Increasing Community Resilience to Extreme Weather-Related Events through Coastal America's Coastal Ecosystem Learning Center Network

Summary of a NOAA Office of Education-Sponsored Workshop
March 14-15, 2013

At the
Aquarium of the Pacific

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Linda Brown did a superb job of handling all the travel and meeting logistics.

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Participants

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Aquarium of the Pacific	David	Bader
Aquarium of the Pacific	Corinne	Monroe
Baltimore/National Aquarium, WA, DC	John	Racanelli
Baltimore/National Aquarium, WA, DC	Gene	Taylor
ESRI	Drew	Stephens
Mississippi River Museum & Aquarium	Jerry	Enzler
Mississippi River Museum & Aquarium	Nicole	Shalla
Mystic Aquarium	MaryEllen	Mateleska
Mystic Aquarium	Kelly	Matis
NOAA	Margaret	Davidson via video Conference
NOAA	Mark	Jackson
NOAA	Louisa	Koch Via conference call
NY Aquarium	Jon	Dohlin
NY Aquarium	Sue	Chin
Pine Knoll Shores Aquarium	Allen	Monroe
Pine Knoll Shores Aquarium	Windy	Arey-Kent
Seattle Aquarium	Jim	Wharton
Seattle Aquarium	Nicole	Killebrew
Texas State Aquarium	Tom	Schmid
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Increasing Community Resilience to Extreme Weather-Related Events

Summary of a NOAA-Sponsored Workshop March 14-15, 2013

Background

On March 14-15, 2013, representatives of eight members of Coastal America's Coastal Ecosystem Learning Center (CELC) network met at the Aquarium of the Pacific in Long Beach, California. The primary goal of the workshop was to explore ways of energizing all, or portions, of the network to engage, educate, and empower the public on major coastal, ocean and environmental issues. The particular issue that was used as the point of departure was "Increasing Community Resilience to Extreme Weather-Related Events." Support for the workshop was provided by the NOAA Office of Education.

Institutions were selected on the basis of geography to give regional representation and national coverage, and at the same time to keep the number of participants small enough to have a productive workshop. The intention from the outset was to focus on identifying strategies that would include the entire CELC network. On the first day, each institution made a brief (5-10 minute) presentation and distributed a short written document outlining the major extreme weather-related events that posed the greatest risk within their region. Because most CELC institutions are located in coastal zones, many are especially vulnerable to the wide range of impacts of hurricanes, other tropical storms, and of Nor'eaters. These documents are included in Appendix 1.

The CELC network has three signature programs—the Student Ocean Summit, Student Ocean Art Contest, and the Oceans Today kiosk program . There have been a few other collaborative programs such as the creation of videos on Marine Protected Areas that involved several CELC institutions, the National Marine Sanctuaries Program, the North America Marine Protected Area Network (NAMPAN), and the Commission for Environmental Cooperation (CEC); but collaborations of more than two CELCs have been rare. There is a strong and growing desire by many members of the network to collaborate to increase the reach and power of the network. To increase the frequency and strength of collaborations will require more active involvement of Coastal America and incentives for multiple CELCs to collaborate. Strength of the network will come from sharing stories and best practices and working together to create and deliver meaningful programs. Coastal Ecosystem Learning Centers should be loci for nurturing local and regional discussions of important coastal and ocean issues, and for scaling these up through the network to provide a national perspective. The potential benefits to NOAA and the Nation of an energized CELC network are huge, but the challenges should not be underestimated. Networks are hard to maintain. They require sustained attention and frequent firing of the synapses to keep them active and to combat the centrifugal forces which are strong and always at work to cause networks to come unraveled.

Collaborations should not be restricted to other CELC institutions. Collaborations with local civic groups, and organizations like the Center for Clean Air Policy can add important dimensions to the CELC network, but the network must first be strong to sustain external collaborations.

The CELC Network

Coastal America's CELC network consists of 24 institutions[1], 22 in the United States, one in Canada, and one in Mexico. The institutions are listed in Table 1 and their locations shown in Figure 1. All but one is an aquarium. The exception is the IGFA Fishing Hall of Fame and Museum. In the aggregate, they attract about 25 million visitors each year. At least one CELC is found in every major coastal region of the country, including the Great Lakes. The power will come through energizing multiple nodes within the network to develop and deliver a set of common messages with accompanying messages tuned to the special qualities of the region in which each institution is located, and creating appropriate partnerships with other institutions in each area to push these messages deeply into the communities .

Coastal America is administratively housed within NOAA's Office of Coastal Resource Management (OCRM), but is a partnership of all those federal agencies that have a mandate in the coastal ocean.

Some important qualities of CELC institutions are listed below.

- They have collections of live animals.
- They are trusted sources of information.
- They are integrated into their home communities.
- They are experts in packaging complex information in ways that engage the general public and a variety of stakeholders.
- They have a range of technological assets ranging from Science on a Sphere and Magic Planet to 2D, 3D, and 4D theaters, and Ocean Today kiosks.
- Most also have changing exhibit galleries of varying size that can be used to explore relevant coastal and ocean issues.
- All have websites and are engaged in social media to varying degrees.
- They are located in every coastal region of the nation, including the Great Lakes.

One of the challenges is to raise the level of awareness by the public and decision-makers at all levels of the existence of the CELC network, and of its potential power. Each CELC can be much more active and should work both regionally and nationally. While each displays a plaque with its designation as a CELC center, they need to promote Coastal America and the CELC network in their programs, on their websites, and in their social networking. Concurrent with these efforts, the network must demonstrate its power.

[1] At the time of the workshop, none of the participants knew that the Rookery Bay National Estuarine Research Reserve had joined the CELC Network. This raises the total to 25 institutions, 23 in the U.S.

Extreme Weather-Related Events

Some High Level/Key Messages

Extreme Weather-Related Events are a national, and indeed a global issue. The specific extreme weather-related events vary regionally and manifest their effects in different ways in different regions. The probability is high that many extreme weather-related events will increase in intensity and frequency in the future because of climate change. It is almost certain that at least one will happen to every community served by a CELC in the next decade.

Being prepared and informed is key to resilience. The CELC network has the potential to play an important role in increasing preparedness. They also can help communities recover more quickly following an Extreme Weather-Related Event. They are important community assets and are integrated into their communities. They can serve as places of refuge, renewal, and restoration of civil society. To help ensure their own resiliency to extreme weather-related events, and to promote preparedness to those who visit our institutions, CELCs could be designated as "StormReady Supporters."

One of the lessons of storms that hit the Northeast over the past year is that the nation's infrastructure is aging and is vulnerable—electrical grids, water supply systems, wastewater systems, transportation systems—all are vulnerable. Vulnerability of infrastructure is not restricted to the Northeast; it is a national issue. As the intensity of storms increase, and as hot spells increase in frequency, intensity, and duration, the demands on our electrical grid will grow and blackouts and power failures can be expected to increase. This will exacerbate the need for access to cooling and heating centers. In some cases, our institutions might serve these functions on a limited basis since we are required to have back-up generating capacity to protect our animal collections. Partnerships with police stations, fire stations, and a variety of community groups would increase effectiveness in emergencies.

Two Parallel Education Tracks

The connection of any single extreme weather-related event to climate change should be made with caution, and in the case of tornadoes may not be possible. Storms make up weather, while weather makes up climate. We live in a probabilistic world and not a deterministic world. Most climate scientists, however, believe that the probability is high that the intensity and frequency of many extreme weather-related events will increase as the earth continues to warm and climate continues to change.

As a network of informal educational institutions, it is important that we inform our multiple audiences about climate change and the need to mitigate it by reducing the emissions of greenhouse gases. It is at least as important that we inform them that change is inevitable and that we must adapt to a different world—one with more frequent and more intense tropical storms, floods, droughts, and heat spells and a higher sea level and more devastating storm surges. Our institutions individually can become active learning and demonstration sites because many have experienced damage from extreme weather-related events and have demonstrated remarkable resilience. Through proper planning, building

codes, and other forms of preparedness, and through education and outreach, communities can reduce their vulnerability to extreme weather-related events. Our aquariums can help. Through education, outreach, and nurturing a stronger sense of community we can increase their resilience following the extreme weather-related events that will inevitably occur. We also can use community response to educate the public that 'getting back to normal' as quickly as possible, might not be as effective as recognizing the 'new normal' and restoring and rebuilding to those conditions. The quality of weather forecasts has shown remarkable improvement over the past decade or so, but further improvements are possible. The capability to forecast the paths of major storms such as hurricanes is generally better than the capability to forecast their intensity, or to forecast associated storm surge.
Accurate forecasts instill a sense of confidence in calls to evacuate while "false alarms" erode public confidence. Aquariums can help the public understand the vagaries of nature and the complexity of forecasting weather events, while educating them on the potential, sometimes catastrophic, impacts of extreme weather. Taken together, the public can better understand the risks involved in not taking action..
The CELC network could collaborate to develop the equivalent of PSAs, but if we do, we need to find sponsorships to get them shown in prime time rather than at 3 AM when no one is watching. We could also show them in our theaters as trailers to our regular movies. Messages about climate change need to be embedded in everything we do.

