OKLAHOMA WEATHER LAB

Hand analysis is a valuable skill to have when it comes to utilizing the surface/upper-air observations that are available to you. Although computer programs can plot maps of their own with the given data, this form of technology can still misinterpret data or resort to unnecessary procedures (like plotting and interpolating data in regions where data is relatively sparse, such as in parts of Canada).

The purpose of this manual is to provide a simple overview on how to construct a hand-analysis based map for the surface, 850, 700, 500 and 300 mb layers. Directions will be explained for each level with real examples from a past case provided. It is important to note that this product is a supplement meant to provide directions on constructing maps only. It is not intended to serve as instruction for the synopsis or background meteorological setups. It is the responsibility of the shift leader to instruct the students on why these maps are constructed, what to look for (and for which cases) etc. Lastly, hand-analysis is a **human made** product. The analysis is **subjective and can be open for debate**, even amongst the maps presented in this manuscript. All tables and Figs 1-2 are displayed within the text of the manual while Figs. 3-10 are displayed at the end.

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Surface:

a. Station Symbols:

Data for the surface level is constructed from observation sites. Nationally, these consist of the Automated Surface Observing Systems (ASOS) and the Automated Weather Observing Systems (AWOS). Some regions possess similar networks on a more local, yet denser scale (i.e. the Oklahoma Mesonet). With the data provided by these networks, a surface hand analysis may be constructed. Before an overview on how to construct a hand analysis with associated examples are provided, a review of the symbols associated with weather stations is necessary.

Each station observation displays 6 key features (although more are possible). Labeled on Fig. 1 below are those six features (with the optional pressure trend) and their respective locations. Temperature and dewpoint can be displayed in either degrees Fahrenheit or Celsius.

Surface (or sea level) pressure is usually displayed with 3 digits. To convert surface pressure to hPa or mb, add either a 10 or a 9 in front of the 3 digits and place a decimal between the last two digits. A 10 is added if the 3 digit number begins with a zero or one (e.g. 133, 067, 004). In showing the conversion, if a value of 107 is present, then convert as follows: 107 → 10107 → 1010.7. A 9 is added to values that begin with a high digit such as an 8 or 9 (e.g. 899, 904, 987) . A conversion would follow as: 913→991.3→991.3 mb.

The wind barb points in the direction the wind is coming from. The example below illustrates a northwesterly wind. The lines on the barb indicate wind speed, with a short line indicating 5 knots, a long line indicating 10 knots, and a shaded in flag indicating 50 knots. A flag is rare to see at the surface but is prevalent on upper air maps. Note that 1 Knot =1.15 mph. The barb lines/flags point to the left and perpendicular to where the winds are coming from. Table 1 summarizes examples below.

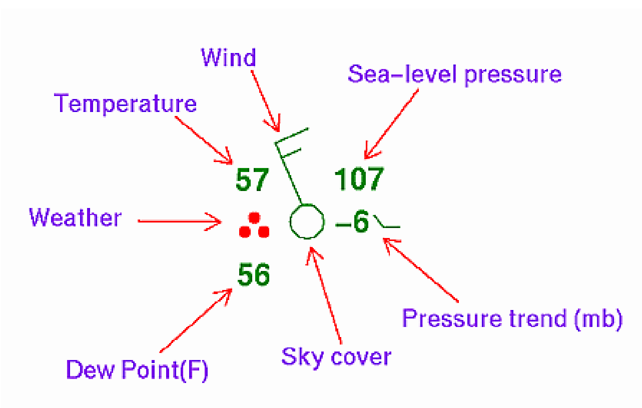

Figure 1: Observation Site Network with temperature (°F), dew-point (°F), sky cover, weather symbol, pressure (and pressure trends in mb), and wind direction/ wind speed labeled by a barb. *Image derived from NOAA (Weather Prediction Center).*

The weather symbol can vary greatly based on the surface conditions present. Table 2 below summarizes the most common cases that may be observed. Sky cover can also vary based on the amount of shading provided within the circle of the observation. Table 3 below shows the types of symbols that can be seen on a surface map.

Table 1: Wind barb examples with respective directions and corresponding magnitudes. Units are in knots (kts).

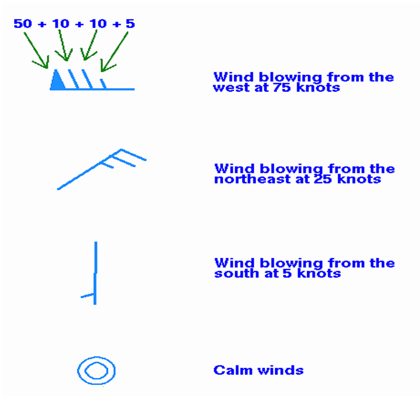

Image copyright NOAA (Weather Prediction Center)

Table 2: Surface Observations located at a surface observation location.

Image copyright NOAA (Weather Prediction Center)

Table 3: ASOS Station Cloud Cover Approximations

Image copyright NOAA (Weather Prediction Center) *b. Contours:*

Surface analyses are typically conducted on both a national and regional scale. Because of this, there is no solid set standard for the information contoured (which variables are contoured and at which specific intervals).

Contours are constructed by connecting stations of constant value with a smooth curve. If a contour passes through multiple stations not of the same value, the contour will be positioned with respect to the value of the station. In other words, if a contour has a value that is less than one station and greater than the other, it will pass between the two stations. Refer to any hand-analysis in this guide or the shift leader to understand this concept. For a clean and successful hand-analysis, it would be wise for the forecaster to trace contours lightly in pencil before solidifying the positions with the colored pencil (at the surface or any other level). Also, some basic rules apply to contouring. **These rules are applied to the surface and all upper-air maps.**

Rule 1: Do not interpolate contours in regions for little to no data. There is no evidence to validate the assumptions proposed.

Rule 2: Do not contour or shade a region based off of the value of **one** station reading.

Rule 3: Beware of false data. Meteorological observational sensors are highly prone to error and some of these errors may be obvious.

Rule 4: Know your topography! Contours over the Rocky Mountains and the Appalachians may be very challenging (perhaps impossible in some cases) due to the terrain elevation. An example would be contouring 850 mb maps in the Rocky Mountains, where certain locations are located above the 850 mb level.

Rule 5: Linear interpolation is highly discouraged as the atmosphere does not operate in this fashion. Use linear interpolation with respect to the atmospheric conditions with extreme caution. Please refer to the current shift-leader for a more thorough explanation.

Rule 6: Do not start and end a contour within the map region (unless it is a closed contour). Make sure the beginning and ends of the non-closed contours are labeled at the edges of the map (refer to all example maps).

Rule 7: Place your last name (in capital letters) in the bottom left portion of your map. Whether it be in the government or private sector, you are responsible for your own analysis.

