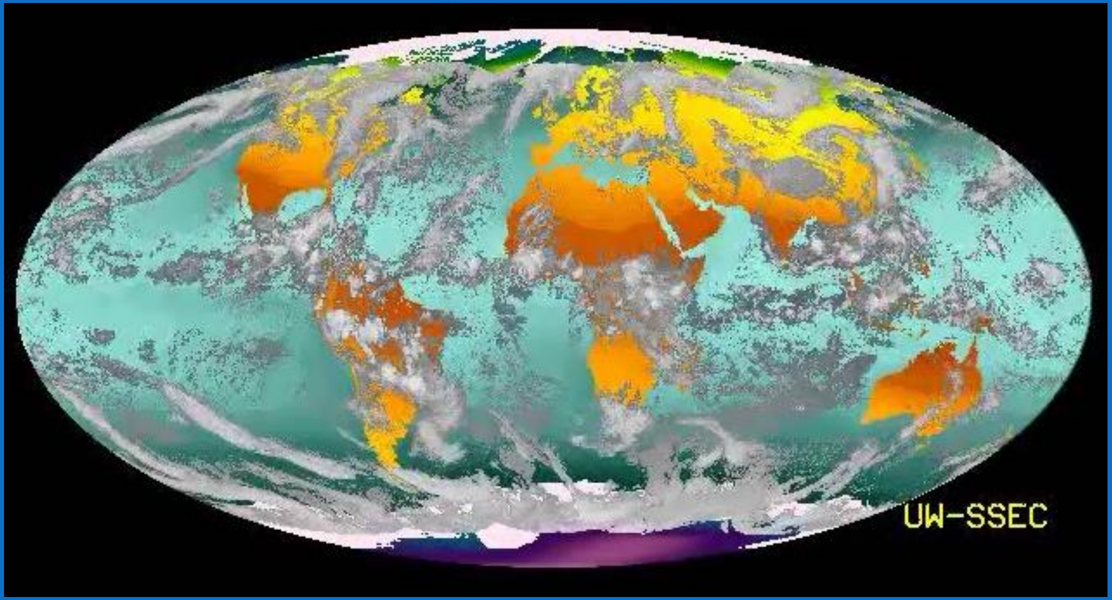
Understanding Atmospheric Circulation, Modeling, and the NGSS

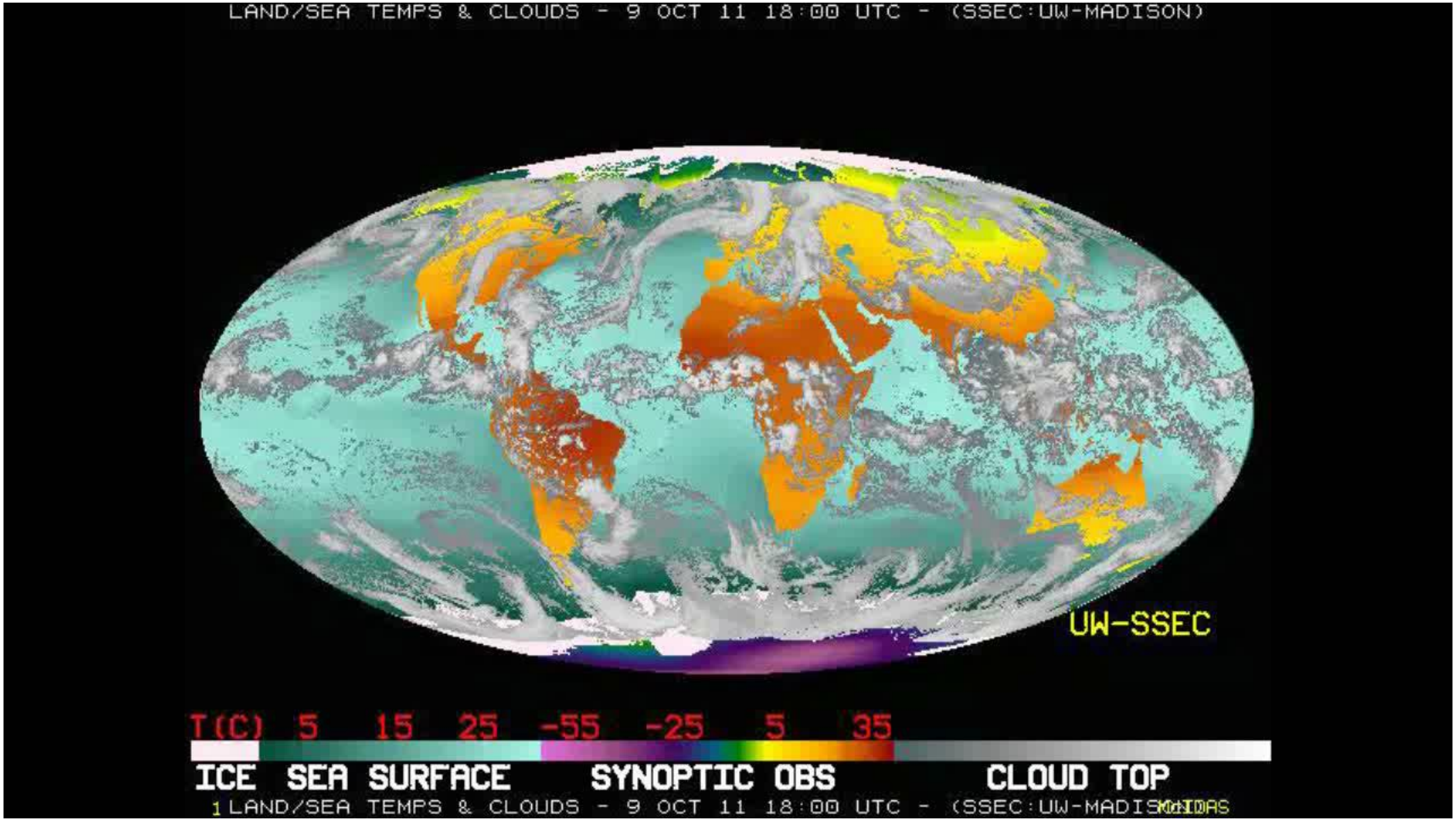


Sacramento Area Science Project

Center for Mathematics and Science Education
California State University, Sacramento

