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Modeling Weather in the Ionosphere using the Navy's Highly Integrated Thermosphere and Ionosphere Demonstration System (Navy-HITIDES)

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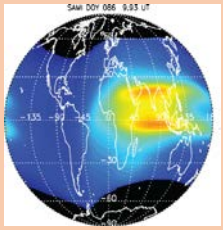
Model Description

Navy HITIDES



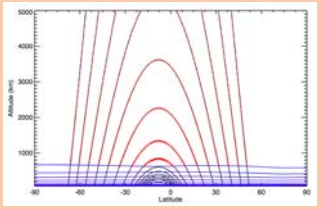
SAMI3 Physics-based model of the ionosphere. Dynamics and chemistry of 7 ion species from 85 km to > 20,000 km

EUV Solar Drivers (NRLSSI)

H, He NRLMSIS

Regridding ESMF

Vertical Extension Of Thermosphere

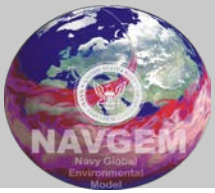


Neutral winds (U, V), Temperature (T_n), Constituents (O, N, NO, O_2, N_2)

N_e

WACCM Whole Atmosphere Community Climate Model

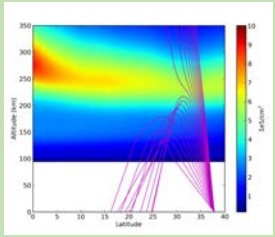
SD-WACCM-X
Global climate-chemistry model
Solves dynamics, physics and chemistry from ground to ~500 km



HA-NAVGEM: Operational Navy Analysis (ground to ~95 km)
Hybrid 4D-Var 3hr data assimilation products

MOJO

Raytracing Code



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Navy-HITIDES/SD-WACCM-X Simulations of January 2010

- Simulations of 1- 31 January 2010
  - Geomagnetically quiet month (average Ap = 3)
    - Except for 20 January when Ap reached 12
  - Stratospheric warming event
    - Increase in stratospheric temperatures between 18 – 22 January

- Nudging of SD-WACCM-X with 2 different data assimilation products
  - NOGAPS-ALPHA (Navy Operational Global Atmospheric Prediction System – Advanced Level Physics High Altitude)
    - 3D-Var, up to ~90 km altitude, 6-hour data products
  - HA-NAVGEM (High Altitude Navy Global Environmental Model)
    - Hybrid 4D-Var, up to ~95 km altitude, 3-hour data products

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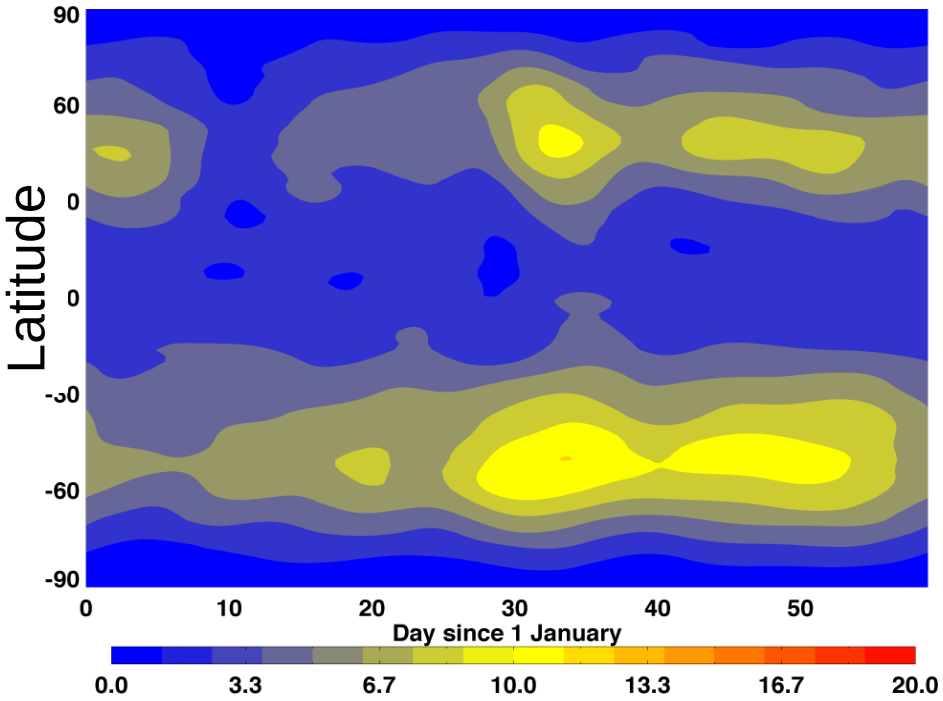
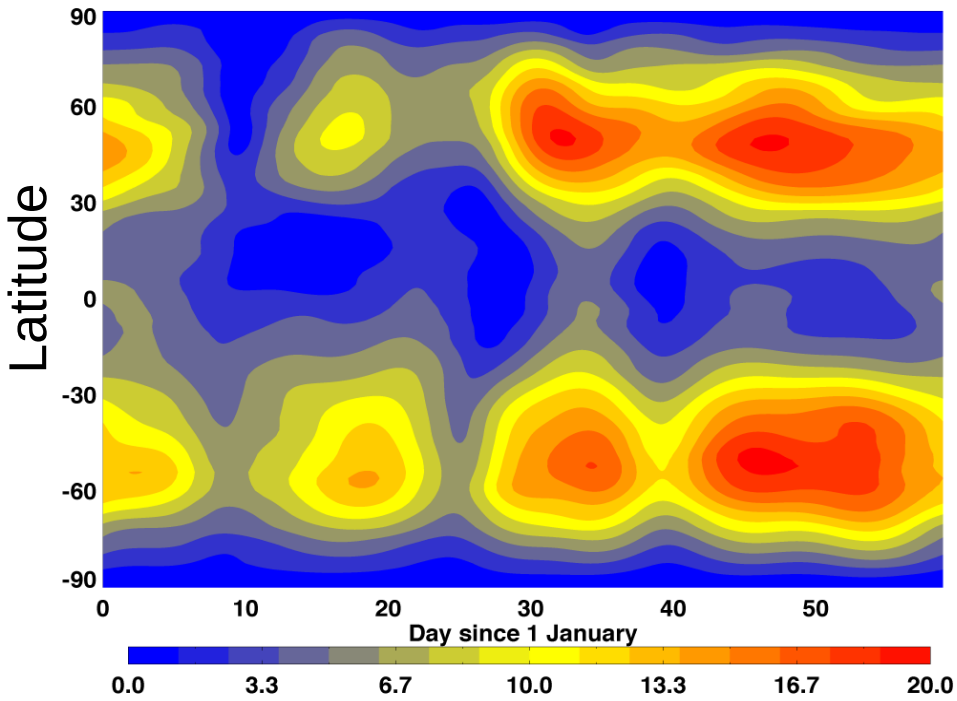
Semi-Diurnal Tide (SW2)

