Funding provided by NOAA
Sectoral Applications Research Project

THE ATMOSPHERE IN MOTION

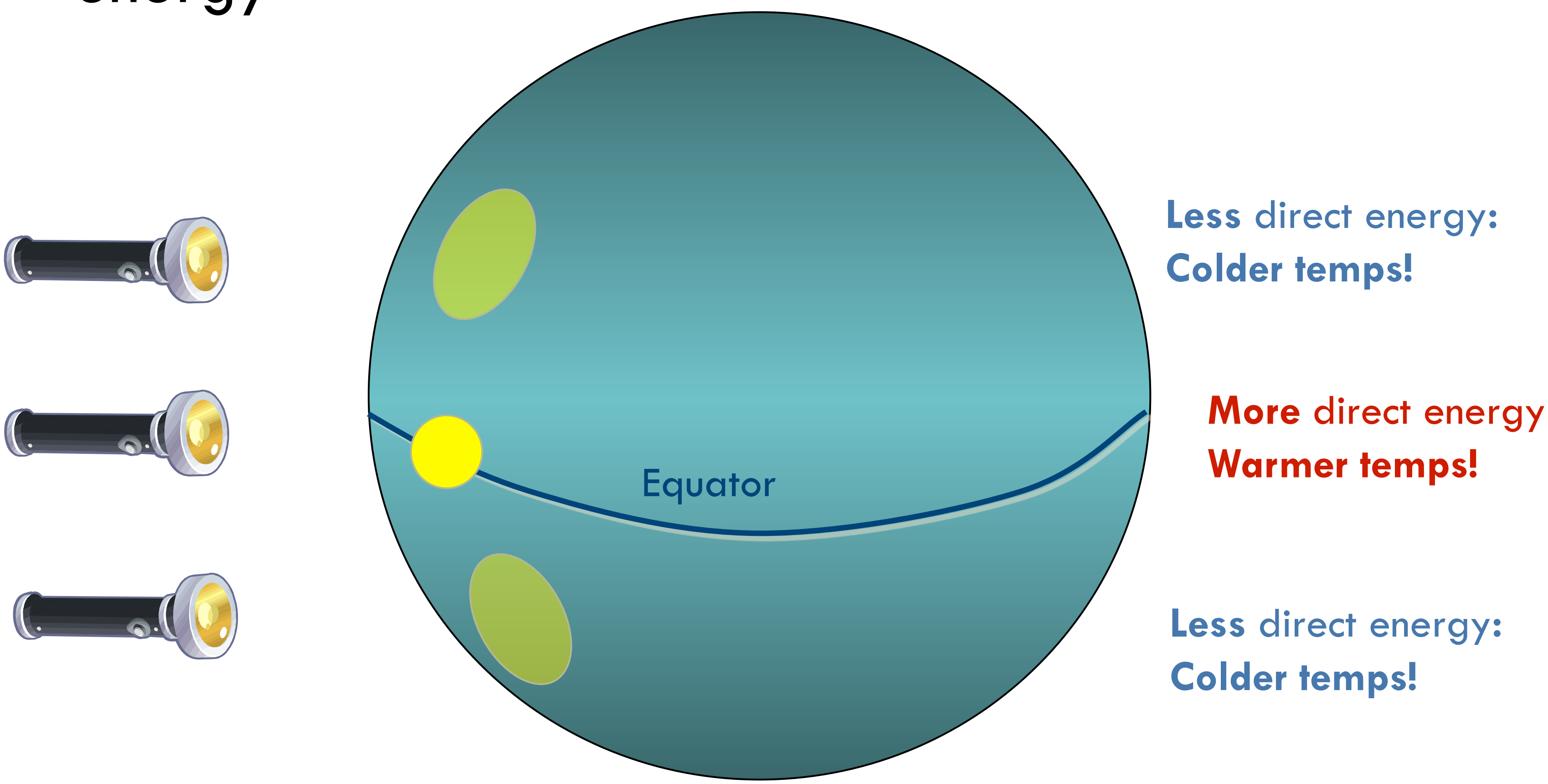
Basic Climatology
Oklahoma Climatological Survey

Factor 1: Our Energy Source

Hi, I'm the Sun! I provide 99.9999+ percent of the energy that drives the Earth's weather and climate patterns. In other words, I pretty much make weather happen on your planet. Also, if it wasn't for me, you wouldn't be here!

Energy From The Sun

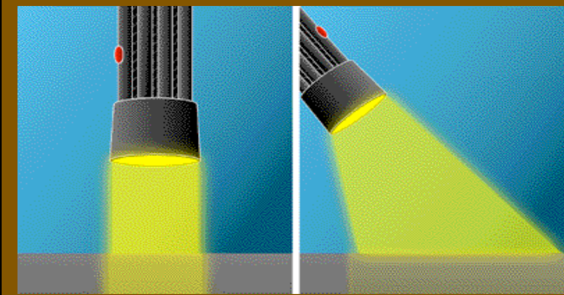
- Direct (more intense) vs. oblique (less intense) energy



Factor 2: Revolution & Tilt

- We're tilted (23½ degrees) relative to the sun.
- We also revolve around the sun (once a year)
- Combined, these give us the *seasons*

Seasons

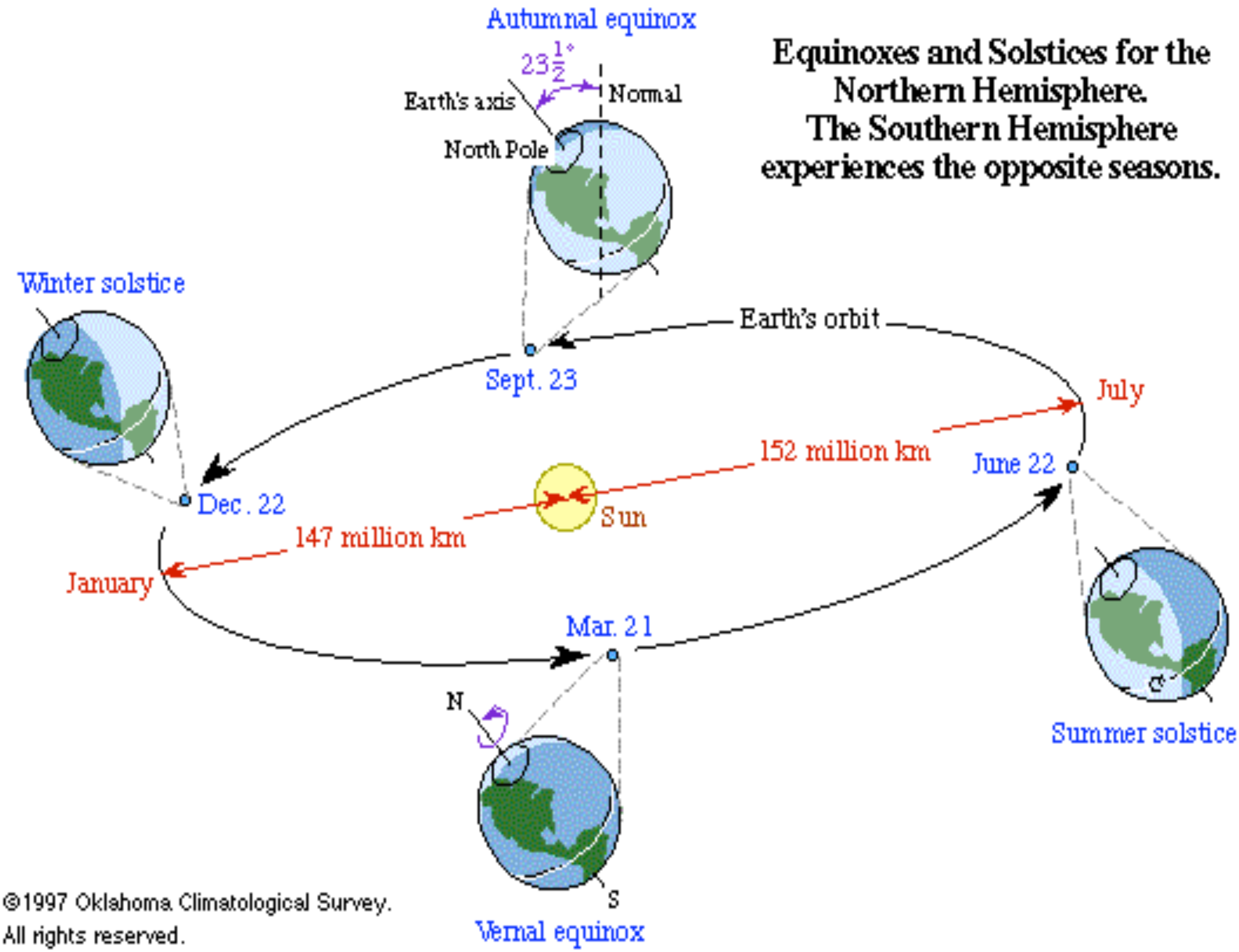


Concept box: perpendicular light strikes more intensely than light from an oblique angle.

