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# Interaction of Gravity Waves and Horizontal Convective Rolls: Observations from CASA Collected 24 April 2007

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## 1. Introduction

The Center for Collaborative Adaptive Sensing of the Atmosphere (CASA; Chandrasekar et al. 2007) designed and deployed in Oklahoma an experimental network of four X-band radars with overlapping beam coverage and dynamic, adaptive scanning capabilities. During the morning of 24 April 2007 a series of gravity waves passed from west to east across Oklahoma, providing additional buoyancy and thereby enhancing a pre-existing field of horizontal convective rolls (HCR). The HCR were observed within the multi-Doppler region of the CASA network for nearly an hour. This paper describes the development and propagation of the gravity waves and their interaction and contribution towards the development of the HCR.

## 2. Synoptic overview and gravity wave propagation

At 0000 UTC on 24 April 2007, a large trough was centered over the western U.S. with an upper-level jet maxima rounding the base of the trough (Figure 1a). A surface low had developed in southwestern Colorado with a dryline stretching south from the surface low through the Texas panhandle to just west of Lubbock and east of Midland (Figure 1b). A warm front oriented east-west had developed across Kansas. Widespread low-level moisture characterized the warm sector, with a significant capping inversion at ~ 815mb (Figure 2a). Winds at the surface were generally ESE at ~ 10 kts, but at ~850mb low level jet winds were observed at 35-40 kts from the S-SSE; helicity values over 300 $m^2s^{-2}$ were observed. Warm, dry WSW winds were observed above the inversion, leading to a classic "loaded-gun" sounding across the entire warm sector region. These conditions were maintained through the night of 23 April and morning of 24 April (Figure 2b).

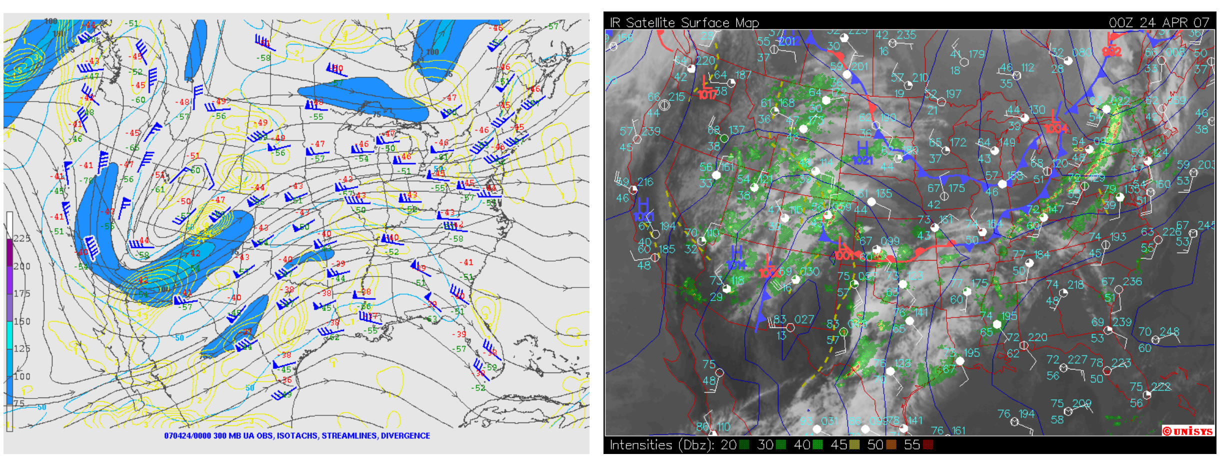


Figure 1: a) Upper air observations and isotachs at 300mb, and b) IR satellite image with surface features at 0000 UTC 24 April, 2007.

