“See the Seas” Script

Program written by Bob Raynolds.

Transcript, below, by Eddie Goldstein and Erin Prestia-Robins

Footnotes by Charlie Lawton

The material contained in this document is based upon work supported by NASA under grant award NNX09AL70G. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessary reflect the views of the National Aeronautics and Space Administration.

Text	Actions
	Show Ocean Draining dataset (1)
Introduce yourself. This is a program called “See the Seas,” which is all about the oceans. Who knows what fraction of our planet is covered with the ocean? (answer: 71%)	Stop animation with full ocean.
What a lot of people don’t realize is this. Not only are there mountains and valleys up on the land, there are mountains and valleys on the sea floor, under the ocean[1]. I’m going to drain out the water from the oceans so that you can see the mountains and valleys.	Start animation so that oceans drain.
Here’s how a scientist can tell how deep the ocean is. I’ll stop it ever so often. (Stop when coastlines are drained.) You can see that the shallowest water is near the coastlines.	Start and stop the animation to show the water drained to different levels.
As we drain more water out, this mountain range, called the mid-ocean ridge, is one of the first things to peek through the water. So, it is one of the tallest underwater mountain ranges.	Turn SOS so Atlantic ocean is showing. Let water drain to expose the mid-ocean ridge, then stop animation. Use laser pointer to show the mid-ocean ridge.
We can see where the deepest parts of the ocean are because they are the last to drain out.	Stop animation when the water is at the deepest parts of the ocean.
	Show Ocean Topography Dataset (2)
Now here we are looking at the same thing, but without any ocean water. This is the biggest mountain range on the planet, The Mid Ocean Ridge[2]. This is the place where new ocean floor is formed and the oceans spread out from[3].	Use laser pointer to follow the Mid Ocean ridge.

Text	Actions
Imagine the molten rock under the sea floor, flowing up and out of cracks. That molten rock then spreads out and creates new ocean floor[4].	Put the laser pointer down for this explanation. You can use your hands to show how the molten rock flows out of cracks to spread out creating new ocean floor.
	Show Sea Floor Spreading Dataset (3)
Let's find out how scientists study this. This red line represent where molten rock is causing spreading of the ocean floor. The colors of this graph show the age of that new floor. Red is the youngest, green is older. Each black line is 20 million years of ocean spreading. So if I am a scientist, when I look at this graph I can see the ocean floor spreading out over 20, 40, 60, 80, 100 million years[5].	Move to look at the Atlantic Ridge.
Now let's look at the Pacific Ridge. Do you see the difference? So which ridge is creating sea floor faster? (answer: the pacific, because the black lines are farther apart, showing that in 20 million years more sea floor was created).	Move to the Pacific Ridge.
	Show Continental Drift Dataset(4)
Here is another way to look at the same thing. What planet is this? (answer: Earth about 500 million years ago)[6]. Looks different doesn't it. That's because scientists have learned that the continents of Earth have moved and changed a lot over 500 million years. This concept was originally called Continental Drift. This animation shows what that looks like. Now, not only are the continents moving but giant pieces of the crust of the earth called plates are also moving with the continents on top of them. Who knows what this is called? (answer: Plate Tectonics)	Start animation.
It was only a little less than 100 years ago that scientist first began to speculate about plates and their movement over time. Before that everyone just believed that the Earth had always been the way that is now. There are several pieces of evidence supporting plate tectonics. Let's take a look at a couple.	Continue animation and stop at about 200 million yrs ago.
This is the area that will become North America. This is the area that will become South America. And this will be Africa[7].	Use laser pointer to point out the area that will become North America, South America and Africa. Adjust sphere as necessary.
One of the pieces of evidence that supports Plate Tectonics is the shape of the west coast of Africa and how it seems to fit like a puzzle piece to the east coast of South America[7].	Start animation and stop at 125 million yrs ago.

Text	Actions
Another piece of evidence is the fossil record. Before this time, the fossil record of animals living here (point to South America area) and here (point to Africa area) are basically the same. That leads scientists to believe that the animals that lived back then could move back and forth. Watch what happens when we go forward in time.	Use laser pointer to show where animals in South America area could also inhabit the Africa area.
What is this? That's right it is water. If you're an animal can you get from here to here now? Not so easy is it? So from this date on, the fossil record shows animals beginning to evolve differently in the two continents. And now there are very different kinds of animals in Africa that there are in South America[8].	Play animation. Stop at 113 million yrs ago. Use laser pointer to point out the water way and the two separate continents.
Here's another cool thing. This is going to become India. (Point to region which is in Southern Hemisphere at this point in time.) Check out how it moves up and slams into here (point to where Himalayas are) and forms the Himalaya mountains[9].	Rotate sphere and press play to watch India collide to form the Himalayas.
So considering these three phenomena, the continents shapes fitting together like puzzle pieces, the fossil record and the formation of mountain ranges, scientist realized that the theory of plate tectonics made sense. But it did take 40 years for scientist to fully accept the idea.	Pause when Himalayas form.
Before we move on I want to show you something else interesting. Let's swing around to Japan and watch how quickly things are changing in this region. We are only about 20 million years ago and we are seeing so much movement over a relatively short period of time. No wonder are there so many earthquakes and tsunamis here.	Use controller to swing around to view Japan. Hit play and watch the area from about 20 million yrs to 1 million yrs.
	Show Ocean Currents Dataset (5)

Text	Actions
So what does all this have to do with the oceans? When you have all this plate tectonic activity forming mountains and valleys under the ocean it sets up water currents[10]. That's what we are going to look at now. All those looping red and blue lines indicate the permanent ocean currents. Who wants to guess why some of them are blue and some are red? (answer: the red are warm water currents close to the surface of the ocean and as the warm water moves toward the poles of the earth where it is cold the water cools off, sinks down to the bottom of the ocean because cold water is heavier and then loops back only to warm up again.) It can take 1000 years for a piece of water to make the whole trip.	Let the globe rotate slowly.
Ok. So now let's look at one specific current. Starting right here in the Gulf of Mexico, this warm water current flows all the way up through the Atlantic to warm parts of Europe. Anybody know what the name of that current is? (answer: The Gulf Stream)[11] Who discovered the Gulf Stream? (answer: Benjamin Franklin). Benjamin Franklin was studying the records of sailing ships that traveled from the Colonies in the Americas to England and back, when he noticed that it took longer for those ships to get from England to the Colonies than it took to get from the Colonies to England. He wondered why, so he hypothesized that an ocean current could cause this to happen.	Rotate globe to show the gulf stream and pause. Use laser pointer to point out warm water current from the gulf of Mexico to Europe.
So the next time he was on a ship to England he measured the ocean temperature right along this red line and also out a little further south east and compared those temperatures. What do you think he found? That's right. He learned that the water was warmer in this area. And because that Gulf Streams flows past Europe it causes the climate in Europe to be warmer than it otherwise would be.	Use laser pointer to show an area within the Gulf stream and then an area just to the right.
I want to show you another interesting ocean current here at the south pole. Do you see how the circle of current moves around and around the pole?	Move the sphere to see the south pole.

