Investigation of the August 7th, 1997 Severe Weather Outbreak in the Desert Southwest

NICOLAS W. LIEN

Department of Atmospheric and Oceanic Sciences, The University of Wisconsin, Madison, Wisconsin

13 May 2007

ABSTRACT

The summer Arizona monsoon season brings with it many elements of change to the state of Arizona. Two of the most significant changes include a wind direction shift from northerly/northwesterly winds to southerly/southeasterly winds, and a shift from dry air advected towards Arizona from parts of Utah and Nevada to moist air off the Gulf of California and the Pacific Ocean. The summertime also brings with it significantly hotter temperatures to the Mojave desert in Arizona, California and Nevada, in turn helping to produce a stagnant surface low-pressure system coincident over the Mojave desert. With the topography obviously remaining the same from season to season, if not century to century, all the ingredients were in place on August 7th, 1997 for a severe convective event to take place. Orographic storm dynamics, coupled with flash flood dynamics helped to make event one of the most impressive storms in the desert southwest during the past decade. This investigation will investigate the means of how the event got started, and the subsequent development of the storm, to help ensure that future damage, if this storm were to be repeated again, wound not be as severe as this one was.

I. Introduction

Between August 7th and August 8th, 1997, two specific episodes of severe weather took place in the Southwestern United States, specifically in Mohave and Yavapai Counties in Arizona, with each taking place identically at around 20Z (3PM MST) and lasting for around 4-5 hours, until around 01Z of the next day (8PM). Episodes of flash flooding, alongside thunderstorm-like winds, and gusts helped to drive the severe weather event. This storm was not specifically in an isolated area: it spanned from much of southern Mohave County towards Yavapai County, a distance of around 200km. Until the precipitation cells jointed together, the storm was spread throughout a significantly large area. Despite an estimated $88,000 worth of damage attributed to the storm alongside 1.75” hail being reported at some locations, the storm reportedly only caused minor damages in the aforementioned counties of Arizona, as most of the areas affected were rural and less inhabited than the major cities in Arizona.

This case study is most interested in studying the specific weather outbreak which occurred between 21Z August 7th, 1997 and 00Z August 8th, 1997. Synoptically, there were not any obvious reasons as to why the severe weather event took place at all. However, when considering the climatology and the topography of Arizona, many clues were gathered as to the mechanisms of the storm. Climatologically speaking, the Arizona monsoon helped to aid the passageway of moisture from the Pacific Ocean and the Gulf of California as a result of the surface low-pressure system centered over the Mojave Desert, and the wind shift associated with the monsoon. Topography aided in the development of the convective cloud. The storms were coincident with the Mogollon Rim, which helped to concentrate rains in a specific location for a significant period of time, a phenomenon known as flash flooding. Flash flooding occurs mostly in convective orographic precipitation events, concentrating all the rain and subsequently, the run-off into a specific area just to the east of the Mogollon Rim. With this, severe weather was brought to Arizona on these two isolated days. While Arizona is generally not an area associated with severe weather, all these factors played into a reason for this notable storm took place in 1997.

II. Data

Data for this case study was obtained from a variety of sources. In investigating the synoptics of this weather outbreak, plots from the GEMPAK program GDPLOT was used to diagnose the relative humidity, surface frontogenesis and mean sea level pressure. The gridded data used for this study were the 00Z August 7th, 1997, 12Z August 7th, 1997 and the 00Z August 8th, 1997 files. These variables were often presented in a four-panel plot. The top left plot was a plot of the 00Z August 7th, 1997 6-h forecast, the top plot was a plot of the 12Z August 7th, 1997 analysis, the bottom left plot was a plot of the 12Z August 7th, 1997 6-h forecast, and the bottom right plot was a plot of the 00Z August 8th, 1997 analysis. Additionally, a graphical user interface named GARP was used to investigate satellite and radar data further, from around 20Z August 7th, 1997 to 00Z August 8th, 1997. The satellite data used was derived from the 6.5-micron visible band of the West-Geostationary Orbiting Environmental Satellite #8 (GOES-8 WEST), and the radar data was derived from Weather System Incorporated's next-generation radar (NOWRAD), at base reflectivity, under both clear air and precipitation mode. The radar images were zoomed into the desert southwest, towards Arizona specifically.

In investigating the mesoscale features, the GEMPAK program GDCROSS was used in order to determine theta-e and upward vertical motions. In addition to the computer-generated images, hand-drawn figures were also utilized. These hand-drawn figures included a conceptual model of orographic cloud formation (and subsequently, thunderstorm formation) through orographic lifting, a cross-section of theta-e values at 18Z August 8th, 1997 (contoured every 6K), and surface and steering level streamlines over the southwestern United States from 00Z August 8th, 1997. Additionally, atmospheric vertical soundings were obtained from the University of Wyoming's Department of Atmospheric Sciences. These atmospheric soundings were taken from Flagstaff, AZ at 12Z August 7th, 1999 and 00Z August 8th, 1999.

