NOT IF, BUT HOW

Munich RE

Preventing the next Katrina

Fifteen years ago Hurricane Katrina devastated New Orleans and the Mississippi coast. Today, climate change and the slow pace of building resilient communities is hastening the arrival of the next catastrophic U.S. hurricane event.

It is difficult to convey the scale and magnitude of destruction that Hurricane Katrina wrought along the northern Gulf Coast in August 2005.

Over 200 miles of coastline were devastated by a storm surge that measured 30 feet in height in some locations. Hurricane-force winds in excess of 120 mph knocked down trees and damaged buildings well over 100 miles inland, while levee and pump failures in New Orleans left the city half underwater for weeks. Few natural disasters have had such a profound and lingering impact on a major American city. New Orleans still reportedly has about 60,000 fewer residents than in 2005, and scars of the storm are still evident in neighborhoods like the Lower Ninth Ward.

For the past 15 years, Katrina has reigned as the costliest insured natural catastrophe event on record, . But how long will Katrina retain this title? The next hurricane to devastate a major U.S. city is coming, it's only a matter of when.

A home near the 17th Street Canal in New Orleans lies in ruins six months after Katrina, the watermark from weeks of flooding still evident on its façade. All photos taken by author unless otherwise noted.

The "when" is coming much sooner than many expect, however, due to the confluence of several factors, including a warming climate and its impacts on tropical cyclones (TCs), limited action to make our cities and towns more resilient, and insurance coverage gaps within our communities. It is now time to make improvements before the inevitable occurs. This article highlights the current scientific understanding of the relationship between hurricanes and climate, as well as a discussion of the three types of resilience that can help mitigate the risk from the next Katrina-like event.

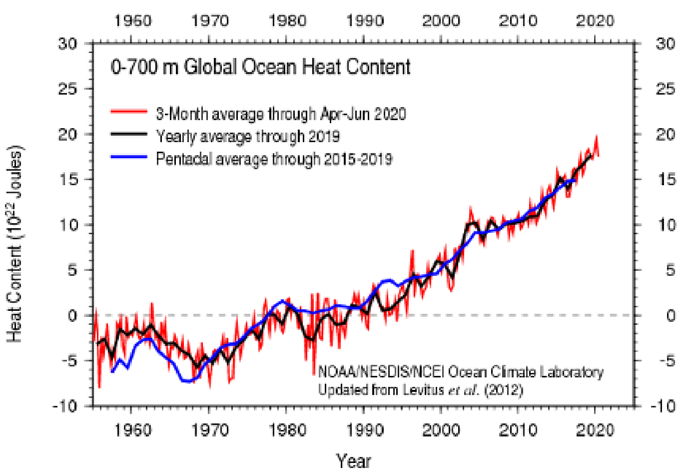
Climate change is influencing hurricane impacts

At the time of Katrina's landfall, the impacts of climate change on tropical cyclones was a subject of intense debate within the meteorological community. In 2005, amid record tropical cyclone activity in the Atlantic and 12 U.S. hurricane landfalls in 15 months, two scientific research papers (Emanuel 2005 and Webster et al. 2005) were published that argued climate change was already making tropical cyclones more intense. Other tropical cyclone experts, however, expressed concerns that the quality of the hurricane historical record before the satellite era is too poor to give confidence to such a conclusion. These experts suggested that recent activity was mostly the result of natural climate variability, as hyperactive seasons and consecutive years with multiple U.S. hurricane landfalls had been observed in the past (i.e., Landsea et al. 2006).

Since that time, significant progress has been made in understanding the complex interaction of tropical cyclones and climate. Based on the latest climate model projections, a recent scientific review found that precipitation rates of tropical cyclones will increase globally with ongoing climate change, the proportion of Saffir-Simpson category 4-5 storms will increase globally, and the frequency of category 4-5 storms will increase globally, among other possible changes (Knutson et al. 2020).

