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AN EVALUATION OF COUNTY LEVEL, CLIMATE-BASED TEMPERATURE ADJUSTMENT FACTORS

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1. INTRODUCTION

In October 1993, the National Weather Service went from forecast zones that were groupings of several counties to the current one county/one zone concept. Leffler and McGovern (1995), from here on referred to as L&M, noted that temperature predictions were a key element when grouping the new smaller zones. Therefore, they developed county-level, climate-based temperature adjustments that can be generated at each office to assist the forecasters.

Only an overview of how L&M produced the temperature adjustment will be discussed here. For a more in-depth understanding of their methodology, the reader is directed to the L&M publication. L&M produced a monthly average maximum and minimum temperature for each county by using only cooperative observer data. They did not use any National Weather Service (NWS) or Federal Aviation Administration (FAA) observation locations, to avoid the urban warm bias exhibited at some of these locations. L&M used sites from within the county along with stations in surrounding counties. This increased the sample size, which reduced the effect of each station's unique microclimate. Next, the most representative MOS (Model Output Statistics) control station was chosen (Table 1). The county averages were then subtracted from the monthly averages for that particular MOS site. This difference is then added or subtracted from the MOS forecast to provide a "first guess" guidance estimate for each county.

An evaluation of the MOS Interpolation Program county level-guidance, Young and Rezek (unpublished and undistributed), from here on referred to as MIP, will also be presented. Instead of producing a county average temperature adjustment like L&M, MIP will produce an adjustment factor for any site (generally cooperative observer sites) that have monthly climatological normals. An adjustment factor is also calculated for the probability of precipitation (POP). Each site is paired with one or more MOS control station(s). If more than one MOS station is selected, an office can either allow each MOS station to provide equal influence to the adjustment, or they can allow one of the MOS stations to carry more "weight". This weighting factor might be used if one of the MOS stations is closer to the guidance site geographically or if the none of the MOS stations are in the same climatological region, but one MOS station is more similar than the other. After the sites and their MOS stations (and any weighting factors) are selected, MIP calculates the adjustment similar to L&M.

2. METHODOLOGY

To test each technique in varying climatic regimes, eleven cooperative observer locations were chosen throughout West

Virginia and Southwest Virginia (Fig. 1). One site was selected in each of the old climatic forecast zones for which the NWS office in Charleston prepared zone forecasts. Charlestons' forecast area at the time of the study ranged from the lowlands of West Virginia (zones 2-6), characterized by rolling hills, to the West Virginia mountains (zones 7-9) with elevations more than 4000 feet. The topography in Southwest Virginia (Virginia zones 15 and 16) is a series of mountains separated by elevated valleys.

Each of the county temperature adjustment programs were run real time twice a day between May and August of 1993. A statistical analysis was then done for each site's forecast temperature departure. The primary verification measures were Mean Absolute Error (MAE), Eq. 1, and the arithmetic mean ($\bar{x}$), Eq. 2, and standard deviation ($X_{\delta n}$), Eq. 3.

$$MAE = (\Sigma | T_f - T_o |) / n \qquad (1)$$

$$\bar{x} = \Sigma(T_f - T_o) / n \qquad (2)$$

$$x_{\delta n} = \sqrt{((\Sigma x^2 - ((\Sigma x)^2/n)) / n)} \qquad (3)$$

Where n is the number of forecasts, T_f is the adjusted temperature (in °F), T_o is the observed temperature (°F), and x is the difference between the adjusted and the observed temperatures ($T_f - T_o$).

MAE is an indicator of the true departure of the forecast from the observed maximum or minimum temperature. Its draw back, however, is that one does not know whether the forecasts are consistently above or below the observed temperature. The arithmetic mean, provides forecast bias. However, for the arithmetic mean, a departure of +10 °F can cancel a departure of -10 °F to give a mean of zero. Therefore, the standard deviation must also be used to examine the spread of the data. A value greater than zero shows a forecast warmer than the observed temperature, while a negative mean suggests a forecast cooler than observed. A percent improvement over MOS was also calculated by comparing the MAE of MOS and the particular technique from Eq. 4.

$$IMP\ MOS = ((MAE_m - MAE_g)/MAE_m) * 100 \qquad (4)$$

Where IMP MOS is the percent improvement over MOS, MAE_m is the MAE for MOS and MAE_g is the MAE for the particular supplemental guidance.

The data were analyzed in two different ways. First, an analysis was produced for each 12-hour forecast period out through 60 hours. The first period is the period between 12 and 24 hours from the beginning of the model run, with the second period running from 24 to 36 hours, etc. This analysis was conducted to test if the skill of the technique differed with time. Secondly, for the first period only, both forecast techniques were analyzed for differing amounts of cloud cover.

3. RESULTS

a. General Performance

0000 UTC Cycle

Since both of the supplemental guidance programs were tested in varying climatic regimes, it was decided that verification would be calculated on both overall performance and how the guidance did throughout the test region. For the 0000 UTC cycle, L&M county guidance produced guidance 8.8% better than MOS (3.1 °F MAE to 3.4 °F). Although L&M produced the same MAE for both maximum and minimum temperatures (from here on referred to as maxs and mins), a greater improvement over MOS was obtained on the maxs, 11.4% to 8.8%. The MAE for the MOS maxs ranged from 2.1 °F to 5.8 °F, while L&M's guidance had MAE's ranging from 2.1 °F to 6.7 °F (Table 2). At eight of the 11 test locations, L&M maximum temperature guidance did better than MOS, at two locations MOS was better, leaving one location where the performance was the same. The improvement over MOS for L&M ranged from a negative 148.1% at Burkes Garden to a positive 165.7% at Pineville.

Both Burkes Garden and Pineville are unique and therefore provided different tests. Burkes Garden is in an elevated valley in Tazewell County Virginia, which is surrounded by mountains on all sides. Under certain conditions its temperatures vary greatly from other locations in the county. Therefore L&M's guidance, which was for Tazewell County as a whole, did not forecast this microclimate very well. As a comparison MIP, which forecasted for Burkes Garden only, improved over the MOS forecasts by 37%.

Pineville (elevation 1,280 ft.), which is in the Southwest Coal Field of West Virginia, is located in a different climatic regime than Beckley (elevation 2,504 ft.) the MOS control site. Beckley, which is located in the Southern Mountains and is more than 1,000 feet higher, routinely has much colder maximum temperatures than Pineville, but has similar minimum temperatures. Therefore the Beckley MOS routinely under predicted the maximum temperatures, giving the Wyoming County guidance an unreasonably high improvement over MOS. Forecasters in Charleston would not use the Beckley MOS to forecast a high temperature in the Coal Fields. If these two unique locations are removed, L&M's guidance improves to around 12%.

L&M 0000 UTC minimum temperature guidance had higher Mean Absolute Errors than the maximum temperature guidance. At only five of the 11 locations did L&M mins produce lower MAE than MOS (at four locations MOS had a lower MAE and at two locations the MAE was the same). Although the range of the MAE was smaller for L&M (2.7 °F to 3.8 °F versus 1.7 °F to 5.3 °F for MOS), L&M was as much as 64% less accurate than MOS.

The L&M guidance was similar in both the West Virginia mountains and lowlands (Figure 2). The MAE in both areas was 2.5 °F for maxs and 3.1 °F for mins. In Southwest Virginia, the MAE for maxs were 2.4 °F and 3.3 °F for mins. Compare these numbers to the MOS guidance which produced a MAE of 4.0 °F for maxs in the lowlands and 3.0 °F in the mountains. Thus, L&M showed a 37.5% improvement in the lowlands compared with 16.6% in the mountains. The same pattern occurred for the minimum temperature guidance, as MOS produced a MAE of 3.2 °F in the lowlands and 2.8 °F in the mountains, therefore the percent improvement for L&M was 3.1% in the lowlands, but -10.7% in the mountains.

L&M tried to design their guidance to remove the urban heat island affect, yet at seven of the 10 locations, the mean was a positive 0.5 °F or greater, with two locations having a mean of less than zero. Maximum temperatures were warmer than mins, with an arithmetic mean of +1.2 °F versus +0.9 °F . This shows that L&M's guidance produced a forecast that was routinely too warm.

