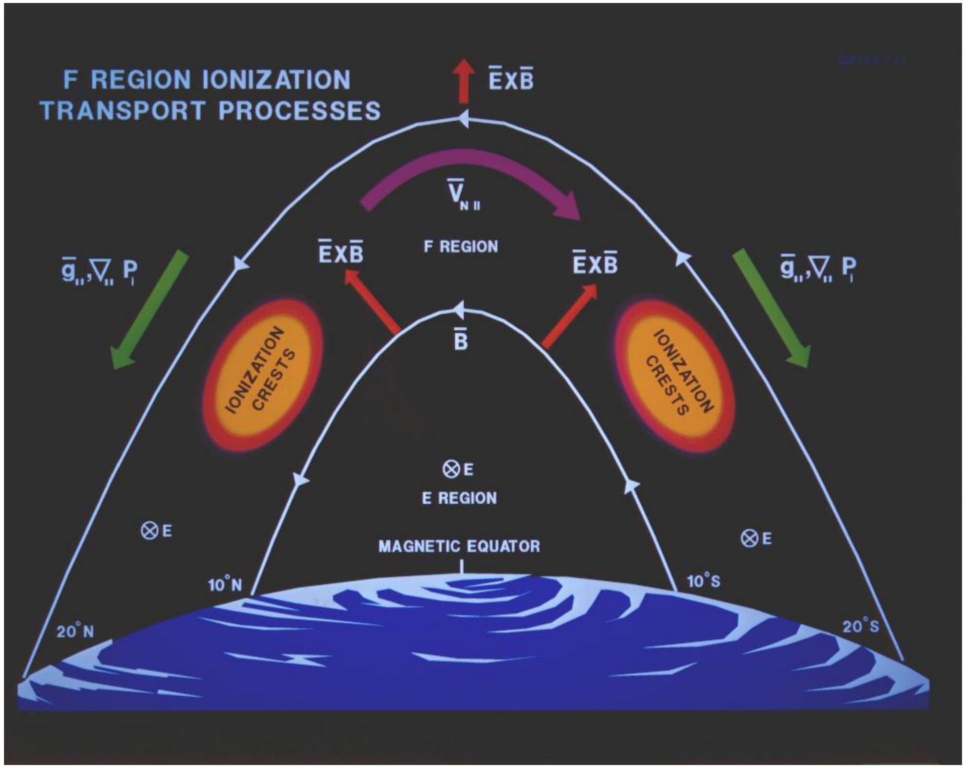
Agenda of Equatorial-PRIMO

(Problems Related to Ionospheric Models and Observations)

First Hour:	**Problems Related to the Models**
10:00 – 10:15	**Current Progress of the Equatorial-PRIMO**
10:15 – 10:35	**Model Development and Updates**
10:35 – 11:00	**Open Discussion**
Second Hour:	**Models and Observations**
11:00 – 11:15	**Cesar Valladares (BC)** **"Introduction of LISN"**
11:15 – 11:30	**Jeff Klenzing (NASA/GSFC)** **"Performance of the IRI-2007 and SAMI2 Models during Extreme Solar Minimum"**
11:30 – 12:00	**Open Discussion**

Motivation: We do not fully understand all the relevant physics of the equatorial ionosphere, so that current models do not completely agree with each other and are not able to accurately reproduce observations.

Objective: To understand the strengths and the limitations of theoretical, time-dependent, low-latitude ionospheric models in representing observed ionospheric structure and variability under low to moderate solar activity and geomagnetic quiet conditions, in order to better understand the underlying ionospheric physics and improve models.



Transport Processes in the Equatorial Ionosphere

Comparative Studies of Theoretical Models in the Equatorial Ionosphere

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Icarus Research, Inc.

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NCAR/HAO

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ASTRA

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Submitted to the AGU Monograph on Modeling the IT System

Participating Models

- A set of theoretical ionospheric models require neutral atmospheric densities and temperatures, neutral winds, E×B drift velocities as inputs and calculate and Ion and electron densities as a function of altitude, latitude and local time. Their calculations are not self-consistently.
  - The Utah State University (USU) "Ionosphere-Plasmasphere Model (IPM)"
  - The Space Environment Corporation (SEC) "Ionospheric Forecast Model (IFM)"
  - The Space Environment Corporation (SEC) "Low Latitude IONosphere Sector model (LLIONS)"
  - The AFRL "Physics Based MODel (PBMOD)"
  - The "Global Ionosphere and Plasmasphere model (GIP)"
  - The NRL "Sami2 is Another Model of the Ionosphere (SAMI2)"
- The other set of ionosphere-thermosphere models are time dependent, three dimensional, non-linear models which solve the fully coupled, thermodynamic, and continuity equations of the neutral gas self-consistently with the ion energy, ion momentum, and ion continuity equations.
  - The NRL "Sami3 is Also a Model of the Ionosphere (SAMI3)"
  - The Coupled Thermosphere Ionosphere Plasmasphere Electrodynamics (CTIPe) model
  - The NCAR "Thermosphere-Ionosphere-Electrodynamics general circulation model (TIE-GCM)"
  - "Thermosphere-Ionosphere-Mesosphere-Electrodynamics general circulation model (TIME-GCM)" run by ASTRA
  - University of Michigan "Global Ionosphere-Thermosphere Model (GITM)"
  - Integrated Dynamics through Earth's Atmosphere (IDEA)

TASK I (All participated models):

Simulating Conditions

- To carry out very preliminary comparisons, these two sets of models theoretically calculated ionospheric parameters at the Peruvian longitude (~ 284°E) in March equinox for an F10.7 cm flux value of 120 and geomagnetic quiet (e.g. Ap<5). The Burnside factor is set to 1.

  Non-self consistent models: Scherliess-Fejer E×B drift model, NRLMSISE-00, and HWM93 are used as drivers.

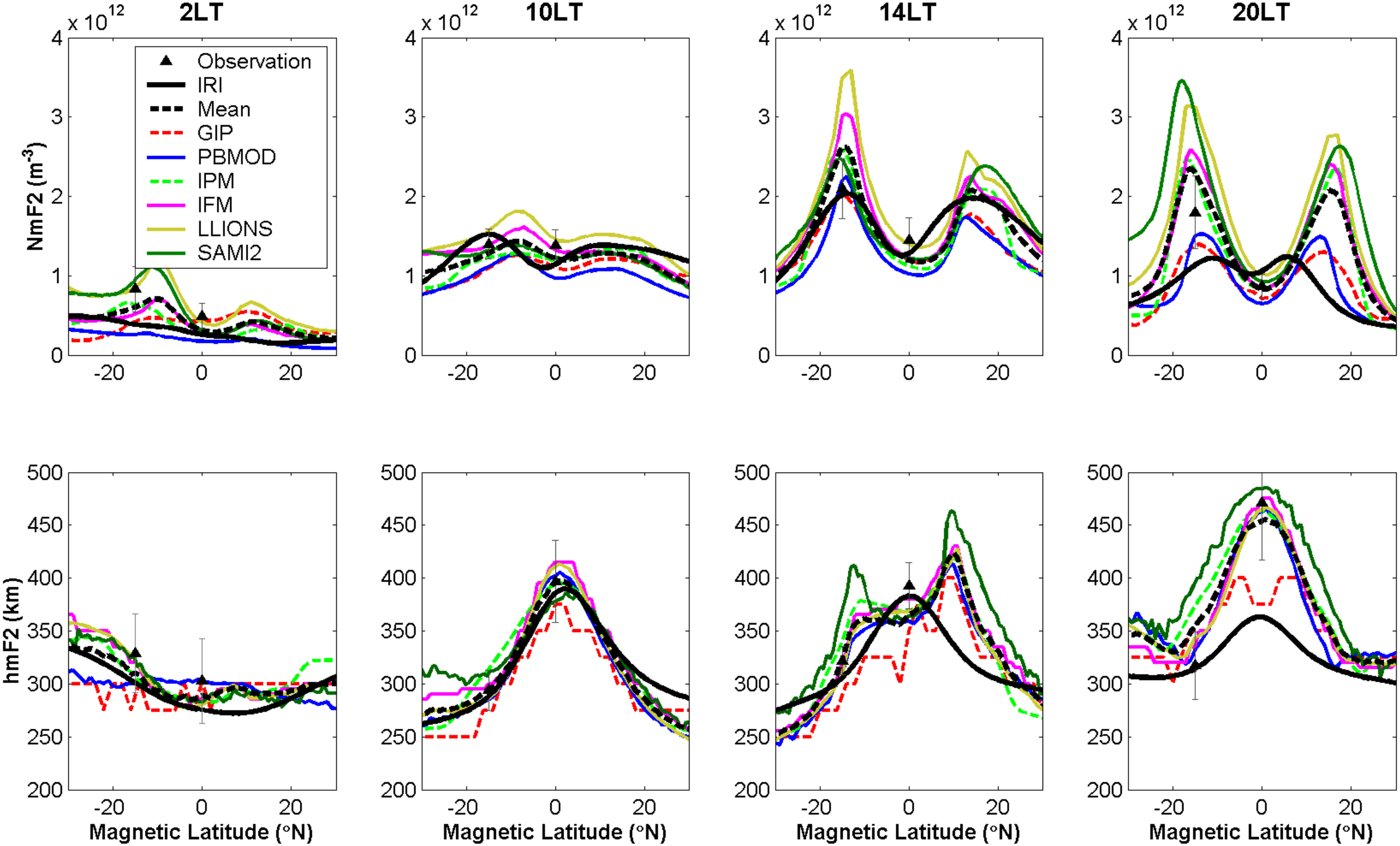
  Self-consistent models: solar energy input (EUVAC) and magnetic Apex coordinates are used, if applicable.

