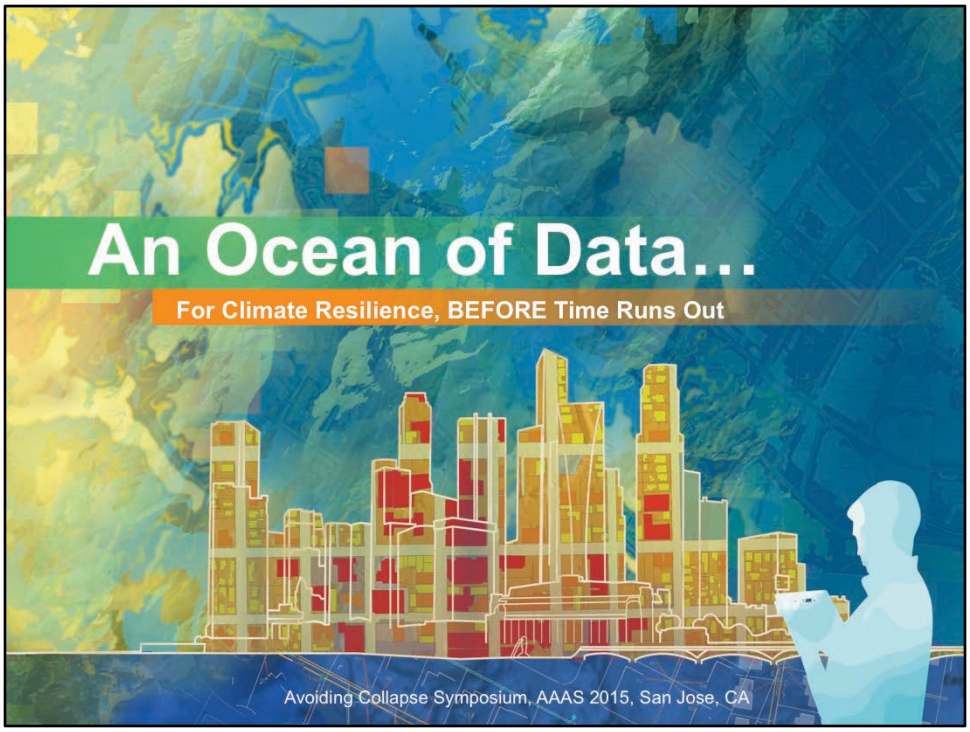
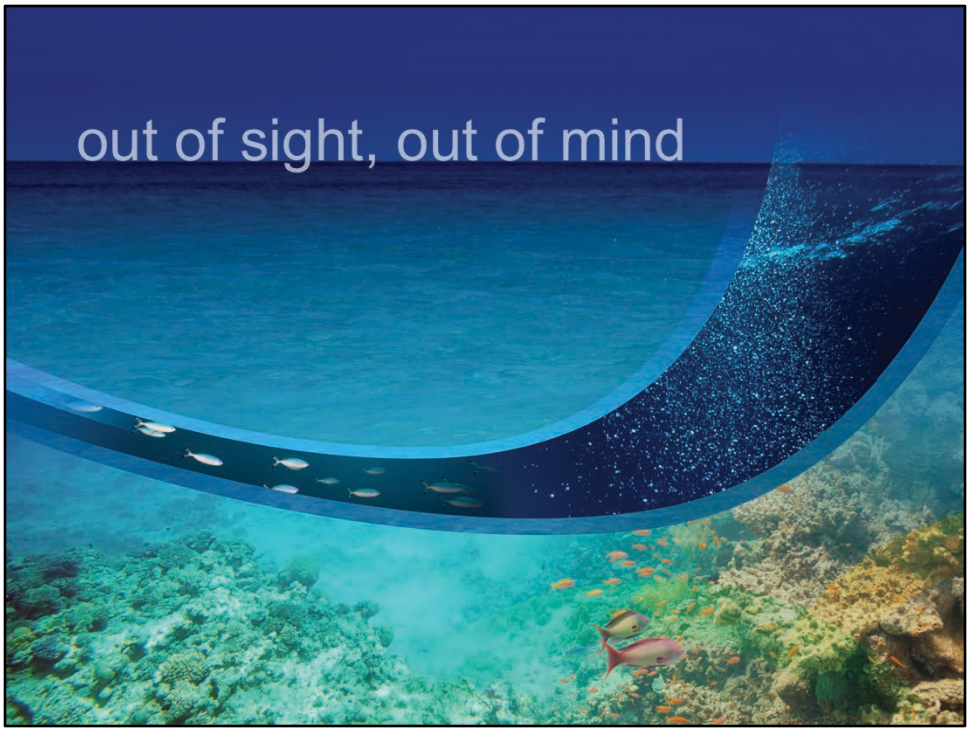
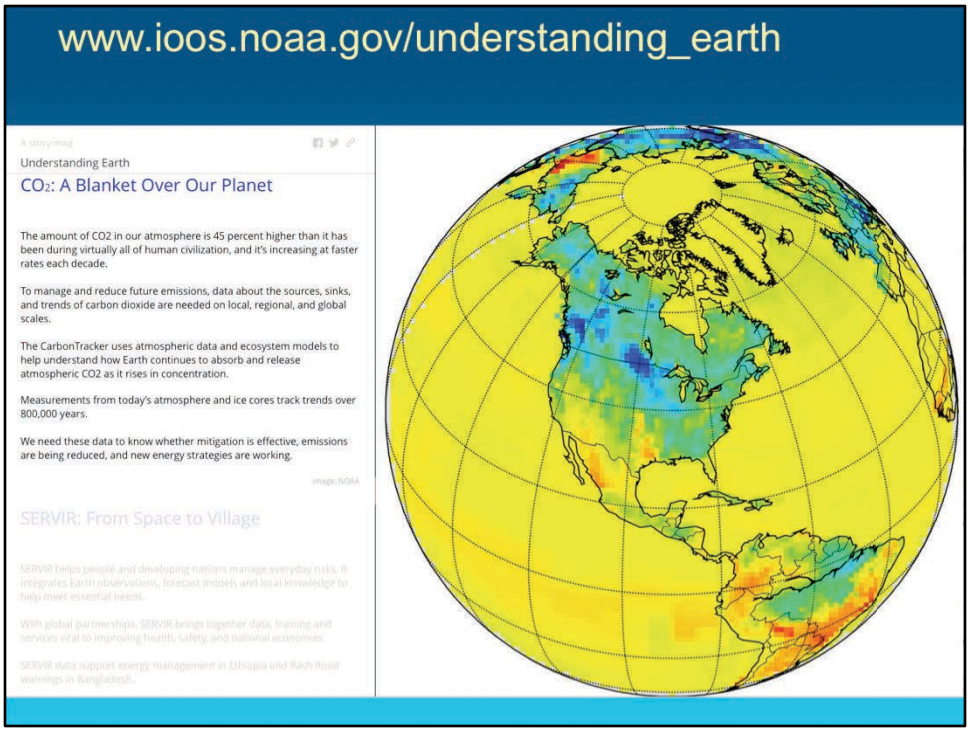

An Ocean of Data…
For Climate Resilience, BEFORE Time Runs Out
Avoiding Collapse Symposium, AAAS 2015, San Jose, CA



For many of us when we think about the oceans it's a situation of "out of sight, out of mind."
In our limited awareness of the oceans, we see only the surface, think only of vast expanses of lifeless water // not realizing all of the complexities at play.