The first variable contoured is pressure. For the amateur hand analyst, it is wise to expand the pressure readings from the abbreviation given (as mentioned on page 1). This step will become obsolete to the forecaster who gains more experience. Fig. 3 display the pressure contours with the expansions. Once positioning is solidified, the contours can be substantiated with a solid contour using a black colored pencil. Although details are vital in the pressure analysis, it is important that the contours are smooth for continuity and neatness. The intervals contoured vary greatly, depending on the synoptic/mesoscale setup present and if the analysis is nationwide or regional. Typically, the forecaster will look for the highest and lowest pressure readings to gage how many contours will likely exist on the map and thus determine the pressure intervals. Gaining this perspective takes practice. On the regional scale contour every 1 or 2 mb. On the national scale, contour every 2 to 4 mb (it may be wise to stay on the higher end i.e. every 4 or 5 mb with a more active pattern in place).

Typically, on the national scale, temperature is contoured at 5 degree intervals (while 2 or even 1 degree intervals are possible on the regional scale assuming a reasonable temperature profile). Temperature can also be contoured at 4°F intervals for national maps, which allows for an even interpolation to 2°F per contour. Unlike the pressure contours, temperature is contoured with dashed lines. The color used is either red or orange. Some analysts choose to contour temperatures of 32°F (or 0°C) or colder with dashed blue lines but this is optional. Although there is no base temperature to begin contouring, it is rather popular to contour temperature with multiples of 5 (i.e. 70°F-75°F-80°F etc).

The same can be said for dewpoint (5 or 4 degree intervals for national maps, 1-2 degree intervals for regional maps). Because dewpoints are contoured with respect for gaining a perception regarding the quality of the warm sector for severe weather events, the base value for dewpoints is 55°F. Sometimes 60°F is preferred as the starting value to contour. Some forecasters also choose to shade in the areal coverage of the dewpoint contour (for areas where the station dewpoints are greater than or equal to the dewpoint contour, but less than the ascending dewpoint contour), with greater dewpoint values having a darker shading. Fig. 3 portrays this notion more thoroughly. Contours of dark green are preferred for dewpoints, especially to distinguish contours for lighter areas that are shaded in.

In terms of a national or regional map:

For dewpoint area 55°F≤X<60°F: Shade in Light Green

For dewpoint area 60°F≤X<65°F: Shade in Medium Green

For Dewpoint area X≥65°F: Shade in Dark Green

Note 1: Potential temperature (in Kelvin; K) may sometimes be plotted and contoured. Moisture may also be plotted in terms of mixing ratio (g/kg) to better quantify the amount of moisture in the atmosphere.

c. Fronts, Boundaries and Cyclone/Anti-Cyclone Center Placement, thunderstorms

Fronts and boundaries can be difficult to identify. Fronts are identified as boundaries with a density discontinuity. Frequently, they are accompanied by a temperature contrast in addition to a sudden wind-shift (as is evident in Fig. 3). Boundaries may have similar characteristics to fronts, but don't necessarily extend/slope in the vertical. A change in air mass usually occurs at the surface.

A cold front is drawn in blue with triangular pips pointing in the direction of motion. The front is placed on the warm side of the temperature gradient/wind-shift (Fig. 2; 1). Note Fig. 3 for an example. A warm front is drawn on the leading edge of a progressively warming/moistening air mass. In addition to a temperature gradient, a pronounced wind-shift (easterly winds on the north side of the warm front, veering with a southerly component on the south side of the front) is typically evident along with a pooling of moisture along the steepest portion of the temperature gradient. A warm front is indicated in red with semicircles pointing in the direction of motion (Fig. 2; 2). Refer to Fig. 3 for an example.

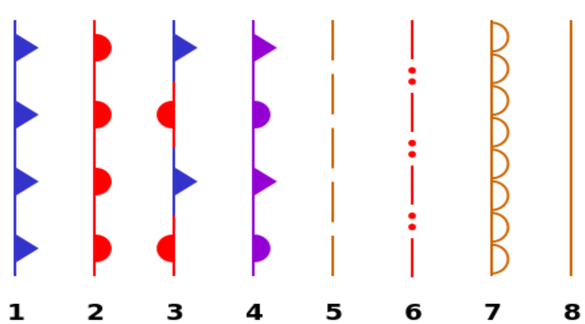

Figure 2: Boundary types labeled as such; 1-cold front, 2-warm front, 3-stationary front, 4-occluded front, 5-baroclinic trough or trough axis, 6-outflow boundary, 7-dryline, 8-ridge axis (zig-zagged). Image Courtesy National Weather Service, NOAA.

A dryline is a boundary that separates a warm and moist air mass with a hot, dry air mass. This can easily be seen on a surface map by a sharp contrast in dewpoints or mixing ratios along with a veering of the winds (Fig. 3). Drylines typically are located in the central and southern plains during active severe weather periods. The air temperature (regardless of which specific temperature variable is plotted) will often increase behind the dryline. The dryline is indicated in brown or peach with the scallops facing the direction of motion (Fig. 2; 7). The dryline will typically progress eastward throughout the afternoon and retreat back westward with the onset of nocturnal cooling.

A stationary front (Fig. 2; 3) delineates the difference between two separate air masses (which may extend into the vertical) that exhibit relatively slow progression over time. The vertical thermodynamic structure of a stationary front vs. the shallow surface features of an outflow boundary delineates the most significant difference between the two frontal features.

An occluded front (Fig. 2; 4) is often located with a decaying surface low pressure cyclone. As this cyclone dissipates, pressure and temperature gradients begin to become more diffuse and the cold front associated with this weakening process morphs into an occluded front.

While typically confined to the mesoscale, an outflow boundary (Fig. 2; 6) is produced by the pooling of cold air associated with and released from convection. This boundary delineates a warmer air mass from a cooler one. It is important to note that outflow boundaries only characterize a temperature contrast at the surface layer of the atmosphere. While these boundaries may be produced initially by convection, they may linger for as long as a day and they can act as surface fronts (especially retreating surface warm fronts). Although these outflow boundaries may be delineated in red, sometimes purple is used. Sometimes pips or semicircles are added to highlight boundary movement.

Although cold fronts are associated with the axis of a surface trough, there are often times when surface troughs are not accompanied by a contrast in air masses. Still, a region of convergence associated with a wind shift along the trough axis often occurs. This is delineated on a map with the symbol (Fig. 2; 5). These boundaries are important because the convergence associated with them (especially with divergence present aloft) may foster the initiation of deep, moist convection. Fig. 5; 8 is drawn in a zig-zag to highlight the axis of the surface ridge. This is a region where maximum subsidence may be expected.

Note 1: A trough is a local minimum in surface pressure while a ridge is a local maximum in pressure. Refer to Fig. 3 to see how this would appear on a surface plot or any upper-air plot.

Note 2: In addition, given the density discontinuity with fronts and given that pressure is a function of density, the pressure contours must be kinked at the location of fronts (as can be seen in Fig. 3).

Cyclone (Low Pressure) centers are marked with a Capital red "L". Anticyclone (High Pressure) Centers are marked with a Capital blue "H". To label a high or a low, the contours must be closed off as in Fig. 3 for the low. This is not a solid rule that is always embraced, but is highly encouraged for meteorological accuracy.

As an option, sometimes convection is labeled by manually inserting a thunderstorm symbol. Note that it is important that a definition of a thunderstorm needs to be defined for this map. Typically, convection contains radar reflectivity values of at least 50 dbZ and an areal coverage greater than 10 square km. The symbol is defined in Table 2 above.

