TESTIMONY

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Subcommittee on Energy and Environment and
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A joint hearing on:
The State of Hurricane Research and H.R. 2407, and the National Hurricane Research Initiative Act of 2007

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Introduction

Chairman Baird, Chairman Lampson, and Members of the two Subcommittees, thank you for the opportunity to speak with you today on the need for advancing hurricane research. My name is Shuyi Chen and I am a Professor at the Rosenstiel School of Marine and Atmospheric Science at the University of Miami. It is an honor for me to testify on the National Hurricane Research Initiative Act of 2007.

My research and professional service have centered on understanding and improving prediction of tropical weather systems, especially hurricanes. I served as an Editor for *Weather and Forecasting* of the American Meteorological Society from 2004-2007. I currently serve on the American Geophysical Union Committee on Cloud and Precipitation and the National Science Foundation Science Steering Committee on Coastal Ocean Processes. I lead a research group at the University of Miami that has developed a next-generation high-resolution coupled atmosphere-wave-ocean model to better understand hurricane structure and intensity and to improve hurricane prediction. I am a principal investigator for two recent major hurricane research programs. One is the National Science Foundation supported Hurricane Rainbands and Intensity Change Experiment (RAINEX), which used three Doppler radar aircraft and collected unprecedented in-situ data in Hurricanes Katrina, Rita, and Ophelia during the 2005 Hurricane Season. The other is the Coupled Boundary Layer Air-Sea Transfer (CBLAST)-Hurricane sponsored by the Office of Naval Research, which aimed to better understand the role of air-sea interaction in hurricane structure and intensity change. These research results have been published in ***Science***[1] and ***BAMS***[2]. Currently I am a lead scientist for a large international program to study the tropical cyclones in the West Pacific.

The U.S. has become increasingly vulnerable to hurricanes, not only because of the uncertainty of hurricane response to a warming climate, but also the rapid growth of the costal population. The averaged annual cost for hurricane-related losses has increased to more than $10 billion in recent years, not to mention the loss of life and human suffering as seen, for example, in the case of Hurricane Katrina. The

[1] Houze, R.A., S.S. Chen, B. Smull, W.C. Lee, M. Bell, 2007: Hurricane intensity and eyewall replacement. *Science*, **315**, 1235-1239.
[2] Chen, S.S., J.F. Price, W. Zhao, M.A. Donelan, and E.J. Walsh, 2007: The CBLAST-Hurricane Program and the next-generation fully coupled atmosphere-wave-ocean models for hurricane research and prediction. *Bull. Amer. Meteor. Soc.*, **88**, 311-317.

devastating landfall hurricane events in 2004-2005 have led to four major national reports calling for action to substantially improve hurricane forecasts (AGU[3], NSB[4], NSAB[5], and OFCM[6]), particularly the rapid intensity change of hurricanes threatening the U.S. Accurate and timely forecasts and warnings can help to avoid unnecessary loss of life and reduce economic losses related to land-falling hurricanes. Recent advance in science and technology gives us hope for optimism. Meeting the challenges put forward by the NSB, AGU, NSAB and OFCM can only be accomplished through fundamental research to increase our understanding of hurricanes as an integrated science and engineering problem, and to use this understanding to improve our ability to predict hurricanes, mitigate their impacts, and react to an impending landfall.

The key to success is development of an integrated hurricane forecasting system that substantially improves upon the current 1-5 day forecasts of intensity and track, and extends it to include detailed forecasts of extreme winds, rain, storm surge, and severe weather such as tornadoes and inland flooding, which are critical for emergency response to hurricane impacts. There is also a need to extend the forecast horizon to a time scale of weeks, which requires making probabilistic forecasts of hurricane genesis, that would provide extremely valuable for emergency planning and preparedness. The bill H.R. 2407, if passed, will represent a real opportunity for the Nation to effectively meet the challenge before us. ***I urge that the Committees give the highest priority to the passage of the H.R. 2407, as this presents an excellent plan for improving hurricane forecasting that will ultimately reduce the damage of these dangerous storms.***

Deficiencies in the Current Forecast System

Hurricane track forecasts and warnings have improved over the past 20 years due mostly to improved computer models, global observations from satellites, and methods of assimilating many observations into models. These improvements have undoubtedly saved countless lives and billions of dollars in property damage. However, hurricane intensity forecasts have shown little improvement. The lack of skill in present forecasts of hurricane structure and intensity, especially rapid intensity change, are attributed in part to deficiencies in the current prediction models: insufficient grid resolution, inaccurate model physics, lack of full coupling to a dynamic ocean, and inadequate observations and data assimilation of hurricane structures.