In fact, the oceans provide over HALF of the oxygen that we breathe // They regulate ALL of our weather patterns - they feed us - and provide for our energy and economy.
So in reality // the oceans are vital to all of us, **no matter WHERE we live.**



The ocean is a champion at absorbing human-derived (anthropogenic) CO_2. Around half of all carbon dioxide produced by humans since the industrial revolution has dissolved into the world's oceans. Coastal habitats store five times more carbon than do inland tropical forests. This has all helped to slow global warming.

Image from NOAA Carbon Tracker, tropospheric CO2, late spring/early summer

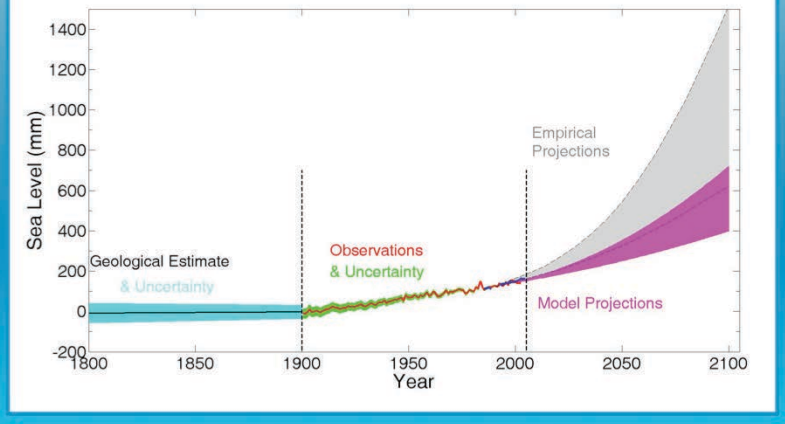
There are indeed many challenges facing the oceans.

There have been many stories in the news about the estimated 1.5 millions TONS of debris headed to the US and Canadian west coast from the 2011 Japanese tsunami, as you can see from the **simulation** above.
The pictures below show some of the debris at sea and already washed ashore in Oregon. One of the big surprises here has been the sheer number of living sea creatures attached to these debris, some of which are invasive and could devastate local populations.

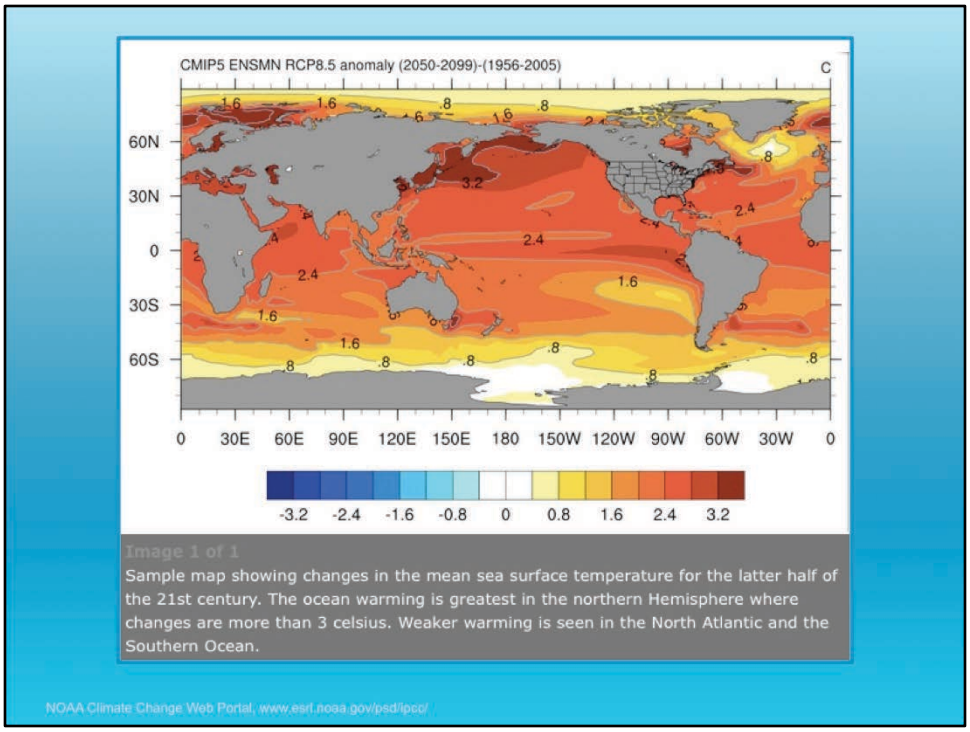
Global sea-level is rising primarily because land ice is **melting** and ocean **water expands as it warms**.

1.7 mm per year over 20th century
(from tide gages)

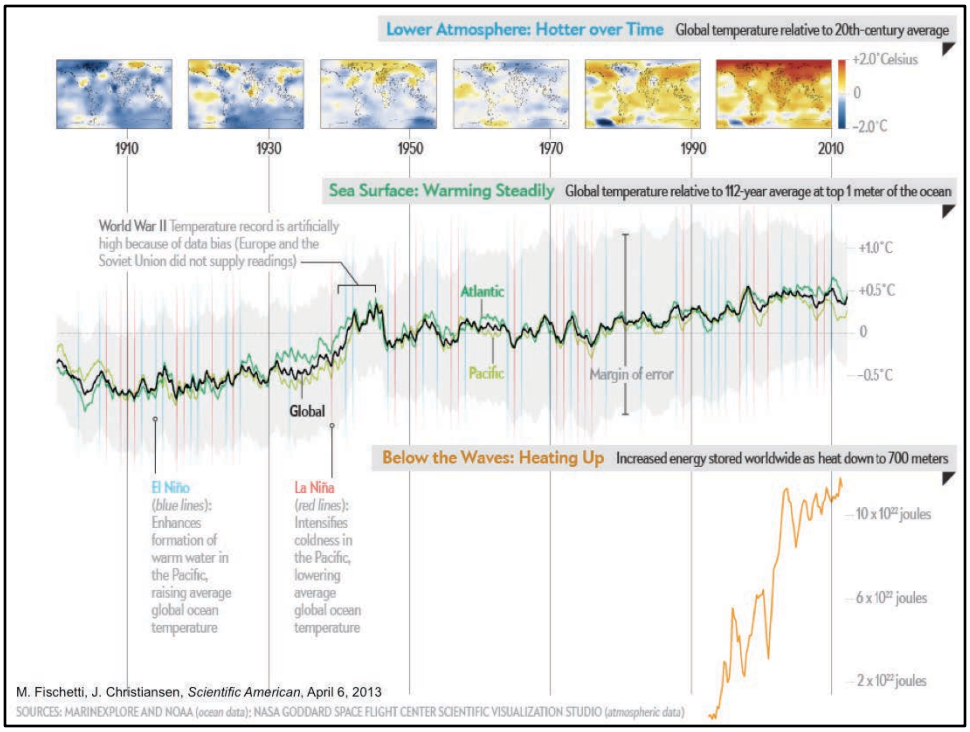
3.1 mm per year since 1993
(from satellites & tide gages)



