Chapter 5 - Ocean Basins

• **Bathymetry** (“**relief**”):
• **SONAR** mapping:
• "**Charts**":

Major provinces of the ocean floor
A. Continental margins:
B. Deep-ocean basins
C. Oceanic (mid-ocean) ridges:

A. **Continental Margins** include features:
• **continental shelf:**
• **continental slope:**
• **continental rise:**
• **submarine canyons:**

What are **continental shelves**?
• general relief (slope)
• relationship to **coastal plains**:

What is the significance of the "**shelf break**?"

Continental slopes: general types of slopes (steep and steeper):

What is the character and origin of **submarine canyons**?
• Where submarine canyons occur relative to the coastline:
• erosion caused by **turbidity currents**:

Continental rises:
• **deep sea fans**:
• physical characteristics:
• accumulation of **turbidity flows** ("t**urbidites**"):
• "**graded bedding**":
• "**graywacke**":

2 Types of **Continental Margins (“active” and “passive”)**
• **Active continental margins**
— plate tectonic setting and landforms (on land and underwater):
— **trenches**
— regions of rapid sedimentation:
— examples: Ring of Fire region

• **Passive continental margins**
— plate tectonic setting and landforms:
— sediments:
— East Coast, Gulf Coast, northern Alaska

Emergent Coasts — features include:
— **sea cliffs**, **wave-cut platforms**
— **marine terraces**:

• **Submergent Coast** features:
— **estuaries** and **fjords**

Deep-Ocean Basins:
• Trenches
— extent and origin:
— **trenches** vs. “**rises**”: Why?
— associated features:

• **Abyssal Plains**:
— extent and origin:
— impact of "**planktonic rain**":

Seamounts, Islands, Atolls, and Guyots:
• **Seamounts**
• **Islands**
• **Atolls:**
— "**fringing reefs":**
• **Guyots**:

Seamounts offshore of San Diego region include:

Mid-ocean Ridges and Rises:
— undersea **rift valleys**:
— **hydrothermal vents**:
— volcanic features:
— thin sedimentary deposits (Why?):
• Plate tectonic setting for "**Ridges**":
• Plate tectonic setting and character of "**Rises**":

Structure of Oceanic Lithosphere:
• origin (relative to **MOR**s):
• **Ophiolite sequence**:
— mantle rocks (**gabbro**):
— “**sheeted” intrusive igneous dikes**:
— "**pillow basalts**”:
— sedimentary deposits on top:

Chemical and physical changes to oceanic lithosphere over time:
— temperature and density changes:
— interactions with seawater with crust:
— What is **serpentinite**?:

Formation and Destruction Cycle of Oceanic Lithosphere:
• **Continental rifting**: birth of new ocean basin
— geologic features
— changes in sedimentation

Destruction of oceanic lithosphere:
— cold, steep subduction:
— warm, shallow subduction:

Formation of continental crust: ("refining processes”):
• What happens to:
— sediments and seawater:
— what causes melting?

— **High temperature vs. low temperature minerals**:
— What melts first?
— Changes from "**mafic**" to "**felsic**" composition:
— **density separation**:
— What happens to "mafic residues"?
— What happens to "felsic residues"?

Hydrothermal Vents on the Seafloor:
• "**Black smokers**":
— origin and composition:
— significance in geologic history and mining:

• "**White smokers**":
— origin and composition:
— significance in geologic history and mining:

• **Deep-sea communities**:
— **chemotrophism**:

Coastal Plains, Climate Change, and Predicted Sea Level Rise
— What is the "**Fall Line**"?

• What is causing **sea-level rise**?
— glacial melting:
— expansion of seawater:
— changes in ocean currents:

• **How fast is sea level rising?**
— Where will sea-level rise have the greatest impacts?
— Changes of selected coastlines:
— — Texas:
— — Florida:
— — East Coast:
— — San Diego:

Chapter 6 - Marine Sediments

"**Sedimentary**" means formed by **deposition (**part of the "**Rock Cycle**:"**):**
— processes:
— products:

Sedimentary deposits include:
— sediments
— sedimentary rocks

• **Lithification**: **consolidation** and **solidification**
• **compaction**
• **cementation**
— common **cements**:

Classification of Sediments and Sedimentary Rocks

Sediments (& sedimentary rocks) are classified in by origin of **source material** and by **grain size**.

4 sources of marine sediments (and sedimentary rocks):
A) Cosmogenous: material that falls to the Earth surface from outer space.
B) Hydrogenous: material precipitated directly seawater.
C) Lithogenous: material derived from erosion of other rocks, typically from continental sources.
D) Biogenous: material formed from the accumulation of remains of living organism.

A) Cosmogenous Sediments
— types:
— **iron-nickel meteorites**
— **"stony" meteorites**
— **tectites** & **impactites**:
— dust & gases
— volume and distribution:
— significance (ancient vs. modern):

B) Hydrogenous Sediments (directly precipitated from water)
— influenced by evaporation
• **Evaporites** (Salts)
— **rock salt** ($NaCl$) and
— **gypsum** ($CaSO_4 \cdot n H_2O$)
— **anhydrite** (lacks H_2O)
• where evaporites occur:

• **Iron-manganese nodules**:
— where they occur, significance:

C) Lithogenous Sediments
• form through the processes of weathering and erosion
• exposed on land and along coastlines.
• also called "terrigenous sediments" or "**clastic sediments**"
• consist of solid fragments of inorganic or organic material
— come from the weathering of rock and soil erosion

• Lithogenous sediments are:
— fragments transported to ocean from land by wind, rivers, glaciers,
— moved by coastal erosion, turbidity currents
— rapid deposition (i.e.: beaches or deltas)

Sediments deposited in **high energy environments** have **coarse grain sizes**
— (coarse sand, gravel, cobbles, and boulders).
• Beach sand is mostly **quartz (SiO_2)**, a mineral very resistant to **weathering**.

• Where are most lithogenic sediments eventually deposited?
— nearshore:
— offshore:
— deep ocean:

Fine-grained lithogenic sediment (**silt** and **clays**) sources for the distant ocean regions:
— desert dust, forest-fire ash, or volcanic ash blown in by the wind.

D) Biogenous Sediments
• composed of the remains of living organisms
— **microscopic phytoplankton** (plants)

— **microscopic zooplankton** (animals)
— “**organic reef**” organisms
— other sources: terrestrial and aquatic plants, shells of invertebrates, and vertebrate material (teeth, bone), and associated organic residues.

• **Coal, oil, and gas:**
— modern and ancient carbonate "reef systems"
— Australian Barrier Reef,
— South Florida, Keys, and the Bahamas
— Yucatan the Caribbean Sea,
— reefs and atolls in South Pacific & Indian Ocean
— Red Sea

Neritic and Pelagic Sediments
• **neritic** means “shallow, nearshore”:
• **pelagic** means "of or relating to the open sea"

Neritic sediments: generally shallow water deposits formed close to land.
— dominated by lithogenous sources (deposited quickly)
— cover about ¼ of sea floor and are near landmasses.

