EVALUATION OF KHNX WSR-88D STORM-RELATIVE VELOCITY PRODUCTS DURING A TORNADIC THUNDERSTORM

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Introduction

On 16 December 2002 a tornadic thunderstorm developed near the city of Merced in the San Joaquin Valley of California. While weak tornadoes are not uncommon in California's central interior, analysis of meteorological data from 16 December 2002 underscores the challenges facing the operational meteorologist when anticipating the potential severity of shallow convection developing in a low buoyancy but highly sheared environment. Analysis of KHNX WSR-88D data was conducted using the Weather Event Simulator, then compared to previous research on storm relative velocity products and their relationship to tornadoes in the central and southern San Joaquin Valley.

Synoptic and Mesoscale Features

Synoptic analysis on the morning of 16 December 2002 indicated a quasi-zonal flow over the Eastern Pacific with an approximately 140 kt upper level jet maximum over central California. Considerable low level wind shear was also evident over the San Joaquin Valley with 10-20 kt south-southeast winds at the surface, while the KHNX WSR-88D VAD Wind Profile evidenced southwest winds in excess of 60 kts as low as 7000 feet AGL (Fig. 1).

Forecast soundings for the central San Joaquin Valley derived from the 1800 UTC Meso-Eta and Rapid Update Cycle (RUC) models on 16 December 2002 projected weak positive buoyancy through 0000 UTC 17 December with mean layer Convective Available Potential Energy (MLCAPE) and most unstable CAPE (MUCAPE) of 160-230 Jkg^-1. Despite weak buoyancy, forecast hodographs from the Meso-Eta and RUC projected 0-3 km storm-relative helicities approaching 290 m^2s^-2. Modifications to the soundings and hodographs using surface observations from the central San Joaquin Valley on the morning of 16 December 2002 resulted in a slight increase in projected 2100 UTC MLCAPE and MUCAPE (325-480 Jkg^-1) and a slight increase in 0-3 km storm-relative helicities (290-325 m^2s^-2). Typical of San Joaquin Valley convection during the winter months, modified soundings indicated the potential for very shallow convection with equilibrium levels of only 17,000 feet AGL.

Scattered showers developed over western Merced County shortly after 1800 UTC 16 December 2002 in an area of strong upward vertical motion that coincided with a surface moisture convergence axis extending south into western portions of the county (Fig. 2). The showers proceeded to move east across the county as the moisture convergence axis shifted south into the central San Joaquin Valley (Fig. 3). Using data derived from the Mesoscale Surface Assimilation System (MSAS), it was determined that moisture convergence at the Merced Municipal Airport (KMCE) increased from a slightly divergent -3.63 g/kg/12hr at 1800 UTC to + 8.33 g/kg/12hr by 2100 UTC. The Local Analysis and Prediction System (LAPS) also showed a concomitant increase in surface based CAPE (SBCAPE) in the vicinity of KMCE from 165 Jkg^-1 at 2000 UTC to 470 Jkg^-1 at 2100 UTC. Accordingly, further cell development occurred along the moisture convergence axis in Merced County with maximum reflectivities increasing from 20-25 dBZ at 1727 UTC to 45-50 dBZ by 2107 UTC (Fig. 4). With KMCE at an elevation of 153 feet and KHNX WSR-88D data indicating echo tops of 15,000 - 20,000 feet MSL, equilibrium levels appeared to be close to the 17,000 feet AGL projections obtained from Meso-Eta and RUC forecast soundings.

With a 0.5 degree sampling height in excess of 7,000 feet AGL over Merced County, the ability of the KHNX WSR-88D to resolve rotational signatures in lower levels of a shallow convective cell becomes compromised. Comparison of 0.5 degree data from adjacent WSR-88Ds serving the Sacramento and San Francisco Bay areas offer little assistance as both radars have 0.5 degree sampling heights in excess of 10,000 feet AGL over Merced County.

As the cells crossed the city of Merced, WFO San Joaquin Valley received word of a possible tornado at 2040 UTC 16 December 2002, 17 minutes prior to the first indications of rotation on KHNX WSR-88D storm relative velocity products. Underscoring the difficulty assessing rotational shear in shallow convection at significant distance from the radar, the first evidence of rotation at 2057 UTC was limited to a weak cyclonic velocity couplet with gate-to-gate azimuthal shear only two radial bins in length. Shear also lacked vertical continuity above the 0.5 degree scan. Intermittent gate-to-gate shear (Fig. 5) continued to appear through 2132 UTC but remained confined to 0.5 degree scans.

