The global energy balance #2

ATM2106

Last time

- Planetary emission temperature
- The atmospheric absorption spectrum
- The greenhouse effect
- **Climate feedbacks**
- **Variability**

4. Climate feedbacks

- A climate sensitivity associated with the blackbody radiation is

$$\frac{\partial T_s}{\partial Q_{BB}} = (4\sigma T_e^3)^{-1} \quad = 0.26\ \mathrm{K}\ (\mathrm{W\ m^{-2}})^{-1}$$

- A combined climate feedback by blackbody and water vapor processes.

$$\frac{\partial T_s}{\partial Q_{BB,H_2O}} = 0.5\ \mathrm{K}\ (\mathrm{W\ m^{-2}})^{-1}$$

4. Climate feedbacks

- How fast the Earth comes back to equilibrium?
  - Suppose there was a increase of T_e by ΔT because of a change in the climate forcing (ex. Doubling CO_2)
  - Then, suppose that we were lucky to revert the CO_2 level in the atmosphere to the original value.
  - What we can expect to see is the decrease of the T.
  - How long does it takes for T to become T_e?

4. Climate feedbacks

- We can use this equation: $$C\frac{dT}{dt} = E_{in} - E_{out}$$

- Using the expression for E_{in} and E_{out} in equilibrium:

$$C\frac{dT}{dt} = (1-\alpha)\frac{S_0}{4} - \sigma T_e^4 = 0$$

- A climate forcing will change T_e to $T_e + \Delta T$, and

$$C\frac{dT}{dt} = (1-\alpha)\frac{S_0}{4} - \sigma\left(T_e + \Delta T\right)^4$$

4. Climate feedbacks

- If we solve this partial differential equation for T(t), then we can find out the time change of T.

$$C\frac{dT}{dt} = (1-\alpha)\frac{S_0}{4} - \sigma\left(T_e + \Delta T\right)^4$$