Pelagic sediments are generally deepwater deposits:
— **oozes** (see below) and **windblown clays**.
— finer-grained sediments are deposited slowly, far beyond the continental margins
— less lithogenous and more biogenous
— depending on biologic productivity.
— cover about ¾ of seafloor mostly in deepwater.

The distribution of neritic or pelagic sediments influenced by:
— proximity to sources of lithogenous sediments
— productivity of microscopic marine organisms.

Volume and distribution of marine sediments
• lithogenous and biogenous sediments are the most abundant
• Lithogenous sediment dominate most continental margins.
— can be many miles thick
— influenced by rivers, geologic time:
• Biogenous sediments accumulations can also be massive
— warn, shallow seas allow massive reef tracts
• Cosmogenous and hydrogenous sediments: insignificant in volume:
— scientific and economic significance:

Sedimentary rocks are exposed throughout the world's continents,
• "sedimentary cover" - about half of the exposed land
— originally deposited mostly in coastal environments & shallow seas
— formed in the last several hundred million years.
— massive sediment “wedges” along continental margins, volcanic chains
— thinnest or non-existant on new ocean crust forming along mid-ocean ridges.

Most lithogenous sediments are on or near a landmass:
• **Coarser sediments** accumulate closer to shore,
• **Finer sediments**:
  — winnowed by waves and currents
  — transported farther from shore to quieter water settings where they can settle out.

"High-Energy" and "Low Energy" Depositional Environments
— flowing water is the dominant natural force causing erosion and deposition
— The faster the water moves, the "higher the energy"
— increases in speed, increases **turbulence**
— turbulence increasing its ability to lift and move particles.
• How does flowing water can carry materials of different sizes?
• How does flowing water sort sediments by size and density?

"High-energy depositonal environments"
— coarser sediments dominate
— river channels, beach and shallow offshore environments, submarine canyons
— changing energy conditions: weather (calm vs. storms)
— influence of passage of time:
— impact of major storms: (example Hurricane Camille, 1969)
— impact of seasonal changes:

"Low energy depositional environments"
— finer-grained sediments dominate
— below "wave base"
— deep-water environments far from shore
— can be suddenly disrupted by the rapid influx of sediments
— underwater landslides or the effects of major storms.

Sources of Lithogenous Sediments
• Continental **weathering** and **erosion**
— **weathering**: the breakdown of earth materials due to exposure
— involves physical and chemical interactions with air and water.
— Weathering produces sediments; erosion moves sediments.
— influence of gravity:
— influence of moving "fluids":
Deposition — process of sediments settling and accumulating from a moving fluid
— sedimentsundergo gradual compaction and cementation to form sedimentary rocks.

• Sediments can be eroded, transported, and deposited, often over and over again.
• Sedimentary deposits preserve evidence about how, when, where, and why they formed.
• Volcanic eruptions can produce large volumes of ash and other sediments

Weathering is the gradual destruction of rock under "surface conditions." Two kinds:
• mechanical weathering:
• chemical weathering:
• biological activity (both?):

— Weathering processes can begin long before rocks are exposed at the surface. This is true in most places on the earth surface where rocky outcrops (bedrock) is not exposed.
— Weathering and erosion can take place simultaneously (rivers in flood, waves on beaches),

Mechanical weathering: processes that break rocks into smaller pieces. Includes:
• **Mass wasting**—processes by which soil and rock move downslope under the force of gravity.
— rock falls, landslides, slumps, and avalanches
• **Erosional grinding**:by fast-moving flood waters and ice flows
— moves boulders and sediments down stream valleys
— wave action batters rocks into sand along a shoreline.
• **Earthquakes and volcanic explosions** - shatter rocks

• **Unloading**: rocks expand and split when erosion unloads overburden pressure
• **Freeze-Thaw cycles**: Rocks split when water freezes and expands in cracks.
• **Daily heating and cooling**: Surface materials are subject to expansion and contraction
• **Organic activity**—expanding tree roots, burrowing, feeding activity, etc.

Mechanical weathering increases **surface area**, which increases exposure for chemical weathering.

Chemical Weathering
— involves the breakdown (decomposition, decay, and dissolution) of rock by chemical means.
• **Dissolution**: action or process of dissolving or being dissolved
— moving soluble components of materials into solution.
• **Leaching**: the process of dissolving and removing the soluble constituents of soil or rock.

• Contributes tp the saltiness of the oceans
• Source of salts deposited along arid coastlines and in desert dry lake basins.

Weathering and erosion are continuous processes in the surface environment,
— enhanced by the presence of water (the "**universal solvent**").
— The journey of sediments can take a long time!
— Sediments can eroded and re-deposited many times along the journey.

Fate of soluble components of rocks: formation of seawater
— As rocks weather and erode, they loose their **soluble elemental components**
— evaporation concentrates salts in seawater.

Composition of "crustal rocks": What elements dominate?
• What elements are concentrated in seawater?
— Why so much chlorine?
— Why so little **silica**?

Sediments based on grain size
— largest to smallest: boulders, cobbles, gravel, sand, silt, and clays.

Clastic sediments and sedimentary rocks:
— “clastic” or “detritus” means broken rock fragments (gravel, sand, silt)
;
How do sediments become sedimentary rocks?

Sediments can become "lithified" into sedimentary rocks (**lithification**)
— involves **burial**, **compaction**, and **cementation,** slowly over time
— rates influenced by the chemistry of the sediments and groundwater passing through
— rates influenced by how quickly or deeply burial takes place.

Porosity and Permeability
• Some sediments have high "**porosity**"—pores are open spaces between grains filled with gas or fluids (water or in some cases, petroleum).
• Some sediments have high “**permeability**” - ability to transmit fluids

“**Compaction**" - the gravitation consolidation of sediments
• Decreasing the volume of pore space between particles of sediment increases “hardness.”
• "**Cementation**" involves processes that harden sediments through the precipitation of minerals in pore spaces between grains (clasts), binding them together

- Common minerals "**cements**" include **quartz, calcite, limonite, hematite**, and **clays**.
- The cementing minerals are slowly deposited between grains by groundwater.

Clastic Sedimentary Rocks include three general groups:
A) coarse-grained:
B) sand-size grained
C) fine-grained ("**mudrocks**")

A) **coarse-grained sediments**
— **gravel** (sediment)
— **conglomerate** (rock)
Where is gravel commonly found?

B) **sand-size grained**
— sand
— sandstone
Where is sand concentrated?