MIP meanwhile produced a MAE of 2.2 °F for maxs (37.1% improvement over MOS), but ballooned to 3.5 °F for mins, resulting in guidance that did 2.9% worse than MOS. MIP provided better guidance in the mountains versus the lowlands for both maxs and mins, with an average MAE of 2.1 °F versus 2.6 °F and 3.2 °F versus 3.6 °F respectively. In the two southwest Virginia locations, the MAE for maxs was 1.7 °F (50% improvement over MOS) and 3.6 °F for mins (28% improvement).

While MIP was better at 10 of the 11 test locations for the maximum temperature guidance, it only provided better guidance for mins at four sites (MOS was better at six sites). MIP's mean was very close to zero for the mountains and Southwest Virginia locations for both the maxs and mins, with only Oak Hill having a mean (for its' maximum) greater than one. In the lowlands, however, MIP produced a strong warm bias in both maxs and mins, since all locations had a mean of +0.7 °F with a high of +3.3 °F at Spencer.

Both guidance techniques were analyzed for the four different forecast periods (Table 4). The MOS guidance was similar with a MAE of 3.5 °F for the first three periods, and then 3.4 °F for the fourth. L&M was most efficient in the first period with a MAE of 2.9 °F. For the other three periods the guidance produced about the same results with a MAE of 3.1 °F, 3.2 °F and 3.1 °F respectively. MIP meanwhile showed no additional skill in the early periods versus the later periods, as the average MAE was 2.4 °F in the first period and 2.3 °F in the third (max temperature guidance) and 3.4 °F in both the second and fourth (min temperatures).

1200 UTC Cycle

Overall, results of the 1200 UTC cycle (Table 3) were very similar to 0000 UTC with the L&M guidance producing a MAE of 3.1 °F. Improvement over MOS increased to 12.5% (15.1% if Pineville and Burkes Garden data are used), as both the maximum and minimum temperature guidance posted a higher skill compared with 0000 UTC. L&M guidance produced a MAE for max temperatures of 3.1 °F and 3.2 °F for mins. With MOS producing a MAE of 3.6 °F for maxs and 3.7 °F for mins, L&M showed a 14.3% and 10.8% improvement respectively (if Pineville and Burkes Garden are removed, the MAE for maximum guidance from L&M fell to 3.0 °F while minimum temperatures were the same).

Across the region, the MAE or maximum temperature guidance ranged from 2.3 °F to 6.9 °F for L&M while for MOS it varied from 2.4 °F to 5.5 °F. Although the percent improvement increased, L&M guidance was not as dominant, only outperforming MOS at six of the nine remaining locations. The MAE for minimum temperature guidance for MOS ranged from 2.7 °F to 5.4 °F while L&M showed a smaller range of 2.6 °F to 4.2 °F. L&M outperformed MOS seven of the 11 locations for both max and mins, but MOS managed to do better at four locations for maximum temperatures and three for minimum.

Although the MAE for maximum temperatures was 2.7 °F (2.8 °F in Southwest Virginia) in both the lowlands and mountains, once again a larger percent improvement occurred in the lowlands (34.1% vs. 3.6%) because MOS was more accurate in the mountains. The percent improvement for the one remaining Southwest Virginia location was 37.8%. The pattern repeated again with the 1200 UTC mins as a L&M had a MAE of 3.1 ^{o}F all regimes, but with improvement higher in the lowlands (11.4% in the lowlands compared to zero improvement in the mountains and 39.2% in Southwest Virginia). L&M guidance for 1200 UTC produced a warm bias, as the arithmetic mean for maximum temperatures was 0.9 ^{o}F, but was 0.3 ^{o}F for minimums.

Although the 1200 UTC MIP guidance produced the same overall MAE of 2.8 ^{o}F, for maxs it rose to 3.0 ^{o}F and for mins it decreased to 2.7 ^{o}F. When compared to MOS, MIP performed well, showing a 16.6% improvement on max temperatures and 27.0% for mins. MIP produced better maximum temperature guidance at eight of eleven sites and better minimum temperature guidance at ten of the eleven sites.

The 1200 UTC guidance did not produce a substantially lower MAE in any one period (Table 5). While L&M had the same MAE through the first three periods, MIP had similar a MAE for maxs and mins, independent of time.

b. First Period Performance

An additional analysis was done using first period data to see how supplemental guidance performed under varying cloud cover. Due to the small number of forecasts with a forecasted cloud cover, this analysis combined both the 0000 UTC and 1200 UTC data. The forecast cloud cover was broken down into four categories: clear (0-1 tenths coverage); scattered (2-5 tenths); broken (6-8 tenths) and overcast (9-10 tenths).

The statistical data base for clear skies was very small, between five and 10 occurrences, so any analysis of that data must be taken very cautiously. Overall, MOS showed the anticipated pattern, with a MAE of 4.6 ^{o}F for clear skies, dropping to 3.2 ^{o}F MAE for overcast skies (Table 6). Southwest Virginia also showed increasing skill as the cloud cover increased, dropping from 6.9 ^{o}F for clear skies to 3.2 ^{o}F for cloudy skies. In the West Virginia lowlands a similar pattern was followed, as the MAE starts at 4.5 ^{o}F for clear skies then falls to 3.2 ^{o}F degrees for broken skies, until it responds a little to 3.5 ^{o}F under overcast conditions. In the mountains however, the MAE for scattered skies (2.9 ^{o}F) was similar to overcast skies (2.7 ^{o}F), while broken skies (3.2 ^{o}F) showed only better verification than clear skies (3.7 ^{o}F).

L&M and the MIP guidance produced the same pattern both overall, and in each geographical break down. Verification under scattered skies was similar if not better than under broken or overcast skies, while for clear skies it lagged well behind. For example, the MAE under scattered conditions was 2.7 ^{o}F degrees, while for broken and overcast skies the MAE was 3.1 ^{o}F for both. A MAE of 3.7 ^{o}F degrees was calculated for the few clear skies cases. Overall verification for MIP had a MAE of 2.4 ^{o}F under scattered skies, 2.7 ^{o}F for broken skies and 2.5 ^{o}F under cloudy skies. The MAE for MIP under clear skies was 3.7 ^{o}F.

4. SUMMARY

Overall both L&M and MIP provided valuable information for the forecasters to use when preparing forecasts for the county level zones. Improvement over the nearest MOS location averaged between five and 10%, with some locations showing more improvement, while for a couple of locations, MOS out performed the county level guidance. The verification scores for the L&M guidance were similar in differing geographic regions, while MIP performed better in the mountains of West Virginia and Southwest Virginia than in the lowlands.

Although L&M county guidance did better in the first period of the forecast, with increasing MAE in the third and fourth periods on the 0000 UTC cycle, this pattern did not repeat when the 1200 UTC data was analyzed. The MIP had a similar MAE for both maxs and mins, as the first and third periods were similar, while the scores for the second and fourth were comparable. Neither guidance showed a pattern of proficiency under differing cloud covers. Both techniques were the similar under scattered, broken and overcast skies. Generally MAE's under clear skies were higher, but the statistical data base was not high enough to provide confidence in the results.

Great care must be taken when choosing the control MOS station for either technique, or even the cooperative observer stations used in calculating the county averages. Although the control station does not have to be in the same climatic regime as the county, an inappropriate control station can end up providing poor guidance to the forecaster. The same effect can occur if a cooperative observer station is added (or omitted) from a surrounding county. The average temperatures for the affected county will be in error, and therefore so will be the forecast.

A survey of the forecasters at Charleston West Virginia, revealed that the supplemental temperature adjustment information was used occasionally, with the usage split between grouping counties into a forecast zone and producing an actual forecast temperature. It is the author's opinion that both techniques would be the most helpful to newer forecasters who are not acquainted with the old climatological zones, as they provide guidance for grouping of the county zones. Although the climatological zones are a useful reference, these techniques also provide a starting point for the forecast. The more experienced forecasters will also find the supplemental guidance helpful in the fine tuning of the temperature forecasts.

