What is the ITCZ, and how can I see it?

A laboratory experiment from the Little Shop of Physics at Colorado State University

Overview

Most of us know that there is a large band of rainforest along Earth's equator that formed, in part, due to a large amount of persistent rain. This experiment aims to explain why it rains so much in this region and show how we can look at such an enormous feature. Students will interpret satellite images and identify features on the ground.

Necessary materials:

- Placemat map of the world
- Dry-erase or transparency markers
- Transparency sheets
- Hole punch
- String or binder rings
- Packet of interesting satellite images
- Internet access

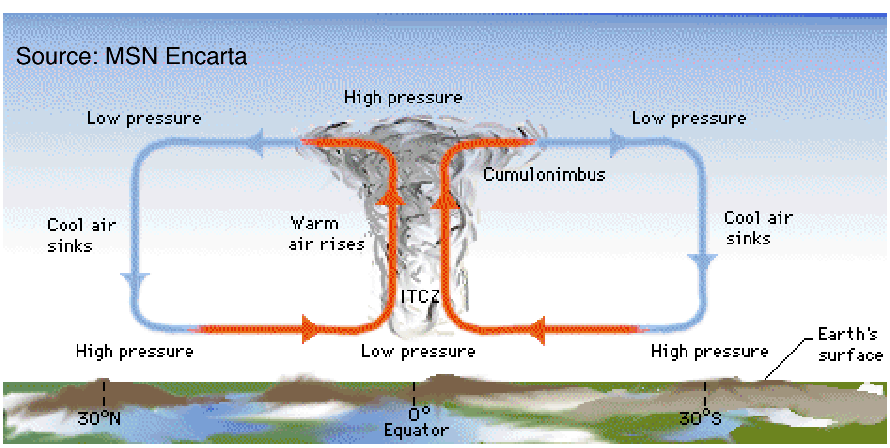
The map does not have to be dry-erase, but it makes mistakes much easier to deal with and is much more fun than paper maps with pencils.

Select satellite images of somewhat-recognizable features to play a "guess what this is?" kind of game.

Theory

It is very warm along and around the equator, a region we call the **tropics** since the sun shines so directly there throughout the year. As you know, when air is heated, it expands becoming less dense and more **buoyant**, that is, it becomes very light and wants to float. Since pressure in the atmosphere decreases as you go up, the rising warm bubble of air expands adiabatically, doing work to push away surrounding air and therefore cooling as it rises and leaving a void of **low pressure** behind.

As the rising air cools, the water vapor in it also cools and then condenses into cloud droplets, which eventually **collide** with one another, **coalescing** to form bigger and bigger droplets until the droplets get so big that they fall out of the cloud as rain. Since it is always so warm in the tropics, this kind of rising motion that forms rain is going on all the time, supplying water to the rainforests.



The motion of the Hadley cell, which is driven by intense solar heating, induces the formation of the ITCZ, which provides precipitation for rainforests.

When the rising air hits the top of the troposphere, it spreads out, going north and south. As it travels poleward, it radiates energy out to space, cooling and becoming more dense along the way. After traveling about 30 degrees of latitude, it begins to fall to the surface, warming, compressing, and collecting on top of itself in a band of **high pressure**. The resultant compressional heating and drying of the air is responsible for the formation of desert regions. Since air always moves from high to low pressure, it rushes back to the equator along the surface, coming from both the north and south, and **converges** near the equator, completing a loop of air flow called the **Hadley cell**. The converging air cannot go sideways or down through the ground, so it is forced to rise once more. The latitudinal band in which this occurs is called the **ITCZ or Intertropical Convergence Zone**, because it is where convergence happens the the tropics. This convergence line is not always on the equator, though. It moves to the north and south as the seasons change, following the location of most intense sunshine.

The ITCZ is a really big feature on our planet! In fact it is about 25,000 miles long! How can people see a feature that big?!

The best way to look at something that is really large is to take a big step back, and the way to get a good look at something like the ITCZ is to step into outer space...well, not literally. Actually, scientists launch satellites over 22,000 miles into space, which can send back pictures of weather features like the clouds of the ITCZ. Sometimes the images that the satellites send back are visible light images like those from a camera, but other times they send back measurements of infrared radiation, which is an indicator of temperature, or microwave radiation if a radar instrument is used.

