Manifestations of the Neutral Density Annual and Semiannual Oscillations in CTIPe

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WAM-IPE Neutral Density, MLT Poster session (Tuesday):

- COUP-01 Tzu-Wei Fang, The coupled Whole Atmosphere Model and Ionosphere Plasmasphere Electrodynamics Model (WAM-IPE)

- COUP-02 Martin McCandless, Identifying the sources of the variability in thermospheric mass density

Coupled Thermosphere Ionosphere Plasmasphere Electrodynamics Model (CTIPe)

• Global thermosphere 80 - 500 km, solves momentum, energy, composition, etc. Vx, Vy, Vz, Tn, O, O2, N2, … Neutral winds, temperatures and compositions are solved self consistently with the ionosphere (Fuller-Rowell et al., 1996);

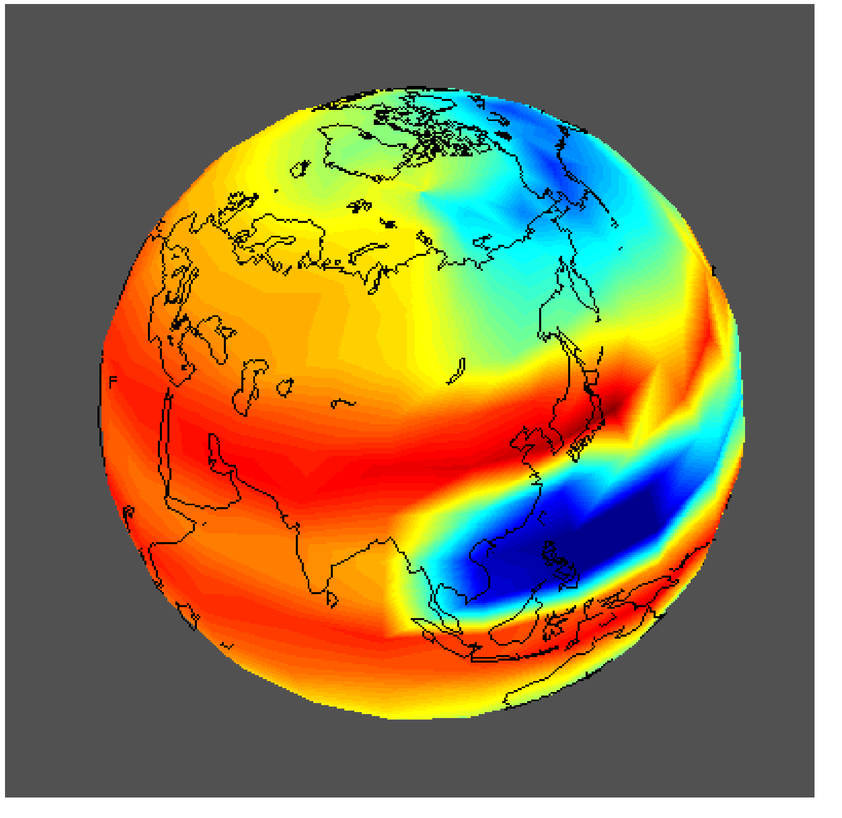
• High latitude ionosphere 80 -10,000 km, solves continuity, momentum, energy, etc. O+, H+, O2+, NO+, N2+, N+, Vi, Ti, …. (open flux tubes);

• Plasmasphere, and mid and low latitude ionosphere, closed flux tubes to allow for plasma to be transported between hemispheres (Millward et al., 1996) ;

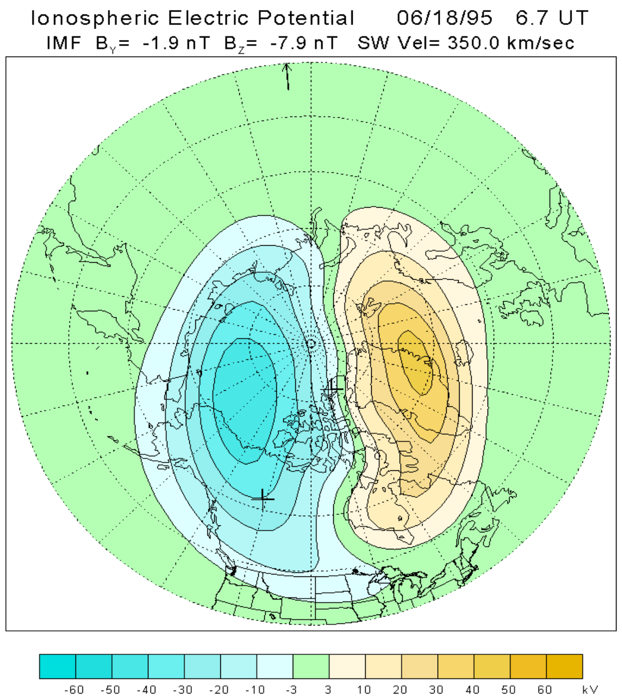
• Self-consistent electrodynamics (electrodynamics at mid and low latitudes is solved using conductivities from the ionospheric model and neutral winds from the neutral atmosphere code);

• Forcing: solar UV and EUV, Weimer electric field, TIROS/NOAA auroral precipitation, tidal forcing;

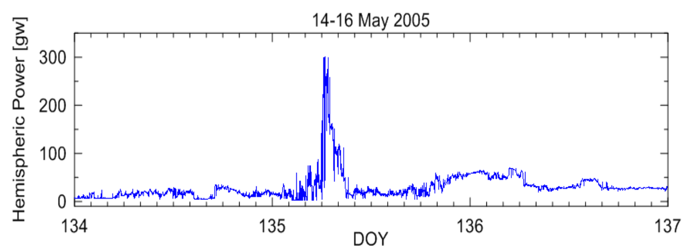
• Resolution: lat 2°, lon 18°, 15 pressure levels (from a lower boundary of 1 Pa at 80 km to more than 500 km altitude).

