NOAA Joint Hurricane Testbed Project
Year-1 progress report
August 2010

A New Secondary Eyewall Formation Index: Transition to Operations and Quantification of Associated Intensity Changes

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Original proposed Year-1 timeline:

1. August 3, 2009 - Project begins
2. Convert the MatLab code to FORTRAN
3. Transition the present prototype model onto the JHT computing platform with the intention of having the model operational before the onset of the 2010 hurricane season. Modifications are needed to use SHIPS to include an additional GOES-based feature.
4. February 1, 2010 - Mid-year report due
5. March 2010 – Present work at the Interdepartmental Hurricane Conference
6. April 1, 2010 – Year-2 renewal proposal due
7. Aug 3, 2010 –Year-1 ends/ Year-1 progress report due

Progress report:

All proposed tasks/milestones have been successfully completed. All of the MatLab code has been converted to FORTRAN. All required subroutines have been completed. All necessary SHIPS code modifications have been completed and all necessary data files have been installed on the IBM in accord with Mark DeMaria's requirements. The additional features required by our model (but beyond those provided by SHIPS) are now derived within the SHIPS code through our suite of new subroutines.

The new model became fully operational as part of the official SHIPS output file in time for the first named storm of the 2010 season (Fig. 1). The model performed well during Hurricane Alex and was able to capture the environmental features that led to an eyewall replacement cycle on 30 June. At this time, the climatological probability of secondary eyewall formation was only ~4%, but the environmental and satellite-derived features raised the probability to 56% (Fig. 2).

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                         *   ATLANTIC SHIPS INTENSITY FORECAST        *
                         *      GOES DATA AVAILABLE                   *
                         *      OHC  DATA AVAILABLE                   *
                         *  ALEX        AL012010  06/29/10  06 UTC    *

TIME (HR)         0     6    12    18    24    36    48    60    72    84    96   108   120
V (KT) NO LAND   60    64    68    73    76    82    84    85    81    76    70    62    56
V (KT) LAND      60    64    68    73    76    82    73    44    32    28    27    27    27
V (KT) LGE mod   60    65    69    73    77    83    87    45    32    28    27    27    27

SHEAR (KT)       14    12    10     8     7     7     9     5     8     4    10     7    11
SHEAR ADJ (KT)    0     0     0    -3    -3    -4    -5    -1    -3     7    -1     3    -5
SHEAR DIR         4   358     4    32    48    79    23   310    10   345   337   320   349
SST (C)        28.5  28.6  28.8  28.8  28.8  28.6  28.3  28.2  28.1  28.1  27.9  27.6  27.3
POT. INT. (KT)  143   145   148   148   148   144   140   137   136   137   134   129   125
ADJ. POT. INT.  128   131   133   134   133   128   122   119   118   119   116   109   104
200 MB T (C)  -50.2 -50.3 -49.8 -49.1 -49.4 -48.9 -48.9 -48.4 -48.4 -48.8 -48.8 -49.2 -49.2
TH_E DEV (C)      9     8    10    12     9    10    10    11    10    13    10    12    11
700-500 MB RH    77    73    75    76    78    81    80    82    82    80    76    74    71
GFS VTEX (KT)    20    20    23    22    22    22    20    17    10     6     5     2     3
850 MB ENV VOR  123   115   128   140   126   116   100    90    82    41    37     8     9
200 MB DIV       59    50    54    58    43    52    71    66    46     7    15    -5     4
LAND (KM)       161   238   325   426   353   165    -9  -143  -257  -387  -496  -605  -609
LAT (DEG N)    21.4  22.2  22.9  23.5  24.1  24.8  25.4  25.7  25.7  26.3  27.6  28.6  29.5
LONG(DEG W)    91.8  92.3  92.7  93.5  94.2  95.9  97.5  98.8 100.0 101.2 102.4 103.4 103.2
STM SPEED (KT)    7     9     9     9     9     8     7     5     6     7     7     5     4
HEAT CONTENT     13    34    35    40    44    29     2     0  9999  9999  9999  9999  9999

  FORECAST TRACK FROM OFCI      INITIAL HEADING/SPEED (DEG/KT):340/  7      CX,CY:  -1/  7
  T-12 MAX WIND:  50            PRESSURE OF STEERING LEVEL (MB):  570  (MEAN=624)
  GOES IR BRIGHTNESS TEMP. STD DEV.  50-200 KM RAD:  15.3 (MEAN=14.5)
  % GOES IR PIXELS WITH T < -20 C    50-200 KM RAD:  81.0 (MEAN=65.0)

