

## Climate Change

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NASA

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## Outline

- What is the Atmosphere?
- Regional Patterns of Weather
- Natural Climate Variability
- Anthropogenic Climate Change
- What Effects are We Seeing?
- Envisioning Solutions

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## Climate and Ocean Basics

Guiding Questions:

- What had the lowest specific heat?
- Why is the weather so nice at the beach?
- Why is the Central Valley so dry?
- Where does a large majority of the trash in the ocean end up?
- Why is Europe so warm when Canada is so cold at the exact same latitude?
- What are the 3 zones and the 3 types of ocean organisms?
- What are the 4 zones in a freshwater lake?

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### The Atmosphere is a Complex System

- **Weather** – short-lived, local patterns; temperature and precipitation due to circulation of the troposphere.
- **Climate** – long-term patterns of temperature and precipitation.
- The atmosphere is composed of:
  - Nitrogen gas
  - Oxygen gas
  - Water vapor
  - Aerosols-minute, suspended particles & droplets

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### The Zones of the Atmosphere

- **Troposphere** is immediately adjacent to the earth's surface
  - Ranges in depth from 18 km over the equator to 8 km over the poles.
  - Convection currents redistribute heat and moisture around the globe.
  - Air temperature drops rapidly with increasing distance from the earth.
    - **Tropopause** - boundary that limits mixing between the troposphere and upper zones as air ceases to rise

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### The Zones of the Atmosphere (cont.)

- **Stratosphere**
  - From tropopause up to about 50 km
    - Has almost no water vapor, but 1000X more **ozone** than the troposphere
    - Ozone absorbs ultraviolet light, which warms upper part of stratosphere.
    - Ozone protects all life on Earth since UV radiation damages living tissues.
    - Ozone is being depleted by pollutants including Freon and bromine.

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### The Zones of the Atmosphere (cont.)

- **Mesosphere**
  - Middle Layer where the temperature diminishes again.
  
- **Thermosphere**
  - Begins at 80 km
    - Ionized gases and high temperatures
      - Lower thermosphere has ions which are struck by high energy radiation resulting in the Aurora borealis (northern lights)

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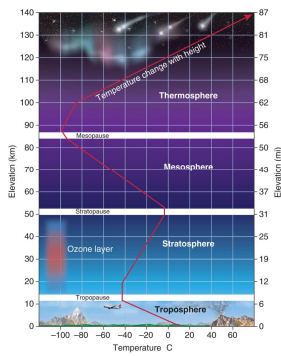
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### The Zones of the Atmosphere




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### Absorbed Solar Energy

- Of the solar energy that reaches the outer atmosphere:
  - About one-quarter is reflected by clouds and the atmosphere.
  - Another quarter is absorbed by carbon dioxide, water vapor, methane, ozone, and a few other gases.
  - About half reaches the earth's surface.
  - Some of this solar energy is reflected back by portions of earth's surface covered with water, snow, ice, and sand.

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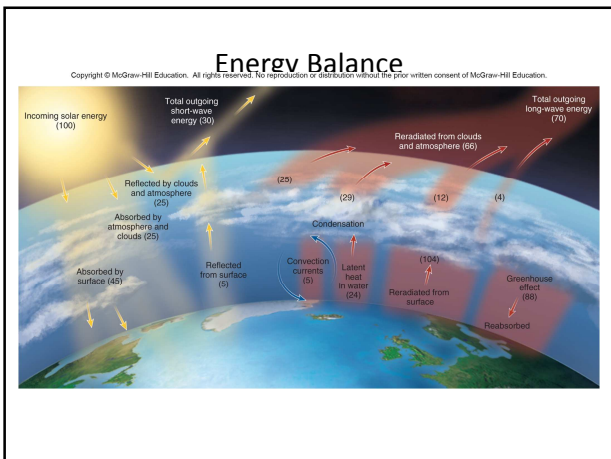
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### Absorbed vs. Reflected Solar Energy

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**Table 15.2 Albedo (Reflectivity) of Surfaces**

Surface	Albedo (%)
Fresh snow	80–85
Dense clouds	70–90
Water (low sun)	50–80
Sand	20–30
Water (sun overhead)	5
Forest	5–10
Black soil	3
Earth/atmosphere average	30

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### Energy and the Greenhouse Effect

- Most solar energy reaching the Earth is near infrared.
  - Energy reemitted by the earth is mainly far infrared radiation (long wavelength, heat)
    - Longer wavelengths are absorbed in the lower atmosphere, trapping heat close to the earth's surface.
      - Greenhouse Effect**
        - »A natural phenomena where the atmosphere transmits sunlight while trapping heat.
        - »This process supports life as we know it.

