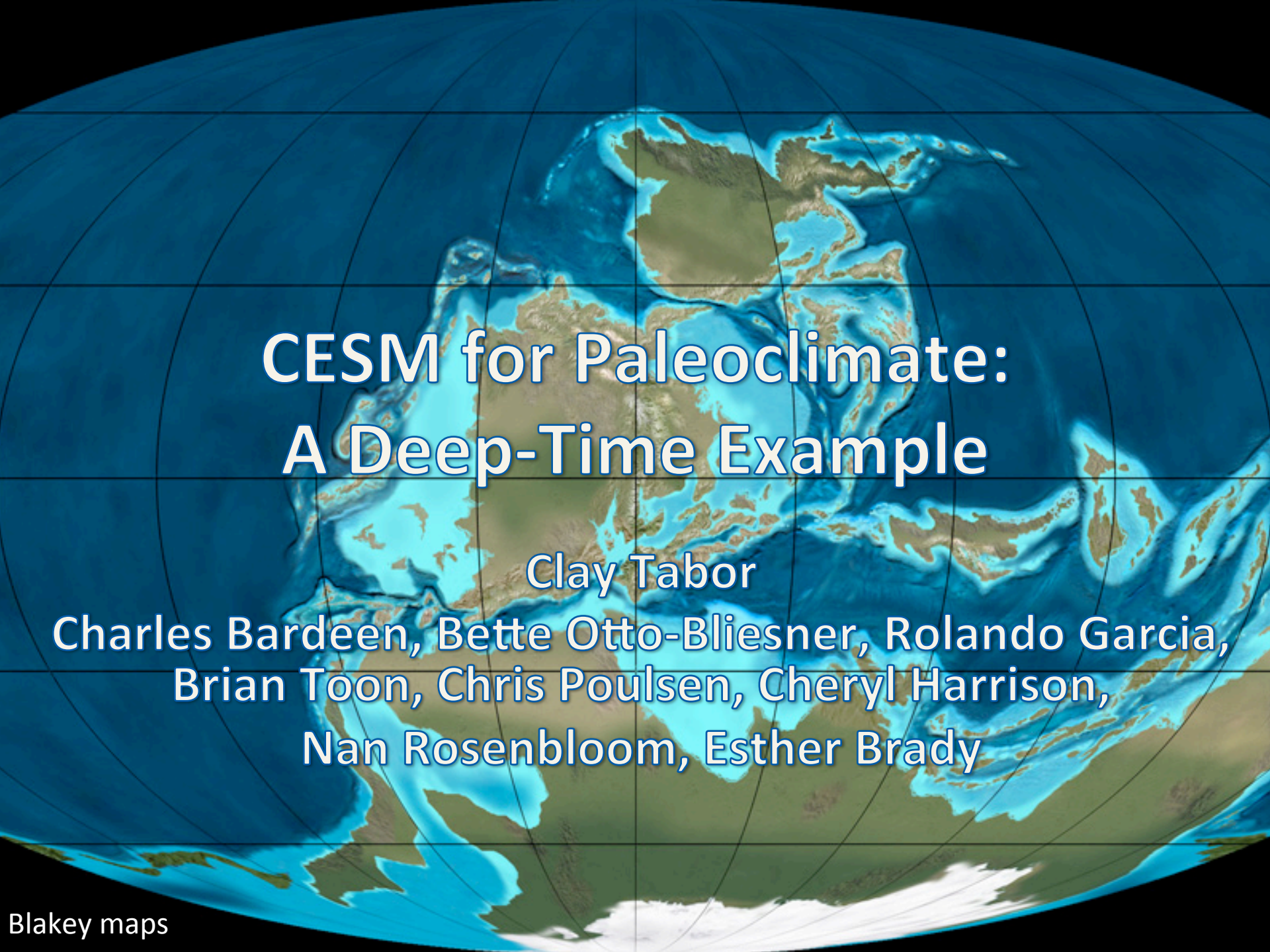

CESM for Paleoclimate: A Deep-Time Example

Clay Tabor
Charles Bardeen, Bette Otto-Bliesner, Rolando Garcia, Brian Toon, Chris Poulsen, Cheryl Harrison, Nan Rosenbloom, Esther Brady

Blakey maps

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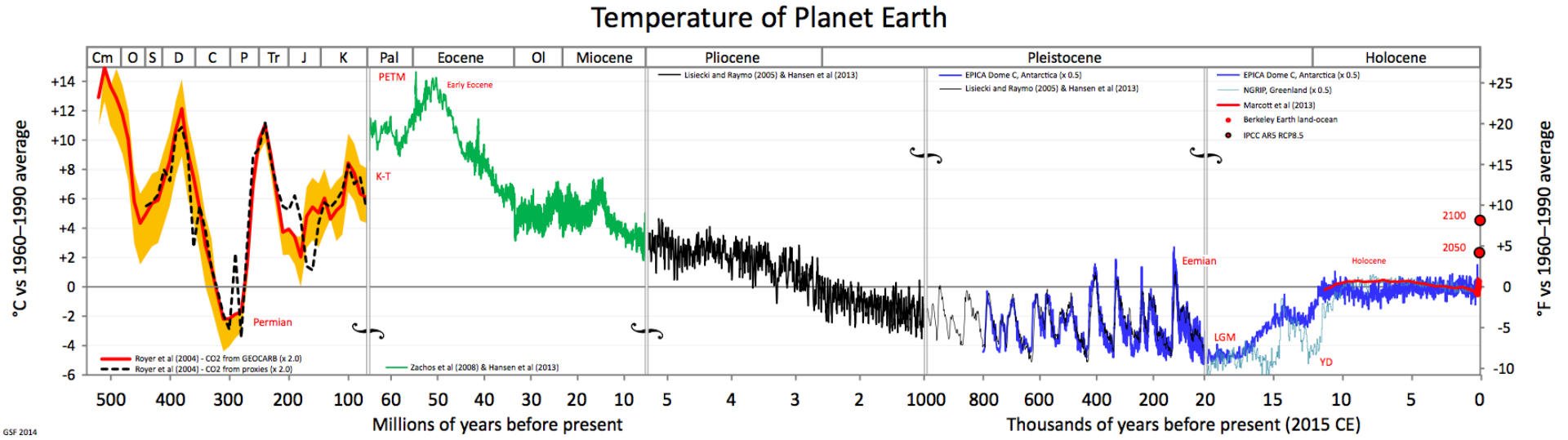
General Paleoclimate

- There are billions of years of climate!
- Why limit yourself to present-day?



Wikipedia.org

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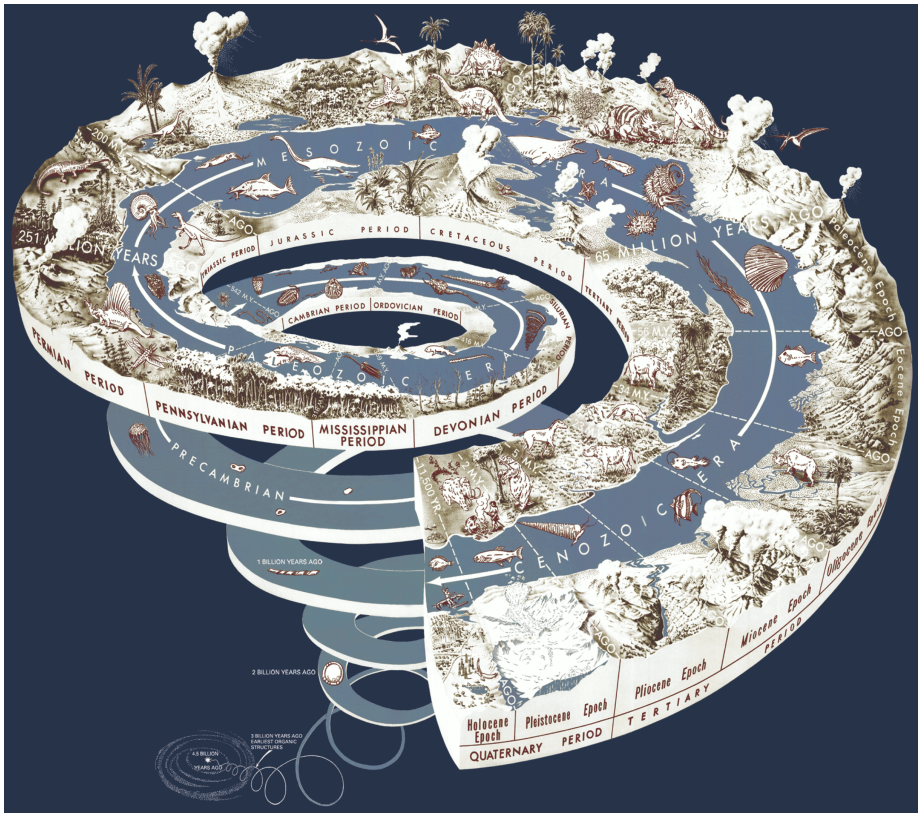
Why Model Paleoclimate?

