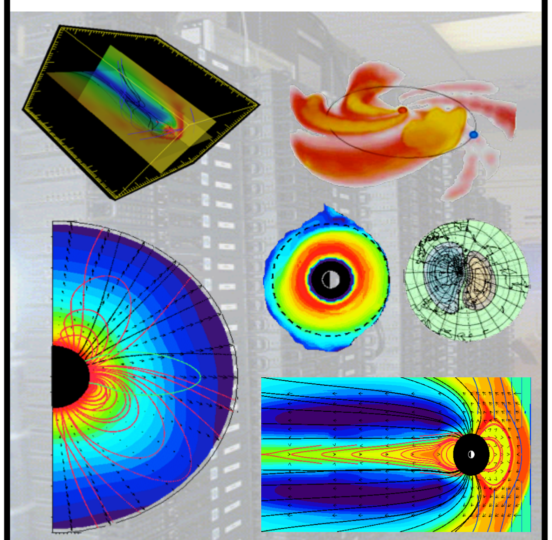
Community Coordinated Modeling Center



CCMC ITM Models & Validation Study

CCMC:
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Modelers & Data providers

http://ccmc.gsfc.nasa.gov

NASA Goddard Space Flight Center

Outline

- CCMC capability of ITM modeling

- Validation study of neutral density
    - Point by point
    - Orbit averaged

- Neutral density at high altitude

- Conclusion

ITM Global Models at CCMC

	Model	ionosphere	thermosphere	service
Empirical	IRI	✓		Instant Run
	NRLMSISE-00		✓	Instant Run
	JB2008		✓	to be IR/RoR
Physics-based	SAMI3	✓		RoR
	CTIPe	✓	✓	RoR, RT
	TIE-GCM	✓	✓	RoR
	GITM	✓	✓	RoR
Physics-based data assimilation	USU-GAIM	✓		RoR
	TRIPL-DA	✓		Test mode
	IDA-4D	✓		to be RoR
	DAS/MEPS	✓	✓	to be RoR

Point by Point Comparison

Physical Parameters

- Vertical drifts at Jicamarca
- **Neutral density at CHAMP orbit (Nden)**
- Electron density at CHAMP orbit (Eden)
- NmF2 from LEO satellites (CHAMP and COSMIC) and ISRs
- HmF2 from LEO satellites (CHAMP and COSMIC) and 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)

* http://ccmc.gsfc.nasa.gov/support/CETI2010/

Setup : Events

GEM events > Strong storms (Kp_max ≥ 7)

E.2006.348: 2006/12/14 12:00 UT - 12/16 00:00 UT (Kp_max = 8)
E.2005.243: 2005/08/31 10:00 UT - 09/01 12:00 UT (Kp_max = 7)

Moderate storms (4 ≤ Kp_max < 7)

E.2007.091: 2007/04/01 00:00 UT - 04/02 12:00 UT (Kp_max = 5)
E.2007.142: 2007/05/22 12:00 UT - 05/25 00:00 UT (Kp_max = 5.7)
E.2008.059: 2008/02/28 12:00 UT - 03/01 12:00 UT (Kp_max = 5.3)
E.2001.243: 2001/08/31 00:00 UT - 09/01 00:00 UT(Kp_max = 4)

Quiet periods (Kp_max < 4)

E.2007.079: 2007/03/20 00:00 UT - 03/22 00:00 UT (Kp_max = 0.7)
E.2007.190: 2007/07/09 00:00 UT - 07/10 00:00 UT (Kp_max = 0.3)
E.2007.341: 2007/12/07 00:00 UT - 12/09 00:00 UT (Kp_max = 1.0)

Metrics

- RMS error : $\sqrt{\dfrac{\sum(x_{obs}-x_{mod})^2}{N}}$

- Prediction efficiency against the mean of observations:

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

- Ratio of maximum change : $\dfrac{\left(x_{mod}\right)_{\max}-\left(x_{mod}\right)_{\min}}{\left(x_{obs}\right)_{\max}-\left(x_{obs}\right)_{\min}}$

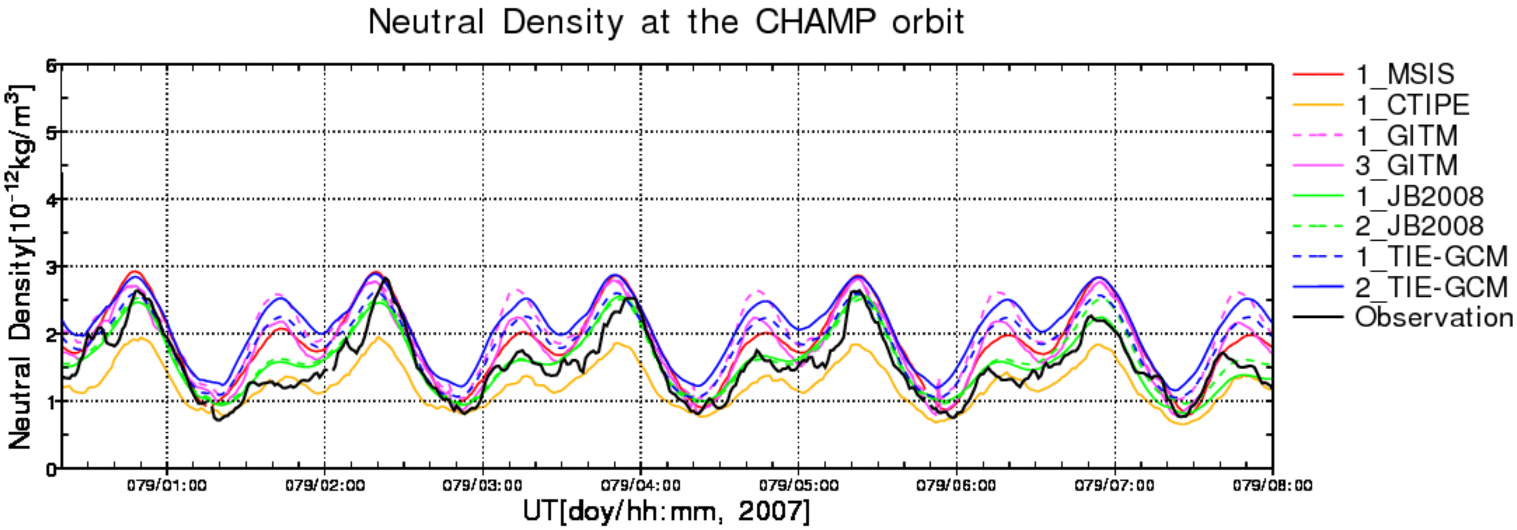
- Ratio of maximum : $\dfrac{\left(x_{mod}\right)_{\max}}{\left(x_{obs}\right)_{\max}}$

