Chp 2: Sept 16: Solar Energy to Earth and the Seasons

Wednesday, September 16, 2015 8:59 AM

- After reading I should be able to;

? - Distinguish between galaxies, stars, and planets, and locate Earth
- Summarize the origin, formation, and development of Earth, and reconstruct Earths annual orbit around the sun.
- Descibe the planets, specfically sun operations, characteristics, solar wind, the electromagnetic spectrum of radiant energy.
- Define solar altitude, solar declinations, and daylength
- And describe the annual variability of each- Earth's seasonality

Getting started

- **The Universe**
- Populated with at least 125 billion galaxies.
- The milky way it self has about 300 billion stars.
- One of these stars is the sun which emits unlimited radiation and energy.

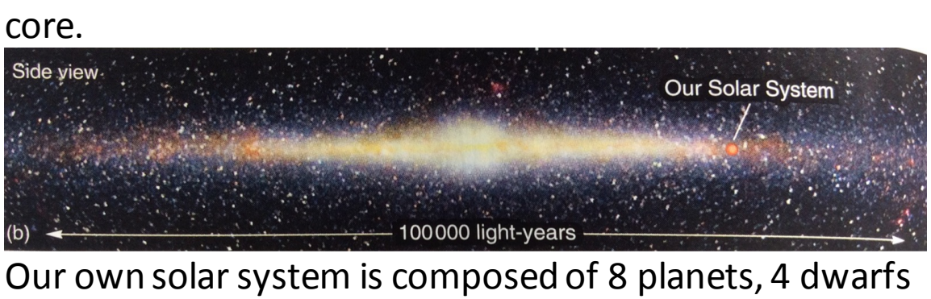
- This solar energy we get from the sun arrives at the top of Earths atmosphere which establishes the pattern of energy input that drives Earths physical systems and influences our daily lives.

How solar energy creates the seasons

- This solar energy input into the atmosphere comnbined with Earths tilt and rotation, produces daily, seasonal, and annual patterns of changing daylength and sun angle.
- The sun is the ultimate energy source for most life processes in our biosphere.

Where are we in the universe?

- Our solar system (in which we are part of) is located on the remote trailing edge of the milky way galaxy.
- The milky way is a flattened disk shaped collection of stars in the form of a barred-spiral.
- Barred-spiral: a spiral with a slightly barred, or elongated core.
-



- Our own solar system is composed of 8 planets, 4 dwarfs and many asteroids 30 000 light years away from the centre of the galaxy (or black hole)

How the solar system formed

- Formed through a condensed from a large, slowly rotating and collasping cloud of dust and gas called a nebula.
- Gravity: the mutual attraction exerted to their mass, was the key force in this condensing solar nebula.
- As the nebular cloud organized and flattened into a disk shape, the early "protosun" grew in mass at the centre, drawing more matter matter to in.
- Materials rotating the protosun and different distances were known as protoplanets.

Planetesimal hypothesis

-also known as the dust cloud hypothesis

- Small grains of cosmic dust and other solids accrete to form planetesimals that may grow to become planets to then eventually planets.

Random moon count

-Earth (1 moon), Jupiter (67), Saturn (62), Uranus (27) and Neptune (13)

Dimensions and Distances

- Speed of light = 300 000 km;s-1 or 9.5 trillion km per year
- Our own moon is 384 400 km from Earth (1.28 seconds ly)
- Earth to the sun is 150 million km (8 min and 20 sec lys)
- Milky way is 100 000 ly side to side
- The universe (as seen by Earth) 12 billion ly in all directions.

- The structure of Earths orbit is not constant but changes or a long period of time.
- Earths distance from the sun varies more than 17.7 million km during a 100 000 year cycle.
- This causes the the perihelion and aphelion to be closer or farther at different time in the cycle

- Perihelion: Earths closest position to the sun. Occurs on Jan 3rd during the northern hemisphere winter. Sun distance= 147 225 000 km.
- Aphelion: Earths farthest position from the sun. Occurs on July 4th during the Northern hemisphere summer. Sun distance= 152 083 000 km.

