LP 2 Energy Budget

# of Days	2		
Prior Knowledge	Students will have conceptions about the orientation of the Earth to the Sun. They will know that the Earth has a tilt. Many will probably think that the seasons are due to the distance from the sun. Finally, students will have a basic understanding that the Sun provides both light and heat for the Earth.	California English-Language Arts Content Standards	Writing 2.3 (homework) Listening and Speaking 1.1
Lesson Objective	Students will be able to apply the concepts of energy and light to create an input/output model of energy budget for the Earth.	Language Goals/Demands	
Lesson Assessment		Changes for Next Time	
California State Science Standard	Physics 3.a,3.b, 4.a, 4.e, 7.a; Earth Science 4.b, 4.c, 4.d, 6.a, 8.a; Investigation 1.d, 1.g		
Materials Needed	Styrofoam balls and lights for Sun-Earth Model Activity Rope for wavelength demonstration, Bottles, buckets, etc for Dynamic Balance Activity	What Worked Well	

Time	Learning Task or Activity	Method & Notes
Day 1		
3 min	BW: Why does someone in Brazil experience different climate than you do in the Bay Area?	INDIVIDUAL SEAT WORK OR PAIR WORK
4 min	Discuss BW and HW: Concept Map - Students share answers	DISCUSSION on concept map challenges and BW See 2.1.1 Bell Work Teacher Guide
4 min	Energy Budget Introduction - Discuss the terms energy, budget, and equilibrium.	LECTURE/PRESENTATION See 2.0.1 Definitions See 2.1.3 Energy Budget Slides #2-5 Use 2.1.4 Student Notes
7 min	Sun-Earth Model Activity Introduction - Where does the Earth get its energy? - How much energy reaches the Earth? Give students directions about the activity. Since they know the Sun is responsible for the Earth's energy, how do we know how much energy reaches the Earth from the Sun?	Q&A/ACTIVITY INSTRUCTIONS See 2.1.2 Sun-Earth Modeling Activity This activity could be shown as a whole class demonstration or in small groups.

12 min	Sun-Earth Model Activity - Student pairs use a light source and styrofoam balls to model the energy input from the Sun.	PAIR WORK/HANDS-ON ACTIVITY or CLASS DEMONSTRATION
5 min	Sun-Earth Model Activity Debrief - Teacher asks students for ideas about quantifying the solar output. - Discuss variables that are important: Size of planets, distance from each other, tilt of the planets - Discuss the impact of changing each of these variables of the input	DISCUSSION See 2.1.2 for Debrief Question Prompts
17 min	Develop the conceptual Energy Budget Model - Step through the incoming energy and the reflected energy - What are reasons why all of the Sun's energy is not warming the Earth? Talk about reflective surfaces and albedo. - Wavelength Demonstration - Optional albedo research video and additional slides	LECTURE/PRESENTATION See 2.1.3 Energy Budget Slides #6-17 Use 2.1.4 Student Notes one 5' long rope or shorter ropes for group work optional video - http://www.youtube.com/watch?v=9UJKVa2ClCU&feature=related
5 min	Concept Map Additions: Sun, Earth, Energy Budget, Albedo - Have students work in pairs to discuss how to add the additional words to their concept maps	INDIVIDUAL SEAT WORK OR PAIR WORK See 2.1.3 Energy Budget Slides #20
HW	Conceptual Questions on Energy Budget - Select a few problems for students to complete on their own.	See 2.1.5 Conceptual Problems

Day 2		
3 min	BW: We know that if the Sun kept inputting energy and it didn't go anywhere, then we would eventually be fried. What do you think happens to this energy? Why don't we all burn up?	INDIVIDUAL SEAT WORK See 2.2.1 Energy Budget Slides #2
4 min	Review energy budget and variables	DISCUSSION/PRESENTATION See 2.2.1 Energy Budget Slides #3-5 See 2.2.2 Student Notes
20 min	Energy Output Model - Building understanding of outgoing radiation - Temperature – What did you observe? - Sun and Earth outgoing wavelengths - Atmoshpere and Greenhouse gases	DISCUSSION/PRESENTATION See 2.2.1 Energy Budget Slides #6-17 See 2.2.2 Student Notes rope for wave length demonstration
25 min	Dynamic Energy Balance - This can be an activity or demonstration. -This provides direct experience of how changes to a system can alter the existing dynamic balance. - Refer to Bell Work. Talk about losing energy and ask for examples of analogies of this.	ACTIVITY/DEMONSTRATION See 2.2.2 for Dynamic Balance Activity
3 min	Concept Map Additions: Longwave radiation, short wave radiation	INDIVIDUAL WORK See 2.2.1 Energy Budget Slides #21
HW	Write 2 paragraphs describing what happens to the flow of energy into the Earth system. Use given image as a guide.	Homework 2.2.4

LP2: Earth's Energy Balance

Teacher Guides:
2.0.1 Definitions

2.1.1 Guide for Bell Work
2.1.2 Sun-Earth Modeling Activity
2.1.3 Energy Budget Slides
2.1.4 Student Notes
2.1.5 Conceptual Problems

2.2.1 Energy Budget Slides
2.2.2 Student Notes
2.2.3 Heat Transfer Demonstration
2.2.4 Homework Problems

3.1.2 Quiz on LP 2

Supplies:
Sun- Earth Modeling Activity
    Styrofoam balls for student pairs, at least 4 light sources for each class
Wavelength Demonstration
    5' long rope
Dynamic Budget Activity/ Demonstration - For each group:
    1 empty 2-liter plastic bottle with paper label removed
    1 measuring cup (2 cup size is better than 1 cup size) or 500 ml graduated cylinder
    1 Funnel
    Duct tape or other good tape
    Stopwatch or clock
    2 five gallon buckets

Optional Video:
http://www.youtube.com/watch?v=9UJKVa2ClCU&feature=related
Begin at 1:50. Researcher out on the ice, measuring albedo.

2.0.1

Definitions

Energy = Something has energy when it has the ability to change its surroundings (work or heat). Energy is usually measured in Joules. Energy used over a given time is Power which is measured in Watts.