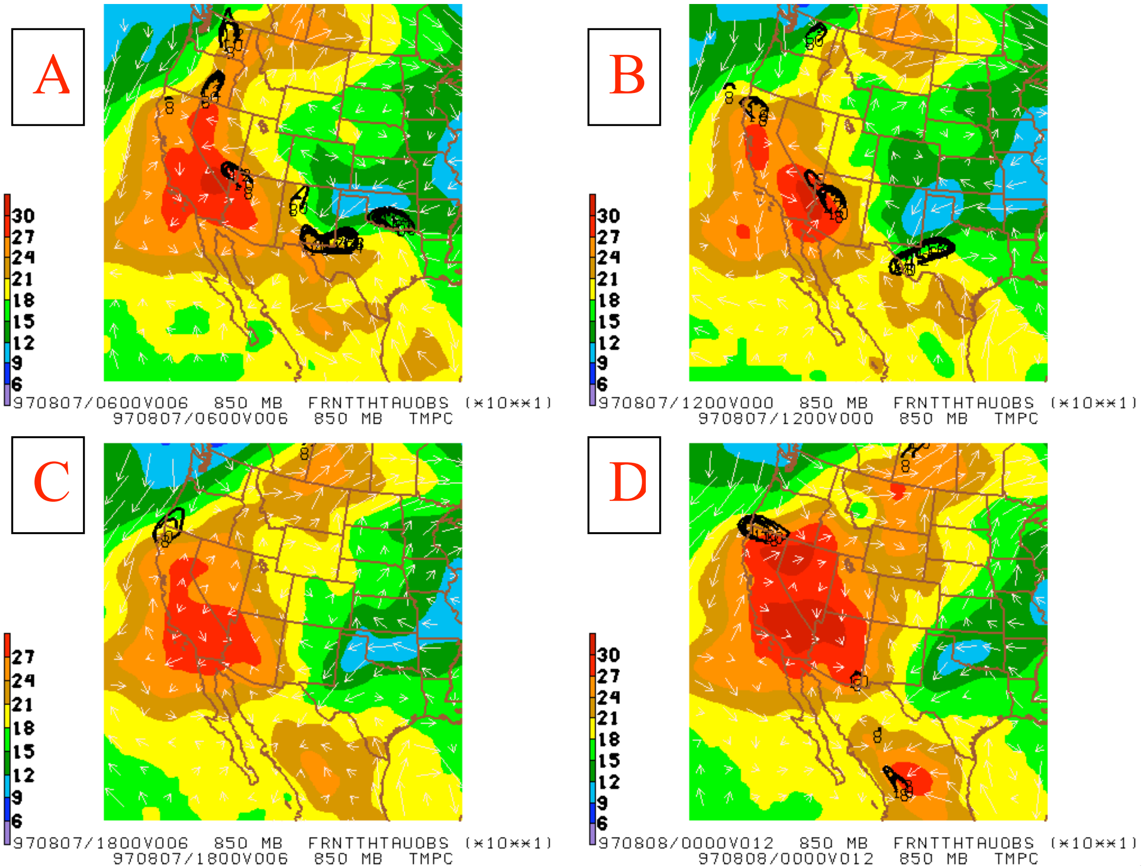

Figure 1. 850mb winds arrows (knots) and temperatures (contoured every 3C) from (a) 06Z August 7th, 1997, (b) 12Z August 7th, 1997, (c) 18Z August 7th, 1997, and (d) 00Z August 8th, 1997.

Finally, a few other sources were utilized in attempting to understand the breath of the weather event. Attempting to uncover and assess the damages brought on by the storm, data from the University Corporation for Atmospheric Research (UCAR) was used. This source was used only because archived storm reports from the National Oceanic and Atmospheric Administration's (NOAA) Storm Prediction Center (SPC) were not available past 1999, and even archived newspaper articles, or online articles regarding the storm were also not available. Background regarding the Arizona Monsoon was also gathered from the Department of Geography at Arizona State University in Tempe, AZ, alongside various journal articles from Thomas Adang and Robert Gall from the Department of Atmospheric Sciences at the University of Arizona at Tucson.

III. Synoptic Overview

The synoptics for this entire weather event were minimal and lacking, and relatively inconsequential. There was a small pocket of surface frontogenesis present around parts of Arizona during the morning hours of August 7th, and associated with this, a slight baroclinic zone oriented in a northwesterly fashion over much of northeastern Arizona was also present. Other than this, there was no foreseeable reason for why the flash floods occurred on the synoptic level.

a) Influence surface frontogenesis

Surface frontogenesis played a very minimal role in the storm, but nonetheless, should be discussed. FIG. 1 is four-panel plot of 850mb temperatures (shaded) and frontogenesis (contoured). At 06Z August 7th (FIG. 1a), a baroclinic zone was present over much of northwestern Arizona, and associated within the presence of the baroclinic zone was a sign of surface frontogenesis. 6 hours later, at 12Z August 7th (FIG. 1b), the baroclinic zone strengthened, and the associated surface frontogenesis also strengthened at this time. However, the upward vertical motions did not lead to anything at this time, and 6 hours later, at 18Z (FIG. 1c), the baroclinic zone weakened significantly, and no surface frontogenesis was observed. Finally, at 00Z August 8th (FIG. 1d), the baroclinic zone further weakened, and no associated frontogenesis was witnessed at this time, coincident with when much of the flash floods occurred.

While it is relatively evident that no upward vertical motions arose as a result of frontogenesis, it just goes to show that this was the closest variable which may have impacted and aided the severe weather, on a synoptic level. More importantly about these plots, however was the fact could be seen coming up from the moisture sources of the Pacific Ocean and the Gulf of California. This will be talked about later in this study. With no other variables present, such as a 300-mb jet or any sign of a vorticity maximum, much of the storm could be attributed the Arizona monsoon on a more climatological level.

IV. Climatological Overview

Knowledge of the Arizona monsoon would prove to be critical for this study. Without the annual nature of the Arizona monsoon and associated with it, the wind shift regime, severe weather in Arizona would never be possible, rendering this case useless. Thus, its importance must be quantified in this climatological overview, geared towards the monsoon.

a) Influence of the Arizona Monsoon

The Arizona Monsoon is a yearly event, marked by a windshift between the winter and summer seasons. Typically, monsoon like conditions are defined as three consecutive days of 55F dew points or higher, occurring exclusively during the summertime. During the wintertime, winds usually come out of the west and northwest towards Arizona. These winds arrive over the Death Valley National Park and the Mojave Deserts, bringing extremely dry and humid air into much of Arizona. The summertime is marked by more southerlies and southeasterly winds, which arrive in Arizona over the Pacific Ocean, the Gulf of California and the Gulf of Mexico, helping to bring drastically moister air into much of Arizona during the summertime, hence the source of moisture for the consecutive days with 55F dew points. Also during the summertime, the waters of the Pacific Ocean, the Gulf of California and the Gulf of Mexico are generally warmer also, aiding in the severe weather in Arizona. The warmer waters of the Gulf of California, the Gulf of Mexico and the Pacific Ocean is important for the shear fact that with increased sea surface temperatures, there is a greater capacity to hold the water vapor supplied by the bodies of water. The warmer temperatures also led to lower stabilities also. While the