- International Reference Ionosphere (IRI) model is run in March 20, 2004.

Observations

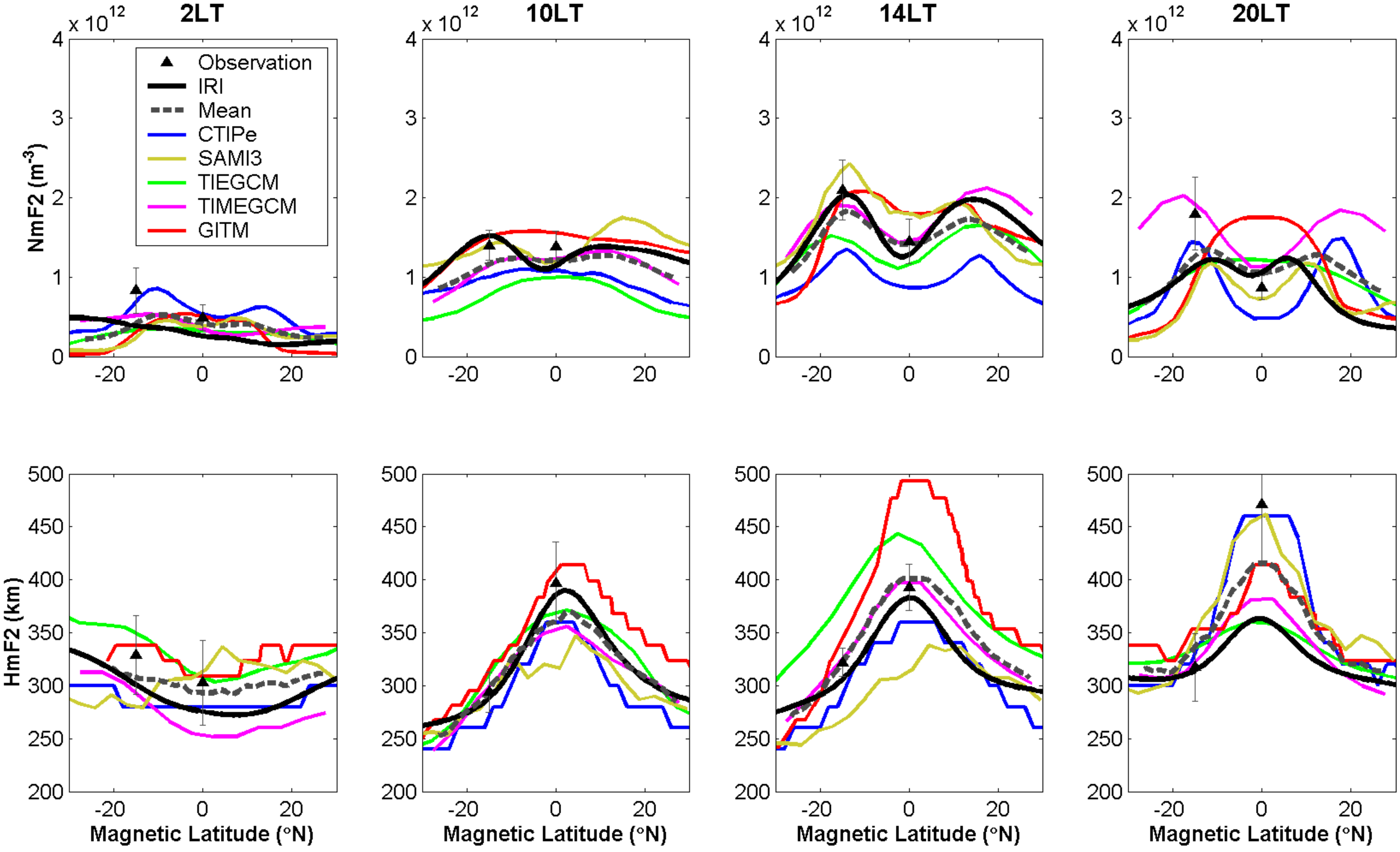
- Observations of NmF2 and hmF2 are averaged values during March 16 to 26, 2004 at Jicamarca Peru (magnetic equator) and Tucuman Argentina (15°S, geomagnetic). The mean F10.7 during this period is 116.

Non-Self-Consistent Models

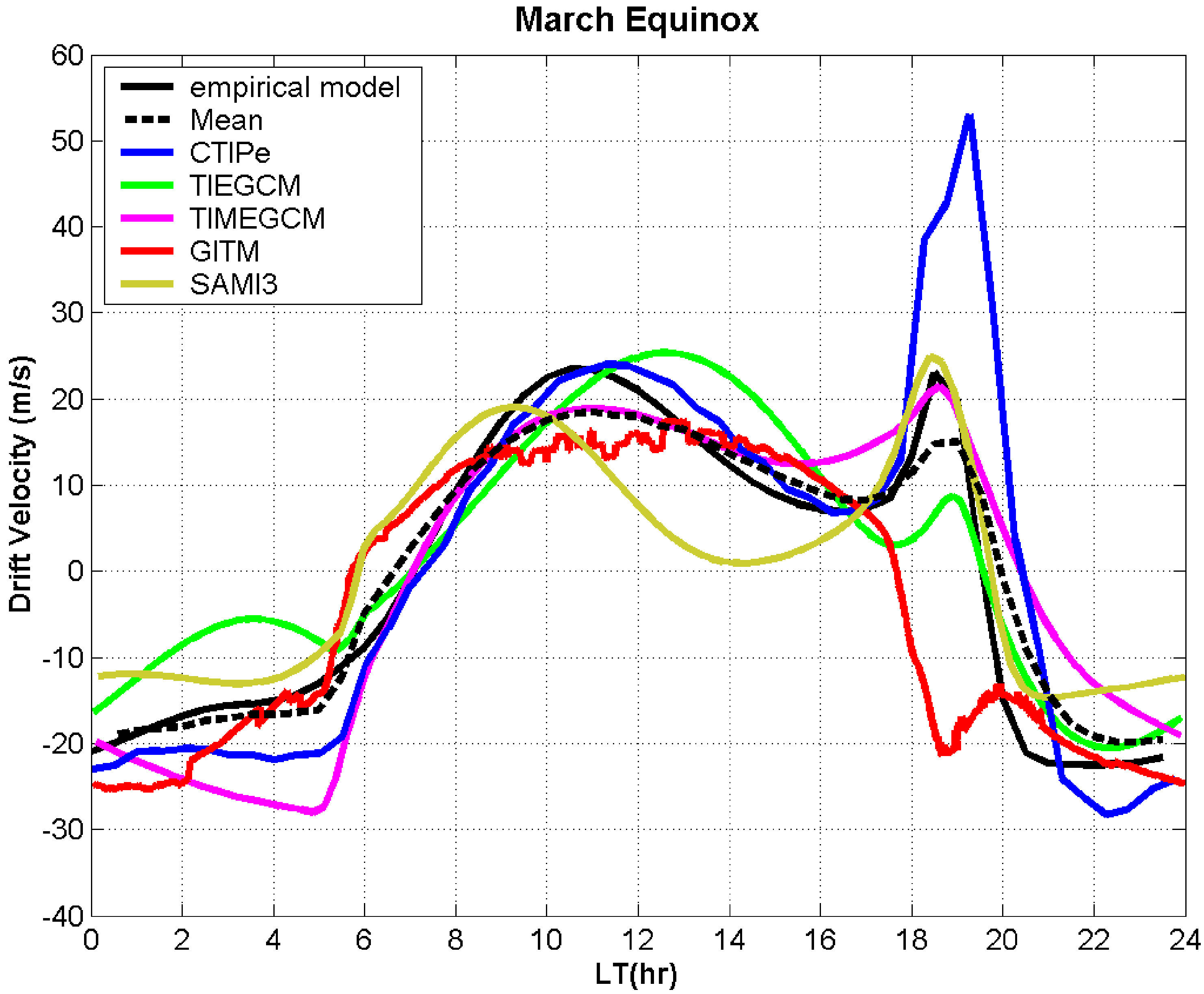


Mean (black dashed line) stands for the averaged values from the theoretical models.

Self-Consistent Models



Self-Consistent Models



TASK II (Non-coupled models):

Simulating Conditions:

S&F E×B drift model, NRLMSISE-00, and HWM93 as inputs

March equinox, $F_{10.7}$=120, geomagnetic quiet, at longitude 120°E

Case 1: No E×B drift, no neutral wind (Production & Loss, diffusion)

Case 2: With E×B drift, no neutral wind (P&L, drift, diffusion)

