

Multiple Equilibria and Hysteresis

1:

Lecture for Spring 2009
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A simple climate model, with a hysteresis:

$$C \frac{dT}{dt} = sB - \left(1 - \frac{\epsilon}{2}\right) \sigma T^4$$

$$\epsilon(t) = 0.8 + 0.2 \sin\left(\frac{2\pi t}{100,000 \text{ yr}}\right)$$

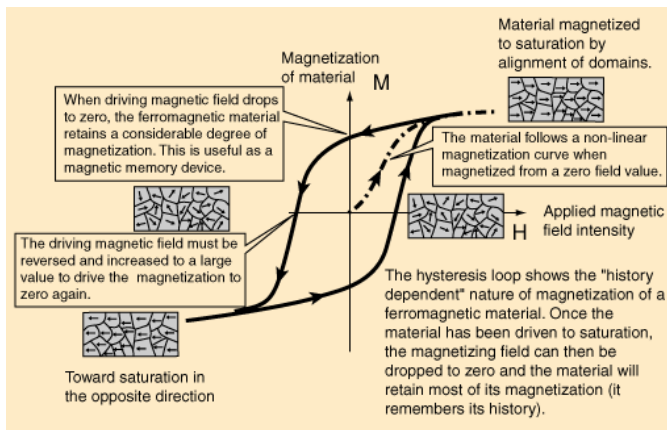
3:

$$B(T) = \begin{cases} 0.33 & : T \leq 245 \\ 0.33 + .00925 \times (T - 245) & : 245 < T \leq 285 \\ 0.7 + .002 \times (T - 285) & : T > 285 \end{cases}$$

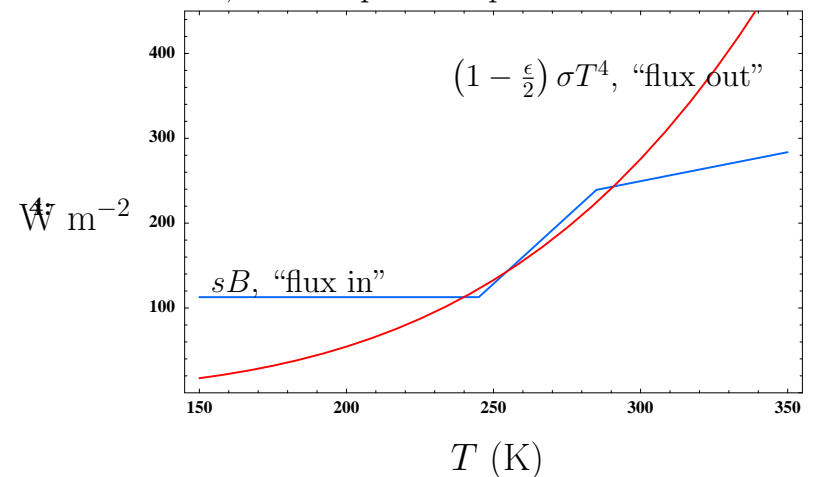
$$s = \frac{1}{4} S_0 \quad C = H \rho_w c_w \quad H = 2738 \text{ m}$$

2:

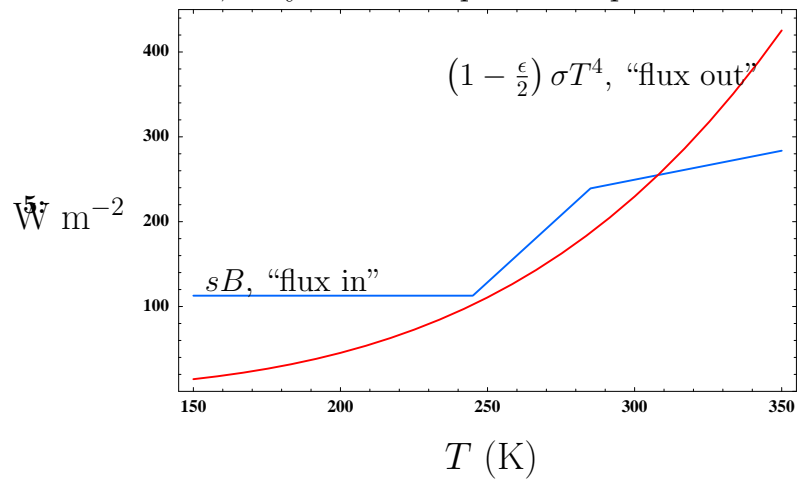
Hysteresis (hyperphysics)



