



Looking at Low Latitudes – Remember the Tides

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Motivation

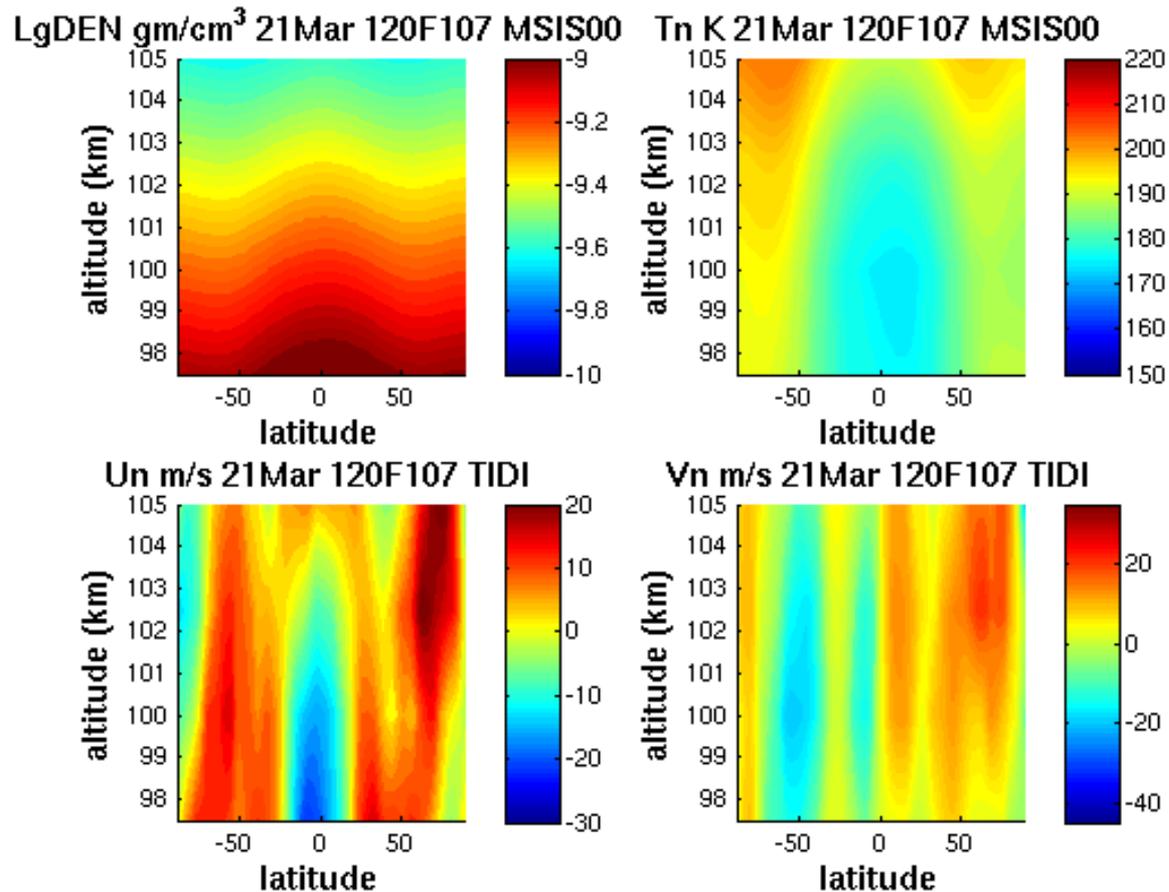
- Tides are produced by variations in water vapor and ozone in the lower atmosphere and propagate upwards to the thermosphere and ionosphere. Mean zonal westward winds can hinder their upward propagation.
- Longitudinal structure in low latitude vertical ion drifts, electron densities, neutral winds, ion drifts, and many other quantities are often caused by tides.
- Studies by Hanli Liu using MERRA/WACCM-X/TIME-GCM reproduced about 50% of the observed variability of NmF2 when day-to-day variations in the tides and mean winds were introduced in the lower atmosphere, nudging the TIME-GCM from 30-90km. Fuller-Rowell and Akmaev showed similar ionospheric variability caused by tides and gravity waves driving CTIPe with WAM.

Low Latitude Climatology

- . Geomagnetic Quiet conditions in December (2008, 2009) and March 2012 in solar minimum (F107~73) and medium (F107~120) conditions
- . NCAR Thermosphere-Ionosphere-Electrodynamics General Circulation Model (TIEGCM) was run with essentially no magnetospheric inputs, but variable tides (GSWM-Global-Scale Wave Model 2002 and 2009, CTMT-Climatological Tidal Model of the Thermosphere, TIDI/SABER) at the lower boundary around 94-99km (nominally 97km).
- . Data sources:
 - . 67-d Communication/Navigation Outage Forecast System (C/NOFS) satellite 400-800km electron density (Ne) and vertical ion drift (Viz)
 - . 131-d CHALLENGING Minisatellite Payload (CHAMP) 325-425km neutral zonal winds

