

CTI_Pe to IPE

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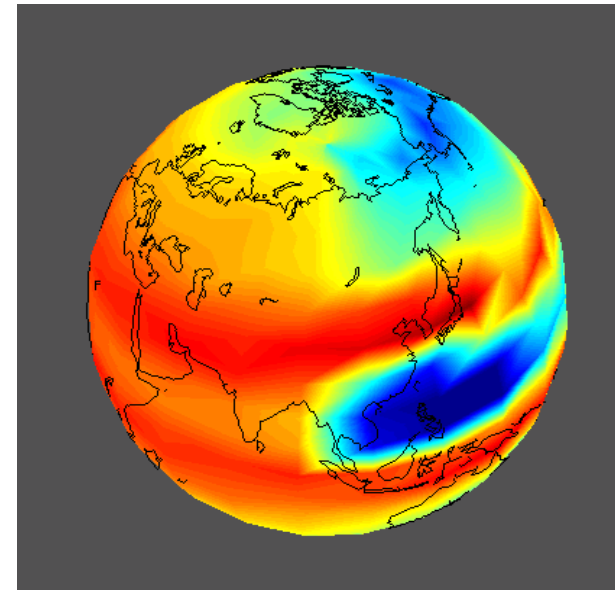
Contributions from Dan Weimer, Larry Paxton,
Qian Wu

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Coupled Thermosphere Ionosphere Plasmasphere Electrodynamics Model (CTIPe)

- Global thermosphere 80 - 500 km, solves momentum, energy, composition, etc. V_x , V_y , V_z , T_n , O, O₂, N₂, ... Neutral winds, temperatures and compositions are solved self consistently with the ionosphere (Fuller-Rowell and Rees, 1980);
- High latitude ionosphere 80 -10,000 km, solves continuity, momentum, energy, etc. O⁺, H⁺, O₂⁺, NO⁺, N₂⁺, N⁺, V_i , T_i , (open flux tubes) (Quegan et al., 1982);
- Plasmasphere, and mid and low latitude ionosphere, closed flux tubes to allow for plasma to be transported between hemispheres (Millward et al., 1996) ;
- Self-consistent electrodynamics (electrodynamics at mid and low latitudes is solved using conductivities from the ionospheric model and neutral winds from the neutral atmosphere code) (Richmond et al.,);
- Forcing: solar UV and EUV, Weimer electric field, TIROS/NOAA auroral precipitation, tidal forcing.



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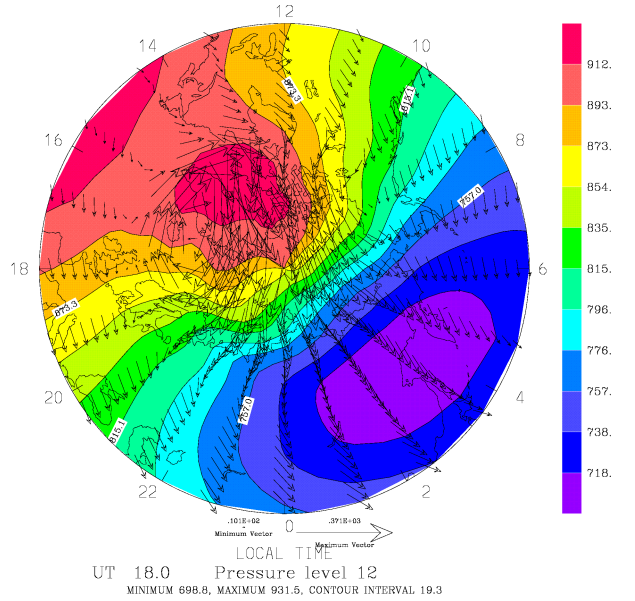
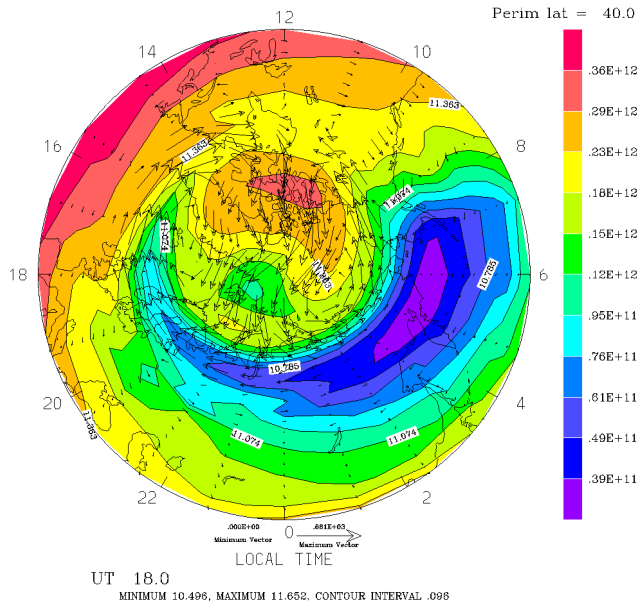
What CTIPe does well.....

- Neutral winds – high and low latitude, quiet and storms
- Neutral composition – particularly storms (quiet seasonal variation has its challenges due to lower atmosphere forcing)
- Neutral density – particularly storms (quiet same as above)
- N_e storm-time negative phase
- hmF2
- Neutral wind dynamo

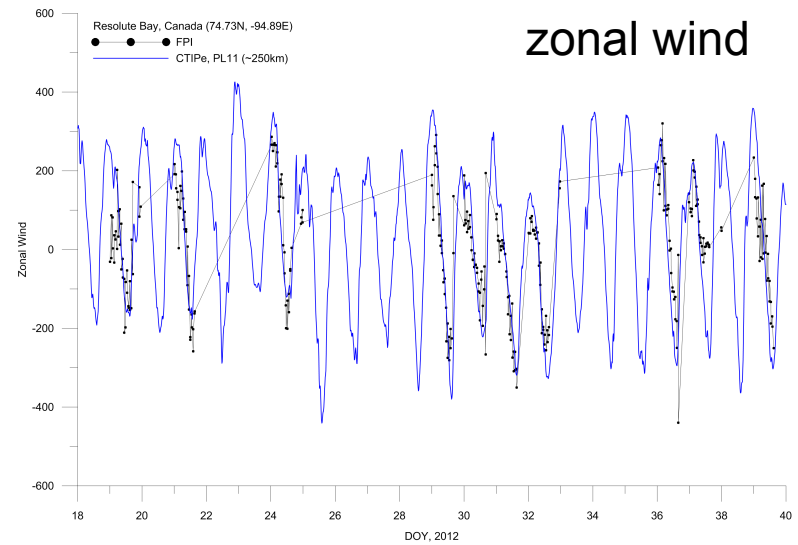
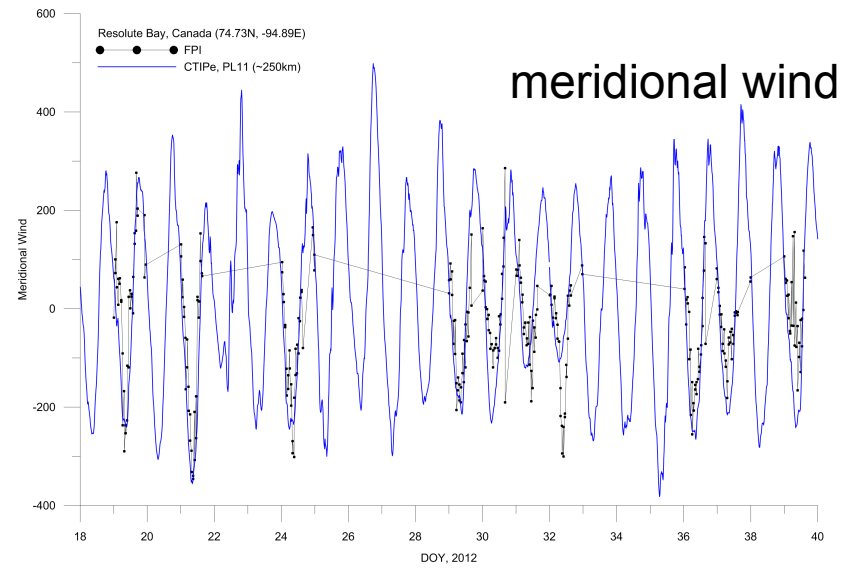
.....and not so well

