2.1

IMPLEMENTING TOTAL LIGHTNING OBSERVATIONS AT CENTER WEATEHR SERVICE UNIT HOUSTON

Roland Nuñez[1] and Geoffrey T. Stano[2]

[1]NOAA National Weather Service Center Weather Service Unit, Houston, Texas
[2]NASA Short-term Prediction Research and Transition (SPoRT) / ENSCO, Inc., Huntsville, Alabama

Abstract

The Center Weather Service Units (CWSUs) are a branch of the National Weather Service whose mission is to provide meteorological support to the Federal Aviation Administration. This is done to safely and efficiently use the National Airspace System. The primary role of the CWSUs is to provide short to medium range forecasts of weather conditions that will impact aviation interests. The CWSUs provide more localized knowledge to the FAA in collaboration with the Aviation Weather Center's national products.

A key concern for the CWSUs is convection. Unlike a Weather Forecast Office conducting decisions support for severe thunderstorms, the CWSUs are concerned with any convection (i.e., radar reflectivity values of >= 35 dBZ) occurring within their airspace. Convection can impact route management as well as generate turbulence. Diversions around storms or having to land to refuel are costly to the airlines and ways to safely mitigate these hazards are a priority. In addition to these impacts, the CWSUs are focused on the timing, coverage, and intensity of convection that may impact the approach and departure gates located 50 miles from the primary airport. For CWSU Houston, this is Bush Intercontinental Airport. Aircraft must follow strict air routes to and from these gates to ensure a clear flight path. Convection in and around these gate regions can force restrictions or closures of these gates that can disrupt ground operations resulting in flight delays.

NASA's Short-term Prediction Research and Transition Center (SPoRT) and CWSU Houston have been investigating ways to implement total lightning observations from the Houston Lightning Mapping Array into CWSU operations. Initial work suggests the lightning data can provide insight as to the intensity of the convection, particularly with respect to how long a given cell may persist. Additionally, these observations may provide additional lead time on the development of convection, supporting the CWSU forecasters' briefings to the Traffic Management Unit. This presentation will discuss the initial work and results as well as describe how these efforts are supporting preparations for the GOES-R Geostationary Lightning Mapper.

COLLABORATIONS WITH THE HOUSTON CENTER WEATHER SERVICE UNIT (CWSU)

NASA's Short-term Prediction Research and Transition Center (SPoRT; Darden et al. 2002; Goodman et al. 2004; Jedlovec 2013) is a leader in transitioning ground-based total lightning observations (intra-cloud and cloud-to-ground) to National Weather Service (NWS) collaborators with access to lightning mapping arrays (LMA; Rison et al. 1999). These LMAs serve as excellent demonstration networks to prepare the National Weather Service for the soon to be available Geostationary Lightning Mapper (GLM; Christian et al. 1989; Goodman et al. 2013) observations aboard GOES-R series of weather satellites. These collaborations have involved close collaboration with various NWS local forecast offices, national centers, and center weather service units. More recently, SPoRT has developed training for the NWS as part of the GOES-R foundational course as well as the prep course for the Science and Operations Officers.

In the course of SPoRT's collaborations, SPoRT personnel reached out to the Aviation Weather Center (AWC) as part of a GOES-R visiting scientist program (Stano et al. 2013; Terborg and Stano 2017). This was driven by an interest at the AWC to prepare for the GLM especially since much of the initial proving ground work was focused on local weather forecast office operations, specifically warning decision support (Goodman et al. 2005; Darden et al. 2010; Stano et al. 2010; White et al. 2012; Stano et al. 2014) and lightning safety (Stano 2012). The visiting scientist trip set the stage for AWC and SPoRT collaborations that continue to this day and have been instrumental in educating SPoRT personnel on the unique forecast needs and challenges faced by the aviation forecaster community. A recommendation by the AWC was for SPoRT to collaborate with center weather service units (CWSUs)

Corresponding author: Dr. Geoffrey T. Stano
NASA SPoRT / ENSCO, Inc.
320 Sparkman Dr., Huntsville, AL 35805
e-mail: geoffrey.stano@nasa.gov

that may have access to a ground-based LMA. Part of this recommendation was to address the scale of operations between the AWC and the CWSUs. The AWC is focused on national scale activities and beyond. However, the CWSUs have a greater focus on regional portions of the national air space as well as supporting the Terminal Radar Approach Control (TRACON) airspace surrounding the major airport(s) in the CWSU's region. With this recommendation, SPoRT was awarded a follow-up GOES-R visiting scientist proposal that met with the Houston, Texas CWSU in 2014.

