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

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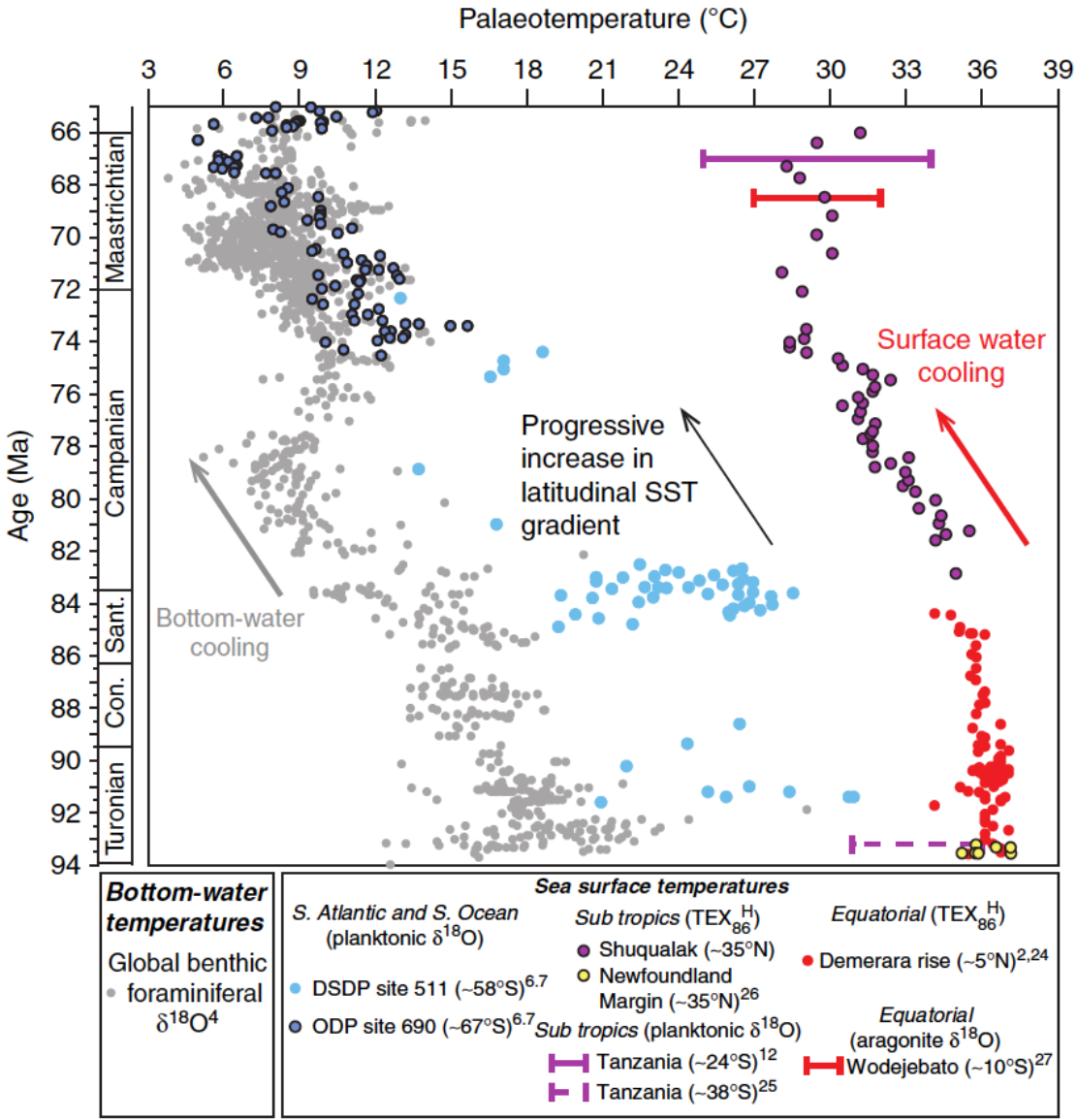
Background: Temperature Records

