CTIPe model at CCMC

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Outlines

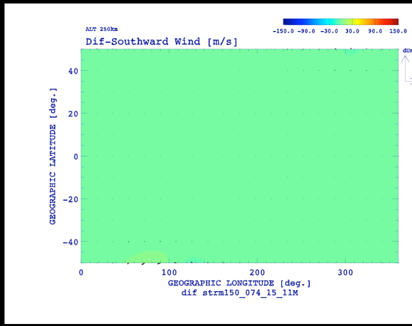
- What is CTIPe model?
- Validation: Neutral mass density, Phase velocity
- Data Assimilation: Neutral mass density
- Real time CTIPe
- CTIPe Model Limitations
- A New Ionosphere Plasmasphere Electrodynamics (IPE) model
- Coupling to other regimes: RCM, OpenGGCM
- Whole Atmosphere Model (WAM)
- Future Challenges
- Summary

Coupled Thermosphere Ionosphere Plasmasphere self-consistent electrodynamics (CTIPe)

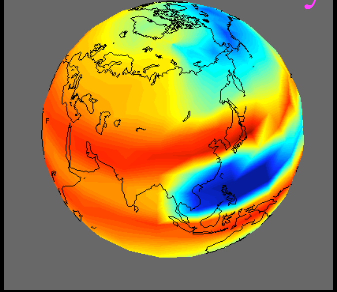
[Fuller-Rowell et al., 1980; Millward et al., 2001]

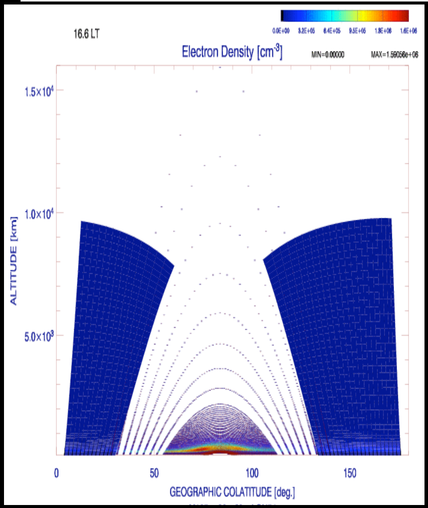
- Global thermosphere 80 - 500 km: eq. momentum, energy, composition, V_x, V_y, V_z, T_n, O, O_2, N_2, ….
- High latitude ionosphere (L>~4): 80-10,000 km: eq. continuity, momentum, energy, O^+, H^+, O_2^+, NO^+, N_2^+, N^+, V_i, T_i,
- Plasmasphere, and mid-/low-latitude ionosphere (L<~4)
- Self-consistent electrodynamics

Neutral Wind



Electron Density

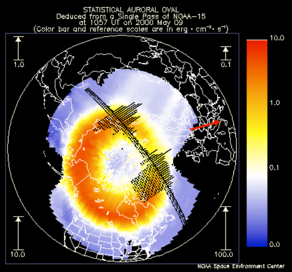




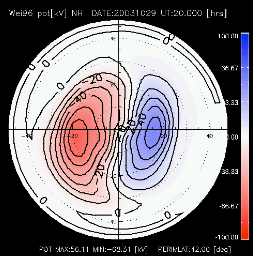
Model Inputs:

- solar UV/EUV
- Tidal forcing
- TIROS/NOAA Auroral precipitation
- Weimer convection E-field