CWSU Houston's airspace is centered on Houston, Texas and extends from Mobile, Alabama westward to south of Midland, Texas. Additionally it remains south of Dallas-Ft. Worth and extends into the Gulf of Mexico (Fig. 1). Through a collaboration with Texas A&M University and New Mexico Institute of Mining and Technology, SPoRT has access to the real-time data from the Houston-Galveston Lightning Mapping Array (HGLMA). As with each LMA the Houston network is a line of sight system, restricting its range to an approximate 200 km radius from its center. This is far smaller than the operational domain of the Houston CWSU as shown by Fig. 1. While this is a limitation, the Houston CWSU was eager to test these data to learn about total lightning and how it could be applied to their operations as well as to prepare for the GLM. Part of this preparation is to compare HGLMA observations to radar observations to better understand the correlation. This will be vital in the future when the CWSU is using GLM data over the Gulf of Mexico without corresponding radar data. The decision was made to focus the collaboration on the TRACON airspace surrounding Houston's Bush Intercontinental Airport.

The TRACON airspace (Fig. 1 and 2) is a critical region extending 50 miles out from the airport. Here, aircraft must be routed into specific "gates" in order to depart (cardinal directions) or arrive (45 degrees off the cardinal directions) at the airport and not interfere with other aircraft. Due to the restrictive nature of these travel corridors any impact, particularly convection, can greatly impact the timeliness and efficiency of flight operations at the airport. The total lightning observations, which are driven by the size and strength of a cell's updraft in the mixed phase region, provide a means to investigate the development and intensity of a given cell. The HGLMA would be used to monitor the development of convection as well as the intensity to gauge how long this might persist. This information would support the CWSU forecasters' briefings to the Federal Aviation Administration's Traffic Management Unit (TMU) on the availability of TRACON gates being available both in a nowcast and short-term sense.

The next section of this extended abstract focuses on a case identified by the Houston CWSU on 1 September 2015. This will describe how the HGLMA data were used to monitor convection across the TRACON airspace and the added value the total lightning data observations provided. The final section will discuss future work in the collaborations with the Houston CWSU.

THE 1 SEPTEMBER 2015 CONVECTIVE EVENT

Before investigating this case in detail, it is beneficial to describe the mission of the CWSUs. A primary task for any CWSU is the need to predict, identify, and monitor convection throughout their airspace. Unlike a local weather forecast office, the CWSUs as well as the AWC are focused on any convection in their airspace and not just severe convection. Convection can and does impact aircraft routing, TRACON gates, as well as impacting ground operations at airports themselves. The Houston Air Route Traffic Control Center, which the Houston CWSU supports, is responsible for six to seven thousand aircraft daily. This ranges from aircraft passing through the airspace to each arrival and departure at the various airports with the majority arriving at or departing from the Houston area airports.

Even before the HGLMA collaborations, lightning from thunderstorms has been a key feature to monitor. Lightning data is used to support all convective monitoring and is especially vital in non- or poor radar locations. The information is essential for impact decision support and providing briefings to the traffic management unit. The inclusion of the HGLMA data is intended to evaluate the impacts of having total lightning available in preparation for the GLM, such as the case from 1 September 2015.

The event begins around 5 AM local time as the CWSU forecasters arrive on shift. At this time a coastal low was situated near the Texas coastal bend to the south-southwest of Houston, Texas. A shear axis was situated from southwest to northeast as observed in the water vapor imagery (not shown). Model forecasts indicated that the low would track to the northeast along the coast (Fig. 3). This was represented in the collaborative aviation weather statement issued at 1040 UTC and tracked the low's progress through 1600 UTC. In the CWSU's initial brief to the traffic management unit, scattered convection was forecast to impact the southern gates (Fig. 4). Figure 4 shows the TRACON gate forecast in a "stoplight" format issued at 1048 UTC (5:48 AM local time). The primary emphasis was on the southern gates, as indicated by the yellow. The forecasters further added that later in the day all gates would be impacted by the convection.

