The Hidden Ocean: Visualizing the Conditions for Life

A Worldviews Network Storyboard (WvN13)

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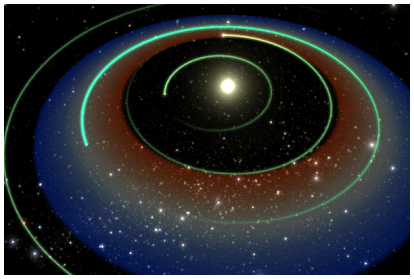
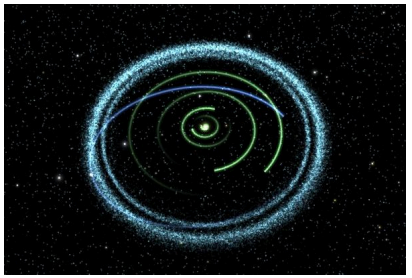
Production Credits
Worldviews Event Website

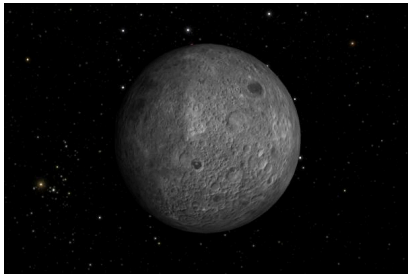
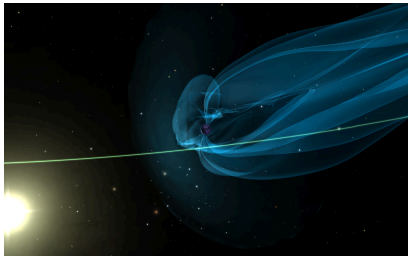
Uniview Install File: wvn13_cas_FINAL.msi
WWW Browser Control Files: wvn13_www.zip
Uniview and Browser Control Installation Instructions **(need this)**
Browser Screenshots
NOAA Climate Literacy Principles and Ocean Literacy Principles

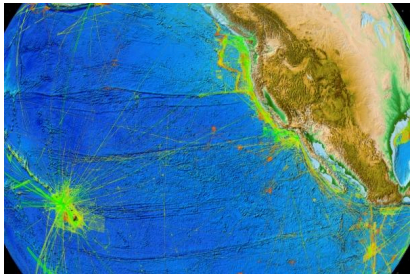
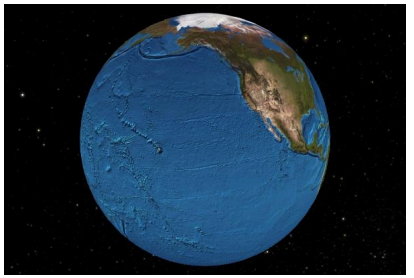
Program Description
Though we live on a blue planet, the ocean is vast and largely unexplored. As scientists have begun to map its vast underwater worlds, they have discovered many ways in which the ocean makes life on Earth possible. Not only does the ocean regulate climate worldwide, but human well-being and the global economy are intimately connected to the health of ocean ecosystems. Audiences in the California Academy of Sciences' Morrison Planetarium were taken on an immersive journey from deep space to the deep blue sea, visualizing previously invisible relationships that are shifting perspectives on the extraordinary conditions of our home planet. The live presentation was guided by Bart Shepherd, Director of the Steinhart Aquarium, and David McConville, Creative Director of the Worldviews Network. After the presentation, audience members participated in a dialogue with scientists and entrepreneurs about the ways in which human activities are affecting the ocean. We'll explore numerous case studies of how combining scientific research and entrepreneurial approaches are creating new opportunities to increase both human and ocean well-being.

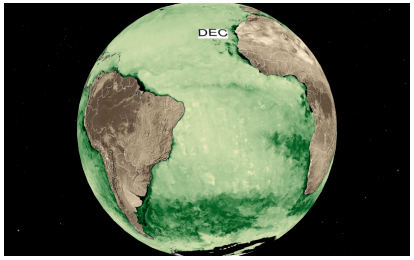
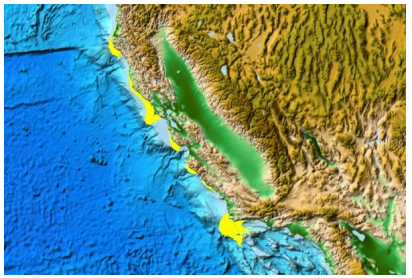
Jump to Scenes:

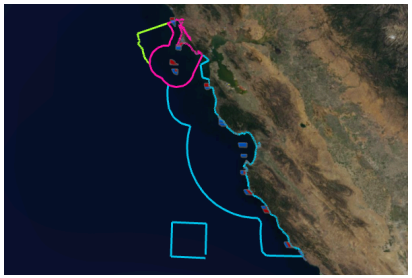
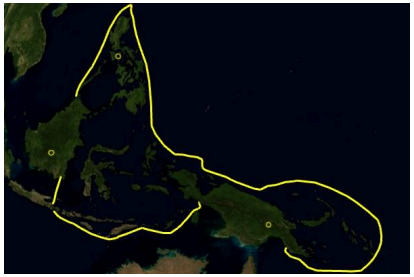
Scene	Narrative	Uniview Commands	Screenshots and Links to Individual Files (KMZs, Images, & Panos)	Citation/Link
01	**Cosmic Scale**			
1.1	In the next 40 minutes, we're going to explore some of the remarkable relationships that support life on our home planet. But the real the star of tonight's show is going to be the oceans and the coral reefs. **Water is Life** But to truly understand the story of Earth's oceans, we have to first turn to the stars. We'll start is by zooming through this interactive Digital Universe Atlas to get a sense of our home planet within its cosmic context. As astronomers have been using powerful telescopes and probes to look for signs of life on other planets in the past few decades, they've gained a greater appreciation of the many conditions necessary to support life as we know it. And chief amongst these is the need for water.	**Custom Events:** ● **Stop Time** **Browser Control (*1. The Global Perspective* tab)** ● **Reset** button		
1.2	**Habitable Zone** But hosting liquid water requires a solid surface, which disqualifies gas giants like Saturn and Jupiter. And on rocky planets, the surface needs to be just the right temperature so water doesn't permanently evaporate or freeze. And it turns out that this can only exist within a very specific distance from the sun. In their search for other habitable planets, astronomers look for planets in what they call the "Goldilocks zone," where	**Custom Events:** ● **HZ On** ● **Planet Labels On** **Uniview Controls:** Fly around the Habitable Zone		Habitable zone marker for the Solar System, created by California Academy of Sciences and SCISS/AB.

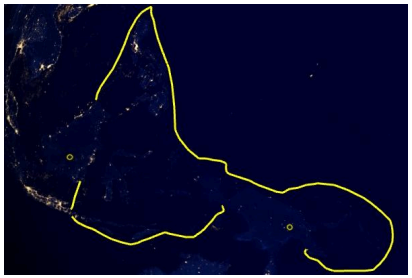
	the temperatures are not too hot and not too cold. And it turns out that in our own solar system, Earth is the only planet within this zone. Unlike Venus and Mars, Earth has temperatures that are just right for liquid water.	**Custom Events:** • **HZ Off** • **Planet Labels Off**		
1.3	**Water in the Solar System** As we pull further away from our home planet, we see the Kuiper belt, a toroidal band of several billion icy bodies that lie outside the orbits of Neptune and Pluto. These are the remnants of planet formation, leftover debris from the early Solar System. And at the outer edge of our solar system, billions of miles from home, we fly through the Oort Cloud, a spherical shell of several trillion icy comets. These bodies, along with many icy moons of the outer planets, contain more than 99% of the water in the Solar System. But the water here is frozen, and inaccessible to life. Astronomers believe that most of the water on Earth came from this cometary ice billions of years ago.	**Custom Events:** • **Kuiper Belt On** • **Oort Cloud On** **Uniview Controls:** Fly around the out to the Kuiper Belt and Oort Cloud **Custom Events:** • **Kuiper Belt Off** • **Oort Cloud Off**		For a review, see T. Encrenaz, 2008, "Water in the Solar System," *Annual Review of Astronomy and Astrophysics*, 46, pp. 57–87. For asteroids contributing to Earth's water, see Alexander, C. M. O'D., Bowden, R., Fogel, M. L., Howard, K. T., Herd, C. D. K., and Nittler, L. R., 2012, "The Provenances of Asteroids, and Their Contributions to the Volatile Inventories of the Terrestrial Planets," *Science,* 337(6095), pp. 721-723. For cometary origins of Earth's water, see Hartogh, P. et al., 2011, "Ocean-like water in the Jupiter-family comet 103P/Hartley 2," *Nature*, 478, pp. 218–220.