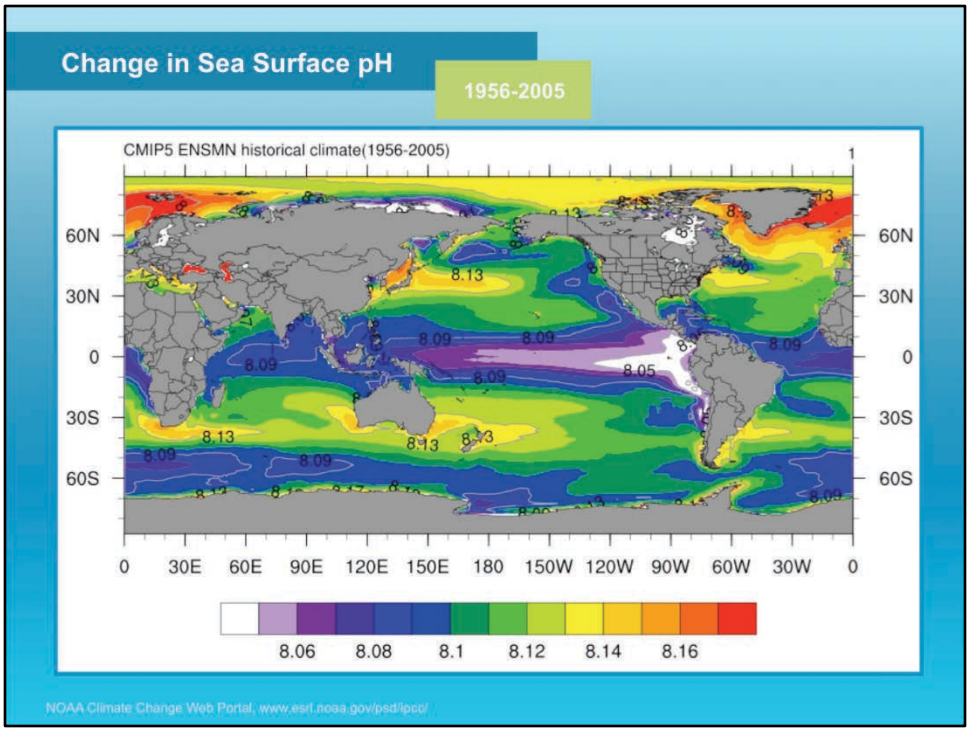
California-Nevada Climate Applications Program, Scripps



CMIP5 (coupled model intercomparison project)



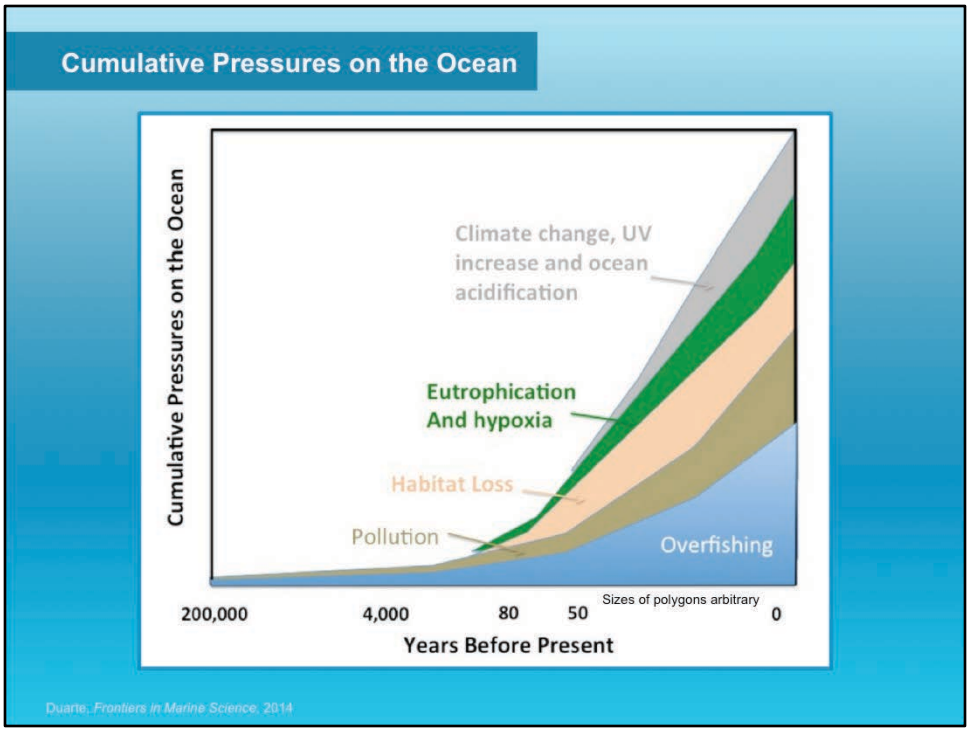
"It stands to reason that as the atmosphere warms from the buildup of greenhouse gases, so does the ocean. Scientists have long suspected this was true, but they did not have enough solid evidence. Now they do. Data compiled by Marinexplore (now PlanetOS) in Sunnyvale, Calif., not only confirm previous studies that the world's oceans are simmering, but they also bring surprising news: the heating extends beyond the first few meters of surface waters, down to 700 meters…"
http://marinexplore.org/news/303-scientific-american-collaborates-with-marinexplore-to-analyze-how-our-oceans-are-warming



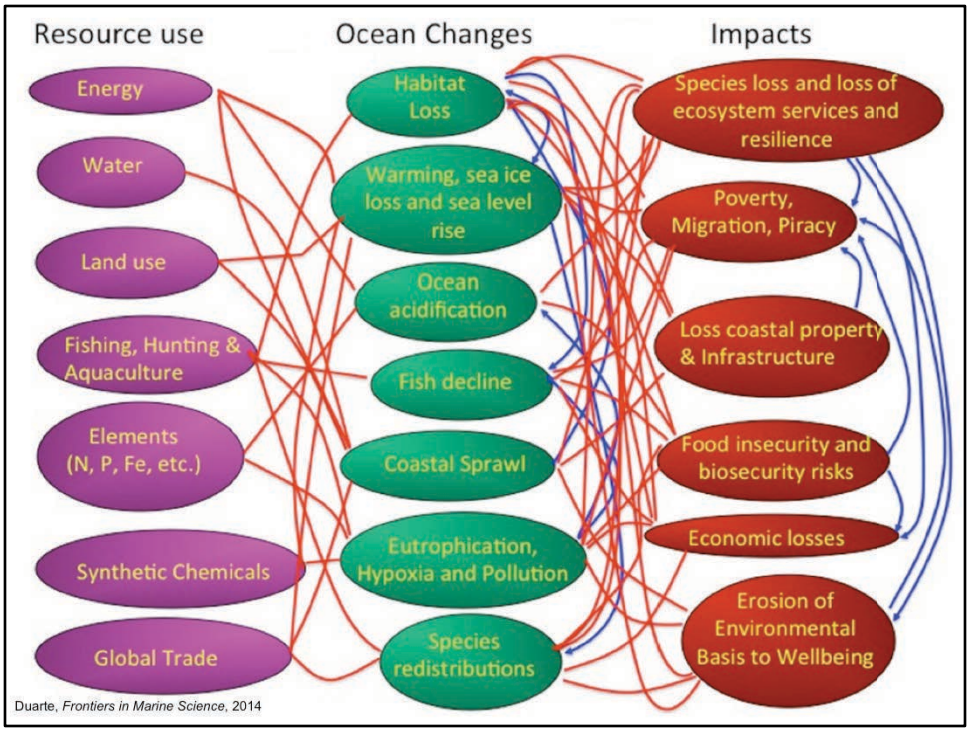
Change in sea surface pH by coupled climate models' CMIP5 (coupled model intercomparison project) experiments (historical and RCP8.5) for the period 1956-2005

RCP = representative concentration pathway

Shows average of all models and how the difference in the mean climate in the future time period (RCP8.5) compared to the historical reference period.



