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Modeling Ionospheric Daily Variability with SAMI3/SD-WACCM-X

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Overview

- Can we capture the daily variability of the ionosphere by including a more realistic thermosphere?
- Model Setup
- Data
- Daytime, Equatorial case (Jicamarca)
- Daytime, Mid-latitude case (Boulder, CO)
- Conclusions

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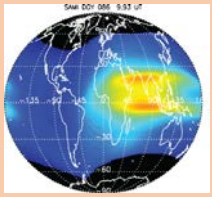
Model Setup

NRLSSI Solar Irradiance Model



SAMI3

Physics based model of the ionosphere
Models dynamics and chemistry of
7 ion species from 85 km to 8 R_E

Thermospheric Composition
Neutral Winds
Temperature

5 minutes

SD-WACCM-X

WACCM
Whole Atmosphere Community Climate Model

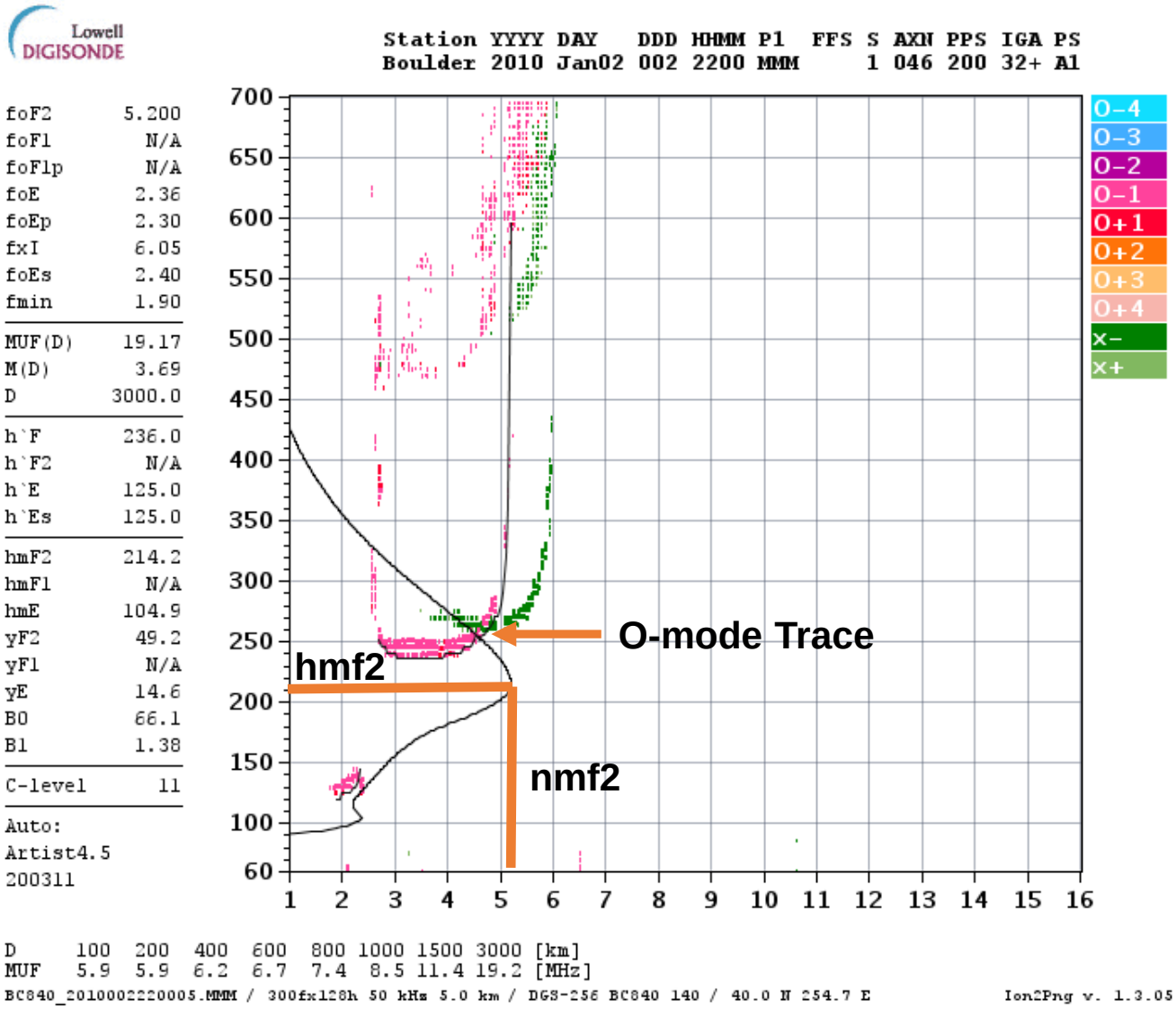
Global climate-chemistry model
Solves dynamics, physics and chemistry
globally from ground to ~500 km

Every 3 hours

NAVGEM
Navy Global Environmental Model

NAVGEM: Operational Navy Analysis (ground to ~92 km)
4DVAR data assimilation products

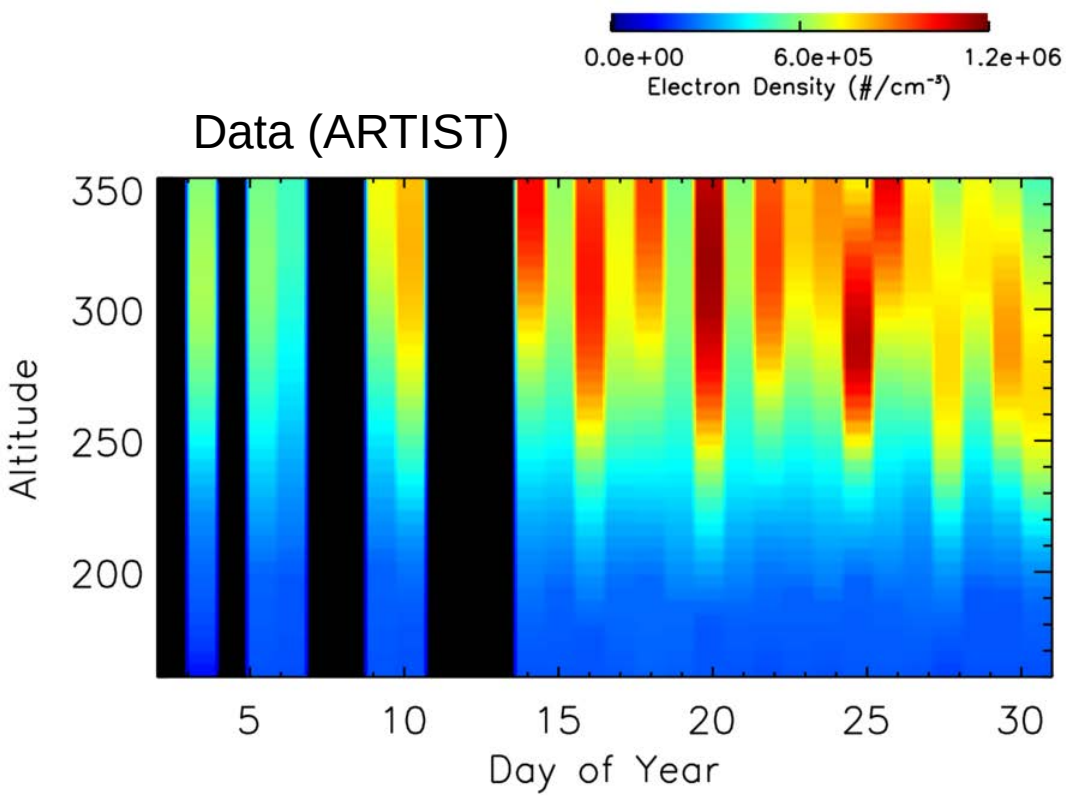
Data

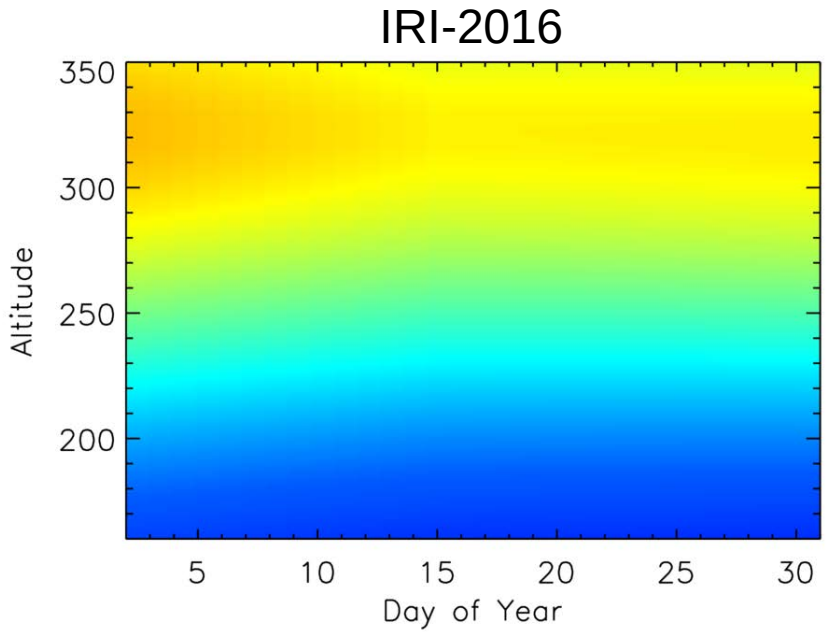


- Two ionosondes from the NOAA digisonde database (JI91J and BC840)
- Using the ARTIST auto-scaled parameters
- Picked a local time where the auto-scaling looks good
- Take the mean value of an hours worth of data centered around the given time

Bottomside shape parameter (B0): hmf2 – height where electron density is ¼ of nmf2

