METR/ENVS 113

Lecture 2: Atmospheric Radiation

SJSU Fall Semester 2020

Module 1: The Natural, Unpolluted Atmosphere

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Outline

- Fundamentals
  - Radiation: Definition and Basic Properties
  - Radiative Emission Spectra
  - Solar versus Terrestrial Radiation
  - Absorption of Radiation by Atmospheric Gases

- Stratospheric Ozone Layer

Atmospheric Radiation
(Fundamentals)

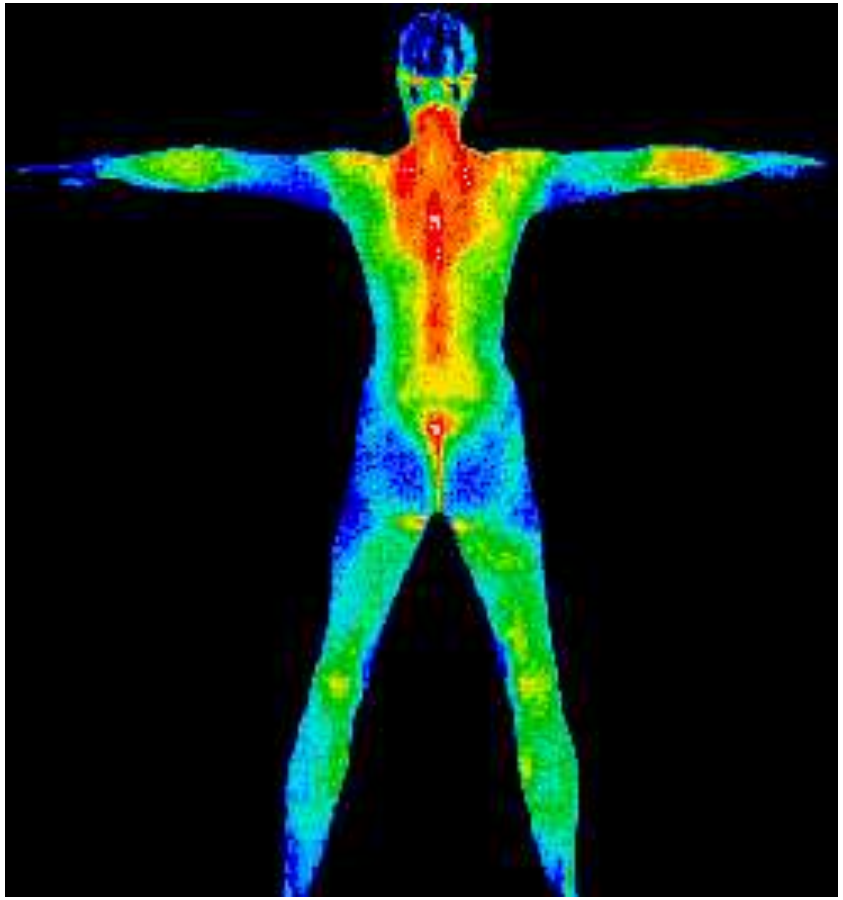
What is radiation?

- Transfer of energy by propagation of electromagnetic waves.
- Sometimes referred to as “particles” (“wave-particle” duality)
- Among the three ways energy is transferred
  - Conduction: molecular by molecule
  - Convection: fluid motion
  - **Radiation: electromagnetic waves**

Properties of Radiation

1. Can transmit energy through a vacuum (e.g. outer space) as well as through matter (e.g. air, water, earth, objects).
2. All bodies with temperature greater than absolute zero (0 deg K) emit radiation
3. In a vacuum, all waves travel at speed of light (= 3.0×10^8 m/s).
4. Energy is transmitted as waves of various wavelengths (or frequencies). Radiation of different wavelengths (or frequencies) are given different names (see next slides)
5. Shorter (higher frequency) waves are more energetic than longer (lower frequency) waves.
6. Warmer objects emit more radiation (across all wavelengths) than colder objects.