C) **fine-grained ("mudrocks"):** Where is mud concentrated?
— “mud”
— “soil”
— mudstone
— shale
— graywacke

How does the composition and appearance of sediment change over time?
— **composition** of particles: (hard vs. soft minerals)?
— **size** of particles?
— **shape** of particles?
— **sorting** of particles?

How do sediments change as they move down a river?
How do waves change sediments over time?

- Sand deposits near mountain ranges may be enriched in feldspars.
- Volcanic regions may produce sand enriched in dark (mafic) minerals.
- "Mature" sand will be enriched in quartz and grains will be very well rounded and well sorted

Fine-grained sediments and sedimentary rocks ("Mudrocks")
- Mud - a mix of clay, silt, and may contain sand - commonly an unsorted mix
- Mud accumulates in quiet water settings separated from e coarser materials
- Most soil is “mud” (not all!)
- Muddy environments: river deltas, swampy coastal regions, tidal flats, lake, deep water

What is the difference between **mudstone** and **shale**?

- **Clays** are composed of any microscopic mineral particles.
- Most **dust** is clay sized particles.
- Clay minerals include many **hydrated aluminum silicates**
- Clays from the weathering of feldspars and other silicate minerals
- Clays are the dominant sediment found on Earth.

Graywacke - a variety of sandstone or mudrock generally characterized by its dark color and poorly sorted angular grains (mix of quartz, feldspar, dark mafic minerals, cemented in a compact, clay-fine matrix — a "dirty" dark brown or gray sandstone or silty mudstone.
-- Most common rock in California

Unique characteristics of lithogenous deposits
• Sediments preserve other characteristics about the **environment** where they occur.
• **particle shapes (rounding)**,
— angular: (near source)
— sub-angular/rounded: (river sand)
— well rounded: (beach sand and dune sand)
• **degree of sorting**
— poorly sorted (river sand)
— well sorted (beach sand and dune sand)
• **bedding** ("layers" visible in most sedimentary deposits)

Sedimentary Processes and **Sedimentary Structures**
• **Lamination and bedding**
— **laminae** (or **lamination**) is a layer of sediment or sedimentary rock layer only a small fraction of an inch (less than a centimeter)
— common is fine-grained sediments deposited in quiet or slack-water environments,
— Lamination is common in **shale**: Each laminae may be an annual cycle of deposition or a seasonal storm flood event (scale is in mm to cm).

• **Bedding** is layers of sediment deposited in an environmental setting on a scale of hundreds to many thousands of years (more than a cm up to many meters thick).

Sedimentary structures preserved in bedding include:
• **ripple marks**:
• **cross bedding**—inclined sedimentary structures in a horizontal unit of rock.
• **desiccation cracks**—mudcracks from atmospheric drying
• **graded bedding**—a layer of sediments characterized by a systematic change in grain or clast size from the base of the bed to the top.
— Large fragments tend to settle out fastest from a slowing turbulent flow.
• **biological structures**—many kinds of organisms burrow or bore into sediments
— Most marine sedimentary beds preserve traces of "biological features"
— **bioturbation** means "churning of the sediments"
— worms, shrimp, and other invertebrates work through the sediments to eat decaying organic matter (or other organisms feeding there).
— Trackways, burrows, or resting sites, shelter or nesting sites.

Turbidity Currents and Development of Submarine Canyons and Fans
— A **turbidity flows** is a turbid, dense current of sediments in suspension moving along downslope and along the bottom of a ocean or lake.
— turbidity flows can travel hundreds of miles across the seabed.
— can be massive episodic events, moving lots of sediments (massive underwater landslides).
— carve submarine canyon
— sediments accumulate near the base of the continental slope on deep-sea fans.
— Turbidity flows produces deposits showing **graded bedding**
— Slowing turbidity currents drop their coarser fractions first (gravel and sand) and the finer silt and clay fractions settle out last.
— **turbidites** usually consist mostly of **graywacke**
— interbedded layers of sandstone, siltstone, and shale. Gravel closer to canyon mouth.
— vey common in rocks exposed in California's coastal ranges.

Biogenous Sediments in the Marine Environment

Biogenous sediments include sediments formed by accumulation of organic materials.
— composed of the remains of organisms (including **skeletal remains)**
— microplankton (both plants and animals),
— plant remains (wood, roots, and leaves)
— shells of invertebrates: shells, coral fragments,
— remains of fish and other vertebrate teeth, bone, and scales,
— fecal material left behind by any type of organism.
— may be partly mixed with lithogenic sediments .

Bioaccumulation is the buildup of organic remains,
— coral reefs, shell or bone beds, and algae and ooze (calcareous and siliceous).
— swampy environments produces peat beds (can be converted to coal).

Carbonate Reefs
— accumulations carbonate material composed of coral, coralline algae, and other carbonate skeletal material.
— not all carbonate reefs are "coral reefs"
— not all organisms that look like corals are actually corals (algae, bryozoans, sponges, stromatoporoids, shells and many other types of invertebrates). \

Carbonate (coral) reefs form ONLY in clear shallow, warm, tropical marine waters.

— **Lime sediments** are produced by biological activity in and around carbonate reefs.
— Carbonate reefs grow at rates of 10-30 feet per thousand years.
— Waves/currents erode and redistribute lime sediments offshore where it may accumulate, slowly building up massive carbonate platforms (becoming regions underlain by **limestone**).
— Examples of **carbonate platform** regions include the Bahamas, South Florida, and the Yucatan Peninsula .

Reef tracts include “reefs,” islands (“**keys**”), and **tidal shoals**, bays, etc.
— The Great Barrier Reef is composed of over 2,900 individual carbonate reefs and about 900 islands stretching for over 1400 miles (2,300 km) along the northeast coast of Australia and encompassing about 133,000 square miles (344,400 km2). It is the largest feature of biological origin on Earth.
— Similar reef tracts have formed throughout geologic history in locations around the world.
— Atolls are volcanic islands or seamounts covered or surrounded by fringing carbonate reefs that build up even long after the volcano stopped erupting.

Limey Sediments and Limestone
— **Lime mud** is sediment composed of **calcium carbonate (CaCO3)**
— derived from the **skeletal remains** of shelled organisms, coral, and calcareous algae and plankton.
Large amounts of lime mud is generated by:
— waves battering reefs and reef organisms:
— reefs being chewed up and excreted by reef-living organisms
— limey sediments become limestone

Limestone — a rock consisting predominantly of calcium carbonate (CaCO3) (>50%)
— limestones commonly preserves large quantities of fossil material
— remains are made up of tiny crystals of two mineral forms of CaCO3—**calcite** and **aragonite**.
• Aragonite is more soluble and “ less stable,” and will usually convert to calcite with time.