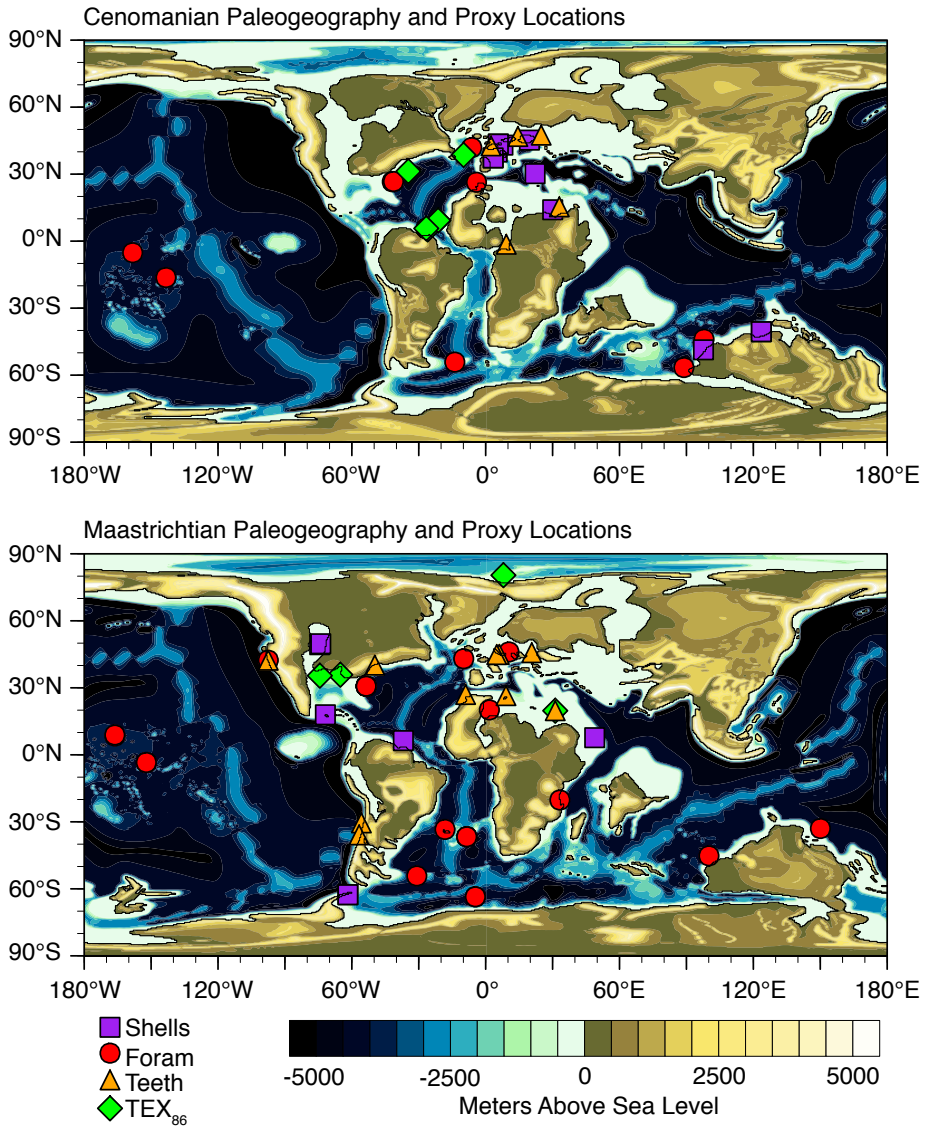
- SST proxy data suggest gradual cooling from 100-66 Ma
  - Tectonically driven?
  - GHG driven?



Linnert et al. (2014)

Background: Paleogeography

- Tectonic changes from Cenomanian (98 Ma) to Maastrichtian (68 Ma)
  - Western Interior Seaway
  - Drake Passage
  - Opening of Atlantic



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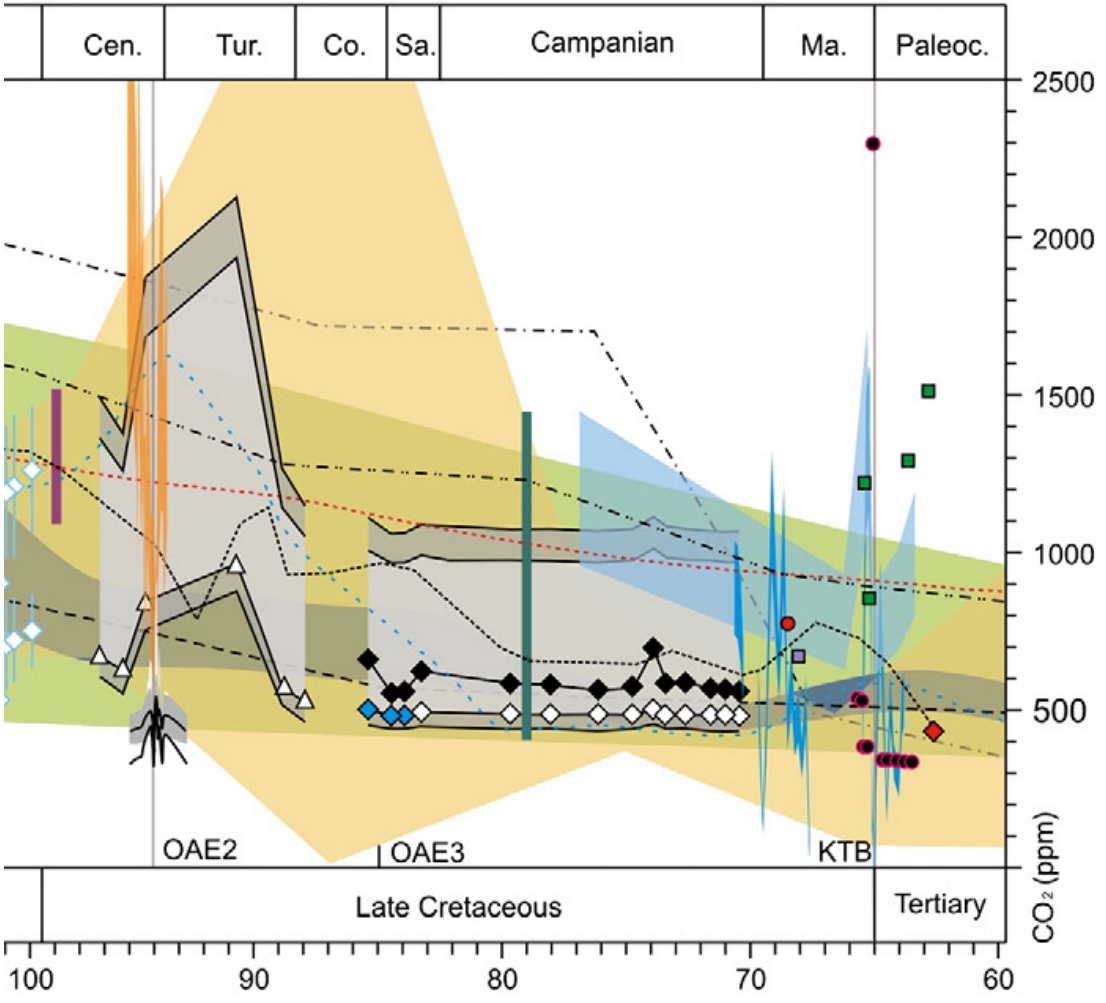
Background: CO_2 Records

