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FORECASTING ELEVATED UPRIGHT CONVECTION USING PC-GRIDDS

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1. Introduction

The development of convection on the cold side of a surface boundary has been attributed to different kinds of atmospheric processes. One process is a combination of the presence of conditional symmetric instability (CSI) and strong frontogenetic forcing, resulting in the development of slantwise convection that yields narrow bands of enhanced precipitation amounts within a large area of otherwise stratiform type precipitation (Moore and Lambert 1993). Colman (1990a) has discussed the process by which elevated convection develops on the cold side of a surface boundary in convectively stable environments due to strong frontogenetic forcing in the presence of weak symmetric stability.

Another process is the isentropic lifting of convectively unstable, high equivalent potential temperature (theta-e) air over a frontal surface, usually a warm front or stationary front. The convection that develops from this process can produce heavy rainfall and severe weather, which most often occurs in the form of large hail (Grant 1995). Convection of this nature can be referred to as "elevated upright convection" (hereafter referred to as EUC as differentiated from the processes discussed above); this is because it is based aloft at the top of the frontal inversion, somewhere between approximately 925 mb and 750 mb; but it does form in a buoyantly unstable environment in which positive Convective Available Potential Energy (CAPE) exists, albeit sometimes in small amounts, when calculated from the top of the inversion. Such convection can be difficult to forecast because traditional procedures for forecasting convection tend to focus on surface-based techniques. The planetary boundary layer (PBL) is very stable in areas where elevated convection develops (Colman 1990b), thus surface based thermodynamic parameters and instability indices cannot adequately diagnose the environment in which elevated convection develops. However, the PC-GRIDDS software package makes available parameters and techniques which can be used to forecast EUC, and this paper will focus on exploring these techniques and their application in forecasting an EUC event from January 1996.

2. Pressure Surface Forecast Techniques

Moore et. al. (1995) have found a correlation between the development of organized, cool-sector elevated convective complexes that form in the presence of convective instability above a frontal surface (i.e., EUC) and several different thermodynamic parameters. At 850 mb, the formation of organized EUC was found to be favored in the area just south of the maximum advection of theta-e, near the maximum moisture flux convergence, and just downstream and east of the maximum moisture flux (transport). These thermodynamic parameters are similar to surface-derived parameters often used in forecasting surface based convection, but focus instead on 850 mb, near the top of the frontal inversion where EUC is based.

The area north of the maximum surface moisture convergence was also found to correlate well to the development of organized EUC; this is reasonable,as surface moisture convergence would tend to be maximized along a warm or stationary front, and the area north of the front is the region where EUC forms. The area of highest K indices (Miller 1972) was also a favorable area for EUC development. Again, this is due to the fact that K indices are computed using only data at 850 mb and above, and thus more accurately depict the moisture and instability present above the stable PBL. Instability for EUC situations can also be analyzed using the Showalter index and the Total-Totals index, both of which are computed using data at 850 mb and above (Miller 1972).

Another important factor in the development of EUC is the presence of a low level jet (LLJ). An LLJ is usually present when EUC develops, as it provides the transport of moisture and instability, as well as produces the isentropic lift which acts as the "trigger" for elevated convective development (Gerard 1993). All other factors being equal, the stronger the LLJ, the more likely EUC is to develop.

All of the meteorological parameters and indices discussed above can be viewed using PC-GRIDDS. The author developed a PC-GRIDDS command file entitled ELEV.CMD (Table 1) that facilitates analysis using all of the discussed techniques for forecasting EUC. Table 2 shows the charts displayed by the macro. In a later section, it will be shown how the ELEV.CMD macro highlighted the potential for an EUC event in central Mississippi on January 26.

3. Isentropic Forecast Techniques

Because EUC usually develops in association with isentropic lifting, using isentropic charts derived from PC-GRIDDS can obviously be very beneficial in the forecasting of EUC. Standard pressure, wind, and mixing ratio/condensation pressure deficit charts can show the forecaster where the best lift and moisture for the development of convection will be in place. In addition, the advection of pressure can quantitatively show the forecaster where the best isentropic lift will be occurring. This can be calculated using ground-relative winds (using the PADV command on PC-GRIDDS), or through the use of macros that use system-relative winds. The latter technique often yields an improved calculation for vertical motion on an isentropic surface (Moore 1993, Gerard 1995).

