Solar Energy to Earth and the Seasons

Physical Geography Lecture - GEOG B1

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The Solar System

We are located on one of the trailing arms of the **Milky Way Galaxy**.

Planetesimal hypothesis: our solar system condensed from a slowly rotating and collapsing cloud of dust and gas (nebula) - all due to **gravity**

The sun condensed first, and the grains of cosmic dust and other solids orbiting the sun accreted into planets.

See Fig. 2.1

Dimensions and Distance

Speed of light: 300,000 kps, or 186,000 mps - how fast light travels.
Light year: 9.5 trillion km, or 6 trillion miles - measure of distance
Our solar system is 11 light hours in diameter, and the Milky Way Galaxy is 100,000 light years in diameter.
Earth's orbit is currently elliptical around the sun, averaging 150,000,000 km (93 million mi) - takes light 8 minutes and 20 seconds to reach us from the sun
Perihelion: Earth closest to sun - 147,255,000 km (91,500,000 mi) - Jan. 3
Aphelion: Earth farthest from sun - 152,083,000 km (94,500,000 mi) - July 4

Solar Activity and Solar Wind

The Sun cycles through stages of more activity (*solar maximum*) and less (*solar minimum*). **Sunspots** and solar flares occur more during the solar maximum, and are caused by magnetic storms (see Fig. 2.2).
The sun constantly emits surging clouds of electrically charged particles, called the **solar wind**, and it can disrupt radio, satellite transmissions, and electronics. Earth's magnetic field, the **magnetosphere**, interacts with the solar wind first, deflecting it towards the poles, so only a small portion enters the upper atmosphere. Creates **auroras** in the high latitudes - north & south of 65°.
See Fig. 2.4

Electromagnetic Spectrum & Radiant Energy

Electromagnetic Spectrum: the spectrum of all possible wavelengths of electromagnetic energy (Fig. 2.5)
The Sun emits radiant energy (shortwave radiation) as mostly visible light and infrared wavelengths, and 8% at ultra-violet, X-ray, and gamma-ray wavelengths.
The Earth emits longer wavelengths, in the middle and thermal infrared portion of the spectrum (see figures 2.6 and 2.7).
Atmospheric gases, like carbon dioxide, water vapor, oxygen, and ozone, absorb some wavelengths and are transparent to others.

Incoming Radiant Energy

The miniscule bit of energy intercepted by Earth is called **insolation** (*in*coming *sol*ar radi*ation*).
Scientist measure incoming solar radiation at the **thermopause**, the outer boundary of Earth's atmosphere, before it is diminished by scattering or absorption in the atmosphere.
The **solar constant**, the average amount of insolation received at the thermopause, is 1,372 W/m^2

Uneven Distribution of Insolation

Earth has a curved surface and rotates on a tilted axis.
Differences in the angle at which solar rays meet the surface at each latitude result in uneven distribution of insolation and heating.

- Higher latitudes get insolation at oblique angle - more diffuse over larger area

Subsolar point - point where insolation arrives perpendicular to the surface
Only occurs in tropical latitudes - between 23.5° N and 23.5° S.

As the Earth rotates around the sun, the subsolar point migrates between the latitudes.

See Figures 2.8 and 2.9

Global Net Radiation

Net radiation - the balance between insolation and the outgoing radiation from Earth and the atmosphere.

See Fig. 2.10 (map uses *isolines* to connect points of equal value)

There is a latitudinal energy imbalance: positive values in lower latitudes and negative values towards the poles.

The energy imbalance is critically important because it drives the global circulation in the atmosphere and the oceans.

Seasonality

Refers to the seasonal variation of the Sun's changing position in the sky and changing daylengths.

The Sun's **altitude**, or angle between the horizon and the Sun, causes the seasonal changes.

The latitude of the Sun at the subsolar point is the Sun's **declination**.

Daylength, the duration of exposure to insolation between sunrise and sunset, varies during the year, depending on the latitude.

Equator: 12 hours 40°-50°: 6-8 hour difference Poles: 6 months

Reasons for Seasons

So… the seasons result from the Sun's altitude above the horizon, its declination at the subsolar point, and daylength during the year. These, in turn, result from:

Orbital **revolution** of Earth around Sun (one revolution = 365.24 days)

Daily rotation (spinning)of Earth on its axis

The unchanging orientation of Earth's *tilted* axis

Earth's sphericity (geoid shape)

Let's break it down…….

