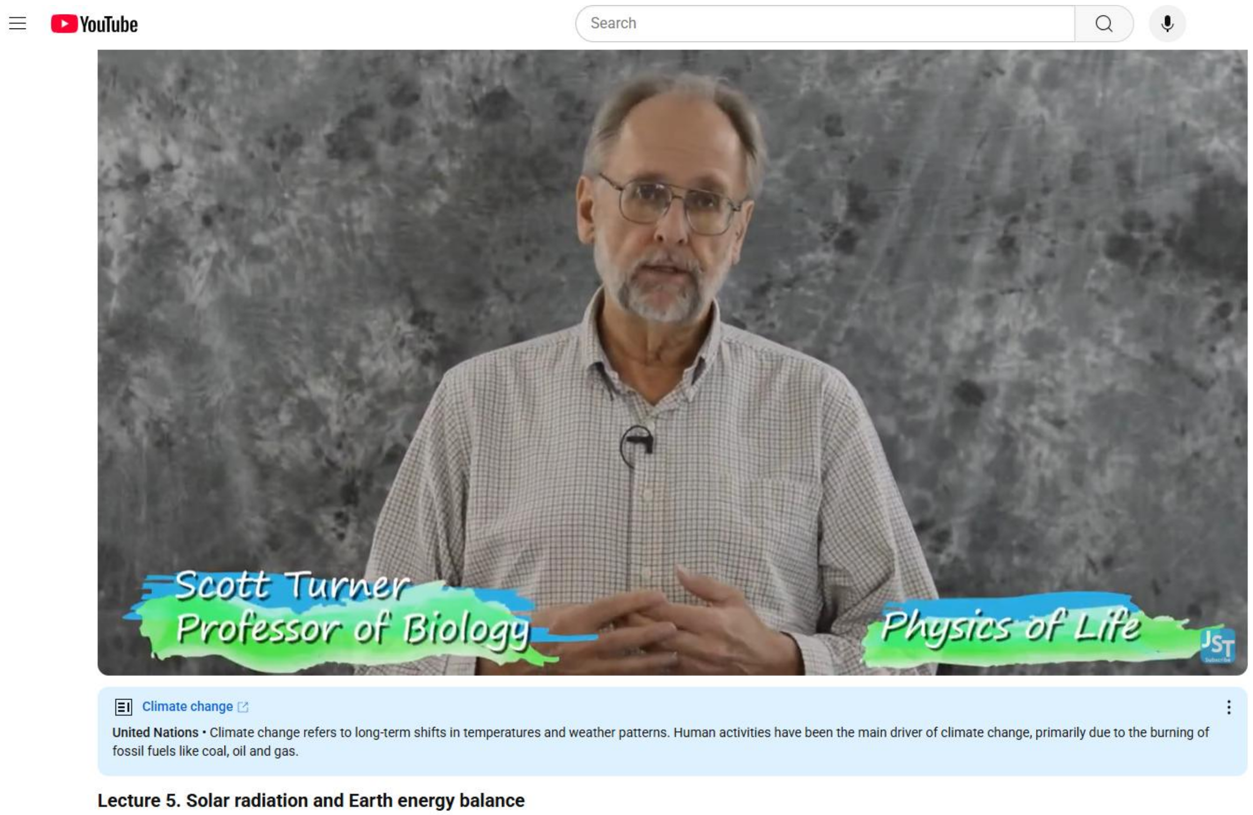
GEO409-FS2026 (3 credits)

Sep 14: Greenhouse Effects on Global Climate & Change

- What is greenhouse effect?
- Major Greenhouse Gases (GHG)



Reading

Chen, J., C. Lei, and P. Sciusco, 2021. Modeling Ecosystem Global Warming Potentials. In *Biophysical Models and Applications in Ecosystem Analysis* (pp. 121-126). MSU Press.

NASA Video:

https://www.youtube.com/watch?v=bk6mCWfVtbw

GEO409-FS2026

Term Papers and Presentations

Update

1) Guidelines for presentations and term papers will be provided on Sept. 21.
2) Quiz 1 and a student survey will also be conducted on Sept. 21.
3) Lecture notes in PDF format will be reposted after each class.
4) A reminder that the Dec. 7 lecture has been moved to Dec. 2 at the MSU Museum.
5) A new reading will **NOT** be assigned until September 23.

Student Name	Topic for Term Paper
Middleton, Danielle Rae	11: Impacts of Climate Change on People and Society
Singh, Aastha	11: Impacts of Climate Change on People and Society
Wax, Stephen Michael	11: Impacts of Climate Change on People and Society
Banek, Gabriel Joseph	7: Climate Change Impacts on Ecosystems
Ismail, Hassan	7: Climate Change Impacts on Ecosystems
Haddix, Morgan	7: Climate Change Impacts on Ecosystems
Mathews, Zach H	15: Climate change imp[acts on freshwater ecosystem
Panis, Daniel J	15: Climate change imp[acts on freshwater ecosystem
Redfield, Dawson	15: Climate change imp[acts on freshwater ecosystem
Hernandez, Lilah	2: Climatic Extremes and Their Impacts
Kensler, Aliya Renee	2: Climatic Extremes and Their Impacts
Ochoa Peterson, Tj Clingfelt	2: Climatic Extremes and Their Impacts
Lee, Danah	2A: Climatic Extremes and Their Impacts
Richard, Emerson Reeh	2A: Climatic Extremes and Their Impacts
Verburg, Ava	2A: Climatic Extremes and Their Impacts
Bradke, Elliot	5: Near-Future Climate Change and Its Consequences
McLuckie, Meghan	5: Near-Future Climate Change and Its Consequences
Morales, Noah	5: Near-Future Climate Change and Its Consequences

