What is WACCM-X?

The Whole Atmosphere Community Climate Model - eXtended

WACCM-X is a model of the entire atmosphere that extends into the thermosphere to ~500 km altitude, and includes the ionosphere. It is the work of many people at the National Center for Atmospheric Research in the Geospace section of the High Altitude Observatory, in the Atmospheric Chemistry, Observations, and Modeling Laboratory, the Climate and Global Dynamics division, and external collaborators.

WACCM-X is built on WACCM
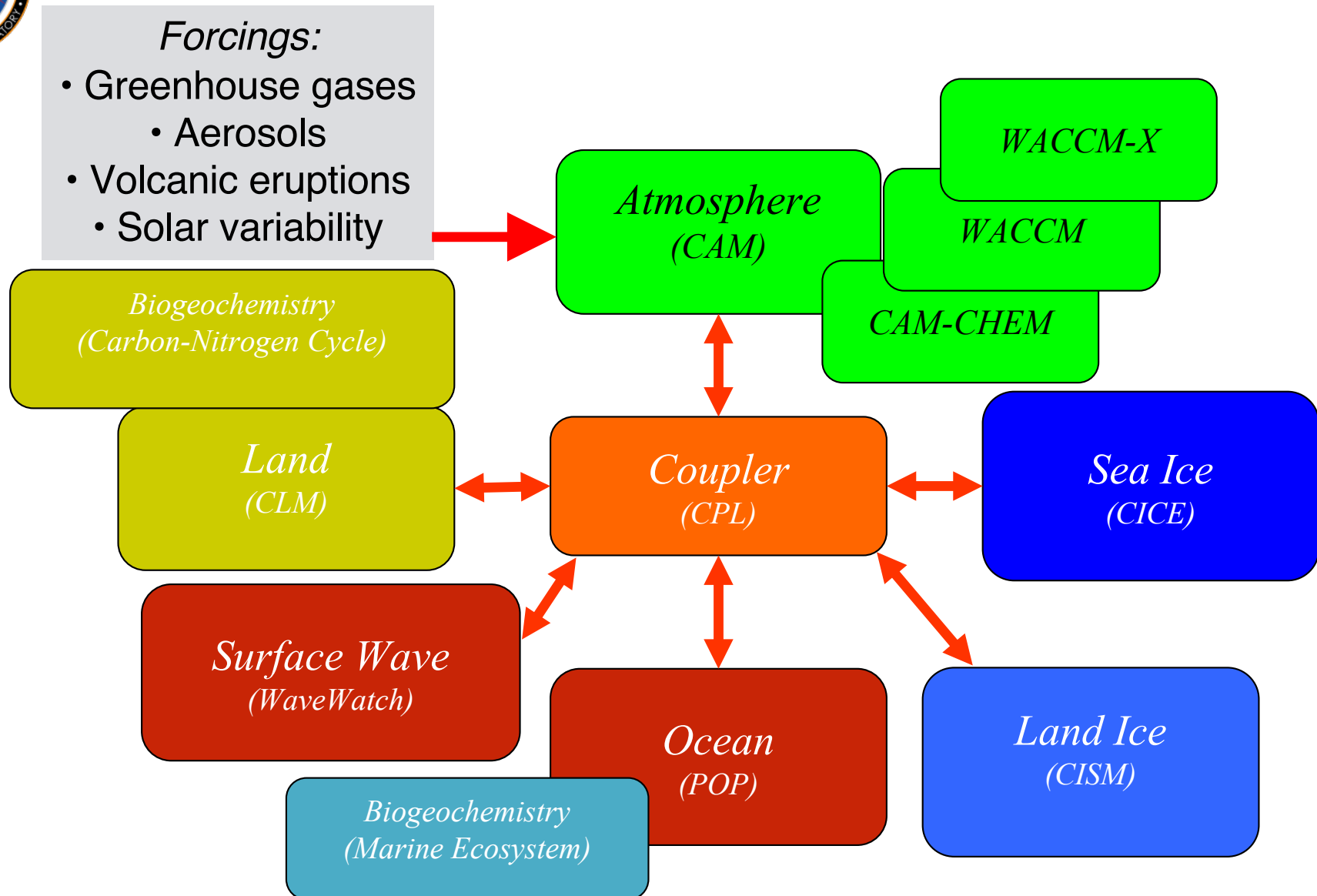WACCM is built on CAM
CAM is the NCAR Community Atmosphere Model