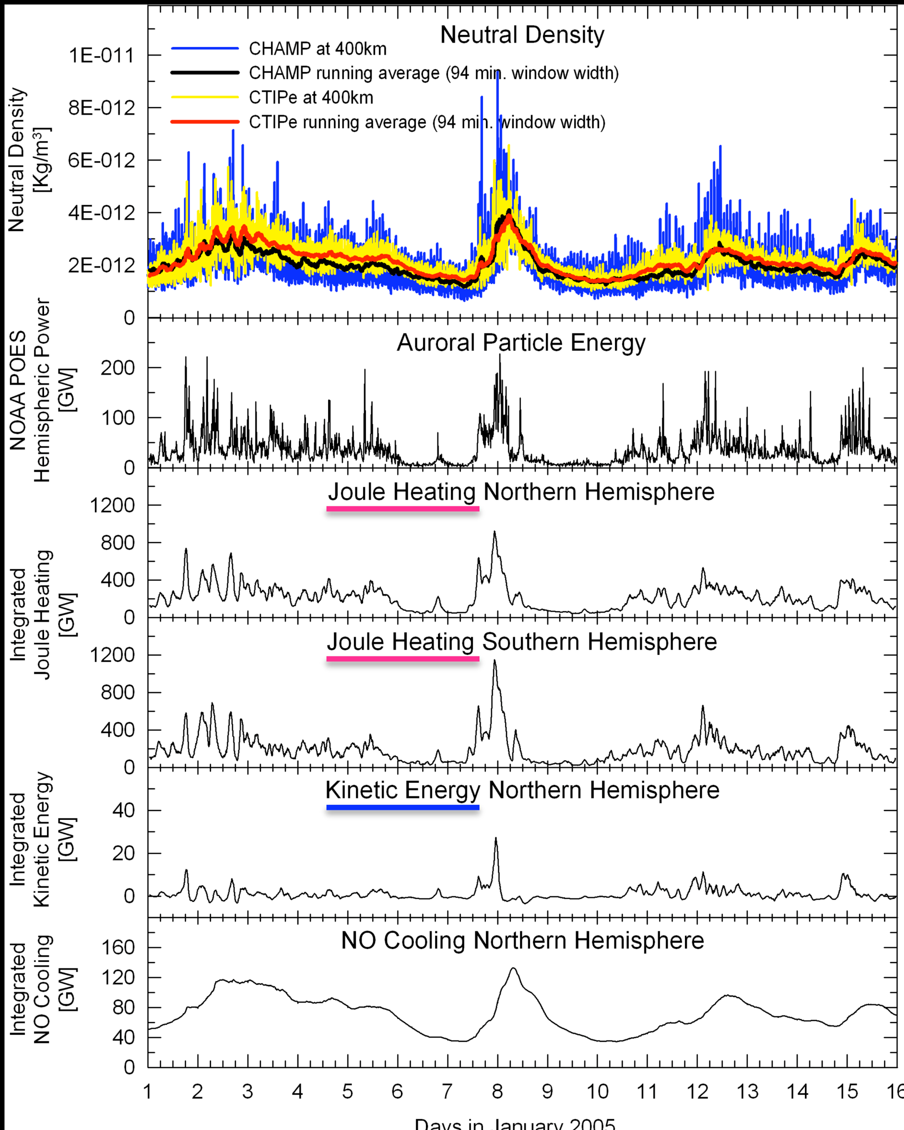
TIROS/NOAA



Weimer



Neutral Mass Density agrees well with Obs.



$$\vec{J}_\perp \cdot \vec{E} = \underline{\vec{J}_\perp \cdot \vec{E}'} + \underline{\vec{U} \cdot \left(\vec{J} \times \vec{B}\right)}$$

Joule Heating

kinetic energy

- response of the neutral density to moderate storms captured by the model.
- indicating energy budget well described in the model.
- JH: major energy source dissipated from magnetosphere to IT system.
- JH >> Auroral precipitation (factor of ~4)
- NO: major cooling process of the thermosphere, controlling the recovery

[Fedrizzi et al., 2011] AFOSR NADIR-MURI

Traveling Atmospheric Disturbances (TAD): phase velocity agrees with obs.

CHAMP
Observed speed: 546 m/s

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- TAD: JH→Pressure gradient→ disturbed U, T,N, propagating to equator, opposite hemisphere
- movie: example of TAD in Un
- Phase velocity of density waves: agrees with obs.
- Great news! No previous wind data!

CTIPe speed: 546 m/s

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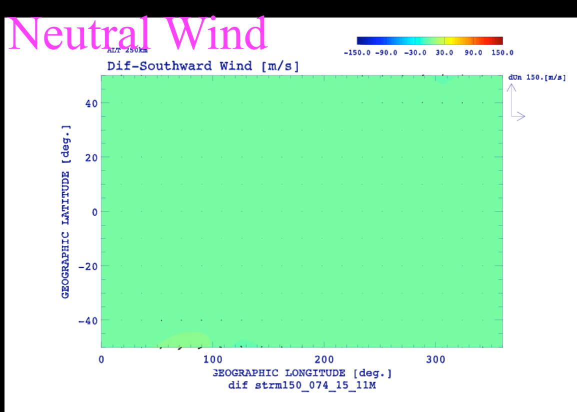
[Bruinsma et al., 2011]

