Joint Hurricane Testbed: Year One Report

Objective and Automated Assessment of Operational Global Forecast Model Predictions of Tropical Cyclone Formation and Life Cycle

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SUMMARY: The objective of this Joint Hurricane Testbed (JHT) project is to deliver an operational product that objectively identifies tropical cyclone precursor circulations in analyzed and forecast fields from operational global numerical forecast models. Additionally, analyzed and forecast physical characteristics that are relevant to tropical cyclone formation are identified with respect to each precursor circulation. Model traits that are related to each current analyzed and/or forecast circulation are summarized at each analysis time. Upon the completion of a circulation's life cycle as either a non-developing (with respect to tropical cyclone formation) or developing system, a comprehensive summary of the model performance is made and cataloged for comparison with future circulations.

In this report, a summary of the tasks completed from August 2003-April 2004 is provided. Progress is placed in the context of the initial timeline agreed upon with the JHT and NCEP/TPC/NHC staff. Also, a budget for the second year, which is the same as originally proposed, is provided.

TASK: Implementation of a prototype system at the Naval Postgraduate School (NPS) and processing of 2002-2003 model analysis and forecast data.

PROGRESS: This task has been completed. Results of the initial findings based on the application of the Tropical Cyclone Vortex Tracking Program (TCVTP) to the NCEP GFS model and FNMOC NOGAPS operational fields were presented at the Interdepartmental Hurricane Conference (IHC).

Details of the implementation and current configuration of the TCVTP and its output were provided in the mid-year report (January 2004) and are summarized in this report. Although the components have not changed since the original proposal, there are additional details supplied here. Also, several modifications are being made based on discussion with NHC Hurricane Specialists and staff during a visit to TPC/NHS in March 2004. The primary components of the TCVTP are defined in Fig. 1, which has not changed since the original proposal.

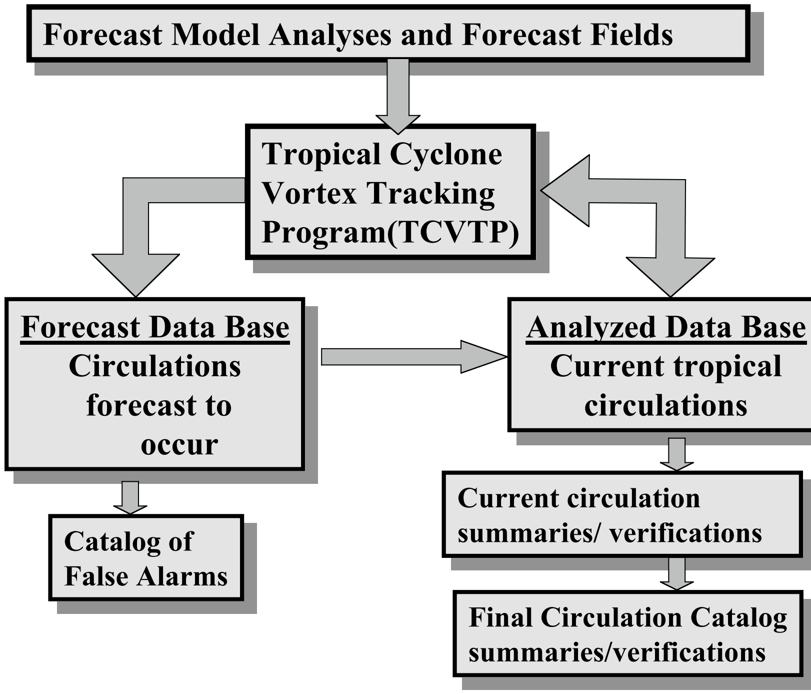

Fig. 1 Schematic of the components of the total system designed to identify, track, catalog, and summarize tropical circulations that may or may not become tropical cyclones (see text for details).

In the original configuration, input data consisted of GRIB formatted fields for GFS and NOGAPS data that are received at the Naval Postgraduate School (NPS). In the processing, the GRIB fields were converted to FORTRAN binary files, which are read by the TCVTP program. The GRIB data are 1^{o} lat. /long. and all processing remains on this grid. During conversion from GRIB to binary, a global tropical strip is saved that extends from 40^{o}S to 60^{o}N. This allows the fields to be applied to all tropical cyclone basins.

