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PLAN FOR THE DEVELOPMENT AND IMPLEMENTATION OF SEVERE WEATHER PROBABILITY RELATIONSHIPS AT NEXRAD SITES

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1. INTRODUCTION

Beginning in 1990, the National Weather Service (NWS), the Air Weather Service (AWS), and the Federal Aviation Administration (FAA) will, over a period of several years, deploy approximately 175 Doppler weather radars. The goals of this program (called NEXRAD for NEXt generation weather RADar) include replacing existing, increasingly hard to maintain NWS and AWS weather radars and improving the value of weather radar in severe weather warning and routine weather forecasting programs. One of the most important aspects of NEXRAD concerning the enhancement of operational use of weather radar data is its automated collection, digitizing, and processing of these data. Anticipating the deployment of such automated radar systems, the NWS Techniques Development Laboratory (TDL) has had an ongoing research effort since the late 1970's to develop algorithms to provide objective guidance to the forecaster on the likelihood of particular radar echoes being associated with severe weather. Thus far, this effort has been based on the collection and analysis of digitized reflectivity data from the National Severe Storms Laboratory (NSSL) and the RADAP II (Radar Data Processor, version II) network. From this research, TDL has produced statistical relationships for Oklahoma that estimate the Severe Weather Probability (SWP) of a cell based on that cell's distribution of Vertically Integrated Liquid water (VIL) values (Elvander, 1980). Implementation of VIL and the Oklahoma-based SWP algorithm at RADAP II sites has led to impressive severe thunderstorm warning verification scores at WSFO Oklahoma City (Winston and Ruthi, 1986). Experiences at other sites and TDL-sponsored research at the University of Oklahoma (Beasley, 1986), however, have illustrated a problem of climatological variations of the relationship between VIL and SWP.

The developmental NEXRAD software includes an SWP algorithm utilizing the current, RADAP II SWP relationship developed for Oklahoma City. A primary TDL task will be to develop SWP relationships better suited for different NEXRAD sites in a time frame that will enable the implementation of a given site's relationship at the time of that site's NEXRAD deployment. This plan is intended to provide a structured approach to accomplishing that task. The plan will be updated periodically to reflect changing NEXRAD particulars and modifications to research approaches.

2. GENERAL APPROACH

TDL efforts concerning NEXRAD SWP usage involve documenting the experience gained from field use of VIL and SWP with RADAP II, using archive RADAP II data to derive SWP relationships for non-Oklahoma areas, and use of NEXRAD archive data as they become available. Extensive algorithm and product descriptions, discussions of product strengths and weaknesses, and suggestions for operational usage have been included in FMH-11, Part C for both VIL and SWP. These FMH-11 contributions include guidelines to assist the forecaster in "self tailoring" the SWP output to the local climatology.

A single station SWP relationship will be derived for each RADAP II site for which sufficient RADAP II archive data and severe storm report data are

available. A particular RADAP II relationship will be used for all NEXRAD sites that are subjectively determined to have climatological characteristics similar to the RADAP II site on whose data the relationship was derived. In some cases, the data from two RADAP II sites will be used to derive a combined SWP relationship that should better represent the climatology of a specific NEXRAD site. As shown in Fig. 1, data from the RADAP II sites will be processed in an order and time frame that ensures that a derived SWP relationship for a given site will be ready 30 days prior to the beginning of the installation phase of the first NEXRAD site that needs that relationship. In addition to providing non-Oklahoma SWP relationships, research with RADAP II data will enable the "fine-tuning" of the development methodology. Streamlined methodology will be necessary to match the rapid pace of NEXRAD installation and database collection.

VIL and many other NEXRAD products (Table 2) will be routinely archived on site and sent to the National Climatic Data Center (NCDC) for permanent storage. NCDC will, in turn, make these data available to the research community for the purpose of improving the operational utility of NEXRAD. As these data become available, TDL will incorporate them into the SWP relationship development effort. Depending on the severe weather occurrence climatology of particular sites, a database sufficient for SWP relationship derivation should be accumulated within approximately 2 to 5 years of NEXRAD installation. This data collection time period will be optimized only if extensive severe weather verification programs are followed at the NEXRAD sites. These programs could be modeled after the current program at WSFO Oklahoma City. After sufficient data collection at a NEXRAD site, another 1 to 2 years will be required for relationship development and implementation.