Time (UTC)	Maximum Cell Reflectivity (dBZ)	Maximum Rotational Velocity (kts)	Maximum Rotational Shear (s^-1)	Range of maximum rotational shear from KHNX WSR-88D (nm)
2037	35-40	No rotational shear evident		
2042	35-40	No rotational shear evident		
2047	45-50	No rotational shear evident		
2052	45-50	No rotational shear evident		
2057	45-50	11.8	0.0065	72
2102	45-50	No rotational shear evident		
2107	45-50	16.0	0.0089	72
2112	50-55	No rotational shear evident		
2117	50-55	11.8	0.0065	72
2122	50-55	7.5	0.0042	72
2127	45-50	No rotational shear evident		
2132	45-50	16.0	0.0088	71

Verification

Amateur photographer Steve Goeken captured an image of the tornado on 16 December 2002 just before 2100 UTC at a location approximately 4 miles northwest of the city of Merced, CA (Fig. 6). A storm survey conducted on 17 December 2002 estimated damage consistent with an F1 tornado. The damage path was determined to be approximately 45 yards in width with a length of 1.25 mile.

Discussion

Previous research conducted by Kruzdlo (1998) recommended the utilization of 1.5 degree or 2.4 degree KHNX WSR-88D data when evaluating rotational shear in the central and southern San Joaquin Valley in order to minimize potential effects of friction on velocity signatures in the near-surface layer. Given the sampling constraints of the KHNX WSR-88D at a distance in excess of 70nm, this recommendation would have proved ineffective on 16 December 2002 as rotational shear was absent above the 0.5 degree scan. The previous guideline was therefore amended at WFO San Joaquin Valley to emphasize the demand for intensive evaluation of all low to mid level data when analyzing rotational shear.

Surface observations at KMCE near the time of the tornado's occurrence indicated a ceiling of 3600 feet AGL. With an estimated equilibrium level of 17,000 feet AGL and no indication of rotation above 0.5 degree, it appears likely that the KHNX WSR-88D was overshooting all but a small portion near the top of the rotation occurring in lower levels of the cell. Reliance upon trained weather spotters to augment WSR-88D data is thus to be emphasized, not only at increased distance from the radar, but during all occasions where the depth of the convection is expected to remain relatively shallow.

Data derived from KHNX WSR-88D storm relative products on 16 December 2002 appeared to confirm several thresholds established by Kruzdlo for distinguishing between tornadic and non-tornadic rotation in central and southern San Joaquin Valley thunderstorms, including the presence of a minimum 16 kt rotational velocity, and maximum azimuthal shear residing in multiple adjacent bins.

When relating 1.0nm diameter mesocyclone strength to range and rotational velocities, Kruzdlo documented that central and southern San Joaquin Valley tornadoes often fall within the "Weak Shear" category. However, the rotational velocities calculated on 16 December 2002 approached the threshold between "Weak Shear" and "Minimal Mesocyclone".

Conclusion

Evaluation of KHNX WSR-88D storm-relative velocity products pertaining to a tornadic thunderstorm on 16 December 2002 supported many conclusions from previous research on central and southern San Joaquin Valley tornadoes. However, analysis of the data also necessitated an adjustment of some operational guidelines in use at WFO San Joaquin Valley for properly evaluating low level rotational shear. The data also confirmed the inherent limitations of the tools currently available to the operational meteorologist for detecting rotation at a significant distance from the radar. While the importance of utilizing trained weather spotters to augment WSR-88D data cannot be overstated, analysis of the data from 16 December 2002 demonstrates that occasions may arise when issuance of tornado warnings will occur in the absence of a significant lead time.

Acknowledgements

The author would like to thank Steve Goeken for allowing use of his photograph of the Merced tornado on 16 December 2002.

References

Kruzdlo, Raymond, 1998: Vr/Shear Interpretation. Western Region Technical Attachment No. 98-12.

