**WRITTEN TESTIMONY OF
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**HEARING ON HURRICANE RESEARCH INITIATIVE LEGISLATION
(H.R. 2407)**

**BEFORE THE
COMMITTEE ON SCIENCE AND TECHNOLOGY
JOINT HEARING: SUBCOMMITTEE ON ENERGY AND ENVIRONMENT
AND SUBCOMMITTEE ON RESEARCH AND SCIENCE EDUCATION
U.S. HOUSE OF REPRESENTATIVES**

JUNE 26, 2008

Thank you, Mr. Chairman and Members of the Committee for this opportunity to testify on the importance of increased hurricane research and preparedness. I am Jack Hayes, Assistant Administrator for Weather Services and the Director of the National Weather Service (NWS). The National Weather Service is a line office of the National Oceanic and Atmospheric Administration (NOAA), within the Department of Commerce (DOC).

The proposed legislation, H.R. 2407, the *National Hurricane Research Initiative Act of 2007*, recognizes the challenge we face as a nation, with regard to hurricane and tropical cyclones, and we applaud the Committee for addressing this complex issue.

<u>Introduction</u>

We agree with the overall goal of the bill to improve hurricane forecasting and preparedness. We also agree the most effective path forward is for NOAA and the National Science Foundation (NSF) to co-chair a committee, such as the National Hurricane Research Alliance, to oversee and coordinate federally funded research efforts, and to ensure successful research efforts can be incorporated into the operational forecast and warning environment to improve hurricane forecasts and services. However, the proposed authorization levels in the bill are significantly higher than current funding levels, and are therefore inconsistent with the Administration's priorities.

NOAA is already addressing many components to the overall hurricane and tropical cyclone issue outlined in HR 2407. Over the past year NOAA developed the Hurricane Forecast Improvement Project (HFIP – described in detail below), which focuses our efforts on improved forecasts of track, intensity, wind fields, and storm surge, which require improved observations, modeling, and computing capability. We are making progress on other activities described in the bill as well, such as improved forecasts for

inland flooding, and these efforts will further benefit from improved hurricane track and intensity predictions.

Many federal agencies, state and local governments, and the academic and research community are focused on improving hurricane prediction. NOAA's expertise can be leveraged for most of the items outlined in the Purposes section of the bill, including research to understand the impact between hurricanes, climate, and natural ecosystems. NOAA conducts much of this relevant research through its laboratories and centers including the Atlantic Oceanographic and Meteorological Laboratory, the Earth System Research Laboratory, the Geophysical Fluid Dynamics Laboratory, and the National Centers for Environmental Prediction. Other federal agencies identified in the bill are better suited to lead the work and provide expertise for engineered structures, the national infrastructure, disaster response/recovery technology and evacuation planning. For example, DOC's National Institute of Standards and Technology does extensive work with the impact of wind on structures and the Federal Emergency Management Agency in the Department of Homeland Security has expertise for evacuation planning and has an extensive program addressing technologies for disaster response and recovery.

Section 4 of the bill proposes a National Infrastructure Database. We do not believe NOAA is properly positioned to lead the effort for such information. We suggest other federal agencies may offer a more suitable lead for this activity. We believe efforts focused on improved track and intensity forecasts will have the greatest impact to the nation, but efforts in all other areas are needed as well.

Since 1990, hurricane forecast track accuracy has increased by about 50 percent through the use of enhanced observations, improved model guidance, and increased forecaster expertise. This has led to increased lead time and somewhat smaller warning areas allowing more time for emergency managers to coordinate their evacuation and preparedness activities. However, little progress has been made during this period to increase the accuracy of intensity[1] forecasts and to identify rapid intensity changes in hurricanes. Rapid intensity change presents a challenge to hurricane forecasters during the life of a storm and a serious problem for emergency managers when it occurs just prior to landfall. Rapid intensity events constitute an approximate two-category change within 1 day, and have a significant impact on preparedness and evacuation actions for emergency managers. Recent cases of rapid intensity changes at or near the U.S. coastline have occurred with little or no warning.

