GEOG 108: Physical Geography-Meteorology and Climatology

Fall 19

Week 1-Earth-Sun Relation and Climate

(This note uses following reference other than noted in resource section:Climate System Course from Columbia University)

Unit Outline

- Introduction
- Energy from the sun
- Physics of radiative heat transfer
- Radiation transfer from sun to Earth and climate
  - Solar energy and atmospheric dynamics
  - Earth’s movement
  - Seasons
  - Insolation variation with latitude

Unit Learning Outcomes

- State specific and broader definitions of climate
- Describe physical laws governing the transfer of energy through radiation
- Describe relationship between sun and the Earth throughout the year
- Discuss how radiation transfer from sun to earth dictates Earth’s climate

Unit Resources

- Power point notes on Earth-Sun relation and climate supplemented by selected pages from the book “Physical Geography: 10th edition by J.F. Peterson, D. Sack, and R. E. Gabbler: http://www.cengage.com/resource_uploads/downloads/0495555061_137178.pdf
- Glossary of Meteorology
- Nature Education Knowledge Project’s article: Global Climate System: https://www.nature.com/scitable/knowledge/library/the-global-climate-system-74649049/

Introduction

- Climate is specifically defined by average of variables such as:
  - Temperature
  - Humidity
  - Windiness
  - Cloudiness
  - Precipitation
  - Visibility etc.
- In a broader sense, climate represents Earth's environment consisting of following components and their interactions:
  - Atmosphere
  - Hydrosphere
  - The land masses (materials and physiography)
  - Cryosphere
  - The biota

*** Find the meaning of each of these terms in Glossary**

Solar Radiation

- The primary energy source for Earth and its climate system is solar radiation.
- Radiant energy (refer pages 39-42 of chapter 2 from the text book)
  - The energy that drives climate system comes from the sun
  - Solar radiation reaching to earth is absorbed in different components of climate system
  - When absorbed radiant energy is converted to heat, it warms up Earth and makes it habitable
  - Uneven absorption of solar radiation in both space and time results into a complex variation (patterns and seasons) of our climate

The sun and its energy

- The Sun, a star located at the center of our planetary system is composed mainly of hydrogen and helium
- Huge amount of energy is produced in the Sun’s interior when hydrogen is converted into helium, a reaction called **thermonuclear fusion**
- Thus produced heat is the energy that travels through space ultimately reaching to our Earth

Energy

- Energy is the ability to perform work.
- Energy is measured in units of work (Joule, Calorie, BTU)
  - **1 joule** = energy spent when a body is moved with a force of 1 Newton over a distance of 1 m.
  - **1 calorie** = energy spent raising the temperature of 1 gram of pure water by 1 degree Centigrade
  - **1 BTU** (British Thermal Unit) = energy spent to raise the temperature of 1 lb of pure water by 1 degree Fahrenheit
  - **1 calorie** = 4.186 joule, 1 BTU = 251.996 calories = 1054.6 joule

***See Appendix A of the text book for units and conversions**

Energy relevant to climate

- **Thermal (heat) energy**: the ability to do work through the release of heat. The energy associated with temperature and the energy associated with evaporation/condensation of water are the forms of heat energy in climate.
- **Kinetic energy**: ability to do work due to motion
- **Gravitational (potential) energy**: ability to do work through changes in body's location within a gravitational field
- **Electromagnetic wave energy**: energy embedded in electromagnetic wave motion (light, microwaves, x-rays)
- **Chemical energy**: ability to do work via chemical interaction

Energy transformation in the climate system

- The key climate process is driven by the transformation of one form of energy to another
- Thermal energy, for example, is responsible for change in atmospheric temperature. Motion of atmosphere (wind) and ocean (currents) is due to kinetic energy. When air or water vapor changes elevation in atmosphere (rise or sink), potential energy is changed. Solar radiation embodies electromagnetic energy. When the gas ozone (O_3) is formed in the atmosphere, chemical energy is absorbed.
- When heat energy is converted into kinetic energy, atmosphere sets off in motion.

Think and write

- Think about climate scenarios where

1. kinetic energy is converted to
    i) potential energy and
    ii) heat energy
2. Electromagnetic energy to
    i) Heat energy
3. Heat energy to
    i) electromagnetic energy
4. Chemical energy to
    i) heat energy

