FINAL JHT PROJECT REPORT

Transition of Dynamical Model Track Prediction Evaluation System (DYMES)

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1. Objectives and potential benefits

This final report of a two-year Joint Hurricane Testbed (JHT) project follows earlier interim reports and mainly describes the second-year progress. The primary goal of the second year was to conduct a pre-operational implementation test of the Dynamical Model Track Prediction Evaluation System (DYMES). The DYMES was developed in recognition that: (i) Dynamical model track guidance has been greatly improved, and yet some forecasts are bad and should be rejected; (ii) A consensus of multiple skillful dynamical model tracks removes random errors and in a large sample will have smaller track errors than the best of the individual models; (iii) Perhaps about 61% of the time, the dynamical model guidance is consistent (track spread around the consensus mean is sufficiently small) and the consensus mean should be a strong constraint on the track forecast; and (iv) Outlier tracks or two-cluster bifurcation situations represent opportunities where the forecaster may add value to the consensus mean track, and these are the situations in which the forecaster may need assistance in interpreting the guidance.

The purposes of this DYMES information management system (or knowledge-based expert system) are then to provide guidance to the forecaster as to when to: (i) Accept the (non-selective) consensus (NCON) of all dynamical model tracks; or (ii) reject one or more of the dynamical model tracks and thus form a selective consensus (SCON) that is more accurate than the NCON track. The DYMES module manages the information flow and presents the forecaster the information in a logical and systematic process. The module does not make the forecast – rather, it guides the forecaster through a decision process based on sound dynamical reasoning and the history of the dynamical model performance in similar scenarios. The key to detection of a likely erroneous dynamical model track forecast is a set of "large-error" conceptual models that were developed for western North Pacific cases by Carr and Elsberry (1999, 2000 a, b). The module "prompts" the forecaster to consider up to three of these large-error conceptual models whenever a dynamical model track has a large spread from the consensus mean track.

The primary goal of DYMES is to assist the forecaster in improving the official track forecast via optimum use of the dynamical model guidance. This is particularly relevant as the TPC/NHC is now issuing 96 h and 120 h outlooks, and dynamical models must be the guidance for such extended track forecasts. That is, if a model is judged to be providing bad guidance at 72 h due to an identifiable error, the extension of that track to 120 h should be rejected. Another goal of the DYMES is to promote consistency in the forecast process and in the product issued each shift. By following a procedure that is based on previous experience and a set of "rules" for when to reject a dynamical model track, the product should be more consistent in time. Since the DYMES model automatically records decisions made, and a summary sheet is prepared, the turn-over to the Hurricane Specialist on the next shift should be short and informative about the intelligence gained during that watch about each storm. Specifically, the next shift is provided information on which dynamical models (if any) that have not been performing well, and reasons why. The DYMES has a trend display feature that makes it easy to detect when the model track guidance has significantly shifted relative to its prior forecasts or relative to the other dynamical models in the consensus. Thus, DYMES can assist the forecaster develop a "storyline" that explains the recent past motion and the rationale for the track forecast, and this storyline can be easily passed to the next shift to begin developing the next forecast.

2. Progress during second-year

The primary objective during the second year was to convert DYMES to run fully on the TPC/NHC communication links and be available each 6 h on a 7 day by 24 h schedule. A number of tasks were laid out in the second-year proposal under Work Plan items a) through d). Although the second-year decision (and thus the funding) was delayed until almost the beginning of the 2002 hurricane season, these objectives were basically achieved. The progress through January 2003 is summarized in the Mid-year, second-year progress report and will not be repeated here. Rather, some achievements since that report will be described here.

(a) **Incorporate and test code upgrades**.

On 20 November and 20 December 2002 the TPC/NHC staff provided lists of code upgrades and fix bugs that they had identified and needed to be addressed. These items included: (i) NOGAPS should be included four times per day; (ii) Full 6 h capability; (iii) Use of TPC/NHC interpolated (I) tracks instead of original DYMES translated tracks; (iv) Creating of a track even if the latest forecast run is not yet available; (v) Allow viewing of fields for a previous run other than the chosen track; (vi) Increase length of Summary Sheet to avoid crashing system; and (vii) Display NCON and SCON at 12 h, 36 h, and 60 h.

