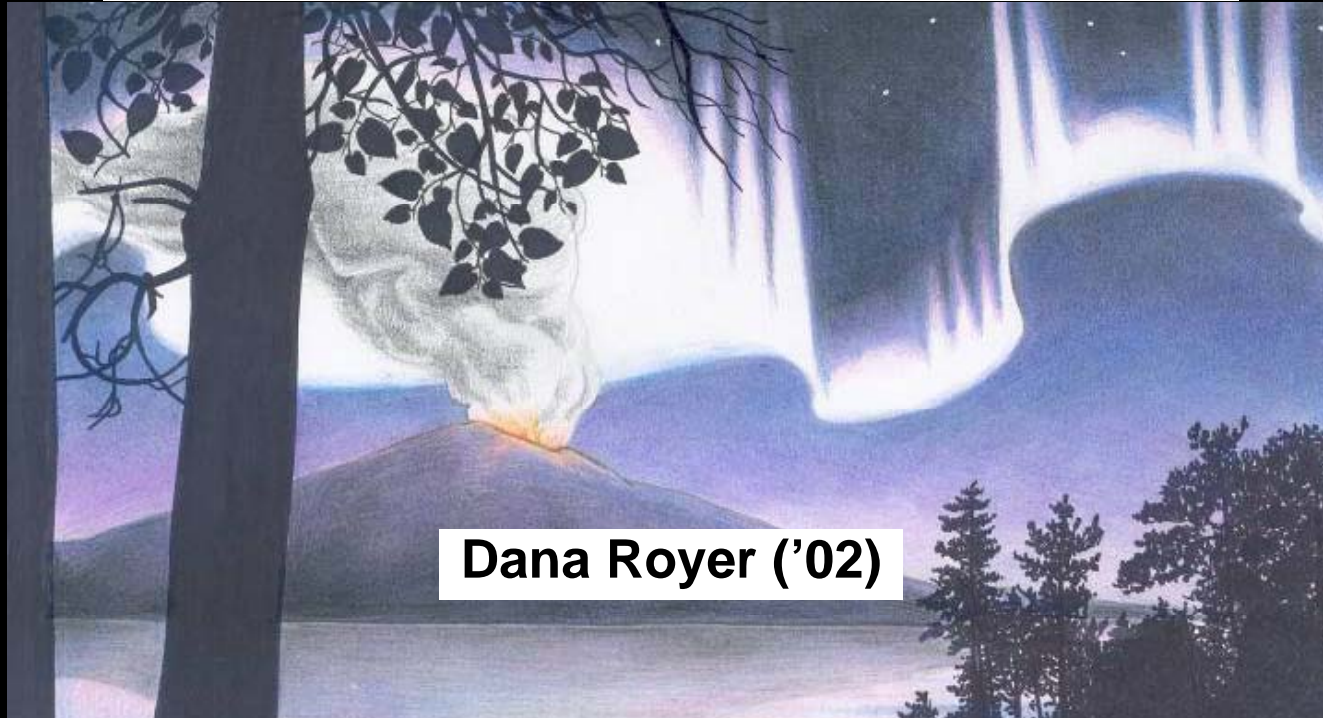
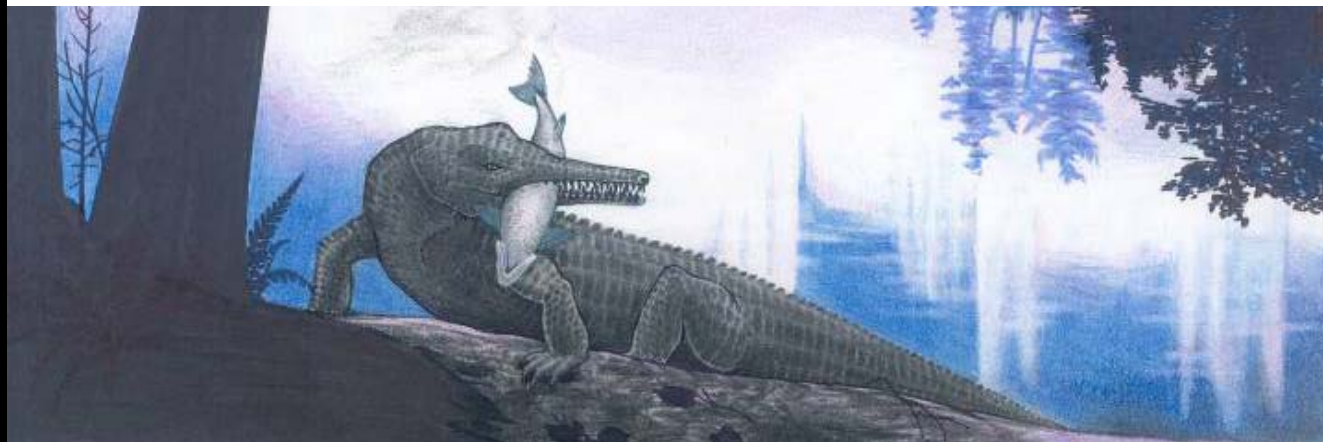