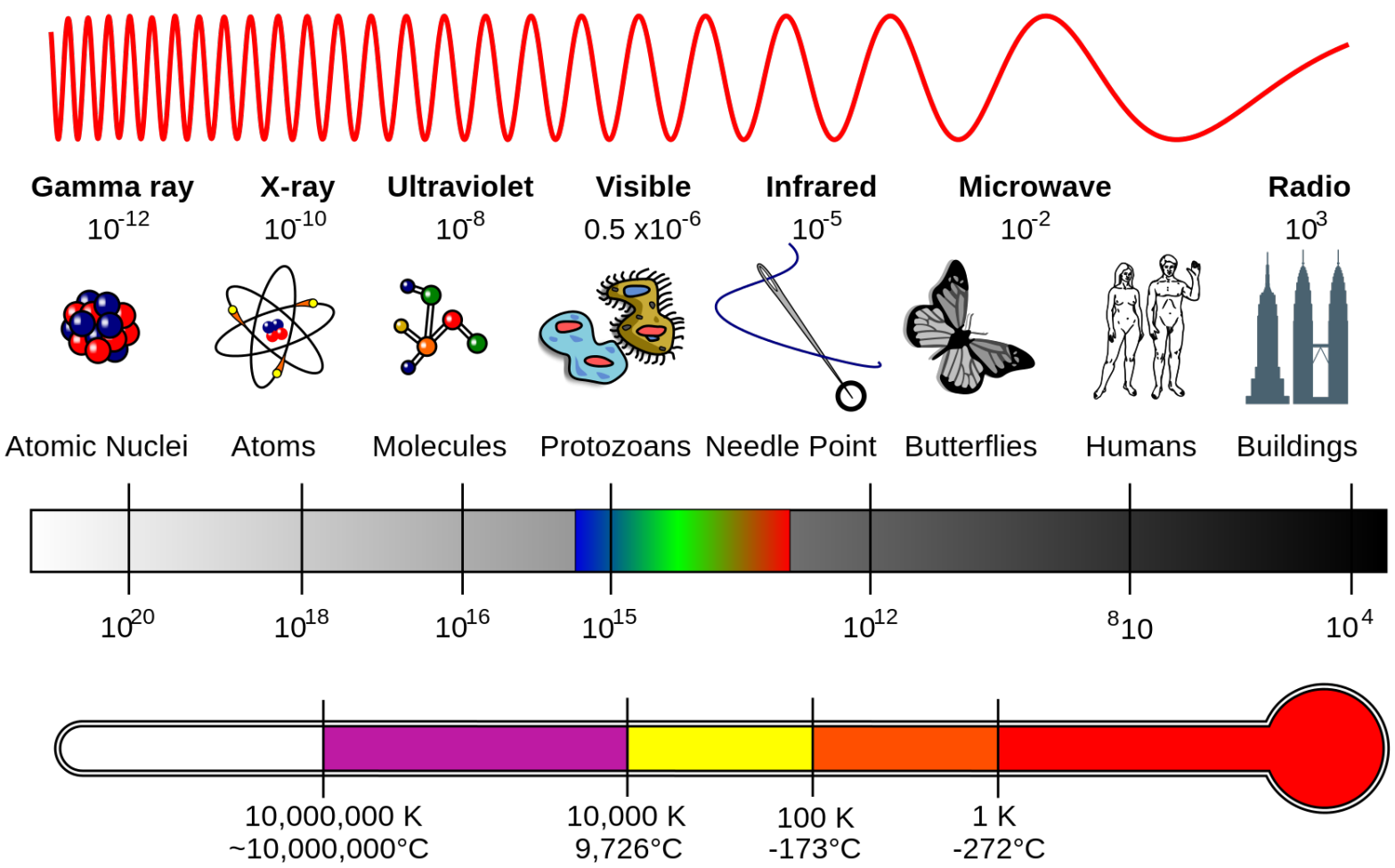
Infrared (“heat”) radiation from human body …



Warmer body parts (red, yellow) emit more infrared energy than cooler (blue) parts

Practical Application - Infrared Camera for night-vision: Person detected by infrared energy emissions