- The solution for $T(t) = T_e + \Delta T(t) = T_e + \Delta T_0 \exp(-t/\tau)$

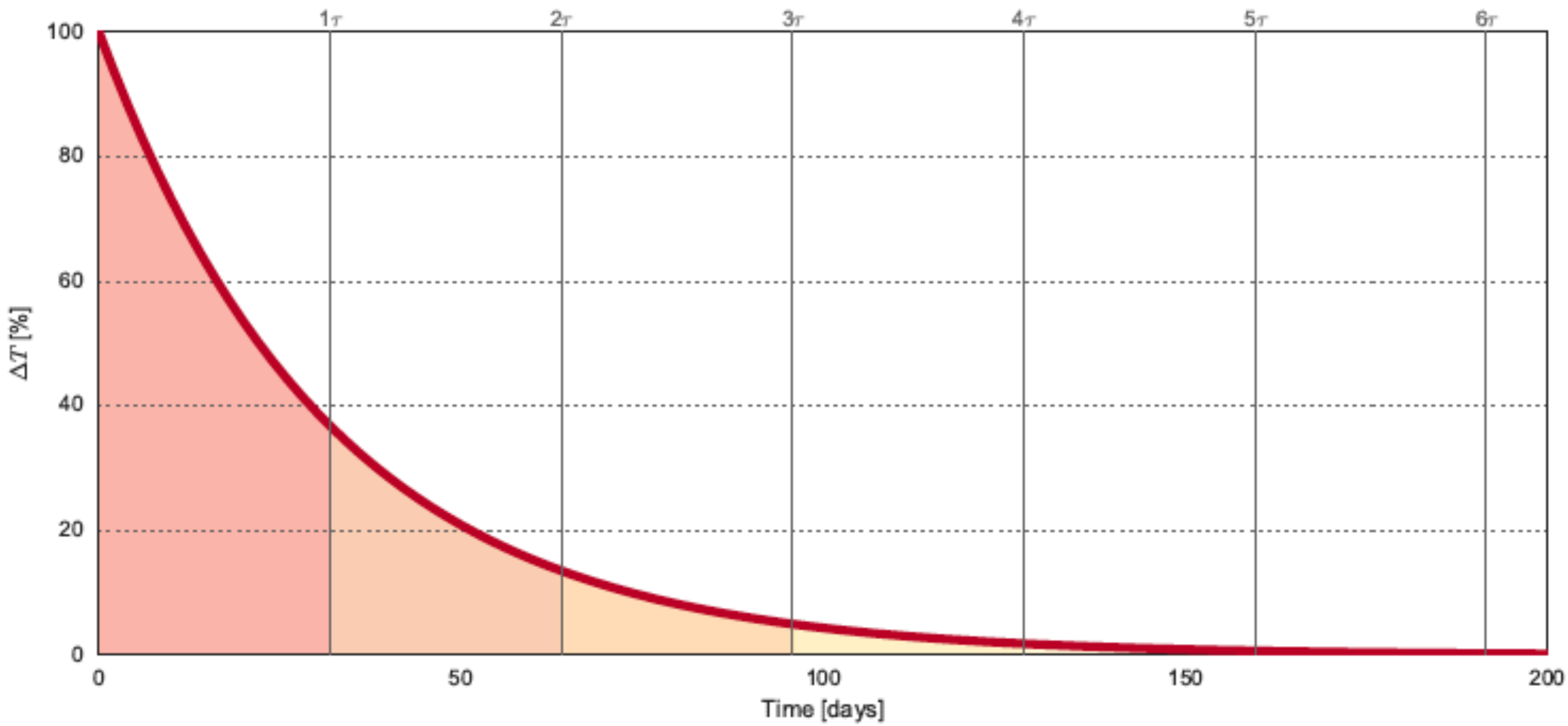
$$\tau = \frac{C}{4\sigma T_e^3}$$

≈ 32 days

- What does this solution suggest?

4. Climate feedbacks

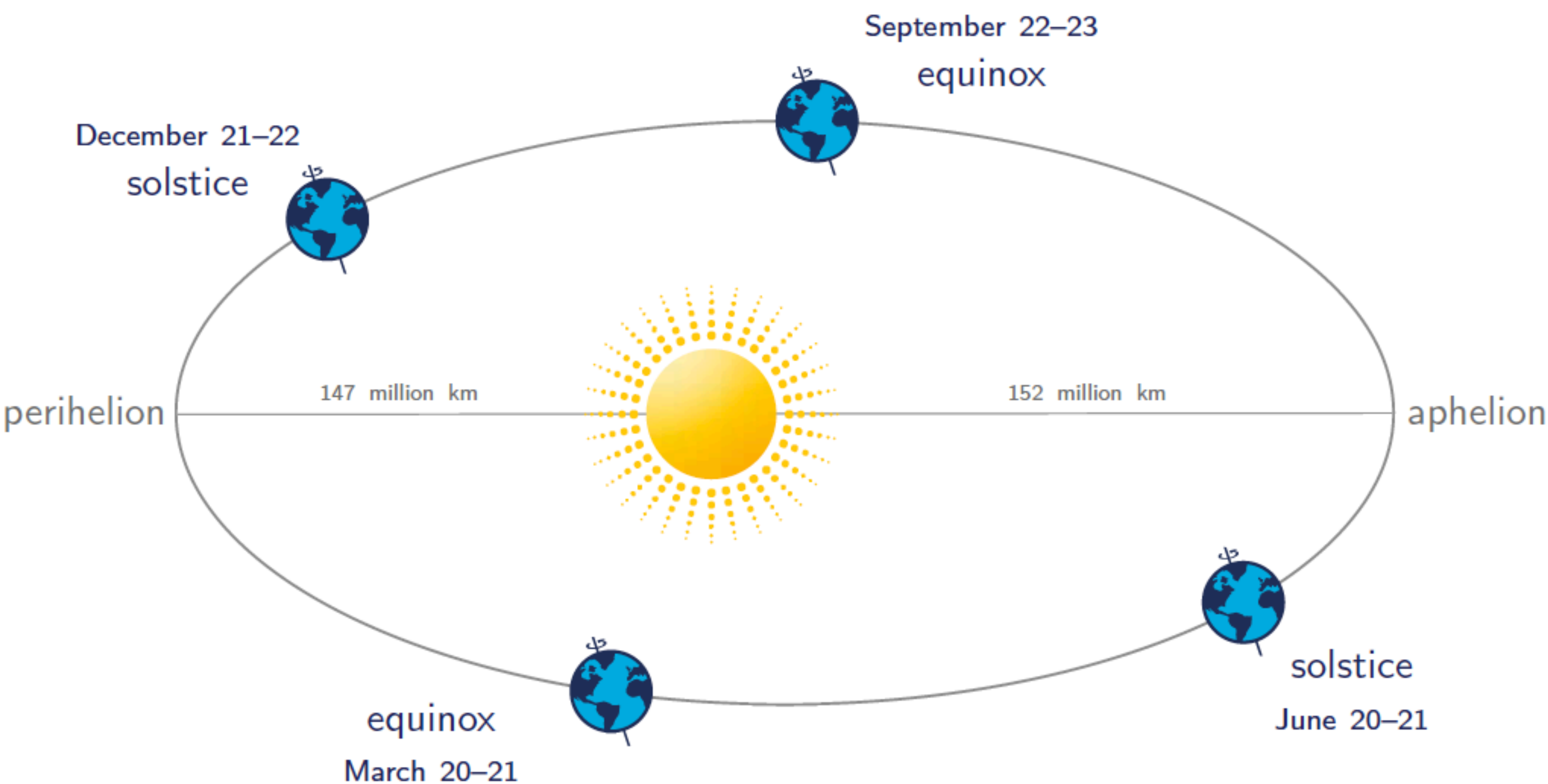
Radiative relaxation timescale $\tau = \frac{Mc_p}{4\sigma T_{\mathrm{e}}^3} \approx 32\,\mathrm{days}$