Following a visit to TPC/NHC and presentation of the prototype system, it was decided that input data should be modified to be in GEMPAK-formatted binary files, which are the standard model fields at NHC. This modification has been completed and the prototype system in operation at the NPS now reads GEMPAK-formatted fields rather than GRIB fields. Following the conversion of the GEMPAK-formatted fields to FORTRAN binary files, the processing in the TCVTP remains unchanged.

Table 1 identifies all of the variables extracted from the model analysis and forecast fields. This set is identical to that originally proposed. This collection was in place through testing of the prototype system and presentation of results at the 2004 IHC. Following analysis of the results from analysis of the 2002, 2003 hurricane seasons and discussion with Hurricane Specialists during the initial visit to NHC, this set is being modified to provide a more clear representation of physical parameters associated with tropical cyclone precursor development. Implementation of these parameters is being tested on datasets from the 2003 period. These periods (mid-August through mid-

September, 2003) have been chosen based on recommendations of NHC staff as representative of tropical cyclone development and recognized model traits.

Table 1. *Analyzed and forecast quantities used to identify physical characteristics associated with each circulation. Ellipse-average values are computed along with quadrant (defined by ellipse major and minor axes) averages. Also, relative maxima or minima are recorded if they exist.*

850 hPa relative vorticity	Sea-level pressure
Shallow vertical wind shear (500-850 hPa)	Deep vertical wind shear (200-850 hPa)
1000-200 hPa geopotential height thickness	1000-500 hPa temperature difference
Vertical motion	Total precipitation
700-400 hPa Vapor pressure	500-200 hPa temperature difference between the area inside the ellipse and outside the ellipse
Latent Heat Flux	

During processing of each model implementation, summaries of current forecast traits are provided for each tropical cyclone precursor. The summaries contain the analyzed track and all forecast tracks plus the analyzed and forecast 850 hPa vorticity. The prototype system was based around a web-page format where gif-formatted images could be viewed to examine the track and vorticity traits. This is being changed to utilize the GEMPAK/NMAP2 environment that is used operationally at NHC. Examples of specific summaries of forecast model performance with respect to several tropical cyclone precursors were presented at the IHC. As an example, comparison of the initial period of the pre-Hurricane Fabian vortex indicated that the GFS model over-developed the circulation as soon as it began to appear in the model analysis (Fig. 2a). However, the NOGAPS model slightly under-developed the initial development of the vortex (Fig. 2b)

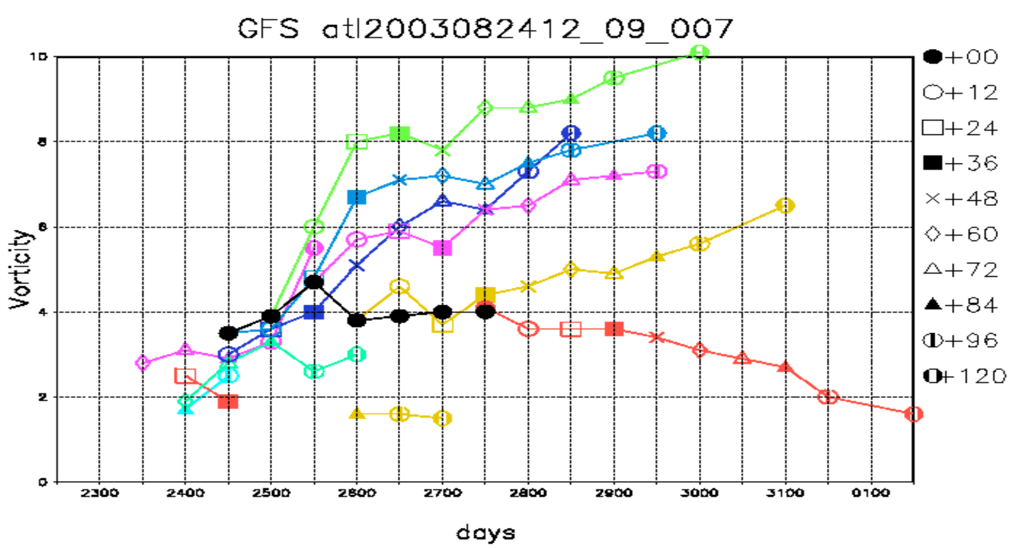

Fig. 2a *Analyzed (solid black dots) and forecasts (see symbol legend at right) of 850 hPa vorticity for the pre-Hurricane Fabian vortex in the GFS model.*

