IMPLICATIONS OF VARYING TIME STEPS WITHIN OPERATIONAL TOTAL LIGHTNING INFORMATION

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1. INTRODUCTION

The Short-term Prediction Research and Transition (SPoRT) Center (Darden et al. 2002; Goodman et al. 2004; Jedlovec 2013) (http://weather.msfc.nasa.gov/sport) has been collaborating with partner Weather Forecast Offices (WFOs) since 2003. This effort has been to transition unique NASA data sets to operations to enhance the National Weather Service's (NWS) mission of protecting lives and properties as well as to demonstrate future capabilities that will be available with the launch of GOES-R. A project that has benefited both of these efforts is the transition of total lightning data (cloud-to-ground and intra-cloud lightning) from ground based lightning mapping arrays (LMAs – Rison et al. 1999) to collaborative WFOs, such as the North Alabama Lightning Mapping Array (NALMA; Koshak et al. 2004) since 2003.

Since the initial transition, total lightning has proven to be a valuable tool in the warning decision environment, especially when compared to cloud-to-ground data alone. Through numerous evaluations and discussions with forecasters, total lightning has been used to improve situational awareness, warning decision support, lightning safety, and providing a lead time on the first cloud-to-ground strike (Bridenstine et al. 2005; Goodman et al. 2005; Nadler et al. 2009; Darden et al. 2010; Stano et al. 2010, 2011; 2014; MacGorman et al. 2011; Stano 2012; White et al. 2012). This use has primarily focused on the concept of a lightning jump (Schultz et al. 2009, 2011; Gatlin and Goodman 2010).

One of the key advantages of total lightning observations is the rapid temporal updates. Most LMAs now operate with a 1 min temporal update. Two of the older networks, NALMA and Washington D.C., operate with 2 min temporal updates. In either case, this gives LMA observations the ability to provide insight into a storm's development (by indirectly monitoring the storm's updraft strength) at sub-radar volume scan update times. In 2014, SPoRT along with multiple new LMA partners conducted an operational assessment of these data in operations (see Stano et al. 2015). Some of the feedback focused on the temporal frequency of the LMA data, particularly from the networks that update every minute (e.g., Colorado, Langmuir Laboratory, New Mexico, West Texas, Houston, and Kennedy Space Center).

Forecasters noted that in several cases, the 1 min data did not appear to show significant trends in total lightning, as would be expected when subjectively monitoring for lightning jumps. Part of this was attributed to the need for an improved color curve for the 1 min data. However, it did appear that the 1 min data updated "too quickly" to make trends easily identified. Forecasters had noted this previously with the NALMA and D.C. networks, which had led to their real-time updates running every two minutes.

This presentation will look at a couple cases from the 2014 SPoRT evaluation and compare source density (Darden et al. 2010; White et al. 2012; Stano et al. 2014) for various time steps. The question that is raised is, what is an appropriate time interval that maintains the advantage that LMAs provide? The question grows in importance as the future Geostationary Lightning Mapper (GLM; Goodman et al. 2013) will have a 20 s streaming update.

Section 2 will focus on the data used, the products developed, and what comparisons were made. Section 3 will discuss the three events selected for the investigation. The final section will provide a summary of results and future work.

2. METHODOLOGY

This presentation is not intended to be an exhaustive study, but to begin to investigate questions raised during the Stano et al. (2015) evaluation of total lightning data in operations. The authors intentionally chose the three examples used from separate LMA networks. Also, while the questions were raised during the evaluation discussed in Stano et al. (2015), two cases investigated occurred outside this assessment. This was deliberate in order to focus on relatively isolated and easy to observe events.

These three events come from the Colorado LMA (COLMA) on 24 June 2014, the

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Houston LMA (HGLMA) on 6 June 2013, and NALMA on 2 March 2012. For each event, four variant products were generated. Each is based on the current source density product (Bridenstine et al. 2005; Goodman et al. 2005; Nadler et al. 2009; Darden et al. 2010; White et al. 2012; Stano et al. 2014) used operationally by SPoRT's National Weather Service partners. The source density product is a 2×2 km, gridded product that sums the number of sources in each grid box for the entire vertical column. The sources detected by the LMAs are very high frequency radiation observations that are due to a developing lightning flash emitting electromagnetic radiation across a broad range of frequencies when charges are accelerated (Rison et al. 1999; Maggio et al. 2005). These very high frequency sources represent stepped leader formation of lightning during the early stage of a lightning flash before the visible return stroke, although some sources can be observed after a return stroke. While these sources can be recombined into flashes (Stano et al. 2010, 2014; Carcione et al. 2015), this short study chose to focus on the raw source density.

The NALMA natively provides observations every 120 s and therefore the source density product is on a 2×2 km grid every 120 s. The COLMA and HGLMA networks have the same spatial resolution, but operate at a 60 s temporal resolution. As the cases used in this brief study were analyzed in a post-event setting, the data could be split temporally for any interval required for each network. As such, a 2×2 km source density product at 20, 60, and 120 s temporal resolutions was produced for each LMA. The 20 s resolution is to simulate the GLM's temporal resolution, while the 60 and 120 s intervals come from the native temporal resolution of the various LMA networks.

In addition to the three basic source density products, a fourth product was included. This is the 2 min summation (SUM) source density. It maintains the 2×2 km spatial resolution, but sums the total sources for the current minute and the previous minute. However, the product updates every 60 s. The idea, suggested by forecasters during the 2014 SPoRT evaluation (Stano et al. 2015) was envisioned as a way to keep the temporal resolution of the 60 s LMAs, but also provide enough time for enough observations to be included to observe relevant trends in total lightning. The concept maintains the relative strengths of the 120 s bin time, but with 60 s temporal frequency. The latter is important given that the National Weather Service is employing newer WSR-88D volume scan strategies to reduce radar data latency.

For the visualization, the various source density products were displayed in AWIPS II using SPoRT's total lightning plug-in. This allowed for an easy side-by-side comparison of each product with equivalent color curves. A single color curve was used for all four products. This inherently adds a level of bias to the analysis as the color curve used was intended for the real-time source density used by collaborating forecast offices. As such, the color curve is not customized for the 20 s data. However, this was balanced with the time series generated for each event, which would provide the raw values irrespective of the color curve used.

Due to the 20 s product and AWIPS only loading 64 frames at one time, the displays covered 20 min at a time. In each event, a single mostly isolated cell was used to pull a time series trend of the four source density products. This time series will be used to compare with the AWIPS II visualization of each of the products. This brief examination is focused solely on the temporal variation of the source density products. A companion evaluation by Carcione et al. (2015) investigated the difference between source and flash densities (Stano et al. 2010) in AWIPS and how color curves can impact the display as well.

3. SAMPLE EVENTS

For this small analysis, three events were chosen, as listed in the previous section. The Colorado and Houston events resulted in severe hail. The NALMA event would result in an EF-3 tornado. For each four-panel display (Figs. 1-3, 5-7, and 9-11) the display shows the 20 s source density (upper left), 60 s source density (upper right), 120 s source density (lower left), and the SUM (lower right).