Heat = thermal energy or energy that increases a body's temperature, energy transfer due to heat can be through conduction, radiation, and convection

Radiation = energy transfer through the electromagnetic spectrum at different wave lengths (ultraviolet, visible light, infrared)

Light = one type of radiation, visible wavelengths

Reflect = change of direction of light/radiation

Absorb = To take up. For example, light energy can be absorbed by an object, and the object then heats up.

Emit = to give or send out. An object emits radiation.

Temperature = measure of internal energy

Equilibrium state = A state of balance

Variable = factors that change and can impact the system. This word can used as a noun or adjective.

System = a set of interactions set apart from the rest of the universe for the purposes of study, observation, and measurement.

Teacher Guide 2.1.1

Bell Work: Student Conceptions of Weather and Climate

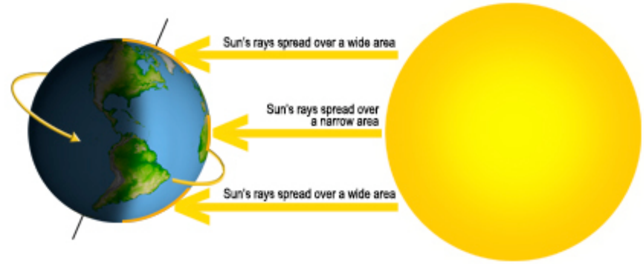
Students are not expected to have all of the following answers for bell work, but they should have an understanding of a few variables that affect climate and weather and how these differ.

Bell Work Question:

Why does someone in Brazil experience different climate than someone in the Bay Area?

Correct Answers:

1. The Earth is relatively the same distance from the Sun all year, but the tilt and curvature of the Earth is responsible for the differences between the two locations. Brazil is close to the equator and receives the direct rays of the Sun whereas the Bay Area is at higher latitudes and receives indirect rays (See Figure). The tilt of the axis causes the seasons in places like the Bay Area.



2. The Bay Area and parts of Brazil may have different altitudes. The climate changes as one gets higher or lower in the atmosphere.
3. The ocean currents bring cold water from the north that affects the climate in the Bay Area whereas the water that reaches the Brazilian coast has traveled across the Atlantic at the equator and is much warmer. Water temperature has an effect on land temperatures as well.

Common Misconception:

The seasonal or regional differences in climate are based on how close the Earth is to the Sun at any given point. When the Earth is close to the Sun it is summer and hottest and when it is furthest from the Sun it is coldest. (See Correct Answer 1 for a proper explanation).

2.1.2 Sun-Earth Modeling Activity Instructions & Debrief Questions

This activity can be used as a whole class demonstration or for small group activities.

Classroom Demonstration Materials:
LCD Projector
Globe or blow up globe
The light of the LCD projector models the light from the sun.

Small Group Activity Materials: one set for each pair of students
Flashlight or light source
4" Styrofoam ball (white or painted)
rubber band that fits around the ball

Turn off the lights so that the light can be seen reflecting off of the ball. (Painting the balls can help, as can placing a pen or pencil into the ball to hold it.)

1. Begin the activity with a few questions. Then pass out the materials to each group. Explain what the materials represent.

Ask students:

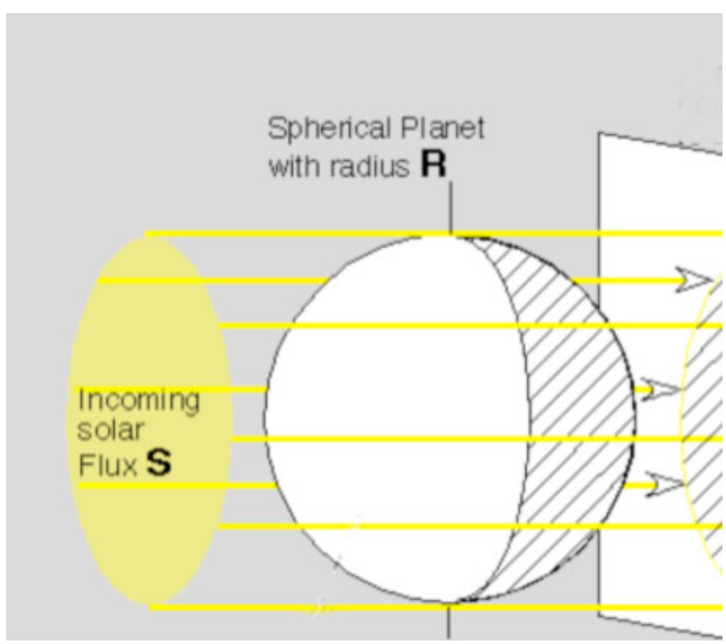
Where does Earth get its energy? Energy drives climate and life. (Sun)
Does all of the light from the Sun reach the Earth? (no)
What happens to light that doesn't reach the Earth? (continues past Earth)

Tell students that they have been given a model Sun (the flashlight) and a model Earth (Styrofoam ball).

2. Tell students that their challenge is to think about how the Sun's radiation hits the Earth.

Does the Earth get equal amounts of sunlight everywhere? (More at equator)
What are the implications of unequal amount of sunlight? (Climate)

Allow students some time to play around with the flashlight and the ball and see what they come up with. After a few minutes, ask students to share their ideas. It isn't necessary for all students to come up with a correct answer. It's much more important that they realize the variables that are involved with the answer: distance from the Sun & size of the Earth.



3. Tell students that we measure the solar radiation per unit area. This is called the solar constant (***S***) and is equal to 1367 W/m^2. If necessary, review the units (W and m^2). But this number just tells us the maximum incoming solar radiation *per unit area*. The actual amount of incoming solar radiation depends on the area that is sun light is hitting the Earth's surface. This is not an easy concept.

4. Pass out a rubber band to each group. This represents the equator. Students should put the rubber band around the Earth where the equator is, and then hold the Earth model in the proper angel to the plane of rotation. Tell students that Earth's axis of rotation (line from pole to pole) is tilted 23° from the plane about which Earth. The teacher should show what the correct orientation is.

5. Discuss with students the intensity of the radiation at various illuminated parts of the globe. A location at the equator will receive much more intense and direct sunlight at noon than it will at sunrise or sunset. This is effectively because one hemisphere is receiving only a circle's area worth of radiation.

Be sure students know what the word variable means.

Ask students about quantifying the solar input to Earth.
- What factors would change the amount of energy reaching a planet? (size of planet, distance from Sun, sunspots).
- Would the rate of rotation or revolution or the tilt of a planet change the total solar energy reaching a planet?