Community Earth System Model (CESM)

Forcings:
- Greenhouse gases
- Aerosols
- Volcanic eruptions
- Solar variability

Atmosphere (CAM)

WACCM-X

WACCM

CAM-CHEM

Biogeochemistry (Carbon-Nitrogen Cycle)

Land (CLM)

Coupler (CPL)

Sea Ice (CICE)

Surface Wave (WaveWatch)

Ocean (POP)

Land Ice (CISM)

Biogeochemistry (Marine Ecosystem)

Why WACCM-X?

Because the thermosphere-ionosphere system responds to variability from the Earth's lower atmosphere as well as solar-driven "space weather"

Including:

Waves and tides
Tropospheric weather
Middle-atmosphere events
Seasonal variations
Anthropogenic trace gases

Illustration from the ICON mission, T. Immel et al.
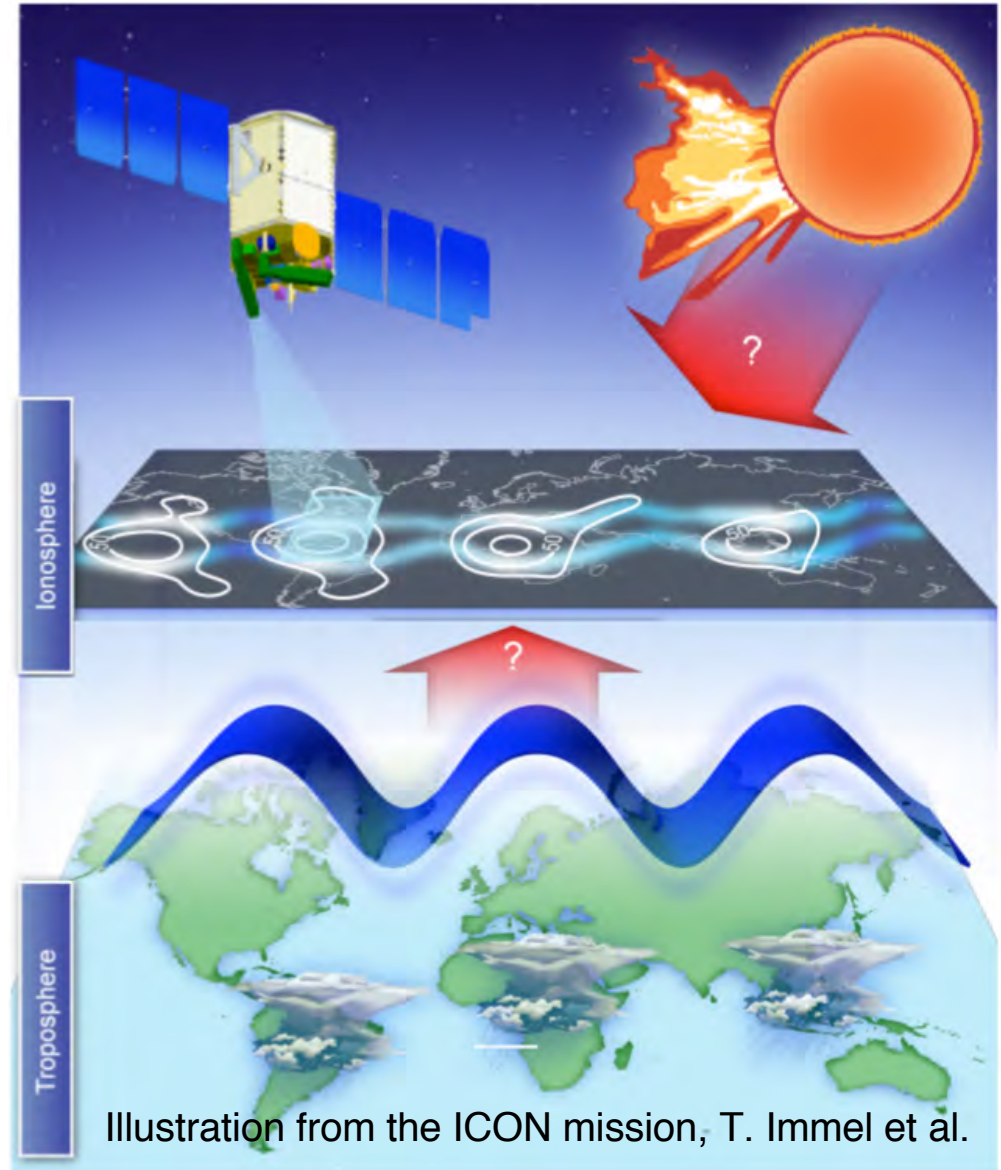
Scientific Goals

- How do solar and geomagnetic influences affect the whole atmosphere?

