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EXPERIMENTAL USE OF GRIDDED NGM OUTPUT AT WSFO LUBBOCK, TEXAS: AN INITIAL REPORT

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1. INTRODUCTION

During the next several years, the National Weather Service (NWS) plans a significant modernization and associated restructuring (MAR) of its forecasting operations. The MAR will bring with it many changes to NWS field forecast offices. One of these is a new forecasting workstation known as the Advanced Weather Interactive Processing System (AWIPS). The AWIPS workstation is designed to provide the forecaster with a wide variety of tools with which to handle the tremendous increase of information which will occur in the modernized era. One of the new data sources planned for AWIPS is National Meteorological Center (NMC) numerical model output in grid point format.

Access to gridded model output in real time will be an improvement over the present system of receiving a fixed set of centrally produced output graphics. Dunn (1991) discusses the potential impact of gridded model output on the evaluation of vertical motion. He points out several ways in which this will enhance forecast operations. Among these are: (1) increasing the usefulness of "traditional" charts by allowing adjustable contour intervals; (2) applying quasi-geostrophic theory (e.g., Hoskins et. al. 1978, Trenberth 1978, Holton 1979, Barnes 1985, Prater 1990) more accurately than is currently possible; and (3) computing various kinematic fields such as divergence, ageostrophic winds, moisture convergence, and so forth, at multiple levels in the troposphere. Schwartz and Rodgers (1985) studied a mesoscale convective complex (MCC) from the 1984 convective season with the conclusion that use of LFM grid point output focused attention on the area of concern much better than did the standard LFM facsimile charts. Rodgers, et. al. (1984) stated that LFM gridded output would have aided in forecasting two MCCs from the 1983 convective season.

Within the National Weather Service, gridded model output is presently available at only a few locations. The forecast offices in Denver, CO, and Norman, OK, are already using a workstation that in many ways is prototypical of AWIPS. It was designed and built by NOAA's Forecast Systems Laboratory in Boulder, CO (Bullock and Walts 1991, Smart and Brundage 1991). Products derived from gridded model output are available on these workstations. Also, the national centers (e.g., National Severe Storms Forecast Center) now have the capability to use gridded model output.

Since April, 1991, the Weather Service Forecast Office (WSFO) in Lubbock has had access to selected gridded model output from NMC's Nested Grid Model (NGM). The remainder of this report: (1) provides some background information about how the data are obtained at Lubbock; (2) presents a short description of the software used to manipulate this information; (3) briefly discusses two cases where the third period of the zone forecast was updated over a fairly small area, based to a large extent on interpretation of fields obtained from the grid point output; and (4) presents a short discussion of the use of model grid point data in the upcoming AWIPS era.

2. RECEIVING THE GRIDDED DATA

In order to use NGM grid point data at WSFO Lubbock, the data must be obtained from the NMC computing system. To accomplish this a temporary arrangement was worked out between NMC and the computing center at Texas Tech University in Lubbock. Under this arrangement, Texas Tech University was granted an account through which NMC's NAS 9000 computer system could be accessed twice daily. In addition, the National Weather Service at Lubbock was provided with an account on one of the Digital Equipment Corporation VAX computers at Texas Tech. This established Texas Tech as an intermediary between the Lubbock Forecast Office and NMC for the purpose of the experimental transfer of gridded NGM output to the WSFO.

To obtain the grid point data, the forecaster dials into the NWS account at Texas Tech, establishes a connection with NMC, copies the gridded data file to the Texas Tech VAX, then downloads the file from the VAX to a PC in the forecast office. When the file has been obtained at the WSFO, the forecaster deletes the grid point data from the Texas Tech VAX and logs off the system.

A typical request of the grid point data involves the following:

a. At about 0430 UTC and 1700 UTC the forecaster logs into the NWS account at Texas Tech.

b. A series of commands is issued which ultimately results in the downloading of the grid point output file to the PC at the WSFO. This file is approximately 465,000 bytes in size. The entire process takes about 55 minutes, although less than five minutes is actually spent by the forecaster at the PC to set up the data transfer.

c. The forecaster logs off of the Texas Tech system and is ready to begin using the grid point output.

Refer to Table 1 for a list of selected products available in the grid point data file which is obtained at the WSFO.

Since this arrangement is experimental, the gridded NGM data are regarded as a supplement to the existing standard NMC guidance suite as available to the WSFO via the Automation of Field Operations and Services (AFOS).

3. LOOKING AT THE GRID POINT DATA

The key to this experiment is a program written by Dr. Ralph Petersen, Chief of the Short Range Modeling Branch at NMC. This program, known as PCGRID, can be used on any PC running a DOS operating system. The software will operate on virtually any PC graphics system (i.e., CGA, EGA, VGA, etc.). At Lubbock, a 386SX IBM-compatible machine with VGA graphics is used. PCGRID executes sufficiently fast to allow an interactive workstation mode of operation. For example, just a couple of seconds are required to calculate and display a field of moisture convergence on a national scale grid using the 386SX. Version 1.0 of this program has been made available to forecasters at WSFO Lubbock.

Many powerful tools are provided by PCGRID for examining NGM grid point data. Among them are: (1) cross section capability; (2) flexible zooming to any part of the country; (3) a host of mathematical operations (i.e., divergence, advection, vorticity, subtraction, addition, vector magnitude, averaging, etc.); (4) selected sigma level output; (5) interpolation to isentropic surfaces; and (6) multiple color overlays. The discussion which follows will illustrate many of these products and show how they may be used to provide more insight into developing situations than can be gained from looking at just those guidance products which have been customarily available to forecasters.

4. TWO EXAMPLES OF UPDATED ZONE FORECASTS BASED ON NGM GRID POINT DATA

This section briefly describes two cases where the gridded NGM output was used to update the third period of West Texas zone forecasts. In both cases, only a few zones were updated, since the forecaster was able to focus on where the NGM was forecasting the most favorable conditions for convective development. These cases were by no means "hits" of major weather events; rather, they involved inserting 20-30 percent probabilities of rain when and where none had been mentioned. The point is this: through use of an interactive program to create products of the forecaster's choosing, the NGM was made more useful as a diagnostic and prognostic tool than it otherwise would have been, given access only to AFOS graphics or the model-based MOS guidance.

The applications described below are not meant to be detailed case studies. The emphasis will be on the reasoning behind the decision to alter the third period of the zone forecasts. Portions of the State Forecast Discussion (SFD) for each case are shown along with selected gridded derived products referenced in the SFD. Radar summary charts show in general what transpired in the areas of interest.

Shown in Fig. 1 is a map of the Texas zones for which WSFO Lubbock is responsible. Zone numbers are referenced in describing the two cases of interest.

Evening shift, Monday May 27, 1991

During the early portion of the evening shift on this day, the forecaster spent time examining various products derived from grid point data from the 36-hour NGM forecast valid Wednesday, May 29, at UTC (early in the third period of the current zone forecast).

A portion of the State Forecast Discussion from this shift is reproduced below:

> WOULD NOT BE TOO SURPRISED TO SEE A FEW TSTMS LATE TMRW AFTN/TMRW EVE ACRS SW TX, ROUGHLY ZNS 51,52. 12Z NGM FCST VALID 00Z WED HAS A FAIRLY DECENT AREA OF 250 DIV AND 850 CONV, AND CORRESPONDING AXIS OF +VV AT ALL MANDATORY LVLS FROM WRN PNHDL SWD INTO ABV NAMED ZNS. MIXING RATIO FCST OF 7 G/KG AT 700 MB SUGG ENUF MSTR FOR CONVCTN. ONE PROBLEM WILL BE WRM TMPS ALF, HWVR SOME SHWRS GOT GOING THIS EVE WITH LESS MSTR AND NOT AS DECENT HI LVL DIV. THUS, IF THE NGM IS RIGHT THERE PROBABLY SHOULD BE SOME WDLY SCT TRW LATE TMRW AFTN/EARLY TMRW EVE ACRS PARTS OF SWRN TX...

The forecaster considered updating zones 51 and 52 (portions of Southwest Texas) based on various products derived from the NGM 36-hour forecast gridded data. Figs. 2 and 3 show products referenced in the SFD. All products are 36-hour progs valid at 0000 UTC Wednesday, May 29.

The forecast 250 mb divergence is shown in Fig. 2a. Virtually all of West Texas and eastern New Mexico were forecast to be under 250 mb divergence. Note, however, the more narrow axis of maximum divergence along the Texas/New Mexico border into parts of southwest Texas. Fig. 2b shows the 300 mb omega (vertical motion) forecast. In the omega field, negative values imply upward vertical motion. An axis of weak upward motion is depicted from the Big Bend area northward through the Texas/Oklahoma Panhandles, with a local maximum (i.e., minimum omega) across the northwest Texas Panhandle and extreme northeast New Mexico.

Fig. 3a depicts the 700 mb wind forecast (shown as arrows parallel to the direction of flow with length proportional to the speed) overlayed by the 700 mb forecast mixing ratio (gm/kgm). Unlike relative humidity, the mixing ratio specifies the actual amount of water vapor contained in a unit of air. Of significance is the axis of higher values being advected northward from the western Big Bend to the western Texas Panhandle. Also, note the small local maximum in extreme southeast New Mexico which extends into a small part of West Texas.