With recent catastrophic events in 2005 of Katrina and Wilma, back-to-back Category 5 storms in the Caribbean Sea in 2007 (Dean and Felix), and storms that rapidly intensified just prior to landfall like Charley in 2004 and Humberto in 2007, the time is now for the federal government and our partners in state and local governments, and the research and academic communities, to undertake an aggressive effort to improve our national hurricane forecasting capability.

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[1] Defined by NOAA's National Weather Service as the peak 1-minute sustained 10-m wind anywhere in the storm (http://www.weather.gov/directives/sym/pd01006004curr.pdf)

This message and sense of urgency for improved hurricane forecasts is consistent with the overarching recommendations in three recent reports: the 2006 NOAA Science Advisory Board Hurricane Intensity Research Working Group report, the 2007 report of the National Science Foundation (NSF) National Science Board (NSB): *Hurricane Warning: The Critical Need for a National Hurricane Research Initiative*, and the 2007 report issued by the Office of the Federal Coordinator of Meteorological Services (OFCM): *Interagency Strategic Research Plan for Tropical Cyclones - The Way Ahead.* All three reports recommend a significant increase in funding for hurricane and tropical cyclone research and development, and transition of research to operations. In addition, many studies and reports have shown that investments in forecasts and other warning information needed for community planners have a significant return for the nation, including the 2007 report issued by the National Hazards Review,[2] *Hurricane Forecasting: The State of the Art*, and a report from the Multihazard Mitigation Council (MMC) of the National Institute of Building Sciences**.**[3]

Need for Improved Hurricane Forecasts

> *"Billions of tax dollars have been provided for rescue, recovery, and rebuilding after hurricanes strike…recent hurricanes have focused public attention on the imperative to enhance our understanding of tropical weather systems and their multi-faceted impacts, ranging from geophysical and engineering elements to human economic dimensions.…improving our nation's ability to become more resilient to hurricane impacts."* [4]

More than 50 percent of the U.S. population is living within 50 miles of the coast,[5] and roughly 180 million people visit the coast annually. The coastal population explosion (Figure 1) over the last half-century translates to increased risks for these coastal communities. As the U.S. coastline continues to develop, more people will be at risk and impacts are expected to further increase. Annual U.S. hurricane losses average about $10 billion and a recent historical analysis of hurricane damages from 1900 to 2005 suggests a doubling of economic losses from land falling hurricanes every ten years.[6] The need for substantial improvements in hurricane track and intensity forecast capabilities has never been greater. This is a sentiment echoed by our partners in the emergency management communities at the national, regional and local levels, who are issuing strong demands to extend hurricane forecast lead times. These extended lead times are necessary to evacuate some coastal locations that now require evacuation "orders" be issued 48 to 72 hours in advance.

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[2] Willoughby, H. et al., "Hurricane Forecasting: The State of the Art", National Hazards Review © ASCE, August 2007, p.45-49.
[3] http://www.nibs.org/MMC/MitigationSavingsReport/Part1_final.pdf
[4] *Hurricane Warning: The Critical Need for a National Hurricane Research Initiative*, National Science Board NSB-06-115, January 12, 2007
[5] http://www.ofcm.noaa.gov/p36-isrtc/fcm-p36.htm
[6] Pielke, R. A., Jr., J. Gratz, C. W. Landsea, D. Collins, M. Saunders, and R. Musulin, 2007: Normalized Hurricane Damages in the United States: 1900-2005. Accepted for publications in the *Bull. Amer. Met. Soc.*

Highly accurate hurricane forecasts are needed to ensure the timely issuance of reliable hurricane watches and warnings. These forecasts are an essential factor in avoiding loss of life and injury and reduced property loss and economic disruption. Without accurate hurricane forecasts, emergency managers are unable to take necessary decisive action to save lives and mitigate economic loses. The expected outcomes of the HFIP are to provide higher quality information with associated probabilities on high impact variables, such as wind speed, precipitation, and storm surge; and to extend the lead time beyond five days, and reduce the length and duration of watches and warnings.

