Forecasting Note

Minimum Temperature Study for Northeast Alabama: Preliminary Results for the Winter and Spring Seasons

by

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1. Introduction

A pilot study of the minimum temperatures across northeast Alabama was recently completed using data from the period 1 September 2002 through 30 April 2003. For this study, the data set was divided into three distinct seasons: Fall (September-October), Winter (November-February) and Spring (March-April). A summary of the fall season (see Richter and Schaub forecaster note, 09/16/03) revealed that large minimum temperature differences across northeast Alabama occur in conjunction with lake effect and urban heat island influences more often than with terrain influences. Based on observations at Guntersville (located a few hundred yards from Lake Guntersville) and Fort Payne (located next to a multi-story building in downtown Fort Payne), minimum temperatures on clear nights were significantly warmer in the fall than other locations in the large valley systems they occupy. Under conditions favorable for radiational cooling, it was common for areas around Guntersville and Fort Payne to remain more than 5 degrees warmer than surrounding valley locations. While the observations from Guntersville and Fort Payne are not representative for most of the valley areas, the readings are from accurate well-maintained equipment and need to be considered in our forecasts.

This portion of the study will now examine the results for clear nights in the winter and spring seasons and compare these results to those of the fall season. It will be shown that the local effects at Guntersville and Fort Payne diminish through the winter and spring, while the minimum temperature differences between valley and ridge locations increase and dominate, with the ridges considerably warmer. It will be emphasized that the main surface pressure pattern that occurs with the largest valley to ridge differences is one with a surface high pressure center to the southwest through southeast of the forecast area.

It is important to note that in the earlier study, and in this one as well, the main focus was on cases where the ridges were warmer than the valleys. The reason is that it is these cases that have the most remarkable differences. We did not address the cases where cold air advection, under clear skies, produces a generally standard dry-adiabatic lapse of temperature with height. Given the terrain in our forecast area, a typical valley to ridge difference in this case has ridges around 5 degrees cooler than the valleys.

2. Results

a. Median and Standard Deviation

Table 1 displays each of the 7 stations along with their calculated median minimum temperature and accompanying standard deviation for each of the three seasons. As expected, Valley Head, Bridgeport and Scottsboro are consistently the coolest locations

	Fall '02		**Winter '02-'03**		**Spring '03**	
Station	***Median***	***Stndrd Dev***	***Median***	***Stndrd Dev***	***Median***	***Stndrd Dev***
Valley Head	60°	± 9.0°	21°	± 5.9°	39°	± 8.1°
Bridgeport	60°	± 8.1°	24°	± 5.6°	43°	± 8.3°
Scottsboro	61°	± 8.8°	25°	± 6.0°	43°	± 8.0°
Sand Mountain	62°	± 8.4°	27°	± 6.2°	44°	± 8.6°
Huntsville	64°	± 9.0°	27°	± 6.9°	46°	± 8.9°
Fort Payne	65°	± 8.0°	26°	± 6.8°	46°	± 7.2°
Guntersville	66°	± 8.5°	28°	± 6.2°	46°	± 7.5°

throughout the three seasons. Valley Head stands out during the winter and spring seasons, showing a much cooler median (3-7 degrees) when compared to the other locations. Bridgeport and Scottsboro are only slightly cooler (1-3 degrees) during the winter and spring seasons. Sand Mountain, which is a representative ridge location, shows a much warmer median (5-6 degrees) than Valley Head during the winter and spring seasons, compared to only a 2-degree difference during the fall season.

Table 1: Median Temperature (°F) and Standard Deviation for the three seasons.

b. Frequency Distributions

In the preliminary fall study, it was shown that frequency distributions of minimum temperatures for the sites had a negative skew. That is, their graphs showed a shift of the normal central tendency to the right of center. This was due to an abrupt drop from unseasonably warm temperatures for most of the season to a few days of cold temperatures late in the season.

In comparison, the winter plots in Figs. 1 and 2 show some positive skew. This is due to a preponderance of colder minimums that occurred during the coldest months of Dec-Feb, as compared to November. In general, the march of the peaks from left to right is from cooler to warmer sites (compare to medians in Table 1). For the spring months, Figs. 3 and 4 show distributions that are closer to normal. Again, the march of peaks is from cooler to warmer sites.

c. Minimum temperature differences (ΔT)

Minimum temperature differences between four key stations and a few of the other stations were calculated. First, the daily minimum temperature differences (ΔT) between the key stations and other stations were determined by subtracting the overnight lows for each station. Then the differences were averaged over a particular season. The key stations include Huntsville, for comparison as our home station; Guntersville, for the lake effect influences; Fort Payne, for the heat island influences; and Sand Mountain, for the terrain influences. The ΔT calculations are summarized seasonally in Table 2.

