AOSC201: Weather and Climate Lab

Week 10: Climate

Sections 103/105

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Stefan-Boltzmann Law

$$E = \sigma A T^4$$

- Relates the energy given off by an object to the temperature of the object
- E = energy, σ = Boltzmann constant, A = area (in the case of this lab, the area of Earth), T = temperature
- We can substitute the amount of solar energy striking earth for energy (E)

$$S \pi R_e^2 = \sigma A T^4$$

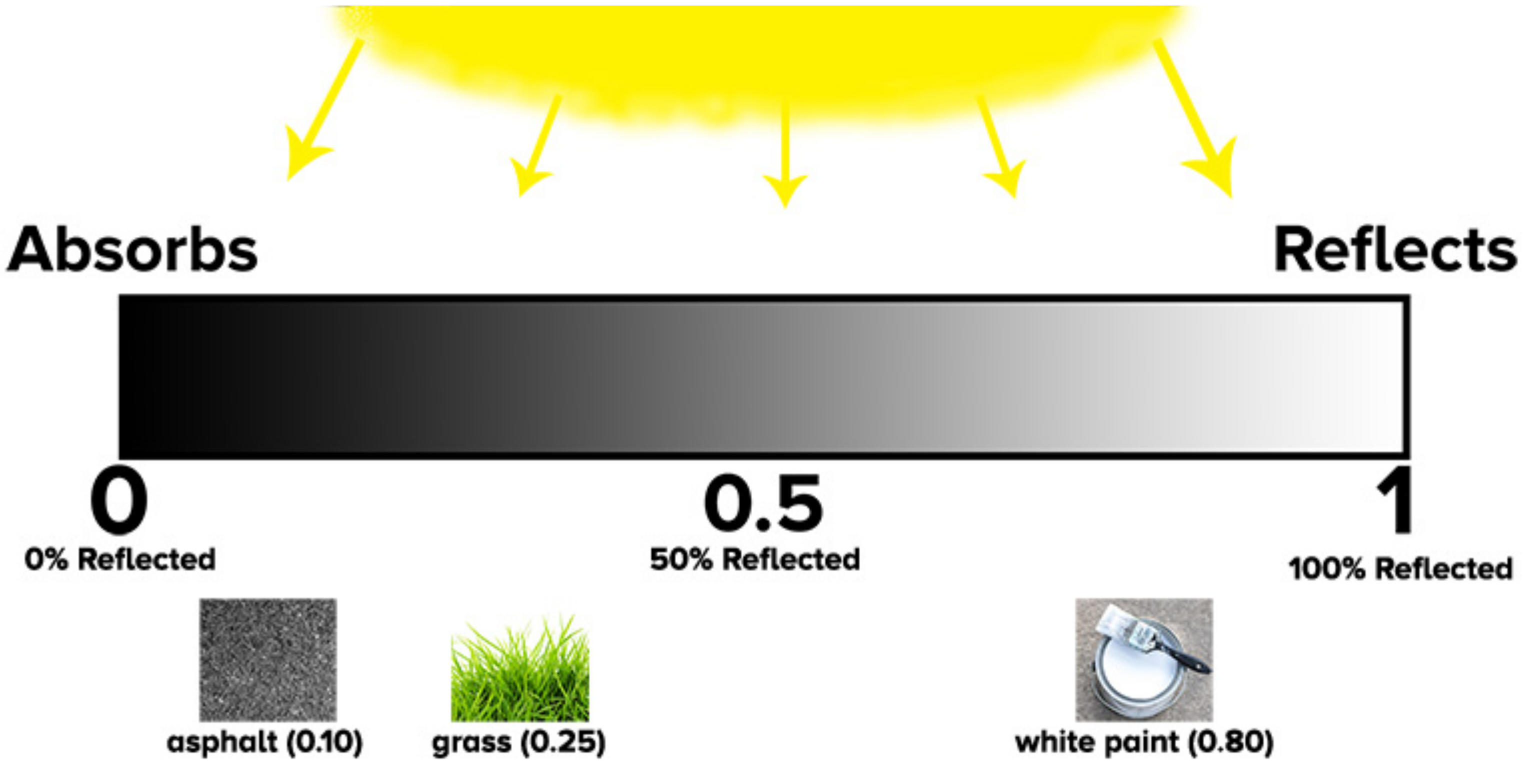
- Where S is the solar constant (what is emitted by the sun) and R_e is the radius of the Earth