WACCM-X w/ NOGAPS-ALPHA
6-hourly cadence
Zonal Wind SW2 Amplitude at 110 km



WACCM-X w/ HA-NAVGEM
3-hourly cadence
Zonal Wind SW2 Amplitude at 110 km



- 3-hour HA-NAVGEM better resolves the semi-diurnal tides
- SW2 is twice as strong in WACCM-X with HA-NAVGEM forcing

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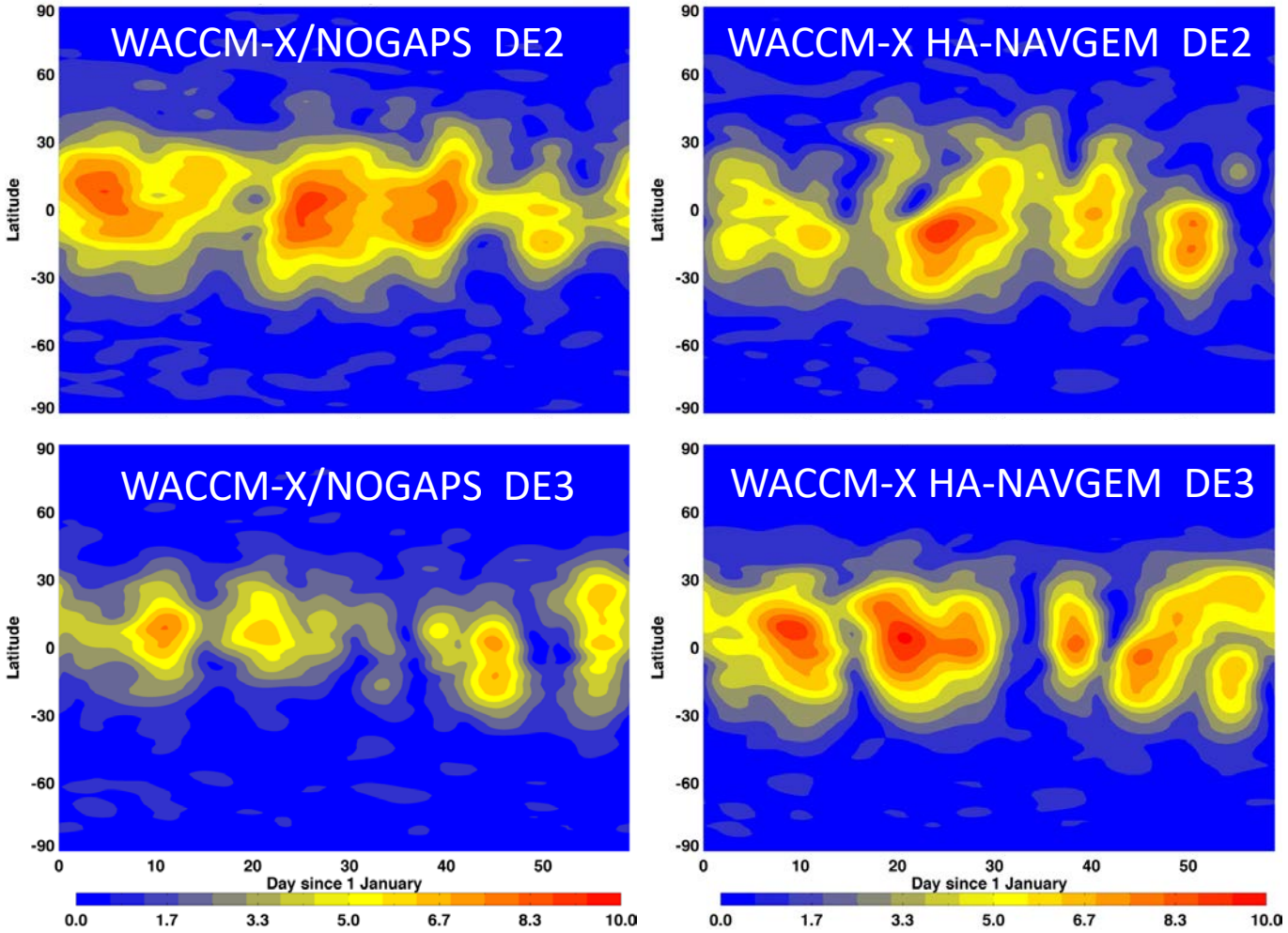
Non-migrating tides (DE2 and DE3)

