# Whole Atmosphere Community Climate Model with Thermosphere and Ionosphere Extension (WACCM-X): Tutorial Session Introduction

Han-Li Liu
High Altitude Observatory
National Center for Atmospheric Research

# Project Goals

- Whole Atmosphere: Earth's Surface to the upper thermosphere/base of exosphere (0-500km).
- Study thermospheric/ionospheric variability as a part of the internal atmospheric variability, subject to strong solar/magnetospheric forcing.
  - Sun-earth connection (irradiance and particulate).
  - Space environment (space weather and space climate).
  - Lower-upper atmosphere coupling.
- Project initiated in 2000 by Ray Roble, Byron Boville, and Rolando Garcia.

# WACCM-X In Perspective

HAO/ACD/CGD WACCMX is WACCM with additional physics and further upward extended vertical range through thermosphere/ionosphere (~500km)

ACD/CGD Whole Atmosphere Community Climate Model (WACCM) is CAM with additional chemistry/physics and upward extended vertical range into lower thermosphere/ionosphere (~140km)

CGD Community Atmosphere Model (CAM) is atmospheric component of CESM

NCAR CGD Community Earth System Model (CESM)

# WACCM-X Model Components

| Model Framework | Chemistry | Physics | Physics | Resolution |
|---|---|---|---|---|
| Extension of the NCAR Community Atmosphere Model (CAM)<br><br>Finite Volume Dynamical Core | MOZART+<br>Ion Chemistry<br><br>Fully-interactive with dynamics. | Long wave/short wave/EUV<br><br>IR cooling (LTE/non-LTE)<br><br>Major/minor species diffusion (+UBC)<br><br>Molecular viscosity and thermal conductivity (+UBC)<br><br>Species dependent Cp, R, m.<br><br>Parameterized GW (including thermosphere) | Parameterized electric field at high, mid, low latitudes. IGRF geomagnetic field.<br><br>Auroral processes, ion drag and Joule heating<br><br>Ion/electron energy equations<br><br>Ambipolar diffusion<br><br>Ion/electron transport due to Lorentz force<br><br>Ionospheric dynamo<br><br>Coupling with plasmasphere/ magnetosphere | Horizontal: 1.9° x 2.5° (lat x lon configurable as needed)<br><br>Vertical: 81 levels (125 levels) 0-~500km<br><br>• < 1.0km in Upper Troposphere/ Lower Stratosphere<br>• 1-2 km in strat.<br>• 0.5 scale height in mesosphere/ thermosphere (0.25 scale height in mesosphere/ thermosphere with 125 levels) |

Green: Thermosphere extension.

Red: Ionosphere extension.

# Capability of CESM1.04-WACCMX

- Study the whole atmosphere compositional, thermal, and wind structure.
- Study thermospheric variability due to changes in the lower atmosphere:
  - Long-term changes in space environment due to lower atmosphere climate change.
  - Seasonal and interannual variability of the thermosphere and ionosphere.
  - Day-to-day thermospheric/ionospheric variability due to interaction among planetary waves, tides and mean circulation.