Hurricanes are getting wetter

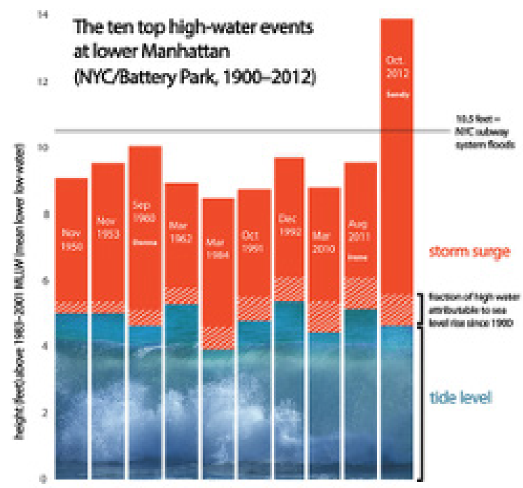
Meteorologists expect heavier rainfall in a warmer world. The amount of water vapor our atmosphere can hold increases by about 7% per degree Celsius. In turn, more available atmospheric moisture can lead to heavier rainfall rates. Since the world's tropical and subtropical oceans are the primary global source of atmospheric moisture and are also warming in response to climate change, tropical cyclones can take advantage of the increased evaporation rates occurring over larger, deeper, and warmer reservoirs of tropical ocean to generate more rain than in the past (Patricola and Wehner 2018; Cheng et al. 2019).



Heat content near the ocean's surface has increased by almost 20 sextillion joules globally over the past 30 years. In tropical and subtropical oceans, the increase in moisture fluxes from the additional heat content can make hurricanes wetter. Source: NOAA/NESDIS.NCEI Ocean Climate Lab

In regard to storm surge, the mechanism is very clear: sea level rise caused by the thermal expansion of water and the melting of land-based ice, such as glaciers and the Greenland and Antarctic ice sheets, has slowly raised global sea levels by about eight inches, on average, over the past 150 years (Church et al. 2013). Other geophysical factors can also play a role in sea level, such as erosion and land subsidence (that can increase the rate of local sea level rise), and post-ice age continental plate rebound (can slow, counteract, or cause a net decrease in local sea level). But in locations where sea levels are rising relative to land, storm surge events today and in the future will occur on top of a higher base than in the past. This not only makes fair-weather tidal flooding a more common occurrence (i.e. "Nuisance Flooding" or "King Tides"), it also allows future storm surge events to penetrate further into coastal communities (Sweet et al. 2014).

A good example of this is New York City's encounter with Hurricane Donna in September 1960, when surge heights in the inner harbor came within six inches of being able to flood subway tunnels in lower Manhattan. If an exact repeat of Donna occurred in September 2020, its storm surge would occur on top of seven additional inches of sea level, flooding the subway and having a far greater impact on the city and its daily life than it did 60 years ago. Although extratropical by the time of its landfall, Sandy's storm surge in 2012 was a stark, costly reminder of this growing risk to New York and its infrastructure.



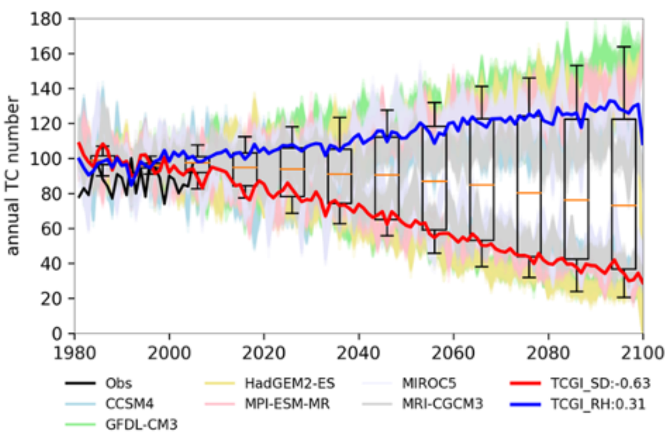
Sea level rise is making storm surge events worse. Hurricane Donna would have flooded the New York subway system if today's sea level existed in 1960. Source: Carlye Calvin, UCAR

Other hurricane-climate links likely but less certain

After Hurricane Katrina's first landfall in south Florida, the storm moved into the Gulf of Mexico where it encountered the Loop Current. The Loop Current flows northward from the Caribbean Sea into the Gulf of Mexico, whose unique geography then forces the current to "loop" back to the south and east before exiting into the Florida Straits. The vorticity caused by the current's abrupt U-turn occasionally creates eddies in the Gulf, spinning reservoirs of deep, very warm water that can persist for several weeks. It was one of these eddies that fueled Katrina's rapid intensification into a category 5 hurricane over the central Gulf, and the same eddy would also cause Hurricane Rita to undergo rapid intensification a month later. While these eddies are a naturally occurring phenomena, the amount of oceanic heat content in the Gulf – in eddies and elsewhere - will continue to rise due to climate change, becoming a potential driver of stronger Gulf storms in a warmer world.

