Changing Hurricane Activity & Forest Risk

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Hurricanes pose a major risk to infrastructure and human safety, but they are also a significant disturbance agent in our forests, often leaving impacts that persist for decades. The 2017 Atlantic hurricane season included a number of record breaking storms that were linked to above-average ocean temperatures (Murakami et al. 2018) and, since that particularly active hurricane season, there has been increasing discussion about changing hurricane risk in the context of climate change. In this bulletin, we summarize various aspects of hurricane activity and how they are projected to change (or not) in the future, with implications for forest health and timber value.

Recipe for a Hurricane

Hurricanes, which are more generally known as tropical cyclones (see box below), are massive storms fueled by warm, moist air over the tropical ocean waters near the equator, with wind speeds of at least 74 miles per hour. As warm, moist air rises it leads to areas of high and low pressure that ultimately create a spinning storm system of clouds and wind. In the simplest sense, the two most important factors in the development and intensification of hurricanes are (1) warm ocean waters and (2) wind shear (changes in wind direction and/or speed with height). These factors work in opposing ways—

Hurricane, cyclone, and typhoon are different regional terms for the same weather phenomenon.

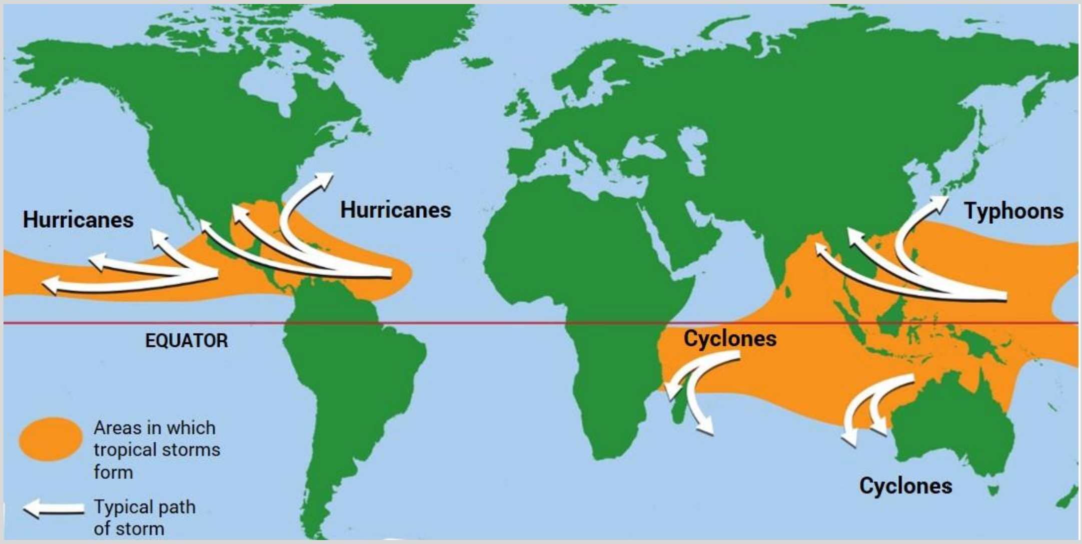


Image adapted from NASA Space Place (https://spaceplace.nasa.gov/hurricanes/en/cyclone_map_large.en.jpg) warm water provides hurricanes with their energy, while wind shear puts on the brakes by tearing storm systems apart (NOAA GFDL 2018a).

Determining how climate change might affect tropical cyclone activity involves figuring out how these two major factors will change, along with a few additional variables, such as the temperature of the upper atmosphere and relative humidity (NOAA GFDL 2018a). Over 90% of the global warming we have experienced to date has been absorbed by the oceans (Rhein et al. 2013), but warming ocean waters alone will not increase the number of hurricanes each year—it will, however, mean more fuel for them when they do form (Climate Central 2018a; Climate Central 2018b).

How is hurricane activity or risk changing, in terms of…

…FREQUENCY?

Detecting changes in hurricane frequency is challenging because records of hurricane activity are less reliable and less complete before the mid-1970's (after which we have more consistent observations from satellites and other sources). When studies account for these data limitations they find there has been **no increase in the global number of hurricanes since the 1800's** (Landsea et al. 2010; NOAA GFDL 2018b).