Figure 5 shows the situation approximately four hours later at 1500 UTC. Storms are situated roughly west to east across the southern section of the Houston TRACON. The strongest storms, observed by both radar and the HGLMA flash extent density product are observed on the eastern side near Galveston, Texas. The HGLMA is highlighting the eastern storms with flash extent density values of nearly 20 flashes per minute. The values drop to approximately 1-2 flashes per minute further to the west. The corresponding National Lightning Detection Network (NLDN; Cummins et al. 1998) observations show the cloud-to-ground flash locations. Only a dozen cloud-to-ground flashes are observed in the whole region at 1500 UTC. At this stage, the initial forecast is in good agreement with the current conditions.

The situation continues to evolve through 1552 UTC (Fig. 6). Here, the main convective activity remains on the southeastern edge of the Houston TRACON air space. An area of weaker convection with reflectivity values in the 40-50 dBZ range is to the southwest of Bush Intercontinental Airport (IAH – Fig. 6). The corresponding NLDN observations are only observing cloud-to-ground flashes around Galveston Island and Galveston Bay. However, the HGLMA flash extent density product shows a different trend. The previously mentioned storms immediately to the southwest of IAH have several intra-cloud flashes observed. Further west, a small intra-cloud flash is observed by the HGLMA where the radar is identifying new cell development. This provided a two minute lead time over the NLDN observing lightning in the far western storm, which had its first cloud-to-ground flash at 1554 UTC. This activity to the west is what the CWSU forecasters briefed the traffic management unit on what may occur later in the day. The total lightning observations were the first indication that convection would begin to develop west of the Houston TRACON air space. These observations led to the update of the TRACON gate forecast, showing the first sign of convection impacting the northwestern gates in the 18Z range (Fig. 7).

The HGLMA observations continue to provide support that the convection to the west is persisting and will likely impact the northwestern TRACON gates both at 1627 UTC (Fig. 8). The HGLMA flash extent density also provides the spatial extent of lightning, which will be another valuable observational feature of the future GLM observations. There is a storm cell observed just to the east of IAH. Here lightning can be observed extending northward from this cell into the region of clear air (as observed by the 0.5 degree radar reflectivity). This spatial extent could indicate potential turbulence as the cell is lofting charged hydrometeors away from the storm core. The NLDN observations are primarily constrained to the Galveston Bay area and only show a point location for the lightning.

The HGLMA flash extent density would continue to show low amounts of total lightning activity throughout the forecast period. This would continue to reinforce the morning forecast calling for the western gates to eventually be impacted by convection. The HGLMA observations provided an additional observation that convection was forming and that the forecast would not have to be amended later in the day. The NLDN observations also provided information about the storms in the region, particularly to the west. However, for the western storms, the NLDN observations were more intermittent and did not show the spatial extent of the lightning.

FUTURE WORK

This presentation has focused on the collaboration between NASA's Short-term Prediction Research and Transition (SPoRT) center and the National Weather Service Center Weather Service Unit (CWSU) in Houston, Texas. This collaboration began in 2014 and has focused on using the ground-based lightning mapping array (owned by Texas A&M University) to incorporate total lightning (intra-cloud and cloud-to-ground) observations into operations. In addition, the use of the lightning mapping array serves as a demonstration for the soon to be operational Geostationary Lightning Mapper (GLM).

The collaborations were driven, in part, to expand the use of total lightning beyond the local weather forecast offices. Unlike the local forecast offices, the CWSUs are focused on all convection and not just severe convection. Utilizing total lightning observations can support the CWSU forecasters in their monitoring and assessment of convective activity.