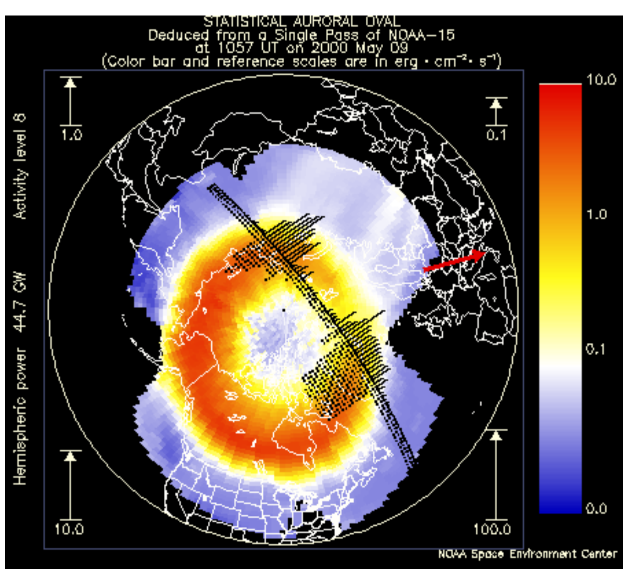


CTIPe Magnetospheric Forcing



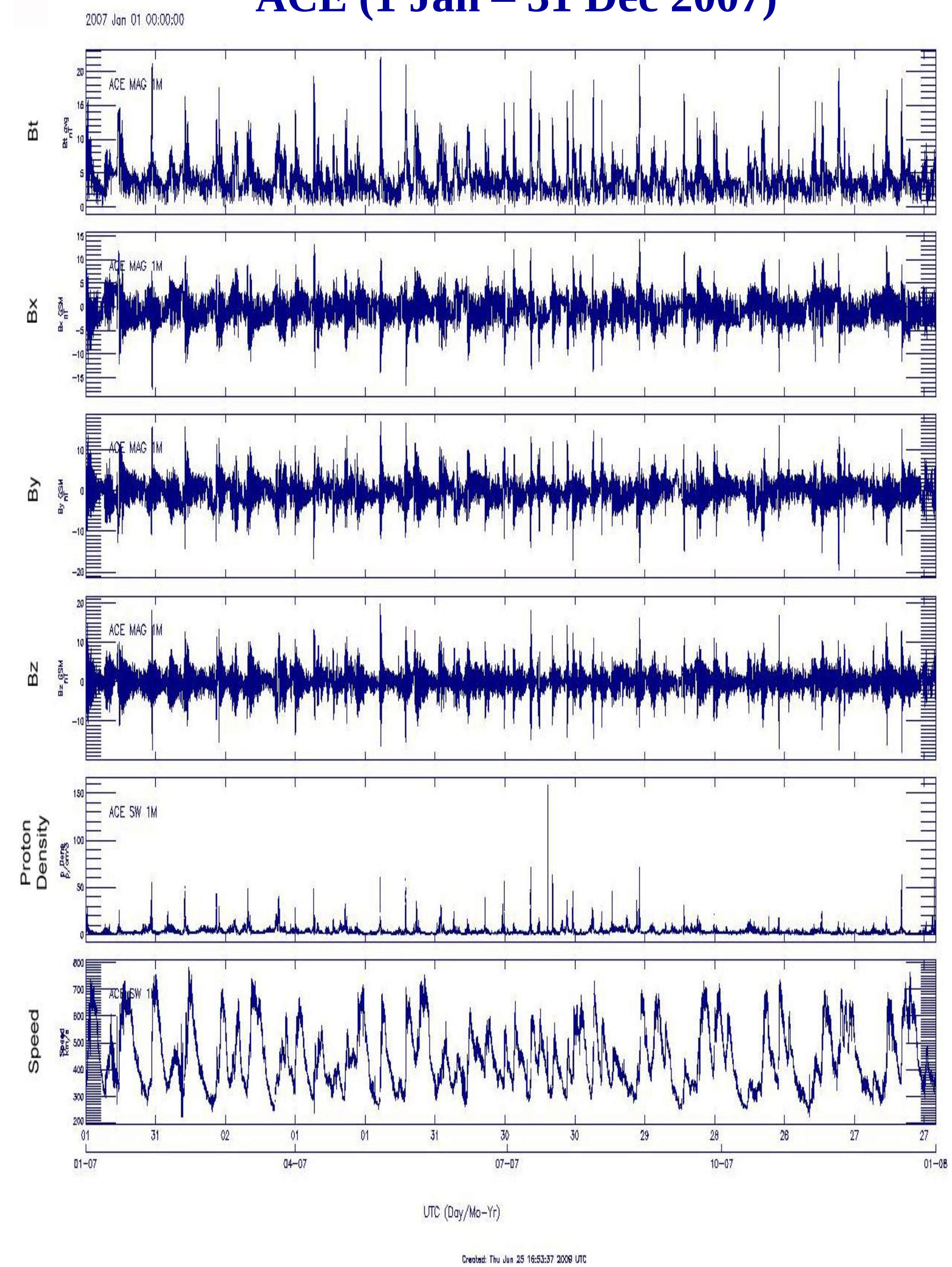
<u>Plasma convection:</u>
patterns driven by Weimer 2005 using ACE/DSCOVR data (IMF, SW vel., SW den.), 1 min. input (SWPC database).





