Science 22 January 2010:
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Reports

Modeled Impact of Anthropogenic Warming on the Frequency of Intense Atlantic Hurricanes

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Several recent models suggest that the frequency of Atlantic tropical cyclones could decrease as the climate warms. However, these models are unable to reproduce storms of category 3 or higher intensity. We explored the influence of future global warming on Atlantic hurricanes with a downscaling strategy by using an operational hurricane-prediction model that produces a realistic distribution of intense hurricane activity for present-day conditions. The model projects nearly a doubling of the frequency of category 4 and 5 storms by the end of the 21st century, despite a decrease in the overall frequency of tropical cyclones, when the downscaling is based on the ensemble mean of 18 global climate-change projections. The largest increase is projected to occur in the Western Atlantic, north of 20°N.

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News of the Week

Global Warming:

Models Foresee More-Intense Hurricanes in the Greenhouse

Richard A. Kerr

Fewer but fiercer and more-destructive hurricanes will sweep the Atlantic Basin in the 21st century as climate change continues, a new modeling study by U.S. government researchers suggests. The results, reported on page 454 of this week's issue of *Science*, bear out tentative

forecasts from earlier studies, although the researchers caution that this is still far from the last word.

Read the Full Text

Science News

Alarming Increase in Flow of Water Into Oceans Due to Global Warming, Accelerated Cycle of Evaporation, Precipitation

ScienceDaily (Oct. 5, 2010) — Freshwater is flowing into Earth's oceans in greater amounts every year, a team of researchers has found, thanks to more frequent and extreme storms linked to global warming. All told, 18 percent more water fed into the world's oceans from rivers and melting polar ice sheets in 2006 than in 1994, with an average annual rise of 1.5 percent.

See Also:

Earth & Climate

- Water
- Global Warming
- Climate
- Environmental Issues
- Weather
- Geography

Reference

- Monsoon
- Climate
- Antarctic ice sheet
- Consensus of scientists regarding global warming

"That might not sound like much -- 1.5 percent a year -- but after a few decades, it's huge," said Jay Famiglietti, UC Irvine Earth system science professor and principal investigator on the study, which will be published this week in *Proceedings of the National Academy of Sciences*. He noted that while freshwater is essential to humans and ecosystems, the rain is falling in all the wrong places, for all the wrong reasons.

"In general, more water is good," Famiglietti said. "But here's the problem: Not everybody is getting more rainfall, and those who are may not need it. What we're seeing is exactly what the Intergovernmental Panel on Climate Change predicted -- that precipitation is increasing in the tropics and the Arctic Circle with heavier, more punishing storms. Meanwhile, hundreds of millions of people live in semiarid regions, and those are drying up."

In essence, he said, the evaporation and precipitation cycle taught in grade school is accelerating dangerously because of greenhouse gas-fueled higher temperatures, triggering monsoons and hurricanes. Hotter weather above the oceans causes freshwater to evaporate faster, which leads to thicker clouds unleashing more powerful storms over land. The rainfall then travels via rivers to the sea in ever-larger amounts, and the cycle begins again.

The pioneering study, which is ongoing, employs NASA and other world-scale satellite observations rather than computer models to track total water volume each month flowing from the continents into the oceans.

"Many scientists and models have suggested that if the water cycle is intensifying because of climate change, then we should be seeing increasing river flow. Unfortunately, there is no global discharge measurement network, so we have not been able to tell," wrote Famiglietti and lead author Tajdarul Syed of the Indian School of Mines, formerly of UCI.

"This paper uses satellite records of sea level rise, precipitation and evaporation to put together a unique 13-year record -- the longest and first of its kind. The trends were all the same: increased evaporation from the ocean that led to increased precipitation on land and more flow back into the ocean."

The researchers cautioned that although they had analyzed more than a decade of data, it was still a relatively short time frame. Natural ups and downs that appear in climate data make detecting long-term trends challenging. Further study is needed, they said, and is under way.

Other authors are Don Chambers of the University of South Florida, Joshua Willis of the Jet Propulsion Laboratory in Pasadena, and Kyle Hilburn of Remote Sensing Systems in Santa Rosa, Calif. Funding is provided by NASA.