Operational Needs

Operational needs expressed by the tropical cyclone operations centers (National Hurricane Center (NHC), Central Pacific Hurricane Center, and the Joint Typhoon Warning Center) are detailed in the OFCM report, *Interagency Strategic Research Plan for Tropical Cyclones – The Way Ahead.* These operational needs support the overarching goal to produce improved wind speed, precipitation, and storm surge analysis and forecast information and to provide associated probabilities, as well as the uncertainty in the forecasts, to emergency managers and other decision makers. To meet these operational needs, critical steps to ensure the future success of the nation's hurricane forecast and warning program include: focused applied research and transition efforts to improve computer models; advanced observations and observational strategies; improved processing capabilities to include those data into the models; expanded forecaster tools; and properly applied human and infrastructure resources. Furthermore, extensive collaboration with social scientists is also needed to help ensure the information presented to the public can be understood in clear terms by non-meteorologists.

NOAA's mission-oriented requirements for operational system development, implementation and sustained operations guide us toward attaining a specific set of short-term forecast goals, related applied research focus areas, and infrastructure investments. Within this mission-oriented context, the research and transition activities needed to improve operational forecasts are accomplished with the aid of testbeds strategically aligned with the needs of the forecast centers. In general, testbeds are a collaborative environment for conducting integrative research, testing new ideas in an end-to-end fashion under the rigors of operational constraints (real and simulated), and facilitating the deployment into operational practice of knowledge gained in research (NSB Report 2007).

Testbeds, such as the Joint Hurricane Testbed in Miami, the Developmental Testbed Center in Boulder, and the Joint Center for Satellite Data Assimilation in Maryland, are oriented toward improving operational hurricane forecasts and guidance. These testbeds provide evolutionary pathways to coordinate applied model and technology advancements to specific forecast requirements and focus on identifying and effecting the transition of research and technologies capable of providing immediate and justifiable improvements to operational hurricane forecasts.

Bridging across the OFCM and NSB reports, the NOAA HFIP plan involves evolutionary and transformational pathways that require coordination between key federal and academic leaders in order to properly support the required research and development and to improve the operational hurricane track and intensity forecasts.

Building off the Nation's Interagency Strategic Research Plan

Within our HFIP, we are working to build upon recent planning efforts of the NSF, NSB and OFCM[7] to engage the broader research community in improving hurricane forecasts. The HFIP's goals include improving the accuracy, reliability, and extending the lead time of hurricane forecasts and increasing confidence in those forecasts by customers and decision makers, especially those in the emergency management community. These goals were also echoed by the NOAA Science Advisory Board's Hurricane Intensity Research Working Group.

Within the framework of operational hurricane forecast improvements, NOAA seeks a partnership among the federal and academic communities to align the broader science and engineering community with the operational community to realize the greatest benefits for the country. This broader partnership is critical to effectively address HFIP goals and for NOAA to transition new research and technology into operations.

NOAA Strategy to Align with the Larger Community

The key to success in improving hurricane prediction is leveraging the capabilities of all partners: federal, state, local, academic, and private sector. Communication between federal partners and the external community on operational needs and associated research focus areas is necessary to achieve both immediate successes and scientific research advances that hold promise for the future. A highly visible and independent oversight activity will be identified. An annual interagency program review with a significant external (to NOAA) role is being planned with the Interdepartmental Hurricane Conference, as a possible venue. This conference leads up to an annual summit attended by agency, academia, and private sector research leadership.