Shown in Fig. 3b is a product which was not used by the forecaster, but illustrates Trenberth's (1978) approach to using advection of vorticity by the thermal wind to help delineate areas of quasi-geostrophic (Q-G) vertical motion. Using PCGRID, a thickness chart (36-hour forecast) was generated for the 500 mb to 300 mb layer, with a contour interval of 20 decameters. Overlayed onto this chart is the forecast of 400 mb vorticity. According to Trenberth, this technique is reasonably valid for approximating Q-G forcing in the mid troposphere, roughly from 700 mb to 350 mb. An area of advection of cyclonic vorticity by the thermal wind can be seen in eastern New Mexico, and therefore mid-level synoptic scale ascent is forecast in this region based on the Trenberth technique.

It was decided to add a slight chance of thunderstorms to the third period of zones 51 and 52, where previously none had been mentioned. Shown in Fig. 4 are sections of the national radar summaries (AFOS graphic 90R) for 2000, 2100, and 2300 UTC on May 28, and 0200 UTC on May 29. Recall the forecast charts previously shown were valid at 0000 UTC May 29. The axis of precipitation corresponds well with the areas of interest as seen on the selected 36-hour forecast charts. Satellite precipitation estimates from NESDIS suggested almost 2.5 inches of rain fell between 2100 UTC on the 28th and 0130 UTC on the 29th across extreme northeast New Mexico and the extreme northwest portions of the Texas Panhandle. In the Lubbock forecast area, one-inch diameter hail was observed between 0027 and 0047 UTC across southern Reeves county and over two inches of rain were estimated from satellite observations in portions of Culberson county. Both of these events were in zone 51.

Midnight shift, June 13, 1991

For several days prior to June 13, a weak closed low pressure center aloft was located south of San Diego, CA. Weak impulses had been rotating northeastward from this low for a few days. A portion of the SFD issued early in the morning of June 13 is given below:

> BLV MORE INTERESTING WX MAY OCCUR TMRW, WHEN SWRN UPR LOW IS PROGGED TO BEGIN TO MOVE TO THE NE IN RESPONSE TO DVLPG S/WV ACRS THE GREAT BASIN. NGM SHOWS SOME POTNTL FOR TSTMS ACRS SW TX, AND PERHAPS FURTHER N ALG OUR WRN BORDER. USING GRIDDED DATA TO REFINE CHART I8L, THE 'N' SOUTH OF MAF IS ACTUALLY A -7 VALUE INSIDE A CLOSED -6 LI CONTOUR FROM MAF DOWN TWD THE BIG BEND. SVRL OTHER PARAMETERS SUGG POTNTL. 48 HR 200 MB WIND FCST SHOWS JET NOSING UP INTO EDWARDS PLATEAU, WITH LF QUAD +VV FCST FROM SOPLNS TO VCNTY MAF. 700-500 LAPSE PROGGED TO BE 20-22 DEG ACRS THE AREA OF INTEREST. TEMP ADV CALC AT 500 MB SHOWS AXIS OF CAA ALG THE TX/NM BORDER, SWD INTO BIG BEND. AS UPR LOW APPCHS, 850 WIND FCST SHOWS CONV FROM WRN SOPLNS SWD. X-SECTION THRU THE UPR TROF SHOWS FAIRLY DECENT VERTICAL WND PROFILE WHERE THE LO LVL BACKED SELY FLO BECOMES SW FLO AHD OF THE UPR LOW. SPEEDS NOT THAT IMPRESSIVE THOUGH. LO LVL MSTR SHUD BACK INTO THIS AREA PER NGM FOUS BNDRY DPTS, AND PROGS OF LO LVL MIXING RATIO...

It appeared that a fairly significant short wave, progged over the Great Basin, would help "kick out" this quasi-stationary low pressure area. Products derived from NGM grid point data were used to add a chance of thunderstorms to the third period of the forecast for a few zones in

Southwest Texas. In the subsequent discussion, all products are derived from the 48-hour NGM forecast valid at 0000 UTC Saturday, June 15.

Fig. 5a shows the NGM lifted index forecast. This is a clear example of how the AFOS or facsimile NGM charts can be refined using model grid point output. A rather large area of less than -4 deg. was forecast across most of New Mexico and Southwest Texas. This is all that was visible on the AFOS graphic, since it is contoured in increments of four C deg. Note, however, the gridded data reveal a -6 deg. area in Southwest Texas which helped focus attention within the larger area of forecast instability.

The NGM was advecting low level moisture northward in advance of the ejecting upper level low pressure system. Fig. 5b shows decoded NGM FOUS output for Lubbock and Midland, TX, produced using a local AFOS application program (Baker 1991). This program, in addition to decoding standard output, computes a "boundary layer dew point" from the T1 and R1 model boundary layer temperature and relative humidity. Note the forecast rise in this dew point between 1800 UTC Friday and 0000 UTC Saturday at Lubbock and Midland, which helps explain the drop in the lifted index.

Another contribution to the increase in forecast instability was the advection of colder air at mid levels. Fig. 6a shows the predicted 500 mb wind field overlayed by the corresponding temperature forecast. Cold advection can be seen across parts of southwest Texas ahead of the thermal trough. Fig. 6b shows the computed thermal advection. Noteworthy is the local minimum (i.e., local maximum in cold advection) across southwest Texas, interpreted as a value of 8 deg. cooling at 500 mb per 12 hours due to cold advection. This helped the forecaster to see where the model was predicting the area of strongest destabilization, even though the "general" area could be inferred from existing AFOS graphics.

The jet level (200 mb) wind forecast associated with this ejecting upper low was also examined (Fig. 7a). Two troughs are evident, one across the northern Rockies (i.e., the kicker), and the other (of interest in this case) across west-central New Mexico. Note the region of greater than 28 m/s (approximately 55 knots) wind speed on the southeast side of this trough.

Fig. 7b shows a forecast vertical cross section of omega. PCGRID allows the forecaster to specify latitude and longitude coordinates of endpoints of any desired cross section. This section extends from roughly San Diego, CA, to Little Rock, AR. Note the axis of fairly deep upward motion forecast between 750 mb and 200 mb from 102W to 105W longitude. The minimum in omega (and thus the maximum in vertical motion) is seen at around 102W at 300 mb.

Another forecast cross section is shown in Fig. 7c, from San Diego to a point about 120 km south of Little Rock. On this section are wind vectors and divergence of the wind. A veering wind profile can be seen ahead of the trough axis, with a local maximum in divergence from 101W to 102W at 250 mb. Thus, the strongest upward motion is forecast in the left front quadrant of the local jet maximum associated with the ejecting upper low pressure system. Given the forecast of favorable wind structure and the predicted amount of instability, the forecaster began to suspect that a few severe thunderstorms would be possible across parts of southwest Texas during the late afternoon of the third period of the forecast.

The national radar summary chart for 0000 UTC June 15 (Fig. 8) reveals that a line of convection did, in fact, develop by late afternoon on the 14th. A severe thunderstorm watch was in effect at this time and a 50,000-foot radar top was seen in the center of the watch area. Severe weather in the form of large hail and high wind gusts was observed in the vicinity of Midland, TX, late in the afternoon of June 14, associated with this particular cell about an hour prior to the time of the summary chart.

5. PLANS AT WSFO LUBBOCK

One very powerful feature of the PCGRID program is the ability to store command line instructions in "command files." The command file is a series of commands which are initiated by one user entry (much like a batch file in DOS, or a procedure on AFOS). Command files can be created with any word processor and stored for future use. Following are just a few examples of ideas which readily lend themselves to the use of command files.

- Loops of forecast mixing ratio on the lower NGM sigma surfaces to better track the axis of low level moisture return from the Gulf of Mexico during the spring convective season.

- Combinations of 200 mb temperature advection and 700 mb temperature so that the B.J. Cook snow accumulation forecasting technique (Cook 1977) can be applied with greater accuracy than was possible in past winters.

- Various combinations of thickness and vorticity to apply the Trenberth (1978) technique of advecting cyclonic vorticity by the thermal wind as an estimate of quasi-geostrophic vertical motion at several middle levels of the troposphere.

Command files for these and other situations will be used at the WSFO this winter and next spring.

6. CONCLUDING REMARKS

In the two cases previously discussed, graphic products derived from gridded NGM output were used to make changes to later periods of zone forecasts (which fortunately also turned out to be improvements). This limited experience does not imply that using gridded output will always allow improvements to the forecast. The products shown in this report are all based only on a single NMC model. Access to gridded data and the PCGRID software make it much easier to look at the output from that model with much more detail.

Early experience has shown that it is easy for forecasters to become overwhelmed with the type and variety of new products provided by PCGRID. So much so, in fact, that they may lose sight of the fact that the model itself may have serious problems on a given day! One must continually guard against being led astray -- which is a finding that has implications for future NWS operations.