3. NEXRAD ALGORITHM CHANGE PROCEDURES

Developing an improved SWP relationship for a particular NEXRAD site is the initial step of an involved process. There will be many demands on limited agency resources for changes to the NEXRAD software. Although some procedures are yet to be formalized, the NEXRAD Configuration Management (CM) process will likely include the following steps related to algorithm changes. These projected steps were compiled from the set of responses to a memo distributed by TDL seeking various agencies' thoughts on future NEXRAD CM.

(1) Research and development to modify existing, or create new, algorithms will be largely the responsibility of non-NEXRAD organizations such as TDL, NSSL, and the Air Force Geophysical Laboratory (AFGL).

(2) NWS will form a review group (OM has proposed a Meteorological Doppler Radar Advisory Committee (MDRAC)) to evaluate requests for changes (RC's) for their meteorological validity and operational usefulness. The MDRAC would provide recommendations on approval/disapproval and implementation priority to the NEXRAD Operational Support Facility (OSF) and to the NEXRAD Program Management Committee (PMC).

(3) Agency approved RC's will be forwarded to the OSF for technical evaluation of the work force investment required for implementation, impact on the OSF budget, and impact on the existing functionality of NEXRAD. The OSF will classify an RC as either Class I (major change) or Class II (relatively minor change within the normal range of OSF activities).

(4) RC's designated Class I will be distributed to all agencies for review, and the PMC will decide approval or disapproval. A PMC decision may be appealed to the NEXRAD Program Council (NPC) for a final decision.

(5) For RC's designated Class II, the OSF will decide approval or disapproval and scheduling priority. OSF decisions may be appealed to the PMC for final decision.

(6) Approved RC's will be implemented within NEXRAD by the OSF. The sponsoring agency (presumably the source scientist) may be required to provide the OSF with Algorithm Enunciation Language (AEL) for the algorithm change.

4. CURRENT SWP RELATIONSHIP

The SWP relationship currently implemented at RADAP II sites was developed by Elvander (1980) using archived data from the NSSL WSR-57 radar for the spring of 1972. Elvander also processed NSSL data for other years around 1972 and developed many SWP relationships based on various sets of archive data and predictors. The 1972-based relationship was picked for implementation because its predictor set produced a very stable range of SWP values over the lifetime of a given cell, and an NSSL field program provided excellent verification data for 1972. The fact remains, however, that this relationship represents only one season for one location and often does not perform well for other areas of the country or even for Oklahoma in other seasons of the year.

5. CURRENT SWP RELATIONSHIP DEVELOPMENT

The methodology that Elvander developed has been adapted for the current TDL efforts to derive SWP relationships based on RADAP II archive data. RADAP II data have been used to derive relationships for Amarillo, Tex. and Oklahoma City, Okla. (Jendrowski, 1988). Other SWP relationships derived from these data will include site specific ones for each RADAP II site as well as some utilizing pairs of RADAP II sites. In addition, TDL must acknowledge the potential complexities of implementing software changes within NEXRAD. The Unisys SWP algorithm implementation calculates only those VIL-based predictors that are involved in the current SWP relationship. The coefficients and constant in this relationship, however, are adaptation data and can be adjusted for any site. The only new SWP relationships that could be implemented within NEXRAD with no software changes, therefore, would be ones that forced the use of the same predictors as in the current algorithm. TDL will derive relationships under this restriction and test their merit relative to relationships derived under a more general approach. Such "current predictor set" relationships will be implemented initially unless more general relationships are shown to be significantly better.

The next level of implementation complexity would involve new SWP relationships that use predictors different from those in the current algorithm but that need only the VIL field for their computation. Such an algorithm change would likely be evaluated as a Class II RC by the OSF and, depending on its assigned priority, be implemented fairly quickly.

