Caribbean Regional Chapter - Stakeholder Engagement Workshop
Fourth National Climate Assessment (NCA4)
March 09, 2017 in San Juan, Puerto Rico
OPEN TO THE PUBLIC

DRAFT AGENDA - Thursday, March 9, 2017

Objective: To gather input from a diverse array of stakeholders throughout the region to inform the Caribbean chapter of NCA4, and to share the process and timeline for the development of NCA4.

- **Main Location:** Conference Room - International Institute of Tropical Forestry in San Juan
- **Satellite Locations:**
  - U.S. Virgin Islands: UVI St. Thomas Campus: GeoCAS Institute, 2nd Floor, room 212
    Contact: Kostas Alexandridis geocas@uvi.edu
  - Raleigh, North Carolina State University: 123 David Clark Labs, 100 Brooks Ave
    Contact: Adam Terando aterando@usgs.gov
  - Washington, DC: 1800 G Street, NW, Suite 9100
    Contact: Apurva Dave adave@usgcrp.gov

Organizers: USDA Caribbean Climate Hub, Puerto Rico Department of Environmental and Natural Resources, University of the Virgin Islands, USGS SE Climate Science Center, and the U.S. Global Change Research Program.

Remote Connection via Adobe Connect: To join the meeting on March 9, 2017 go to:

- https://usfs.adobeconnect.com/climate_hub/
- Audio via computer or Call-in by phone: USA Toll-Free: 888-844-9904, Access Code: 7518378

AGENDA

9:00 Registration opens

9:30 Welcome, Workshop goals and brief introductions Ernesto Diaz, William Gould

9:45 Overview of the National Climate Assessment and NCA4 Apurva Dave/Chris Avery

- U.S. Global Change Research Program
- Mandate, timeline, and structure of NCA4
- Ways to get involved
- Areas of desired input from public comments
- Questions and Answers

10:15 Caribbean Chapter Outline William Gould, Ernesto Diaz

10:30 Presentation of chapter components

1. Observations – Odalys Martinez
2. Climate projections – Adam Terando (*remote*)

Five key messages

3. Freshwater availability – Eric Harmsen
4. Changing oceans –Julio Morell (*remote*)
5. Warming temperatures – Pablo Mendez

6. Rising sea levels and coastal erosion – Aurelio Mercado
7. Extreme events – Félix Aponte-González

Perspectives

8. US Virgin Islands – Wayne Archibald
9. International – Roger Pulwarty

11:30 Stakeholder Perspectives

- Seeking input on:
  - Are we capturing key attributes, assets and things of greatest value?
  - Are those things vulnerable to or at risk from climate change?
  - What type of information will be useful for their industry? (per sector)
  - What is missing from the outline chapter?
  - If there was a final report, what would you want to get out of it? (datasets, etc)

11:55 Instructions for afternoon exercise

12:00 LUNCH - provided

1:00 Breakout Groups based on the 5 topics of the key message

- *(Participants will rotate to visit 2-3 groups)* Seeking input on:
  - How is or has climate change affected this topic (i.e., observed change)?
  - How is climate change projected to affect this topic in the next 20-30 years and at the end of the century (i.e., projected change)?
  - Are there resources (reports, studies, etc.) or case studies we should be aware of?
  - What challenges, opportunities and success stories for addressing risk can be highlighted?
  - Are there case studies or specific resources to highlight?
  - What are the emerging issues and/or research gaps on this topic?
- *Freshwater availability* Facilitator: Eric Harmsen
- *Changing oceans* Facilitator: TBA
- *Warming temperatures* Facilitator: Pablo Mendez
- *Rising sea levels and coastal erosion* Facilitator: Aurelio Mercado
- *Extreme events* Facilitator: Felix Aponte
- *Satellite site NCSU* Facilitator: Adam Terando
- *Satellite site UVI* Facilitator: Kostas Alexandridris

2:15 ***BREAK***
2:30 REPORT Back from Breakout Groups *(10 minutes per group)*
3:45 Concluding remarks and next steps
4:00 END of meeting

Fourth National Climate Assessment Regional Engagement Workshop Caribbean Chapter Outline

William Gould, USDA Forest Service
Ernesto Diaz, Director, Coastal Zone Management
Puerto Rico Department of Natural and Environmental Resources

March 9, 2017

U.S. Global Change Research Program

Chapter outline

Geographic Scope of the Caribbean Regional Chapter: Puerto Rico and the U.S. Virgin Islands, with articulation of unique attributes, vulnerabilities, capacities, and activities relative to the continental United States and international links with the wider Caribbean.

Intended audience: Policy makers, planners, researchers, educators, managers, and the public in Puerto Rico, the U.S. Virgin Islands, nationally and internationally.

General format: Organized around 5 Key messages that identify vulnerabilities, climate trends: observed and projected risks, impacts and benefits, capacities, solutions, and gaps in research and action.

Chapter contents

Author Introductions

- **Adam Terando** USGS Southeast Climate Science Center, Raleigh NC
- **Annmarie Goulbourne** Environmental Solutions Limited, Jamaica
- **Aurelio Mercado** University of Puerto Rico, Mayagüez PR
- **Eric Harmsen** University of Puerto Rico, Mayagüez PR
- **Azad Henareh Khalyani** Colorado State University, Fort Collins CO
- **Félix Aponte-González** University of Puerto Rico, Río Piedras PR
- **Grizelle González** USDA FS, International Institute of Tropical Forestry, Río Piedras PR
- **Jared Bowden** University of North Carolina, Chapel Hill NC
- **Julio Morell** University of Puerto Rico, Mayagüez PR
- **Kathleen McGinley** USDA FS, International Institute of Tropical Forestry, Raleigh NC
- **Lisamarie Carrubba** NOAA Office of Protected Resources, Silver Spring MD
- **Odalys Martinez-Sánchez** NOAA National Weather Service, San Juan PR
- **Melissa Meléndez** University of New Hampshire, Durham NH
- **Pablo Méndez Lázaro** University of Puerto Rico Medical Sciences, San Juan PR
- **Ricardo J. Colón-Rivera** Puerto Rico Department of Natural and Environmental Resources
- **Roger Pulwarty** NOAA Office of Oceans and Atmospheric Research, Boulder CO
- **Wanda Crespo** Estudios Técnicos, San Juan PR
- **Wayne Archibald** University of the Virgin Islands, Saint Thomas VI

Odalys Martinez-Sánchez NOAA National Weather Service, San Juan PR

Climate observations and trends

Adam Terando USGS Southeast Climate Science Center, Raleigh NC

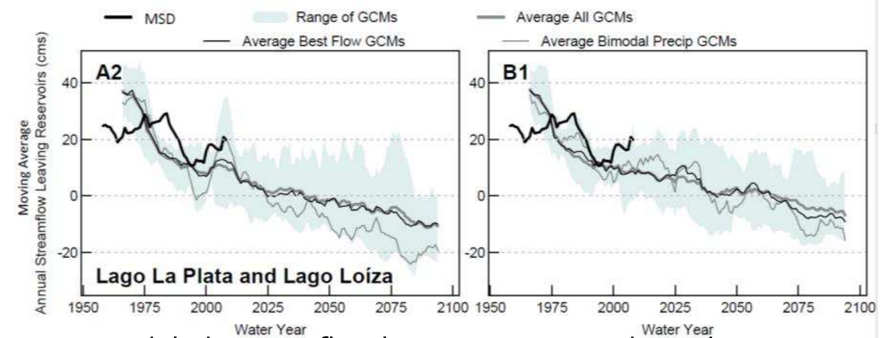
Climate projections

Eric Harmsen University of Puerto Rico, Mayagüez PR

Focal Area – Freshwater availability

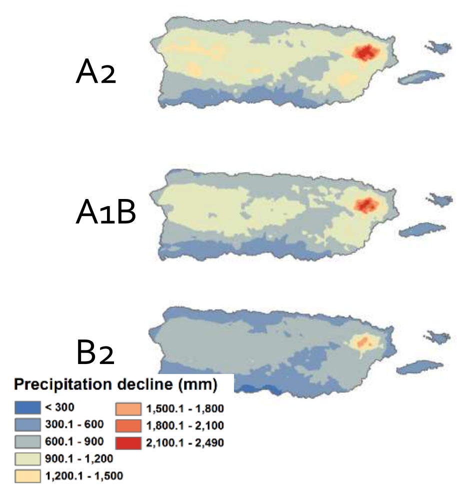
Aspects to Consider:

- **Uncertainty in projections.**
- **Increasing variability** – Projected decreases in annual precipitation, increases in extreme events.
- **Drought** – Higher temperatures, increasing number of days without rain.
- **Flooding** – Increasing frequency in extreme rain events.
- **Water management** – Balancing consumption, recreation, wildlife, agriculture.

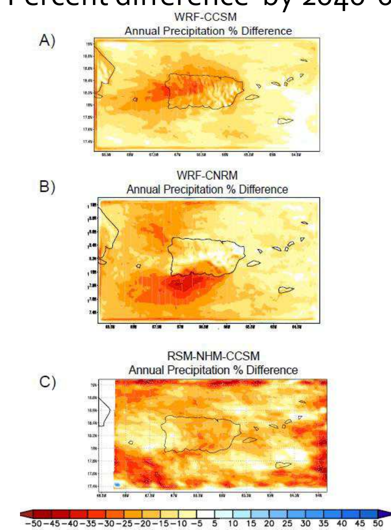


Modeled stream flow leaving reservoirs through 2100.

CMIP3, Statistical downscale
12 model ensemble
Precipitation decline by 2100



CMIP5, Dynamical downscale
3 models
Percent difference by 2040-60

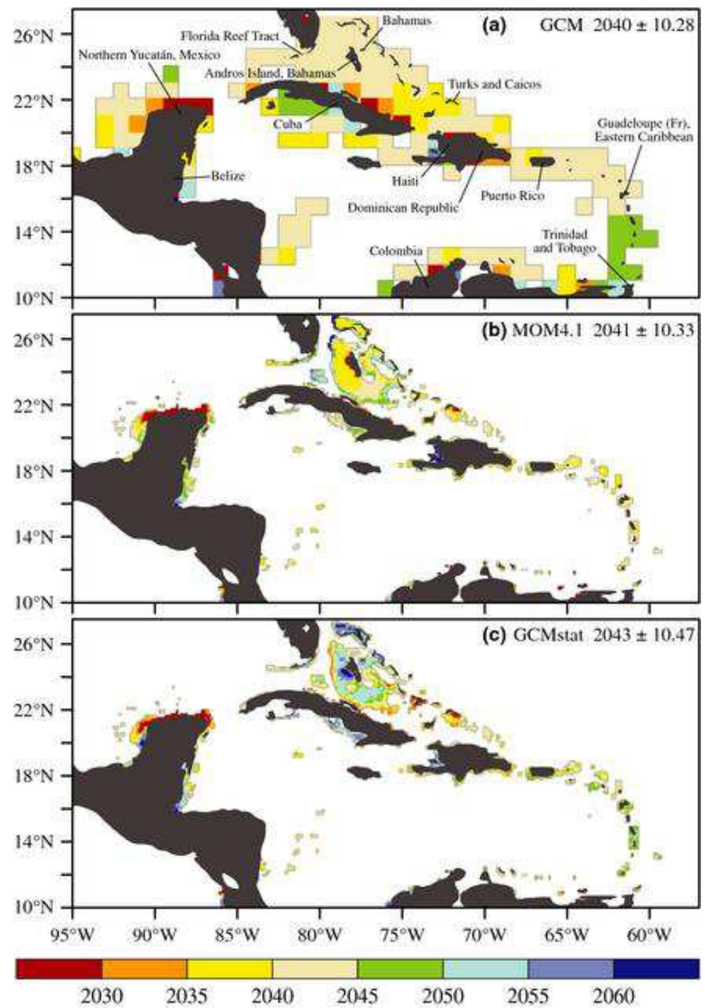


Julio Morell University of Puerto Rico, Mayagüez PR

Focal Area – Changing Oceans

Aspects to Consider:

- **Warming & Acidification –** Affecting marine ecosystems, biodiversity, recreation, food security and economic development.
- **Island systems and societies –** Impacts expected on vulnerable populations and coastal-reliant communities.
- **Adaptation Needs –** Fishermen, communities, and industries dependent on living marine resources need to prepare for and adapt to ongoing and future changes.



Downscaled projections of Caribbean coral bleaching
From Hooidonk et al. 2015. Projected timing in the onset of annual severe bleaching (>8 DHW) in years for: (a) an ensemble of GCMs at model resolution (1° × 1°), (b) dynamical downscaling through using GCM outputs to force the GFDL Modular Ocean Model (MOM4.1, ~0.1° resolution), and (c) statistically downscaling GCM outputs by replacing the model mean and annual cycle for SST with observed data from 1982 to 2008 re-gridded to the scale of MOM4.1.

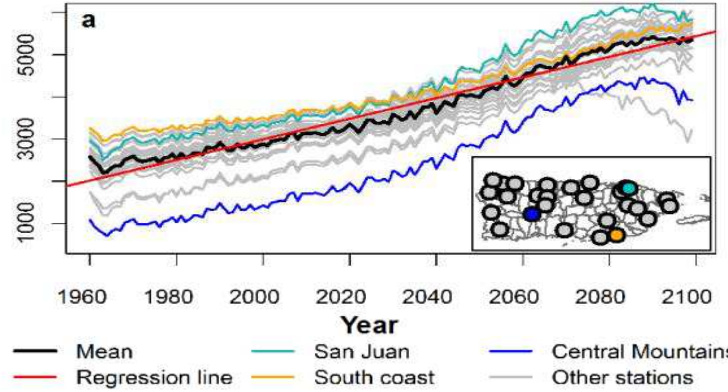
Pablo Méndez Lázaro University of Puerto Rico Medical Sciences, San Juan PR

Focal Area – Warming temperatures

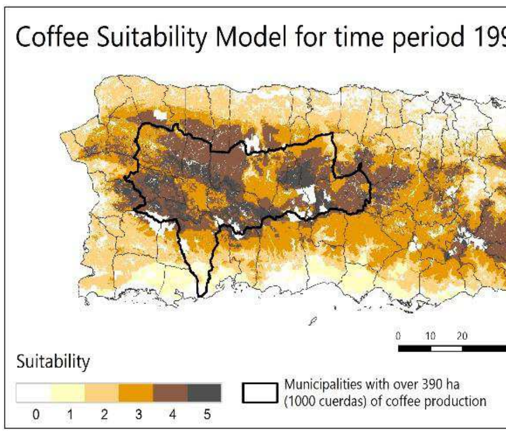
Aspects to Consider:

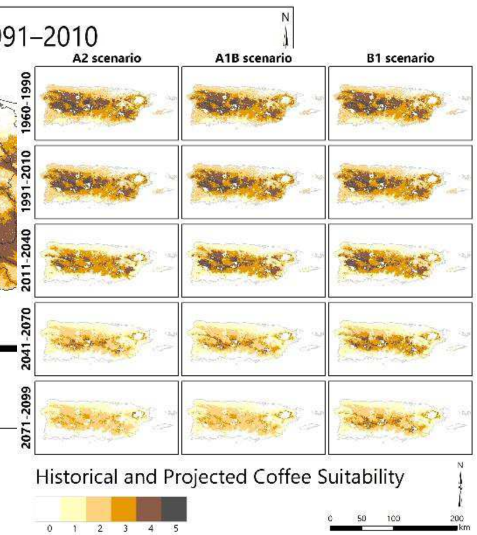
- **Increasing mean temperatures** – Less cool nights, greater evapotranspiration, more frequent extreme heat events.

- **Broad implications** – Cooling costs, plant phenology and distribution, pest and disease occurrence and distribution, increasing likelihood of drought and fire occurrence, food security, wildlife, and human health.



Henareh et al. 2016. Projected increase in cooling degree days through 2100.





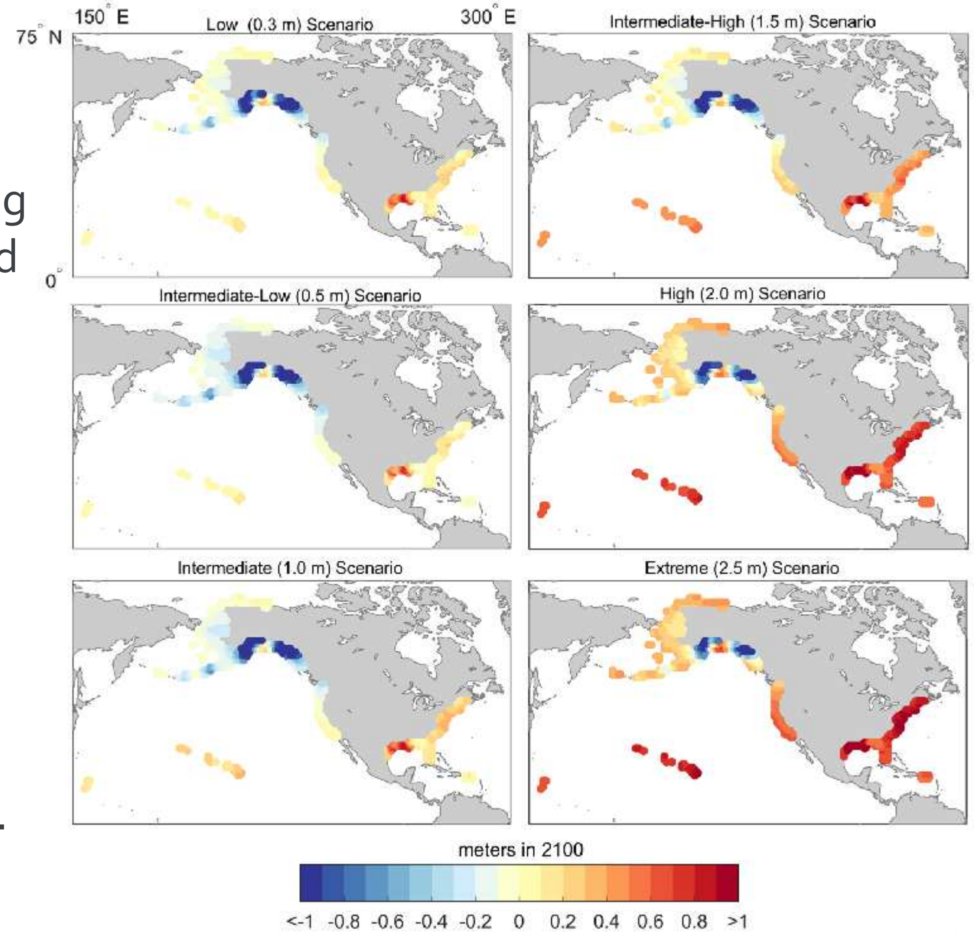
Fain et al. in press.

Aurelio Mercado University of Puerto Rico, Mayagüez PR

Focal Area – Rising sea levels and coastal erosion

<u>Aspects to Consider:</u>

- **Vulnerable infrastructure** – Low lying urban areas, poor drainage, increased flooding, recreational facilities (beaches).
- **Critical Infrastructure** – Low lying transportation hubs and routes, schools and hospitals.
- **Coastal habitats** – Limited potential for landward migration.
- **Agricultural land** – Limited resource.
- **Coastal aquifers** – Increasing salinization.



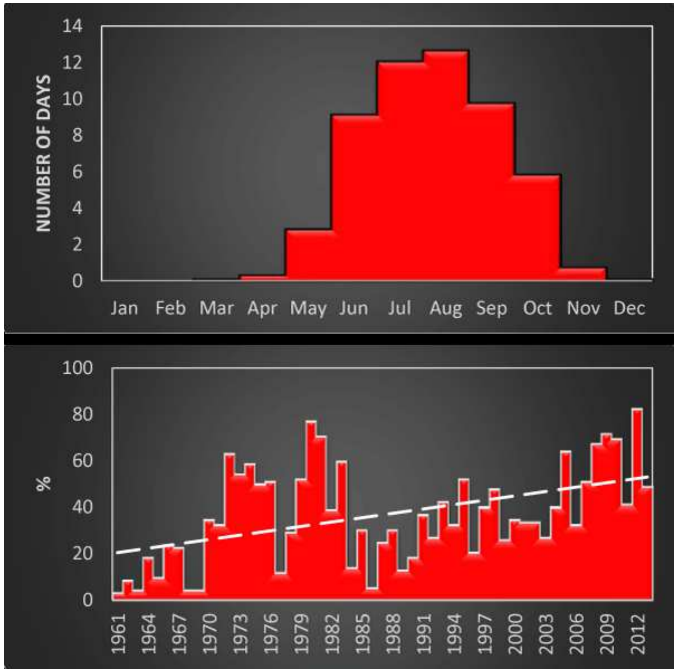
Sweet et al. 2017, Relative (to GMSL scenario) Sea Level Rise for year 2100

Félix Aponte-González University of Puerto Rico, Río Piedras PR

Focal Area – Extreme events

Aspects to Consider:

- **Changing frequency and intensity** – Heat waves, storm surges, hurricanes, tropical storms, drought.
- **Changing vulnerability and risk** – Human health, economic development, tourism, conservation, agriculture, fire and flood danger
- **Adaptation** – Linking short term actions to long term risk reduction.



From Méndez-Lázaro et al. 2015 **Extreme Heat Events in San Juan Puerto Rico: Trends and Variability of Unusual Hot Weather**. Average occurrence of the E1 Category (Very warm). Number of days per month. Lower panel: E1 Category percent of occurrence in summer days. 1981-2013.

