Agenda of Equatorial-PRIMO

(Problems Related to Ionospheric Models and Observations)

First Hour: **Non Self-consistent Ionospheric Models**

16:00 ~ 16:10	**Introduction of Equatorial-PRIMO (Dave Anderson)**
16:10 ~ 16:20	**Brief Introduction of Models (Participated Modelers)**
16:20 ~ 16:40	**Model Comparisons w/o Neutral Winds and Drifts (Tzu-Wei Fang)**
16:40 ~ 17:00	**General Discussion**

Second Hour: **Self-consistent Ionospheric Models**

17:00 ~ 17:10	**Introduction of Coupled Model Results (Dave Anderson)**
17:10 ~ 17:20	**Brief Introduction of Models (Participated Modelers)**
17:20 ~ 18:00	**General Discussion**

Equatorial-PRIMO

(Problems Related to Ionospheric Models and Observations)

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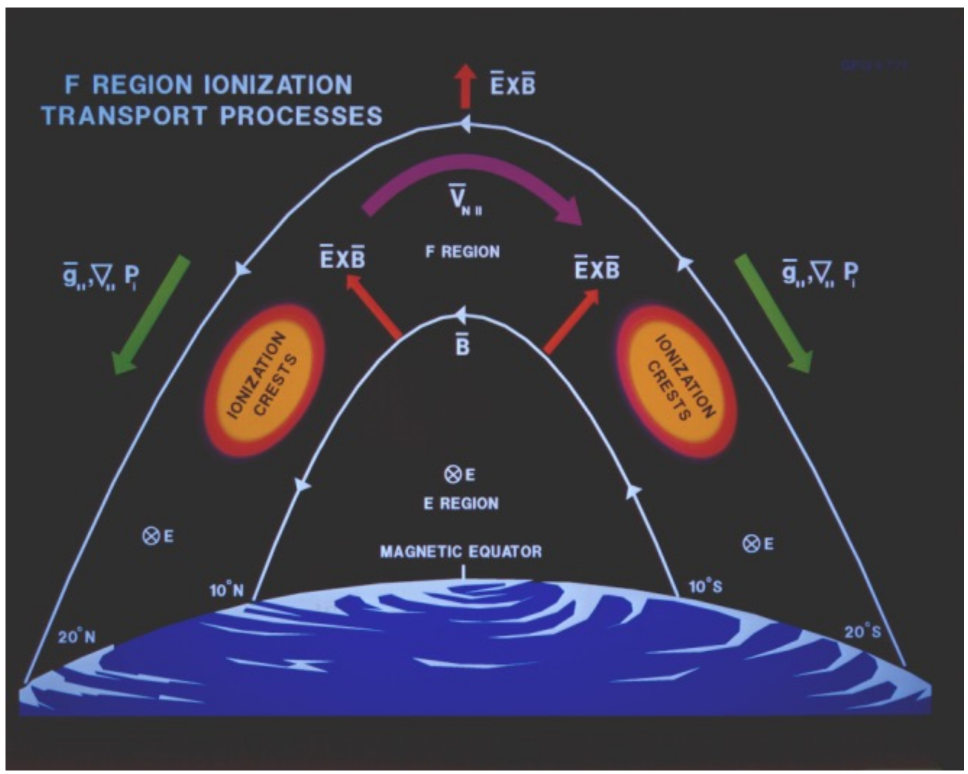
Participating Models

- A set of theoretical ionospheric models require neutral atmospheric densities and temperatures, neutral winds, ExB 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) "Ionospheric Forecast Model (IFM)"
  - The Utah State University (USU) "Ionosphere-Plamasphere Model (IPM)"
  - The Space Environment Corporation (SEC) "Low Latitude Ionosphere Sector Model (LLIONS)"
  - The AFRL "Physics Based Model (PBMOD)"
  - The "Global Ionosphere and Plasmasphere (GIP)" model.
  - 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)" and "Thermosphere-Ionosphere-Mesosphere-Electrodynamics general circulation model (TIME-GCM)"
  - University of Michigan "Global Ionosphere-Thermosphere Model (GITM)"
  - Integrated Dynamics through Earth's Atmosphere (IDEA).

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 develop improved models.



Transport Processes in the Equatorial Ionosphere

Simulating Conditions and Observations

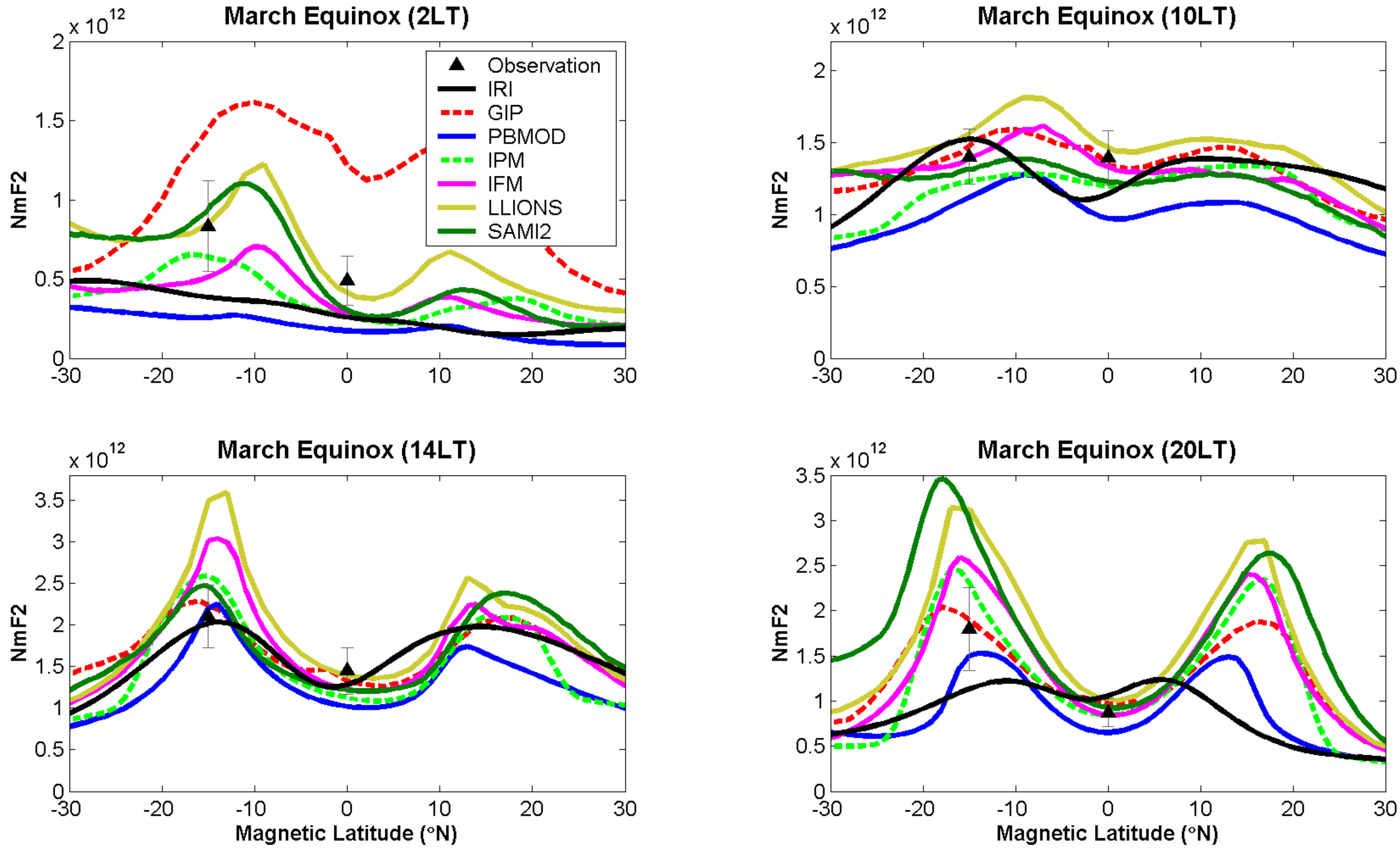
- In order to carry out very preliminary comparisons, these two sets of models theoretically calculated ionospheric parameters in the Peruvian longitude sector (~ 284°E) in March equainox for an F10.7 cm flux value of 120 and geomagnetic quiet (e.g. Ap<5). The burnside factor is set to 1.

  – For non-self consistent models, Scherliess-Fejer, climatological E×B drift model, NRLMSISE-00 neutral atmosphere model, and HWM93 neutral wind model are used to drive models.