Audiences
Every CELC serves multiple audiences. The general public—the public that walks through our doors—is the primary audience, but not the only one, for most of our institutions in terms of raising awareness and deepening understanding of important/complex environmental issues such as Extreme Weather-Related Events. Social media—of all kinds—play an increasingly important roles in extending the reach of our messages by enlisting orders of magnitude more messengers than those who come through our doors. Social media also give us the opportunity to have more timely messages with a greater sense of urgency. Social media connect us with the younger part of the population. Most of our exhibits are expensive and time-consuming to create and deal with "timeless" or at least much longer-term issues. Most of our institutions need to become more nimble in dealing with social media. It is important to recognize the difference in breadth vs. depth in dealing with these two audiences.

Organized school groups are an important audience for our institutions. They are important linkages to our communities, and the source of support, both direct and indirect, for many CELCs.

Aquariums make important contributions to STEM education. Perhaps no contribution is greater than kindling a sense of excitement among children about science by providing opportunities to be junior scientists in an environment unfettered by learning standards.

Another important audience is decision-makers. They require a different approach. Forums that bring together decision-makers with scientific experts and stakeholders to explore alternative ways of responding to timely/complex issues can be effective, and a number of CELCs are engaged with these audiences.

Relevance

To be effective, our programs must be seen as being relevant. Elements of relevance include:

- It affects me and my family
    - It has economic implications that affect me
    - It affects the future of my kids and grandkids
    - It affects my health and safety and that of my family
    - It affects my food supply
- It is NOW or in the near future, not in 2100.

Timely events can underscore relevance. Adding timely information to Ocean Today Kiosks would make them much more relevant to many of our guests. Live feeds from NOAA before, during, and immediately after extreme weather-related events, for example, and downloads to smart phones, and even the addition of games would make them more relevant. The capacity to do this might require changes to the present curating/editorial functions that are centralized in the Smithsonian Institution.

Science on a Sphere is another technology that has considerable untapped potential, although only two CELC aquariums in the U.S. have these facilities. Science on a Sphere can bring down a variety of oceanographic and meteorological and other data sets from the web in real time. Data sets however, have limited capacity to capture an audience's attention unless they are integrated into a story by someone who can transform the data into information on the spot. Pre-recorded stories can also be created at much lower cost and in a more timely way than is the present mode. The Aquarium of the Pacific prepared a four minute experience on "Cities Through Time" in less than two weeks for less than $15,000 including purchasing film rights and staff time. An advantage of the Science on a Sphere program is that all organizations that have these facilities commit to uploading any program they develop so that it can be used by the others—a mark of a network.

The use of media delivery methods that are bold and grab the public's attention –such as through a Science on a Sphere, or short videos that are shown in common areas – are needed to help drive forward the message. To help make these productions attractive and memorable, we should seek assistance from experienced film producers, some of whom have already collaborated with CELC member institution.

Programs created for Science on a Sphere can be played on Magic Planet and vice versa. A much larger number of CELC institutions have Magic Planets.

It would be useful to survey CELC institutions to inventory the platforms they have for delivering information and to assess which of those platforms are most effective with different audiences in different regions of the country. There is a growing use of iPads and Apps. Some are being created by CELC institutions. Collaboration would reduce cost and time to develop and perhaps result in more powerful Apps.

The Power of Story

Storytelling is perhaps the most powerful way of engaging and conveying content in context that is relevant and matters to the listener. All of our institutions use story, but all can use it in new and more powerful ways to increase resilience of individuals, families, communities, and the nation to extreme weather-related events. The importance of our live animal collections in stories should not be underestimated. They make powerful emotional connections and many of their relatives in the wild must also cope with the effects of climate change and extreme weather-related events. Local stories developed by individual CELCs should be shared across the network in real time, or near real time, to capture the sense of urgency associated with coping with events.

Aquariums need to be careful not to focus too heavily on stories of "gloom and doom", but a story arc that includes the darker side is fine as long as the arc ends with hope and ways out of the problem. We should include uplifting stories such as "Joplin Rebuilds" and the lessons from "Viet Village in New Orleans during and after Katrina."

The arts—in all their modalities—can be an important component of story-telling. They often are a more effective way of communicating environmental messages to the public than traditional forms of science communication.

GIS can be a powerful way for integrating spatial data, transforming it into information, and displaying it in ways that can deliver messages clearly. Esri's StoryMaps tell stories in powerful ways that have "stickiness" and that can be updated readily to incorporate new data and new dimensions.

The purpose of programs of all kinds is to raise awareness, to deepen understanding, and to inspire appropriate actions. Programs must be evaluated to assess their efficacies in achieving these goals, and modified as appropriate. The CELC network provides opportunities to collaborate to enrich programs, to lower development costs, and to reach larger audiences. The network also expands access to experts of all kinds—science, media, etc.—to create more powerful programs and exhibits. SurfRider might provide a useful model for the CELC network. Dynamic, interactive experiences are more powerful than static experiences, but both have their place.

Whenever an extreme weather-related event occurs, it provides important learning opportunities, opportunities that should be seized. Other kinds of opportunities should be created such as "weather awareness weekends and weeks." Emergency kits could be distributed on a limited basis. For these events, it is important that we seek support of foundations and corporate sponsors, including local media outlets. Using the media not only helps spread the message of resiliency, but also increases an institution's visibility.

The Need for Assessment

Assessment will be an important element of securing and sustaining funding for the CELC network. It will require both formative and summative evaluations. Formative evaluation to test messages developed by a small group of CELCs before launching them network-wide;

and summative to assess changes in awareness and ultimately in behavior as a result of the programs designed and developed by the CELC network.

One of our goals is to increase public awareness of NOAA and all the benefits the Nation receives from NOAA. This will require a survey to establish baseline awareness and surveys after the network has been active on extreme weather-related events, and perhaps other national coastal and ocean issues. The Ocean Project might be a good partner given its experience in surveying our communities.

Conclusions & Recommendations

- Coastal America's Coastal Ecosystem Learning Network is a potentially powerful education and outreach network to those living in the nation's coastal areas. Because Coastal America is housed in NOAA and NOAA is the nation's ocean and atmosphere agency, the CELC network can be a major vehicle for transfer of NOAA's, and partner agencies of Coastal America, data, information, and services to the nation. Neither NOAA nor any of the other agencies participating in Coastal America has an outreach network that can reach such large numbers in so many ways as the CELC network. But, it will not just happen. It will require work and resources, but the return on the investment will be huge.
- Coastal America needs to create an electronic directory of CELC institutions with contact information for directors, directors of education, and other individuals who play key roles in CELC. The directory should be updated on at least an annual basis. This is essential if we are to enhance the collaboration of member institutions and realize the potential power of the network.
- The CELC institutions that participated in the workshop will work with guidance from Esri to create a dynamic, interactive map. The initial layers will include the member institutions and their locations, and the history of extreme weather-related events over the past 10 years. The Aquarium of the Pacific will work with Esri to create the model. Once posted, each member institution can update their section, but the enterprise needs to be curated to maintain some degree of symmetry among institutional profiles.
- The institutions that participated in the workshop have agreed to work collaboratively to develop a proposal on behalf of the entire CELC network to seek network funding for a national program to enhance the resilience of communities to extreme weather-related evens.[2] This effort will be tied to NOAA's Next Generation Strategic Plan and to NOAA's Weather Ready Nation Program. The CELC network can add a powerful outreach component in contributing to creating a Weather Ready Nation.

[2] It's not clear whether we can include the Canadian and Mexican representatives since we intend to seek funding from the U.S. government.