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Journal Reference:

1. T. H. Syed, J. S. Famiglietti, D. P. Chambers, J. K. Willis, K. Hilburn. **Satellite-based global-ocean mass balance estimates of interannual variability and emerging trends in continental freshwater discharge**. *Proceedings of the National Academy of Sciences*, 2010; DOI: 10.1073/pnas.1003292107

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River. Freshwater is flowing into Earth's oceans in greater amounts every year, a team of researchers has found, thanks to more frequent and extreme storms linked to global warming. All told, 18 percent more water fed into the world's oceans from rivers and melting polar ice sheets in 2006 than in 1994, with an average annual rise of 1.5 percent. (Credit: iStockphoto/Johnny Lye)

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Global Warming Surpassed Natural Cycles In Fueling 2005 Hurricane Season, NCAR Scientists Conclude

ScienceDaily (June 22, 2006) — Global warming accounted for around half of the extra hurricane-fueling warmth in the waters of the tropical North Atlantic in 2005, while natural cycles were only a minor factor, according to a new analysis by Kevin Trenberth and Dennis Shea of the National Center for Atmospheric Research (NCAR). The study will appear in the June 27 issue of Geophysical Research Letters, published by the American Geophysical Union.

See Also:

Earth & Climate

- Global Warming
- Climate
- Hurricanes and Cyclones
- Severe Weather
- Environmental Issues
- Geography

Reference

- List of major natural disasters in the United States
- National Hurricane Center
- Great Hurricane of 1780
- Hurricane Opal

"The global warming influence provides a new background level that increases the risk of future enhancements in hurricane activity," Trenberth says. The research was supported by the National Science Foundation, NCAR's primary sponsor.

The study contradicts recent claims that natural cycles are responsible for the upturn in Atlantic hurricane activity since 1995. It also adds support to the premise that hurricane seasons will become more active as global temperatures rise. Last year produced a record 28 tropical storms

and hurricanes in the Atlantic. Hurricanes Katrina, Rita, and Wilma all reached Category 5 strength.

Trenberth and Shea's research focuses on an increase in ocean temperatures. During much of last year's hurricane season, sea-surface temperatures across the tropical Atlantic between 10 and 20 degrees north, which is where many Atlantic hurricanes originate, were a record 1.7 degrees F above the 1901-1970 average. While researchers agree that the warming waters fueled hurricane intensity, they have been uncertain whether Atlantic waters have heated up because of a natural, decades-long cycle, or because of global warming.

By analyzing worldwide data on sea-surface temperatures (SSTs) since the early 20th century, Trenberth and Shea were able to calculate the causes of the increased temperatures in the tropical North Atlantic. Their calculations show that global warming explained about 0.8 degrees F of this rise. Aftereffects from the 2004-05 El Nino accounted for about 0.4 degrees F. The Atlantic multidecadal oscillation (AMO), a 60-to-80-year natural cycle in SSTs, explained less than 0.2 degrees F of the rise, according to Trenberth. The remainder is due to year-to-year variability in temperatures.

Previous studies have attributed the warming and cooling patterns of North Atlantic ocean temperatures in the 20th century—and associated hurricane activity—to the AMO. But Trenberth, suspecting that global warming was also playing a role, looked beyond the Atlantic to temperature patterns throughout Earth's tropical and midlatitude waters. He subtracted the global trend from the irregular Atlantic temperatures—in effect, separating global warming from the Atlantic natural cycle. The results show that the AMO is actually much weaker now than it was in the 1950s, when Atlantic hurricanes were also quite active. However, the AMO did contribute to the lull in hurricane activity from about 1970 to 1990 in the Atlantic.

Global warming does not guarantee that each year will set records for hurricanes, according to Trenberth. He notes that last year's activity was related to very favorable upper-level winds as well as the extremely warm SSTs. Each year will bring ups and downs in tropical Atlantic SSTs due to natural variations, such as the presence or absence of El Nino, says Trenberth. However, he adds, the long-term ocean warming should raise the baseline of hurricane activity.