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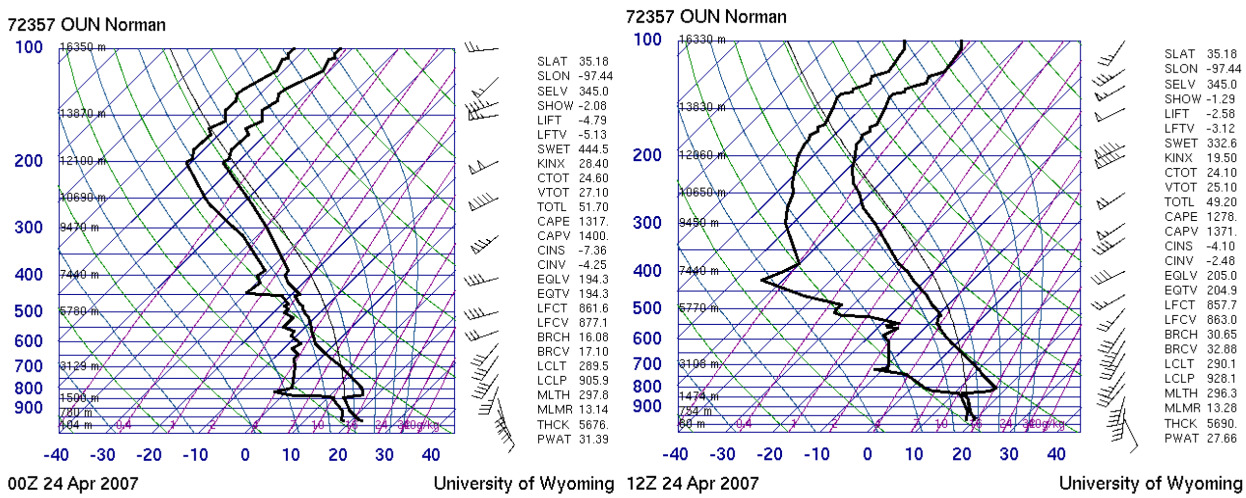


Figure 2: Vertical sounding observations collected at a) 0000 UTC and b) 1200 UTC on 24 April, 2007, from the National Weather Service Forecast Office in Norman, Oklahoma.

## 3. Gravity wave genesis and propagation

During the early evening of 23 April 2007, several bands of precipitation had developed in north-central New Mexico, located about 180 km west of the KFDX radar. These bands were oriented southwest to northeast parallel with the mean wind flow. A series of fine lines, parallel to the precipitation bands, were also evident in radar reflectivity in the vicinity and to the east of the KFDX NEXRAD site. By 0300 UTC (24 April), a new series of lines, or waves, were observed moving east towards KFDX from the precipitation area. These waves were initiated directly beneath the jet exit region, perhaps as a result of baroclinic instability and/or geostrophic adjustment (Uccellini and Koch 1987).

At the same time, a north-south oriented dryline was observed from the KAMA and KLBB radars, visible from Brownfield to Lubbock to Hereford, TX. By 0400 UTC, the dryline had retreated west to the NM-TX border. At approximately 0600 UTC, the wave packet began to intersect the dryline. The interaction between the wave packet and dryline led to momentary wave amplification and a brief line of higher reflectivity. By 0620 UTC, the packet of three to five closely spaced gravity waves continued to move rapidly east from the dryline.

The series of gravity waves propagated east from the NM-TX border just ahead of the dryline at 0615 UTC and reached the TX-OK border by 1015 UTC with an average speed of 19.2 $ms^{-1}$ (Figs. 3, 4). The initial gravity wave was coincident with a surface pressure maxima 1-2 hPa greater than the surface pressure minima coincident with the dryline. The dryline followed approximately 3 hours behind, reaching the TX-OK border by 13 UTC (Fig. 5).

## 4. Horizontal convective rolls

As the gravity waves moved east across Oklahoma, the waves encountered an area of much higher surface dewpoints. The additional buoyancy provided by the waves led to an area of higher reflectivity within the high dewpoint field as observed from KFDR (Fig 5). The precipitation was light enough such that no rainfall was recorded by any Oklahoma Mesonet (Brock et al. 1995) sites.