- The size of the planet and distance from the sun have a direct impact, as measured by the temperature on Mars.
- Sun spots change the amount of sunlight over an 11 year cycle.
- The rate of rotating around the Sun will not change the amount of solar input on average, nor will the length of a day (revolution around Earth's axis).
- The tilt of the axis does not change the total energy. Instead, the tilt of the axis changes when and where that solar energy is

Notes:
At Earth's average distance from the Sun (about 150 million kilometers), the average intensity of solar energy reaching the top of the atmosphere directly facing the Sun is about 1,367 watts per square meter, according to measurements made by the most recent NASA satellite missions.

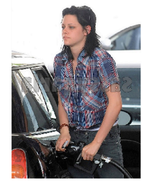
Averaged over the entire planet, the amount of sunlight arriving at the top of Earth's atmosphere is only one-fourth of the total solar irradiance, or approximately 340 watts per square meter.

Lesson Plan 2 – Day 1

Earth's Energy Budget

Earth's Energy

- Energy is the ability to change the surroundings
  – Examples: fuel for a car, ball falling from a window, electricity to turn on a light



Energy is all around us. It can take many forms and it is a difficult concept to understand, but it is important for many different things that we do. Energy helps us play sports, drive our cars, watch television, and stay warm. Just like people, the Earth is affected by different forms of energy which determine how warm or cold the Earth is.

Budget

- Budget is the amount of incoming or outgoing energy allocated to a system
  - Money
  - Time

The amount of energy is not static. While energy cannot be created or destroyed – it does move from place to place and it can change form. Thus, just like a bank account where money is going in and out, the Earth has an energy budget. Energy enters and exits and, in the process, can change its surroundings. Specifically energy changes the temperature and climate of the Earth.

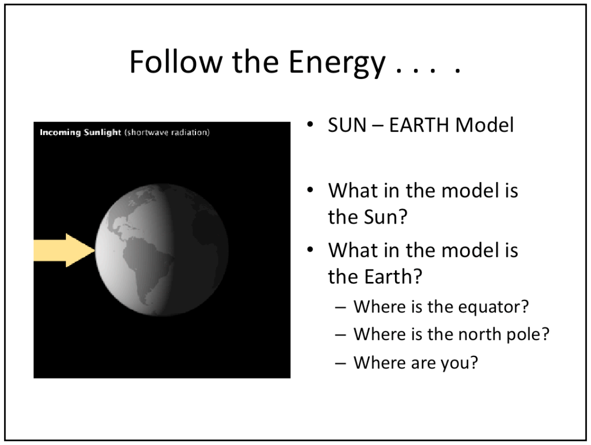
Equilibrium

- Equilibrium is the state of balance between things
  - Emotional
  - Chemical reactions
  - Forces
- Equilibrium means that the total amount may change over time, but the proportion in the budget parts stay fairly the same.

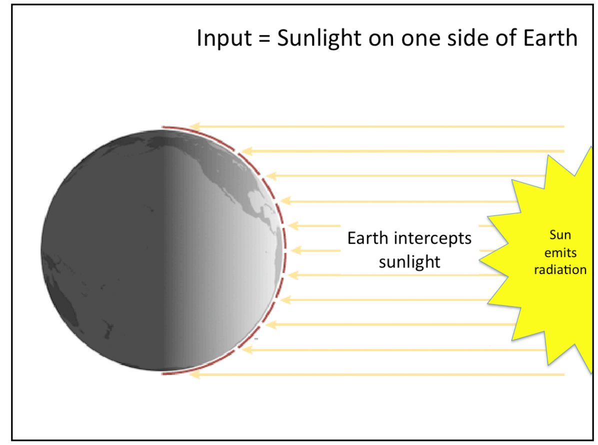
In this lesson, the focus is on temperature equilibrium. Equilibrium is very important, and it may be dynamic as demonstrated in the second day of this lesson.

Many organisms need a balanced environment so that their bodies don't get too cold or too hot. While an equilibrium point might change over time – that is the temperature of a time period, normally it stays within a small range. This allows organisms to live, and work, and reproduce.

The Earth also has an equilibrium that is established by the Earth's energy budget.



We are going to examine the incoming sunlight in a hands-on activity. Go to Sun-Earth Activity Description.



This slide is another model of the Sun-Earth system. The sun is the source of the incoming radiation (light) on the right. Point out that the right side of the Earth in this picture is lit up just like the Styrofoam ball in the 3-D model.

We are going to talk about some of the properties of sunlight and what happens to the sunlight as it interacts with the Earth system. The next lesson in this unit will focus on the output or outflow of the energy.

Sunlight is Energy

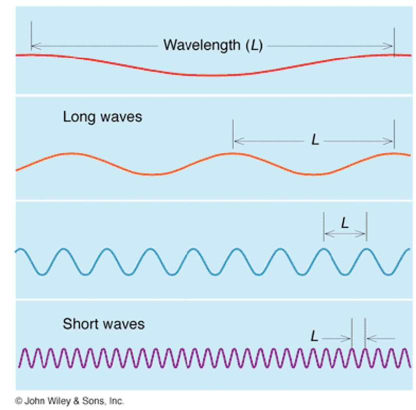
Sunlight comes in a range of SHORT wavelengths called visible light

Use this slide to introduce the idea that light can be divided into wave lengths.

Goal: Students will see that the rope can move in different wave lengths. This demo will be repeated on day 2 of lesson 2.

Demonstration:
With a 5’ long rope, have one student hold one end while the teacher holds the other end. Rotate the rope to get a wave pattern. Have students count the number of waves. Make sure everyone is counting the same thing. Now increase the amount of energy and there should be more waves. Ask students to compare the amount of energy that is put into the rope if there are are more waves (shorter) or less waves (longer). They should see that you have to put in more energy to create more shorter waves. Explain that with sunlight the waves are short and in the visible range so that we can see sunlight.

This demonstration could be done in small groups, with shorter ropes.



This image is to talk about the different wave lengths. Sunlight has short waves. The length of the wave is dependent on the amount of energy. The Sun is very hot and produces short waves of light – we see it as visible light.

This is a key point because the behavior of long wave radiation (sunlight) is different than short wave radiation (re-emmited energy from earth) in the energy balance.