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### Greenhouse Effect

- Greenhouse Gases - gases in the atmosphere, especially carbon dioxide, water vapor, nitrous oxides, methane, and other substances that retain heat.
- Burning fossil fuels releases extra carbon dioxide.
- Deforestation destroys carbon sinks.

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### Convection and Atmospheric Pressure

- Much of solar energy absorbed by the Earth is used to evaporate water.
  - Energy stored in water vapor as latent heat.
  - When water vapor condenses, heat energy is released.
  - Heat and water move from warmer areas near the equator toward cooler areas at poles. Heat redistribution prevents extreme temperature fluctuation.

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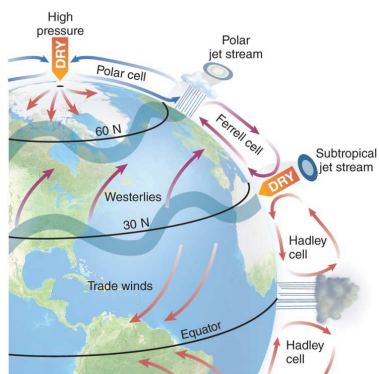
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### Circulation Patterns

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### Convection Currents

- Releasing latent heat causes air to rise, cool, and lose more water vapor as precipitation.
- Warm air close to equator vs. cold air at poles also produces pressure differences that cause weather.
  - Air near surface warms and becomes less dense than the air above it; rises above cool air creating vertical convection currents.
    - Low pressure - air is rising
    - High pressure - air is sinking
  - The movement of air from high to low pressure areas we call winds.

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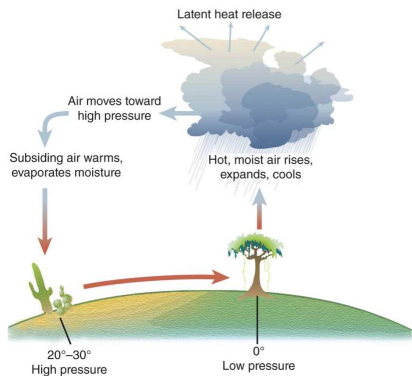
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### Convection Currents

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### Weather Events Follow General Patterns

- Weather - physical conditions in the atmosphere (humidity, temperature, air pressure, wind, and precipitation) over short time scales
  - Why does it rain?
    - Air cools as it rises, and water condenses as air cools.
    - Pressure decreases as air rises, causing cooling.
    - Condensation nuclei (tiny particles) must also be present to have precipitation.

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### The Coriolis Effect

- As air warms at the equator, rises, and moves northward, it sinks and rises in several intermediate bands, forming circulation cells.
  - This curving pattern results from the fact that the earth rotates in an eastward direction as winds move above it.
  - Surface flows do not move straight north and south, but are deflected due to **Coriolis effect**.
  - Winds and currents appear to move clockwise in Northern Hemisphere and counterclockwise in the Southern Hemisphere.

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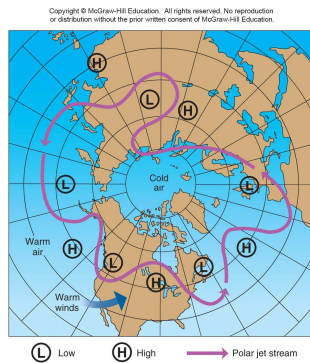
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### Jet Streams

- Hurricane force winds at the top of the troposphere
- Follow an undulating path
- Affect weather patterns



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### Ocean Currents Modify Weather

- Warm and cold ocean currents strongly influence climate conditions on land.
  - As surface water moves, deep water wells up to replace it, causing deeper ocean currents.
  - Ocean circulation also driven by differences in water density due to temperature and salinity of water
    - Currents can shift abruptly.

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### Many People Rely on Seasonal Rains

- **Monsoon** - seasonal reversal of wind patterns caused by differential heating and cooling rates of oceans and continents
  - Most prevalent in subtropical and tropical areas.
  - Tilt of Earth's axis changes location where the Sun is most intense over the course of the year. Places where the Sun shines most directly have evaporation and convection currents which bring thunderstorms.
  - Seasonal rains support tropical forests and fill great rivers such as Ganges and Amazon.
  - Supports life, but flooding can also take it away.

