2003 BELTWIDE COTTON CONFERENCES, NASHVILLE, TN – JANUARY 6-10

NOCTURNAL MIGRATIONS OF COTTON INSECT PESTS INDICATED BY DOPPLER RADAR OBSERVATIONS

J.K. Westbrook and R.S. Eyster
Areawide Pest Management Research Unit
USDA, ARS, SPARC
College Station, TX

Abstract

An outbreak of beet armyworms and other lepidopterous pests devastated cotton production in the Lower Rio Grande Valley of Texas in 1995. Major infestations occurred later in the year at San Angelo and other cotton production areas in Texas and Oklahoma, but there have been no reports that connected the infestations by these migratory pests. The objective of this study was to evaluate the capability of a WSR-88D Doppler radar to locate and monitor pest emigration from severely infested areas. We found that discrete (source) areas of maximum radar reflectivity (13.5 to 16.5 dBZ) appeared approximately 0.5 h after sunset, and displaced downwind. The source areas were located in the vicinity of major infestations in cotton by beet armyworms, loopers, and bollworms/budworms reported in Willacy County, TX. We envision that, at a minimum, the WSR-88D Doppler radar data can be coupled with atmospheric data to estimate the timing and intensity of dispersal of migrating insect pests for use in crop advisories.

Introduction

Historical Pest Outbreak in the Lower Rio Grande Valley

Cotton production in the Lower Rio Grande Valley of Texas suffered catastrophic losses and substantial control costs in 1995 due to infestations by the beet armyworm, *Spodoptera exigua* (Hübner), and cabbage looper, *Trichoplusia ni* (Hübner) (Summy et al. 1996). Beet armyworms reduced 1995 cotton yields in the Lower Rio Grande Valley by 50%, despite receiving five insecticide applications for their control (Williams 1996). Heavy beet armyworm and cabbage looper infestations in cotton in 1995 were reported in the Lower Rio Grande Valley in late-May and early-June and San Angelo, TX, in late-July, and moderate infestations were reported in other cotton production areas of Texas and Oklahoma (Norman and Sparks 1995, Huffman 1996).

Entomological Radar Detection of Moth Flights

For more than 30 years, scientists have used radars to monitor high-altitude migratory flights of moths. Since 1982, the U. S. Department of Agriculture (USDA) has operated entomological radars to detect flights of adult corn earworms (bollworms), *Helicoverpa zea* (Boddie), from infested corn fields in the Lower Rio Grande Valley. The USDA entomological radars detect bollworm-size targets to a maximum range of about 1.2 km, with the antenna pointed toward zenith or scanning at one revolution per three seconds.

Bollworm moths begin migratory flights at about 0.5 h after sunset. Flight activity near source areas peaks at about 1.0 h after sunset and decreases steadily until about 0.5 h before sunrise. Migrating moths are distributed within the lowest 1 to 2 km of the atmosphere and often congregate in dense layers at approximately 500 m altitude where nocturnal wind jets prevail (Wolf et al. 1995). Entomological radars determined that migrating bollworm moths ascend at approximately 1.5 m/s (Wolf et al. 1994) and fly at approximately 4.5 m/s (Westbrook et al. 1994). Thus, migrating bollworm moths could ascend to an altitude of 500 m in 5 to 6 minutes.

WSR-88D Doppler Radar (NEXRAD) Detection of Airborne Biota

The National Weather Service replaced a 1950-era radar (WSR-57) with a state-of-the-art WSR-88D Doppler radar at Brownsville, TX, in 1995. The WSR-88D radar operates with increased detection sensitivity and with the capability to measure the radial velocity of radar targets including insects. The WSR-88D radar completes a 360-degree azimuthal scan at seven to eleven elevation angles within six minutes for precipitation-tracking mode or ten minutes for clear-air mode. The WSR-88D radar measures volume reflectivity within 1° X 1° X 1 km radar sample volumes (approximately one billion cubic meters). The reflectivity within the radar sample volume is set equal to 10 * $\log_{10}$ (concentration of small water droplets that would return the amount of energy received by the radar), and defined in units of decibels (dBZ). Higher reflectivity values indicate higher amounts of transmitted energy are reflected back to the radar receiver by several large targets, numerous small targets, or a combination of targets.