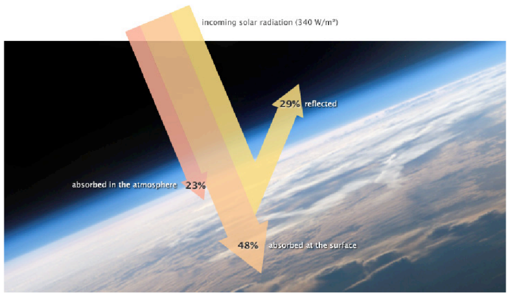
Once the sunlight reaches the Earth’s surface, what happens?

Ask students to share their ideas. When they say reflection or light bounces off, move to the next slide.

Reflected or Absorbed

The rest of this day’s lesson is on the reflection. Absorption will be covered in the next class.

Follow the Energy



What does 340 W/m2 represent the the Sun-Earth model?
What is one way to describe the energy that is absorbed? How much is absorbed?
What does reflected mean? How much is reflected?

Following the energy . . .we need to understand the 3 different arrows here to see how the energy leaves the Earth system .

Albedo = Reflection

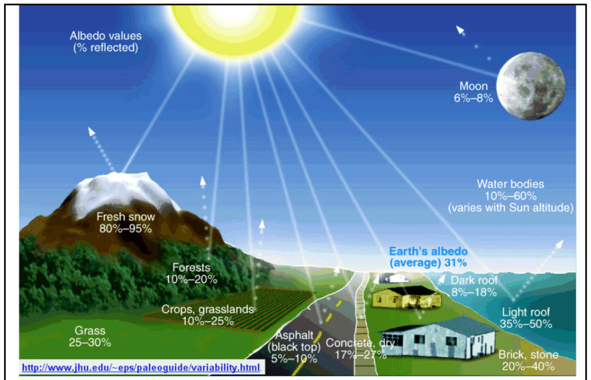
- How much is reflected?
- Scale is 0-1
- White =1,
  - High reflectivity
- Black = 0
  - Low reflectivity

- What do you think? High or low albedo?
- Grass
- Ice
- Rocks
- Asphalt
- Concrete

The list of materials are on the next figure.

Grass – 0.3
Ice – high (.9)
Rocks
Asphalt – very low (.05)
Concrete – low (.25)

More information:
http://agsys.cra-cin.it/tools/solarradiation/help/Albedo.html



Albedo = Reflection

Look at the diagram and discuss what types of surfaces have high albedo and what types of surfaces have low albedo. How did they do on their predictions?

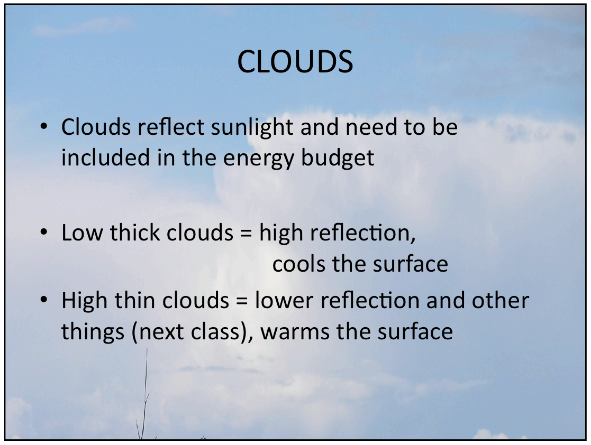
(0.31, the average albedo for the Earth).

What happens when there is a large volcanic explosion?
What happens where there is a major forest fire?

Optional Video

- http://www.youtube.com/watch?v=9UJKVa2ClCU&feature=related
- Begin at 1:50. Researcher out on the ice, measuring albedo.

http://www.youtube.com/watch?v=9UJKVa2ClCU&feature=related
Begin at 1:50. Video is a total of 6:30 minutes long.

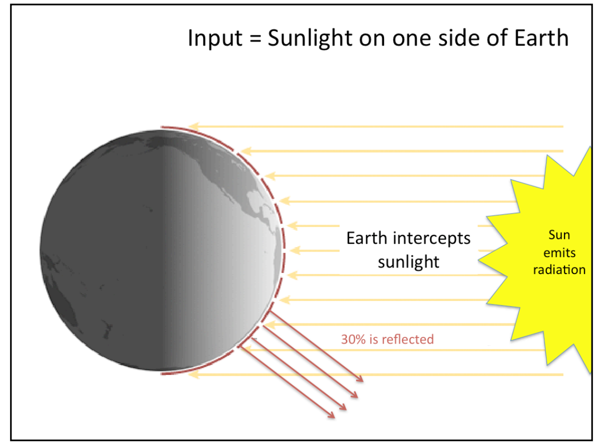


Clouds are part of the energy budget. They are important in both incoming radiation because they reflect some incoming radiation. And as will be discussed on day 2 of this lesson, clouds also absorb the long wave radiation emitted by Earth.

The goal of this slide is for students to include clouds in their understanding of what impacts the energy budget.

Because a cloud usually has a higher albedo than the surface beneath it, the cloud reflects more shortwave radiation back to space than the surface would in the absence of the cloud, thus leaving less solar energy available to heat the surface and atmosphere. Hence, this "cloud albedo forcing," taken by itself, tends to cause a cooling or "negative forcing" of the Earth's climate.

The study of clouds, where they occur, and their characteristics, play a key role in the understanding of climate change. Low, thick clouds primarily reflect solar radiation and cool the surface of the Earth. High, thin clouds primarily transmit incoming solar radiation; at the same time, they trap some of the outgoing infrared radiation emitted by the Earth and radiate it back downward, thereby warming the surface of the Earth. Whether a given cloud will heat or cool the surface depends on several factors, including the cloud's altitude, its size, and the make-up of the particles that form the cloud. The balance between the cooling and warming actions of clouds is very close although, overall, averaging the effects of all the clouds around the globe, cooling predominates. http://earthobservatory.nasa.gov/Features/Clouds/



Point out the addition to our model – 30% is reflected. This is the Earth's cumulative albedo.

What happens to the energy that enters the Earth system?