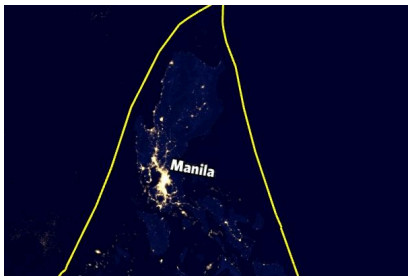
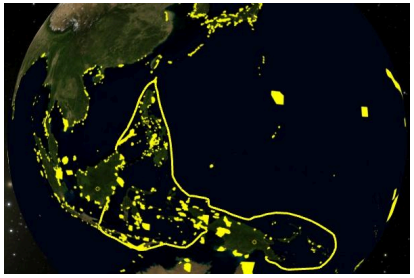
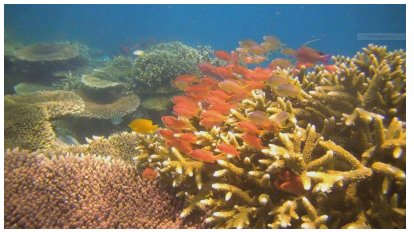
1.4	**Synergy of Earth-Moon-Sun system** And the more we study deep space, the more we continue to find ways that Earth's relationship to its cosmic environment has been conducive to life. For instance, the gravity of our planet's disproportionately large Moon drives the tides of Earth's ocean, which have been essential for evolutionary processes and transporting heat around the planet.	**Uniview Controls:** Fly me to the Moon		NASA/AMNH Digital Universe Atlas http://www.amnh.org/our-research/hayden-planetarium/digital-universe
1.5	**Magnetosphere** Even the magnetic field generated by Earth's molten core—called the magnetosphere—prevents our ocean and atmosphere from being blown away by the solar winds that are constantly bombarding us from the sun.	**Custom Events:** • **Magneto On** **Uniview Controls:** Fly around the Magnetosphere **Custom Events:** • **Magento Off**		Earth's magnetosphere and bow shock is based on model from Charles Goodrich and group (Boston University) of effects from the "Halloween Solar Storms of 2003." For more information about the storm, see this USGS website, and the 2004 NOAA report *Service Assessment: Intense Space Weather Storms october 19 - November 07, 2003* (PDF). Also see the links here and here. Created by the American Museum of Natural History and SCISS/AB.
02	**Global Scale**			

2.1	**Earth has one big ocean** And though we often talk about many oceans on Earth, it actually has one big ocean with many features largely hidden from our view.	**Uniview Controls:** Fly over ocean in a single path over Earth showing that it is one connected system.		Blue Marble Next Generation
2.2	**The ocean is largely unexplored.** And just as we've begun exploring outer space in the past few decades, we're also just really beginning to explore this massive ocean. This is a visualization of the ship's trajectories mapping the ocean floor, but only 5-10% of it has been mapped and explored. This visualization of the oceans bathymetry is what they're revealing. Even so, we still know much less about the bottom of our own planet's ocean than the surface of the Moon or Mars.	**Custom Events:** • **Load California layerset** • **Surveys On** • **Surveys Off** • **Bathymetry On** • **Bathymetry Off**	  **Need to update and Multibeam Bathymetric Surveys and ETOPO1 Hillshade layers with correct Geoscope Tileset reference in layerset**	Ship Tracklines of Multibeam Bathymetric Surveys http://sos.noaa.gov/Datasets/dataset.php?id=146 Earth Topography and Bathymetry http://sos.noaa.gov/Datasets/dataset.php?id=91
2.3	**The ocean and life in the ocean shape the features of Earth.** But as they've studied the ocean, scientists are beginning to better understand the extraordinary degree to which the ocean and the life it supports have shaped the habitability of the entire planet.			

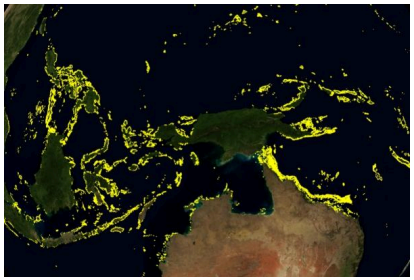
2.4	**The ocean also makes Earth habitable** For instance, the ocean provides over half of the oxygen that we breathe. This visualization show the photosynthesis in the oceans, made possible by microscopic plankton that take CO2 out of the atmosphere to produce "biomass" and oxygen. Both fish and land-based organisms depend on this cycle.	**Custom Events:** • **Load NPP** **Uniview Controls:** Circle the globe. Cycle through the NPP layers in Geoscope.		Net Primary Productivity (NPP) with Sea Ice and monthly labels Visualization by Ned Gardiner based on data from Oregon State University http://www.science.oregonstate.edu/ocean.productivity/
2.5	**Upwelling** An important aspect of the ocean's productivity is determined by interactions between the shape of the ocean floor, Earth's rotation, and the nutrients sweeping up from the deeper, colder waters. The flow of these nutrients up from the deep along coastlines is known as "upwelling," a process that supports the growth of seaweed and plankton. And this provides food for fish, marine mammals, seabirds, and of course, humans. Though upwelling zones are less than 1% of the oceans—shown here—they are responsible for nearly 25% of wild fish catches.	**Custom Events:** • **California layerset** • **Upwelling On** **Uniview Controls:** Explore California coast **Custom Events:** • **Upwelling Off**		Upwelling data provided by Matt Merrifield, Kirk Klausmeyer, Katie Andrews, and Jeanette Howard at The Nature Conservancy. Compiled by Cynthia Powell.
2.6	**Economic value of the oceans** Due to this coastal productivity, nearly one billion people living in coastal communities depend on fish as their primary source of protein. The fisheries sector alone creates jobs for an estimated 180 million people.	**Uniview Controls:** Fly around the California coast.		