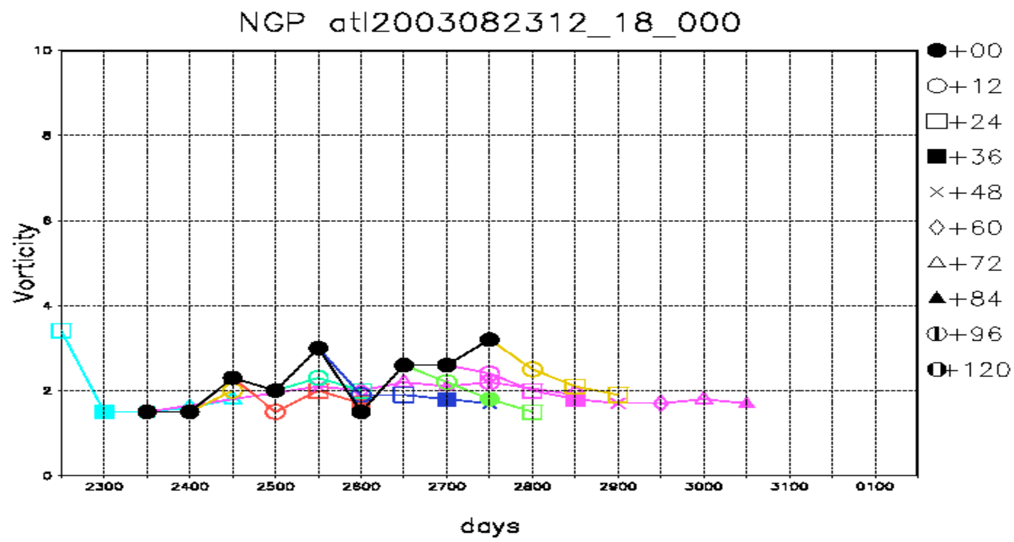

Fig. 2b As *in Fig. 2a, except for the NOGAPS model.*

Summaries such as illustrated with respect to the pre-Hurricane Fabian vortex are produced for each vortex that is contained in each model's analysis.

Also, graphics images (in gif format) of select model analysis and forecast fields are created. The fields are 850 hPa vorticity, SLP, 200 hPa winds, 850 hPa winds, 200-850 hPa vertical wind shear, precipitation, and 500 hPa heights. These fields are stored for animation on the TCVTP web site. Also computed and stored as graphics images are forecast error fields for the above parameters and forecast intervals 12 – 120 h in 12-h increments. These fields, which were chosen because of their physical relevance to tropical cyclone formation, will remain in the TCVTP prototype system at NPS but will not be needed in the operational version since model fields are available in NMAP2 format at NHC.

The TCVTP program identifies and tracks vorticity centers in the model analysis and forecast fields. Additionally, the model environmental fields are used to extract the parameters in Table 1 that are identified with each vortex. TCVTP is a stand-alone FORTRAN program that currently executes on a Silicon Graphics UNIX workstation and is in the final stages of conversion to LINUX – Red Hat 9 and Enterprise.

Input to the TCVTP program consists of the model fields and output from the previous TCVTP operation. Other than the model fields, which are in GEMPAK format, all input and output files are ASCII text files that may be viewed in a standard text editor.

Output of the TCVTP program consists of catalogs of the tracked vortices. The catalog contains the unique vortex name, and the history of forecast and analysis fields associated with the vortex. Each model initiation time is labeled a group and a group consists of lines that contain the data for one forecast time during the entire run. The partial catalog in Fig. 3 contains several groups that correspond to model initiation times at 2003072912, 2003073000, etc. In both of these groups, there are lines that represent the +24, +30,

+36,… parameters for this vortex. In the group for 2003072912, the first line is at +24, which indicates that this vortex does not exist in the current 2003072912 analysis but is forecast to occur at 2003073012.