Concept Map – additions

- Sun or Sunlight
- Earth
- Energy Budget
- Albedo

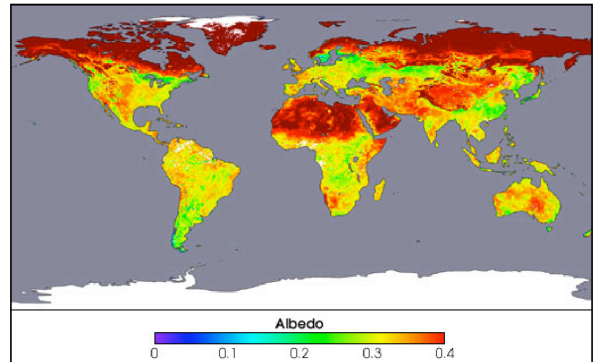
Have students work in pairs to discuss how they will add the words to their concept maps.

End of Day

What types of areas of Earth have
- a high albedo?
- a low albedo?

(think urban, farmland, desert, etc.)

Optional Slides:
This is to prep students for next slide. Think of different types of areas on land.



Earth's albedo

Collected by NASA satellite and averaged. Does not include the ocean and no data for white areas.

Optional Slide:
The colors in this image emphasize the albedo over the Earth's land surfaces, ranging from 0.0 to 0.4. Areas colored red show the brightest, most reflective regions; yellows and greens are intermediate values; and blues and violets show relatively dark surfaces. *White indicates where no data were available, and no albedo data are provided over the oceans.*

Remind student of what they learned about the distribution of sunlight with the Sun-Earth model. Sunlight does not reach everywhere equally.

This image was produced using data composited over a 16-day period, from April 7-22, 2002.

A new sensor aboard NASA's Terra satellite is now collecting the most detailed and accurate measurements ever made of how much sunlight the Earth's surface reflects back up into the atmosphere. By quantifying precisely our planet's reflectivity, or albedo, the Moderate Resolution Imaging Spectroradiometer (MODIS) is helping scientists better understand and predict how various surface features influence both short-term weather patterns as well as longer-term climate trends.

A low albedo mean that lots of energy is absorbed and only some is reflected. A high albedo like snow and ice means little absorption and lots of reflection. The most northern and southern areas are shown in white which means no data were available.

Ask student - What would you predict for Antarctica? What would you predict about the temperature from this data? Does this give us the whole picture of climate? What about weather? What might cause a change in albedo in one location?

2.1.4 Student Notes on Earth's Energy Budget

In my own words, energy means . . . . .

In my own words, an example of a budget is . . . .

In my own words, equilibrium means . . .

What is the source of energy that drives climate?

In my own words, albedo means . . .

When a surface has a high albedo, is the amount of sunlight reflected high or low?

How much of the sunlight is reflected?

2.1.5 Energy Budget Conceptual Problems

The following questions and answers can be used as in-class or homework problems. The last page has just the questions.

1. You are a city planner for your local neighborhood. You notice that the air temperature in your city is slightly higher than a nearby farming suburb. What are some ways that you could increase the albedo so that your city does not absorb as much solar radiation?

Answers may vary. Possible answers include: Placing solar panels on top of buildings to absorb light and turn it into energy while also reflecting some light, painting tops of buildings white, painting tops of city buses white, use mirrored windows to reflect the sun. Trees and parks to reduce the amount of black asphalt.

2. There is a constant amount of solar radiation that reaches the Earth. If Jupiter, the largest planet, was the same distance from the Sun as the Earth, how much solar radiation would reach Jupiter's surface?
    a. More than Earth
    b. Less than Earth
    c. The same as Earth

Explain why you chose your answer:
The amount of solar radiation that hits a surface is based on the area of the surface. Since Jupiter has a larger radius than Earth, it will intercept more solar radiation.

3. One effect of climate change is that higher air temperatures melt polar ice. How does this affect the energy balance of the Earth? Please be specific by stating what happens to a) albedo, b) the absorption and re-radiation of energy on the Earth, c) the Earth's temperature.

a) Melting ice caps will decrease albedo
b) Decreased albedo will increase the amount of energy that is both absorbed and re-radiated.
c) The earth's temperature will increase as a result of the increased solar absorption.

4. Las Vegas is built in a desert. Does the city (buildings, roads, parks) increase or decrease the Earth's albedo?

The building of a city added more concrete, asphalt, and buildings that have low albedo. Sand in deserts naturally has a very high albedo. Therefore, the Earth's albedo would have decreased.

5. Your friend learns how to make clouds. He thinks that if he produces clouds on a large enough scale that this will slightly decrease temperatures on Earth. Do you think you should invest in your friend's company or try to convince him to start a different business?

The effect of the clouds depends on their size and shape. Long, thin clouds do not add to the albedo and end up trapping radiation. Large, fluffy cumulous clouds increase the Earth's albedo by reflecting the solar radiation. Unless he can constantly manufacture large, fluffy clouds, I would not invest in his company. Another consideration is the cloud height – higher clouds will create warming.

Earth's Energy Balance Conceptual Problems for Students

1. You are a city planner for your local neighborhood. You notice that the air temperature in your city is slightly higher than a nearby farming suburb. What are some ways that you could increase the albedo so that your city does not absorb as much solar radiation?

2. There is a constant amount of solar radiation that reaches the Earth. If Jupiter, the largest planet, was the same distance from the Sun as the Earth, how much solar radiation would reach Jupiter's surface?
    a. More than Earth
    b. Less than Earth
    c. The same as Earth

    Explain why you chose your answer.

3. One effect of climate change is that higher air temperatures melt polar ice. How does this affect the energy balance of the earth? Please be specific by stating what happens to a) albedo, b) the absorption and re-radiation of the Earth, c) the Earth's temperature.

4. Las Vegas is built in a desert. Does the city (buildings, roads, parks) increase or decrease the Earth's albedo?

5. Your friend learns how to make clouds. He thinks that if he produces clouds on a large enough scale that this will slightly decrease temperatures on Earth. Do you think you should invest in your friend's company or try to convince him to start a different business?