3.1 Colorado: 24 June 2014

(animation)
http://weather.msfc.nasa.gov/sport/conference/imagesForQrCodes/lma/ams2015/colma_example_animation.gif

The Colorado LMA case is shown in Figs. 1-3 with the corresponding time series in Fig. 4. The event starts at 21:14:00 UTC (Fig. 1) and continues through 21:30:00 UTC. (Note, the times listed for each source density product indicate the valid time. Therefore, the 20 s product at 21:14:20 contains LMA data from 21:14:00 – 21:14:19 UTC.) Three general clusters of storms are observed. These include one on the southwest side of Cheyenne, Wyoming, another in the northeast corner of Larimer County, Colorado north of Buckeye, Colorado, and the third (circled in yellow) along the Albany and Laramie County, Wyoming border west of Cheyenne. The time series focuses on this storm.

The first item to note in Fig. 1 is the general weakness of the magnitude of the circled storm in the 20 s source density versus the other three products. Part of this is certainly the color curve used, but this will be revisited with the time series in Fig. 5. Beyond the circled storm, note how the other two storms to the east and southeast appear to have a greater spatial extent in the 60 and 120 s bins and the SUM product.

This general trend repeats itself in Fig. 2, which is roughly valid at 21:18:00 UTC. The 20 s source density had some difficulties in time matching in AWIPS II compared to the other products. Again we see that the magnitude would not catch a forecaster's eye, at least with the current color curve. This could be corrected. The greater concern is the missing eastward branch of lightning from the circled storm west of Cheyenne, Wyoming in the 20 s source density. This does not mean that the 20 s product did not observe this eastward extension; it is just that the particular 20 s segment did not cover when this occurred. This shows an advantage of the larger temporal bins, as transient features, such as a longer flash will remain on the screen longer before an update refreshes the image. An animated loop will show this, but even then, small and short-lived features can be missed. This is particularly true in the active environment of warning operations.

Figure 3 shows that when enough lightning is occurring, the 20 s source density does show the location of the main storm core. Again, the decision to use the same color curve does bias the visualization against the 20 s source density. However, as observed in Fig. 2, the spatial extent is much less. This is particularly true in the storm in northeast Larimer County Colorado. Here, the 20 s observations show almost no lightning activity, while the other products show a much more active storm. An animation reduces this issue, but again, the longer time intervals allow for a better picture of just what the spatial extent of the lightning is in the area, which improves lightning safety.

The time series (Fig. 4) provides a less biased view of what is occurring as it does not rely on the color curve. The time series is showing the maximum source density value for each product for the circled storm in Figs. 1-3. The immediate item that stands out is the differences in magnitude for all four products. Each product shows the same, rough trend in activity. The longer temporal products appear to show lightning earlier, but this is an artifact of the raw LMA data. The LMA data are displayed in AWIPS with the time period of when the data file starts. Therefore, the 21:10:00, 120 s file includes observations from 21:10:00 – 21:11:59. However, the 20 s data are time stamped much closer to when the observations occur and are less latent.

Still the magnitude is the major issue in this event. The 20 s source density does show a general increase in activity, but the overall trend is flat. Based on previous total lightning assessments (by SPoRT directly and with the Hazardous Weather Testbed) it is unlikely that even with an improved color curve in the visualization, that a forecaster's subjective analysis of a storm, would indicate a lightning jump (Schultz et al. 2009, 2011; Gatlin and Goodman 2010) occurred. An objective analysis may indicate a lightning jump from the 20 s data, but a visual inspection (how forecasters currently assess lightning jumps) would be difficult. However, this is a speculation at this point and would require a more in-depth assessment to evaluate.

The 60 s and 120 s products show a more distinct ramp up in activity around 2114 UTC with the 120 s products more than doubling this value by 2122 UTC. As expected the SUM product will match up with the 120 s source density every other minute when their time spans overlap. Severe hail was later observed at 2210 UTC.

3.2 Houston: 6 June 2013

(animation)
http://weather.msfc.nasa.gov/sport/conference/imagesForQrCodes/lma/ams2015/hglma_example_animation.gif

The Houston LMA case comes from 6 June 2013 and spans from 23:00:00 – 23:20:00 UTC. Figures 5-7 show the AWIPS II visualizations while Fig. 8 is the corresponding time series for the storm cell in the yellow circle. The circled cell occurs in the northeastern section of Harris County, Texas (northeast of Houston), although a significant amount of activity continues eastward into Liberty County. Unlike the Colorado case, this event is less isolated.

Figure 5 starts roughly at 23:03:00 UTC for all four products. Also, unlike the Colorado event, the storm circled is just developing. As such, the color curve is less of an issue as the values were generally small in all four products. The 20 and 60 s products do show a small amount of total lightning observed right on the Harris and Montgomery

County border with a larger cell to the east. The two 120 s products show more overall lightning over their temporal range, but as a whole all four products note a storm cell developing. Looking beyond the circled storm, the longer temporal span products better show the overall coverage of lightning. Since total lightning is observing both cloud-to-ground and intra-cloud lightning, this spatial coverage is important to be able to observe. From an aviation perspective, the single 20 s snapshot shows less coverage, which may indicate a flight route may be safer than it is in reality.

Moving ahead roughly four minutes later (Fig. 6) we observe the low values from the 20 s data that were present in the Colorado case. This again shows the color curve bias, but there is another issue. Looking beyond the circled storm cell, the 20 s source density field appears spotty or noisy and lacks much lightning across northern Liberty County. This trend continues into Fig. 7 another six minutes later at 21:13:00 UTC. The larger temporal products, including the 60 s source density observe obvious storm cores with a large area covered by lightning activity. The 20 s source density also highlights the storm core, but given the small window of observation for this time, the spatial extent is less obvious.

The time series (Fig. 8) shows a clearer picture. The Colorado event observed a modest lightning jump starting around 2112 UTC. Meanwhile, for this case, a clear, rapid increase is starting around 2304 UTC and is an obvious lightning jump by 2307 UTC. Between 2304 and 2307 UTC the 60 s source density went from ~12 to 130 sources, while the 120 s source density went from 12 (at 2302) to 190 (at 2306). Meanwhile, the 20 s source density went from ~12 sources to just 60 in the same period of time. Overall, the same number of sources are observed, but the longer "window of observation" made the increases far easier to make out visually. The 20 s source density could have an optimized color curve, but a forecaster may be less able to note a significant increase in the very rapid update product.

3.3 North Alabama: 2 March 2012

(animation)
http://weather.msfc.nasa.gov/sport/conference/imagesForQrCodes/lma/ams2015/nalma_example_animation.gif

The overall trend observed in the Colorado and Houston cases are repeated for the North Alabama event, but here the differences are magnified. This case from 2 March 2012 spans from 14:30:00 – 14:50:00 UTC. Figures 9-11 show the AWIPS II visualization with the time series shown in Fig. 12. The circled cell of interest follows a storm that eventually produced an EF-3 tornado beginning at 1510 UTC as the storm moved northeastward from Lawrence County Alabama and into Limestone County towards Athens, Alabama (west of Huntsville).