Zonal Wind Amplitudes at 110 km
Latitude vs Day of Year



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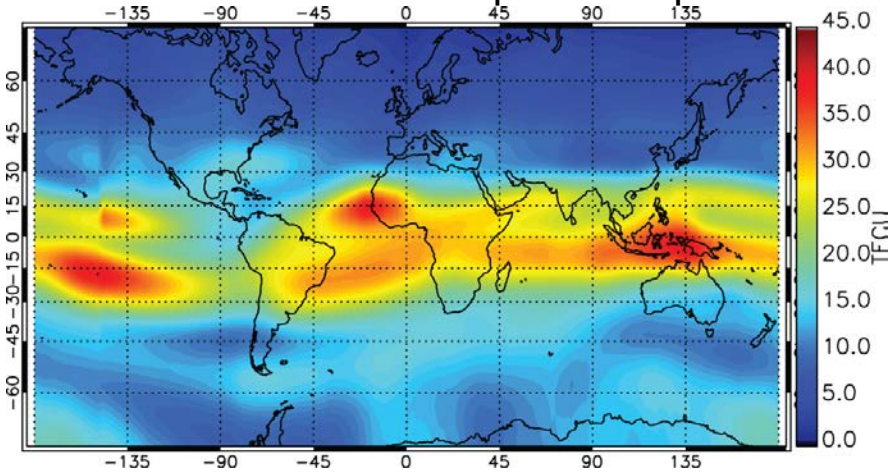
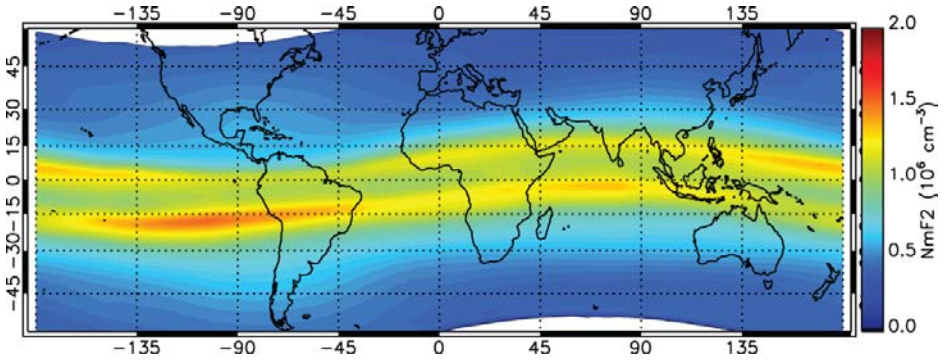
12 Jan 2010 at 1400 LT

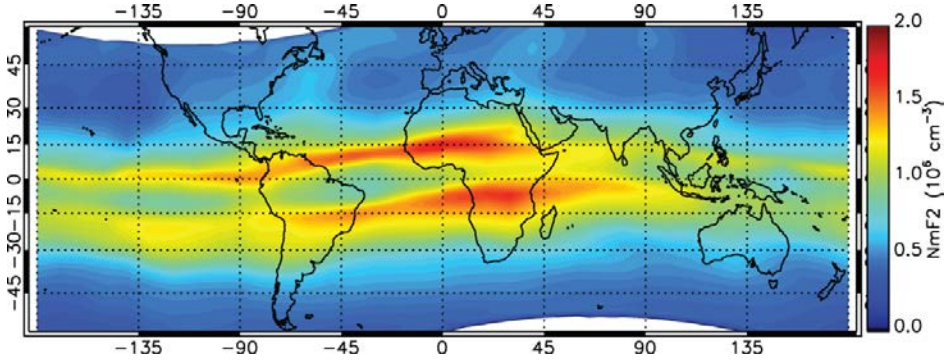
JPL 15-min Global Ionosphere Map



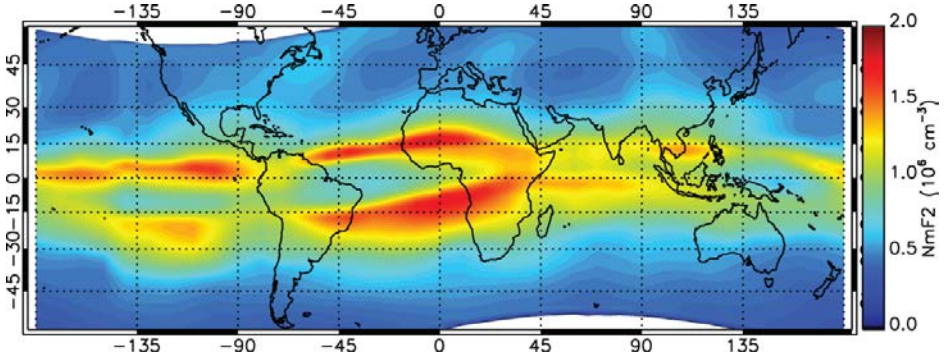
Climatology (SAMI3 with HWM14 & NRLMSIS)



Navy-HITIDES/WACCM-X w/ NOGAPS-ALPHA



Navy-HITIDES/WACCM-X w/ HA-NAVGEM



Simulations with HA-NAVGEM forcing capture more <u>longitudinal</u> variability in the ionosphere and compare better to observations.