WSR-88D radar reflectivity data have been correlated with entomological radar count data to derive a quantitative relationship between radar reflectivity and aerial concentrations of bollworm-size insects. Westbrook et al. (1998) found that the logarithmic transformation of bollworm-size insect concentration was highly correlated with WSR-88D radar reflectivity (maximum $R^2 = 0.89$). We assumed in this study that the WSR-88D radar could similarly detect beet armyworm and cabbage looper moths which are slightly smaller than bollworm moths.

Beet armyworm moths are migratory like many other noctuids, including bollworm moths, and it is possible that the population of beet armyworms in the Lower Rio Grande Valley contributed to subsequent infestations across Texas and Oklahoma. In cases like this, it would be valuable to have a method of predicting the timing and intensity of the pest migrations as a warning to growers, extension agents, consultants, and farm suppliers. The objective of this study was to evaluate the capability of a WSR-88D Doppler radar to identify pest emigration from a known infestation of beet armyworms.

Methods

Land Use Information and Geography

Farm and tract information and a 1-m resolution satellite image of Willacy County, TX, was obtained from the USDA / Farm Service Agency at College Station, TX. This information was displayed in an ArcGIS map along with the boundaries of high reflectivity areas detected by the WSR-88D radar at Brownsville, TX. The farm tract information was extracted by intersecting the high reflectivity polygons and the tract information. The resulting crop data layer included those tracts which were either fully or partially contained within the high reflectivity polygons.

Crop Infestation Records

Heavy pest infestations were reported in the Raymondville, Lyford, and Sebastian areas of Willacy County in 1995 (J. E. Christian, personal comm.). Insecticide applications targeted heavy aphid infestations from 10-15 May 1995. Egg counts of beet armyworms, loopers, and bollworms/budworms began increasing substantially from 15-20 May 1995, and peaked from 7-15 June 1995 with values as high as 180,000 beet armyworms per acre, 200,000 loopers per acre, and 12,000 bollworms/budworms per acre.

WSR-88D Doppler Radar Data

WSR-88D radar data was purchased on 8-mm tape for the time period corresponding to the beet armyworm outbreak in the Lower Rio Grande Valley of Texas in early June 1995. Each tape contains reflectivity, velocity, and velocity spectrum width data for each scan of the WSR-88D radar at Brownsville. Data were read from the tapes using the Interactive Radar Analysis Software (IRAS) package (Version 102797). Minor revisions were made to the code to output mean and maximum reflectivity and area of reflectivity. The raw data from the tapes was transferred to another computer for further analysis using ArcGIS 8.2.

IRAS software was used to display the reflectivity, velocity and velocity spectrum width for each scanned elevation angle. The two lowest scan angles (0.5° and 1.5°) were used because radar reflectivity did not exceed 0 dBZ at angles > 1.5° over the analysis area from the evening of 31 May 1995 through the evening of 10 June 1995. During this period, maximum radar reflectivity occurred over the western half of Willacy County, TX. Three areas were defined for analysis in this study. The smallest area (i.e., source) was defined by the boundary around radar reflectivity ≥ 8 dBZ at 2044 CDT on 10 June 1995. A second, larger area (i.e., cloud) was defined by the boundary around radar reflectivity ≥ 10 dBZ at 2107 CDT on 10 June 1995. The third area was defined as the western half of Willacy County. Data analysis was restricted to the period from 2030 to 2200 CDT.

Maximum reflectivity, mean reflectivity, and the area of reflectivity ≥ 0 dBZ were determined using the ATI Analysis routine in IRAS. Mean reflectivity was converted to a color number from 0 to 64, where color number 0 = -32 dBZ and color number 64 = 32 dBZ. The color number for each 1° X 1° X 1 km radar sample volume was summed for each analysis area and divided by the total number of radar sample volumes in each analysis area. Mean color number was converted back to a mean reflectivity value. Maximum reflectivity was the actual maximum reflectivity value within each sampling area. Area of reflectivity ≥ 0 dBZ was determined by taking the area of each radar sample volume with reflectivity ≥ 0 dBZ and summing them for each analysis area. Data were analyzed between 2038 CDT and 2148 CDT during the study period.