1) Radiant emittance from the sun (T = 6000 K) varies from 0.2 nm to 3.0 nm and peaks at spectra of ~0.55 nm, with most energy coming from a wavelength of 0.3-0.7 nm (>50%). These wavelengths are loosely called “shortwave radiation” or “visible light”).

2) The Earth’s (T = 288 K) peak emittance is 9.5-10.0 nm. Earth’s temperature is mostly maintained by the balance of incoming shortwave radiation from the sun and outgoing longwave radiation from the Earth.

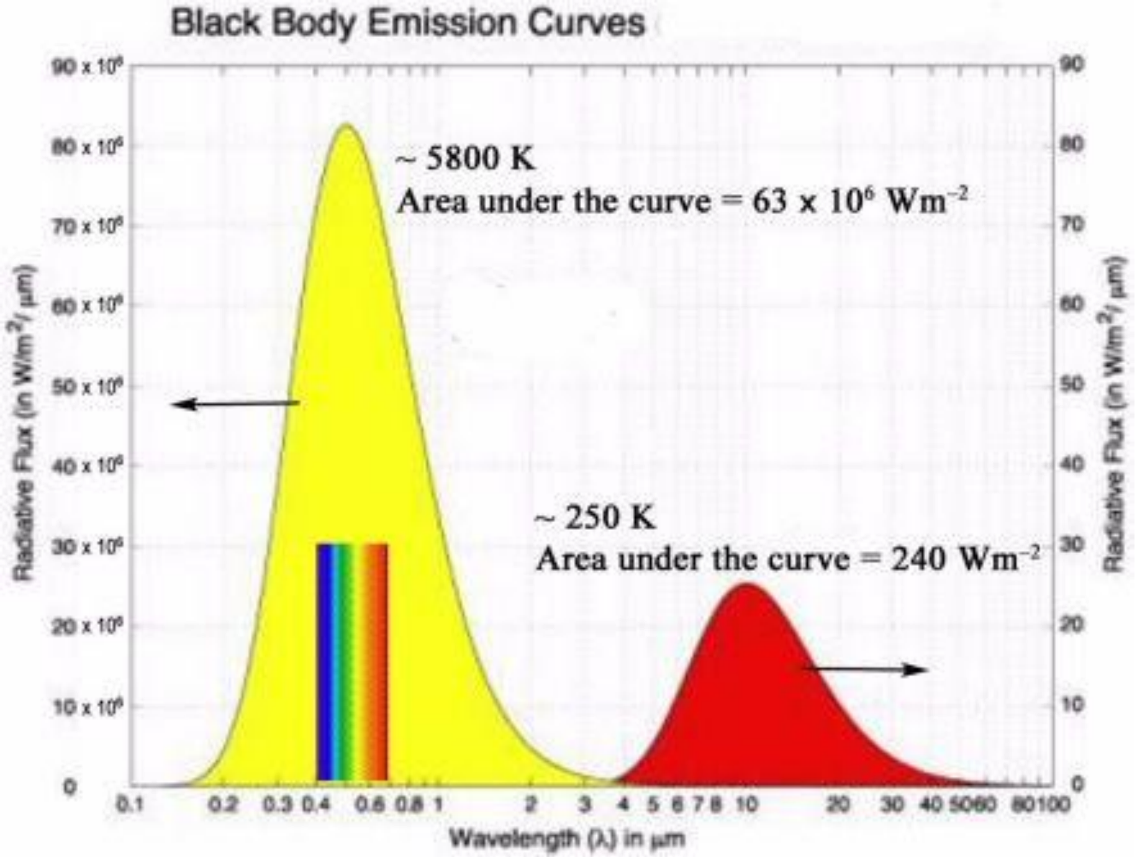
Planck’s Radiation Law describes the electromagnetic radiation emitted by a black body in thermal equilibrium at a given temperature. This is described by :

$$E = \frac{h \cdot c}{\lambda}$$

h = Planck’s constant; $6.62607015 \times 10^{-34}$ joule/s (J/s)