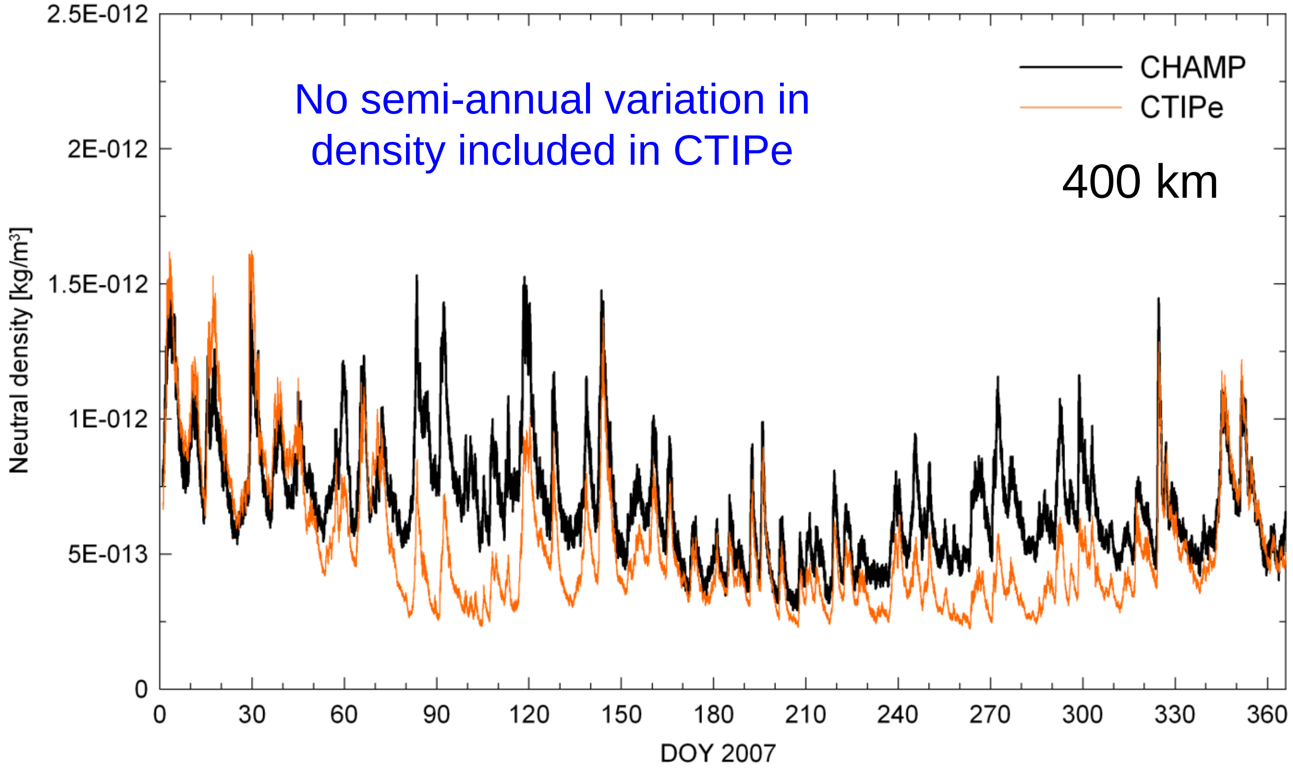
<u>Particle precipitation:</u>
patterns driven either by power index TIROS/NOAA auroral precipitation or derived from ACE solar wind and IMF data.

ACE (1 Jan – 31 Dec 2007)



