High climate sensitivity during an ancient greenhouse

Dana Royer ('02)

Department of Earth & Environmental Sciences, Wesleyan University
CO$_2$ estimates from stomata for two ‘greenhouse’ intervals

Modified from Royer et al. (2001, Science 292:2310-2313)
The Paleogene mess


Stomatal CO₂ proxy
- Royer (2002)
- Retallack (2001)
- Kürschner et al. (1996, 2001)

Other CO₂ proxies
- Pedogenic carbonate (Ekart et al., 1999)
- Boron (Pearson and Palmer, 2000)
- Phytoplankton (Pagani et al., 1999)

Geochemical models
- Berner and Kothavala (2001)
- Wallmann (2001)
- Tajika (1998)
2009 update: less mess

- Stomatal data revised (Royer, Retallack)
- Paleosol estimates revised downward (Breecker)
- Older boron estimates excluded
- Estimates based on rarely-used methods excluded (goethite, nahcolite, liverworts)
Climate sensitivity during the Paleogene


- **55 Ma**
  - CO₂ = 560 ppm
  - GMST = +5 °C
  - ΔT₂x = 6 °C

- **47.5 Ma**
  - CO₂ = 900 ppm
  - GMST = +5 °C
  - ΔT₂x = 3.1 °C

- **52 Ma**
  - CO₂ = 800 ppm
  - GMST = +8 °C
  - ΔT₂x = 7 °C

- **Warm**
- **Cool**
Climate sensitivity is linked to global temperature and to latitudinal temperature gradient.
Latitudinal temperature gradient (three time slices)

E. Tasman plateau

Global climate models are missing something

GCM from: Shellito et al. (2003, *Palaeo3* 193:113-123)
Task: how to warm the high latitudes

• Clouds
  – More vigorous high-latitude convection (due to warm, ice-free ocean) leads to more stratospheric clouds (Abbot & Tziperman 2008 GRL)
  – Elevated methane fluxes from polar swamps lead to formation of polar stratospheric clouds (Sloan et al. 1992 Nature) [mechanism fails]
  – Fewer cloud condensation nuclei in pristine environments leads to thinner clouds and a drop in albedo (Kump & Pollard 2008 Science)

• Vegetation feedbacks
  – Volatile organic compound emissions from polar forests cause a variety of climate feedbacks (Beerling et al. 2007 Phil Trans R Soc A)

• Atmospheric heat transport (implies a temperature gradient)
  – More vigorous hydrologic cycle (Ufnar et al. 2004 Geology), perhaps facilitated by ‘hyper-canies’ (Korty et al. 2008 J Climate), transfers heat from the tropics to high latitudes