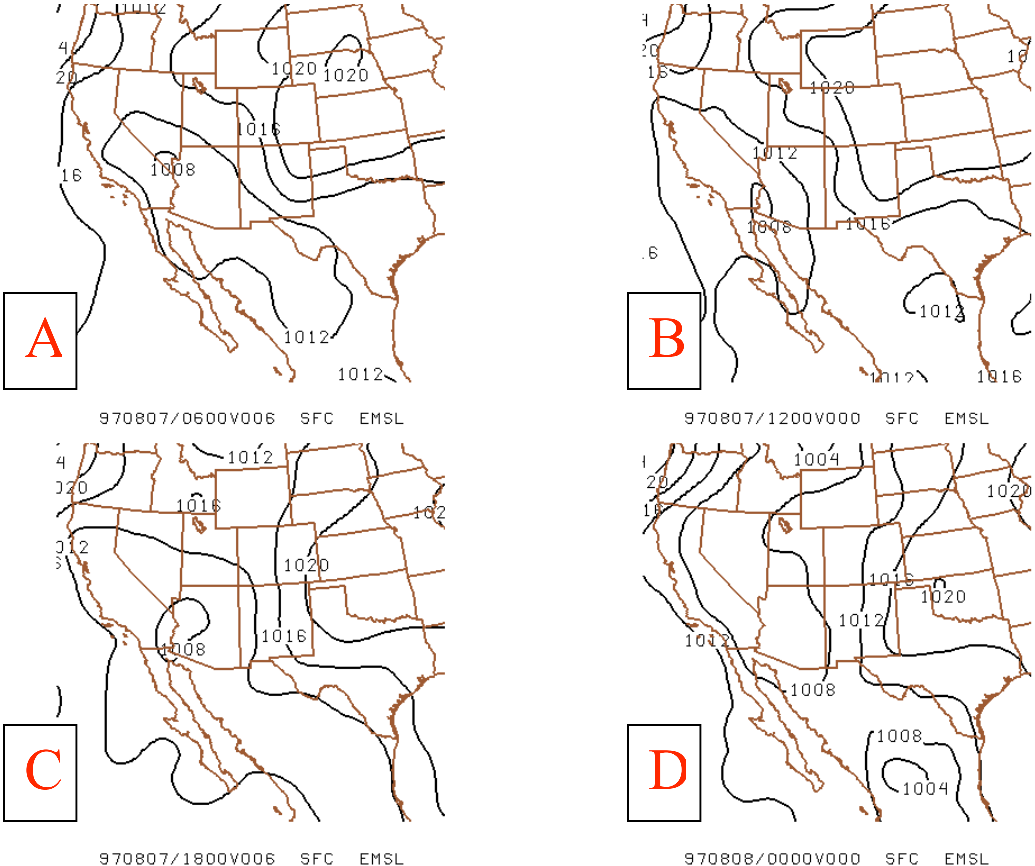

Figure 2. Mean Sea Level Pressure (contoured every 4mb) at (a) 06Z August 7th, 1997, (b) 12Z August 7th, 1997, (c) 18Z August 7th, 1997 and (d) 00Z August 8th, 1997.

exact source of moisture for the Arizona monsoon is not yet known, these three areas are believed to be the main sources. The increased moisture during the summertime in much of the desert southwest is a major reason why thunderstorms and significant amounts of severe weather occur in Arizona during this time of the year. (Cerveny, 1996)

There are a few reasons for the wind shift helping to aid the Arizona Monsoon. The first reason stems from the northward movement of high-pressure cells, referred to often as the Bermuda High or the Azores High. Alongside this, heating of the extremely hot Mojave Desert in the northwestern quadrant of Arizona leads to rising air, leading to a low-pressure system coincident and stagnant over the Mojave Desert. In terms of the case being studied, figure 2 shows the mean sea level pressure at four different times. Its significance is the sheer fact that the surface low-pressure remained coincident somewhere over the Mojave Desert throughout the event, helping to continuously bring moisture towards Arizona from the moisture sources in a cyclonic motion. The intense surface heating which helps to aid the stagnant low-pressure system in the Mojave Desert leads to the convective nature of thunderstorms in the desert southwest. (Cerveny, 1996)

The importance of the Arizona Monsoon cannot be overstated enough. By considering solely the 700mb map of relative humidity and surface winds (FIG. 3), it can be clearly seen that the summer

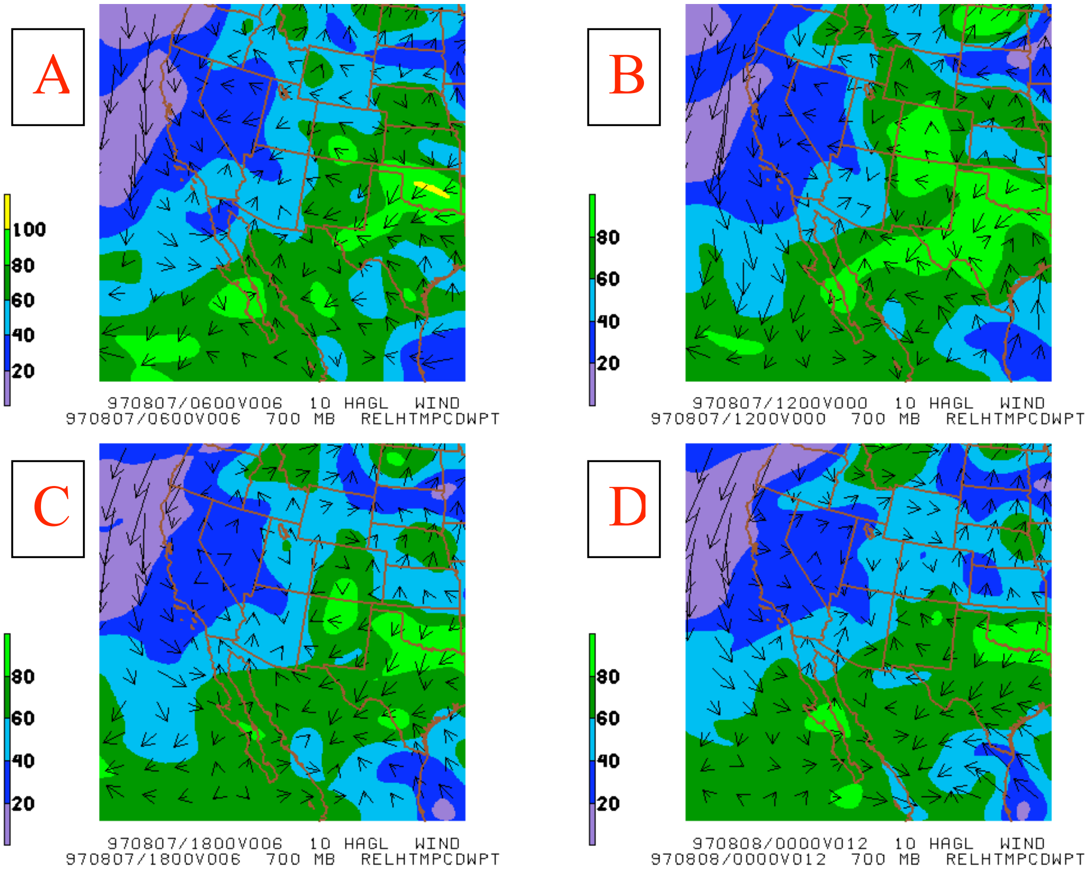

Figure 3. Relative humidity (contoured every 20%) and 700mb winds (arrows) from (a) 06Z August 7th, 1997, (b) 12Z August 7th, 1997, (c) 18Z August 7th, 1997 and (d) 00Z August 8th, 1997.

season for much of Arizona turns into a very moist area. Dewpoints were around 60F for the case in question, with winds at the surface coming in from the Pacific Ocean and the Gulf of California. This was one of the elements necessary for this strong and intense convective event to take place.