2007 CHAMP/CTIPe Orbit Average Comparisons

CHAMP data provided by Eric Sutton

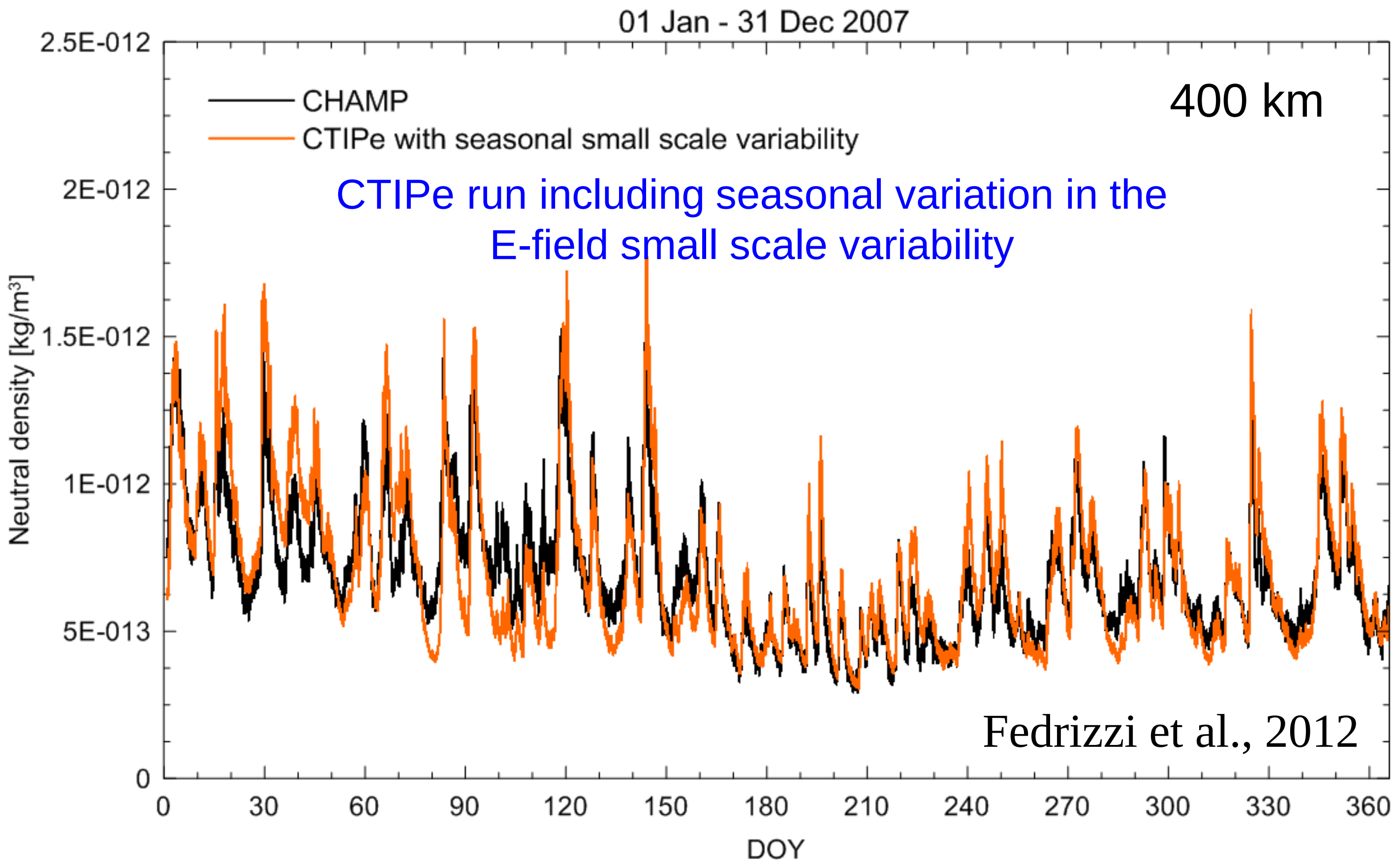


Some of these mechanisms were not included in this CTIPe model version, and it is possible that a combination of these effects (and others listed by Qian et al., 2009) could be responsible for the semi-annual variation in density.

<u>Possible Mechanisms for Semi-Annual Variation</u>:

- Seasonal variation in eddy diffusivity in the upper mesosphere and lower thermosphere regions due to gravity wave breaking (Qian et al., 2009)
- Thermospheric spoon mechanism associated with the global scale interhemispheric circulation at solstice (Fuller-Rowell, 1998)
- Asymmetry in conductivity distribution at solstice due to inequality of solar radiation between hemispheres (e.g, Lyatsky et al., 2001)
- Semi-annual variation in geomagnetic activity peaking at equinoxes (Russell and McPherron, 1973)
- Conduction mode oscillation of the thermosphere forced by the semi-annually varying Joule heating at high latitudes (Walterscheid,1982)

2007 CHAMP/CTIPe Orbit Average Comparisons (cont'd)



• Main purpose of this study was to simulate the model response to short-period variations in geomagnetic activity during the year.

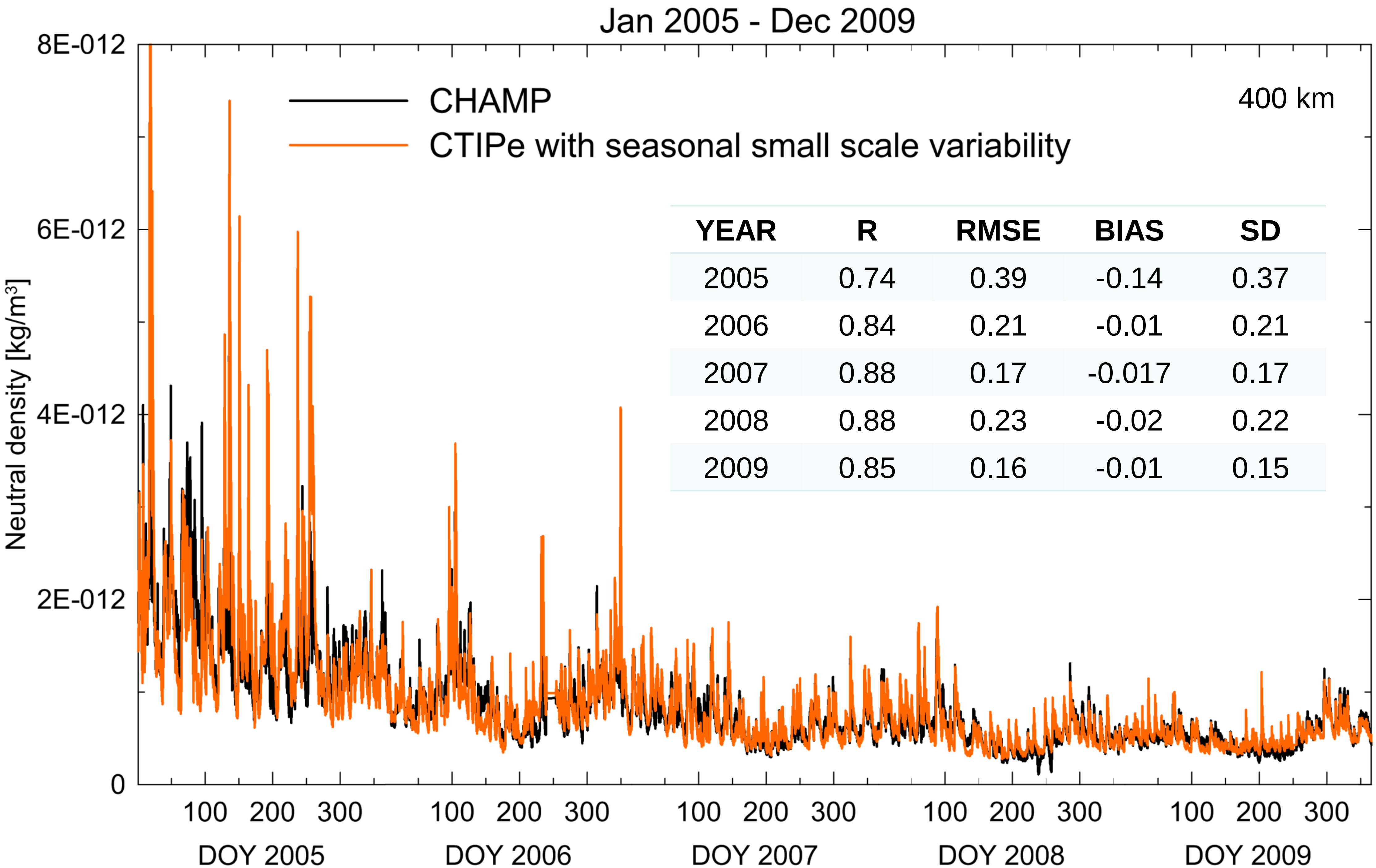
• To accommodate this goal, a semi-annual variation in electric field small-scale variability was introduced in CTIPe, improving the agreement of modeled neutral density with CHAMP measurements.