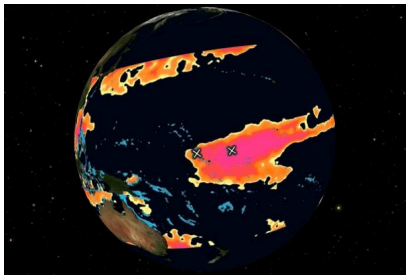
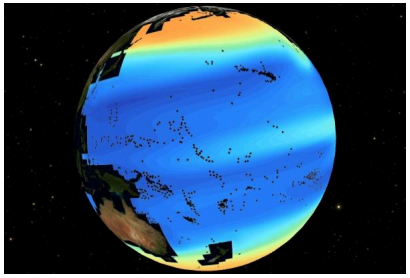
	And the yearly services provided by the oceans, including the provision of food, oxygen, water and climate regulation, are valued at over $21 trillion.			
2.7	**Ecosystem services** The upwelling that exists off our coast fuels tremendous productivity and supports a wide range of species – from plankton all the way up to charismatic megafauna like whales and sharks. And in recent decades, through city, state, Federal and private partnerships, we've done a great job of protecting our coastline, both for future generations and for benefits to our society that we experience and enjoy right now. In California, we've been a leader in coastal conservation and ocean stewardship. And,that's important, because as you will see in the rest of the program, there are other areas around the globe that are tremendously productive and vital to a healthy planet, and that need to be protected at the scale at which we are doing in California.	**Custom Events:** • **Cali MPAs On** **Uniview Controls:** Fly around MPAs **Custom Events:** • **Cali MPAs Off**		National Marine Sanctuary data from the National Marine Sanctuaries Library. Compiled by Kathi Koontz.
2.8	**Coral Triangle** Coral reefs are special places that are only found in a narrow band around the equator and within the tropics, where warm, clear, clean, shallow water provides the right conditions for them to grow. Corals are the ocean's engineers - small, simple animals that work together as a community to build magnificent structures that can even be seen from space. Reef-building corals actually make rock from water - forming their limestone skeletons from dissolved calcium and carbonate ions. The Coral Triangle—'the center of marine biodiversity'—is a region in the Pacific Ocean defined by the island nations of the Philippines, Indonesia and Papua New Guinea. Over 120 million people live in the Coral Triangle and rely on coral reefs for food, protection from storms and economic livelihood.	**Custom Events** • **Philippines Layerset On** • **Coral Triangle On** **Uniview Controls** Fly west across Pacific to get the Coral Triangle into view.		The Coral Triangle outline was provided by ReefBase.org.

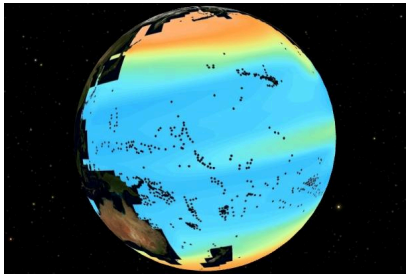
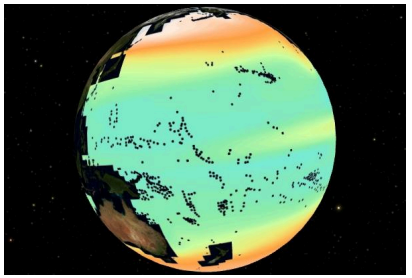
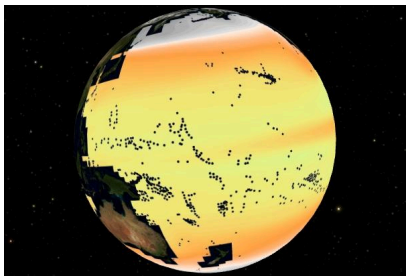
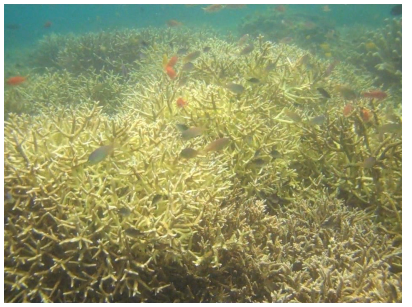
	Though it is just one percent of Earth's surface, the coral triangle contains 1/3 of all coral reefs, 3/4 of the world's corals, and more than 1/3 of all coral reef fish species. It is the spawning ground for many commercially important fishes, including tuna. Commercial fisheries provide a significant amount of the food for people living in the coral triangle and elsewhere. Although this is vital for the economics of the region, the scale at which we are removing fish from the ocean is something that is hard to grasp. In order to help visualize this, we are going to look at the Earth after sunset, when the skies are dark.			
2.9	**Black Marble in the Coral Triangle** What you are seeing right now is the area known as the Coral Triangle. The lights that you see on land are cities and towns, while the lights that you see on the ocean help us to visualize the impacts of global industrial fishing. The scale of this fishing activity is truly astonishing, and it is far from sustainable. And all of this activity is taking place in and around one of the most delicate and critical ecosystems on our planet: coral reefs. Healthy coral reefs support commercial and subsistence fisheries as well as jobs and businesses through tourism and recreation. Within the US, approximately half of all federally managed fisheries depend on coral reefs and related habitats for a portion of their life cycles. And these fisheries that we depend on are at risk. 87% of measured species are fully exploited or collapsed. Globally, coral reefs provide a net benefit of $9.6 billion/year from tourism and recreation revenues and $5.7 billion/year from fisheries. Recreational fisheries on coral reefs account for more than $100 million a year, in the US alone.	**Custom Events** ● **Black Marble On** ● **City Labels On** **(DM: Fix Black Marble/Planet FX issue so the City Labels show up)**	 	Coral reef data from Natural Earth. Compiled by Cynthia Powell.

	Coral reefs are beautiful. They offer tremendous benefits to human society—and not just people living adjacent to reefs. They are an essential part of the diversity in our one connected ocean, and nowhere are they more concentrated than an area known as the Coral Triangle.			
2.10	**Marine Protected Areas** Academy scientists are working with partners in the Philippines on the restoration of damaged and human-impacted coral reefs. And we work with local governments to improve the resilience of this globally important region. This is a story about the Philippines, but it's also a story about the rest of the world because reef ecosystems need protection—by all of us—to keep communities vibrant and resilient worldwide. One form of protection is a "Marine Protected Area", For MPA" Today the Philippines hosts about 10% of the world's MPAs—over 500, a figure far greater than any other country in Southeast Asia. Established largely through local government initiatives and maintained through the blood, sweat and tears of local coastal communities, these undersea enclaves are scattered throughout the archipelago to provide vital safe havens for Philippine marine life.	**Custom Events** • **Global MPAs On** **Uniview Controls** Start in Coral Triangle/Philippines and go around the world and end in Philippines **Custom Events** • **Global MPAs Off** • **Coral Triangle Off**		Data from UNESCO. Compiled by Kathi Koontz.
2.11	**Coral Reef Biology** Coral reefs are places that embody the mystery and beauty of the ocean and also bring to light some of the challenges we have as a species when dealing with the enormous ocean environment that dominates our planet. Coral reefs are among the oldest ecosystems in the world. Ancestors of today's reef building corals go back 200	**Video (outside of Uniview)** • **beauty.mpv** video		Video provided/copyrighted by Bart Shepherd, California Academy of Sciences.

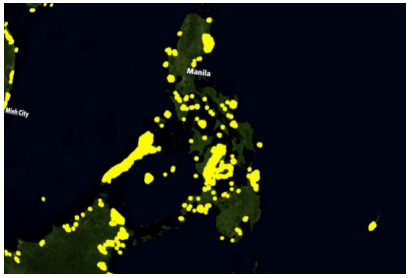
	million years. This means they've weathered at least 3 mass extinctions. Coral reefs are often called the Rainforests of the Sea. Much like these lush terrestrial forests, they are areas of exceptionally high biodiversity, containing many of the ocean's species. Since I am a marine biologist, and admittedly ocean-biased, I prefer to think of this the other way around: that Rainforests are the "Coral Reefs of the Land". When we look at coral reefs, we often feel a sense of peace and tranquility. Nothing could be farther from the truth! Because such an immense amount of biodiversity is packed into such a small area, there is tremendous competition for space and resources. In fact, rather than being peaceful and serene, coral reefs are more like a major city—say New York City—but with complex biological and chemical warfare going on at all times! On a mature reef, new substrate (bare rock) is rare, and is subject to intense competition. Corals and other animals, are fiercely competing for space—deploying specialized stinging tentacles to kill and digest their neighbors, and releasing toxic compounds into the water to poison their neighbors in an attempt to create more space for them. Other species compete through rapid growth—by forming tables, thickets of branches that shade their neighbors—starving them of the sunlight that they need to nourish their life-giving symbiotic algae. On mature coral reefs, biodiversity is maintained by periodic disturbances—such as waves, wind and storms that break off or flip over corals and expose bare limestone rock. On healthy reefs, coral recruits, encrusting algae and other invertebrates immediately colonize these spaces. When reefs aren't healthy or where herbivorous fishes have been removed, we often see a shift to an ecosystem dominated by filamentous algae or seaweed, and an overall loss of		 beauty.mpv (380.7)	