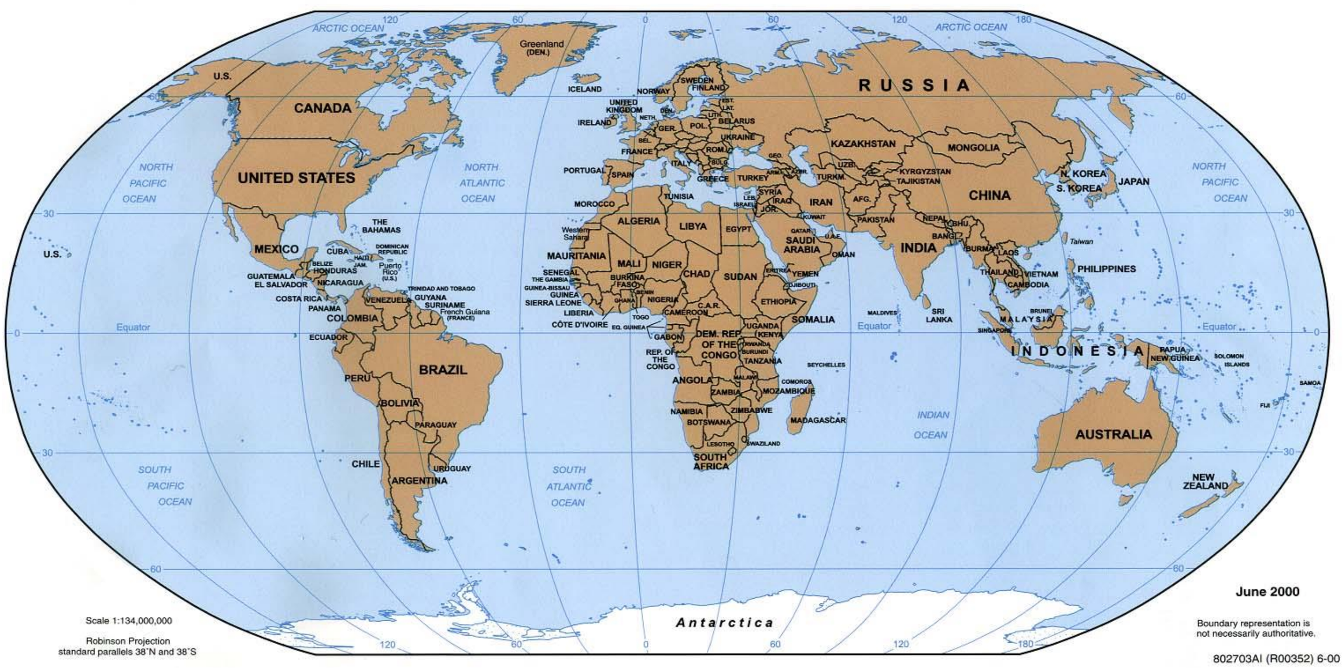
Driving Question

- **What causes the patterns in earth's atmospheric circulation?**



Consider the Earth

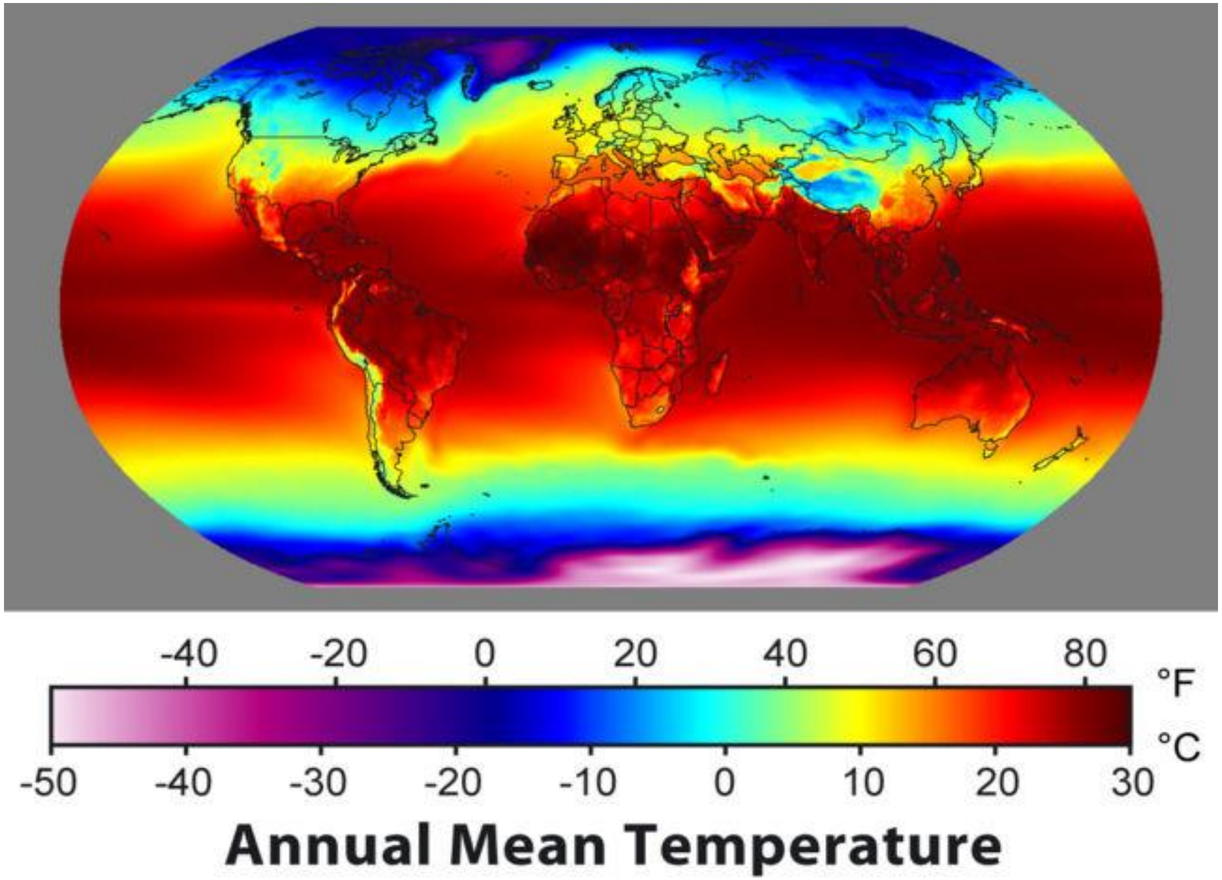
- Where is it usually warm on earth?
- Where is it usually cold on earth?



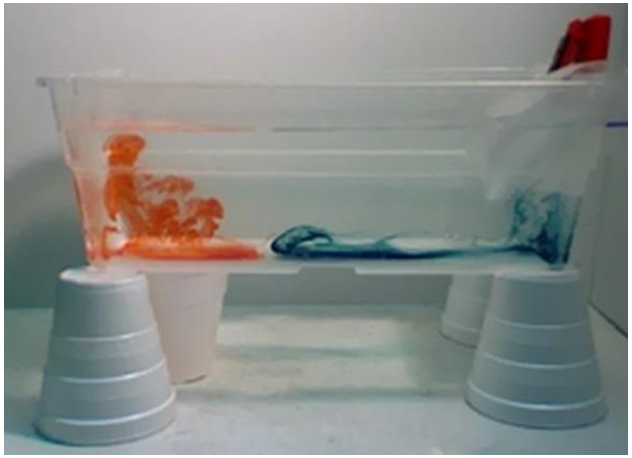
How do we know?

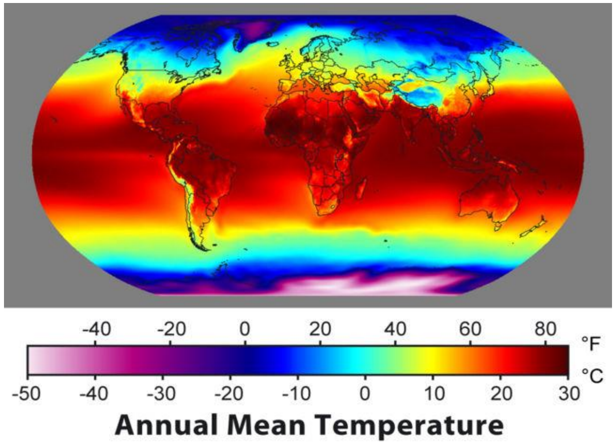
- Where is it usually warm on earth?
- Where is it usually cold on earth?

DATA!