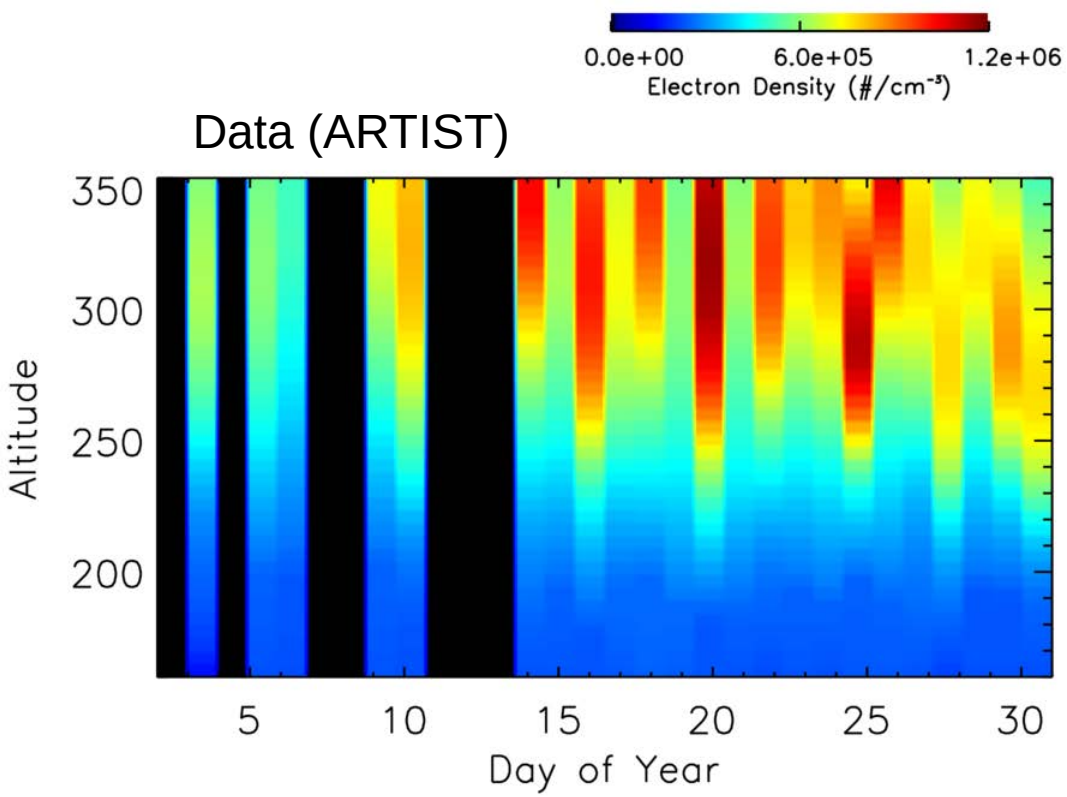
Jicamarca at 15 LT

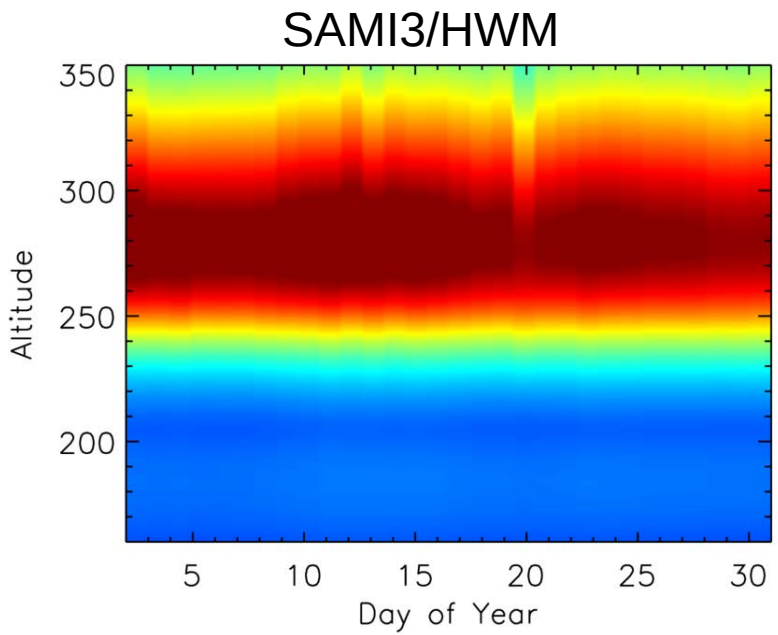




IRI-2016 is an empirical model, so no daily variability

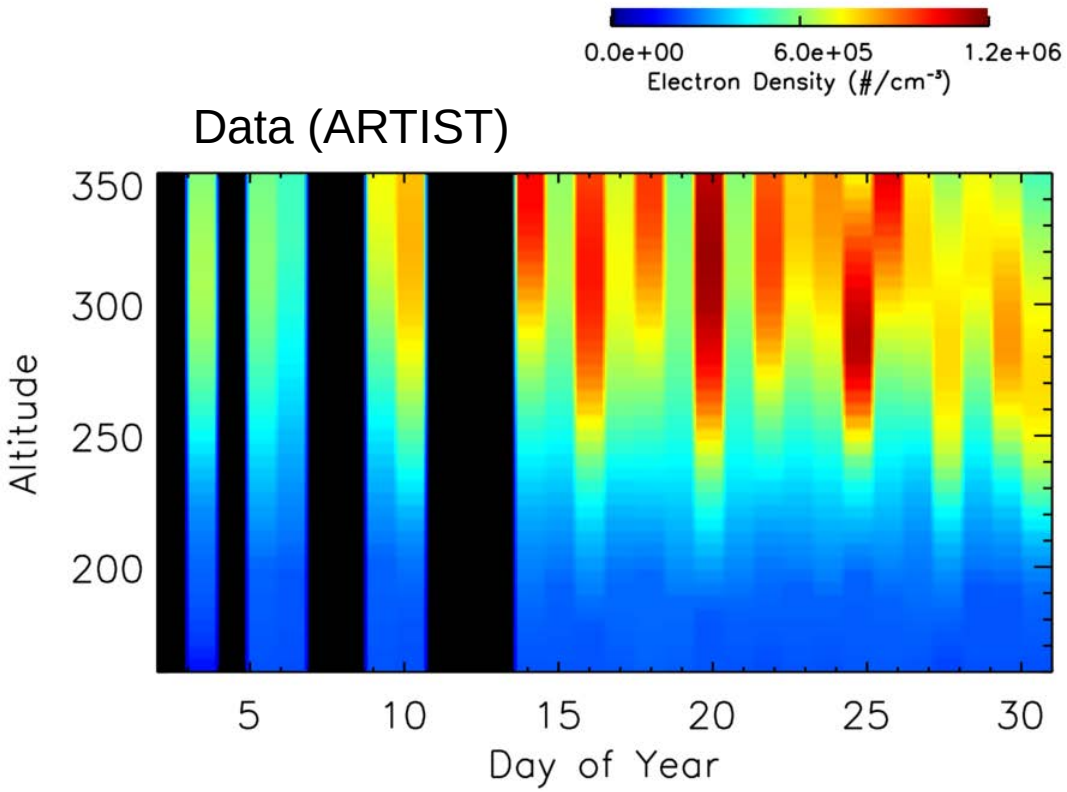
Jicamarca at 15 LT

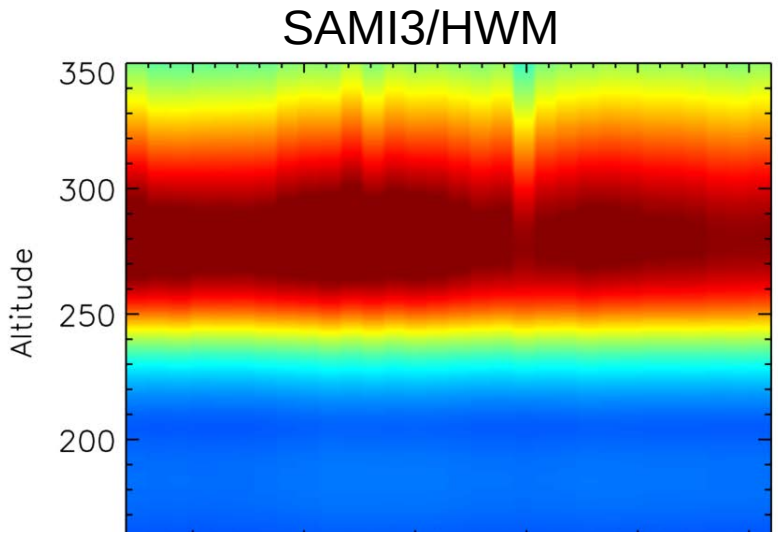


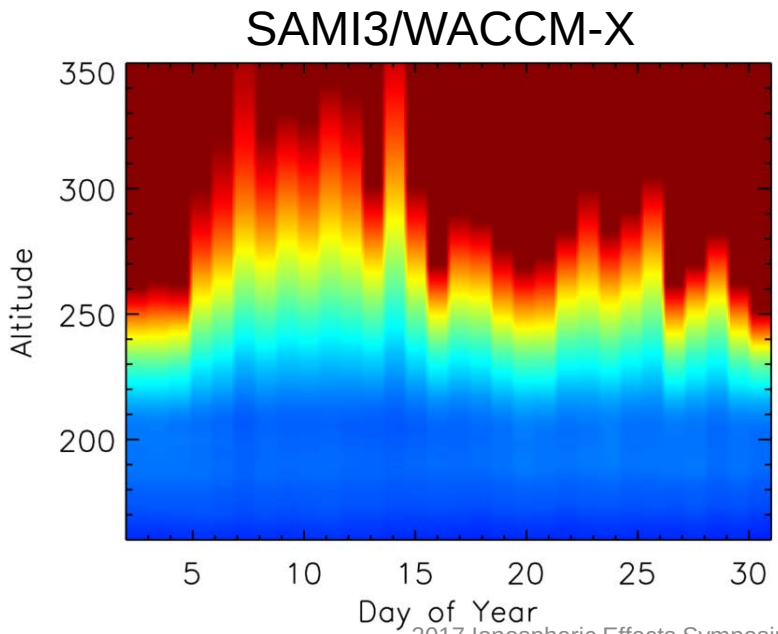


SAMI3 driven with a climatological thermosphere (NRLMSIS-00 and HWM-14) does not show daily variation of the electron density profile