Doing the Experiment

This experiment can be done in a number of different ways, each with varying levels of detail. More advanced methods should include a discussion of the Coriolis force that causes the wind to turn to the right in the Northern Hemisphere and the the left in the Southern Hemisphere or the physics of how satellites measure water vapor in the atmosphere.

Part I: Prevailing Wind and Surface Pressure Bands

- Using the world map and markers, have the students sketch the locations of the low and high pressure bands beginning with the location of the ITZC. Knowledge of the other bands should be presented prior to this experiment.
- Next, punch holes in the map and a transparency sheet, and attach the two with the string or binder rings, laying the transparency over the map. Have the students indicate the direction of surface air flow that should ONLY result from the orientation of the pressure bands on the transparency.
- Next, include Coriolis turning of the winds on another layer of transparency. A new color marker will be helpful to see the difference in the new wind patterns due to Coriolis turning.
- Use the maps you have just created, have the students determine the general climate and direction of the direction of the prevailing winds at a number of previously determined locations. It is fun to choose difficult-to-find locations in the world to add a little geography lesson, and it is best to select locations that are unambiguously located within prevailing wind bands.
- Finally, students should make a note of the prevailing climatic conditions that are characteristic of each location. What type of weather is expected where surface winds converge? Where they diverge? They should be able to explain why certain climate types exist at each location.

Part II: What are we looking at? - Interpreting Images from Space

- Using a selection of satellite images showing different parts of the Earth, see if you can figure out what each image is showing.
- It may be useful to supply hints with each images.
- More advanced examination might include discussion of the particular satellite that took the images and the type of enhancements performed (infrared, water vapor, etc.) on the images.

Part III: Global Visible and IR Satellite Images

- Obtain global composite satellite images and animations from:
  - http://www.ssec.wisc.edu/data/composites.html
- Examine the cloud patterns across the globe.
  - Have the students point out the banded features, especially the ITCZ and the extratropical cyclones.
  - Play the animations to see if the clouds move as suggested by the generalizations from Part I.
- Note the Coriolis effect and how it operates in opposite hemispheres. Have the students point out the mid-latitude cyclones and explain why they rotate specific directions in the differnt hemispheres
- More advanced study might include an examination of various hemispheric weather maps from: http://wxmaps.org/pix/analyses.html
  - Here you can relate features like jet streams to cloud motions and the global temperature distribution.
  - Introducing vorticity maps is a challenging exercise in being able to decipher contour plots.

Summing Up

Clearly, there is much more to this experiment than just a discussion of the ITCZ. Many aspects of the general circulation can be gleaned by examination of satellite imagery, and there is also room for discussion of the physics of both launching a satellite and how satellites remotely sense the earth. After completing these exercises, students should have good feel for how the rainforests stay green and why the deserts are located where they are, having drawn it out themselves. Of course, prior discussion of the general circulation of the atmosphere is essential to these activities.

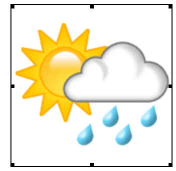
For More Information

CMMAP, the Center for Multi-Scale Modeling of Atmospheric Processes: http://cmmap.colostate.edu

Little Shop of Physics: http://littleshop.physics.colostate.edu

What is the ITCZ, and how can I see it?

Related Questions



Part I: Prevailing Wind and Surface Pressure Bands

1. Using the world map and dry erase markers, label the typical locations of the HIGH and LOW pressure bands near Earth's surface beginning at the equator and extending into both the North and South hemispheres. This is most easily accomplished by drawing a labeled line for each band, i.e. ----L----L---- for a LOW.

2. Using a marker of a different color, draw arrows indicating the direction of winds near the SURFACE that would result from the orientation of the pressure bands across the globe as labeled in #1.

3. If the concept of the CORIOLIS FORCE has been explained in your class, use another color of marker to draw arrows indicating the direction of the winds at the SURFACE that would result from the combination of the CORIOLIS FORCE and the PRESSURE GRADIENT FORCE (PGF) created by the set-up in #1.

