ArcGIS StoryMaps

Coral Reefs: On The Other Tide

An investigation of coral reefs, climate change, and flooding in Florida

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Introduction

What Are Coral Reefs?

Coral reefs, home to millions of aquatic species, play an important role in maintaining the Earth's oceanic ecosystem. Composed of colonies of coral polyps, they rely on the symbiotic algae for 90% of their energy.

Why are Coral Reefs Important?

Coral reefs provide shelter and nutrients to millions of organisms. They also protect shorelines from wave damage, tropical storms, and floods, as well as assist in carbon and nitrogen fixation.

What is Coral Bleaching?

Coral bleaching occurs when coral expels algae due to high water temperatures. Coral can survive coral bleaching, but due to global warming, and the resulting rising sea temperatures, rising water levels, and ocean acidification, it is very difficult for coral to survive as its ecosystem changes. When the ocean temperature is raised by at least 1-3 degrees Celsius due to ocean acidification, shallow corals start to expel their algae.

How do we Monitor Coral Bleaching?

There are several ways of monitoring coral bleaching. The two indicators we used in our research were sea surface temperature and chlorophyll A concentration. Chlorophyll A indicates eutrophication, which occurs when there are too many nutrients and dense plant growth in coral. This results in algal blooms, or excessive growth of algae, which in turn causes lack of oxygen and loss of aquatic life, including fish and coral. Both the data for sea surface temperature and chlorophyll A concentration can be obtained from NOAA and NASA's satellites, specifically MODIS, or Moderate Resolution Imaging Spectroradiometer.

Coral reefs are located in deep and shallow waters, growing along the coastlines. They are normally found in tropical locations such as

Florida. Coral reefs not only benefit humans with their ability to process carbon but also protect coastlines from the damage of wave action and tropical storms. Coral reefs are vital to Florida because they provide revenue from tourism (1.8 billion) and support the economy of small coastal municipalities (USGS, 2019). The corals in Florida are located from Martin County to Miami - Dade county extending into the key west (Figure 1).

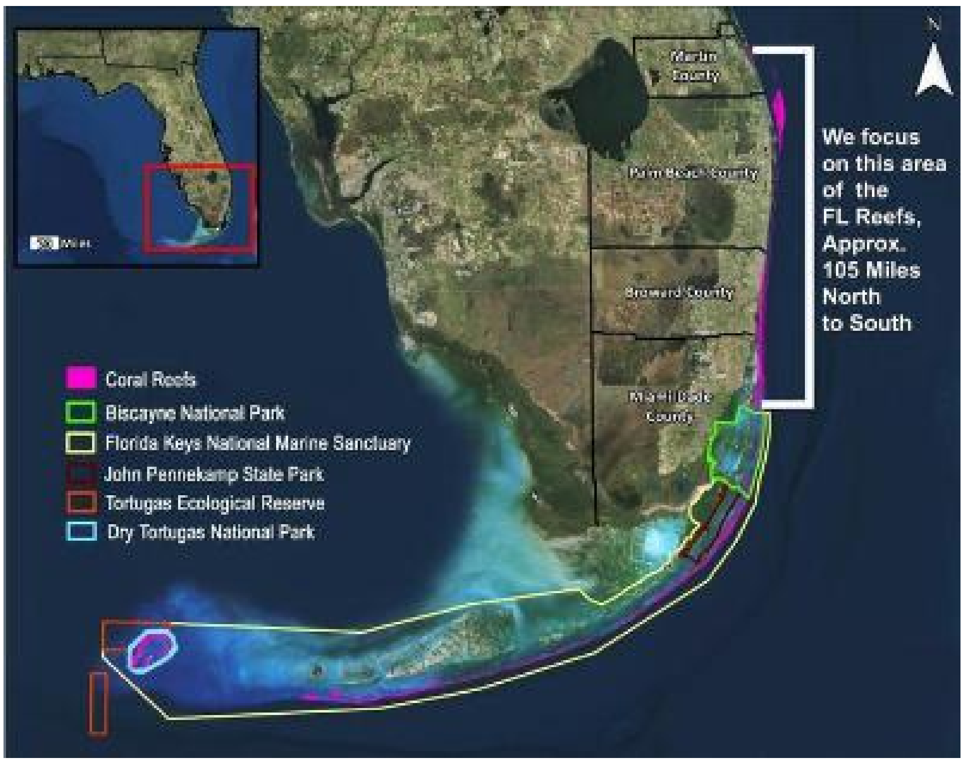


Figure 1: Map of Florida coastline and coral location. Map Credit: FDEP Coral Reef Conservation Program

