ANALYSIS OF A HEAVY CONVECTIVE RAINFALL EVENT USING VAS RETRIEVALS

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ABSTRACT

VAS retrieval and conventional surface and upper-air data are utilized to investigate a heavy rainfall-producing convective event across the Plains states on 8–9 May 1986. Emphasis is placed upon VAS-derived precipitable water and lifted index imagery, and the information provided concerning convective development. Reasons for the convective heavy rainfall also are discussed.

1. INTRODUCTION

VISSR Atmospheric Sounder (VAS) data provide radiance data from which mesoscale retrievals of atmospheric temperature and water vapor can be obtained. VAS sounding data have been evaluated and utilized for operational forecasting at the National Severe Storms Forecast Center (NSSFC) (e.g., Wade et al., 2; Anthony and Leftwich, 3) and at the National Hurricane Center (NHC) (e.g., Gerrish, 4). The National Meterological Center's (NMC) EPAC studies (Mostek and Olson, 5) evaluated the impact of VAS data in model forecasts over the eastern Pacific Ocean. Cram and Kaplan (6) utilized VAS retrievals as input to mesoscale numerical models.

The NSSFC has found that VAS-derived fields and images of stability and precipitable water have often proven helpful (when available) in revealing trends and spatial gradients in the pre-severe convective environment (e.g., Mosher and Schoeni, 7). Note that at least three VAS data sets are necessary to establish trends. The NHC utilizes VAS-derived heights, gradient winds, and Band 9 (7.3 μm) and 10 (6.7 μm) water vapor imagery winds to help produce deep-layer mean wind fields over water areas during tropical storm season. Band 10 water vapor imagery is one of the most useful VAS products.

VAS retrievals are generated (by physical algorithm) on the VAS Data Utilization Center (VDUC) in the Synoptic Analysis Branch (SAB) of NESDIS. VAS heights, gradient winds, and Band 9 and 10 water vapor imagery winds are produced and carefully edited. SAB generates multi-layered VAS wind sets at 1200 and 0000 GMT for NHC during tropical storm season. In addition, during the 1988 convective season, SAB produced 3-hourly VAS-derived stability and moisture fields for NSSFC. The data are available to NMC as well.

An objective of VAS assessments is determination of the degree of usefulness and reliability of the data as compared to radiosonde (RAOB) data. The lack of vertical resolution due to the volume-averaged nature of satellite measurements and the inability to sound in cloudy areas are limiting factors of VAS. This paper evaluates VAS retrieval data in a pre-convective environment that resulted in heavy convective rainfall over the Plains states on 8–9 May 1986. Four VAS times were available: 1000, 1130, 1300, and 1430 GMT 8 May. The data were provided by the Advanced Satellite Products Project group at the University of Wisconsin. Fields of geopotential height, precipitable water, and stability are investigated and compared to the conventional data. Reasons for the convective outbreak and the usefulness of VAS in this case are discussed.

2. SYNOPTIC DISCUSSION

The period 8–9 May 1986 featured a major spring storm system that brought severe weather and heavy rainfall across the Plains states. Thunderstorms caused rainfall amounts of 1–4 in. from central Texas to the Dakotas with a small, but pronounced 9-in. maximum in southwest Nebraska (Fig. 1). Convection began developing over the Plains near 1430 GMT 8 May, maximized into a squall line during the late afternoon and early evening, and then dissipated by about 0600 GMT 9 May (Fig. 2).

