This Week: Greenhouse Effect

- Review Simple Energy Balance Model

- What we got right and more importantly, what we got wrong…

Earth's Energy Balance—No Atmosphere

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$$T_E = \left[\frac{S_o(1-A)}{4\sigma}\right]^{\frac{1}{4}}$$

Same approach for ANY planet!

Earth's Energy Balance

$$T_E = \left[\frac{S_o (1 - A)}{4\sigma} \right]^{\frac{1}{4}}$$

Plug in known values for S_o (~ 1370 W/m^2), A (~ 0.28), and σ (5.67x10^{-8} W/m^2/K^4) and predict

T_E ~ 256 K

-16°C (below freezing!)

Earth's Energy Balance

Plug
σ and

Not a very good prediction!
What's wrong with our model?

Where did we go wrong?

Examine the validity of our assumptions

1. $F_{in} = F_{out}$

2. Radiation only form of energy

3. Sun only energy source, constant

4. Solar energy deposited uniformly

5. Atmosphere plays no role

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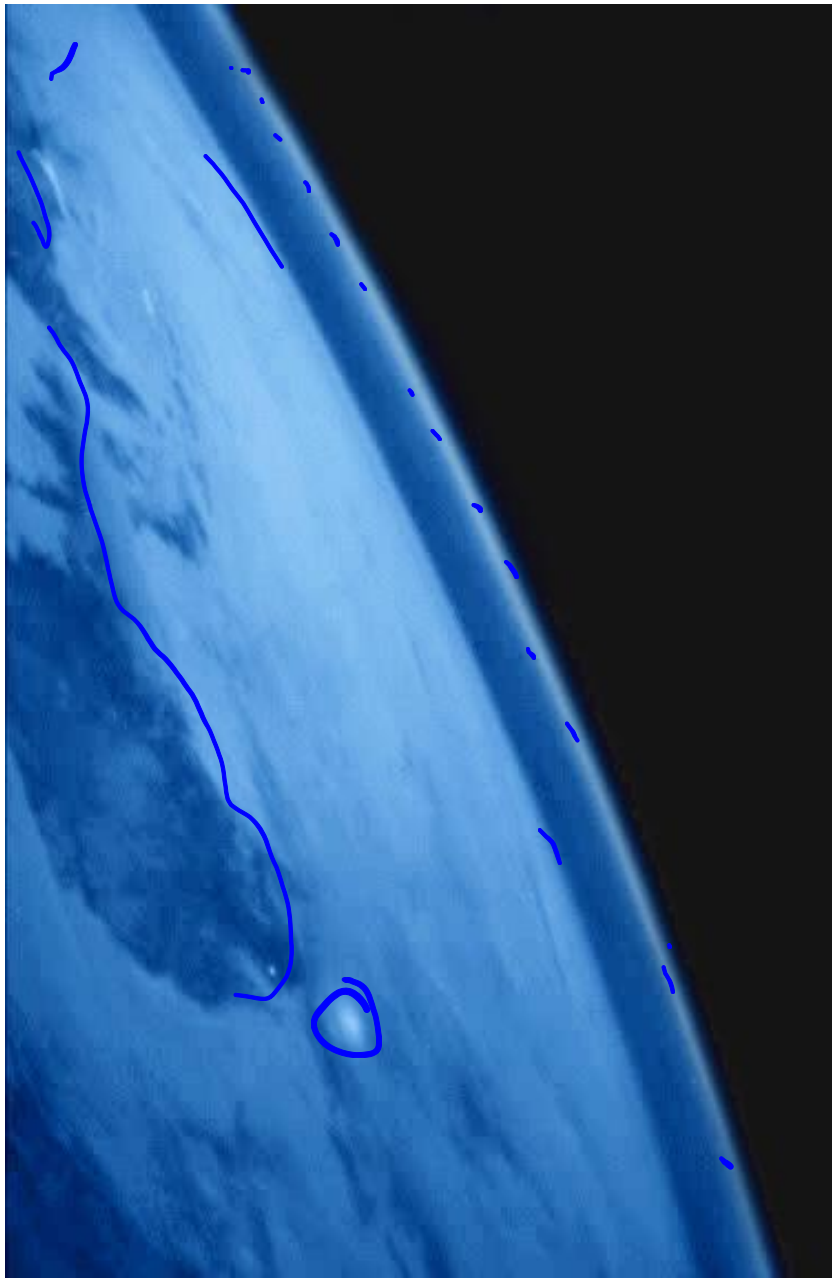
5. Atmosphere plays no role Hmmm…

