

SIXTH INTERNATIONAL WORKSHOP on TROPICAL CYCLONES

Topic 5a : Report to the IWTC-VI On the PROGRAM FOR IMPROVEMENTS TO HURRICANE INTENSITY FORECASTS AND IMPACTS PROJECTIONS (HiFi)

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Executive Summary

The Program for Improvements to Hurricane Intensity Forecasts and Impacts Projections (**HiFi**) will provide the basic and applied research needed to reduce the error in 48-hour intensity forecasts for hurricane-strength storms by at least 10 kt (approximately one half of a Saffir-Simpson category) within the next five years, with an emphasis on improved forecasting of rapid intensification and decay, and decay and reintensification cycles. In addition, improved projections of likely hurricane activity over the next 50-100 years will be developed. An appropriately balanced program of observations, modeling and theoretical research is to be developed and the research results will be transitioned to operational status for short-term predictions and for hurricane impacts projections on longer time scales.

The National Center for Atmospheric Research will be the lead organization for the **HiFi** program, working with university, government and industry scientists. A Science Steering Committee is in the phase of developing the Research and Implementation Strategy for **HiFi**. Implementation of the basic research agenda will take place during the first five years, and the transition to operational applications will be completed during the subsequent five years.

5.a.1 Background

The devastating 2005 hurricane season in the Gulf of Mexico and the previous record four hurricanes striking Florida during 2004 have strongly underscored the need for improved prediction of hurricane risk and assessment of the longer-term risk level. The marked increase in impacts over the past decade have arisen from an increase in the frequency and intensity of hurricanes affecting US coastal and offshore resources combined with increasing populations, infrastructure and economic activities in vulnerable regions. This is already a major issue for the United States and projected future increases in vulnerability combined with potential increases in hurricanes require urgent action to minimize the impacts. Minimizing such hurricane impacts is a complex activity that requires attention to potential wind damage, heavy rain and flooding, wave and storm surge inundation, coastal erosion, and pollutant pathways, all of which depend critically on accurate forecasts of hurricane intensity and structure. The time scales range from forecasts over several days for immediate responses, to projections over years and decades to support proper planning and engineering design decisions.

A major commitment of resources for research and development in the 1990s initiated by the Office of Naval Research led to remarkable improvements in track forecasting skill, with the 48 h forecasts now better than those at 24 hours a decade ago. This now places emphasis on hurricane intensity and structure forecasts, which have barely improved and have little skill against climatological techniques. The unprecedented hurricane activity since 1995 in the North Atlantic, and particularly the last two seasons, has also generated intense debate in both scientific and political arenas on whether this is due to natural variability, or if it has an element of global climate change. Despite this growing importance to the Nation of improved hurricane intensity forecasts and projections, funding for theoretical and applied hurricane research remains completely inadequate.

In light of the high level of impacts, the National Science Board established a Hurricane Research Task Force; the NOAA Science Advisory Board tasked a Hurricane Intensity Research Working Group (HIRWG), and the American Geophysical Union called a forum of experts to provide advice and recommendations. An ad hoc group of researchers also developed a prospectus for a hurricane process study. All have called for urgent increases in hurricane research and forecast technique improvement⁵². For example, the key recommendation of the HIRWG is:

To reduce the error in 48-hour intensity forecasts for hurricane-strength storms by at least 10 kt (approximately one half of a Saffir-Simpson category) within the next five years, with an emphasis on improved forecasting of rapid intensification and decay, and decay and reintensification cycles.

5.a.2 Requirements

Producing these essential improvements in forecasts and projections of hurricane intensity and structure is a complex undertaking that covers the entire theoretical and applied research spectrum and has three major components.

First we need to improve critical deficiencies in our understanding of the manner in which the hurricane couples with the underlying ocean, of the interactions of the storm with its immediate environment, and of the small scale processes in the hurricane core that lead to rapid changes in hurricane intensity (both intensification and decay). These rapid changes have been identified by the Director of the National Hurricane Center as being the highest priority for improvement (HIRWRG report). Longer-term projections of hurricane impacts also require improvements in our understanding of how future hurricanes will respond to the atmospheric and oceanic changes associated with both natural variability and greenhouse warming.

Second we need to improve the computer models that will both support the theoretical analysis and then carry them forward to become the mainstay of operational forecast and projection techniques.

⁵² Report of the Hurricane Intensity Research Working Group of the National Oceanic and Atmospheric Administration Science Advisory Board, July 2006.
http://www.sab.noaa.gov/Working_Groups/Working_Groups.htm;

Hurricanes and the U.S. Gulf Coast: Science and Sustainable Rebuilding, June 2006.
American Geophysical Union.
<http://www.agu.org/report/hurricanes/>

Recent research has shown the critical need for very high resolution to enable explicit modeling of the details of the high wind region, of the air-sea interaction and of the precipitation processes in the hurricane clouds over 3-5 day time periods. Projections of changes in hurricane intensity and structure also require climate projections with the capacity to resolve features of importance. But such high resolution comes at a very considerable cost in computer purchase and operation (potentially hundreds of millions of dollars). The model improvements will therefore need to include clever ways of producing the maximum improvement while minimizing the infrastructure costs.