For expediency, the current TDL SWP relationship development efforts do not include the potential use of non-VIL-related predictors.

Table 3 presents initial thinking on which RADAP II sites should be used for developing "initial capability", SWP relationships for specific NEXRAD sites. In the event that sufficient archive or verification data are not available for a particular RADAP II site, a different RADAP II site's single station SWP relationship will be chosen for the affected NEXRAD sites. The effectiveness of using these data to represent NEXRAD sites at considerable distances from any RADAP II site is limited, however. It is anticipated that archive data from NEXRAD sites themselves will be used in the future to continue the SWP derivation effort. Therefore, Table 3 also presents initial thinking on how much archive data are required from a given NEXRAD site for SWP development purposes.

6. FUTURE DIRECTIONS

Although current TDL work is following Elvander's SWP relationship development methodology, it is recognized that new approaches should also be investigated. A primary goal of such research will be to develop a generalized SWP relationship that will automatically account for the variations in airmass characteristics that lead to regional differences in site-specific relationships. Also, event-specific (tornado, hail, straight line winds, downbursts, etc.) SWP relationships will likely be more beneficial than a single, all-event relationship. Archive NEXRAD data will provide a rich source of new, radar-based predictors utilizing velocity and spectrum width data as well as output from algorithms such as HAIL and UPPER LEVEL DIVERGENCE. Expanding the SWP implementation environment to AWIPS will allow the complementary use of non-radar predictors including lightning, mesonet, satellite, and profiler data. Such development will require a substantial personnel resource commitment, but the potential rewards are great.

7. REFERENCES

Beasley, R. A., 1986: An analysis of operational RADAP II parameters, corresponding synoptic variables, and concurrent severe weather events in Oklahoma. MS. thesis, University of Oklahoma, Norman, Oklahoma, 223 pp.

Elvander, R. C., 1980: Further studies on the relationship between parameters observed with objectively defined echoes and reported severe weather events. Preprints 19th Radar Meteorology Conference, Miami Beach, Amer. Meteor. Soc., 80-86.

Jendrowski, P. A., 1988: Regionalization of the NEXRAD severe weather probability algorithm. Preprints 15th Conference on Severe Local Storms, Baltimore, Amer. Meteor. Soc., 205-208.

Winston, H. A., and L. J. Ruthi, 1986: Evaluation of RADAP II severe storm-detection algorithms. Bull. Amer. Meteor. Soc., 67, 145-150.

Table 1. RADAP II sites.

Station	Call letters	Latitude (deg)	Latitude (min)	Longitude (deg)	Longitude (min)
Amarillo, Tex.	AMA	35	13	101	42
Binghamton, N.Y.	BGM	42	12	75	59
Charleston, W. Va.	CRW	38	23	81	36
Garden City, Kans.	GCK	37	55	100	42
Jackson, Ky.	JKL	37	35	83	18
Limon, Colo.	LIC	39	11	103	42
Monett, Mo.	UMN	36	52	93	53
Nashville, Tenn.	BNA	36	15	86	34
Oklahoma City, Okla.	OKC	35	24	97	36
Pittsburgh, Pa.	PIT	40	32	80	13
Tampa Bay, Fla.	TBW	27	42	82	24
Wichita, Kans.	ICT	37	39	97	26

Table 2. NEXRAD Archive Products.

Product	Areal Resolution	Archive Frequency
Reflectivity, lowest slice	1 km x 1 km	once per volume scan
Velocity, lowest slice	1 km x 1 km	once per volume scan
Spectrum width, lowest slice	1 km x 1 km	once per volume scan
Composite reflectivity	4 km x 4 km	every third volume scan
Echo tops	4 km x 4 km	every third volume scan
One-hour precipitation	2 km x 2 km	once per hour
Severe weather analysis	variable	whenever produced
Layer composite turbulence	4 km x 4 km	every third volume scan
Digital precipitation array	1/40 LFM	twice per hour
Vertically integrated liquid	4 km x 4 km	once per volume scan
Radar coded message	1/4 LFM	twice per hour
Combined shear	variable	every third volume scan
Storm structure	n/a	every third volume scan
Significant weather overlay	n/a	once per volume scan
VAD winds, last 12 profiles	n/a	once per volume scan

Table 3. Site-specific details of NEXRAD SWP derivation.