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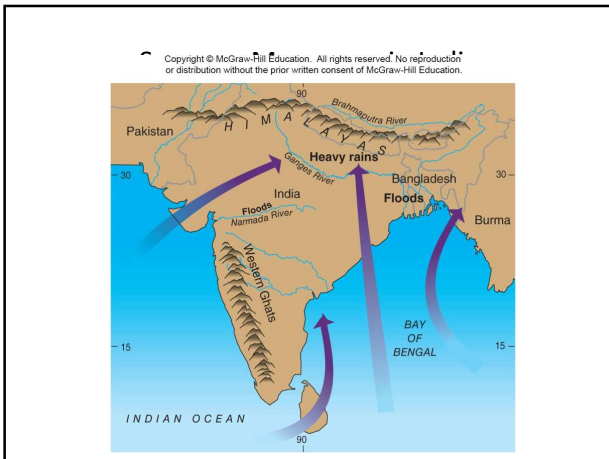
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### Frontal Systems Create Local Weather

- **Cold Front** - boundary formed when cooler air pushes away warmer air
  - Cold air is more dense, tends to hug ground and pushes warm air up.
    - The warm air is cooled
    - Triggers strong thunderstorms
- **Warm Front** - boundary formed when warm air slides over cooler air
  - Warm air is less dense and slides over cool air
    - A long wedge-shaped band of clouds is formed
    - Can bring days of drizzle.

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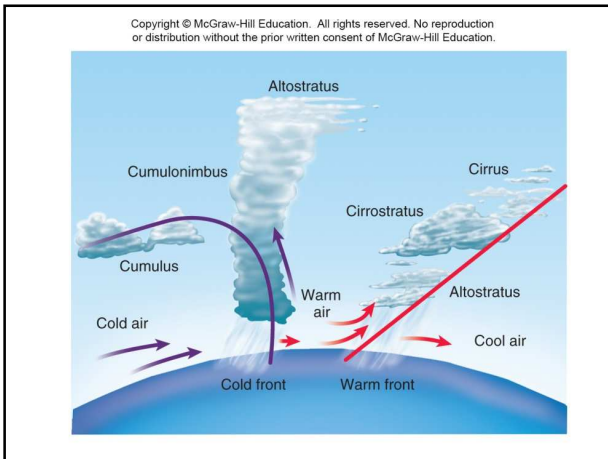
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### Cyclonic Storms

- When water vapor is abundant the latent heat released by condensation intensifies convection currents and draws up more warm air and water vapor.
  - Storm cell will exist as long as temperature differences exist.
    - Hurricanes (Atlantic)
      - Katrina in 2005 caused most devastation primarily due to storm surge.
    - Typhoons (Western Pacific)

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### Cyclonic Storms


- Tornadoes - swirling funnel clouds over land
  - Generated by “supercell” frontal systems where strong dry cold fronts collide with warm humid air
    - Greater air temperature differences in the spring, thus more tornadoes



(a) Hurricane Floyd 1999  
Images produced by Hal Pierce, Laboratory for Atmosphere, NASA Goddard Space Flight Center/NOAA



(b) Gulf Shores, Alabama 2005  
© Marc Serota/Corbis



(c) A tornado touches down  
© William P. Cunningham

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### Natural Climate Variability

- Climates shift on scales of decades, centuries, or millennia.
- **Ice cores** - collected from glaciers, have revolutionized our understanding of climate history.
  - Air bubbles trapped in ice can be analyzed for atmospheric composition.
  - Reveals information about past atmospheric conditions.
  - We can reconstruct past temperature patterns.
  - Vostok ice core gives us a record back 420,000 years.

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### Historical Climate Changes

- A historical climate change that had destabilizing effects on human populations was the **Little Ice Age** that began in the 1400s.
- Temperatures dropped, crops failed, fish migrations changed, and shipping lanes were blocked with ice.
- Ice cores show drastic changes may have occurred over short periods of time (years or decades rather than centuries).

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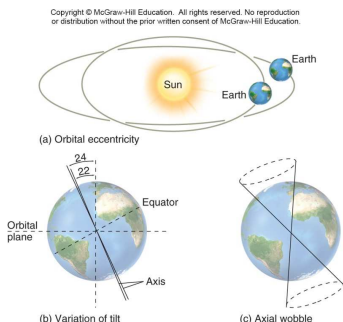
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### Earth's Movements Explain Some Cycles

– **Milankovitch Cycles** - periodic shifts in Earth's orbit and tilt which change distribution and intensity of sunlight.