Make a Prediction





Make a prediction:

1. Where would air be rising from earth's surface?
2. Where would air be sinking toward earth's surface?

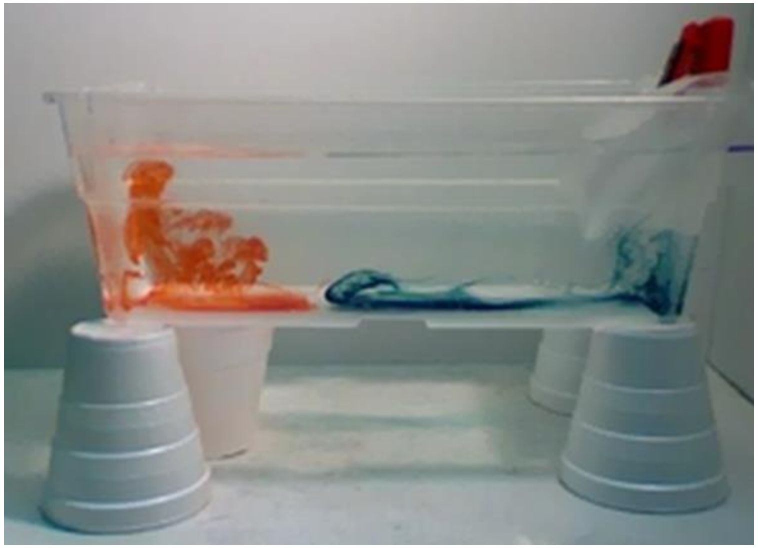
Basic Model

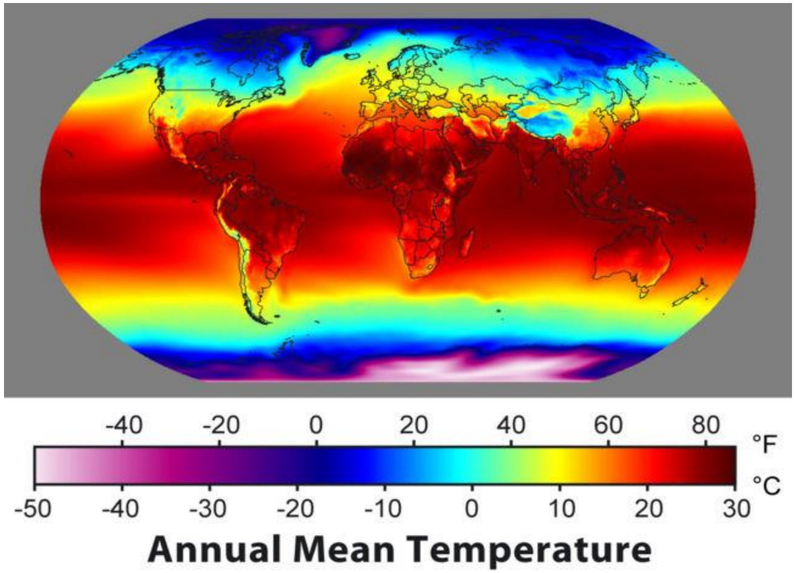
Based on your understanding of…

1) air as a fluid- **Temp** differences produce density differences

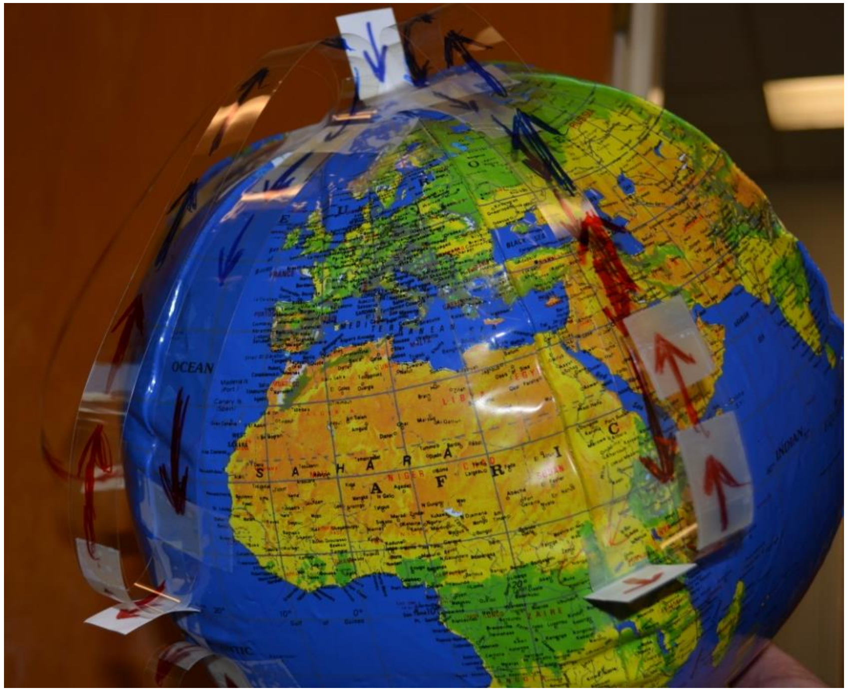
2) convection currents

3) the earth temperature map, predict the convection cells these ideas imply in our atmosphere.



