A WES Case Study of the July 14, 2002 Arizona Severe Thunderstorm Outbreak in Southeast Arizona

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Introduction

The first severe thunderstorm outbreak of the 2002 monsoon season was illustrative of what can happen when the lack of a well-defined meteorological trigger is trumped by a variety of other highly favorable factors, including: considerable convective available potential energy (CAPE); moderate shear just above the convective condensation level; a deep and dry subcloud layer; moderate upper divergence; and orographically-driven near surface flow which fed into the developing Mesoscale Convective System (MCS) and aided in its propagation toward higher precipitable waters over the western and central deserts. This outbreak which developed in southeast Arizona would eventually spread into the Phoenix CWA later on the evening of July 14th, as is detailed in a future TA-Lite to be published by WFO Phoenix.

Synoptic Situation

The ramp-up to the summer thunderstorm season began July 9, 2002 when the first rather dry, high-based, and isolated severe thunderstorms developed over the Tucson County Warning Area (CWA). During the early morning hours on the 14th, however, moisture surged north from decaying convection over the Sierra Madres of Mexico. In addition, the outer fringes of Tropical Storm Cristina passed across the southern end of the Gulf of California, which set the stage for a significant low level moisture surge up the Gulf of California and into the Arizona deserts. The Yuma AZ 12Z sounding on the 14th showed a 20-30kt surge underway (Figure 1) with precipitable waters over 1.5 inches. The Tucson sounding at 141200Z also showed a significant moisture increase (Figure 2) with precipitable waters near 1.3 inches. More importantly, CAPE values were unusually high for the region with the 1200Z Tucson sounding showing max parcel values around 4000 J/kg and mean boundary layer values around 2500 J/kg. The 1200Z sounding also showed about 30 kts of shear in the 700-500mb layer which is supportive of organized multicell convection. The Tucson sounding exhibited a deep inverted-V type profile, which is typically supportive of strong thunderstorm downdrafts. Finally, the 1200Z soundings at both Tucson and Phoenix (not shown here) indicated a weak capping inversion around 750mb, which helped to suppress thunderstorm development until daytime temperatures in the deserts climbed over 100 F. As the thunderstorms developed, the 700-500mb flow would initially support a general west-southwest storm motion off the mountains of eastern Arizona and West Central New Mexico.

While potential buoyancy, moderate mid level shear, decent steering flow and weak capping were all highly supportive of organized severe convection, there was no well-defined synoptic-scale trigger in the area. The 1200Z Eta model (Figure 3) indicated no discernable short wave heading into southeast Arizona underneath the strong mid level high center near the Four Corners region. Yet mid- and upper-level conditions were otherwise quite favorable for at least some thunderstorm development. The 1200Z data at 500mb showed a noticeable mid level cold pool over southeast Arizona. At 300mb, a concentrated area of divergence was situated over the same general area (Figure 4). With the mid level cold pool and upper level divergence area juxtaposed over a hot and moist low level airmass, and with moderate mid level shear also present, thunderstorms were able to develop over the mountains, break through the cap, and maintain fairly long life cycles (about an hour per cell). The resulting outflows, instead of a large-scale synoptic system, served as the necessary triggers for subsequent and explosive development in the valleys and deserts.

Storm Evolution

Skies were clear over southeast Arizona until 1900Z on the 14th when convective temperatures were reached in the highest mountains of southeast Arizona and west central New Mexico. In just one hour, thunderstorms were approaching severe limits over the Chiricahua. White, Huachuca and Whetstone Mountains, with the 2000Z visible GOES-10 image (Figure 5) showing overshooting tops at these locations. The first Severe Thunderstorm Warning of the day was issued on the cluster over the Huachucas and Whetstones of far eastern Santa Cruz County at 2008Z. Meanwhile, outflows pushing southwest off the White and Gila Mountains triggered dust storms with wind gusts of 40 to 50 mph across southern Greenlee and Graham County west of Safford (KSAD).

By 22Z, the outflows from the initial clusters started to trigger valley-based convection which rapidly became severe. By 2345Z, The KEMX WSR-88D was detecting numerous strong and severe thunderstorms to the east, south, and southwest of the Tucson metro area (Figure 6). A nearly solid short line of severe thunderstorms had formed over extreme eastern Pima County and was moving west-southwest toward Tucson. A second broken line of strong thunderstorms extended from southwest Graham County to northern Cochise County, northeast to east of Tucson. These storms were associated with outflow which dropped off the White and Gila Mountains earlier in the afternoon. By 0024Z (on the 15th), the short line had swept into the Tucson metro area (Figure 7), with new severe thunderstorms firing near Tucson International Airport at the intersection of at least two outflow boundaries. Meanwhile, the broken line, also moving to the west-southwest, began to weaken as it moved into rain-cooled air left by the previous convection, although one cell in extreme northeast Pima County briefly reached severe levels as it formed on the intersection of the two outflow boundaries. At 0030Z the striking visible (Figure 8) and infrared (Figure 9) satellite images highlighted the ferocity of the maturing Mesoscale Convective System with several overshooting tops cooling below -70C. The loosely-organized MCS then pushed outflow boundaries into central Pima and Pinal Counties, northwest of Tucson. These outflows, accompanied by wind gusts near 60 mph, generated a large dust storm, and triggered still more severe thunderstorms. This new development, aided by typical afternoon flow upslope from the Phoenix metro area toward Tucson effectively turned the propagation of the MCS to the west-northwest and toward the Phoenix metro area.

Results and Conclusions

During the southeast Arizona portion of the outbreak extending from 2000Z on the 14th until around 0100Z on the 15th, a total of 11 Severe Thunderstorm Warnings (10 verified), 3 Dust Storm Warnings (all verified), 2 Urban and Small Stream Flood Advisories (both verified), and 1 Flash Flood Warning (did not verify) were issued. The highest wind gust of 79 mph measured by retired NWS HMT on the near southwest side of Tucson, with a gust to 67 mph at the University of Arizona and numerous reports of wind damage and dust storms (visibilities briefly falling as low as 1/8 of a mile) in all counties of our CWA.