Appendix 1

Brief Summaries of Major Extreme Weather-Related Events In Regions Represented by Participating Aquariums

Aquarium of the Pacific

Southern California Extreme Weather

Summary created from a Forum hosted by the Aquarium of the Pacific.
http://www.aquariumofpacific.org/downloads/ExtremeWeather-RelatedEventsReport.pdf

When Southern Californians think of natural disasters, they think of earthquakes. However, extreme weather-related events actually pose the greatest risk to Southern Californian life, property, and natural ecosystems, not earthquakes. The four events that have the greatest potential to cause serious disruptions in Southern California are droughts, floods, wildfires, and heat waves. A group of twenty-eight scientists, planners, and emergency responders who convened at the Aquarium for a an Aquatic Forum held in November 2012, unanimously concluded that Southern California may experience more frequent and more intense weather-related events than have been observed in the historical record, and that the region should be better prepared to deal with these threats.

Drought: Summarized from a presentation by Jeanine Jones, Department of Water Resources
Because much of Southern California's population relies heavily on imported water for its basic water needs, careful management of water resources and deliberate drought preparedness are essential. Drought impacts can be mitigated by preparation and planning, but several challenges exist. In particular, drought impacts can be difficult to predict in intensity, duration, and economic impact. The long-term effects of climate change complicate planning and management further. Increasing water storage and redeveloping water resources, including managing gray water and storm water, are ways that communities and water resource management districts can increase resiliency in the face of pressing drought issues. Promoting water conservation and low-impact development as well as establishing secure reserves are additional ways that communities can effectively manage water resources.

Actions to Increase Resiliency and to Reduce Vulnerability
• Promote public education on water in Southern California - a precious and limited resource important to people and nature.
• Develop a public campaign to promote conservation during droughts.
• Continue to promote water conservation targeting landscaping, industrial and commercial uses, and agricultural efficiency.
• Make the policy and permitting process for ocean desalinization more transparent and predictable.

Flooding: Summarized from a presentation by Rudy Lee, Los Angeles County Department of Public Works
Perhaps owing to its network of cement lined "rivers," people living in greater Los Angeles mostly are unaware that they live in a riverine system. In the 1930s, the Los Angeles River was diverted into a series of cement channels to prevent flooding. The Los Angeles County Flood Control District (FCD) protects people, businesses, property, and habitats that are within this vast system of rivers and urban streams, maintaining a balance among the needs of all. Today the region's FCD encompasses 3,000 square miles that include a vast drainage infrastructure of over 85,600 units, all designed, operated, or maintained to decrease vulnerability to those in the path of flooding: dams, catchment basins, seawater intrusion barriers, stormwater pumping stations and drains. While flooding is not common in this area, a major challenge is maintaining education and awareness of this real potential flooding threat.

Actions to Increase Resiliency and Reduce Vulnerability
• Review adequacy of existing county-level flood alert networks and related communications tools.

• Improve public education on flood risks; personal safety measures, living in flood-prone areas, e.g. on alluvial fans.
• Improve education for local-level use, planning agencies, and public officials on risks of floodplain development.
• Improve understanding of debris flow hazards and management options.

Wildfire Risk in Southern California: Summarized from a presentation by Jon E. Keeley, U.S. Geological Survey and UCLA Department of Ecology and Evolutionary Biology
Wildfires are a major and normal part of Southern California's landscape. Long droughts can exacerbate fires and fire risk and transform native landscape to non-native weedy vegetation. In addition, strong Santa Ana winds normal to this area can spread fires rapidly. The vulnerability of communities to fire has increased over the past fifty years with Southern California's growing population. Climate change may play a role in future drought and Santa Ana wind conditions, although this impact is difficult to predict. Better land-use planning and more research on the impact of climate, drought, and high winds are needed to mitigate the impacts of future fires on our communities.

Actions to Increase Resiliency and Reduce Vulnerability
• Educate all California residents and visitors about wildfires and the extreme conditions associated with Santa Ana wind events.
• Improve fire prevention by increasing citizen vigilance in reducing arson fires, particularly during Santa Ana wind events.
• Embrace fire safe land use planning to place greater emphasis on reducing wildfire vulnerability by guiding development away from fire-prone areas.
• Promote existing programs of "Fire Ready Community" designation, e.g., Firewise Communities and FireSafe Counsels, and incorporate new research on the dangers of certain types of landscaping.

Heat Waves
Forecasts indicate that heat waves in Southern California are likely to increase in frequency, duration, and intensity as we move further into this century. Effects will be experienced by both coastal and inland communities; in fact, impacts of heat waves on human health could be greater in the latter. Heat waves are at, or near, the top of all extreme weather-related events in terms of loss of life, and Southern California needs to be prepared.

Actions to Increase Resiliency and Reduce Vulnerability
• Educate all California residents and visitors about heat stress and how to prevent it.
• Improve public's awareness of cooling centers: locations, the public transportation options, services.
• Support development of a "California Beat the Heat" webpage.
• Disseminate consistent heat stress alerts through all available resources.
• Educate the public and city, county, and state agencies about factors in urban development effective in reducing temperature rise such as reflective roofs, replacement of blacktop, new development, etc.

National Aquarium Institute

Maryland Regions

Maryland features a vast diversity of landscapes, each of which has a unique geography and climate. The state is separated into five main geographical areas including the Atlantic Coastal Plain, the Piedmont, the Blue Ridge Region, the Appalachian Ridge and Valley and the Appalachian Plateau. The Atlantic Coastal Plain is flat and is generally characterized by marshlands. The Piedmont region is marked by hills and valleys. The Blue Ridge Region features dense woodlands, and the Appalachian Ridge and Valley features farmland and mountainous terrain. The Appalachian Plateau is heavily forested and includes many rivers and mountains.

The weather within a region can vary widely, especially where the hills and mountains become more prominent in north central and the western mountains of Maryland. The coldest temperatures generally are on clear nights with light winds. The coldest air can settle in the valleys, while the warm air rises to the hill tops. Central Maryland does have some river valleys with water that drains into the Chesapeake Bay. Baltimore City has the added influence of the Urban Heat Island Effect. This is the presence of asphalt, brick, steel, and concrete that make the city's infrastructure; these materials can hold heat at night, delaying the onset of colder or cooler weather.

The Chesapeake Bay is the largest estuary in the world, and also provides a lot of jagged inlets and harbors. This gives Maryland the largest shoreline of all the states in our nation. Yes, more than California and Florida.

Central Maryland Region (National Aquarium) Is the primarily the urban and suburban area between Baltimore, Annapolis, and Washington DC. It also includes the northern portion of the Eastern Shore counties of Kent and Cecil. It is around the I-95 corridor where there are some hills, but also the proximity of the Chesapeake Bay. It is the chameleon of the state. This region can get some of the cold air from the north or be influenced by the water and warmer regions to the south.

Ty Christopher Taylor 4th Grade William Winchester Elementary

Nor'easters & Snowstorms

The Appalachian Mountains can affect the type of precipitation that falls in the region. If cold air gets trapped east of the mountains, this can lead to ice storm conditions along and just east of the mountains. The damming effect can also contribute to new storm development off the mid-Atlantic shore. When coastal storms develop, the colder air remains over the region and significant snowfalls are more likely. Still, the location of the rain-snow line, or the position that decides the type and location of precipitation areas often lies across the larger Baltimore/Washington, D.C. metro area. Sometimes the northwest suburbs receive heavy snowfall while southeastern areas experience all rain or a snow-to-rain transition (I-95 corridor). If the coastal low pressure system is far to the southeast, the northwest suburbs might get no snow, while the southern suburbs are snowed in. This scenario, which often involves a shift in the snow band of 50-100 miles, makes a major difference in observed weather conditions anywhere in the region. Overall, snowfall amounts decrease from about 80 inches in the far western mountain areas to about a foot on Maryland's eastern shore and across Delaware.

The region's average annual snowfall (15-20 inches except for mountain locales) often accumulates in a few major storm events. One of the most memorable snowfalls in the region was part of the "Blizzard of '96." This massive storm system formed along the Gulf Coast and then moved northeastward, passing just southeast of Washington, D.C., during the January 6-7 weekend. While only reaching blizzard strength (winds of at least 35 mph and less than 1/4 mile visibility for at least 3 hours) at a few observing locations in this region, blizzard-like conditions occurred elsewhere along its path. Some two to three feet of snow fell across the region and caused the federal government, schools, and businesses to shut down for almost a week.

While nor'easters might sometimes look like hurricanes on a satellite image, they are actually different in several ways. Nor'easters (which only occur in the cold season) feed off of cold and warm air interactions in middle latitudes, while hurricanes (occurring in the warm season) thrive on warm air and water in the tropics. Historically more devastating than hurricanes, stalled nor'easters can batter the coast for days, causing severe beach erosion and flooding from high storm surges.