The thermodynamic parameter moisture stability flux can also be very helpful in the forecasting of elevated convection using isentropic surfaces. This parameter is a combination of moisture advection, advection of static stability, and convergence; taken through a layer between two isentropic surfaces, positive values show where the layer is becoming more moist and less statically stable due to advection and/or convergence (Moore 1993). Several cases examined for this paper using moisture stability flux showed that the parameter is often most effective when the isentropic layer is selected to lie between approximately 850 mb and 750 mb over the area where EUC might develop. Further study is needed to confirm the most effective layer to examine, although the layer described above would seem logical much of the time as it would show the lowest 100 mb above a frontal inversion lying at 850 mb, which is around the height where many frontal inversions peak. Thus, the thermodynamic support in the "lower layer" of the EUC convective environment would be analyzed by examining this layer.

Moisture stability flux can be viewed by using the MSFX.CMD macro on PC-GRIDDS or from the CMD menu (after setting a layer between two isentropic surfaces). Pressure advection averaged through the same layer can then show if isentropic lift is present in the same location as the high moisture stability flux.

4. The EUC Event of January 26, 1996

On the morning of January 26, EUC developed over west central Mississippi around 0900 UTC, and expanded quickly across the region, with showers and thunderstorms widespread across central Mississippi by 1200 UTC. This convection developed north of a warm front in association with a 50 kt 850 mb low-level jet, which was producing strong warm air advection, isentropic lift, and moisture inflow across the region. Some severe weather was reported, including wind damage on the northwest side of Jackson, Mississippi, and several reports of hail up to 0.75 inches in diameter. Measurable precipitation fell both prior to and after 1200 UTC at Jackson and Meridian, Mississippi.

As late as the 0000 UTC January 25 model run, the numerical models were having a difficult time forecasting this convective event. In fact, the Model Output Statistics (MOS) from the Nested Grid Model (NGM) generated a zero percent probability of precipitation for both Jackson and Meridian for the 12-hr period ending at 1200 UTC on the 26th. As was mentioned above, both locations received measurable precipitation during this period.

However, using the ELEV.CMD macro on gridded data from the 0000 UTC January 25 run of the Eta model clearly showed the potential for EUC across the region. As can be seen in Figs. 1-5, the forecast from the 0000 UTC January 25 Eta, valid for 1200 UTC January 26, showed that central Mississippi would be south of the 850 mb maximum theta-e advection (Fig. 1); north of the maximum 1000 mb surface moisture flux convergence (Fig. 2); near the maximum 850 mb maximum moisture flux convergence (Fig. 3); downstream and northeast of the maximum moisture flux (Fig. 4); and in the area of maximum K indices (Fig. 5). All of these factors are favorable for the formation of EUC, as described earlier.

Moisture stability flux was also useful in the forecast for this event. The layer selected for use in this event was 296K through 300K, which, as discussed above, yielded a layer between approximately 850 mb and 750 mb over the area of concern. Figure 6 shows that moisture stability flux at 1200 UTC on January 26 was forecast to be maximized for this layer over west central Mississippi, near where the EUC developed.

The ELEV.CMD macro and moisture stability flux thus clearly showed the potential for elevated convection and associated precipitation by 1200 UTC January 26, in spite of the low PoP shown by the NGM MOS. In fact, the public forecaster working the January 25 midnight shift used these data to forecast a 60 percent PoP for Jackson and a 40 percent PoP for Meridian for the 12-hr period ending at 1200 UTC January 26, in spite of the zero PoPs shown by MOS. Obviously, this forecast was a great improvement over the MOS guidance. This is just one example of how the forecast techniques for elevated upright convection can contribute to an enhanced understanding of the meteorology of events and improved forecasts of development.

5. Conclusion

The forecasting of elevated upright convection (EUC) can often present a difficult challenge, due to the problem of trying to evaluate thermodynamics and instability at some height above the surface. However, this paper has shown that PC-GRIDDS can effectively be used to analyze the environment in which EUC might occur. This analysis can be made through the examination of several different thermodynamic parameters which previous research has shown to be correlated to the development of EUC. Also, the instability present above the frontal inversion can be examined by looking at several different stability indices, including the Showalter index, K index, and Total-Totals.

In addition, isentropic analysis can be performed on PC-GRIDDS which can help in the forecast of EUC. This includes standard analysis of pressure, wind, and moisture, as well as the use of moisture stability flux, a thermodynamic parameter that shows convergence, moisture advection, and the advection of static stability in one parameter.