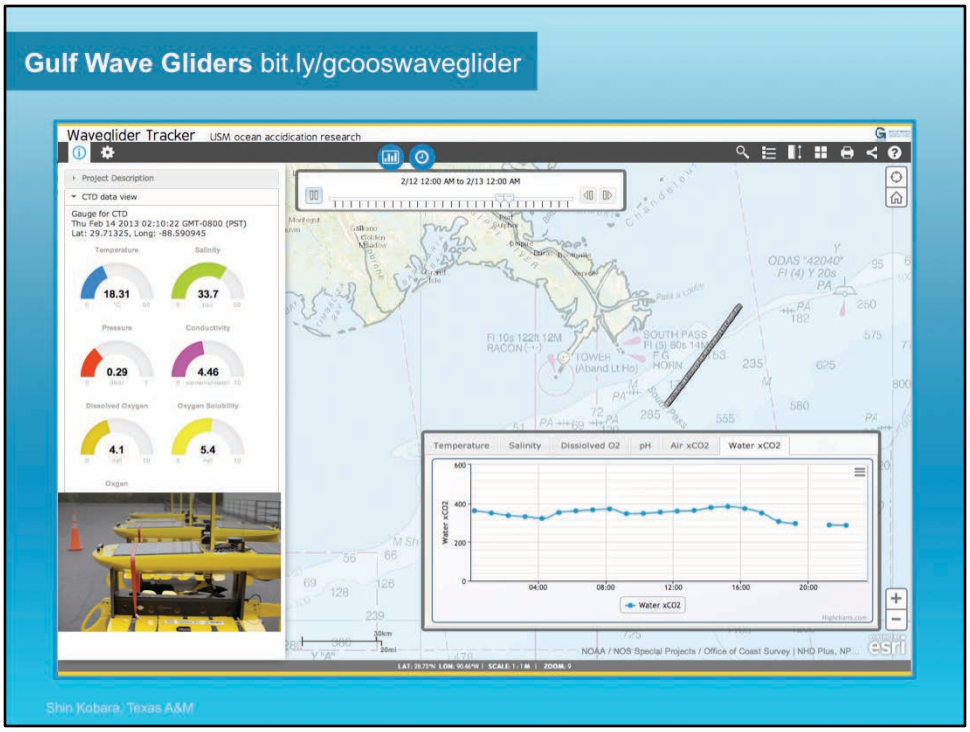
A time line of cumulative pressures on the global ocean. The size of the polygons corresponding to each pressure is arbitrary and is not meant to reflect their objective impacts.



A description of the human pressures, in terms of resource use, oceans changes, and impacts conforming the global change syndrome as affecting the ocean. Red lines indicate links between these components and blue lines denote feedback effects.

As an example from ocean OBSERVATORIES, here is a look at the technology currently and ~20 years into the future. This graphic, courtesy of the NRC ocean infrastructure report, captures a variety of issues, environments, and tools.

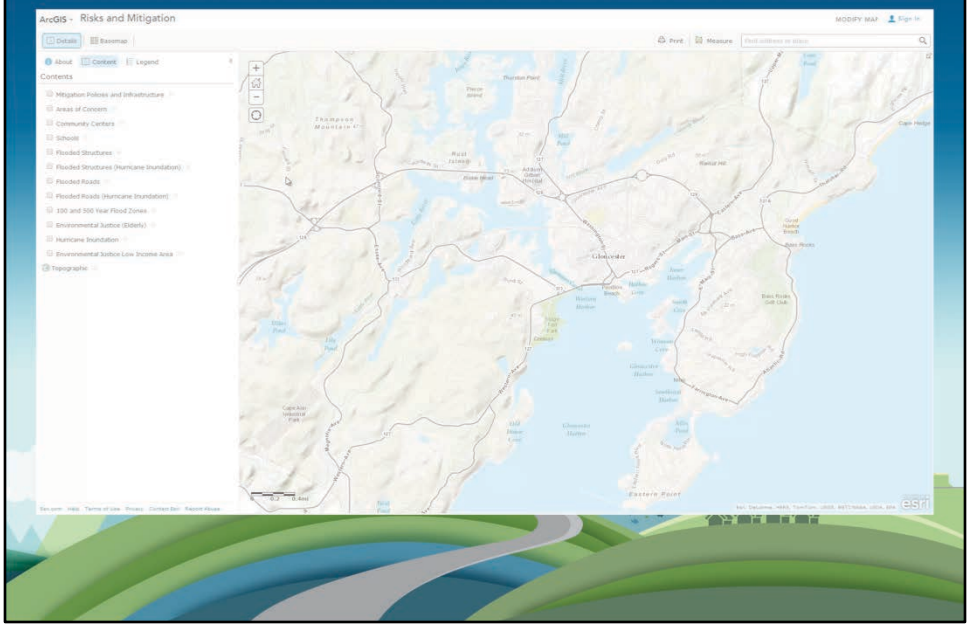
- Monitor, track, and report events and day-to-day operations across a network of people within your organization. Look at services, deliveries, people, vehicles, weather events, and social media— anywhere in the world —then share that insight with stakeholders.

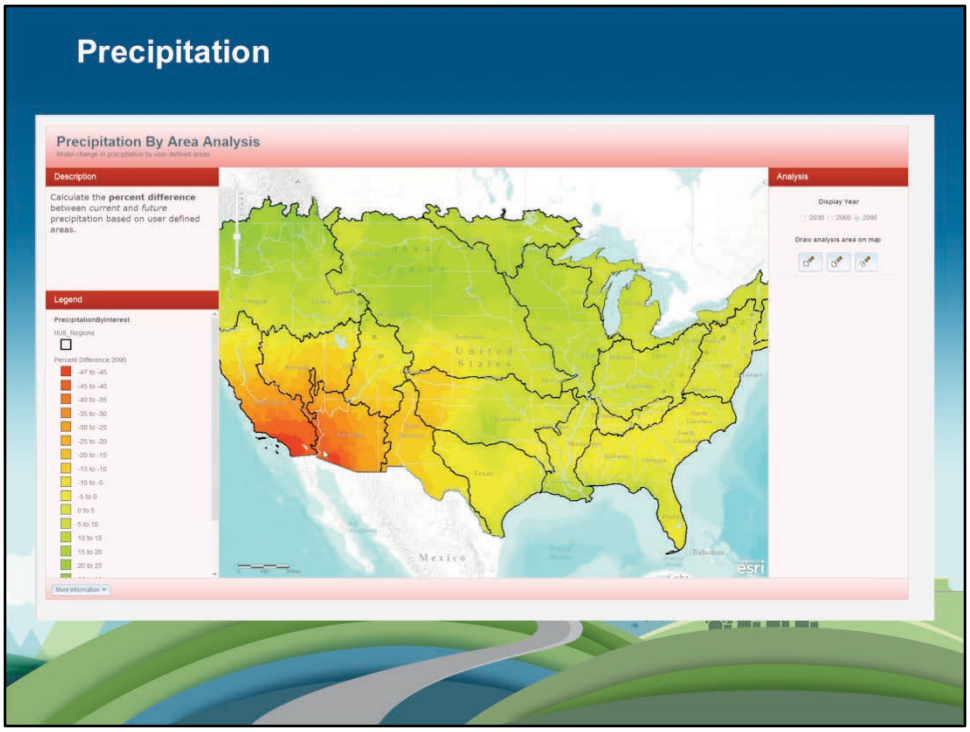


Demonstration of use of Esri Geoevent Processor to track Liquid Robotics wave gliders in the Gulf of Mexico, with the Operations Dashboard app displaying the parameters measured by the wave glider in near real time. Courtesy of Shin Kobara of Texas A&M working in concert with the U. of Southern Mississippi and for the Gulf Coast Ocean Observing System. Luca Centurioni's global drifter lab at Scripps has a modified Liquid Robotics Wave Glider.