• **Limestone rock formations** occur under about 40% of the continental United States!
— formed in ancient shallow seaways that flooded portions of the continent in the geologic past.
— formed in all geologic time periods from Precambrian age to the present
— limestone layers are often many thousands of feet thick.
— Most **caverns** form in limestone.
— **Sinkholes** form in limestone regions

• **Significance of Limestone**
— used in the manufacture of "lime" (CaO) for **cement**
— used as building stone
— used to manufacture steel and many other products.
— Ancient carbonate deposits contain the world's largest petroleum reserves.

Oozes
— slimy mud sediment (soft and mushy) on ocean bottom.
— accumulation of skeletal and organic remains of microscopic organisms.
— (phytoplankton and zooplankton).
— dominately calcareous or siliceous in composition.
— consist of >30% biogenous material.
— accumulating at a rate of 1/2 to 2 1/2 inch per 1000 yrs.
— low energy environments and very fine grained (clay sized particles).

Calcareous oozes
• composed dominantly calcium carbonate ($CaCO_3$). Composed mostly of
— **Coccolithopores** (phytoplankton) and **Foraminifera** (zooplankton)

Coccolithopores
— single-celled marine phytoplankton (microscopic plants)
— live in large numbers throughout the upper layers of the ocean.
— secrete shells of microscopic plates made of calcite ($CaCO_3$).
— part of base of the food chain
— contribute vast quantities of coccoliths as sediment to large regions of the ocean basins.
— Coccoliths first appear in Triassic time.
— easily fossilized and preserved in sedimentary rocks.

Foraminifera (Forams)
— single-celled zooplankton
— most species have calcareous shells (or tests).
— usually less than 1 mm in size, but some species grow much larger, reaching up to 20 cm.
— most benthic (meaning they live on or within the seafloor sediment)
— smaller varieties are floaters (planktonic)
— contribute sediments to carbonate reefs and carbonate oozes.
— Over 10,000 species are recognized, both living and fossil.
— first appeared in the fossil record in Cambrian time.

Calcium carbonate compensation depth (CCD)
— Calcareous sediments are influenced by the solubility of calcium carbonate.
— $CaCO_3$ forms and is **stable** in shallow, warm seawater, it will **dissolve** in cold seawater.
— Carbon dioxide dissolves easily in cold water, so $CaCO_3$ will dissolve in cold water.
— TCCD) is the depth where the the rate of calcium carbonate material forming and sinking is equal with the rate the material is dissolving.
— Below the CCD no calcium carbonate is preserved— none below 15,000 feet (4500 meters).
— small fragments dissolve faster than larger fragments

The **Lysocline** is the depth at which $CaCO_3$ begins to dissolve rapidly.
— lysocline and CCD are at the surface near the poles where the water is cold.
— Calcareous oozes accumulate only above the CCD.

Chalk — soft, fine-grained, white to grayish variety of limestone: coccoliths and foraminifera.
— **White Cliffs of Dover**, England
— **Cretaceous**-age chalk deposited about 89 to 85 million years ago in more tropical conditions

Siliceous oozes
— composed dominantly of **SiO_2 (silica)**.
— siliceous remains: **diatoms** and **radiolarians**.

Diatoms — most common types of plankton.
— Diatoms are phytoplankton (single-celled microscopic marine plants).
— most common in polar regions, also know from tropical and subtropical regions.
— supported by upwelling nutrients

Radiolarians
— single-celled aquatic animal (zooplankton) with a rigid spiny skeleton of silica.
— hundreds of known species of radiolarians
— form siliceous marine sediments known as radiolarian ooze (a form of siliceous ooze).
— first appear in the geologic record in early Cambrian time
— more common in equatorial regions.

Chert is a fine-grained siliceous sedimentary rock.
— hard, dense, and consist chiefly of interlocking microscopic crystals of quartz (and opal).
— date back to early Precambrian time.
— Banded-iron formations (BIFs) are layers of iron-oxide minerals and chert.
— Younger marine cherts are mostly formed from diatoms and radiolarian oozes.

Sedimentary Rock Formations
— A primary unit of stratigraphy, consisting of a succession of strata ("beds" or bedding)
— Rock formations are "**mappable**" - useful for mapping or description.
— consists of a **unique lithology** (rock type) with a **defined geologic age**
— can be of igneous, sedimentary, or metamorphic origin.
— Sedimentary rock formations preserve information (fossils and sedimentary structures)
— associated with **ancient sedimentary environments** they formed in.

Note:The **Anthropocene** started in 1950 (the new, modern geologic aged dominated by humans) (Name for the new, modern geologic aged dominated by humans)

Nuclear bomb testing and nuclear **power-plant disasters** have created a new identifiable sediment boundary preserved in Holocene sediments worldwide.

The United States conducted nuclear testing at **Bikini Atoll** in the South Pacific.
— US testing took place between 1946 and 1958. During that time,
— 23 nuclear devices were detonated at 7 test sites on the reef itself, on the sea, in the air and underwater.
— So far, 8 nations have successfully tested nuclear weapons.
— last atmospheric nuclear test was in 1980, underground testing has continued.

Chapter 7 - Properties of Seawater

Seawater is the most abundant resource on Earth!
Seawater has evolved to what it is over the billions of years that oceans have existed on Earth.

Distribution of Water on Earth
— 97.2% in the world ocean
— 2.15% frozen in glaciers and ice caps
— 0.62% in groundwater and soil moisture
— 0.02% in streams and lakes
— 0.001% as water vapor in the atmosphere

Components of Seawater
• Water
• **Dissolved matter**: solids and gas (as ions)
• **Suspended matter** (dust and organic residues - "cloudy" component)

Ions in seawater
• Cl - 55%
• Na - 30.4%
• SO4 - 7.6%
• Mg - 3.9%
• Ca - 1.2%
• K - 1.1%
• all other dissolved components - <1 %

Properties of Water
• Water is a **polar substance**: (charges: 2 +H, --O)
• **Cohesion**: water has "**high surface tension**" —water molecules stick together.
• **Adhesion**: water "sticks" to things.
• **High capillary action**: allow water to move upward against gravity in small confined spaces.
—helps plants to move water upward from their roots to their leaves.

• Water is a powerful **solvent**:
—A **solvent** is a substance that dissolves a **solute** resulting in a **solution**.
—water's pollar molecule allows it to form weak bonds with other polar molecules.
—solubility of chemical compounds in water is highly variable.
—The solubility of a chemical compound in water is defined as the maximum amount of the chemical that will dissolve in pure water at a specified temperature.

Seawater is a solution.

Why don't oil and water mix?
—Organic compound containing only carbon and hydrogen (hydrocarbon) are nonpolar and will dissolve in nonpolar solvents (like oil).
—Organic compounds with "functional groups with very electronegative elements" (i.e. oxygen), make the whole molecule polar, allowing them to dissolve in water (ex: sugar and starch can dissolve in water).