Figure 9 starts at 14:36:00 UTC prior to the main ramp up in the storm's lightning activity, as seen in Fig. 12. Here, the 20 s source density is ~12 sources, while the 60 s version is near 50 sources, and the 120 s versions are just over 100 sources. Again, the 20 s version can be described as "choppy". The same sources are being observed, but are being split over 3-6 frames versus the 60 or 120 s versions of the product.

The effect of the 20 s window for observations is further illustrated in Fig. 10. This is about 5 min later from Fig. 9. Here, the storm cell in question has a very confined spatial extent, and is nearly completely encompassed by the yellow circle. However, for the longer duration products, the image is far more dramatic. The spatial extent indicates lightning extending tens of kilometers away from the storm. In particular, lightning is extending well into Limestone County to the northeast. As the links to the animations at the end of this write-up show, the 20 s source density captures this spatial extent. In fact, the individual flashes are more obvious when they extend from the main core of the storm. However, due to the extremely rapid update cycle, it is far easier to miss these features, and is more difficult to synthesize the implications of the various data sources.

The final image, Fig. 11 demonstrates how the 20 s source density does observe the larger spatial extents, as observed by the longer duration products. However, as discussed in the Colorado and Houston examples, the time series (Fig. 12) provides a much clearer, quantifiable comparison. The North Alabama case exhibits two very clear lightning jumps, one starting around 1436 UTC and the second at 1442 UTC. These are very obvious in the 60 and 120 s products. The 20 s source density maintains a similar increase, but the overall trend is muted. Given that an objective lightning jump algorithm is not yet in operations, forecasters must visually and subjectively identify jumps. In the case of the 20 s data, even with an optimized color curve, this could be difficult to attempt.

4. SUMMARY AND FUTURE WORK

This short project aimed to compare the operational source density product using varying temporal windows with which to bin the total lightning observations. This was encouraged for two reasons. First, SPoRT's National Weather Service partners have access to various ground-based lightning mapping arrays throughout the country. Two, such as the North Alabama Lightning Mapping Array, update every 120 s. The others, such as the Colorado and Houston networks used here, update every 60 s. During an evaluation of these data in operations in the spring and summer of 2014 (Stano et al. 2015), forecasters noted that the higher temporal resolution data sometimes did not provide as clear of a picture of the lightning activity that forecasters with access to the 120 s data noted in their evaluations. This led to the second reason, which is that the Geostationary Lightning Mapper will provide total lightning observations in a streaming format that updates every 20 s. Having a minimum in latency, particularly for lightning observations, is necessary for the operational implementation of these data. However, the question is how should these data be visualized? The 2014 evaluation indicated that viewing the raw data at a high temporal frequency may, in fact, make it harder to subjectively diagnose useful features.

Only three cases from Colorado, Houston, and North Alabama are investigated, but some basic conclusions can be drawn. Additionally, a level of bias was introduced as the color curve used for the AWIPS II visualizations was not optimized for the 20 s data. The visualizations still provide some insight and the three time series plots provide a better, quantitative comparison. The 20 s source density products observe the same observations as the 60 and 120 s products. The animation links demonstrate this quite well. The 20 s source density still highlights the main storm core, in general, and when a longer flash occurs in the 20 s window, the flash shows up just as well as in the longer duration products (e.g., Fig. 11).

The issue is that the overall magnitude of the individual products varies greatly as the temporal window in which the sources are binned into the grid is shortened or lengthened. The time series (Figs. 4, 8, and 12) show that the trends in the 20 s source density observations follow those with the longer duration products. However, the much smaller magnitude means that the trend is more difficult to identify. For an operational forecaster, where time is of the essence, a product should be visually eye-catching when a feature is rapidly changing. For the 20 s source density, this is far more difficult to achieve.

The second issue is that although the 20 s source density product has all the same observations as the longer duration products, the high temporal refresh makes it more likely that a specific feature, either a spike in magnitude or a wide spatial extent, could be missed. Even with an animation, a forecaster during warning observations will be dividing their attention across multiple observational inputs and not total lightning alone. Therefore, a quick, transient feature can be missed. The longer duration products capture a longer history of what is occurring. Instead of trying to synthesize 3-6 image frames with the 20 s data, a single 60 or 120 s frame gives a better "summary" of the lightning activity in the storm.

All of this implies that a raw, 20 s temporal frequency product may not be as viable to operational forecasters as the other products. However, that does not imply that the 20 s observations are not valuable. During the 2014 SPoRT evaluation, forecasters from the Cheyenne and Melbourne weather forecast offices separately suggested a running 2 min summation product that updates every minute and this was demonstrated here. As expected, this closely matched the 120 s source density product. The summation source density has a larger temporal window to bin the individual observations, but also can update rapidly. This combines the advantages of each individual product while minimizing the disadvantages.

Based on these results and the feedback from the 2014 evaluation, SPoRT and its forecast partners will further investigate this time interval issue. First, the 2 min summation source density will be transitioned for evaluation by a few key offices. Additionally, a 1 or 2 min running summation product that updates every 20 s will be tested offline, to simulate potential Geostationary Lightning Mapper visualization techniques.