Radiative Emission Spectra



Radiation Type

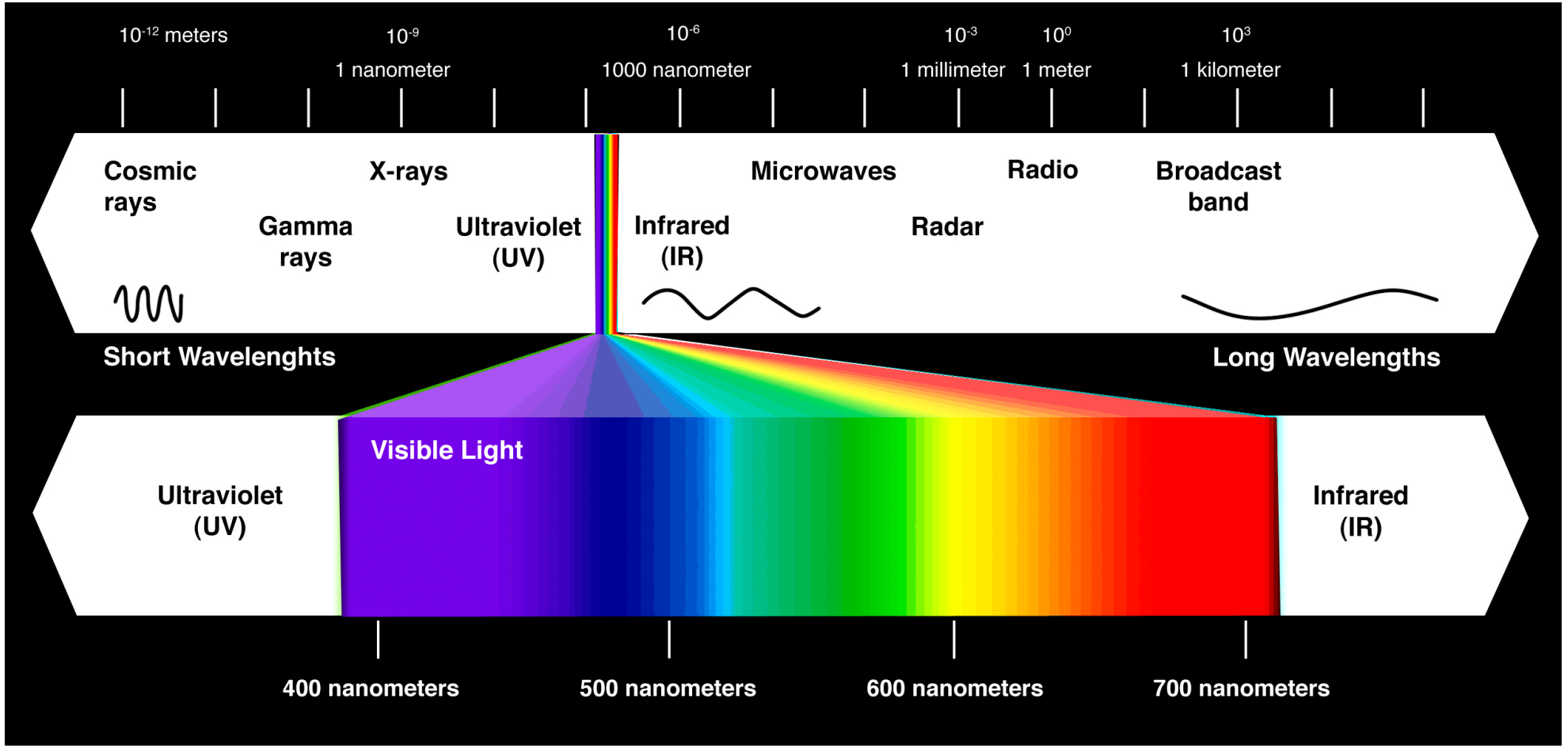
Wavelength / m

Approximate Scale of Wavelength

Frequency / Hz

Temperature of objects at which this radiation is the peak wavelength emitted

Radiative Emission Spectra
(focused on ultraviolet, visible and infrared)

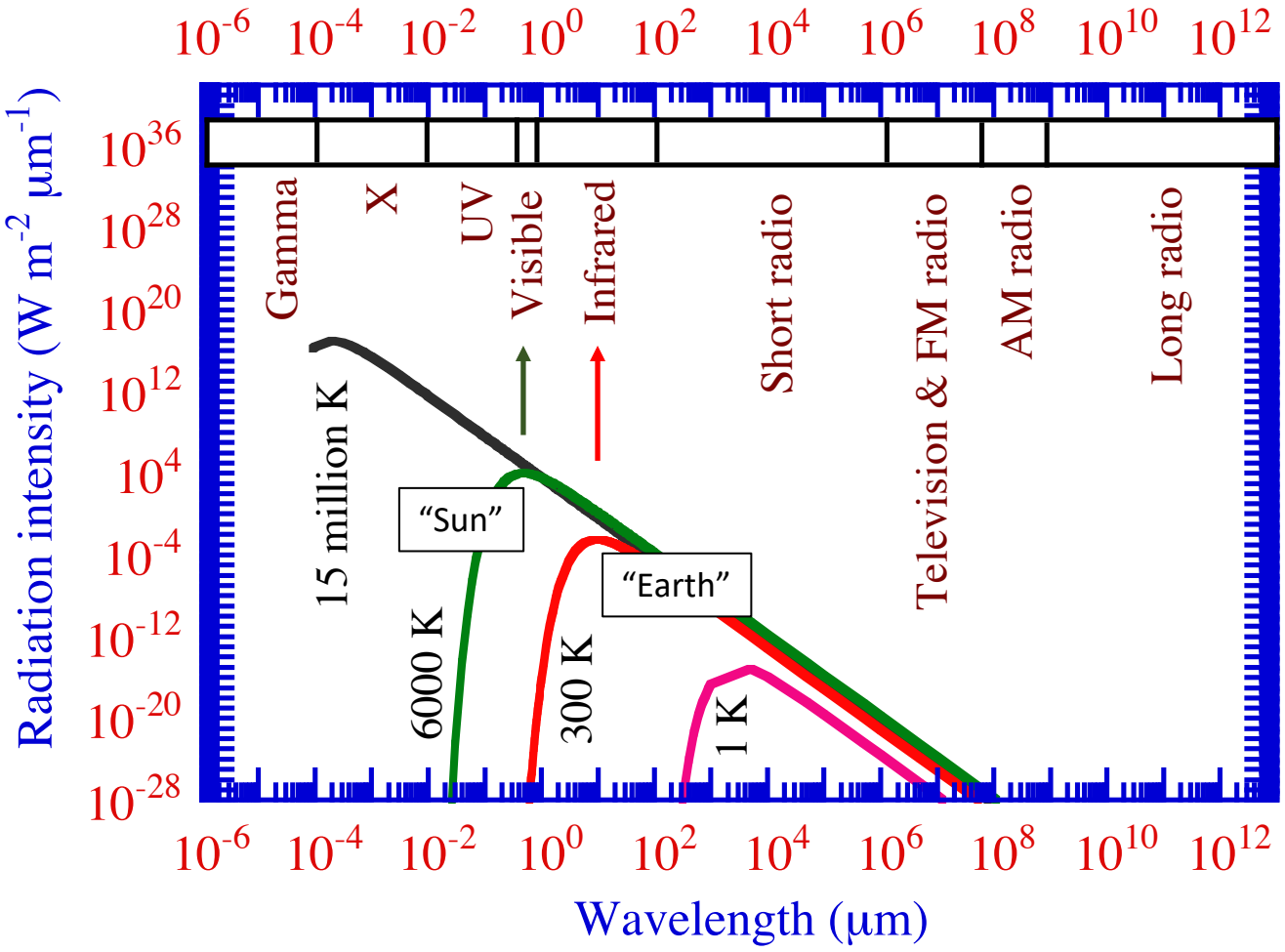


"ROY G BIV" – **R**ed, **O**range, **Y**ellow, **G**reen, **B**lue, **I**ndigo, **V**iolet