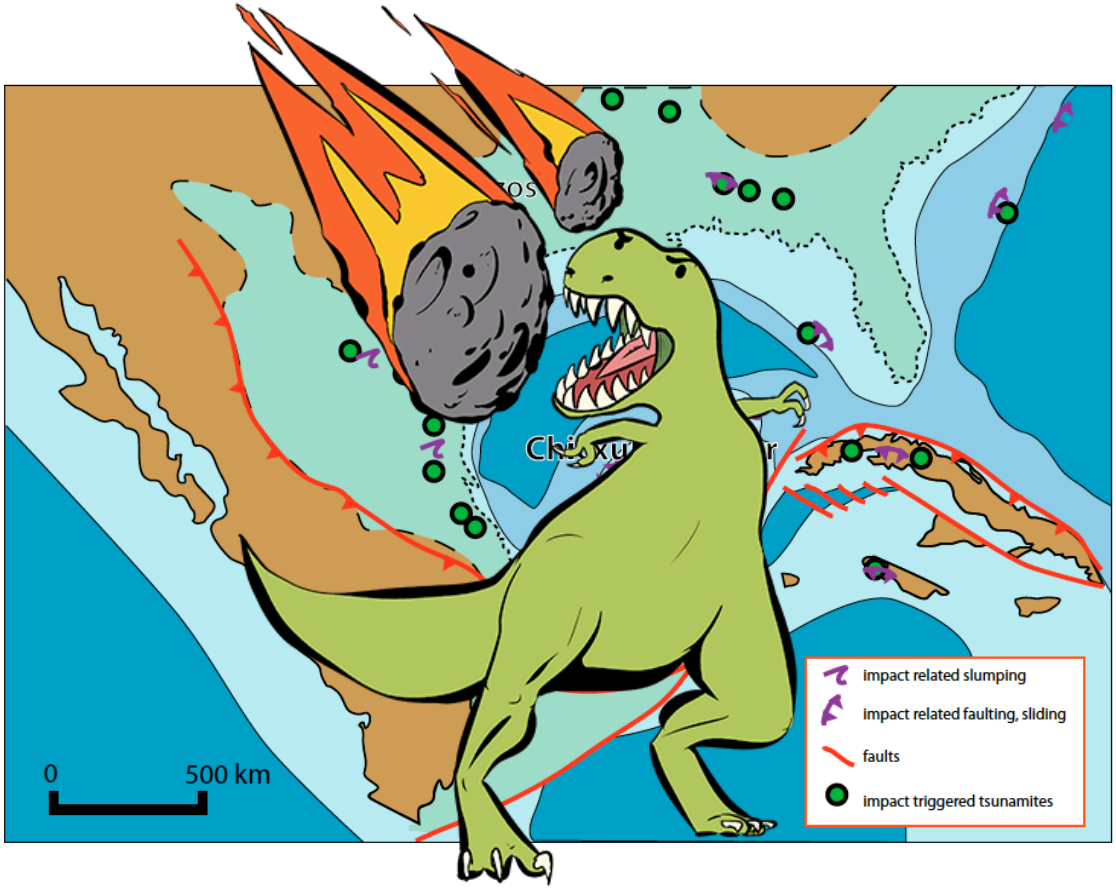
- Those who do not learn history are doomed to ~~repeat it~~ incorrectly forecast the future!
  - Model validation
  - Earth system sensitivity
  - Rapid climate change



Wikipedia.org

Example: Chicxulub Impact

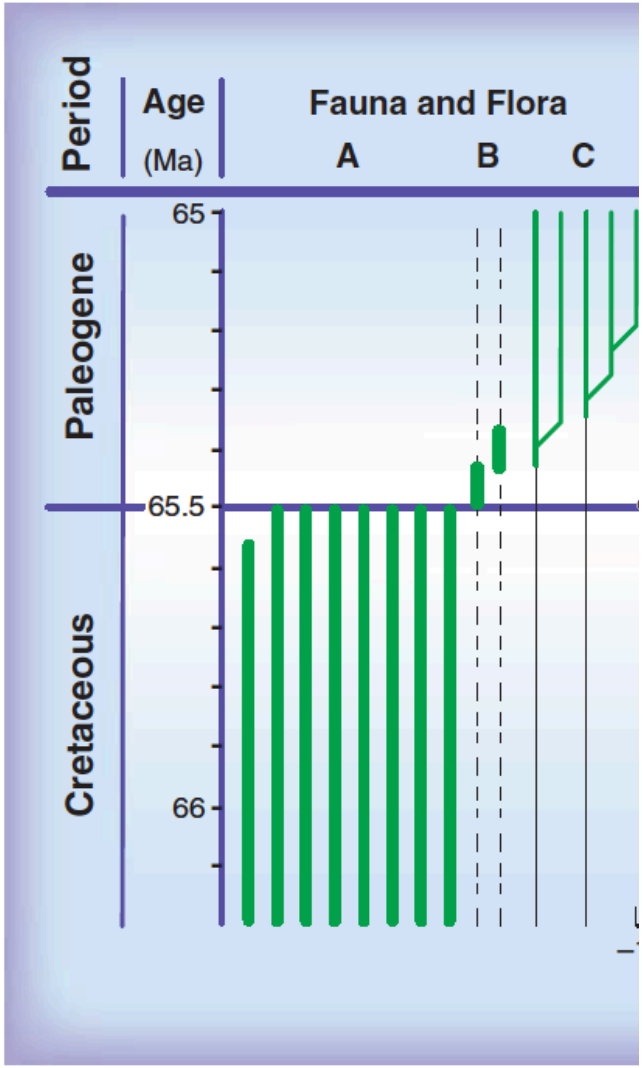
- **Time**: 66 Ma
- **Size**: 10 km
- **Crater:** 180 km
- **Where**: Yucatan Peninsula



Vellekoop et al. (2014)