- Working on improved lower boundary forcing, gravity wave mixing and spectrum of tidal and other resolved waves for improved quiet-time neutral composition, density, and $N_m F2$
- New IPE for positive storm phase, no ionospheric boundaries

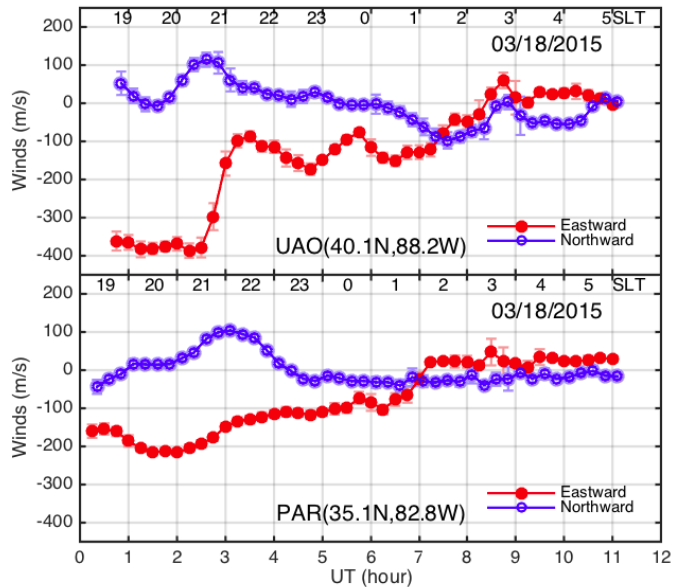
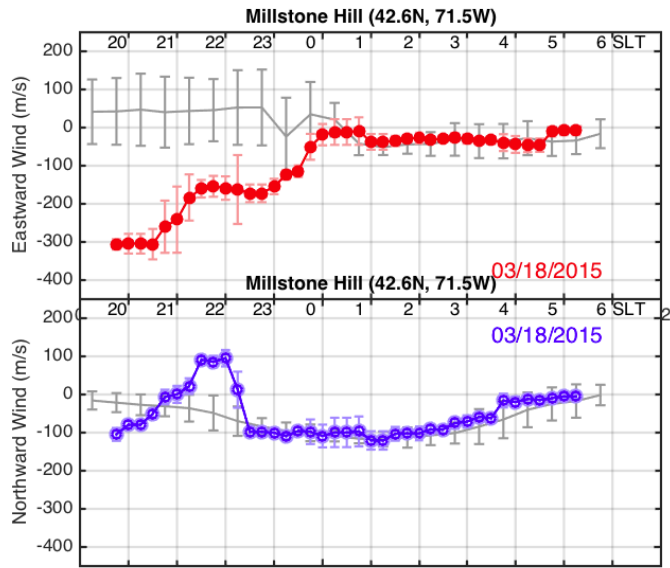
CTIP NmF2 (m-3) M125ws30z



Resolute Bay FPI neutral winds courtesy of Qian Wu



Shun-Rong Zhang et al., 2015

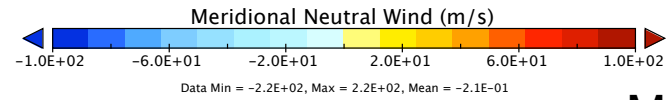
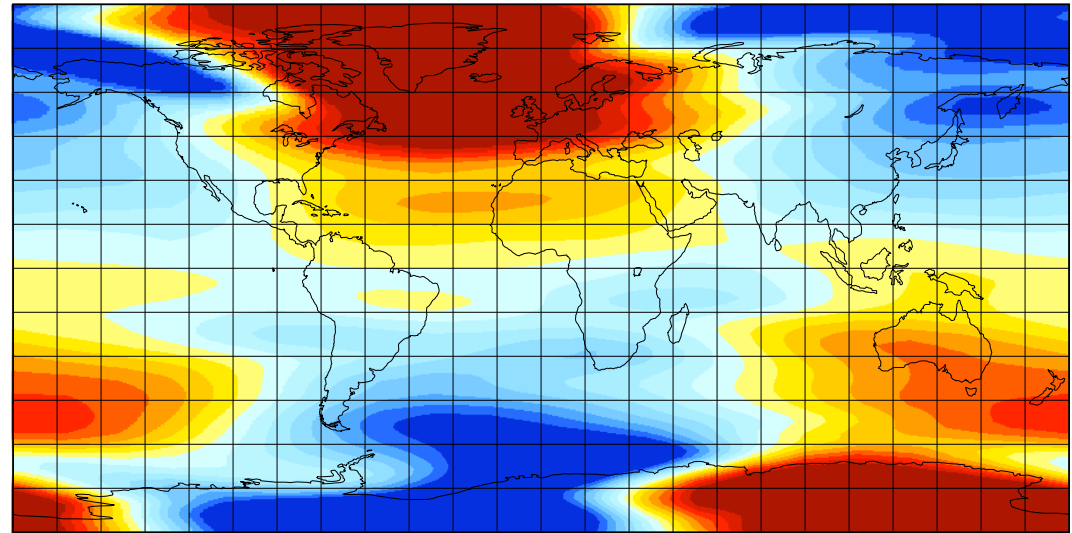


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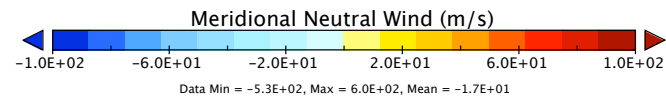
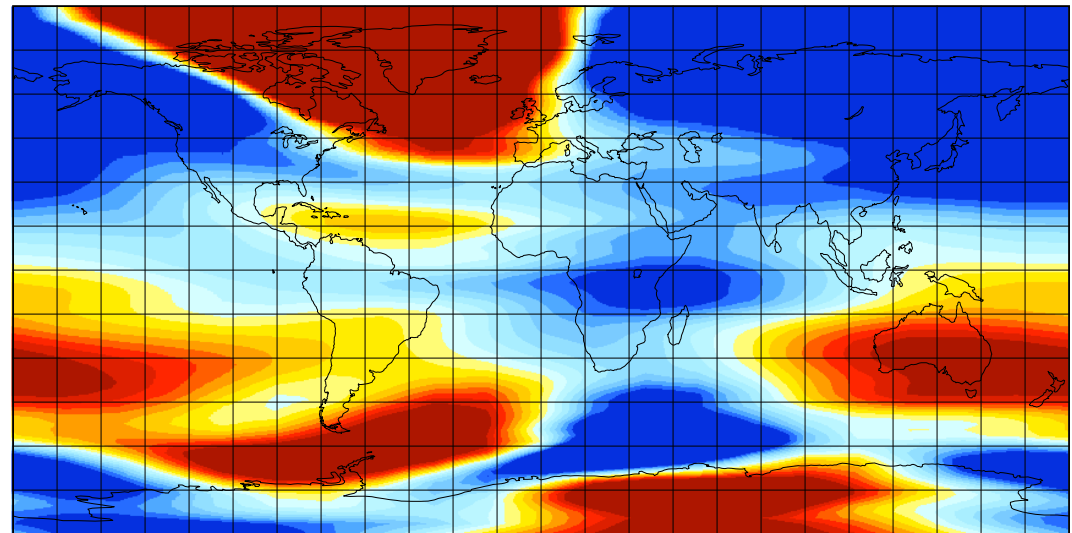
CTIPE meridional winds 2:30 March 17th