Current operational forecast models are not adequate for predicting hurricane wind and rain structure and intensity change, as highlighted by the report of the NOAA SAB Hurricane Intensity Research Working Group. Recent research results[2] Chen et al. (2007) have demonstrated the impact of increasing model grid resolutions on forecasting of hurricane structure and intensity change (Fig. 1). Clearly the lower resolution models are incapable of predicting critical details in the hurricane core region controlling the rapid intensification of a hurricane. A research experiment carried out during RAINEX in Hurricane Katrina (Fig. 2) shows the potential capability of high-resolution models in forecasting rapid intensification. The required computer power increases by 5-10 times for each halving of the grid spacing, so this requires a substantial investment in high performance computing. Moving to high resolution also

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[3] American Geophysical Union, 2006: *Hurricanes and the U.S. Gulf Coast: Science and Sustainable Rebuilding.* www.agu.org/report/hurricanes/.

[4] NOAA Science Advisory Board, 2006: *Majority Report, Hurricane Intensity Research Working Group*, www.sab.noaa.gov/Reports/HIRWG_final73.pdf

[5] National Science Board, 2007: *Hurricane Warning: The critical need for a national hurricane research initiative*. National Science Foundation, Arlington, Virginia, www.nsf.gov/nsb, 36 pp.

[6] Office of the Federal Coordinator for Meteorological Services and Supporting Research, 2007: *Interagency strategic research plan for tropical cyclones: The way ahead*, FCM-P36-2007. Silver Spring, Maryland, www.ofcm.gov/p36-isrtc/pdf/entire_p36_2007.pdf

requires an investment in research to further our understanding and our ability of reproducing in forecast models the manner by which air-sea interactions and cloud development are incorporated. Improvement in computer models, high performance computers, innovative observations and data assimilation of the hurricane structure will have to be achieved in concert to guarantee substantive progress in predicting hurricane intensity change.

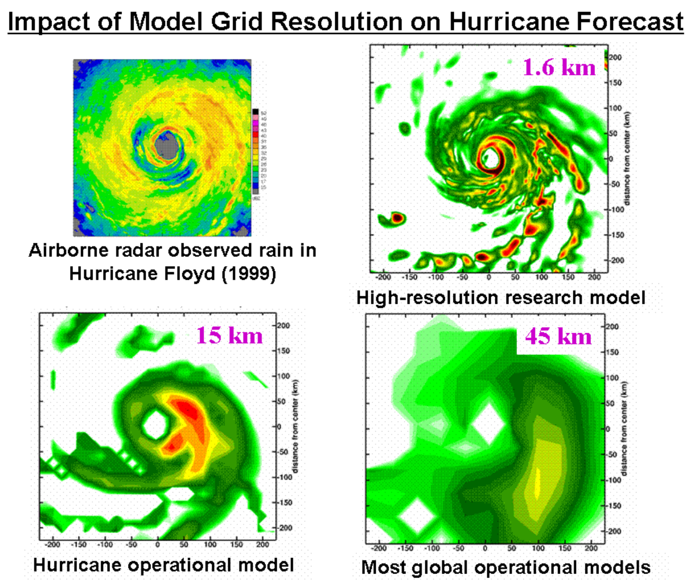

Figure 1. The top left is a radar observation for Hurricane Floyd (1999). The other panels (in clockwise order) are forecast precipitation patterns obtained from a high-resolution (1.6 km) research model, from the typical resolution used by current hurricane models (15 km), and from current global operational models (45 km). The top right-hand corner of each panel shows the scale of the model grids relative to the hurricane.