- CO_2 reconstructions suggest draw-down from 100-66 Ma
  - Large uncertainty



Y. Wang et al. (2014)

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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)

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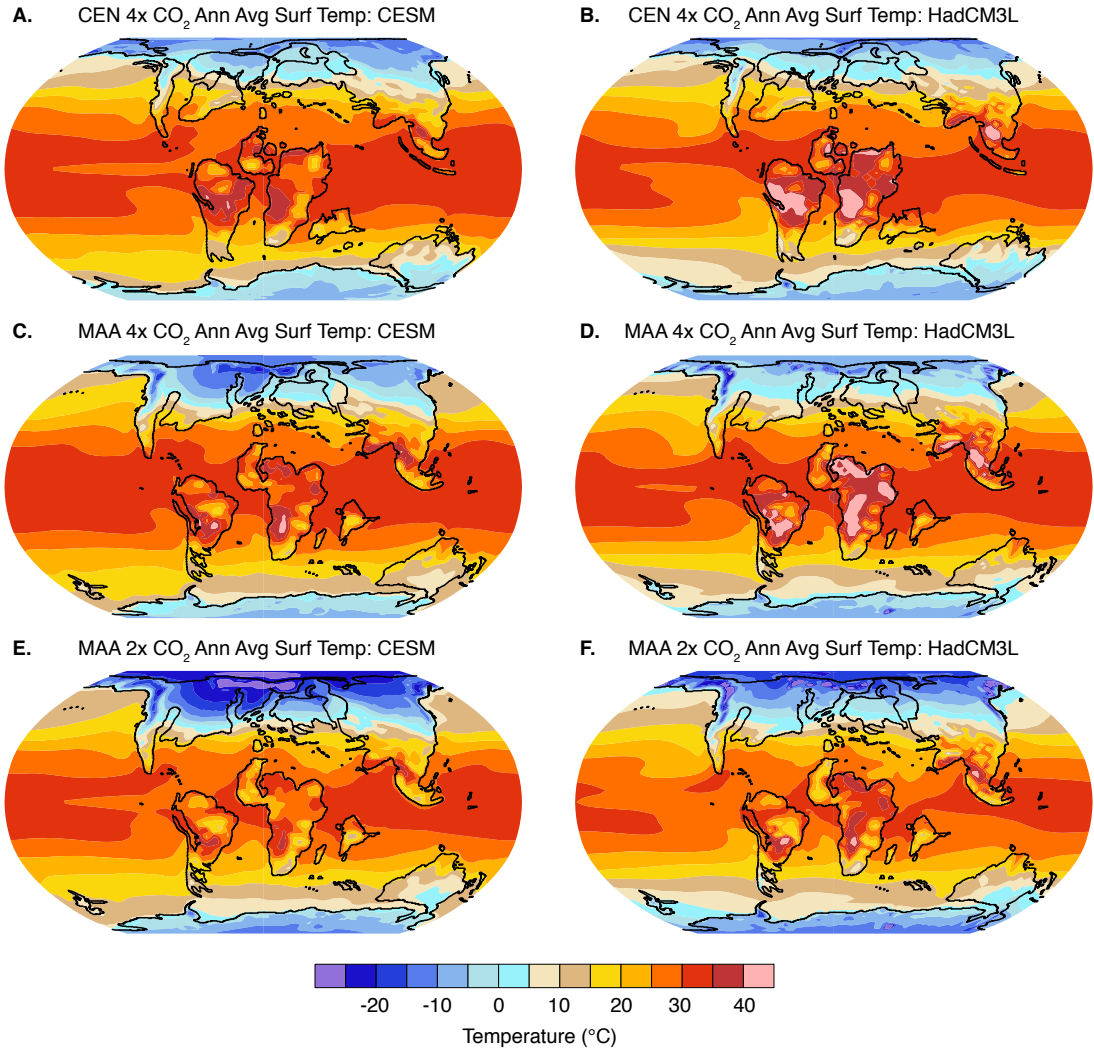
Models: Surface Temperature

- Global MAT:
  - 4x CO_2 Cenomanian
    - CESM: 22.80°C
    - HadCM3L: 22.18°C
  - 4x CO_2 Maastichtian
    - CESM: 22.92°C
    - HadCM3L: 22.34°C
  - 2x CO_2 Maastichtian
    - CESM: 19.82°C
    - HadCM3L: 19.02°C



