



Climate change

On the back of an envelope



25

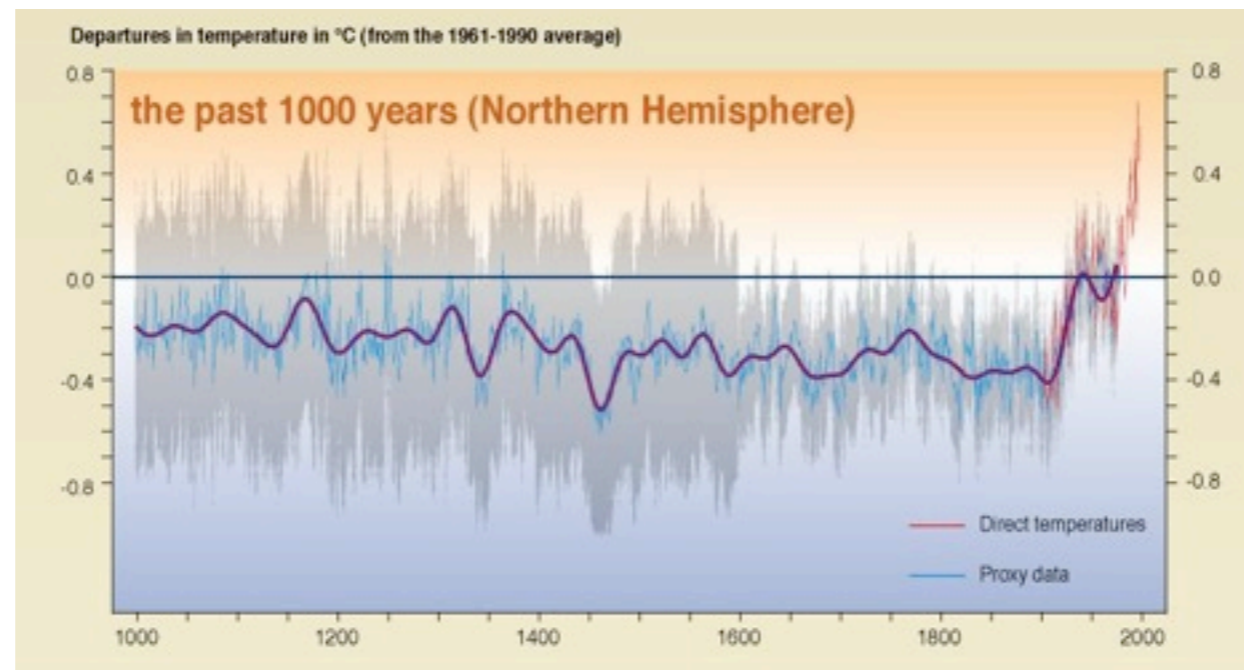
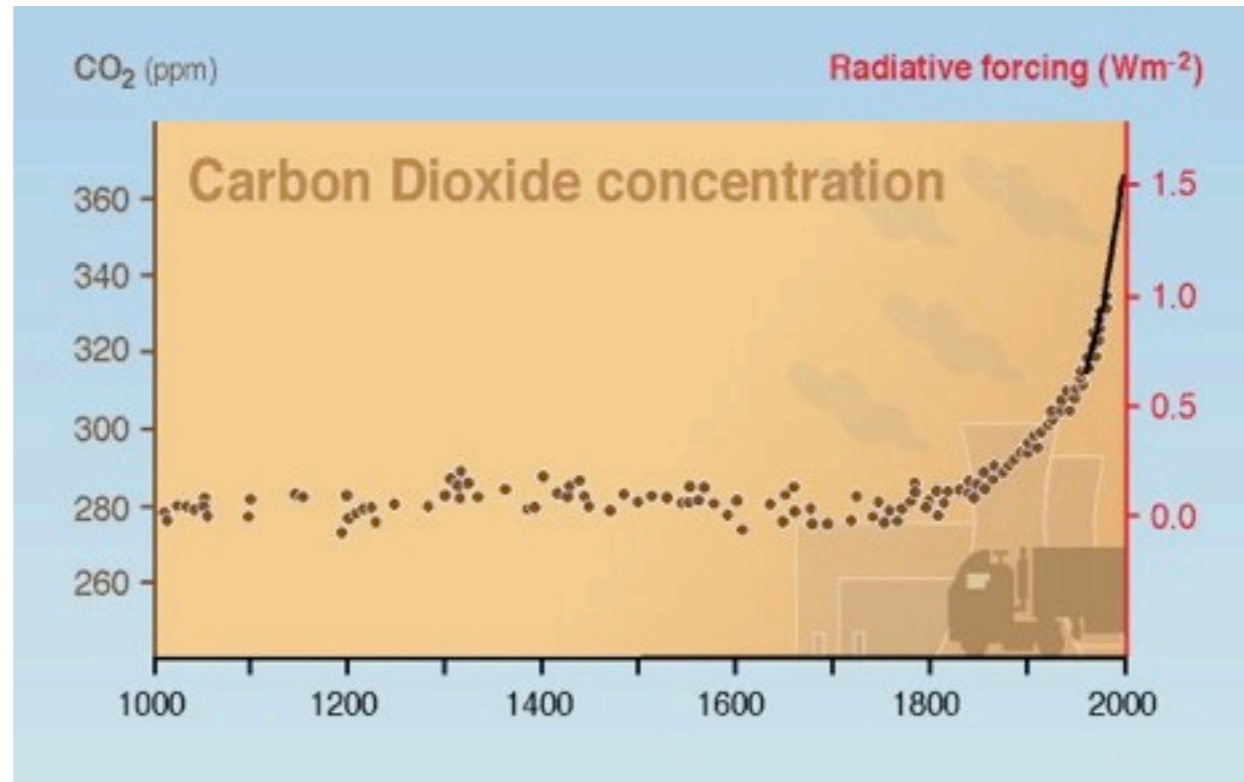


