Hurricane Intensity Forecast Improvement: Is it Possible?

Richard J. Pasch

Senior Hurricane Specialist

National Hurricane Center

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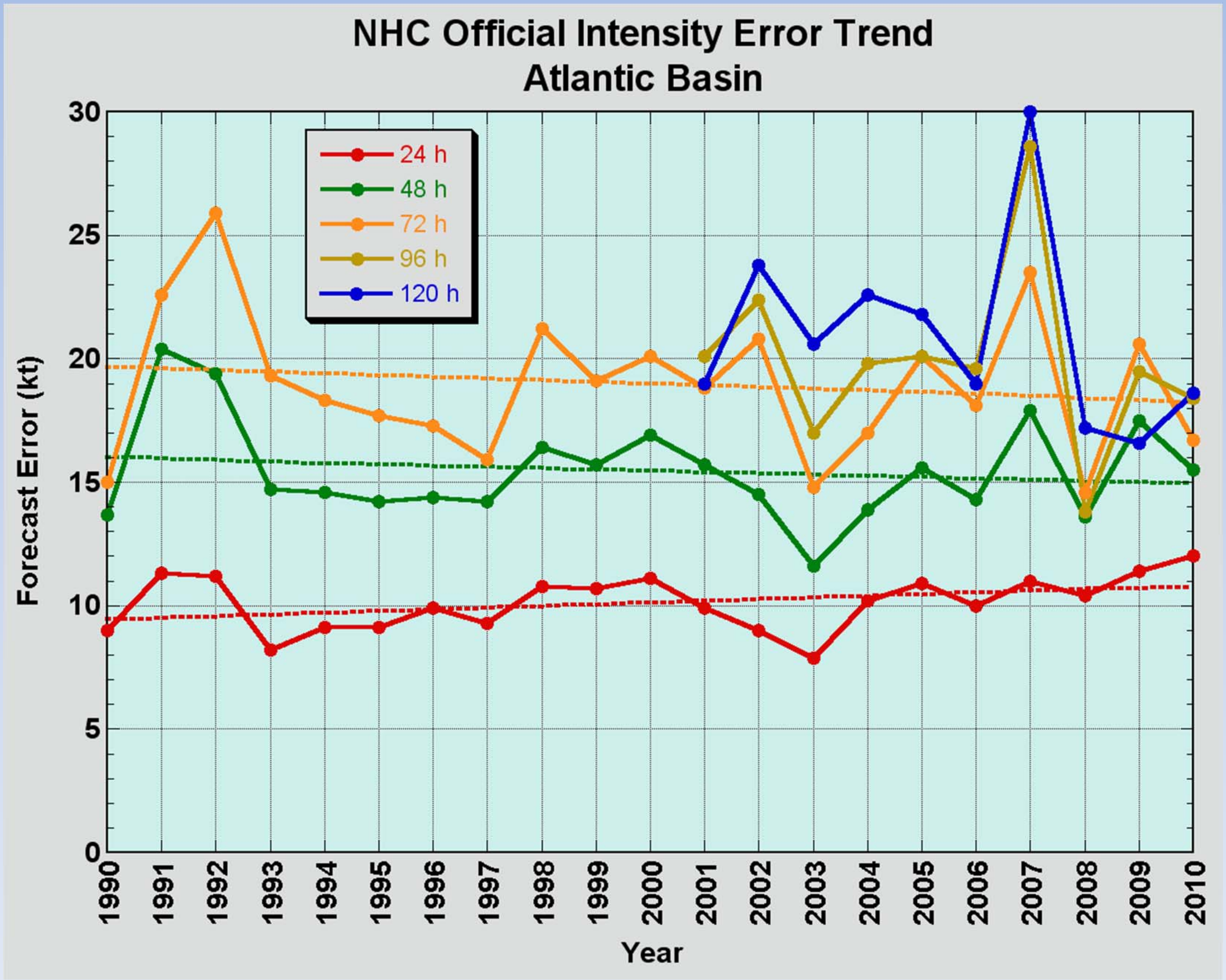
No.

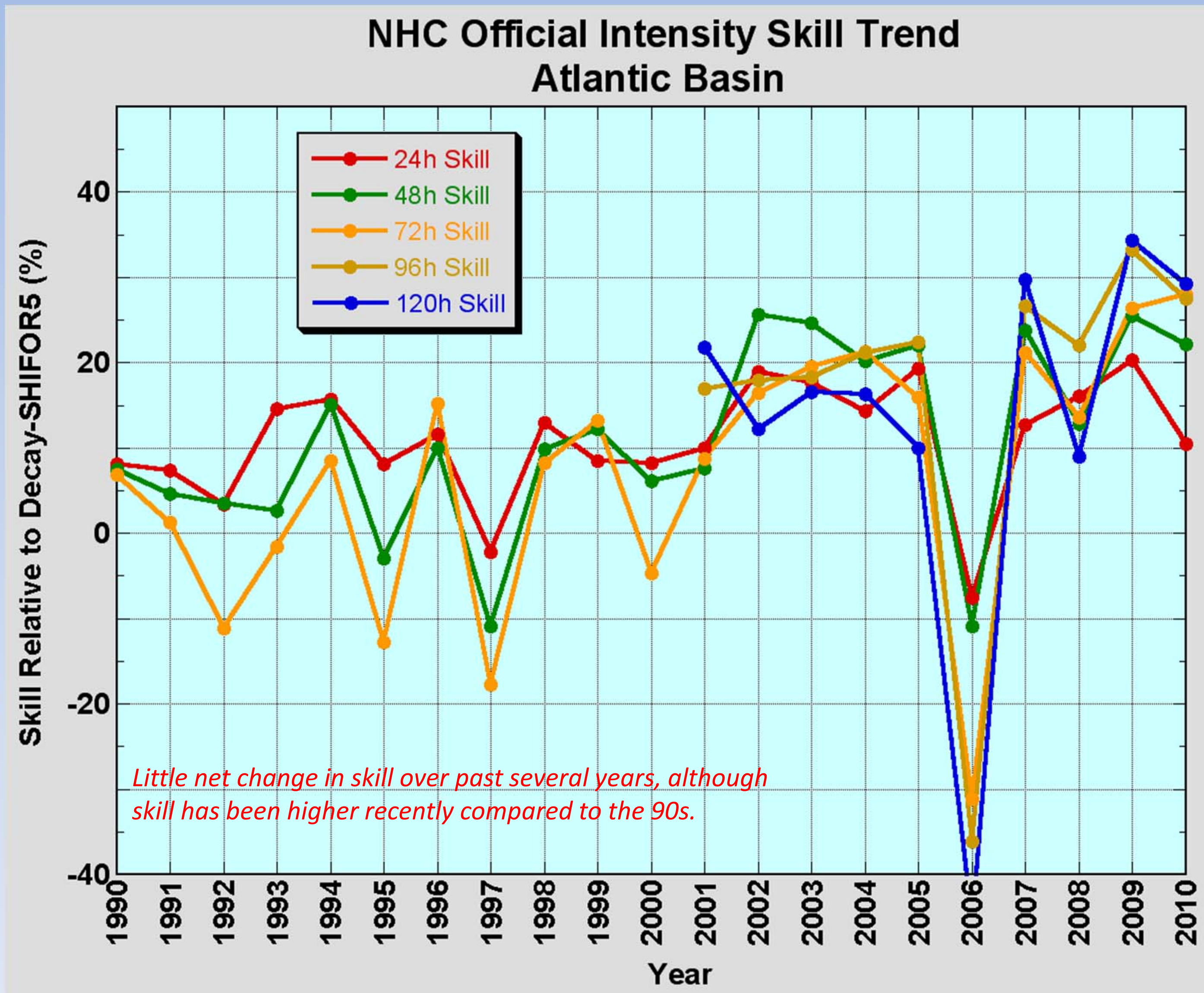
NOAA's Hurricane Forecast Improvement Project (HFIP):