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### Weather vs Climate

- What's the difference?
- **Defn.** - *weather* - condition of the atmosphere at a particular time and place
  - ex. Temperature, winds, moisture right now in Tallahassee
- **Defn.** - *climate* - the average weather for a particular area over a certain time period
  - ex. Average temperature, winds, moisture during the winter in Tallahassee

**Climate is what you expect.  
Weather is what you get.**

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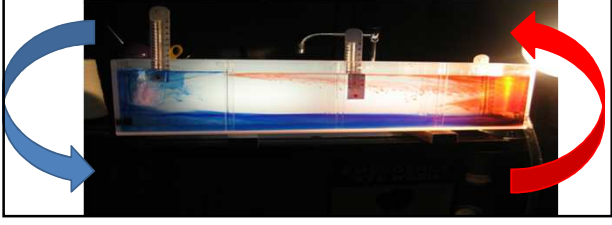
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How am I going to create a convection current with: plastic box, water, lamp, frozen peaches container, red and blue food coloring, hot water,

Draw your model in your APES Notebook



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### Ocean/Atmosphere Cycle

- There are also decades long oscillations in the oceans and atmosphere.
- The ocean and the atmosphere have regular patterns of flow or currents, but these may shift from time to time.
- Winds and rains may change as a consequence of these shifts.
- **El Niño or ENSO** is an example of such a shift.

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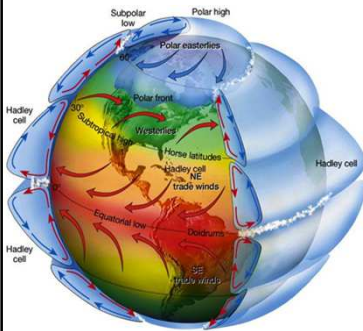
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### How did the atmosphere work again?



- Warm air rises, Cool air sinks.
- 3 convection cells in each hemisphere.
- Air flowing towards the equator is deflected to the west.
- Air flowing towards the poles is deflected to the east.

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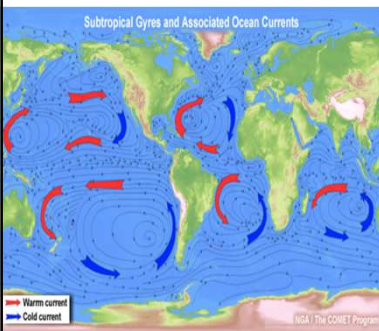
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### What about the ocean surface?



- Wind pushes the water.
- Water flowing towards the equator is deflected to the west.
- Water flowing towards the poles is deflected to the east.
- Creates Gyres

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### What's in the Gyres?




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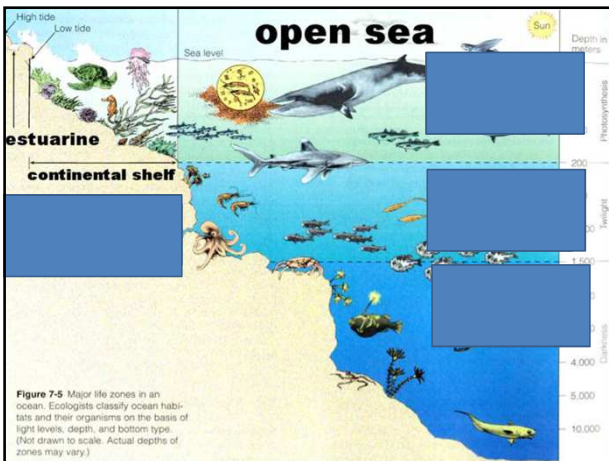
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**Three major groups of ocean life**

**Plankton- Float near the surface**

- Phytoplankton – microscopic organisms that photosynthesize that live in water.
- Zooplankton – tiny animals found near the surface in aquatic environments

**Phytoplankton**      **Zooplankton**

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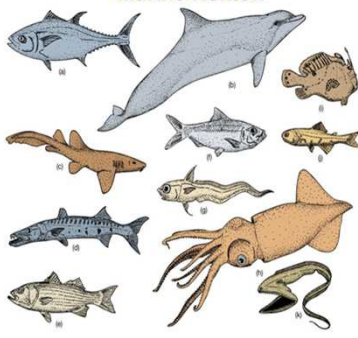
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**Nekton- all the organisms that swim in the ocean freely such as fish , whales , squid, octopus etc.**