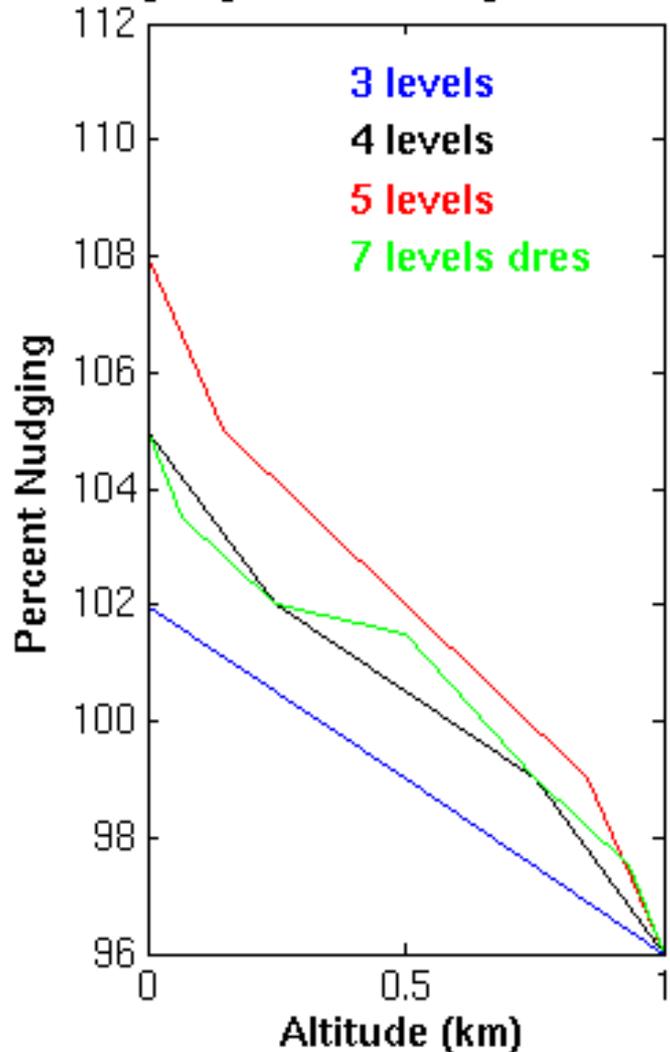
Zonal Means in The Lower Thermosphere

(~Truth from MSIS00 and TIMED/TIDI)



Nudging Pressure Levels in the TIEGCM

Nudging Percentage vs Height



There are 29 pressure levels in the TIEGCM from -7 to +7 every 0.5 of $\ln(p/p_0)$, where the first 7 levels are: -7.0 ~96km, -6.5 ~99km, -6.0 ~102km, -5.5 ~105km, -5.0 ~108km, -4.5 ~112km, -4.0 ~120km. The nudging parameter for `ctmt_nlev` pressure levels is:

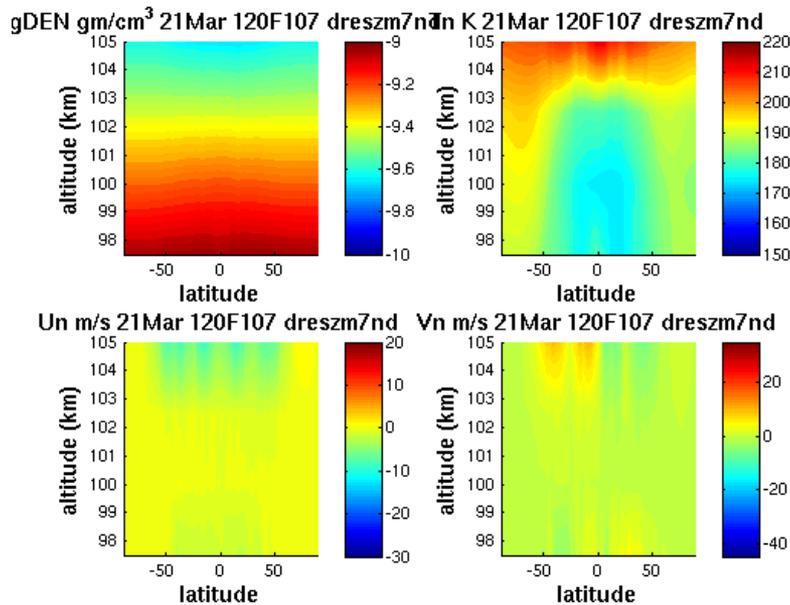
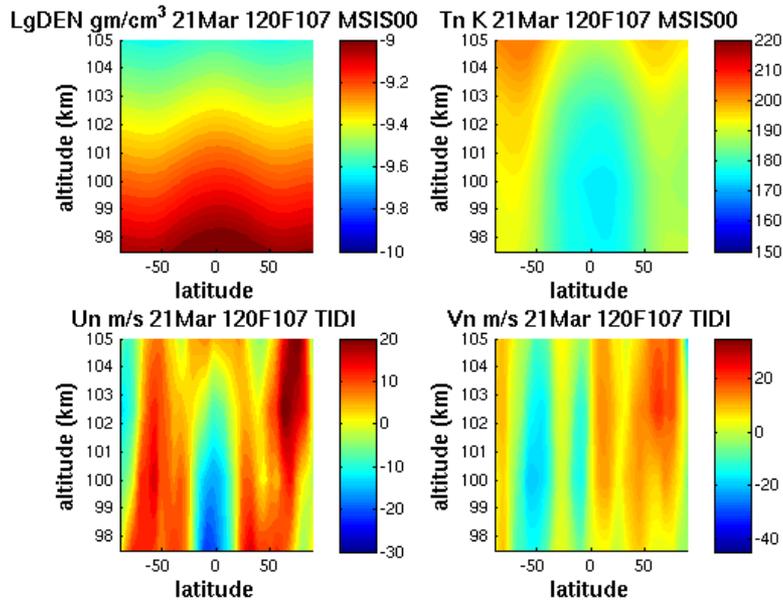
$$\cos(90 * (z_p(i) + 7) / (z_p(\text{ctmt_nlev}) + 7))$$

Tried `ctmt_nlev=4` for single resolution and `ctmt_nlev=7` for double resolution (green, dres).

