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Assessing rainfall risk from tropical cyclones

PROBLEM

Tropical cyclones, or hurricanes as they are known in the North Atlantic, are intense storms capable of producing extreme rainfalls with devastating social and economic consequences. Yet a methodology to assess the risks posed by extreme cyclonic rainfall does not exist. Such a methodology would help engineers more properly size and design hydraulic infrastructure and goverment officials make better informed decisions about public safety. In principle, a hurricane rainfall model could be inferred from data or constructed using the results of sophisticated atmospheric circulation models, but adequate data is not available, and running atmospheric circulation models under a wide variety of scenarios is impractical.

APPROACH

MIT Professor Daniele Veneziano and postdoctoral associate Andreas Langousis followed four steps to determine the rainfall risk from hurricanes. They first described the hurricane in terms of key parameters like location, size, strength and translation velocity at landfall; then estimated the rate at which hurricanes with different parameters occur (recurrence model); calculated the probability that a hurricane with given parameters produces different rainfall intensities at a site of interest (maximum-rainfall model); and finally combined the recurrence and maximum-rainfall models to quantify risk.

Hurricane Katrina made landfall along the Louisiana coast on August 29, 2005. The storm's center passed about 35 miles from New Orleans. Image / NASA/Jeff Schmaltz, MODIS Land Rapid Response Team

Recurrence models have been developed for many tropical cyclone-prone areas, whereas existing maximum-rainfall models are rather primitive. To address this deficiency, Veneziano and Langousis developed a general and robust maximum-rainfall method that combines physical modeling with statistical data analysis. The physical model describes the circulation of air inside the hurricane and in particular predicts the vertical flow of water vapor, which is converted into rainfall. The end product of this physical model is a smooth rainfall intensity field that depends on the hurricane parameters. However, actual hurricane rainfall does not vary smoothly in space or time. The statistical component of the model accounts for this variability and, in combination with the physical model, gives the probability of different rainfall intensity levels at a chosen location during the hurricane.

FINDINGS

The researchers combined a hurricane recurrence model for the Gulf of Mexico with their maximum-rainfall model to assess the hurricane rainfall risk for New Orleans. They found that the highest rainfalls are produced by intense and slow-moving hurricanes that pass at a distance of about 18 miles from the city. From comparison with the risk posed by other storm types, they further concluded that hurricane rainfall is important for the design of critical hydraulic structures—those structures designed for long return periods of 100 years or more—whereas for short return periods other rainfall events dominate.

IMPACT

An interesting finding is that the instantaneous rainfall intensity during a hurricane may have the same order of magnitude as the intensity from a convective summer storm. But a hurricane is able to sustain those high rain rates over long periods. This understanding and the increased accuracy with which hurricane rainfall risk is evaluated will allow more effective mitigation of hurricane losses in coastal areas. One may also use the model to assess the risk effects of changes in the hurricane proneness of a region, for example, those brought about by changes in the global climate.

MORE

This research was the topic of Langousis' Ph.D. thesis and was published as a chapter by Veneziano and Langousis in "Hurricanes and Climate Change," (Springer 2008) and as a paper in the January 2009 issue of the Journal of Geophysical Research.

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