Lesson Plan 2 – Day 2

Earth's Energy Budget

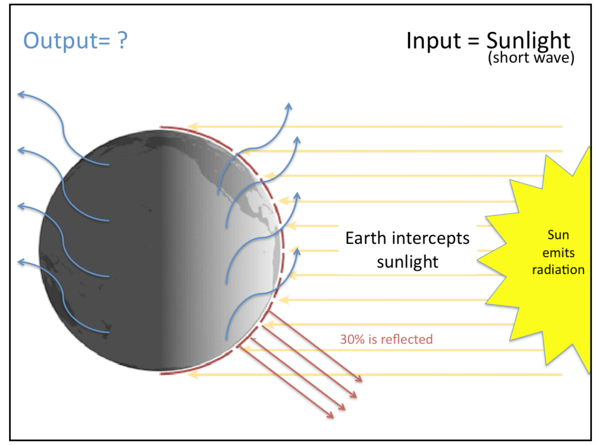
Bell Work:

We know that if the Sun kept inputting energy and it didn't go anywhere, then we would eventually be fried. What do you think happens to this energy? Why don't we all burn up?

Variables in the Energy Budget

- Where on Earth
  - Pole vs. Equator
- Reflection (albedo)
  - Material type
- Clouds
- Atmosphere
- Absorption and Re-radiation

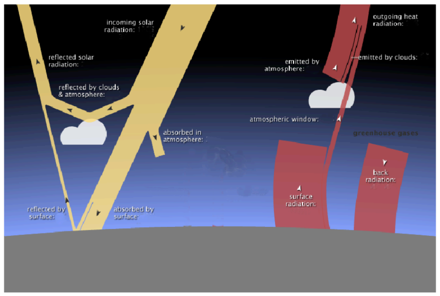
Variable can be used as a noun and an adjective. This is a list of variables (noun form) which are factors that vary. Variables may or may not impact the system. These variables impact the flow of energy through the Earth system.



Review yesterday’s budget.

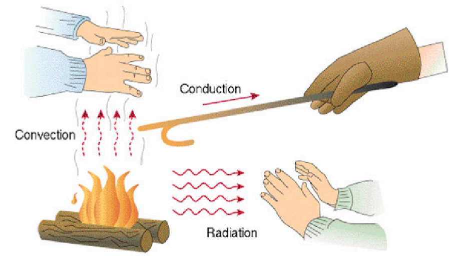
This is the model that was developed on the first day of this lesson.

Follow the Energy



This figure follows the energy from the sun to the earth. It is helpful to start with the thickest yellow line on the left and follow the energy in the yellow lines. Focus on the left side of the image. The right side is today's discussion.

Energy Moves in Three Ways

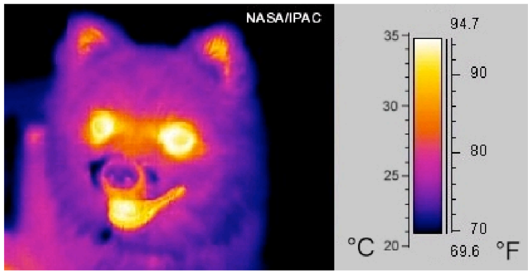


Conduction • Convection • Radiation

Conduction – Conduction is the process of handing on energy from one thing to the next. Example: A piece of metal that is hot at one end and cold at the other
Convection – Convection is the process by which heat is transmitted in liquids and gases by the actual movement of the heated particles. Example: Heating a liquid in a container
Radiation – Radiation is the process by which heat energy is transmitted from one place to another. Example: The sun

Image from http://blogs.saschina.org/sophie01pd2016/2009/10/24/science/

Radiation seen in Infrared Images



In this image, student can see the temperature of this animal. The temperature is detected as infrared waves of radiation.

Image from http://en.wikipedia.org/wiki/Image:Infrared_dog.jpg

Radiation

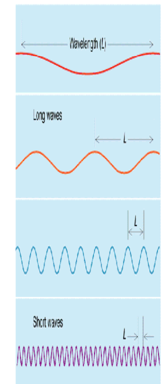
- When energy is absorbed by an object (rock, water, building), the temperature of the object increases.
- All objects emit radiation. The amount and wavelength range is dependent on the temperature of the object.
- As the temperature increases (hotter), the wavelengths emitted by the object decreases (becomes shorter wavelengths).

Objects Radiate Heat

- Earth absorbs and re-radiates energy
- In Earth's Energy Budget, all of Earth is considered together
  - Air (Atmosphere)
  - Land (Lithosphere)
  - Ice (Cryosphere)
  - Ocean/Water (Hydrosphere)
  - Life (Biosphere)

What can you say about emitted heat?

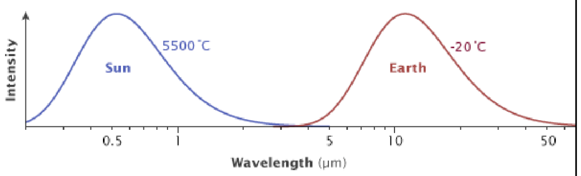
It comes in a range of LONG wavelengths



Goal: Students will see that the rope can move in different wave lengths. This demo is expanded from day 1 of lesson 2.

Demonstration:
With a 5' long rope, have one student hold one end while the teacher holds the other end. Spin the rope from your wrist to get a wave pattern. Have students count the number of waves. Make sure everyone is counting the same thing. Now increase the amount of energy and there should be more waves. Ask students to compare the amount of energy that is put into the rope if there are are more waves (shorter) or less waves (longer). They should see that you have to put in more energy to create more shorter waves. Explain that with sunlight the waves are short and in the visible range so that we can see sunlight.

Wavelengths of Energy Emitted by the Sun and Earth

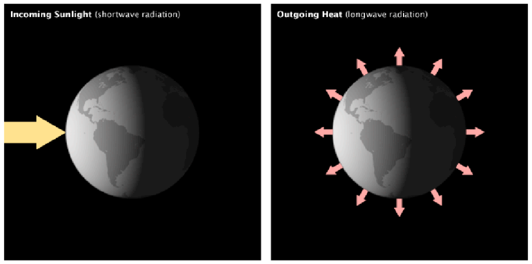


SHORT LONG

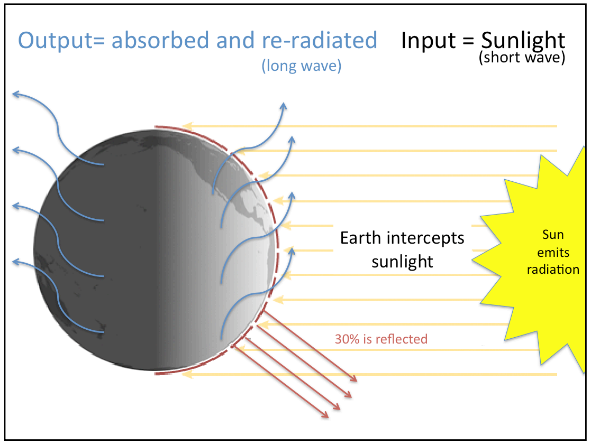
The Sun's surface temperature is 5,500° C, and its peak radiation is in visible wavelengths of light. Earth's effective temperature—the temperature it appears when viewed from space—is -20° C, and it radiates energy that peaks in thermal infrared wavelengths. (Illustration adapted from Robert Rohde.)

http://earthobservatory.nasa.gov/Features/EnergyBalance/page2.php

Follow the Energy . . . .