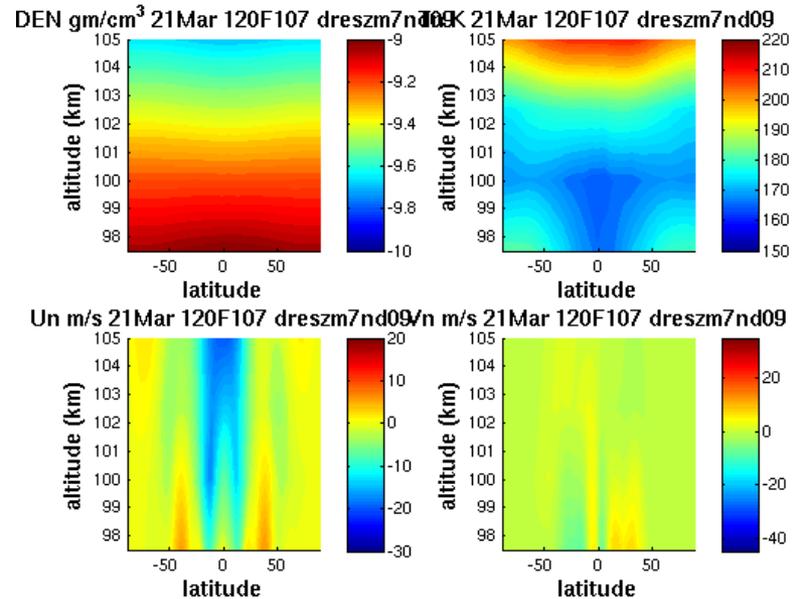
Nudged: T_n , V_n , U_n (not neutral density)

Compare 'Nudging' with 'Truth'

CTMT temperature is
'best' and GSWM09
winds are 'best'.



CTMT



GSWM09

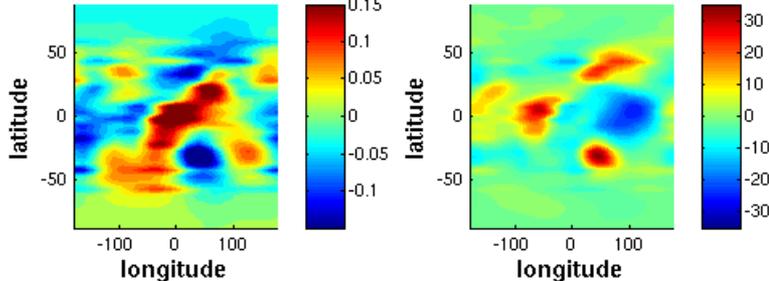
Nudging 4 levels (actually 3)

Density and Tn are still out of phase from CTMT at 105km.

