

Whole Atmosphere Community Climate Model – eXtended



NCAR



What is WACCM-X?

The Whole Atmosphere Community Climate Model - eXtended

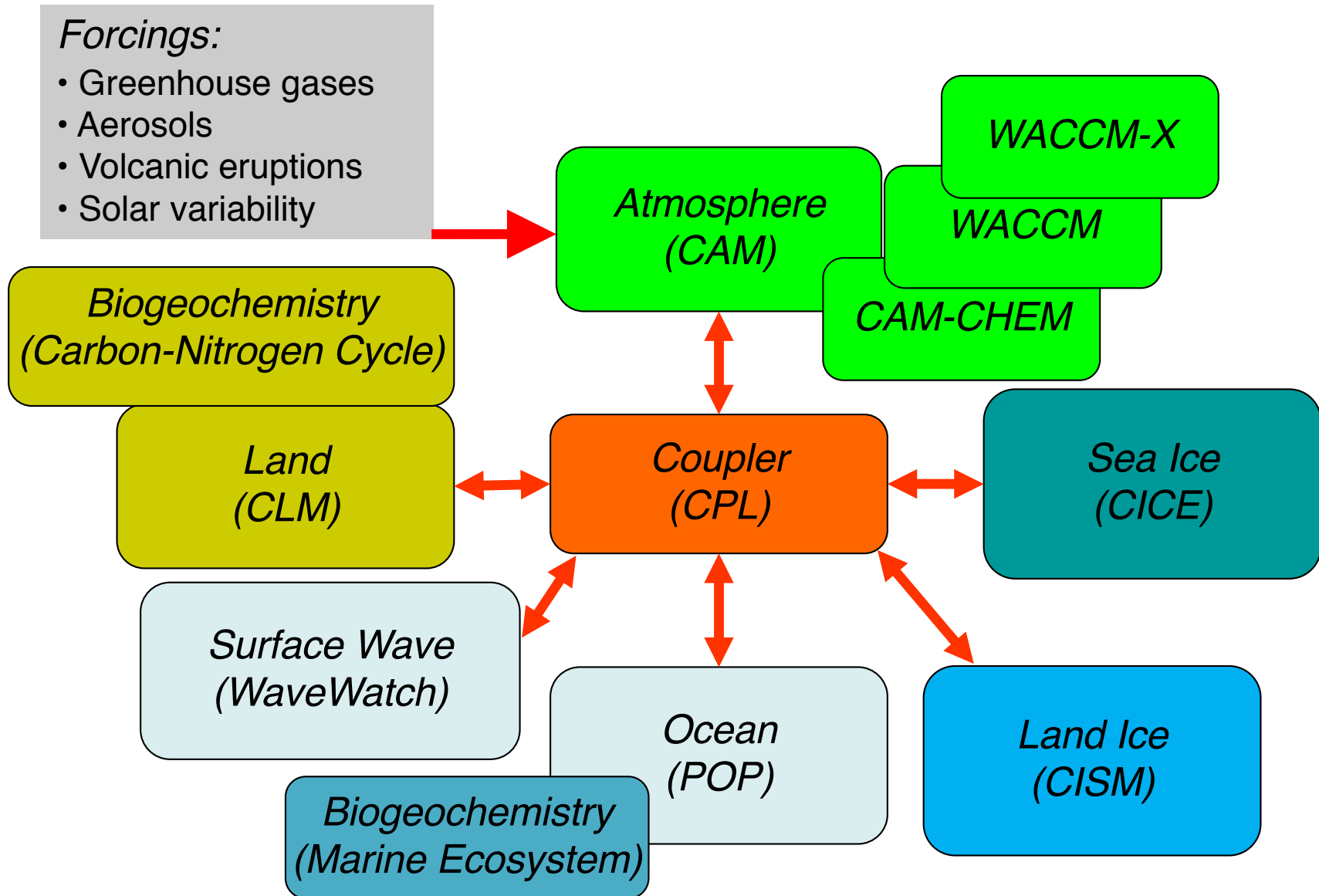
WACCM-X is a model of the entire atmosphere that extends into the thermosphere to ~500 km altitude, and includes the ionosphere. It is the work of many people at the National Center for Atmospheric Research in the Geospace section of the High Altitude Observatory, the Atmospheric Chemistry, Observations,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

WACCM-X is built on WACCM

WACCM is built on the Community Atmosphere Model (CAM)

CAM is the Atmosphere Component of the Community Earth System Model

Community Earth System Model (CESM)



CESM v. 2.0 release scheduled for August 2017

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 electrodynamic 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
- Solar inputs, auroral inputs, $O(^3P)$ cooling, O^+ metastables, hydrogen upper boundary condition, stability improvements, performance improvements, diagnostic fields, etc., etc....

