NOAA Technical Memorandum NWS SR-105

CASE STUDY OF A SIGNIFICANT THUNDERSTORM WAKE DEPRESSION ALONG THE TEXAS COAST : MAY 29-30, 1981

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UNITED STATES DEPARTMENT OF COMMERCE
Malcolm Baldrige, Secretary

National Oceanic and Atmospheric Administration
John V. Byrne, Administrator

National Weather Service
Richard E. Hallgren, Director

Case Study of a Significant Thunderstorm Wake Depression Along the Texas Coast : May 29-30, 1981

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1. Introduction

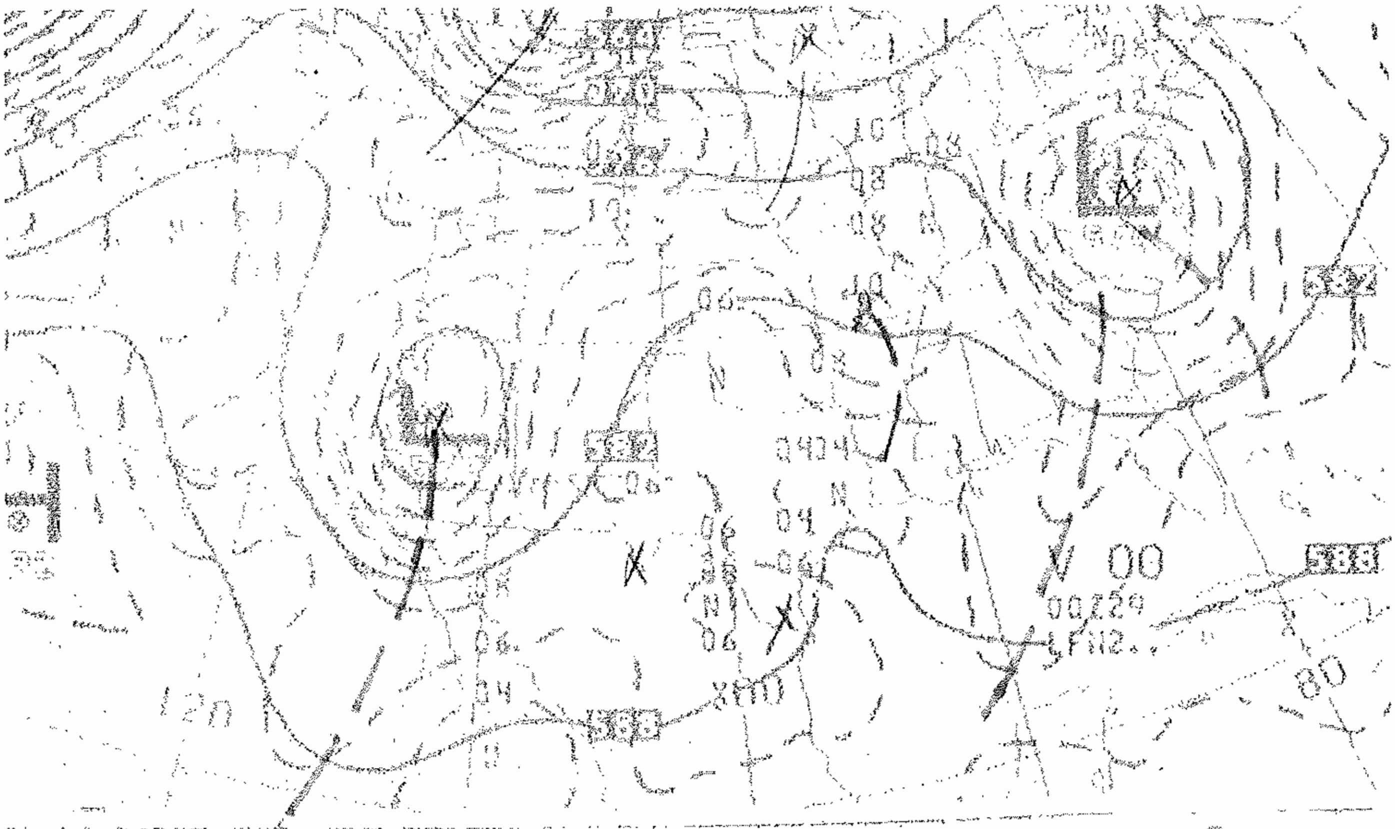
An intense thunderstorm complex developed over south Texas during the afternoon and evening of May 29, 1981. The storm system moved southeast over the Lower Texas Coast and adjacent waters during the night and produced a significant mesoscale perturbation in the surface pressure field in the form of a large "bubble high" and accompanying wake depression. The strong pressure gradient associated with the high and its trailing mesolow resulted in gale force winds along the coast as well as high seas in the coastal waters. The significance of this event lies in the fact that the strong winds were associated with an organized weather system which maintained itself for 12-15 hours as it propagated southeastward, not simply the result of much more common thunderstorm outflows. The fact was properly analyzed in real time and led to correct forecasts of subsequent weather events.

This report is, in effect, a review of that significant event. It is presented from the viewpoint of forecast office operations and emphasizes mesoscale analysis as a tool for understanding. Upper-air analyses from the LFM, satellite imagery, radar depictions and locally-produced mesoscale surface analyses are presented for various hours during the lifetime of the thunderstorm complex. Supplementary data and analyses which were available to the forecaster are presented in Appendix 1. A detailed theoretical treatment of mesohighs/wake lows is not the goal of this study; for that the reader is directed to the references cited. The emphasis here is on an analytical approach to finding such systems and anticipating their effects.

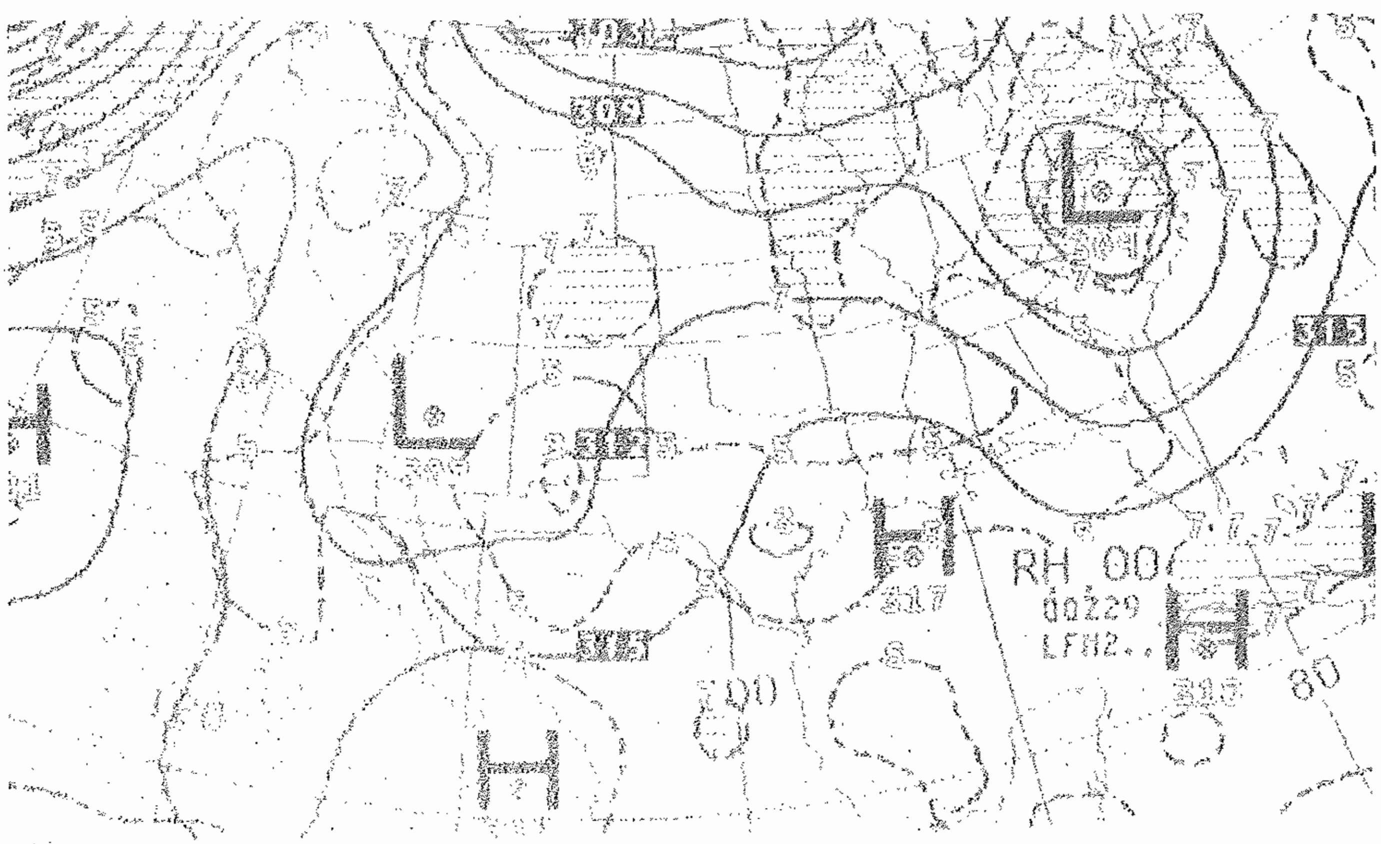
It should be obvious from this review that a careful analysis of local surface data, coupled with a basic understanding of recent studies of thunderstorm dynamics, is indispensable in accurate forecasts for these and similar mesoscale systems. To further enhance the utility of this study for forecasters, Appendix 2 contains unanalyzed surface maps for a second similar wake depression event which affected the Texas Coast on June 2-3, 1981.

2. The Event

<u>The Synoptic Situation</u>: For several days prior to May 29th a weak ridge aloft had been situated over Texas. Numerous short waves had moved through the ridge and some had been associated with dramatic convective outbreaks over Oklahoma and north and west Texas (Figs. 1 and 2). By 1200 GMT on the 29th the ridge had been eroded noticeably, a large cutoff low at 500 mb was located over Arizona and another vigorous short wave had triggered thunderstorms from San Angelo to San Antonio (Figs. 2-4).



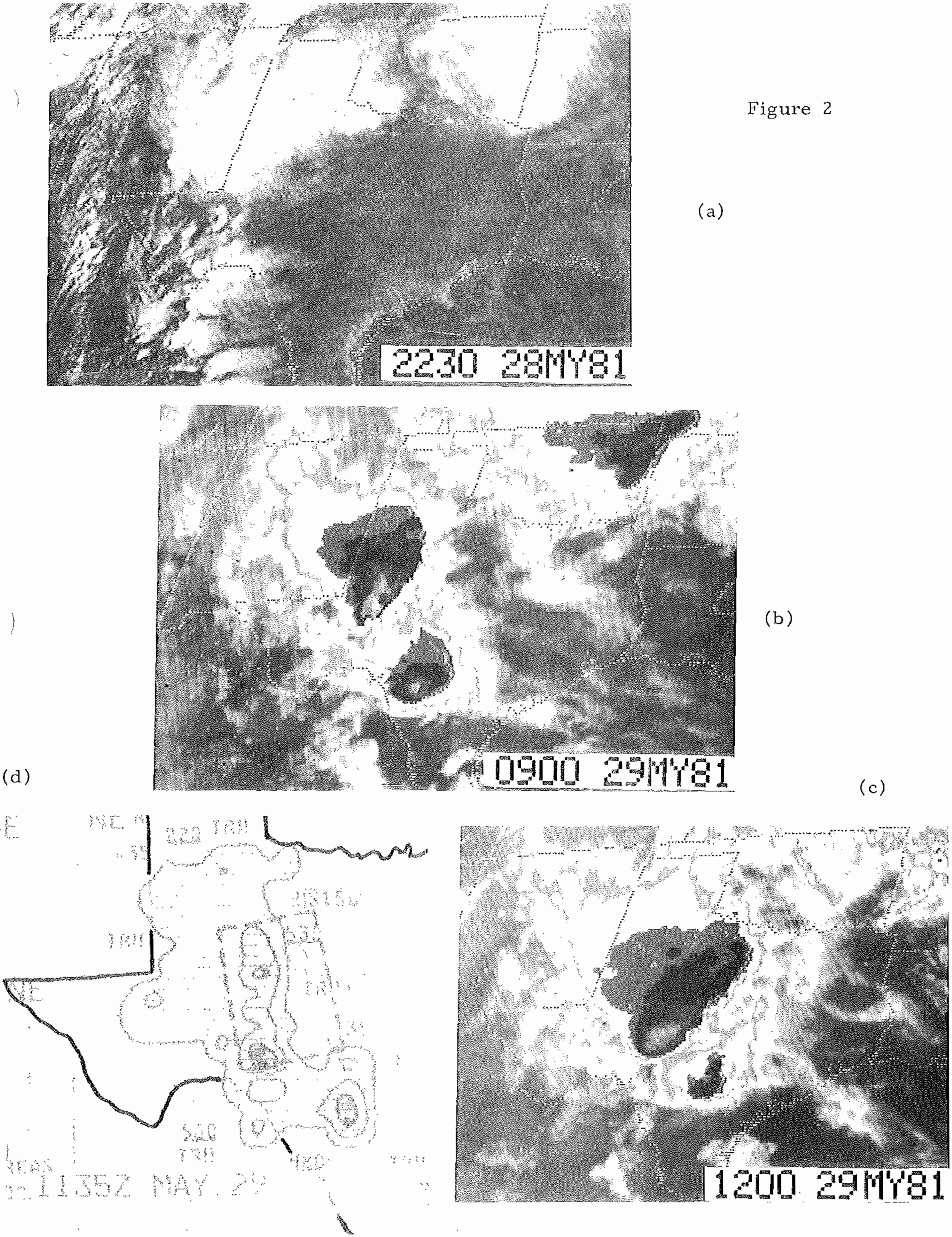
500MB ANALYSIS HEIGHTS/VORTICITY 00Z FRI 29 MAY 1981



ANALYSIS 700 HEIGHT/REL HUMIDITY 00Z FRI 29 MAY 1981

Figure 1

Figure 2

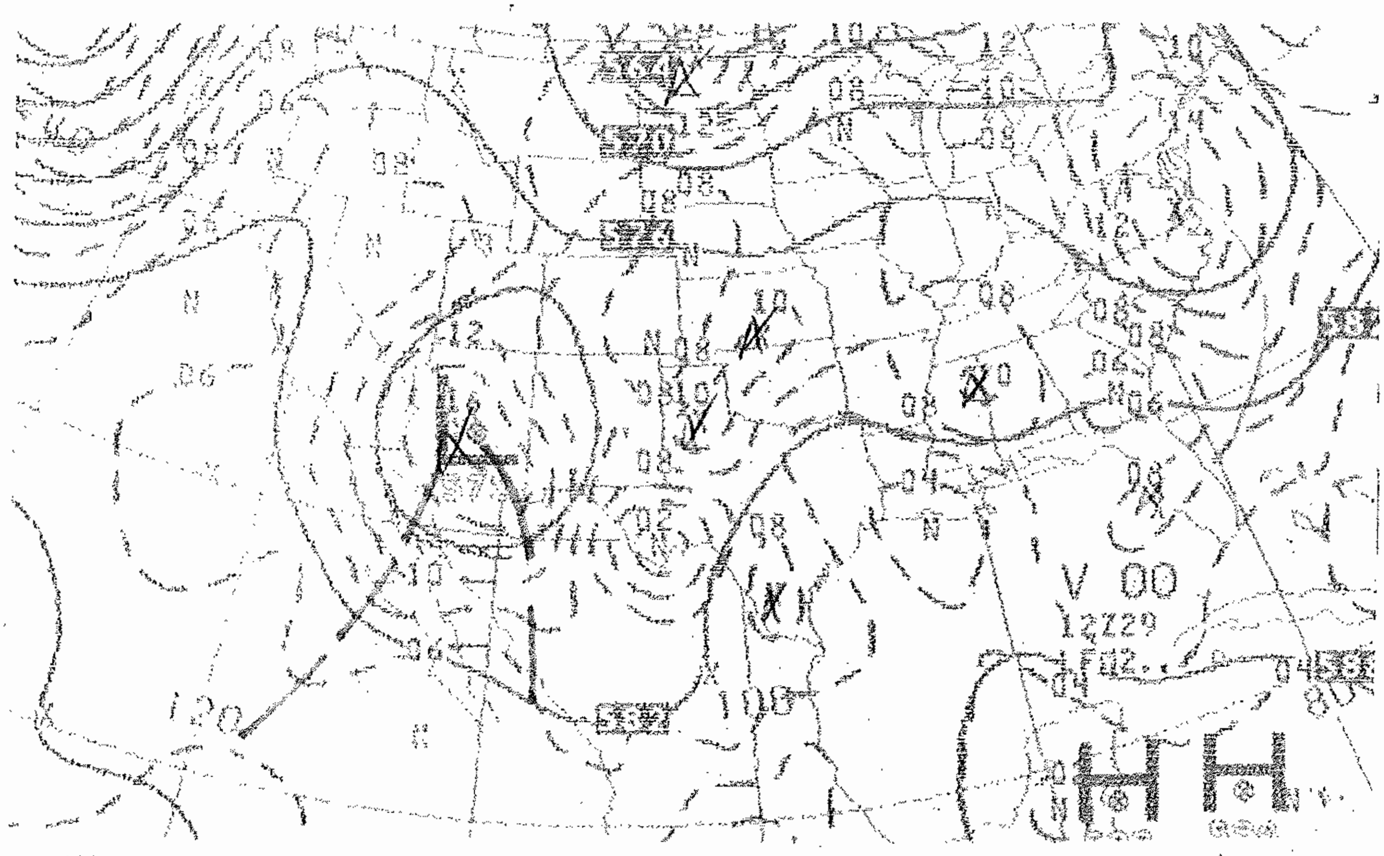


(a)

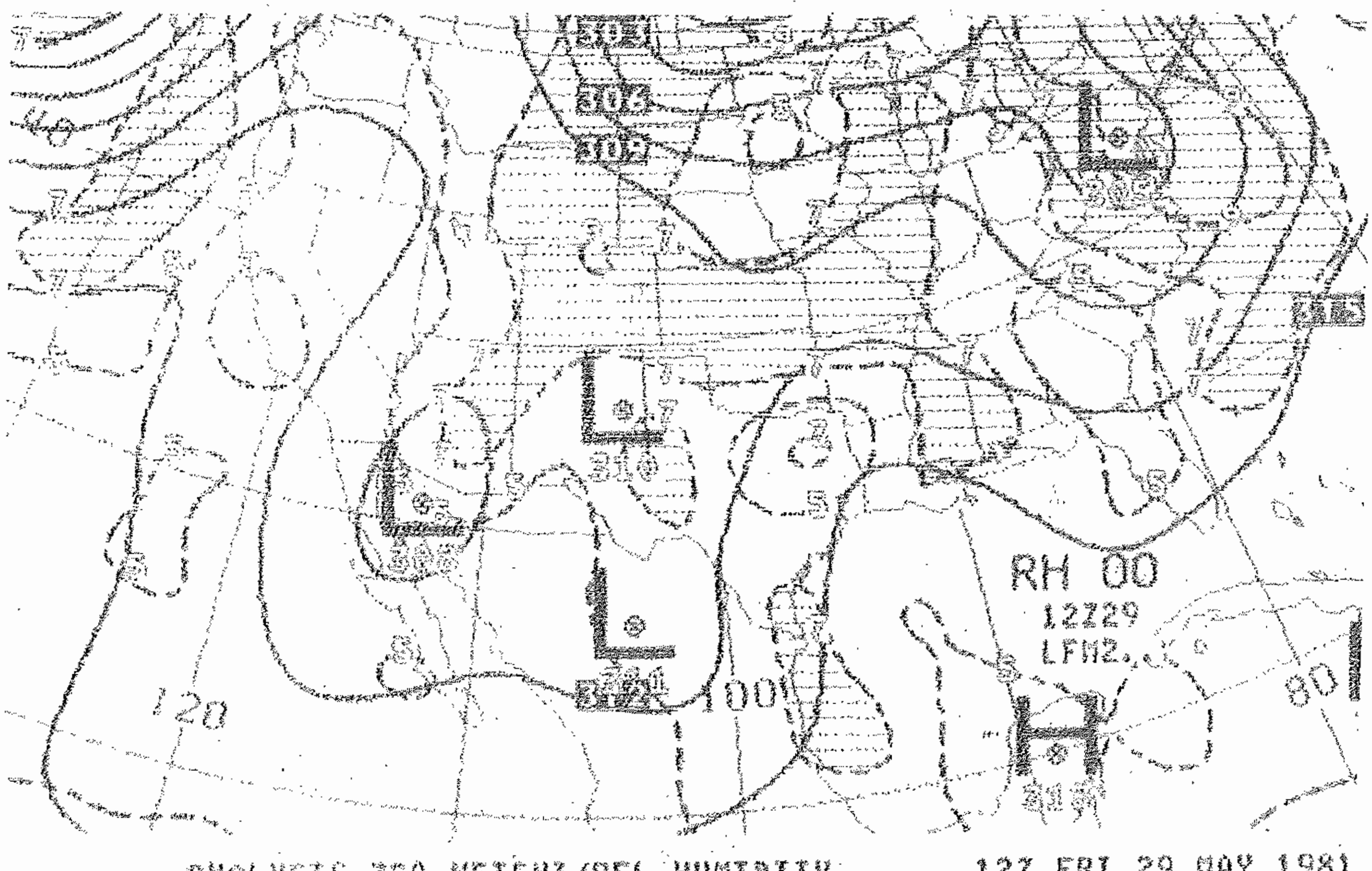
(b)

(d)

(c)



500MB ANALYSIS HEIGHTS/VORTICITY 12Z FRI 29 MAY 1981



ANALYSIS 700 HEIGHT/REL HUMIDITY 12Z FRI 29 MAY 1981

Figure 3

Mesoscale Considerations: During the night a small cluster of thunderstorms moved from west of Del Rio to near San Antonio by 1200 GMT on the 29th (see satellite imagery, Figs. 2a-2c). The thunderstorms left behind a distinct density discontinuity (outflow boundary) which stretched from just east of San Antonio to near Laredo. An even more distinct boundary stretched from Wichita Falls to Junction to about 50 miles northwest of Del Rio, the result of earlier thunderstorms. These small scale boundaries were easily identifiable in a local mesoscale analysis prepared at 1200 GMT (Fig. 4). Notice that the undisturbed air mass ahead of the boundaries was quite moist with dewpoints in the mid- and upper 70s. The surface pressure gradient was weak, but soundings revealed 20 knot winds just off the surface.

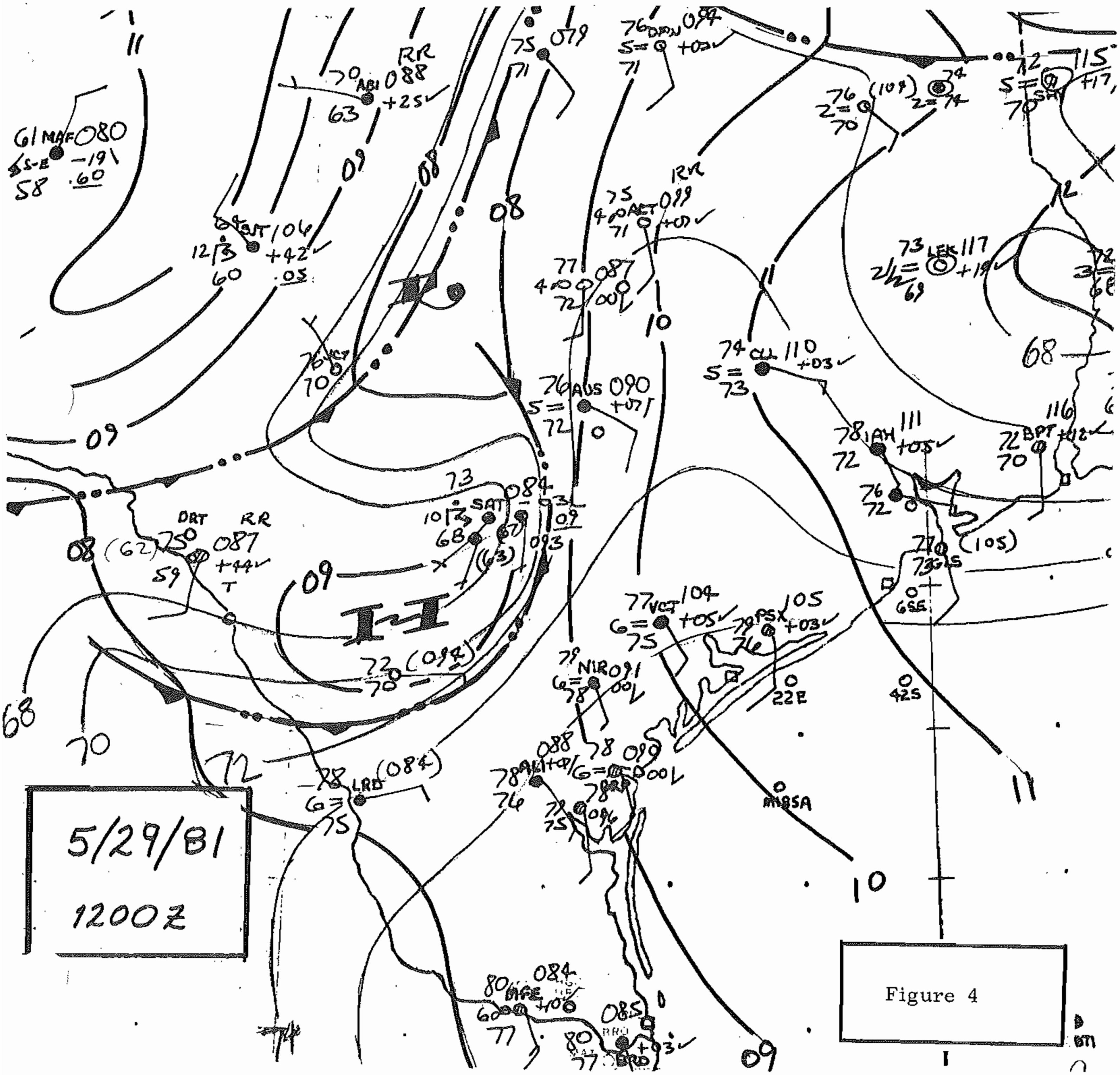
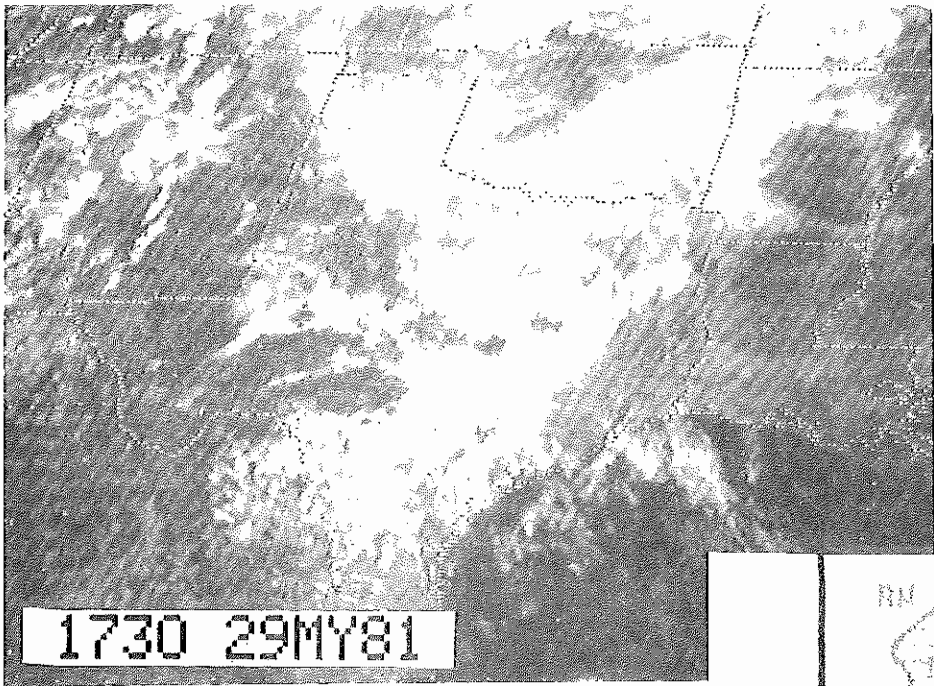
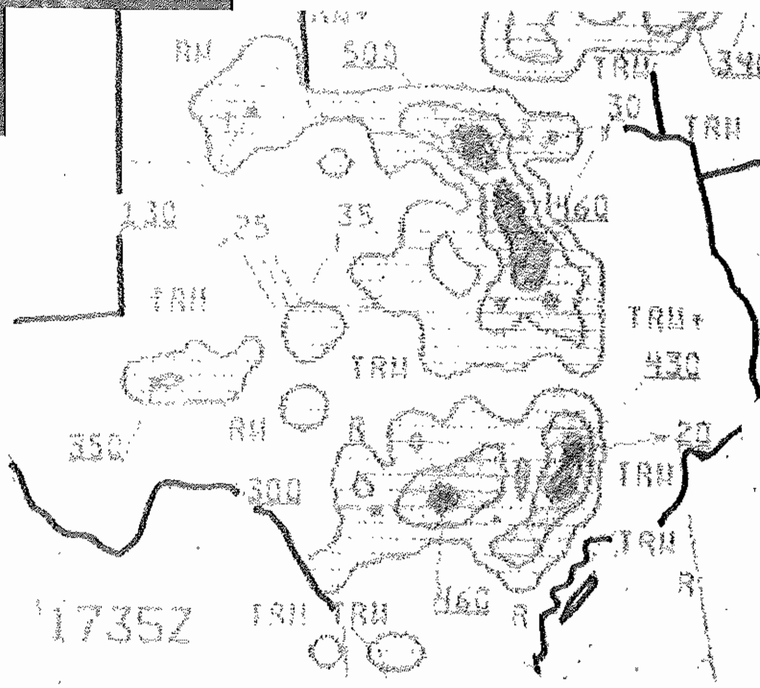


Figure 4


1730 29MY81

(a)


500
340
TRW
30
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230
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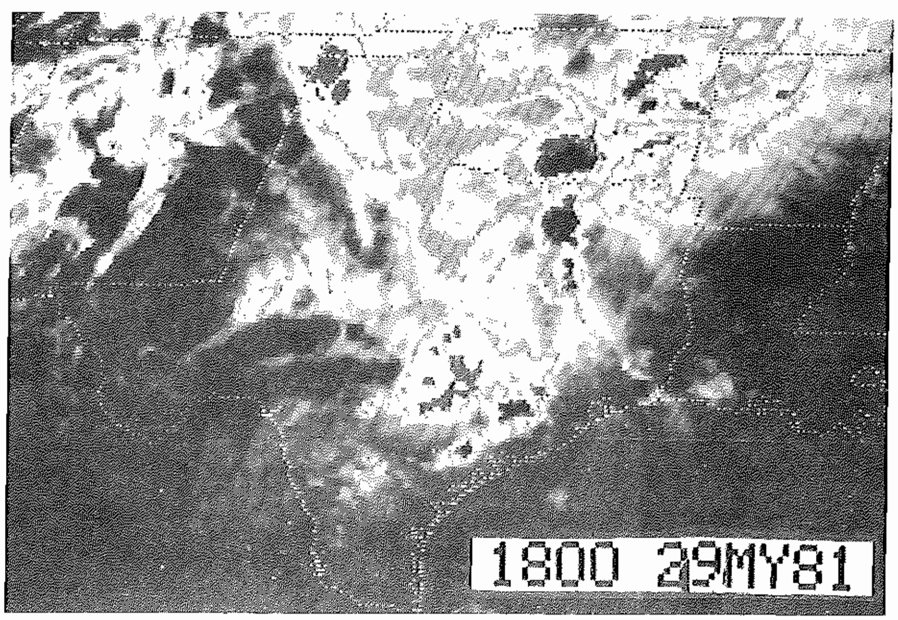
1735Z

Figure 5

(b)


1800 29MY81

(c)

By 1800 GMT the general area of thunderstorms had moved east to a position from between Dallas and Tyler, south to near Victoria and Cotulla (Figs. 5 and 6). Although infrared satellite imagery during the morning hours of the 29th indicated a warming (lowering) of cloud tops, by 1800 GMT the thunderstorms were again increasing in intensity. Mesoanalysis (Fig. 6) revealed a weak bubble high over central Texas associated with the thunderstorms near San Antonio. Convection had been developing repeatedly since about 1400 GMT along a weak east-west oriented boundary and 3-6 inch rains had fallen in San Antonio by 1800 GMT.