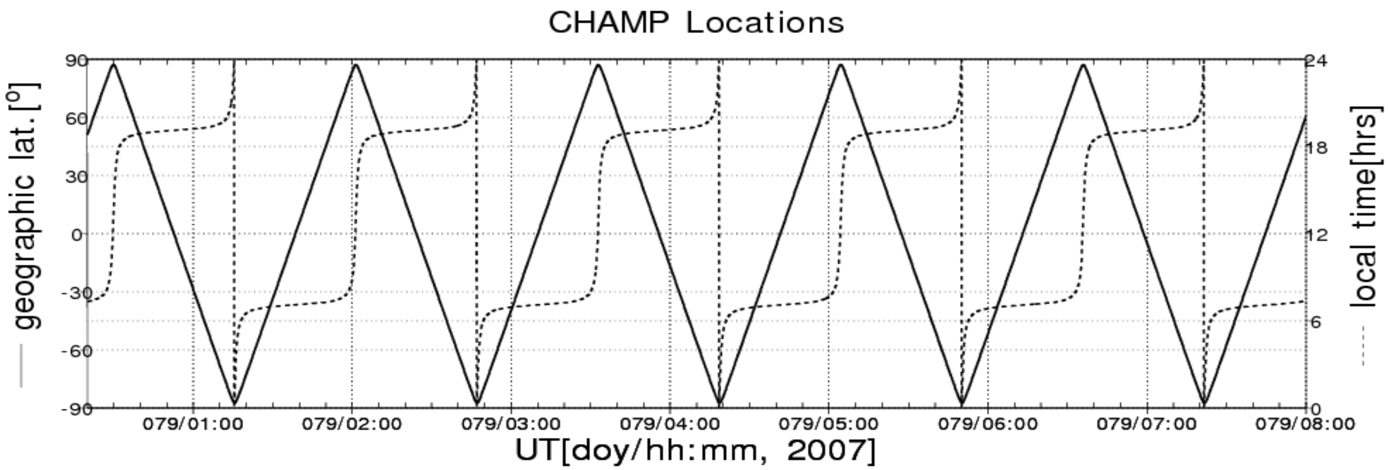
Model Settings

	Model Setting ID	
1	1_MSIS	NRLMSISe00, empirical model : http://sisko.colorado.edu
2	1_JB2008	JB2008 empirical thermospheric density model
3	2_JB2008	JB2008 with temperature correction derived from W05 total Poynting fluxes
4	1_CTIPE*	CTIPe driven by Weimer electric potential model, 2°×18°, 15 levels in logarithm of pressure
5	1_GITM	GITM, 25x50x13
6	3_GITM	GITM, 25x50x13, with the equatorial electrojet
7	1_TIE-GCM*	TIE-GCM1.93 driven by Heelis electric potential model
8	2_TIE-GCM	TIE-GCM1.94 driven by Weimer electric potential model with dynamic critical co-latitudes

