Written Testimony of

Dr. James M. Done
Deputy Director, Capacity Center for Climate and Weather Extremes,
National Center for Atmospheric Research,
and
Willis Research Fellow

before the

House Committee on Science, Space, & Technology

Understanding, Forecasting, and Communicating Extreme Weather in a Changing Climate

Sept 26, 2019

Good morning Chairwoman Johnson and Ranking Member Lucas. I am Dr. James Done, deputy director of the Capacity Center for Climate and Weather Extremes at the National Center for Atmospheric Research. Thank you for this opportunity to participate in this important hearing. I'm a physical scientist specializing in extreme weather. In my role of Senior Academic Fellow of the Willis Research Network I collaborate with the reinsurance industry to advance our understanding of extreme weather and effective risk management. It's my pleasure to testify today on the state of the science of extreme weather under climate change and to outline opportunities to bolster our science, risk management, and protection of lives and property.

Executive Summary

Extreme weather is the main vehicle that delivers the impacts of climate change. We have already detected a signal of climate change in deadly heatwaves and flooding rains. And further changes in extreme weather are anticipated. Whereas the incremental warming of our earth system may seem small, on-the-ground impacts are anything but. In addition to local devastation, extreme weather impacts reverberate through our natural, physical, and social systems.

The U.S. has excelled at producing breakthrough research advances and technologies that benefit science, human safety, economic prosperity, and national security. It's now more important than ever to have effective communication of solid short-term forecasts, and robust longer-term risk management strategies. A deeper integration of science and practice is urgently needed to strengthen protection of lives and property, ensure military readiness, and sustain economic competitiveness. Our choice is clear: Implement solutions, or face greater catastrophes.

1. Introduction

Thank you for the opportunity to discuss this urgent topic. I shall begin outlining the state of today's extreme weather and how it's different from the past. Then I'll outline what we can expect in the future. I'll close with some recommendations for how we can respond by bolstering our science and risk management practice.

We have entered a new era of extreme weather. While the U.S. is no stranger to extreme events, impacts from recent events have been unprecedented. We've experienced the devastating floods brought by Harvey, Florence and Imelda. We've baked under deadly heat. We've endured multi-year droughts. And we've experienced the tragedy of fast-moving, intensely hot wildfires. New forms of extreme weather have appeared. The Carr Fire near Redding, California in 2018 produced a long-lived tornado with winds up to 150mph, uprooting trees and downing power lines. Alaskan coastlines previously protected by sea-ice are now seeing erosion from Arctic cyclones. What is causing these rising impacts?

Extreme weather has changed. So have we. Impacts arise from the intersection of extreme weather with our rising populations and increasingly interconnected systems. Enter climate change, a pervasive and growing risk multiplier. All these factors contribute to impacts. Questions of whether climate change caused an event miss this point. Sure, our shifting demographics are a strong contributor. And on top of that, evidence is building for a climate change signal in our rising losses. As a physical scientist I know that the events that cost money and lives, such as coastal flooding from sea level rise or flooding rains from intense thunderstorms, have increased.

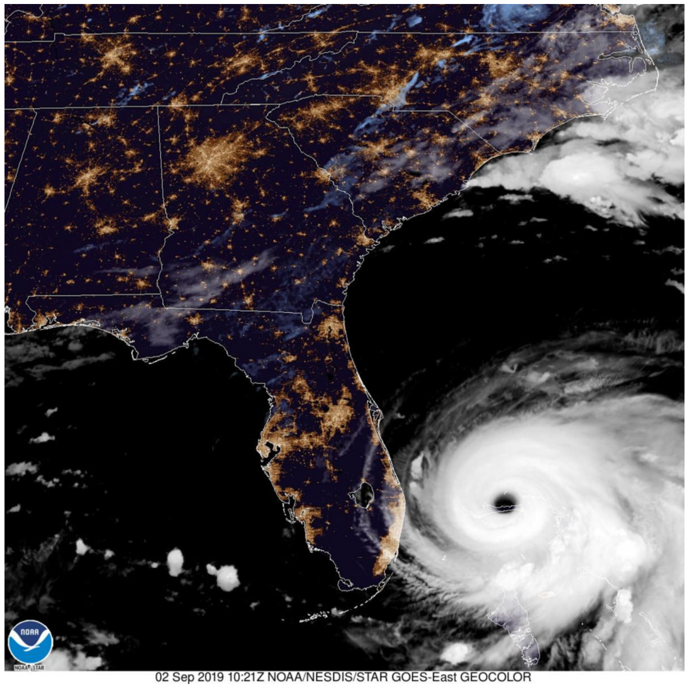


Figure 1: A striking visual of Category 5 Hurricane Dorian on Sept 2, 2019 showing the exposure of our rising population to todays' record-breaking extreme weather.