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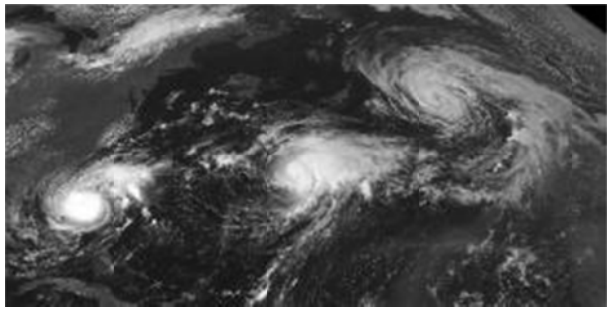

Hurricanes Ophelia, Nate, and Maria were among 15 hurricanes that raged across the Atlantic, Gulf of Mexico, and Caribbean in 2005. Click here or on image to enlarge. (Image by NASA-GSFC, data from NOAA GOES)

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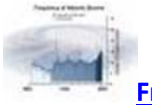
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Global Warming Increases Wind Shear, Reduces Hurricanes, Climate Model Shows

ScienceDaily (Apr. 18, 2007) — Climate model simulations for the 21st century indicate a robust increase in wind shear in the tropical Atlantic due to global warming, which may inhibit hurricane development and intensification. Historically, increased wind shear has been associated with reduced hurricane activity and intensity.

See Also:

Earth & Climate

- Climate
- Hurricanes and Cyclones
- Environmental Issues

Computers & Math

- Computer Modeling
- Mathematical Modeling
- Computational Biology

Reference

- National Hurricane Center
- Consensus of scientists regarding global warming
- Saffir-Simpson Hurricane Scale
- 1991 Halloween Nor'easter

This new finding is reported in a study by scientists at the Rosenstiel School of Marine and Atmospheric Science at the University of Miami and NOAA's Geophysical Fluid Dynamics Laboratory (GFDL) in Princeton, N.J., and, scheduled to be published April 18th in Geophysical Research Letters.

While other studies have linked global warming to an increase in hurricane intensity, this study is the first to identify changes in wind shear that could counteract these effects. "The environmental changes found here do not suggest a strong increase in tropical Atlantic hurricane activity during the 21st century," said Brian Soden, Rosenstiel School associate professor of meteorology and physical oceanography and the paper's co-author. However, the study does identify other regions, such as the western tropical Pacific, where global warming does cause the environment to become more favorable for hurricanes.

"Wind shear is one of the dominant controls to hurricane activity, and the models project substantial increases in the Atlantic," said Gabriel Vecchi, lead author of the paper and a research

oceanographer at GFDL. "Based on historical relationships, the impact on hurricane activity of the projected shear change could be as large -- and in the opposite sense -- as that of the warming oceans."

Examining possible impacts of human-caused greenhouse warming on hurricane activity, the researchers used climate models to assess changes in the environmental factors tied to hurricane formation and intensity. They focused on projected changes in vertical wind shear over the tropical Atlantic and its ties to the Pacific Walker circulation -- a vast loop of winds that influences climate across much of the globe and that varies in concert with El Niño and La Niña oscillations. By examining 18 different models, the authors identified a systematic increase in wind shear over much of the tropical Atlantic due to a slowing of the Pacific Walker circulation. Their research suggests that the increase in wind shear could inhibit both hurricane development and intensification.

"This study does not, in any way, undermine the widespread consensus in the scientific community about the reality of global warming," said Soden. "In fact, the wind shear changes are driven by global warming."

The authors also note that additional research will be required to fully understand how the increased wind shear affects hurricane activity more specifically. "This doesn't settle the issue; this is one piece of the puzzle that will contribute to an incredibly active field of research," Vecchi said.

