# 2.1 APPLICATION OF VAISALA VHF TOTAL LIGHTNING MAPPING NETWORK DATA AT NWS FORT WORTH/DALLAS

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## 1. INTRODUCTION

Data from the Dallas – Fort Worth (DFW), Texas area Lightning Detection and Ranging (LDAR II) system has been delivered in real-time to the Fort Worth/Dallas (FWD) Weather Forecast Office (WFO) since late 2004. LDAR II detects > 95% of all total (cloud plus cloud-to-ground) lightning flashes and can map the horizontal extent of these flashes in three dimensions. Since the majority of lightning stays in the clouds and never reaches the ground (typically 3:1 cloud:cloud-to-ground ratio across the continental U.S., Boccippio et al. 2001), VHF total lightning mapping networks, such as LDAR II, can provide valuable thunderstorm data for the meteorological community. Data with a 2 minute update interval is being sent to the FWD Advanced Weather Interactive Processing System (AWIPS) system from Vaisala, Inc. via a server located at the National Weather Service Southern Region Headquarters Office in downtown Fort Worth TX. Images of Flash Extent Density (FED), Flash Initiation Point Density, and Source Density can be viewed on AWIPS workstations running Display 2-Dimensional (D2D) software. FED imagery seems to be the most versatile of the three available data types for use in an operational forecast setting and is not as susceptible to range degradation effects.

This paper focuses on recent uses of total lightning mapping data at WFO FWD. Several specific examples are used to illustrate how the data was especially valuable to forecasters for visualizing and understanding the cloud-to-ground (CG) lightning threat in areas well-removed from the higher radar reflectivity regions. While other studies have shown examples focused heavily on the use of total lightning mapping data as a severe thunderstorm aid (McKinney 2008; Patrick and Demetriades 2005; Goodman et al. 1998), this work will highlight cases in which total lightning data provided startling clues on CG lightning threat in areas up to 150 km away from radar reflectivity cores. These cases have significant implications with regard to strategies dealing with aviation forecasting and public safety and awareness.

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## 2. BACKGROUND AND DATASETS

The DFW LDAR II network is currently comprised of 9 sensors with 20 to 30 km baselines (Fig. 1). These sensors detect pulses of radiation (sources) produced by the electrical breakdown processes of lightning in 5 MHz VHF bands that currently have center frequencies ranging from 61 to 64 MHz. These pulses of radiation are used to reconstruct the path of individual cloud and CG lightning flashes in three dimensions. Two sensors were added to the 7-sensor network in 2007, which effectively upgraded the reliability and quality of the data.

The DFW LDAR II network can map lightning flashes in three dimensions within approximately 150 km of the center of the network, degrading in performance with increasing range. Lightning flash detection efficiency is expected to be greater than 95% within the interior of the network (a range of 30 km from DFW International Airport – sensor labeled as DFW in Fig. 1) and greater than 90% out to a range of 120 km from DFW. Expected three-dimensional location accuracy for individual pulses of radiation is between 100 m and 200 m within the network interior, and better than 2 km to a range of 150 km from the center of the network.

Nine total lightning mapping products are currently being sent to WFO FWD. Seven of these products consist of VHF lightning source densities that are accumulated in different altitude slices. The other two total lightning mapping products consist of lightning flash information: Flash Initiation Point Density and Flash Extent Density (FED). The initiation point of a flash is defined as the first VHF lightning source detected by a lightning detection network after all lightning sources are grouped together into flashes according to specific time and space criteria. FED is defined as the number of lightning branches that pass through a specific 1 $km^2$ grid box during a two-minute interval after all sources are grouped into flashes. FED has proven to be the single most useful product at WFO

FWD since it provides forecasters with a consistent product that is not as susceptible as source density to range degradation effects.

The times and locations of CG lightning flashes were provided by Vaisala's National Lightning Detection Network (NLDN). This network detects ~95% of all CG lightning flashes within the continental U.S. with a median location accuracy of 500 meters (Biagi et al. 2007; Jerauld et al. 2005).

All radar reflectivity imagery shown in this paper was taken from data derived from the network of Weather Surveillance Radars - 1988 Doppler (WSR-88Ds). Klazura and Imy (1993) give an overview and description of the base and derived products produced by WSR – 88Ds.