Our challenge then, is to understand these factors, and use that knowledge to inform actions to reduce future losses and maximize potential benefits. It's now more crucial than ever to fully integrate our science with our risk management practice to strengthen protection of lives and property, and support military readiness and economic competitiveness.

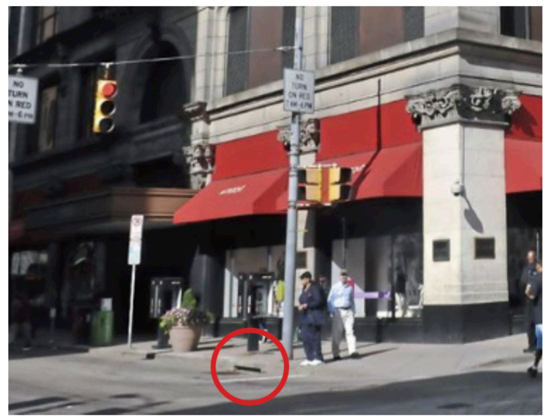
2. We Live in a New Era of Changing Extreme Weather

Today's warmer atmosphere drives more moisture out of our vegetation, soil, and oceans. We have a fundamental scientific principle that tells us that the moisture in the atmosphere increases by about 6-7% for every degree Celsius of warming. What does this mean for extreme weather? Given that some warming has already occurred it's inconceivable that today's weather, that operates within this warmer, moisture-rich environment, has not changed. Indeed, the hand of climate change has already been detected across a range of extreme weather phenomena.

Heavy rainfall for example has followed the same rate of increase as moisture. We have detected increases in heavy precipitation across the U.S. with the largest increases in the Northeast. There is also some evidence that rain rates may be rising even faster than the rate of moisture increase. Recent studies found the climate change contribution to Hurricane Harvey's rainfall could have been as much as 20%. But more work is needed to understand this rather alarming possibility.

What does this mean for our aging storm water infrastructure? Figure 2 compares two photos of the same street corner in downtown Pittsburgh, PA taken almost 100 years apart. Much has changed in 100 years. What hasn't changed is the storm water infrastructure. Can our aging storm water infrastructure adequately collect and convey today's deluges?

Downtown Pittsburgh, 1912



Downtown Pittsburgh, 2010

Figure 2: Two photos of the same street corner in downtown Pittsburgh, taken almost 100 years apart. (PG Archive, left), (Pittsburgh Post-Gazatte, right). With thanks to T. Lopez-Cantu (CMU).

Hurricanes are multi-hazard phenomena that combine flooding rains with dangerous surge and destructive winds. What do we know about changes to these other characteristics? Sea levels are higher today than a few decades ago. Today's storm surges ride on top of these higher seas. We don't know yet whether climate change has contributed to changes in North Atlantic hurricane numbers or peak wind speeds. This does not mean that climate change is not playing a role - we just don't have the data to be sure. But most scientists agree that climate change has contributed to a global increase in the fraction of Category 4, 5 hurricanes. Other observed changes include a global slowdown in tropical cyclones, including a trend in stalling storms over our vulnerable coastal populations. But this has not yet been linked to climate change.

The good news is that our ability to forecast hurricanes has improved markedly. Hurricane Dorian is a case in point. It's remarkable to me that we had a Category 5 hurricane 150 miles off the coast of Miami (Fig. 1) yet no evacuations in the Miami area were required and people could go about their business as usual. A robust observing network, and vast strides in prediction technologies, both funded by the federal government, paid dividends.

What of our other extreme weather phenomena? The regions favored by tornadoes have shifted east across the central U.S. But we don't yet understand the cause. There is also evidence that tornadoes are clustering in greater numbers, with longer tornado-free periods in-between. But again we don't understand the cause.

Now consider wildfire. California is one of the most flammable places on Earth. While the numbers of wildfires are holding steady, today's fires are much larger than in the past. They are also moving faster and burning more intensely.