$$\boxed{\Delta T(t) = \Delta T_0 e^{(-t/\tau)}}$$

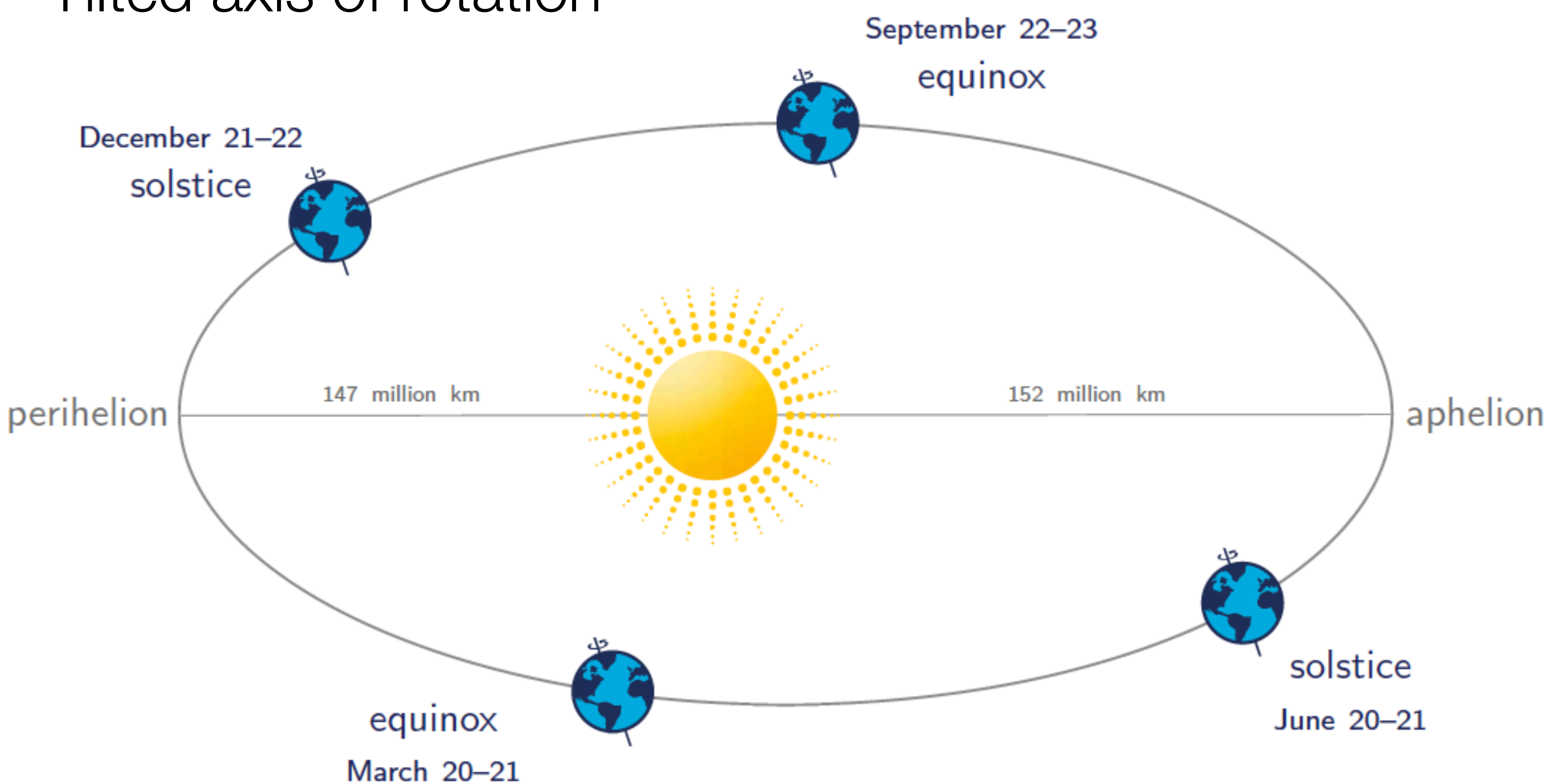
5. Seasonal variability

- The Earth follows on the elliptical orbit around the sun.



5. Seasonal variability