Summary: Radiation Fundamentals

- Radiation is a form of energy emitted from a body or object
- Propagates outward from object in the form of electromagnetic waves
- Waves span a range of wavelengths
- Short wavelengths are more powerful, and are emitted at higher temperatures
- Long wavelengths are less powerful, and are emitted at cooler temperatures

Solar vs. Terrestrial Radiation



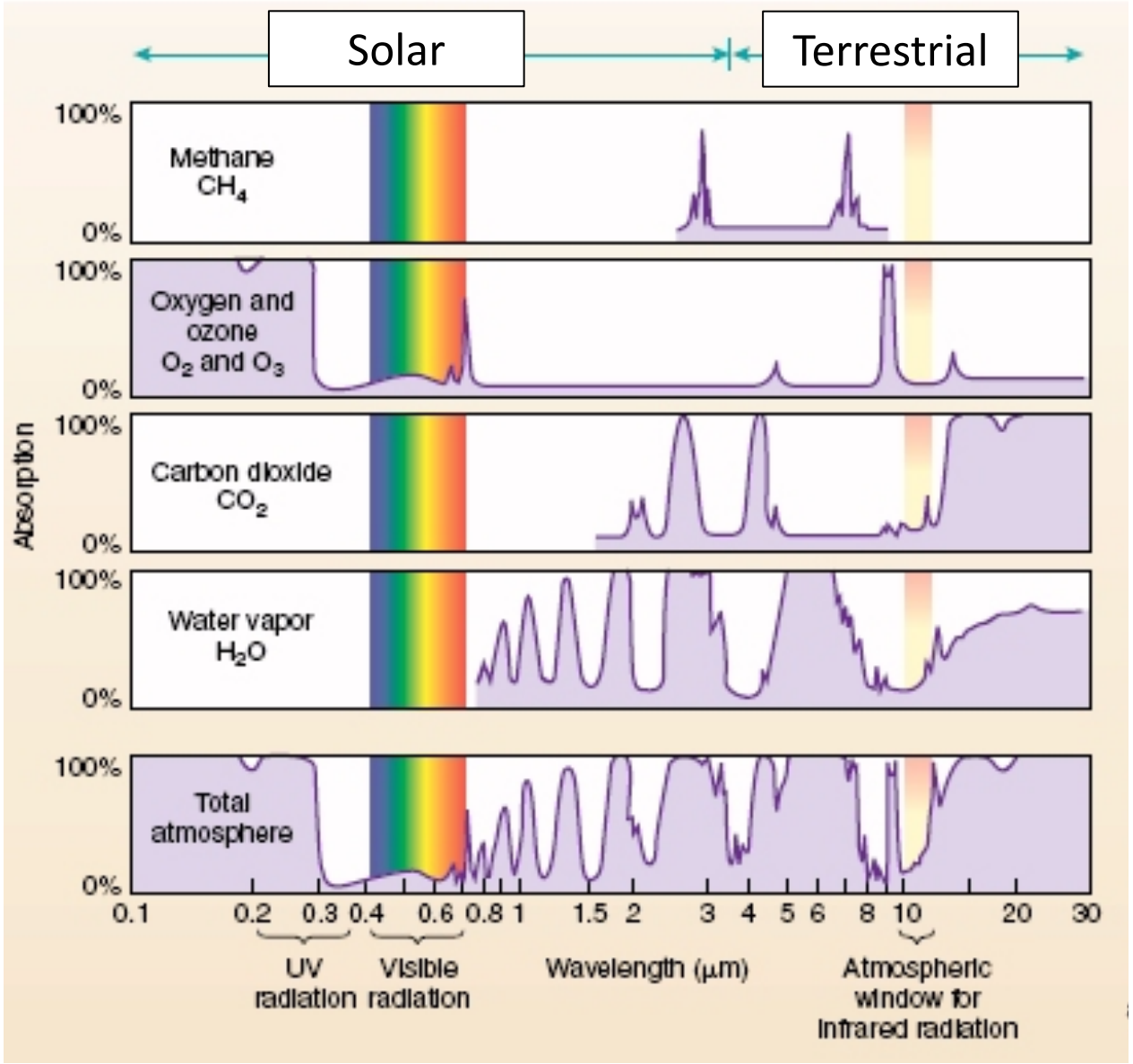
KEY POINTS

- Warmer bodies emit more radiation than cooler bodies at all wavelengths
- Warmer bodies emit at shorter wavelengths than cooler bodies
- Green line (sun, ~ 6000 degrees K), emits mostly in the visible spectrum. Will refer to this as "solar radiation".
- Red line (earth, ~ 300 degrees K), emits mostly in the infrared spectrum. Will refer to this as "terrestrial radiation".

What happens to radiation through the earth's atmosphere?

- **Scattering**
  - Air molecules and clouds reflect or otherwise alter path of radiation
  - Blue light more efficiently scattered by air molecules (why sky is blue)
  - Clouds reflect all colors equally (why clouds are white)
- **Absorption**
  - Air molecules and clouds absorb radiation
  - Reemitted to surface and to space as infrared radiation
  - For gases, wavelength of absorption depends on wavelength
- **Transmission**
  - Some radiation not scattered or absorbed
  - Sunlight travels directly to surface
  - Terrestrial radiation from earth travels directly to space

Absorption of Radiation by Atmospheric Gases



KEY POINTS

- Plot indicates the percentage of radiation passing through various gases that is absorbed by the gas depending on the wavelength of radiation.