Wayne Archibald University of the Virgin Islands, Saint Thomas VI

Perspectives – US Virgin Islands

Roger Pulwarty NOAA Office of Oceans and Atmospheric Research, Boulder CO

Perspectives – International

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GlobalChange.gov

www.globalchange.gov/nca4

U.S. Global Change Research Program

NCA4: Climate Projections for the US Caribbean

Adam Terando
Southeast Climate Science Center (USGS)
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NORTH CAROLINA

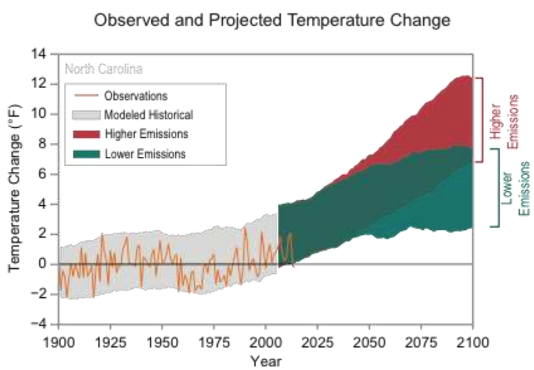
Key Messages

Mean annual temperature has increased by under 1°F since the beginning of the 20th century. Under a higher emissions pathway, historically unprecedented warming is projected by the end of the 21st century.

The number of landfalling hurricanes in North Carolina is highly variable from year to year. Hurricane-associated storm intensity and rainfall rates are projected to increase as the climate warms.

A large portion of North Carolina's coastline is extremely vulnerable to projected sea level rise due to its low elevation and subsidence of land in the northern part of the Coastal Plain. Global sea level is projected to rise by 1 to 4 feet by the end of the 21st century.

North Carolina has a humid climate with very warm summers and moderately cold winters. The climate exhibits substantial regional variation due to the state's diverse geographic elements, which include the Appalachian Mountains in the west, the Piedmont Plateau in the central region, and the Coastal Plain to the east. Elevations in the state range from sea level along the Atlantic Coast to over 6,000 feet in the western mountains (the largest elevation range of any state east of the Mississippi River). Average annual temperatures in the state vary more than 20°F from the highest elevations to the lowest points on the coast. Winter temperatures are moderated somewhat by the Appalachian Mountains which partially block cold air coming from the Midwest.



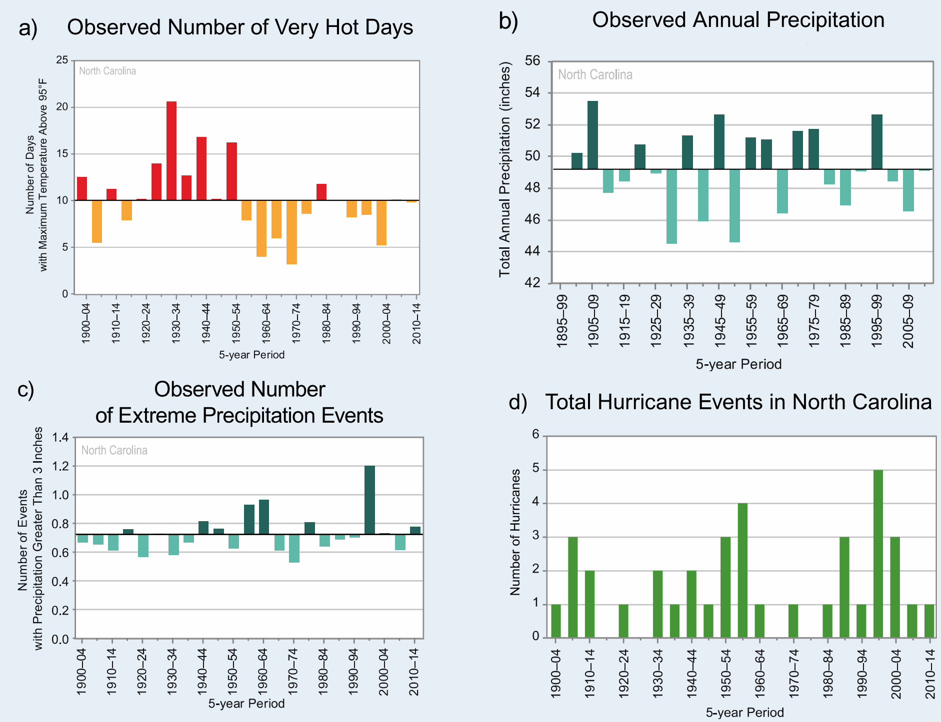


Figure 3: The observed (a) number of very hot days (days with maximum temperature above 95°F; 1900–2014), (b) annual precipitation (1895–2014), (c) extreme precipitation (greater than 3 inches; 1900–2014), averaged over 5-year periods, and (d) total number of hurricane events (wind speeds reaching hurricane strength somewhere in the state). Figures 3a and 3c are averages from all available long-term reporting stations (19 for temperature and 24 for precipitation). Figure 3c is from NCEI's version 2 climate division dataset. The dark horizontal lines in Figures 3a, 3b, and 3c represent the long-term average. In North Carolina, the frequency of very hot days has declined compared to the mid 20th century. The higher frequencies of such days during the 1930s and 1950s correspond to periods of exceptionally dry weather. Hurricanes reach the North Carolina coast with hurricane force winds about once every three years. All measures of precipitation have been near normal during the most recent 5-year period (2010–2014). Source: CICS-NC and NOAA NCEI.

State Summaries from NCEIs: ***Not available for US Caribbean***

Global Climate Models (GCMs)

- Output from the last two IPCC Assessments (CMIP3/CMIP5)
- These are VERY coarse model outputs
- Puerto Rico and USVI do not “show up”
- Still useful for understanding regional climatic changes
- Too dry and too cold….main features of GCMs in this region, CMIP3 higher bias (worse) than CMIP5

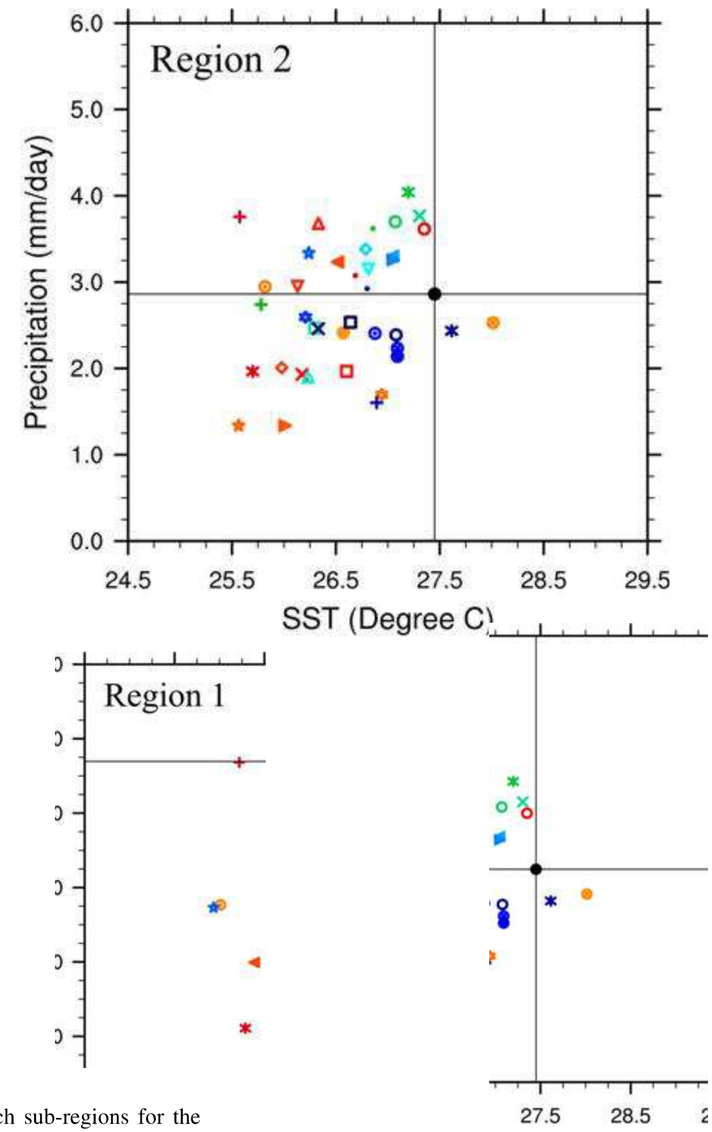


Fig. 3 *Scatter plots* of the climatological means of sea surface temperature (SST) and precipitation averaged over each sub-regions for the 30-year period from 1979 to 2008 from observations (*black closed circle*), the CMIP3 (*orange–red*) and the CMIP5 (*green–blue*) simulations

What *IS* available

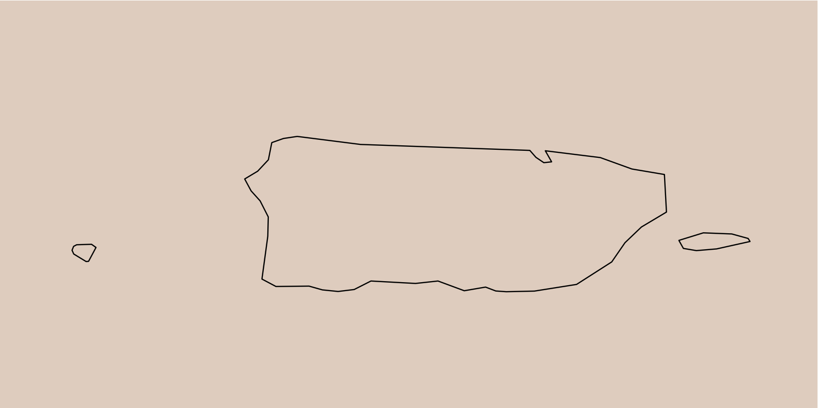
Ryu and Hayhoe (2013) *Climate Dynamics*

- Downscaled Global Climate Models
  - Way to get higher resolution, more detail, can ‘see’ PR and USVI
  - ‘Quick and cheap’ Statistically downscaled GCMs
    - Can downscale lots of GCMs
    - Usually only a few climate variables (Temperature and Precipitation)
  - ‘Slow and expensive’ Dynamically downscaled GCMs
    - Usually only a couple of GCMs are downscaled
    - Lots of climate variables available
- Two main statistically downscaled datasets and one dynamically downscaled dataset
  - Statistically downscaled
    - Katharine Hayhoe downscaled temperature and precipitation for CMIP3 and CMIP5 GCMs for Puerto Rico at long-term weather station locations
    - Khalyani et al. took these results and applied Climatologically Aided Interpolation to obtain gridded projections of Temperature and Precipitation
  - Dynamically downscaled
    - New 2km resolution output available for 2-3 GCMs for the period 2040-2060

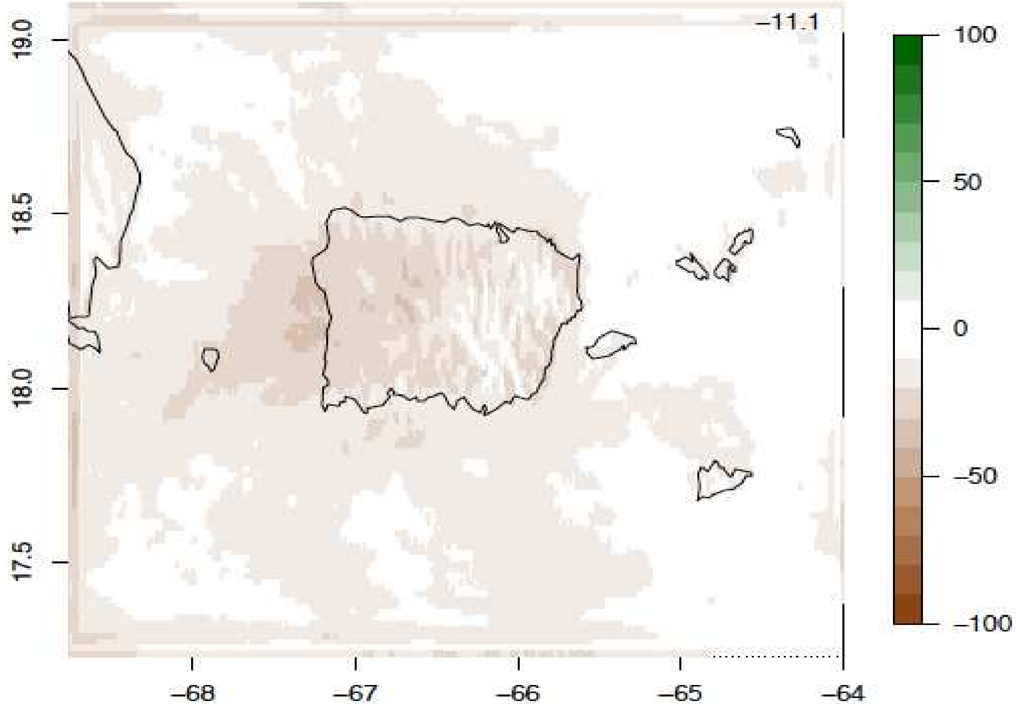
What IS available

Precipitation Change (% Change)

GCM



Downscaled



An indigenous peoples context for this region…

- Is there a working/accepted definition of "indigenous" for communities or individuals in Puerto Rico or the U.S. Virgin Islands? We'd like to use the accepted/functional vernacular – any citations would be particularly helpful.
  - We have the data from the U.S. 2010 Census on how people self-reported their tribal affiliation(s) in Puerto Rico (about a quarter identify as Taino, with the rest as various other mainland U.S. or Alaska Native tribal groupings or one of the Central/South/Mexican/Spanish American Indian affiliations).

- Is there published literature that would be useful in describing climate change risks and impacts more specifically on traditional communities (and w/indigenous identities) in Puerto Rico and the Caribbean? For example, are any characteristics of traditional indigenous lifeways at risk from climate change, such as the following? –
  - Subsistence lifestyles
  - Indigenous culture/shared traditions/identity/etc.
  - Traditional uses of natural resources (medicinal plants, important wildlife species, etc.)
  - Traditional knowledge of the environment or natural resources

- Are there land tenure or cultural characteristics/issues that ameliorate/exacerbate climate impacts and/or assist/complicate adaptation efforts by traditional and/or indigenous communities in Puerto Rico and the Caribbean?

- If a robust peer-reviewed literature does not yet exist for this topic, would the authors consider an emerging issues section of this chapter as an appropriate place to include discussion of any of these issues?

4th National Climate Assessment: Caribbean Regional Engagement Workshop
International Institute of Tropical Forestry/San Juan, PR – March 9, 2017

U.S. Global Change Research Program

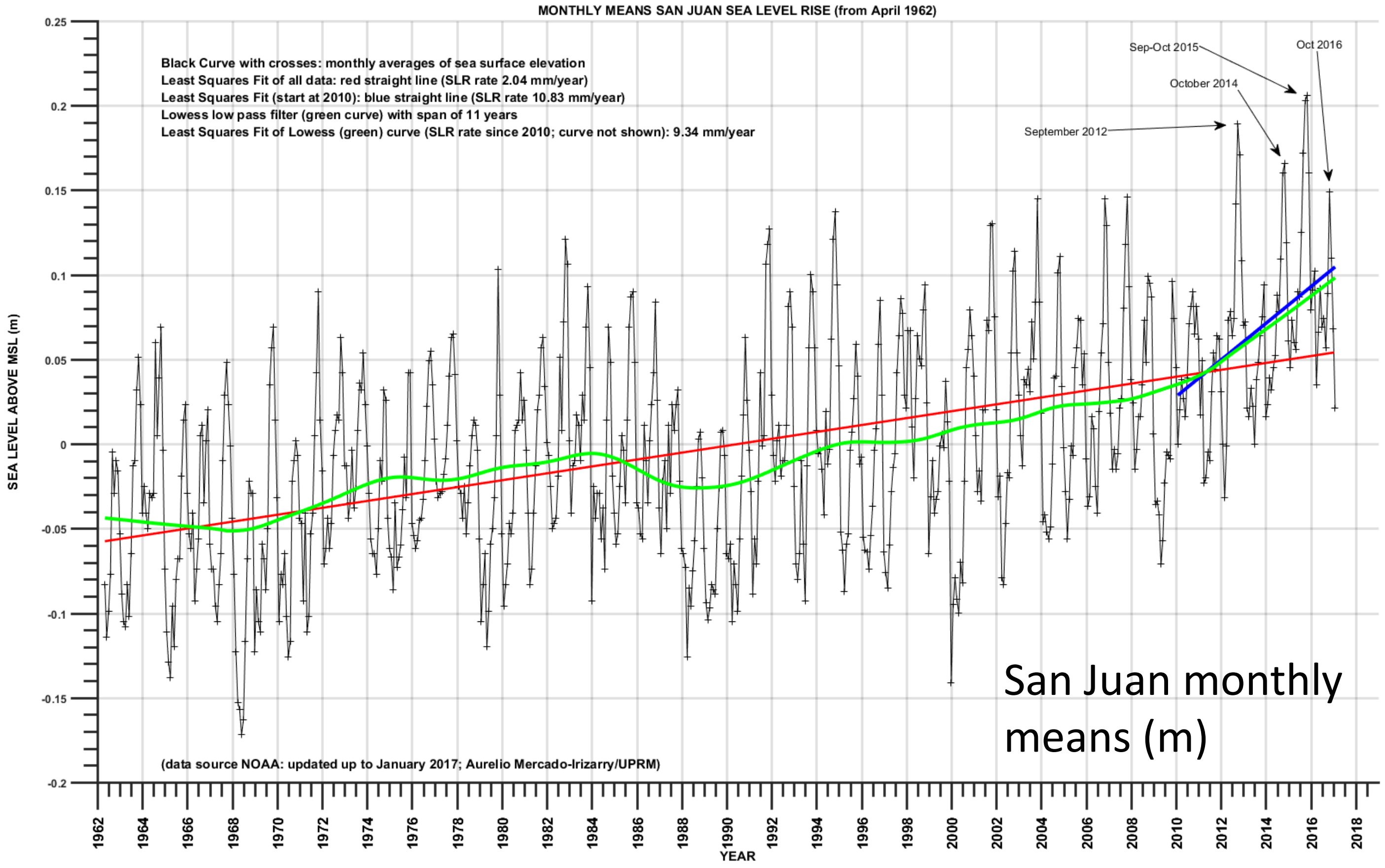
Sea Grant Universidad de Puerto Rico

Marine Sciences, UPRM

Five key Messages:

1. **Sea level is rising around Puerto Rico**
2. **It is accelerating!!**
3. **Many beaches are receding, specially during late summer**
4. **Nuisance flooding, coastal acquifer contamination, and drainage problems everywhere near the coast**
5. **Critical infrastructure at risk (airport!)**

- Red line slope: 2.04 mm/yr
- Green curve: Locally Weighted Scatterplot Smoothing (Lowess)
- Blue line slope: 10.8 mm/yr
- Slope of green curve since 2010-2011: 9.3 mm/yr