## 3. RECENT EXAMPLES OF FED

Several examples of Flash Extent Density imagery in AWIPS D2D and related CG lightning flashes between 40 km and 105 km away from the highest radar reflectivity values will be shown and discussed. The examples are grouped into two main categories: lightning flashes that propagated downwind (i.e. anvil regions) of significant deep convection and lightning flashes that propagated through regions of lower radar reflectivity (i.e. stratiform regions) near mesoscale convective systems (MCSs).

### *3.1 CG Lightning Downwind of Significant Convection*

Figure 2 depicts an example of cloud lightning that propagated approximately 95 km away from the highest radar reflectivity region on 17 April 2008. Figure 2a shows a supercell thunderstorm east of Mineral Wells TX (KMWL) over Parker County. The total lightning product in Fig. 2b depicts a maximum in FED values near the 65 dBZ reflectivity core associated with the supercell in Parker County. An area of low FED extends northeast from the FED maximum for 95 km, which stretches halfway across Denton County to a point just northeast of Denton TX (KDTO). Although no CG flashes were detected by the NLDN across Denton County during this time, this example serves to document the lightning threat in areas far downwind of high radar reflectivity signatures and CG flash maxima.

Figure 3 shows an example of a cloud flash that originated in the anvil region of the supercell thunderstorm on 17 April 2008. The intense supercell storm was in Parker County (Fig. 3a) with the detached downwind flash centered across southern Denton County (Fig. 3b). Based on observations of FED at WFO FWD, most anvil lightning activity has a continuous path that originates close to the highest radar reflectivity values (as in Fig. 2). The cloud lightning flash depicted in Fig. 3b was one of several anvil-initiated flashes noted with the supercell on 17 April 2008.

Another example of lightning in regions downwind of highest radar reflectivity is shown in Fig. 4. In this case, the northern part of a linear MCS was associated with radar reflectivity values over 50 dBZ and FED maxima located across Johnson County and southern Tarrant County. Figure 4b depicts the extensive lightning activity that was propagating downwind of the MCS, with several CG flashes noted on NLDN data across Dallas County. Three CG flashes occurred in one minute across Dallas County despite the lack of any 40 dBZ or higher radar returns; the most distant CG was 60 km from the nearest 40 dBZ radar echoes. The FED imagery in this case served to illustrate the origins of the charges associated with the CG activity across Dallas County.

### *3.2 CG Lightning in Stratiform Regions of MCSs*

Lightning activity occurred northwest of the highest radar reflectivity associated with a linear MCS on 18 April 2008. Figure 5 highlights an example of both cloud and CG lightning northwest of the MCS at 0412 UTC. The highest radar reflectivity values (50 dBZ – 60 dBZ) were noted across Kaufman and Van Zandt Counties as the MCS moved to the east. A large cloud flash, with an apparent origin near the highest reflectivity in Kaufman County, extended northwest and then southwest across Dallas County (Fig. 5b). Two cloud-to-ground flashes occurred across Dallas County and were associated with the large cloud flash. This example illustrates the complex nature of lightning flash origins: the Dallas County flashes did not initiate near the high radar reflectivities across Dallas County but instead appeared to initiate near convection with even higher reflectivities that was located 40 km to the east.

Figure 6 is a startling illustration of extensive cloud and isolated CG lightning activity that is well removed from the highest reflectivity region of an MCS that occurred during the fall of 2006. The movement of the convective system was to the southeast at 8 m $s^{-1}$. The composite radar reflectivity (Fig. 6a) shows the highest reflectivity values in several clusters across Parker, Hood, and Johnson Counties. The corresponding image of FED and NLDN (Fig. 6b) shows low values of FED extending across a large part of Dallas County and Collin County where composite reflectivity values were generally between 20 dBZ and 30 dBZ. Two isolated CG lightning flashes occurred at great distances from the initiation of their parent cloud flash near the radar reflectivity core in Johnson County: one CG flash was noted in northeast Dallas County 95 km northeast of the radar reflectivity core; another CG flash in southern Collin County was 105 km from the reflectivity core. In this example, the FED imagery serves to both highlight the lightning threat in areas removed from higher reflectivity and to aid real-time understanding of seemingly random isolated CG flashes across Dallas and Collin Counties.