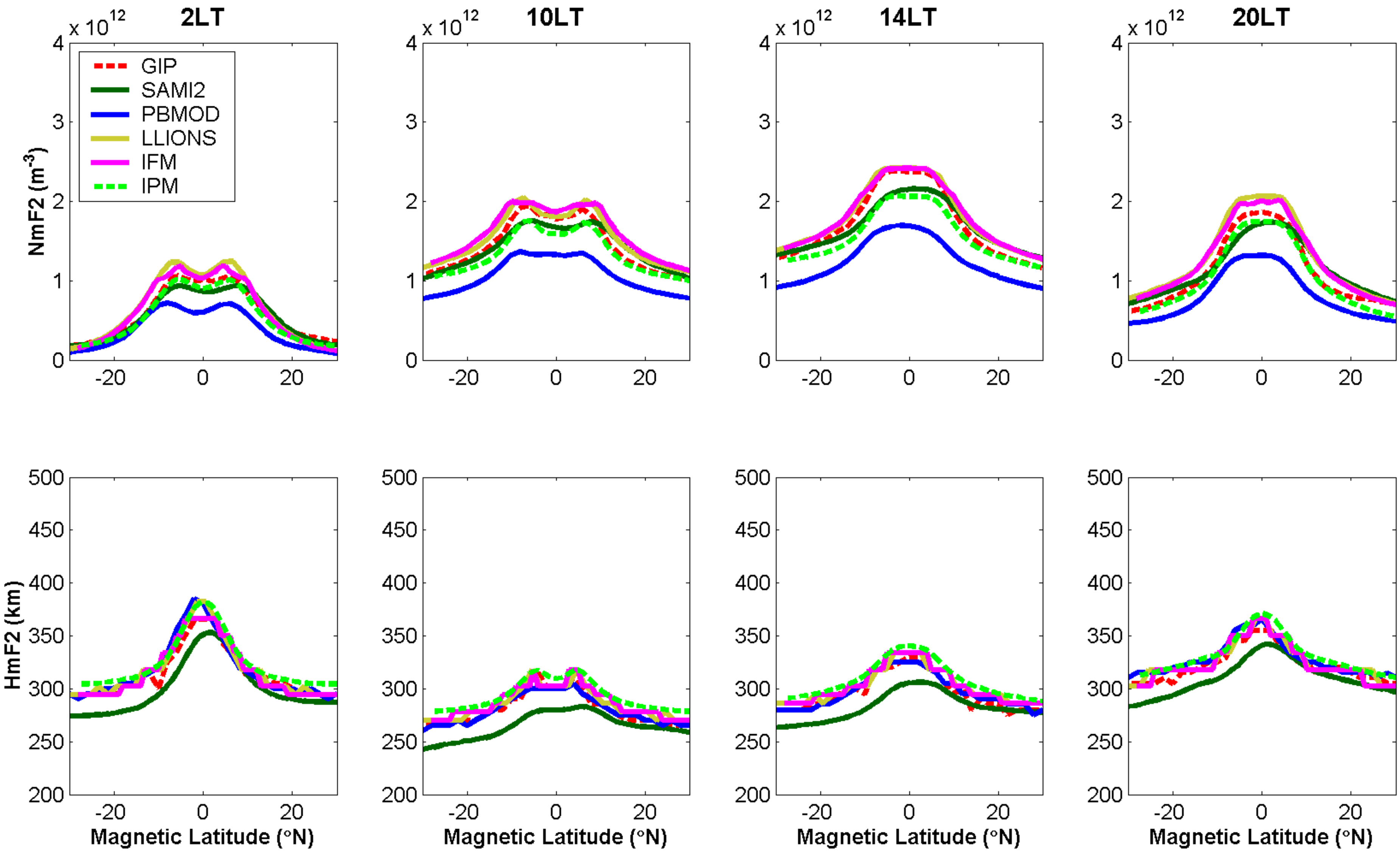
Case 3: With E×B drift and neutral wind (P&L, wind, drift, diffusion)

Continuity Equation

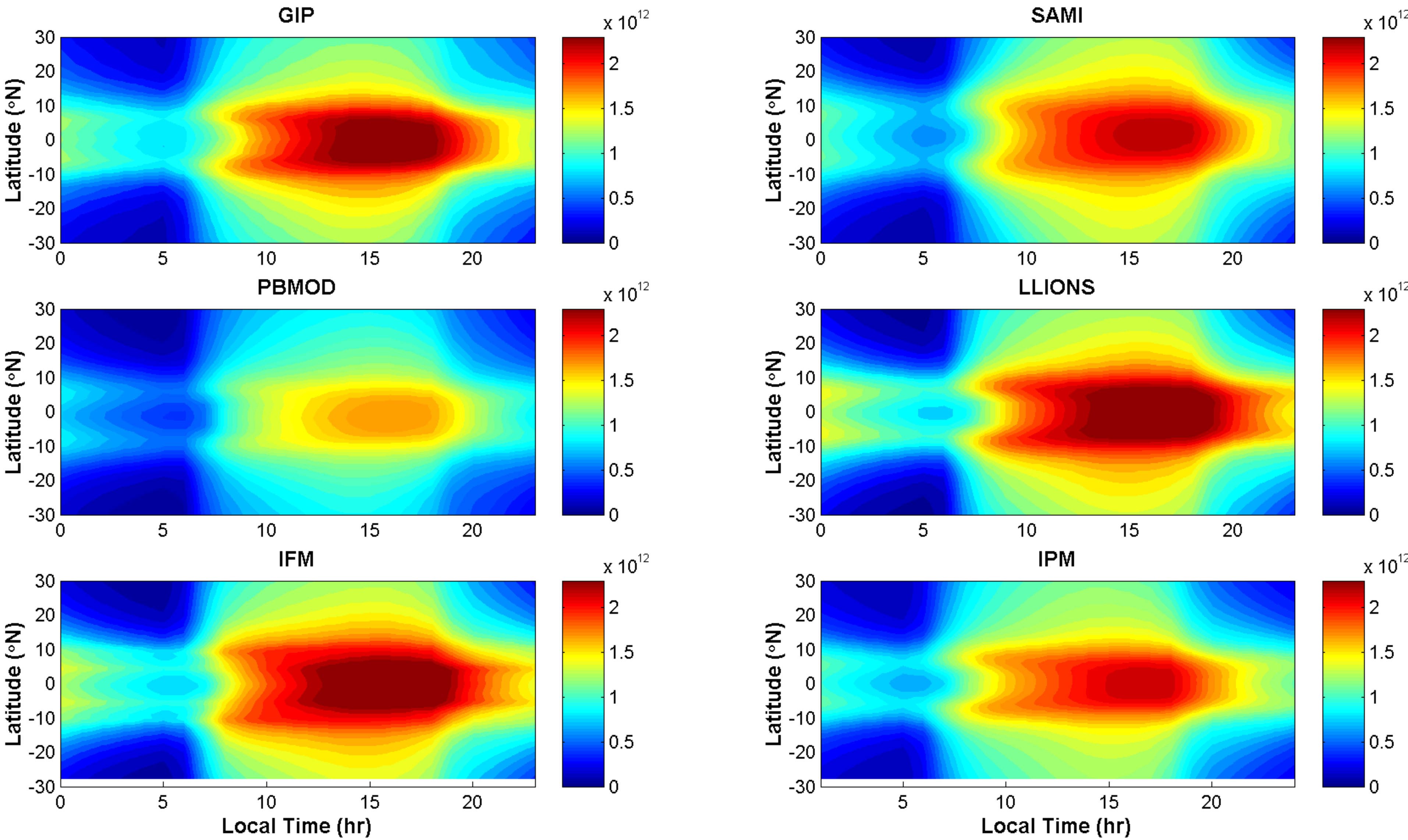
$$\frac{\partial N}{\partial t} = \underbrace{q}_{\text{Production}} - \underbrace{\beta(N)}_{\text{Loss}} - \underbrace{div(NV_{\parallel} + NV_{\perp})}_{\text{Transport}}$$

- Perpendicular transport ($V_{\perp}$)
  - E×B drift
- Parallel transport ($V_{\parallel}$)
  - Neutral wind effect
  - Plasma diffusion
  - Thermo expansion/contraction
- Zonal transport (neglect here)

Case 1: No ExB drift, no neutral wind ➔ Production and Loss



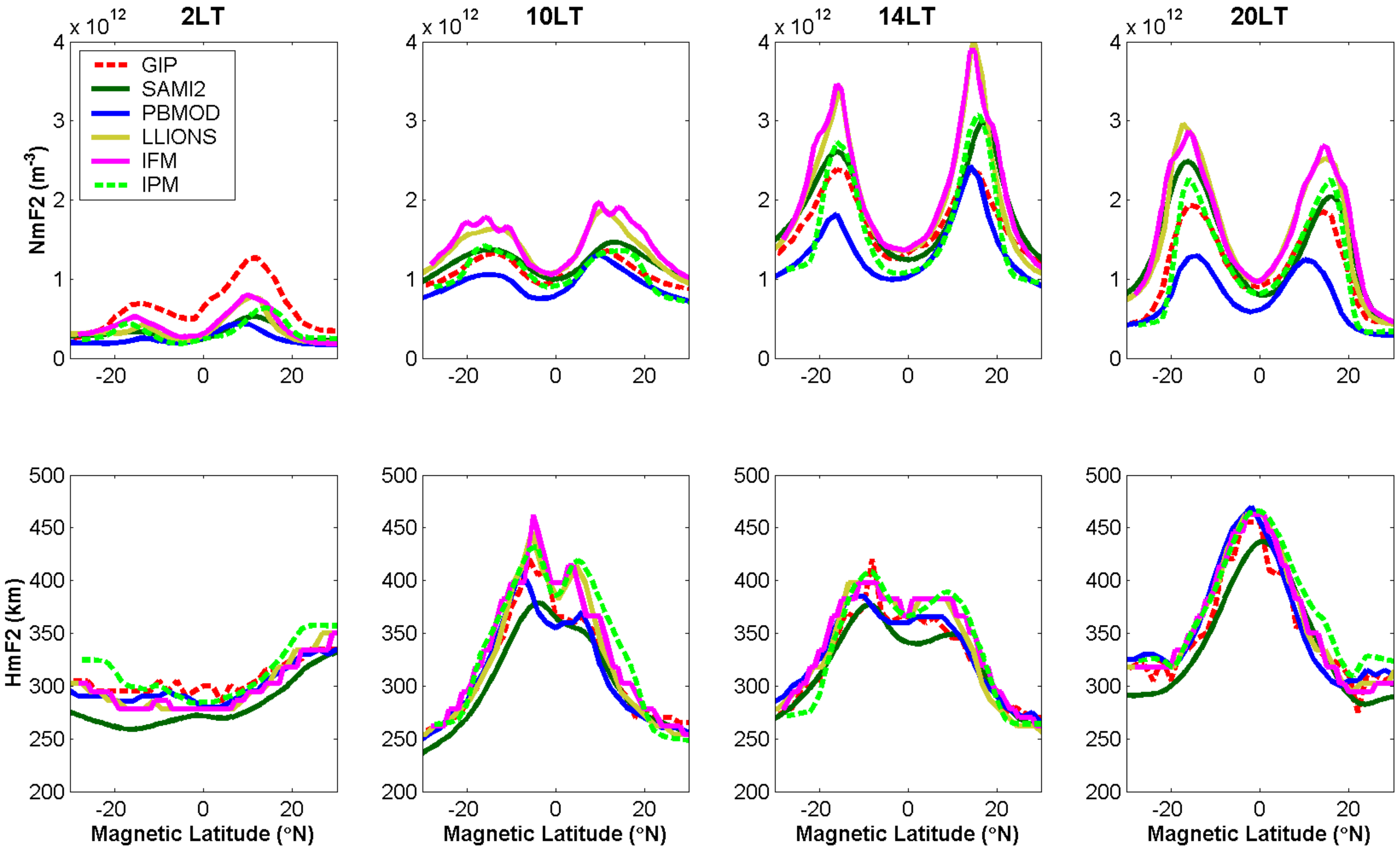
Case 1: No ExB drift, no neutral wind (Nmax) ➔ Production and Loss