**Why do we think
that more CO₂ will make
the climate warm up?**



Is it because of

Trends in the observational record?



Is it because of
Computer models?



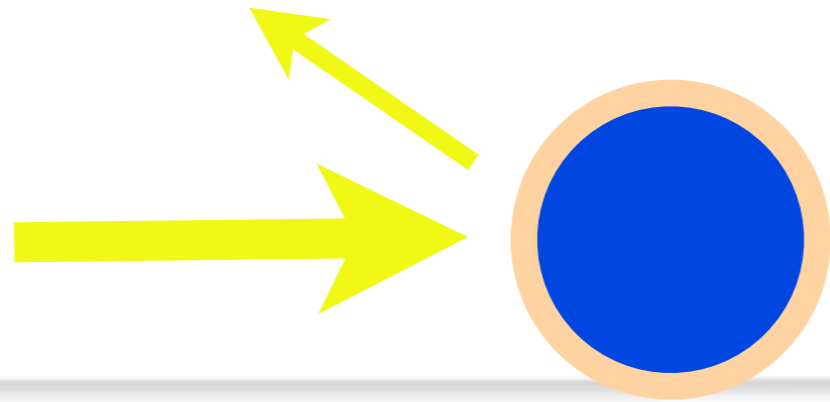
No, it's simpler than that.



Warning:
The next two slides have equations.



Increasing CO₂ Perturbs the Earth's Radiation Budget



$$(1 - \alpha)S\pi a^2 = \varepsilon(\sigma T_S^4)4\pi a^2$$

$$(1 - \alpha)S = 4\varepsilon(\sigma T_S^4)$$

$$0 = 4(\Delta\varepsilon)(\sigma T_S^4) + 4\varepsilon(4\sigma T_S^3 \Delta T_S)$$

Assumptions: 1) Only CO₂ is perturbed; 2) No feedbacks.

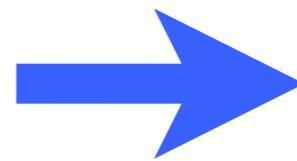
$$\Delta T_S = -\frac{T_S}{4} \frac{\Delta\varepsilon}{\varepsilon}$$

Let's put in some numbers:



$$\Delta T_S = -\frac{T_S}{4} \frac{\Delta \varepsilon}{\varepsilon}$$

$$\varepsilon(\sigma T_S^4) = 240 \text{ W m}^{-2}$$



$$\frac{\Delta \varepsilon}{\varepsilon} = -\frac{4}{240}$$

~2%

$$(\Delta \varepsilon)(\sigma T_S^4) = -4 \text{ Wm}^{-2}$$

$$T_S = 288 \text{ K}$$

$$\Delta T_S = \left(-\frac{288}{4} \right) \left(-\frac{4}{240} \right) = 1.2 \text{ K}$$