As is typical for the first couple of summertime thunderstorm events, blowing dust was a significant problem. The dust storms were most likely made worse by extreme drought conditions prior to monsoon onset. Tucson's longest dry spell on record (100 days) ended just a week before, and no widespread heavy rains fell across the CWA until this event. As is also typical for the first round of monsoon-related thunderstorms, rainfall was not terribly heavy, with spotty 1 inch totals around central Tucson, and Doppler estimates of around 4 inches in an isolated area of far southwest Pinal County.

Situational awareness by the forecasters, despite the lack of a triggering synoptic-scale feature, was key in providing excellent lead times and forecast accuracy. The possibility of a significant moisture increase was recognized the day before the outbreak when the probability of precipitation (PoP) was raised to 40 to 50 percent. Upon receiving the 1200Z upper air data, Tucson forecasters added heightened wording for damaging winds and brief heavy rain to the public forecasts, while the Storm Prediction Center highlighted southern Arizona for a "slight risk" of severe thunderstorms.. Severe Thunderstorm Watch Number 510 was issued by SPC at 245 pm, valid until 900 pm, which in turn prompted forecasters to raise PoPs even further into the 60-80 percent range. The watch redefining statement for southeast Arizona mentioned the greatest threat would be from "wind gusts well over 60 mph along with blowing dust." Warning lead times were also unusually high, with the warning for the Tucson metro area having the longest lead time of the event – up to 45 minutes.

[Figure 1](#): Yuma (KYUM) skew-T sounding, 1200Z July 14, 2002. The low level moisture surge from the south extended up to around 5000ft AGL.
[Figure 2](#): Tucson (KTUS) skew-T sounding, 1200Z July 14. Note the extreme instability and moderate 700-500mb wind shear.
[Figure 3](#): Eta 500mb initialization of height, wind and temperature, 1200Z July 14. A cold pool with temperatures around -8 C was situated over far southeast Arizona with rather strong flow between the high near the four corners and a weak low over Baja California.
[Figure 4](#): Eta 300mb initialization of wind and deformation vectors, 1200Z July 14.
[Figure 5](#): GOES-10 visible satellite image and surface observations, 2000Z July 14. Overshooting thunderstorm tops were indicated near several mountaintops. Upslope flow is also underway from the central deserts around Phoenix into southeast Arizona.
[Figure 6](#): KEMX WSR-88D composite reflectivity, 2345Z July 14. A short line of severe thunderstorms was developing near the Rincon Mountains east of Tucson with apparent dry echo channels on the rear side. Another line is visible behind it from southwest Graham County into northern Cochise County. Also note the outflow boundary at the center of the image near Tucson International Airport (KTUS).
[Figure 7](#): KEMX WSR-88D composite reflectivity, 0024Z July 15.
[Figure 8](#): GOES-10 visible satellite image, 0030Z July 15.
[Figure 9](#): GOES-10 infrared satellite image, 0030Z July 15.