Meridional Neutral Wind 02:30 17th March



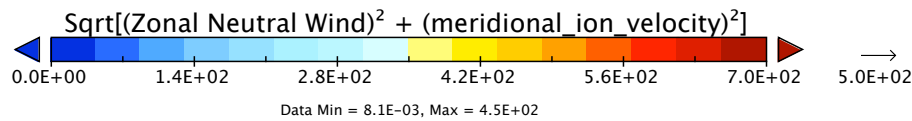
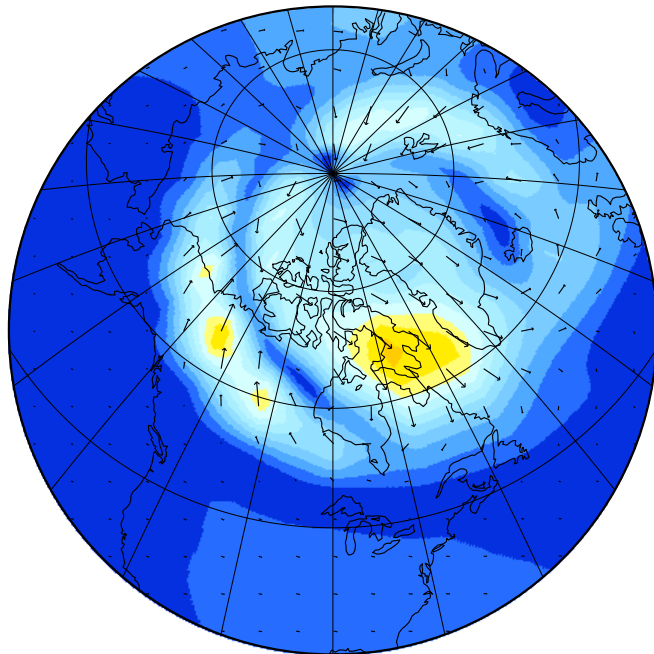
March 18th

Meridional Neutral Wind 02:30 March 18th

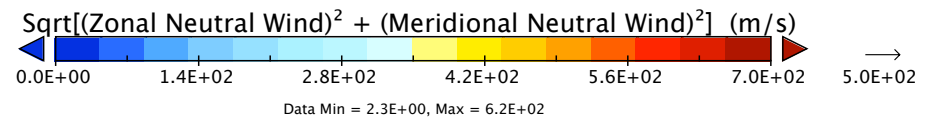
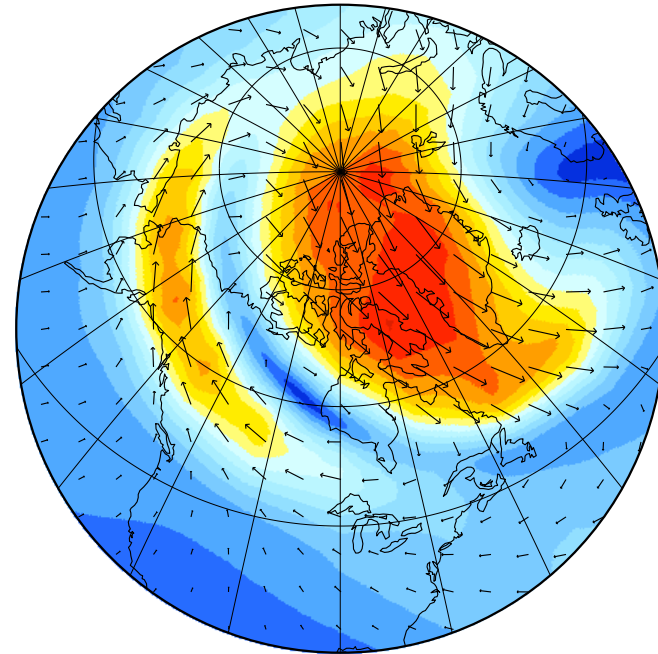


Thermospheric Poleward Wind

Neutral Wind 02:30 March 17th



Neutral Wind 02:30 March 18th

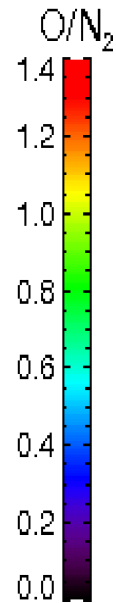
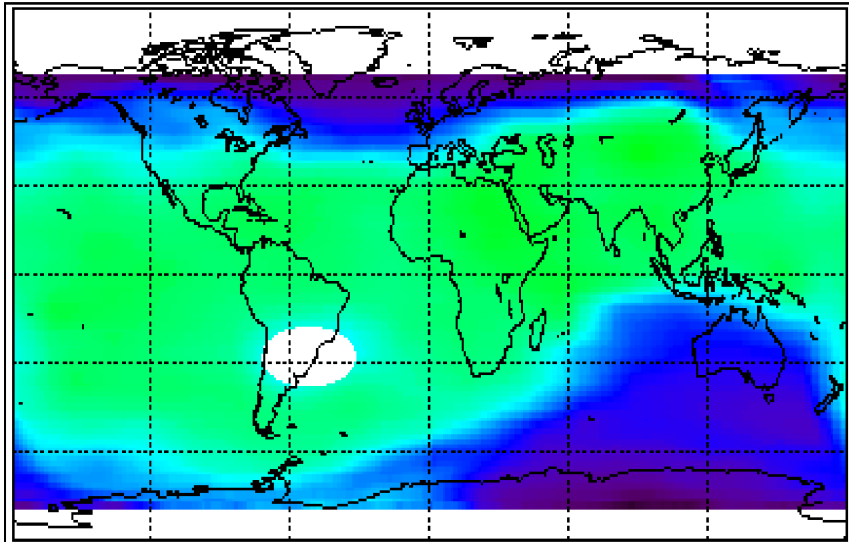


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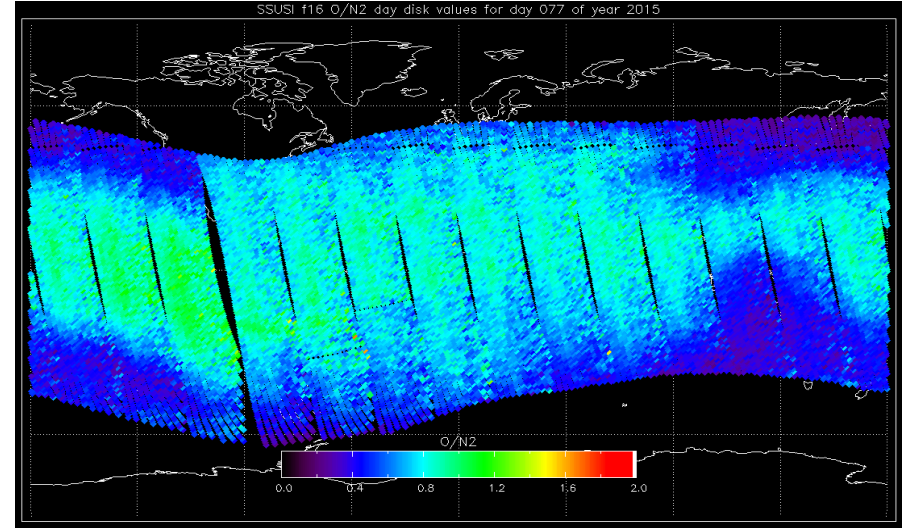
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Neutral composition: 2013 and 2015 St. Patrick's Day storms

