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

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

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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).

		ATI	ANTIC	SHIPS	INTEN	SITY FOR	ECAST						
:					AVAILABLE				•				
	:	ALEX				LE 06/29/1			:				
	-	ALLA	•	ALV.	12010	06/23/1	0 00		-				
TIME (HR)	0	6	12 68	18	24	36 82	48	60	72	84 76 28 28	96	108	120
V (KT) NO LAND	60	64	68	73	76	82		85	81	76	70	62	56
V (RT) LAND V (RT) LGE mod	60	64	68		76	82		44	32	28	27	27	27
V (KI) LGE mod	60	65	63	/3		83	87	45	32	28	21	27	27
SHEAR (KT)	14	12	10	8	7	7 -4 79	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 SST (C)	4	358	4	32	48	79	23	310	10	845	337	320	349
BOT THT (NT)	142	145	28.8	140	28.8	28.6	140	127	176	127	124	179	175
POT. INT. (KT) ADJ. POT. INT.	128	131	133	134	133	128	122	119	118	119	116	109	104
ADJ. FOT. INT. 200 MB T (C) TH_E DEV (C) 700-500 MB RH GFS VTEX (RT) 850 MB ENV VOR 200 MB DIV LAND (RM) LAND (RM) LANT (DEG N) LONG(DEG W) STM SPEED (RT)	-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
SES VIEX (KT)	123	115	128	140	126	116	100	90	82	41	37	ź	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(DEC 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 (RT) HEAT CONTENT		34	35	40	44	29	2	0	9999	9999			
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SST POTENTIAL	HANGE R MAG	1. 1. 0.	0.	1.	2.	6. 8. 5. 5. 4. 6.	9.	11.	13.	13. 1	3. 14	-	
SST POTENTIAL	HANGE R MAG R ADJ	1. 1. 0.	0.	1.	2.	4. 6. 1. 2.	9.	11.	13.	13. 1	3. 14 1. 1	-	
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SST POTENTIAL VERTICAL SHEA VERTICAL SHEA PERSISTENCE 200/250 MB TE THETA_F EXCES 700-500 MB RE GFS VORTEX TE 850 MB ENV VO 200 MB DIVERG 200ML STORM M STEERING LEVE DAYS FROM CLI GOES PREDICTO OCEAN HEAT CO TOTAL CHANGE ** 2010 ATLA	R MAG R ADJ R DIR MP. 8 NDENCY RTICIT ENCE 0TION L PRES M. PEA RS NTENT	0. 0. 2. -1. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.	0. 0. 3. -2. 0. 1. 1. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.	1. 0. 3. -3. 0. 0. 1. 0. 0. 1. 0. 1. 0. 1. 0. 1. 0. 1. 1. 0. 0. 1. 1. 1. 2. 1. 1. 2. 1. 1. 2. 1. 1. 2. 1. 2. 1. 2. 1. 2. 1. 2. 1. 2. 1. 2. 1. 2. 1. 2. 1. 2. 1. 2. 2. 1. 2. 2. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.	2. 0. 1. 3. -3. 0. -1. 3. 1. 0. 0. 0. 1. 0. 0. 1. 0. 0. 1. 3. 1. 0. 0. 1. 3. 1. 0. 0. 1. 3. 1. 0. 0. 1. 3. 1. 3. 1. 0. 0. 1. 3. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0	4. 6. 1. 2. 1. 2. 3. 3. -68. -11. 12. 1. 0. 4. 5. 2. 3. 0. 0. 0. 0. 01. 2. 2. 0. 0. 02. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 3. 2. 3. 35. -8. -11. -1. -1. -1. -2. -2. -2. -2. -3. -2. -2. -2. -2. -2. -2. -3. -2. -3. -3. -5. -8. -1. -1. -2. -2. -3. -2. -3. -5. -2. -3. -2. -3. -2. -3. -2. -3. -2. -3. -2. -3. -2. -3. -2. -3. -2. -3. -2. -3. -2. -3. -2. -3. -2. -3. -2. -3. -2. -3. -2. -2. -3. -2. -2. -2. -2. -2. -2. -2. -2	9. 