However, due to recent human activities, the increase of anthropogenic atmospheric carbon has caused our oceans to acidify. This is harmful to corals because rising temperatures of the ocean result in coral bleaching, which affects coral mortality. Coral has heavily impacted the coastlines of Florida, thus, our group decided to research the major coral bleaching event of 2014-2015 in Florida. We aim to draw parallels between coral bleaching and if the loss of coral reefs could have an impact on flooding that occurs in that area.

Research Objectives

- What effects does climate change have on coral reefs?
- Assessing coral bleaching events of 2014- 2015 in Florida through means of Ocean color data.
- Analyzing how this event affected flood amounts in coastal areas during this time period.

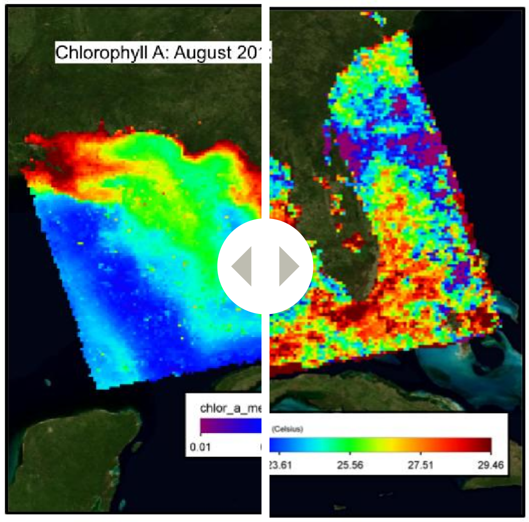
Hypothesis

- The effects of coral bleaching will result in the weakening of protection from floods
- Coral mortality is important to monitor and ensure because resulting harm can cause a significant impact on coastal area flooding.

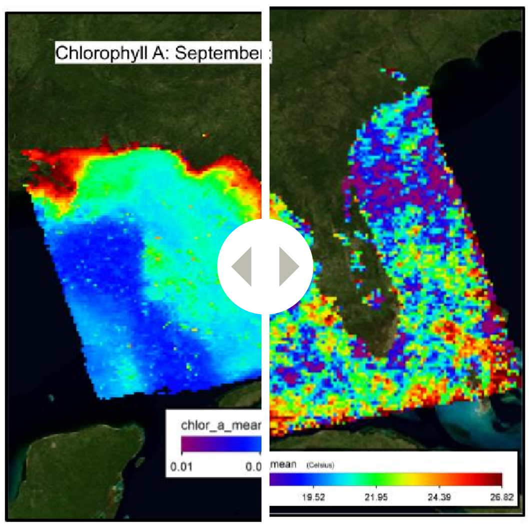
Methodology

- Processed data for ocean color output analysis was obtained from NASA for Florida 2014 - 2015.
- Ocean Color data at a resolution of 750 m was projected into NASA SeaDAS to compare Chl-a and SST for each month.
- Daily images were compounded into monthly images by Conducting Level 3 Binning for mean SST and Chl-a values.
- Monthly Maps were created to visualize data results.

