Studies of Atmospheric Response to the Solar Cycle Using the NCAR Whole Atmospheric Community Climate Model

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Motivation for the WACCM Model

- Coupling between atmospheric layers:
  - Waves transport energy and momentum from the lower atmosphere to drive the QBO, SAO, sudden warmings, mean meridional circulation
  - Solar and geomagnetic inputs, e.g., auroral production of NO in the mesosphere and downward transport to the stratosphere
  - Stratosphere-troposphere exchange
- Climate Variability and Climate Change:
  - What is the impact of the stratosphere on tropospheric variability, e.g., the Arctic oscillation or “annular mode”?
  - How important is coupling among radiation, chemistry, and circulation? (e.g., in the response to O₃ depletion or CO₂ increase)
- Response to Solar Variability:
  - Recent satellite observations have shown that solar cycle variation is 0.1% for total Solar Irradiance
  - 5-10% at ~200 nm
  - Radiation at wavelengths near 200 nm is absorbed in the stratosphere
  - Impacts on tropospheric climate may be mediated by stratospheric chemistry and dynamics

Heritage and Structure of the WACCM Model

- MOZART: Model for Ozone and Related Tracers
- CAM3: Thermosphere-Ionosphere-Mesosphere Electrodynamics General Circulation Model
- WACCM: Non-interactive chemistry Valid to ~100 km
- WACCM2: Interactive chemistry Valid to ~100 km
- Current Work: Include ionosphere Extend validity to ~150 km

Some Recent Results

- Use solar and geomagnetic inputs from one “typical” cycle
- Probably a recent one so that good measurements are available
- Proxy-based models using TBD inputs (F₁₀.7, MgII c/w, S_n, K_p…)
- Daily / hourly cadence
- Repeat using identical inputs for ~8–10 cycles
- Necessary to average the natural variability out of the troposphere
- Considerable computational expense
- For the future: Long-term runs with combined forcing, using historical proxy record
  - Extreme computational expense

Plan for Solar Cycle Studies

- For l > 200 nm:
  - Heating rates based on CAM3 parameterization
  - Photolysis using lookup table based on TUV model
  - [Madronich & Flocke, 1998]
- For l < 200 nm:
  - Schumann-Runge bands parameterization:
    - [Koppier & Murtagh, 1996; Mischwasser & Siskind, 1993]
  - Schumann-Runge continuum:
    - Direct calculation using ~5-nm bins
  - Lyman-α parameterization:
    - [Chabrillat & Kockarts, 1997]
  - EUV & X-ray parameterization, including photoelectrons:
    - [Solomon & Chai, 2003 AGU, SA41B-0427]