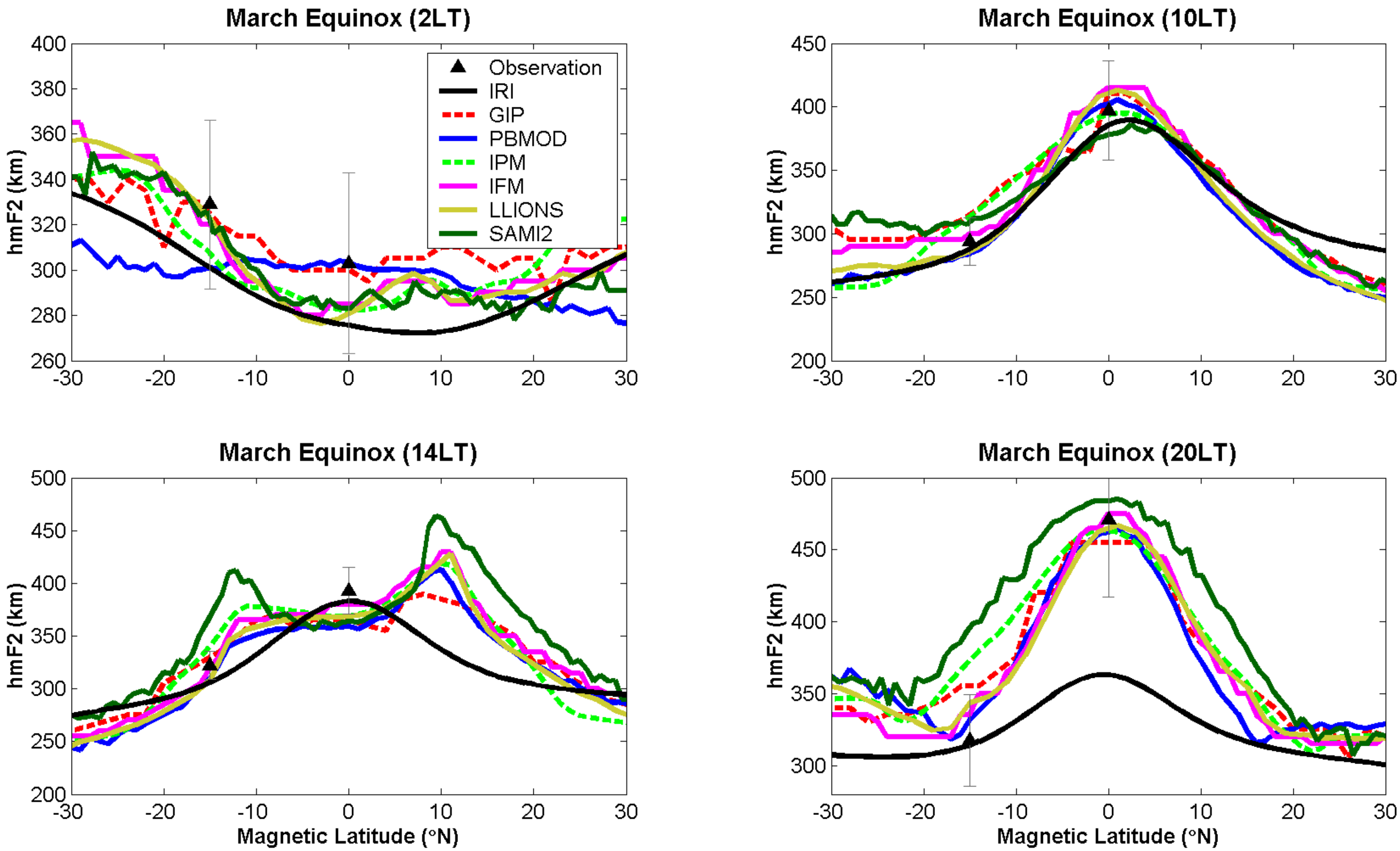
  – For self-consistent models, solar energy input (EUVAC) and IGRF like magnetic coordinate are used, if applicable.

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

- 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.

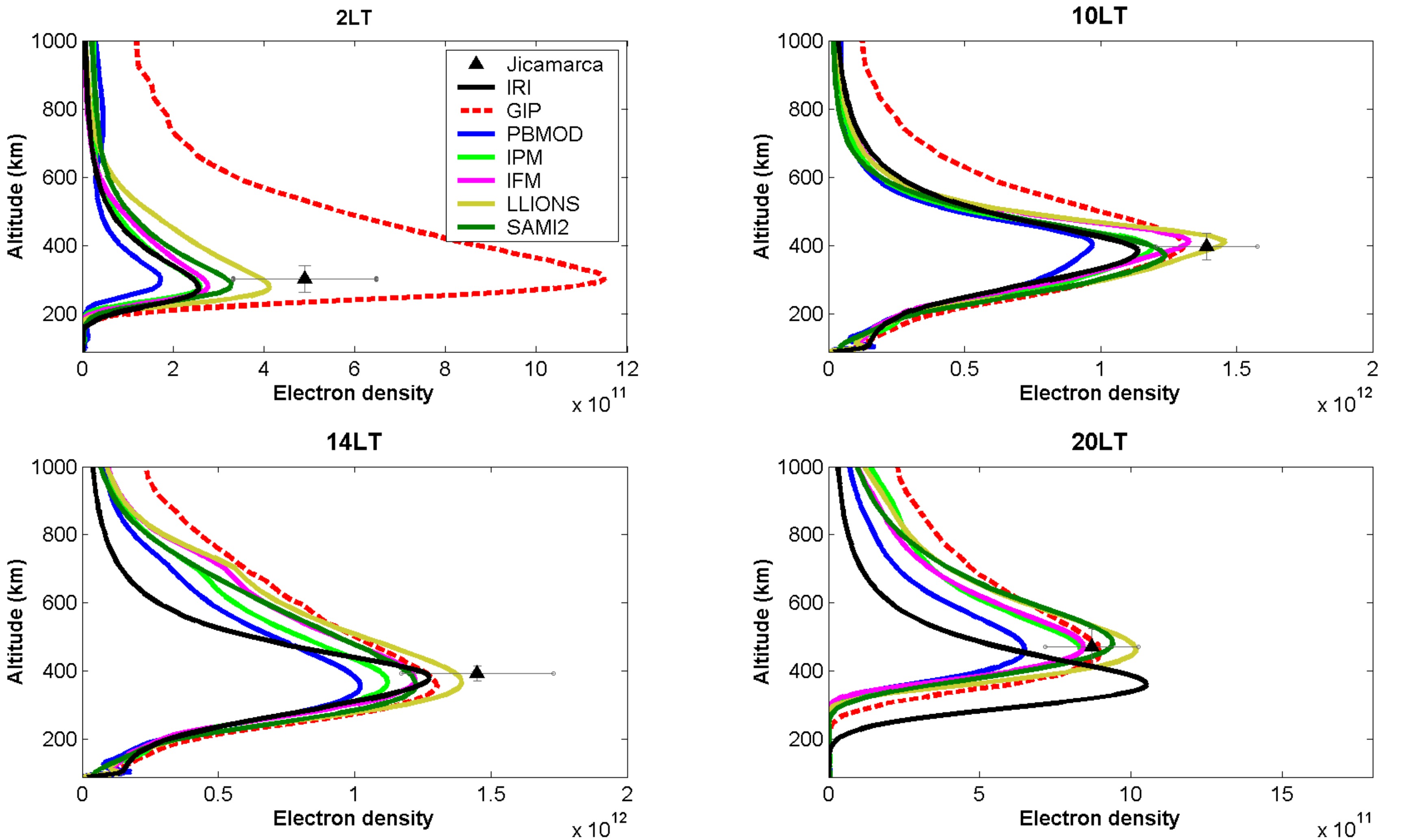


- GIP nighttime is not correct which might be due to incorrect TE.
- Daytime NmF2 in physical models are consistent with each other and IRI.
- NmF2 in physical models also agree well with observation at equator.
- At 20LT, differences in physical models are larger.



- hmF2 in physical models are quite consistent with each other.
- At 14LT, IRI shows a peak above magnetic equator while physical models show two crests away from the equator.
- hmF2 at equator from physical models agree well with observation.

	Model	Output	Boundary Condition	Ionosphere Coverage (km)	Thermosphere Coverage (km)	Ionosphere Resolution	Magnetic Coordinate	Photoionization
Non Self-consistent	IFM	Ni (O^+, H^+, NO^+, O_2^+), Ne, Ti, Te		90-1600	MSIS86 HWM93	Various Long: 5°-15° Lat: 2°-5°	Best-fit IGRF dipole for each longitude	EUVAC
	IPM	Ni (O^+, H^+, NO^+, O_2^+, He^+,N_2^+, N^+), Ne,Ti, Te	Chemical Equilibrium at 90 km altitude	90 - 20,000	NRLMSIS00 HWM93	Lon: 3.75° Lat: 1.0° at mid-lat ; < 1° at low-lat	IGRF	EUVAC
	LLIONS	Ni (O^+, H^+, NO^+, O_2^+), Ne, Ti, Te		90-10,000	NRLMSIS00 HWM93	Single longitude Lat: 2°	Best-fit IGRF dipole for longitude	EUVAC
	PBMOD	Ni (O^+, H^+, Mol^+), Ne	Ni = 0 at end of flux tube	90 – 4000 (upper end is user selectable)	NRLMSIS00 HWM93	User Selectable (typically Long: 7.5, Lat: 1)	IGRF Apex	Hinteregger Fluxes, Jasperse CSD (1977)
	GIP	Ni (O^+, H^+, NO^+, O_2^+, N_2^+, N^+), Ti, Ne, Te		90 - 20,000	NRLMSIS00 HWM93	Long: 4° Lat: 1°	IGRF Apex	Fluxes (Tobiska model) Cross sec. (Torr and Torr, 1982)
	SAMI2	Ni(H+,O+,He+,N+, NO+,N2+,O2+), Ti(H+,O+,He+),Te		90 – 20,000	NRLMSIS00 HWM93	Lat: 1 deg	IGRF-like	EUVAC
Self-consistent	SAMI3							
	TIEGCM	Tn, Un, Un, Ω, O_2, O, N(4S), NO,O^+,N(2D),Ti, Te, Ne, O_2^+, Z, Φ	GSWM02 migrating tides at LB, prescribed O+ flux at UB	97 to 450-600 depend on solar activity	97to 450-600 depend on solar activity	Low resolution: 5° by 5° (magn. grid has different resolution)	IGRF Apex	EUVAC for λ<1050A Woods & Rottman [2002] for λ>1050A
	TIMEGCM	Tn, Un, Vn, W, O2 , O, N(4S), N(2D), NO, Ne, O+, O2+, NO+, N2+, N+, Ti, Te, dynamo E-fields, Z (also many middle atmosphere parameters)		30 km (10 mb) to 450-600 depends on solar activity	30 km (10 mb) to 450-600 depend on solar activity	5° by 5° High Resolution: 2° by 2° (magn. grid has different resolution)	IGRF Apex	EUVAC for λ<1050A Woods & Rottman [2002] for λ>1050A
	GITM	Neutral Composition, UN,VN,WN,TN, Vi, Ti, Ni (O^+, O_2^+, NO^+, N_2^+, N^+), Te, Ne	GSWM migrating diur and semidiur tides	100-700	100-700	Long: 5° MagLat: 1°	IGRF Apex	EUVAC Hinteregger's SERF1 model
	CTIPe	Neutral Compositions, UN,VN,TN, Ni, Ti (O^+, H^+, O_2^+, NO^+, N_2^+, N^+), Ne	(2,2) mode	80 -10,000	80 - 500	Long: 18° Lat: 2°	Tilt Dipole	EUVAC
	IDEA	Same as GIP but use Whole Atmosphere Model as lower boundary						



- Height variation of density at magnetic equator in all models (except GIP) are consistent than IRI results at 2LT and 10LT.
- At 14LT, upper ionosphere decrease faster in IRI than other models.
- At 20LT, peak height in IRI is much lower than other models.