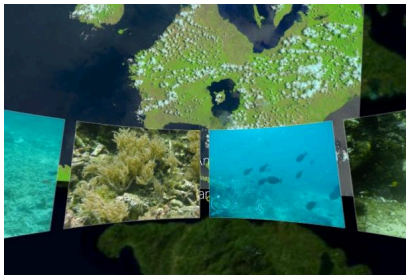
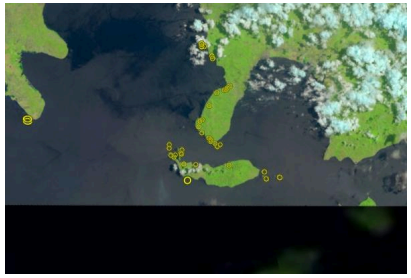
	diversity. Because reef-building corals require clean, clear, warm, shallow ocean waters they are limited to a small range around the globe.			
2.12	**Global Distribution of Reefs** Corals are the oceans' engineers. These tiny, simple, gelatinous animals build massive, complex, 3-dimensional structures by taking dissolved carbon and converting it to limestone. Essentially, they make rock from water. The hard structures they create, coral reefs, are critical habitat for thousands of species: fish, algae, and invertebrates, even humans. This process is largely due to a complex symbiotic relationship between an animal (the coral polyp) and a plant (called zooxanthellae, or symbiotic algae). The coral hosts the plant, giving it shelter and providing it with animal wastes in the form of carbon dioxide and organic molecules. In turn, the algae produces oxygen and converts sunlight to sugar, providing the coral with more than 90% of the energy that it needs to live and grow. The coral animals supplement this by feeding on plankton that they catch with their small stinging tentacles. Coral polyps live in colonies of genetically identical clones formed through division, or "budding". All of the polyps in a colony are derived from a single larvae that settled out of the plankton on to a suitable site on the reef, metamorphosed into a coral polyp and then started cloning itself over and over again. Individual corals can grow rather quickly, assuming conditions are ideal. Coral reefs, however, take decades to grow. Although individual polyps may be relatively short-lived, coral colonies can live for centuries, preserving the genetics of that original larva over many, many lifetimes.	**Custom Events** • **World Reefs On** **Uniview Controls** Pull out from the Coral Triangle and pan around the world. **Custom Events** • **World Reefs Off**		Coral reef data from Natural Earth. Compiled by Cynthia Powell.

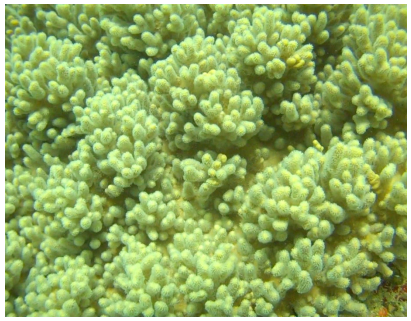
2.13	**Reef Threats** Pollution impacts coral reefs in a variety of ways. Trash and garbage introduced into the ecosystem obviously causes problems, but one of the more pressing issues is the release of organic waste in the form of sewage. In developing countries, where wastewater treatment has not been modernized, or doesn't even exist, the release of raw sewage onto coral reefs introduces nutrients, pharmaceuticals, and disease agents. Because coral reefs exist so close to shore, they are particularly vulnerable to pollution. Increasing nutrient levels fuel algae growth, and what scientists call a "phase-shift", where the coral reef ecosystem changes into an algae-dominated ecosystem. The removal of herbivores by subsistence fishers enhances this impact.			
2.14	**Climate change** The symbiotic relationship between corals and zooxanthellae is a complex arrangement that only works within a narrow environmental range, so it is especially vulnerable to the impacts of climate change. When the temperature increases above 30'C (or 86' F), the algae actually start to poison the corals by producing too many free radicals, so the coral "expels" the algae through its mouth—a process known as "bleaching". When conditions improve, the corals can re-infect themselves with zooxanthellae that they collect from the water column. When you combine repeated bleaching episodes with other impacts such as pollution and disease, the corals simply cannot recover, and the reefs begin to die. Here you see a graphic documenting the accumulated heat stress that occurred during a global bleaching event in 2010, the warmest year on record. Blue regions show the distribution of coral reefs. The yellow and orange areas are zones where the water has stayed too warm over several weeks, leading to	**Video (outside of Uniview)** • **bleaching.mpv** video **Custom Events** • **Load Threats** layerset • **Heat Stress On** • **Heat Stres Off**	 	Heat stress on coral reef layer from NOAA SOS and AMNH's Science Bulletin. This visualization features 2010 Degree Heating Weeks data from the NOAA Coral Reef Watch program, which are based on sea-surface temperature measurements taken every three days from the AVHRR sensor on NOAA's polar-orbiting satellites. Coral reef locations are from the World Resource Insitute's *Reefs at Risk Revisited* report, The coral bleaching observations are derived from reports to

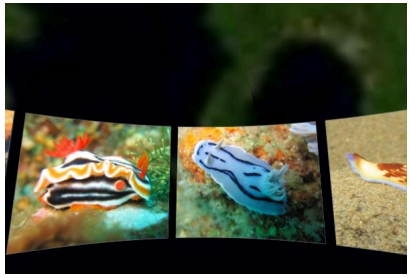
	accumulated heat stress. Orange regions show where bleaching is likely to occur, while the pink indicates that coral death is likely. The large X's mark where scientists have observed massive coral bleaching. Ocean acidification is a major concern and could become one of the primary reasons for the collapse of coral reefs. As atmospheric carbon dioxide levels increase, the pH of the ocean decreases—making the water more acidic. This acidity has the potential to make it harder for corals to build their skeletons. So, in the near future, corals will grow more slowly and build less robust reefs—and we don't know if they will be able to keep up with the constant damage caused by waves, storms and other eroding organisms. Here is what ocean pH looked like in pre-industrial times, in 1885. As the color moves from blue to orange, you see the ocean becoming more acidic: what it is today, and in a projection of what it will be like mid-century, in 2048 and at the end of the century, in 2094. The grey dots you see are the current location of coral reefs. As we move to later in the century, these areas will no longer support this kind of life. Approximately 30% of the Earth's coral reefs have been destroyed to date and another 30% could be gone by 2040. But all is not lost. By identifying areas of species richness, like the coral triangle, and protecting reefs that are located in areas less impacted by climate change, such as those adjacent to deep, cooler waters, we can help preserve healthy reef ecosystems far into the future.	**Custom Events** • **OA 1885 On** • **OA 2013 On** • **OA 2048 On** • **OA 2094 On** • **OA 1885 Off** • **OA 2013 Off** • **OA 2048 Off** • **OA 2094 Off**	    bleaching.mpv (124.1MB)	ReefBase and the NOAA Coral Reef Watch program. Ocean acidfication data from NOAA SOS; also see link for more information. The dataset shows computer model simulations of surface ocean pH from 1885-2094, with continents and coral reefs marked. The low-pass filtered monthly pH of the surface ocean os as modeled by the Community Climate System Model 3.1 (CCSM3.1 Doney, S.C. et al., 2009, "Skill metrics for confronting global upper ocean ecosystem-biogeochemistry models against field and remote sensing data," *Journal of Marine Systems*, 76(1-2), pp. 95-112). The model simulation is driven with atmospheric emissions based on records of atmospheric carbon dioxide levels, for past dates, and the A2 IPCC SRES scenario for future dates

				(approx. 850 ppm atmospheric CO2 by 2100). Low-pass filtration removes seasonality and interannual variability with a period of less than 10 years. White indicates no data. Video provided/copyrighted by Bart Shepherd, California Academy of Sciences.
3	**Continental Scale**			