"The specific goals of the HFIP are to reduce the average errors of hurricane track and intensity forecasts by 20% within five years and 50% in ten years with a forecast period out to 7 days. The benefits of HFIP will significantly improve NOAA's forecast services through improved hurricane forecast science and technology. Forecasts of higher accuracy and greater reliability (i.e., user confidence) are expected to lead to improved public response, including savings of life and property."

Little or no progress in forecasting intensity over the past couple of decades?



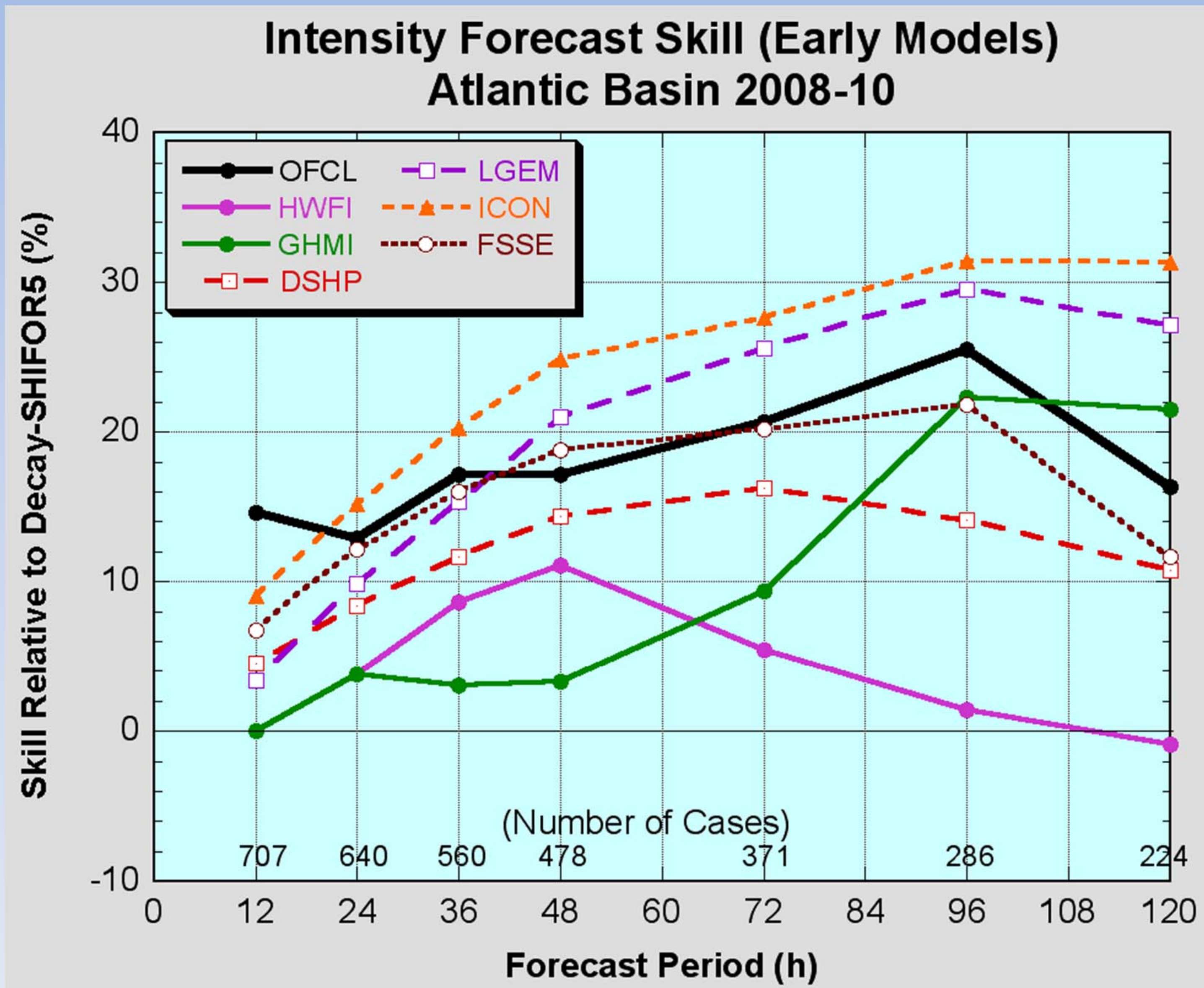
Perhaps there has been a slight increase in skill in recent years