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Table 1. MOS control and cooperative observer sites and their elevations for locations used in this study.

MOS Control Stations

Station	Abbreviation	Elevation (ft.)
Beckley, WV WSO AP	BKW	2,504
Bluefield, WV FAA AP	BLF	2,870
Bristol, TN WSO AP	TRI	1,525
Charleston, WV WSFO AP	CRW	1,015
Elkins, WV WSO AP	EKN	1,992
Huntington, WV WSO AP	HTS	827
Morgantown, WV FAA AP	MGW	1,240
Parkersburg, WV FAA AP	PKB	831
Roanoke, VA WSO AP	ROA	1,140

Cooperative Observer Stations

Station	County	Abbreviation	Elevation (ft.)	L&M Control Station	MIP Control Station(s)
Burkes Garden	Tazewell, VA	BURV2	3,300	BLF	50% BKW/50% TRI
Creston	Wirt, VA	CREW2	650	PKB	67% PKB/33% CRW
Lewisburg FAA AP	Greenbrier, WV	LWB	2,287	BLF	50% BKW/50% ROA
Oak Hill	Fayette, WV	OAKW2	2,330	BKW	BKW
Parsons 1 SE	Tucker, WV	PSNW2	1,680	EKN	EKN
Pineville	Wyoming, WV	PINW2	1,280	BKW	67% BKW/33% CRW
Pulaski 2 E	Pulaski, VA	PSKV2	1,850	ROA	ROA
Ripley 4 NNE	Jackson, WV	RIPW2	610	PKB	50% CRW/50% PKB
Spencer 1 SE	Roane, WV	SPEW2	740	CRW	50% CRW/50% PKB
Webster Springs 1 E	Webster, WV	WEBW2	1,540	EKN	EKN
Weston	Lewis, WV	WTNW2	925	MGW	67% MGW/33% PKB

Table 2. Overall verification of both Leffler and McGovern (L&M) and Young and Rezek (MIP) techniques for the 0000 UTC cycle, based on arithmetic mean ($\bar{x}$), Mean Absolute Error (MAE) and Percent Improvement over MOS (IMP MOS). Values for $\bar{x}$ and MAE are in ^{o}F, while IMP MOS is in percent.

		MOS			L&M				MIP			
		n	$\bar{x}$	MAE	n	$\bar{x}$	MAE	IMP MOS	n	$\bar{x}$	MAE	IMP MOS
Creston	maximum	141	3.6	3.8	132	2.4	3.0	21.1%	49	2.5	2.7	28.9%
	minimum	136	-3.2	4.0	132	0.9	3.4	15.0%	49	1.2	3.7	7.5%
	all	277	0.2	3.9	264	1.7	3.2	17.9%	98	1.8	3.2	17.9%
Ripley	maximum	119	0.9	2.1	124	-1.0	2.1	0.%	45	-0.8	1.9	9.5%
	minimum	129	-0.3	2.4	127	1.6	2.9	-20.8%	44	3.3	3.7	-54.2%
	all	248	0.2	2.3	251	0.3	2.5	-8.6%	89	1.2	2.8	-21.7%
Spencer	maximum	72	2.3	2.9	76	2.5	3.1	-6.9%	41	3.3	3.4	-14.7%
	minimum	78	-2.4	3.4	85	1.0	2.8	17.6%	47	1.9	3.6	-5.9%
	all	150	-0.2	3.2	161	1.7	2.9	9.3%	88	2.5	3.5	-9.4%
Weston	maximum	124	3.9	4.6	125	2.8	3.9	15.2%	47	2.2	3.0	34.8%
	minimum	124	-0.7	3.0	127	2.0	3.3	-10.0%	52	3.0	4.1	-26.8%
	all	248	1.6	3.8	252	2.4	3.6	5.3%	102	2.6	3.5	7.9%
Pineville	maximum	127	5.6	5.8	130	0.8	2.3	165.7%	58	0.7	2.0	65.5%
	minimum	128	-1.4	3.0	131	1.9	3.0	0.%	55	0.7	3.0	0.%
	all	255	3.5	4.4	261	0.7	2.7	38.6%	113	0.7	2.5	43.2%
Oak Hill	maximum	123	2.4	2.9	122	1.4	2.3	20.7%	47	-1.5	2.1	27.6%
	minimum	125	-0.7	1.7	126	1.7	2.8	-64.7%	48	0.7	3.0	-76.5%
	all	248	0.9	2.3	248	1.5	2.6	-13.0%	95	-0.4	2.6	-13.0%
Lewisburg	maximum	116	2.9	3.6	122	1.5	2.7	25.0%	59	-0.1	2.2	38.9%
	minimum	114	-1.9	3.4	120	-2.8	3.8	-11.8%	59	-0.3	3.5	-2.9%
	all	230	0.5	3.5	242	-0.6	3.3	5.7%	118	-0.2	2.9	17.1%
Parsons	maximum	94	0.9	2.3	101	0.9	2.2	4.3%	34	0.1	1.5	34.8%
	minimum	96	2.1	3.4	102	1.4	2.9	14.7%	34	-0.3	2.8	17.6%
	all	190	1.5	2.8	203	1.1	2.6	7.1%	68	-0.1	2.1	25.0%
Webster	maximum	84	1.5	3.1	93	1.4	2.9	6.4%	37	-0.3	2.3	25.8%
Springs	minimum	85	1.1	2.7	91	1.1	2.7	0.%	37	0.4	3.1	-14.8%
	all	169	1.3	2.9	184	1.3	2.8	3.4%	74	0.0	2.7	6.9%
Pulaski	maximum	127	-3.4	4.0	132	0.1	2.4	40.0%	53	-1.3	1.8	55.0%
	minimum	128	-4.1	4.7	132	1.3	3.4	27.7%	51	0.5	3.7	21.3%
	all	255	-3.7	4.3	264	0.7	2.9	32.6%	104	-0.4	2.7	37.2%
Burkes	maximum	116	-2.0	2.7	120	-6.5	6.7	-148.1%	54	-0.1	1.7	37.0%
Garden	minimum	113	-4.5	5.3	118	-0.1	3.2	39.6%	54	0.3	3.5	34.0%
	all	229	-3.2	4.0	238	-3.3	-5.0	-25.0%	108	0.1	2.6	35.0%
Overall	maximum	1243	-1.7	3.5	1277	-0.5	3.1	11.4%	524	-0.4	2.2	37.1%
	minimum	1256	1.3	3.4	1291	-0.9	3.1	8.8%	530	-1.0	3.5	-2.9%
	all	2499	-0.2	3.4	2568	-0.7	3.1	8.8%	1054	-0.7	2.8	17.6%

Table 3. Same as Table 2, except for the 1200 UTC cycle.