At first glance, the link between climate-warmed oceans and tropical cyclone intensity seems relatively straightforward: Climate change is trapping more heat in our oceans, and the additional "fuel" can cause tropical cyclones to become more intense. The reality, however, is more complicated, as oceanic heat content is just one factor that governs TC intensity. It is less clear how other factors that inhibit hurricanes, such as Saharan Air Layers and wind shear over the Atlantic, may change in a warmer climate (Sun et al. 2009; Nolan & Rappin 2008). But in years where shear and dry air are less of a factor, tropical cyclones that pass over climate-warmed oceans (exceeding 82 ºF) will have increased potential to intensify into dangerous Category 4 or 5 storms.

Significant uncertainties also remain in regard to how tropical cyclone frequency and motion has (or will) changed in our warming world. While there is currently no obvious or significant trend in the number of tropical cyclones that occur annually across the globe (about 100 per year), a recent study from Columbia University (Lee et al. 2020) indicates that the number of tropical cyclones that climate models produce depend in part on how atmospheric moisture is parameterized. One method shows a slight increase in the number of TCs by the end of the 21st century, the other produces a modest decrease by the end of the century. Although it is unclear at this time which parameterization produces the more accurate solution, it is revealing that the most likely answer is that future TC frequencies will be different than the historical baseline, illustrating the uncertainties that remain in understanding the link between climate and tropical cyclone frequency.



Time series of the Columbia Hazard Model (CHAZ) simulated annual global tropical cyclone frequency. Thick black line is historical observations. The thick blue and red lines show the ensemble mean number of TCs from experiments when saturation deficit (TCGI_SD) is used as a moisture variable versus when column relative humidity (TCGI_RH) is used. Note the sensitivity of future TC frequency from this single change in variable. (Source: Lee et al. 2020)

Theory and recent studies also provide hints to how tropical storm motion has or may change. As the tropical Hadley circulation expands around the equator in response to climate change (Seidel et al. 2008), tropical cyclones may be pushed more poleward and reach their maximum intensities at higher latitudes than in the past. Such a trend is already being observed in the Southwest Pacific and Northwest Pacific Oceans, the latter being the most active tropical cyclone basin on the planet, but has not been observed yet in the North Atlantic (Kossin et al. 2016). Another concerning trend in regard to motion is that tropical cyclones appear to move slower today than in the past, possibly as a result of weakening atmospheric currents in the summer that can be linked to climate change (Kossin 2018). Slower storms or ones that stall, like 2017s Harvey or 2019s Dorian in the Bahamas, allow torrential rains, wind, and/or surge conditions to persist over one location for long periods of time, leading to more damage and disruption than if the storm passed though quickly.

Resiliency is key

Hurricane Katrina was the first natural catastrophe in the 21st century that forced an extended, complete shutdown of a major U.S. city and metropolitan area, and it will probably not be the last. As the impacts of climate change accelerate over the coming decades, more and more coastal communities will become vulnerable to similarly disruptive events. Thus, it is imperative that steps are taken to ensure the individuals and communities at risk are protected from both the physical and financial risks of future hurricanes.

A new home in Punta Gorda, FL, (left), sustained no visible damage despite experiencing wind speeds approaching 150 mph during Hurricane Charley in 2004, while new construction near Slidell, LA, (right) did not fare as well in lower wind speeds during Katrina. A lack of statewide building codes in Louisiana and Mississippi contributed to the severity of wind damage seen after Katrina.

Building resiliency into our homes and businesses

There are two complementary levels at which physical resiliency can be built into our communities. The first is making our homes and businesses more resilient to wind and water.

Comparing wind damage from Katrina with the Florida hurricanes of 2004 helped confirm that homes and businesses can be affordably constructed to be more resilient to intense wind events. After Florida's devastating encounter with Hurricane Andrew in 1992, the state made significant improvements to its building codes, which were enacted and went into effect in the early 2000s. A couple of years later, these codes would endure their first major test from Hurricane Charley, a powerful category 4 storm with sustained winds of 150 mph at the time of landfall in southwest Florida. In the aftermath of the most intense Florida windstorm since Andrew, it was confirmed that construction built under the new Florida Building Code (FBC) had performed far better than pre-code structures in the state, with some new residential construction surviving wind speeds in excess of 150 mph with only minimal damage.

