USE OF DYNAMICAL HURRICANE GUIDANCE AT NHC & FUTURE CHALLENGES

Richard J. Pasch
Senior Hurricane Specialist
National Hurricane Center

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OUTLINE

- What does NHC forecast?
- Track forecasting
- Intensity forecasting
- Genesis forecasting
- Future challenges

WHAT DOES THE NHC FORECAST?

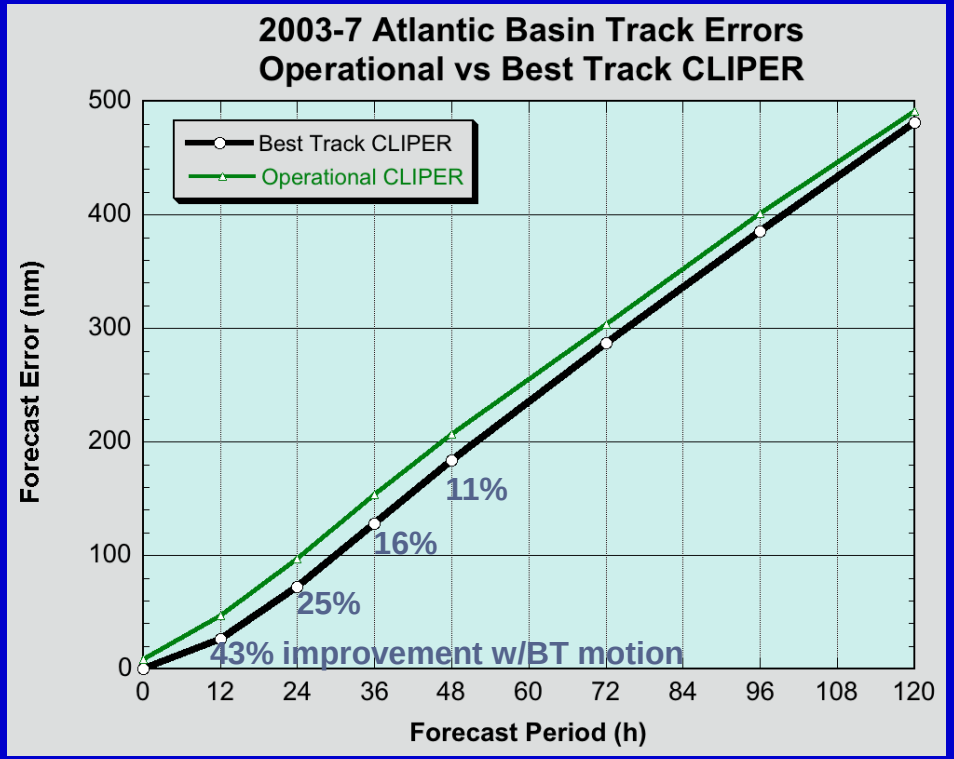
- Track: center positions at 0, 12, 24, 36, 48, 72, 96, and 120 hours
- Intensity: max sustained winds (and gusts) at 0, 12, 24, 36, 48, 72, 96, and 120 hours
- Size/Structure: radii (by quadrant) of 34-, 50-, and 64-kt winds at 0, 12, 24, and 36 hours, and radii of 34- and 50-kt winds at 48 and 72 hours
- Likelihood (probability to the nearest 10%) of TC formation within 48 hours
- Storm surge (including inundation levels)
- Rainfall (HPC), Tornadoes (SPC)

Track Forecasting at the NHC:

- Initial motion importance/determination
- Dynamical models
- Synoptic (subjective) analysis
- Continuity constraints

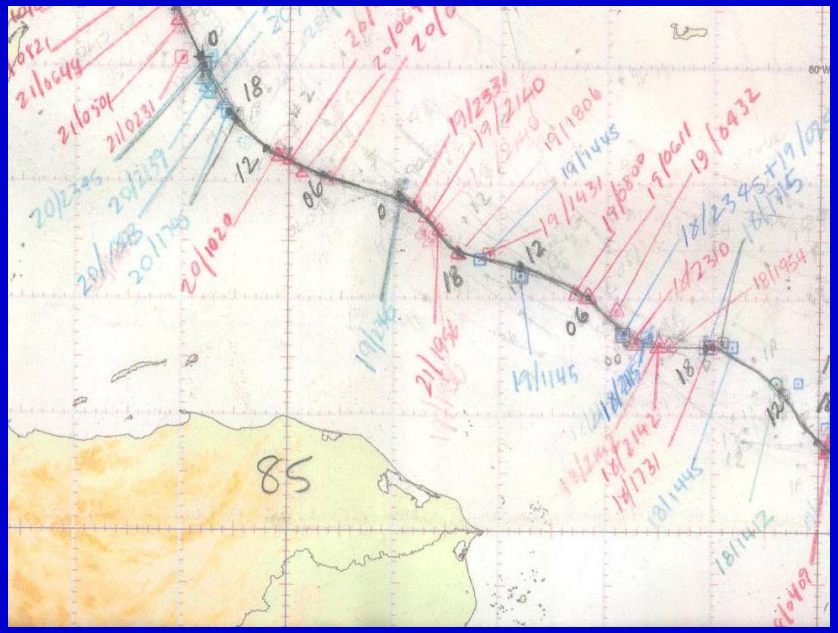
Track Forecasting at the NHC: Importance of Initial Motion

- Accurate estimate of initial motion is extremely important.
  - Has dramatic impact on accuracy of the CLIPER model at shorter ranges.
  - Initial motion vector is also used in some vortex bogussing schemes.
  - 12-h NHC forecast is heavily weighted by the initial motion estimate.
- Not always easy to determine, particularly for systems with ill-defined centers.



Track Forecasting at the NHC: Determination of Initial Motion

- Initial motion typically computed using the average motion over the previous 6, 12, or 18 h.
  - Shorter when known changes in track are occurring, longer when center location is uncertain.
  - Initial motion estimate should not reflect short-term track wobbles (e.g., trochoidal oscillations) that will not persist.



- NHC philosophy is that it is better to lag events a little bit than to be going back and forth with analyses or forecasts. We will usually wait several hours before "calling" a change in track.

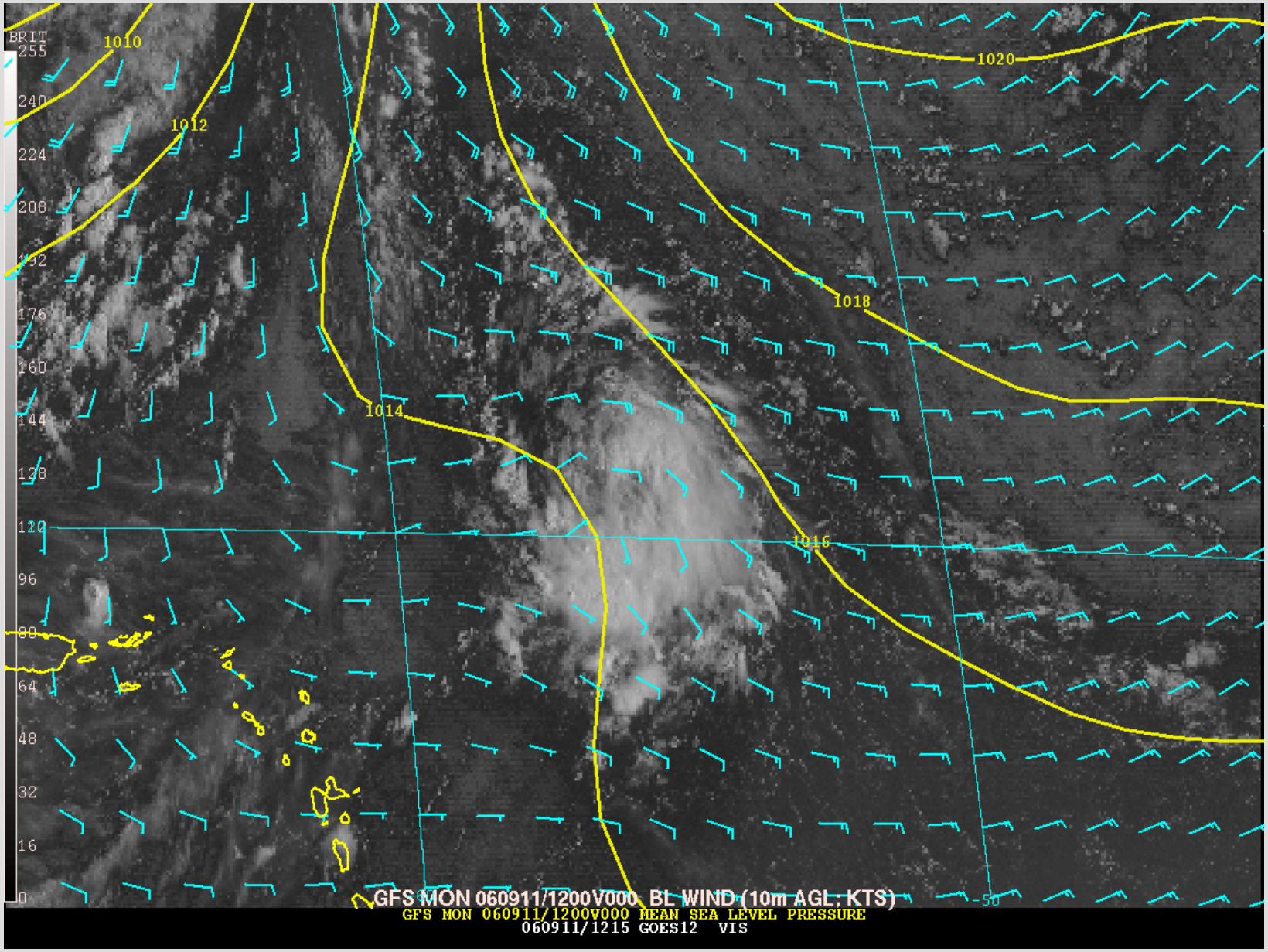
Track Forecasting at the NHC: Using Dynamical Models

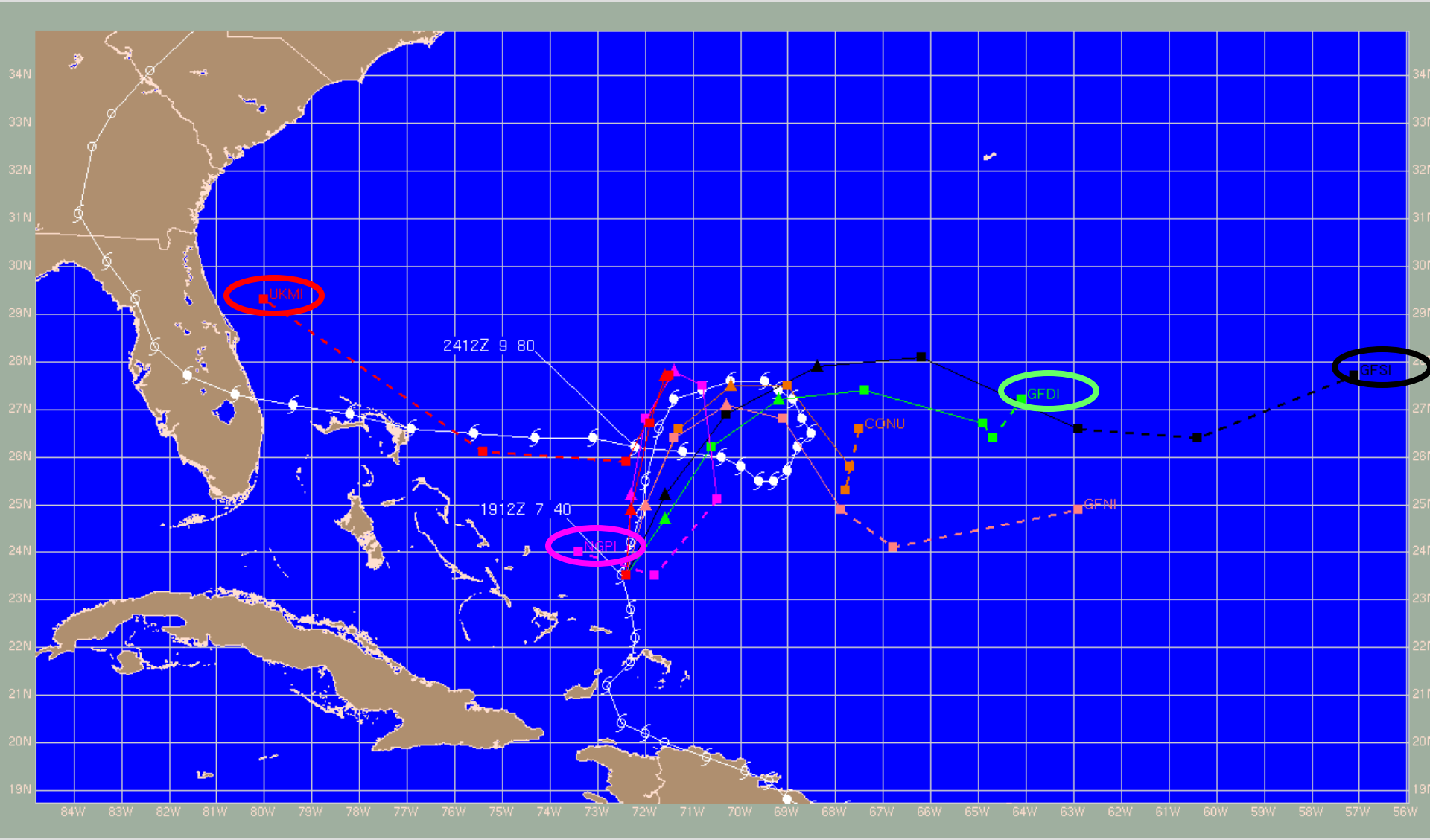
- Dynamical model consensus is an excellent first guess for the forecast (and often a good final guess!). Continuity dictates that it must be considered in view of the previous official forecast, however.
- Evaluate the large-scale environment using conventional data and satellite imagery (e.g., water vapor)
  - Try to assess steering influences so that you understand and perhaps evaluate the model solutions.