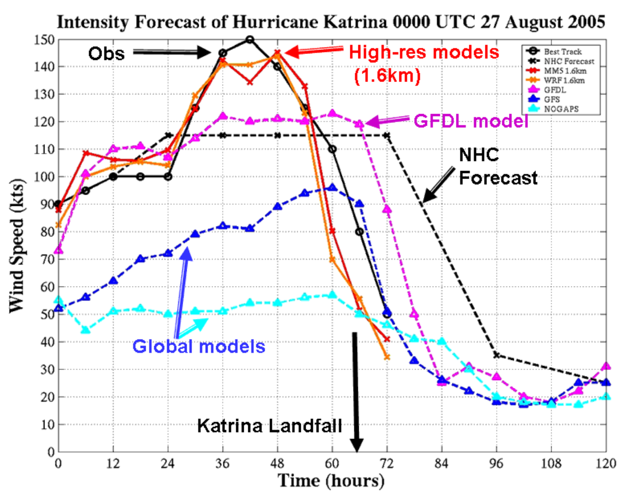

Figure 2. Observed storm intensity (the best track in black), the NHC official forecast made ~70 hr before landfall (dashed black line), and forecast made by computer models with various grid resolutions. Vertical axis is max wind speed and horizontal is time in hours. Current operational global models have no skill, the best current operational hurricane model by the GFDL (magenta) did not capture the rapid intensification, and two high-resolution research models (WRF and MM5 with 1.6 km grid spacing, brown and red) were able to forecast the rapid intensification.

The Next-Generation Hurricane Forecast System

A key to improving forecast of hurricane intensity and landfall impact is to develop computer models that are capable of resolving the inner core structures (eye and eyewall) and rainbands in a hurricane and realistically representing the physical processes governing rapid intensity change, such as the transfer of heat, moisture, and momentum at the air-sea interface and the phase changes of water vapor in the atmosphere. The next-generation prediction models must be able to resolve features on a horizontal scale of ~1 km or less to capture the gradients across the eyewall boundaries and the interactions between the inner core and rainbands. Furthermore, the intensification and decay of a hurricane largely depends upon two competing processes at the air-sea interface: 1) the heat and moisture fluxes that fuel the storm and 2) the dissipation of kinetic energy associated with wind stress on the ocean surface. Figure 3 shows an example of the high-resolution coupled models developed at the University of Miami in collaboration with NCAR capable of capturing the detailed structure of rain, wind, ocean surface waves, sea surface temperature and currents. These detailed forecast fields can bridge the gap between the traditional forecast of track and intensity and realistic hurricane impacts at landfall.

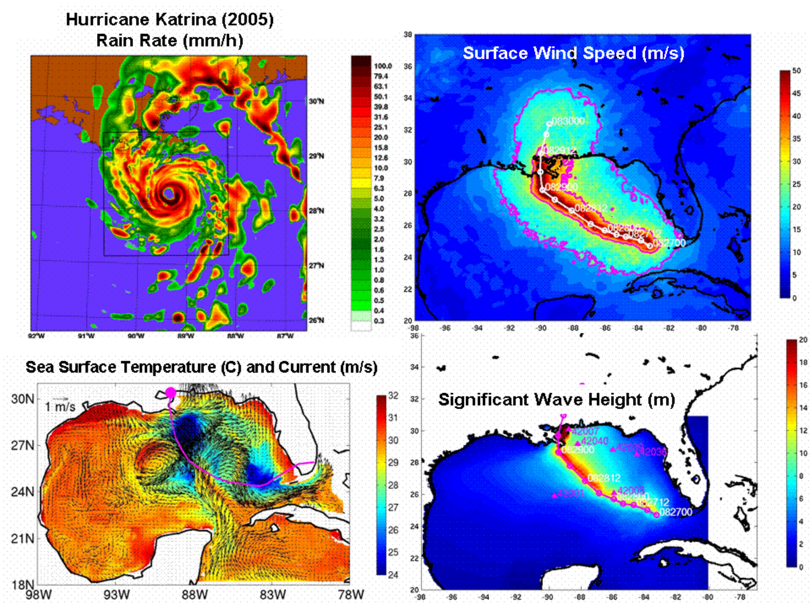

Figure 3. High-resolution coupled forecast of rain rate (top-left), surface wind speed (top-right), sea surface temperature and ocean current (bottom-left), and significant wave height (bottom-right) in Hurricane Katrina from 0000 UTC 27 Aug – 0000 UTC 30 Aug 2005.

