GPC Newsletter
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APS TOPICAL GROUP ON THE PHYSICS OF CLIMATE

IN THIS ISSUE

Message from the Editor

This is the eighth GPC Newsletter, published twice per year. You, the GPC membership, can be of enormous value. We invite comments, event notices, letters, and especially specific suggestions for content. Any of the above, addressed to GPCnews@aps.org, will be gratefully acknowledged in a timely fashion.

Message from the GPC Chair

Brad Marston, Brown University

Welcome to the autumn Newsletter of the APS Topical Group on the Physics of Climate. I spent much of the summer attending meetings and workshops on climate physics, and would like to share some impressions, and also point to some resources generated by these meetings, before closing with a brief update on GPC activities.

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2018 APS March Meeting

The upcoming 2018 APS March meeting will take place March 5-9 in Los Angeles, CA.

(1) GPC will be cosponsoring a **Focus Session**, together with DFD and GSNP, on "Multi-Scale Flows and Pathways in the Climate System." It will be co-convened by Hussein Aluie of Rochester and Laure Zanna of Oxford. Invited speakers are Tapio Schneider of Caltech and Annalisa Bracco of Georgia Tech. Flows in the climate system involve strong multi-scale interactions between processes and structures ranging from global to microscales. These physical processes are complex and very inhomogeneous, often characterized by mean currents, eddies, waves, turbulence, instabilities, and subject to forcing and dissipation. The complexity of these flows and processes presents a major difficulty in understanding, modeling, and predicting climate dynamics. Identifying and understanding the pathways that exist across different scales is essential to balancing budgets such as those of heat, momentum, and energy, and also to formulating physics-based parameterizations in numerical models. In this session, we solicit talks that address any aspect(s) of the multi-scale physics of flows in the climate system. deadline for abstract submission (sorting category 23.1.1) is November 3.

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Feature Article

Physics-Based Approaches to Tropical Cyclone Risk

Kerry Emanuel, Lorenz Center, Massachusetts Institute of Technology
Adam Sobel, Department of Applied Physics and Applied Mathematics and Lamont-Doherty Earth Observatory, Columbia University

Basic physics and numerical models consistently show that frequency of the strongest tropical cyclones should increase as the climate warms, and that these storms should produce more rain. Yet current methods of assessing tropical cyclone risks are based almost exclusively on statistics compiled from short and flawed historical records. Here we show how a physics-based approach can produce more robust estimates of current risk and help us assess how this risk will change as the climate warms.

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Message from the GPC Chair – *continued from p. 1*

The biennial meeting of the American Meteorological Society on Atmospheric and Oceanic Fluid Dynamics was held in Portland, Oregon in June. I had greatly enjoyed the meeting 4 years ago when it met in Newport, Rhode Island. AOFD in the past had focused almost exclusively on geophysical fluid dynamics, but this time I felt that too many of the talks dealt with the Climate Model Intercomparison Project (CMIP5) and there was too little time set aside for informal discussion. Nevertheless there were some fine talks and much to learn. Most of the talks were recorded and can be viewed here.

Non-equilibrium statistical mechanics is a rather young branch of theoretical physics that aims to identify overarching principles governing the behavior of strongly driven systems, an endeavor that has been remarkably successful in recent years. The statistical analysis of long time series, such as records of temperature or flooding, has a longer history but new mathematical ideas are now transforming the field. So far there has been only limited interactions between researchers in climate science, non-equilibrium statistical mechanics, and time series analysis, despite important implications of the work in each of the three fields for the other. During a 3 week long workshop on "Climate Fluctuations and Non-Equilibrium Statistical Mechanics: An Interdisciplinary Dialogue" held at the Max Planck Institute for the Physics of Complex Systems in Dresden Germany, senior and junior scientists in all three fields engaged in dialogues that benefitted from cross-fertilization. I spoke on how we are all actually living inside a giant topological insulator.

A four week summer school at Les Houches in the French Alps on "Fundamental Aspects of Turbulent Flows in Climate Dynamics" was organized by Freddy Bouchet and Antoine Venaille (both of ENS Lyon) and Tapio Schneider (Caltech). The school consisted of an intense series of lectures by distinguished climate scientists, as well as seminars on specialized topics. A highpoint during the 4 days that I attended were lectures by Ted Shepherd on geophysical and Hamiltonian fluid dynamics. Videos of most of the lectures can be found here. (Tapio Schneider will be speaking in our Focus session at the upcoming March meeting.) The school epitomized climate physics at its best.