Vortex File : /d/trop5/harr/tcvtp/AT/2003/astrm/atl2003080100_09_038

Vortex	Date/Time	Tau	Lat	Lon	Vort	Size	Shape	Major	Minor	Angle	Correlation	SHR 500-850 av	Q1	Q2	Q3	Q4	Par	SHR 500-850 av	
atl2003080100_09_038	2003072912	024	11	032	2.6	23.0	0.5	3.8	2.0	3.1	-0.3	1.518	-0.357	6.050	3.637	-1.838	8.837	5.028	1.
atl2003080100_09_038		030	10	033	3.0	26.0	0.5	3.8	2.1	3.1	-0.2	1.487	0.129	3.120	4.227	-0.281	-999.000	4.853	2.
atl2003080100_09_038		036	10	034	3.4	33.0	0.6	4.2	2.6	3.1	-0.1	0.081	-1.114	1.178	1.467	-0.838	5.608	3.362	-0
atl2003080100_09_038		042	10	035	3.6	36.0	0.6	4.1	2.6	1.6	0.0	-1.240	-1.752	-0.833	-0.150	-1.787	4.898	-0.221	-4
atl2003080100_09_038		048	10	036	3.7	34.0	0.6	4.3	2.6	0.1	0.1	-1.532	-1.761	-1.063	-1.546	-1.740	4.994	-1.903	-5
atl2003080100_09_038		060	10	038	4.1	32.0	0.9	3.8	2.8	0.3	0.1	-2.037	-2.927	-1.878	-1.040	-2.093	1.381	-2.443	-6
atl2003080100_09_038		072	11	039	4.3	29.0	0.7	3.6	2.6	0.2	0.1	-2.332	-2.635	-2.911	-1.165	-2.380	-0.353	-4.728	-5
atl2003080100_09_038		084	12	041	4.6	27.0	0.7	3.3	2.7	0.2	0.1	-2.573	-3.601	-2.889	-0.370	-2.598	4.384	-6.118	-8
atl2003080100_09_038		096	13	043	4.5	24.0	0.8	2.7	2.5	1.6	0.0	-2.277	-3.729	-2.631	0.427	-2.244	4.709	-6.545	-8
atl2003080100_09_038		120	15	044	4.7	26.0	0.8	2.3	1.6	1.6	0.0	-3.641	-4.558	-3.421	-2.229	-3.564	1.932	-13.967	-1:
atl2003080100_09_038	2003073000	024	10	035	3.2	53.0	0.4	8.5	2.2	3.1	0.0	1.167	-0.376	3.194	3.790	-1.114	6.303	5.166	-0
atl2003080100_09_038		030	10	035	3.4	19.0	0.3	3.7	1.6	0.1	0.2	-0.787	-0.728	-0.417	-0.671	-1.384	3.030	1.107	-2
atl2003080100_09_038		036	10	036	3.6	47.0	0.4	7.7	2.2	0.2	0.5	0.555	-0.225	2.024	0.708	-0.250	2.733	2.034	-3
atl2003080100_09_038		042	10	037	3.6	39.0	0.5	7.1	2.3	0.2	0.7	-0.663	-0.859	-0.320	-0.587	-0.848	0.697	2.091	-2
atl2003080100_09_038		048	11	037	3.6	39.0	0.8	4.7	2.7	0.4	0.4	-1.220	-0.173	-2.508	-1.268	-0.862	2.372	0.013	-2
atl2003080100_09_038		060	12	038	4.2	34.0	0.9	4.1	2.7	0.7	0.4	-1.220	-1.045	-3.226	-1.073	0.207	4.030	-4.327	-3
atl2003080100_09_038		072	13	039	4.6	32.0	0.9	3.5	3.0	0.2	0.1	-2.138	-3.536	-3.476	0.645	-2.044	7.375	-4.114	-5
atl2003080100_09_038		084	14	040	4.3	28.0	0.7	3.4	2.7	0.4	0.2	-2.140	-2.405	-2.600	-1.378	-1.939	-999.000	-6.838	-8
atl2003080100_09_038		096	15	041	4.5	27.0	0.7	3.3	2.7	3.1	0.0	-1.359	-2.049	-1.133	-0.897	-1.057	1.059	-6.951	-8
atl2003080100_09_038		120	15	042	3.9	29.0	1.0	3.2	3.0	0.6	0.1	-2.155	-2.391	-1.695	-1.376	-2.842	-999.000	-5.334	-7
atl2003080100_09_038	2003073012	024	10	037	2.7	23.0	0.5	4.0	1.9	0.1	0.2	-0.687	-0.646	-0.154	-0.101	-1.709	4.781	4.081	-0
atl2003080100_09_038		030	10	038	2.7	25.0	0.5	9.1	1.8	3.1	-0.3	-0.041	-0.399	0.550	-0.367	-0.094	2.363	2.090	-0
atl2003080100_09_038		036	10	039	3.1	33.0	0.6	4.5	2.4	0.2	0.3	-1.045	-0.769	-1.909	-1.144	-0.505	-999.000	2.106	-0
atl2003080100_09_038		042	10	040	3.2	30.0	1.0	3.9	2.5	0.6	0.4	-1.220	-1.257	-2.022	-1.026	-0.580	1.248	1.167	-1
atl2003080100_09_038		048	11	040	3.4	29.0	1.0	3.8	2.6	0.6	0.3	-1.049	-1.147	-2.275	-0.923	0.210	3.430	-1.829	-3