Table 2a displays the minimum temperature differences between Huntsville and the six COOP stations. The temperature differences increase between Huntsville and Valley Head by approximately 3 degrees during the winter and spring seasons. Also, the percentage of ΔT values greater than 5 degrees increases from 22% in the fall season to 57% in the spring season. This is probably due to an increase in the frequency and strength of surface based inversions through the winter and spring. Overall, Huntsville remains on average 2-4 degrees warmer than Scottsboro and Bridgeport, with very little temperature difference noted versus Fort Payne.

As shown in Table 2b, large lake effect influences occur in Guntersville during the fall, where for example an average of 5 to 6 degrees difference was found between the Guntersville lows and those of Valley Head, Bridgeport and Scottsboro. However, with the exception of Valley Head, these temperature differences are shown to decrease by approximately 2 to 3 degrees for all other locations during the winter and spring seasons. In fact, by the spring season, Huntsville becomes just slightly warmer than Guntersville. The persistent large differences between Guntersville and Valley Head through the seasons are because Valley Head consistently cools efficiently on clear nights. This is due to the geometry of the valley it is in, which is addressed in a later paragraph. Also of note in Table 2b are the percentages of ΔT values greater than 5 degrees. Low temperatures at Guntersville were greater than Bridgeport and Scottsboro by more than 5 degrees 52% of the time during the fall, before decreasing to only 17% of the time by the spring season. Thus, as would be expected, lake effect influences begin to have less importance by November and December as the water finally begins to lose that differential heat source.

Table 2c shows that a heat island influence by Fort Payne was also fairly large during the fall season. Low temperatures were on average from 3 to 5 degrees warmer than those from Valley Head, Bridgeport and Scottsboro. However, during the winter and spring seasons, these temperature differences decrease to less than 3 degrees for all locations except Valley Head during the winter and spring seasons. Thus, the influences provided by a local heat island effect at Fort Payne can be expected to be minimal throughout the winter and spring, except within De Kalb county itself where the difference between minimum temperatures at Fort Payne and Valley Head widens during the winter and spring.

Terrain influences are shown to be least important during the fall season. It can be seen in Table 2d that Sand Mountain only shows slightly warmer temperatures (1 to 2 degrees) than the valley locations of Scottsboro, Bridgeport and Valley Head. However, temperature differences begin to increase through the winter and spring seasons. The largest difference occurs with Valley Head, while temperature differences are only slightly larger against Scottsboro and Bridgeport. Overall, temperature differences have increased to an average of 5 degrees warmer for Sand Mountain versus Valley Head. Also, the percentage of ΔT values greater than 5 degrees between Sand Mountain and Valley Head has increased from 4% in the fall season to 38% and 35% respectively, in the winter and spring seasons. This increase occurs as surface high pressure centers shift from east of our area in the fall, to the quadrant to our south which is conducive to stronger surface based inversions. Thus, an increase in ridge to valley temperature differences can be expected as we move through the winter and into the spring season.

Large differences in temperatures between Sand Mountain and Valley Head as compared to Scottsboro and Bridgeport may be explained in part by the actual geometric configurations of the respective valleys. The geometry of a valley has been shown to be very important in regards to radiational cooling. As discussed by Whiteman (1990), a narrow v-shaped valley, compared to a box-shaped valley with the same area at the top, will cool more strongly for the same amount of heat loss through the top. This is, in part, why valleys are usually cooler in the morning than on the plain. Other contributing factors are downslope flow from the valley walls and cold air advection. As shown in Tables 1 and 2, minimum temperatures within valley locations of De Kalb county were consistently lower than those from locations in Jackson and Marshall counties. Thus, the broad-floored valley that runs from northeast Jackson county to central Marshall county radiates more like on the plain, except near Lake Guntersville, while the narrow-floored valley that runs the length of De Kalb county radiates more strongly due to its geometry.

d. Composite surface maps

Using a plotting and analysis feature located on the CDC webpage, seasonal surface composites of mean sea-level pressure were created for all clear nights. This was done in order to determine any particular synoptic patterns that dominated the clear nights during each of the three seasons. The results of this map typing were then compared to a much larger study done by the U.S. Air Force (1974) for what was called the Alabama window. In that study, a computer was used on a 26-year period of record (1946-1971) to determine what surface map types occurred most frequently each month. All days were evaluated, not just clear days.