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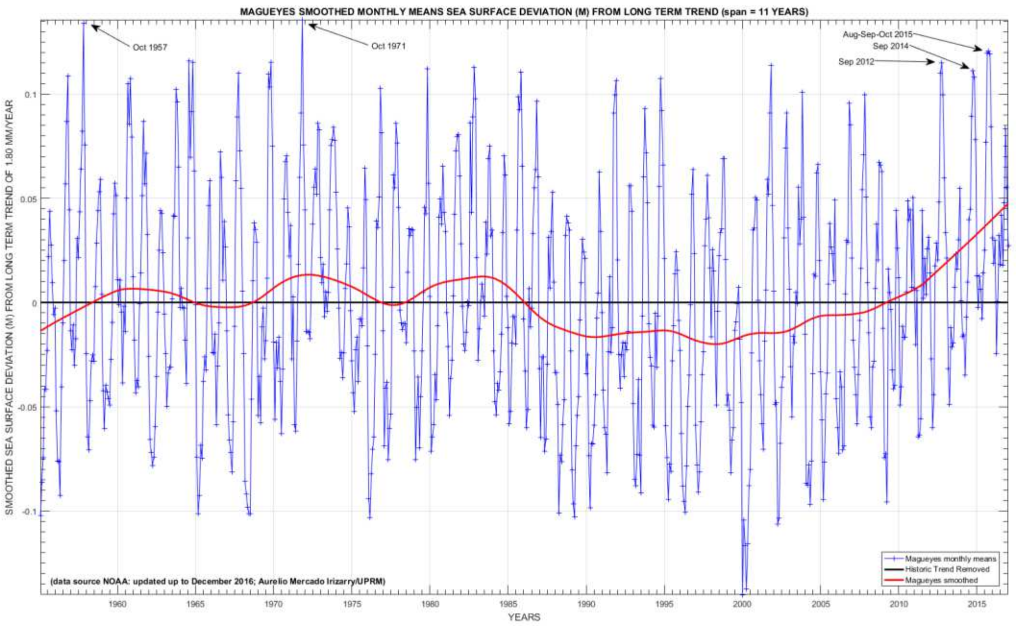
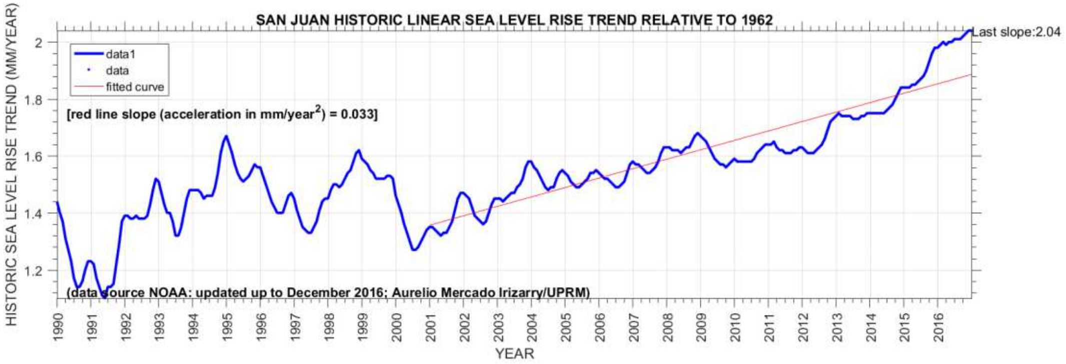
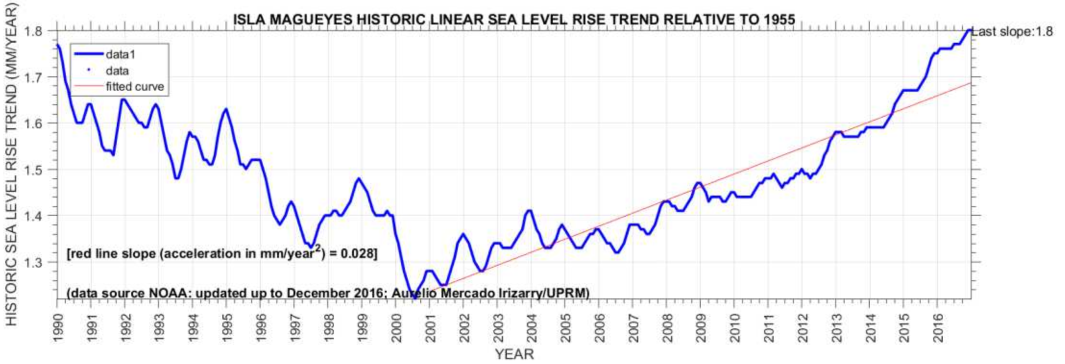
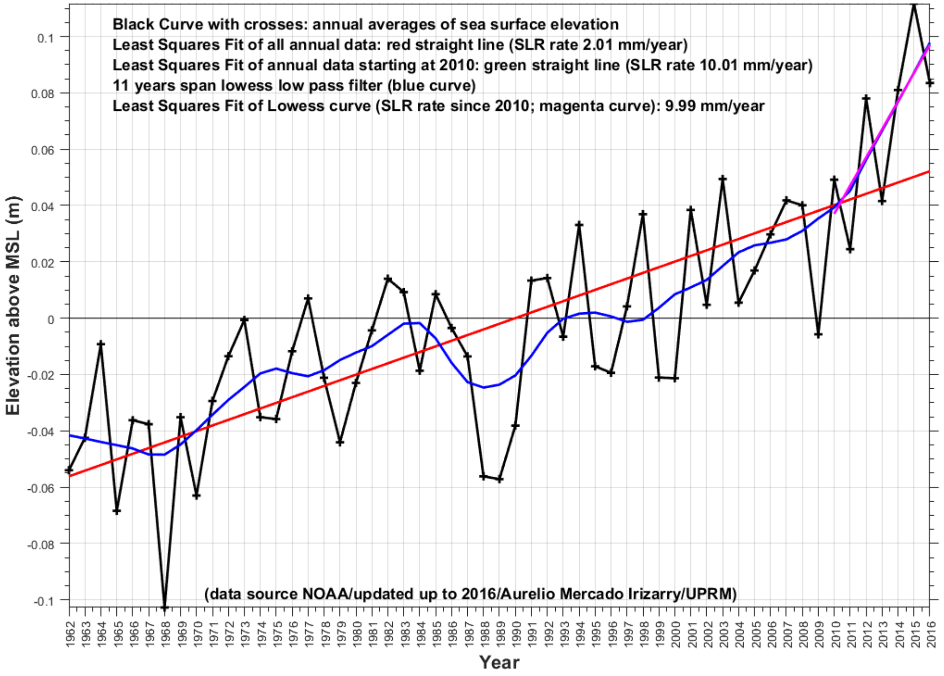


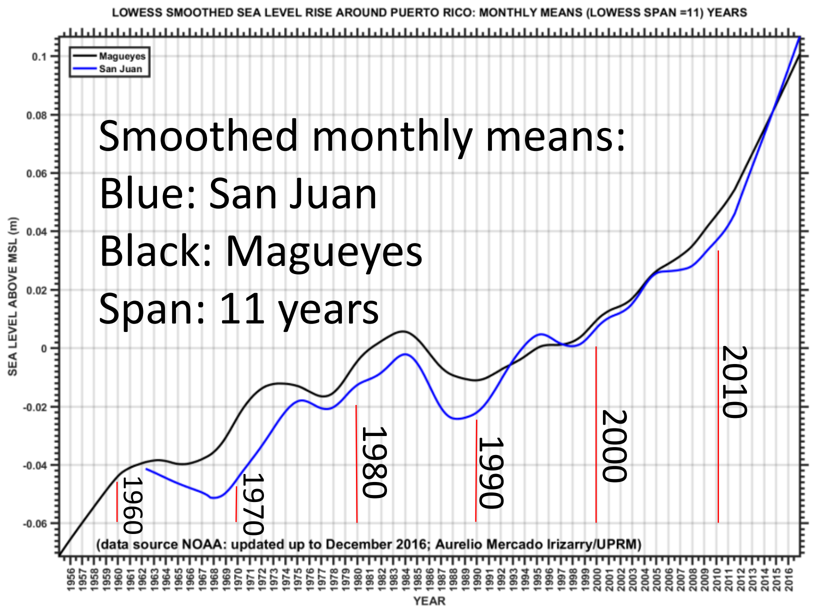




San Juan: Annual Means



Yi, S., W. Sun, K. Heki, and A. Qian, 2015. An increase in the rate of global mean sea level rise since 2010. Geophys. Res. Lett. 42:1-9.



<u>SEA LEVEL RISE PROJECTIONS:</u>

<u>Global and Regional Sea Level Rise Scenarios for the United States</u> (January 2017; NOAA Technical Report NOS CO-OPS 083) – Sweet et al.

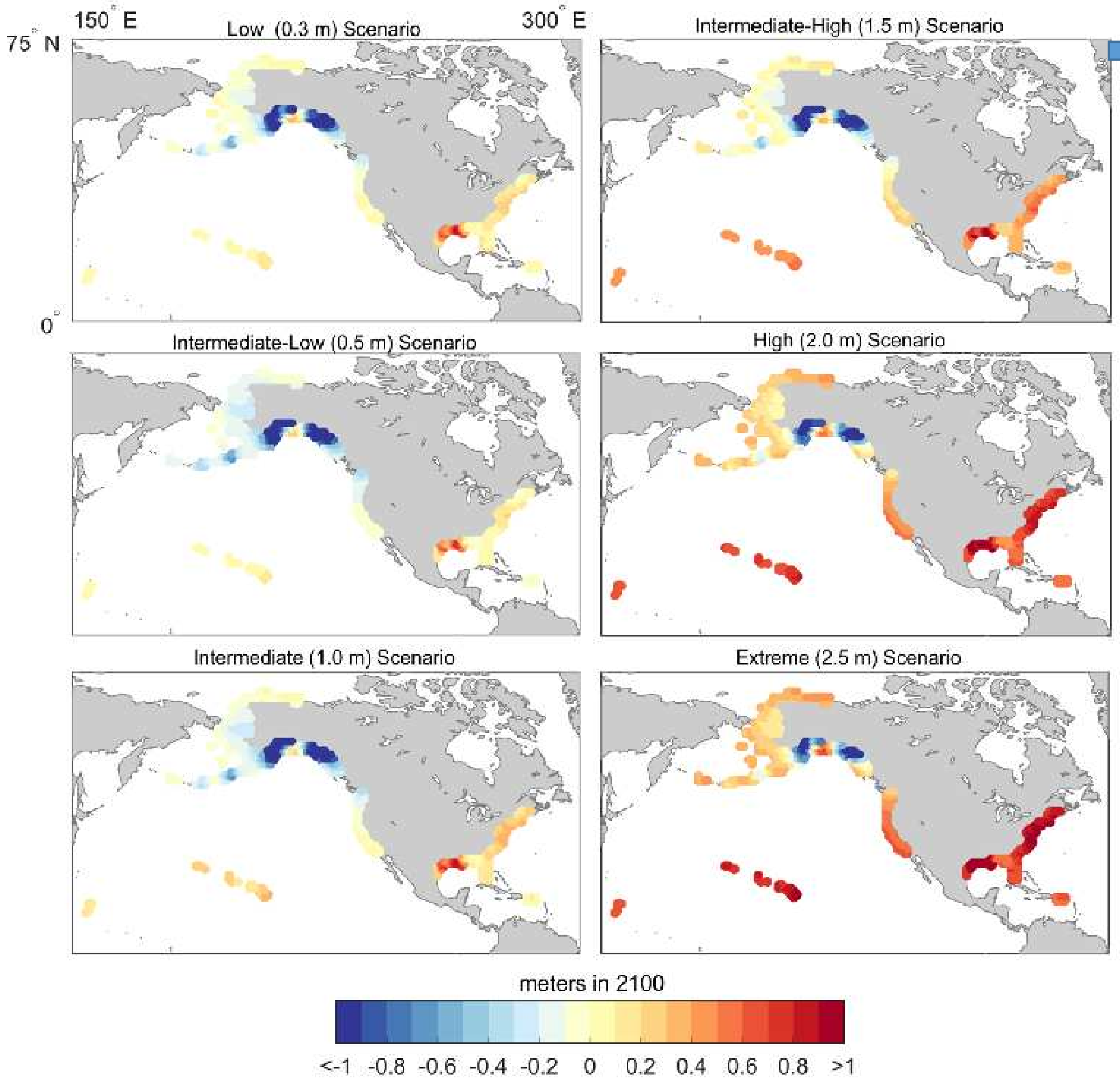


Figure 13. Total RSL change at 1-degree resolution for 2100 (in meters) relative to the corresponding (median-value) GMSL rise amount for that scenario. To determine the total RSL change, add the GMSL scenario amount to the value shown.

Based on six process-based (climate models) scenarios, and using results for Puerto Rico and the USVI:

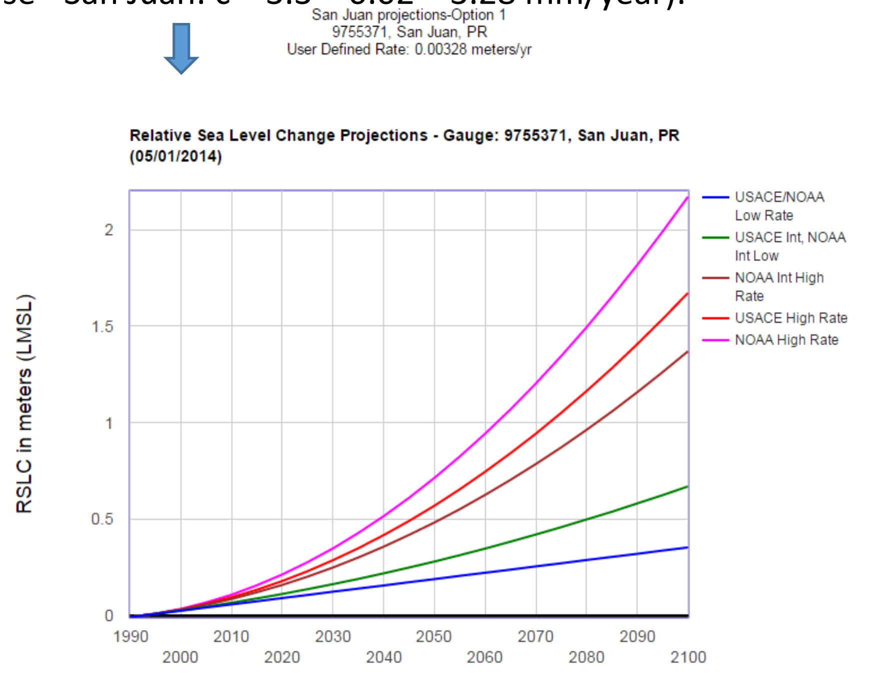
- ***Low (0.3 m) Scenario:*** ***LRSL rise = 0.33 to 0.36 m.***
- ***Intermediate-Low (0.5 m) Scenario:*** ***LRSL rise = 0.45 to 0.50 m.***
- ***Intermediate (1.0 m) Scenario:*** ***LRSL rise = 1.0 to 1.1 m.***
- ***Intermediate-High (1.5 m) Scenario:*** ***LRSL rise = 1.95 to 2.1 m.***
- ***High (2.0 m) Scenario:*** ***LRSL rise = 2.8 to 3.0 m.***
- ***Extreme (2.5 m) Scenario:*** ***LRSL rise = 3.5 to 3.75 m.***

We should also have in mind the more dramatic projections by Hansen et al. (2016) and DeConto and Pollard (2016), which use very sophisticated modeling.

Based on the USACE Sea Level Rise calculator, 2100 projection of LSLR:

- ***USACE and NOAA Low:*** ***LRSL rise = 0.36 m***
- ***USACE Intermediate/NOAA Intermediate Low:*** ***LRSL rise = 0.67 m***
- ***NOAA Intermediate High:*** ***LRSL rise = 1.37 m***
- ***USACE High:*** ***LRSL rise = 1.67 m***
- ***NOAA High:*** ***LRSL rise = 2.17 m***

Sea Level Change (SLC) Rate (based on the satellite-derived Global Mean Sea Level Rise - San Juan: c = 3.3 – 0.02 = 3.28 mm/year):



Storm surge erosion
 hours

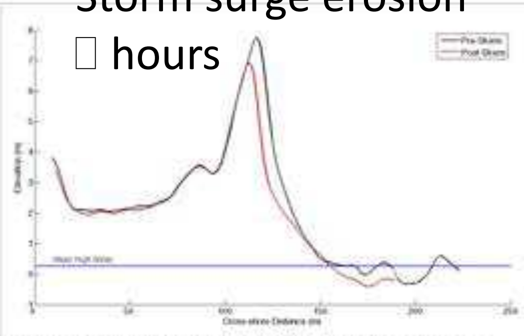
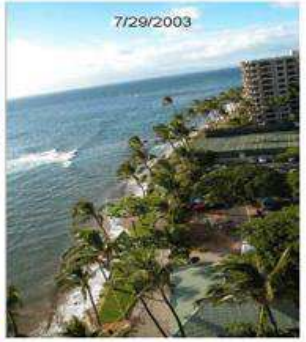


Figure 1. Dune erosion in Rodanthe, NC resulting from Hurricane Isabel's 2003 landfall. The elevation of the dune decreased by almost a meter. [larger version]

Figure 2. High storm surge and wave runup during Hurricane Isabel (2003) caused widespread dune erosion in Nags Head, NC. [larger

Hawaii beach erosion due to warm core Eddy (weeks)

It is still unclear at exactly what scale and timeframe the Hawaiian Islands will experience accelerated sea level rise. It is also difficult to predict exactly how shorelines will respond. However, there are already analogs in Hawaii for the type of erosion impacts that can be expected. On Maui, the erosion experienced in Kaanapali in the summer of 2003 is one example. That summer, short-term increases in sea level were experienced as mesoscale eddies (large



An analog on Maui for the impact of sea level rise on coastal erosion is the beach erosion that occurred at Kaanapali Beach during the summer of 2003 due to short-term elevated sea levels along with a sustained south swell. *Photo credit: Hyatt Regency Maui Resort.*

rotating water masses) propagated through the islands. These eddies produced tides that were 0.5 ft higher than normal. The elevated water levels, coupled with a minor south swell, resulted in enough wave energy traveling alongshore to transport massive amounts of beach sediment to the opposite end (north) of the beach system. The beach in the resort area disappeared entirely at some locations and there was high anxiety about possible infrastructure damage. Fortunately, temporary emergency protection measures were implemented and the beach recovered after a period of weeks. However, the implication is that a small increase in water level, only 0.5 ft in this case, can contribute to substantial shoreline retreat.

Combination of SLR + waves = disaster

EN ESCALA DE POCAS SEMANAS EL MAR SE TRAGA UNA PLAYA

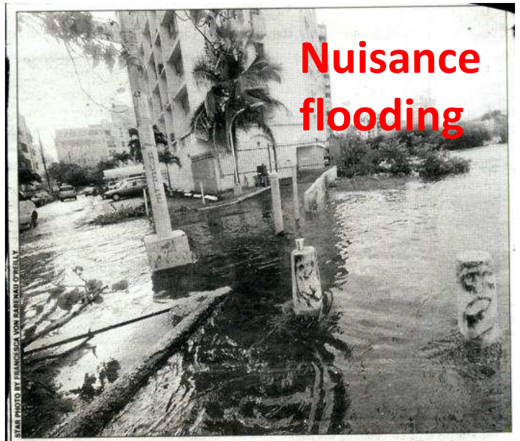
OJO (EFECTO BRUUN?)

weeks. However, the implication is that a small increase in water level, only 0.5 ft in this case, can contribute to substantial shoreline retreat.

Palominito Island: some years ago

http://www.puertoricodaytrips.com/palominito-island/

Nuisance flooding



Streets surrounding the Condado Lagoon are flooded by the heavy surf Thursday.

EL OCCIDENTAL 28 de septiembre al 4 de octubre de 2012 MI REGIÓN 5

MAYAGÜEZ

Sube la marea y se inundan las calles en El Seco

Inacción El portavoz de los vecinos denuncia que se han quejado ante las autoridades y que no han hecho nada

MAELO VARGAS SAAVEDRA
maelo.vargas@gfrmedia.com

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Este medio pudo observar que el lugar que más se afecta con la acumulación de agua salada, es donde está un negocio, la pescadería y la villa pesquera de la comunidad El Seco.

"Esta situación lleva muchos años, nos afecta a todos, porque estamos hablando de agua salada y los vehículos tienen que cruzar por los lugares inundados, incluso para llegar y entrar a sus residencias, por lo que clamamos que se busque una solución al problema lo antes posible" expresó el pescador.

Indicó que han hecho la denuncia en varias ocasiones e, incluso cuando los políticos en campaña pasan por la comunidad cada cuatro años, se les ha explicado el problema sin que hasta el momento ninguno haya tomado acción.

"Ahora mismo no sabemos si esto le compete a quién, si al municipio o a la Autoridad de Acueductos y Alcantarillados, porque es la tubería de las calles y el desagüe, pero lo que necesitamos es una pronta solución al problema y menos promesas", sentenció.

Para El Occidental / Olimpo Ramos

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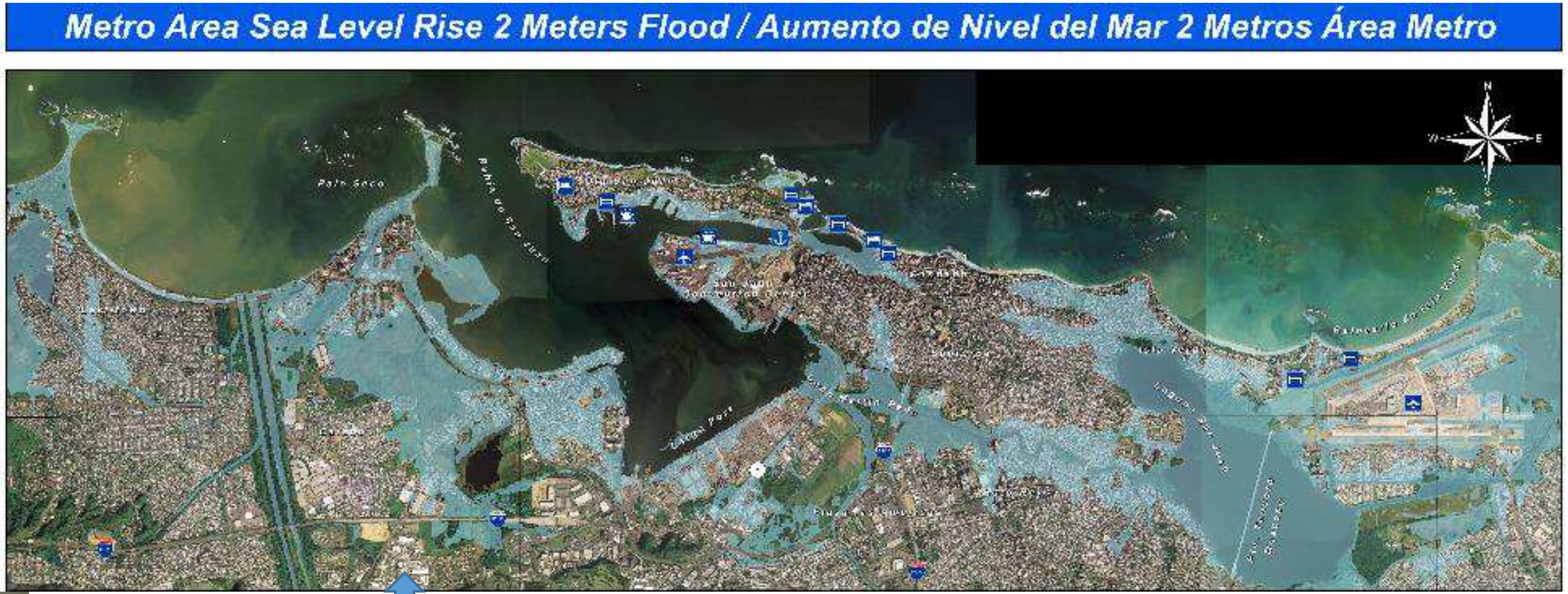

Permanent flooding

Nuisance flooding

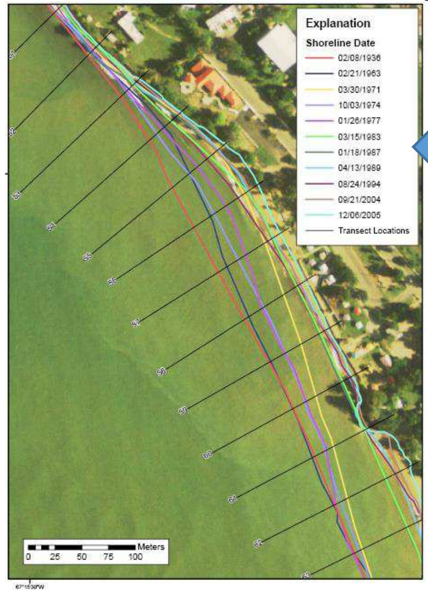

Figure 16. Map showing the historical shorelines and transect locations in Reach B-1.