Albedo

- An object's albedo is equivalent to the amount of sunlight it reflects (as a percentage of total sunlight it interacts with)
- Objects with high albedo (~1) reflect a lot of solar radiation
- Objects with low albedos (~0) absorb a lot of solar radiation

- A planet's albedo can affect its temperature
  - Just because a planet is close to the sun doesn't mean it is hot → it could have a large albedo

- If albedo = α, then the absorption of an object is equal to $(1-\alpha)$


Absorbs
Reflects
0
0% Reflected
0.5
50% Reflected
1
100% Reflected
asphalt (0.10)
grass (0.25)
white paint (0.80)

Albedo

Effective Temperature

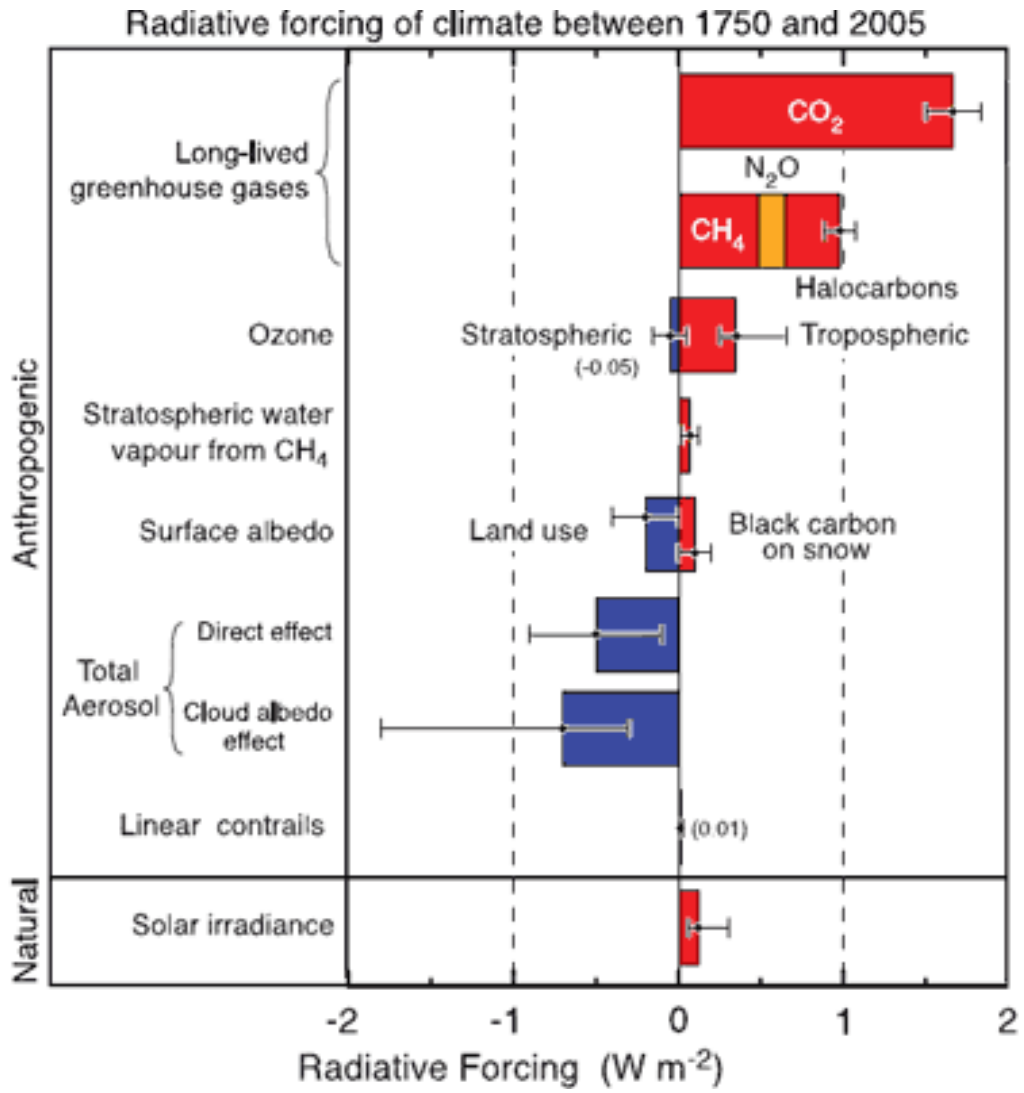
- We can find the temperature we'd expect a planet to have (assuming it has no atmosphere) by taking into account its albedo → this temperature is called the **effective temperature**

