# Annual Report 2016

Risk
Prediction
Initiative

BIOS
Bermuda Institute of
Ocean Sciences

# RPI By the numbers in 2016

**20** Number of dataset, coding and mapping deliverables developed for our research projects in 2016;

**15** RPI workshops, seminars and in-house meetings conducted;

**11** Research projects conducted during 2016;

**10** Science and industry conference presentations;

**7** Manuscripts published in peer reviewed scientific journals;

**4** Local outreach events;

**3** Student interns mentored;

**2** Bermuda storms successfully weathered!

## RPI Member Companies 2016

with additional support from

*Many thanks to our sponsors and academic network, for supporting our efforts and partnering with us.*

# Contents



Cover image: A team of NOAA aviators captured the images of Princeville, North Carolina using specialized remote-sensing cameras aboard NOAA's King Air aircraft flying above the area at an altitude between 500 - 2,000 meters. Credit: NOAA

This is a visible image of Major Hurricane Matthew taken from NASA's Terra satellite on Oct. 7 at 12 p.m. EDT as it continued moving along Florida's East Coast. Matthew was a Category 3 hurricane at the time of this image. Credit: NASA's Goddard MODIS Rapid Response Team

# Selected Research and Collaborative Initiatives


Track and rainfall totals for Hurricane Matthew estimated by NASA. Image credit: NASA/JAXA, Hal Pierce

## Tropical Cyclone Research

2016 saw a large delivery of datasets, maps and programming code focused on tropical cyclones, particularly focused on US landfalling hurricanes.

Interacting cyclones, the hurricane drought, track variability and Bermuda storms were the subjects of recent and ongoing work in 2016. These were all topics which had relevance to the 2016 hurricane season.

October 2016 saw an end to the so-called 'drought' in Florida landfalls with Hurricane Matthew's raking the east coast of Florida after causing life-threatening impacts in the Caribbean. Hurricane Matthew later caused widespread rainfall flooding in the Carolinas. In our RPI-funded journal article (published in May 2016), *The Arbitrary Definition of the Current Atlantic Major Hurricane Landfall Drought*, we questioned the sensitivity of the of the term 'major hurricane' to different metrics and thresholds, and identified some systematic biases in the historical record of US hurricane landfalls.

Hurricane Nicole was the next hurricane in 2016, and it impacted Bermuda as a Category 3 storm (the second to do so in as many years), raising questions about the variability of tracks, and whether Bermuda is in a new phase of landfall risk.

Hurricane Nicole's erratic track in relation to Hurricane Matthew demonstrated nicely how interacting storms could affect the track of one another, as was also highlighted in 2014 and 2015 in Prof. Robert Hart's RPI-funded study. Following on from that work, Prof. Hart continued the theme of examining cyclone tracks in his 2016 project, *Evolution of Some Factors Influencing U.S. TC Landfall Probability: Formation Location, Steering, and TC-EC Interaction*.

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Questions have also arisen from our Members about the worst case scenario of hurricane numbers in the Atlantic basin – was 2005 representative of the highest activity we can expect, from a physical and thermodynamic basis? Prof. Kevin Walsh from the University of Melbourne and colleagues have set about answering this question by utilizing output from climate model ensemble solutions to set boundary conditions on 10,000 years of simulated hurricanes. Prof. Walsh's ongoing RPI project is titled, *How Unusual was the 2005 Hurricane Season in the Atlantic? A Millennial Model Analysis*, and is available to our members on RPI's website.

Datasets from the projects *An Improved Database of Tropical Cyclone Size Parameters* by Dr. Jonathan Vigh at NCAR and Dr. Chris Hennons' *Cyclone Center: Toward a Global Reanalysis of the Tropical Cyclone Record* have yielded new views of hurricane intensity, size and track based on flight reconnaissance and crowd-sourced approaches. These datasets may be used by our Members for comparison with the historical record of tropical cyclones, and hazard event catalogues.

## Severe Convective Storms

*The Intensity and Frequency of Severe Hailstorms* is being investigated under RPI funding by Dr. Brian Tang of SUNY Albany. This project seeks to increase the understanding of hailstorms using 3+ decades of US Doppler radar data in order to better assess the meteorological fingerprint of changing and emerging hail risk. In the first quarter of his projects, Dr. Tang has already identified the top 50 hail events between 1995-2016.