GUVI O/N₂ Ratio March 18, 2013



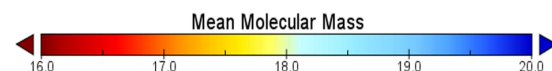
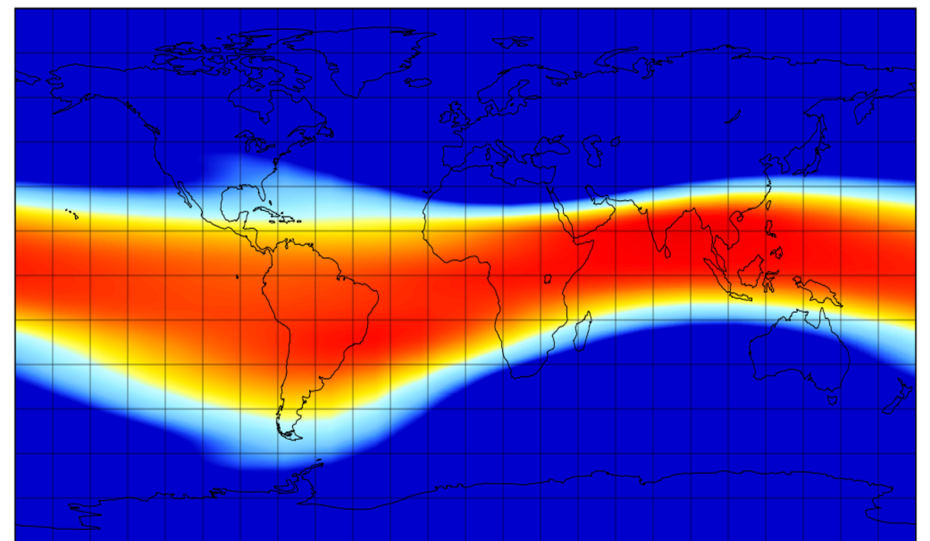
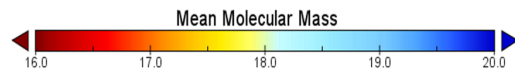
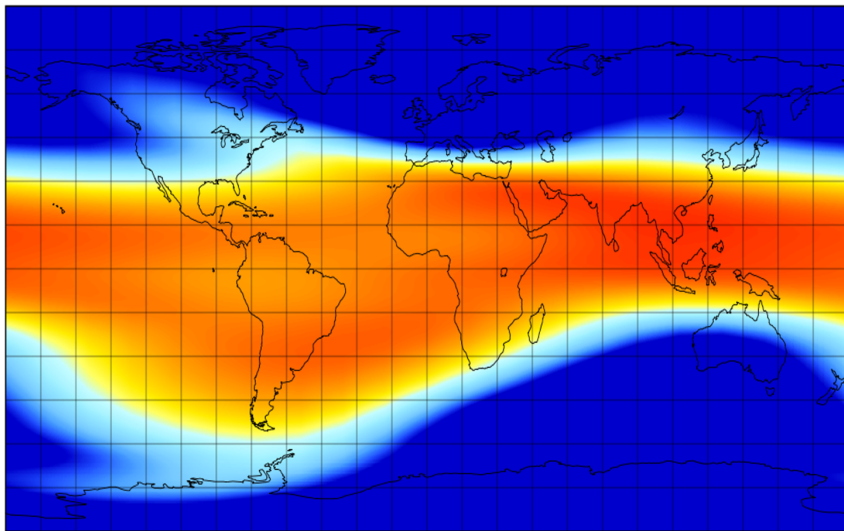
GUUVI O/N₂ Ratio March 18, 2015



CTIPe Mean Molecular Mass 2013-03-18 00:00UT

CTIPe mean mass

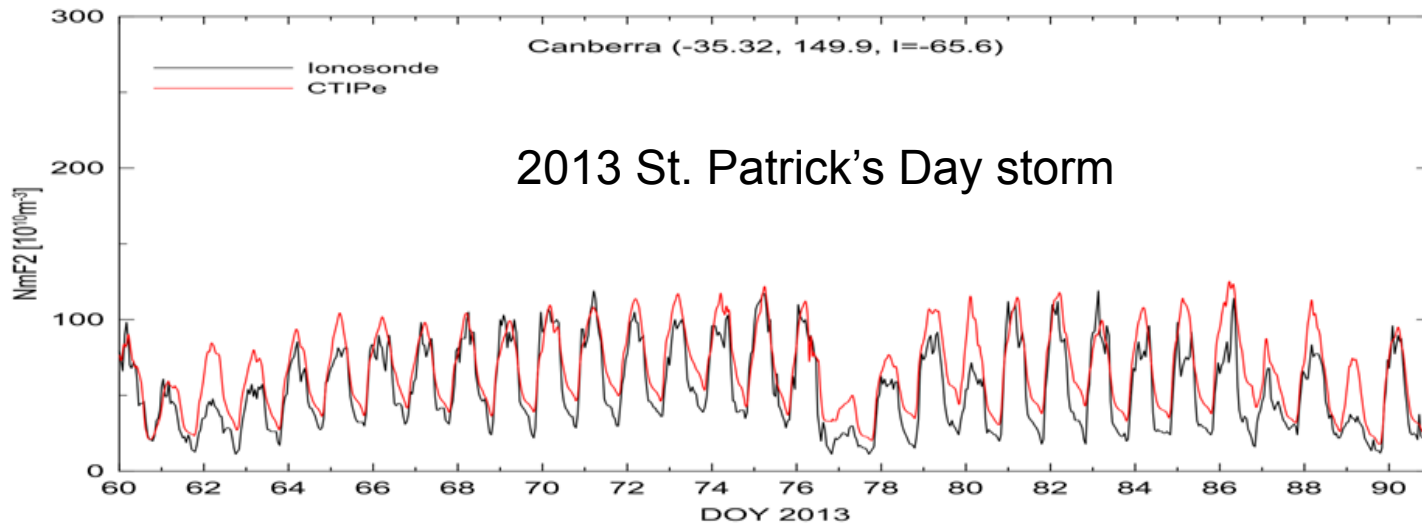
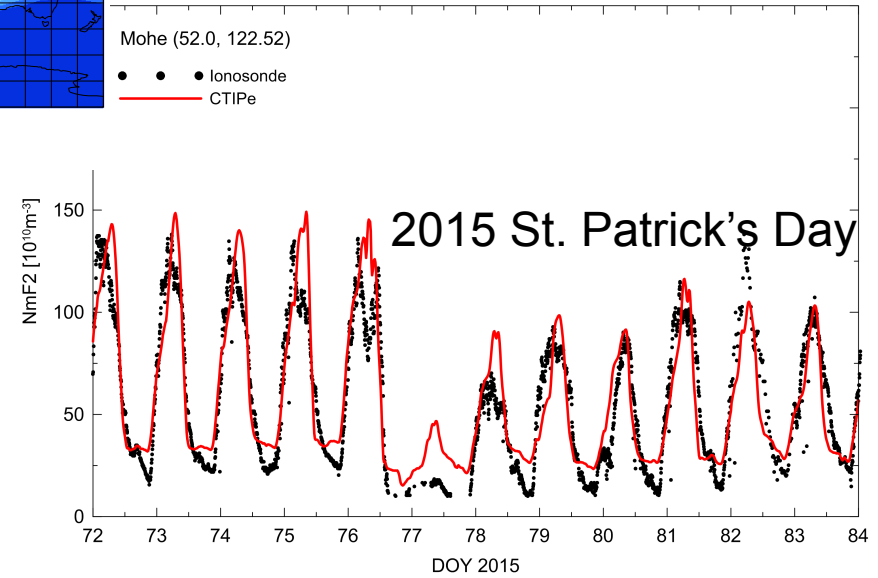
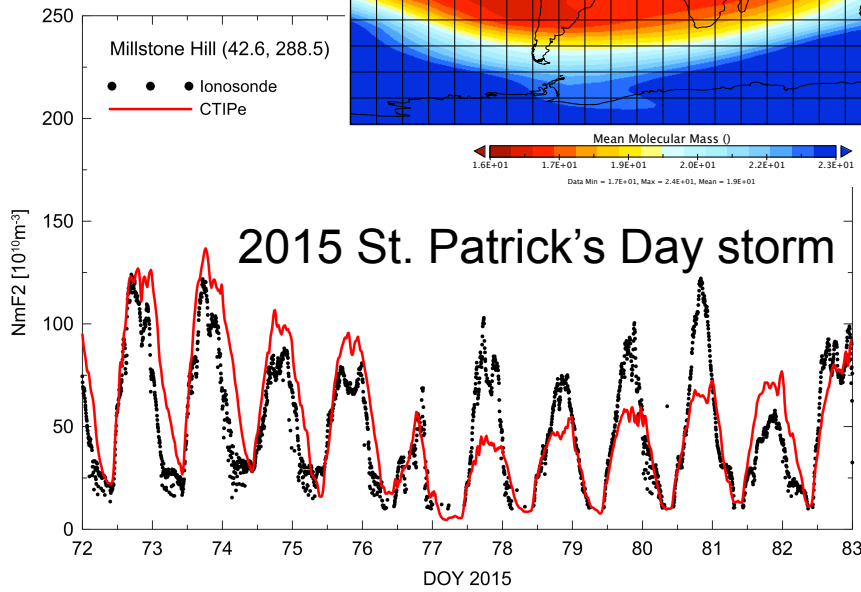
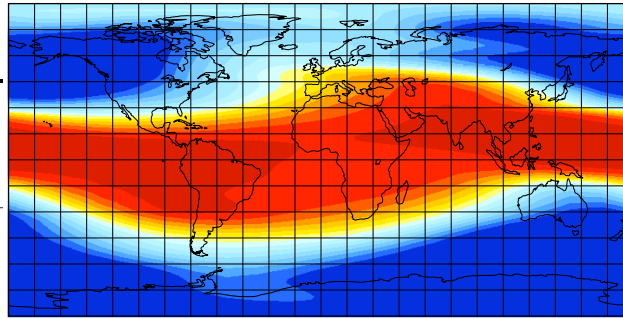
CTIPe Mean Molecular Mass 2015-03-18 00:00UT