With the assistance of contractors Dan Martinez and Sean Wells of Computer Science Corporation, all of these code modifications have been made and test runs have been made to check that the modifications are successful.

(b) **Present analysis of DYMES performance at IHC**

This task was accomplished based on the evaluations through early March 2003. This trip was a good opportunity to coordinate with TPC/NHC staff and receive additional feedback as well as more data, which have been added to the database since the IHC. The updated results are more promising than those presented at the IHC, and they are presented later in this report.

(c) **Analysis of track error mechanisms**

Since the end of the 2002 hurricane season, a post-analysis of a number of the large model errors has revealed that a basic flaw in the test has been the assumption of the western North Pacific error mechanism distributions for use in the Atlantic (Boothe and Elsberry 2003). The Atlantic errors are much more related to incorrect predictions of midlatitude circulations affecting the tropical cyclone than occurs in the western North Pacific where internal or adjacent tropical circulation error predictions occur more. While this midlatitude importance is consistent with physical reasoning, the post-analysis study was necessary to quantify the error distribution.

This exercise really demonstrates the desirability of post-storm analysis of dynamical model performance that goes beyond just a statistical summary of errors. The goal should be to increase knowledge of what situations each model may be expected to fail and for what reason. In principle, a consistent application of DYMES provides the basis for such a model performance evaluation. However, additional value is provided from a careful post-storm analysis when reality is known, and without the pressures of real-time operations. This on-going analysis is particularly important as the dynamical models are changed, and a more substantial knowledge base of model errors traits needs to be built. For example, it would be quite useful to the Hurricane Specialists to now have available at the season start (15 May 2003) such a careful analysis of the new 2003 Geophysical Fluid Dynamics Lab (GFDL) model retrospective runs for the entire 2002 season. The optimist expects that the test statistics show an improvement because some major forecast busts have been eliminated, and thus there will be fewer cases of likely erroneous tracks to be detected and rejected (in DYMES terminology, fewer SCON tracks need to be formulated). However, the concern from the DYMES perspective is that an error mechanism that previously only appeared in an excessive sense will be "overcorrected" and now be insufficient. For example, a typical error with the old GFDL model was Insufficient-Response to Vertical Wind Shear (I-RVS). What if the new GFDL model would now begin to have an Excessive-RVS because of the new cumulus parameterization scheme and additional vertical resolution?

As indicated above, the quality of the dynamical model guidance for Atlantic tropical cyclones is generally good, which is probably in part due to the excellent data coverage upstream of the target region and the enhanced observations from aircraft and satellites. However, the complexity of the forecasts is high during the late season when interaction with midlatitude circulations is common. As in any multi-body interaction problem, more opportunities exist for the model guidance to be wrong either in relation to the tropical cyclone, the subtropical anticyclone, or the midlatitude circulation. The large track error analysis has discovered the subtlety of these interactions. Some notable examples during 2002 are: (i) Long-lived, erratic track of Hurricane Kyle while interacting with midlatitude circulations resulted in a large number of model errors; (ii) Kyle acting the part of a midlatitude cyclone as it interacted with a weak subtropical anticyclone poleward of Lili; and (iii) Outflow from Hurricane Isidore being incorrectly predicted by the UK Met Office (UKMO) model and creating a downstream track error for Kyle.