Figure 1

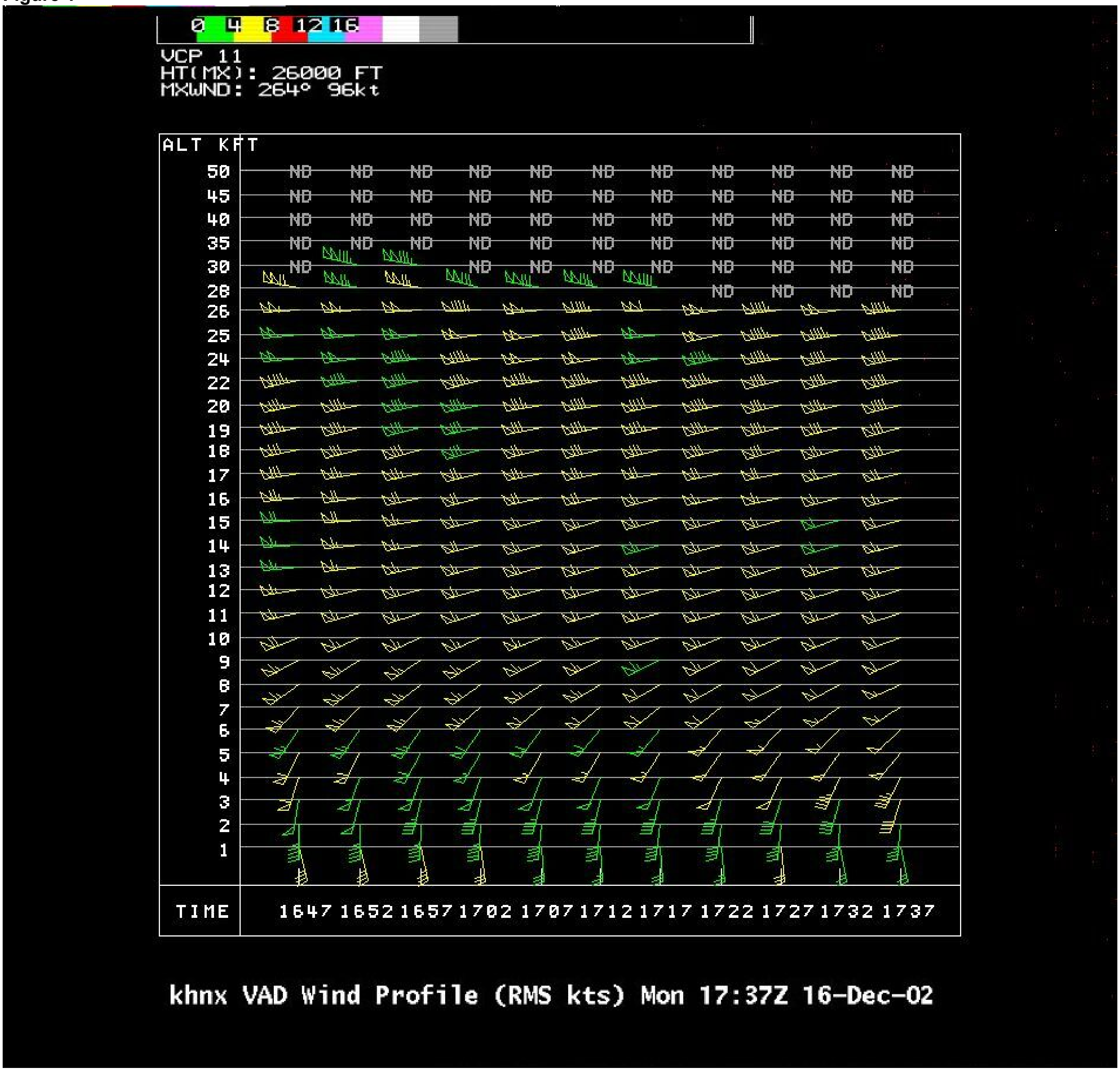