Ionosonde NmF₂ +ve and - ve phases

mid-latitude negative phase

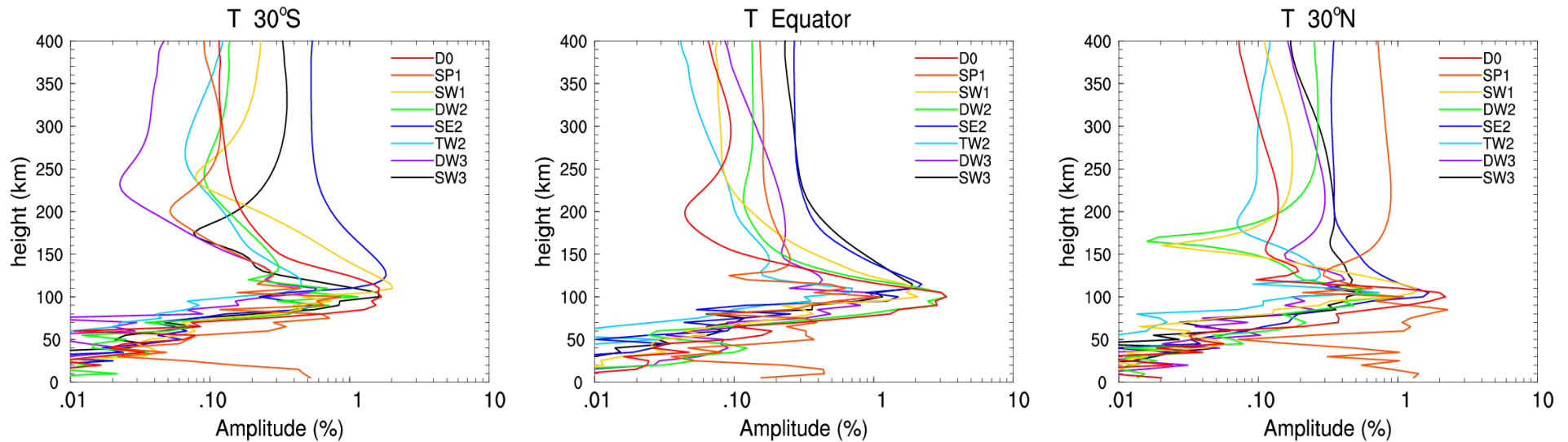
Mean Molecular Mass 16:15 UT March 17th 2015



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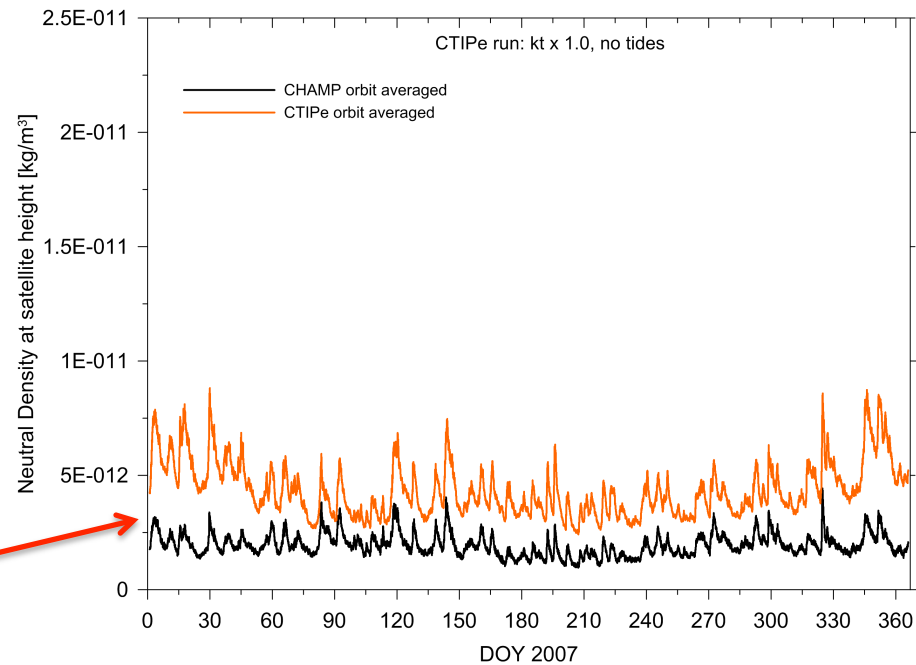
WAM spectrum of tides