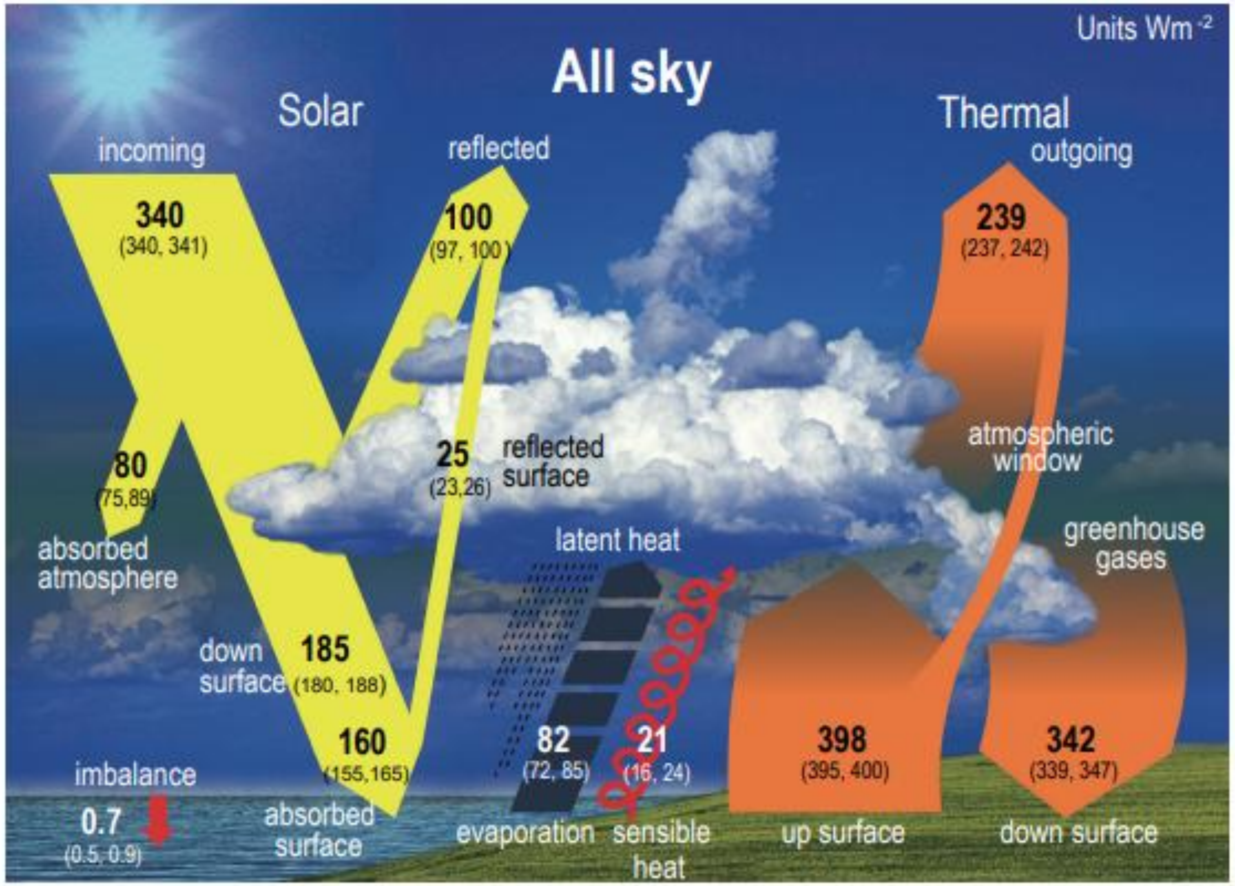
λ = frequency of radiation (nm)

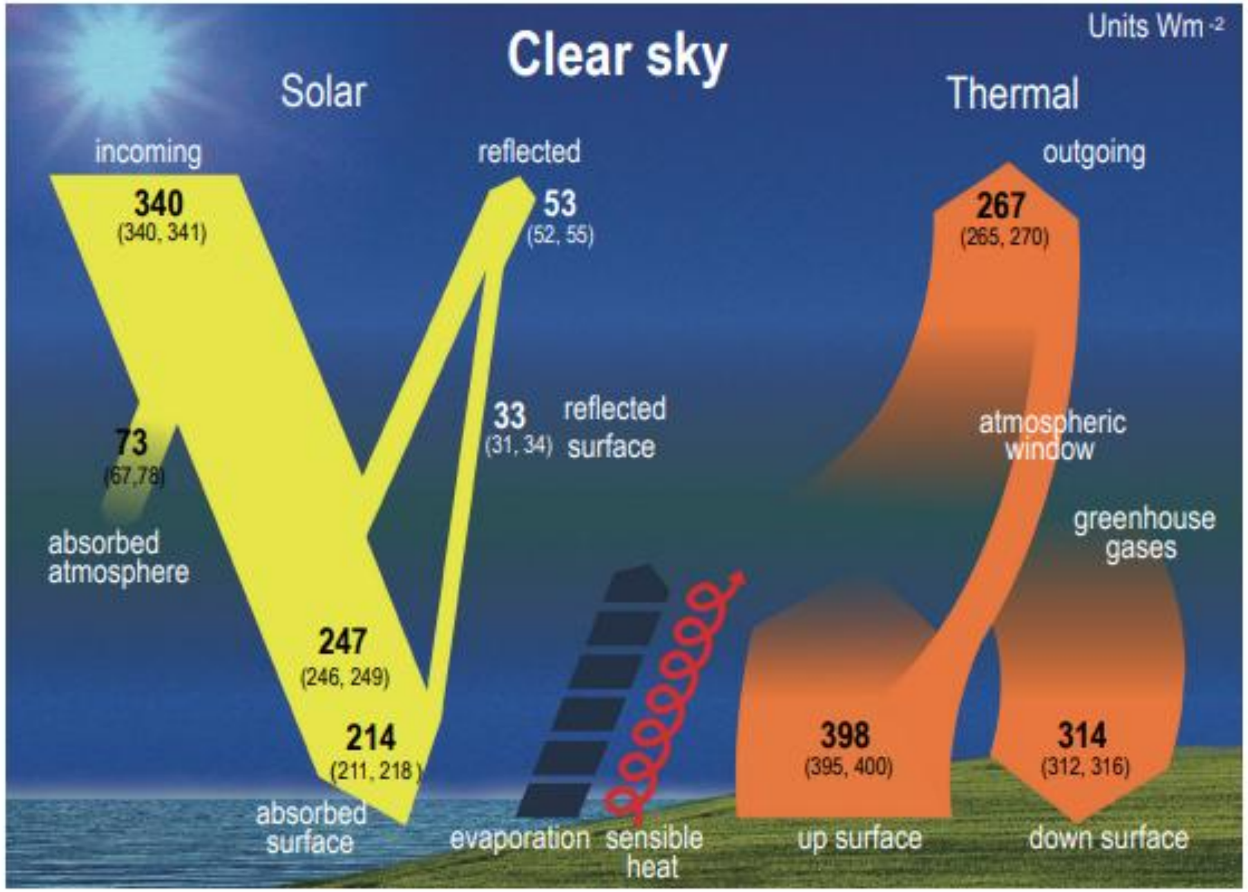
c = speed of light (m/s)



