NOAA Intensity Forecasting Experiment 2005 (IFEX05)

1. Statement of Need

One of the key activities in NOAA's Strategic Plan Mission Goal 3 "Reduce Society's Risks from Weather and Water Impacts", Strategy 2 "Understand and Describe" is to improve the understanding and prediction of tropical cyclones. The National Centers for Environmental Prediction Tropical Prediction Center (TPC) in Miami is responsible for forecasting tropical cyclones in the Atlantic and East Pacific basins, while the Environmental Modeling Center (EMC) in Washington provides numerical guidance for the forecasters. Together they have made great strides in improving forecasts. With support from the research community, forecast errors of tropical cyclone track have decreased by about 50% over the past 30 years. However, there has been much less improvement in forecasts of tropical cyclone intensity and rainfall. The lack of improvement in intensity and rainfall forecasting is largely the result of deficiencies in routinely collecting data and assimilating it into the modeling system, limitations in the numerical models themselves, and gaps in our understanding of the physics of tropical cyclones and their interaction with the environment. Accurate forecasts will rely heavily on the use of improved numerical modeling systems, which in turn will rely on accurate observational datasets for assimilation and validation.

The next-generation tropical cyclone model, the Hurricane Weather Research and Forecasting model (HWRF), currently under development at EMC, is planned to become operational in 2006. The HWRF will run at high resolution (≈10 km grid length initially), using improved data assimilation techniques and physical parameterizations. Such a configuration holds the hope of improving our understanding and forecasting of tropical cyclone track, intensity, and rainfall. In order to realize such improvements, however, new data assimilation techniques must be developed and refined, physical parameterizations must be improved and adapted for tropical cyclone environments, and the models must be reliably evaluated against detailed observations from a variety of tropical cyclones and their surrounding environments.

2. Proposed Experiment

For the proposed Hurricane Field Program in 2005, called the Intensity Forecasting Experiment in 2005 (IFEX05), HRD is requesting flight hours and expendables to provide observations that will improve the operational forecasting models. HRD's efforts will target this goal by providing data to improve the operational numerical modeling system (i.e., HWRF) and by improving our understanding of the physics of intensity change and rainfall. A unique aspect of IFEX05 is the focus on providing measurements of tropical cyclones at all stages of the tropical cyclone's life cycle, from pre-genesis to intensification and subsequent landfall or decay over water. This strategy of observing the entire life cycle of a tropical cyclone is new and unique, and it will provide invaluable information from traditionally sparsely observed environments. Given the interests in different stages of the lifecycle of a tropical cyclone, basins of operations will change for different time periods during the field program. For example, the eastern Pacific is an ideal location for genesis studies, since that region has the highest frequency of tropical cyclogenesis per unit area in the world. However, tropical cyclones will likely be out of range for many flights in this basin once they reach hurricane status. Therefore, operations will emphasize the genesis and organizational stages of the lifecycle in the eastern Pacific in the early part of the season (i.e., July 15-August 15), and the mature stage of the lifecycle in the Caribbean Sea, Gulf of Mexico, and western Atlantic for the latter part of the season (i.e., August 15-September 30).

a) Operational requirements

Numerous requirements have been listed from the operational hurricane forecasting community that will aid them in improving tropical cyclone intensity and rainfall forecasts (e.g., Hurricane Weather and Research Forecast (WRF) Model Workshop Report, Evans and Surgi, 2003). These requirements fall into one (or more) of four categories which address the deficiencies mentioned above: 1) improvements in the assimilation of data into the numerical modeling system (hereafter called **DA**); 2) improvements in the parameterization of physical processes in the models (**PARM**); 3) availability of comprehensive datasets for the evaluation and validation of the models (**EVAL**); 4) improvements in our basic understanding of the important physical processes (**PHYS**). The proposed HRD experiment will address many of these requirements. These requirements, many of which have been taken from the HWRF Workshop Report under the section entitled "Key recommendations on high resolution coupled modeling of hurricanes", are listed below, along with a classification (in parentheses) of which deficiency(ies) they address:

1. There must be an improvement in the capability of assimilating wind and thermodynamic observations from the inner core of a tropical cyclone. In particular, assimilation techniques must be developed for airborne Doppler radar winds, microwave radiometer surface winds, GPS-dropsonde wind and thermodynamics, NOAA/NESDIS scatterometer/wind profiler for surface wind direction and lower tropospheric winds, NASA DIAL laser (LASE) humidity and aerosol profiles, and NASA microwave temperature profiler. This entails the development of observations covariance matrices for the different observations, as well as a data delivery method from the aircraft to the ground. (**DA**)
2. The appropriate balance conditions for use in the assimilation of data for incipient or weak tropical cyclones must be determined. This requires detailed observations and analyses of 3-D wind and thermodynamic variables in these types of situations. (**DA**)
3. "Rainfall estimations over water are critical to understand the energy balances. Those estimates are poor at best." (HWRF Workshop Report, statement a5; **PARM**)
4. "The entire understanding of the phase changes of moisture needs serious review. For example ice formation in updrafts is poorly understood and the role of graupel needs much better definition. Parameterizations of the phase changes range greatly in sophistication and none seem to give reliable results when compared to available observations." (HWRF Workshop Report, statement a6; **PHYS, PARM**)
5. "Ocean and interface models: wind/wave coupling strategy should be developed; vertical mixing parameterizations for ocean models should be evaluated against observed data. Work should progress towards an ocean model assimilation system." (HWRF Workshop Report, statement b5; **DA, PARM, EVAL**)
6. "Validation: standardized atmosphere and ocean evaluation and validation packages – including a suite of test storm cases – should be developed to assess the impact of future model upgrades. The variables included in this validation suite should include fields