Un and Vn similar to CTMT at 105km

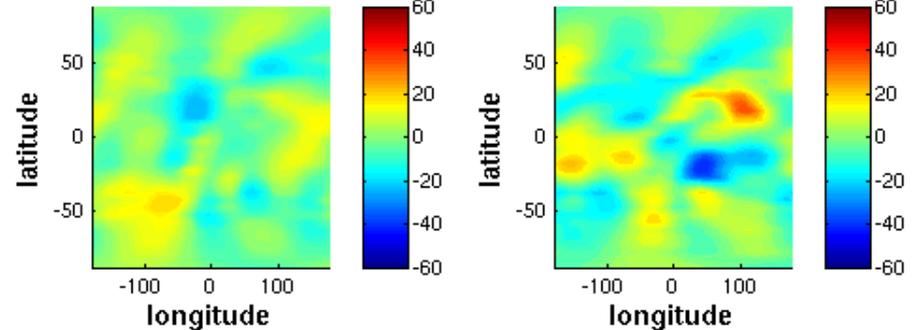
nudged

JT zm4nd pcDEN gm/cm3 21Mar 105.0km

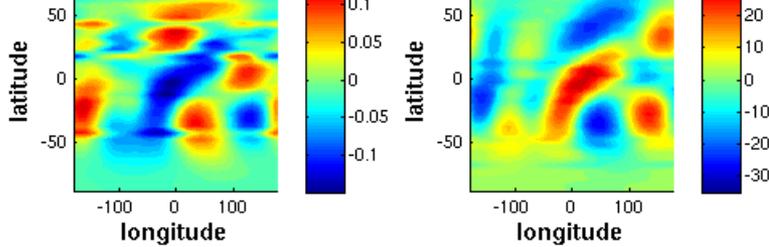


OUT zm4nd Tn K 21Mar 105.0km

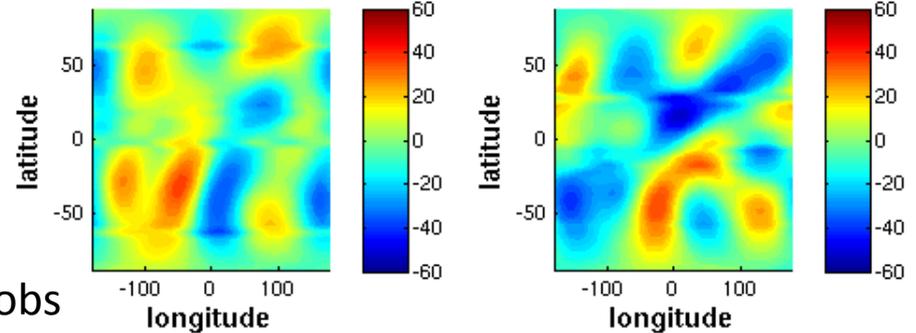
OUT zm4nd Un m/s 21Mar 105.0km



OUT CTMT pcDEN gm/cm3 21Mar 105.0km



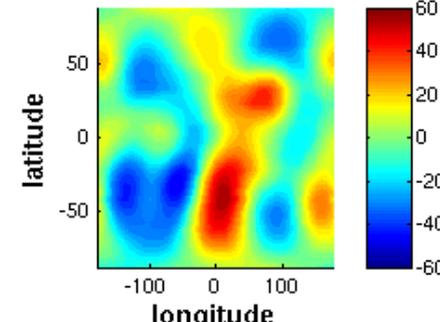
OUT CTMT Un m/s 21Mar 105.0km



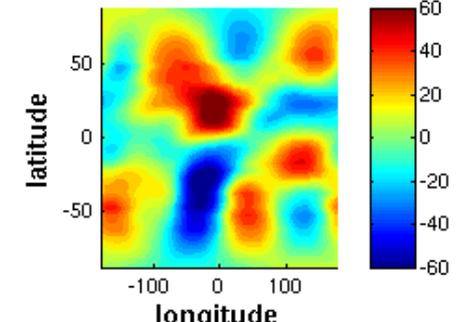
CTMT Fit to obs

Lbc+zm from before shows Un and Vn 4-6 hours out of phase at 105 km from CTMT

OUT zm Un m/s 21Mar 105.0km



OUT zm Vn m/s 21Mar 105.0km

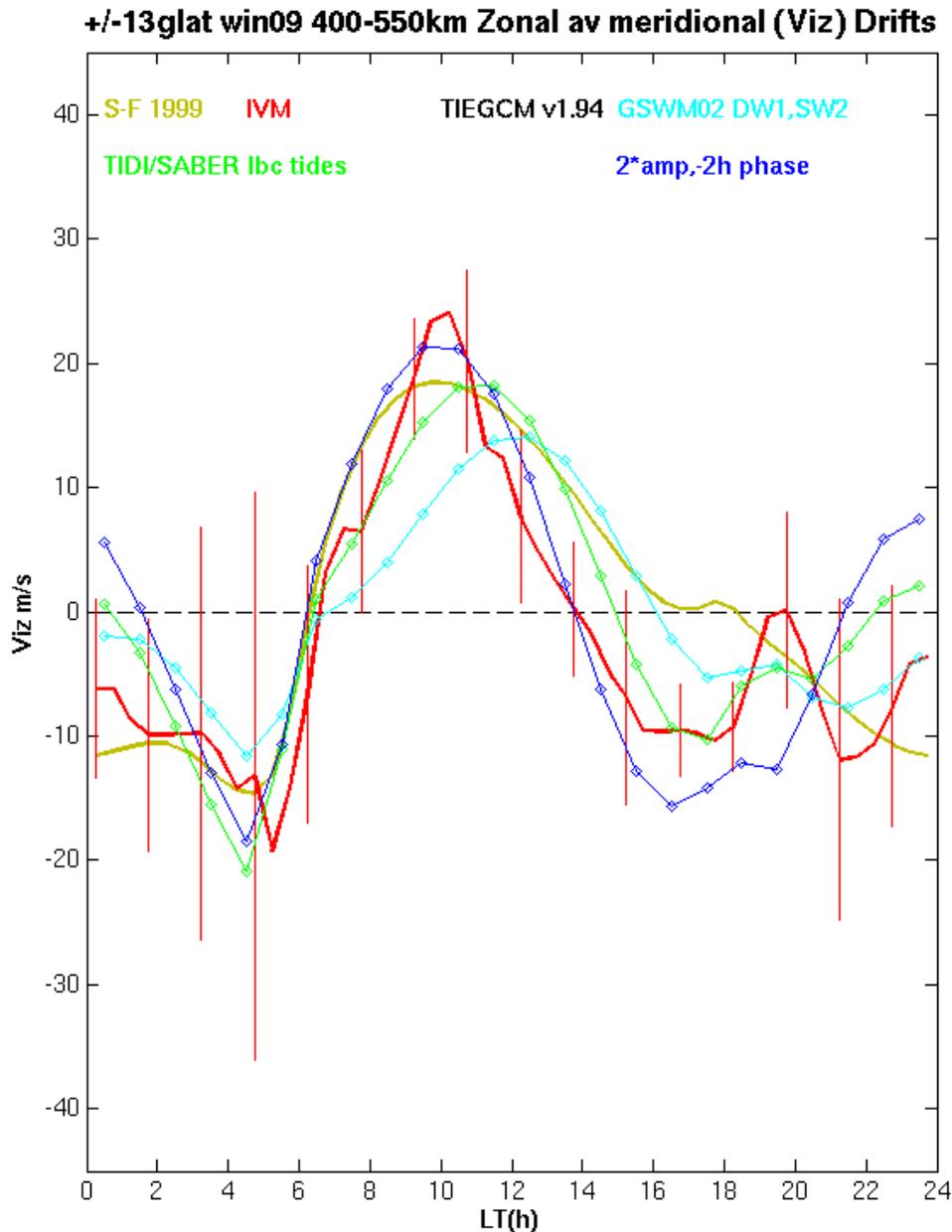


Zonally

Averaged Viz

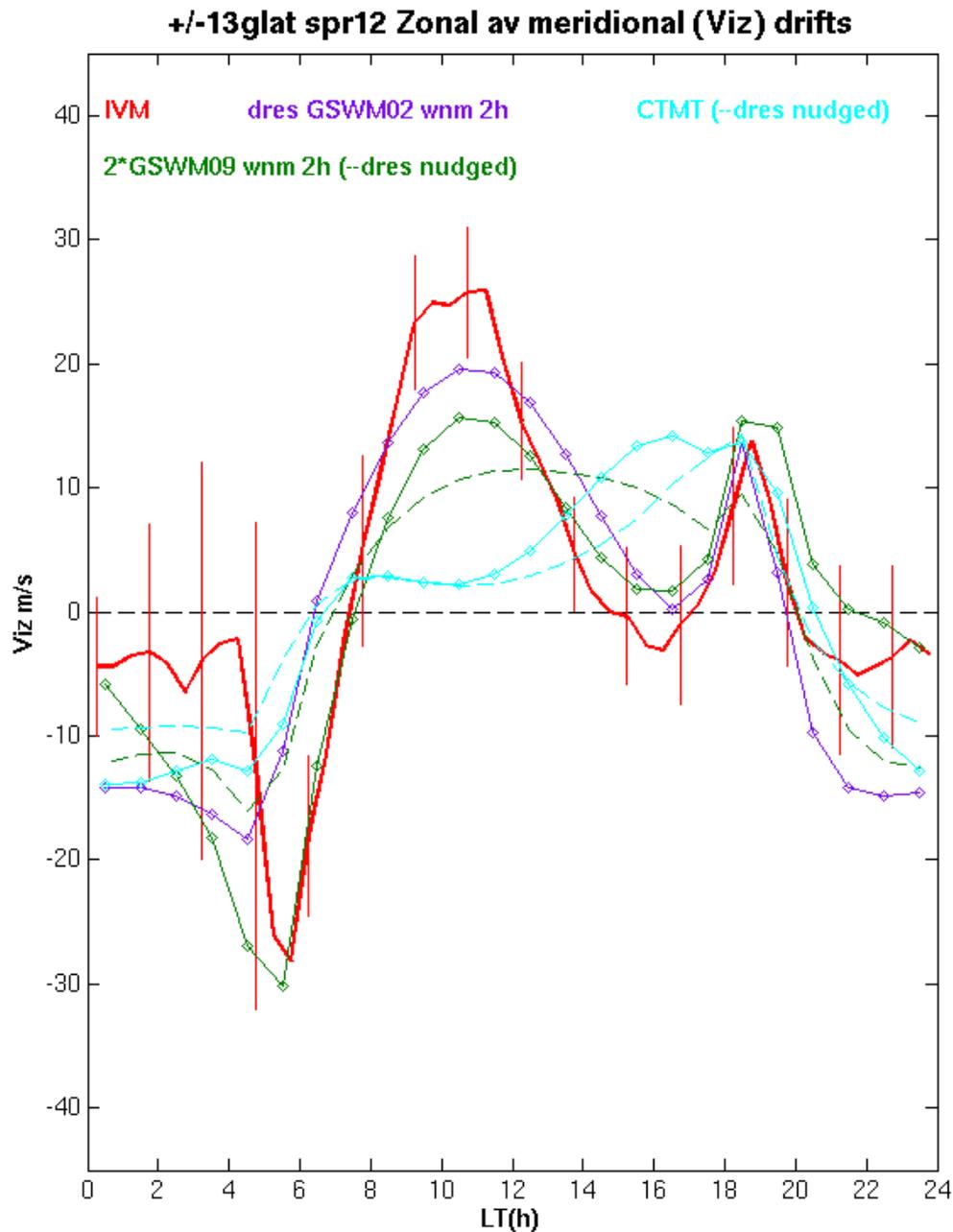