High climate sensitivity during an ancient greenhouse



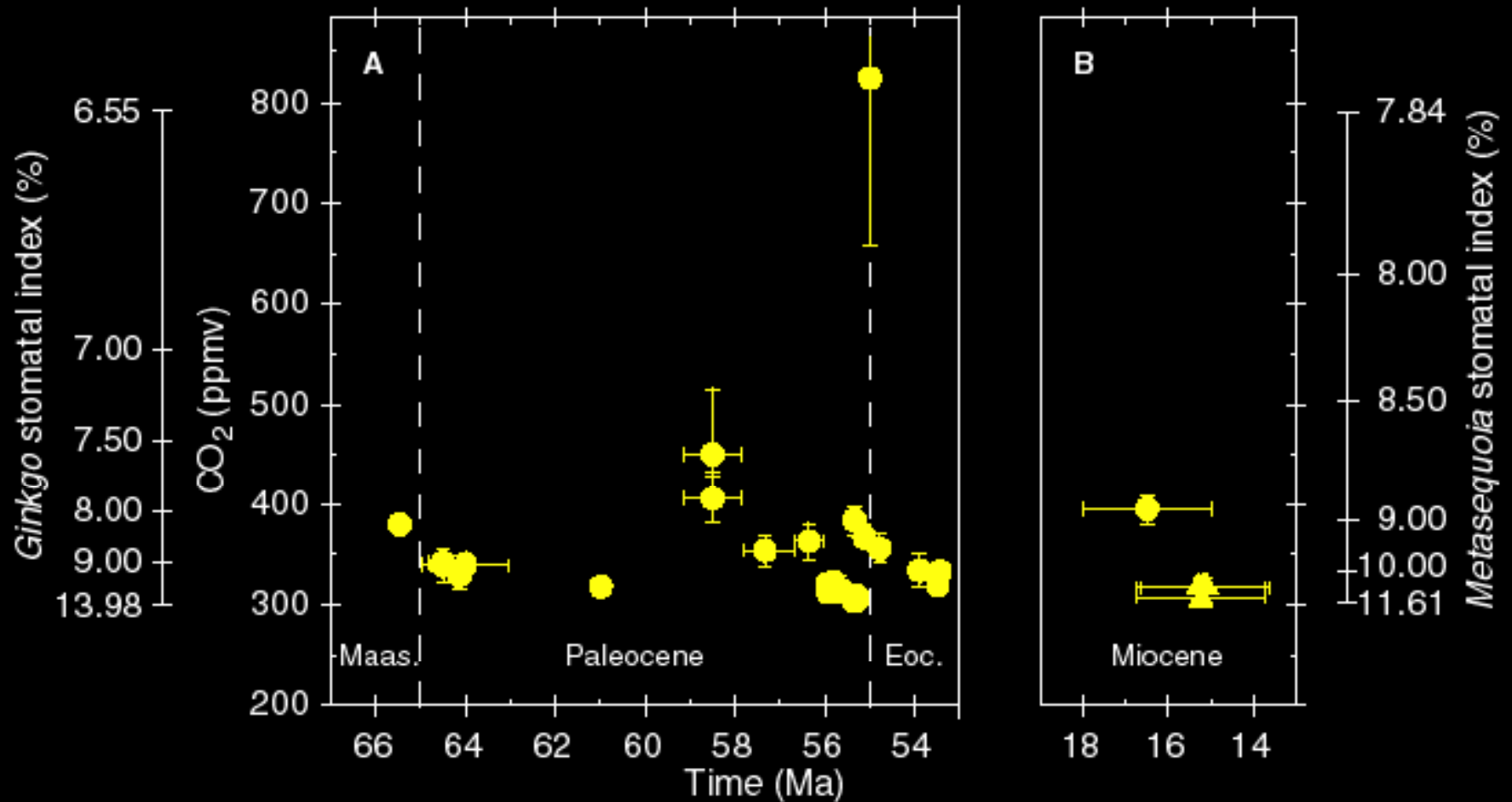
Dana Royer ('02)