**Marine Nekton**





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**Benthos- live on the ocean floor**

- Plants where there is sunlight
- Animals like crab, oyster, star fish



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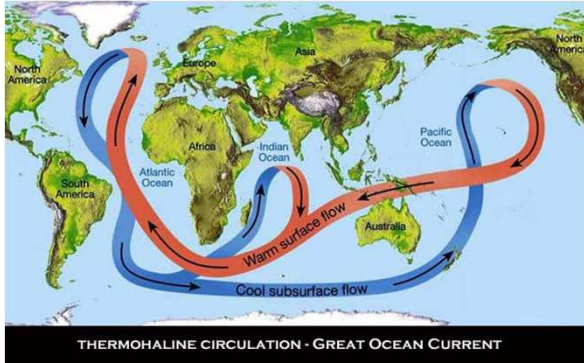
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What about the deep ocean?  
Where is the warm water sinking? Why?



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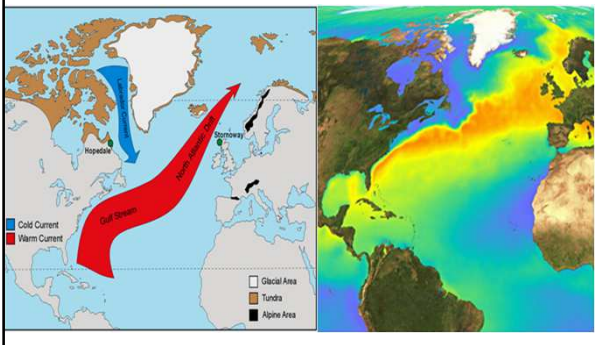
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Why is Europe so warm when Canada is so cold?



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### The El Niño Southern Oscillation (ENSO)

- Occurs when warm surface waters in Pacific Ocean move back and forth between Indonesia and South America.
- Most years, the pool is held in western Pacific by steady equatorial trade winds.
- Surface waters driven westward by trade winds allow upwelling of cold, nutrient-rich waters off west coast of South America, benefiting fisheries.
- Every three-five years the Indonesian low collapses and the mass of warm surface water surges back east

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### ENSO Effects on North America

- During an El Niño year, the northern jet stream pulls moist air from the Pacific over the U.S.
  - Intense storms and heavy rains from California to the Midwestern states
- During intervening **La Niña** years, hot, dry weather is often present. Resulting high sea surface temperatures cause hurricanes to be more violent.

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### Multi-Decade Oscillations

- Pacific Decadal Oscillation** - very large pool of warm water moving back and forth across the North Pacific every 30 years.
  - This affects the size of salmon harvests in Alaska and the Pacific Northwest.
- North Atlantic Oscillation, or NAO** is another oscillation which occurs between Canada and Europe.

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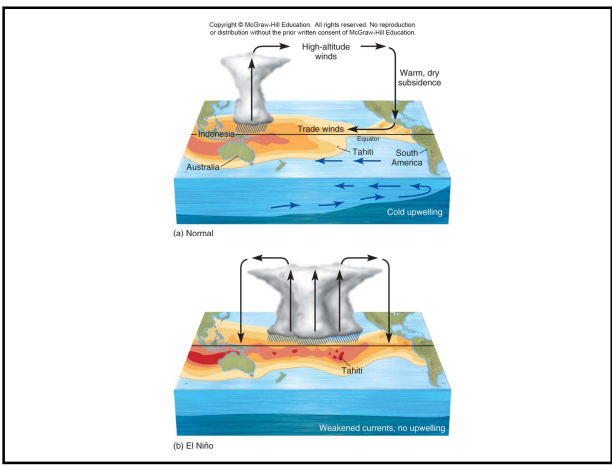
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**Recent Changes are Unusually Rapid**

- Many scientists believe that anthropogenic climate change is the most important environmental issue of our time.
- The earliest data came from an observatory on Mauna Loa volcano in 1957.
- Initial measurements showed carbon dioxide levels increasing at 0.5% per year since data collection began.
- Levels have risen from 315 ppm in 1958 to 397 ppm in 2011.
- If this trend continues, we could double atmospheric CO<sub>2</sub> levels within a century.