As pointed out by Junker et. al. (1989), the NGM still contains weaknesses. In the upcoming AWIPS era of gridded model output, the forecaster must still assess the accuracy of the numerical forecast. Doswell (1982, chapter V) makes the following observation:

> A basic element in the short-term evaluation of any given model is the forecaster's knowledge and experience of how the atmosphere behaves. When model output is examined, the forecaster already should have in mind what is anticipated in the overall trend. Should the model output contradict this trend, a further examination of the possible explanations for this difference is called for. If the forecaster examines the model output first, then there is the tendency to be biased with what is seen, and to accept the model results less critically.

We have entered the era where the phrase "model output" means for field offices not only a pre-determined selection of guidance charts or products, but also a virtually unlimited number of products locally derived from model grid point data. Therefore, even in the AWIPS era, forecasters will still need to develop an accurate picture of the current state of the atmosphere (i.e., perform analyses) ***prior*** to diving into application programs which will have the potential to create hundreds of different products derived from model grid point output. To put it another way, it will be important for the forecaster to have some idea what he or she is looking for! The new technology and data sources will provide improved tools with which to employ sound meteorological principles to the preparation of a forecast; they will not provide final answers.

Nevertheless, when the model makes an accurate forecast, the ability to closely examine that forecast via locally produced and forecaster selectable graphics offers the potential of preparing forecasts with more detail than is possible with any standard set of charts. As pointed out by Dunn (1991), much of what is available today in the way of standard products has arisen through a long tradition of looking at only certain tropospheric levels (i.e., 500 mb for vorticity advection, 850 mb temperature and heights, as well as surface isobars and 1000-500 mb thickness for low level thermal advection). With grids, a host of other products are available and should be used. For example, Maddox and Doswell (1982) strongly recommend keying on low level thermal advection patterns in cases of weak mid level vorticity advection to ascertain the favored areas for upward motion. They presented analyses of advection of temperature by the geostrophic wind at 850 mb and 700 mb for a severe weather case in eastern Nebraska. With grid point data, these types of fields can be produced. The forecaster can decide what types of products to generate, based on the particular meteorological situation with which he or she is faced. Early experience with model grid point data on personal computers, such as forecasters are gaining at Lubbock, will help with the transition to the AWIPS era in the modernized National Weather Service.

Since the NGM grid point data have been available locally only for a few months, an assessment of their impact on forecast operations can only be preliminary. As shown above, however, there have already been instances in which zone forecasts were improved, based to a large extent on interpretation of products derived from the grid point output. The two forecasts previously discussed would likely not have been updated based solely on information available on the AFOS system. We look forward to applying these data to cool season forecast problems such as precipitation type, strong winds, and ejecting cutoff lows.

7. ACKNOWLEDGEMENTS

Foremost, I would like to thank Dr. Ralph Petersen for writing such a useful PC program and for making an early version available to us on an experimental basis. In many cases, "initial versions" of programs offer only limited capabilities; however, this is not the case with PCGRID. Also, Dan Smith, and especially Lans Rothfusz (NWS Southern Region Scientific Services Division) are recognized for their help in organizing this project. I would like to thank Andy Anderson, Meteorologist-In-Charge WSFO Lubbock, for his enthusiastic support in seeing this effort come to pass. Many thanks are also due the Texas Tech University Computing Center and the National Meteorological Center for their efforts in establishing a connection such that the experimental transfer of NGM grid point data to the forecast office would be possible.

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Table 1: Selected parameters from the NGM gridded data file

'X' = available
'-' = not applicable/
not available

	Mandatory pressure levels (mb)										Sigma surfaces		
	1000	850	700	500	400	300	250	200	150	100	.982	.896	.784
Height	X	X	X	X	X	X	X	X	X	X	-	-	-
Pres	-	-	-	-	-	-	-	-	-	-	X	X	X
Temp	X	X	X	X	X	X	X	X	X	X	X	X	X
U-comp	X	X	X	X	X	X	X	X	X	X	X	X	X
V-comp	X	X	X	X	X	X	X	X	X	X	X	X	X
Moisture	X	X	X	X	X	X	-	-	-	-	X	X	X

Miscellaneous parameters

- Lifted index
- Sea level pressure
- Precipitable water
- Quantitative precipitation

Notes:

a) All information is available for the 12, 24, 36, and 48 hour forecasts, in addition to the initial analysis.

b) Moisture information is displayable via several different parameters:

- relative humidity
- mixing ratio
- saturation mixing ratio
- mixing ratio saturation deficit

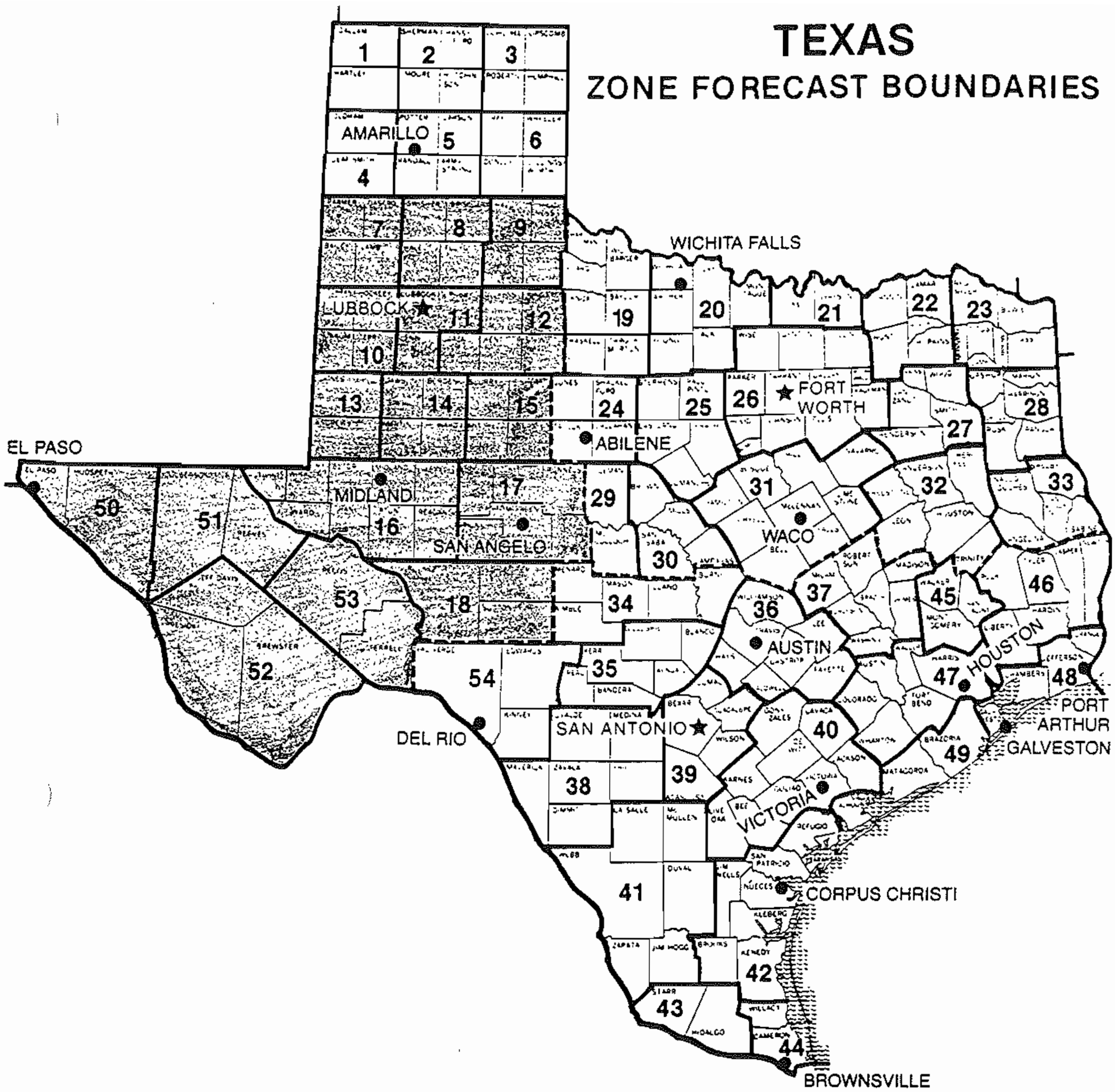

Fig. 1. National Weather Service Texas Zone Forecast Boundaries

Zones 1-6 . . . . Prepared by WSO Amarillo
Zones 7-18, 50-53 . . . . Prepared by WSFO Lubbock (shaded)
Zones 19-33 . . . . Prepared by WSFO Fort Worth
Zones 34-49, 54 . . . . Prepared by WSFO San Antonio