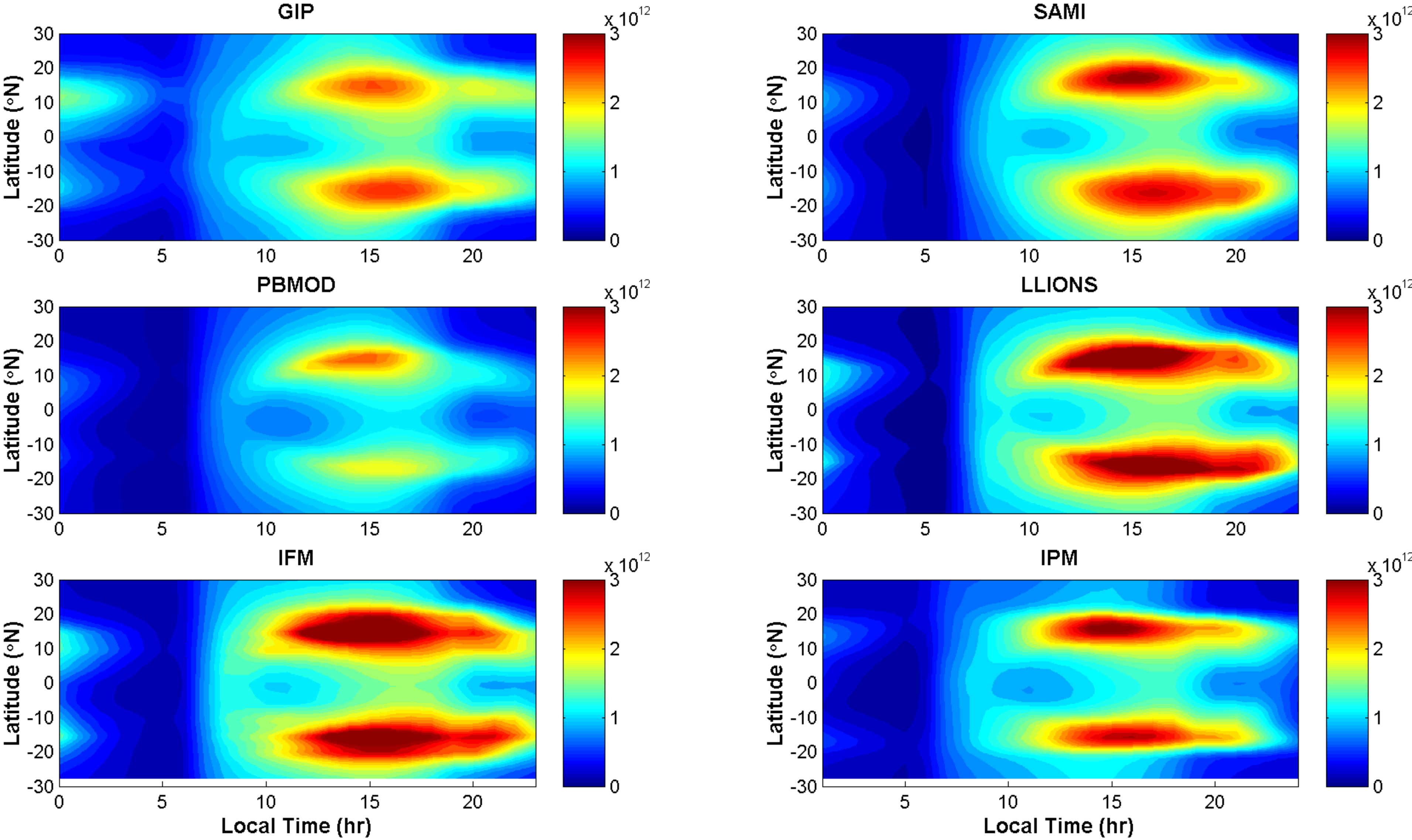
Any nighttime production? Differences in early morning and nighttime

Differences between IFM and IPM?

Case 3: With ExB drift and neutral wind ➔ P&L, wind, drift, diffusion



Case 3: With ExB drift and neutral wind (N_{max}) ➔ P&L, wind, drift, diffusion



The lower daytime density in PBMOD is associated with the production while those in GIP is probably related to the transport processes.

TASK III (Non-coupled models):

Comparisons:

a. zonal and meridional neutral winds (HWM-93)

b. vertical drifts (S&F empirical model)

c. ion-neutral collision frequency (O-O^+)

SAMI2 uses *Baily and Balan* [1996] in cgs,

$$\nu_{in} = 4.45 \times 10^{-11} n(O) T^{1/2} (1.04 - 0.067 \log_{10} T)^2$$

IFM, IPM, LLIONS, and PBMOD use *Schunk and Nagy* [1980] in cgs,

$$\nu_{in} = 3.67 \times 10^{-11} n(O) T^{1/2} (1 - 0.064 \log_{10} T)^2$$

GIP uses *Raitt et al*. [1975] in MKS,

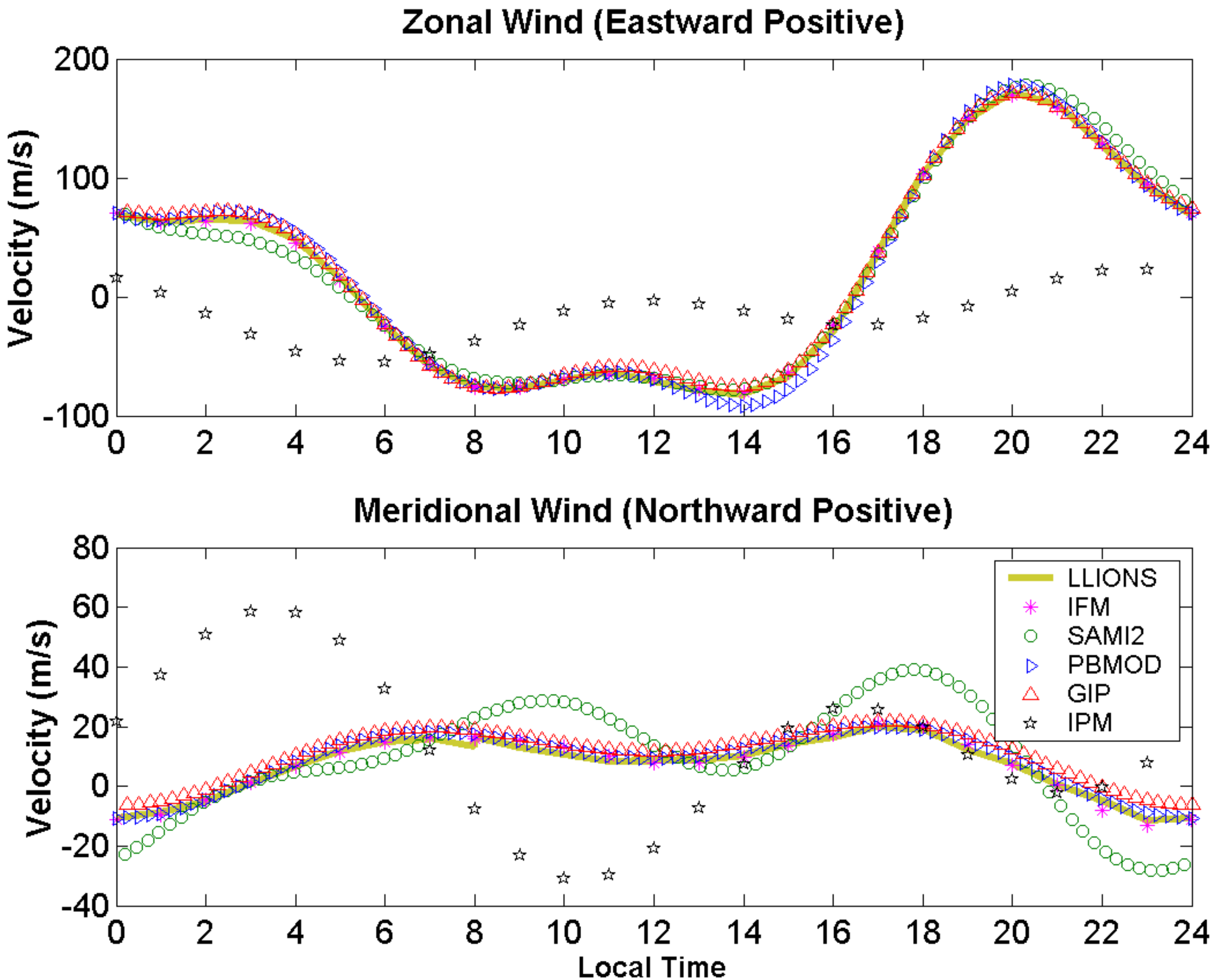
$$\nu_{in} = 3.42 \times 10^{-17} n(O) T^{1/2} (1.04 - 0.067 \log_{10} T)^2$$

$$T = (T_i + T_n)/2$$

- Temperature solvers in these models are different!