Earth's Atmosphere

- 78% N_2, 21% O_2

- 1 ppm to 1% H_2O
- 400 ppm CO_2
- 1.9 ppm CH_4
- …



Magnitude (Definition) of Greenhouse Effect

$$T_{true} - T_{\text{"bare rock"}}$$

$$289\ K - 256\ K = 33\ K$$

The Greenhouse Effect

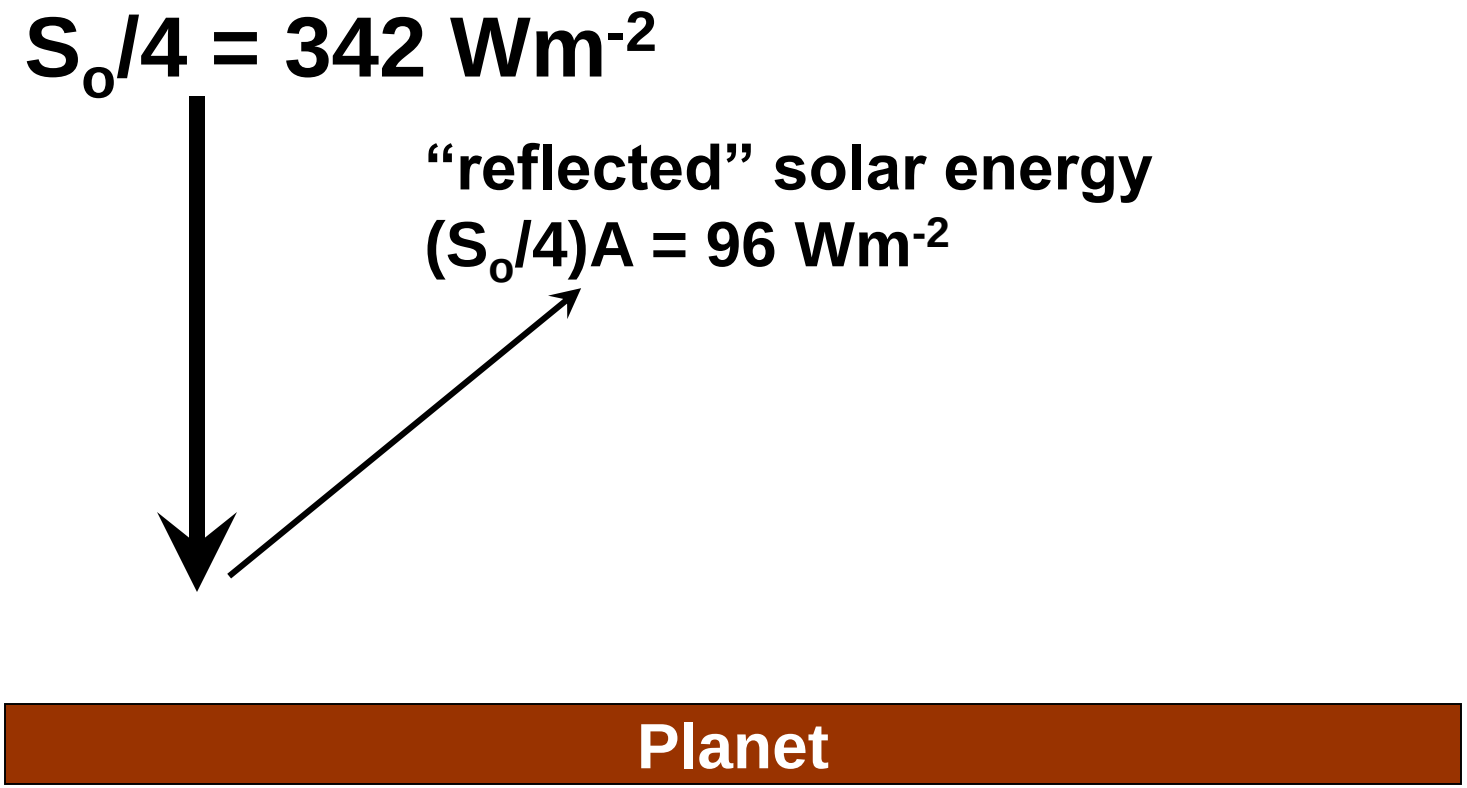
$$T_{true} - T_{\text{"bare rock"}}$$

$$289\ K - 256\ K = 33\ K$$

from Earth surface

Definition: **Absorption of *terrestrial* Outgoing Long-wave Radiation (OLR) by the atmosphere, causing the surface T to be larger than the planet's "emission" T**

Energy Balance Cartoon (no Atmosphere)



"Bare rock" Model (i.e. no atmosphere)

Predict T_E ~ 256 K when atmosphere is neglected

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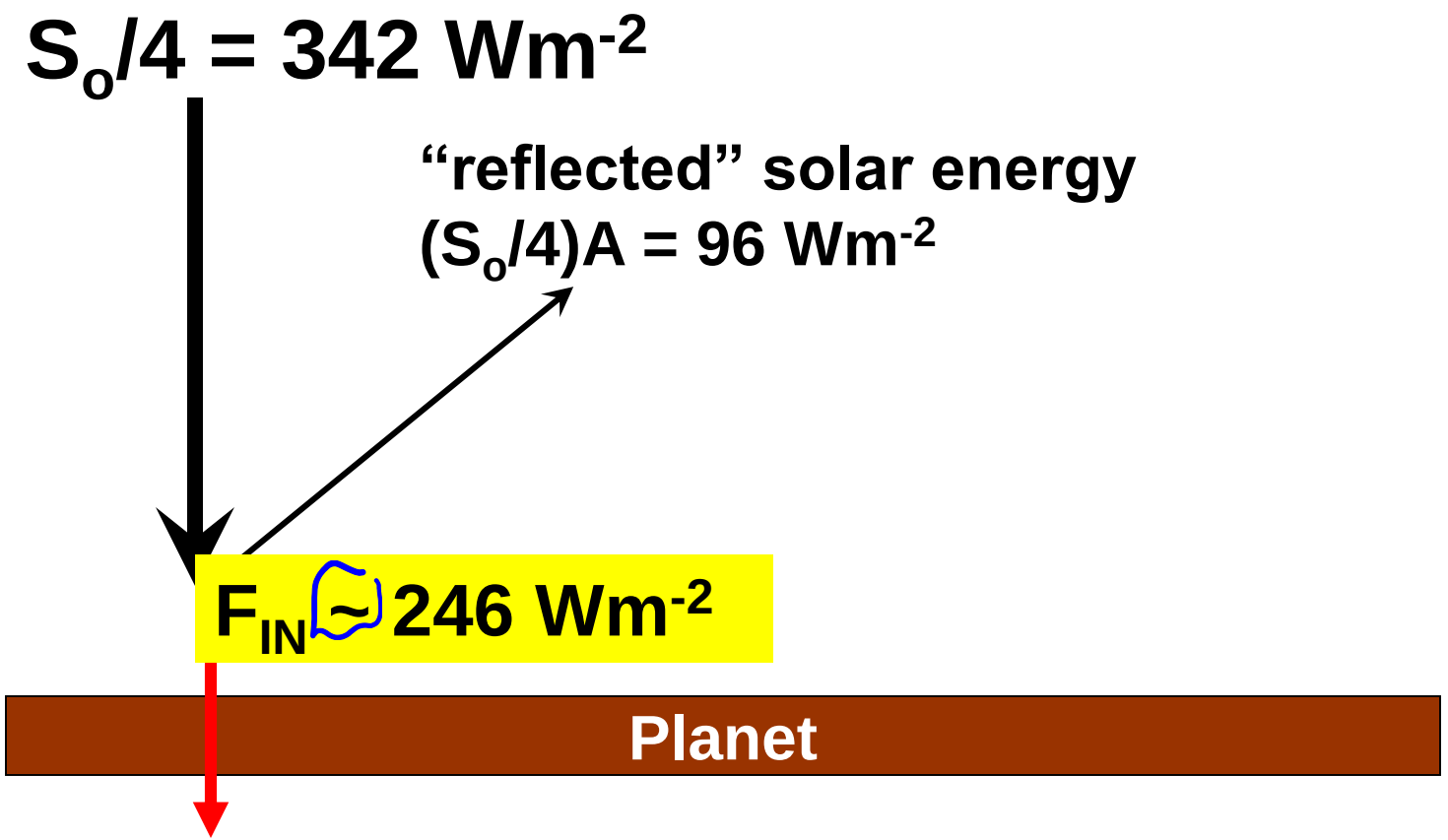