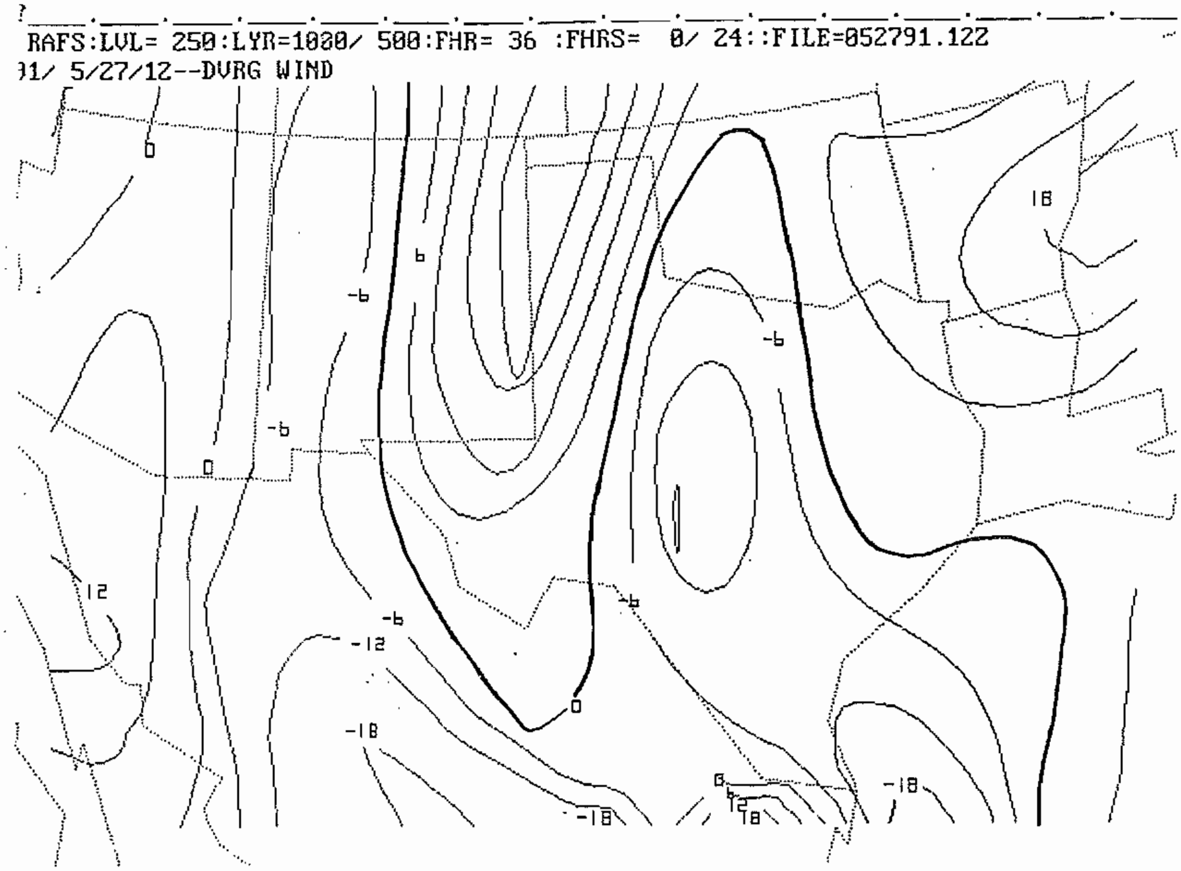

Fig. 2(a). NGM 36 hour forecast 250 mb divergence (/sec X 10E-5), valid at 00Z, Wednesday, May 29, 1991.

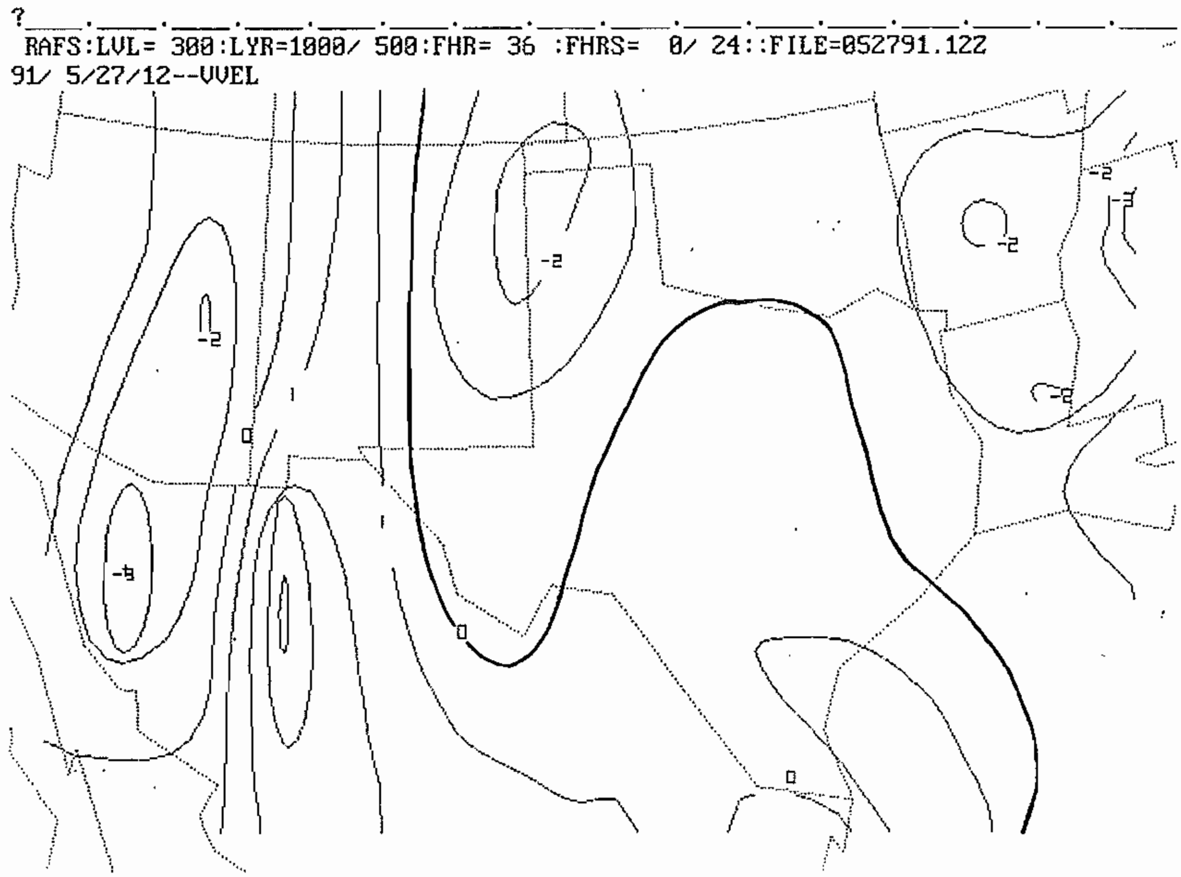

Fig. 2(b). NGM 36 hour forecast 300 mb omega (microbars/s), valid at 00Z, Wednesday, May 29, 1991. Negative values imply upward vertical motion.

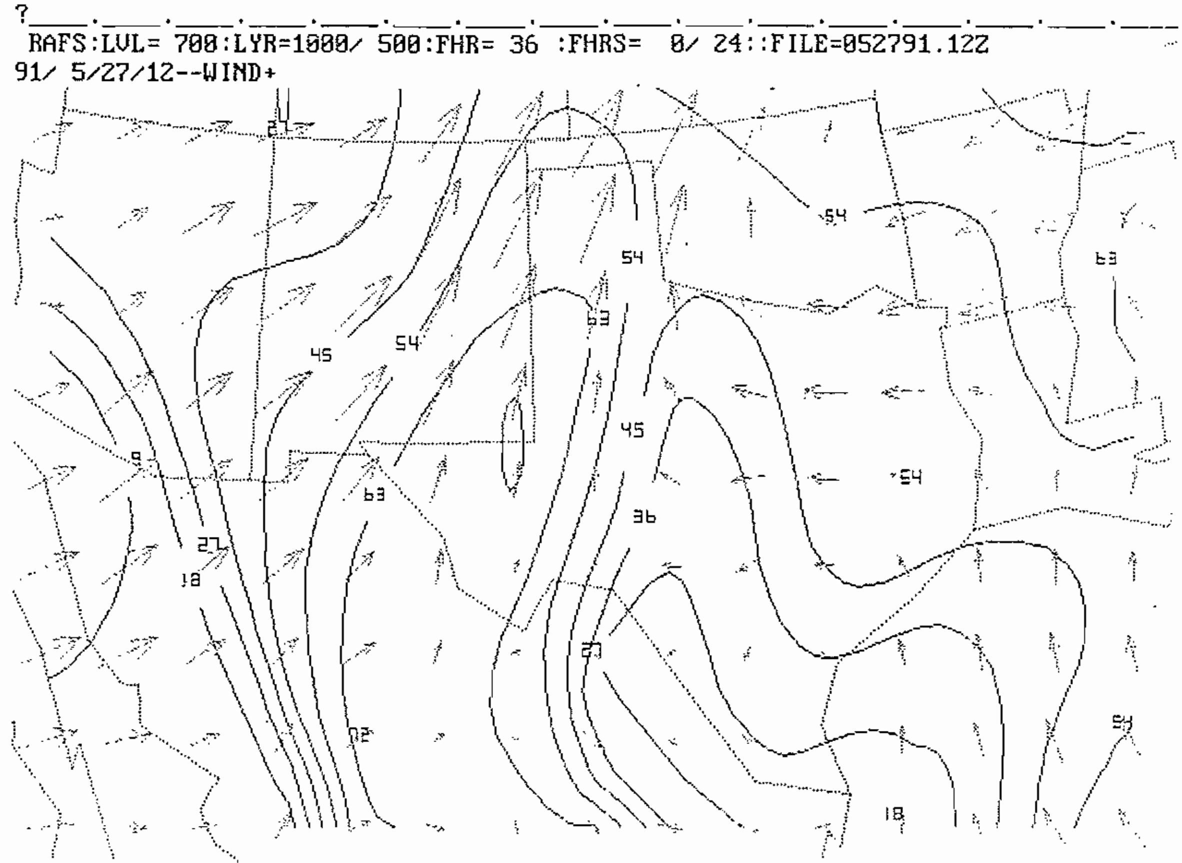

Fig. 3(a). NGM 36 hour forecast 700 mb wind (arrows) and mixing ratio (solid contours, g/kg X 10) valid at 00Z. Wednesday, May 29, 1991 (i.e., 63 = 6.3 g/kg).