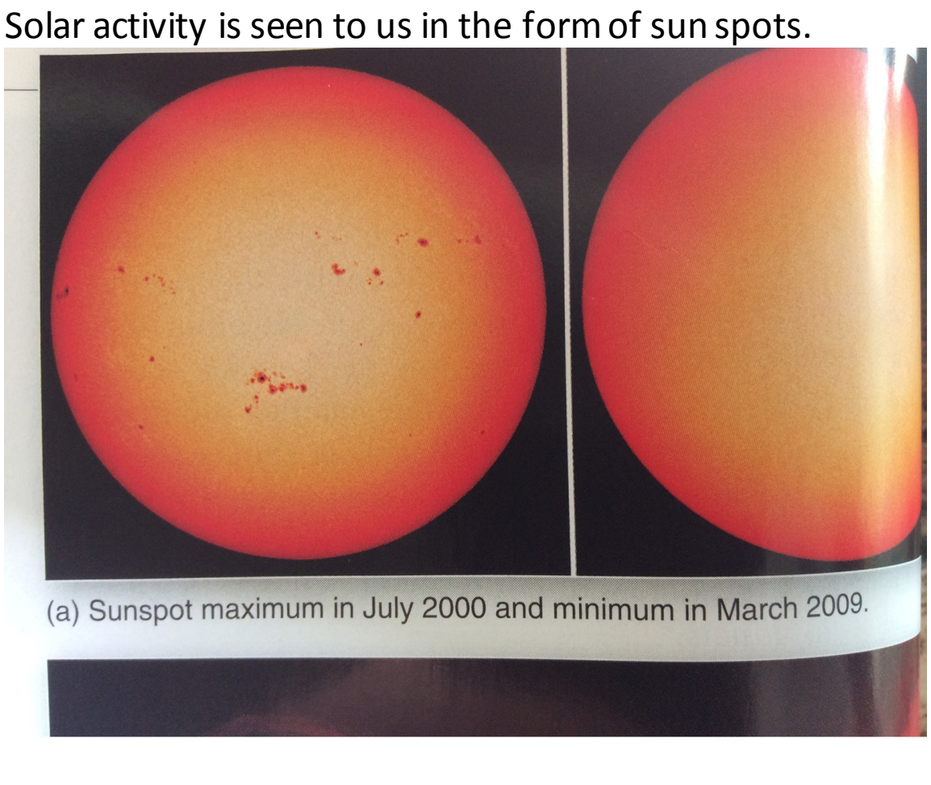
Solar energy: from sun to the earth

- The sun captures around 99.9% of matter from the original nebula.
- The other remaining 0.1% formed all the planets (satellites, asteroids, comets and debris).
- This solar mass from the sun (being that it's the most dominant object in our solar system) produces tremendous pressure and high temperatures deep in its dense interior.
- Under these conditions, the suns abundant hydrogen atoms are forced together and pairs of hydrogen nuclei are joined in the process of fusion.
- In the "fusion" reaction, hydrogen nuclei form helium, the second lightest element in nature and from this reaction enormous amounts of of energy are liberated.
- Quite literally- disappearing solar mass because energy.

-The suns principle outputs consist of the solar wind and of radiant energy spanning portions of the electromagnetic spectrum.

Solar activity and solar wind

- Solar activity is seen to us in the form of sun spots.
-



(a) Sunspot maximum in July 2000 and minimum in March 2009.

- The solar cycle is the periodic variation in the suns activity and appearance over time.
- Sun spots: surface disturbances caused by magnetic storms.
- Can range from 10 000 to 50 000 km with some as large as 160 000km (12 times larger than Earths diameter).
- Solar minimum: period of years when few sun spots are visible.
- Solar maximum period during which sunspots are numerous.
- Activity can include solar flares, magnetic storms (that cause surface explosions as well as prominence eruptions, outbursts of gases arcing from the surface.
- Although much of the material from these eruptions is pulled back toward sun by gravity, some moves into space as part of solar wind.

Solar wind effects

- The sun constantly emits clouds of electrically charged particles (hydrogen nuclei and free electrons) that surge outward in all directions from the suns surface.
- The genetic material from the sun travels much slower than light, taking about 3 days to reach earth (50 million km a day).
- Solar wind originates from the sun solar corona (outer atmosphere).
- The corona is the suns rim (can be seen with the human eye during a solar eclipse)

- As the charged particles of the solar wind come to Earth they first start to interact with Earths magnetic field. The magnestosphere which is genertaed by dynamo-like motions.
- The magnetosphere deflects the solar wind at both of Earths poles so that only a small portion ever enters earth through the upper atmosphere.

