WESTERN REGION TECHNICAL ATTACHMENT
NO. 98-43
DECEMBER 29, 1998

AN ASSESSMENT OF EXPERIMENTAL THUNDERSTORM AND RAINFALL FORECAST TECHNIQUES FOR THE GREATER PHOENIX METROPOLITAN AREA DURING THE SUMMER CONVECTIVE SEASON

Chris Breckenridge - NWSFO Phoenix, AZ

Introduction

A number of experimental forecast techniques, derived from the early years of the SWAMP (SW Area Monsoon Project) field program, were assessed during SWAMP 1994. An attempt was made to further evaluate two of these techniques using data obtained during the 1995 Arizona summer convective season. The first involved use of McCollum severe thunderstorm patterns (McCollum, 1993; Maddox et al., 1995) to determine the threat for severe thunderstorms across the south-central deserts, specifically in what was formerly known as Arizona forecast zone 8 (Fig. 1). The second involved the use of the Monsoon Climatological Index (MCI) (Ostapuk, 1992), to determine the probability of convective precipitation at Luke AFB during the 24 hours following 1200 UTC.

McCollum Severe Thunderstorm Pattern Technique

This study used pattern recognition, under the assumption that certain synoptic patterns, occurring in association with a favorable 1200 UTC moisture profile, can be used to help predict the occurrence of severe thunderstorms across south-central Arizona. Four different McCollum patterns (500 mb streamline patterns covering the continental United States) have been identified and associated with severe weather outbreaks across south-central Arizona (Fig. 2).

Procedures

1. Examine the 1200 UTC 500mb height analysis to determine whether or not one of the four McCollum patterns is in place. If a McCollum pattern (or a close approximation) existed, then the preliminary forecast was for severe thunderstorms. The 500 mb height initial analyses were obtained from the ETA and NGM.

2. Examine the 1200 UTC Tucson sounding to determine if adequate low-level moisture is present. The following criteria must be met:

925mb	dewpoint ≥ 10° C
850mb	dewpoint ≥ 9° C
700mb	dewpoint ≥ 2° C

IF the Tucson sounding met the above criteria AND a McCollum pattern existed, a "YES" (severe thunderstorms expected) forecast was made. The valid period for the forecast was for 24 hours following the 1200 UTC sounding (1200 UTC today through 1200 UTC the following morning). A "NO" (severe thunderstorms not expected) forecast was made if the moisture criteria were not met - EXCEPT when a McCollum pattern 3 was identified. With a pattern 3, low-level moisture availability must be assessed - if sufficient moisture advects into central Arizona from the southwest, pattern 3 can support severe thunderstorms over south-central Arizona, even if the 1200 UTC Tucson sounding is dry.

3. Verify the occurrence of severe weather across south-central Arizona (former forecast zone 8) for the next 24 hours. The following were used to determine if severe weather occurred:

* Severe criteria measured or observed (wind ≥ 50 knots, hail ≥ 3/4 inch in diameter (dime sized) or tornado.
* Wind damage (e.g. telephone poles downed, roofs blown off, trees downed, mobile homes damaged, etc.).
* Radar echoes with maximum dbz > 65.
* Base scan Doppler radial velocities > 60 knots.

Surface observations, PRISMS[1] (Phoenix Real-time Instrumented Surface Meso-meteorological System) wind data, Emergency Services and AZTC (AriZona Thunderstorm Chasers) reports, spotter reports, reports of damage to the SRP[2] (Salt River Project) power grid or facilities, and the Phoenix WSR-88D were all used to determine whether severe weather occurred on a given day. The bulk of the information used for verification purposes in this study came from Phoenix and Luke surface observations, Phoenix spotter logs, and office severe weather warning/statement logs.

One important note regarding verification must be mentioned. Because this study was done well after the 1995 monsoon had ended, access to WSR-88D archive data was limited. Due to this limitation, the following assumption was made: if a severe thunderstorm warning had been issued, based solely (or partly) on WSR-88D data, it was assumed that

[1] PRISMS refers to a network of automatic weather sensors scattered across the Phoenix metropolitan area

[2] SRP is a major private utility company located in north Tempe, AZ

either of the last two criteria listed above had been met and the warning was thus used as positive verification of severe weather.