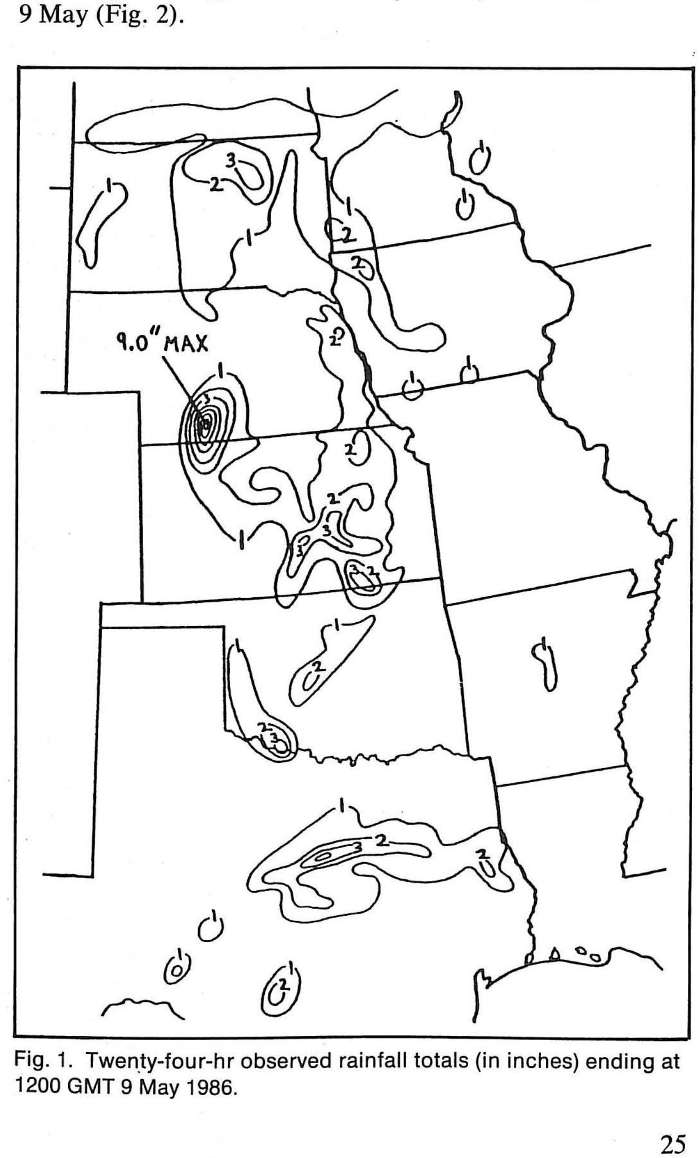
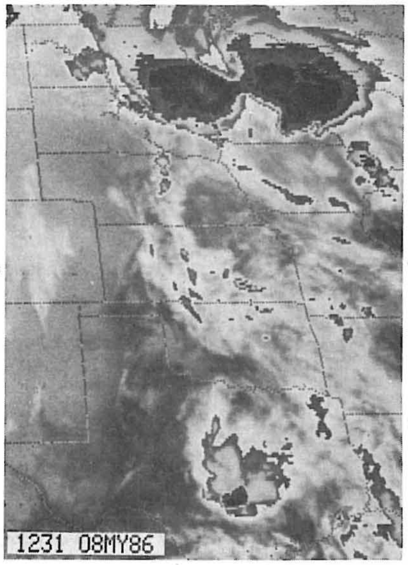
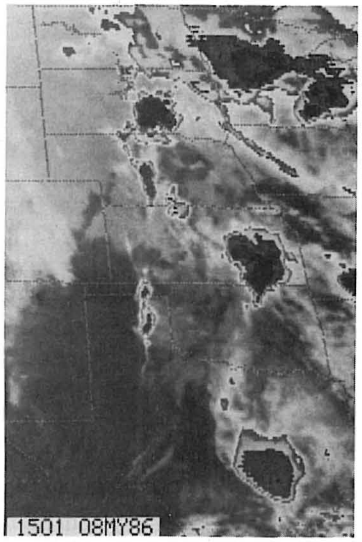
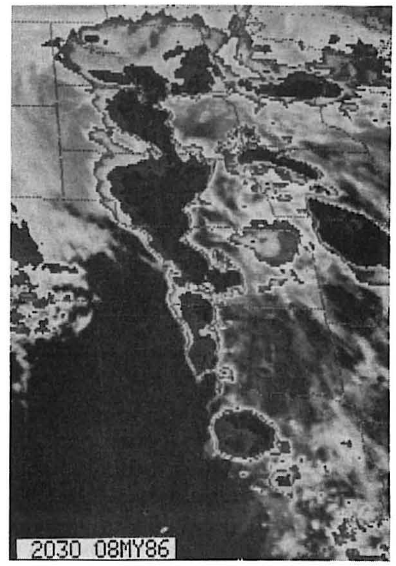
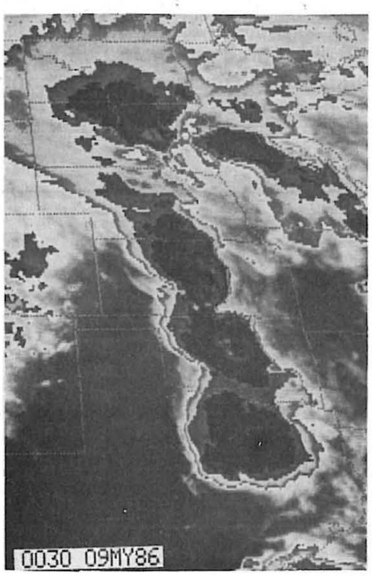


Fig. 1. Twenty-four-hr observed rainfall totals (in inches) ending at 1200 GMT 9 May 1986.









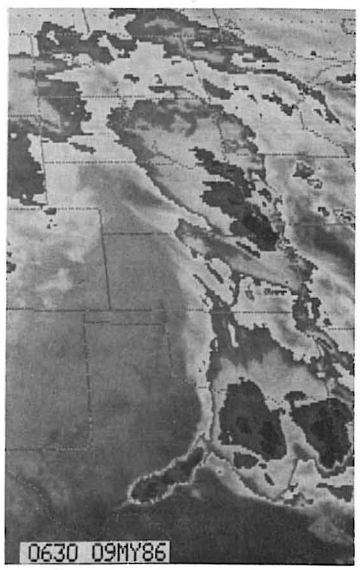


Fig. 2. Enhanced (Mb curve) infrared satellite imagery between 1230 GMT 8 May and 0630 GMT 9 May 1986.