In a similar effort which has now been completed, Prof. David Schultz and Dr. Bogdan Antonescu of the University of Manchester have delivered catalogues, GIS shapefiles and gridded datasets showing the top damaging severe convective events, in the completion of their

Hail storm damage. Image courtesy of NOAA

project *What's the Worst That Can Happen? Re-examining the Most Destructive Convective Storms over Europe*.

Dr. David Prevatt has been funded to carry out a continuation of his work on evaluating a damage model from data collected during surveys following some of the most damaging tornado outbreaks in the last decade. His project, *Development and Validation of an Engineering-Based Approach to Predict Tornado-Induced Damage* focuses more on the vulnerabilities of buildings


Image courtesy of NOAA

to tornadoes than the wind speed hazard itself. This attention to damage ratios and vulnerability curves constitutes another part of the catastrophe modelling challenge.

Prof. James Elsner of Florida State continues to impress with his statistical analysis of the factors affecting *Seasonal Tornado Activity*. Prof. Elsner has been working to establish an un-biased baseline climatology that accurately reflects where tornadoes are more and less likely to occur in the U.S., and develop a space-time model for tornado frequency/intensity whose output can be conditioned on slowly varying climate factors (e.g., El Niño). Open source R code is delivered to the Member companies with a view to reproducibility

## Spotlight on Research: A Granular National Assessment of Coastal Flood Exposure Growth By: Dr. Ben Strauss and Dr. Scott Kulp - Climate Central

The evolution of coastal exposure is often neglected in many storm surge risk assessments. The output from this RPI-funded project estimates the effect of growing coastal populations on the overall risk from seawater inundation, and incorporates historical and projected sea level rise. This builds on existing work at Climate Central to deliver applications that drive an understanding of coastal risk.

The focus of much of our research is on the hazard component of risk, whereas this project also examines an element of the vulnerability of exposed populations. Here, Climate Central focusses on assessing the impact of exposure growth and sea level rise on the overall risk. This is a novel approach to evaluating two phenomena that have a potentially profound impact on storm surge risk.

The elevation data produced in the development of this project are comprised of state-, county- and city-resolution coastal elevations above a given tidal datum, accounting for areas that are protected by levees and natural topography. The 'exposure' associated with each elevation consists of US census-based housing stock and population data from 1940-2010, and modeled historic and future development between 1930 and 2050. The elevation data include historic sea level rise contributions and projected sea level rise increments. The end results are datasets that can reveal places which were/are/will be under threat from inundation, and estimates of properties and population at risk under each scenario.

# Geologic Hazards

Damaged houses sit after an earthquake in Mashiki, Kumamoto prefecture, southern Japan Saturday, April 16, 2016. Powerful earthquakes a day apart shook southwestern Japan, as thousands of army troops and other rescuers on Saturday rushed to save scores of trapped residents before weather turned bad. Credit: Kyodo News via AP

Over the past year, large earthquakes in Taiwan, Japan, Ecuador, Italy and New Zealand resulted in significant economic loss. The economic cost of the M7.0 quake which struck the Kumamoto prefecture in Japan on 16 April 2016 was at least USD 20 billion, of which USD 5 billion was insured (Swiss Re Cat Perils, 2016). The Kumamoto quakes were the costliest disaster event globally of the year. Although RPI did not directly fund research on earthquakes in 2016, we facilitated interactions between seismologists and the industry, revealing new insights about how earthquake hazards may need to be modelled.

In April 2016, RPI's Science Program Coordinator, Dr. John Wardman, participated in a field trip to the US Midwest to gain insight into the New Madrid Seismic Zone where extensive liquefaction and ground shaking were observed during the 1811-12 earthquake sequence. While such phenomena have been studied in detail for decades, their intricacies are still not well understood, and constitute major uncertainties in current earthquake hazard estimates.

A subsequent report by Dr. Wardman and presentations to RPI Member companies indicated the similarities between the geology of the region and that of the Canterbury Plains in New Zealand, highlighting some lessons to be learned about co-seismic hazards such as liquefaction. In October 2016, we invited Dr Susan Hough from the United States Geological Survey (USGS) to present to our Member companies on ground shaking effects such as liquefaction and topographic amplification of seismic waves.

This year also saw the United States' largest-to-date induced earthquake (M5.8) in Pawnee, Oklahoma. Quantifying the emerging seismic risk from human activities in oil and gas production continues to be a challenge for modern risk assessment tools, and is an area that necessitates further research. Specifically, more information on empirically-based ground motion attenuation relationships, the location and geometry of seismic sources, the magnitude of potential induced earthquakes and their recurrence is needed.