The future plans for this project will begin to shift to the use of the GLM data as they become available to the CWSU in 2017. The CWSU will take part in a SPoRT-led operational assessment of the GLM observations starting in the summer of 2017. Part of this assessment will evaluate the utility of the decision support efforts learned from the ground-based lightning mapping array and how they transition to the use of GLM data. This will also identify cases for applications training that can be applicable to other CWSUs in the country. Lastly, the collaboration will continue to identify derived tools and products for the GLM that address the CWSU's forecast needs and concerns.

Acknowledgments: The authors would like to thank Texas A&M University and the New Mexico Institute for Mining and Technology for the use of the real-time Houston-Galveston Lightning Mapping Array data for this collaboration.

REFERENCES

Christian, H. J., R. J. Blakeslee, and S. J. Goodman, 1989: The detection of lightning from geostationary orbit. *J. Geophys. Res.*, **94**, 13329–13337, dx.doi.org/10.1029/JD094iD11p13329.

Cummins, K. L., M. J. Murphy, E. A. Bardo, W. L. Hiscox, R. B. Pyle, and A. E. Pifer, 1998: A combined TOA/MDF technology upgrade of the U.S. National Lightning Detection Network, *J. Geophys. Res.*, **103**, 9038-9044.

Darden, C., B. Carroll, S. Goodman, G. Jedlovec, B. Lapenta, 2002: *Bridging the gap between research and operations in the National Weather Service: Collaborative activities among the Huntsville meteorological community*. NOAA Technical Memorandum, PB2003-100700, NWS Southern Region, Fort Worth, TX.

Darden, C. B., D. J. Nadler, B. C. Carcione, R. J. Blakeslee, G. T. Stano, and D. E. Buechler, 2010: Using total lightning information to diagnose convective trends. *Bull. Amer. Meteor. Soc.*, **91** (2), 167-175, doi:10.1175/2009BAMS2808.1.

Goodman, S. J., W. M. Lapenta, G. J. Jedlovec, J. C. Dodge, and J. T. Bradshaw, 2004: The NASA Short-term Prediction Research and Transition (SPoRT) Center: A collaborative model for accelerating research into operations. *20th Conf. on Interactive Information Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology*, Amer. Meteor. Soc., Seattle, WA, P1.34.

Goodman, S. J., R. Blakeslee, H. Christian, W. Koshak, J. Bailey, J. Hall, E. McCaul, D. Buechler, C. Darden, J. Burks, T. Bradshaw, and P. Gatlin, 2005: The North Alabama Lightning Mapping Array: Recent severe storm observations and future prospects. *Atmos. Res.*, **76**, 423-437.

Goodman, S. J., R. J. Blakeslee, W. J. Koshak, D. Mach, J. Bailey, D. Buechler, L. Carey, C. Schultz, M. Bateman, E. McCaul Jr., G. Stano, 2013: The *GOES-R* Geostationary Lightning Mapper (GLM). *Atmos. Res.*, **126**, 34–49, dx.doi.org/10.1016/j.atmosres.2013.01.006.

Jedlovec, G., 2013: Transitioning Research Satellite Data to the Operational Weather Community: The SPoRT Paradigm. *Geosci. & Remote Sens. Mag.*, 62-66, doi:10.1109/MGRS.2013.2244704.

Rison, W., R. J. Thomas, P. R. Krehbiel, T. Hamlin, and J. Harlin, 1999: A GPS-based three-dimensional lightning mapping system: Initial observations in central New Mexico. *Geophys. Res. Lett.*, **26**, 3573–3576.

Stano, G. T., H. E. Fuelberg, W. P. Roeder, 2010: Developing empirical lightning cessation forecast guidance for the Cape Canaveral Air Force Station and Kennedy Space Center. *J. Geophys. Res.*, **115**, 18 pp. DOI: 10.1029/2009JD013034.

Stano, G. T., 2012: Using total lightning observations to enhance lightning safety. *7th Symposium on Policy and Socio-Economic Research*, Amer. Meteor. Soc., New Orleans, LA, 22-26 Jan 12, 327, 9 pp.

Stano, G. T., J. A. Sparks, S. J. Weiss, and C. W. Siewert, 2013: Fusing total lightning data with Aviation Weather Center and Storm Prediction Center operations during the GOES-R visiting scientist program. *6th Conf. on Meteorological Applications of Lightning Data*, Amer. Meteor. Soc., Austin, TX, 5-10 Jan 13, 724, 8 pp.