Background: Effects

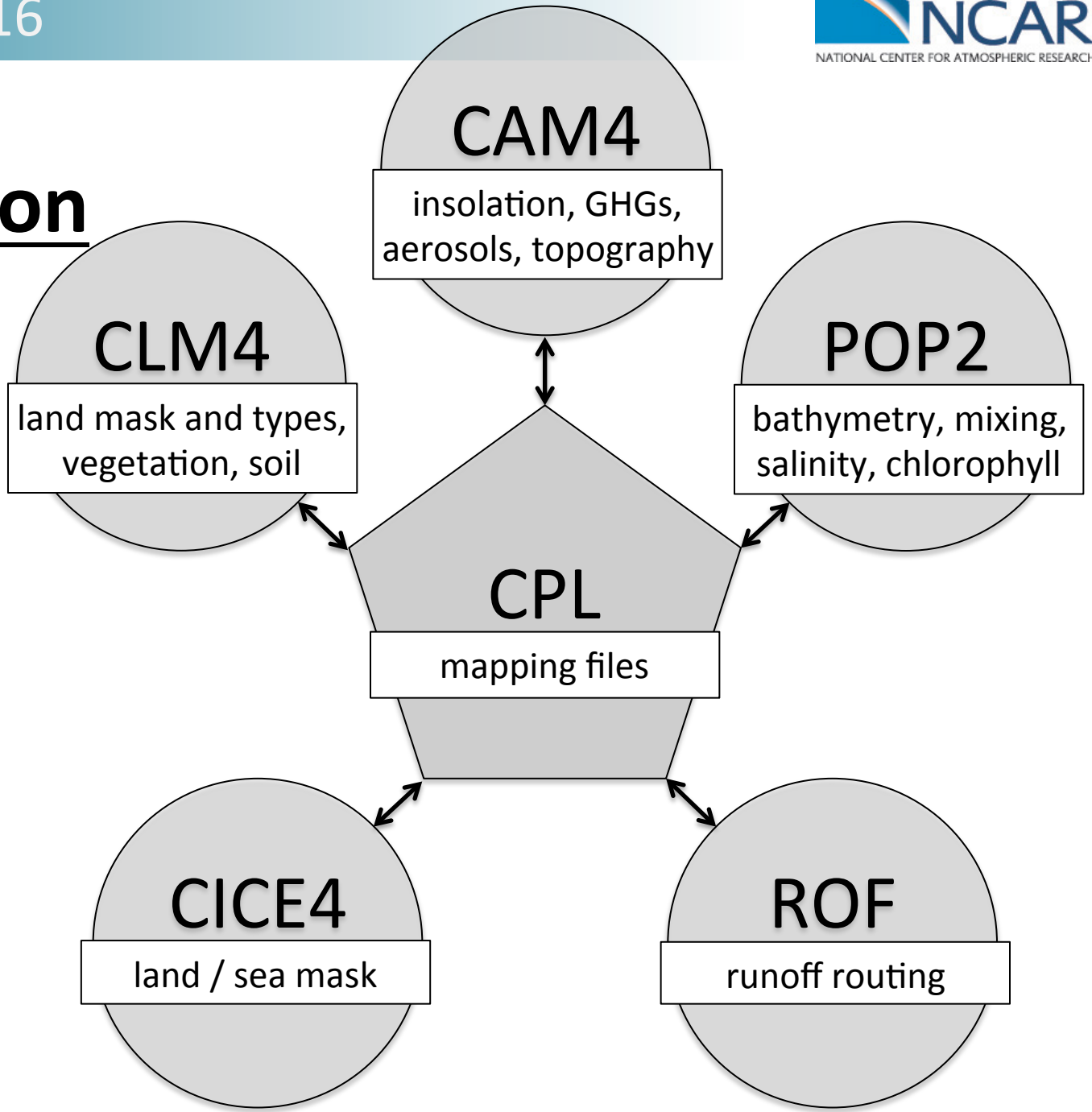
- Huge blast
- Heat and fire due to ejecta
- Tsunamis and earthquakes
- Emissions of soot, dust, GHGs, etc..
  - Potential for rapid cooling
  - Possible CO_2 increase
- Mass extinction



Toon et al. (1998)

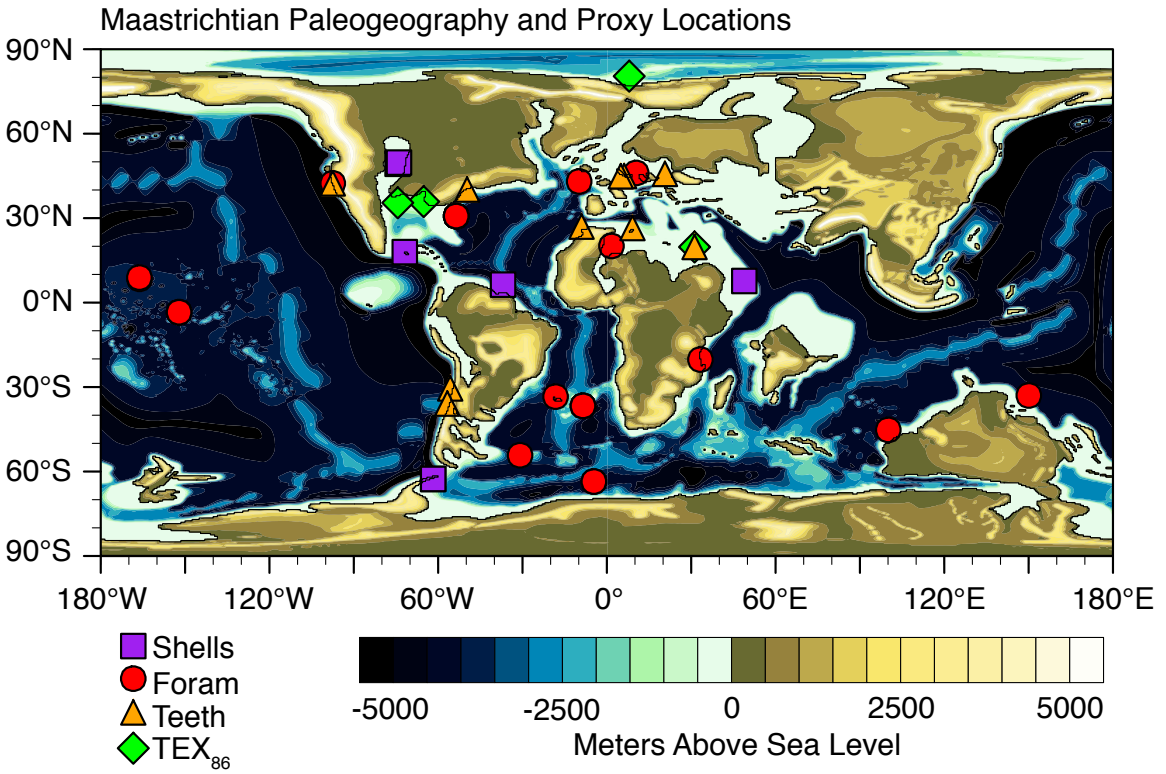
Schulte et al. (2010)