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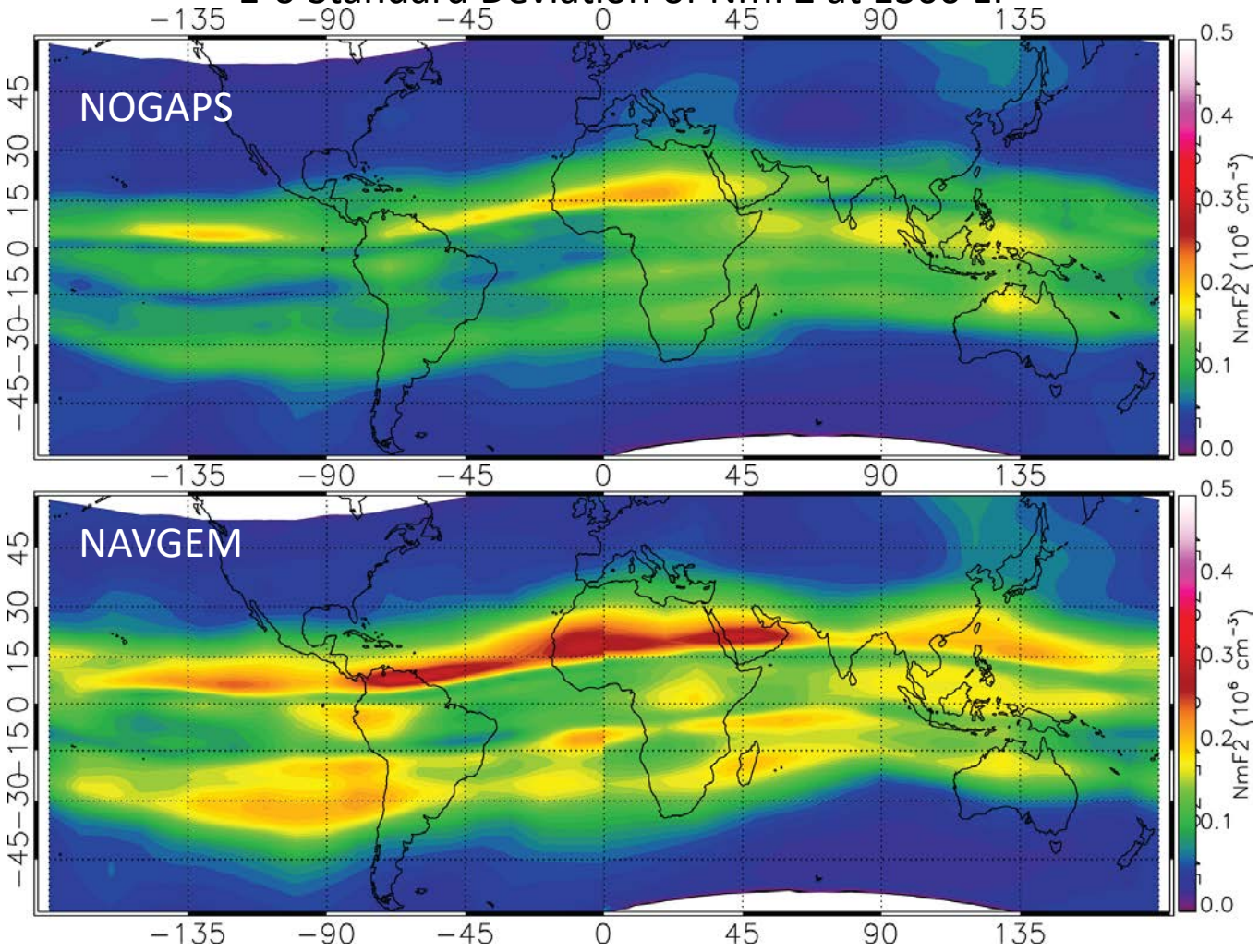
Day-to-day variability in NmF2

Navy-HITIDES/WACCM-X Variation in NmF2 during January 2010

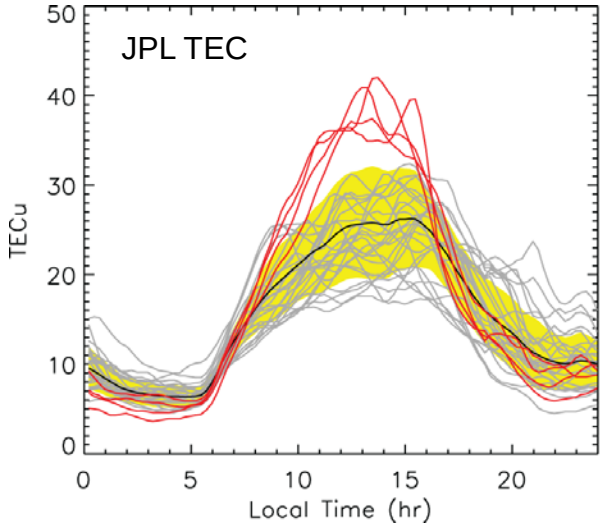
1-σ Standard Deviation of NmF2 at 1300 LT