- We can find this temperature by rearranging the Stefan-Boltzmann law and using the **surface-absorbed** radiation in place of S, the solar constant
  - Hint: S is the solar radiation that makes it to earth, but we want to find the amount of solar radiation that is **absorbed** by the earth
  - Must take albedo into account

Greenhouse Gases (GHGs)

- Because the distance from the sun has only *some* effect on a planet's temperature, we need to diagnose why some planets have high temperatures
  - Answer: presence of greenhouse gases and a thick atmosphere

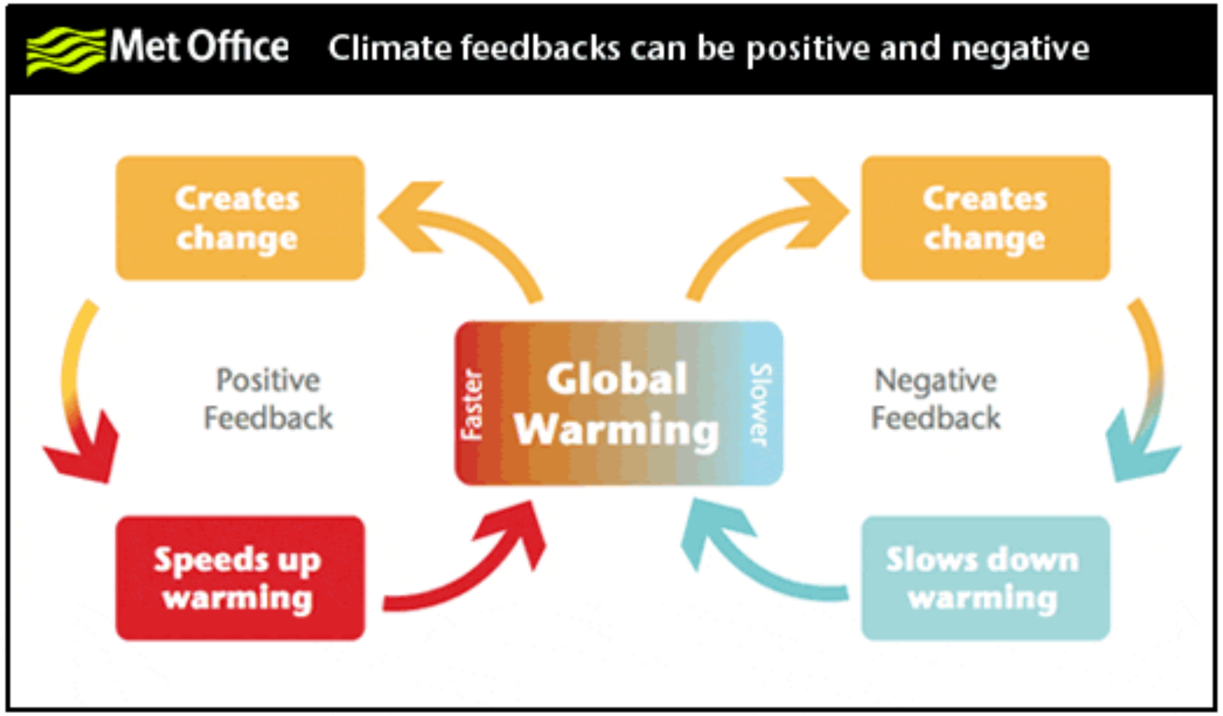
- GHGs absorb infrared radiation, warming the atmosphere
  - Common GFGs: carbon dioxide, nitrous oxide, ozone, CFCs and HFCs, methane, etc
  - We can compute how much radiation these gases absorb (radiative forcing), as well as their effect on average global temps