One such storm, the Ash Wednesday storm of 1962, was said to be comparable in strength to some of the most intense hurricanes on record. It was also the strongest nor'easter of the century, according to the U.S. Geological Survey. Waves reaching 25-40 feet in height slammed into the coastlines of Maryland and Delaware, destroying millions of dollars of beachfront property, claiming 40 lives, and causing significant beach erosion throughout its 5-day visit.

Because they typically occur during the winter months, nor'easters can also become major snow-producers and have been the cause of some of the Northeast's most memorable snowstorms and blizzards.

***March 12-14, 1993:** SUPERSTORM 20 YEARS AGO THIS WEEK…some refer to this storm as "The storm of the Century". Produced wind gusts of 90 MPH at the beaches, Blizzard conditions in the I-95 Corridor with 10 to 20 inches of snow, and 30 to 35 inches in the Western Maryland Mountains! 270 U.S. deaths from this storm; 44 in Florida via tornados, 200 in NY Over 200 hikers were rescued from North Carolina and the Tennessee mountains. Curfews were enforced in many counties and cities as 'states of emergency were declared from Florida to Maine.

January 7-13, 1996:** The ***Blizzard of '96 or the ***Great Furlough Storm*** began early on Sunday, January 7. Just two days earlier, a six week impasse between a republican congress and a democratic president over the 1996 Federal Budget had finally come to an end. Many federal employees had been on furlough with government offices shut down. Employees would finally return to work on Monday, January 8. Mother Nature had something else in mind. By Monday morning, Washington, DC was buried under 17 to 21 inches of snow. As much as 30 to 36 inches of snow fell over Frederick and Washington Counties. Baltimore recorded over 22 inches and even Ocean City received 10 inches of snow. A two-foot swath of heavy snow fell across Dorchester and Caroline Counties into southern Kent County, DE. The entire state was paralyzed and the Federal Government remained shut down. As road crews worked hard to clear the snow, an "Alberta Clipper" shot through on Tuesday, January 9 dumping an additional 3 to 5 inches from Washington northeast through Baltimore. Plows that would have been working on secondary roads and residential areas were sent back to the primary roads. The government remained shut for 4 days that week and many schools and businesses announced their closure for the entire week. A third storm struck on Friday, January 12 dumping another 4 to 6 inches over the metro areas. A maximum of 6 to 12 inches of snow fell over Frederick and Carroll Counties. By the week's end, most of Maryland, west of Baltimore, had seen 3 to 4 feet of snow! Most areas to the east had received 1 to 2 feet!

Just one week later, a dramatic warming would occur melting the snow pack with an additional two to three inches of rain falling. No one expected that such a deep snow pack could disappear in just one night. A flood was the result. It had been 60 years since a flood of this type had hit Maryland. The Potomac and Susquehanna saw major flooding. Ice Jams on the lower Susquehanna River compounded the flood. An ice jam broke sending a surge of ice and water down to the Conowingo Dam. It was more than the dam could handle and operators had no choice but to open all of their gates to prevent the dam from being topped. Once water tops a dam, the entire dam can fail. With the gates open, the water surged to the Upper Chesapeake Bay causing a rapid and significant flood to hit the town of Port Deposit just a few miles below the dam. People were able to flee the cold waters, but there was no time to save any belongings.

***February 2-3 and February 16, 1996, storms:** The Delmarva area received 4 snowstorms in about 5 weeks from January 7 through February 16. The series of big snow storms went on to break an all time record at Baltimore with a season total of 62.5 inches. It broke the old record of 52 inches (set 1963-64 winter season) by almost a foot! Snow records at Baltimore go back to 1883.

January 14-15, 1999: A low pressure system pushed northeast from the Tennessee Valley spreading rain across the Baltimore-Washington Region. The rain instantly froze to surfaces creating a glaze. After a half to three-quarter inch of ice accumulated on trees and wires, 40 mph winds was enough to bring many of them down. Trees fell on cars, houses, utility lines and roads. The Governor declared a state of Emergency in Harford, Baltimore, Carroll, Howard and Montgomery Counties.

About a half a million customers were without power and 800 pedestrians were reported injured from falls on ice. Washington Hospital treated 250 patients for storm-related injuries on the 15th.
30+ school buses slipped off the road in the region.

January 25, 2000: A storm that was expected to move away from the coast, instead rapidly intensified off Georgia and headed almost due north. The nor'easter spread heavy snow into Maryland by the early morning hours of the 25th. Storm warnings were posted by 10 pm on the 24th, but those who went to bed early without catching the news were startled to see the heavy white stuff falling in the morning. With just 2 to 4 inches of snow on the ground at daybreak, the storm began to pound the area through the morning hours with one and a half inch per hour snow fall and wind gusts of 25 to 45 mph. Blizzard conditions quickly brought the area to a stand-still. Airports and transit systems were shut down. Schools were closed. Federal and state government offices quickly closed once the full impact of the storm was realized. However, some people who begin their commutes well before 7 am were left battling the storm to attempt to return home. The Chesapeake Bay Counties and a band west into Frederick County were hardest hit with a foot to a foot and a half of snow. Drifts of four to five feet were common. Seven storm related fatalities were recorded and numerous injuries. One elderly man died from hypothermia and six more people died of heart attacks while shoveling the heavy snow.

***Feburary 5-6, 9-10 2010:** The 'Snowmageddon' storm as referred to by President Obama was the biggest snowstorm in nearly 90 years and was the 2nd, 3rd, and even 4th significant winter storm for some parts of the Mid-Atlantic states during the 2010 winters season. Baltimore was hit with its 3rd heaviest snowfall with 24.8 inches. Washington D.C. was hit hard with its 4th heaviest snowfall with nearly 18 inches recorded at Reagan National Airport. At nearby Dulles International Airport, the record was shattered with 32 inches.

Parts of the Mid-Atlantic states were pounded by yet another major winter storm leaving many areas from Northern West Virginia eastward across Southern Pennsylvania, Northern Virginia, Maryland, Delaware, and Southern New Jersey buried under 1 to 3 feet of snow.

1st storm (Feb. 1st) developed over Baja California over warmer than normal Gulf Stream waters.

Hurricanes & Tropical Storms

Since 1985, 5 major hurricanes and more than a dozen tropical storms and depressions have made their way up the East Coast to inundate the Northeast and mid-Atlantic with heavy rainfall and strong, damaging winds. One of the most devastating, Hurricane Floyd, dropped more than a foot of rain in several areas along Maryland's Eastern Shore and Delaware. Property damage totaled $14.75 million on the Eastern Shore and $8.37 million in Delaware. Two children in Delaware drowned during this event.

***Hurricane Isabel September 18-19, 2003:** Heavy rain and storm surge due to Hurricane Isabel's high winds flooded coastal areas of Maryland and Delaware. The storm track (a southeast-to-northwest trajectory west of the Chesapeake Bay) allowed for a storm surge to move up the Bay, inundating parts of downtown Baltimore, vast storm surge impact on the Inner Harbor, including the National Aquarium, which is usually removed from coastal storm surge areas. Not only did Isabel cause more than 1 million residents of Maryland and Washington, D.C., to lose power, but her damage totals crept close to $1 billion.

August 27-28, 2011: Hurricane Irene caused localized flooding and widespread power outages on August 27-28. The Eastern Shore and Southern Maryland were particularly hard hit.
From September 6-9, the remnants of Tropical Storm Lee combined with other weather elements to produce widespread flooding in central Maryland. Forecasters on the day believed that conditions were unfavorable for the development of dangerous thunderstorms and/or super cells. Skies cleared enough to heat the atmosphere, and the air became unexpectedly unstable coming from the west to the east, within Baltimore's Inner Harbor. Radar spotted a line of thunderstorms that suddenly formed moving northwest to southeast across the region towards Baltimore, 40 to 50 mph. High winds, high waves came in contact with a Harbor Water Taxi capsizing it with 25 passengers and 2 crew members on board, 5 guest died from drowning.

Severe Weather, Derecho, Heat Waves
March 6, 2004: Forecasters on the day believed that conditions were unfavorable for the development of dangerous thunderstorms and/or super cells. Skies cleared enough to heat the atmosphere, and the air became unexpectedly unstable coming from the west to the east, within Baltimore's Inner Harbor. Radar spotted a line of thunderstorms that suddenly formed moving northwest to southeast across the region towards Baltimore, 40 to 50 mph. High winds, high waves came in contact with a Harbor Water Taxi capsizing it with 25 passengers and 2 crew members on board, 5 guest died from drowning.