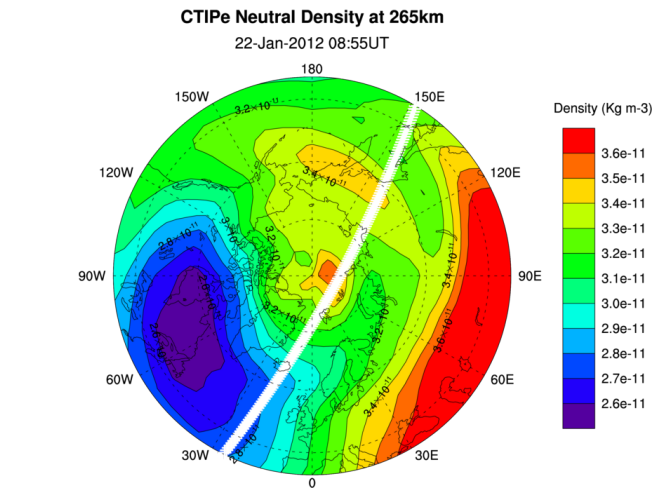
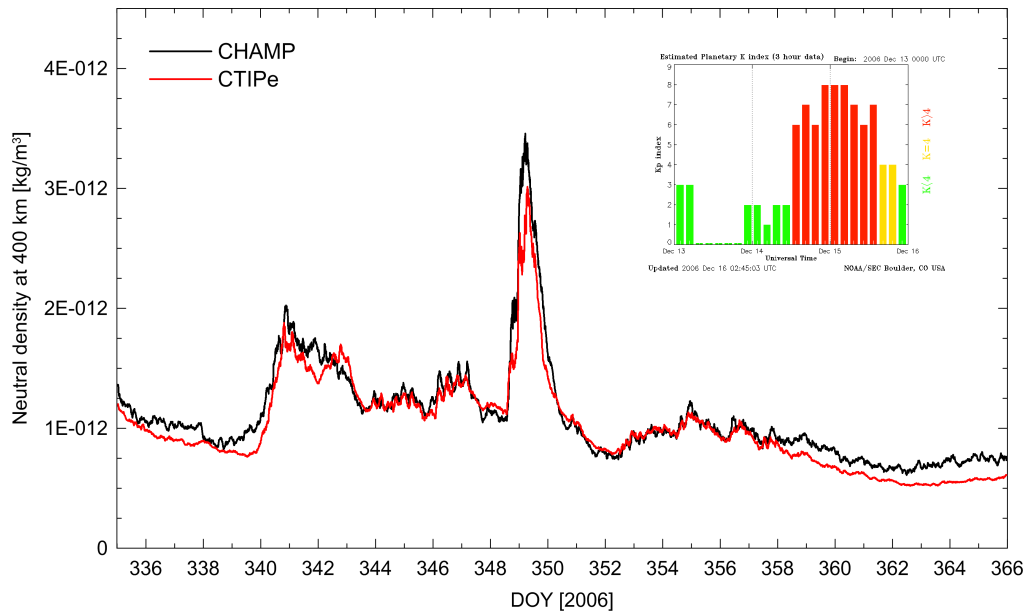
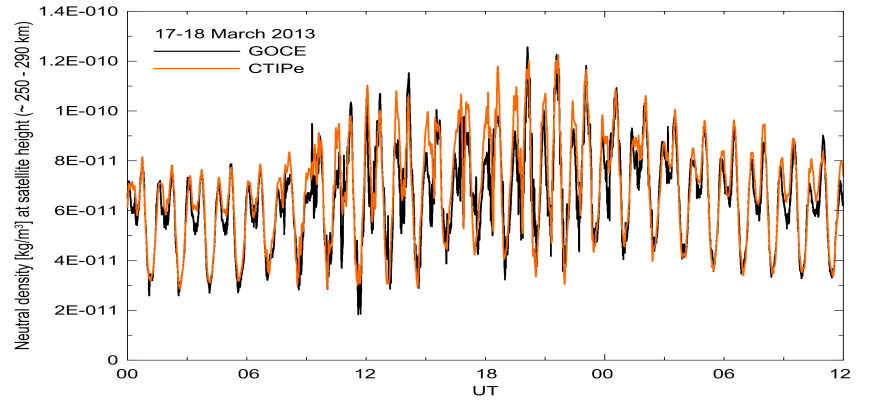
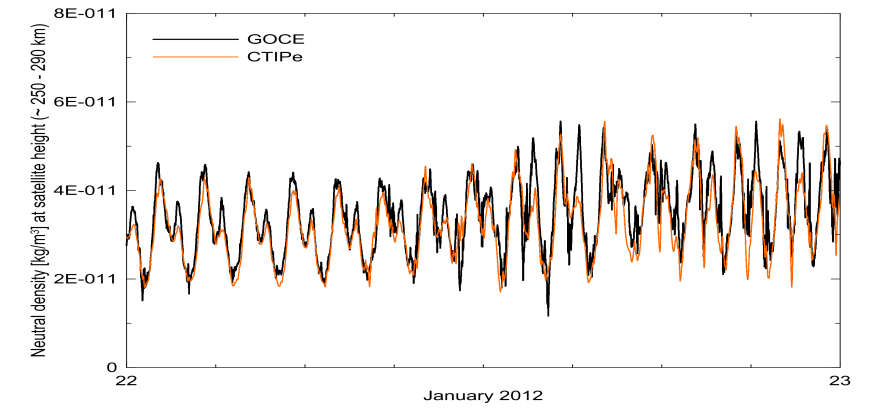
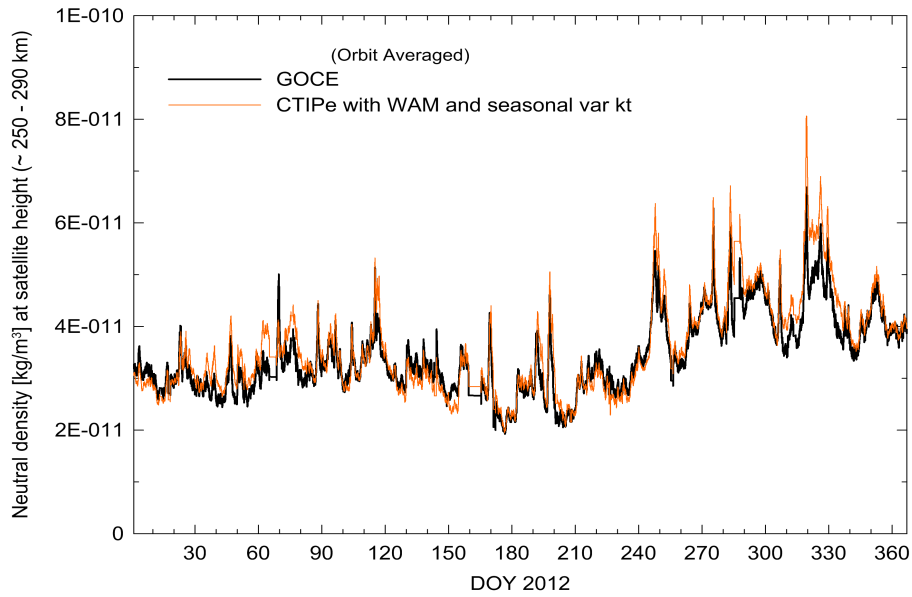
WAM has a rich spectrum of migrating and non-migrating tides

Can the WAM tidal fields provide the necessary mixing?