## 4. CONCLUSIONS

The examples shown suggest that FED imagery can be used operationally to more fully comprehend the lightning threat, especially in situations where lightning is occurring in areas well-removed from the highest radar reflectivity. In all of the examples, the lightning threat would be difficult to ascertain using only a combination of WSR-88D imagery and traditional NLDN data. By assimilating total lightning data with radar and NLDN data, operational forecasters are able to visualize the horizontal extent of the CG lightning threat and assess that CG threat over time. This visualization has a high potential to increase the quality of not only short term forecast products related to public safety but also services relating to aviation weather and airport operations.

The Geostationary Lightning Mapper (GLM) instrumentation on Geostationary Operational Environmental Satellite Series R (GOES-R) will provide continuous day and night observations of total lightning over the full-disk (Goodman et al. 2008). Based on recent experiences at WFO FWD, some of which are discussed in this paper, one of the highest valued applications of the GLM dataset may be the real-time knowledge of the horizontal extent of the lightning threat near ongoing convection.

## 5. FUTURE WORK

This paper provides further confirmation that isolated thunderstorms and MCSs can routinely produce cloud lightning flashes that propagate distances of 50 – 150 km through attached forward anvils and stratiform rain regions (see also Carey et al. 2005; Ely et al. 2008; Patrick and Demetriades 2005). We have also shown cloud lightning flashes that initiated in the forward anvil region of a thunderstorm and remained isolated in space from active charge separation occurring in the higher reflectivity core of the storm. This raises a few questions for future research. First, why do some long-distance anvil and stratiform cloud lightning flashes produce isolated CG lightning flashes and others do not? Second, why are isolated cloud lightning flashes initiating in forward anvil regions of thunderstorms and how often do they occur?

The idea of creating a time-integrated flash density product is being explored. An enhanced, graphical lightning hazard message could be distributed from AWIPS by creating a 20 to 30 minute summation of total lightning activity; this type of product could help delineate the CG lightning threat in stratiform regions of mesoscale convective systems and thunderstorm anvils.

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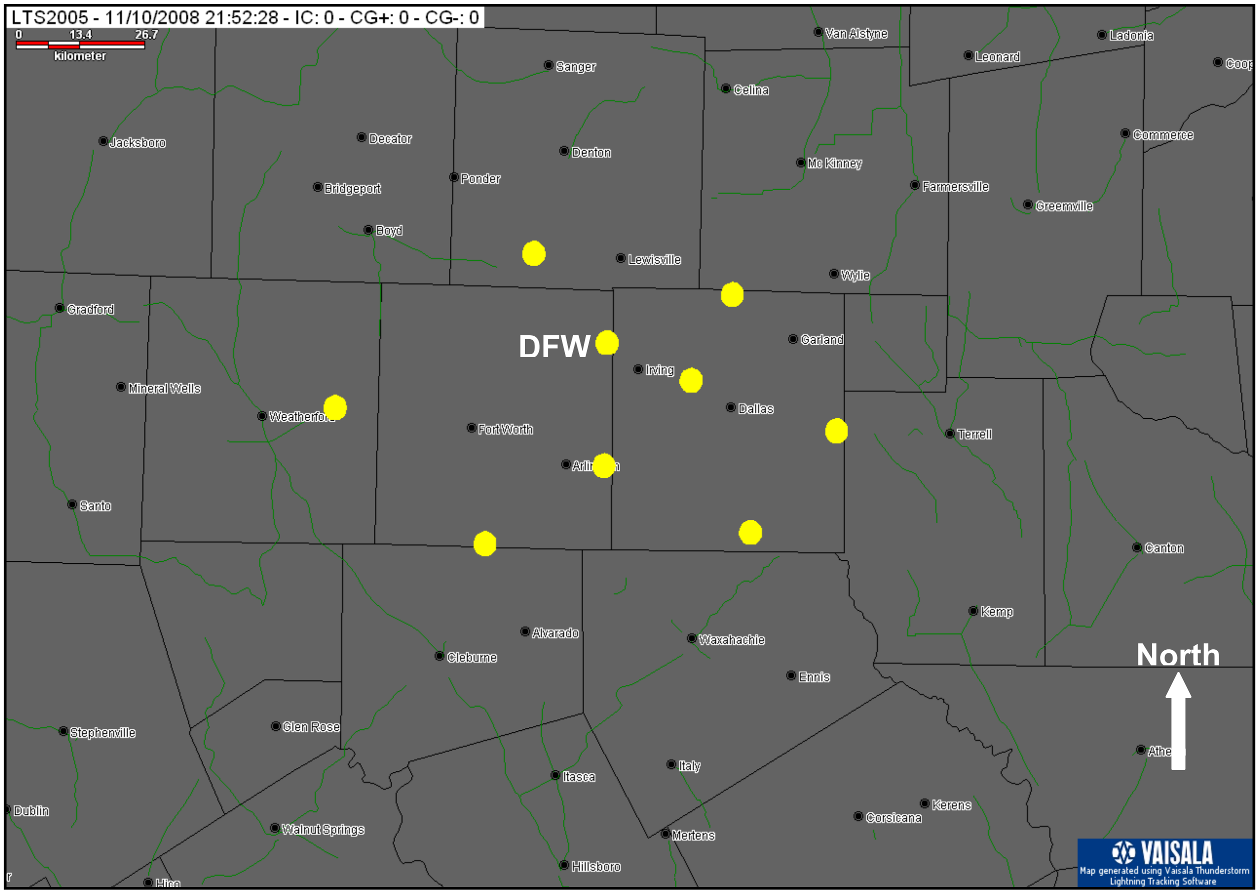


