



As you come in:

- If you are new, come say hi to me!
- Choose a table to sit at
- Put your name on a name tent
- Introduce yourself to your neighbors
- Start chatting!

Physics of Weather and Climate

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Tentative Schedule

Week 1: Why do I always ride my bike into the wind?

Week 2: Why do clouds stay up in the air?

Week 3: If you can't predict the weather, how can you predict the climate?

Week 4: Why are there rainforests on the equator?

Week 5: How could aliens know there is life on Earth?

Week 6: How does the earth keep warm, and why is it getting warmer?

Week 7: What can we do about climate change?

Today's Questions

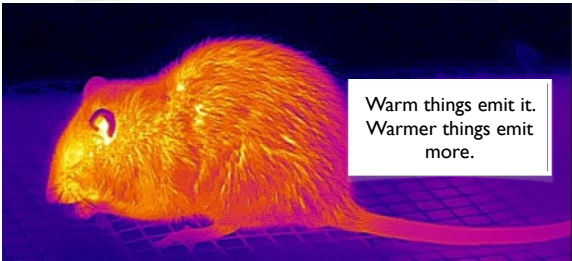
- Why do clouds stay up in the air?
- Why is it colder on clear nights than cloudy?

Physics Principles

Thermal Radiation

Phase Transitions

Thermal Radiation



Warm things emit it.
Warmer things emit more.

Thermal Radiation



This is a 150 W bulb.

Tools

Thermal Imager

Bright means lots of thermal radiation.
The screen shows the temperature at the position of the center cursor.



Tools

The "Thermal Radiation Sensor"

High temperature means lots of emission



Thermal Radiation



Look around the room.

A few things to notice:

- What things are emitting a lot of thermal radiation?
- Can you “see” through the windows?

Exploration

Cloud Bowl

Observations

Notice that the cloud doesn't rise.... It stays in the bowl! A cloud is more dense than clear air.



Exploration

Cloud Bowl

Observations

Use the thermal imagers to look at the cloud. Do you “see” the cloud?



Exploration

Cloud Bowl

Observations

Water is an excellent absorber and emitter of thermal radiation.



Exploration

Cloud Bowl

Experiments

Can you make a “tornado” with the cloud?
What else could you try?



Exploration

Cloud Bowl

Question

What is the cloud made of?
Why does it appear white?