		MOS			L&M				MIP			
		n	$\bar{x}$	MAE	n	$\bar{x}$	MAE	IMP MOS	n	$\bar{x}$	MAE	IMP MOS
Creston	maximum	124	3.4	4.2	126	1.7	3.4	19.0%	71	3.6	4.0	4.8%
	minimum	121	-3.7	4.3	130	0.6	3.4	20.9%	72	1.2	3.2	25.6%
	all	245	-0.1	4.3	256	1.2	3.4	20.9%	143	2.4	3.6	16.3%
Ripley	maximum	126	0.3	2.4	126	-0.6	2.5	-4.2%	71	-1.2	2.4	0.%
	minimum	130	-0.9	2.8	132	1.2	2.8	0.%	73	2.0	3.1	-10.7%
	all	256	-0.3	2.6	258	-0.1	2.7	-3.8%	144	0.4	2.7	-3.8%
Spencer	maximum	108	1.4	3.2	95	1.9	3.4	-6.3%	72	-3.6	3.6	-12.5%
	minimum	108	-3.4	3.9	104	0.2	2.6	33.3%	73	1.8	3.2	17.9%
	all	216	-1.0	3.6	199	1.0	3.0	16.7%	145	2.2	3.4	5.5%
Weston	maximum	144	3.1	4.7	143	2.7	4.2	10.6%	78	2.0	3.3	29.8%
	minimum	143	-0.9	3.6	143	1.9	3.7	-2.8%	81	2.1	3.1	13.9%
	all	287	1.6	3.8	252	2.4	3.6	5.3%	102	2.6	3.5	7.9%
Pineville	maximum	146	4.9	5.5	136	0.2	2.3	58.2%	82	0.0	2.6	52.7%
	minimum	147	1.8	3.2	143	-2.0	3.1	3.1%	82	1.3	2.6	18.8%
	all	293	3.3	4.4	279	1.2	2.7	38.6%	164	0.6	2.6	40.9%
Oak Hill	maximum	128	2.1	2.9	134	1.1	2.5	13.8%	76	-1.0	2.6	10.3%
	minimum	128	-0.6	2.7	134	1.9	3.0	-11.1%	74	0.5	2.2	18.6%
	all	256	0.8	2.8	268	1.5	2.7	3.6%	150	-0.3	2.4	14.3%
Lewisburg	maximum	142	-2.3	3.3	143	0.8	2.8	15.1%	78	0.0	3.0	9.1%
	minimum	141	-1.8	3.8	139	-3.3	4.2	-10.5%	77	0.0	2.5	34.2%
	all	283	0.3	3.5	282	-1.2	32.5	0.%	155	0.0	2.7	22.9%
Parsons	maximum	104	.0	2.8	108	-0.7	2.6	7.1%	56	-0.3	2.3	17.9%
	minimum	100	2.1	3.2	106	1.3	2.7	15.7%	34	0.2	2.3	28.1%
	all	204	1.5	3.0	214	1.0	2.6	13.3%	110	0.0	2.3	23.3%
Webster Springs	maximum	103	1.1	2.1	101	0.7	2.8	-33.3%	55	-1.0	3.2	-52.4%
	minimum	98	1.5	3.0	97	1.3	2.8	6.7%	53	-0.4	2.0	33.3%
	all	202	1.3	2.5	198	-1.0	2.8	-12.0%	108	-0.7	2.6	4.0%
Pulaski	maximum	136	-4.1	4.5	139	-0.3	2.8	37.8%	73	-0.7	2.9	35.6%
	minimum	137	-4.3	4.9	138	1.1	3.0	38.8%	72	0.9	2.9	40.8%
	all	273	-4.2	4.7	277	0.4	2.9	38.3%	145	0.1	2.9	38.3%
Burkes Garden	maximum	136	-2.4	3.3	135	-3.5	6.9	-109.1%	78	-0.3	2.6	21.2%
	minimum	131	-4.4	5.4	130	-0.3	3.2	40.7%	79	0.0	2.1	61.1%
	all	267	-3.4	4.3	265	-1.9	5.1	-18.6%	157	-0.2	2.3	46.5%
Overall	maximum	1397	-1.2	3.6	1386	0.4	3.1	13.9%	790	-0.4	3.0	16.6%
	minimum	1384	1.4	3.7	1396	-0.6	3.2	13.5%	771	0.9	2.7	27.0%
	all	2781	0.1	3.7	2782	-0.1	3.1	15.1%	1561	0.3	2.8	22.7%

Table 4. Verification of Leffler and McGovern (L&M) and Young and Rezek (MIP) for the 0000 UTC model cycle, based on arithmetic mean ($\bar{x}$), standard deviation ($x_{\sigma n}$), Mean Absolute Error (MAE) and Percent Improvement over MOS (IMP MOS), stratified by forecast period. Maximum temperature forecasts are in bold. Values for $\bar{x}$ and MAE are in °F, while IMP MOS is in percent.

		MOS				L&M					MIP				
		n	$\bar{x}$	$x_{\sigma n}$	MAE	n	$\bar{x}$	$x_{\sigma n}$	MAE	IMP MOS	n	$\bar{x}$	$x_{\sigma n}$	MAE	IMP MOS
Creston	**1st Period**	**69**	**3.8**	**2.59**	**3.8**	**65**	**2.6**	**2.74**	**3.0**	**21.1%**	**21**	**2.7**	**2.62**	**2.8**	**26.3%**
	2nd Period	66	-3.1	4.58	4.2	65	0.9	4.72	3.7	11.9%	21	1.3	5.17	4.0	4.8%
	3rd Period	**72**	**3.4**	**3.26**	**3.7**	**67**	**2.2**	**3.51**	**3.0**	**18.9%**	**28**	**2.4**	**2.88**	**2.6**	**29.7%**
	4th Period	70	-3.4	3.51	3.8	67	1.0	3.90	3.0	21.1%	28	1.1	4.30	3.5	7.9%
Ripley	**1st Period**	**54**	**1.6**	**2.06**	**1.6**	**60**	**-0.3**	**2.11**	**1.7**	**-6.3%**	**22**	**-0.2**	**2.42**	**2.0**	**-25.0%**
	2nd Period	63	0.0	3.16	2.4	63	1.7	3.79	3.2	-33.3%	22	3.9	2.80	4.1	-70.8%
	3rd Period	**65**	**0.3**	**2.88**	**2.2**	**64**	**-1.8**	**3.85**	**2.6**	**78.2%**	**23**	**-1.4**	**1.81**	**1.9**	**13.6%**
	4th Period	66	-0.7	3.23	2.5	64	1.5	3.07	2.7	-8.0%	22	2.7	2.69	3.2	-28.0%
Spencer	**1st Period**	**36**	**2.3**	**2.55**	**2.7**	**38**	**2.5**	**2.71**	**2.9**	**-7.4%**	**19**	**3.6**	**2.50**	**3.6**	**-33.3%**