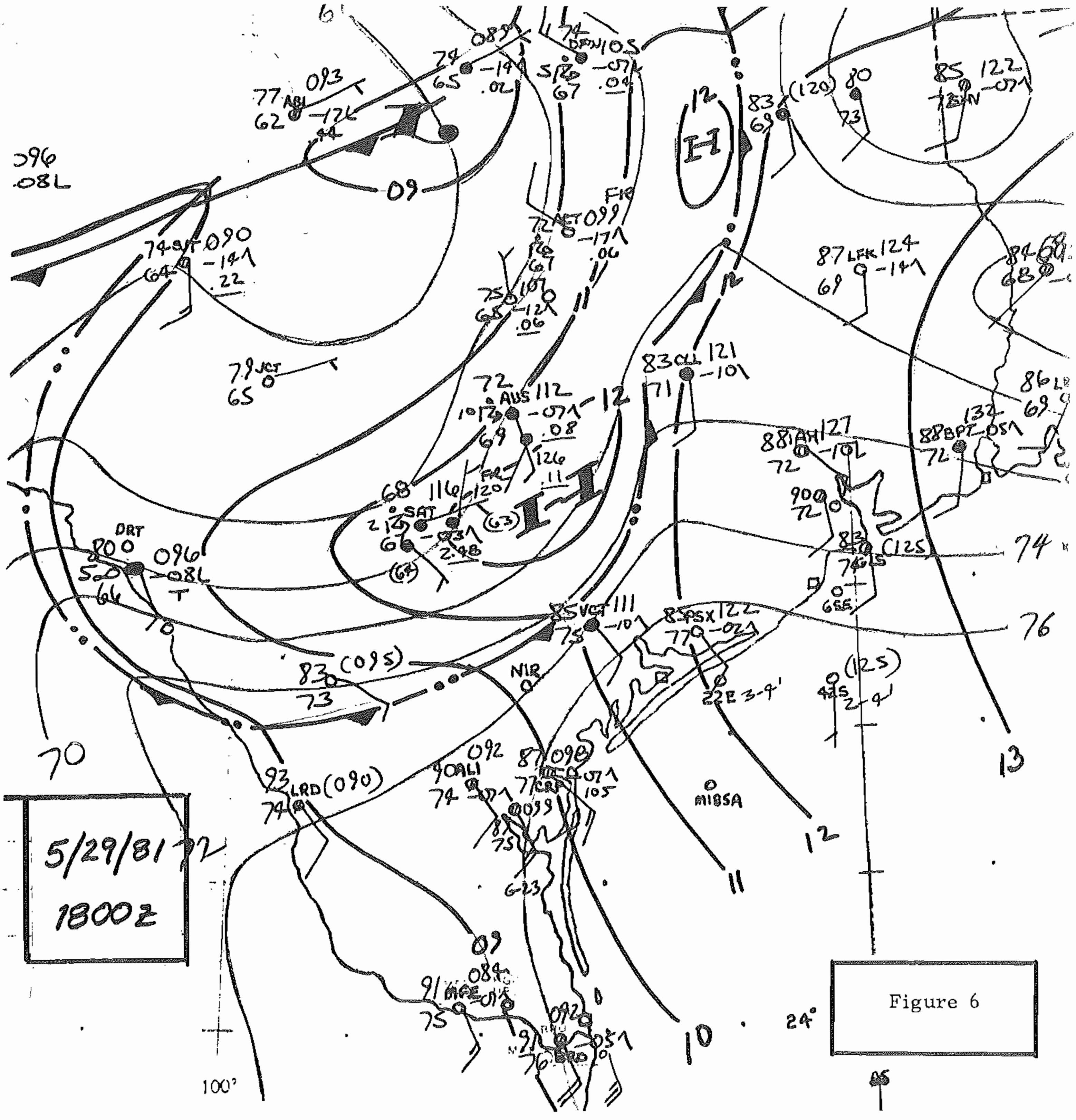


Figure 6

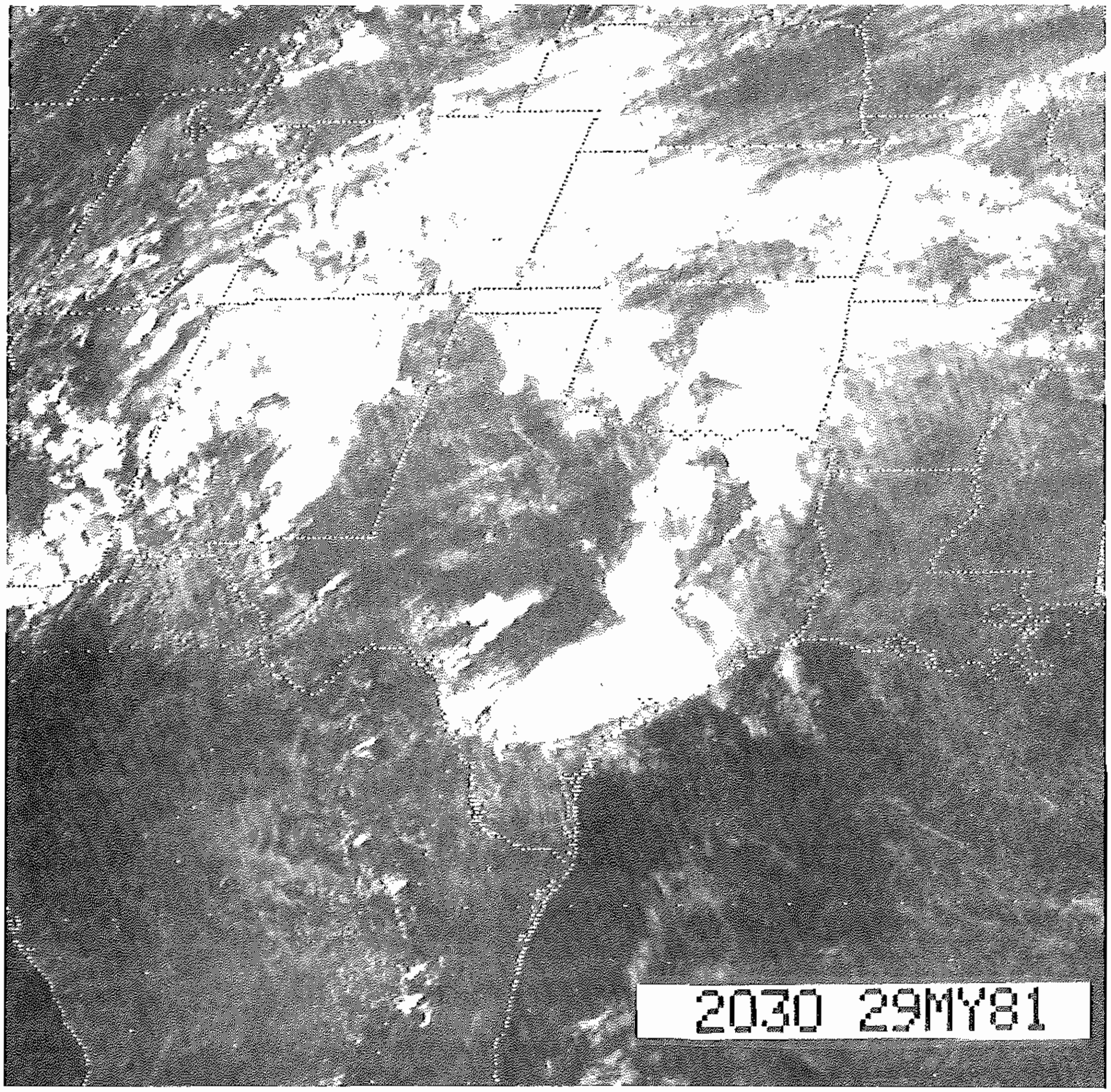


Figure 7

An outflow boundary through south Texas is clearly visible in the 2030 GMT satellite image (Fig. 7). The corresponding radar depiction (Fig. 8) shows that thunderstorms are being initiated along the southern edge of the boundary as it moves into moist unstable air.

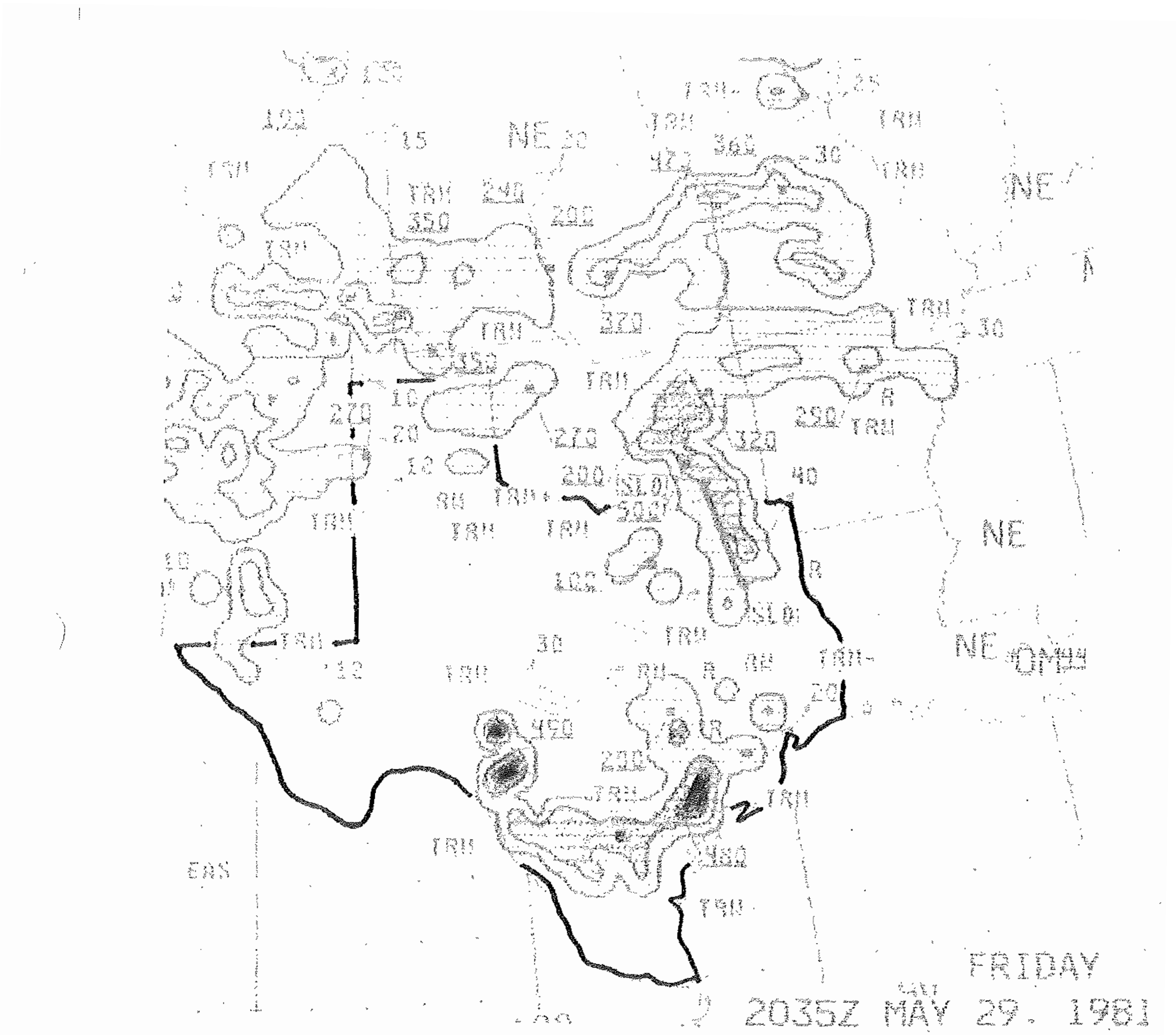
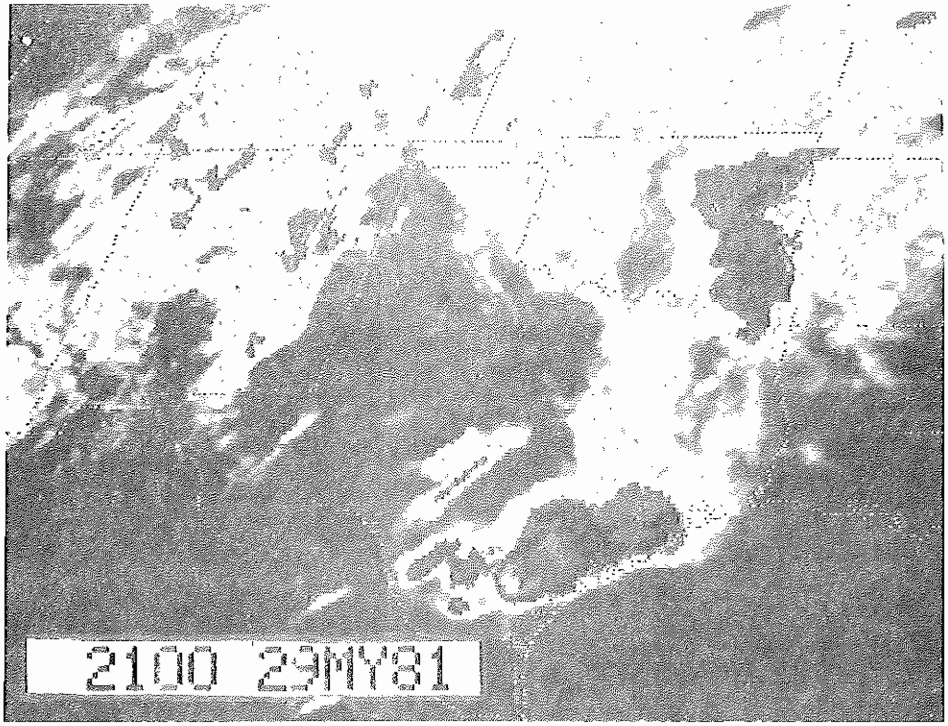


Figure 8

Figure 9



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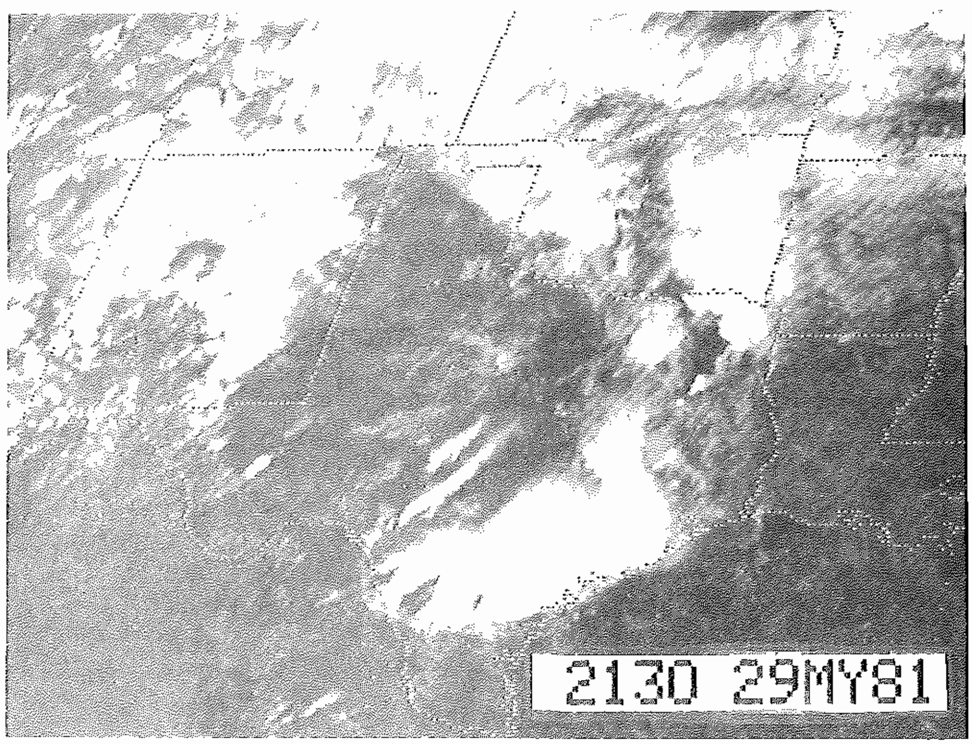


(b)

A mesoscale analysis at 2100 GMT (Fig. 10) was aided by the corresponding satellite images and clearly reveals the progress of the thunderstorm outflow boundary. Note particularly the strong inflow of warm, moist air along the boundary between Palacios (PSX) and Corpus Christi (CRP).

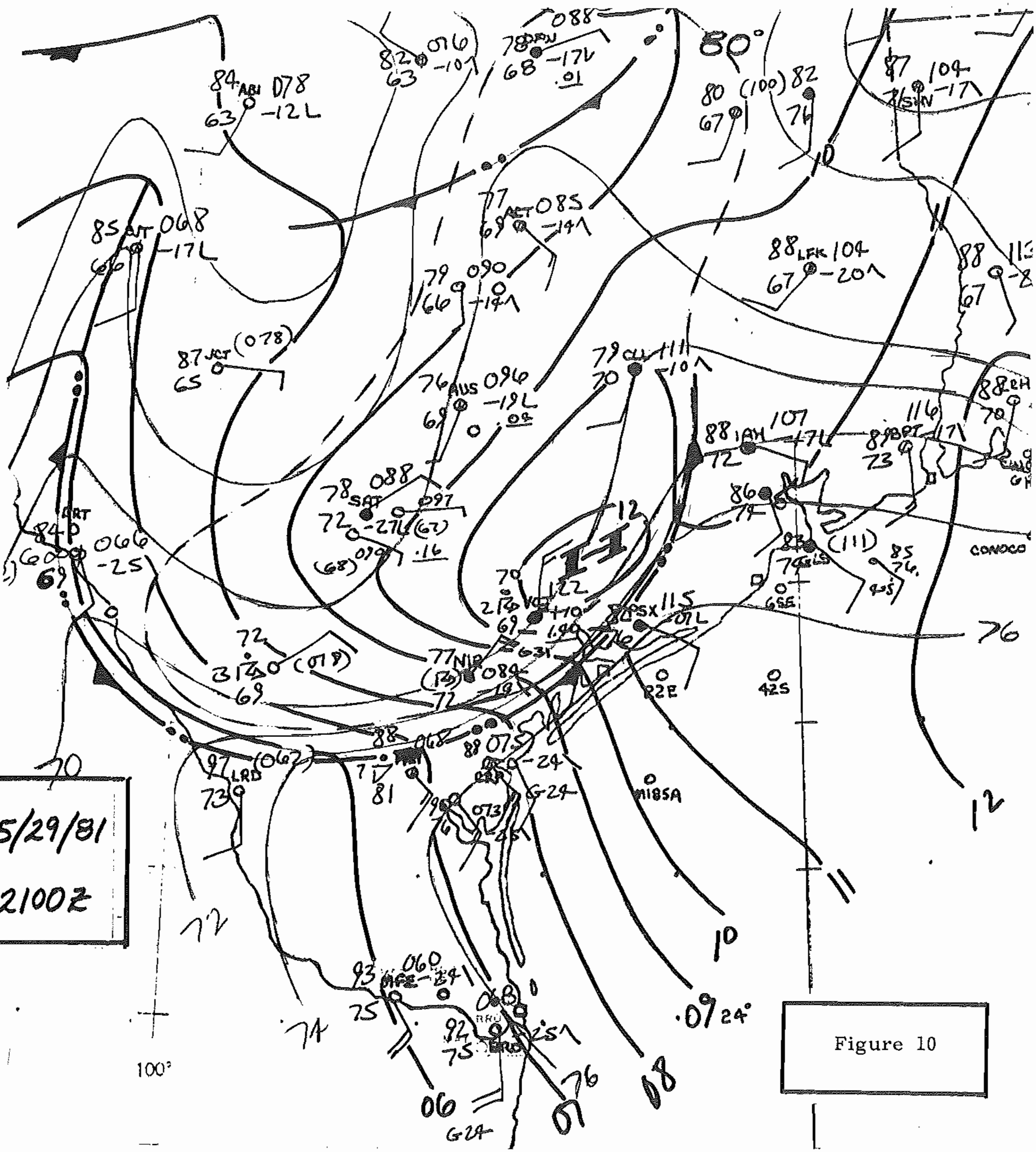


Figure 10

(a)

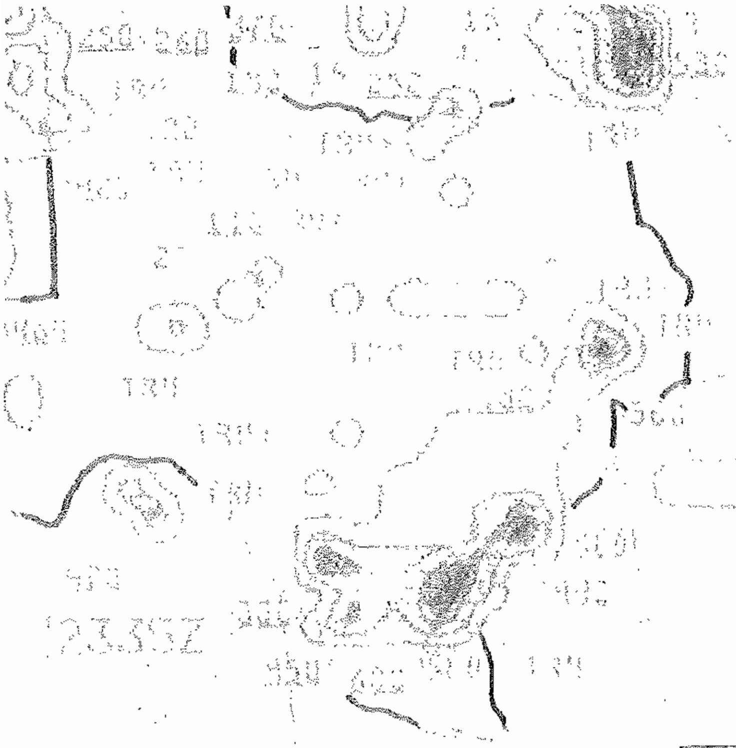
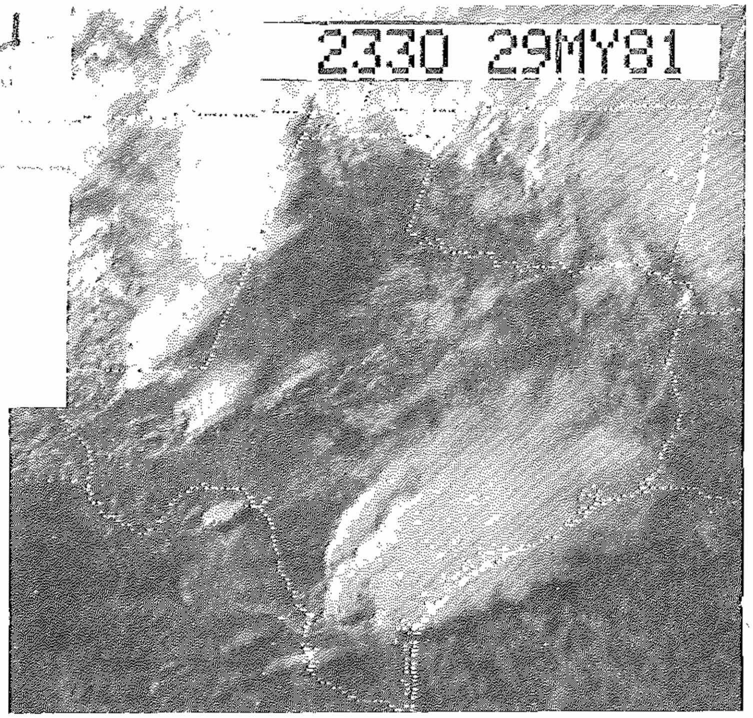


Figure 11

(b)



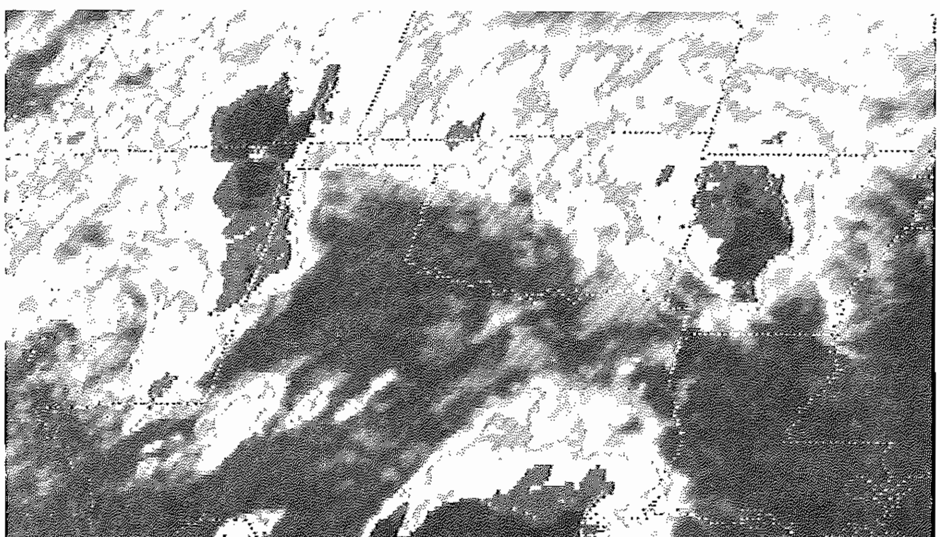


Figure 12

At 0000 GMT thunderstorms are still very active along the outflow boundary in south Texas. The mesohigh is easily identifiable in the surface analysis centered just north of Palacios. Note the spectacular "enhanced 'V'" in the satellite image at 0001 GMT (Fig. 12). This is indicative of intense convection (McCann, 1981).

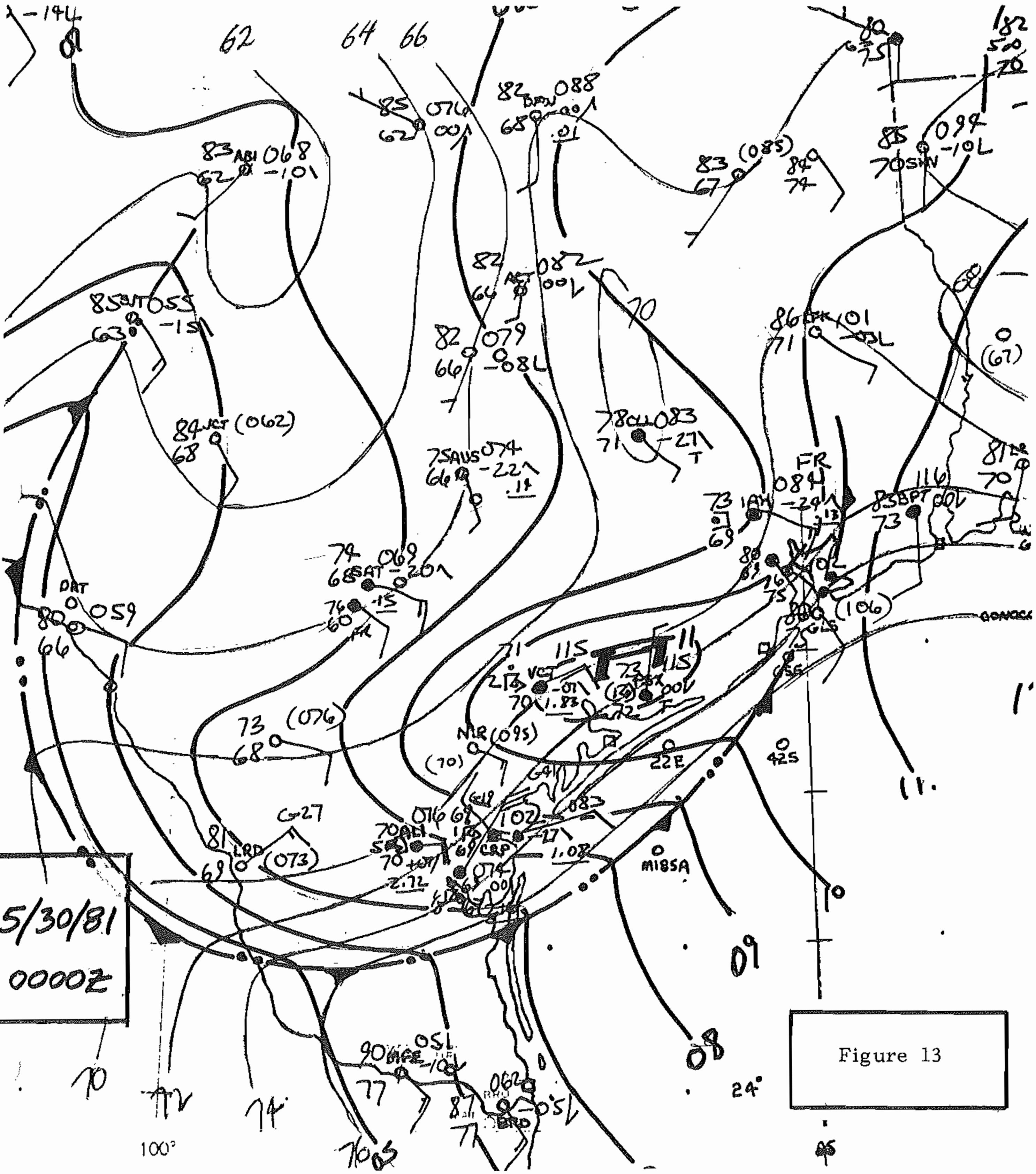


Figure 13

On the synoptic scale at 0000 GMT, the LFM analysis reveals a weak short wave (or vorticity lobe) from central Oklahoma to eastern Texas. A missing sounding at Victoria (see Appendix) makes it difficult to assess the influence of this feature in south Texas. Meanwhile, the cutoff low in the southwest has moved east. Considerable low level moisture exists east of a line from Oklahoma City to Midland and the Big Bend of Texas.

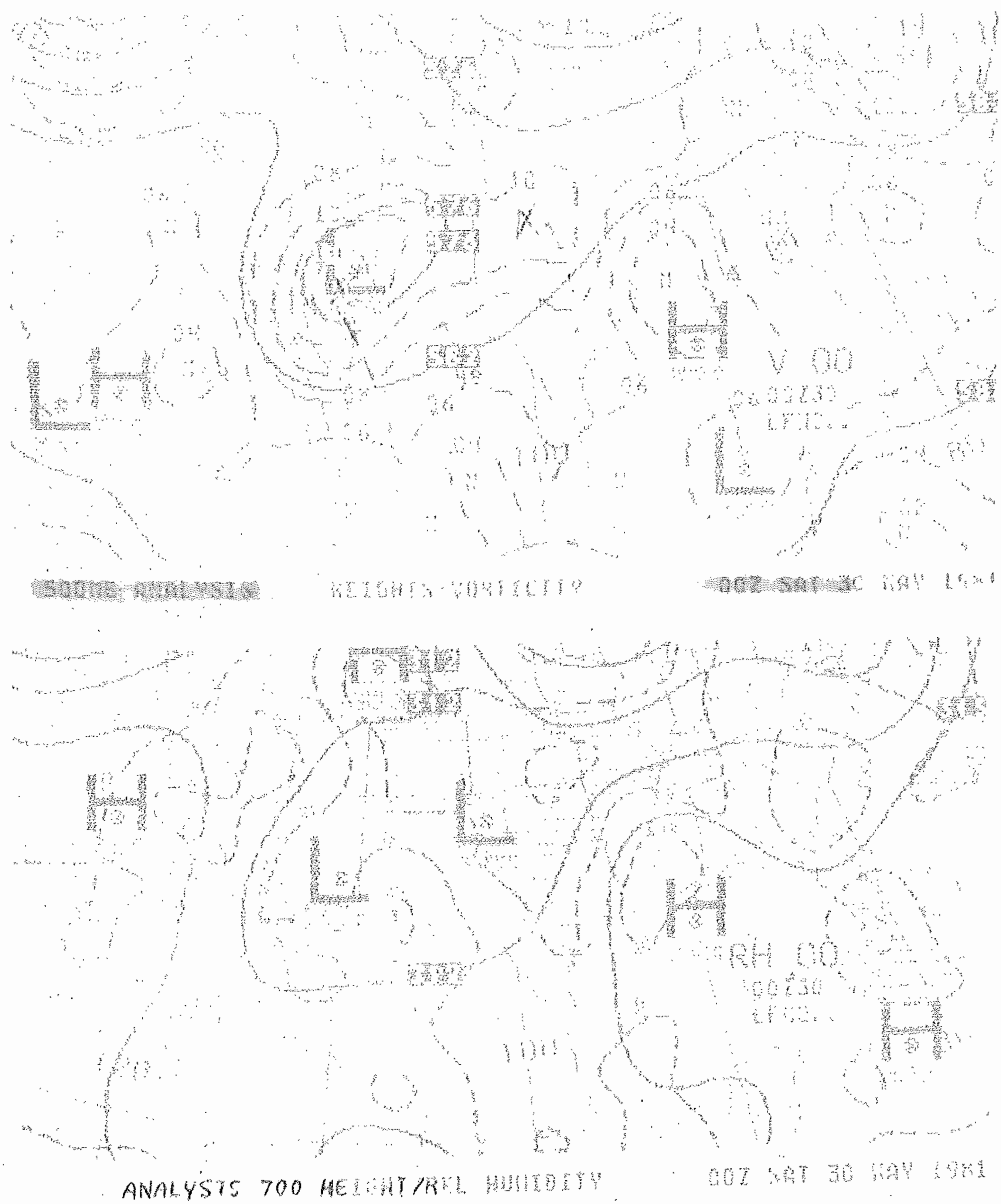


Figure 14

The next mesoanalysis, at 0300 GMT shows an expansion of the bubble high and first indications of the wake low. Winds are ageostrophic and blow right through the mesolow. Notice gusts as high as 43 knots. Radar indicates thunderstorms developing along the boundary into Mexico.

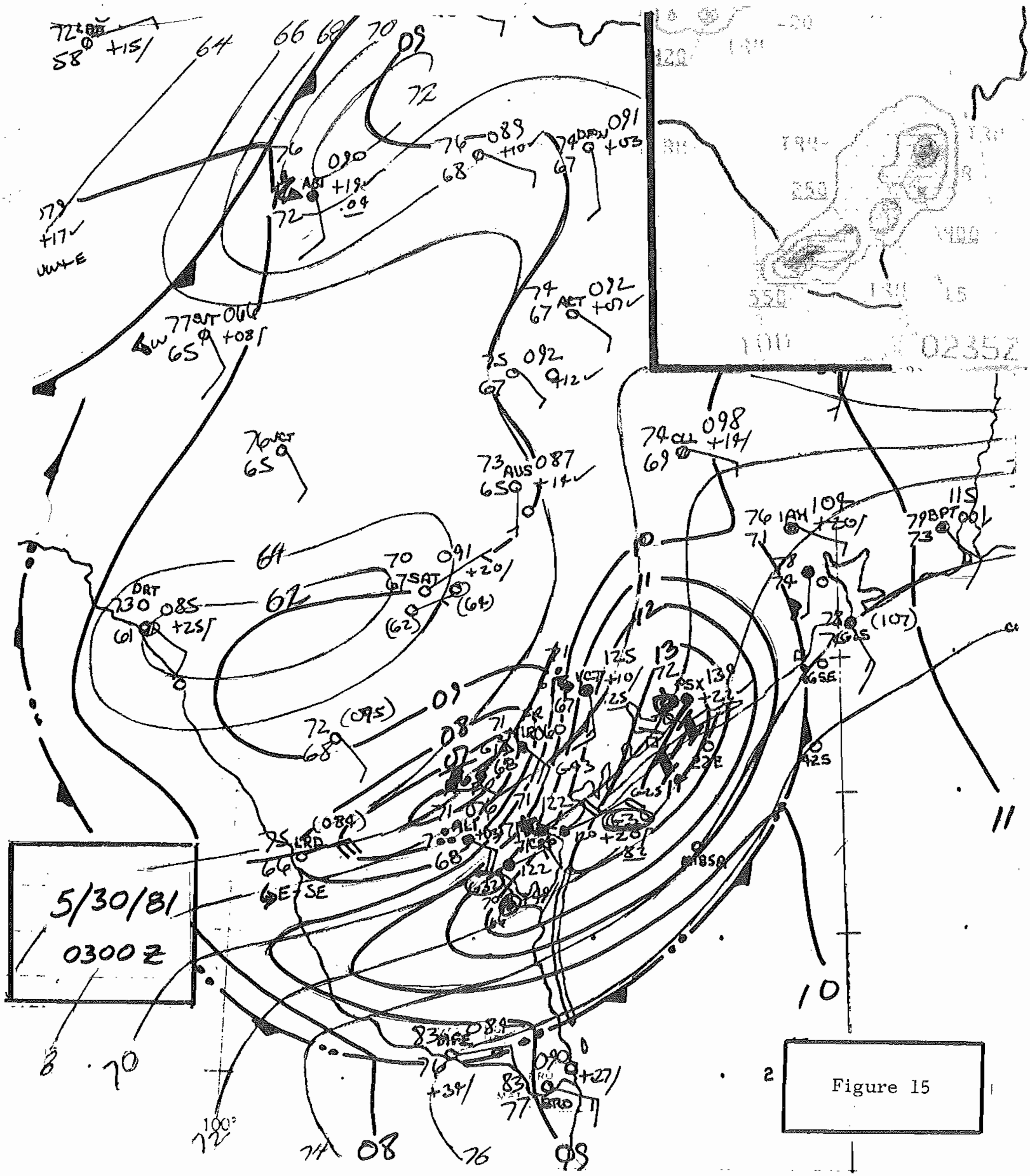


Figure 15

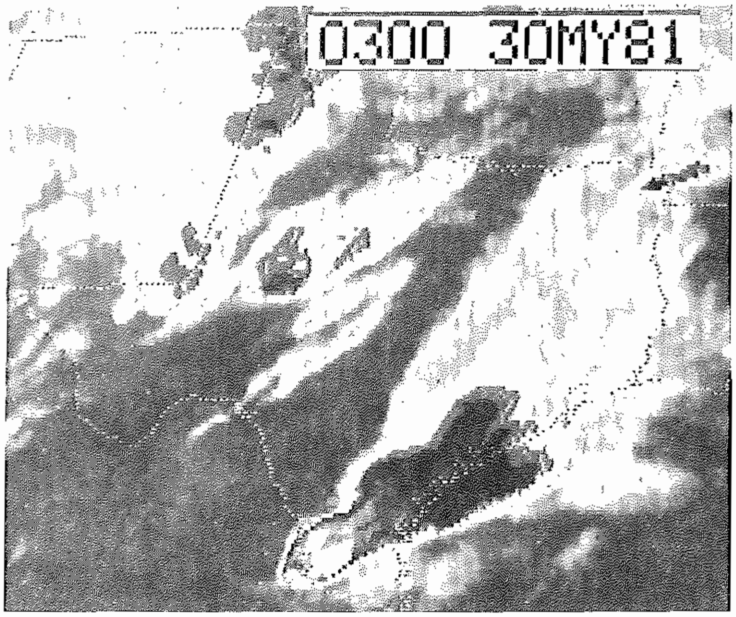
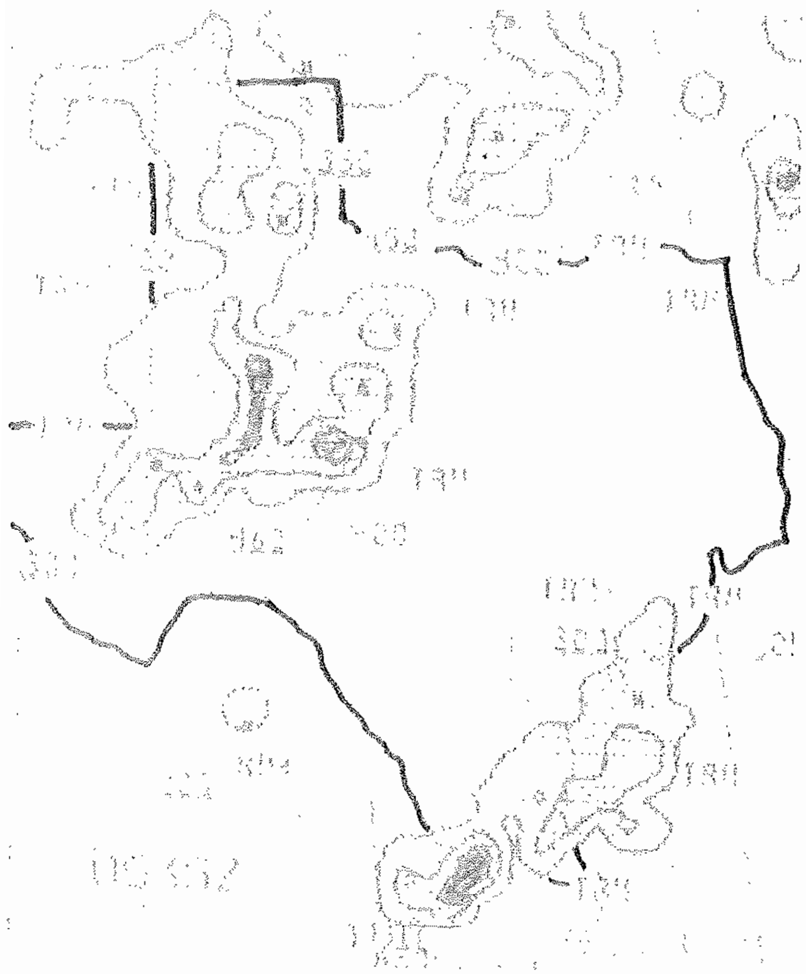
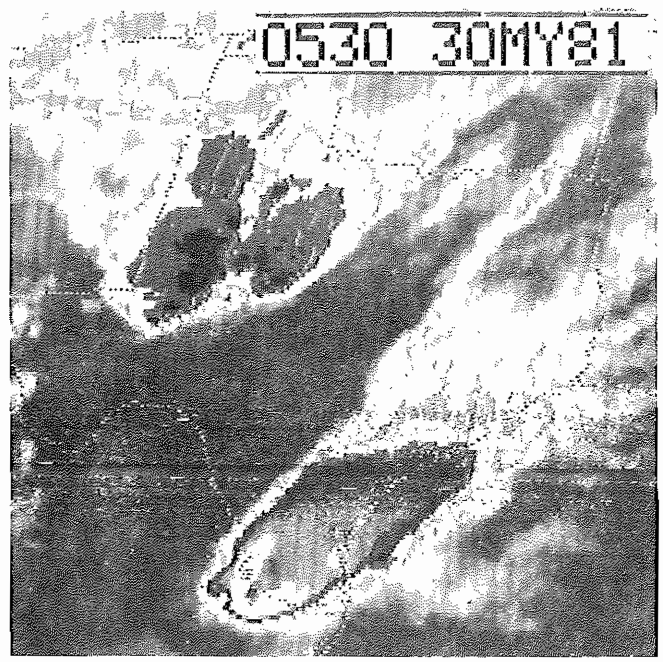


Figure 16



(a)



(b)

Figure 17

After somewhat of a lull between 0000-0300 GMT (Figs. 12 and 16), convection has intensified between 0300-0530 GMT (Figs. 16 and 17). Notice the growth of the enhanced "V" signature in the satellite imagery. By 0600 GMT the mesohigh has moved into the Gulf, but some indication of it is seen in the McAllen observation. A dominant feature of the mesoanalysis is the wake low along the middle Texas coast. Note very strong wind gusts all along the coast. Fig. 17 shows that another area of convection has developed in West Texas along the cold front.