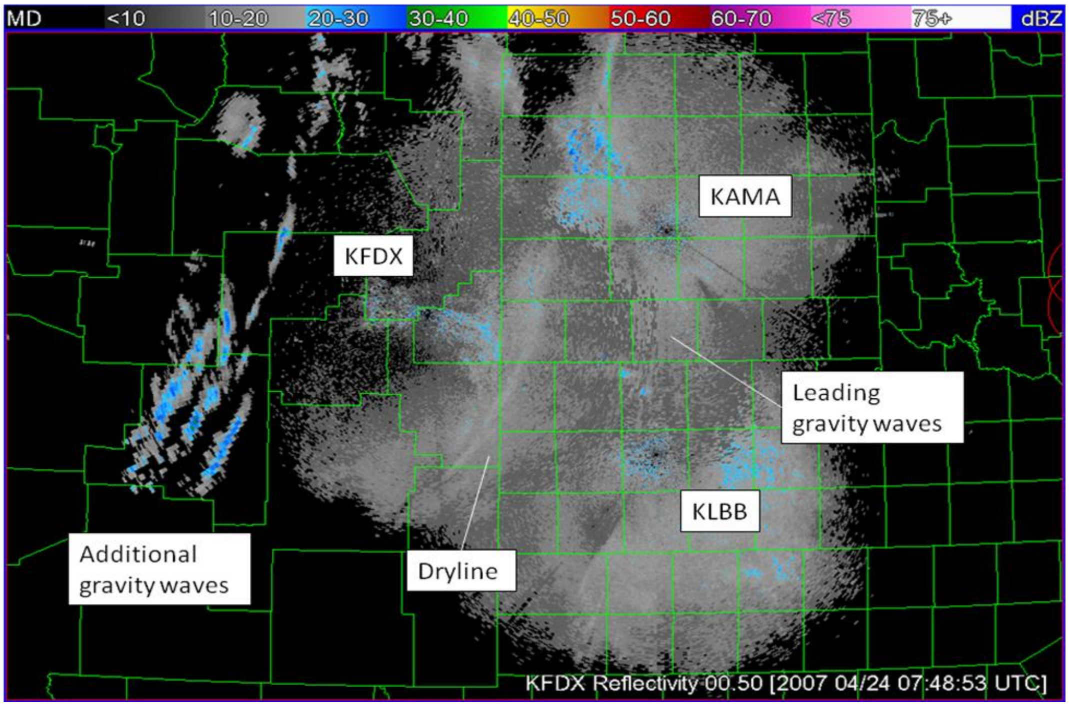


Figure 3: Radar reflectivity from KFDX, KAMA, and KLBB at 0.50 deg elevation at 0748 UTC. Note the leading gravity waves at this time are between the KAMA and KLBB radars, and the dryline is now visible between KAMA and KFDX along the NM-TX border. Additional gravity waves are seen moving east from central New Mexico towards the KFDX radar site.

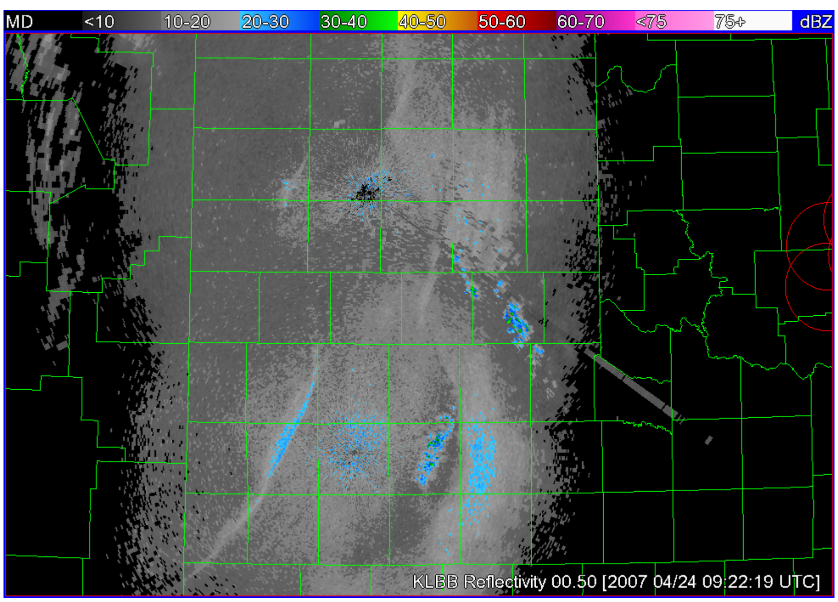


Figure 4: Radar reflectivity from KAMA and KLBB at 0.50 deg elevation at 0922 UTC. The leading gravity waves at this time are approximately 100km to the east of KAMA and KLBB, and the dryline is now visible just to the east of KAMA and to the west of KLBB. Additional gravity waves are seen moving east from central New Mexico towards the KFDX radar site.