- Another contributer of solar wind is called coronal mass ejections (CME's).
- CME's are massive outbursts of charged material.
- Contributes to the flow of solar wind and are often viewed as an aurora up north.

- Solar wind disrupts certain radio broadcasts ad satellite transmissions and can cause overloads on Earth-based electrical systems.

Electromagnetic Spectrum of Radiant Energy

- The essential solar input to lifee is electromagnetic energy of various wavelengths.
- Electromagnetic spectrum: a spectrum of wavelengths of electromagnetic energy.
- Wavelength: is the distance between corresponding points of any two waves.
- The sun emits radiation energy composed of 8% ultraviolet, 47%/ infrared wavelengths, 47% visible light wl, and 45% infrared wavelengths.
- *The hotter the wavelength, the shorter the mean wavelength of maximum intensity emitted.*

- Earth acts like a blackbody- radiating nearly all that it absorbs. Earth emits longer wavelengths (mostly in infrared)

Incoming energy at the top of the atmosphere

- Thermopause: region at the top of the atmosphere, approx 480 km above Earth's surface.
- It is the outer boundary of Earths energy system and provides a useful point at which to assess the arriving solar radiation before it is diminished by scattering and absorption in passage through the atmosphere.
- Insolation: solar radiation that is intercepted by Earth.
- Measured as the rate of radiation delivery to a horizontal surface, as watts per square metre (W'm-2)

Solar constant

- Fourteen hundred watts of radiation coming to Earth
- Is the average insolation received at the thermopause when Earth is at its average distance from the sun.
- As it moves through the atmosphere towards Earth, it becomes reduced by more than half due to reflection, scattering, and absorption of shortwave radiation.
- The earths axis controls mhow much radiation is entering Earth

Uneven distribution of insolation

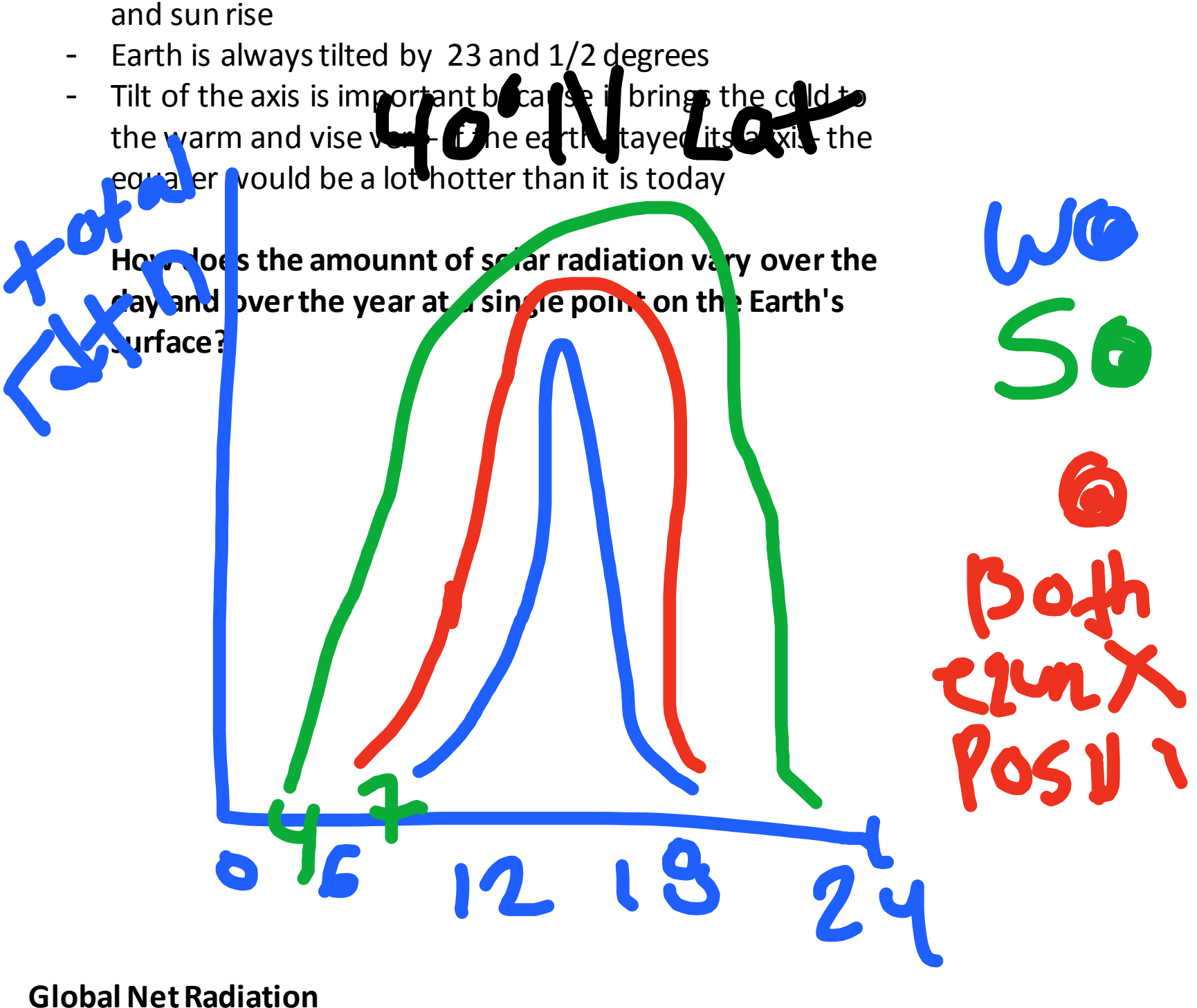
- Earths curved surface presents a continually varying angle to the incoming parallel rays of insolation,
- The only point where insolation arrives perpendicular to the surface (hitting it from over head straight on) is called subsolar point.
- The thermopause above the equilateral region receives 2.5 times more insolation annually than the thermopause above the poles
- Lecture notes on this
- ****What controls the angle of incidence?******