Figure 3 presents a schematic composite of surface and upper air features associated with the event. At 1200 GMT 8 May (top of Fig. 3), a surface Low and cold front were located over western Texas while a warm front meandered eastward from a second low over Nebraska. Surface streamlines at 1500 GMT indicated southeast winds at 15–20 kt in the warm sector and westerly winds behind the Texas cold front (Fig. 4). Surface dew-point contours indicated a sharp gradient across western Texas. For example, the dew-point at Childress, Texas, just ahead of the cold front (dry line), was 64° F at 1500 GMT while that at Amarillo, just behind the front, was only 30° F and fell to 15° F by 2100 GMT. Strong dry air advection is evident behind the frontal zone. Surface moisture convergence (not shown) was greatest along the frontal boundary from Nebraska to northern Texas. In addition, unstable air was located from the southern states to the central Plains; a sharp gradient was present between this unstable air and the stable air over the northern Plains (bottom of Fig. 5).

The upper-air analysis at 1200 GMT 8 May reveals several important features (top of Fig. 3). At 850 mb, a southerly 35-kt jet axis extended from Texas to Nebraska, which advected warm, moist, unstable air into the convective complex over the northern Plains at 1200 GMT (Fig. 2). At 500 mb, a deep Low center was situated over western Colorado with short-wave axes extending to northern Texas and through New Mexico. A middle and upper-level southerly jet axis was just east of the Low center (top of Fig. 3).

The strong environmental forcing and the lifting of ambient unstable air resulted in a mature convective squall line by 0000 GMT 9 May (Fig. 2). The surface analysis at 0000 GMT (bottom of Fig. 3) reveals that the frontal system, and the squall line, over the Plains, especially the central Plains, showed only slow eastward progress, thereby resulting in heavy rainfall amounts (Fig. 1). Surface streamline and dew-point analyses at 2300 GMT 8 May (Fig. 4) showed a continued pronounced convergence zone and dew-point gradient from southwest Nebraska to central Texas, which focused the convection. Moist, unstable southeasterly flow fed the convection while dry advection caused rapid clearing behind the line, e.g., over western Texas (Fig. 2).

The upper-air analysis at 0000 GMT 9 May (bottom of Fig.

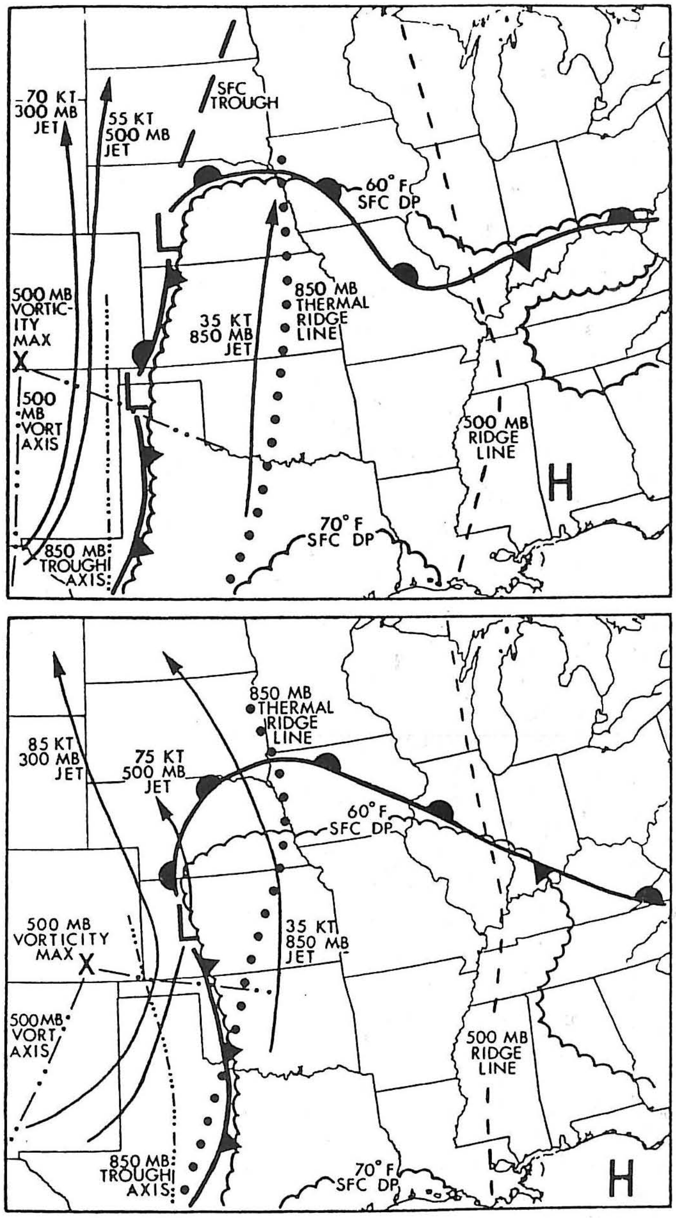


Fig. 3. Composite schematic of surface and upper-air features at 1200 GMT 8 May (top panel) and at 0000 GMT 9 May 1986 (bottom panel).