https://www.pinterest.com/pin/561964859722645297/

Figure 7.2 | Schematic representation of the global mean energy budget of the Earth. Numbers indicate best estimates for the magnitudes of the globally averaged energy balance components in W m^{-2} together with their uncertainty ranges in parentheses (5–95% confidence range), representing climate conditions at the beginning of the 21st century.





Major Terminology

Global Warming Potential (GWP)

Greenhouse Gases (GHG)

Earth System Models (ESMs)

Global Surface Air Temperature (GSAT)

Radiation Forcing (RF)

Top Of the Atmosphere (TOA)

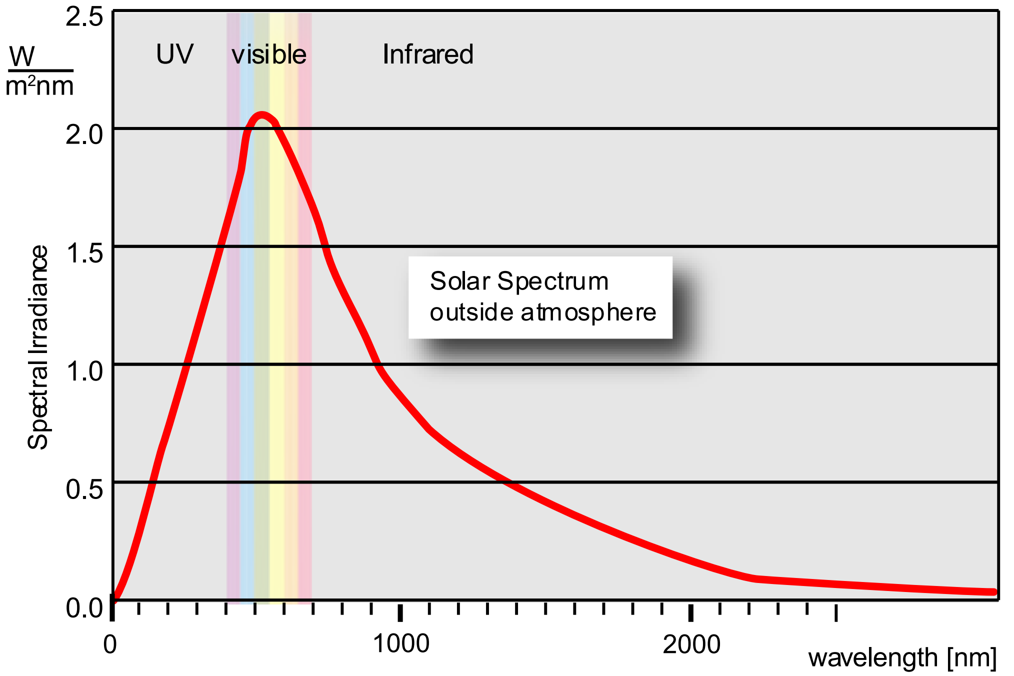
Intergovernmental Panel on Climate Change (IPCC)