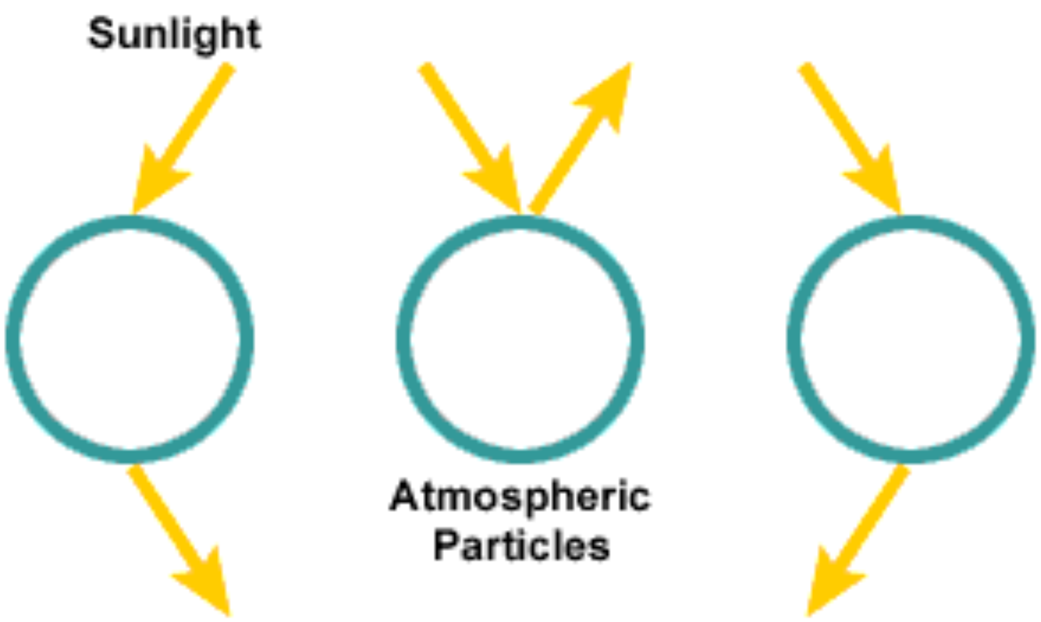
Climate feedbacks

- Change in the climate which has an effect that then causes further climatic change