850 mb:

The 850 mb is an important level to contour. It is useful for indicating areas of likely cloud cover, low level jets, tight pressure gradients, or cold/warm air advection.

For upper-air charts being constructed at a level of constant pressure, the relation of pressure is plotted in terms of geopotential heights (the location at an upper air station in the z-component where the indicated pressure level is established). Please refer to this statement in regards to the other pressure levels plotted.

The 850 mb level may often be found anywhere from 1000 m to 1500m. Since the heights are often displayed using the last 3 digits, a “1” is added in front of the value to get the height in meters. In other words, a height reading would proceed as such: 386 → 1386→1,386 m. Although it may vary somewhat, heights are often contoured for every 30 meters. Please refer to Fig. 4 or 5 for an example.

For all upper air maps, temperature is almost always displayed in Celsius (C). Typically, temperature is contoured every 3 to 4°C. There is no set initial value. Like the surface, it is best to obtain the total range of temperatures and use this to establish judgment for a base value and exactly what interval to use. Temperatures above 0°C are plotted with a dashed red (or orange) line. Temperatures at or below 0°C are contoured with dashed blue lines (as in Fig. 4).

Dewpoints could be plotted (in Celsius) and are contoured in dashed green lines. Dewpoints are contoured at 2°C intervals, typically beginning at 8°C. Light green is used for contours between 8 and 12°C, darker green lines are used for contours over 12°C. Note that most upper air charts plot temperature dewpoint depressions in place of dewpoint.

As an option to detect saturation/near saturation conditions (an indication of likely cloud cover) at the 850 mb level, temperature/dewpoint depressions are often plotted. This is done on a separate 850 mb chart without temperature or dewpoint contours (for neatness). Areas where T/Td depressions of 5 or less are shaded in light green, with T/Td depressions at or less than 2 are shaded with a darker green. Refer to Fig. 4 for an example.

The convention of plotting wind is the same as page 1 (and table 1). Although it is not popular to contour winds at 850 mb, this is often assigned to the amateur meteorology student to highlight the low-level jet (LLJ). Typically, low-level jets have wind speeds varying anywhere from 35 to 70 or even 80 kts. A base value to contour is 35 kt and the interval is entirely based on judgment. Again, calculating a range is the best option to guide the judgment process. Refer to Fig. 5 as an example.

Note: As mentioned in Rule #4, 850 mb can be penetrated by higher terrain, such as mountains. In the Continental U.S. (CONUS), the Rocky Mountains extend above the 850 mb level. This makes contouring 850 mb in the western portion of the CONUS very challenging. Note that computer analyses typically use values on the first vertical coordinate level above the ground for all levels where surface pressure is below the pressure surface.

700 mb:

The 700 mb layer is often a good level to search for cloud cover. It is also a layer that is critical for analyzing directional and speed shear for severe thunderstorm events, particularly those involving tornadoes.

The 700 mb layer is typically located between 2500 m to just over 3000 m. Heights are usually abbreviated with 3 digits. If the 3 digit number begins with a small value like a 0, 1, 2 or 3, then a “3” is added in front or 142→3142→3,142 m. Similarly, if the 3 digit number begins with a larger number such as a 7, 8, or 9, then a “2” is added in front or 889→2889→2,889 m. Sometimes, very high heights may be associated with the 700 mb layer (i.e. 3,500 m or 2500 m). These kinds of cases are rather rare and the shift leader will be able to identify them. The trick to detecting these anomalies is looking at the range of the 3 digit numbers in combination with experience and understanding of the atmospheric patterns and seasons in effect. Typically, contours are constructed at intervals of every 30 m. Refer to Fig. 6 for an example.

Temperature is contoured in the same manner as the 850 mb layer. 0°C is often the base temperature contoured (Fig. 6).

Dewpoints (if contoured) are done in the same manner as the 850 mb. The one difference is that the base value for contouring dewpoints is typically -4°C while 2°C and higher values are contoured in a darker shade of green.

Similar to 850 mb, temperature dewpoint depression values of 5 or less are shaded in a light green while values of 2 or less are shades in a darker green (Fig. 6).

500 mb:

The 500 mb layer is often used to grasp an understanding of the mean flow of the atmosphere. In addition, longwave and shortwave weather patterns are evaluated here. This layer is also used to determine mean convective storm motion and speed. Just like the previous two pressure levels, the 500 mb level is also analyzed for regions of saturation/near saturation which would induce cloudiness.

The 500 mb layer is typically located over 5,000 m above the surface of the earth and is plotted in decameters. The height value is rounded to the nearest decameter with a zero trailing the end, or in other words; 576→5760→5,760 m estimated (this could have been 5757 m or 5762 m for example). Contours are constructed at 60 m or 6 dm intervals. There is no set height to begin contouring.

Temperature is contoured in the same manner as 850 mb and 700 mb with the base value likely beginning well below 0°C during the winter. 0°C is more realistic as a base value during the summer. Refer to Fig. 7 for an illustration.

Typically, dewpoint is not practical to contour at this level. Still, temperature/dewpoint spreads are noted and these are shaded in the same manner as the 850 mb and 700 mb levels. Refer to Fig. 8. for more details.

To understand the magnitude of the flow field present, wind speeds are also contoured/ shaded in at this level. For an area bearing 35 kts or greater, the perimeter is outlined in a very light blue contour. Within this area, a region bearing 50 kts or greater is shaded in a darker blue while 75 kts is shaded in at yet an even darker blue. From here, the shaded in areas are contoured in at 25 kt intervals. If the blue shaded colors run out, it is conventional to resort to lighter yellow colors and move towards the red portion of the color spectrum. To develop a neat wind contoured chart, it would be strategic to look for regions of the strongest flow and contour your way outward. After these contours are finalized, the respective regions can be colored in, starting with the inward most contours (to avoid redundancy of coloring the same region twice and keeping the analysis neat and orderly). Be aware to not contour/shade area based off of one station measurement alone (as was mention in Rule 2 at the beginning of this manual). Refer to Fig. 9. as an example.

300 mb:

300 mb is a level often consulted to analyze the characteristics of the jet stream and the associated features (such as jet streaks for example). As such, mainly heights and winds are contoured at this level.

The 300 mb level is often located between 9000m and 12000 m from the surface. When the heights are on the lower end of the spectrum (below 10,000 m), then the height is labeled with the first three digits, or in other words; 915→9150→9,150m. For values that are 10,000 m or greater, a one is added as the first digit and a zero as the last digit, or in terms of notation, 142→11420→11,420 m. Heights are contoured approximately every 12 decameters. Refer to fig. 10 for example.

Note: The jet stream is located on the tropopause. Since the tropopause tends to be higher in the mid-latitudes during the summer and lower during the winter, we tend to evaluate the jet stream at 200 mb (summer) and 300 mb (winter) respectively. Often, the 250 mb map is consulted during the equinox transition periods. Still, the same rules apply. In either case, since the tropopause does not lie on a pressure surface, some portions of the pressure surface will lie in the upper troposphere while others in the lower stratosphere; use caution when interpreting data on these levels.