Emphasize that the incoming radiation is short wave and the outgoing radiation is long wave. This is important because in the next lesson we will discussion something that interacts with the long wave radiation but not the short wave radiation



Review yesterday's budget.

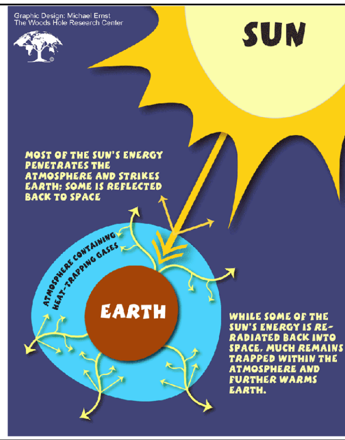
This is the model that was developed on the first day of this lesson.

Missing one more variable

- A small part of the atmosphere is made of heat-trapping gases.
- These gases absorb long wave radiation.
- They are called greenhouse gases.

- Examples:
  Water Vapor (H_2O), Carbon Dioxide (CO_2)

Students may or may not have heard of greenhouse gases.



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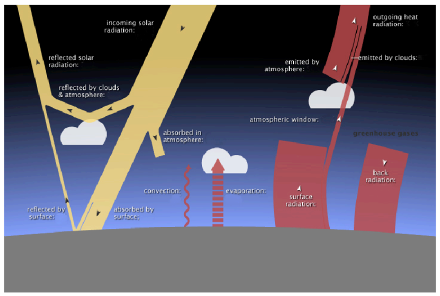
The greenhouse is created by part of the atmosphere. The atmosphere is made up of gases including water vapor, some of which we see as clouds. Not all gases are greenhouse gases. Only those that absorb the long-wave radiation are called greenhouse gases.

Most students have probably heard of carbon dioxide, but don't know much about it. In the next lesson, the focus will be about these special gases.

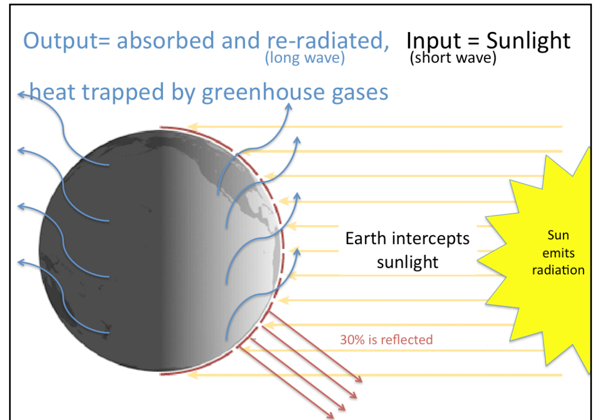
Not all gases have the same behavior

Some gases are greenhouse gases.
Most of the gases in the atmosphere do NOT absorb long wave radiation.

Follow the Energy



At this point you will want to point out the different concepts you have discussed including the albedo, the role that clouds play for both incoming and outgoing radiation, and surface radiation. The back radiation is caused by the greenhouse gases.



Review yesterday's budget.

This is the model that was developed on the first day of this lesson.

Only a little over half of the absorbed energy is re-radiated.

What happens to the other energy?

It remains absorbed by the Earth and causes a change in temperature

What if there wasn't an atmosphere?

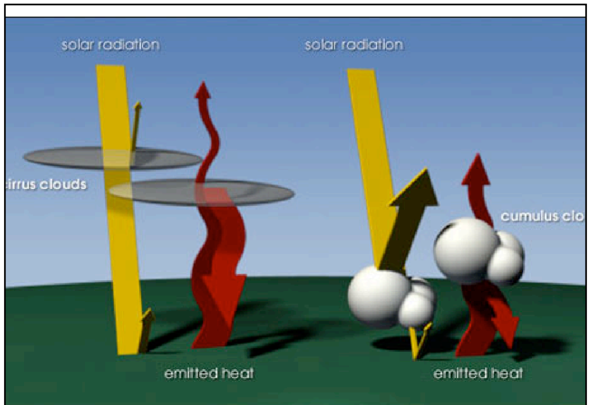
The last question here is a teaser for the next lesson plan.

Concept Map Additions

- Long wave radiation
- Short wave radiation

- Write 2 paragraphs describing what happens to the flow of energy into the Earth system.

Optional Slides

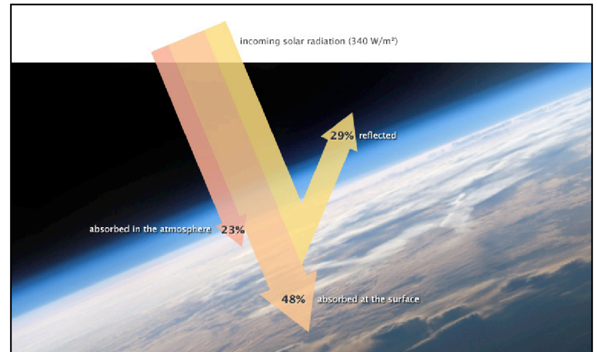


Thus far, the discussion has represented the average of Earth. Clouds and gases are very important in the energy budget. This slide shows that different types of clouds – cirrus and cumulus clouds – have a different impact on how much energy reaches the Earth's surface.

The thickness of the line represents the amount of energy. Yellow is the solar radiation. Red is the emitted heat.