- What are the interactions between lower atmosphere and solar/geomagnetic forcing on the ionosphere-thermosphere system?

- How do atmospheric waves affect the energy and momentum coupling between the lower atmosphere and the ionosphere-thermosphere?

- What are the connections between small and large scale features in the system, e.g., ionospheric instabilities or "plasma bubbles"?

- How does anthropogenic change affect the thermosphere and ionosphere? What are the implications for atmospheric drag on satellites, and on hazards from orbital debris?

Recent Progress on WACCM-X

- Ion and electron energetics implemented:
    - Now calculating T_i and T_e in WACCM-X.

- Equatorial electrodynamo installed:
    - Mostly parallel, ESMF interpolation from geographic to geomagnetic coords.

- Ionospheric dynamics implemented:
    - Vertical diffusion and horizontal transport of O^+ in the upper ionosphere.

- Variable mean molecular mass and heat capacity (C_p) included in dynamical core

- Capability for using Assimilative Mapping of Ionospheric Electrodynamics (AMIE)

Integrating Ionospheric Dynamics
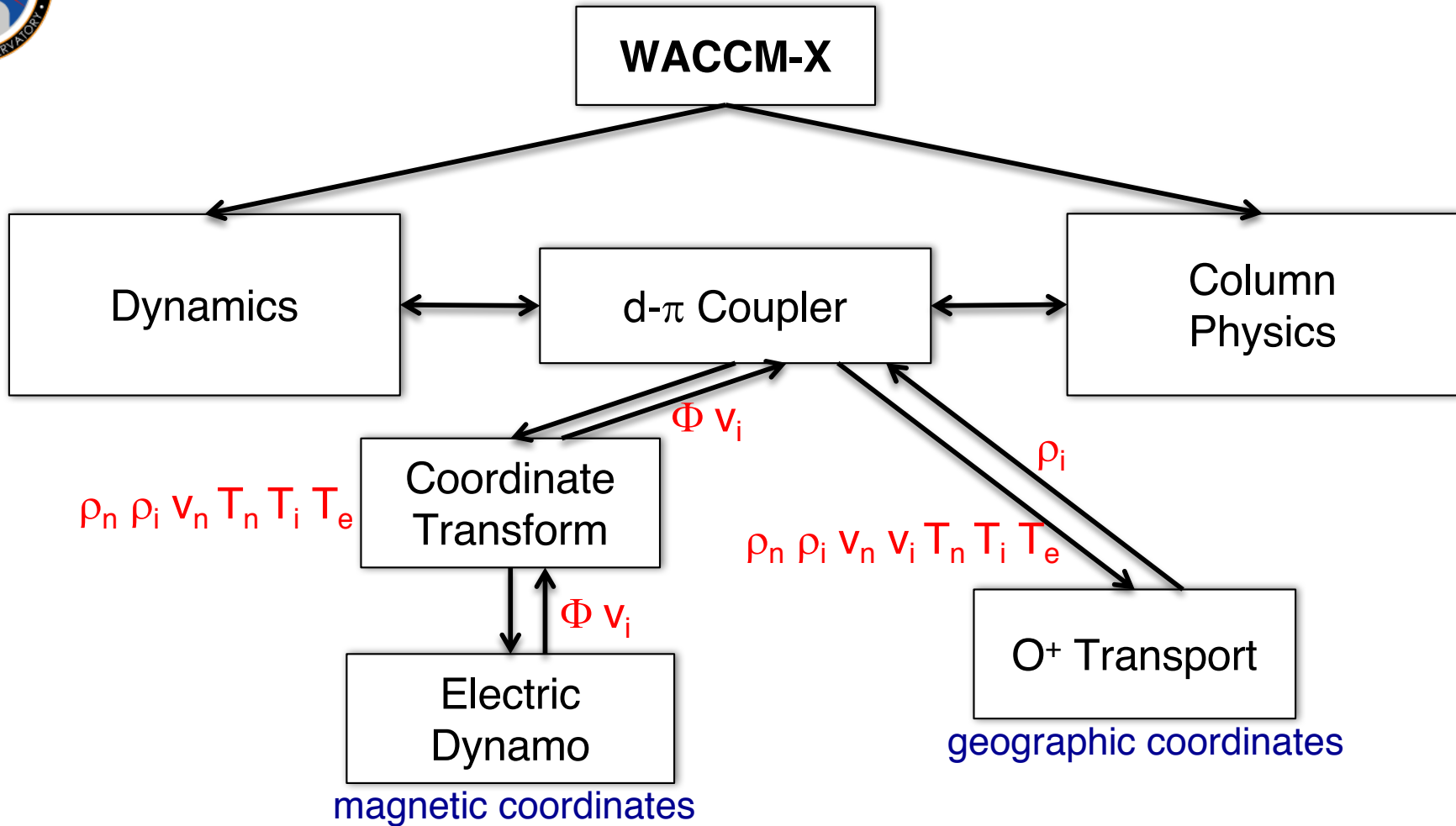
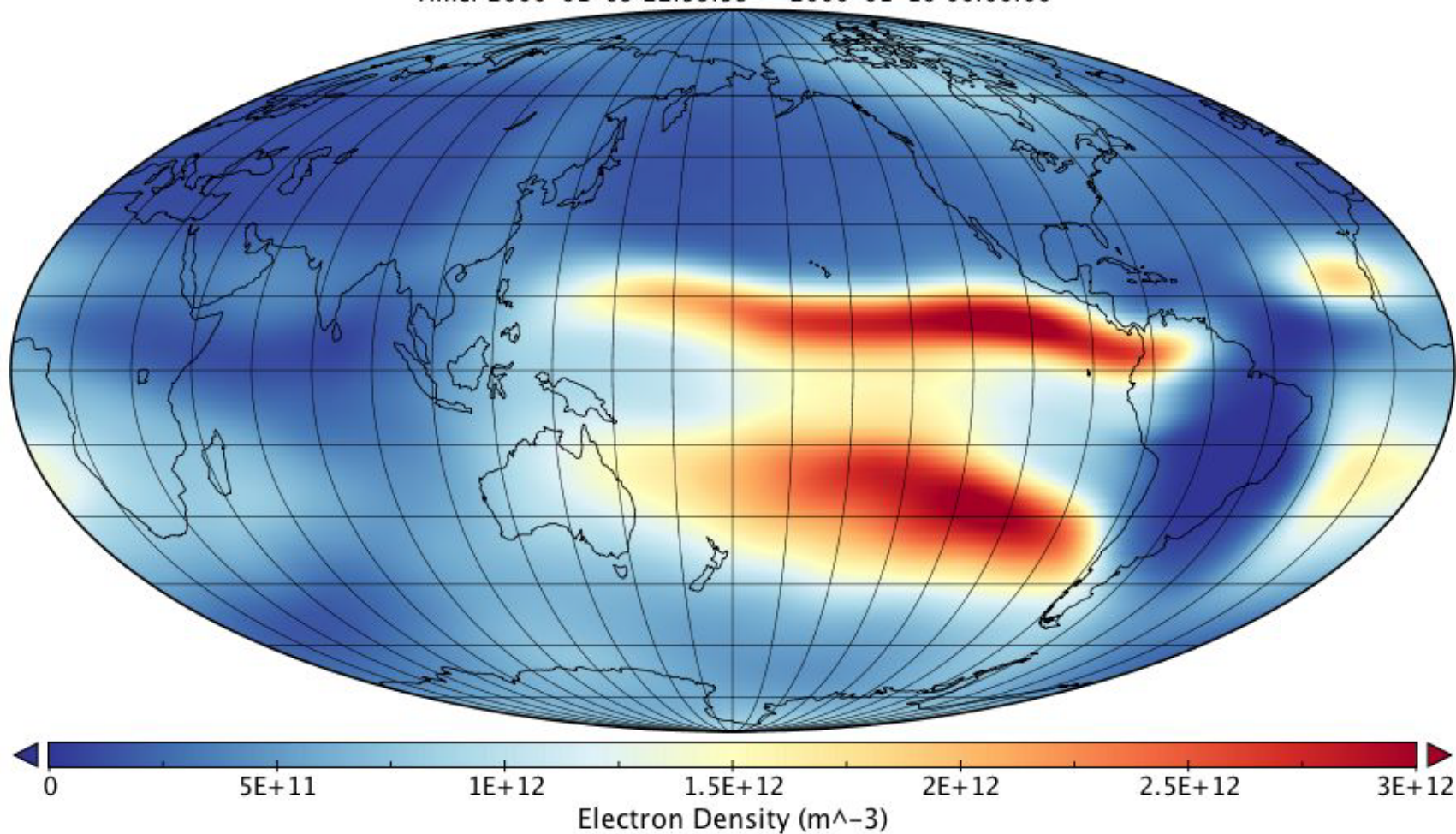d-π Coupler: dynamics-physics-ionosphere-electrodynamics (D-PIE) coupler
Electric Dynamo: calculates global electric potential resulting from wind-driven ions
ρ: density   v: velocity   T: temperature   n: neutral   i: ion   e: electron   Φ: electric potential

