Hurricane intensity rises with sea surface temps

Some variations linked to warming air temperatures

By Melanie Lenart

High sea surface temperatures (SSTs) fuel stronger hurricanes.

No one argued about that at a recent workshop on tropical cyclones and climate change held at the International Research Institute for Climate Prediction in New York. The distinguished experts at the March workshop even agreed that Atlantic hurricane seasons are likely to remain active for at least several decades to come.

But what is driving the rise in SSTs so strongly linked to hurricane activity—global warming or natural variability? And how might other factors influence hurricane activity as the world warms? That was up for debate.

The answers have important implications for society. If hurricanes and other tropical cyclones are drawing their extra strength from global warming, then the world can expect to face a century or more of intense hurricanes For the landlocked Southwest, storms that start out as tropical cyclones can provide welcome rains and the occasional flood.

If the observed increase in hurricane intensity relates only to naturally recurring fluctuations, residents along the South and East coasts menaced by Atlantic hurricanes could expect a reprieve within a few decades. The East Pacific hurricane seasons that moisten the Southwest, meanwhile, could slow down in the near future, based on previous experience. A busier-than-average Atlantic season often means a calmer-than-usual East Pacific season, which many attribute to the influence of El Niño.

The power behind North Atlantic and North Pacific seasonal hurricanes combined has more than doubled since about the mid-1970s, as shown by research by Kerry Emanuel of the Massachusetts Institute of Technology (*Nature*, August 4, 2005). Reliable records go back to the 1940s. The power dissipation index (PDI) he used tallies tropical cyclones of any strength and includes their size and life span when considering how much energy they contained.

SSTs explained about 88 percent of the variability in Atlantic seasonal hurricane energy since 1970 when compared in multi-year trends, Emanuel noted during the workshop. As ocean temperatures rise, so does hurricane intensity (Figure 1).

Ocean temperatures have been rising around the world, most notably since the mid-1990s, as documented by Sydney Levitus and colleagues at the National Oceanographic Data Center (*Science*, March 24, 2000). The scientific community agrees that rising temperatures in the ocean and air relate to global warming from society's use of fossil fuels like coal, oil, and gas.

Emanuel showed evidence that Atlantic SSTs generally move in synch with northern hemisphere air temperatures when considered at the decadal scale (Figure 2). His results challenge the existence of the Atlantic Multidecadal Oscillation, a mode of natural variability in SSTs that was originally proposed by Michael Mann, Emanuel's co-author in the new study (*Eos*, June 13, 2006).

"I would submit to you that there's just no plain evidence now that you have an oscillation," Emanuel said. "There just isn't evidence in nature, as opposed to models, for this."

These findings imply that Atlantic SST will continue to increase with warming air temperatures, strengthening hurricanes at least to some degree as it does. Northern hemisphere temperatures are projected to rise by another 3 to 10 degrees Fahrenheit (F) throughout the twenty-first century.

Those arguing that natural variability, not global warming, is driving SST increases and other factors that influence hurricane strength include Christopher Landsea of the Hurricane Research Division. His paper with lead author Stanley Goldenberg, Alberto Mestas-Nuñez, and William Gray maintains that hurricane activity reflects a pattern of ups and downs that stay in place for decades at a time (*Science*, July 20, 2001).

"With Kerry's very interesting results today, I don't know if I'd say it's a cycle or not, but there is multi-decadal variability," Landsea said at the workshop, referring to Emanuel's work pairing air temperature with SST (Figure 2).

Landsea and Emanuel have been facing off on whether the increase in intense hurricanes stems from natural variability or global warming in a variety of venues, including a May media briefing and the pages of scientific journals (e.g., *Nature*, December 22, 2005).

Landsea argues that researchers have gotten better at detecting hurricanes in recent years, making it challenging to compare recent tallies with earlier ones. Even the Atlantic dataset, considered the world's best from about the mid-1940s, contains potential wind speed biases, he said. Meanwhile, he has little faith in the data used to assess global increases in cyclone strength, such as that used in the analysis by Peter Webster of the Georgia Institute of Technology and several colleagues that made headlines in 2005.

Webster and the others compared cyclone records derived from satellite images for six ocean basins around the world for 1975 through 2004. They found the number of intense storms

continued on page 4

Hurricanes, continued

had increased by 57 percent when they compared the second half of the record to the first half (*Science*, September 16, 2005). For these purposes, intense hurricanes refer to Category 4 and 5 cyclones, which have sustained wind speeds above 130 miles per hour.

SST had increased during the second half of the record as well, the authors noted. Their analysis of the East Pacific basin showed the number of intense hurricanes jumped from 36 in the first period (1975–1989) to 49 in the second period (1990–2004), even though the total number of hurricanes remained about the same for the two time frames.