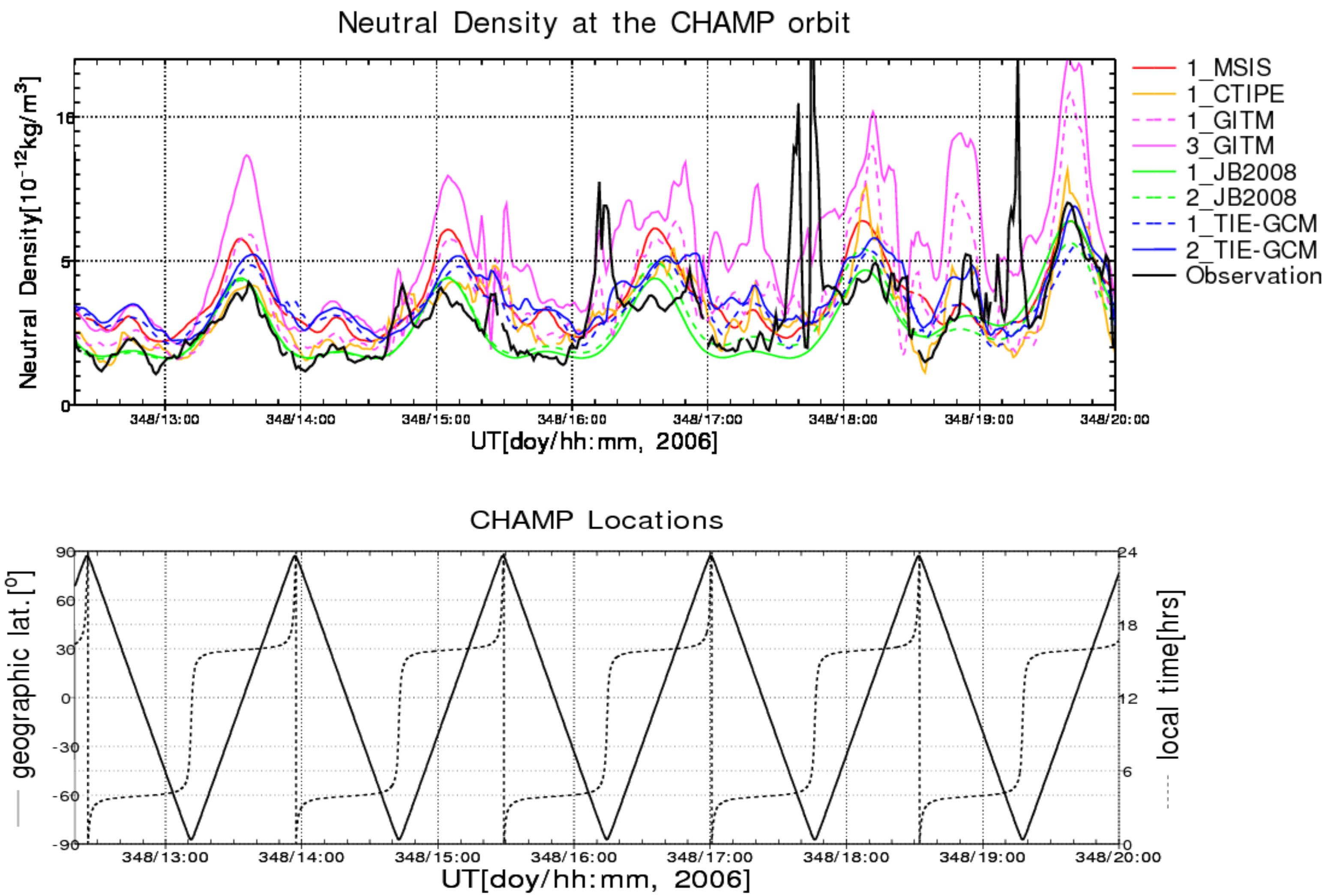
* Runs performed at the CCMC

Quiet Period: E.2007.079





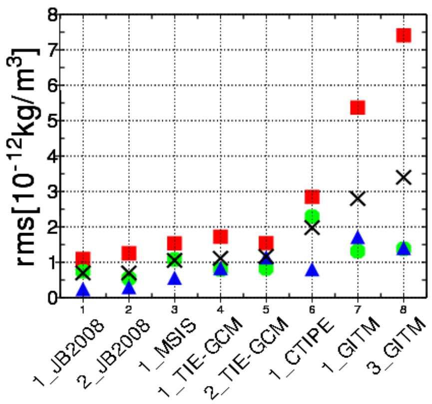
Strong Storm Event: E.2006.348



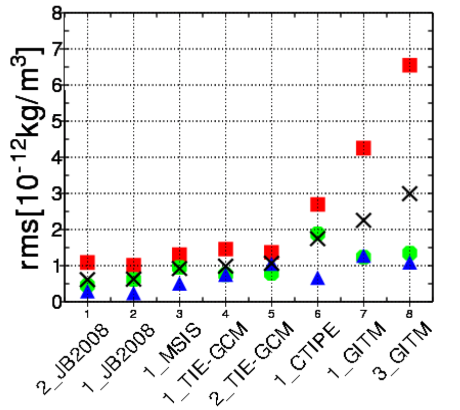
RMS & Ratio

RMS

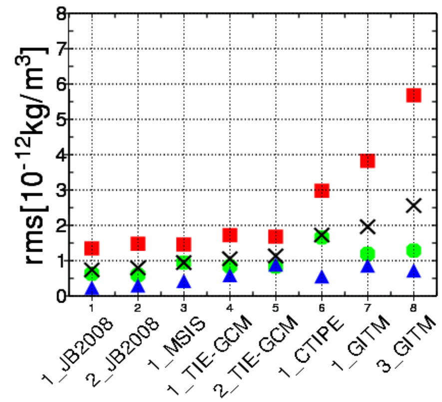
low (|lat| < 25°)



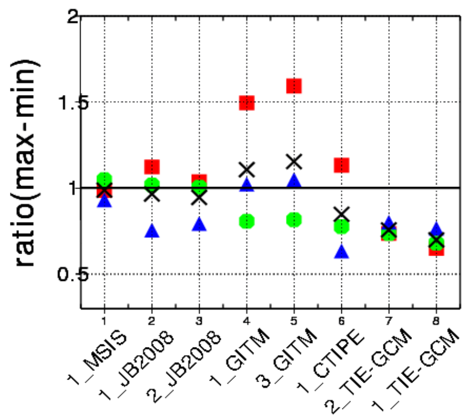
middle (25° < |lat| < 50°)

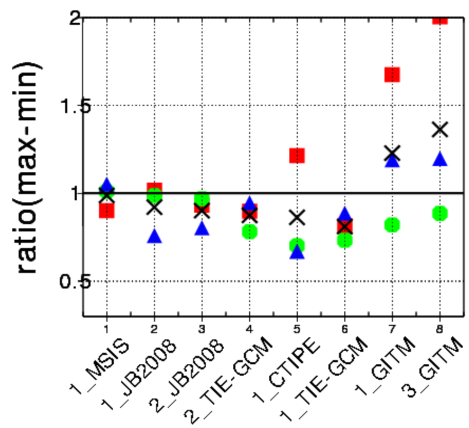


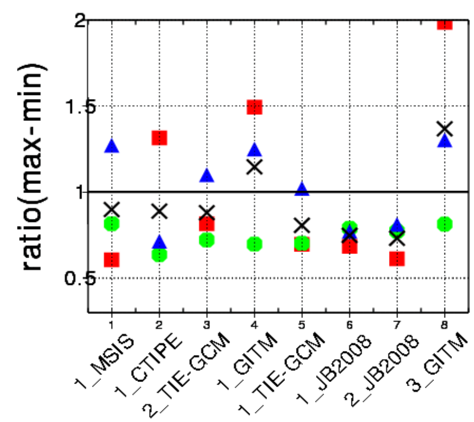
high (|lat| > 50°)



Ratio of maximum change







■ strong ● moderate ▲ quiet × average

Summary of CETIC

- Model performance depends on
  - geomagnetic activity
  - latitude
  - metrics selection
- Model performance varies from event to event.
- None of models ranks at the top for all used metrics.
  - empirical models : ranked high on the average or during the quiet time
  - physics based models : better represent dynamics in high latitude
- First step to establish a baseline for future versions and models

Shim, J. S., et al. (2011), CEDAR Electrodynamics Thermosphere Ionosphere (ETI) Challenge for systematic assessment of ionosphere/thermosphere models: NmF2, hmF2, and vertical drift using ground-based observations, Space Weather, 9, S12003, doi:10.1029/2011SW000727.

