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A RECORD ARKANSAS RAINFALL - THE EL DORADO DELUGE

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1. INTRODUCTION

Excessive 24-hour rainfalls of three to five inches are not uncommon over southwest Arkansas and the Ouachita Mountains of west-central Arkansas, especially during the winter and spring. The recurrence of this phenomenon over the same area can be linked in part to the terrain.

During the four day period 5-8 June, 1974 much of the Southern Plains and Lower Mississippi Valley was struck by a series of violent storms including killer tornadoes, severe thunderstorms and floods. One significant facet of the outbreak was the occurrence of over 18 inches (45 cm) of rain in less than 12 hours in Union County Arkansas. This phenomenal release, proceeding in the absence of any apparent terrain interaction, was quite unexpected and is the subject of this investigation.

Union County is in extreme south-central Arkansas. The area is rolling, forested countryside with topographic relief of 60 m or less. Scattered showers and thunderstorms had occurred over this area during the day of 7 June. Around 9:00PM CDT the thunderstorms intensified and appeared to remain stationary over Union County until they moved northward at sunrise on the 8th. The Flight Service Station at El Dorado airport (about 10 miles west of town) measured 11.54 in (29.2 cm) of rain during the night. A Monsanto Company observatory approximately 8 miles north of the airport recorded 17.40 in (44.2 cm) during the same period with 9.50 in (24.1 cm) falling between 2:00AM and 7:00AM of the 8th. An Arkansas Forestry Commission station 15 miles east of the airport had 18.19 in (46.2 cm). Amounts tapered off quite rapidly outside this small area, although totals in excess of four inches (10 cm) covered most of the southwest quarter of the state (see Fig. 1). Along with the deluge, winds up to 50 knots and a possible tornado occurred just east of El Dorado about 4:00AM.

2. SYNOPTICS

At 0000GMT on June 8th, the height contour pattern at 500mb over the western two-thirds of the country was dominated by a large diffluent trough. A weak circulation center was found in extreme northeast Utah. This general diffluent trough had persisted for several days prior to this time and was beginning what turned out to be its final phase of development as the circulation in northeast Utah would initiate major cyclogenesis in the Texas Panhandle during the next twelve to eighteen hours.

Short wave impulses had moved eastward from the southern Rockies into the Lower Mississippi Valley from this large trough for the preceding couple of days and at 0000GMT another rather well-defined impulse was entering the western border area of the state (Fig. 3A). Consequently, a line of active thunderstorms had organized during the afternoon in south-central Arkansas. This line then moved into northern Mississippi and northern Louisiana in the evening as a well developed meso-system (Figs. 2A-B).

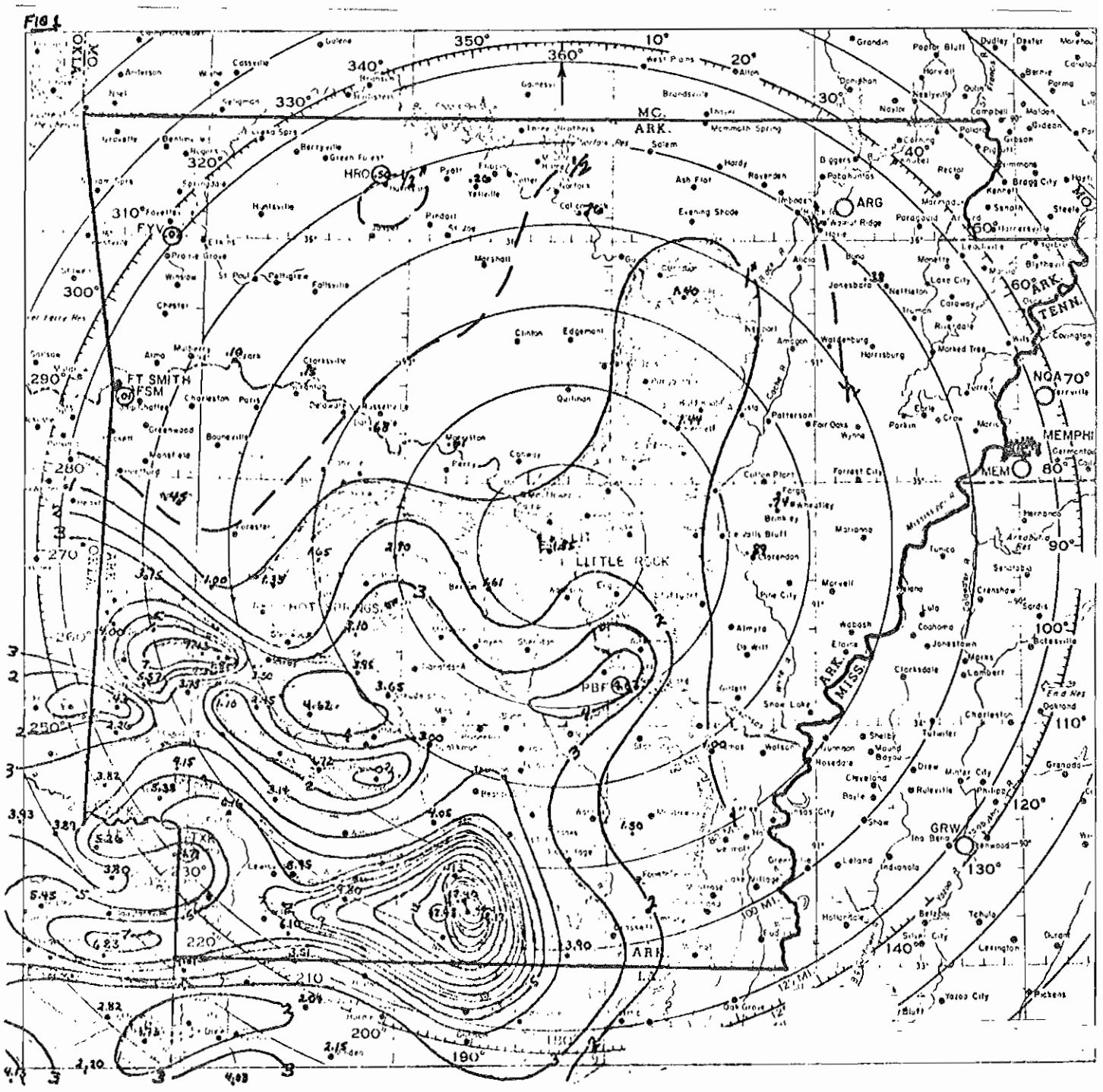

Fig. 1.

24-Hr. Rainfall - Ending 7AM 6/8/74

Moisture was abundant through the 850mb level over northeast Texas and Louisiana. Surface dew points were in the mid 70's while at 850mb conditions were near saturation with dew points exceeding 18 deg C. Low level winds were from the south and southwest at 20 to 30 knots with weak anticyclonic curvature in south Arkansas.

By 1200GMT on the 8th the 500mb circulation in Utah had moved southeastward into Colorado (Fig. 3E). Surface cyclogenesis had subsequently begun in the Texas Panhandle. The short wave which was along the western Arkansas border at 0000GMT had moved into northeastern Arkansas and northern Mississippi. Winds at 850mb had strengthened and become southerly from the northeast Texas coast into central Arkansas. Although moisture at 850mb was streaming northward into central Arkansas (Fig. 3D), it was still retarded at the surface along the Arkansas-Louisiana border (Fig. 2E).

3. DISCUSSION

A quick glance at the synoptic situation presented would indicate a substantial precipitation release for some portion of Arkansas during the night of 7-8 June. As stated earlier the southwest and hilly west-central portions of the state are prone to excessive release when conditions are favorable, as indeed they were here. These areas did receive abundant rainfall but the record-breaking totals fell near El Dorado -- some distance from the major terrain influence.

To determine the probable reasons for the occurrence of such a large amount of rainfall, let us consider the events and circumstances which were present. We will also consider how some of the circumstances may have interacted where and when they did. Therefore, let us examine first the more common parameters which may have given a clue to this event.

