

Risk Prediction Initiative

2018 Annual Report



Celebrating 25 years
of
Climate and Catastrophe Science

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Bermuda Institute of Ocean Sciences (BIOS)
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Cover image: Category 5 Hurricane Andrew in 1992. Andrew was the costliest hurricane to ever hit Florida, causing the rapid growth of the reinsurance industry in Bermuda. Source: NOAA

RPI 2018

Letter from the Program Manager



I'm proud to have been one of the many people who have enabled RPI to achieve this 25-year milestone in the advancement of knowledge and insights into natural hazard and climate risk. As brokers of science, RPI has been the nexus of academia and industry, connecting business leaders with foremost experts in the field of natural hazard variability.

Over the last quarter century, RPI has not only facilitated academic output in the form of over 150 peer-reviewed publications in the scientific literature; we have also partnered with the re/insurance industry to develop answers to some critical questions about catastrophe risk, particularly hurricanes, climate change, winter storms, flood risk and tornadoes. We helped to pioneer the young field of paleotempestology by

supporting research into the analysis of regional geologic histories in order to provide insights about the current and future states of risk.

Outreach and spinoff collaborations have enabled wider societal benefits, especially with respect to students, young career scientists, risk practitioners and local initiatives focused on climate change and disaster risk reduction.

As we round out 25 years of knowledge transfer, please join me in celebrating some of our key accomplishments this past year.

Dr. Mark Guishard,
RPI Program Manager
BIOS Director of Corporate & Community

RPI 25 Years

Selected Highlights

2018

Partnership with XL Catlin on the Ocean Risk Summit and Grants
 Publication on Bermuda flood variability and presentations on local impacts of climate change

2016

European Windstorm Workshop, London
 First publication of results on risk from tornadoes in Europe

2014

Support of the 1st International Summit on Tornadoes and Climate Change - Crete
 Results published on the impact of El Niño/La Niña on global river flood risk

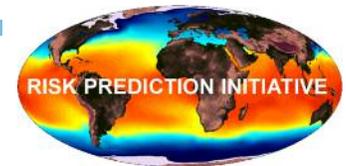


2017

Presentation of Bermuda hurricane wind risk catastrophe model results
 Publication of US coastal flood exposure trends in partnership with Climate Central

2015

Hurricane Volatility Workshop - London
 Bermuda Risk research, education and outreach program initiated - first reports on Bermuda hurricanes and critical infrastructure



RPI2.0
Connecting Science and (Re)Insurance

BermudaRisk

Risk
 Prediction
 Initiative

2013

Risk modelling workshop on European winter storm clustering - Zurich
 Publication of results on sensitivity of hurricane intensity to warming seas

RPI 25 Years

Selected Highlights

2012

Risk modelling workshop on hurricane landfall rates, in partnership with RMS - Bermuda
Crowd-sourced Seasonal Forecast Competition

2010

Research Update included presentation of 2003 Hurricane Fabian's wind regime in Bermuda and influence of topography
Publication of results revealing climate influence on hurricane tracks

2008

Climate Extremes and Society published.
Editors Henry Diaz & Rick Murnane

2006

First Cat. Modeling course: Tropical Cyclone and Earthquake Hazard, Vulnerability and Uncertainties

2011

RPI2.0 refocuses research on business-relevant applications and timescales
Research Update incorporates contributions from tsunami experts focused on Tohoku event
Climatology of Arabian Sea Cyclones published

2009

Publication of a 1,500 years synthesis of Atlantic Hurricanes
Atlantic subtropical storm climatology published
Historical tropical cyclone landfall probability maps produced