Another benefit from the post-storm analysis is the discovery of model errors that might be addressed by the model developers. Among the many cases of poor initial vortex representations in the fields, the NCEP Global Forecast System (GFS) repeatedly had difficulty in representing the vertical structure of Hurricane Kyle. Because of the weak and vertically-sheared steering currents, the initial vertical structure of the vortex was critical in getting the initial motion correct. Once the short-term model track was in error, and then this improper vortex structure was simply translated to the new storm position in the next model integration 6 h later, the error was perpetuated. The Hurricane Specialist may add value by recognizing the reason for the erroneous initial motion is the vortex relocation technique in GFS – it may be more difficult for the model developers to develop a correction. Without necessarily picking on only the GFS, some cases were also found in which that model was not successfully initialized in weak storm cases, which resulted in a forecast of an erroneously early dissipation. Thus, the Hurricane Specialist was missing guidance from one of the best models. Another case during Tropical Storm Dolly in which the GFDL model was clearly improperly initialized again emphasizes the need for attention to the initial conditions for each model. Les Carr of Computer Sciences Corporation (CSC) is addressing this problem, and a module may become available as a future modification of DYMES.

In summary, the detailed analysis of track error mechanisms has produced sufficient evidence for modifying the guidance as to expected error mechanisms that will be appropriate for the Atlantic, rather than the western North Pacific as was available during the 2001 and 2002 tests. This modification is easy to insert and is expected to improve the application of DYMES during the 2003 season.

3. Experience gained and retrospective

(a) Successes achieved?

The most fundamental question from this project is: Does the DYMES approach “work” for Atlantic tropical cyclone forecasting? First, the DYMES procedures and processes are designed to help the Hurricane Specialist decide when the consensus of the dynamical model tracks will provide good guidance to follow in preparing the official track forecast. In the DYMES terminology, these are the situations in which the NCON track is good guidance. During the 2002 season, DYMES was applied in 202 situations (evidently Stacy Stewart applied parts of the technique in a number of other cases but did not record a NCON or SCON). In 124 cases (61%), a sufficiently small spread about the consensus mean existed that NCON should have been considered good guidance. Each of the Hurricane Specialists applies consensus reasoning to some degree, so the objective of the DYMES approach is to provide the information in a systematic manner to achieve consistency in approach and application of the consensus of dynamical model tracks.

The second goal in the DYMES approach is to guide the Hurricane Specialist in the evaluation of the dynamical model track guidance to detect likely large track errors. During the 2002 season, a total of 78 cases had at least one 72-h model position that exceeded the 225 n mi consensus spread threshold, and the forecaster is then alerted to evaluate the possibility of a large track error. Two possibilities exist: (1) More than one dynamical model may have a large error such that compensation occurs, and the consensus mean (NCON) track still is good guidance (in DYMES terminology, these cases are “large spread, small error –LSSE”); or (2) Only one model (or more than one member if in a “cluster”) is likely to have a large 72-h track error and should be rejected to form a selective consensus (SCON), which in DYMES terminology is “large spread, large error (LSLE).” That is, the forecaster can add value relative to simple consensus forecasting by correctly detecting and rejecting a bad model track so that the SCON track error is smaller than the NCON track error. The forecaster can also add value when the spread is relatively large (but does not exceed the 225 n mi threshold) and he/she is confident that an error mechanism is present – in this case, the official track can be shifted to the opposite side of the NCON track from the likely erroneous model track.

During the 2002 DYMES test, 53 cases (26%) were assigned a SCON not equal to NCON (possibility 2 above) and only 25 cases (12%) of compensating errors were detected. Based on the experience with the development sample for DYMES, these percentages should have been reversed. That is, the DYMES application in 2002 led to too many SCONs being formulated, and too few of the compensating error cases were detected. Reasons for this less-than-desirable application of DYMES will be described below.

The 2002 test may be considered to be a partial success in a statistical sense based on the 72-h track error summary for a non-homogeneous sample, including the DYMES-generated translated, interpolated, and extrapolated (operational) tracks of the dynamical models.