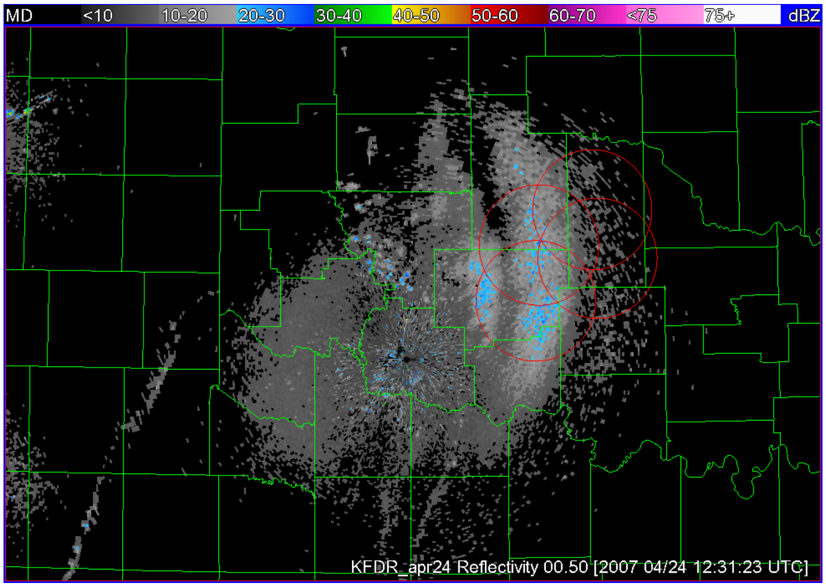


Figure 5: Radar reflectivity from KFDR at 0.50 deg elevation at 1231 UTC. The leading gravity waves at this time are approximately 80 km to the east of KFDR, and the dryline is still visible approximately 125 km to the west of KFDR. Several gravity waves are generating areas of stronger reflectivity within the CASA network test bed (CASA radar coverage area outlined in red).

Fortunately, the location of this area of higher reflectivity coincided with the location of the CASA radar test bed (McLaughlin et al. 2004, Brotzge et al. 2007), a network of four radars with overlapping beam coverage. Each CASA radar scans with an azimuthal sampling of 1.8 degrees (with 1 degree oversampling) and a range resolution of 26 m. At least one 360º PPI is sampled every 60 seconds. Because of the much higher spatial resolution provided by CASA, a field of horizontal convective rolls was identified from the broader region of reflectivity from NEXRAD (Figs. 6, 7). Each roll was estimated at approximately 20 to 30 km or more in length, about 1 km in width, and extended up to 5 km in height. Approximate spacing between rolls was 1.5 to 2 km.

The propagation of the gravity waves could be tracked across the state using Oklahoma Mesonet surface wind and atmospheric pressure data (Fig 8). The leading edge of the gravity wave packet coincided with a small negative perturbation followed by a distinct pressure rise of approximately 1-2 hPa and a temporary veering of the winds. Evidence of two distinct waves was observed at each site. No other surface variables exhibited any significant changes with the passage of the gravity waves.

A number of HCRs were observed throughout the warm sector prior to dryline passage. The development of the HCRs can be attributed to the extreme low-level shear in wind speed and direction and by the strong stability imposed by the inversion at 815 mb. As the gravity wave packet moved east towards Tulsa, it encountered additional, more organized HCRs (Figs. 9, 10). Those observed from NEXRAD data were larger, up to 50 km in length, 1-2 km wide, and spaced approximately 2-8 km apart. Light precipitation was observed from the HCRs across eastern Oklahoma.

## 5. Summary

Research is now underway to assimilate in-situ surface, WSR-88D and CASA radar data, satellite data, and model background field information into the Advanced Regional Prediction System (ARPS; Xue et al. 2003) and ARPS Data Analysis System (ADAS). Once completed, a more careful analysis will be done examining the interaction of the gravity waves and convective rolls. In addition, short-term (3-hour) forecasts will be run to examine the impact of low-level moisture and pressure perturbations on the subsequent development of convection.