The same could not be said after Katrina, however, as new and old construction alike suffered similar levels of damage in the storm's 120 mph winds. In fact, newer buildings along the northern Gulf Coast sustained more damage at lower wind speeds during Katrina than new construction in Florida under more severe conditions, in large part driven by the lack of statewide residential building codes and lack of widespread hurricane shutter usage in Louisiana and Mississippi at the time (Munich Re 2006). This poor performance lead the state of Louisiana to adopt a statewide residential building code that has significantly improved the resiliency of new construction in the state.

But despite the success that statewide building codes have had in reducing hurricane damage, several Gulf Coast states have not implemented them (IBHS 2018). The adoption of building codes is left up to individual cities and towns, and many coastal communities in these states have done so. However, this patchwork approach could leave some residents as vulnerable as before. Ultimately, statewide building codes similar to Florida's should be implemented in high-wind regions nationwide, not just in coastal states, to reduce the vulnerability of new construction to all types of windstorm events. The severe derecho event in Iowa in August 2020 is one such example of inland wind damage, the severity of which could have largely been prevented with stronger building codes.

A section of damaged and eroded levee along the 17th Street Canal in New Orleans.

Ensuring community resiliency via land use & water management

The second level of physical resiliency is around land use and water management, especially in regard to both coastal and inland flood risk.

Over the past century, manmade flood barriers, such as levees, have been built to protect communities nationwide. While these barriers can be quite effective, they can fail without proper engineering and maintenance, and older systems may not be designed to withstand the extreme events of both today and tomorrow. A good example of this is the network of levees surrounding the city of New Orleans, which is located mostly below sea level. In locations where levees failed during Katrina, it was found that unexpectedly poor subsoil conditions allowed the storm surge to push levee walls over and flood the city (Seed et al. 2005).

The levees that were repaired post-Katrina used this new information in their design to prevent such a failure from happening again. Unfortunately, the New Orleans area still has tens of miles of older, vulnerable levee network that survived Katrina but could fail in the next large event. Similarly, other manmade flood prevention systems, such as seawalls or coastal flood barriers, can be effective as well, but they can be prohibitively expensive to build and maintain, and they cannot be modified quickly in response to unexpected climate impacts.

Aside from earthen, metal, and concrete barriers, there are additional solutions offered by experts that can help reduce the impact of storm surge. Restoring or strengthening coastal ecosystems is one effective approach, particularly in respect

New Orleans' Lower Ninth Ward Neighborhood was obliterated by storm surge. Many residents of this economically disadvantaged neighborhood were uninsured and left with nothing after Katrina destroyed their homes, thus interrupting lives, livelihoods, and the speed of the city's overall recovery.

to protecting property from the battering, destructive waves that occur on top of storm surges that can reduce homes to rubble and cause significant land erosion. Restoring sand dunes and planting native vegetation to help hold them together is one natural solution that reduces the impacts of storm surge. Mangroves, coral reefs, and oyster beds, where viable, can also act as natural (or "manmade natural") barriers that work to dissipate wave energy before it reaches populated areas.

In addition to the above, the state of Louisiana should take steps to allow spring floods on the Mississippi and other local rivers to overflow into adjacent, unpopulated wetlands down river of New Orleans, as the sediments deposited help prevent the state's marshy coastline from eroding away further and help revitalize bayou ecosystems. This could help protect New Orleans and other towns by restoring the miles of natural barrier that once stood between it and the Gulf of Mexico, one that has continued to weaken further over the past 15 years.

Aside from large-scale projects, there are only two ways to mitigate flood risk in a community: elevating homes or not building in areas where flooding is common or expected in a warming climate. Since elevating pre-existing homes is a costly endeavor, a better (but still costly) solution would be for local government to purchase properties in flood zones with the purpose of creating greenways and parks that can act as natural flood barriers that help protect the rest of the community. The conversion of flood zones along rivers and coastlines into public parks also provides new usable outdoor spaces for residents and tourists, and can lead to higher home values and local tax revenues (Kousky et al. 2014). Grant programs around this concept already exist and should be expanded in light of the increased flood risk climate change brings. Insurance policy wordings should also allow policyholders to cover the full cost of purchasing new property in lower-risk areas to help facilitate the movement of populations away from high-risk flood zones.