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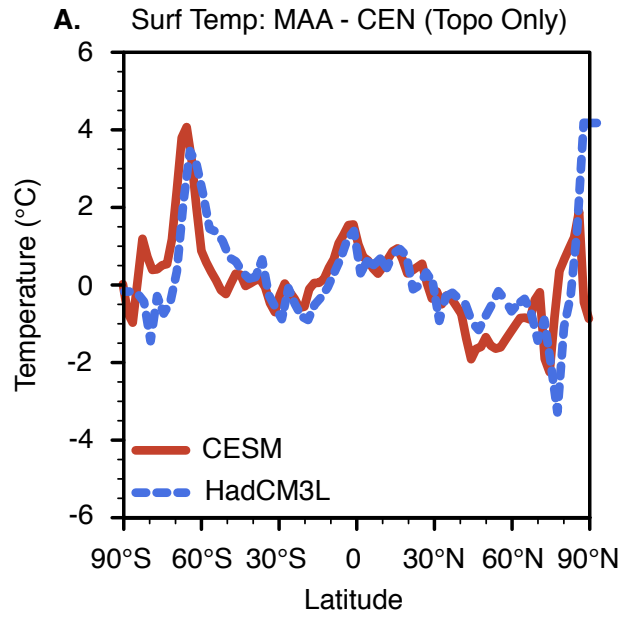
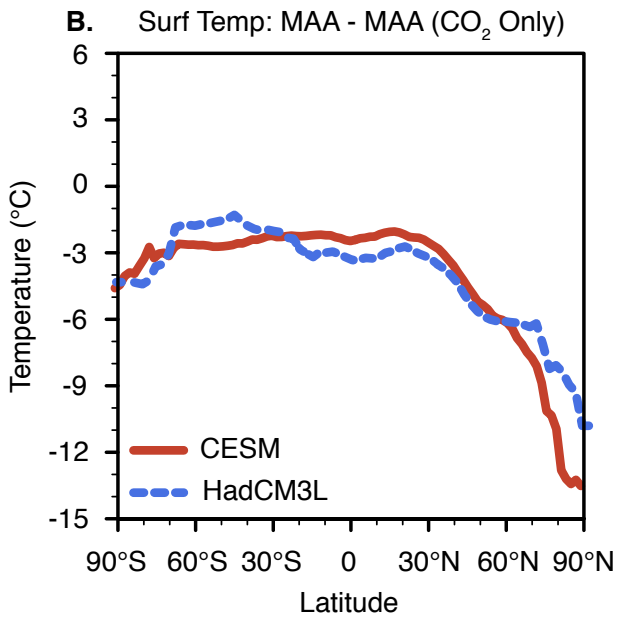
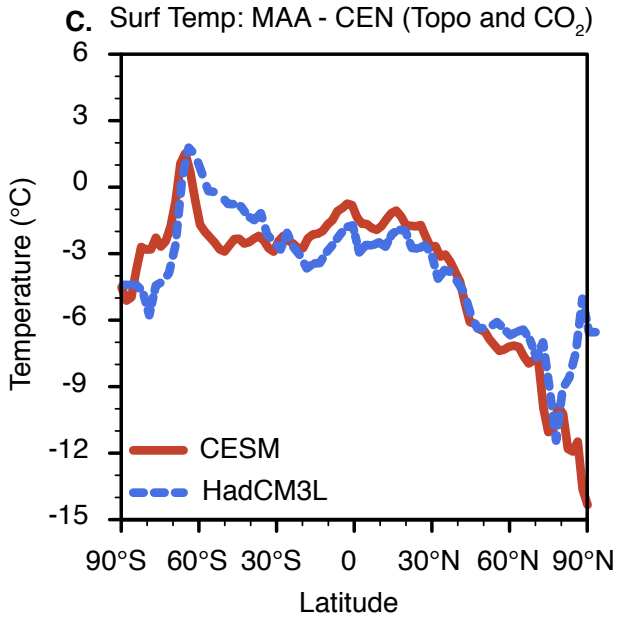
Models: Temperature Change