At the opposite extreme in style from Les Houches, the last 3 weeks of the summer program at the Aspen Center for Physics included a workshop on "Vorticity in the Universe: From Superfluids, to Weather and Climate, to the Universe." (Full disclosure: Peter Weichman and I helped to organize this workshop, and I co-organized the one at Dresden MPIPKS.) In very informal sessions that met on the outdoor patio, participants used only a blackboard and occasional handouts to discuss vorticity at scales ranging all the way from the quark-gluon plasma, to superfluids and superconductors, to potential vorticity in atmospheres and oceans, to dark matter and the large-scale structure of the universe. It was the widest-ranging physics meeting that I've experienced.

Back to the newsletter and the GPC: In this issue we are very pleased to include an article on "Physics-based Approaches to Tropical Cyclone Risk" by Kerry Emanuel and Adam Sobel, two of the foremost experts on hurricanes. (Prof. Sobel was one of the Invited speakers at the 2017 APS March Meeting in New Orleans.) The authors argue that physics-based thinking will yield better estimates of how hurricanes will change as the climate warms. This article offers important food for thought in the aftermath of the destructive 2017 hurricane season.

I'd like to give special thanks to Peter Weichman for all the work that he has done as chair of the Communications Committee, and as editor of the GPC newsletter since its start in 2012. Several other GPC committees have been busy during the past few months organizing sessions at the 2018 March Meeting that will be held in Los Angeles, finding excellent candidates to run in the annual election, and working out a new travel award program from graduate students and young climate physics researchers. Please look inside to find out the latest!

2018 APS March Meeting – *continued from p. 1*

(2) GPC will also be sponsoring an **Invited Session** on "Energy Flows in The Climate System". The session will address atmospheric radiative transfer, radiation and planetary energy balance/budgets at regional and global scales, focusing on anything from basic processes to applications (e.g., climate change mitigation). Invited speakers are John Dykema of Harvard University, Ron Miller of the NASA Goddard Institute for Space Studies, Martin Mlynczak of the NASA Langley Research Center, Sarah Purkey of UCSD/Scripps Institution of Oceanography, and Katharine Ricke of UCSD/Scripps Institution of Oceanography.

(3) Finally, the **Climate Cafe** has been a successful GPC activity at our Annual Meetings. It takes place in the evening. Attendees mingle and talk shop at a restaurant/bar close to the conference hall. We invite all GPC members and guests to the Cafe, to meet our invited speakers, get more details about the talks, discuss climate issues, network. The Climate Cafe place and time will be announced at our invited and submitted talks.

Further program details will be published in the Spring 2018 GPC Newsletter.

Physics-Based Approaches to Tropical Cyclone Risk – *continued from p. 1*

Tropical cyclones (known as hurricanes in the Atlantic and eastern North Pacific regions) are enormously destructive, as the recent spate of Atlantic hurricanes reminds us. Globally, these storms have taken an average of 10,000 lives per year and cost $700 billion in 2015 dollars annually since 1971 (EM-DAT, 2016). They are the largest source of loss for the private insurance industry. Yet the quantitative assessment of risks of such events, which include wind, storm surges, and flooding caused by extreme rainfall, today relies almost entirely on statistics of past events (including statistical models that generate synthetic events consistent with those historical statistics, but that do not account for climate change; e.g., Mahdyiar and Porter 2005). But the historical record of hurricanes is strongly compromised by the paucity and poor quality of observations, particularly before the satellite era. Even in the United States, more than half the hurricane-related damage, normalized for inflation and changing infrastructure, has been caused by just 10 events between 1900 and 2005 (Pielke et al., 2008). Moreover, the utility of historical statistics rests on the stationarity of the system, and there is abundant evidence that the climate system is now changing fairly rapidly.

Thus there are strong reasons to use physics to advance beyond a purely actuarial approach to hurricane risk assessment. To do so, we begin by reviewing some very basic hurricane physics.