August 4, 2004: Derecho storm formed in Kentucky, moving northeastward spawning high wind reports in Ohio, West Virginia, Maryland and Pennsylvania. Power lines and trees were downed from Oakland in Western Maryland to Frederick and Taneytown and Central Maryland.

***June 29-30, 2012: Derecho** Due to an extremely hot and highly unstable atmosphere, temperatures on the south side of a stationary front well in excess of 100°F prompting wide spread excessive heat warnings, the derecho strengthened and produced isolated instances of severe weather as it moved from the west to the east (Chicago through Washington D.C & Central Maryland) The derecho was

one of the most destructive and deadly fast-moving severe thunderstorm complexes in North American history. It resulted in 22 deaths, widespread damage and millions of power outages across the entire affected region, some residents without power for over 3 weeks!

Heat Wave

July 1995: Baltimore/Washington, D.C., is popularly known for being one of the hotter metro areas on the East Coast in summer, and the reputation is well deserved. The entire region can experience severe heat waves. In July, 1995, temperatures peaked at 99°F, heat indices, which incorporate dew point effects, remained above 120°F. This contributed to two deaths from hyperthermia and eight others due to heat-related exposure. Later that month, oppressive heat was responsible for four more deaths. Heat wave conditions were likely intensified by the urban heat island effect. Farther toward the coast, however, a strong high pressure system during the Independence Day weekend of 1999 caused a heat wave responsible for the deaths of 4 people as well as thousands of chickens along the Delmarva Peninsula. High temperatures and humidity caused heat indices to exceed 110°F and led to record utility demands.

East Coast Extreme Hurricanes - History

1954 *Hurricane Hazel* on October 15. Hurricane-force gusts swept the eastern half of Maryland. Heavy rains pounded the west. Washington National Airport reported a record sustained wind of 78 mph; a gust of 98 mph. Gusts near 100 mph were common throughout the Chesapeake Bay region and on the Eastern Shore. Severe flooding occurred along the bay and its tidal tributaries. Flash flooding plagued western Maryland, where 3-6 inches of rain fell. Generally, less than 2 inches of rain fell in the eastern half of the state.

1955 Hurricanes *Connie* and *Diane* on August 12 and 18, respectively. Strong gales from *Connie* sunk the tour schooner *Levin J. Marvel*, about 20 miles south of its home port of Annapolis. Fourteen passengers drowned. Combined heavy rain from *Connie* and *Diane* caused major flooding in central Maryland, particularly along the Potomac River.

1972 *Hurricane Agnes* on June 21-23. Widespread and in some places record flooding made this one of the state's most destructive natural disasters. Many dams were menaced, Thousands of evacuations, primarily in central Maryland. The run-off from tributaries caused an ecological calamity in the Chesapeake Bay.

1975 The remnants of *Hurricane Eloise* combined with other weather systems to pelt the state from September 23-26. Widespread flooding plagued central Maryland.

1979 *Hurricane David* produced a tornado outbreak on September 5-6. Gusts of 45 to 60 mph, swept central Maryland. The Baltimore metropolitan area experienced disastrous flash flooding.

1985 *Hurricane Gloria* tracked about 50 miles offshore on September 27 and caused extensive damage to the Ocean City boardwalk. Several inches of rain fell on the eastern half of Maryland. Gloria brought gusts of 80 to 90 mph to the coast.

1996 *Hurricane Fran* lashed the state with gales and heavy rain on September 5. A track west of the Chesapeake Bay and lengthy strong winds, gusting 40 to 60 mph, caused severe flooding along the bay and lower Potomac River. Also, flooding from torrential rain resulted in significant losses in western Maryland.

1999 *Hurricane Floyd* dumped more than 10 inches of rain on the Eastern Shore and along the Chesapeake Bay on September 16-17. Chestertown collected 14.00 inches. Annapolis had 11.60 inches. Floyd's eye passed over Ocean City, with a barometric pressure of 28.88 inches. Gusts in Ocean City peaked at about 60 mph.

2003 *Tropical Storm Isabel* tracked through the state on September 18, bringing widespread gales. More than nine hours of high winds created extreme flooding/storm surge along the Chesapeake Bay and its tidal tributaries. Isolated gusts near hurricane force blasted the Chesapeake region. Record power outages plagued the state.

2004 Hurricanes *Frances* (Sept. 8), *Ivan* (Sept 17) and *Jeanne* (Sept. 28) brought tornado outbreaks and flooding, particularly to central and western Maryland

2011 Hurricane Irene caused localized flooding and widespread power outages on August 27-28. The Eastern Shore and Southern Maryland were particularly hard hit. From September 6-9, the remnants of Tropical Storm Lee combined with other weather elements to produce widespread flooding in central Maryland.

2012 Hurricane Sandy lashed Maryland on October 29-30 with isolated hurricane force gusts and widespread gales, heavy rain in the eastern two-thirds of the state and significant snow wet snow, 30” in the western Maryland. The Ocean City fishing pier was partially destroyed and bay sections flooded.

References, Graphs, and Photo Credits

Ty Christopher Taylor 4th Grade William Winchester Elementary
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Storm Data, Dept. of Commerce, NOAA, NWS, January and February, 1996
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Local Climatic Data for Washington, DC. Dept. of Commerce, NOAA, NWS, 1996.
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Local records from the Washington DC Forecast Office, DOC, NOAA, NWS.
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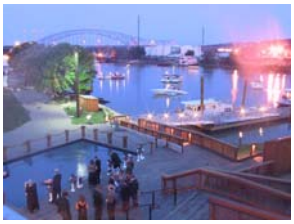
Derecho Summary Map by G. Carbin, NWS/Storm Predication Center
NWS National Hurricane Center for graphs, charts, animation radar.
AccuWeather.com

NATIONAL MISSISSIPPI RIVER MUSEUM & AQUARIUM
IN ASSOCIATION WITH THE SMITHSONIAN INSTITUTION


Weather Related Events in the 31 State Mississippi River Valley

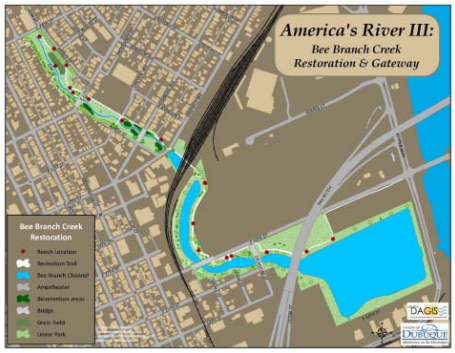
Rain, drought, and flooding are just three of the major weather related events which have occurred in the Mississippi Valley in the past 20 months. The frequency and severity of these events seems to be increasing. Examples of each are shown below.

….……Rain Events……

On July 27-28, 2011, a mesoscale convective system (MCS) stalled over Dubuque, Iowa and Jo Daviess County, Illinois. Thunderstorms developed repeatedly on the back of the storm and then "trained" across the same areas.

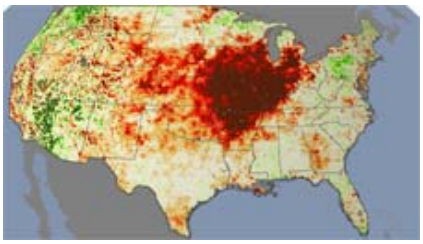
Numerous roads were washed out and many others closed. It was the most rainfall ever in a 24-hour period in Dubuque. 10.62 inches fell from the evening of 7/27/11 through the morning of 7/28/11 (previous record was 8.96 inches on 8/21-22/2002).

The Mississippi River rose 4 feet in 1 day, then fell, beaching several large boats and boat houses



Rain events have repeatedly flooded a storm drain system known as the Bee Branch in Dubuque. Once a creek carrying runoff through the neighborhoods of Dubuque, the creek was buried 100 years ago and funneled into underground drain pipes. Now they overflow regularly. The Bee Branch restoration project is a $61 million effort to "day-light" this former creek and create a greenway in the neighborhood. It involves voluntary buy out of 1,115 homes.