NOAA is working with the NSF to formally establish the National Hurricane Research Alliance to ensure coordination across the broad spectrum of activities from observations to data assimilation to modeling to basic research. The Alliance will include key federal agencies, including NSF, the National Aeronautics and Space Administration (NASA), and the Navy (including the Office of Naval Research). This Alliance will leverage existing federal hurricane coordination efforts, including those from the OFCM Services and Supporting Research, to manage overall roles and responsibilities to improve overall

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[7] - Office of the Federal Coordinator for Meteorology (OFCM) P-36, 2007; *Interagency Strategic Research Plan for Tropical Cyclones - The Way Ahead.*
  - National Science Board, 2007; *Hurricane Warning: The Critical Need for a National Hurricane Research Initiative.*
  - National Oceanic and Atmospheric Administration Science Advisory Board, Hurricane Intensity Research Working Group Majority Report

accuracy and reliability of hurricane forecasts. Through this Alliance, NOAA and NSF will work with other federal agencies to maximize the use of the considerable non-federal assets in conducting much of the hurricane research and development described in the National Hurricane Research Initiative Act of 2007, and in developing and disseminating related products and services.

Federal Investments

NOAA needs to ensure new breakthroughs in hurricane research and technology can be accelerated into operational forecasting systems. The importance of addressing operational forecast requirements and related research focus areas requires sufficient investments that include:

- Easy access to current and planned observing systems:
- Increased high performance computing capacity and capability to allow for higher resolution models:
- Institutionalized and transition research to operations to ensure an efficient process to incorporate demonstrated research results in modeling and observing systems:
- A plan for sufficient operations and maintenance resources: and
- Enhanced interactions with the broader science and engineering community to provide increased understanding of hurricanes while using all available resources.

Therefore, a sustained and broad hurricane research initiative would make the best use of these capabilities and improve our understanding of and ability to predict hurricanes.

<u>Hurricane Forecast Improvement Project (HFIP)</u>

NOAA established the Hurricane Forecast Improvement Project (HFIP) to develop a unified 10-year plan to improve our one to five day tropical cyclone forecasts, with an emphasis on rapid intensity change. The goal of HFIP is to improve the accuracy and reliability of hurricane forecasts and warnings and to increase the confidence in those forecasts to enhance mitigation and preparedness decisions by emergency management officials at all levels of government and by individuals.

The scope of the HFIP plan (Figure 2) encompasses research and development:
- To improve understanding, with emphasis on the phenomena related to predictability of rapid intensity[8] change and secondary eyewall phenomena;
- To improve observations and observational strategies for the hurricane and its environment;
- To uncover novel methods for data assimilation, to utilize the diverse range of existing and new observations;
- To advance high-resolution numerical prediction and ensemble predictions systems for hurricane forecast guidance; and

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[8] Rapid intensification is defined at a 30kt increase of sustained maximum winds in 24 hours or less.

- To accelerate the transfer of research results into operational forecasting.

While NOAA is developing its level of involvement in the broader spectrum of issues identified in the NSB report, NOAA focused HFIP on the research and development issues identified by operational needs that will lead to improved hurricane forecast guidance and tools. HFIP aims to reduce and quantify the uncertainty in all forecast guidance, including high spatial/temporal resolution gridded wind speed, precipitation, storm surge analysis and forecast information. Our efforts will focus on improved track forecasts, improved intensity forecasts, improved rapid intensity change forecasts, and improved lead time.

Below are four examples of our metrics:

1) Reduce average track error by 50 percent for Days 1 through 5 (Figure 3)

Based on input from emergency managers at all levels, the forecast of the location or track of the tropical cyclone is most important. Over the past couple of decades the hurricane community has put most of its effort and resources into reducing the track error. While the limits of predictability for track error are not fully understood, NOAA will seek to reduce the track error by 50 percent over the next decade, which is the same level of improvement as NOAA was able to achieve between 1990 and the present. More accurate information on the location of the storm will allow emergency managers to focus on a more precise coastal area at landfall and avoid unnecessary evacuations.