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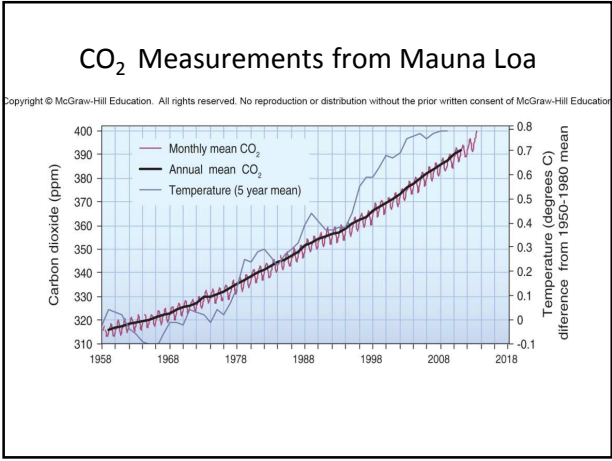
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### The IPCC Provides Data to Policy Makers

- **Intergovernmental Panel on Climate Change or IPCC** - an international group of scientists and governmental representatives from 130 countries formed to review the scientific evidence for climate change.
- The 2007 report stated that there is a 90% probability that the observed climate changes are the result of human activities.
- The report projects warming of 1 to 6°C by 2100 with the best estimate being 2 to 4°C (3 to 8°F)
  - For perspective, there has only been a 5°C rise since the last ice age 20,000 years ago.

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### Effects of Global Warming

- People will experience more extreme weather including droughts, floods, heat waves, and hurricanes.
- These could have disastrous economic and human costs.
- Estimates published in 2009 project a sea level rise of 0.6 meter.
- This could flood low-lying coastal cities like New Orleans, Miami, Boston, New York, London, and Mumbai.

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### Projected Sea Level Rises by 2100

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### CO<sub>2</sub> is the Most Important Greenhouse Gas

- **Carbon Dioxide** – emissions have doubled from 1970 to 2010
  - fossil-fuel burning is the major human caused source of carbon dioxide.
- **Methane** – ruminants and rice paddies are sources
  - Absorbs more energy than CO<sub>2</sub>.
- **Nitrous Oxide** – vehicle engines, agriculture processes are major sources.
  - Highly effective at capturing heat energy.
- The relative effects of each greenhouse gas can be seen by converting them to CO<sub>2</sub> equivalents.

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### Computer Models Provide Evidence of Human-Caused Climate Change

- Traditional controlled experiments on the climate are impossible, but complex computer models can be used to simulate climate based on known natural fluctuations and human inputs.
- If a computer model can accurately predict past climate, this is an indication of its effectiveness at predicting future climate.
- When the models are run without human inputs the predictions don't match historical climate records.
- When they are run with the human inputs they do predict historical climate records.

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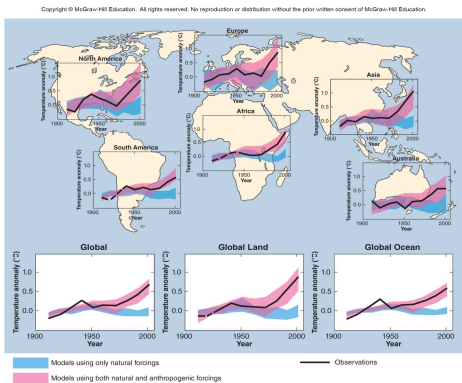
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### Climate Models vs. Observed Climate Change




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Climate Change Effects: Why Should I Care?

- Evidence of climate change is overwhelming:
- “As best as can be determined, the world is now warmer than it has been at any point in the last two millennia, and, if current trends continue, by the end of the century it will likely be hotter than at any point in the last two million years.”
- -- American Geophysical Union

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Observations of Climate Change

- Average global temperature climbed 0.6°C (1°F) in last century.
  - 19 of 20 warmest years in the past 150 yrs have occurred since 1980.
  - Poles are warming fastest (4°C, 7°F over past 50 years).
  - Permafrost is melting in Alaska and Canada and houses and pipelines are being damaged and trees are being toppled.

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Observations of Climate Change

- Arctic Sea ice is half as thick as it was 30 years ago, and the ocean area covered by ice has decreased by 1 million km<sup>2</sup> in 30 yr.
  - Polar bears are dying as they attempt to find pack ice (which is declining) on which to hunt.
- Antarctic ice shelves are disappearing.
  - Penguins declined 50% in last 50 yrs.
- Glaciers are retreating all over the world.
- The oceans are absorbing and storing more heat.
- Sea level has risen 15 to 20 cm in last century.
- Oceans are absorbing some of the extra CO<sub>2</sub> but that is acidifying the ocean and damaging corals.