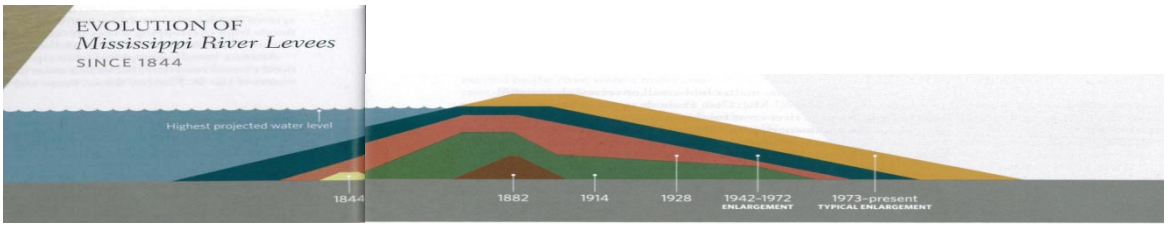
…….Drought……



In 2012, the central United States experienced one of its most severe droughts.
Percent Area of Lower 48 States in Drought, - **54.6% in June 2012**;

The Corps of Engineers hired contractors to use dynamite to remove the underwater pinnacles south of St. Louis, MO which were obstructing traffic.

……..High Water on the Mississippi……..



Levees have been built and augmented to increase their ability to keep the Mississippi River in its channel. The illustration above shows how the levees were made higher in 1844, 1882, 1914, 1928, 1942-1972, and 1973-present. But levees are sometimes purposely breached

During the flood of 2011, the Birds Point-New Madrid Floodway was activated for the first time since 1937, intentionally flooding farmland and homes lying in the spillway. Crews pumped 115 tons of binary blasting agents into 27,000 linear feet of buried pipes within the center of the levee. On May 2, a series of massive explosions shook the ground and lit up the night sky, audible 50 miles away. The nearly one mile long upper fuseplug was blown away; the area once protected was flooded, relieving the flood for others downstream.

Mystic Aquarium Extreme Weather-Related Events, Long Island Sound Region

With estimates ranging as high as fifty percent of the US population living within 50 miles of a coastline, extreme weather related events pose a tremendous threat to property, valuable resources, diverse ecosystems, and even humans lives. As with many coastal areas, the Long Island Sound region is incredibly vulnerable to extreme weather events and their varied impacts. The entire Connecticut coastline is bordered by the Long Island Sound, a protective estuary which serves as the economic engine for the state. In addition to generating over $5.5 billion annually through commercial and recreational fishing, tourism, etc., the coastline is densely populated with close to twenty three million people living within fifty miles of the Long Island Sound. More frequent, severe storms with stronger winds, larger waves and bigger storm surges are severely impacted the region and leading stakeholders to face the question on how to foster the continued use and enjoyment of the coastline while also preparing for the impacts of extreme weather events.

From the severe flooding of 2007 which resulted in of $23.7 million in residential damage and $7.4 in business damage, to the most recent impacts of Super Storm Sandy; the vulnerability of the Long Island Sound region to not only extreme but unpredictable weather events has become clear. In 2011 alone, the Long Island Sound region was affected by multiple tornados, Tropical Storm Irene as well as a freak blizzard in October. Although not every storm had a direct hit along the coast line, the Long Island Sound was significantly impacted by each event. Tropical Storm Irene resulted in coastal flooding from increased storm surges but also severe river flooding as the storm traveled across Vermont and New Hampshire producing unprecedented amounts of rain. Traveling along the Connecticut River, this excess water deposited immense quantities of debris, silt, and freshwater into the Long Island Sound that shellfish beds were impacted by the change in turbidity and salinity.

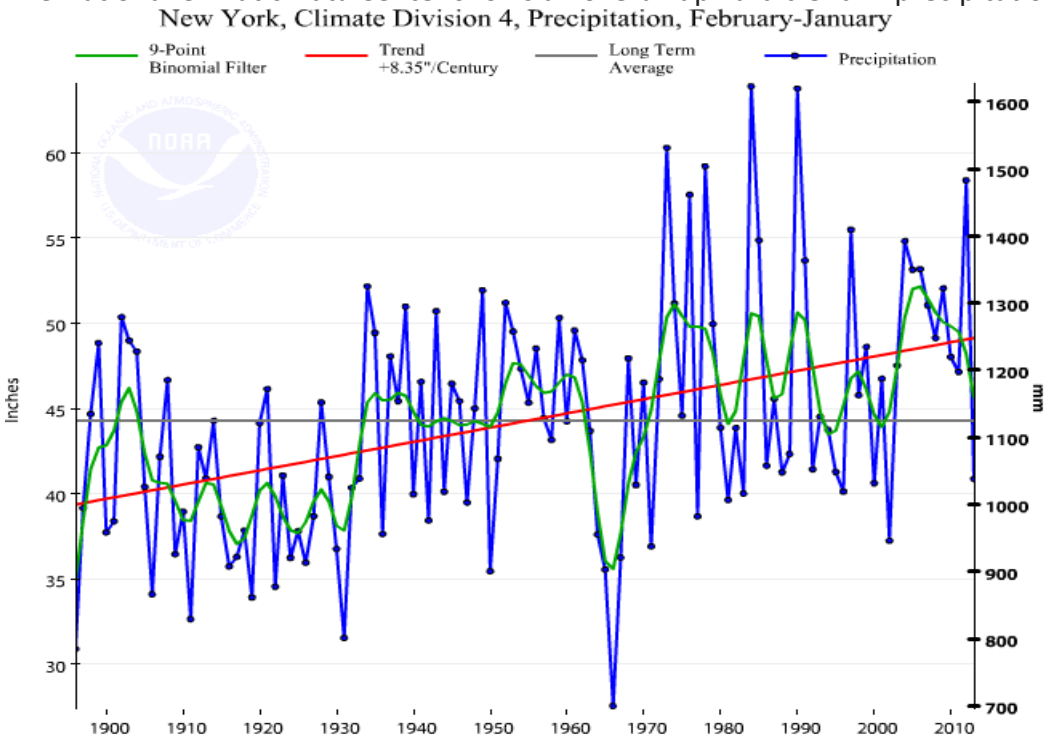
Less than three months after Tropical Storm Irene impacted the region, an unusual October blizzard resulted in some areas receiving more than 30 inches of snow. This storm resulted in multiple deaths and more than three million people or over 700,000 homes were left without power, breaking the previous record which was set by Tropical Storm Irene. These two significant weather events had a great impact on the economy, residents and ecosystems throughout the region.

Basing research on recent coastal flooding on five east coast cities, researchers predict that, when coupled with sea level rise, there will be substantial increases in major coastal flooding and an increase in the frequency of “100-year” floods. It is this challenge that has brought extreme weather related events and climate change to the forefront of city and state concerns with a new focus to develop strategies to best inform citizens on these events as well as prepare the coastal regions for an increase in extreme weather related events.

New York Aquarium: Extreme weather related events in New York City

Hurricanes, Tropical Storms, Nor'easters, Severe Thunderstorms

The National Climatic Data Center shows an overall upward trend in precipitation from 1900-2012.



According to the Washington Post, Superstorm Sandy was the second costliest hurricane in U.S. history, surpassed only by Hurricane Katrina in 2005. Much of Sandy's damage was flooding. Coastal Flooding occurs when intense, offshore low-pressure systems drive ocean water inland. In addition to flooding caused by storm surges, New York City also experiences flash flooding from thunderstorms and other intense rainstorms. Much of New York's infrastructure — particularly low-lying and poor drainage areas — cannot cope with rainfall of more than one inch per hour. High Winds are commonly associated with severe thunderstorms, hurricanes and nor'easters, they may also occur as a result of differences in air pressures, such as when a cold front passes across the area. High winds can cause downed trees and power lines, flying debris and building collapses, which may lead to power outages, transportation disruptions, damage to buildings and vehicles, and serious injury.

