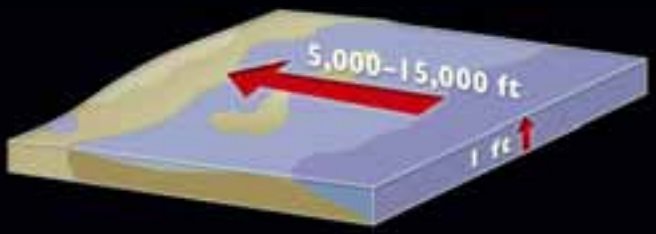
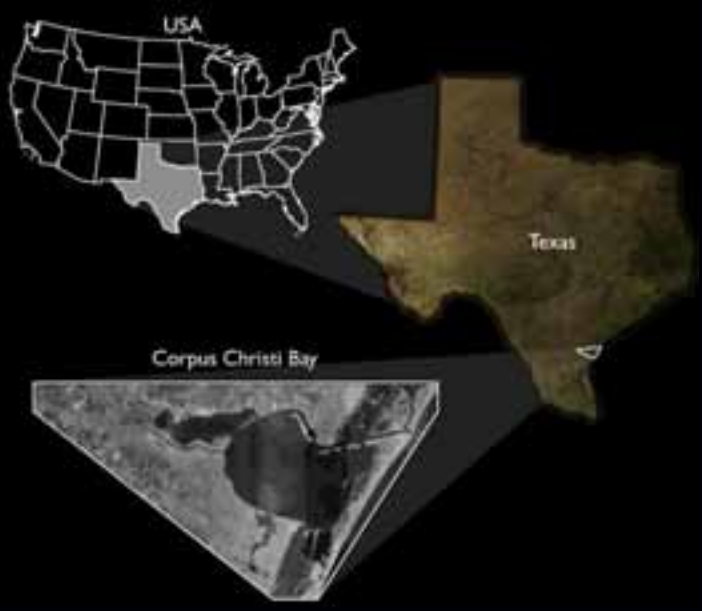
Impacts of Global Warming on Hurricane-related Flooding in Corpus Christi, Texas

TEXAS A&M UNIVERSITY

Sea-level Rise and Flood Elevation



A one-foot rise in flood elevation due to both sea-level rise and hurricane intensification leads to an inundation of 5000–15,000 feet.



Global Sea-level Rise

Global warming causes sea level to rise through two major mechanisms. First, as water warms, it expands, taking up more space. Second, as ice on land melts (including mountain glaciers around the world as well as the polar ice sheets), this water flows to the oceans. The thermal expansion of the oceans and the melting of mountain glaciers are well understood. Increased melting and loss of ice on parts of the polar ice sheets has recently been observed, especially on Greenland, although how much and how fast the ice sheets will increase sea-level rise is not well known, and this introduces significant uncertainty into estimates of future sea-level rise.

Thus, some projections of sea-level rise, including those of the Intergovernmental Panel on Climate Change (IPCC) that were used in this study, do not fully account for potential changes in the large ice sheets, and are thus considered conservative. Studies since the IPCC 2007 report have estimated that sea level could rise by considerably more than the 8 inches to 2 feet by 2100 mentioned in IPCC (which explicitly did not consider increased ice sheet melting).

Taking these new studies into account, sea-level rise between 1.5 and 6.5 feet is considered possible by the end of this century, with increases of around 3-4 feet considered most likely. This is an area of active research.

Limitations of the Analysis

This analysis looked only at damages due to flooding by storm surge and sea-level rise. It is not a comprehensive analysis of the wide array of hurricane-related damages. Other simplifying assumptions were made and there were limitations due to lack of data. For example, no data on historical flood damage to oil refineries was available to the researchers.

In addition, the study assumes that the barrier island retains its elevation and volume as sea level rises, though under high rates of sea-level rise, the relative condition of the barrier island would be expected to weaken, posing additional risk for erosion of the island and for flooding in the bay, both of which would increase economic damages. For large storm surges, structural damage on the barrier islands might be as much as $1.3 billion, if all homes on the island were completely destroyed.

Further, the appraised property values used in the study are lower than the values of properties listed for sale. Damage estimates using the listed values of homes would be more than 30% higher. Actual property damages for future scenarios will also likely be higher than projected in this study in response to the current trends of increased population and infrastructure construction along the coast. Other factors not considered in this analysis include future population growth, the possible acceleration in property values, and adaptation measures that might be taken by property owners to reduce losses.

While the results presented here offer an indication of the expected increase in damages as a result of global warming, the estimates are most likely low. Furthermore, the broader impact of hurricane damage to the local and national economy was not considered. Because Corpus Christi is a tourist area, local tourism revenue and other business-related revenue will likely be slower to recover following storms of higher intensity. There is also an increasing risk to the national economy, mainly because of Corpus Christi's role in the petroleum industry. Finally, potential community adaptation to accelerating flood levels was not included in this analysis.