~0.5%

Feedbacks enhance the warming.

$$\Delta T = \frac{\Delta T_0}{1 - f}$$

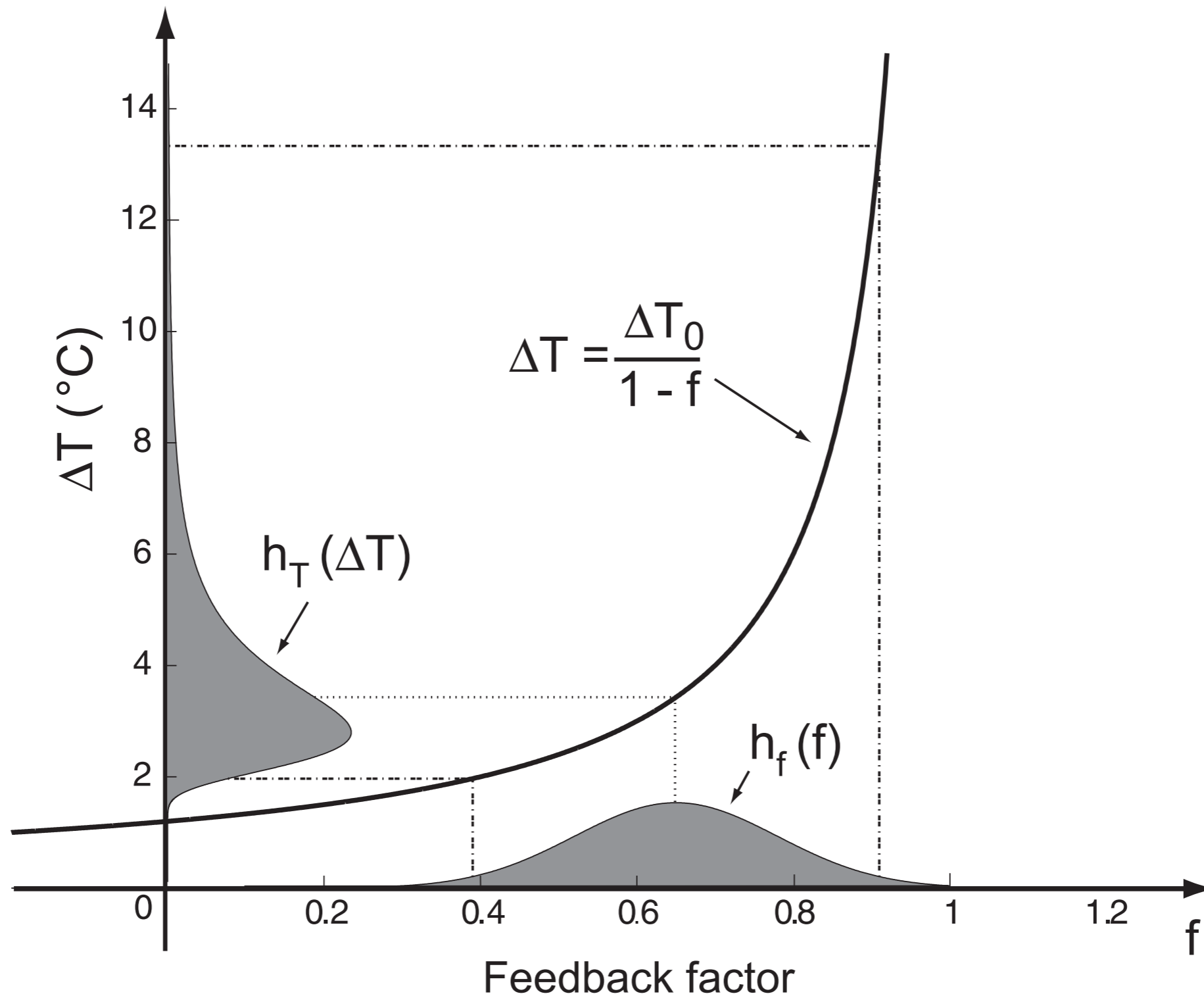
With no feedbacks, we would get 1.2 K for a doubling of CO₂.