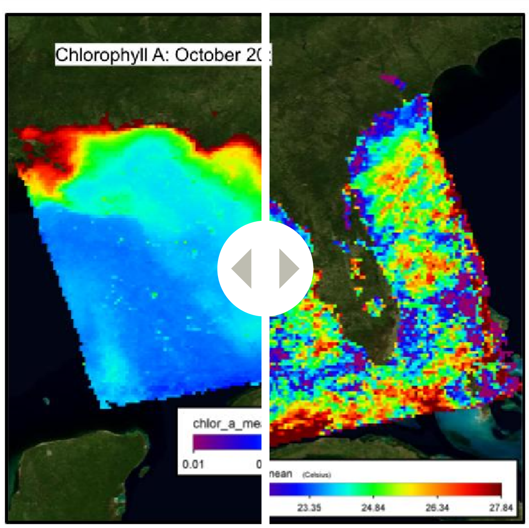
Results



Chlorophyll A Concentration vs. Sea Surface Temperature, August 2014



Chlorophyll A Concentration vs. Sea Surface Temperature, September 2014



Chlorophyll A Concentration vs. Sea Surface Temperature, October 2014

Discussion

In the last decade, flooding in the United States and other countries worldwide has steadily increased, as a direct result of the rising sea levels, melting ice caps, carbon emissions, and the moon's gravitational pull. "Extreme sea-level events, such as surges from tropical cyclones, that are currently historically rare will become common by 2100 under all emissions scenarios due to increasing global mean sea level rise" (WMO, 2019). By the end of the century, hundreds of thousands of square miles of coastline are expected to be made uninhabitable due to rising sea levels, displacing millions of people from their homes, and damaging infrastructure and businesses.

The areas most affected by such events are coastal cities, especially areas such as the Florida Keys. Coastal areas of Florida regularly experience tidal flooding, or 'sunny day flooding', which is when an area floods purely due to high tides, rather than rain or storms. Due to these events, coastal properties are being damaged without warning.

Bleaching event’s rapid occurrence affects coral reef’s ability to protect coastlines. The reef structure is no longer able to slow down wave actions and prevent floods from creating a large impact. This plays a large issue in Florida as the state is surrounded by large bodies of water. Without the coral reefs, the increasing water levels will be able to destroy large amounts of land and homes.

Table 3. Spatial extent, in square kilometers, protected by coral reefs from flooding for different return-interval storms by island or region.

Location	Sublocation	Storm return interval			
		10-year	50-year	100-year	500-year
American Samoa	Tutuila	1.60	1.91	1.88	1.23
American Samoa	Ofu and Olosega	0.20	0.22	0.24	0.26
American Samoa	Ta'ū	0.14	0.15	0.16	0.19
Northern Mariana Islands	Saipan	0.34	0.55	0.57	1.11
Northern Mariana Islands	Tinian	0.28	0.49	0.49	0.60
Guam	Guam	0.88	1.11	1.26	1.28
Florida	Peninsula	6.96	10.01	11.52	28.62
Florida	Florida Keys	3.19	5.36	8.13	2.58
Hawai'i	Island of Hawai'i	6.23	7.17	7.69	9.15
Hawai'i	Maui	10.84	9.27	7.57	4.48
Hawai'i	Lāna'i	0.73	0.81	0.86	1.02
Hawai'i	Moloka'i	1.59	1.71	1.80	2.18
Hawai'i	Kaho'olawe	0.40	0.44	0.45	0.47
Hawai'i	O'ahu	11.08	9.71	9.52	9.00
Hawai'i	Kaua'i	2.60	3.85	4.32	5.89
Hawai'i	Ni'ihau	0.73	0.88	1.07	1.35
Puerto Rico	Isla de Puerto Rico	22.71	26.11	29.57	37.74
Puerto Rico	Isla de Culebra	0.29	0.40	0.62	0.77
Puerto Rico	Isla de Vieques	0.75	1.26	1.39	1.75
Virgin Islands	Saint Croix	2.17	2.75	3.01	3.34
Virgin Islands	Saint John	0.14	0.22	0.31	0.27
Virgin Islands	Saint Thomas	0.32	0.41	0.50	1.33

Table 5. Total number of people protected by coral reefs from flooding for different return-interval storms by island or region.

[–, no value determined]

Location	Sublocation	Storm return interval			
		10-year	50-year	100-year	500-year
American Samoa	Tutuila	1,046	1,009	990	649
American Samoa	Ofu and Olosega	6	8	9	12
American Samoa	Ta'ū	15	17	17	25
Northern Mariana Islands	Saipan	704	878	560	1,580
Northern Mariana Islands	Tinian	9	51	58	23
Guam	Guam	197	156	198	312
Florida	Peninsula	7,820	15,981	20,130	53,584
Florida	Florida Keys	1,064	3,344	3,938	2,099
Hawai'i	Island of Hawai'i	600	724	743	796
Hawai'i	Maui	6,248	6,013	4,235	2,749
Hawai'i	Lāna'i	0	0	0	0
Hawai'i	Moloka'i	2	3	3	13
Hawai'i	Kaho'olawe	–	–	–	–
Hawai'i	O'ahu	5,586	5,637	3,957	3,553
Hawai'i	Kaua'i	193	189	313	355
Hawai'i	Ni'ihau	0	0	0	0
Puerto Rico	Isla de Puerto Rico	6,840	12,424	17,609	35,279
Puerto Rico	Isla de Culebra	17	32	39	90
Puerto Rico	Isla de Vieques	1	1	1	1
Virgin Islands	Saint Croix	482	699	914	429
Virgin Islands	Saint John	6	8	25	8
Virgin Islands	Saint Thomas	108	113	93	80