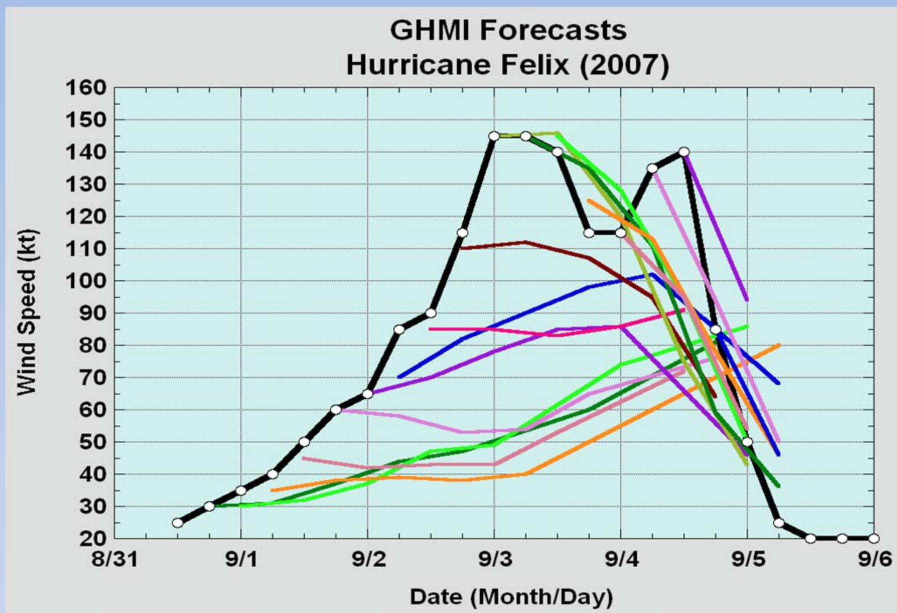
Tropical cyclone intensity forecast models

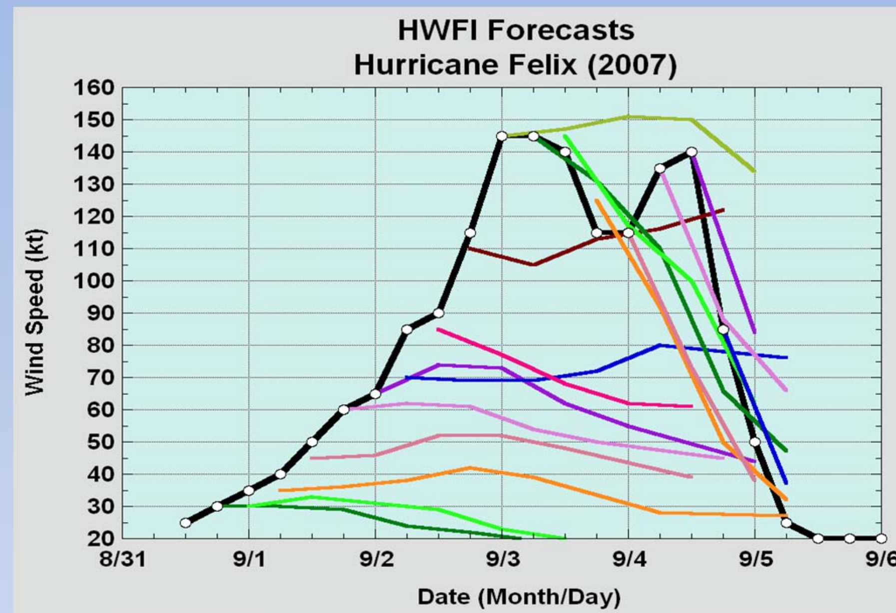
- **Statistical Models:**
  - **Decay SHIFOR** (Statistical Hurricane Intensity FORecast with inland decay).
    - Based on historical information - climatology and persistence (uses CLIPER track).
    - Baseline for skill of intensity forecasts
- **Statistical-Dynamical Models:**
  - **SHIPS** and **DSHIPS** (Statistical Hurricane Intensity Prediction Scheme):
    - Based on climatology, persistence, and statistical relationships to current and forecast environmental conditions (with inland decay applied in DSHIPS)
  - **LGEM** (Logistic Growth Equation Model):
    - Uses same inputs as SHIPS, but environmental conditions are variable over the length of the forecast (SHIPS averages over the entire forecast)
    - More sensitive to environmental changes at the end of the forecast, but also more sensitive to track forecast errors.
- **Dynamical Models:**
  - **HWRF, GFDL, GFDN, GFS, UKMET, NOGAPS, ECMWF**
    - Based on the present and the future by solving the governing equations for the atmosphere (and ocean).

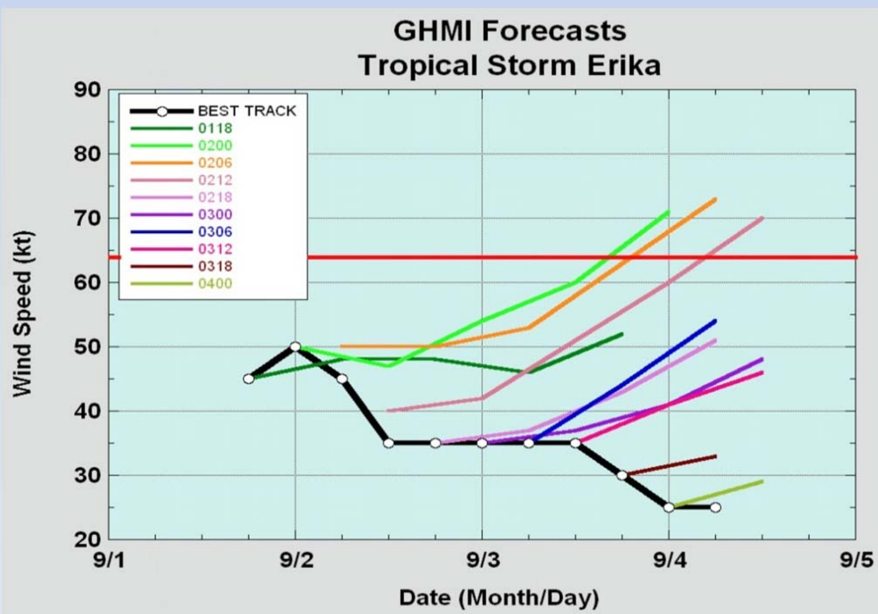
Best individual model for predicting intensity has been a statistically-based one