Shim, J. S., et al. (2012), CEDAR Electrodynamics Thermosphere Ionosphere (ETI) Challenge for systematic assessment of ionosphere/thermosphere models: Electron density, neutral density, NmF2, and hmF2 using space based observations, Space Weather, 10, S10004, doi:10.1029/2012SW000851.

Quantitative Assessment of the Storm Time Performances of IT Models for the Orbit Averaged Neutral Densities on CHAMP orbit

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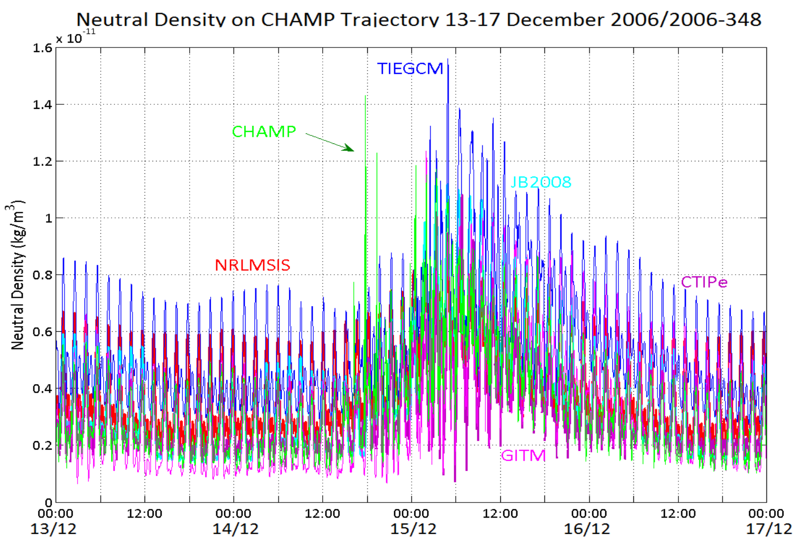
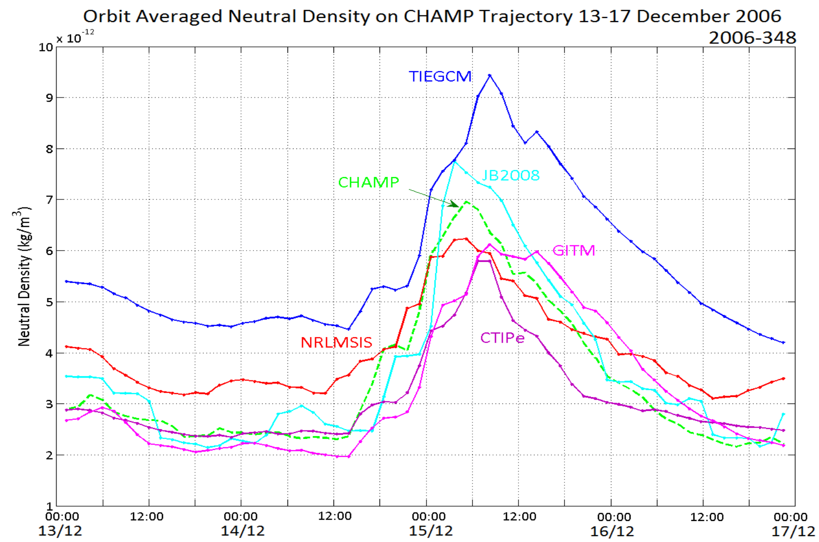
Orbit Averaging Tool (OAT)

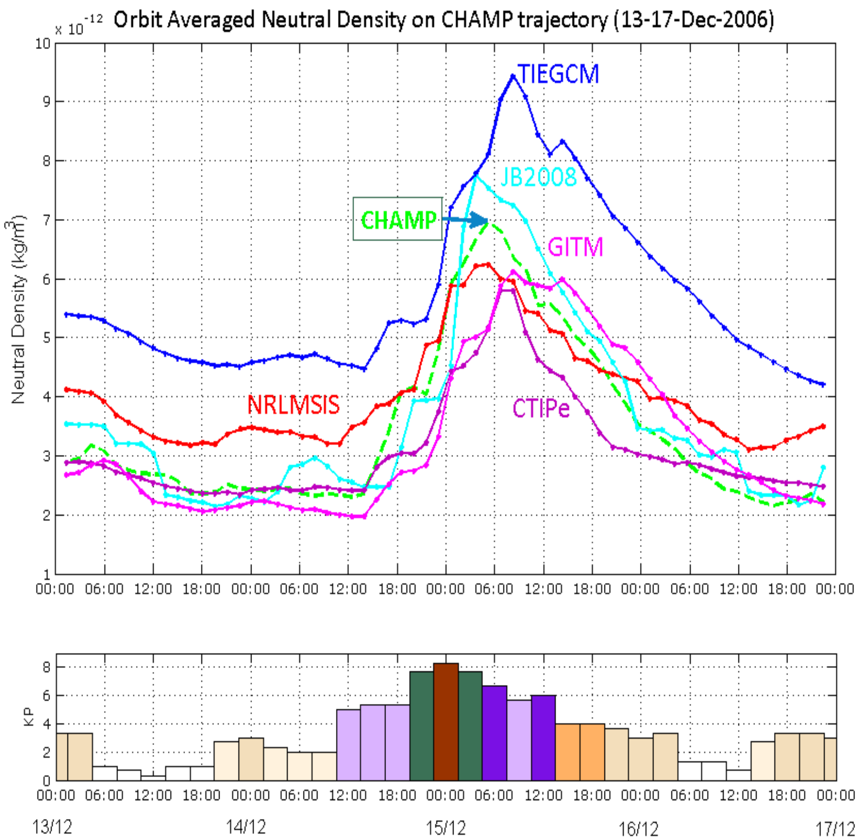




- Determining the global response of the ionosphere-thermosphere system to a geomagnetic storm more easily

- Cross examining and validating ionosphere-thermosphere model results with the measurements of the thermosphere from LEO satellites (e.g., CHAMP, GRACE)

Data and Methodology



Event:

- 2006 Dec. geomagnetic storm, Kp_{max}>8
- Latest version of models at the CCMC : driven by Weimer 2005 potential

Problem: How to assess the storm time performances of the models?