Department of Earth & Environmental Sciences, Wesleyan University



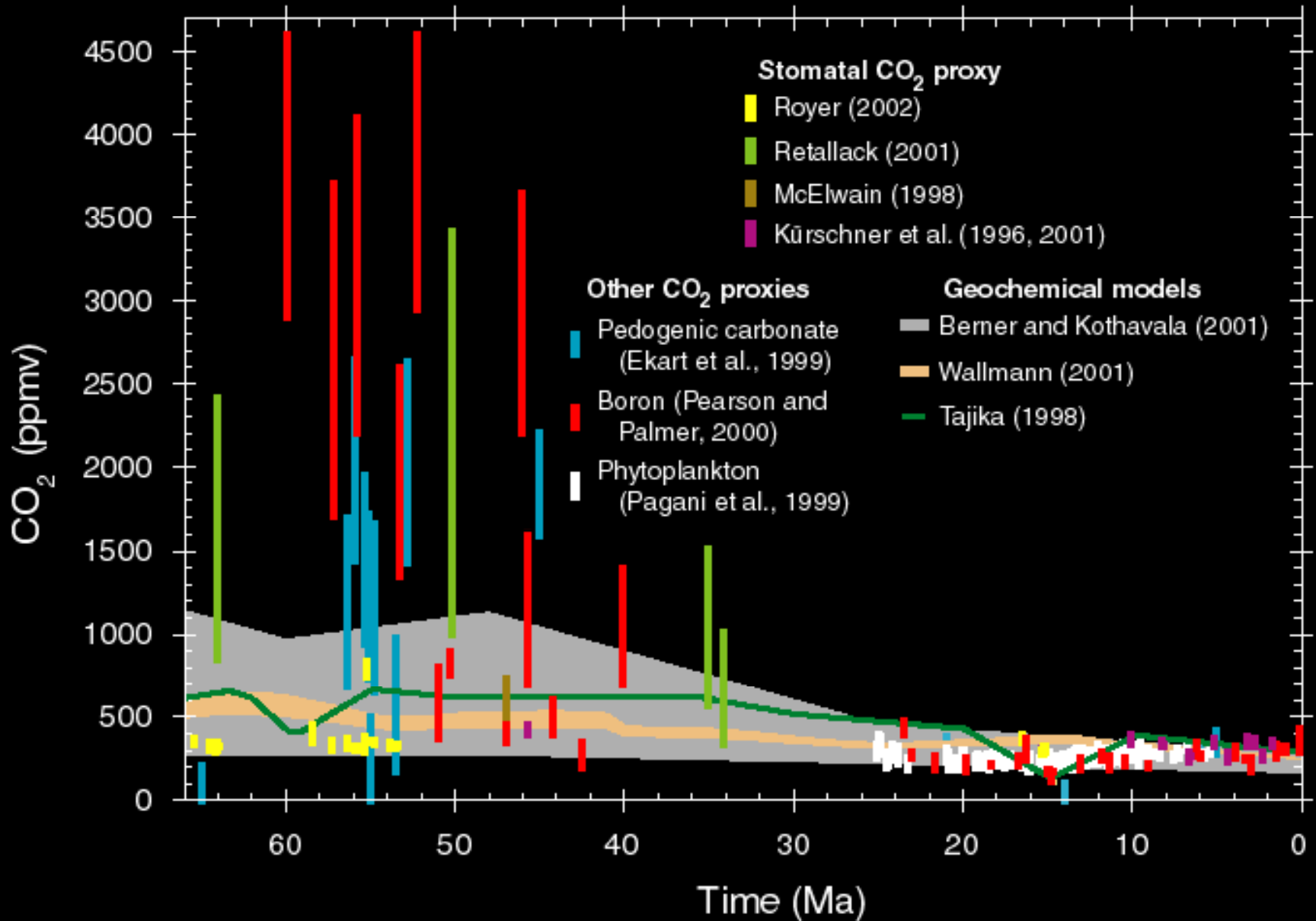
Artwork: Rebecca Horwitt