Text	Actions
Scientists believe that the circular pattern of these currents keeps the warmer water from the rest of the planet from getting to Antarctica and may be one of the reasons that Antarctica remains so cold all year long.	Use laser to point to water outside the pole currents
	Show Sea Surface Temperature Dataset (6)
This is a map that shows the ocean temperatures. Red is the warmest, blue is the coldest. Let's find that Gulf Stream. Now this model is based on actual temperature measurements. Do you see the Gulf Stream?[12]	Press play and let the sphere rotate slowly. Stop at the Gulf Stream. You should stop the animation at a point where the Gulf Stream is easy to see.
	Show Earth's Biosphere Dataset (7)
Check this one out. You are looking at photosynthesis on the planet, mainly due to phytoplankton in the oceans. Black means no photosynthesis detected, blue is average and bright green or red means large amounts.[13]	Press play and allow to rotate slowly.
What is needed for photosynthesis to take place? Or put another way what does a plant need to grow? (answer: water, sunlight, nutrients)[14]	Pause anywhere.
So keeping that in mind let's visit the South Pole again. Look at this big black circle surrounding the pole. This image is showing the change in photosynthesis over the course of the year. That's why we see the black ring growing and shrinking.	Rotate globe to show the South Pole.
Can anyone tell what time of year it is when this black ring is the largest? (Answer: wintertime in the southern hemisphere. That's because during winter, the South Pole gets no sunlight 24 hours a day, so no photosynthesis.)	Freeze the image at the point where the black ring is the largest.
Now look at all the green along the coast lines of the continents. Anyone know why there is so much life here? (answer: because the shallow water allows nutrients on the sea floor to well up, and because nutrient rich soil and silt washes down from the land into the ocean here.)	Rotate sphere back to normal and press play pointing at coastlines.
You can see this very clearly in New Orleans. This is where the Mississippi River dumps nutrients into the gulf.	Rotate around to New Orleans area.
And in the Atlantic dust blown from Africa during the dry season feeds a huge increase in plant life.	Rotate to Africa. Use laser pointer to show increase in photosynthesis off the west coast of Africa.
You can skip this next dataset and jump directly to the conclusion if you choose to.	
	Show Acid Ocean Dataset(8)

Text	Actions
Introducing… The OTHER carbon problem. In this dataset it is clear how the acidity of the ocean is affected by the absorption of carbon dioxide. Starting 1885 watch how the overall color in the ocean changes. The more carbon dioxide we release into the air, the more is absorbed into our ocean resulting in increasing levels of carbonic acid. Blue colors indicate fairly basic or alkaline, but increasing green and yellow shows growing acidity levels. *Why is this problem? Because increasing levels of acidity threaten life in our oceans. Small animals with shells for instance are especially vulnerable. The acidity softens their shells making them easier targets for larger fish. Increasing acidification also leads to the dissolving of the thin shells of these critters, so they cannot survive. So imagine if these little guys can't protect themselves any more. They may not get a chance to reproduce. And if they all get eaten up, then what do the larger fish eat? The larger fish start to die out because they don't have the shell fish to eat, and then the fish that eat them have nothing to eat and so on and so on. The whole food chain is affected.* [15]	*Press play and just allow globe to cycle through time.*
This is where we are today with acidity.	*Reset to 1885 and press play stopping at around 2012.*
This is how acidic the oceans will be in 2094 at the rate that we are currently releasing carbon dioxide. Clearly, this is a problem.[16]	*Press play and stop at 2094.*
Conclusion	**Show Ocean Draining Dataset (1)**
Let's take a look at what we have learned today. Plate Tectonics are responsible for the formation of mountains and valleys on the ocean floor which set up ocean currents that can warm continents like Europe and cool continents like Antarctica. These currents are also responsible for affecting climates in these regions which in turn determines what sorts of life can thrive there. This is just one more example of how many different aspects of our planet all work together to form one system. To understand our planet, you need to see how all of the pieces fit together. Thank you for joining us for our See The Seas demonstration.	Let the dataset play thru the end.

Ocean Draining Dataset

1. This dataset is useful to get viewers oriented geographically and introduce the concept of what the Earth would look like with no oceans to mask ocean bathymetry (like topography, but of the seafloor.) Pointing out high, low, and notable features, especially the mid-ocean ridge system and notable mountains seamounts, is a good way to do this.   You can also “drain” the ocean to demonstrate the relative height of different features and drive home the concept that the seafloor has mountains and valleys just as land surface does.

Ocean Topography Dataset

2. The mid-ocean ridge systems are also seafloor biodiversity hotspots.   Geothermally or volcanically active regions of these features are especially diverse, due to the especially warm water and the presence of highly reduced (energy-containing) chemical compounds that nourish microorganisms and simple animals. These are the foundations of complex ecological communities of microorganisms, simple worms, crabs, and fish. Unlike more familiar ecosystems, these communities derive energy not from the sun, but from the energy-rich reduced chemistry of vent fluids. A connection to astrobiology could be made here, as geothermally active regions of the mid-ocean ridges may have analogues in other locations in the solar system, like the watery moons Europa and Enceladus.

3. The mid-ocean ridges represent divergent boundaries, where new material is pushing up from below and creating new seafloor. The trenches, like the Marianas Trench, are regions where one plate dives underneath the other.