The most well-understood climate change impact on wildfire behavior is through warmer summers driving more moisture out of vegetation. This crisp vegetation provides the fuel for when fire weather conditions arise. There is also evidence that Fall rains are starting later. These first rains of the Fall bring critical moisture that shut down the fire season. Take the case of the tragic Camp fire in Paradise, California last November. This fire would almost certainly not have occurred had the Fall rains arrived as usual. Last year's near-record warm summer desiccated the vegetation. While strong winds were a key factor, strong winds in damp forest just don't drive large, fast-spreading wild fire.

3. What Can we Expect in the Future?

Many people question whether we have reached a new normal of extreme weather? The answer is emphatically no. There's no evidence to suggest we've reached some kind of stable state of extreme weather. We understand that extreme weather will continue to worsen. And it will combine with demographic and ecological shifts to bring new risks.

Looking to the future, there is mounting evidence that, rather ominously, the more extreme the event, the more intense and more frequent it will become. Take heavy rainfall for example. A recent study by my colleagues found a 4-fold increase in the frequency of the heaviest summer thunderstorm rainfall by the end of this century. Not only does the rainfall rate increase by a 6-7% rise per degree warming, but there is some evidence that the storms may cover greater areas. These compounding effects would double total water volumes falling from these storms, with catastrophic simultaneous multi-watershed flooding. For the case of hurricanes, recent work suggests will we will see more storms reaching the most intense hurricane categories. But more work is needed to ensure this result is robust.

For hurricanes in general most scientists will say they expect faster wind speeds and worse hurricane-related flooding due to heavier rains and stronger storm surges. Unfortunately for us property damage rises about 3 times as fast as the rise in wind speed. So even modest increases will lead to large changes in damage.

Changes to other impactful characteristics of hurricanes are less certain. We don't know, for example, whether we'll see more stalled hurricanes on the U.S. coast. Nor do we know how the likelihood of very large hurricanes will change. Likewise, we don't understand how hurricane-spawned tornadoes may change.

Looking at other extreme weather, evidence is mounting for future changes in large hail. The warmer and more-moist atmosphere provides more fuel for hail-generating thunderstorms. There is some evidence for an overall increase in hail size. But the U.S. Gulf States may see fewer large hail events due to the suppressing effect of elevated freezing heights. For tornadoes, it's not clear whether climate change will make them stronger or more frequent. This is not because there will be no change, but because we don't have the understanding or data to be sure.

Fire seasons are getting warmer, meaning that tinder dry vegetation will become more common, all other things being equal. But what about precipitation? Will dry Falls become commonplace, thereby extending fire seasons? There is evidence emerging that Western U.S. winter precipitation may concentrate into the heart of winter, at the expense of Spring and Fall.

There is a clear need to deepen our understanding of how these key damaging characteristics of weather extremes may change. We need to stay ahead of all possible event scenarios. Hurricanes exploding into life right along the U.S. coast is just one example of possible future hurricane behavior that would seriously compromise our ability to issue warnings and enact emergency responses.

4. Innovating our Science and Risk Management

Given this era of unprecedented high-impact weather events, and the expectation of worse to come, it's more important than ever to have solid short-term forecasts and robust longer-term risk management strategies. This is essential to protect lives and property, ensure viable populations in our coastal regions, and to ensure military readiness and economic competitiveness.

The weather enterprise, including sponsorship of the National Center for Atmospheric Research by the National Science Foundation, has transformed our knowledge, research infrastructure, and community capacity for extreme events. Despite these leaps in capacity, we still suffer from poor understanding of some of the most high-impact weather events, and a disconnect between scientific advances and societal benefit.

Our changing extreme weather is fundamentally a question of risk assessment. We need to understand what impacts are possible, and how likely they are. This requires us to focus on the impacts to understand the science that needs to be done. Impacts are driven by a confluence of factors: our demographics, characteristics of the weather events, with climate change an all-pervasive and growing threat multiplier. Our response, then, must consider all these ingredients of risk and their interactions at the same time. This requires deep integration of science with risk management.

My experience as a Willis Research Fellow taught me that there are huge potential gains in our ability to protect life and property through deep integration of science and risk management. Allow me to give a current example.