Hurricanes are giant heat engines that are powered by the enormous transfer of heat from the ocean to the atmosphere when seawater evaporates (Kleinschmidt, 1951; Emanuel, 1986). The thermal cycle of the storms is quite close to that of an ideal Carnot engine. Air spirals in near the sea surface, expanding nearly isothermally as the pressure falls toward the storm center. In addition to the isothermal expansion, enthalpy fluxes from the ocean, mostly from evaporation, increase the entropy of the air. Then the air turns abruptly upward at the eyewall, undergoing a nearly moist adiabatic expansion upward and outward near the tropical tropopause. The entropy gained from the sea is then slowly lost by infrared radiation to space, nearly isothermally in the lower stratosphere and then following the environmental vertical temperature profile, which is also nearly moist adiabatic, back down to the surface.

The rate Q at which enthalpy is transferred by turbulence from the ocean to the hurricane in the region of high surface winds is given by

$$Q = C_k \rho |\mathbf{V}| (k_0^* - k), \qquad (1)$$

where C_k is a non-dimensional enthalpy transfer coefficient, ρ is the air density, $|\mathbf{V}|$ is the near-surface wind speed, k_0^* is the specific enthalpy of air in local thermodynamic equilibrium with the sea surface, and k is the actual enthalpy of near-surface air. (The enthalpy includes contributions from both sensible and latent heat.) From Carnot's theorem, the rate at which mechanical energy is generated is

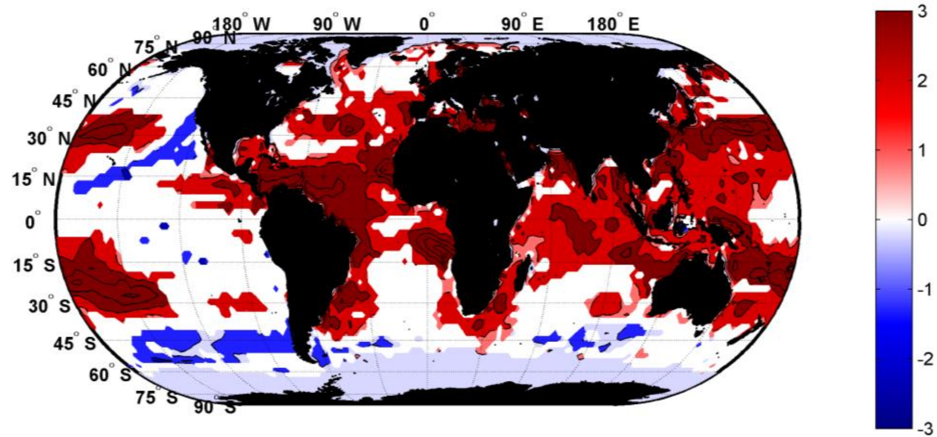

Figure 1: Trends in hurricane potential intensity (in m/s per decade) calculated from National Centers for Environmental Prediction (NCEP) climate analyses over the period 1980-2010. The trends are only shown where they are statistically significant.

$$E = \left(\frac{T_s - T_o}{T_s}\right) Q, \qquad (2)$$

where T_s is the surface temperature, and T_o is the temperature of the hurricane's outflow near the tropopause. In the tropics, typical values of T_s and T_o are 300 K and 200 K, respectively, giving a Carnot efficiency of about 1/3.

The rate at which mechanical energy is dissipated in the high wind region of the storm is given by

$$D = C_D \rho |\mathbf{V}|^3, \qquad (3)$$

where C_D is a non-dimensional coefficient of momentum transfer, otherwise known as the drag coefficient.

In equilibrium, the dissipation of mechanical energy must equal its generation. Equating (2) to (3) and using (1) gives

$$V_p^2 = \frac{C_k}{C_D}\left(\frac{T_s - T_o}{T_s}\right)(k_0^* - k), \qquad (4)$$

where V_p is known as the "potential intensity". Note that the term "intensity" is commonly used in meteorology to refer to a tropical cyclone's maximum sustained surface wind speed. Thus potential intensity, being the theoretical upper bound on that quantity, has units of velocity, rather than power per area as is common in other areas of physics.

A detailed treatment of the problem (e.g., Bister and Emanuel, 1998) contains some interesting bells and whistles, but the resulting, exact form of the equation for V_p does not differ much from (4). The potential intensity can be easily computed from atmospheric and sea surface temperatures.