Story Source:

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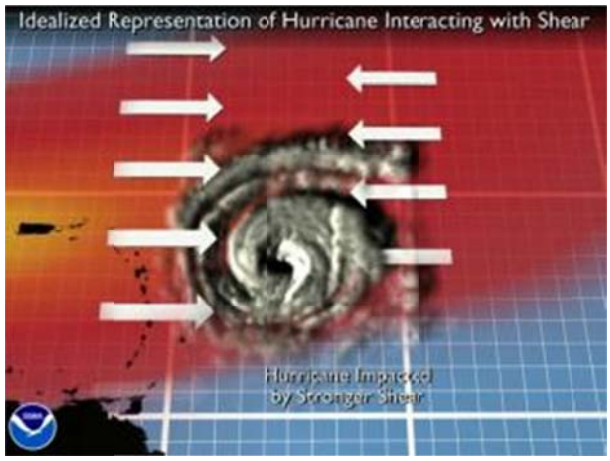

The white arrows represent strong cross winds, also known as wind shear. These winds are predicted to become more common in the Atlantic due to global warming. They can disrupt or destroy a hurricane by blowing the top away. (Credit: NOAA)

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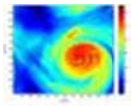
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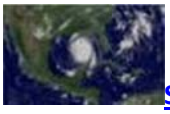
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ScienceDaily (May 20, 2008) — A new model simulation of Atlantic hurricane activity for the last two decades of this century projects fewer hurricanes overall, but a slight increase in intensity for hurricanes that do occur. Hurricanes are also projected to have more intense rainfall, on average, in the future.

See Also:

Earth & Climate

- Hurricanes and Cyclones
- Severe Weather
- Global Warming
- Climate
- Environmental Issues
- Weather

Reference

- National Hurricane Center
- Great Hurricane of 1780
- List of major natural disasters in the United States
- Hurricane Opal

"This study adds more support to the consensus finding of the Intergovernmental Panel on Climate Change and other reports that it is likely that hurricanes will gradually become more intense as the climate continues to warm," said Tom Knutson, research meteorologist and lead author of the report. "It's a bit of a mixed picture in the Atlantic, because we're projecting fewer hurricanes overall."

The findings are reported in a study by scientists at NOAA's Geophysical Fluid Dynamics Laboratory in Princeton, N.J., scheduled to be published online on May 18 in Nature Geoscience. Knutson's co-authors are Joseph Sirutis, Stephen Garner, Gabriel Vecchi, and Isaac Held.

The scientists performed hurricane simulations using a new regional model that offers both higher resolution and an improved ability to simulate past observed changes in Atlantic hurricane activity. In a preliminary study published last October in the Bulletin of the American Meteorological Society, the new model was shown to successfully reproduce Atlantic hurricane counts year-by-year from 1980 to 2006, including the observed increasing trend.

In the new study, the model was used to test the influence of greenhouse gas warming on Atlantic hurricane activity through the end of the 21st century. Simulations reveal higher levels

of wind shear and other changes, which act to reduce the overall number of hurricanes in the model.

Tropical Atlantic sea surface temperatures have increased over the past century and several studies have reported strong correlations between increasing tropical Atlantic sea surface temperatures and measures of hurricane activity since at least 1950. Although it is widely accepted in the climate change research community that increases in greenhouse gases have caused most of the global warming of the last half century, the link between increasing greenhouse gases and hurricane activity has been a topic of wide debate and of little consensus.

This new study suggests that in the Atlantic basin, global warming from increasing greenhouse gases will have little impact, or perhaps cause some decrease, in tropical storm and hurricane numbers.

“We'll need to keep an eye on upcoming model studies to see how robust the projected increase in wind shear over the Atlantic turns out to be,” said Knutson.

Large-scale environmental changes in circulation, such as wind shear, as well as possibly moisture, are likely the dominant factors producing the reduced storm frequency. These results support recent research showing that the primary driver of the recent increase in Atlantic hurricane numbers was the warming of the tropical Atlantic relative to the other tropical basins.

These results are also consistent with a number of previous modeling and theoretical studies that have examined the influence of global warming from increasing greenhouse gases on hurricane intensity. An increase in hurricane intensities globally is assessed as "likely" in the Intergovernmental Panel on Climate Change Fourth Assessment Report issued in 2007.