- Visible light ("solar") generally passes through gases without much absorption.

- Substantial amount of infrared radiation (between 1 – 30 microns) absorbed by CO2 and H2O. Acts to keep radiation from earth within atmosphere, keeping planet warmer than it otherwise would be ("greenhouse effect").

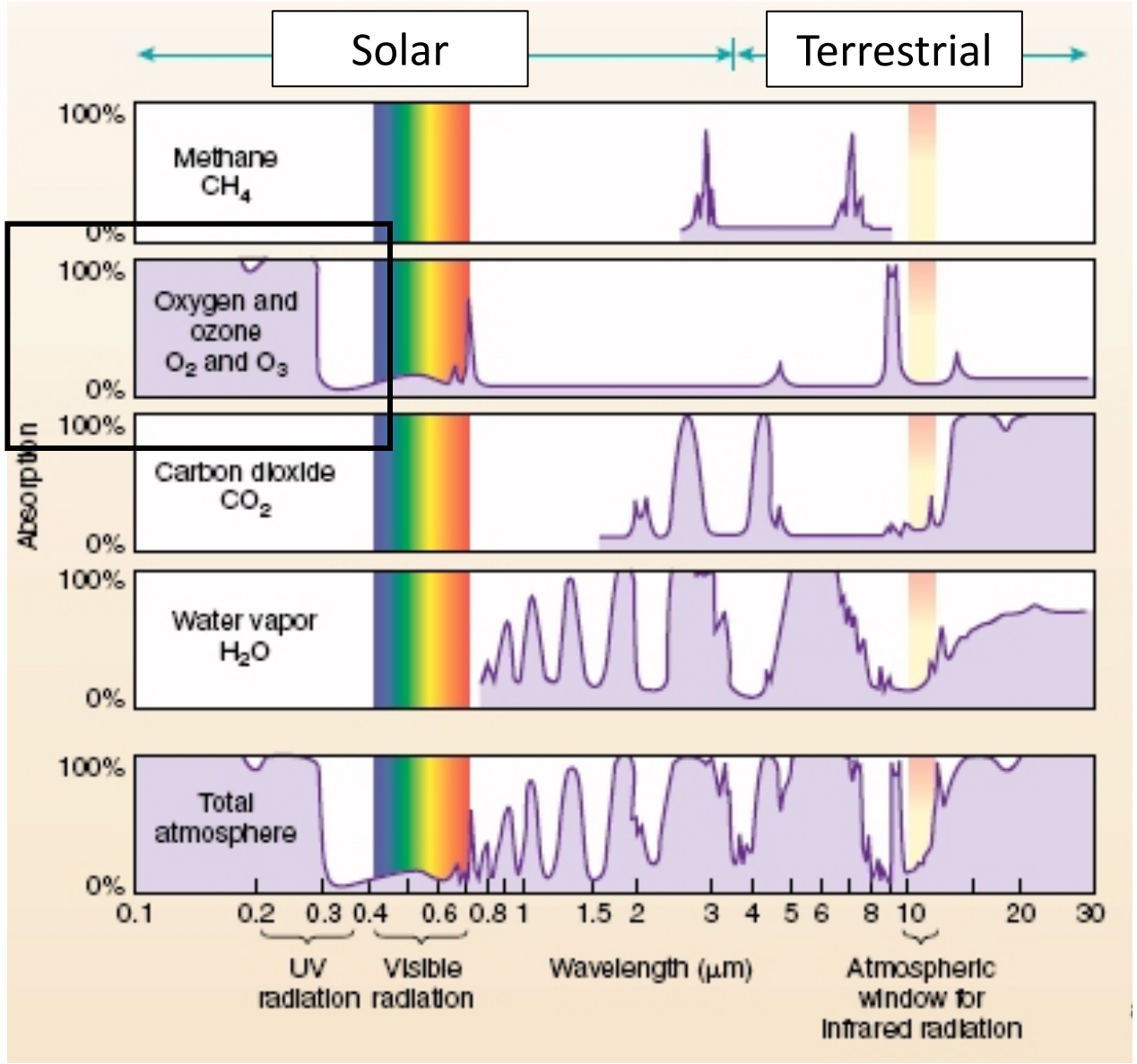
- O2 (atmospheric oxygen) and O3 (ozone) absorb most of the ultraviolet radiation (0.1 – 0.3 microns). this occurs in stratosphere (see next slides).