Model	72-h error (n mi)	Count
CLIPER	416	218
GFDL	232	142
GFDN	228	119
GFS	214	136
NOGAPS	209	143
UKMO	201	118
OFCL	202	200
NCON	181	150
SCON	180	147

The 72-h CLIPER error of 416 n mi is included here as a measure of difficulty relative to the 10-year mean of about 350 n mi, and indicates that 2002 was a more difficult sample of forecasts. Surprisingly, the regional models (GFDL, GFDN) had a relatively poor performance compared to their "mother global models" (GFS, NOGAPS) that provide the initial and lateral boundary conditions for the regional models. For this sample, the official track errors were slightly larger (but not statistically significant) than the best model (UKMO) errors. As has been consistently found for a consensus of skillful models, the simple dynamical model consensus (NCON) results in a smaller error than the best of the individual models. In addition, the NCON track error is 21 n mi (10%) better than the official error. Even with the problems during this preliminary test, the SCON track error was the smallest. Thus, the metric for this project (SCON error smaller than NCON error) was barely achieved.

(b) Potential for improvement of official forecast?

The above "raw" comparison may be criticized because the different models had different counts. A homogeneous comparison of 72-h track forecasts results in a smaller count (90), but is a more fair comparison:

Model	72-h error (n mi)	Count
CLIPER	403	90
GFDN	214	90
GFS	206	90
GFDL	204	90
UKMO	203	90
NOGAPS	195	90
OFCL	180	90
NCON	157	90
SCON	156	90

Notice that this comparison is for all cases in which all five dynamical models were available, and the 72-h track forecast could be verified as a tropical system. This restriction excludes some 72-h forecasts beyond the end of the life cycle, and probably some forecasts early in the life cycle. Since both of these scenarios are typically associated with larger track errors, it is not surprising that the CLIPER (measure of degree of difficulty) and the model, official, NCON, and SCON errors are all smaller than in the non-homogeneous sample above. Some shifts among the model rankings are noted. Again, the "daughter GFDN model" has a rather poor performance (214 n mi) compared to the "mother NOGAPS model," which has the best model performance. However, the GFDL model error is now slightly smaller than the GFS error, which slipped to be the second-worse model in this sample. The official error is now clearly smaller than any of the individual model errors, which was not true for the non-homogeneous sample.

Although this sample is small, it is interesting that the two best models are the NOGAPS and the UKMO, which were only available for 00 UTC and 12 UTC times during the 2002 season (NOGAPS was integrated at 06 UTC and 18 UTC from June 2002, but this modification was too late for inclusion in DYMES). Thus, these two global model tracks had to be translated as much as 12 h twice per day to make them available every 6 h. On the other hand, the GFS and GFDL models were integrated at 00 UTC, 06 UTC, 12 UTC, and 18 UTC and thus were translated at most 6 h. The question is whether the 06 UTC and 18 UTC tracks from the GFS and GFDL models are significantly degraded owing to reduced observations relative to the 00 UTC and 12 UTC integrations.

The answer as to whether DYMES has potential to improve the official forecasts is very clear from this sample. The NCON error of 157 n mi is 12.8% better than the official error (180 n mi). Again, the SCON is only one n mi better than the NCON (our metric for success), and reasons for this smaller than expected improvement over NCON will be discussed below.

(c) Potential for improvement of DYMES?

As indicated above, the DYMES test during the 2002 season was less than desired because cases of compensating errors were not detected so that too many SCON tracks different from NCON tracks were formed. In the 30 times a SCON was formulated (Table 1), only 15 resulted in an improvement over the NCON track and one was a tie. Whereas only one of the 10 SCON formulations during Hurricane Kyle resulted in degradation (by 37 n mi), 8 of the 11 SCON formulations during Lili resulted in degradations relative to the NCON forecasts. In eight of the 14 cases in which SCON was degraded compared with NCON, the cause was the failure to detect a second erroneous model track in a compensating error scenario. In these cases, the DYMES guidance is to not reject both tracks, but to go with the NCON track. The implication of the consensus spread exceeding the 225 n mi threshold is that these compensating error cases are less predictable. That expectation is validated in these 30 cases in that the magnitudes of NCON (219 n mi), SCON (214 n mi), and official (223 n mi) errors are considerably larger than their 2002 seasonal average values in the either of the above two tables. That is, these are cases in which the forecaster has the best opportunities to add value. If the DYMES approach had been correctly applied, fewer of the SCONs would have been generated (so the SCON track would be the same as the NCON track) and a larger reduction of the SCON errors relative to the official forecasts would have been achieved.