CO₂ estimates from stomata for two 'greenhouse' intervals



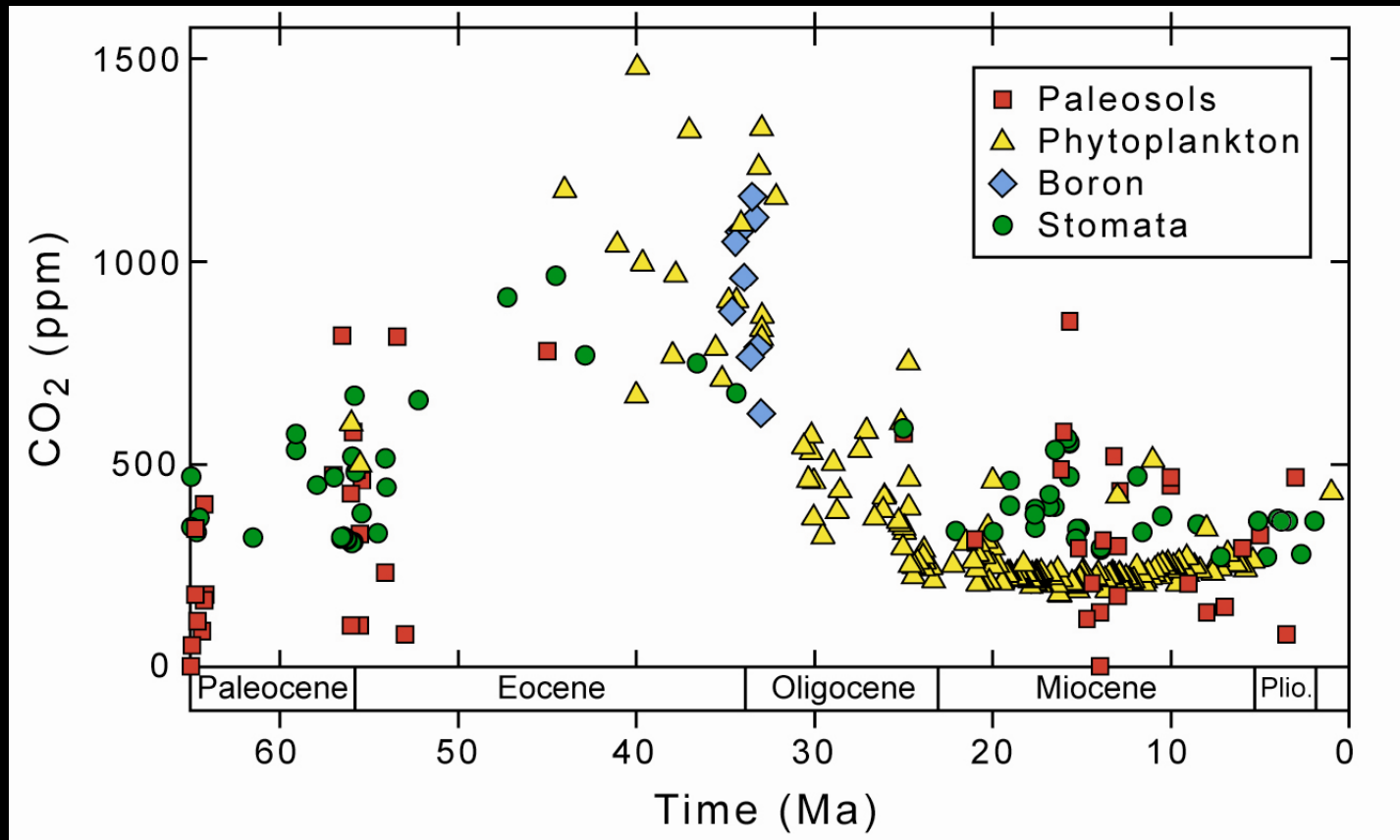
Modified from Royer et al. (2001, *Science* 292:2310-2313)