Rotation

Earth's **rotation**, or turning on its axis, takes about 24 hours. Rotation determines daylength and produces ocean tides (in relation to gravitational pull of the Sun and Moon). See Fig. 2.12

Earth rotates west to east (eastward) about its **axis**, an imaginary line extending through the planet from the North Pole to the South Pole.

Velocity varies with latitude (see Table 2.1)

Earth's rotation produces the diurnal (daily) pattern of day and night.

The dividing line between day and nights is the **circle of illumination**.

See pp. 52-53

Tilt of Earth’s Axis

Demonstration Time!!!

To understand the **axial tilt**, imagine a plane that bisects the Earth in its orbit around the sun (**plane of the ecliptic**). See Fig. 2.13

Now think of a perpendicular line passing through that plane and the Earth.

From this perpendicular line, Earth’s axis is tilted about **23.5°** from that line.

Earth’s axis remains fixed relative to the plane of the ecliptic as it revolves around the Sun. If we compared the axis to itself at different points in the Earth’s revolution, the axis would always be parallel to itself - **axial parallelism**.

Sphericity

Remember: Earth's geoid shape is more like a slightly flattened sphere.
This causes the Sun's parallel rays fall on the surface at uneven angles.
Insolation angles and net radiation received vary greatly between the poles and the equator.
Go back to Figures 2.8 and 2.9

Annual March of Seasons - Part I

Daylength is an easy way of sensing the changes in seasons at latitudes away from the equator. The extremes of daylength occur in <u>December</u> and <u>June</u>. Around Dec. 21 and June 21, we have a solstice (*Sun stance*) at which the Sun's declination is at its farthest south position (**Tropic of Capricorn**), or at its farthest north (**Tropic of Cancer**) respectively.

During the year, latitudes beyond the equatorial region experience a continual but gradual shift in daylength - a few minutes per day. The Sun's altitude increases or decreases a small amount - becoming more pronounced heading into spring or autumn.

Annual March of Seasons - Dec. Solstice

See pp. 52-53 - Fig 2.1 (side view) and Fig 2.2 (top view)
Dec. 21 or 22: **December solstice** - Sun's declination at Tropic of Capricorn

\>>Northern Hemisphere's *winter solstice* --- Northern Hemisphere is tilted *away* from the Sun (more diffuse insolation) --- Circle of illumination *excludes* the North Pole region = 6 months of night for the **Arctic Circle** (66.5° N - 90° N)
\>>Southern Hemisphere's *summer solstice* --- Southern Hemisphere is tilted *toward* the Sun (more direct insolation) --- Circle of illumination *includes* the South Pole region = 6 months of day

Annual March of Seasons - March Equinox

See pp. 52-53 - Fig 2.1 (side view) and Fig 2.2 (top view)

March 20 or 21: **March Equinox** - Sun's declination at the equator

>>Northern Hemisphere's *vernal equinox* --- Northern Hemisphere has been slowly gaining daylight hours --- Circle of illumination passes through both poles. All locations on Earth experience a 12 hour day and night

>>Southern Hemisphere's *autumnal equinox* --- Southern Hemisphere has been slowly losing daylight hours.

Annual March of Seasons - June Solstice

See pp. 52-53 - Fig 2.1 (side view) and Fig 2.2 (top view)

June 20 or 21: **June solstice** - Sun's declination at Tropic of Cancer

>>Northern Hemisphere's *summer solstice* --- Northern Hemisphere is tilted *toward* the Sun (more direct insolation) --- Circle of illumination *includes* the North Pole region = 6 months of day in the Arctic Circle

Discussion: Based on what you know is going on in the Northern Hemisphere during the June solstice, what do you think is going on in the Southern Hemisphere at the same time? Why?

Annual March of Seasons - Sept. Equinox

See pp. 52-53 - Fig 2.1 (side view) and Fig 2.2 (top view)
Sept. 22 or 23: **September Equinox** - Sun's declination is back at the equator

>>Northern Hemisphere's *autumnal equinox* --- Northern Hemisphere has been slowly loosing daylight hours --- Circle of illumination again passes through both poles. Another day where all locations on Earth experience a 12 hour day and night.
Discussion: What is happening in the Southern Hemisphere? Why?

Seasonal Observations

Other than the slow loss or addition of daylight time in the midlatitudes, there is something else to observe during the changing seasons.

The position of sunrise and sunset on the horizon migrates each day (see Fig. 2.11b), and the angle of the sun changes each day as well.

See p. 53 - Fig 2.3