Figure 1

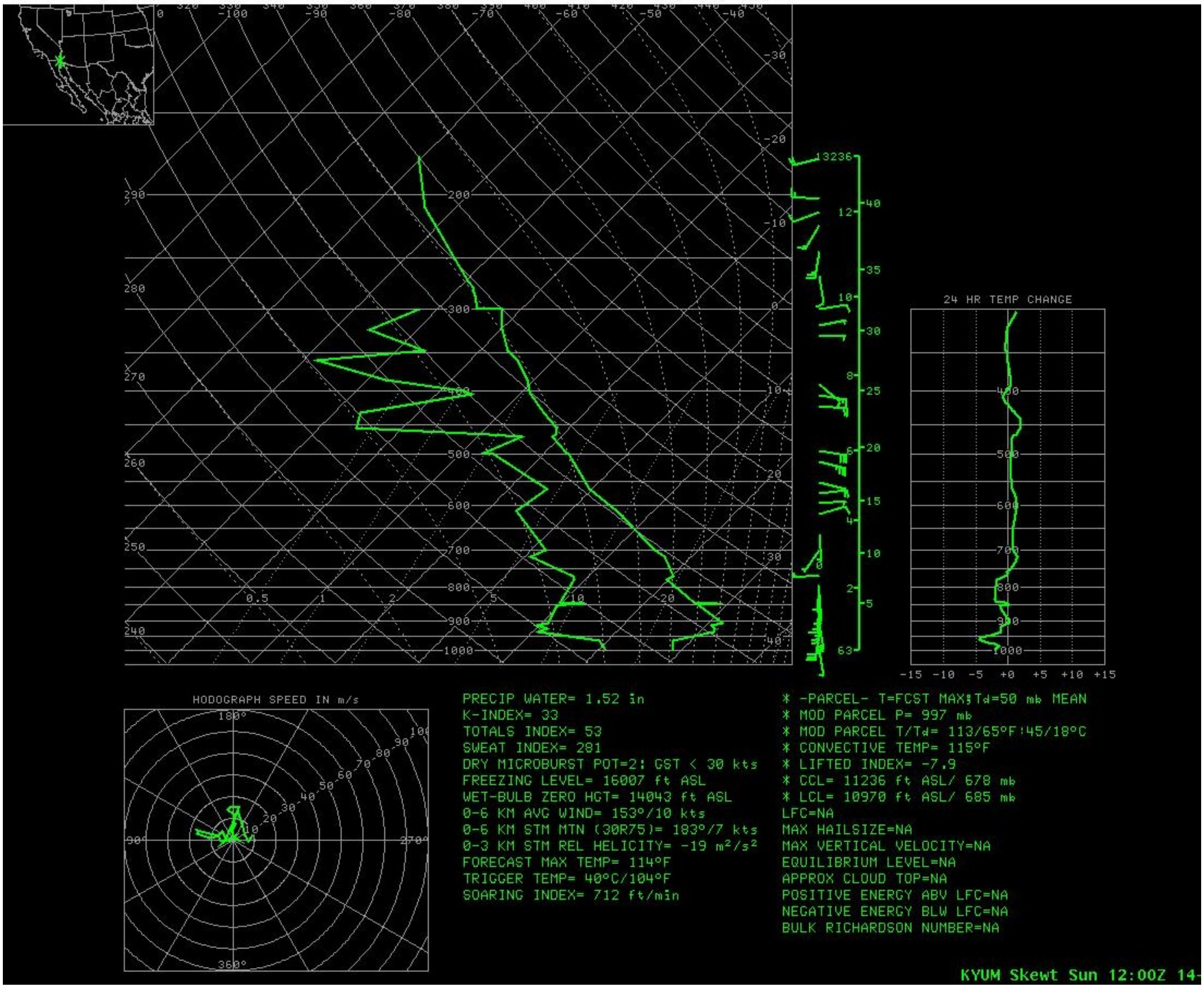