The Paleogene mess



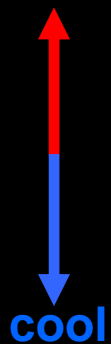
2009 update: less mess

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

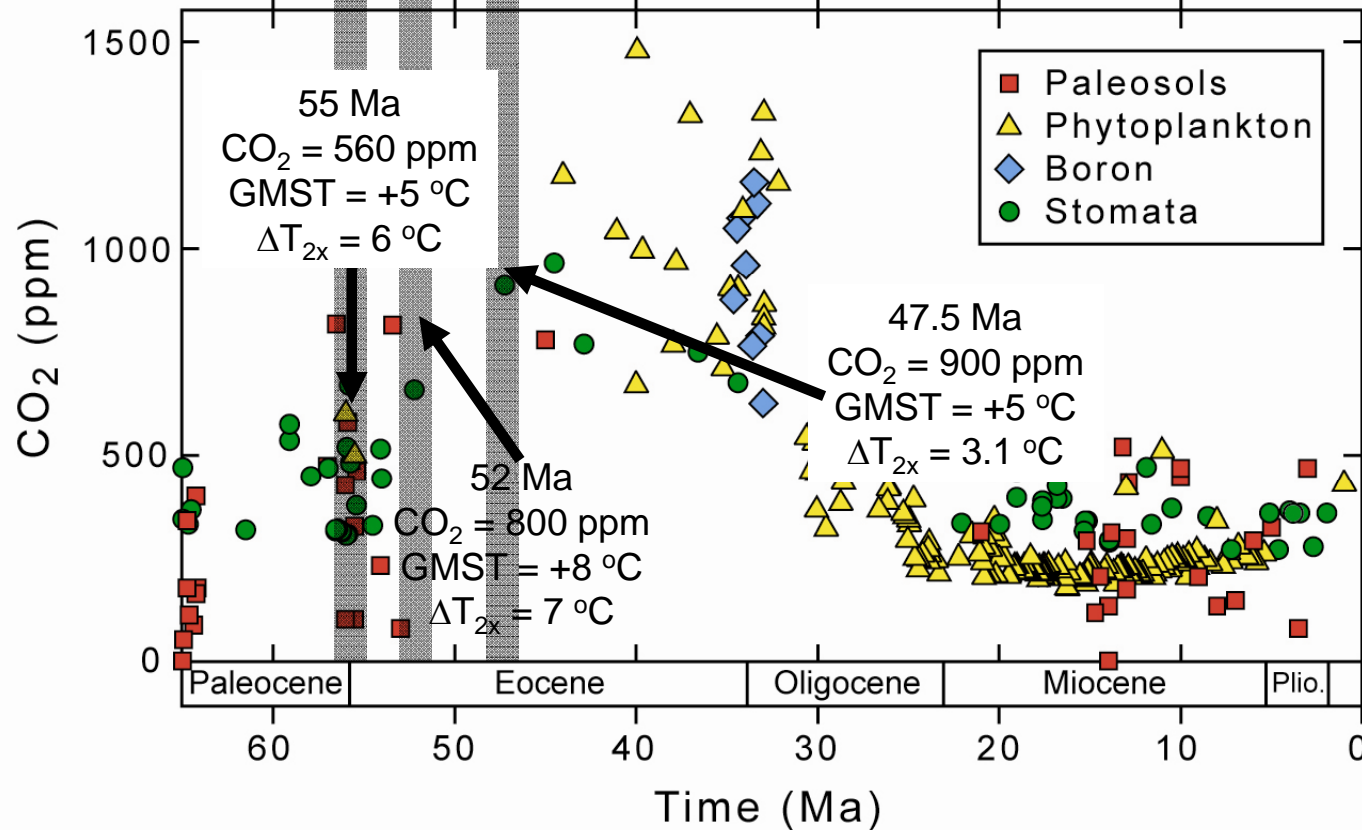
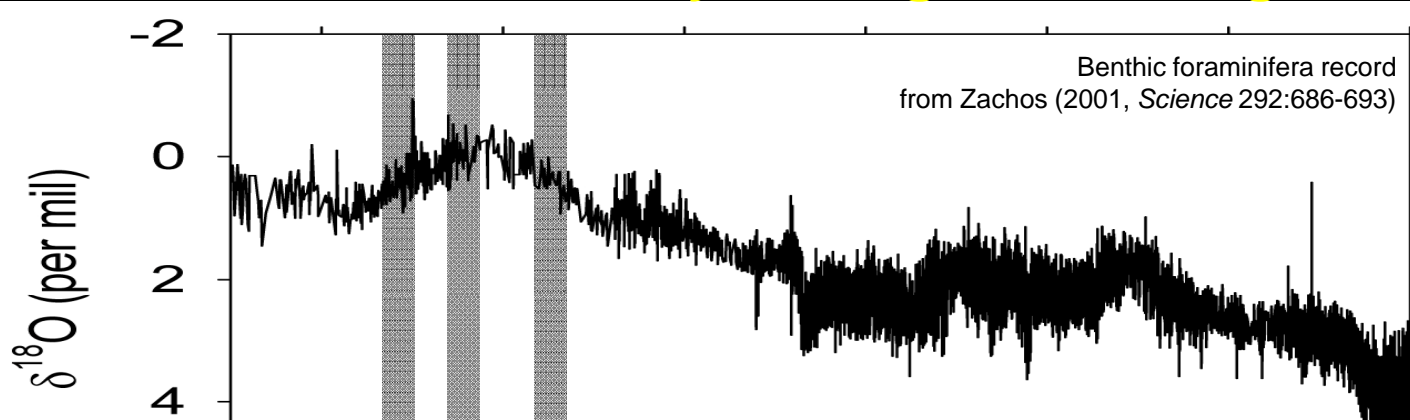