Increasing the infrared opacity of the atmosphere by increasing greenhouse gas concentrations reduces the net radiative flux from the ocean to the atmosphere. To maintain energy equilibrium, the ocean must lose more energy by a turbulent enthalpy flux, as given by (1). This generally requires an increase in $(k_0^* - k)$ and therefore in the potential intensity given by (4). Emanuel (1987) showed that V_p increases by roughly 4 m/s for every 1 degree centigrade increase in ocean temperature when the ocean and atmosphere are in energy equilibrium and the temperature change is forced by changing greenhouse gas concentrations. This may not seem like very much, but since the dissipation of wind energy rises with the cube of the wind speed, an 84 m/s wind is about 16% more destructive than an 80 m/s wind.

Figure 1 shows the trend in V_p – the speed limit on hurricane winds – from 1980 to 2010, calculated from an observation-based climate data set. There are a few places where the trend is very fast – about 3 m/s per decade. Such places include much of the tropical North Atlantic and the Caribbean. This increase in potential intensity is broadly consistent with what we expect from global warming due to greenhouse gas increases. The increase does not mean that we necessarily expect *more* hurricanes, or even that the average wind speed in hurricanes will increase. But it does imply that we should see more of the very intense storms like Katrina and

Irma. A paper one of us published this year (Emanuel, 2017) suggests that not only will storms become stronger, but they should also intensify faster; indeed, the intensification rate scales with the square of the potential intensity, and most historical storms reaching the greatest intensities do so only after at least one period of rapid intensification (Lee et al. 2016). Increasing intensification rates pose a potential problem for hurricane forecasters, because we are not very good at forecasting hurricane strength and if a storm intensifies very rapidly just before striking land, there may not be enough time to move people out of harm's way.

The Clausius-Clapeyron equation yields about a 7% increase in water vapor for each degree centigrade increase in temperature. While global mean rainfall does not increase at the same rate, being constrained by global energy balance (e.g., Allen and Ingram, 2002), extreme rain events are not so constrained, are predicted to increase at rates comparable to (and possibly exceeding) that of water vapor, and already show increasing trends in observations in many parts of the world. Hurricanes are in this respect similar to other extreme rain events. Those that occur in warmer environments will rain more than they would in a colder climate, given the same wind circulation. Hurricane Harvey demonstrates the devastating consequences of tropical cyclone rain.

Theory and observations also show that hurricanes are impeded by wind shear. Wind shear exists when the wind speed and/or direction changes with altitude in the atmosphere. It can vary strongly from one day to the next, even in the tropics. Theoretically, as the climate warms, wind shear should decrease in the lower part of the tropical atmosphere but increase in the upper part, on the global scale. These changes will likely vary from one region to the next, however, and it is difficult to decide based on theory alone whether, in the net, changes in shear should be favorable or unfavorable to hurricane development and intensification.

Climate change invariably changes the large-scale wind circulation systems in the atmosphere, which will affect how hurricanes move. But theory does not yet have much to say about how wind patterns might respond to climate change.