Properties of Water

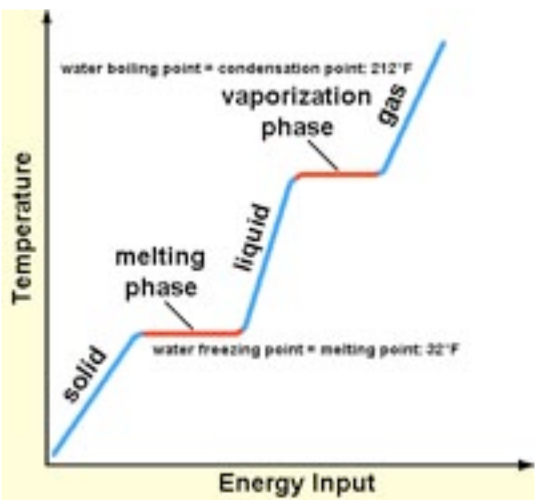
pH (acidity and alkalinity)

—pH is a measure of the acidity or alkalinity of a solution
—expressed on a logarithmic scale (range 1-14) on which **7 is neutral** (pure water).
—lower values are more acid (toward 1)
—higher values more alkaline (toward 14)

• **pH is an important measurement in seawater**.
—seawater's "natural buffering system"
—involve interaction with carbon dioxide and other dissolved compounds.
—Seawater is generally always within a range of pH of 7.5 to 8.5.

• **Bicarbonate buffering of seawater**
-- Organisms living in or near seawater have a limited tolerance for variations in pH.
—**calcite** (as in shell material) is stable within this range, dissolves in acidic conditions.
—Carbonate buffering keeps pH stable by precipitation (increase pH) or dissolution (decrease pH) of calcium carbonate - $CaCO_3$.

Specific Heat (SH) and Latent Heat (LH) Capacity of Water



Specific Heat —Materials vary in their **capacity to store thermal energy**.

Material	Specific Heat, c C/g°C°	Specific Heat, c, J/kgC°
Silver	0.06	251
Copper	0.09	377
Iron	0.11	461
Steel	0.12	502
Brass	0.22	921
Ice	0.50	2093
Steam	0.50	2093
Water	1.00	4187

NASA

—copper will heat up much faster (low SH)
—water or wood (high SH).
—SH is a measure of the energy required to **heat 1 gram of substance 1° C**.

—SH is recorded in "**calories**" for “**mass in grams**” (and “**Joules for kg**”).
-- Note the difference of **water, ice, and steam**.

• **Seawater's high specific heat capacity** allows oceans to store vast quantities of energy.
-- has huge significance of ocean and atmospheric interactions!
-- Heat absorbed in equatorial regions is carried to polar regions.

Latent Heat - When any material is heated to the temperature where it **changes state** (converting from solid to liquid, or liquid to gas), **the temperature will remain the same until all the material changes state**.
—Because it takes more energy to convert a substance from one physical state to another (solid to liquid, or liquid to gas) —**transitions require a larger amount of energy**.
—Latent heat is the heat required (measured in calories burned) to convert a solid into a liquid or vapor, or a liquid into a vapor, without a change of temperature.
—The temperature will remain the same until all the material changes state.
—The same thing applies when cooling the materials.
—energy must be withdrawn to change the state when cooling the material.

High Latent Heat Capacity of Water (Example)
• **When water boils... or steam condenses**
—a pot filled with water on the stove will gradually warm up until the water temperature approaches 212° F (or 100° C)
— it will stay at that temperature (212° F or 100° C) until all the water has boiled away.
• **The same is true as water freezes or melts.**
—As water cools it will reach 32°F (or 0° C) and stays there until all the water freezes.

** To convert **1 gram of water at 100° C to 1 gram of steam at 100° C requires 540 calories**.
** To convert **1 gram** of **water** at **100° C** to **1 gram** of **steam** at **100° C** requires **540 calories**.

Example for exam: How much “energy” would it require to heat one 1000 grams of ice at -10° C to steam at 120° C?

Energy associated with evaporation and condensation of water in the air

• Evaporation/vaporization takes a large amount of energy (to break hydrogen bonds).
—water absorbs energy as it evaporates on your skin. Evaporation on the surface of a swimming pool will cool the water.
• Condensation releases a large amount of energy
— steam will burn you as it releases energy on your skin.
— When water vapor in the air condenses to form water droplets in clouds it releases large amounts of energy.

• As water evaporates into in air it cools the air and increases its **humidity**.

• Air at surface conditions can hold up to about **4% water**
-- air becomes “saturated” then...
-- **precipitation** occurs
-- **condensation** of water releases a lot of energy.
-- release of energy through condensation “drives” thunderstorms.

• Heat is absorbed as ice **melts** and it is released as it **freezes**.
• The latent heat of water is an important factor in weather systems and the stability of climates around the world.

Salinity - a measure of the total amount of solid material (salts) dissolved in water, defined as:

Weight (mass) of salt
———————————— = Salinity (‰)
Weight (mass) of water

Units are described as:
- % is part per hundred (pph)
- ‰ is **parts per thousand (ppt) -** usual reporting method
- **Average seawater is about 35 ‰** (ppt). Open ocean seawater ranges is 33 to 37 ‰ ppt.

Evaporation of seawater results in precipitation of mineral salts
- As seawater evaporates in a **restricted basin** it is concentrated becoming a **brine**.
- salts will **precipitate** out in the **reverse order** of their **solubility**.
- Salty sedimentary deposits produced by evaporation are called **evaporites**.

Order of Precipitation of salts from seawater:
- The first mineral to precipitate is **calcite** - **$CaCO_3$** (if not consumed by organisms first).
- Next come **$CaSO_4$ (gypsum and anhydrite** varieties).
- This is followed by salt **(NaCl) (halite/rock salt)**. NaCl is most abundant salt from seawater.
- Last to precipitate are **potassium salts (sylvite: KCl**) and **magnesium salts (epson salt: $MgSO_4$**) and other important and rare compounds).
- 80 different salt minerals found in evaporite deposits.

Formation of Sea Ice
- Fresh water freezes at 32° Fahrenheit (0° Celcius).
- Seawater freezes at about 28.4° F (-2 ° C). Why?
- Sea ice melts to form freshwater. Why is this important?
- Importance to deep-ocean currents:

Relation ship of Salinity, Density and Temperature
- **Temperature and Density: Inverse** (as temperature increases, density decreases)
- **Salinity and Density: Proportional** (as salinity increases, density increases)
- T**emperature and Salinity: None** (as temperature changes, salinity remains the same)

*** See animations of Satellite and Surface Oceans DataNASA animations of
Average Sea Surface Temperature, Salinity and Density

Salinity and Latitude
- The tropics (equatorial region) is humid and cloudy: receives much more rain than evaporates.
- The temperate regions receive less precipitation, so evaporation dominates.
- The polar regions have low evaporation rates relative to the amount of precipitation they receive.