Stano, G. T., C. J. Schultz, L. D. Carey, D. R. MacGorman, and K. M. Calhoun, 2014: Total lightning observations and tools for the 20 May 2013 Moore, Oklahoma, tornadic supercell. *J. Operational Meteor.,* **2** (7), 71-88, doi: http://dx.doi.org/ 10.15191/nwajom.2014.0207.

Terborg, A., and G. T. Stano, 2017: Impacts to Aviation Weather Center operations using total lightning observations from the Psuedo-GLM. *J. Operational Meteor.*, **5** (1), 1-13, doi: http://dx.doi.org/10.15191/nwajom.2017.0501.

White, K., B. Carcione, C. J. Schultz, G. T. Stano, and L. D. Carey, 2012: The use of the North Alabama Lightning Mapping Array in the real-time operational warning environment during the March 2, 2012 severe weather outbreak in Northern Alabama. *NWA Newsletter*, Oct. 2012, No. 12-10.

IMAGES

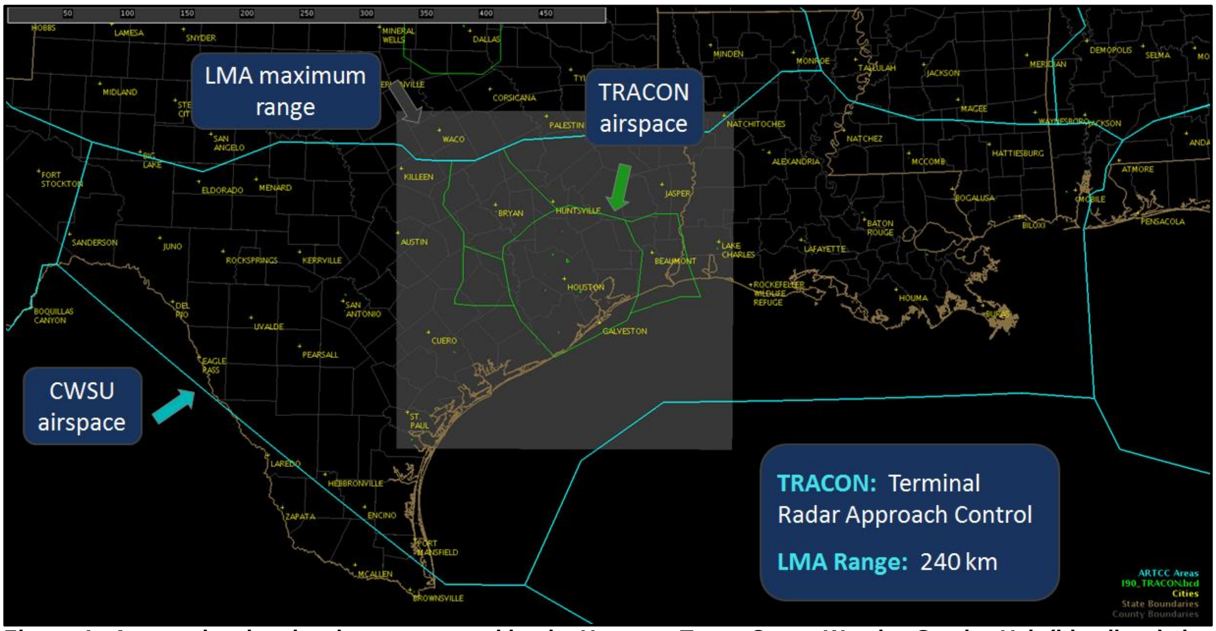

***Figure 1*:** **A map showing the airspace covered by the Houston, Texas Center Weather Service Unit (blue lines), the maximum range of the Houston-Galveston Lightning Mapping Array (shaded grey square), and the Houston, Texas Terminal Radar Approach Control airspace (green lines) as shown in AWIPS.**