References

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Table 1. PC-GRIDDS Macro ELEV.CMD

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LOOP
ERAS
TXTA        A PCGRIDDS MACRO TO FORECAST
TXTB        ORGANIZED ELEVATED CONVECTION
TXTC          (SET FORECAST HOUR FIRST)
TXTD        CREATED BY A. GERARD NWSFO JAN
TXTE        BASED IN PART ON MOORE, ET.AL.
TXTF      PRESENTATION AT 1995 NWA CONFERENCE
5SEC
ADVT THTE WIND 850 GT00 CLR3
ADVT THTE WIND 850 LT00 CLR1&
TXTP 850 MB THETA-E ADVECTION
TXTQ (ELEVATED CONVECTION FAVORED IN GRADIENT AREA JUST S OF MAX)
ENDL
LOOP
DVRG FLUX MIXR WIND 1000 GT00 CLR1
DVRG FLUX MIXR WIND LT00 CLR3&
TXTP 1000 MB MOISTURE FLUX DIVERGENCE
TXTQ (ELEVATED CONVECTION FAVORED IN GRADIENT AREA N OF MAX
CONVERGENCE)
ENDL
LOOP
DVRG FLUX MIXR WIND 850 GT00 CLR1
DVRG FLUX MIXR WIND LT00 CLR3&
TXTP 850 MB MOISTURE FLUX DIVERGENCE
TXTQ (ELEVATED CONVECTION FAVORED NEAR MAX CONVERGENCE)
ENDL
LOOP
SMLC 1E+3 MAGN FLUX MIXR WIND CI20 CLR1/FLUX MIXR WIND CLR3
TXTP 850 MB MOISTURE FLUX (TRANSPORT)
TXTQ (ELEVATED CONVECTION FAVORED DOWNSTREAM AND EAST OF MAX
FLUX)
ENDL
LOOP
CONT SSUM DWPT 850 SSUM SDIF TEMP 850 TEMP 500 SDIF DWPT 700 TEMP 700
CIN4 CLR3 GT16
TXTP K INDICES
TXTQ
ENDL
LOOP
LNDX CI02 SLYR 1000 500&BKNT 1000
TXTP SURFACE (1000 MB) BASED LIFTED INDEX AND 1000 MB WINDS
TXTQ (ELEVATED CONVECTION FAVORED IN GRADIENT AREA N OF SFC
BOUNDARY)
ENDL
LOOP
LNDX CI02 SLYR 850 500&BKNT 850
TXTP 850 MB LIFTED INDEX AND 850 MB WINDS
TXTQ
ENDL
LOOP
LNDX CI02 SLYR 850 500&LNDX CI02 DASH SLYR 1000 500
TXTP 1000 MB BASED (WHITE) AND 850 MB BASED (RED) LIFTED INDICES
TXTQ (COMPARE TO FIND ELEVATED INSTABILITY)
ENDL
LOOP
SSUM SDIF TEMP 850 TEMP 500 SDIF DWPT 850 TEMP 500 CIN4 CLR2 GT36
TXTP TOTAL TOTALS
TXTQ
ENDL
STOP COMM
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Table 2. List of charts displayed by the PC-GRIDDS macro ELEV.CMD

Chart No.	Chart Type
Chart 1	850 mb theta-e advection
Chart 2	1000 mb moisture flux divergence
Chart 3	850 mb moisture flux divergence
Chart 4	850 mb moisture flux vectors and magnitude of moisture flux
Chart 5	K indices
Chart 6	Surface (1000 mb) based lifted indices and 1000 mb winds
Chart 7	850 mb based lifted index (Showalter Index) and 850 mb winds
Chart 8	Surface (1000 mb) based lifted indices, overlaid with 850 mb based lifted indices
Chart 9	Total-Totals