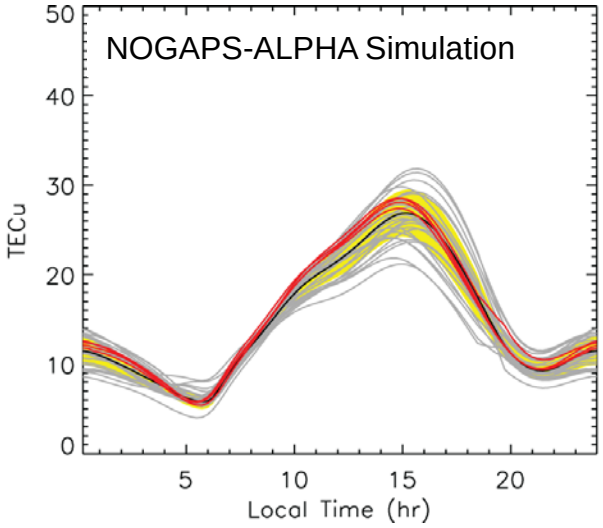


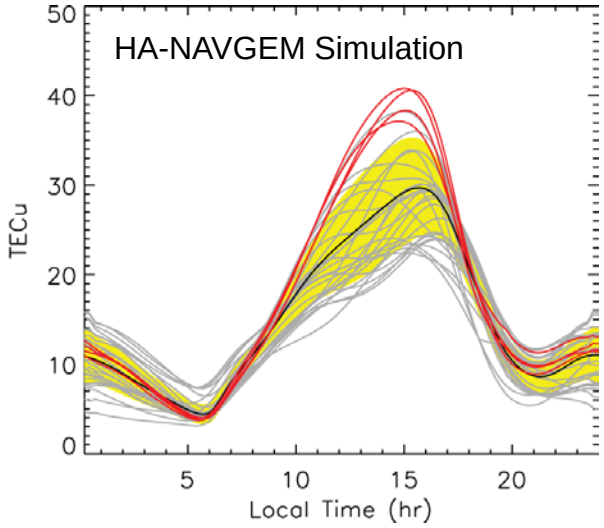
Simulations with HA-NAVGEM forcing capture more day-to-day variability in the ionosphere

January 2010 TEC during SSW period

Jicamarca Longitude Sector: Lon=285°E, Lat=0°N





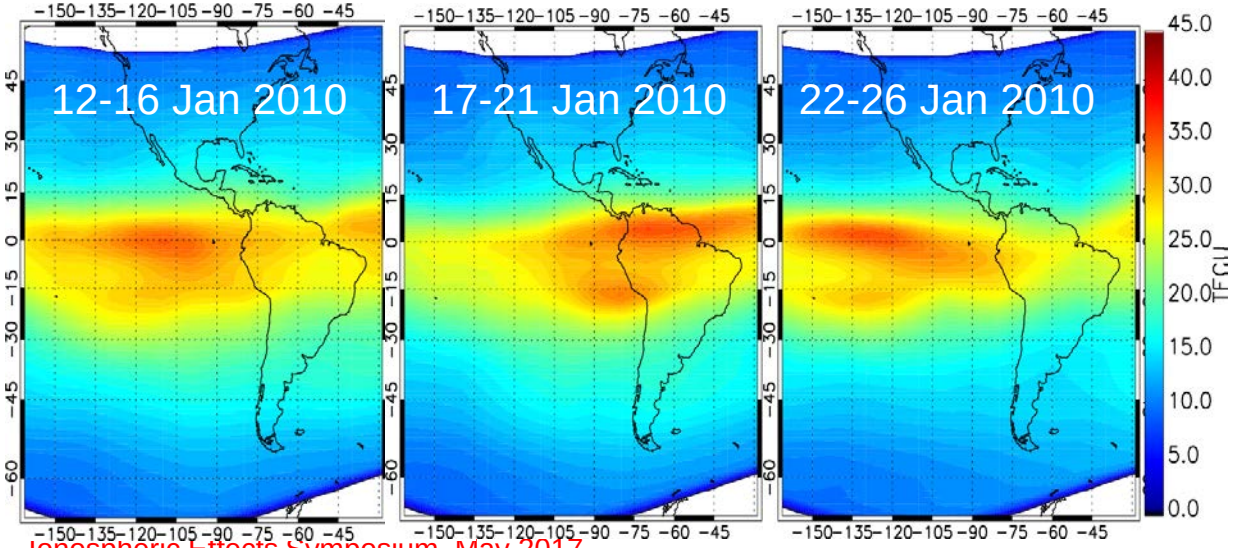


Enhanced TEC observed in S. America on 17, 19 – 21 January (shown in red).

SSW period - 18 – 22 Jan.

Navy-HITIDES/WACCM-X with HA-NAVGEM forcing captures this variability.