3. -10. -1. -2. -3. 6. 4. -1. 0. -1. 25. 29/10	11. 3. 2. -13. -1. -2. -5. -1. 1. 2. 0. -2. -2. -2. -2. -2. -2. -2. -1. -2. -2. -1. -2. -2. -1. -2. -1. -2. -1. -2. -1. -2. -1. -2. -1. -2. -1. -2. -2. -1. -2. -1. -2. -2. -1. -2. -1. -2. -2. -1. -2. -2. -1. -2. -2. -1. -2. -2. -1. -2. -2. -1. -2. -2. -1. -2. -2. -2. -1. -2. -2. -1. -2. -2. -1. -2. -2. -2. -2. -1. -2. -2. -2. -2. -2. -2. -2. -2	13. 2. 2. -15. -1. -2. -11. -2. -1. -1. -1. -1. -1. -1. -1. -1	13. 1 2. 1. -172 -12 -2 -121 7. 4. -2 1. -1. 2. 0.	3. 14 1. 1 2. 2 0. 0 0. -22 1. -1 3. -3 4. -14 7. 6 3. 3 2. -2 0. 0 0. 0 1. 1 0. 0 1. 1 0. 0		
SST POTENTIAL VERTICAL SHEA VERTICAL SHEA VERTICAL SHEA PERSISTENCE 200/250 MB TE THETA_E EXCES 700-500 MB RH GFS VORTEX TE 850 MB ENV VO 200 MB ENV VO 200 MB DIVERG ZONAL STORM M STEERING LEVE DATS FROM CLI GDES PREDICTO OCEAN HEAT CO TOTAL CHANGE ** 2010 ATLA (30	R MAG R ADJ R DIR MP. S NDENCY RTICIT ENCE OTION L PRES M. PEA RS NTENT NTIC R RT OR	0. 0. 2. -1. 0. 0. Y 1. 0. V 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.	0. 0. 0. 0. 0. 1. 1. 0. 0. 0. 0. 1. 0. 0. 0. 8. X AL01 MAX WI	1. 0. 1. 3. 0. 0. 0. 1. 2. 1. 0. 0. 0. 1. 0. 0. 1. 1. 0. 0. 1. 1. 0. 0. 1. 1. 2. 1. 1. 2. 1. 1. 2. 1. 1. 2. 1. 1. 2. 1. 1. 2. 2. 1. 2. 2. 1. 2. 2. 1. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2.	2. 0. 1. 3. -1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0	4. 6. 1. 2. 1. 2. 3. 3. 68. -11. -12. 1. 0. 4. 5. 0. 0. 01. 2. 2. 0. 0. 01. 2. 2. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.	9. 3. 2. 3. -10. -1. -2. -3. 6. 6. 4. -1. 0. -1. 25. 29/10 24 H	11. 3. 2. -13. -1. -2. -1. -5. -1. -1. -1. 2. 0. 0. 0. 0. R)	13. 2. 2. -15 -1. -1. -1. -1. -1. -1. -1. -1	13. 1 2. 1. -172 -21 -21 7. -21 7. -21 -1. -21 10.	3. 14 1. 1 2. 2 0. 0 022 11 33 22 0. 0 01 1. 1 0. 0 24		
SST POTENTIAL VERTICAL SHEA VERTICAL SHEA VERTICAL SHEA PERSISTENCE 200/250 MB TEI THETA_E EXCES 700-500 MB RE GFS VORTEX TE 850 MB ENV VO 200 MB ENV VO 200 MB ENV VO 200 MB DIVERG ZONAL STORM M STEERIMC LEVE DAYS FROM CLI GOES PREDICTO OCEAN HEAT CO TOTAL CHANGE ** 2010 ATLA (30 12 ER PERSISTE 850-200 MB SHE	R MAG R ADJ R DIR MP. S NDENCY ENCE OTION L PRES NTENT NTIC R NTIC R NTIC R NTIC R KT OR	0. 0. 0. 2. -1. 0. 0. 0. Y 1. 0. 0. V 1. 0. 0. V 1. 0. 0. V 1. 0. 0. V 1. V 1. V 1. V 1. V 1. V 1. V 1. V 1	0. 0. 3. -2. 0. 1. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.	1. 0. 1. 3. -3. 0. 0. 1. 2. 1. 0. 0. 0. 0. 1. 1. 2. 1. 1. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2	2. 0. 1. 3. -1. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 1. 0. 0. 0. 1. 2. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0	4. 6. 1. 2. 1. 2. 1. 2. 3. 3. -68. -11. -12. 1. 0. 4. 5. 2. 3. 0	9. 3. 3. -10. -1. -2. -3. 6. 4. -1. 0. -1. 25. 29/10 24 H Soale Soale	11. 3. 2. -13. -1. -2. -8. 7. 5. 1. -1. -1. 21. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0	13. 2. 2. -15. -1. -1. -2. -11. -2. -1. -1. -2. -1. -2. -1. -1. -2. -1. -1. -2. -1. -1. -2. -1. -1. -2. -1. -1. -2. -1. -1. -2. -1. -1. -2. -1. -1. -2. -1. -1. -2. -1. -1. -2. -1. -1. -2. -1. -1. -2. -1. -1. -2. -1. -1. -2. -1. -1. -1. -1. -1. -2. -1. -1. -1. -1. -1. -1. -1. -1	13. 1 2. 1. -172 -12. -21 -21 7. 4. -21 10. 10.	3. 14 1. 1 2. 2 0. 0 022 11 33 414 7. 6 3. 3 22 0. 0 0. 0 01 1. 1 0. 0 24 1.6 0.8		
SST POTENTIAL VERTICAL SHEA VERTICAL SHEA VERTICAL SHEA PERSISTENCE 200/250 MB TE THETA_E EXCES 700-500 MB RH V0 200 MB ENV V0 200 MB OVERE 200 ATLA (30 12 ER PERSISTE 850-200 MB SHE D200 (10**7a-1	R MAG R ADJ R DIR MP. S NDENCY RTICIT ENCE OTION L PRES M. PEA RS NTENT NTIC R RT OR NTIC R RT OR NTIC (FT AR (FT)	0. 0. 2. -1. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.	0. 0. 3. -2. 0. 1. 1. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.	1. 0. 1. 3. 0. 1. 0. 1. 0. 0. 1. 0. 0. 1. 1. 0. 0. 1. 1. 0. 0. 1. 1. 0. 1. 1. 0. 1. 1. 0. 1. 1. 0. 1. 1. 0. 1. 1. 0. 1. 0. 1. 0. 1. 0. 0. 1. 0. 0. 1. 0. 0. 1. 0. 0. 1. 0. 0. 1. 0. 0. 1. 0. 0. 1. 0. 0. 1. 0. 0. 1. 0. 0. 0. 1. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0	2. 0. 1. 3. -1. 0. 1. 0. 1. 0. 1. 0. 1. 0. 1. 0. 1. 0. 1. 0. 1. 0. 1. 0. 0. 1. 1. 0. 0. 1. 1. 0. 0. 1. 1. 0. 0. 1. 1. 0. 0. 1. 0. 1. 2. 0. 1. 2. 1. 2. 1. 2. 1. 2. 1. 2. 1. 2. 1. 2. 1. 2. 1. 2. 1. 1. 2. 1. 1. 2. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1	4. 6. 1. 2. 1. 2. 3. 3. -68. -11. -12. 1. 0. 4. 5. 2. 3. 0. 0. 0. 0. 0. 0. 2. 2. 0. 0. 2. 2. 0	9. 3. 3. -10. -1. -2. -3. 6. 4. -1. 0. -1. 2. 0. -2. 25. 29/10 24 H Soale Soale Soale	11. 3. 2. -13. -13. -2. -8. -1. 1. -1. 2. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0	13. 2. 2. -15. -1. -1. -1. -1. -1. -1. -1. -1	13. 1 2. 2. 1 -172 -12 -2 121 7. 4. -1 2 10. 0. 0. 7. 7. 7. 7. 7. 7. 7. 7. 7. 7	3. 14 1. 1 2. 2 0. 0 022 11 33 414 7. 6 3. 3 22 0. 0 01 1. 1 0. 0 		
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 ##
 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
 **
 **
 O6/29/2010
 00 UTC **

** PROBLTY OF AT LEAST 1 SCNDRY EYEML FORMIN EVENT AL012010 ALEX 06/29/2010 00 UTC ** TIME(ER) 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)

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.

** 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</th>

 PROB(%)
 4
 51(53)
 0(53)
 0(53)
 <-- FULL MODEL PROB (RAN NORMALLY)</td>
 0(53) ** 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) 4 6(10) 0(10) 0(10) 56 0(56) 0(56) 0(56) CLIMO(%) <-- PROB BASED ON INTENSITY ONLY 0(56) 0(56) <-- FULL MODEL PROB (RAN NORMALLY) PROB(%) 0(56)

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.

Travel/Training/Dissemination:

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).

Notes:

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.