NEXRAD Site	Installation Date	RADAP II Site	Est. Req. NEXRAD Data (yr)
Norman, Okla.	Jan 90	OKC	2
Melbourne, Fla.	Apr 90	TBW	2
Sterling, Va.	Jun 90	PIT	5
Frederick, Okla.	Aug 90	OKC	2
NW Florida, Fla.	Oct 90	TBW	3
St Louis, Mo.	Dec 90	UMN	3
Denver, Colo.	Jan 91	LIC	2
Kansas City, Mo.	May 91	UMN:ICT	2
Wichita, Kans.	May 91	ICT	2
Topeka, Kans.	Jun 91	ICT	2
Tulsa, Okla.	Jun 91	ICT:UMN	2
Goodland, Kans.	Jul 91	GCK	2
Grand Island, Neb.	Aug 91	ICT:GCK	2
Amarillo, Tex.	Aug 91	AMA	2
State College, Pa.	Sep 91	PIT	3
Binghamton, N.Y.	Sep 91	BGM	3
Philadelphia, Pa.	Sep 91	PIT	3
Dover, Del.	Oct 91	PIT	3
Charleston, W. Va.	Oct 91	CRW	4
Louisville, Ky.	Oct 91	JKL	3
Indianapolis, Ind.	Nov 91	UMN:PIT	2
Chicago, Ill.	Nov 91	UMN:PIT	2
Pittsburgh, Pa.	Nov 91	PIT	3
Detroit, Mich.	Dec 91	UMN:PIT	3
Cleveland, Ohio	Dec 91	PIT	3

Table 3. (Continued).

NEXRAD Site	Installation Date	RADAP II Site	Est. Req. NEXRAD Data (yr)
Buffalo, N.Y.	Jan 92	BGM	3
Memphis, Tenn.	Jan 92	BNA	3
East Alabama, Ala.	Mar 92	BNA	3
Little Rock, Ark.	Mar 92	OKC:UMN	3
Jackson, Miss.	Mar 92	BNA	3
New Orleans, La.	Apr 92	BNA	3
Central Texas, Tex.	Apr 92	OKC	2
San Francisco, Calif.	Apr 92	BGM	5
Los Angeles, Calif.	May 92	BGM	5
Vandenberg, Calif.	May 92	BGM	5
New York City, N.Y.	May 92	PIT	3
Albany, N.Y.	Jun 92	BGM	3
Boston, Mass.	Jun 92	BGM	3
Salt Lake City, Utah	Jul 92	LIC	5
Portland, Maine	Jul 92	BGM	5
Omaha, Nebr.	Jul 92	ICT	2
Des Moines, Iowa	Jul 92	ICT	2
Cheyenne, Wyo.	Aug 92	LIC	4
Robins, Ga.	Aug 92	BNA	3
Sioux Falls, S. Dak.	Aug 92	GCK:ICT	3
Birmingham, Ala.	Sep 92	BNA	3
Atlanta, Ga.	Sep 92	BNA	3
Miami, Fla.	Sep 92	TBW	2
Columbia, S.C.	Oct 92	BNA	3
Grissom, Ind.	Oct 92	PIT	3

Table 3. (Continued).