- Similar response between models

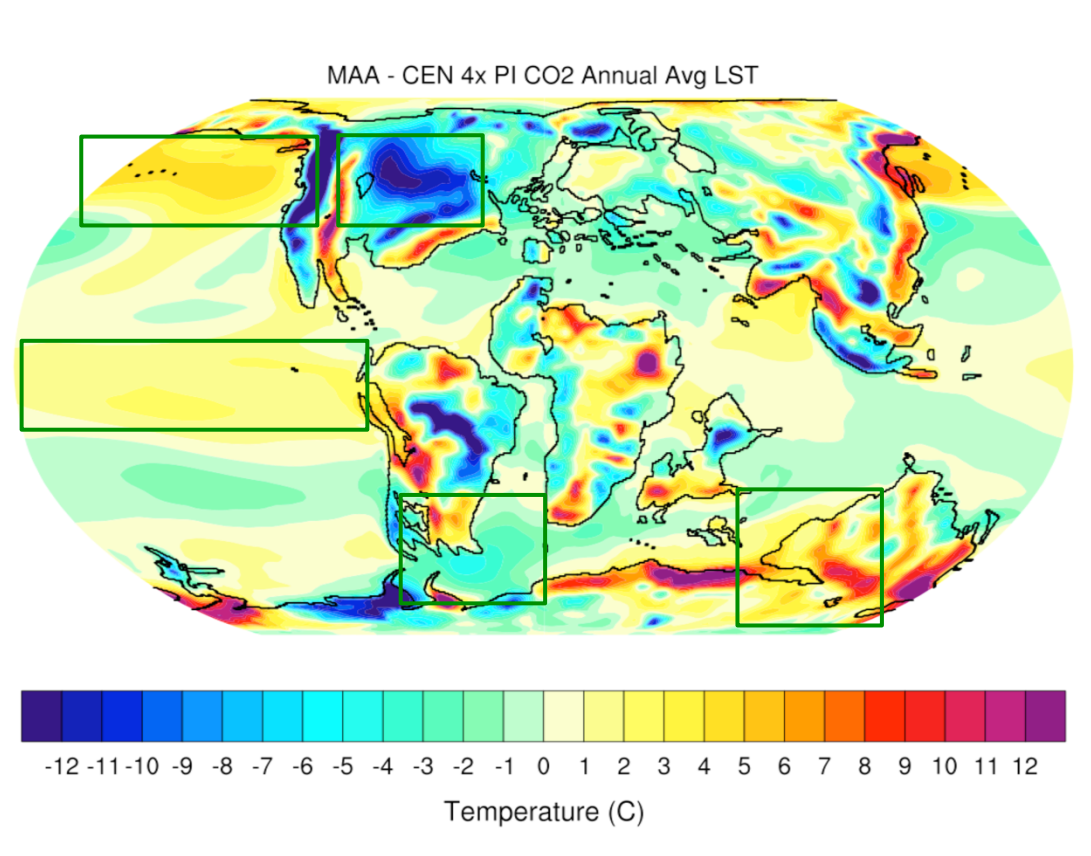






Models: Paleogeographic Response

- Changes important for interpreting proxy records
  - Equatorial Pacific warms
  - North Pacific warms
  - Eastern North America cools
  - South Atlantic cools
  - Australia warms



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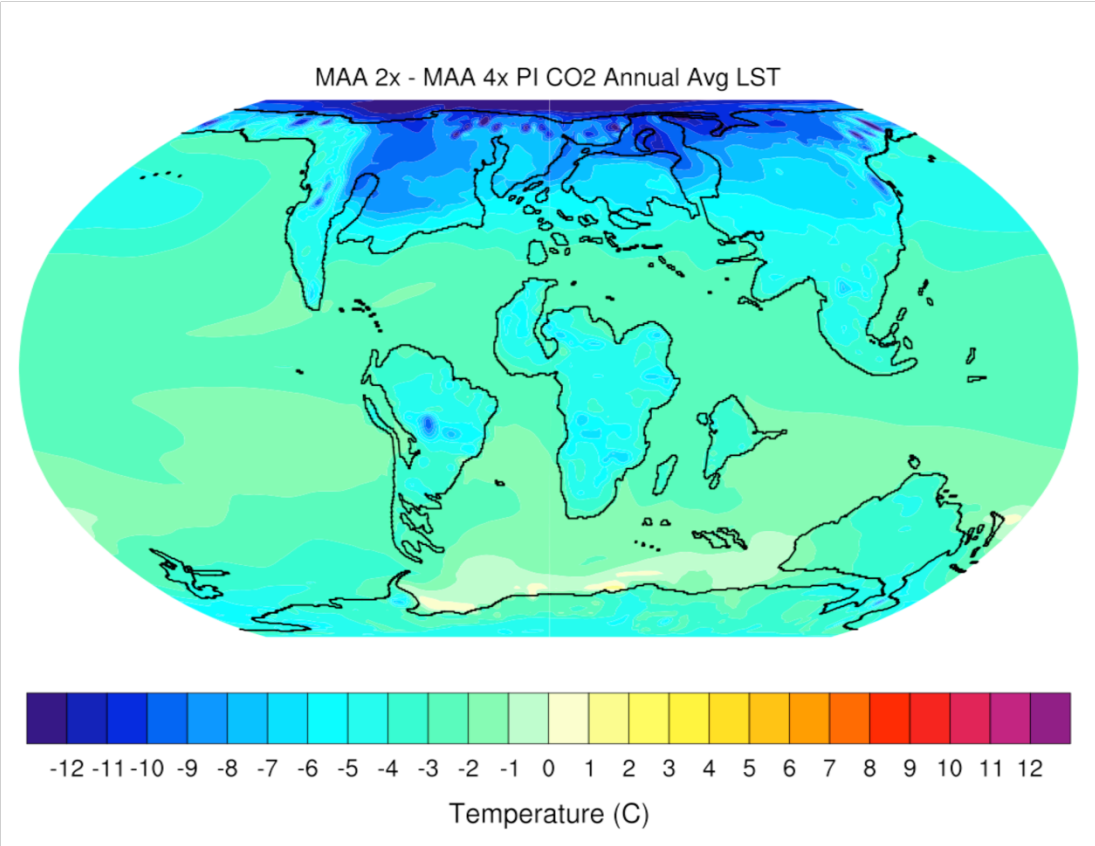
Models: CO_2 Response

- Polar amplification of the cooling
  - More snow and sea ice
- Only a few degrees of cooling in low latitudes
- Global temperature sensitivity of ~3°C



