4D.8 PROSPECTS FOR OPERATIONAL TROPICAL CYCLOGENESIS FORECASTING

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1. INTRODUCTION

The rarity of tropical cyclogenesis despite the favorable thermodynamic environment that is in place during the hurricane season makes the prediction of such events an interesting problem. Recent research has shown the importance of the strength and spatial characteristics of tropical deep convection in initiating the spin up of a low-level vorticity maximum (Simpson et al. 1997). Difficulties in parameterizing tropical convection compounded with an observational data void over the ocean basins make predictions of tropical cyclogenesis with dynamical models difficult.

To overcome this problem and disseminate skillful tropical cyclogenesis forecasts in a regular fashion requires a step back from the mesoscale events that conclude the process and examination of the precursor environment. A long tradition of research has shown that a tropical depression cannot be born without a favorable large-scale environment to harbor it (e.g. Gray 1979). The necessary thermodynamic conditions (warm sea surface temperature, moist sounding, conditional instability) are almost always present in the tropics during summer and autumn. There is almost always an abundance of deep convective seedlings with the potential for formation. Hence, the critical factor that is responsible for the rarity of tropical cyclogenesis is the large-scale wind field. If a favorable large-scale field is not present, convection remains unorganized and the mesoscale processes are uninitiated.

The purpose of this study is to determine if a degree of predictability exists in a large-scale dataset for forecasting the development of observed tropical cloud clusters, and whether there is the potential for developing a probabilistic, objective model for forecasting tropical cyclogenesis.

2. DATA AND METHODOLOGY

The NCEP-NCAR reanalysis (Kalnay et al. 1996) provides global observations of many meteorological variables at a 6-hour temporal resolution on a 2.5° x 2.5° grid. The addition of satellite data into the reanalysis produces high confidence wind and temperature data over the oceans despite the rarity of in situ observations.

Archived satellite imagery were obtained from the 1998-2000 Atlantic hurricane seasons. GOES and METEOSAT images were remapped and merged to form a single image nearly coincident in time. Between 1-Jun and 30-Nov, cloud clusters were identified on the IR image if they were at least 3° in diameter, not elongated in shape, not associated with a mid-latitude system, persisted for at least 24 hours, and formed within the domain bounded by the equator to the south and 30°N. Table 1 illustrates the number and characteristics of the cloud clusters that met the criteria.

TABLE 1

	1998	**1999**	**2000**
Total Number of Clusters	90	91	110
Longest in duration (hours)	198	258	294
Mean duration (hours)	58.9	55.1	54.8
Median duration (hours)	42	36	42
Number of African waves	42	32	41
African wave /Total clusters (%)	46.7	35.2	37.3
Number of TDs	14	16	18

Only tropical systems that exhibited persistent convection were included in the analysis. Eight large-scale predictors, summarized in table 2, were calculated by taking a radial average of all grid points within four degrees of the cluster 'center'. The predictors were chosen in part through a literature review of large-scale factors important to tropical cyclogenesis. The maximum potential intensity (MPI) was computed by the Holland (1997) algorithm (with Reynolds SST as the lower boundary). The daily genesis parameter is the same as McBride and Zehr (1981), except the lower level in this study is 850 mb (since 900 mb is not available in the NCEP-NCAR reanalysis). A scaled Coriolis parameter is used to represent latitude.

Predictor	**Level (mb)**	**Unit**
Coriolis Parameter (latitude)	-	$10^{-5} * s^{-1}$
Daily Genesis Parameter	850,200	$10^{-5} * s^{-1}$
Moisture Divergence	850	$10^{-7} * gkg^{-1}s^{-1}$
Maximum Potential Intensity	Surface to 70	mb
Precipitable Water	Column	mm
24-hour Pressure Tendency	Surface	mb $24hr^{-1}$
6-hour Vorticity Tendency	Surface	$10^{-5} *s^{-1}6hr^{-1}$
6-hour Vorticity Tendency	700	$10^{-5} *s^{-1}6hr^{-1}$

TABLE 2

All cloud clusters were grouped into one of nine bins: non-developing, 6-hour developing (developed 6 hours after image time), and 12-48 hour developing (6 hour intervals). Genesis is deemed to have occurred when the storm is identified in the National Hurricane Center's best-track database. A linear discriminant analysis was then performed for each forecast interval. Discriminant analysis is a statistical classification procedure that computes a linear combination of the independent predictors in such a way that maximizes the separation between the developing and non-developing groups.