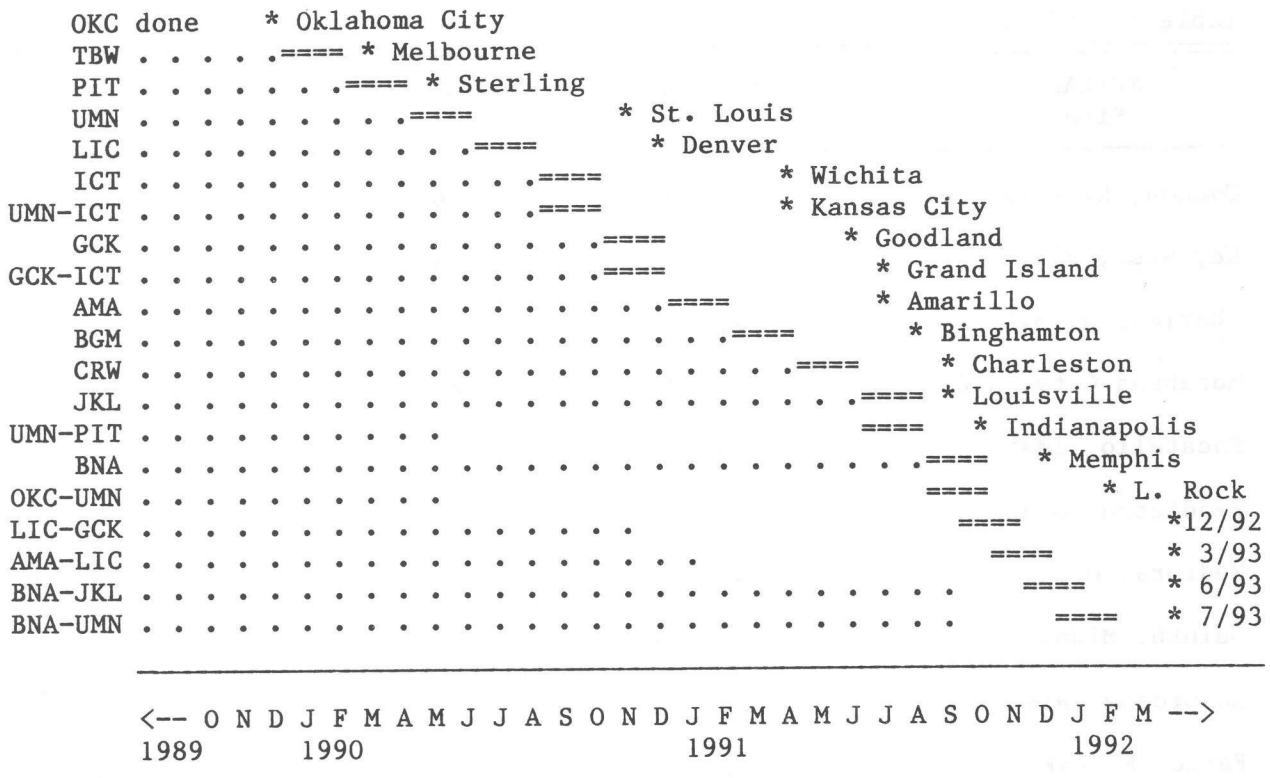
NEXRAD Site	Installation Date	RADAP II Site	Est. Req. NEXRAD Data (yr)
Raleigh/Durham, N.C.	Oct 92	BNA	3
Portland, Oreg.	Oct 92	BGM	5
England, La.	Nov 92	BNA	2
Seattle, Wash.	Nov 92	BGM	5
Boise, Idaho	Nov 92	BGM	5
Minneapolis, Minn.	Nov 92	ICT	3
Milwaukee, Wis.	Dec 92	ICT:UMN	2
Bismark, N. Dak.	Dec 92	LIC:GCK	3
Columbus, Ohio	Dec 92	BNA	2
Great Falls, Mont.	Jan 93	LIC	5
Dallas/Ft.Worth, Tex.	Jan 93	OKC	2
Austin/San Antonio, Tex.	Jan 93	OKC	2
Lubbock, Tex.	Mar 93	AMA	2
Albuquerque, N. Mex.	Mar 93	AMA:LIC	4
Phoenix, Ariz.	Mar 93	AMA:LIC	5
Minot, N. Dak.	Apr 93	LIC:GCK	3
Reno, Nev.	Apr 93	LIC	5
Cincinnati/Dayton, Ohio	Apr 93	PIT	3
Missoula, Mont.	Apr 93	LIC	5
Houston/Galveston, Tex.	May 93	BNA	2
Knoxville/Tri City, Tenn.	May 93	JKL	4
Lake Charles, La.	Jun 93	BNA	2
Norfolk/Richmond, Va.	Jun 93	BNA	3
Roanoke, Va.	Jun 93	BNA:JKL	3
Quad Cities, Iowa	Jul 93	ICT:UMN	2

Table 3. (Continued).