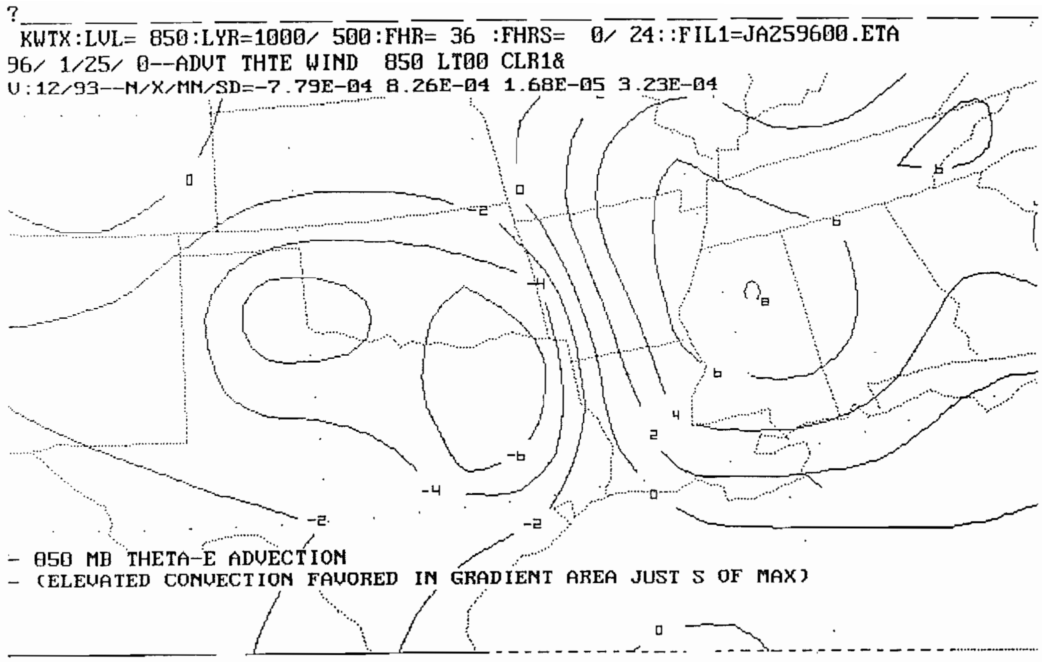

Fig. 1. 36-hr forecast of theta-e advection for 850 mb valid at 1200 UTC January 26, 1996 from the 0000 UTC January 25, 1996 run of the Eta model.

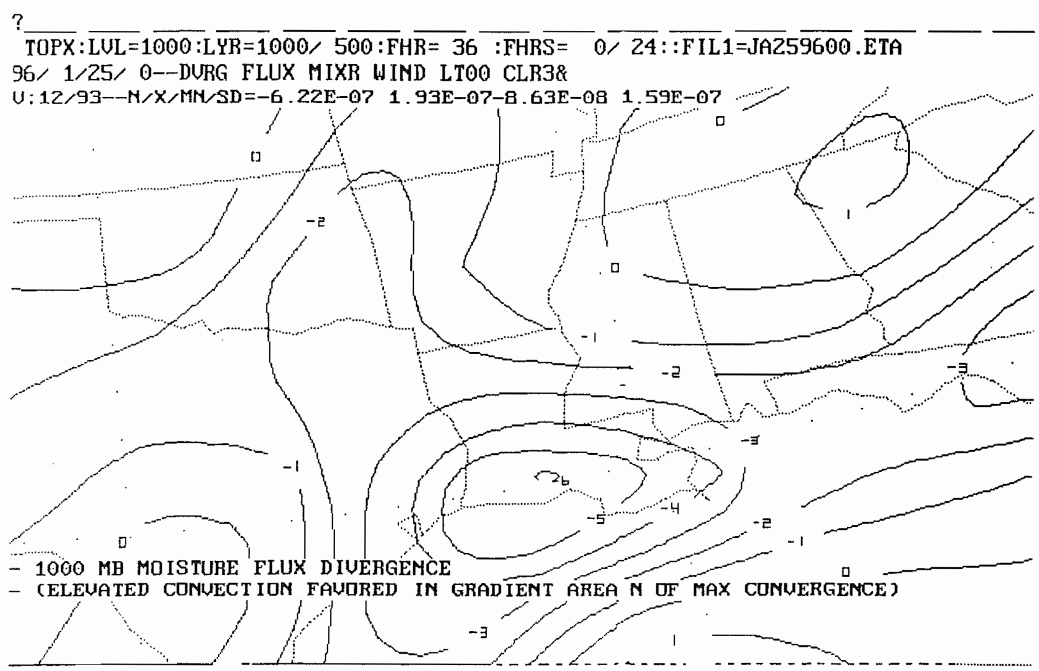

Fig. 2. Same as Fig. 1, only 1000 mb moisture flux divergence.