The wind fields are analyzed very much the same way as they are in the 500 mb layer (refer to that section for the details). The main difference (in an operational sense) is that 300 mb is often contoured with just the height and wind fields while winds tend to be more optional at the 500 mb level. In addition, wind speeds are typically much stronger at 300 mb then the 500 mb levels. Refer to Fig. 10 for an example of a complete 300 mb analysis.

Note: On occasion, a meteorologist may wish to show T/Td depressions (as in the previous upper-air maps) to show areas of cloud cover (such as an overhead cirrus deck). Although these are not often important, they can matter in cases of severe weather days, where a cirrus deck may hold daytime highs a degree or two below the convective temperature, thus eliminating convective chances for what could have been an outbreak.

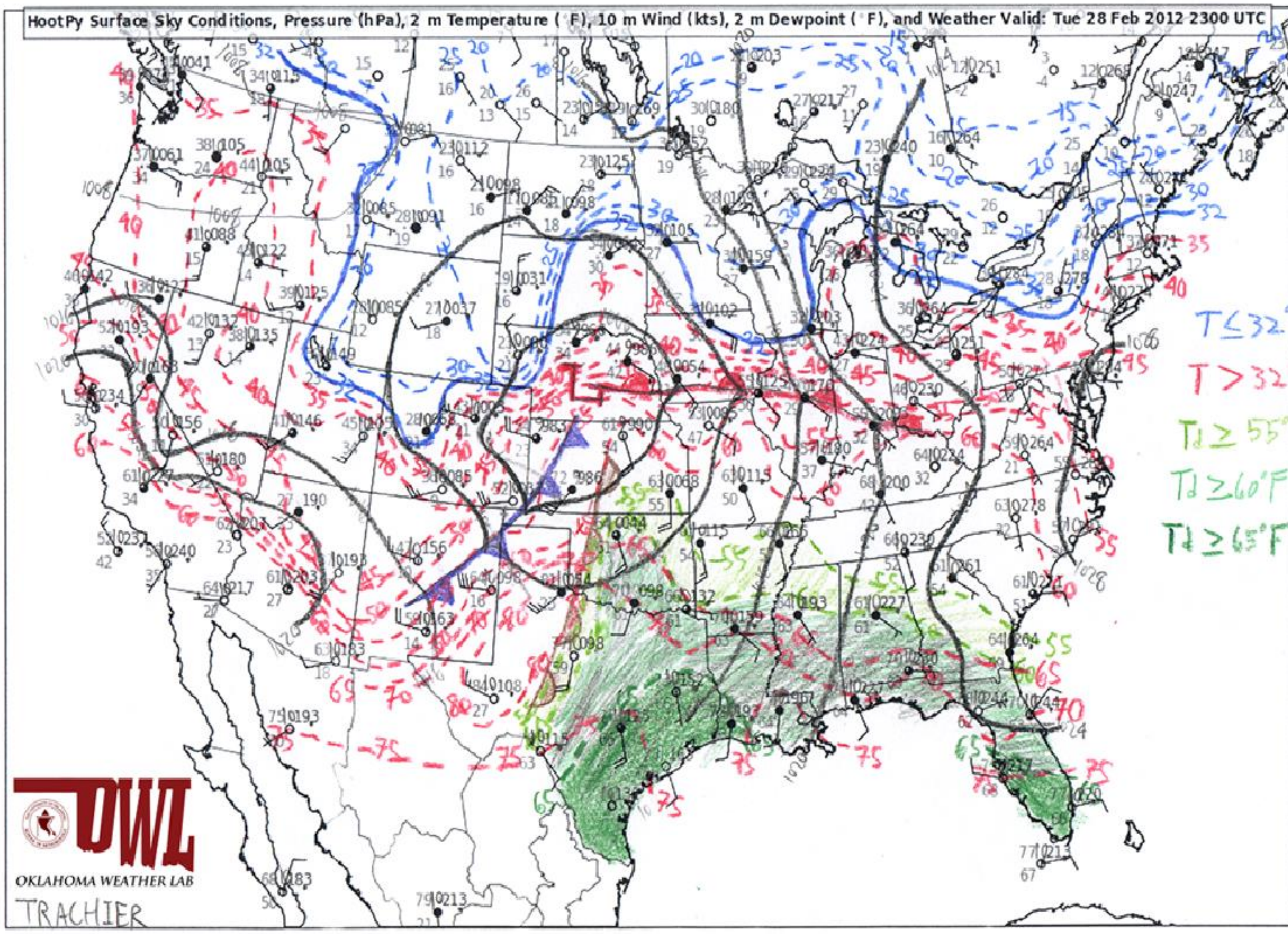

Figure 3: Surface Hand Analysis constructed with pressure contours in mb (black solid contours), temperature contours in degrees F (T) in dashed red (T>32°F), solid blue contour (T=32°F), blue dashed contours (T≤ 32°F), Dewpoints (Td >55°F) at 5 degree intervals, Td≥55°F Shaded light green, Td≥60°F shaded medium green, Td≥65°F shaded dark green, Low Pressure Cyclone delineated with capital 'L' with defined warm front, cold front and dryline. Map constructed by OU undergraduate Bryan Trachier and sponsored by the Oklahoma Weather Lab. All hand analysis is considered subjective.