Coupled Models

Model	Output	Boundary Condition	Ionosphere Coverage (km)	Thermosphere Coverage (km)	Ionosphere Resolution	Magnetic Coordinate	Photoionization
SAMI3							
TIEGCM	Tn, Un, Vn, Ω, O_2, O, N(4S), NO,O $^+$,N(2D),Ti, Te, Ne, O_2^+, Z, Φ	GSWM02 migrating tides at LB, prescribed O^+ flux at UB	97 to 450-600 depend on solar activity	97to 450-600 depend on solar activity	Low resolution: 5° by 5° (magn. grid has different resolution)	IGRF Apex	EUVAC for λ<1050A Woods & Rottman [2002] for λ>1050A
TIMEGCM	Tn, Un, Vn, W, O2 , O, N(4S), N(2D), NO, Ne, O+, O2+, NO+, N2+, N+, Ti, Te, dynamo E-fields, Z (also many middle atmosphere parameters)	GSWM migrating diur and semidiur tides	30 km (10 mb) to 450-600 depends on solar activity	30 km (10 mb) to 450-600 depend on solar activity	5° by 5° High Resolution: 2° by 2° (magn. grid has different resolution)	IGRF Apex	EUVAC for λ<1050A Woods & Rottman [2002] for λ>1050A
GITM	Neutral Composition, UN,VN,WN,TN, Vi, Ti, Ni (O^+, O_2^+, NO^+, N_2^+, N^+), Te, Ne	GSWM migrating diur and semidiur tides	100-700	100-700	Long: 5° MagLat: 1°	IGRF Apex	EUVAC Hinteregger's SERF1 model
CTIPe	Neutral Compositions, UN,VN,TN, Ni, Ti (O^+, H^+, O_2^+, NO^+, N_2^+, N^+), Ne	(2,2) mode	80 -10,000	80 - 500	Long: 18° Lat: 2°	Tilt Dipole	EUVAC
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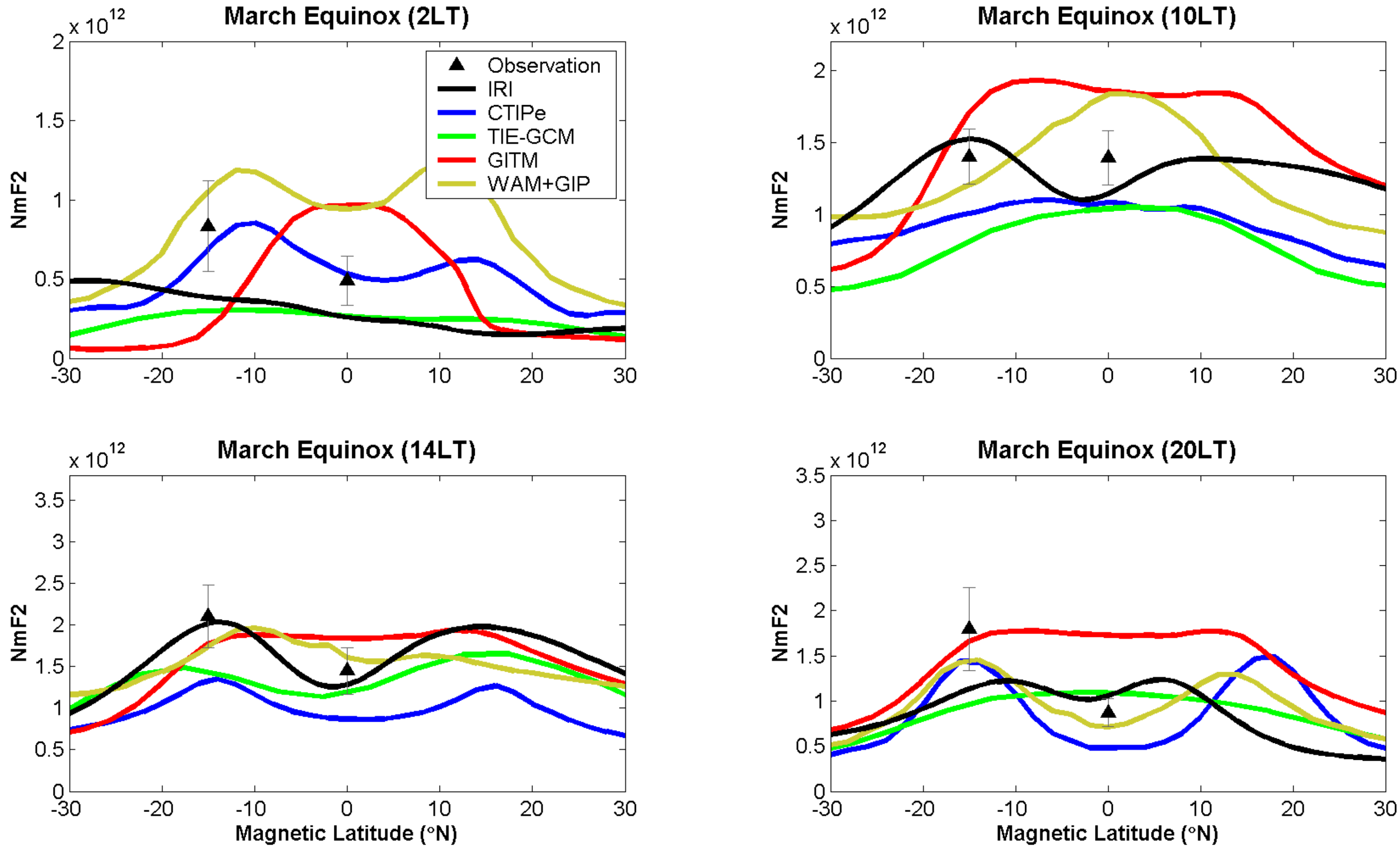
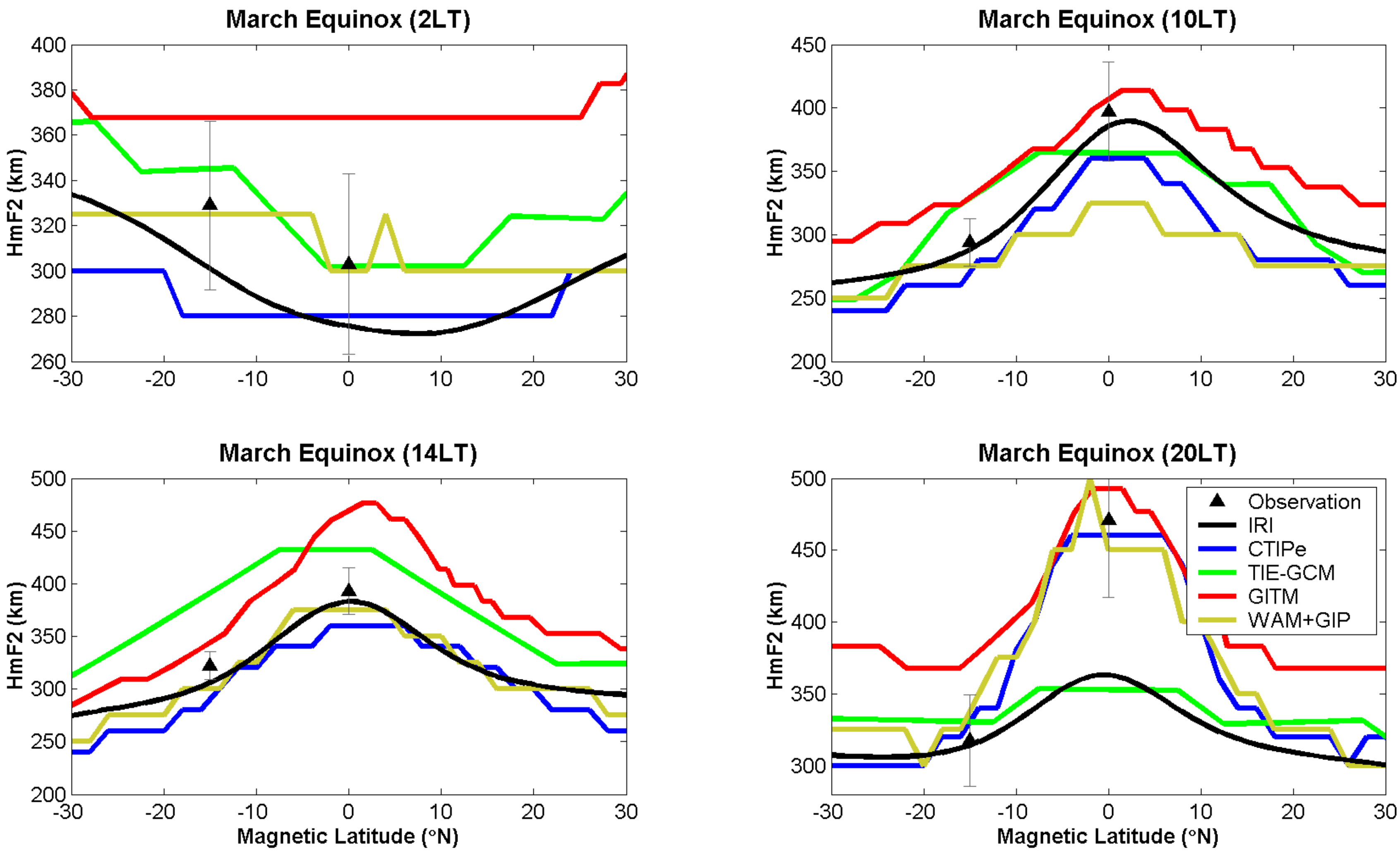
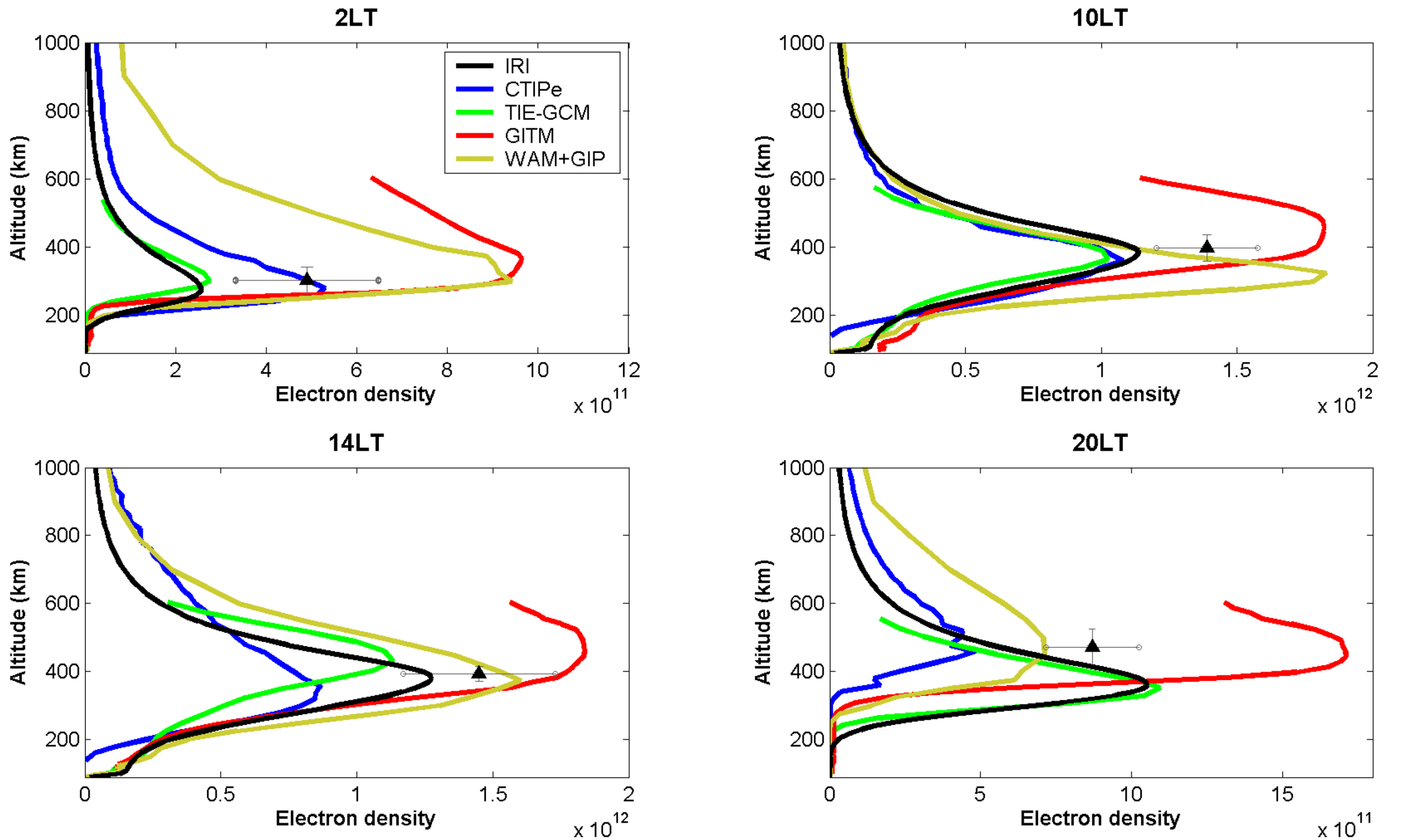


