMC
1_GITM	GITM		A. Ridley, Univ. of Michigan
1_JB2008	JB2008 empirical model by Bruce Bowman, Kent Tobiska, et al.	(validated for 175 km < alt< 1,000 km)	D. Weimer, Virginia Tech
2_JB2008	JB2008 with temperature correction derived from W05 total Poynting fluxes	(validated for 175 km < alt< 1,000 km)	D. Weimer, Virginia Tech
1_MSIS	NRLMSISe0, empirical model		http://sisko.colorado.edu

Goals of the CETIC Challenge

- to help to evaluate the current state of the IT models,
- to track model improvements over time,
- to facilitate collaboration among modelers and data providers and research communities,
- to facilitate interaction between research and operation communities

Challenge Setup : Event

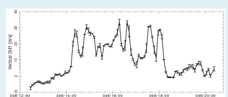
GEM events
E.2006.348: 2006/12/14(doy 348) 12:00 UT - 12/16 (doy 350) 00:00 UT
E.2001.243: 2001/08/31(doy 243) 00:00 UT - 09/01 (doy 244) 00:00 UT
E.2005.243: 2005/08/31 (doy 243) 10:00 UT - 09/01 (doy 244) 12:00 UT

Moderate storms (Kp_max = 5~6)
E.2007.091: 2007/04/01 (doy 091) 00:00 UT - 04/02 (doy 092) 12:00 UT
E.2007.142: 2007/05/22 (doy 142) 12:00 UT - 05/25 (doy 145) 00:00 UT
E.2008.059: 2008/02/28 (doy 059) 12:00 UT - 03/01 (doy 061) 12:00 UT

Quiet periods (Kp_max = 0~1)
E.2007.079: 2007/03/20 (doy 079) 00:00 UT - 03/22 (doy 081) 00:00 UT
E.2007.190: 2007/07/09 (doy 190) 00:00 UT - 07/10 (doy 191) 00:00 UT
E.2007.341: 2007/12/07 (doy 341) 00:00 UT - 12/09 (doy 343) 00:00 UT

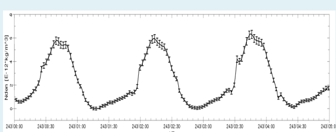
Physical Parameters & Measurements for Validation

- Vertical drifts at Jicamarca (VperpN):
  - Vertical Drifts obtained from Jicamarca-Piura dH Magnetometer measurements
  - Vertical drifts from the 150-km echoes measured by the 50 MHz JULIA radar



Vertical drift from JULIA with error bars (E.2006.348)

- Neutral density at CHAMP orbit (Nden)
  : Estimated values obtained using accelerometer measurements from the CHAMP (Univ. of Colorado, http://sisko.colorado.edu/sutton/index.html)

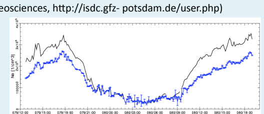


Neutral density from the CHAMP with error bars (E.2001.243)

- Electron density at CHAMP orbit (Eden)
  : PLP (Planar Langmuir Probe Data) measurements from CHAMP (GFZ German Research Centre for Geosciences, http://isdc.gfz- potsdam.de/user.php)

- NmF2 and HmF2 from ISRs

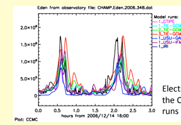
  Millstone Hill (42.62 N, 288.51 E)
  EISCAT Svalbard (78.09 N, 16.02 E)
  Poker Flat (65.13 N, 212.53 E)
  Sondrestrom (66.99 N, 309.05 E)



Electron density at 300 km height with error bars (blue) and NmF2 (black) from the Sondrestrom ISR (E.2007.079)

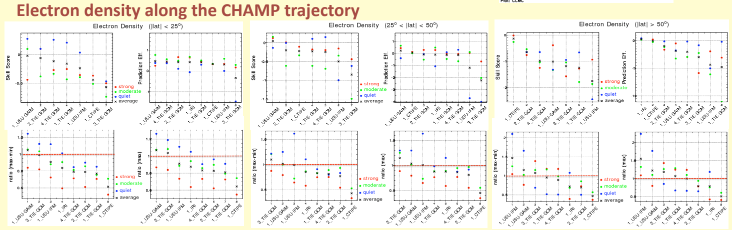
Results :