Snow storms

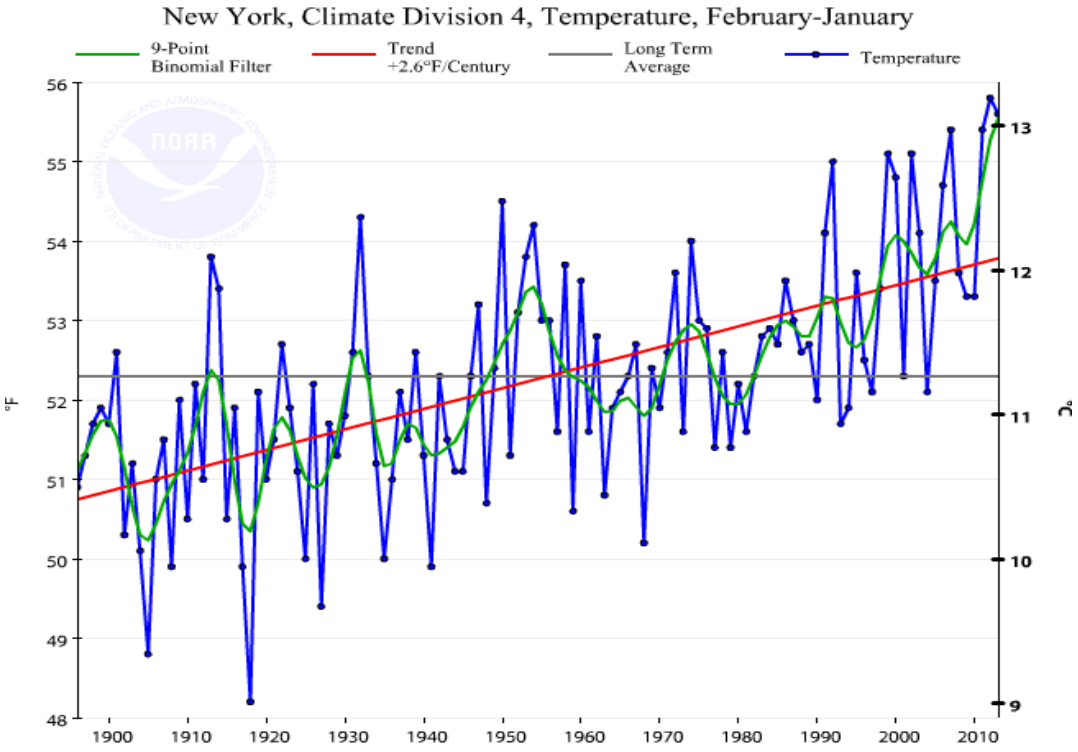
Weather data has been collected in NYC in Central Park since 1869. Since then, there have been only seven snowstorms that dumped over 20 inches of snow in Central Park. Five of the six snowstorms have all occurred in the last 14 years. And four of the snowstorms have occurred in the last 4 years. And two of the snowstorms occurred in 2010. Three of the top ten snowiest months in New York City history have all occurred in the last few years. And most of the years in the last decade have seen above average snowfall.

Tornadoes

Nine tornadoes have been confirmed in New York City since 1974. There were none in the city in the 24 years before that, according to the Weather Service's list of tornadoes since 1950 in the territory from Long Island to Orange and Putnam Counties.

The most recent was September 8, 2012, a tornado occurred in Queens and Brooklyn, yielded by an isolated severe storm in the morning.

Extreme Heat



During the summer months, New Yorkers are especially vulnerable to heat-related hazards. On warm summer days, the city can be as much as 10 degrees warmer than its surrounding areas. The city's infrastructure — largely made up of asphalt, concrete and metal — traps the heat. This is known as the "urban heat island" effect. In July and August of 2006, extreme heat waves gripped New York City, claiming 46 lives and disrupting power throughout pockets of the city.

Sea Level Rise

The New York City Panel on Climate Change's 2010 assessment suggests that local sea level could rise by 0.3–1.4 metres by 2080. http://www.nature.com/news/natural-hazards-new-york-vs-the-sea-1.12419

North Carolina Aquariums at Pine Knoll Shores

Climate Issues Impacting the Southeastern US

- The Southeast is likely to see the largest regional increase in the heat index. The higher the heat index, the more dangerous the heat wave can be.
- Atlantic hurricanes are expected to intensify as carbon pollution increases. Strong hurricanes are immense threats to all the southeastern and mid-Atlantic states.
- Sea level rise, combined with flooding and increased precipitation with storms may inundate low lying areas even more and could threaten to groundwater as well.
- Sea Level rise could impact over 2400 miles of the Gulf Coast and rates of relative sea level rise in the mid-Atlantic are higher than global averages.
- Tidal wetlands are already on the decline, in part due to sea level rise. With a predicted 1 meter rise in the next century, many narrow barrier islands may disappear. (i.e. Outer Banks of NC)

Impacts on NC

The NC State Climate Office Data suggests:

- Temperature: A review of the entire period of record suggests that the warming since the mid-1970s may not be unprecedented, especially when compared with the warming observed from 1910-1950. Overall, the trend over the 113-year period is flat, with no long-term trend over the period.
- Precipitation: Note that the linear trend is slightly positive over this period, but that this trend is so slight as to not be meaningful (i.e. statistically significant) given that the year-to-year variability is so high. Again, the signal-to-noise ratio is too low to detect a significant trend
- Drought: Similar to statewide patterns since 1895, this longer-term data suggest no trend and high variability. Indeed, it suggests drought periods in the past that may have been more severe than those witnessed in NC in modern times.
- Severe Events: The available data on severe thunderstorms, high winds, hail, flooding, and tornadoes are limited, and generally show no trend.
- Hurricanes: trend analysis of landfalling hurricane records suggests that there is no meaningful increase over the entire 150+ year record.
- Sea Level Rise: There is one aspect of North Carolina's environment that is closely linked to global warming: our rising sea level…Since our coastline is made of dynamic shifting sands and bogs that slowly grow with the rising sea level, out coast line may look different in 100 years than it does today, but it will likely not be a simple increase of 2-3 feet of water over the current land structure.

How the Aquarium will address and inform the public on the science:

- Interpretive/Facilitated Programs elaborate on climate change impacts and threats to animals and habitats.
- Discovery Carts include hands on activities and information to better interpret the carbon problem and human impacts; distribution of materials to inform public on how to make better choices as consumers.
- Small group programs which are more inquiry based will explore and investigate scientific concepts around climate change (i.e. greenhouse effect, ocean acidification, thermal expansion of water)
- Exhibits interpret climate change impacts and threats to animals and habitats.
- Volunteers at exhibits incorporate specific messages such as ocean acidification at touch tanks.

Issues the Aquarium faces:

- Since NC data shows no current trends or impacts directly related to climate change, we have to encourage visitors to be very forward thinking and trust the models and the science.
- Convincing visitors accept some responsibility and to ACT!
- Follow-up with visitors to evaluate our efforts and measure our impacts.

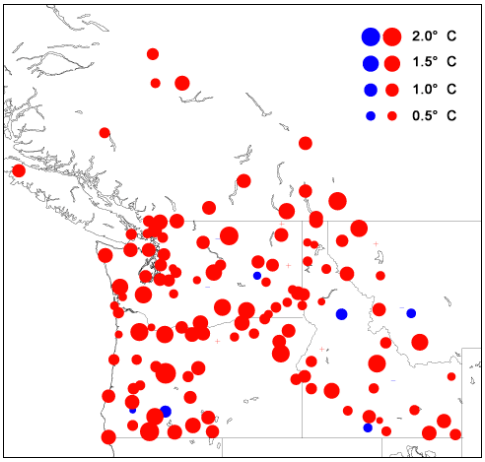
Seattle Aquarium

Extreme Weather and Climate Impacts

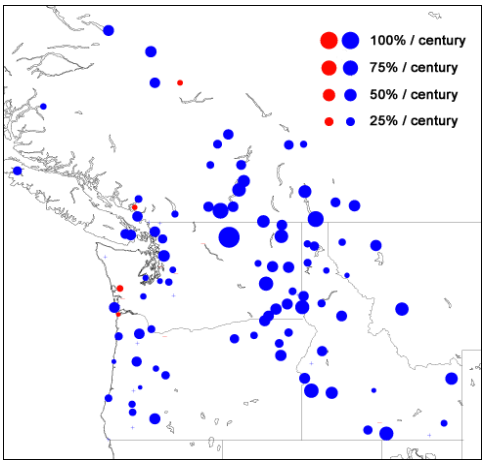
Pacific Northwest

General Climate Trends in PNW[3]