Jicamarca at 15 LT



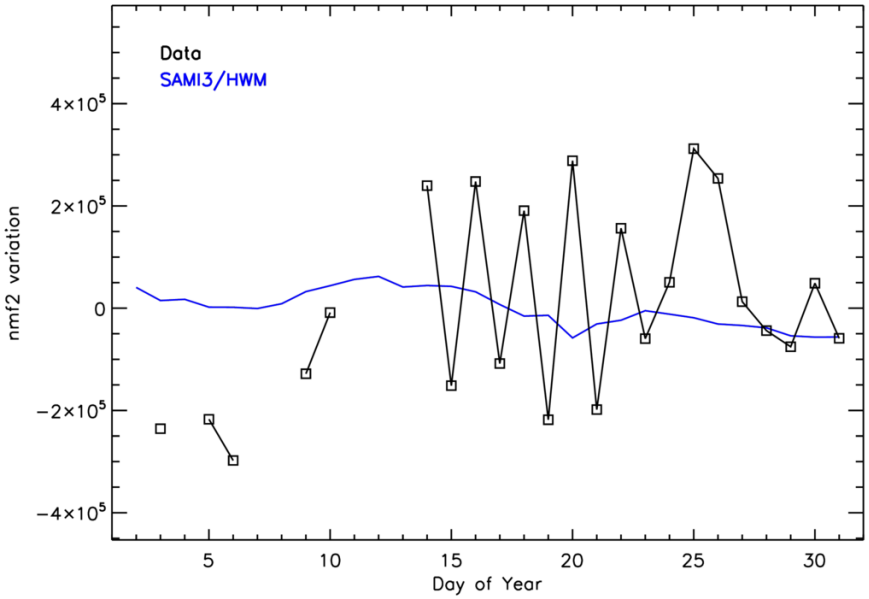




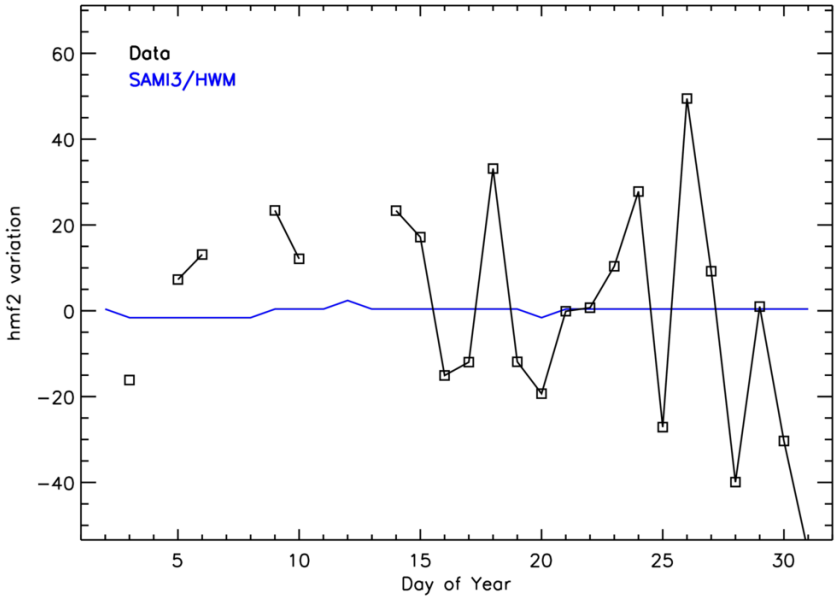
SAMI3 driven with a WACCM-X does show daily variation

Parameter Variability (Jicamarca at 15 LT)

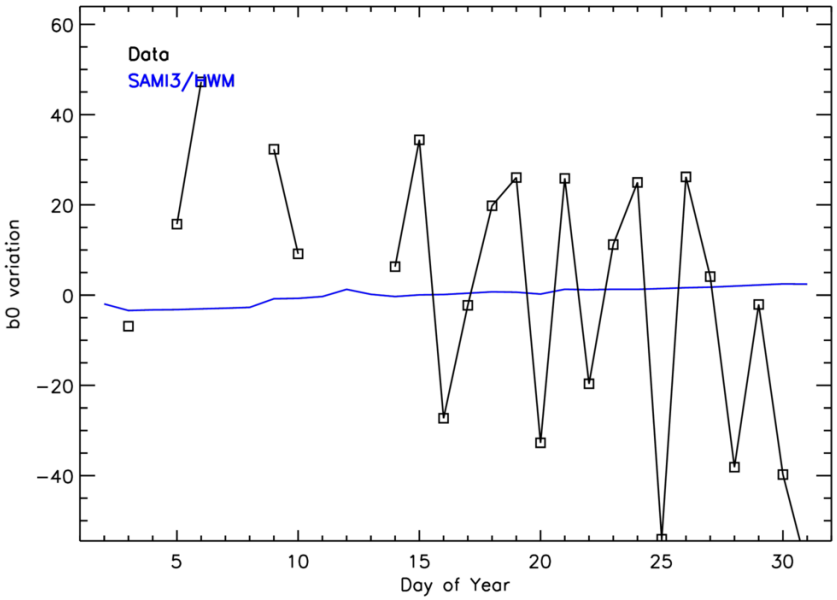
nmf2



hmf2



b0

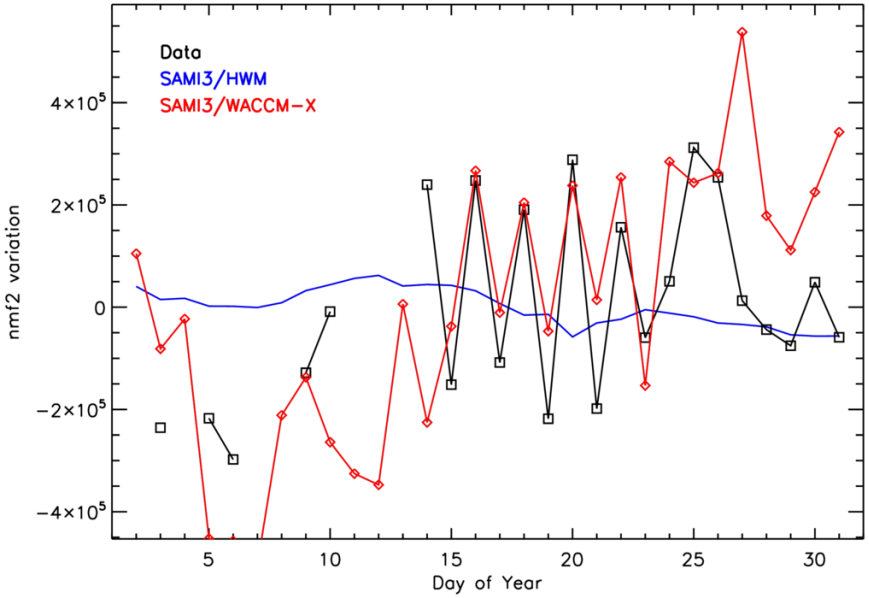


Data
SAMI3/HWM

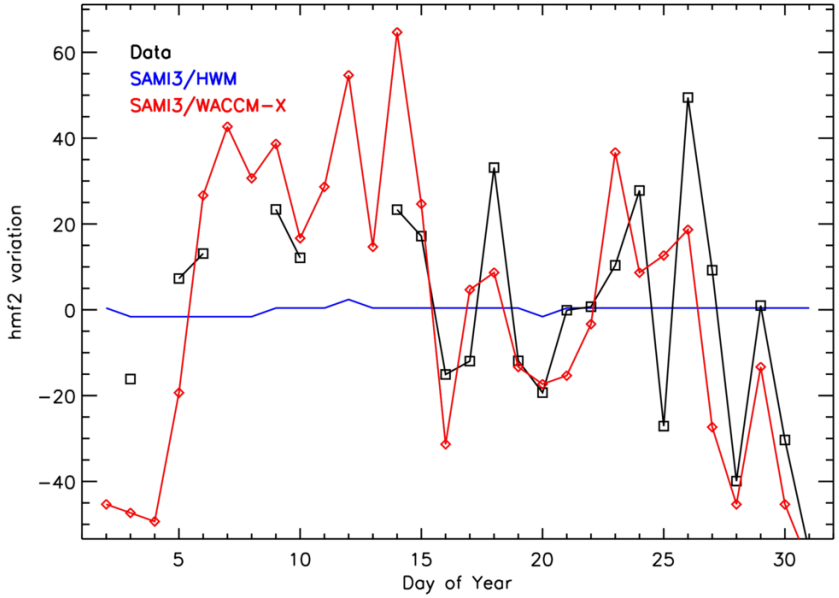
parameter variation = mean – daily value

Parameter Variability (Jicamarca at 15 LT)

nmf2



hmf2



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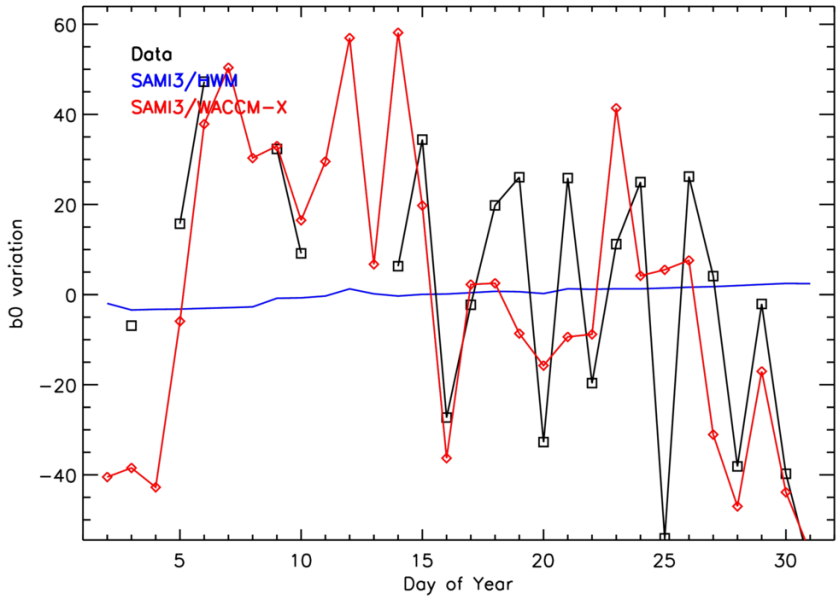