Story Source:

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National Oceanic And Atmospheric Administration (2008, May 20). Global Warming Has Little Impact In Tropical Storm And Hurricane Numbers, NOAA Reports. *ScienceDaily*. Retrieved October 10, 2010, from http://www.sciencedaily.com /releases/2008/05/080519134306.htm?sms_ss=email&at_xt=4caf2532e3786d19,0

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Satellite of Hurricane Ophelia on September 14, 2005. (Credit: NOAA)

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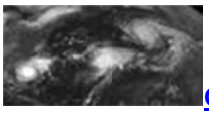
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ScienceDaily (Dec. 13, 2007) — Natural climate variations, which tend to involve localized changes in sea surface temperature, may have a larger effect on hurricane activity than the more uniform patterns of global warming, a report in Nature suggests.

See Also:

Earth & Climate

- Global Warming
- Environmental Issues
- Climate
- Hurricanes and Cyclones
- Severe Weather
- Weather

Reference

- Consensus of scientists regarding global warming
- National Hurricane Center
- Saffir-Simpson Hurricane Scale
- Climate model

In the debate over the effect of global warming on hurricanes, it is generally assumed that warmer oceans provide a more favorable environment for hurricane development and intensification. However, several other factors, such as atmospheric temperature and moisture, also come into play.

Drs. Gabriel A. Vecchi of the NOAA Geophysical Fluid Dynamics Laboratory and Brian J. Soden from the University of Miami Rosenstiel School of Marine & Atmospheric Science analyzed climate model projections and observational reconstructions to explore the relationship between changes in sea surface temperature and tropical cyclone 'potential intensity' - a measure that provides an upper limit on cyclone intensity.

They found that warmer oceans do not alone produce a more favorable environment for storms because the effect of remote warming can counter, and sometimes overwhelm, the effect of local surface warming. "Warming near the storm acts to increase the potential intensity of hurricanes, whereas warming away from the storms acts to decrease their potential intensity," Vecchi said.

Their study found that long-term changes in potential intensity are more closely related to the regional pattern of warming than to local ocean temperature change. Regions that warm more than the tropical average are characterized by increased potential intensity, and vice versa. "A

surprising result is that the current potential intensity for Atlantic hurricanes is about average, despite the record high temperatures of the Atlantic Ocean over the past decade." Soden said. "This is due to the compensating warmth in other ocean basins."

"As we try to understand the future changes in hurricane intensity, we must look beyond changes in Atlantic Ocean temperature. If the Atlantic warms more slowly than the rest of the tropical oceans, we would expect a decrease in the upper limit on hurricane intensity," Vecchi added. "This is an interesting piece of the puzzle."

"While these results challenge some current notions regarding the link between climate change and hurricane activity, they do not contradict the widespread scientific consensus on the reality of global warming," Soden noted.

The journal article is entitled "Effect of Remote Sea Surface Temperature Change on Tropical Cyclone Potential Intensity."

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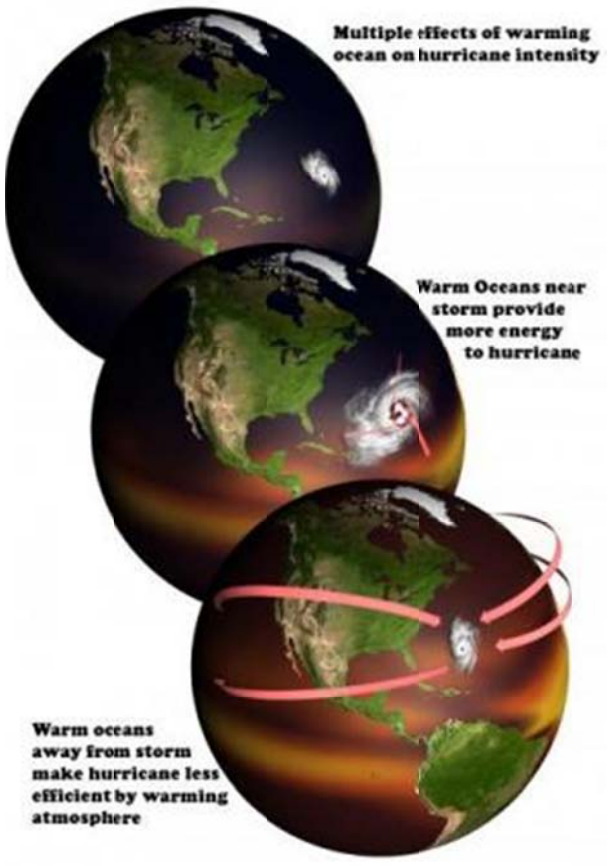

