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Getting to the Heart of the Storm

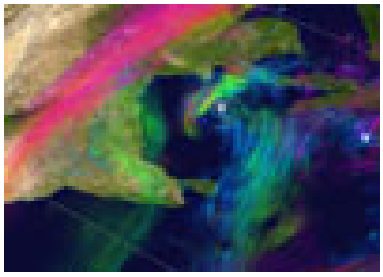
As the world's supercomputing community heads to New Orleans for the SC10 conference, who can forget the immense destruction wrought by Hurricane Katrina just 5 years ago? The costliest Atlantic Ocean hurricane in history, Katrina caused $80 billion in damage, killed over 1,800 people, and displaced thousands more.

On the other side of the world, Cyclone Nargis devastated Myanmar (formerly Burma) along the Indian Ocean in 2008, causing over 133,000 fatalities and $10 billion in damage. Nargis was one of the 10 deadliest tropical cyclones.

One way to reduce such catastrophic losses is to extend the lead-time for accurate hurricane predictions, giving residents more warning. Researchers running a high-resolution global climate model on NASA's Pleiades and Discover supercomputers have made remarkable progress with some of hurricane prediction's thorniest problems.

"During the past 20 years, track forecasts have been steadily improving," said Bo-Wen Shen, research scientist at NASA Goddard Space Flight Center, Greenbelt, Maryland. Shen and collaborators' simulations of Katrina realistically track its movement through the Gulf of Mexico over 5 days.

A greater challenge with simulating Katrina was the rapid intensification of its winds. Katrina increased from a Category 3 to a Category 5 hurricane overnight, reaching sustained winds of 175 miles per hour (280 kilometers per hour) before making landfall as a Category 3 storm.



Genesis of the very severe cyclonic storm Nargis (2008) associated with the equatorial Rossby wave: (a) A pair of low-level vortices at 96h simulation (labeled with ´V´) indicate formation of the Rossby wave. Cyclone Nargis formed when the northern vortex strengthened. (Bryan Green, NASA/Ames; Bo-wen Shen, NASA/Goddard)

Intensity forecasts have lagged behind track forecasts in accuracy. The major reason is that "hurricane development involves multiscale interactions," Shen said. While hurricanes are classified as medium-scale events, they are impacted by things at much larger and smaller scales. With rapid intensification, factors such as large-scale atmospheric waves and deep convection provide the fuel.

A high-resolution global model can realistically capture these multiple scales, which are conventionally classified as large-scale, mesoscale, and convective-scale. Running at 1/8-degree (about 10-kilometer) resolution, Shen's Katrina simulations produce rapid intensification and the characteristic drop in minimal sea-level pressure. The model also properly simulates Katrina's eyewall, the area of maximum wind speed surrounding the eye.

With later storms, Shen has been focusing on forecasts of tropical cyclone formation and subsequent movement and intensity with a lead-time beyond 2 days. "There is no operational center doing them," he explained. Nargis represents an especially tough case, as it formed and made landfall within 5 days. "That is very short, and it had huge impact on the area," Shen said.

In Shen's 7-day, 1/4-degree simulations, two vortices form in the Indian Ocean, one in the Northern Hemisphere and the other in Southern Hemisphere. Due to interactions among a large-scale atmospheric wave, regional monsoonal circulation, and smaller-scale precipitation processes, the northern vortex intensifies into Nargis. Increased vertical wind shear suppresses the southern vortex, which dissipates.

Shen's is the first model to indicate the formation of Nargis 5 days in advance, and it predicts intensification quite well during days 5 to 7.

Back in the Atlantic, some of the most powerful hurricanes form near Africa's Cape Verde. Nearly 85 percent of intense hurricanes originate as African easterly waves (AEWs). Shen's recent 30-day simulations predict multiple AEWs and the subsequent formation of hurricanes. In one simulation, a vortex appears after 22 days and then intensifies into Hurricane Helene (2006). The simulation results show good agreement with scientific observations.

"If we can provide reliable predictions associated with AEWs, we can extend the lead-time of forecasting major hurricane formation and give people more time to prepare," Shen said.

More information:

+ Recent Advances in Global Hurricane Modeling after Katrina (PDF-270 KB)
+ Supercomputer Reproduces a Cyclone's Birth, May Boost Forecasting

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