                      INDIVIDUAL CONTRIBUTIONS TO INTENSITY CHANGE
                       6   12   18   24   36   48   60   72   84   96  108  120
                      ----------------------------------------------------------
  SAMPLE MEAN CHANGE   1.   2.   3.   4.   6.   8.   9.  11.  11.  12.  13.  13.
  SST POTENTIAL        1.   2.   3.   4.   5.   5.   4.   3.   2.   1.   0.  -2.
  VERTICAL SHEAR MAG   0.   0.   1.   2.   4.   6.   9.  11.  13.  13.  13.  14.
  VERTICAL SHEAR ADJ   0.   0.   0.   0.   1.   2.   3.   3.   2.   2.   1.   1.
  VERTICAL SHEAR DIR   0.   0.   1.   1.   1.   2.   2.   2.   2.   2.   2.   2.
  PERSISTENCE          2.   3.   3.   3.   3.   3.   3.   2.   2.   1.   0.   0.
  200/250 MB TEMP.    -1.  -2.  -3.  -3.  -6.  -8. -10. -13. -15. -17. -20. -22.
  THETA_E EXCESS       0.   0.   0.   0.  -1.  -1.  -1.  -1.  -1.  -1.  -1.  -1.
  700-500 MB RH        0.   0.   0.  -1.  -1.  -2.  -2.  -2.  -2.  -2.  -3.  -3.
  GFS VORTEX TENDENCY  0.   1.   1.   1.   1.   0.  -3.  -8. -11. -12. -14. -14.
  850 MB ENV VORTICITY 1.   1.   2.   3.   4.   5.   6.   7.   7.   7.   7.   6.
  200 MB DIVERGENCE    0.   0.   1.   1.   2.   3.   4.   5.   4.   4.   3.   3.
  ZONAL STORM MOTION   0.   0.   0.   0.   0.   0.  -1.  -1.  -1.  -2.  -2.  -2.
  STEERING LEVEL PRES  0.   0.   0.   0.   0.   0.   0.   1.   1.   1.   0.   0.
  DAYS FROM CLIM. PEAK 0.   0.   0.   0.   0.  -1.  -1.  -1.  -1.  -1.   0.  -1.
  GOES PREDICTORS      0.   1.   1.   1.   2.   2.   2.   2.   2.   2.   1.   1.
  OCEAN HEAT CONTENT   0.   0.   0.   0.   0.   0.   0.   0.   0.   0.   0.   0.
                      ----------------------------------------------------------
  TOTAL CHANGE         4.   8.  13.  16.  22.  24.  25.  21.  16.  10.   2.  -4.

   ** 2010 ATLANTIC RI INDEX AL012010 ALEX       06/29/10  06 UTC **
           ( 30 KT OR MORE MAX WIND INCREASE IN NEXT 24 HR)

 12 HR PERSISTENCE (KT):  10.0 Range:-45.0 to  30.0 Scaled/Wgted Val:  0.7/  1.6
 850-200 MB SHEAR (KT) :  10.3 Range: 26.2 to   3.2 Scaled/Wgted Val:  0.7/  0.8
 D200 (10**7s-1)       :  52.8 Range:-21.0 to 140.0 Scaled/Wgted Val:  0.5/  0.7
 POT = MPI-VMAX (KT)   :  71.8 Range: 33.5 to 126.5 Scaled/Wgted Val:  0.4/  0.3
 850-700 MB REL HUM (%):  80.8 Range: 56.0 to  85.0 Scaled/Wgted Val:  0.9/  0.5
 % area w/pixels <-30 C:  76.0 Range: 17.0 to 100.0 Scaled/Wgted Val:  0.7/  0.1
 STD DEV OF IR BR TEMP :  15.3 Range: 30.6 to   3.2 Scaled/Wgted Val:  0.6/  0.9
 Heat content (KJ/cm2) :  33.2 Range:  0.0 to 130.0 Scaled/Wgted Val:  0.3/  0.0

 Prob of RI for 25 kt RI threshold=    32% is   2.6 times the sample mean(12.6%)
 Prob of RI for 30 kt RI threshold=    22% is   2.8 times the sample mean( 8.1%)
 Prob of RI for 35 kt RI threshold=    12% is   2.5 times the sample mean( 4.8%)
 Prob of RI for 40 kt RI threshold=     9% is   2.7 times the sample mean( 3.4%)