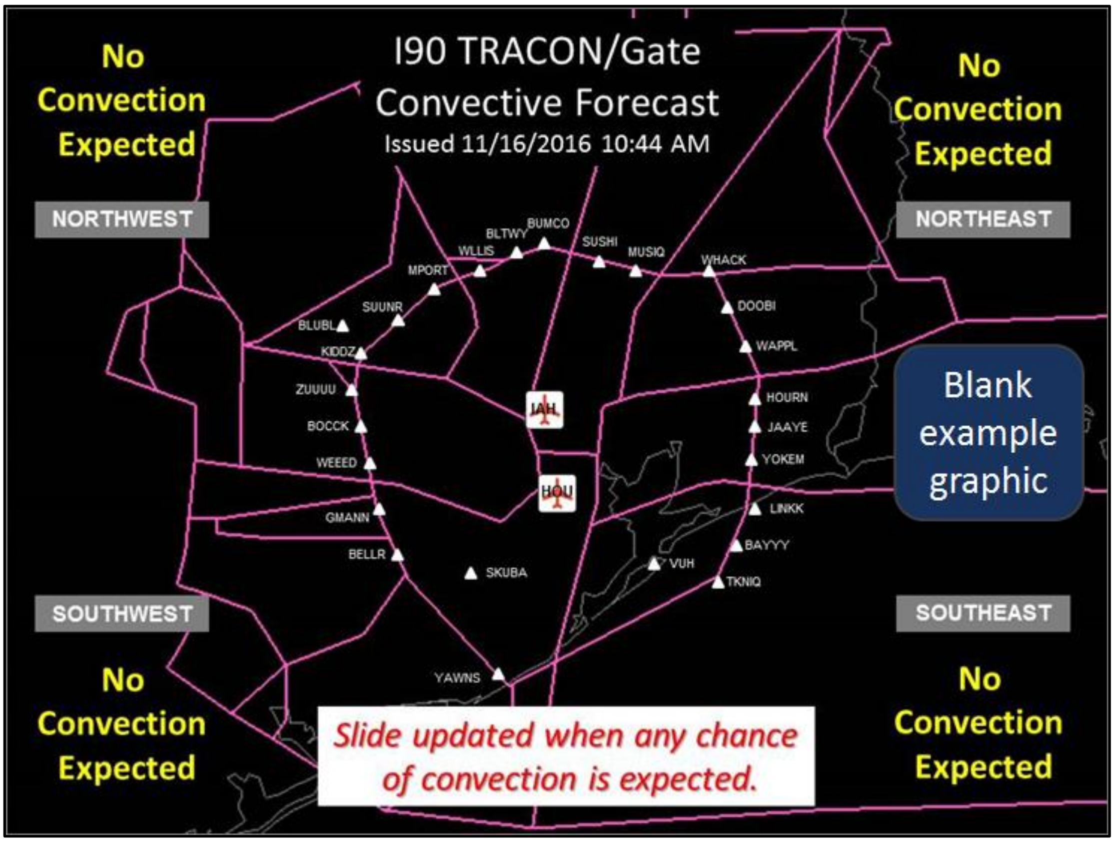

***Figure 2*:** **A blank Houston, Texas TRACON airspace convective forecast map showing the aircraft arrival and departure gate locations surrounding the Houston Bush Intercontinental and Houston Hobby airports. On days where convection is expected, a color coded "stoplight" display will show the approximate timing and coverage of convection for each region.**

