CLIMATE CHANGE & HURRICANES

Climate change is increasing hurricane precipitation, intensifying hurricane winds, and boosting storm surge. Increases in air and ocean temperatures due to climate change are having wide-ranging effects on hurricane precipitation, intensity, and coastal flooding. Warmer temperatures increase the rate of water evaporation from land and sea surfaces, which feeds moisture and energy into storms. Warmer air can hold more moisture, which increases the amount of water available for storms to dump out as rain. Additionally, warming oceans and melting land ice have caused sea level rise, which boosts storm surges, the name for the temporary increase in sea level due to storm conditions.

Climate change is worsening hurricane precipitation:

- Scientists have identified the fingerprint of climate change on the rainfall during Hurricanes Florence (Reed et al. 2020; Paerl et al. 2019), Maria (Keellings and Ayala 2019; Patricola and Wehner 2018), Irma (Patricola and Wehner 2018), Harvey (Trenberth et al. 2018; Wang et al. 2018; Risser and Wehner 2017; Van Oldenborgh et al. 2017), Sandy (Trenberth et al. 2015), Katrina (Patricola and Wehner 2018; Trenberth et al. 2007), and Tropical Storm Imelda (Van Oldenborgh et al. 2019).

Climate change is leading to more intense hurricanes, as measured by wind or central pressure:

- In almost every region of the world where hurricanes form, their maximum sustained winds are getting stronger due to human-caused climate change (Kossin et al. 2020).
- Climate change is contributing to sea surface temperature increases in the Atlantic and Pacific regions where hurricanes form, increasing the energy available to intensifying storms (Gillett et al. 2008; Santer et al. 2006).
- Global warming has likely increased the relative number of hurricanes reaching Category 4 or 5 intensity since the 1980s (Knutson et al. 2019; Holland and Bruyère 2014).

Due to climate change, hurricane storm surges are reaching further inland and causing more flooding:

- Climate change increased the area flooded and infrastructure damaged during Hurricanes Florence (Porter et al. 2018), Sandy (Miller et al. 2013), and Katrina (Irish et al. 2014).

WHAT ARE HURRICANES?

At the most basic level, a hurricane is a type of storm, and a storm is any interruption of the prevailing atmospheric pressure and wind fields that causes high winds and precipitation. Storms that form in the tropics are called tropical cyclones. When a tropical storm's maximum sustained winds reach 74 mph, it is called a hurricane. Hurricane intensity is usually measured by a storm's wind speed. Category 5 hurricanes are the most intense and have wind speeds of 157 miles per hour or higher.

HOW DOES CLIMATE CHANGE AFFECT HURRICANE INTENSITY?

Warmer ocean water due to climate change strengthens hurricanes and other storms that feed on heat energy from bodies of water, effectively increasing how powerful a storm can become (Walsh et al. 2015). Some of the substantial evidence that climate change is intensifying hurricanes shows a global increase in the proportion of storms reaching Category 3 strength or higher (Kossin et al. 2020) and in the intensity of the strongest storms (Kossin et al. 2013; Webster et al. 2005). The biggest and most damaging hurricanes are now three times more frequent than they were 100 years ago (Grinsted et al. 2019).

"THE PUBLIC SHOULD KNOW, AND POLICYMAKERS SHOULD KNOW, THAT ANY PLANNING THAT YOU MIGHT HAVE MADE BASED ON THE HISTORICAL RECORD IS INADEQUATE. IT'S A DIFFERENT WORLD. IT'S A WARMER WORLD, AND HURRICANES BEHAVE DIFFERENTLY."

- Michael Wehner,
Senior Staff Scientist, Lawrence Berkeley National Laboratory

HOW DOES CLIMATE CHANGE AFFECT ATLANTIC OCEAN HURRICANE ACTIVITY?

In the Atlantic, climate change is likely responsible for long-term trends in cyclone activity (Mann and Emanuel 2011). Scientists identified the fingerprint of climate change in the increase in the number of hurricanes occurring in the North Atlantic since the 1980 (Murakami et al. 2020). Unusually warm sea surface temperatures likely played a key role in the active 2017 Atlantic hurricane season (Lim et al. 2018). From 2016 to 2019, the Atlantic basin had the most consecutive years on record with at least one Category 5 storm, topping the last record set from 2003 to 2005.

HOW DOES CLIMATE CHANGE AFFECT PACIFIC OCEAN HURRICANE ACTIVITY?

Climate change is also behind the observed increase in hurricane activity in the Central Pacific since 1980 (Murakami et al. 2020), and the fingerprint of climate change has been found in the unusually active 2015 eastern Pacific (Murakami et al. 2016) and 2014 central Pacific (Murakami et al. 2015) hurricane seasons. Climate change has also increased the risk of intense tropical cyclone season in the Western North Pacific (Zhang et al. 2017).

EVENTS SPOTLIGHT: CLIMATE CHANGE AND RECENT TROPICAL STORMS & HURRICANES

TROPICAL STORM IMELDA

- **Texas (2019):** Imelda brought over 43 inches of rain to Southeast Texas in September 2019, making it the fifth wettest storm on record in the continental US. Climate change made the extreme rainfall and flooding caused by Tropical Storm Imelda more likely and intense (Van Oldenborgh et al. 2019).

HURRICANE FLORENCE

- **North Carolina (2018):** Human-caused climate change has increased rainfall during recent hurricanes in North Carolina (Paerl et al. 2019), including Hurricane Florence, which brought up to 36 inches of rain to the state (Reed et al. 2020; Reed et al. 2018). Because of sea level rise, Hurricane Florence flooded an additional 11,000 homes that would have otherwise stayed dry (Porter et al. 2018).

HURRICANE MARIA

- **Puerto Rico (2017):** Maria devastated Puerto Rico and the US Virgin Islands and is one of the costliest storms in US history at $93.6 billion. Due to climate change, a storm of Maria's rain magnitude is nearly five times more likely to occur today compared to the 1950s (Keellings and Ayala 2019).

HURRICANE HARVEY

- **Texas (2017):** Harvey is the wettest and second costliest hurricane on record in the US. By one estimate, up to two-thirds (or $67 billion) of Hurricane Harvey's $90 billion price tag is attributable to human-caused climate change (Frame et al. 2020). Five studies identified the fingerprint of climate change on Harvey's extreme precipitation (Trenberth et al. 2018; Wang et al. 2018; Risser and Wehner, 2017; Van Oldenborgh et al. 2017; Emanuel, 2017).

HURRICANE SANDY

- **New York & New Jersey (2012):** Sandy cost $65 billion, making it the fifth most expensive weather or climate event in US history. Human-caused sea level rise extended the reach of Hurricane Sandy by 27 square miles, affecting 83,000 additional people in New Jersey and New York City and adding over $2 billion in storm damage (Miller et al. 2013). Climate change also contributed to the volume of moisture in the atmosphere during Hurricane Sandy (Trenberth et al. 2015).

HURRICANE KATRINA

- **Louisiana (2005):** Katrina was one of the worst natural disasters in US history, causing a record $152.5 billion in damages and more than 1,800 deaths, and displacing 1.2 million people. A wetter atmosphere due to climate change increased Hurricane Katrina's rainfall (Patricola and Wehner 2018; Trenberth et al. 2007).

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