V. Geography

Before the mesoscale variables can be discussed and elaborated on, the geography of Arizona will be briefly touched on. The topographical map of Arizona shown in figure 4a shows an area in northeastern Arizona which is covered by moderately high elevations. This area is the Colorado Plateau. The province is coincident over parts of four states: Utah, Colorado, Arizona and New Mexico, the so-called 'Four Corners' region of the United States, stretching for over 130,000 miles. Areas surrounding the Colorado Plateau are named escarpments, delineating a transition zone between two varying physiogeographic regions. The Colorado Plateau itself has six distinct escarpments, stretching around the entire plateau. The escarpment that this case study will be most concerned with is the Mogollon Rim. The Mogollon Rim stretches upslope from southwestern Arizona towards southern Yavapai County (FIG. 4b), where the Colorado Plateau meets it. It stretches for over 200 miles long, from Yavapai County towards the south-central border of New Mexico. The

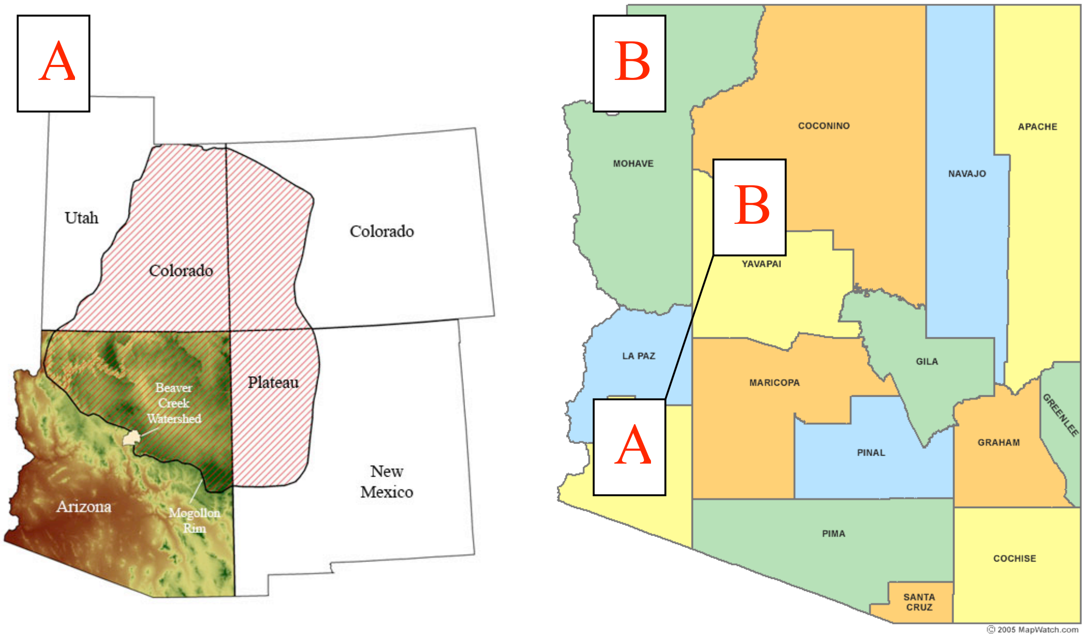

Figure 4. (a) Map of the four corners region of the United States, with the Mogollon Ridge shown in central Arizona. (b) Map of the counties of Arizona. Mohave and Yavapai Counties are in the top right-hand corner of the state, the green and yellow shaded regions, respectively. Photos courtesy of beavercreek.nau.edu and www.mapwatch.com, respectively.

Mogollon Rim is the transition zone spanning anywhere from 4000-5000ft above sea level, dependent on location. This height will become extremely important for this case, because the height which the winds need to be traversed to reach the top of the transition region is high enough so orographic precipitation may occur.

Additionally, most of the soundings for this case study were taken from Flagstaff, Arizona, as mentioned earlier. Flagstaff is located in northern Arizona, in the midst of the Colorado Plateau, and substantially close to the Mogollon Rim. Flagstaff's importance is the fact that it is 6,910ft above sea level, rendering phenomenon such as elevated mixed layers as important. The geographical features, in general will prove to play a significant role in this case study.

VI. Mesoscale Overview

Two significant and associated mesoscale features occurred during this severe weather event, which aided not only in the development of the event, but also in its continuation. Orographic cloud formation, through orographic lifting helped to initiate and develop the cumulus cloud necessary for thunderstorm formation, and associated with the thunderstorms, flash flooding helped to concentrate the severe weather in the Mojave, Yavapai and Maricopa Counties of Arizona throughout a period of over four hours.

a) Influence of Orographic Cloud Formation through Orographic Lifting

Orographic cloud formation through orographic lifting was seen as the mechanism for the cumulus cloud formation which helped to induce the

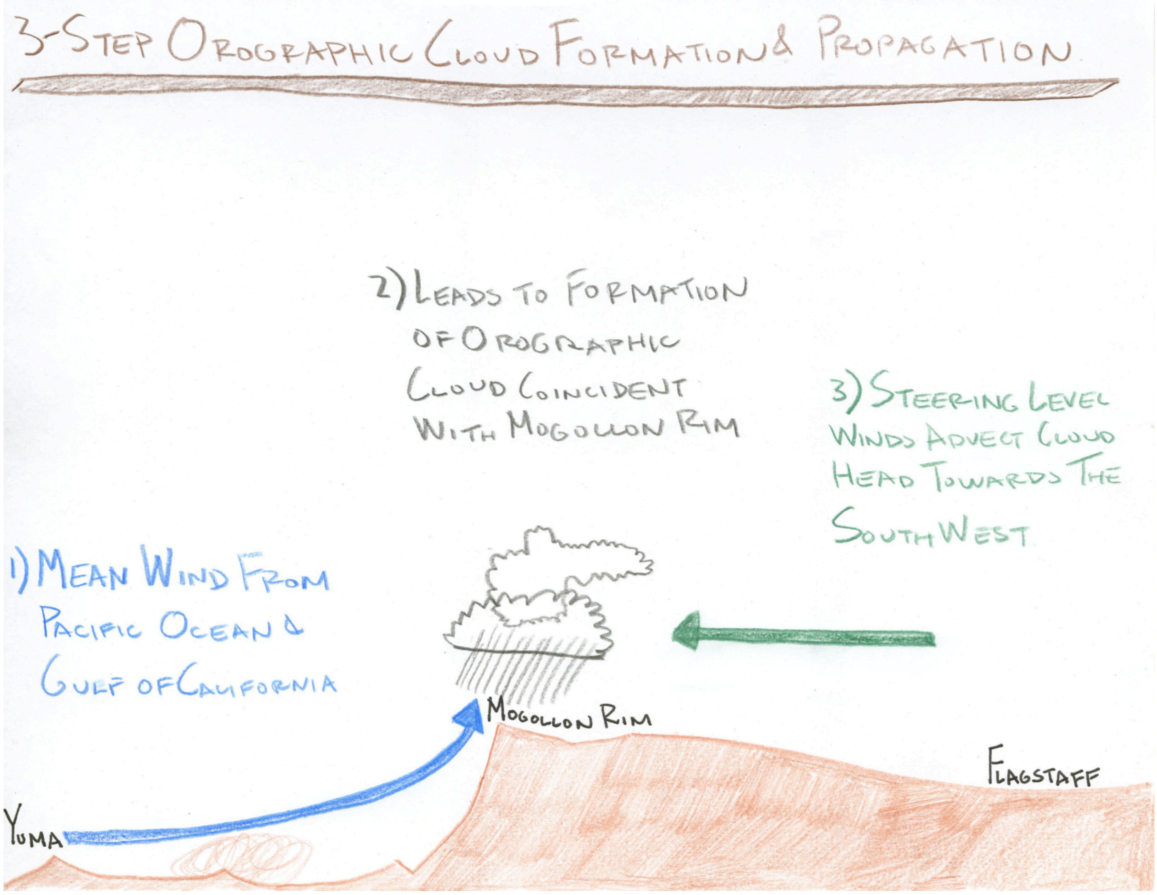

Figure 5. Hand-analyzed conceptual model cross-section from Yuma, AZ to Flagstaff, demonstrating the creation of an orographic cloud through orographic lifting.