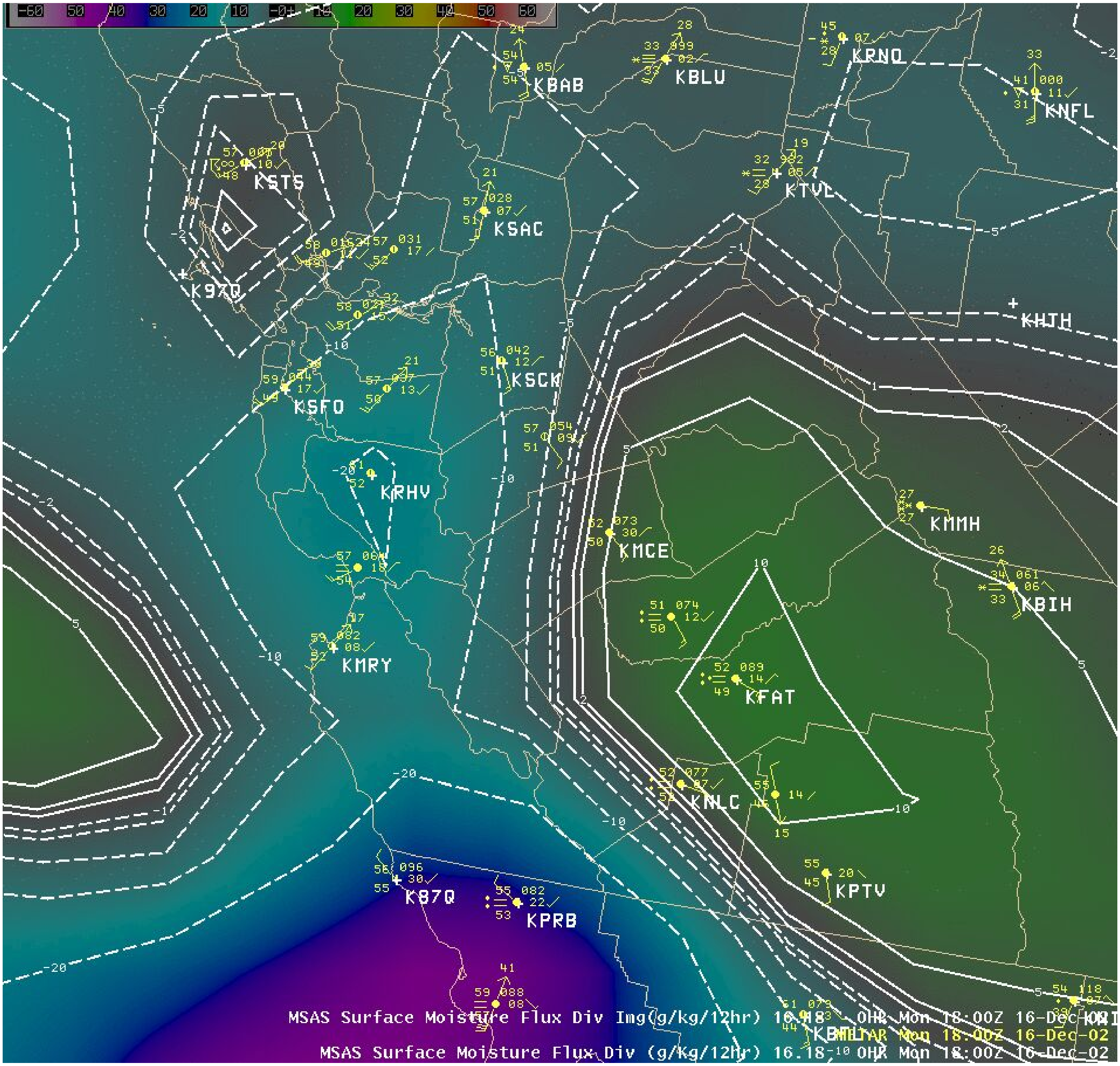