15 May 2005
dayside results (LT=9.3)



DA Improves Neutral Mass Density Specification

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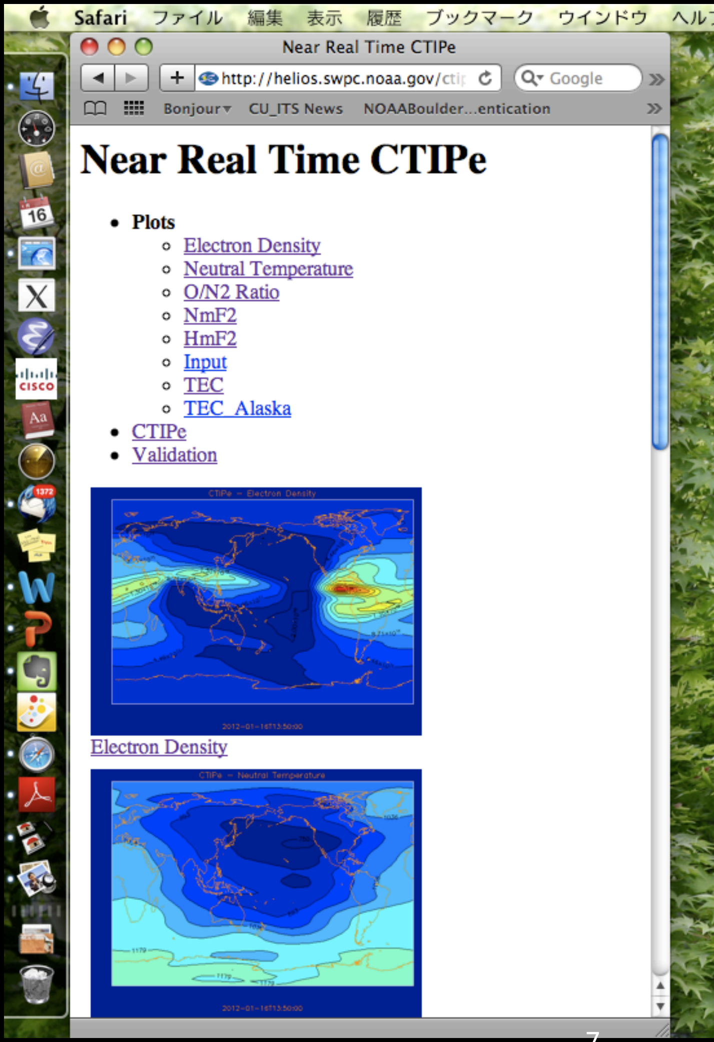
[Matsuo et al., 2012] AFOSR NADIR-MURI

Real Time CTIPe

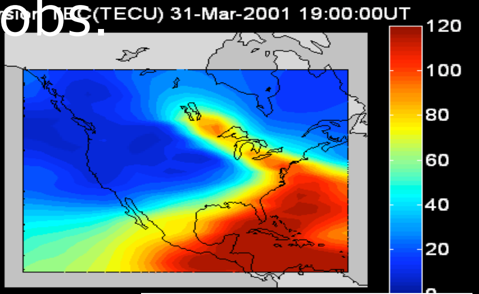
- http://helios.swpc.noaa.gov/ctipe/TEC.html
- Automatically get the ACE (solar wind) data to drive WEIMER and NOAA/TIROS hemispheric power to drive the auroral precipitation.
- ~20 min. ahead of real time (forecast)
- Figures updated every 10 min: Ne, Tn, O/N2, NmF2, HmF2, TEC, etc.
- Automatically validated everyday @60 stations: NmF2 & hmF2
- http://helios.swpc.noaa.gov/ctipe/VandV_Stations_nmf2_hmf2.html

[Codrescu et al., 2012, in press]

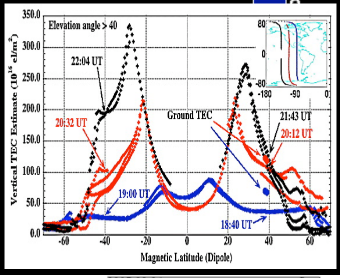


CTIPe Model Limitations

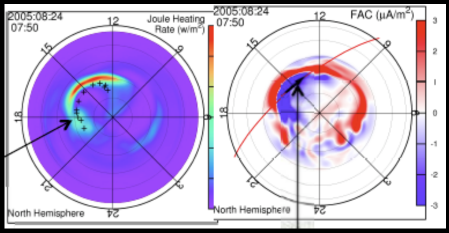
- Tilted dipole geomagnetic field: disagreement with obs.



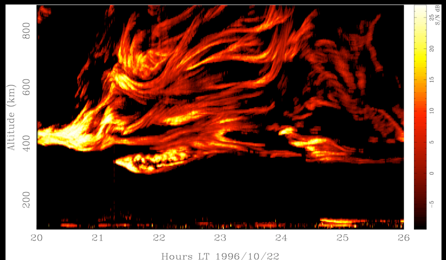
- No transport in zonal direction & across boundary:
  - → SEDs, TEC gradients
- No self-consistent calculation of Te/Ti:
  - → a NEW IPE model