One way to deal with the limitations of theory is to run detailed models of the

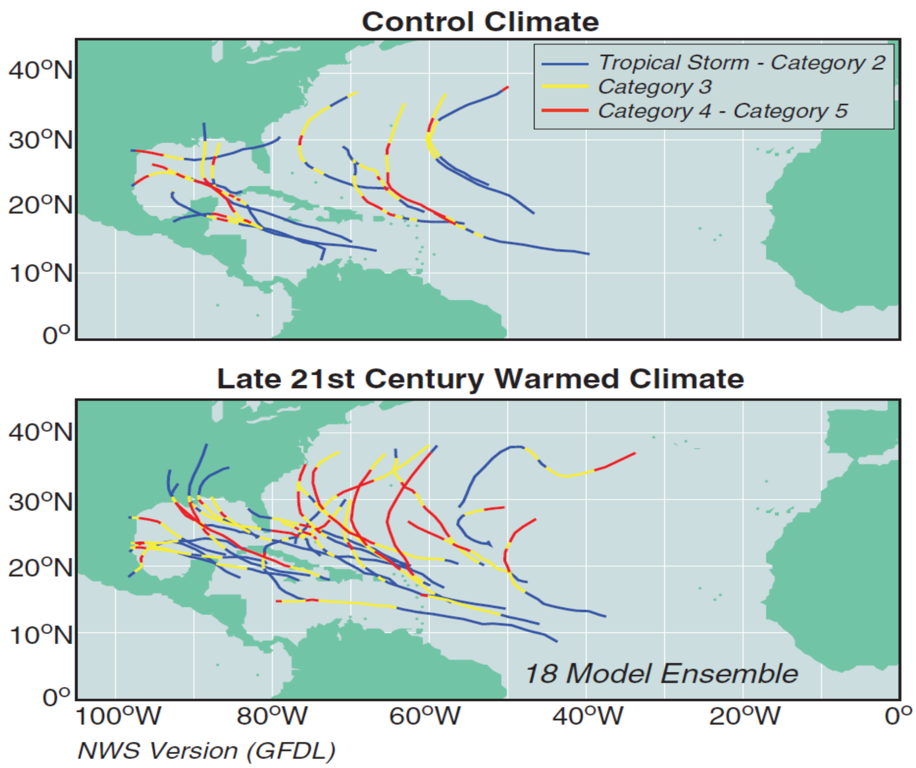

Figure 2: Tracks of North Atlantic hurricanes that reaches at least Category 4 intensity in the climate of the late 20th century (1981-2000) (top) and late 21st century (2081-2100) (bottom). These storms were simulated by a high resolution regional model driven by the global climate state representing an average of 18 global climate models. The regional model was developed at NOAA's Geophysical Fluid Dynamics Laboratory in Princeton, NJ. From Bender and co-authors, Science Magazine, 2010.

climate system. There are, in very rough numbers, about 20 climate models in use around the world today. But the computational nodes in today's climate models are typically at least 100 km apart. We know from highly detailed small-scale models that in order to properly resolve an intense hurricane, the computational nodes in models must be only around 1-2 km apart. We are thus quite far from being able to properly resolve hurricanes. In spite of this limitation, many climate models do develop storms that resemble hurricanes and the spatial and seasonal distributions of such storms seems reasonable, although most models produce too few storms in the North Atlantic. Because of inadequate resolution, most models are incapable of simulating the high intensity (Category 3-5) hurricanes that in reality are responsible for most of the destruction and loss of life. The relatively weak storms they do produce tend to decline in number as the climate warms. A small number of higher-resolution models (around 25 km) are beginning to produce high-intensity storms and show promise in prediction on a range of time scales (e.g., Murakami et al., 2015).

To circumvent the problem of low resolution, we can use high resolution models in limited geographic areas prone to hurricanes, with larger-scale information required by the model provided from lower-resolution global models or observation-based data sets. Since we are only solving equations for these regional models over a limited area, we can afford somewhat higher spatial resolution. This strategy has become known as 'downscaling'. Currently, regional models used for this purpose have computation nodes around a few km to a few tens of km apart. One of us developed a downscaling technique that embeds a specialized, coupled ocean-atmosphere hurricane model within climate or climate model data sets (Emanuel et al., 2006; Emanuel et al., 2008). This model uses absolute angular momentum about the storm's central axis as the independent radial coordinate, simplifying the differential equations and allowing very high resolution where it is needed in the storm's core. Even though this model is highly resolved, it is so fast that it can be used to simulate thousands or even hundreds of thousands of tropical cyclones.

All these downscaling simulations consistently show increases in the incidence of the destructive, high category storms as the climate warms. For example, **Figure 2** compares the tracks of all simulated storms that reach Category 4 to 5 intensity at some point in their life when a regional model is driven by the average state of 18 global climate models in conditions representing the late 20th century (top) and the late 21st century (bottom) (Bender et al., 2010). There are a greater number of these intense storms, they maintain high intensity for longer, and they stay at high intensity at higher latitudes in the warmer climate state.

The regional models are not consistent in their prediction of the response of the far more numerous weak storms to climate change. Most suggest that these weak storms should occur less frequently, but some studies show that even these weaker storms might become more numerous. It is fair to say that the jury is still out on this issue. Although such storms are more numerous, they collectively do less damage because they are weak.

But virtually all models, whether global or regional, show that, as predicted, tropical cyclones will produce more rain as the climate warms. This is a serious problem because freshwater flooding is a major cause of damage and loss of life in tropical cyclones. More than 13,000 people were killed by Hurricane Mitch in Central America in 1998, almost all from freshwater floods.

But the leading cause of mortality and damage in tropical cyclones is from storm surges. Storm surges were the major problem in Hurricanes Katrina and Sandy, for example. These are the same phenomenon as tsunamis, except that they are driven by wind rather than shaking seafloor, and arrive typically in the middle of a raging wind and rainstorm. Their magnitude depends not only on how strong the tropical cyclone is, but on its overall diameter, the speed and direction of its approach to the coast, and the shape of the coast and depth of the water offshore.