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	Hours prior to genesis (number of cases)							
	12 (n = 43)		24 (n = 41)		48 (n = 31)		Ndev (n = 1193)	
Predictor	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev
Coriolis Parameter (latitude)	**4.55**	1.72	**4.53**	1.75	**4.07**	1.57	**3.43**	1.76
Daily Genesis Parameter	**2.46**	1.84	**2.16**	1.80	**1.98**	1.76	**1.27**	1.92
Moisture Divergence	-0.01	0.26	-0.16	0.30	-0.12	0.26	-0.04	0.24
Maximum Potential Intensity	902.1	28.3	901.0	27.9	902.3	25.8	904.3	23.0
Precipitable Water	46.5	6.5	46.4	6.2	46.4	4.7	43.9	4.7
24-hour Pressure Tendency	**-0.81**	1.51	**-0.06**	1.24	**N/A**	N/A	**0.27**	1.42
6-hour Sfc Vort Tendency	**0.18**	0.33	**0.24**	0.37	**0.22**	0.26	**0.03**	0.34
6-hour 700 Vort Tendency	0.08	0.41	0.10	0.37	0.02	0.46	-0.01	0.41

TABLE 3

3. RESULTS

The NCEP-NCAR reanalysis can differentiate between developing and non-developing cloud clusters. Table 3 illustrates the composite means and standard deviations for all of the developing and non-developing cloud clusters in the study at the 12, 24, and 48 hour forecast period. The thermodynamic predictors (MPI, moisture divergence) show little differentiation between cases. It appears that the columnar precipitable water in the developing cluster's environment does exhibit significant separation from the non-developing clusters. However, the largest differences are seen in the dynamical variables (DGP, 6-hour surface vorticity tendency), the cluster pressure field, and latitude (shaded in table). These results are in agreement with modeling studies (e.g. Tuleya 1991) and observational work (McBride and Zehr 1981).

Those four predictors were used to train the discriminant analysis classification algorithm. A jackknife procedure was employed, where the regression equation was calculated with one case left out of the procedure. This case was then independently classified using the derived equation, and the procedure repeats for every other case. The algorithm predicts a cluster to develop if the independent predictors produce a probability of development $p > 0.50$. Table 4 shows cross validation matrices for the 12 and 48 hour forecast ('0' signifies non-developing and '1' developing). At 12 hours, the probability of detection (POD) is 70% with a false alarm rate (FAR) of nearly 25%. These measures degrade to a POD (FAR) of 64.5% (30.7%) at the 48 hour forecast period.

TABLE 4

		12-hour forecast				**48-hour forecast**	
		0	1			0	1
Obs	0	75.1	24.9	**Obs**	0	69.3	30.7
	1	29.4	70.6		1	35.5	64.5

4. DISCUSSION

Given that approximately 10-15% of all cloud clusters achieve tropical depression status in any given year, the coarse resolution dataset analyzed with a linear classification scheme do not yield any skill in forecasting tropical cyclogenesis. However, there were positive discoveries. It has been shown that the NCEP-NCAR reanalysis is able to capture some of the large-scale predictive signal despite the limitations of resolution and the linear analysis scheme. These results are also aligned with the thought that the large-scale wind field is more important in deciding tropical cyclogenesis than the thermodynamic environment, which appears to only provide a threshold for development.

5. CONCLUSIONS AND FUTURE WORK

It is believed that a more robust classification scheme, such as quadratic discriminant analysis or a non-linear neural network architecture, combined with a higher spatial resolution analysis field, may provide enough predictive skill to disseminate daily objective guidance for tropical cyclogenesis. Currently a neural network is being trained on the NCEP-NCAR reanalysis predictors to ascertain any gain in forecast skill. It is yet to be seen if the positive results presented here will translate into the operational environment.

6. REFERENCES

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