Beach erosion

See http://coastalhazardspr.wordpress.com:

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- Implications for critical infrastructure, like San Juan airport and power plants
- By the end of the year: results of adding wave runup/overtopping to the (stillwater) maps (XBeach)
- Also later: tsunami flood maps for all of Puerto Rico

USGS Rincon study

4th National Climate Assessment: Caribbean Regional Engagement Workshop
International Institute of Tropical Forestry/San Juan, PR – March 9, 2017

U.S. Global Change Research Program

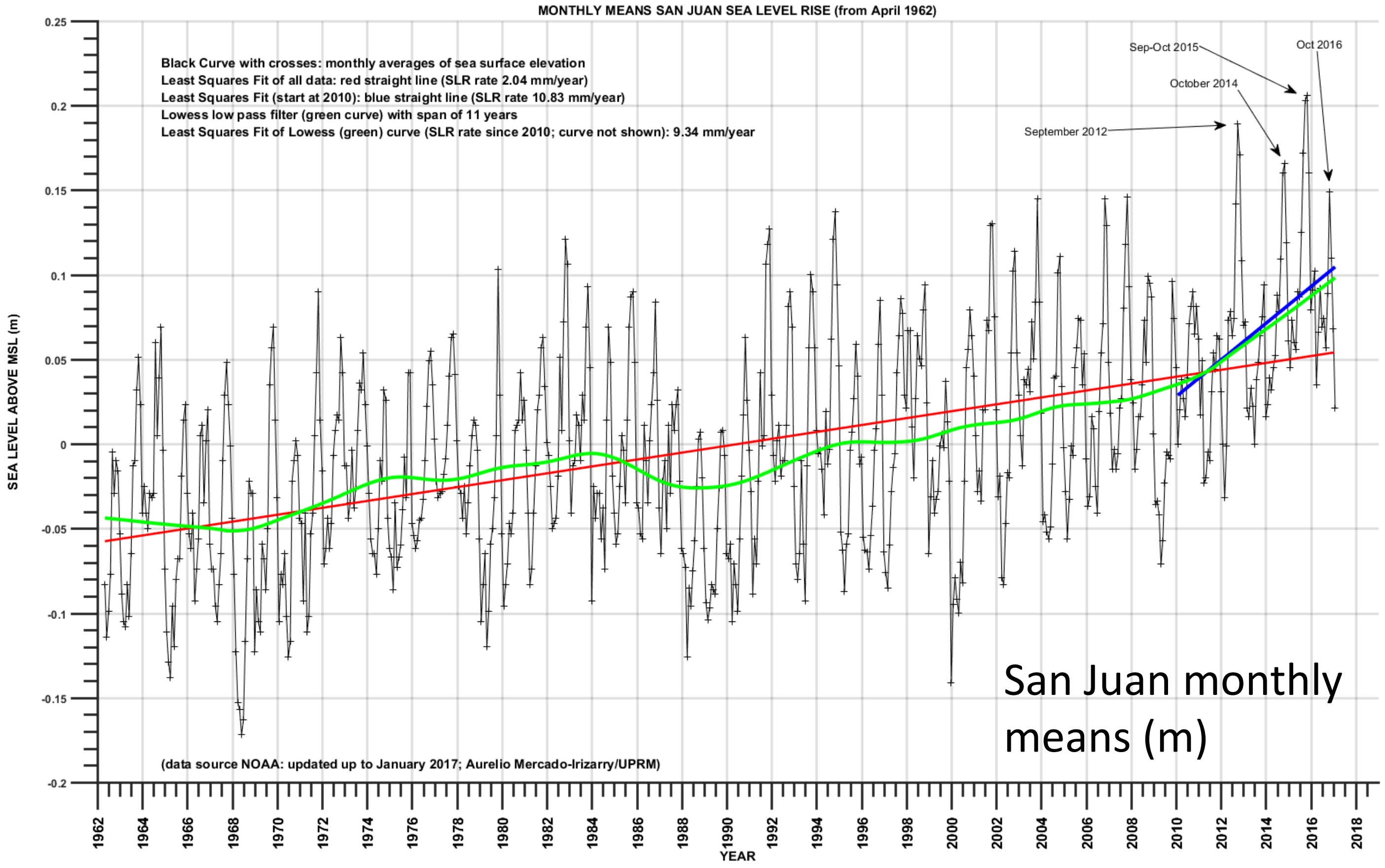
Sea Grant Universidad de Puerto Rico

Marine Sciences, UPRM

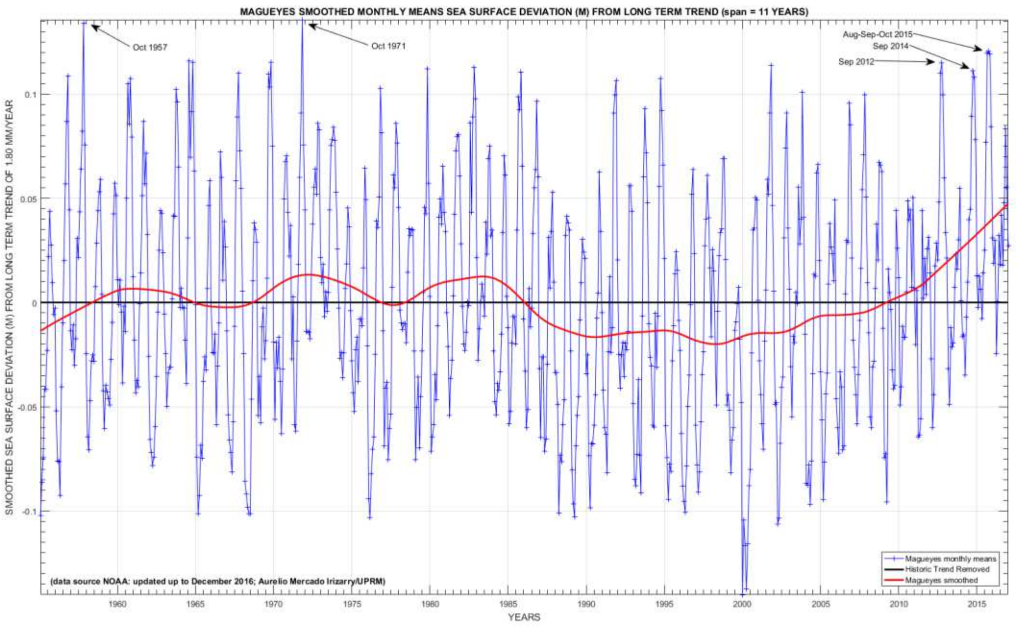
Five key Messages:

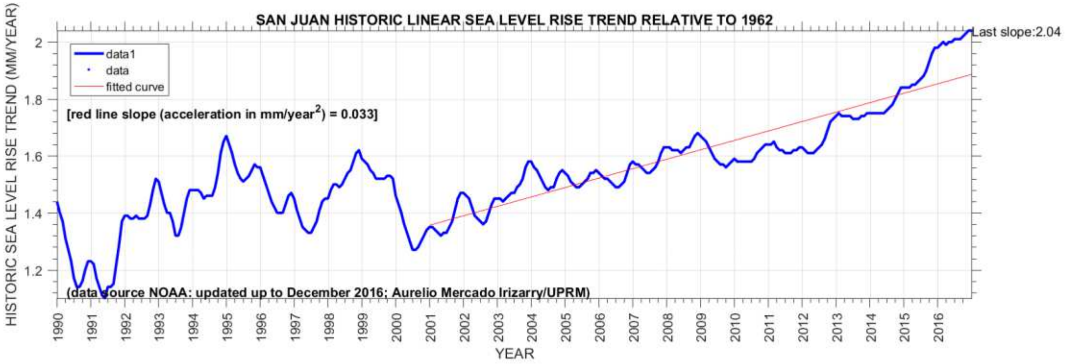
1. **Sea level is rising around Puerto Rico**
2. **It is accelerating!!**
3. **Many beaches are receding, specially during late summer**
4. **Nuisance flooding, coastal acquifer contamination, and drainage problems everywhere near the coast**
5. **Critical infrastructure at risk (airport!)**

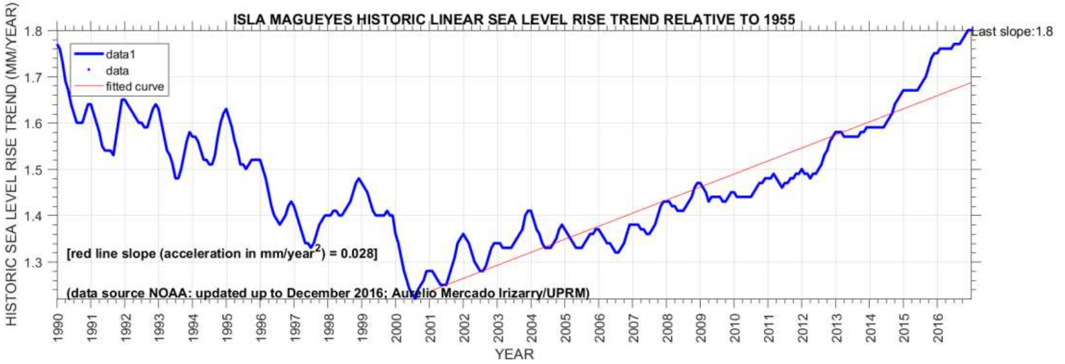
- Red line slope: 2.04 mm/yr
- Green curve: Locally Weighted Scatterplot Smoothing (Lowess)
- Blue line slope: 10.8 mm/yr
- Slope of green curve since 2010-2011: 9.3 mm/yr



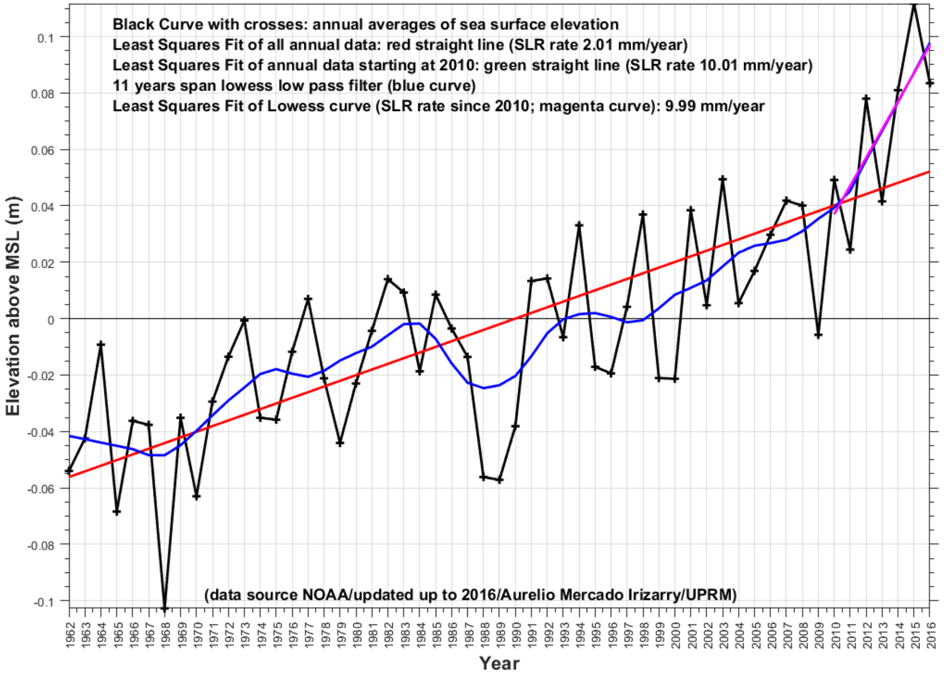
Aurelio Mercado Irizarry
Professor of Physical Oceanography
Dept. of Marine Sciences/UPRM
aurelio.mercado@upr.edu



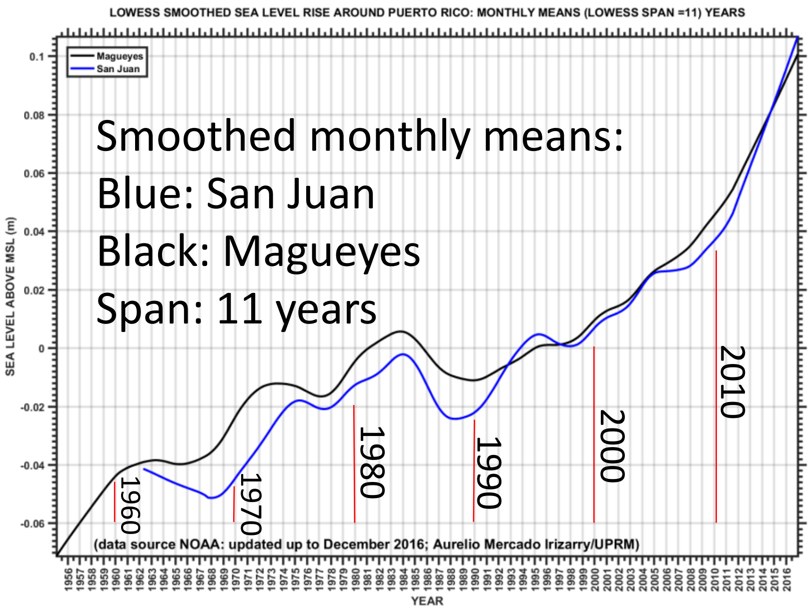




San Juan: Annual Means



Yi, S., W. Sun, K. Heki, and A. Qian, 2015. An increase in the rate of global mean sea level rise since 2010. Geophys. Res. Lett. 42:1-9.



SEA LEVEL RISE PROJECTIONS:
Global and Regional Sea Level Rise Scenarios for the United States (January 2017; NOAA Technical Report NOS CO-OPS 083) – Sweet et al.

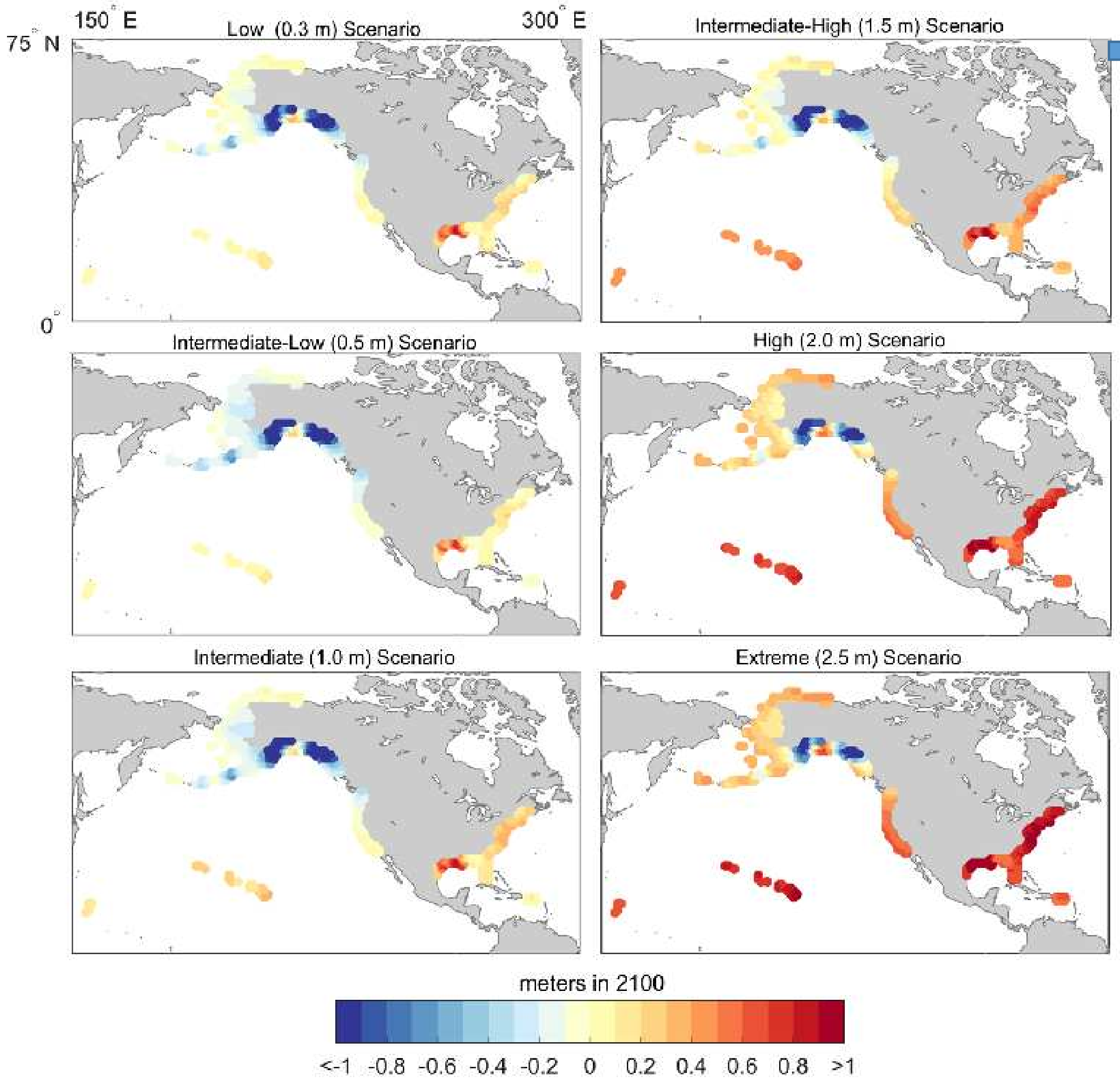


Figure 13. Total RSL change at 1-degree resolution for 2100 (in meters) relative to the corresponding (median-value) GMSL rise amount for that scenario. To determine the total RSL change, add the GMSL scenario amount to the value shown.

Based on six process-based (climate models) scenarios, and using results for Puerto Rico and the USVI:

- ***Low (0.3 m) Scenario:*** ***LRSL rise = 0.33 to 0.36 m.***
- ***Intermediate-Low (0.5 m) Scenario:*** ***LRSL rise = 0.45 to 0.50 m.***
- ***Intermediate (1.0 m) Scenario:*** ***LRSL rise = 1.0 to 1.1 m.***
- ***Intermediate-High (1.5 m) Scenario:*** ***LRSL rise = 1.95 to 2.1 m.***
- ***High (2.0 m) Scenario:*** ***LRSL rise = 2.8 to 3.0 m.***
- ***Extreme (2.5 m) Scenario:*** ***LRSL rise = 3.5 to 3.75 m.***

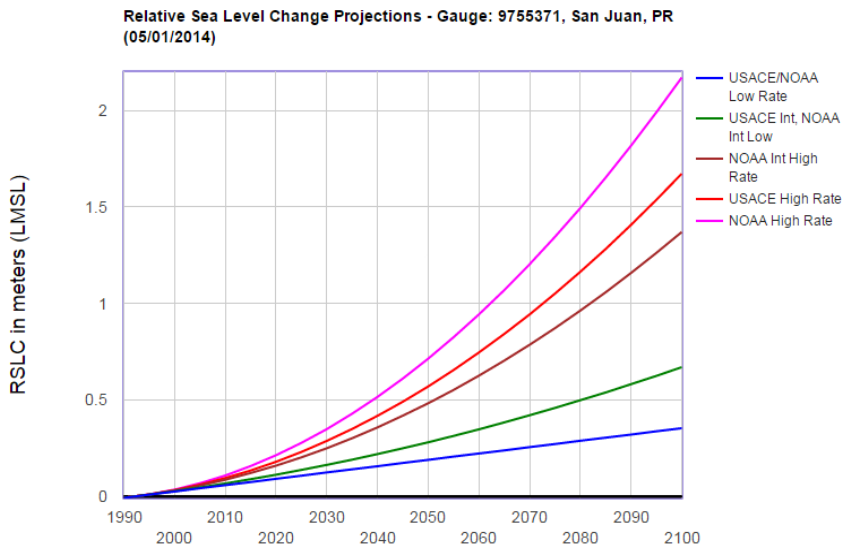
We should also have in mind the more dramatic projections by Hansen et al. (2016) and DeConto and Pollard (2016), which use very sophisticated modeling.