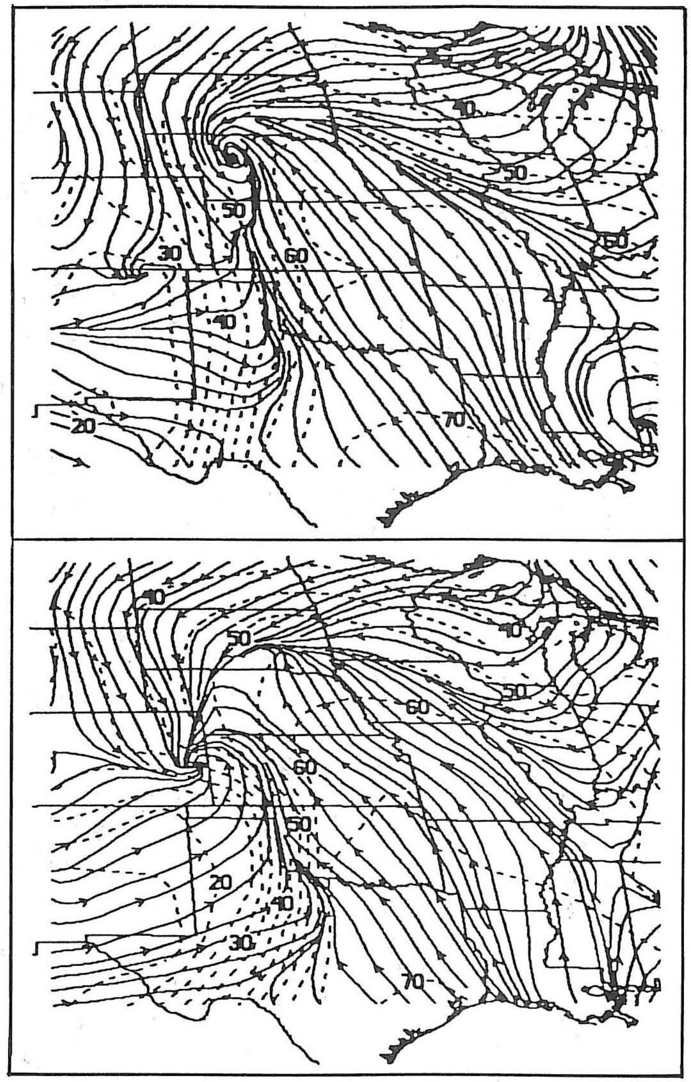


Fig. 4. Surface streamline (solid) and dew-point (dashed in degrees Fahrenheit) contours at 1500 GMT (top panel) and 2300 GMT (bottom panel) 8 May 1986.

3) continued to show strong upper support for the convection. A low-level jet was still evident across the Plains while the middle and upper-level jet, which nearly paralleled the squall line, extended across the western Plains. At 500 mb, the short wave through northern Texas earlier now extended into western Oklahoma, further aiding the convection. The heavy rainfall event ended later as the storms moved east slowly and dissipated across the eastern Plains (Fig. 2).

3. VAS GEOPOTENTIAL HEIGHTS

Fields of geopotential height were examined to assess VAS's depiction of the overall synoptic height pattern. Of course, no VAS retrievals are possible in cloudy regions. VAS and RAOB-derived 1200 GMT height patterns and values (contours produced by VDUC) at 850 and 500 mb generally are similar, albeit the VAS heights are a bit "noisier" (Fig. 6). VAS, however, does show a deeper (lower height values) Low center at 850 mb over Colorado than does the RAOB. A finer resolution contouring program was also used on the VAS 500-mb heights; results (not shown) revealed a much noisier pattern with considerably more short-wave amplitude across the central United States. Fuelberg and Funk (8) showed that VAS retrievals were quite susceptible to response parameters used in the Barnes (9) objective analysis scheme. In that study, finer responses led to noiser patterns resulting in possible meteorological insignificant features. Careful attention should be given to processing VAS data, being particularly aware of time and space continuity, so that only meteorologically important phenomena are retained.

4. VAS PRECIPTABLE WATER

An accurate depiction of the evolution of environmental moisture is very important in the forecasting of convection and heavy rainfall events. VAS offers potential for mesoscale depiction of ambient moisture outside cloudy areas. However, VAS absolute moisture values can be suspect and differ

