communiqué

Hurricanes and coastal zone vulnerability in Central America and the Caribbean

The month of November has been hit with news about Hurricane Tomas, which poured torrential rains over already severely stricken Haiti. Also in this season, four cyclones developed in the western Caribbean and brought much rain and flooding to Central America and Mexico, where thousands had to be evacuated, since the heavy rains in the mountains had river banks bursting in coastal regions downstream. People had to live in temporary shelters for weeks.

Large populations that settle in floodplains and coastal lowlands are commonplace in many developing countries where regulations on urban sprawl are not usually enforced. As the end of the 2010 hurricane season approaches, two major questions remain: is the frequency of hurricanes really increasing in the Caribbean as a result of climate change? And can we predict them in better ways, to reduce damage and death?

Recent IAI project findings comparing current and medieval hurricane intensities confirm that warmer Atlantic surface temperatures lead to more hurricanes. Investigators have also estimated the number of people most vulnerable to hurricane risks and sea-level rise for some countries in the Caribbean region.

Whether tropical cyclone activity increases under a warmer climate is important for society. In particular, urban managers, real-estate developers, civil defense organizations and insurance companies have great interest in assessing the chances of greater hurricane incidence. Much interest is directed towards understanding the variability in genesis and landfall of the cyclones that develop in the North Atlantic basin.

IAI-sponsored hurricane and tropical cyclone research

Scientists in two projects sponsored by the IAI in its Collaborative Networks Program (CRN) are studying different aspects of tropical cyclones: a study of historic and prehistoric (paleo-) records of landfalling hurricanes, and another on the prediction of intensity and trajectory of cyclones in the North Atlantic and Eastern North Pacific basins.

The climate system is characterized by large-scale variability related to a number of different phenomena, such as the El Niño Southern Oscillation, the Atlantic Multidecadal Oscillation and the Pacific Decadal Oscillation. However, given the limited length of some of the observational records, there might be variability associated with not yet fully identified phenomena. Paleo-records show changes in large-scale meteorological and climate patterns that may account for the observed patterns of landfalling cyclones in the North Atlantic and West Pacific basins over centennial to millennial time scales.

Kam-biu Liu of Louisiana State University, in collaboration with a team of scientists in Costa Rica, Canada , Mexico, and other institutions in the United States, is leading a collaborative-research project on *Paleotempestology of the Caribbean region: a multi-proxy, multi-site study of the spatial and temporal*

variability of Caribbean hurricane activity[1]. Project investigators analyze past Caribbean hurricane activity using coastal lagoon sediments as well as isotopic composition of stalagmites, tree-rings, and corals from across the Caribbean basin. Their research has also improved our understanding of tropical jet streams. The team found that warm Atlantic sea surface temperatures are associated with more hurricanes. Findings from the 5-year project are providing the following regional picture:

- A new coral-based proxy record of Atlantic sea surface temperatures from the Bahamas for the period AD 1552-1991, the longest-ever established, suggests that higher hurricane activity before 1550 and after 1750 coincides with warmer sea surfaces. This confirms earlier data that showed that fewer storms formed in the Atlantic basin when the sea surface was cooler (*IAI Global Change Snapshot 2: http://bit.ly/d4HsI7*).

- Atlantic hurricane activity varies with climate patterns such as the Atlantic Multidecadal Oscillation and El Niño. Proxy data and modeling reveal peaks in Atlantic hurricane activity during medieval times (AD 900-1100) and again since 1980, explained by the prevalence of warmer sea surface temperatures in the Atlantic and cooler La Niña like conditions in the Pacific.

- Tropical cyclone activity in the Caribbean is not only sensitive to El Niño influences as commonly known, but also to the strength of the Intra-Americas Low-Level Jet vertical wind shear, to conversions of barotropic energy associated with the strong lateral wind shear, to the intensity of the regional-scale descending motion associated with the jet entrance, and to the Sea Surface Temperature cooling generated by the Intra-Americas Low-Level Jet at the sea surface.

One of the objectives of the IAI project on *Tropical Cyclones: current characteristics and potential changes under a warmer climate*[2] led by Graciela Binimelis de Raga of the Universidad Nacional Autónoma de Mexico, is to study the variability of tropical cyclones that develop in the Eastern North Pacific (EPAC) basin. Investigators from Costa Rica, Cuba and the US involved in this project aim to improve the understanding and prediction of tropical cyclones in the East Pacific, and on identifying potential global warming effects on cyclones.

The results of the study indicate that increases in the intensity of a cyclone are related to the low-level convergence of absolute vorticity. As the cyclone intensifies, the vertical layer, in which this low level convergence occurs, decreases in height. However, the intensification of tropical cyclones depends not only on mass and energy budgets in the atmosphere but also on their interaction with oceanic features, such as anticyclonic ocean eddies. During 1993-2007, 42 tropical cyclones experienced rapid and explosive deepening, and 68% of those showed an interaction with anticyclonic ocean eddies. Out of these, 93% reached major hurricane classification.

Employing a new theory about the relationship between precipitation and environmental variables, the team developed good approximations for predicting the intensity changes in the cyclone. But predicting the trajectory of hurricanes is currently still fraught with uncertainties, partly due to the lack of sufficient upper air measurements needed for the forecasting models *(IAI Global Change Snapshot 1: http://bit.ly/d6pUfV)*. Some progress has been made since the Mexican Weather Service now provides those upper air measurements twice per day, and researchers hope that this excellent support will continue in the future.

