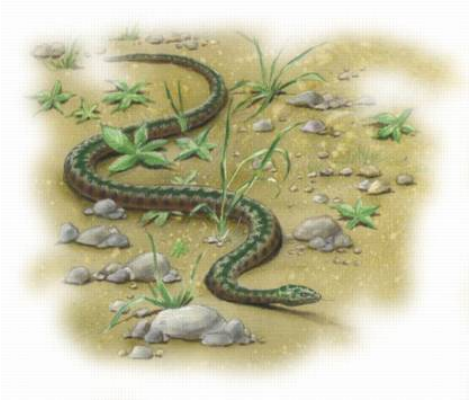
La Ciencia del Cambio Global: Modelos, Millones y Culebras



René D. Garreaud y Roberto Rondanelli

Departamento de Geofísica
Universidad de Chile

Universidad de Concepción, 2 de Octubre 2009

GF45A, Introducción a la Meteorología

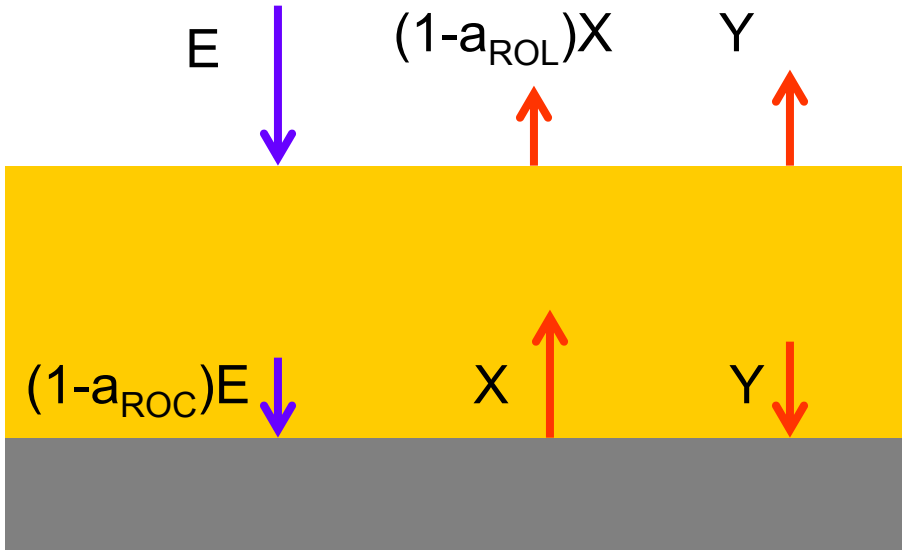
Un modelo simple de efecto invernadero

Para el planeta tierra:

E=241 W/m^2

a_{ROL}=0.8

a_{ROC}=0.1



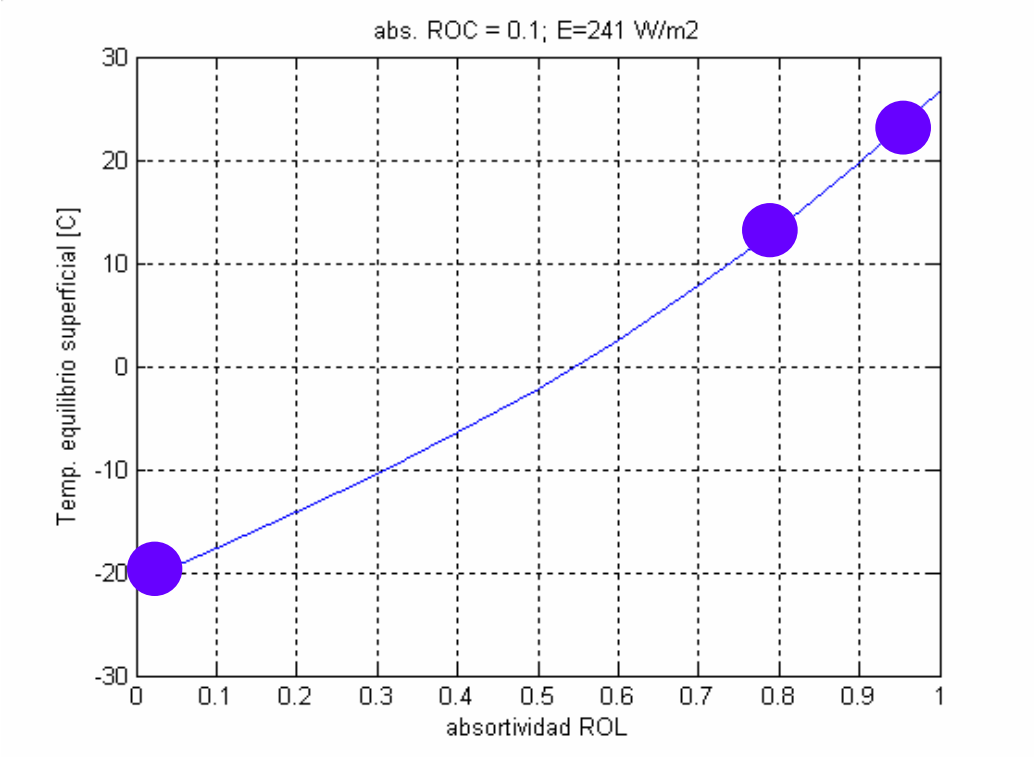
Bal. Rad. al tope $(1-a_{ROL})X + Y = E$

Bal. rad. superficie $(1-a_{ROC})E + Y = X$

$X = \sigma T_s^4 = E\,(2-a_{ROC}) / (2-a_{ROL})$

GF45A, Introducción a la Meteorología

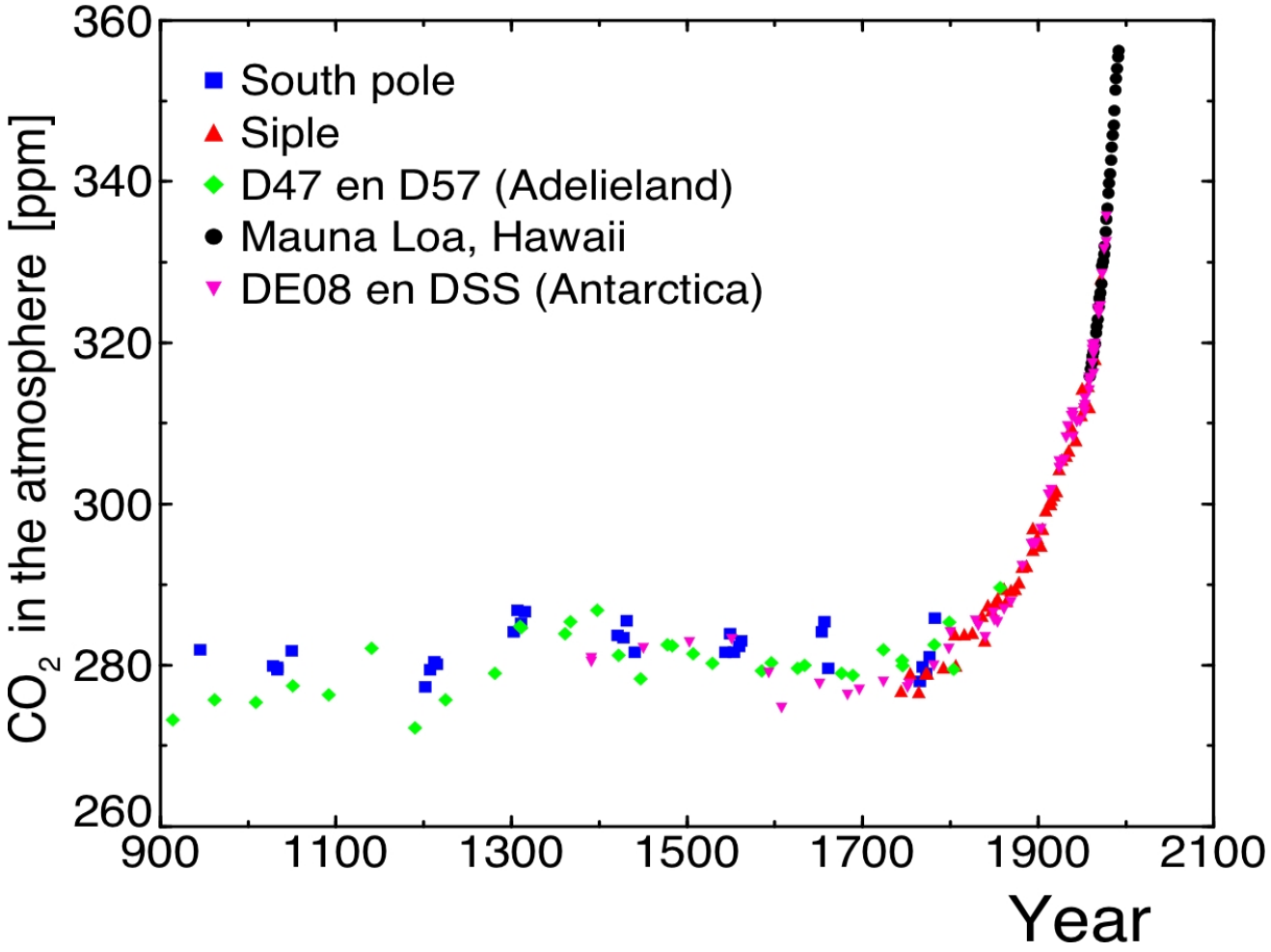
Un modelo simple de efecto invernadero



$\rightarrow a_{ROL}$ aumenta con pCO_2

$\rightarrow$Ts aumenta si se incrementa a_{ROL}

Cambios observados en CO2 → Cambios observados en Tsfc



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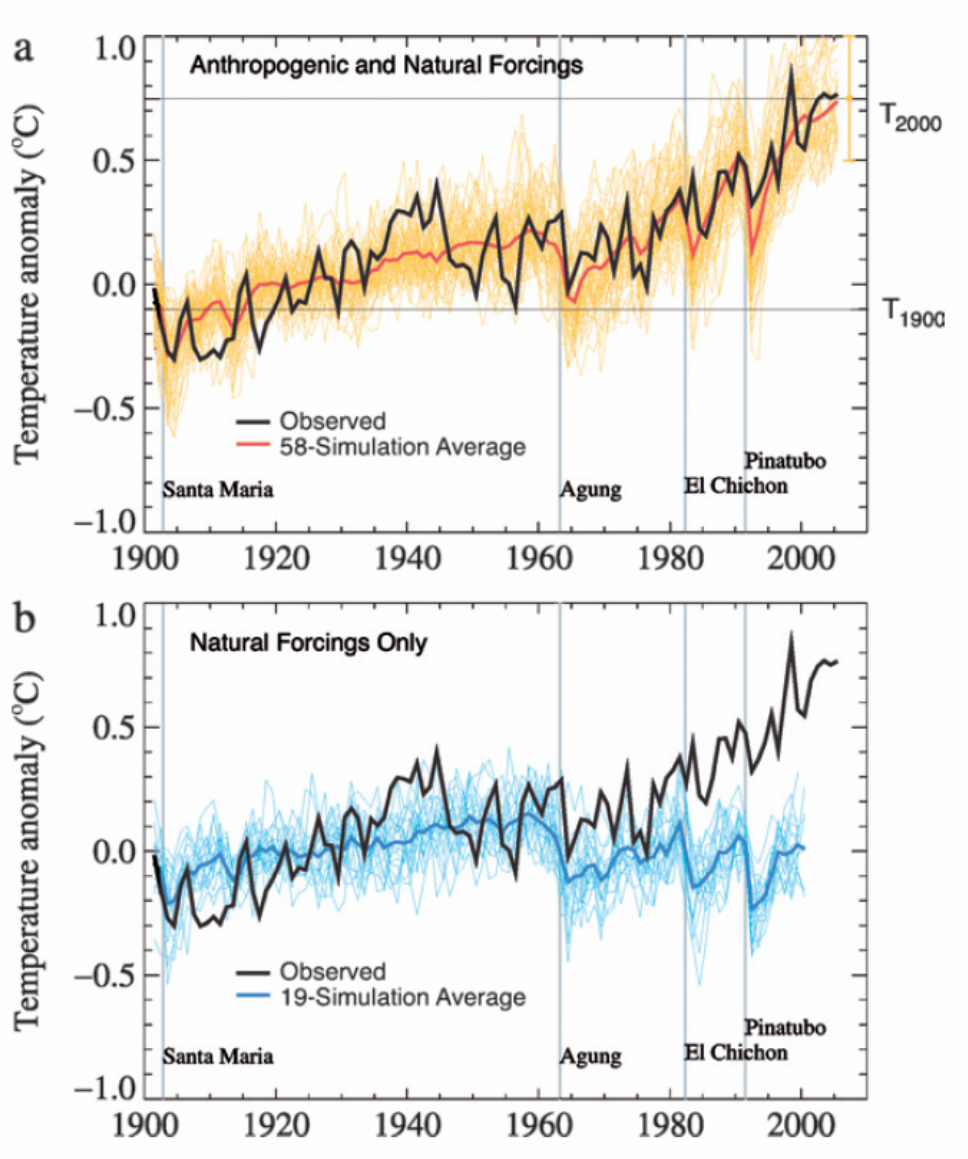
Cambios observados y simulados en Tsfc