• Electric fields can directly change Joule heating by varying the ion convection at high-latitudes (Deng and Ridley, 2007). An increase in Joule heating raises the neutral temperature, which enhances the neutral density at constant heights.

• Electric field variability changes the distribution of Joule heating significantly, and can introduce interhemispheric asymmetries (Codrescu et al., 1995, 2000).

• Previous studies have identified a significant seasonal dependence in the magnitudes of small-scale electric field variability in DE-2 (e.g., Golovchanskaya, 2007; Matsuo and Richmond, 2008) and SuperDARN data (Cousins and Shepherd, 2012).

2005-2009 CHAMP/CTIPe Orbit Average Comparisons

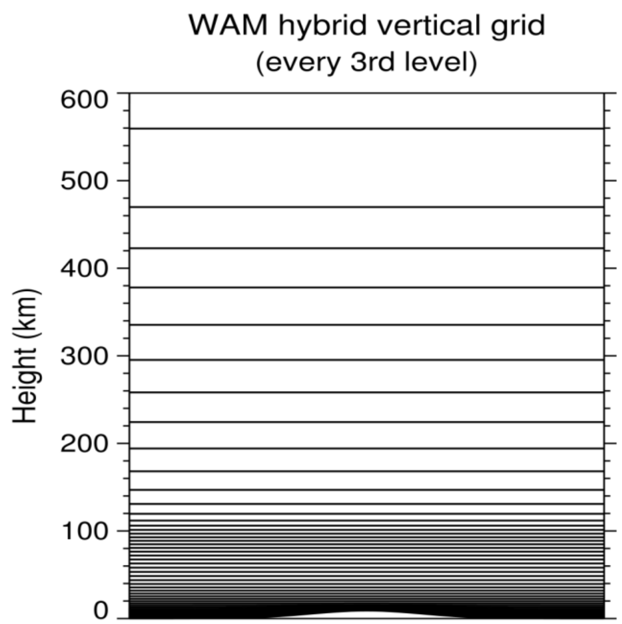


YEAR	R	RMSE	BIAS	SD
2005	0.74	0.39	-0.14	0.37
2006	0.84	0.21	-0.01	0.21
2007	0.88	0.17	-0.017	0.17
2008	0.88	0.23	-0.02	0.22
2009	0.85	0.16	-0.01	0.15

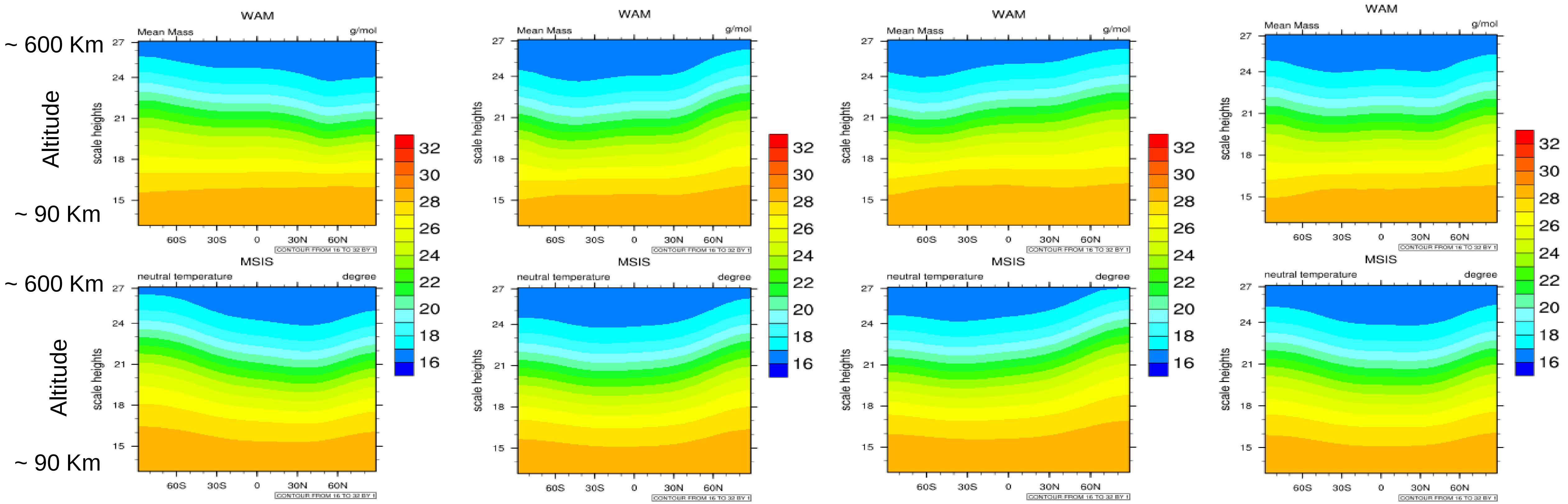
CHAMP data version 2.3 provided by Eric Sutton

Whole Atmosphere Model (WAM)