Results

This study covered the period from 1 August - 15 September 1995. Due to missing data, only 40 days were available for review. Of these 40 days, a forecast of "severe thunderstorms expected" was generated 11 times. On the remaining 29 days a forecast for "no severe thunderstorms expected" was made. On 5 of the 11 "YES" days, severe weather DID verify in the forecast area for a success rate of 45% (5/11). However, severe thunderstorms occurred on 7 of the 29 "NO" days, for a percentage of just 24% (7/29).

McCollum Severe Thunderstorm Pattern Study Conclusions

Although the data set used here was rather limited, some potentially useful conclusions can be gleaned. First, the occurrence of a McCollum pattern, coupled with adequate low-level moisture at Tucson, was a relatively infrequent event; only 11 of the 40 days met the "severe thunderstorm likely" criteria. Additionally, it was rather difficult to find a day where the 500 mb pattern exactly matched one of the four McCollum patterns; in most cases where a McCollum pattern was considered to exist, in truth there was only a relatively close approximation.

Second, severe weather occurred about twice as often on "severe thunderstorms expected" (YES) days as compared to "severe thunderstorms not expected" (NO) days (45% vs 24%). Thus, although a McCollum pattern in the upper atmosphere is not a frequent event, when it DOES occur the odds of severe weather happening over the south-central deserts of Arizona appear to improve dramatically! The McCollum pattern technique has the potential to steer the forecast in the right direction and allow the meteorologist to better determine if the severe weather threat is enhanced for that day.

Monsoon Climatological Index (MCI) Study

The MCI was originally designed to use upper-air data collected at Page, Arizona, in order to predict the chance for measurable rainfall at Page. In this study, it was calculated using input from the 1200 UTC sounding taken at Luke AFB. Each of the four input parameters - 800 mb dew-point temperature, 600 mb dew-point depression, 500 mb temperature, and dry air cap- was assigned a score ranging from +4 to -4. The four scores were then added to derive the final value, which ranged from +16 to -16. Thunderstorms are possible within 24 hours when the MCI is positive; the higher the positive number, the greater the chance for measurable precipitation at Luke.

Procedures

1. Using the 1200 UTC Luke AFB RAOB, fill out the MCI Forecast Matrix (Fig. 3a). Assign a score to each of the four input parameters and total them to derive the Raw Score.

a. Enter the score for the 800 mb dew-point temperature parameter. Copious low-level moisture is favorable for convection, thus high 800 mb dew-points receive positive scores.

b. Enter the 600 mb dew-point depression parameter score. As the MCI is an "air mass" index, high values of mid-level moisture are also favorable for convection. Thus, low 600 mb dew-point depressions receive positive scores.

c. Enter the score for the 500 mb temperature parameter. The colder the temperature, the greater the observed lapse rate (on most days). An unstable atmospheric lapse rate is favorable for convection; thus, highly negative 500 mb temperatures receive positive scores.

d. Enter the score for the dry air cap parameter. The "dry air cap" is defined as the lowest layer (at least 50 mb thick) which maintains a relative humidity below 35 percent. A low altitude dry air cap tends to inhibit air mass convection and, as a result, only caps at or above 450 mb receive positive scores.

e. Add the four category scores from above to derive the "Raw Score".

Data for the parameters listed above were obtained by hand-plotting the 1200 UTC Luke sounding. Numbers for "a", "b", and "c" above were quickly read off the sounding. To obtain the dry air cap parameter, dry layers were visually identified, then the relative humidity was calculated via $(w/w_{sat})x100$ in order to determine if the criterion of 35% or lower was met. If it was, the base of the layer nearest the surface with a RH $\leq$ 35% was used to compute the category score; bases higher than 300 mb received a +4 score, bases between 300 mb and 450 mb were assigned a +2.