While discussing risk management with my colleagues at Willis Towers Watson I learned that hazard risk is commonly based on the assumption that extremes are independent of each other. But I've seen in the data that extreme events know about each. Some are like buses – you wait forever then three arrive at once. These groups of extremes bring potential vulnerabilities for risk management. For example, water managers up and down the U.S. West Coast are all too familiar with parades of winter storms that raise flood risk and stress water management practice. Scientists are excited about the potential for this understanding of connections between extreme events to lead to better forecasts. In turn, risk managers are looking for ways to innovate practice to design away this vulnerability.

My recent work exploring the effectiveness of building codes provides another example of the value of integration. The devastation caused by Hurricane Andrew in 1992 was largely attributed to poor construction. In response the state of Florida retrofitted their building code to mitigate future hurricane losses. But how effective is this code? I conducted a study with economists to explore that question. We found up to a 72% reduction in losses for homes built to the new code, thereby demonstrating that the code is indeed very effective.

But it costs money to build to code so is it worth the expense? Our research found that for every dollar spent building to code, you get between 2 and 8 dollars back in mitigated losses. My colleagues found similar levels of cost benefits of building codes against tornado risk in Oklahoma.

If Hurricane Michael's impacts on the Florida Panhandle (Fig. 3) and into Georgia last year are indicative of the future then the benefits of effective building codes will continue to rise. Yet these benefits will only accrue if we understand the future conditions to which codes should be responsive to. Without codes designed for future conditions, deteriorating levels of protection may lead to people choosing to leave impacted areas. Intensifying drought, wild fires, and hurricanes may all begin to enter people's decisions of where to live.

Figure 3: Mexico Beach, FL after Hurricane Michael (2018). Older homes not built to code are completely destroyed. But newer homes built to code suffered relatively minor damage. (Dronebase/Reuters, Handout/Reuters).

Not only do building codes mitigate losses, but can also make insurance more affordable thereby closing the so-called protection gap. Better understanding of the range of future extreme weather events is critically needed to gauge the effectiveness of current codes, analyze the effects of policy decisions, and inform retrofitting our nation for the future.

These experiences lead me to ask: What other opportunities are we missing to bolster our science and practice? Finding these opportunities won't happen by accident. It requires leadership.

The federal government has a vital role to play in discovering and pursuing these opportunities to better protect lives and property. The new NOAA and NCAR weather and climate community modeling partnership serves as a model for accelerating our science and guiding it in the direction of society's most pressing needs. In addition, the establishment of the Earth Prediction Innovation Center promises to further accelerate the weather enterprise. Furthering these efforts, and funding other opportunities for success are urgently needed. Let me outline one immediate opportunity we can't afford to miss out on.

Scientists are at the cusp of a breakthrough in our ability to simulate weather over many decades at a level of granularity not previously possible. With continued federal support we'll have the capacity to simulate many hundreds of hurricanes for example, or many hundreds of flooding rain events over the Mid-West. All of them physically possible in today's climate. Of course, these simulations will not be without error, but they have the potential to be incredibly useful if developed in concert with risk managers.

Resources are required to build capacity for sustained, coordinated and integrated efforts across science and practice. This includes providing continued support in the form of observational platforms, computational infrastructure, and research grants. One specific need is the establishment of a national multidisciplinary dataset of extreme weather impacts. This vital national asset will catalyze scientific understanding and risk management solutions at the forefront of societal needs. In this era of changing extremes, integrated science and practice is not optional.

5. Conclusion

Extreme weather impacts continue to increase. A confluence of factors drives these impacts, including characteristics of what's in harm's way and the weather events themselves. Climate change acts as a pervasive and compounding threat multiplier. Indeed, the hand of climate change has already been detected in some extreme weather phenomena. We understand that extreme weather will continue to worsen. And it will combine with demographic and ecological shifts to bring new risks.

This era of changing risk demands solid and well-communicated short-term forecasts and robust longer-term risk management strategies. A deeper integration of science and practice is urgently needed to strengthen protection of lives and property, and ensure military readiness and economic competitiveness. Extreme weather is inevitable, extreme weather catastrophes don’t have to be.

Dr. James Done, Project Scientist III and Willis Research Fellow, Capacity Center for Climate & Weather Extremes, Mesoscale & Microscale Meteorology Lab, National Center for Atmospheric Research.