The satellite measurements use factors such as eye definition and apparent cloud height to estimate cyclonic wind speeds. Landsea suggested the data may contain flaws because the measurements come from a variety of people who made their assessments during the year in question. Since the earlier time period, satellite coverage, hurricane recognition, and technology all have improved. The researcher said when he and a colleague applied modern detection techniques to satellite images from the earlier period for the Indian Ocean, they found several intense hurricanes that had not been included in the dataset used by Webster and others.

Webster, in turn, pointed to a recent reanalysis of the South Indian Ocean—the region where data presented the most problems—which reached similar results as their 2005 paper. The random errors canceled each other out in the end, he said, leading to the result that the Indian Ocean has seen an increase in intense hurricanes like the other five basins.

Other researchers are finding similar results from an independent data set that does not involve satellite images, Webster added. He pointed to a paper published earlier this month by Ryan Sriver and

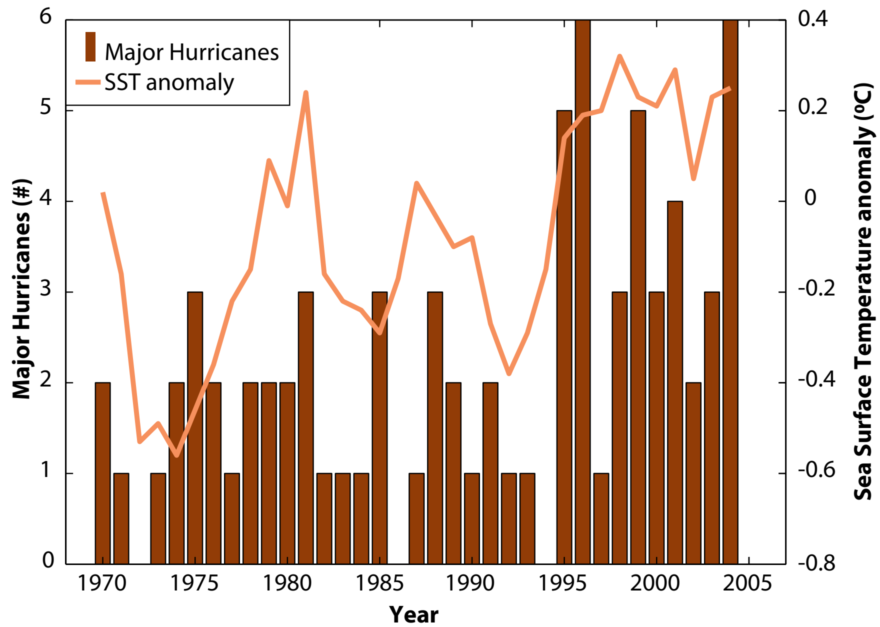

Figure 1. The number of major hurricanes a year in the northern Atlantic (bars) tends to reflect sea surface temperatures (SSTs) fluctuations (line). Major hurricanes have sustained winds above 110 miles per hour. Data courtesy of Christopher Landsea of the National Hurricane Center.

Matthew Huber of Purdue University (*Geophysical Research Letters*, June 2006).

The researchers used data for 1958–2001 developed by a European weather forecasting center to calculate the power dissipated by hurricanes and other tropical cyclones around the world. When comparing the pre-1979 data to the later part of the record, they found the overall PDI had increased by about a quarter. The Purdue researchers' results for the globe looked almost identical to Emanuel's results, even though they used a different approach to average out annual variability, and they considered the world rather than just the northern Atlantic and Pacific. The results also support Webster's results, as the authors note.

A global assessment using hurricane tracking data found only a small increase in intense hurricanes when splitting the last 20 years of data into two halves for comparison (*Geophysical Research Letters*, May 2006). By this assessment, global activity peaked between 1992 and 1998, a time frame that was split by the comparison of 1986–1995 to 1996–2005.

Researchers on both sides of the argument are puzzled by the extent of the apparent hurricane response to a relatively minor rise in SST. SSTs have risen by only about half a degree F on average globally, and slightly less than 1 degree F in the Atlantic region where hurricanes tend to develop.

Yet the average annual number of major hurricanes per year in the Atlantic more than doubled when comparing the 1995–2004 to the period 1971–1994, based on data from Landsea (Figure 1).

During the earlier time frame, Atlantic SSTs averaged below 83 degrees F during the peak hurricane season (August–October) in all but three years. Since 1995, Atlantic seasonal mean SST has averaged above 83 degrees—but the difference between the two averages represents only about 1 degree F.

"The sensitivity is a lot more than we would have predicted," Emanuel said, referring to his Atlantic research that showed a similar jump in intense hurricanes. The combined measure of

continued on page 5

Hurricanes, continued

hurricane power increased roughly four times more than his earlier models had projected it would based on the seasonal SST rise, he indicated. While his model suggested a 5 percent increase in peak winds with a 1 degree Celsius (C) warming, his analysis showed a 10 percent in peak winds with little more than half a degree C warming.