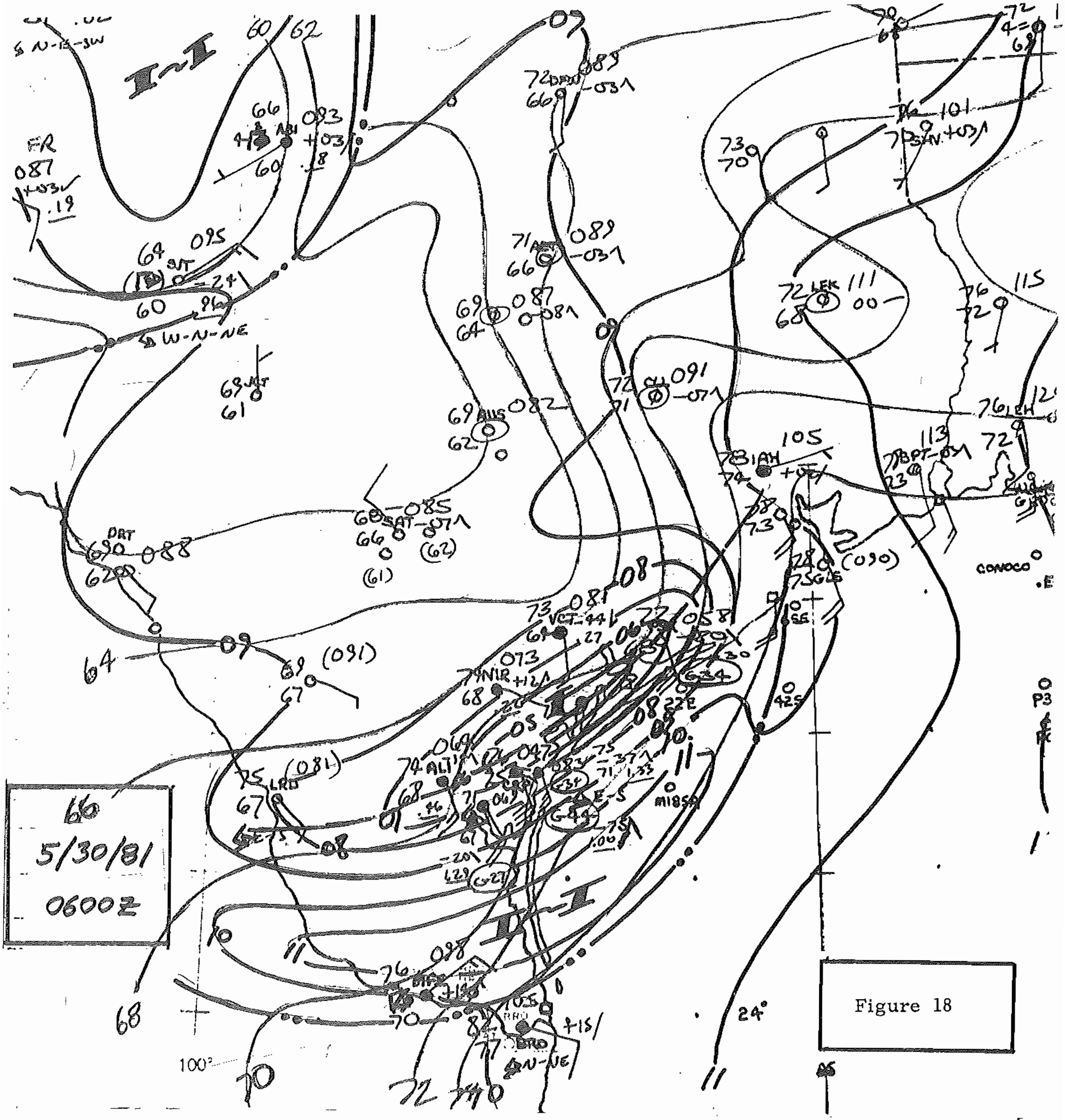


Figure 18

At 0900 GMT the rising pressures at Palacios and Corpus Christi indicate that the wake low has moved offshore. Satellite imagery and continuity are used to support analysis of the mesohigh in advance of the low. It is probably a safe assumption that winds are blowing at gale force over a large area of the Gulf coastal waters; a peak wind of 35 knots at Galveston this hour provides additional support for this assumption.

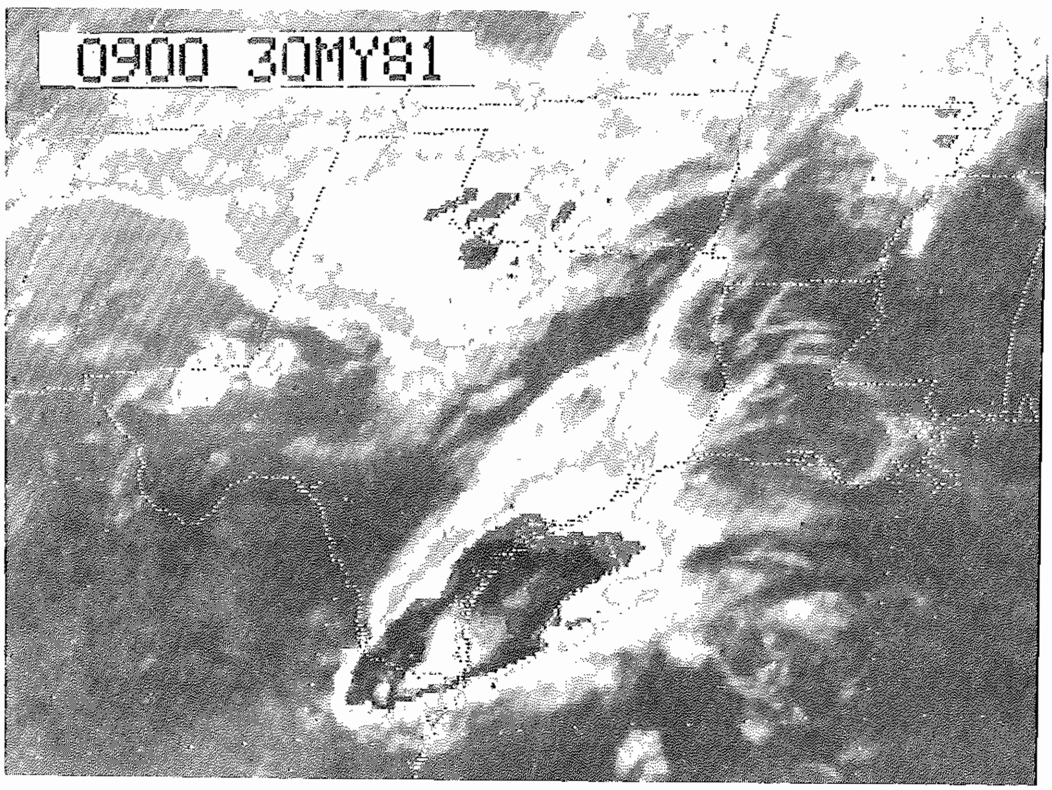


Figure 19

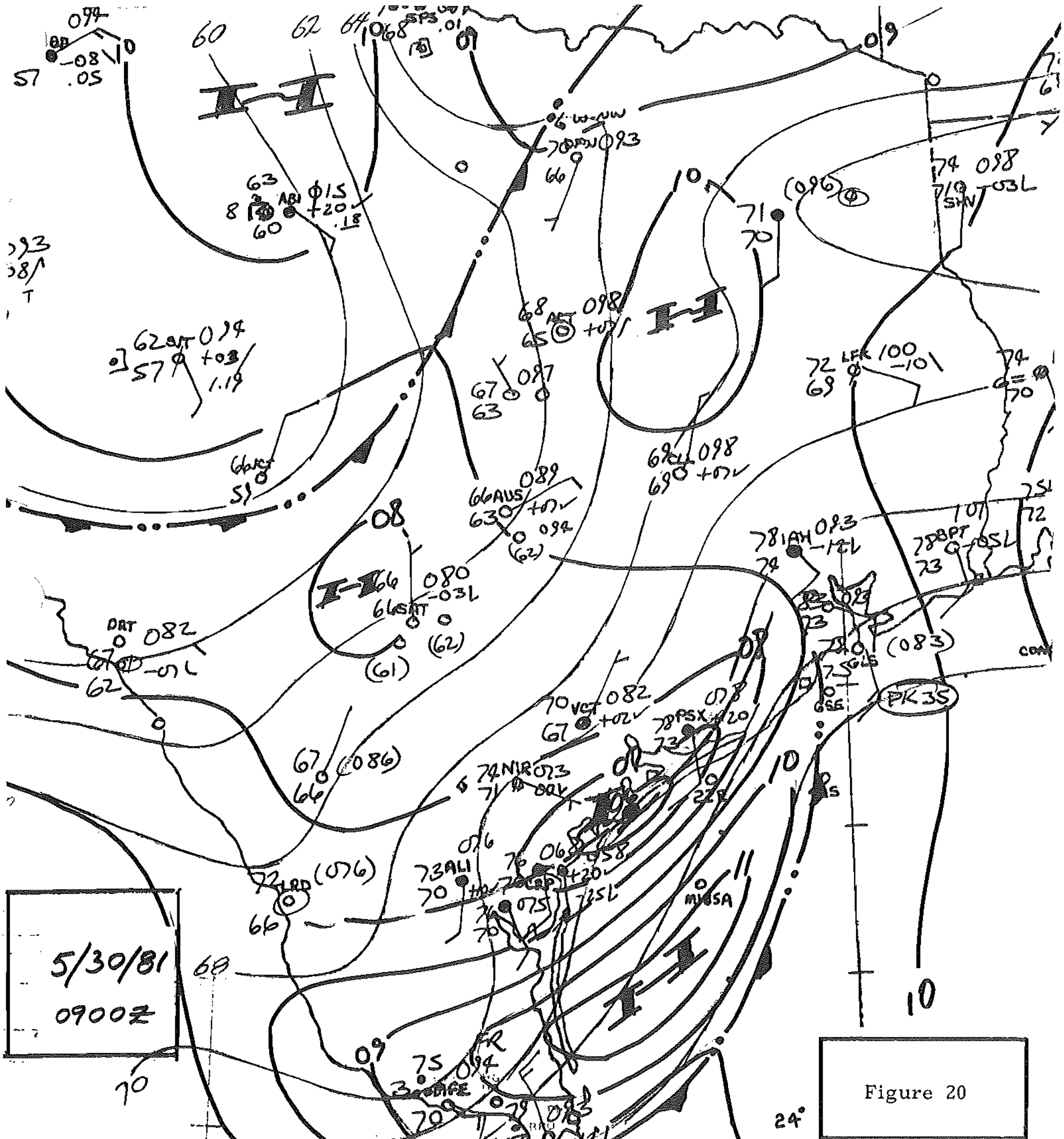
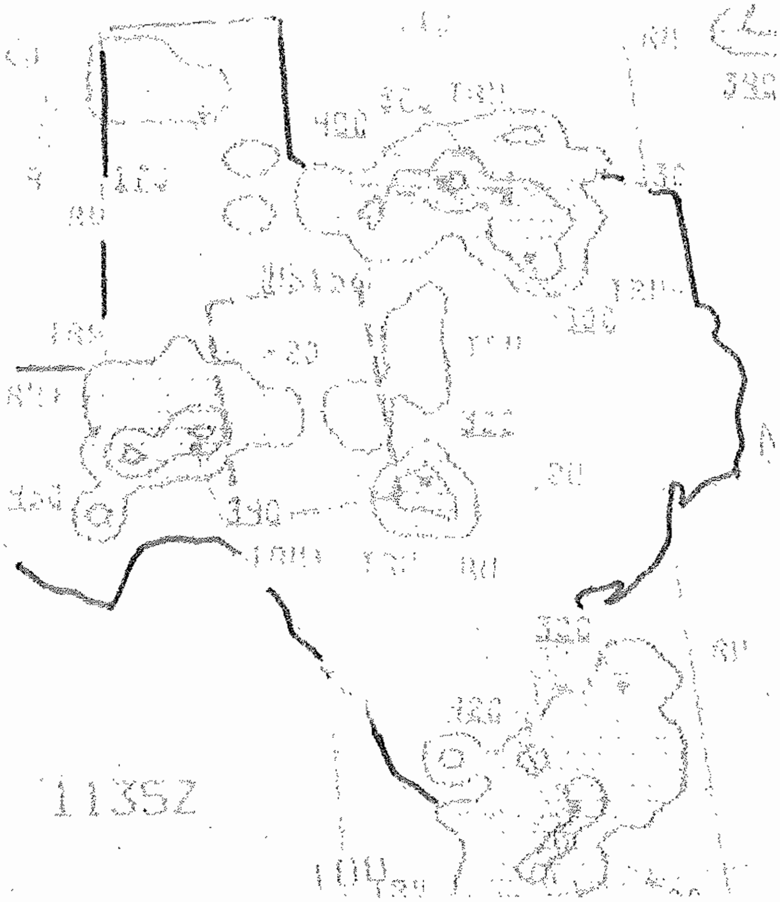


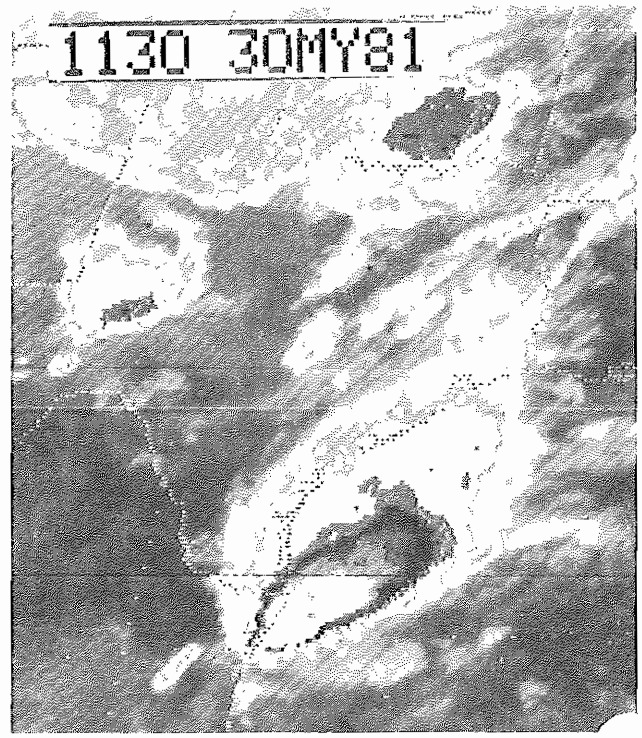
Figure 20

Figure 21

(a)



(b)



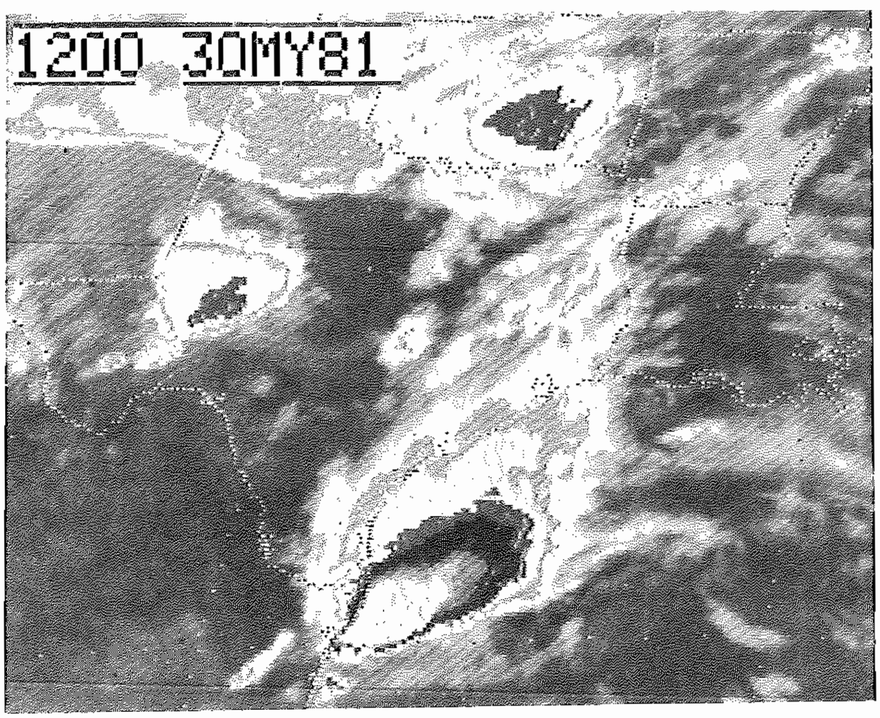


Figure 22

By 1200 GMT satellite imagery shows the most intense convection well off the Texas coast. While the gradient has relaxed over land, there is every reason to believe that the mesohigh/wake low couplet has not vanished. The oil rig report south of Freeport (42S) shows only 25 knot gusts, but seas are 9-10 feet, up from 2-4 feet the previous afternoon.

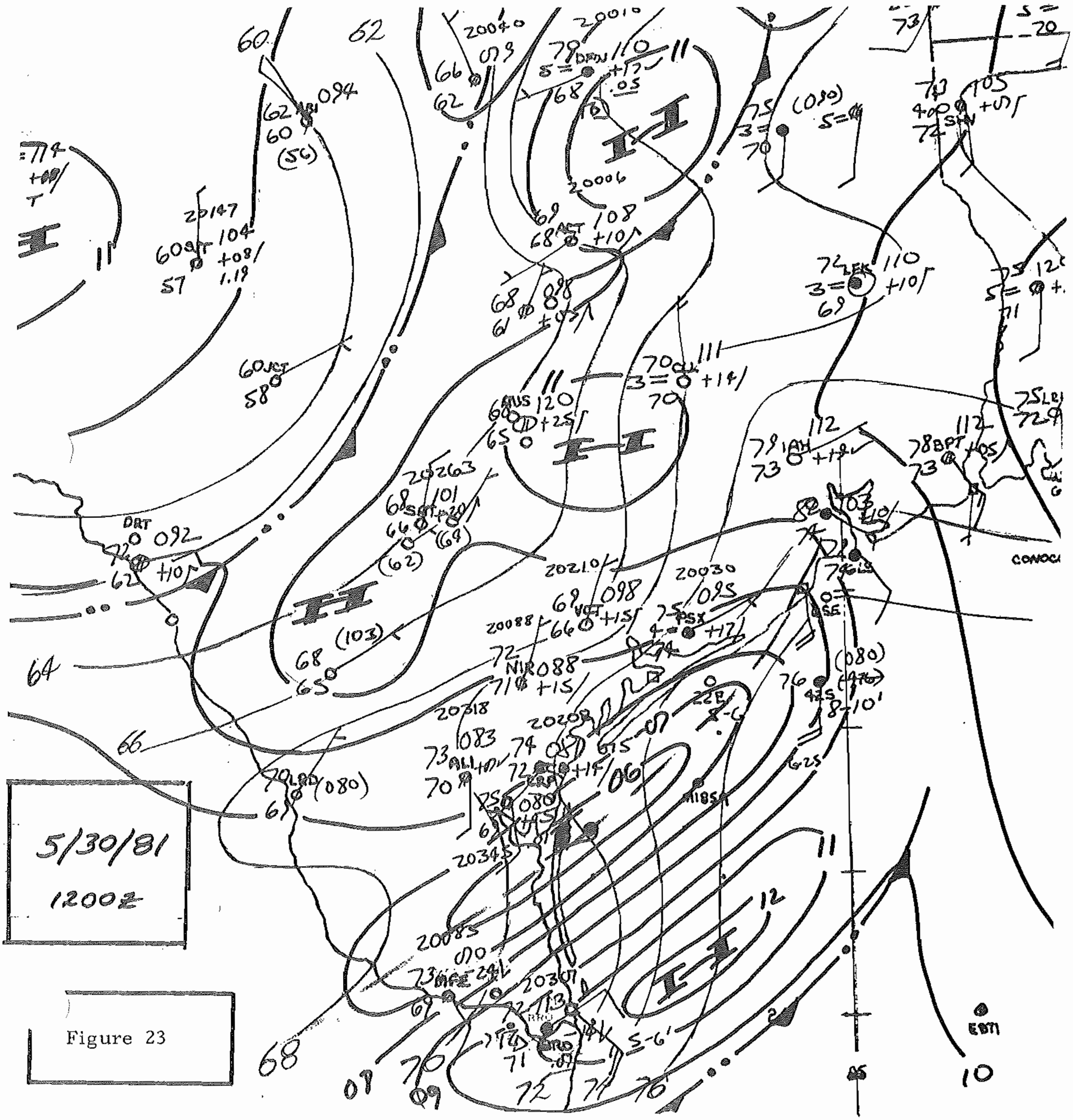
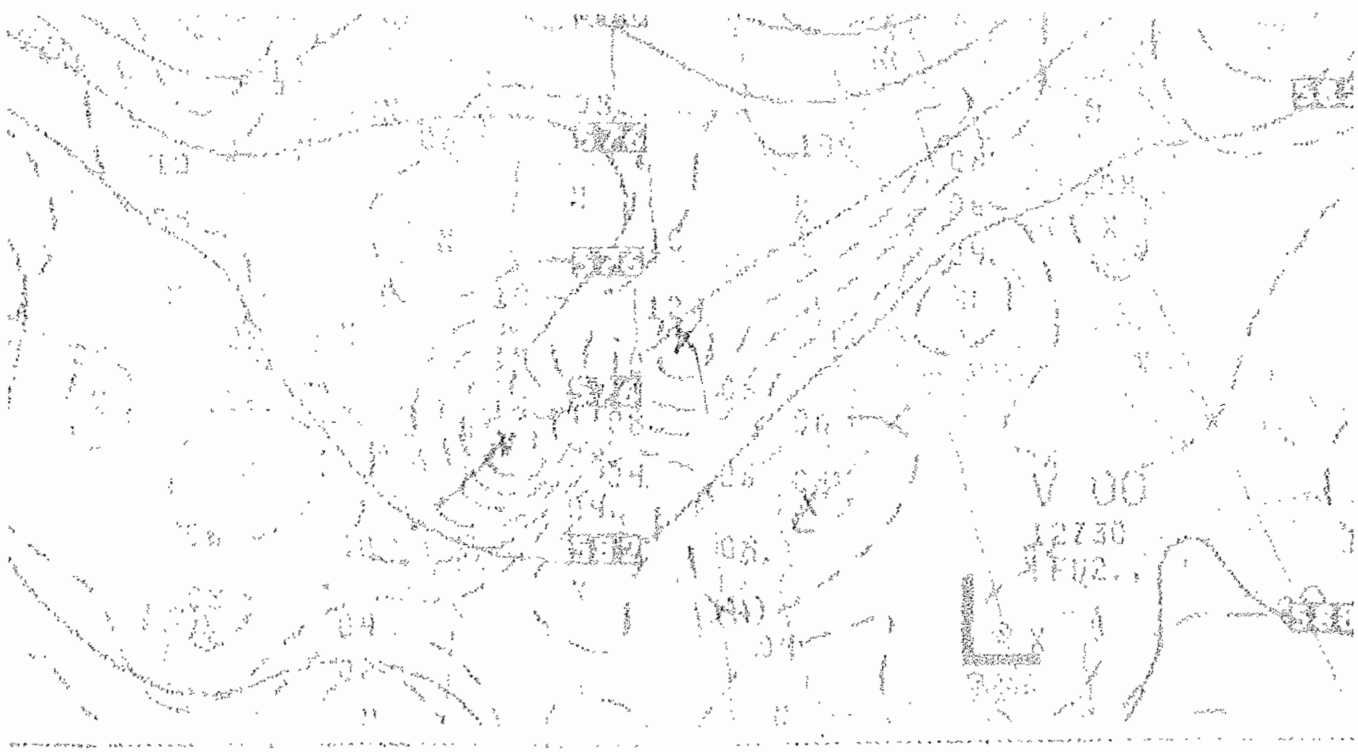
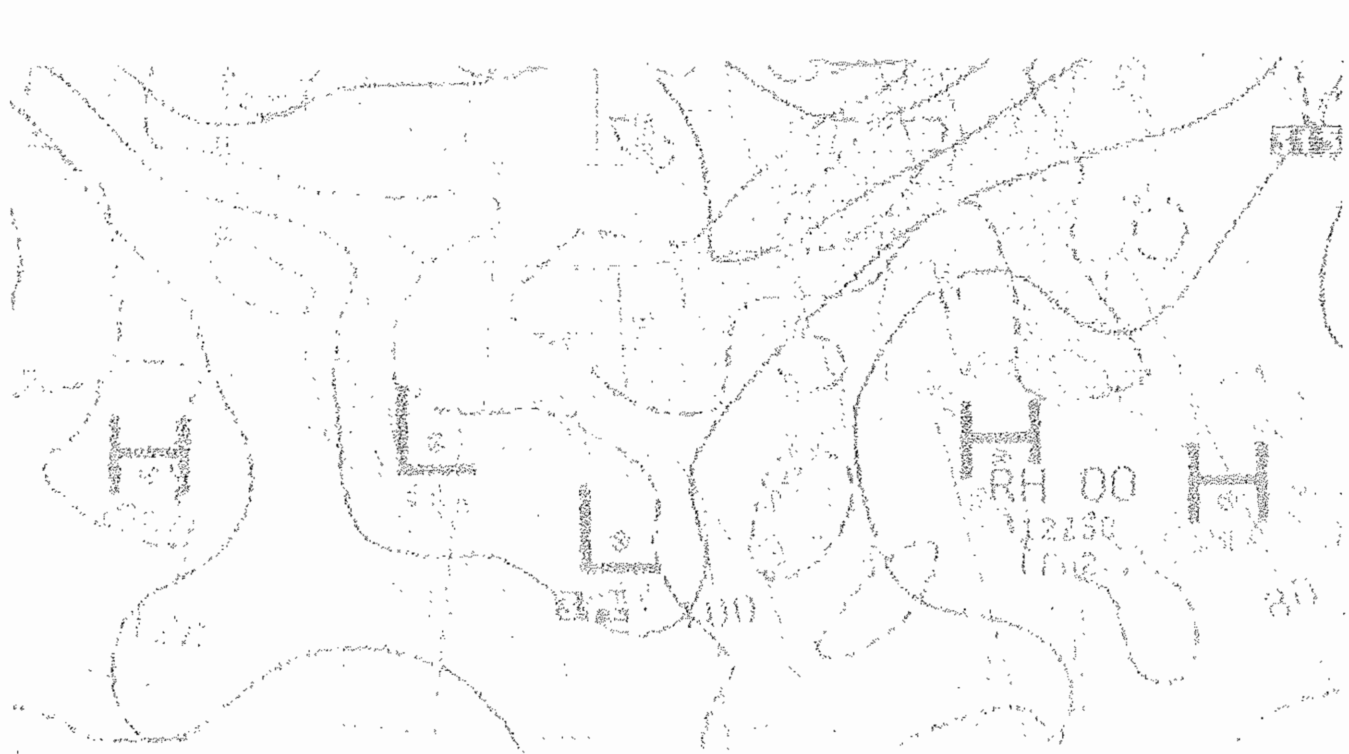


Figure 23

Returning for a final look at the synoptic scale, the LFM analysis at 1200 GMT reveals that the cutoff low in the southwest has opened and is moving eastward. A short wave and associated vorticity at 500 mb which was instrumental in the dynamics of the south Texas thunderstorm complex is weakening.



HEIGHT/VORTICITY 12Z SAT 30 MAY 1981



HEIGHT/REL HUMIDITY 12Z SAT 30 MAY 1981

3. Summary and Conclusions

This May 29/30 event was the second "wake depression" over south Texas which was documented by local studies in the past year. The first was observed in May of 1980. Yet another subsequently occurred on June 2, 1981.

The wake depression phenomenon was first noted by Williams (1948, 1953, 1954) and Brunk (1949, 1953) in their studies of midwest squall lines. They described it as a "depression type wave", and observed that such waves were frequently observed in areas where severe thunderstorms had recently ended. They pointed out that the winds associated with the waves did not conform to the pressure fields as in synoptic or large scale systems, but tended to blow at right angles to the isobars toward lower pressure. Fujita (1955) refined the observations further and defined the low pressure area behind a thunderstorm-induced bubble high as a "wake depression". It forms behind a strong, rapidly moving bubble high much like what is observed when a solid body moves through a fluid.

Wake depressions are not usually associated with severe weather and should not be confused with tornadic mesolows. However, their occurrence along a coast can be potentially hazardous since surface friction over the water is small, and so many marine operations (recreational boating, commercial fishing, oil company operations, etc.) are sensitive to high winds and seas. In the cases documented so far at San Antonio, the wake lows were detectable over land one to two hours prior to their moving over water. This allowed time for an adequate diagnosis of the event through mesoanalysis of surface data, which in turn allowed adequate lead time for marine warnings for offshore operations.

Acknowledgements: My thanks to Gary Grice, Jim Ward and Bill Read, forecasters at WSFO San Antonio, and to Dr. Robert Maddox, Environmental Research Laboratory, Boulder, for their counsel and advice in the preparation of this study. Dan Smith, SSD, Fort Worth, provided technical assistance and edited the study into its present form.