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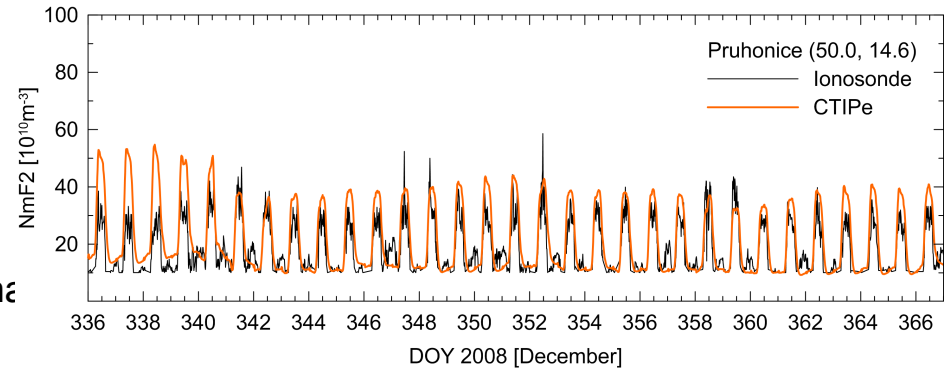
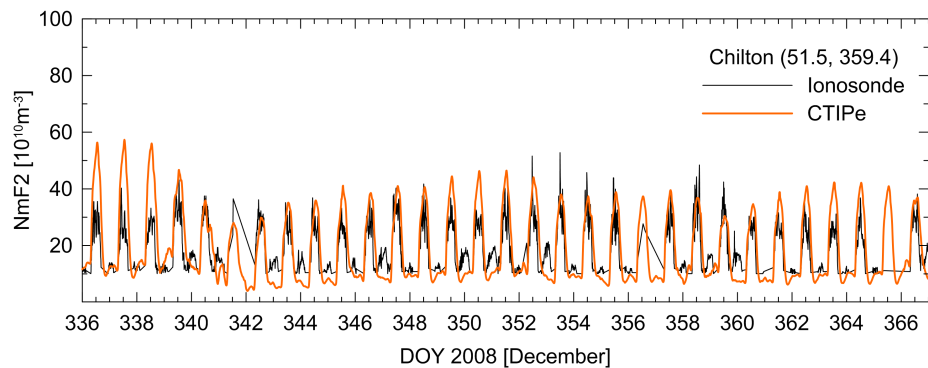
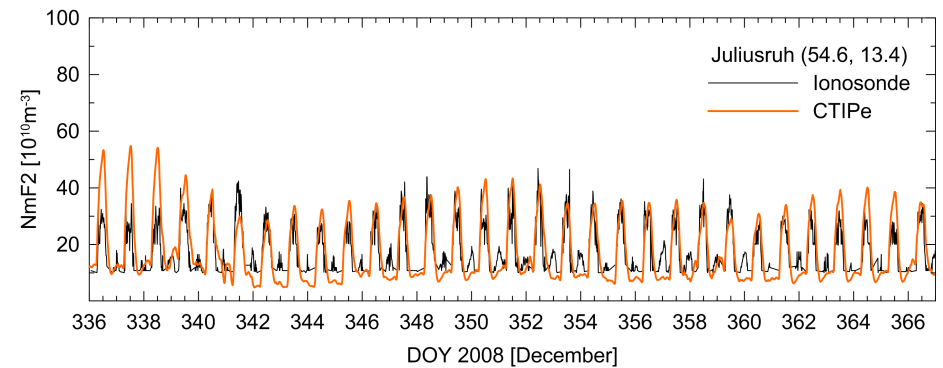
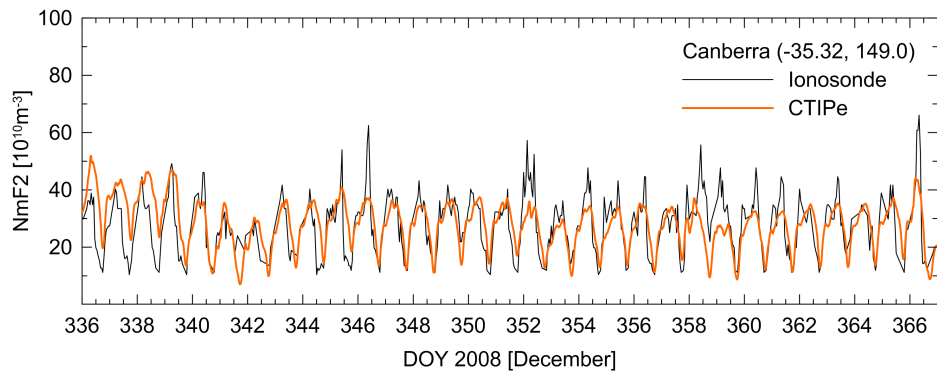
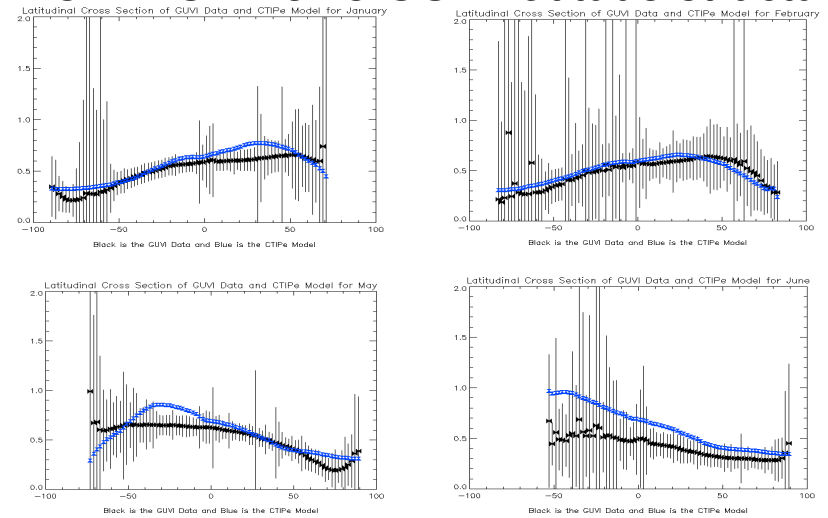


Neutral density CTIPe vs GOCE

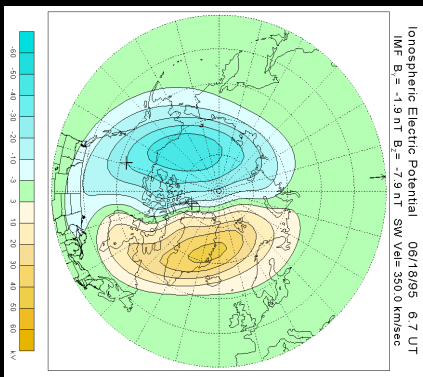


Impact of mixing by WAM tides and GW on quiet mid-lat $N_m F2$: CTIPe vs Ionosondes

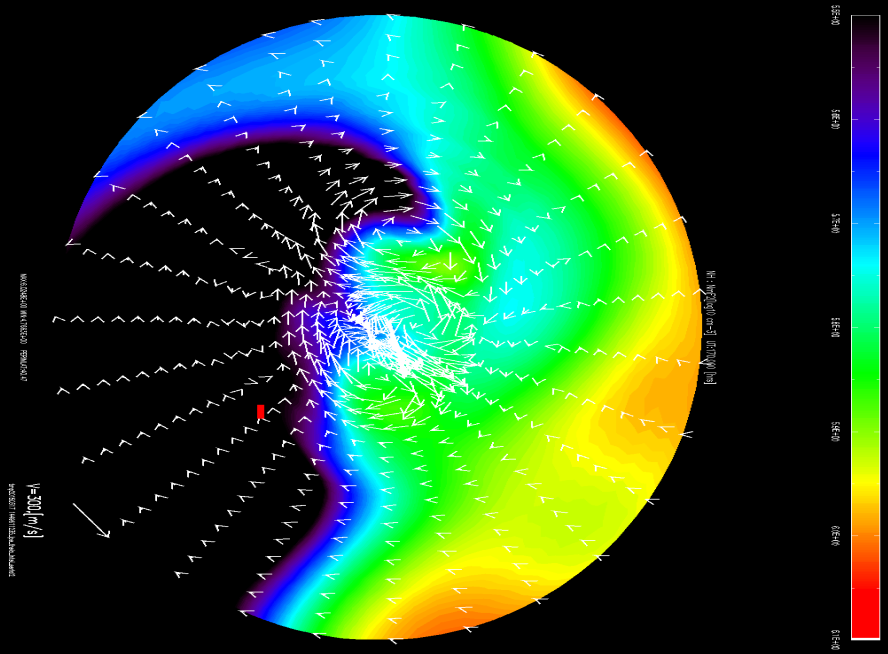
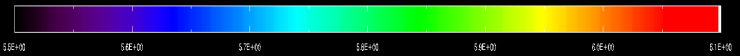
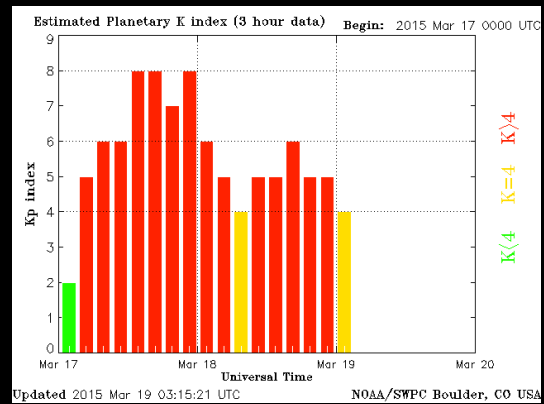
O/N2 CTIPe vs GUVI latitude structure