In some cases, the application was incorrect because the DYMES rules were not followed, which can be corrected by more training and gaining experience. In other cases, the DYMES test was hampered by having to use the western North Pacific Model Traits Knowledge Base (see the interim progress reports for the reasons for this necessity). Thus, realizing some of the potential for DYMES to improve use of the dynamical model guidance in an optimum manner requires an Atlantic Model Traits Knowledge Base. The presumption that the global and regional models common to the Pacific and Atlantic areas would have the same Model Traits Knowledge Base unfortunately proved to be false.

2002 Atlantic Season Verifying 72-h Forecasts
(30 cases when SCON not equal NCON)

		NCON	SCON	OFCL	NCON -SCON	OFCL -NCON	OFCL -SCON

04 Dolly	**Aug 29/18**	**578**	**525**	**421**	**53**	**-157**	**-104**
	Aug 30/06	**562**	**514**	**405**	**48**	**-157**	**-109**
05 Edouard	**Sep 02/12**	**92**	**118**	**160**	**-26**	**68**	**42**
06 Fay	**Sep 06/12**	**98**	**51**	**114**	**47**	**16**	**63**
	Sep 07/00	**132**	**150**	**137**	**-18**	**5**	**-13**
09 Hanna	**Sep 12/12**	**522**	**427**	**269**	**95**	**-253**	**-158**
10 Isidore	**Sep 23/06**	**159**	**237**	**252**	**-78**	**93**	**15**
	Sep 23/18	**114**	**198**	**262**	**-84**	**148**	**64**
	Sep 24/12	**371**	**451**	**353**	**-80**	**-18**	**-98**
12 Kyle	**Sep 26/12**	**173**	**210**	**223**	**-37**	**50**	**13**
	Sep 27/18	**147**	**75**	**208**	**72**	**61**	**133**
	Sep 28/00	**119**	**71**	**168**	**48**	**49**	**97**
	Sep 28/06	**134**	**86**	**151**	**48**	**17**	**65**
	Sep 28/18	**78**	**78**	**105**	**0**	**27**	**27**
	Sep 30/00	**352**	**270**	**351**	**82**	**-1**	**81**
	Oct 01/06	**110**	**26**	**131**	**84**	**21**	**105**
	Oct 01/12	**339**	**229**	**230**	**110**	**-109**	**1**
	Oct 07/12	**360**	**308**	**328**	**52**	**-32**	**20**
	Oct 08/00	**301**	**254**	**343**	**47**	**42**	**89**
13 Lili	**Sep 23/00**	**108**	**97**	**99**	**11**	**-9**	**2**
	Sep 23/12	**216**	**189**	**168**	**27**	**-48**	**-21**
	Sep 24/06	**242**	**268**	**248**	**-26**	**6**	**-20**
	Sep 24/12	**210**	**229**	**265**	**-19**	**55**	**36**
	Sep 25/00	**181**	**231**	**240**	**-50**	**59**	**9**
	Sep 25/06	**214**	**229**	**271**	**-15**	**57**	**42**
	Sep 26/00	**120**	**194**	**132**	**-74**	**12**	**-62**
	Sep 26/06	**122**	**120**	**139**	**2**	**17**	**19**
	Sep 26/12	**173**	**274**	**283**	**-101**	**110**	**9**
	Sep 27/00	**155**	**169**	**163**	**-14**	**8**	**-6**
	Sep 27/12	**102**	**155**	**74**	**-53**	**-28**	**-81**

Table 1. Storm number and dates during the Atlantic 2002 season in which SCON forecasts different from NCON forecasts were formulated, and the resulting 72-h errors (n mi) for these two techniques and the official (OFCL) forecasts. Differences between these errors are shown in the last three columns. A negative (positive) value indicates the first (second) technique in the difference had the smaller error.