Latitude and longitude of the WSR-88D radar at Brownsville was projected to UTM NAD83 Zone 14 coordinates. Raw azimuth and range data for each sample volume were projected to UTM coordinates. True areas and distances were calculated and imported into ArcGIS v8.2 for GIS display and analysis. Imported data were limited to a sector from 310° azimuth to 355° azimuth and a range from 40 km to 100 km. Data were gridded using Standard Kriging with default values. Raw radar data were output to a grid with a horizontal resolution of 1 km. A masking polygon was applied to limit the radar data to the area of western Willacy County.

Results and Discussion

Early-evening maximum reflectivity was consistently located in south-central Willacy County from 2-10 June 1995. Nightly radar scans (0.5 degrees elevation) at the onset of increased radar reflectivity between 2049 CDT and 2056 CDT revealed a recurring area of reflectivity ≥ 0 dBZ (Figure 1). Maximum reflectivity areas (i.e., possible sources of moths) were located about 12 km and 23 km east-southeast of Lyford, TX.

The evolution of increasing reflectivity in a single evening is shown in Figure 2. Reflectivity on 8 June 1995 first exceeded 0 dBZ on the radar scan at 2046 CDT in south-central Willacy County. Two reflectivity maxima were detected in the subsequent scan at 2052 CDT. Reflectivity ≥ 0 dBZ covered all of western Willacy County by 2013 CDT. The area of maximum reflectivity ≥ 15 dBZ spread out and displaced downwind from 2110 CDT to 2139 CDT.

Radar reflectivity over the source areas from 2030 to 2200 CDT was generally consistent from 2 June to 10 June 1995 (Figure 3). Maximum radar reflectivity ranged from 13.5 to 16.5 dBZ. Mean radar reflectivity ranged from approximately 6 to 8 dBZ.

Radar reflectivity over the source areas in south-central Willacy County remained above 0 dBZ from approximately 2038 CDT until at least 2158 CDT (Figure 4). The mean value of nightly maximum radar reflectivity peaked (14 dBZ) at approximately 2118 CDT. The mean value of nightly mean radar reflectivity peaked (9 dBZ) at approximately 2114 CDT.

Two source areas of maximum reflectivity (> 6 dBZ) were located 12.5 km and 23.5 km east-southeast of Lyford, TX, at 2052 CDT on 8 June 1995 (Figure 5). The areas of maximum reflectivity were over areas of extensive cotton or "other" crop cover. The "other" crop classification represents an uncertain crop type and does not preclude the possibility of representing cotton for particular fields. Data from the National Agricultural Statistics Service indicate that there were 102,400 acres of cotton planted of which 30,300 acres were harvested in 1995. From the Farm Service Agency data, there were approximately 32,000 acres listed as cotton and approximately 36,000 acres listed as "other." There were several areas that had no crop information, including one which was known to have been planted in cotton in 1995.

The results of this study suggest that the national network (NEXRAD) of WSR-88D Doppler radars can detect highly-infested source areas of emigrating noctuid pests including beet armyworms and cabbage loopers. One challenge that must be addressed is to completely document crop types for all fields and eliminate the uncertainty of the "other" crop category. Also, field surveys of pest insects would lead to the addition of a pest infestation (and life stage) data layer. Finally, identification of the airborne targets is needed and may be obtained by physical sampling (e.g., aircraft nets) or by remote sensing (e.g., entomological radars). We envision that, at a minimum, the WSR-88D Doppler radar data can be coupled with atmospheric data to estimate the timing and intensity of dispersal of migrating insect pests for use in crop advisories.