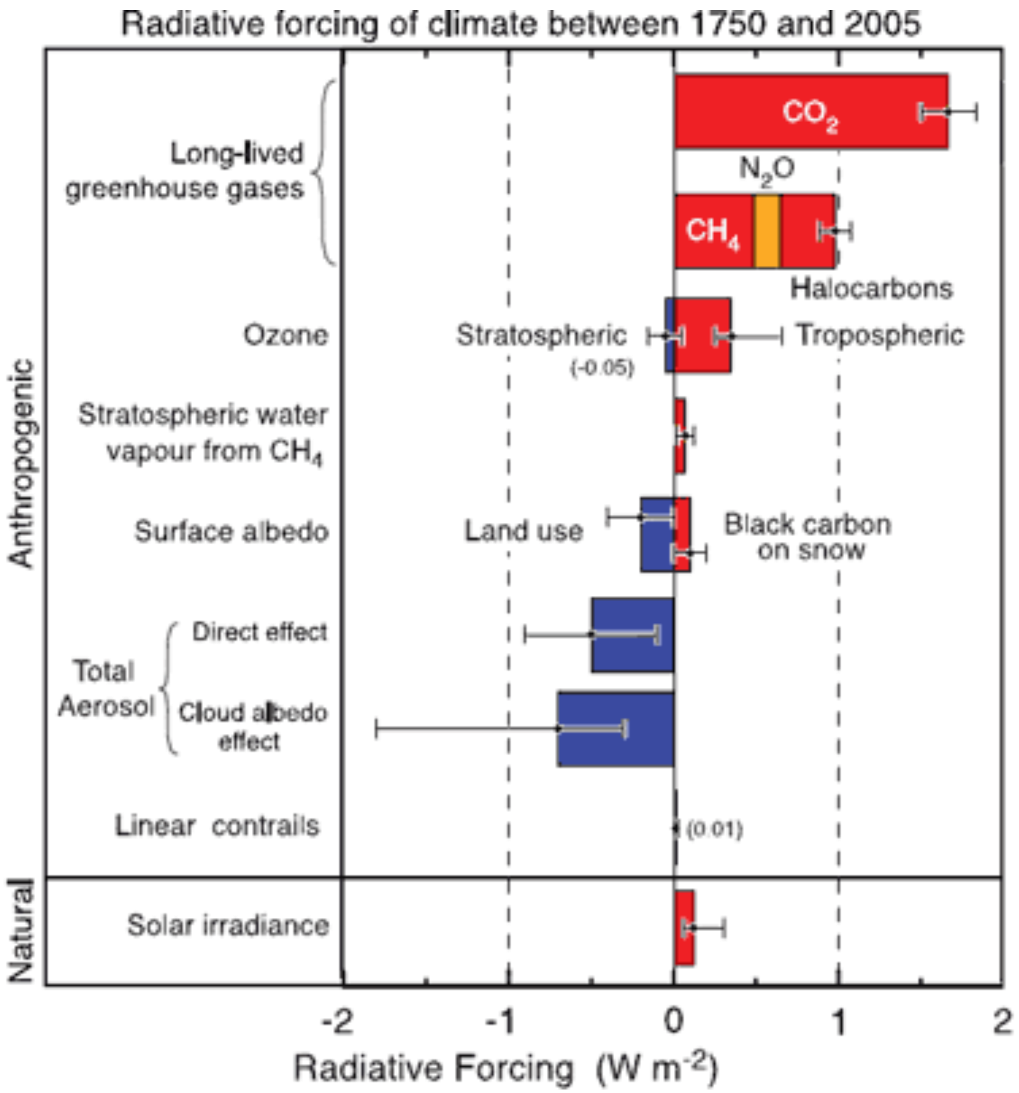
- Ex: ice-albedo feedback
    - Increasing temperatures increases the rate at which ice melts → exposes more ocean water (albedo decreases) → oceans warm → more ice melts
- Need to account for feedbacks in order to determine how much GHG have actually raised global temps



Aerosols



Sunlight
Atmospheric Particles



Radiative forcing of climate between 1750 and 2005
Long-lived greenhouse gases
CO2
N2O
CH4
Halocarbons
Ozone
Stratospheric
(-0.05)
Tropospheric
Stratospheric water vapour from CH4
Surface albedo
Land use
Black carbon on snow
Total Aerosol
Direct effect
Cloud albedo effect
Linear contrails
(0.01)
Solar irradiance
Anthropogenic
Natural
-2
-1
0
1
2
Radiative Forcing (W m-2)

Aerosols

- Aerosols are solids or liquids suspended in the atmosphere
  - Can be natural (sea spray) or anthropogenic (soot)

- Aerosols reflect and scatter incoming solar radiation
  - Typically have a cooling effect on the surface (except for black carbon, which absorbs solar radiation)

- Must account for feedbacks **AND** aerosols when determining how much anthropogenic activity has increased global temperatures

- As we clean our air and decrease aerosols in the atmosphere, we may lose the cooling effect that aerosols provide (this is why research is important and proactivity is required)