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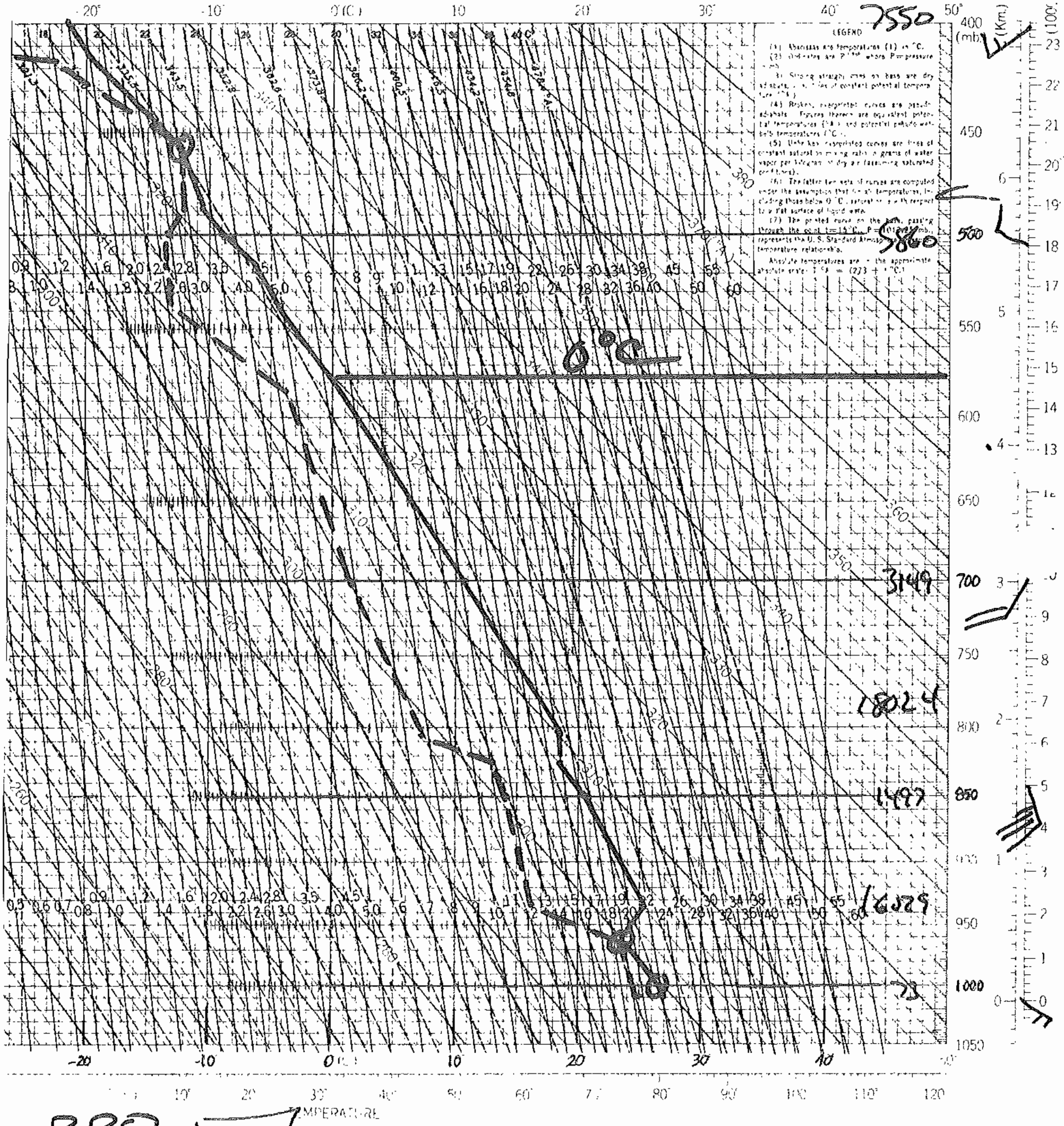
APPENDIX 1

Supplemental maps and analyses for May 29-30, 1981 wake low event

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

PSEUDO-ADIABATIC CHART



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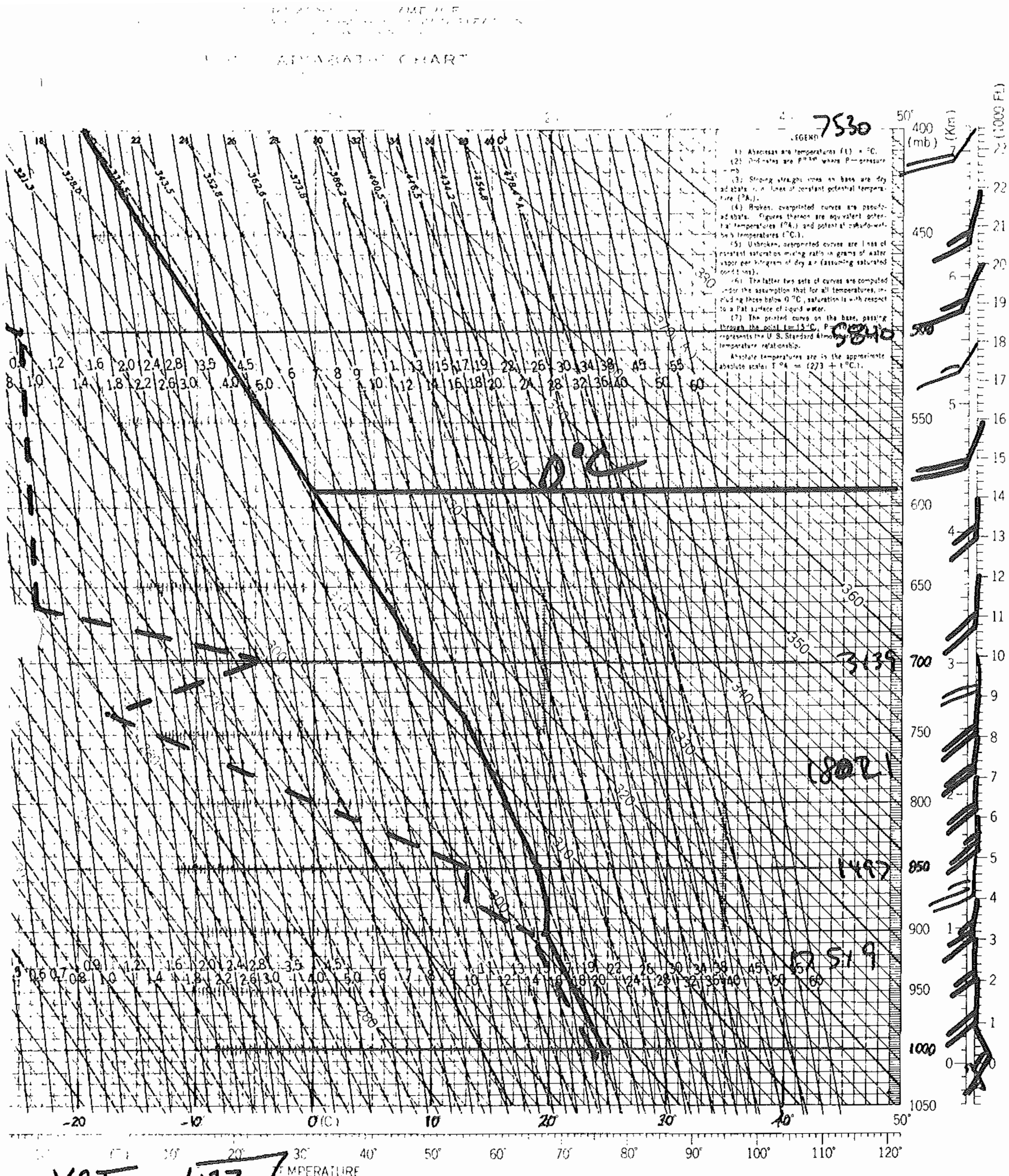
5/29/81



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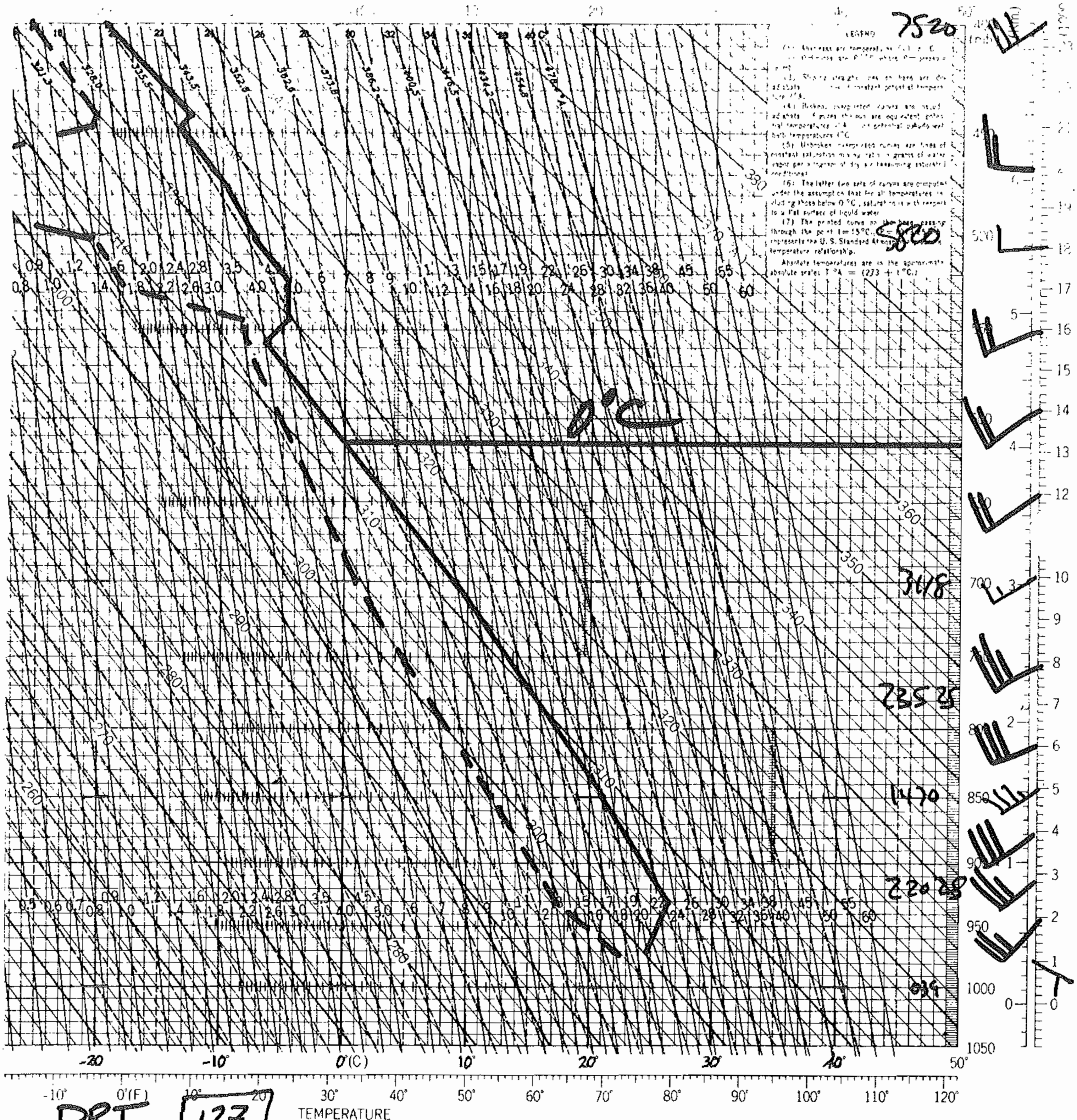
U.S. DEPARTMENT OF COMMERCE

PSEUDO ADIABATIC CHART



DRT 12Z

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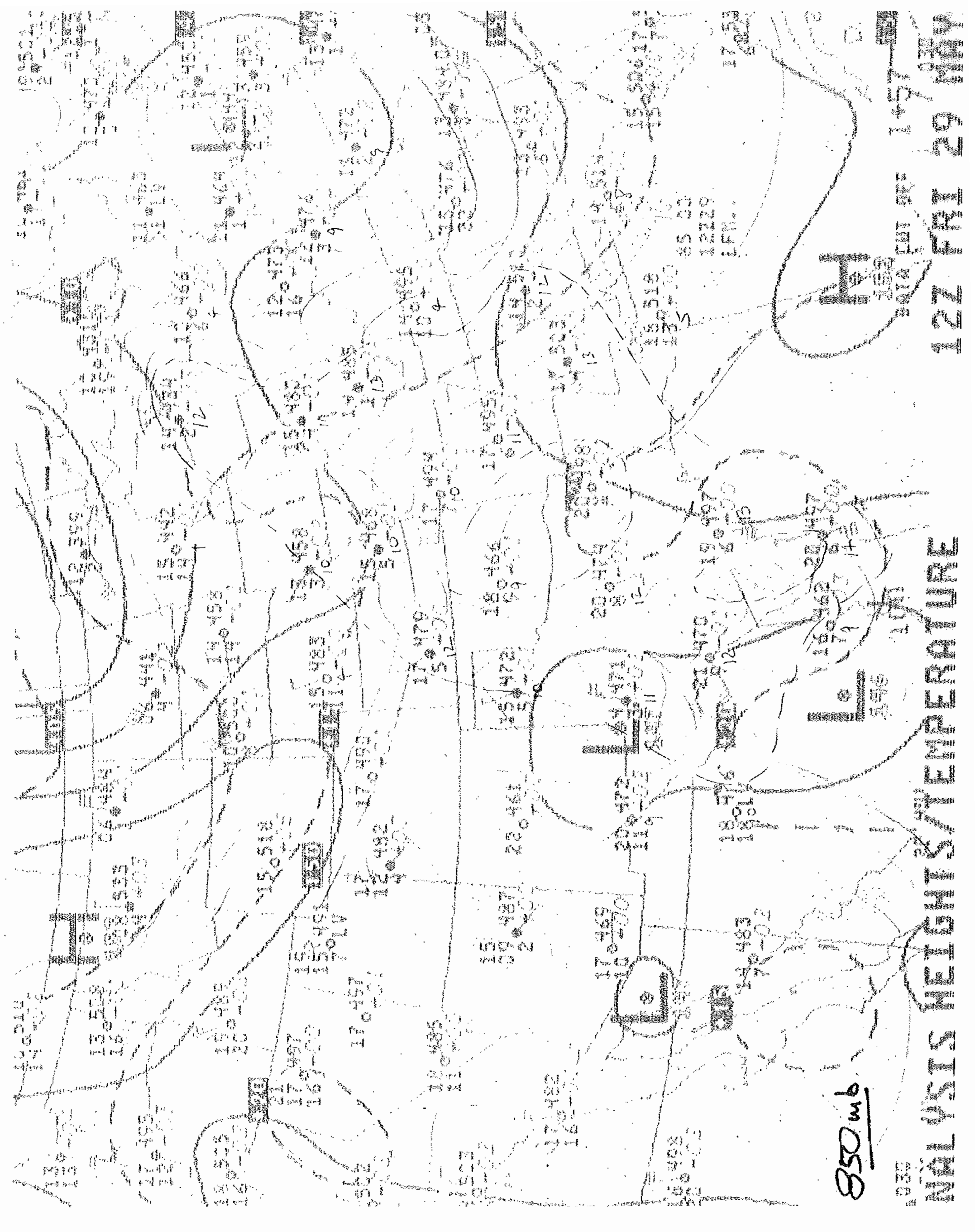
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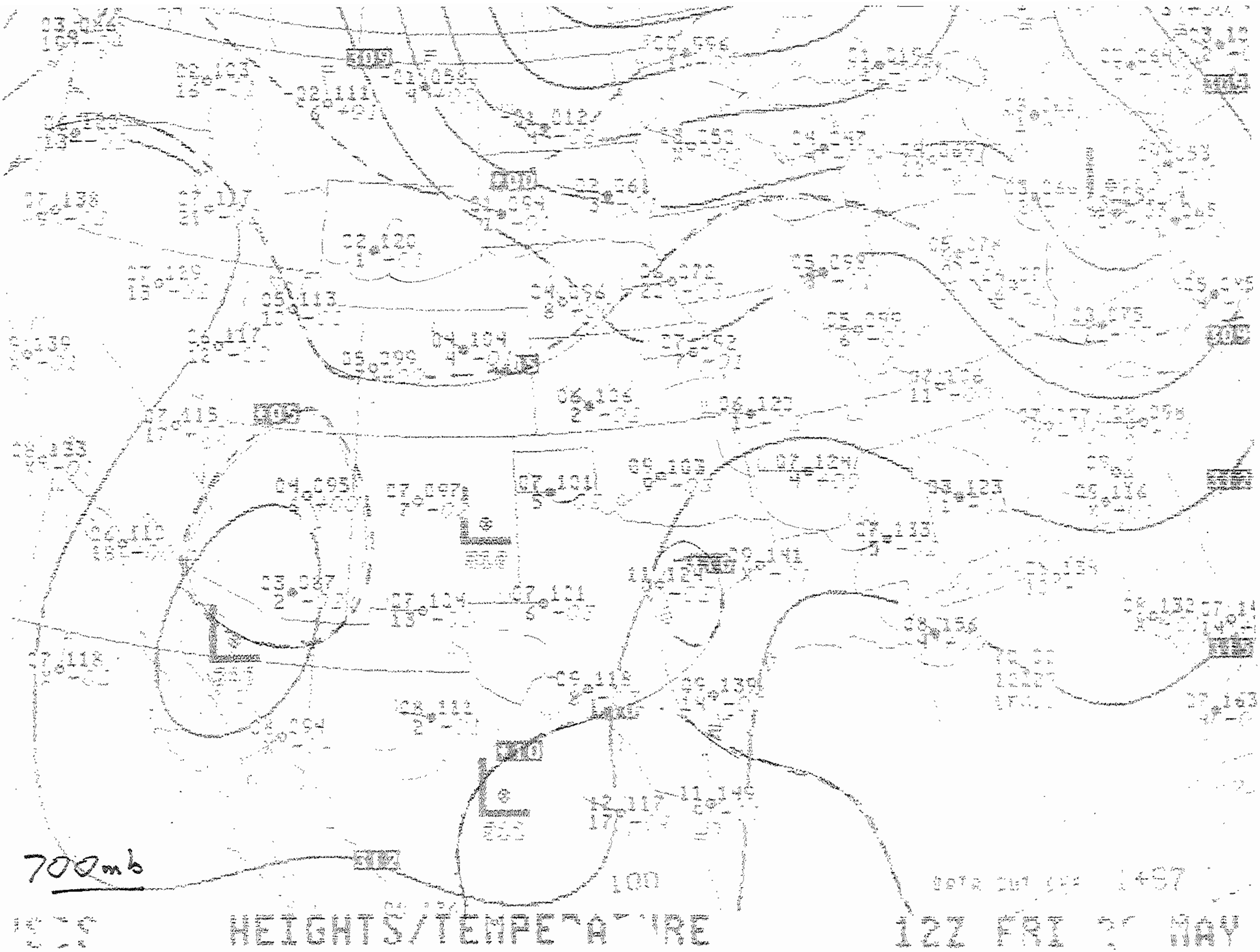
ANALYSIS HEIGHTS/TEMPERATURE
12Z FRI 29 MAY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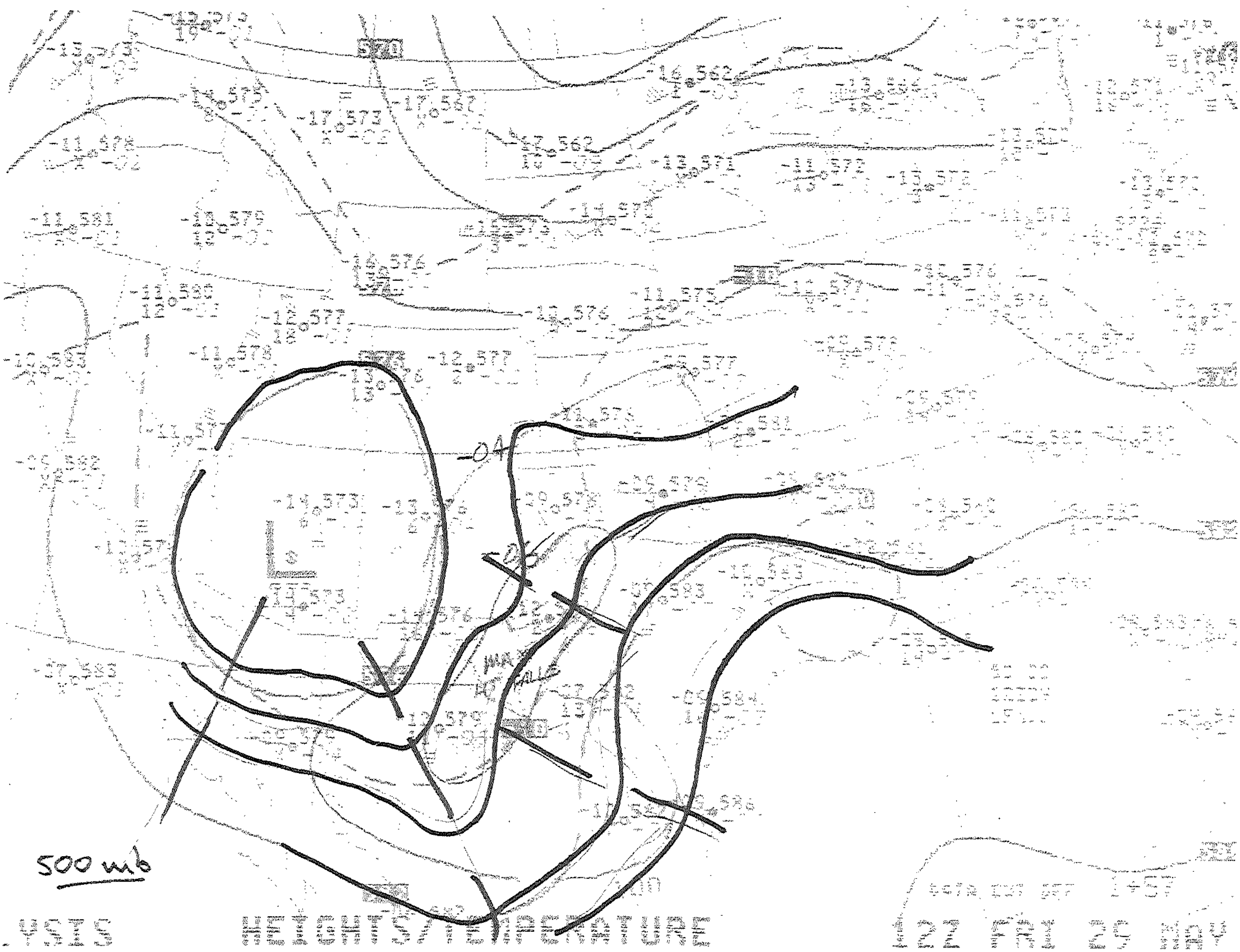
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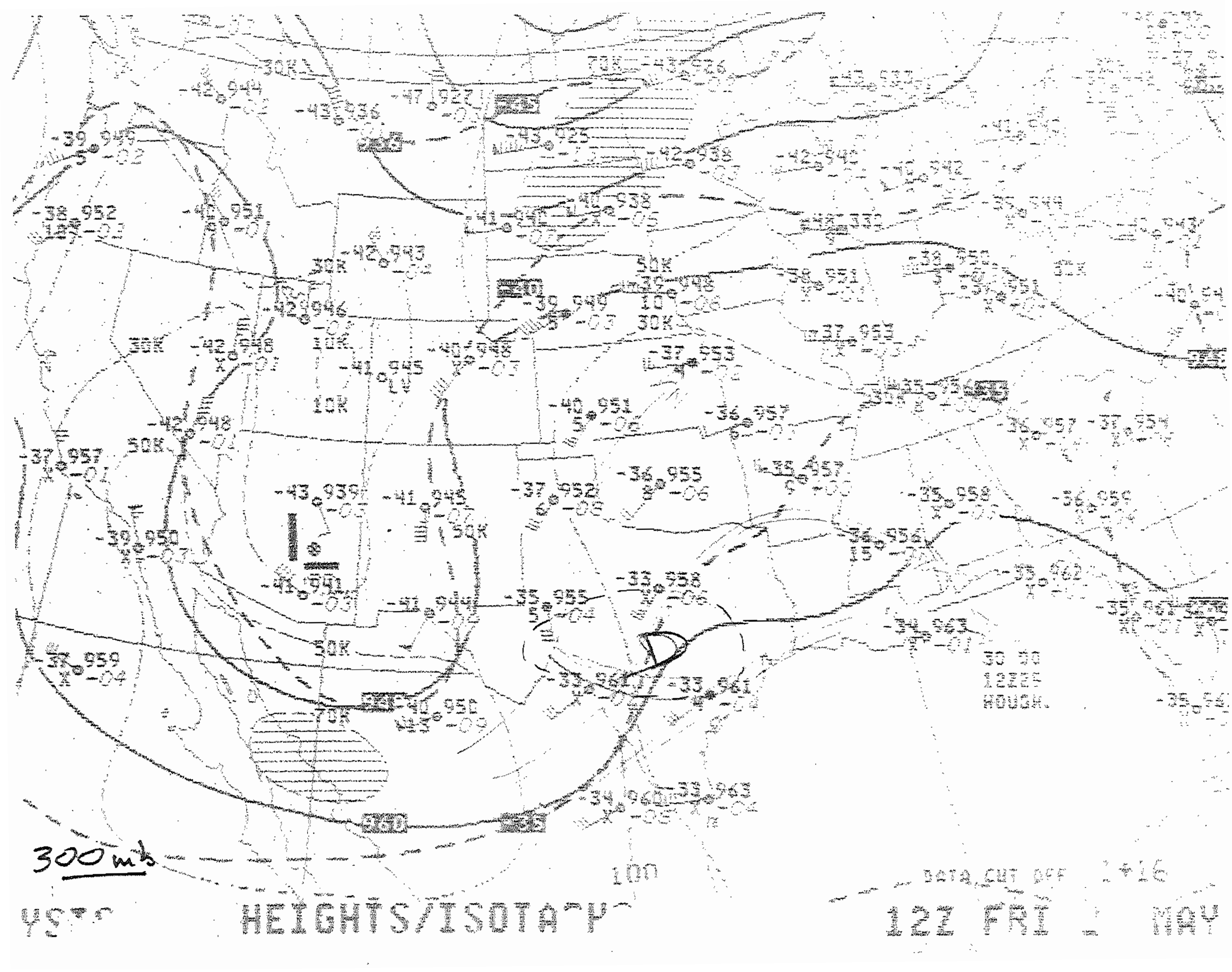
12Z FRI 29 MAY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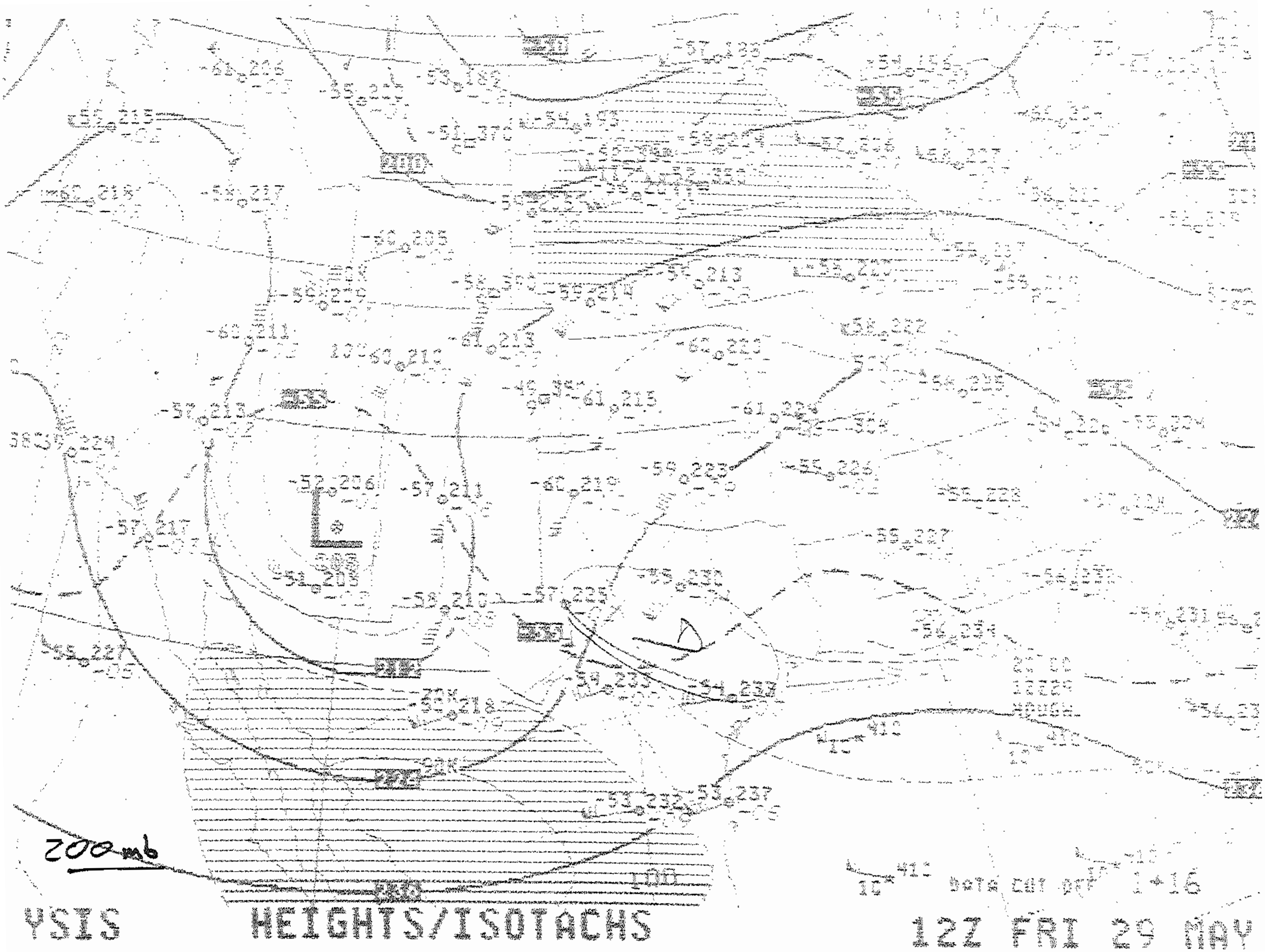
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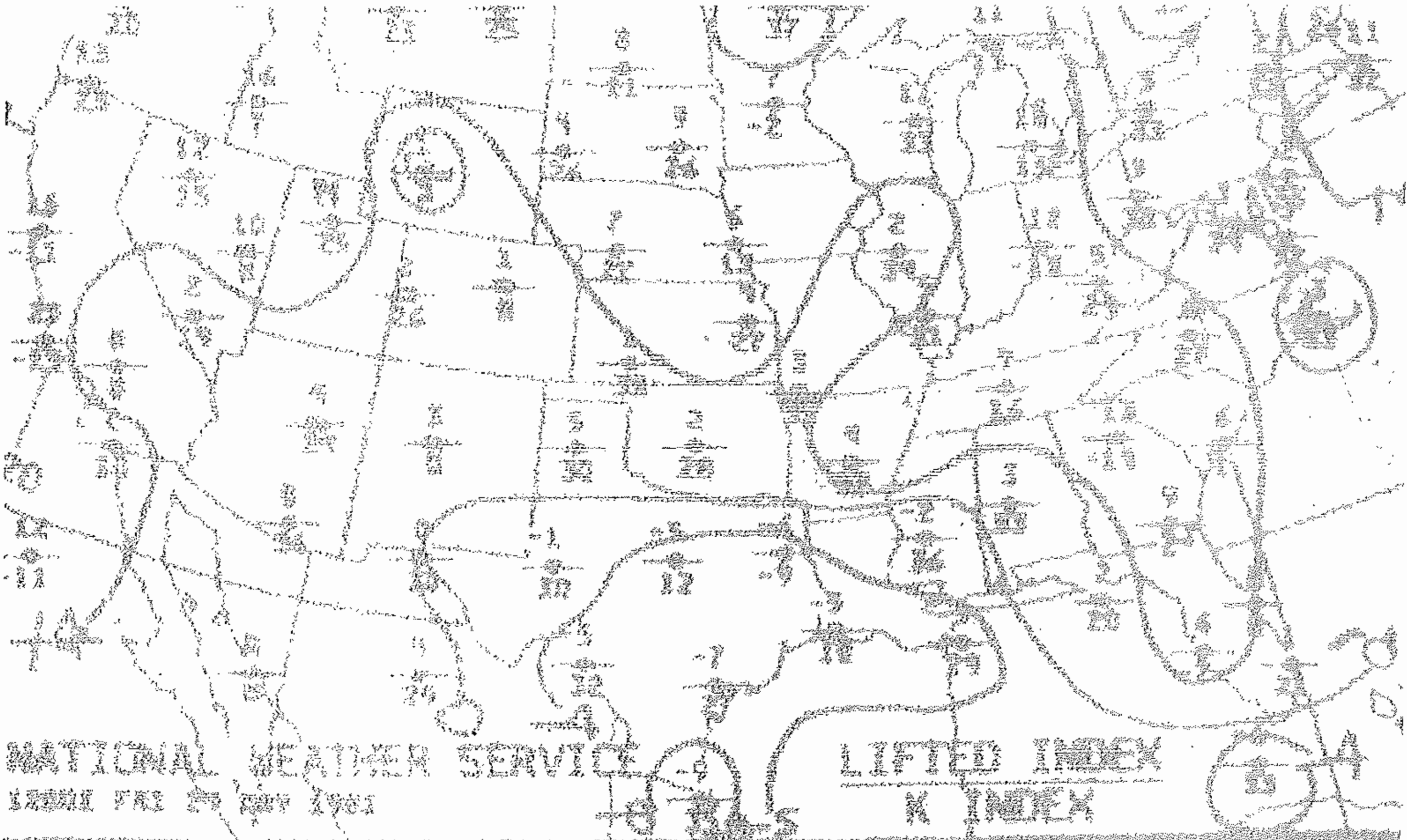
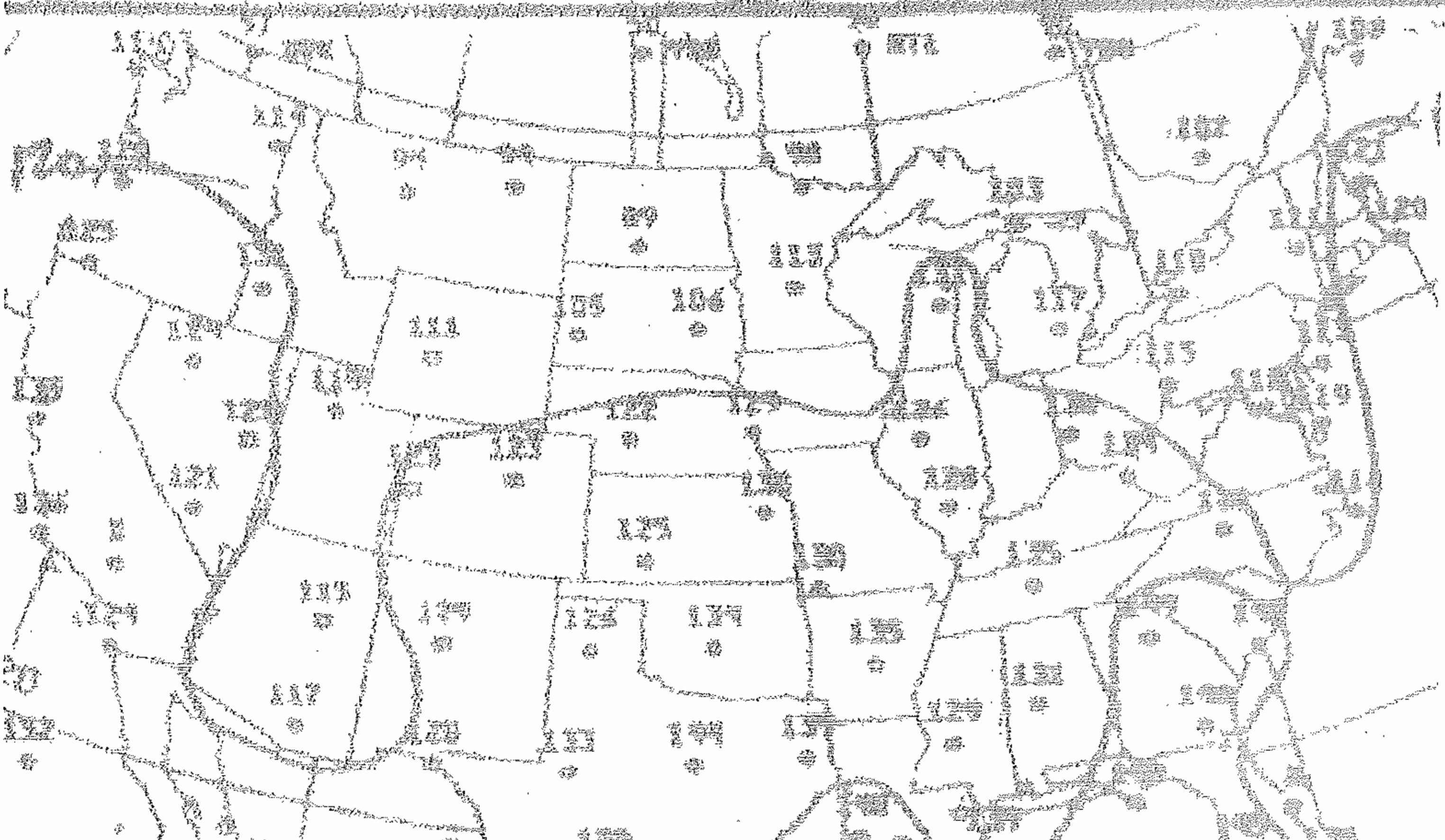