useful for direct model evaluation and elements needed directly to contribute to NHC forecasts." (HWRF Workshop Report, statement b6; **EVAL**)

7. "New results on sea spray/surface flux effects on the PBL should be closely diagnosed and tested for potential transition to the operational HWRF." (HWRF Workshop Report, statement b9; **PHYS, PARM**)
8. "The effect of wind/wave coupling on momentum flux needs further exploration." (HWRF Workshop Report, statement c2; **PHYS, PARM**)
9. "Air/sea (sea spray) exchange affects the boundary layer structure and microphysics, especially in the core and rain bands. The effects of these exchanges have been little more than hinted at by current research, but warrant further study to quantify their importance." (HWRF Workshop Report, statement c4; **PHYS, PARM**)
10. "Virtually all available research cases and statistics exist for the most intense 50% of storms. This not only biases the statistics, but ignores the very different importance of physical processes that occur in the weaker as opposed to the stronger storms. The weaker storms making landfall often cause the largest damage from flooding." (HWRF Workshop Report, statement a9; **EVAL, PHYS**)
11. Determine the storm intensity and structure during decay over cold water such as in the EPAC basin. In these situations the Dvorak satellite intensity estimates seem biased. This requires detailed observations and analysis of upper ocean temperature, as well as 3-D wind and thermodynamic structure of the storm, with particular emphasis on the boundary layer static stability. Does the passage of the storm over cold water stabilize the boundary layer and decouple the surface wind from the rest of the tropospheric structure? This experiment is best done in the EPAC, but it may be relevant in the Atlantic north of the Gulf Stream. Also, it is essential for testing microwave radiometer surface winds as the current algorithm has not been tested over cold SST conditions. (**PHYS**)

b) Experimental approach

The main goal of IFEX05 is to improve intensity and rainfall forecasting by addressing the operational requirements stated above. This will be accomplished by performing a series of proposed experimental modules consisting of different flight plans and observational strategies. The flight plans include a genesis module, a module for studying the intensity change of mature storms, one for measuring the synoptic flow and its impact on storm track, and a landfalling module (see appendix for descriptions of modules). These modules span the spectrum of stages of a tropical cyclone's life cycle, from pre-genesis to landfall or decay. Data that will be collected during these experiments will observe many facets of the tropical cyclone and its environment: airborne Doppler radar will provide three-dimensional wind fields within the core of the storm; GPS dropwindsondes will obtain profiles of wind, pressure, temperature, and humidity; flight-level data will provide those variables along the flight path; cloud physics probes will provide cloud, rain, and ice particle measurements; the Stepped-Frequency Microwave Radiometer will provide surface rain and wind fields; and expendable bathythermographs will provide measurements of the surface and subsurface temperatures of the ocean.

For all the modules, data collected from the flights will be interpolated to a standard analysis grid that can be used to address all classes of deficiencies listed above. Such datasets can be used in a case-study mode to provide datasets for assimilation into the HWRF (**DA**) and conduct process-oriented studies (**PHYS**), or they can be used in a statistical mode, whereby relevant statistics from numerous cases are compared to corresponding fields from the models to evaluate the performance of the model (**EVAL**) and identify possible biases in the parameterization schemes (**PARM**). Each individual module will address its own specific set of operational requirements listed above. The genesis module, for example, will address requirements 2, 3, 4, 6, and 10 by providing three-dimensional wind and thermodynamic variables within the core of an incipient storm. The mature storm module will address requirements 1, 3, 4, 5, 6, 7, 8, and 9, while the synoptic flow module will address requirements 1, 2, 6, and 10. The landfall/decay module will address requirements 1, 6, 10, and 11.

c) Partnerships with other experiments

In addition to the IFEX05 experiment proposed here, NASA and NSF-supported scientists have expressed a strong desire to partner with NOAA during this time period. A brief summary of the objectives for each of these other proposed experiments is provided below, while Figure 1 shows the time periods covered by each of the experiments:

- Fifth Convection and Moisture Experiment (CAMEX V; NASA) – NASA, in partnership with NOAA, has proposed that CAMEX V have as its primary goals to increase the overall understanding of tropical cyclone genesis, intensity change, motion, and rainfall; to identify remote sensing measurements and modeling requirements for improved hurricane predictability; and to validate the performance of NASA space-borne sensors to accurately monitor the short-term impacts and long-term trends of tropical storms and hurricanes. An overview of this experiment can be found at http://camex.bloki.com/index.jsp?name=Draft_White_Paper&folderId=17787.
- Second Tropical Experiment in Mexico (TEXMEX II; NSF) – The goal of TEXMEX II is to improve the understanding of tropical cyclogenesis by studying the dynamic and thermodynamic changes that incipient tropical cyclones undergo during the genesis process. An overview of this experiment can be found at ftp://ftp.aoml.noaa.gov//hrd/pub/rogers/HFP/TEXMEXII.pdf.
- Rainband and Intensity Experiment (RAINEX; NSF) – The aim of RAINEX is to investigate the role that the interactions between a tropical cyclone's inner core and rainbands play in determining the intensity change of mature storms. An overview of this experiment can be found at ftp://ftp.aoml.noaa.gov/hrd/pub/rogers/HFP/RAINEX.pdf.

These experiments bring their unique objectives and expertise to study aspects of tropical cyclone structure and intensity change at all time periods of the cyclone's lifecycle. The scientific goals of each of the experiments also complement the goals of IFEX; namely, to improve tropical cyclone intensity and rainfall forecasting. The additional resources brought by all of these experiments, both in terms of added resources and added expertise, will enhance the ability of IFEX05 to provide data that will improve forecasts of tropical cyclone intensity and rainfall.

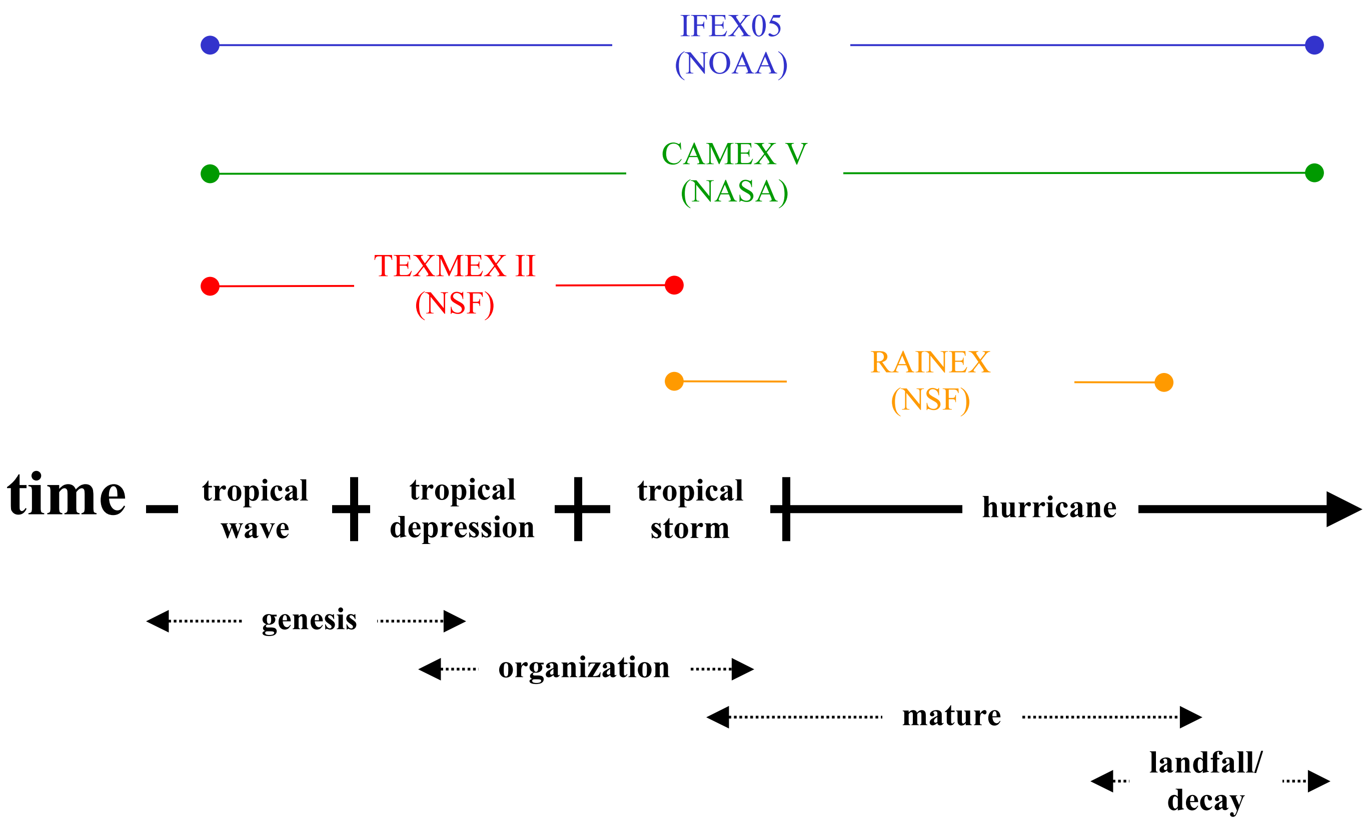

Figure 1. Time line of life cycle of a tropical cyclone and the portions of the life cycle that will be covered by the proposed experiments.