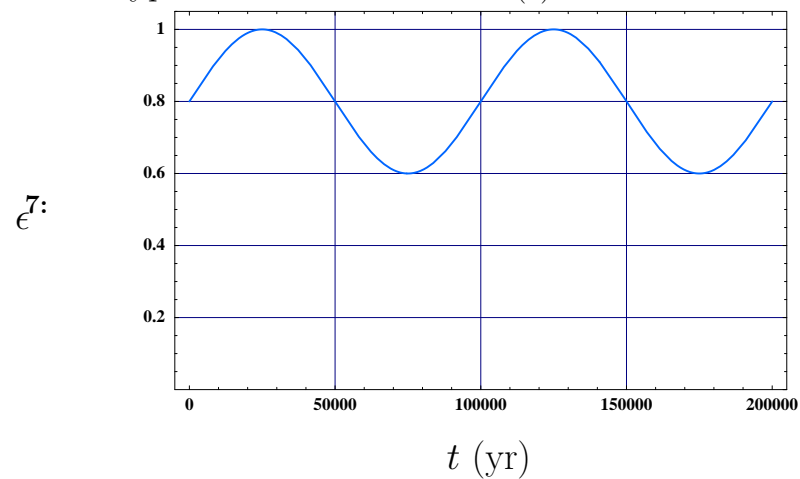
$\epsilon = .80$, three equilibria possible



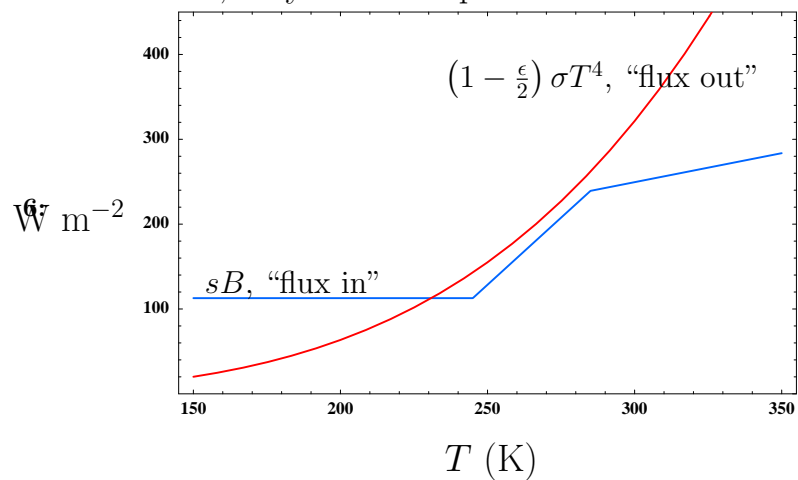
$\epsilon = 1.0$, only de-iced equilibrium possible