The First “C” Stands for Community

What does it mean to be a “Community Model?”

- The scientific community has access to simulation output data
- The scientific community has access to the source code for research purposes
- We hope that other researchers will contribute to validation and improvement
- We invite development contributions from collaborating scientists
- The scientific community has a voice in development priorities

Web site:

- If you google “WACCM-X” it will take you to:
<https://www2.hao.ucar.edu/modeling/waccm-x>

Which has links to:

- CESM documentation site
- Whole atmosphere working group
- Mailing list sign up page

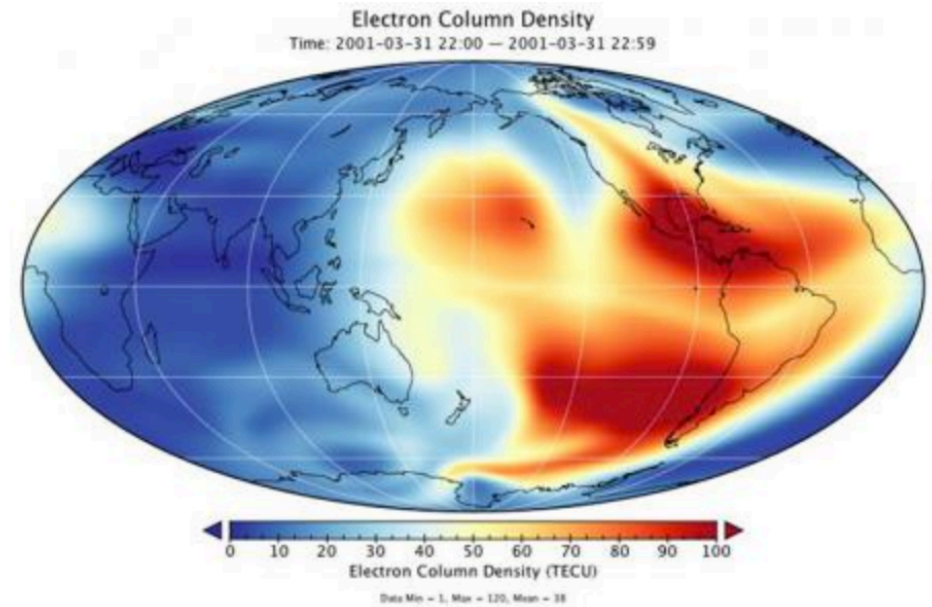
WACCM-X

The Whole Atmosphere Community Climate Model with thermosphere and ionosphere extension (WACCM-X) is a comprehensive numerical model, spanning the range of altitude from the Earth's surface to the upper thermosphere.

The scientific goals of the model include studying solar impacts on the Earth atmosphere, couplings between atmosphere layers through chemical, physical and dynamical processes, and the implications of the coupling for the climate and for the near space environment. The development of the model is inter-divisional collaboration that unifies certain aspects of the upper atmospheric modeling of [HAO](#), the middle atmosphere modeling of [ACOM](#), and the tropospheric modeling of [CGD](#), using the NCAR Community Earth System Model ([CESM](#)) as a common numerical framework.

MORE INFORMATION:

- WACCM-X information and tutorials at CESM:
<http://www.cesm.ucar.edu/models/waccm-x/>
- Whole Atmosphere Working Group:
http://www.cesm.ucar.edu/working_groups/Whole-Atmosphere/
- WACCM at ACOM:
<https://www2.acom.ucar.edu/gcm/waccm>
- Sign up for WACCM-X Mailing list
<https://www2.hao.ucar.edu/modeling/waccm-x/mailling-list>