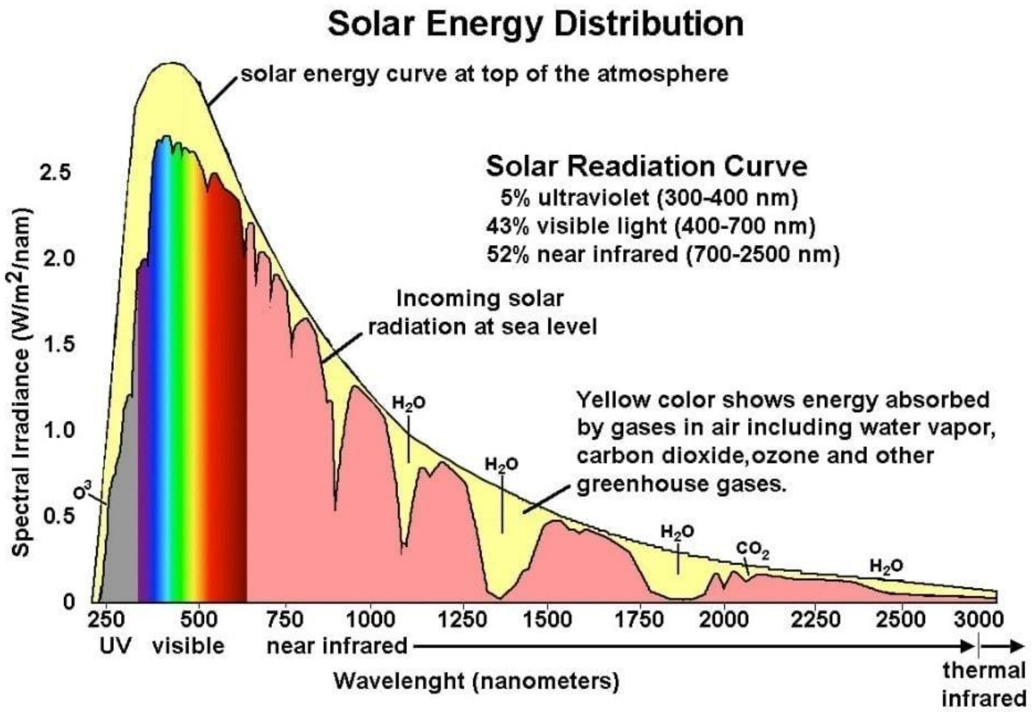
Unit & Conversations

- Temperature (Earth's temperature?)
- Wind Speed
- Energy (1 W=1 J/s)
- Solar Constant: ≈ 1361 $W{\cdot}m^{-2}$
- Stefan–Boltzmann Law
- Planck's Radiation Law
- Short- vs long-wave radiation
- ?