- No storm time penetration E-field: →coupling to RCM



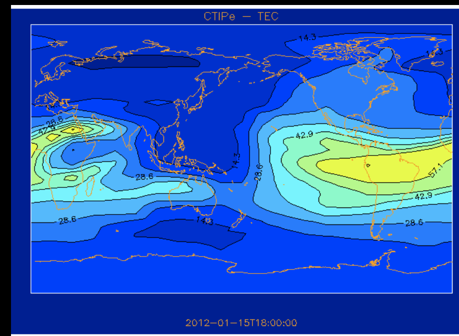
- Empirical Polar Cap Potential (Weimer):
  - → coupling to global MHD
- Climatological tidal forcing from lower atmosphere:
  - →WAM
- No plasma irregularity physics included
  - → coupling to Irregularity model



New Ionosphere-Plasmasphere-Electrodynamics (IPE) model

Ne

Tilted Dipole (CTIPe)

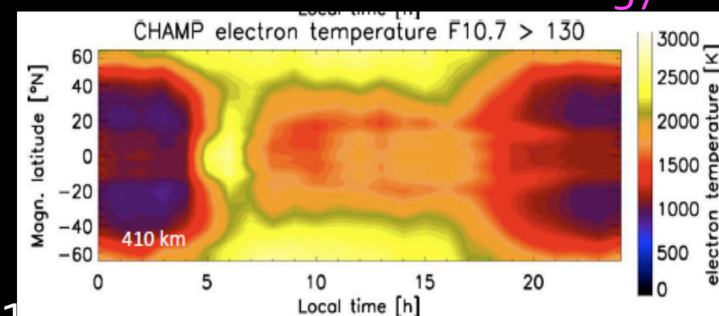


Te: IPE

Te

IGRF (IPE)

Te: CHAMP obs. Climatology



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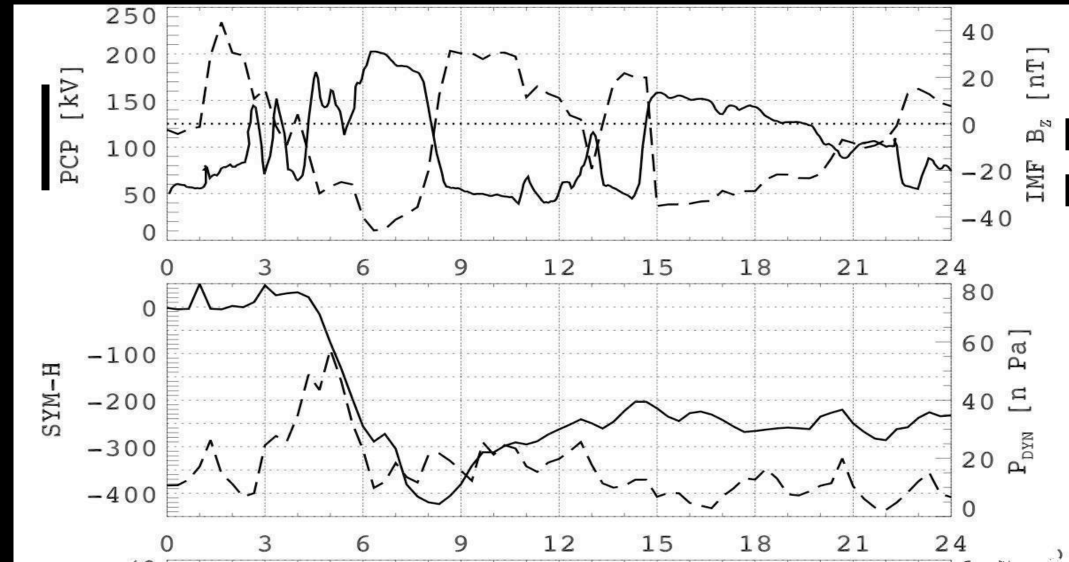
- Realistic geomagnetic field (IGRF) by APEX [Richmond, 1995]
- Global & seemless transport all the way to the poles
- Te/Ti & photoelectron flux: self-consistent calculation [Richards et al.]
- Te: qualitative agreement with CHAMP obs. climatology
- High/flexible Spatial Resolution (TEC gradients)
- Self-consistent calculation of ionospheric potential [Richmond et al.] on the same grid
- New CTIPe coming soon with the new IPE model

Electrodynamic Coupling to RCM: Penetration E-fields



GLON=122[deg]

March 31 2001 Storm

- Observation is obtained from ΔH-magnetometer inferred Drift: limited to Dayside only.
- Daytime eastward E-field dominated by PP effect in both Philippine (122deg) and Jicamarca (283deg).
- Nightside: Both PP and DD effects are comparable. PP is westward, whereas DD is eastward. The combination makes the total storm time E-field look more complicated.

day

GLON=283[deg]

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day

ΔH-inferred Drift from Dave Anderson

IT system feedback on Magnetosphere (Overshielding)

Eradial[mV/m]

Eazimuth[mV/m]

Plasma pressure [nT]