severe weather event. When first investigating the storm, thermal forcing was thought of as the mechanism for the orographic cloud formation. Thermal forcing is the idea of upsloping convergence from both sides of a mountainous region, converging at the peak of the mountainous region, leading to an upward jet of flow, helping to initiate the orographic cloud-head necessary for convection. Further investigation, however demonstrated that this did not happen. The topography of the western boundary of the Mogollon Rim was associated with a ridge leading up towards the Colorado Plateau, seen again in the topographical map of Arizona. Winds from the southwest, thus raced up the ridge towards the peak of the Rim and the Colorado Plateau. The eastern boundary of the Mogollon Rim is characterized as being extremely flat, at an elevated level, but with this, winds off the Colorado Plateau were extremely weak southwesterly winds, missing the convergence necessary for thermal forcing. Orographic lifting only involves strong winds from the western boundary of the transition zone up, and with this present in the study of this specific weather event, this was recognized as the major reason for the orographic cloud formation.

Before assessing this specific event any further, a conceptual model will be considered first of orographic lifting. Figure 5 is a model cross-section taken from Yuma, AZ in the southeastern

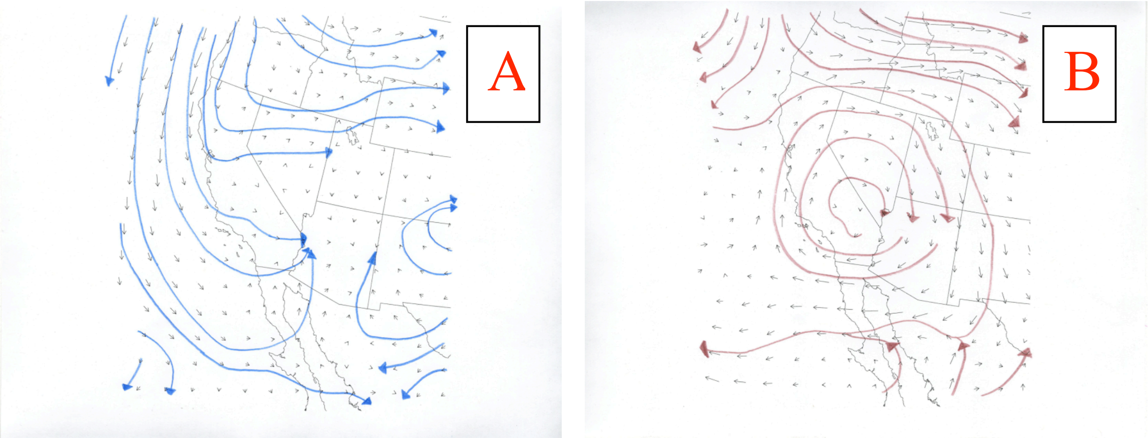

Figure 6. Streamline analysis from 18Z August 7th, 1997 at (a) 850mb and at (b) 600mb.

quadrant of the state towards Flagstaff, AZ. Substantially strong and moist winds were advected off the Gulf of California and the Pacific Ocean towards the western boundary of the Mogollon Rim because of the aforementioned Arizona monsoon and the surface low-pressure system centered over the Mohave Desert. Surface observations reported winds within the area of the surface upslope at around 5-10 knots, demonstrating that these winds sloping up the Mogollon Rim were the ones which helped to initiate the convective clouds, and subsequently, the storms. The importance of the Mogollon Rim as the transition zone cannot be stated enough, as this allowed for the upsloping air mass to meet the peak of the Mogollon Rim and form the cloud head. After upsloping occurred, an upward jet of flow was initiated, and this helped to initiate the cloud head present for much of the severe weather. The steering level of thunderstorms is around 600mb, and with southeasterly winds witnessed at this level, winds helped to steer the thunderstorm further towards the southwest, leading to increased and concentrated precipitation on the western half of the Mogollon Rim. Conceptually, this was how orographic lifting occurred in order to create the cumulus cloud necessary for severe weather.

This conceptual model can be seen in action during this weather event. Streamline hand analysis drawn at 18Z (FIG. 6a) demonstrate the cyclonic motions of the low level winds. This demonstrates the winds were being advected off the moisture sources and into Arizona at low levels, flowing towards the Mogollon Rim, and eventually hitting the rim, leading to the formation and development of the convective clouds. Similarly significant was the lack of convergence towards the Mogollon Rim. Again, this was a reason for why thermal forcings could not have occurred as the forcing for the orographic cloud's formation, as winds off Utah veered towards the east and not directly coincident on the Mogollon Rim. The satellite image from 20Z showed the beginnings of the developing cumulus cloud, and with the continued sloping winds from the moisture sources throughout much of the night, orographic lifting would help to further develop the cumulus cloud head. This will be discussed in further detail in the radar and satellite analysis section, where relation to steering level winds will also be made.

b) Radar and Satellite Analysis, in Relation to the Steering Level

Relating the event to satellite and radar images will help to further understand the severe weather event. As mentioned earlier, the satellite image from 20Z August 7th (FIG. 7a) demonstrated evidence of developing cumulus cloud heads right near the eastern edge of the Mogollon Rim. Because the storm was only at its developmental phase at this time, the radar activity (FIG. 7b) demonstrated little to no activity in the aforementioned area in terms of precipitation, as there were only clear air echoes present throughout much of Arizona and unassociated precipitation towards eastern Arizona. Evidence of the lack of an event occurring was the fact that Yuma reported 75% sky cover under clear skies during this time. However, an hour later at 21Z (FIG. 7c), the satellite started to show the beginnings of the convective event. Right along the Mogollon Rim, cumulus clouds continued in their developmental phase, now covering most of central portions of Mohave and Yavapai Counties. Associated with this, the radar (FIG. 7d) showed signs of developing cells across the Mogollon Rim coincident with the cloud heads. At this time period, the cells were relatively spare, were small in size, and relatively independent from each other, causing precipitation in separate portions of the Mohave and Yavapai Counties in Arizona. Thus, at this time, not much was occurring with the storm, as the storm was just starting to get started at this time.

Further developments of the severe weather event were witnessed an hour later, at 22Z. The satellite (FIG. 8a) demonstrated cumulus cloud heads continuing to develop over the Mogollon Rim, and increased precipitation was seen throughout much of the area through the radar (FIG. 8b), with decibel levels reaching around 50dbz for this storm, a significantly high value demonstrating the severity of the weather that hit the area. At this time also, the steering level of the cumulus cloud also started to become especially important. The steering level, the level at which winds help to drive the cumulus clouds and thereby, the severe thunderstorms, is generally thought of as anywhere between 500mb-700mb. Applying this to the severe weather event, 18Z winds at 600mb shown in figure 6b demonstrate substantially strong anti-cyclonic winds swirling literally over where the surface low was indicated earlier. These winds moving towards northwestern Arizona towards southeastern Arizona demonstrated the steering flow moving around where the cumulus clouds were located. This would eventually help to shift the cumulus clouds further towards the southwest, along with this, shifting the convection event with it. While the satellite images at this time didn’t show this unequivocally, the radar analysis showed that the cells became more organized and centered over mostly the Mohave County, and through portions of the Yavapai County. With the cells merging at this time, the precipitation increase in intensity and more concentrated at this time, with decibel levels reaching around 65 decibels in some areas, extremely high, and demonstrative of probably hail at this time. Even the cells out of the concentration area converged at this time, to form stronger precipitation at this location.