During the fall, the most frequent surface map type in our study featured a high pressure center over Virginia or the Carolinas (see Figure 5). This type occurred on 7 of the 23 nights or 30% of the time. The U.S. Air Force (1974) study also identified this map type as dominant during the fall months with a frequency of 30%. By the winter season, the high pressure center was now located further west across the southern Gulf Coast (Figure 6). This type occurred on 12 of the 48 nights or 25% of the time. By way of comparison, a composite of map types from the U.S. Air Force (1974) study for Nov-Feb would show a high center over Louisiana most of the time. This is almost an exact match with our composite for just one season. Finally, in the spring season, the high pressure center was shifted back to the east across Georgia and the Carolinas (Figure **7**). This particular map type occurred on 10 of the 23 nights or 43% of the time. It also compares very closely with the U.S. Air Force study that showed a high center just of the South Carolina coast with a strong cold front from the Midwest to the southern plains. These common map types are not always associated with the most extreme differences in minimum temperatures, but may be identified as one of several synoptic situations favorable for larger temperature differences across the higher terrain. Additional years of data will help clarify these patterns and resultant temperature trends.

To form the core of this preliminary study, a subset of seasonal surface composites was also created using only those nights in which stronger inversions likely existed. A night was deemed a strong inversion case whenever the temperature difference between Sand Mountain and Valley Head exceeded 5 degrees. This criterion was selected subjectively, based on the fact that larger differences are more interesting and dramatic. Also, lesser temperature differences could be readily described in the zone forecasts with typical 5-degree forecast ranges, while the larger differences would need specialized wording. As it turned out, only one strong inversion case existed during the fall season. However, 17 cases occurred throughout the winter and 8 cases were noted during the spring.

The core composites were created in order to show what the typical synoptic pattern looks like when the larger ridge to valley differences exist. The composites are shown in Figs. 8-10. The winter and spring composites are nearly identical, with a surface high centered just off to our south and a ridge axis extending northeastward into the Ohio Valley. This particular synoptic pattern is favorable for very light or calm winds in our forecast area, which in turn enable ideal radiational cooling and inversion development in the valleys, as the flow there decouples from that above. Furthermore, due to winds with a southerly component above the valleys near the ridges, warm advection is commonly occurring, which further strengthens the overnight inversion. Hence, we see stronger inversions and larger ridge to valley temperature differences with this surface pattern**.**

Since the winter and spring composites include surface high pressure centers that varied in location, there was no particular low-level wind direction or speed associated with extreme temperature differences. For example, of the 25 cases of strong inversions noted above, the low-level winds at 2,000 ft and 850 mb from the 1200 UTC KBMX soundings had mostly a south-west-northwest component. This implies that surface high pressure would be mainly in the quadrant to our south, and corresponds well with the composites shown in Figs. 9 and 10. As an aside, Figs. 9 and 10 also fit well with observations over the years by the NWS office in Jackson, Kentucky. Forecasters there have found that extreme ridge to valley temperature differences occur in rugged terrain of their forecast area with low-level winds from the southwest.

3. Concluding Remarks

Our earlier study for the fall season alone showed that larger minimum temperature differences across northeast Alabama occur in conjunction with lake effect and urban heat island influences more often than with terrain influences. In contrast, the present study shows that the terrain elevation influences become dominant during the winter and spring seasons, while the lake effect and heat island influences diminish.

Based on analyses of composite surface pressure patterns on clear nights, and coincident wind directions at 2,000 feet and 850 mb, we recommend a focus on forecasting and recognition of specific surface pressure patterns in our area. This appears to be the best tactic for determining what clear nights will have large differences in minimum temperatures in northeast Alabama. In particular, for the winter and spring seasons, a forecast of a clear night, with a surface high pressure center in the quadrant south of our forecast area, is a flag that large temperature differences are likely in the rugged terrain. There is an important note to include about this pattern. If warm advection is occurring or anticipated at the gradient level, the magnitude of the inversion, and hence the ridge top temperatures, could be larger than expected. While this pattern is favorable for the larger temperature differences, other surface patterns can also be conducive to valley-ridge temperature splits. For example, a high pressure center or a low-level ridge axis near or over the area on a clear dry night with light or calm winds, can also enable development of an overnight inversion and a valley-ridge temperature split.

An approximation of any potential ridge to valley temperature differences can be made using model sounding data, by taking the difference in magnitude of temperatures at both the valley height and the ridge height from an inversion. This is a good first guess as to how extreme the temperature differences will be between ridges and valleys across the northeast counties. Also, if a large valley-ridge temperature split occurred the night before, and conditions are not expected to change much, a check of the morning OSO may give a clue as to how cold the temperatures will be across the northeast counties the following night. A general rule-of-thumb type procedure for estimating the valley to ridge temperature difference that worked well in eastern Kentucky, and seems to work well here too, is included in Appendix A. This is followed in Appendix B by an example from a recent case in our area.