(d) Requirements for improved Model Traits Knowledge Base

Two requirements exist for an improved Model Traits Knowledge Base to achieve an improved application of DYMES in the Atlantic. The first requirement is to specify the applicable track error mechanisms relative to the track orientations in both tropical (Fig. 1) and entering-midlatitude (Fig. 2) scenarios. These error mechanism assignments are model-independent and just attribute potential error mechanisms that would account for a model track (or cluster) ending in one quadrant relative to the consensus forecast and another track (or cluster). Recall that each of the error mechanisms in Figs. 1 and 2 are based on the model having an excessive (E) or insufficient (I) tendency to predict a real physical mechanism known to cause tropical cyclone motion. For example, a model may have a tendency in some situations to have an excessive (insufficient) Midlatitude Cyclogenesis (MCG) in which a near-by midlatitude cyclogenesis leads to tropical cyclone tracks that are too far poleward (not as far poleward). The conceptual models (see Carr and Elsberry 1999, 2000 a,b) in the DYMES Model Traits Knowledge Base provide the sea-level pressure or wind field patterns that are associated with each of these potential error mechanisms. These conceptual models provide a physical rationale for why such an error mechanism would lead to a track error in one of the quadrants in Figs. 1 and 2.

Thus, the first purpose of the Atlantic model track error assessment is to determine entries in Figs. 1 and 2 for track error orientations in tropical or entering-midlatitude scenarios. Most of the quadrants have four potential error mechanisms that could account for a track landing in a different quadrant relative to a correct forecast. However, other quadrants have five or six potential error mechanisms. The Atlantic Model Traits Knowledge Base has more entries in each quadrant than did the western North Pacific Knowledge Base because of the greater dependence on midlatitude circulations as a source of errors, and because many of these midlatitude errors were found to exist in both an excessive and insufficient sense. The DYMES tool includes all of these potential error mechanisms because they have occurred when one of the model large track errors arose due to that track being in that quadrant relative to the consensus cluster position for either a tropical or an entering-midlatitude scenario.