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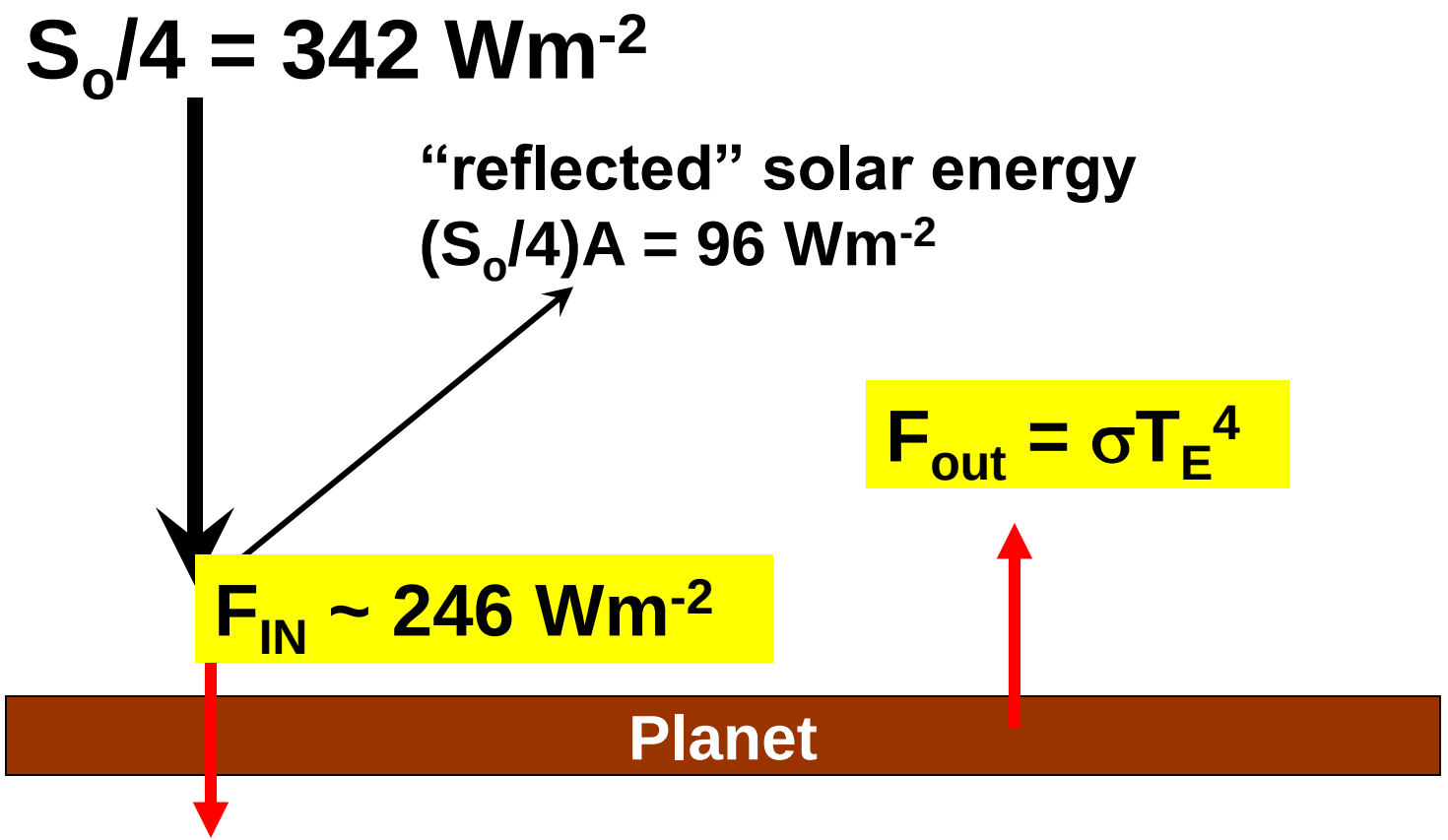