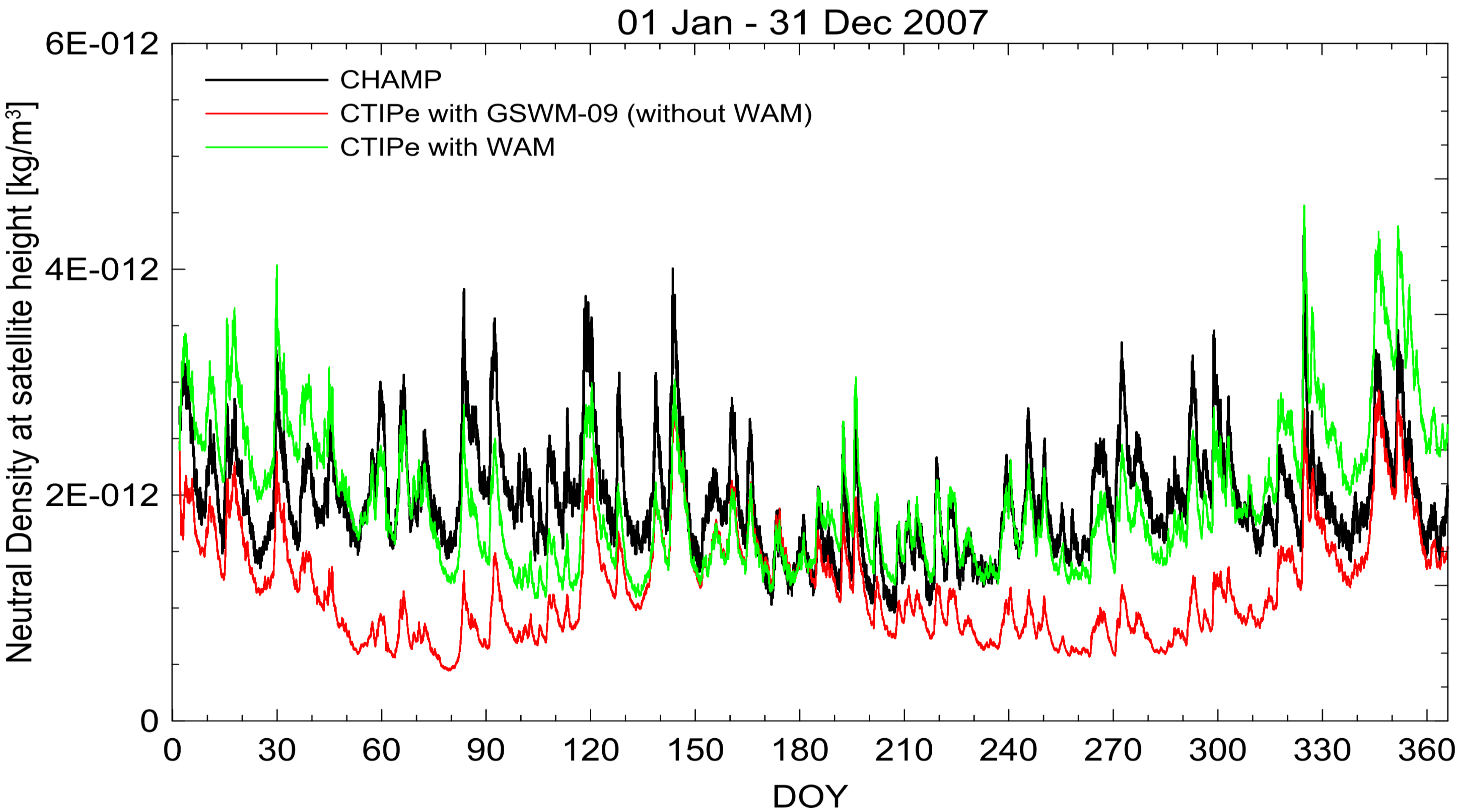
- Akmaev et al., 2008; Fuller-Rowell et al., 2011; Fang et al., 2013.
- Global seamless whole atmosphere model (WAM) 0-600 km, 0.25 scale height, 2° x 2° lat/long, T62, hydrostatic, 150 levels, 10-fold extension of Global Forecasting System (GFS) US weather model.
- O_3 chemistry and transport
- Radiative heating and cooling
- Cloud physics and hydrology
- Sea surface temperature field and surface exchange processes
- Orographic gravity waves parameterization
- Diffusive separation, ion drag, Joule heating, etc.