Acknowledgment

John Norman, entomologist with the Texas Agricultural Extension Service at Weslaco, TX, and John Christian, crop consultant from Raymondville, TX, provided weekly summaries of crop infestations in the Lower Rio Grande Valley. Bryan Crook, geographic information systems specialist with the U. S. Department of Agriculture, Farm Service Agency at College Station, TX, provided crop distribution data.

Disclaimer

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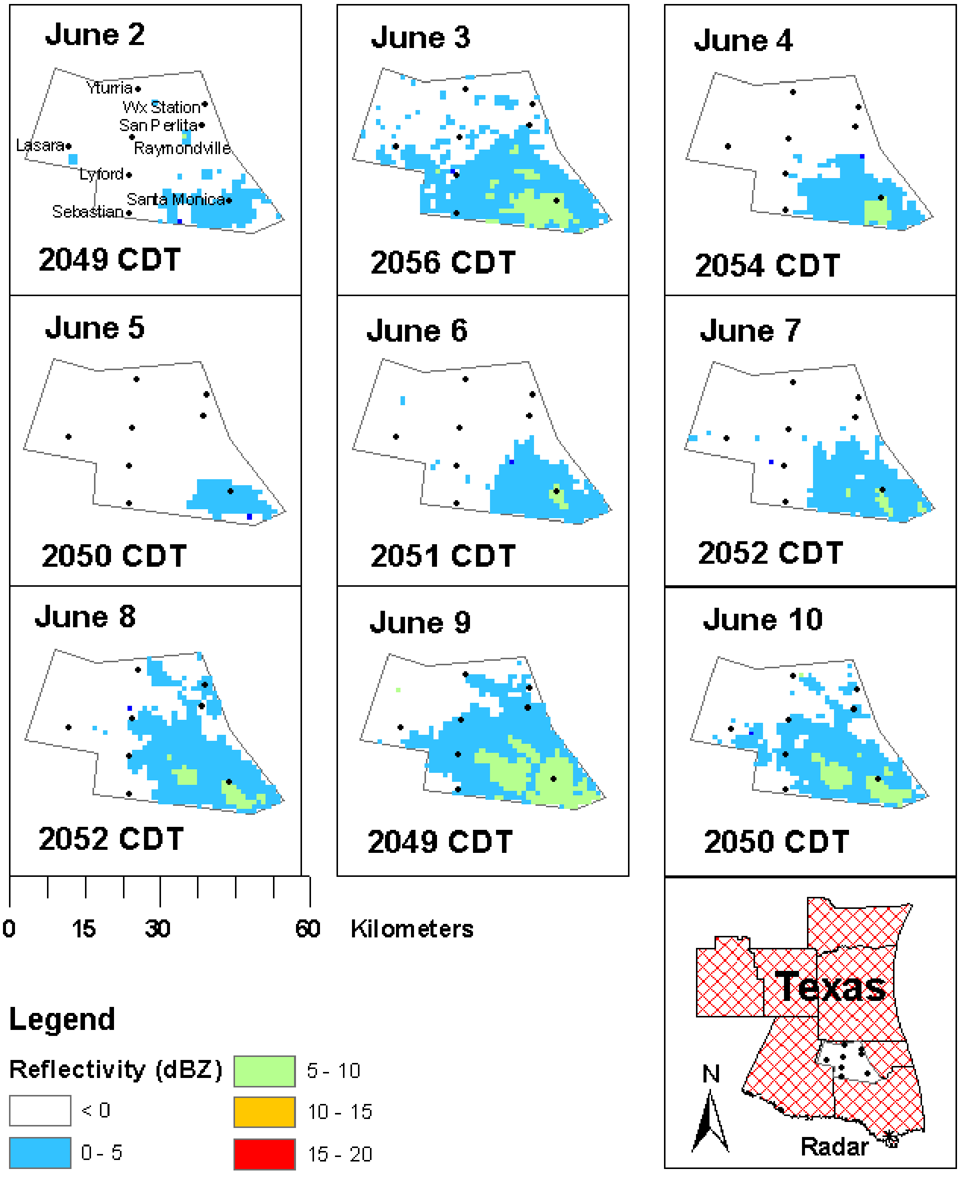

Figure 1. Nightly onset of increased radar reflectivity over western Willacy County, TX, from 2-10 June 1995.