4. What type of climate is expected where the near-surface winds CONVERGE? Why?

5. What type of climate is expected where the near-surface winds DIVERGE? Why?

6. Describe the general climatic conditions and prevailing winds at the following locations:

   Madagascar:

   Falkland Islands:

   Ecuador:

   Sri Lanka:

   Mongolia:

   Svalbard:

7. Match each location to its corresponding general circulation cell.

   A. Polar Cell
   B. Ferrel Cell
   C. Hadley Cell

   Madagascar:

   Falkland Islands:

   Ecuador:

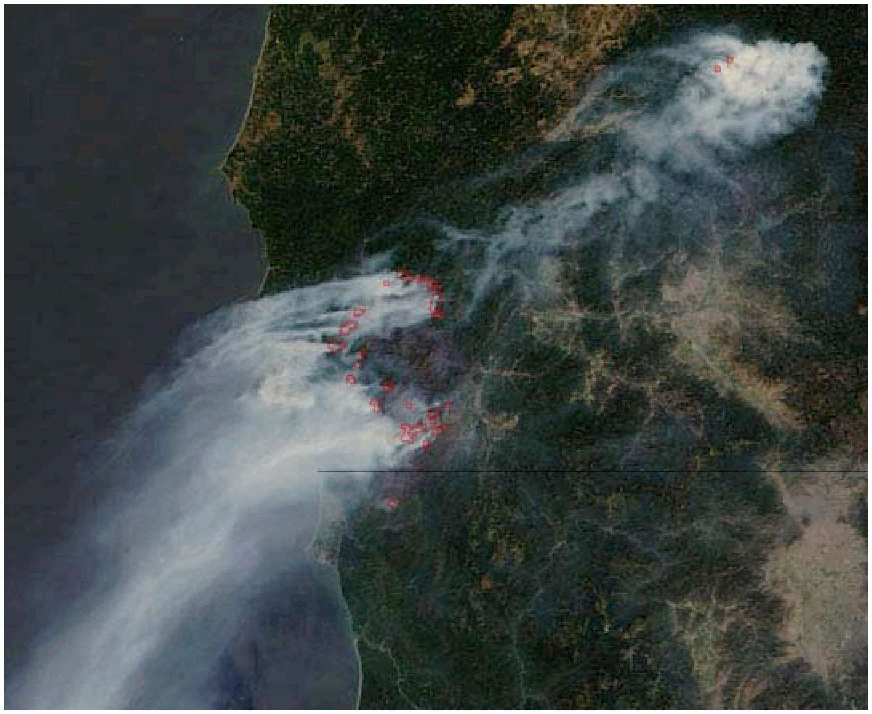
   Sri Lanka:

   Mongolia:

   Svalbard:

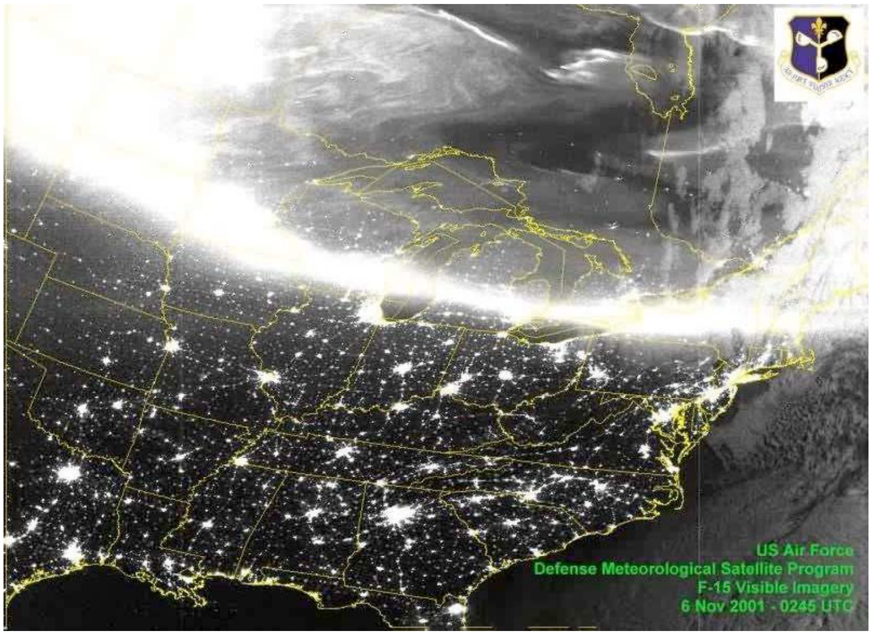
8. How does the ITCZ move with the seasons? (i.e. How is it displaced from January to July?)