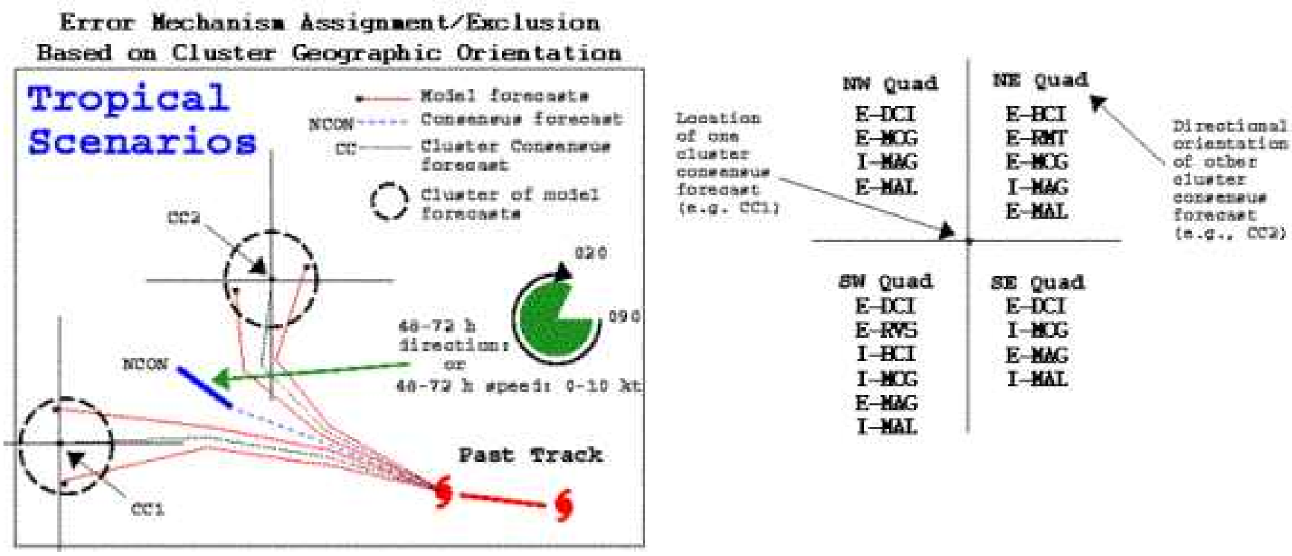

Fig. 1. Error mechanisms (see list of acronyms in Table 2) in either an E-Excessive or an I-Insufficient sense that would account for a model track for one cluster of model tracks (CC1 relative to CC2 or vice versa) to end in each of four quadrants relative to a second cluster when the target storm is in a tropical scenario.

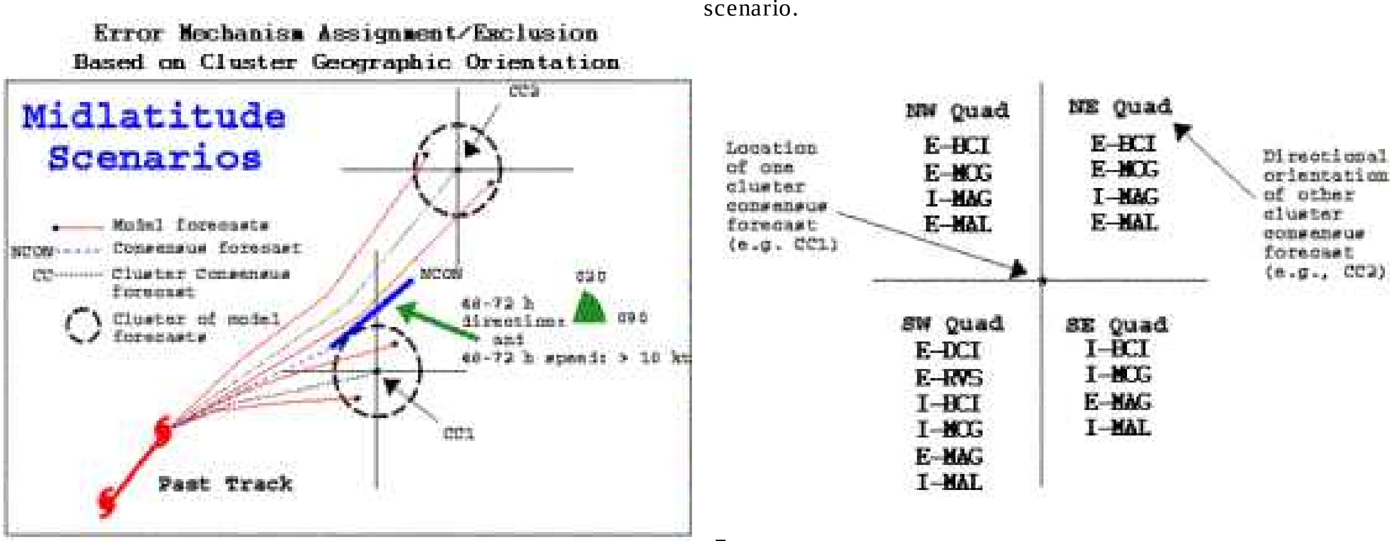

Fig. 2. Error mechanisms in each of four quadrants as in Fig. 1, except when the target storm is in an entering-midlatitude scenario.