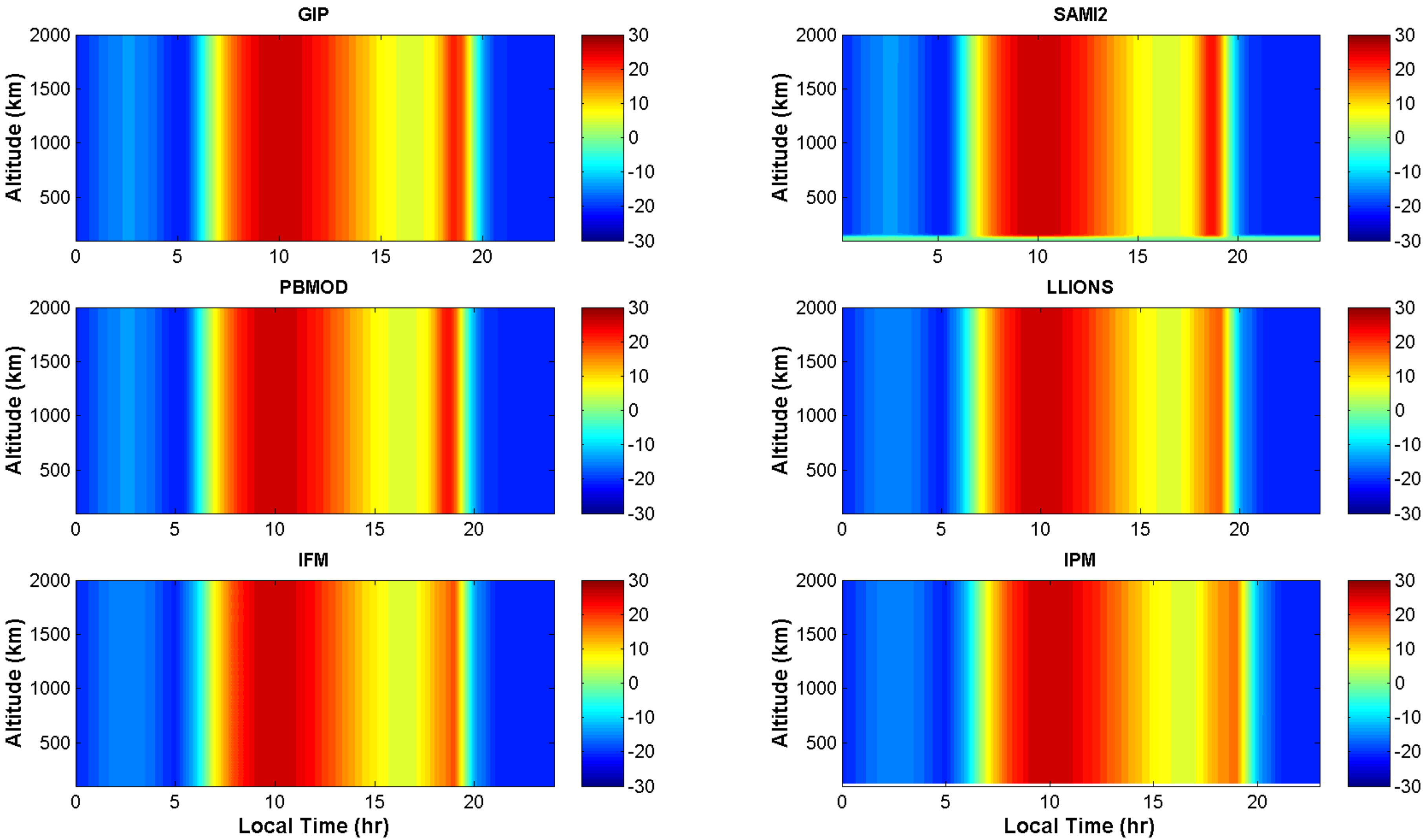
Wind Comparisons:

At 300 km above the geographic equator in longitude 120˚E under $F_{10.7}$=120



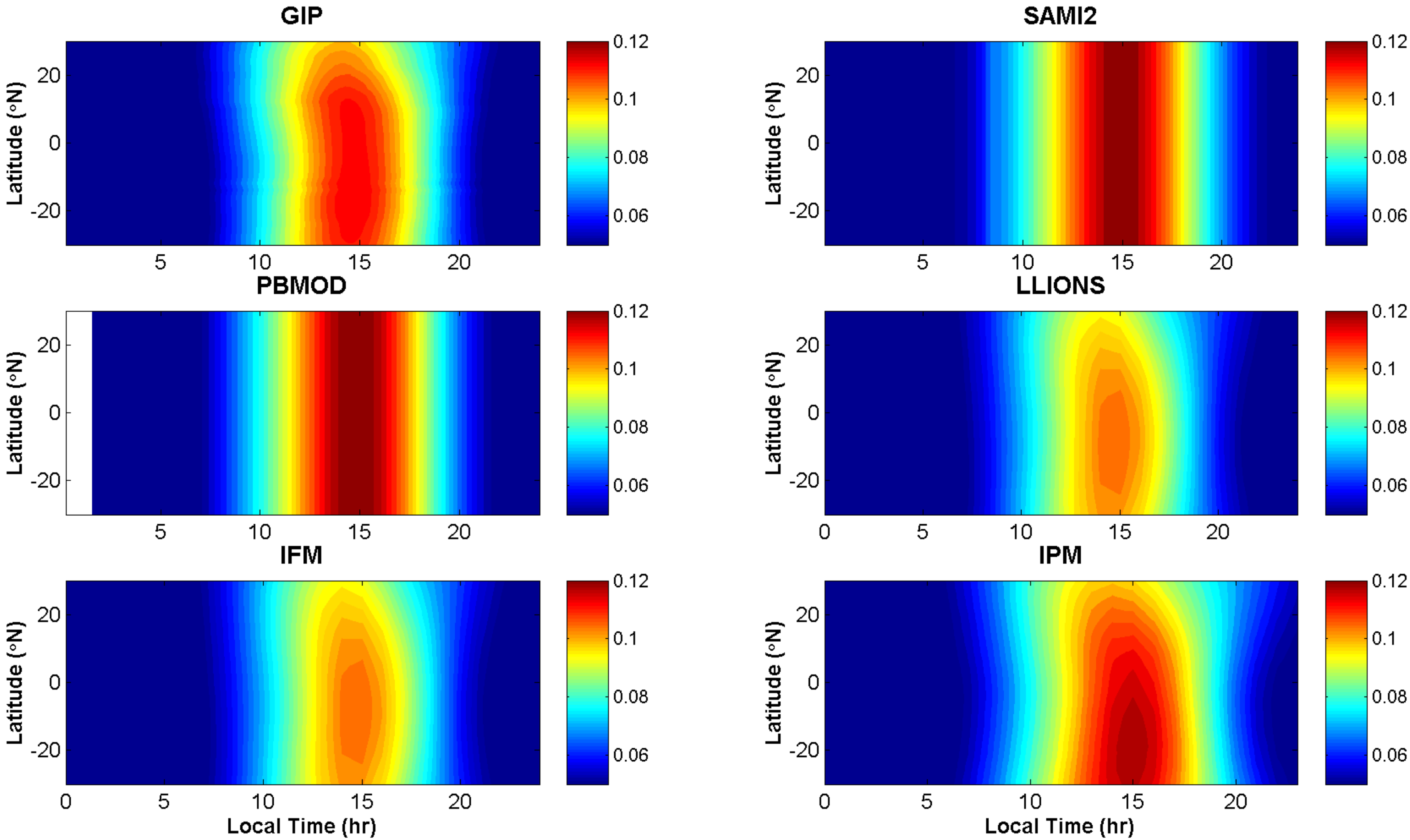
Vertical Drift Comparisons:

Above the magnetic equator at longitude 120˚E under $F_{10.7}$=120



O-O$^+$ Collision Frequency Comparisons:

At 400 km in longitude 120˚E under $F_{10.7}$=120



1st Open Discussion

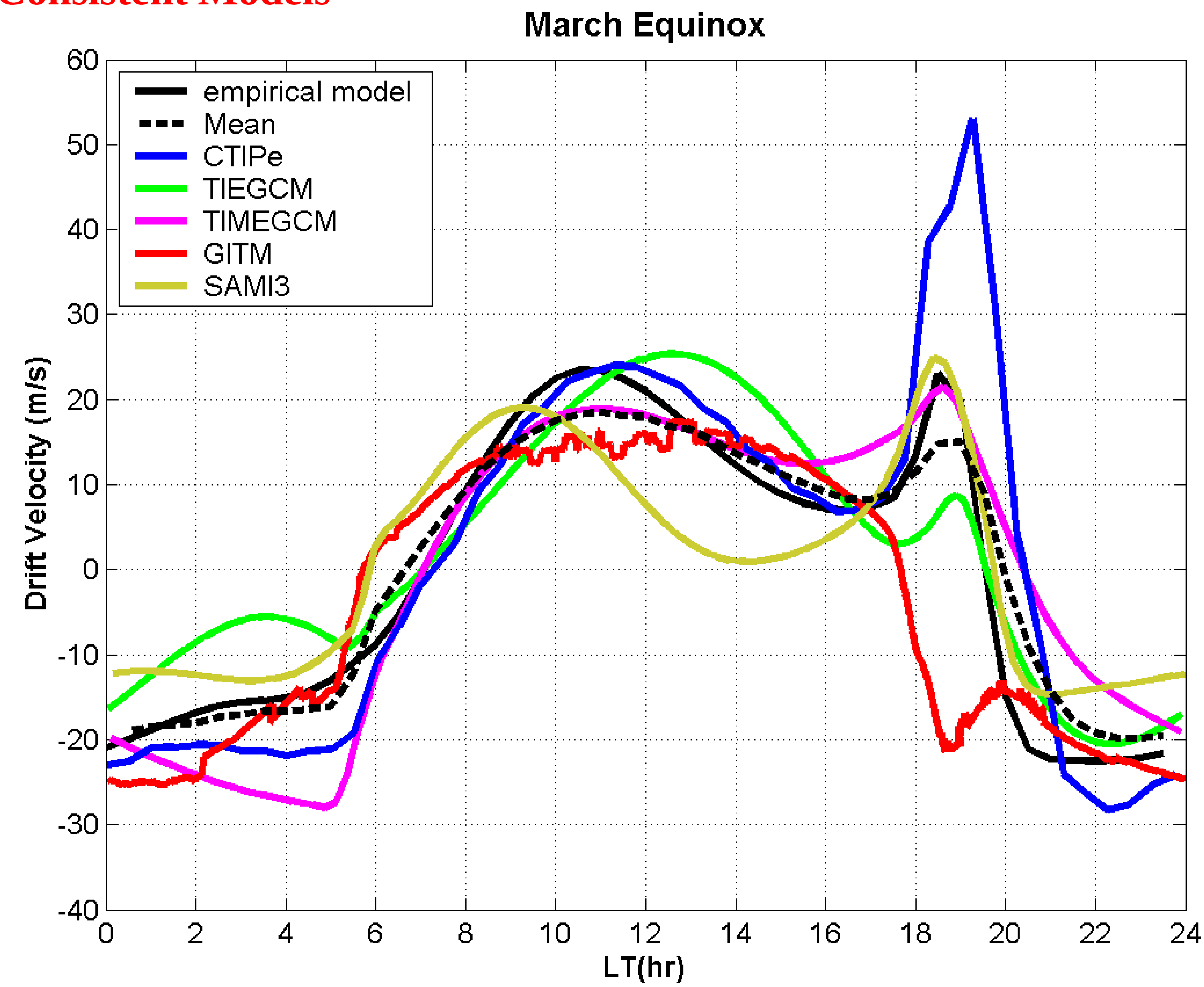
- Before Equatorial-PRIMO, we had no idea of the model-model disparity. How close do the non-self consistent models need to be to say they are in agreement?
- What can be used as “Metrics”? Averaged values from all model results?
- What are the important features or phenomena in the equatorial ionosphere that the self-consistent models should be able to reproduce?
- Which is the important parameter for the self-consistent models? How to improve the vertical drift? PRE?
- E region density, ion/electron temperatures, nighttime ionization
- Should we use one model (e.g. GIP) from the non-self-consistent models and one (e.g. TIEGCM) from the self-consistent models for sensitivity studies to determine how the different factors and parameterizations affect the plasma densities?
- What comes next?

Updates of PBMOD from John Retterer

The main updates for the ambient (global scale) density modelling in PBMOD are refinements in numerical algorithms: checking additional error criteria and subdividing time steps when necessary to control error. I haven't yet tried the EUVAC solar spectrum model.

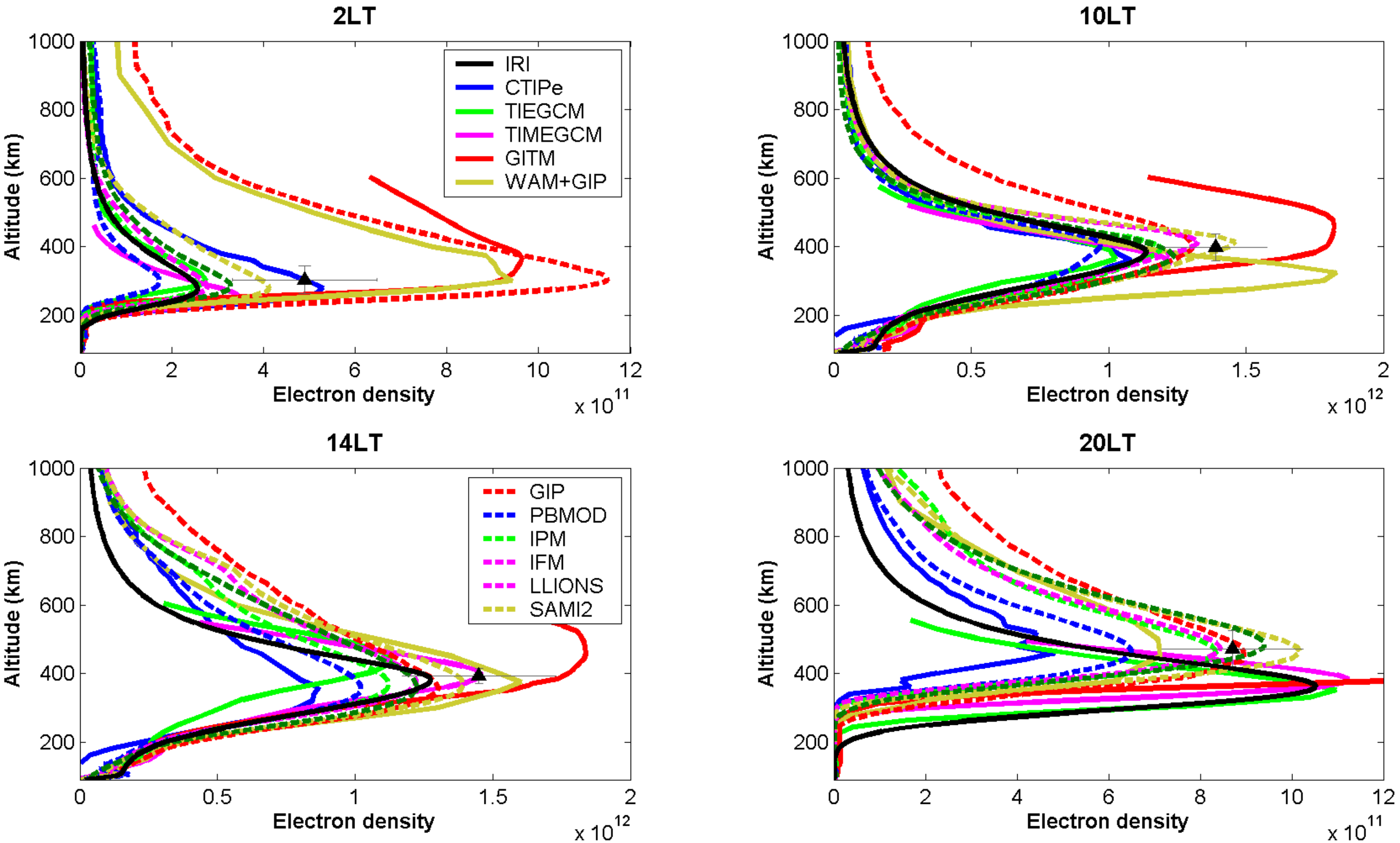
PBMOD is involved in a number of several data-assimilation projects, both assimilation of 'drivers' (neutral winds, electric fields), and constraint of the model with densities and TEC. Data come from SOFDI, CNOFS, and LISN, among other sources. Coupling with the Whole Atmosphere Model is another exciting project.