Aside

Mystery Blocks

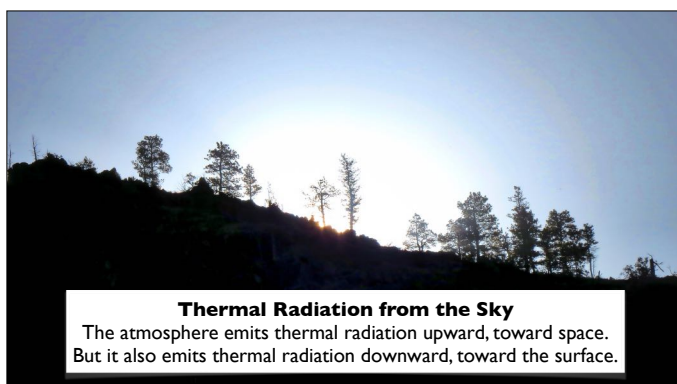
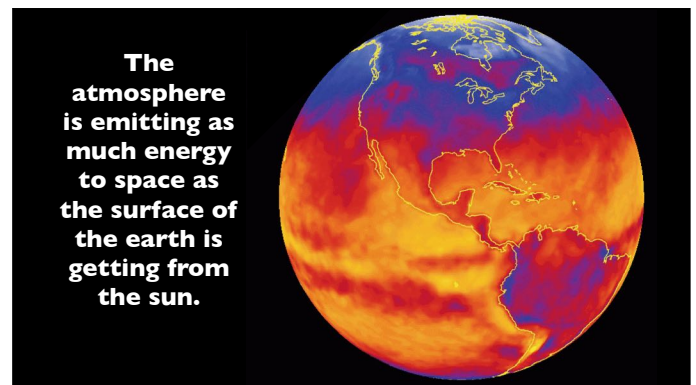
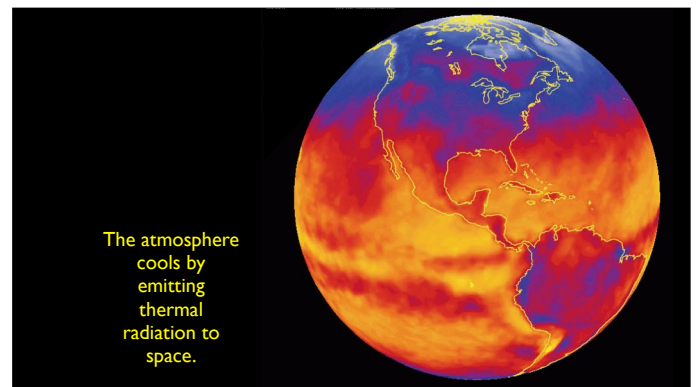
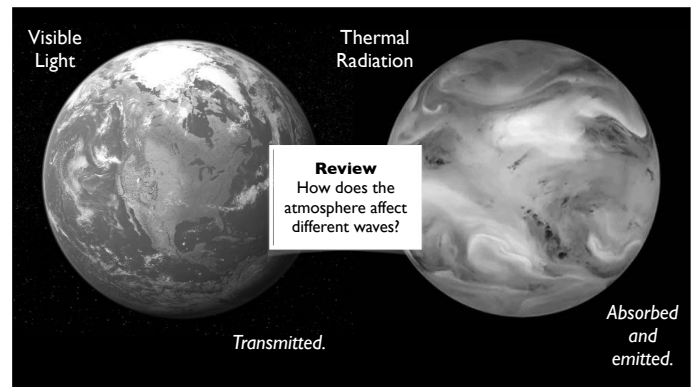
Experiments

What color is the top block? The bottom?
Now, flip it over....
What is happening?



Thunderstorm from Below





Atmosphere & Earth Model

Observations

- Leave the board with the glass plate in the sun for 30+ minutes.
- Use the thermal imager to measure the temperature of the glass.
- Remove the glass and quickly use the thermal imager to see where the board is hottest.

Atmosphere
Transmits visible light, absorbs and emits thermal radiation.

Earth
Absorbs visible light, emits thermal radiation.

Atmosphere & Earth Model

Questions

- Why does the temperature of the glass increase?
- Why is the board warmer under the glass?



Atmosphere
Transmits visible light, absorbs and emits thermal radiation.

Earth
Absorbs visible light, emits thermal radiation.

Thermal Radiation from the Sky

Observations

- In the sky, which emits more radiation: Clear blue sky or clouds?
- Which emits more, the earth or the sky?

The surface of the earth receives more radiated thermal energy from the atmosphere than it does radiant energy from the sun.

The sun shines during the day.
The sky shines 24/7.

The Greenhouse Effect

No atmosphere: 0°F
With atmosphere: 59°F

Question:

Why does it get colder on clear nights than cloudy?

The atmosphere warms from the bottom...

A key fact about energy in the earth system.

This is the thing that makes weather happen.

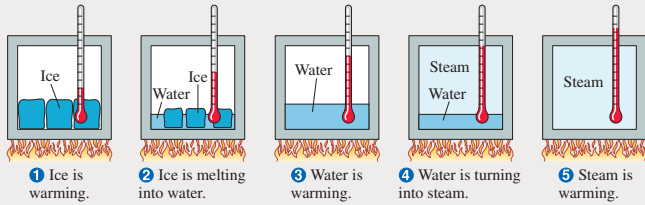
...and cools from the top.

The atmosphere warms from the bottom...

Energy has to be moved upward in the atmosphere. This drives the vertical motion of air and water.

...and cools from the top.

Phase Transitions



When you add heat to a solid, it turns to a liquid.
When you add heat to a liquid, it turns to a gas.

Phase Changes

It takes energy to convert a solid to a liquid, and to convert a liquid to a gas.