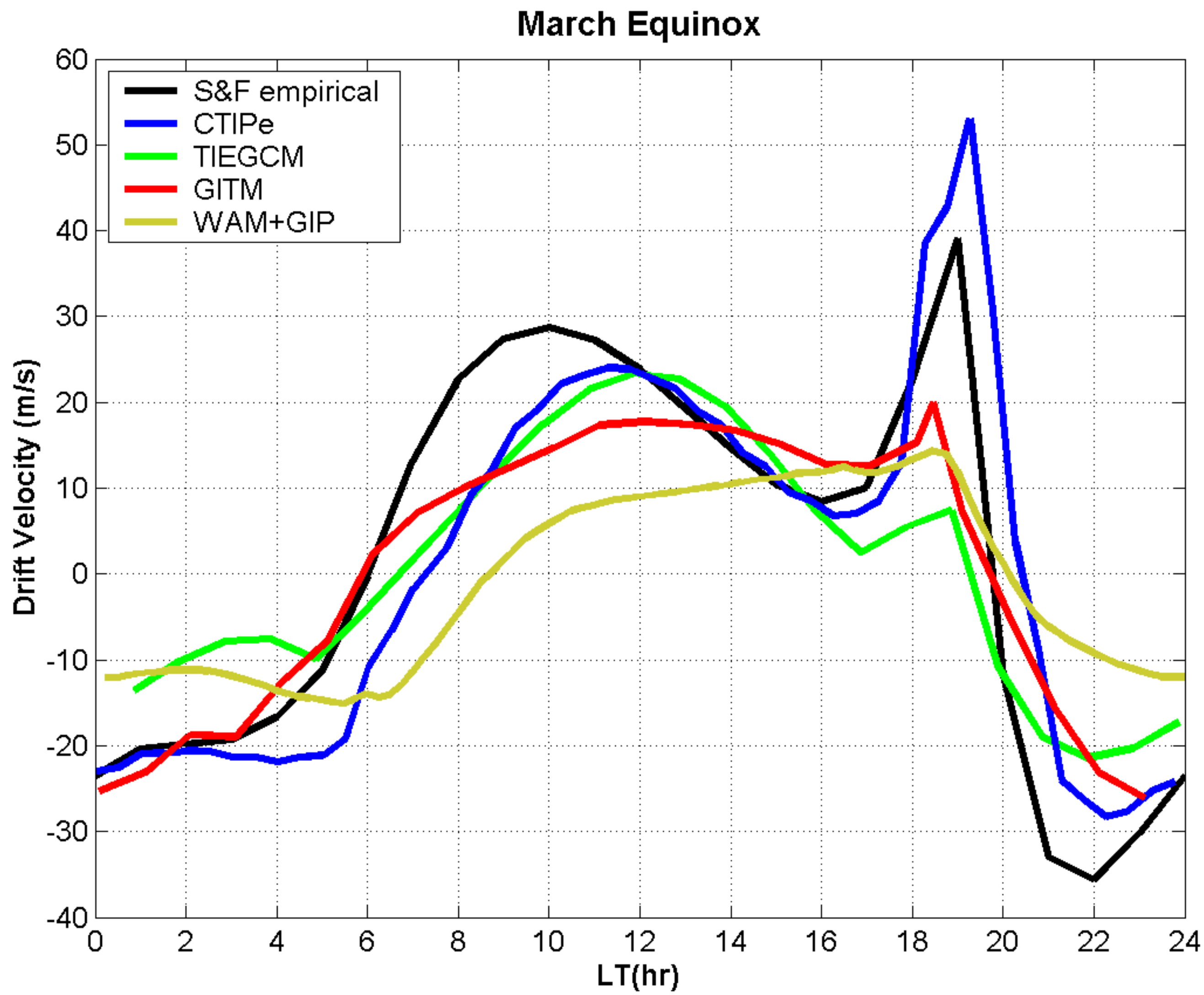
- Larger nighttime NmF2 in WAM+GIP is due to the TE problem in GIP.
- GITM also has problem in electron temperature and still in working progress.
- Daytime EIA signature is more pronounced in IRI and non-self consistent models than self-consistent models. Caused by smaller E×B drift? Wind?



- hmF2 differences among self-consistent models are larger in the nighttime.
- hmF2 in all models show a peak above magnetic equator at 14LT which is very different from non-self consistent models.