Although only the last fall through spring seasons of data were used in this study to provide some useful forecasting tips for the present seasons, it is surmised that analysis of several years of data would show the same basic results. As a matter of fact, a larger study with several years of data is planned. This would lend more statistical credence to the results presented here.

References

Whiteman, C. D., 1990: Observations of thermally developed wind systems in mountainous terrain. *Atmospheric Processes over Complex Terrain, Meteor. Monogr.*, No. 45, Amer. Meteor. Soc., 5-42.

U. S. Air Force, 1974: Map Type Catalog for the Alabama Window. 12 WS TP 74-5, Ent Air Force Base, CO., 173 pp.

Table 2: Average daily minimum temperature difference (ΔT) and the % of ΔT differences that exceed 5 degrees.

a. Huntsville

Station	Fall '02		Winter '02-'03		Spring '03	
	Avg Daily Min ΔT	**% of ΔT's > 5°**	**Avg Daily Min ΔT**	**% of ΔT's > 5°**	**Avg Daily Min ΔT**	**% of ΔT's > 5°**
Valley Head	3.4°	22%	6.0°	45%	6.6°	57%
Bridgeport	3.7°	22%	3.6°	21%	3.2°	4%
Scottsboro	2.4°	9%	2.8°	15%	3.0°	22%
Sand Mountain	1.1°	4%	1.1°	4%	1.6°	13%
Fort Payne	-1.0°	9%	0.9°	4%	0.3°	4%
Guntersville	-2.7°	13%	-0.9°	4%	0.4°	9%

b. Guntersville

Station	Fall '02		Winter '02-'03		Spring '03	
	Avg Daily Min ΔT	**% of ΔT's > 5°**	**Avg Daily Min ΔT**	**% of ΔT's > 5°**	**Avg Daily Min ΔT**	**% of ΔT's > 5°**
Valley Head	6.2°	78%	6.8°	74%	6.2°	61%
Bridgeport	5.7°	52%	4.5°	36%	2.8°	17%
Scottsboro	5.1°	52%	3.7°	21%	2.6°	17%
Sand Mountain	3.9°	17%	2.0°	11%	1.2°	9%
Huntsville	2.7°	13%	0.9°	4%	-0.4°	9%

c. Fort Payne

Station	Fall '02		Winter '02-'03		Spring '03	
	Avg Daily Min ΔT	**% of ΔT's > 5°**	**Avg Daily Min ΔT**	**% of ΔT's > 5°**	**Avg Daily Min ΔT**	**% of ΔT's > 5°**
Valley Head	4.5°	30%	5.0°	23%	6.1°	48%
Bridgeport	4.1°	26%	2.5°	9%	2.8°	13%
Scottsboro	3.5°	4%	1.9°	9%	2.5°	13%
Sand Mountain	2.4°	0%	0.2°	2%	1.1°	0%
Huntsville	1.0°	9%	-0.9°	4%	-0.3°	4%

d. Sand Mountain

Station	Fall '02		Winter '02-'03		Spring '03	
	Avg Daily Min ΔT	**% of ΔT's > 5°**	**Avg Daily Min ΔT**	**% of ΔT's > 5°**	**Avg Daily Min ΔT**	**% of ΔT's > 5°**
Valley Head	2.3°	4%	4.9°	38%	5.0°	35%
Bridgeport	1.8°	4%	2.5°	6%	1.6°	13%
Scottsboro	1.2°	4%	1.7°	11%	1.4°	4%
Huntsville	-1.1°	4%	-1.1°	4%	-1.6°	13%