Impacts of Global Warming on Hurricane-related Flooding in Texas

Global warming is projected to increase:

- *Sea-level rise*
- *Hurricane intensity*
- *Coastal flooding*

Causing increased:

- *Property damage*
- *Displacement of families and businesses*
- *Local and national economic impacts*

Context

Almost half of the world's people live within 100 miles of the coast. Many of these coastal communities, particularly those in lower-lying, hurricane-prone regions, are vulnerable to the devastating impacts of coastal storm surge. These impacts were recently illustrated in the United States by the widespread surges generated by hurricanes Katrina, Rita, and Ike. Global sea-level rise is projected to accelerate and hurricane intensity to increase with continued global warming. Both of these are expected to cause higher coastal flooding and an increase in related damages.

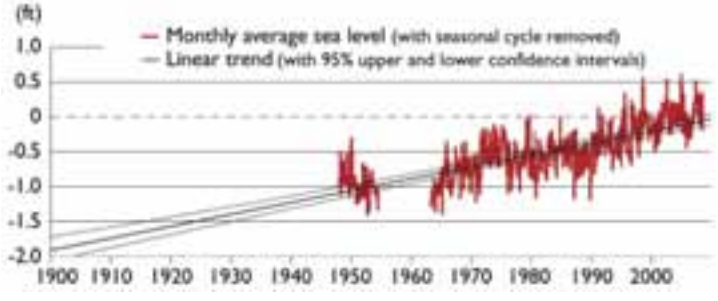
An analysis of impacts to Corpus Christi, Texas was undertaken to help understand and quantify the potential impacts of global warming on coastal flooding and related damages. Corpus Christi is home to a diverse industry base, including petroleum refineries, a naval base, a university, and businesses supporting coastal tourism. The city's location on the Gulf of Mexico makes it particularly vulnerable to climate change impacts.

If sea-level rise projections and the hurricane intensification scenarios used in this analysis are realized, significant increases in flood levels are projected, especially under higher emissions scenarios. This would lead to major economic consequences resulting from increased property damage and displacement of families and businesses.

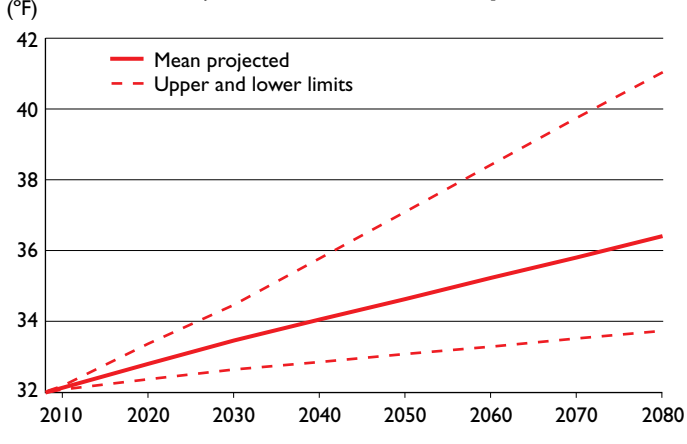
The Analysis

To evaluate the impact of global warming on future coastal flooding in Corpus Christi, three historical storms were chosen. These allowed the validation of the hurricane-surge model used in the analysis and served as a benchmark for comparing future hurricane scenarios. The study assumed that these storms occur in the future as they did in the past, but with higher sea levels and greater intensity resulting from climate change under various scenarios, providing analogs for future occurrences of these historical storms.

Sea-level Rise at Rockport, Texas 1950-2007



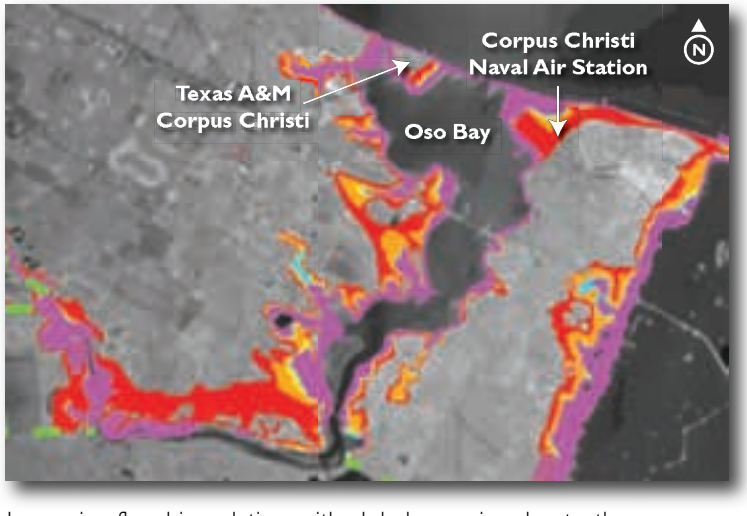
Projected Sea Surface Temperature



Sea-level Rise in Corpus Christi

The coastal area around Corpus Christi is particularly vulnerable to sea-level rise for several reasons. First, the coastal land in this area is slowly sinking due to geologic forces and oil extraction, and this "subsidence" combines with global sea-level rise to produce more "relative" sea-level rise here than in places where the coastline is stable or rising. Second, while the city has historically benefited from the protection of barrier islands, these islands are eroding as sea level rises, becoming narrower and lower in elevation, thus providing less protection from storm surge and a greater probability that the islands will be breached or over-washed.