The number of hurricanes making landfall in the U.S. has not changed significantly either, but there has been an increase in hurricane activity over the entire Atlantic Ocean basin since the 1970's (NOAA 2012). However, too little time has elapsed to say whether that increase is part of an on-going trend related to human-induced climate change or whether it is within the realm of natural variability (Kossin et al. 2017).

There is still some debate about whether we will have more or fewer tropical cyclones in the future as the climate changes. While there are modeling studies that suggest the frequency will increase (Emanuel 2013), **the general consensus is that, globally, the total number of hurricanes will stay about the same or perhaps decrease by up to a third** (Knutson et al. 2010; NOAA 2012; Kossin et al. 2017). Although, research suggests we are likely to have an increasing number of the most intense storms, even if overall numbers go down (see section on *Intensity*, below). In the Atlantic Ocean, in particular, there is currently no consensus about how hurricane frequency will change (NOAA 2012).

…INTENSITY?

The intensity or strength of tropical cyclones is usually measured in terms of wind speed, such as the well-known categories of the Saffir-Simpson Hurricane Wind Scale. The maximum intensity a hurricane can achieve is determined by the temperature of the surface ocean and the thermodynamics of the atmosphere above it (Emanuel 1986; Emanuel 1995; Emanuel 1997). All else being equal, rising ocean surface temperatures will increase the potential intensity of tropical cyclones.

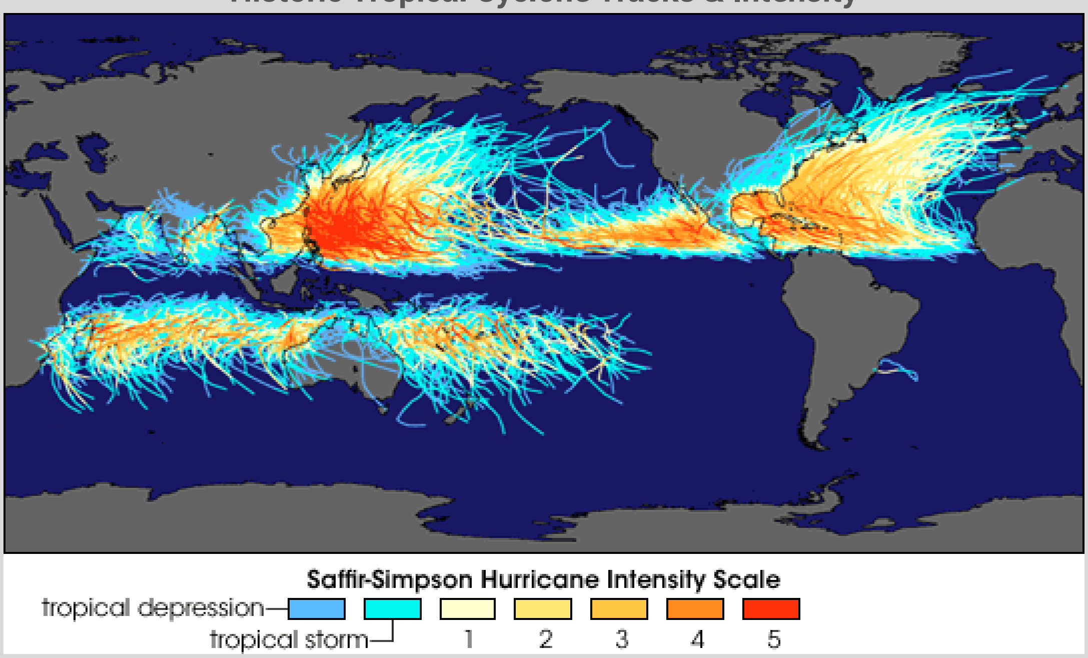
This is borne out by the latest scientific research, which indicates that **we will most likely see an overall increase in tropical cyclone intensity, including an increase in wind speed between 1 and 10%, as well as a greater number of category 4 and 5 storms in a warmer world** (Kossin et al. 2017; Bender et al. 2010; Knutson et al. 2015; NOAA GFDL 2018b). As one recent publication put it: “We thus expect tropical cyclone intensities to increase with warming, both on average and at the high end of the scale, so that the strongest future storms will exceed the strength of any in the past” (Sobel et al. 2016).