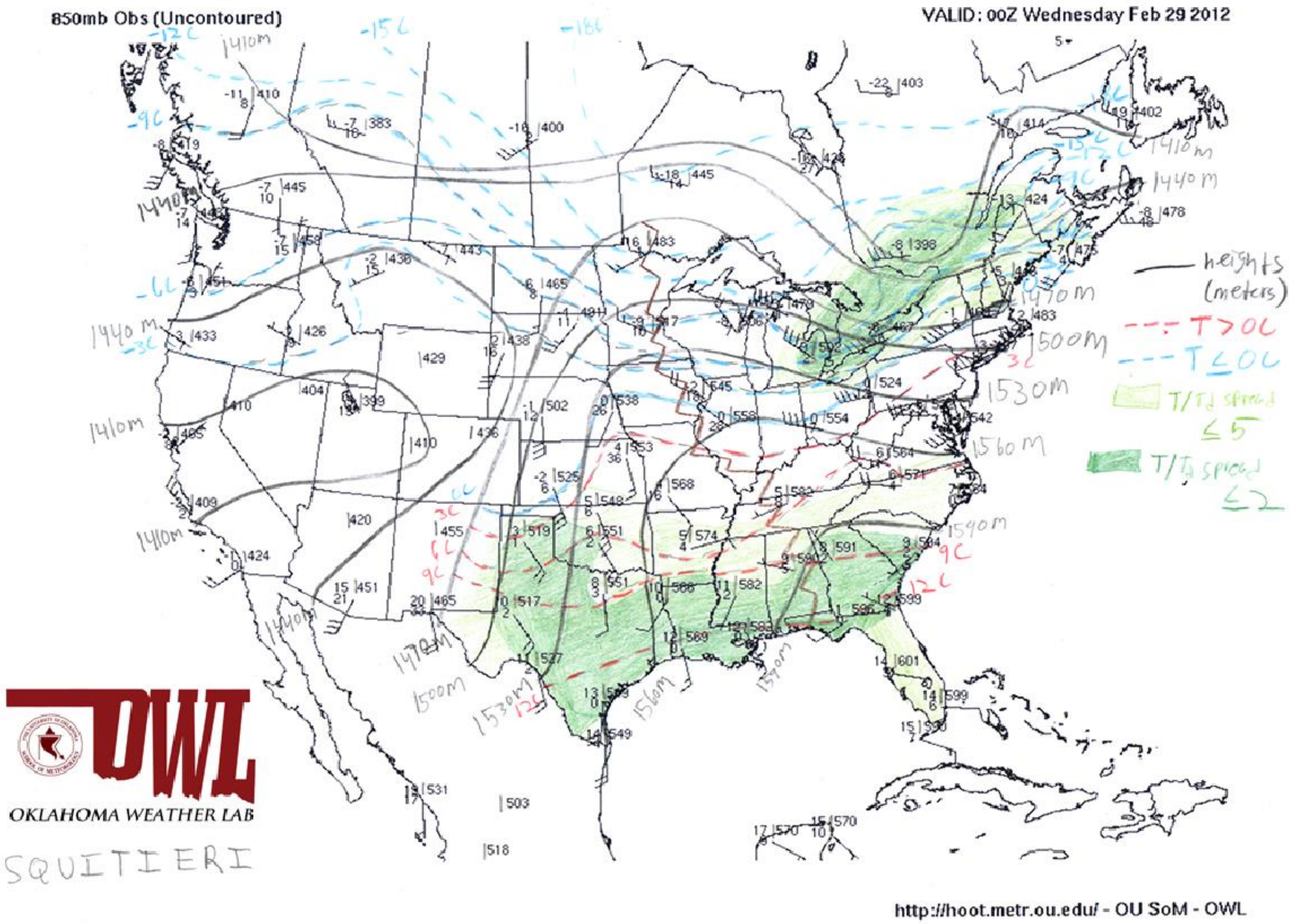

Figure 4: 850 mb Hand Analysis (with T/Td Spread) constructed with Height contours in meters (black solid contours), temperature contours in degrees C (T) in dashed red (T>0ºC), solid blue contour (T=0ºC), blue dashed contours (T≤ 0ºC), Temperature/Dewpoint depressions (T/Td ≤5 Shaded light green and T/Td ≤2 shaded dark green), Ridge axis approximated by brown dashed line. Map constructed by OU undergraduate Brian Squitieri and sponsored by the Oklahoma Weather Lab. All hand analysis is considered subjective.

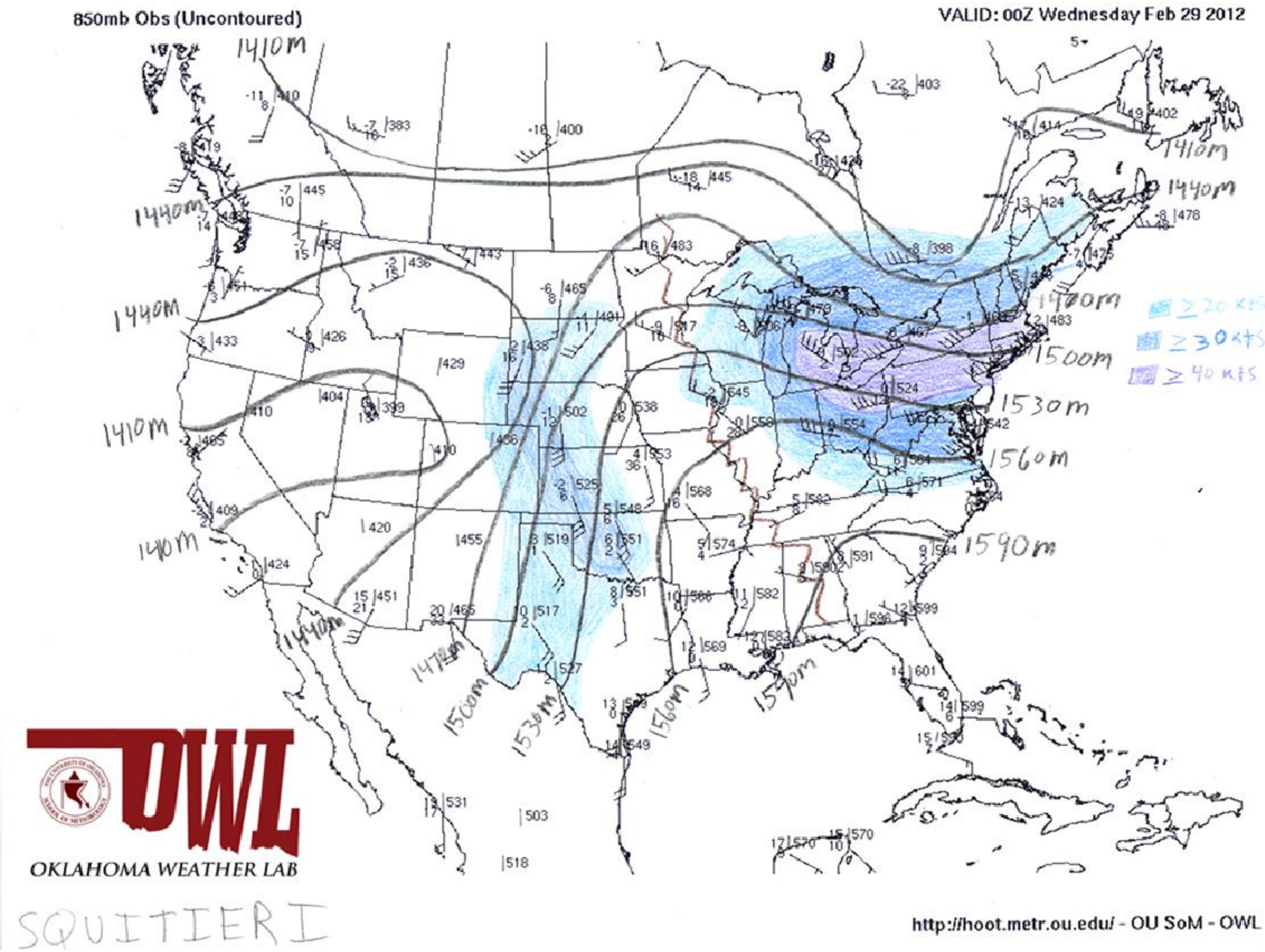

Figure 5: 850 mb Hand Analysis (with winds) constructed with Height contours in meters (black solid contours), winds ≥20 kts shaded in light blue, winds ≥30 kts shaded in medium blue, winds ≥ 40 kts shaded in purple. Ridge axis approximated by brown dashed line. Map constructed by OU undergraduate Brian Squitieri and sponsored by the Oklahoma Weather Lab. All hand analysis is considered subjective.