Figure 2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KNLC
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KPRB
MSAS Surface Moisture Flux Div Img(g/kg/12hr) 16.18 0HR Mon 18:00Z 16-Dec-02
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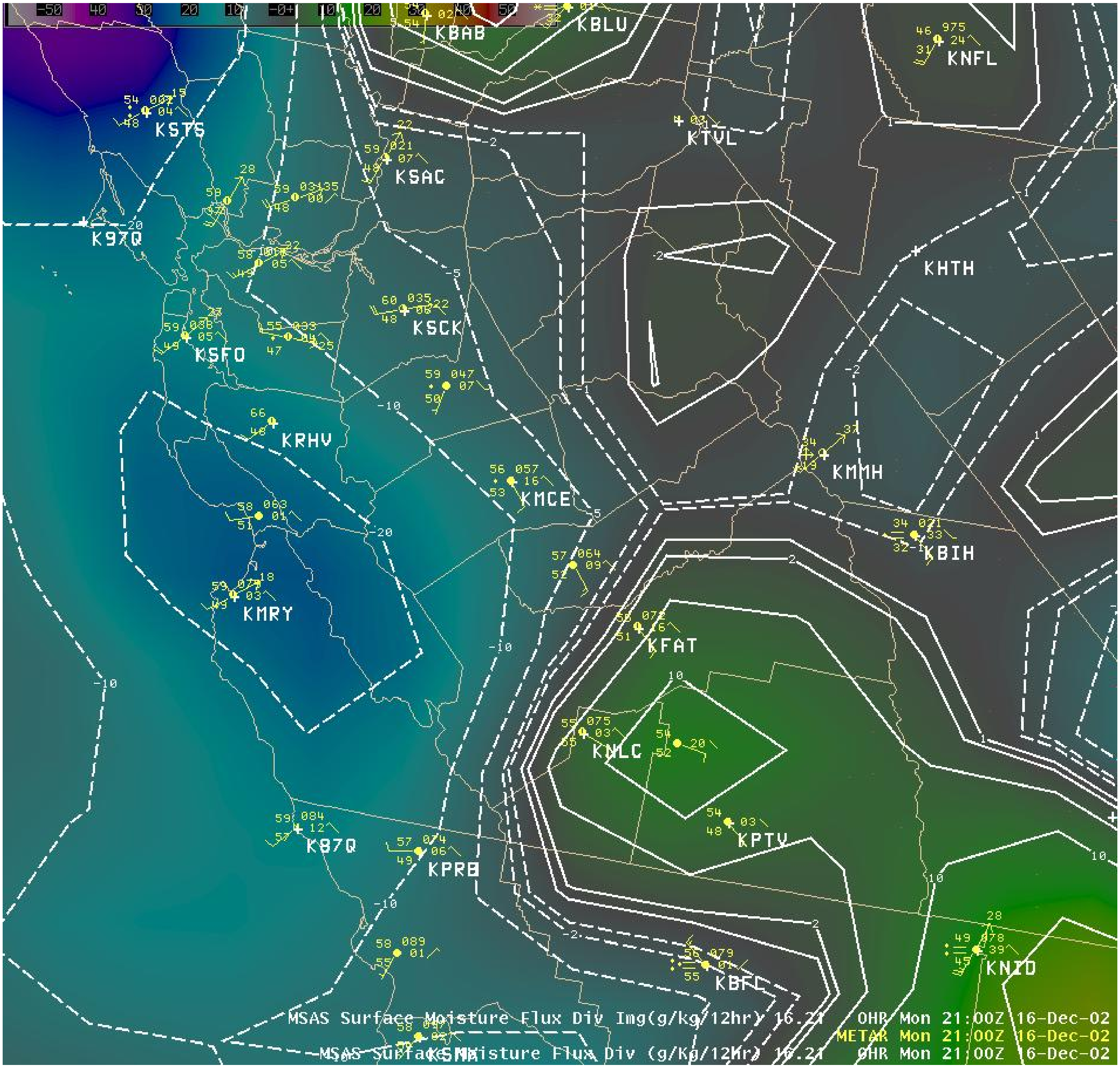
MSAS Surface Moisture Flux Div (g/kg/12hr) 16.18 0HR Mon 18:00Z 16-Dec-02