Thin cirrus clouds permit sunlight to pass through them, while blocking a significant amount of the heat radiating (long wave infrared) from the surface. Thick cumulus clouds reflect most sunlight, and block the majority of heat radiating from the surface. Compare the red arrows coming out of the clouds. In general, more cirrus means warming and more cumulus clouds mean cooling.

Image above: The Earth's energy balance refers to the amount of energy received from the sun (yellow arrows) minus the energy reflected and emitted from the Earth (red arrows). Clouds play an important role in regulating this balance. Thin cirrus clouds permit sunlight to pass through them, while blocking a significant amount of the heat radiating from the surface. Thick cumulus clouds reflect most sunlight, and block the majority of heat radiating from the surface. Credit: NASA
http://www.nasa.gov/centers/goddard/news/topstory/2005/earth_energy.html



Recall – this was used on day 1.

About 23 percent of incoming solar energy is absorbed in the atmosphere by water vapor, dust, and ozone, and 48 percent passes through the atmosphere and is absorbed by the surface. Thus, about 71 percent of the total incoming solar energy is absorbed by the Earth system.

When matter absorbs energy, the atoms and molecules that make up the material become excited; they move around more quickly. The increased movement raises the material's temperature. If matter could only absorb energy, then the temperature of the Earth would be like the water level in a sink with no drain where the faucet runs continuously.

Follow the Energy

- VIDEO Energy Budget in Equilibrium

VIDEO REVIEW – This video emphasized equilibrium. About 4 minutes.
http://earthobservatory.nasa.gov/Experiments/PlanetEarthScience/GlobalWarming/GW_Movie2.php

2.2.2 Student Notes

What are two variables that influence the Earth's Energy Balance?

Which type of energy come in long wavelengths? Short wavelengths?

Solar energy (sunlight)

Earth's heat energy

In my own words, equilibrium means . . . .

2.2.3 Dynamic Balance Activity or Demonstration

Background:
The energy budget of Earth is just one example of a system on Earth that is in dynamic balance. There are influences that cause increases and there are influences that cause decreases, but the over-all result is that the total amount of the "planet thing" tends to remain the same.

Dr. Art's Guide to Planet Earth (Pages 28-31) provides an example of dynamic balance. The amount of water in each of the reservoirs of the water cycle stays fairly constant even though water is constantly flowing into and out of that reservoir.

We call this kind of situation dynamic balance. Dynamic means things are happening. Balance means there is no total change. Water in the ocean is dynamic - it keeps leaving through evaporation and returning through precipitation and runoff. Yet, the total amount of water in the ocean is not changing, so we say it is in balance.

Purpose:
Many different Earth systems demonstrate stability even though matter and energy are constantly flowing through them. These systems are examples of dynamic balance. The "Dynamic Balance in a Bottle" experiment illustrates the phenomenon of dynamic balance. It provides direct experience of how changes to a system can alter the existing dynamic balance. This experiment can help explain a wide variety of phenomena including each of the cycles of matter, Earth's energy budget, and the issues of ozone depletion and global climate change.

Equipment and Supplies:
For each group:
1 empty 2-liter plastic bottle with paper label removed
1 measuring cup (2 cup size is better than 1 cup size) or 500 ml graduated cylinder
1 Thumb tack
1 Funnel
Duct tape or other good tape
Stopwatch or clock
Ruler
2 five gallon buckets

Teacher Preparation:

1. Carefully using the thumb tack, poke 20 evenly-spaced holes in the bottle along the outside about 1/2 inch up from the bottom.

Procedures:
PART A

1. Fill one bucket of water. The second bucket is to catch all the water.
2. Practice pouring the water at a rate of 400 ml per minute or about 1.5 cups per minute. Use the stop watch to see how long it takes to fill 1.5 cups.

3. Put the bottle (and funnel if it helps) under the pouring bucket so all the water flows into it.
4. Carefully watch what happens with the water in the bottle. Write down your observations from the beginning until there is no longer any measurable change. If you do not get a steady level, adjust the flow rate so you do.
5. When the first bucket is empty, switch buckets quickly.

PART B

1. Experiment with increasing the rate at which water enters the bottle. Determine a rate that increases the level without overflowing the bottle. Measure that rate and record it. Record any observations that may help explain your result.
2. Reduce the flow rate back to the rate used in Part A. Using the tape, experiment with covering some of the holes in the bottle. Determine a number of holes covered that increases the level without overflowing the bottle. Record your procedure and results.

Analysis

1. Discuss whether Part A of this experiment models dynamic balance.
2. Describe how the exit flow rate from the holes changes as the level of water in the bottle increases. Discuss how this change in rate affects the establishing of a stable level.
3. Compare the effects of increasing the flow rate, covering the holes, and increasing the number of holes.

Conclusions and Discussion

1. Which of the experiments provides a model of how the amount of water in the atmosphere remains the same even though water is constantly entering and leaving the atmosphere?
2. One example of something that humans are doing to change an existing balance on planet Earth is that we are burning oil, coal and gas. This results in extra carbon dioxide going into the air. Before humans started burning large amounts of these fossil fuels, the amount of carbon dioxide in the atmosphere had been fairly constant for many hundreds of years. Which experiment models a change in dynamic balance due to increasing the rate of in-flow?
3. These experiments can also be used to model Earth's energy budget. In that case, what does the rate of water flowing into the bottle represent? What does the rate of water leaving the bottle represent? What does the level of the water in the bottle represent?
4. Which experiment models how increasing the greenhouse effect may affect the Earth system? Based on that experiment, what would you predict will be the result of increasing the greenhouse effect?

DON'T WASTE THE WATER: Many of us are concerned about wasting water. Don't waste the water. The idea is that doing these experiments helps all of us understand that there are natural balances in the kinds and amounts of things and living organisms on our planet. The amount of fresh, usable water is limited. It is the result of a dynamic balance among processes that increase that amount and processes that decrease it. Now that you understand dynamic balance, hopefully you will do things that save lots more water than the amount you used in these experiments. Reuse the water for all classes, then pour

This activity was modified from *Dr. Art's Guide to Planet Earth* at http://www.planetguide.net/cool/dynamic-bottle_activity.html

What happens to the energy that enters the Earth system?

2.2.4 Homework

Concept Map – additions

- long wave radiation
- short wave radiation

Write 2 paragraphs describing what happens to the flow of energy into the Earth system. Use this image as a guide.