	2nd Period	40	-2.8	3.27	3.6	43	1.1	3.02	2.6	27.7%	23	2.4	3.65	3.7	-2.7%
	3rd Period	**36**	**2.3**	**3.21**	**3.1**	**38**	**2.4**	**3.48**	**3.2**	**-3.2%**	**22**	**3.0**	**2.78**	**3.2**	**-3.2%**
	4th Period	38	-2.0	3.49	3.2	42	0.9	3.43	3.0	6.3%	24	1.3	3.99	3.5	-9.4%
Weston	**1st Period**	**63**	**3.9**	**3.33**	**4.5**	**63**	**2.7**	**3.34**	**3.7**	**17.8%**	**22**	**2.6**	**2.67**	**2.9**	**35.6%**
	2nd Period	63	-0.6	3.78	3.1	65	1.9	3.27	3.2	-3.2%	25	2.9	3.87	4.1	-32.3%
	3rd Period	**61**	**4.0**	**4.19**	**4.7**	**62**	**2.9**	**4.19**	**4.1**	**12.8%**	**25**	**1.9**	**3.33**	**3.0**	**36.1%**
	4th Period	61	-0.8	3.71	3.0	62	2.2	3.73	3.3	-10.0%	27	3.1	4.30	4.1	-36.7%
Pineville	**1st Period**	**64**	**6.0**	**2.49**	**6.0**	**65**	**1.0**	**2.53**	**1.7**	**58.8%**	**28**	**0.9**	**2.61**	**1.8**	**7.0%**
	2nd Period	65	1.4	3.54	3.0	65	1.9	3.22	3.0	0.%	26	0.7	3.66	3.1	-3.3%
	3rd Period	**63**	**5.2**	**3.61**	**5.7**	**65**	**0.6**	**3.51**	**2.5**	**56.1%**	**30**	**0.6**	**3.13**	**2.2**	**61.4%**
	4th Period	63	1.4	3.54	3.0	66	2.0	3.23	3.0	0.%	29	0.7	3.62	3.0	0.%
Oak Hill	**1st Period**	**62**	**2.6**	**2.55**	**3.0**	**62**	**1.6**	**2.55**	**2.4**	**20.0%**	**24**	**-0.7**	**2.51**	**1.9**	**36.7%**
	2nd Period	63	-0.7	2.95	2.4	64	1.8	2.88	2.8	-16.7%	25	0.6	4.04	3.2	-33.3%
	3rd Period	**61**	**2.2**	**3.11**	**2.9**	**60**	**1.1**	**2.92**	**2.3**	**20.7%**	**23**	**-2.4**	**1.93**	**2.4**	**17.2%**
	4th Period	62	-0.6	3.18	2.6	62	1.6	3.00	2.8	-7.7%	23	0.7	3.35	2.8	-7.7%
Lewisburg	**1st Period**	**58**	**3.0**	**3.10**	**3.7**	**61**	**1.8**	**2.61**	**2.8**	**24.3%**	**27**	**0.0**	**2.97**	**2.2**	**40.5%**
	2nd Period	57	-1.8	4.30	3.7	59	-2.7	4.03	3.9	-5.4%	29	0.0	4.83	3.6	2.7%
	3rd Period	**58**	**2.8**	**3.08**	**3.4**	**61**	**1.3**	**3.14**	**2.7**	**3.4%**	**32**	**-0.2**	**2.98**	**2.2**	**35.3%**
	4th Period	57	-2.1	3.89	3.2	61	-3.0	4.12	3.7	-15.6%	30	-0.5	4.38	3.4	-6.3%
Parsons	**1st Period**	**47**	**0.9**	**2.84**	**2.2**	**51**	**0.8**	**2.75**	**2.0**	**9.1%**	**18**	**0.6**	**1.34**	**1.1**	**50.0%**
	2nd Period	47	2.7	3.07	2.7	51	1.7	2.99	2.8	3.7%	17	0.9	3.39	2.5	7.4%
	3rd Period	**47**	**0.9**	**3.13**	**2.4**	**50**	**0.9**	**3.11**	**2.4**	**0.%**	**16**	**-0.5**	**2.92**	**2.0**	**16.7%**
	4th Period	49	1.6	3.71	3.4	51	0.8	3.67	3.1	8.8%	17	-1.5	4.13	3.1	8.8%
Webster Springs	**1st Period**	**42**	**1.8**	**3.46**	**3.0**	**47**	**1.6**	**3.30**	**2.7**	**37.0%**	**17**	**0.3**	**2.56**	**2.2**	**26.7%**
	2nd Period	42	1.3	3.27	2.6	45	1.2	3.29	2.7	-3.8%	17	1.4	3.88	3.1	-19.2%
	3rd Period	**42**	**1.3**	**4.22**	**3.2**	**46**	**1.2**	**4.08**	**3.1**	**3.1%**	**20**	**-0.9**	**3.00**	**2.5**	**21.9%**
	4th Period	43	1.0	3.11	2.7	46	1.0	3.10	2.6	3.7%	20	-0.5	3.73	3.1	-14.8%
Pulaski	**1st Period**	**62**	**-3.6**	**3.17**	**4.0**	**65**	**-0.1**	**3.17**	**2.4**	**40.0%**	**25**	**-1.5**	**3.25**	**1.5**	**62.5%**
	2nd Period	64	-4.0	3.96	4.6	66	1.1	3.61	3.0	34.8%	24	-0.2	4.32	3.5	23.9%
	3rd Period	**65**	**-3.2**	**3.51**	**4.0**	**67**	**0.3**	**3.61**	**2.5**	**37.5%**	**28**	**-1.1**	**2.70**	**2.1**	**47.5%**
	4th Period	64	-4.1	4.46	4.8	66	1.5	4.40	3.8	20.8%	27	1.1	4.29	3.8	20.8%
Burkes Garden	**1st Period**	**57**	**-1.7**	**2.35**	**2.4**	**59**	**-6.2**	**2.84**	**6.4**	**-166.7%**	**26**	**0.0**	**2.03**	**1.7**	**29.2%**
	2nd Period	55	-4.5	4.27	5.3	58	0.7	3.85	3.0	43.4%	25	-0.2	4.34	3.5	34.0%
	3rd Period	**59**	**-2.2**	**3.02**	**3.0**	**61**	**-6.8**	**3.36**	**7.0**	**-133.3%**	**28**	**-0.3**	**2.26**	**1.7**	**43.3%**
	4th Period	58	-4.4	4.64	5.4	60	-0.3	4.35	3.5	35.2%	29	0.8	4.36	3.6	33.3%