2007

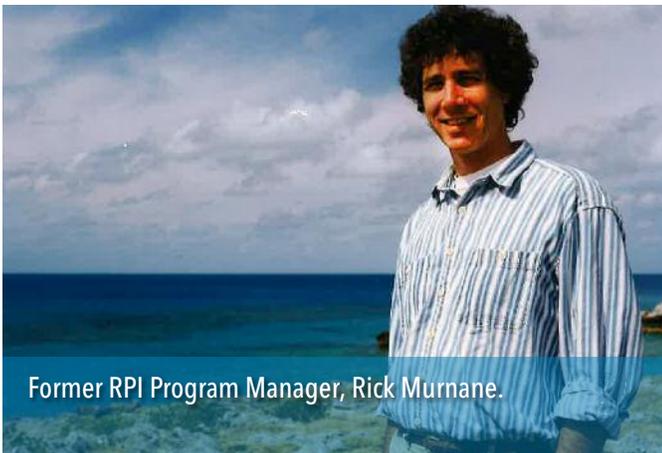
Co-sponsorship of the 1st International Summit on Hurricanes and Climate Change

2004

Hurricanes and Typhoons: Past, Present, and Future published.
Editors Rick Murnane & Kam-bui Liu

2003

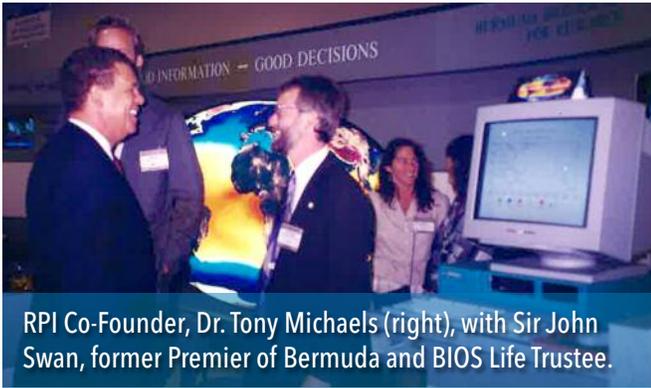
First translation of Jesuit records on Northwest Pacific typhoons
Publication of RPI primer on Weather Extremes and Atmospheric Oscillations



Former RPI Program Manager, Rick Murnane.

RPI 25 Years

Selected Highlights



RPI Co-Founder, Dr. Tony Michaels (right), with Sir John Swan, former Premier of Bermuda and BIOS Life Trustee.

2000

First RPI seasonal forecast for US hurricane landfall

1999

First publication of RPI Science Review

1997

First workshop devoted to RPI-funded research
Initiated development of RPI wind speed probability model

Historical US hurricane losses normalized for changes in inflation, population and wealth

1995

First workshops on the influence of the El Niño-Southern Oscillation on Tropical Cyclone Activity, Climate Prediction and Insurance Risk

1994

The Risk Prediction Initiative founded at the Bermuda Institute of Ocean Sciences

2002

First proxy results for prehistoric New York hurricane
Development of US hurricane risk model for insured loss
Workshop devoted to RPI-funded research

2001

Joint RPI-NOAA-WRMA workshop on climate data and forecast needs
First proxy records of prehistoric hurricane landfall in Mid-Atlantic region
Publication of RPI primer on tornadoes and hail

1998

Creation of "extended best-track" data for North Atlantic
First workshop on the extra-tropical transition of tropical cyclones

1996

Development of real-time Maximum Potential Intensity maps
Workshop on climate variability and tropical cyclone prediction



RPI Co-Founder and former Director of BIOS, Dr. Tony Knap (left).

Research Spotlight

North Atlantic Hurricanes



Satellite image of Hurricane Florence, Isaac and Helene. Hurricane Florence slowed to a crawl as it impacted the US southeast coast, releasing unprecedented amounts of rainfall for some areas, shattering precipitation records for North Carolina, and devastating the region with widely-felt flooding impacts. The only landfall of a Major Hurricane (Category 3+) in 2018 was Hurricane Michael's impact on Florida's Gulf of Mexico coastline. Indications from ratings agencies, catastrophe modelers and risk advisors have been that the insurance industry will be able to handle the losses incurred during the 2018 season, but that there is a continued challenge with a lack of protection against hurricane rainfall-induced flooding. Source: NOAA