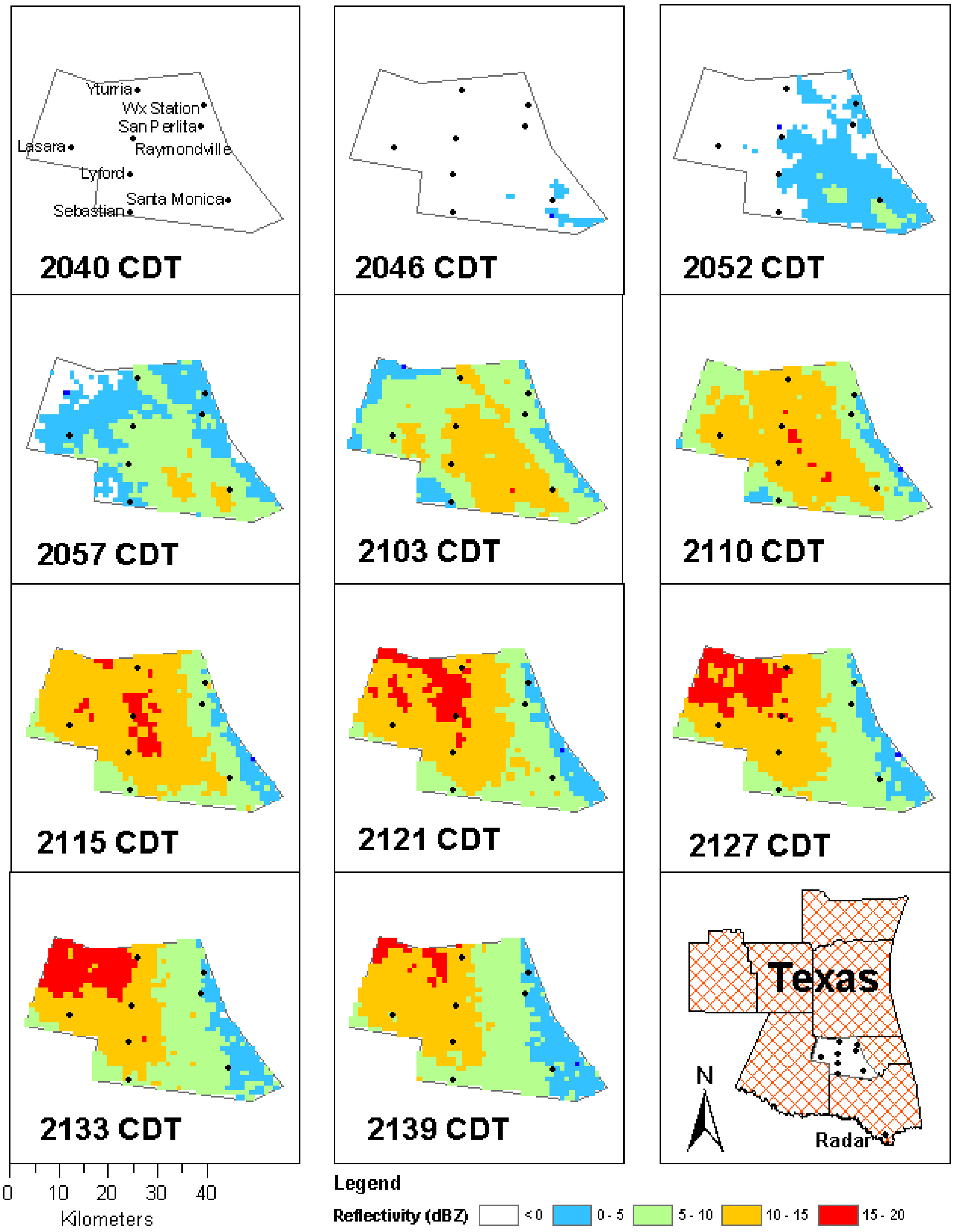

Figure 2. Evolution of increasing radar reflectivity over western Willacy County, TX, on 8 June 1995.