Based on the USACE Sea Level Rise calculator, 2100 projection of LSLR:

- ***USACE and NOAA Low:*** ***LRSL rise = 0.36 m***
- ***USACE Intermediate/NOAA Intermediate Low:*** ***LRSL rise = 0.67 m***
- ***NOAA Intermediate High:*** ***LRSL rise = 1.37 m***
- ***USACE High:*** ***LRSL rise = 1.67 m***
- ***NOAA High:*** ***LRSL rise = 2.17 m***

Sea Level Change (SLC) Rate (based on the satellite-derived Global Mean Sea Level Rise - San Juan: c = 3.3 – 0.02 = 3.28 mm/year):

San Juan projections-Option 1
9755371, San Juan, PR
User Defined Rate: 0.00328 meters/yr



Storm surge erosion
□ hours

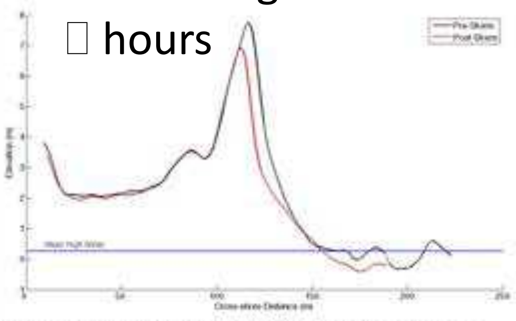
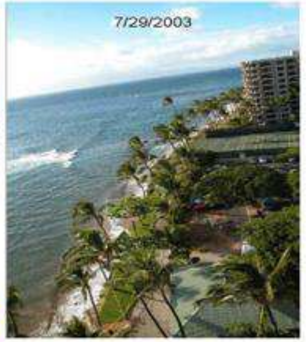


Figure 1. Dune erosion in Rodanthe, NC resulting from Hurricane Isabel's 2003 landfall. The elevation of the dune decreased by almost a meter. [larger version]

Figure 2. High storm surge and wave runup during Hurricane Isabel (2003) caused widespread dune erosion in Nags Head, NC. [larger

Hawaii beach erosion due to warm core Eddy (□weeks)

It is still unclear at exactly what scale and timeframe the Hawaiian Islands will experience accelerated sea level rise. It is also difficult to predict exactly how shorelines will respond. However, there are already analogs in Hawaii for the type of erosion impacts that can be expected. On Maui, the erosion experienced in Kaanapali in the summer of 2003 is one example. That summer, short-term increases in sea level were experienced as mesoscale eddies (large



An analog on Maui for the impact of sea level rise on coastal erosion is the beach erosion that occurred at Kaanapali Beach during the summer of 2003 due to short-term elevated sea levels along with a sustained south swell. *Photo credit: Hyatt Regency Maui Resort.*

rotating water masses) propagated through the islands. These eddies produced tides that were 0.5 ft higher than normal. The elevated water levels, coupled with a minor south swell, resulted in enough wave energy traveling alongshore to transport massive amounts of beach sediment to the opposite end (north) of the beach system. The beach in the resort area disappeared entirely at some locations and there was high anxiety about possible infrastructure damage. Fortunately, temporary emergency protection measures were implemented and the beach recovered after a period of weeks. However, the implication is that a small increase in water level, only 0.5 ft in this case, can contribute to substantial shoreline retreat.

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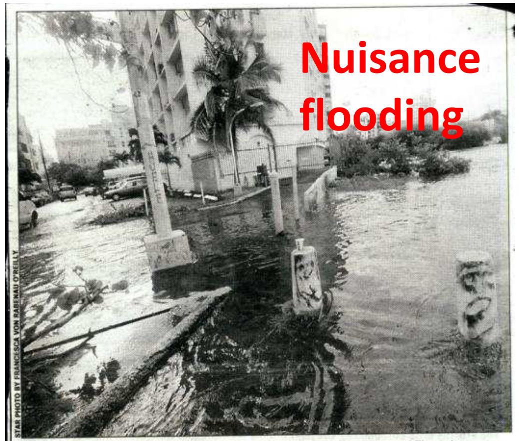
Combination of SLR + waves = disaster

EN ESCALA DE POCAS SEMANAS EL MAR SE TRAGA UNA PLAYA

OJO (EFECTO BRUUN?)

Palominito Island: some years ago

http://www.puertoricodaytrips.com/palominito-island/



Streets surrounding the Condado Lagoon are flooded by the heavy surf Thursday.

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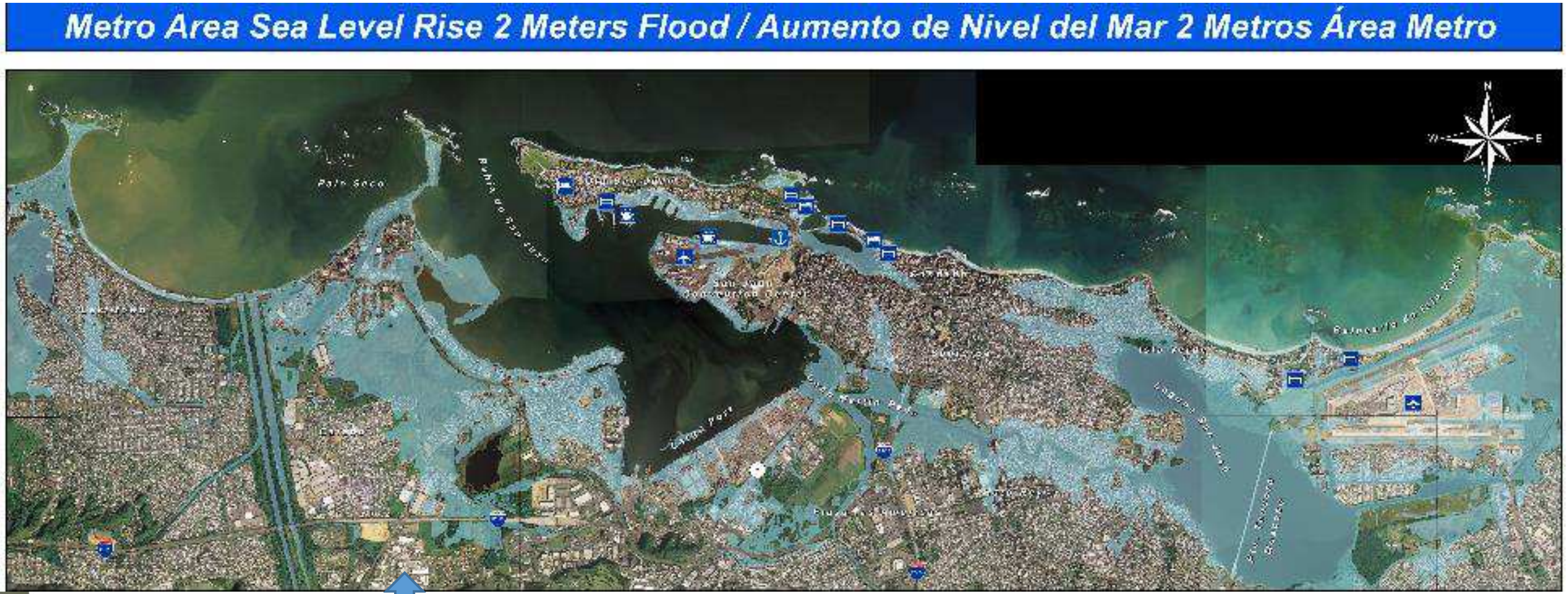

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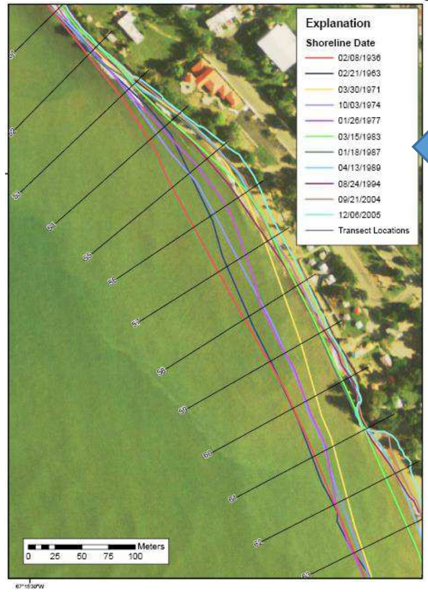

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USGS Rincon study

Fourth National Climate Assessment Regional Engagement Workshop

FRESH WATER AVAILABILITY

Eric Harmsen
University of Puerto Rico-Mayaguez

March 9, 2017

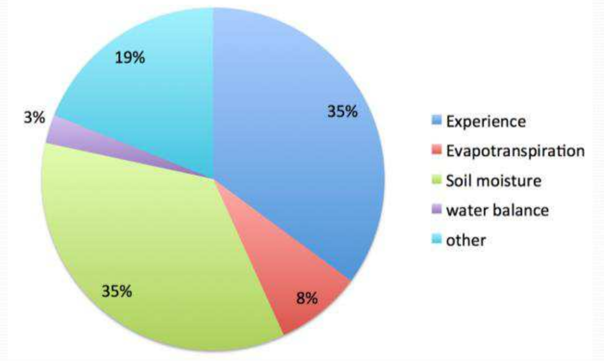
The Water Problem

- Efficient use of water for agricultural production has become a ***moral and ethical issue***.
- Increasing global population, dwindling water supplies, degraded water quality, climate variability, and the various sectors competing for it, all affect the management of water resources.
- Seventy percent of all water withdrawals are used for agriculture, and most of this is used for irrigation
- 68, 136, 863 and 1,791 gallons of water are required to produce 1 pound of oranges, corn, shelled almonds and beef, respectively (UNESCO).

Puerto Rico's Irrigation Districts

- History
- Sedimentation Problem
- Water wasted on the way to farms
- The water subsidy – Water is free
- More than have the Districts' water goes to AAA
- AAA loose half of all the water it sends to customers (315,000,000 gal/day)
- Southern Coast Aquifer, current situation, plan, sea level rise.

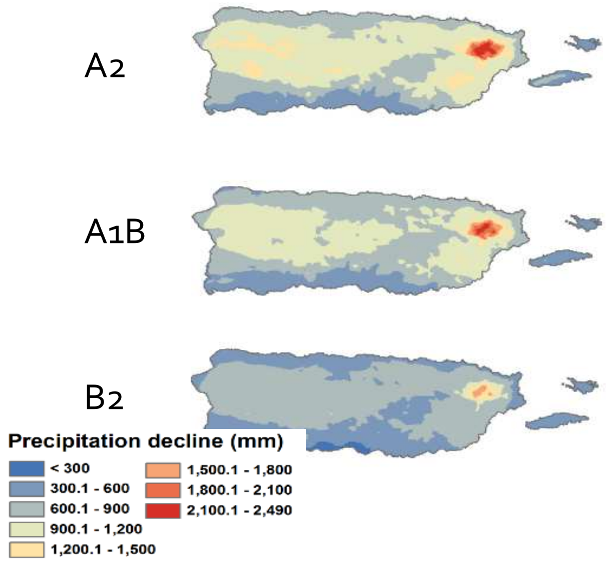
Water Management on Farms



Irrigation Scheduling Methods used in PR

- Irrigation scheduling attempts to replace soil water that has been evapotranspired.
- Many farmers do not use scientific methods for scheduling irrigation
- Over-application of irrigation can result in the loss of water, fuel, pesticides, fertilizer and crop yields, farm income, and may contaminate surface or groundwater.
- Under application results in reduced crop yields and farm income.

Future outlook



- Climate change
  - Elevated temperatures, reduced rainfall
  - Extreme weather (droughts and rainfall)
  - Increased crop water requirements
  - Increased soil erosion, resulting in loss of fertility and surface water degradation.
  - Increasing saltwater intrusion in coastal areas
  - Aquifer recharge rates may increase (positive impact)
- Agriculture will likely increase in the future
- Areas needing irrigation will increase across the island due to increased agriculture and dry conditions.

Some Recommendations

- Require or encourage farmers to use scientific methods for irrigation scheduling to save water and avoid wasting the water subsidy. (We are currently developing mobile app at UPRM).
- Determine crop water requirements for PR crops.
- Breed plants for extreme conditions (drought, flood, heat, etc.) for Puerto Rico's major crops.
- Conduct crop modeling research to evaluate potential crop responses to climate change and extreme weather.
- Research methods for improving soil health that will provide improved fertility, less erosion and increased carbon sequestration.
- Perform optimization research in the operation and management the island's irrigation infrastructure.
- Stress test irrigation infrastructure under different levels of agriculture growth (e.g. 50%, 90%)
- Greatly reduces water losses from the AAA system
- AAA will need to plan for the expected demand for water from urban agriculture
- Harvest more water from northwest PR
- Water harvesting should be expanded to include individual homes by use of cisterns.

Sea Surface Temperature and Ocean Acidification trends in the Caribbean

Julio M. Morell, Melissa Melendez

`

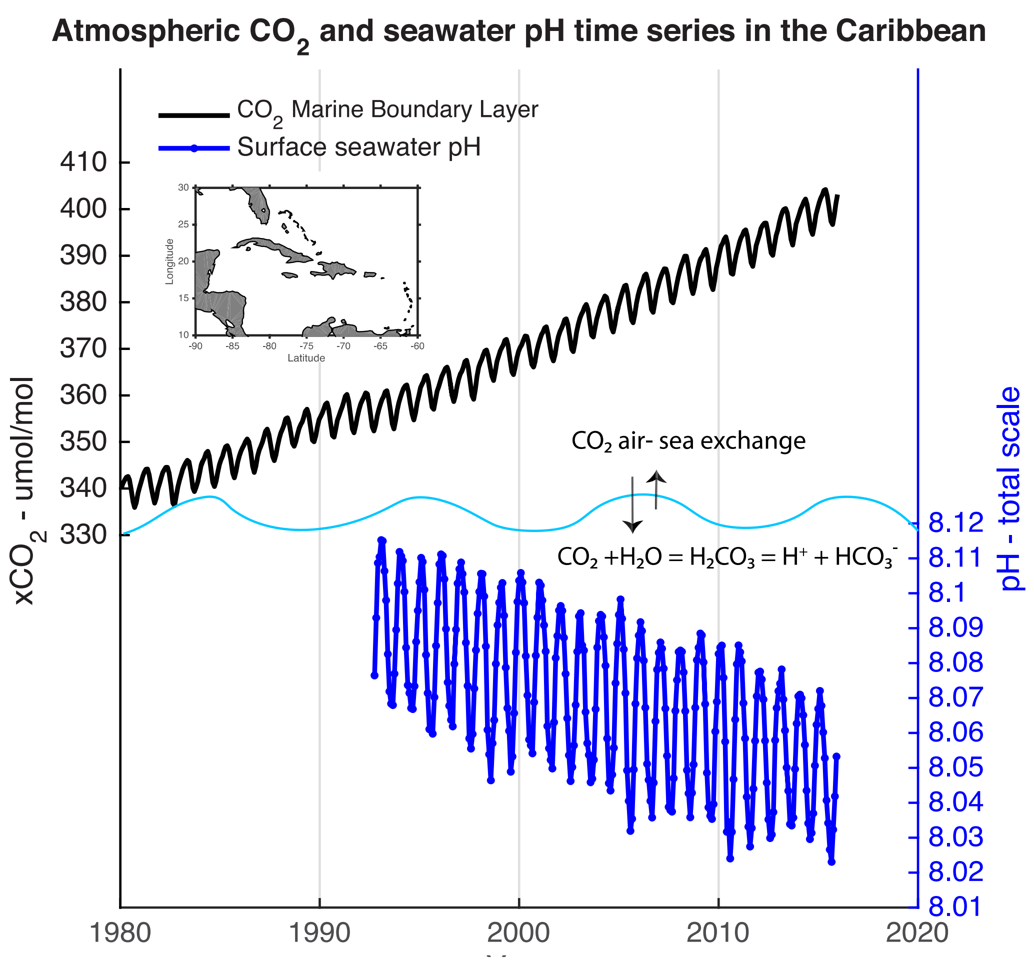
CARICOOS

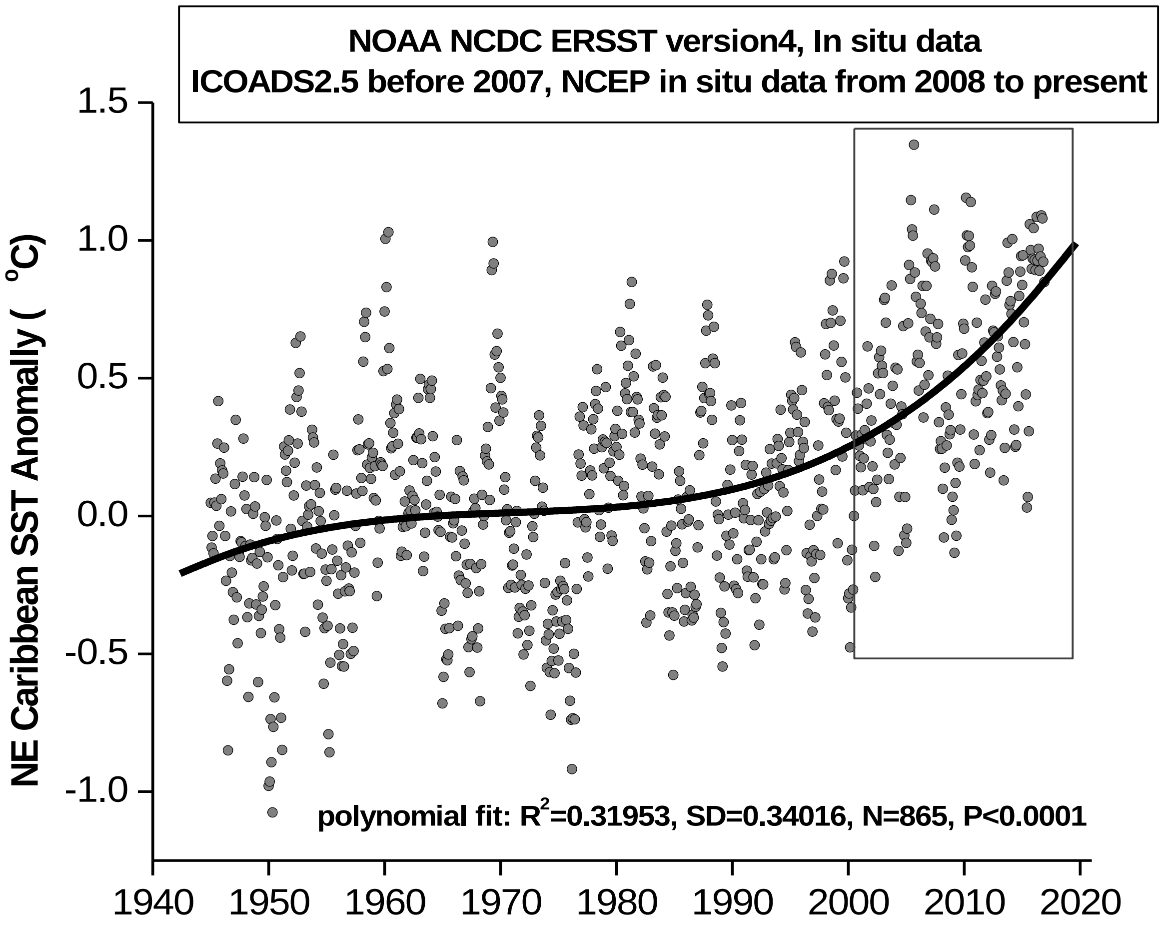
Some impacts of increased ocean temperature & acidification:

- Coastal ecosystems: coral bleaching, hypoxia, decreased calcification
- Coastal barriers & reef framework (non-living): dissolution
- Fisheries: displacement of species, decreased diversity?
- Sea level rise: SW expansion, ice melting..
- Extreme climatic events: Tropical cyclones, precipitation, draught..
- Global ocean circulation: global climate alterations…
- Socio-economics : e.g. tourism

CARICOOS

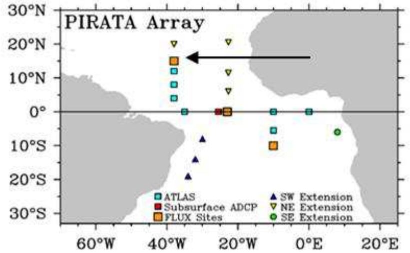
Atmospheric CO2 = increase in SST and ocean acidity