Furthermore, the success of forecasting hurricane intensity change will depend on the ability of assimilating new observations and ensemble-based probabilistic forecasts using the high-resolution atmosphere-wave-ocean coupled models. A better understanding of the predictability of fine scale features in the extreme wind and rain fields associated with hurricanes is also critical. The NSB report and the H.R. 2407 Section 3 have highlighted these urgent needs as high-priority for the research community to address.

A further issue in increasing the fidelity of hurricane intensity and track forecasts, especially for increasing the forecast horizon beyond 5 days, is improved global weather predication models that provide the large-scale forcing for the high resolution storm-scale forecasts. The resolution and number of ensemble members of the NOAA NCEP Global Forecasting System are significantly lower than that of the European Centre for Medium Range Weather Forecasting (ECMWF). The higher resolution ECMWF model is being used as the basis for extended range hurricane forecasting, and the synergy of the higher resolution global weather model having a large number of ensemble members with the high-resolution coupled atmosphere-wave-ocean storm-scale model provides the foundation for a substantially improved hurricane forecasting system with improved accuracy, more specific information regarding impacts, and an extended time horizon for the forecasts.

An Integrated Approach for Improving Hurricane Forecast and Emergency Response

To improve preparedness in response to hurricane impacts, a new integrated approach in hurricane forecasting and warning is sorely needed. This system should be capable of:

- Providing accurate forecast of high-resolution wind, storm surge, rain, and flood on the short lead time of days to hours, and potential hurricane genesis and track on extended lead time of weeks;
- Assessing potential hurricane impacts on human lives (fatalities and suffering) and broad-range economy loss (property and infrastructure damage, power outage, insured losses) based on the forecast of wind, surge, rain, and flood;
- Communicating with federal and local government to optimize the utility of the forecast and assessment products in emergency response;
- Rapidly transferring research products to NOAA and other operations;
- Training the next-generation scientists and forecasters with innovative tools for hurricane prediction and impact mitigation;
- Educating vulnerable residents on the application value of the new information coming out of the integrated forecast system on short and long lead times.

The ultimate goal of this integrated system is to improve risk assessment and mitigation over the U.S. coastal regions so lives will be saved and economic loss reduced.

Conclusion

The research required to address these challenges requires an ambitious, transformative and risky research agenda that stimulates new directions and styles of inquiry in research including collaborative, cross-disciplinary and interdisciplinary approaches. New centers and partnerships between university researchers, government agencies and the private sector are needed to meet these challenges. The academic hurricane research community is ready to lead an ambitious and transformative interdisciplinary research agenda required to lay the foundations for development of an integrated hurricane forecast and response system that will help mitigate hurricane damage. The envisioned research agenda will advance our ability to collect accurate observations from the atmosphere, air-sea interface, and the ocean and to assimilate such observations for hurricane forecasting, to improve prediction models, to use forecast products for better risk assessment, and ultimately to mitigate hurricane damage. There is critical need for the involvement of the NSF to support the ambitious and risky interdisciplinary research agenda, in ways that go beyond what is feasible in individual mission oriented government agencies. The development and operation of such an integrated hurricane forecast and response system requires collaboration and coordination among many research disciplines and among the research community and government and impacted sectors. Further, successful implementation of such a system requires the education of a new generation of scientists, technicians, forecasters, government managers, and be guaranteed with a smooth transition from research to NOAA operations.

In closing, it is of no doubt that improving the hurricane forecast and response to save lives and reduce economic loss should be a national priority. The rapid advancement of science and technology presents us with an unprecedented capability and opportunity to develop the integrated hurricane forecast and response system that will support risk assessments and emergency management by reducing warning areas and providing forecasts with longer lead time. There is no reason for further delay of full-scale support for such development, which is long over due. We are confident that with the requested fiscal support the hurricane research community will meet the scientific and engineering challenges and in collaboration with the relevant government agencies will develop and implement such an integrated hurricane forecast and response system for operations in the coming decade.