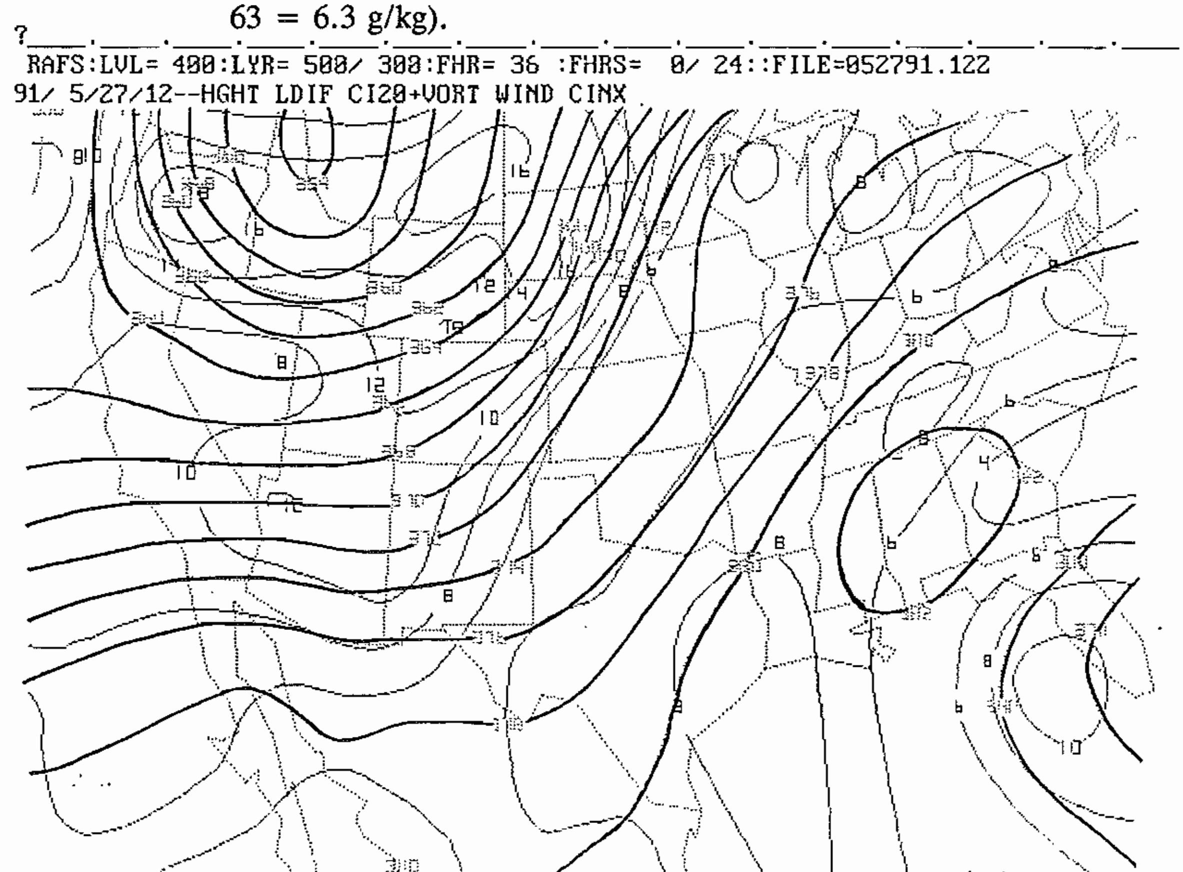

Fig. 3(b). NGM 36 hour forecast of 500-300 mb thickness (lighter lines, decameters) and 400 mb vorticity (darker lines, /sec X 10E-5) valid at 00Z, Wednesday, May 29, 1991. Advection of cyclonic vorticity by the thermal wind is seen in eastern New Mexico.

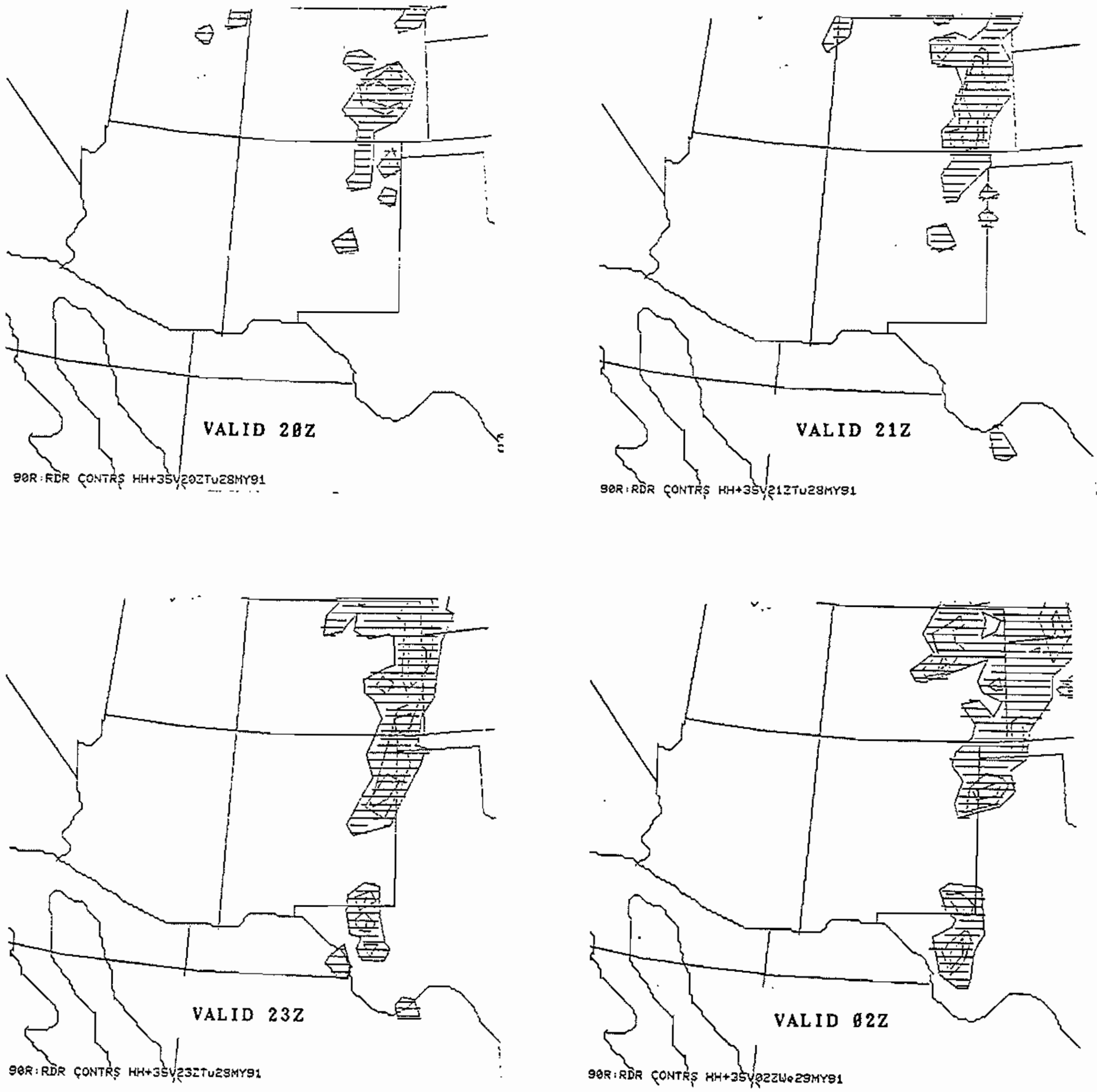

Fig. 4. Portions of the national radar summary charts valid at 20Z, 21Z, 23Z on Tuesday, May 28, 1991, and at 01Z on Wednesday, May 29, 1991.