2018 saw yet another year of damage-inducing hurricanes with major impacts in the insurance industry and questions regarding how landfall risk and impacts are changing over time. Some of the work RPI researchers published in 2018 examine hurricane activity by using sophisticated climate modelling techniques to answer the question of whether the 2005 hurricane season constituted the highest number of annual hurricanes in the Atlantic. This multi-national collaborative study published in *Science Advances* concluded that physical constraints on hurricane activity make it highly unlikely that we will see more hurricanes than the 2005 season had in store. However, the authors make it clear that storm counts are not equivalent to impacts; a small number of storms affecting large coastal settlements will cause more damage than many storms that stay out at sea (or make landfall in sparsely populated areas). *Lavender et al. 2018*. In a follow-up study initiated in 2018, the team is now working to understand the damage potential



RPI Program Manager, Mark Guishard, on a panel at the Association of Bermuda Insurers and Reinsurers' 25th anniversary discussions.

associated with the worst case hurricane activity in the Atlantic. They are examining the intensity metrics associated with hurricanes, simulated in numerical models. Results are anticipated in the next year.

The impacts of tropical cyclones (called hurricanes in the Atlantic) are of course not limited to North America, but the Atlantic is the best-monitored region, based on observing capacity, the availability of flight reconnaissance and remote sensing data. Efforts to understand the physical constraints on tropical cyclone activity, and its changes over time require homogeneous time series and gridded datasets of meteorological parameters in and surrounding each storm system. Following a 2017 RPI-supported workshop, several hurricane experts published a position in the Bulletin of the American Meteorological Society in 2018, proposing a way towards a) a universally-consistent historical dataset of tropical cyclones, globally, and b) an equivalent dataset that incorporates all of the best data available from surface and upper-air observations, aircraft measurements, radar and satellite based data retrievals. While the first dataset would be homogeneous, enabling more robust apples-to-apples comparisons between tropical cyclone basins; the second would contain the best available data on a given storm. *Emanuel et al. 2018.*

US hurricane landfall potential - a new study

Researchers at the University of Wisconsin-Madison are working on behalf of RPI to quantify and improve the understanding of decadal variability that directly affects hurricane hazard exposure and risk along the U.S. coast. They will undertake advanced statistical analysis and modeling of the historical record of Atlantic hurricanes, and simulations of future climate scenarios to reveal what past, present and future hurricane activity has in store for a key insurance market - the highly-exposed US coastline.