GSWM02 migrating (DW1 and SW2) tides were used in the TIEGCM v1.94 (cyan) and adjusted (blue, *2 amp, -2h phase) at the 97km lower boundary (lb). The adjusted tides did not give a Pre-Reversal Enhancement (PRE) after sunset for $F107=80$. Using TIDI/SABER tides at the lb (green), gave the best Viz.

Upward/downward Viz leads to increased/decreased N_e .



Feb-Apr 2012

Viz

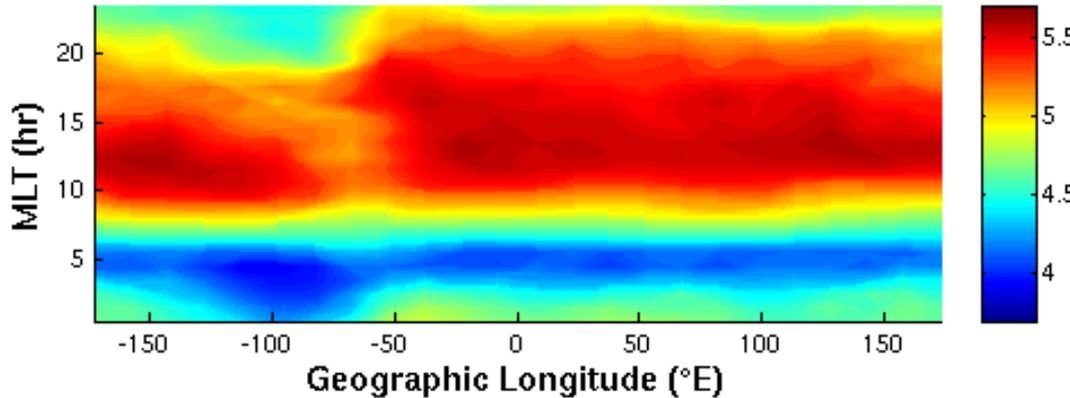


Use F107=120 and run TIEGCM v1.94 with 97 km tides for dres GSWM02 non-migrating tides with a 2 hour shift (purple), with 2*GSWM09 tides with a 2h shift (dark green), and with CTMT (TIDI/SABER) tides (cyan) with no shift. Dashed lines are the double resolution runs with nudging to ~105km.