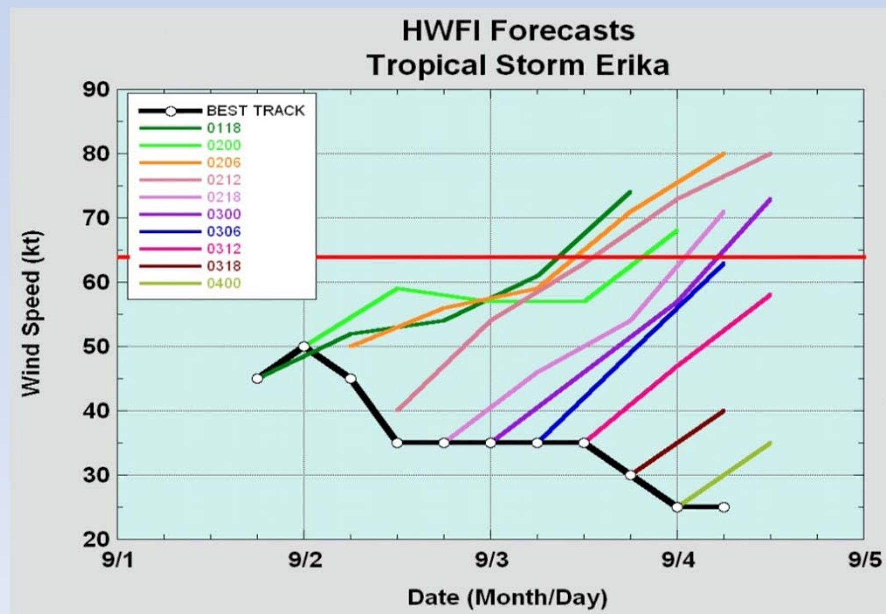


Lots of problems with dynamical guidance for predicting intensity change









RII guidance for Hurricane Rick (October 2009)

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*   EAST PACIFIC SHIPS INTENSITY FORECAST   *
*      GOES DATA AVAILABLE                  *
 *      OHC  DATA AVAILABLE                  *
 *  RICK        EP202009  10/16/09  18 UTC   *

TIME (HR)          0     6    12    18    24    36    48    60    72    84    96   108   120
V (KT) NO LAND    70    79    86    92    97   104   108   111   111   107   107   101    93
V (KT) LAND       70    79    86    92    97   104   108   111   111   107   107   101    93
V (KT) LGE mod    70    79    86    92    96    99    95    91    87    85    83    80    76

             ** 2009 E. Pacific RI INDEX EP202009 RICK       10/16/09  18 UTC **
                            ( 30 KT OR MORE MAX WIND INCREASE IN NEXT 24 HR)

       12 HR PERSISTENCE (KT):  20.0 Range:-20.0 to  35.0 Scaled/Wgted Val:  0.7/  1.6
       850-200 MB SHEAR (KT) :   6.0 Range: 15.2 to   1.6 Scaled/Wgted Val:  0.7/  0.8
       D200 (10**7s-1)       :  70.0 Range:-10.0 to 129.0 Scaled/Wgted Val:  0.6/  0.4
       POT = MPI-VMAX (KT)   :  96.7 Range: 46.6 to 134.3 Scaled/Wgted Val:  0.6/  0.6
       850-700 MB REL HUM (%):  79.4 Range: 64.0 to  88.0 Scaled/Wgted Val:  0.6/  0.2
       % area w/pixels <-30 C:  98.0 Range: 26.0 to 100.0 Scaled/Wgted Val:  1.0/  0.5
       STD DEV OF IR BR TEMP :   8.3 Range: 35.4 to   2.7 Scaled/Wgted Val:  0.8/  1.3
       Heat content (KJ/cm2) :  46.8 Range:   4.0 to  67.0 Scaled/Wgted Val:  0.7/  0.4

       Prob of RI for 25 kt RI threshold=    78% is   6.8 times the sample mean(11.5%)
       Prob of RI for 30 kt RI threshold=    71% is   9.3 times the sample mean( 7.7%)
       Prob of RI for 35 kt RI threshold=    66% is  12.6 times the sample mean( 5.2%)
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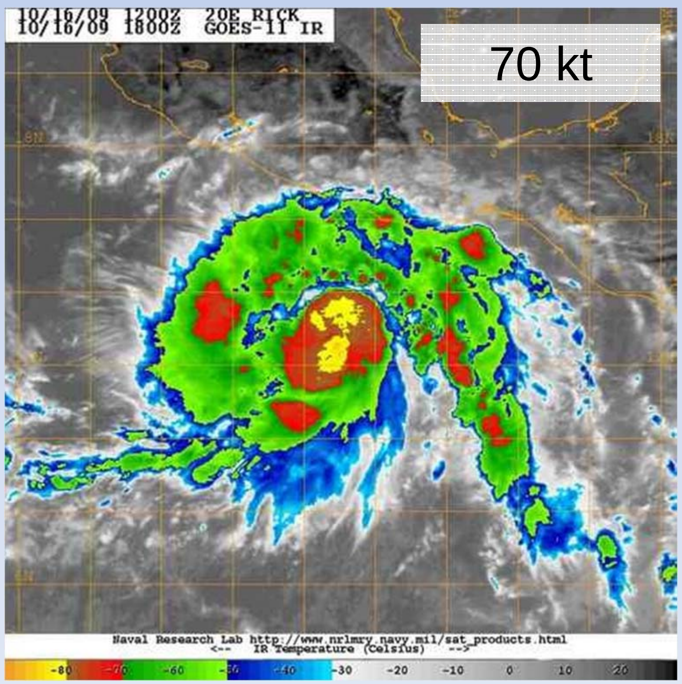
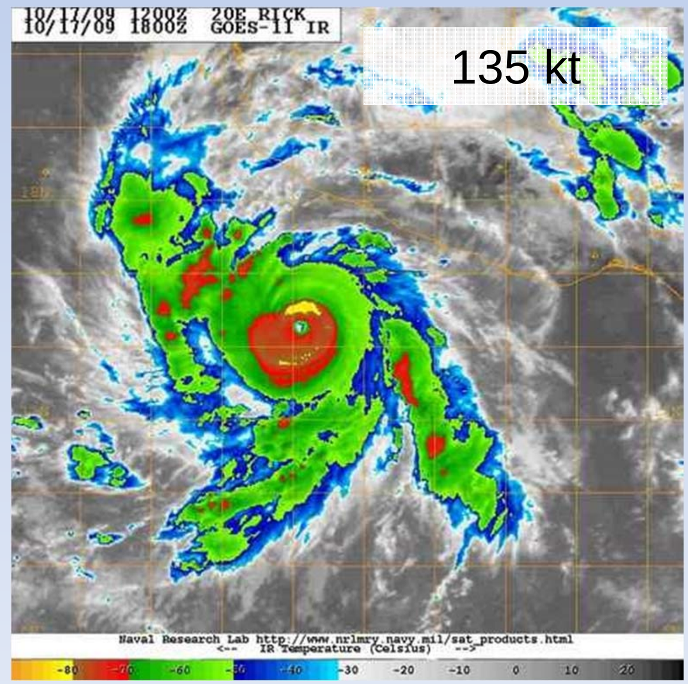
Rapid intensification of Hurricane Rick (October 2009)

