American Meteorological Society's
Environmental Science Seminar Series

Hurricanes: Are They Changing and Are We Adequately Prepared for the Future?

A breached levee in New Orleans, LA, after Hurricane Katrina.
http://rst.gsfc.nasa.gov/Sect14/Sect14_10a.html

Are hurricanes, or certain categories of hurricanes, changing? Are these changes more likely tied to a globally-averaged climate warming or are they more likely to be manifestations of natural climate variability? Can large storms be unaffected by a globally-averaged climate warming that has resulted, in part, in an altered hydrologic cycle (i.e., more water vapor in the atmosphere)? Is it reasonable to presume that natural cycles and oscillations can go unaffected by a globally-averaged climate warming? Are there limits on a hurricane's intensity and, if so, what are they? Is there any scientific basis for concern over the plausibility of hurricanes in excess of a category 5 hurricane in the foreseeable future, in a climatically-altered world?

Public Invited

Tuesday, October 25, 2005, 12:00 noon - 2:00 p.m.
Location: Dirksen Senate Office Building, Room G-50
Washington, DC

Reception Following

Moderator: **Dr. Anthony Socci,** Senior Fellow, American Meteorological Society

Speakers

Dr. Kevin Trenberth, Head of the Climate Analysis Section, National Center for Atmospheric Research (NCAR), Boulder, CO

Dr. Judith Curry, Professor and Chair of the School of Earth and Atmospheric Sciences, Georgia Institute of Technology, Atlanta, GA

Dr. Kerry Emanuel, Professor of Atmospheric Science, Massachusetts Institute of Technology, Cambridge, MA

Is There Evidence That a Global Warming is Altering Hurricanes? – Setting the Context:

Are the bonanza Atlantic hurricane seasons of 2004 and 2005 becoming the norm? Is the record breaking number of typhoon hits in Japan in 2004 a wave of the future? Does the first known hurricane, Catarina, in the South Atlantic in March 2004 signal more? The climate is changing, and humans are partly responsible. Global mean temperatures continue to increase and are running 1°F or more above pre-1970s values. While 1998 remains the warmest year on record, 2002, 2003 and 2004 follow closely behind. These changes have been definitively linked to increases in greenhouse gases in the atmosphere, most notably carbon dioxide, which has increased 30% in the past century and half of that increase has occurred since 1970. This increase is from human activities and especially the burning of fossil fuels. As part of this global warming, sea surface temperatures (SSTs) in the tropics have increased 0.9°F since the early 1970s, and this increase is unprecedented over at least the last 150 years and perhaps the last several thousand years. It is almost certainly a result of the additional greenhouse gases mankind has put into the atmosphere. Associated with this is an observed increase in atmospheric moisture (water vapor) on the order of 4%. *This increases the energy available for storms and enhances the chances of heavy rains.

Hurricanes occur only where SSTs are above about 80°F, but they also require favorable atmospheric circulation patterns to occur. There is a natural competition within the tropics for where these conditions are most favorable for hurricane formation; during El Niño it is the Pacific, but since 1995 the Atlantic has been favored except in 1997 and 2002 (both El Niño years). Locally in the Atlantic, natural variability is large from year to year, and even from decade to decade, as the ocean currents alter SSTs and change the odds of hurricanes forming.

Observations clearly reveal increases in heavy rains in the United States and many other places around the world. Sea level has risen over an inch in the past decade, as the ocean waters warm and expand and glaciers melt. An estimate of the effect of global warming is for about 7.8% enhancement of heavy rainfall and associated latent heating in the storms since the 1970s. An unanswered question is how many of these hurricanes will make landfall and where. Nevertheless, the environmental changes related to human influences on climate are increasing the risk of major flooding associated with hurricanes.

***Note**: The relationships among changing atmospheric moisture, energy availability and how storms develop is a topic of considerable ongoing research.*

New Data/Evidence for Increased Hurricane Intensity:

About 90 tropical cyclones develop around the world each year, and roughly half become strong enough to classify as hurricanes (or typhoons in the western Pacific region). While this global number changes little from year-to-year, there can be large changes in the frequency of events in individual regions. For example, Atlantic hurricanes are subject to large year-to-year and decade-to-decade fluctuations, both in the number of storms and in their intensity and duration. The fluctuations have been related to natural climate oscillations that affect the whole North Atlantic region, and to the well-known El Niño phenomenon. For example, the 1940s and 50s were very active years in the Atlantic, wile the 70s and 80s were quiet. During this most recent quiet period there were large increases in coastal population and infrastructure in the U.S. These increases, coupled with the return of an increase in the frequency of hurricane activity beginning in 1995, has led to a very substantial increase in hurricane-related losses in the U.S.

Recent scientific research suggests that the duration and intensity of hurricanes worldwide has increased dramatically over the last 30-50 years. Analysis of global hurricane data from satellites (which is available since 1970) shows that the strongest hurricanes (categories 4+5) have almost doubled for the period 1970-2004, and this increase is seen in each of the ocean basins for which hurricanes occur. This increase in hurricane intensity is coincident with a global increase in tropical sea surface temperature, which is evident in each of the ocean basins. In fact, tropical ocean temperature has increased by about 1°F over the past 50 years, and this increase is unprecedented over at least the last 150 years and perhaps the last several thousand years. While sea surface temperature is not the only thing that determines hurricane intensity, there is strong empirical and theoretical evidence that on average an increase in sea surface temperature will increase the average intensity of hurricanes. What has been producing this warming? Solar and volcanic activity have actually been working during this period to produce a slight global cooling. As stated above, the decadal scale variability seen in the North Atlantic is regional and cannot explain the global increase in tropical sea surface temperatures. Particularly during the period since 1970, greenhouse warming is the best explanation that we have for this temperature increase.