+Earthward

DAWN

coupled CTIP-RCM

SUN

DUSK

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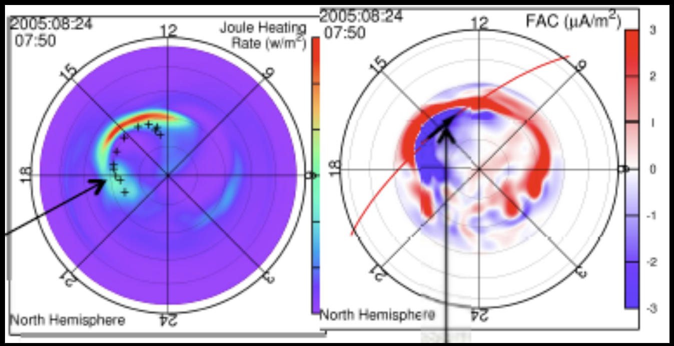
standalone RCM

Coupling to OpenGGCM: improved specification of high latitude forcing



OpenGGCM JH
DMSP Poynting flux

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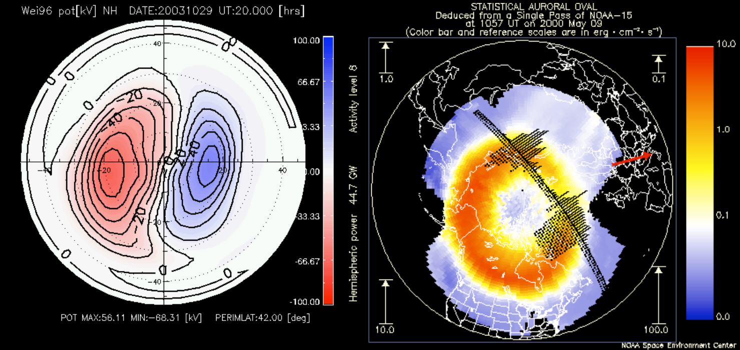
OpenGGCMHCTIM
CHAMP density