1. Latitude
2. Time of year
3. Time of day ones rotating around the sun the other around the axis

Geometric relationships (lecture class notes)

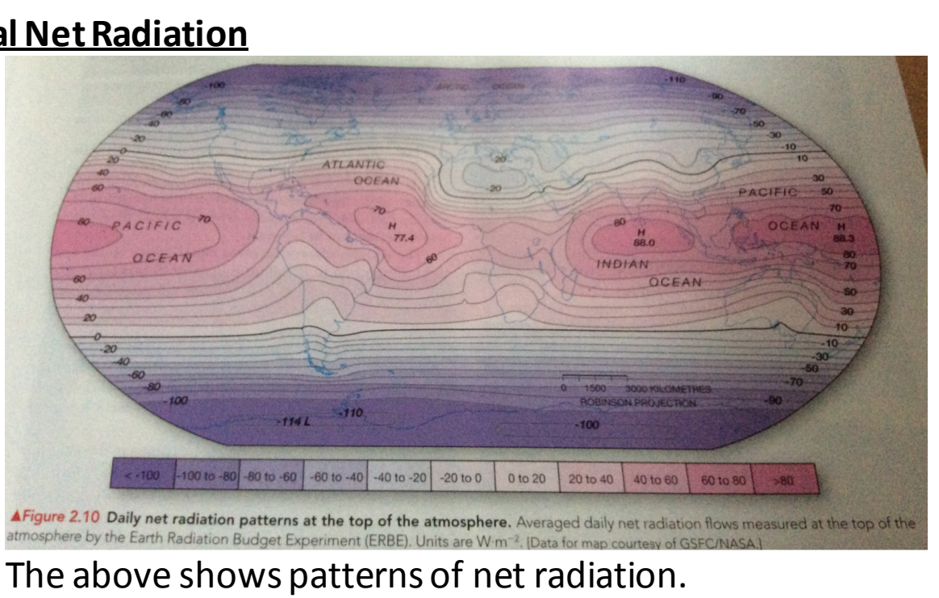
- Rotates on its axis, revolves around the sun
- Equnox position (equal day light no matter where you are on the planrt) solar moon, sun over head (time)
- The subsolar point is right on the equator (equnox position)
- Is a place on the earth when it is halway through sun set and sun rise
- Earth is always tilted by 23 and 1/2 degrees
- Tilt of the axis is important because it brings the cold to the warm and vise versa if the earth stayed its axis the equator would be a lot hotter than it is today

How does the amounnt of solar radiation vary over the day and over the year at a single point on the Earth's surface?