NATIONAL WEATHER SERVICE
LIFTED INDEX
K INDEX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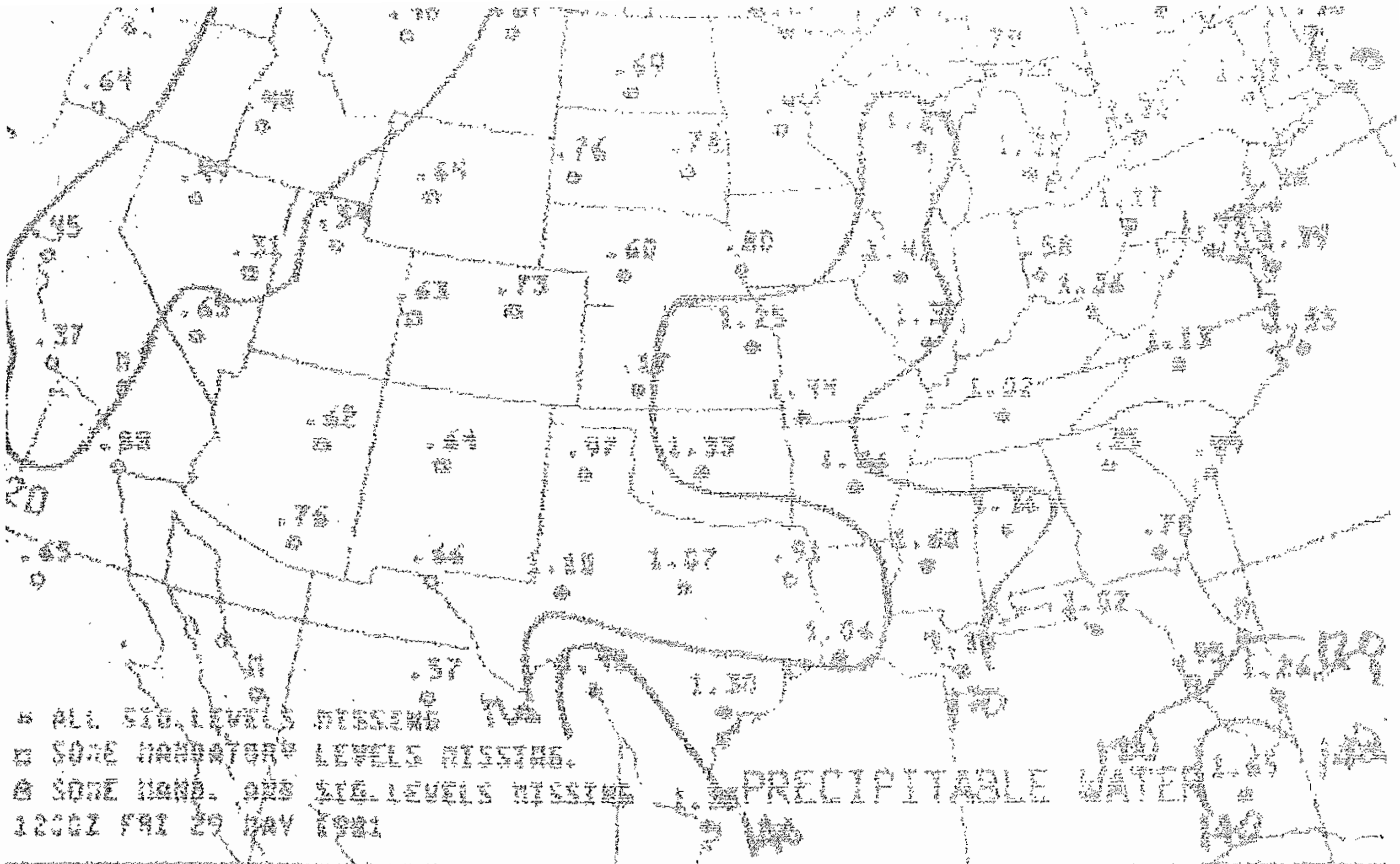
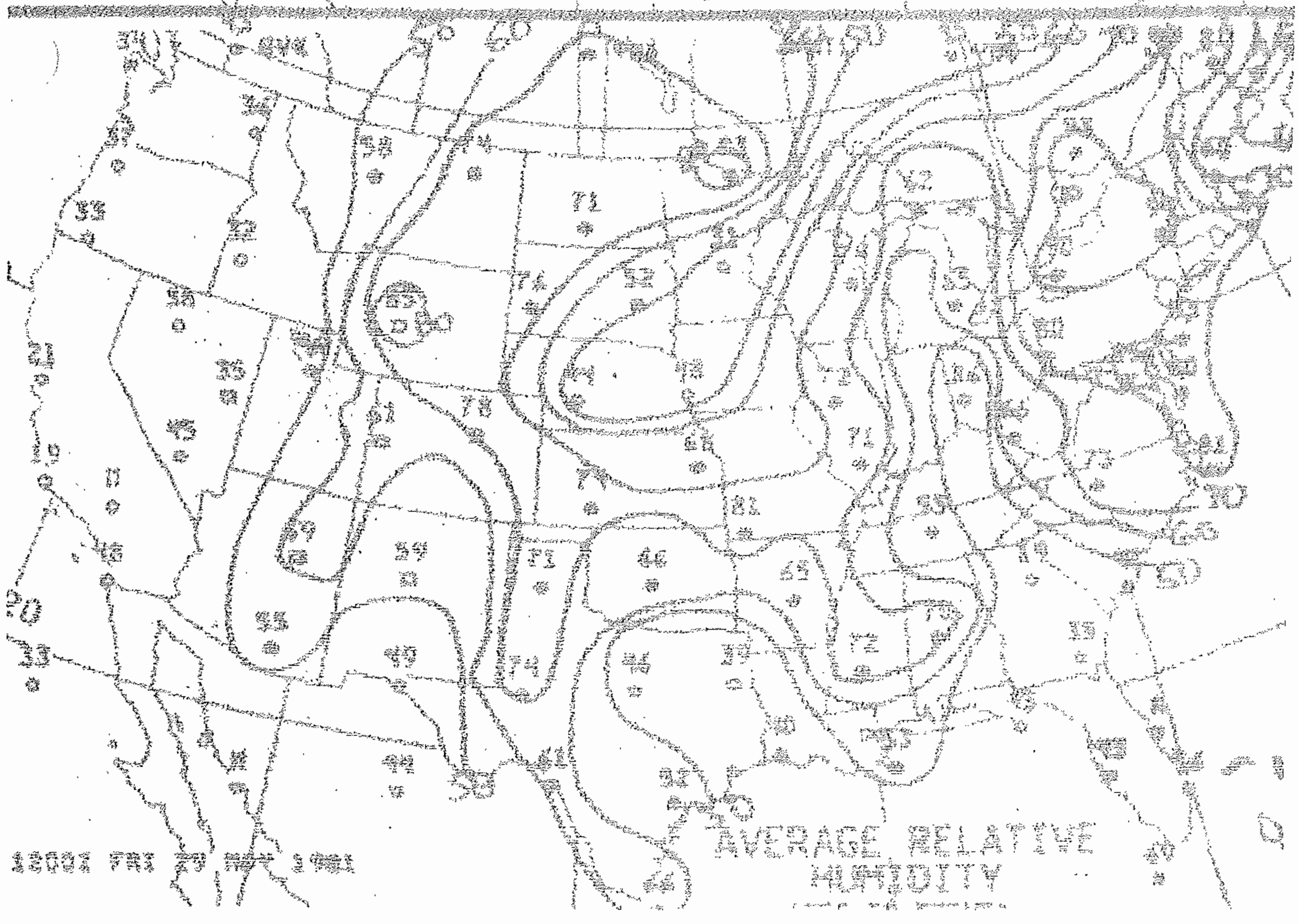


PRECIPITABLE WATER
1200Z FRI 29 MAY 1981



AVERAGE RELATIVE HUMIDITY

U. S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

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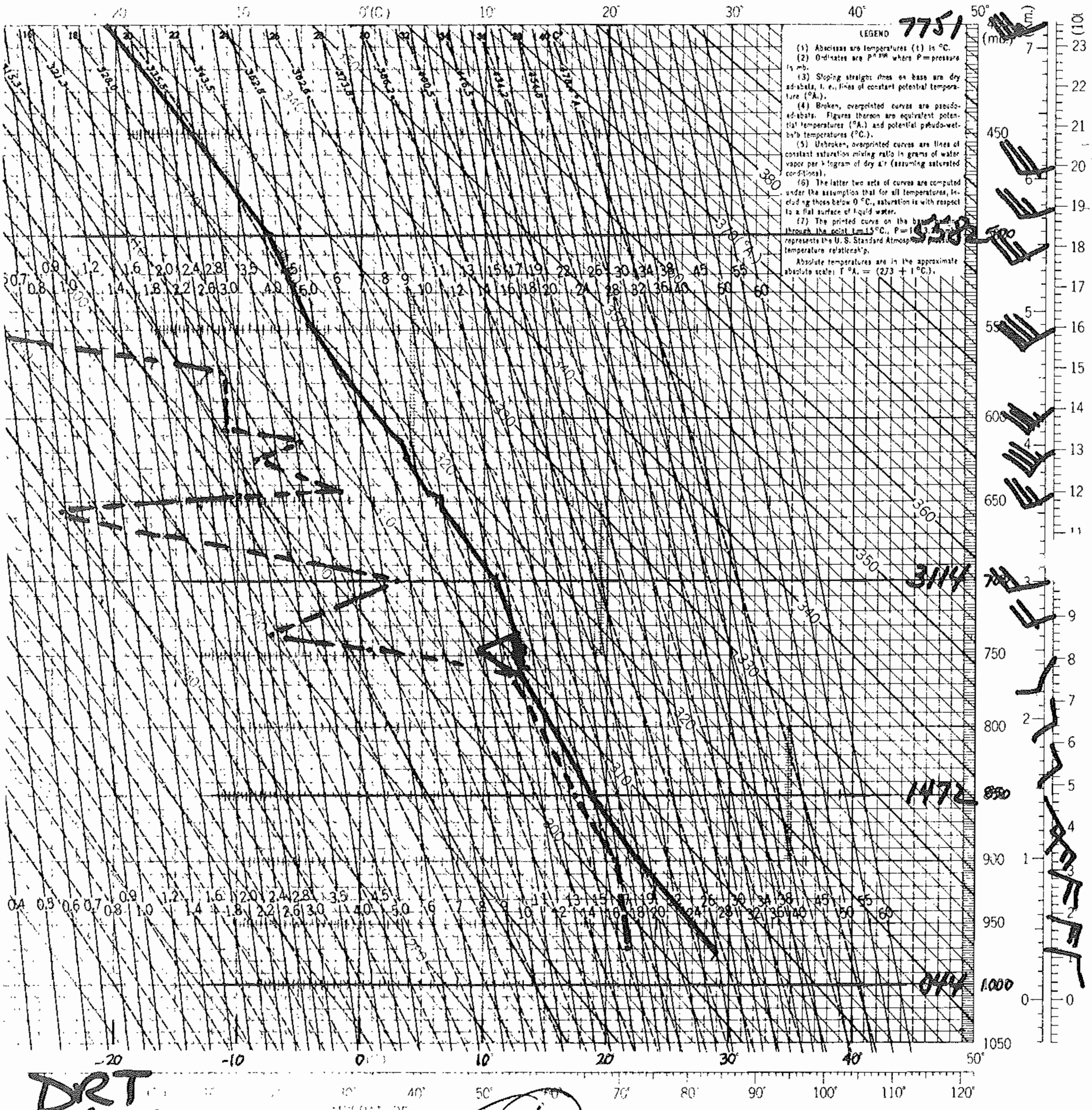
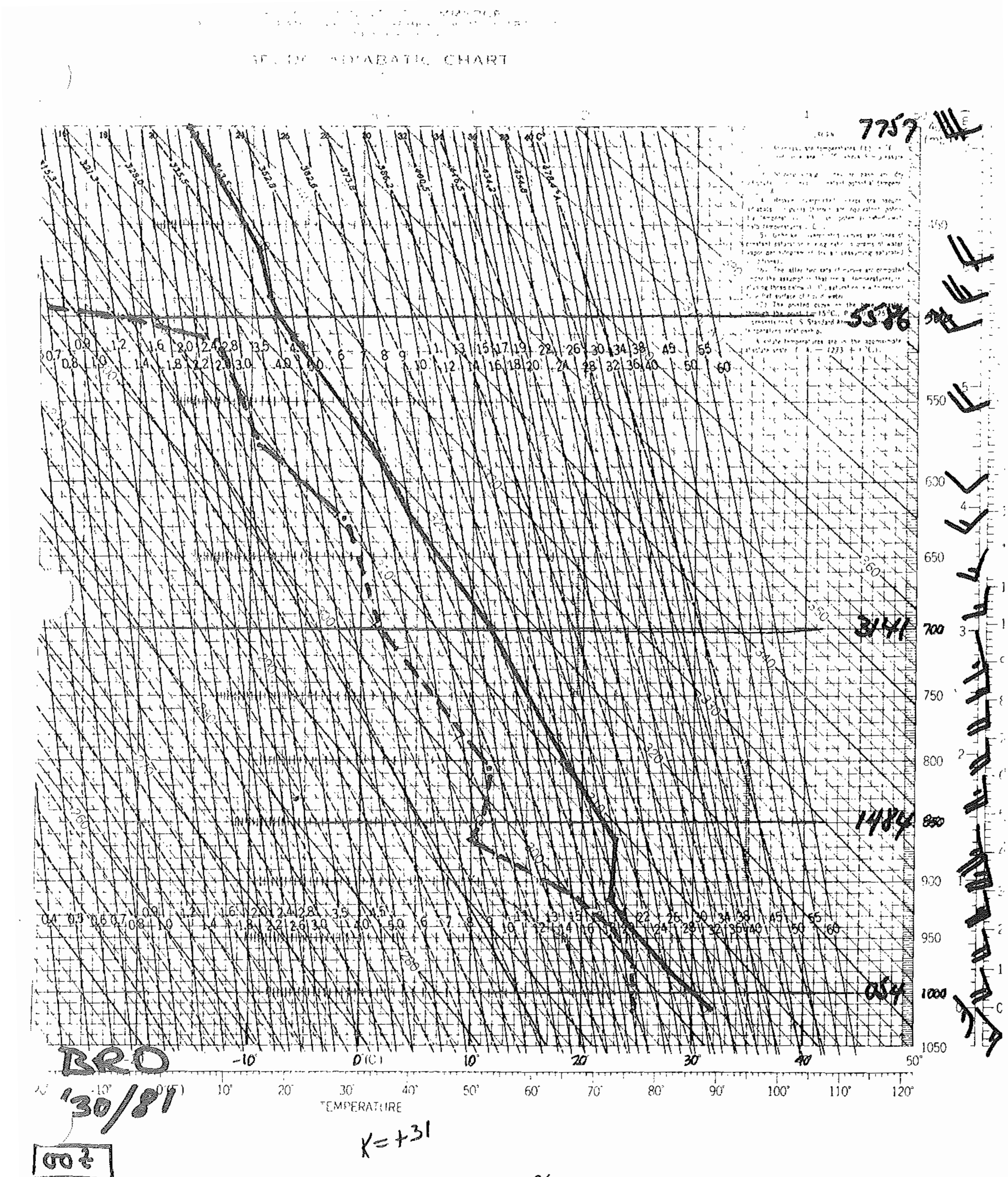


DRT
5/30/81
00Z

K=+36


ADIABATIC CHART
7757
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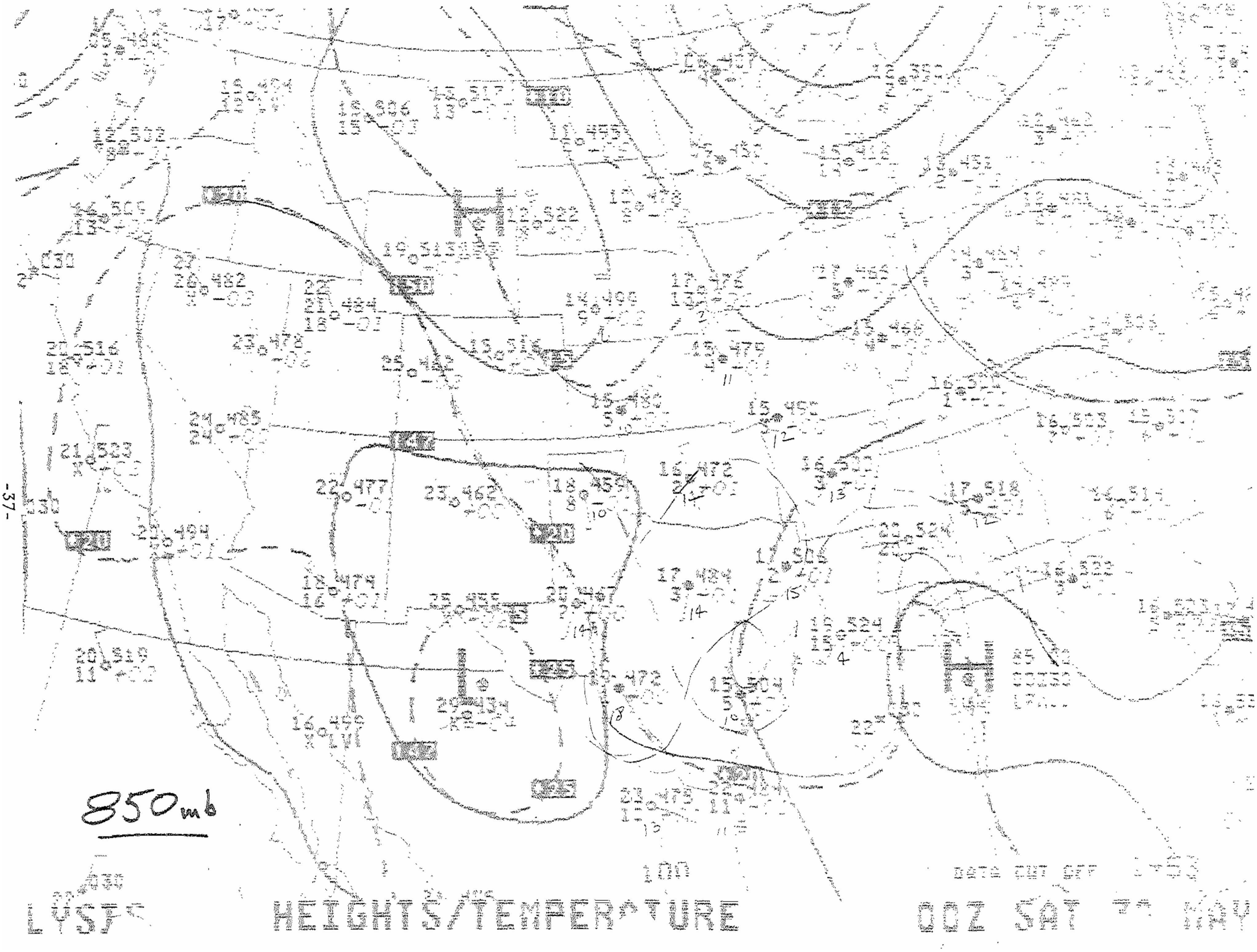
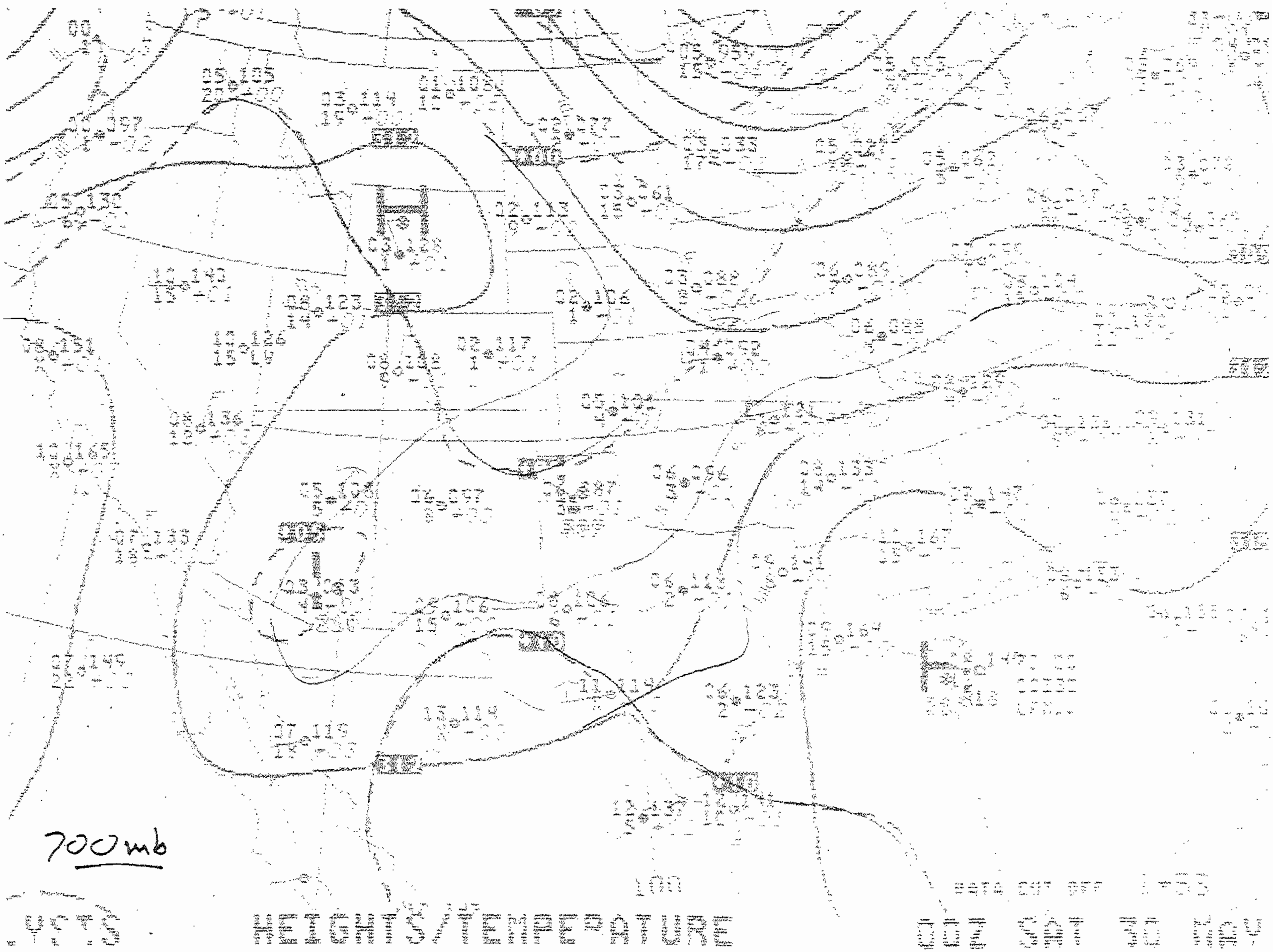
30/81
00Z
TEMPERATURE
K=+31


850mb
HEIGHTS/TEMPERATURE
00Z SAT
MAY
DATA CUT OFF
100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HEIGHTS/TEMPERATURE
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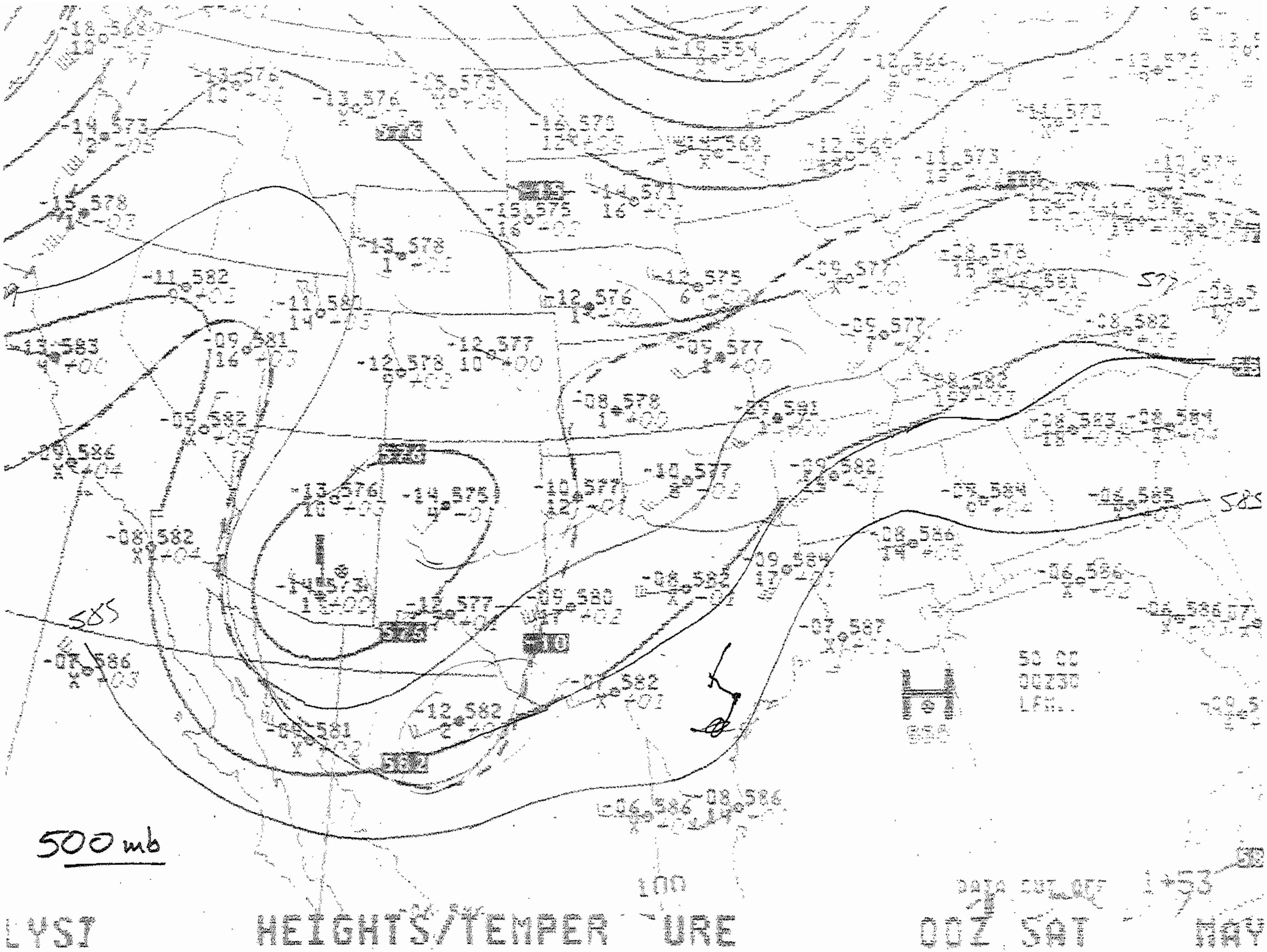
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LYST HEIGHTS/TEMPER URE 00Z SAT MAY
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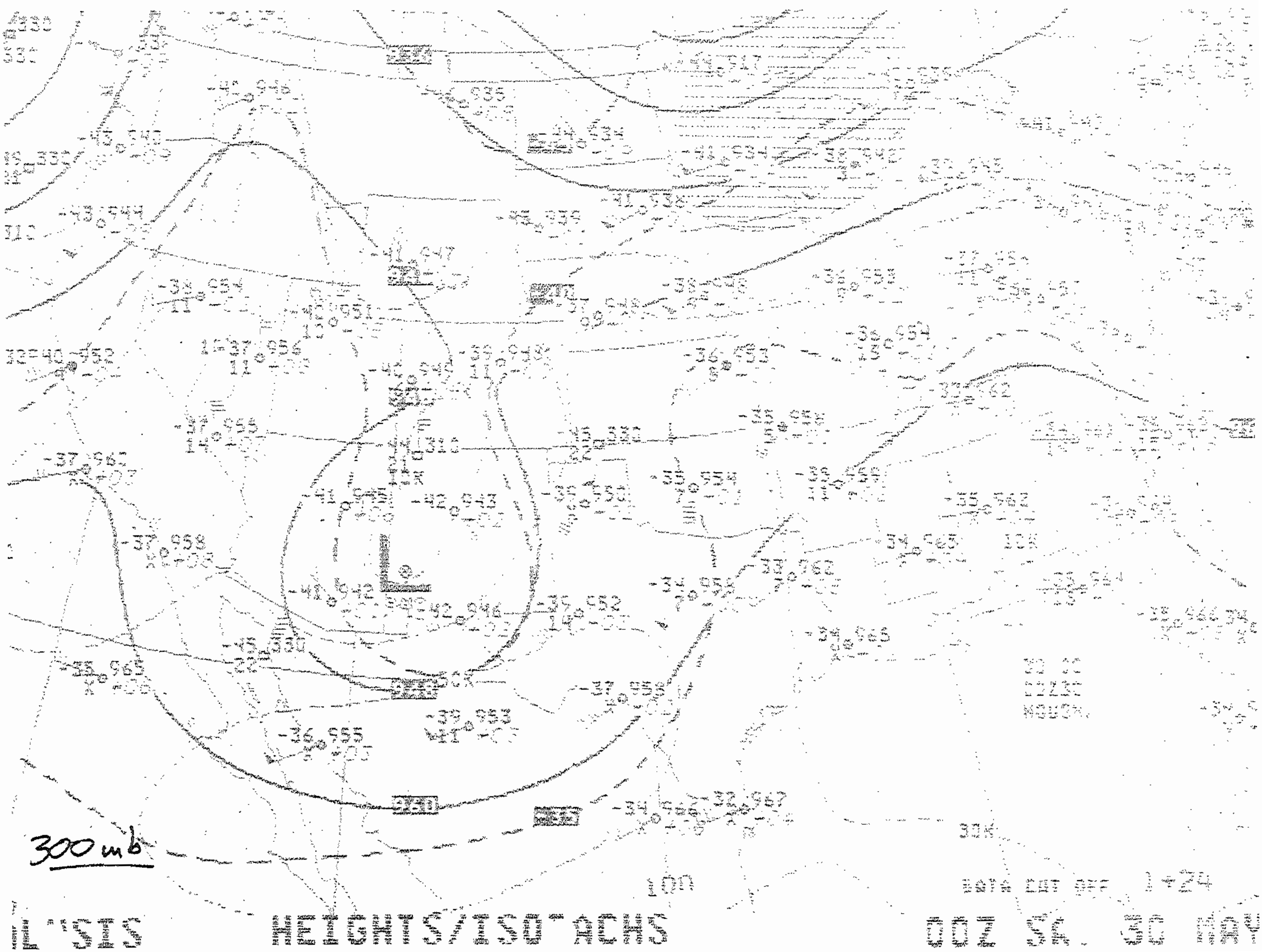
100
585
H
L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L
HEIGHTS/ISO"ACHS
00Z SA. 30 MAY
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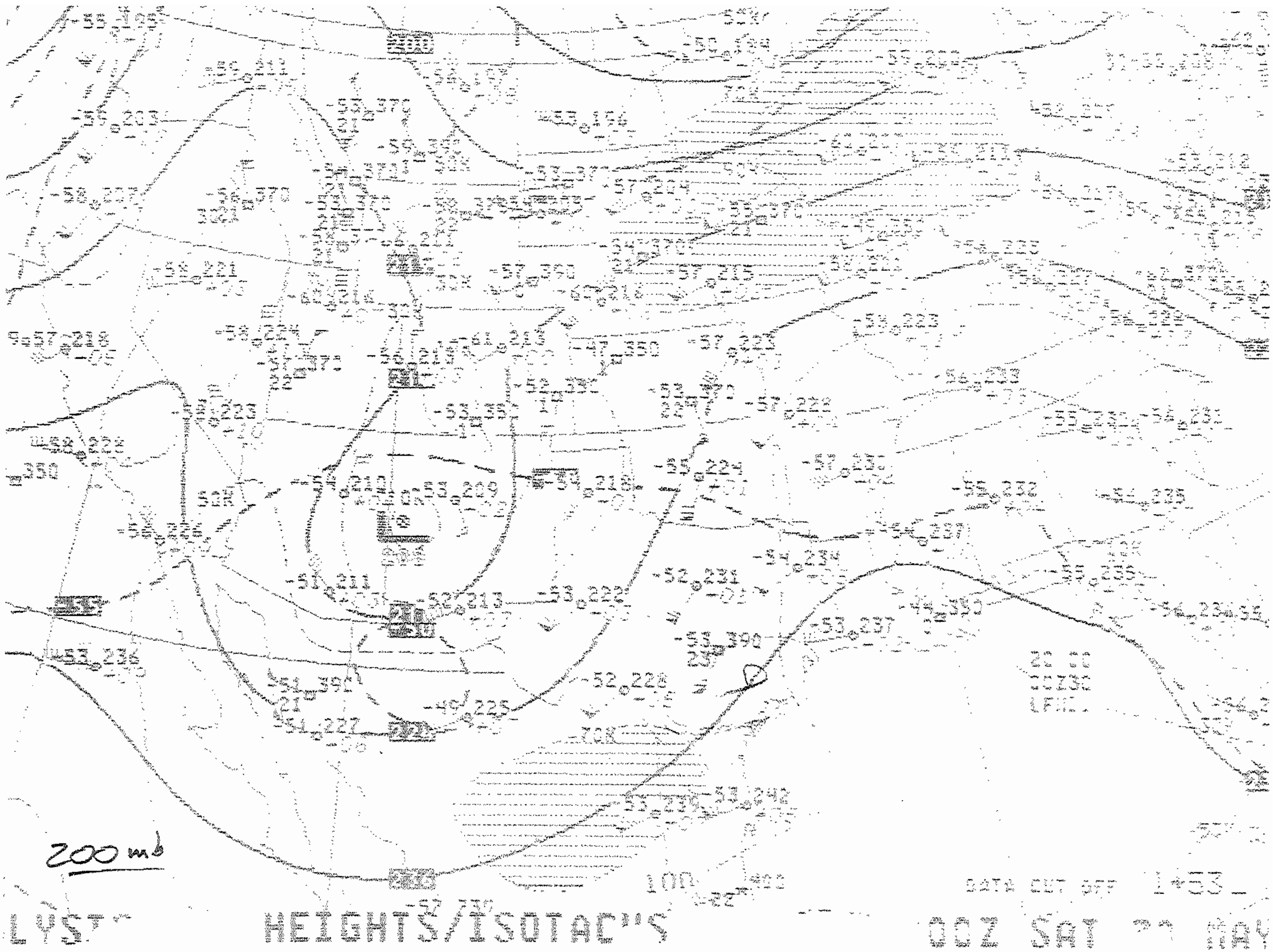
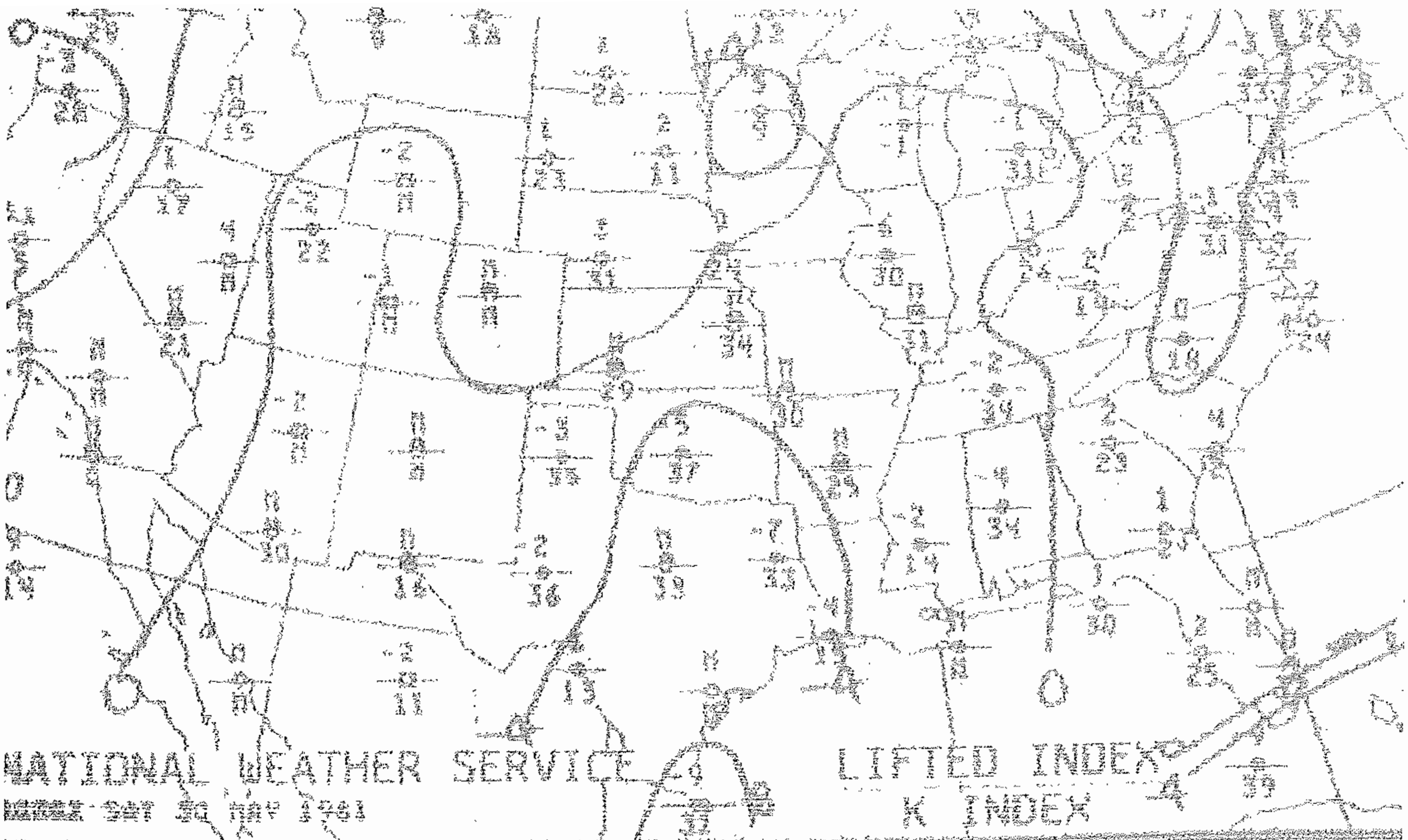
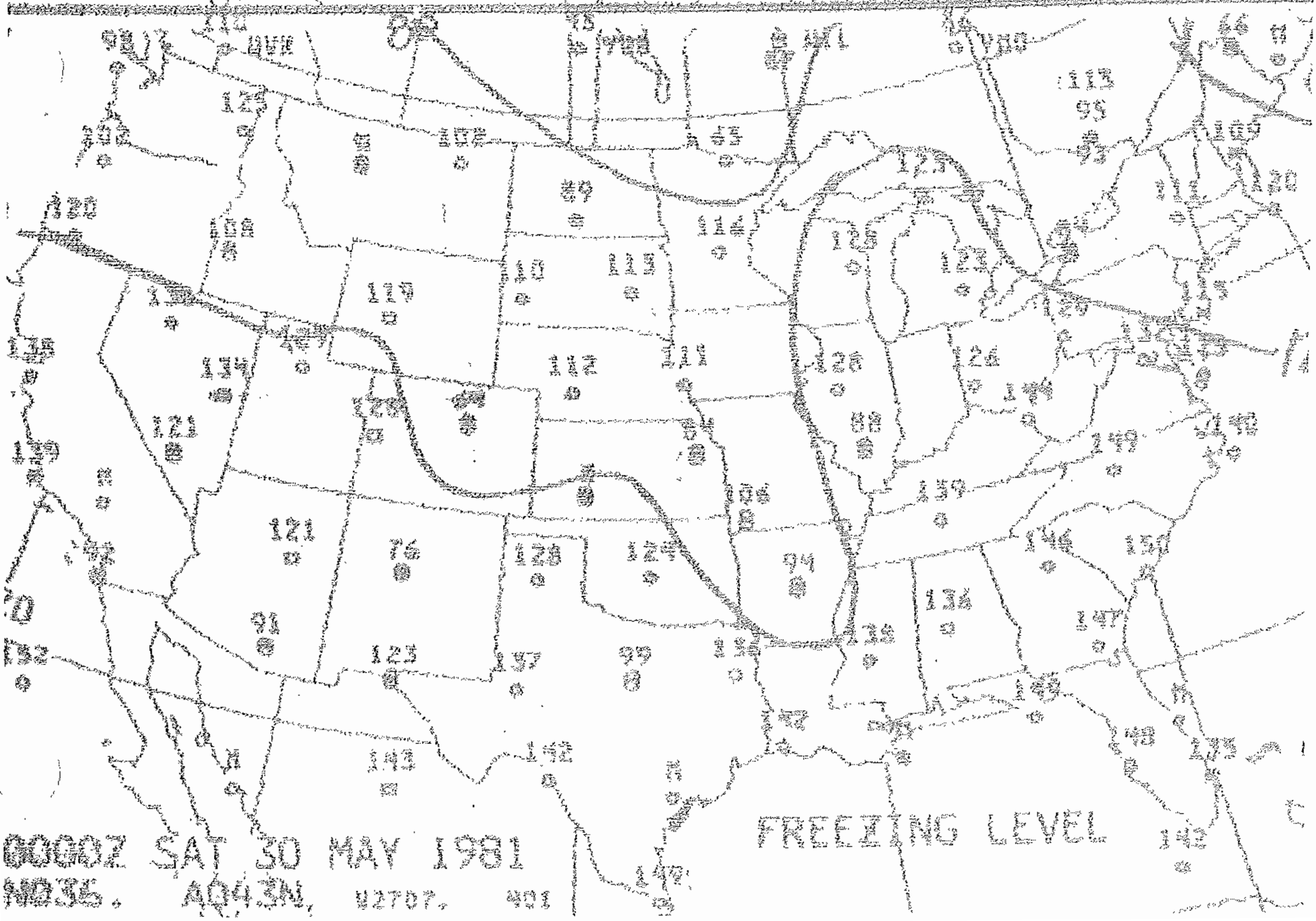