In addition, care should also be taken by communities to determine how new developments might alter runoff patterns that can influence flood frequency and severity in downstream locations. For example, a pair of severe flash flood events in Ellicott City, Maryland, over the past 10 years were in part due to a new upstream residential development that directly exacerbated the amount of runoff heading toward the town's business district. (Logan 2019). Equally important is ensuring that our infrastructure, particularly roads, bridges, and electrical grid, are built to withstand natural disasters and are still functional after an event.

Financial resiliency

At the time of Katrina's landfall, an estimated 85,000 National Flood Insurance Program (NFIP) flood insurance policies were active in New Orleans, covering only about 40% of the city's estimated 213,000 homes and businesses (Munich Re 2006). Today, the flood insurance take-up rate in the city is still about 40%. And should the levees overtop or fail during the next major event, once again there will be a significant population of New Orleans residents who will be severely impacted. .

The above example illustrates why it is imperative to strengthen the financial resiliency of coastal communities and their residents. Even with stronger building codes and improved land use planning, hurricanes will continue to cause destruction. Much of the building stock in the U.S. were built before the implantation of modern codes and remains highly vulnerable to wind and water. Without the financial resources to quickly rebuild after an event, the recovery effort becomes a significantly longer and more challenging process.

Insurance can provide families and communities the financial resilience they need to hasten their recovery. After natural catastrophe events, insurers and reinsurers pump billions of dollars into impacted communities to help get them back on their feet faster, providing covered policyholders the money they need to be made whole again. And, in turn, that money feeds into the local economy, keeping municipal tax flows from collapsing and keeping vital public services afloat.

However, there are significant gaps in insurance coverage in the U.S. that can threaten the financial resilience of individuals and communities alike. These gaps need to be closed to help reduce the impacts of future storms. The largest insurance gap in the U.S. is around the peril of flood. Due to decades of adverse selection (only people at high flood risk would buy flood insurance) that made insuring against the peril unprofitable, most insurance companies in the U.S. left the flood market in the late 1960s, opting to let the federal government assume flood risk via the newly formed NFIP. But as compared to wind and fire insurance, which is purchased by roughly 95% of U.S. homeowners according to the Insurance Information Institute, flood insurance take-up in the U.S. is an abysmal 15%. Although coastal counties typically have a flood insurance take-up rates much higher than the national average, residents of inland counties rarely buy flood insurance, despite the risk from river and flash flooding.

There are many reasons why flood insurance is not purchased by U.S. homeowners. Some people are simply not aware that a standard homeowners policy in the U.S. doesn't cover flood. Proof of flood insurance is not required to obtain a mortgage from a bank unless you're purchasing a home in a high-risk zone. And in these high risk zones, about one-half of policyholders let their flood coverage elapse within three years of purchase because the banks do not ask for continued proof of coverage, (Michel-Kerjan et al. 2012). In some areas, premiums for flood insurance may be prohibitively expensive due to the level of risk. Finally, the NFIP's coverage limits, set by acts of Congress, have not kept up with home values or inflation over the decades, leaving many homeowners unable to get full coverage for their home from the NFIP. In these cases, homeowners can either purchase a separate flood policy to cover losses above the NFIP limit or self-insure and carry that risk themselves.

Over the past 20 years, the tools available to insurers in regard to flood risk have improved dramatically, and the private sector is now learning how to successfully underwrite flood by taking slow, cautious steps into the market. The reintegration of flood insurance back into a standard homeowner policies, for example, is just one future possibility that could cause a dramatic jump in flood insurance coverage nationwide.

But even with more private market participation in underwriting flood risk, the cost of flood insurance may be too high for consumers to afford, particularly in coastal locations vulnerable to storm surge. To close the insurance gap in these locales, innovative new risk transfer solutions need to be developed. One potential option is the concept of community-based insurance, whereby a municipality buys flood insurance for itself and its residents, thereby pooling the risk across the community and lowering average premiums.