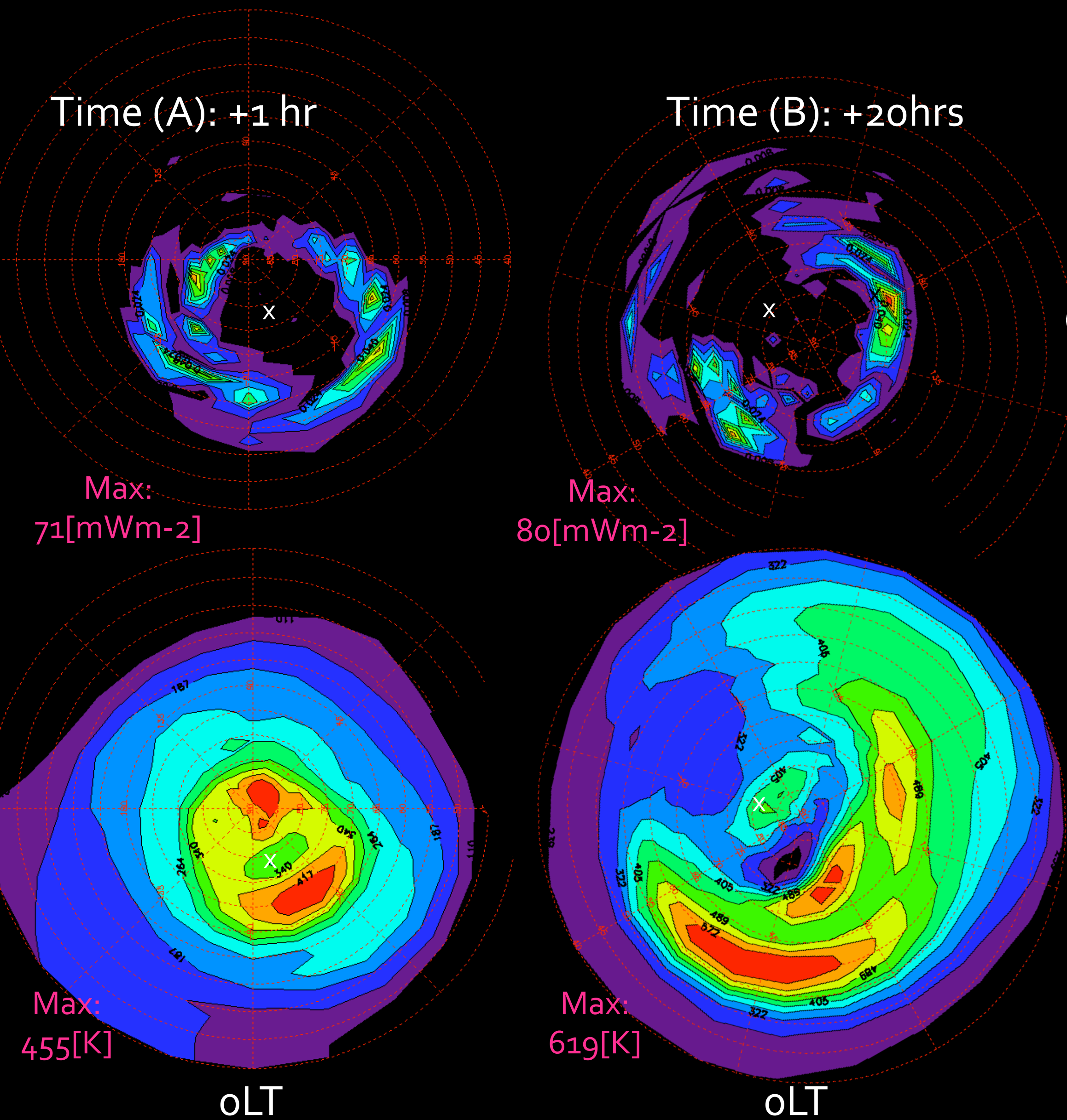
IMF By
IMF Bz

[Jimmy Raeder and Wenhui Li, 2012]

Joule heating /= Tn (Nn)

Enhanced Convection & auroral Σ





CTIPe Joule Heating (JH):

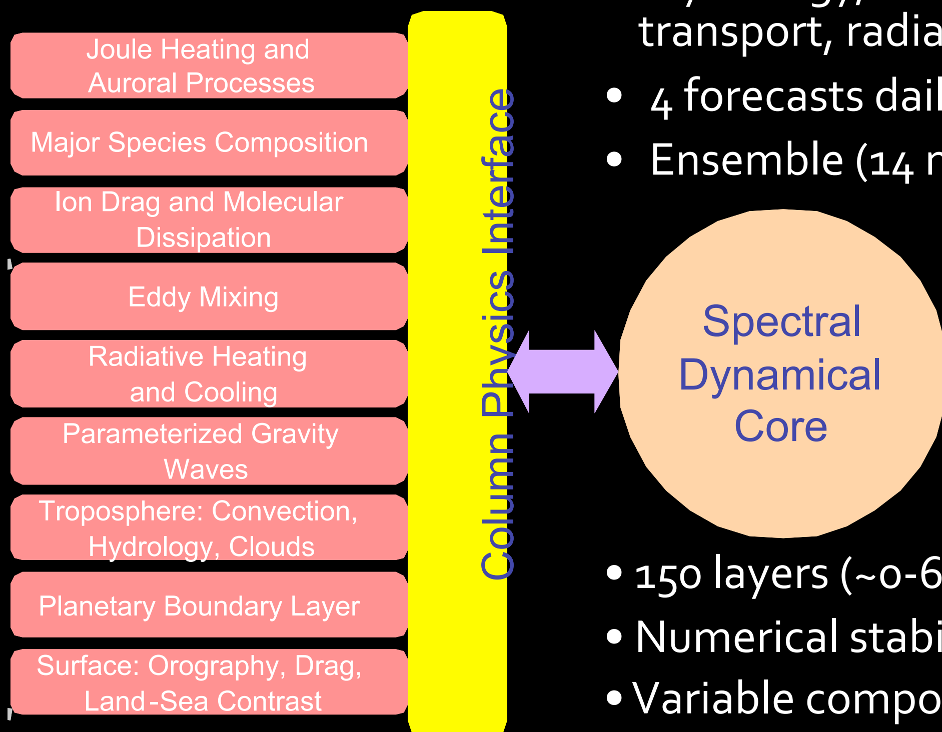
(A) Enhanced convection and aurroral Σ increase JH.
(B) JH enhances both in magnitude & space.

Tn response:

- Tn increases as a result of the JH
- spatial distribution: JH /= Tn because Tn increases as a result of integrated effect over the previous 20 hours [*Fuller-Rowell et al., 1994*].

Whole Atmosphere Model (WAM)