HA-NAVGEM Simulation at 1300 LT



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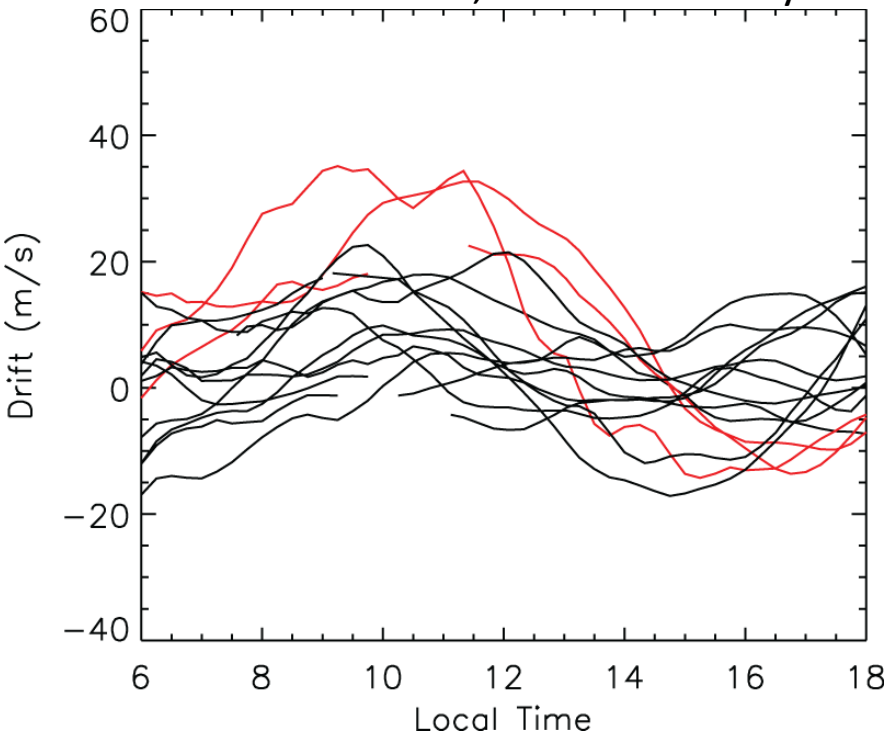
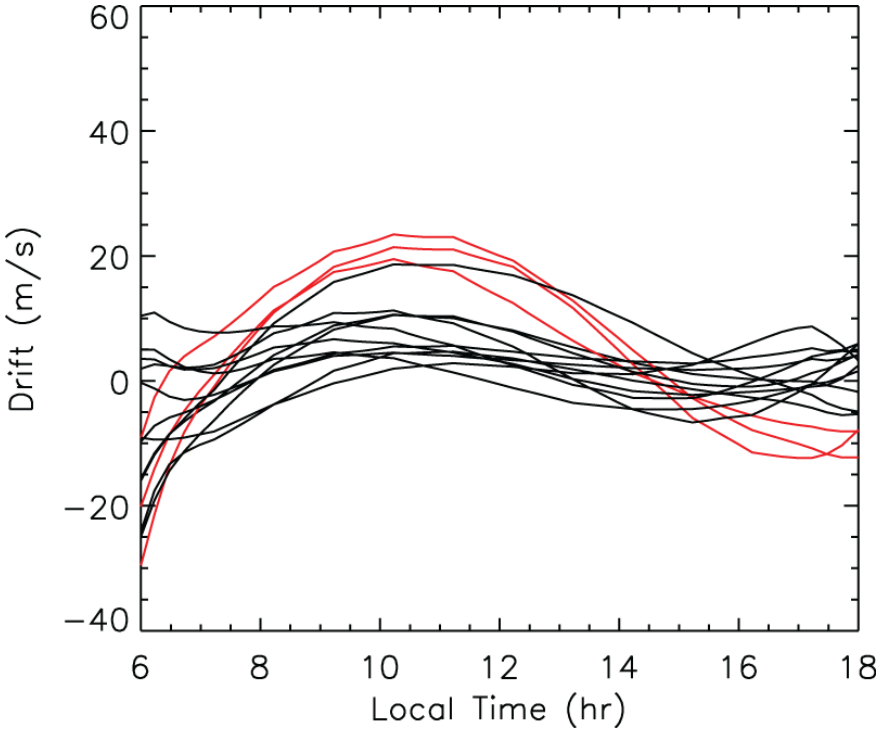
ExB Drifts at Jicamarca