We have run thousands of model simulations of storm surges driven by downscaled tropical cyclones at various locations, including New York City, using the downscaling technique of Emanuel et al. (2008). These show increasingly serious surge risk, partially as a simple result of the fact that sea level in general is rising, and partially because of stronger storms (Lin et al., 2010).

Downscaling can be used to address very specific questions. For example, one can quantitatively assess the probabilities of particular features of Hurricanes Harvey and Irma, which have had devastating impacts on Texas and Florida, respectively, not to mention the terrible destruction wrought in the Caribbean by Irma. At least 70 people were killed in the U.S. and damage totals for both storms combined are currently estimated to be in the range of $150-$290 billion. To put things in perspective, the upper estimate is about half of the Department of Defense's current annual budget.

Harvey produced more rain than any U.S. hurricane on record. Irma was the most intense storm ever measured in the North Atlantic outside the Caribbean and the Gulf of Mexico, and sustained category 5 winds for longer than any tropical cyclone on record anywhere on the planet.

To help address how the probabilities changed in the case of Hurricane Harvey, we used the technique described in Emanuel et al. (2008) to downscale 2000 tropical cyclones using large-scale environmental inputs from each of six climate models from each of two periods: 1981-2000, and 2081-2100. In the second case, we downscaled climate models that were run under the assumption that not much will be done to curb greenhouse gas emissions. We simulated only storms that passed within 300 km of Houston, Texas and had winds of at least 45 MPH sometime while within this range of Houston. This downscaling model also calculated rainfall accumulated over metro Houston during the course of each event.

According to this analysis, Harvey's Houston rainfall of about 500 mm would have been about a once in 2000 year event in the late 20th century, but will become a once in a 100 year event by the end of this century. If we were to assume that the frequency of tropical cyclone rain is changing linearly between the period 1981-2000 and the period 2081-2100, then the probability of Harvey's rain in the year 2017 would be about once in 325 years. If we consider Texas as a whole, then tropical cyclone rains of Harvey's magnitude in Texas would evolve from about a once in 100 year event at the end of the 20th century to a once in 5 or 6 year occurrence by the end of this century. A linear increase in frequency would yield a 2017 annual probability of Harvey's rain in Texas of about once in 16 years. Thus we think that climate warming has already greatly increased the odds of Harvey-like rainfalls in Texas.

We can do the same kind of calculation for Irma's near surface winds. For this purpose we downscaled 2000 simulated tropical cyclones each from six climate models and from the same two periods of time as we used for Harvey, each passing within 300 km of the island of Barbuda. In this case, there is much more scatter among the models, but on average, the probability of a storm of Irma's wind intensity near Barbuda decreases from about once in 800 years at the end of the 20th century to once in 60 years at the end of this century. This would imply that the probability in 2017 was once in 185 years, a substantial increase over its value just 25-30 years ago. Still, Irma was a meteorologically rare event.

Large changes in the probabilities of extreme events are to be expected when there are even comparatively minor shifts or shape changes in normally distributed quantities. In the case of tropical cyclones, we can and do use physics to quantitatively assess probabilities in the current climate and in future climates. By and large, the assessments confirm inferences from basic physical theory that the frequency of intense tropical cyclones will increase and they will produce heavier rains. Alas, the confluence of rising sea levels and stronger and wetter hurricanes with increasing coastal population and unwise development policies portends ever-increasing hurricane disasters.

References

Allen, M. R., and W. J. Ingram, 2002: Constraints on future changes in climate and the hydrologic cycle. *Nature,* **419**, 224-232.

Bender, M. A., T. R. Knutson, R. E. Tuleya, J. J. Sirutis, G. A. Vecchi, S. T. Garner, and I. M. Held, 2010: Modeled impact of anthropogenic warming on the frequency of intense Atlantic hurricanes. *Science*, **327,** 454-458

Bister, M., and K. A. Emanuel, 1998: Dissipative heating and hurricane intensity. *Meteor. Atmos. Physics*, **50,** 233-240.

EM-DAT, 2016: The OFDA/CRED International Disaster Database http://www.emdat.be/.

Emanuel, K., 1987: The dependence of hurricane intensity on climate. *Nature*, **326,** 483-485.