75% of the cooling comes from the melting.

Freezing is hot???

Why does heat come out of the pack as it freezes?



Cooling Cocoa

Why does blowing on a hot cup of cocoa cool it off?



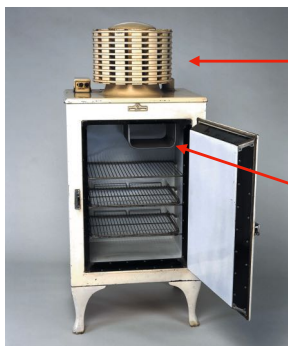
Blowing on
your hands



Keeping your cool.



Heat Pumps



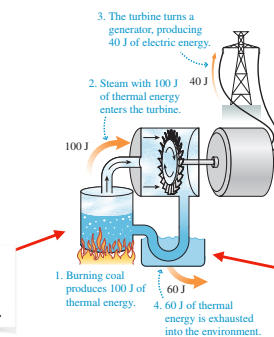
Condenser
Gas turns to liquid; heat comes out.

Evaporator
Liquid turns to gas; heat goes in.

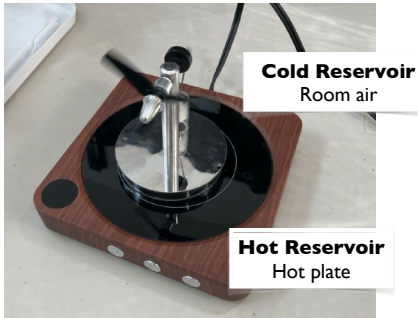
Heat Engine

Evaporation
Liquid turns to gas; heat goes in.

Condensation
Gas turns to liquid; heat comes out.



Heat Engine



A hurricane is a heat engine.

Cold Reservoir
Upper atmosphere

Hot Reservoir
Ocean water

Due to climate change:
The ocean is warmer.
The stratosphere is colder.

Motion of Air in the Atmosphere

In a thunderstorm, air can be moving upward at 110 mph.

Lapse Rate

For dry air, rising air will cool by 5.5 °F per 1000 ft.

Lapse Rate

For moist air, rising air will cool by 3.3 °F per 1000 ft.

Lapse Rate

Why does moist air cool off less?
OR:
Where does the extra energy come from???

Energy

Water in the form of water vapor has more energy than water in the form of liquid water.

As sunlight warms the water and it evaporates, energy is "stored" in the water vapor.

Energy
As warmed air rises, it cools, and the water vapor condenses—clouds form.

This condensation releases thermal energy where the clouds form. This transports energy upward.

What Happens Next?

Remember
For dry air, rising air will cool by 5 °F per 1000 ft.
For moist air, rising air will cool by 3° per 1000 ft.

5000 feet	50 °F
4000 feet	54 °F
3000 feet	58°F
2000 feet	62 °F
1000 feet	66 °F
0 feet	70 °F

What Happens Next?

Dry Air
Rising air will cool by 5 °F per 1000 ft.

5000 feet	50 °F
4000 feet	54 °F
3000 feet	58°F
2000 feet	62 °F
1000 feet	66 °F
0 feet	70 °F

What Happens Next?

Moist Air
Rising air will cool by 3° per 1000 ft.

5000 feet	50 °F
4000 feet	54 °F
3000 feet	58°F
2000 feet	62 °F
1000 feet	66 °F
0 feet	70 °F

Question
Which will give rise to more intense weather, dry air or moist air? *Explain.*

The upward motion is powered by the energy of condensing water vapor.

That's why watery weather is weatherier.

Rising Air Forms Clouds

As the air rises, it cools. Water vapor condenses: Clouds form.

Rising Air Forms Clouds

Puffy clouds sit in a column of rising air.



The Clouds are Falling

Relative to the air.... But the air is rising!



“Cloud Suck”

Something paragliders speak of.

Question
What's really happening?



Rising Air Forms Clouds

A lenticular cloud above a mountain.



Puffy clouds are flat on the bottom.

The bottom is defined by the “lifting condensation level”.



The awesomeness of solar power.