Climate sensitivity during the Paleogene

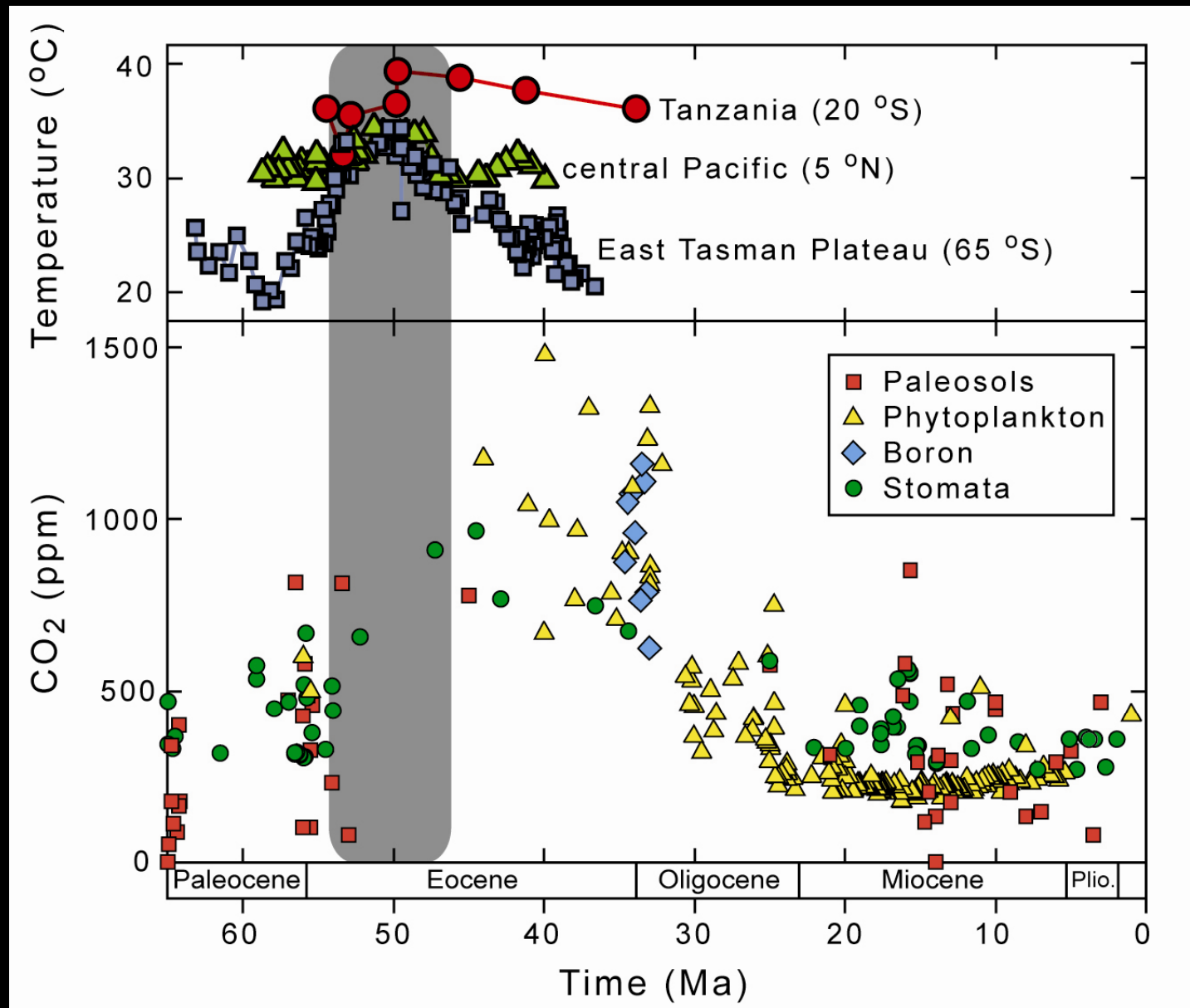
warm



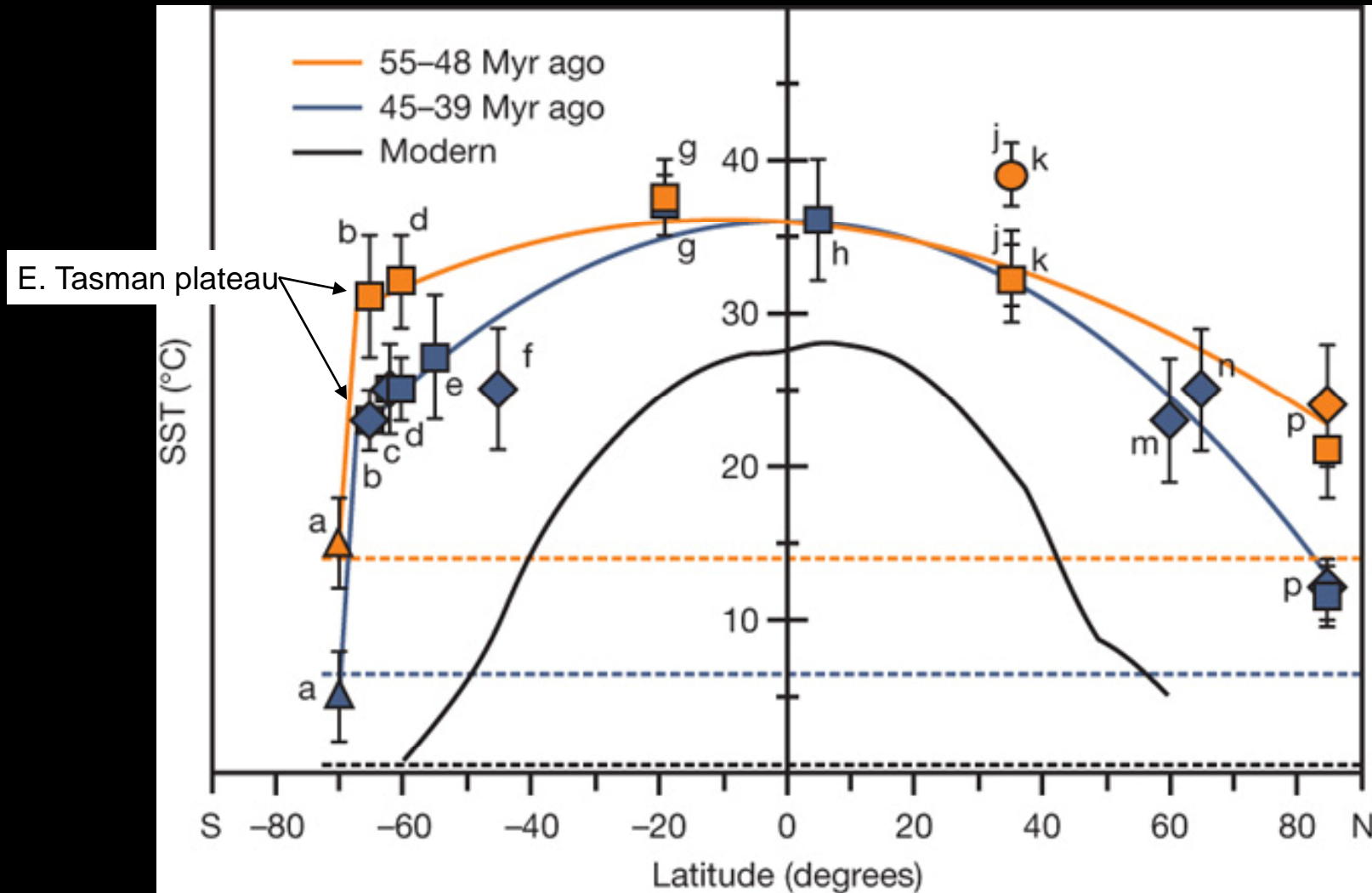
cool



Climate sensitivity is linked to global temperature and to latitudinal temperature gradient