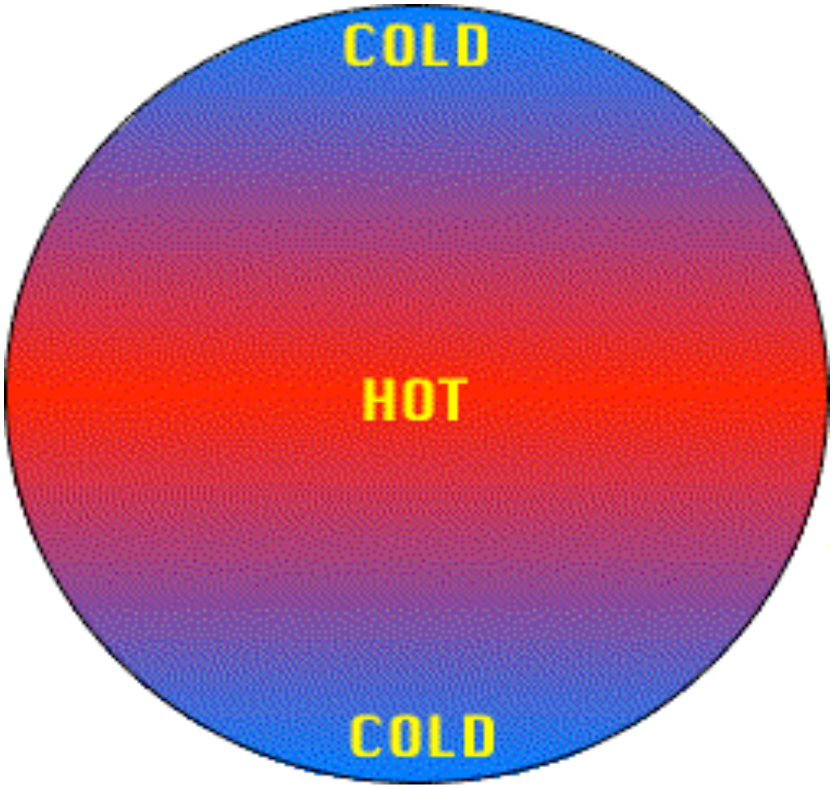
- Two main effects of tilt:
  - Affects the sun angle
    - sun rises to a lower angle in the sky in winter
    - less direct light in winter
  - Affects the time-per-day exposed to sunlight
    - Days in the winter are shorter

N.H. Summer (tilted toward)

N.H. Winter (tilted away)


Equinoxes and Solstices for the Northern Hemisphere.
The Southern Hemisphere experiences the opposite seasons.
Autumnal equinox
$23\frac{1}{2}°$
Earth's axis
Normal
North Pole
Winter solstice
Earth's orbit
Sept. 23
July
152 million km
June 22
Dec. 22
Sun
147 million km
January
Mar. 21
N
S
Summer solstice
Vernal equinox

Consequences of Uneven Heating



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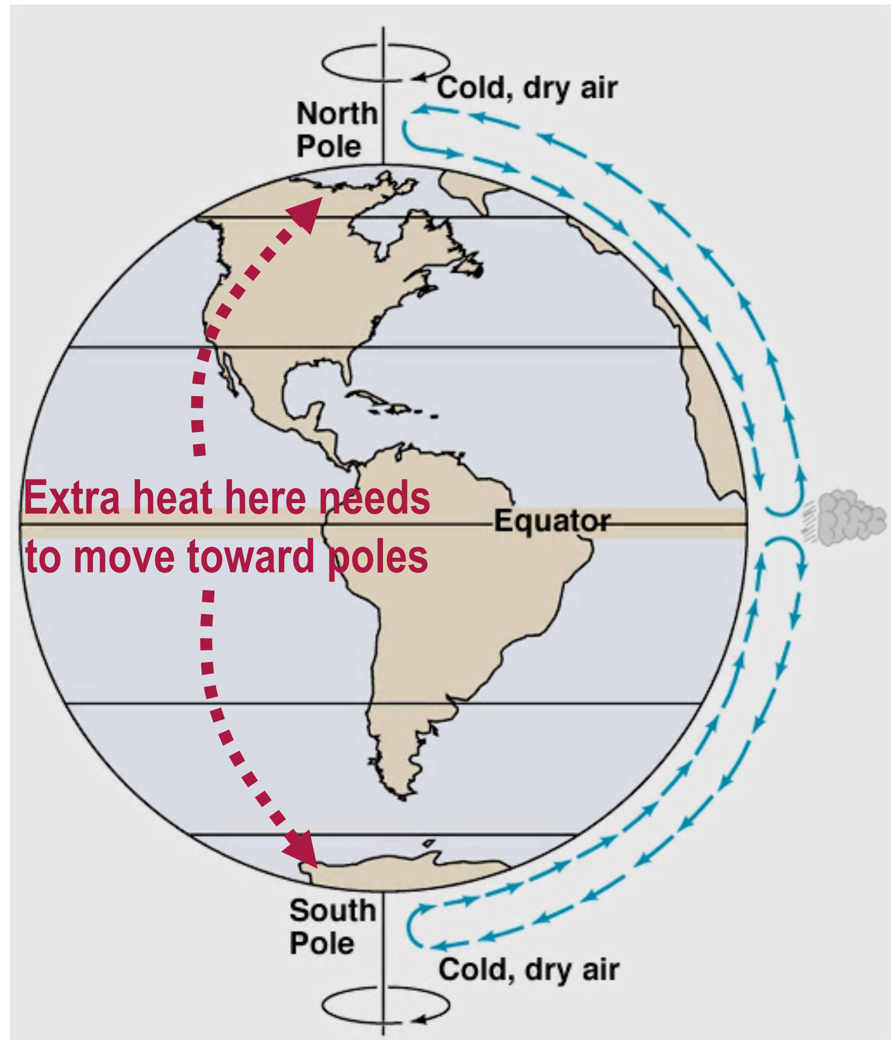
- Uneven heating should produce a global temperature pattern that looks like this… ***Does it?***
  - Yeah, pretty much.