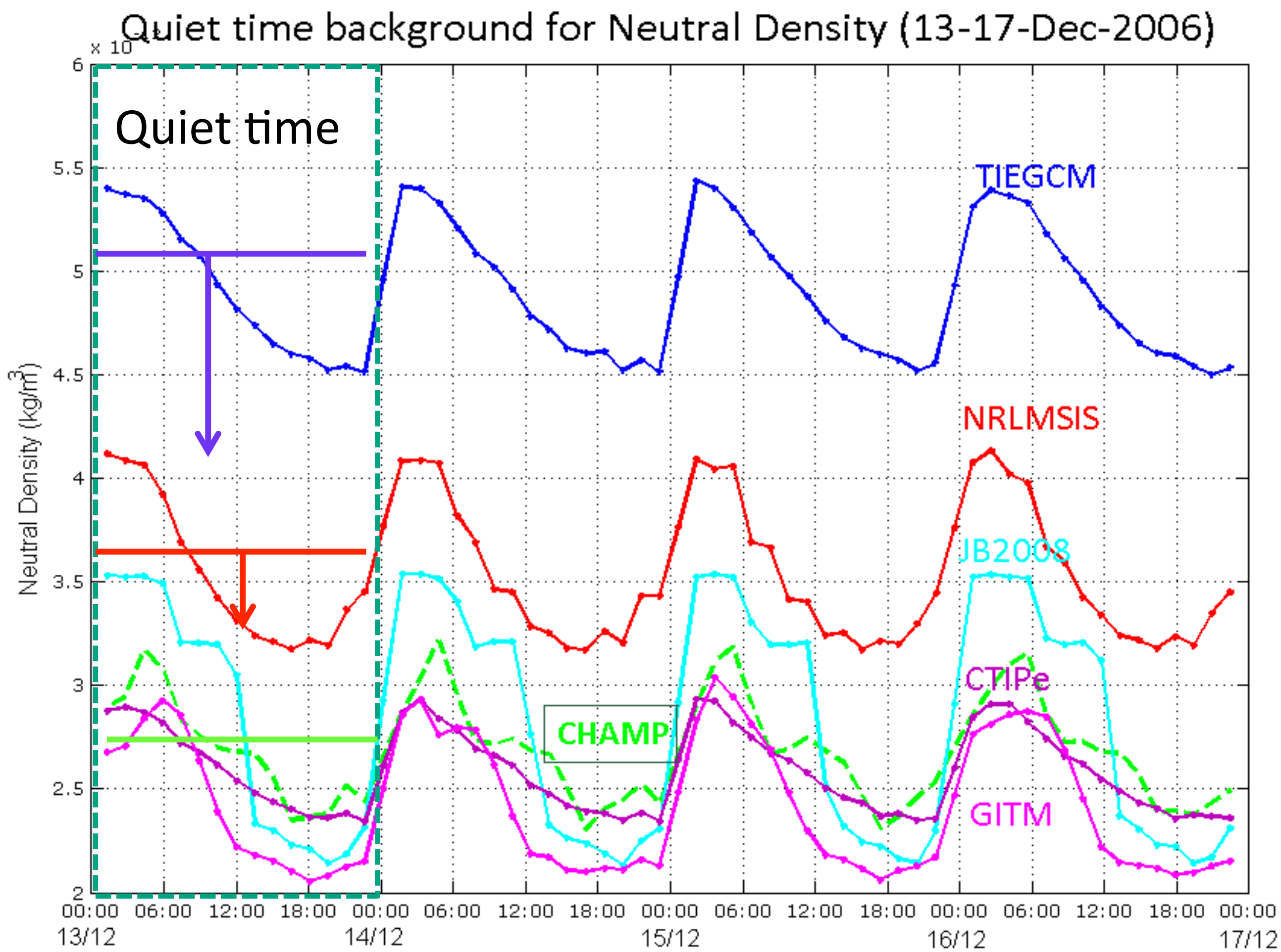
Suggestion: Removing the background climatology

How?