Community-based insurance helps link risk transfer and mitigation efforts together. These programs can be designed to pay out either on an indemnity or parametric basis, and the latter option could also provide the chance for additional funding for post-event mitigation and resiliency efforts as well. Alternatively, government or NGO grants that help subsidize flood policies for those who can't afford them could also be another way to close the flood insurance gap. If a sufficient number of homeowners participated, those who opt into this program could, in theory, choose from coverage limit options and payout structures to supplement or replace flood coverage on their homeowners or NFIP policy, and premiums could be collected as a tax or fee on participating households.

Other types of insurance gaps, ones that are not peril-specific, exist as well, such as coverage for municipal property and assets. Local governments rely on local tax revenues, as well as state and federal grants, to fund their operations. However, if revenues or funding is below expectations, municipalities may need to start making spending cuts, and insurance is one of the items that may often get the budget axe. This can leave the town in even greater financial difficulty if a major event occurs since the town will not be indemnified for any damage city property sustains. Combined with a potential drop in tax revenues post-storm, lack of insurance can easily leave a community on the brink of financial ruin.

A final insurance gap that also needs to be addressed lies within our economically disadvantaged neighborhoods. Ultimately, community resiliency is only as strong as its weakest link, and if the whole town isn't resilient, its post-event recovery will suffer. While the economically advantaged can afford insurance and take steps to mitigate damage to their homes and businesses, economically disadvantaged neighbors may not be able to. Programs that help everyone obtain some level of insurance coverage – from grants to premium subsidies to community-based coverage – should be considered to help insure that everyone can resume their lives as fast as possible once the storm passes

Our future needs to be resilient

The next Katrina-like event in the U.S. has already occurred: 2017s Hurricane Maria in Puerto Rico devastated the entire island with violent winds and torrential rains. The island's power grid was left in ruins and countless roads and bridges were wiped out from flash flooding, taking months to restore. Like Katrina, Maria resulted in significant loss of life and caused a migration of residents to other parts of the United States. Today, Puerto Rico continues to struggle to return to normal. The recovery remains fragile, and could easily be hampered or undone by future events, like the strong earthquake sequence experienced along the island's southern coast in January 2020.

New construction along the Mississippi Coast in February 2007, 18 months after Katrina. Local building codes have improved resiliency to both wind and water in the region, but countless vulnerable risks still remain.

Other U.S. hurricanes have come close to a Katrina-like disruption over the past 15 years, including Sandy in New York / New Jersey in 2012 and Hurricane Harvey's unprecedented flooding of Houston and southeast Texas in 2017. We've also seen near misses – both Hurricanes Irma and Dorian were at one point expected to make landfall along Florida's densely populated east coast at or near Category 5 intensity.

New Orleans remains a likely candidate for another Katrina-like event due to its extreme vulnerability to storm surge events. While New York, Houston, and Florida's major coastal cities (Miami / Fort Lauderdale / Palm Beach, Tampa / St. Petersburg, and Jacksonville) are all vulnerable to a Katrina-like disruptions, there are other lesser-known areas where such an event is also possible. Southwest Florida, especially Lee and Collier counties, is extremely vulnerable to storm surges that could travel miles inland and flood hundreds of thousands of homes. Cities along the Chesapeake Bay and its tidal tributaries, including Norfolk, Baltimore, and Washington, D.C., could all experience flooding by an event that funnels surge into the bay, causing tidal rivers like the Potomac to back up and spill over their banks. Similar to Puerto Rico post-Maria, the threat of significant disruptions after a major hurricane also exists in Honolulu, Hawaii, as the island chain's isolation lengthens response and recovery time. Inland cities are not entirely immune either, as catastrophic flash flood events are possible everywhere, especially if a storm stalls over a region for several days producing rainfall that can be measured in feet, not inches. Atlanta, Charlotte, San Antonio, and Austin are just a few cities that are at elevated risk of such a possible outcome.

Hurricanes are inevitable. Damage and human suffering from hurricanes are not. Studies from the National Institute for Building Standards estimates that every $1 in resilience spending saves $6 dollars in future damage (NIBS 2019). As tropical cyclones become wetter and more likely to become violent windstorms, we must act, at an individual level as well as the community, state and federal level. We must act with the collective will to break out of the cycle of damage followed by rebuilding to the standards (and in the locations) that helped cause the damage in the first place. But we need to act faster, because the clock is ticking towards the next Katrina… in a warmer climate…at an increasingly faster rate.

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