**Fig. 1. Current locations of the nine sensors that participate in the DFW LDAR II total lightning mapping network. The two most-southern sensors were added to the network in 2007.**

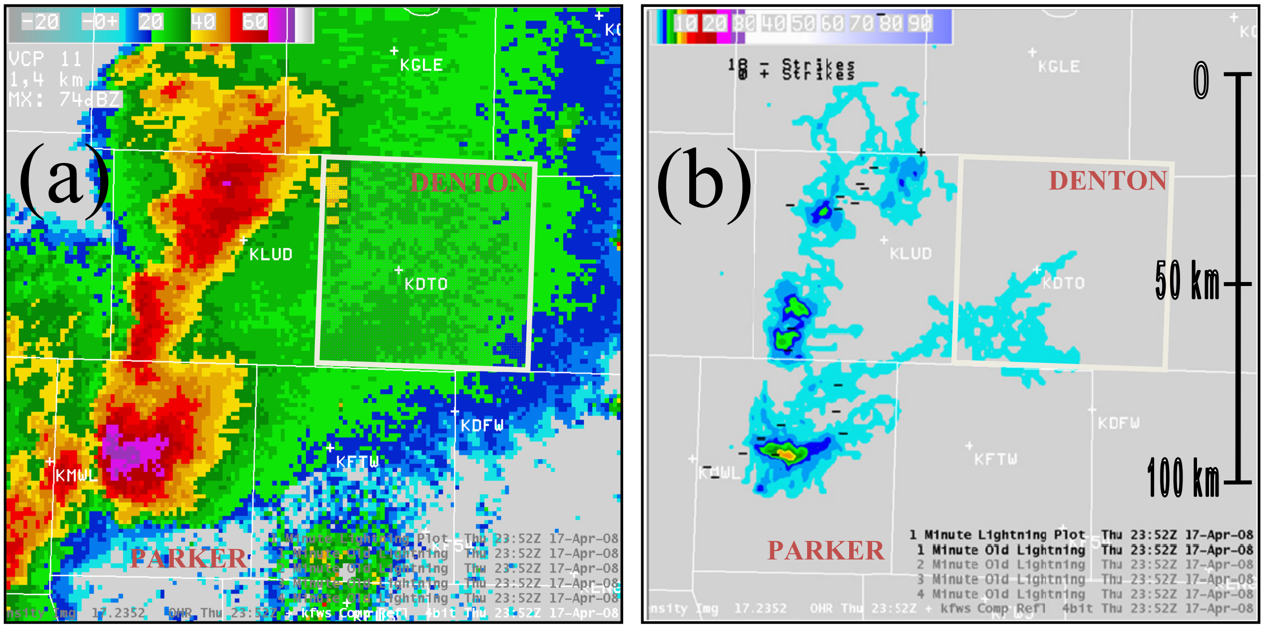


**Fig. 2. Illustration of extremely long cloud lightning flash in anvil region of a supercell thunderstorm. (a) Composite reflectivity image from WSR-88D at Fort Worth TX (KFWS) at 2352 UTC on 17 April 2008. (b) Flash Extent Density image for the two minute period ending at 2352 UTC on 17 April 2008 with cloud-to-ground lightning plot from the NLDN (black "+" and "-" symbols) for the same two minute period. In both images, solid white lines depict county outlines, white "+" symbols designate surface observation sites, and light red text gives names of selected counties. An approximate horizontal scale for both images is shown on the right side of (b).**