   ##         ANNULAR HURRICANE INDEX (AHI) AL012010 ALEX       06/29/10  06 UTC         ##
   ## STORM NOT ANNULAR, SCREENING STEP FAILED, NPASS=4 NFAIL=3                          ##
   ## AHI=  0   (AHI OF 100 IS BEST FIT TO ANN. STRUC., 1 IS MARGINAL, 0 IS NOT ANNULAR) ##
   ##     ANNULAR INDEX RAN NORMALLY

** PROBLTY OF AT LEAST 1 SCNDRY EYEWL FORMTN EVENT AL012010 ALEX       06/29/2010  00 UTC **
TIME(HR)   0-12  12-24(0-24)  24-36(0-36)  36-48(0-48)
CLIMO(%)     0       3(  3)       5(  8)       8( 15)     <-- PROB BASED ON INTENSITY ONLY
PROB(%)      0       9(  9)      34( 40)       4( 42)     <-- FULL MODEL PROB (RAN NORMALLY)
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Figure 1: Operational SHIPS output file for Hurricane Alex (2010). The bottom 4 lines show the output of the new model. Probabilities are provided in four 12h periods, 0-12h, 12-24h, 24-36h, and 36-48h. The climatological probability based solely on intensity is provided for comparison above the probabilities provided by the full model. Values in parentheses are cumulative probabilities for 0-24h, 0-36h, and 0-48h. This format was arrived at through direct communication and iteration with NHC forecasters.

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** PROBLTY OF AT LEAST 1 SCNDRY EYEWL FORMTN EVENT AL012010 ALEX       06/30/2010  00 UTC **
TIME(HR)   0-12  12-24(0-24)  24-36(0-36)  36-48(0-48)
CLIMO(%)     2      5(  7)       8( 14)       0( 14)     <-- PROB BASED ON INTENSITY ONLY
PROB(%)      4     51( 53)       0( 53)       0( 53)     <-- FULL MODEL PROB (RAN NORMALLY)

** PROBLTY OF AT LEAST 1 SCNDRY EYEWL FORMTN EVENT AL012010 ALEX       06/30/2010  12 UTC **
TIME(HR)   0-12  12-24(0-24)  24-36(0-36)  36-48(0-48)
CLIMO(%)     4      6( 10)       0( 10)       0( 10)     <-- PROB BASED ON INTENSITY ONLY
PROB(%)     56      0( 56)       0( 56)       0( 56)     <-- FULL MODEL PROB (RAN NORMALLY)
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Figure 2: Operational model output at 2 different times prior to an eyewall replacement event in Hurricane Alex (2010). The top output was at 06/30/2010 00UTC and estimates a 51% probability in 12-24 h. This is 10 times greater than the climatological probability of 5% for a storm of this intensity. At 12UTC (12 h later), the model estimated the probability as 56% in the next 12 h (14 times greater than climatology of 4%). An eyewall replacement event occurred shortly thereafter and just prior to landfall in Mexico, although the event was a-typical.

The secondary eyewall formation that appeared in the microwave imagery in Hurricane Alex (and was confirmed to some extent by aircraft) was far from typical and as such is not an ideal test case for the model. Still, the model behavior and performance in this first trial run was encouraging as it correctly identified the anomalously favorable mid-level moisture and upper-level winds and pushed the probabilities well above climatology.

<u>Travel/Training/Dissemination:</u>

Matt Sitkowski visited the NHC where he presented a formal overview of the new model to management and forecasters (Sep 2009).

Jim Kossin presented the new model at the 64th Interdepartmental Hurricane Conference (Mar 2010) and at the NHC as part of the Visiting Scientist program (Jul 2010).

<u>Notes:</u>

In addition to the specific proposed Year-1 tasks described here, we have also made good early progress toward the Year-2 tasks, some of which was reported on in the Year-2 renewal proposal. Our initial results toward constructing a climatology of intensity and structure changes associated with eyewall replacement cycles have been extremely fruitful and encouraging, and we expect our second year to yield the level of results we were hoping for when this work was first being discussed with the JHT Steering Committee. There was an experimental aspect to the proposed Year-2 tasks, as we could not be sure at that time that the flight-level data would be adequate (in volume or in quality) for our needs. After great efforts compiling a large enough dataset, it has become clear that the data are indeed adequate and there is no remaining doubt that we can provide the first formal objective climatology of intensity and structure changes associated with eyewall replacement.