Table 9. Annual value of protection provided by coral reefs from flooding by island or region.

[–, no value determined]

Location	Sublocation	Number of people	Buildings (2010 U.S. dollars)	Economic activity (2010 U.S. dollars)
American Samoa	Tutuila	570	25,019,327	7,074,370
American Samoa	Ofu and Olosega	3	77,852	41,228
American Samoa	Ta'ū	8	753,845	148,637
Northern Mariana Islands	Saipan	396	5,003,426	8,047,866
Northern Mariana Islands	Tinian	7	672,257	145,767
Guam	Guam	107	6,839,500	10,155,754
Florida	Peninsula	4,947	323,835,761	276,082,074
Florida	Florida Keys	716	32,125,237	42,970,125
Hawai'i	Island of Hawai'i	336	23,997,824	26,686,848
Hawai'i	Maui	3,381	112,716,317	264,474,795
Hawai'i	Lāna'i	0	53,732	1,359
Hawai'i	Moloka'i	1	42,071	73,122
Hawai'i	Kaho'olawe	–	–	–
Hawai'i	O'ahu	3,040	200,942,259	194,404,235
Hawai'i	Kaua'i	107	5,854,742	6,466,170
Hawai'i	Ni'ihau	0	0	1,066
Puerto Rico	Isla de Puerto Rico	4,210	65,880,224	117,301,923
Puerto Rico	Isla de Culebra	11	148,502	286,275
Puerto Rico	Isla de Vieques	0	94,075	9,710
Virgin Islands	Saint Croix	278	18,021,883	21,325,668
Virgin Islands	Saint John	3	527,814	323,358
Virgin Islands	Saint Thomas	59	3,319,769	3,565,110

Conclusion

Sea levels will continue to rise as carbon usage increases, which will play a part in these issues as bleaching events occur, preventing them from having the ability to slow down floods. We are able to use our research to map out areas that are being affected by monitoring the amount of heat in the sea. As the likelihood of environmental and property damage due to flooding increases, our research on coral bleaching events will allow us to analyze the coral reefs in the areas that will be the most affected by extreme sea-level events, and create ways to protect and conserve the coral reefs most crucial to maintaining Florida's coasts and infrastructure. In the future, more research can be done to target areas most at-risk for flooding, in order to create protection systems for flooding in tandem with solutions to prevent further coral bleaching and carbon emissions.

Acknowledgements

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References

1.Storlazzi, Curt, and Ryan McClymont. "Coral Reef Barriers Provide Flood Protection for More Than 18,000 People and $1.8 Billion Worth of Coastal Infrastructure and Economic Activity Annually." *Coral Reef Barriers Provide Flood Protection for More than 18,000 People and $1.8 Billion Worth of Coastal Infrastructure and Economic ACTIVITY Annually*, U.S. Geological Survey , 30 Apr. 2019, www.usgs.gov/news/coral-reef-barriers-provide-flood-protection-more-18000-people-and-18-billion-worth-coastal.

2."WMO Statement on the State of the Global Climate in 2019." *United Nations Climate Action*, WMO, 2019, www.un.org/en/climatechange/reports.

3.Storlazzi, C.D., Reguero, B.G., Cole, A.D., Lowe, E., Shope, J.B., Gibbs, A.E., Nickel, B.A., McCall, R.T., van Dongeren, A.R., and Beck, M.W., 2019, Rigorously valuing the role of U.S. coral reefs in coastal hazard risk reduction: U.S. Geological Survey Open-File Report 2019–1027, 42 p., https://doi.org/10.3133/ofr20191027. .