9. What does the seasonal motion of the ITCZ mean for the January and July climates in the Amazon? In India?

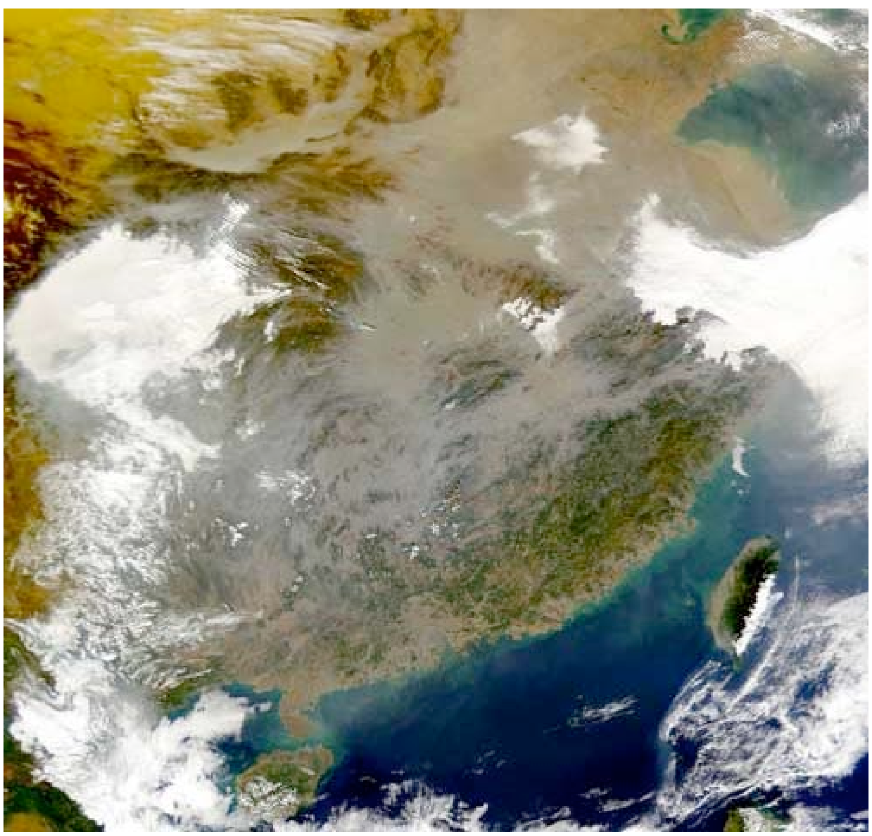


Redwoods grow here. The clouds at the left are made from carbon, not from water vapor.

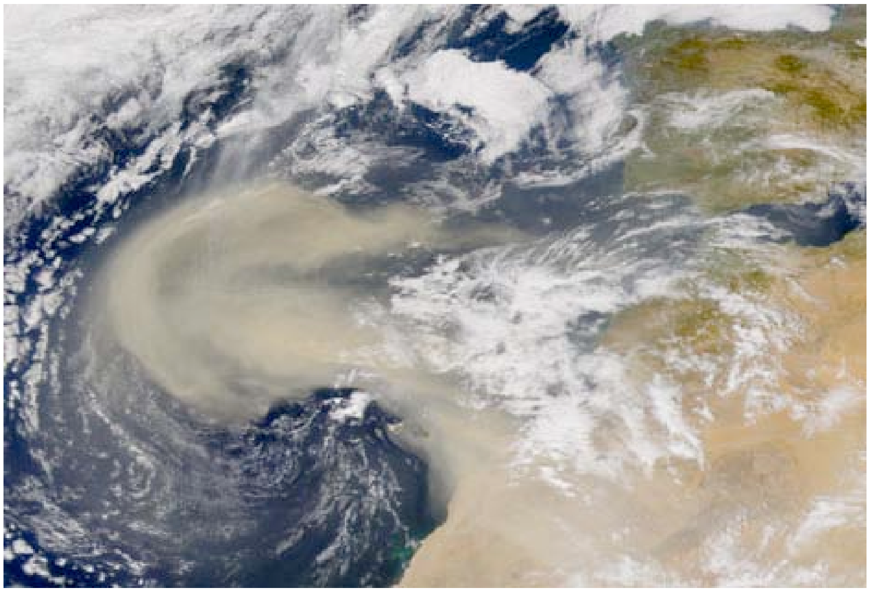
Just over 300,000 people live on this frozen island.



