A proposal to establish a dedicated Hurricane Model Evaluation and Improvement Project

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Motivation....

- <u>Overall objective:</u> Improve HWRF forecast performance through a systematic evaluation process, whereby model biases are documented, understood, and ultimately eliminated by implementing accurate observation-based physical parameterizations

- Goals:
  - Assemble comprehensive observational databases (buoy, dropsonde, Doppler radar, microphysics, etc)
  - Establish a framework for comparing numerical model output with observations (sampling, statistics, etc)
  - Systematically evaluate numerous physical and dynamical aspects of HWRF coupled model system against historical observational database at HRD
  - Seek to eliminate model biases by developing observation-based parameterizations of physical processes
  - Target and eliminate data gaps that impede effective model evaluation

Additional Motivation:
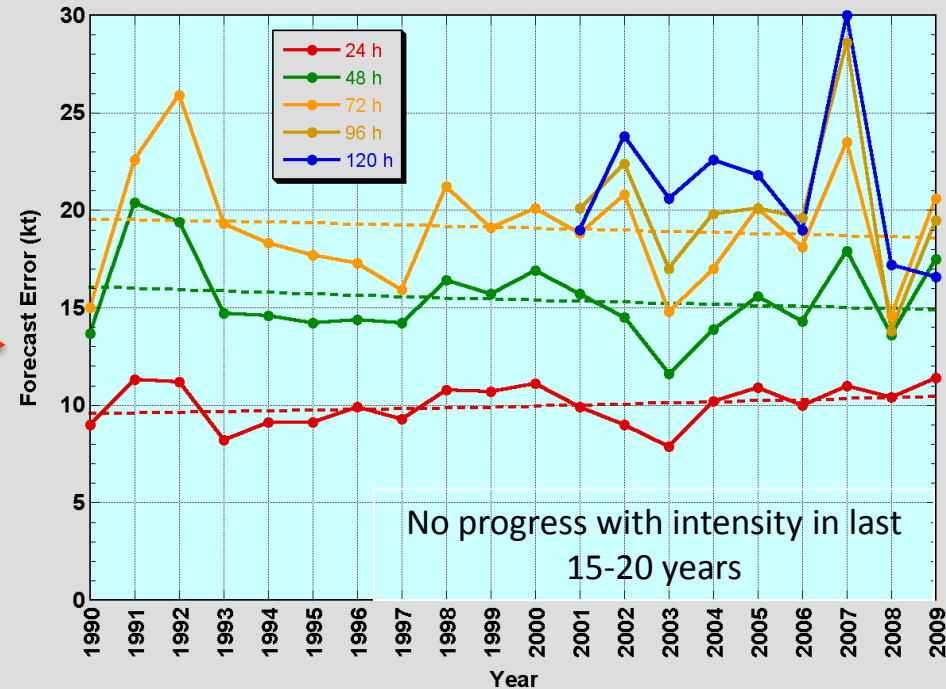# Long-term forecast trends….

The Good – track forecast improvements

The Bad - Intensity no real gains
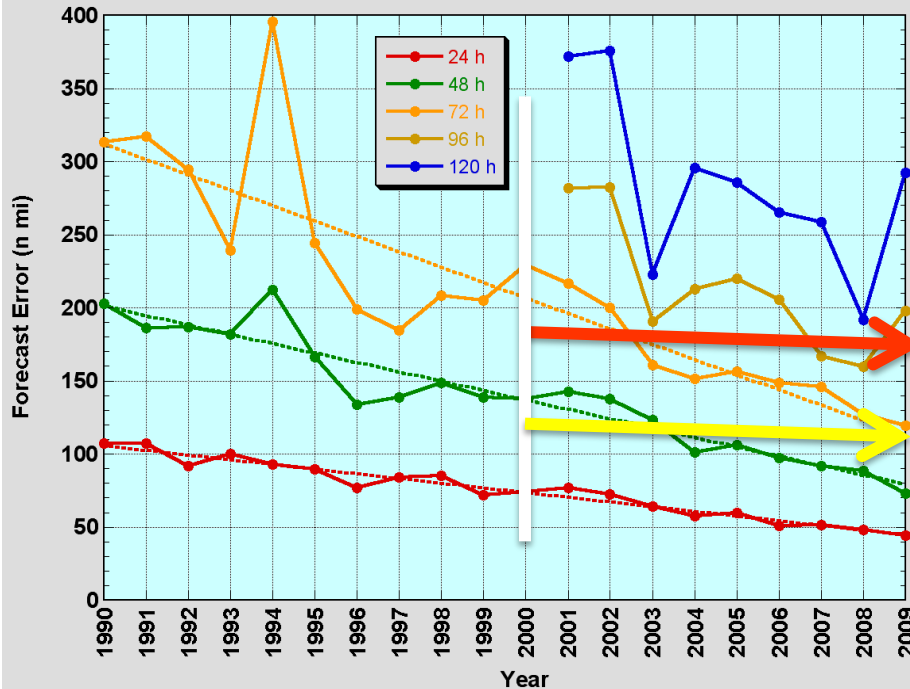
- Errors cut in half over past 15
- 10-year improvement - As accurate at 48 hours as we were at 24 hours in 1999