"Bare rock" Model (i.e. no atmosphere)

Predict $T_E \sim 256$ K when atmosphere is neglected

The Greenhouse Effect (GHE)

$$T_{true} - T_{\text{"bare rock"}}$$

$$289\ K - 256\ K = 33\ K$$

The *atmosphere* increases the average surface temperature by about 13%

- **If we explain the physics of the GHE will we predict the correct T?**

Global “Climate Model”: Take 2

Simplifying Assumptions

1. The atmosphere absorbs only ***outgoing*** “terrestrial” *radiation (**no absorption** of solar radiation)*

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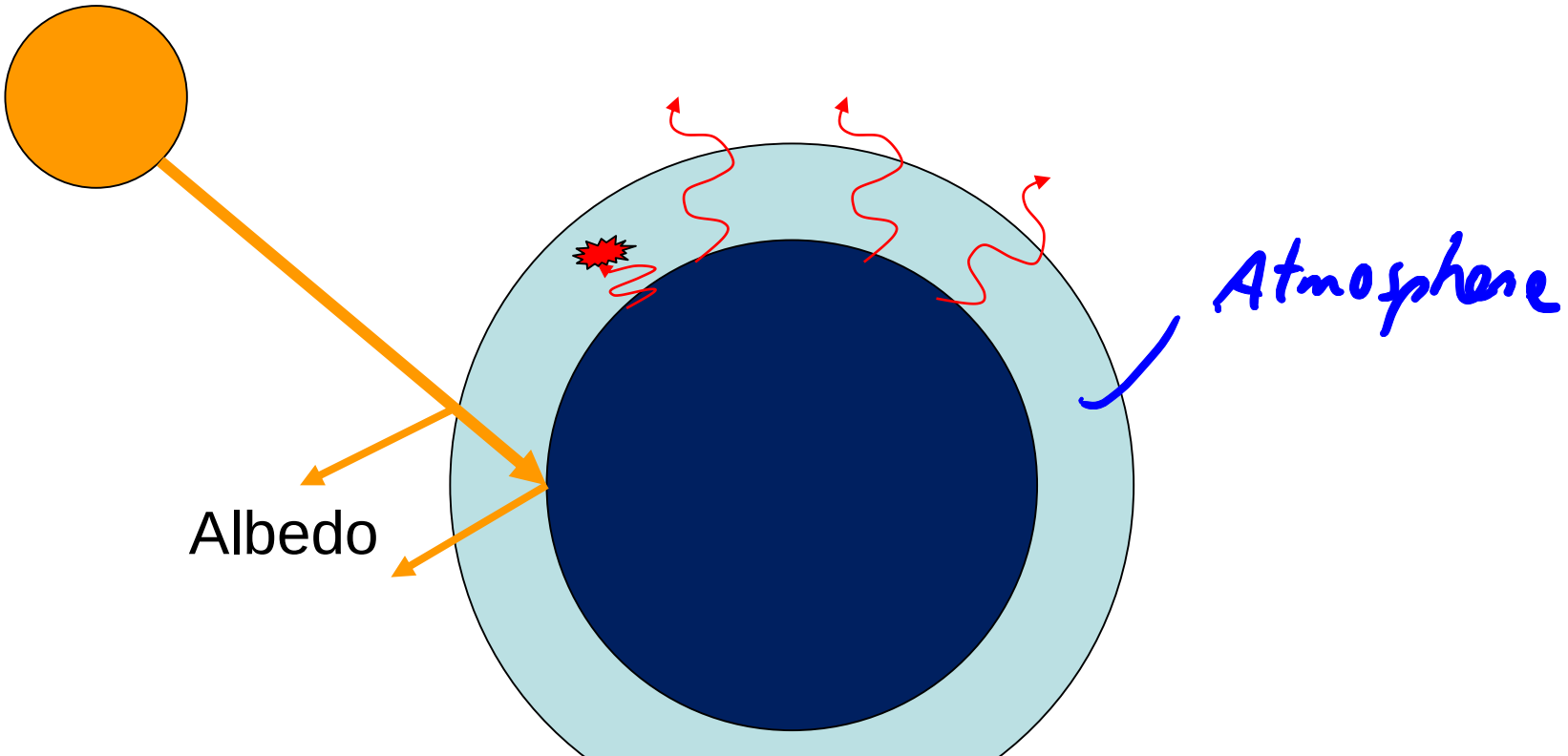

Global "Climate Model": Take 2

Simplifying Assumptions

1. The atmosphere absorbs only ***outgoing*** "terrestrial" *radiation (**no absorption** of solar radiation)*

2. The atmosphere absorbs the same fraction of terrestrial radiation at each wavelength.

efficiency of absorption ≡ ε "epsilon"
fraction 0 → 1 of OLR absorbed by atmosphere