200 mb
DATA CUT OFF
HEIGHTS/ISOTAC'S
00Z SAT


NATIONAL WEATHER SERVICE
LIFTED INDEX
K INDEX
SAT 30 MAY 1981


FREEZING LEVEL
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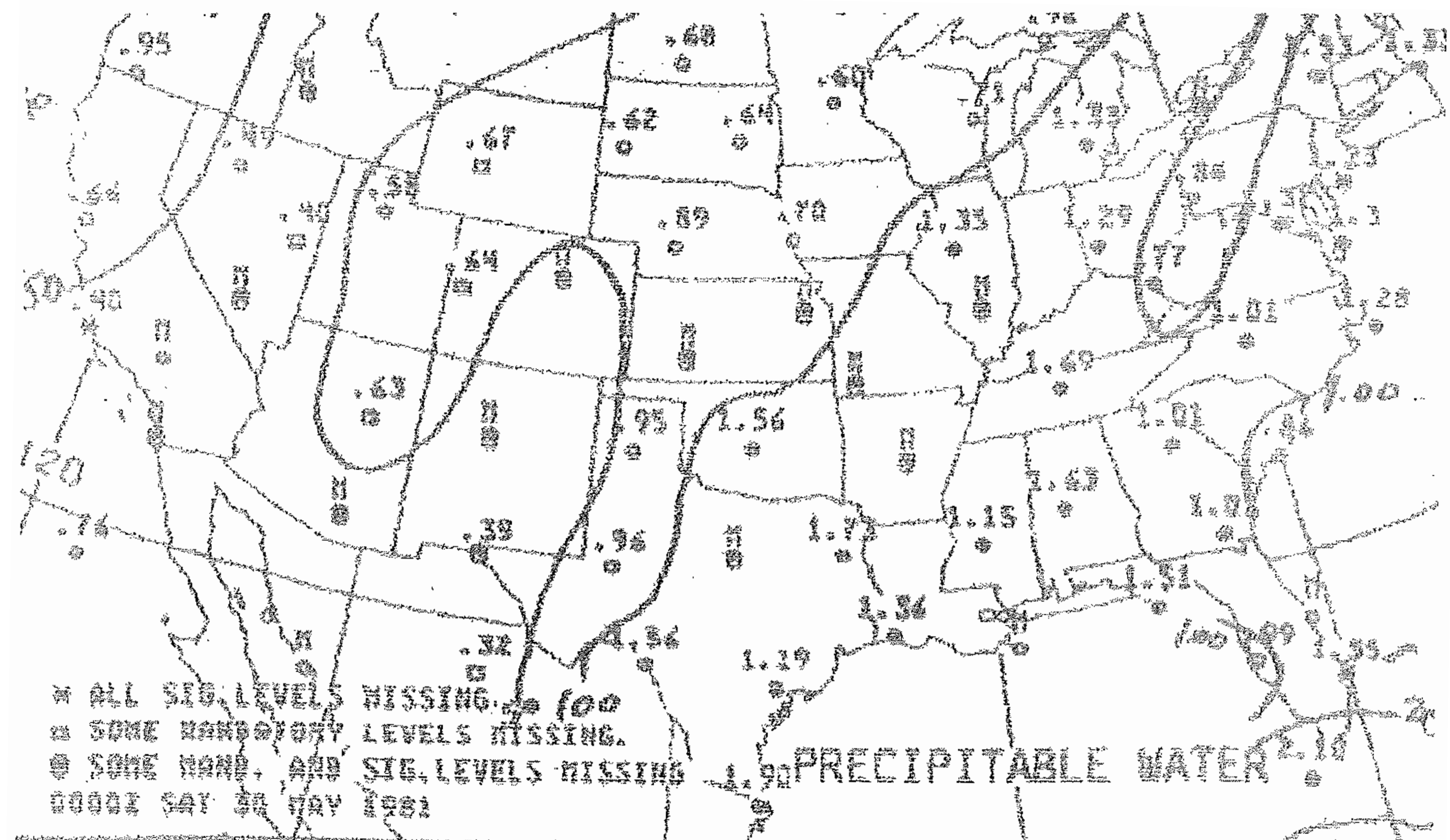
NO35. AQ43N, U2707. 401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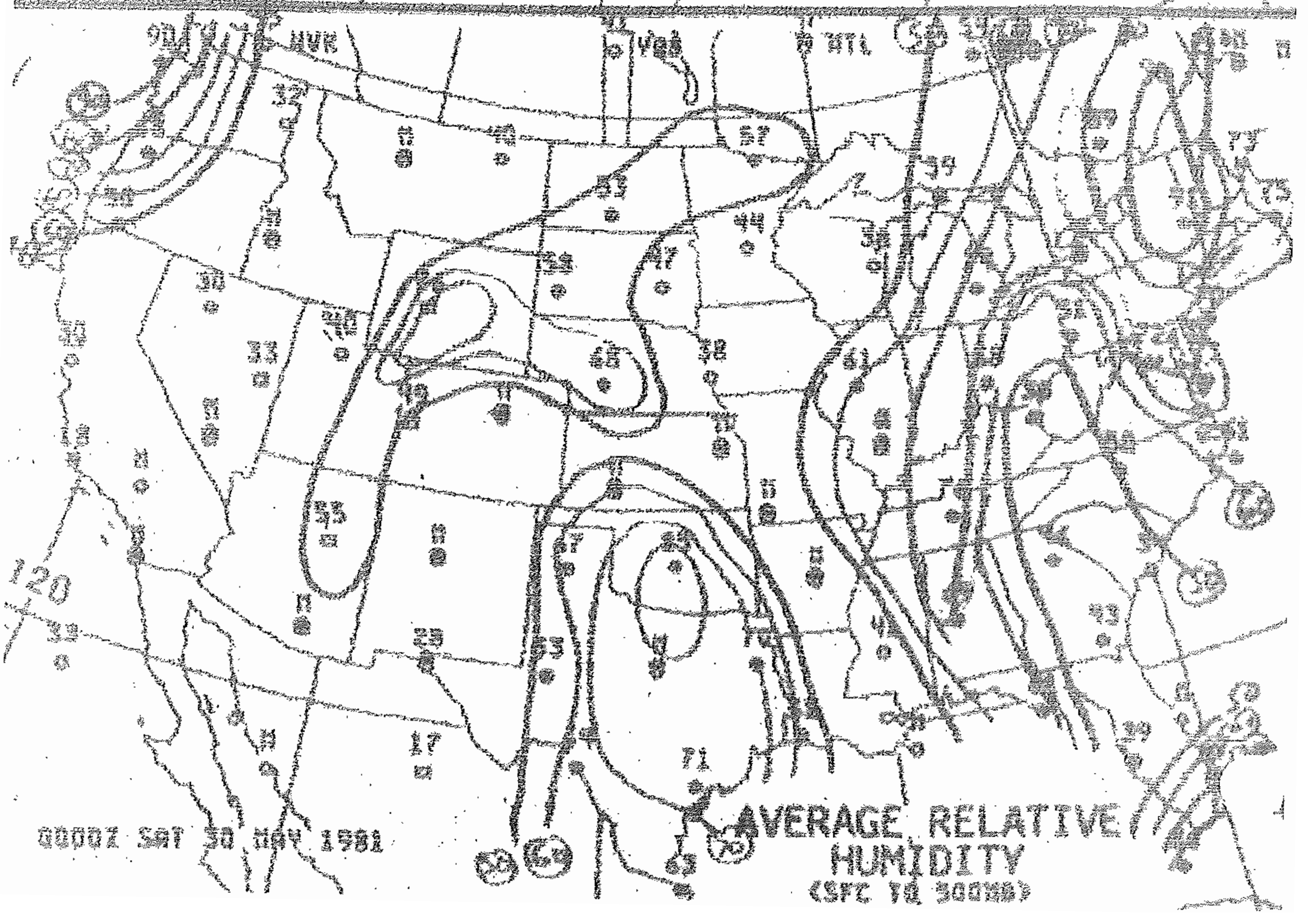
□ SOME MANDATORY LEVELS MISSING.
● SOME MAND. AND SIG.LEVELS MISSING
0000Z SAT 30 MAY 1981
PRECIPITABLE WATER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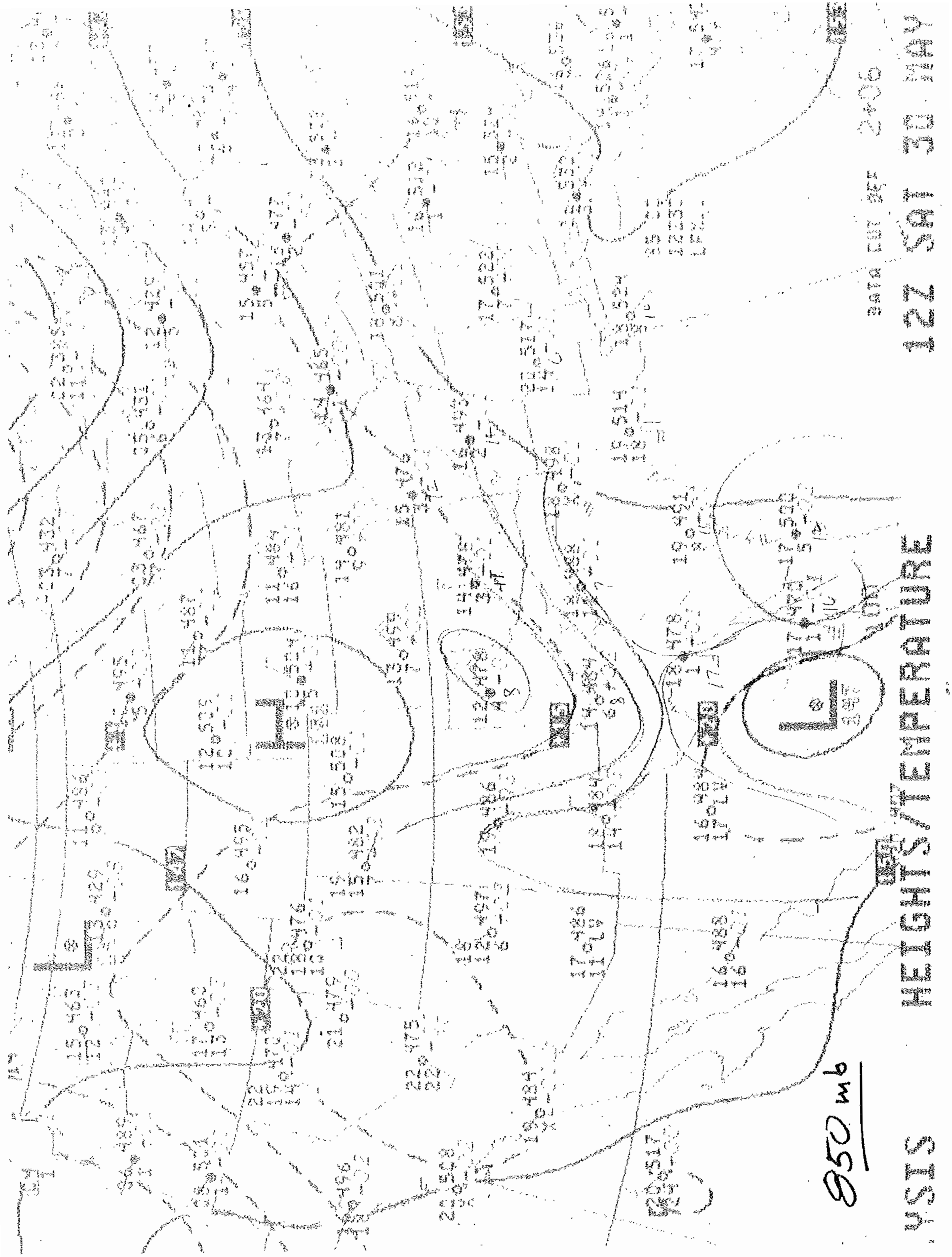
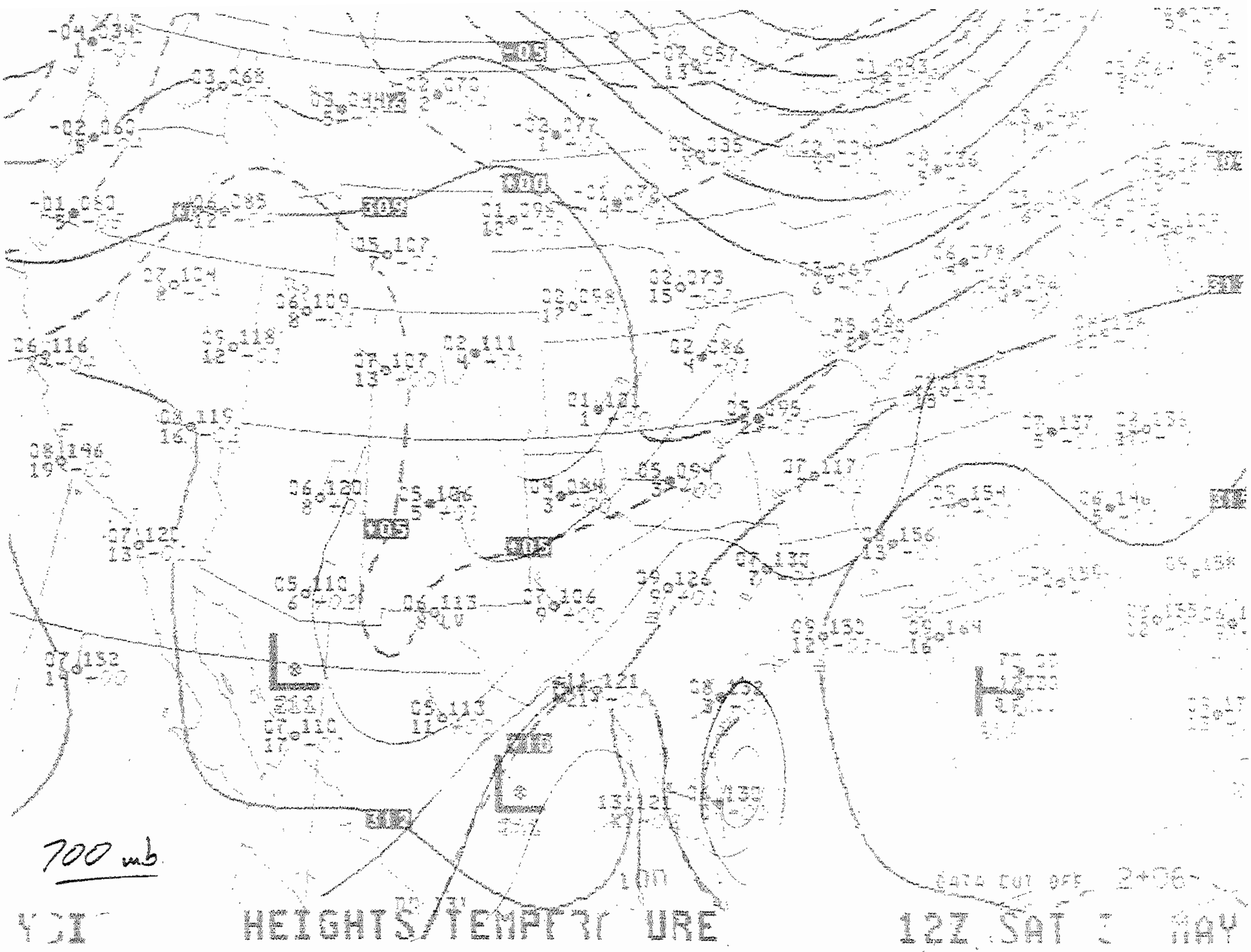
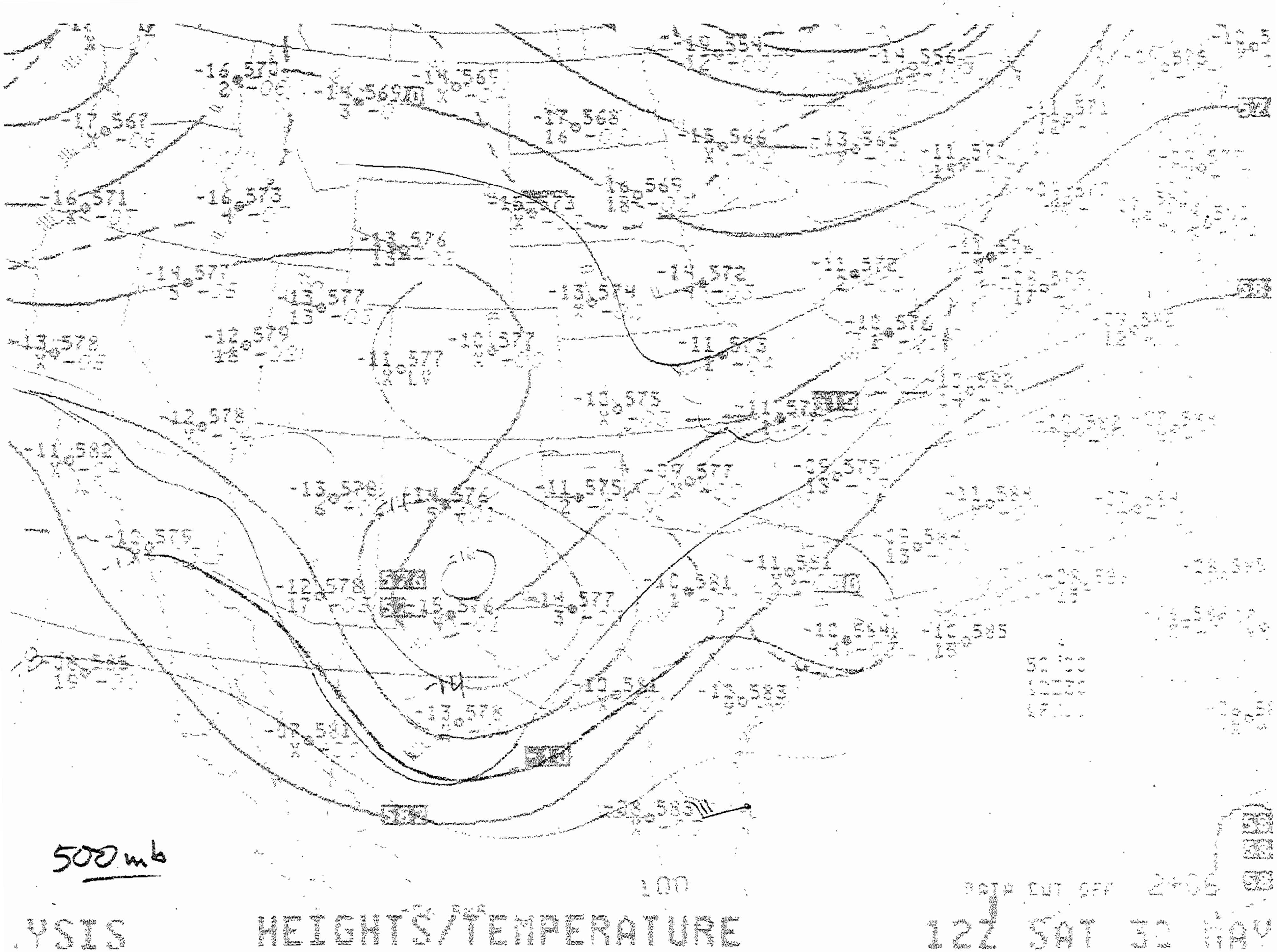
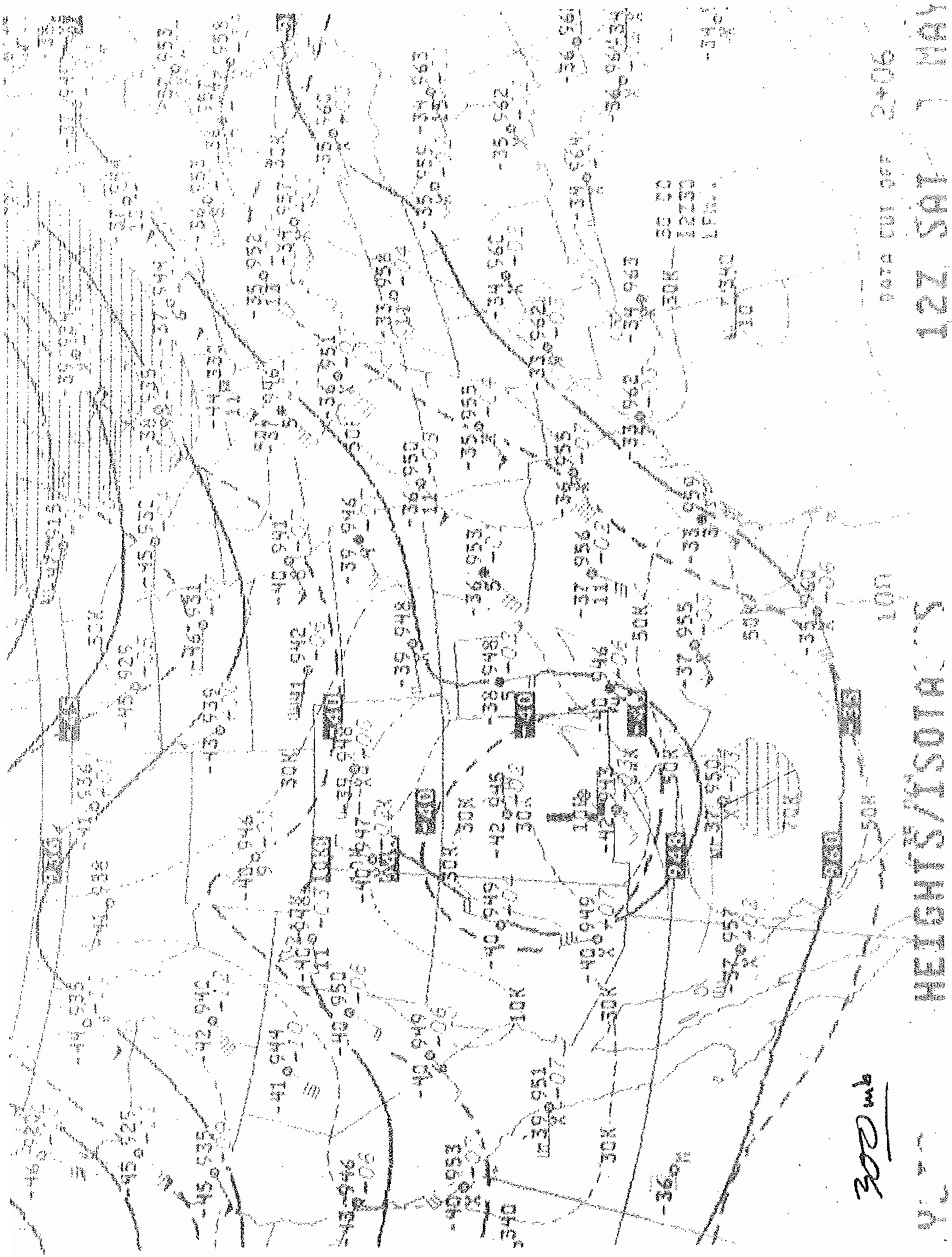
AVERAGE RELATIVE HUMIDITY
(SFC TO 500MB)