Deep-Time Configuration



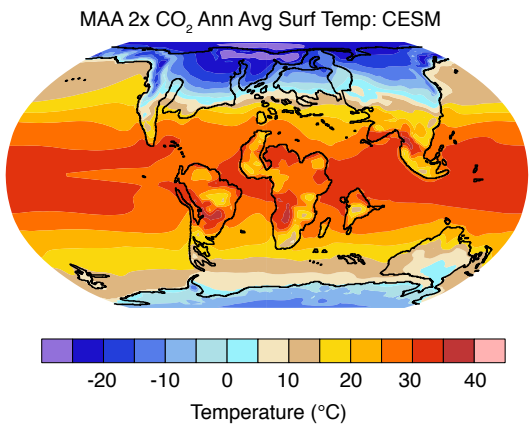
Setup: Model Spin-up

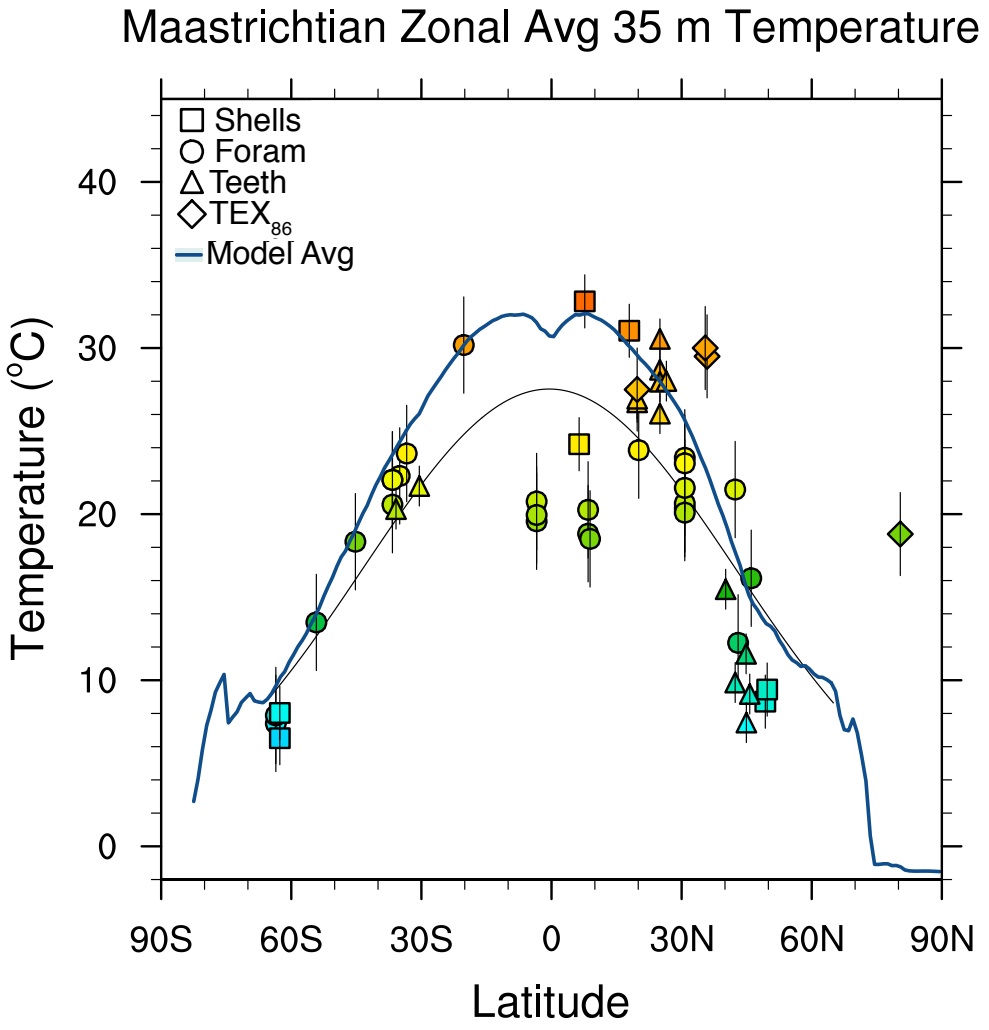
- **Models:**
  - CCSM4–CAM4, POP2, CLM4, CICE4
    - 1.9˚x2.5 / ~1°
- **Configuration:**
  - Maastichtian (72-66 Ma) paleogeography
  - 560 ppm CO_2
  - Adjusted solar constants
  - 2200 years run



Setup: Equilibrium Cretaceous

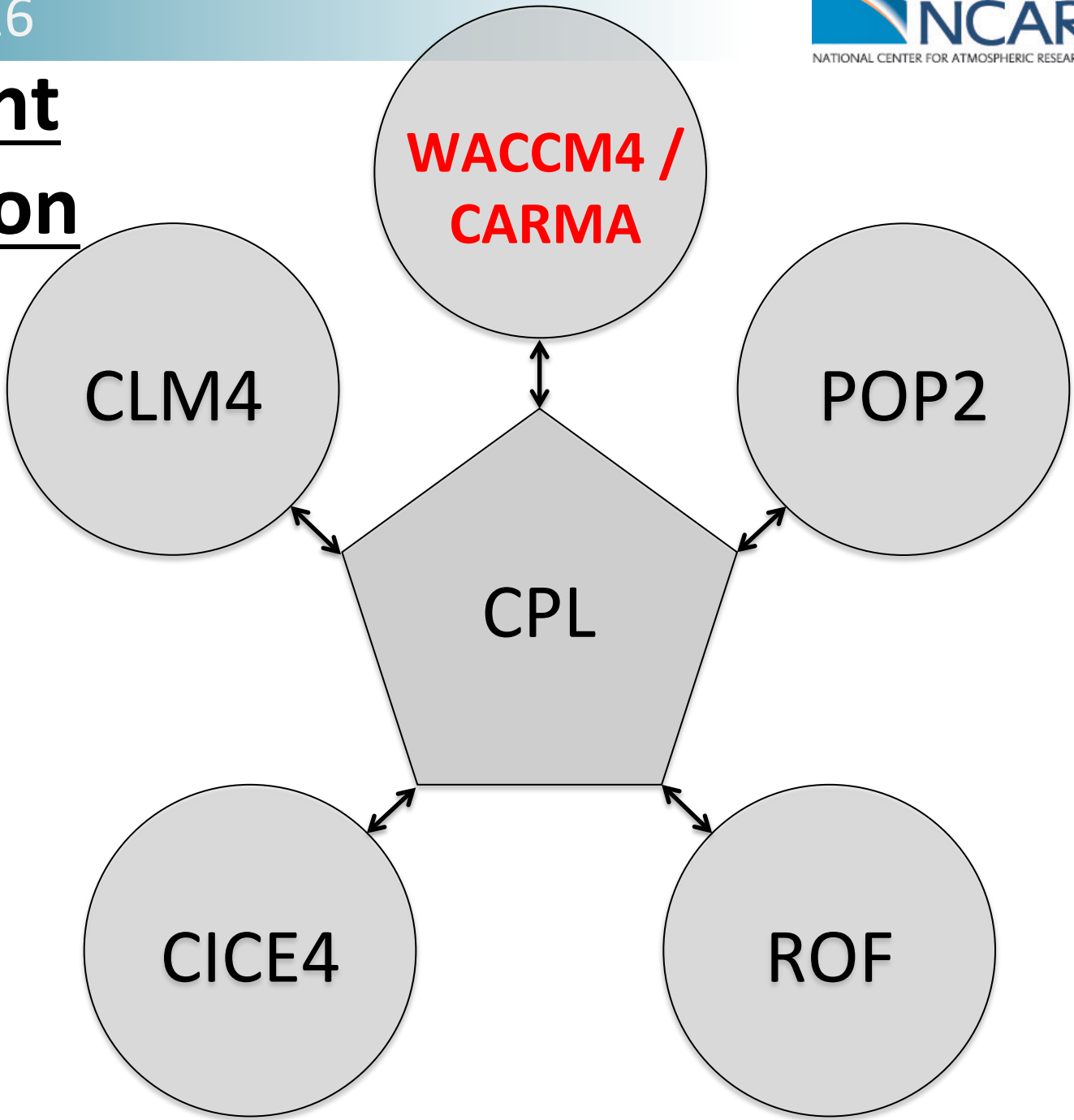
- Global surface temp: 22.3°C
- General agreement between model and SST proxies