Variability of ocean salinity:
- Salinity is stable at depth but can be highly variable at the surface.
- The upper surface layers of the ocean impacted by wave energy is a mixing zone.
- The more waves, the more mixing.
- freshwater will float (stratify) on top of seawater.

Factors that decrease salinity:
- Precipitation
- Runoff
- Melting icebergs/sea ice

Factors that increase salinity:
• Evaporation
• Freezing sea ice

"**Cline Curves**" - observable changes in **temperature, salinity, and density with depth**
• **Thermocline** - a steep temperature gradient in a body of water marked by a layer above and below which the water is at different temperatures.
• **Halocline** - a vertical zone in the oceanic water column in which salinity changes rapidly with depth.
• **Pycnocline** - a layer in an ocean or other body of water in which water density increases rapidly with depth.

Mixing (Surface) Zone
Uppermost water where mixing from waves and currents make temperature, salinity, and density mostly constant.
— The mixing zone is above the "clines" (which in turn, overlies deep cold water

Vertical changes in temperature with latitude:
• **Polar regions** have almost **no thermocline**.
• **Temperate regions** have **weak thermoclines** (moderate in summer, less in winter).
• **Tropical regions** have a **strong thermoclin**e.

Gases dissolved in seawater:

Oxygen (O2) in air is ~21%, in water it is a tiny fraction of 1%.
• Diffusion occurs along boundary between air and water.
• When wind blows creating waves, it increases the surface area, allowing more diffusion to occur.

Carbon dioxide (CO2) is much more soluble in water than oxygen, but concentrations in the atmosphere are comparatively very low.
• When dissolved in water it becomes a bicarbonate ion (-HCO3), so carbon dioxide readily diffuses into the atmosphere if it is not consumed in the production of calcium carbonate (CaCO3).
• Biological respiration releases -HCO3 (some as CaCO3).
burning of fossil fuels negatively impacts production of carbonate shells and skeletons

Methane (CH4) has very low solubility in seawater, however, it is very abundant in sediments in cold settings -- can form al form of ice called a methane hydrate (a clathrate).
-- Warming of the oceans can release of tremendous amounts of CO2 and CH4 from the seafloor, contributing to anoxia conditions, with possible catastrophic consequences.

Sulfur dioxide (SO2) is extremely soluble in water (smells like "rotten eggs.")
-- released in large quantities by volcanic eruptions, forest fires, and by burning fossil fuels.
-- SO2 is extremely soluble -- form sulfate ions (-HSO4).
-- precipitates as the salts gypsum & anhydrite (CaSO4), epsom salt (MgSO4), etc.

Local Conditions in San Diego region
• In San Diego has a temperate thermocline
• During El Niño years we may get a strong thermocline all year.
• California's weather patterns are cyclical on multi-year periods of rain and drought.

Chapter 8 - Atmospheric Circulation

An atmosphere is the gaseous mass or envelope surrounding planets and moons plays many --important roles in moving water in the world's ocean basins, and for supporting life!

Earth's **atmosphere** is:
• The outermost "sphere"
• **Density stratified** - air is compressed and most dense near the surface - "**rarified**" skyward.
• About 60 mils (100 km) thick between the ocean/land surface and the vacuum of space.

Structure of the Atmosphere -- The Earth's atmosphere is subdivided into levels:
* **Troposphere** -- the lowest portion (up to about 6-8 miles) where all weather takes place -- contains about 80% of the air's mass and 99% of water vapor.
* **Stratosphere** -- contains an abundance of ozone which absorbs ultraviolet radiation -- protecting life on land and in the shallow ocean extends up to about 31 miles.
* **Mesosphere** -- earth's upper thin atmosphere above the stratosphere
* **Thermosphere** -- the region where the solar wind begins to interact with atmospheric gases.

Energy Transfer Through the Atmosphere

• Energy coming into Earth from the Sun equals energy reflected and radiated back into space.
• The atmosphere, oceans, and land absorb and release energy.
• Living things also absorb and release energy.
• Some of the energy stored in organic matter is preserved when it is buried in sediments.
• Geothermal energy is also a trace of the energy radiated into space.
• Rate of energy transfer also varies due to cloud cover and ice and snow coverage.

Incoming solar radiation involves all wavelengths of the electromagnetic spectrum.
• The atmosphere is transparent to most wavelengths
• part of the solar spectrum are absorbed by certain "**greenhouse gases**" in the atmosphere.
--Greenhouse gases include water vapor, carbon dioxide, ozone, methane, and others.

Question: Why is the sky blue? Why are sunsets and sunrises red?

Composition of the Atmosphere
• Nitrogen (N_2) - 78%
• Oxygen (O_2) - 21%
• Argon - 0.9%
• Carbon Dioxide (CO_2) - 0.036%
• Others < 1 % - Neon, Helium, Methane (CH_4), Krypton, Hydrogen (H_2)
• trace gases in include nitrogen oxides, ozone (O_3), sulfur dioxide, hydrocarbons, CFCs, etc.

Gases are released by volcanic eruptions, lightning, erosion, and pollutants from human activity (energy consumption, industrial releases, and agriculture).

Water in the Air (moisture)
• Water vapor in the air can range from trace amounts up to about 4% by volume.
• Warm air can hold more moisture than cold air.
• The amount water moisture in air can depends on factors: temperature, air pressure, and the amount and kinds of particulate matter dispersed in the air.

• When air has reached the maximum amount or water it can hold it is called saturated - this occurs when it is raining or snowing!

The “**Water Cycle**” involves all processes by which water circulates between the Earth's oceans, atmosphere, and land. It involving **precipitation** as rain, snow, hail, **drainage** in streams and rivers, and return to the atmosphere by **evaporation** and **transpiration**.

Weight of the atmosphere provides pressure needed to keep water liquid on the surface. Planets and moons with thin or no atmosphere may have water as ice, but there will be no permanent bodies of liquid water. Ice will **sublimate** directly to water vapor in a vacuum.

Atmospheric (Barometric) Pressure

• **Barometer** -- an instrument measuring atmospheric pressure, used especially in **forecasting**.
• **Air pressure** is directly related to the mass of the air column above at any location under the influence of gravity: **Pressure = Force/Area**
• “Average air pressure” measured relative “standard sea level.”

Units to describe atmospheric pressure includes **atmospheres**, **PSI** (pounds per square inch) and **millibars**. **One atmosphere** (Earth) is equal to the weight of the earth's "average air pressure" at "standard sea level."

1 atmosphere (Earth) is equivalent to:
• 14.7 pounds per square inch (psi)
• 29.92 “inches of mercury”
• 406.8 inches of water (33.9 feet)
• seawater (33.4 feet)
• 1.01325 bars or 1013.25 millibars (mb)

Elevation and air pressure have an inverse relationship - air pressure decreases with increasing elevation.
At ~18,000 feet is about “half the mass” of the atmosphere. That... depends on the weather!