The multiple effects of warming oceans on hurricane intensity. (Credit: NOAA, GFDL)

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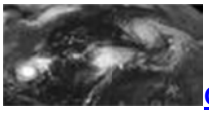
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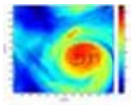
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Global Warming Will Do Little To Change Hurricane Activity, According To New Model

ScienceDaily (Aug. 13, 2008) — In a study published in the July 2008 issue of Geophysical Research Letters, Drs. David S. Nolan and Eric D. Rappin from the University of Miami's Rosenstiel School of Marine and Atmospheric Science describe a new method for evaluating the frequency of hurricane formation in present and future tropical climates.

See Also:

Earth & Climate

- Hurricanes and Cyclones
- Severe Weather
- Climate

Computers & Math

- Computer Modeling
- Computer Science
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Reference

- National Hurricane Center
- Planetary boundary layer
- Saffir-Simpson Hurricane Scale
- List of major natural disasters in the United States

While current thinking about changes in hurricane frequency comes mostly from computer simulations of global climate, the computer models used for these studies can only represent the coarsest features of hurricanes, thus casting doubt in their predictions of hurricane activity.

The new approach by Nolan and Rappin, developed in collaboration with Dr. Kerry Emanuel of the Massachusetts Institute of Technology, uses computer models with much more accurate representation of the processes that lead to hurricane formation, much the same way a digital image with more pixels allows for a more detailed photographic image.

The models are used to simulate the rate of hurricane development in tropical atmospheres with varying values of sea surface temperature and vertical wind shear (which is the extent to which wind speed and direction changes with height in the atmosphere). These two variables – ocean temperature and wind shear -- are considered to be the two most important factors in predicting hurricane activity, both in operational forecasting and in consideration of climate change.

"We designed the computer simulations to show that as the ocean temperature increased, hurricanes would form more rapidly and easily, even in the presence of wind shear," says Nolan, associate professor of Meteorology at the Rosenstiel School. "Instead, we got exactly the opposite result. As the water temperature increased, the effectiveness of the wind shear in suppressing hurricane formation actually became greater."

The simulations show that if they do form, hurricanes become stronger in the warmer environments. Together, these results suggest that in a global warming world, there would be less hurricanes, but those that do form could become stronger. The same prediction has recently been made by other studies using global climate models, and the similarity of the two predictions enhances confidence in the results.

"The additional aspect that our method offers is a much more accurate picture of the process of tropical storm and hurricane formation, as compared to the global models," Nolan said. "Our ongoing work with this model and others should lead to a much better understanding of the relationship between climate and global hurricane activity."

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University of Miami Rosenstiel School of Marine & Atmospheric Science (2008, August 13). Global Warming Will Do Little To Change Hurricane Activity, According To New Model. *ScienceDaily*. Retrieved October 10, 2010, from http://www.sciencedaily.com /releases/2008/08/080812160615.htm?sms_ss=email&at_xt=4caf25df7fb02470,0

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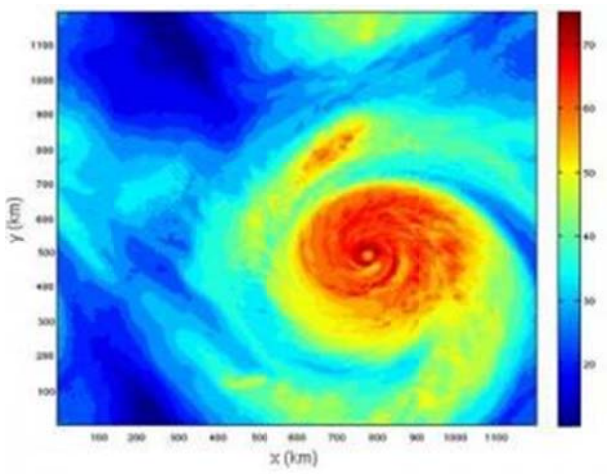