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6. FIGURES

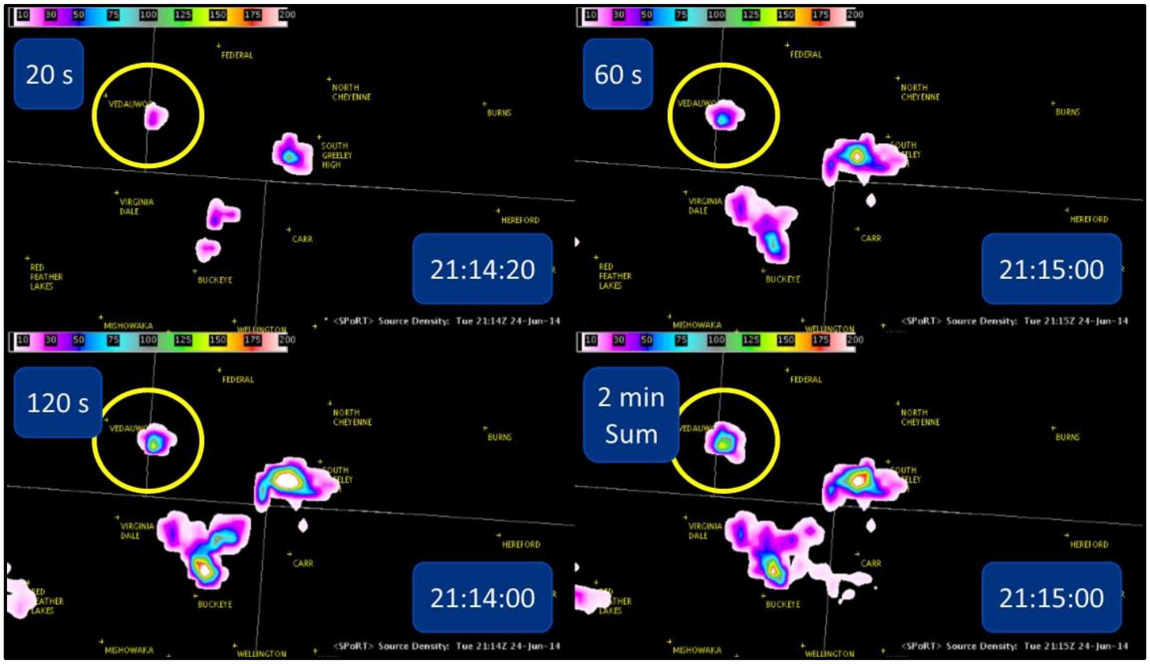

Figure 1: An AWIPS II four-panel display showing the four source density products used during this study for the Colorado Lightning Mapping Array on 24 June 2014. These include the 20 s (upper left), 60 s (upper right), 120 s (lower left), and 2 min running summation that updates every 60 s (lower right). The specific start times for each product are listed on the image with an approximate start time around 21:14:00 UTC. The main storm cell of interested in circled in yellow.

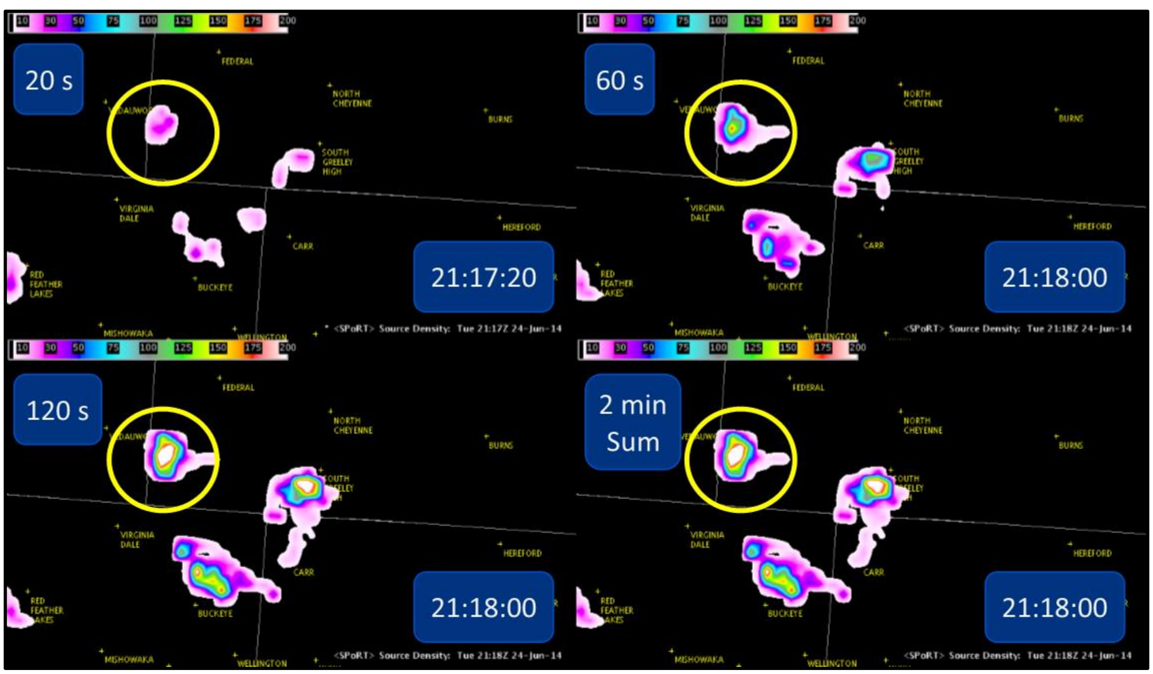

Figure 2: Same as Fig. 1, but with valid start times at approximately 21:18:00 UTC.

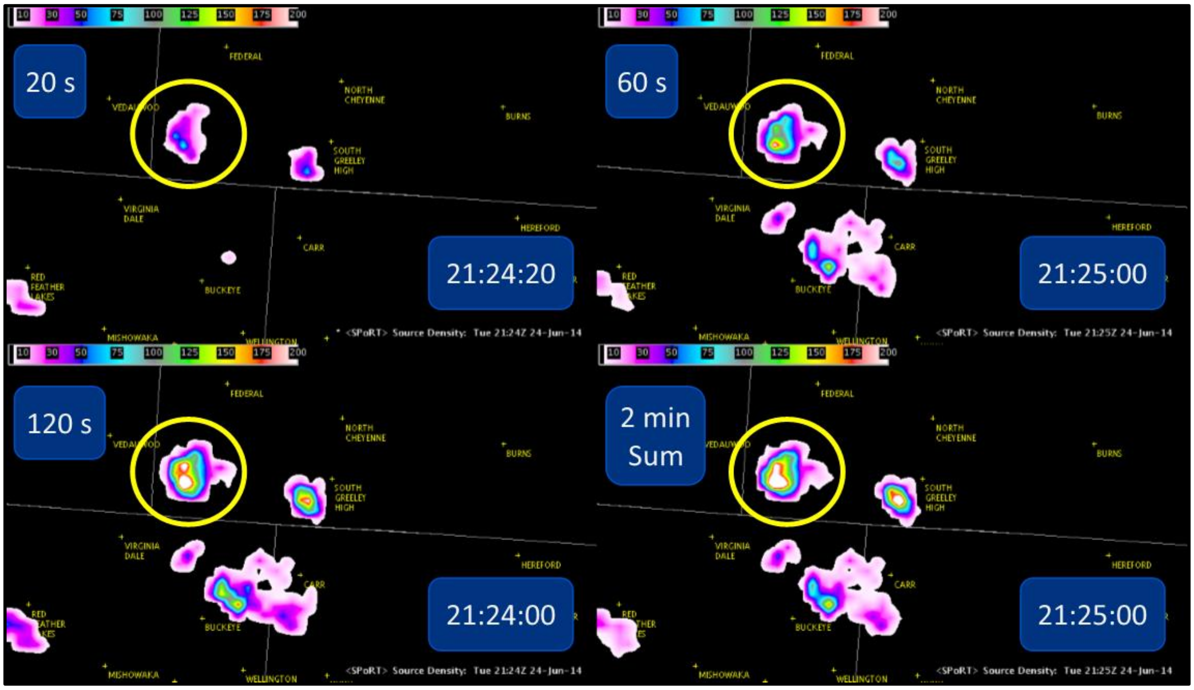

Figure 3: Same as Fig. 1, but with valid start times at approximately 21:24:00 UTC.