Track Forecasting at the NHC: Using Dynamical Models (cont.)

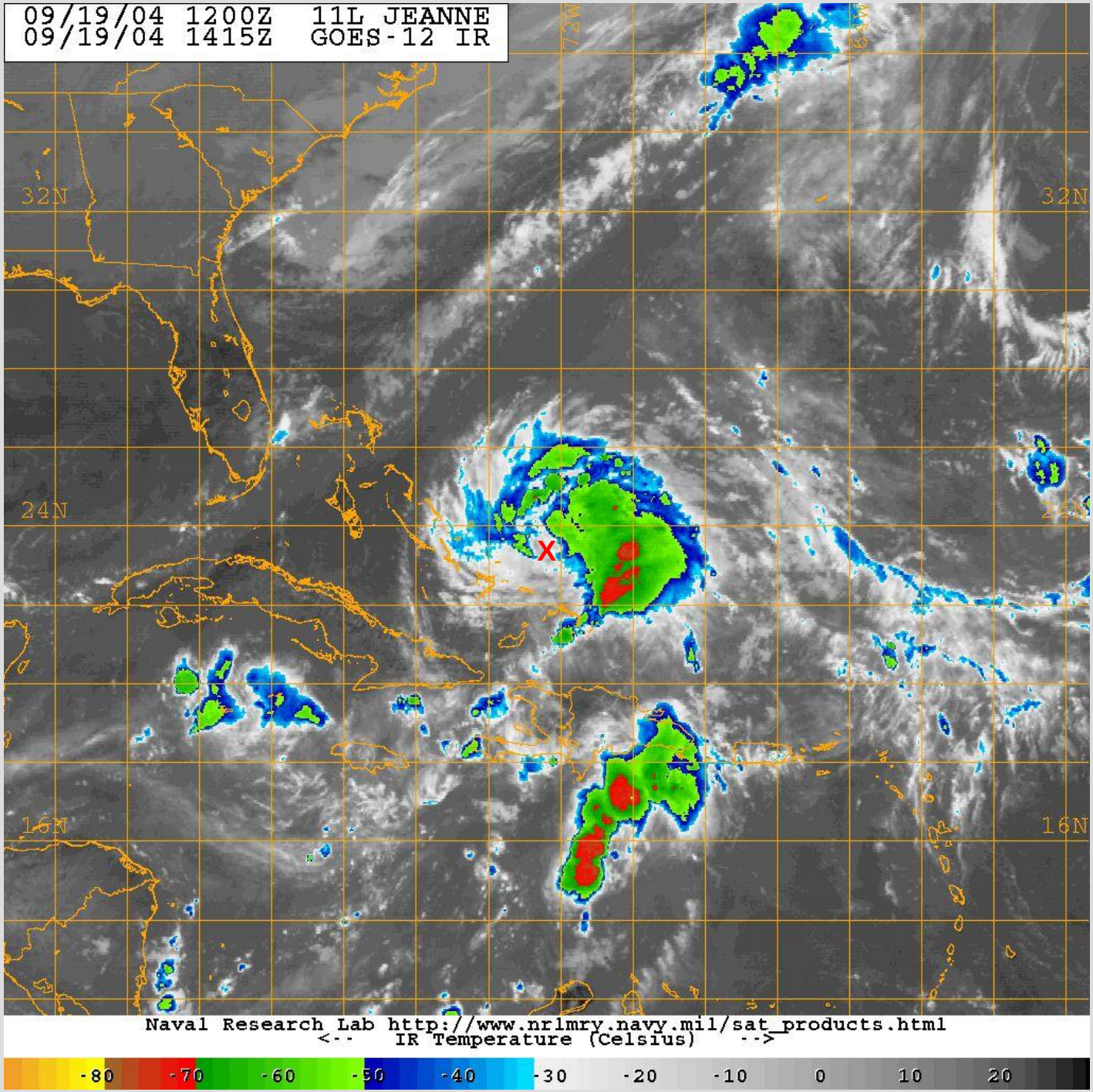
- Compare the models' forecast of the environmental features, not just the TC tracks.
  - Evaluate the initialization of the TC in the model fields. Unrealistic initial TC structure can affect the likelihood of a successful forecast.
  - Consider the recent performance of the various models, both in terms of accuracy and consistency.
  - Spread of models can dictate forecaster confidence.

Bad Initialization for Tropical Storm Gordon
1200 UTC 11 September 2006





How to resolve the difference between guidance models?



Poor organization (esp. lack of deep convection in the core) would argue against Jeanne being carried eastward by upper-level westerlies.

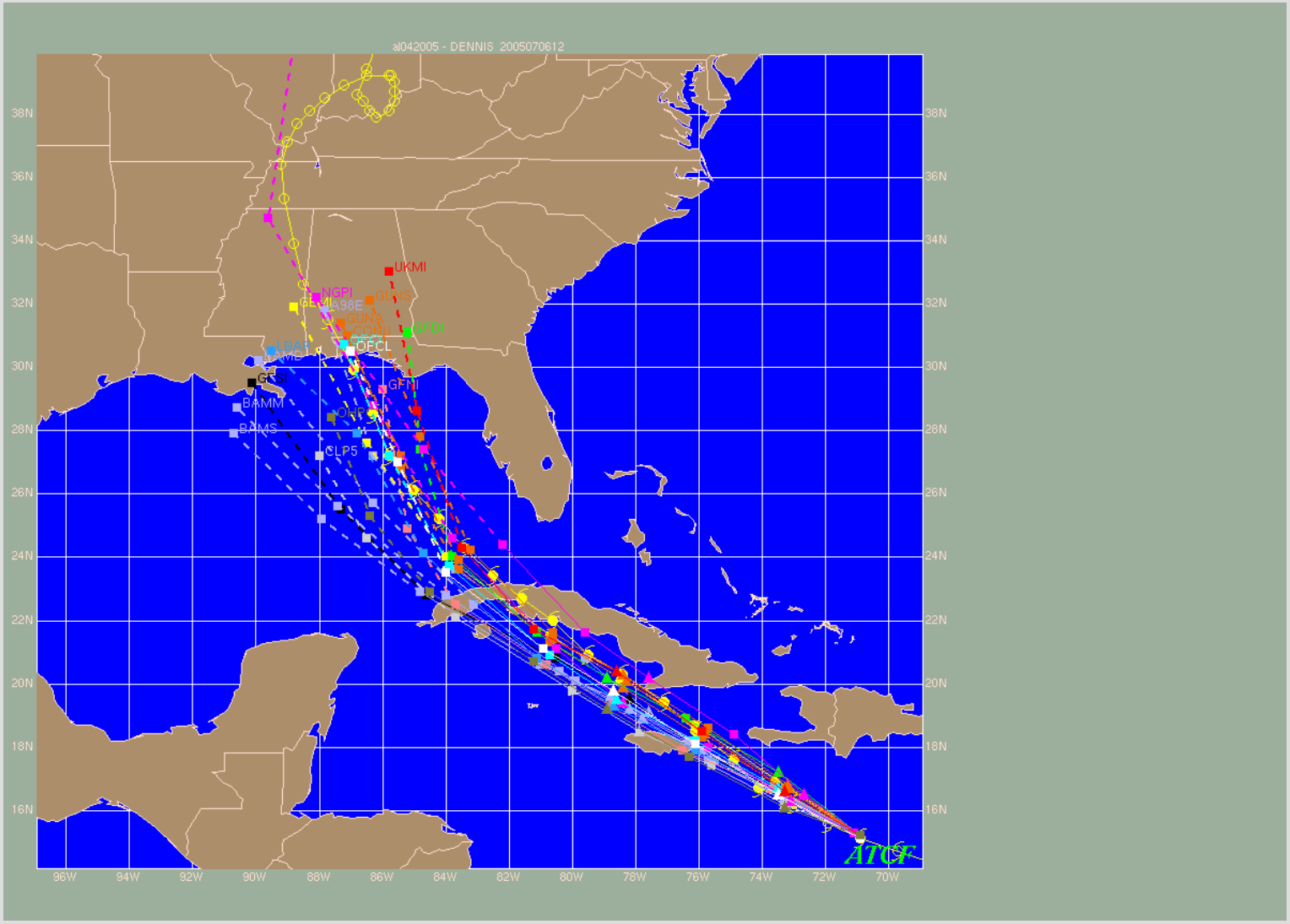
This reasoning allowed the forecasters to largely disregard the GFS and form a “selective consensus” of the remaining models.

Track forecast is therefore affected by the intensity forecast.

Track Forecasting at the NHC: Continuity

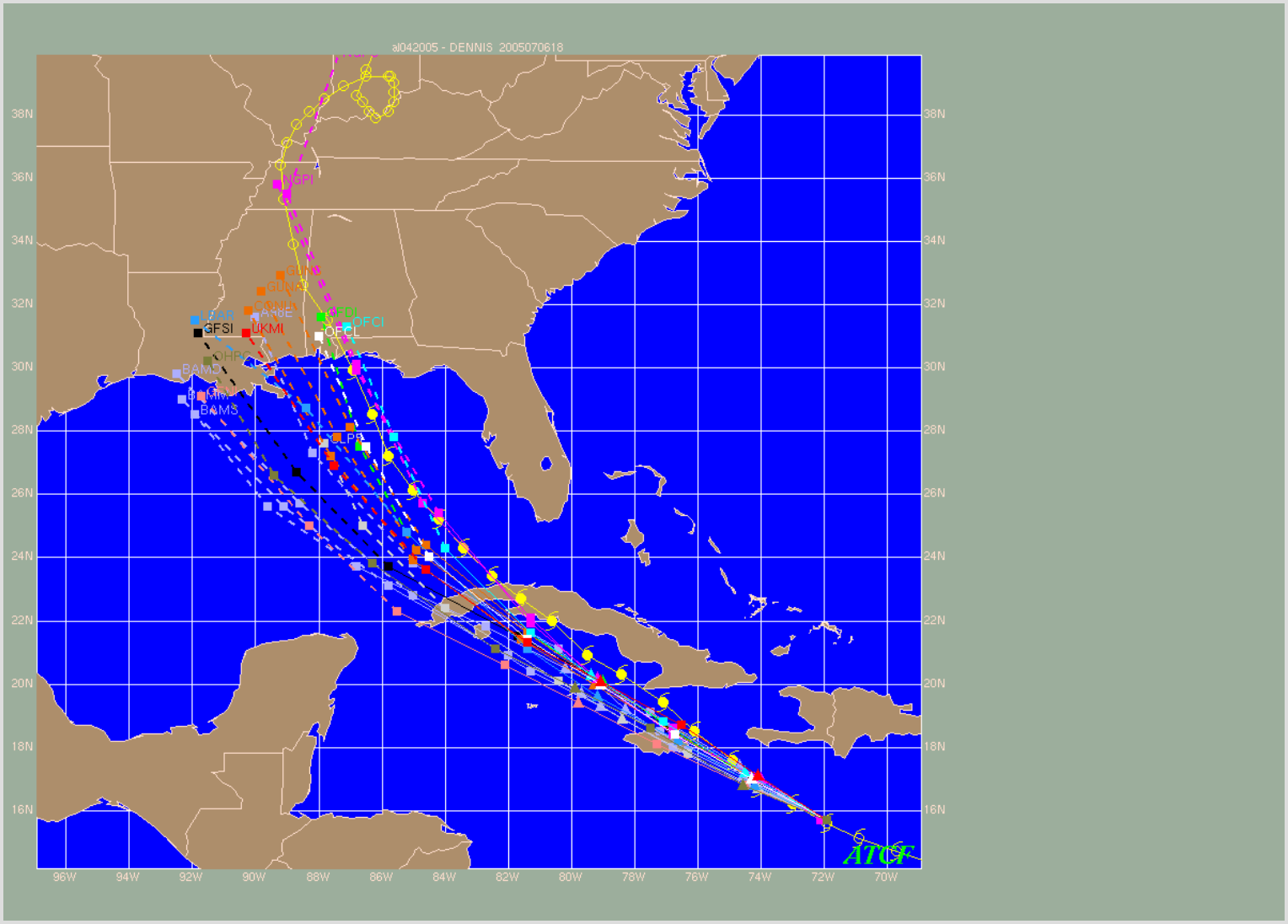
- Previous official forecast exerts a strong constraint on the current forecast.
- Credibility can be damaged by making big changes from one forecast to the next, and then having to go back to the original (flip-flop, windshield-wiper).
- Consequently, changes to the previous forecast are normally made in small increments.
- We strive for continuity within a given forecast (e.g., gradual changes in direction or speed from 12 to 24 to 36 h, etc.