At the outset we see the broad diffluent trough over the western portion of the country with impulses propagating eastward into the Lower Mississippi Valley. A rather well-supported 500mb short wave with a marked tongue of cold air is approaching south-central Arkansas at 0000GMT and will be positioned over the impact area during the heavy release. The initial 500mb baroclinic vorticity analysis (Fig. 4) shows a tongue of high vorticity values associated with the impulse and which will also be over the El Dorado area during the night. Absolute vorticity values were forecast to be well in excess of $10 \times 10^{-5} s^{-1}$, well above the value of the coriolis parameter (about $8 \times 10^{-5} s^{-1}$), at the latitude of south Arkansas.

It is obvious that moisture supplies were abundant and were being advected into the impact area by the low level wind field (represented by the 850mb winds). Gradient wind directions were from the south-southwest which experience has demonstrated is often associated with heavy rains over Arkansas.

Initially, one might wish to counteract these positive rain indicators with a negative one. The squall line and meso-system which developed in south Arkansas during the afternoon of the 7th would normally tend to stabilize the atmosphere and inhibit convection. Perhaps it did initially, but therein lies a key to the phenomenon which was to unfold during the night.

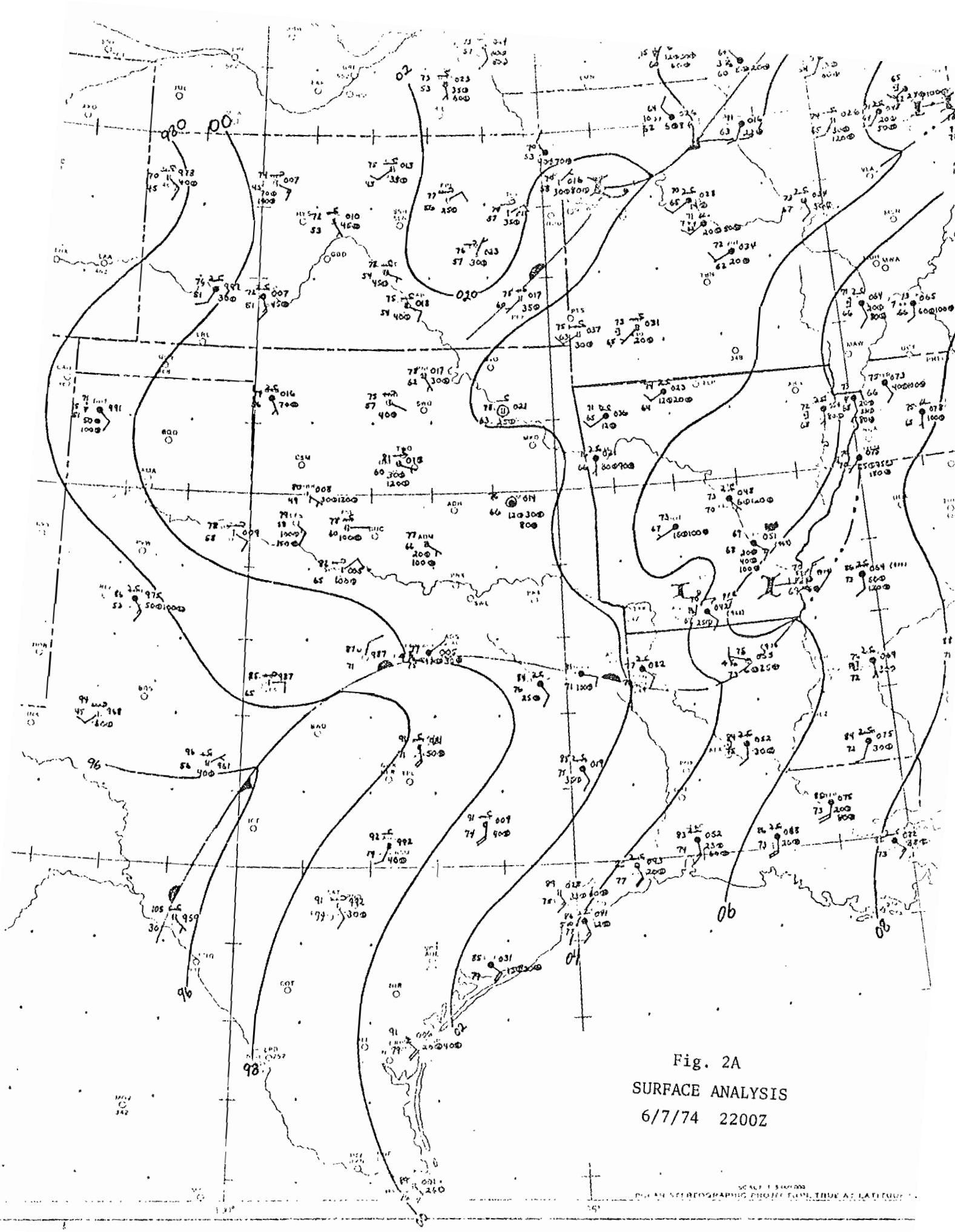

Fig. 2A
SURFACE ANALYSIS
6/7/74 2200Z

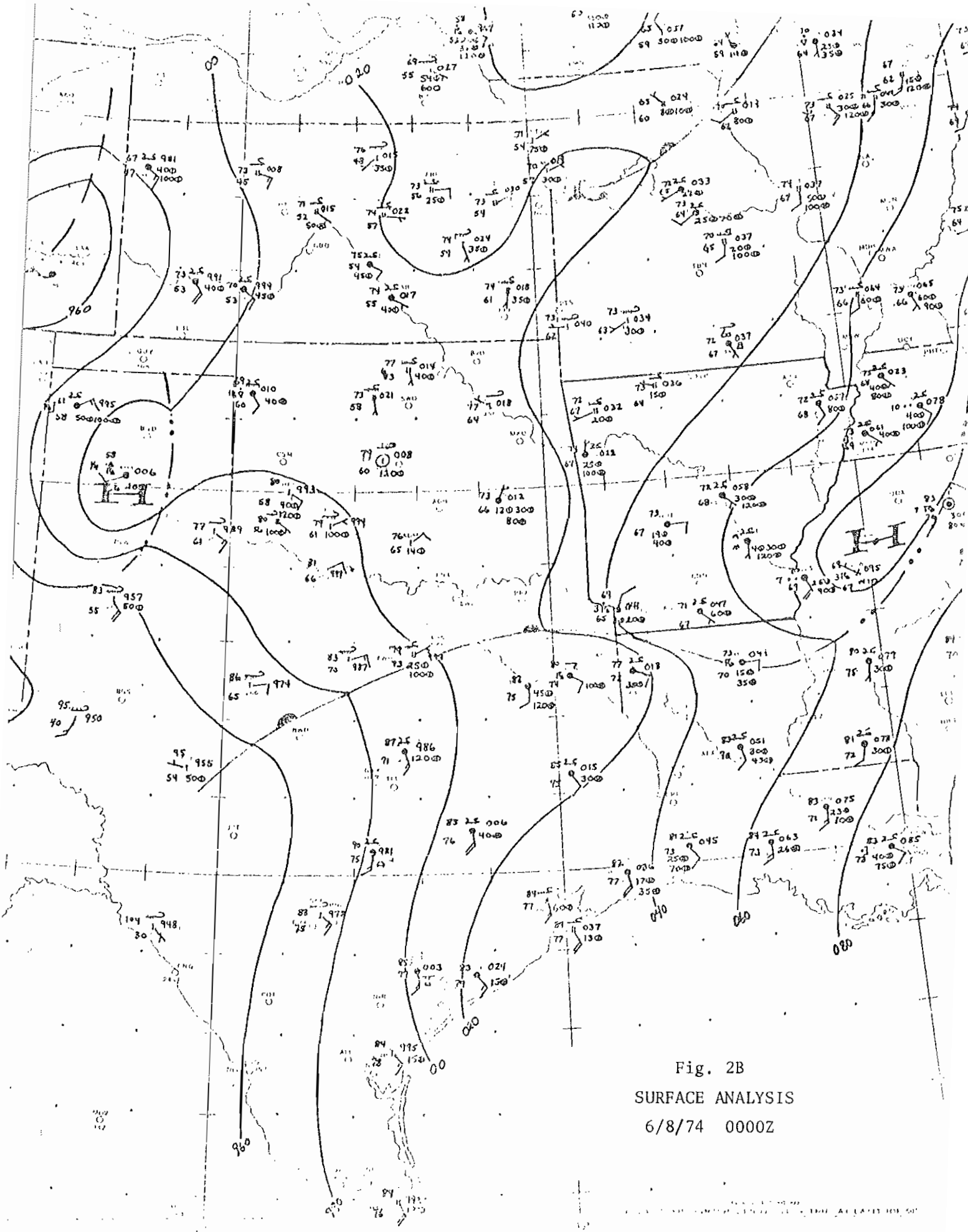

Fig. 2B
SURFACE ANALYSIS
6/8/74 0000Z

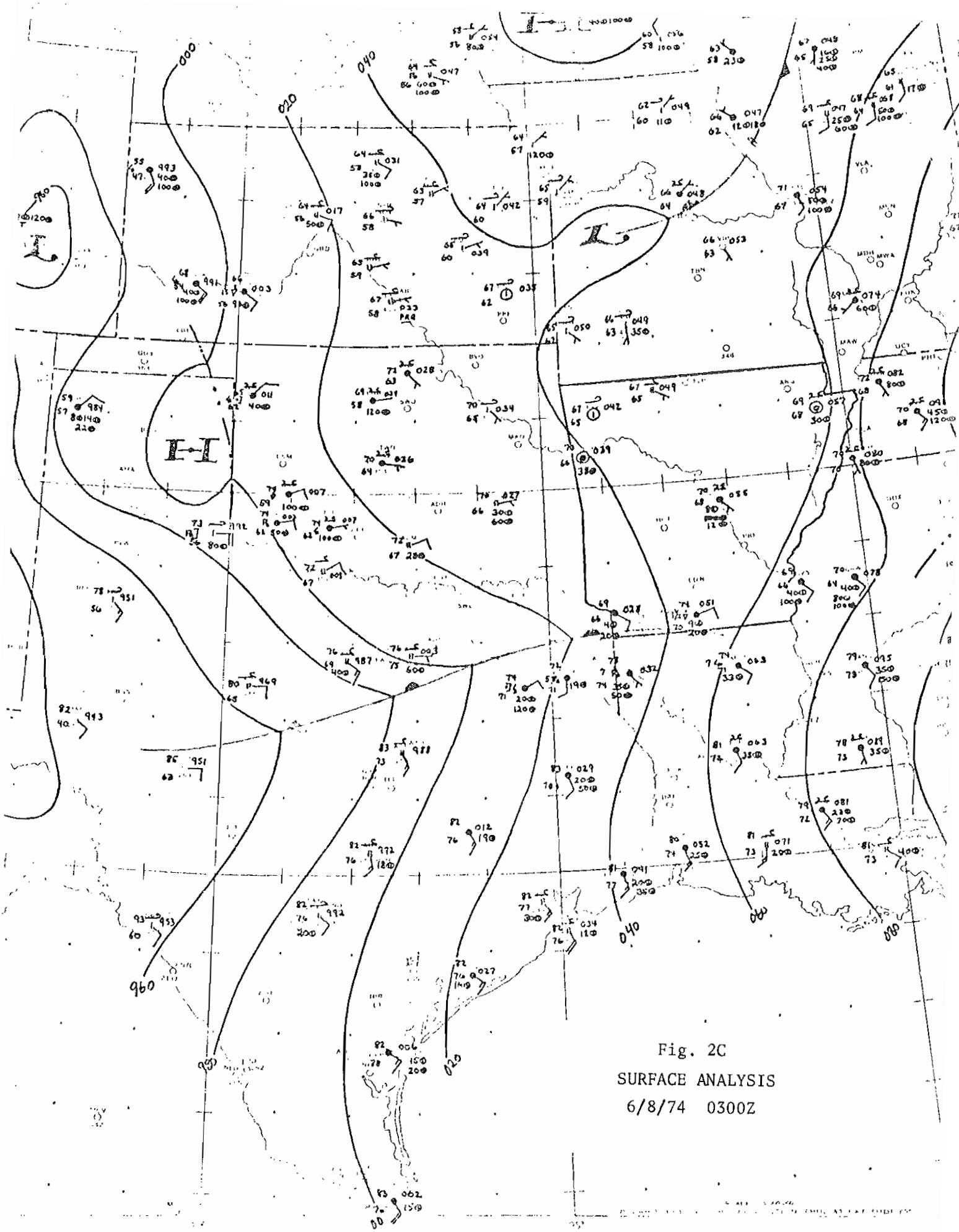

Fig. 2C

SURFACE ANALYSIS

6/8/74 0300Z

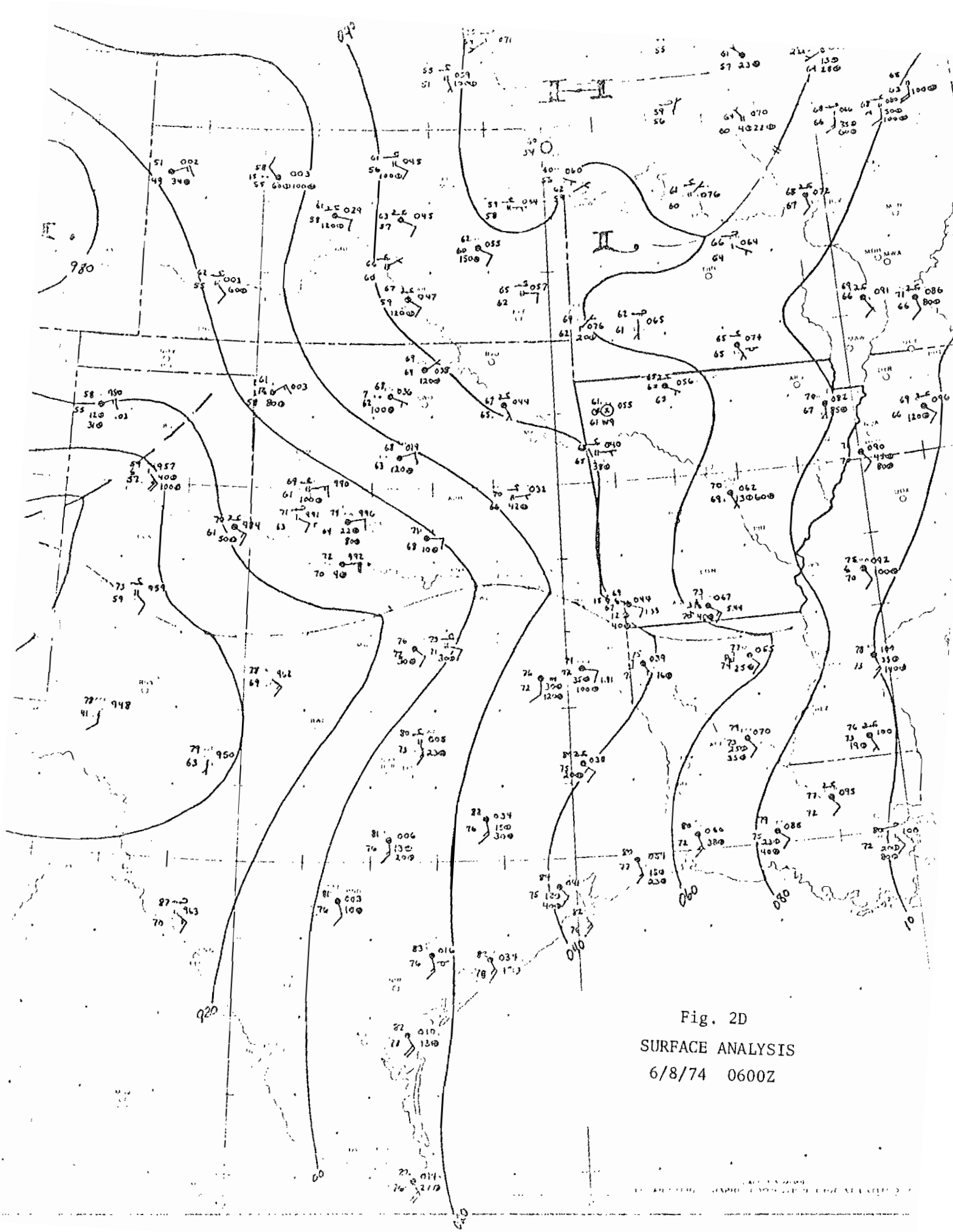

Fig. 2D
SURFACE ANALYSIS
6/8/74 0600Z