Figure 3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MSAS Surface Moisture Flux Div Img(g/kg/12hr) 16.21 0HR Mon 21:00Z 16-Dec-02
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Figure 4

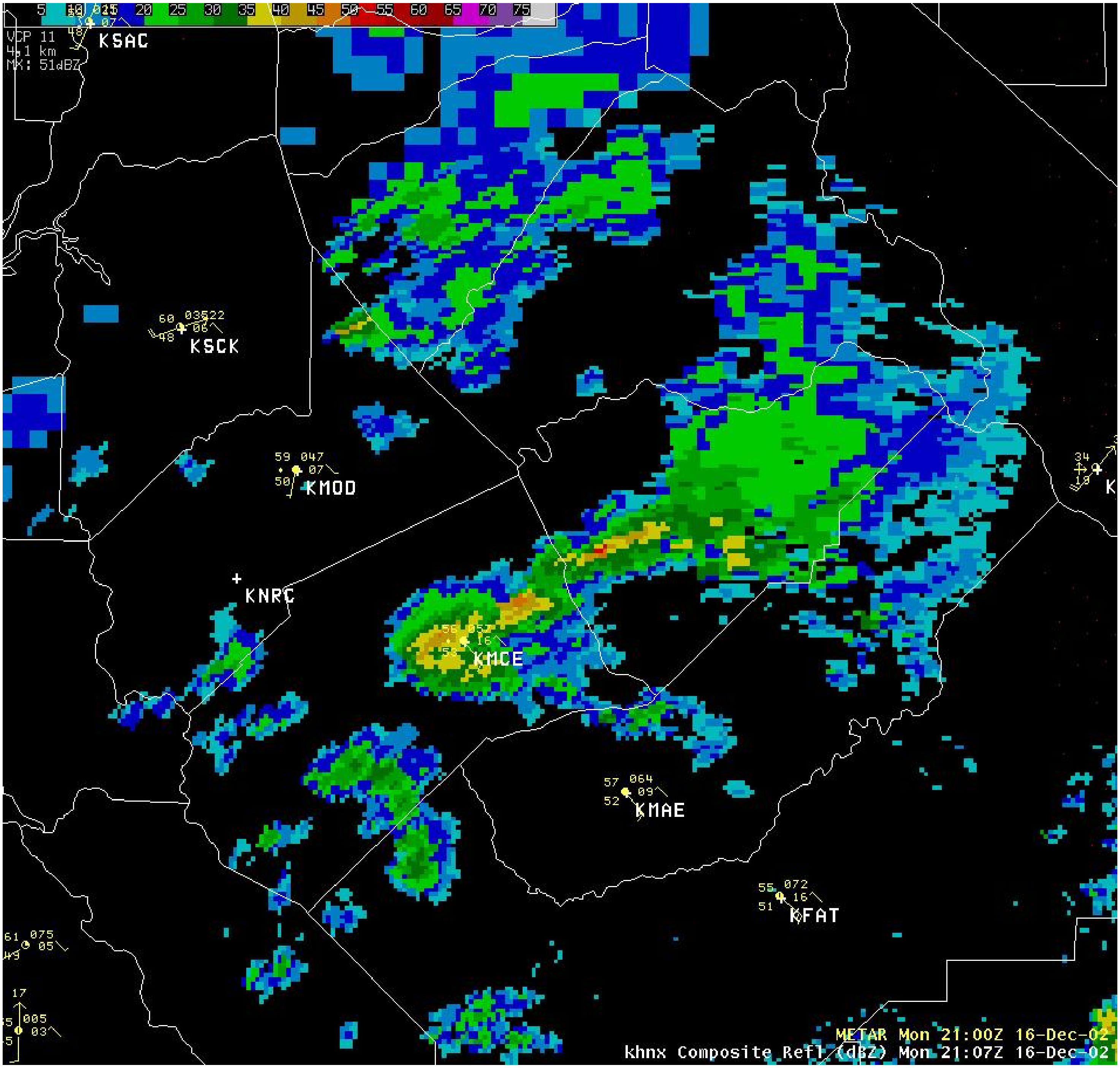