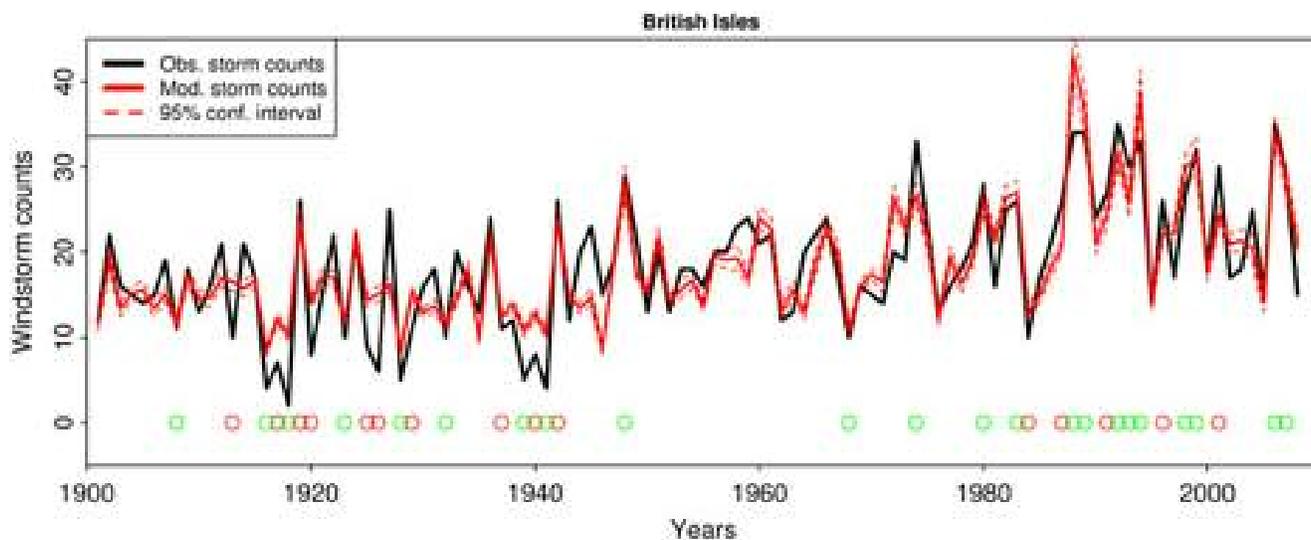
Research Spotlight

European Storms

Across the pond in Europe, RPI has been facilitating work on winter wind storm impact frequency, subject to the influences and variability of the jet stream, and climate scale indices which are in turn affected by ocean temperatures. In a study facilitated by the involvement of graduate students, collaborators in the UK and Germany investigated the frequency of 'clustered' winter wind storms in Europe. *Walz et al 2018*. outlines the development and performance of a statistical model to estimate seasonal clustering and also active/inactive seasons.



Confirmed tornado reports in 2018 in Europe. Map is preliminary, based on European Severe Weather Database (ESWD) output. Data and map source: ESWD.



Output from the statistical model of European winter windstorm counts affecting the British Isles (red), measured against observations (black). From *Walz et al. 2018*.

Also in Europe, RPI colleagues at the University of Manchester published *Antonescu et al.* their study of the worst case scenario of a European tornado - determined to have been an outbreak of storms in France, Belgium and the Netherlands in June 1967 - impacting other jurisdictions and populations in Europe. In other words, they assessed the impact over a more modern landscape, population and the built environment. The researchers concluded that there is increased exposure in modern times, highlighting the need for more proactive disaster management strategies to evolve over time.

Research Spotlight

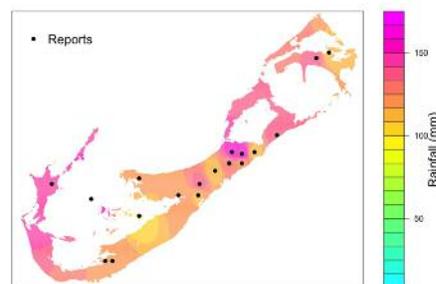
Bermuda Flood Risk

Closer to home, a former intern, RPI staff, colleagues at the Bermuda Weather Service and the Spanish Meteorological Service published a study on flood return periods in Bermuda. Michael Johnston, a former RPI intern currently undertaking doctoral studies in the UK, was lead author on a paper examining the threshold rainfall amounts that lead to reports of flooding in Bermuda.