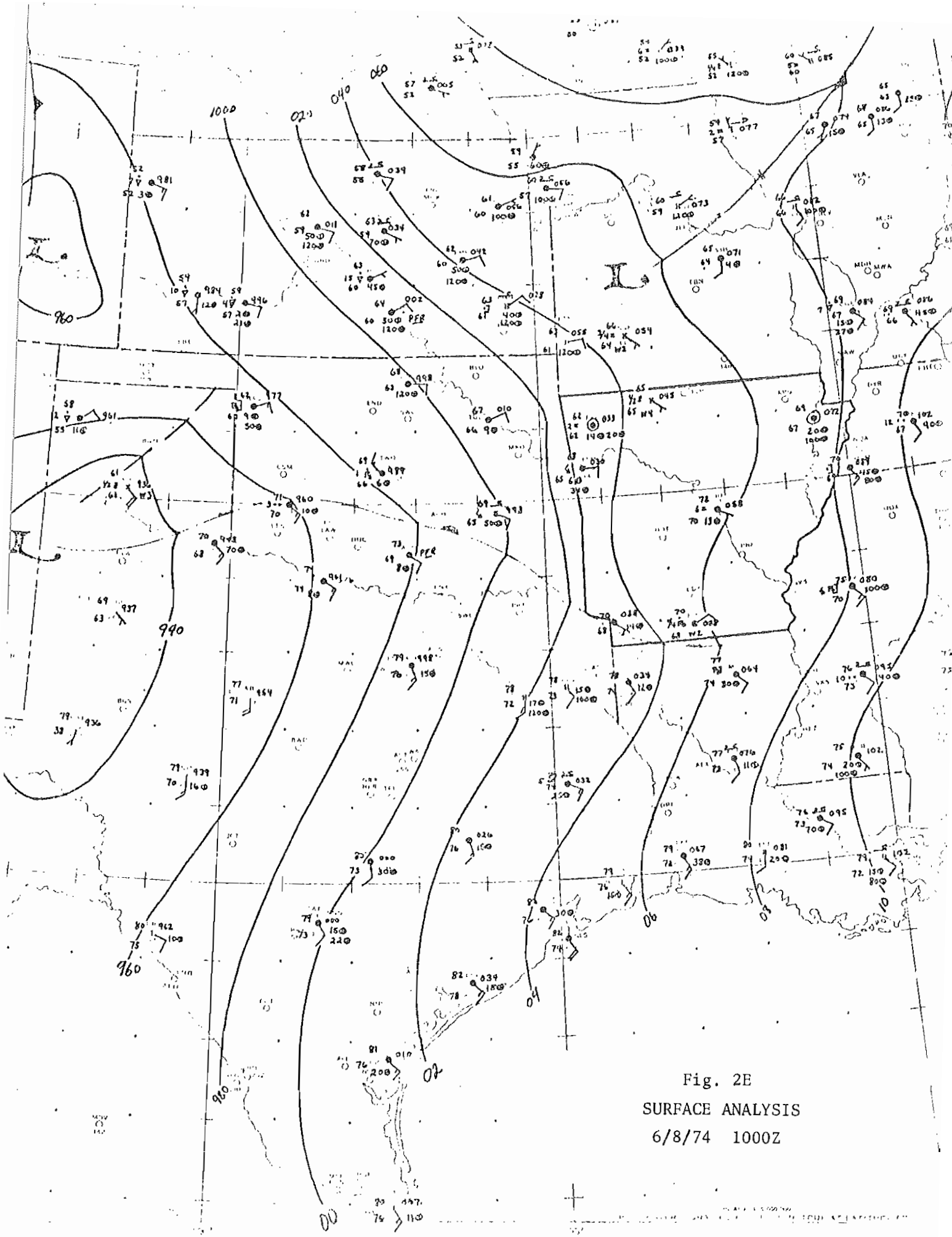

Fig. 2E
SURFACE ANALYSIS
6/8/74 1000Z

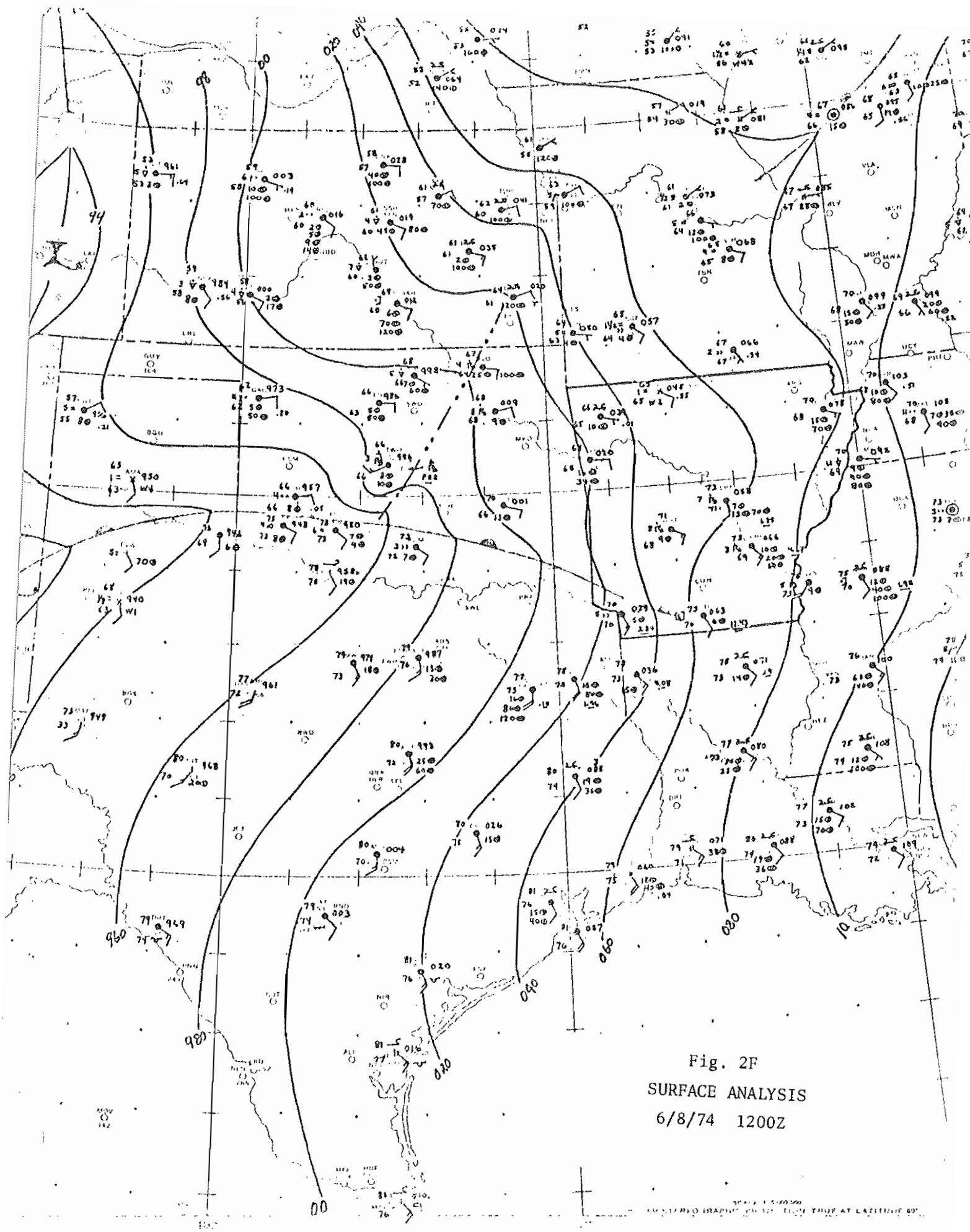

Fig. 2F

SURFACE ANALYSIS

6/8/74 1200Z

As the squall line developed near El Dorado during the afternoon, convective overturning of the atmosphere brought low θw (wet bulb potential temperature) air to the surface (as denoted by surface dew points lowering into the mid and upper 60's) within the confines of the meso-high/low dipole. A minimum in θw can contribute to intense convection in two significant ways: (1) if lifted or stretched (elevated minimum), low θw air will become colder than the undisturbed environment and the temperature lapse rate will steepen; (2) if rained into, it will become colder "in situ" than the surrounding undisturbed environment, and a downdraft will result which can serve to provide lift to the low level high θw air.