2. Fill out the Adjustment Factor worksheet (Fig. 3b) to determine if any adjustments are needed to the Raw Score.

Much of the western U.S. summertime convection is driven by the interaction of minor impulses. The MCI employs adjustment factors that use 24 hour trends in pressure and temperature in order to track the passage of weather systems. Adjustment Factor input parameters are: 24 hour change in both 800 mb and 500 mb heights as well as change in 500 mb temperature.

a. Calculate the 24-hour changes in the three parameters above using the 1200 UTC Luke sounding. Enter these in section 1 of the Adjustment Factor worksheet and answer "Yes" or "No" to the following questions: "Are the 800 mb heights falling?", "Are the 500 mb heights falling?" and "Is the 500 mb temperature falling or steady (increase less than 0.2°C)?".

b. If the answers to two or more of the above questions are "yes", proceed to the option 1 significance test and fill out the appropriate section on the worksheet. Answer "Yes" or "No" to the following questions: "Is any height fall > 10 meters?" and "Is the 800 mb dew point > 2°C?". If both answers are "Yes", use the +4 adjustment factor. If both answers are "Yes" but the 500 mb temperature has warmed by 1°C or more, use the +2 adjustment factor. No adjustment is needed if only one answer is "yes". Finally, take the 800mb dew-point score (calculated from the MCI matrix) and add either 2 or 4 (as determined above) to obtain the "Adjusted Score". This value is used only if its value is greater than the Raw Score.

c. If the answers to all three questions in "a" above are "No", proceed to the option 2 significance test and fill out the appropriate section on the worksheet. Answer "Yes" or "No" to the following questions: "Has the 500 mb temperature warmed by 2°C or more?" and "Are both height rises greater than 10 meters?". If both answers are "yes", then subtract 2 from the Raw Score to obtain the "Final Score".

3. Verify the MCI score (either the Raw, Adjusted or Final). MCI scores equate to Precipitation Probability Forecasts for Luke in the following manner:

Table 1. MCI Score and Probability of Measurable Precipitation (POP)

MCI Score	POP
Negative	0%
+2	10%
+4	20%
+6	40%
+8	50%
+10	75%
>10	80-100%

The forecast was evaluated (verified) primarily using the Luke AFB surface observations. Rainfall reports from the Phoenix ASOS, as well as reports from the PRISMS sites, were used as a secondary verification source, as well as to determine areal coverage of rainfall across the Phoenix metropolitan area.

Results

This study covered the period 1 August - 16 September 1995. Due to missing data, only 38 days were available for review. Of these days, 20 had a positive MCI. Using Luke AFB rainfall reports for verification ONLY, 6 of the positive MCI days registered measurable rainfall (30%), and if trace events were included, then 9 days verified (45%). Of the 18 days with a zero or negative MCI, only 1 registered either measurable or trace rainfall

(5.5%). The addition of Phoenix ASOS and PRISMS data for verification purposes increased the success rate to 50% - 10 of the 20 positive MCI days reported either measurable or trace amounts of rainfall (8 measurable/2 trace events). The average MCI score for measurable only days was +5.5, while the average MCI for measurable and trace event days was +5.4.

MCI Study Conclusions

The most obvious conclusion to be gleaned from this exercise was that days with a positive MCI had a much better chance of producing measurable rainfall at Luke (and the south-central deserts in general). Using the Luke AFB and Phoenix surface observations along with PRISMS data as verification, at least a trace of rain fell on 50% of the days with a positive MCI, but only 5.5% of the negative MCI days reported a trace of rainfall or greater.

The conceptual model of the MCI score is such that positive values reflect a threat for convective precipitation; the higher the positive number, the greater the chance for measurable rainfall. In this study, 20 days exhibited a positive MCI score, with an average MCI of +5.4. According to Table 1, this average would correlate to about a 35% chance of rain at Luke. In reality, 30% of the positive MCI days registered measurable rainfall at Luke alone, and 40% of those days netted a measurable report from either Luke, Phoenix, or a PRISMS site. Thus, although the case study contained a limited data set, the MCI scores correlated well with the precipitation probabilities.

As mentioned earlier, the MCI was designed to use upper-air data collected at Page, Arizona in order to predict the chance for measurable rain at Page. As such, the input parameter levels, e.g.: 800 mb dew point, were optimized for the higher elevation of Page (about 4300 feet MSL). These levels were not altered to reflect the lower elevation of Luke (about 1100 feet MSL); even so, the index appeared to work quite well in forecasting measurable precipitation over the south-central deserts of Arizona.