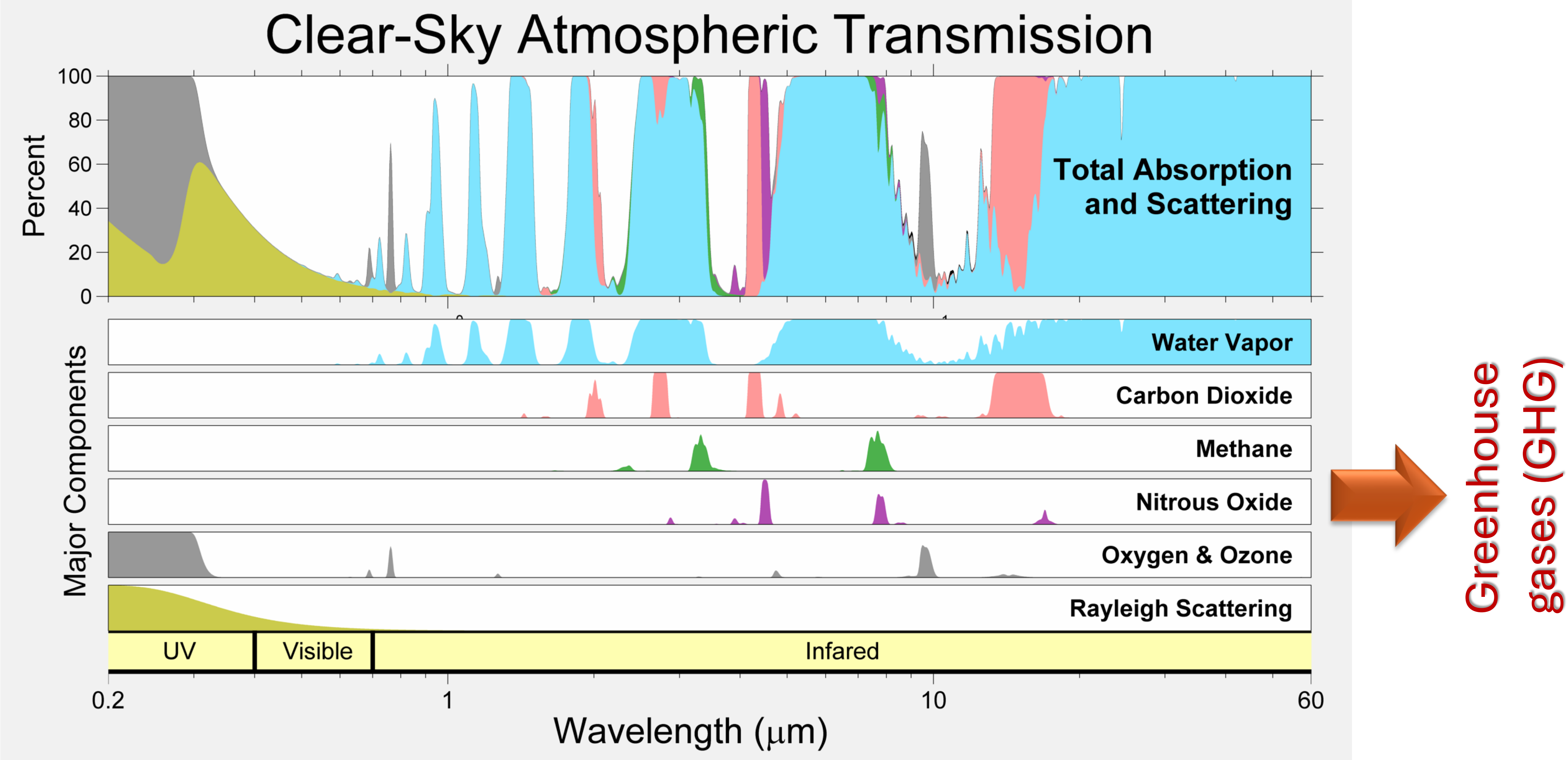
Study Questions

- How is the energy balance at the top of the atmosphere (TOA) determined?
- How are the Stefan–Boltzmann Law and Planck's Radiation Law applied to understanding Earth's temperature?
- Why is it difficult to accurately quantify the TOA energy budget?
- What is the greenhouse effect from a radiation perspective?
- Do volcanoes, or large wildfires, keep the Earth warmer or cooler?





- Earth's atmosphere is composed of many gases and particles. Nitrogen (~78%) and oxygen (~21%) are the two major chemical species. Other species, including water, argon, carbon dioxide, neon, helium, methane, krypton, hydrogen, nitrous oxide, xenon, ozone, carbon monoxide, and ammonia, account for <1%.
- The atmosphere also contains a large amount of particulate matters and biological materials that can affect the energy balance of the Earth. For example, an increase in the amount of aerosol deposition on snow and glacier surfaces will reduce and, consequently, keep more energy within the Earth system. Volcanic eruptions, large-scale fires, and industrial production are major sources of aerosols at global scale.


Clear-Sky Atmospheric Transmission
Percent
100
80
60
40
20
0
Total Absorption and Scattering
Major Components
Water Vapor
Carbon Dioxide
Methane
Nitrous Oxide
Oxygen & Ozone
Rayleigh Scattering
UV
Visible
Infared
0.2
1
10
60
Wavelength (µm)
Greenhouse gases (GHG)

Chen, J. 2020

Brief History

- In 1896 Swedish scholar Svante Arrhenius concluded that fossil fuel combustion may eventually result in enhanced global warming. He predicted that a doubling of CO_2 concentration would lead to a 5 ^oC increase in global temperature. His warning was mostly ignored until the late 1950s.

- Roger R.D. Revelle and other pioneering scholars started scientific investigations on anthropogenic influences on global warming (see more detailed history in Archer & Pierrehumbert 2011). However, they hypothesized that oceans would absorb all the CO_2.

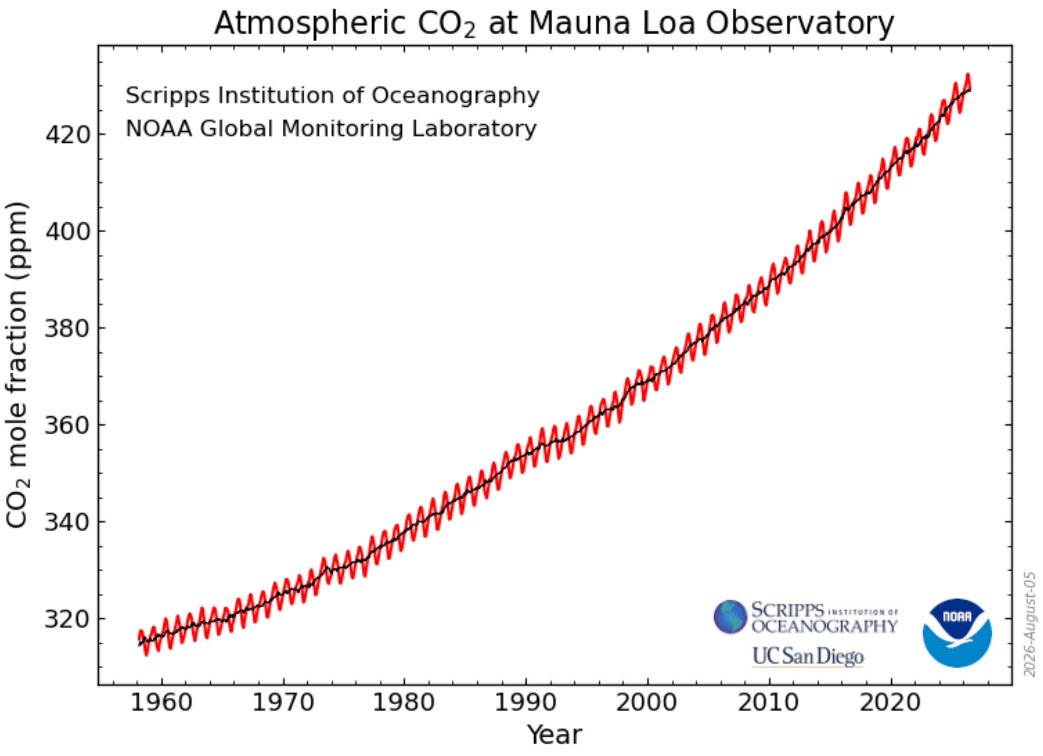
- In late 1980s, there was a general hypothesis that terrestrial ecosystems can be managed effectively to reduce GHG to slow down global warming.