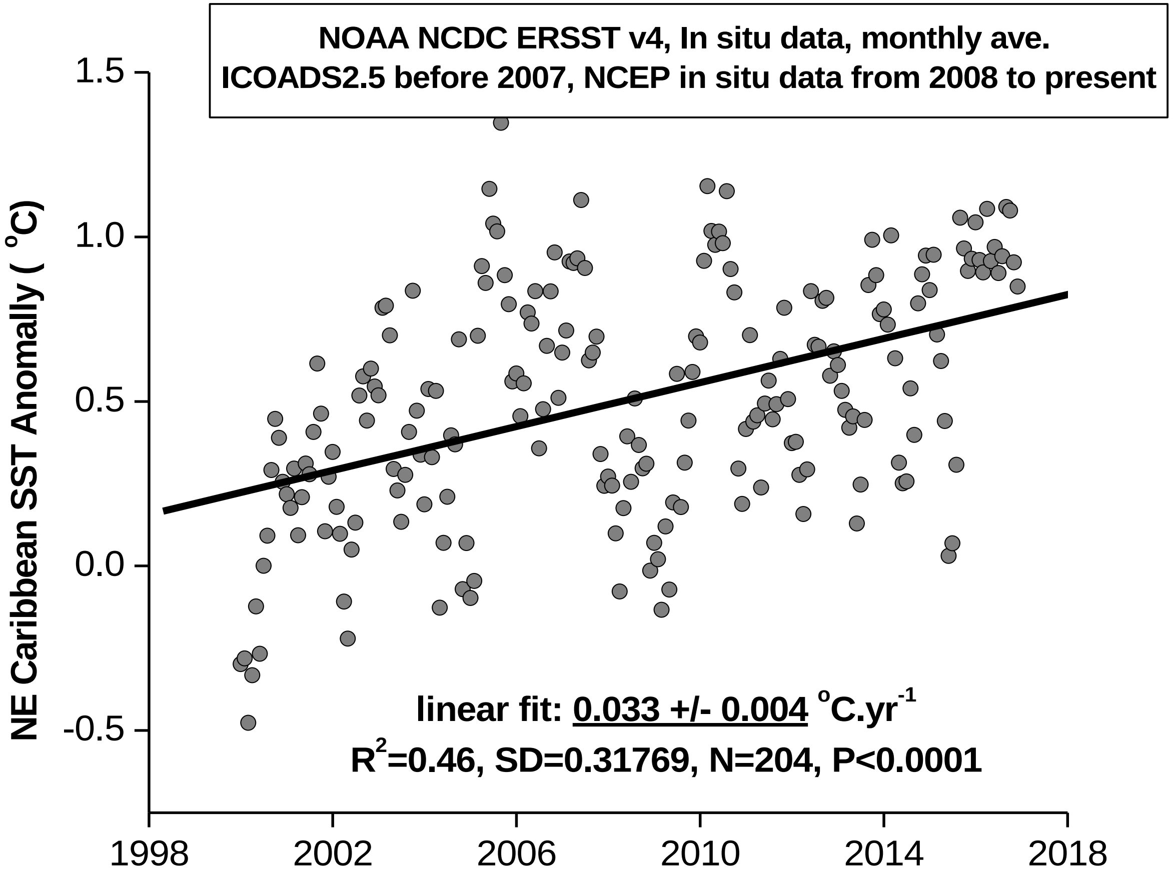


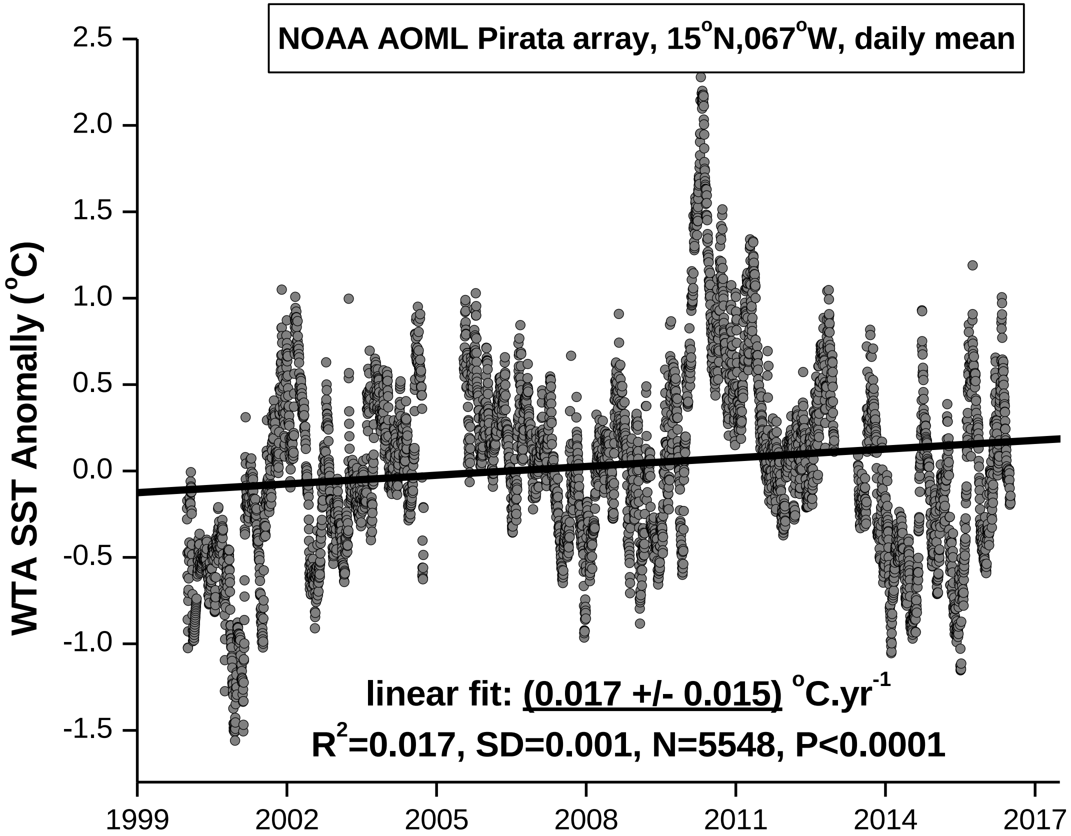


CARICOOS

Recent SST trends (2000 to 2016):



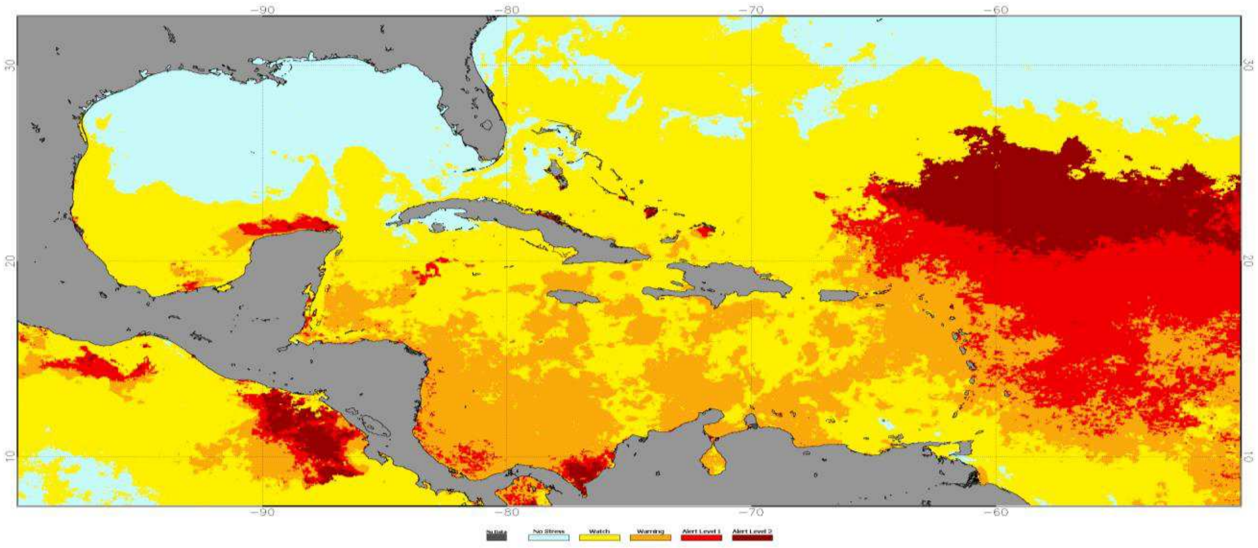


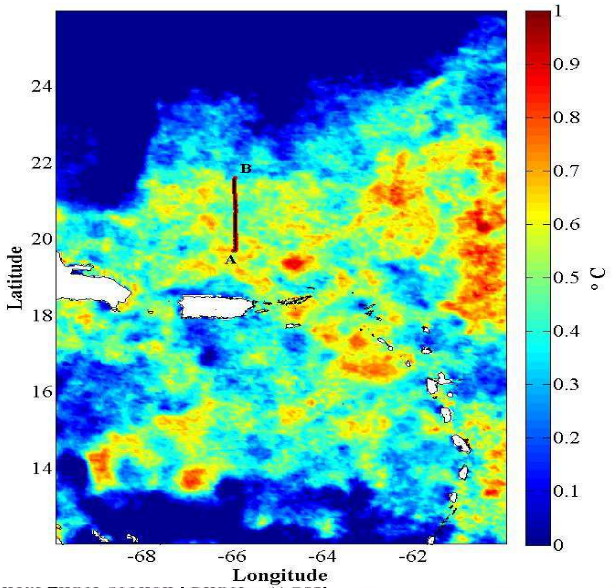


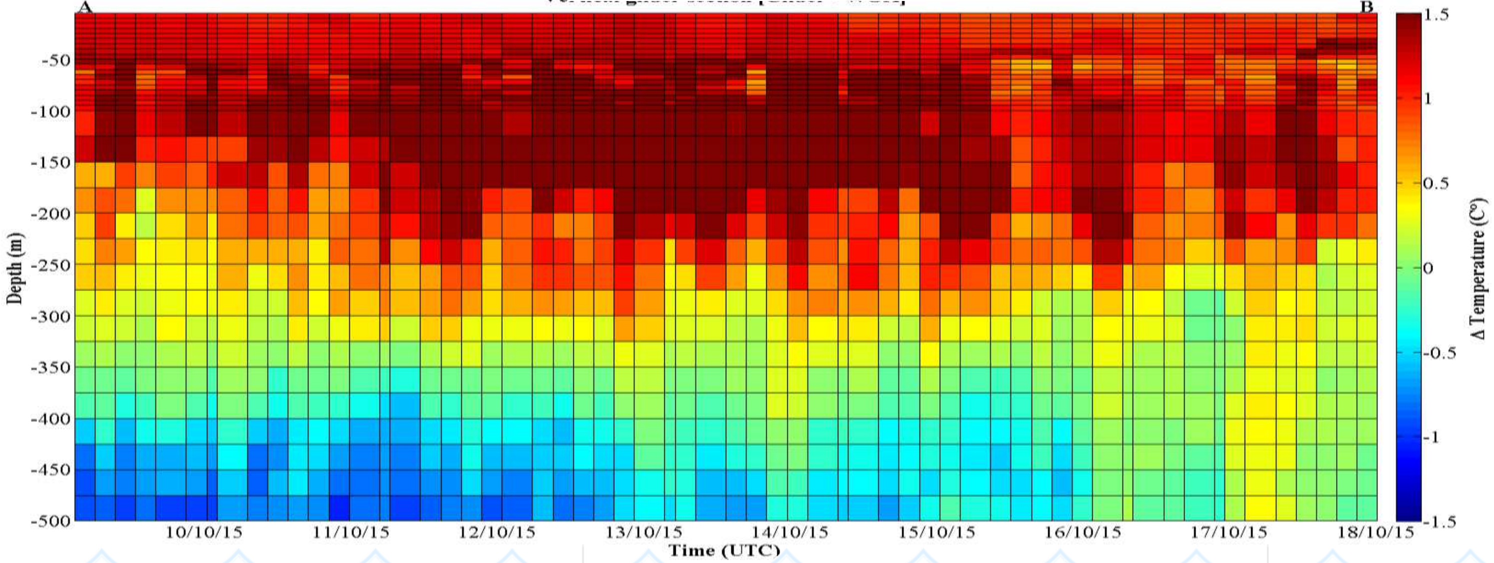
In > 100 years, coral reefs will be exposed to "bleaching" temperatures for months!

CARICOOS

Warm water “blobs”; not just skin deep!

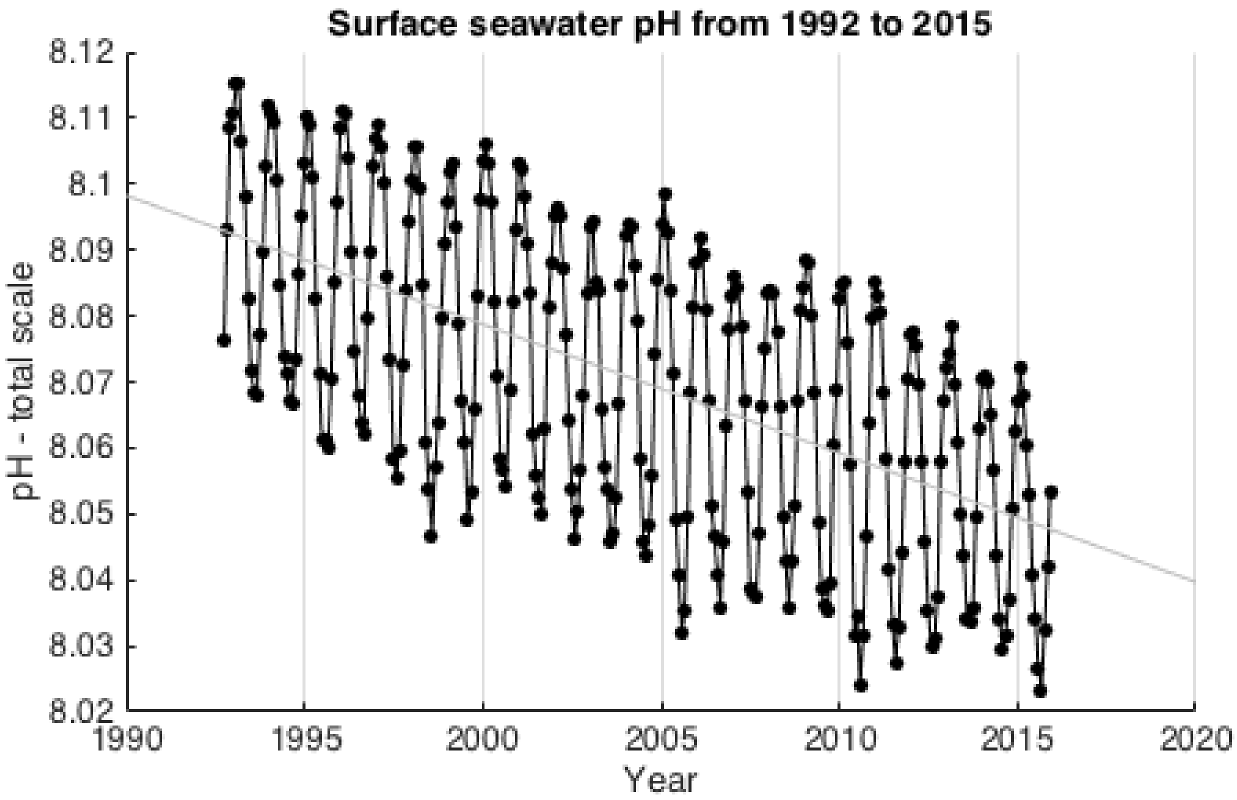


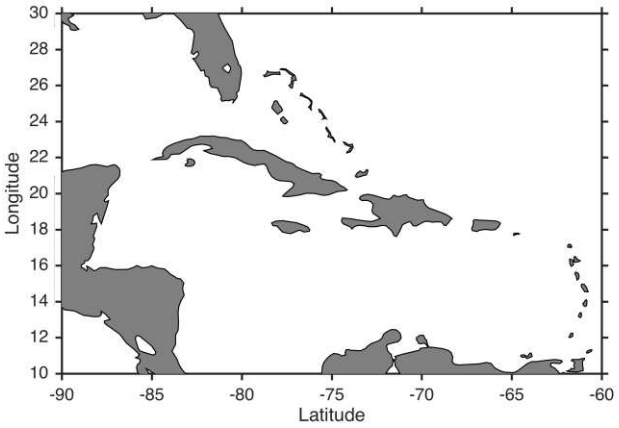




CARICOOS

Recent pH trends (1992 to 2015) in the Caribbean:





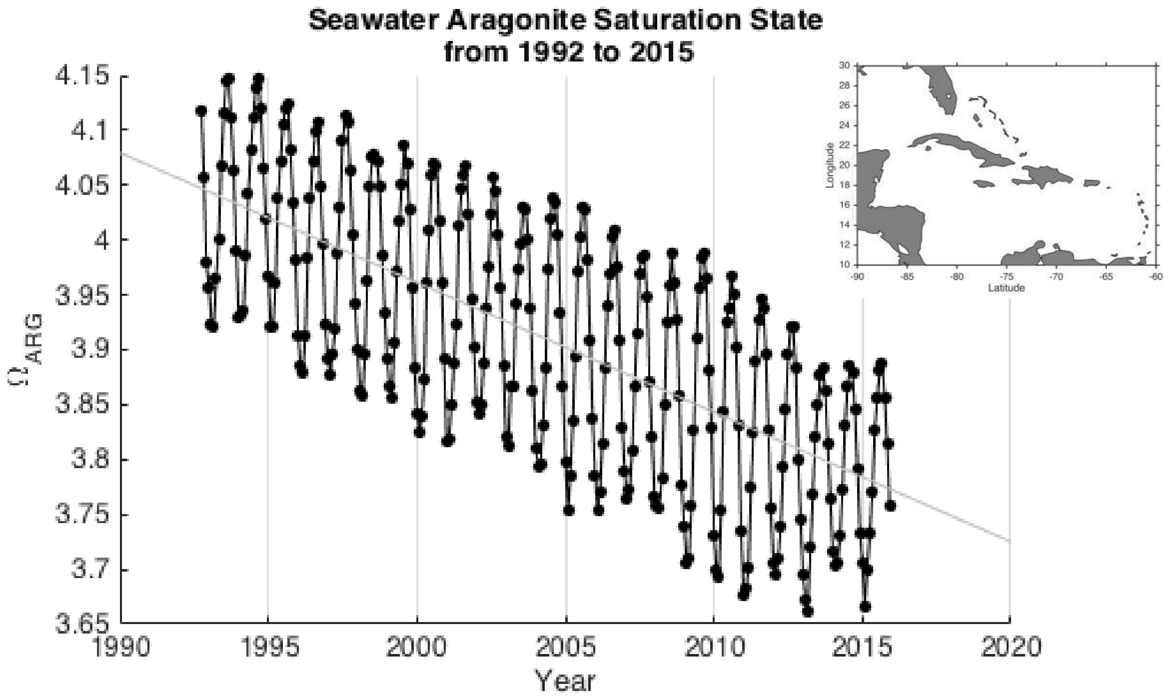
Regional empirical model

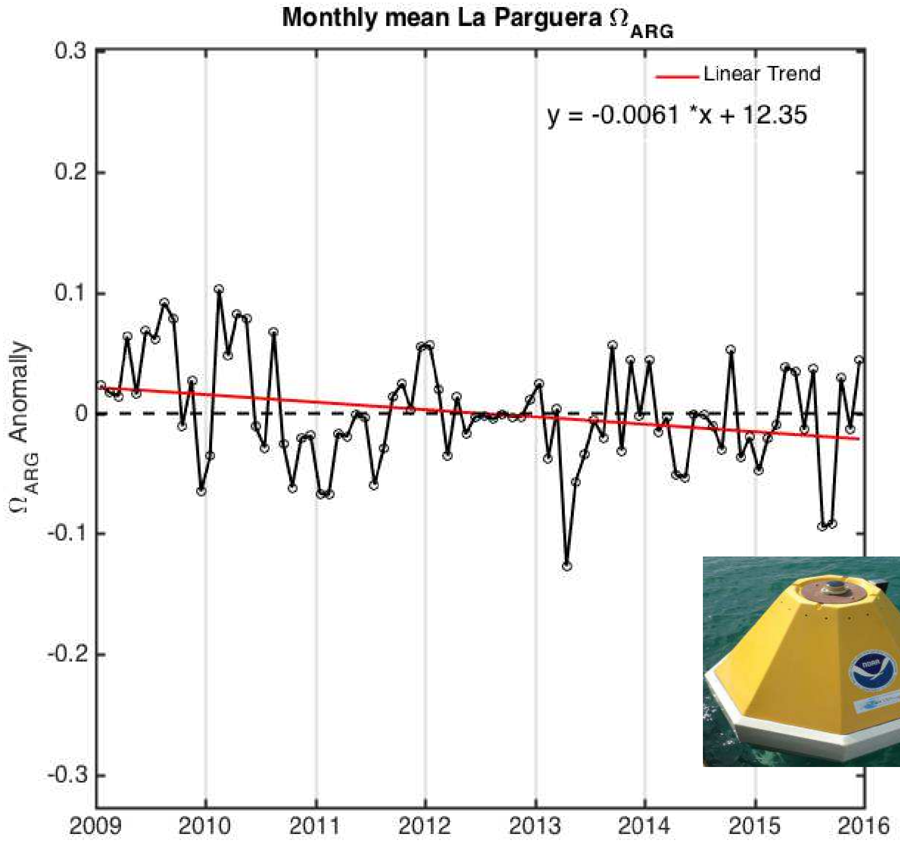
Surface ocean pH has decreased by ~0.04 (-0.0018 yr-1) units

This represent an increase in Caribbean surface ocean acidity of about 11%

CARICOOS

Recent Omega trends (1992 to 2015) in the Caribbean & Puerto Rico:





Regional empirical model:

Ωarg has decreased by -0.29 (-0.0121 yr-1) units

This represent a decrease in Caribbean surface Ω_{arg} of ~ 7.4 %

In < 100 years, coral reefs will be exposed to critical Ωarg !