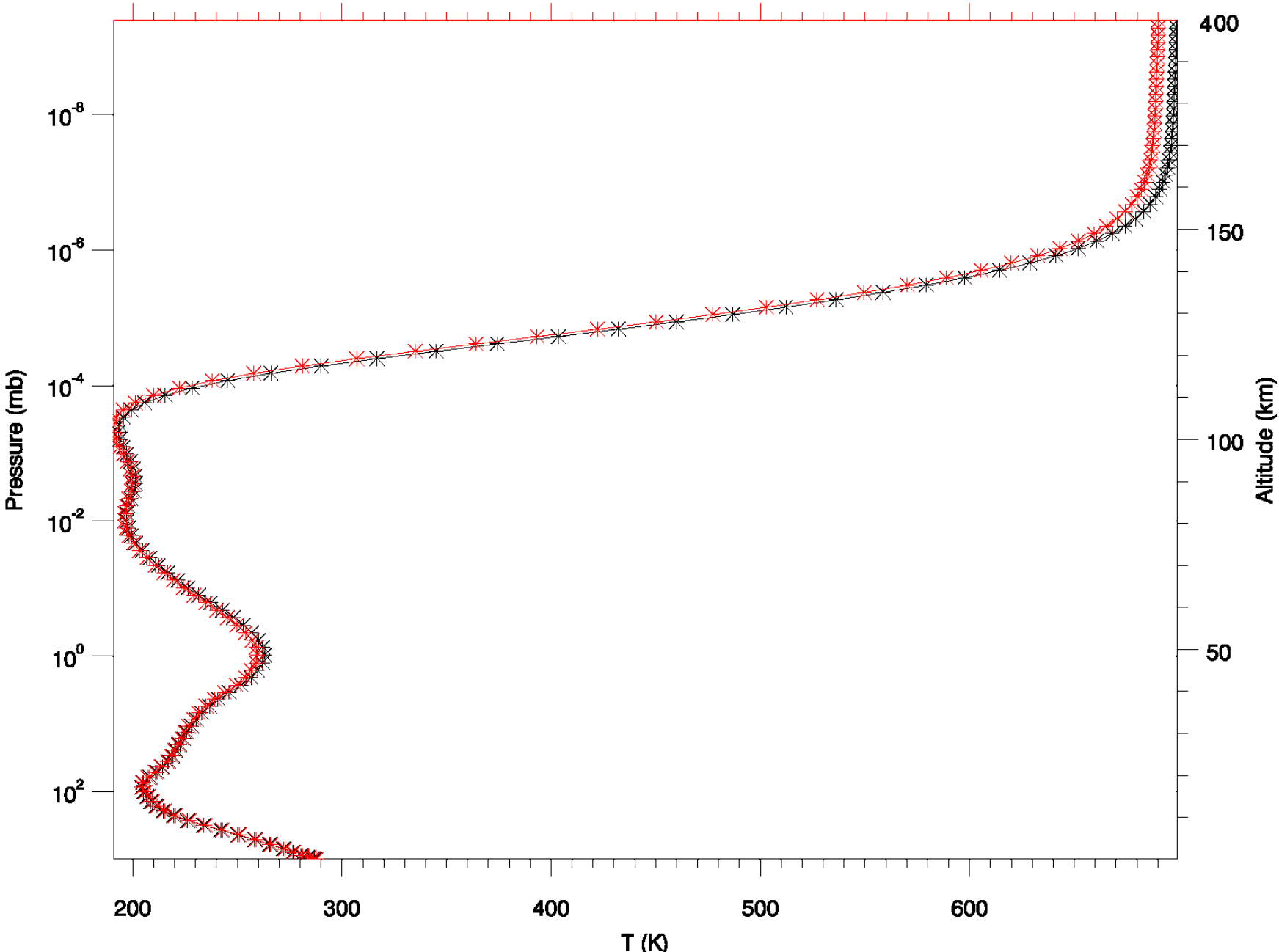
WACCM-X simulation of the "April Fools" geomagnetic storm in 2001, showing the global electron column density in units of 10^{12} cm^{-2} . Note the "tongue of ionization" extending out of both the north and south auroral regions into the dayside low-latitudes, and the highly distorted equatorial ionosphere.