Data
SAMI3/HWM
SAMI3/WACCM-X

parameter variation = mean – daily value

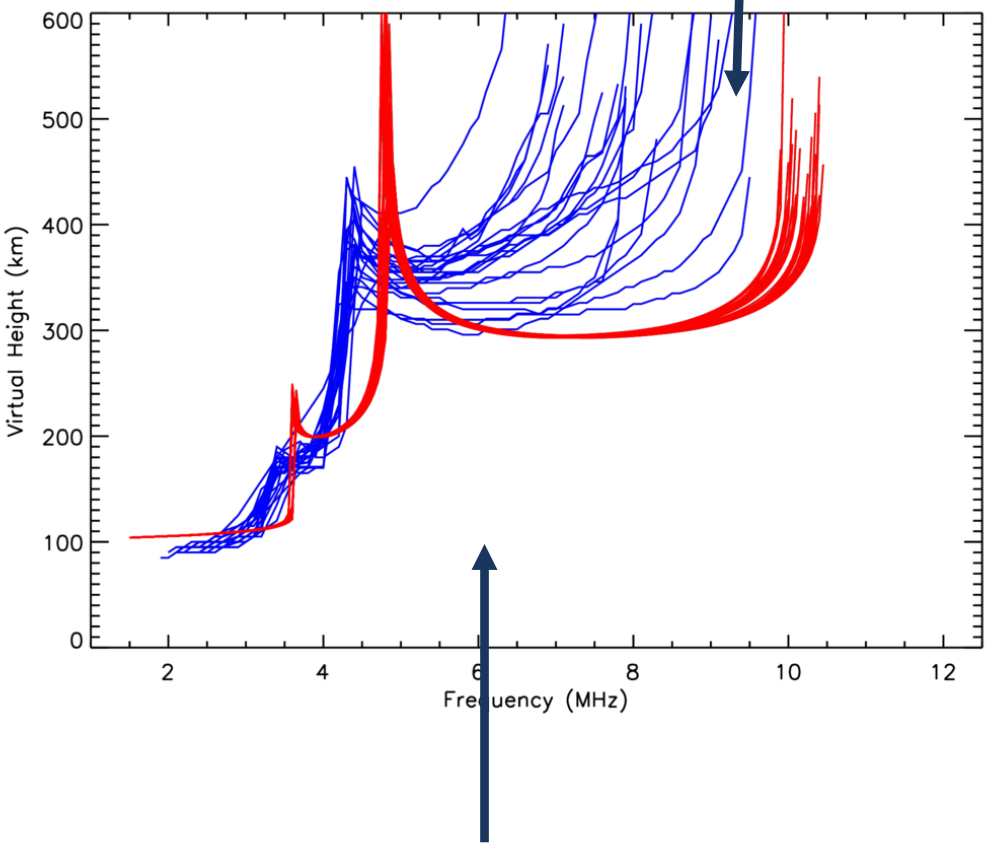
Ionogram Variability

Ionosonde O-mode trace

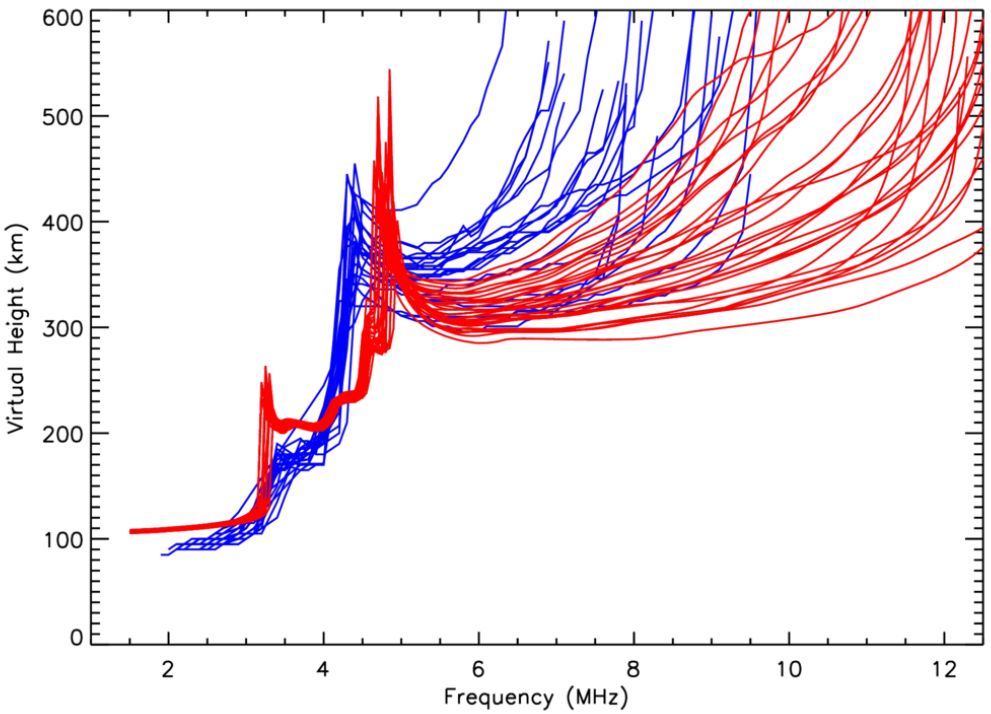
Simulated trace

Very little daily variability

SAMI3/HWM



SAMI3/WACCM-X



E-, F1- and F2-region peak density is too large

Ionogram Variability

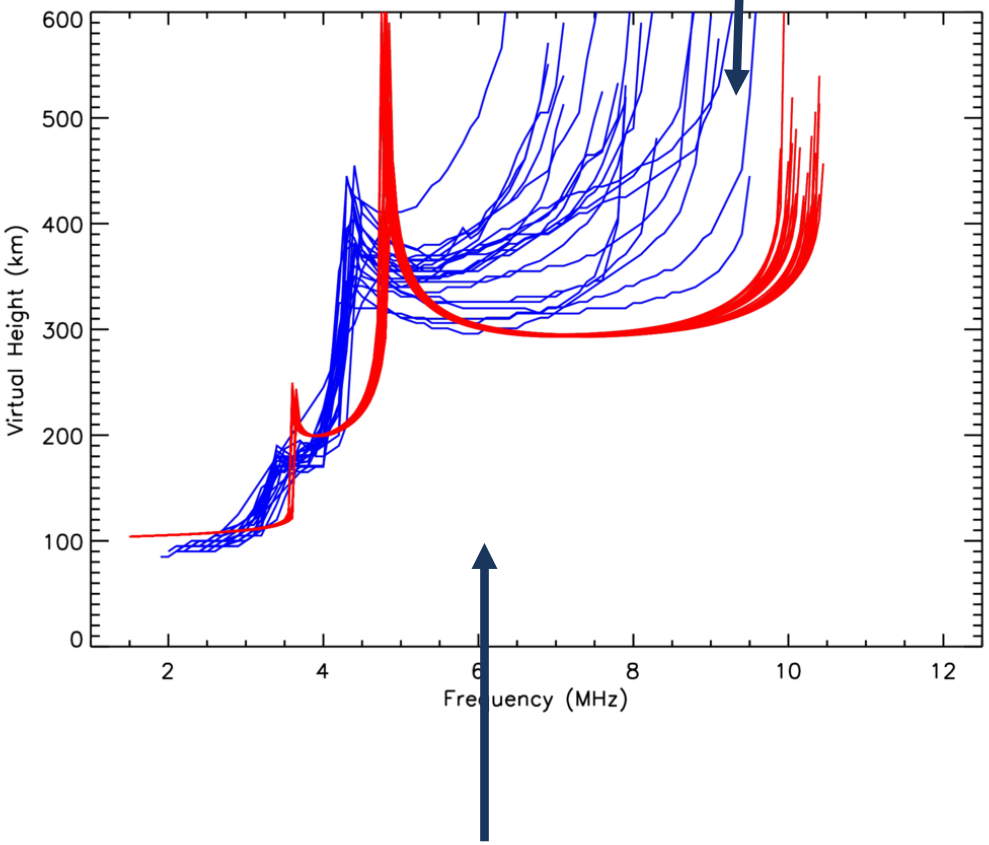
Ionosonde O-mode trace

Simulated trace

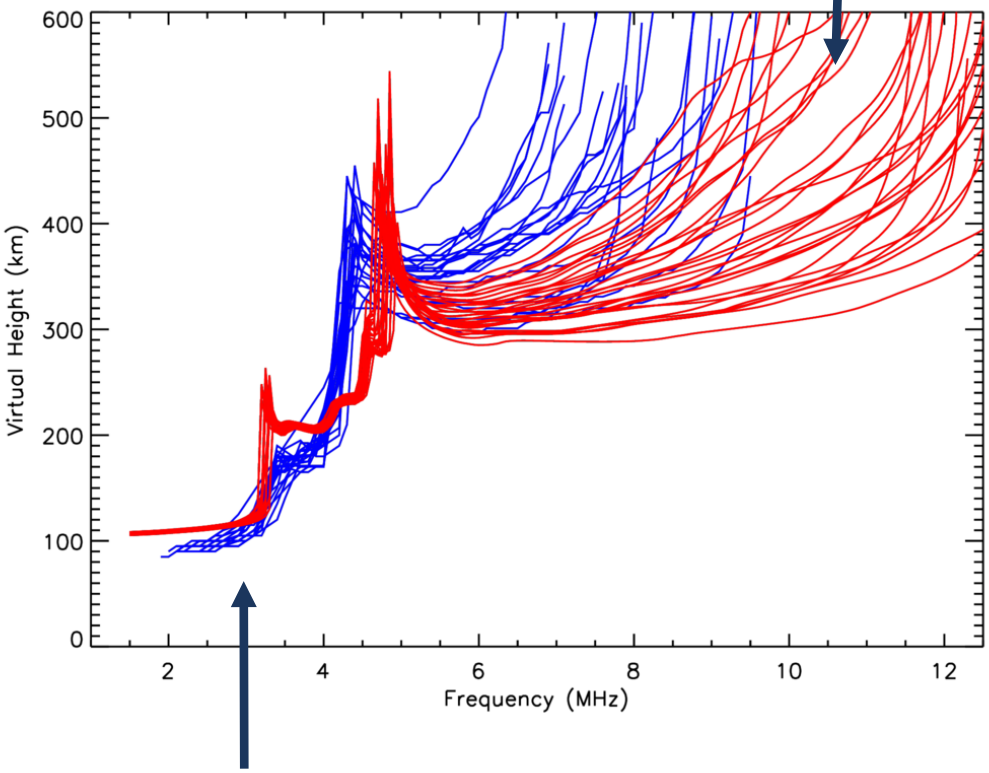
Very little daily variability

Too much O+

SAMI3/HWM



SAMI3/WACCM-X