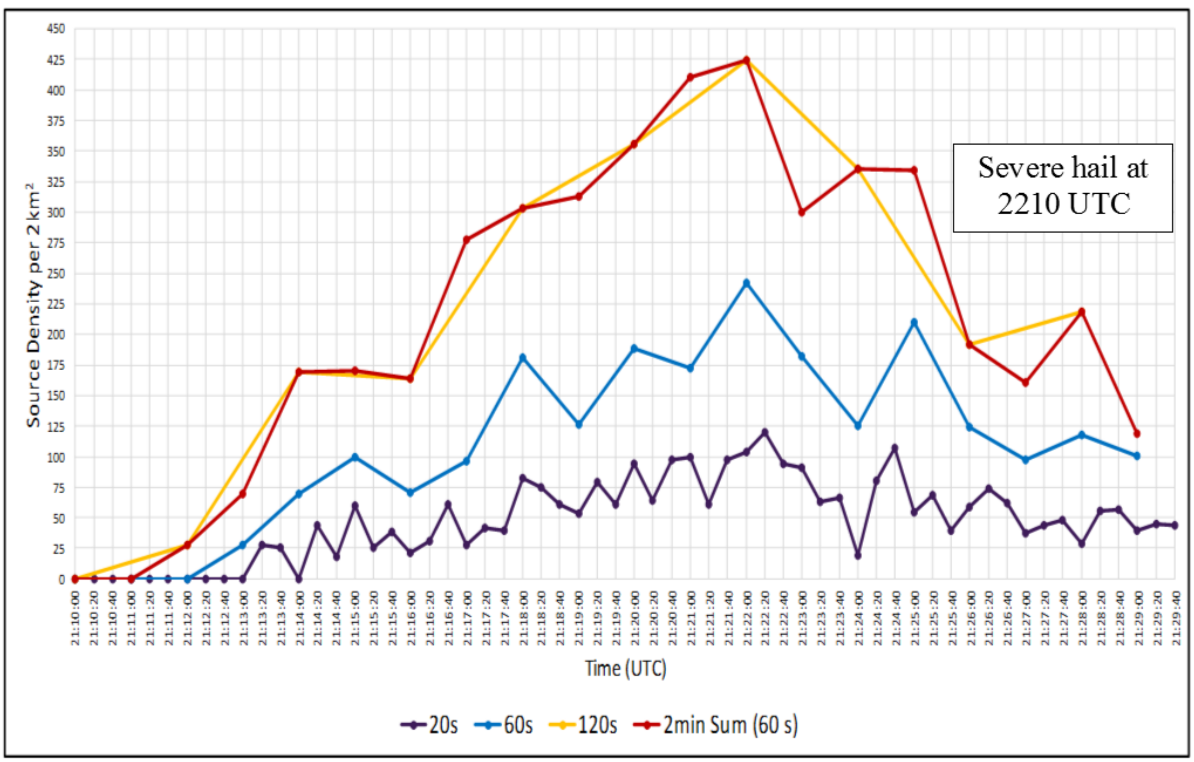

Figure 4: A 20 min time series (21:10:00-21:30:00 UTC) of the maximum source density value for the storm cell circled in yellow in Figs. 1-3 for the Colorado LMA example. Each source density product's color is labeled in the image above.

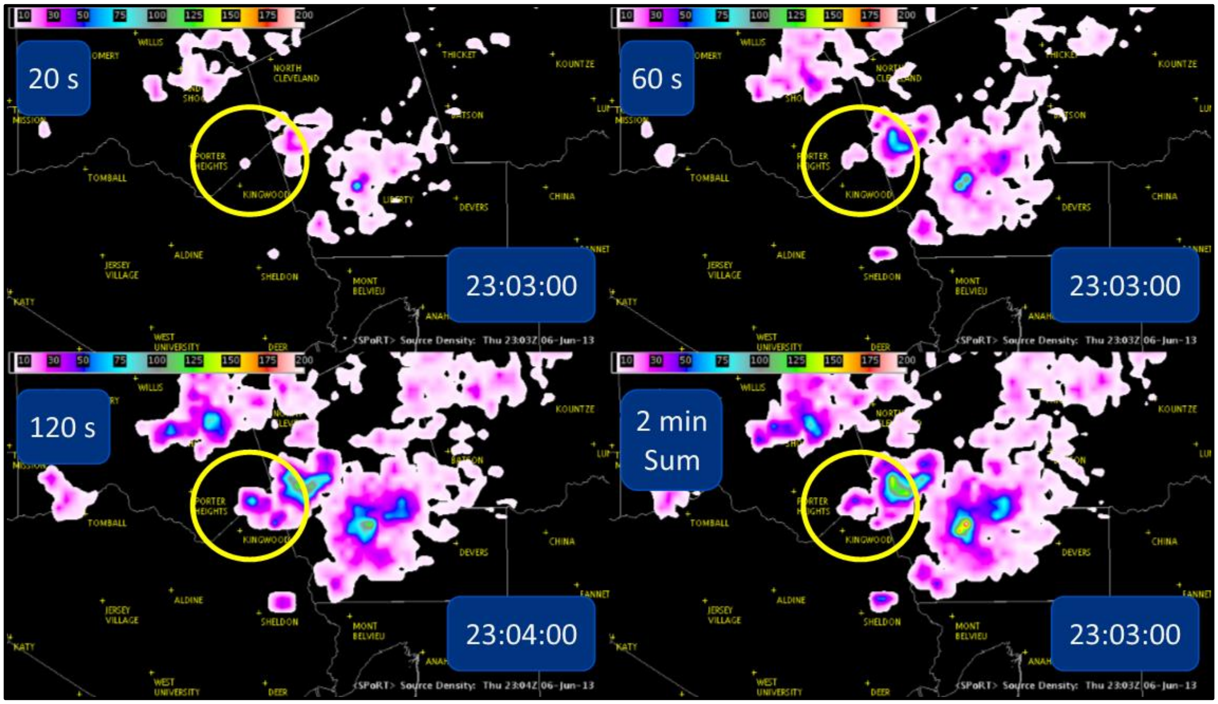

Figure 5: Same as Fig. 1, but now for the Houston LMA on 6 June 2013 with an approximate start time of 23:03:00 UTC.