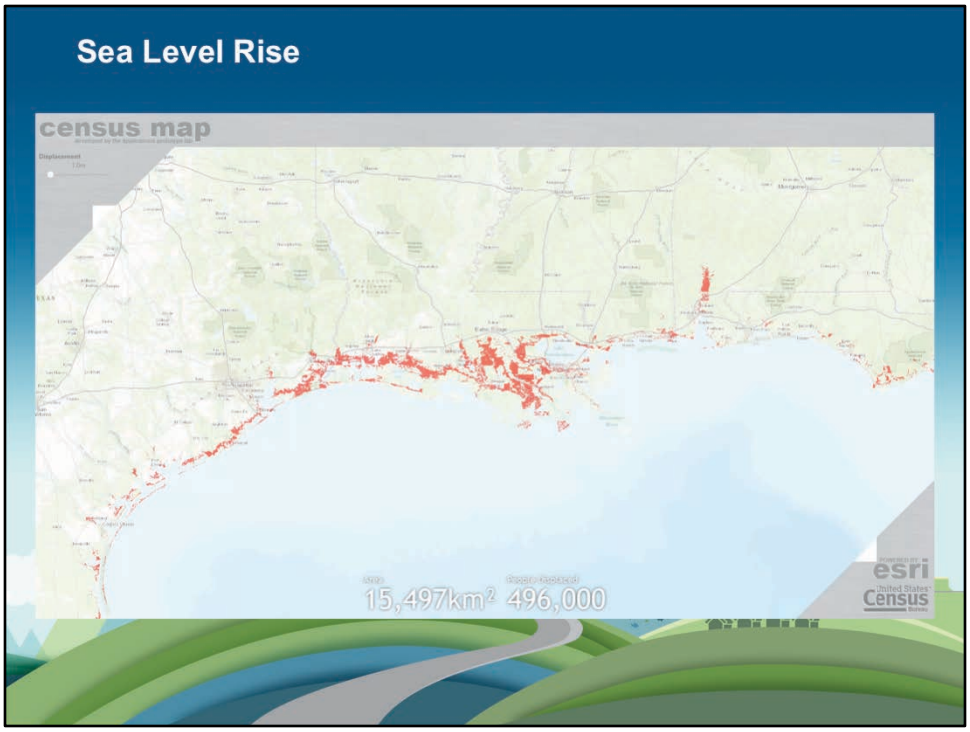

Climate Resilience
Making Communities More Resilient
Shareable Apps
Creative Ideas
Innovative Methods
Open Data
Many Participants
Governments
Startups / Developers
Businesses
Academics & NGO's
esri.com/climate-app / esriurl.com/climateapp2
resilience.maps.arcgis.com
esriurl.com/resilientcomm
Building a Resilient Platform

Risks and Mitigation





Looking at 44% reduction in precip in this region – huge for a region in crisis already



Overlaying census data on SLR to show population that would be displaced (e.g, 770,000 people displaced)

Partnerships for Resilience

Resource Portal - resilience.maps.arcgis.com

Governments

New Orleans
Washington, D.C.
Boston
Kansas City
Richmond
Connecticut
Los Angeles
Wake County
….

Professional Organizations

ICMA · NACo · National League of Cities · pti · NAHDO · TUMMLC · NACCHO · APA · NISC · ASCE · APWA

Creating and Sharing Knowledge

“People are moved by emotion. The best way to emotionally connect other people to our agenda begins with “Once upon a time…”
Science backs up the long-held belief that story is the most powerful means of communicating a message. Over the last several decades psychology has begun a serious study of how story affects the human mind. Results repeatedly show that our attitudes, fears, hopes, and values are strongly influenced by story. In fact, fiction seems to be more effective at changing beliefs than writing that is specifically designed to persuade through argument and evidence.”

http://www.fastcocreate.com/1680581/why-storytelling-is-the-ultimate-weapon

Scientists are often encouraged not to publish their work until it constitutes a complete story.

Why not combine BOTH, especially to take advantage of the power of maps and geography to educate, inform, and inspire people to action as well?

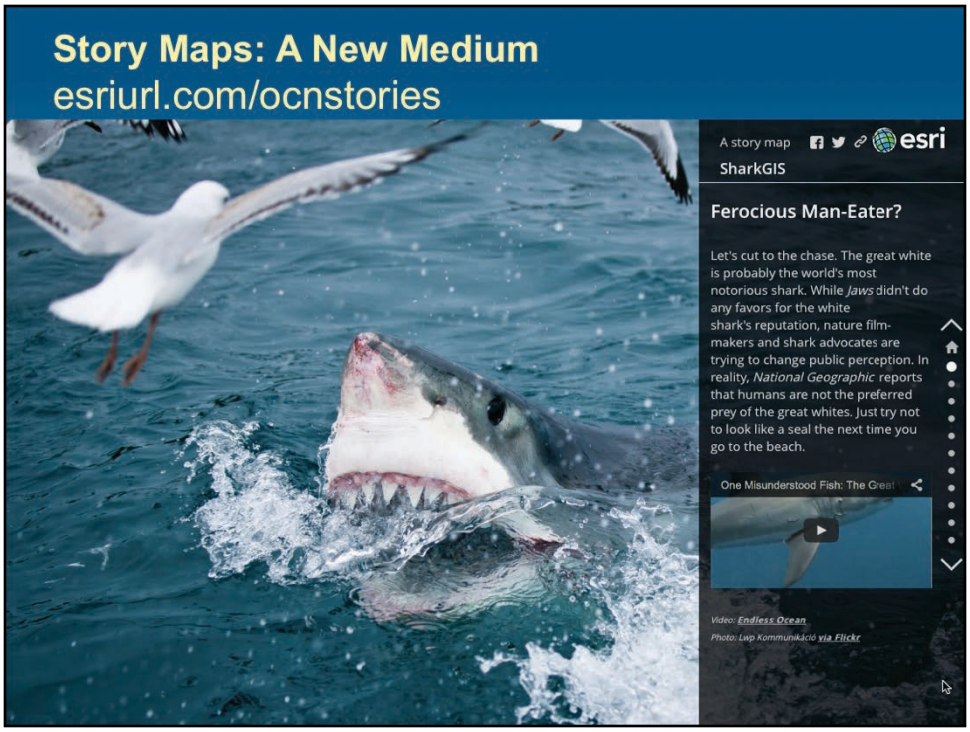
Story maps is about using maps in new and innovative ways to get people excited and involved in the world.

Thanks to continuing changes in **the Internet, cloud computing, mobile and tablet platform**s, and to constant improvements in the software itself, we can now put the power of GIS into the hands of managers, CEOs, reporters, school kids—*even policy makers.*


Story Maps: A New Medium
esriurl.com/ocnstories
esrigram
presents
SHARK
GIS
A story map
esri
SharkGIS
Human fascination with sharks dates back ages—long before *Jaws* or *Sharknado*. What is it about these mysterious creatures of the deep that sparks so much interest across time and cultures? In honor of Shark Week, we're taking a closer look at sharks using media and maps to better understand the ocean's fiercest predator.