During her October visit to our Members' Research Update Workshop, Dr. Hough also informally discussed some new findings indicating that California earthquake records are not necessarily immune to influences from induced seismicity. This may have profound implications for the way that catastrophe models incorporate these particular earthquakes into their event catalogues.

Under external funding, Dr. Wardman also travelled to Chile in November 2016 to present his postdoctoral work on vulnerabilities to volcanic ashfall hazards at a volcano risk conference. Initial reports from that meeting suggest that there is a lack of insurance in the area of volcanic risk, despite there being significant exposures to a large event. RPI will continue to monitor this unmodelled peril for future scientific developments with industry implications.

*"I love working with RPI because it's great to see our research get applied by the insurance industry. Our RPI funding supplements—and enhances—research funding that we get from other organizations, enabling us to do much more than either funding alone would have allowed. So, 1+1 = 3."*

-Professor David M Schultz, Centre for Atmospheric Science, School of Earth and Environmental Sciences, The University of Manchester

A satellite image shows Hurricane Nicole, a powerful Category Four storm, as it approaches Bermuda. Image by NOAA.

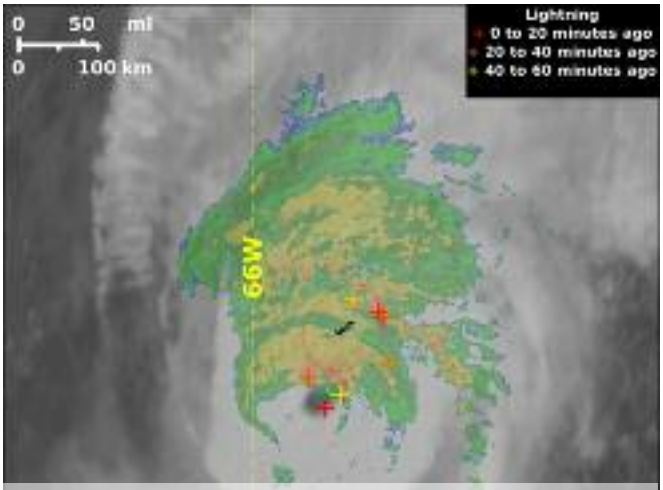
# BermudaRisk

In 2016, RPI expanded its locally-focused project called Bermuda Risk. Bermuda Risk investigates, through academic research, the natural hazard risk to Bermuda's society. This effort leverages RPI's decades of experience in managing scientific research with relevance to risk management, and by collaborating with a network of local and international contacts in the fields of environmental science, catastrophe modeling, policy development, re/insurance, and disaster risk reduction.

While the main attention of RPI remains on global catastrophic risk, this project brings a new element of focus to the local implications of climate change, natural hazard variability, and changes in vulnerability.

A team from the University of Southern Mississippi preparing to extract a sediment core for paleotempestological analyses. Image source: Davin Wallace

Bermuda Risk has helped to lead the conversation locally about tsunami risk by participating in educational meetings with the Emergency Measures Organization following this year's annual regional tsunami exercise. Ongoing engagement on this topic with partner organizations will lead to better understanding about this rare but dangerous phenomenon.




Satellite, radar and lightning imagery associated with Hurricane Nicole approaching Bermuda October 13, 2016. Image courtesy of Bermuda Weather Service

A Bermuda Risk project was completed this year by Dr. Davin Wallace of the University of Southern Mississippi, to examine 1,000-year scale reconstructions of hurricane activity, by looking at periodic sediment deposits from storm surge in the island's Spittal Pond and Mangrove Lake. These layers of coarse-grained sand and marine deposits in otherwise quiescent, algae-rich environments, are "signatures" of hurricane overwash, and can be used to construct a record of intense hurricane events.

In addition to developing research and providing scientific advice, Bermuda Risk contributed to outreach and education activities such as the 2016 Hurricane Preparedness Week.

We are currently preparing a post-mortem of Hurricane Nicole, which impacted Bermuda on October 13, 2016.