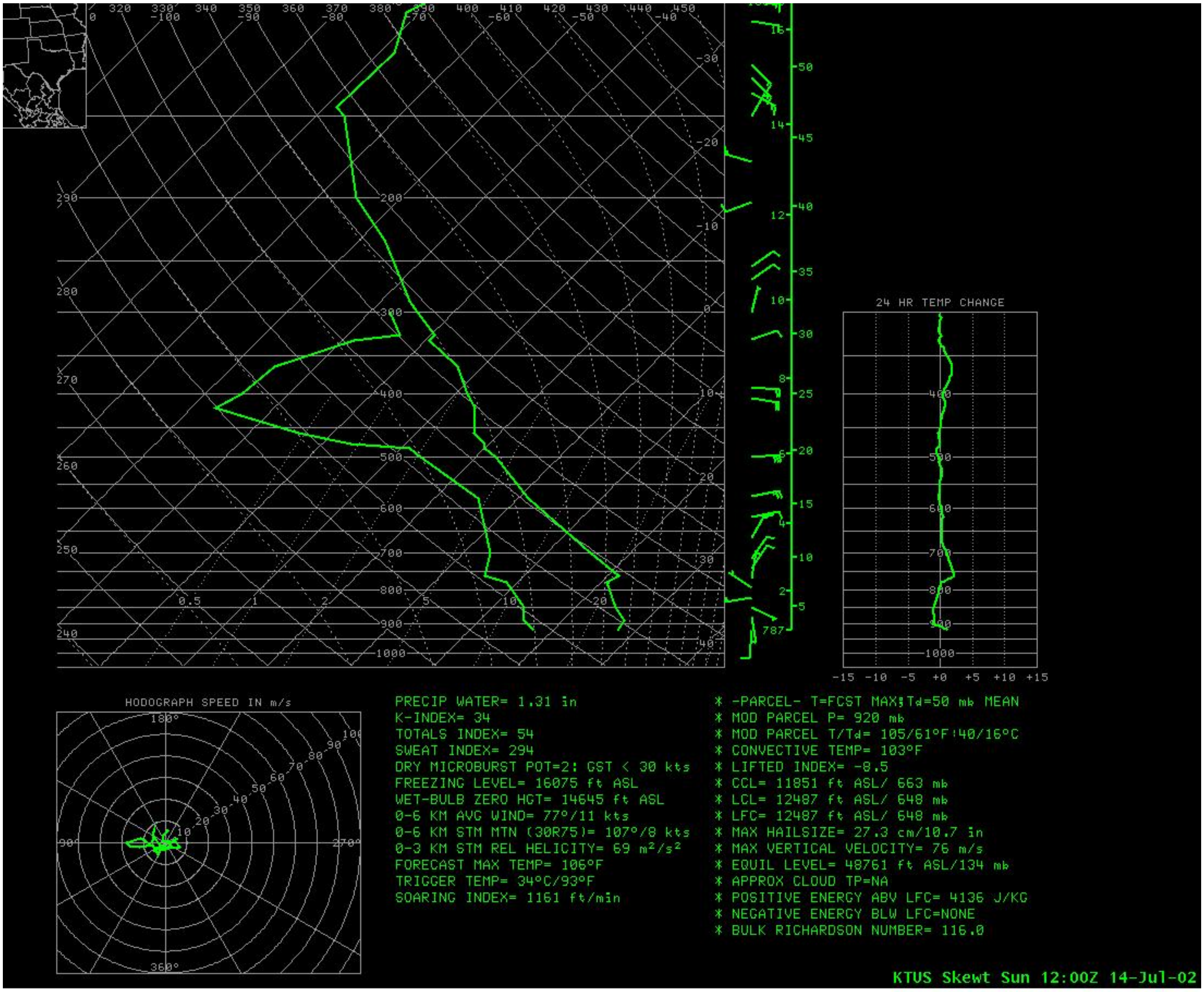
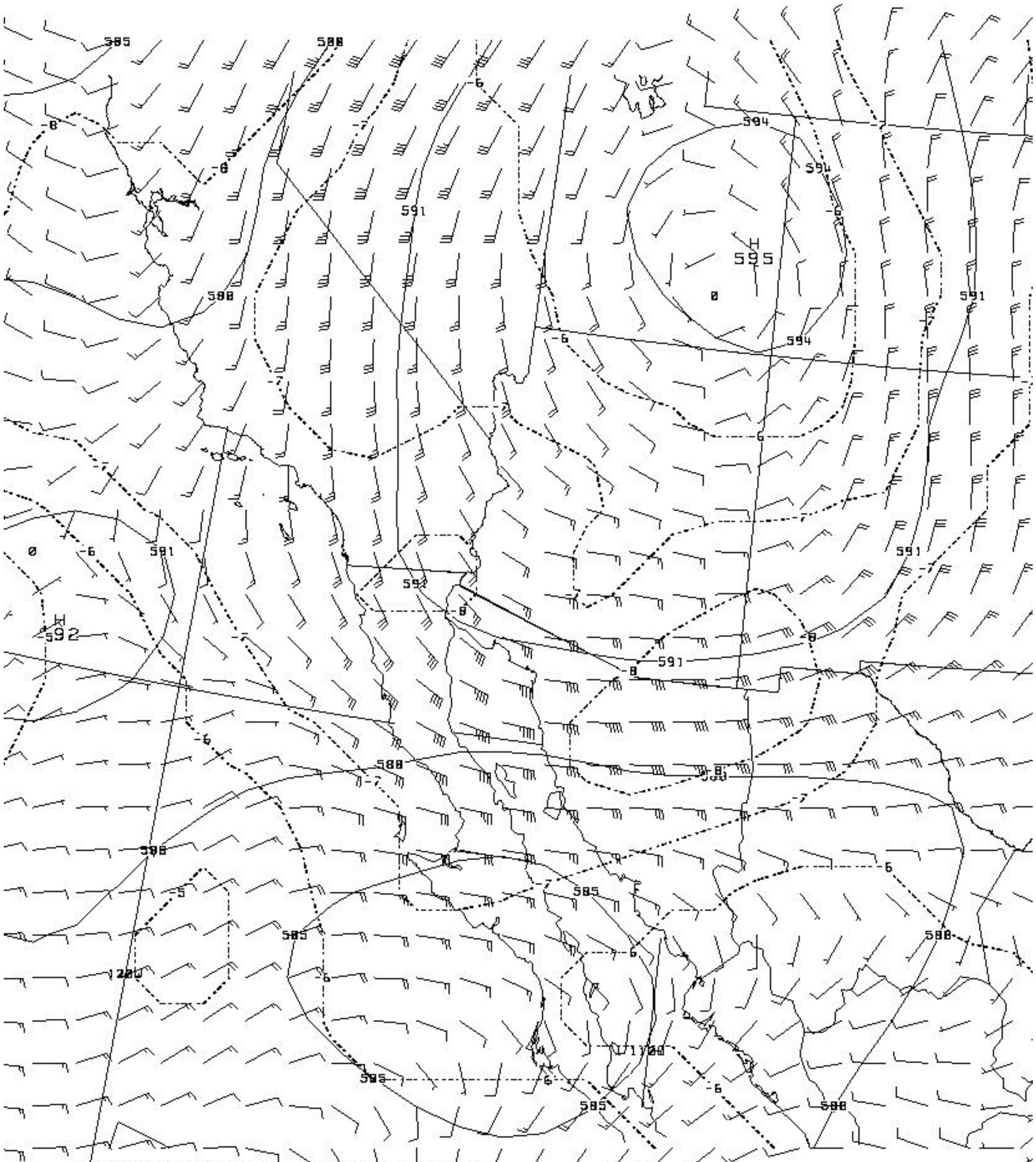