Electromagnetic waves

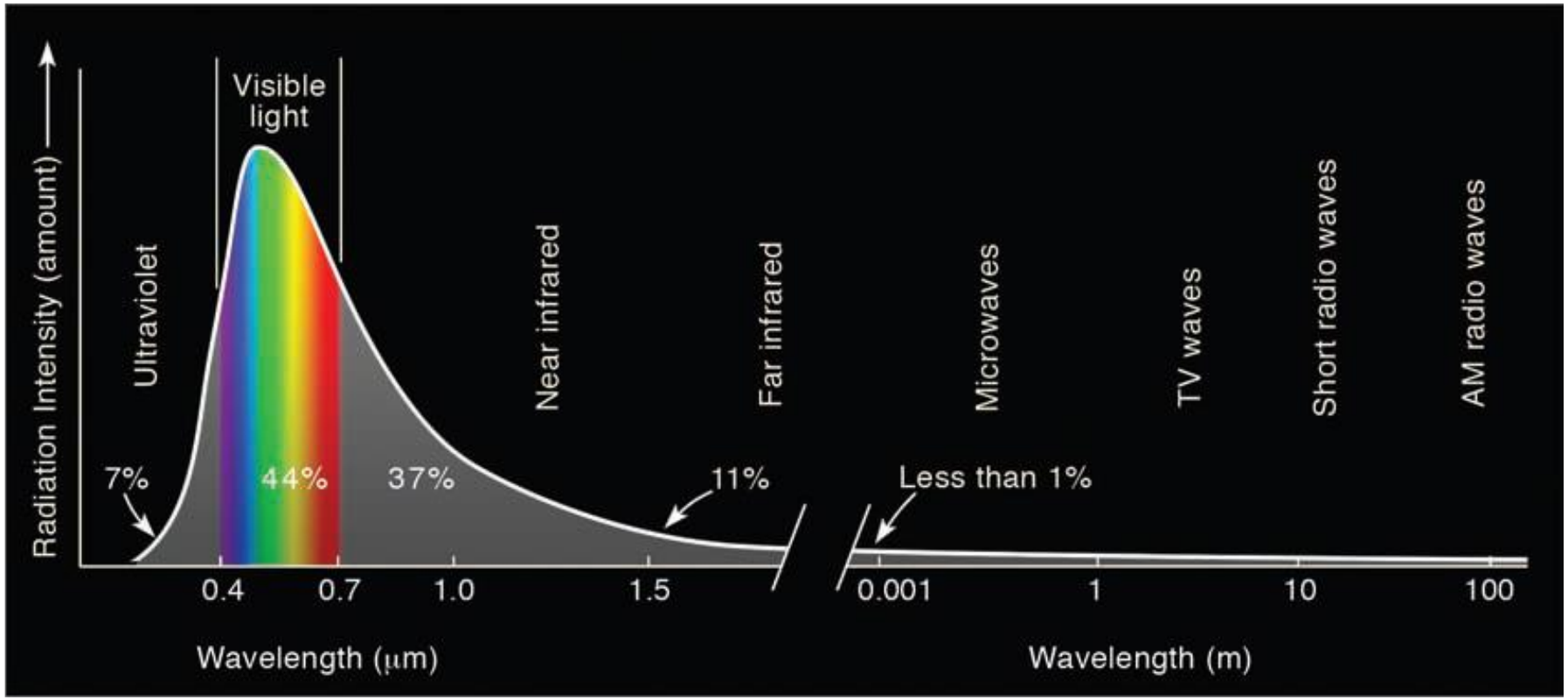


FIGURE 2.10 The sun's electromagnetic spectrum and some of the descriptive names of each region. The numbers underneath the curve approximate the percentage of energy the sun radiates in various regions.

Laws governing radiative transfer

- Radiative transfer does not require presence of matter; heat is moved even through empty space
- All bodies emit radiation and body's temperature solely determines how much they emit (**Stefan-Boltzman law**):
  - $E = \sigma T^4$ (read as: E equal sigma times fourth power of T)
  - E = maximum radiation emitted by object
  - σ = Stefan-Boltzmann constant
  - T = object's surface temperature in degree Kelvin (degree kelvin is denoted as K)
  - Doubling the absolute temperature of an object increases the maximum energy output by a factor of 16, i.e. 2^4

  - **Question to practice:** Earth's average surface temperature is about 288 K and Sun's surface temperature is nearly 6000 K. How many times more energy the sun radiates than the Earth?

Laws governing radiative transfer

- Energy flux drops as the square of distance from the radiating body.
- Radiative transfer goes through transformation of energy depending on the physical properties of the object

Radiation transfer from sun to Earth

- Surface of the sun radiates approximately $63 \times 10^6 \frac{W}{m^2}$ (read as watt per square meter; watt is the unit of power which is defined as energy per unit time) energy
- The radiative flux reaching to the outer limit of Earth's atmosphere is 1360 $\frac{W}{m^2}$. This is sometimes referred to as **solar constant.**

Radiation transfer from sun to Earth

- **Effect of elliptical orbit:**
- **Effect of spherical shape of Earth:**
- **Effect of tilted Earth's Axis**
- **Solstice and Equinox**
- For the details of above concepts go to this link: http://www.cengage.com/resource_uploads/downloads/0495555061_137178.pdf
- Read from Page 71 (Solar Energy and Atmospheric Dynamics) to the end.