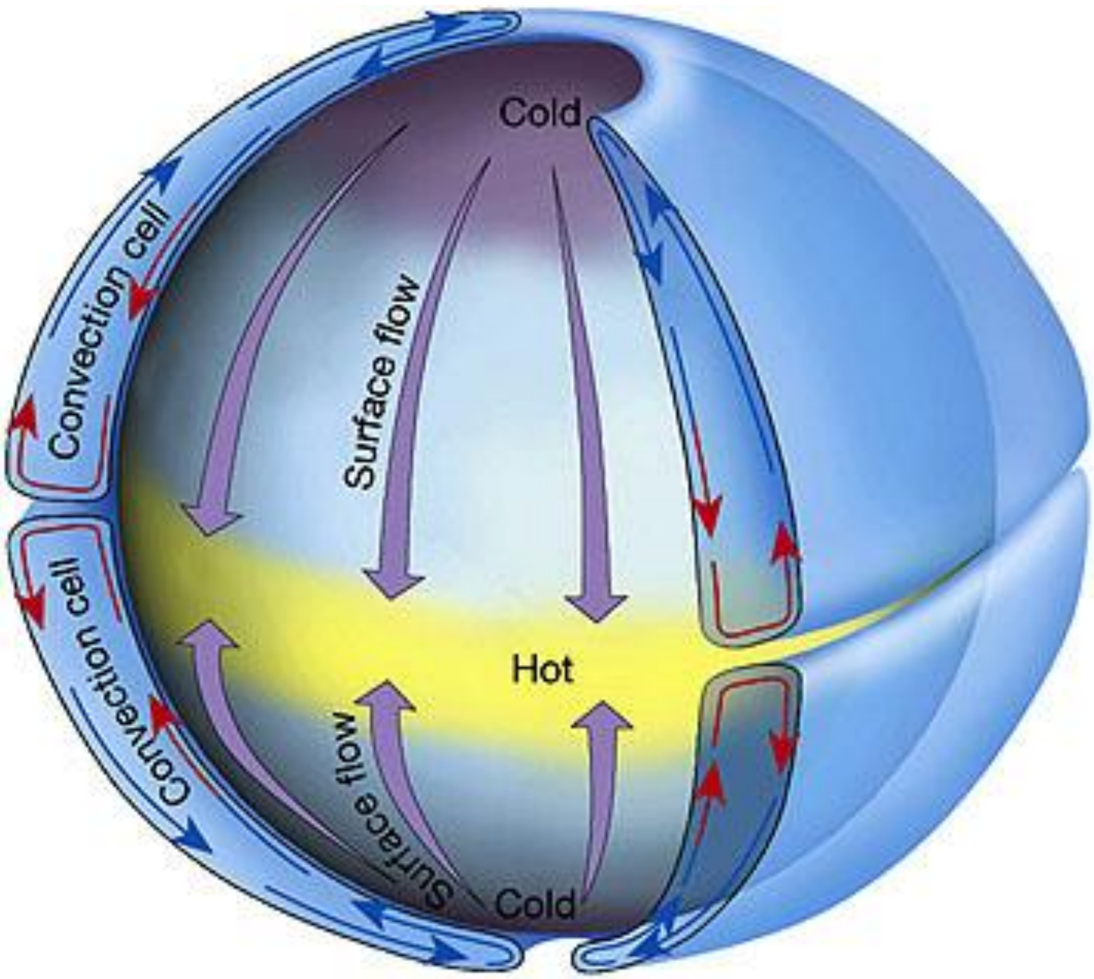


Representation of Basic Model



What causes the patterns in earth's atmospheric circulation

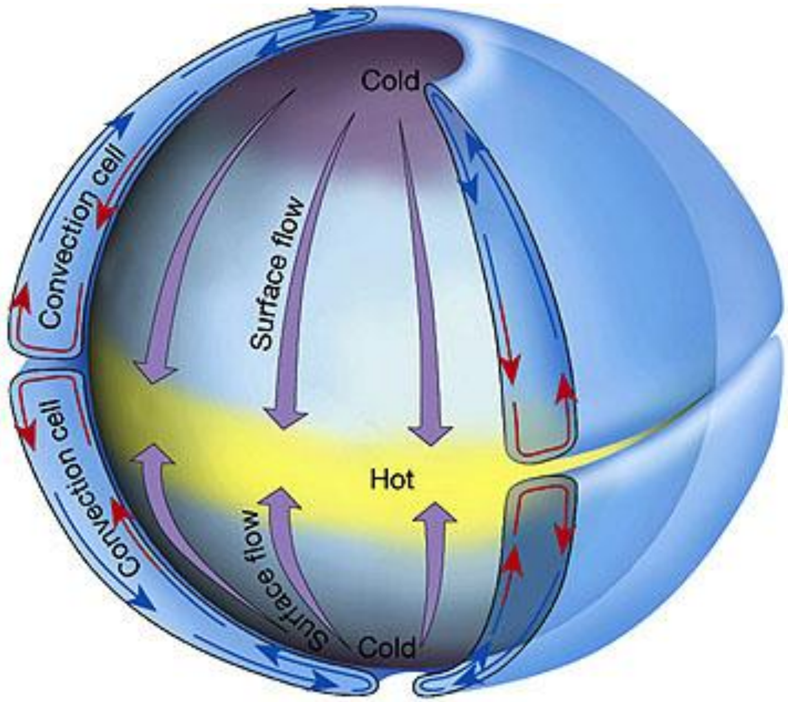
shift from 3-D representations to 2-D flat drawings

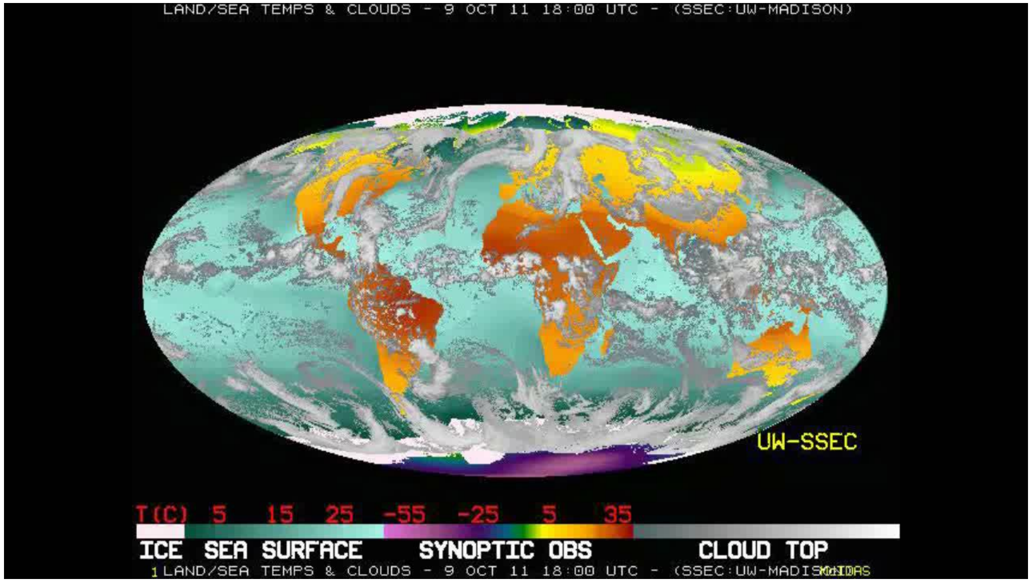


<u>Basic Model:</u>

- Earth's air is **heated** differentially by the sun ***(warm equator, cold poles).***
- **Temp** differences produce density differences in air. (warm air rises)
- **Gravity** differentially effects air masses with different densities.
  - **~Warm air rises at equator; cold air sinks at poles.**
- The **result** is one large convection cell the N. and S. hemispheres.

Compare Basic Model to Phenomena





Our Basic Model

Actual Phenomena

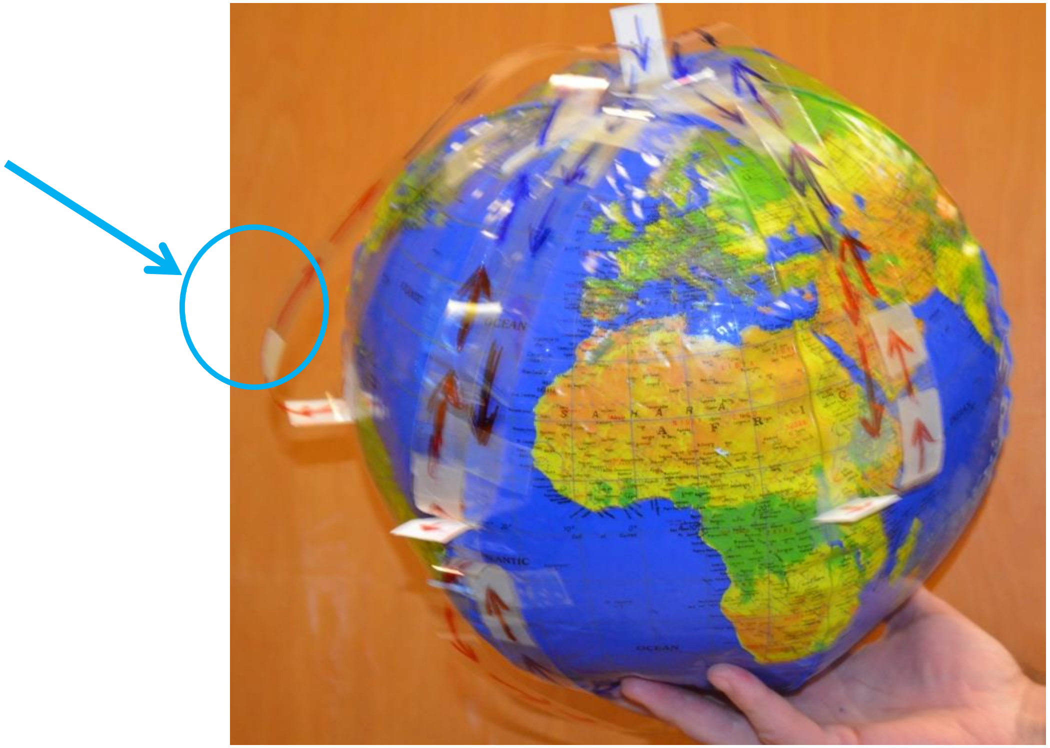
Our basic model has a problem!

We need more data.

Data: Earth is Big!