Dennis Guidance 6 July 1200 UTC



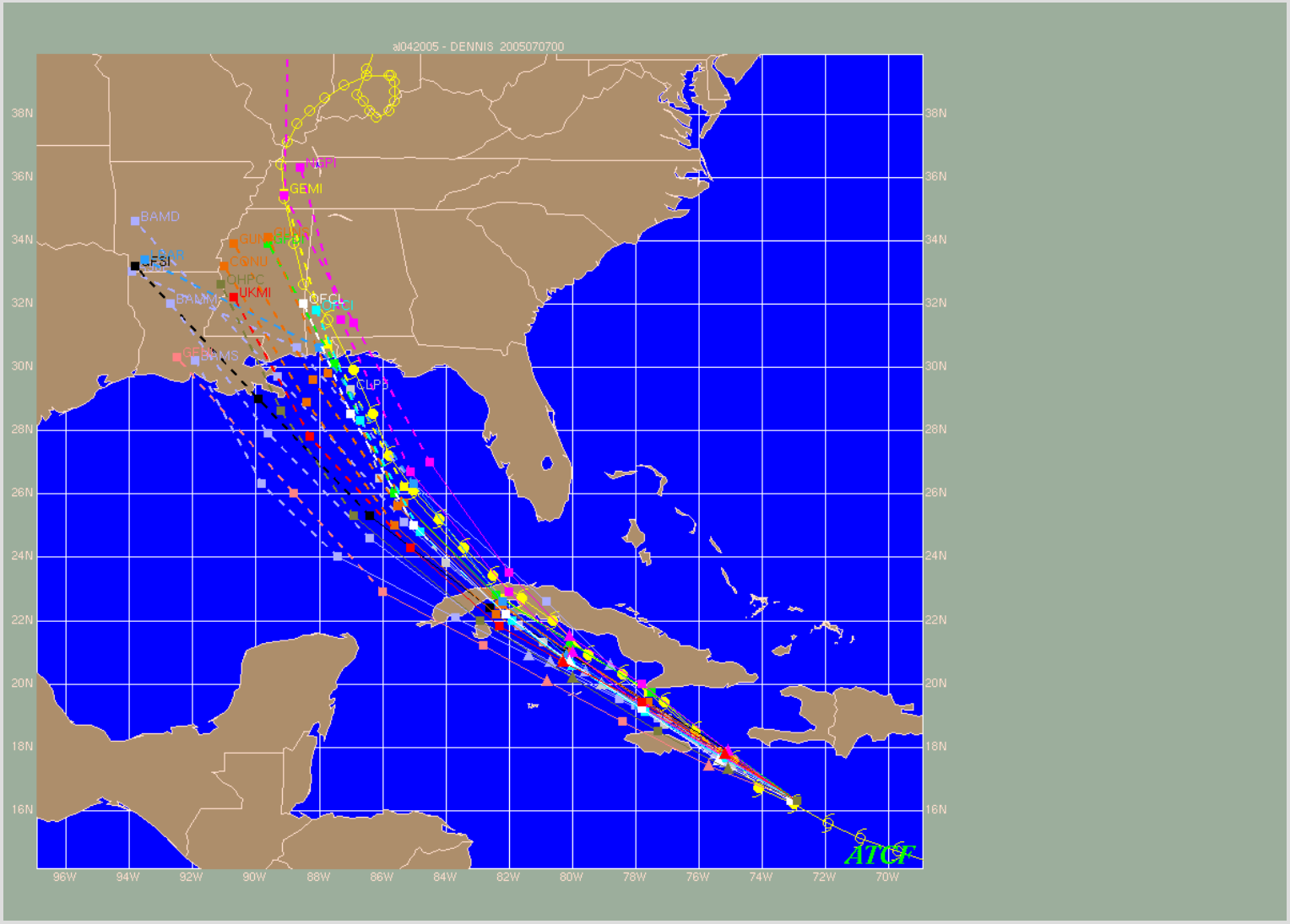
- Official forecast near model consensus in extreme western FL panhandle.

Dennis Guidance 6 July 1800 UTC



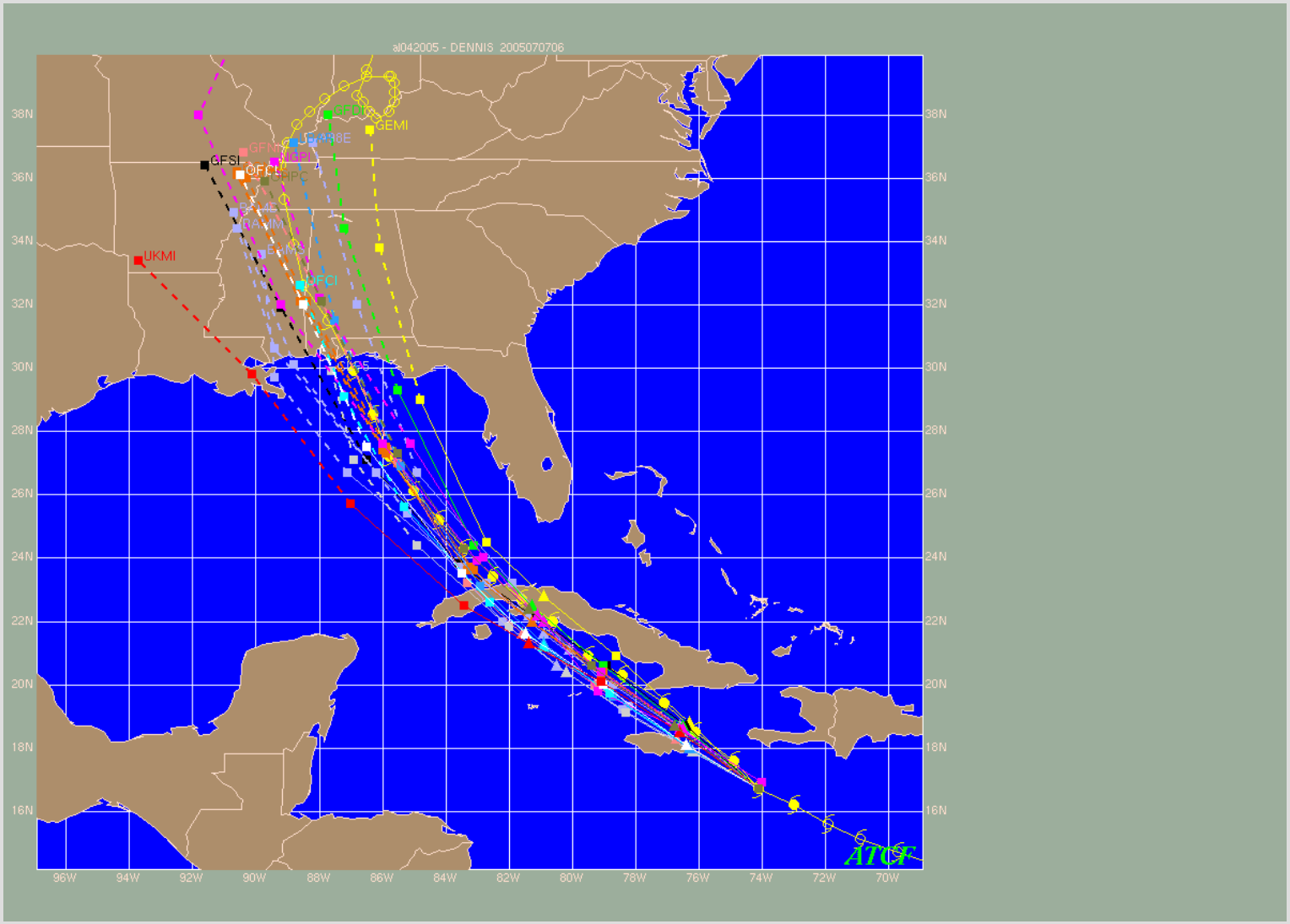
- Guidance shifts sharply westward toward New Orleans. Official forecast nudged westward into AL.

Dennis Guidance 7 July 0000 UTC



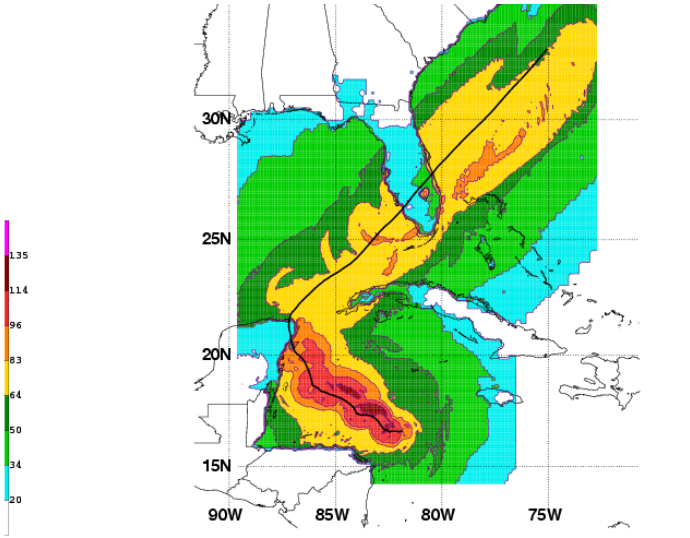
- Little overall change to guidance, but NGPI shifts slightly eastward. Little change in official forecast.

Dennis Guidance 7 July 0600 UTC

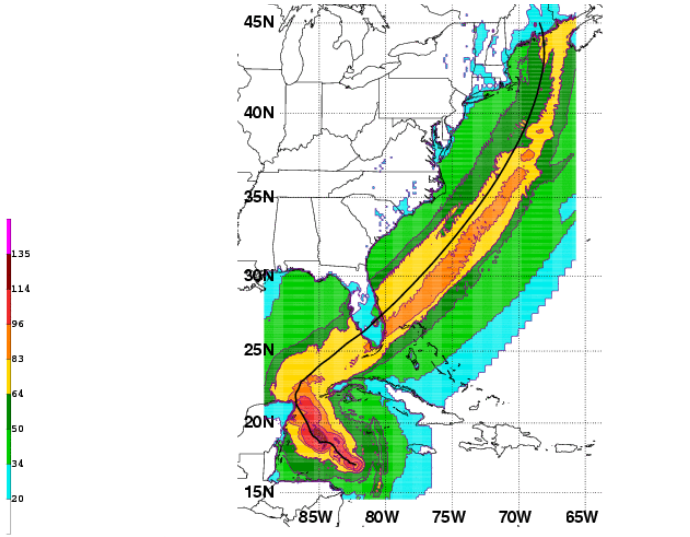


- Rest of the guidance shifts sharply eastward, leaving official forecast near the center of the guidance envelope (and very close to the actual track of Dennis).

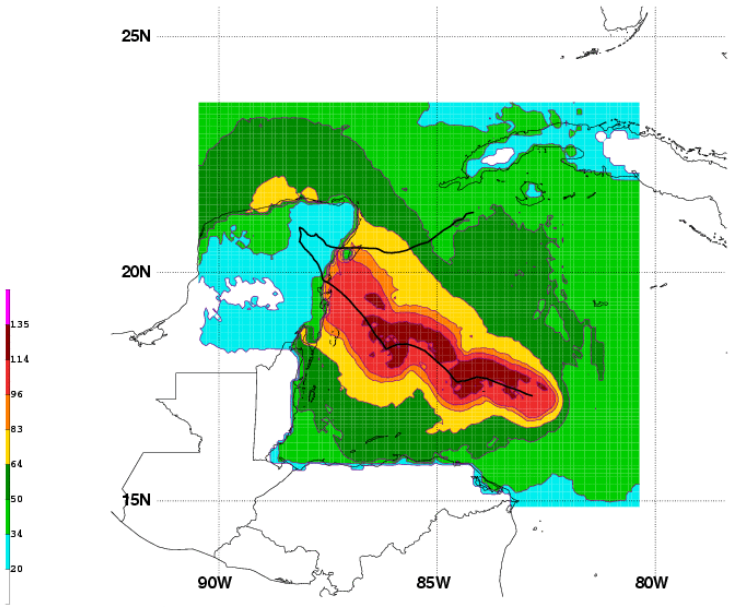
Lack of consistency in GFDL forecasts for Wilma 19 October 2005