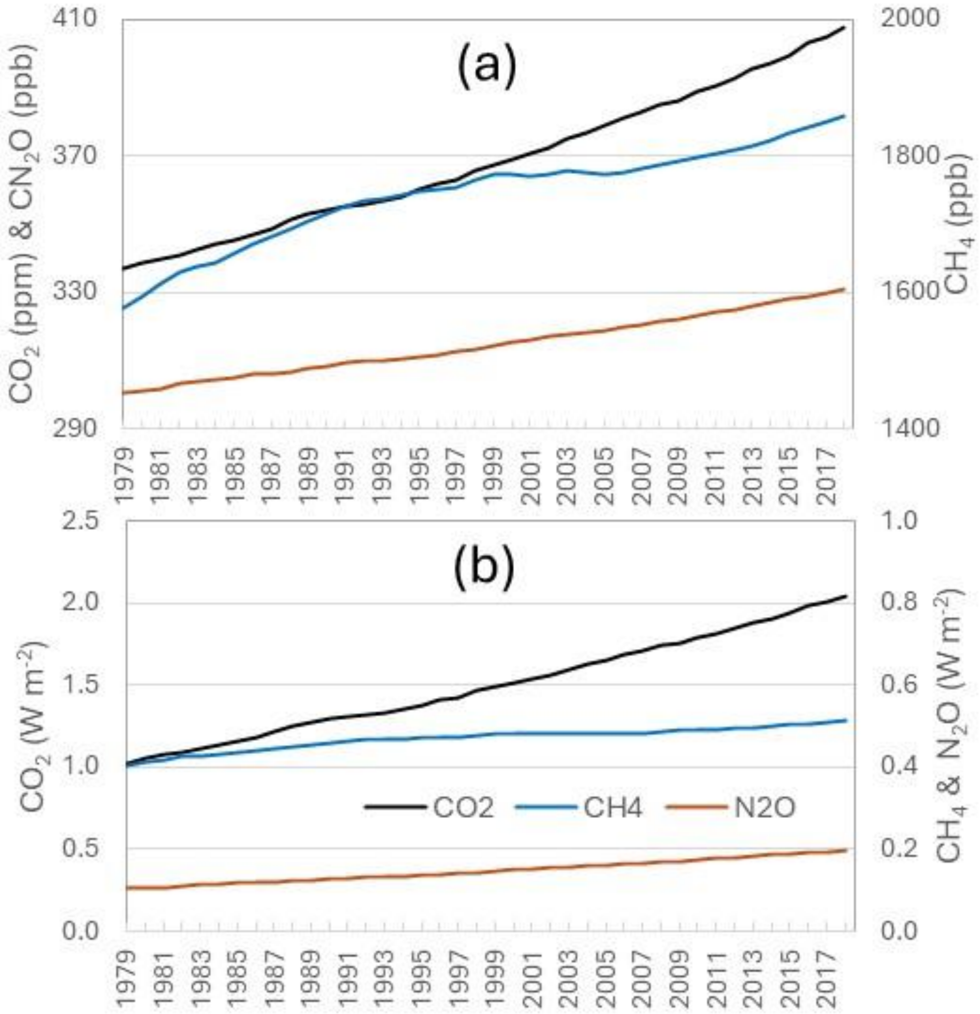
- Since 1990s, IPCC and other organizations have been calling for reductions in GHG.

Increasing in emission of GHG and air pollution

5.1 Introduction

Long-term changes in three major GHG species (CO_2, CH_4 & N_2O) concentrations (a), their radiative forcing (RF) (b during 1979-2018. Data source: https://www.esrl.noaa.gov/gmd/aggi/NOAA_MoleFractions_2019.csv (downloaded on 29 March 2020).





https://gml.noaa.gov/ccgg/trends/

GWPs provide a common unit of measure, which allows analysts to add up emissions estimates of different gases (e.g., to compile a national GHG inventory) and allows policymakers to compare emissions reduction opportunities across sectors and gases. Other than H_2O, these are the major greenhouse gases (GHG):

- CO_2, by definition, has a GWP of 1 regardless of the time period used, because it is the gas being used as the reference. CO_2 remains in the climate system for a very long time: CO_2 emissions cause increases in atmospheric concentrations of CO_2 that will last thousands of years.
- Methane (CH_4) is estimated to have a GWP of 28–36 over 100 years (Learn why EPA's U.S. Inventory of Greenhouse Gas Emissions and Sinks uses a different value.). CH_4 emitted today lasts about a decade on average, which is much less time than CO_2. But CH_4 also absorbs much more energy than CO_2. The net effect of the shorter lifetime and higher energy absorption is reflected in the GWP. The CH_4 GWP also accounts for some indirect effects, such as the fact that CH_4 is a precursor to ozone, and ozone is itself a GHG.
- Nitrous Oxide (N_2O) has a GWP 265–298 times that of CO_2 for a 100-year timescale. N_2O emitted today remains in the atmosphere for more than 100 years, on average.
- Chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs), hydrochlorofluorocarbons (HCFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6) are sometimes called high-GWP gases because, for a given amount of mass, they trap substantially more heat than CO_2. (The GWPs for these gases can be in the thousands or tens of thousands.)