2) Extend the lead time for hurricane forecasts out to Day 7 (Figure 4)

In 2001 the NHC extended the lead time of its forecasts from three to five days. However state and federal emergency managers have expressed that five days is not enough time to prepare certain areas, due to population growth, infrastructure, resources, etc. Extending the forecast out to seven days would help address their concern and need for longer lead times to ensure those impacted (the public, businesses, etc.) have sufficient time to prepare for, and evacuate from, an approaching hurricane.

3) Reduce average intensity error by 50 percent for Days 1 through 5 (Figure 5)

The current hurricane 48-hour official forecast intensity error is ~14 knots or roughly the wind speed range for one category on the Saffir-Simpson Hurricane Scale. Due to the uncertainty in today's intensity (strength of storm) forecast, NHC suggests that emergency managers prepare for one category above the NHC official intensity forecast (e.g., if NHC forecasts a Category 3 hurricane at landfall, emergency managers should prepare for a Category 4). A 50 percent reduction in intensity error will allow emergency managers to better focus their preparedness efforts. Reducing the uncertainty in the hurricane intensity forecasts will also support evacuation decisions by identifying the coastal and inland areas of greatest concern for wind and associated storm surge.

When the impacts of the 50 percent improvement in track and intensity errors are

combined for the Gulf Coast, forecasts provided to the emergency managers will be a more confined area of concern with a more precise wind estimate (Figure 5).

4) Increase the accuracy of rapid intensity change forecasts

Rapid intensity change presents a great challenge to hurricane forecasters during the life of a storm and a serious problem for emergency managers when it occurs just prior to landfall. Rapid intensity events constitute an approximate two-category change within 1 day, and have a significant impact on preparedness and evacuation actions for emergency managers.

While improving the accuracy of rapid intensity change forecasts within 1 day of landfall is a high priority, given the uncertainty in track forecasts of landfall and the need by some to make decisions on protective actions more than one day before landfall, these improvements are needed at all lead times over the entire life of the storm. Increasing the forecast accuracy of rapid intensity change events can lead to greater confidence in forecasts. Emergency managers and the public will be able to make decisions and take appropriate action. Today, emergency planning is based on a storm one category higher than what is predicted. More accurate rapid intensity change predictions, will allow for more efficient evacuations and preparedness.

Key Strategies for HFIP

I will now briefly describe key strategies outlined in our Hurricane Forecast Improvement Project plan to implement the activities needed to improve hurricane forecasts, with an emphasis on rapid intensity change. Full HFIP details are available at http://www.nrc.noaa.gov/plans_docs/HFIP_Draft_Plan-1.pdf.

Engage the expertise of the operational tropical/hurricane numerical prediction and research community, including stakeholders

NOAA recognizes the broad scope of the scientific challenges associated with understanding and predicting hurricanes. Addressing these challenges and improving forecasts of hurricane track and intensity will involve increased interaction with the external research community to leverage and coordinate research activities. NOAA plans to broaden the base of expertise in the tropical cyclone operational numerical prediction and research communities and broaden our interaction with the research and development community by improving our efforts through workshops, symposia, and conferences to:
- Improve computer modeling of hurricanes;
- Improve the use of data;
- Better coordinate with our federal, academic, and private sector partners of needs and opportunities;
- Increase grants; and
- Support additional education and outreach activities.

Optimize observing systems for research and operations

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The advancement of observational capabilities for tropical cyclone analysis, forecasting, and numerical weather prediction is a vital component of the HFIP. These observational capabilities extend from exploratory scientific research conducted with new types and new generations of advanced instruments and platforms, to proven operational systems used for analysis and forecasting. Over the past four decades, satellite and airborne observing systems developed and flown by NASA, NOAA, NSF, and the Department of Defense have made major contributions to the operational tropical cyclone forecast systems. With several new observational platforms and sensors meant to enhance observing capabilities for hurricane forecasters, and hurricane numerical prediction systems potentially available in the next several years, NOAA will evaluate the usefulness of these data to ensure investment decisions are made to select the optimal systems/platforms for improvements in hurricane forecasts.