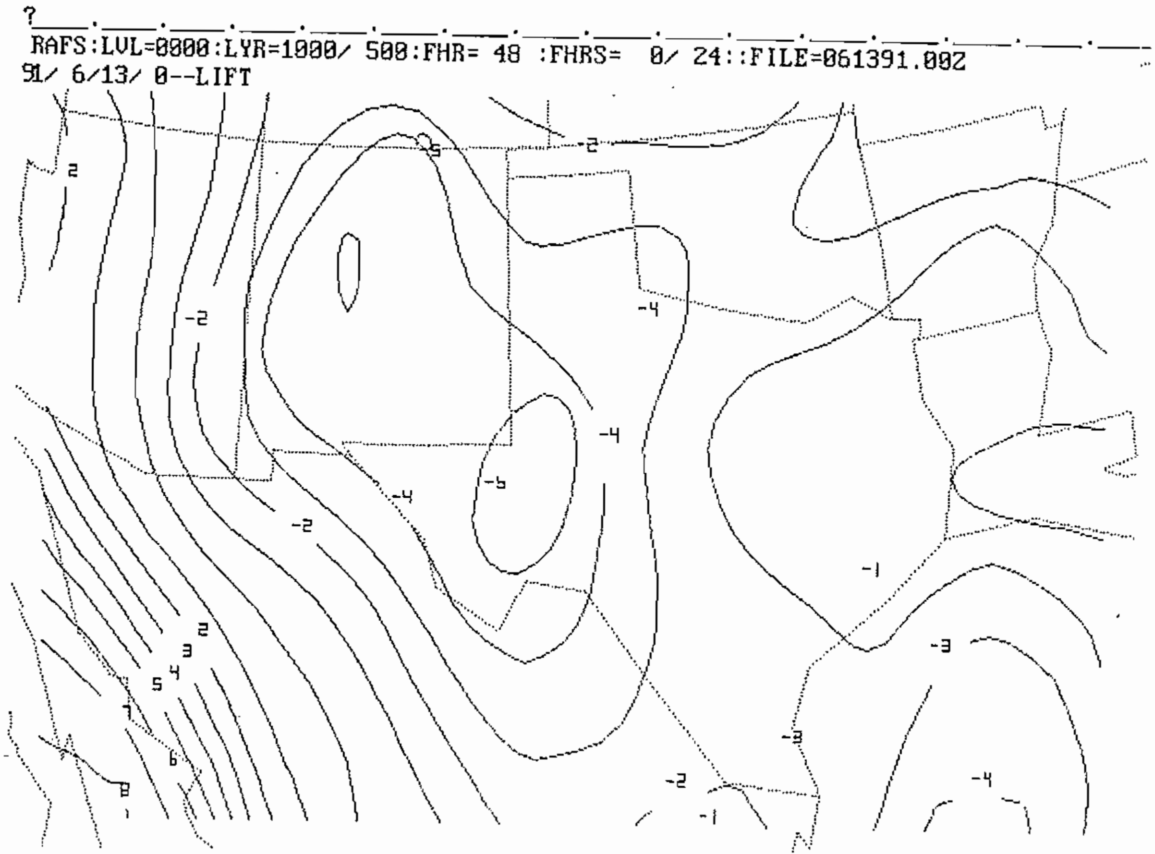

Fig. 5(a). NMC 48 hour forecast lifted index (deg C), valid at 00Z, Saturday, June 15, 1991.

SELECTED NGM FOUS OUTPUT FOR: 06/13/00Z

	00Z THU	06Z THU	12Z THU	18Z THU	00Z FRI	06Z FRI	12Z FRI	18Z FRI	00Z SAT	STA: LBB
DDFF	2220	2217	2519	2313	2117	2125	2322	2208	1714	SFC WIND
VVV	+00.9	+03.3	+00.0	-02.8	-01.5	+01.6	-00.8	-01.0	+00.6	700 VV
LI	-01	-01	+02	+01	+00	-01	-01	-03	-05	LIFTED IDX
T1	+84	+78	+71	+82	+87	+78	+69	+84	+78	BLYR T(F)
TD1	+43	+41	+39	+40	+41	+45	+47	+48	+55	BLYR TD(F)
T3	+22	+21	+20	+20	+23	+21	+21	+20	+21	922-872 T
T5	+11	+11	+11	+11	+12	+12	+12	+11	+12	816-755 T
HH	578	576	575	577	580	577	576	578	577	THICKNESS
R1	24	27	31	23	20	31	45	29	45	BLYR RH
R2	37	46	37	38	39	54	59	53	62	965-473 RH
R3	29	43	63	64	91	86	58	44	65	473-181 RH
PTT	----	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	6HR PRECIP

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	00Z THU	06Z THU	12Z THU	18Z THU	00Z FRI	06Z FRI	12Z FRI	18Z FRI	00Z SAT	STA: MAF
DDFF	2213	2220	2317	2209	1811	1823	2021	1905	1614	SFC WIND
VVV	+00.0	+04.1	+00.6	-01.5	-01.2	-00.2	-01.4	-00.1	-01.3	700 VV
LI	-03	-01	+01	-01	-01	-02	-02	-04	-06	LIFTED IDX
T1	+84	+82	+71	+82	+86	+78	+68	+84	+84	BLYR T(F)
TD1	+46	+41	+41	+43	+43	+48	+49	+49	+55	BLYR TD(F)
T3	+22	+22	+20	+21	+22	+20	+21	+22	+21	922-872 T
T5	+12	+11	+11	+11	+12	+12	+12	+12	+12	816-755 T
HH	578	576	574	577	579	577	575	578	579	THICKNESS
R1	27	24	34	26	23	35	51	30	38	BLYR RH
R2	43	40	42	46	54	62	54	50	58	965-473 RH
R3	40	63	79	85	82	64	36	49	58	473-181 RH
PTT	----	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	6HR PRECIP

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Fig. 5(b). Selected output from a local AFOS application program which decodes the NGM FOUS bulletins. Parameter TD1 is a dew point derived from the model T1 temperature and R1 relative humidity.

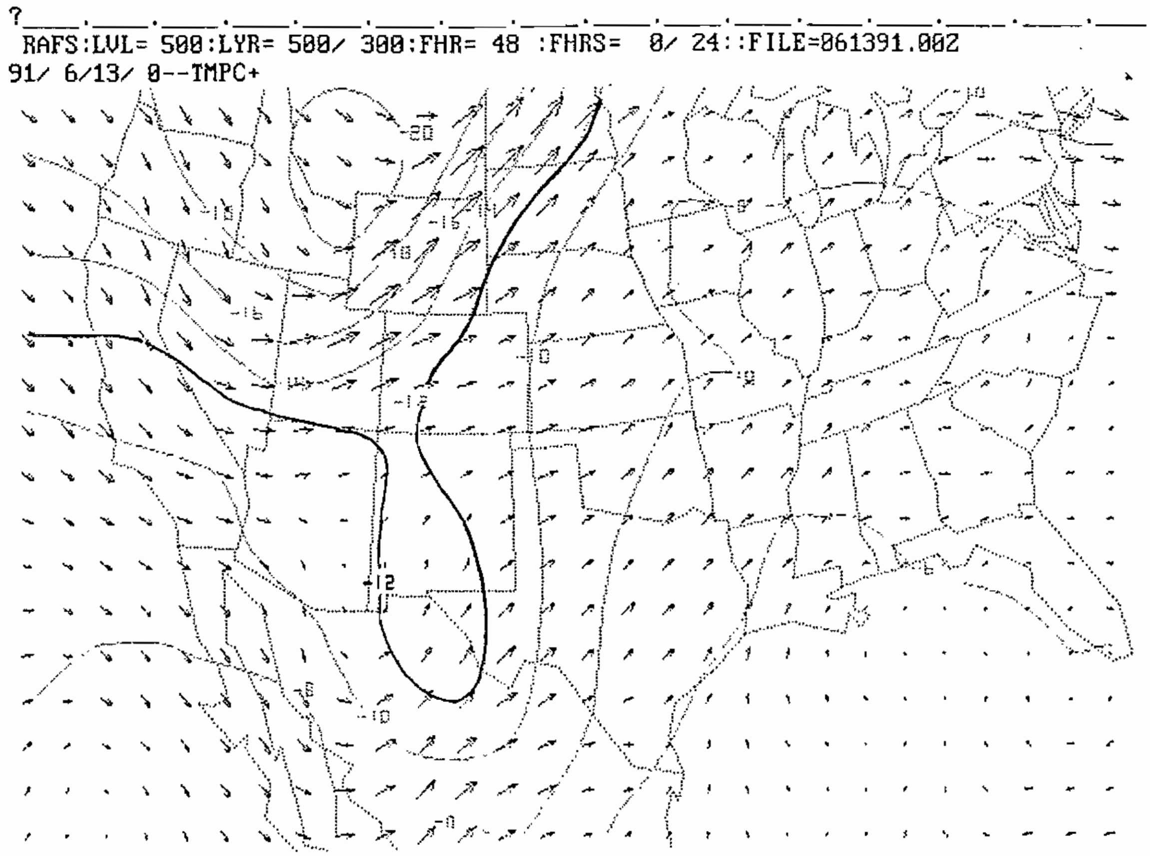

Fig 6(a). NGM 48 hour forecast 500 mb wind (arrows) and temperature (solid lines, deg C) valid 00Z, Saturday, June 15, 1991. Note the thermal trough over western New Mexico.