NEXRAD Site	Installation Date	RADAP II Site	Est. Req. NEXRAD Data (yr)
Springfield, Ill.	Jul 93	UMN:BNA	2
Paducah, Ky.	Jul 93	JKL	3
Grand Rapids, Mich.	Jul 93	UMN:PIT	3
Alpena, Mich.	Jul 93	UMN:PIT	3
Marquette, Mich.	Jul 93	UMN:PIT	3
Shreveport, La.	Aug 93	BNA	2
Nashville, Tenn.	Aug 93	BNA	2
Sacramento, Calif.	Aug 93	LIC	5
San Joaquin, Calif.	Sep 93	LIC	5
Eureka, Calif.	Sep 93	BGM	5
San Diego, Calif.	Oct 93	BGM	5
Burlington, Vt.	Oct 93	BGM	4
Pueblo, Colo.	Oct 93	LIC	3
Grand Junction, Colo.	Nov 93	LIC	3
Springfield, Mont.	Nov 93	UMN	2
Loring, Maine	Nov 93	BGM	4
Aberdeen, S. Dak.	Nov 93	LIC:GCK	3
North Platte, Nebr.	Dec 93	GCK:ICT	2
Laughlin, Tex.	Dec 93	OKC	2
Rapid City, S. Dak.	Dec 93	LIC:GCK	3
Riverton, Wyo.	Dec 93	LIC	4
Tampa Bay, Fla.	Jan 94	TBW	2
Mobile, Ala.	Jan 94	BNA	2
Jacksonville, Fla.	Jan 94	TBW	2
Wilmington, N.C.	Mar 94	BNA	3
Tallahassee, Fla.	Mar 94	TBW	2

Table 3. (Continued).

NEXRAD Site	Installation Date	RADAP II Site	Est. Req. NEXRAD Data (yr)
Cannon, N. Mex.	Mar 94	AMA:LIC	4
Key West, Fla.	Apr 94	TBW	3
Charleston, S.C.	Apr 94	BNA	3
Morehead City, N.C.	Apr 94	BNA	3
Pocatello, Idaho	May 94	LIC	5
Pendleton, Oreg.	May 94	BGM	5
Medford, Oreg.	Jun 94	BGM	5
Duluth, Minn.	Jun 94	ICT	3
La Crosse, Wis.	Jun 94	ICT:UMN	2
Fargo, N. Dak.	Jul 94	GCK:ICT	3
Green Bay, Wis.	Jul 94	ICT:UMN	3
El Paso, Tex.	Jul 94	AMA:LIC	4
Glasgow, Mont.	Jul 94	LIC	5
Corpus Christi, Tex.	Jul 94	BNA	3
Brownsville, Tex.	Jul 94	BNA	3
San Angelo, Tex.	Jul 94	AMA	2
Midland/Odessa, Tex.	Aug 94	AMA	2
Billings, Mont.	Aug 94	LIC	5
Las Vegas, Nev.	Aug 94	LIC	5
Tuscon, Ariz.	Aug 94	LIC	5
Flagstaff, Ariz.	Sep 94	LIC	5
Yuma, Ariz.	Sep 94	LIC	5
Elko, Nev.	Sep 94	LIC	5
Cedar City, Utah	Sep 94	LIC	5
Caribou, Maine	Sep 94	BGM	5



. . . . Initial processing of site data: quality control, cell tracking, predictor/predictand matrix generation. (Responsible personnel: Saffle, Kitzmiller)

======= Derivation of SWP relationship. (Responsible personnel: Miller, Lang)

* Earliest date a given SWP relationship is needed, i.e., 30 days prior to the date of installation of the first NEXRAD site to use it. The particular NEXRAD sites involved are named for the dates through March 1992.

Figure 1. Milestone chart indicating completion dates for different phases of the development of RADAP II-based SWP relationships for use at individual NEXRAD sites.