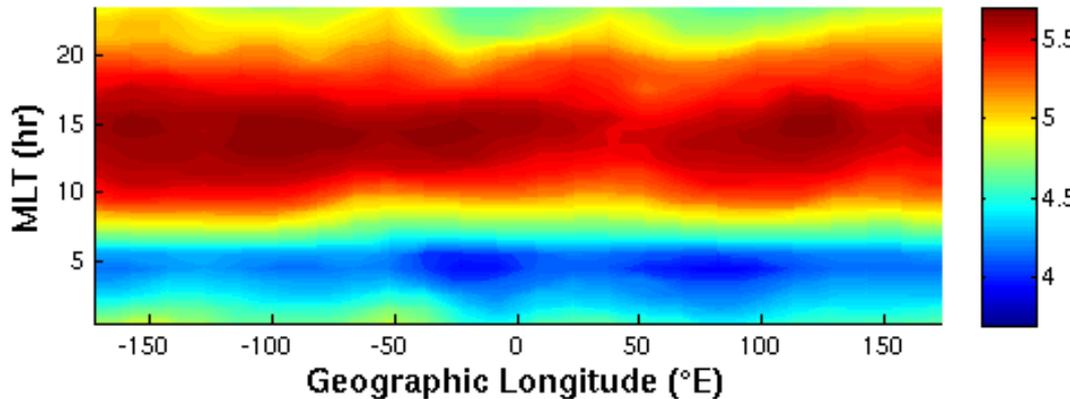
Tides from Below Influence

Longitude Peaks in Ne $\sim 450\text{km} \pm 13 \text{ glat}$

450km Ig10Ne Nov-Jan 2008-09

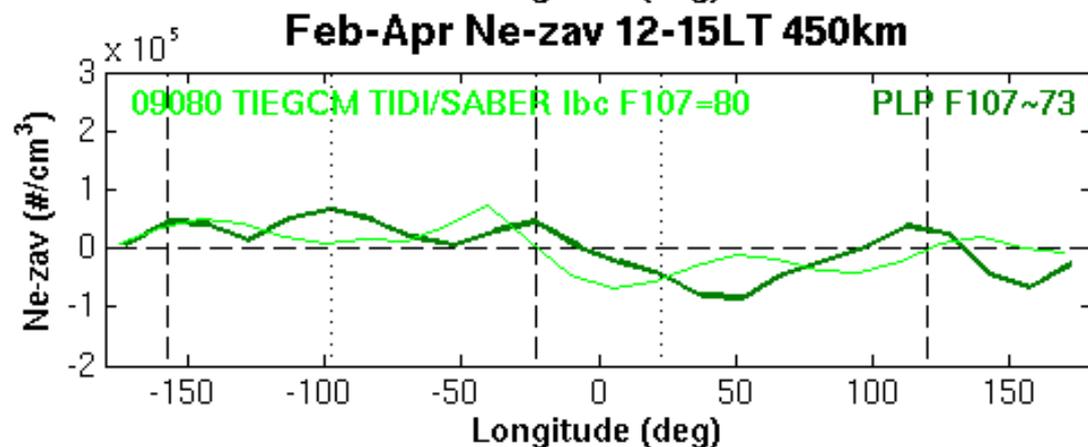
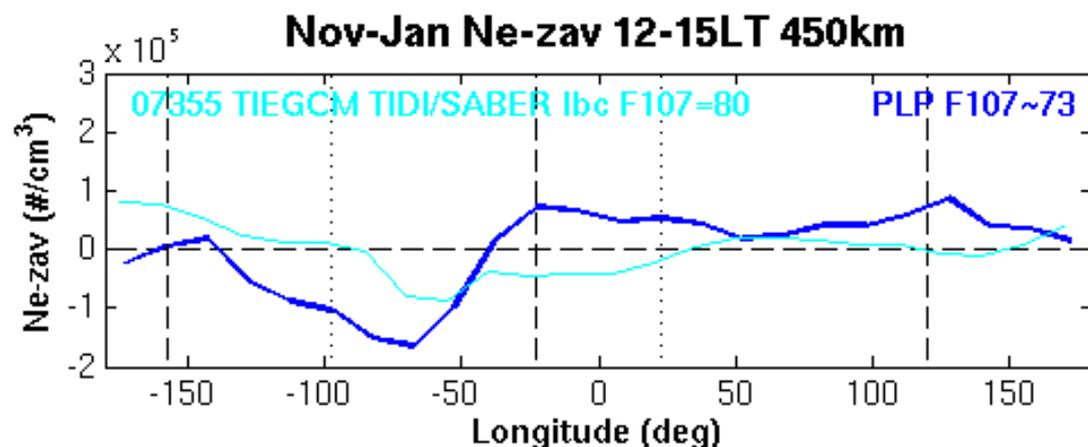


450km Ig10Ne Feb-Apr 2009-10



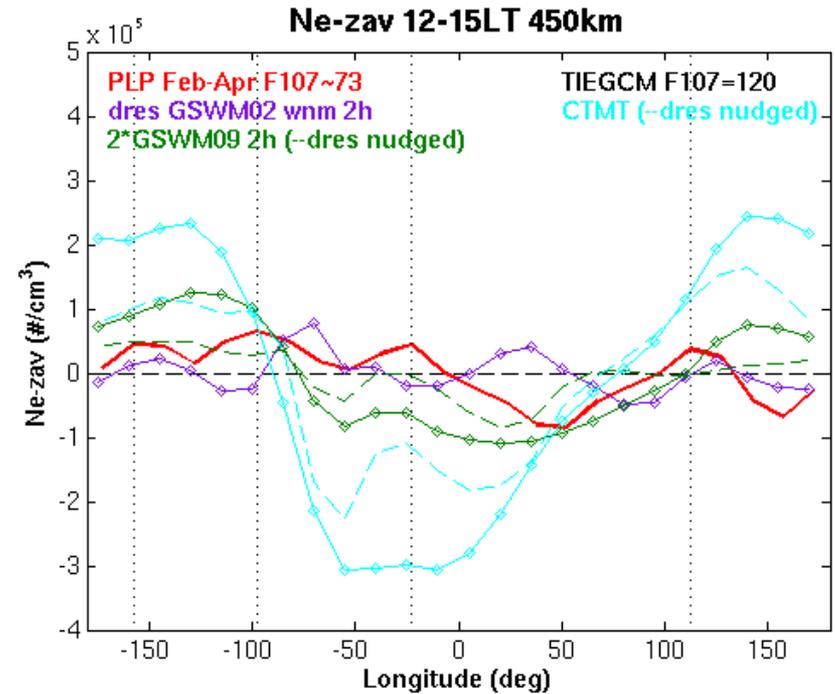
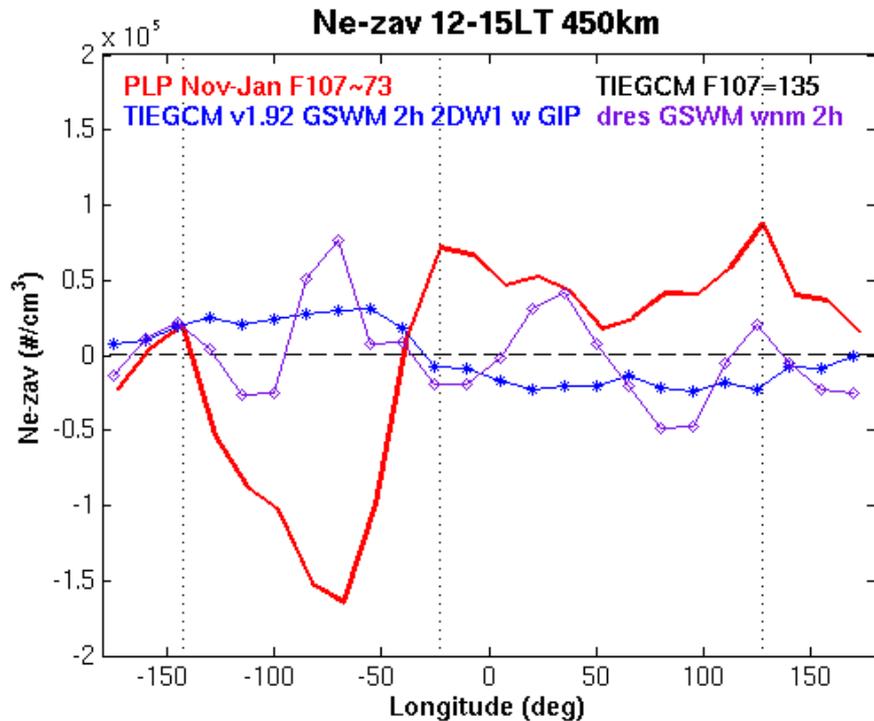
C/NOFS PLP Ne for $F107 \sim 73$ shows 3 peaks $\sim 13\text{LT}$ in Nov-Jan near 150W, 20W, 120E, with a fourth peak in Feb-Apr near 100W. 4 peaks are from DE3 from the lower atmosphere. In-situ non-migrating tides from the offset of the magnetic field and hence ion drag can give 2 peaks (DE1,S0), 3 peaks (DE2,SE1), and 1 peak (DW2,D0,SW3,SE1) from Jones et al. [JGR, 2013].