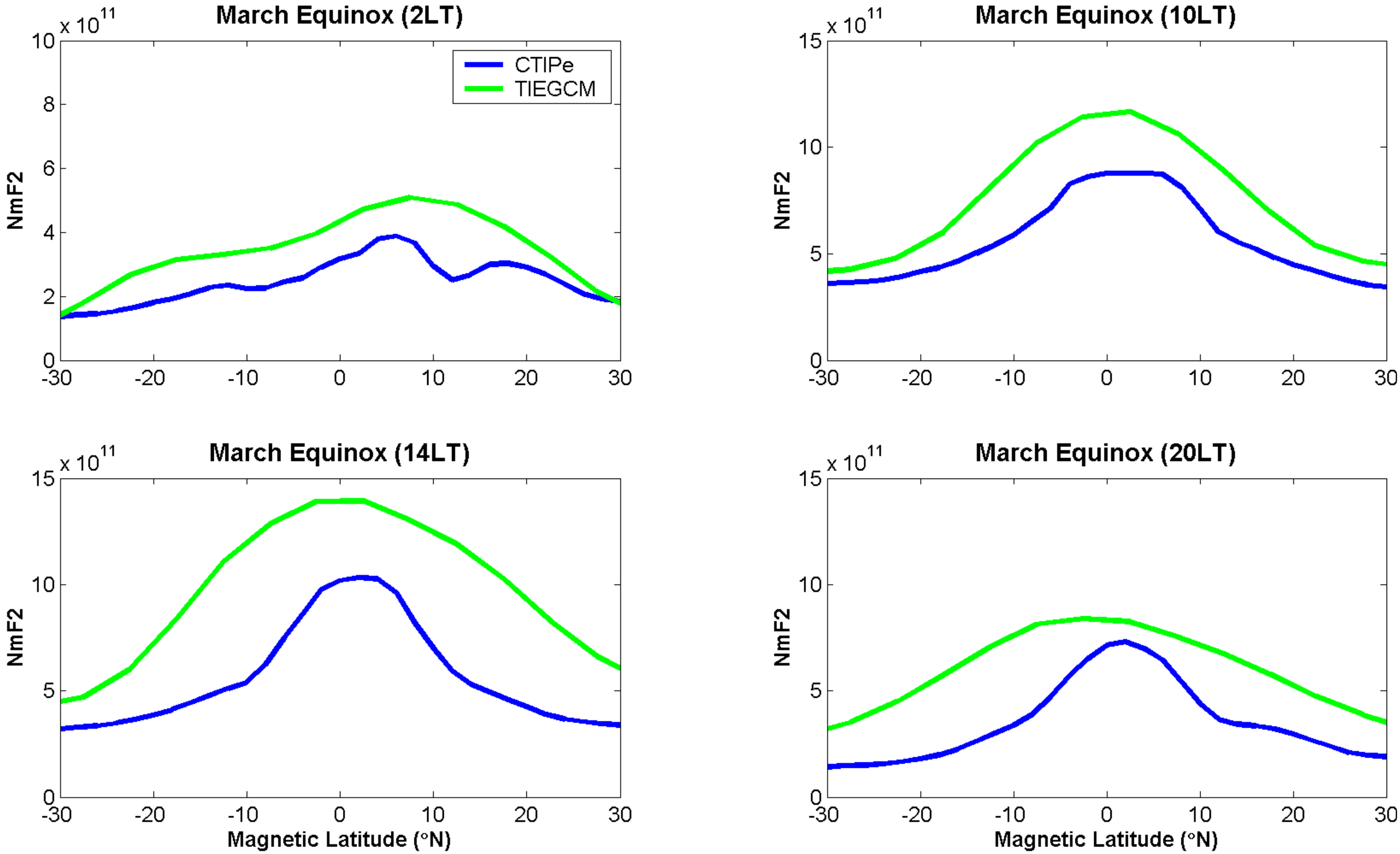


- Daytime Density prolife in CTIPe and TIEGCM are very similar at 10LT but not at 14LT.
- TIE-GCM agrees with IRI results rather well.
- Electron density profile at equator in WAM+GIP and GITM are too large.
- Height of density peak in nighttime CTIPe is higher than other models.

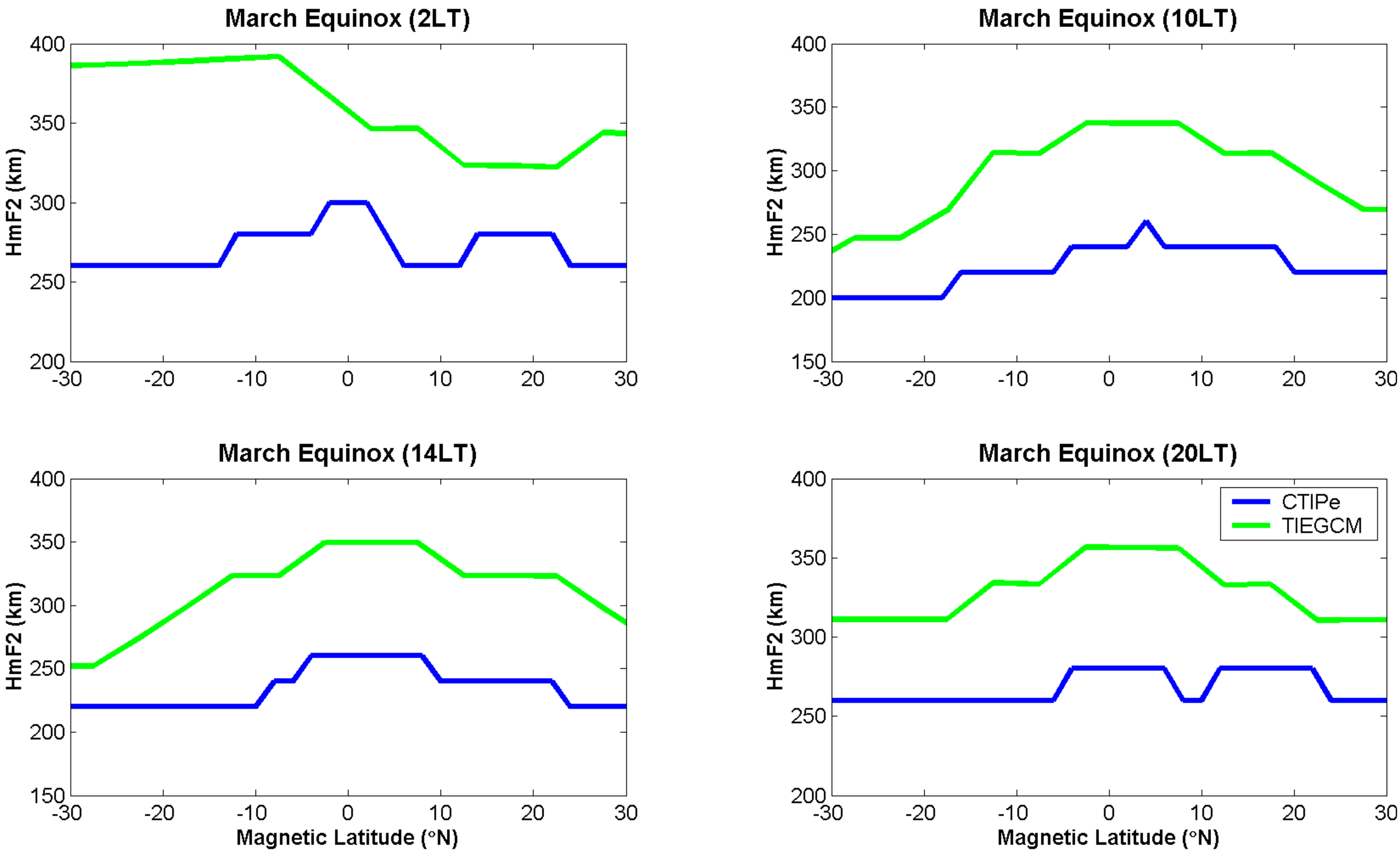


- Daytime vertical drift in CTIPe and TIEGCM are very similar.
- Significant LT differences in daytime peak drift may may due to different lower boundary conditions.
- In PRE, CTIPe gets larger value than empirical model while other models show smaller values.
- After sunset, empirical model show much stronger downward drift than all physical models.

