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"An Investigation of the detection of Tornadic Thunderstorms by observing storm top features using Geosynchronous Satellite Imagery"

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Final Report

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This contract permitted us to increase the number of tornado outbreak cases studied in detail from the original 8 under previous contract NAS8-36546 to 11 under the just completed contract. In addition, the contract permitted us to carry out detailed ground and aerial studies of two outbreak cases of considerable importance to NCSU and to MSFC. These two were the Raleigh tornado 28 November 1988 and the Huntsville tornado 15 November 1989. These two special cases were used to produce 4 M.S. thesis and the possibility of associated journal articles.

This report deals with the continuation in the work reported in the Final Report Contract NAS8-36547 dated December 1, 1988 wherein we demonstrated that multiple regression was able to predict the tornadic potential of a given thunderstorm cell by its cirrus anvil plume characteristics. In this previous work, we showed that the plume outflow intensity (UMAX) and the deviation of the plume alignment (MDA) from the storm relative winds at anvil altitude could account for the variance in tornadic potential for a given cell ranging from 0.37 to 0.82 for linear to values near 0.9 for quadratic regression.

In the present work, we refined our statistical techniques to concentrate on linear models only and experimented with several predictors which might be used as a third predictor variable representing the synoptic scale pre-storm meteorological environment. These predictors (UMAX, MDA, and meteorological) were used in various discriminant analysis models and in censored regression models to obtain forecasts of whether a cell is tornadic and how strongly tornadic it could be potentially. In this research we experimented with the synoptic scale vertical shear in the horizontal wind and with the synoptic scale surface vorticity (SFCVOR) in the proximity of the cell.

The discriminant analysis showed two main features: 1) The determination of whether a cell would be tornadic could be made quite accurately using either two (UMAX, MDA) or three (UMAX, MDA, and SFCVOR) variables in the classification scheme, and 2) the determination of the potential strength of a tornadic cell could be based on either the mean or the maximum possible tornadic intensities. When mean intensities are sought, surface vorticity was quite helpful in the classification scheme but not very helpful when maximum intensities were sought.

The regression analysis developed in the previous contract was redirected under the current contract in two ways: 1) we concentrated on linear regression techniques only and 2) we tried to adjust to the fact that no intensity exists when there is no tornado, ie, the non-tornadic nature of a cell cannot be assessed. Consequently the statistical model under which the analysis was performed is called the Tobit or censored regression model (Ameniya; 1984). Using maximum surface vorticity along with UMAX and

MDA (Tobit model 3) gave skill scores for probability of detection (POD) at 0.825, false alarm ratio (FAR) at 0.132, and critical success index (CSI) at 0.733 on the base sample data. Two test cases were run: South Carolina outbreak 5 May 1989 and Alabama outbreak 15 Nov. 1989. Here the inclusion of surface vorticity decreased skill scores for the Tobit model. However, the discriminant analysis correctly predicted tornadic vs non-tornadic cells 100 percent. A summary of the results for the base data set and the test cases are shown in Table 1.

Table 1. Skill scores for 2 different models using base data set vs test data sets.

	Base Data Set (9 Cases)			Test Data Set (2 Cases)		
Model	POD	FAR	CSI	POD	FAR	CSI
Discriminant (0 or 1)	0.950	0.269	0.704	1.00	0.400	0.600
Tobit (mean)	0.825	0.132	0.733	0.833	0.286	0.625

In conclusion, the discriminant model works very well in identifying tornadic vs non-tornadic cells when the 3 predictors (UMAX, MDA, and SFCVOR) are used as predictors. However, the more difficult task of predicting the mean intensity of those tornadoes expected from a given tornadic cell seems to be overcome if a censored regression technique (Tobit) is used. The most difficult task of predicting the maximum intensity of a given tornado which might emerge from a tornadic cell remains to be addressed by future research. Table 2 lists the individual outbreaks, their dates, and other pertinent information.

Table 2. List of tornado outbreaks used in this research.

Outbreak Name and area affected	Date	#of tornadoes	#killed/ #injured	Damage path (in miles)
OK/OK-SD	26 Apr 1984	07	0/5	106
WI/WI-IL	27 Apr 1984	07	03/038	046.7
IA/KS-WI	07 June 1984	34	04/117	454.0
NE/NE-KS	10 May 1985	08	00/004	148.0
OH/OH,PA,NY	31 May 1985	29	76/905	535.0
SK/SD,NE,IA	28 July 1986	12	00/001	077.5
KS/CO,WY,KS,NE	18 Sept 1986	05	00/007	043.5
TX/TX-LA	15 Nov 1987	17	11/287	145.0
NC/NC-VA	28 Nov 1988	07	04/157	125.0
SC/SC-VA	05 May 1989	16	07/164	104.3
AL/MS/AR/GA	15 Nov 1989	10	21/67	45.5

The Raleigh tornado was studied in detail by Carl S. Funk in his M.S. thesis (1991) and by John Roth in his M.S. thesis (1990). In Funk's study, the importance of pre-existing surface vorticity centers in close proximity to the developing thunderstorm cell was very evident in the case of the rapid development of the Alberta, Va. and Raleigh tornadoes. Both storms formed in a meso scale low pressure trough which had good surface wind convergence and identifiable centers of surface vorticity. Roth's study produced the surprising finding that the passage of the tornado funnel through north Raleigh was accompanied by several occurrences of microbursts on both sides of the damage path. This type of phenomena had been reported before by Fujita but it was believed to be rare. Roth's study indicates that microbursts may be a common artifact of tornadic circulations and as such, must be taken seriously when estimating the damage likely to ensue from a tornado.

The Huntsville, AL tornado of 15 November 1989 was the subject of a M.S. thesis by Burzinski (1990) who showed again that surface vorticity played a prominent role in the tornado genesis aspect of this ease. Although the evidence is clear that the supercell which produced the Huntsville tornado had mesocyclones and funnel cloud manifestations as early as one hour before the actual tornado appeared, it was not until the interception of the supercell storm by a squall line that the tornado funnel formed. Burzinski showed that the surface convergence and vorticity fields united with the mid level mesocyclone in the supercell storm to produce the Huntsville tornado in a time interval of 10 minutes or less. This same tornado seemed to have produced at least one (1) microburst based on studies by Fujita.

The final M.S. thesis was produced by Perry 1989, in which he demonstrated that linear regression and stratification of the sample cases along common threshold intercept values were the most promising analytically. Although, Perry was not able to identify an environmental factor, his findings encouraged us to search for one or more meteorological parameters which could be surrogates. It was his work which lead us to try shear and then surface vorticity as the meteorological predictors.

Publications

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Funk, C.S. 1991. "An analysis of the tornado-producing Raleigh thunderstorm of November 28, 1988" M.S. Thesis, North Carolina State University, Raleigh, N.C.

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