Global Net Radiation

-



▲Figure 2.10 Daily net radiation patterns at the top of the atmosphere. Averaged daily net radiation flows measured at the top of the atmosphere by the Earth Radiation Budget Experiment (ERBE). Units are W·m⁻². (Data for map courtesy of GSFC/NASA.)

- The above shows patterns of net radiation.
- GNR is the balance between incomming short wave energy from the sun and all out going radiation from Earth and the atnosphere (energy inputs minus energy outputs).
- Isolines: like a topographic map using lines to show the values of highest and lowest areas for radiation.
- Earths climate system looses more energy to space than it gains from the sun.

The Seasons

- Seasonality: refers both to the seasonal variation of the Sun's position above the horizon and to changing day lengths during the year.
- These seasonal variations are a response to changes in the suns altitude (or the angle between the horizon and the sun.

Placement of the sun in the sky

- At sunrise or sunset the sun is at 0 degrees
- If reaches halfway between the horizon or directly overhead: 45 degrees altitude
- If the sun reaches the point directly overhead; 90 degrees altitude.
- ^ altitude can also be called "zenith".
- ^^ 90 degrees zenith can only happen at the at the subsolar point where isolation is at a maximum.

- At all other surface points, the sun is at a lower altitude angle, producing more diffuse insolation.

- Suns declination: is the latitude of the subsolar point. Declination annually migrates 47 degrees of latitude moving between the tropic of cancer and tropic of capicorn latitudes.
- The subsolar point does not reach the continental united states or Canada; to up far north.

The duration of exposure to insolation is daylength, which varies during the year, depending on latitude. Daylength is the interval between sunrise, the moment when the disk of the sun first appears above the horizon in the east, and sunset, that moment when it totally disappears below the horizon in the west.

Reasons for the seasons

- Sun altitude, sun declination, and daylength are created by five physical factors that operate in concert:

1. Revolution: orbit around the sun; requires 365.24 days to complete at 107 280 km.h^-1
2. Rotation: Earth turning on its axis; takes approx. 24 hours to complete.
3. Tilt: Alignment of axis at about 23.5 degrees angle from perpendicular to the plane of the ecliptic (the plane of Earth's orbit)
4. Axial Parallelism: Unchanging (fixed) axial alignment, with Polaris directly overhead at the North Pole throughout the year.
5. Sphericity: Oblate spherodial shape lit by the sun's parallel rays; the geoid.

Revolution

- Speed of the Earth as it rotates around the sun; 107 280 km.h^-1
- This speed together with Earths distance from the sun , determines the time required for one revolution around the sun an therefore, the length of the year and duration of the seasons.
- It takes 365.2422 days to complete an annual revolution.
- ^ this number is based on "tropical year" measured from equinox to equinox (or between two lapse times between two crossings of the equator by the sun).

Rotation

- A complex motion that averages slightly less than 24 hours in duration.
- Determines daylength
- Creates the apparent deflection of winds and ocean currents, as well as produces the twice daily rise and fall of the ocean tides in relation to the gravitational pull of the sun and moon.
- Rotates counterclockwise about its axis. (rotates east to west [eastward]
- ^ this eastword rotation creates the suns apparent westward daily journey from sunrise in the east to sunset in the west.
- The dividing line between day and night is called the; circle of illumination.
- Because this day-night dividing circle of illumination intersects the equator (and because both are great circles, and any two great circles on a sphere bisect one another), daylength at the equator is always evenly divided- 12 hours a day & 12 a night.
- ^ all other latitudes expereince uneven daylength- except for 2 days a year (the equinox's)
- Earths mean solar time is 24 hours (or 86 400 seconds)
- The Earths rotation is gradually slowing. That even the earths "day" is has a much longer numer of hours than it was 4 billion years ago.