FORECAST POSITIONS AND MAX WINDS

INITIAL	16/2100Z	13.0N	100.0W	75 KT
12HR VT	17/0600Z	13.2N	101.3W	90 KT
24HR VT	17/1800Z	13.7N	103.3W	105 KT
36HR VT	18/0600Z	14.3N	105.8W	115 KT
48HR VT	18/1800Z	15.0N	108.1W	125 KT
72HR VT	19/1800Z	16.5N	111.5W	120 KT
96HR VT	20/1800Z	18.5N	113.0W	105 KT
120HR VT	21/1800Z	20.5N	113.0W	85 KT



24 hrs



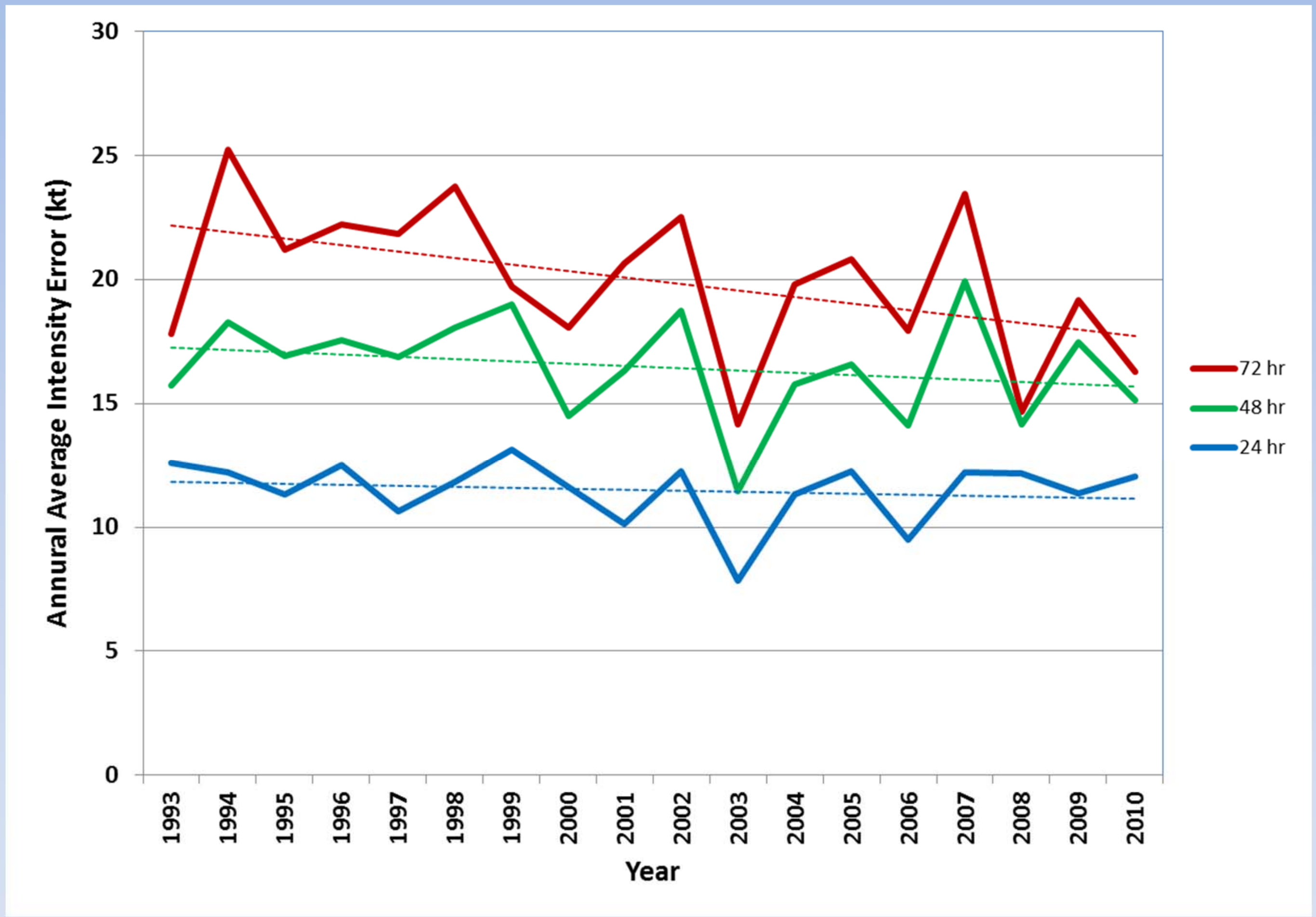
Tropical cyclone intensity change is governed by:

- The evolution of the large-scale atmospheric environment
- The evolution of the oceanic environment
- The evolution of the structure of the tropical cyclone, particularly the inner core
- Physical processes that relate the above 3 factors to strengthening or weakening, such as the warming of the air in the eye that leads to lower pressure and intensificiation

In order to substantially improve intensity forecasts we need:

- Improved prediction of the large-scale atmospheric environment
- Better prediction of the evolution of the ocean, both the surface and the subsurface
- High resolution, e.g. a model grid with a spacing small enough to resolve cloud-scale processes
- Much better prediction of the tropical cyclone’s inner core structure, including the eyewall and any asymmetries in the distribution of showers and thunderstorms about the center
- A better understanding and improved simulation of physical processes that are associated with intensity change, including exchanges of heat and moisture at the air-sea interface, turbulent exchanges of heat, moisture and momentum, and how clouds cause changes in temperature, moisture and momentum in the tropical cyclone’s circulation

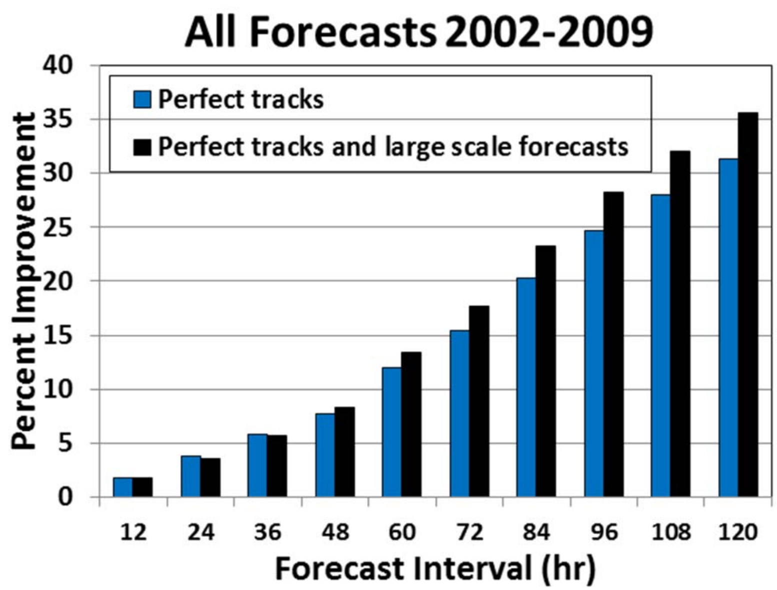
Statistical-Dynamical Intensity Model Forecast Error Trend

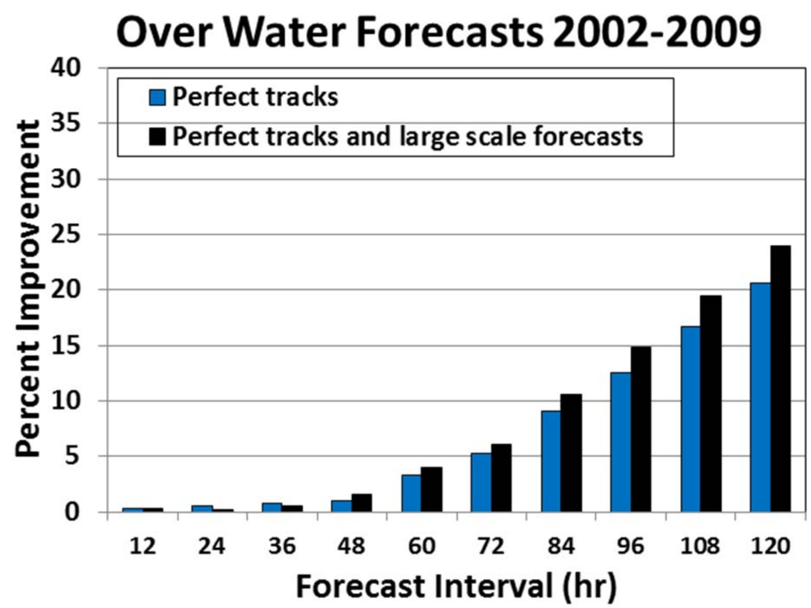


SHIPS 1993-1999, D-SHIPS 2000-2005, LGEM 2006-2010

18 Year Improvements of 6%, 10% and 20% at 24, 48 and 72 hr

Potential Intensity Forecast Improvements From Better Track and Large Scale Environment Predictions





Based on LGEM model forecasts with "perfect" tracks and "perfect" large scale environment forecasts relative to those with operational input

These results suggest that:

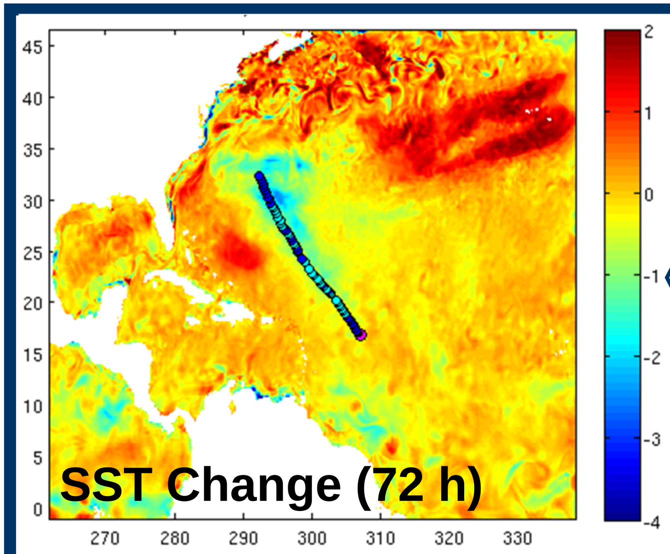
- We can improve the forecast of the tropical cyclone’s large-scale environment mainly by making a more accurate prediction of the cyclone’s track
- We can probably squeeze just 10 to 20% more improvement in intensity forecasts via the statistical-dynamical approach

Coupling to the ocean:

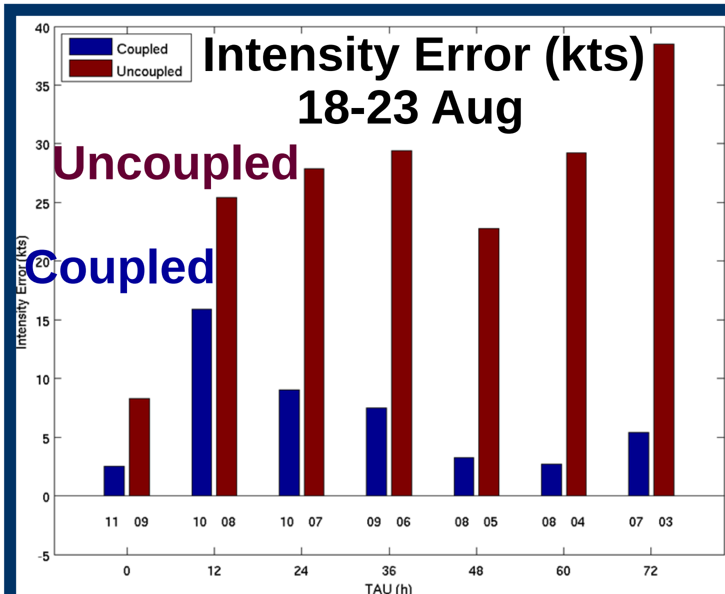
- Accurate intensity forecasts often require consideration of how the hurricane interacts with the underlying ocean
- One of the main aspects of this interaction is the cooling of the sea surface beneath the hurricane due to upwelling and mixing of subsurface waters
- Other aspects, such as the effect of waves, sea spray and ocean currents, also play a role
- The following example is from the U.S. Navy's Coupled Ocean-Atmosphere Mesoscale Prediction System for Tropical Cyclones (COAMPS-TC)

COAMPS-TC: New Capabilities

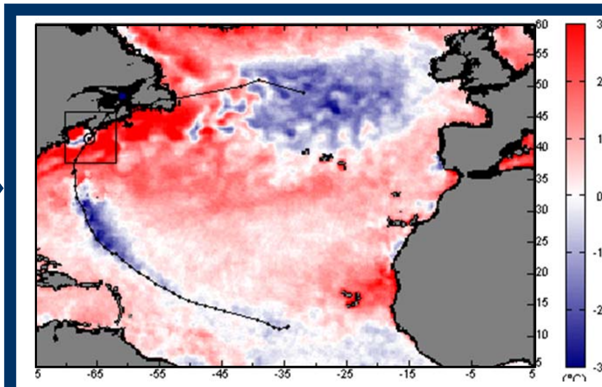
Coupled Air-Sea Forecasts of Hurricane Bill



Air-Ocean Coupling in COAMPS-TC Predicts SST Cool Wake of 2-3°C



Microwave Satellite Derived SST Shows 2-3°C Cool Wake Similar to the Coupled Model



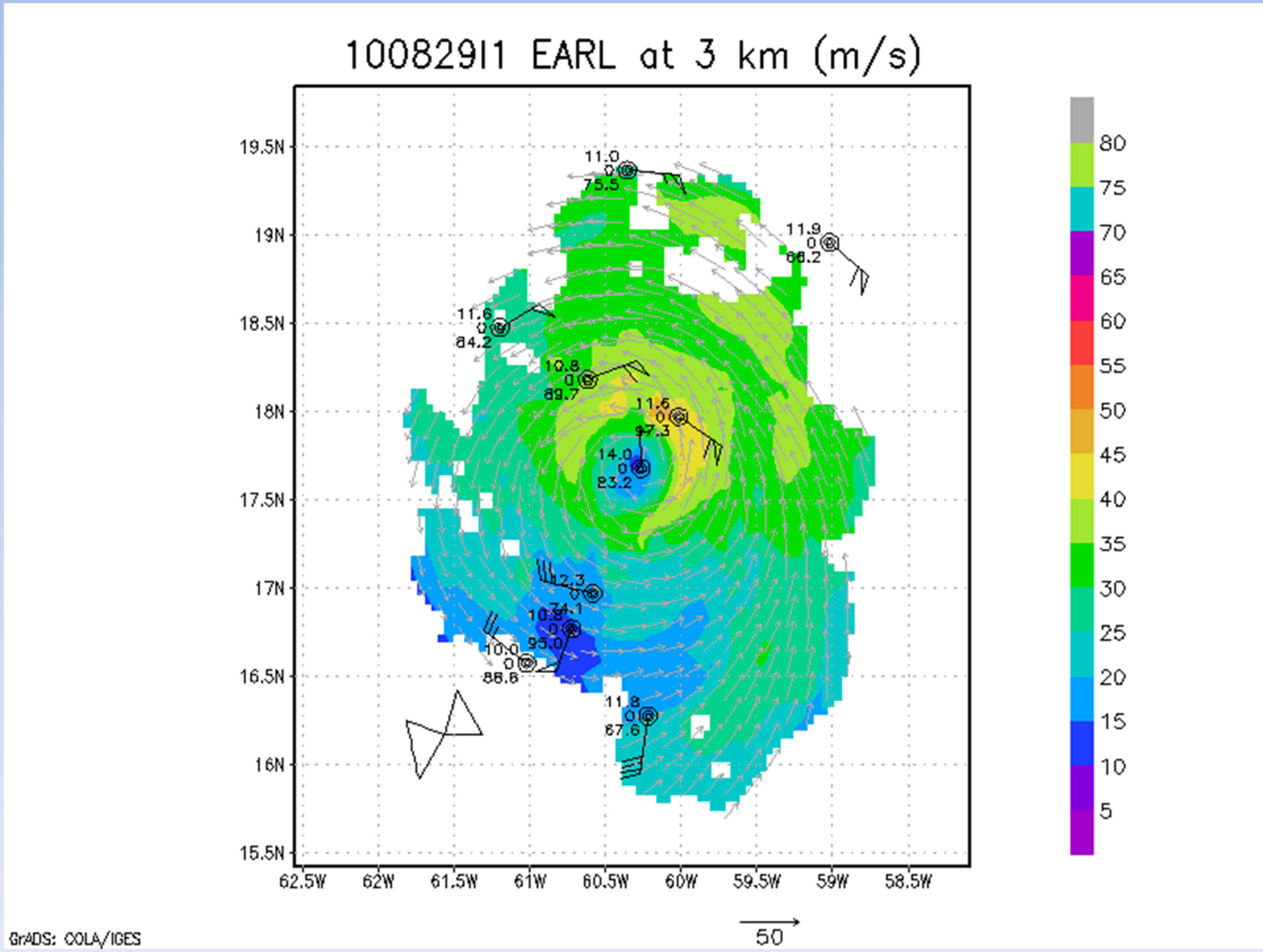
Intensity Error Markedly Improved using Coupled Model