Third we need to substantially improve the observational base and the methods of bringing those observations into the forecast models. A deficiency of observations limits both our understanding of hurricane physics and our ability to verify and apply enhanced models. Here there are two major limitations – the cost of maintaining a targeted observing program, and our current incapacity to take detailed observations in critical areas, such as the high-wind layer near the ocean surface. Improvements here will require a careful combination of sophisticated techniques for assimilating data into the models, and targeted observations in the most critical regions. The targeted observations require a careful combination of current satellite, aircraft and surface observations with innovative new approaches. As with the models, this must include clever ways of minimizing the considerable cost whilst maximizing the improvements.

This is obviously a major undertaking, which requires:

- Collaborative planning and research by university, government and industry scientists;
- Cooperative planning and support by federal and state agencies;
- Utilization of the most advanced computing and observational resources; and,
- Careful attention to ensuring that the research advances are transferred to operations in a manner that produces the maximum impact.

5.a.3 HiFi Program

HiFi takes up the challenge proposed by the NSB and HIRWG reports for a focused program to enable critical details of the atmospheric convective processes, upper ocean heat, salt and momentum budgets, and the interactions between the upper ocean and the hurricane to be understood and included in next generation weather prediction models specifically tuned for hurricane prediction. This will occur through bringing together US and international expertise in hurricane and upper ocean physics, forecasters and climatologists in a carefully considered program of research, field studies and advanced numerical model and data assimilation development,

Our major goal is:

To make substantial and continuing improvements to the ocean and atmospheric models used to simulate hurricanes on both forecast and longer time scales.

Achieving this goal will require focused research into understanding the fundamental processes together with improvements to observing programs, data assimilation, and modeling of key physical processes. Especially important are the modeling of clouds and the 2-way interaction of the hurricane with the underlying ocean. A fundamental set of issues concerns the nature of the air-sea interface and the coupled exchanges of heat, moisture and momentum between the atmosphere and ocean in hurricane cores.

HiFi will build on and extend current research and operational programs that are currently dedicated to improved observing, understanding, forecasting and projection of hurricane intensity and structure. Some of the ongoing research activities include:

- Recent field programs such as RAINEX (NSF and NOAA) and CBLAST (ONR and NOAA);
- The Weather Research and Forecast (WRF) model, which is coordinated by the National Center for Atmospheric Research (NCAR) as a cooperative activity between all government and private sector operational centers and academia, to enable rapid transfer of research improvements into operations;
- Inclusion of a coupled ocean model with the WRF by NOAA and NCAR, which enables both studies and forecasting of the interaction between the ocean and hurricane circulation;
- Major mobile observing facilities maintained by NOAA, NCAR and the USAF maintain with a long record of targeted hurricane observations;
- Several new satellite observing facilities that have recently been launched, or are in the advanced development stage, for example the NASA A-Train satellites and the US-Taiwan COSMIC program;
- Satellite altimeter missions supported by NASA and ONR that provide the basis for ocean heat content estimation and model initialization;
- New generation observing systems, such as Unmanned Aerial Vehicles (UAVs), Autonomous Underwater Vehicles (AUVs) and Lagrangian Floats being tested by NASA, NOAA and ONR, which hold potential for continuous observations over long periods in hitherto unobservable regimes, such as the high wind and upper ocean layer;
- The WRF model has been recently extended to a Nested Regional Climate Model mode, which brings a capacity for forecast-mode improvements to support improvements in hurricane activity projections, and vice-versa;
- NASA and DOE have major computing facilities and NCAR is leading the establishment of a peta-scale computing facility that will increase our current capacity by up to 1000 times.

These programs provide important capacity for observing and modeling the atmosphere and ocean within hurricanes, and the interactions between them. They provide the basis for establishment of HiFi, which will extend these facilities and promote developments towards a more skillful and efficient forecasting system that incorporates state-of-the-art research advances with affordable observing and forecasting facilities.

HiFi will extend this existing base to provide:

- Improvements in understanding and models for, research, forecasting and impact projections;
- Testing and development of new observing platforms and instruments, together with targeting and data assimilation techniques to maximize the utilization of observing systems;
- Transition of research results into operational use.

This is a major effort that will require coordination of researchers dedicated to improved understanding, with model and observing system developers, and with careful attention to the requirements of forecasters and vulnerable communities.

Subject to the further planning efforts that are to be provided in the **HiFi** Science Strategy Reports, the work is to be broken down into three overlapping phases.

Phase I will encompass an intensive research and development phase aimed at improving forecasts out to 5 days. This will include a series of intensive observation periods to build a sufficient database of ocean, interfacial and atmospheric fields to support the requirements of the theoretical research, analysis of efficient observing system approaches, and evaluation and validation of the next generation hurricane intensity models. The oil industry can uniquely contribute to this program through the use of their exploration and production platforms for critical atmospheric and oceanographic instrument deployment.