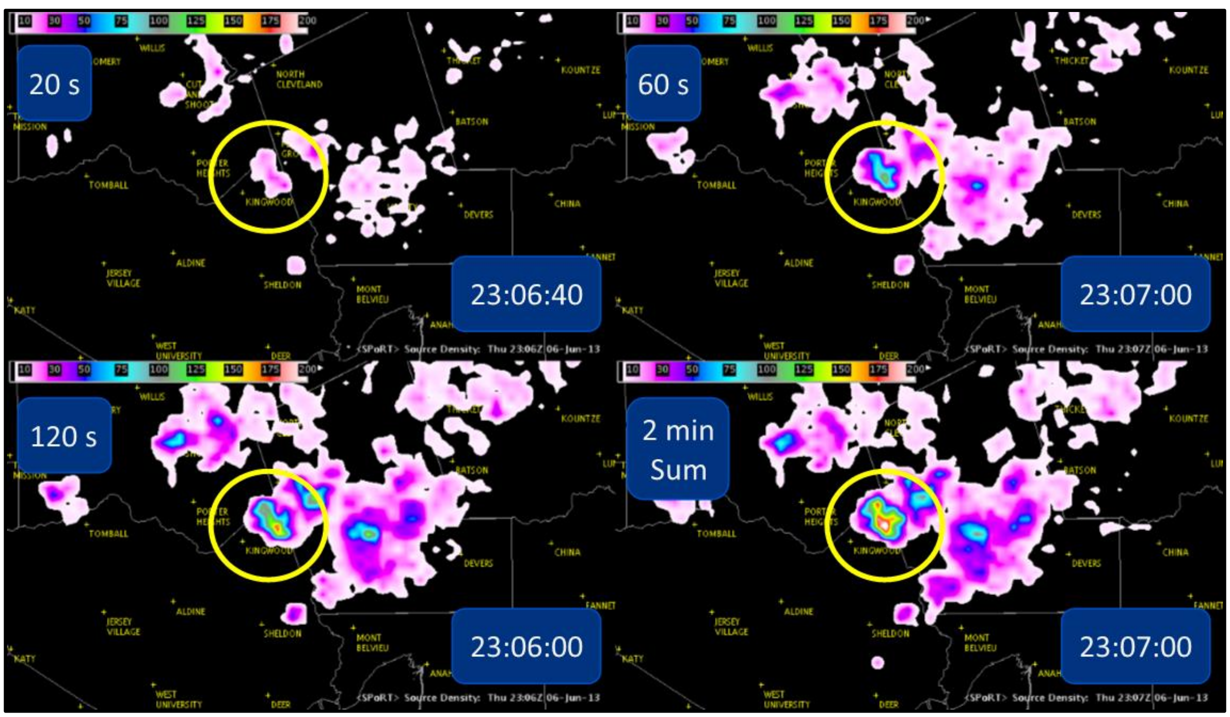

Figure 6: Same as Fig. 5, but with an approximate start time of 23:06:00 UTC.

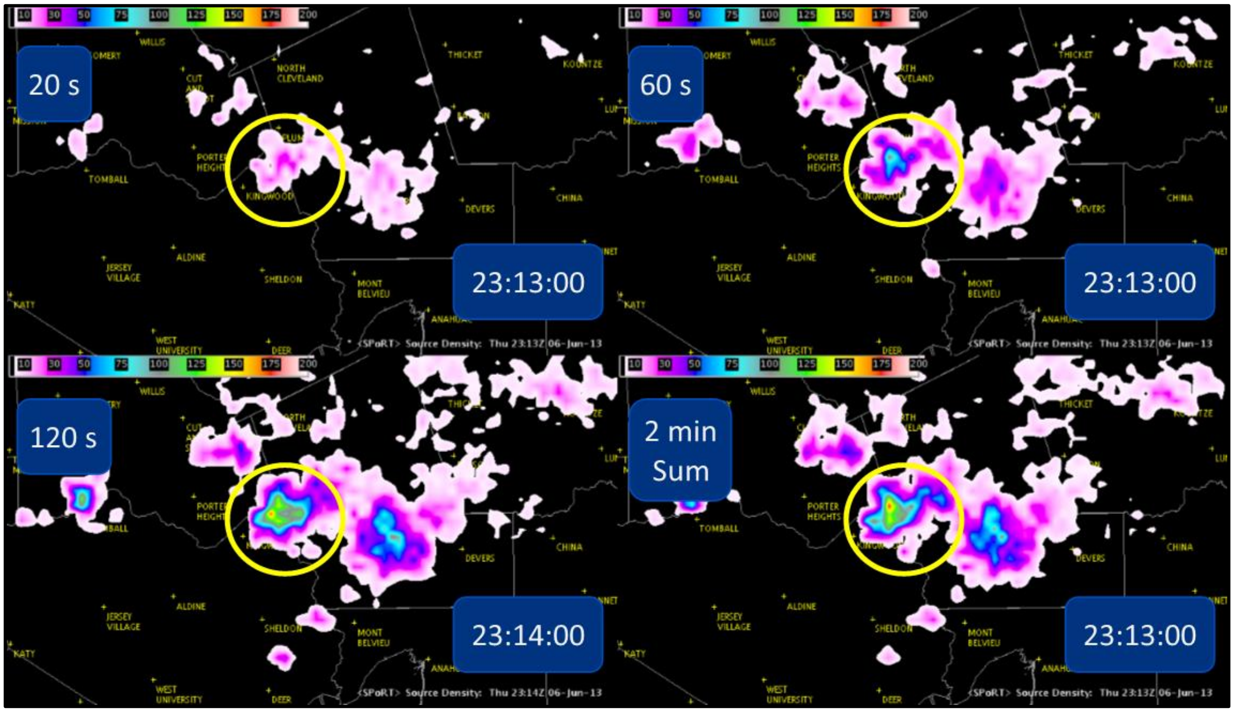

Figure 7: Same as Fig. 5 but with an approximate start time of 23:13:00 UTC.