Self-Consistent Models



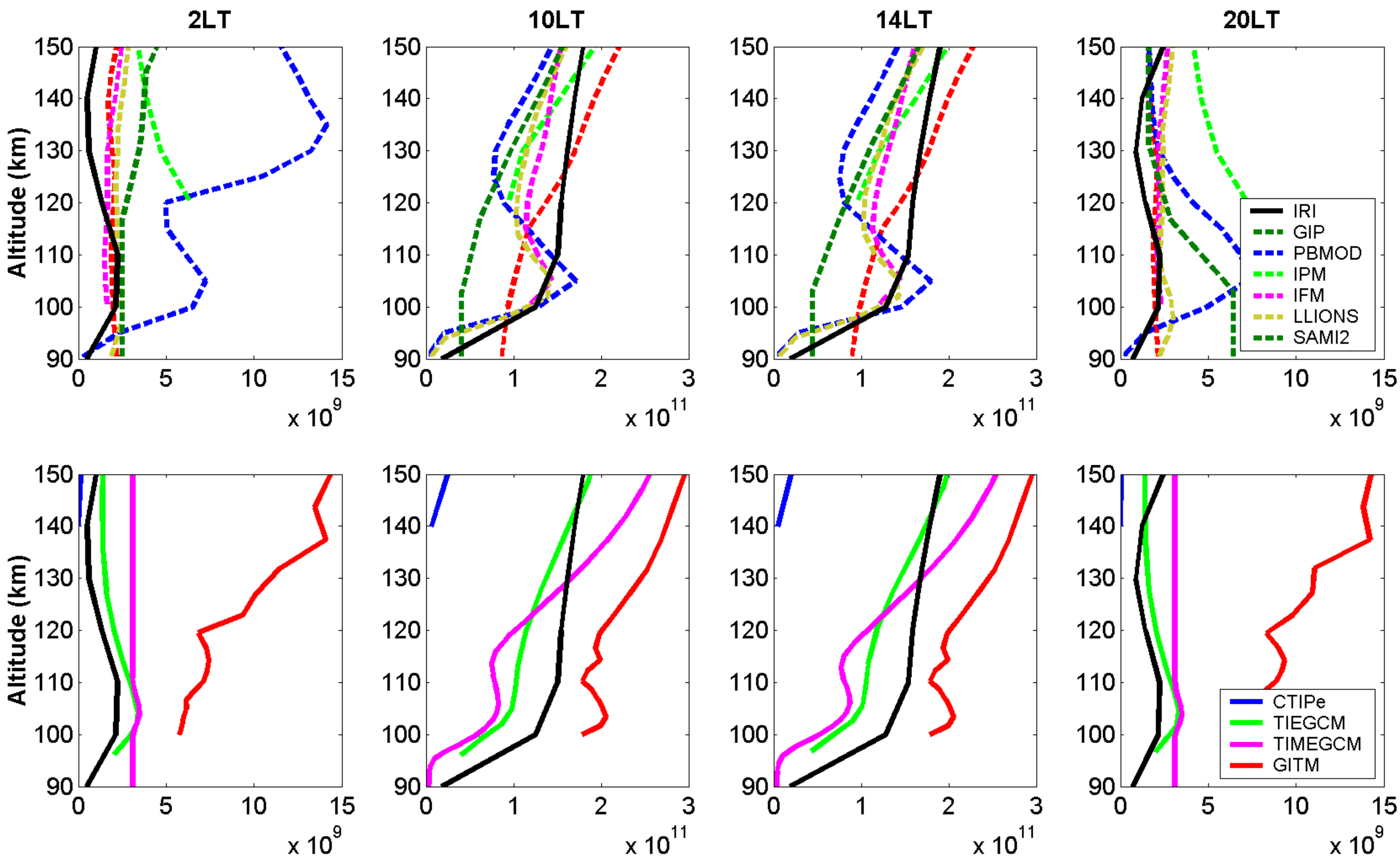
Height profiles of electron densities above magnetic equator at Jicamarca longitude

Non-self-consistent models (dashed lines) and self-consistent models (solid lines)

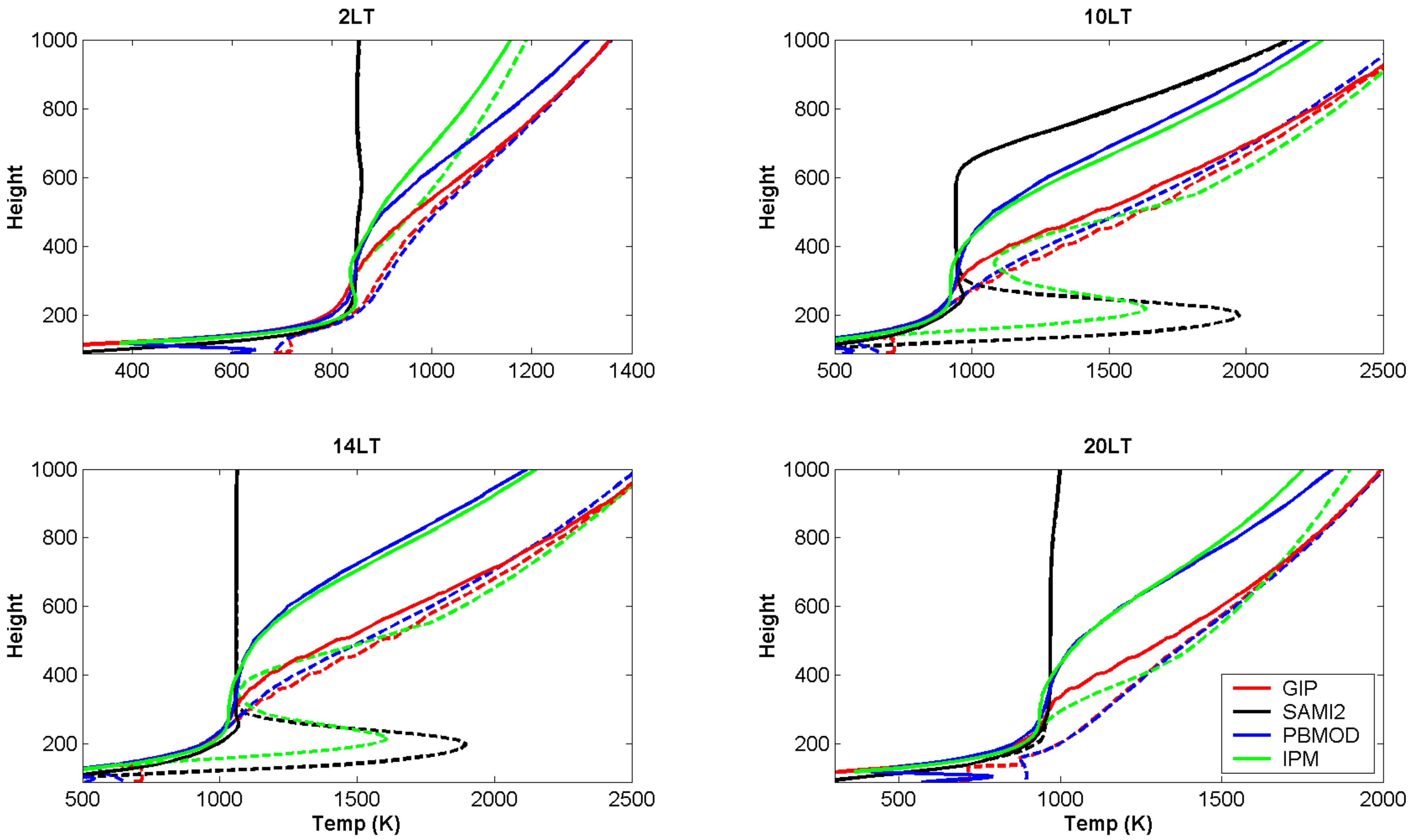


E region density profiles for the non-self-consistent and self-consistent models

Above magnetic equator at Jicamarca longitude sector



Ion and Electron Temperatures: With E×B drift and neutral wind



Solid line: Ti (O+)   Dashed line: Te

1st Open Discussion

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CHAMP (Black) vs. IRI-2007 (Grey)

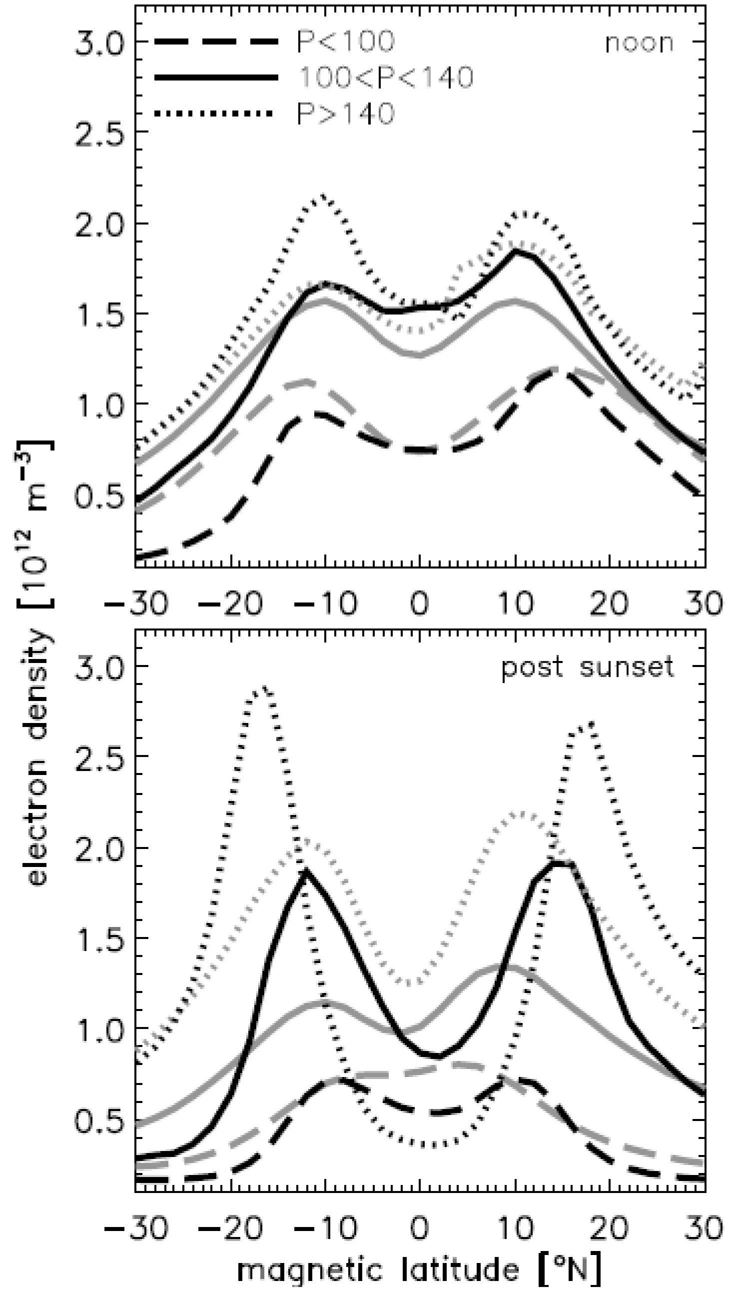
Long. -90˚E to -60 ˚E (Jicamarca longitude)
Noon (11-15 LT) Postsunset (18-22LT)
Kp<3

IRI results agree better with CHAMP in the daytime.