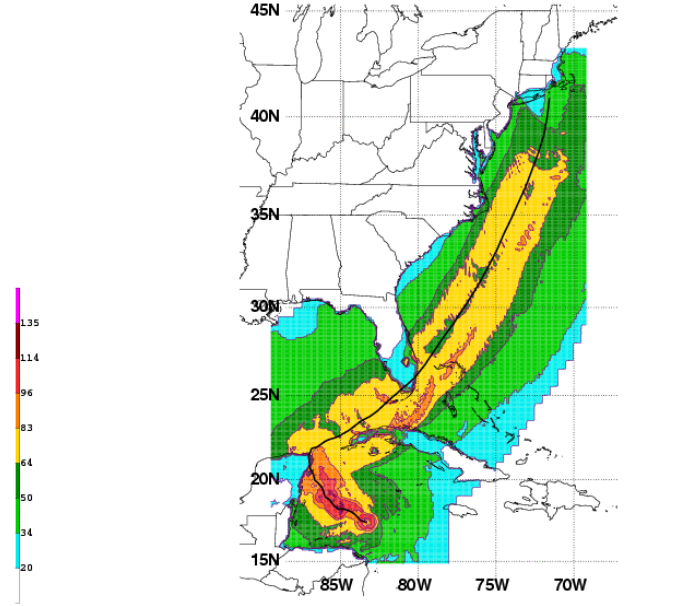
00Z



06Z



12Z



18Z

HURRICANE WILMA DISCUSSION NUMBER 18
NWS TPC/NATIONAL HURRICANE CENTER MIAMI FL
5 PM EDT WED OCT 19 2005

AGREEMENT AMONG THE TRACK GUIDANCE MODELS...WHICH HAD BEEN VERY GOOD OVER THE PAST COUPLE OF DAYS...HAS COMPLETELY COLLAPSED TODAY. THE 06Z RUNS OF THE GFS...GFDL...AND NOGAPS MODELS ACCELERATED WILMA RAPIDLY TOWARD NEW ENGLAND UNDER THE INFLUENCE OF A LARGE LOW PRESSURE SYSTEM IN THE GREAT LAKES REGION. **ALL THREE OF THESE MODELS HAVE BACKED OFF OF THIS SOLUTION...WITH THE GFDL SHOWING AN EXTREME CHANGE...WITH ITS 5-DAY POSITION SHIFTING A MERE 1650 NMI FROM ITS PREVIOUS POSITION IN MAINE TO THE WESTERN TIP OF CUBA.** THERE IS ALMOST AS MUCH SPREAD IN THE 5-DAY POSITIONS OF THE 12Z GFS ENSEMBLE MEMBERS...WHICH RANGE FROM THE YUCATAN TO WELL EAST OF THE DELMARVA PENINSULA. WHAT THIS ILLUSTRATES IS THE EXTREME SENSITIVITY OF WILMA'S FUTURE TRACK TO ITS INTERACTION WITH THE GREAT LAKES LOW. OVER THE PAST COUPLE OF DAYS...WILMA HAS BEEN MOVING SLIGHTLY TO THE LEFT OR SOUTH OF THE MODEL GUIDANCE...AND THE LEFT-MOST OF THE GUIDANCE SOLUTIONS ARE NOW SHOWING WILMA DELAYING OR MISSING THE CONNECTION WITH THE LOW. I HAVE SLOWED THE OFFICIAL FORECAST JUST A LITTLE BIT AT THIS TIME...BUT IF WILMA CONTINUES TO MOVE MORE TO THE LEFT THAN EXPECTED...SUBSTANTIAL CHANGES TO THE OFFICIAL FORECAST MAY HAVE TO BE MADE DOWN THE LINE. NEEDLESS TO SAY...**CONFIDENCE IN THE FORECAST TRACK...ESPECIALLY THE TIMING...HAS DECREASED CONSIDERABLY.**

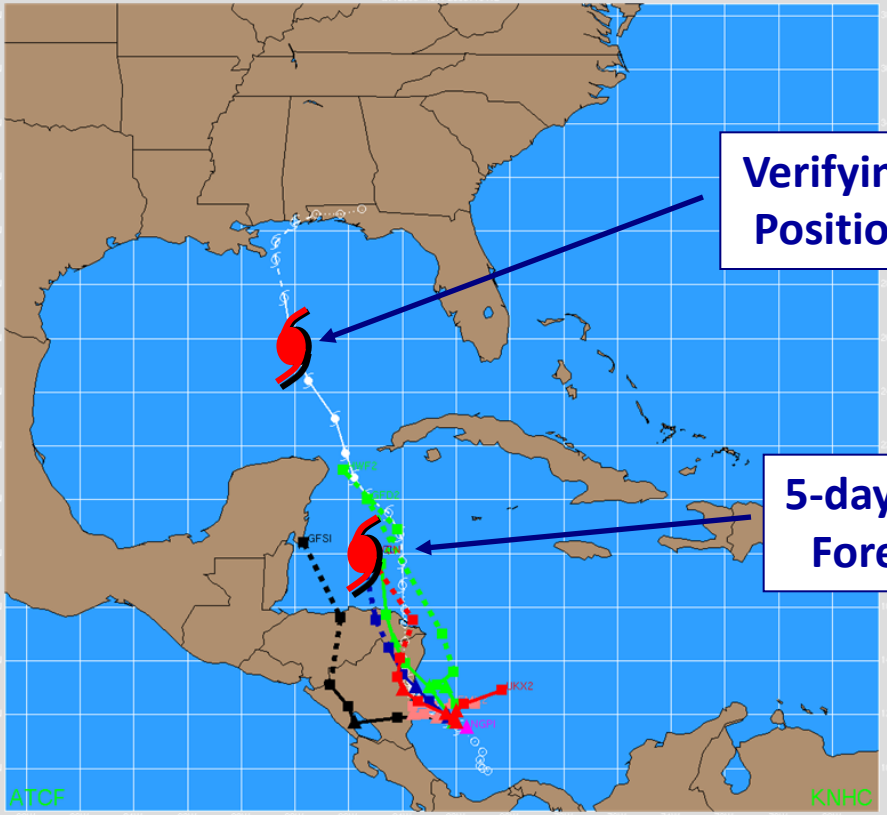
...DELETED DISCUSSION TEXT...

FORECASTER FRANKLIN

FORECAST POSITIONS AND MAX WINDS

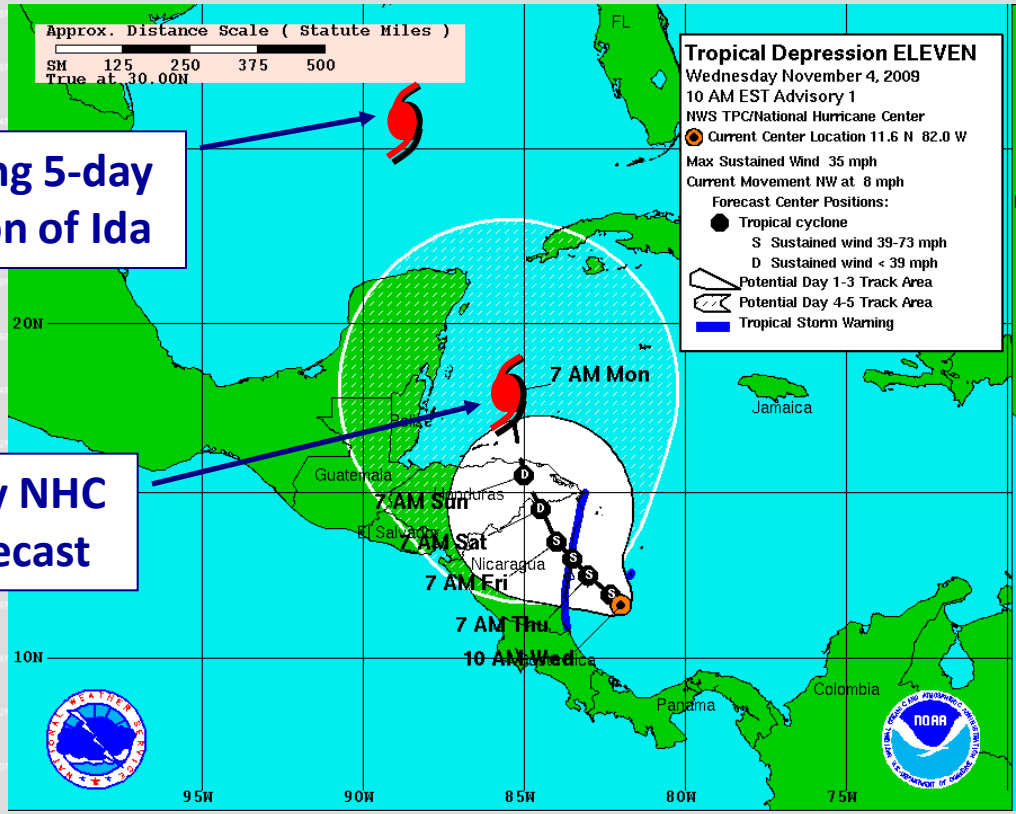
INITIAL	19/2100Z	17.7N	83.7W	140 KT
12HR VT	20/0600Z	18.0N	84.6W	135 KT
24HR VT	20/1800Z	19.2N	85.6W	145 KT
36HR VT	21/0600Z	20.4N	86.2W	145 KT
48HR VT	21/1800Z	21.6N	86.3W	120 KT
72HR VT	22/1800Z	24.0N	84.5W	105 KT
96HR VT	23/1800Z	27.5N	79.0W	80 KT
120HR VT	24/1800Z	36.0N	70.0W	65 KT

Timing (along-track error) is often an issue; example of NHC track forecast for Ida of 2009



Verifying 5-day Position of Ida

5-day NHC Forecast



Track Model Guidance

NHC Forecast

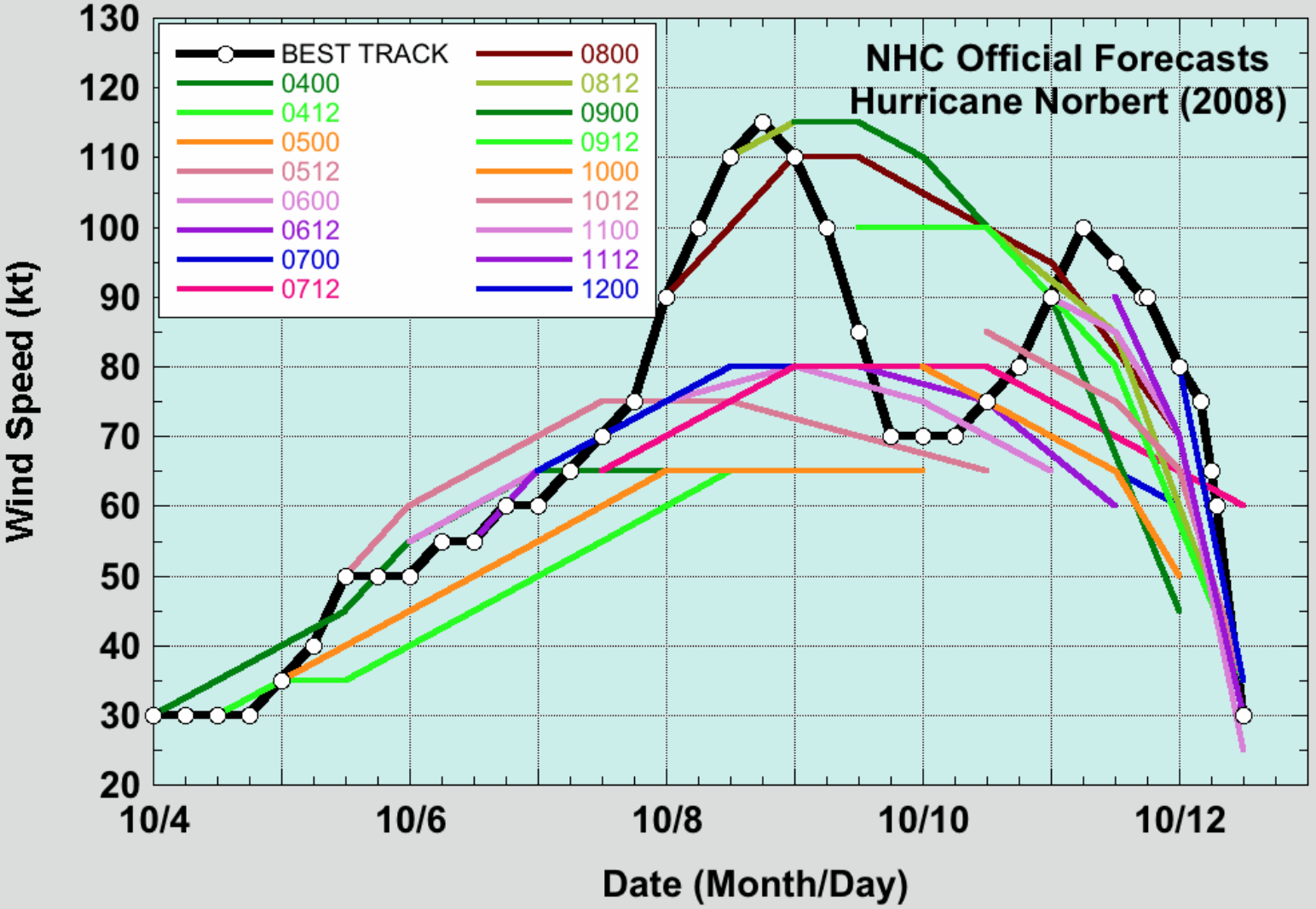
Intensity Forecasting at the NHC:

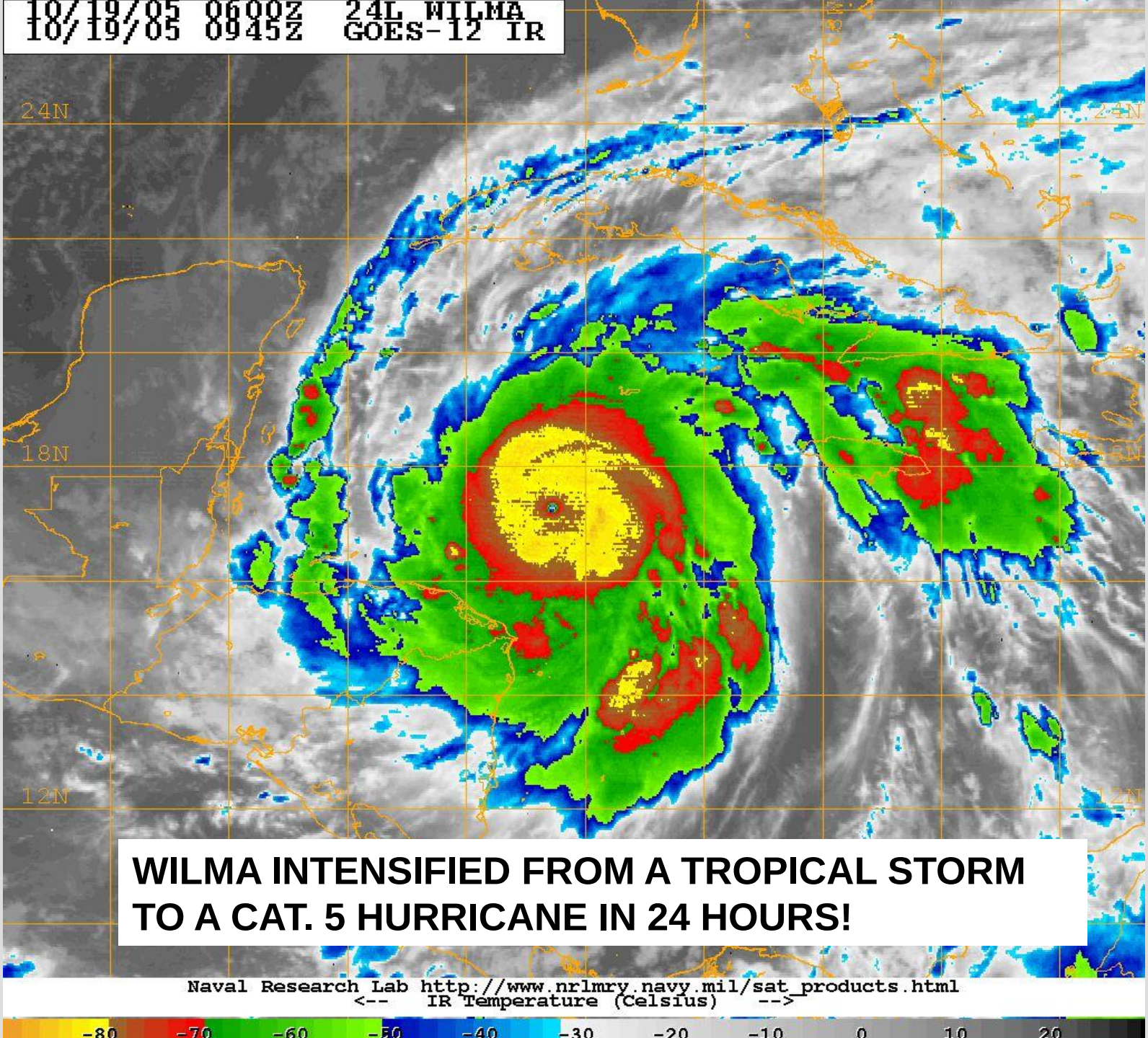
- Guidance models
- Synoptic (subjective) analysis
- General guidelines

Guidance models used by NHC for intensity forecasting

- Decay-SHIPS & LGEM (Statistical-Dynamical)
- GFDL, GFDN, & HWRF (adjusted for biases in initial intensity) – these models are capable of predicting rapid changes in intensity, *but they do not do it reliably*
- Consensus of some or all of the above
- Global models (esp. for predicting environmental changes, e.g. changes in vertical shear, that could cause intensity change)
- SHIPS Rapid Intensification (RI, 30 kt or greater increase in 24 h) index (gives probability of RI)

Difficulty with Rapid Change




10/19/05 0600Z 24L WILMA
10/19/05 0945Z GOES-12 IR
24N
18N
12N
WILMA INTENSIFIED FROM A TROPICAL STORM
TO A CAT. 5 HURRICANE IN 24 HOURS!
Naval Research Lab http://www.nrlmry.navy.mil/sat_products.html
<-- IR Temperature (Celsius) -->
-80 -70 -60 -50 -40 -30 -20 -10 0 10 20

VERIFYING: 160 KNOTS

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*    ATLANTIC SHIPS INTENSITY FORECAST        *
*         GOES/OHC INPUT INCLUDED             *

                    WILMA  10/18/05  18 UTC

TIME (HR)          0     6     12    18    24    36    48    60    72    84    96   108   120
V (KT) NO LAND    70    75    81    86    92   100   105   108   109   106   101    92    80
V (KT) LAND       70    75    81    86    92   100   105   108   109   106   101    67    61

          ** 2005 ATLANTIC RAPID INTENSITY INDEX **
        ( 25 KT OR MORE MAX WIND INCREASE IN NEXT 24 HR)

                    WILMA     10/18/05     18 UTC

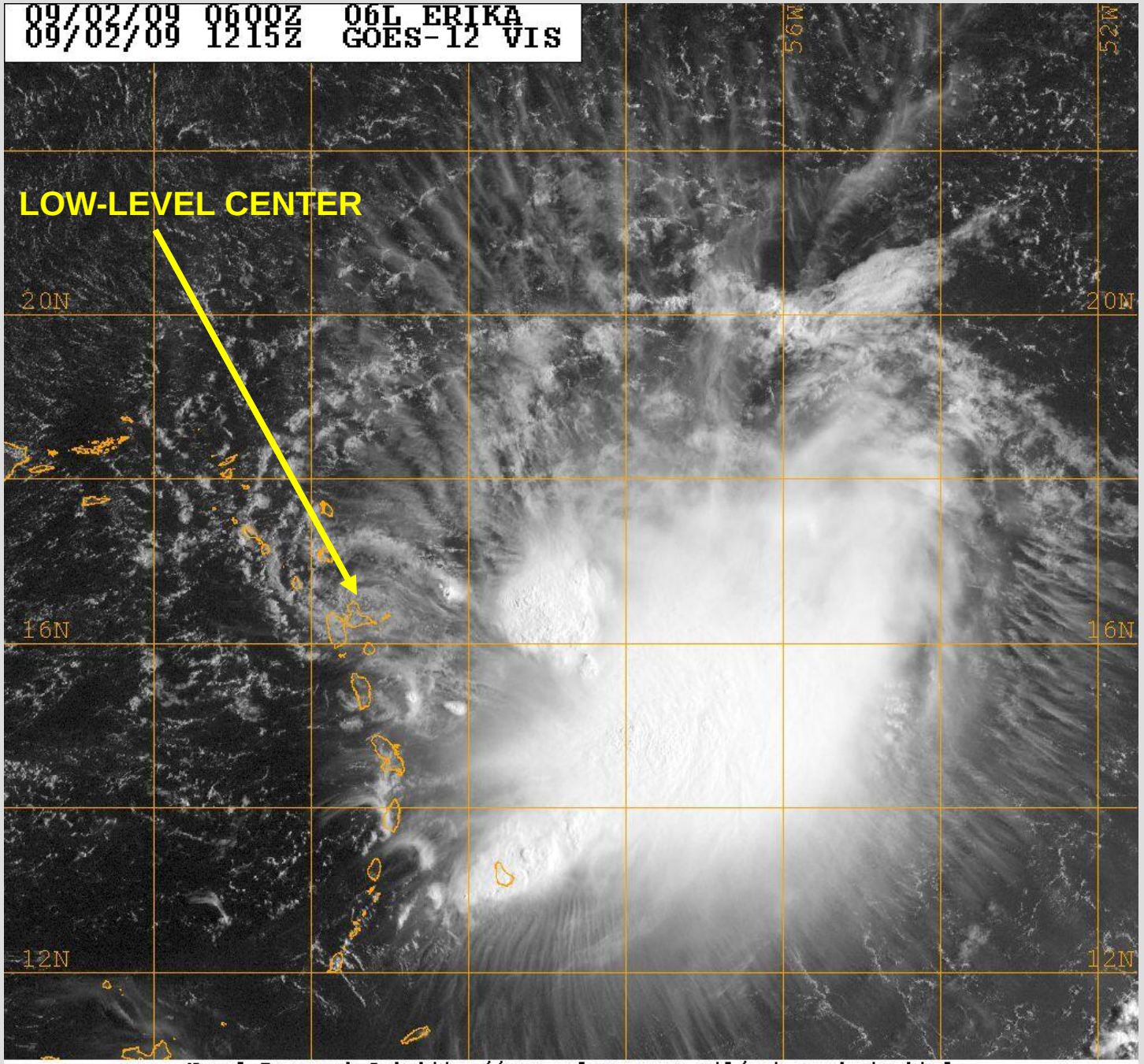
 12 HR PERSISTENCE (KT): Value:  10.0 Range: -20.0 to  25.0 Scaled value:  0.90
 850-200 MB SHEAR (KT) : Value:   8.1 Range:  42.5 to   2.5 Scaled value:  0.86
 SST (C)               : Value:  29.3 Range:  24.3 to  30.4 Scaled value:  0.82
 POT = MPI-VMAX (KT)   : Value:  92.0 Range:  27.1 to 136.4 Scaled value:  0.59
 850-700 MB REL HUM (%): Value:  81.6 Range:  57.0 to  88.0 Scaled value:  0.79
 % area w/pixels <-30 C: Value:  98.0 Range:  17.0 to 100.0 Scaled value:  0.98
 STD DEV OF IR BR TEMP : Value:  15.8 Range:  37.5 to   8.0 Scaled value:  0.74