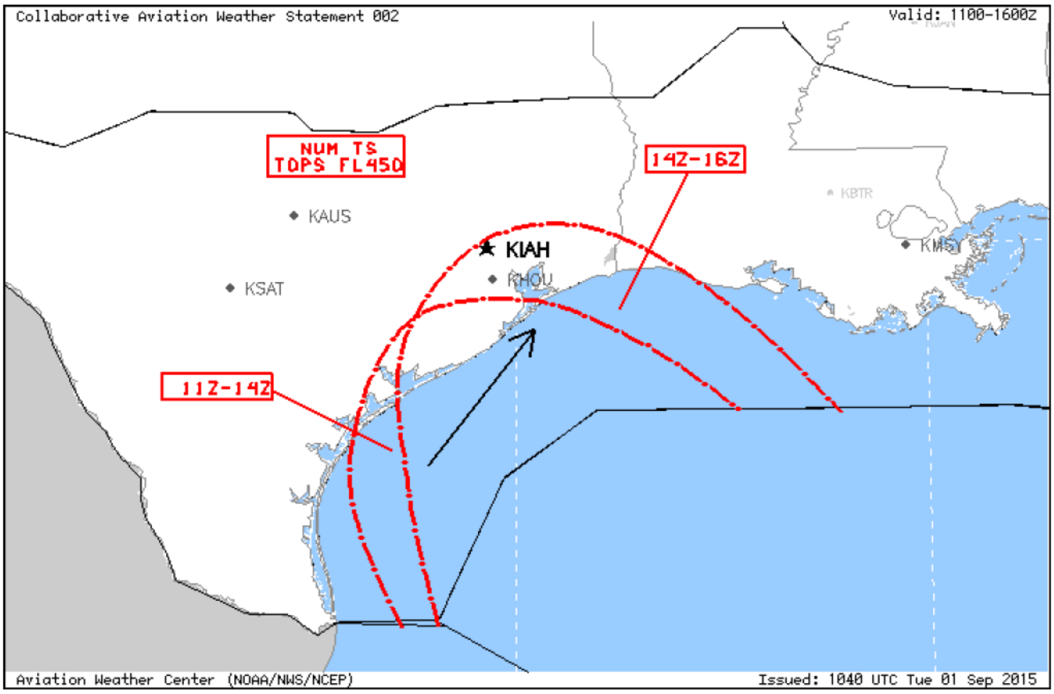

Figure 3: The Collaborative Aviation Weather Statement, issued at 1040 UTC on 1 September 2015, outlines the time and location of convection for the low moving northeastward along the Texas Gulf Coast.