Tilt of Earths Axis

- The plane of ecliptic: a plane touching all four of Earths orbit.
- The axial tilt of earth ranges from 22 degrees to 24.5 degrees. But the most present tilt is 23.45 degrees (or 66.5 degrees from a plane)
- Scientific evidence shows that the angle of tilt is currently lessening in its 41 000- year cycle.

Axial Parallelism

- Earths axis maintains the same alignment relative to the plane of the ecliptic and to polaris and other stars.
- If we compare the axis in different months, it would always appear parrallel to itself, a condition known as axial parallelism.

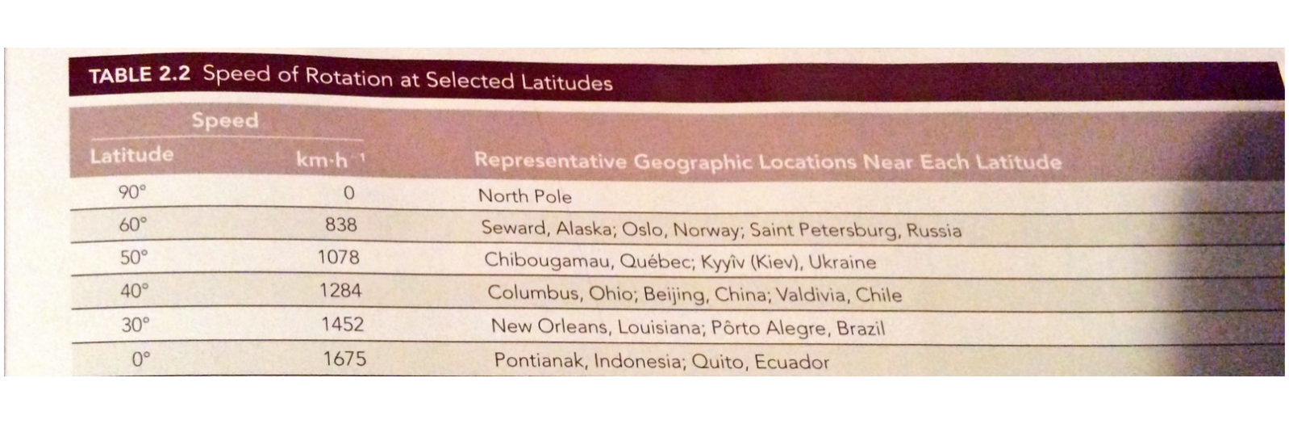


TABLE 2.2 Speed of Rotation at Selected Latitudes

Latitude	Speed km·h⁻¹	Representative Geographic Locations Near Each Latitude
90°	0	North Pole
60°	838	Seward, Alaska; Oslo, Norway; Saint Petersburg, Russia
50°	1078	Chibougamau, Québec; Kyyiv (Kiev), Ukraine
40°	1284	Columbus, Ohio; Beijing, China; Valdivia, Chile
30°	1452	New Orleans, Louisiana; Pôrto Alegre, Brazil
0°	1675	Pontianak, Indonesia; Quito, Ecuador

Sphericity

- Earths approximately spherical shape causes the parallel rays of the sun to fall at uneven angles on Earth's surface.
- Earths curvature means that insolation angles and net radiation received vary between the equator and the poles.

Annual March of the Seasons

- The extremes of daylength occur in December and June. These times around dec. 21 and June 21 are solstices.
- Solstices are specific points in time at which the sun's declination is at its position farthest north at the Tropic of Cancer or south at the Tropic of Capricorn.
- "tropic" is from *tropicus,* meaning a turn or change, so a tropic latitude is where the sun's declination appears to stand still breifly (sun stance, or sol stice) and then "turn" and head toward other tropic.