In fact, there is evidence this is already happening. Across the globe, **there have been increases in the strongest tropical storms, especially in the North Atlantic where the strongest storms are getting stronger** (Kossin et al. 2013; Elsner et al. 2008). There is also at least one study that suggests tropical cyclones are intensifying faster (Kishtawal et al. 2012). In a recent essay, several leading researchers in this field also noted that: “Of these seven [major tropical cyclone] regions, five had the strongest storm on record in the past five years, which would be extremely unlikely just by chance” (Rahmstorf et al. 2017).

There are other measures, beyond wind speed, that give a more holistic assessment of hurricane activity, such as the accumulated cyclone energy (ACE) index or the power dissipation index (PDI). These are functions of wind speed AND storm duration, which are accumulated for a particular region to estimate the overall intensity of the hurricane season (NOAA NWS CPC 2017; Emanuel 2005).

One study found that PDI more than doubled in the Atlantic and increased 75% in the western North Pacific between the mid-1970’s and the early 2000’s. The increase was due to a combination of longer-lasting storms and faster winds (Emanuel 2005). Although, a recent update indicates that annual PDI has actually fallen in the North Atlantic since that study was published (see EPA Climate Change Indicators: Tropical Cyclone Activity, Figure 3). Another recent study (Lin and Chan 2015) found a ~35% drop in PDI from 1992 to 2012 in the western North Pacific. In that case, storm intensity increased, but it was offset by having fewer storms

Historic Tropical Cyclone Tracks & Intensity



Map depicts 150 years of tropical cyclone activity (through September 2006). Image credit: NASA -- www.globalwarmingart.com/wiki/Image:Tropical_Storm_Map_png Image by Robert A. Rohde, www.globalwarmingart.com/wiki/ Global Warming Art.

that were not as long-lasting. This is an example of the way indices like PDI can be useful for understanding the interplay between changing intensity, frequency, and duration.

…RAINFALL?

Often times, it is the incredible volume of rain associated with hurricanes that does the most damage. All the resesarch to date points toward **increasing rainfall rates in a warmer world—on the order of 10-20% by the end of the century** (NOAA GFDL 2018b; Knutson et al. 2010). This is true on a global scale and for the Atlantic basin in particular. Rainfall rates are expected to increase because a warmer atmosphere will hold more water vapor and because these storms may move more slowly, dropping more precipitation in a given location (see section on *How Fast They Move*, below). As a recent example, the evidence suggests human-induced climate change contributed to the historic rainfall totals from Hurricane Harvey, making the heavy downpours 3 times more likely and 15% more intense (van Oldenborgh et al. 2017; Climate Central 2017).

…STORM SURGE?

Sea levels have been rising and will continue to do so for the foreseeable future. This is because ocean water expands slightly as it warms and warming temperatures are releasing large volumes of water that were previously frozen in mountain glaciers and polar regions. All else being equal, **rising sea levels will increase the height of hurricane storm surges** and the vulnerability of coastal communities to that type of flooding (Knutson et al. 2010; Kossin et al. 2017; NOAA GFDL 2018b).

…WHERE THEY PEAK?

One measure of tropical cyclone activity that is easier to accurately pin down is when a storm reaches its peak intensity. This is more straightforward than metrics like duration or absolute intensity because you only need to know when a storm is at its relative strongest, without needing to know the absolute wind speed in miles per hour. **When researchers looked at global records of tropical cyclone activity for the last 30 years, they found these storms now reach their maximum strength about 200 miles farther from the equator** (that is a trend of around 72 (+/- 43) miles per decade). This poleward migration appears to be happening globally, albeit at different rates in different regions, and it is consistent with the expansion of the tropics that has been linked to human-induced climate change (Kossin et al. 2014). If this movement in the location of peak storm intensity continues, it will change the historic patterns of storm risk across different regions.

…HOW FAST THEY MOVE?

Recent research indicates that **tropical cyclone are moving slower—translation speed (i.e. forward-moving speed, as opposed to rotation speed) has decreased globally by 10% since 1950** (Kossin et al. 2018). The slowdown has been even more dramatic in some regions, with tropical cyclones moving 30% slower over land areas near the western North Pacific and 20% slower over land areas near the North Atlantic. This has big implications for storm-related rainfall because a slower moving tropical cyclone will drop much more water in one region (the historic rainfall totals from Hurricane Harvey were an example of this). Tropical cyclones move within large-scale atmospheric circulation patterns that are affected by climate change, but the observed slowdown cannot be confidently linked to human-induced warming at this time (Kossin et al. 2018).