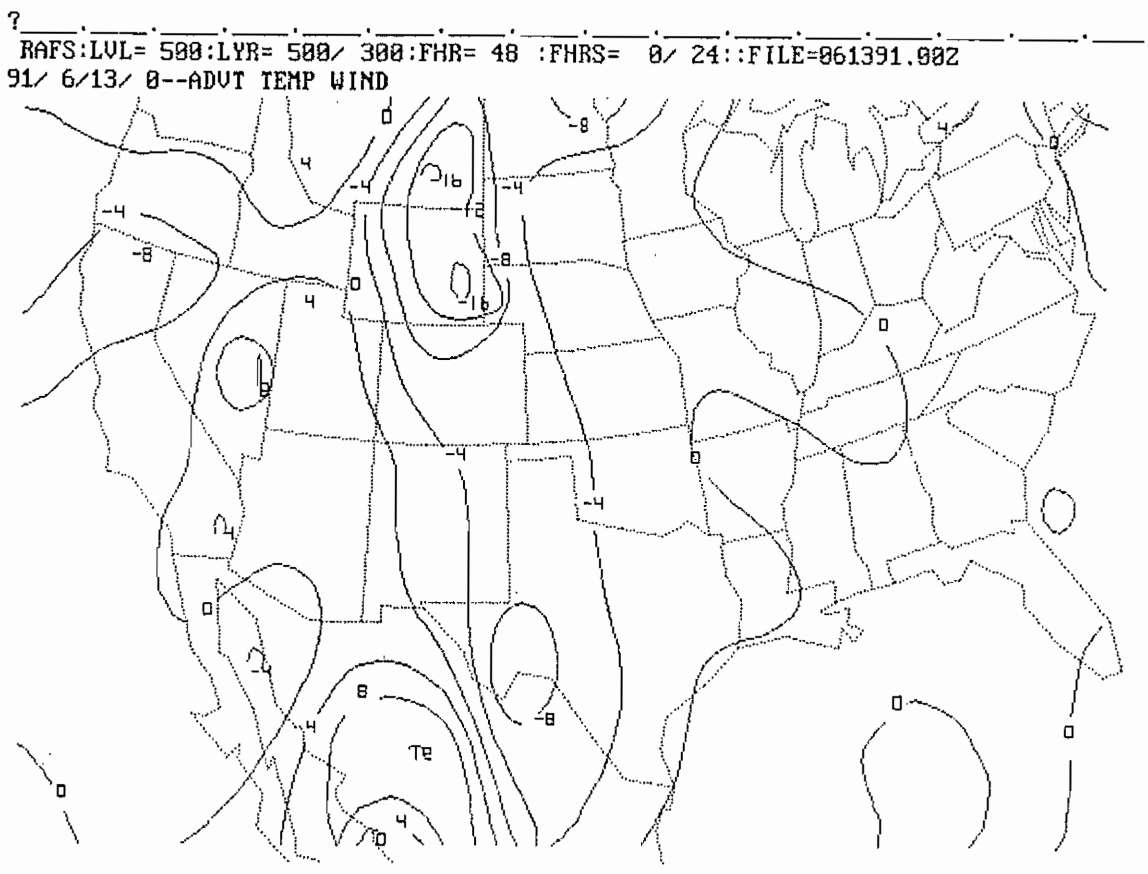

Fig. 6(b). NGM 48 hour forecast 500 mb temperature advection (deg C/12 hr) valid 00Z, Saturday, June 15, 1991. Note the two pockets of cold advection, one along the east slopes of the northern Rockies, and the other across far southwest Texas.

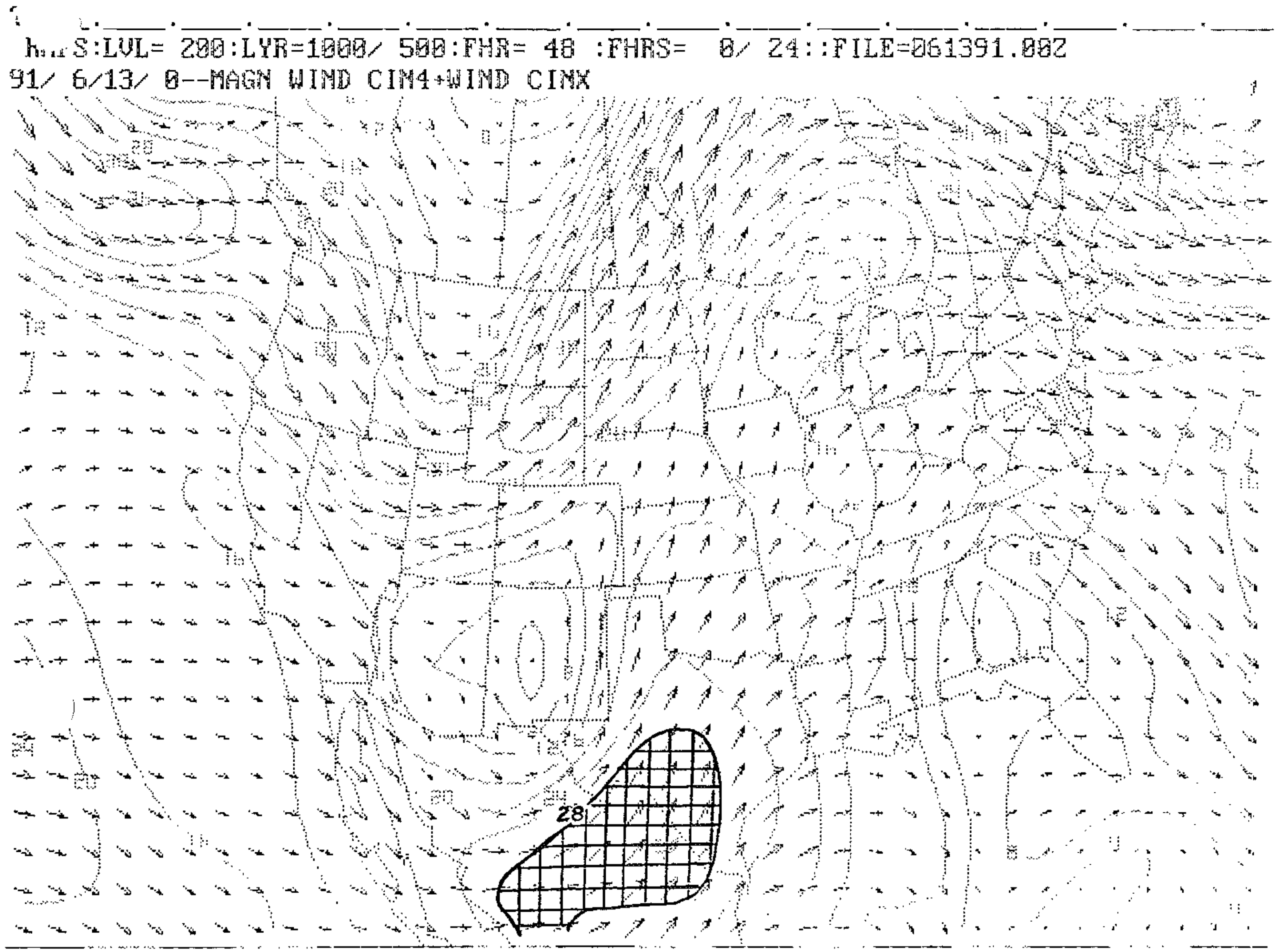

Fig. 7(a). NGM 48 hour forecast 200 mb wind field, valid 00Z, Saturday, June 15, 1991, shown as wind arrows overlayed by isotachs (m/sec). Note the area greater than 28 m/sec (shaded) southeast of the Big Bend.