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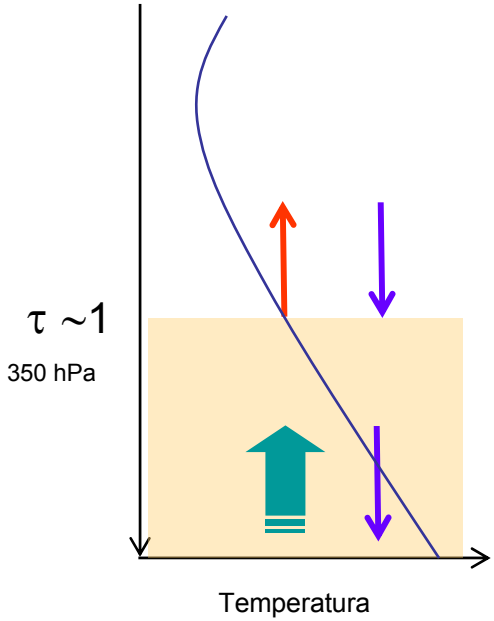
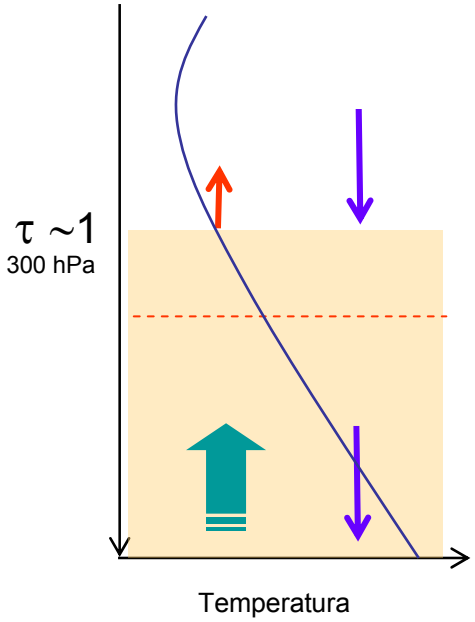
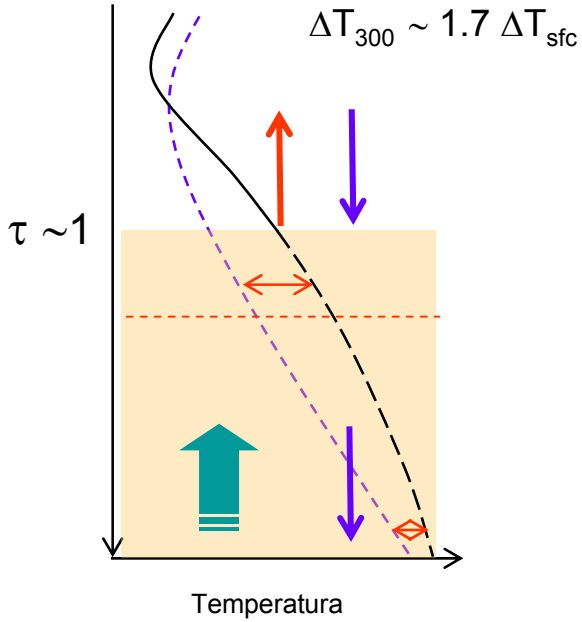
Efecto invernadero, versión 2
(Lindzen 1999, 2007)



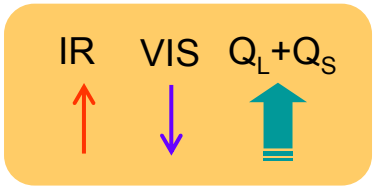
CO_2: 280 ppm
Equil. actual



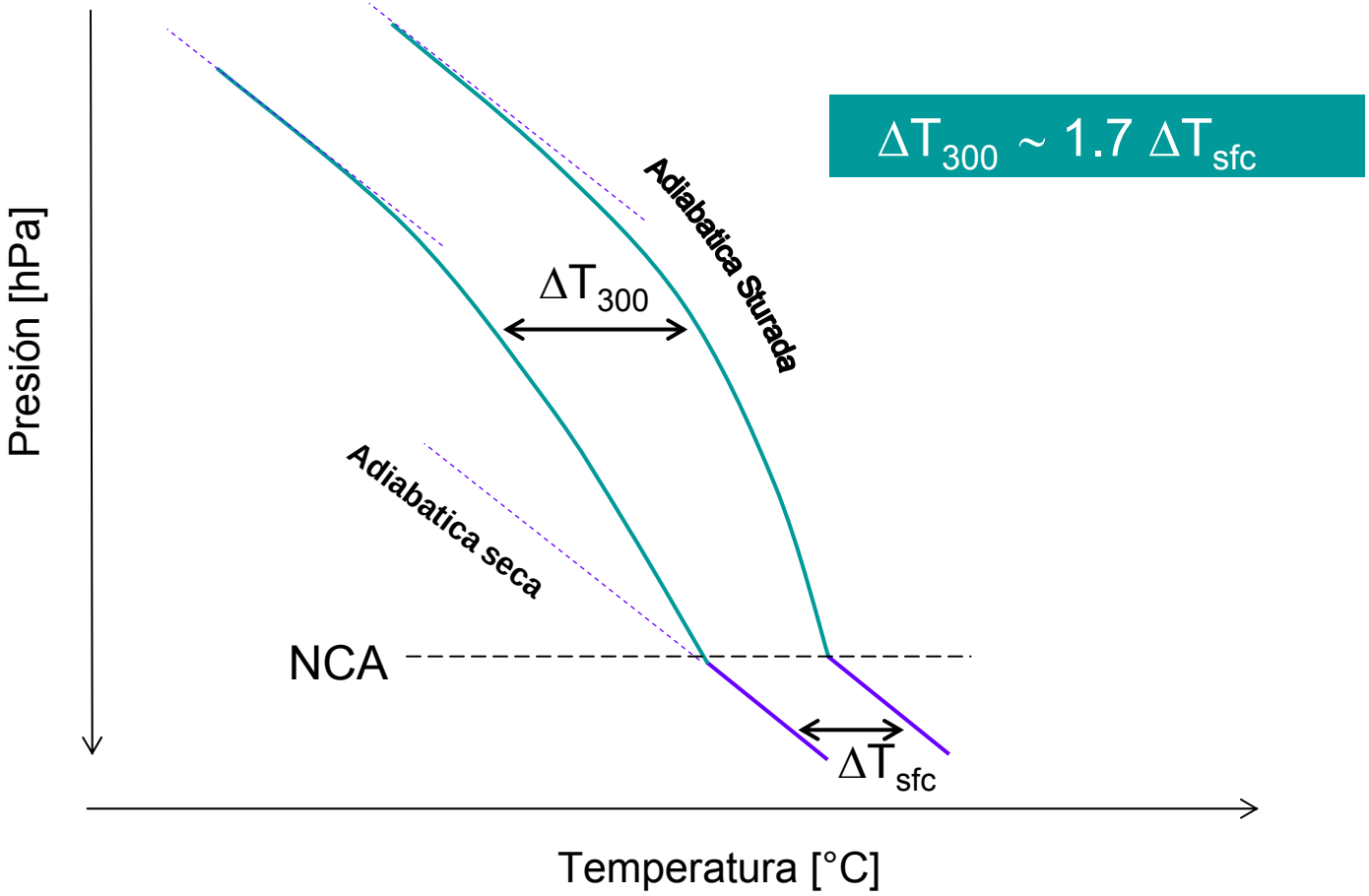
CO_2: 540 ppm
Transiente



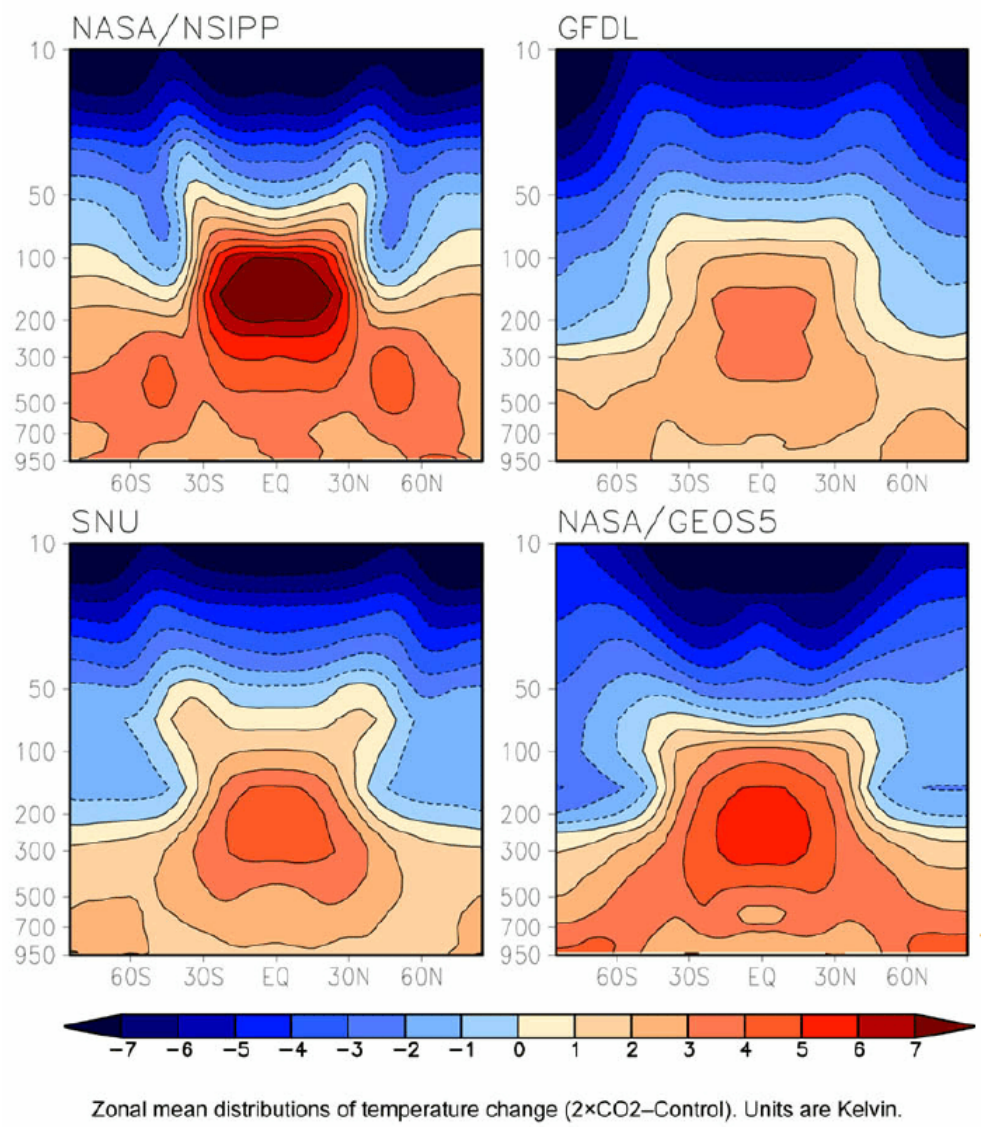
CO_2: 540 ppm
Equil. Futuo
No feedback



Efecto invernadero, versión 2
(Lindzen 1999, 2007)



Efecto invernadero, versión 2
Promedio zonal cambio temperatura 2*CO_2-CTR



Zonal mean distributions of temperature change (2×CO2–Control). Units are Kelvin.