Forest Impacts from Hurricane Activity

It is estimated that, on average, hurricanes affect almost 3 million acres of forest and cost around $700 million dollars each year in the U.S. (Dale et al. 2001). By that measure, some recent hurricane seasons certainly qualify as above average. The Florida Forest Service puts the timber damage from Hurricane Michael in October of this year at $1.3 billion over 3 million acres of forestland (FDACS 2018). Another estimate of the damage from both Hurricane Michael and Hurricane Florence (which made landfall a month earlier), puts the total loss of timber value around $1.6 billion over 5 million acres across Florida, Georgia, and Alabama (SAF 2018).

This loss of value is also related to loss of aboveground carbon. A study of the impact of Hurricane Katrina on forests in the Gulf Coast estimated there was mortality or damage to ~320 million large trees, which represents a significant portion of the annual U.S. forest tree carbon sink. That same study noted that the predicted increase in storm activity “will reduce forest biomass stocks, increase ecosystem respiration, and may represent an important positive feedback mechanism to elevated atmospheric carbon dioxide” (Chambers et al. 2007). In other words, **we expect to have stronger, slower-moving storms in the future that drop more rain, so it is reasonable to expect that the risk to timber resources may change, including loss of value and forest carbon stocks in some places.**

In the aftermath of a major storm event, there is an immediate loss of merchantable value due to structural damage or tree mortality, but there are also longer-term impacts to consider—wounded and stressed trees are more vulnerable to attack from insects and pathogens, the increased volume of downed wood can provide additional fuel for wildfires, and there may be infrastructure and access-related issues if forest roads, culverts, etc. have been damaged.

Importantly, surviving trees may also experience growth impacts that can persist for a while after the storm event. One study of coastal forests in Virginia found a decline in radial growth that lasted for up to 4 years after an extreme storm before beginning to recover. They also found that there was a strong correlation between the amount of growth decline and the strength of the storm (as measured by wind speed or storm surge height) (Fernandes et al. 2018). This suggests that **the projected increase in hurricane intensity may have corresponding impacts on forest growth in impacted areas.**

Things to Do

Of course it is not possible to prevent trees from being severely damaged or uprooted in the strongest winds of category 4 and 5 hurricanes, but there are steps you can take to **build windfirmness in forest stands** and help them withstand lower intensity storm systems. We recommend re-visiting two of our earlier bulletins on that topic for more detailed information about the factors that increase the risk of wind damage (see Part 1) and the management actions that can maximize resilience to wind-related disturbance (see Part 2).

Other key actions are to **maintain forest access** and **have systems in place for carrying out rapid assessments of forest damage after storm events** (with field surveys and/or aerial/satellite imagery). This will help prioritize salvage efforts, which can be time-sensitive if the goal is to limit additional loss of value due to rot, pests, or disease. In some cases, it may also be worthwhile to **consider acquiring insurance to hedge against catastrophic timber loss due to extreme wind events**.

There are useful resources on this topic that are geared toward urban forestry, but which may have some useful insight, such as this series from the University of Florida. One of the publications in that series (see link under *Recommended Resources*) outlines a number of lessons learned from 10 hurricanes that hit the Gulf Coast and Puerto Rico between 1995 and 2005, including:

- The higher the wind speed of the hurricane, the more likely trees will fail.
- Trees in groups survive winds better than trees growing individually.
- Some species resist wind better than others.
- Pines may show no immediate visible damage after hurricanes but may decline over time.
- Trees that lose all or some of their leaves in hurricanes are not necessarily dead.
- Native trees survived better in South Florida hurricanes.
- Older trees are more likely to fail in hurricanes.
- Unhealthy trees are predisposed to damage.
- Trees with poor structure or bark inclusions are more vulnerable in the wind.
- Trees with more rooting space survive better.
- Damaged root systems make trees vulnerable in the wind.

RECOMMENDED RESOURCES:

- Managing Forest Stands to Minimize Wind and Ice/Heavy Snow Damage: Part 1 (CSLN Bulletin)
- Managing Forest Stands to Minimize Wind and Ice/Heavy Snow Damage: Part 2 (CSLN Bulletin)
- Chapter 5—Wind and Trees: Lessons Learned from Hurricanes (University of Florida, IFAS Extension, Publication No. FOR 118)
- How do hurricanes affect forest resources? Lessons from Katrina and Rita (US Forest Service, Southern Research Station, COMPASS, Issue 12, October 2008)

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