3.1	**Philippines** The Coral triangle region has been hailed by globally-renowned coral expert Dr. Charles Veron as 'the center of world marine diversity'—an area so implausibly productive that a single square kilometer can keep on producing over 40 metric tons of fresh seafood year over year. With proper protection, these coral reefs can eradicate Asian poverty and feed billions—a coral-coated cornucopian horn unlike any other. The Philippine MPA story begins in 1974—a time when cyanide and blast fishing were at their peak. Under the capable guidance of Silliman University, a portion of Sumilon Isle off the southeastern tip of Cebu was declared a no-take zone—and the country's first MPA was born. From 1974 onwards, 25% of Sumilon's coral reefs were meticulously protected. Ten years of improved fish yields from both within and outside the protected zone proved the strategy was sound. Protection waned in 1985 however, causing fish yields to dwindle. The Sumilon experience proved that constant vigilance was essential to keep MPAs alive and productive. Today the Philippines hosts about 10% of the world's MPAs—over 500, a figure far greater than any other country in Southeast Asia. Established largely through local government initiatives and maintained through the blood, sweat and tears of local coastal communities, these undersea enclaves are scattered throughout the archipelago to provide vital safe havens for Philippine marine life.	**Custom Events** • **Load Philippines** layerset • **Coral Triangle On** • **Global MPAs On** **Uniview Controls:** Zoom out and show Philippines MPAs and coral triangle. **Custom Events** • **Coral Triangle Off** • **Global MPAs Off**		Philippine MPAs from ReefBase.org and compiled by Kathi Koontz.

3.2	**MPAs and Princess** Sometimes all it takes the brave, selfless actions of a single individual to protect and preserve a habitat for future generations. In Anilao, Princess realized that decades of unsustainable fishing, especially blast fishing, was causing irreparable damage to the reef off of her home. Despite hostility from the fishermen in her village, including threats on her life, she led the charge to designate this reef as a marine protected area. All fishing and diving are off-limits—giving the reef time to recover from the damage caused by irresponsible fishing practices. A few years ago, on an Academy expedition to the Philippines, we were presented with the opportunity to dive on Princess's reef. While much of the bottom still showed evidence of the destruction of dynamite fishing, huge schools of fish—species we did not see elsewhere—populated the water column. You could see clearly that with mitigation of destructive practices and community-based protection the reef will rebound. What really struck me was that Princess did all of this without knowing what the reef looked like. Never in her life had she put her head underwater and seen the beauty that lies beneath the sea just off the shores of her small village	**Custom Events** • **Princess Reef On** • **Princess Reef Off** • **Load Threats** layerset • **Princess Reef pan** button **Uniview Controls:** Fly to Anilao	 	Landsat 8 Image Landsat Scene Identifier: LC81160502013115LGN01 Date Acquired: 25-APR-13
3.3	**Anilao and Dive Sites** The Philippines forms the apex of the Coral Triangle and is the world's second-largest archipelago. Within this exquisite region sits 7107 emerald isles fringed by 27,000 square kilometers of coral reef. The area known popularly as "Anilao" lies within the Verde Island Passage, on the southwest end of the main island of	**Custom Events** • **Anilao On** • **Anilao Off** • **Dive Sites On**		Dive Sites from Dr. Terry Gosliner, Senior Curator, Invertebrate Zoology & Geology, California Academy of Sciences. Video provided/copyrighted

	Luzon. This area is one of 4 major biodiversity hotspots in the coral triangle region, and has been called the "center of the center" of marine biodiversity by several prominent scientists. Through scientific study, we know that more species of reef fishes are found here than anywhere else on earth. We know that more species of nudibranchs, colorful sea slugs, are found here than anywhere else on earth. And we have witnessed one dive site, Devil's Rock, where there are more species of soft corals than in the entire Caribbean basin. We think what makes this region so productive is the upwelling—cooler, nutrient-rich waters coming up from the depths bring food into the community and support a rich assemblage of species. In some ways, this is similar to the upwelling that occurs off our coast here in California. And these cool waters may provide a buffer against some of the impacts of climate change, making the Verde Island Passage of particular importance for conservation.	• **Dive Sites Off** (move to philippines) • **Video (outside of Uniview)** Show 2 minutes of Spawning video • **devilsrock.mpv** video	HEP_Dives.kmz  devilsrock.mpv (51.5MB)	by Bart Shepherd, California Academy of Sciences.
3.4	Terry Gosliner, the Dean of Science and Collections at the Academy has been traveling to the Verde Island Passage for more than 20 years, diving and documenting the nudibranchs (colorful sea slugs) found in these waters. Even though he has been diving on the same dive sites, on the same small peninsula, on the same island, year after year, he still finds a new species of nudibranch on nearly every dive. In fact, he and his colleagues have documented the presence of more than 1000 species of nudibranchs in this region, and the species accumulation curve (the rate of discovery of new occurrences or species) doesn't seem to be slowing down. This is just one example and evidence of the immense biological diversity in this region.	**Custom Events** • **Gosliner On** • **Goslinger Off** • **Nudibranchs On** • **Nudibranchs Off**		Images provided by Meg Burke, Terry Gosliner, and Bart Shepherd, California Academy of Sciences.

				
3.5	**Sexual reproduction of corals and SECORE** One way that we are working to continue to enhance the study and conservation of marine biodiversity in the Philippines is through the expansion of Project SECORE into the Philippines. SECORE is a network of scientists, public aquarium professionals, conservation biologists and concerned citizens, united with the goal of utilizing the corals' natural methods of sexual reproduction for conservation purposes. During coral spawning events, coral colonies release bundles of gametes into the water column. These gametes float to the surface, where fertilization takes place, and then they become part of the plankton, drifting and developing into tiny coral larvae that will then swim down and form new colonies. Because such a small percentage of these survive to adulthood, scientists can collect the gametes, culture them through the delicate larval phase, settle them, and then use the resulting colonies to enhance populations of target species on wild coral reefs. SECORE has had proven success working with 2 species of endangered stony corals in the Caribbean. Through our partnerships in the Philippines, and as a member of the SECORE network, we are working to introduce these techniques for conservation in the Philippines.	**Custom Events** • **SEC PANO On** • **SEC PANO Off** (move to Philippines) • **Video (outside of Uniview)** Show 2 minutes of Spawning video • **coralspawn.mpv** video	  	Video provided/copyrighted by Bart Shepherd, California Academy of Sciences.

	In addition, as a way to create jobs and provide an economic incentive to protect coral reefs, the Philippines Government Bureau of Fisheries is exploring the possibility of allowing coral farming for export to the global aquarium trade if it is undertaken using SECORE techniques. We are currently involved in discussions with partners in the Philippines about this project and plan to conduct the first SECORE Philippines spawning workshop sometime in 2014. Please join us in the classroom after this program for an open discussion on community-based conservation and socio-economic connections to reef restoration.		 coralspawn.mpv (181.3MB)	
4	**Local Scale**			
4.1	**Steinhart Aquarium** Here at the California Academy of Sciences, our Philippine Coral Reef exhibit is not only a beautiful place to sit, relax and watch the activities of thousands of fish, it is also a stage- where we engage audiences in conservation education, and deliver programs that address complex topics such as ocean acidification and sustainable fishing. I'd like to invite you to join us for a Coral Reef Dive show, which takes place every day at 11:30am and 2:30pm. The Academy's Philippine Coral Reef exhibit is a simulated, simplified ecosystem of sorts, designed to reflect the beauty and diversity of the coral reefs of Anilao in the Verde Island Passage. The exhibit consists of a central 200,000-gallon aquarium—the largest and deepest indoor coral reef in the world—surrounded by several galleries of smaller tanks that highlight various evolutionary and ecological themes associated with coral reefs. The design and development of this exhibit took more than 6 years, and we are celebrating the 5 year anniversary of its opening	**Uniview Controls:** Fly to the Academy. • **Video (outside of Uniview)** Show 2 minutes of Spawning video • **coral.mpv** video	 coral.mpv (242.4)	Coral video provided/copyrighted by Will Love, California Academy of Sciences. Coral spawn video provided/copyrighted by Bart Shepherd, California Academy of Sciences.