Tabor et al. 2016

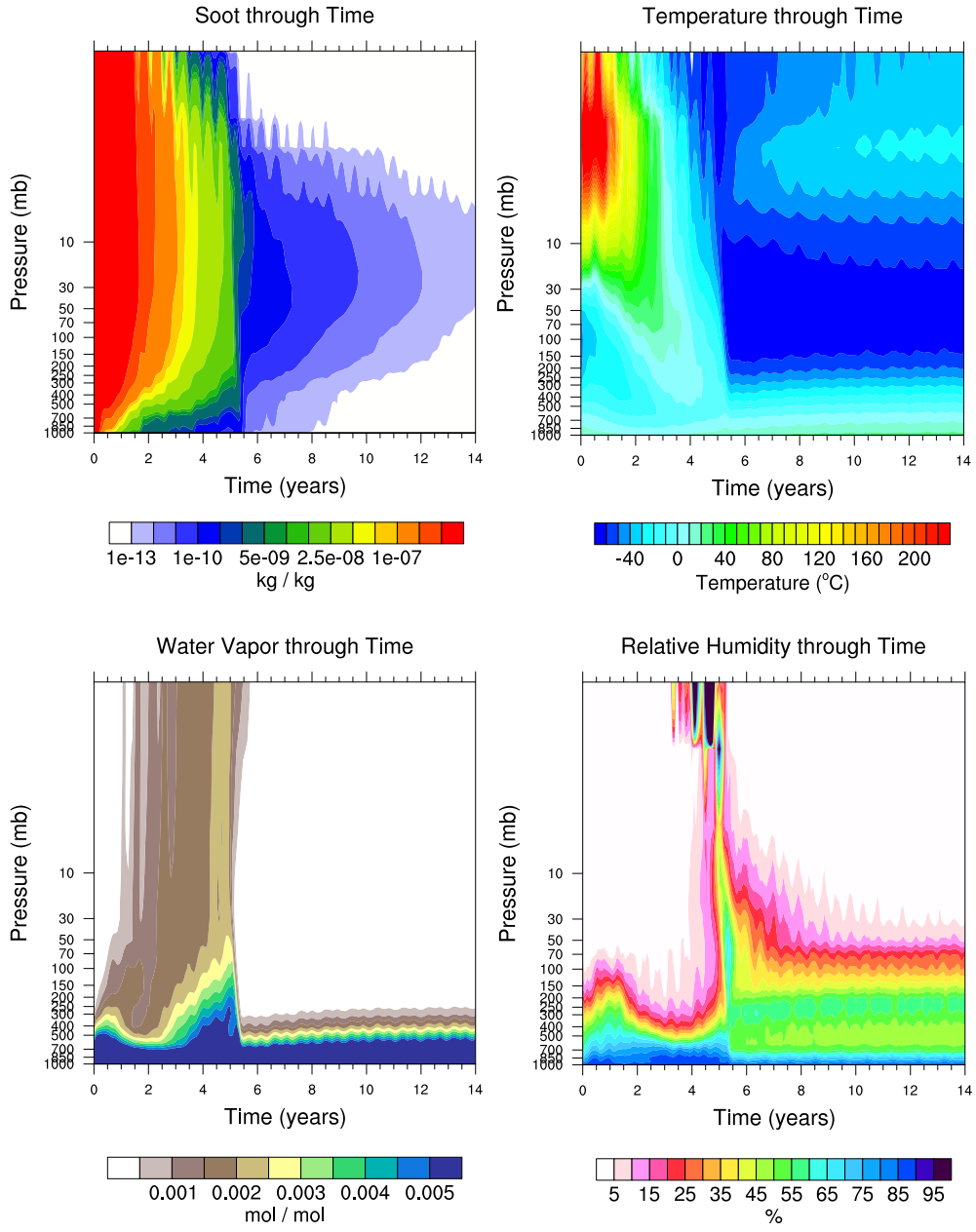
Impact Event Configuration



Setup: Perturbation Experiment

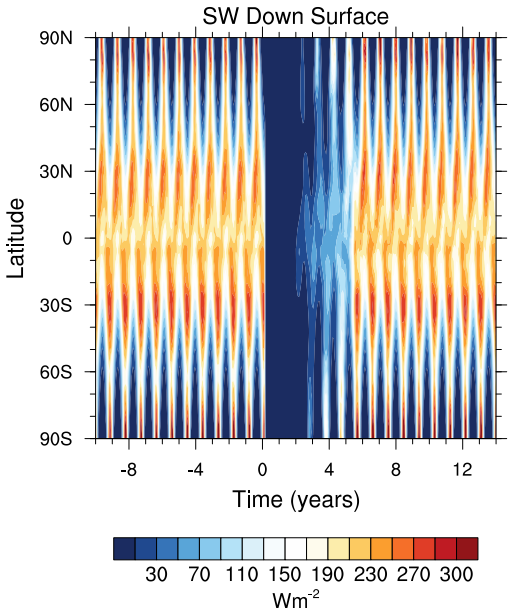
- **Models:**
  - WACCM4
    - Coupled chemistry
    - CARMA for impact soot aerosols (Bardeen et al., 2016, *in prep*)
- **Configuration:**
  - Pre-impact: 15-year run
  - Post-impact: 15-year run
    - 70,000 Tg global soot release in 1 day (Toon et al;, 2016, ACP-D)
    - CO_2 increase to 2000 ppm

Soot Response

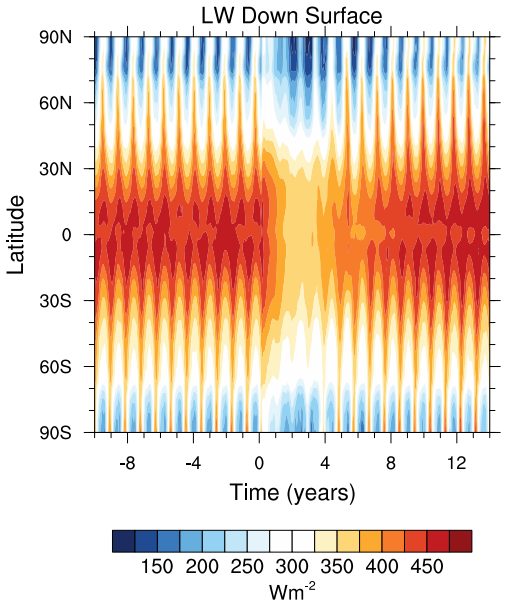


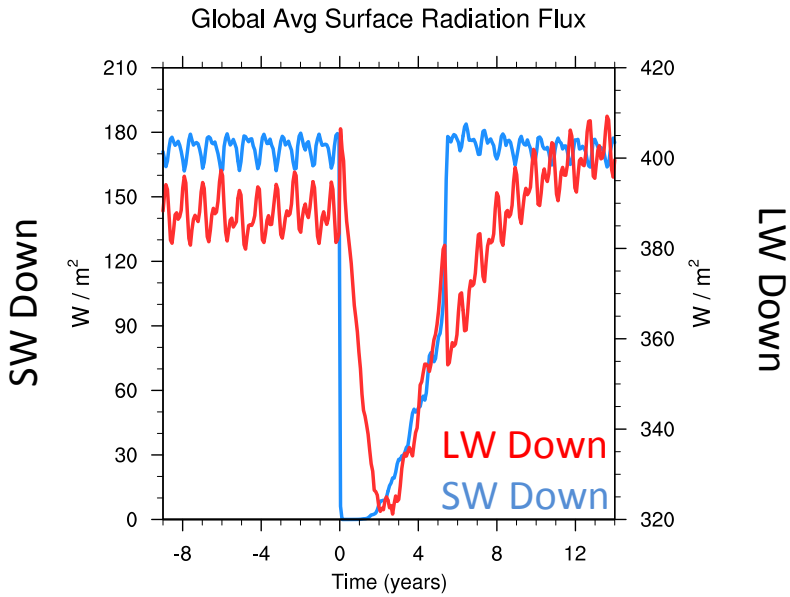
- Soot fills the atmosphere
- Upper atmosphere warms and inversions break down
- Large increase in upper atmosphere water vapor
- Cooling causes condensation and wet removal

Radiation Response

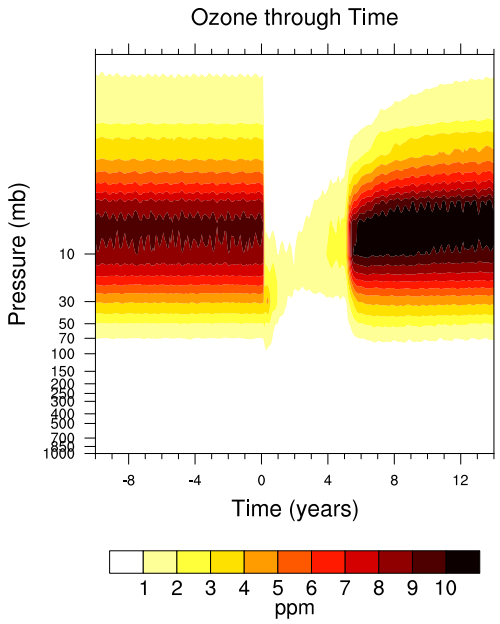


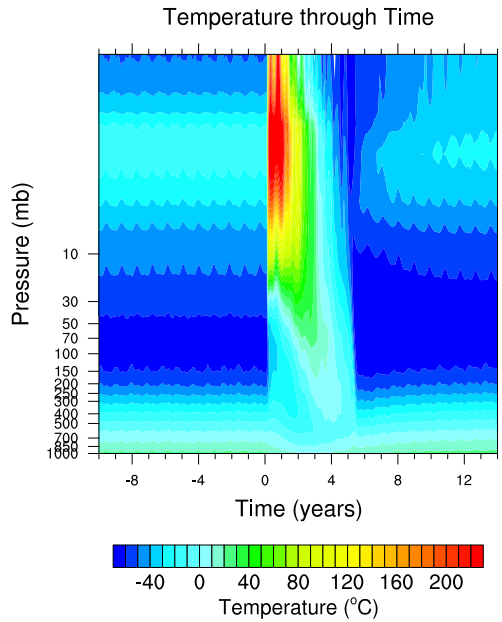
- Soot blocks SW from reaching the surface for 2 years
- Soot blocks escape of LW
  - Reduces amount of cooling