- 24-48h intensity forecast off by **1** category
- Off by **2** categories perhaps 5-10% of time

- ***Goals***

- Improve Forecast Accuracy
  - Hurricane impact areas (track) – 50% in 10 years
  - **Severity (intensity) – 50% in 10 years**
  - Storm surge impact locations and severity

EXPERIMENTAL
TROPICAL STORM IRENE ADVISORY #28
PROBABILITY (IN PERCENT) OF TROPICAL STORM FORCE WINDS
WINDS AT LEAST 39 MPH

VALID FOR 120 HOURS FROM
8 AM AST Thu Aug 11 ...TO... 8 AM AST Tue Aug 16

- Extend forecast reliability out to 7 days

- Quantify, bound and reduce forecast uncertainty to enable risk management decisions
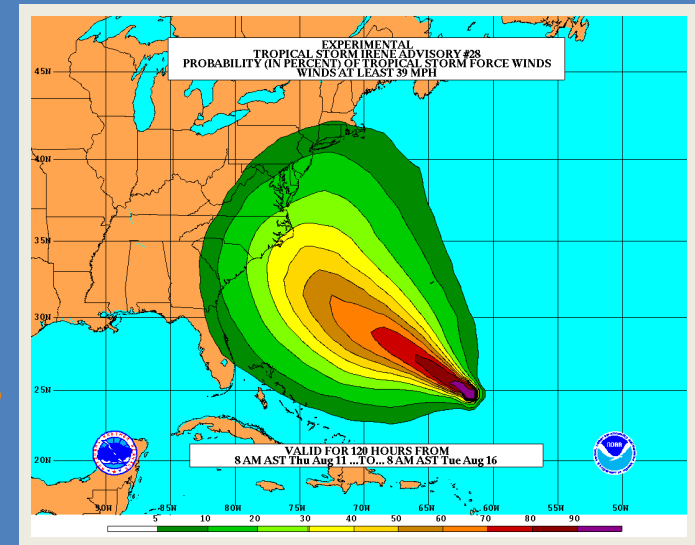
Accurately predicting hurricane intensity change…

How did we get here and how do we get where we want to go?

- Over the past 50 years NOAA has amassed a treasure trove of valuable (and often unique) observations within the hurricane environment.

- Working closely with government and academic partners, NOAA's Hurricane Research Division (and the NHRL in earlier times) has remained at the forefront of an ongoing effort to better understand the hurricane environment through the use of targeted observations.

- More recently, advances in computing as well as access to additional resources through HFIP, have allowed NOAA to also make significant (and accelerated) advancements in tropical cyclone numerical modeling.

- The next critical step in the prediction improvement process is to effectively merge these two areas of strength by establishing a dedicated, long-standing effort to methodically evaluate and ultimately improve NOAA's operational hurricane forecast system.

A proposal to establish a…

Hurricane Model Evaluation and Improvement Project

Overall Goal: To improve numerical forecasts of intensity change by strategically and systematically utilizing observations.

Proposed path to achieve this goal…

Begin a systematic, 'holistic', physics-driven, approach to evaluate and improve NOAA's operational hurricane forecast system by utilizing new and existing observations in order to significantly enhance current operational model physics and parameterization routines.

Evaluation and Improvement Methodology…

- Compare output from discrete aspects of the operational hurricane modeling system (e.g. air-sea interaction) with similar observationally-based corollaries over appropriate spatial & time scales.

- Emphasize analyses highlighting wave number 0/1 (i.e. mean/asymmetry) structure.