Further Reading …

- http://www.physicalgeography.net/fundamentals/7f.html
- https://scied.ucar.edu/carbon-dioxide-absorbs-and-re-emits-infrared-radiation
- https://www.earthobservatory.nasa.gov/features/RemoteSensing/remote_04.php

Stratospheric Ozone Layer

Absorption of Radiation: Oxygen (O_2) and Ozone (O_3)

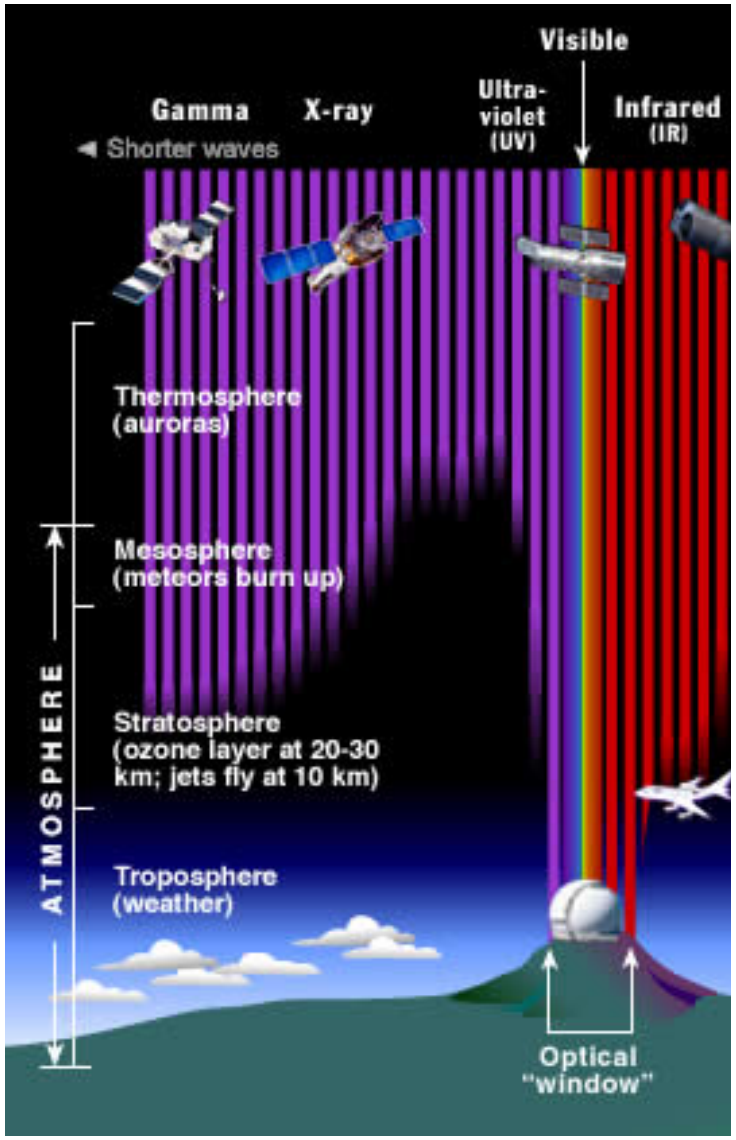


Recall One of the Key Points …

- O2 (atmospheric oxygen) and O3 (ozone) absorb most of the ultraviolet radiation (0.1 – 0.3 microns).

- This occurs in stratosphere (see next slides).