Because Earth is so BIG, **warm air rising at the equator cools well before it reaches the poles.**

This air at altitude doesn't reach the north pole, it cools and sinks long before it reaches the pole.



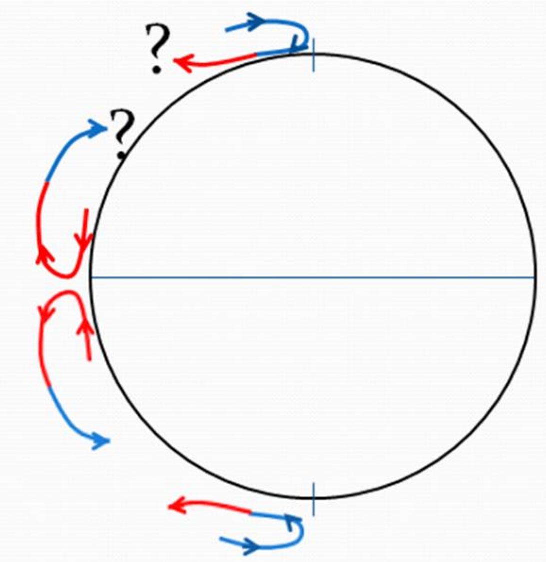
Earth is Big! (Cont.)

Also, because Earth is so Big, **cold air sinking at the poles warms well before it travels back to the equator.**

This surface air doesn’t reach the equator, it warms up and rises well before it reaches the equator.

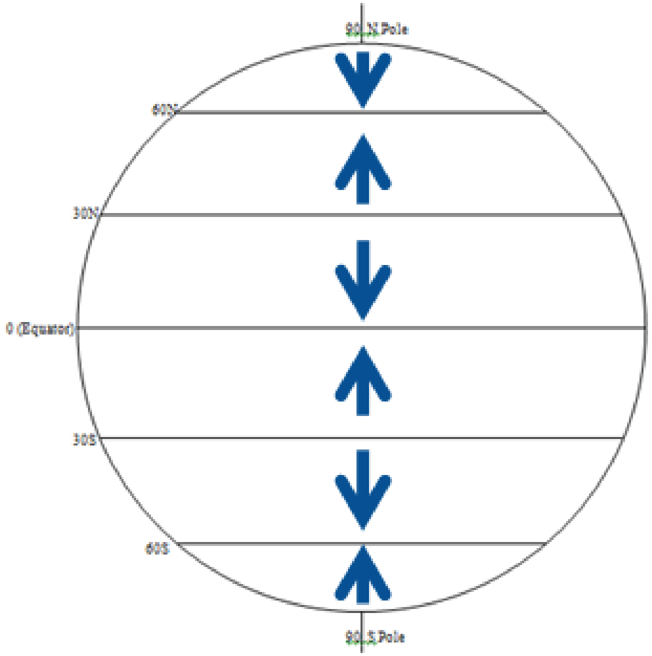
Warm air cools before reaching the poles and warms before reaching the equator…

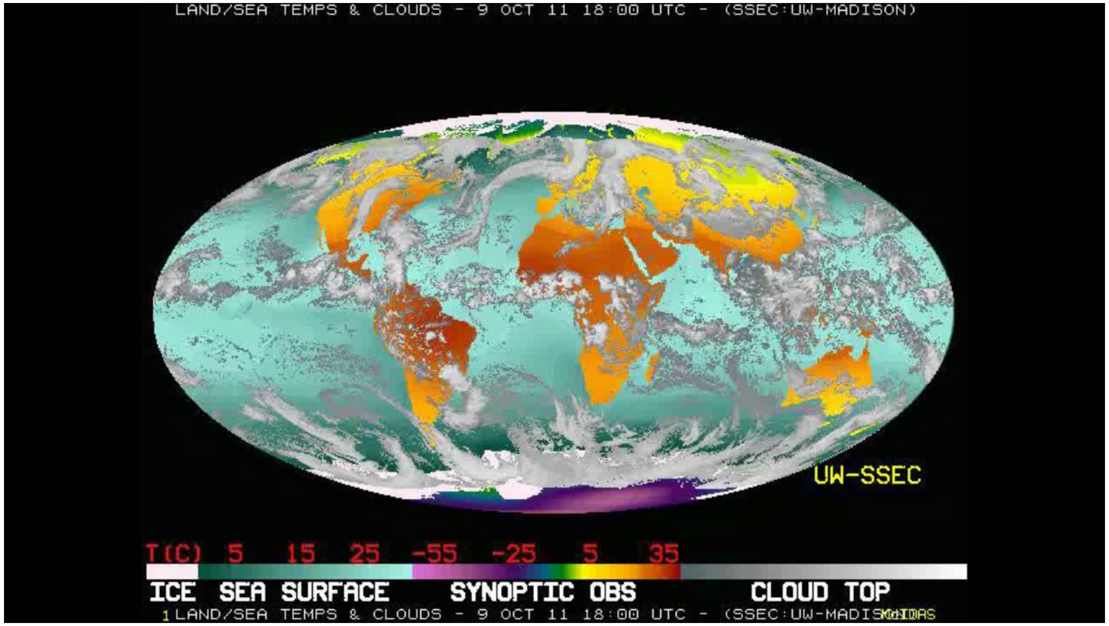
•Because the earth is so large, density differences produce multiple (an odd number) convection cells in the N. hemisphere and multiple (an odd number) convections cells in the S. hemisphere.



Not just 2 hemispheres (North and South)…Each hemisphere is broken into bands of different latitudes… resulting in 3 convection cells (Hadley, Polar & Ferrell cells) in each hemisphere.

Compare Class Model to Phenomena





Our Class Model

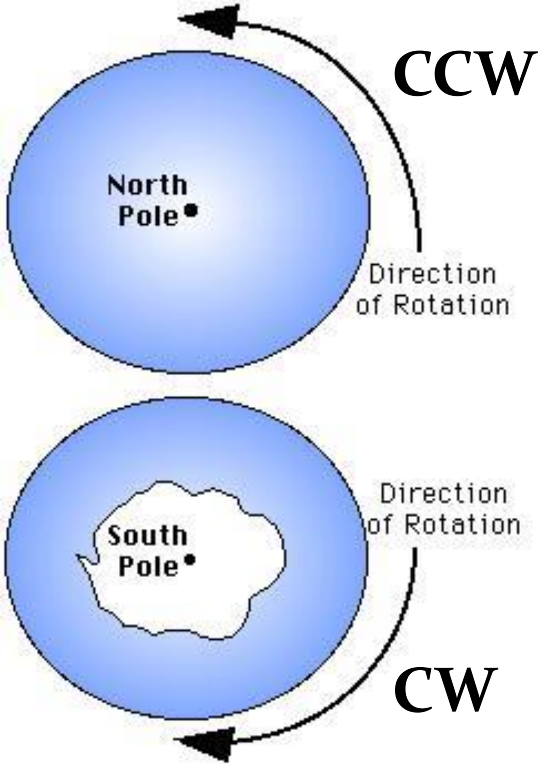
Actual Phenomena

Our model still has a problem!

We need YET MORE DATA

Data: Earth is Spinning!

- Earth's spin is counter-clock wise (CCW) when **viewed from the North Pole.**
- Earth's spin is clockwise (CW) when **viewed from the South Pole.**



Data: Earth is Spinning!

While watching MIT video, pay attention to the data patterns.

If spinning clockwise, the ball is deflected?