https://www.epa.gov/ghgemissions/understanding-global-warming-potentials

Table 5.1 Global warming potential (GWP) of greenhouse gases (GHGs) based on the fourth Assessment Report (AR_4) of the IPCC (2007). The release of 1 kg CH_4, for example, is equivalent to 25 kg of CO_2 (from Forster *et al.* 2007).

GHG Species	Formula	Lifetime (years)	20-year	100-year	500-year
Carbon Dioxide	CO_2	Variable	1	1	1
Methane	CH_4	12±3	72	25	7.6
Nitrous Oxide	N_2O	120	289	298	153

It takes time for greenhouse gas (GHG) emissions to dissipate, as each gas has a different residence time in the atmosphere!

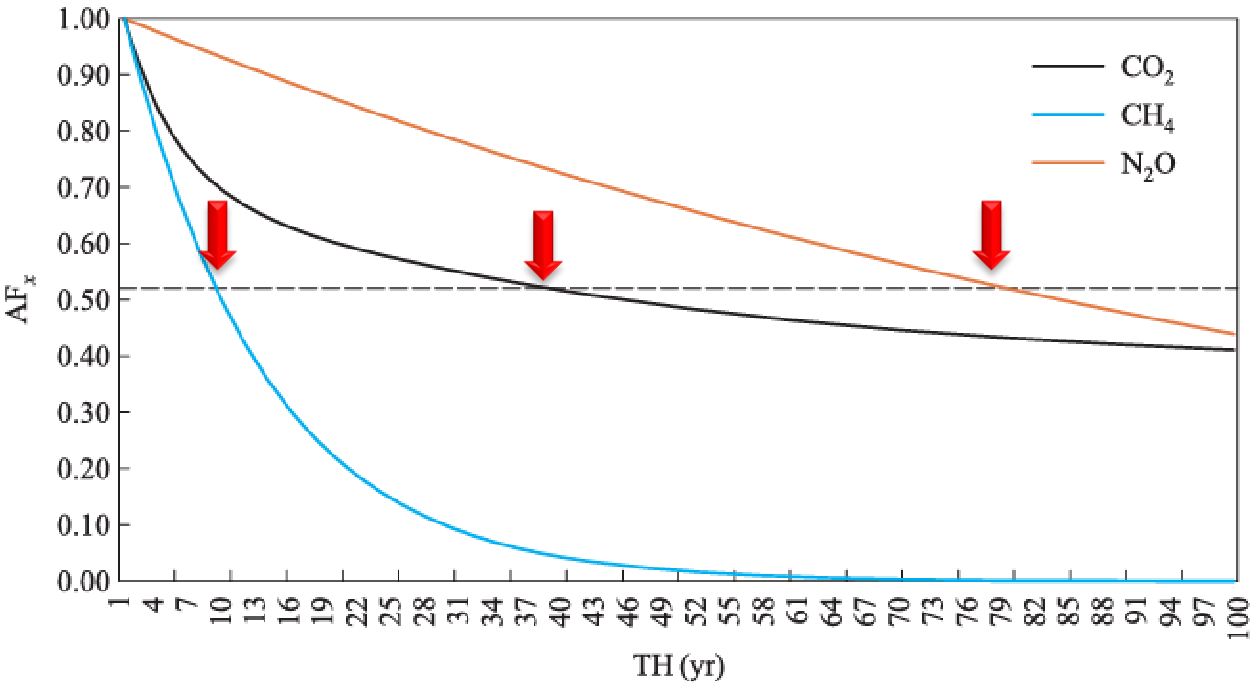


Fig. 5.4 The impulse response functions from the fifth IPCC Annual Report (AR_5) for calculating AF_x of CO_2, CH_4 and N_2O (Eqs. 5.5 and 5.6). The horizontal dashed line indicates the average AF_{CO_2} (0.52) over 100 years (TH = 100) (IPCC 2014 SM). This means that 52% of the emitted CO_2 pulse remains in the atmosphere after 100 years.

Radiation Balance

GEO409-FS2026 (3 credits)

Sep 16: Albedo Effects on Earth's Climate: Warming and Cooling

(Dr. Cheyenne Lei)

Albedo is a measure of how much light or radiation a surface reflects compared to how much it receives. It's expressed as a fraction or percentage.

Examples:

- Fresh snow: 0.8–0.9
- Grass: 0.2–0.3
- Asphalt: 0.05–0.1
- Ocean water: 0.06
- Coniferous forests: 0.08–0.15
- Deciduous forests: <0.18
- Corn fields: ~0.18–0.25
- Desert: 0.35–0.45
- Urban: 0.10–0.25