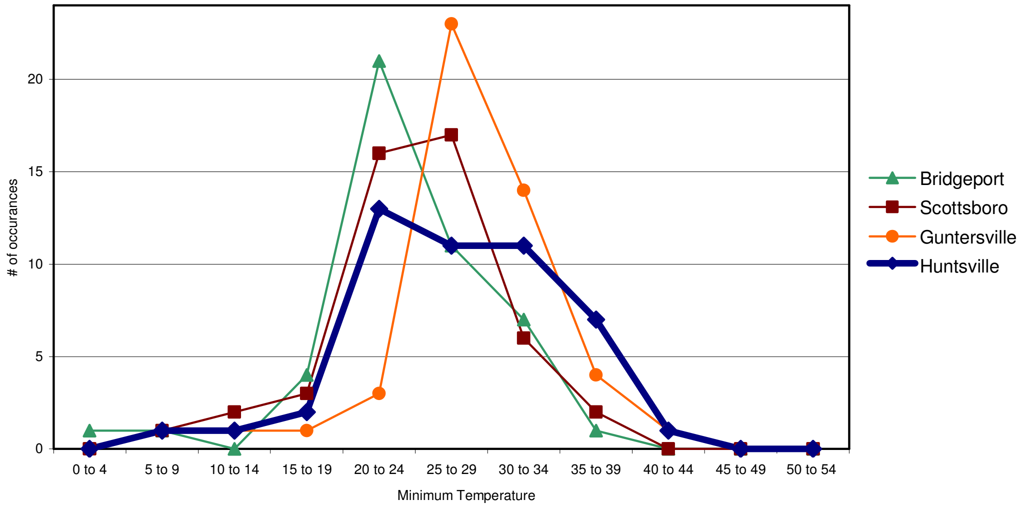

Figure 1: Frequency distributions of the minimum temperatures (°F) for Huntsville and the three sites in the broad valley in Jackson and Marshall counties for the winter season.

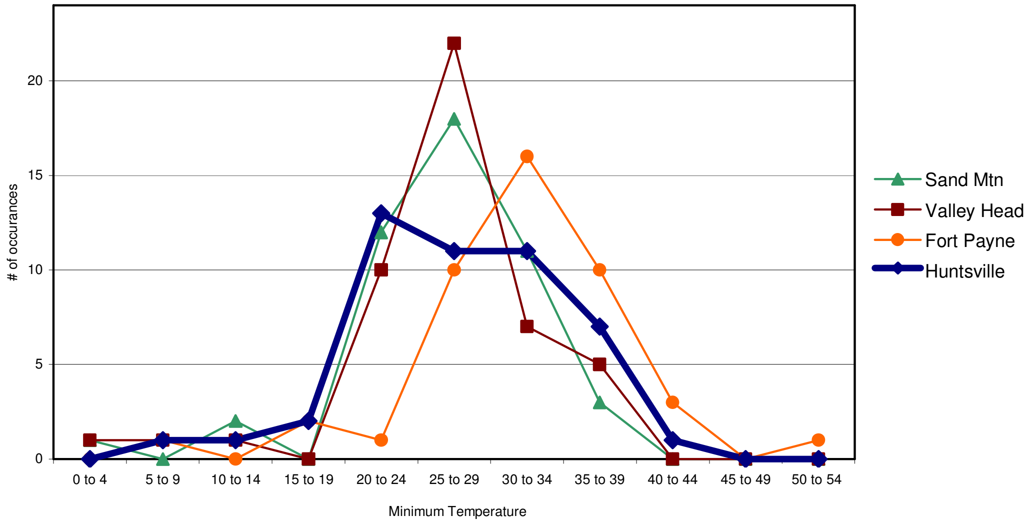

Figure 2: Frequency distributions of the minimum temperatures (°F) for Huntsville and the three sites in Dekalb County for the winter season.

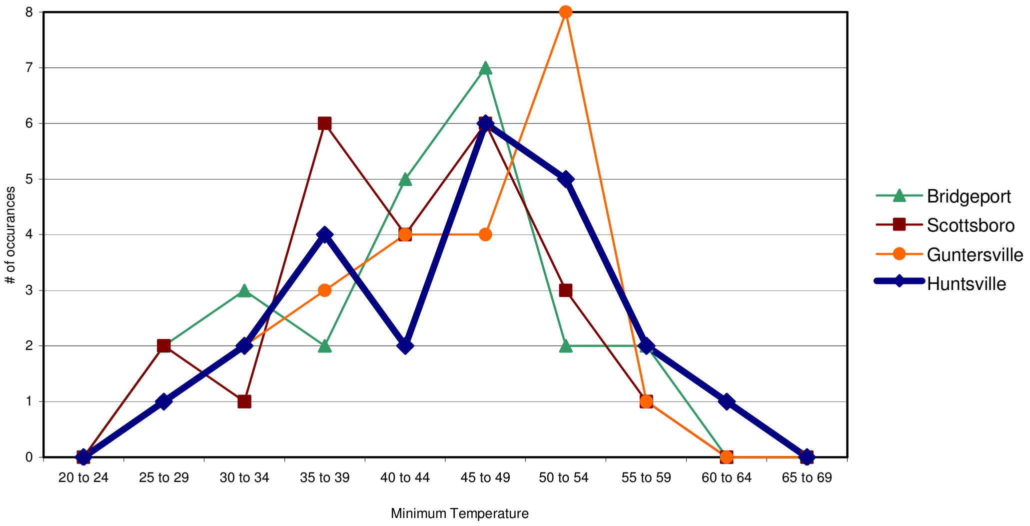

Figure 3: Same as in Figure 1, except for the spring season.