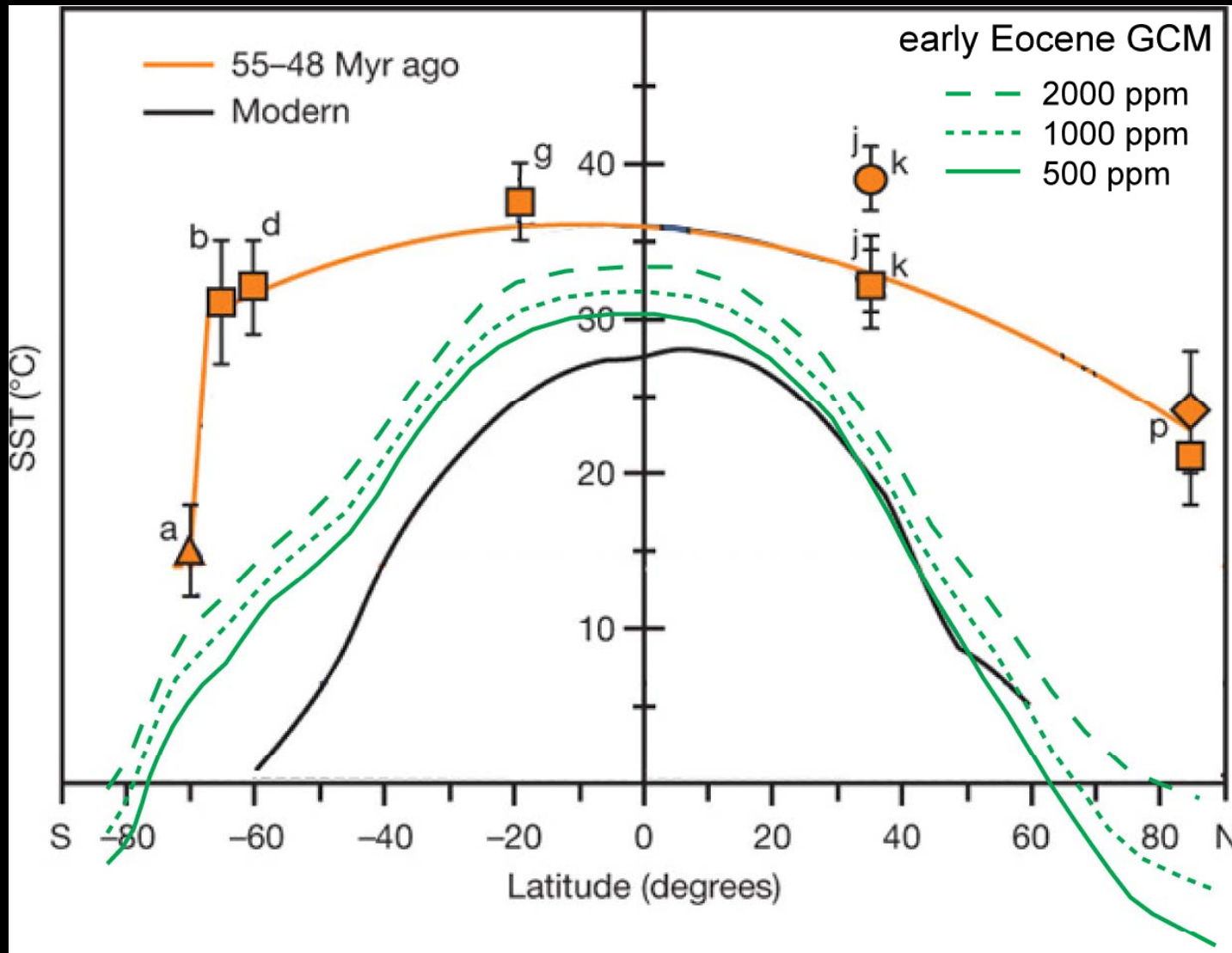


Latitudinal temperature gradient (three time slices)



Bijl et al. (2009, *Nature* 461:776-779)

Global climate models are missing something



GCM from: Shellito et al. (2003, *Palaeo* 3 193:113-123)

Compilation of proxy data from: Bijl et al. (2009 *Nature* 461:776-779)

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-canes' (Korty et al. 2008 *J Climate*), transfers heat from the tropics to high latitudes