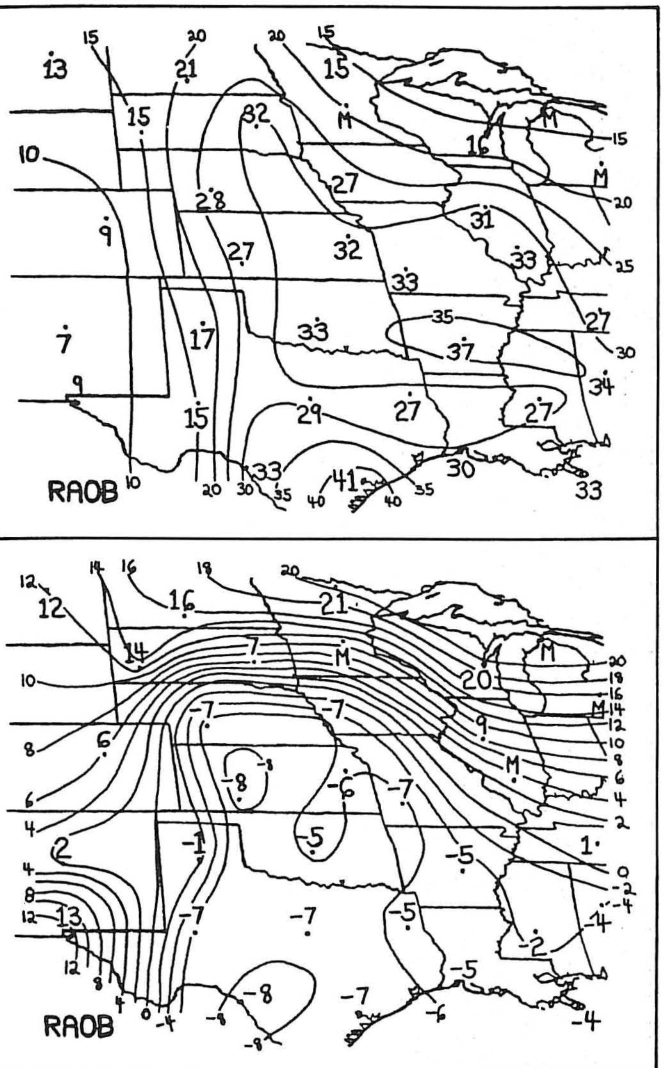


Fig. 5. RAOB-derived surface-500 mb precipitable water (PW in mm) (top panel) and RAOB-derived lifted index (LI) (bottom panel) at 1200 GMT 8 May 1986. The contour patterns were hand-analyzed for the data.

from RAOB values; despite this, VAS spatial gradients and relative temporal changes usually are meaningful.

VAS total column precipitable water data were available at 1000, 1130, and 1430 GMT 8 May; the data are displayed as derived images in Figure 7. The images represent composites of precipitable water data and infrared (IR) satellite imagery (where VAS data voids exist) (Smith et al., 10). The merged images allow meteorologists to monitor changes in both total moisture and convective cloud tops simultaneously. The enhancement curve in Figure 7 contains two slopes of gray shades. The first slope shows gradients in the precipitable water field, where dark regions represent low moisture values and light areas represent high values. The second slope reveals gradients in cloud top temperatures, where lightest shades represent the coldest tops. In real-time, color enhancements are very useful for delineating changes. The images show a large area of moist air from the Plains and Midwest to the Gulf Coast, where scattered showers were occurring. A significant feature is the sharpening of the precipitable water gradient between 1000 and 1430 GMT from southwest Nebraska to the western half of Texas, which possibly aided convective development along the gradient.

The total precipitable water also can be displayed in plotted and contoured form (Fig. 7). The 1430 GMT plot clearly reveals the moisture pattern and sharp moisture gradient from which the 1430 GMT image was derived. The contour pattern over the western Great Lakes states is suspect due to data voids. A comparison of the 1430 GMT VAS plot with the 1200 GMT RAOB plot (top of Fig. 5) reveals that VAS numbers are higher in the most moist regions but comparable over the western Plains and Southwest. The contour patterns of each data set are similar; however, one should note that the VAS contours are computer (VDUC) analyzed (resulting in some data smoothing) while the RAOB contours are hand analyzed (no smoothing). RAOB and VAS dew-points can also be compared by analyzing the RAOB sounding at North Platte, Nebraska at 1200 GMT and the nearest VAS sounding at 1130 GMT (Fig. 8). The temperature curves are very similar, although VAS is consistently slightly colder. The dew-point curve (TD), on the other hand, shows more discrepancy at individual levels. Moreover, had significant RAOB levels been shown, further variability would have occurred. Note, however, that both sources show a total precipitable water (PW) of 28 mm, due largely to the low-level moisture indicated in both profiles. Other VAS-RAOB dew-point profile comparisons revealed lower discrepancies than that in Fig. 8. VAS's poor vertical resolution can result in smoothed or altogether missed vertical moisture gradients, a crucial limitation during certain convective situations when detailed moisture profiles are essential. Forecasters should be aware of these limitations; however, it appears the moisture data can be useful (as in this case) in detecting relative changes and gradients in moisture (i.e., patterns).

5. VAS LIFTED INDEX

The existence, advection, and time rate of change of unstable air (called instability bursts, Jiang Shi and Scofield, 11) are extremely important for possible convective development. VAS offers potential for better delineation of unstable areas and regions of destabilization than does RAOB data. Figure 9 shows VAS lifted indices displayed as derived images between 1000 and 1430 GMT. The images, similar to the derived precipitable water images in Figure 7, show a composite of lifted index data, represented by the first of two gray shade enhancements where dark is stable and light is unstable air, and IR satellite imagery, represented by the second enhancement where, again, lightest shades show coldest cloud tops. The images reveal an unstable (light) area over the Plains and Midwest which lightens slightly by 1430 GMT indicating some destabilization. In addition, a distinct stability gradient exists from southwest Nebraska to western Texas which appears to sharpen slightly between 1000 and 1430 GMT, as also was observed in the precipitable water field. By 1430 GMT, the convection begins developing along the tight gradient in VAS moisture and stability. The 1430 GMT plotted/contoured version in Figure 9 shows the indices from which the corresponding image was derived.