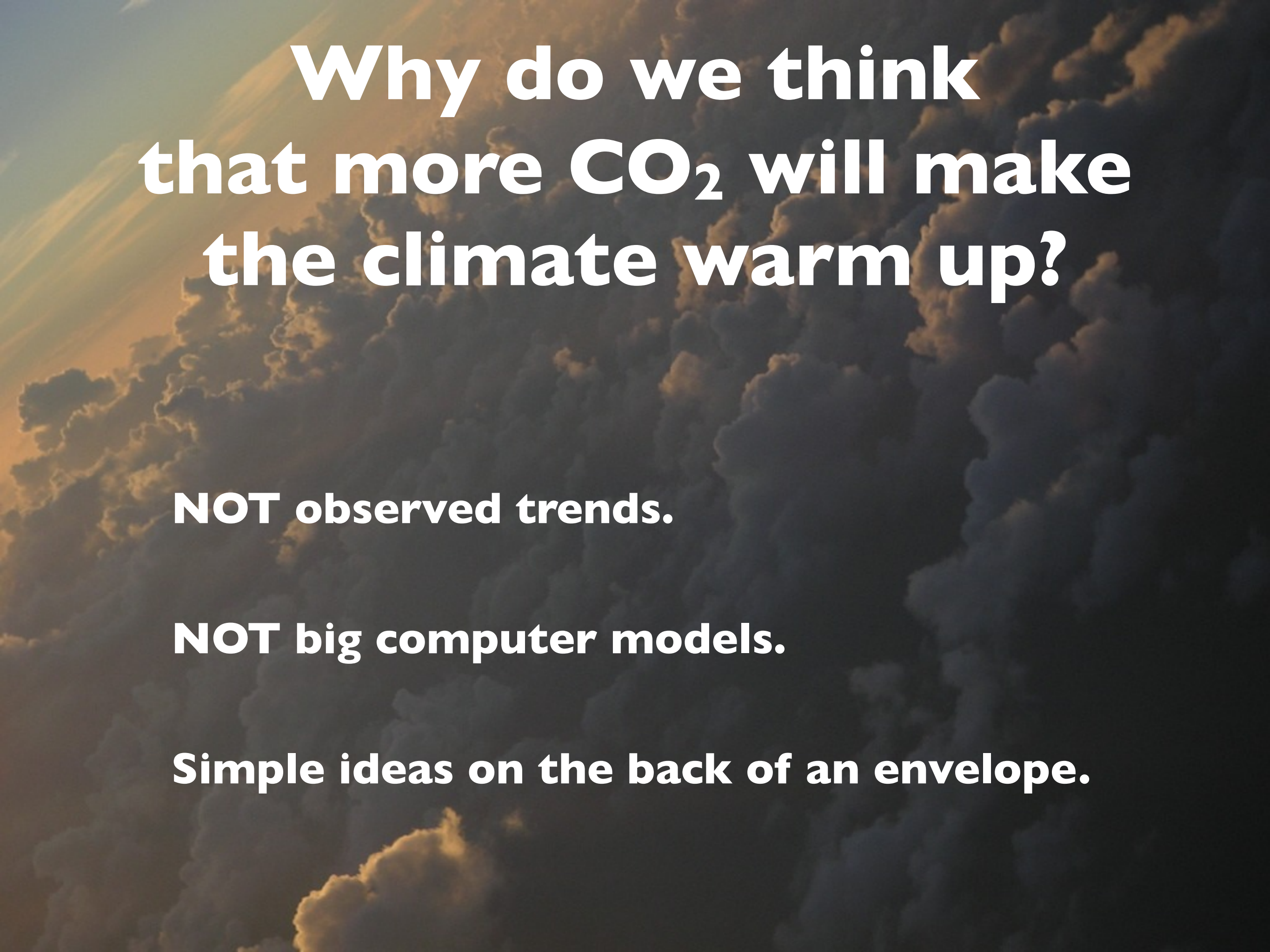
With feedbacks, we get about double that.

Kinds of Feedbacks

- **Snow & sea ice feedbacks**
- **Water vapor feedback**
- **Lapse-rate feedback**
- **Cloud feedbacks**
- **Carbon feedbacks**
- **Ice sheet feedback**

Uncertainty in feedback strength \rightarrow Uncertainty in climate sensitivity





**Why do we think
that more CO₂ will make
the climate warm up?**

NOT observed trends.

NOT big computer models.

Simple ideas on the back of an envelope.

Climate change on the back of an envelope