At 23Z, the satellite showed that the steering level continued to affect the cumulus cloud (FIG. 8c), leading to further convergence of the thunderstorm cells and increased frequency of the precipitation. Also, in comparison to the

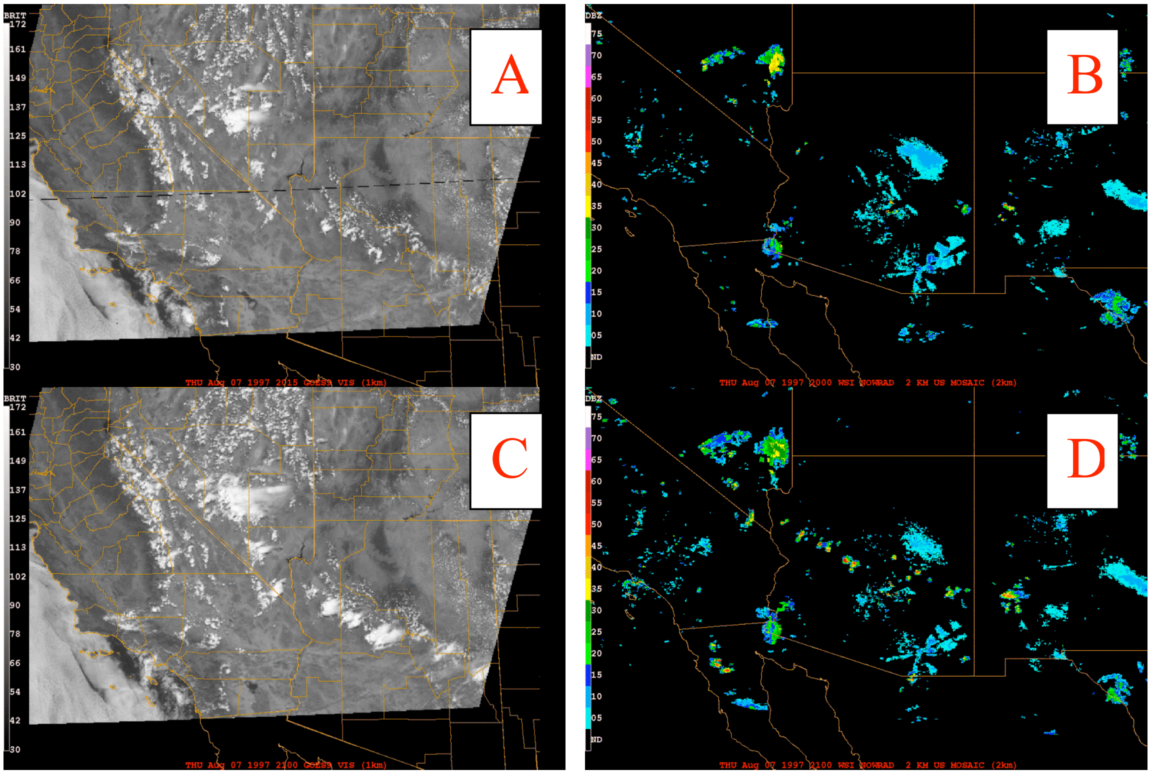

Figure 7. These images include a (a) satellite image at 2015Z and (b) radar image at 2000Z, (c) satellite image at 2100Z and (d) radar image at 2100Z, all taken from August 7th, 1997.

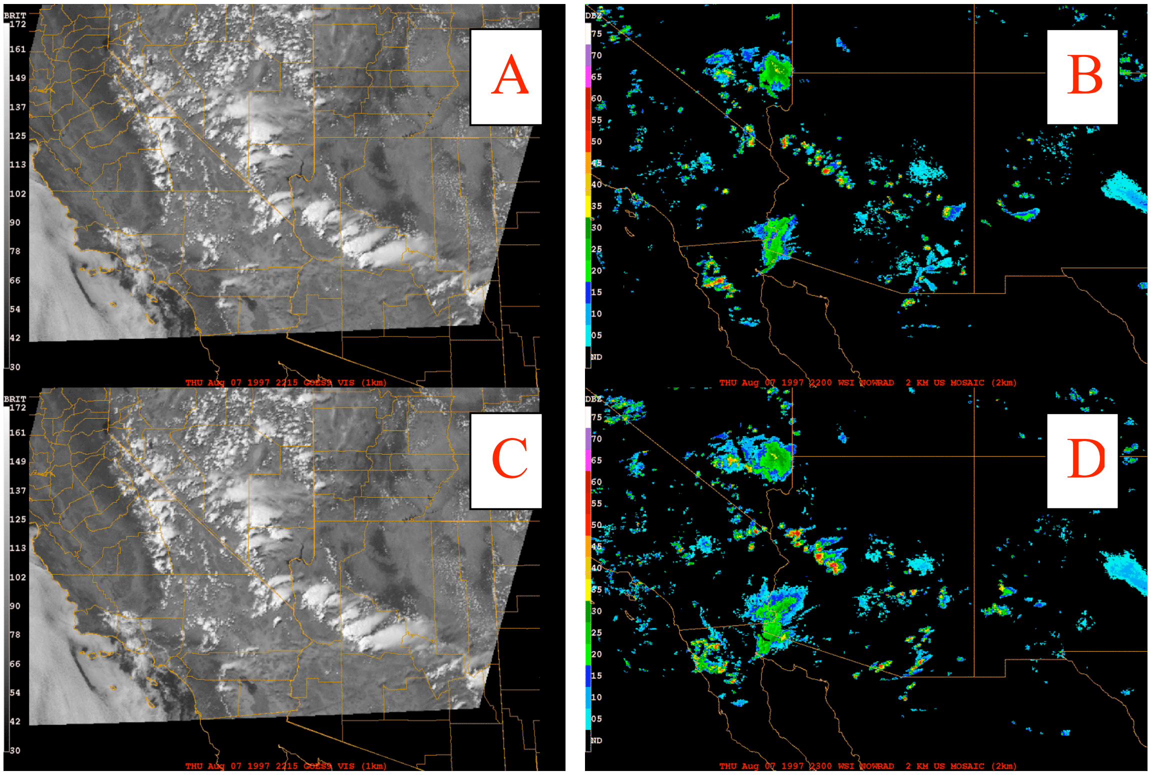

Figure 8. These images include a (a) satellite image at 2215Z and (b) radar image at 2200Z, (c) satellite image at 2300Z and (d) radar image at 2315Z, all taken from August 7th, 1997