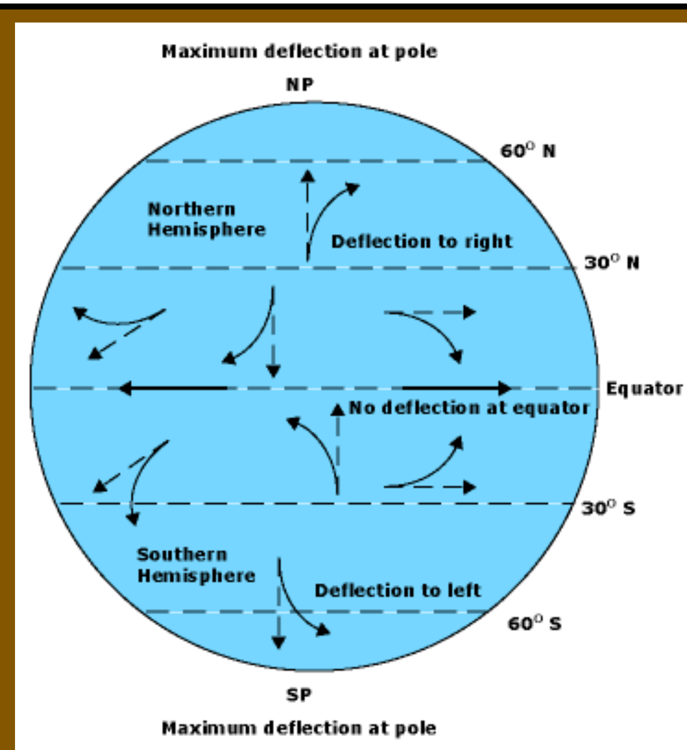
Major Circulation Patterns

- Earth's oceans and atmosphere move heat from the equator (and cold from the poles).
- Warm air (less dense) rises at the equator and sinks as it cools (at the poles)
- This drives our weather patterns!
- This is what our circulation patterns could look like, if …
  - **the earth didn't rotate!**



Factor 3: Rotation!

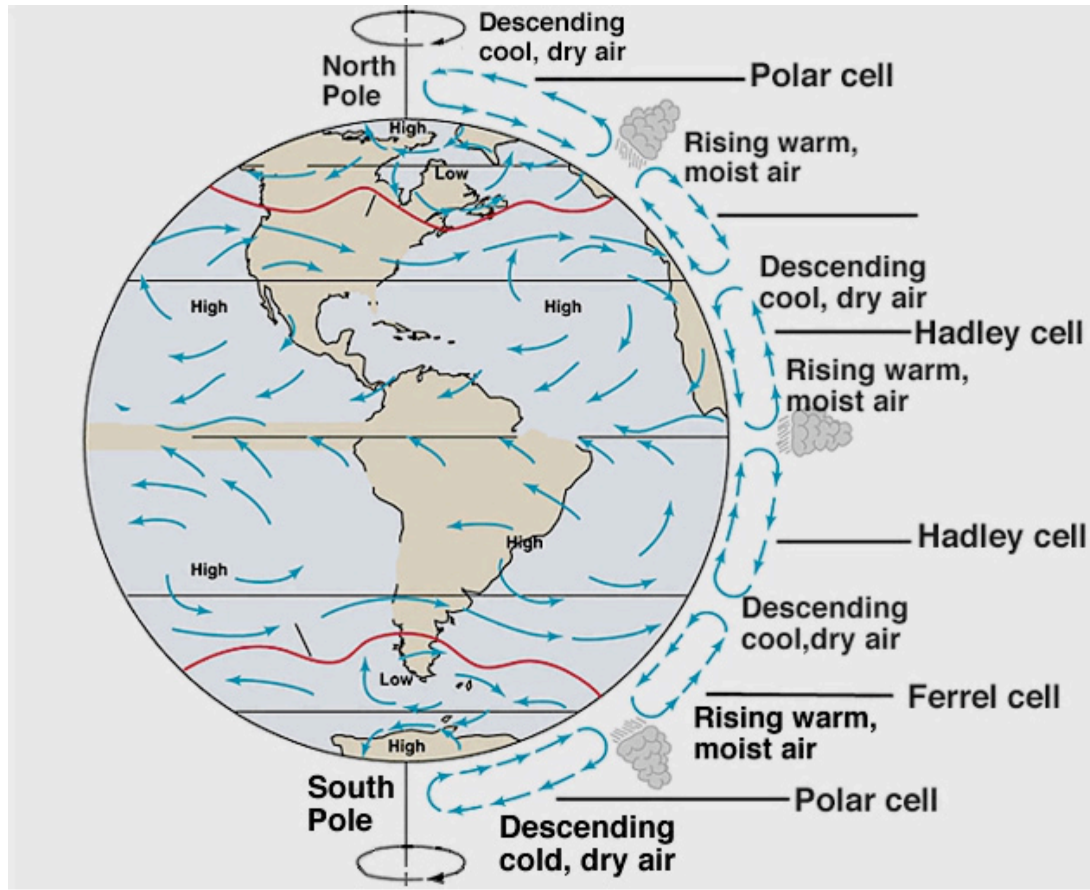
- The earth spins
  - which gives us day and night.
- It also throws a curve (literally!) at our weather patterns.
- On a global scale, stuff doesn't travel in long, straight lines.



Concept box: The *Coriolis Effect* deflects motion to the right in the Northern Hemisphere (to the left in the S.H.). The effect increases nearer the poles.

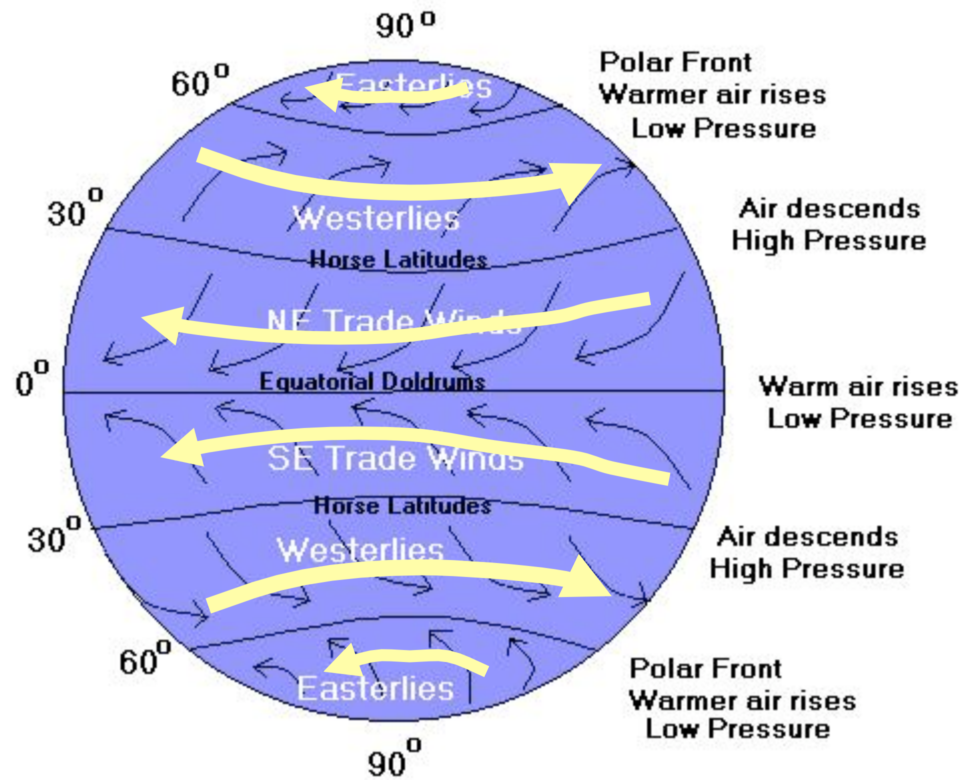
Major Circulation Patterns

- The earth's rotation breaks the equator-to-pole travel into three major circulation belts in each hemisphere
- Sinking air is dry
- Rising moist air makes precipitation



Major Circulation Patterns

- Generally speaking:
  - Easterly winds near the equator;
  - Westerly winds in temperate regions (most of the U.S., most of the time)
  - Easterlies again near the poles.