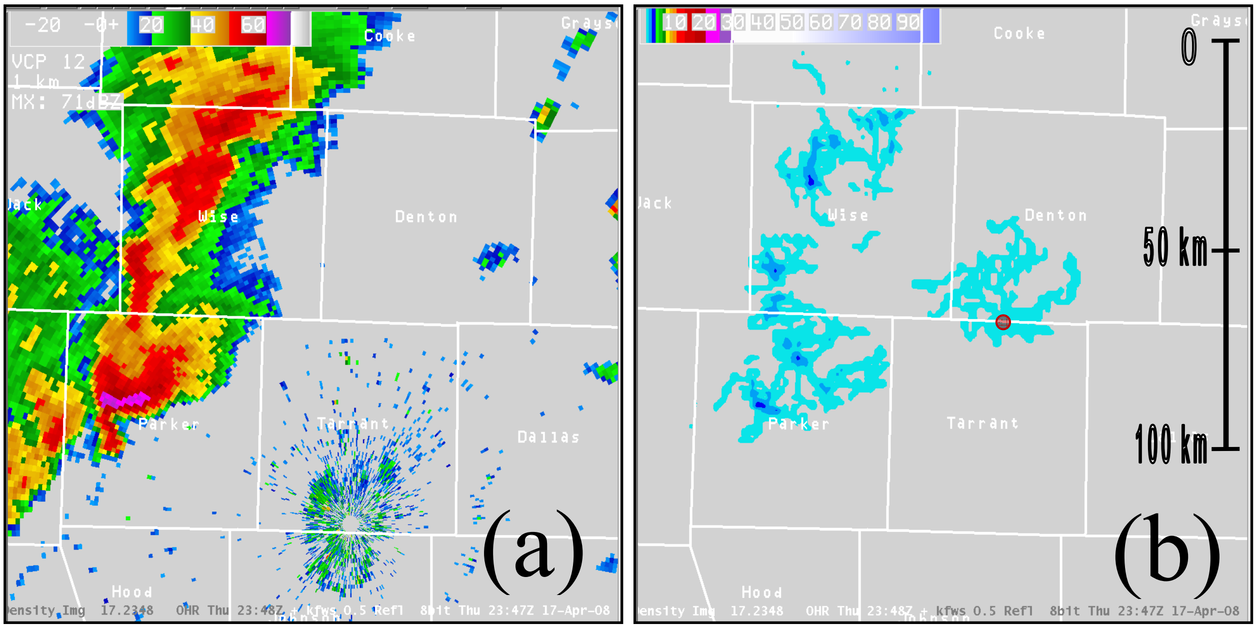


**Fig. 3. Illustration of anvil-initiated lightning activity downwind of a supercell thunderstorm. (a) WSR-88D reflectivity at 0.5° from KFWS at 2347 UTC on 17 April 2008. Image shows only reflectivities greater than 10 dBZ. (b) Flash Extent Density image for the two minute period ending at 2348 UTC on 17 April 2008. In both images, solid white lines depict county outlines and white text gives county names. Note the low values of FED in southeast Wise County, southern Denton County and northern Tarrant County that are detached from the high reflectivity core in Parker County. The small red circle along the Denton – Tarrant County line in (b) shows the approximate location of flash initiation for the detached anvil flash. An approximate horizontal scale for both images is shown on the right side of (b).**