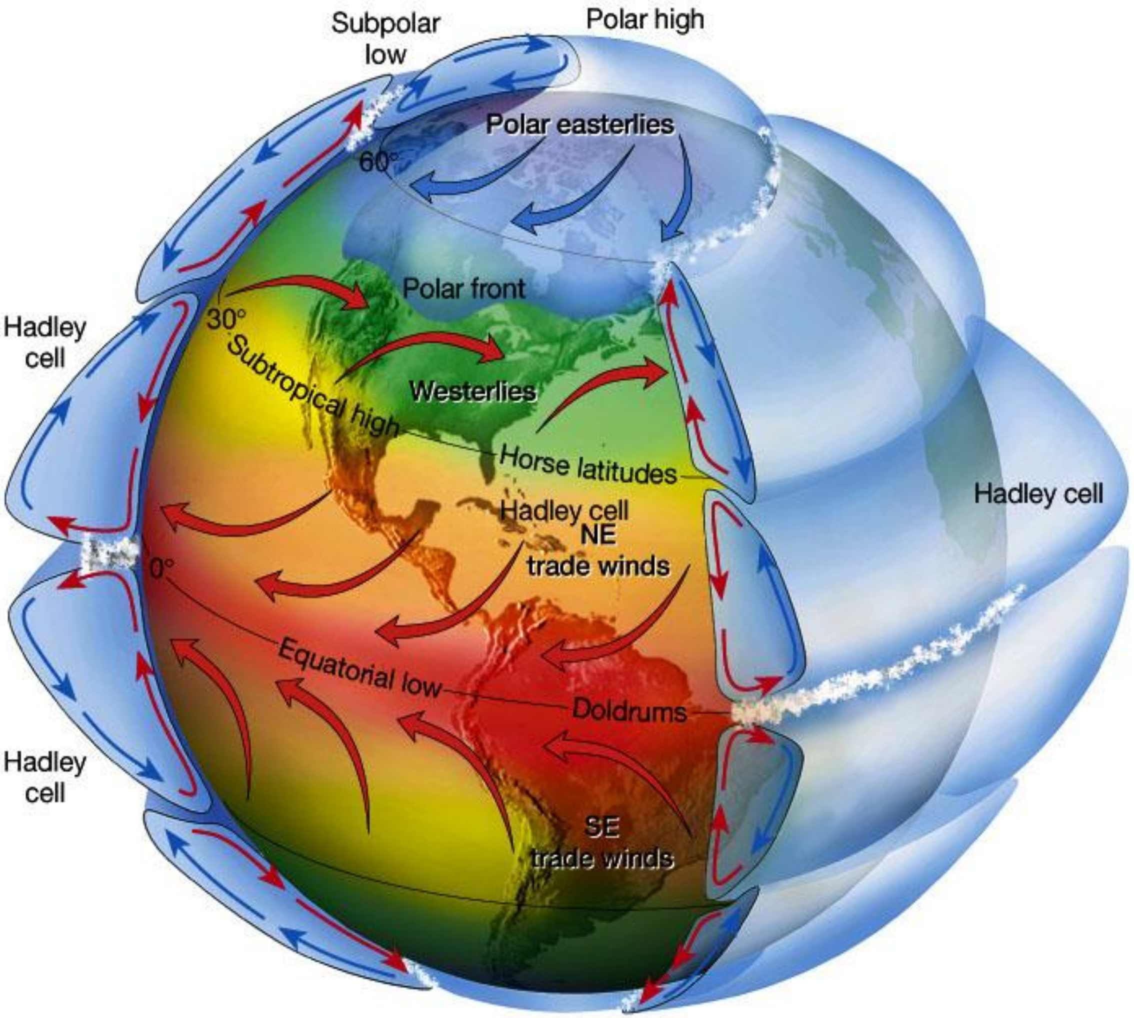
If spinning counter-clockwise, the ball is deflected?

Spinning Data Pattern

- Summarize the data patterns you noticed on the board:
  - If spinning clockwise, the thrown ball is always deflected ____________________?
  - If spinning counter clockwise, the thrown ball is always deflected ____________________?

Coriolis Effect

Representation of Final Model



<u>What we added to our model:</u>

- **Earth's spin** deflects poleward wind west and equatorward wind east.

Representation of Final Model of Surface Winds

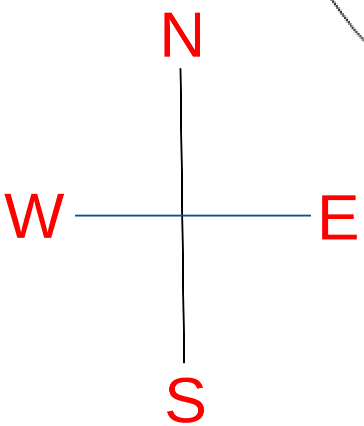
N. Hemisphere winds deflected to the right of original path.

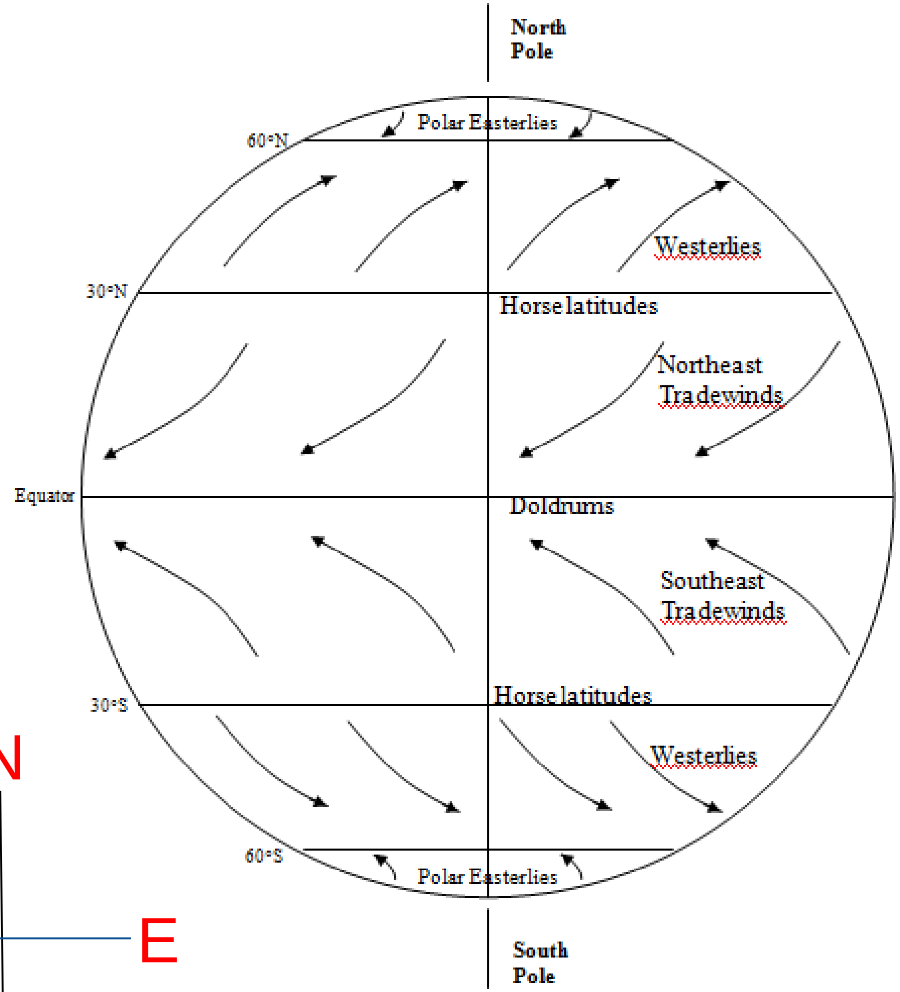
S. Hemisphere winds deflected to the left of original path.