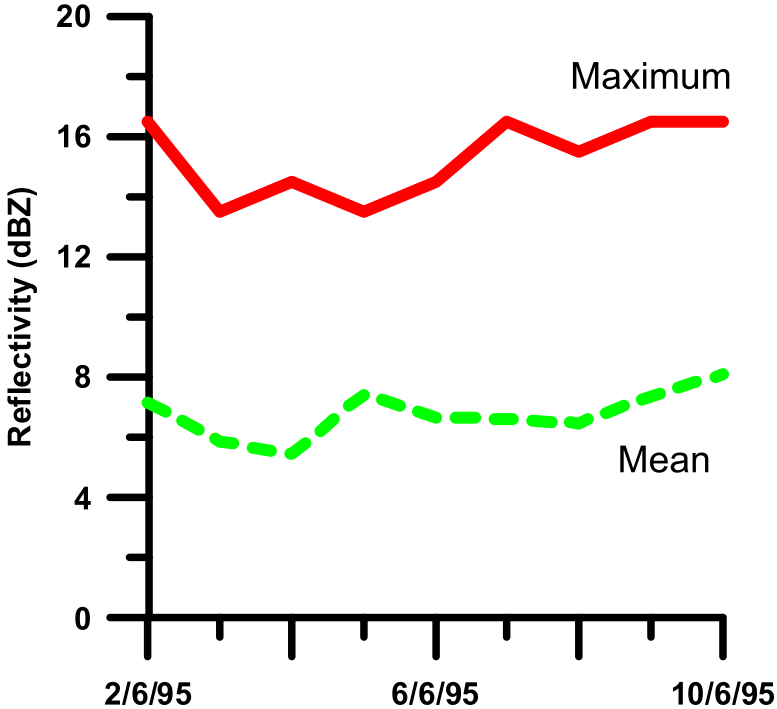

Figure 3. Maximum radar reflectivity and mean radar reflectivity from approximately 2030 to 2200 CDT over source areas in south-central Willacy County, TX, from 2-10 June 1995.

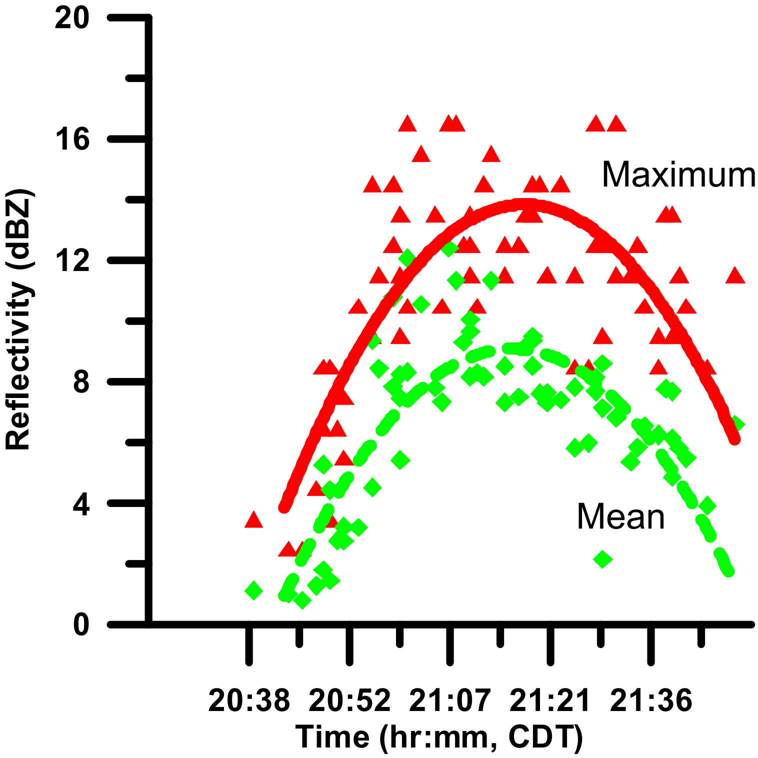

Figure 4. Evolution of radar reflectivity over source areas in south-central Willacy County, TX, from approximately 2030 to 2200 CDT on 9 June 1995.