The two research teams have identified several sites in three Mexican States as suitable for paleo studies, and sedimentary core samples have already been taken from a number of coastal lakes and lagoons. Those samples are currently being analyzed and the results will allow investigators to reconstruct the changing patterns of tropical cyclone landfalls on Mexico's Pacific coast during the past centuries to millennia. The combined research of the two projects will be important in developing better estimates of future tropical

[1] Project web page: *http://www.oceanography.lsu.edu/liu.htm*

[2] Project web page: *http://cabernet.atmosfcu.unam.mx/IAI*

cyclone activity in the East Pacific basin and may reveal correlations with past periods of global or regional climate change associated with long-term variations in the El Niño Southern Oscillation and the Pacific Decadal Oscillation.

If warmer Atlantic surface leads to more hurricanes, is the same true for the Pacific? The role of the Pacific Decadal Oscillation

The two IAI projects have assembled a more complete record of landfalling cyclones developing in the East Pacific basin that impact Mexico. Historical records for colonial times and the early years of the Mexican Republic indicated that the landfalls show a multi-decadal variability that appears to be linked to atmospheric patterns known as the Pacific Decadal Oscillation (PDO). The warm phase of this oscillation is characterized by low pressure in the North Central Pacific and enhanced high pressure in the sub-tropical region. The opposite is observed in the cold phase of the Pacific Decadal Oscillation. This oscillation also affects the Eastern North Pacific basin and the number of tropical cyclones that form there. The Pacific Decadal Oscillation has recently been in a cold phase and appears to be reversing, which will lead to a decrease in the frequency of tropical cyclones in the Eastern North Pacific basin.

In fact, the number of tropical cyclones in the Eastern North Pacific basin has been decreasing recently. In contrast, the equivalent period for the North Atlantic basin shows an increasing trend. While different climate models have shown somewhat different cyclone frequencies under warmer conditions, on average they indicate a slight decrease in the Eastern North Pacific basin. Models that indicate consistent increases in cyclone frequencies in other basins, such as the North Atlantic and the western Pacific, give varying predictions for the Eastern North Pacific basin, and the reason for those mixed results remain unclear. To increase confidence in such predictions, one way forward may be to analyze high-resolution runs (e.g. 20 km), which is currently being done as part of the project.

Increased vulnerability

The vulnerability of coastal regions has increased over the last few decades. In recent years more people are moving to coastal areas as part of beachfront development and increased tourism. Mexico has also seen a large increase in population in coastal regions, and major investments have been made by the tourism industry in regions such as Cancun, the Mayan Riviera and Los Cabos. All of these tourist centers are located in regions frequently impacted by tropical cyclones. This has increased the number of people at risk, and the increase in property values has raised the financial stakes, too. As current global warming is also warming the oceans, future higher hurricane frequency can be expected (*IAI Global Change Snapshot#2: http://bit.ly/d4HsI7*). In many instances, the effects of landfalling or land-grazing tropical cyclones can be quite severe, such as the devastation in Cancun as a result of Wilma in 2005.

An IAI-sponsored analysis of geographical and demographic data (from 2006) using state-of-the-art geospatial techniques was undertaken by Nina Lam, also at Louisiana University, and shows that approximately 19 million people are currently living within vulnerable areas less than 1 km from the coast line in the conterminous U.S. and 12 million people live within three-meter elevation along the coast (*IAI Global Change Snapshot#3: http://bit.ly/c9OlM5*). Where these changes in population density and property development coincide with hurricane risk, they have caused very large increases over the last decades in the costs of damage when cyclones make landfall.

A similar study is now being developed by Dr. Liu´s team for the island countries in the Caribbean. According to recent, yet unconfirmed projections, a few small island countries would be inundated even with a 3-meter sea level rise. These estimates are the first step towards the development of a more comprehensive vulnerability assessment to be conducted for the region in the near future.

Recent publications have focused on the results of simulations of numerical climate models to assess the changes in tropical cyclones in the future. While numerical climate models have been improved over time, the majority do not have spatial resolution fine enough to identify tropical cyclones. They show only large-scale patterns associated with tropical cyclogenesis and look at the trends of those patterns in the

future. Several studies have indicated a possible higher frequency of more intense cyclones towards the end of the 21st century. Models that adequately reproduce the current climatology can also provide insight on how changes in large-scale atmospheric patterns may determine future trends. However, several coupled atmosphere-ocean models have not done a very good job in simulating the current climatology of tropical cyclones in the Eastern North Pacific basin, possibly because the ocean dynamic in the region is poorly represented. That ocean dynamic appears to be affecting cyclone development, particularly those close to the coast and most likely to make landfall. Our understanding of the mechanisms of tropical cyclone development and intensification in the East Pacific basin needs to improve before scenarios and projections to the latter part of the 21st century can be taken at face value.

Conclusions

From comparisons between current and medieval hurricane intensities it is clear that warmer Atlantic surface temperatures lead to more hurricanes. As current global warming is warming the oceans, an increase of hurricanes is to be expected. On the other hand, more recent data from sediment cores elsewhere have shown that hurricane track patterns may also change across the region and that much needs to be done to improve our understanding of the dynamics of hurricanes and their drivers.

More reliable hurricane forecasts are needed to better manage the vulnerabilities of people living in coastal areas. There is a critical lack of data for models used in forecasting (e.g. upper air soundings) that needs to be closed. As hurricanes and sea level rise don't stop at borders, the transnational collaboration between weather services in the region needs strengthening. IAI-funded research is contributing to model improvements, and hence, preparing the ground for better forecasts.

A comprehensive assessment about the potential increase in the intensity and frequency of hurricanes and other extreme events under rising temperatures is important to plan appropriate adaptation measures and policies. Findings from these IAI-sponsored research projects will guide IAI and its member countries in the development of vulnerability assessments and adaptation strategies.

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