WAM = Extended GFS + Physics



<u>Operational Global Forecast System@NCEP</u>

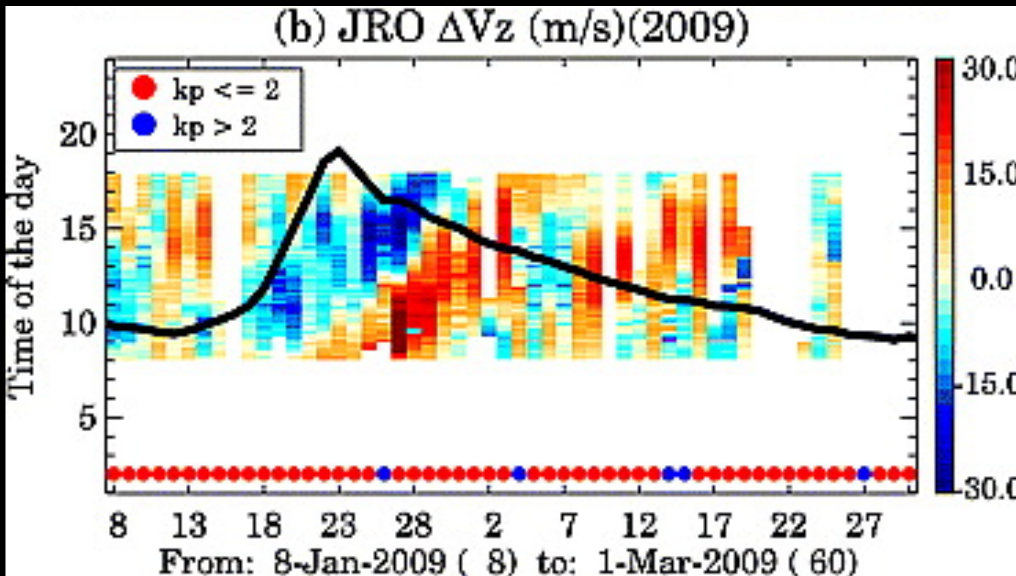
- T382L64 (~.3°X.3°, ~0-62 km)
- Hydrology, surface exchange processes, ozone transport, radiation, cloud physics, etc.
- 4 forecasts daily
- Ensemble (14 members) forecast up to 16 days

<u>WAM</u>

- 150 layers (~0-600 km) $\Delta\rho/\rho \sim 10^{13}$
- Numerical stability issues
- Variable composition thermodynamics
- Column physics (some exceptions)
- Timing: ~13 min/day on 21 nodes @ T62L150

[Fuller-Rowell et al., 2008; Akmaev et al., 2011]

Sudden Stratospheric Warming (SSW) Impacts IT system



- Modified polar vortex, T increase several tens [K]
- ionospheric equatorial E-field reversed in PM
- SSW reproduced by WAM
- Response of the Equatorial E-field to SSW reproduced by feeding the WAM winds into the electrodynamics solver.
- Very hot! ISSI workshop, Bern, Nov 2011

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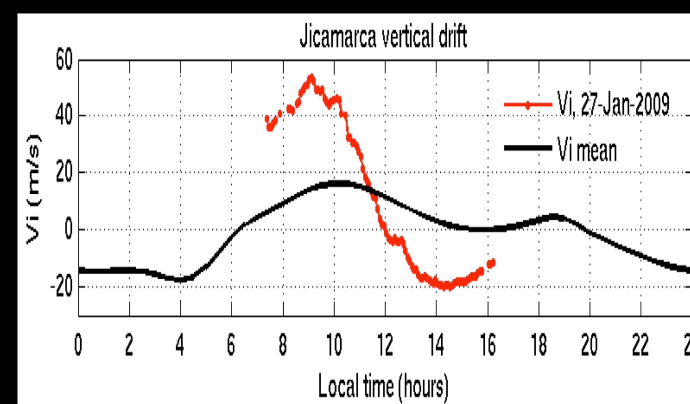
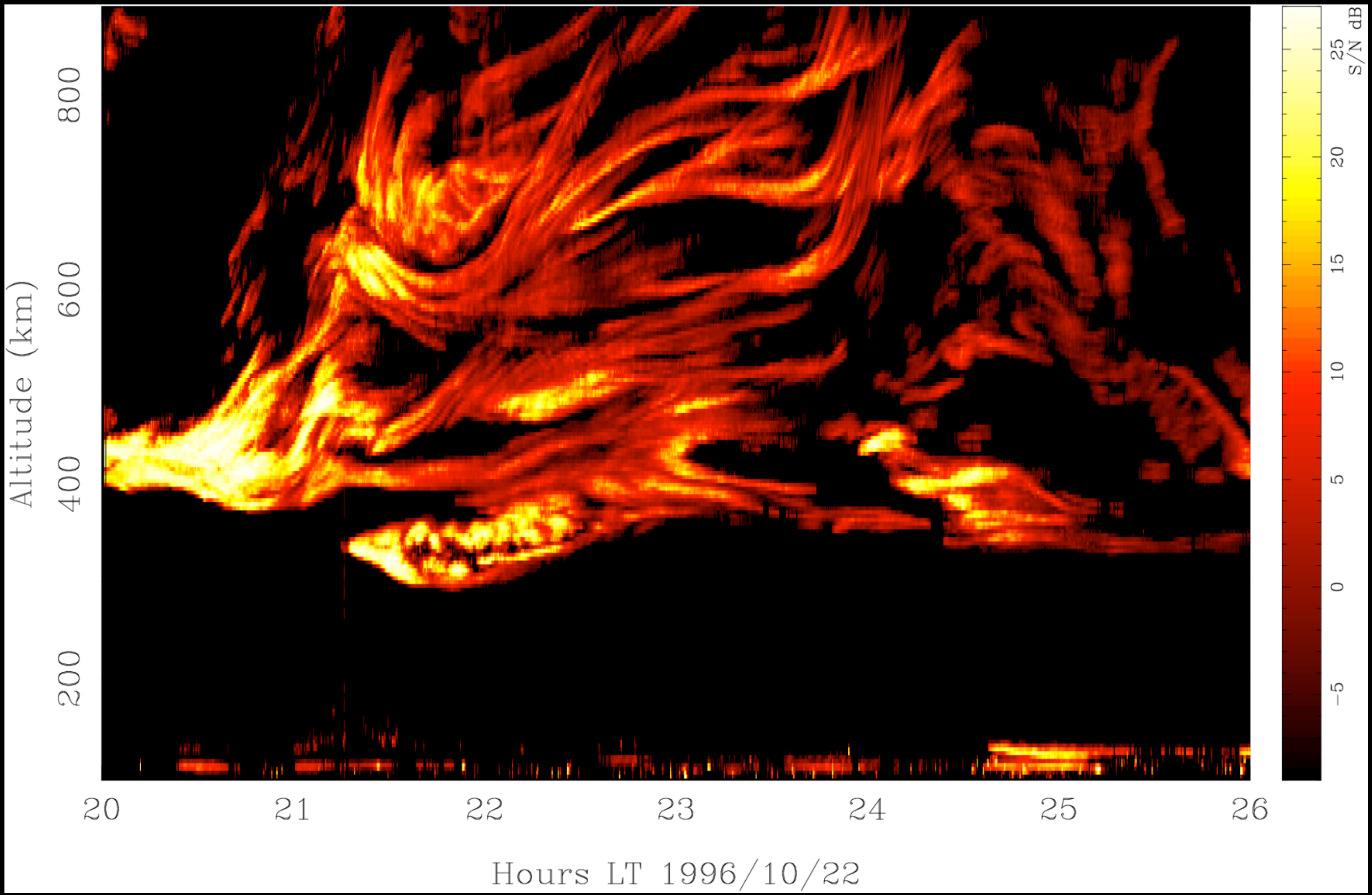