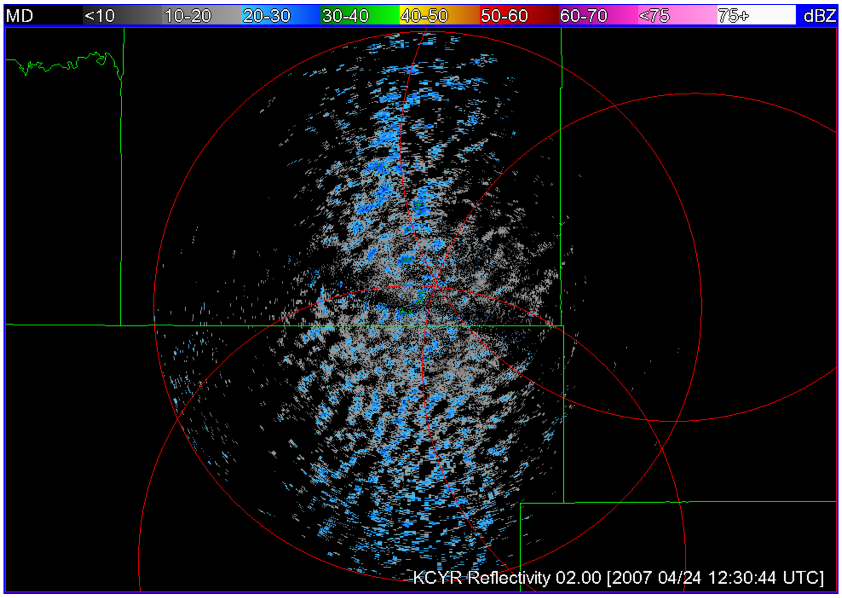


Figure 6: Radar reflectivity from the CASA radar near Cyril (KCYR) at 2 deg elevation at 1231 UTC. Radar range is 30 km. Individual horizontal convective rolls are approximately 1 km in width with approximately 1.5 – 2.0 km spacing between rolls.

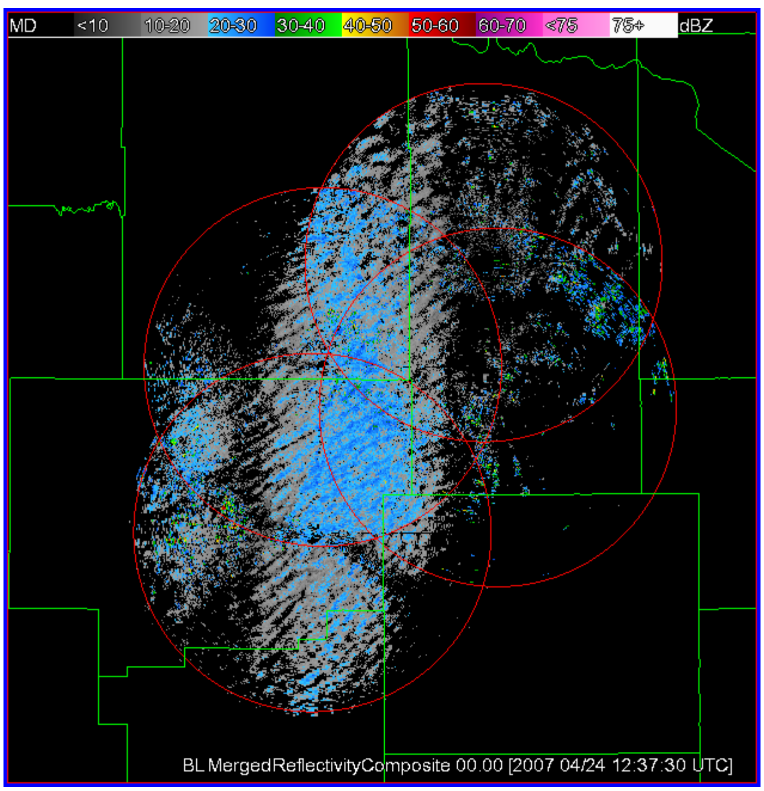


Figure 7: Radar reflectivity merged from all four CASA radars at 1238 UTC. Reflectivity data are merged by displaying the maximum reflectivity observed from within each vertical column.