Using

1. quiet time mean
2. background run

Shifting Methods

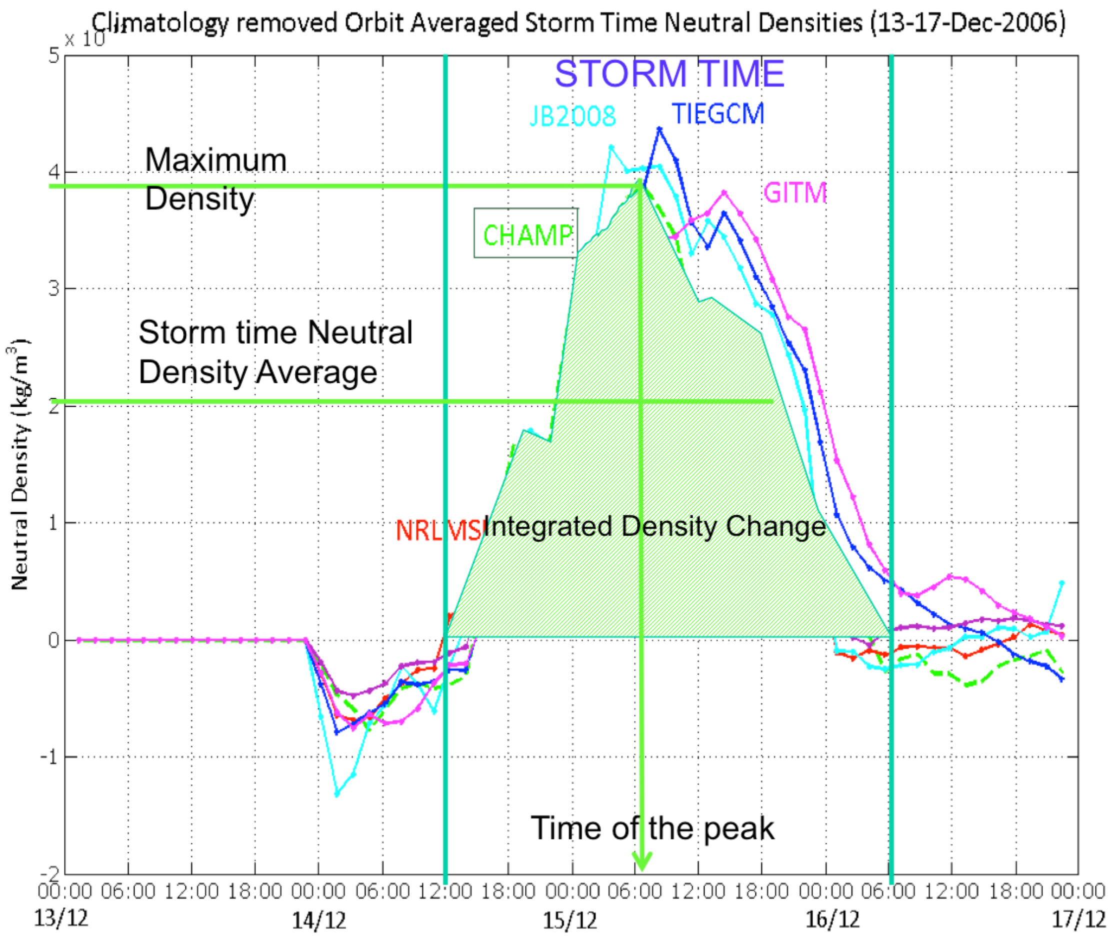


How?

1. using the mean
   a) Shift to CHAMP levels
   b) Shift to zero
2. doing point to point subtraction
   a) Shift to CHAMP
   b) Shift to zero

Assumption: The following day neutral density variations would have been the same with the quite day neutral density variations if there weren't any geomagnetic storms.

Assessment of Model Performances



All calculations are done for the storm time interval.

Selected Metrics:

•RMSE: Root mean square error

•Average density

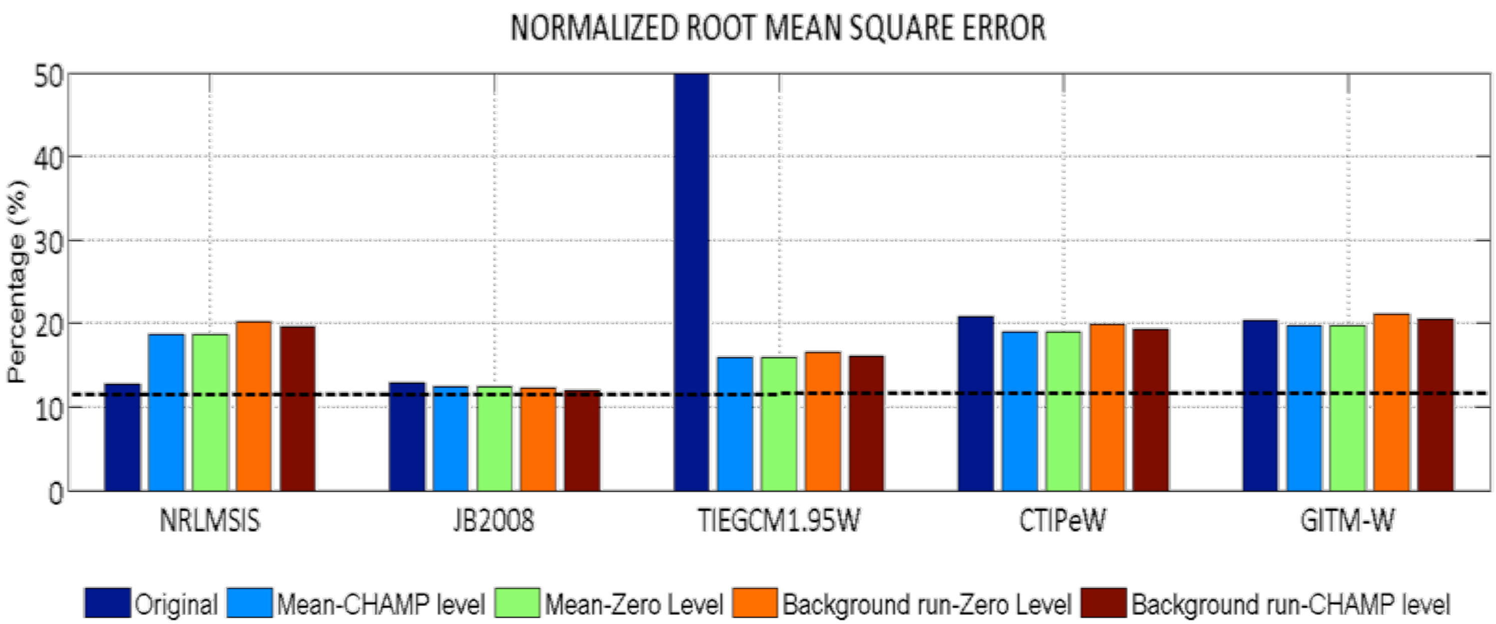
•Maximum density

•Time of the maximum

•Integrated density change

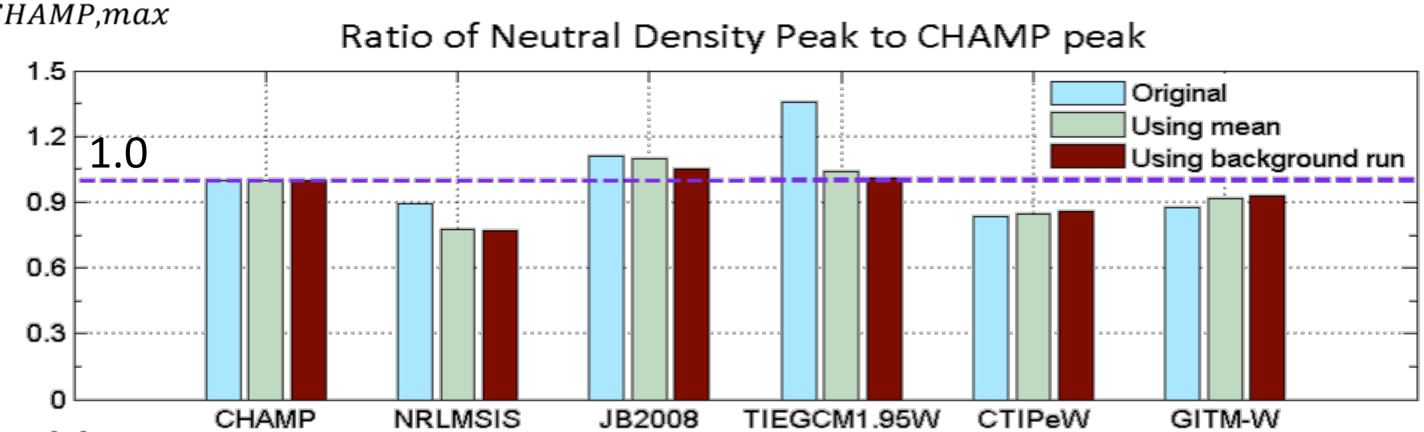
RMSE

$$NRMSE = \frac{RMSE}{(n_{CHAMP,max} - n_{CHAMP,min})} \times 100$$

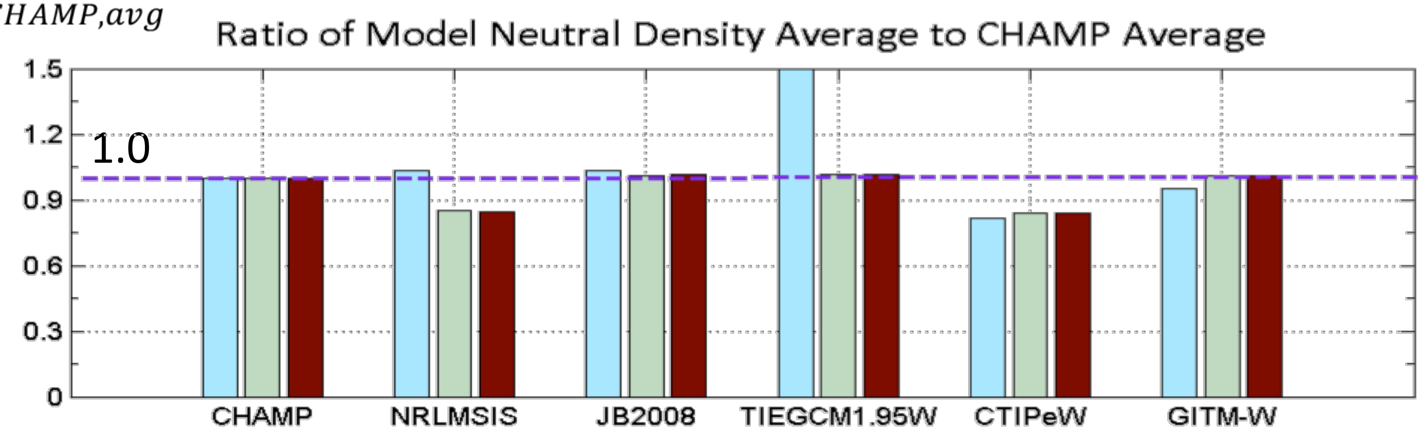


Ratios

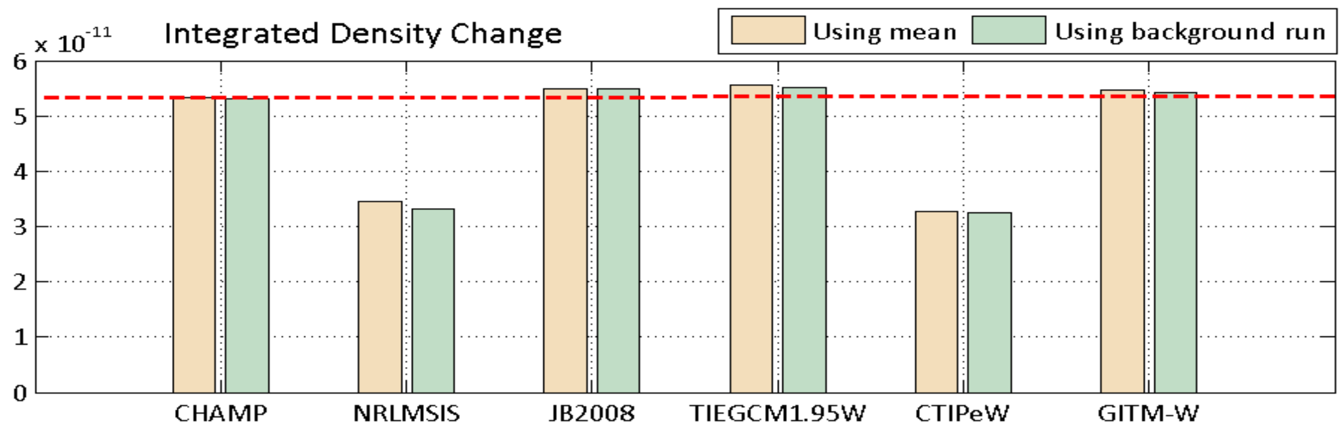
$$Ratio_{max} = \frac{n_{model,max}}{n_{CHAMP,max}}$$