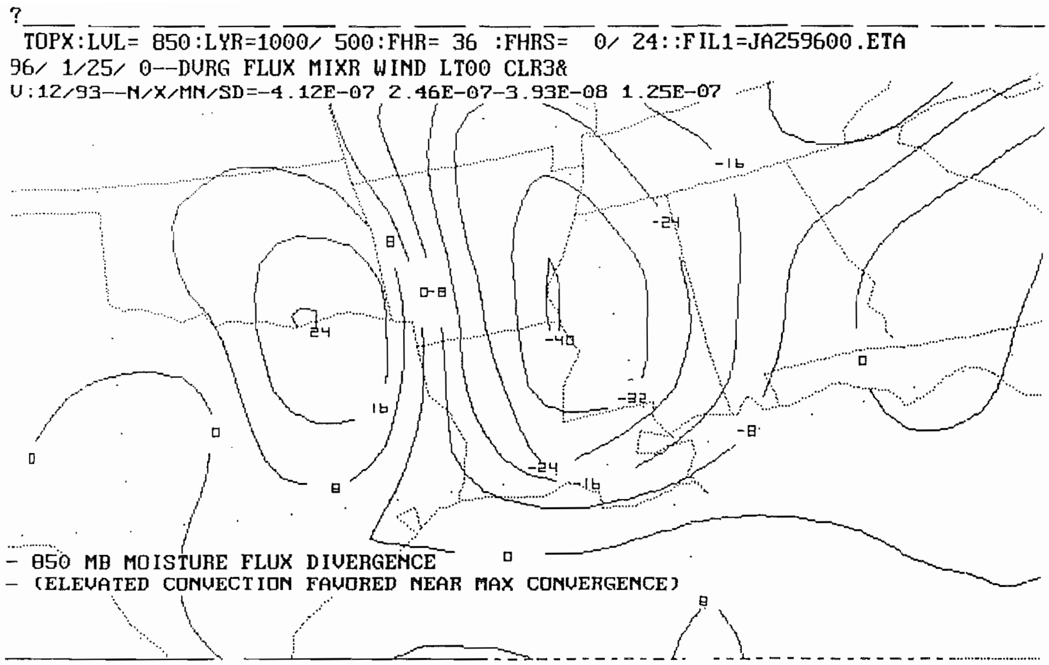

Fig. 3. Same as Fig. 1, only 850 mb moisture flux divergence.

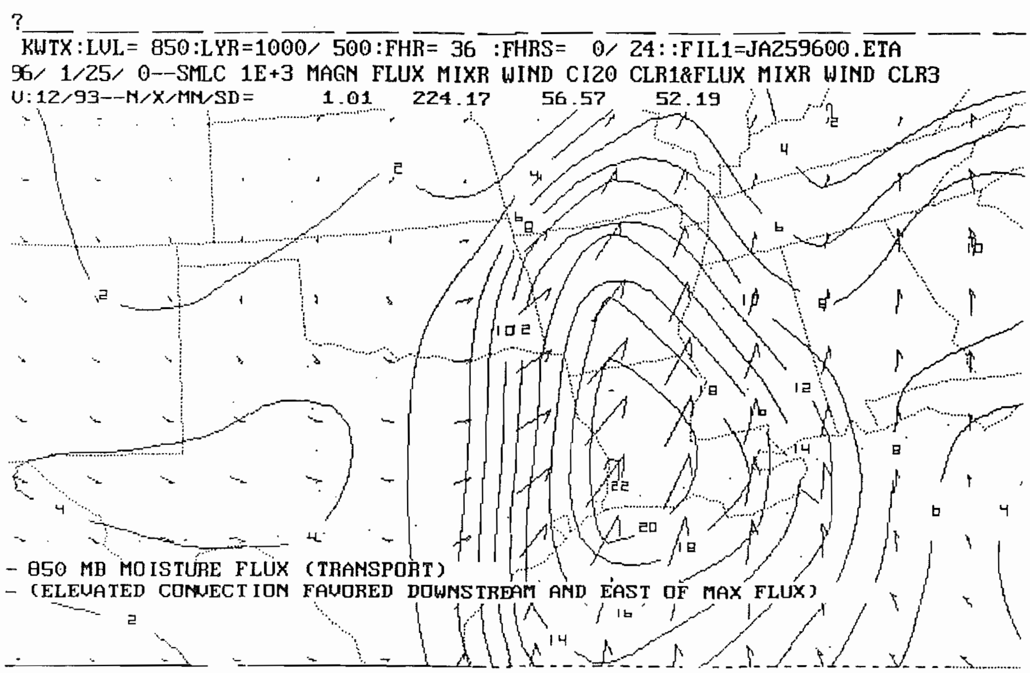

Fig. 4. Same as Fig. 1, only 850 mb moisture flux.