Figure 2



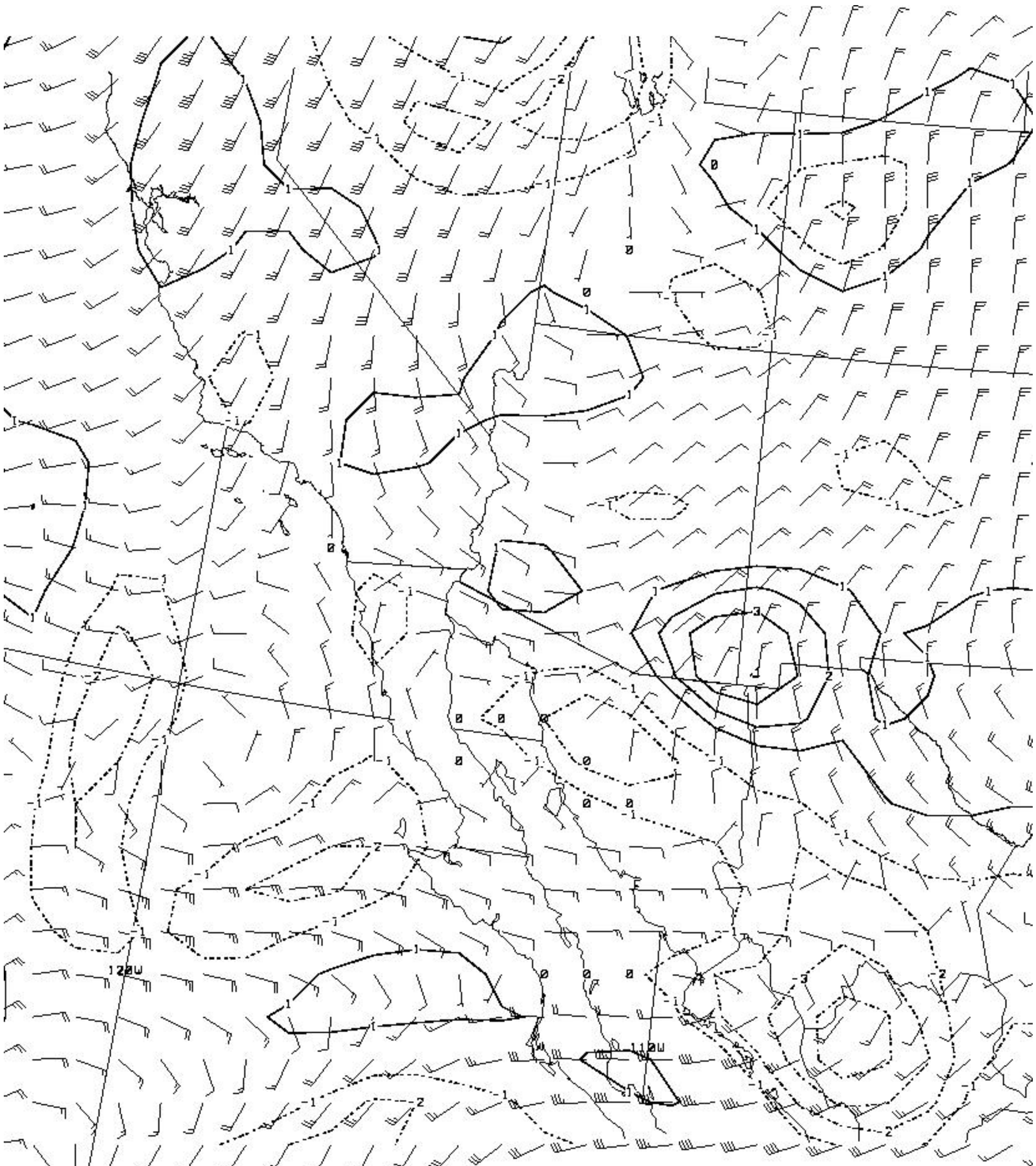
24 HR TEMP CHANGE
HODOGRAPH SPEED IN m/s
PRECIP WATER= 1.31 in
K-INDEX= 34
TOTALS INDEX= 54
SWEAT INDEX= 294
DRY MICROBURST POT=2: GST < 30 kts
FREEZING LEVEL= 16075 ft ASL
WET-BULB ZERO HGT= 14645 ft ASL
0-6 KM AVG WIND= 77°/11 kts
0-6 KM STM MTN (30R75)= 107°/8 kts
0-3 KM STM REL HELICITY= 69 m²/s²
FORECAST MAX TEMP= 106°F
TRIGGER TEMP= 34°C/93°F
SOARING INDEX= 1161 ft/min
* -PARCEL- T=FCST MAX;Td=50 mb MEAN
* MOD PARCEL P= 920 mb
* MOD PARCEL T/Td= 105/61°F:40/16°C
* CONVECTIVE TEMP= 103°F
* LIFTED INDEX= -8.5
* CCL= 11851 ft ASL/ 663 mb
* LCL= 12487 ft ASL/ 648 mb
* LFC= 12487 ft ASL/ 648 mb
* MAX HAILSIZE= 27.3 cm/10.7 in
* MAX VERTICAL VELOCITY= 76 m/s
* EQUIL LEVEL= 48761 ft ASL/134 mb
* APPROX CLOUD TP=NA
* POSITIVE ENERGY ABV LFC= 4136 J/KG
* NEGATIVE ENERGY BLW LFC=NONE
* BULK RICHARDSON NUMBER= 116.0
KTUS Skewt Sun 12:00Z 14-Jul-02