Cambios observados y simulados en T(z): Santers et al.

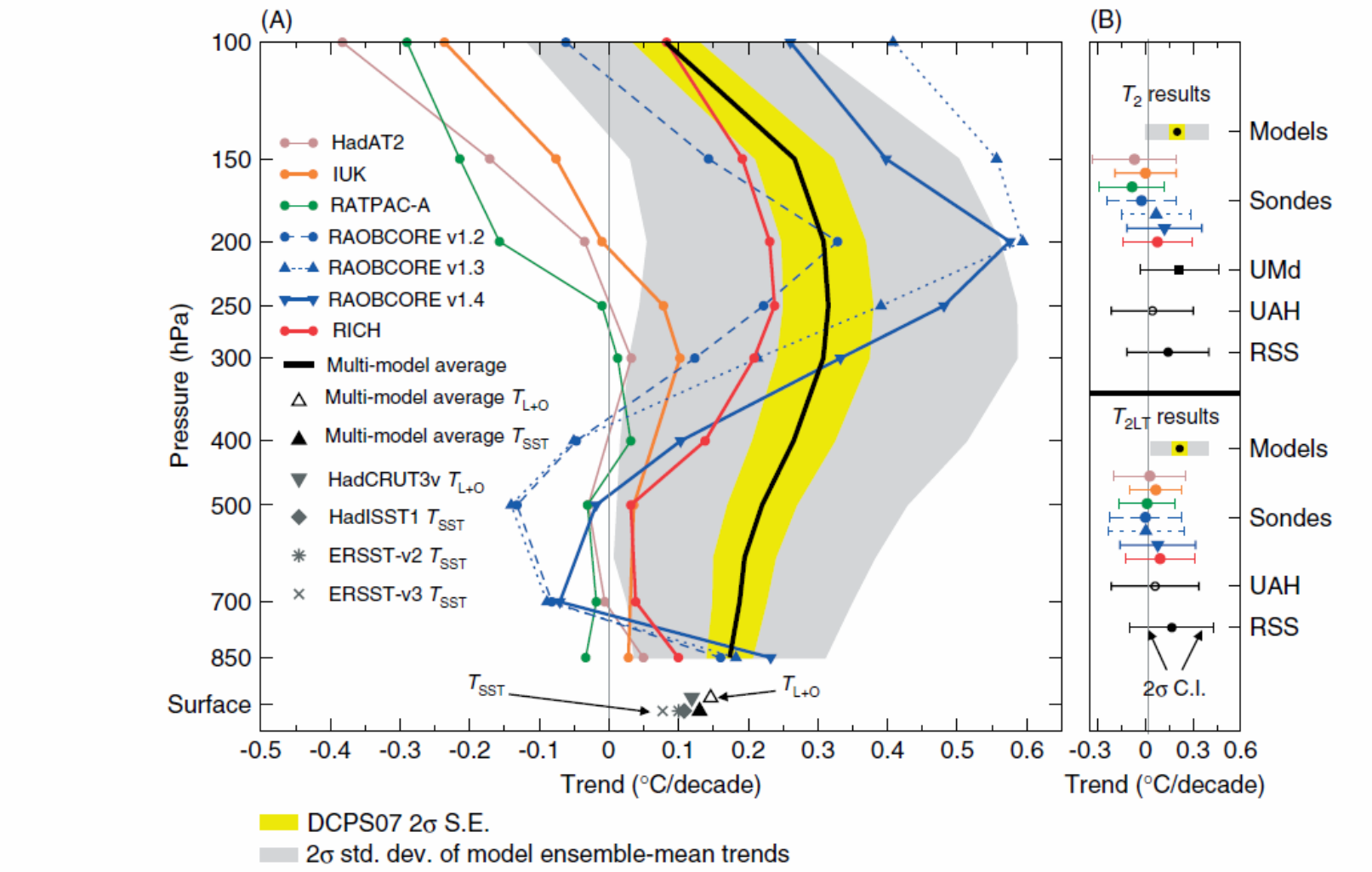
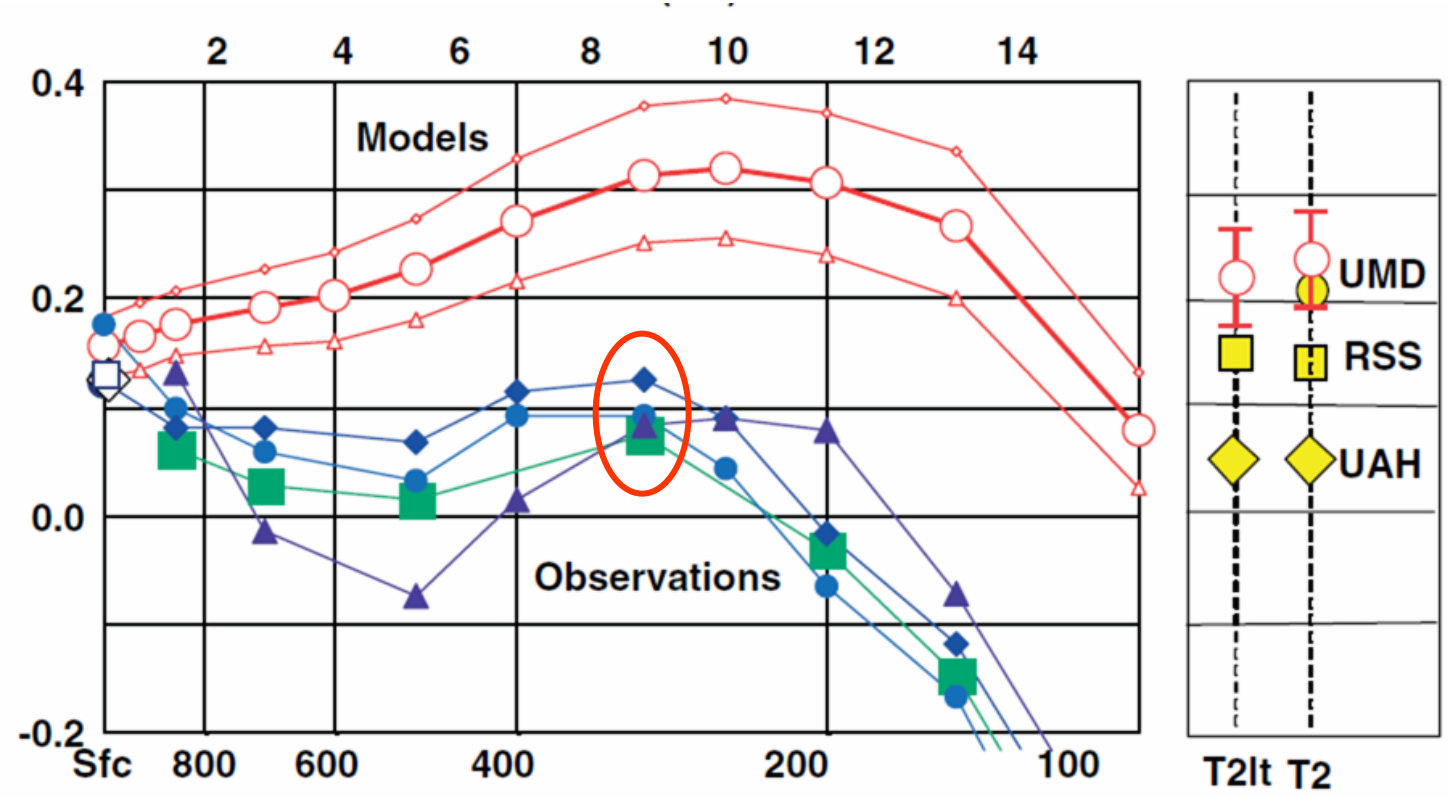


Figure 6. Vertical profiles of trends in atmospheric temperature (panel A) and in actual and synthetic MSU temperatures (panel B).

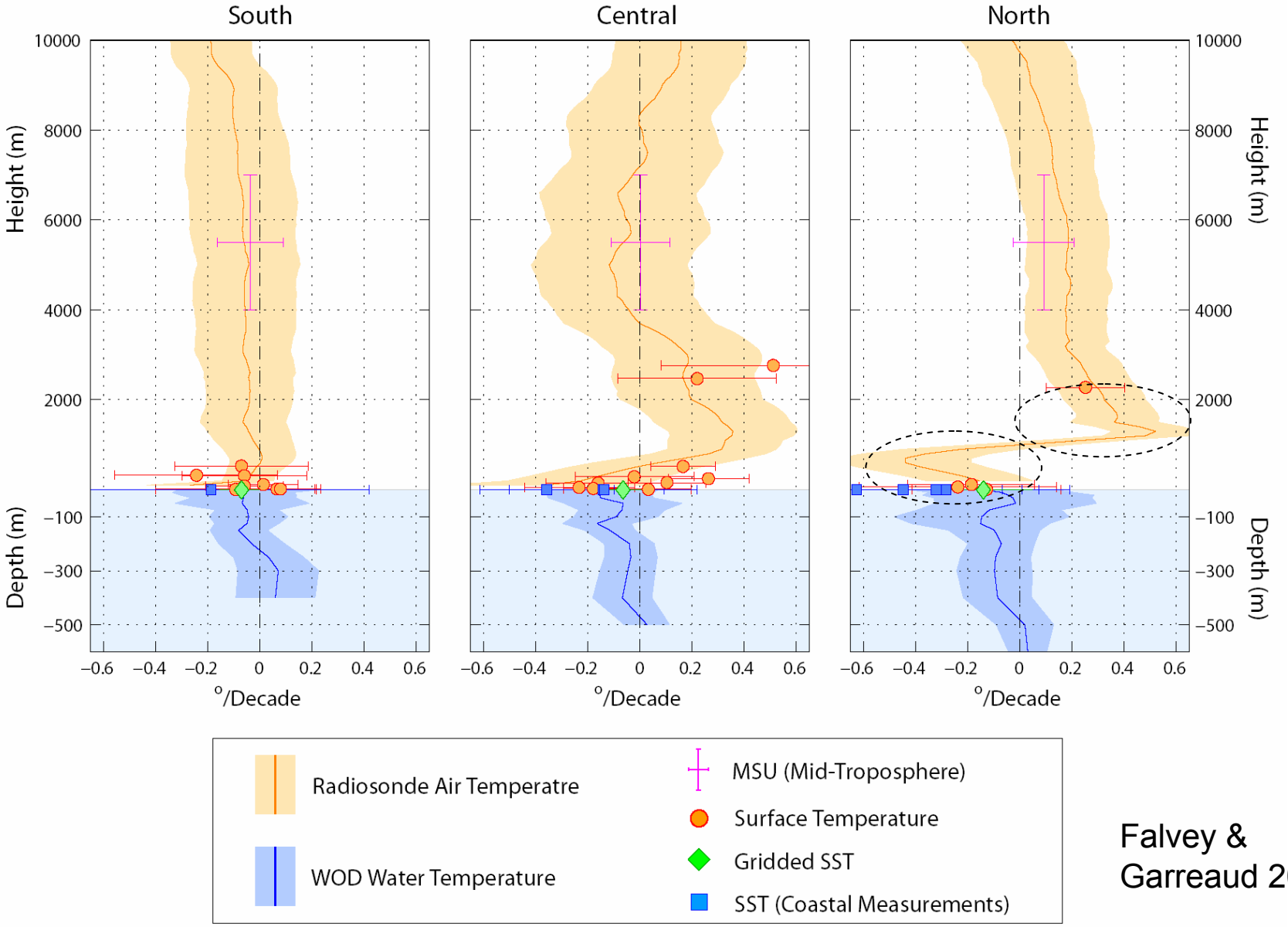
Santer et al. 2008 (IJOC)

Cambios observados y simulados en T(z): Douglas et al.



Douglass et al. 2008 (IJOC)

Cooling MBL / warming lower free troposphere → increased lower tropospheric stability …. Sc?