 Scaled RI index=  5.68 Prob of RI= 59.4% is   4.9 times the sample mean(12.1%)
```

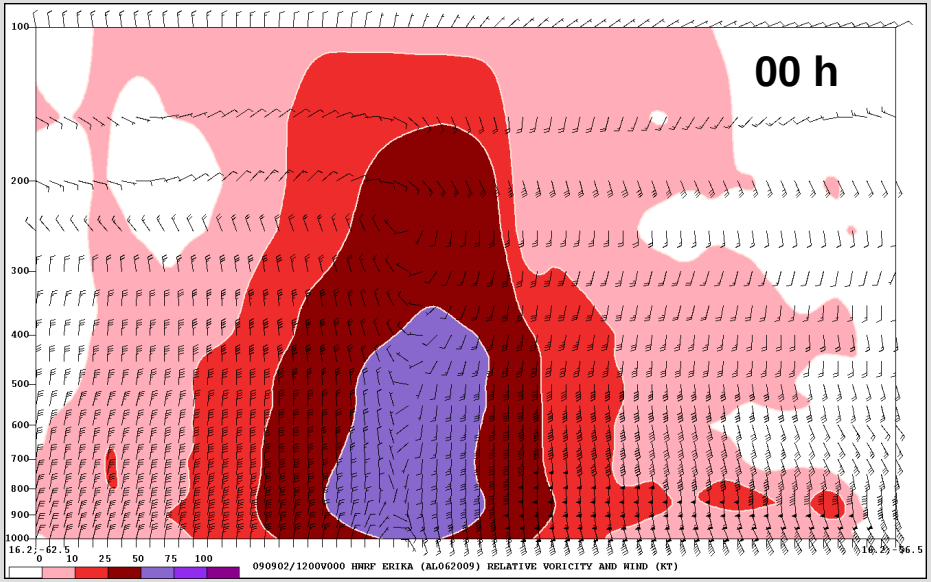
OFFICIAL FORECAST CALLED FOR 90-100 KNOTS IN 12-24 HOURS

INITIAL 18/2100Z 16.7N 81.5W 70 KT
12HR VT 19/0600Z 17.3N 82.3W 90 KT
24HR VT 19/1800Z 18.2N 83.5W 100 KT
36HR VT 20/0600Z 19.1N 84.5W 110 KT
48HR VT 20/1800Z 20.2N 85.2W 115 KT
72HR VT 21/1800Z 22.5N 85.5W 110 KT
96HR VT 22/1800Z 25.0N 82.5W 100 KT
20HR VT 23/1800Z 30.5N 75.5W 70 KT

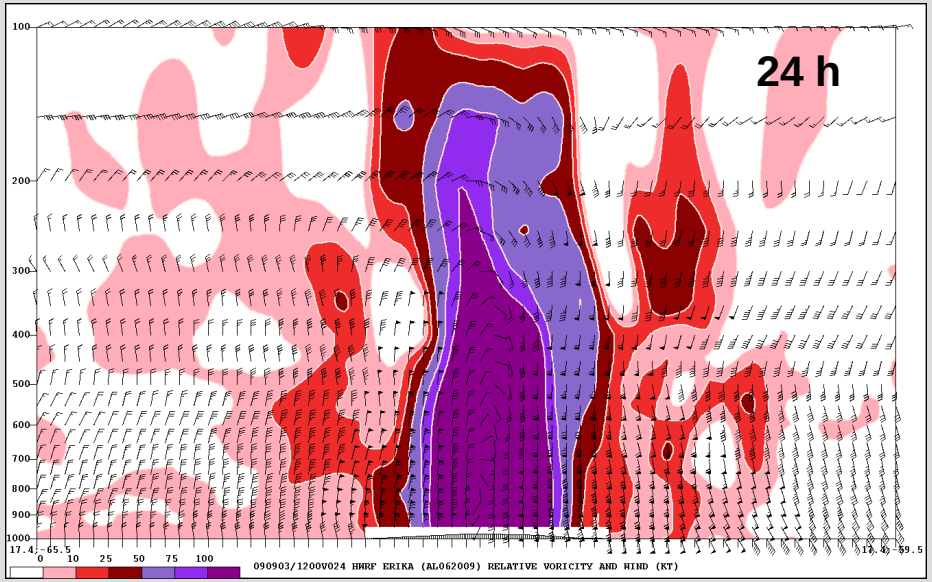
Tropical Storm Erika, 2 September 2009



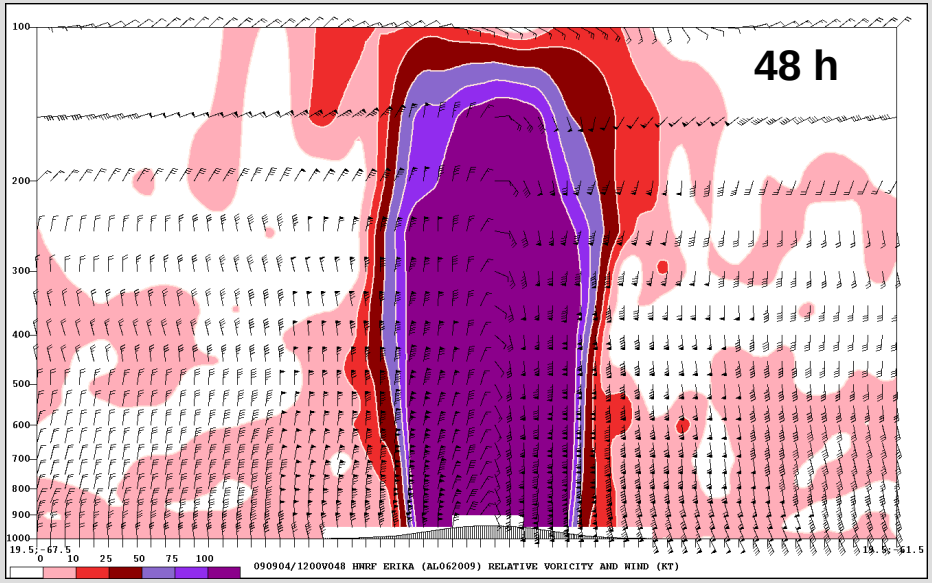
Zonal cross-section of wind and relative vorticity through HWRF forecast of Tropical Storm Erika, initialized at 1200 UTC 2 Sept. 2009

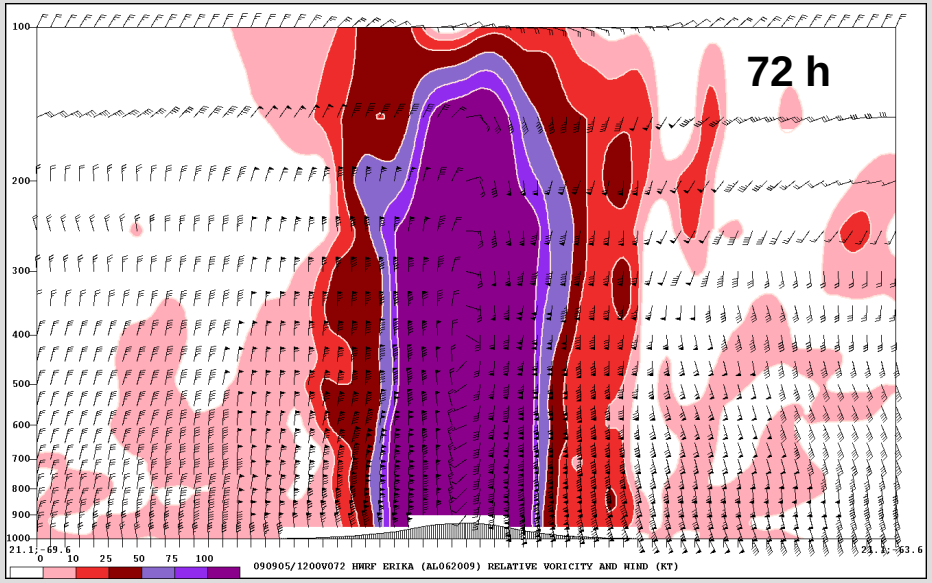


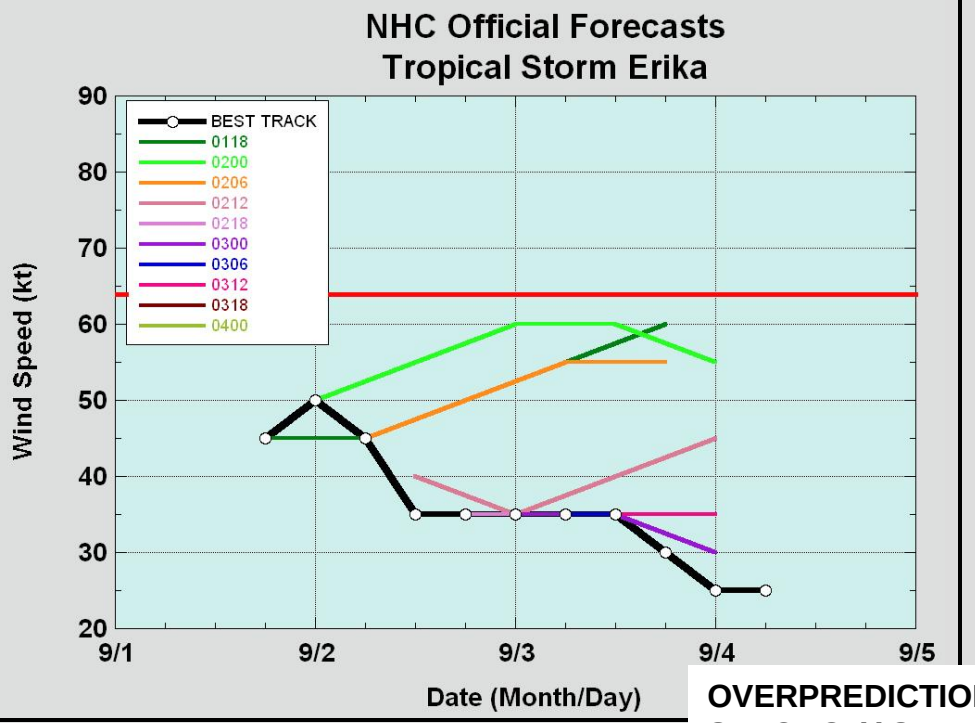
16.2°N
62.5°W

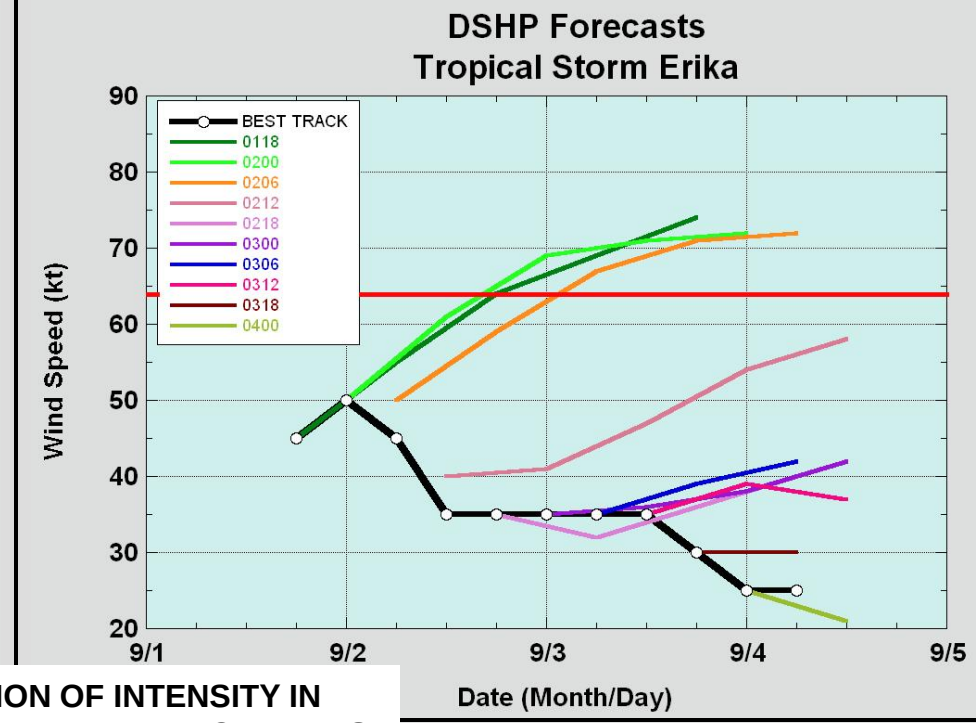


16.2°N
56.5°W

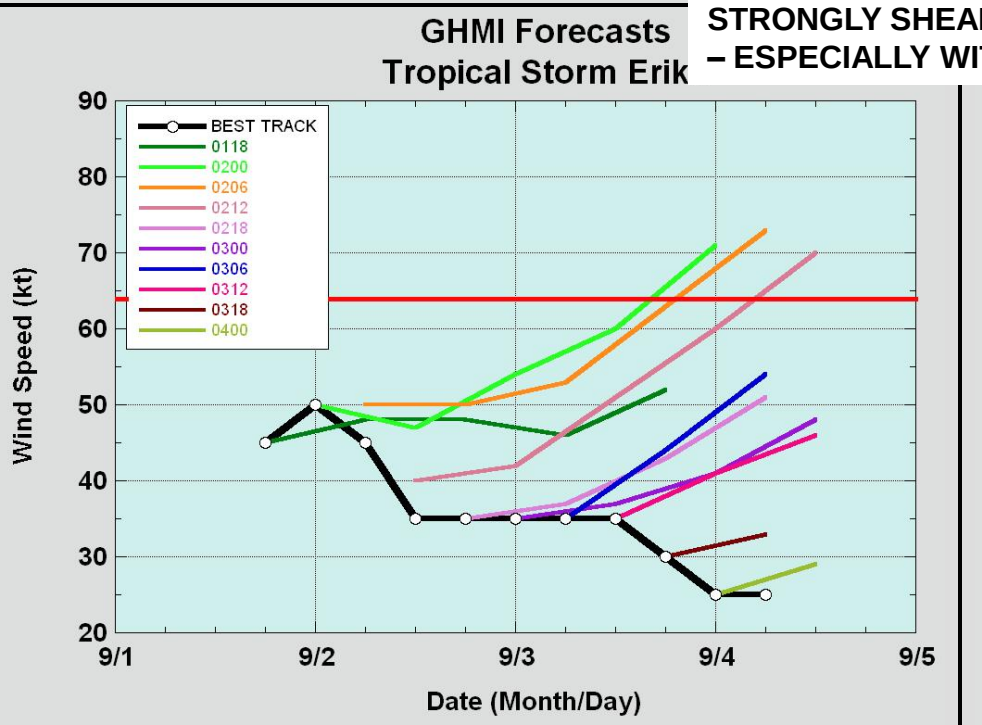


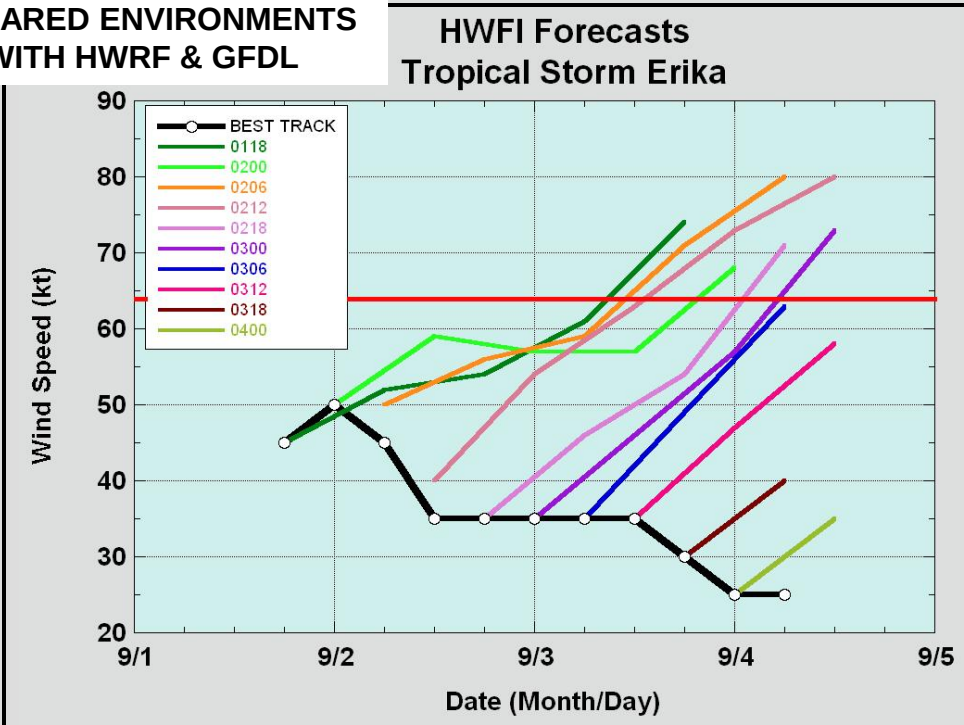


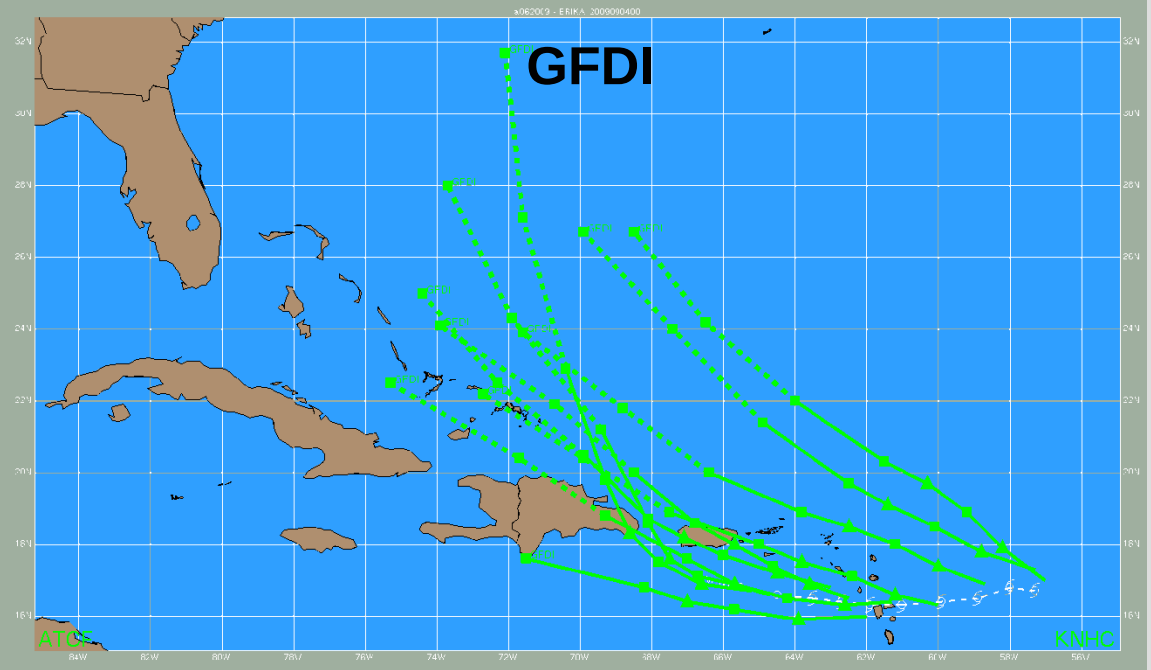


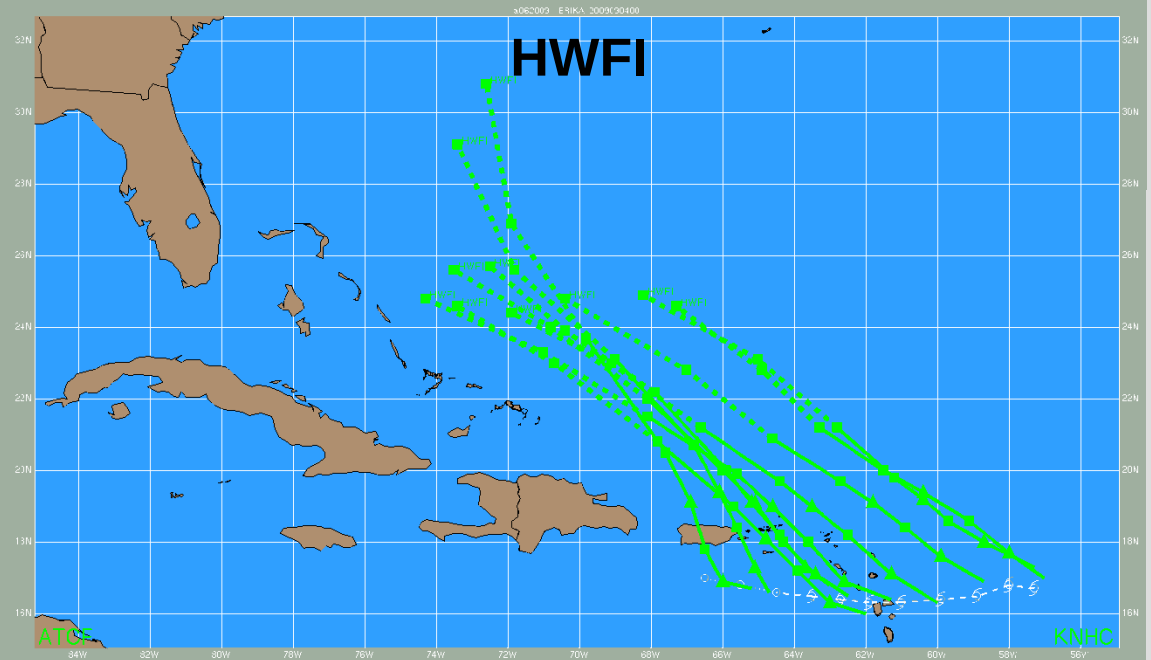


OVERPREDICTION OF INTENSITY IN STRONGLY SHEARED ENVIRONMENTS – ESPECIALLY WITH HWRF & GFDL









Impact of bad model intensity forecast on track forecast; example of T.S. Erika, 2009:

Significant northward bias in GFDL and HWRF (storm forecast to be too strong in these models)

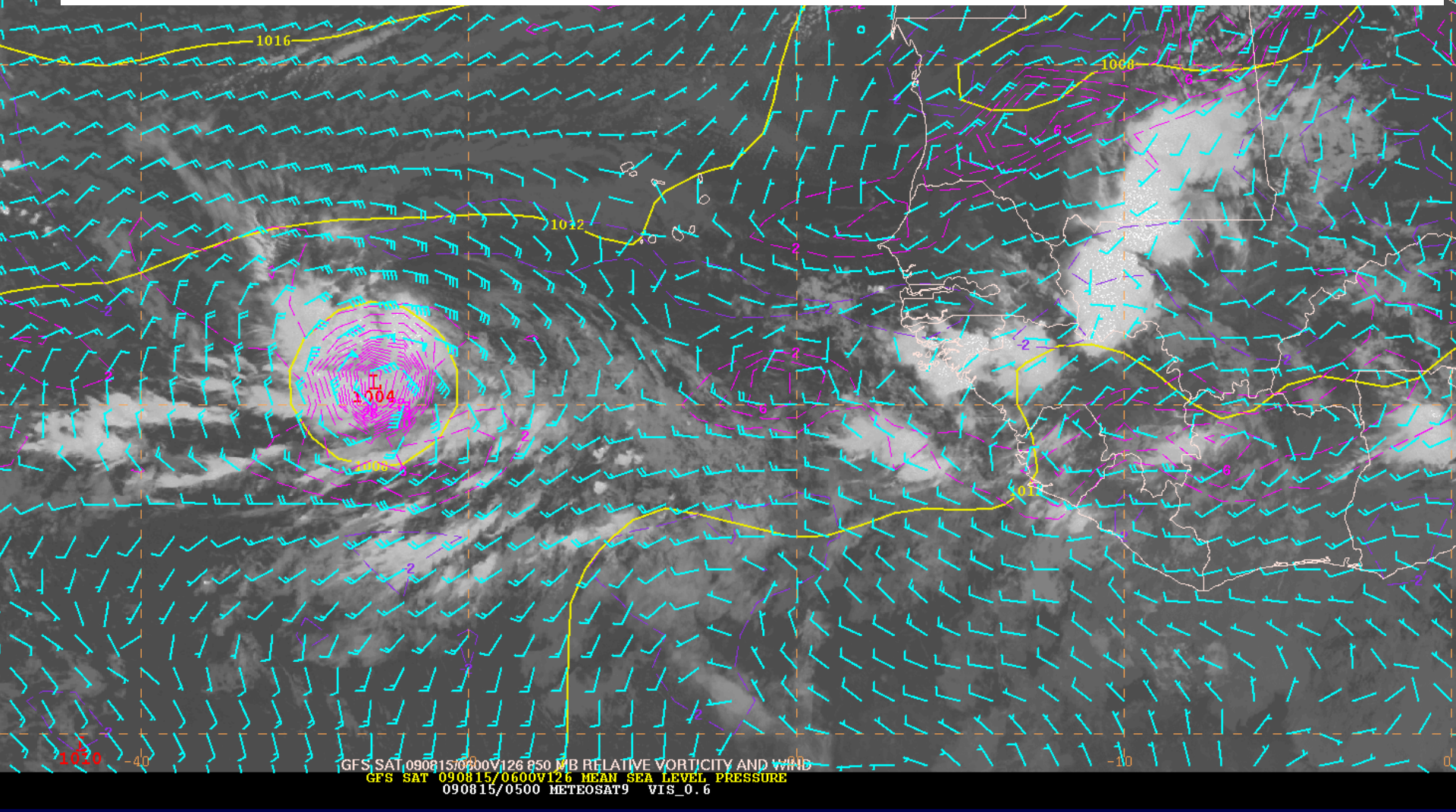
NHC official intensity forecasts