RAOB-derived lifted indices at 1200 GMT (bottom of Figure 5) are quite similar to those from the satellite. Again, VAS contours are computer-analyzed while those from the RAOB are done by hand. In addition to 12-hr stability data, hourly surface data-based lifted indices can be calculated. In this scheme, a well-mixed daytime boundary layer is assumed so that surface temperature and dew-point along with inter-

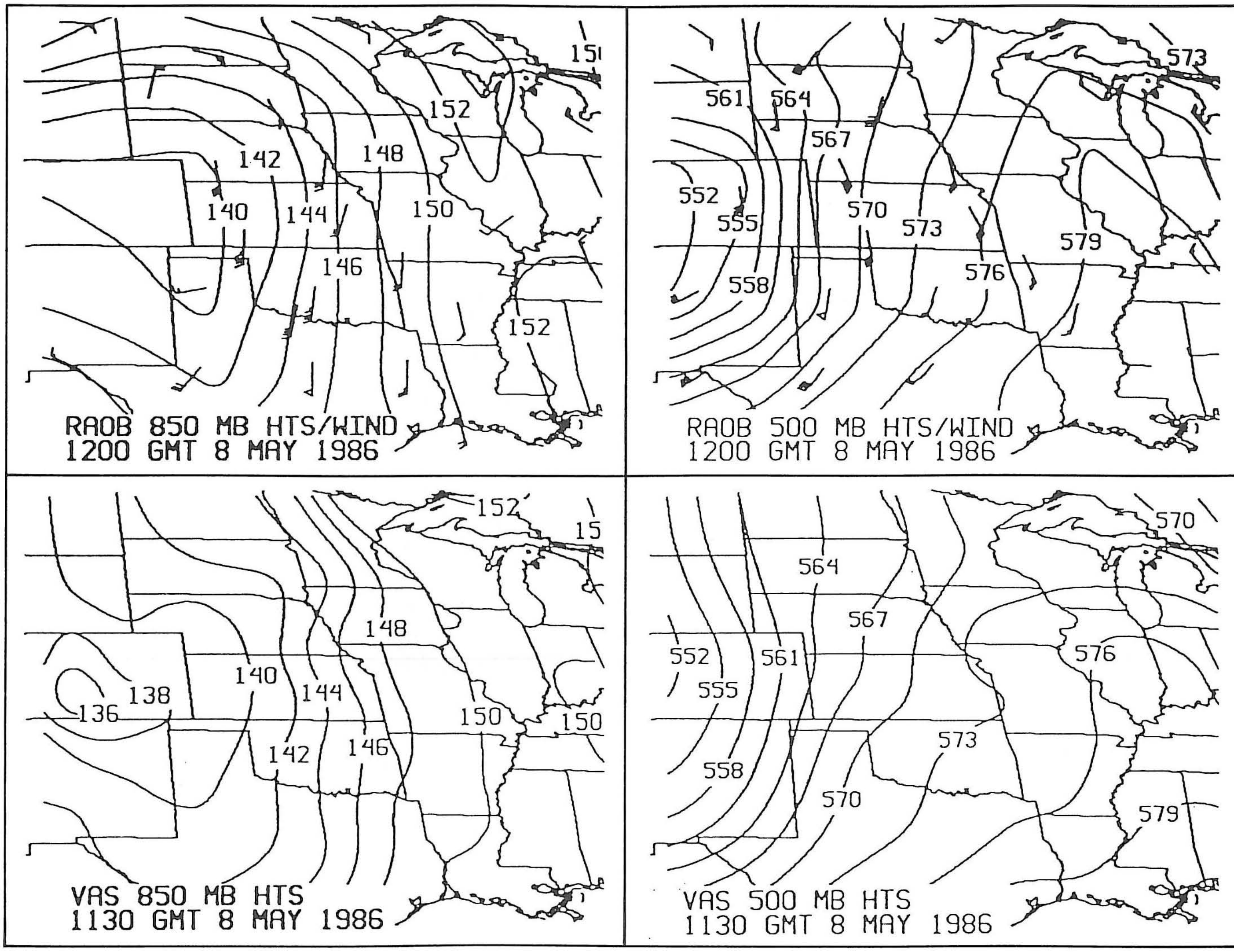


Fig. 6. RAOB and VAS-derived 850-mb and 500-mb height contours and plotted RAOB winds for 1200 GMT 8 May 1986.

prolations of 500-mb temperatures are used for calculation. With surface-based and RAOB-derived stability data available, one could question whether VAS lifted indices can provide further useful information. As previously mentioned, the NSSFC has found VAS stability to be useful in certain instances and generally such was the case in this study.

6. CONCLUSIONS AND OUTLOOK

This paper has presented a case study showing the performance of VAS data in a preconvective environment. Results indicate that the data added some additional information to that obtained from the conventional surface and upper-air data. The addition of VAS retrievals 1) showed a trend toward a slightly more moist, unstable air mass and 2) located the sharp moisture and stability gradient along which the convection developed. Unfortunately, only three VAS-derived images were available (four times overall), barely enough to establish a trend. Perhaps VAS would be even more useful during periods of weak environmental forcing of convection (e.g., summertime flash flood situations). Continued research and evaluation of VAS data will further reveal its degree of usefulness and limitations in an operational environment and whether forecasters can use the data as an additional reliable information source.