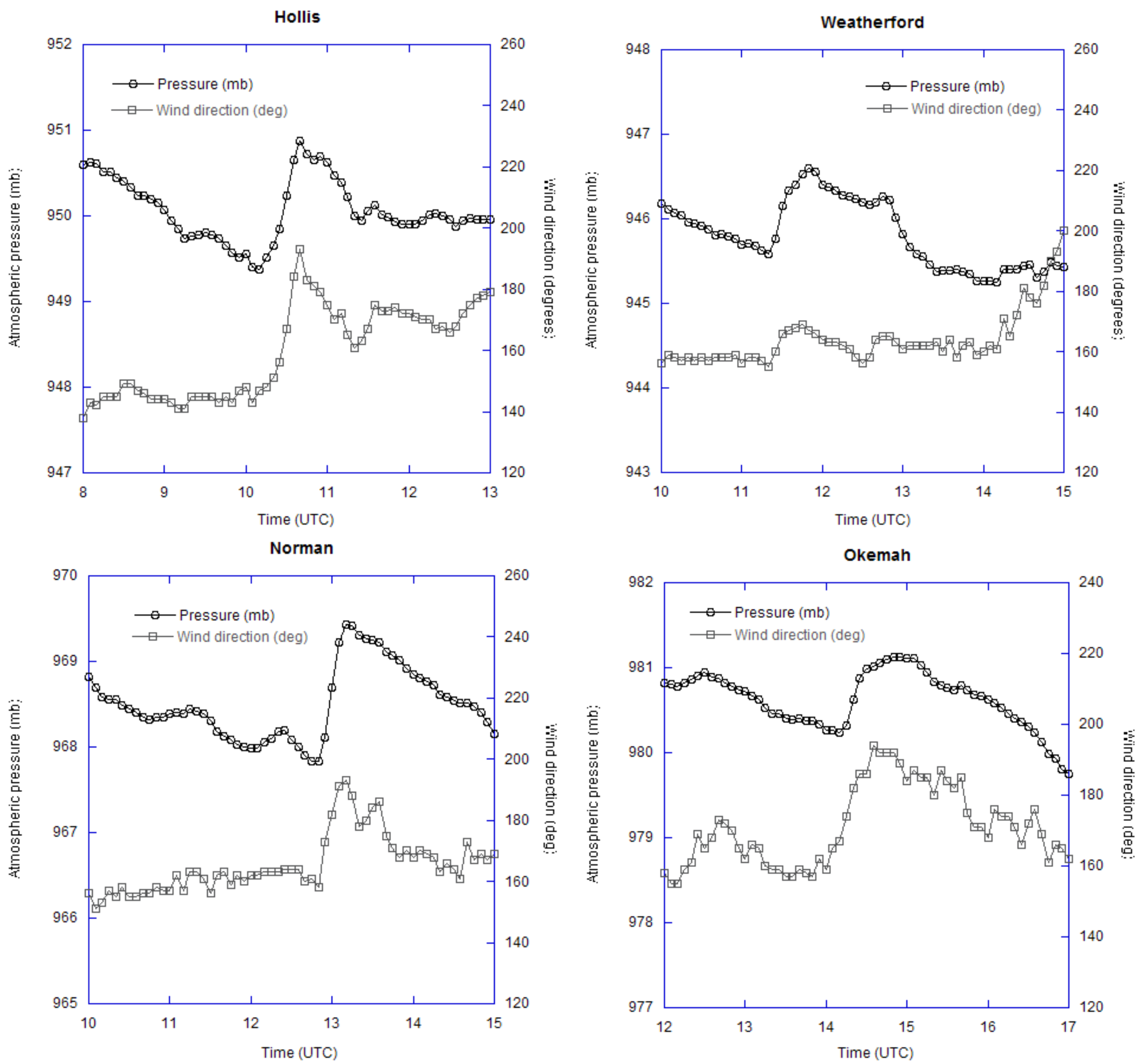


Figure 8: Atmospheric pressure (mb) and wind direction (degrees) data are shown from four Oklahoma Mesonet sites – Hollis (southwest OK), Weatherford (west-central OK), Norman (central OK), and Okemah (east-central OK).