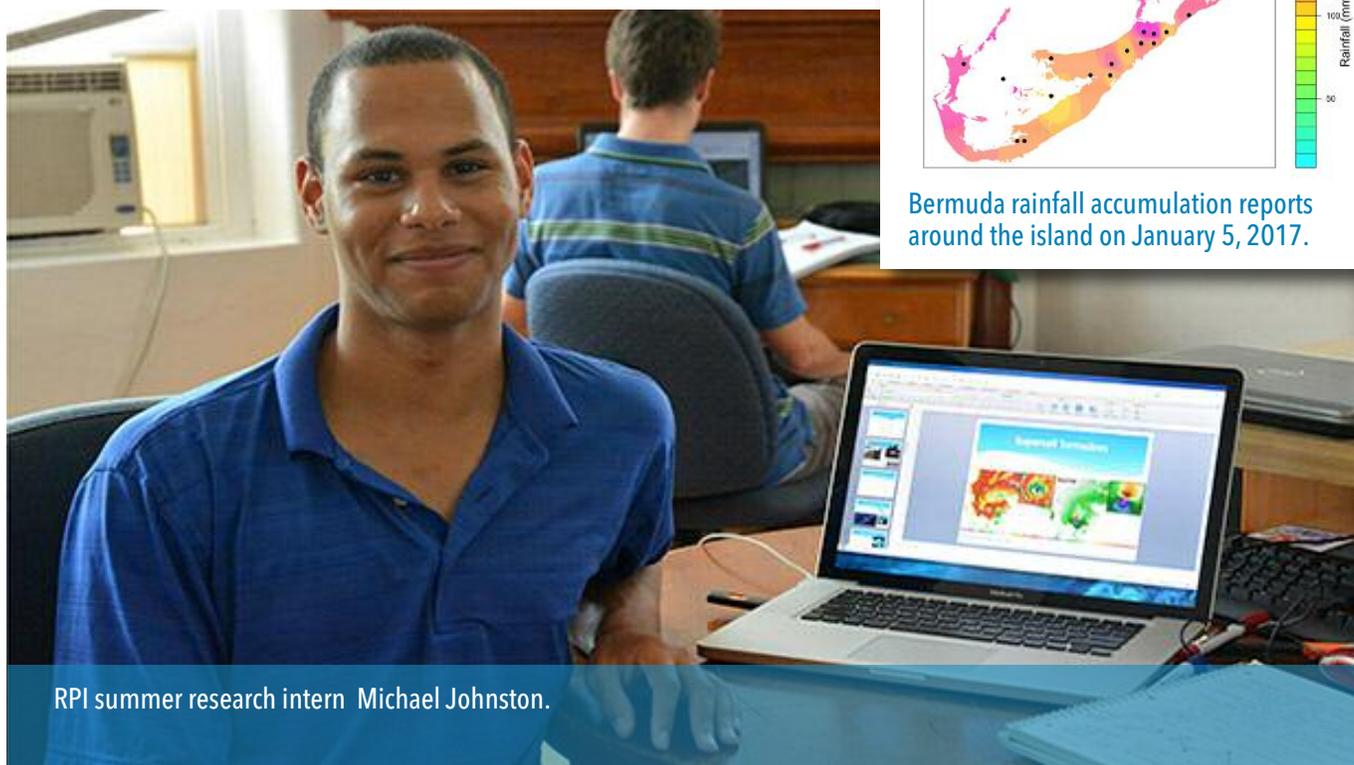
This work not only provides welcome insight into the frequency of rain-induced flooding events in Bermuda, it also provided a young Bermudian scientist with an opportunity to contribute to the scientific record early in his career.



Within a single day on January 5, 2017, the island received slightly more rain than the average for the entire month (5.3in), causing widespread flooding in low lying areas such as Bakery Lane, Woodlands Road and Canal Road. Source: *The Royal Gazette*