- **Based on statistical guidance from SHIPS and D-SHIFOR, qualitative guidance from dynamical models.**
- **Persistence is used quite a bit!**
- **Obvious signs in the environment, i.e. cooler waters, increasing upper-level winds, are taken into account.**
- **Generally corresponds to what is *normal* for a storm in any particular situation (e.g. the standard Dvorak development rate).**
- **Tends to be conservative; *extreme events are almost never forecast*.**
- **For forecasts 24 h and beyond, the average error is roughly 1 SSHS Category (15-20 knots).**

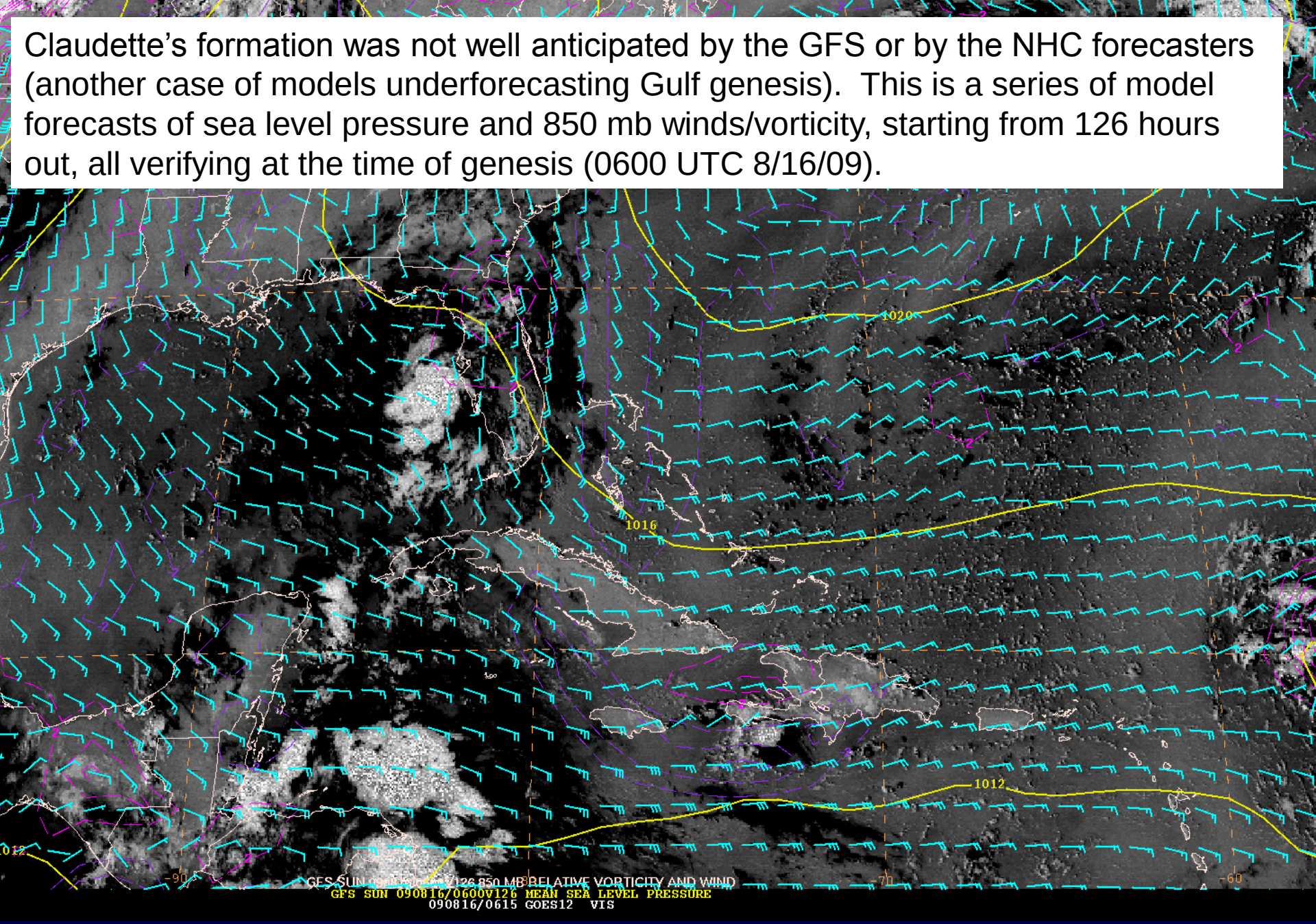
TC Genesis Forecasting at the NHC:

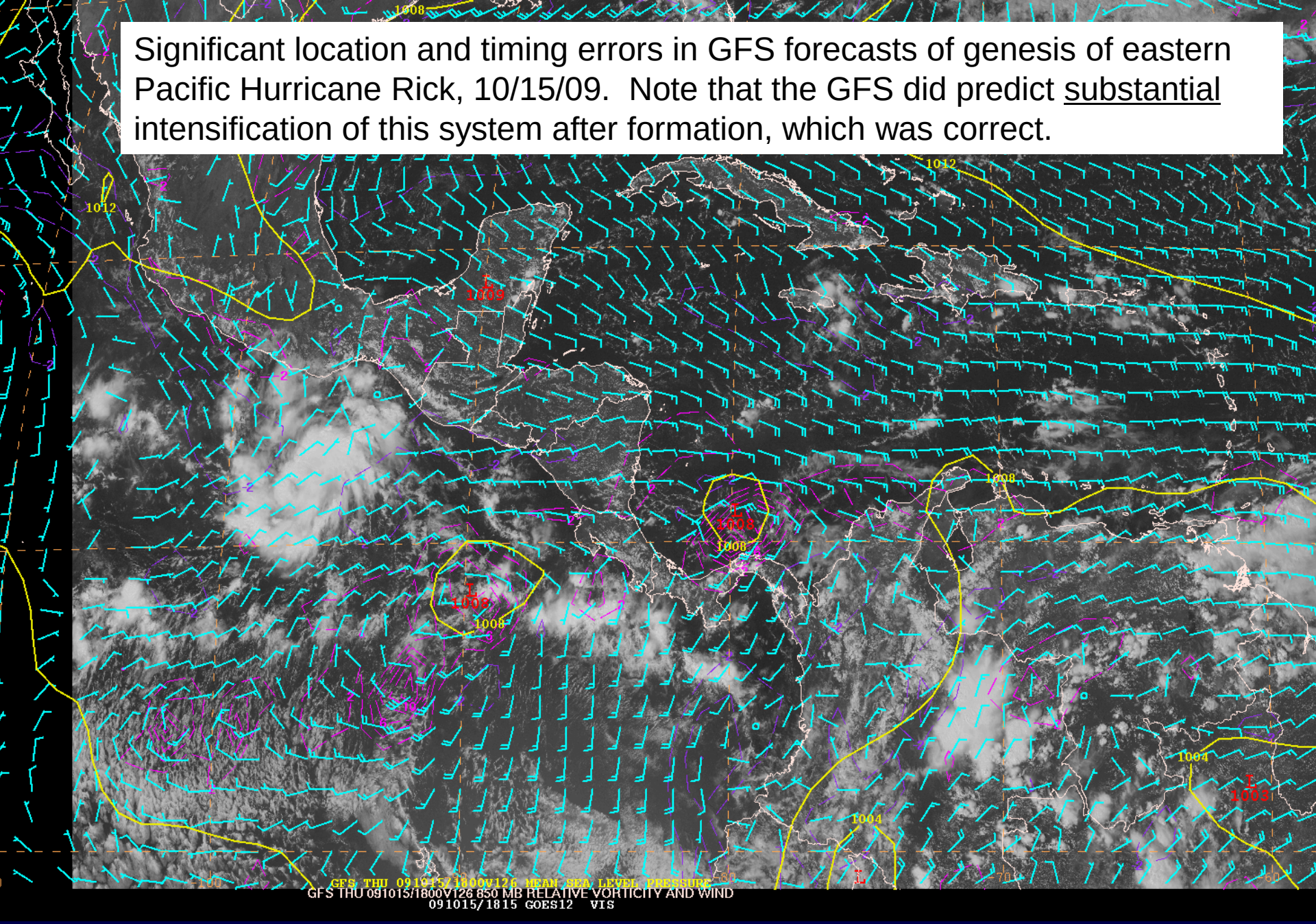
- Primary numerical guidance comes from global models
- GFS and ECMWF seem to have greatest skill, but more systematic verification is needed
- Models appear to have some geographical biases, and seem to do better when large-scale influences are the dominant mechanism (e.g. monsoonal flow near western Africa)
- Considerable subjectivity involved in NHC genesis forecasts
- Genesis forecasts are more problematic in Gulf of Mexico since models have difficulty depicting genesis in that region (smaller-scale processes play a bigger role?)

Genesis of Bill was well predicted by the GFS (another case of good GFS forecasts of eastern tropical Atlantic genesis). This is a series of model forecasts of sea level pressure and 850 mb winds/vorticity, starting from 126 hours out, all verifying at the time of genesis (0600 UTC 8/15/09).