This low θw surface air and associated lower dew points were to remain in south-central Arkansas through the night. Its effect on the surface analysis was constant from late afternoon through the night, showing up as a minor frontal boundary essentially along the Arkansas/Louisiana border. Characteristic of the boundary was cyclonic curvature and convergence in the surface (and near surface) wind field. Further, the dome of low θw air near the surface was to be perpetuated through the night by additional convective overturning and evaporative cooling.

From available data and analysis it appears as if the following reasoning would explain the occurrence of the Union County deluge. As will be noted later, a number of other interesting conditions existed during this period which may have had a role in the event.

During the period 0000GMT to 1200GMT June 8th, a distinct short wave with very cold temperatures and high vorticity values was located over south-central Arkansas in the mid troposphere (700-500mb). An afternoon squall line and meso-system had developed in the same area leaving a pool of low θw air in the boundary layer (surface to about 970mb). Exceedingly warm and moist high θw air was located over Louisiana and northeast Texas and was being advected northward into south-central Arkansas by the gradient flow. This flow (represented by the 850mb winds) had some anticyclonic curvature in Arkansas at 0000GMT but was to back and become uniformly southerly with increasing speed during the night. This was in response to cyclogenesis which commenced after 0600GMT in the Texas Panhandle as a major 500mb circulation drifted southeastward toward central Colorado.

The warm moist air moving northward into south-central Arkansas was lifted over the "cold dome" of low θw air which remained below 970mb. The lifted air was underneath the cold pocket and high vorticity values associated with the mid tropospheric short wave drifting across from the west. Convection was thus greatly enhanced. Evaporative cooling near the surface and convective overturning perpetuated the low θw bubble, therefore conditions conducive to lift and massive convection remained essentially unchanged for many hours.

Radar patterns during the night support this hypothesis. An east-west elongated area of convection developed during the evening along the Arkansas/Louisiana border and intensified markedly after 0500GMT. The northern edge of the area spread slowly northward during the early morning hours but the southern edge remained nearly stationary until moving north of the El Dorado area about 1300GMT. During the entire event, radar indicated cell movement backing from 260/40kts early in the night to 210/18kts by dawn which would seem reasonable under the synoptic circumstances. A stationary convective area with elements forming and moving through it would lend credence to the quasi-static meso-scale boundary hypothesis.