Falvey & Garreaud 2009

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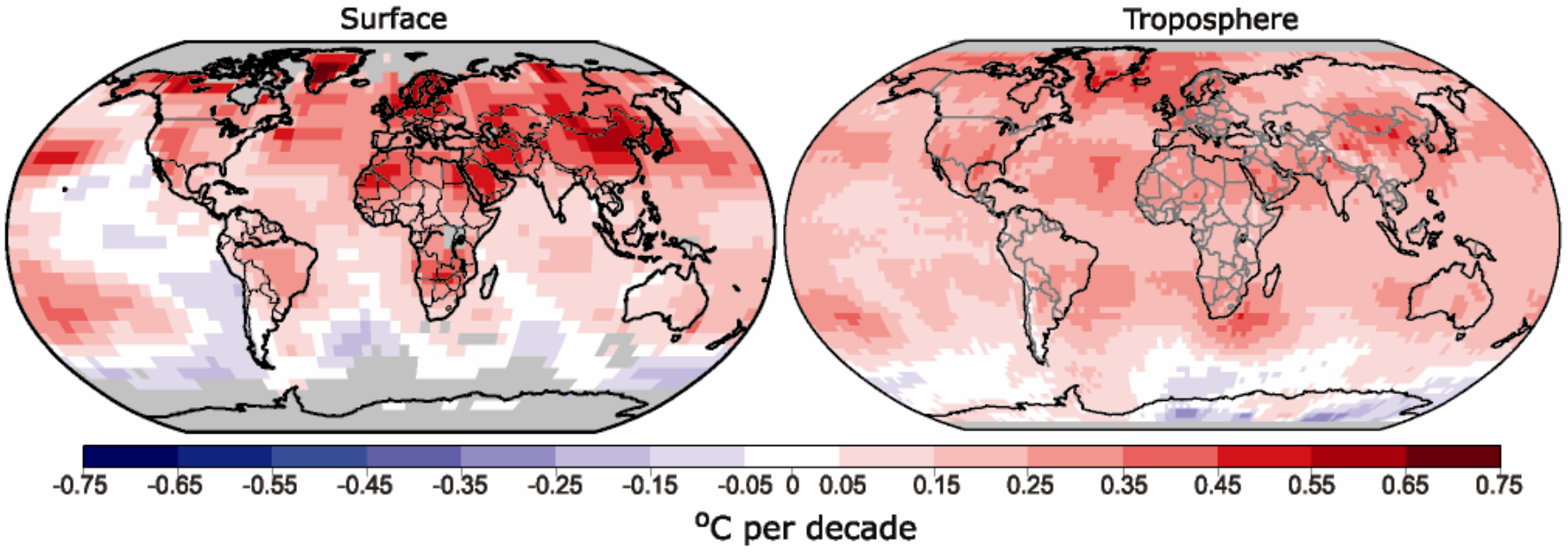
$\partial T/\partial t$ 1979-2005

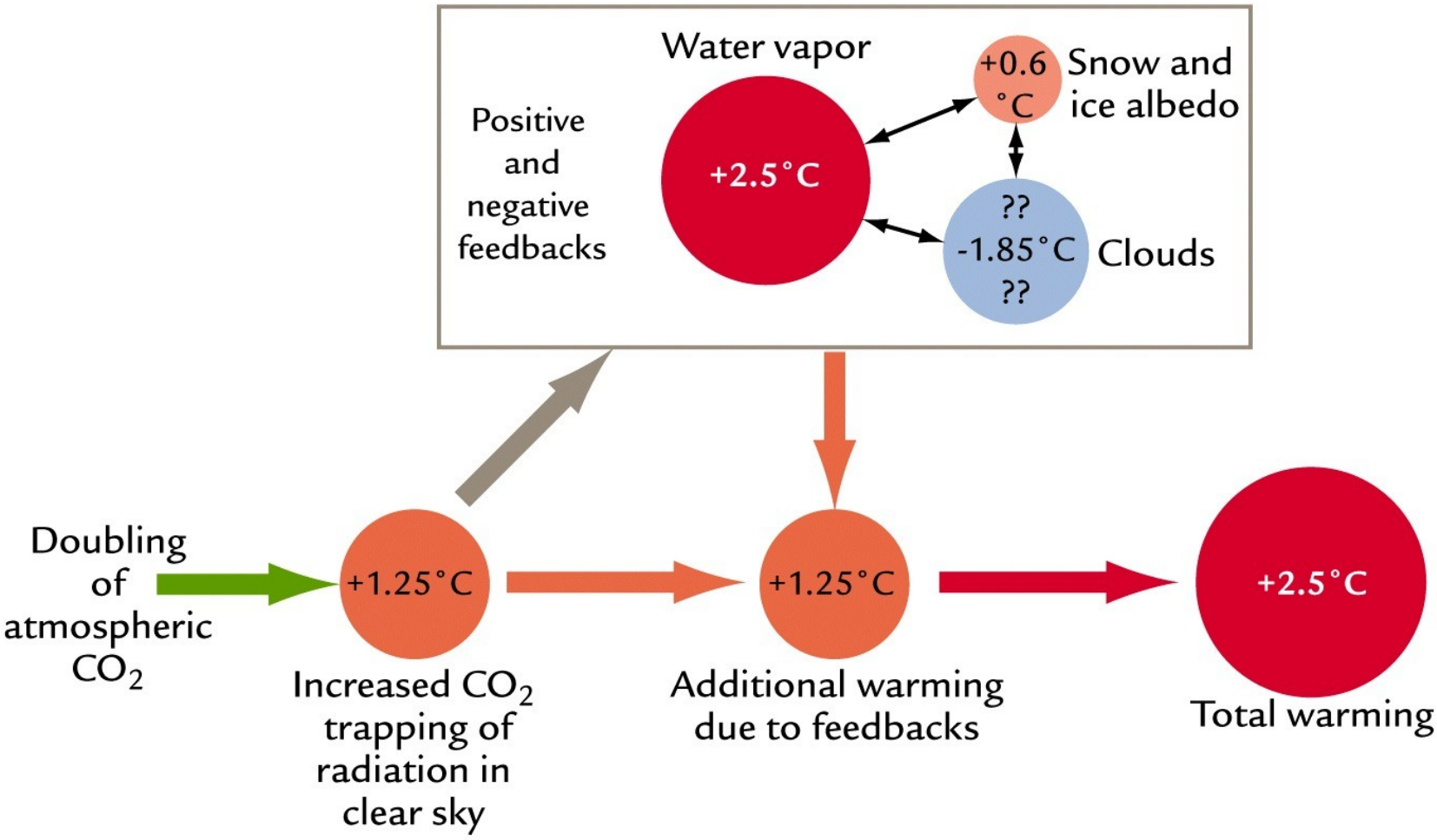


Teoría & Modelos $\Delta T_{300} \sim 1.7\ \Delta T_{sfc}$

Observaciones $\Delta T_{300} \sim 0.3\ \Delta T_{sfc}$

- Modelos “insuficientes”?
- Observaciones “malas”?
- Teoría muy simple?

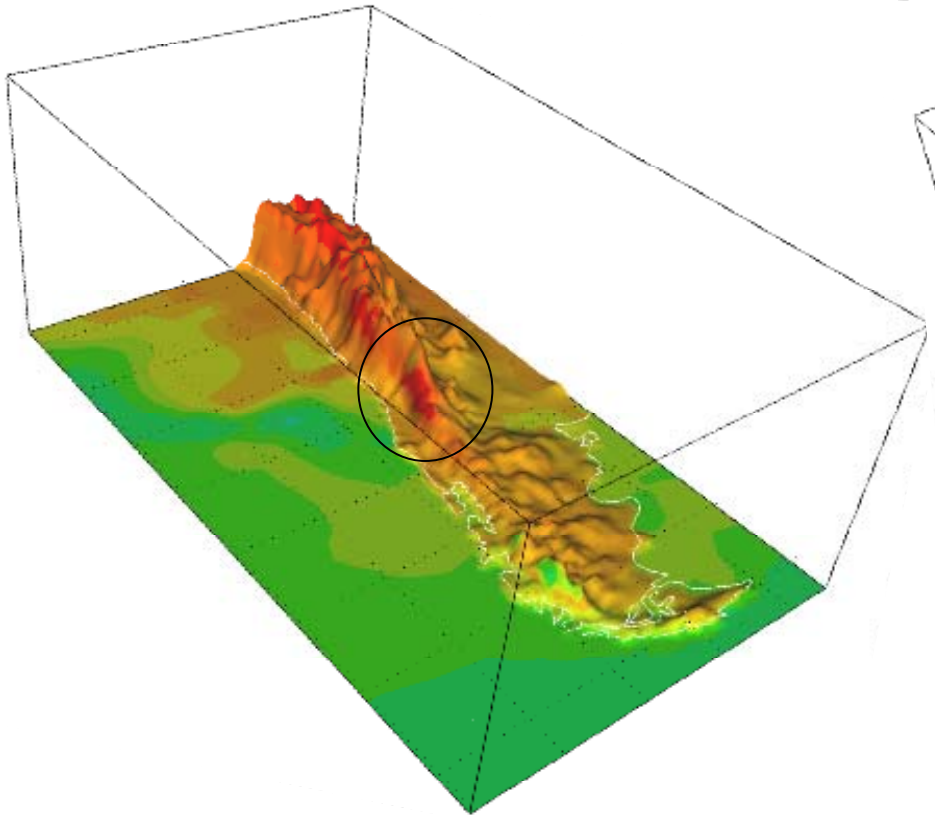
Desajuste ΔT_{300} - ΔT_{sfc} debido a retro-alimentación del sistema climático



Ruddiman: Earth's Climate, Chapter 4

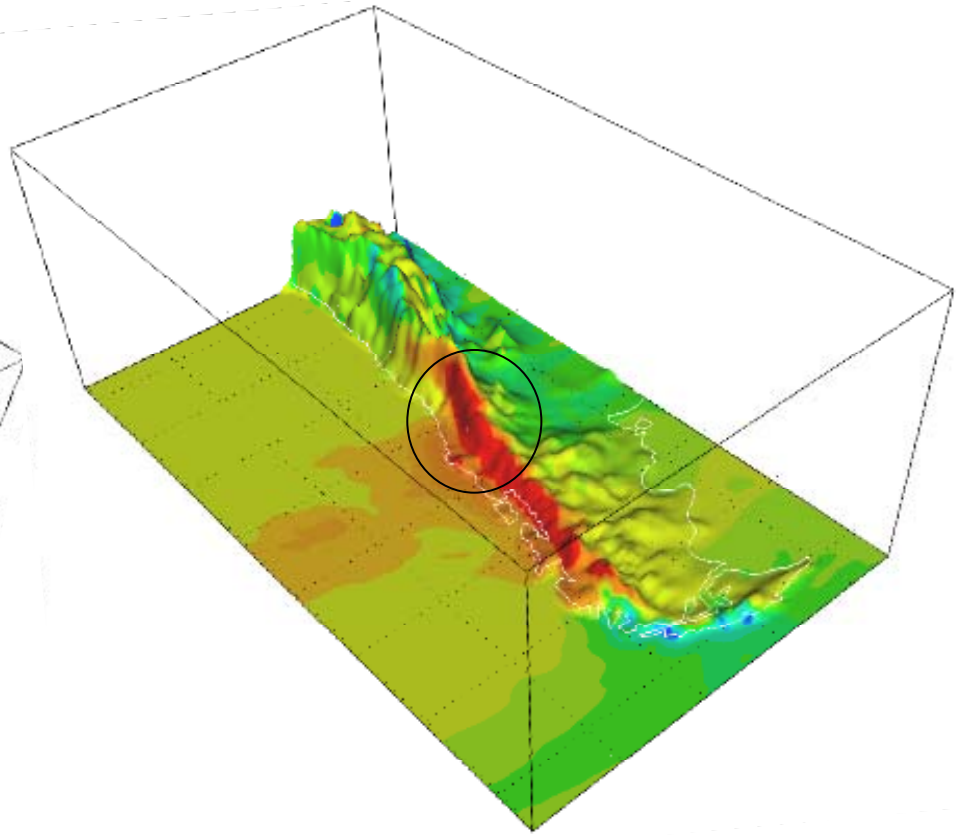
Diferencias A2(2100-2070) – BL(1960-1990)