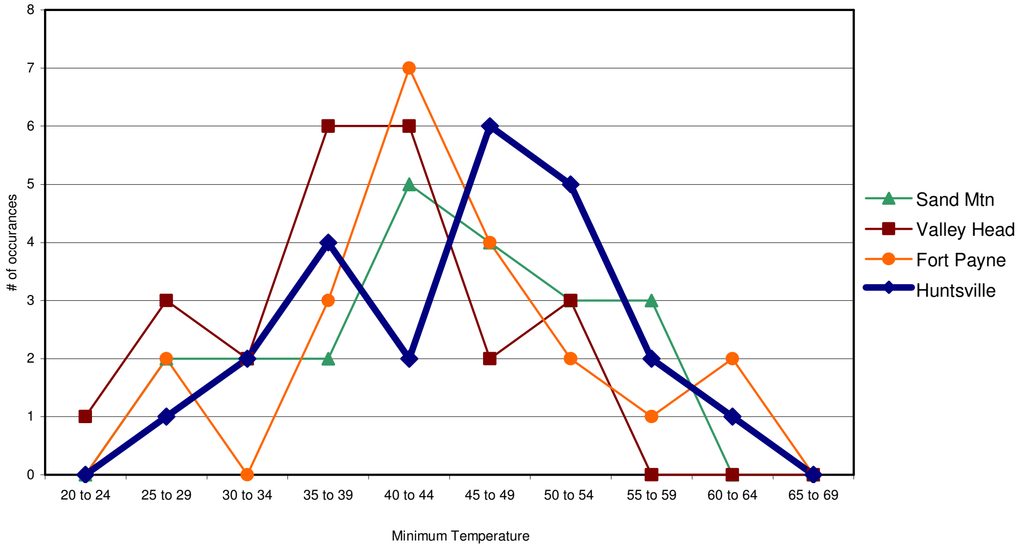

Figure 4: Same as in Figure 2, except for the spring season.

Appendix A

Rule-of-thumb procedure for estimating the valley to ridge temperature difference in rugged terrain of northern Alabama, and parts of southern middle Tennessee, on clear nights favorable for radiational cooling.

- Decide on the lows for the Huntsville area.
- For the valleys, forecast lows that are two categories below those for Huntsville. For example, if the forecast lows for Huntsville are mid 30s, forecast upper 20s for the valleys.
- From a model (e.g., mesoeta) forecast sounding, make note of the largest magnitude of the overnight inversion from the surface to elevations between 1,500 and 1,800 feet. This is the general range of most ridge top elevations in our forecast area.
- Add the magnitude of the inversion to the forecast lows for the valleys to get an estimate for the lows on the ridges. Assuming that the inversion magnitude is around 10 degrees, in the present example this would give upper 30s for the ridges.
- The wording in the zone forecasts for this example would be something like… LOWS FROM THE UPPER 20S IN VALLEYS TO THE UPPER 30S ON RIDGES.

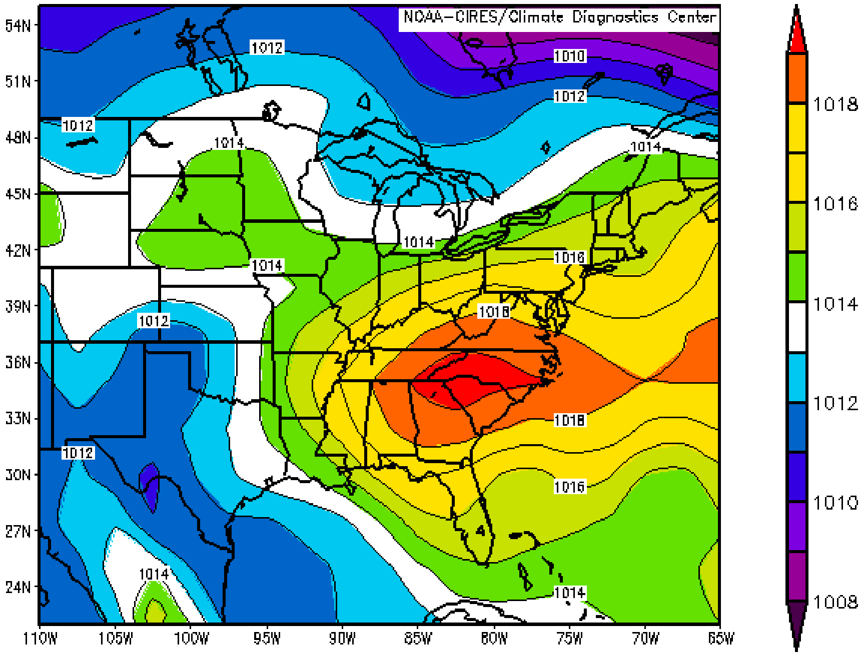

Figure 5: Composite mean sea level pressure (mb) map type most common for all clear nights in Fall 2002.