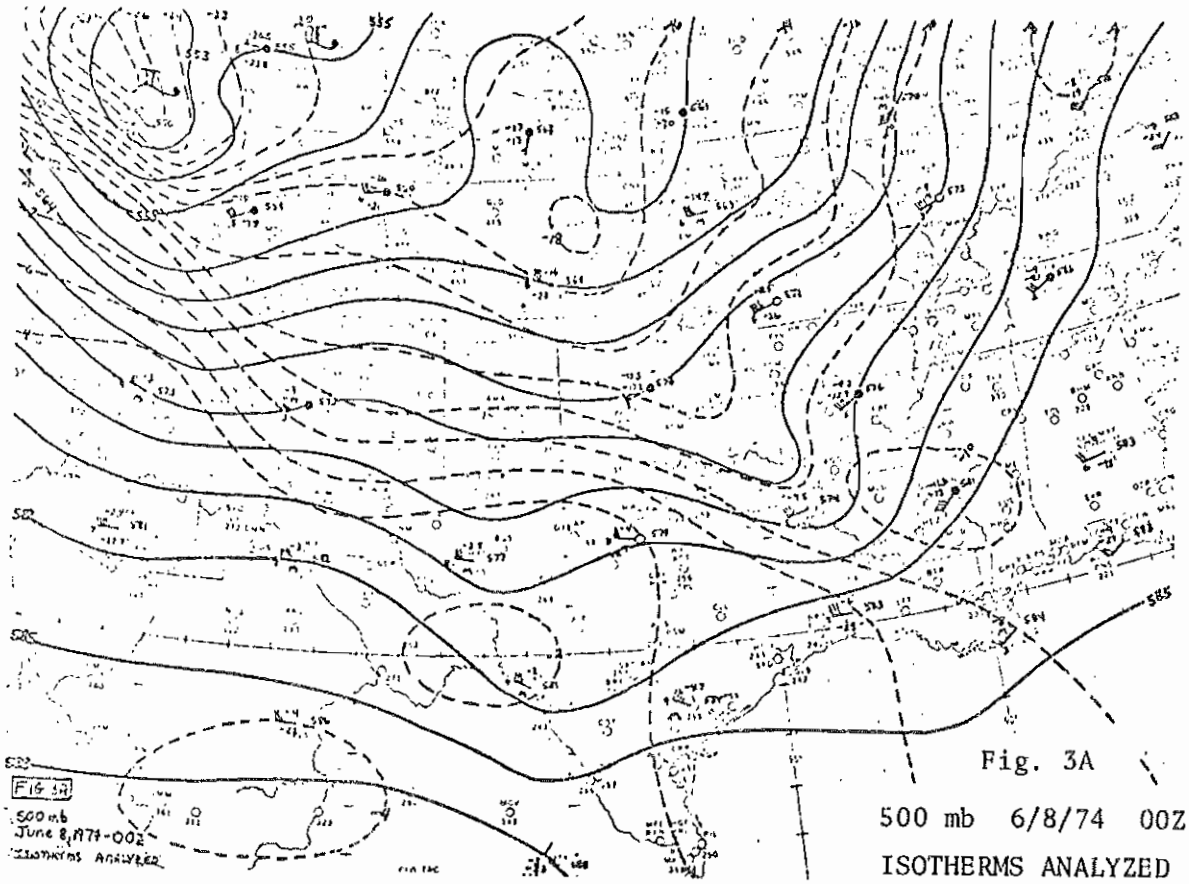

Fig. 3A

500 mb 6/8/74 00Z

ISOTHERMS ANALYZED

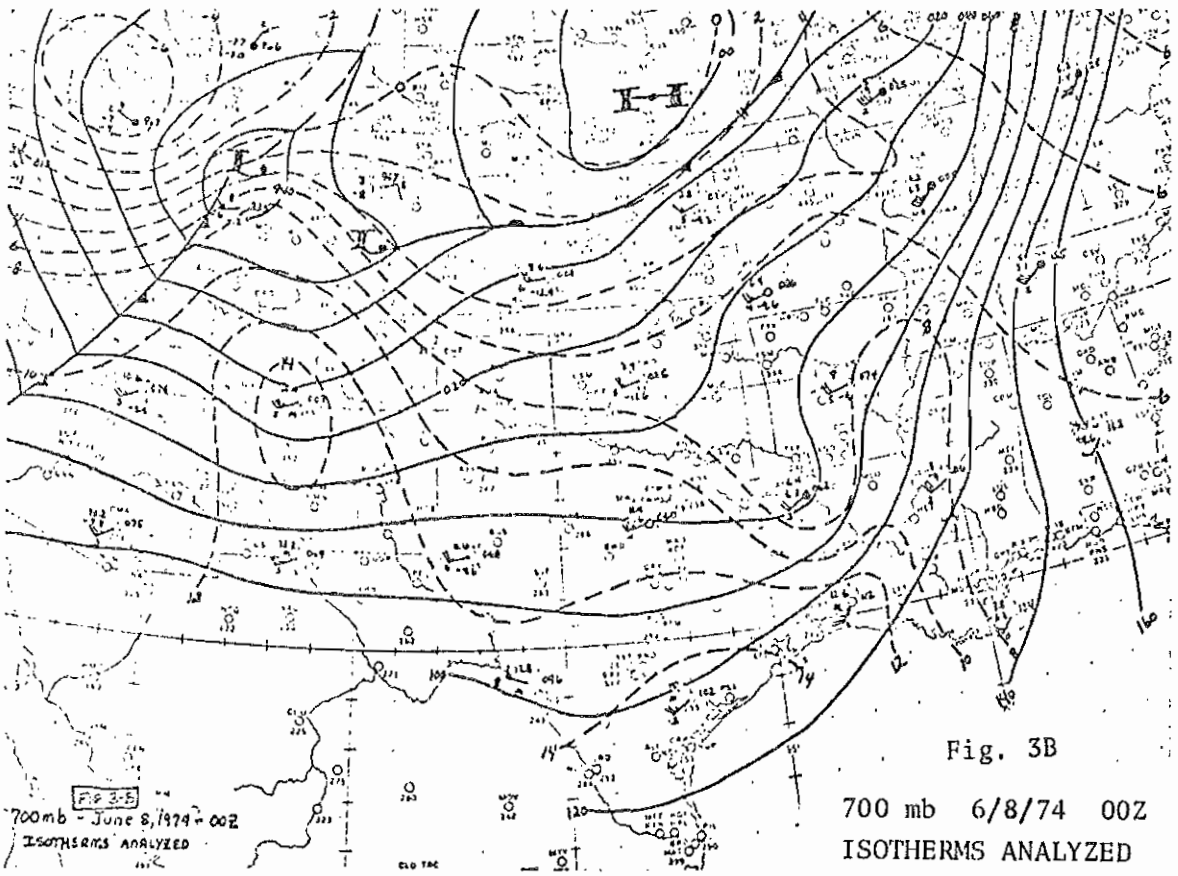

Fig. 3B

700 mb 6/8/74 00Z

ISOTHERMS ANALYZED

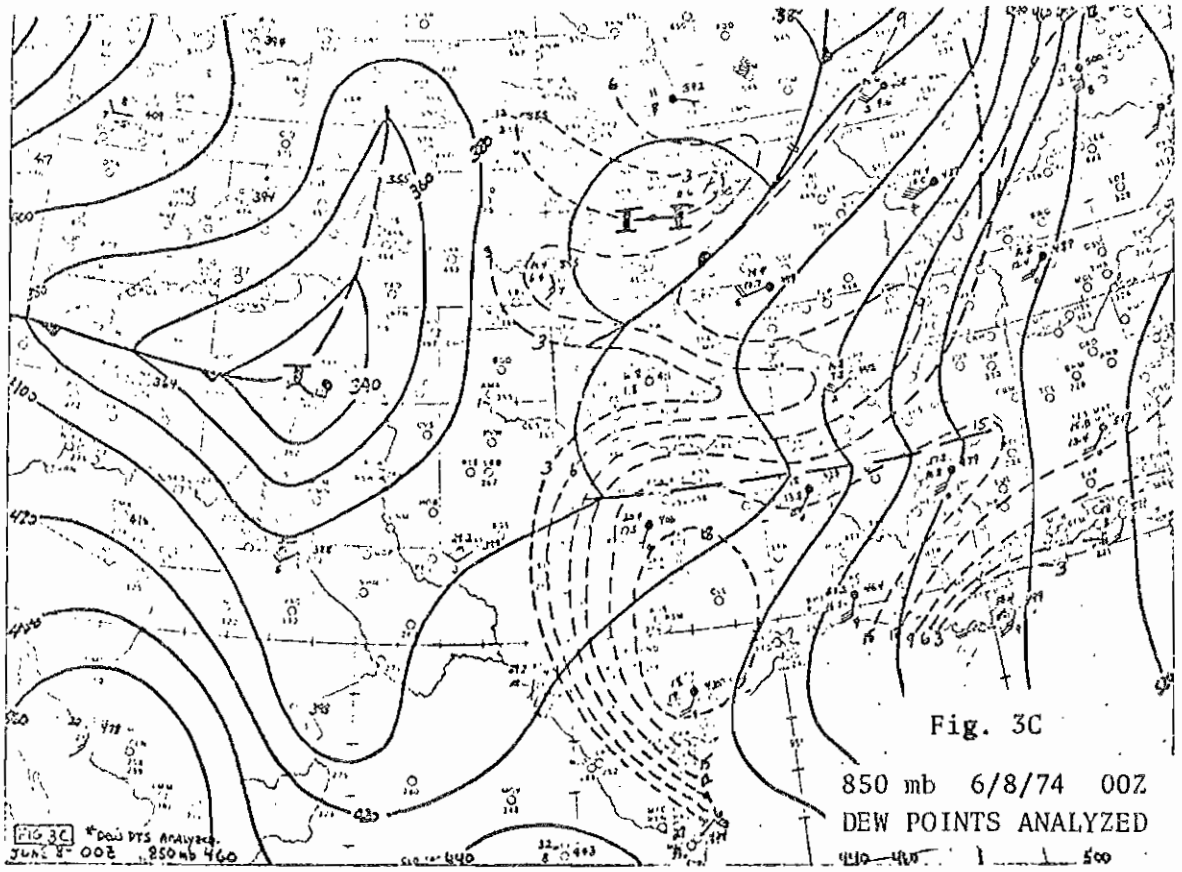

Fig. 3C

850 mb 6/8/74 00Z
DEW POINTS ANALYZED

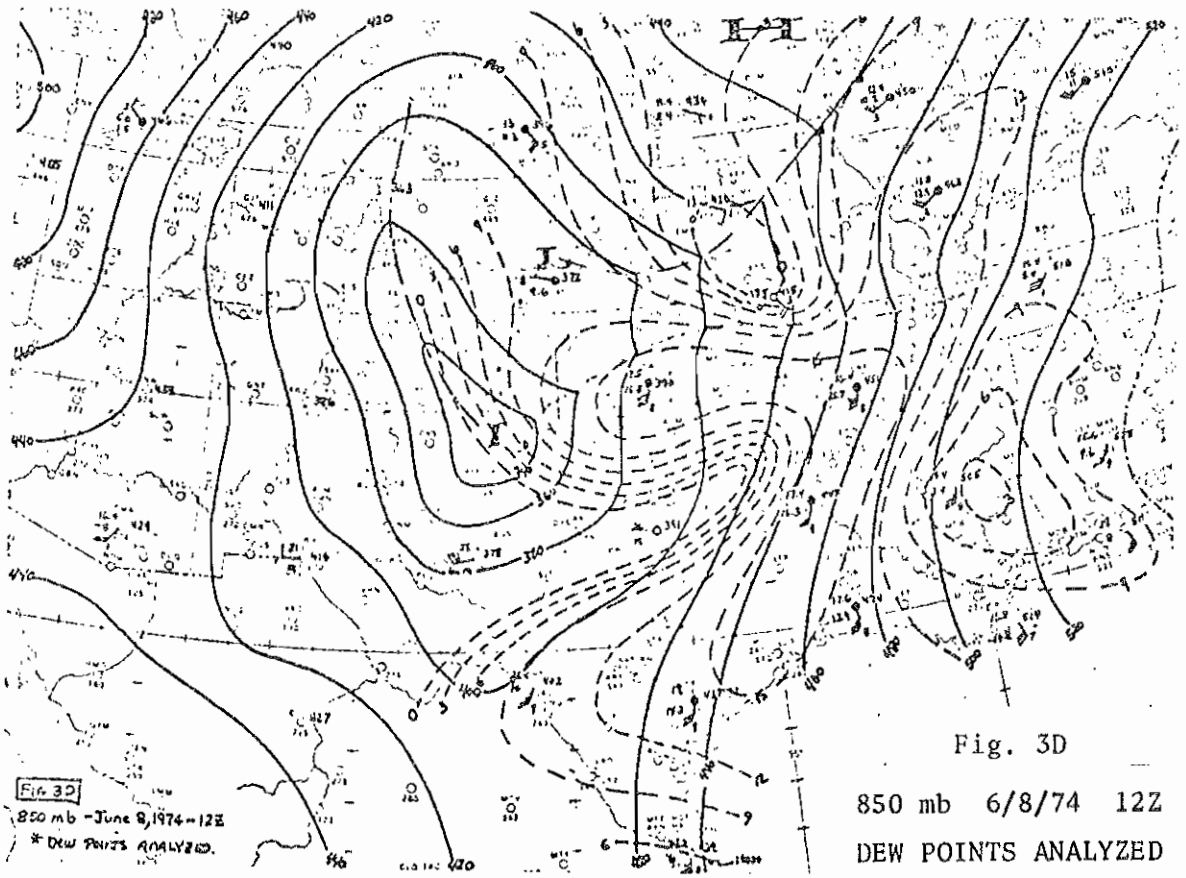

Fig. 3D

850 mb 6/8/74 12Z
DEW POINTS ANALYZED

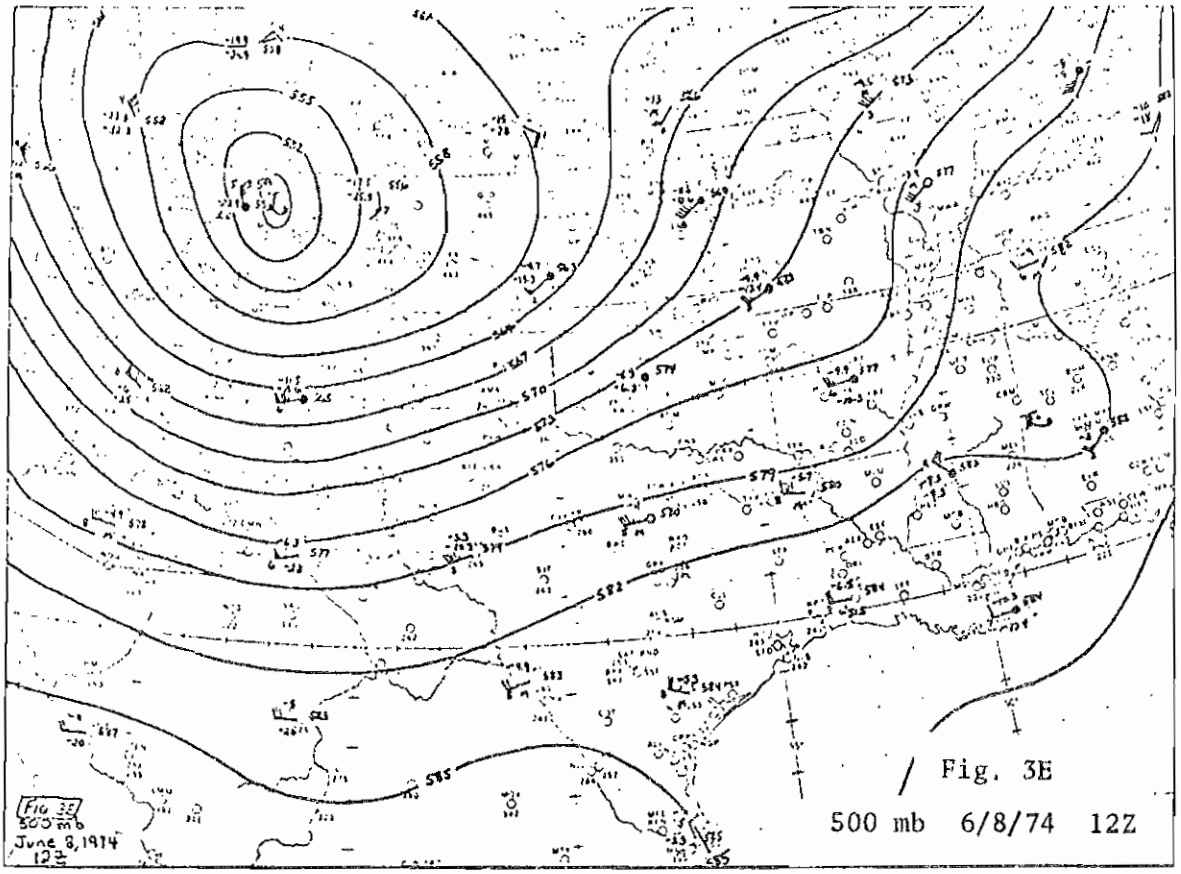

Fig. 3E
500 mb 6/8/74 12Z

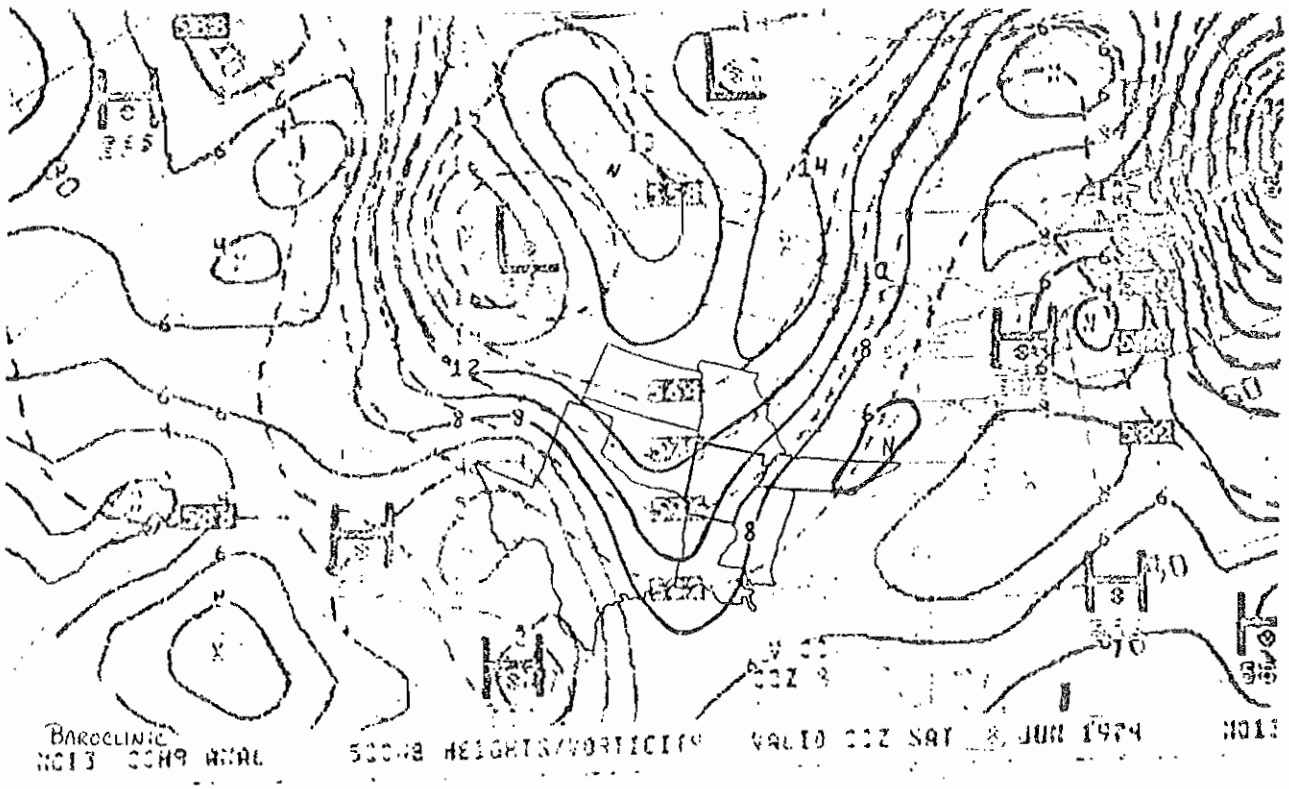

Fig. 4.
500mb Heights/Vorticity Analysis
6/8/74 00Z

Additional evidence of the lift in the moist column can be found when one examines the θw profile of SHV (Shreveport) and LIT (Little Rock) (Fig. 5). We are assuming that θw is a pseudo-conservative property of an air parcel, i.e., it does not change for wet or dry adiabatic motion or for rain falling into the air parcel. Comparison of the θw profile from 995mb to 700mb at SHV (0000GMT) with the profile of 922mb to 647mb at LIT (1200GMT) would seem to suggest that the column of air present over LIT was an elevated reflection of the column which passed SHV (under the added assumption that the air between 995mb and 700mb passing northward over SHV had remained essentially uniform in character through the night). The initial lift which reached 73mb (995mb to 922mb) by the time the air mass reached LIT likely occurred along the boundary south of El Dorado.