The second requirement for an Atlantic-specific Model Traits Knowledge Base is to specify whether each model has a propensity to have each error mechanism (in either an excessive or an insufficient sense). That is, the list of potential error-mechanisms in Figs. 1 and 2, which are model-independent, may not have occurred in the developmental sample for a specific model, and thus the DYMES guidance to the forecaster would not include that error mechanism as an option. However, if the model has predicted in more than one case a track that falls into that quadrant and has exhibited a propensity to have large 72-h track errors in such a scenario, that potential error mechanism will be provided in the DYMES guidance to the forecaster. If the forecaster examines the analysis and forecast fields for that model using the DYMES and is confident that the error is present, that model track becomes a candidate for rejection (however, another model may also have a compensating error – see above). If a second model track in the same cluster also has evidence of that error in its analysis and forecast fields, additional confidence is then available for potential rejection of the model tracks in that cluster.

The most desirable situation is that a specific model has exhibited an error mechanism in a one-sided sense (i.e., is always an excessive or an insufficient sense). In that case, the detection of a likely track error of that sense is good support that an erroneous track is being predicted.

The attributions of model error mechanisms in cases of 72-h errors exceeding 250 n mi for the 2002 Atlantic season are given in Table 2. These error frequencies, in combination with similar error studies in earlier years, are the basis for assigning each error mechanism as being a "commonly occurring" mechanism for each of the five models. As indicated in section 2c, the major result from this analysis of error mechanisms is that it documents that Atlantic track errors are much more related to incorrect predictions of midlatitude circulations affecting the tropical cyclone tracks than occur in the western North Pacific. Had this knowledge been available and utilized in DYMES during the 2002 test, it is clear that a more consistent and accurate error assignment could have been achieved.

The Atlantic model traits in Table 2 have been included in the most recent update of DYMES for testing during the 2003 season. After the laborious characterization of all the error sources as listed in Table 2, this DYMES update is an easy code modification because it is either a value of zero (not suspected) or one (error has commonly occurred) for each error mechanism for each model. Used in combination with the geographical orientation of potential error mechanisms in Figs. 1 and 2, the DYMES will guide the forecaster to search for specific error mechanisms for each model that are the most likely based on the development sample. The larger the development sample, the better this guidance will be. However, this model error assignment will always need to be updated whenever a major change has been implemented in the model. The consistent application of DYMES in real-time during the season will document in the Summary Sheet the presence of detected (suspected) model errors and thus provide the basis for an on-going update of Table 2. As indicated in section 2c, a post-storm analysis when actual errors are known is necessary.

ERROR MECHANISM NAME AND ACRONYM		Number of 72-h track forecasts with error > 250 n mi				
		NGPS	GFDN	UKMO	GFS	GFDL
Direct Cyclone Interaction	DCI		2-0		1-0	5-0
Semi-direct Cyclone Interaction	SCI					
SCI on Western TC	SCIW					
SCI on Eastern TC	SCIE				0-1	
Indirect Cyclone Interaction	ICI					
ICI on Western TC	ICIW			1-0		
ICI on Eastern TC	ICIE					1-0
Ridge Modification by TC	RMT	5-0		2-0	2-0	4-0
Response to Vertical Shear	RVS	1-0			10-0	0-1
Baroclinic Cyclone Interaction	BCI		0-2		0-3	0-5
Midlatitude System Evolutions	MSE					
Midlatitude Cyclogenesis	MCG	3-0	1-0	2-1	0-1	4-2
Midlatitude Cyclolysis	MCL		1-0			
Midlatitude Anticyclogenesis	MAG			2-1	0-1	1-3
Midlatitude Anticyclolysis	MAL	2-0	0-2	4-1	1-0	2-1
Tropical Cyclone Size	(TCS)					0-1
Bad tracker		1				
Not discernible or explainable		2	3		2	15
Fields not available		40	11	4	25	18
Total of all poor forecasts		54	22	18	47	63

Table 2. Possible track error mechanisms in either an Excessive (E-first number) or Insufficient (I-second number) sense in the Atlantic Model Traits Knowledge Base and the number of 72-h track forecasts with greater than 250 n mi errors based on storms of the 2002 season. The errors are shown separately for the five dynamical models used in DYMES.

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