Temperatura Superficial



-1° 0° 1° 2° 3° 4° 5° C

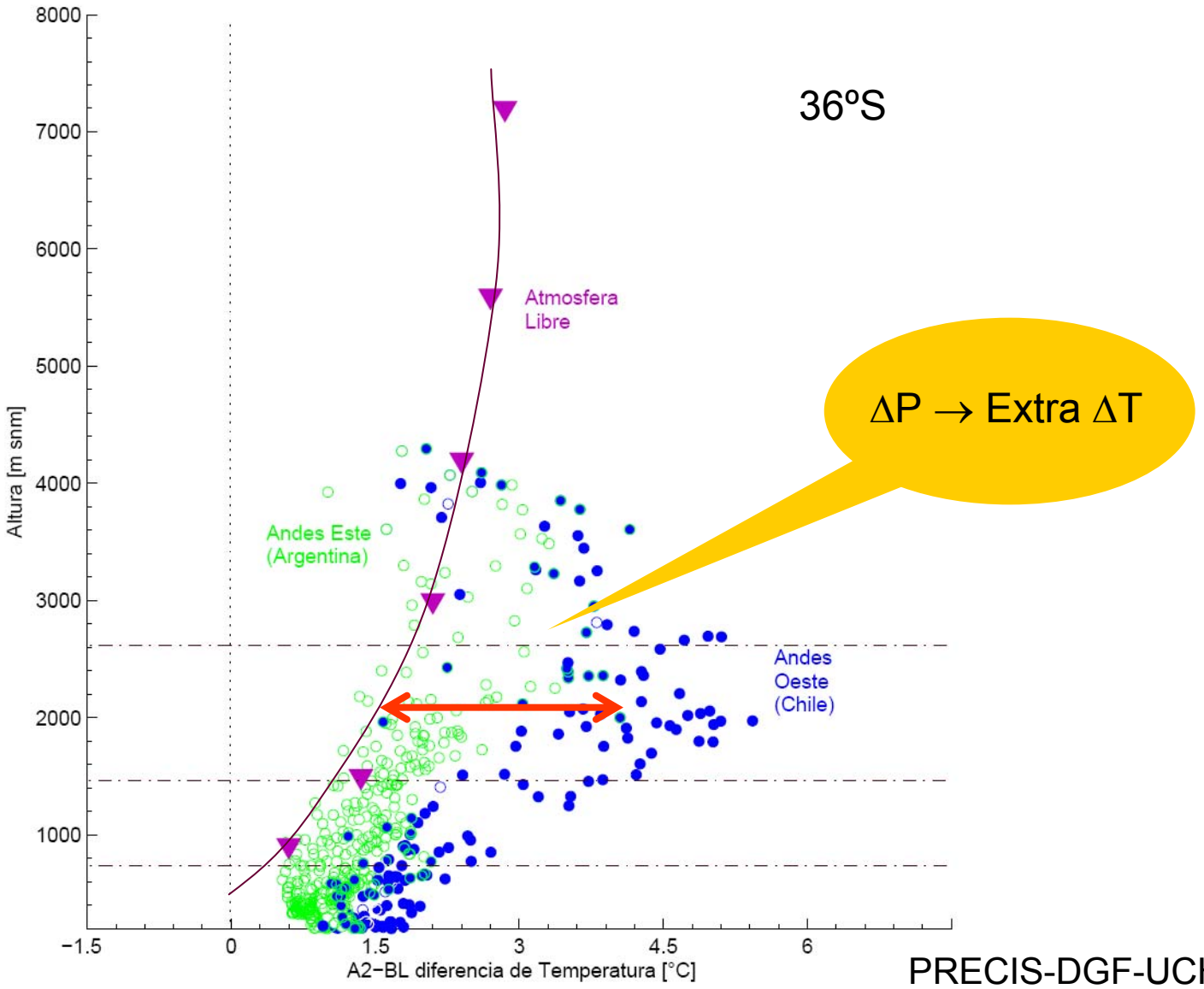
Precipitación



-50 0 +50 mm/mes

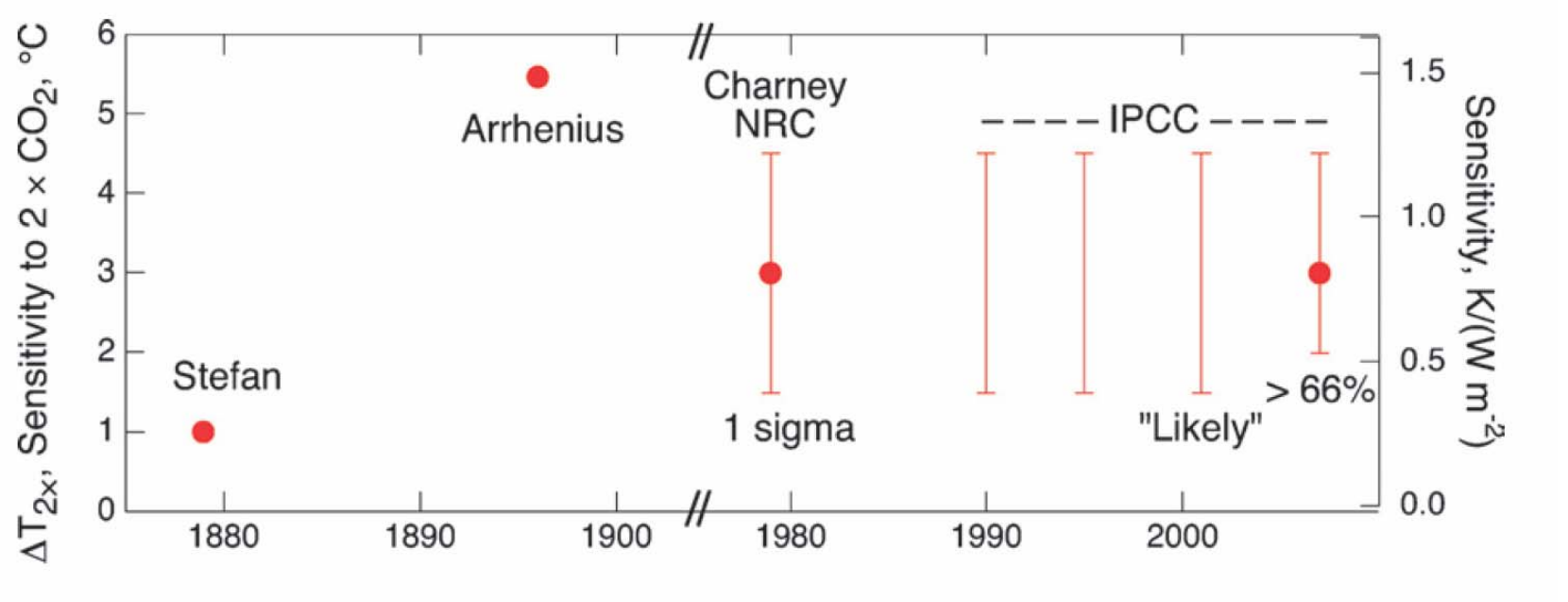
PRECIS-DGF-UCH

ΔT (A2-BL) versus Height



PRECIS-DGF-UCH

$\Delta T(2xCO_2)$: Sensibilidad climática
Fácil de calcular en los modelos GCMs



Schwartz 2008, EES

Modelos logran ajuste a Tsfc con bastante esfuerzo

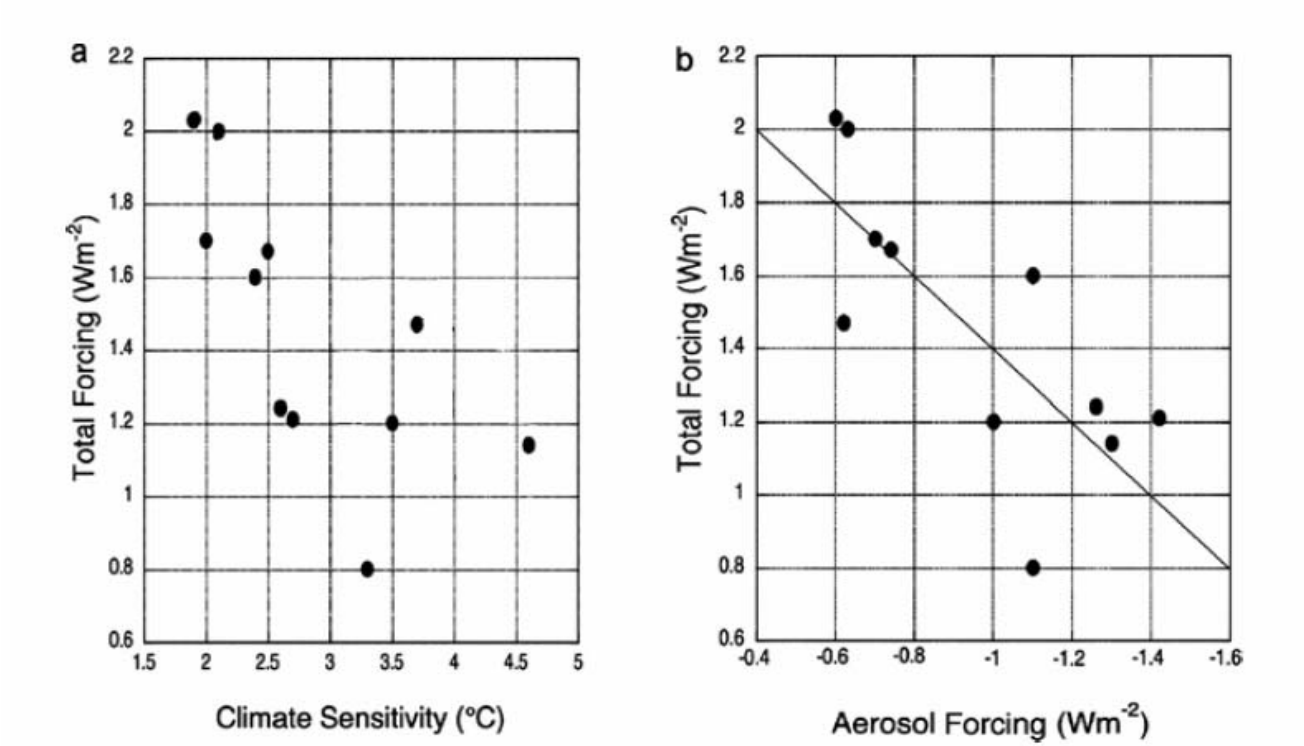
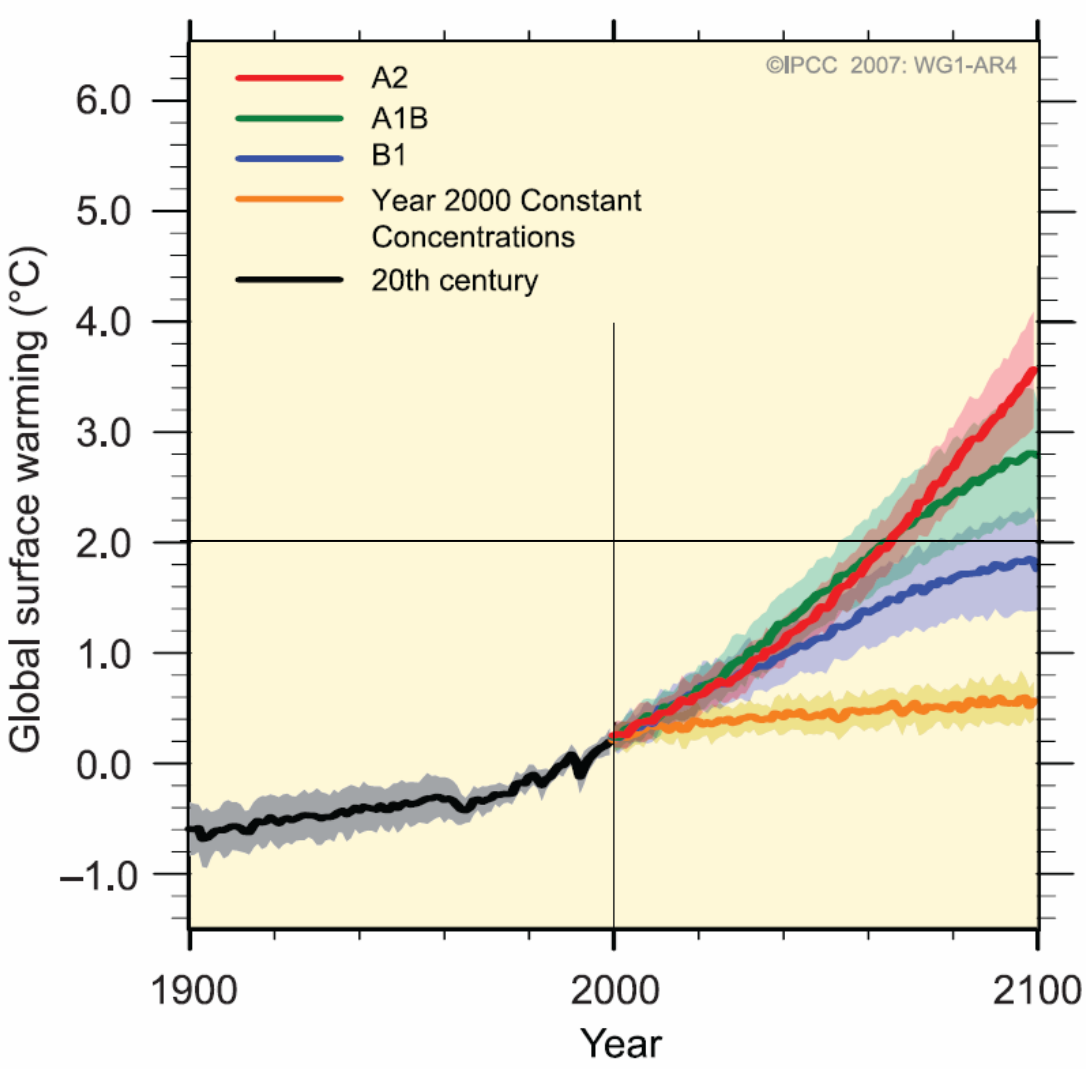