ACKNOWLEDGMENTS

The author wishes to express sincere gratitude to Dr. Roderick Scofield, NESDIS/Satellite Applications Laboratory, for his helpful comments in preparing this manuscript. The author also thanks Mr. Dane Clark, NESDIS/Synoptic Analysis Branch, for his review of and comments on the paper. Mr. Gene Dunlap, NESDIS/Satellite Applications Laboratory, prepared the satellite imagery.

NOTES AND REFERENCES

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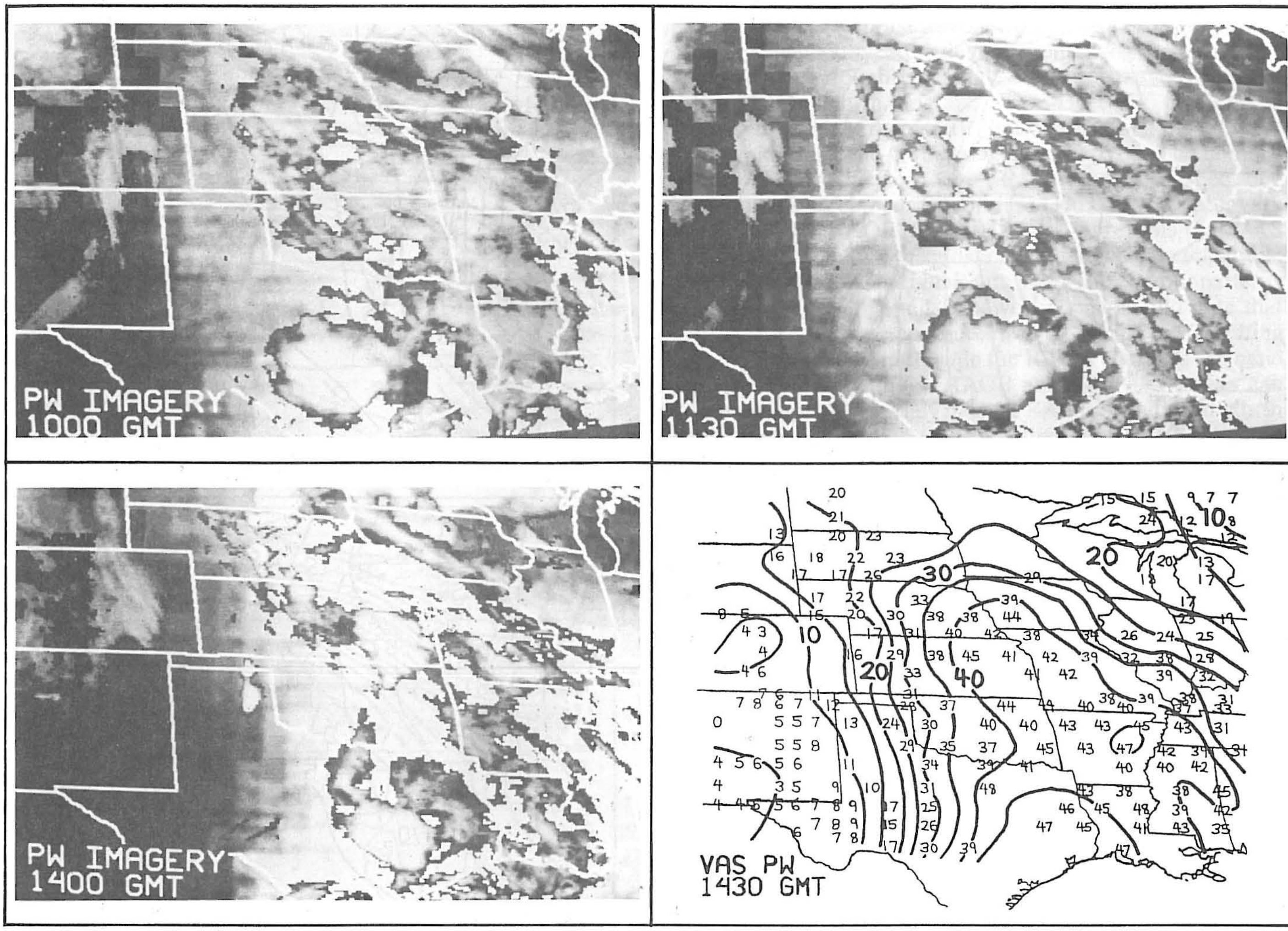

Fig. 7. VAS-derived total column precipitable water imagery at 1000, 1130, and 1430 GMT 8 May 1986. Note that the image labelled 1400 GMT actually is 1430 GMT. The bottom-right panel shows the 1430 GMT plotted and computer-contoured precipitable water values (in mm) from which the 1430 GMT image was derived.