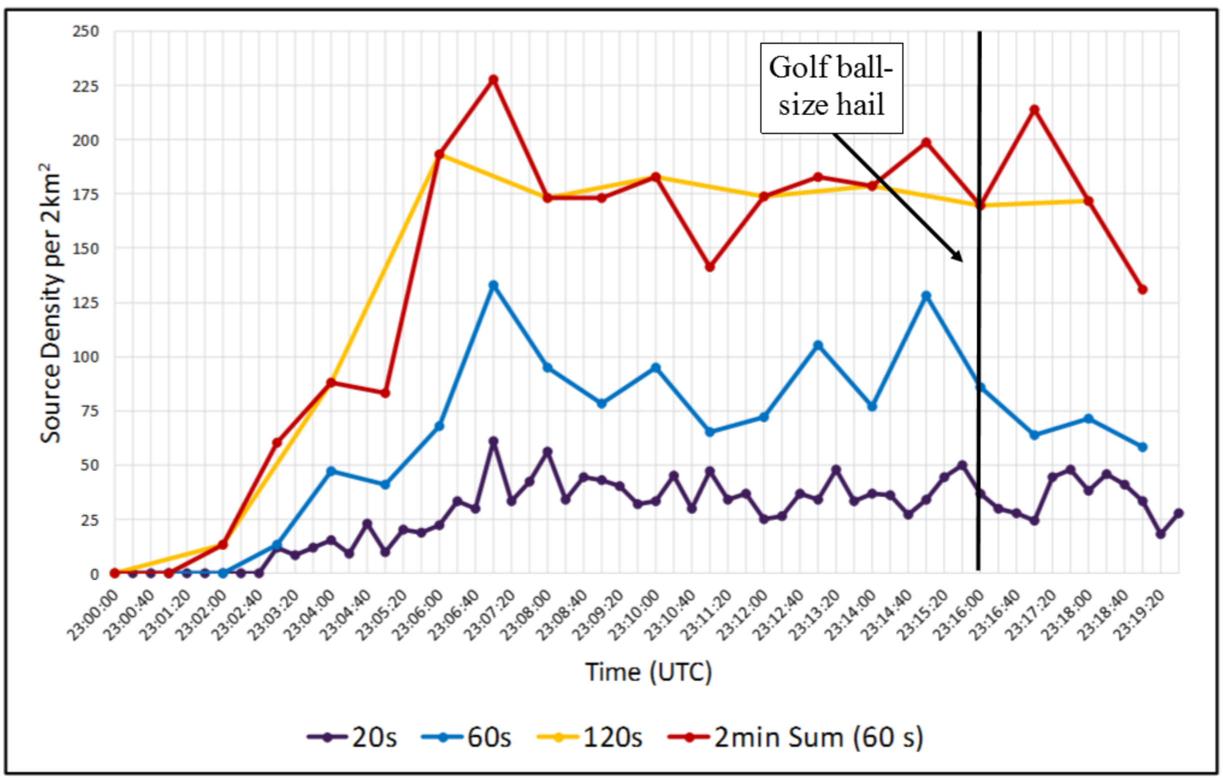

Figure 8: A 20 min time series (23:00:00-23:20:00 UTC) of the maximum source density value for the storm cell circled in yellow in Figs. 5-7 for the Houston LMA example. Each source density product's color is labeled in the image above.

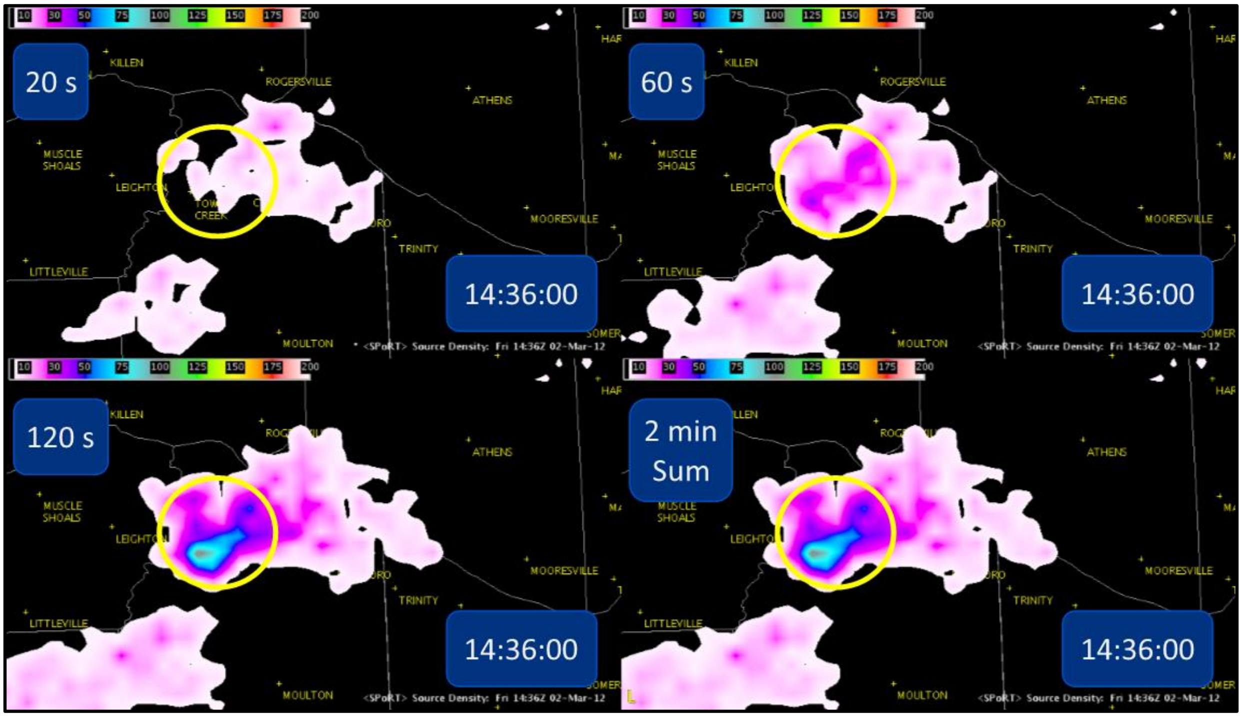

Figure 9: Same as Fig. 1, but now for the North Alabama LMA on 2 March 2012 with an approximate start time of 14:36:00 UTC.

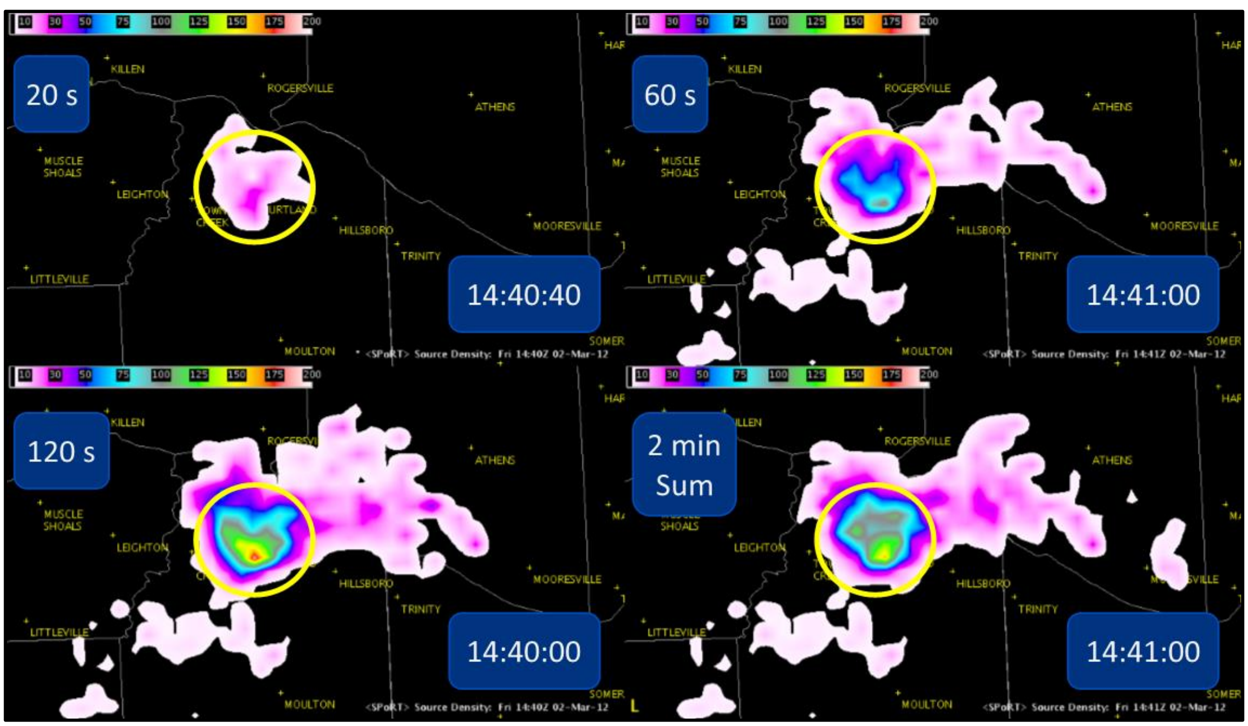

Figure 10: Same as Fig. 9 but with an approximate start time of 14:40:00 UTC.