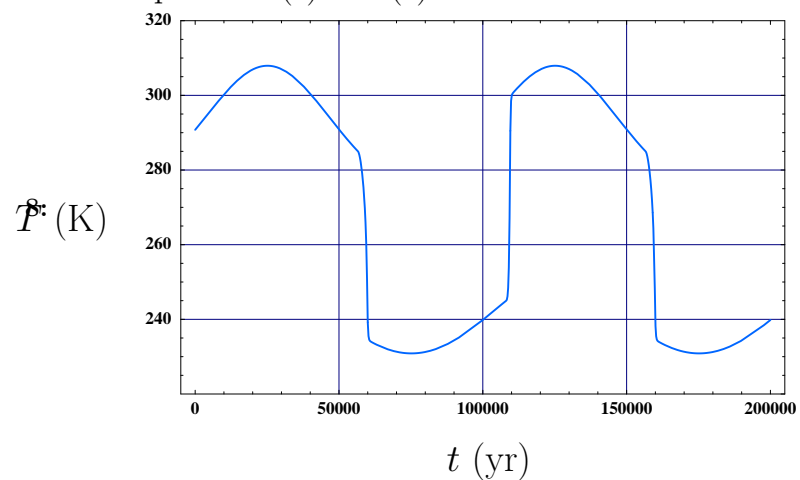
hypothetical variation of $\epsilon(t)$

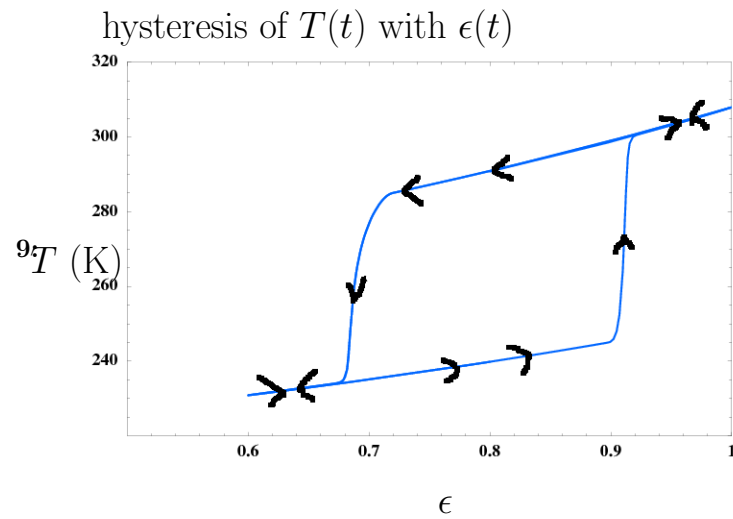


$\epsilon = 0.6$, only snowball possible

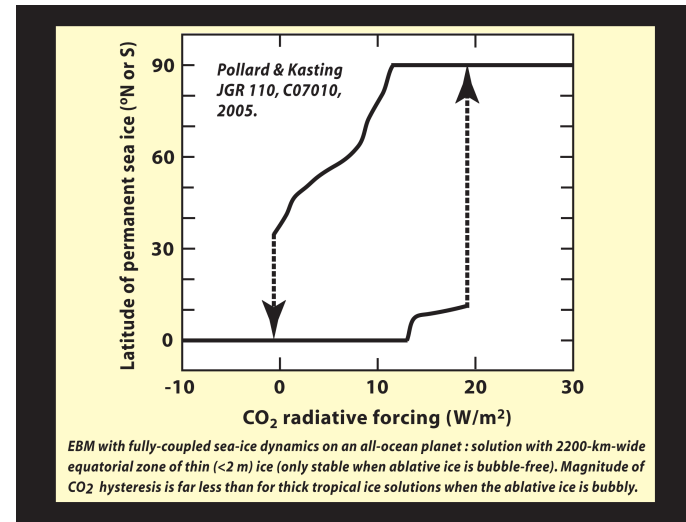


response $T(t)$ to $\epsilon(t)$



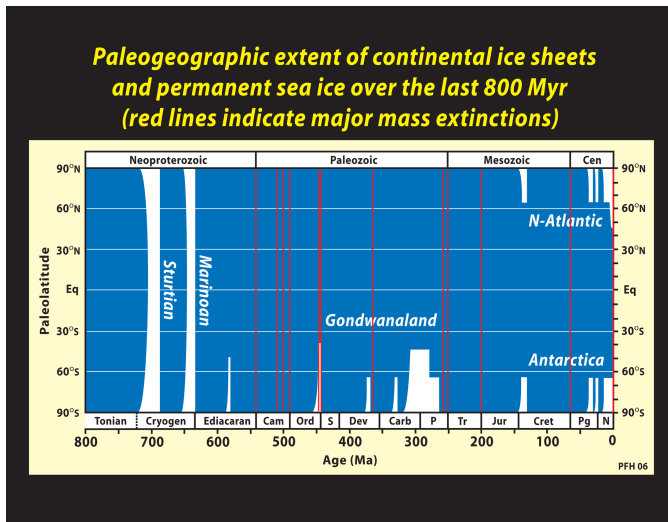


11:



<http://www.snowballearth.org>

10:



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