Emanuel suggested that the lack of major volcanic activity since Mount Pinatubo's eruption in 1991 could be affecting relevant dynamics of the upper atmosphere as well as SSTs. Volcanic eruptions can temper the warming for a year or so when their explosions spew aerosol particles up into the stratosphere. Pollution involving sulfate aerosols can have a similar temporary cooling effect. In fact, he suspects aerosols from pollution and volcanoes may have been behind the Atlantic's calm phase from the mid-1970s through the mid-1990s.

Vertical wind shear also has an important influence on individual storms, Emanuel noted, even though it doesn't show up as important in "smoothed" data in which values for several consecutive years are averaged together. Wind shear occurs when high-level winds move much faster or in a different direction than those at the surface. Hurricanes tend to form and persist more frequently in situations of low vertical wind shear.

Landsea agreed wind shear wielded an important influence on individual storms. "Most of the time, hurricanes are like people. They don't live up to anywhere near their potential. And most of the time it's because of wind shear," he said.

At the seasonal scale, vertical wind shear tends to decrease as SSTs increase, as Goldenberg and Landsea and their coauthors note in their 2001 paper.

Scientists have long known that SSTs must reach about 80 degrees F before

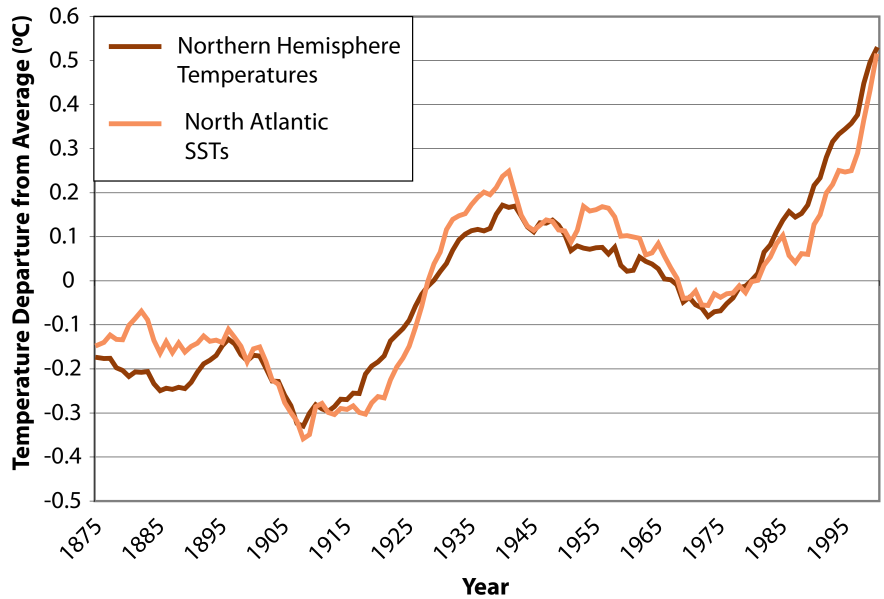

Figure 2. North Atlantic sea surface temperatures (SSTs) tend to closely match northern hemisphere air temperatures when both are smoothed at the decadal scale. In both cases, temperature values cover the peak hurricane season of August-October. Data courtesy of Kerry Emanuel of the Massachusetts Institute of Technology.

hurricanes can form. In the current climate, this temperature seems to serve as a general threshold for tropical convection—the process behind hurricanes, monsoons, and even many thunderstorms.

For instance, David Mitchell's research on the North America's monsoon system has found Arizona's summer monsoon rains won't begin until its moisture source, the Gulf of California, reaches close to 80 degrees Fahrenheit at the surface (*Journal of Climate*, September 1, 2002). Similarly, Chidong Zhang's research links this temperature threshold to the tropical convection behind many thunderstorms (*Journal of Climate*, October 1993).

What's more, Mitchell has found that the Gulf's SST must top 84 degrees to trigger the heavy rains that mark a strong monsoon in Arizona. Increases beyond that temperature don't have as dramatic of an impact, he indicated.

If a similar threshold applied to hurricane activity, that could help explain the sudden jump in intense Atlantic hurricanes from a relatively small change in temperature (Figure 1).

A threshold scenario would imply some good news: It could mean society is not necessarily facing a doubling in intense hurricane numbers for every rise of 1 degree Fahrenheit. On the other hand, it could imply that intense hurricanes will continue to thrive unless ocean basins drop below the threshold temperature.

In a warming world, even the threshold temperature for spawning hurricanes can shift. The SST needed to launch tropical convection rises with global air temperature, Emanuel said. This further complicates the issue.

Given the impact of hurricanes on society, this topic will continue to generate debate until the scientists involved reconcile their results with their models and each other. But it's worth remembering that nobody is predicting a decrease in Atlantic hurricane activity anytime soon.

Melanie Lenart is a postdoctoral research associate with the Climate Assessment for the Southwest (CLIMAS). The SWCO feature article archive can be accessed at the following link: http://www.ispe.arizona.edu/climas/forecasts/swarticles.html