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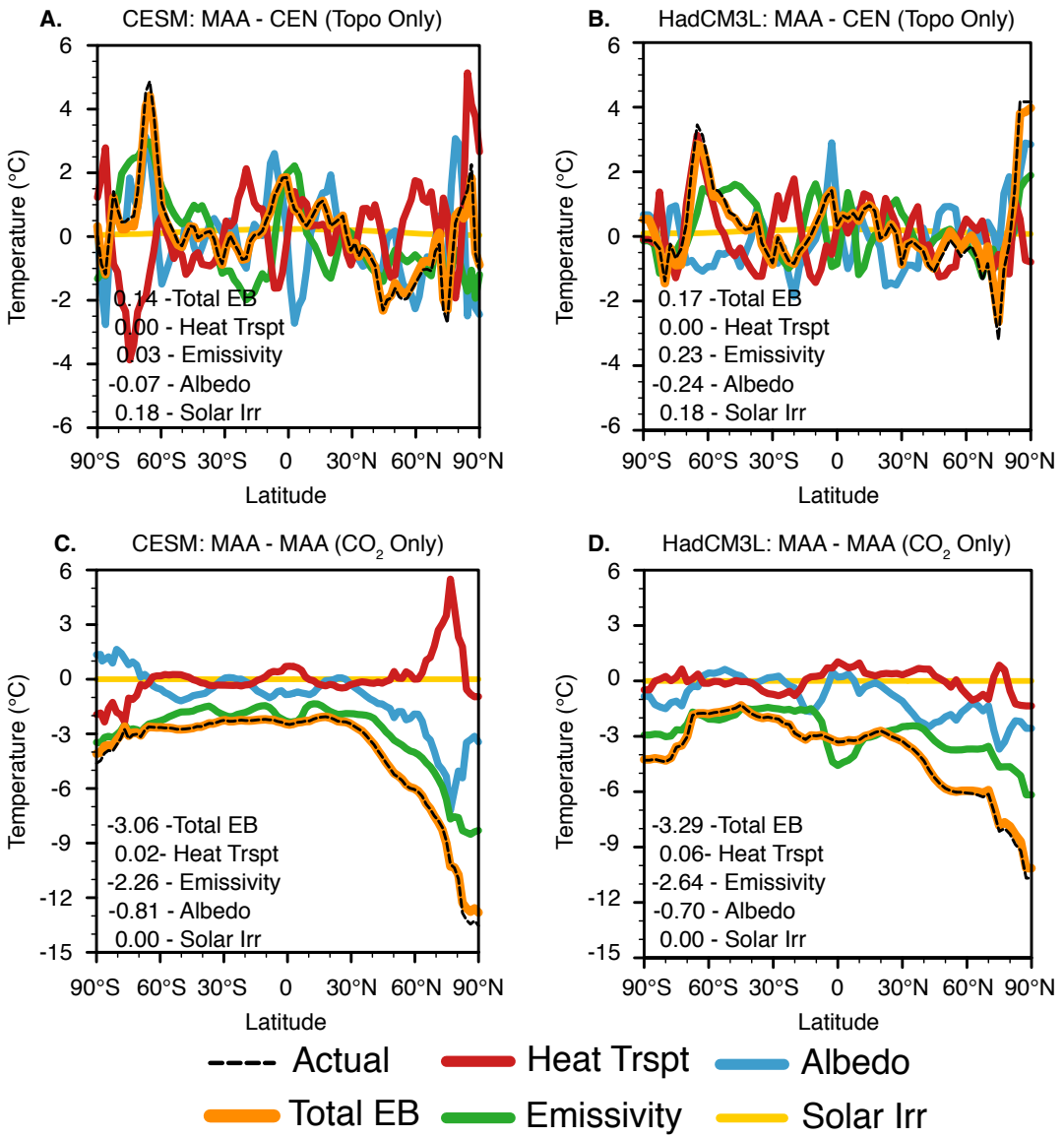
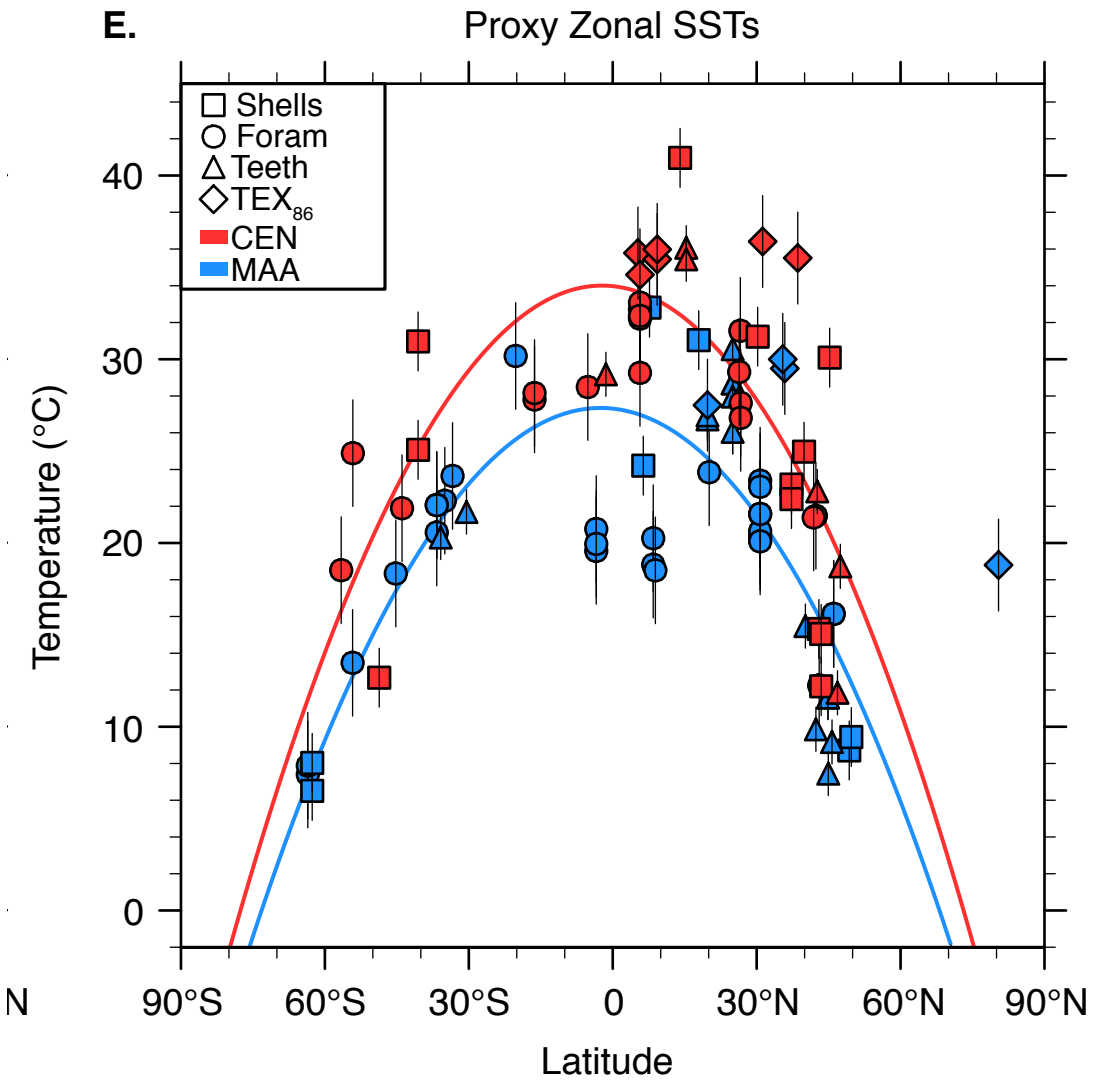
Models: Temperature Decomposition