Factor 4: Latitude

- Variation of sunlight affects temperature (more total energy: higher temps)

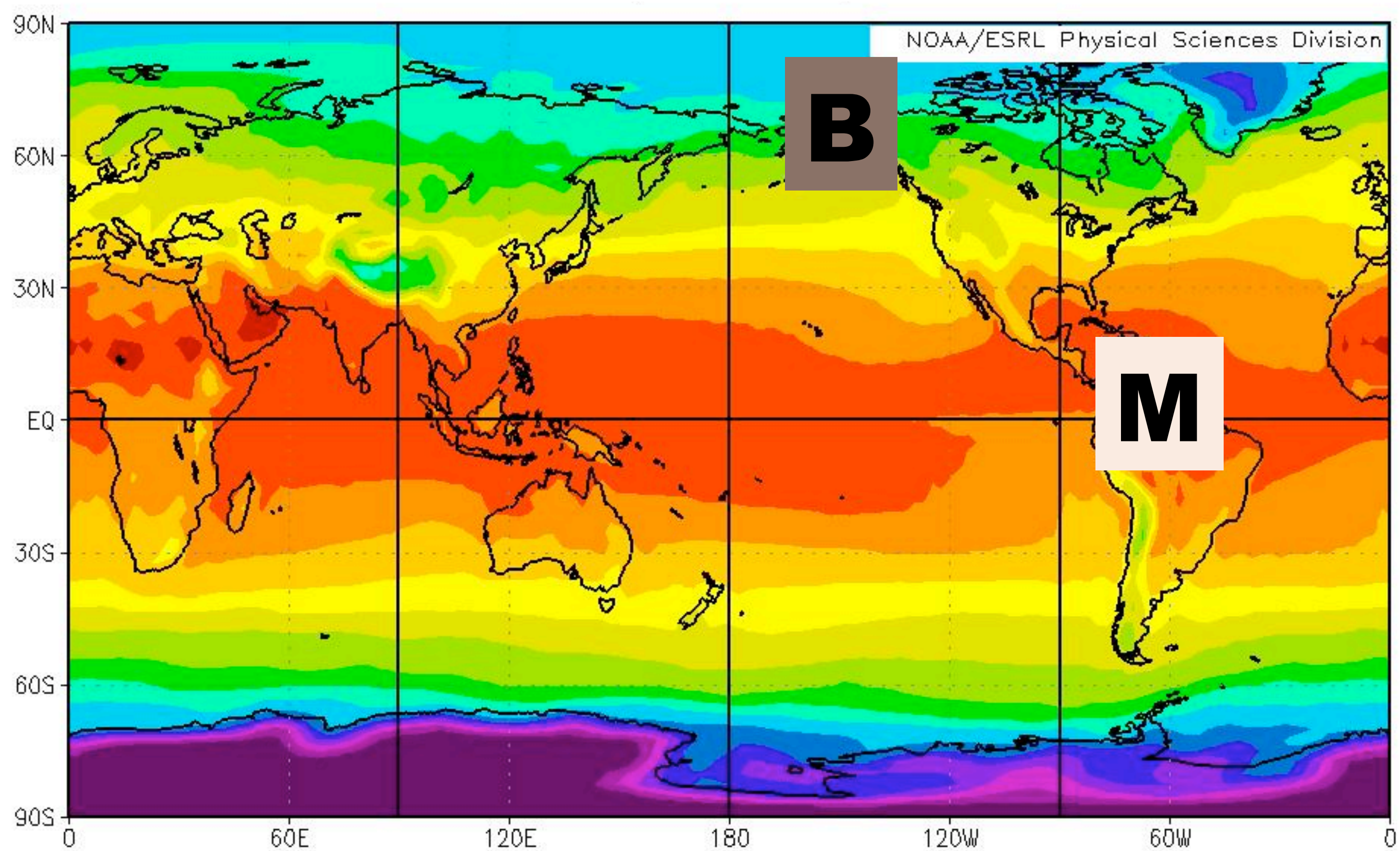
- **Least variation** at the equator:
  - generally warm year round (most direct sunlight)
- **More variation** at mid-latitudes:
  - warm in the summer, cool in the winter (Oklahoma)
- **Most variation** at high-latitudes:
  - cool in the summer, cold in the winter (least direct sunlight).

The Role of Latitude

Barrow, AK (71N)

July: Two straight months of sun (still cool, though, because the sunlight is less direct). Average Temp: 40 F

January: Two straight months of darkness. Avg Temp: -14 F



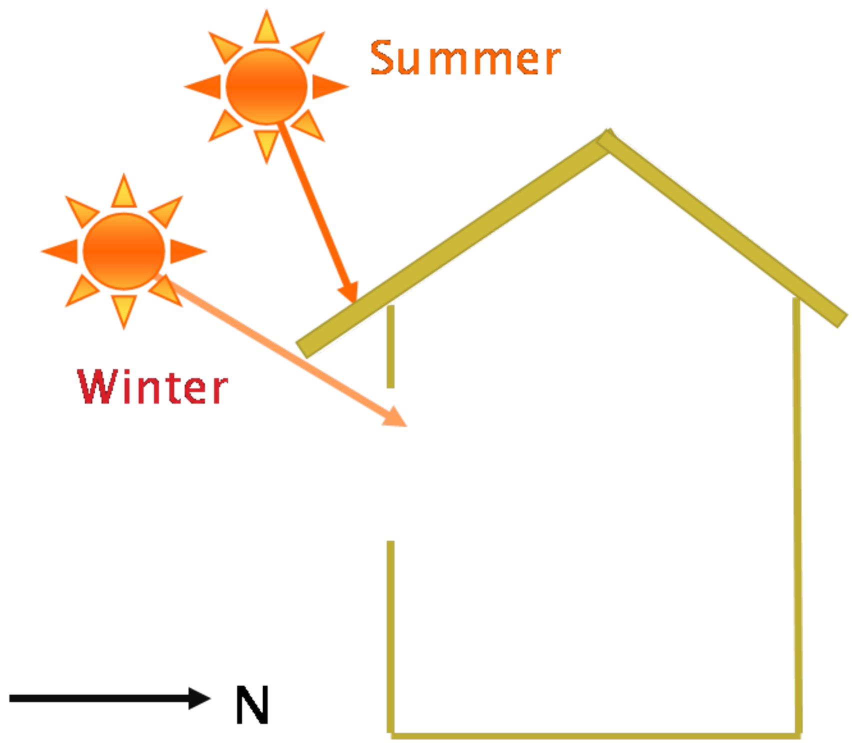
Maracaibo, Venezuela (8N)

July: Avg Temp: 83 F

January: Avg Temp: 81 F

Hey, we build for this stuff!

- Mid-Latitude Home Design
  - Summer in OK, peak sun angle: ~78 degrees
  - Winter in OK, peak sun angle: ~31 degrees
- Overhang should be long enough for summer shade, yet short enough to allow winter sun



Factor 5: Altitude

Generally Speaking: Higher Altitude → Cooler, drier climate

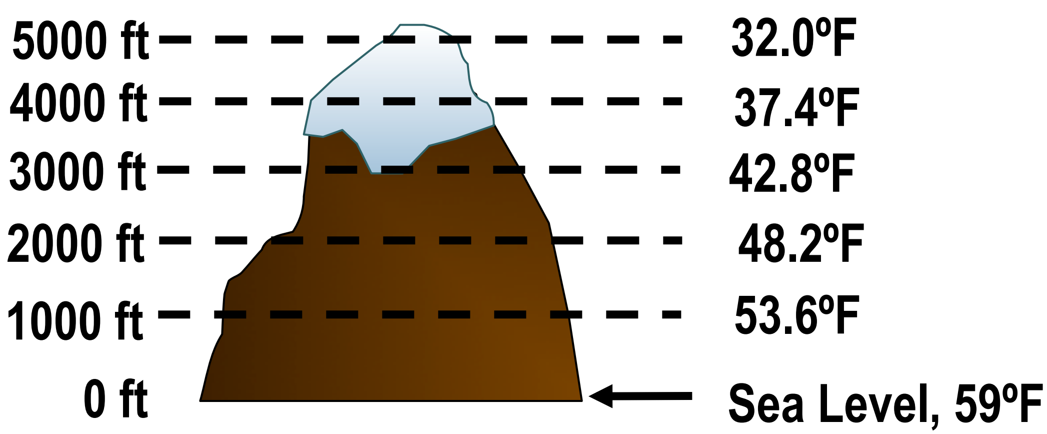
(In climate, like in life, there are exceptions to every rule!)