E-, F1- and F2-region peak density is too large

E-region peak density improved

Ionogram Variability

Ionosonde O-mode trace

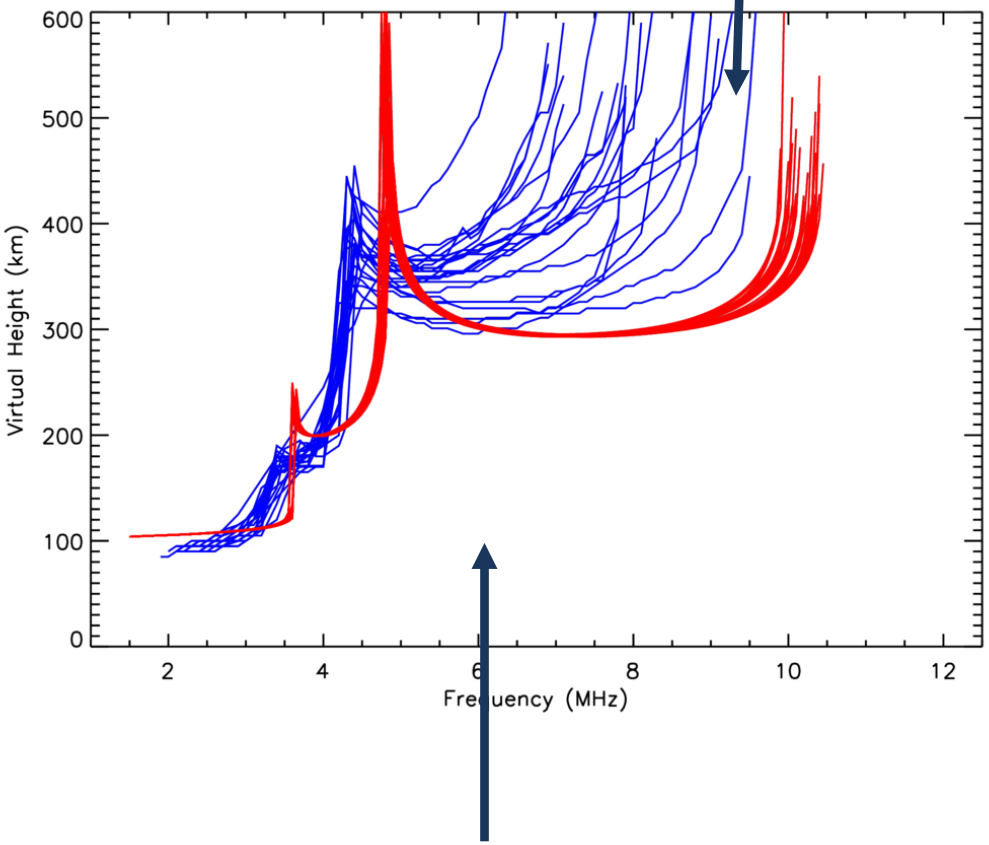
Simulated trace

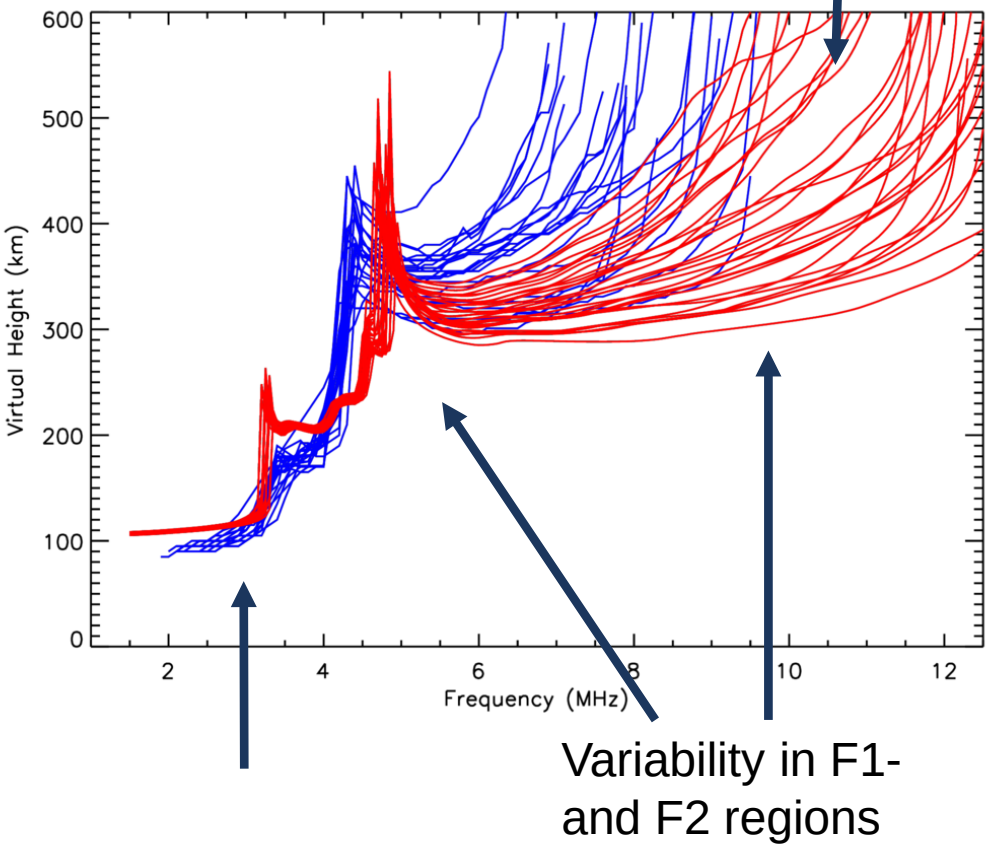
Very little daily variability

Too much O+

SAMI3/HWM

SAMI3/WACCM-X





Variability in F1- and F2 regions

E-, F1- and F2-region peak density is too large

E-region peak density improved

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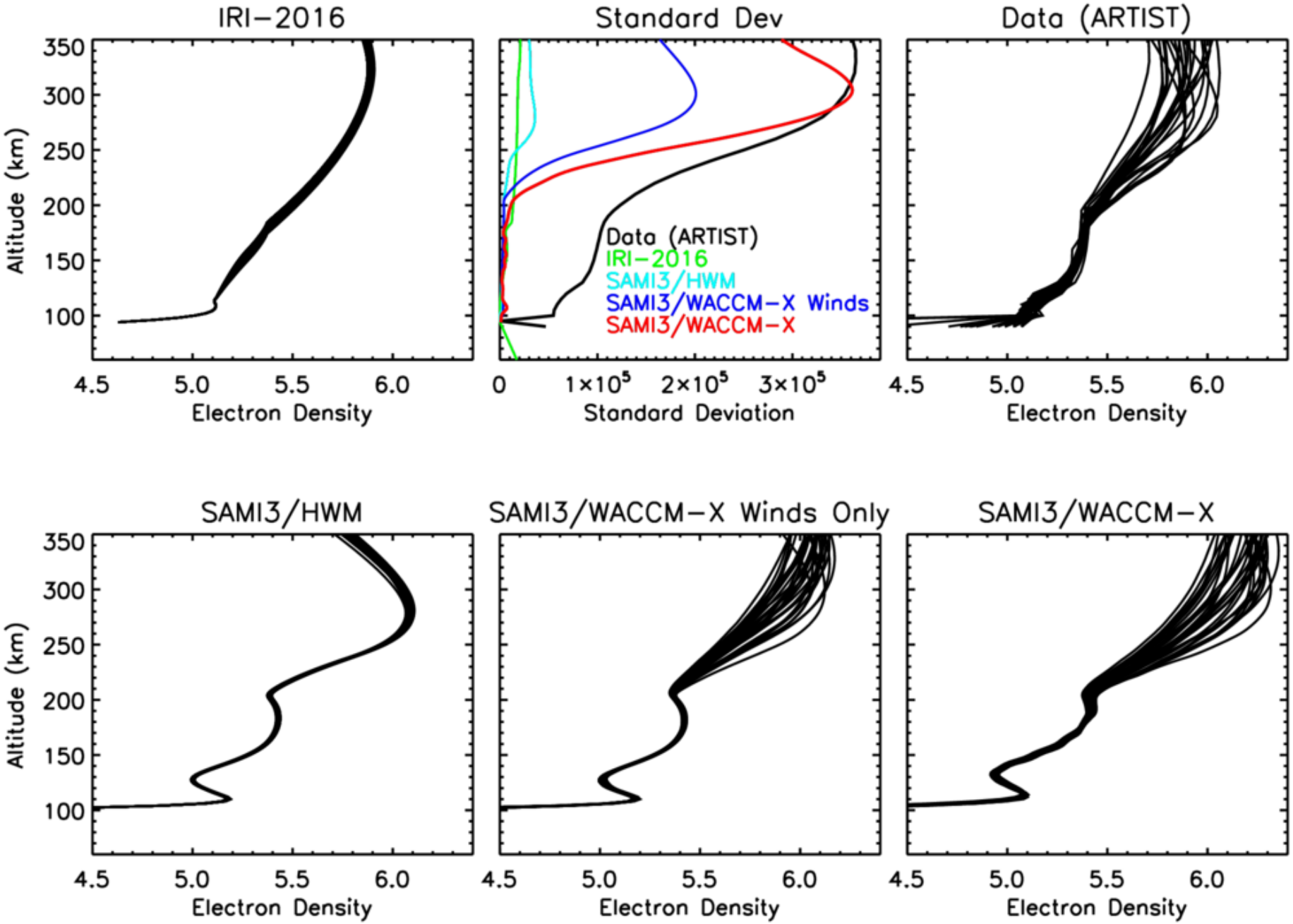
Electron Density Profile Variability