Define and build the next generation hurricane forecast framework, including the Hurricane Forecast System/Global Forecast System

The next generation hurricane forecast framework is a multi-model suite containing both high resolution and ensemble forecasts produced by NOAA and other numerical prediction entities on the national and international scales. Within this framework, a next-generation Hurricane Forecast System/Global Forecast System will also be defined and constructed to accurately represent the physical processes responsible for rapid intensity change through research and development activities within NOAA and the broader research community. This strategy builds upon NOAA's long-standing operational numerical prediction capabilities and related research efforts to improve understanding of the physical processes that lead to track, intensity/structure, and precipitation changes in hurricanes. This plan focuses on developing a capability to accelerate numerical modeling developments to drive improvements in the hurricane forecast guidance through enhanced research between NOAA and the larger research community.

The need for an ensemble approach for all forecast applications, including hurricane forecasting, was highlighted by a 2006 National Research Council Report.[9] The report states, as one of their nine major recommendations, "NOAA should develop and maintain the ability to produce objective uncertainty information from the global to the regional scale."

Institutionalize and transition research to operations

The transition of research to operations – referred to by the OFCM and defined by the Board on Atmospheric Sciences and Climate, National Research Council as "bridging the valley of death" – requires robust interaction between the research and operational

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[9] *Completing the Forecast: Characterizing and Communicating Uncertainty for Better Decisions Using Weather and Climate Forecasts*, National Research Council of the National Academies, ISBN 0-309-66261-3, 2006.
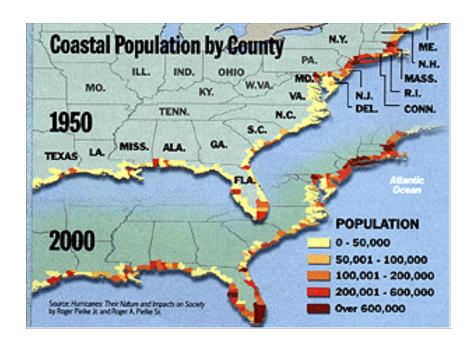
communities, as well as a strong interface with the user community. Also required is a healthy infrastructure for the transition, including resources and processes for evaluation and demonstration, operational implementation and operations and maintenance.

Increase High Performance Computing and Information Technology capacity and capability

High quality hurricane forecasting will require a 5000 fold increase in high performance computing and information technology capabilities. The framework of combining information from different forecast centers involves virtual grid computing as the system leverages and relies on computing capability across the numerical prediction centers, but may also require significant enhancements in telecommunication. In addition, each center, including the NOAA computing centers, will produce higher-resolution analyses and forecasts by running the numerical models on massively parallel processors, including NOAA's supercomputer. Therefore, increases in NOAA's high performance computing capability and capacity are required to enable and support advancements in the NOAA Hurricane Forecast System/Global Forecast System, including ensemble capabilities.

<u>**Conclusion**</u>

NOAA applauds the Committee's broad perspective of hurricane impacts and the need for research in areas including storm structure, rapid intensity change, ocean-atmosphere interactions, storm surge, rainfall and inland flooding forecasts. However, the Administration is concerned that the bill's funding levels are significantly higher than current funding levels. NOAA's HFIP already addresses a path forward for many of the items outlined in the *National Hurricane Research Initiative Act of 2007*. HFIP efforts are currently focused on improved track and intensity forecasts, wind fields, and storm surge, as well as the accompanying need for improved observations and computing capability. We agree the most effective role is for NOAA and NSF to co-chair a committee to oversee and coordinate federally funded hurricane research efforts to ensure successful work can be incorporated into the operational forecast and warning environment with the overall goal of improved hurricane forecasts and services. The key to success in improving hurricane prediction is leveraging all available national assets and capabilities to address this national need. I thank the Committee for the opportunity to speak about this challenge and we look forward to working with the committee as this legislation moves forward.