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### Observations of Climate Change

- Growing seasons are lengthening in Northern hemisphere. Some animals are breeding earlier or extending their range, others are disappearing.
- Droughts are more frequent and widespread and storms more severe.
- Animal breeding and migratory schedules are changing.
- Some species are declining or going extinct due to warming temperatures and loss of habitat.

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### Global Warming will be Expensive

- At present, reducing greenhouse gas emissions would cost 0.5% of world GDP according to Stern report. (IPCC report says less than that.)
- If we delay, it could cost as much as 20% of world GDP.
- Energy production will need to be 80% decarbonized by 2050 to stabilize climate.
  - Those in richer countries will be able to blunt the effects of climate change.
  - Those in poorer countries will suffer the most; at least 200 million people will become refugees of floods or victims of drought.

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### 4 Steps For Combating Climate Change

- Implement emissions trading
- Technology sharing with less developed countries
- Reducing deforestation
- Helping poorer countries respond to climate change

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### Flooding, Storms and Disease

- Melting of the glacial ice caps in Greenland and Antarctica could raise global seal levels 100 meters flooding coastal areas where 1/3 of the world's population live.
- Insurance companies have \$2 trillion in insured properties along U.S. coastlines at risk from flooding or severe storms.

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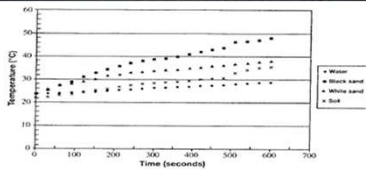
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### What had the lowest specific heat? White Sand, Black Sand, Water, or Soil




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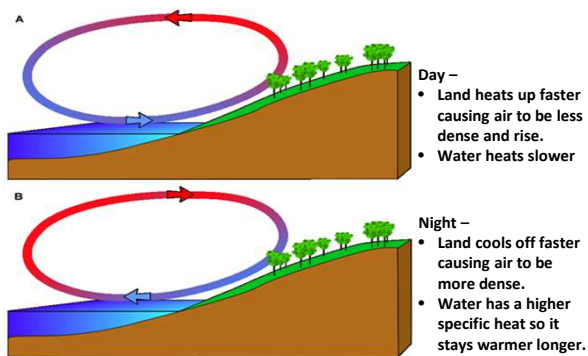
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### Why is it so nice in Santa Barbara? Day or night? How can you tell?




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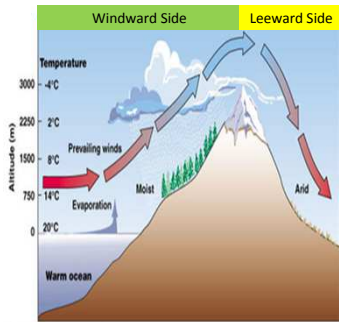
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## The Rain Shadow Effect



- Air over the ocean has a lot of moisture in it.
- Wind blows the air towards the land.
- Wind pushes air higher in altitude.
- The air cools and the water vapor condenses (molecules slow down and get closer together)
- Rain Falls on the Windward side of the Mountain.
- The Leeward side of the mountain is dry (arid) with no rain... the Rain Shadow Effect

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## Name That Freshwater Lake Zone




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## Brain Pop - Climates




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## Climate and Ocean Basics

### Guiding Questions:

- What had the lowest specific heat?
- Why is the weather so nice at the beach?
- Why is the Central Valley so dry?
- Where does a large majority of the trash in the ocean end up?
- Why is Europe so warm when Canada is so cold at the exact same latitude?
- What are the 3 zones and the 3 types of ocean organisms?
- What are the 4 zones in a freshwater lake?

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## Envisioning Solutions Kyoto Protocol (1997)

- Called on nations to roll back carbon dioxide, methane, and nitrous oxide emissions about 5% below 1990 levels by 2012.
  - Sets different limits for different countries, depending on prior output
    - China and India were both exempt from this agreement.
    - Many countries ratified the Protocol.
    - The legislatures of both Australia and the U.S. declined to ratify the agreement.

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## An Option for Controlling Emissions

- Carbon Trading: legal limits on emissions are set and countries that want to emit more must purchase emissions credits from others.
  - This approach is favored under Kyoto.
- A global market for trading carbon emissions has already developed.
- In 2006, 700 million tons of carbon credits were exchanged with a value of \$3.5 billion.
- This market may grow to \$500 billion a year by 2050.
- Some large businesses like BP America, Dupont, and GE are for this approach if the rules are clear and fairly applied.