4. Plate tectonics is usually described in terms of drifting plates bumping into each other, but a better analogy to use while explaining this concept is conveyor belts. Essentially, each tectonic plate operates like a very slow, vast conveyor belt, with material coming up from the hot mantle below at the divergent boundary and diving down into the mantle at the convergent boundary. This dataset shows the age of the sea floor, and by extension, how far the “conveyor belt” has moved over the past several hundred million years. The youngest sea floor is close to the mid-ocean ridges, where new crust forms.

The “motor” that drives the tectonic plates is convection. As we all know, hot air rises, while cool air falls. The same process applies to the fluid rock in the mantle, which rises, flows, and falls in giant convection cells like giant ferris wheels. Where very hot rock rises from the deep mantle, its pressure domes the thin seafloor crust upwards, and a bit of hot rock seeps through the crack that is created. This can be seen in Iceland where the mid-ocean ridge is above sea level.   It solidifies and becomes new sea floor. The hot mantle flows, moving the crustal plate with it, until, as it cools, it becomes dense and begins to fall inwards towards the earth’s core and the crust is shoved under the next plate over. The areas where this occurs are where trenches have formed. Earthquakes, volcanoes, and tsunamis are very common in areas where this occurs - the March 2011 tsunami that affected Japan was the result of a powerful undersea earthquake along the fault where the Pacific plate subducts under a portion of the North American Plate called the Honshu Microplate.

Sea Floor Spreading Dataset

5. Scientists have been able to estimate the age of the crust by measuring its magnetic polarity. The Earth’s magnetic field shifts polarity randomly, changing the magnetic orientation of iron-rich lava on the sea floor.

By mapping where these polarity shifts occur, it's possible to determine how many polarity shifts, and by extension how many years, ago a particular area of the sea floor was formed.

6. The Plate Tectonics and Paleo Animation dataset contains an animation which shows the activity of plate tectonics through history. At its start, the large southern landmass called Pannotia or Rodinia. It began to break apart into the ancient continent Gondwana, as well as several smaller landmasses, 550 million years ago. Gondwana's landmass encompassed the cores of North America, Northern Europe, and Siberia. The smaller landmasses that also broke away from Pannotia/Rodinia drifted together to form another famous ancient continent, Laurasia. Gondwana and Laurasia drifted apart for more than 200 million years, and then came back together again to form the famous supercontinent Pangaea. This collision pushed up a great mountain range, taller and longer than the current-day Himalaya. Today, we can still see these mountains - they have slowly eroded into the low, rolling Appalachian Mountains.

Continental Drift Dataset

7. The supercontinent, Pangaea, then began its break up around 300 million years ago, and its fragments formed the continents we know today. During the Cretaceous period, 140-180 million years ago, the North Atlantic opened up as a rift valley and narrow sea, separating Eurasia and North America. This breakup was mirrored South America and Africa pulling apart to create the South Atlantic. One can still see how the coastlines of Africa and South America mirror each other, and animals and plants from each continents have evolved from common ancestors that were geographically separated as the continents drifted aparts.

8. Ecologists refer to the process of forming one species from two geographically isolated populations of the same species allopatric speciation. When two populations are reproductively isolated from each other, they can no longer exchange genes. Separated populations experience dissimilar evolutionary pressures, mutations, and genetic drift; their gene frequencies change, affecting their phenotype (physical expression of genes) and eventually becoming genetically or behaviorally incompatible for mating. Speciation occurs when two populations are reproductively incompatible. Species in South America and Africa have been separated so long that this has occurred.

9. The final break up of Gondwana created the landmasses of India, Australia, and Antarctica. When India broke free from other landmasses, exceptionally fast seafloor creation conveyed it at great speed toward the landmass we know as Asia.. The collision between the two land masses caused the Himalaya to form and raised the Tibetan plateau, in a process analogous to the collision that created the Appalachians.

Ocean Currents Dataset

10. Ocean currents strongly effect climate, biogeochemical cycling, and biological activity worldwide, forming a conveyor belt that transports water on a 1000-year circuit of Earth's oceans. The belt is driven by wind and convection, similar to the mantle convection that drives plate tectonics. Ocean convection is largely driven by temperature and salinity, both of which change the density of water and make it rise or sink. Wind helps maintain the current's speed while it is on the surface.

11. A "start" of the ocean conveyor belt is the Caribbean Sea, southeast of the US. Here, the great Gulf Stream current flows northeast towards the UK and Scandanavia, driven by wind and convection. By time the tropical

water that originated in the Caribbean hits the Norwegian Sea it has cooled significantly, as it has given up its heat to the atmosphere around northwestern Europe. This loss of heat to the atmosphere makes the water cooler and denser, causing it to sink to the bottom of the Norwegian Sea. As more warm water is transported north, the cooler water on the bottom flows south, pushed incoming water from above. This cold bottom water flows south of the equator all the way down to Antarctica. Eventually, the cold bottom waters rise to the surface, warm, and continue the conveyor belt that encircles the globe.

As the warm tropical water reaches the high latitudes in northwestern Europe, it interacts thermodynamically with cold air from the Poles. The water is cooled, and the air is warmed. This current-driven warming strongly affects northern Europe's climate, which is far warmer and more temperate than other locations at similar latitude. If the Gulf Stream did not exist, the UK would have a climate similar to that of southern Canada! In this way, currents strongly control the climate in many regions.

Ocean currents are also strong drivers of biological productivity. As water at the bottom of the ocean rises, it brings nutrients from the seafloor with it. Where this water comes to the surface, in areas known as upwelling zones, its nutrient load fuels the growth and reproduction of plankton - which form the basis of many shallow-water marine ecosystems. This supports diverse ecosystems, such as the California kelp forests, and economically invaluable fisheries.

Sea Surface Temperature Dataset

12. Sea surface temperature tends to reflect season and climate, as well as affecting them. Generally, water in warmer areas close to summer is warmest, as it absorbs heat from the air, and polar areas and those experiencing winter are the coldest. This climate interaction drives currents and circulation patterns, as described in the last section. The Gulf Stream current is clearly visible in this temperature map, as are several other warm surface currents.

Sea surface temperature dynamics play a critical role in the dynamics of coastal climates, as the water buffers temperature changes by absorbing and releasing heat. Coastal climates are more stable year-round than continental climates like Denver's. As a majority of the human population lives in coastal areas, these processes play a huge role in human quality of life. Moderate, stable coastal climates, with their warm summers and cool winters, support long growing seasons, productive agriculture, and human comfort.
As global warming raises worldwide surface atmospheric temperatures, the oceans have played this buffering role on a global scale, storing heat and cooling the atmosphere. It is unknown, however, how much heat the ocean can absorb, and whether heating the ocean past a certain point will affect ocean circulation and other temperature-driven processes.