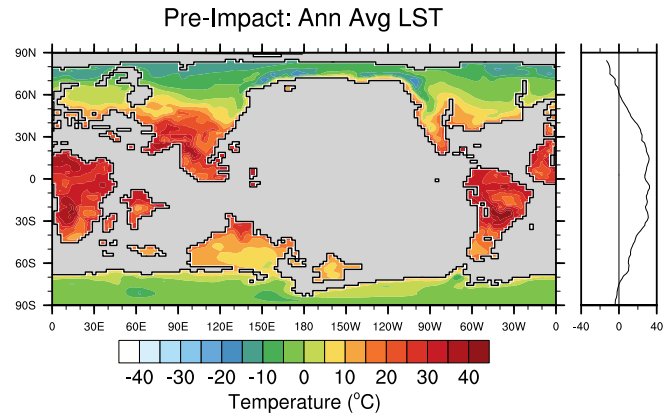
Ozone Response

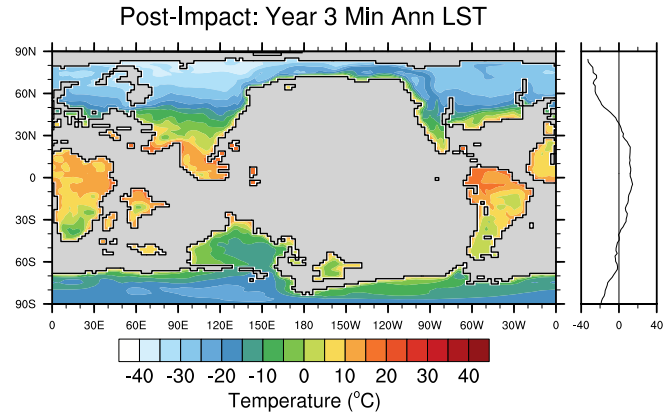


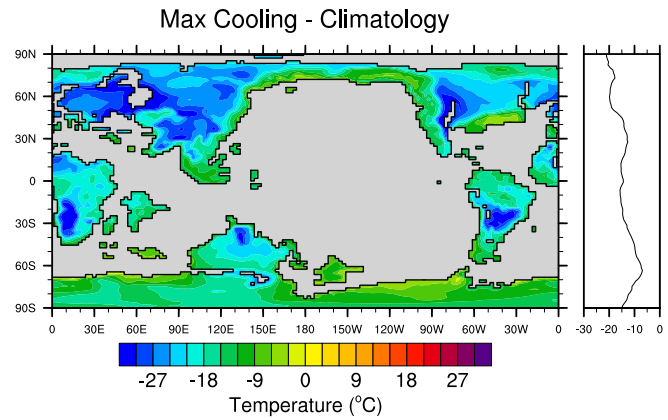


- Soot and water vapor in upper atmosphere destroy O_3 layer
- Soot also blocks most UV radiation
- Rapid recovery of O_3 after soot removal
- Additional CO_2 cools the upper atmosphere, leading to more O_3 formation

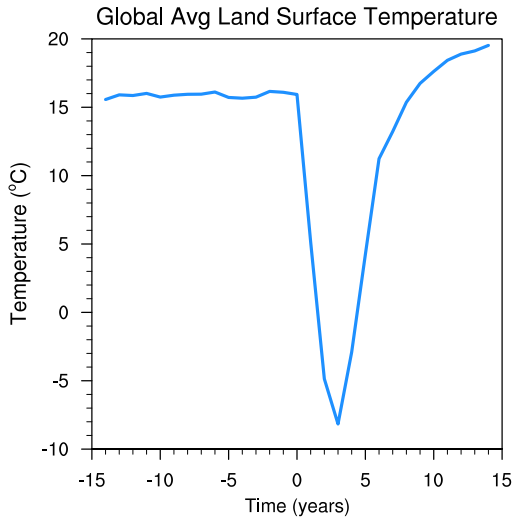
Temperature Response



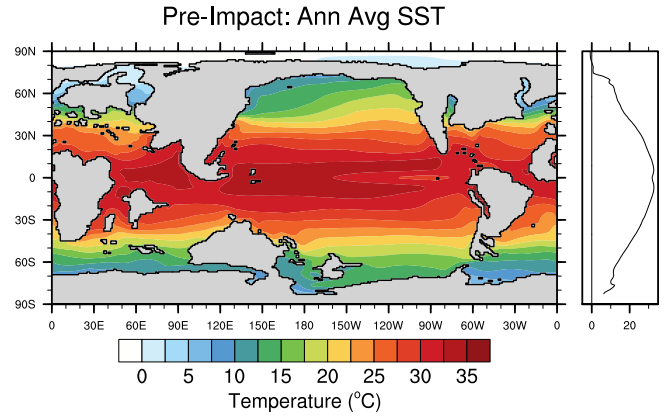


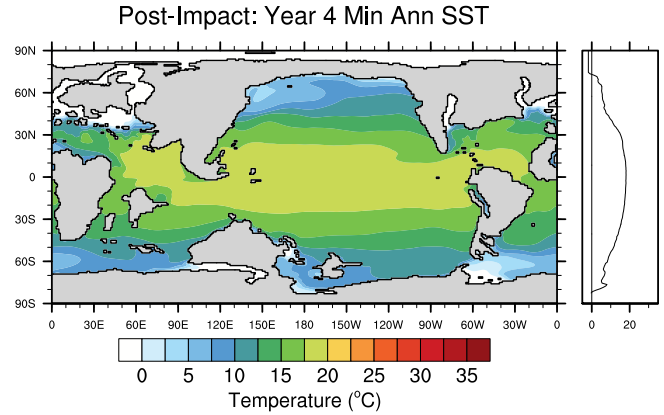


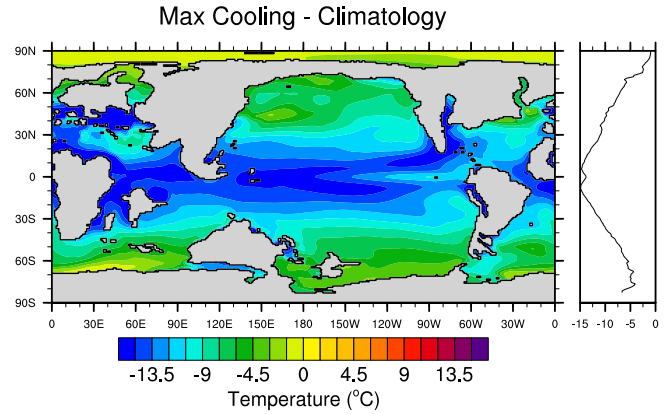
- Land surface responds rapidly
  - Minimum in year 3
    - ~25°C of total cooling
  - Pre-impact levels by year 8