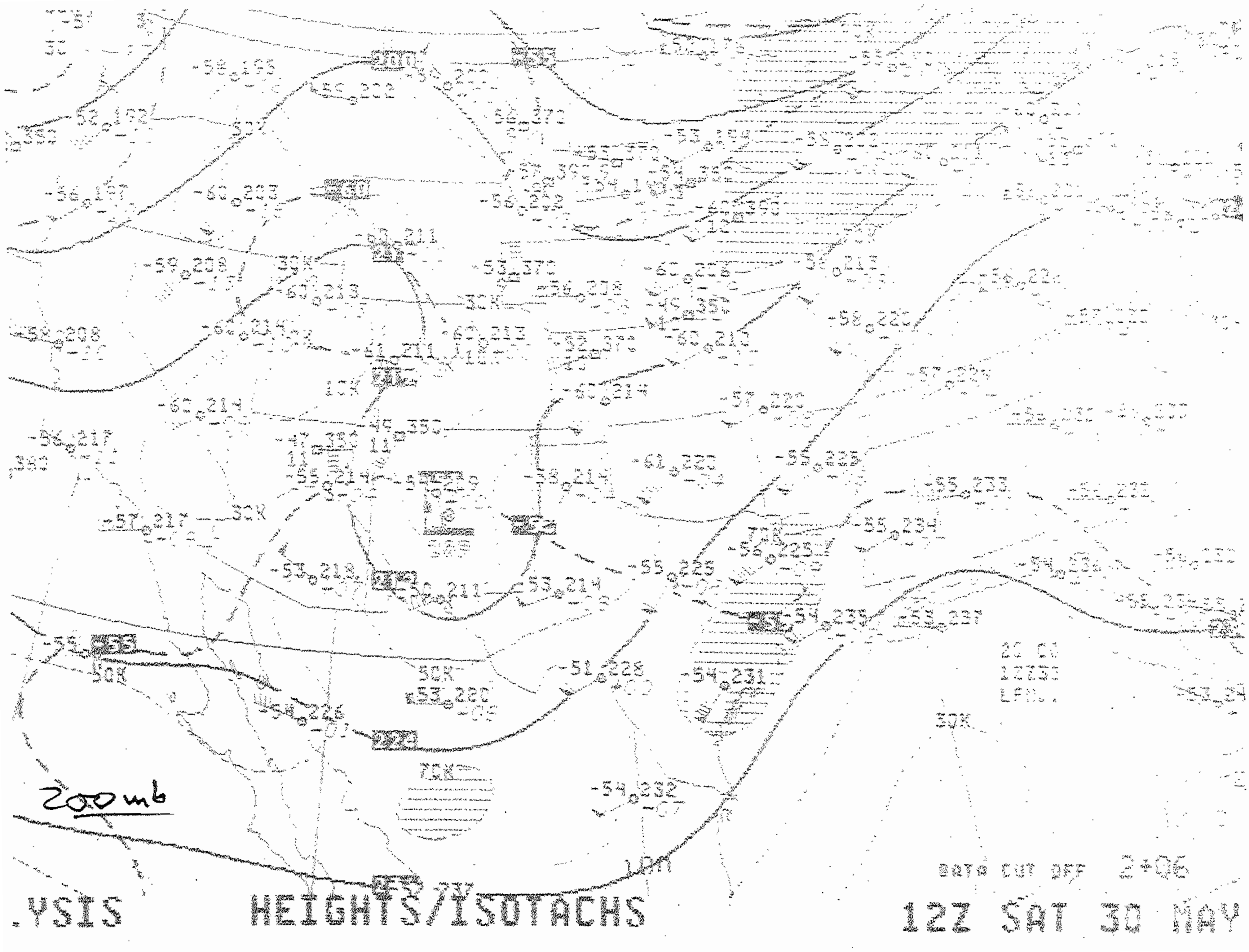

850 mb
USTIS HEIGHTS/TEMPERATURE
12Z SAT 30 MAY

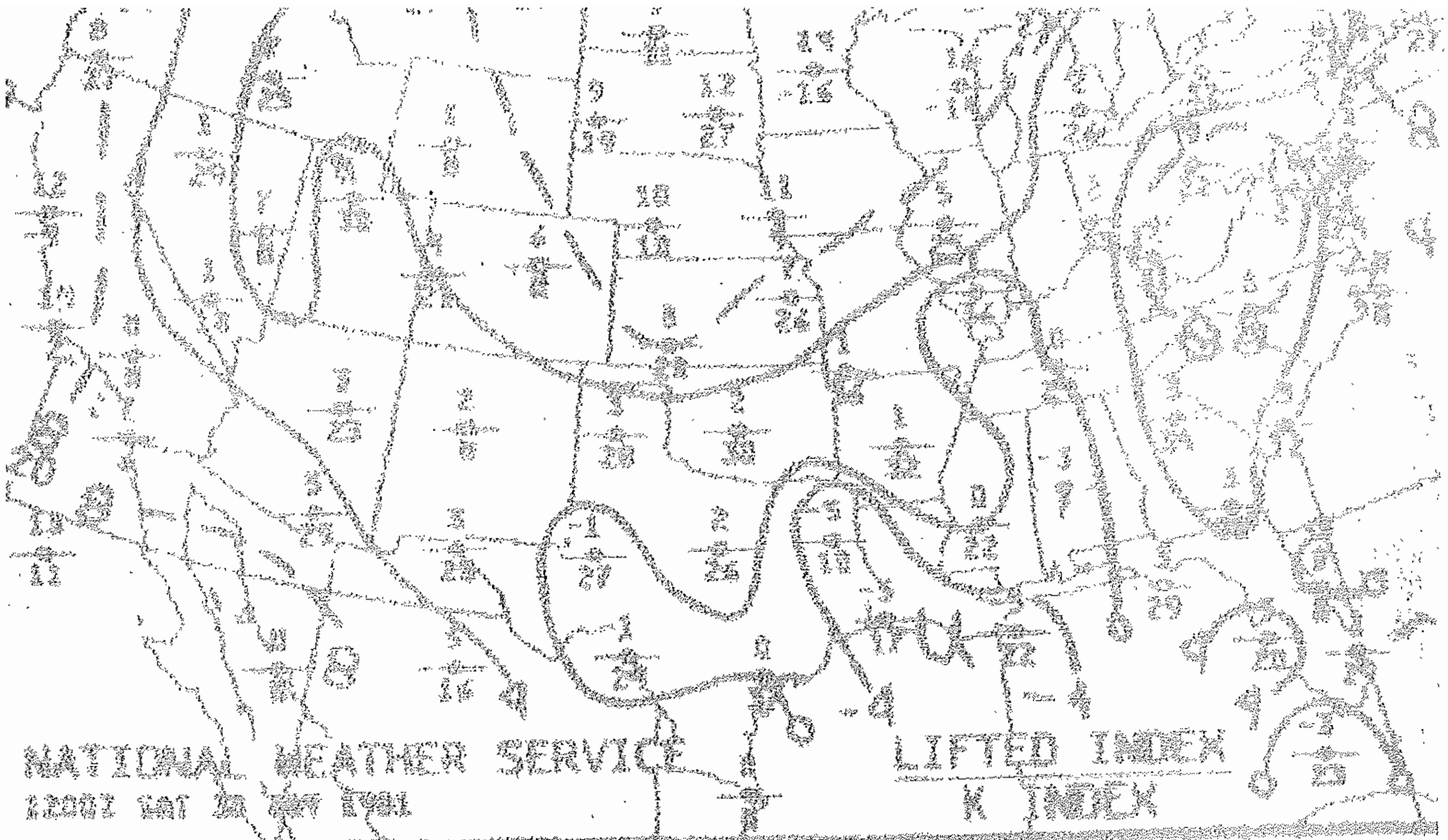

700 mb
HEIGHTS/TEMP
URE
12Z SAT
MAY
DATA CUT OFF

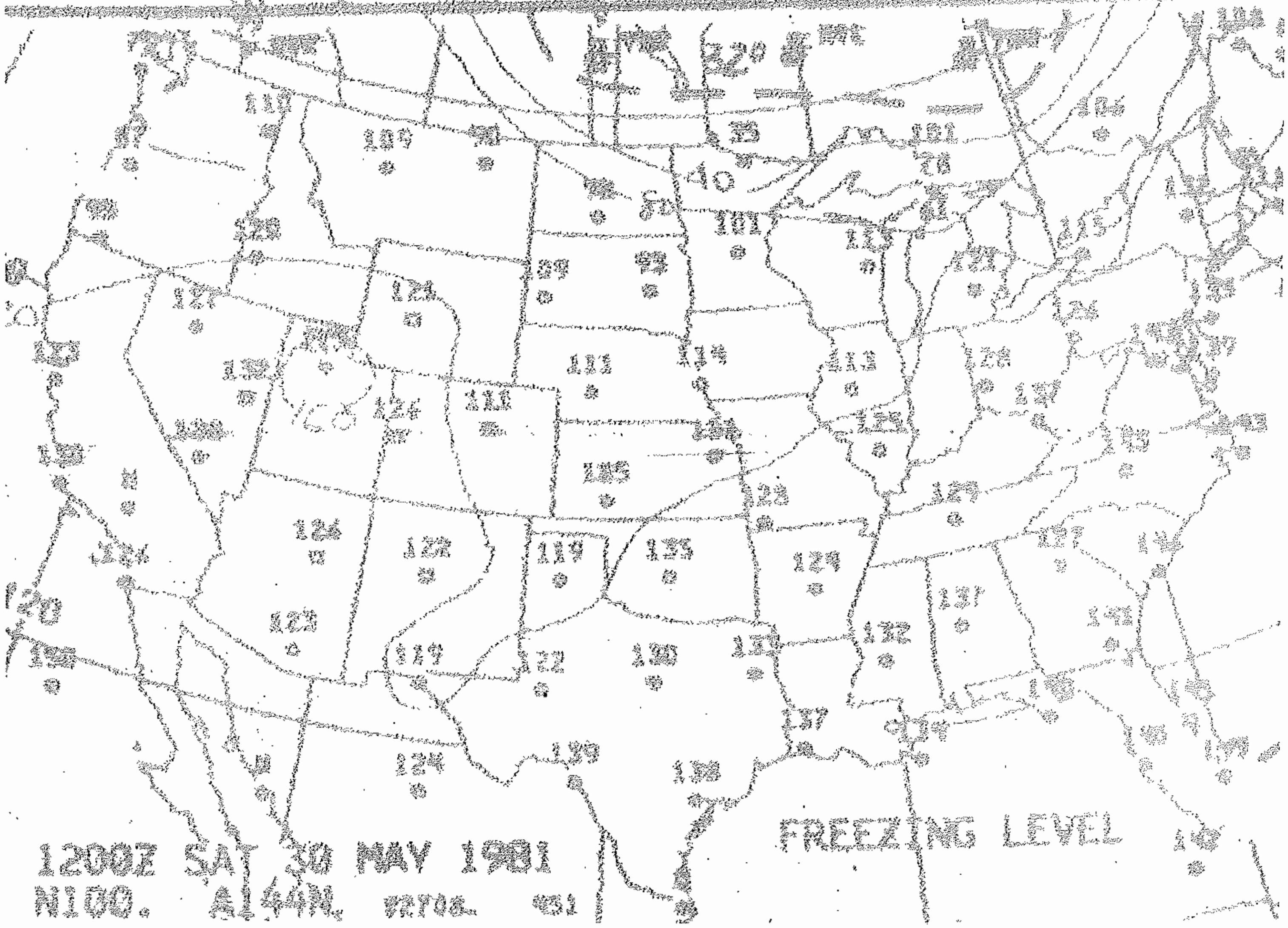


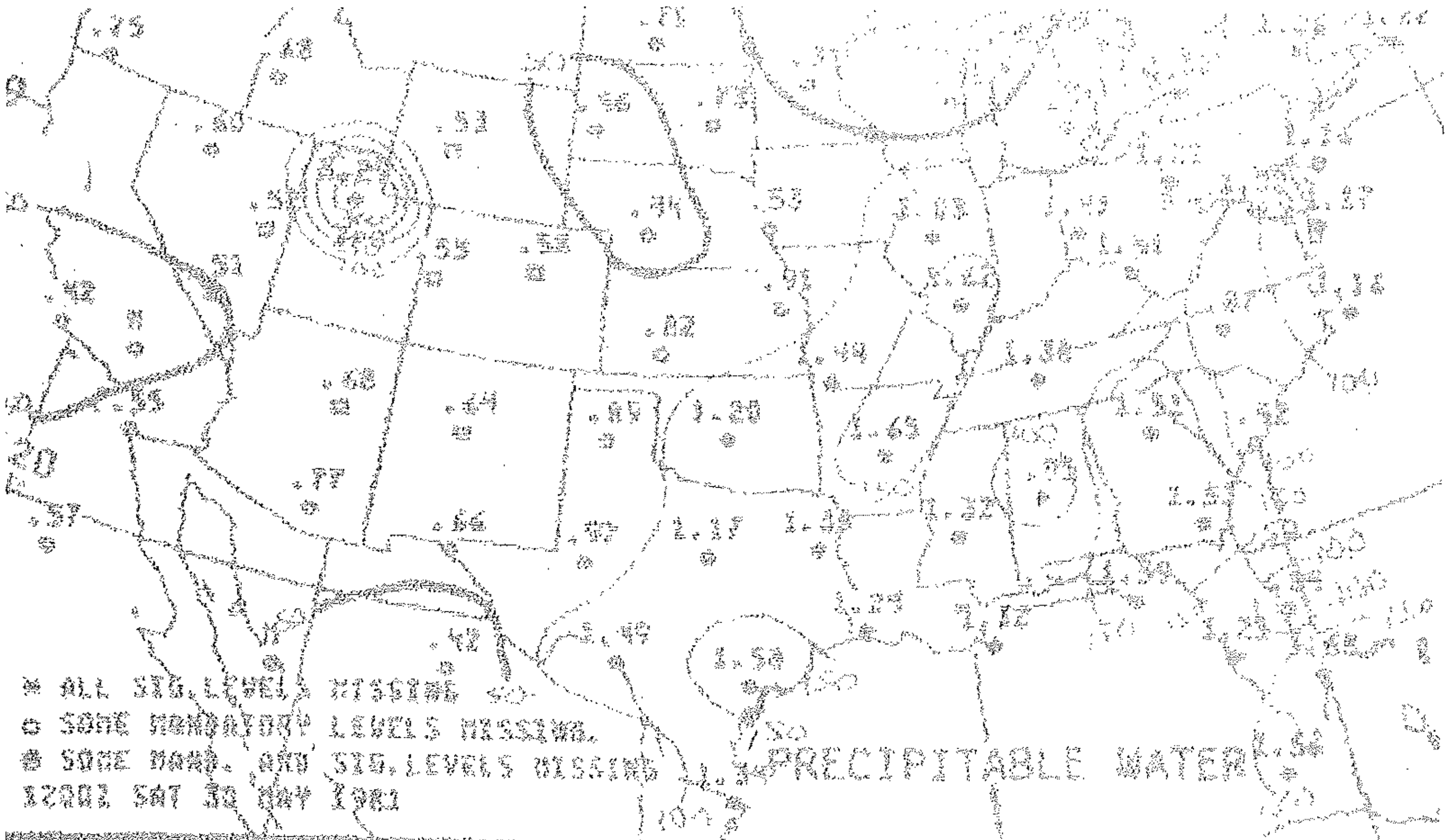
500 mb
DATA CUT OFF
.YSIS HEIGHTS/TEMPERATURE
12Z SAT 30 MAY

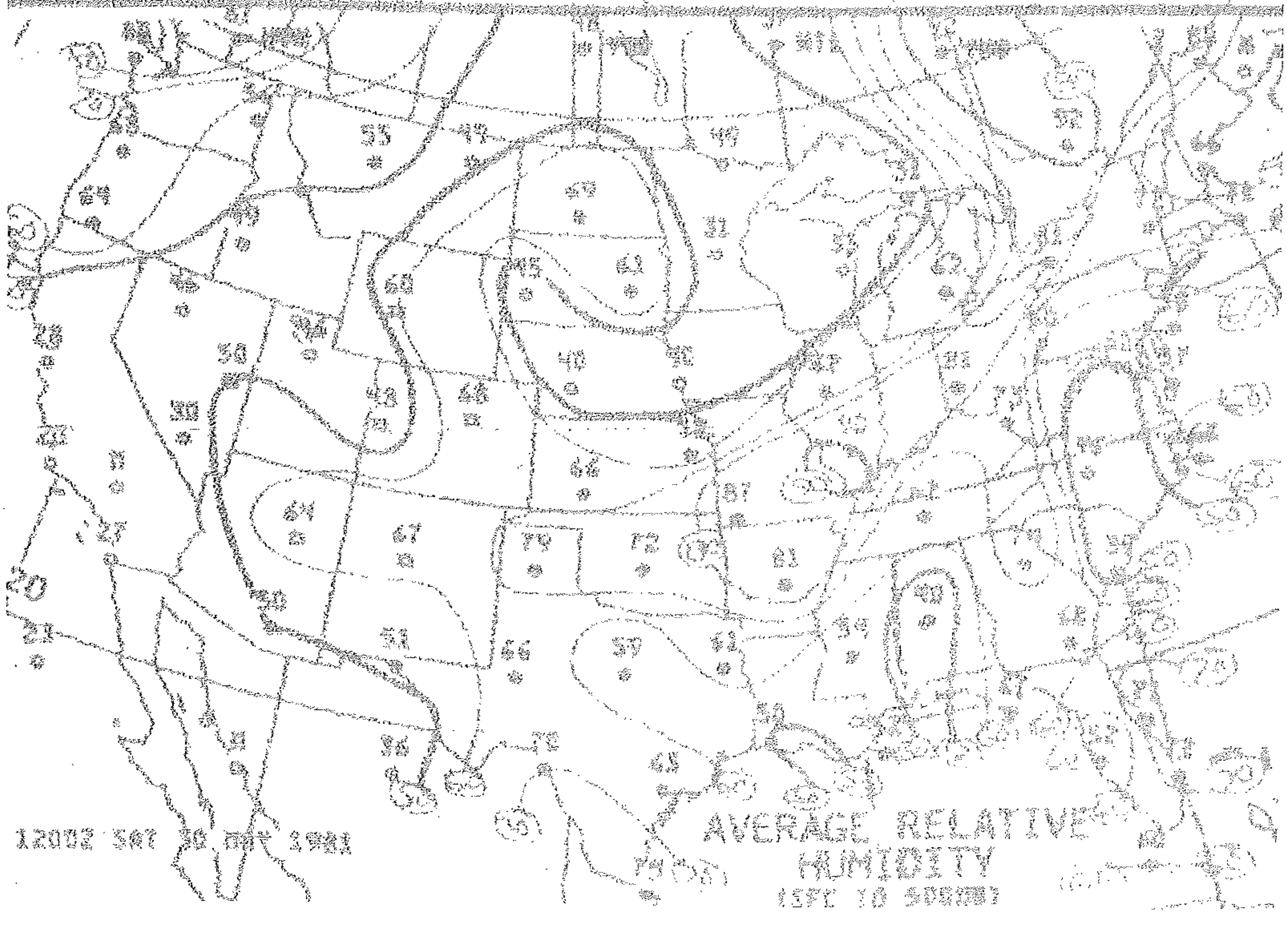

300 mb
HEIGHTS/ISOTA
12Z SAT


200mb
DATA CUT OFF 2+06
.YSIS HEIGHTS/ISOTACHS
12Z SAT 30 MAY


NATIONAL WEATHER SERVICE
1200Z SAT 30 MAY 1981
LIFTED INDEX
K INDEX


FREEZING LEVEL
1200Z SAT 30 MAY 1981
N100. A144N.


* ALL SIG.LEVELS MISSING
o SOME MANDATORY LEVELS MISSING.
⊛ SOME MAND. AND SIG.LEVELS MISSING
12002 SAT 30 MAY 1981
PRECIPITABLE WATER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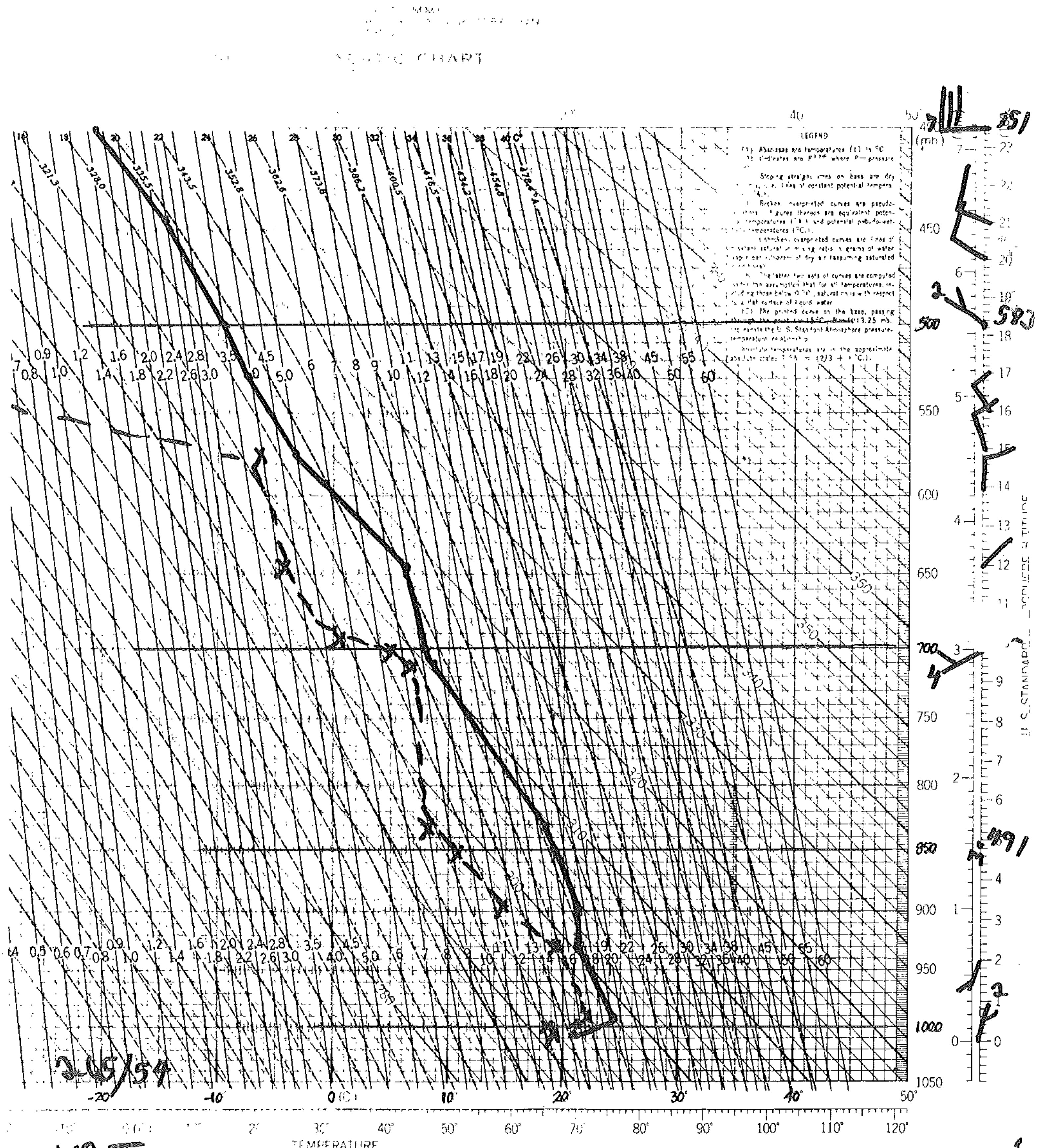
AVERAGE RELATIVE
HUMIDITY
(SFC TO 500MB)

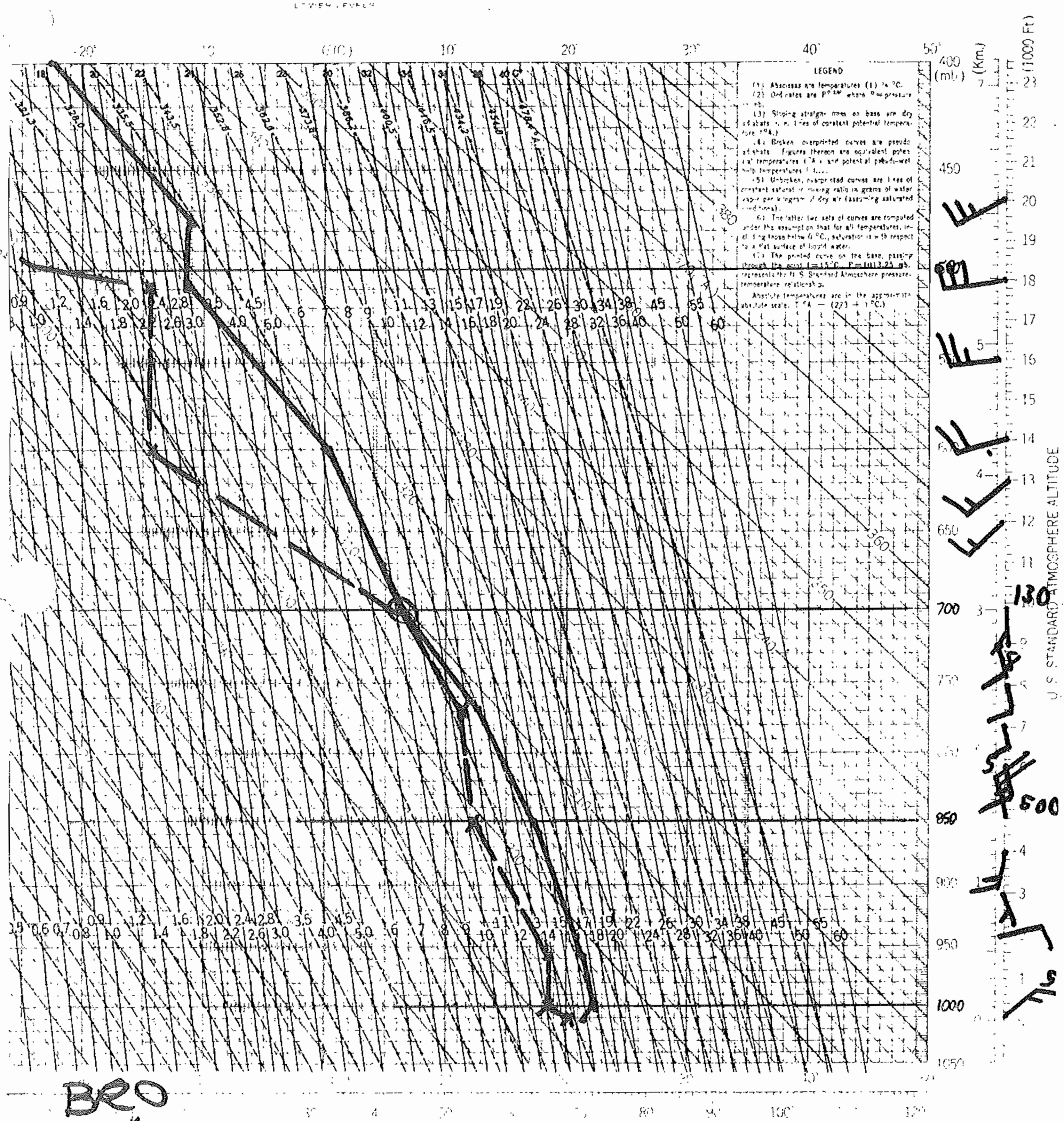


VCT

122 5/30/81 K=37 285/02 /////

U. S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

PSEUDO-ADIABATIC CHART



BRO
-130/81
12Z

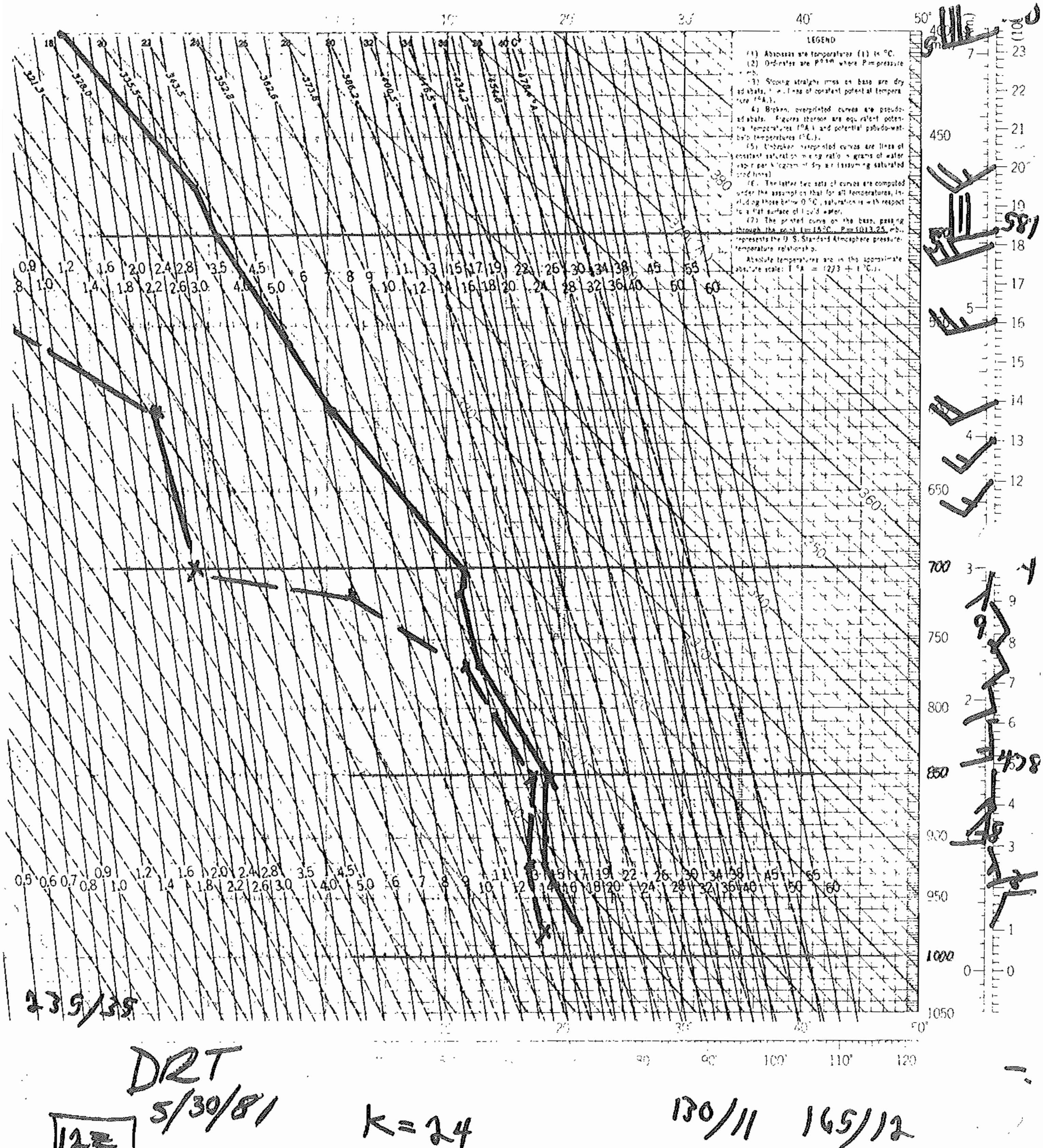
K=M

010/22 020/09

92

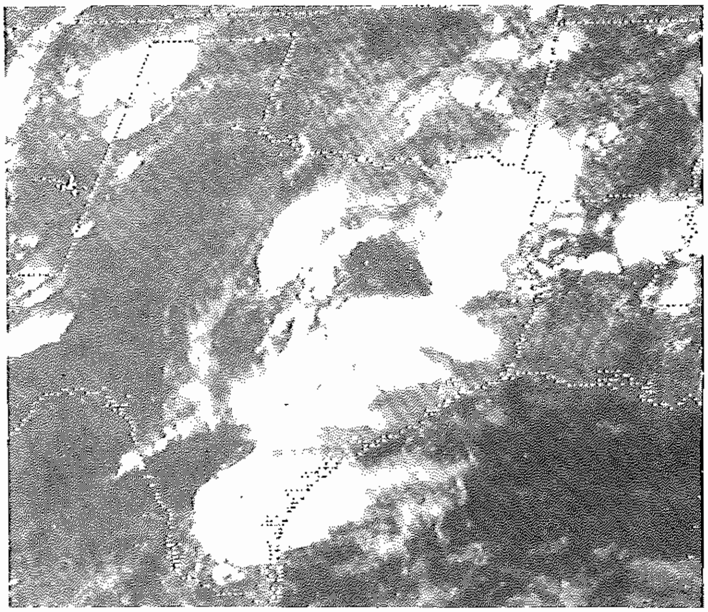
U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

PSEUDO-ADIABATIC CHART

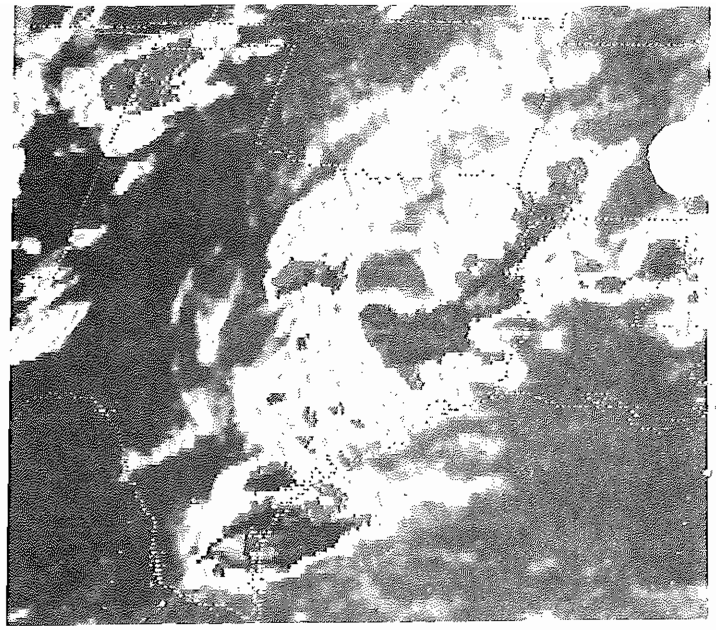


APPENDIX 2

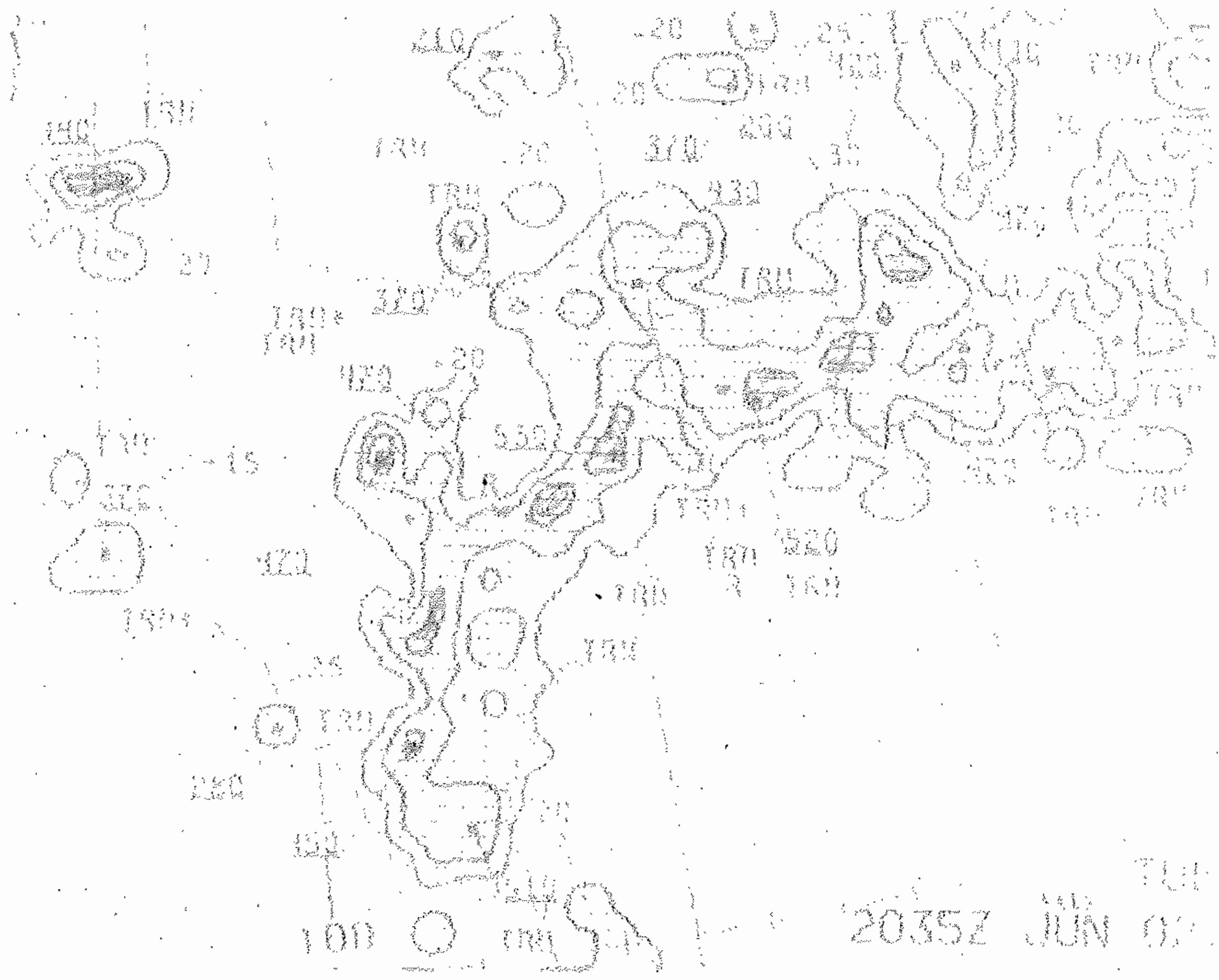
Maps for wake low event of 2-3 June, 1981, along the Texas Coast.