Conclusion

Both of the NSSL experimental thunderstorm forecast techniques assessed in this study appeared to help the Phoenix forecaster with the challenge of predicting both general and severe convection over the deserts of south-central Arizona. When a McCollum pattern was present in the upper atmosphere, in conjunction with sufficient low-level moisture, the chances for severe convection over the south-central deserts doubled. In addition, on days when the Luke MCI was positive, the chances for measurable rainfall increased substantially as compared to days with a negative MCI.

Acknowledgments

The author would like to acknowledge the researchers who have been involved with the SWAMP program, especially Dr. Robert Maddox and Ken Howard, whose efforts provided the inspiration and foundation for this study.

References

Maddox, R. A., D.M. McCollum, K.W. Howard, 1995: Large-Scale Patterns Associated with Severe Summer Thunderstorms over Central Arizona. *Wea. Forecasting*, **10**, 763-778.

Maddox, R. A., K. W. Howard, J.J. Gourley, 1995: SW Area Monsoon Project Daily Operations Summary. *NSSL Report Series*, NSSL-3-95

McCollum, D.M., 1993: Synoptic-scale patterns associated with severe thunderstorms in Arizona during the summer monsoon. *M.S. thesis*, School of Meteorology, University of Oklahoma, 166 pp.

Ostapuk, P.A., 1992: Forecasting the Colorado Plateau Monsoon using a Single Station Climatological Index. *Proceedings of the 4th Arizona Weather Symposium*, 108-115.

Fig. 1. Former Arizona forecast zone 8.

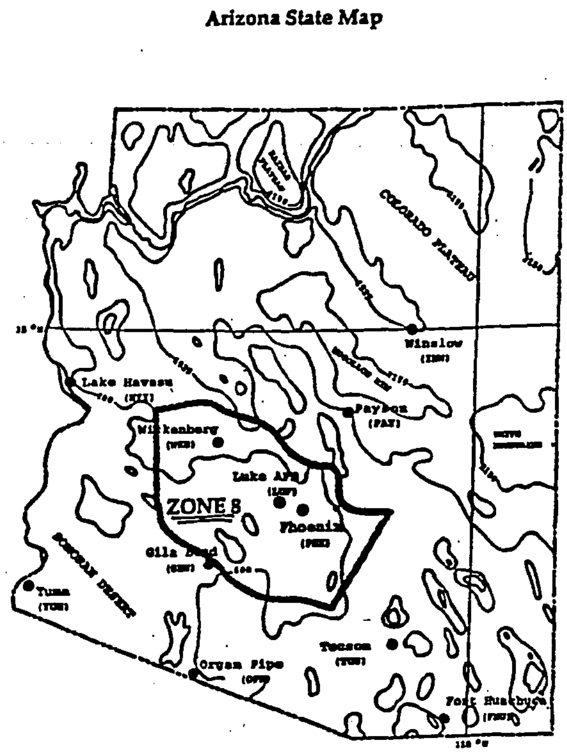

Fig. 2. McCollum patterns associated with severe weather outbreaks across south-central Arizona.

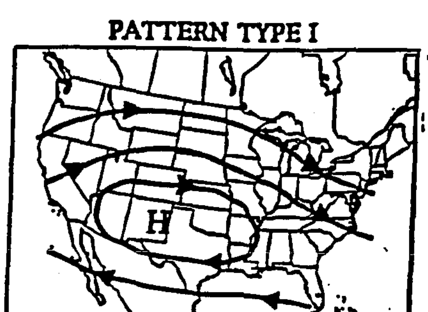

Fig. 1. General 500 mb streamlines for pattern Type I.

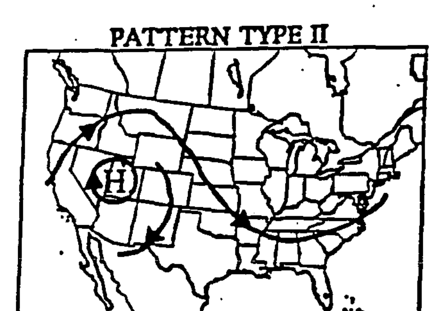

Fig. 2. General 500 mb streamlines for pattern Type II.