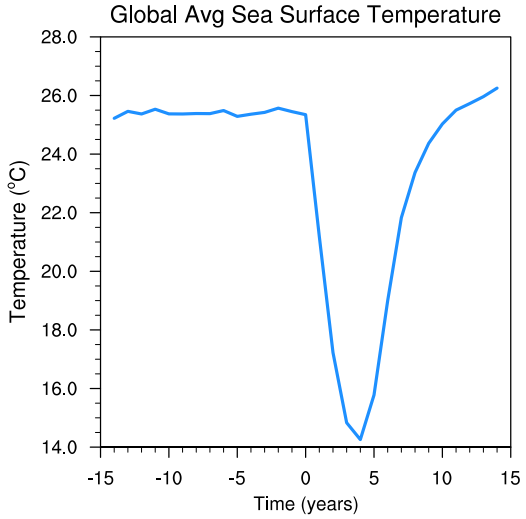
Temperature Response



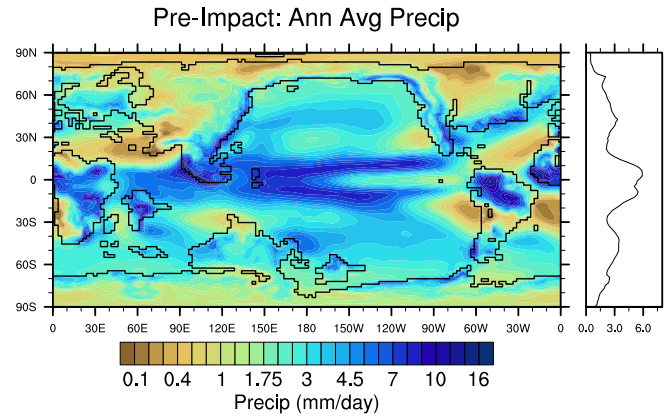


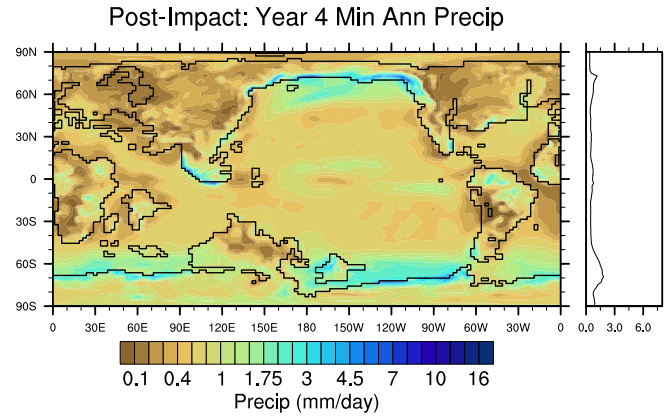


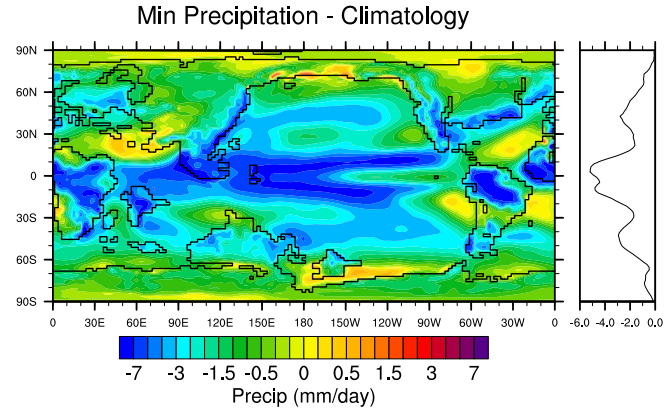
- Ocean surface responds less
  - Minimum in year 4
    - ~11°C of total cooling
  - Pre-impact levels by year 11



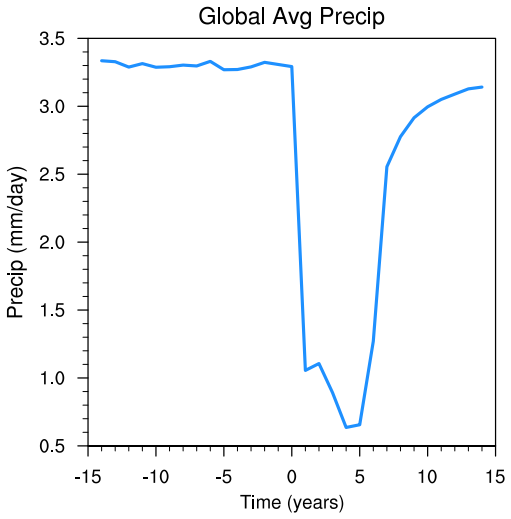
Precipitation Response



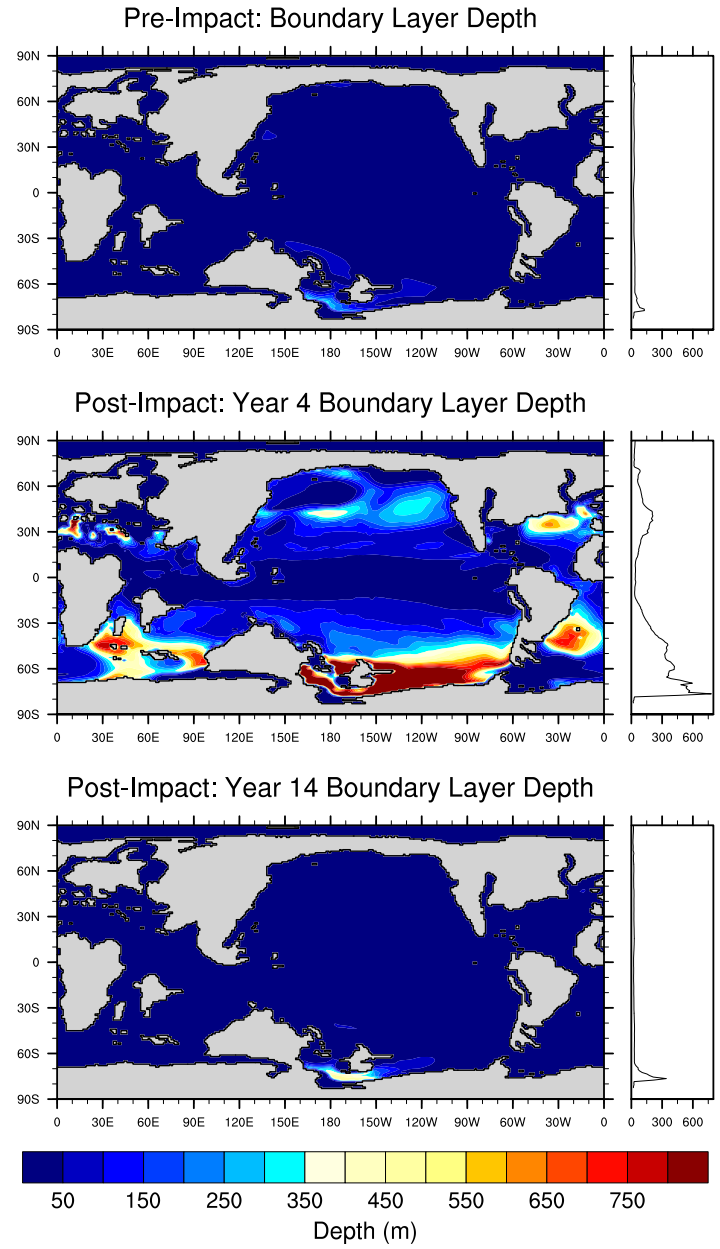




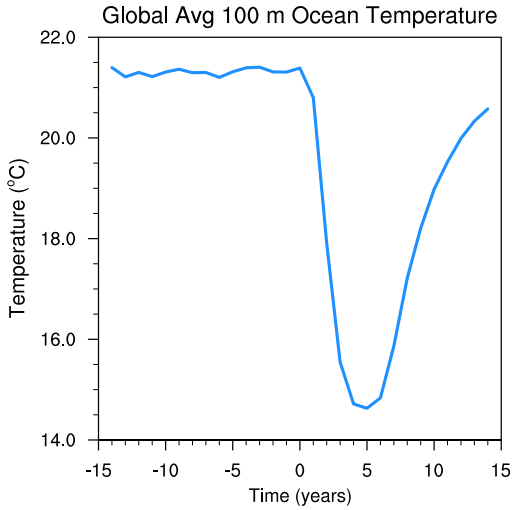
- Stability increases post-impact
- Convective precip slows down
- Slight precip increase where SST cooling muted