Story Maps: A New Medium

esriurl.com/ocnstories



Story Maps: A New Medium

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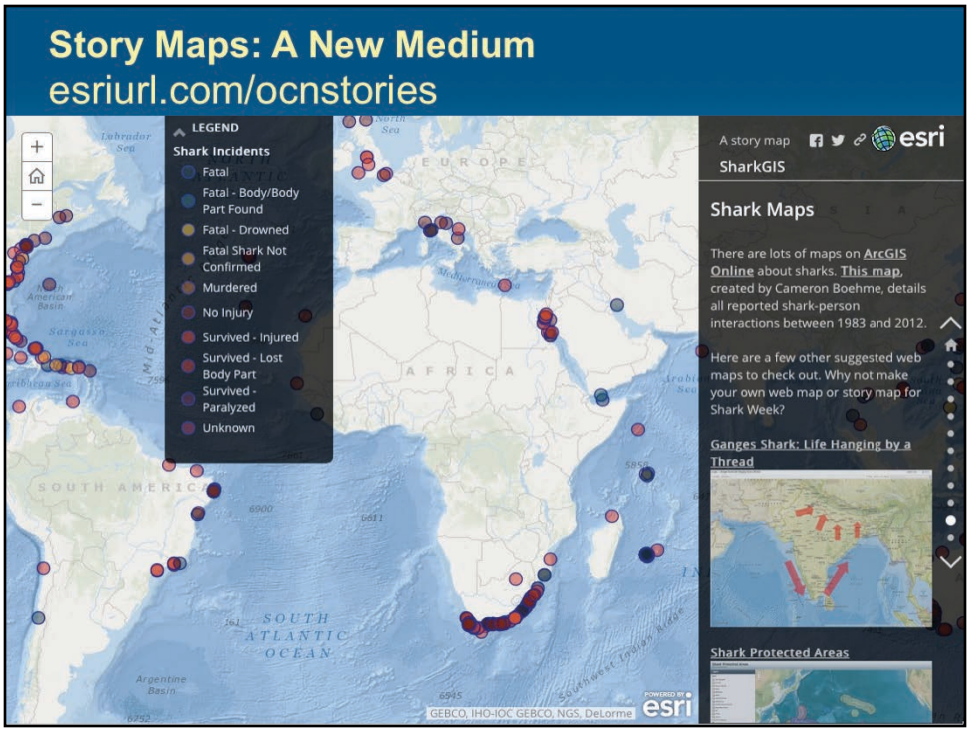
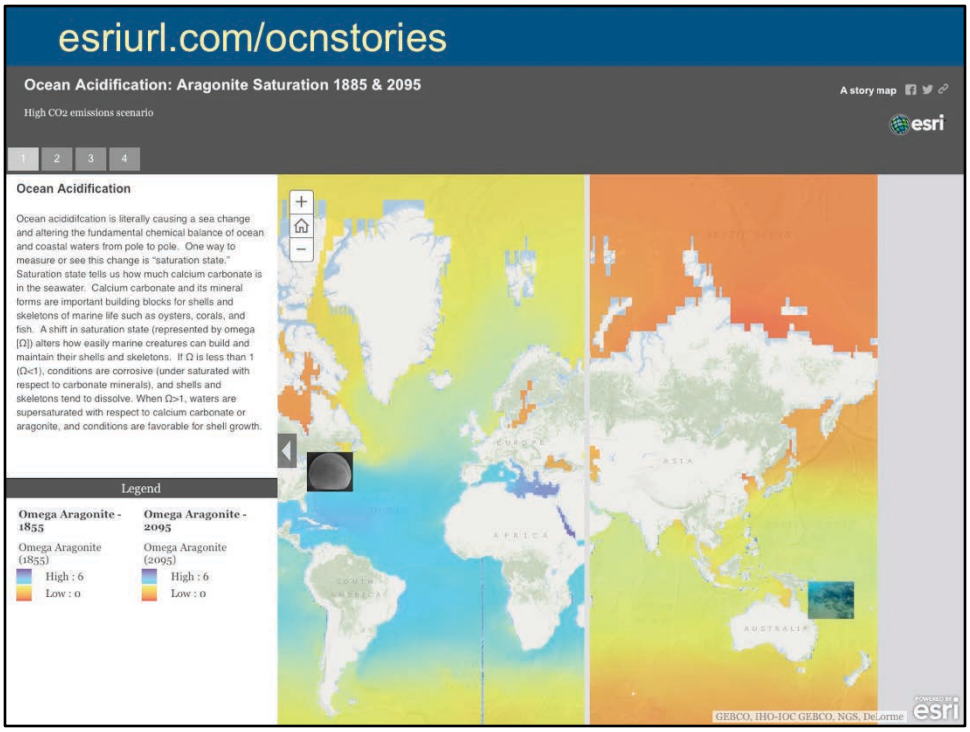
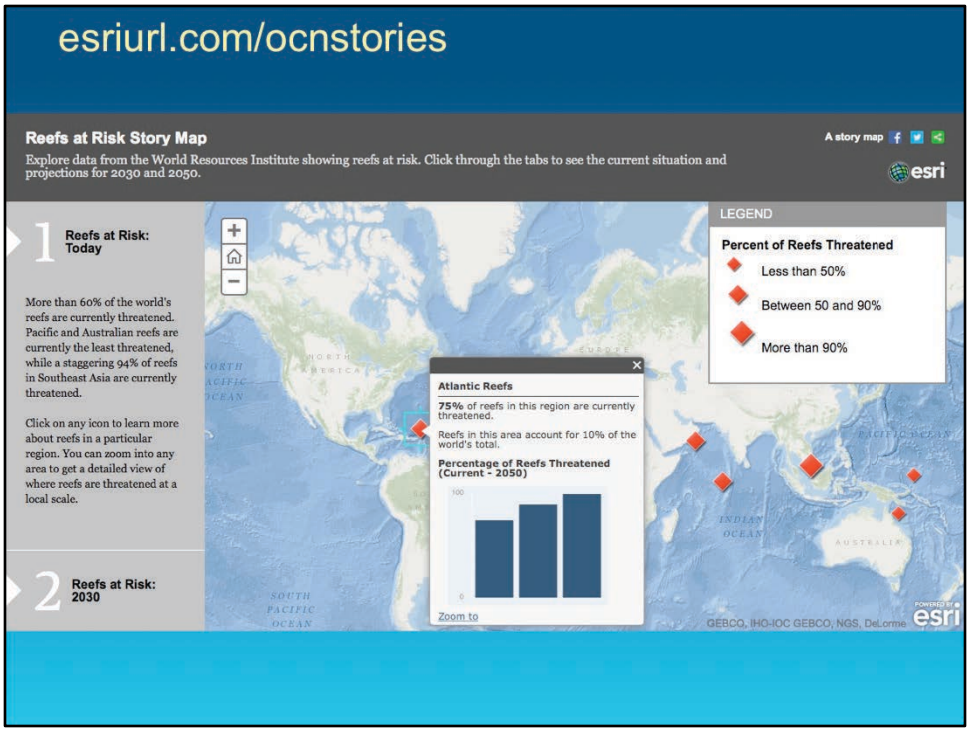