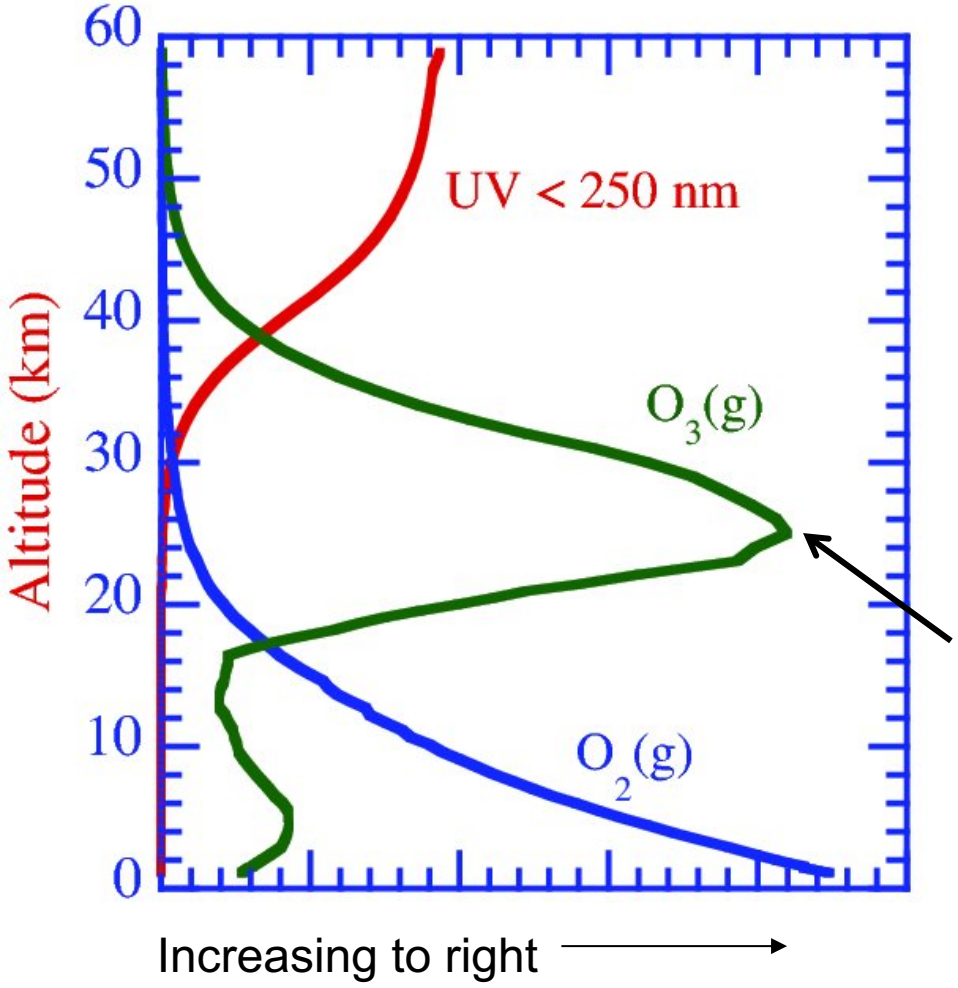
Absorption of Sunlight in Stratosphere



KEY POINTS

- Practically all high energy, short solar wavelengths (gamma, x-rays, ultraviolet) do not reach the surface.
- This is because of absorption of this radiation by O_2 (atmospheric oxygen) and O_3 (ozone) absorb most of the shortwave and ultraviolet radiation (0.1 – 0.3 microns). This occurs in stratosphere. Details of process on next slides.
- Protective of life at surface since these are very high energy, damaging wavelengths.
- Visible light not absorbed since O_2 and O_3 do not absorb visible light. Visible light therefore reaches ground.

Stratospheric Profiles: Ultraviolet, O_2 and O_3



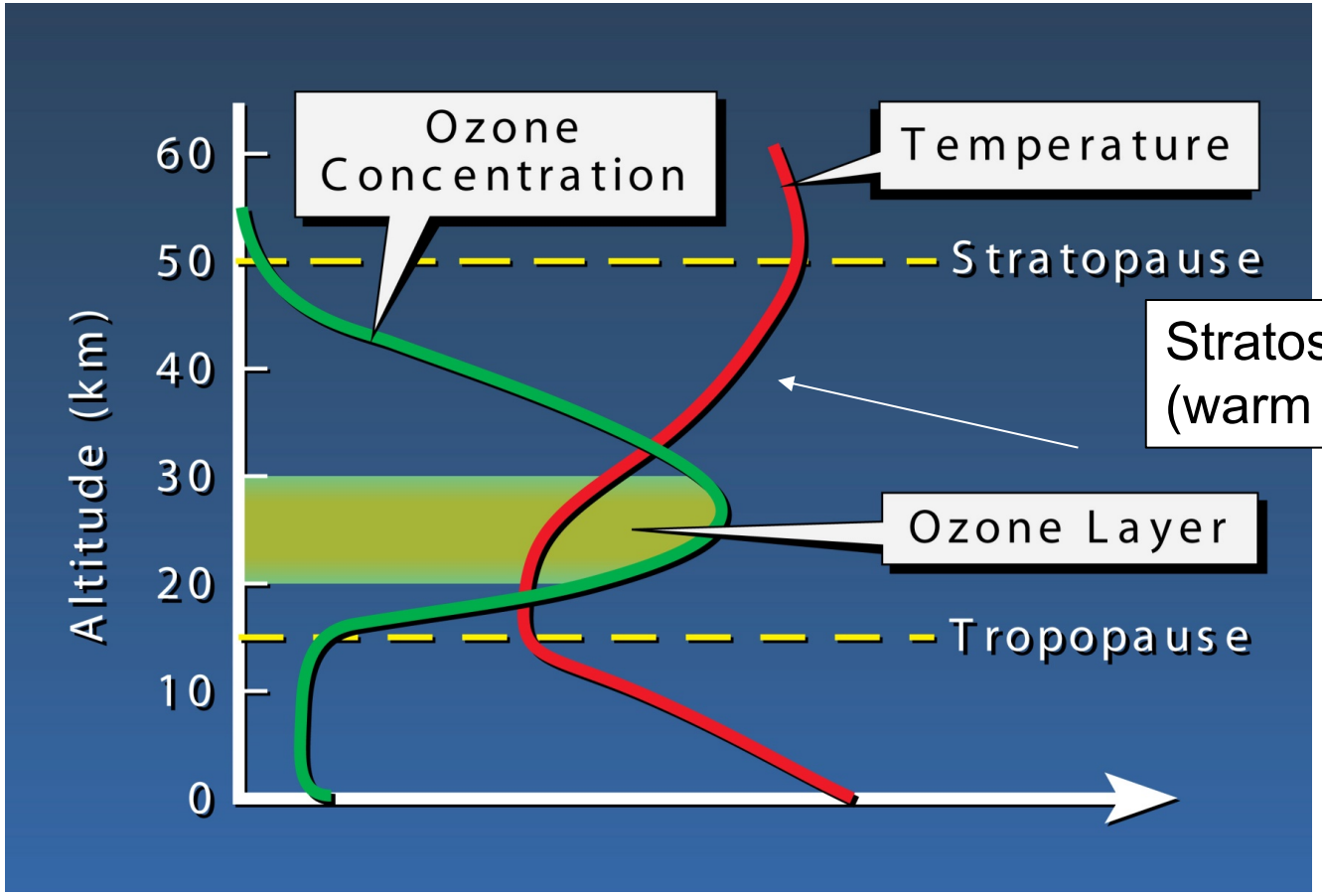
KEY POINTS

- Removal of ultraviolet radiation by O_2 and O_3 as sunlight penetrates further into the stratosphere.
- Ozone maximum at ~ 30 km above surface
- Ozone forms from absorption of ultraviolet radiation. Specifics on next slide.