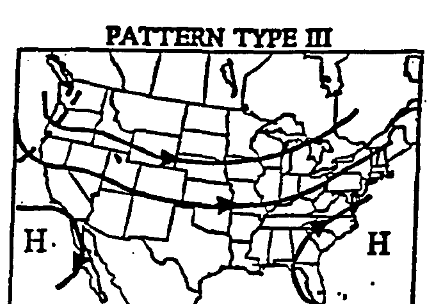

Fig. 3. General 500 mb streamlines for pattern Type III.

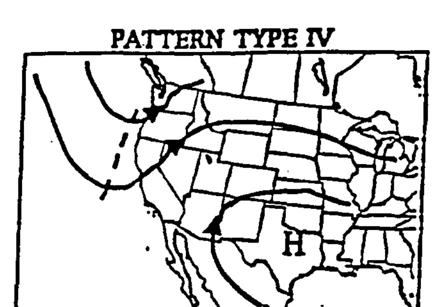

Fig. 4. General 500 mb streamlines for pattern Type IV.

Monsoon Climatological Index (MCI) Forecast Matrix

____

Date

	+4 Explosive	+2 Good	0 Neutral	-2 Poor	-4 Suppressive	Score
800 mb Dew Point Temp (°C)	More Than 12° C	12°C To 7° C	4°C To 7° C	4°C To 0° C	Less Than 0° C	______
600 mb Dew Point Depression (°C)	Less Than 1.5°C	1.5°C To 5°C	5°C To 10°C	10°C To 20°C	More Than 20°C	______
500 mb Temp (°C)	Colder Than -12°C	-12°C To -9° C	-7°C To -9° C	-7°C To -3° C	-3°C Or Warmer	______
Dry Air Cap RH<35% (mb)	Higher Than 300 mb	300 mb To 450 mb	450 mb To 500 mb	500 mb To 650 mb	Lower Than 650 mb	______

Procedures: Score each category and total.

Raw Score - ________

Adjustment Options (If needed) from Table 1

Option 1: 800 Dewpoint Score _____ +2 OR +4 = _____ Adjusted Score
Needed Only if Adjusted Score > Raw Score

Option 2: Raw Score _____ -2 = _____ Final Score

Forecast Scoring

Negative values indicate no thunderstorm activity

+2 = CBs mainly over mountains

+4 = CBs mainly over mtns and higher terrain, 20% chance of rain

+6 = 30% chance for measurable rain in Page, AZ.

+8 = 50% chance for measurable rain in Page, AZ.

+10 = 80% chance for measurable rain in Page, AZ.

By Paul M Ostapuk

Fig. 3a. Monsoon Climatological Index Forecast Matrix

ADJUSTMENT FACTOR PROCEDURES

GOAL: To identify the allobaric pattern and identify those days where an adjustment to the raw MCI value is needed.

INPUT PARAMETERS: 24 hour change in 800 millibar height.
24 hour change in 500 millibar height.
24 hour change in 500 millibar temperature.

	YES	NO	AMOUNT
800 mb heights falling?	______	______	______
500 mb heights falling?	______	______	______
500 mb temperature falling or steady? (increase less than 0.2 degrees C)	______	______	______

If two or more are yes, proceed with **OPTION 1** significance test.

If all three are no, proceed with **OPTION 2** significance test.

****

OPTION 1

Is any height fall > 10 meters YES ______ NO ______

Is 800 mb dew point > 2 deg. C YES ______ NO ______

If both conditions are met, use +4 adjustment factor. If the 500 mb temperature has warmed by 1.0 deg. or more, use +2 adjustment factor. These adjustments are needed only if it produces a value greater than the raw score.

800 Dew point score ____+2 or +4 = ____ adjusted score

****

OPTION 2

Has 500 mb temperature warmed by 2.0 degrees or more? YES ______ NO ______

Are both heights rises greater than 10 meters? YES ______ NO ______

If both are yes, use -2 adjustment factor:

Raw Score ____ - 2 = ______ Final Score

Fig. 3b. Monsoon Climatological Index Adjustment Factors Worksheet