Case 1: No ExB drift, no neutral wind (N_{max}) ➔ Production and Loss



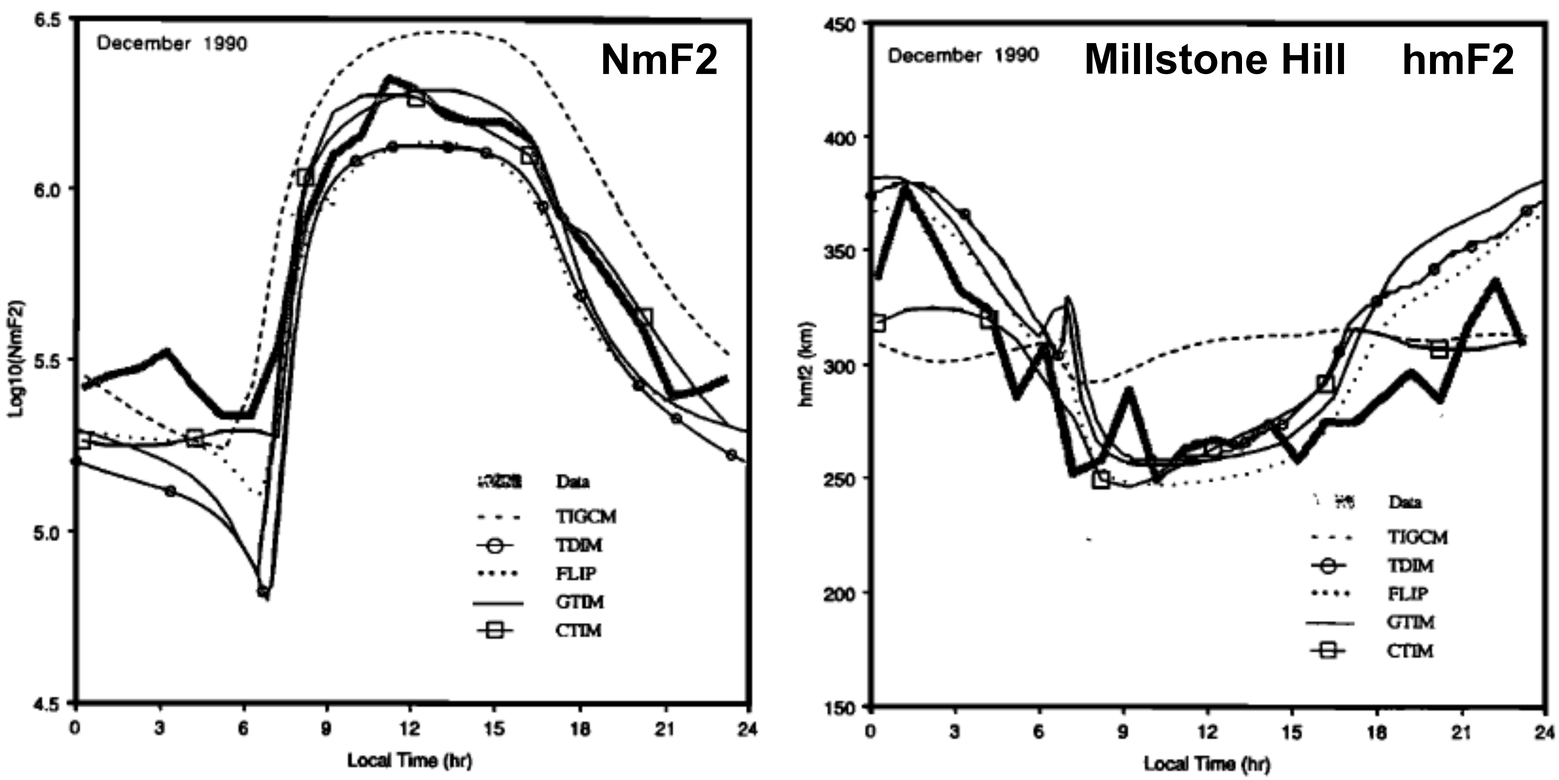
Case 1: No ExB drift, no neutral wind (N_{max}) ➔ Production and Loss



Backup Slides

Motivation and Objective

- Original PRIMO dealt with mid-latitude comparisons
  - Most theoretical models underestimated the noon-time, Nmax values by a factor of 2 at solar maximum.
  - Burnside Factor (the collision frequency between O^+-O) in the topside was multiplied by 1.7. But today, the evidence suggests the factor is closer to 1.0.

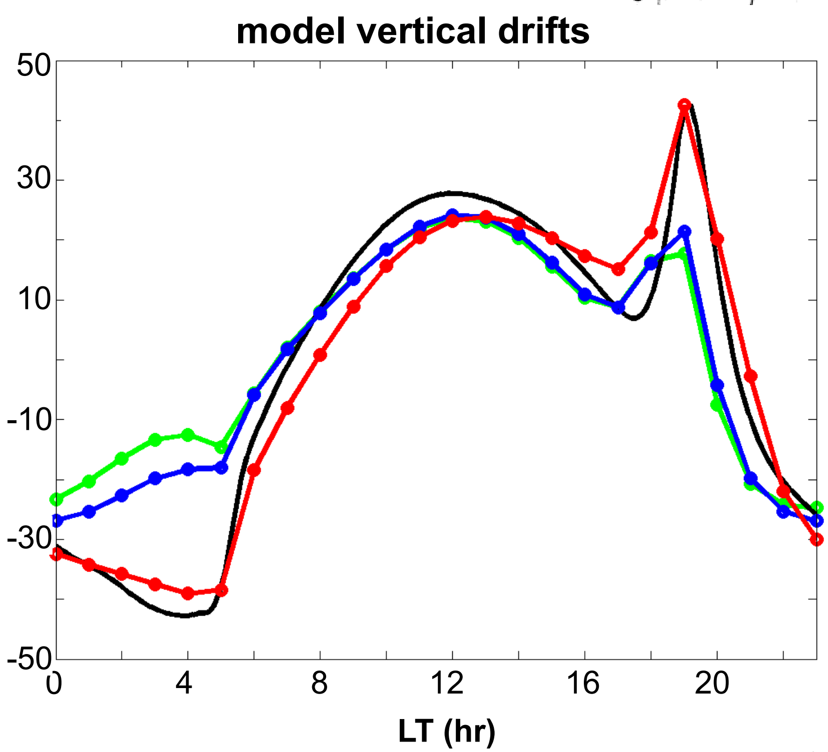


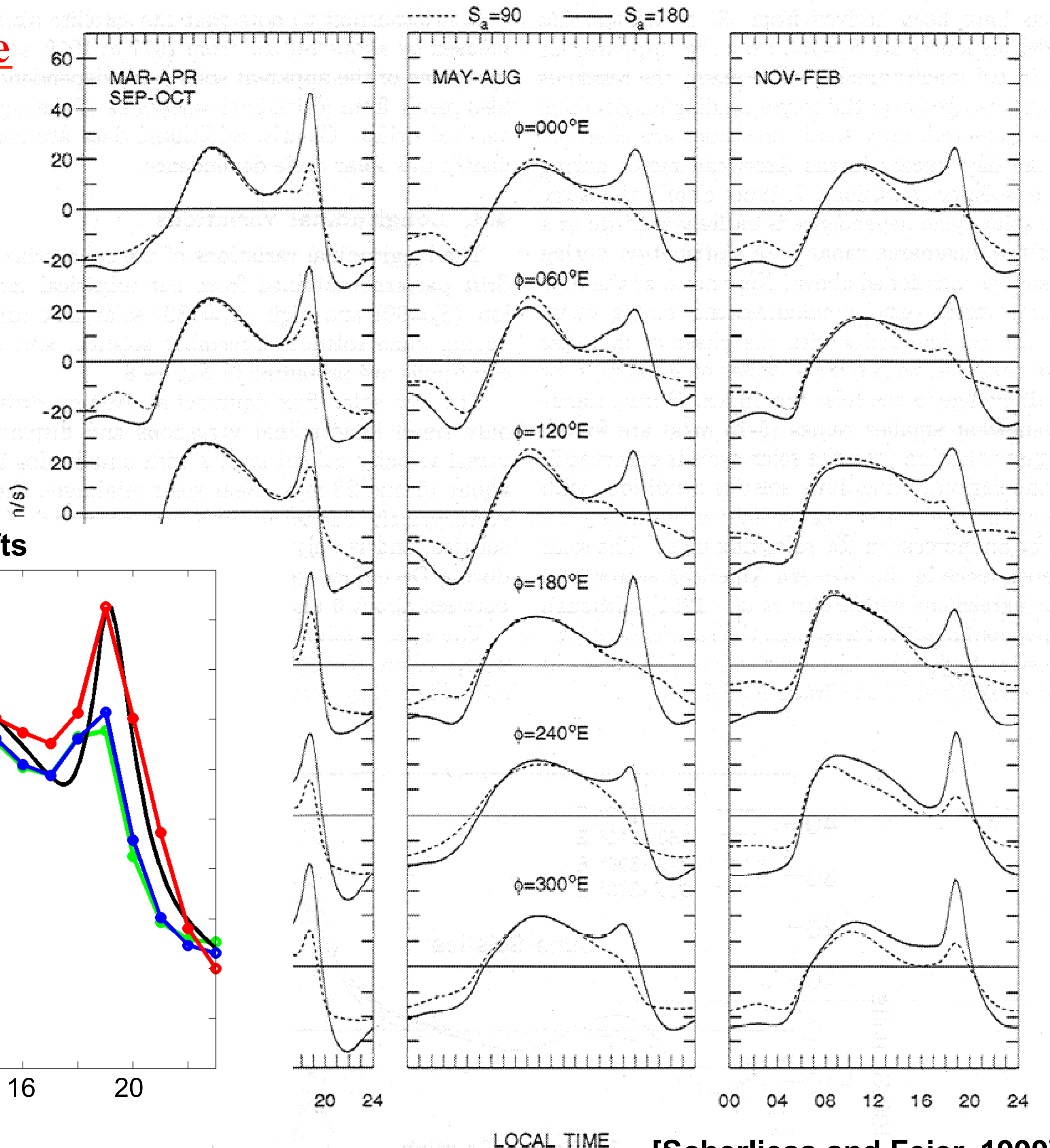
Self consistent model – TIGCM and GTIM

[Anderson et al. JGR, 1998]

Motivation and Objective

The vertical drift and global electric field at equatorial region are calculated through the electrodynamics process which is strongly controlled by the neutral wind velocity, ionospheric conductivity, and geomagnetic field.