$$Ratio_{avg} = \frac{n_{model,avg}}{n_{CHAMP,avg}}$$

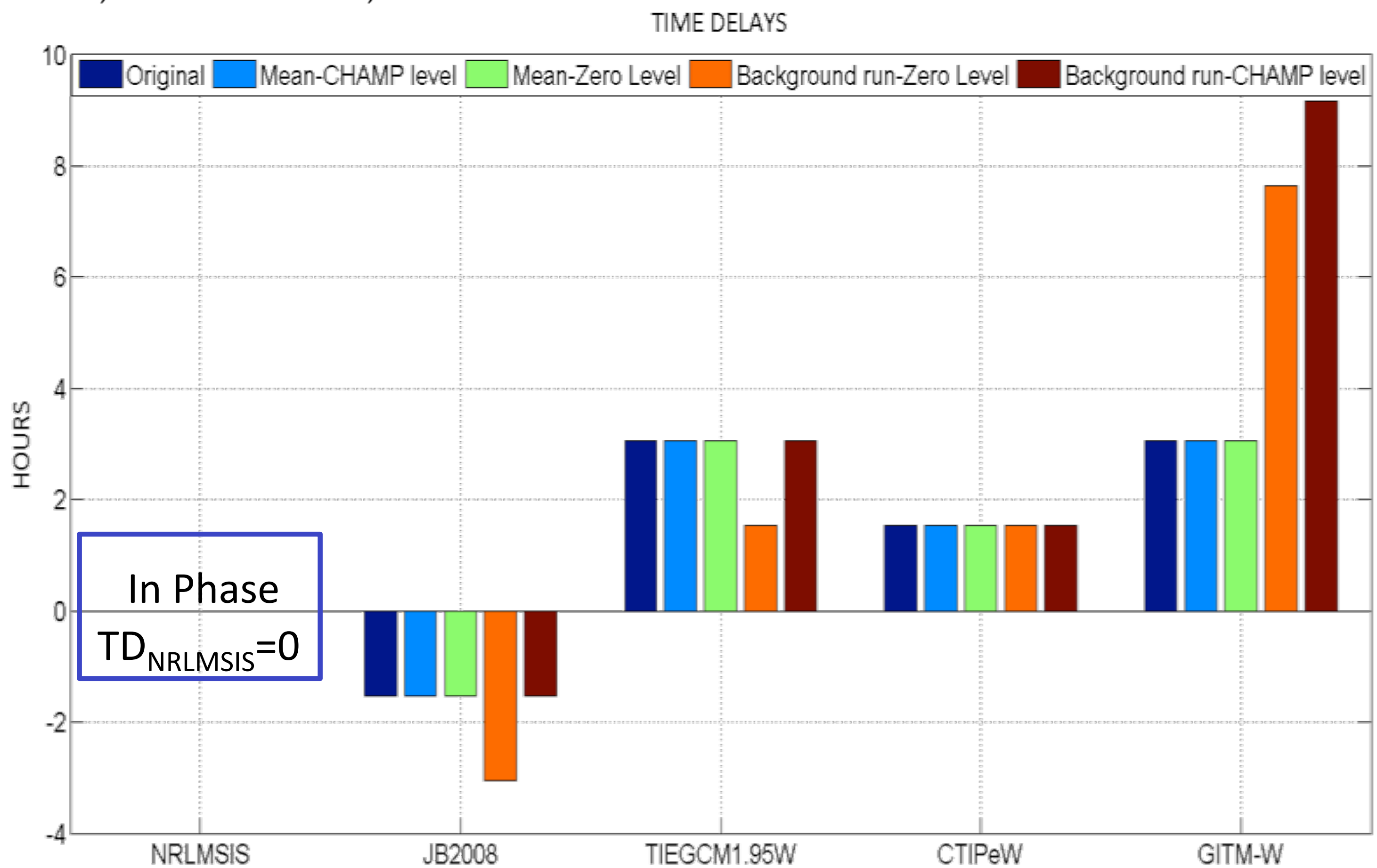


Integrated Density Change



Time Delays

$$TD = t_{MODEL,max} - t_{CHAMP,max}$$



Summary of IT model performance

for storm time orbit averged neutral density prediction

- Orbit averaging is proven to be useful in determining the global response of the thermosphere to the ongoing storm.

- Background climatology removal is essential in assessing the storm time performances of the models correctly.

- Physics based and empirical models' storm time performances are comparable.

- Time delay is an effective error source for the models even when model neutral density average and peak values are similar to CHAMP observations.

Kalafatoglu E. C., J. S. Shim, M. M. Kuznetsova, B. R. Bowman, M. Codrescu, B. Emery, B. Foster, T. Fuller-Rowell, A. Ridley, Quantifying the storm-time thermospheric neutral density variations using model and observations, to be submitted to JGR, 2014.

Addressing high altitude (> 600 km)

- Limited altitude range of physics based models
- Working with model developers:

  e.g., at a given height h above the height of the top pressure level ht(15) (~ 10^{-7} Pa)

  $n(O,h) = n(O,15) * \exp((ht(15)-h) / H(O))$ m^{-3}

  H(O) : scale height of the species $R*T(15)/M_O g$.

  R = 8.3141e+03,

  M_O = 16 amu,

  $g=g_0(r_e/(r_e+h))^2$.

  The mass density at any height = (n(O) * 16. + n(O2) * 32. +n(N2) * 28.) * amu kg/m3

- Data needed for validation

Conclusion

•Model performance highly depends on physical parameters and metrics.

Therefore,

•it is critical to select appropriate metrics for specific applications.

•assessment of model predictive capabilities requires users' participation in defining appropriate metrics for specific applications.