Note that the CHAMP sees a horizontal cut, rather than N_mF_2 comparisons that have been done in Equatorial-PRIMO.

The coupled models show better agreements with CHAMP during the daytime, but might underestimate the EIA at postsunset.

The non-coupled models seem to overestimate EIA, especially during daytime.



Courtesy of Claudia Stolle

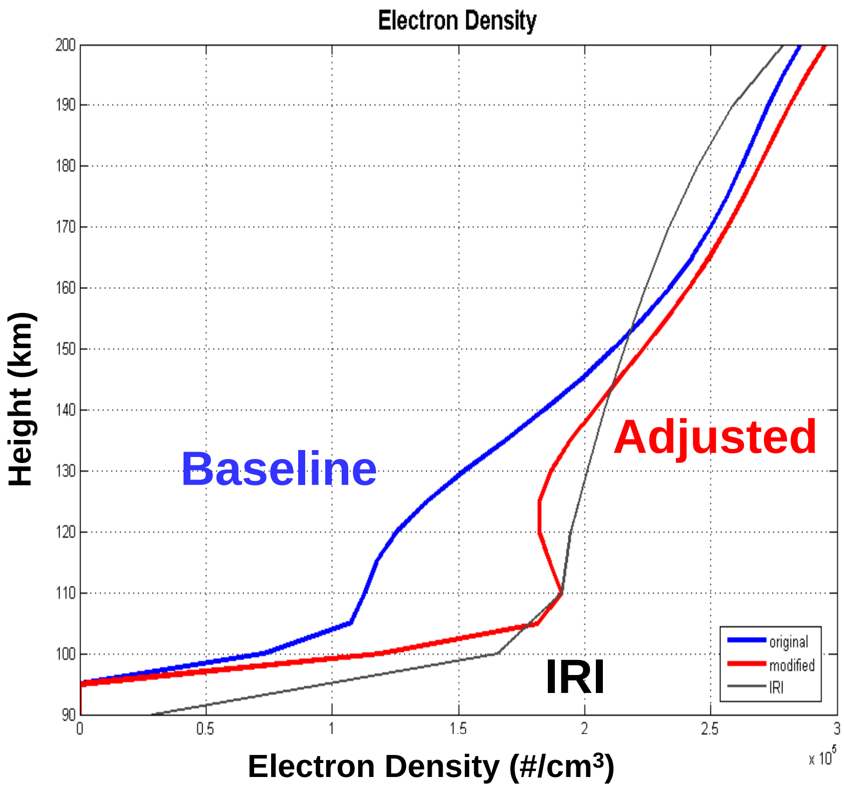
2nd Open Discussion

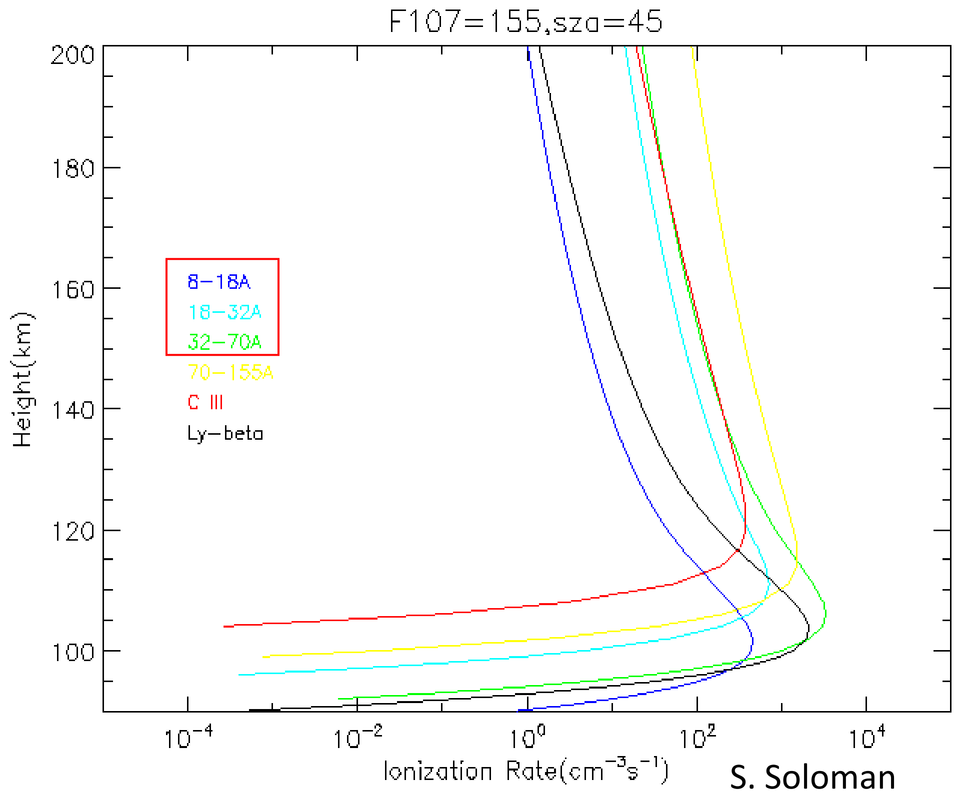
- What observations are needed – global or local? CHAMP, C/NOFS, LISN
- What type of data-sets are required?
- What is the best way to combine models and observations?
- What metrics should be used?
- What information can the Equatorial-PRIMO provide to the community? What kind of observations are crucial for improving the model capability? e.g. neutral wind and ion/electron temperatures.

Summaries after the workshop

- Plasma flux from the flux-tube models. Lower boundaries
- Plot O-O+ collision frequency vs. Te
- E region nighttime photoionization for PRE
- Incorporate data to the TIEGCM, GIP
- Metrics for comparisons
- Compare the conductivities among models
- Get good observations and make consistent runs. (LISN)

TIEGCM E-region Density Enhancement





S. Soloman

Compare with the International Reference Ionosphere (IRI) model, the TIE-GCM underestimates the E region electron density by 37% in noontime electron density profiles above the magnetic equator in PERU sector in March equinox and moderate solar activity.

Multiplied the baseline TIE-GCM solar fluxes in wavelengths between 8-70Å, which dominate the ionization in E region, by a factor 4.4.

Non-Self-Consistent Models

Model	Output	Altitude Range (km)	Resolution	Magnetic Coordinate	Photoionization
IFM	N_i (O^+, H^+, NO^+, O_2^+), N_e, T_i, T_e	90 – 1600	Long. 5°-15° Lat. 2°-5°	Best-fit IGRF dipole for each longitude	EUVAC
IPM	N_i (O^+, H^+, NO^+, O_2^+, He^+, N_2^+, N^+), N_e, T_i, T_e	90 – 20000	Long. 3.75 ° Lat. < 1° at low-latitude	IGRF dipole	EUVAC
LLIONS	N_i (O^+, H^+, NO^+, O_2^+), N_e, T_i, T_e	90 – 10000	Single longitude Lat. 2°	Best-fit IGRF dipole for each longitude	EUVAC
PBMOD	N_i (O^+, H^+, NO^+, O_2^+, N_2^+), N_e, T_i, T_e	90 – 4000	Long. 7.5° Lat. 1°	IGRF Apex	Hinteregger Fluxes Jasperse CSD (1977)
GIP	N_i (O^+, H^+, NO^+, O_2^+, N_2^+, N^+), N_e, T_i, T_e	90 – 20000	Long. 4.5° Lat. 1°	IGRF Apex	Fluxes (Tobiska model) Cross sec. (Torr and Torr, 1982)
SAMI2	N_i (H^+, O^+, He^+, N^+, NO^+, N_2^+, O_2^+), N_e, T_i (H^+, O^+, He^+), T_e	90 – 20000	Single longitude Lat. 1°	IGRF-like	EUVAC

Self-Consistent Models

Model	Output	Lower Boundary Condition	Altitude Range (km)	Ionosphere Resolution	Mag. Coord.	Photo-ionization
SAMI3	H^+, O^+, He^+, N^+, NO^+, N_2^+, O_2^+, N_e, T_i (H^+, O^+, He^+), T_e, Φ	HWM93	85 – 20000	Long. 3.75° Mag. Lat. 1°	Tilt Dipole	EUVAC
TIEGCM	Neutral Composition, U_n, V_n, T_n, T_i, T_e, N_e, O^+, NO^+,O_2^+, Z, Φ	GSWM02 migrating diurnal and semidiurnal tides	97 to 450 – 600	Long. 5° Lat. 5°	IGRF Apex	EUVAC for <1050 Woods & Rottman [2002] for >1050A
TIMEGCM	Neutral Composition, U_n, V_n, W, T_n, T_i, T_e, N_e, O^+, O_2^+, NO^+, N_2^+, N^+, Z, Φ	GSWM migrating diurnal and semidiurnal tides	30 to 450 – 600	Long. 5° Lat. 5°	IGRF Apex	EUVAC for <1050 Woods & Rottman [2002] for >1050A
GITM	Neutral Composition, U_n,V_n,W_n,T_n, V_i, T_i, O^+, O_2^+, NO^+, N_2^+, N^+, T_e, N_e, Φ	GSWM migrating diurnal and semidiurnal tides	100 – 700	Long. 5° Mag. Lat. 1°	IGRF Apex	EUVAC Hinteregger's SERF1 model
CTIPe	Neutral Compositions, U_n,V_n,T_n, T_i, O^+, H^+, O_2^+, NO^+, N_2^+, N^+, N_e, Φ	migrating semidiurnal tides	Thermosphere 80 – 500 Ionosphere 80 –10000	Long. 18° Lat. 2°	Tilt Dipole	EUVAC for <1050 Woods & Rottman [2002] for >1050A

Task II Non-Self-Consistent Models (with E×B, no wind)