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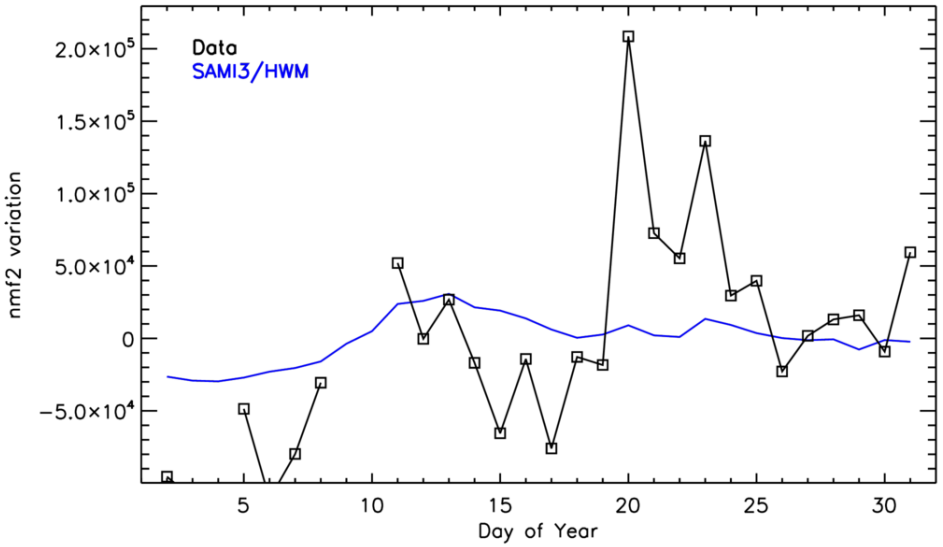
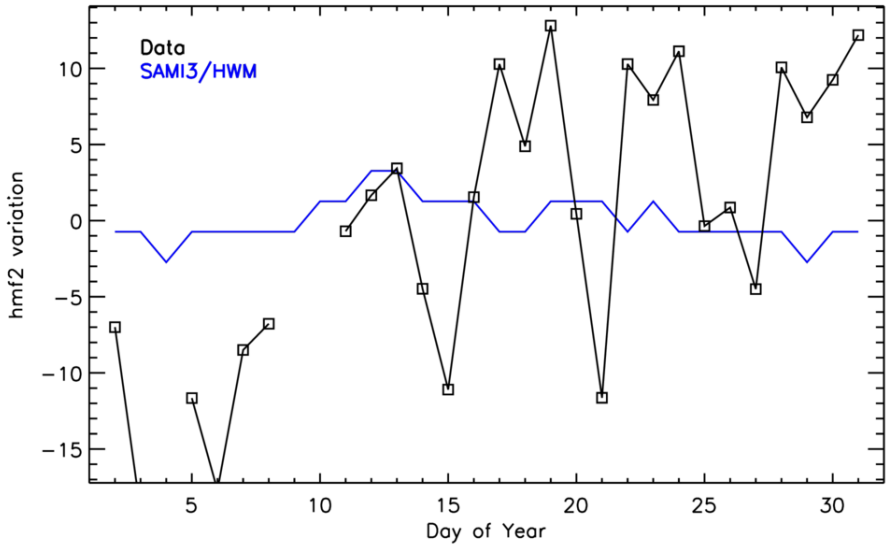
Parameter Variability (Boulder, CO at 15 LT)

nmf2



hmf2



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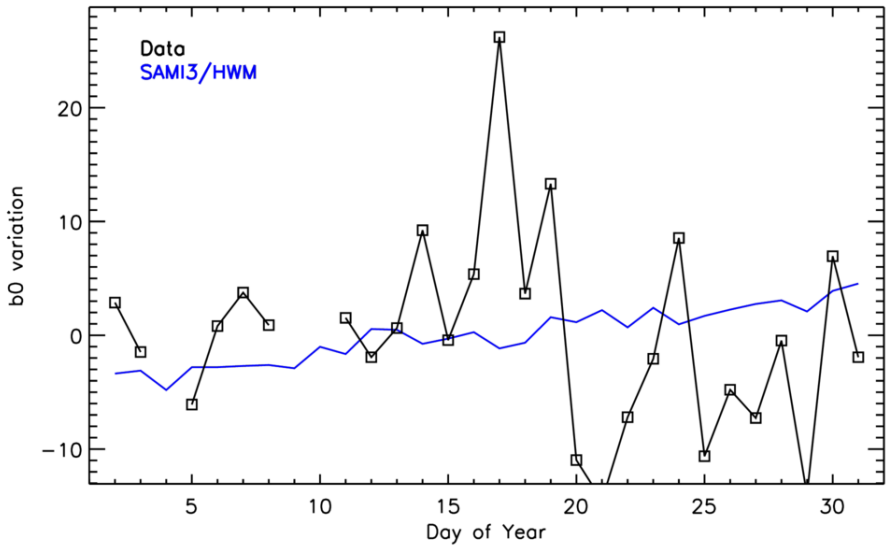
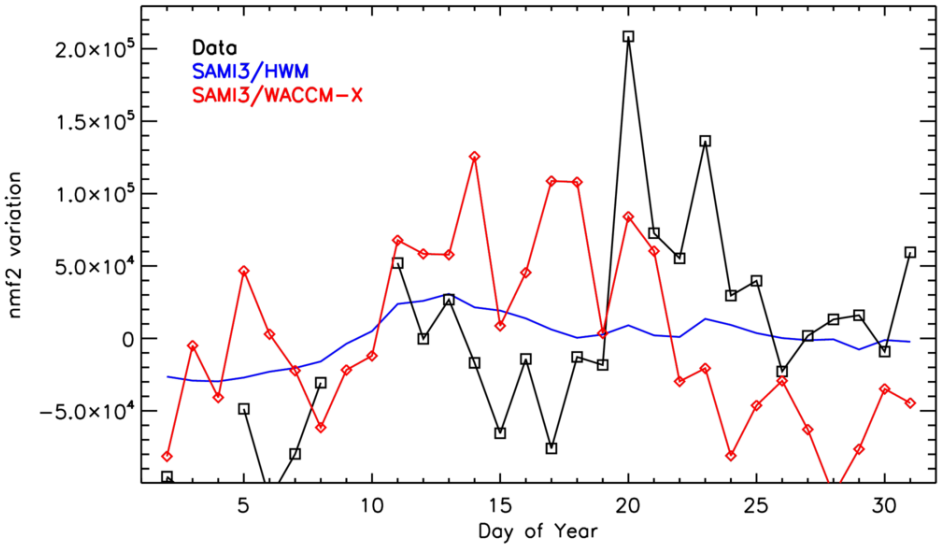


Data
SAMI3/HWM

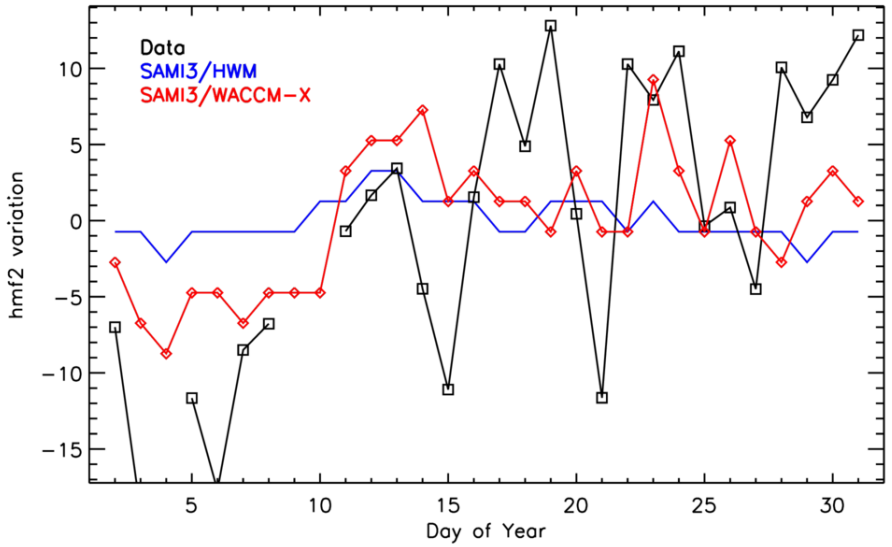
SAMI3 with climatological thermosphere does not show daily variation

Parameter Variability (Boulder, CO at 15 LT)

nmf2



hmf2



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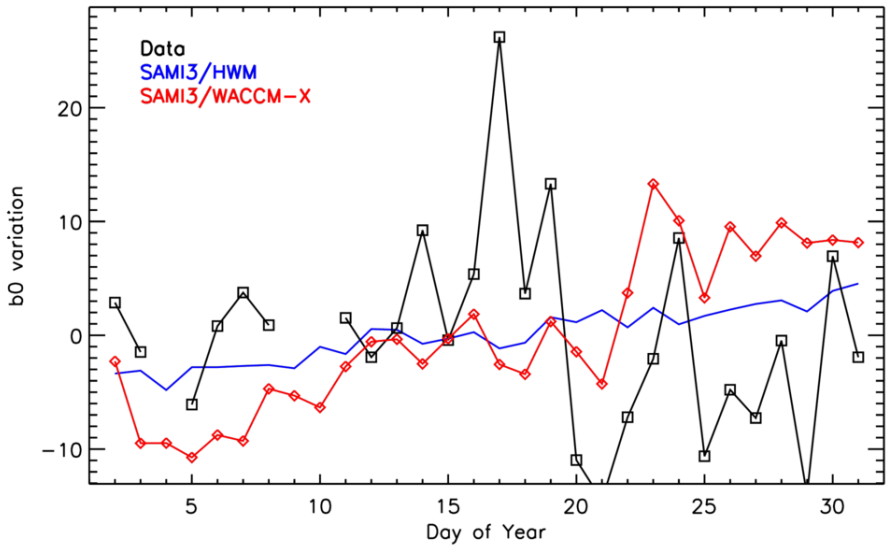