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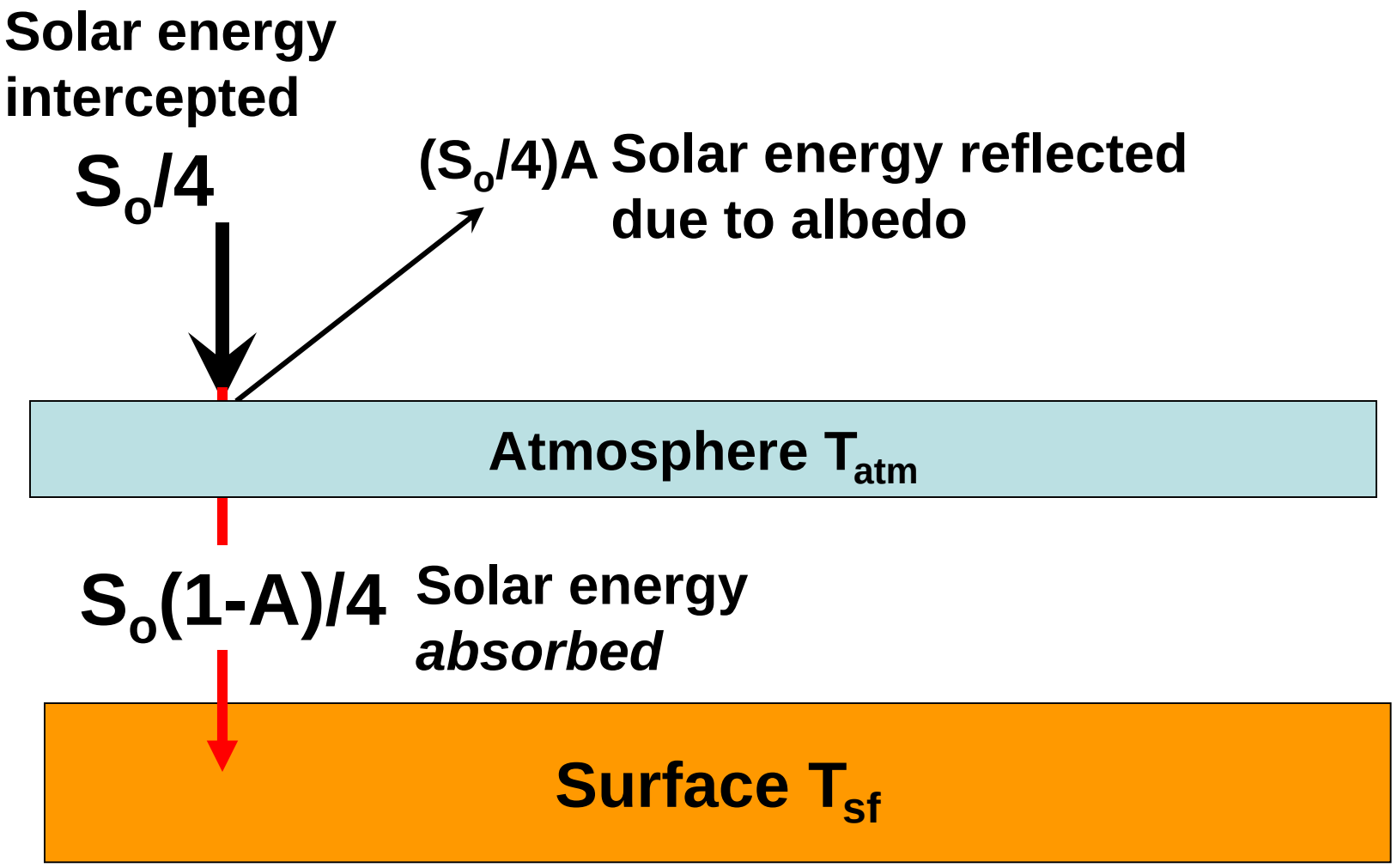
3. The atmosphere has a single temperature.

4. $F_{in} = F_{out}$ for each component and whole system.

Global Climate Model: Take 2



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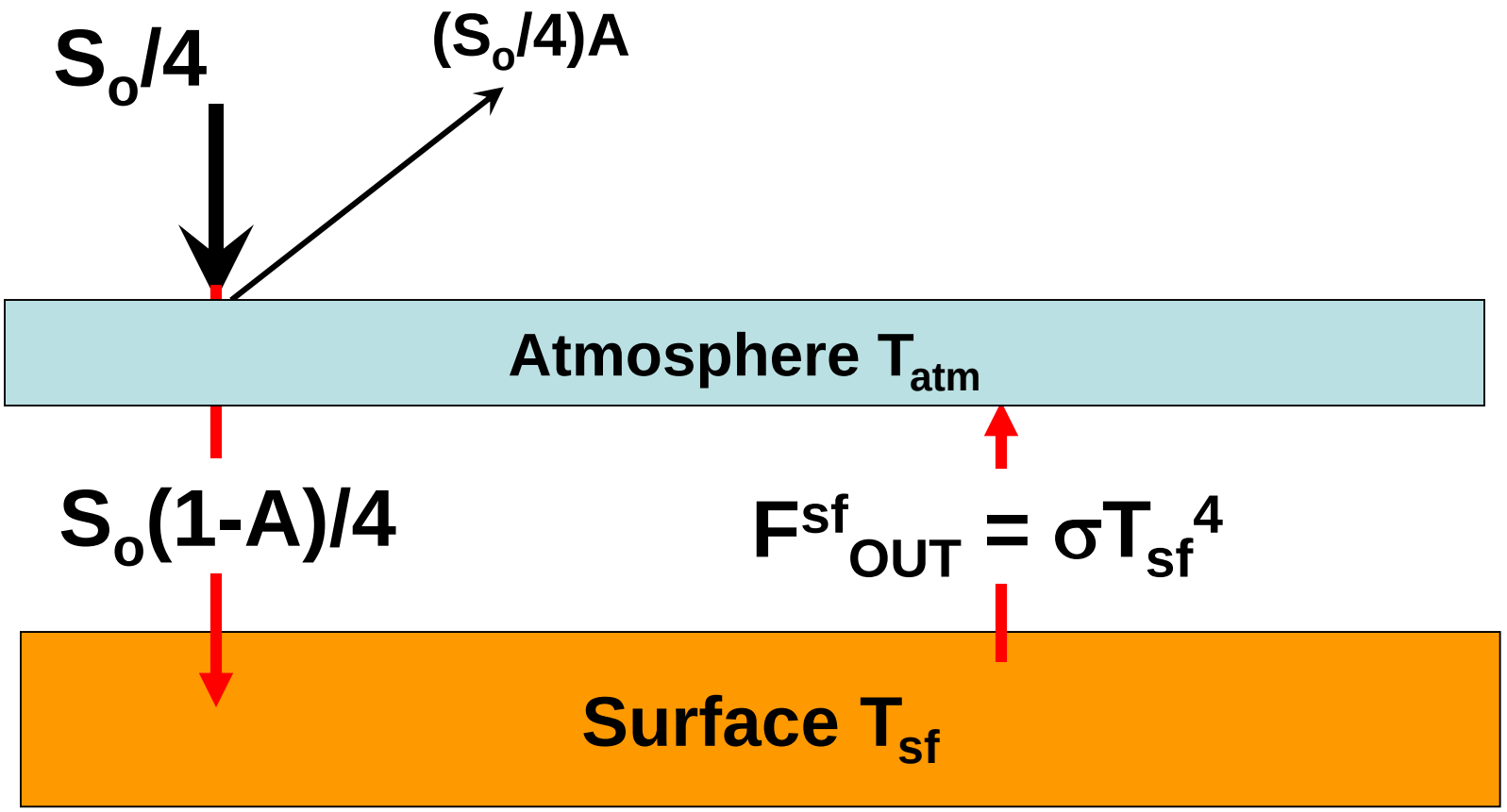