12-15 LT Ne minus zonal ave at 450 km from C/NOFS PLP and from TIDI/SABER LBC Tides



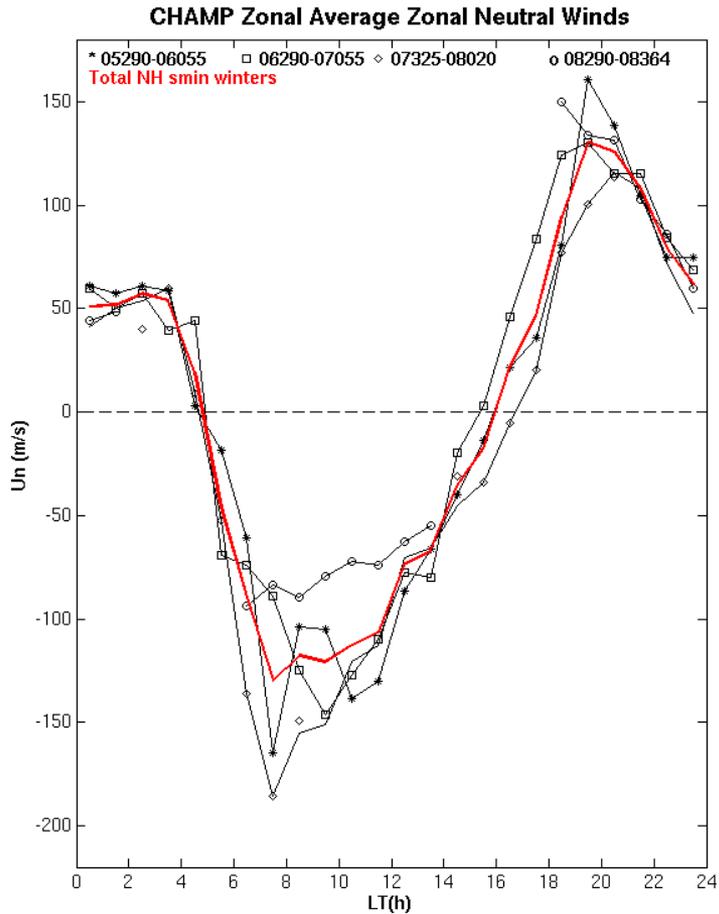
The best tides are specific daily TIDI/SABER tides for the lower boundary condition (lbc) ~ 97 km. These runs for specific solar minimum days similar to the C/NOFS PLP periods show 3-5 peaks in Ne ~ 450 km for December and March similar to the data. However, the peaks at 50E in the TIEDGCM are at a minimum in C/NOFS data, but close to a minor max at 22E.