Earth's Biosphere Dataset

13. These data were collected by an instrument called SeaWiFS, which was installed on a now-defunct satellite called OrbView-2 . A research collaboration called the SeaWiFS project collects, processes, and distributes data received from the instrument's sensor - which very precisely measured the color of the water at the ocean surface. The sensor was able to measure the color of every square kilometer of cloud-free ocean every 48 hours, providing global information on the oceans in near-real time. The oceans are shaded based on the chlorophyll concentration in the water, a proxy measurement for phytoplankton abundance and primary productivity. Purple

and blue denote low abundance of phytoplankton, while yellow, orange, and red shading denotes high abundances. Areas covered by clouds have no data and are shown as black. The continents are shaded according to local average vegetation cover. Green areas have abundant vegetation, yellow areas have sparse vegetation, and brown areas have no vegetation.
SeaWiFS also was used to offer real-time monitoring of red tides and other harmful algae, which can bloom in polluted waters and be deadly to fish and oysters.

Sea WiFS measured the abundance the phytoplankton that form the basis of the oceanic food web, and because it measured every two days, it provided a high-resolution view of the blooms and die-offs of phytoplankton populations. The rate and distribution of the growth of phytoplankton controls oceanic primary productivity - the rate at which they use photosynthesis to turn carbon dioxide and sunlight into biomass. Much like plants on land, phytoplankton are critical to the diversity and health of the entire biological community. Their abundance and primary productivity is a direct indicator of the seas' health and ability to sustain diverse life.

14. Surface biological productivity also plays a major role in the Earth's global climate. Global warming is attributable largely to increased concentrations of CO2 in the atmosphere, derived from our use of fossil fuels. This has caused fundamental changes in the carbon cycle - the global movement of carbon between so-called "sinks" or reservoirs (such as seafloor sediments, vegetation, and fossil deposits), living organisms, and the atmosphere. We've always known that phytoplankton play a critical role in taking up carbon from the atmosphere, but how their abundance is geographically distributed, the rate at which they take up carbon to produce biomass, and how those rates change with a warming climate, are now critical to our understanding of global warming and our ability to predict future climate change.

Acid Ocean Dataset

15. Ocean acidification is a consequence of humankind's release of carbon dioxide emissions to the atmosphere. The current concentration of carbon dioxide is currently at 392 parts per million, an unusually high value in recent Earth history. CO2 dissolves into seawater at a rate proportional to its atmospheric concentration. Once dissolved, it reacts with water to form carbonic acid, which decreases ocean pH (i.e., makes seawater less basic), and lowers carbonate ion concentrations.
Carbonate ions are the building blocks that marine animals like corals, sea stars, clams, and some algae use to make hard shells and skeletons. Ocean acidification is typically measured in terms of a value called "omega," which is defined as the saturation state of calcium carbonate minerals. In this dataset, areas with high omega values - corresponding to abundant carbonate ions for building shells and skeletons - are mapped in blue; these are areas friendly to corals, clams and other shellfish. These areas are usually ecologically rich and diverse. Areas with lower omega and fewer carbonate ions are in orange. Areas with the lowest omega, where calcium carbonate minerals will dissolve, show up in light gray. These, sadly, are very harsh to corals and shellfish, and do not support their populations. Very high acidity in ocean water can contribute to the acidification of animal tissues themselves, a harmful condition known as hypercapnia.

The fast pace of ocean acidification might not give some marine life enough time to adapt to the new conditions. Some animals might die or move somewhere else. But ocean life is so diverse that other animals will do well. The winners might include mostly seagrasses and algae, which are common and abundant worldwide, while the losers might include many shelled creatures and corals. Unfortunately, the organisms that may suffer are critical to ocean food webs. They also provide humans with benefits like food, protection, and medicine.

16. Ocean acidification decreases omega over time, so blue areas become lighter and then disappear. The legend shows how this affects ocean life. In blue areas with high omega, many corals and shellfish are present. In areas with medium omega that are green and yellow in the movie, fewer corals and shellfish are present. In areas with low omega that are orange or gray, corals and shellfish may be rare, injured, or gone. By 2094, the oceans will be very different from 1885, and the blue areas best for corals and shellfish will be gone.

Back to **Ocean Draining Dataset** and conclusion

See the Seas Background Information and Talking Points

Dataset: ETOPO2 Datasets with Landsat

Topics: Geography, Topography, Bathymetry

Background:

This dataset is useful to get viewers oriented geographically and introduce the concept of what the Earth would look like with no ocean waters to mask the topography of the sea floors. Pointing out high, low, and notable features, especially the mid-ocean ridge system and notable mountains (seamounts), is a good way to do this. You can also "drain" the ocean to demonstrate the relative height of different features and drive home the concept that the seafloor has mountains and valleys just as the land surface does.

The mid-ocean ridge systems are also seafloor biodiversity hotspots. Geothermally or volcanically active regions of these features are especially diverse, due to the especially warm water and the presence of highly reduced (energy-containing) chemical compounds that nourish microorganisms and simple animals. These are the foundations of complex ecological communities of microorganisms, simple worms, crabs, and fish. Unlike more familiar ecosystems, these communities derive energy not from the sun, but from the energy-rich reduced chemistry of vent fluids. A connection to astrobiology could be made here, as geothermally active regions of the mid-ocean ridges may have analogues in other locations in the solar system, like the watery moons Europa and Enceladus.