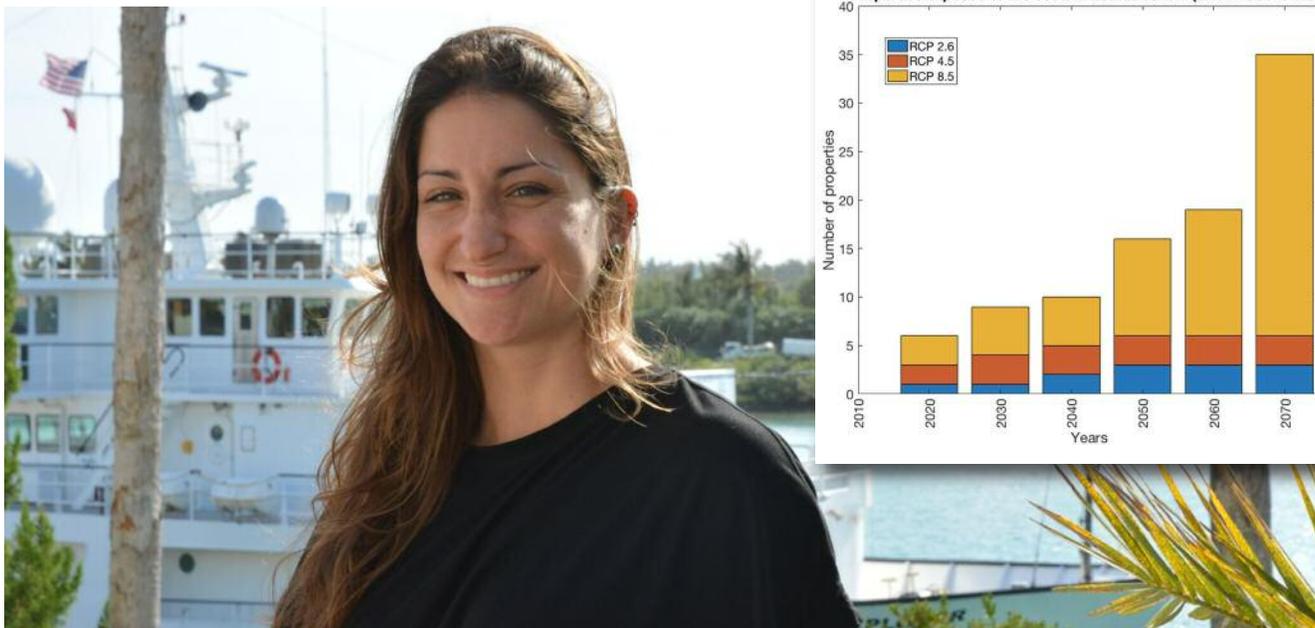
Bermuda rainfall accumulation reports around the island on January 5, 2017.



RPI summer research intern Michael Johnston.

Education in 2018

RPI Program Manager Dr. Mark Guishard mentored 2 interns in 2018, both on projects related to local impacts from natural hazards, and contributing to the growing information on Bermuda's disaster risk.



Growth of Bermuda property counts exposed to coastal flooding under sea level rise projections - BIOS Independent Research Intern Ximena Boza, 2018

Ximena Boza, of Panama, working with RPI as a BIOS Independent Research Intern, developed a study on sea level rise and the contributions of storm surges to coastal flooding. Boza found that some of the most intense flooding events in recent years have been from non-hurricane events like warm oceanographic anomalies and winter storms. She also highlighted that the highest storm surge experienced to date was during Hurricane Nicole in 2016, but that fortunately for Bermuda's impacts, the maximum water level occurred during low tide, sparing

Bermuda from the worst coastal damage. Boza further investigated the exposure of coastal properties using Government of Bermuda property valuation and elevation data. She found that while there are generally minimal levels of property exposure to the worst flooding, marginally-exposed properties will see rapid increases in the frequency of flooding events under published IPCC sea level rise projections for Bermuda. Collaborations on this project were also facilitated by former BIOS scientist, Dr. Kevin Mayall.



Dr. Mark Guishard and NSF-REU Intern Adriana Formby-Fernandez attending the ILS Bermuda Convergence Meeting , October 2018, Hamilton, Bermuda



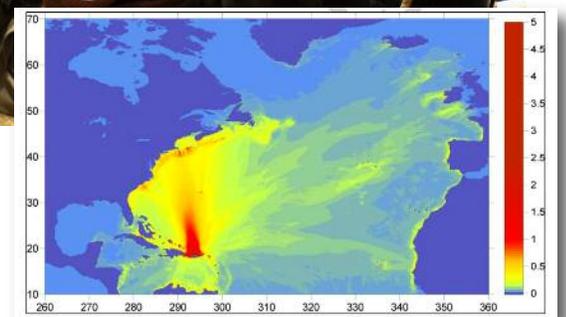
Adriana Formby-Fernandez, of Florida, joined RPI as an NSF Research Experience for Undergraduates (REU) intern, supervised by Guishard. She investigated the interplay between the slow-down of Hurricane Bertha's forward speed south of Bermuda in 2008, and the knock-on effects for intensity and steering. Formby-Fernandez discovered that the storm's deceleration led to more cold water upwelling in the ocean, causing a feedback mechanism to weaken the storm and steer it in an erratic manner, making it less predictable by weather forecast models. This internship enabled Formby-Fernandez to explore different data collection techniques at sea on the RV Atlantic Explorer, to spend time at the Bermuda Weather Service launching weather balloons and examine Hurricane Florence in real-time. These activities, coupled with theory and practical exercises in meteorology led to a newfound interest in weather, and a successful application to participate in a hurricane research field campaign in summer 2019.