	later this month. A team of biologists, water quality specialists, life-support engineers and SCUBA divers work everyday to ensure the health and vitality of the exhibit as we try and grow a living coral reef far from where it would naturally be found. As you can imagine, growing a mature coral reef from a bare concrete structure in a concrete and glass building, in a public park, in a major metropolitan area in Northern California is not without its challenges. One of our main challenges with this exhibit was acquiring the corals. While it is possible to obtain permits to collect and export 1000 square feet of a reef from countries that export living coral as a natural resource, that really didn't fit with the mission of the Academy—"to explore, explain and sustain life". So, we went about obtaining our corals in an entirely different way—by cultivating them from cuttings, or fragments, grown in aquaria all around the country. Approximately 50% of the corals that you see in our display were grown at the Academy over a period of many years, from small branches taken from corals growing in other aquaria. Greenhouse gardening, if you will, except with animals. We also partnered with the US Fish and Wildlife Service to place corals that were confiscated as they entered the United States due to improper permits, misidentification, or downright smuggling. About ¼ of the corals in our exhibit were confiscations that would otherwise die if they could not be placed with a public aquarium. To date, with nearly 1000 colonies of coral, representing more than 100 species, we have not purchased a single piece of wild-collected coral for our exhibit. This acquisition policy directly reflects our mission of sustainability and conservation education.	**Video (outside of Uniview)** Show 2 minutes of Spawning video • **coralspawn.mpv** video	 collecting.mpv (63.6MB)	
5	**Conclusion**			

5.1	Real reefs are not aquaria—they are part of a connected ocean system. People are using a variety of strategies to protect them in a changing world. MPAs, social entrepreneurial (come to discussion), studying/understanding supply chains.	**Custom Events** ● **Closing ASKY** button		Photograph provided/copyrighted by Tim Horn, California Academy of Sciences.
5.2	Human well-being is tied to our ocean ecosystems and less than 2% of marine ecosystems are protected, while subsidies still encourage overfishing and oil drilling in fragile ecosystems like the Arctic. Need to prioritize protection. We live in a special place. You're visiting a special building. You can engage with the natural world and make a difference.			

Credits
Partners

- California Academy of Sciences http://www.calacademy.org
- NOAA Climate Program Office http://www.climate.noaa.gov
- The Elumenati http://www.elumenati.com

Funders

- National Oceanic and Atmospheric Administration Office of Education NA10SEC0080011, NA10SEC0080017 http://www.oesd.noaa.gov
- California Academy of Sciences http://www.calacademy.org

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Technical Support: Dan Tell (CAS), Ka Chun Yu (DMNS)

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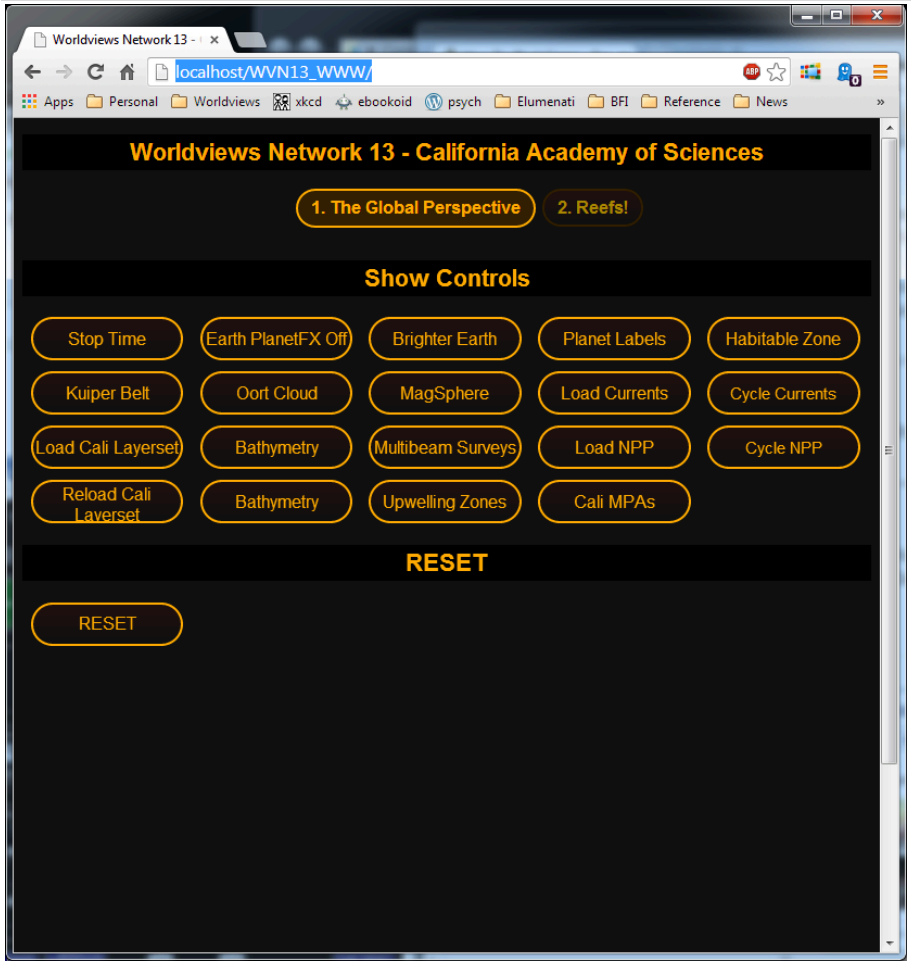
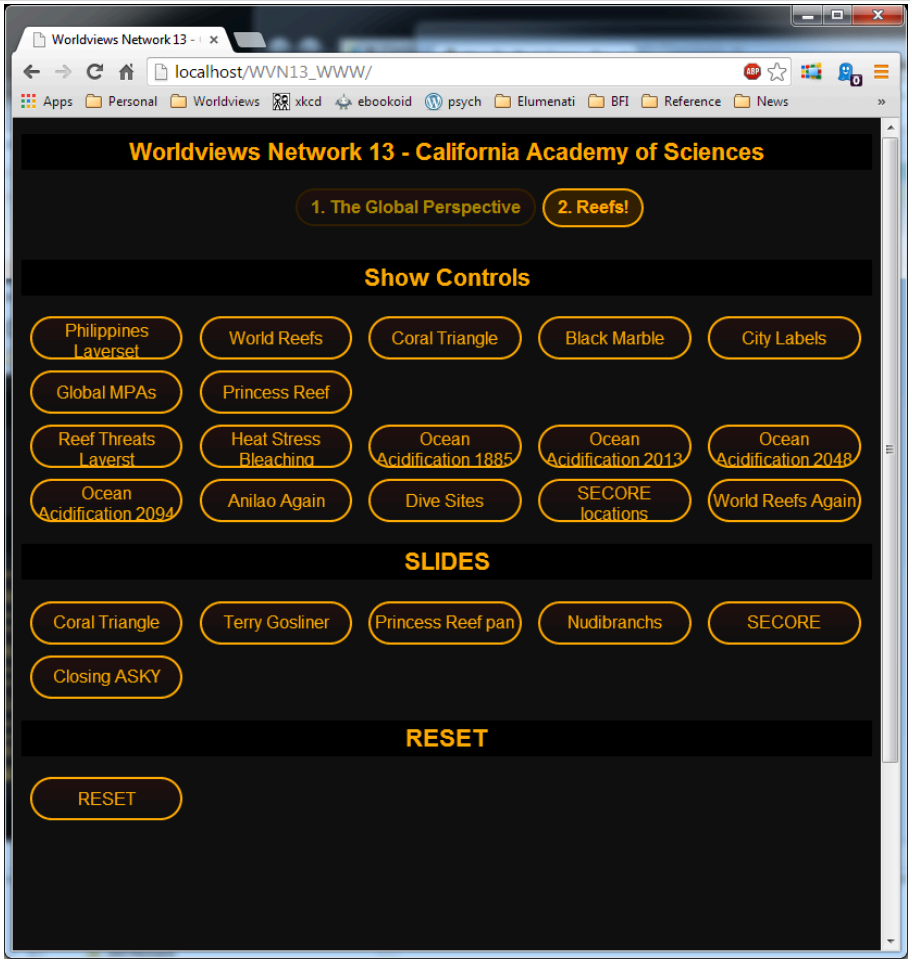
Browser Screenshots