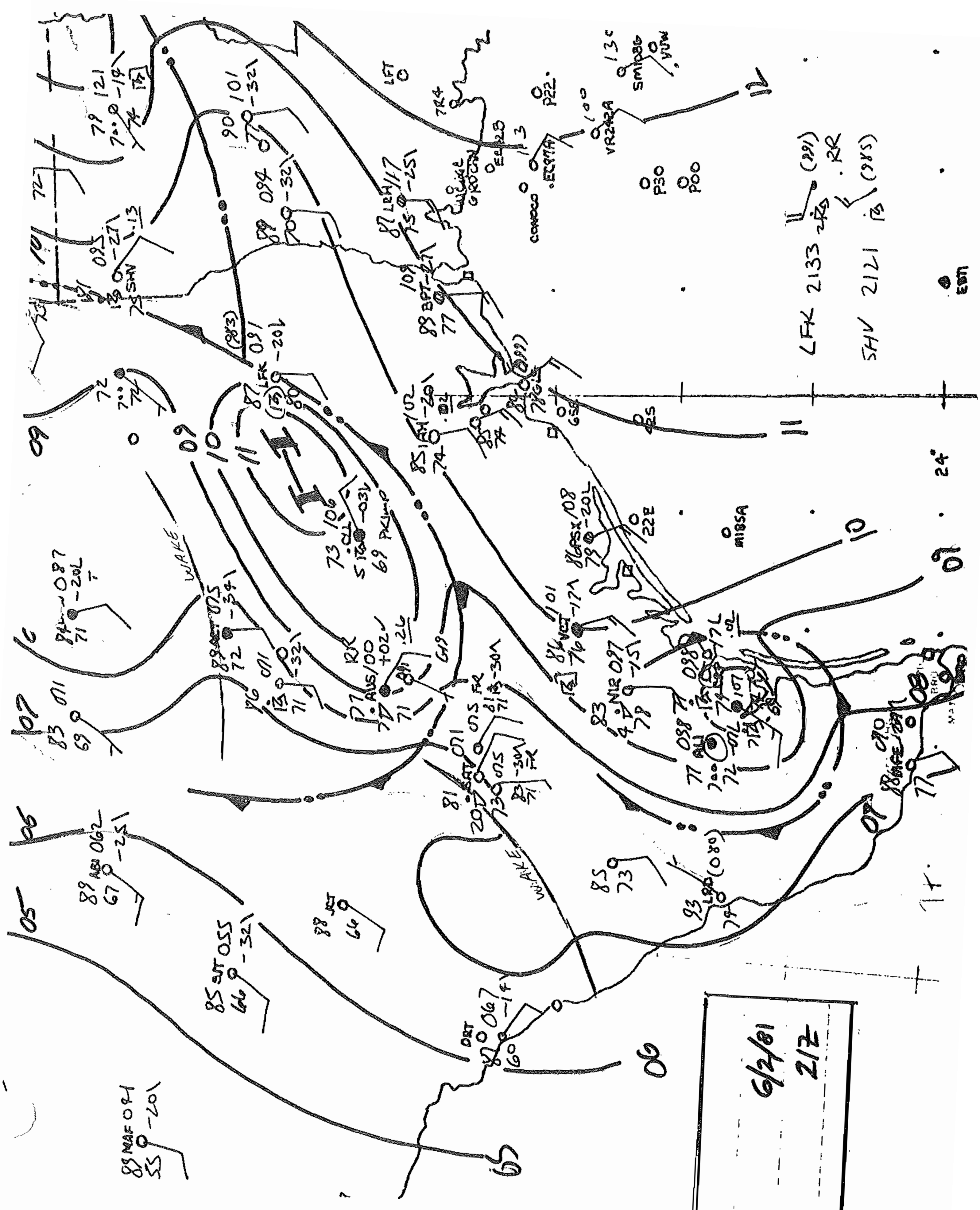


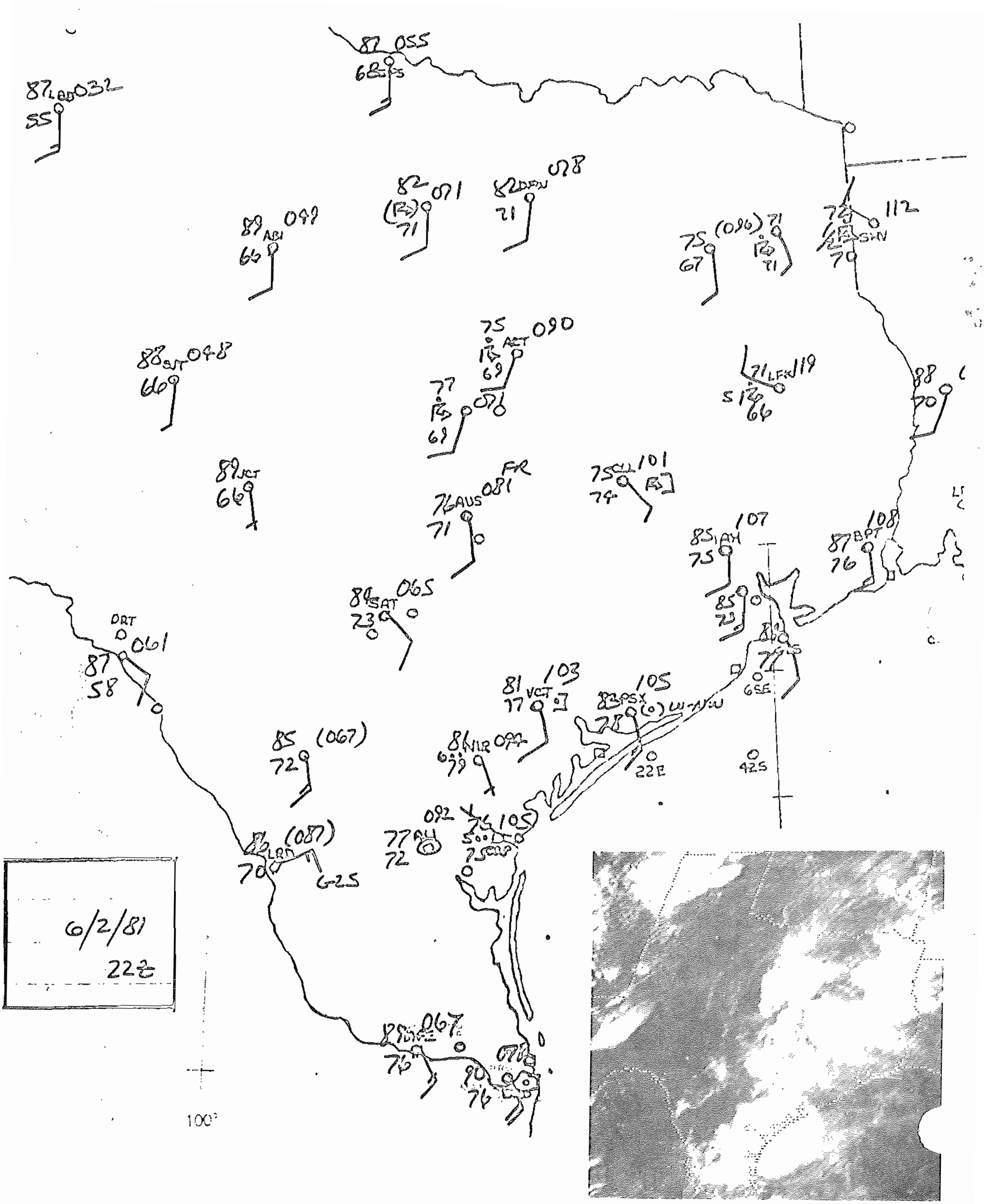
2030 02JN81



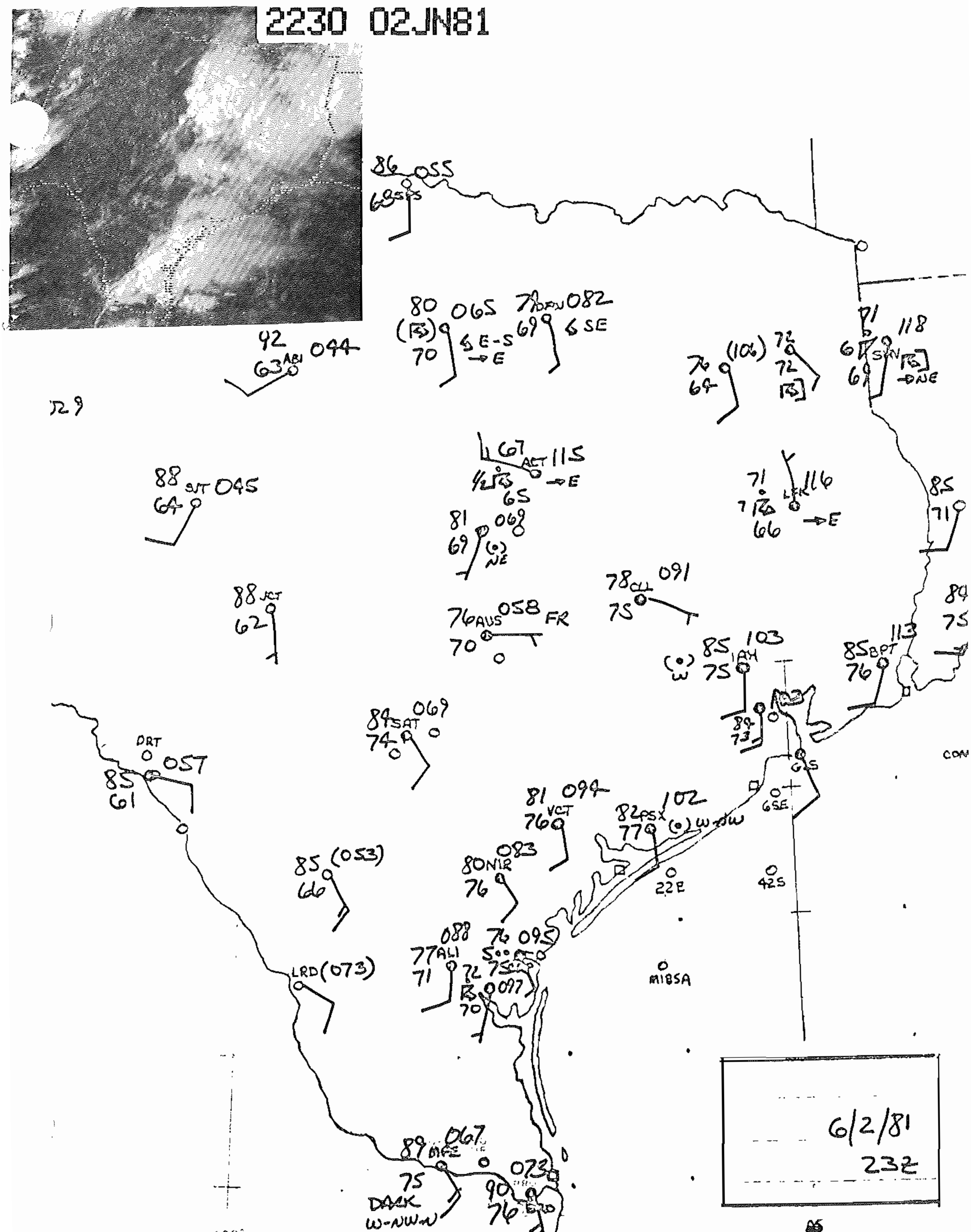
2100 02JN81

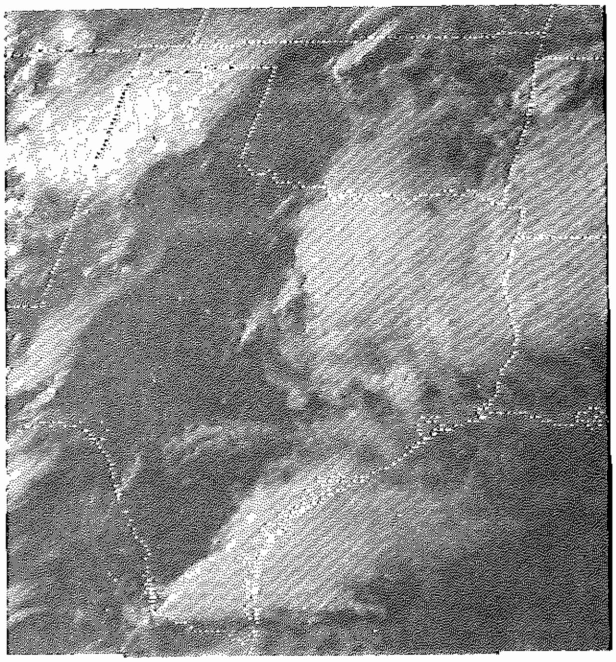



WAKE
WAKE
LFK 2133
SHV 2121
6/2/81
21Z

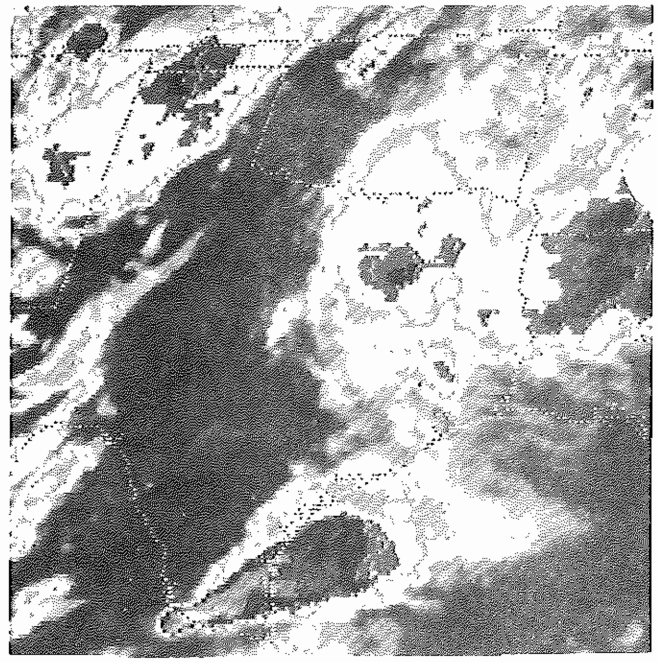


2130 02JN81

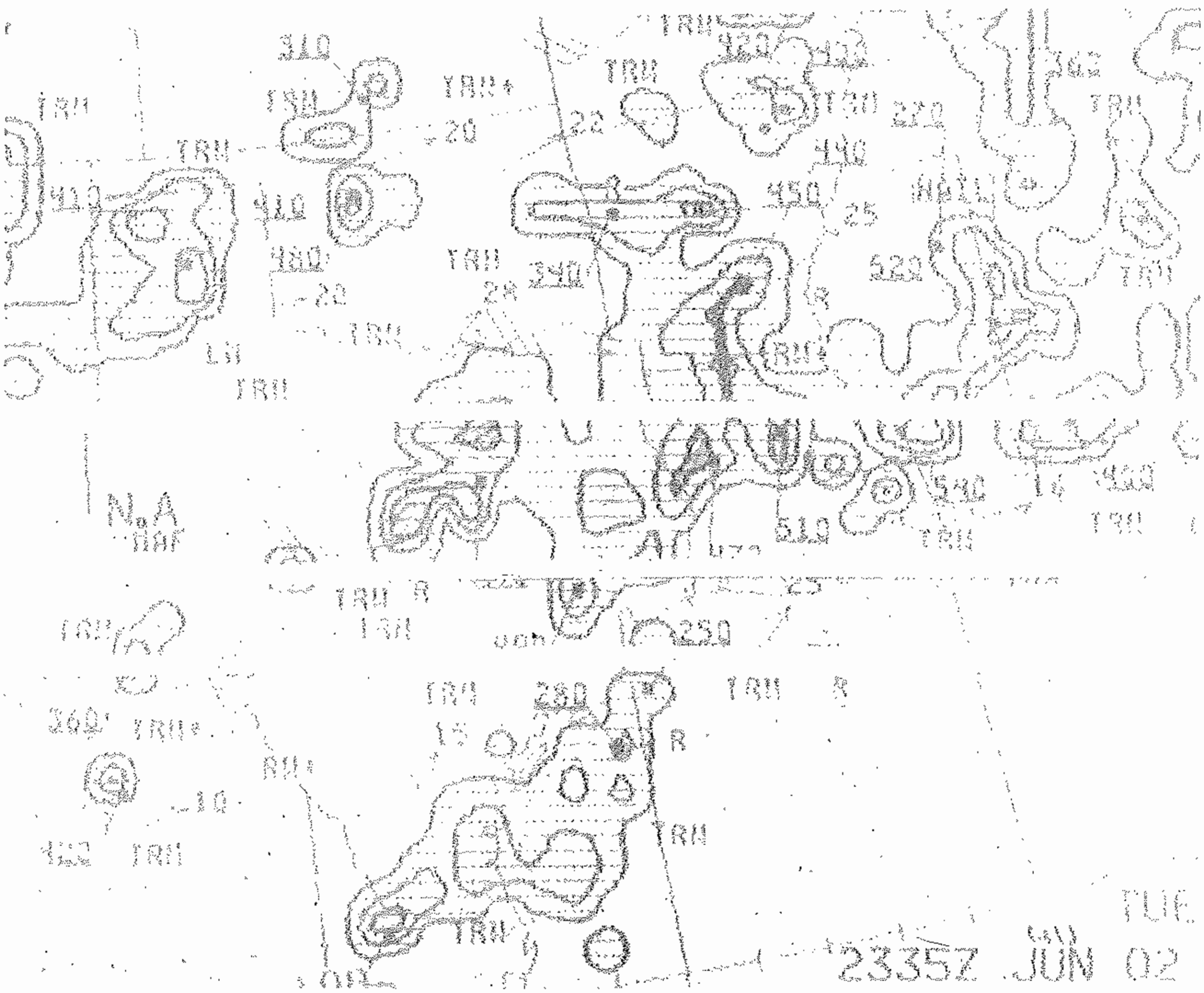

2230 02JN81
6/2/81
23Z
SPS
ABI
DFW
SJT
ACT
LFK
SHV
CLL
JCT
AUS
IAH
BPT
DRT
SAT
VCT
PSX
GLS
NIR
ALI
LRD
MFE
BRO
MIBSA
100°

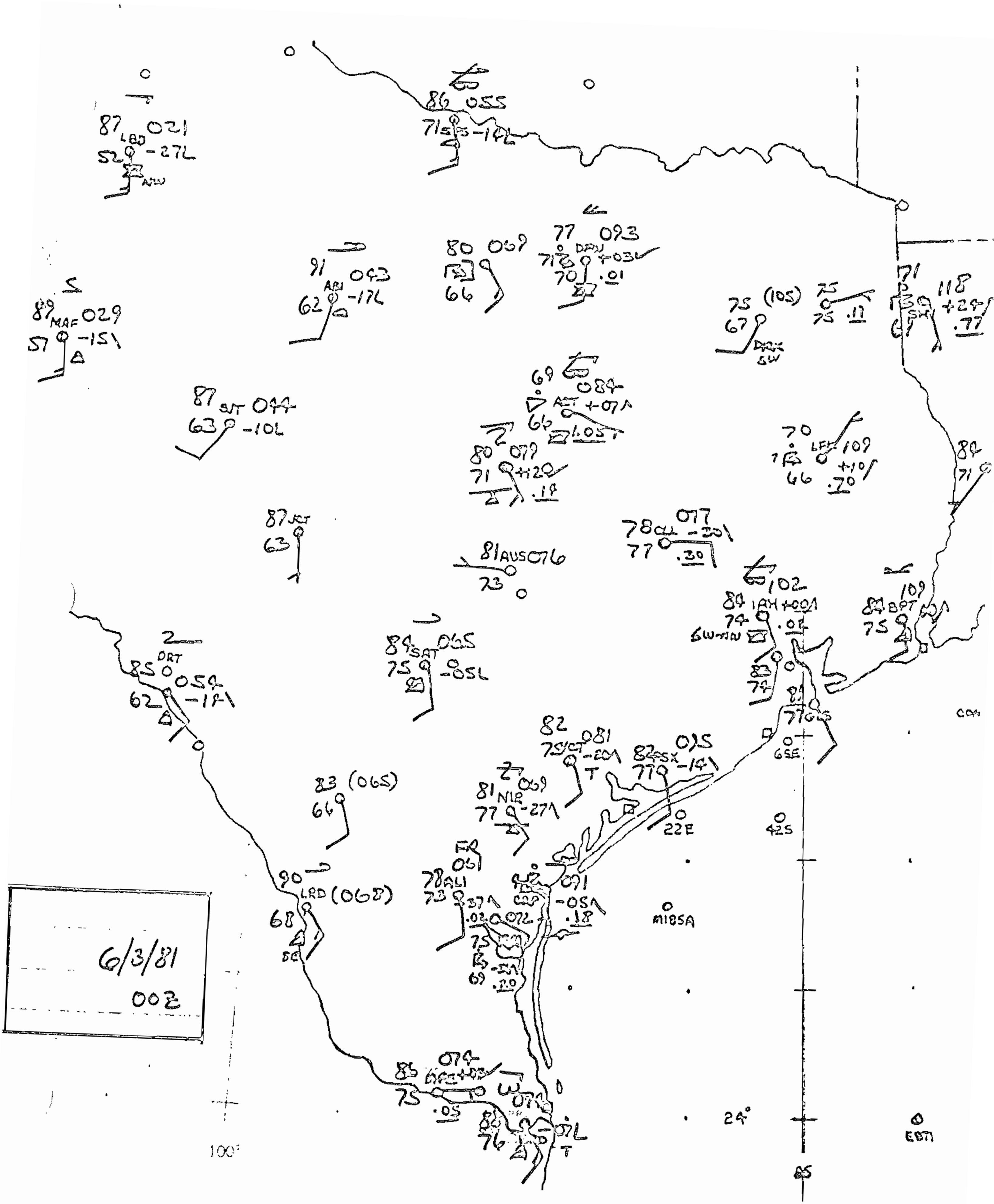


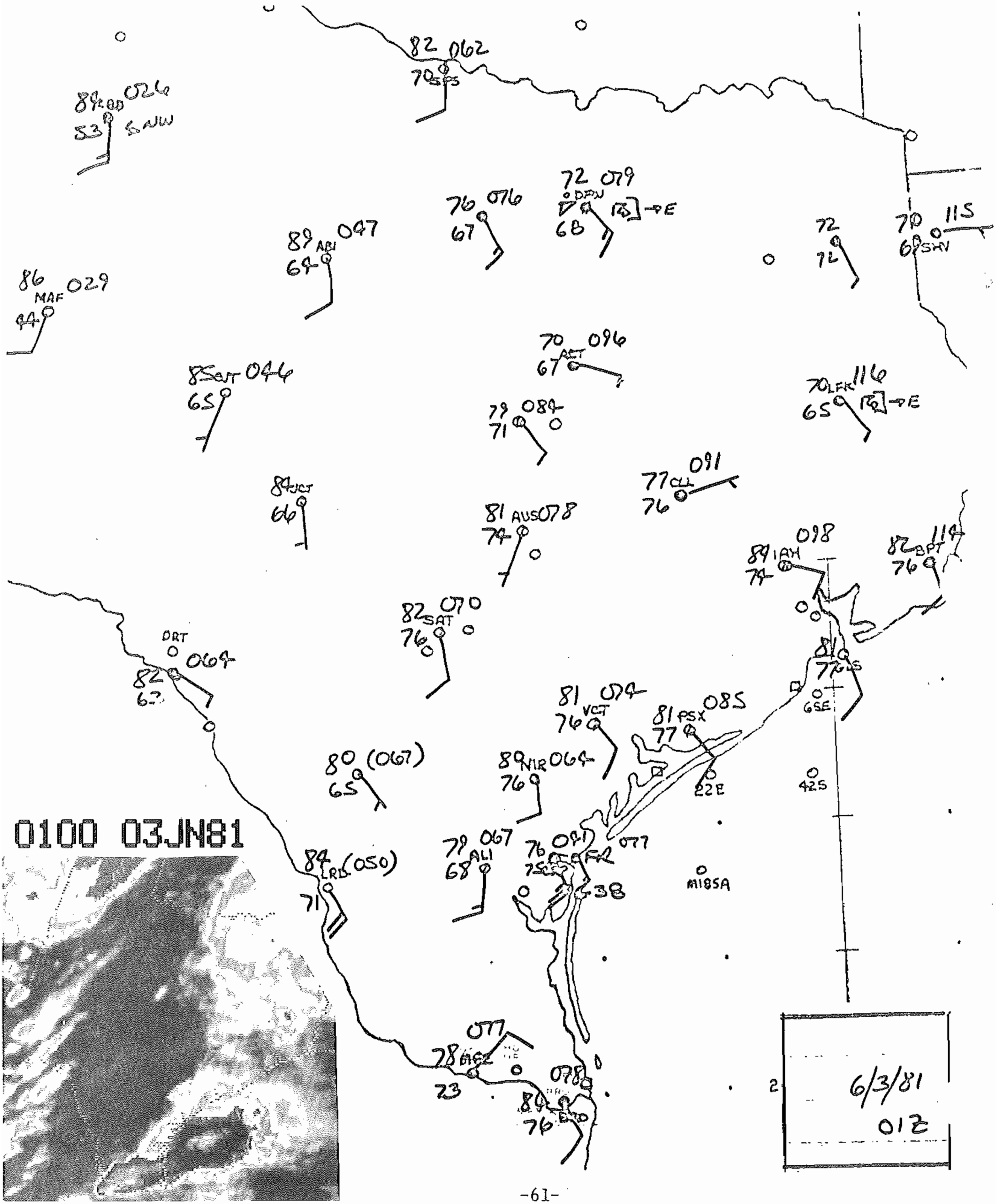
2330 02JN81

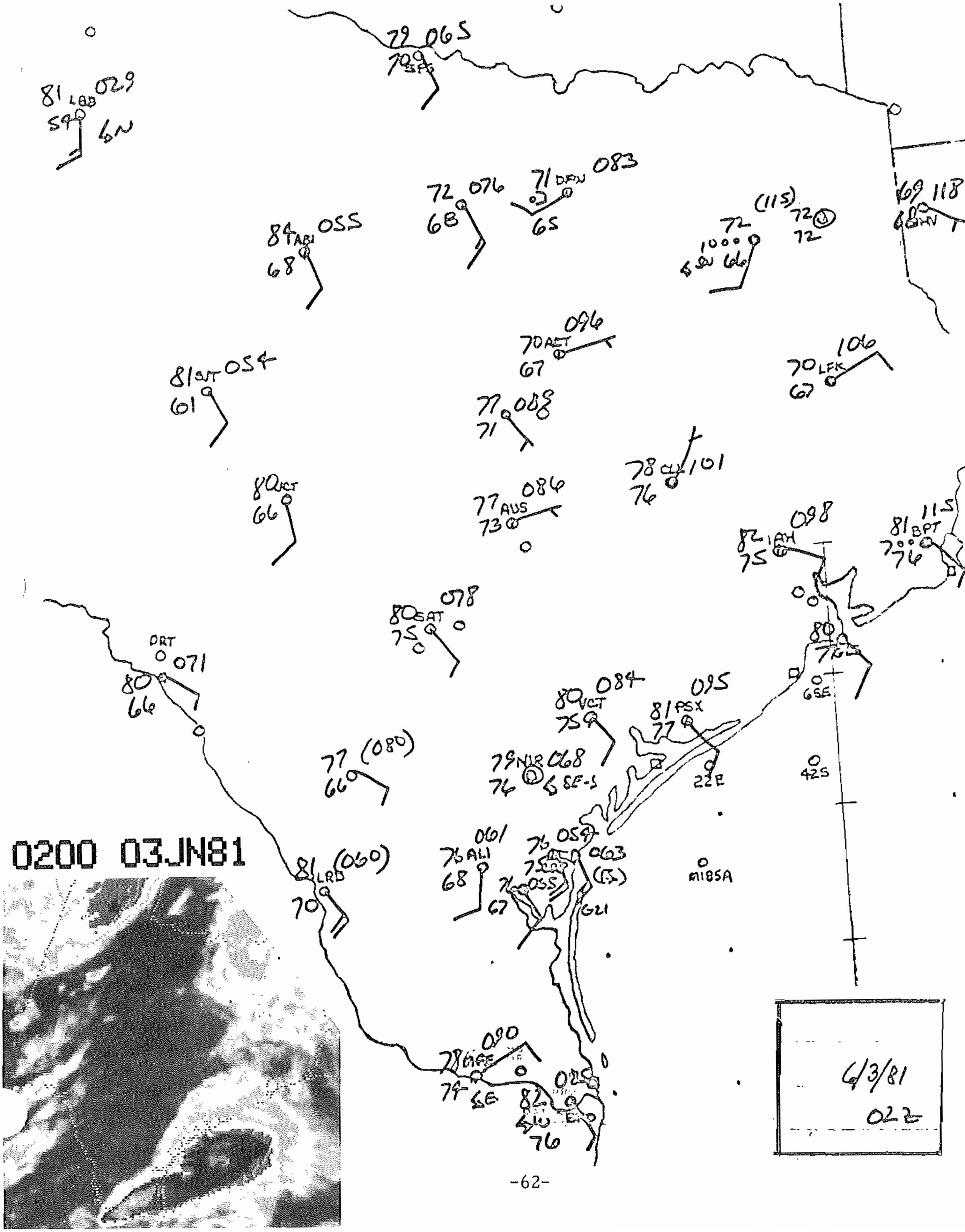


0001 03JN81



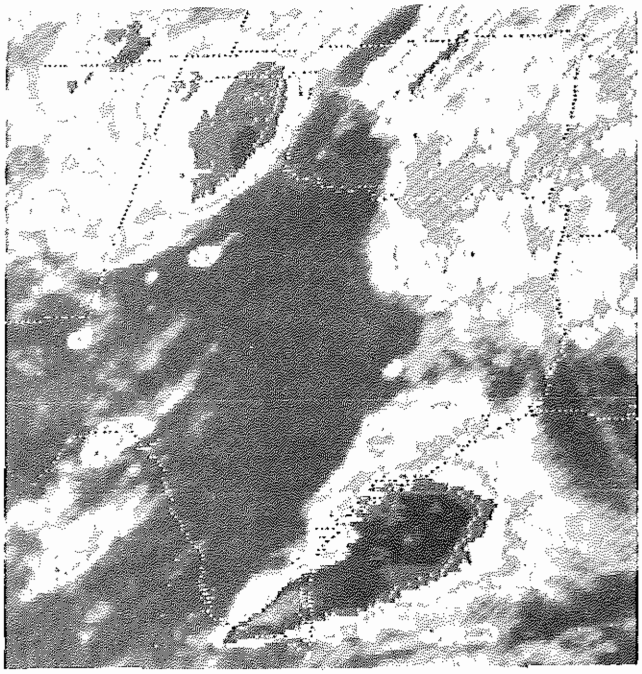

6/3/81
00Z


0100 03JN81
6/3/81
01Z
82 062
70 SPS
84 LBB 026
53
SNW
72 079
DFW
68
76 076
67
89 ABI 047
64
86 MAF 029
44
70 115
69 SHV
72
72
70 ACT 096
67
85 SJT 044
65
70 LFK 116
65
79 084
71
77 CLL 091
76
84 JCT
66
81 AUS 078
74
89 IAH 098
74
82 BPT 114
76
82 SAT 070
76
DRT
82 064
81
77
65E
81 VCT 074
76
81 PSX 085
77
80 (067)
65
89 NIR 064
76
22E
42S
79 067
68 ALI
76 081
75
CRP
077
038
MI8SA
84 LRD (050)
71
077
78
23
078
84
76
BRO

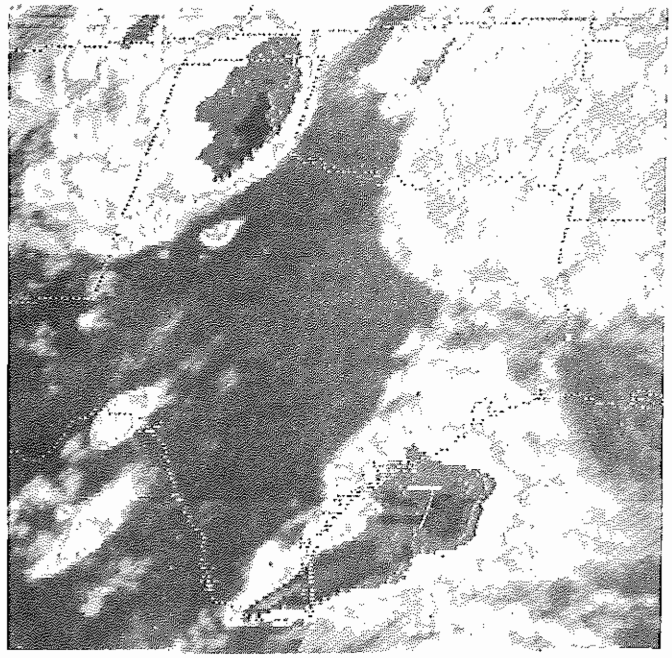


LBB
ABI
SJT
DFW
ACT
LFK
AUS
SAT
DRT
VCT
PSX
IAH
BPT
LRD
ALI
NIR
22E
42S
6/3/81
02Z

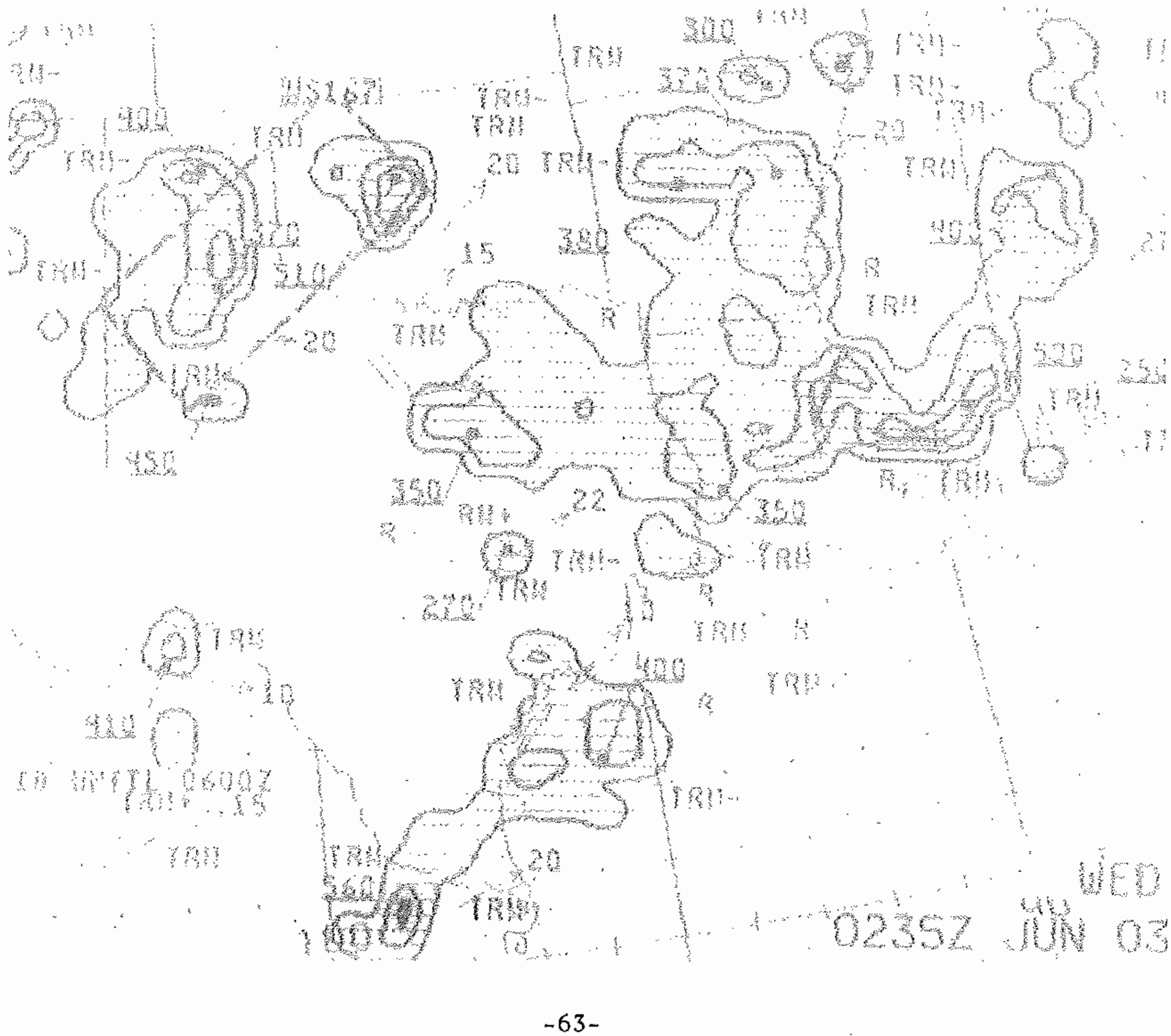
0200 03JN81

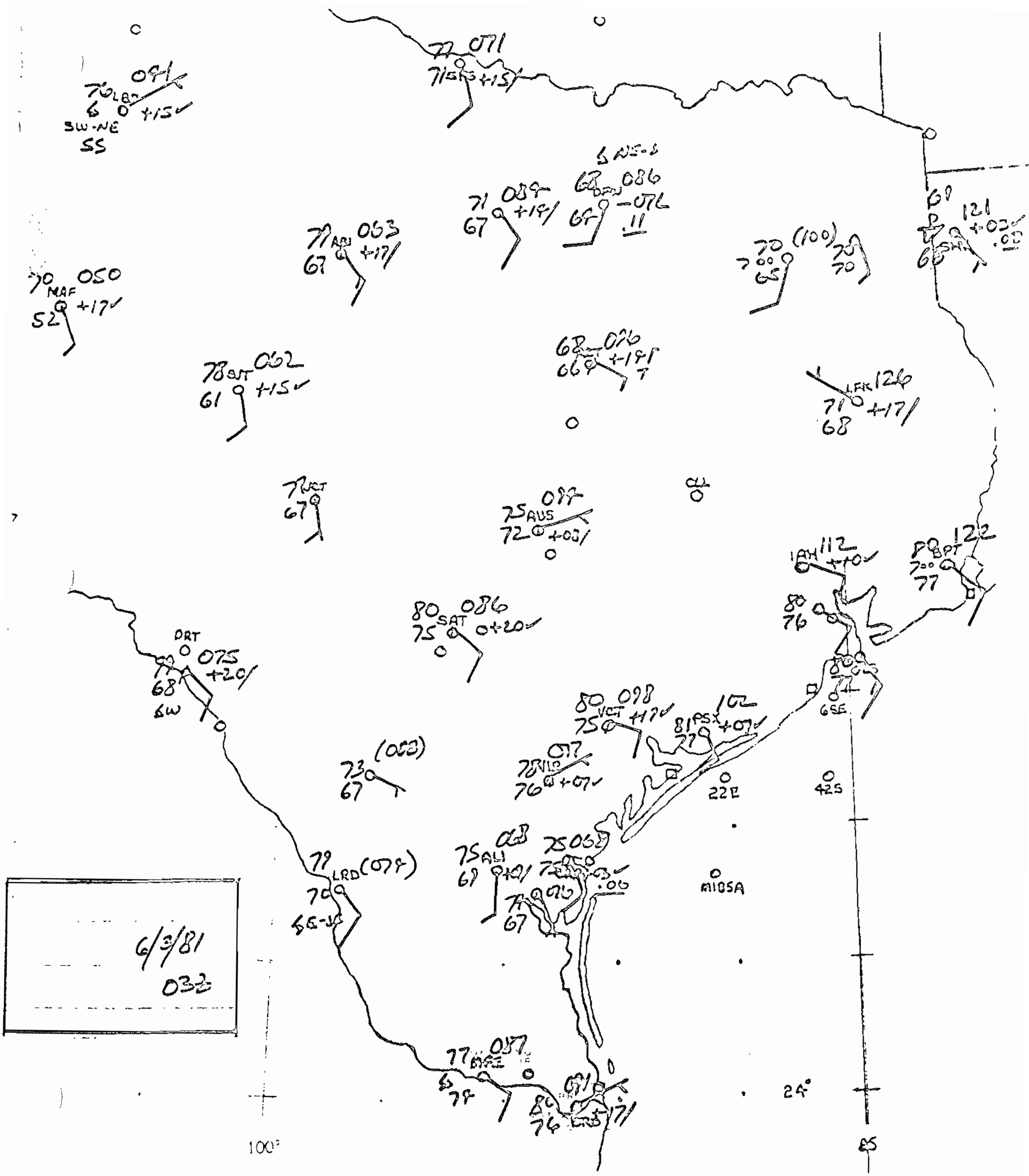


0230 03JN81



0300 03JN81





6/3/81
LRD
SAT
AUS
MAF
VCT
ALI
BPT
IAH
LFK
100°
24°