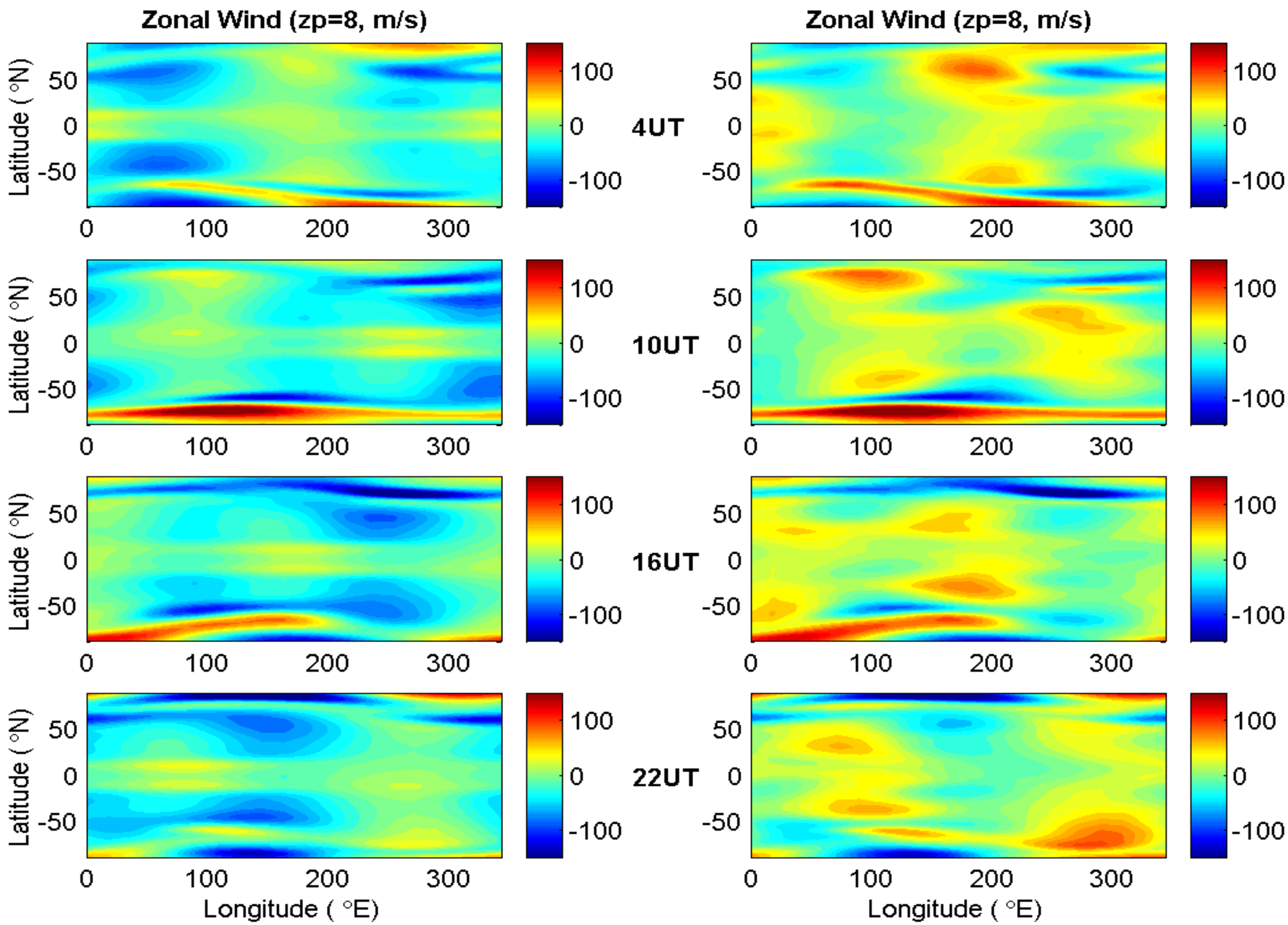
[Scherliess and Fejer, 1999]

Conclusions:

- Basically, the non-self consistent models are in good agreement with each other, except the nighttime portion of GIP. They also agree well with IRI and observation especially in the daytime.
- The self-consistent models produce daytime N_{max} values at the crests of the equatorial anomaly that are substantially less than the non-self consistent model values – does not seem to be due to E×B drift velocities.
- The differences among self-consistent models are quite significant which imply very different electric field, neutral wind, and temperature may be resulted in each model.
- The occurrence time of daytime maximum drift are different in self-consistent models which indicates the possible differences of lower boundary condition in models. The magnitude of pre-reversal enhancement can directly result in different nighttime ionosphere.

The Way Forward:

- Initially try to reconcile the difference between the two sets of models.
  - Lower boundary conditions, magnetic coordinate
  - Photoionization, electron temperature model, reaction rates, etc.
- Conduct similar comparison in June and December solstice.
- Compare neutral density, temperature, and wind velocity among self-consistent models.



Global zonal wind velocity (eastward positive) at 4, 10, 16 and 22UT at zp=8 (~135 km) from original CTIPe (left) and from CTIPe with Whole Atmosphere Model (WAM) at lower boundary (right).

Example: We implement the geopotential height, neutral temperature, zonal and meridional wind from the Whole Atmosphere Model (WAM) as the lower boundary of the CTIPe. Larger changes can be found in zonal and meridional wind at dynamo region of ionosphere. These changes can result in different vertical drift at magnetic equator and further modulate the distribution of global ionospheric density.

Current Progress:

Generally, results of non-self consistent models agree well with each other in the daytime. But large discrepancy in N_mF_2 can be found at EIA crests. We propose to understand the diffusion coefficient among non-self consistent models as our first step to figure out the causes.

Diffusion Coefficient:

In GIP, the ion temperature (T_i) is calculated through the energy balance equation. T_i depends on electron temperature (T_e) and neutral temperature (T_n). Tn is directly from MSIS. However, T_e is scaled T_n through empirical relation. Ion-ion collision frequency followed Quegan et al. (1981) and ion-neutral collision frequency followed Raitt et al. (1975).

E×B drift:

In GIP, vertical drift is zero at 100km. F&S empirical drift is used for flux-tubes with apex heights from 300km to 1000km. Linear interpolation between 100-300km. The Richmond model is used for flux-tubes with apex heights greater than 2000km. Between 1000km and 2000km a linear interpolation between the two is used.

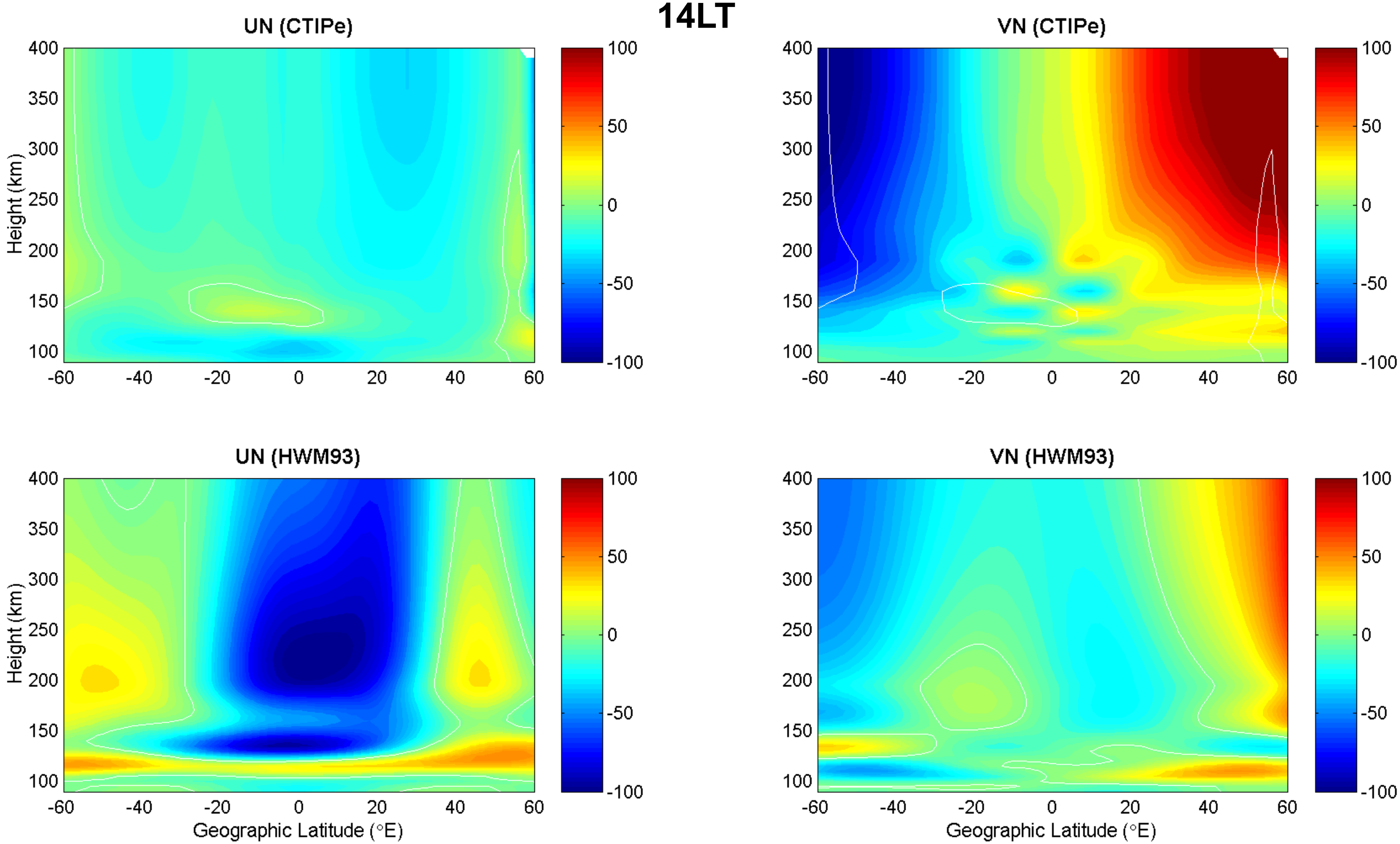
Questions to modelers:

1.) How are the T_i, T_e calculated in different models? Is T_n from MSIS?

2.) What kind of ion-ion and ion-neutral collision frequency are used in the model?

3.) Is there any height dependent on applying E×B drift in the model?