Time for bed.



The air is not so clean in this heavily polluted nation.

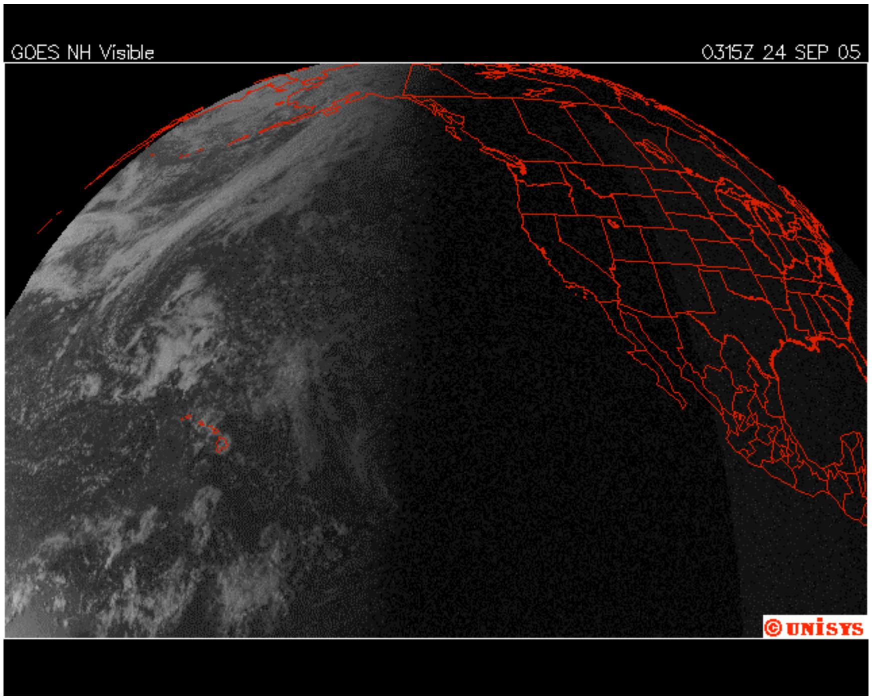


What is there quite a bit of at around 30° N?