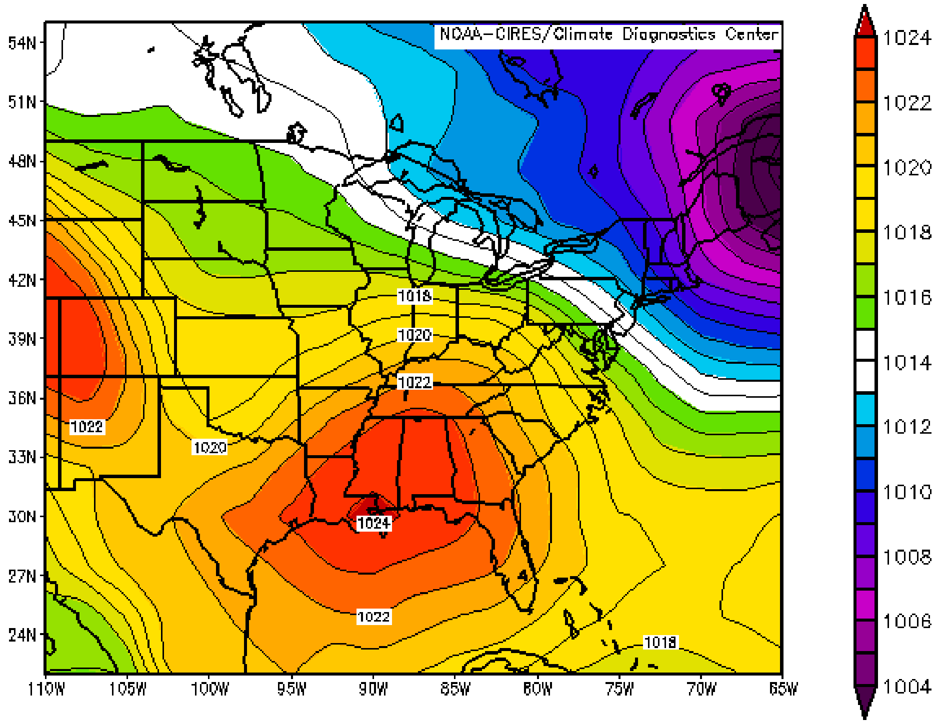

Figure 6: Composite mean sea level pressure (mb) map type most common for all clear nights in Winter '02-'03.

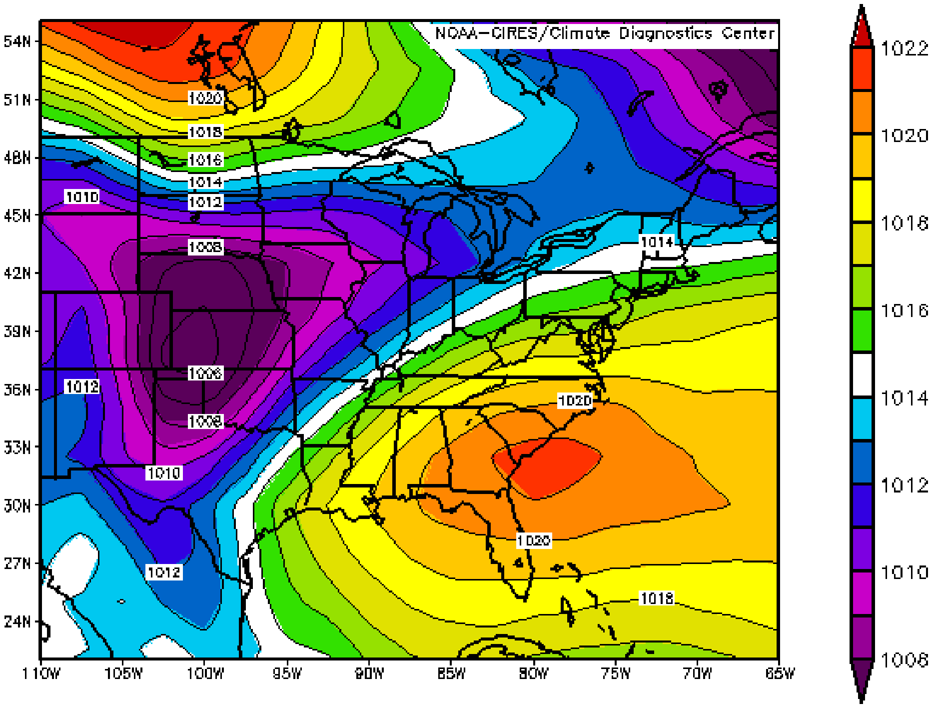

Figure 7: Composite mean sea-level pressure (mb) map type most common for all clear nights in Spring 2003.