"ozone layer" at around 30 km

Stratospheric Profiles: O_3 and Temperature

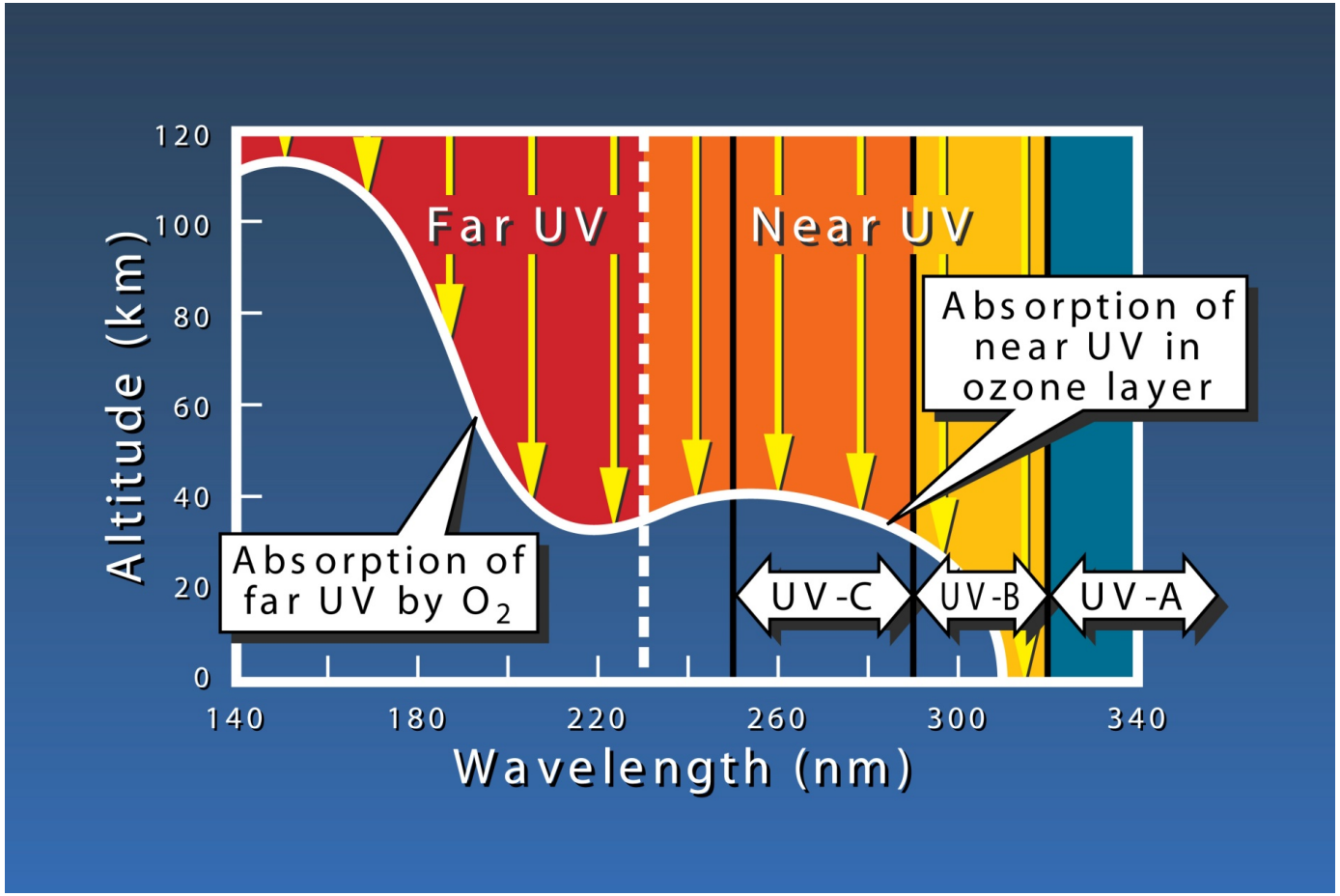
Maximum ozone concentrations occur in the stratosphere, with a peak in the lower to middle stratosphere. Formation of ozone layer causes a global-scale temperature inversion to form.



Stratospheric temperature inversion (warm air atop cold)

Stratospheric Profiles: O_3 and Temperature

The overlying ozone absorbs UV solar radiation, filtering it from the solar spectrum and preventing the most harmful UV-C rays from reaching the ground. Some UV-B, and most UV-A radiation penetrates to the surface.



Stratospheric Ozone Formation

O_2 + ultraviolet sunlight → O + O

(O_2 absorbs ultraviolet sunlight and breaks up O_2 into two separate oxygen atoms)

$O_2 + O \rightarrow O_3$

(O_2 recombines with O formed from reaction above to form ozone, O_3)

O_3 + ultraviolet sunlight → O_2 + O

(O_3 absorbs ultraviolet sunlight and breaks up O_3 into O_2 and O)

- These reactions occur in stratosphere
- Three main consequences
  1. Creation of “ozone layer” in stratosphere.
  2. Stratospheric temperatures increase due to absorption of ultraviolet sunlight by O_2 and O_3. Causes stratospheric temperature inversion (warming of air with height in stratosphere).
  3. Ultraviolet sunlight does not penetrate in great amount to surface. Protects life at surface from damaging ultraviolet sunlight.

Further Reading …

- https://www.ozonelayer.noaa.gov/
- https://aura.gsfc.nasa.gov/ozone.html