- The Earth follows on the elliptical orbit around the sun.
- Tilted axis of rotation



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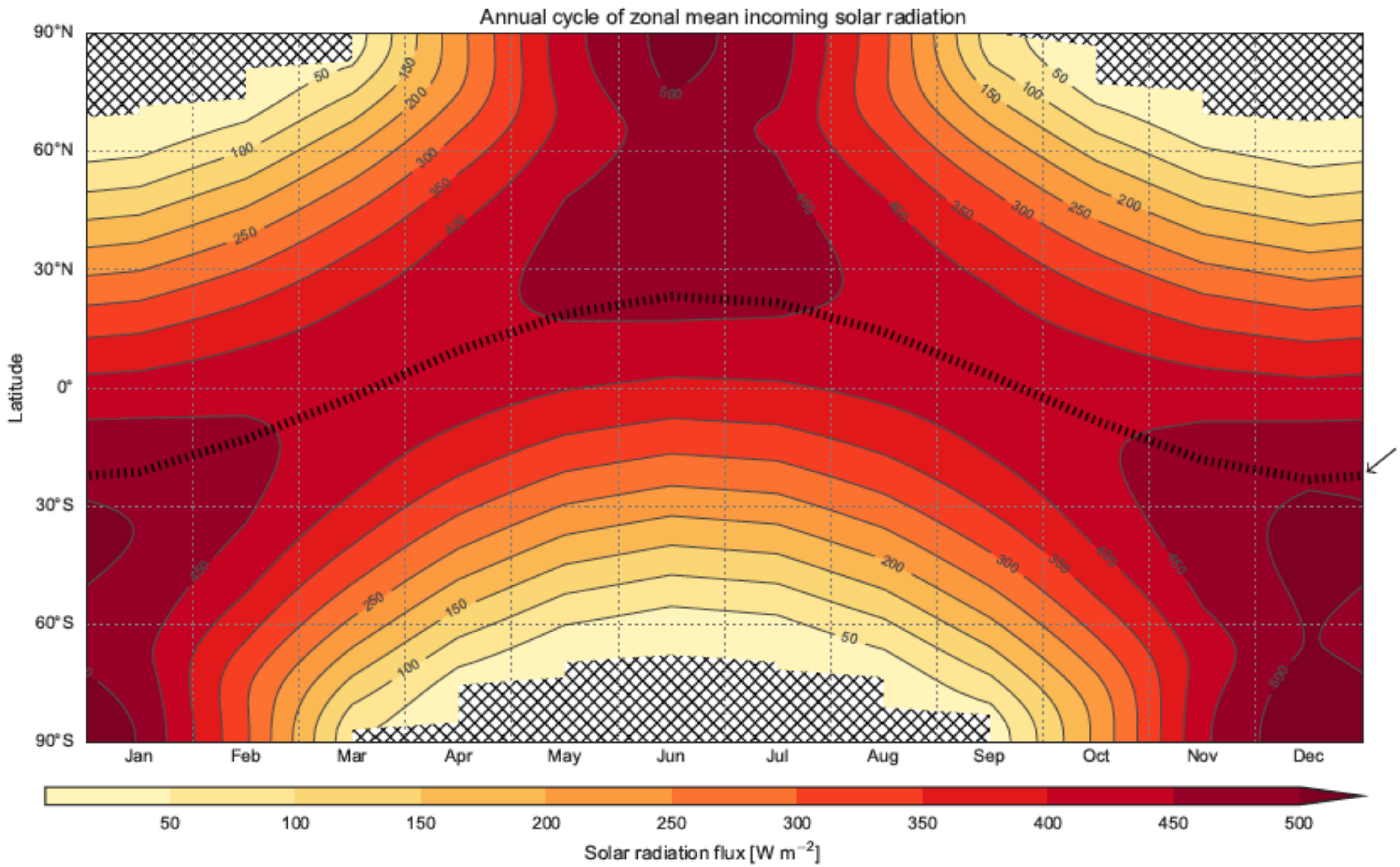