1. The Global Perspective



2. Reefs!



Essential Principles of Climate Science

For complete listing of the Climate Literacy Essential Principles, see http://cpo.noaa.gov/OutreachandEducation/ClimateLiteracy.aspx
Only those principles that are addressed in the "CAS The Hidden Ocean" narrative are listed below. Only scenes 1 & 2 address the Climate Literacy Principles. Due to the content of this narrative, the remainder of the content has been aligned with NOAA's Ocean Literacy Framework (below).

Climate Literacy Principles and their alignment with Scenes	1	2
1. The Sun is the primary source of energy for Earth's climate system.	**X**	
A. Sunlight reaching the Earth can heat the land, ocean, and atmosphere. Some of that sunlight is reflected back to space by the surface, clouds, or ice. Much of the sunlight that reaches Earth is absorbed and warms the planet.	**X**	
2. Climate is regulated by complex interactions among components of the Earth system.		**X**
B. Covering 70% of Earth's surface, the ocean exerts a major control on climate by dominating Earth's energy and water cycles. It has the capacity to absorb large amounts of solar energy. Heat and water vapor are redistributed globally through density-driven ocean currents and atmospheric circulation. Changes in ocean circulation caused by tectonic movements or large influxes of fresh water from melting polar ice can lead to significant and even abrupt changes in climate, both locally and on global scales.		**X**
D. The abundance of greenhouse gases in the atmosphere is controlled by biogeochemical cycles that continually move these components between their ocean, land, life, and atmosphere reservoirs. The abundance of carbon in the atmosphere is reduced through seafloor accumulation of marine sediments and accumulation of plant biomass and is increased through deforestation and the burning of fossil fuels as well as through other processes.		**X**
F. The interconnectedness of Earth's systems means that a significant change in any one component of the climate system can influence the equilibrium of the entire Earth system. Positive feedback loops can amplify these effects and trigger abrupt changes in the climate system. These complex interactions may result in climate change that is more rapid and on a larger scale than projected by current climate models.		**X**
3. Life on Earth depends on, is shaped by, and affects climate.	**X**	**X**
A. Individual organisms survive within specific ranges of temperature, precipitation, humidity, and sunlight. Organisms exposed to climate conditions outside their normal range must adapt or migrate, or they will perish.	**X**	**X**

B. The presence of small amounts of heat-trapping greenhouse gases in the atmosphere warms Earth's surface, resulting in a planet that sustains liquid water and life.	**X**	
C. Changes in climate conditions can affect the health and function of ecosystems and the survival of entire species. The distribution patterns of fossils show evidence of gradual as well as abrupt extinctions related to climate change in the past.		**X**
5. Our understanding of the climate system is improved through observations, theoretical studies, and modeling.		**X**
A. The components and processes of Earth's climate system are subject to the same physical laws as the rest of the Universe. Therefore, the behavior of the climate system can be understood and predicted through careful, systematic study.		**X**
B. Environmental observations are the foundation for understanding the climate system. From the bottom of the ocean to the surface of the Sun, instruments on weather stations, buoys, satellites, and other platforms collect climate data. To learn about past climates, scientists use natural records, such as tree rings, ice cores, and sedimentary layers. Historical observations, such as native knowledge and personal journals, also document past climate change.		**X**
C. Observations, experiments, and theory are used to construct and refine computer models that represent the climate system and make predictions about its future behavior. Results from these models lead to better understanding of the linkages between the atmosphere-ocean system and climate conditions and inspire more observations and experiments. Over time, this iterative process will result in more reliable projections of future climate conditions.		**X**
6. Human activities are impacting the climate system.		**X**
B. Emissions from the widespread burning of fossil fuels since the start of the Industrial Revolution have increased the concentration of greenhouse gases in the atmosphere. Because these gases can remain in the atmosphere for hundreds of years before being removed by natural processes, their warming influence is projected to persist into the next century.		**X**
C. Human activities have affected the land, oceans, and atmosphere, and these changes have altered global climate patterns. Burning fossil fuels, releasing chemicals into the atmosphere, reducing the amount of forest		**X**

cover, and rapid expansion of farming, development, and industrial activities are releasing carbon dioxide into the atmosphere and changing the balance of the climate system.		
D. Growing evidence shows that changes in many physical and biological systems are linked to human-caused global warming.[3] Some changes resulting from human activities have decreased the capacity of the environment to support various species and have substantially reduced ecosystem biodiversity and ecological resilience.		**X**
E. Scientists and economists predict that there will be both positive and negative impacts from global climate change. If warming exceeds 2 to 3°C (3.6 to 5.4°F) over the next century, the consequences of the negative impacts are likely to be much greater than the consequences of the positive impacts.		**X**
7. Climate change will have consequences for the Earth system and human lives.		**X**
D. The chemistry of ocean water is changed by absorption of carbon dioxide from the atmosphere. Increasing carbon dioxide levels in the atmosphere is causing ocean water to become more acidic, threatening the survival of shell-building marine species and the entire food web of which they are a part.		**X**
E. Ecosystems on land and in the ocean have been and will continue to be disturbed by climate change. Animals, plants, bacteria, and viruses will migrate to new areas with favorable climate conditions. Infectious diseases and certain species will be able to invade areas that they did not previously inhabit.		**X**

For complete listing of the Ocean Literacy Framework, see http://oceanliteracy.wp2.coexploration.org/brochure/
Only those Ocean Literacy Essential principles that are addressed in the “CAS The Hidden Ocean” narrative are listed below.
Only scenes 2, 3 & 4 address Ocean Literacy Principles.

1. The Earth has one big ocean with many features.	**2**	**3**	**4**
a. The ocean is the defining physical feature on our planet Earth—covering approximately 70% of the planet’s surface. There is one ocean with many ocean basins, such as the North Pacific, South Pacific, North Atlantic, South Atlantic, Indian, Southern, and Arctic.	**X**		
b. Ocean basins are composed of the seafloor and all of its geological features (such as islands, trenches, mid-ocean ridges, and rift valleys) and vary in size, shape and features due to the movement of Earth’s crust (lithosphere). Earth’s highest peaks, deepest valleys and flattest plains are all in the ocean.	**X**		
c. Throughout the ocean there is one interconnected circulation system powered by wind, tides, the force of Earth’s rotation (Coriolis effect), the Sun and water density differences. The shape of ocean basins and adjacent land masses influence the path of circulation. This “global ocean conveyor belt” moves water throughout all of the ocean basins, transporting energy (heat), matter, and organisms around the ocean. Changes in ocean circulation have a large impact on the climate and cause changes in ecosystems.			
d. Sea level is the average height of the ocean relative to the land, taking into account the differences caused by tides. Sea level changes as plate tectonics cause the volume of ocean basins and the height of the land to change. It changes as ice caps on land melt or grow. It also changes as sea water expands and contracts when ocean water warms and cools.			
e. Most of Earth’s water (97%) is in the ocean. Seawater has unique properties. It is salty, its freezing point is slightly lower than fresh water, its density is slightly higher, its electrical conductivity is much higher, and it is slightly basic. Balance of pH is vital for the health of marine ecosystems, and important in controlling the rate at which the ocean will absorb and buffer changes in atmospheric carbon dioxide.	**X**		
f. The ocean is an integral part of the water cycle and is connected to all of Earth’s water reservoirs via evaporation and precipitation processes.			
g. The ocean is connected to major lakes, watersheds, and waterways because all major watersheds on Earth drain to the ocean. Rivers and streams transport nutrients, salts, sediments, and pollutants from watersheds to coastal estuaries and to the ocean.			