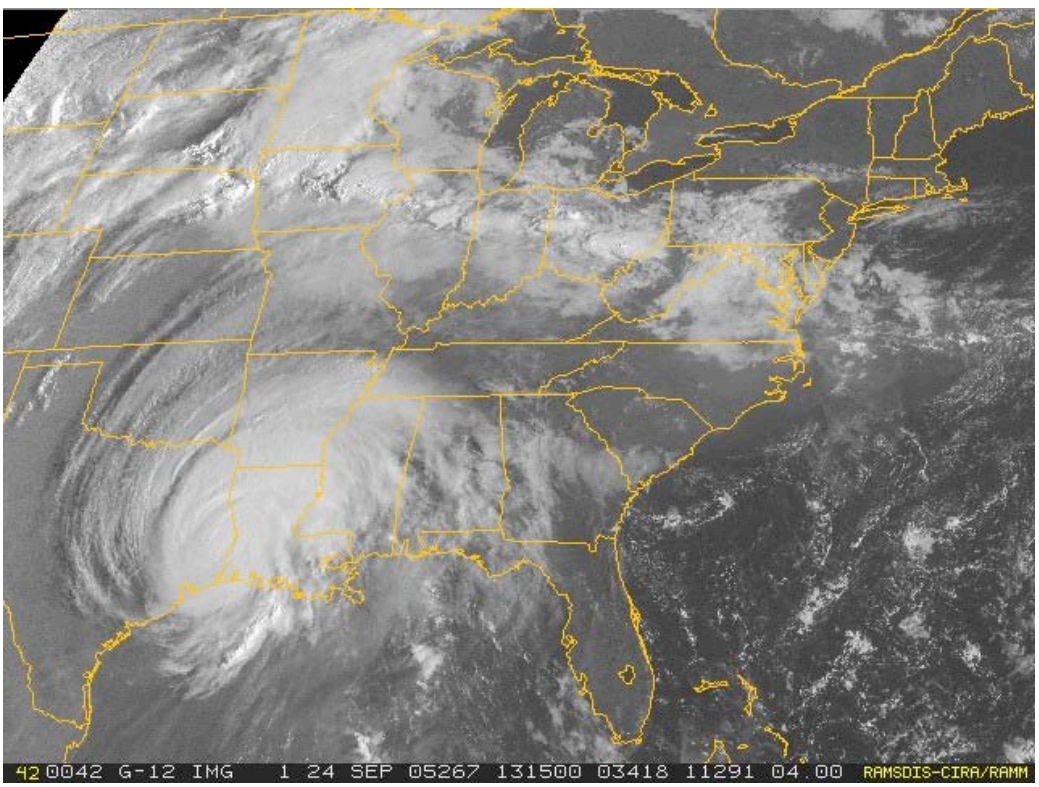
Astronauts get a real blast from here.

What hydrocarbon is found underground in Texas?

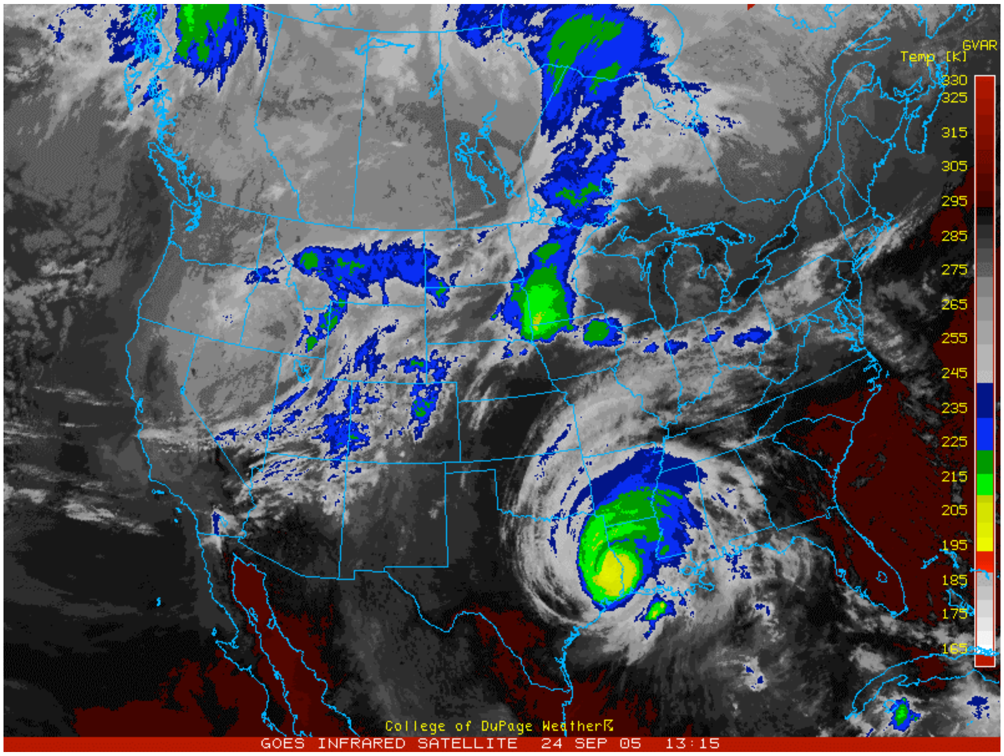
Might these be crop circles?



Why are there no clouds over the North America?



What kind of storm is this?



Why are the clouds so colorful? Why are some of the oceans red?