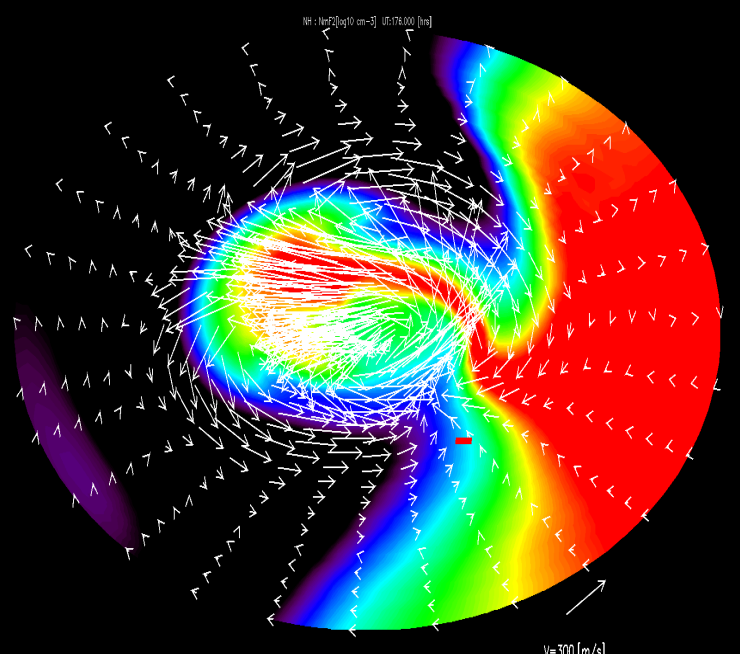
Driver: Weimer



SED and plume NmF2 from IPE



3 UT

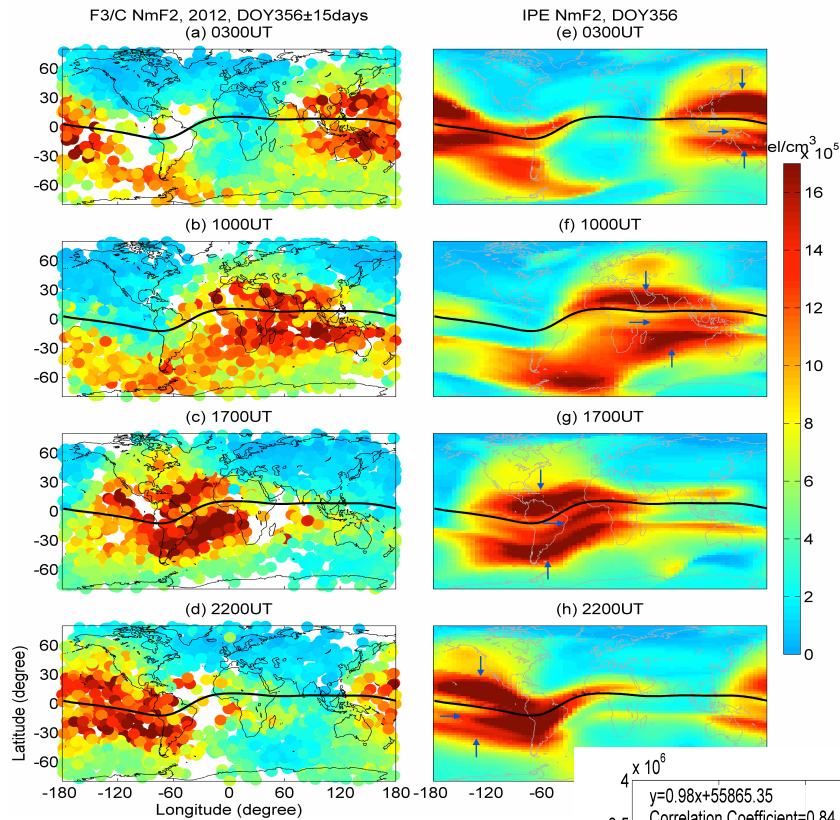


9 UT

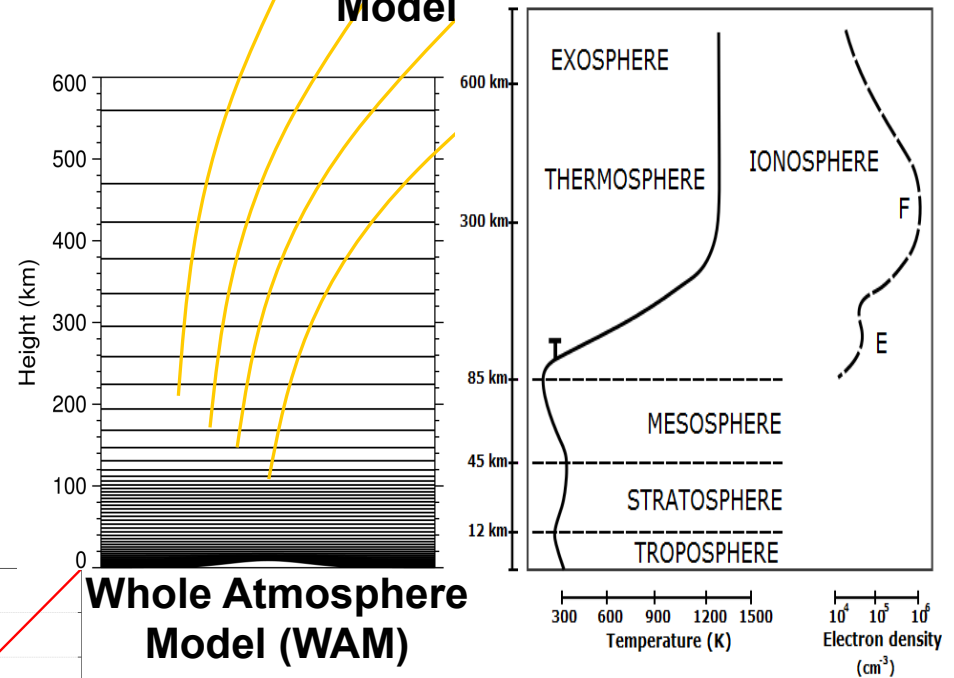
IPE: Features

- Based on Field Line Inter-hemisphere Plasma (FLIP) [P. G. Richards et al]: Ne, Te, Ti, multiple ions
 - has been validated for ~20yrs
 - photoelectron routine: secondary ionization and heating rates including conjugate effects.
 - comprehensive photochemical scheme
 - stable flux-preserving numerical scheme accommodates large time steps
 - comprehensive neutral gas heating rates → coupling to thermosphere models
- International Geomagnetic (IGRF)→more accurate ionospheric prediction
- Semi-lagrangian transport: robust, allowing for longer time steps
- Global coverage/seamless transport: no more boundaries!
- Flexible spatial resolution: to resolve fine structure e.g., TEC gradients
- Same grid as the self-consistent electrodynamic solver → no interpolation required

Ionospheric Plasmasphere Electrodynamics (IPE) Model Developed by Naomi Maruyama



Ionosphere Plasmasphere Electrodynamics Model

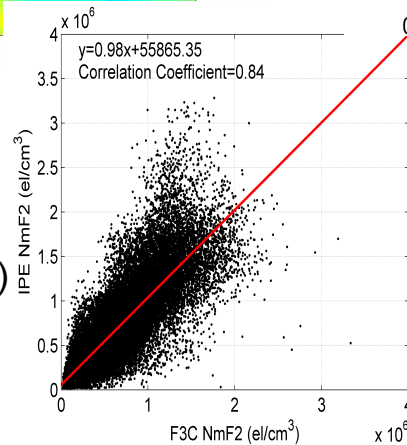


Whole Atmosphere Model (WAM)

The Ionosphere-Plasmasphere-Electrodynamics (IPE) model is being coupled to WAM using the Earth System Modeling Framework. WAM-IPE is scheduled to be transitioned into operations at NOAA National Weather Service in 2017/18

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IPE validation shows excellent agreement with ionospheric climatology from COSMIC radio occultation (Maruyama et al., 2015) correlation coefficient 0.84



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Conclusion

- CTIPe does some things very well.....and some things not so well
- Tidal dissipation and gravity wave mixing from lower atmosphere sources improves quiet-time and seasonal/latitude neutral density and NmF2
- Migrating to IPE will improve the storm time ionosphere response
- Modelers should be clear about the things their model does well and not so well
- Authors know the model capabilities best