WACCM-X Ionosphere at ~250 km

Electron Density at 3e−8 hPa
Time: 2000-01-09 22:59:59 — 2000-01-10 00:00:00

Electron Density (m^−3)

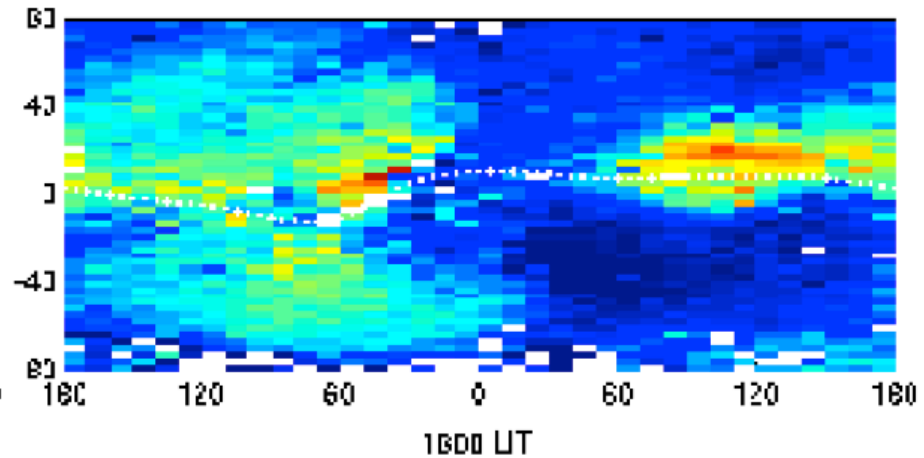Mollweide projection centered on −180.00°E

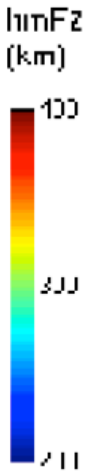# Height of the Ionospheric F-region Peak
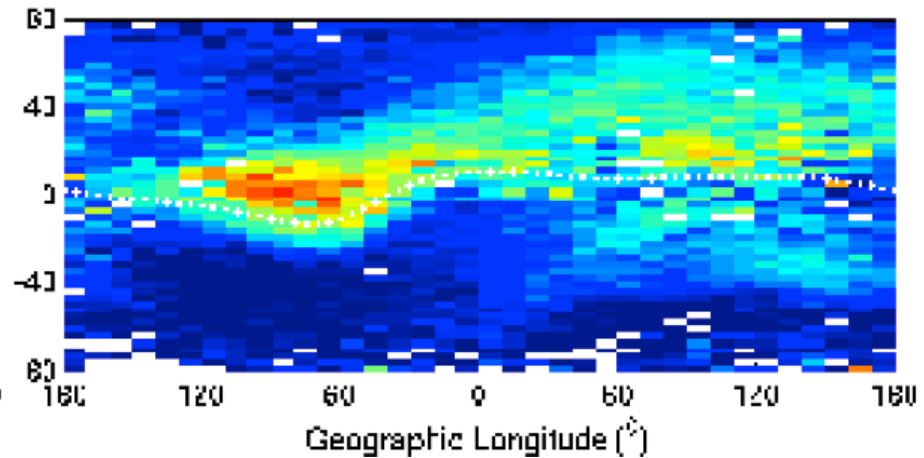
July 2008