Figure 3



ETA 500MB Wind (kts) 14.12 0HR Sun 12:00Z 14-Jul-02
ETA 500MB Temperature (C) 14.12 0HR Sun 12:00Z 14-Jul-02
ETA 500MB Height (dam) 14.12 0HR Sun 12:00Z 14-Jul-02

Figure 4



ETA 300MB Divergence (/1e5s) 14.12 0HR Sun 12:00Z 14-Jul-02
ETA 300MB Wind (kts) 14.12 0HR Sun 12:00Z 14-Jul-02

Figure 5

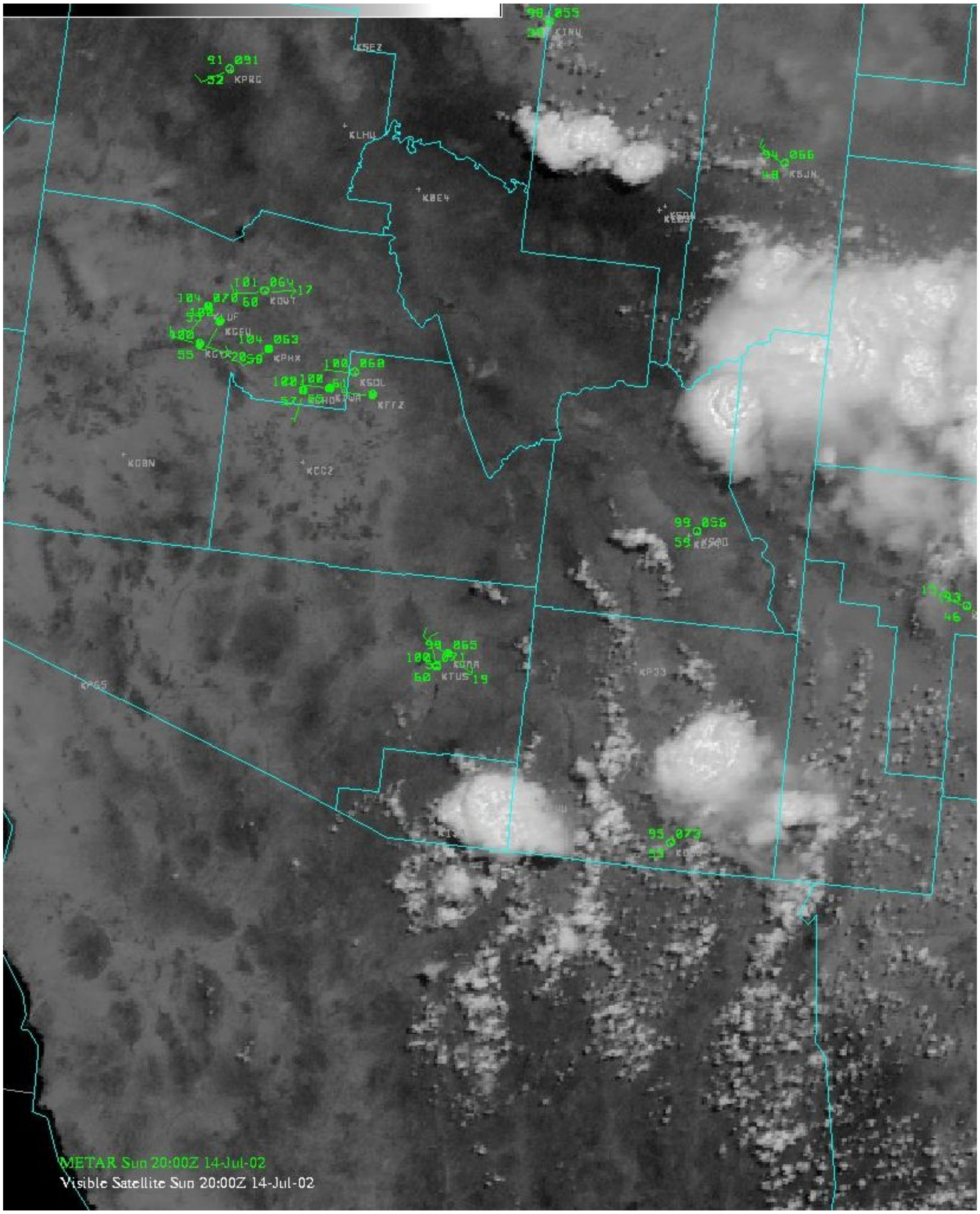