Mt. Washington, NH (44°N, 6288 ft.)
annual temp: 27.2F

Rapid City, SD (44°N, 3,202 ft.)
annual temp: 46.7F

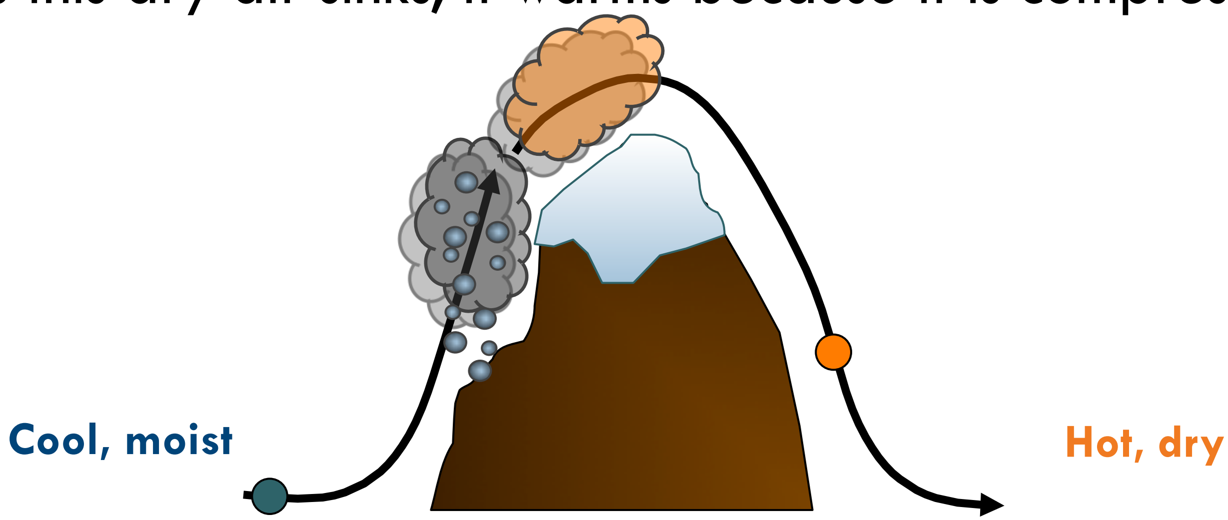
Altitude

- *Lapse rate* = rate of change of temperature with height
- Lapse rate = ~-5.4°F/1000ft (up to top of troposphere, around 7.5 miles)
  - For every 1000 feet you ascend, the temperature drops ~5.4°F!



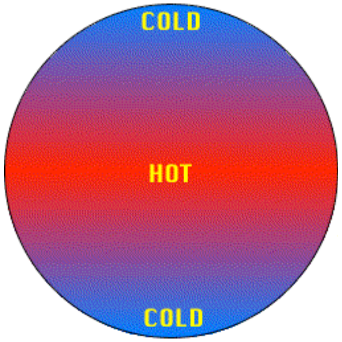
Altitude: Rain Shadow Effect

- Rain on one side of the mountain, dry on the other
  - Air is lifted up, expands and cools, and forms clouds
  - Any precipitation falls on this side of the mountain
  - Air continues over mountain, but without its moisture
  - As this dry air sinks, it warms because it is compressed

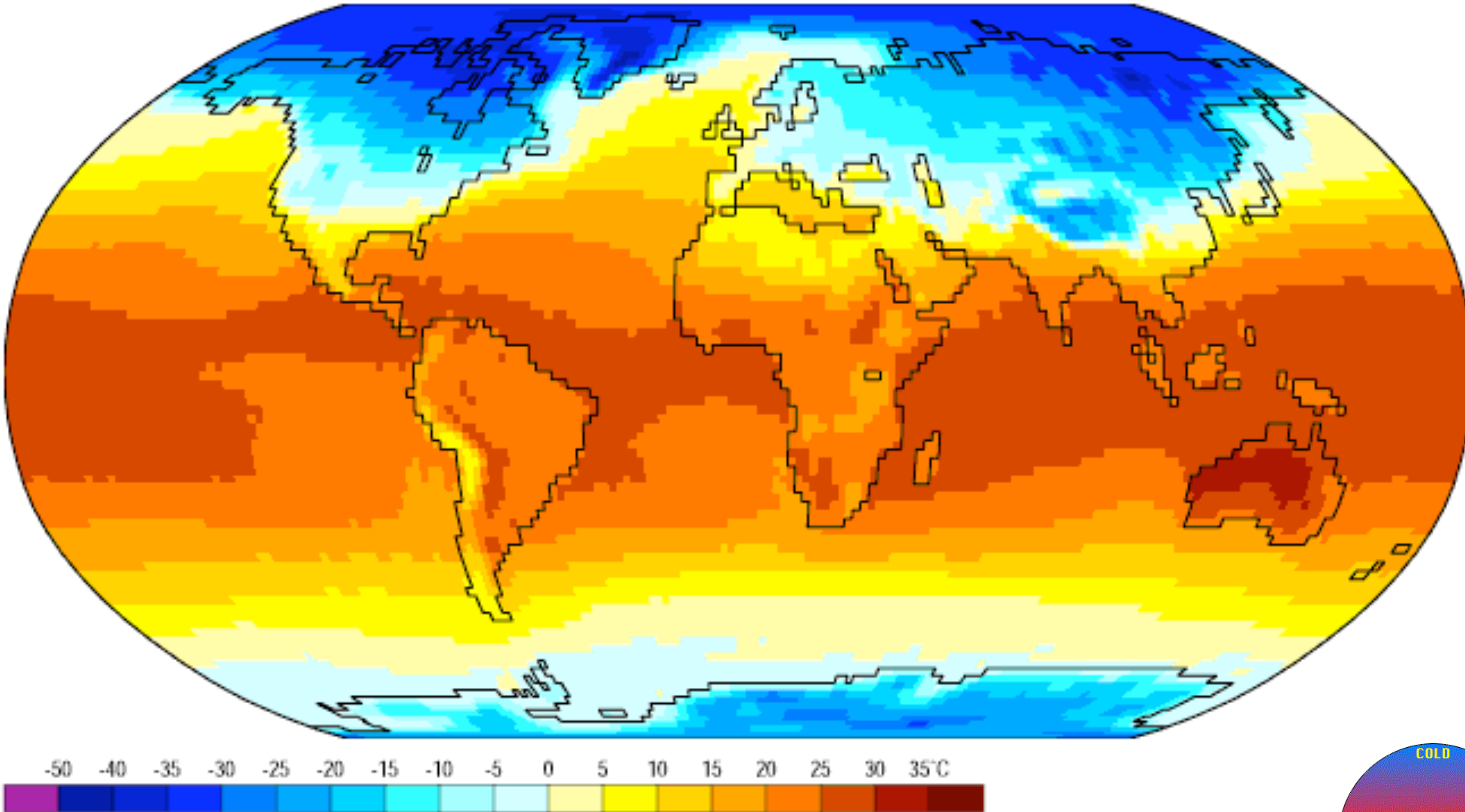


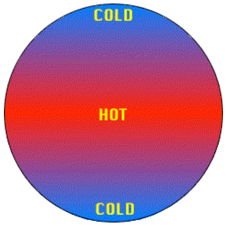
Factor 6: Land & Water are Different

- Land surfaces heat and cool much more quickly than water/oceans.
  - This is important because the atmosphere is mostly heated from below.
- Also, continents get in the way of oceans
- Remember our idealized "bowling ball" world?