Points of Interest:

- Mt. Everest, eastern Nepal : Highest point on Earth at 8,848 meters (29,029 ft)
- Volcan Chimborazo, central Ecuador: Furthest point from Earth's center and closest land to space, 6,268 meters (20,565 ft). Earth is an oblate spheroid – with a wider diameter at the equator than through the poles. Because the equator bulges, Chimborazo is further from the Earth's center point than Everest is, even though Everest is almost 9,000 feet higher above sea level!
- Mauna Kea, Hawaii: Highest relief from base to summit of any mountain on Earth, 13,796ft above sea level but 10,000 m (33,000 ft) above ocean floor.
- Challenger Deep, Marianas Trench: Deepest part of any ocean, with a depth of 10,902 meters (35,768 ft).
- Dead Sea, Israel/Jordan: Lowest point below sea level on land; Its surface and shores are 423 meters (1,388 ft) below sea level and are falling as incoming waters are diverted to human use. The Dead Sea is 377 m (1,237 ft) deep at its deepest point.
- Major mountain ranges:

- Alps, tallest mountains in Europe
- Andes (longest continental mountain range, also includes the world's tallest volcano, Nevado Ojos de Salado at 22,615 ft (6,893m)).
- The Rockies
- Himalayas (the highest continental mountain range, includes Everest),
- Rift Valley volcano chain (includes Mt. Kilimanjaro)
- Mid-Ocean Ridges: The longest mountain chain in the world, 65,000 km (40,400 mi) long (several times longer than the Andes, the longest continental mountain range). The total length of the oceanic ridge system is 80,000 km (49,700 mi) long, but this includes ridge areas not characterized by mountainous terrain.

Dataset: Age of the Sea Floor with Topography and 20 million year contours

Topics: Plate tectonics, convection, young and old seafloor, ridges and trenches

Background:

Plate tectonics is usually described in terms of drifting plates bumping into each other, but a better analogy to use while explaining this concept is conveyor belts. Essentially, each tectonic plate operates like a very slow, vast conveyor belt, with material coming up from the hot mantle below at the divergent boundary and diving down into the mantle at the convergent boundary. The mid-ocean ridges represent divergent boundaries, where new material is pushing up from below and creating new seafloor. The trenches, like the Marianas Trench, are regions where one plate dives underneath the other. Continents are like boxes sitting on the conveyor belt, moving to and fro as the belt underneath them shifts. Continental rocks are older and less dense than seafloor basaltic bedrock, and continents move slowly around the surface of the Earth, occasionally colliding or moving away from each other, as the seafloor conveyors transport them to and fro.

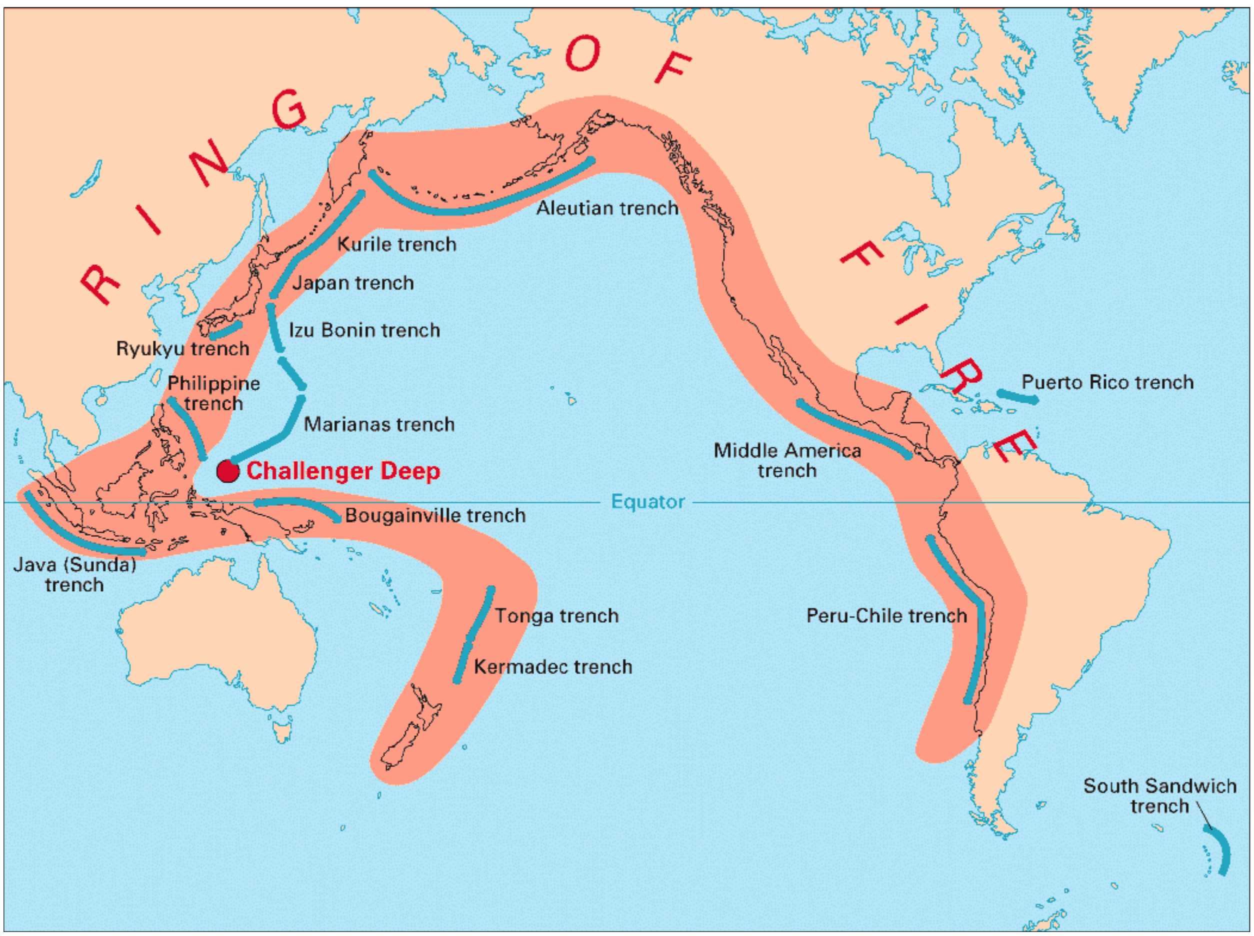
The "motor" that drives the tectonic plates is convection. As we know, hot air rises, while cool air falls. The same process applies to the fluid rock in the mantle, which rises, flows, and falls in giant convection cells like giant Ferris wheels. Where very hot rock rises from the deep mantle, its pressure domes the thin seafloor crust upwards, and hot rock seeps through the crack that is created. It solidifies and becomes new sea floor. The hot mantle flows, moving the crustal plate with it, until, as it cools, it becomes dense and begins to fall inwards towards the earth's core and the crust is shoved under the adjacent plate. The areas where this occurs are where trenches have formed. Earthquakes, volcanoes, and tsunamis are very common in areas where this occurs - the March 2011 tsunami that affected Japan was the result of a powerful undersea earthquake along the fault where the Pacific plate subducts under a portion of the North American Plate called the Honshu Microplate.