Density of Warm Air vs. Cool Air
• As air is heated it expands (moving atoms apart) - reduces density of air in unconfined space.
-- Warm air rises. Cool air sinks (moving atoms together and increases it's density).
-- Because the atmosphere is unconfined, dense cool air will sink and flow to displace warm air in another location.

Density of Moist Air vs. Dry Air
• Air saturated with water vapor is less dense than dry air.
• As a result, moist air will rise relative to dry air if air temperatures and pressures are the same.

Atmospheric Convection
• Convection is the circulation of fluid due to density differences.
• A rising storm thunderhead is an example of atmospheric convection.
• Warm moist air rises, expands, releases energy as clouds form.
• After releasing its heat and moisture, the cooled air sinks, displacing warm air below.

Air Pressure Gradients and Air Pressure Systems
• Surface winds blow from high to low pressure - this is called a pressure gradient
— displayed as lines of equal barometric pressure on a weather map.
• An **air mass** is a body of air with a relative horizontally uniform temperature, humidity, and pressure:

• **High pressure systems** have dry conditions with sinking air masses.
• **Low pressure systems** have wetter conditions with rising air masses.

Types of air mass are classed by where they form (around North America):
• **Polar** - source regions above 60° north and south:
— Polar **Maritime** (cold and moist)
— Polar **Continental** (cold and dry)
• **Temperate** - between 25° and 60°N/S:
— Temperate Maritime (cool and wet)
— Temperate Continental (warm and dry)
• **Tropical** - source regions within about 25° of the equator:
— Tropical Maritime (warm and wet)
— Tropical Continental (hot and dry)

As air masses move they change to match the attributes of the next region, either gaining or loosing warmth and moisture.
— Air masses can move rapidly (if air pressure gradients are high).
— Air masses can control the weather for a relatively long periods ranging from days to months.
— They can also stagnate in one region causing long periods or rain or drought.
— Most weather occurs along around air masses at boundaries called fronts.

Dust, Aerosols, and Cloud Condensation Nuclei (CCNs)

Cloud condensation nuclei (also known as "**cloud seeds**") are small dust particles
— typically 0.2 μm, or 1/100th the size of a cloud droplet on which water vapor condenses.
— CCNs are **aerosols**, an aerosol is a colloidal suspension of microscopic particles dispersed in air or gas.
— The aerosols can be a combination of solid particles and liquid compounds (liquid water or organic residues).

Examples of CCNs include:
- dust particles (clays) - soot from fires
- volcanic ash
- salts from sea spray
- sulfate compounds released by phytoplankton in the oceans
- pollen and organic aerosol compounds released by land plants
- pollution (smog)

CCNS are abundant in the air. The **adhesion** properties of water, allows water droplets (or ice) to form and grow on CCNs, until gravity is strong enough for droplets to fall as rain or snow.
— **too many CCNs** in the air can prevent water droplets or ice crystals from growing large enough to fall as precipitation (rain or snow), contributing to often thick "haze" or "smog".

How does air pressure relate to weather?
— Increasing “high pressure” (above 1000 millibars) corresponds with “clear, sunny weather.”
— Decreasing pressure (below 1000 millibars) corresponds with “cloudy, rainy weather.”

Highest barometric pressure (record): **1084 millibars** (32.01 inches of mercury) occurred in Siberia, on December 31, 1968. The weather was clear and very cold at the time, -40° and -58°

Lowest barometric pressure (record): **870 millibars** (25.69 inches of mercury) occurred near Guam (Pacific Ocean) in 1979 In the eye of Super Typhoon with wind speeds of 190 mph.

Why does San Diego have the “best weather” in the US?
— Highest air pressure: 1033 millibars (February, 1883)
— Lowest air pressure: 987 millibars (January, 2010)
— This is the lowest range in the United States! (46 mb)!

“Weather” is the state of the atmosphere at any place and time in regards to "conditions:" sunshine, heat, dryness, cloud cover, wind, precipitation (rain, sleet, snow, hail), etc. Clouds

Clouds form when water vapor in the air condenses into visible water droplets or ice crystals.
— The **dew point** is when the relative humidity reaches 100%.
— **Cloud base** marks the boundary where relative humidity has reached saturation.
— **Cloud tops** can rise until they encounter warmer air in the stratosphere (thunderheads form)

4 general types of clouds (there are many sub-types)
— **Cirro**-form: “high-wispy”
— **Cumulo**-form: “puffy”
— **Nimbo**-form: "rain clouds"
— **Strato**-form. uniform flat cloud layer (ex: coastal "marine layer" fog)

Names of clouds can include combinations of forms as they change.
— cumulus clouds build up, become an **altocumulus**, then **cumulonimbus** (thunderstorm)

Weather Fronts - a boundary separating two masses of air of different densities
— **cold front** forms along leading edge of a cold air mass displacing a warmer (less dense) air mass. **-** typically narrow bands of showers and thunderstorm.
— **warm front** is the leading edge of a warmer air mass replacing (riding up and over) a colder air mass.
— **stationary front -** front is essentially not moving.

How do you say which way is the wind blowing?
— **Wind direction** is which direction it is coming from (from high pressure to low pressure).

What is a Santa Ana wind?

Weather and Climates
— Weather is localized conditions in the short term (hours - weeks).
— Climate is the prevailing weather conditions in an area over a long period (years, decades).

Climates are controlled by both geographic factors and regional weather patterns.
— Different regions (climates) typically have seasonal cycles.
— Eastern United States typically has 4 seasons and have frequent weather fronts between polar air masses from Canada and tropical air masses from the Gulf and Atlantic regions.
— California typically has 2 seasons, summers are dry and winters have short rainy periods.
— Patterns in weather repeat each year and are typically consistent and predictable. Examples include "**monsoons**" in India and the US Desert Southwest, **Hurricane season** in the tropics, etc.

History shows that climates change. The time spans for changes can range in cycles ranging from years and decades to centuries and millennia. Droughts can start an last for years.
— **Desertification** (such as what is happening in Africa) has been progressing for centuries.
— "**Mini-Ice Age**" conditions world-wide between the 13th and 19th centuries.
Climate change has impacted civilizations - example: Chaco Culture in the US Desert Southwest.

Climate Variability
— California's current drought is an example of climate variability.
— Climate vary on a seasonal and annual basis, or on longer-term scales (100s-1000s years)
— larger scale fluctuations impact different regions of the world. Example: El Niño Cycles
— during the last ice age, Southern California was very wet, and large lakes filled many basins.
— By about 5,000 years ago, the lakes dried up - then came back years later.
— The last major drying period began about 500 years ago (paleoindian village sites associated with fishing on the shores of SoCal lakes are now mostly barren desert - es:Anza Borrego.