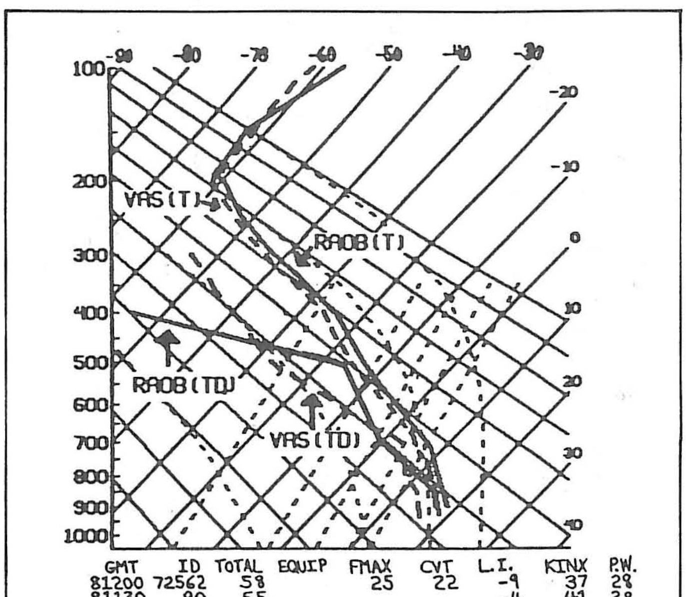

Fig. 8. Atmospheric RAOB sounding at North Platte, Nebraska at 1200 GMT and the nearest VAS sounding at 1130 GMT 8 May 1986.

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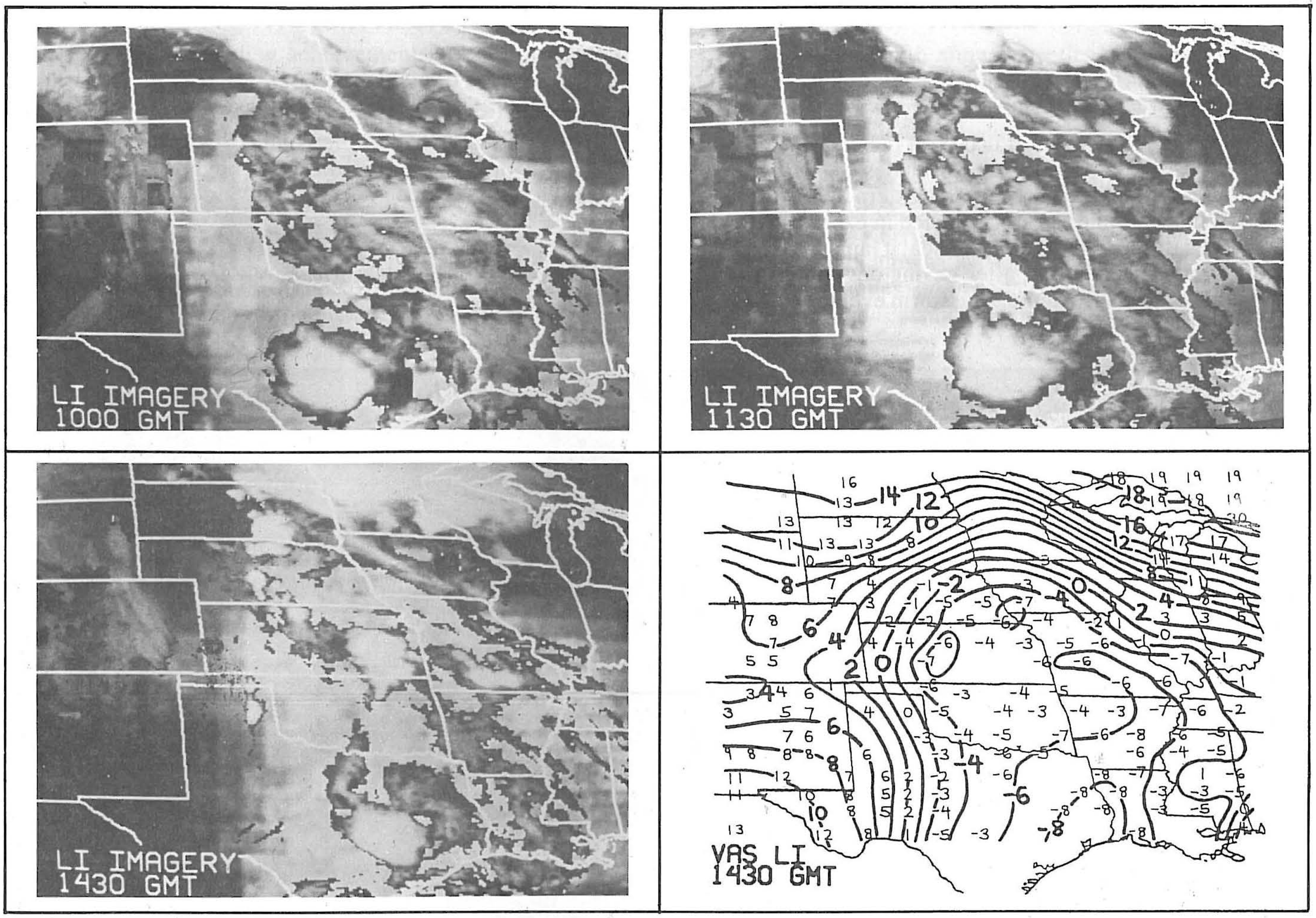

Fig. 9. VAS-derived lifted index imagery at 1000, 1130, and 1430 GMT 8 May 1986. The bottom-right panel shows the 1430 GMT plotted and computer-contoured lifted indices from which the 1430 GMT image was derived.

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