Detail of Hurricane Beulah (Image at Right)



Increasing flood inundation with global warming due to the combined influences of sea-level rise and hurricane intensification near Oso Bay and the U.S. Naval base, part of mainland Corpus Christi. Key: Purple: 2000s; blue: low estimate for 2030s; yellow: high estimate for 2030s; orange: mid-range estimate for 2080s; and red: high estimate for 2080s. (See color key in image at right).

Hurricane Ike

Not included in this study was Hurricane Ike, which struck the Texas coast in September 2008. Ike was one of the five costliest hurricanes of all time in the U.S., with an estimated $27 billion in damages. Ike caused some 80 deaths in the U.S., with additional Americans still missing. Ike was the most massive Atlantic hurricane ever recorded, and before making landfall, it had the highest total energy of any storm in history. Fortunately, Ike's power decreased before it made landfall, and a small change in its course avoided significantly worse damage as the center of the storm missed the concentration of oil refineries in the Houston area.

KEY FINDINGS:

1. Sea level around Corpus Christi is projected to rise by about 2.6 feet by the 2080s under a high heat-trapping gas emissions scenario (but not including the potential for larger rises due to increased ice sheet melt). This would come on top of the 1.7 feet of sea-level rise already experienced over the past 100 years in this area. Higher sea level means higher flood levels. It also affects the barrier islands, reducing the protection they provide.

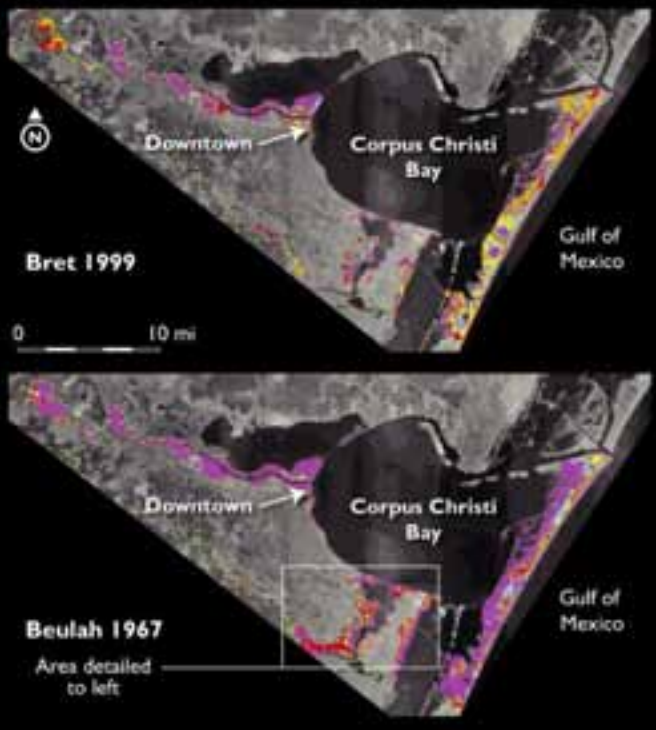
2. Hurricanes are projected to become more intense as ocean waters continue to warm. In particular, models project increases in wind speeds and rainfall rates for the strongest hurricanes. Intensity (measured by the fall in central pressure) is projected to increase by about 8 percent for every 1.8°F (1°C) increase in sea surface temperature.

3. By the 2030s, hurricane flood levels could increase by 3 to 27 percent, depending on emissions scenario. By the 2080s, hurricane flood levels could increase by up to 100 percent.

4. Structural damage to homes and buildings affected by flooding due to a major hurricane is projected to rise by 60 to 100 percent, depending on storm size, by the 2030s and by more than 250 percent by the 2080s.

5. For a catastrophic storm surge event in Corpus Christi, such as the surge that would have accompanied Hurricane Carla if it had followed a more southerly track, by the 2030s, structural damages are projected to increase by $102 million to $265 million, depending on the heat-trapping gas emissions scenario; by the 2080s, property damages are expected to increase between $265 million to over $1 billion. The higher the emissions scenario, the more damage is projected.

Projections of Flooding (If these hurricanes were to occur in the future under various scenarios)



Flood Levels	Flooded Area (Square Miles)		Structural Damages (2008 prices & values)
Historical (2000s)	Bret	12	$ 7,500,000
	Beulah	32	124,750,000
Low Estimate 2030s	Bret	15	17,250,000
	Beulah	36	174,500,000
High Estimate 2030s	Bret	19	35,000,000
	Beulah	39	226,000,000
Middle Estimate 2080s	Bret	33	143,250,000
	Beulah	44	362,250,000
High Estimate 2080s	Bret	39	286,000,000
	Beulah	51	499,000,000

This study was conducted by:

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**The study is available online at
http://ceprofs.civil.tamu.edu/jirish/NCEPreport/**

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