In both hemispheres,

poleward wind is deflected to the EAST

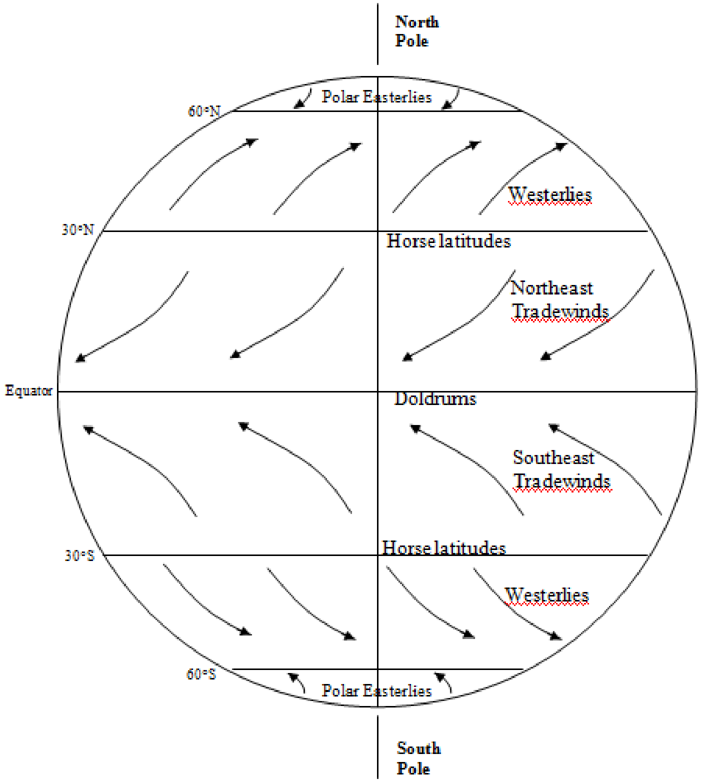
equatorward wind is deflected to the WEST

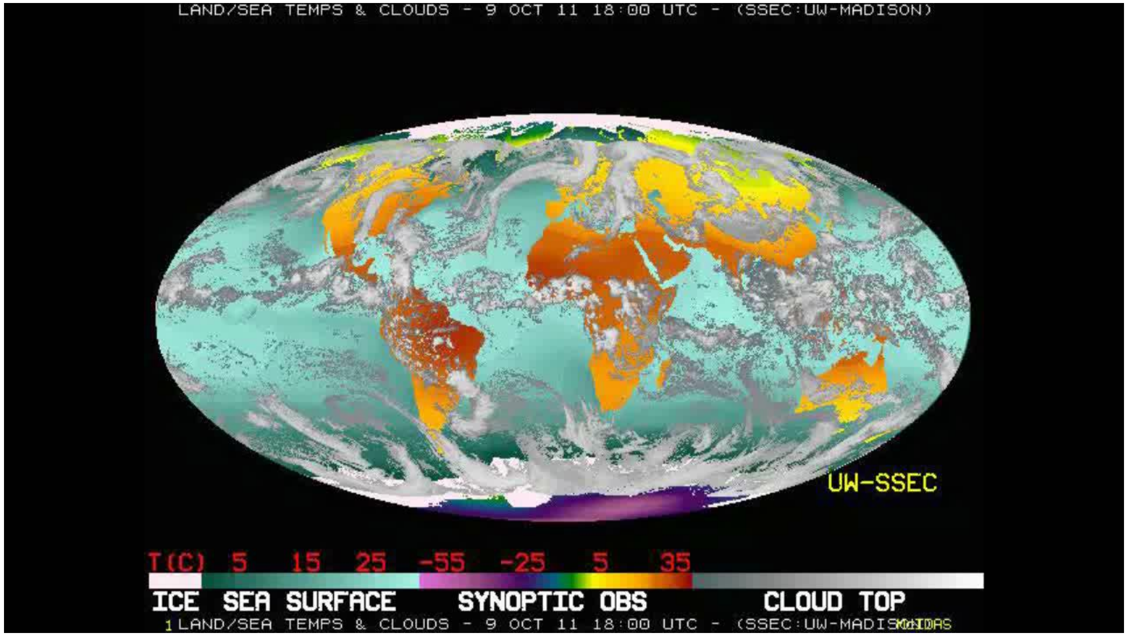




Final Model

Compare Final Model to Phenomena





Final Model

Actual Phenomena

Our final model predicts the actual wind patterns!

Simple Version of Final Model

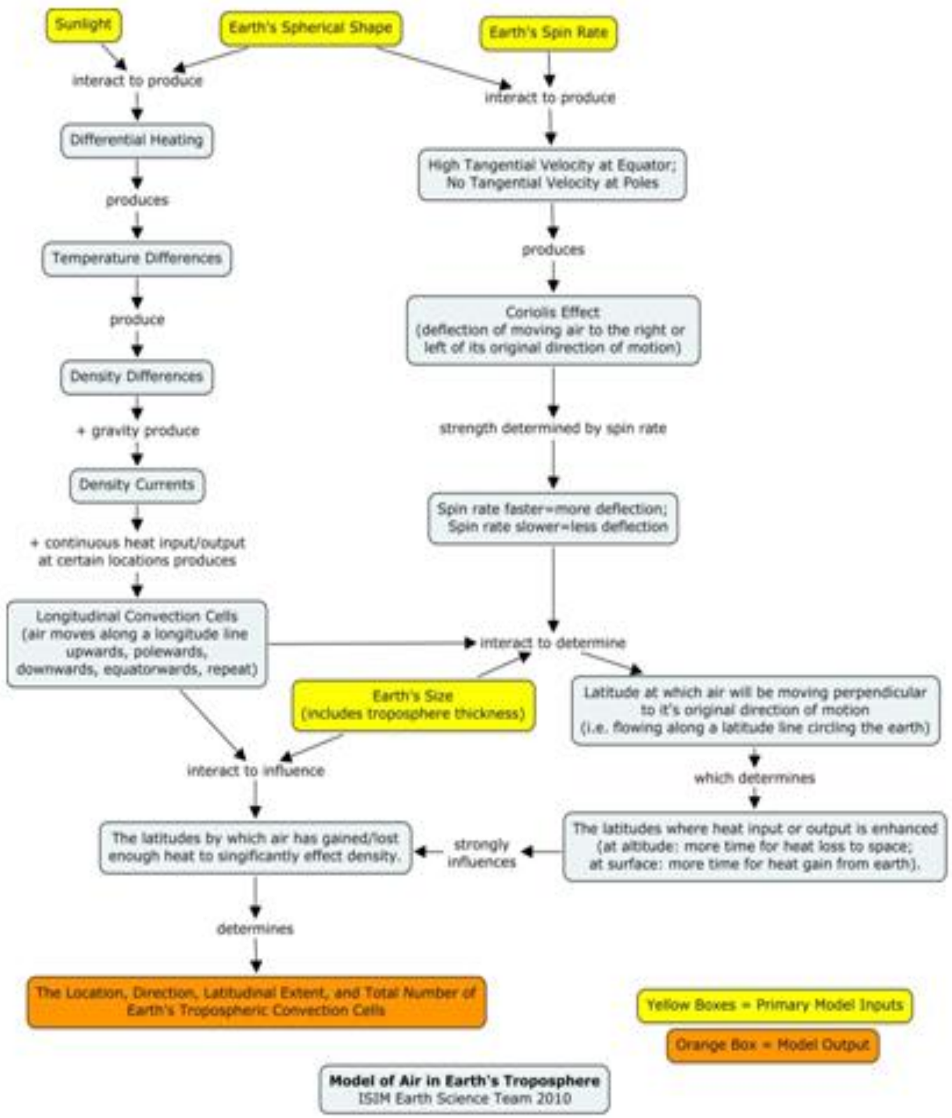
Our simple model which explains earth's atmospheric circulation:

Uneven heating of earth + earth's **large size** + earth's **spin rate** => observed **global wind patterns.**

We can describe the causal relationships within this model in much more **detail** . . . (next slide)

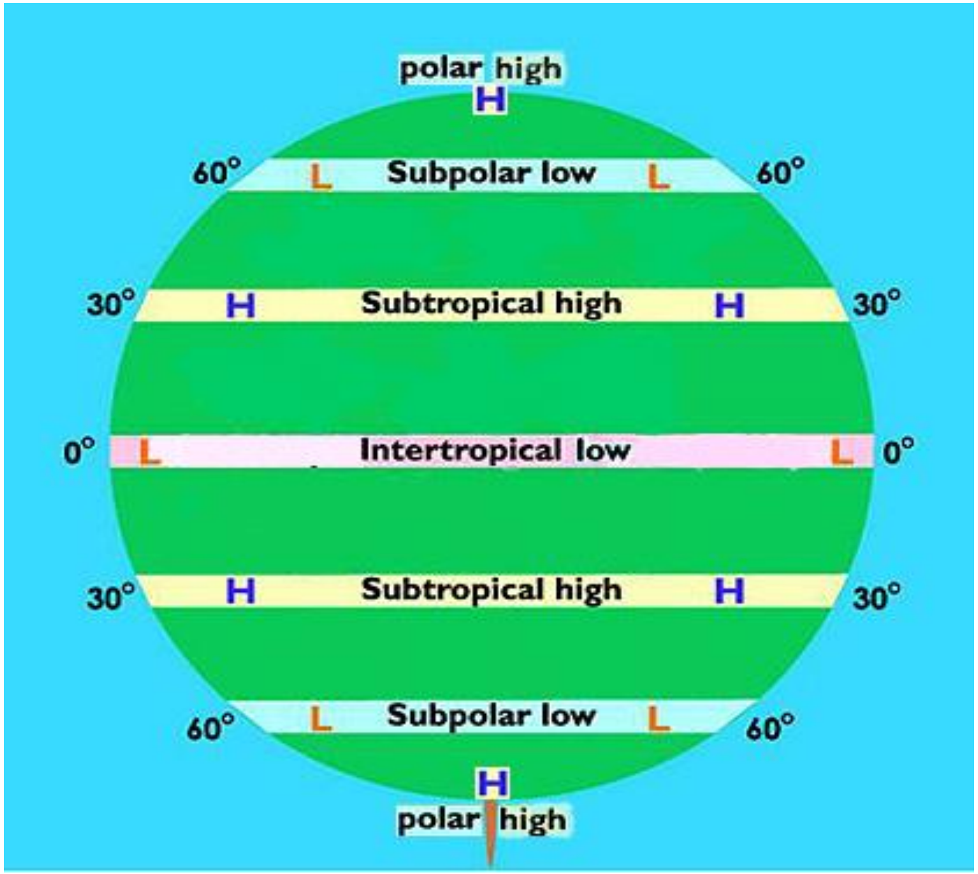
Earth's Live Current Feed

Detailed Model



Assessing Student Understanding

the high pressure at the poles and 30˚ latitude lines and low pressure along the equator and 60˚ latitude lines:



Extensions or Assessment

Even with the simple model:

Uneven heating of earth + earth's large size + earth's spin rate

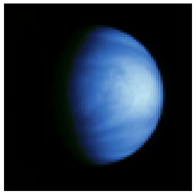
=> observed global wind patterns

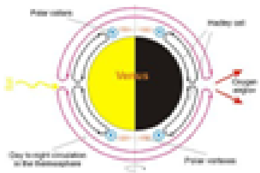
We can ask a lot of interesting questions:

- What happens if we vary the planet's spin rate?
- What happens if we change the spin direction?
- What happens if we have a small planet?
- What happens if we have a giant planet?
- What happens if the temperature differential is greater?
- What happens if the temperature differential is less?

Extension Example: Other Planets

Winds and the Coriolis Effect on Other Planets





Venus

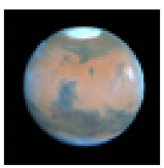
Venus is about the same size as the Earth. Its atmosphere is extremely dense. Because the planet rotates very slowly the Coriolis Effect on Venus is extremely weak.

Galileo image, courtesy National Space Science Data Center

Earth

Rotating on its axis about once every 24 hours the Coriolis Effect on the motion of the Earth's atmosphere is quite strong, creating continent sized swirls of cloud systems which are easily visible from space.

Apollo 17 image, courtesy National Space Science Data Center

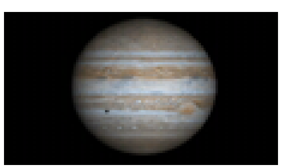


Mars

Mars has a very tenuous atmosphere. With the exception of vast dust storms, visible weather systems are not easily seen on Mars.

Mars' small size reduces the Coriolis Effect.

Hubble Space Telescope image, courtesy National Space Science Data Center

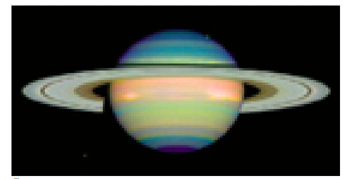


Jupiter

Jupiter is more than 11 times the diameter of the Earth, and rotates on its axis (one Jovian day) in 9.8 hours. Jupiter's large size and rapid rotation create a very large Coriolis Effect in its atmosphere. The winds in the Jovian atmosphere are deflected so strongly that they form hurricane-force gales blowing in East-West bands around the planet.

It is the Coriolis Effect that is responsible for Jupiters banded appearance.

Hubble Space Telescope image, courtesy National Space Science Data Center

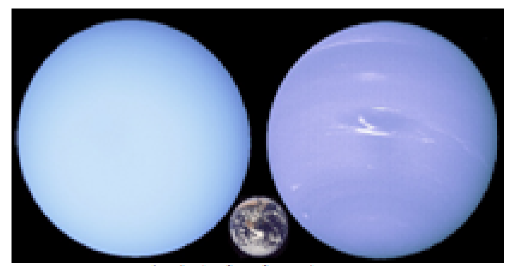


Saturn

Saturn is also a very large planet, almost 9.5 times the diameter of the Earth. A full day (one complete rotation) of Saturn lasts only 10.5 hours. As with Jupiter, the combined effect of rapid rotation and large size create a very large Coriolis Effect in Saturn's atmosphere.

The striped appearance of Saturn is created by a very large Coriolis Effect.

Hubble Space Telescope image, courtesy National Space Science Data Center



Uranus (earth size for reference) **Neptune**

Uranus and Neptune also have thick cloud decks but Uranus' atmosphere does not have the prominent bands and storms seen on the other jovian planets. This is because Uranus does not have an extra internal heat source like the other jovian planets, so it does not have the convective motions in its atmosphere. Neptune's clouds are deflected to form bands parallel to its equator because of its rapid rotation. Neptune can also have turbulent eddies form in its atmosphere. When the Voyager spacecraft flew by Neptune in 1989, it found a large dark storm, called the Great Dark Spot (very original, yes?), that was about the size of Jupiter's Great Red Spot. However, recent Hubble Space Telescope photographs show that the Great Dark Spot seems to have dissipated.

Prepared by R.Hedman 2010 from these two sources:

http://www.asc-csa.gc.ca/eng/educators/resources/mars/grade5_winds_planets.asp

http://www.astronomynotes.com/solarsys/s5.htm