WACCM-X Simulation   COSMIC Data
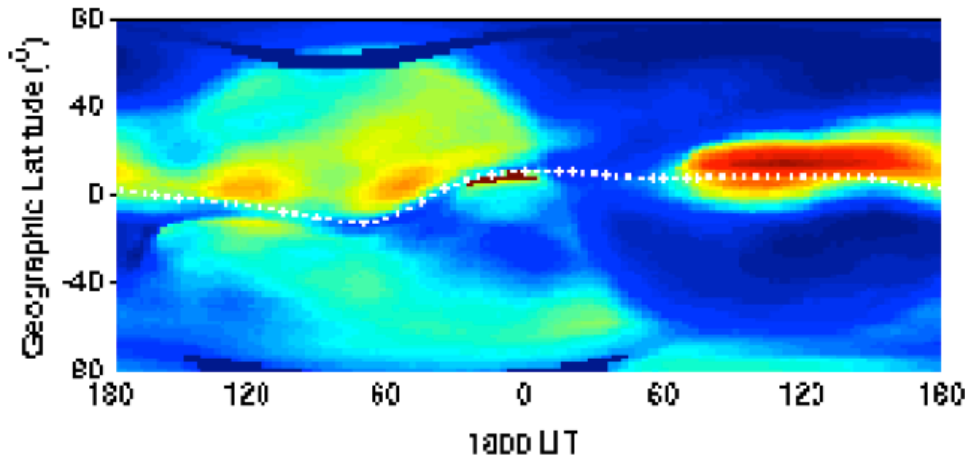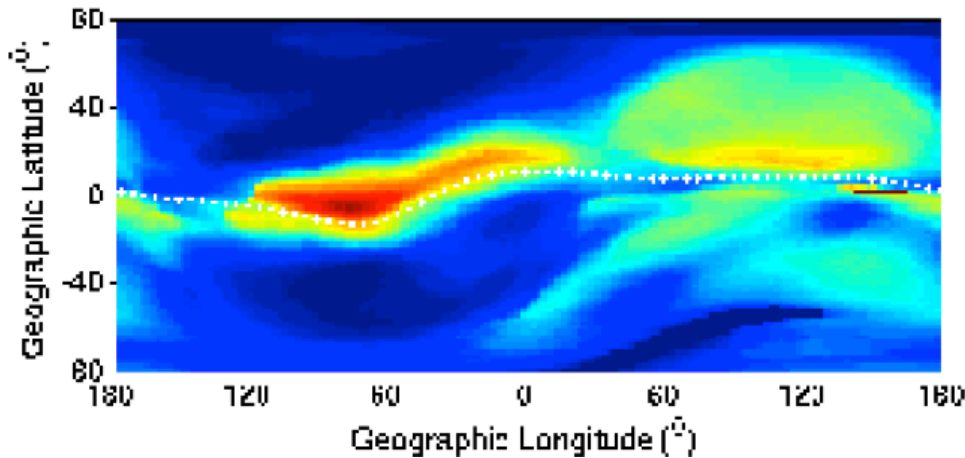

Courtesy of Jing Liu, HAO postdoc

WACCM-X — Current Developments & Future Plans

- Ongoing WACCM-X development:
  - — Ionosphere module released as a component of CESM v. 2, summer 2017
  - — Next step is to include a fully-coupled ionosphere-plasmasphere module
  - — Coupled atmosphere-ionosphere data assimilation
- Other key research developments include:
  - — Solar irradiance inputs and "grand minima" simulations
  - — "Top-down" propagation of solar cycle changes
  - — Anthropogenic change and solar cycle interactions
  - — Ultra-high-resolution simulations that resolve mesoscale gravity waves
  - — Analysis of new mission data from GOLD, ICON, and COSMIC-2
- Long term plans:
  - — Geomagnetic inputs — coupling to magnetospheric models and specifications
  - — Ultra-high-resolution simulations of ionospheric instabilities.