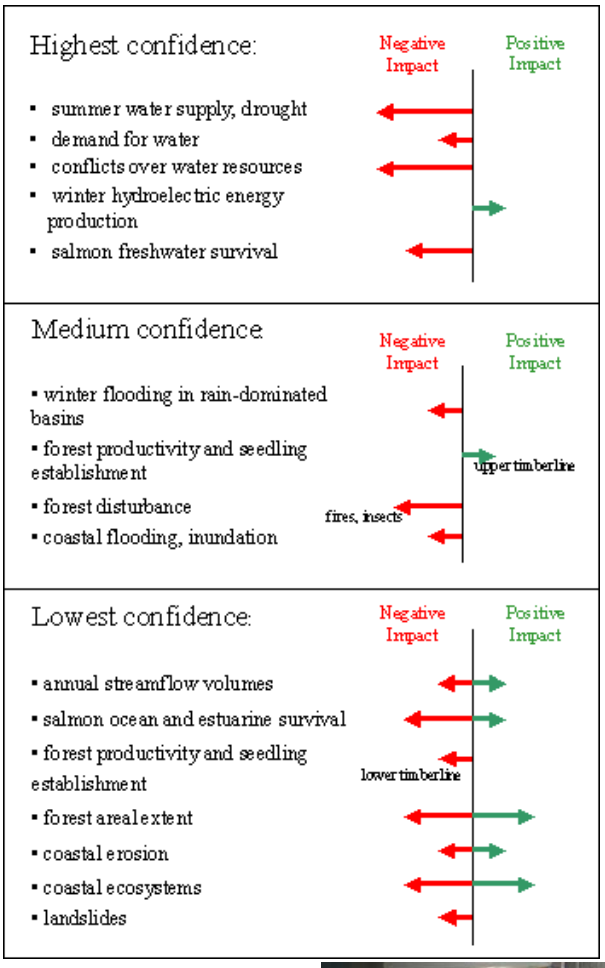
- 1.5°F (1920-2003) …rate of change projected to increase
- Precipitation increased across the region (1920-2003) …future average rate of change projected near zero
  - ★ Project higher in winter, lower in summer. While these could lead to extreme events, events are not a facet of the current models.



Temperature



Precipitation



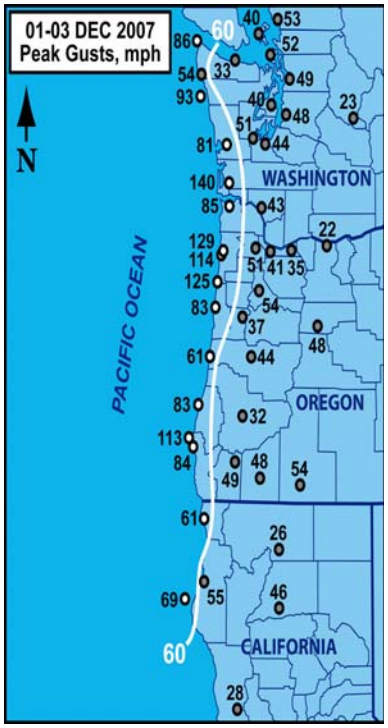
Exemplar Event: King Tide of December 17, 2012

- 12.9' king tide + storm surge = 14.51' (highest tide level since 1901)
- Likely *not* CC-related, but an opportunity for sea level rise discussion

[3] *Climate Impacts Group, University of Washington, www.cses.washington.edu/cig*

Exemplar Event: Great Coastal Gale of 2007[4]

- 3 successive storms + hurricane force winds + extreme rainfall
- Flooding, wind damage, avalanches, > 1,000 landslides
- 11 fatalities, 55k without power, $1 billion event
- Regional scale: 10-15k mi^2 affected by winds



Established Players/Partners/Networks

Western Governors Association/NOAA

- Forum: *Dealing with Extreme Events: The Pacific Northwest* (April 2012)[5]
- Early Warning System
- Better link between science and decision-makers

UW Climate Impacts Group[6]

- Link between science and policy (+outreach)
- Dr. Amy Snover, Director, interested in partnering

Northwest Zoo and Aquarium Alliance (NWZAA)[7]

- Collaboration of seven zoos and aquariums in Washington, Oregon, and Idaho
- Working together on teen-oriented climate change education programming

Informal Science Education Consortium (ISEC)

- Six ISEIs in Seattle including the Aquarium, Woodland Park Zoo, Pacific Science Center, Museum of Flight, The Burke Museum, and Islandwood
- Working collaboratively on a range of projects

Resistance to climate change planning, according to UW-Climate Change Impacts Group[8]

What prevents interested organizations from taking proactive steps to address impacts?

- *Resource constraints and issue fatigue* – no room on the plate for one more issue…
- *Differing planning horizons* – impacts may occur over longer scales than typical planning
- *Desire for more specificity* – waiting for information specific to a particular situation
- *CC = global problem* – exacerbated by discussions of international treaty agreements (ex. Kyoto Protocol)
- *Need for more certainty* – waiting to know 'for sure' about the degree of impacts
- *Uncertainty over how to plan* – fear of expensive, divergent strategies for adapting to impacts

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[4] *Dr. Brad Coleman, NOAA/National Weather Service, http://bit.ly/pnwgale2007*

[5] *Agenda and materials available at: http://www.westgov.org/initiatives/climate/397-pnw-weather-climate-forum*

[6] *Learn more about the UW Climate Impacts Group at http://www.cses.washington.edu/cig*

[7] *Learn more about NWZAA at http://www.nwzaa.org*

[8] *Summarized from http://cses.washington.edu/cig/fpt/planning.shtml*

Texas Coastal Resilience to Weather and Climate-Related Events

Setting the Stage

Texas State Aquarium is situated on the northeast corner of the Port of Corpus Christi. At an elevation of just seven feet at latitude 27.8° and longitude -97.4°, the Aquarium's location exemplifies the vulnerabilities of the city and the Texas Gulf Coast to extreme weather events.

Looking at the wider picture, the Corpus Christi Bay estuary is one of 7 systems on the Texas Coast. Texas has 367 miles of coastline and 3300 miles of bay shores. Corpus Christi is the "birdiest" city in the country. Galveston Bay serves the Houston metroplex, the third (or fourth) largest city, with the largest concentration of oil and gas facilities and the number one producing chemical complex in the nation. Three of the ten largest ports in total tonnage are also located on the Texas Coast, including the Port of Corpus Christi. Coastal tourism adds 7.5 billion annually to the Texas Economy, with commercial fisheries adding another 170 million; and Texas' Gulf Intercoastal Waterway moves more than 65 million short tons of cargo each year. Texas depends upon its coasts! And yet it's all under threat by erosion and storm tides and surges.

Corpus Christi Bay and the Texas Gulf Coast are home to unique and productive habitats and business concerns. Our bays are semi-tropical to semi-arid and even small changes create significant impacts. Some habitats will be diminished by extreme weather events like drought or hurricanes, while others will grow and migrate. Texas barrier islands, the longest barrier islands remaining in the United States, and backbay ecosystems and businesses, including the ports and petrochemical complexes, may suffer the greatest losses due to storm tide inundation, erosion, and drought.

Extreme Weather Threats

Erosion and drought are persistent problems that will increase with sea-level rise and global warming, with no end in sight and numerous implications for agriculture, estuarine health, fisheries, and fresh water resources. Storms and hurricanes cause the greatest periodic coastal erosion. Long-term erosion, which affects 64 percent of the Gulf shoreline, is caused by the rate of relative sea level rise and the lack of new sediment coming into the coastal system from Texas river systems. Erosion has consumed 26 miles of State Highway 87, which once connected Galveston to Sabine Pass. As of January, 96% of the state of Texas is experiencing drought, with almost all of the state at least abnormally dry. Groundwater levels declined in most of the major aquifers over December 2012, unusual for a time of year that usually produces rebounds.

Since 1851, 63 hurricanes have made landfall on the Texas coast. Hurricanes Ivan and Ike have more recently caused devastation on the Texas Gulf Coast, however, Corpus Christi has not experienced a damaging storm since Hurricane Celia in 1970. How will current residents respond? The category four hurricane of 1919 hit Corpus Christi with winds of more than 110 miles an hour and a 16-foot storm surge. The storm sank more than 10 major vessels and killed hundreds of people, making it the fourth deadliest hurricane of the century. The official death toll

for the Corpus Christ area was 287, but realistic estimates put the total at between 600 and 1,000. In terms of resilience, this storm was the impetus for the construction of a protective seawall that was eventually completed by the WPA. How would it fare today?
Conversely, 1970's Hurricane Celia produced devastating winds and less storm surge damage. Celia brought gusts of 150 miles per hour that blew down the anemometer at Aransas Pass; gusts an hour later were estimated near 180 mph. Corpus Christi reported sustained winds of 125 mph with gusts to 161 mph. Much of the Celia's damage came in short bursts of extremely high winds that carried debris from ruptured homes and structures for 1000 yards or more in a single direction. This was the first time such a pattern of wind swaths was noted, and changed our thinking about hurricane-proof design. Sixteen lives were lost due to Celia, including five in Cuba and five in Corpus Christi. Property losses in Celia rose to a record for Texas at that time of $444.9 million with an additional $8.8 million in crop damage. All that said, the City of Corpus Christ was praised for its resilience to Celia due to excellent preparation and coordination.