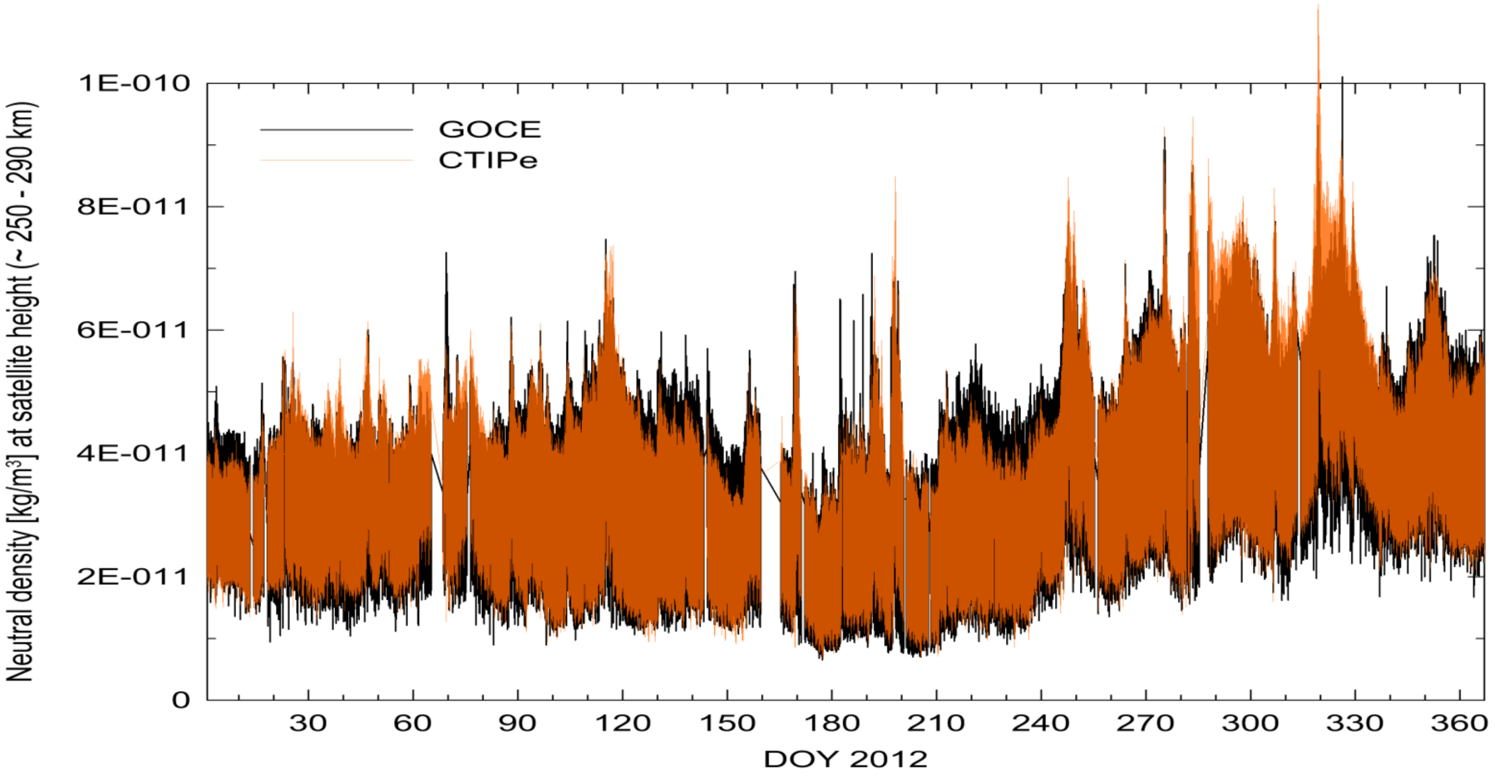
Monthly Zonal Mean: WAM (top), MSIS (bottom), (Zhuxiao Li) F107=120, Kp=3