CESM Working Groups
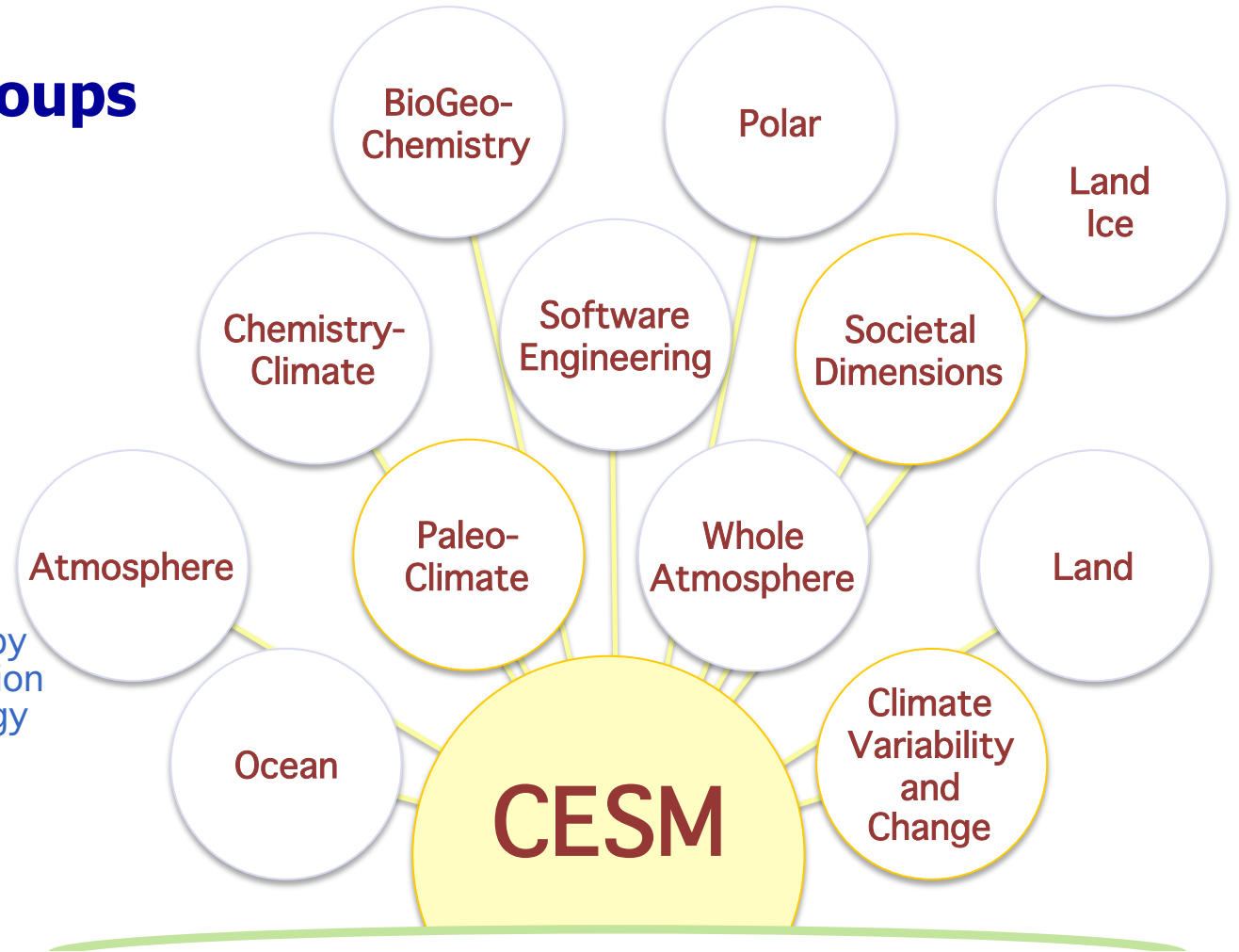
# Tutorial Session

- CESM: Sean Santos (NCAR/CGD)

- WACCM: Dan Marsh (NCAR/ACD)

- WACCM-X: Joe McInerney (NCAR/HAO)

Further information:

*http://www.cesm.ucar.edu/*

*http://www.cesm.ucar.edu/working_groups/WACCM/*

*http://bb.cgd.ucar.edu/*

WACCM: *Garcia, R. R., D. R. Marsh, D. E. Kinnison, B. A. Boville, and F. Sassi (2007), Simulation of secular trends in the middle atmosphere, 1950-2003, J. Geophys. Res., 112, D09301, doi: 10.1029/2006JD007485.*

WACCM-X: *Liu, H.-L., et al. (2010), Thermosphere extension of the whole atmosphere community climate model, J. Geophys. Res., 115, A12302, doi:10.1029/2010JA015586.*