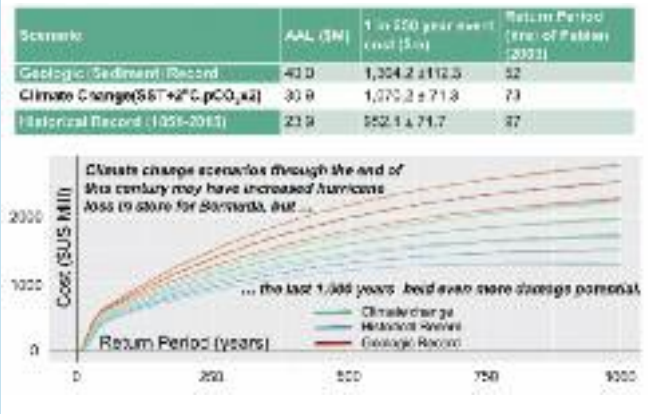
Leveraging BIOS's physical oceanography and atmospheric science expertise, locally-based monitoring programs, and a wide network of expert contacts, Bermuda Risk is at the forefront of progress towards answers to important questions about the island's vulnerability.

# 2016 Interns at RPI

In 2016, RPI personnel mentored and supervised 3 interns from universities in the US, Canada and the UK, through existing collaborative education programs at BIOS.

The undergraduate and graduate students from the University of Toronto, Cambridge University, and Penn State University conducted their own research projects into hurricane risk, flooding from extreme rainfall and coastal inundation. They worked with open source coding languages to conduct analyses such as determining return periods of flooding and storm surge events. Another outcome of the summer internship research was the construction of an open source hurricane catastrophe model for Bermuda. This simple stochastic model enabled students (and the supervisors!) to learn about the uncertainties inherent in modelling, and allowed RPI to explore methodologies for incorporating different types of hurricane records. Using data from one of the RPI funded projects (by Davin Wallace, see previous pages), the intern was able to simulate wind risk return periods under pre-historic conditions, to compare against present day and climate change scenarios.

As part of their internships, the students were exposed to the fields of meteorology, oceanography, geologic hazards, reinsurance, and risk modelling. The continued interaction with students and interns will allow RPI to help foster a new generation of risk scientists and catastrophe analysts.




Results from a simple catastrophe model for Bermuda indicate that the past 1,000 years of hurricane risk ('Geologic Record') may have been riskier than the shorter Historical Record or future Climate Change scenarios. References to the Average Annual Loss (AAL, in $US millions), the 1/25-year event damage cost and the return period of the damage cost 2003's Hurricane Fabian are incorporated in the table above.

*"How much of a difference my time at RPI has already made! I've used R extensively in my Master's project to not only produce all my graphs but also to code a model which formed a large section in my final report. It was also great to learn about meteorology."*

-Thomas Perkins, Master's candidate, University of Cambridge, BIOS Cawthorn-Cambridge Intern with RPI (Summer 2016)

Over a seven-day period in August 2016, rain totals in southern Louisiana were at least 600 percent of normal, according to the Lower Mississippi River Forecast Center of the U.S National Weather Service. This photograph was acquired on August 14, 2016, with the Trimble Digital Sensor System (DSS), which was flown on an aerial photography mission conducted by the NOAA Remote Sensing Division. It shows flooded areas in Port Vincent, along a segment of the Amite River southeast of Baton Rouge, LA. The photo was captured from an altitude of 1,500 meters (5,000 feet)–high enough to broadly survey the damage, but not so high that clouds block the view.

# Program Management and Expertise


Mark Guishard was elected in June as a Fellow of the Royal Meteorological Society, an organization of professionals and scientists dedicated to the understanding of weather and climate. He also received the designation Registered Meteorologist from the society's chief executive Prof. Liz Bentley during their annual conference, held at the University of Manchester in the United Kingdom.

The RPI team members have backgrounds in meteorology, geologic risk, catastrophe modelling, marine science, and experience in research, education, policy, communications and management. RPI is ideally suited to source, design and manage scientific research for addressing industry questions on catastrophe risk.

**Dr. Mark Guishard, FRMetS, RMet is the Director of Corporate and Community Relations at BIOS**, responsible for the strategic development of the Risk Prediction Initiative. He has general oversight of the overall program, and specific responsibilities for liaising with existing and prospective Member companies. Additionally, as RPI's meteorologist, he advises RPI on weather and climate science. Mark also manages relationships with Bermuda-based individuals and organizations interested in supporting BIOS's activities.

**Dr. John Wardman, FGS is RPI's Science Program Coordinator and point of contact for geologic hazards**. John joined RPI with a multi-disciplinary background in research into volcanology, natural hazards and electrical engineering. He also has first-hand experience of the 2010-12 Canterbury earthquake sequence in New Zealand from academic and personal perspectives. John administers RPI's scientific research projects, liaising directly with partner academic institutions to develop relevant and timely science deliverables.