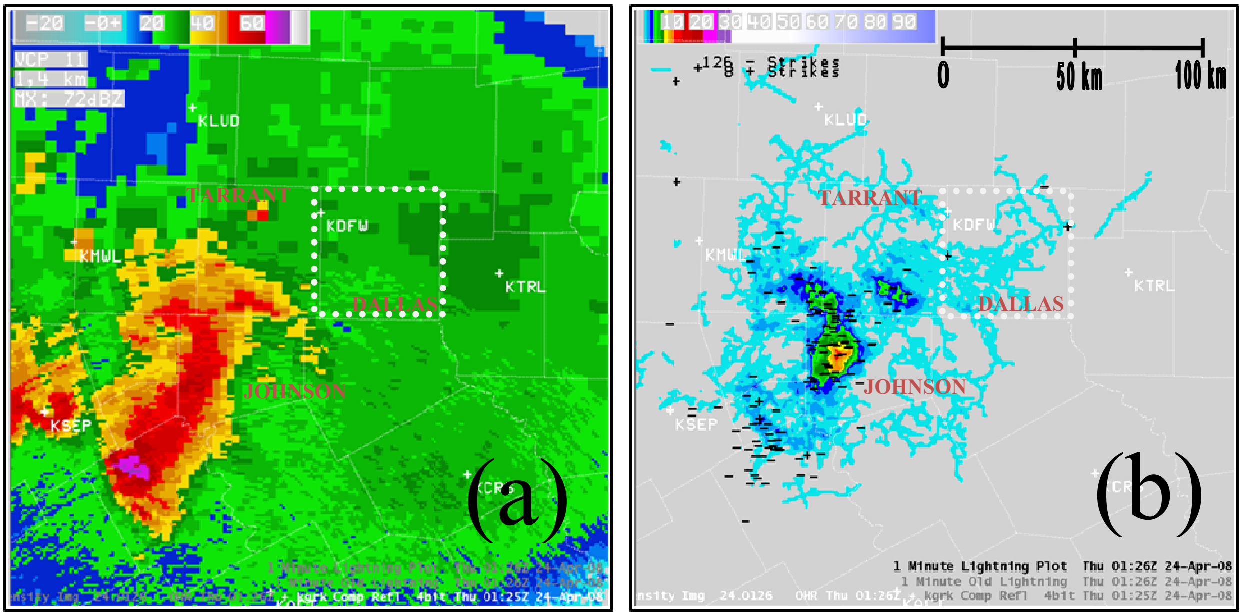


**Fig. 4. Illustration of extensive lightning activity downwind of a mesoscale convective system. (a) Composite reflectivity image from WSR-88D at Granger TX (KGRK) at 0125 UTC on 24 April 2008. (b) Flash Extent Density image for the two minute period ending at 0126 UTC on 24 April 2008 with cloud-to-ground lightning plot from the NLDN (black "+" and "-" symbols) for 0125 UTC – 0126 UTC. Note the three CG flashes in Dallas County associated with the extensive anvil flash downwind of the MCS across Tarrant and Johnson Counties. In both images, dotted white lines depict the Dallas County outline, white "+" symbols designate surface observation sites, and light red text gives names of selected counties. An approximate horizontal scale for both images is shown in the upper right corner of (b).**