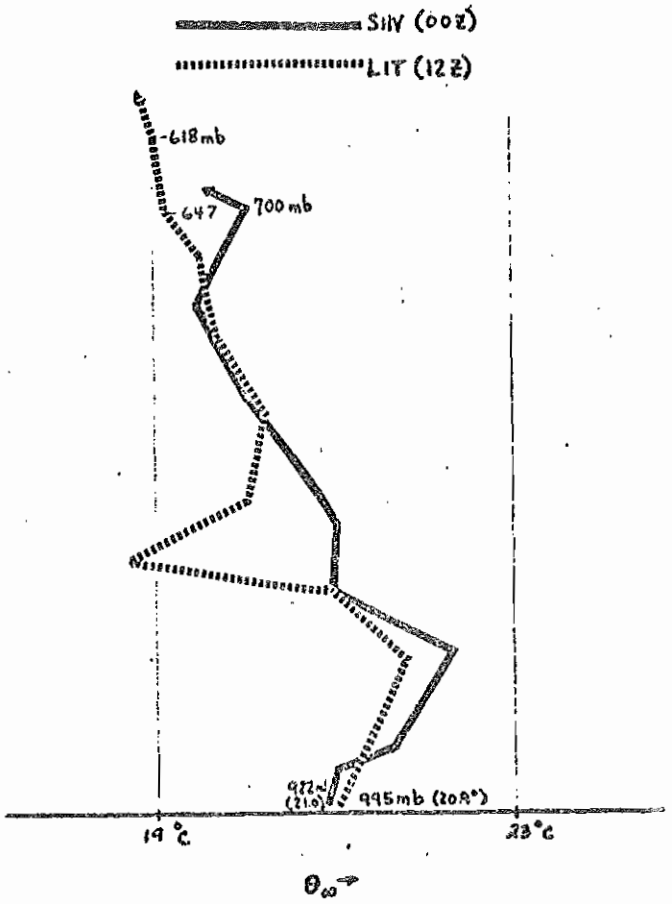

Fig. 5

During the early morning hours, the northern edge of the convection area developed slowly northward toward central Arkansas. By shortly after sunrise the southern boundary also finally had begun to shift northward ending the rainfall rather abruptly over Union County. Termination of precipitation over south Arkansas can be linked to at least two synoptic events. The first was the intrusion of warmer and drier air at mid levels (near 500mb) over the impact area. This air can be identified over the western half of Texas at 0000GMT (Fig. 3A) and further east into northwest Louisiana by 1200GMT (Fig. 3E). The second event concerns the development of the cyclonic circulation over the Texas Panhandle by 1200GMT. In response to this development, the 850mb (low level) jet was shifted westward toward the mid Red River Valley creating strong anticyclonic horizontal shear over the impact area. Relocation of the low level jet into eastern Oklahoma and Texas may have helped end the record rains in south Arkansas but it served to set the stage for the killer Drumwright and Tulsa tornadoes which occurred on the evening of the 8th.

Investigation of this event disclosed a number of other circumstances which may have played a role in the excessive release of rain. First, it appears that the maximum undisturbed moisture inflow at low levels took place over south-central Arkansas. During the night drier air at 850mb was being advected into northeast Texas from the southwest and into central Mississippi from the south. Between these areas the flow was unchanged.

Secondly, the expected diffluence at upper levels (above 300mb) was evident over the impact area. However, a time series plot of the SHV RAOB shows an additional interesting feature. Approximately 24 hours prior to the heavy rains, a closed cyclonic circulation passed SHV at 200mb. Subsequently the tropopause rose and cooled significantly (from 160mb/-66.3°C to 115mb/-74.3°C). This high, cold tropopause feature continued through the rain sequence. A similar but less dramatic cooling and lifting occurred at LIT during the same period.

Thirdly, only massive convection over a prolonged period would result in the rainfall totals observed with this event. Radar tops continuously near 60,000 feet for many hours are evidence that this was indeed occurring. Cell diameters were mostly quite large or the cells grouped in clusters. The cores were therefore well insulated from environmental entrainment, thus allowing for a very high efficiency of rain production.

4. SUMMARY

There is no question that a rainfall event of this magnitude is rare and, realistically, impossible to forecast. Historically, this was the greatest 24-hour rainfall ever recorded in Arkansas.

A number of common indicators pointed toward a significant rainfall release in southern Arkansas and northwestern Louisiana. These include: (1) an abundant moisture supply in the form of unstable Gulf air over northeastern Texas and Louisiana being advected rapidly northward; (2) a short wave impulse moving eastward from southeastern Oklahoma into southern Arkansas; (3) the jet at 300mb and above was about 4° latitude north and west of the release area resulting in (4) diffluent flow at high levels over southern Arkansas and northern Louisiana.

Further examination of the data reveals additional circumstances which were present over the impact area and may have had a significant role to play. These include: (1) a persistent dome of low θ_w air near the surface in south Arkansas which was initiated by an afternoon squall meso-system and perpetuated through the night by evaporative cooling and convective downdrafts; (2) a very high and cold tropopause over the area; (3) the convective area, once formed, remained stationary with cells moving through it and; (4) massive cell diameters allowed minimal outside entrainment and maximum rain producing efficiency.

It is felt that the circumstance mainly responsible for the 18 inch release near El Dorado was the thrust of the moist Gulf air being lifted over the dome of low θ_w air and simultaneously cooled aloft under the mid tropospheric short wave.

Precipitation was ended when warm dry air was introduced at mid levels and the low level wind jet receded westward in response to cyclogenesis over the southern Plains resulting in strong anticyclonic shear in southern Arkansas.

5. FORECAST NOTES

This event was unique. As stated earlier it was the greatest 24-hour rainfall ever recorded in Arkansas...and it fell in less than 12 hours! A critical combination of circumstances occurred over one particular area and although a repeat performance is highly unlikely it does serve to point out several factors which may be conducive to major rainfall release somewhere over the state. Some of them are listed below:

...An abundant moisture supply (and inflow) from the western Gulf of Mexico should be present. Surface dew points $\geq$ 70°F and minimal anticyclonic curvature in the low level wind field ($\leq$ 5,000 ft) should be evident. The most favorable low level wind for heavy release in Arkansas is 180°-220°. Check the FOUS data for LIT boundary winds and their speeds. Speeds in excess of 20 kts are favorable. FOUS is usually effective at indicating favorable winds and moisture levels (3-layer RH forecasts at the beginning of the message).

...A diffluent upper trough working toward Arkansas is a positive sign, especially if the diffluent portion ahead of the system will cross the state. If the upper air pattern (500mb and above) is slow to change, timing becomes complicated as minor impulses will have more influence, as in this case. The baroclinic (or LFM) is better than the barotropic model at picking up amplitude with these smaller features.

...Arkansas should be on the anticyclonic side (to the right) of the 300mb jet axis and ideally 2 to 5 deg latitude away from it.

...The topography of the state often results in large release from otherwise marginal conditions. Although they apparently did not come into play this time, the E-W elongated Ouachita Mts. can wring a lot of water out of a good southerly jet. The Ozarks can do just as well but more often with southwesterly rather than southerly winds.

...Check "K" values (and forecast "K" values). Values above 35 and into the low 40's approach the "potential K" and indicate heavy rain rather than severe weather.

...Precipitable water nearing 2 inches at Little Rock, Longview, or Monette should alert one to potential excessive rain release. To estimate precipitable water: beginning at 950mb, sum the actual mixing ratio at 50mb intervals to 500mb (you will have 10 numbers). Multiply the sum by .02. The result will approximate the PW. Maximum rainfall can be estimated by 3 times the PW.

...Be alert to unusual complications (like the meso-system in this case study) which may add further lift to the moist air...or stabilize the air enough so convection may not occur at all.