- Changes in paleogeography:
  - Emissivity: +0.13°C
  - Heat Convergence: 0.00°C
  - Albedo: -0.16 °C
- Changes in CO_2:
  - 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



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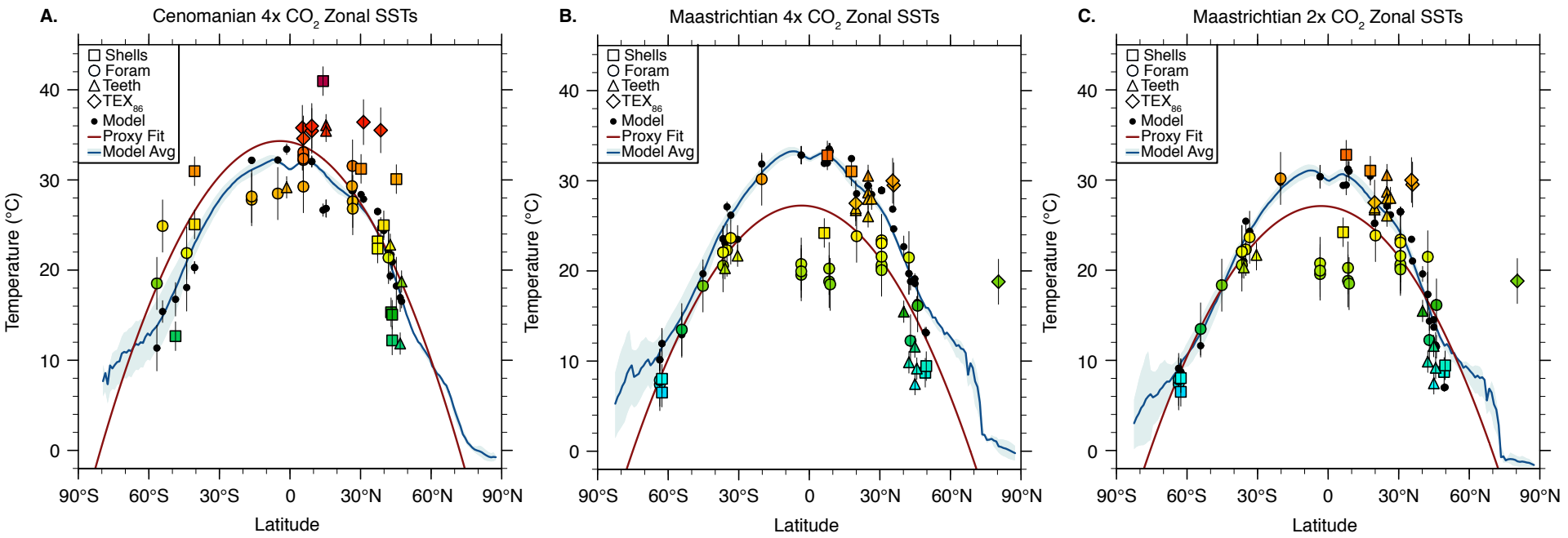
Model / Proxy SST Comparison