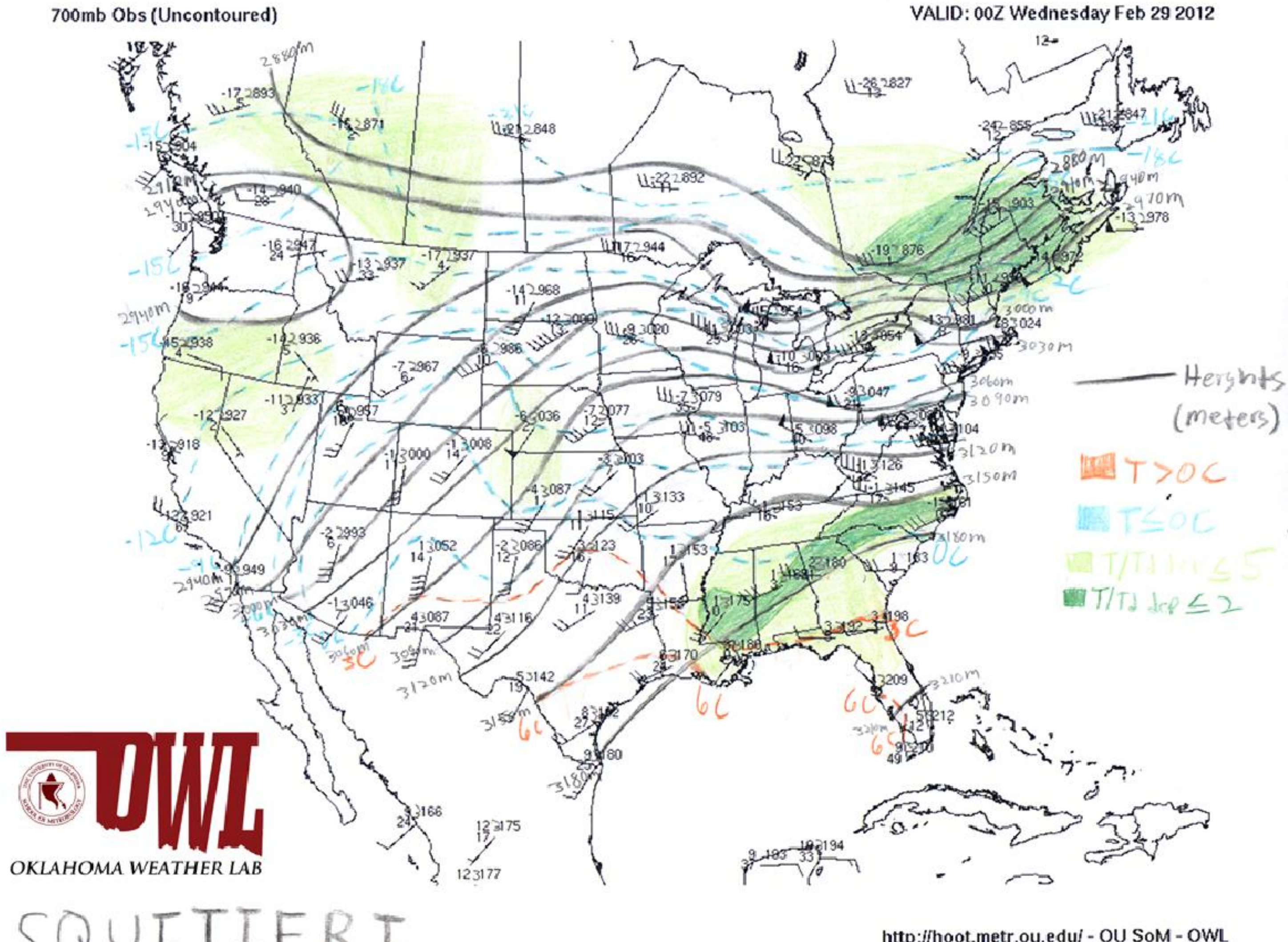

Figure 6: 700 mb Hand Analysis constructed with Height contours in meters (black solid contours), temperature contours in degrees C (T) in dashed red (T>0°C), solid blue contour (T=0°C), blue dashed contours (T≤ 0°C), Temperature/Dewpoint depressions (T/Td ≤5 Shaded light green and T/Td ≤2 shaded dark green), Ridge axis approximated by brown dashed line. Map constructed by OU undergraduate Brian Squitieri and sponsored by the Oklahoma Weather Lab. All hand analysis is considered subjective.