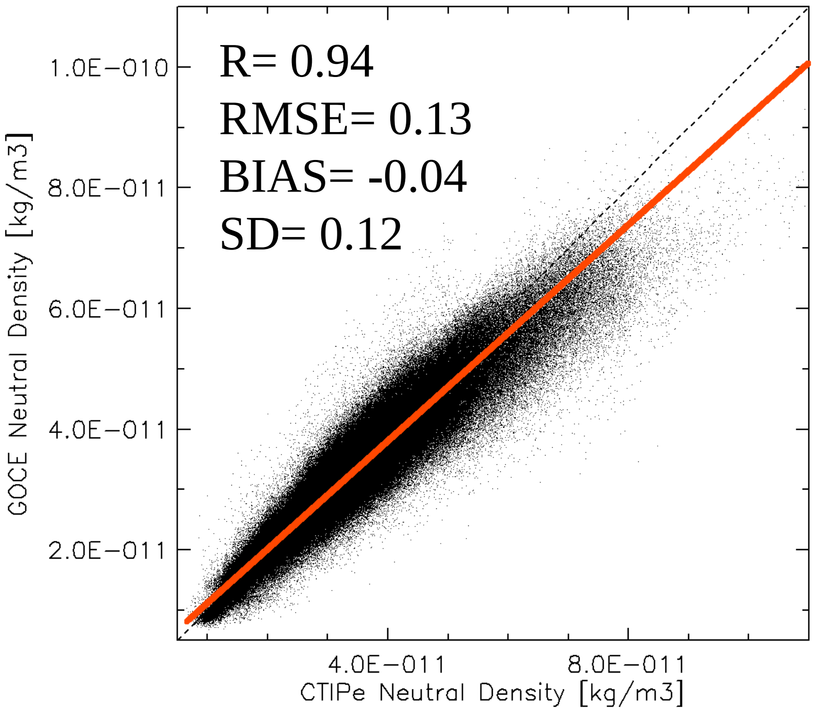


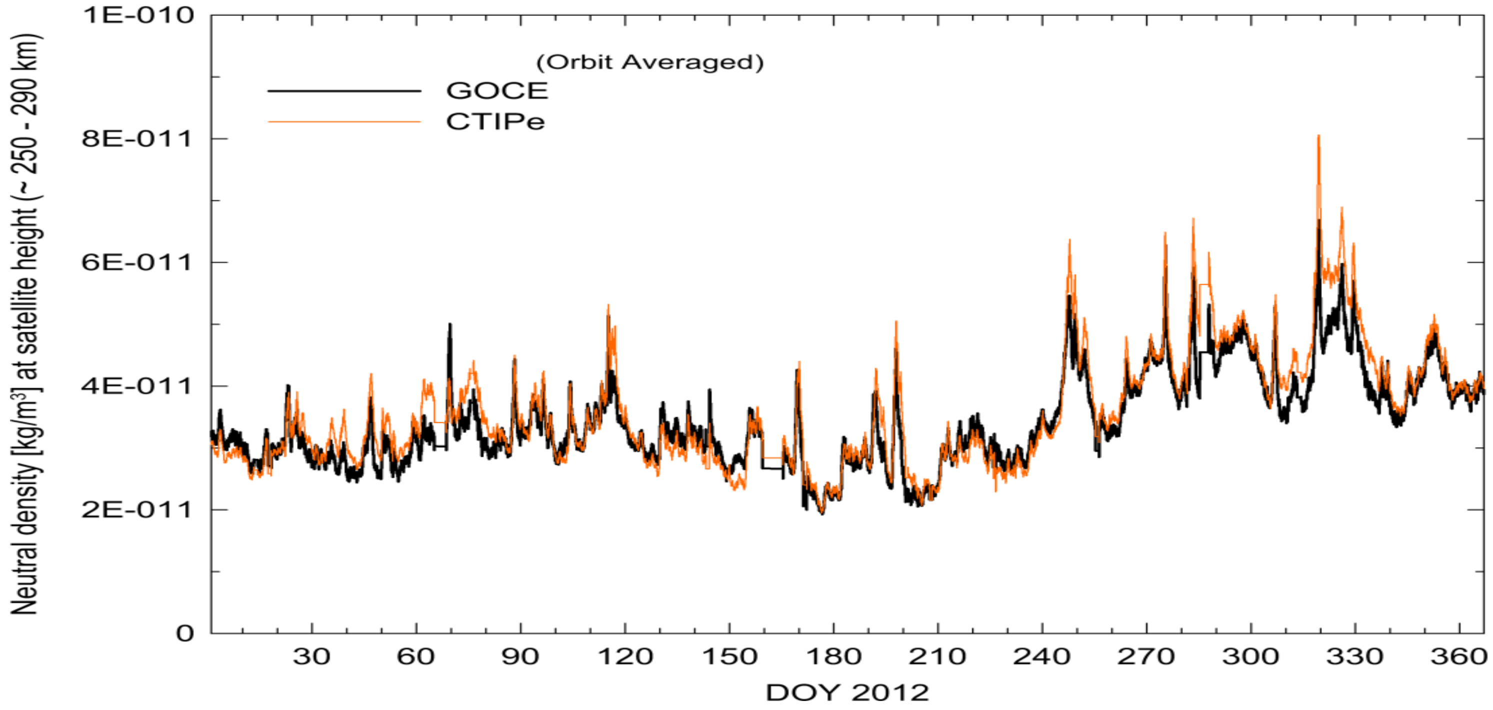
Impact of Lower Atmospheric Forcing

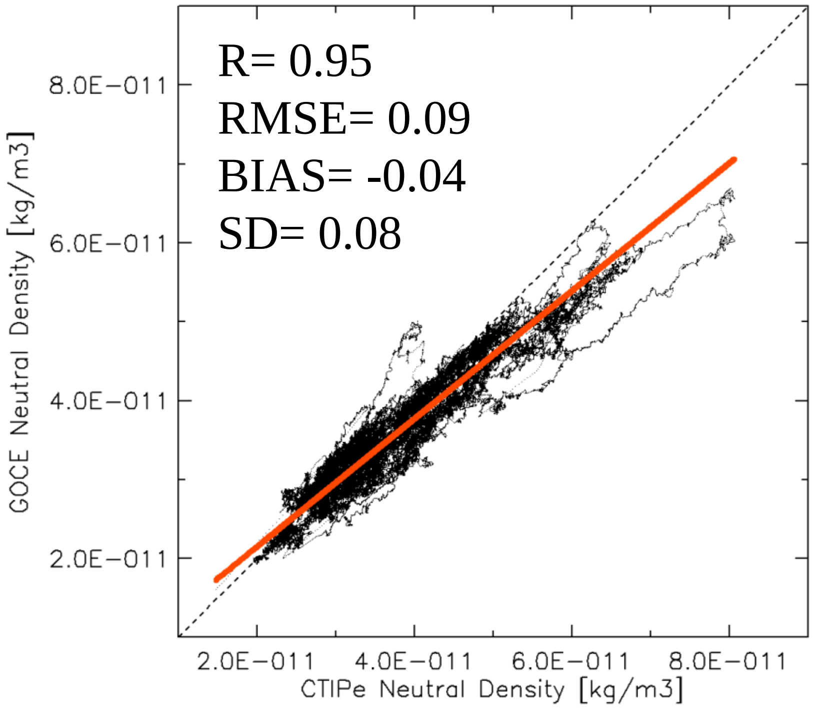


2012 GOCE/CTIPe Comparisons: Along Orbit vs. Orbit Averaged









GOCE data provided by Eelco Doornbos and Sean Bruinsma

WAM-IPE

Tim Fuller-Rowell (CIRES/University of Colorado and NOAA/SWPC), **Rashid Akmaev**, **Naomi Maruyama**, **Houjun Wang**, **Tzu-Wei Fang**, Joe Schoonover, **Zhuxiao Li**, **George Millward**, Mariangel Fedrizzi, **Valery Yudin**, Dominic Fuller-Rowell, Rodney Viereck, Phil Richards, Arthur Richmond, Mark Iredell, Adam Kubaryk, Weiyu Yang, Bob Oehmke, Cecelia Deluca, Raffaele Montuoro, and Jacques Middlecoff

- WAM-IPE is running in real-time in a test operational mode with one-way coupling.
- Includes WDAS – the GSI physics-based data assimilation system in the lower atmosphere (below 60 km) using the NWS-NCEP 6-hour assimilation cycle.
- The system launches a new WAM-IPE run from the forecast to bring the system closer to the current time driven by the current space weather solar wind drivers from DSCOVR.
- System appears robust, currently validating, improving transport and electrodynamics, and evaluating Geospace model storm drivers.
- In the future: 2-way coupling, expand the GSI data assimilation to 100 km, improve gravity wave parameterization, FV3 non-hydrostatic core and higher resolution, shorter assimilation cycle, thermosphere/ionosphere data assimilation in upper levels with GOLD and COSMIC-II, drive irregularity model, O2R opportunities.