Inclusion of air-sea coupling for Bill alleviates an over-intensification bias as a result of cool SST wakes.

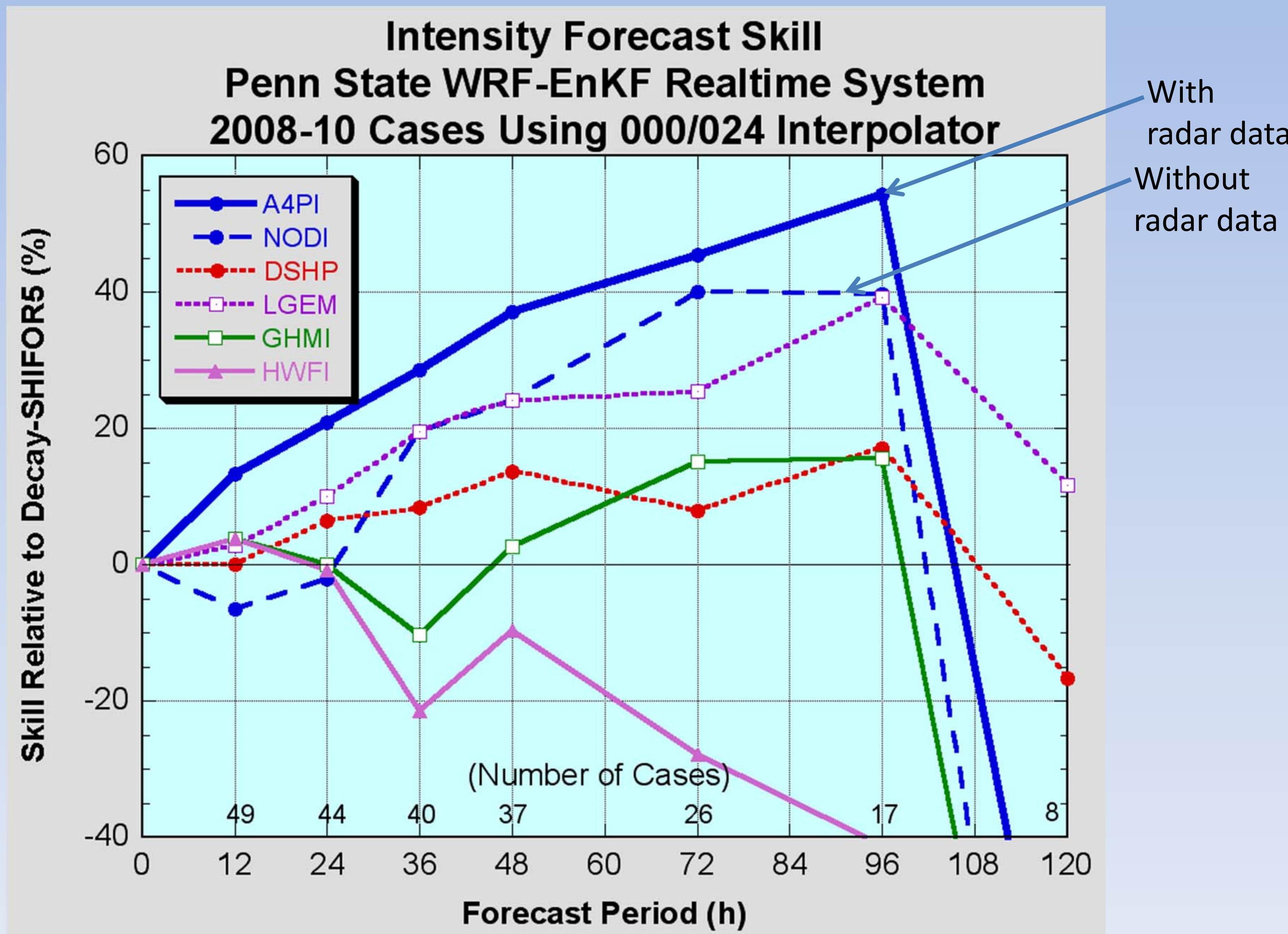
Model resolution:

- A necessary, but not sufficient, condition for making improved hurricane intensity forecasts
- Grid spacing will likely need to be reduced to a mile or less in order to resolve thunderstorm clouds
- Research thus far has shown that decreasing the grid spacing alone does not necessarily produce more accurate model predictions of intensity
- In particular, a high-resolution model needs high-resolution data to provide an accurate initial structure of the inner core

Reconnaissance aircraft can obtain some inner-core data with flight-level observations, dropsondes, and Doppler radar



Some experimentation has already been done with a high-resolution model assimilating the tail Doppler data collected by NOAA aircraft flying in various storms



Concluding Remarks

- There has been some slight improvement in the skill of NHC intensity forecasts over the past decade or so.
- So far, statistical-dynamical models have provided the most accurate guidance for intensity prediction. There has been a slight improvement in the accuracy of these models over the past generation or so.
- A little more improvement in intensity prediction, perhaps as much as 10 to 20% is possible in the statistical-dynamical models, but not much more.
- Dynamical atmospheric models, with high resolution, coupled to a realistic ocean model, with an accurate initial representation of the tropical cyclone inner core, and a proper simulation of physical processes such as the effects of clouds, showers and thunderstorms, offer the best hope of making significant improvements in intensity forecasts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