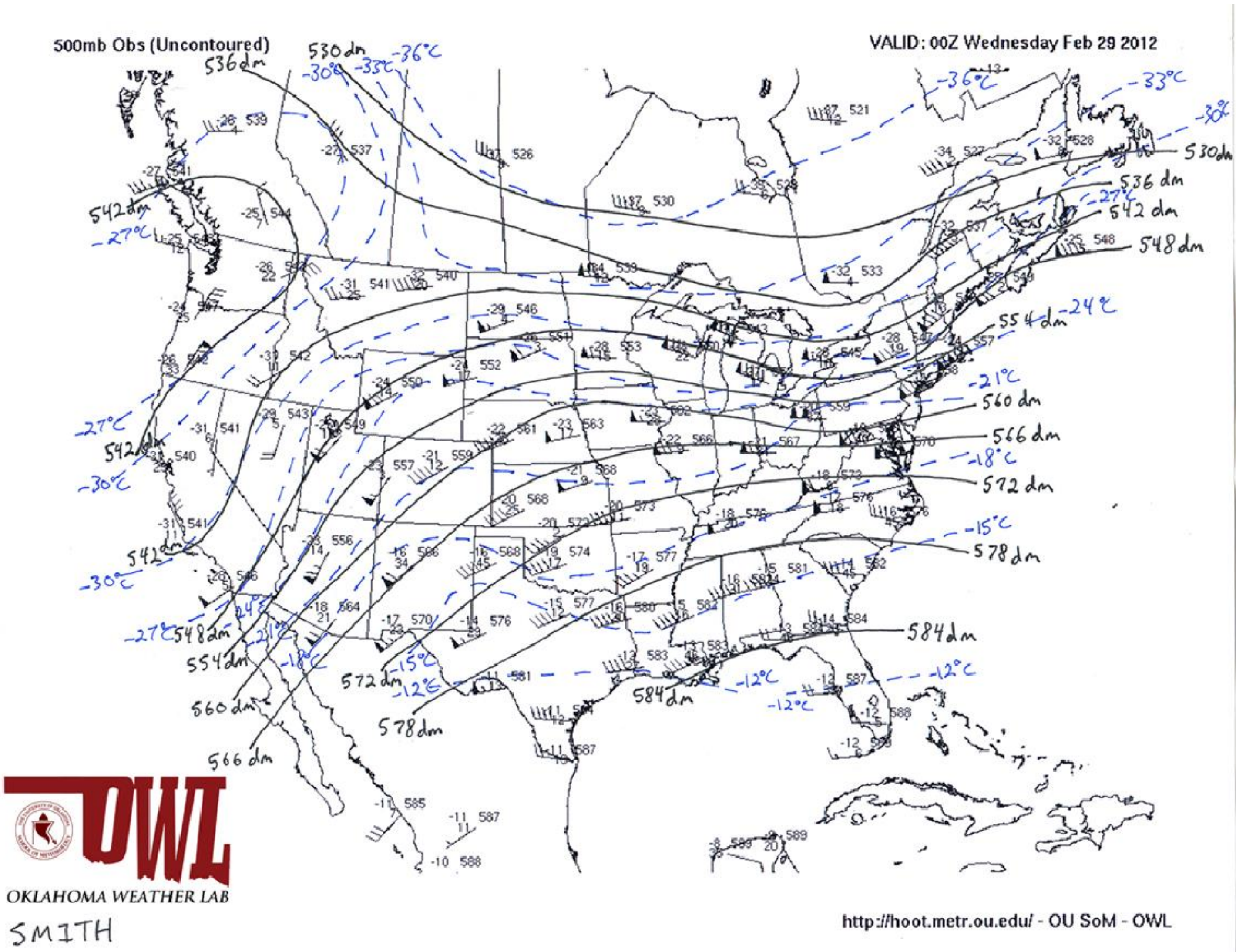

Figure 7: 500 mb Hand Analysis constructed with Height contours in meters (black solid contours), temperature contours in degrees C (T) in blue dashed contours (T≤ 0°C). Map constructed by OU undergraduate Brandon Smith and sponsored by the Oklahoma Weather Lab. All hand analysis is considered subjective.

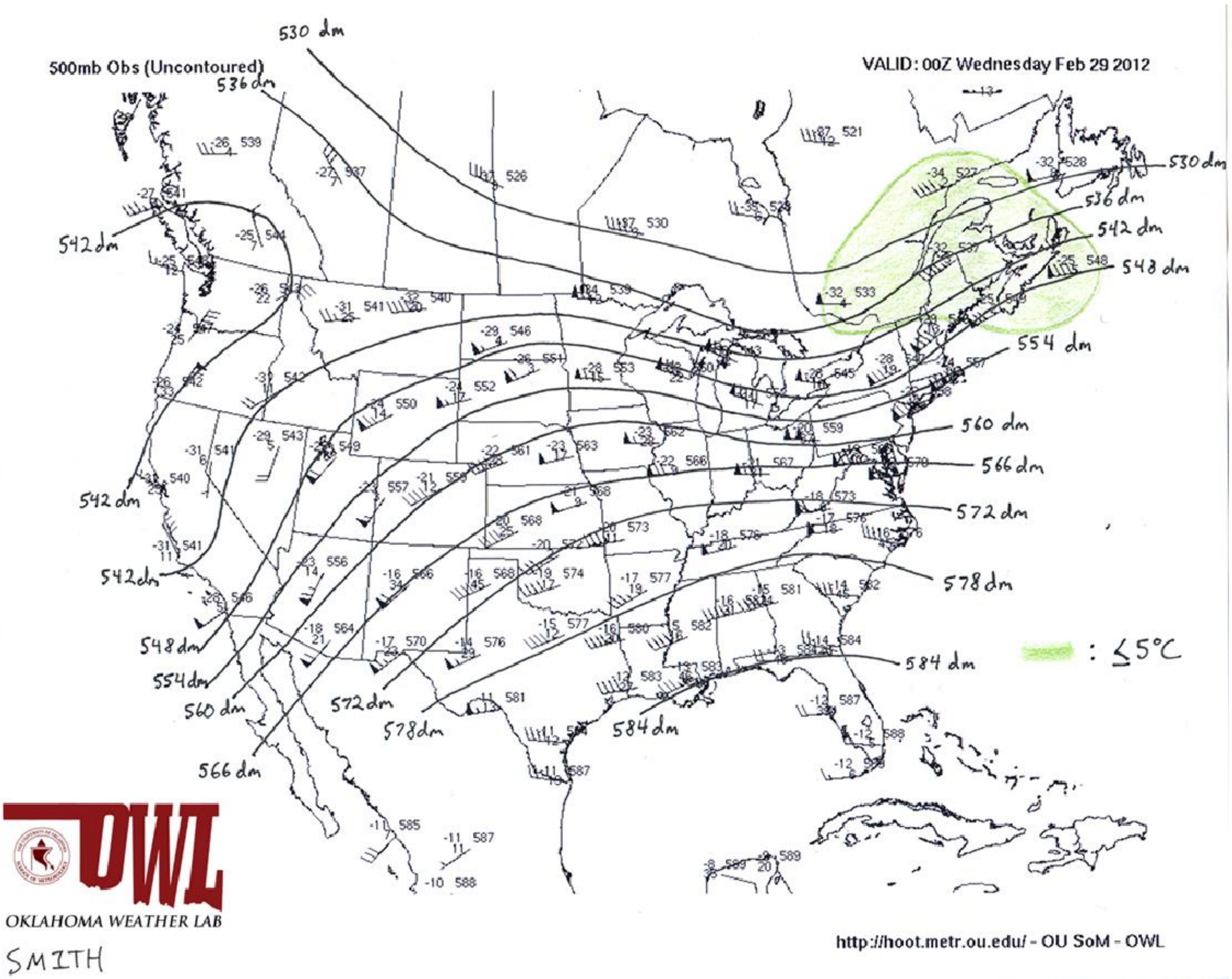

Figure 8: 500 mb Hand Analysis constructed with Height contours in meters (black solid contours), Temperature/Dewpoint depressions in degrees C (T/Td ≤5 Shaded light green and T/Td ≤2 shaded dark green), Map constructed by OU undergraduate Brandon Smith and sponsored by the Oklahoma Weather Lab. All hand analysis is considered subjective.