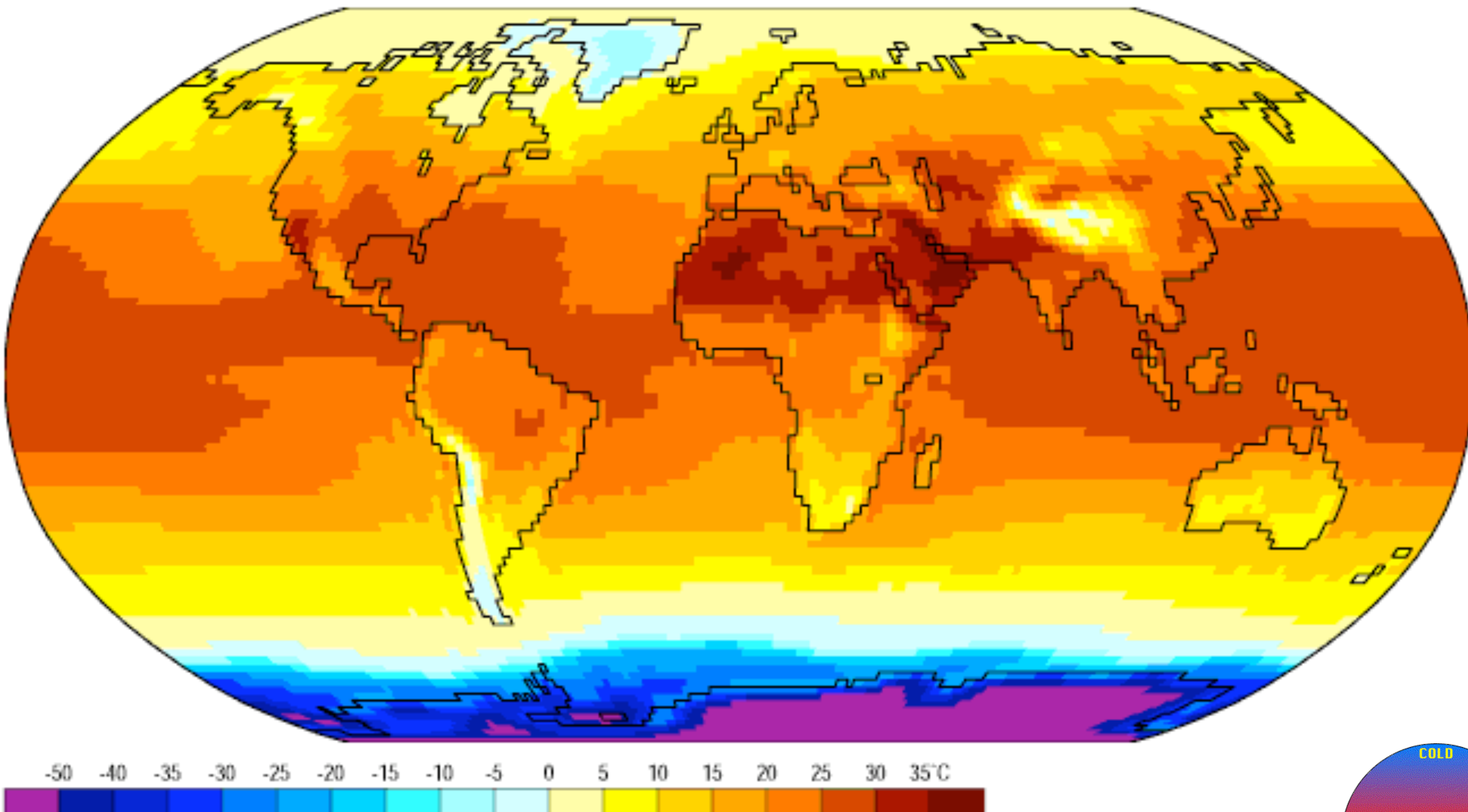
Actual January temperatures



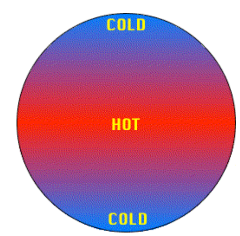


This is *January*. How do the observations differ from our ideal bowling ball? Why?

Actual temps in July.



This is *July*. What has changed since January? Which hemisphere has more land?



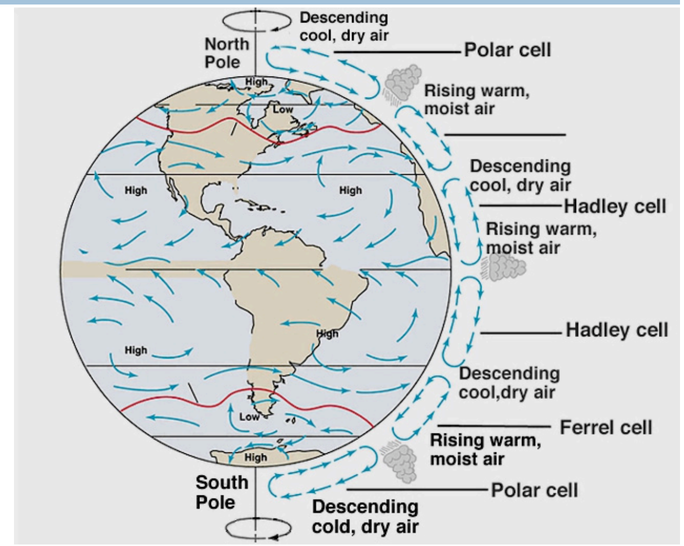
Let's Review…

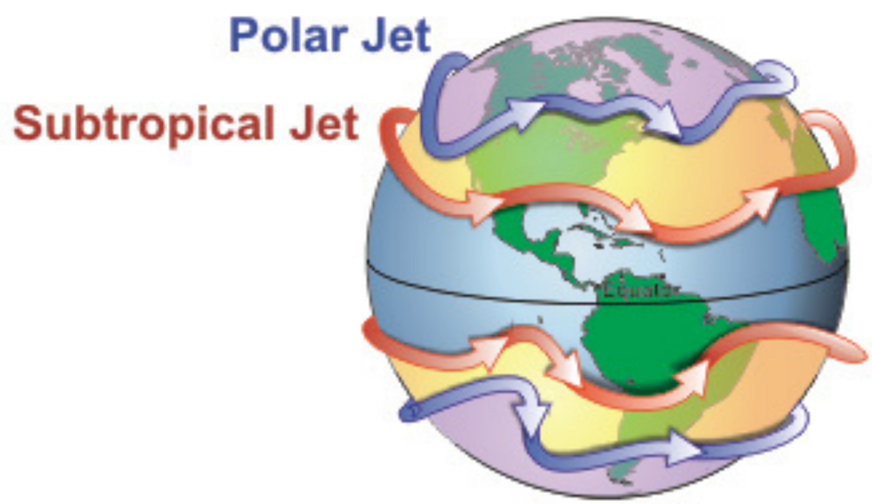
- Factor 1: Our Energy Source
- Factor 2: Revolution & Tilt
- Factor 3: Rotation!
- Factor 4: Latitude
- Factor 5: Altitude
- Factor 6: Land & Water are Different