- model ranking is arranged by the average score over the all events (denoted by black cross).
- red circle : average value for strong storm events (E.2005.243 and E.2006.348)
- green circle : average value for moderate storm events (including E.2001.243 event)
- blue circle : average value for geomagnetically quiet periods
- the best performing model is located in the extreme left in the plot of the skill score and prediction efficiency.
- the closer to the red line, the better the model is in the plot of the ratio.
  - * Note that not all models have data for all event

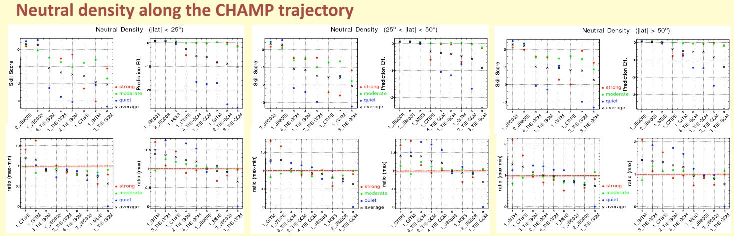


Electron density from the CHAMP and model runs (E.2006.348)

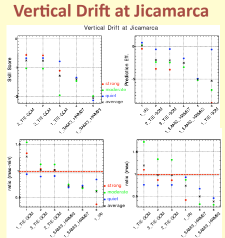
Electron density along the CHAMP trajectory

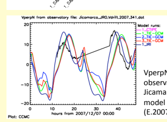


Neutral density along the CHAMP trajectory



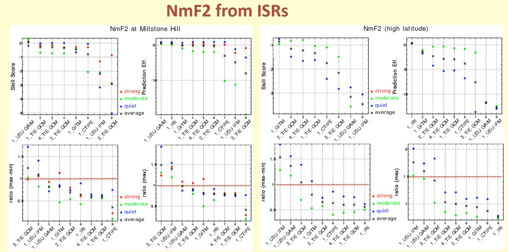
Vertical Drift at Jicamarca





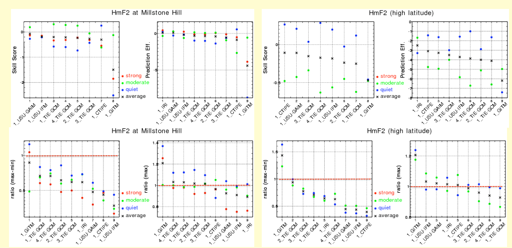
VperpN from observatory Jicamarca and model runs (E.2007.341)

NmF2 from ISRs



- in most cases, physics based models have negative skill score especially in the high latitudes for storm events.
- empirical models show better performance in terms of the prediction efficiency.
- physics based models tend to underestimate (overestimate) the maximum values or difference between maximum and minimum values during the storm event (quiet period).
- empirical models tend to underestimate the maximum values or difference between maximum and minimum values.

hmF2 from ISRs



- in the plot of NmF2 and hmF for high latitude, the raking is based on the averages taken over three high latitude ISR stations (EISCAT Svalbard, Poker Flat, and Sondrestrom).
- none of the models is the best for all used metrics.
- none of the models is the best for all latitude regions.

Conclusions and Future Plans

- **Model performance**
  - varies significantly with geomagnetic activity,
  - differs in different latitudes,
  - strongly depends on the type of metric used to evaluate the model performance.

  Therefore,
  - it should be careful to choose appropriate metric for model validation and verification.
  - modeled signal characteristics of interest should be clearly defined first and the suitable metric should be selected accordingly.

- The CEDAR Challenge will be expanded to include
  - TEC
  - Joule heat
  - a yearlong climatological study:
    Year of incoherent scatter radar (ISR) observations from 2007/03/01– 2008/03/31

CCMC will continue to

- expand V&V activity :
  - repeatable comparison between model output and measurements
  - determine suitable metrics
- support GEM & CEDAR modeling challenges and facilitate joint GEM-CEDAR model validation project.

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