h. Although the ocean is large, it is finite, and resources are limited.			
2. The ocean and life in the ocean shape the features of Earth.			
a. Many earth materials and biogeochemical cycles originate in the ocean. Many of the sedimentary rocks now exposed on land were formed in the ocean. Ocean life laid down the vast volume of siliceous and carbonate rocks.	**X**		
b. Sea level changes over time have expanded and contracted continental shelves, created and destroyed inland seas, and shaped the surface of land.			
c. Erosion—the wearing away of rock, soil and other biotic and abiotic earth materials—occurs in coastal areas as wind, waves, and currents in rivers and the ocean, and the processes associated with plate tectonics move sediments. Most beach sand (tiny bits of animals, plants, rocks, and minerals) is eroded from land sources and carried to the coast by rivers; sand is also eroded from coastal sources by surf. Sand is redistributed seasonally by waves and coastal currents.			
d. The ocean is the largest reservoir of rapidly cycling carbon on Earth. Many organisms use carbon dissolved in the ocean to form shells, other skeletal parts, and coral reefs.	**X**		
e. Tectonic activity, sea level changes, and the force of waves influence the physical structure and landforms of the coast.			
3. The ocean is a major influence on weather and climate.			
a. The interaction of oceanic and atmospheric processes controls weather and climate by dominating the Earth's energy, water, and carbon systems.			
b. The ocean moderates global weather and climate by absorbing most of the solar radiation reaching Earth. Heat exchange between the ocean and atmosphere drives the water cycle and oceanic and atmospheric circulation.			
c. Heat exchange between the ocean and atmosphere can result in dramatic global and regional weather phenomena, impacting patterns of rain and drought. Significant examples include the El Niño Southern Oscillation and La Niña, which cause important changes in global weather patterns because they alter the sea surface temperature patterns in the Pacific.			
d. Condensation of water that evaporated from warm seas provides the energy for hurricanes and			

cyclones. Most rain that falls on land originally evaporated from the tropical ocean.			
e. The ocean dominates Earth's carbon cycle. Half of the primary productivity on Earth takes place in the sunlit layers of the ocean. The ocean absorbs roughly half of all carbon dioxide and methane that are added to the atmosphere.	**X**		
f. The ocean has had, and will continue to have, a significant influence on climate change by absorbing, storing, and moving heat, carbon, and water. Changes in the ocean's circulation have produced large, abrupt changes in climate during the last 50,000 years.	**X**		
g. Changes in the ocean-atmosphere system can result in changes to the climate that in turn, cause further changes to the ocean and atmosphere. These interactions have dramatic physical, chemical, biological, economic, and social consequences.	**X**		
4. The ocean made Earth habitable.			
a. Most of the oxygen in the atmosphere originally came from the activities of photosynthetic organisms in the ocean. This accumulation of oxygen in Earth's atmosphere was necessary for life to develop and be sustained on land.	**X**		
b. The ocean is the cradle of life; the earliest evidence of life is found in the ocean. The millions of different species of organisms on Earth today are related by descent from common ancestors that evolved in the ocean and continue to evolve today.			
c. The ocean provided and continues to provide water, oxygen, and nutrients, and moderates the climate needed for life to exist on Earth.	**X**	**X**	
5. The ocean supports a great diversity of life and ecosystems.			
a. Ocean life ranges in size from the smallest living things, microbes, to the largest animal on Earth, blue whales.	**X**		
b. Most of the organisms and biomass in the ocean are microbes, which are the basis of all ocean food webs. Microbes are the most important primary producers in the ocean. They have extremely fast growth rates and life cycles, and produce a huge amount of the carbon and oxygen on Earth.	**X**		
c. Most of the major groups that exist on Earth are found exclusively in the ocean and the diversity of major groups of organisms is much greater in the ocean than on land.	**X**		

d Ocean biology provides many unique examples of life cycles, adaptations, and important relationships among organisms (symbiosis, predator-prey dynamics, and energy transfer) that do not occur on land.		**X**	
e. The ocean provides a vast living space with diverse and unique ecosystems from the surface through the water column and down to, and below, the seafloor. Most of the living space on Earth is in the ocean.	**X**	**X**	
f. Ocean ecosystems are defined by environmental factors and the community of organisms living there. Ocean life is not evenly distributed through time or space due to differences in abiotic factors such as oxygen, salinity, temperature, pH, light, nutrients, pressure, substrate, and circulation. A few regions of the ocean support the most abundant life on Earth, while most of the ocean does not support much life.	**X**	**X**	
g. There are deep ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms. Hydrothermal vents, submarine hot springs, and methane cold seeps, rely only on chemical energy and chemosynthetic organisms to support life.			
h. Tides, waves, predation, substrate, and/or other factors cause vertical zonation patterns along the coast; density, pressure, and light levels cause vertical zonation patterns in the open ocean. Zonation patterns influence organisms' distribution and diversity.	**X**		
i. Estuaries provide important and productive nursery areas for many marine and aquatic species.			
6 The ocean and humans are inextricably interconnected.			
a. The ocean affects every human life. It supplies freshwater (most rain comes from the ocean) and nearly all Earth's oxygen. The ocean moderates the Earth's climate, influences our weather, and affects human health.	**X**		
b. The ocean provides food, medicines, and mineral and energy resources. It supports jobs and national economies, serves as a highway for transportation of goods and people, and plays a role in national security.	**X**	**X**	
c. The ocean is a source of inspiration, recreation, rejuvenation, and discovery. It is also an important element in the heritage of many cultures.	**X**		**X**
d. Humans affect the ocean in a variety of ways. Laws, regulations, and resource management affect what is taken out and put into the ocean. Human development and activity	**X**	**X**	

leads to pollution (point source, nonpoint source, and noise pollution), changes to ocean chemistry (ocean acidification), and physical modifications (changes to beaches, shores, and rivers). In addition, humans have removed most of the large vertebrates from the ocean.			
e. Changes in ocean temperature and pH due to human activities can affect the survival of some organisms and impact biological diversity (coral bleaching due to increased temperature and inhibition of shell formation due to ocean acidification).	**X**		
f. Much of the world's population lives in coastal areas. Coastal regions are susceptible to natural hazards (tsunamis, hurricanes, cyclones, sea level change, and storm surges).	**X**		
g. Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.	**X**	**X**	**X**
7. The ocean is largely unexplored.			
a. The ocean is the largest unexplored place on Earth—less than 5% of it has been explored. The next generation of explorers and researchers will find great opportunities for discovery, innovation, and investigation.	**X**		
b. Understanding the ocean is more than a matter of curiosity. Exploration, experimentation, and discovery are required to better understand ocean systems and processes. Our very survival hinges upon it.			
c. Over the last 50 years, use of ocean resources has increased significantly; the future sustainability of ocean resources depends on our understanding of those resources and their potential.	**X**	**X**	
d. New technologies, sensors, and tools are expanding our ability to explore the ocean. Scientists are relying more and more on satellites, drifters, buoys, subsea observatories, and unmanned submersibles.	**X**		
e. Use of mathematical models is an essential part of understanding the ocean system. Models help us understand the complexity of the ocean and its interactions with Earth's interior, atmosphere, climate, and land masses.			
f. Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists,	**X**		**X**

physicists, animators, and illustrators. And these interactions foster new ideas and new perspectives for inquiries.			