December Solstice	On December 21 or 22 at the moment of the solstice or "northern hemisphere winter soltice", the circle of illumination excludes the North Pole region from sunlight but includes the South Pole region.	The subsolar point is about 23.5 degrees south latitude, the tropic of Capricorn parallel. The northern hemisphere is tilted away rom these more direct rays of sunlight- our northern witer- therby creating a lower angle for the incoming solar rays and thus a more diffuse pattern of insolation.
March Equinox	In the northern hemisphere as Earth completes 1/4th of its orbit. The moment of the March Equinox, or vernal equinox in the Northern Hemisphere, occurs on March 20 or 21.	At that time, the circle of illumination passes through both poles, so that all locations on Earth experience a 12-hour day and a 12-hour night.
June Solstice	From March, the seasons move on to June 20 to 21st, the moment of the June Solstice , or summer solstice in the Northern Hemisphere.	The subsolar point migrates from the equator to 23.5 degrees north latitude, the Tropic of Cancer. Because the circle of illumination now includes the north polar region, everything north of the Arctic circle receives 24 hours of daylight- the midnight sun
September Equinox	September 23 or 2 is the time of the September equinox, or autumnal equinox in the Northern Hemisphere, when Earths orientation is such that the circle of illumination again passes through both poles, so that all parts of the globe experience a 12-hour day and a 12-hour night.	The Subsolar point returns to the equator, with days growing shorter to the north and longer to the south. In the Northern Hemisphere, autumn arrives, a time of many colourful changes in the landscape, whereas in the Southern Hemisphere it is spring.

- The parallel at about 66.5 degrees north marks the Arctic Circle; this is the southermost parallel (in the Northern Hemisphere) that experiences a 24-hour period of darkness. During this period, twilight and dawn provide some lighting for more than a month at the beginning and end of the Arctic night.

Twilight and Dawn

- Dawn is the period of diffused light that occurs before sunrise.
- Twilight is the corresponding evening time after sunset.
- During both periods light is scattered by molecules of atmospheric gases and reflected by dust and moisture in the atmosphere.
- The duration of both is a function of latitude, because the angle of the suns path above the horizon determines the thickness of the atmosphere through which the suns rays must pass.
- Illumination may be enhanced by the presence of pollution aerosols and suspended particles from volcanic eruptions or forest and grassland fires.
- Dawn and twilight are only 30-45 minutes each.
- These times increase to 1-2 hours each at 40 degrees latitutude and at 60 degrees latitude they each range upward from 2.5 hours.
- The poles experience about 7 weeks of dawn and 7 weeks of twilight, leaving only 2.5 months of "night" during the 6 month when the sun is completely below the horizon.

******class notes********

What controls the total amount of solar radiation

-source of energy, earths tilt, atmospheric filtering

Solar energy to earth and the season

- Solar radiation is the fuel for most natural phenonmena
- How does solar radiation flow through through the earths atmosphere, and interact with it and the ground surface an oceans?
- To answer this er need to know: nature ad forms of radiation, laws governing energy flows, laws describing energy flows, laws describe radiation from surfaces.

1. Describes the flow of heat and light.
2. Energy moves from areas of surplus to areas of deficit. Rate of energy gradient is proportional to the energy gradient. Energy can not be created not destroyed (conservation of energy).
   Where I= incident radiation, t= transmission, a= absorption, a= reflection.
   I= t+ a + (fancy "a" meaning reflection)
3. 1 an inverse relationship between the temp of an object and the wavelength it emits. Weins law.
   2 flow of radiant energy from a surface is directly related to the surface temp raised to the 4th power. Described by the stefan-boltzman law;
   . Where o is the stefan-boltzman constant and T is the surface temperature.
4. Budgets of radiation and energy

How does solar radiation pass throughout the Earths atmosphere?

- The atmosphere is an "energy filter" to scatter the rays
- When ever there is absorption, that particle re-condenses and becomes the particle it touches.
- Filter is a transformer of short wave to long waves.
- Scatters short waves- direct. If reflected it stays as short waves

Characteristics about the earths filter

- Extends to -489km -97% within 30km. 78 N, 21 O2, 1% Ar, CO2, and H2O vapour.
- Green house gases (i.e absorb long waves)
- Warm air, photosynthesis and respiration, vary in concentration
- Combustion
-

How does the atmospheric filter vary with time?

- 100 percent of the energy is coming in.
- 5% is reflected
- 15% is absorbed (alpha)
- 80% reaches the ground surface (t)

- Now the filter is less transparent as the filter above
- A lot of diffuse short wave radiation
- 25% is absorbed in clouds
- As low as 10% will be able to make It to the ground surface

- The equator recieves a lot of radiation
- But it is equalled out by the very thick layer of clouds at the equator to absorb the wave radiation.