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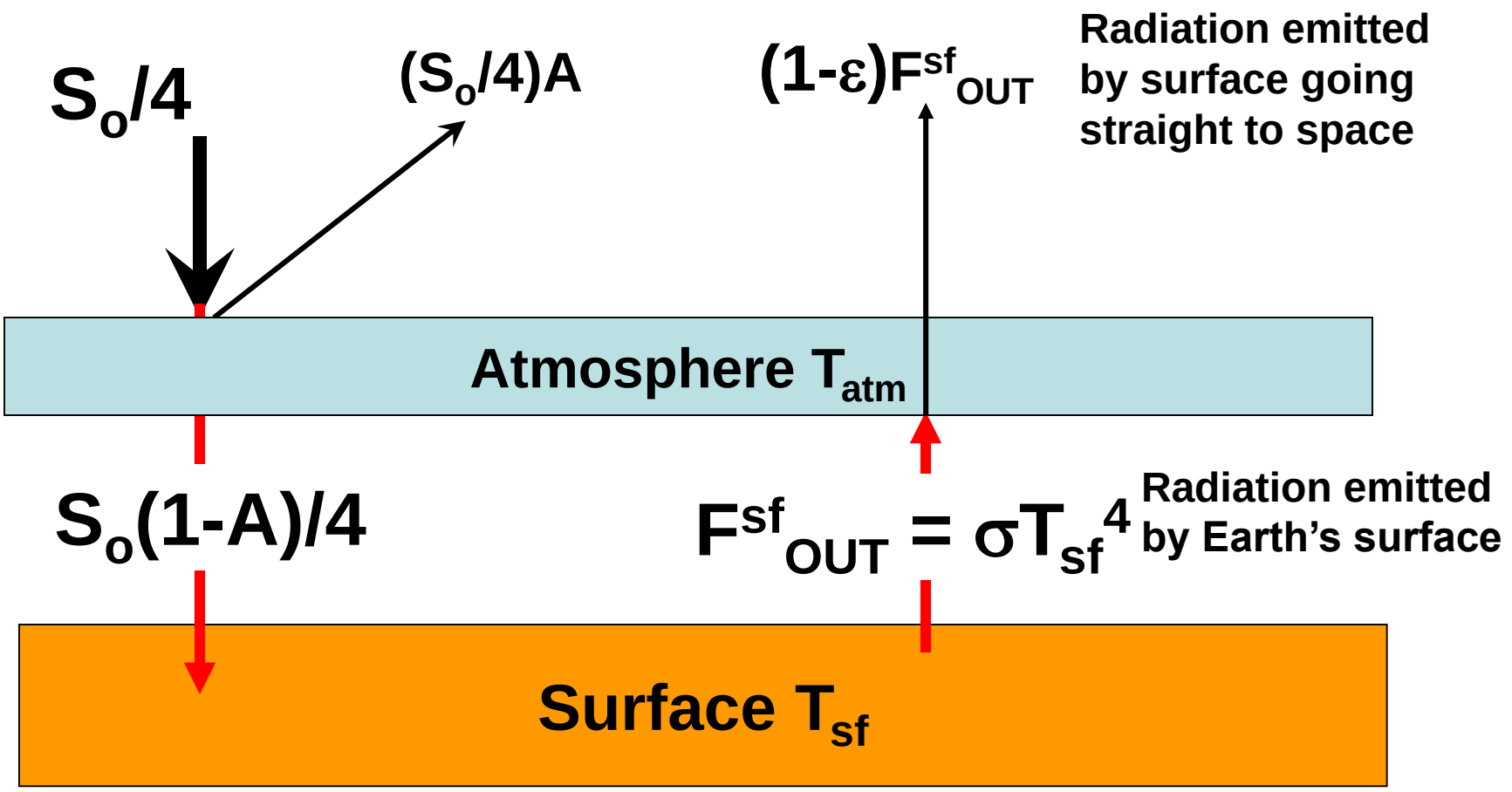
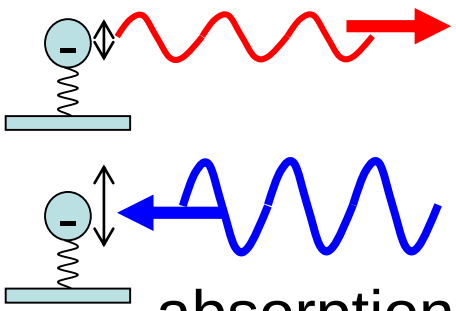