storymaps.arcgis.com
A story map
esri
WELCOME TO THE
Anthropocene
We are Living in
The Age of Humans
Earth is changing rapidly, and an increasing number of scientists say that humans have become the dominant force driving these changes. While the term has no formal definition, many agree that we are now living in an age shaped by human activity: the Anthropocene.
Evidence for the Anthropocene ranges from worldwide population booms to the expansive transformation of the landscape. But solutions are cropping up at the local level that could help create a more resilient global community.
Explore the maps below to see an atlas of human influences, as well as the cities that are helping


esriurl.com/ocnstories
Ocean Acidification: Aragonite Saturation 1885 & 2095
High CO2 emissions scenario
A story map
esri
1
2
3
4
Ocean Acidification
Ocean acididfcation is literally causing a sea change and altering the fundamental chemical balance of ocean and coastal waters from pole to pole. One way to measure or see this change is "saturation state." Saturation state tells us how much calcium carbonate is in the seawater. Calcium carbonate and its mineral forms are important building blocks for shells and skeletons of marine life such as oysters, corals, and fish. A shift in saturation state (represented by omega [Ω]) alters how easily marine creatures can build and maintain their shells and skeletons. If Ω is less than 1 (Ω<1), conditions are corrosive (under saturated with respect to carbonate minerals), and shells and skeletons tend to dissolve. When Ω>1, waters are supersaturated with respect to calcium carbonate or aragonite, and conditions are favorable for shell growth.
Legend
Omega Aragonite - 1855
Omega Aragonite (1855)
High : 6
Low : 0
Omega Aragonite - 2095
Omega Aragonite (2095)
High : 6
Low : 0
EUROPE
ASIA
AFRICA
AUSTRALIA
GEBCO, IHO-IOC GEBCO, NGS, DeLorme
esri

esriurl.com/ocnstories



Geospatial technology provides a set of innovations in information and imaging that connect cities, governments, and private organizations toward assessing their risk exposure and increasing their overall resilience.
This is not JUST about your eyeballs on a map or on a series of numbers, it's looking at the invisible rubber bands of mathematical manipulation of these different layers.
It's about COUPLING of the appropriate data, analysis, and compelling design to effectively communicate the scientific results, to transform scientific data into actionable information that people can use in their decision cycles to be more resilient to climate change and even to reverse its effect. To use the example of extreme weather, this can be critical for decision cycles in the **short term** (e.g., get in storm shelter now), **medium term** (e.g., evacuate), or **long term** (e.g., infrastructure planning as communities recover from Hurricane Sandy).

An Ocean of Information for Climate Resilience … Before Time Runs Out

Dawn Wright, Environmental Systems Research Institute (aka "Esri")

For the Symposium, **Innovations in Information and Imaging: Avoiding Collapse**
(Barnosky and Ehrlich)

This symposium examines how recent innovations in information, analyses, and science-policy linkages can help guide the planet in favorable, rather than "doomsday" directions. Innovations such as acquisition of data from satellites and mining megadatabases now allow synthesis of environmental information to track human impacts at global to local scales. Analysis of such data provides new ways to identify macro-scale patterns and processes through long time periods. The emerging information highlights the speed at which humans are altering the biosphere, and offers opportunities for forecasting detrimental outcomes in time to avoid them.

An Ocean of Information for Climate Resilience … Before Time Runs Out

ORDINARY WORLD

For many of us when we think about the ocean it's a situation of "out of sight, out of mind."

In our limited awareness of the ocean, we see only the surface, think only of vast expanses of lifeless water // not realizing all of the complexities at play.

In fact, the ocean provides over HALF of the oxygen that we breathe // It regulates ALL of our weather patterns, it feeds us, and provides for our energy and economy.

The ocean is a champion at absorbing human-derived (anthropogenic) CO_2. Around half of all carbon dioxide produced by humans since the industrial revolution has dissolved into the world's oceans. Coastal habitats store five times more carbon than do inland tropical forests. This has all helped to slow global warming.

So in reality // the ocean is vital to all of us, **no matter WHERE we live.**

CALL TO ACTION:

But again, it is not out of sight, out of mind. The ocean is paying a price. All the absorption of CO2 is raising the acidity of the oceans, which will lead to the loss off corals and thousands of other species. Rising temperatures are linked to rising frequency and severity of storms, threatening Arctic habits, raising sea levels, and may enhance the release of gas hydrates on the seafloor. These factors along with reduced oxygen levels are all

causing shrinking habitats and altering the entire food web in the ocean, placing fish at risk.

Technology, particularly information technology, and within that the information technology known as geographic information systems (GIS) has long provided effective solutions to similar problems on ***land*** through innovations in information and imaging***.*** But our mission is to take what we've learned on land and apply these innovations more effectively to the ocean so that we may build resilience and avoid collapse.

REFUSAL OF CALL:

But this is a hard mission

The ocean presents to us some very challenging 3- and 4-dimensional problems

The ocean is very hard to access at full depth from sea surface to sea floor. Satellites and LiDAR, for example, while providing broad, comprehensive views of the surface of the ocean, can't see all the way through the water in all places, and as a result, only 5-10% of the ocean is mapped in the same detail as on land.

MEET THE MENTOR:

However, the mission is totally within our grasp.

We are in an era of regional- to global-scale observation and simulation of the oceans. As an example from the world of ocean OBSERVATORIES, the graphic below from a recent National Academy of Sciences ocean infrastructure report, provides a look at the technology of today, as well as ~20 years into the future.

These observatories programs produce big data. Big data are leading to a new science paradigm, a new data science (that deals with, among many issues, the inundation of data from satellites, sensors, and other measuring systems and the issues associated with those large data sets). Indeed we are seeing the fruition of ideas expressed in 2009 book by Hey et al., *The Fourth Paradigm*, which posits a new paradigm of scientific discovery beyond the existing 3 paradigms of empiricism, analysis, and simulation to a 4th where insight is discovered through the manipulation and exploration of large data sets. **This is not only about the 4th paradigm of scientific discovery, but the 4th paradigm of government** (where the future of democratic governance lays in the 3 pillars of executive, legislative and judicial but also a 4th pillar of information).

There is a growing ocean data industry to help meet this need. According to studies by Marinexplore (now PlanetOS): 80% of decision-making processes in ocean science and business depend on data collection, management, processing, and distribution and the data acquisition market is currently $80 BILLION including ships, buoys, satellites, robots, ship-to-shore communications. The data management market will be $5 billion, including software and associated costs.

EXTRA*ORDINARY WORLD:*

There is further hope in the emergence of global initiatives such as the Deep Ocean Stewardship Initiative (DOSI), the Deep Ocean Observing Strategy (DOOS) as part of the Global Ocean Observing System (GOOS), and the Global Earth Observation System of Systems (GEOSS) which seek to address the grand societal issues of climate change adaptation, ecosystem conservation and sustainable resource management. These will be mentioned in the main talk.

Creating and sharing knowledge toward effective action, and doing this through **public-private partnerships** will also be key. For example, In June 2013, President Obama announced the Climate Action Plan, an effort to leverage data to help the American people understand and prepare for climate change. This blueprint for action includes the Climate Data Initiative, which encourages innovators from the private sector and the general public to convey data on climate change risks and impacts in compelling and useful ways that help citizens, businesses, and communities make smart choices in the face of climate change.

One example is a **public-private partnership** between the US Geological Survey and Esri that resulted in the recent release of world[1]s most detailed ecological land units map at a global scale (250 m resolution). This new global ecosystems map product, which portrays nearly 4000 distinct terrestrial ecosystems of the Earth, provides scientific support for planning and management, and enable understanding of impacts to ecosystems from climate change and other disturbances. Among other benefits of our map, it fulfills one of the recommendations from the White House PCAST report on environmental natural capital. Work on a similar map of global ecological ocean units is now underway.