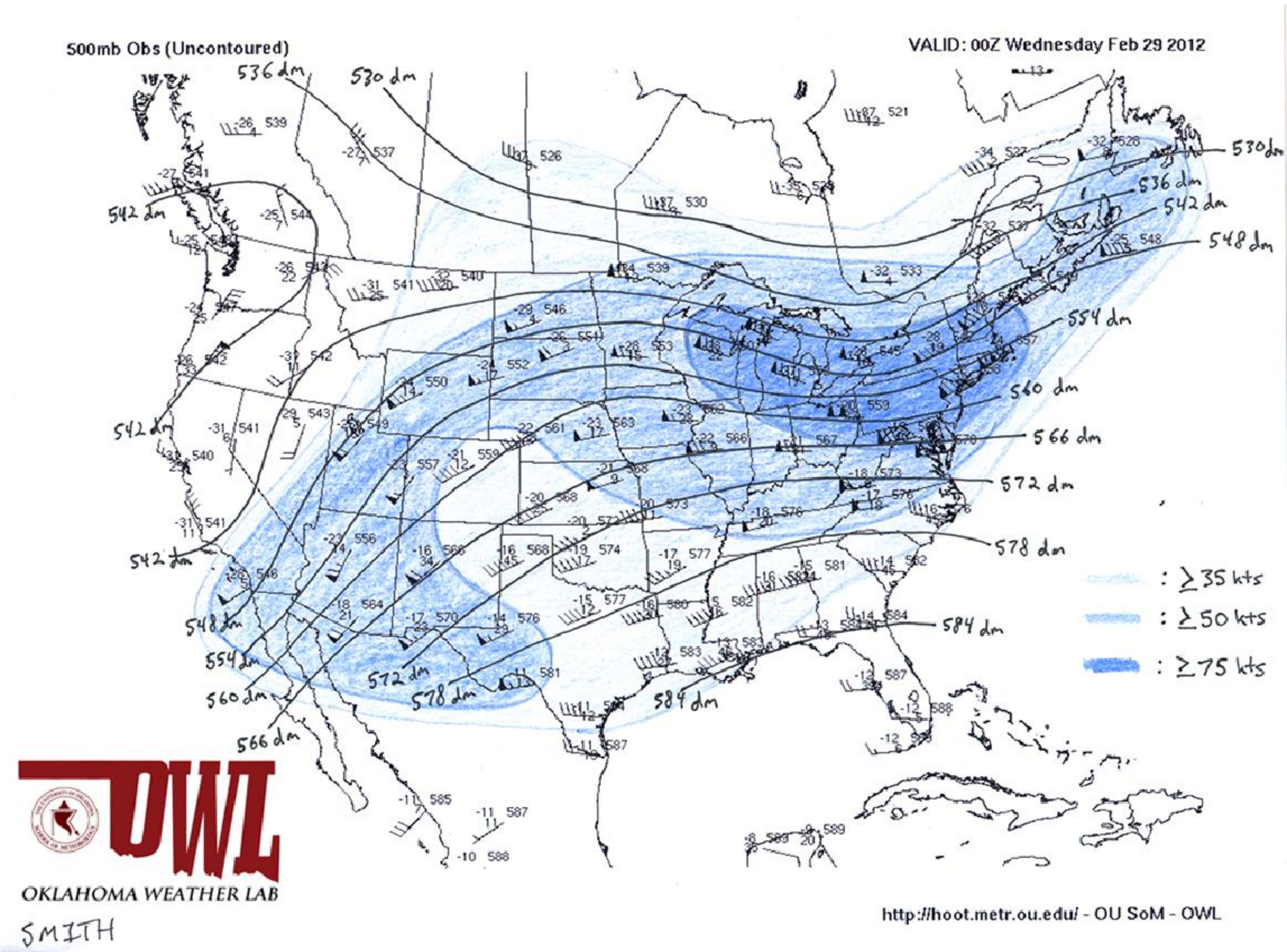

Figure 9: 500 mb Hand Analysis (with winds) constructed with Height contours in meters (black solid contours), winds ≥35 kts shaded in light blue, winds ≥50 kts shaded in medium blue, winds ≥ 75 kts shaded in dark blue. Map constructed by OU undergraduate Brandon Smith and sponsored by the Oklahoma Weather Lab. All hand analysis is considered subjective.

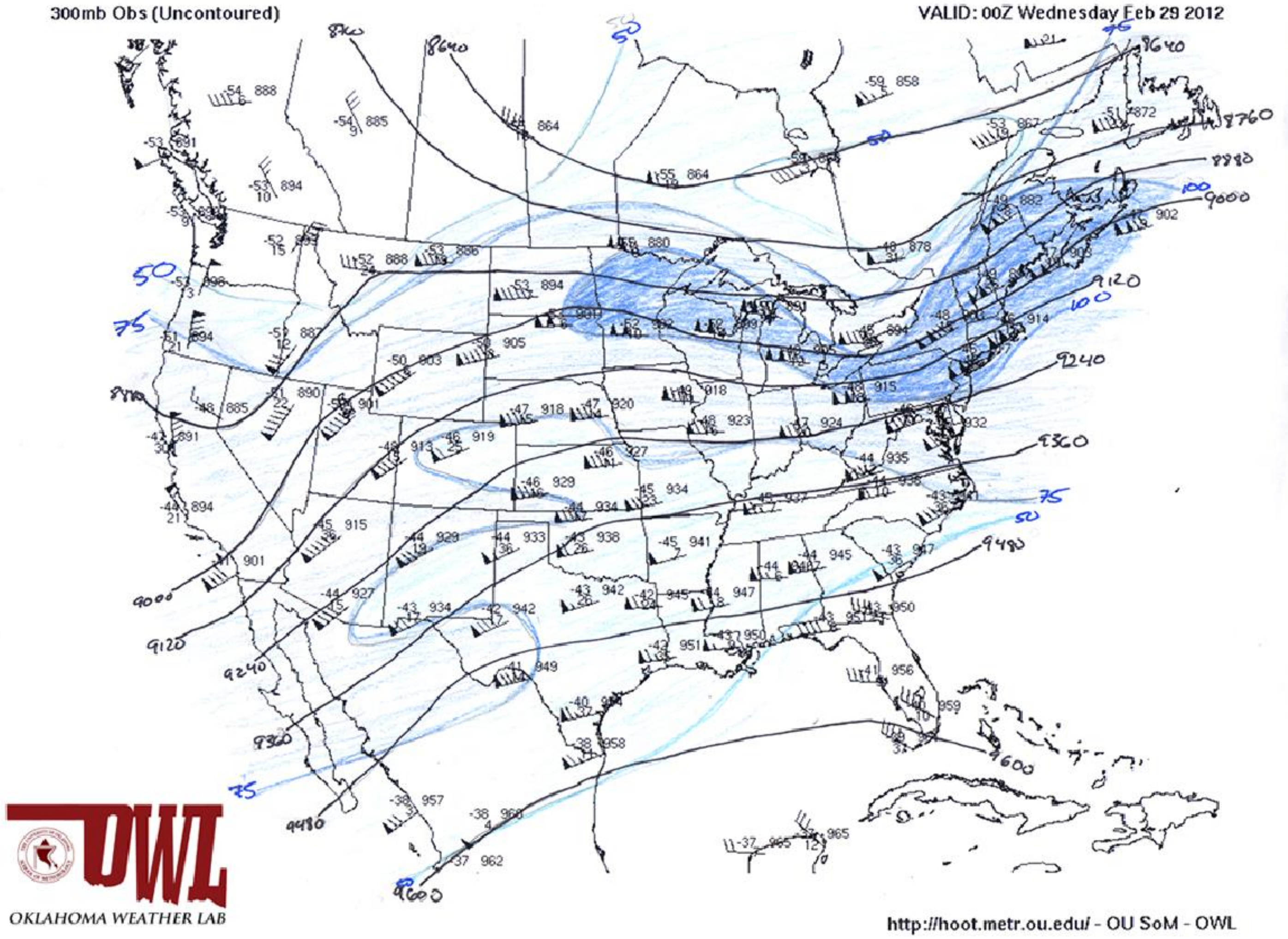

Figure 10: 300 mb Hand Analysis (with winds) constructed with Height contours in meters (black solid contours), winds ≥50 kts shaded in light blue, winds ≥75 kts shaded in medium blue, winds ≥ 100 kts shaded in dark blue. Map constructed by OU undergraduate Autumn Losey and sponsored by the Oklahoma Weather Lab. All hand analysis is considered subjective.