The Second “C” Stands for Climate

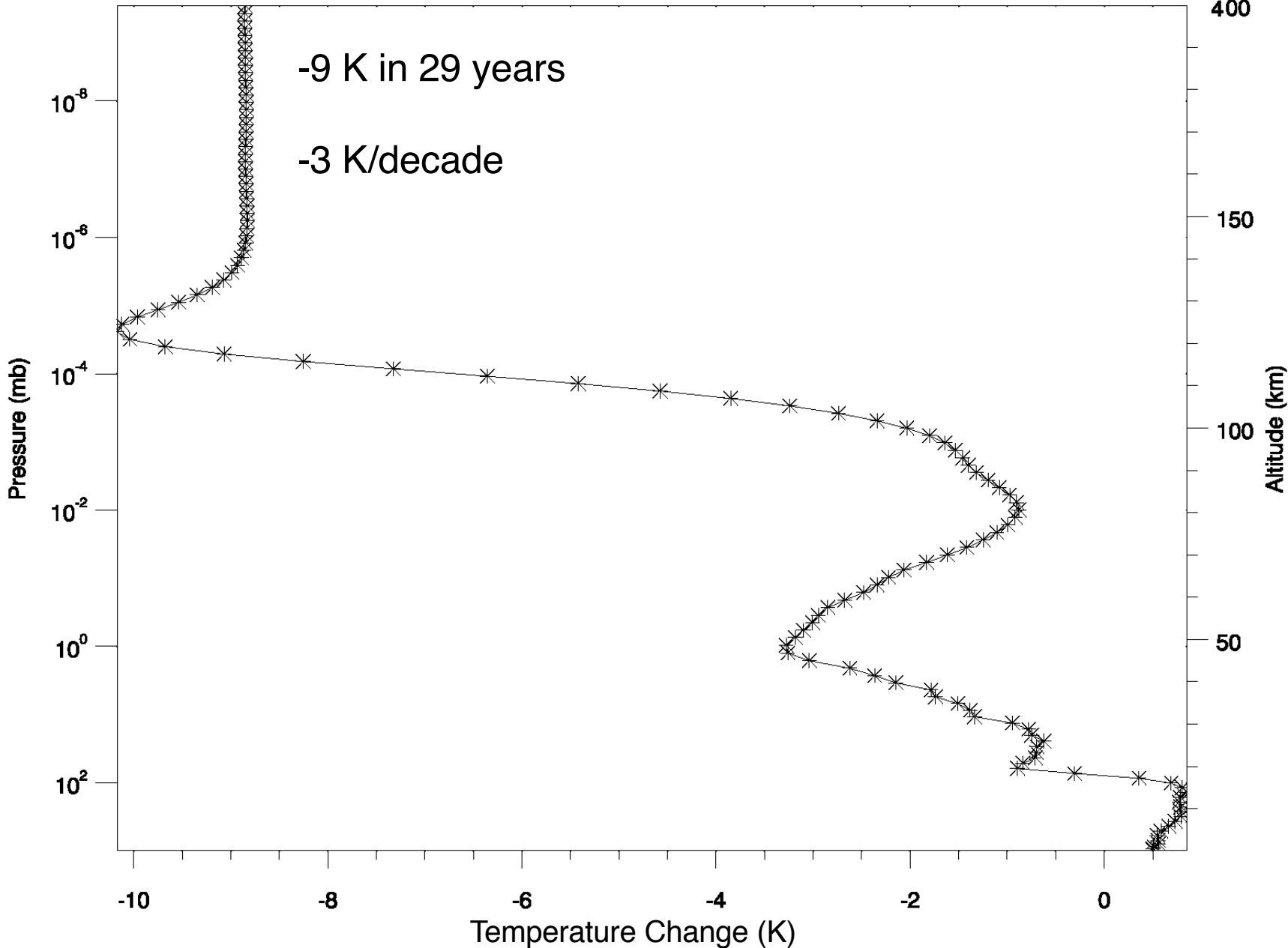
- Preliminary results from 5-year ensemble simulations of whole atmosphere response to anthropogenic forcing.
- Performed with pre-release version of WACCM-X.
- Includes anthropogenic changes in CO₂, CH₄, H₂O, CFCs, O₃
- Perpetual solar minimum conditions

Global Annual Mean Temperature Change, 1974 to 2003

Solar Minimum Conditions



Global Annual Mean Temperature Change, 1973 to 2002 Solar Minimum Conditions



Where We Stand Today

- WACCM-X v. 2.0 is fully functional, but not fully validated
- Several long runs, both free-running and specified-dynamics, are in progress
 - Results from these runs are available for analysis
 - Also serve as initialization conditions for event studies (e.g., solar flares)
- There are several known issues that need to be addressed
 - Electron temperature solver unstable in regions of very low electron density
 - Eddy diffusion generated by gravity waves in the lower thermosphere
- Meanwhile, the release of CESM v. 2.0 is delayed until August
 - We can't release WACCM-X v. 2.0 until this is done
 - But, the issues that are holding up CESM don't affect WACCM-X
- So, in the meantime, we have extensive runs that you can analyze
 - And, friendly users can run the development code in our environment
 - Plenty of time available on the new NCAR supercomputer "cheyenne"
- We need your help to identify where and how to improve the model
 - Our expectation is that colleagues will do so in a constructive manner
 - This is a developmental model, so please communicate with the developers.