Remote Sensing

- Remote sensing is gathering information about something without being in physical contact with it – typically using electromagnetic radiation
- Passive sensors simply detect the radiation emitted by objects in certain frequency bands
- Active sensors send out a pulse of radiation and then measure what comes back to them
- Useful for seeing the whole picture of the current weather, and seeing where there are no other types of observations

Satellites

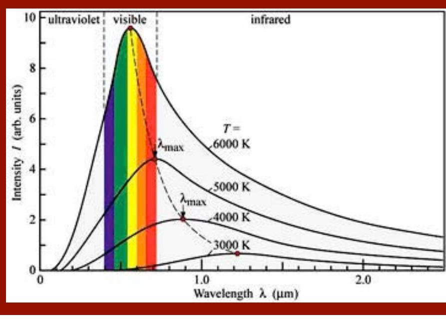
- A satellite, by definition, is something that revolves around a larger body – we, of course, are talking about man-made satellites
- Multiple weather satellites (in addition to satellites for things like communication and navigation) are in orbit around the Earth as we speak
- Most instruments carried on weather satellites are passive sensors – they receive and measure radiation from the earth at specific frequencies and use this information to calculate a brightness temperature
- Most satellites carry several instruments, and many instruments look at multiple frequencies

Visible Satellite

- Measures radiation in the visible wavelengths
- Basically takes a picture of the earth
  - sees what our eyes would see

Brightness Temperature

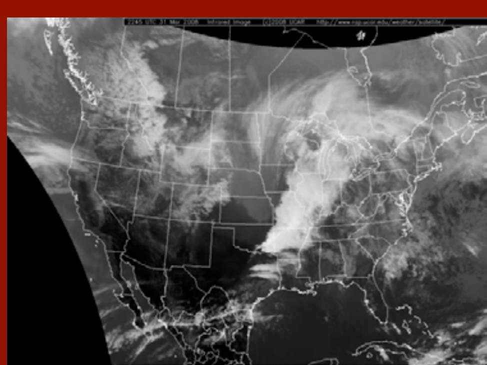
- The brightness temperature is basically the temperature that a satellite "sees"
- Represents what the temperature of the object would be if it emitted perfectly according to a black body curve



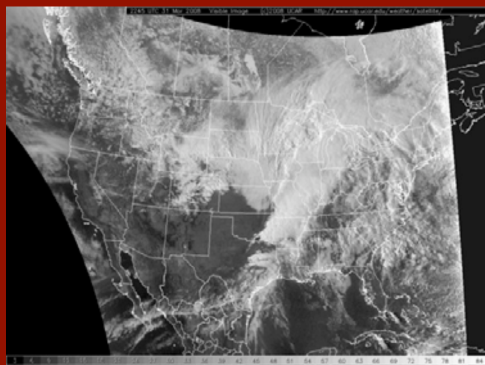
Infrared Satellite

- Measures radiance in the infrared, typically in the "atmospheric window"
- Calculates a brightness temperature based on the amount of radiance
- The ground will show up as a higher brightness temperature
- Typically, higher clouds have lower brightness temperatures, so cloud types are more easily distinguished
- Doesn't need daylight to work, and can sometimes see clouds that visible satellites miss

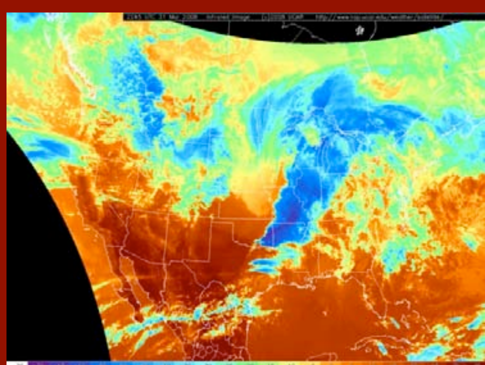
Infrared Satellite



Visible Satellite



Infrared Satellite



Other Types of Satellite Imagery

- Water vapor
  - Water vapor imagery looks at a specific wavelength in the infrared which is very sensitive to the presence of water vapor
- Microwave
  - Longer wavelengths in the microwave are scattered by raindrops, but not by smaller cloud drops and aerosols