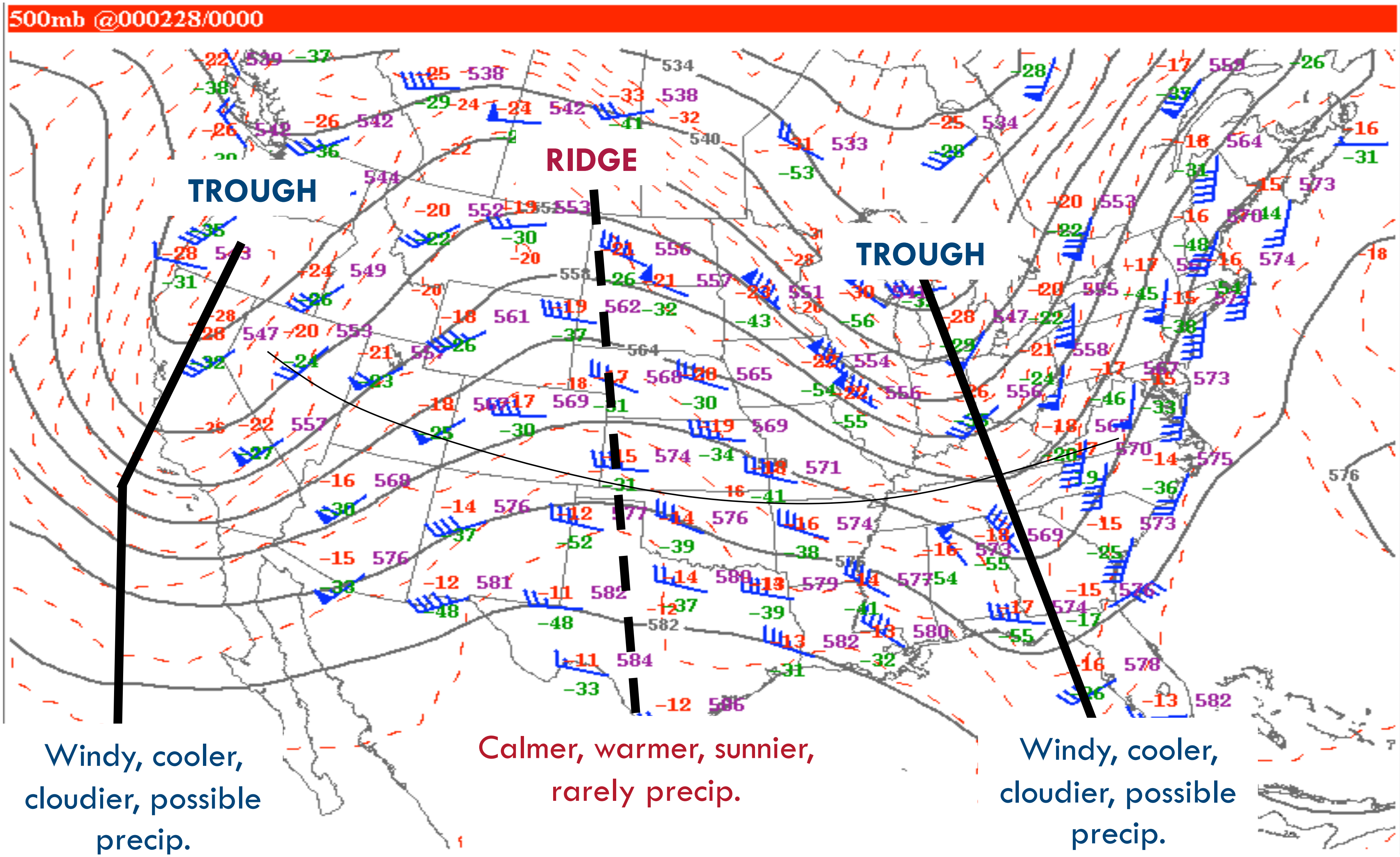
GLOBAL WEATHER PATTERNS

Jet Stream

- Relatively narrow bands of strong winds in the upper levels of the troposphere
- Generally west-to-east, but parts can be north-south
- Forms at the boundaries of circulation cells
- The Polar Jet is usually stronger because the temperature differences are greatest



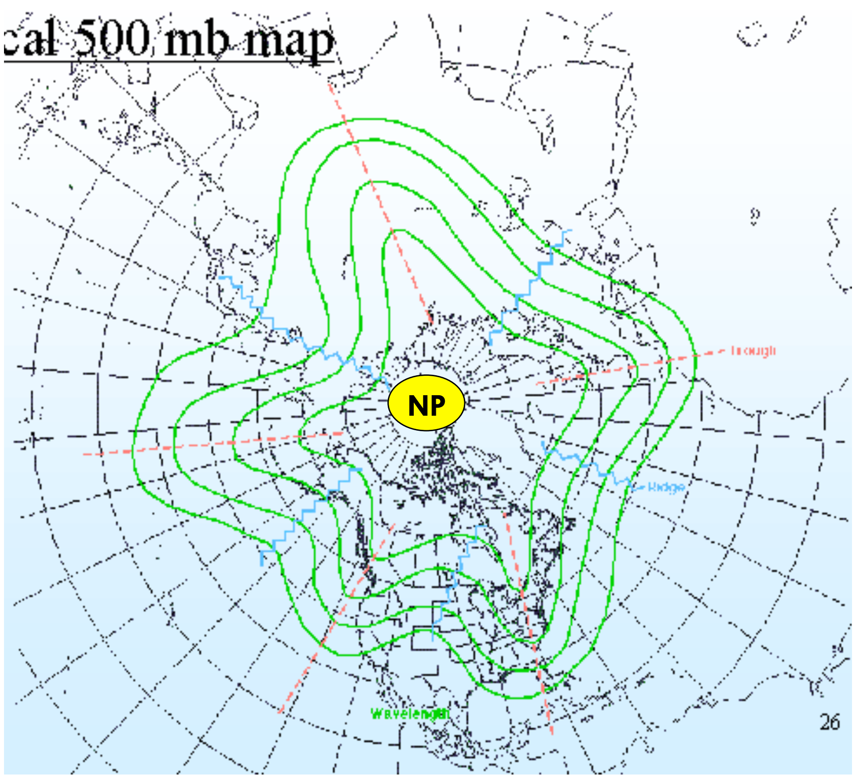




Ridges: Warm air, usually moving from equator to pole. Associated with: tranquil weather, lighter winds, clearer skies, this is summer's "heat dome".

Troughs: Cold air, usually moving from pole to equator. Associated with: disturbed weather, stronger winds, clouds, precipitation and "weather systems".

Global Weather Patterns

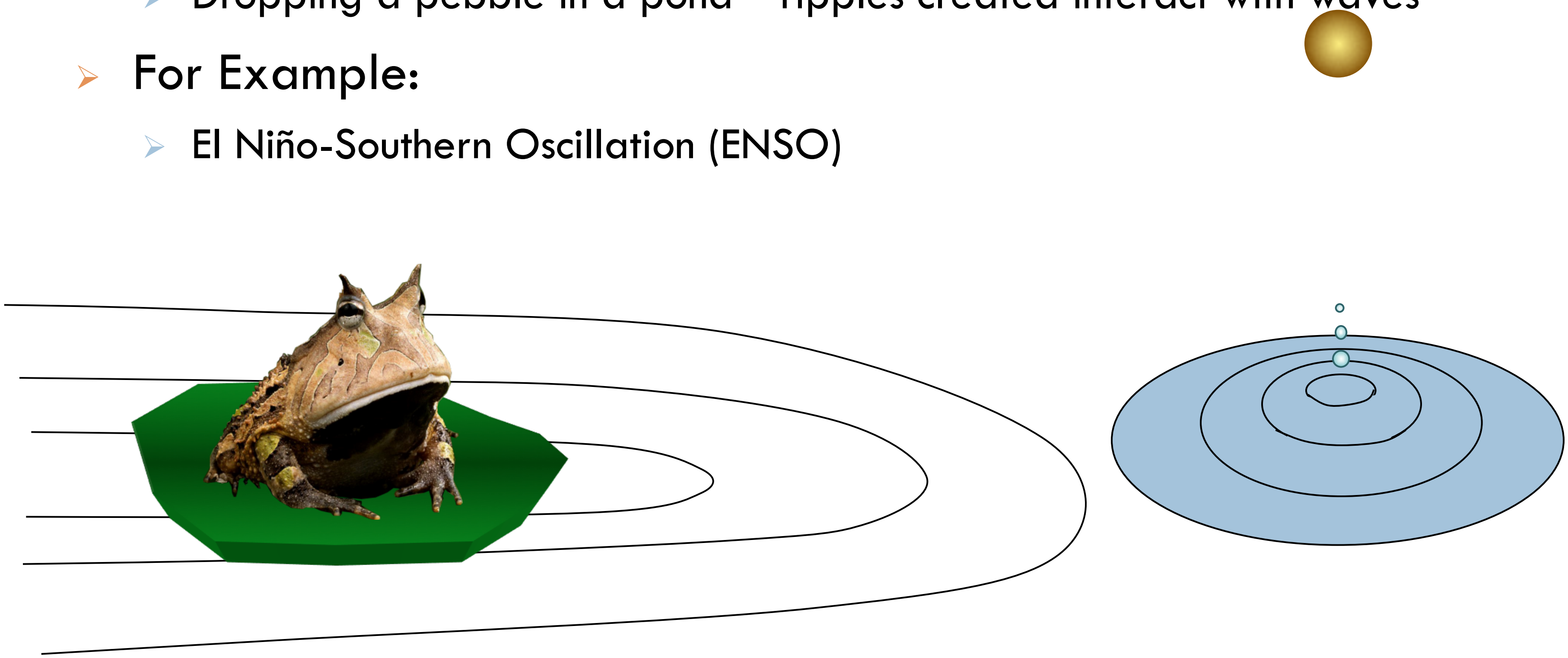


A typical 500 mb map showing series of troughs and ridges

- These *ridges* and *troughs* make a pattern around the world
- Energy moves through these “waves” as they migrate around the globe
- Disruptions in one place can have impacts at far distant locations