Table 5. Same as Table 4, except for the 1200 UTC model cycle.

		MOS				L&M					MIP				
		n	$\bar{x}$	$x_{\sigma n}$	MAE	n	$\bar{x}$	$x_{\sigma n}$	MAE	IMP MOS	n	$\bar{x}$	$x_{\sigma n}$	MAE	IMP MOS
Creston	1st Period	61	-3.2	4.37	4.1	64	0.8	4.40	3.5	14.6%	36	1.1	3.64	3.1	24.3%
	2nd Period	**62**	**3.3**	**3.33**	**3.8**	**65**	**2.0**	**3.44**	**3.1**	**18.4%**	**35**	**3.9**	**3.23**	**4.1**	**-7.9%**
	3rd Period	60	-4.2	3.99	4.5	66	0.4	4.28	3.3	26.7%	36	1.3	3.95	3.3	26.7%
	4th Period	**62**	**3.6**	**4.08**	**4.6**	**61**	**1.4**	**4.34**	**3.7**	**19.6%**	**36**	**3.3**	**3.40**	**4.0**	**13.0%**
Ripley	1st Period	65	-0.6	3.57	2.6	66	1.5	3.38	2.9	-11.5%	37	1.9	3.29	3.1	-19.2%
	2nd Period	**63**	**0.4**	**2.90**	**2.2**	**63**	**-0.8**	**3.00**	**2.3**	**-4.5%**	**33**	**-0.9**	**3.13**	**2.2**	**0.%**
	3rd Period	65	-1.1	3.61	3.0	66	0.8	3.50	2.7	18.0%	36	2.0	3.10	3.0	0.%
	4th Period	**63**	**0.2**	**3.16**	**2.5**	**63**	**-1.1**	**3.34**	**2.6**	**-4.0%**	**38**	**-1.3**	**2.90**	**2.5**	**0.%**
Spencer	1st Period	53	-3.6	2.92	3.9	54	-0.1	2.98	2.3	41.0%	39	2.2	3.26	3.0	23.1%
	2nd Period	**52**	**1.6**	**3.35**	**3.0**	**46**	**1.8**	**3.65**	**3.2**	**-6.7%**	**35**	**3.3**	**3.43**	**4.0**	**-33.3%**
	3rd Period	55	-3.2	3.54	3.9	50	0.6	3.51	2.9	25.6%	34	1.4	3.80	3.4	12.8%
	4th Period	**56**	**1.1**	**4.13**	**3.4**	**49**	**1.9**	**4.04**	**3.6**	**-5.9%**	**37**	**2.0**	**3.50**	**3.3**	**2.9%**
Weston	1st Period	72	-0.6	4.62	3.5	70	2.4	4.24	4.0	-14.3%	42	2.3	3.89	3.6	-2.9%
	2nd Period	**71**	**3.0**	**4.62**	**4.6**	**71**	**2.4**	**4.18**	**3.9**	**15.2%**	**38**	**2.2**	**3.64**	**3.3**	**28.3%**
	3rd Period	71	-1.3	4.63	3.9	73	1.5	4.16	2.9	25.6%	39	1.9	2.71	2.5	35.9%
	4th Period	**73**	**3.3**	**4.72**	**4.9**	**72**	**2.9**	**4.50**	**4.5**	**8.1%**	**40**	**1.9**	**3.87**	**3.4**	**30.6%**
Pineville	1st Period	74	1.6	3.38	2.9	72	1.9	2.93	2.9	0.%	43	1.1	3.16	2.7	2.7%
	2nd Period	**72**	**4.7**	**3.27**	**5.2**	**72**	**0.2**	**2.79**	**1.9**	**63.5%**	**40**	**0.3**	**3.56**	**2.4**	**53.8%**
	3rd Period	73	2.0	4.00	3.6	71	2.1	3.28	3.2	11.1%	39	1.6	2.48	2.5	30.6%
	4th Period	**74**	**5.0**	**4.28**	**5.9**	**64**	**0.3**	**4.06**	**2.9**	**50.8%**	**42**	**-0.4**	**3.75**	**2.7**	**54.2%**
Oak Hill	1st Period	64	-0.8	3.03	3.0	67	1.7	2.88	2.7	3.3%	37	0.1	2.80	2.0	33.3%
	2nd Period	**63**	**1.9**	**3.15**	**2.7**	**66**	**1.0**	**3.08**	**2.3**	**14.8%**	**36**	**-2.5**	**1.96**	**2.5**	**7.4%**
	3rd Period	64	-0.3	3.06	2.3	67	2.2	2.89	3.1	-34.5%	37	0.9	2.87	2.5	-8.7%
	4th Period	**65**	**2.2**	**3.19**	**2.3**	**68**	**1.2**	**3.20**	**2.7**	**12.9%**	**40**	**0.1**	**3.35**	**2.0**	**35.5%**
Lewisburg	1st Period	67	-2.0	4.96	4.1	69	-3.7	4.44	4.5	-9.8%	41	-0.1	3.32	2.6	36.6%
	2nd Period	**70**	**2.2**	**3.21**	**3.1**	**71**	**0.8**	**3.49**	**2.5**	**19.4%**	**37**	**-0.2**	**4.13**	**3.0**	**3.2%**
	3rd Period	74	-1.6	4.40	3.6	70	2.9	4.24	4.0	-11.1%	36	0.2	3.04	2.4	33.3%
	4th Period	**72**	**2.5**	**3.40**	**3.5**	**72**	**0.8**	**3.78**	**3.1**	**11.4%**	**41**	**0.2**	**3.70**	**3.0**	**14.3%**
Parsons	1st Period	51	2.5	2.91	3.1	54	1.5	2.83	2.5	19.4%	26	0.3	2.57	2.1	32.2%
	2nd Period	**51**	**0.6**	**2.90**	**2.3**	**53**	**0.3**	**3.02**	**2.2**	**4.3%**	**28**	**-0.5**	**2.93**	**2.4**	**-4.3%**
	3rd Period	49	1.8	3.51	3.3	52	1.0	3.38	2.9	12.1%	28	0.1	3.58	2.4	27.3%
	4th Period	**53**	**1.3**	**4.01**	**3.3**	**55**	**-.0**	**3.44**	**2.9**	**12.1%**	**27**	**0.0**	**2.88**	**2.3**	**30.3%**
Webster Springs	1st Period	47	1.6	3.43	2.8	45	1.7	3.51	3.0	-7.1%	26	-0.1	2.75	2.3	17.9%
	2nd Period	**52**	**1.2**	**3.52**	**2.8**	**51**	**0.9**	**3.57**	**2.7**	**3.6%**	**27**	**-0.9**	**3.89**	**3.1**	**-10.7%**
	3rd Period	53	1.4	3.72	3.0	52	0.9	3.35	2.7	10.0%	27	-0.7	2.41	1.7	43.3%
	4th Period	**51**	**1.2**	**3.95**	**3.4**	**50**	**0.6**	**3.79**	**2.9**	**14.7%**	**28**	**-1.1**	**3.73**	**3.3**	**2.9%**
Pulaski	1st Period	71	-4.3	3.74	4.7	71	1.1	3.43	2.8	48.4%	38	0.9	3.78	2.6	44.7%
	2nd Period	**69**	**-4.3**	**3.48**	**4.6**	**69**	**-0.3**	**3.61**	**2.6**	**43.5%**	**35**	**-0.9**	**4.15**	**3.0**	**34.8%**
	3rd Period	66	-4.4	4.16	5.0	67	1.0	3.90	3.1	38.0%	34	0.9	4.29	3.2	36.0%
	4th Period	**69**	**-4.0**	**3.59**	**4.4**	**70**	**-0.4**	**3.79**	**3.0**	**31.8%**	**38**	**-0.4**	**3.65**	**2.8**	**36.4%**
Burkes Garden	1st Period	66	-4.2	4.62	5.3	67	-0.6	4.18	3.4	35.8%	40	-0.6	2.67	2.4	54.7%
	2nd Period	**68**	**-2.4**	**2.72**	**3.0**	**66**	**-6.7**	**2.77**	**6.8**	**-126.7%**	**39**	**-0.5**	**3.55**	**2.5**	**16.7%**
	3rd Period	65	-4.6	4.16	5.6	63	-0.0	3.84	2.9	48.2%	39	0.5	2.41	1.9	66.1%
	4th Period	**68**	**-2.5**	**3.67**	**3.6**	**69**	**-6.2**	**4.27**	**7.0**	**-94.4%**	**39**	**-0.1**	**3.07**	**2.6**	**27.8%**

Table 6. First period verification (data for 0000 UTC and 1200 UTC were combined) of both Leffler and McGovern (L&M) and Young and Rezek (MIP), using arithmetic mean ($\bar{x}$), population standard deviation ($x_{\sigma n}$), Mean Absolute Error (MAE) and Percent Improvement over MOS (IMP MOS), broken down by forecast cloud cover. Values for $\bar{x}$ and MAE are in ^{o}F, while IMP MOS is in percent.