22Z readings, the radar showed that the precipitation had become advected significantly further towards the southwest (FIG. 8d), concentrating winds into an area now southwest of the Mogollon Rim. The highest decibel values were witnessed to be around 65 decibels, so again, extremely strong precipitation occurred. At this time also, the orographic cloud increased in both size and magnitude, as the cloud head now covered much of Yavapai County and parts of southern Mohave County in Arizona. The leading edge of the cloud could be seen moving towards the southwest also, as a result of the steering level. By the end of the time being investigated, at around 2345Z on August 7th, while the satellite demonstrated that the cumulus clouds had elongated further down towards the southwestern-most border of Yavapai (FIG. 9a), the precipitation cells on the radar also became further concentrated near that area of Arizona, leading in fact to continued precipitation at this area, during this time. Although maximum decibel levels ranged from around 55-60dbz (FIG. 9b), rains were still persistent and the steering level continued to affect the precipitation, now moving further towards the southwest, at around the same rate, while helping to converge the individual storm cells. Vertical motion at this time was significant also because of its intense nature, as shown in figure 10. Vertical motions reached over 60m/s, so they were significant in generating the updrafts for the thunderstorms and maintaining the upward motions. Thus, the steering level helped to advect the storm towards the southwest. Generally, these were the actions of the storm, driven by the steering level winds, which were at 600mb.

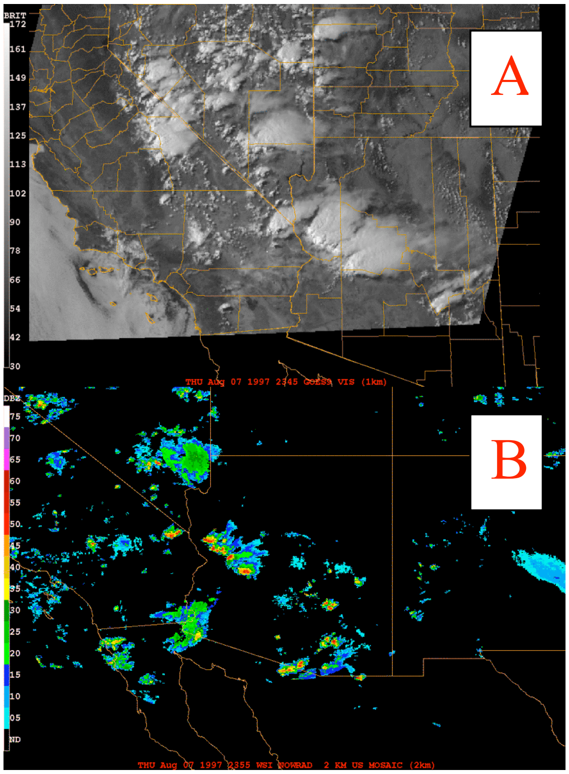

Figure 9. These images include a (a) satellite image from 2345Z and a (b) radar image from 2355Z, taken from August 7th, 1997.

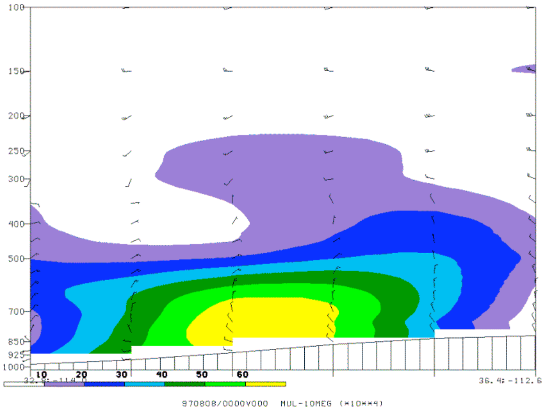

Figure 10. Vertical motions (contoured every 10m/s) from 00Z August 8th, 1997. The place where the cross-section was taken from is listed on figure 4b.

c) *Influence of Flash Flooding on the Storm*

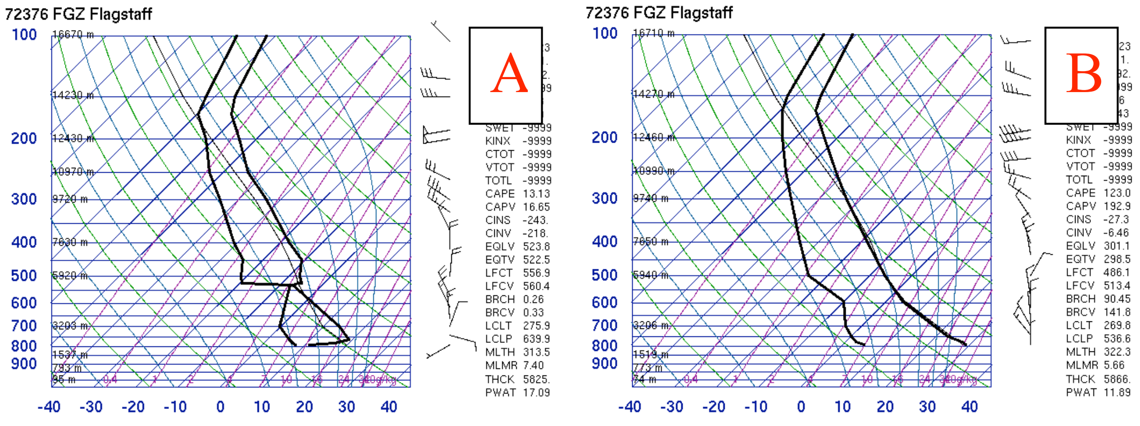

Figure 11. Vertical profiles taken from Flagstaff, AZ at (a) 12Z August 7th, 1997 and (b) 00Z August 8th, 1997.

Related to the developed orographic cloud heads and its associated thunderstorms was the idea of flash flooding. Discussed briefly in the introduction, flash flooding is a rain event generally associated with convective orographic precipitation events occurring when significant amounts of rain fall in a short period of time. Topography aids in intensifying an orographic lifting event in a few distinct ways. Topography does this by aiding in focusing the runoff, breaking a strong cap, focusing convective release and aiding in the increase of conditional instability. When these pre-requisites are met, flash floods can ensue, as it did in this case.

Soundings helped to aid in the investigation of flash flooding. The biggest issue with the sounding was the fact it had to be taken from Flagstaff, AZ, which was relatively far from where the severe weather event took place. Nonetheless, the first sounding considered was the 12Z August 7th vertical profile from Flagstaff, AZ (FIG. 11a). At this time, there was a conditionally unstable surface layer at Flagstaff, alongside an elevated mixed layer. The elevated mixed layer was capped at around 525mb. The capping of the mixed layer was relatively weak, but the cap was present nonetheless. Additionally at this time, there wasn't a dry layer present in the middle levels at this time, but there seemed to be a pocket of dryness between 450mb-550mb. The surface layer was extremely moist and close to being saturated, as the temperature and dew point were only a few degrees apart from each other. This was a relatively lackluster setup for the convective event to occur, but with the cap in place, convection had the ability to spring up, through the breaking of the cap.