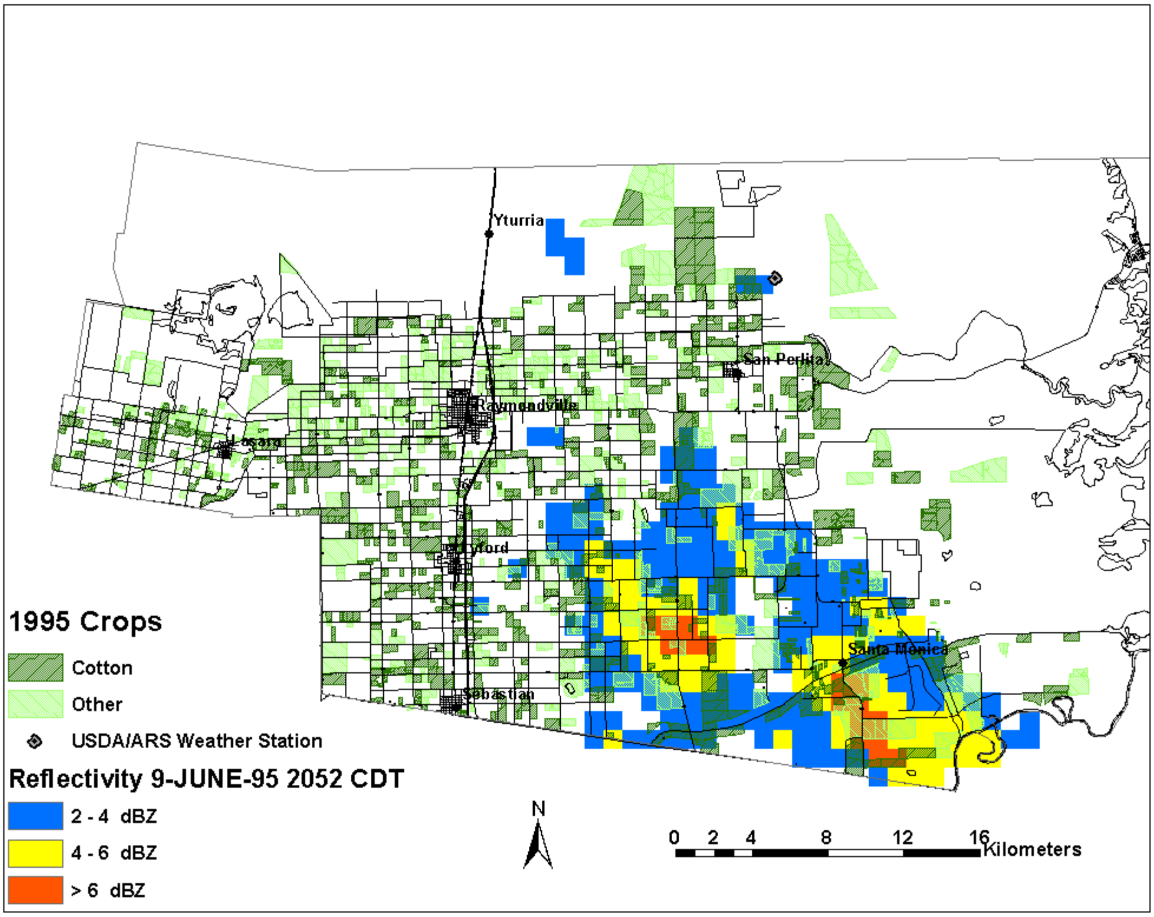

Figure 5. Overlay of the 1995 cotton distribution and radar reflectivity at 2052 CDT on 8 June 1995 in Willacy County, TX.