METAR Sun 20:00Z 14-Jul-02
Visible Satellite Sun 20:00Z 14-Jul-02

Figure 6

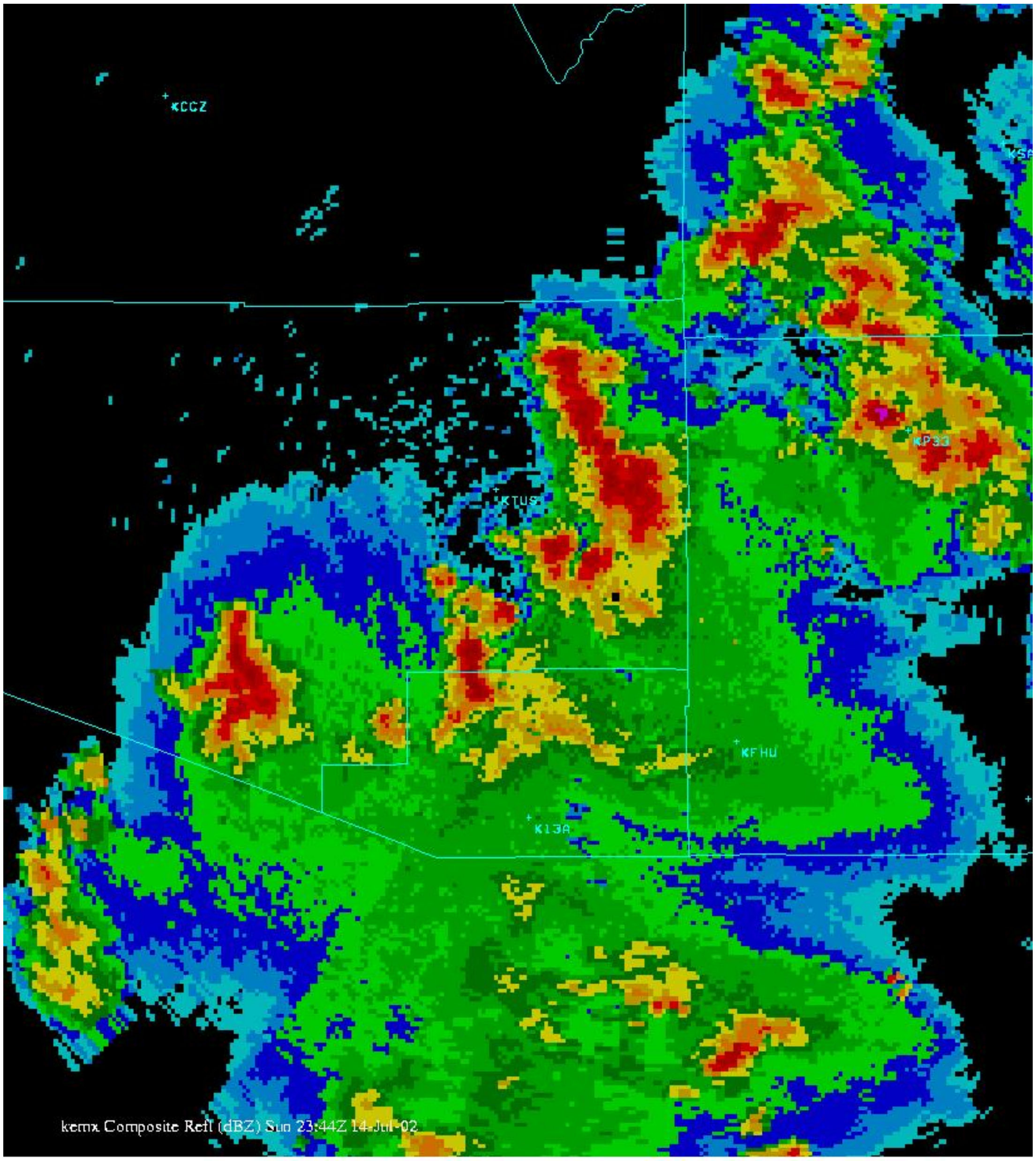

KCCZ
KSA
KP33
KTUS
KFHU
K13A
kemx Composite Refl (dBZ) Sun 23:44Z 14-Jul-02

Figure 7

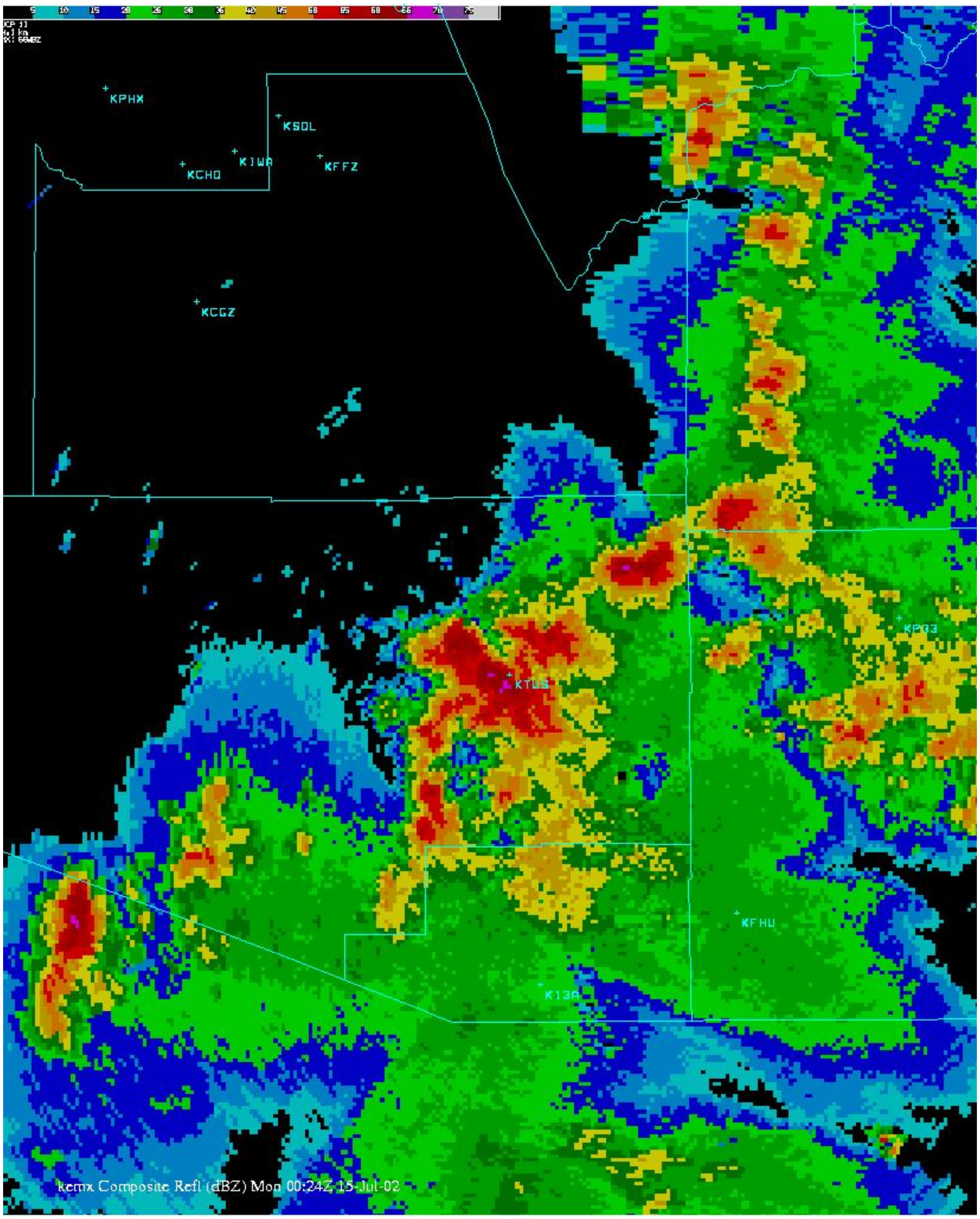

KPHX
KSOL
KIWA
KFFZ
KCHD
KCGZ
KTUS
KP33
KFHU
K13A
kemx Composite Refl (dBZ) Mon 00:24Z 15-Jul-02