		MOS				L&M					MIP				
		n	$\bar{x}$	$x_{\sigma n}$	MAE	n	$\bar{x}$	$x_{\sigma n}$	MAE	IMP MOS	n	$\bar{x}$	$x_{\sigma n}$	MAE	IMP MOS
Spencer	Clear	8	-3.5	2.96	4.0	7	0.1	2.53	2.1	46.5%	4	1.5	3.50	3.8	6.3%
	Scattered	35	-0.6	4.33	3.6	35	1.3	3.31	2.8	22.2%	19	0.8	2.52	2.1	40.7%
	Broken	18	-0.8	3.76	2.9	18	1.8	3.04	2.9	-1.7%	7	2.9	2.58	3.1	-8.7%
	Overcast	12	-2.0	4.28	3.7	12	0.8	3.47	2.8	24.5%	9	1.0	3.71	2.8	25.1%
Weston	Clear	13	0.1	6.84	5.8	14	1.6	5.22	4.6	20.8%	7	2.9	5.14	5.1	10.9%
	Scattered	49	1.0	4.50	4.1	41	2.4	4.10	3.8	7.4%	29	1.8	3.79	3.6	12.1%
	Broken	19	2.6	4.03	4.1	26	3.5	2.48	3.8	22.2%	7	2.4	2.26	3.0	25.9%
	Overcast	21	-0.7	3.67	2.8	20	1.8	3.61	3.4	-21.4%	9	3.0	2.05	3.2	-16.7%
Creston	Clear	14	-1.3	5.64	4.7	14	0.5	5.09	3.8	18.7%	7	0.3	3.45	2.9	39.3%
	Scattered	43	1.0	5.27	4.2	43	1.6	3.91	3.3	20.5%	18	1.8	3.02	2.8	32.5%
	Broken	16	0.8	4.22	3.3	16	2.9	3.17	3.2	3.6%	5	0.8	1.93	1.6	51.5%
	Overcast	10	-2.9	3.73	3.5	13	0.5	3.00	2.2	36.3%	4	1.8	2.93	2.6	25.7%
Ripley	Clear	11	-1.0	3.79	3.2	10	0.5	3.96	2.9	8.8%	6	-0.8	4.37	3.5	-10.1%
	Scattered	38	0.7	3.37	2.6	43	0.7	2.92	2.2	13.2%	20	1.4	2.85	2.7	-5.1%
	Broken	22	0.1	1.73	1.4	18	0.8	2.19	1.9	-42.6%	6	1.2	3.29	2.2	59.6%
	Overcast	13	-2.2	4.24	3.1	13	1.2	3.25	2.5	17.5%	5	3.0	2.61	3.0	2.6%
Pineville	Clear	4	-2.3	4.76	4.8	5	0	4.10	4.0	15.8%	1	-4.0	0.00	4.0	15.8%
	Scattered	43	3.6	4.04	4.6	48	1.3	2.55	2.3	49.1%	23	0.5	3.10	2.1	53.3%
	Broken	35	4.1	2.68	4.1	29	2.0	2.13	2.3	43.8%	14	1.1	2.79	2.5	39.2%
	Overcast	28	4.1	3.09	4.3	28	2.2	3.20	3.5	18.9%	14	3.2	2.27	3.2	25.2%
Oak Hill	Clear	4	-2.0	5.34	4.0	4	1.3	4.97	4.8	-18.8%	2	-4.0	4.00	4.0	0.%
	Scattered	34	0.5	3.07	2.5	41	1.1	2.09	1.9	23.1%	19	-0.7	2.29	1.9	23.5%
	Broken	34	1.5	2.43	2.2	33	2.1	2.46	2.7	-21.9%	14	0.6	3.20	2.7	-21.%
	Overcast	29	1.3	3.27	2.8	27	2.1	2.87	3.0	-9.0%	12	1.0	2.20	1.8	33.5%
Lewisburg	Clear	4	-10.5	4.50	-10.5	2	-11.0	4.85	11.0	-4.8%	2	-5.5	4.50	5.5	47.6%
	Scattered	38	-0.3	4.15	3.6	33	-1.9	4.23	3.8	-6.5%	18	-0.4	3.11	2.6	26.5%
	Broken	30	1.2	5.26	3.5	30	0.1	5.00	3.7	16.8%	14	0.4	4.03	3.3	26.4%
	Overcast	31	0.8	3.76	3.0	31	-0.2	3.60	2.8	4.4%	13	0.5	2.34	2.1	30.0%
Parsons	Clear	5	0	0.63	0.4	4	-0.2	0.40	0.2	50.0%	3	-1.3	1.25	1.3	-232.5%
	Scattered	31	1.9	2.61	2.6	33	1.1	3.08	2.2	12.2%	14	0.4	2.02	1.5	41.2%
	Broken	20	2.4	2.11	2.7	20	1.8	2.23	2.5	9.3%	8	1.3	2.28	2.3	16.7%
	Overcast	11	0.7	2.70	2.0	11	0.4	2.38	1.6	18.0%	6	1.3	1.97	2.0	0.%
Webster Springs	Clear	5	0.4	3.01	2.8	5	0	3.29	2.8	0.%	3	-1.7	2.05	2.3	16.8%
	Scattered	29	2.6	2.84	2.8	30	2.3	2.93	2.7	3.3%	12	0.9	2.78	2.4	12.3%
	Broken	22	2.5	2.59	3.3	19	2.2	2.67	3.1	6.7%	8	0.4	2.45	2.4	27.2%
	Overcast	13	-1.9	3.73	2.7	15	0.5	2.78	2.0	25.7%	6	-2.2	2.03	3.0	-11.5%
Pulaski	Clear	7	-6.9	4.73	6.9	7	-1.9	4.19	3.3	52.0%	4	-2.5	5.41	4.5	34.4%
	Scattered	40	-3.6	3.37	4.2	40	0.6	3.04	2.4	44.0%	27	0.3	3.25	2.4	40.7%
	Broken	23	-3.6	4.24	4.6	25	0.6	4.18	3.3	28.9%	6	0.8	5.27	4.4	4.6%
	Overcast	18	-3.4	3.15	3.6	17	1.5	3.18	2.7	24.9%	9	1.2	2.25	2.1	41.6%
Burkes Garden	Clear	3	-7.0	5.10	7.0	3	-3.0	3.74	3.7	47.6%	1	-5.0	0	5.0	28.9%
	Scattered	33	-3.9	4.84	5.0	35	-3.4	3.06	3.8	25.0%	17	-1.4	2.03	2.2	56.7%
	Broken	34	-2.4	3.60	3.3	32	-2.5	4.63	4.4	-33.8%	14	-0.4	2.41	2.0	39.6%
	Overcast	29	-1.4	3.21	2.9	29	-0.7	5.96	5.0	-70.6%	13	1.8	1.80	1.9	34.5%

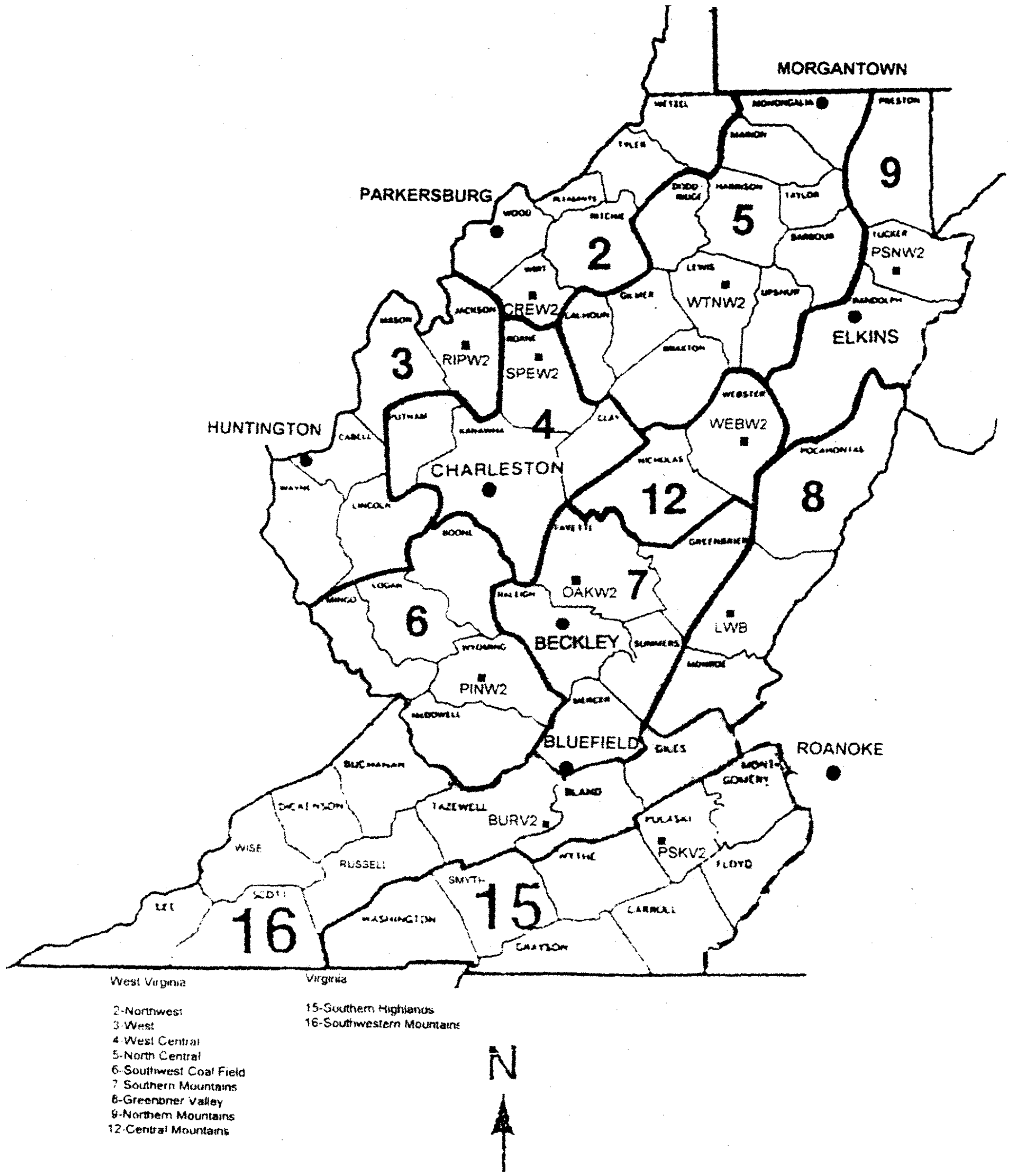

Figure 1. West Virginia and Southwest Virginia zone boundaries prior to October 1, 1993. Locations marked by a circle are MOS control sites, while locations marked by a square are cooperative observer stations used in this study (see Table 1 for the names of the cooperative observer stations).