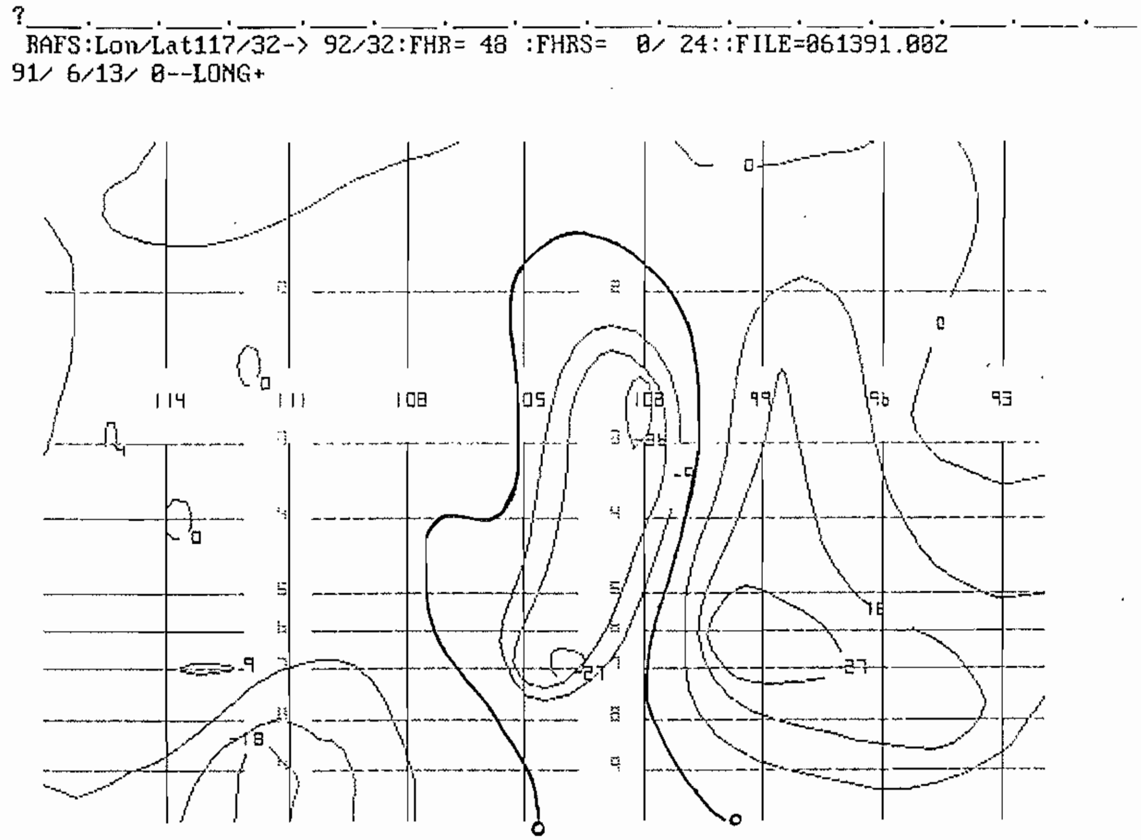

Fig. 7(b). Vertical cross section of omega (microbar/s) from 32N/117W and 32N/92W. Horizontal lines are pressure (mb/100) and vertical lines are longitude (deg W). Deepest upward is from 102W-103W roughly near Midland, TX.

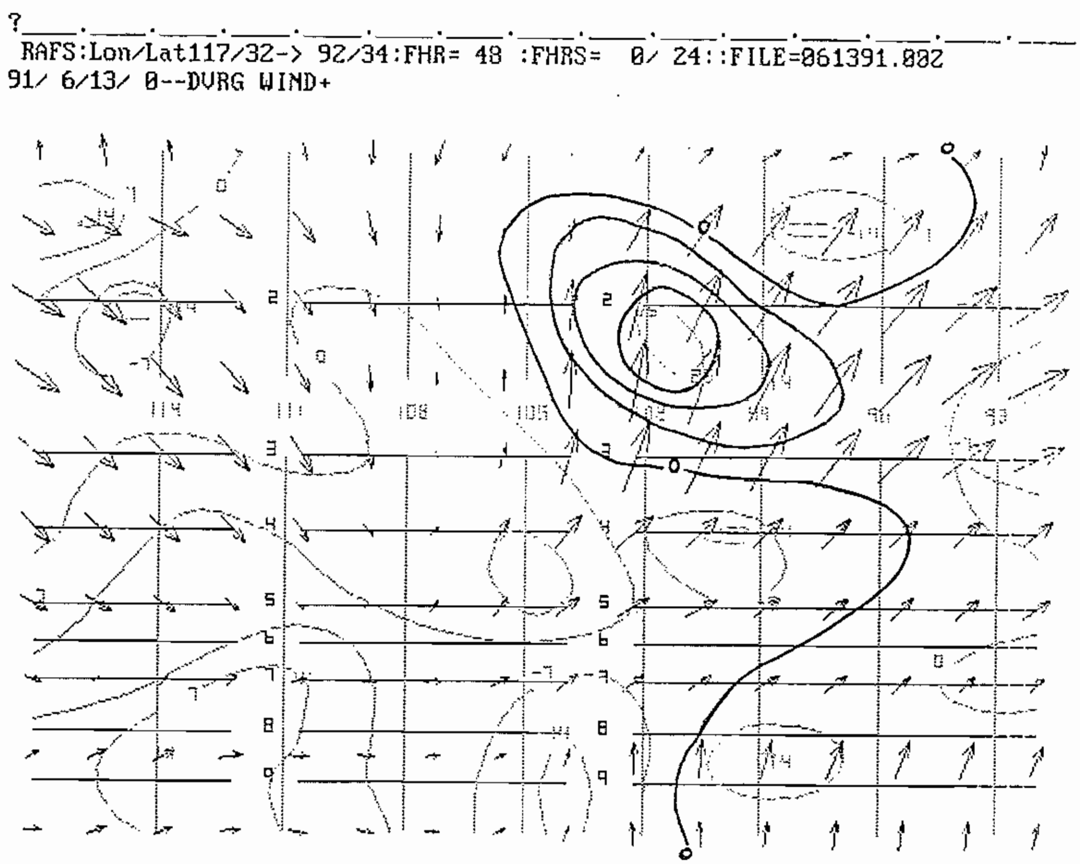

Fig. 7(c). Vertical cross section of winds and divergence (/sec X 10E-5) from 32N/117W to 34N/92W. Coordinates are pressure vs. longitude as in Fig. 8(b). Strongest divergence seen to the east of trough axis from 200-250 mb.

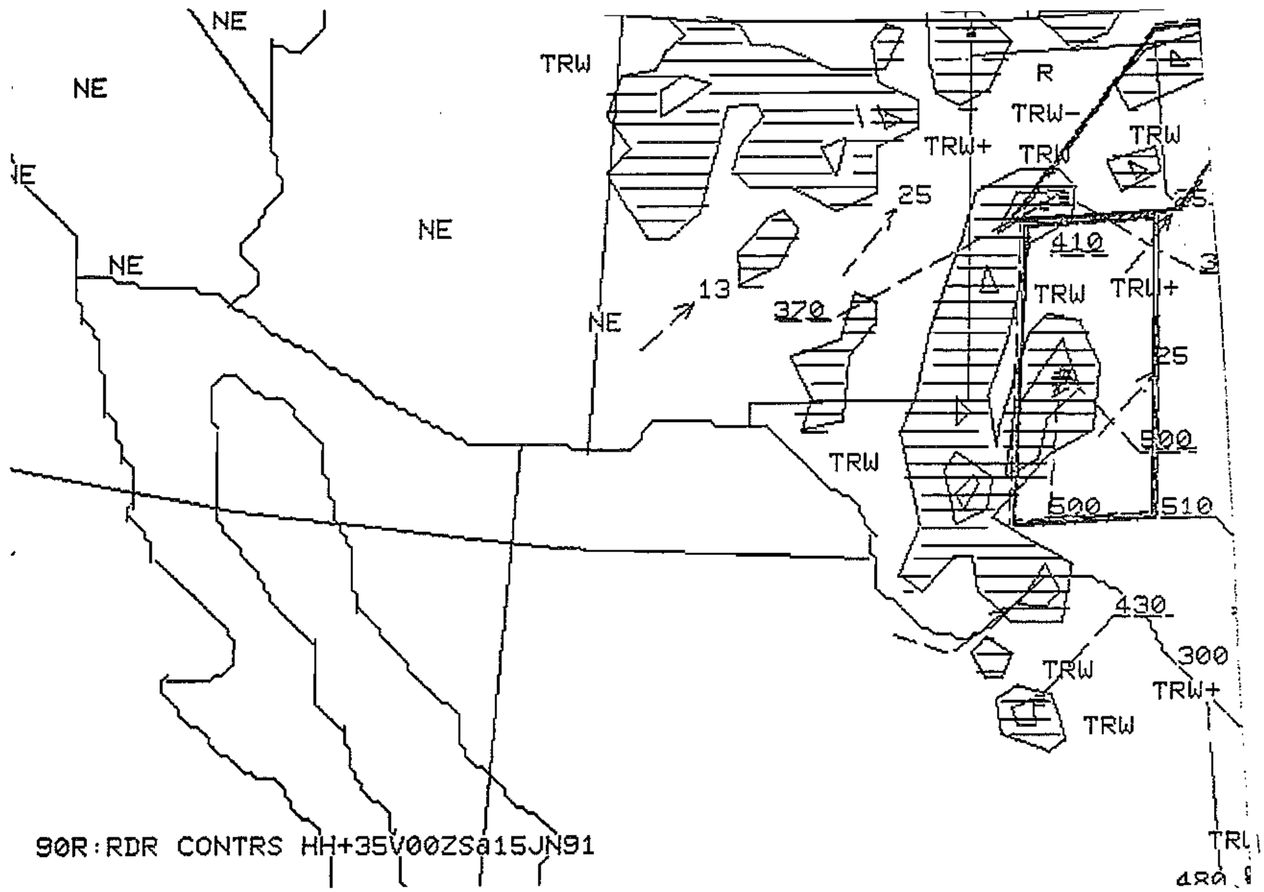

Fig. 8. Section of national radar summary chart for 00Z Saturday, June 15, 1991. Note the line of activity from around zone 7 back down to western zone 16 into zone 53. A severe thunderstorm watch was in effect at the time for the area enclosed by the dark rectangle. The 50 thousand foot storm in the center of this watch earlier produced severe weather near Midland.