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### Stabilization Wedges Could Work Now

- By utilizing Wedge Analysis the problem of climate stabilization can be broken down into smaller, bite-sized pieces.
- To stabilize carbon emissions we would need to cut 7 GT (gigatons) over the next 50 years.
- Doubling vehicle efficiency, and halving the miles we drive would save up to 1.5 GT.
- Installing energy efficient appliances, lighting, and building insulation could save another 2 GT.
- Capturing and storing carbon emissions from power plants and gas wells could save another GT.

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### Stabilization Wedges

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**Table 15.3 Actions to Reduce Global CO<sub>2</sub> Emissions by 1 Billion Tons over 50 Years**

1. Double the fuel economy for 2 billion cars from 30 to 60 mpg.
2. Cut average annual travel per car from 10,000 to 5,000 miles.
3. Improve efficiency in heating, cooling, lighting, and appliances by 25 percent.
4. Update all building insulation, windows, and weather stripping to modern standards.
5. Boost efficiency of all coal-fired power plants from 32 percent today to 60 percent (through cogeneration of steam and electricity).
6. Replace 800 large coal-fired power plants with an equal amount of gas-fired power (four times current capacity).
7. Capture CO<sub>2</sub> from 800 large coal-fired or 1,600 gas-fired power plants and store it securely.
8. Replace 800 large coal-fired power plants with an equal amount of nuclear power (twice the current level).
9. Add 2 million 1 MW windmills (50 times current capacity).
10. Generate enough hydrogen from wind to fuel a billion cars (4 million 1 MW windmills).
11. Install 2,000 GW of photovoltaic energy (700 times current capacity).
12. Expand ethanol production to 2 trillion liters per year (50 times current levels).
13. Stop all tropical deforestation and replant 300 million ha of forest.
14. Apply conservation tillage to all cropland (10 times current levels).

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### Alternative Practices Can Be Important

- Carbon capture and storage is beginning to be practiced.
  - Some companies, like Norway’s Statoil, are pumping carbon dioxide into an aquifer beneath the seafloor via a gas well.
  - The carbon is sequestered, the company avoids carbon taxes on emissions, and the increased pressure on oil reserves enhances oil recovery.

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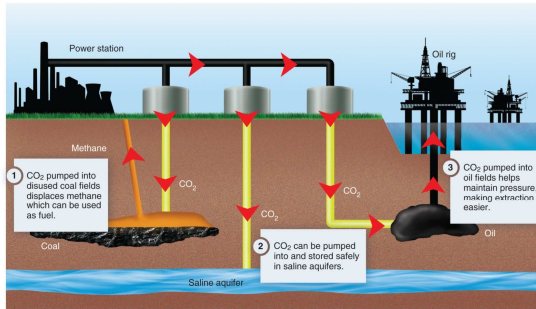
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### Carbon Capture and Storage

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### Should We Focus on Methane Instead?

- Methane is a more powerful absorber of heat energy than carbon dioxide.
- Reducing methane emissions from landfills, rice paddies, oil wells, and coal mines could reduce warming.
- Reducing the number of ruminants could help also.

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### Regional Initiatives Are Emerging

- The U.K., New Zealand, Germany, and many other countries are working to reduce carbon emissions voluntarily.
- The United Kingdom has rolled back its CO<sub>2</sub> emissions to 1990 levels and is aiming for a 60% reduction by 2050.
- New Zealand has pledged to be the first **Carbon Neutral** country by reducing green house gas emissions to zero.
- Germany has reduced CO<sub>2</sub> by 10%.

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## Conservation and Renewable Energy Offer the Best Solutions

- Denmark gets 20% of its electricity from windmills, and plans to increase that to 50%.
- China reduced its emissions 20% between 1997 and 2005 by implementing more efficient burning of coal in power plants and industry.
- Individual cities like Copenhagen, Helsinki, and Toronto have pledged to reduce carbon emissions by 20% by 2010.
- Benefits: Conservation efforts save energy costs and shifting to renewable energy frees us from dependence on foreign oil.

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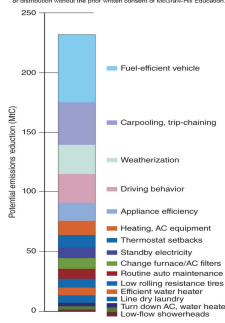
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## What Can You Do?

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