Fig. 9 (a) Total anthropogenic forcing *versus* equilibrium climate sensitivity $\Delta T_{2\times}$ from nine coupled climate models and two energy balance models that were used to simulate the climate of the 20th century. (b) Total anthropogenic forcing *versus* aerosol forcing; note reverse sense of the abscissa scale; slope of diagonal corresponds to Δ(total forcing)/Δ(aerosol forcing) equal to unity. Modified from ref. 43.

Schwartz 2008, EES

Rango de sensibilidad + incertidumbre emisiones = incertidumbre en proyección climática



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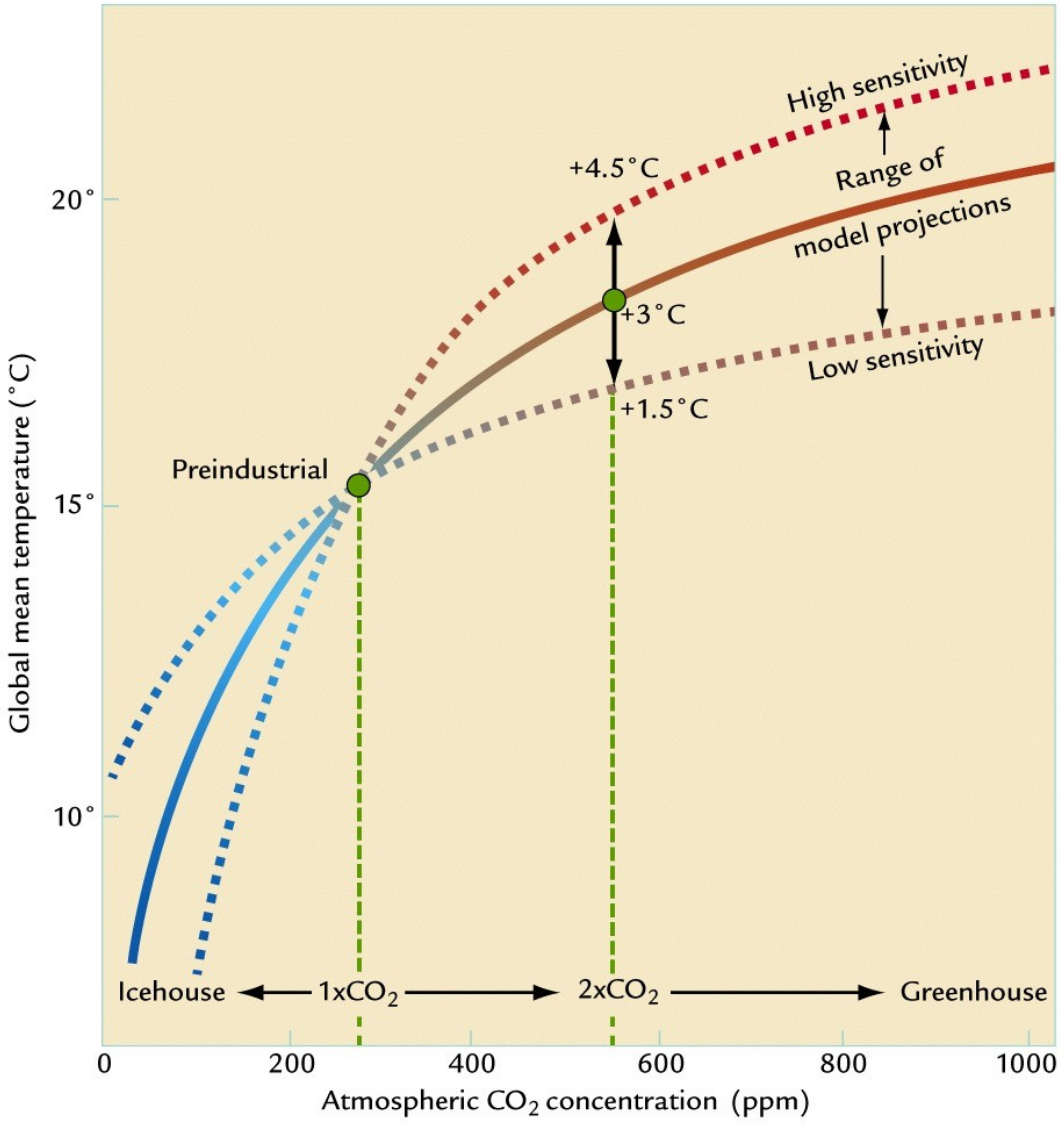
Rango de sensibilidad = incertidumbre en proyección climática



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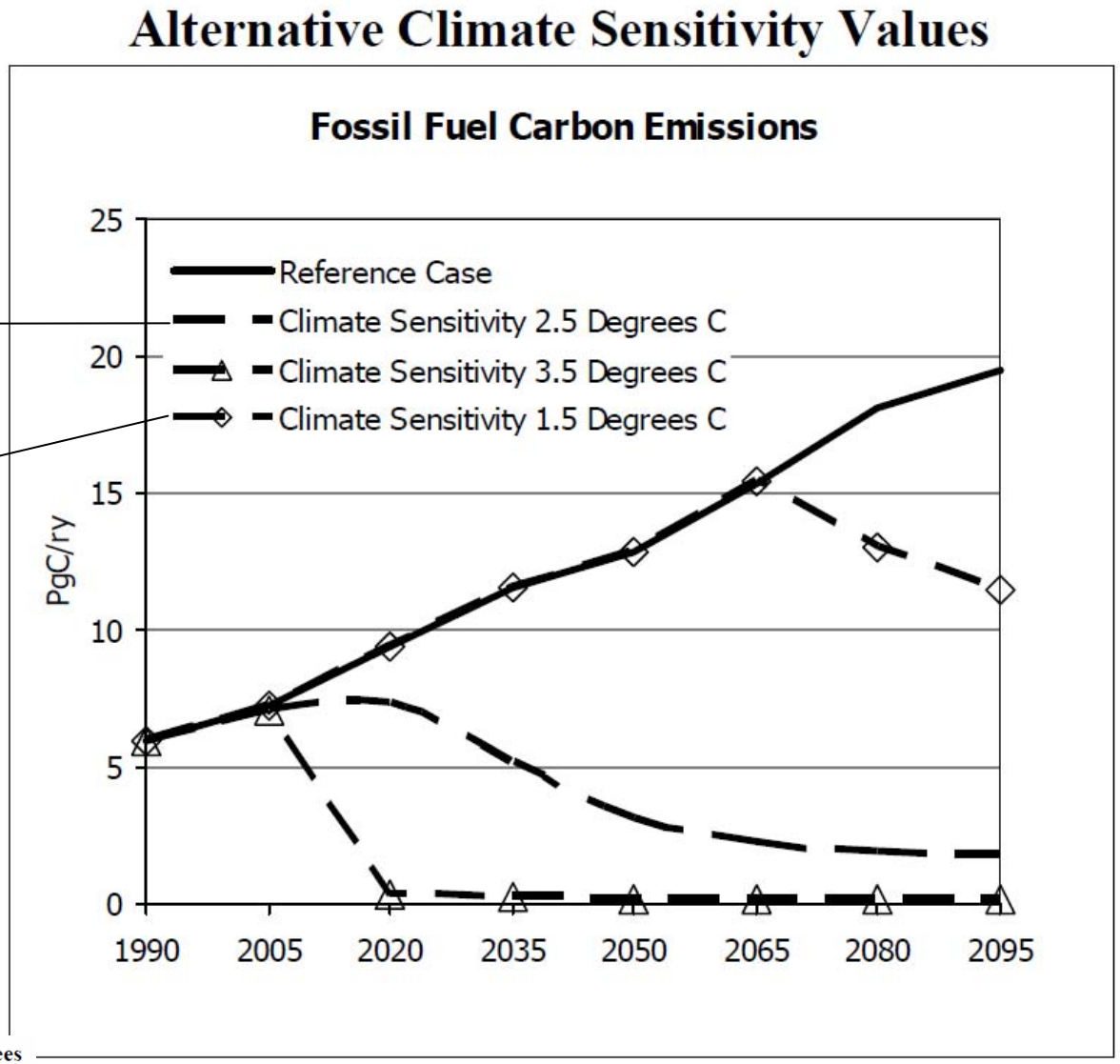
¿Que debemos hacer para evitar los +2ºC?