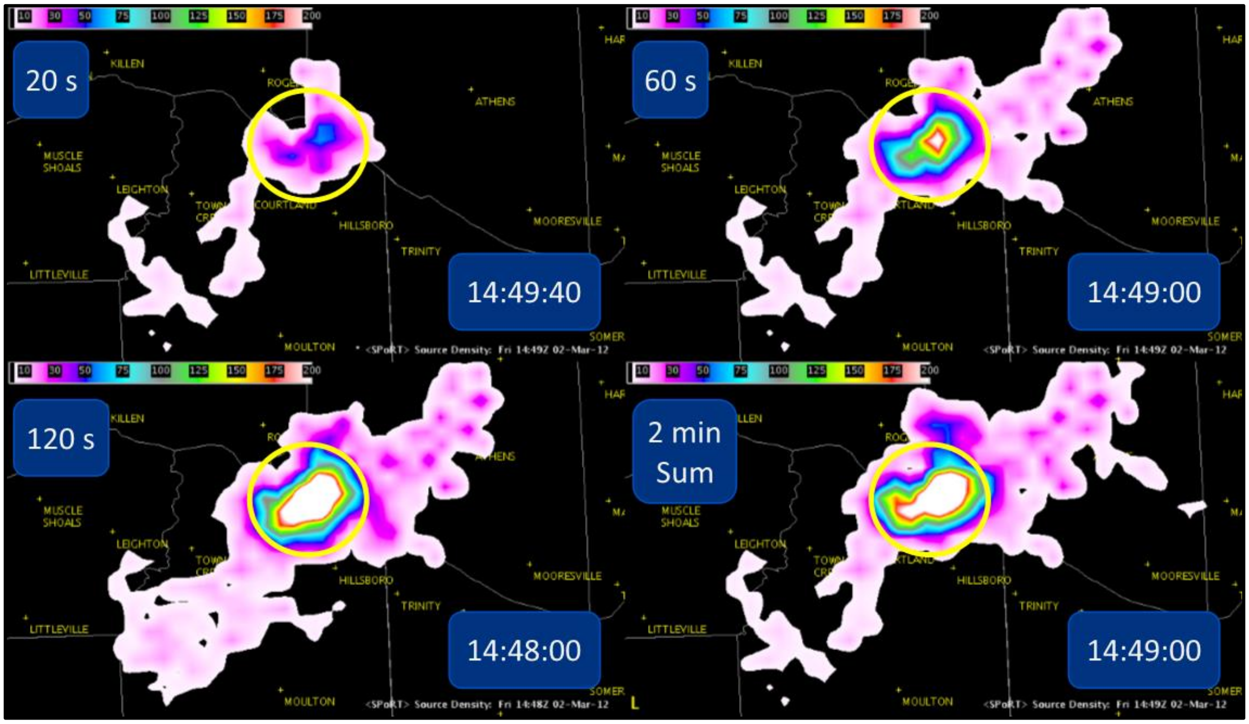

Figure 11: Same as Fig. 9 but with an approximate start time of 14:48:00 UTC.

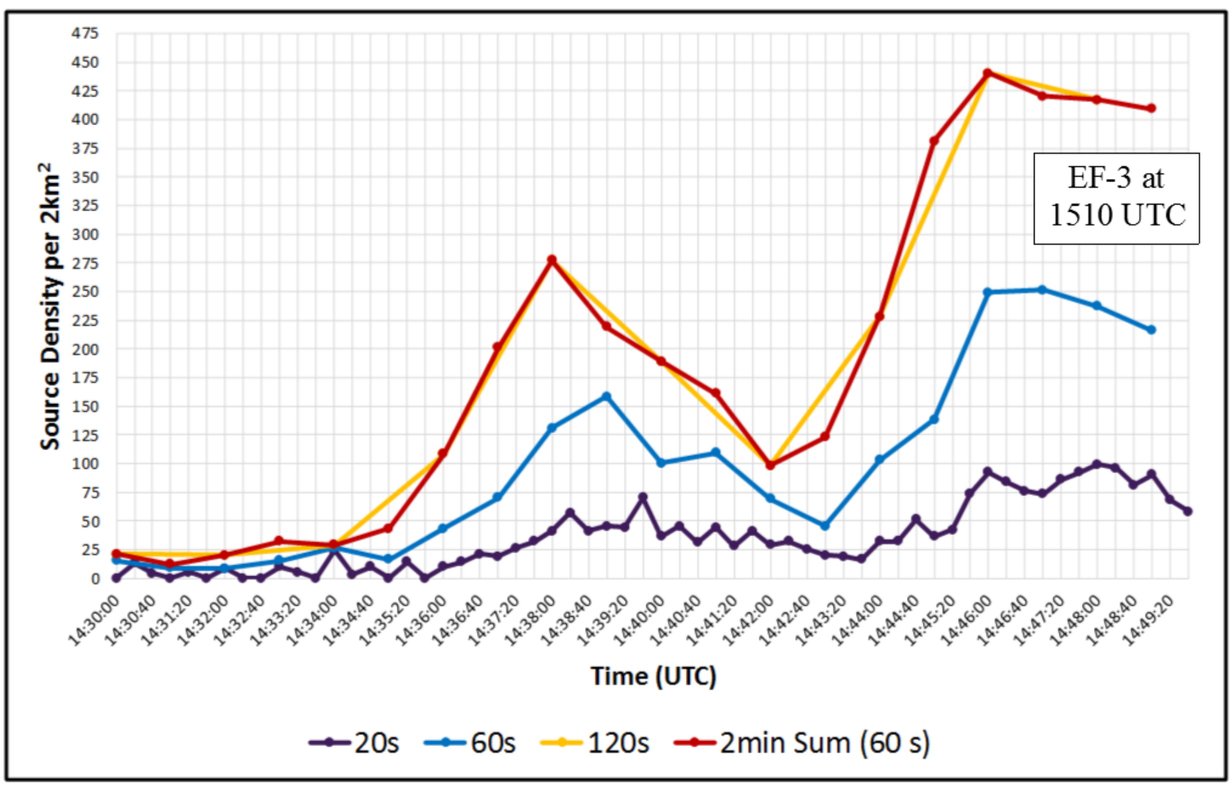

Figure 12: A 20 min time series (14:30:00-14:50:00 UTC) of the maximum source density value for the storm cell circled in yellow in Figs. 9-11 for the North Alabama LMA example. Each source density product's color is labeled in the image above.