Future Challenges: Application to plasma irregularities?

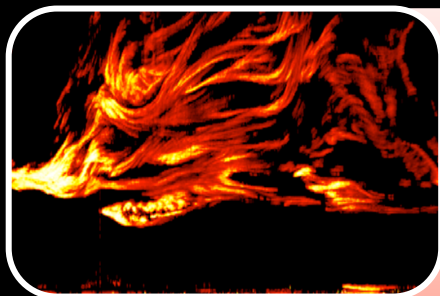


JULIA radar observations (Hysell & Burcham, 1998)

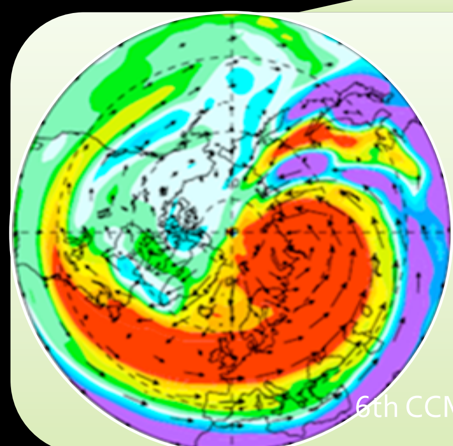
WSA-ENLIL
Solar Wind

Magnetospheric Models

- Convection electric fields
- Auroral precipitation



Irregularity Models



WAM-IPE

- Large-scale dynamics
- Wave seeding
- Plasma densities
- Electric fields
- Plasma drifts

Summary

- Ionosphere-Thermosphere models have become mature
- Basic climatology understood, reproduced, but not yet weather
- Validation needed to identify what's missing in the model: e.g., penetration E-field, Cusp Poynting flux enhancement, SSW, plasma irregularities, etc.
- Coupling to other regimes & DA have become more important to address the new science questions in our group (& in the IT community as well?)
- Choose the appropriate model(s) to tackle your science question

Collaboration with CCMC

- Continue to provide updates when the latest version available
- Flexible Model Inputs: e.g., Weimer (empirical) → AMIE (data assimilation)
- Real Time Forecasts for International Space Station (ISS) (M. Hesse)
- NASA Heliophysics Summer School 2010/2011 (J. Sojka):

http://ccmc.gsfc.nasa.gov/support/HSS_2011.php

- Participate in challenges: CEDAR CETI (B. Emery), joint GEM-CEDAR

Thanks!

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- NOAA & SWPC