~10^{10} US$

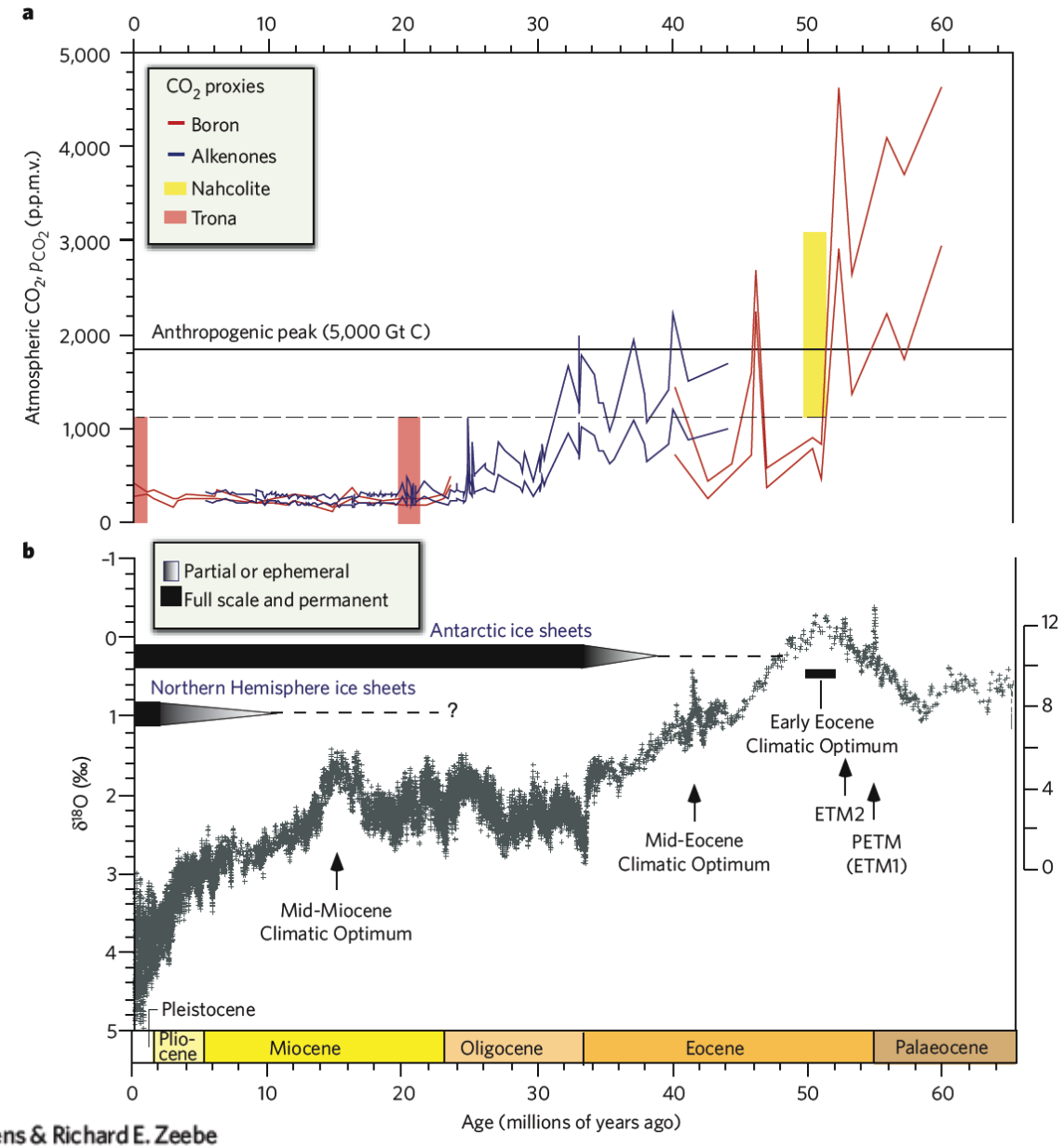
~0 US$



The Technology of Two Degrees

Jae Edmonds and Steven J. Smith

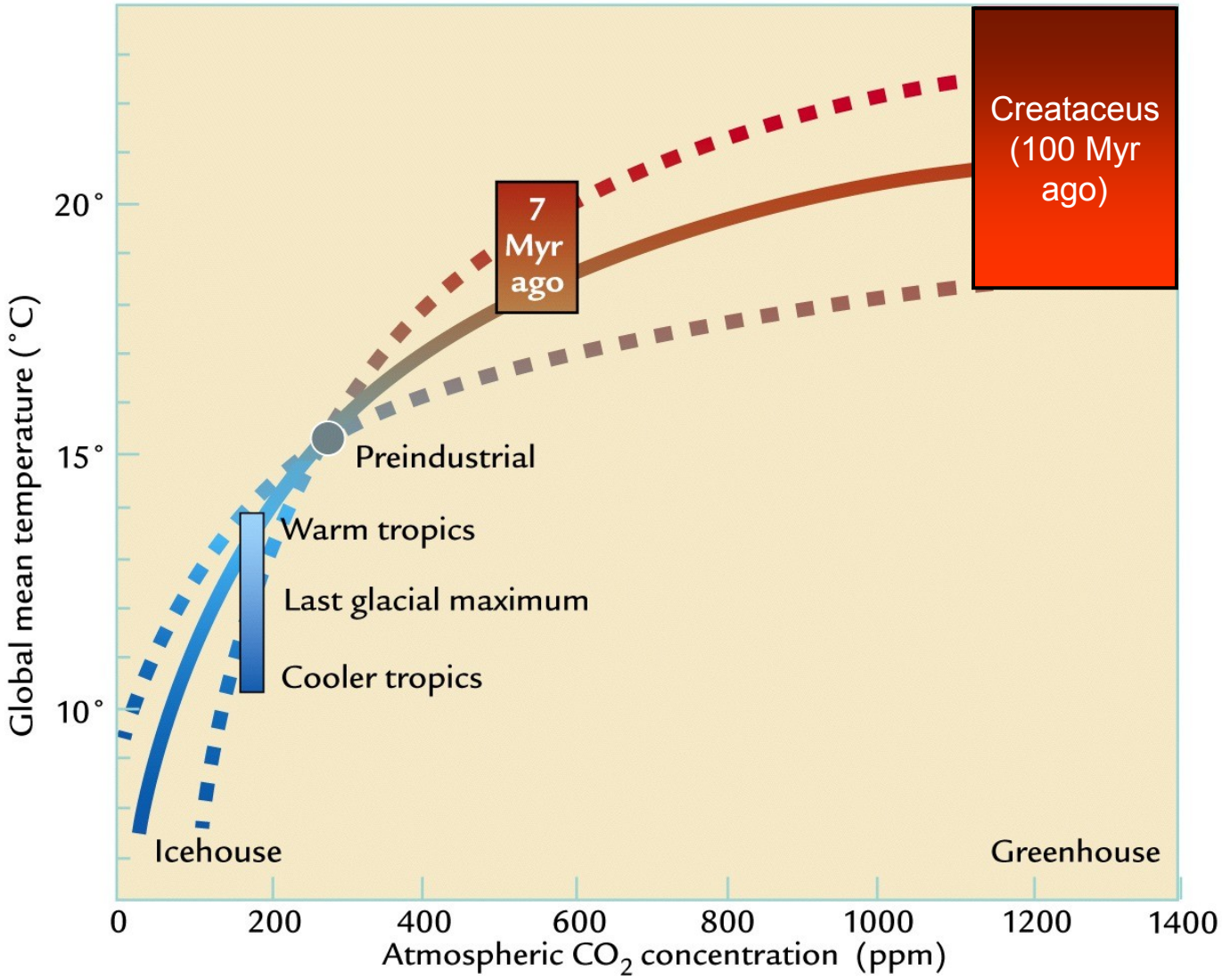
Paleos al rescate?



James C. Zachos, Gerald R. Dickens & Richard E. Zeebe

NATURE|Vol 451|17 January 2008|doi:10.1038/nature06588

Sensibilidad climática
Difícil de estimar en la realidad



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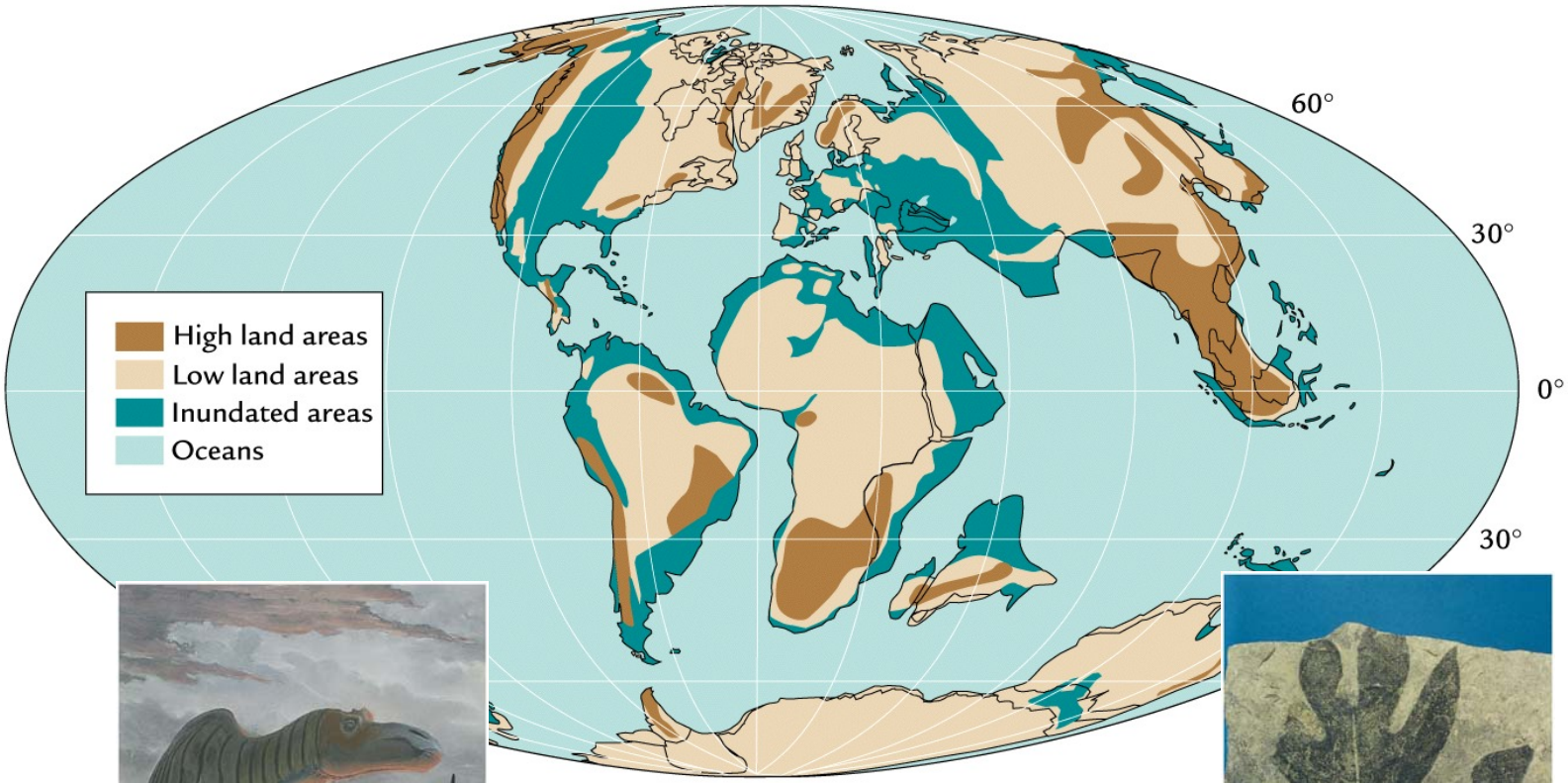
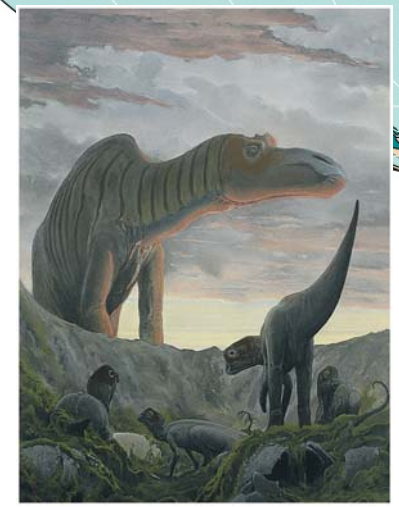
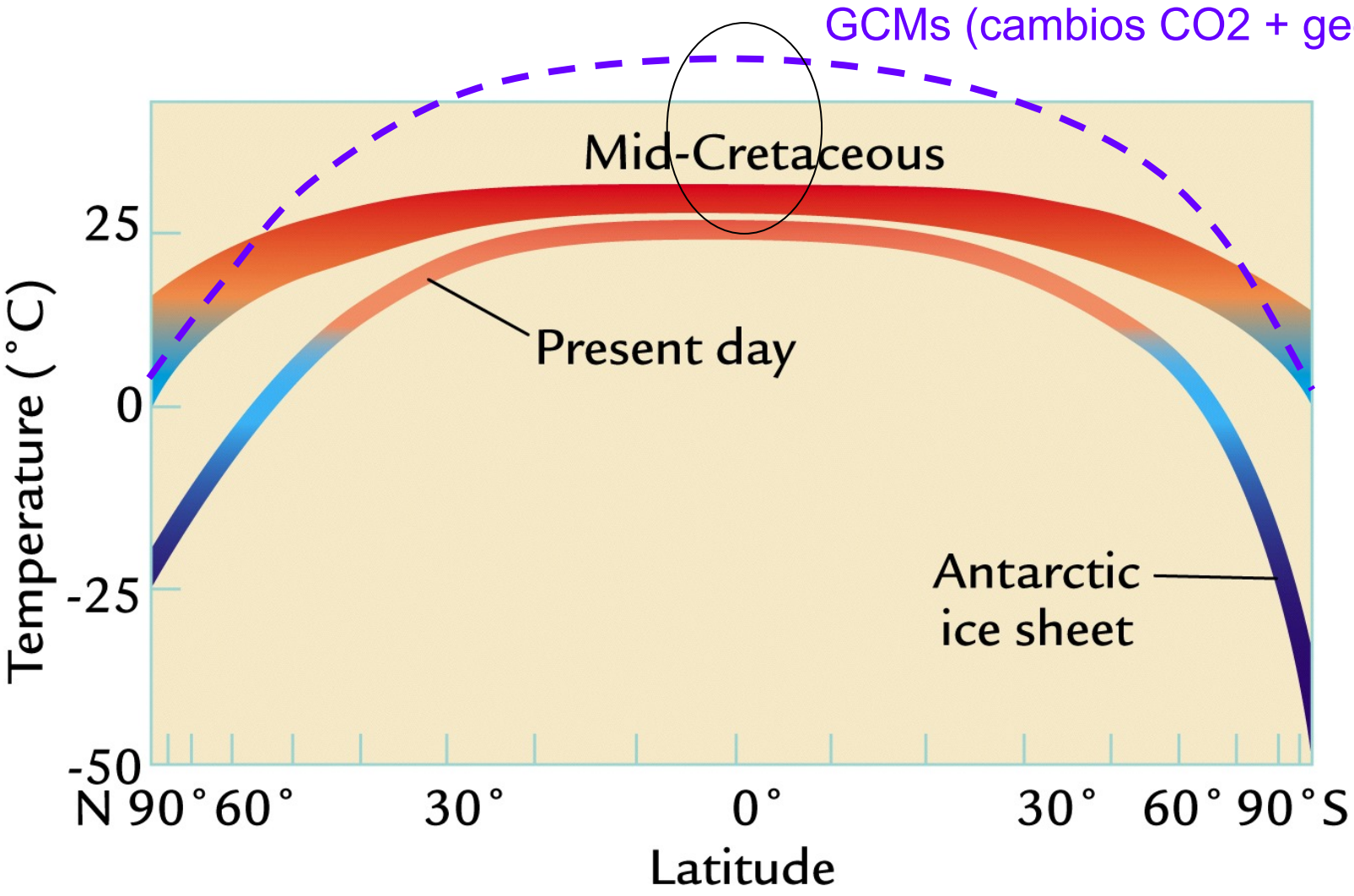
Early Cretaceous world