Jicamarca ISR, 19 – 31 January



HA-NAVGEM Simulation



19 – 21 January 2010

22 – 31 January 2010

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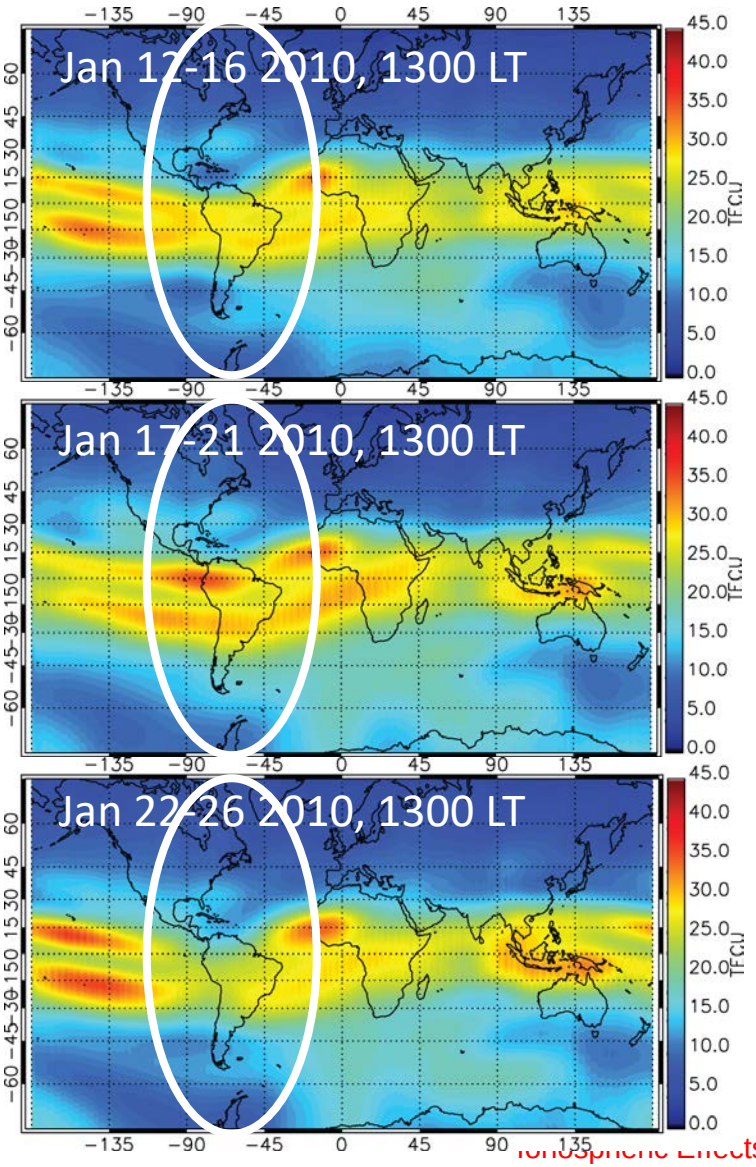
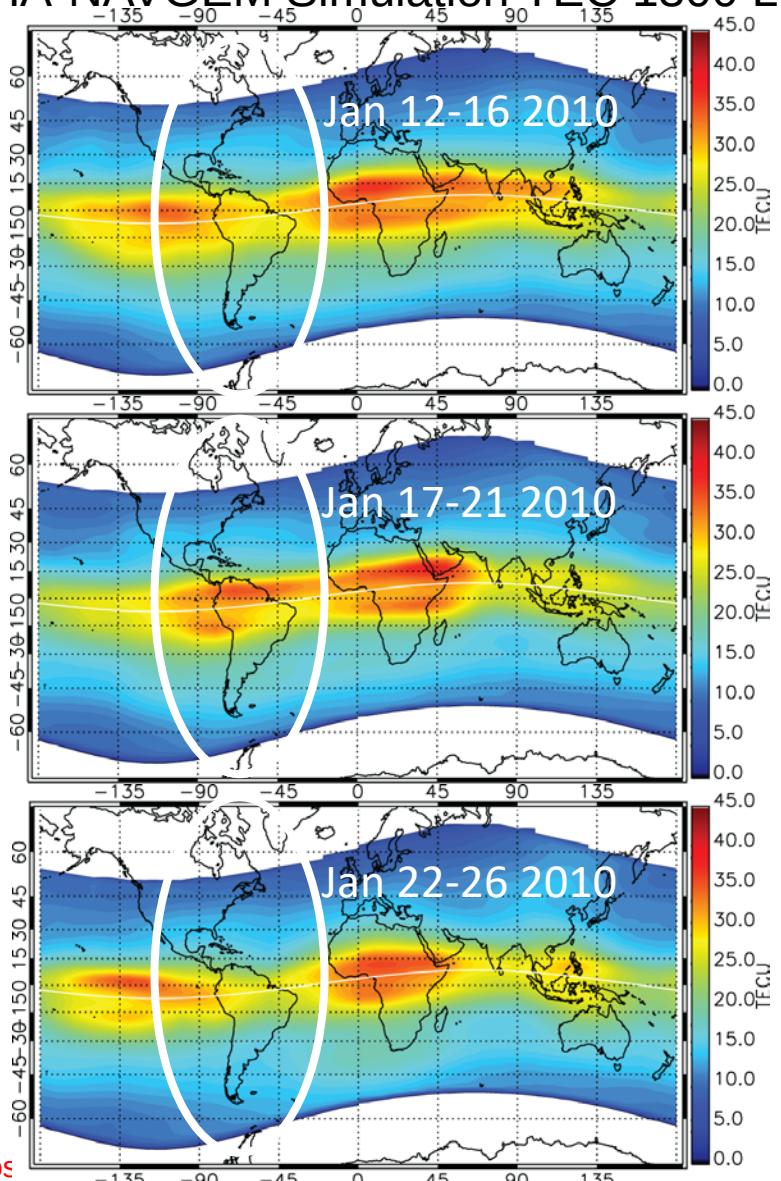
Global TEC

JPLTEC 1300 LT

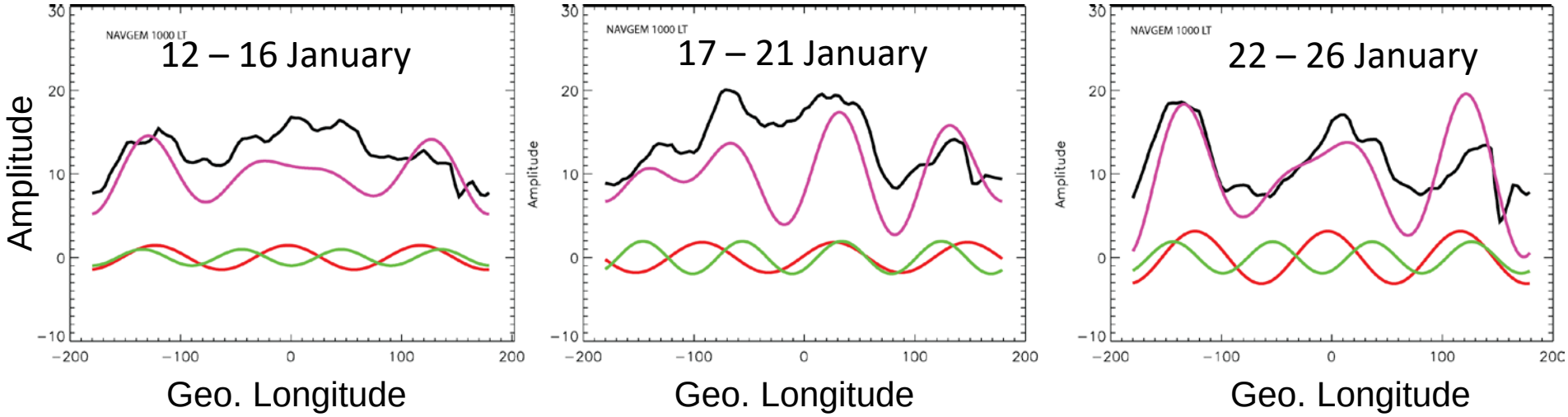


HA-NAVGEM Simulation TEC 1300 LT



Wave-3 and Wave-4 Amplitudes at 1000 LT

HA-NAVGEM Simulation



Vertical ExB drift at 1000 LT
Wave-3 amplitude (DE2, sPW3, SW5, DW4)
Wave-4 amplitude (DE3, sPW4, SE2)
Wave-3 + Wave-4 amplitude (*shifted up and amplified to match ExB drift*)