Fig. 3 *An example of a catalog for a vortex being tracked by the TCVTP.*

DATA BASES

TCVTP writes to two data bases that change with each model time. The data assigned to all vortices forecast to begin (i.e., do not exist in the current analysis) during the current model integration are written to the Forecast Data Base. Here, the data wait until they are matched to an analyzed vortex. If they are never matched, they remain in this data base and are a potential false alarm. All data that pertain to a current analyzed vortex are stored in the Analyzed Data Base. The catalogs remain until the vortex is no longer identifiable in the analysis. At this time, the catalog is written to the Final Circulation Catalog. Various summaries may then be generated.

TCVTP INTERFACE

The interface to the prototype TCVTP is via a series of web pages. Examples of this interface were provided in the mid-year report. However, based on discussions with NHC hurricane specialists and NHC staff, the interface to the operational TCVTP will be via NMAP2. These modifications are being made currently.

TASK: Present results at the Interdepartmental Hurricane Conference.

PROGRESS: This task was completed and a presentation was made that highlighted analysis of the performance of the GFS and NOGAPS models with respect to forecasts of tropical vortices over the North Atlantic and eastern North Pacific basins.

TASK: Visit TPC/NHC

PROGRESS: A visit was made to TPC and NHC immediately following the IHC. During this visit, two presentations/demonstrations were made. One presentation was made to highlight the implementation issues that would be associated with the TCVTP. A second presentation was made to highlight the envisioned use of the TCVTP in NHC operations and to examine results from implementation during the 2003 hurricane season.

TASK: Modifications based on initial TPC/NHC recommendations.

PROGRESS: The visit to TPC/NHC was very productive and resulted in the planning of several modifications to the prototype system. The need for several modifications became clear during test implementation on the 2002 and 2003 hurricane seasons, and additional modifications were identified through discussion with NHC hurricane specialists and staff.

Modifications are of two types. Several modifications are being made to the collection and cataloging of relevant analyzed and forecast physical parameters associated with each tropical vortex. Most of these were described above. One modification that is being tested is definition of the vortex environment. During development, the vortex environment has been defined by the fit of a bivariate normal ellipse to the outer-most closed 850 hPa vorticity contour that is greater than $1.5 \times 10^{-5}\ s^{-1}$. Another method that is similar to the technique used in the NOAA/GFDL hurricane model is being tested. In this technique, the hurricane circulation is defined based on radially-oriented filters relative to the vortex center. Tests are concentrating on whether the variability in vortex size that is often large in the ellipse representation is reduced with the GFDL technique.

The second group of modifications concentrates on the operational interface to the TCVTP. As described above, the interface to the prototype system was via web-pages and gif images. Based on the visit to NHC, it was decided that the interface should be via the GEMPAK-based NMAP2 system. These systems are in place at NPS and have recently been installed on the LINUX workstations, which is where the modifications will be made and tested during May and early June 2004.

SUMMARY

To date, progress has been consistent to that proposed in that the prototype system was successfully implemented and used to evaluate the 2002 and 2003 hurricane seasons. Results of these implementations were presented at the IHC to demonstrate the utility of the system for evaluation of forecasts of potential tropical cyclone formation. Based on performance during testing, and discussions with NHC Hurricane Specialists and staff, modifications are being implemented to improve characterization and diagnosis of model performance with respect to tropical cyclone formation. Also, modifications are being made to develop an operational interface in the GEMPAK/NMAP2 environment.

The prototype system will be available in real-time via a web interface until the modifications for the NMAP2 implementation are complete. At that time, a test implementation at NHC will be completed.

No modification of the budget for Year-two is required.

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YEAR TWO BUDGET – UNCHANGED FROM ORIGINAL PROPOSAL

A.	LABOR		
	1. FACULTY TIME & SALARY	80 d/year	$46,902
B.	NON-LABOR		
	1. TRAVEL		
	a. Domestic	Miami FL (2 trips)	$4,000
		Interdepartmental Hurricane Conference	$2,000
	TOTAL TRAVEL		$6,000
C.	INDIRECT COST:		$9,269
D.	TOTAL PROPOSAL COST (YEAR 2)		$62,171