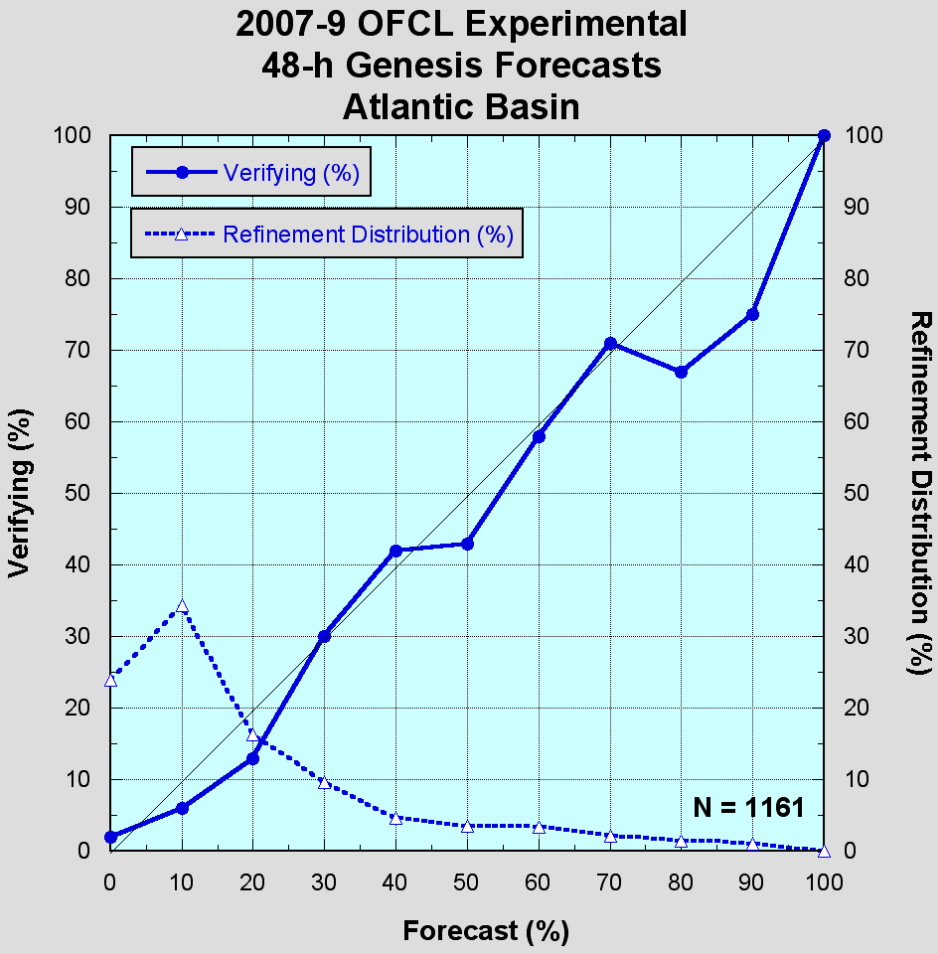
Claudette's formation was not well anticipated by the GFS or by the NHC forecasters (another case of models underforecasting Gulf genesis). This is a series of model forecasts of sea level pressure and 850 mb winds/vorticity, starting from 126 hours out, all verifying at the time of genesis (0600 UTC 8/16/09).

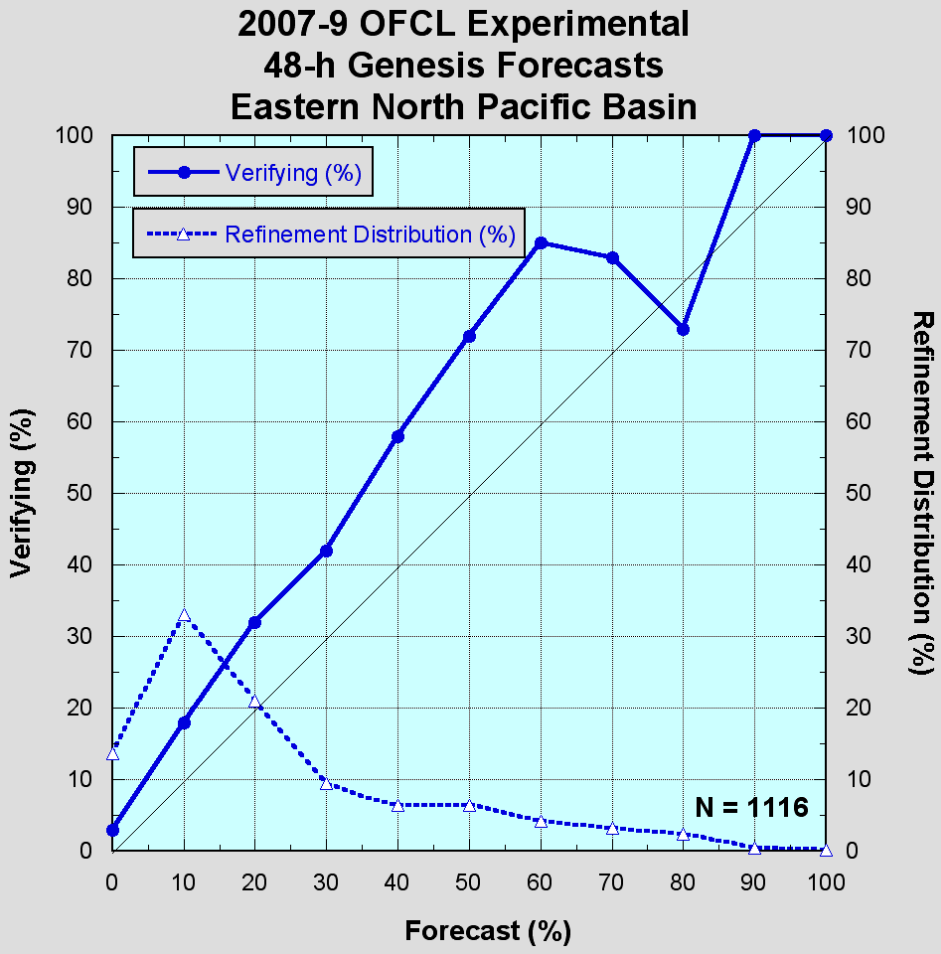




Significant location and timing errors in GFS forecasts of genesis of eastern Pacific Hurricane Rick, 10/15/09. Note that the GFS did predict substantial intensification of this system after formation, which was correct.

Verification of NHC genesis forecasts for their 2 basins of responsibility: numerical genesis probabilities will be released to the public for the first time in the 2010 season.





Forecast probabilities verify quite well in the Atlantic,although NHC tends to underpredict TC formation a bit in the east Pacific.

FUTURE CHALLENGES

- **Track: center positions out to 7 days**
- **Intensity: out to 7 days?**
- **Size/Structure: additional radii (by quadrant) of 34-, 50-, and 64-kt winds beyond 36 hours? Full 2-d distribution of surface winds?**
- **Likelihood of TC formation within 120 hours**
- **Track/intensity forecasts for TCs that have not yet formed**
- **More detailed storm surge (including waves at the coast), rainfall, and tornado(?) information**

THANKS TO:

MIKE BRENNAN, JAMES FRANKLIN, AND MY OTHER COLLEAGUES AT NHC