14LT

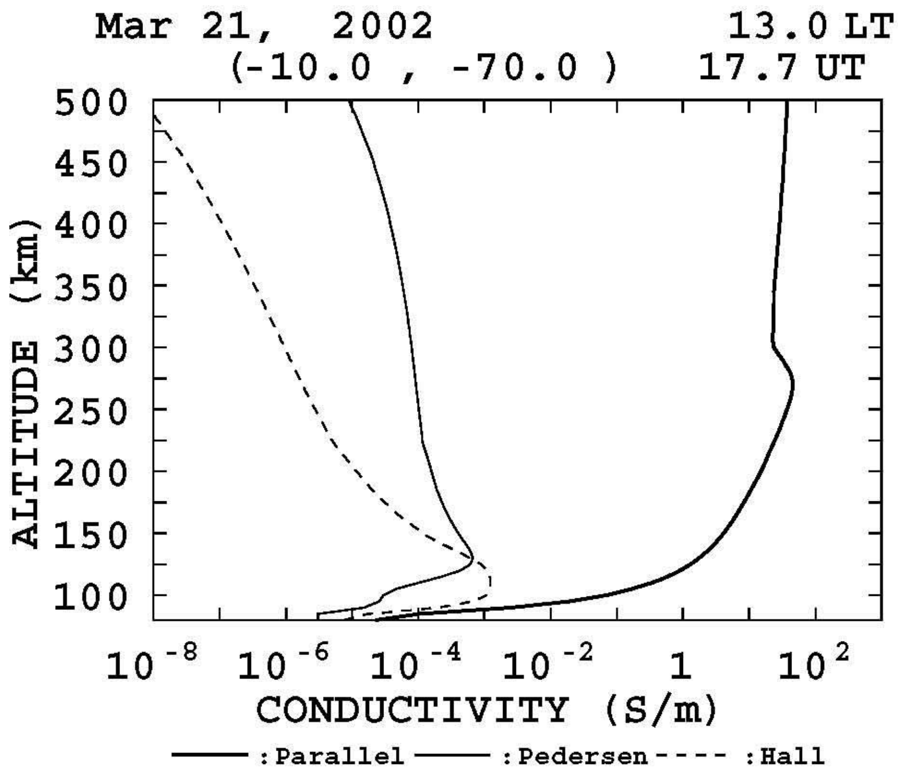


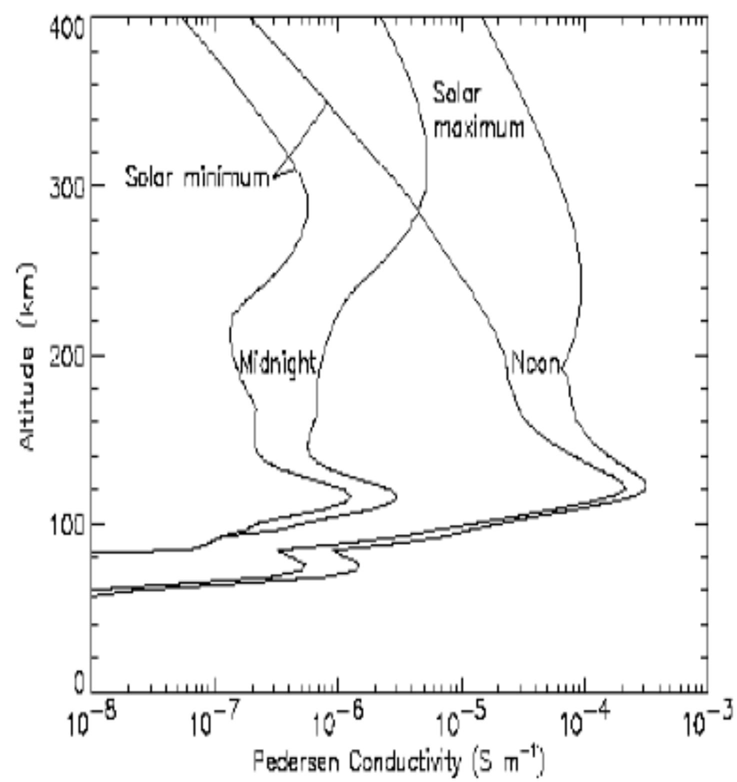
The comparisons of zonal and meridional wind from the CTIPe and HWM93. It shows that HWM produces larger zonal wind and smaller meridional wind compared to the CTIPe.

Will the neutral wind be a good start for understanding the difference between the two sets of models?

Thank You

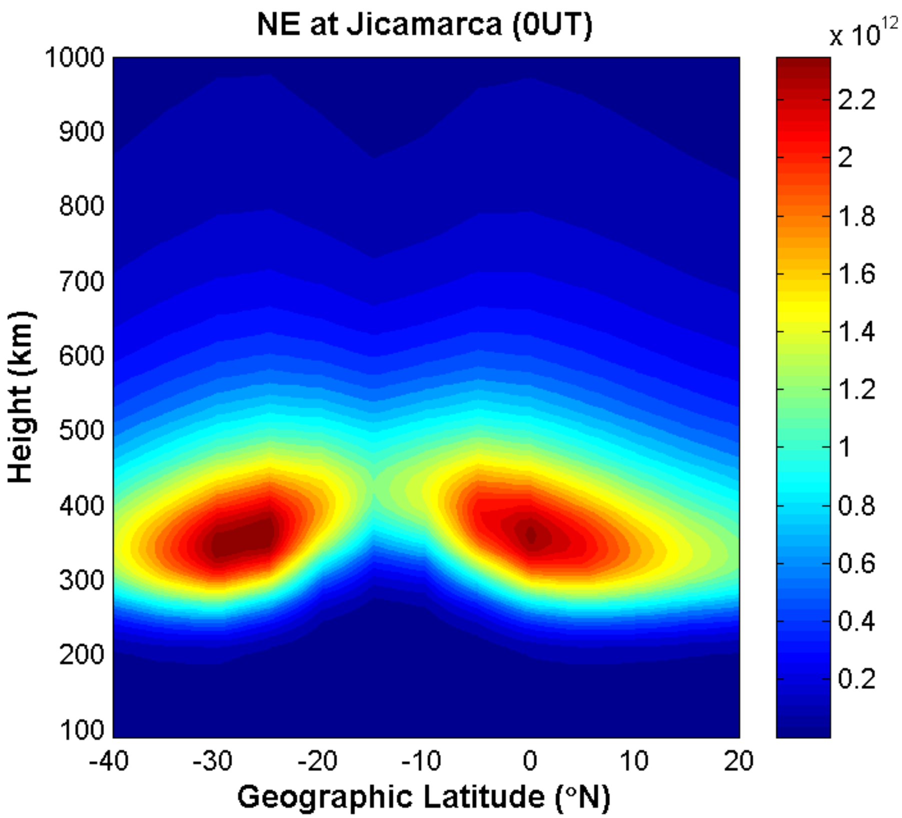
For self-consistent models, the daytime and nighttime Pederson and Hall conductivities (±30° Lat vs. height) in Jicamarca longitude.

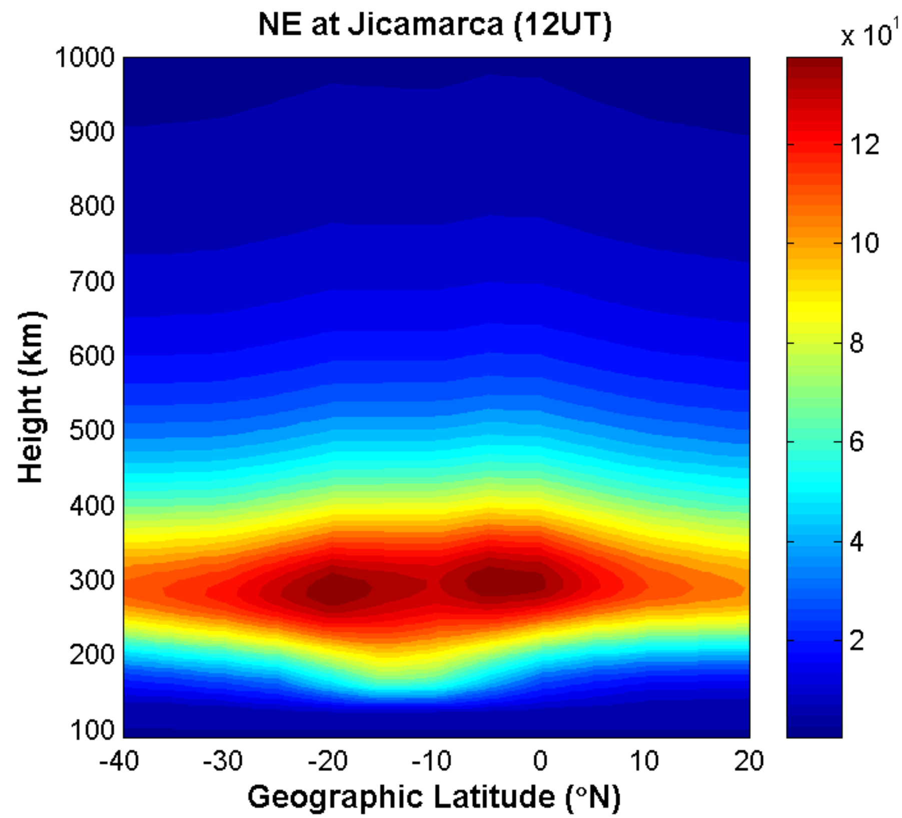




http://wdc.kugi.kyoto-u.ac.jp/ionocond/sigcal/index.html

The daytime and nighttime electron density distribution (±30° Lat vs. height) at Jicamarca longitude.





The zonal and meridional wind velocity (Lon vs. ±60° Lat at 0UT) at 120 km (or E region) and 300 km (or F region) used as specified input or generated by the model.