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



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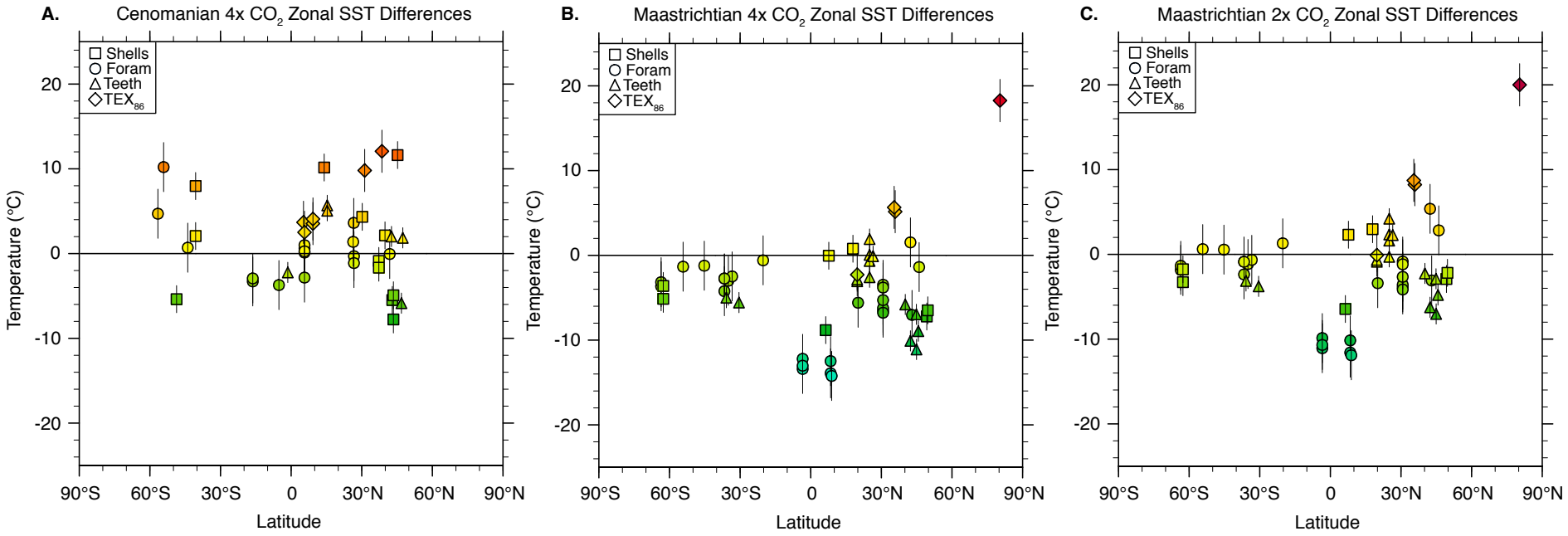
Model / Proxy SST Comparison

- 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?



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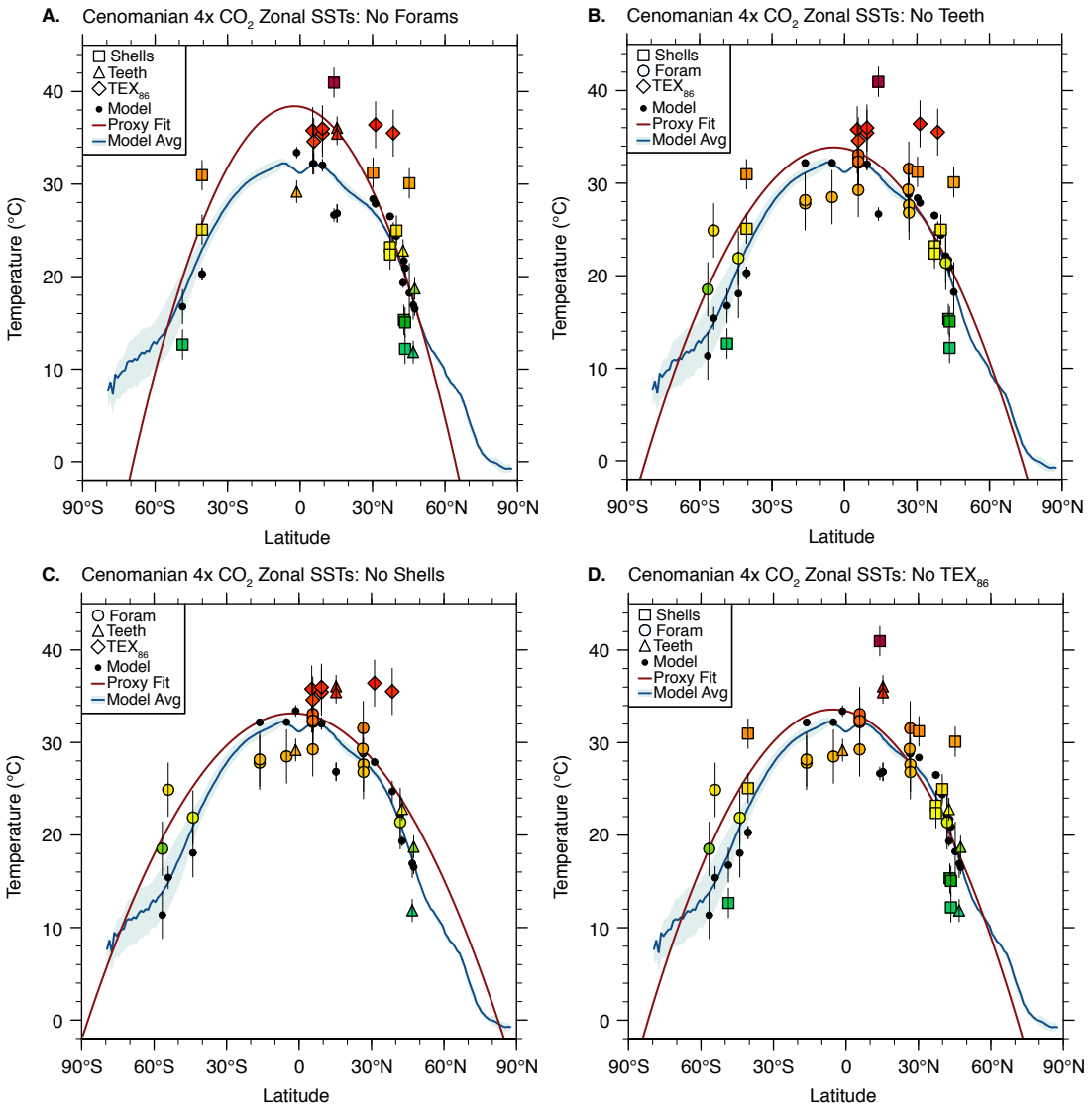
Proxy Bias: 4x CO_2 Cenomanian

- Removal of SST proxy reconstruction data from individual methods



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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

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