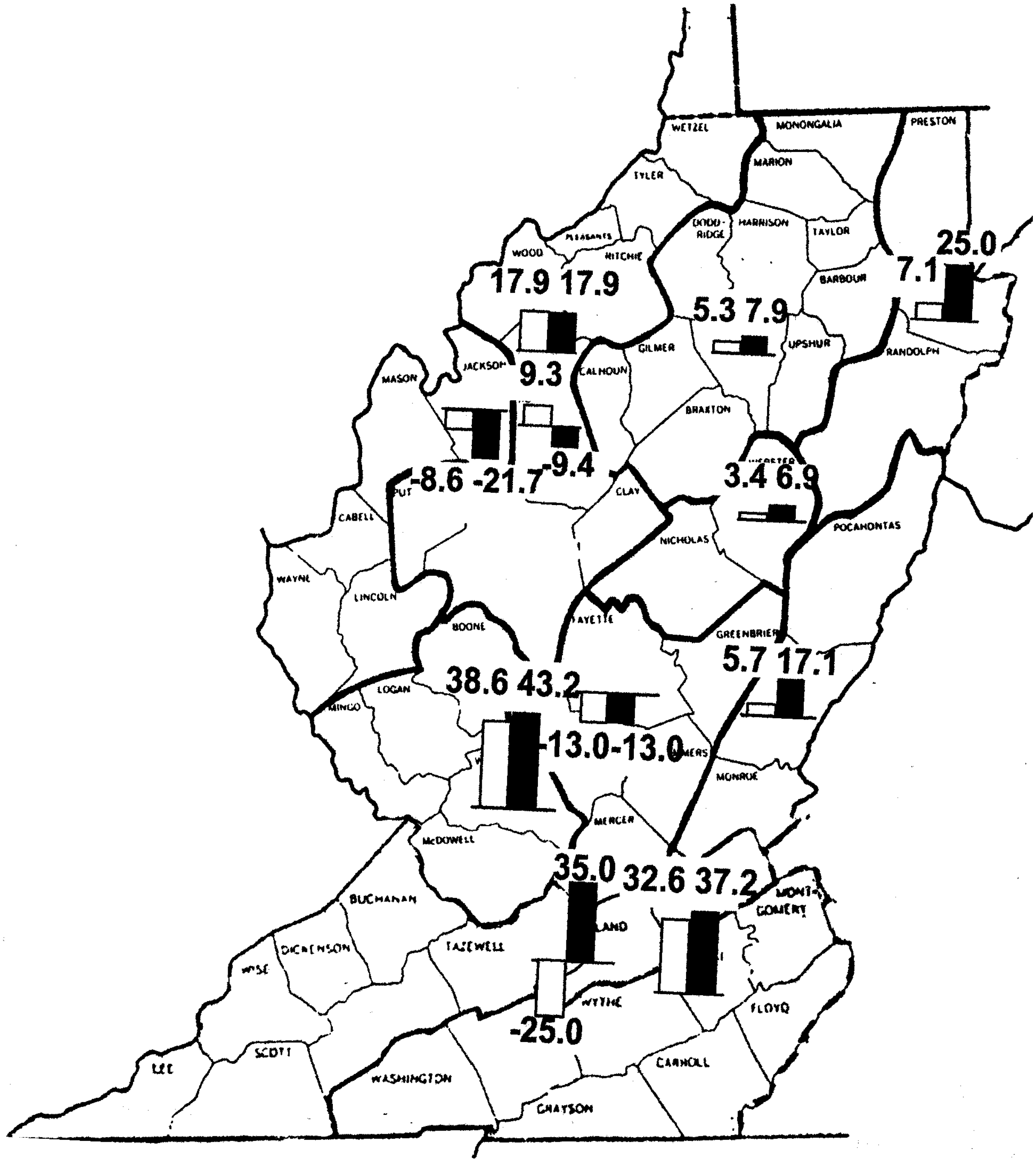

Figure 2. Improvement over MOS for both L&M and MIP supplemental guidance for the 0000 UTC cycle. The permanent improvement is listed for each of the 11 test locations.

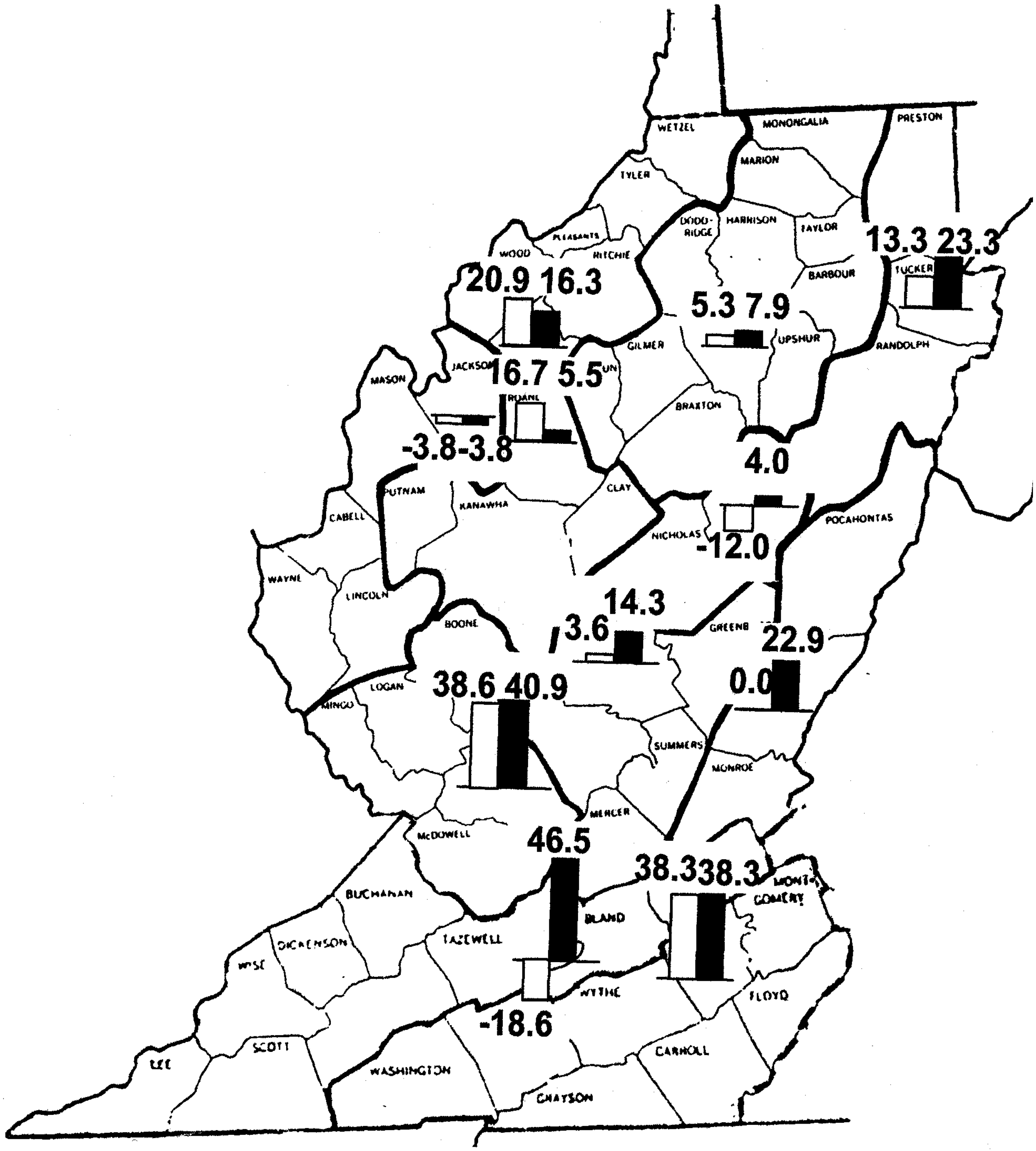

Figure 3. Same as Fig. 2, except for 1200 UTC.