BermudaRisk Outreach



Since 2015, RPI has conducted a locally-focused subset of project activities called Bermuda Risk. In 2018, RPI worked with and advised a number of local stakeholders on disaster risk and climate change through outreach events, educational blog entries on the Bermuda Risk website and invited meetings. We engaged with the following groups and meetings in 2018.

- Bermuda Business Development Agency
- Bermuda Fiscal Responsibility Panel
- Bermuda Tourism Authority
- Bermuda Tsunami Exercise
- Bermuda Weather Service
- Environmental Coalition of Organizations (ECO)
- Greenrock's Green Building Forum
- Institute of Risk Managers Bermuda
- Ministry of National Security



Output from a hypothetical tsunami simulation – content contributing to a two-part Bermuda Risk blog series entitled “Tsunami Risk in Bermuda”, by Science Program Coordinator, Dr. John Wardman. Map source: NOAA.



Dr. Bill Curry, President and CEO of BIOS speaking at the inaugural Ocean Risk Summit held in Bermuda. A first-of-its-kind event bringing together individuals from the economic, environmental, political, and risk sectors to examine the challenges and risks posed by ocean change and identify innovative approaches to building resilience.

RPI also had multiple interactions with students and young scientists on catastrophe risk, climate change, environmental science and career advice. In 2018, students from the following local and overseas schools and organizations were reached through our Bermuda Risk outreach engagements.

- Appalachian State University (BIOS-based lecture)
- Bermuda College
- BIOS Ocean Academy
- Cedarbridge Academy
- Purvis Primary Career Fair

Workshops and conferences in 2018

- Artemis ILS NYC 2018, New York - February 2
- Reinsurance Association of America Catastrophe Risk Management 2018 - February 13-15
- 33rd Conference on Hurricanes and Tropical Meteorology, Ponte Vedra, FL - April 16-20
- Ocean Risk Summit, Bermuda - May 8-10
- National Centre for Atmospheric Sciences/Royal Meteorological Society Atmospheric Science Conference: Weather, Climate and Air Quality, University of York, UK - 3-4 July
- Bermuda Energy Summit, Bermuda - November 15
- Lloyd's of London - Hurricane Clustering in the North Atlantic: A Discussion - November 29

Workshops and conferences in 2018

Dr. Brian Tang was supported to attend the North American Hail Workshop in Boulder, CO, 14 August 14-16. He reported, "The North American Hail Workshop brought together scientists, insurers, engineers, and other representatives from hail-affected entities to share and discuss the latest in basic and applied science on hail, and challenges going forward to mitigate hail damage and losses."

RPI Program Manager Dr. Mark Guishard was pleased to represent BIOS and Bermuda on industry panel discussions and invited talks, as outlined below.