Figure shows an example of a hurricane computer simulation generated by the Rosenstiel School team. The colors indicate water vapor in a vertical column of the atmosphere, where the dark red areas would indicate extremely heavy rainfall. The small size of each pixel, 3 km x 3 km provides remarkably accurate detail in the storm. In comparison, the number of pixels in an image used to represent storms in global climate models are typically 100 km x 100 km, at best. (Credit: UM/RSMAS)

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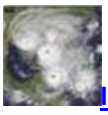
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Recent Hurricane History Provides Diverging Interpretations On Future Of Hurricane Activity

ScienceDaily (Nov. 2, 2008) — In a paper published in the journal Science, scientists Gabriel A. Vecchi of NOAA's Geophysical Fluid Dynamics Laboratory, Kyle L. Swanson of the University of Wisconsin - Milwaukee Atmospheric Sciences Group and Brian J. Soden from the University of Miami's Rosenstiel School of Marine and Atmospheric Science teamed up to study hurricane data observed over more than 50 years.

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Earth & Climate

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The study explores the relationship between sea surface temperature (SST) and seasonal hurricane activity, and show how differing interpretations of the observational record can imply vastly different futures for Atlantic hurricane activity due to global warming. The two interpretations arise from assumptions of whether it is the local SST in the Atlantic in isolation, or whether it is the SST in the Atlantic 'relative' to the rest of the tropics, that drives variations in Atlantic hurricane activity.

If one assumes the former (the local SST hypothesis), then by 2100, the lower bound on Atlantic hurricane activity is comparable to that of 2005, when four major hurricanes struck the continental United States, causing more than $100 billion in damage. The upper bound exceeds 2005 levels by more than a factor of two. However, if one assumes the latter (the relative SST hypothesis), then the future is similar to the recent past, with periods of higher and lower hurricane activity relative to present-day conditions due to natural climate variability, but with little long-term trend.

The statistical relationship between either interpretation of the SST/hurricane activity link is ambiguous over the period 1946-2007 (they are statistically indistinguishable, though both are significant), but they imply fundamentally different projections for the future and interpretations of the past. The team further argues that the consistency between theory, numerical models, and historical observations offers compelling evidence that the 'relative' SST hypothesis is more accurate and provides a better framework for projections of future changes in hurricane activity.

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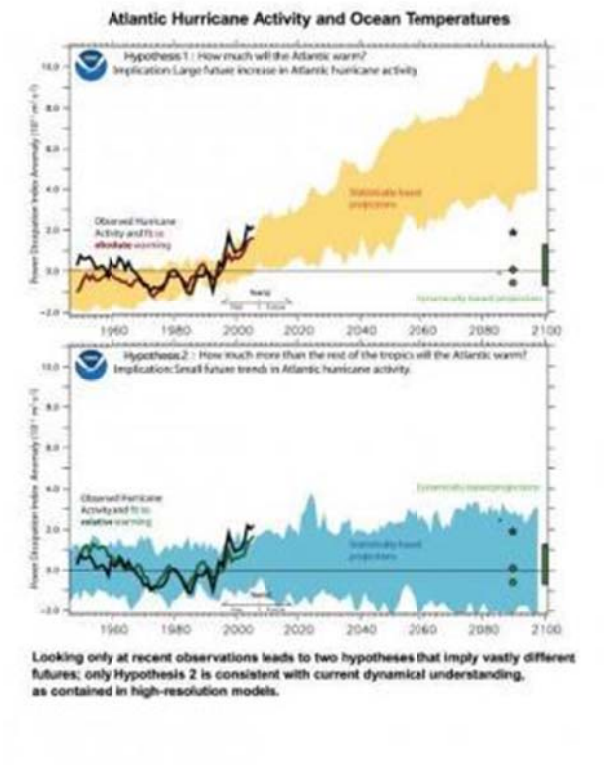

Looking at recent observations leads to two hypothesize that imply vastly different futures; only hypothesis two is consistent with current dynamical understanding, as contained in high-resolution models. (Credit: NOAA GFDL)

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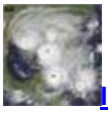
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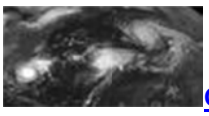
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