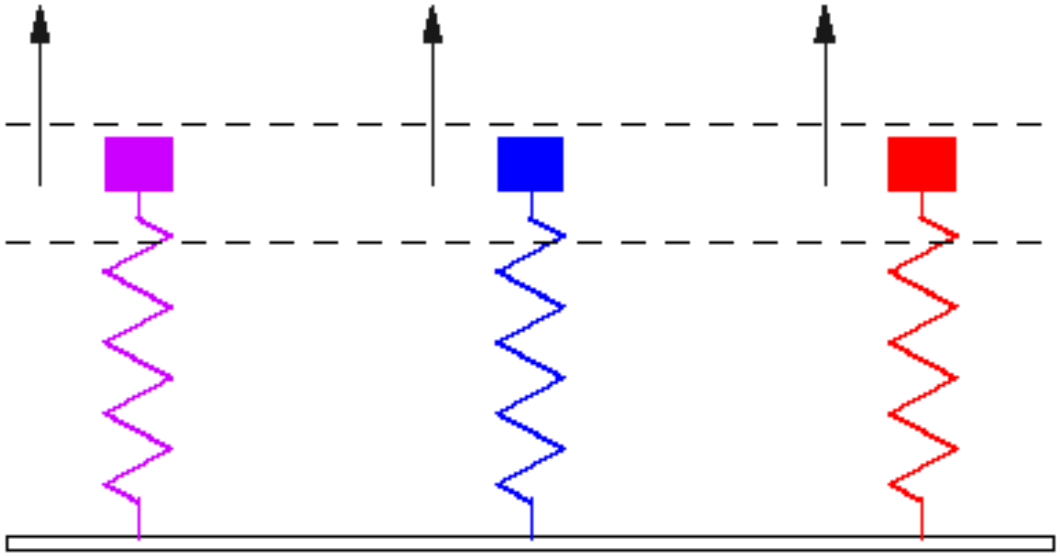
Non-Blackbodies (<100% absorption)



emission

absorption

The same springs (represent “matter”) forced with three different frequencies

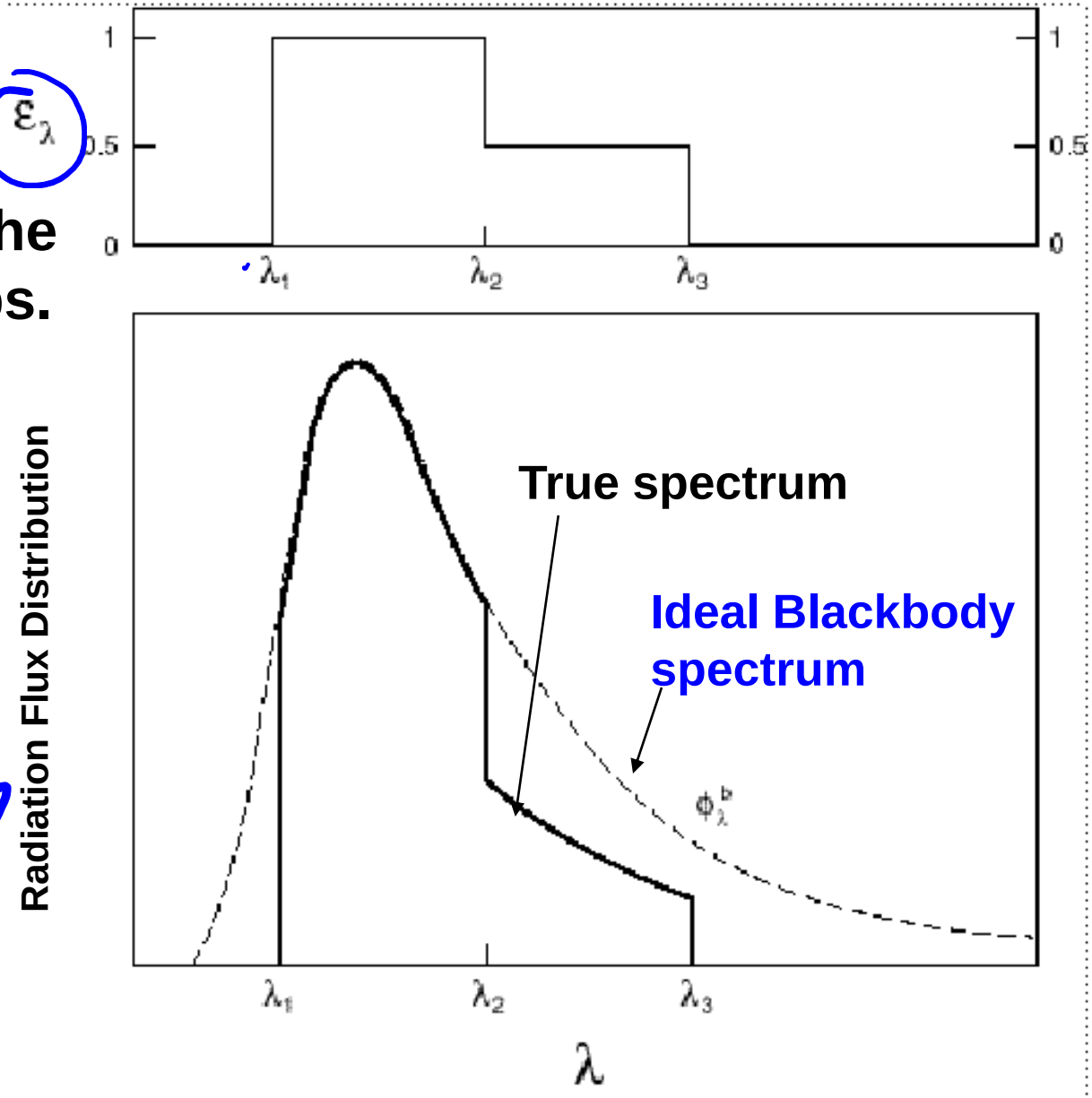


Kirchoff's Law: Imperfect Blackbody

Object will only emit the wavelengths it absorbs.