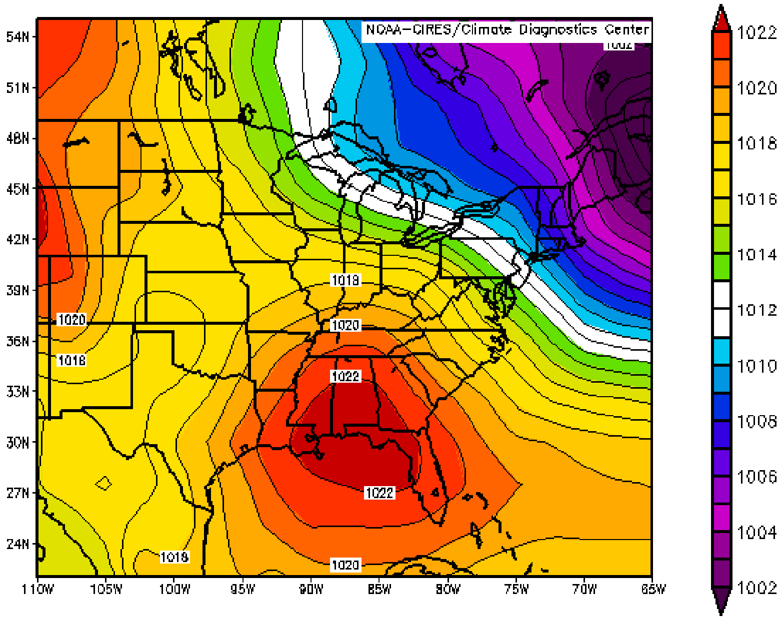

Figure 9: Composite mean sea level pressure (mb) map type most common for strong inversion nights in Winter '02-'03.

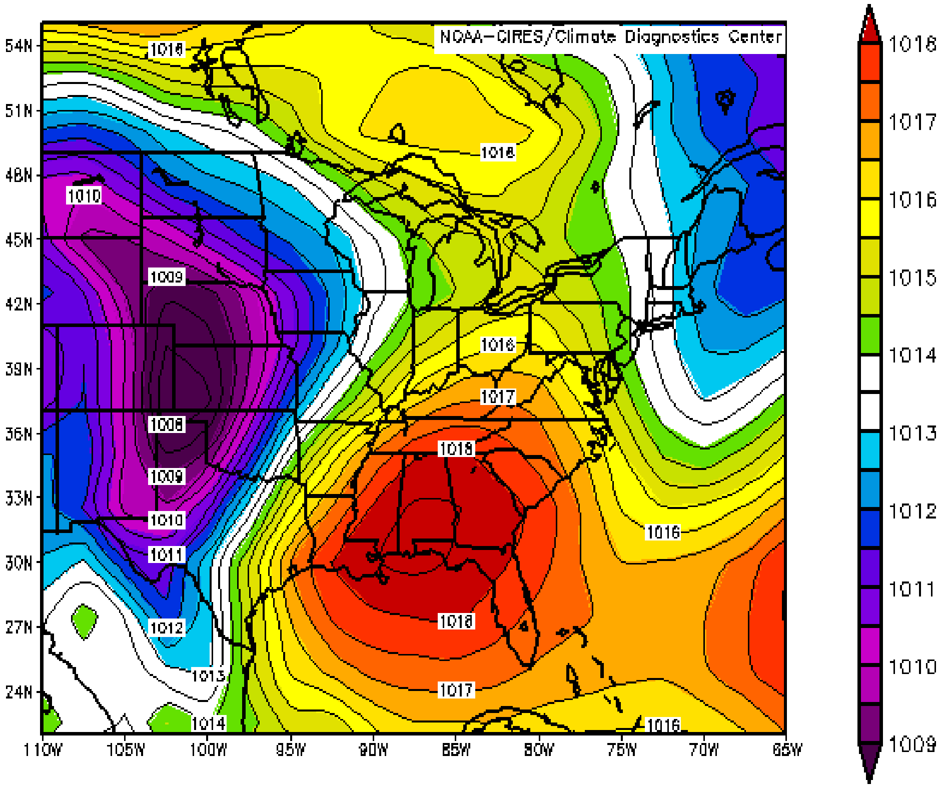

Figure 10: Composite mean sea level pressure (mb) map type most common for strong inversion nights in Spring 2003.