Effects of uneven heating of Earth by the Sun - sunlight is not evenly distributed
— More solar energy (per unit area) is delivered to the equator than near the poles.
• Equatorial regions are warmer than poles: direct sunlight is concentrated and little is reflected.
• Polar regions: light strikes the earth at an angle; is diffuse and much is reflected back into space.
• **Seasonal variations** (winter and summer) also affect the distribution of heating of the planet.

The **Coriolis Effect** on Atmospheric and Ocean Circulation Systems

Heat from "**insolation**" (INcoming SOLar radiATION) is the driving force behind the fluid motion of the atmosphere and the oceans. However, the patterns of motion are also influenced by the forces created by the **rotation of the Earth on its axis**. Because air and seawater have **mass**, they maintain **momentum** when moving from a location of high pressure to low pressure. However, because the earth is rotating, the **rotation causes**
— a **right-turn deflection** in the **Northern Hemisphere**.
— a **left-turn deflection** in the **Southern Hemisphere**.

The coriolis affect:
• Influences all moving objects, especially ones moving over large distances (such as ICBMs)
• Objects (like air masses or rockets) change direction—not speed!
• **Maximum coriolis effect occurs at poles.**
• **No coriolis effect at equator.**

Rotation of pressure systems due to the coriolis effect:
• **Northern Hemisphere**:
— High pressure turns clockwise
— Low pressure turns counter-clockwise
• **Southern Hemisphere**: (opposite of N.H.)
— High pressure turns counter-clockwise
— Low pressure turns clockwise

Earth's Atmospheric Circulation System
— rotating air masses move in "wind belts" within zones around the planet.
— wind belts seem relatively stable when viewed in a long-term view (decades).
— fluctuations may occur on seasonal or annual basis.
— wind belts are influenced by the coriolis effect and large-scale convection patterns
— relatively stationary wind belts impact the surface of the oceans
— wind belts drive currents that circulate waters in the oceans.
— major atmospheric wind systems are called **circulation cells.**

Circulation Cells in Earth's Atmosphere
• **Hadley cells** (0° to 30° N and S of equator)
— Responsible for the **Trade Winds**: They blow NE in N. Hemisphere and SE in S. Hemisphere.
• **Ferrel cells** (30° to 60° N and S of equator)
— Responsible for the **Prevailing Westerlies** in both hemispheres.

• **Polar cells** (60° to 90° N and S)
— Responsible for the **Polar Easterlies** in both hemispheres.

"**jet stream**" - a narrow, variable band of very strong winds in the upper troposphere.
— predominantly westerly air currents encircling the globe several miles above the Earth.
— typically two or three jet streams in each N and S hemispheres.
— high-speed wind currents (~250 miles per hour at altitudes of 6 to 9 miles.
— influenced by moving air masses and coriolis effect causing them to meander and split.

Equatorial Doldrums and Inter-Tropical Convergence Zone (ITCZ)
• equatorial **doldrums** are associated with ITCZ - circles the Earth near the equator
• located where the trade winds of the Northern and Southern Hemispheres converge.
• The doldrums are:
— Area of low atmospheric pressure with lots of rain.
— Located on equator where there is least influence of the coriolis effect.
— Low wind area with calms, sudden storms, and light unpredictable winds

Seasonal shifts in the ITCZ affects rainfall in many equatorial regions, resulting in:
— the wet and dry seasons of the tropics
— The ITCZ moves north during winter in the northern hemisphere and south in the summer.

"**Horse latitudes**" are belts of calm air and sea occurring in both the northern and southern hemispheres between the trade winds and the westerlies (roughly 30-38 degrees north and south of the equator).
— Horse latitudes separate the Hadley and Ferrel Cells.
— also called the s**ubtropical high**—a belt of very dry because of high pressure, little rain.
— Horse latitudes roughly correspond with major desert regions of the world.
— How did horse latitudes got it name?

The Coriolis Effect Influences **Superstorms (cyclones)**
• **hurricanes** (near North America)
• **typhoons** (near Southeast Asia)
• **cyclones** (in the Indian Ocean).
— **All are the same**, caused by warm moist winds being drawn to the center of **low pressure** near the center of the storm (called the "**eye**" in well developed storms).

— North of the equator the coriolis effect causes low pressure to rotate counterclockwise
— South of the equator they rotate in a clockwise direction.
— The lower the air pressure in the eye of the storm, the greater the wind speed and rotation.
— **Why are there no hurricanes at the equator or poles?**

Superstorms can cause:
— major wind damage and flooding
— can erode and redeposit vast quantities of sediments, both offshore and onshore
— heavily impacting impact both communities and natural ecosystems.

Tropical Cyclones
• Storms Intensify over warm water (>77 degrees F); warm water provides water vapor.
• Water vapor provides fuel for storm in the form of latent heat energy as water vapor condenses.
• Storms die over land and cool water.
• High winds, tornados occur near storm center and along "feeder bands."
• Sea level can rise in front of storm called a "**storm surge**."
• Classified by maximum sustained wind speed (see "rating storms" below).
• Hurricanes and other storms rotate counterclockwise in the Northern Hemisphere.

Ratings storms (by maximum sustained wind speed)
• **Tropical depression** (<38 mph)
• **Tropical storm** (between 38 and 74 mph)
• **Tropical cyclone** (>74 mph)

Saffir-Simpson Scale: 5 categories of hurricane intensity based upon wind speed
• Category 1 is from 74 to 96 mph
• Category 2 is from 96 to 110 mph
• Category 3 is from 111 to 130 mph - level considered a "superstorm" (Katrina, 2005)
• Category 4 is from 130 to 155 mph (examples: Andrew, 1992, Hugo, 1989)
• Category 5 is >155 mph (Camille, 1969)

Naming storms: Alphabetical lists of names are assigned each year to storms that develop in each of the ocean basins. Names of notoriously damaging storms are "retired" to remind people of their impacts and legacy.

Greenhouse effect— the trapping of the sun's warmth in a Earth's lower atmosphere.
— lower atmosphere due to the greater transparency of the atmosphere to visible radiation from the sun than to thermal infrared radiation emitted from the surface.
— **greenhouse gas** is any gas that absorbs and emits energy in the thermal infrared range. Primary greenhouse gases: water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and ozone (O_3).

Global Warming and Earth's Greenhouse

— Earth is currently growing warmer at an alarming rate!
— World weather data indicate a rise in global temperatures over the past century.
— linked to the increasing amount of carbon dioxide and other gases accumulating in the air.
— a result of consumption of fossil fuels, deforestation, and other human impacts.
— There are many "knowns" and "unknowns" about the future of global warming. Highlights include sea level rise, climate changes, changes in storm intensity and regional precipitation, changes in air and ocean chemistry (acidification), and other impacts on humanity and natural ecosystems.