Emanuel, K., 2017: Will global warming make hurricane forecasting more difficult? *Bull. Amer. Meteor. Soc.*, **98,** 495-501.

Emanuel, K., R. Sundararajan, and J. Williams, 2008: Hurricanes and global warming: Results from downscaling IPCC AR4 simulations. *Bull. Amer. Meteor. Soc.*, **89,** 347-367.

Emanuel, K. A., 1986: An air-sea interaction theory for tropical cyclones. Part I. *J. Atmos. Sci.*, **43,** 585-605.

Emanuel, K. A., S. Ravela, E. Vivant, and C. Risi, 2006: A statistical-deterministic approach to hurricane risk assessment. *Bull. Amer. Meteor. Soc.*, **19,** 299-314.

Kleinschmidt, E., Jr., 1951: Grundlagen einer Theorie der tropischen Zyklonen. *Archiv fur Meteorologie, Geophysik und Bioklimatologie, Serie A*, **4,** 53-72.

Lee, C.-Y., M. K. Tippett, A. H. Sobel, and S. J. Camargo, 2016: Rapid intensification and the bimodal distribution of tropical cyclone intensity. *Nature Communications*, DOI: 10.1038/ncomms10625.

Lin, N., K. A. Emanuel, J. A. Smith, and E. Vanmarcke, 2010: Risk assessment of hurricane storm surge for New York City. *J. Geophys. Res.*, **115**. doi:10.1029/2009JD013630.

Mahdyiar, M., and B. Porter, 2005: The risk assessment process: The role of catastrophe modeling in dealing with natural hazards. *Catastrophe Modeling: A New Approach to Modeling Risk.* P. Grossi and H. Kunreuther, eds., Springer, pp. 45-68.

Murakami, H., and coauthors, 2015: Simulation and prediction of category 4 and 5 hurricanes in the high-resolution GFDL HiFLOR coupled climate model. *J. Climate*, **28**, 9058-9079.

Pielke, R. A., Jr., J. Gratz, C. W. Landsea, D. Collins, M. A. Saunders, and R. Musulin, 2008: Normalized hurricane damage in the United States: 1900-2005. *Nat. Hazards Rev.*, **9,** 29-42.

GPC Elections

The upcoming GPC election features openings for Vice Chair and Member-at-Large (two positions). The election is to be held in October and elected candidates would begin their terms in January 1, 2018. We strongly encourage you to help shape your GPC by voting.

The Nominating Committee consisted of members Ann Karagozian (UCLA), Sharon Sessions (NM Tech), Paul Williams (Reading), William Newman (UCLA) and Juan Restrepo (Oregon State).

Prospective candidates were considered for their scientific standing and activity, their history of involvement with GPC and the APS, their perspective on the activities of the Group, and their likelihood of service to GPC if elected. Diversity in the GPC leads to vitality and innovation.

The Nominating Committee fielded many candidates, keeping central the desire to look into our membership for a diverse roster of candidates. Both senior candidates as well as junior scientists and a Ph.D. student agreed to run for office. All of the candidates are researchers or science writers, working in a many GPC-related fields. We also had our share of disappointments, as two superb candidates declined to run, due to the current research and political climate.

The position of the Vice Chair of GPC (currently held by Chris E. Forest) is a four-year commitment: after a year as vice chair the officer becomes in successive years the chair-elect (currently Michael Mann), chair (currently Brad Marston), and then past chair (currently Juan Restrepo) - each with distinct duties. The chair officers play a crucial role in providing leadership in organizing the scientific content of the March Meeting and other meetings and in representing climate physics within the American Physical Society.

The members-at-large (two positions, replacing Mark Boslough and Raymond Shaw) serve a three-year term; they constitute the fellowship committee, help select the invited symposia and invited talks for the March Meeting and provide advice on issues important to the GPC.

Identifying excellent candidates who can provide a broad view of the diverse field that is climate physics is key to maintaining the vitality of GPC.

Application Announcement: GPC Students and Early Career Investigators Prizes

This year, GPC is creating a scholarship for young GPC members to attend the APS March Meeting 2018 and participate in the GPC sessions.

In this inaugural year, we will make two awards of $500 to a graduate student and an early career investigator. In future years, the GPC may expand the award if the Physics of Climate community grows and continues its success.