Dr. Done is a Senior Willis Fellow and deputy director of the Capacity Center for Climate and Weather Extremes at the National Center for Atmospheric Research. Dr. Done works with stakeholders from the energy, water and insurance sectors to understand future weather and climate extremes and their impacts. Examples of recent work include; assessing future hurricane impacts on the offshore energy industry, exploring the value of decadal climate prediction for water resource and flood risk management, and understanding the drivers of hurricane wind losses. Dr. Done received his PhD in meteorology from the University of Reading, UK.

James M. Done

Current Affiliation

Deputy Director, Capacity Center for Climate and Weather Extremes, Mesoscale and Microscale Meteorology Laboratory, National Center for Atmospheric Research, 3090 Center Green Drive, Boulder CO 80301.
Senior Willis Fellow.
Tel: 303-497-8209. Email: done@ucar.edu

Appointments

2019 – :	Project Scientist III and Senior Willis Fellow, NCAR, US
2017 – 2019:	Project Scientist III and Willis Research fellow, NCAR, US
2011 – 2017:	Project Scientist II and Willis Research fellow, NCAR, US
2008 – 2011:	Project Scientist I and Willis Research fellow, NCAR, US
2007 – 2008:	Visiting Scientist and Willis Research fellow, NCAR, US

Professional Preparation

University of Reading, UK, Meteorology, BSc Hons	1999
University of Reading, UK, Meteorology, PhD	2003
National Center for Atmospheric Research, US, Post-doctoral training	2004-2006

Active Research Awards

- 2014-2019, $1.185m, PI, NSF EaSM-3: Integration of Decision-Making with Predictive Capacity for Decadal Climate Impacts. National Science Foundation.
- 2019-2022, $719,232, PI, NSF PREEVENTS Track 2: Collaborative Research: COEXIST: Connected EXtremes In Space and Time
- 2019-2021, $260k, PI, Willis Research Network. Understanding Our Changing Weather and Climate Risk.

Selected Talks

- Understanding the Impacts of Correlated Extremes on Flood Risk and Water Resource Management. Workshop on Correlated Extremes, Columbia University, NY. May 30, 2019.
- Global Tropical Cyclone Wind Footprints. EGU 2019, Vienna, Austria. Apr 9, 2019.
- Understanding the Role of Decadal Climate Prediction in Risk Management. NCAR Seminar, Boulder, CO. Mar 18, 2019.
- Connecting Physics with Tropical Cyclone Risk Management. Reinsurance Association of America's Cat Risk Management 2019, Orlando FL. Feb 27, 2019.
- Assessing and communicating uncertainty in decadal climate predictions: Connecting predictive capacity to stakeholder needs. CLIVAR Variations Webinar. Sept 6, 2018.
- The Role of Effective and Well-Enforced Building Codes in Reducing Wind Driven Losses: The Case of Florida, Verisk Webinar. 2016.
- Advances in Simulating Tropical Cyclone Activity and Societal Impacts, Meteorological Research Institute, Tokyo, Japan. 2015.

Publications (past five years)

2019

1) Bruyère CL, Done JM, Jaye AB, Holland GJ, Buckley B, Henderson D, Leplastrier M, Chan P. Physically-Based Landfalling Tropical Cyclone Scenarios in Support of Risk Assessment. *Weather and Climate Extremes. [Accepted]*
2) Dominguez, C, Done JM and Bruyère CL. Easterly wave contributions to seasonal rainfall over the tropical Americas in observations and a regional climate model. *Climate Dynamics [Accepted]*
3) Teng HF, Lee CS, Hsu HH, Done JM, and Holland GJ (2019) Tropical Cloud Cluster Environments and Their Importance for Tropical Cyclone Formation. *Journal of Climate [Accepted]*.
4) Done JM, Bruyère CL, Ge M (2019) *Metocean Conditions in Future Hurricane Environments*. *In*: Collins J., Walsh K. (eds) Hurricane Risk. Hurricane Risk, vol 1. Springer, Cham, doi:10.1007/978-3-030-02402-4_11
5) Holland GJ, Done JM, Douglas R, Saville G, Ge M. (2019) *Global Tropical Cyclone Damage Potential*. In Hurricanes and Climate Change, J.M. Collins (ed.), Springer International Publishing.
6) Prein AF, Bukovsky MS, Mearns LO, Bruyère C, and Done JM (2019) Simulating North American Weather Types with Regional Climate Models. *Frontiers in Environmental Science,* 7, p.36.