Modelos además presentan problemas en climas pasados
Termostato tropical? Múltiples equilibrios?



Ruddiman: Earth's Climate, Chapter 4

La aparente existencia de un termostato tropical y su no representación en GCMs es un problema… Sin embargo una buena culebra ayuda

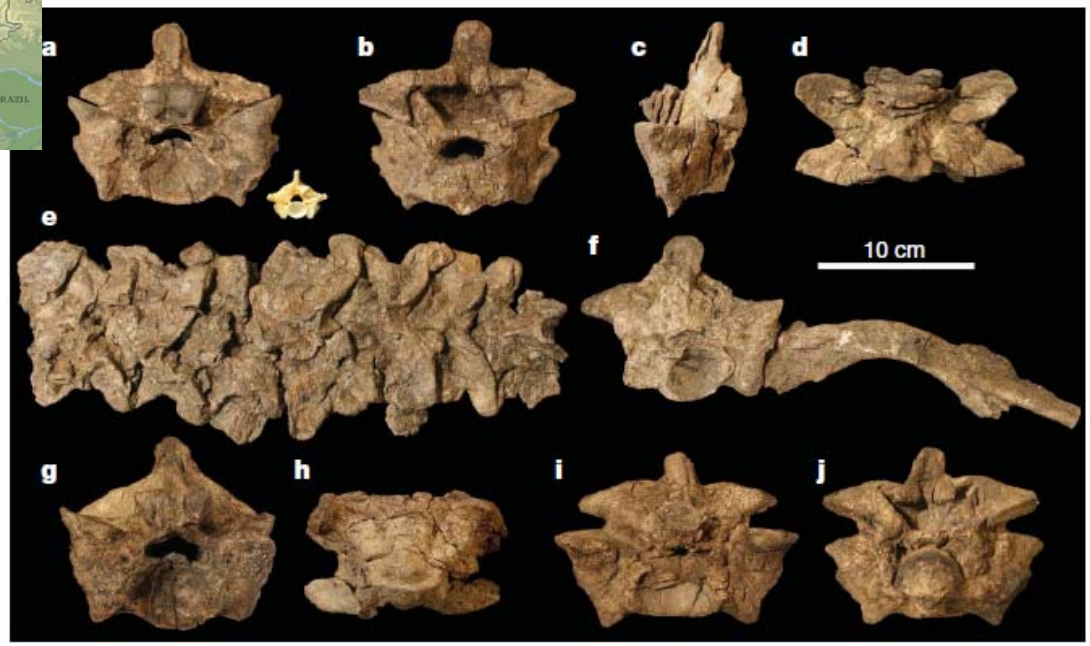


Figure 1 | *Titanoboa cerrejonensis* precloacal vertebrae. **a**, Type specimen (UF/IGM 1) in anterior view compared to scale with a precloacal vertebra from approximately 65% along the precloacal column of a 3.4 m *Boa constrictor*. Type specimen (UF/IGM 1) shown in posterior view (**b**), left lateral view (**c**) and dorsal view (**d**). Seven articulated precloacal vertebrae (UF/IGM 3) in dorsal view (**e**). Articulated precloacal vertebra and rib (UF/IGM 4) in anterior view (**f**). Precloacal vertebra (paratype specimen UF/IGM 2) in anterior view (**g**) and ventral view (**h**). Precloacal vertebra (UF/IGM 5) in anterior view (**i**) and posterior view (**j**). All specimens are to scale.

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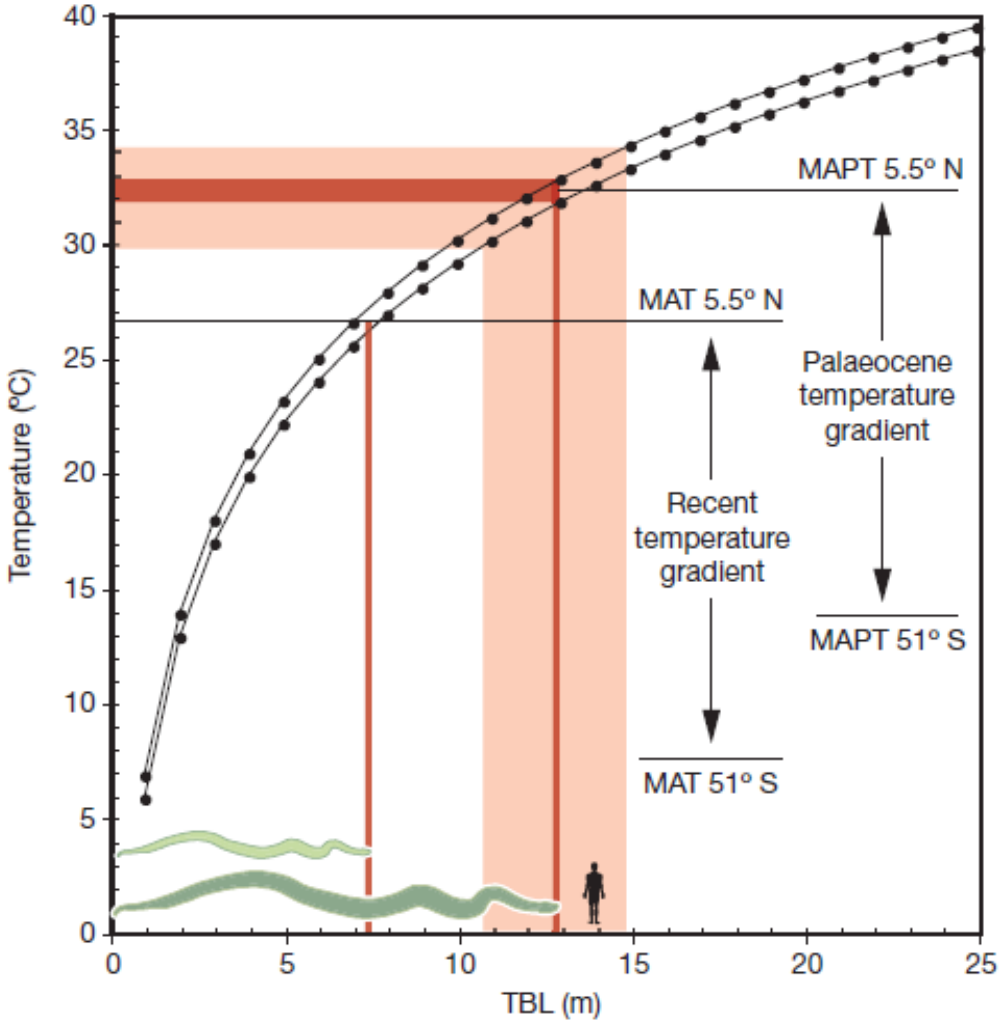

Figure 3 | Mean annual palaeotemperature and Palaeocene latitudinal temperature gradients derived from body size of the green anaconda *Eunectes murinus* (light green) and body size estimates of *Titanoboa cerrejonensis* (dark green). Curves represent model body size increases with

Head et al. Nature 2009

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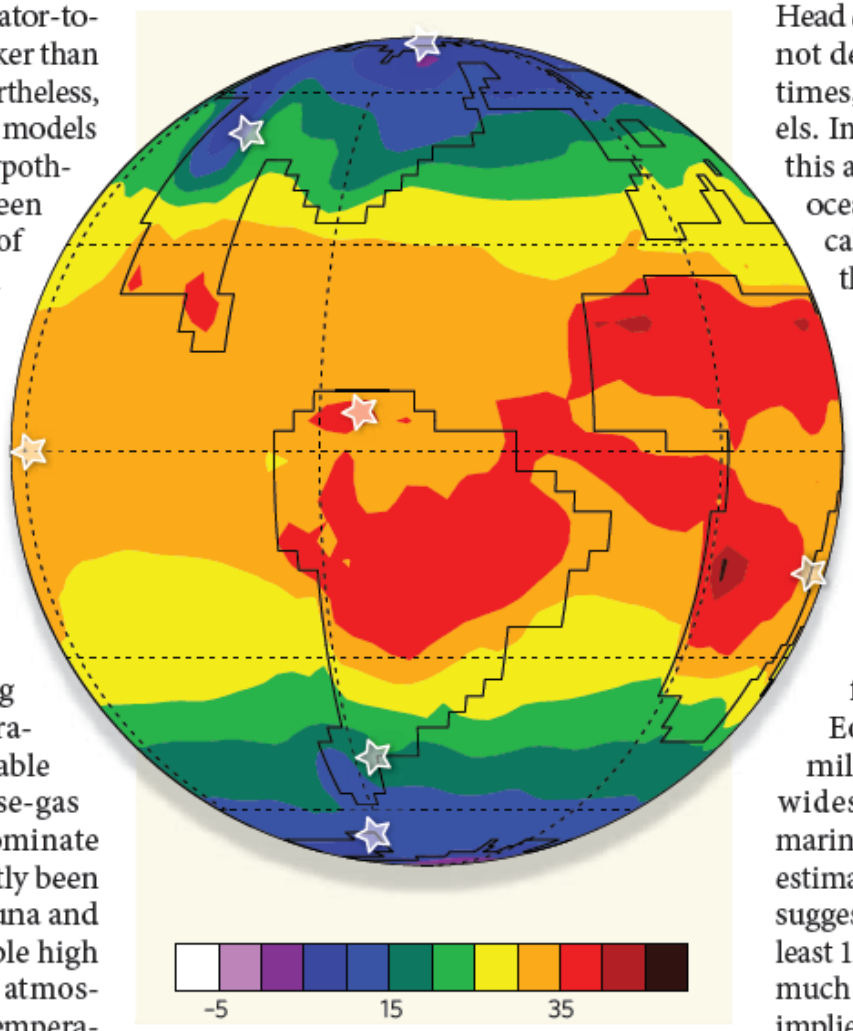

Figure 1 | Simulation of annual average surface temperatures about 58 million years ago. Stars

Head *et al.* find t
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Head et al. Nature 2009

Conclusiones

- No hay duda del incremento del CO2. Calentamiento de la troposfera media es relativamente modesto. Calentamiento superficial es mas fuerte, debido a superposición de variabilidad natural y/o retro-alimentaciones

- Los GCMs / RCMs son la unica herramienta para mirar al futuro
- Es bueno mantener un ojo critico en los modelos y continuar su mejoramiento

Incertidumbre en modelos tiene tremendas consecuencias en la toma de decisiones para la mitigación y adaptación al CCA

- Para avanzar en ciencia hay que simplificar, pero no sobre-simplificar
- Una buena culebra siempre ayuda