The first award will be "The GPC Students Prize" and will be given to a graduate student member of the APS that is pursuing work related to the GPC mission. The second award will be "The GPC Early Career Investigators Award" and will be given to an early career investigator (less than 5 years out of Ph.D.) and be a member of the APS GPC. Both awards will help cover the costs to attend and participate at the March Meeting in a GPC related session.

To apply for the scholarship, applicants should submit a CV, an abstract for a contributed (10 minute) talk, and a short summary (200-300 words) of how their work fits with the GPC mission.

Please send these items to ceforest@psu.edu with the heading:

"APS GPC Scholarship Application 2018"

Deadline for applications: December 15, 2017

The scholarship committee consists of the GPC Vice Chair (currently, Prof. Chris E. Forest) as the committee chair and three additional members.

For additional information, please contact Prof. Forest if needed.

Upcoming Events and Other Links of Interest

1. GPC is a co-sponsor of a mini-symposium on fluid mechanics of atmospheric clouds at the DFD meeting in Denver, CO, November 19-21, 2017.
2. A Physics Today obituary presents a tribute to Roger Cohen, a founding member of GPC who died on September 10, 2016 at age 76:

   While at Exxon, Roger initiated and led the only industrial research activity in basic research on climate change. His Exxon team participated in the worldwide scientific efforts to understand climate better, and they were lead authors of key chapters of major IPCC reports. Having more time to study details of climate science after retirement, he became increasingly skeptical that increasing CO_2 levels from human activities would be harmful. In the last few years of his life Roger was convinced that more CO_2 would benefit the Earth. He was a founding member of the CO_2 Coalition and served on its Board.

   Roger was a founding member of the APS Topical Group on the Physics of Climate (GPC). His work, as a member of GPC, demonstrated that he was a force for getting at the truth. A source of tremendous integrity, Roger was an uncompromising believer in the principle that "Honesty must be regarded as the cornerstone of ethics in science."

   Among other things, Roger was a cosigner of the 2012 Wall Street Journal Op-Ed titled *No Need to Panic About Global Warming*, whose scientific basis has been widely criticized (see, e.g., here and here).
3. Past GPC Chair Juan Restrepo has been honored with a Society for Industrial and Applied Mathematics (SIAM) Geosciences Career Prize:

   Mathematician Juan Restrepo's impressive and extensive leadership in mathematical modeling and numerical simulation of oceanography and climate dynamics, which has had substantial impact in computational geosciences, has earned him the Society for Industrial and Applied Mathematics (SIAM) Geosciences Career Prize.

   The award recognizes an outstanding senior researcher who has made broad and distinguished contributions to the field of geosciences.
4. KITP Program on "Planetary Boundary Layers in Atmospheres, Oceans, and Ice on Earth and Moons", UC Santa Barbara, CA, April 2-June 22, 2018 (application deadline is Dec. 18, 2016).
5. 5th International Conference on Reanalysis (ICR5), November 13-17, 2017. Rome, Italy.
6. The 2nd WCRP Summer School on Climate Model Development, 22-31 January 2018. Cachoeira Paulista, SP, Brazil.
7. SPARC 2018 General Assembly, 1-5 October 2018. Kyoto, Japan.
8. Pan Ocean Remote Sensing Conference, Jeju Island, South Korea November 4-7, 2018.
9. 98th American Meteorological Society Annual Meeting: 'Transforming Communication in the Weather, Water, and Climate Enterprise Focusing on Challenges Facing our Sciences', Austin, TX, January 7-11, 2018.
10. 33rd Conference on Hurricanes and Tropical Meteorology, April 16-20, 2018,Ponte Vedra, FL
11. AMOS-ICSHMO, February 5-9, 2018 2018 UNSW Kensington Campus, Sydney, Australia.
12. 23rd Symposium on Boundary Layers and Turbulence/21st Conference on Air-Sea Interaction, June 11-15, 2018,Oklahoma City, OK
13. 15th Conference on Cloud Physics/15th Conference on Atmospheric Radiation July 9- 13, 2018, Vancouver, BC.
14. AGU Fall meeting, Dec. 11-15, New Orleans, LA.
15. 2018 Ocean Sciences Meeting, February February 11–16, Portland, Oregon.
16. European Geosciences Union General Assembly 2018, April 8–13, Vienna, Austria. AMS AOFD meeting, Portland, OR June 26-30, 2017.