The 00Z August 8th sounding (FIG. 11b) from Flagstaff really helped to demonstrate the idea of flash floods for the storm. The first thing noticed was the extreme temperature change from the morning to early evening. In the morning, temperatures were around 12C, or 54F. However, at the time of this sounding, temperatures were around 30C, or 86F. With the air being so warm, a lot of moisture could be held, one of the factors of the flash flood having the abundant amount of moisture it did, to potentially rain out. The dew points actually dropped a few degrees, but there was still more than enough moisture. But of course, the

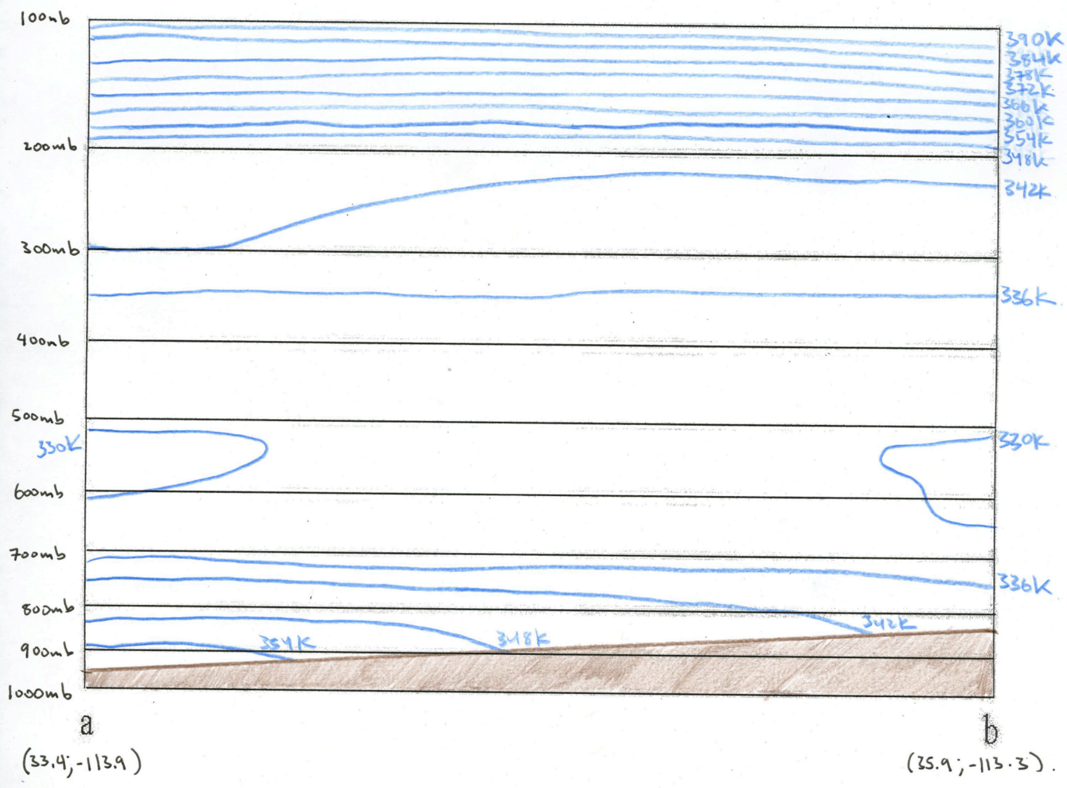

Figure 12. Hand-drawn cross-section from 18Z August 17th of theta-e from the cross-section listed on the Arizona topographical map.

most important aspect of the sounding was the fact the cap broke. At middle levels where previously the dew points had met with the temperatures, they were now drastically separated, as the most significant indication of the cap breaking. Despite the fact the reading was essentially from the southeastern-most portion of the Colorado Plateau, it shows did demonstrate the broken cap, which would help to concentrate precipitation down the slopes of the Mogollon Rim, down towards the southern portions of Yavapai and Mohave Counties. Also, with the fact there was a significant amount of moisture in the air when the cap was broken, there was a significant release of energy. This release of energy manifested itself in latent heating (as evidenced by the increased temperatures at Flagstaff) to high rainfall amounts. The high rainfall amounts formed through deep convection, as the high rainfall amounts led to the severe weather, and to the flash floods, which was the reason for the severe weather occurring. Theta-e hand-drawn analysis from the same time was also considered. Theta-e is the temperature after all the latent heat is released in the air and is brought down adiabatically towards the surface. The plot of theta-e in figure 12 demonstrated that while the surface was relatively stratified at this time, the middle layers were not, as there was an area where the sloping Mogollon Rim was located with an empty pocket of theta-e, signaling the area with the updraft and the concentrated rain, which had broken through the surface. This helped to further verify the severe weather which had gone on in the desert southwest at this time.

VII. Conclusion

The desert southwest storm of August 7th, 1997 provided a glimpse of the destructive potential destruction the Arizona monsoon bring along with it, in terms of producing cases of severe weather. With the Arizona monsoon in full swing, winds became advected off the Gulf of California and from the Pacific Ocean, in a cyclonic manner, through Arizona. This surface low-pressure system helped to spin the winds towards the Mogollon Rim, subsequently helping also to lift the winds from the surface, up through the transition zone. The lifting led to the development of a convective cloud, which produced thunderstorms throughout much of the southern portions of Mohave and Yavapai Counties, in Arizona. Along with this, a mean steering flow helped to move the cumulus clouds, and thereby the rains more towards the southwest. The lifting would also helped to break an inversion cap, and concentrate the precipitation in the southern portions of the aforementioned counties, thereby leading to the severe weather event. Generally not thought of as an area where a lot of exciting weather really takes place, or has taken place, the desert southwest storm proved skeptics wrong in a large way, as it was evidence that a severe weather event could've taken place. Seeing as this storm caused over $80,000 in damages in an rural and less populated area, better preparations could be made the next time a similar event occurs in the future. More precautionary measures, thereby lessening the extent to the damages caused by the storm could help future residents of Arizona maintain their houses, and keep them safe throughout this ordeal, as it's not a question of when the next time this will occur, but how soon it will happen, and will the residents of Arizona be prepared.

VIII. References

Adang, Thomas C and Gall, Robert L., 1988: Structure and Dynamics of the Arizona Monsoon Boundary. Monthly Weather Review: 1423-1438.

Moore, Thomas J, et. al., 1988: Disturbances along the Arizona Monsoon Boundary. Monthly Weather Review: 932-941.

Mullen, Steven L. et. al., 1997: Intraseasonal Variability of the Summer Monsoon over Southeast Arizona. Monthly Weather Review: 3016-3035.

Smith, Walter P and Gall, Robert L., 1988: Tropical Squall Lines of the Arizona Monsoon. Monthly Weather Review: 1553-1569.

Tripoli, Gregory. Lecture Notes. Revised 2007.

Basics of the Arizona Monsoon & Desert Meteorology. Dr. Raymond Cerveny. January 3rd, 2006. Arizona State University. May 1st, 2007 <http://geography.asu.edu/aztc/monsoon.html>.