**Charles King, MAq is RPI's Research Specialist, focusing on communications and data management.** Building on a career in marine science and business, Charles brings an interest in the practical applications of scientific research as well as a strong technical aptitude for Information and Communications Technology (ICT). Charles coordinates the communication of scientific reports and data, and administers RPI's web portal.

## Contact Information

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# Membership Levels and Benefits

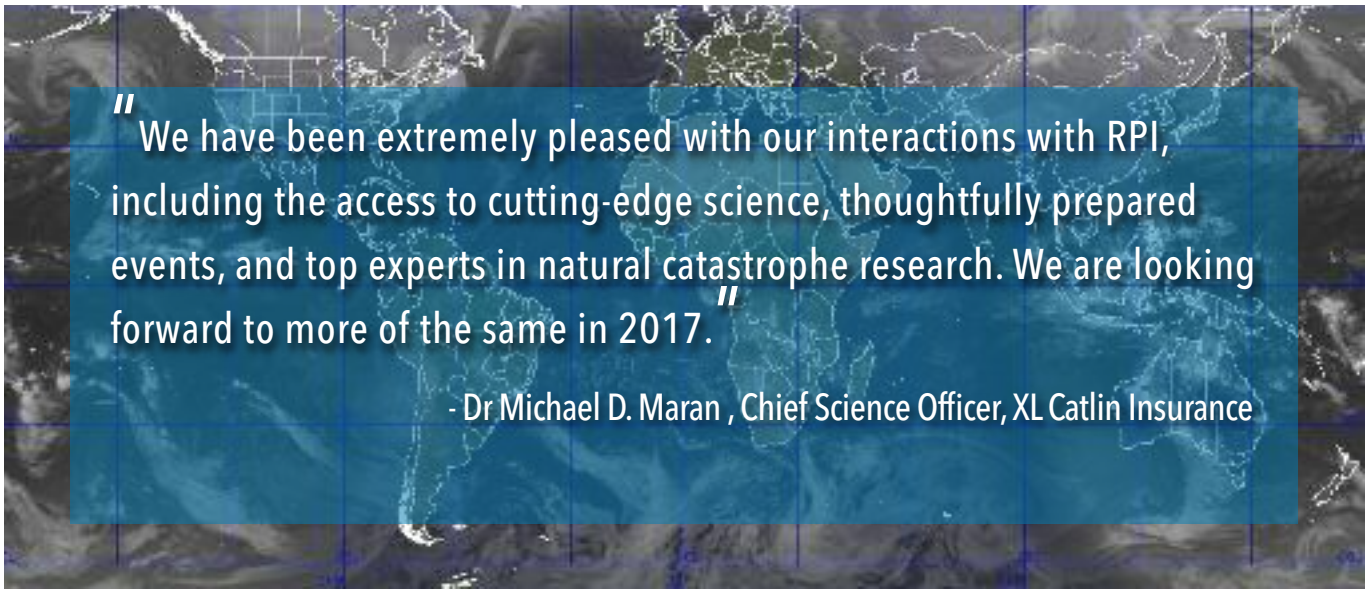
Member companies of the Risk Prediction Initiative participate in the selection, direction & guidance of research, and gain exclusive access to annual Research Updates, all RPI workshops & seminars, plus in-house events. All past and ongoing research deliverables are available through Member engagement.

- **RPI Bronze Membership - $65K/year**
  The basic subscription includes Member-only access to current and past research projects and reports, one in-house presentation, data/modelling deliverables, and your corporate logo displayed prominently on the RPI website. These services are also included in Silver and Gold membership.

- **RPI Silver Membership - $85K/year**
  The Silver Membership facilitates more access to the researchers, with a view to developing more targeted and specific research deliverables and reports. There are two additional in-house events, one of which includes attendance by an independent scientist.

- **RPI Gold Membership – $125K/year**
  This membership level includes support for a student, or an internship in a relevant discipline. In addition, quarterly visits to your company will be made, two of which include attendance by an independent scientist.

There are also opportunities to sponsor RPI's activities beyond the constraints of Membership. Investor education opportunities and access to selected data output from published work are made available to sponsors. Recognition of sponsors via their logos displayed on our website highlight the contribution to the scientific understanding of natural hazards. If you are interested in Membership or Sponsorship of RPI, please get in touch directly at rpimail@bios.edu.



# Publications in 2016


Antonescu, B., D. M. Schultz, F. Lomas, and T. Kühne, 2016: Tornadoes in Europe: Synthesis of the observational datasets. Mon. Wea. Rev., 144, 2445–2480, doi: 10.1175/MWR-D-15-0298.1.