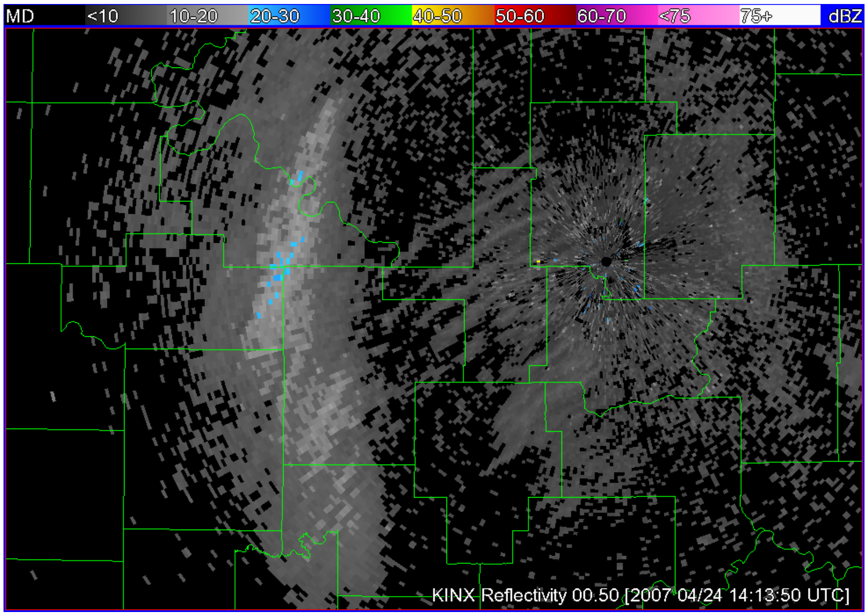


Figure 9: Radar reflectivity from the NEXRAD radar at Tulsa (KINX) at 0.5 deg elevation at 1413 UTC.

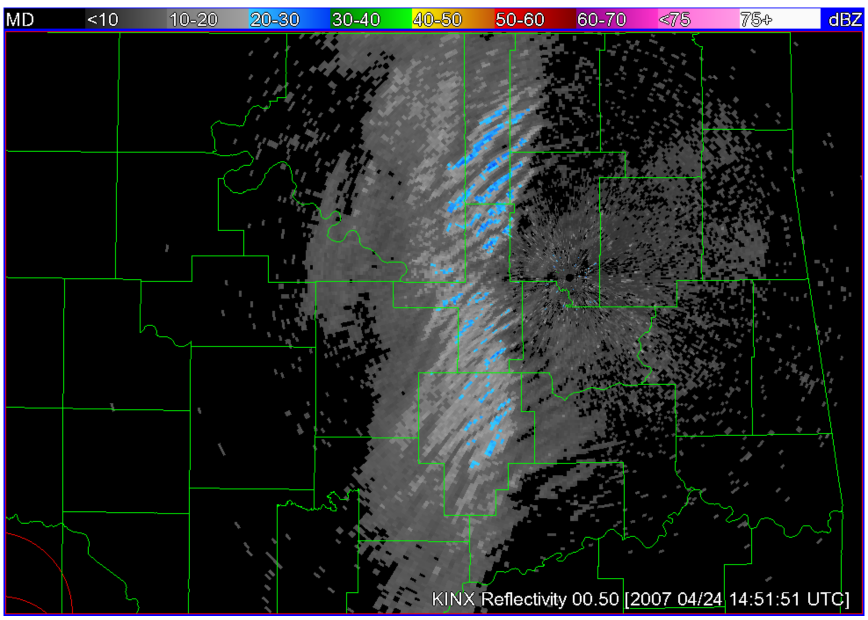


Figure 10: Radar reflectivity from KINX at 0.5 deg elevation at 1451 UTC.

## ACKNOWLEDGEMENTS

This work was supported primarily by the Engineering Research Centers Program of the National Science Foundation under NSF Cooperative Agreement No. EEC-0313747. Any Opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect those of the National Science Foundation.

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