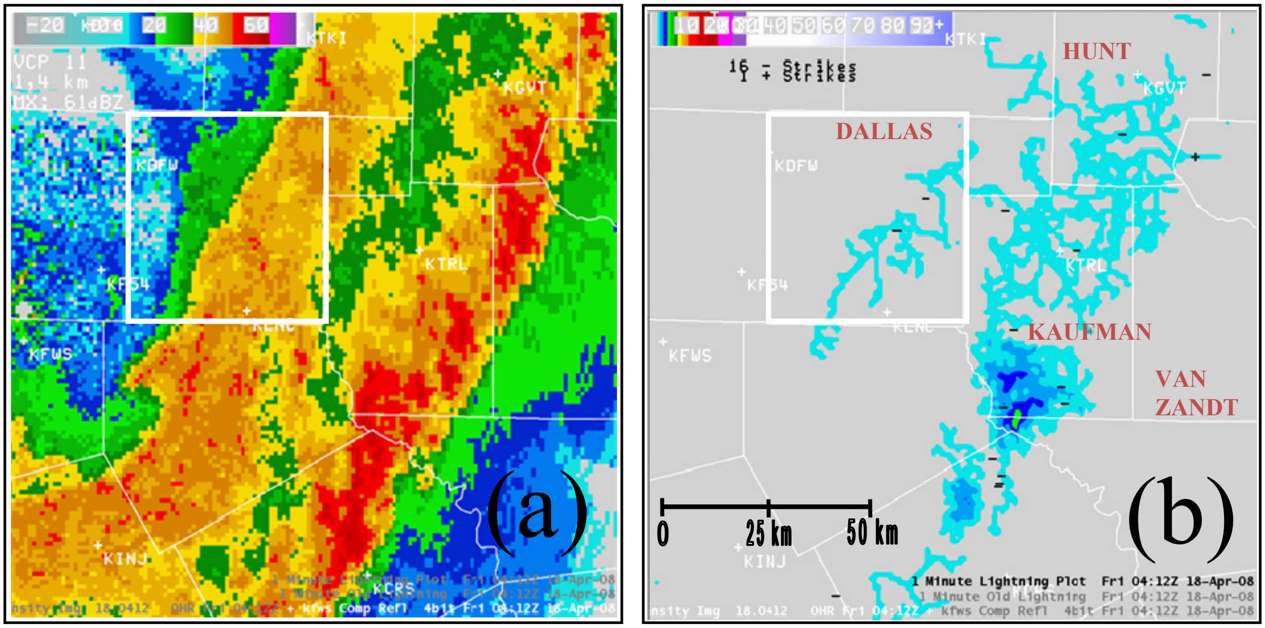


**Fig. 5. Illustration of lightning activity northwest of a mesoscale convective system. (a) Composite reflectivity image from KFWS at 0412 UTC on 18 April 2008. (b) Flash Extent Density image for the two minute period ending at 0412 UTC on 18 April 2008 with cloud-to-ground lightning plot from the NLDN (black "+" and "-" symbols) for 0411 UTC – 0412 UTC. In both images, solid white lines depict county outlines, white "+" symbols designate surface observation sites, and light red text gives names of selected counties. An approximate horizontal scale for both images is shown on the lower left side of (b).**

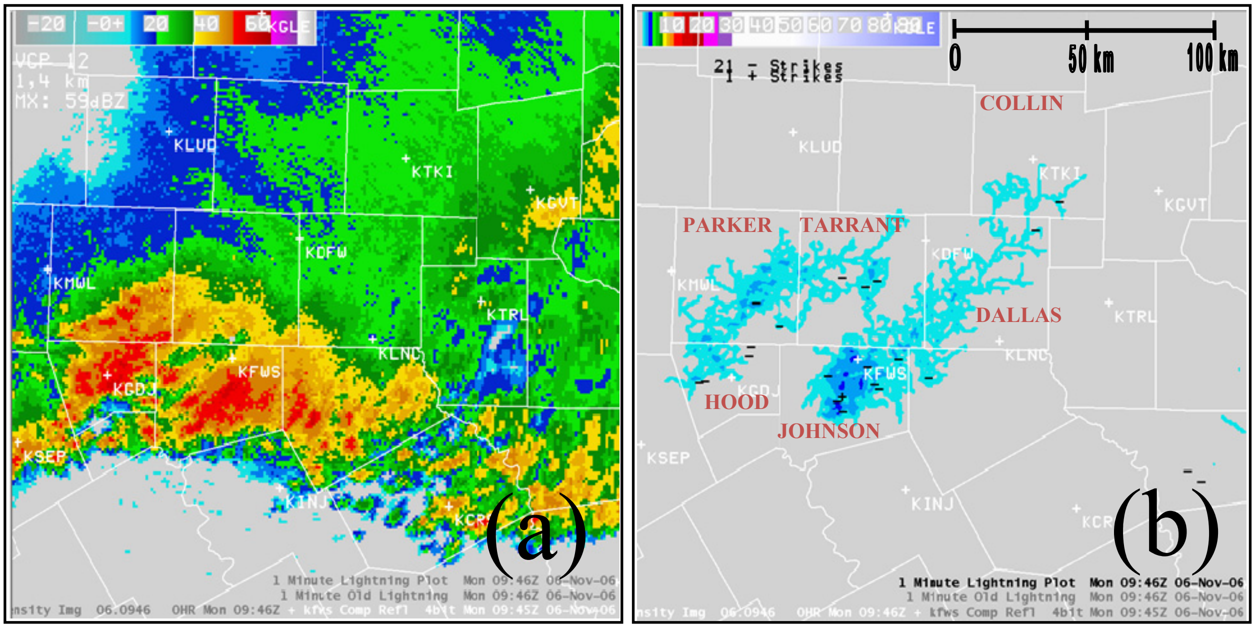


**Fig. 6.** Illustration of lightning activity north of a mesoscale convective system. (a) Composite reflectivity image from KFWS at 0945 UTC on 06 November 2006. (b) Flash Extent Density image for the two minute period ending at 0946 UTC on 06 November 2006 with cloud-to-ground lightning plot from the NLDN (black "+" and "-" symbols) for 0945 UTC – 0946 UTC. In both images, solid white lines depict county outlines, white "+" symbols designate surface observation sites, and light red text gives names of selected counties. An approximate horizontal scale for both images is shown on the upper right side of (b).