Apsley, M. L., K. J. Mulder, and D. M. Schultz, 2015: Reexamining the United Kingdom's greatest tornado outbreak: Forecasting the limited extent of tornadoes along a cold front. Wea. Forecasting, 31, 853–875, doi: 10.1175/WAF-D-15-0131.1.

Camp, J. and Caron, L.-P., (2016) Analysis of Atlantic hurricane landfall forecasts in coupled GCMs on seasonal and multi-annual timescales. Chapter 9 in Hurricanes and Climate Change. 3rd edition. Springer.

Hart, R., D. Chavas, and M. Guishard, 2016: The Arbitrary Definition of the Current Atlantic Major Hurricane Landfall Drought. Bull. Amer. Meteor. Soc., 97, 713–722, doi: 10.1175/BAMS-D-15-00185.1.

Knapp, K., J. Matthews, J. Kossin, and C. Hennon, 2016: Identification of Tropical Cyclone Storm Types Using Crowdsourcing. Mon. Wea. Rev., 144, 3783–3798, doi: 10.1175/MWR-D-16-0022.1.

Strazzo, S. E., J. B. Elsner, T. E. LaRow, H. Murakami, M. Wehner, and M. Zhao (2016), The influence of model resolution on the simulated sensitivity of North Atlantic tropical cyclone maximum intensity to sea surface temperature, J. Adv. Model. Earth Syst., 8, 1037–1054, doi:10.1002/2016MS000635.

Vigh, J. L., N. M. Dorst, C. L. Williams, E. W. Uhlhorn, B. W. Klotz, J. Martinez, H. E. Willoughby, F. D. Marks, Jr., D. R. Chavas, 2016: FLIGHT+: The Extended Flight Level Dataset for Tropical Cyclones (Version 1.1). Tropical Cyclone Data Project, National Center for Atmospheric Research, Research Applications Laboratory, Boulder, Colorado.


## RPI Reports


Guishard, M.P., Bermuda Risk Report - A Tale of Two Storms: The Impacts of Hurricane Fay and Hurricane Gonzalo on Bermuda, January 2016

Wardman, J.B., American Geophysical Union 2015 Fall Meeting, February 2016.

Wardman, J.B., Earthquake Risk in the Central US: the New Madrid Seismic Zone, May 2016.

Guishard, M.P., American Meteorological Society's 32nd Conference on Hurricanes and Tropical Meteorology, May 2016.


Image by NOAA/NASA

# Risk Prediction Initiative Events

**Tropical Cyclones Seminar** 19 April 2016 San Juan, Puerto Rico (at the AMS Hurricanes Conference)
**European Storms Seminar and Oasis LMF Meetings** 29-30 June, 2016, XL Catlin London Offices
**Bermuda Risk Seminar** 3 October 2016, Bermuda Institute of Ocean Sciences
**Research Update Workshop** 4 October 2016, Bermuda Institute of Ocean Sciences

*In addition to the events listed above, RPI conducted 9 in-house meetings at Member companies' offices, and met informally with countless industry representatives.*

## Conferences, Meetings and Industry Events Attended

**Reinsurance Association of America's Catastrophe Risk Management 2016**: PRAGMATIC DECISIONS - IMPRECISE DATA POINTS, Portofino Bay Hotel, Orlando, FL, February 16-18, 2016
**Securities Industry and Financial Markets Association (SIFMA) Insurance and Risk Linked Securities Conference**: 23-24 February, 2016 New York, New York, USA
**American Meteorological Society's 32nd Conference on Hurricanes and Tropical Meteorology**: 17 – 22 April 2016 San Juan, Puerto Rico*
**Royal Meteorological Society Student and Early Careers Conference, and RMetS/NCAS Conference 2016**: 4-8 July 2016, University of Manchester.*
**Sector Engagement for the Copernicus Climate Change Service:** Translating European User Requirements (SECTEUR) Workshop – 5 October 2016, XL Catlin Bermuda Offices*
**American Meteorological Society's 28th Conference on Severe Local Storms:** 7 – 11 November 2016 Portland, Oregon, USA*
**ILS Bermuda's Convergence 2016** 9-10 November, 2016, Hamilton, Bermuda*
**Cities on Volcanoes 9 Conference** November 20-25, 2016, Puerto Varas, Chile*

*Events at which RPI personnel or scientists presented research or participated in panel discussions.

# Risk Prediction Initiative

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