The cause of Late Cretaceous cooling: A multi-model / proxy comparison

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Background: Temperature Records

- SST proxy data suggest gradual cooling from 100-66 Ma
  - Tectonically driven?
  - GHG driven?

Linnert et al. (2014)
Background: Paleogeography

- Tectonic changes from Cenomanian (98 Ma) to Maastrichtian (68 Ma)
  - Western Interior Seaway
  - Drake Passage
  - Opening of Atlantic
Background: CO$_2$ Records

- CO$_2$ reconstructions suggest drawdown from 100-66 Ma
  - Large uncertainty

Y. Wang et al. (2014)
Experiment Design

• **Models:**
  – CESM1.2 – CAM4, POP2, CLM4, CICE4
  – HadCM3L – HadAM3, TRIFFID, HadOM3

• **Configuration:**
  – Detailed Cretaceous topographies
  – Fixed GHG concentrations
  – Adjusted solar constants

• **Experiments:**
  • 4x PI CO$_2$ Cenomanian (100-94 Ma)
  • 4x PI CO$_2$ Maastichtian (72-66 Ma)
  • 2x PI CO$_2$ Maastichtian (72-66 Ma)
Models: Surface Temperature

- Global MAT:
  - 4x CO₂ Cenomanian
    - CESM: 22.80°C
    - HadCM3L: 22.18°C
  - 4x CO₂ Maastichtian
    - CESM: 22.92°C
    - HadCM3L: 22.34°C
  - 2x CO₂ Maastichtian
    - CESM: 19.82°C
    - HadCM3L: 19.02°C
Models: Temperature Change

• Similar response between models
Models: Paleogeographic Response

- Changes important for interpreting proxy records
  - Equatorial Pacific warms
  - North Pacific warms
  - Eastern North America cools
  - South Atlantic cools
  - Australia warms
Models: CO$_2$ Response

- Polar amplification of the cooling
  - More snow and sea ice
- Only a few degrees of cooling in low latitudes
- Global temperature sensitivity of $\sim$3$^\circ$C
Models: Temperature Decomposition

- Changes in paleogeography:
  - Emissivity: +0.13°C
  - Heat Convergence: 0.00°C
  - Albedo: -0.16 °C
- Changes in CO₂:
  - Emissivity: -2.45°C
  - Heat Convergence: +0.05°C
  - Albedo: -0.75°C
Proxies: SST Compilation

- SST averages from Cenomanian and Maastrichtian
- Standardized calibrations
- SST cooling of almost 6°C
Model / Proxy SST Comparison

- No evidence for a significantly reduced equator-to-pole gradient
- SST gradient suggests sea ice formation in agreement with simulations
Model / Proxy SST Comparison

- 4x PI CO\(_2\) Cenomanian:
  - mean SST difference of +2.27 without foraminifera
- 2x PI CO\(_2\) Maastrichtian:
  - mean SST difference of -0.65 without foraminifera
- Higher CO\(_2\) in Cenomanian to explain discrepancy?

A. Cenomanian 4x CO\(_2\) Zonal SST Differences
B. Maastrichtian 4x CO\(_2\) Zonal SST Differences
C. Maastrichtian 2x CO\(_2\) Zonal SST Differences
Proxy Bias: 4x CO₂ Cenomanian

- Removal of SST proxy reconstruction data from individual methods
Conclusions

• Cooling from Cenomanian to Maastrichtian likely due to GHG reduction, not geographic change

• Latitudinal SST gradients are not unreasonably shallow

• Land surface temperature reconstructions remain warmer than models
PWG Winter Meeting

Questions?

http://globe-views.com/dreams/dinosaur.html