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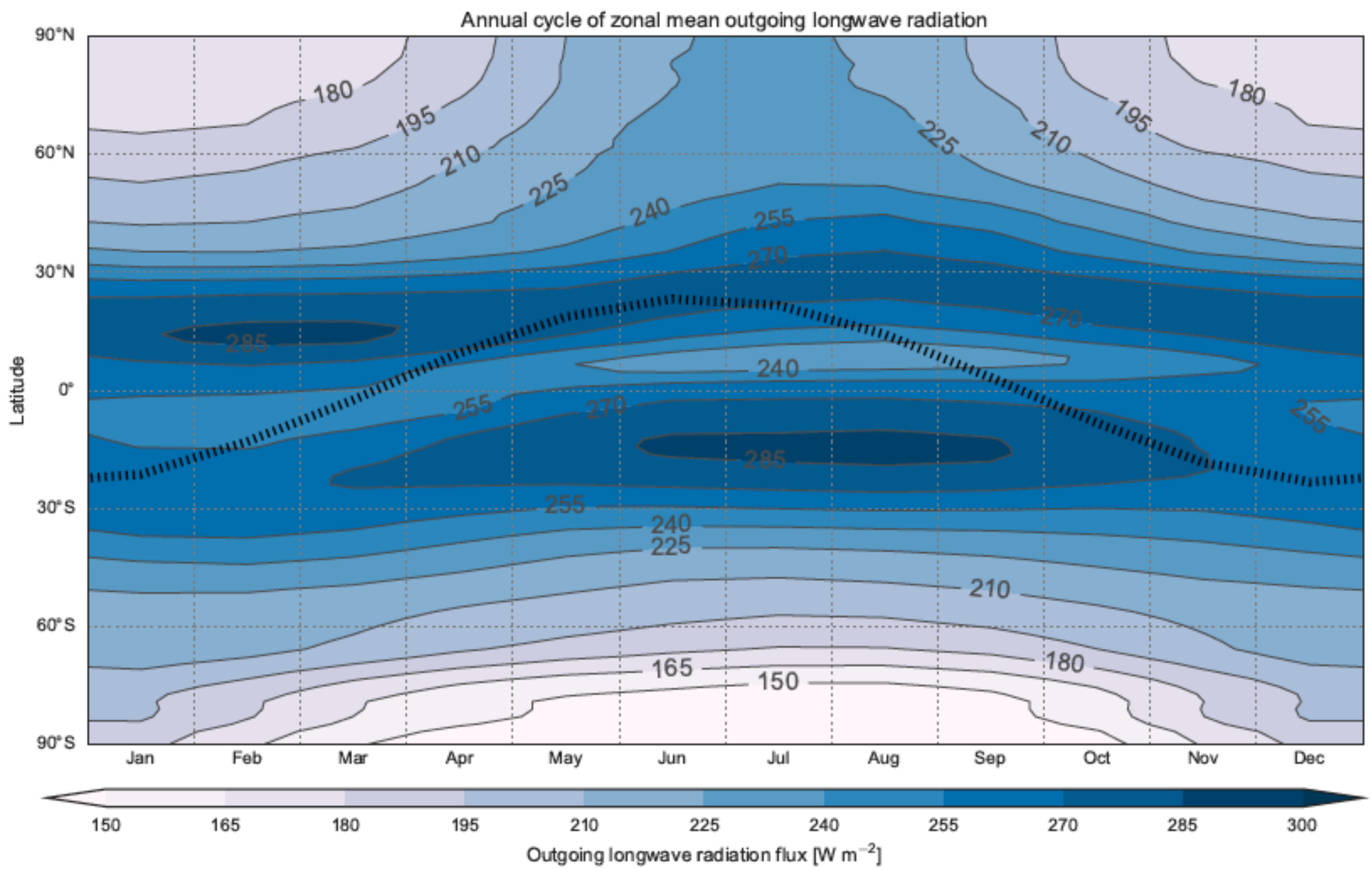

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