Figure 8

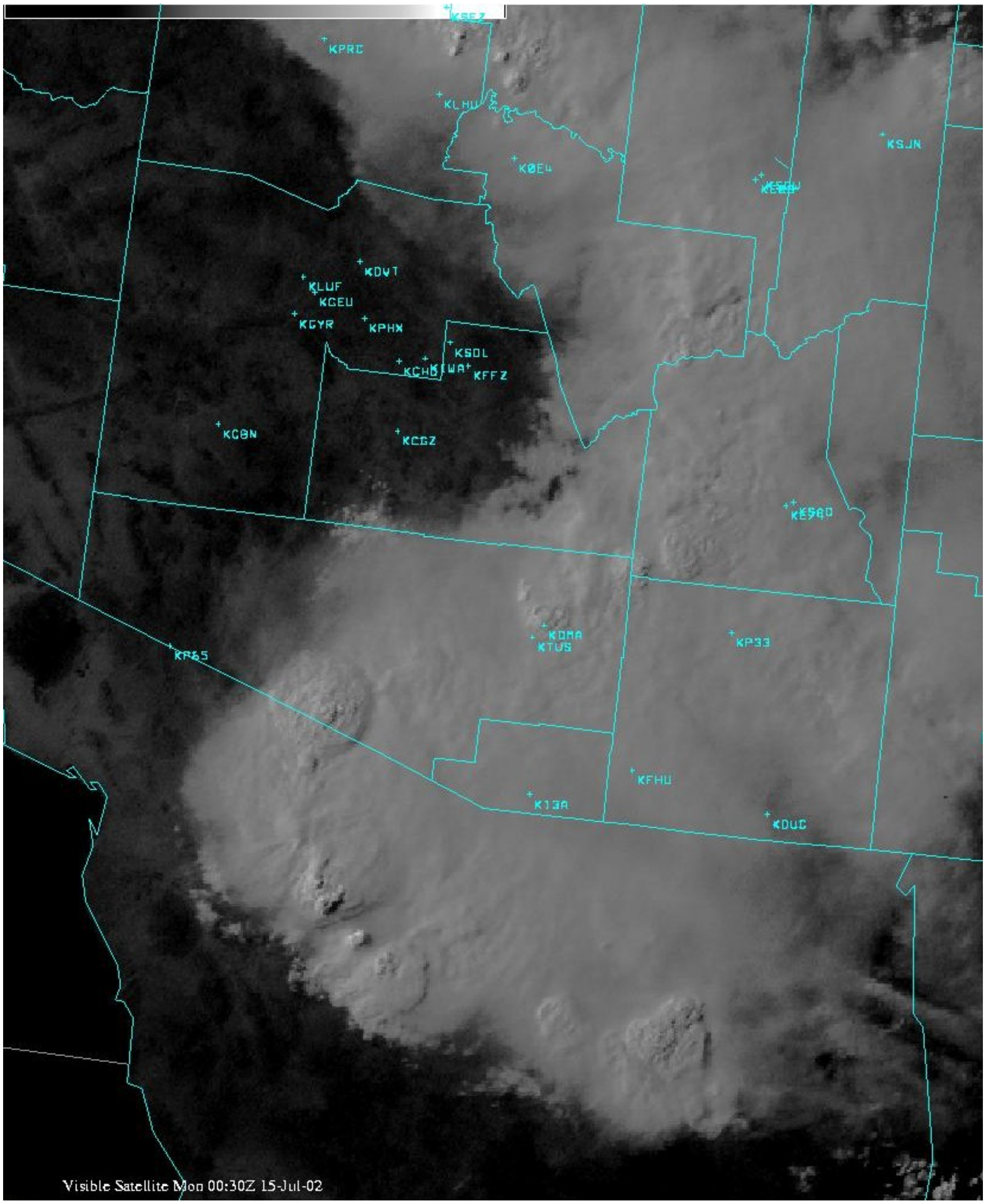
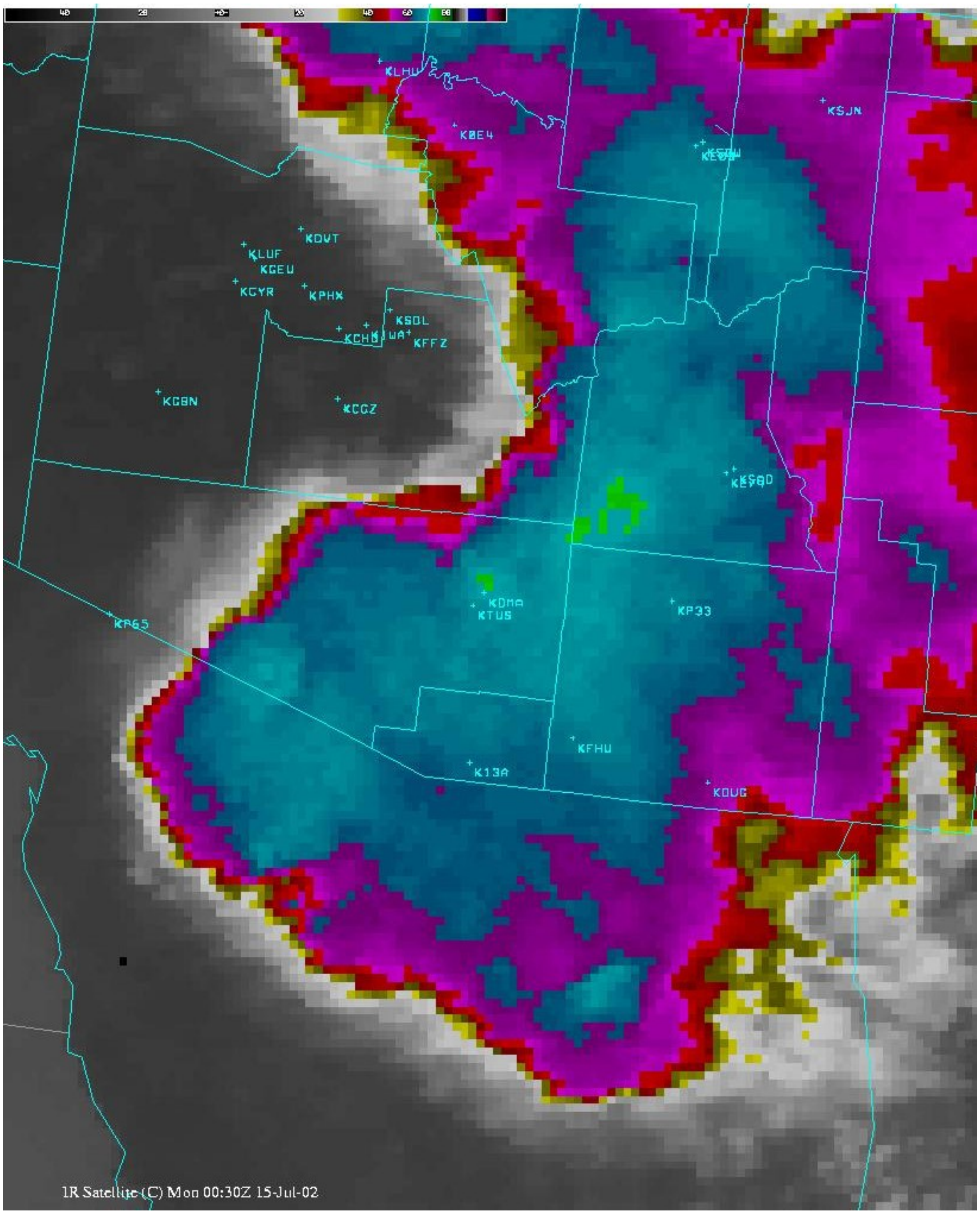

KPRC
KLHU
KSJN
KDVT
KLUF
KCEU
KGYR
KPHX
KSOL
KFFZ
KCGZ
KGBN
KOMA
KTUS
KP33
KP65
KFHU
K13A
KDUG
Visible Satellite Mon 00:30Z 15-Jul-02

Figure 9


KLHU
KSJN
KDVT
KLUF
KGEU
KCYR
KPHX
KSDL
KFFZ
KGBN
KCGZ
KP65
KTUS
KP33
KFHU
K13A
KDUG
IR Satellite (C) Mon 00:30Z 15-Jul-02