La Parguera OA buoy located at the southwest of PR shows a Ω_{arg} decrease of ~1.2 % over the last 7 years

CARICOOS

Rainfall and Temperature Observations across Puerto Rico

Odalys Martínez-Sánchez

Senior Forecaster and Climate Team Leader WFO San Juan

UPRRP Environmental Sciences PhD Student

Introduction

- **Data Availability**
(60 *active* COOP Stations, 20 stations were analyzed (1st phase), 1970- 2014)
(Homogenized data sets are not available for USVI at this time)

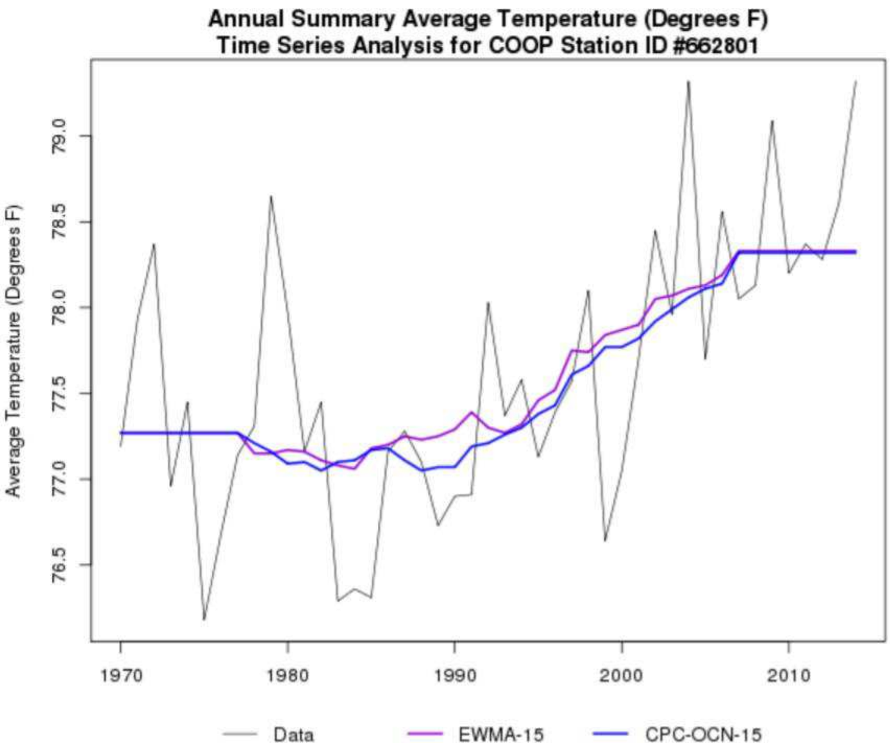
  - Period of record must be at least 30 years long.
  - Missing values are less than 9 days per month and are filled-in using interpolation techniques.
  - Temperature observations have been homogeneity corrected to remove biases associated with non-climatic influences, such as changes in instrumentation and observing practices, and changes to the environment including station relocations.

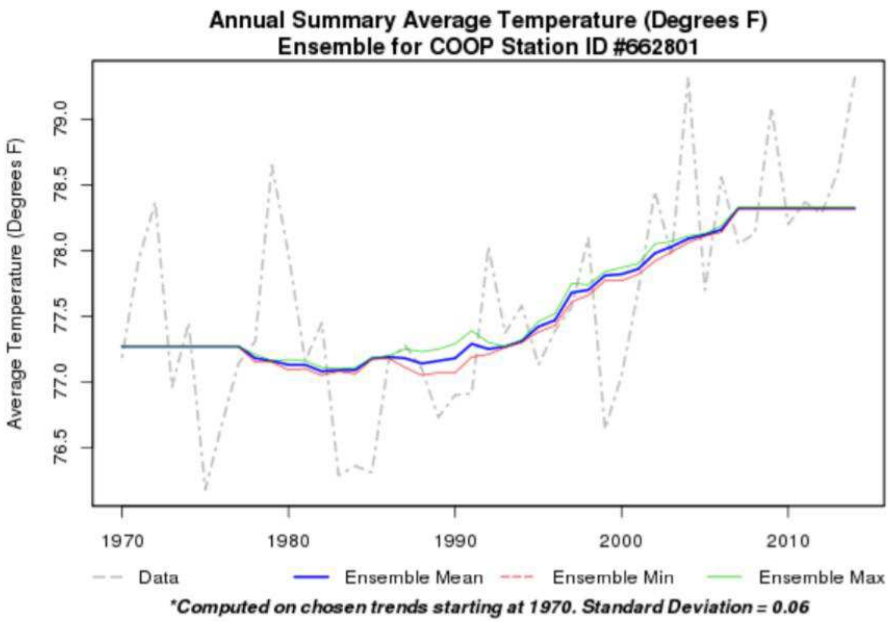
- **Methodology**

  - National Weather Service's **L**ocal **C**limate **A**nalysis **T**ool (LCAT)
    - Climate Prediction Center Optimum Climate Normals (CPC OCN)
    - Exponentially Weighted Moving Average (EWMA)
    - Rate of Change (ROC)
      - It is calculated using the linear slope of the ensemble mean between Climate Prediction Center Optimum Climate Normals and Exponentially Weighted Moving Average.

Temperature

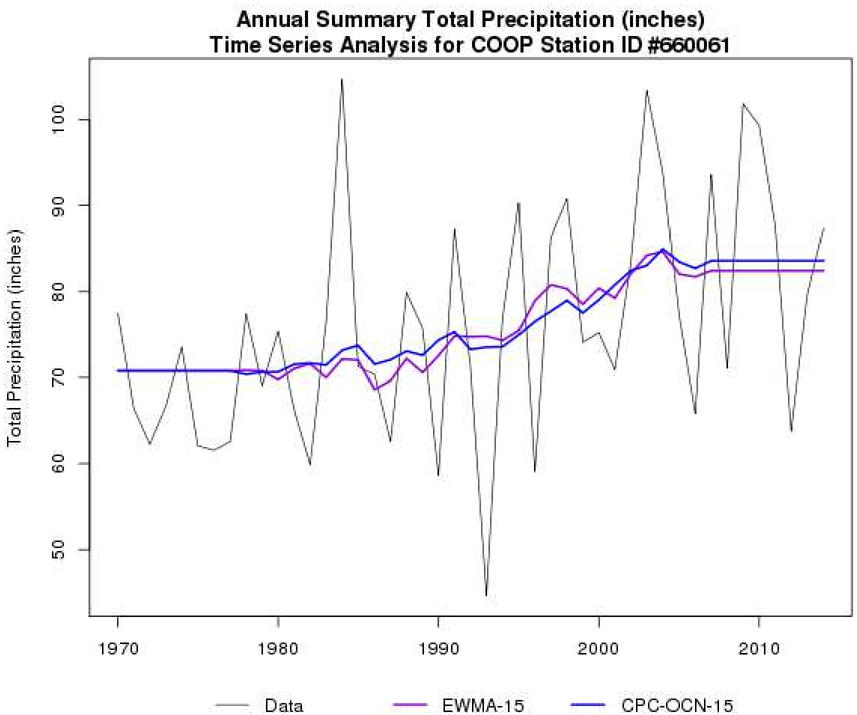
- Although WFO San Juan has been collaborating with local climate studies, it's the first time that the National Weather Service's Local Climate Analysis Tool is used to perform temperature analysis across Puerto Rico.
- 100% of the stations showed a positive trend (Tmean, Tmax and Tmin).

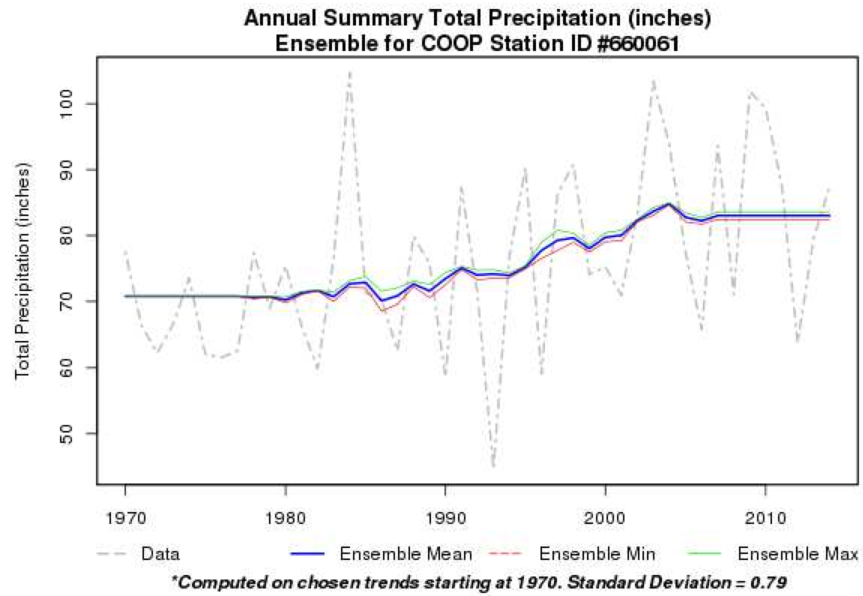




Rainfall

- A positive trend has been observed across most of the stations. 85, 80 and 75% showed a positive trend for the total rainfall as well as rainfall during the wet and dry season, respectively.
- The ROC is faster during the wet season particularly across central and north coastal areas of PR.





Analysis in progress and summary of preliminary results

- **Analysis in progress to answer the following:**
  - Are those changes in rainfall associated with extreme rainfall events?
  - Can we expect similar trends if the time frame is changed? i.e. using DJF,MAM,JJA,SON.
  - Homogenized data sets for USVI.
  - Up to date data.
- **Summary**
  - 100% of the stations showed a positive trend in terms of Tmean, Tmax and Tmin.
  - A positive trend in rainfall has been observed across most of the stations.
  - Between the dry and the wet season, the rate of change is faster during the wet season.
  - These results cannot be interpreted as the expected or most likely value during the climate change conditions.

Fourth National Climate Assessment Regional Engagement Workshop Warming Temperatures

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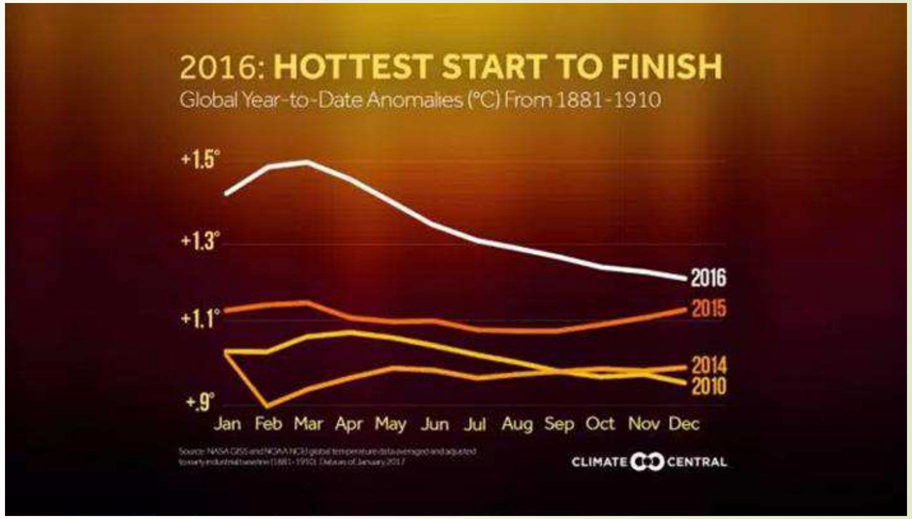
Environmental Health Department

Warming Temperatures

- Warming is evident for the Whole Planet
- For Human Health and Well Being rising AST is one of the biggest climate related treats.
- Rising temperature are affecting natural and built environments, energy, agriculture, forestry, economic productivity.



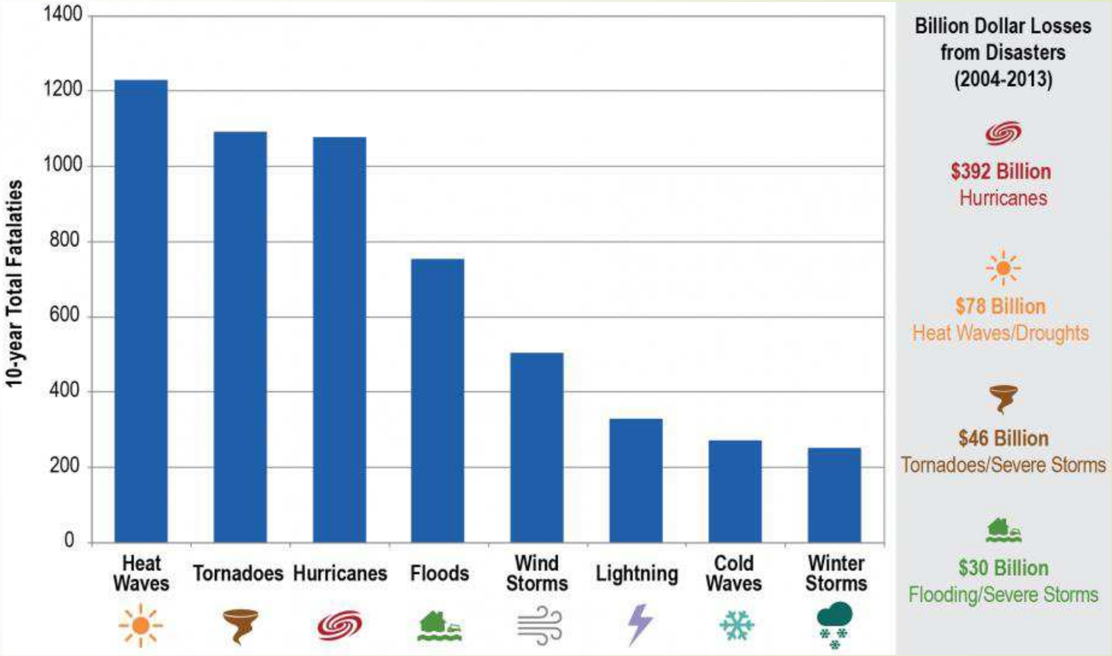
Warming Temperatures

- The negative effects of heat on human health (cardiovascular, cerebral, and respiratory systems) have been well established.

- Despite other important factors that could diminish heat impacts
  - accessibility to cooling systems (economic)
  - Mobility of the population (exposure)
  - Implementation of early warning systems (technology)
  - Public perception (social)
  - response to heat warnings (social)
  - Behavioral and pre-existing medical conditions (health)

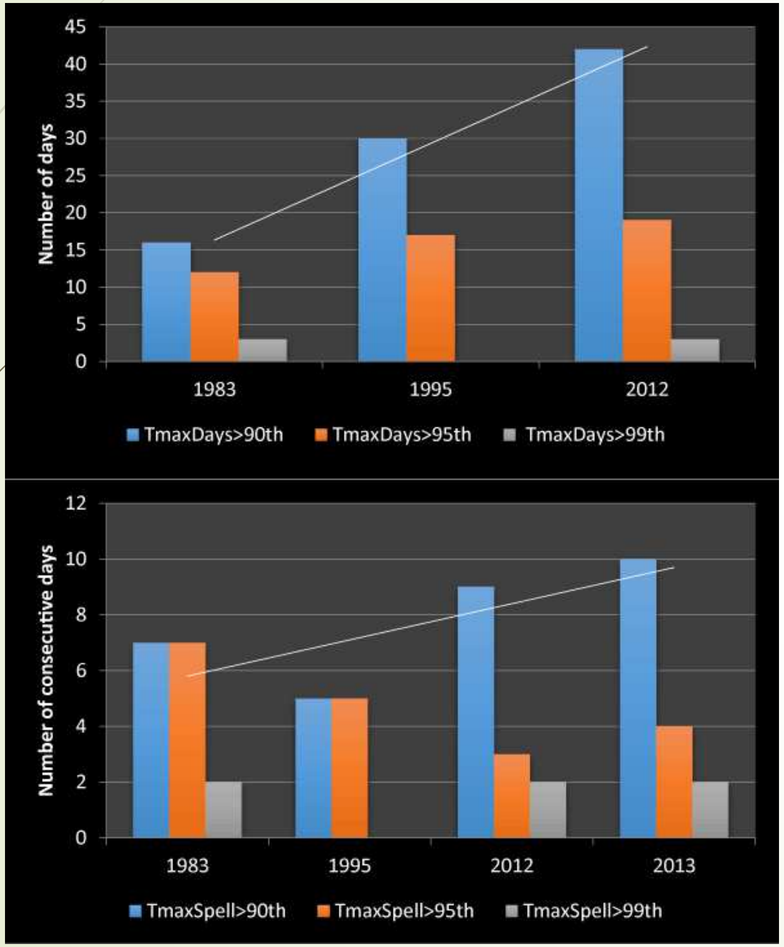
- Heat is the number one hazard in terms of mortality, emergency room visits and hospital admissions in the US and Europe.

- Nevertheless, there is a lack of a monetary index for heat as it exist for SLR or Floods.



https://health2016.globalchange.gov/

Warming Temperatures



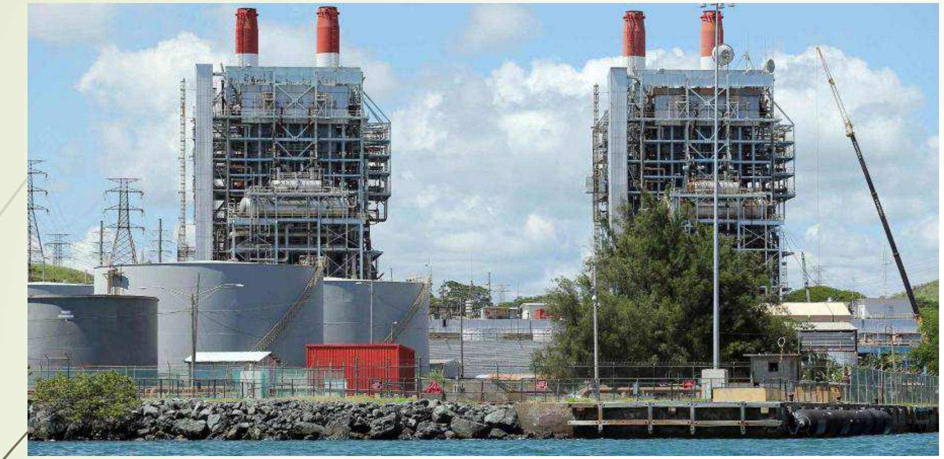
ID	Indicator Name	Indicator Dentitions	Units
TN10p	Cool nights	Percentage of time when daily min temperature < 10th percentile	%
TX10p	Cool days	Percentage of time when daily max temperature < 10th percentile	%
TN90p	Warm nights	Percentage of time when daily min temperature > 90th Percentile	%
TX90p	Warm days	Percentage of time when daily max temperature > 90th percentile	%
TX95p	Warm days	Percentage of time when daily max temperature > 95th percentile	%
TN95p	Warm nights	Percentage of time when daily min temperature > 95th Percentile	%
TN99p	Warm nights	Percentage of time when daily min temperature > 99th Percentile	%
TX99p	Warm days	Percentage of time when daily max temperature > 99th percentile	%
WSDI	Warm spell duration indicator	Annual count when at least six consecutive days of max temperature > 90th percentile	Days

Table 1: The Extreme Temperature Indices. Source International Expert Team on Climate Change Detection and Indices (ETCCDI).

The heat episode recorded in the summer of 2012 in San Juan registered a new climate record for Puerto Rico (**42 days**, from May 15, 2012 to August 15, 2012, **comprising the longest heat episode registered**).