- Based on results from these inter-comparisons, identify and begin work in specific areas where model improvement may be possible (e.g. model physics enhancement, parameterization modification, etc).

- In addition, also identify areas within the hurricane system that cannot currently be effectively evaluated due to inadequate data sampling.

- Target these "observational gaps" by strategically utilizing NOAA's Hurricane Field Program and other data acquisition opportunities (e.g. partner field programs, satellite measurements, new sensor/platform technologies) in order to improve our ability to effectively evaluate, and ultimately improve, model fields going forward.

- In parallel, conduct targeted OSE/OSSE experiments to help determine the optimal mix of new and existing observations that are most likely to result in improved future forecasts of hurricane intensity change.

- As model improvements are made, conduct process-oriented simulations that investigate key elements of the hurricane forecast system. Such efforts will help improve basic physical understanding and better quantify model sensitivity and overall variability.

Project Stage I: Hurricane Air-Sea Interaction…

The hurricane model evaluation and improvement project is envisioned as a multi-stage effort that includes several iterative phases. The first stage that is being proposed is an in-depth model/observational inter-comparison of the hurricane air-sea environment. It is proposed that this particular region of the storm be analyzed first since it is believed that existing air-sea observations can adequately describe the mean and asymmetric state associated with this region of the hurricane (i.e. waves 0/1). As such, properly scaled analyses derived from model output should enable a realistic and reasonably accurate assessment of model performance (relative to observations) as it relates to this critically important region of the storm.

How?

Hurricane Air-Sea Interaction Evaluation and Improvement Methodology…

- Establish a 'clear picture' of air-sea conditions based on 30+ years of direct measurements collected within the inner and outer core hurricane environment over a wide array of storm conditions.

- Compare observed fields with comparable/appropriately-scaled model air-sea analyses over a wide array of storm conditions (e.g. hurricane, tropical storm, intensifying, weakening, fast/slow moving, etc).

- In addition, model/observational comparisons using various flow-relative frameworks (e.g. earth-relative, storm motion-relative, shear-relative).

- Consistent with the project's objectives, analyses and inter-comparisons would concentrate on model/observational differences associated with mean and asymmetric structure (i.e. wave # 0/1).

- Analyses would include assessment of near surface atmospheric and oceanic model performance.

- Once specific areas of improvement are targeted, key HRD, AOML, ESRL, EMC and HFIP personnel would work closely and interactively to improve atmospheric model surface layer, upper ocean physics and associated parameterization routines.

- After necessary improvements to the modeling system have been made, conduct targeted idealized modeling studies to ensure documented findings are correct for the right (physical) reason(s). Such studies should also help improve overall physical understanding and better document model variability associated with the air-sea coupled system.

- Highlight any "observational gaps" that may exist within the air-sea interactive environment and provide an assessment of how to best target such gaps going forward (e.g. new field experiments, new observing platforms (UAS, UOV), new/improved sensors, etc).

- If appropriate, work closely with AOML, ESRL and other collaborative scientists to implement targeted OSE/OSSE experiments designed to determine the optimal mix of new and existing observations most likely to improve future forecasts of hurricane intensity change.

- Once/if significant changes have been made to the model, conduct "before and after" simulations that highlight the improvements that were achieved (e.g. improved physical representation of the air-sea environment (mean and asymmetric fields), appropriate variability attained, and (hopefully) a measure of improved forecast accuracy).

- As needed, conduct periodic updates to HFIP and other NOAA leadership as progress is made.

- Maintain existing funding & explore avenues for additional resources (i.e. new data/funding opportunities as they arise).

After air-sea evaluations *and improvements* have been made….

Project Stage II: Hurricane Boundary Layer

Building upon successes and incorporating lessons learned from the air-sea effort already described, expand activities to include model/observation comparisons within the hurricane atmospheric boundary layer environment…

Resource requirements to establish and maintain such a Project…

- Establish full-time leadership to oversee, manage and develop the highly-interactive group dynamic.

- Maintain ongoing and develop new collaborative relationships and activities with HFIP-funded institutions actively involved in hurricane model development, data collection and assimilation.

- Maintain NOAA's annual Hurricane Field Program in some form *(preferably with, but also in the absence of a manned P-3 contingent).*

- Maintain ongoing efforts (and the necessary financial support) to adequately investigate, test and acquire new and/or evolving observing technologies that could potentially lead to improved operational forecasts.