- Bermuda Captive Conference, Bermuda - June 11-13: Climate and Environment Change: How to Be Proactive (Dr. Mark Guishard - Panel Moderator)
- ABIR @25: Disrupting Risk, Bermuda - July 10 - Risk Management Leadership: Natural Disasters, Cyber, Terrorism (Dr. Mark Guishard - Panelist)
- Reinsurance Association of America: Extreme Events Committee, New York - September 13 - (Dr. Mark Guishard - Invited Speaker)
- Convergence 2018, Bermuda - October 3-4: Natural Catastrophes (Dr. Mark Guishard - Invited Speaker)
- Bermuda Executive Forum, Miami - October 18: Climate and Ocean Risks - Implications and Opportunities (Dr. Mark Guishard - Panelist)
- Bermuda Executive Forum, London - November 27: The Ocean Economy - Its Importance and Protection (Dr. Mark Guishard - Panelist)

Ocean Risk Summit

This year, BIOS supported XL Catlin's Ocean Risk Initiative by contributing to the program for the Ocean Risk Summit, participating in the Ocean Risk Grants selection process, and assisting with the administration of the Grants through RPI.

On May 8-10, XL Catlin with partners including BIOS, convened an historic gathering of scientists, policy makers, industry leaders and non-profit experts to discuss the theme of Ocean Risk. BIOS President and CEO, Dr. Bill Curry gave an address entitled "Ocean Change: A Bermuda perspective", in which he outlined research undertaken locally at BIOS, and facilitated globally through RPI, revealing the trends of ocean impacts, indicating the fragility of our marine environment, and making a case for supporting the next generation of ocean and risk scientists through education.

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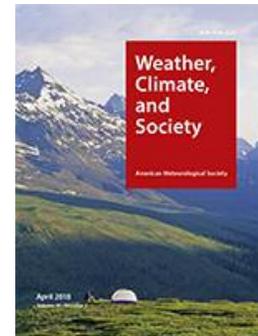
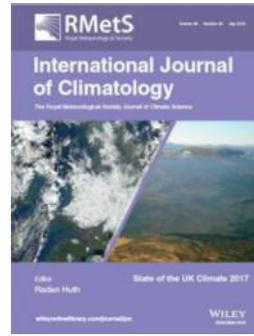
RPI Member Companies



with additional support from



Locus



Publications in 2018

RPI's research has yielded decades of scientific publications in peer-reviewed journals, ensuring that our science is communicated to the wider scientific community for societal benefit. Please visit our website to review our contributions at <http://risk.bios.edu/>.

Antonescu, B., J.G. Fairman, and D.M. Schultz, 2018: *What is the Worst That Could Happen? Reexamining the 24-25 June 1967 Tornado Outbreak over Western Europe*. *Wea. Climate Soc.*, 10, 323-340, <https://doi.org/10.1175/WCAS-D-17-0076.1>

Caron, L., L. Hermanson, A. Dobbin, J. Imbers, L. Lledó, and G.A. Vecchi, 2018: *How Skillful are the Multiannual Forecasts of Atlantic Hurricane Activity?*. *Bull. Amer. Meteor. Soc.*, 99, 403-413, <https://doi.org/10.1175/BAMS-D-17-0025.1>

Emanuel, K., P. Caroff, S. Delgado, C. Guard, M. Guishard, C. Hennon, J. Knaff, K.R. Knapp, J. Kossin, C. Schreck, C. Velden, and J. Vigh, 2017: *Desirability and Feasibility of a Global Reanalysis of Tropical Cyclones*. *Bull. Amer. Meteor. Soc.*, (February 2018), <https://doi.org/10.1175/BAMS-D-17-0226.1>

Johnston, M. C., Guishard, M. P., Peñate, I. and Currie, I. D. (2018), *Flooding threshold rainfall events in Bermuda*. *Weather*. doi:10.1002/wea.3096

Lavender, S.L., K.J.E. Walsh, L-P. Caron, M. King, S. Monkiewicz, M. Guishard, Q. Zhang, and B. Hunt, 2018: *Estimation of the maximum annual number of North Atlantic tropical cyclones using climate models*. *Science Advances*, 4, doi: 10.1126/sciadv.aat6509.

Walz MA, Befort DJ, Kirchner-Bossi NO, Ulbrich U, Leckebusch GC. *Modelling serial clustering and inter-annual variability of European winter windstorms based on large-scale drivers*. *Int. J. Climatol.* 2018;1-14.<https://doi.org/10.1002/joc.5481>

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