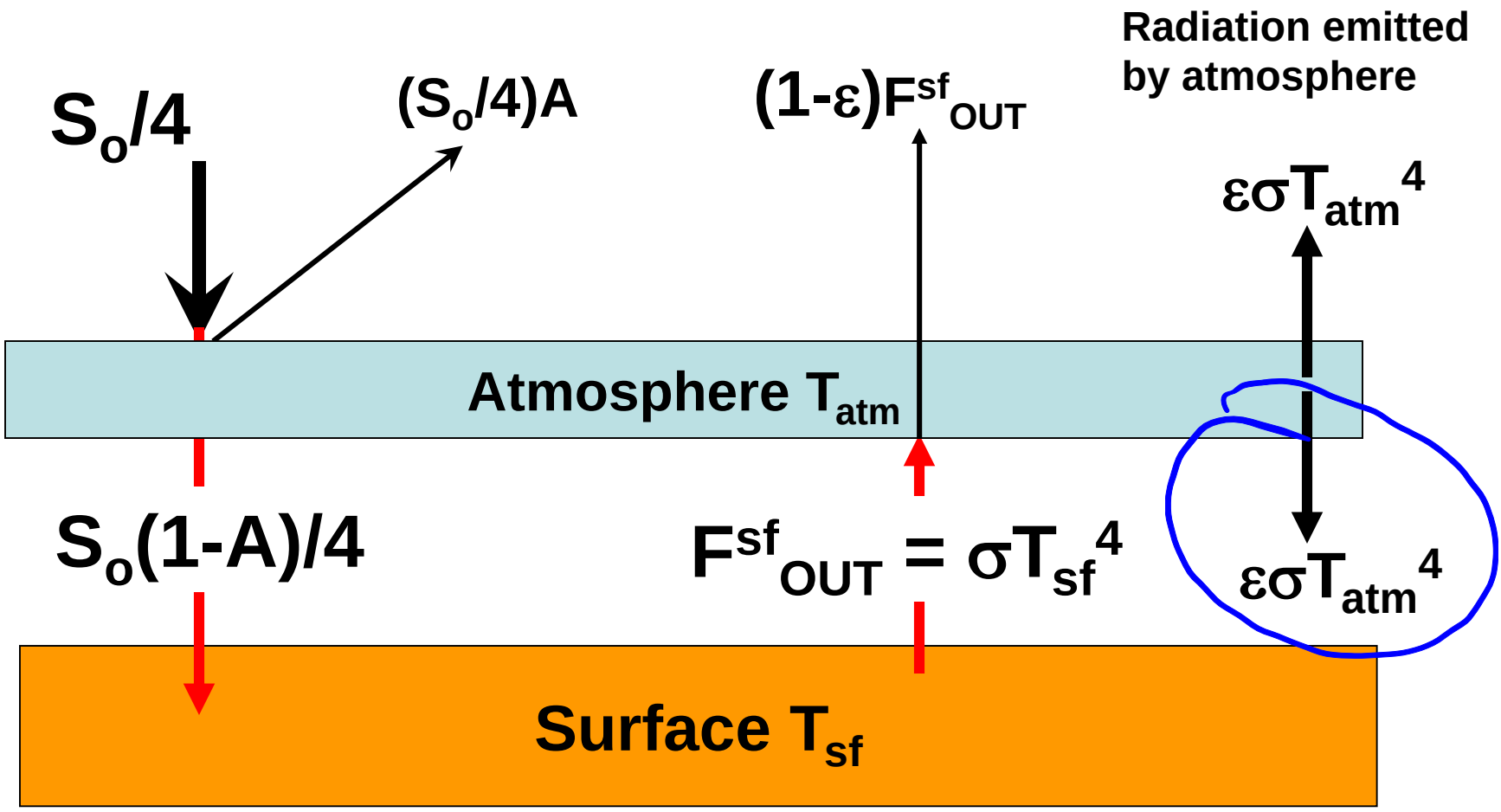
$F_{out} = \varepsilon \sigma T^4$

↑ scale total flux radiation by absorptivity



Global Climate Model: Take 2

$F_{in} = \left(\frac{S_0(1-A)}{4} + \varepsilon \sigma T_{Atm}^4 \right)$



Global "Climate Model": Take 2

$$T = \left[\frac{S_o(1-A)}{4\sigma\left(1-\frac{\varepsilon}{2}\right)} \right]^{\frac{1}{4}}$$

new!

absorptivity of atmosphere

This is the one you should wear, sleep on, put it on your cereal box, …

Global Climate Model: Take 2

$$T_{Earth}^{sf} \sim \left[\frac{246}{\sigma \left(1 - \frac{\bar{\varepsilon}}{2} \right)} \right]^{\frac{1}{4}}$$

If $\varepsilon \sim 0.75$, then $T_{surface} \sim 289$ K

Poll

If the absorptivity of Earth's atmosphe

increases, Earth's surface temperature

Visual settings

Activate

Show results

Show correct

Lock

Clear results

Fullscreen

Poll locked. Responses not accepted.

- increase
- decrease
- stay the same

Next

Previous

Total Results: 0