Data
SAMI3/HWM
SAMI3/WACCM-X

SAMI3/WACCM-X shows variation in nmf2, hmf2 at mid-latitude, but not as much as the data

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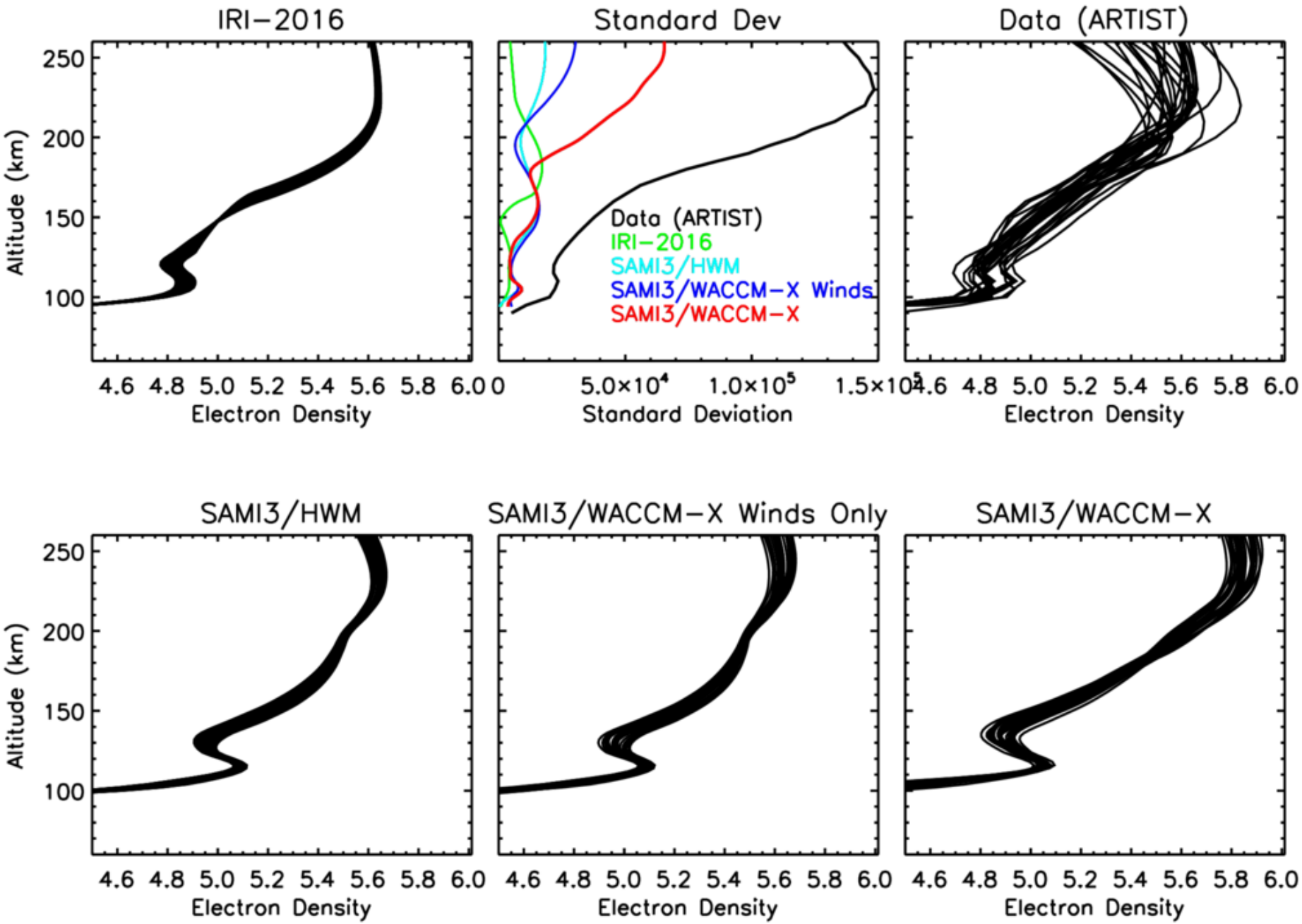
Electron Density Profile Variability



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Conclusions

- For one equatorial case, the SAMI3/WACCM-X run shows good daily variability in the F-peak, but very little variability below 200 km altitude
- For one mid-latitude case, the SAMI3/WACCM-X run shows some variability of the F-peak, but very little variability below 180 km altitude
- Including winds and composition from WACCM-X produce more variability than winds alone. Main source of variability: changes to electrodynamics
- To Do:
  - Fix O density in WACCM-X
  - Look at variability of the neutral constituents
  - Look at more data

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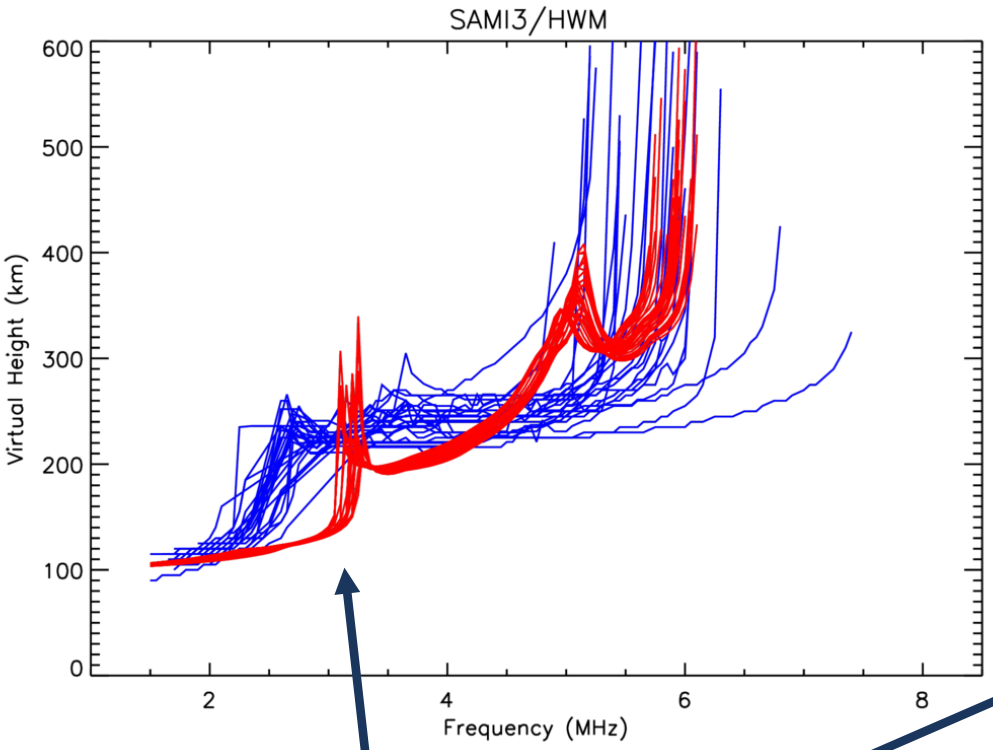
Acknowlegements

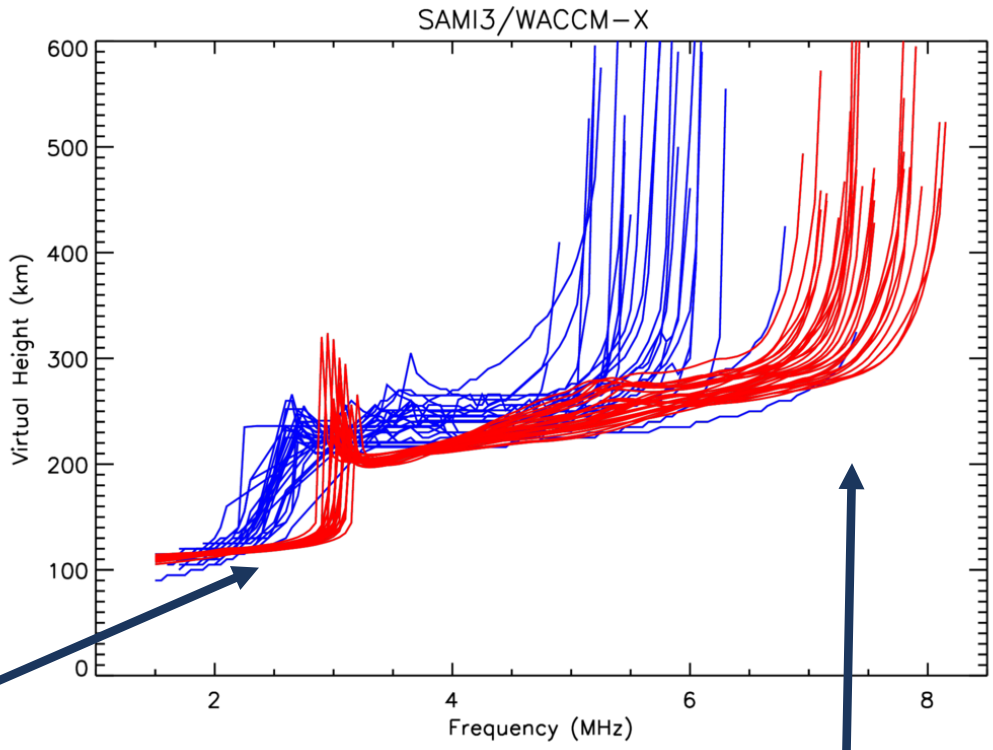
This work was supported by the Chief of Naval Research (CNR) under the NRL 6.1 Base Program.