This dataset shows the age of the sea floor, and by extension, how far the "conveyor belt" has moved over the past several hundred million years. The youngest sea floor is close to the mid-ocean ridges, where new crust forms. Scientists have been able to estimate the age of the crust by measuring its magnetic polarity. The Earth's magnetic field shifts polarity regularly, changing the magnetic orientation of iron-bearing minerals in the lava cooling at the Mid Ocean Ridges. By mapping where these polarity shifts occur, it is possible to determine how many polarity shifts, and by extension how many years ago a particular area of the sea floor was formed.

Points of Interest:

- Mid-Atlantic Ridge and extended Mid-Ocean ridge system: 65,000 km (40,400 mi) long (several times longer than the Andes, the longest continental mountain range). The total length of the oceanic ridge system is 80,000 km (49,700 mi) long, but this includes ridge areas not characterized by mountainous terrain. This is where the conveyor belt "comes up".

- Trenches: In addition to the Marianas Trench, the Pacific Rim is ringed by trench systems. This is, of course, where the conveyor "goes down".



http://pubs.usgs.gov/gip/dynamic/graphics/Fig22.gif

More Information:

Mid-Ocean Ridges: http://en.wikipedia.org/wiki/Mid-ocean_ridge

Mid-Atlantic Ridge: http://en.wikipedia.org/wiki/Mid-Atlantic_Ridge

Plate Tectonics: http://en.wikipedia.org/wiki/Plate_tectonics

Mariana Trench: http://en.wikipedia.org/wiki/Mariana_Trench

Dataset: Plate Tectonics and Paleo Animation

(n.b. At the Denver Museum of Nature and Science we use an animation showing plate tectonics. You may be using the NOAA supplied dataset which is a series of still images instead.)

Background:

The Plate Tectonics and Paleo Animation shows the activity of plate tectonics through history. It is a time-lapse animation visualizing the evolution of the Earth's surface due to plate tectonics from 600 million years ago to the present day, with original artwork depicting the colors of the Earth's surface.

Continents are like boxes sitting on the conveyor belt, moving to and fro as the belt underneath them shifts. Continents are islands of granite and other rocks atop the thin basalt of the sea floor. Continental rocks are much older than seafloor basin rock, and move slowly around the surface of the Earth, occasionally colliding or moving away from each other as their "conveyor belts" shift. In addition, sea level rises and falls, mountain ranges form, plateaus rise, and basins fall, creating a complex dance of wheeling continents and shifting coastlines.

The animation shows, at its start, the large southern landmass called Pannotia or Rodinia. It began to break apart into the ancient continent Gondwana, as well as several smaller landmasses, 550 million years ago. Gondwana's landmass encompassed the cores of North America, Northern Europe, and Siberia. The smaller landmasses that also broke away from Pannotia/Rodinia drifted together to form another famous ancient continent, Laurasia. Gondwana and Laurasia drifted apart for more than 200 million years, and then came back together again to form the supercontinent Pangaea. This collision pushed up a great mountain range, taller and longer than the current-day Himalaya. Today, we can still see these mountains - they have slowly eroded into the low, rolling Appalachian Mountains.

This new supercontinent, Pangaea, then began its break up around 300 million years ago, and its fragments formed the continents we know today. During the Jurassic period, 140-180 million years ago, the North Atlantic opened up as a rift valley and narrow sea, separating Eurasia and North America. This breakup was mirrored South America and Africa pulling apart to create the South Atlantic. One can still see how the coastlines of Africa and South America mirror each other, and animals and plants from each continent have evolved from common ancestors that were geographically separated as the continents drifted apart. The final break up of Gondwana created the landmasses of India, Australia, and

Antarctica. When India broke free from other landmasses, exceptionally fast seafloor creation conveyed it at great speed toward the landmass we know as Asia. The collision between the two land masses caused the Himalayas to form and raised the Tibetan plateau, in a process analogous to the collision that created the Appalachians.

About 70 million years ago, the Laramide Orogeny began as the North American plate was compressed, pushing up the Rocky Mountains. This event can be clearly seen on the North American continent. A nice tie to Ancient Denvers can be created here, and guests may wish to watch this process in more detail.

Points of Interest:

Note how the Mid-Ocean ridges never move!

700-550mya: Panottia, the first supercontinent.

550mya: breakup of Pannotia creates Gondwana and, later, Laurasia.

350mya: Reformation of supercontinent, now called Pangea. Formation of paleo-Appalachians.

200mya: Breakup of Pangea.

180-140mya: breakup of North America and Eurasia, followed by South America and Africa

130mya: Breakup of Gondwana. Separation of East Gondwana from Africa 130mya created open ocean channel. India/Madagascar break off 120mya, then separate from each other. India heads north; during this time, massive volcanic eruptions created the Deccan Traps. New Zealand separates from Antarctica around this time. Australia-New Guinea separates from Antarctica about 80mya, fully separates about 40mya. Gondwana continues to break apart at the divergent boundaries we know as the Rift Valley and Red Sea.

3mya: North and South America connect and form the Isthmus of Panama. Plants and animals from each continent migrate across the isthmus, causing great ecological changes.

More Information:

Plate Tectonics: http://en.wikipedia.org/wiki/Plate_tectonics

Gondwana: http://en.wikipedia.org/wiki/Gondwana

Pangea: http://en.wikipedia.org/wiki/Pangaea

Laramide Orogeny: http://en.wikipedia.org/wiki/Laramide_orogeny

Dataset: Ocean Conveyor Belts

Topics: Ocean Currents

Background:

Ocean currents strongly affect climate, biogeochemical cycling, and biological activity worldwide, forming a conveyor belt that transports water on a 1000-year circuit of Earth's oceans. The belt is driven by wind and convection, similar to the mantle convection that drives plate tectonics. Ocean convection is largely driven by temperature and salinity, both of which change the density of water and make it rise or sink. Wind helps maintain the current's speed while it is on the surface.