What is the future likely to hold?

How will hurricanes change in the future? Our best estimate is that tropical sea surface temperature will continue to increase, driven largely by greenhouse warming. While climate models do a good job at simulating the past surface temperature record and arguably are producing reliable projections of future surface temperature changes, we do not have much confidence in projections of future hurricane characteristics. Climate models do not do a good job of simulating hurricanes because their resolution is too coarse and there are numerous uncertainties in modeling hurricane processes. These uncertainties include incomplete understanding of hurricane intensification and processes occurring in the hurricane eye wall and the nature of the interactions between the atmosphere and upper ocean during the hurricane evolution. Based upon our current understanding relating hurricane intensity to tropical sea surface temperature, we would expect hurricane intensity to continue to increase at least in the short term as sea surface temperatures rise. However, our basic understanding of the global climate dynamics of hurricanes is not adequate to have much confidence in future projections. Nevertheless, research indicates that we are facing a serious risk in the coming decades of increasing hurricane intensity. Moreover, increases in associated heavy rainfall events and risk of flooding is also real. Even as better hurricane forecasts have reduced losses and loss of life, increases in coastal population and wealth, coupled with the return of large hurricane activity beginning in 1995, has led to a very substantial increase in hurricane-related losses in the U.S. It is important to recognize that because of global warming, the past is no longer a good guide to the future, and planning of all sorts should build in the best estimates for changes in the range of risk especially in potential damage to infrastructure, flooding and water management, and in insurance. The failure of the levees near New Orleans is a case in point.

Biographies

Dr. Kevin E. Trenberth is Head of the Climate Analysis Section at the National Center for Atmospheric Research. Originally from New Zealand, Dr. Trenberth obtained his Sc. D. in meteorology in 1972 from Massachusetts Institute of Technology. He was a lead author of the 1995 and 2001 IPCC Scientific Assessment of Climate Change and is now a Coordinating Lead Author of the 2007 AR4 IPCC assessment. He recently served on the Scientific Steering Group for the Climate Variability and Predictability (CLIVAR) program and was co-Chair from 1995 to1999. He serves on the Joint Scientific Committee of the World Climate Research Programme and chairs the WCRP

Observation and Assimilation Panel, as well as many national committees. He is a fellow of the American Meteorological Society (AMS) and American Association for Advancement of Science, and an honorary fellow of the Royal Society of New Zealand. In 2000, he received the Jule G. Charney award from the American Meteorological Society and in 2003 he was given the NCAR Distinguished Achievement Award. Dr. Trenberth was the editor of the book *Climate System Modeling*, published in 1992 by Cambridge University Press. He has also published over 378 scientific articles or papers, including 38 books or book chapters, and over 157 peer-reviewed scientific journal articles, and has given many invited scientific talks as well as appearing in a number of television, radio programs and newspaper articles.

Dr. Judith Curry is Professor and Chair of the School of Earth and Atmospheric Sciences at the Georgia Institute of Technology. Dr. Curry received a Ph.D. in atmospheric science from the University of Chicago in 1982. Prior to joining the faculty at Georgia Tech, she has held faculty positions at the University of Colorado, Penn State University and Purdue University. Dr. Curry's research interests span a variety of topics in climate; current interests include air/sea interactions, climate feedback processes associated with clouds and sea ice, and applications of satellite data to interpreting recent variations in the climate data record. Dr. Curry currently serves on the National Academies Climate Research Committee and the Space Studies Board, and the NOAA Climate Working Group. Dr. Curry is author of the book *Thermodynamics of Atmospheres and Oceans* and is editor for the *Encyclopedia of Atmospheric Sciences*. She has published over 130 refereed journal articles. Dr. Curry is a Fellow of the American Meteorological Society and the American Geophysical Union. In 1992, she received the Henry Houghton Award from the American Meteorological Society.

Dr. Kerry Emanuel is a professor of atmospheric science at the Massachusetts Institute of Technology, where he has been on the faculty since 1981, after spending three years as a faculty member at UCLA. Professor Emanuel's research interests focus on tropical meteorology and climate, with a specialty in hurricane physics. His interests also include cumulus convection, and advanced methods of sampling the atmosphere in aid of numerical weather prediction. He is the author or co-author of over 100 peer-reviewed scientific papers, and two books, including *Divine Wind: The History and Science of Hurricanes*, recently released by Oxford University Press and aimed at a general audience.

This seminar is open to the public and does not require a reservation. Please feel free to forward this notice.

The **Next Seminar** is scheduled for **Wednesday, November 16, 2005.**
Topic: The Earth's Surface Temperature Record: Have the Satellite and Land-Based Thermometer Records Converged?

Please see our web site for seminar summaries and future events:
www.ametsoc.org/atmospolicy

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