Backup Slides

Ionogram Variability (Boulder, CO)

O-mode trace
Simulation





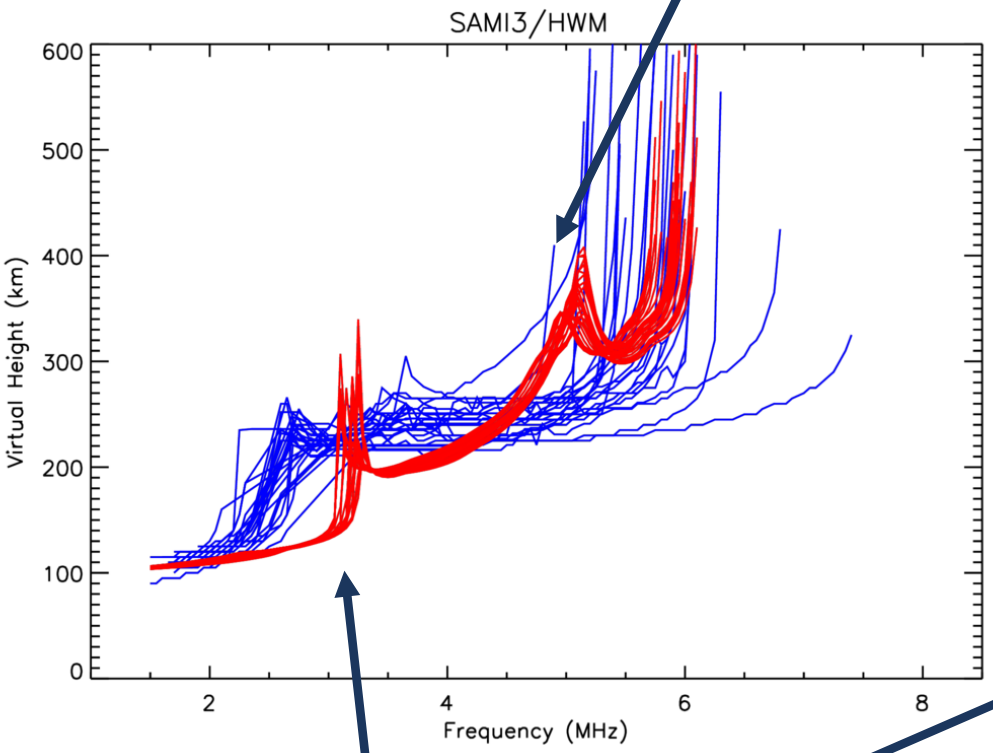
E-region too high/large

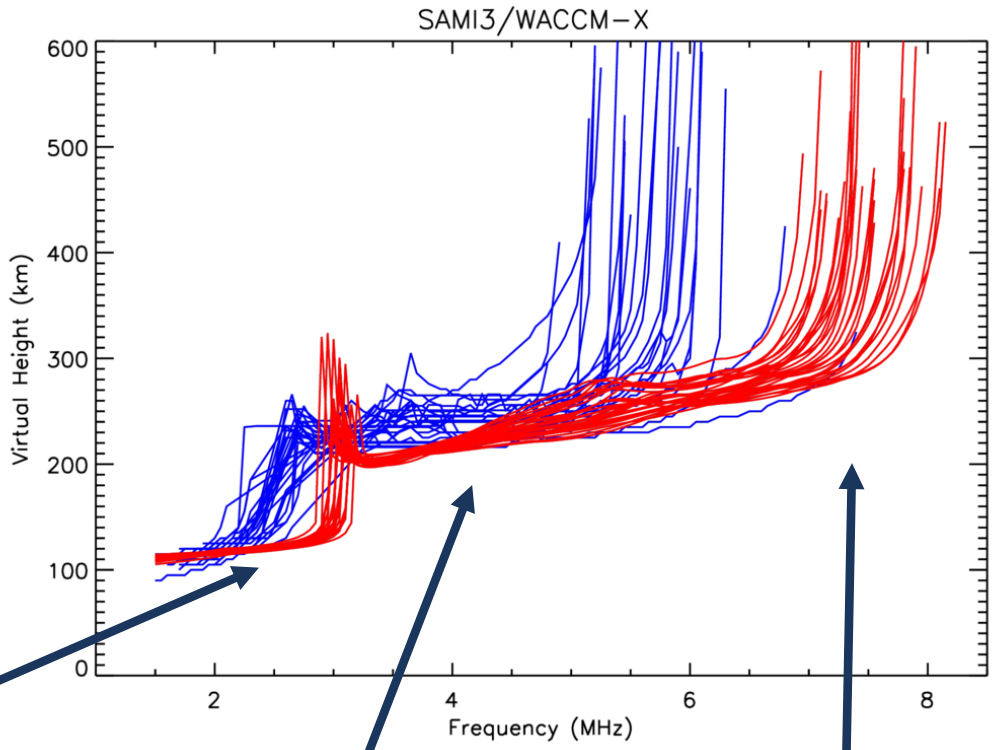
Too much O+

Ionogram Variability (Boulder, CO)

O-mode trace
Simulation

F1 region too large, valley well defined





E-region too high/large

F1 valley less defined

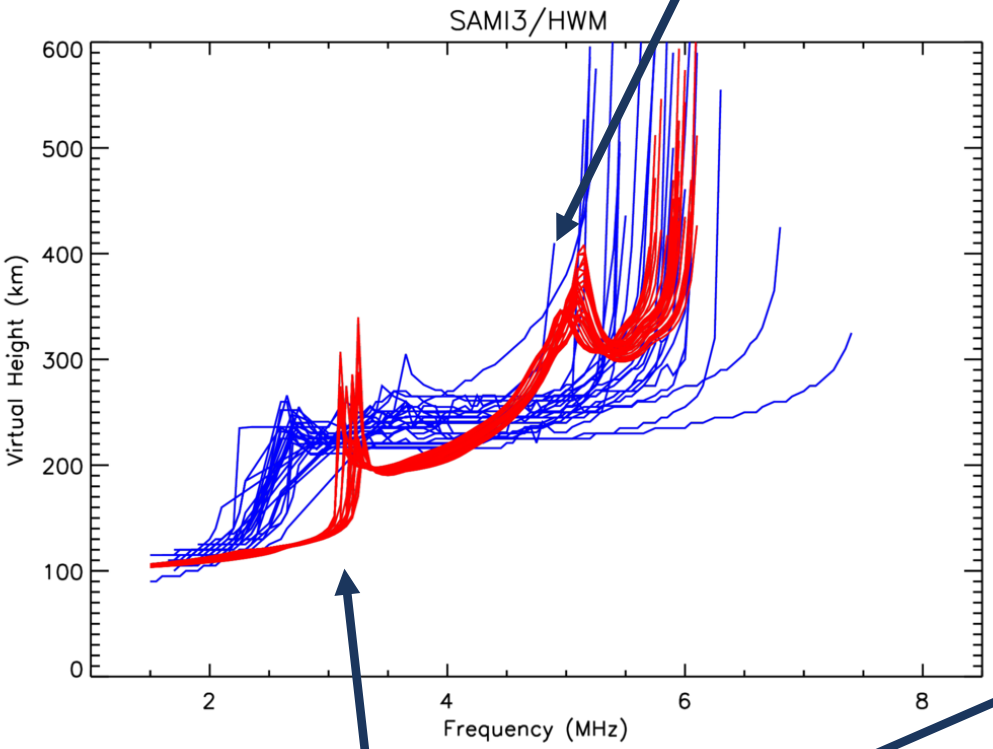
Too much O+

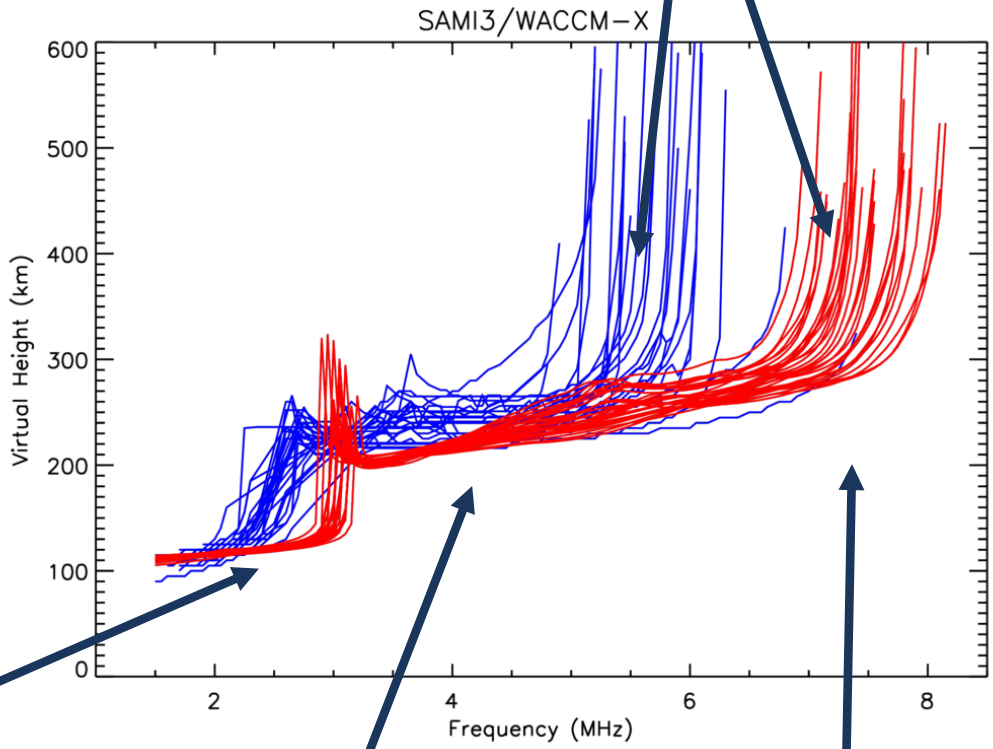
Ionogram Variability (Boulder, CO)

O-mode trace
Simulation

F1 region too large, valley well defined

More variability





E-region too high/large

F1 valley less defined

Too much O+

HF Propagation Model: MoJo

Integrates the Haselgrove raytrace equations in 3D spherical coordinates using a 4th order Runge-Kutta scheme, assuming the following for the index of refraction:

$$n^2 = 1 - 2X\frac{1 - iZ - X}{2(1 - iZ - X) - Y_T^2 \pm \sqrt{Y_T^4 + 4Y_L^2(1 - iZ - X)^2}}$$

$$X = \frac{\omega_e^2}{\omega^2} \qquad Y = \frac{\omega_{ecf}}{\omega} \qquad Z = \frac{\nu_e}{\omega}$$

$$Y_T = Y\sin\psi$$

$$Y_L = Y\cos\psi$$

Ψ = angle between the wave normal and the earth's magnetic field

Includes iterative homing algorithm for eigenrays