The "start" of the ocean conveyor belt is the Caribbean Sea, southeast of the US. Here, the great Gulf Stream current flows northeast towards the UK and Scandinavia, driven by wind and convection. By the time the tropical water that originated in the Caribbean hits the Norwegian Sea it has cooled significantly, as it has given up its heat to the atmosphere around northwestern Europe. This loss of heat to the atmosphere makes the water cooler and denser, causing it to sink to the bottom of the Norwegian Sea. As more warm water is transported north, the cooler water on the bottom flows south, displaced by incoming water from above. This cold bottom water flows south across the equator all the way to Antarctica. Eventually, the cold bottom waters are able to rise to the surface, warm and continuing the conveyor belt that encircles the globe. It takes water almost 1000 years to move through the whole conveyor belt.

In addition to flowing currents, the motion of water around the oceans creates eddies, like vast, slow whirlpools, as the water swirls around the coastlines of continents. Also, vast vortexes of slowly spinning water called gyres have formed in the Indian, Pacific, and Atlantic oceans. The Coriolis Effect of Earth's rotation is responsible for maintaining these swirls, and most ocean currents swerve around them or merge with them.

As the warm tropical water reaches the high latitudes in northwestern Europe, it interacts thermodynamically with cold air from the Poles. The water is cooled, and the air is warmed. This current-driven warming strongly affects northern Europe's climate, which is far warmer and more temperate than other locations at similar latitude. If the Gulf Stream did not exist, the UK would have a climate similar to that of southern Canada! In this way, currents strongly control the climate in many regions. The circular current that rings Antarctica prevents warm tropical waters from reaching the continent, and is largely responsible for the severity of its cold climate.

Ocean currents are also strong drivers of biological productivity. As water at the bottom of the ocean rises, it brings nutrients from the seafloor with it. Where this water comes to the surface, in areas known as upwelling zones, its nutrient load fuels the growth and reproduction of plankton - which form the basis of many shallow-water marine ecosystems. This supports diverse ecosystems, such as the California kelp forests, and economically invaluable fisheries.

Points of Interest:

- Gulf Stream- starts near Bermuda, ends near Norway

- Circumpolar current around Antarctica

- Eddies forming on coastal areas, particularly off the NE coast of South America

More Information:

Ocean Surface Currents: http://en.wikipedia.org/wiki/Ocean_current

Thermohaline Circulation: http://en.wikipedia.org/wiki/Thermohaline_circulation

Ocean and Atmosphere Circulation:
http://www4.uwsp.edu/geo/faculty/ritter/geog101/textbook/circulation/ocean_circulation.html

Gulf Stream: http://en.wikipedia.org/wiki/Gulf_Stream

Dataset: Sea Surface Temperature

Topics: Sea Surface Temperature and Climate

Background:

Sea surface temperature tends to reflect season and climate, as well as affecting them. Generally, water in areas experiencing summer is warmest, as it absorbs heat from the air, and polar areas and those experiencing winter are the coldest. This climate interaction drives currents and circulation patterns, as described in the last section. The Gulf Stream current is clearly visible in this temperature map, as are several other warm surface currents.

Sea surface temperature dynamics play a critical role in the dynamics of coastal climates, as the water buffers temperature changes by absorbing and releasing heat. Coastal climates are more stable year-round than continental climates like Denver's. As a majority of the human population lives in coastal areas, these processes play a huge role in human quality of life. Moderate, stable coastal climates, with their warm summers and cool winters, support long growing seasons, productive agriculture, and human comfort.

As global warming raises worldwide surface atmospheric temperatures, the oceans have played a buffering role on a global scale, storing heat and cooling the atmosphere. It is unknown, however, how much heat the ocean can absorb, and whether heating the ocean past a certain point will affect ocean circulation and other temperature-driven processes.

Several El Niño and La Niña episodes are visible in these data, as well. When an El Niño forms, the strong trade winds that usually push equatorial Pacific surface water towards the region of Indonesia weaken, and the warm water flows towards the eastern Pacific near Peru. This, in turn, further weakens the trade winds, creating a positive feedback. It significantly alters rainfall patterns, causing extensive drought in Southeast Asia and rainfall in the normally dry deserts of western South America. El Niño causes warm, dry winters in the northern US, sometimes affecting Denver, and can cause abnormally cool, wet winters in Southern California and Mexico. El Niño's warm rush of nutrient-poor tropical water, heated by its eastward passage in the Equatorial Current, replaces the cold, nutrient-rich surface water of the Humboldt Current. When El Niño conditions last for many months, extensive ocean warming and the reduction in Easterly Trade winds limit the upwelling of cold nutrient-rich deep water, impacting sea surface biological productivity and fisheries.

La Niña, in contrast, is a pool of colder-than-average water in the eastern Pacific. The alternating cycle between La Niña and El Nino events is called the El Niño/La Niña-Southern Oscillation, or ENSO. La Niña events generally cause wet, cold winters in the northern US, along with generally drier conditions in the Southwest and the Great Plains. Their effects on the Denver area vary; the current La Niña has brought extensive snowfall to the Rockies but has kept the Great Plains very dry. The current La Niña, the strongest on record, formed in 2010 and will last until at least early 2012. It has contributed to the formation of powerful, moisture-laden storms that brought catastrophic flooding to Queensland, Australia and the area around Rio de Janeiro, Brazil, precipitated the 2010 blizzard that affected the Northeastern US, and caused record rains in California.

These unusually severe storms may be attributable to intensified evaporation rates in the tropics, attributable to global warming; interacting with La Nina's shifted precipitation patterns and cool surface water. ENSO episodes have been statistically more common since 1990.

Points of Interest:

- Gulf Stream- starts near Bermuda, ends near Norway

- Seasonal warming and cooling of water in each hemisphere

- El Nino and La Nina events in the Pacific, distinguishable by persistent warm (or cool) "pools" in the eastern Pacific near Peru and Bolivia. In these data, unusually strong ENSO events can be seen in the 1982–83 and 1997–98 winter seasons.