12-15 LT Ne minus zonal av at 450 km



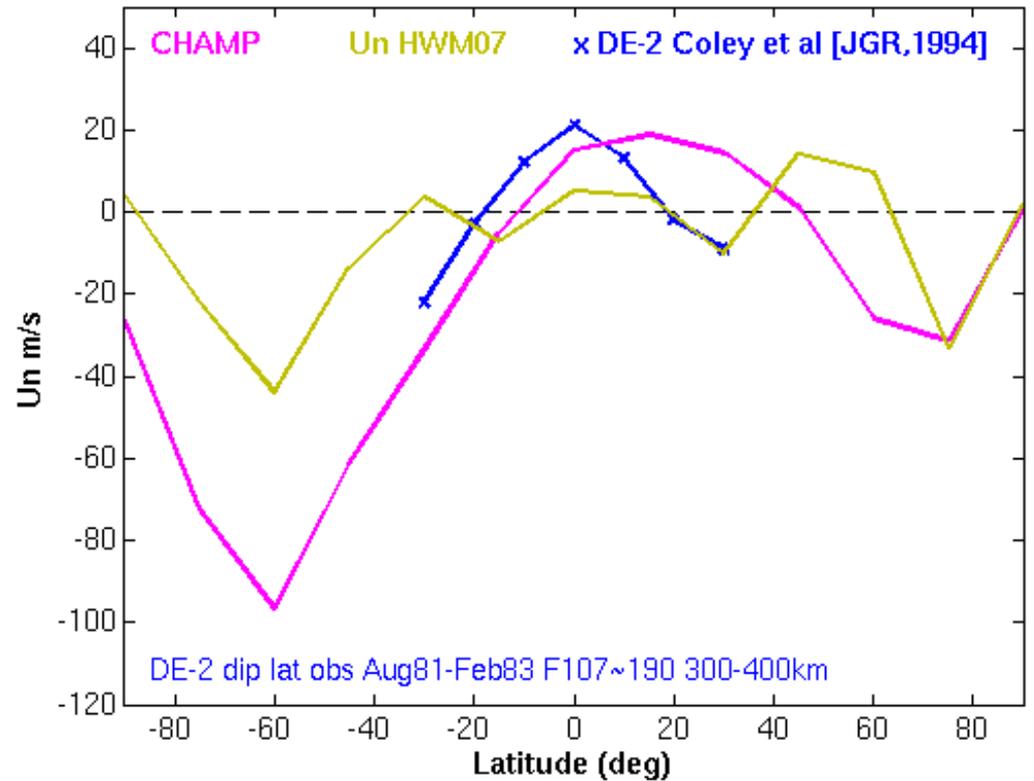
Only GSWM with non-migrating tides (purple) has 4 peaks in March and December from DE3 for Ne at 450 km. The single resolution CTMT(cyan) and GSWM09 (dark green) tides at the lower boundary have approximately 1 peak, where their double resolution nudged runs have multiple peaks where GSWM09 is 'best'. DE3 is too big in the December GSWM02 run.

Zonal Neutral Winds - Superrotation at Equator



Average over $\pm 13^\circ$ lat of 4 solar minimum periods from Oct-Feb from 2004-2008 to compare with C/NOFS satellite observations.

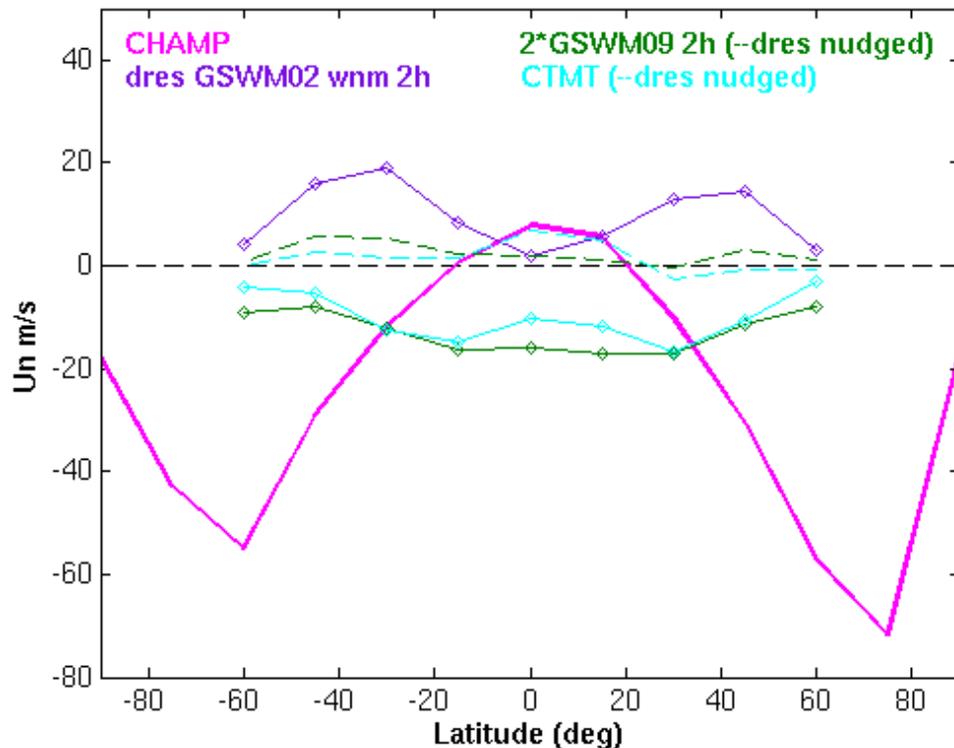
Zonal Av Neutral Zonal Winds (m/s) ~400km Oct-Feb F107~135



Zonally averaged CHAMP winds as a function of latitude from Oct-Feb with F107 105-195 compared with DE-2 winds for 1.5 years F107 ~ 190 .

March Un Zonal Means ~375km

Zonal Av Neutral Zonal Winds (m/s) ~350km March F107~120



The CHAMP zonal means for the zonal neutral wind ~375km show superrotation (+E) at the equator and subrotation at higher latitudes, similar to the DE-2 study of Coley et al. [1994]. All the TIEGCM runs show a minimum at the equator, and are mostly westward (subrotation).

Nudging the Un and Vn tides and mean winds to 105 km, show near zero zonal means, or slight superrotation – an improvement.

Summary of Tides in the TIEGCM to Match Data in Low-Latitude Climatology

- Propagating tides (and geopotential heights) from the lower atmosphere influence V_z and the latitude structure of the neutral zonal wind, and produce low-latitude longitude peaks in N_e etc for double resolution (2.5 deg) runs, but not for single resolution runs.
 - Lower boundary double resolution GSWM09 with non-migrating tides doubled in amplitude and shifted 2 h earlier and nudged or SABER/TIDI tides for specific dates are “best”.
 - TIEGCM does not propagate the tides properly between 97 and 105 km, where CTMT tides are 4-6 hours out of phase.
 - “Nudging” TIEGCM with Hough mode extensions of CTMT and GSMW09 tides and mean values (MSIS,TIDI) improves the tides for U_n and V_n at 105, but not T_n or density.
 - Future: Use double resolution to investigate tides, nudge density also, and try nudging to 110 km.