2018

1) Done JM, Simmons KM, Czajkowski J (2018) Relationship between residential losses and hurricane winds: role of the Florida building code. *ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems, Part A: Civil Engineering*, 4(1), p.04018001
2) Gutmann ED, Rasmussen RM, Liu C, Ikeda K, Bruyere CL, Done JM, Garrè L, Friis-Hansen P, Veldore V. (2018) Changes in Hurricanes from a 13-Yr Convection-Permitting Pseudo–Global Warming Simulation. *Journal of Climate*. 31(9):3643-57.
3) Hewitt J, Hoeting JA, Done JM, Towler E. (2018) Remote effects spatial process models for modeling teleconnections. *Environmetrics*, 29(8):e2523.
4) Morss RE, Done JM, Lazrus H, Towler E, Tye MR (2018) Assessing and Communicating Uncertainty in Decadal Climate Predictions: Connecting Predictive Capacity to Stakeholder Needs. *CLIVAR Variations*, 16 (3), doi:10.5065/D62N513R
5) Towler E, PaiMazumder D, and Done JM (2018) Towards the Application of Decadal Climate Predictions. *Journal of Applied Meteorology and* Climatology 57,555-568, doi:10.1175/JAMC-D-17-0113.1

2017

1) Bruyère C, Raktham C, Done JM, Kreasuwun J (2017) Major Weather Regime Changes over Southeast Asia in a Near-Term Future Scenario. *Clim Res* 72:1-18. doi.org/10.3354/cr01442
2) Cobb A, Done JM (2017) *The Use of Global Climate Models for Tropical Cyclone Risk Assessment*. In Hurricanes and Climate Change, J.M. Collins, K. Walsh (eds.), Springer International Publishing.
3) Czajkowski, J., Simmons, K., and Done JM (2017) Demonstrating the Intensive Benefit to the Local Implementation of a Statewide Building Code. *Risk Management and Insurance Review*. doi:10.1111/rmir.12086

4) Done JM, Owens B (2017) *Tropical Cyclones, in Natural Catastrophe Risk Management and Modelling: A Practitioners Guide*, edited by Hillier J, Foote M. Wiley.
5) Gadian, A., A. Blyth, C. Bruyere, R. Burton, Done JM, J. Groves, G. Holland, S. Mobbs, J. Thielen-del Pozo, M. Tye and J. Warner. (2017) Future changes in summer wind and convective precipitation over the UK and Europe from a regional climate simulation. *International Journal of Climatology*. doi:10.1002/joc.5336
6) O'Neill B, Done JM and CoAuthors (2017) The Benefits of Reduced Anthropogenic Climate changE (BRACE): A synthesis. *Climatic Change*. doi.org/10.1007/s10584-017-2009-x
7) Simmons, K, J. Czajkowski and Done JM (2017) Economic Effectiveness of Implementing a Statewide Building Code: The Case of Florida. *Journal of Urban Economics*. doi:10.2139/ssrn.2963244

2016

1) PaiMazumder D, Done JM (2016) Potential predictability sources of the 2012 U.S. drought in observations and a regional model ensemble, *J. Geophys. Res. Atmos.*, 121, doi:10.1002/2016JD025322

2015

1) Done JM, PaiMazumder D, Towler E, Kishtawal D (2015) Estimating Tropical Cyclone Impacts Using an Index of Damage Potential. *Climatic Change*. 10.1007/s10584-015-1513-0
2) Done JM, Holland GJ, Bruyère CL, Leung LR, Suzuki-Parker A (2015) Modeling high-impact weather and climate: Lessons from a tropical cyclone perspective. *Climatic Change* 129(3) 381-395, doi:10.1007/s10584-013-0954-6
3) Hashimoto A, Done JM, Fowler LD, Bruyère CL (2015) Tropical Cyclone Activity in Nested Regional and Global Grid-Refined Simulations. *Climate Dynamics*. 10.1007/s00382-015-2852-2

Synergistic Activities

1) Deputy Director, NCAR's Capacity Center for Climate and Weather Extremes.
2) Named Senior Willis Fellow to study tropical cyclone impacts and risk management.
3) Authors over 15 insurance industry reports each year on global seasonal climate impact forecasts and real-time hurricane impact briefings.
4) Leads community climate change discussions through Climate Voices.
5) Leads research programs for students from groups underrepresented in science.