More Information:

ENSO/El Nino: http://en.wikipedia.org/wiki/El_Ni%C3%B1o-Southern_Oscillation

Sea Surface Temperature: http://en.wikipedia.org/wiki/Sea_surface_temperature

Dataset: Sea WiFS - Ocean Phytoplankton

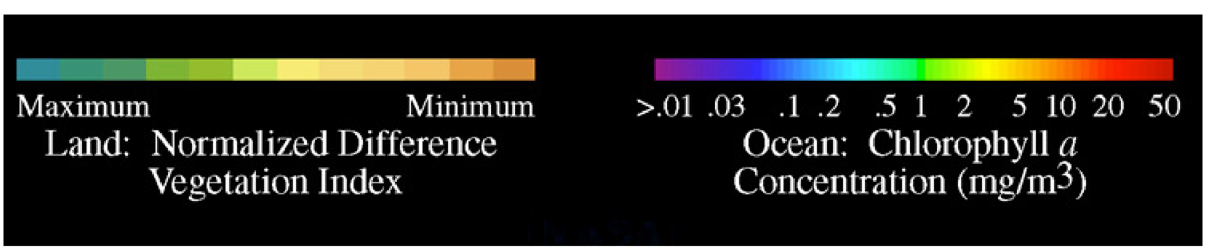
Topics: Biological productivity, carbon cycle,

Background: These data were collected by an instrument called SeaWiFS, which was installed on a now-defunct satellite called OrbView-2 . A research collaboration called the SeaWiFS project collects, processes, and distributes data received from the instrument's sensor - which very precisely measures the color of the water at the ocean surface. The sensor was able to measure the color of every square kilometer of cloud-free ocean every 48 hours, providing global information on the oceans in near-real time. These color observations can be used to derive the concentration of microscopic marine plants called phytoplankton. In this dataset, greener water signifies an abundance of phytoplankton, while bluer water indicates less. SeaWiFS also was used to offer real-time monitoring of red tides and other harmful algae, which can bloom in polluted waters and be deadly to fish and oysters.

Sea WiFS measured the abundance the phytoplankton that anchor the center of the marine food web, and because it measured every two days, it provided a high-resolution view of the blooms and die-offs of phytoplankton populations. The rate and distribution of the growth of phytoplankton controls oceanic primary productivity - the rate at which they use photosynthesis to turn carbon dioxide and sunlight into biomass. Much like plants on land, phytoplankton are critical to the diversity and health of the entire biological community. Their abundance and primary productivity is a direct indicator of the seas' health and ability to sustain diverse life.

Surface biological productivity also plays a major role in the Earth's global climate. Global warming is attributable largely to increased concentrations of CO2 in the atmosphere, derived from our use of fossil fuels. This has caused fundamental changes in the carbon cycle - the global movement of carbon between so-called "sinks" or reservoirs (such as seafloor sediments, vegetation, and fossil deposits), living organisms, and the atmosphere. We've always known that phytoplankton play a critical role in taking up carbon from the atmosphere, but how their abundance is geographically distributed, the rate at which they take up carbon to produce biomass, and how those rates change with a warming climate, are now critical to our understanding of global warming and our ability to predict future climate change.

The oceans are shaded based on the chlorophyll concentration in the water, a proxy measurement for phytoplankton abundance and primary productivity. Purple and blue denote low abundance of phytoplankton, while yellow, orange, and red shading denotes high abundances. The continents are shaded according to local average vegetation cover. Green areas have abundant vegetation, yellow areas have sparse vegetation, and brown areas have no vegetation. As an addition to this dataset, another version is available that has the Carbon Dioxide record from NOAA's Mauna Loa Observatory included in the images. A second version of SeaWiFS is also available with the land as a still image, showing only the changes in the ocean through the year. Black areas are cloud covered and have no data.



More Information:

NASA's SeaWIFFs site: http://oceancolor.gsfc.nasa.gov/SeaWiFS/

Primary Productivity: http://en.wikipedia.org/wiki/Primary_production

Phytoplankton: http://earthobservatory.nasa.gov/Features/Phytoplankton/

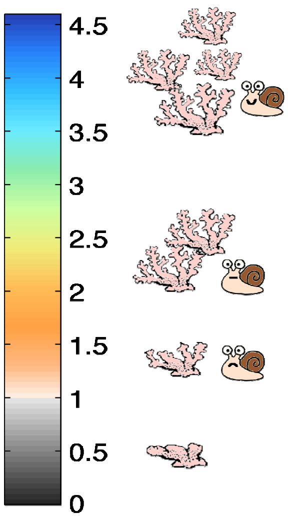
Science on a Sphere: http://sos.noaa.gov/Datasets/dataset.php?id=172

Dataset: Ocean Acidification

Topics: Climate Change, Corals, Ocean Chemistry

Background:

Ocean acidification is a consequence of humankind's release of carbon dioxide emissions to the atmosphere. The current concentration of carbon dioxide is currently at 396 parts per million, an unprecedented high value in recent Earth history. CO2 dissolves into seawater at a rate proportional to its atmospheric concentration. Once dissolved, it reacts with water to form carbonic acid, which decreases ocean pH (i.e., makes seawater more acidic), and lowers carbonate ion concentrations.



Carbonate ions are the building blocks that marine animals like corals, sea stars, clams, and some algae use to make hard shells and skeletons. Ocean acidification is typically measured in terms of a value called "omega," which is defined as the saturation state of calcium carbonate minerals. In this dataset, areas with high omega values - corresponding to abundant carbonate ions for building shells and skeletons - are mapped in blue; these are areas friendly to corals, clams and other shellfish. These areas are usually ecologically rich and diverse. Areas with lower omega and fewer carbonate ions are in orange. Areas with the lowest omega, where calcium carbonate minerals will dissolve, show up in light gray. These, sadly, are very harsh to corals and shellfish, and do not support their populations.

The pace of ocean acidification might not give some marine life enough time to adapt to the new conditions. Some animals might die or move somewhere else. But ocean life is so diverse that other animals will do well. The winners might include mostly sea-grasses and algae, which are common and abundant worldwide, while the losers might include many shelled creatures and corals. Unfortunately, the organisms that may suffer are critical to ocean food webs. They also provide humans with benefits like food and medicine.

Ocean acidification decreases omega over time, so blue areas become lighter and then disappear. The legend shows how this affects ocean life. In blue areas with high omega, many corals and shellfish are present. In areas with medium omega that are green and yellow in the movie, fewer corals and shellfish are present. In areas with low omega that are orange or gray, corals and shellfish may be rare, injured, or gone. By 2094, the oceans will be very different from 1885, and the blue areas best for corals and shellfish will be gone.

Points of Interest:

- Dark gray dots show cold-water coral reefs, medium gray dots show warm-water coral reefs