Phase 2 will focus on hurricane impacts projections on longer time scales than 5 days, where ensemble forecasts of hurricane statistics are required. Regional climate modeling capability and capacity will be

improved to the level necessary to resolve and project the influences of natural variability and greenhouse warming on hurricane distributions and intensities. Coordinated theoretical and modeling studies will be used to provide the best scientific assessment of future trends in support of engineering design requirements, urban planning, and design of the relevant forecasting system. The timing and funding of this phase will have to be carefully considered at the initial science strategy and implementation planning meeting.

Phase 3 will be the development and transition to operations of the next generation operational forecast system aimed at efficiently providing the information required for minimizing hurricane impacts on vulnerable coastal communities and facilities. The resulting improvements in intensity forecasts, and their translation into impacts prediction, will be of significant value to the coastal states, to the oil industry, to the reinsurance industry, and ultimately to the Nation. We estimate that this phase will commence during the first 5 years, but will extend for a further five years to ensure complete use of relevant research results.

5.a.4 Process

5.a.4.1 Program Leadership

The magnitude of this integrated research and development effort requires leadership by a major national institution. We recommend that NCAR take on this leadership role, with the related calls for research and development proposals and distribution of awarded funds being managed by the University Corporation for Atmospheric Research (UCAR). NCAR already coordinates the development, support and operational transfer of the WRF model, which will be the mainstay of the **HiFi** program. NCAR also is a world leader in climate modeling and projection and has recently combined the WRF and Community Climate models to provide a capacity for resolving hurricane and other severe weather responses to global change. The capacity to undertake leading-edge experiments with these models will be given a major boost by NCAR's moves towards a peta-scale computing facility. A national field operations facility also is maintained by NCAR's Earth Observing Laboratory, which includes radars, surface instrumentation, and aircraft facilities.

While the work will be lead and coordinated by UCAR/NCAR, the bulk of the research will be done by university collaborators and close coordination would be maintained with relevant government laboratories and offices. Selection of Dr. G. Holland and Professor R. Lukas as Principle Investigators will facilitate this coordination. Dr. Holland will lead the coordination of the UCAR/NCAR activities and serve as the lead atmospheric scientist. Professor Lukas will coordinate the academic program and serve as the lead oceanographic scientist.

Dr Holland and Professor Lukas co-Chair a Steering Committee comprised of representatives of the major research and forecast organizations involved in **HiFi**. This steering committee will meet at regular periods to monitor progress with **HiFi** and advise on major directions and outcomes. Because of the high-level of impact on Gulf and Atlantic communities, Dr. Alexander Soloviev of Nova Southeastern University Oceanographic Center (NSU OC) in Dania Beach, Florida will serve on the **HiFi** Steering Committee to help coordinate with local communities and particularly the Coastal Ocean Observing System community. An Interim Project Office will be established at NSU OC in order to coordinate initial stages of the project development. We also propose that Dr. Frank Marks of the Hurricane Research Division in the Miami NOAA Atlantic Oceanic and Meteorological Laboratory take the lead in advising the committee on operational hurricane observing system developments.

5.a.4.2 Implementation

This is an ambitious and complex program, for which this prospectus can provide only a minimum of detail. We propose a staged process for establishment and operation of the program and justification of the funding.

Stage 1 will bring together the major potential scientific contributors, forecasters and community representatives to coordinate a substantial proposal, which will provide program details, expected major collaborators, coordination process and major milestones for the first five years. This will include development of a draft collaboration agreement between the Department of the Interior and UCAR/NCAR and could be completed in 3-6 months. A grant of \$200,000 will be required to cover the related expenses, including salaries of the PIs and travel costs for focused meetings and the development of the **HiFi** Science Strategy Report and related documents.

Stage 2 will be review of the proposed research program coordinated by a leading national body. While there are a number of groups that could undertake this, we recommend the National Research Council (jointly through its Board on Atmospheric Sciences and Climate and its Ocean Studies Board). This group would be tasked to assign a committee of experts to review the proposed work as provided in the **HiFi** Science Strategy Report and related documents, provide recommendations on the scope and activities and recommend continuation or cancellation to the Department of the Interior.

Stage 3 will follow approval of the full program and will consist of the execution of the first five year research and development plan. We recommend that the NRC expert committee be tasked with an annual review of progress with this plan.

Stage 4 will be development of a comprehensive operational plan in the 4th year of the program. This will detail a further 5-year plan for the full transfer of research and development results to a new generation operational observing and forecast system. It will include recommendations for carry-on applied research. We recommend that this be submitted to a committee chaired by the Director of the National Hurricane Center and consisting of representatives from NOAA, coastal community organizations, the offshore oil industry and academia.

Stage 5 will be the execution of the second 5-year program to establish the next generation forecast and observing system.