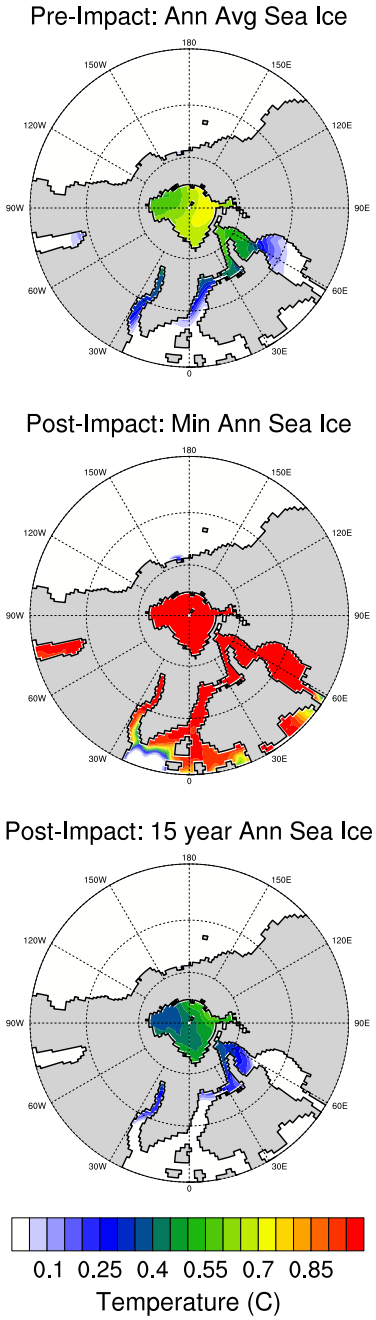
Ocean Overturning



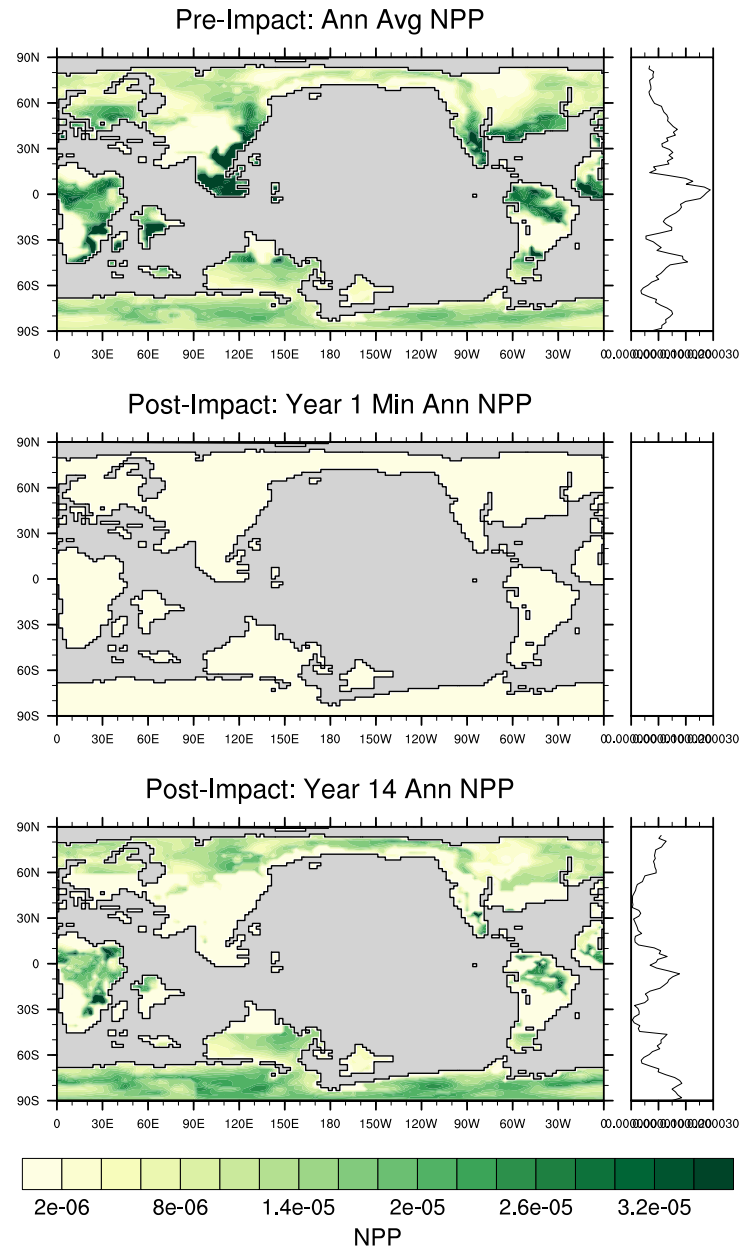
- Extreme increase in deep-water formation
- Rapid cooling followed by rapid warming increases stratification



Sea Ice Response



- Significant increase in perennial sea ice where circulation is poor and seas are shallow
  - Expansion to mid-latitudes!
- In open ocean, increased poleward heat transport prevents additional sea ice formation



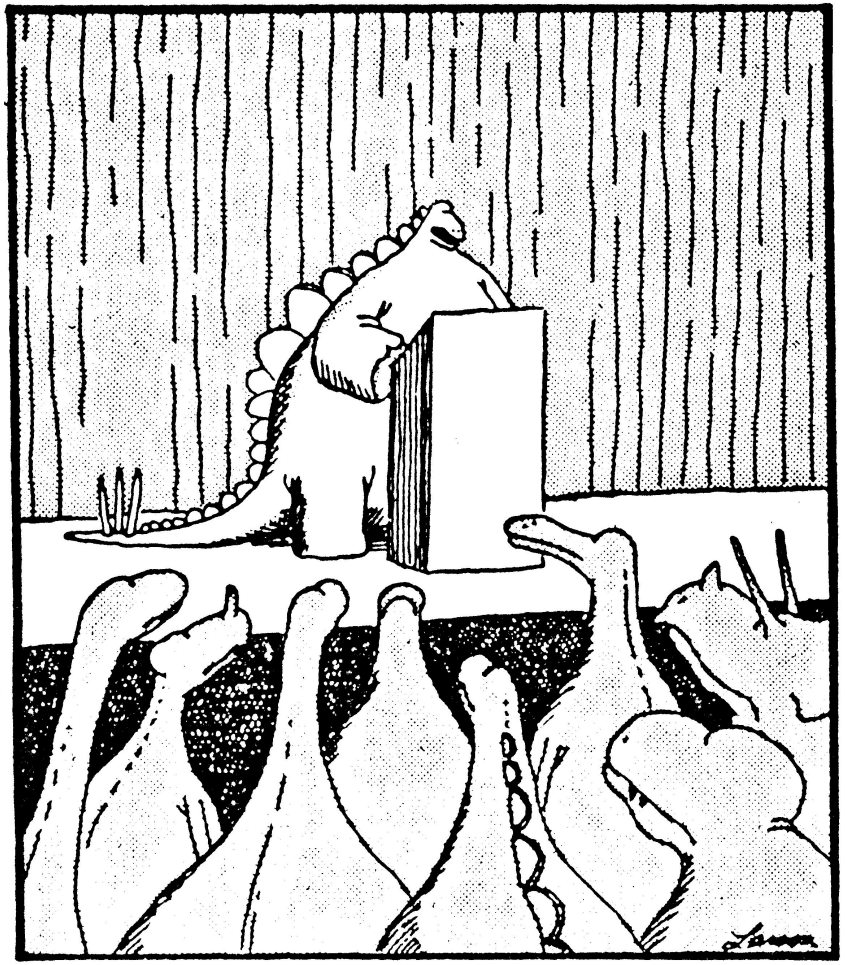
Vegetation

- Lack of sunlight stops net primary productivity for several years
- Low latitude vegetation does not recover after 15 years
- High latitude vegetation increases due to warm /wet temperatures after 15 years

CESM Paleoclimate Tools

- CAM5 now works for hot climates!
- CESM can track water and carbon isotopes
- User friendly P-CESM in progress
- Last Millennium, Last Glacial Maximum, and Pliocene data available
- For more information visit: http://www2.cesm.ucar.edu/working-groups/pwg

Happy modeling! Questions?



"The picture's pretty bleak, gentlemen. ... The world's climates are changing, the mammals are taking over, and we all have a brain about the size of a walnut."

Gary Larson's Far Side