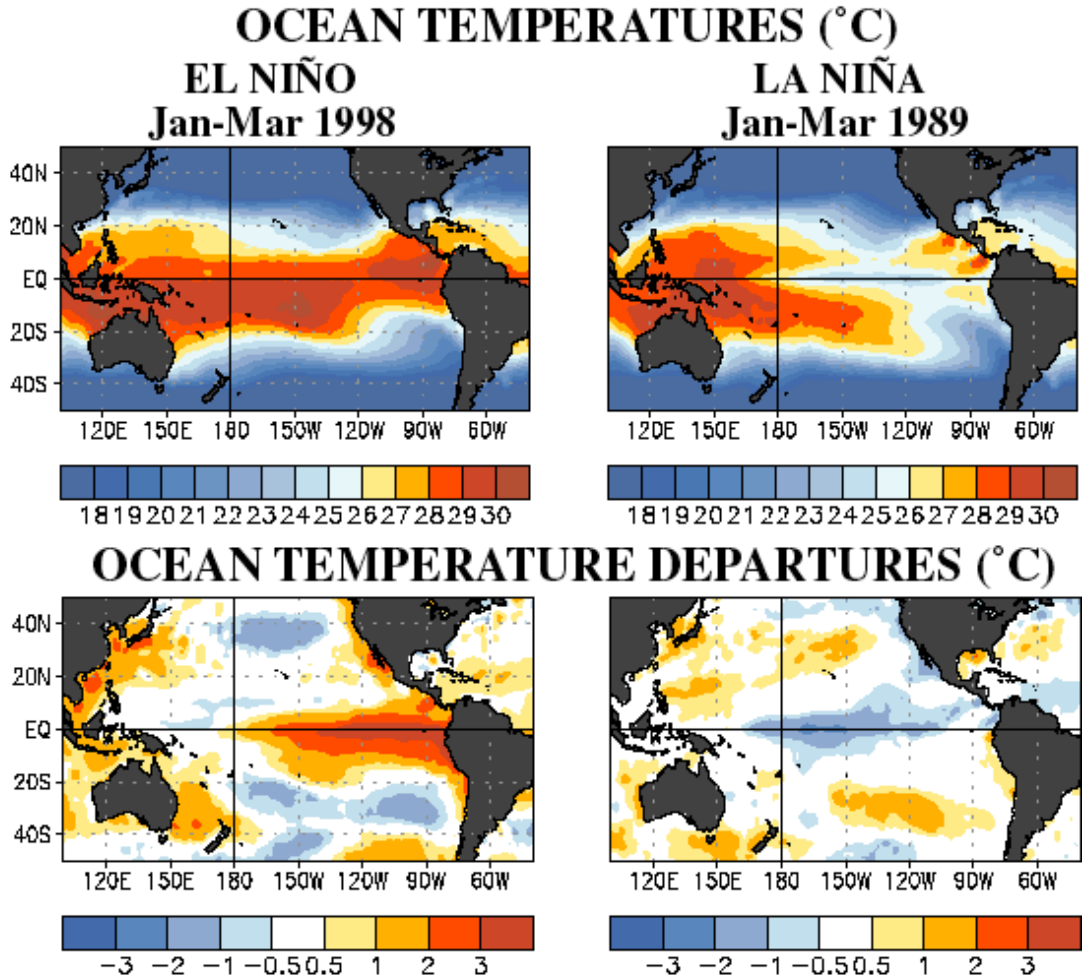
Teleconnections

- Connectedness of large-scale weather patterns across the world
  - If you poke one area, another area is affected as well (can be across the world, very far away)
  - Dropping a pebble in a pond—ripples created interact with waves
- For Example:
  - El Niño-Southern Oscillation (ENSO)



El Nino / La Nina

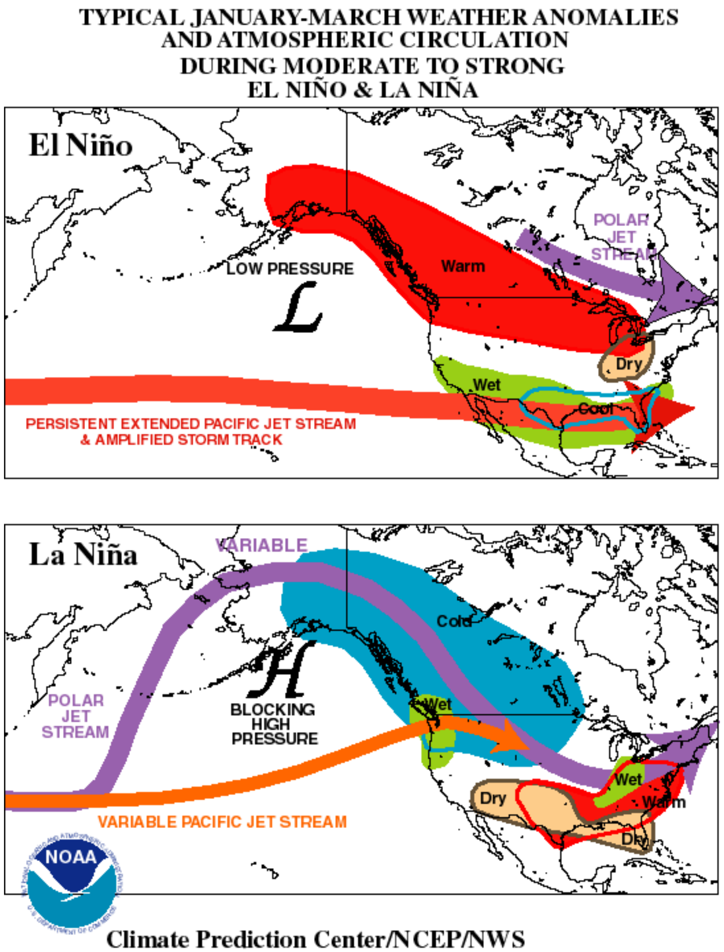
Equatorial Pacific temps significantly warmer than "normal"



Equatorial Pacific temps significantly cooler than "normal"

Right now, we are in an El Nino phase

Typical ENSO Winter Effects



- **El Nino:**
  - Lots of [non-Arctic] storms tracking rapidly from west-to-east across southern half of U.S.
  - Very wet across Southern states; very warm across Northern states
- **La Nina:**
  - Storm track often stays north of us
    - OK warm & dry for extended periods.
  - When it jumps south (quickly) we get weather systems, but they often lack sufficient moisture
    - We go from warm, dry and windy to cold, dry and windy
  - The storm system finally explodes with precipitation somewhere around Memphis

Other "Teleconnections" Features

- PDO: Pacific Decadal Oscillation
  - "Sloshing" between northern and central Pacific, typically 20-30 year period.
  - Effects similar to El Nino
  - May be a major contributor to extended drought patterns
- NAO: North Atlantic Oscillation
  - From Iceland to Azores: more pressure oscillations
  - Stronger impact on N. American east coast & Europe
  - "overcame" El Nino effects this past winter in eastern U.S.
- PNA: Pacific – North American Oscillation