Figure 1. Coastal population by county. Source *Hurricanes: Their Nature and Impacts on Society*, by Roger Pielke, Jr. and Roger A. Pielke, Sr.
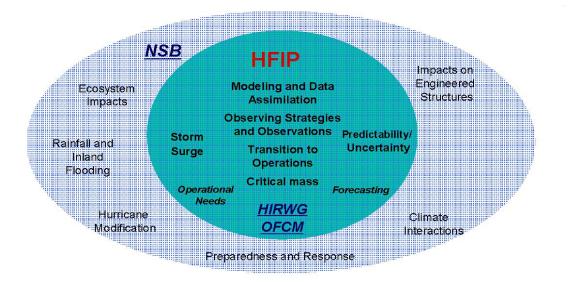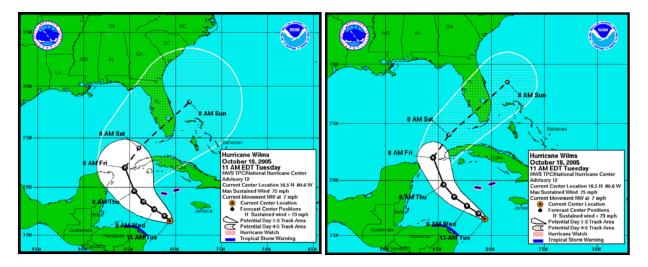
Figure 2. Scope of the NOAA Hurricane Forecast Improvement Project (HFIP).

Figure 3. The panels above are examples of the NHC track forecast (cone graphic). The black line denotes the NHC forecast track for the center of the storm over a 5 day period The cone is calculated such that the center remains within it two-thirds of the time based on official forecast errors over the previous 5 years. The panel on the left shows what the NHC hurricane cone graphic would look like today. The panel of the right shows the same storm with a 50% reduction in track error, the first goal of the HFIP.
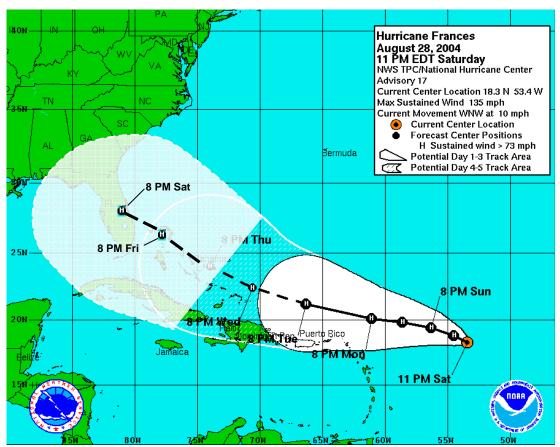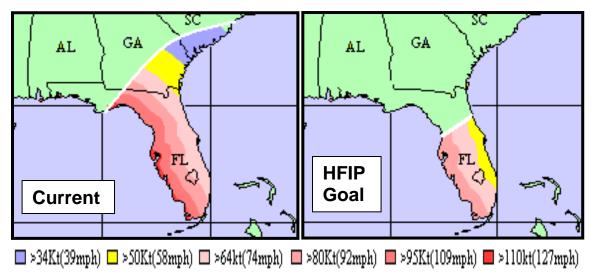
Figure 4. An example of a proposed 7-day NHC track forecast product.

Legend: >34Kt(39mph) >50Kt(58mph) >64kt(74mph) >80Kt(92mph) >95Kt(109mph) >110kt(127mph)

Figure 5: A depiction of a 50% improvement in intensity and track for the Gulf Coast. The HFIP goal (on the right) will allow a more focused effort by the emergency managers for their preparedness and evacuation activities.