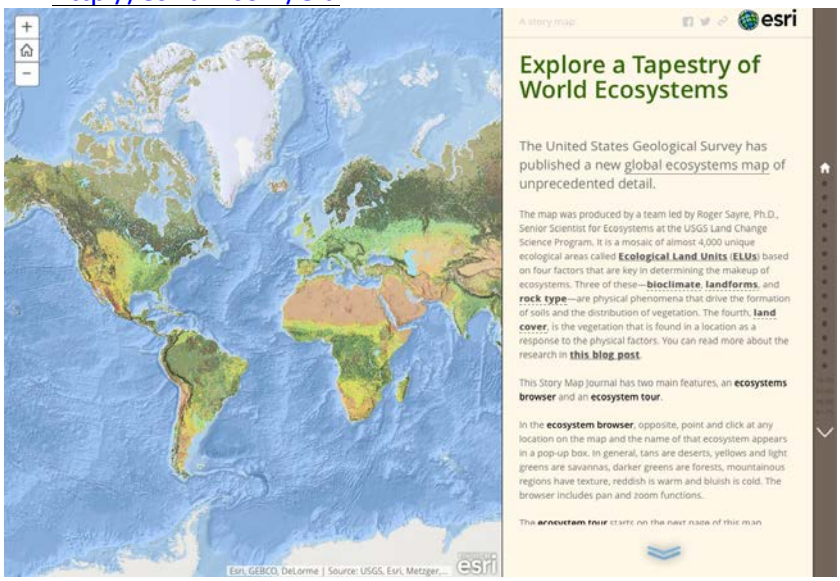
Esri is actively participating to meet the challenge the White House has set forth. Resources shared at **http://resilience.maps.arcgis.com** and **http://esriurl.com/resilientcomm** are the combined contributions of Esri and the GIS user community (including government agencies and NGOs). They provide maps, data, apps (including winners of 2 climate resilience app challenges – **http://esri.com/climate-app** , **http://esriurl.com/climateapp2** **),** interactive demonstrations and other actionable resources, all

with an eye toward inspiring people to address and solve climate resilience issues. There are many resources there for avoiding collapse in the oceans.

There is also great power in story telling, and the new medium of "**story maps"** that take advantage of the power of interactive web maps and geography to educate, inform, and inspire people to action as well

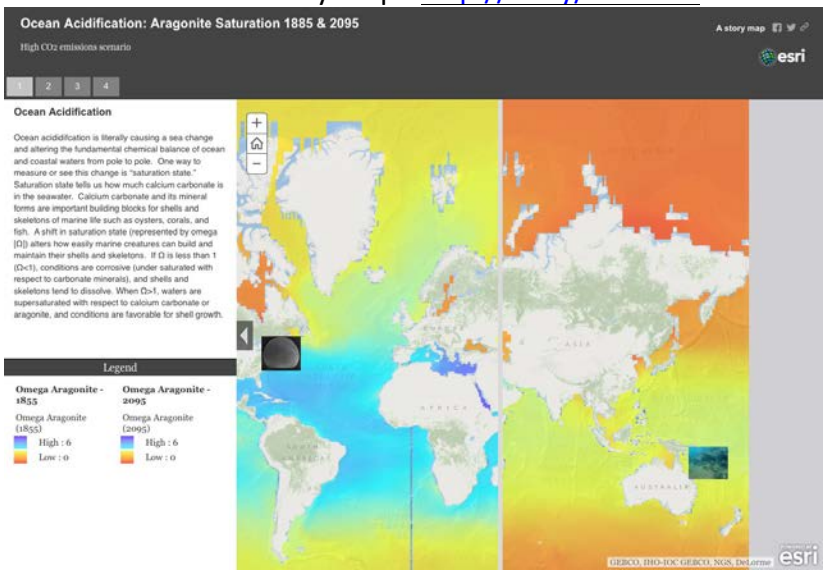
A story map and related web app about the aforementioned global ecosystems project was released at the ACES 2014 conference in Washington, DC, December 2014 after Interior Secretary Jewell made her announcement there about the President's Climate Data Initiative and related efforts, including this one. They generated quite a bit of media attention (e.g., **This Interactive Map Shows the World's Ecosystems in Freakish Detail**
http://io9.com/this-map-shows-the-worlds-ecosystems-in-freakish-detail-1669325905)

Explore a Tapestry of World Ecosystems Story Map – http://esriurl.com/elu

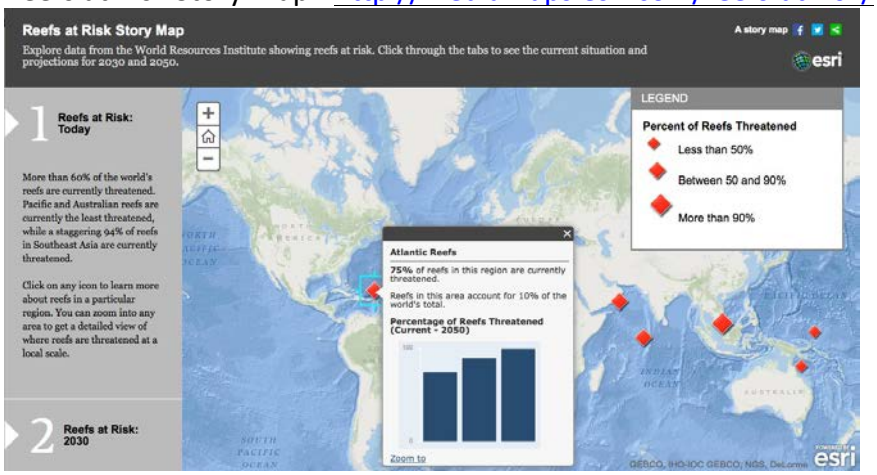


A story map about the Anthropocene - http://bit.ly/1uGgg6X

Ocean Acidification Story Map - http://bit.ly/181VoSv



Reefs at Risk Story Map - http://mediamaps.esri.com/reefs-at-risk/



FINAL CALL TO ACTION

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example of extreme weather, this can be critical for decision cycles in the **short term** (e.g., get in storm shelter now), **medium term** (e.g., evacuate), or **long term** (e.g., infrastructure planning as communities recover from Hurricane Sandy).

We hope that attendees of AAAS will explore these resources. The goal of my colleagues and I is to work with governments, communities, NGOs, and universities to go beyond just an exploration and discussion of ideas to rapidly prototyping and delivering repeatable solutions that all of these organizations can use…. before time runs out.

Audience: Policy Makers, Media

Problem?

We don't yet have accessible data at the right scale and format to allow us to manage consistently in terms of ecosystems. Despite the "information age," we're making data-poor decisions, often along (political) boundaries that aren't relevant to ecosystem function – and thus can't help us *avoid collapse*.

Benefits?

- Better (more efficient) use of existing resources
- Assess economic, social value from ecosystems
- Directly implement White House PCAST recommendations
- Leverage public data and private-sector innovation through public-private partnerships

Describing our environment in terms of ecosystems will enable more effective management in the face of (climate) change.

So What?

We are prone to making inefficient and inconsistent decisions about how we manage our natural resources, including the landscapes we live in. In a world of accelerating change, this means we are exposing ourselves to unnecessary risk.

Solution

- Take advantage of existing tools, public-private partnerships to optimize existing data, and guide the collection of additional (useful) data.
- See more resources in Dawn Wright's presentation