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Figure 5

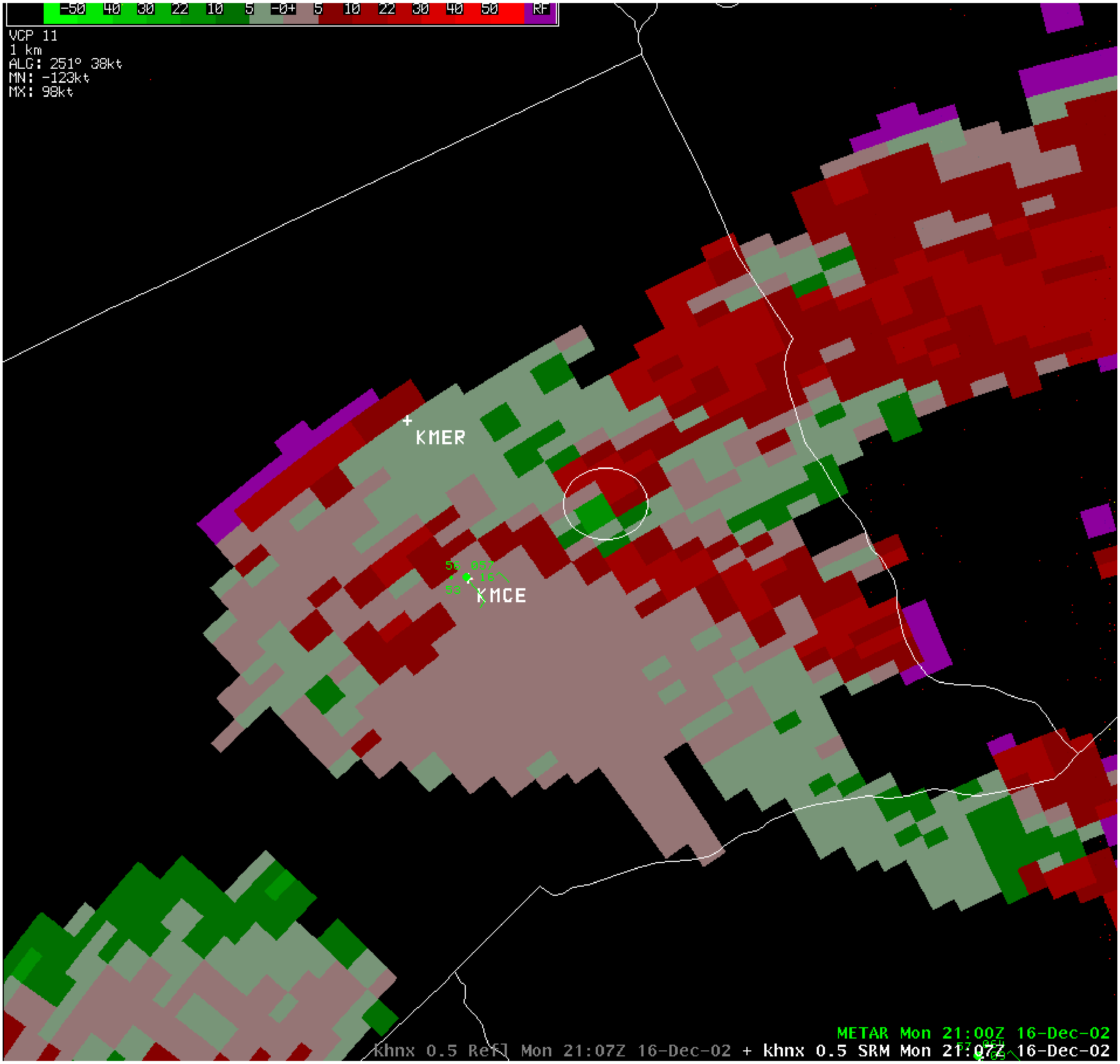
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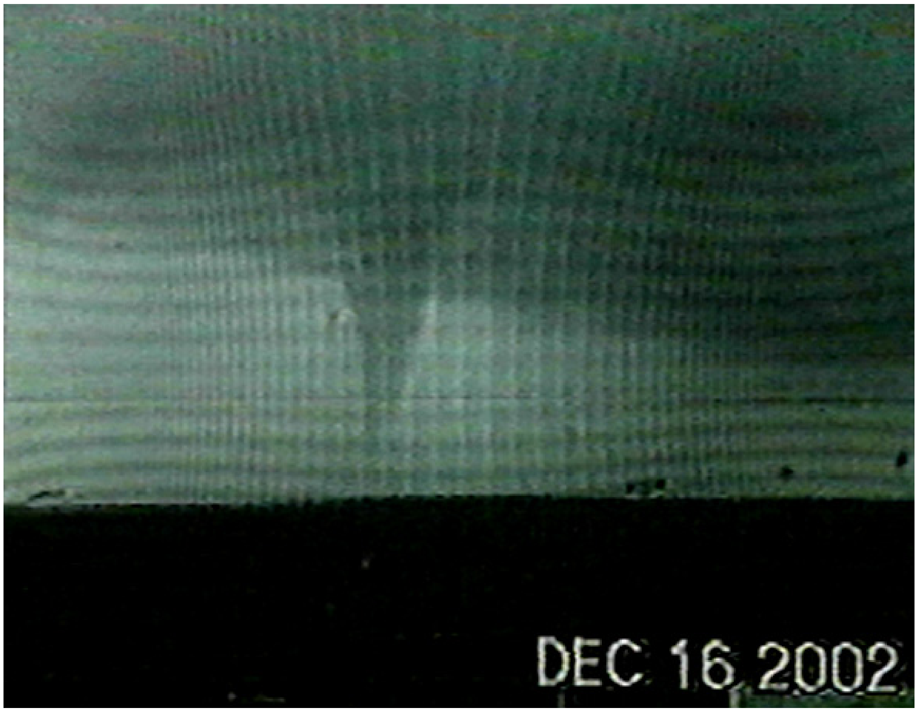
Figure 6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