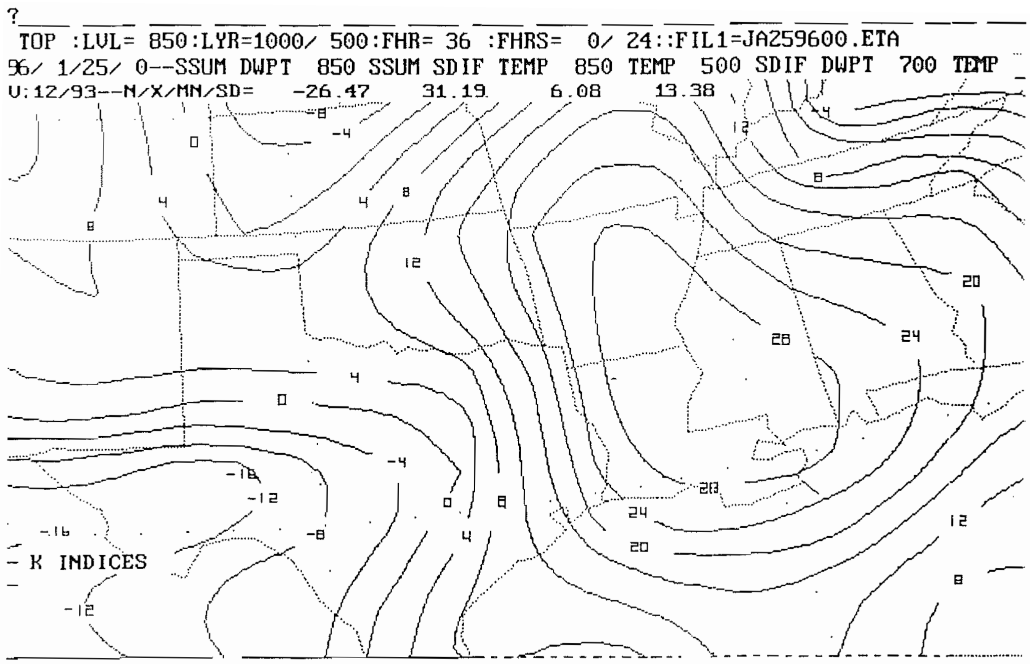

Fig. 5. Same as Fig. 1, only K indices.

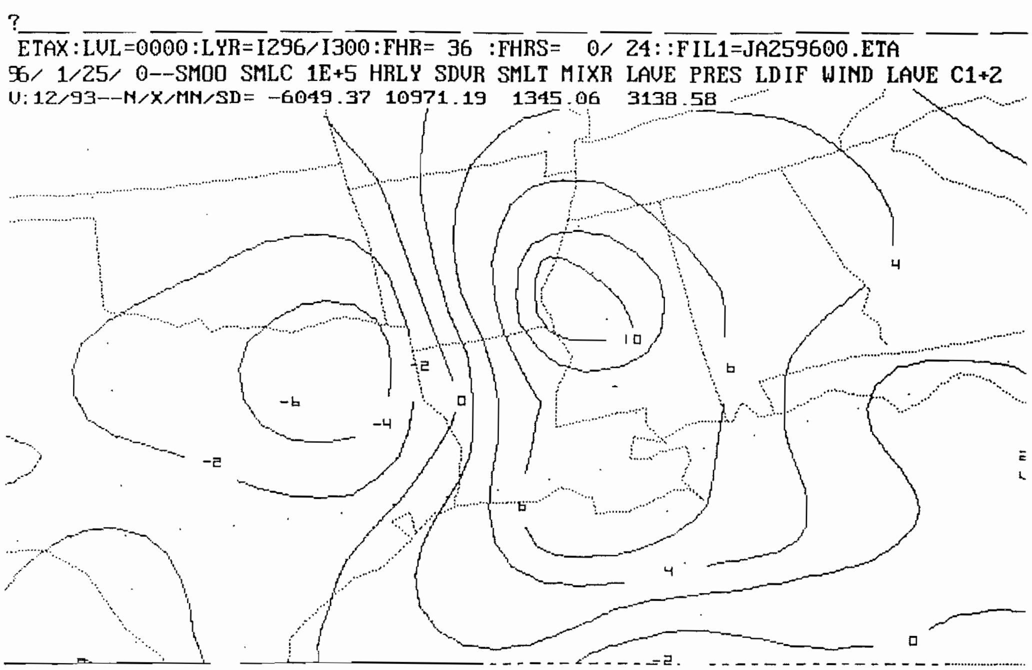

Fig. 6. Same as Fig. 1, only moisture stability flux taken through the 296K through 300K layer.