90th = 33.3 (92ºF), 95th = 33.9 (93ºF), 99th = 35.6 (96.1ºF)

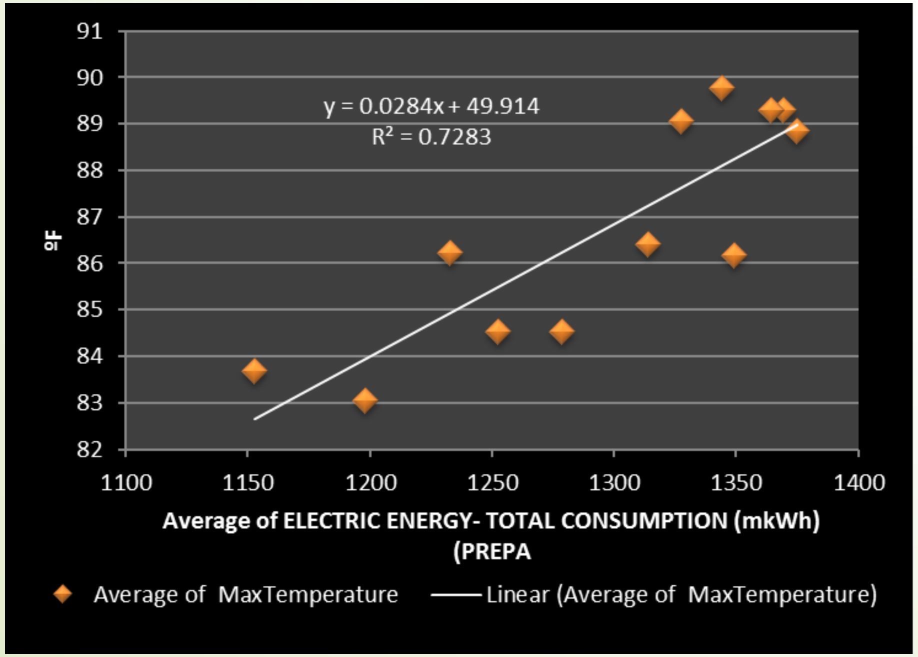
Warming Temperatures

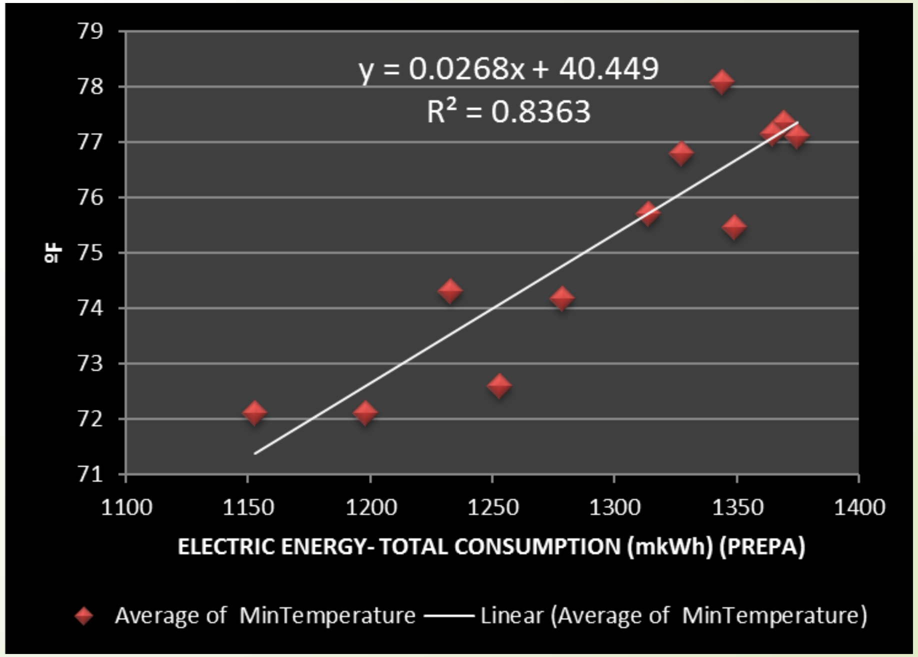


In warm weather with elevated summertime temperatures, energy is needed to **cool buildings and interior environments, increasing energy demand.**

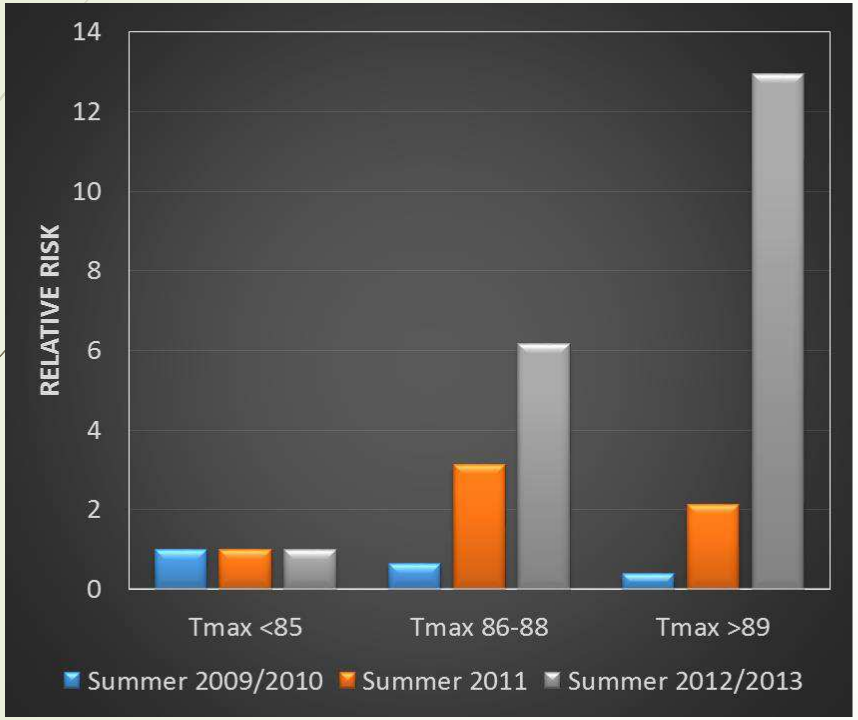
The heat episode recorded in the summer of 2012 in San Juan registered a new climate record for Puerto Rico

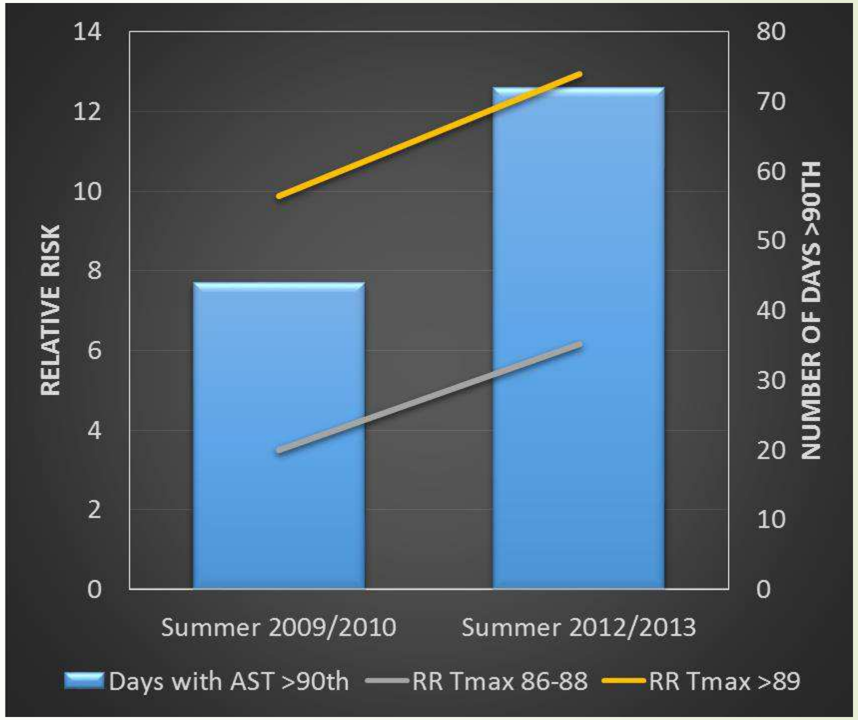
It also marked a new record for **energy consumption and a significant increase in mortality due to high temperatures** (Méndez-Lázaro et al. 2015, 2016).





Warming Temperatures

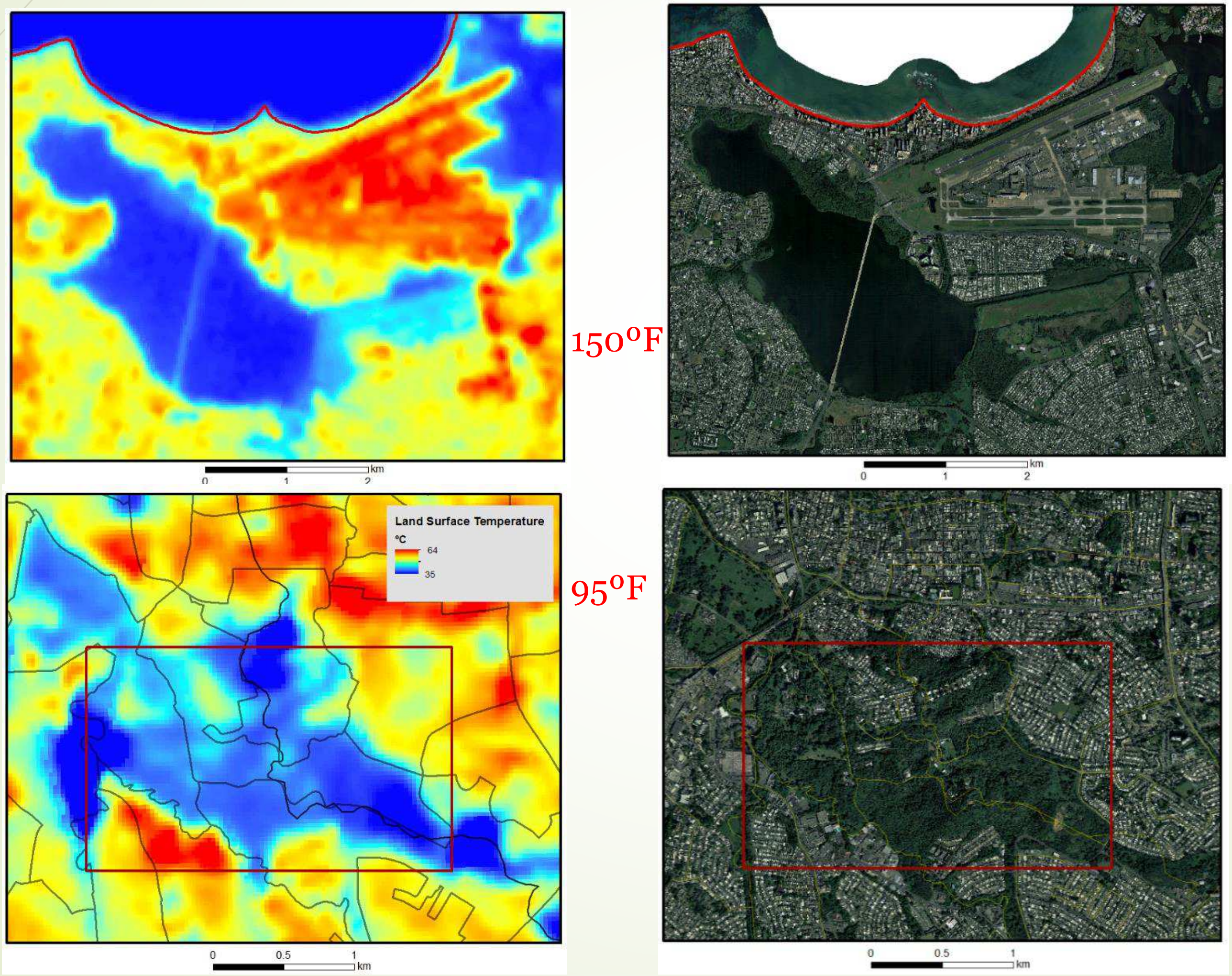




It also marked a **significant increase in mortality due to high temperatures** (Méndez-Lázaro et al. 2015, 2016). Results show a significant increase in the effect of high temperatures on mortality, during the summers of 2012 and 2013.

Stroke and cardiovascular diseases were the primary causes of death most associated with elevated summer temperatures.

Warming Temperatures



With urbanization, land use and land cover have enhanced the urban heat island (UHI) effect: buildings, roads, and paved surfaces store heat during the day and then release it during the evening, keeping urban lands warmer on average than surrounding areas.

This effect compounds the local impacts of large-scale changes that may be related to large-scale changes such as those related to climate (Kardinal Jusuf et al. 2007; Stone et al. 2014; Blake et al. 2011; Maimaitiyiming et al. 2014; Yang et al. 2015; Mohan and Kandya 2015).

Occupational Exposure?

Warming temperatures

- **General Message**
  - Puerto Rico's AST has risen and is expected to rise more
  - Puerto Rico's AST has increase since records keeping (at least 1899)
  - The most recent decade was the warmest on Record
  - An urban heat island effect, which leads to foci of higher temperatures in some urban areas, can raise heat-related mortality.
  - Despite other important factors that could diminish heat impacts, heat is the number one hazard in terms of mortality, emergency room visits and hospital admissions in the US and Europe.
  - There is a question on how humans, animals and plants that have established themselves in a particular location can adapt to higher average temperatures (Tomlinson et al. 2011).

- **General Questions**
  - Which population are most vulnerable to heat?
    - Elderlies >65 years old
    - Population below poverty level
    - Medical Pre-conditions
    - Children <5 years old
  - What could be the main factors that contribute to heat vulnerability?
  - How can green infrastructure could help to mitigate heat in urban areas?
  - Which ecosystems are most vulnerable to heat?
  - Are our livestock adapted for more frequent and intense heat?
  - Are our crops adapted for more frequent and intense heat?
  - Do farmers have the necessary tools and information to protect their products?
  - Do the Energy Authority have the capacity to fulfill the energy demand during these extreme prolonged heat episodes?

CLIMATE CHANGE ADAPTATION PLANNING ASSESSMENT AND IMPLEMENTATION

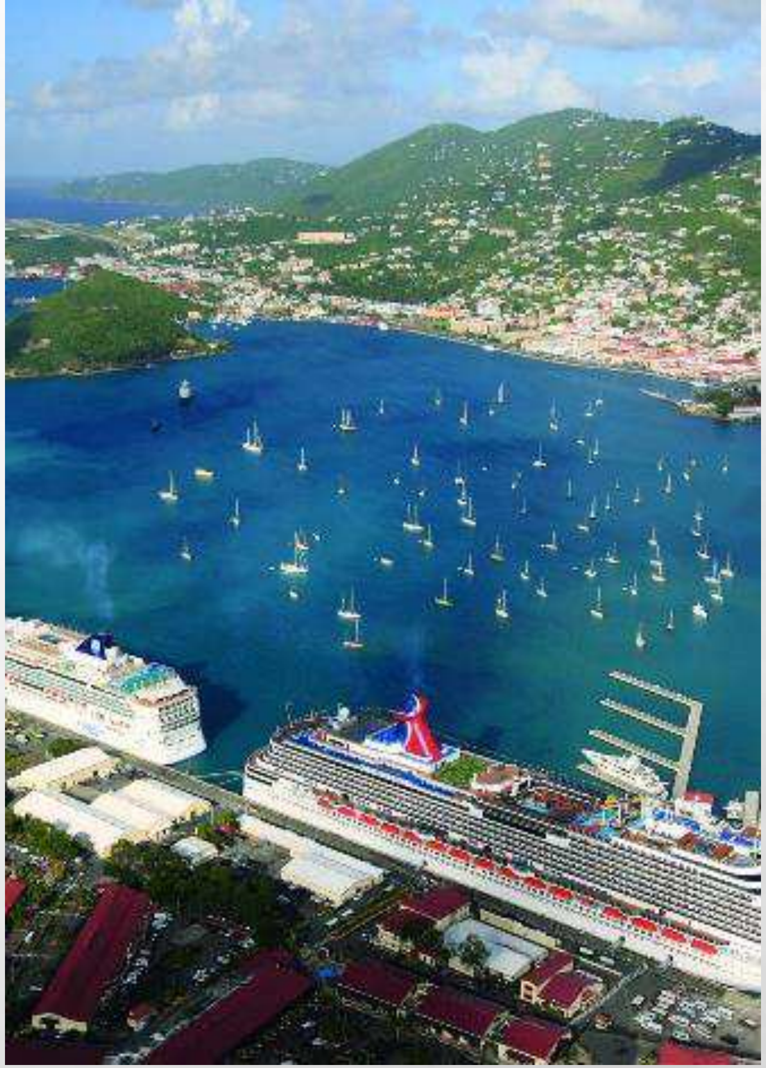
UNITED STATES VIRGIN ISLANDS

PROJECT GOAL

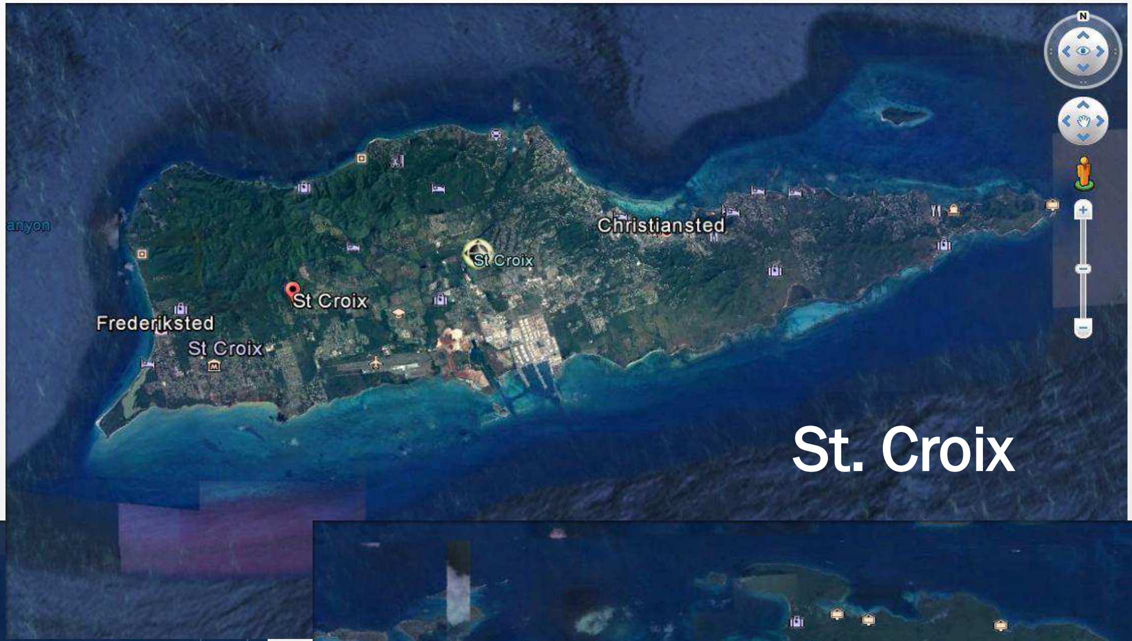
- GOAL: ASSIST THE USVI TO DEVELOP A FRAMEWORK WITH THE CAPACITY TO
  - ASSEMBLE AND MAKE USE OF A COMPREHENSIVE BASE OF INFORMATION RELATED TO CLIMATE CHANGE VULNERABILITY AND RISK ASSOCIATED WITH SEVERAL SECTORS OF SOCIETY
  - ESTABLISH RELATIONSHIPS AMONG KEY TERRITORIAL PLAYERS TO PRIORITIZE ADAPTATION AND MITIGATION PLANS AND ACTIONS, MAXIMIZE USE OF RESOURCES, PROMOTE ECONOMIC DEVELOPMENT AND HUMAN WELL-BEING AND REDUCE RISKS ASSOCIATED WITH CLIMATE CHANGE, AND
  - DEVELOP A ROBUST MULTI-SECTOR CLIMATE ADAPTATION STRATEGY.

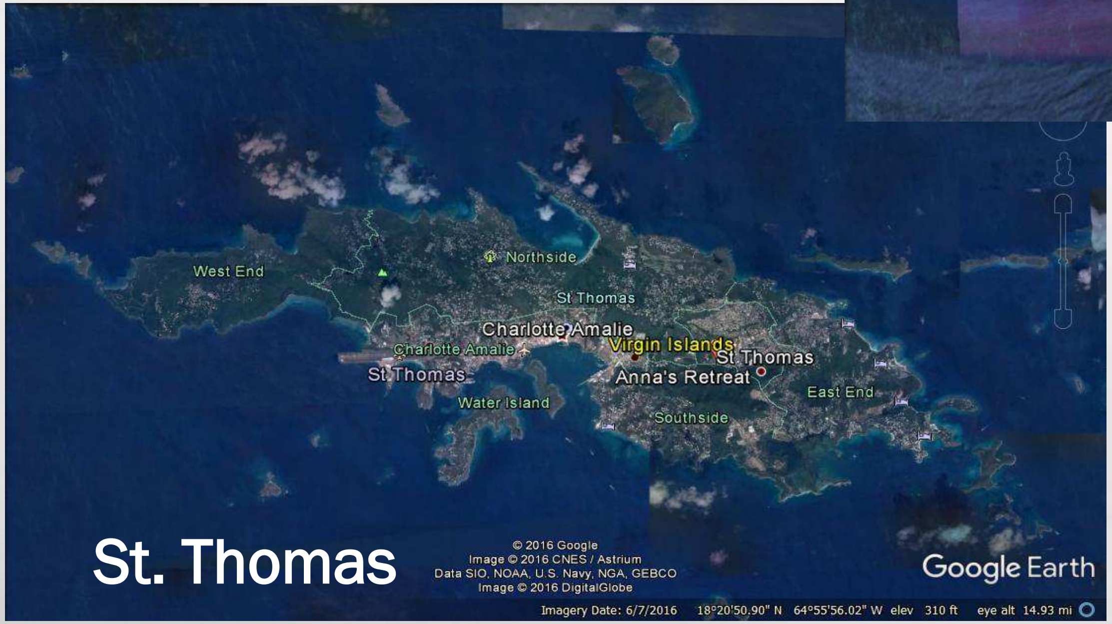
PROJECT OBJECTIVES

- IDENTIFY EXISTING VULNERABILITIES OF THE KEY ECONOMIC SECTORS AND INFRASTRUCTURE,
- IDENTIFY GAPS IN INFORMATION AND CAPACITY,
- IDENTIFY RISKS OF CLIMATE CHANGE TO THE TERRITORIES' INFRASTRUCTURE ASSETS, RESOURCES AND LONG-TERM GOALS
- IDENTIFY SPECIFIC CLIMATE ADAPTATION ACTIONS THAT FEASIBLY AND REALISTICALLY CAN ADDRESS THE NEEDS OF THE US VIRGIN ISLANDS
- PROMOTE INTER-AGENCY COLLABORATION
- ENGENDER A MORE INFORMED PUBLIC TO THE RISKS AND IMPACTS OF CLIMATE CHANGE AND WAYS TO REDUCE INDIVIDUAL AND COMMUNITY RISKS.



PROJECT LOCATION





PROJECT PHASES

1. INCEPTION PHASE
2. SENSITIVITY ANALYSIS PHASE
   a) CLIMATE SENSITIVITY/RISK
   b) SECTOR SENSITIVITY
3. ADAPTIVE CAPACITY ANALYSIS PHASE
4. HAZARD MODELLING PHASE
5. INTERIM REPORTING AND DISSEMINATION WORKSHOP
6. VULNERABILITY ASSESSMENT AND MAPPING PHASE
7. RISK ASSESSMENT FOR INFRASTRUCTURE PHASE
8. ADAPTATION STRATEGY AND ACTION PLANNING PHASE
9. CONSULTATIVE WORKSHOP AND DRAFT FINAL REPORTING PHASE
10. REPORT FINALIZATION PHASE