- Amplitudes of wave-3 and wave-4 are similar during each of the 5-day periods
- Appearance of 4 peaks during 17 – 21 January primarily due to shift in phase of wave-3

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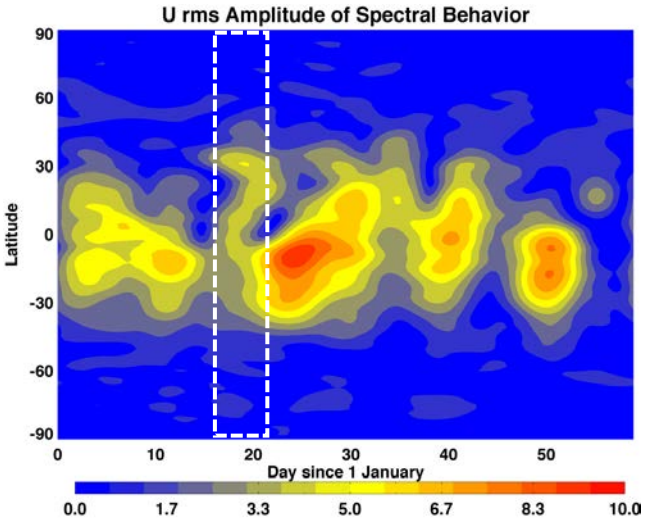
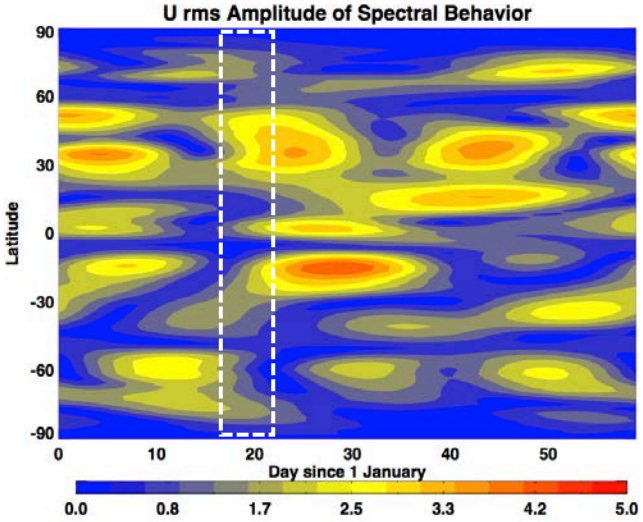
Tides that contribute to wave-3 feature

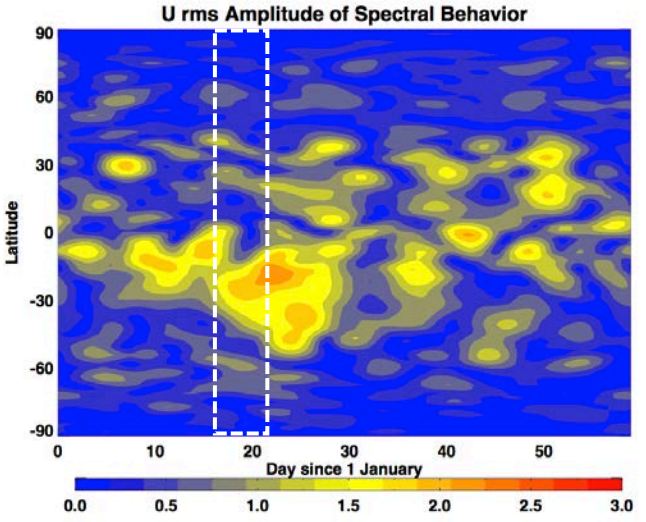
DE2



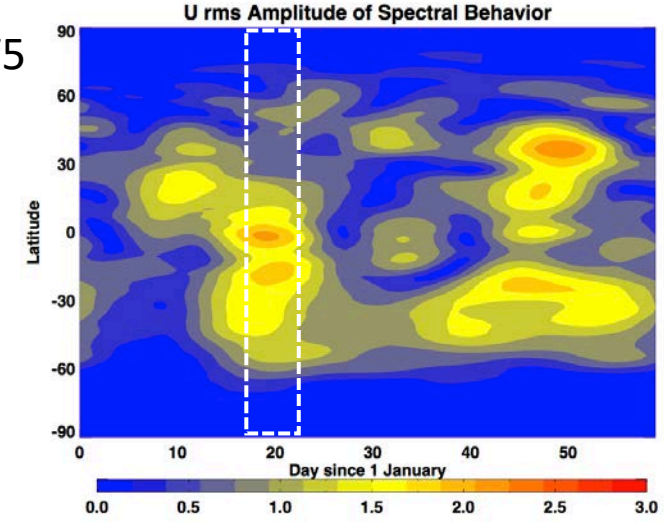
sPW3



DW4



SW5



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Summary and Conclusions

- Navy-HITIDES has been one-way coupled to WACCM-X
- Simulated January 2010 using forcing from:
  - NOGAPS-ALPHA (6-hour)
  - HA-NAVGEM (3-hour)
- 3-hour HA-NAVGEM forcing results in better resolution of SW2 in SD-WACCM-X
- Navy-HITIDES/WACCM-X with HA-NAVGEM improves ionospheric specification
  - Better day-to-day and longitudinal variability
  - Closer match to observations
- Stratospheric warming period
  - Observed enhanced TEC and upward vertical drifts over S. America during 17 – 21 January
  - NAVGEM simulation captured this enhancement
  - Simulations show the enhancement due to shift in wave-3 phase during these days with likely contribution from SW5 tide

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Wave-3 and Wave-4 in Vertical ExB Drifts

NAVGEM Simulation

12 – 16 January | 17 – 21 January | 22 – 26 January