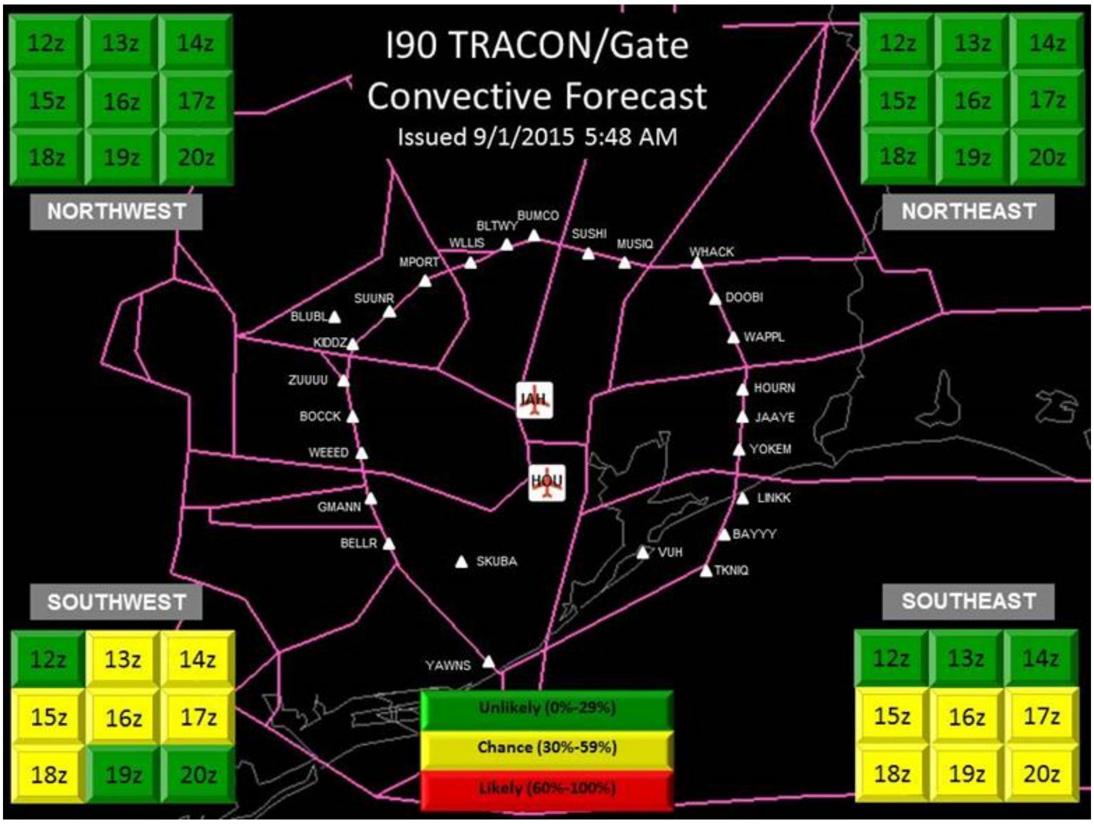

Figure 4: This is the same layout as Fig. 2, but now shows the TRACON gate forecast as issued at 1048 UTC on 1 September 21015. The CWSU forecast was calling for a chance of convection in the southwest and southeastern gates starting at 13Z and 15Z, respectively and how long this would persist (as shown in yellow).

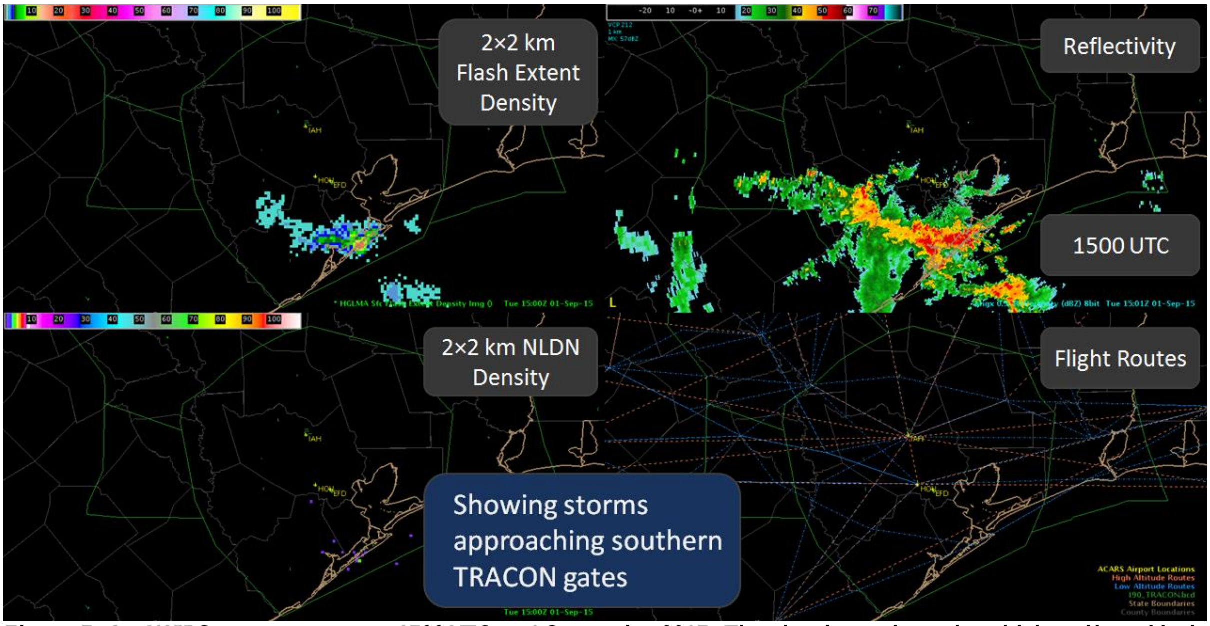

Figure 5: **An AWIPS screen capture at 1500 UTC on 1 September 2015. The plot shows the various high and low altitude flight routes in the Houston air space (lower right), the radar reflectivity (upper right), the 2x2 km National Lightning Detection Network cloud-to-ground flash density, and the Houston-Galveston Lightning Mapping Array 2x2 km flash extent density. The TRACON airspace is outlined in green in all four panels. Note how the flash extent density highlights the spatial extent of the total lightning as well as shows more overall lightning than the National Lightning Detection Network data alone.**

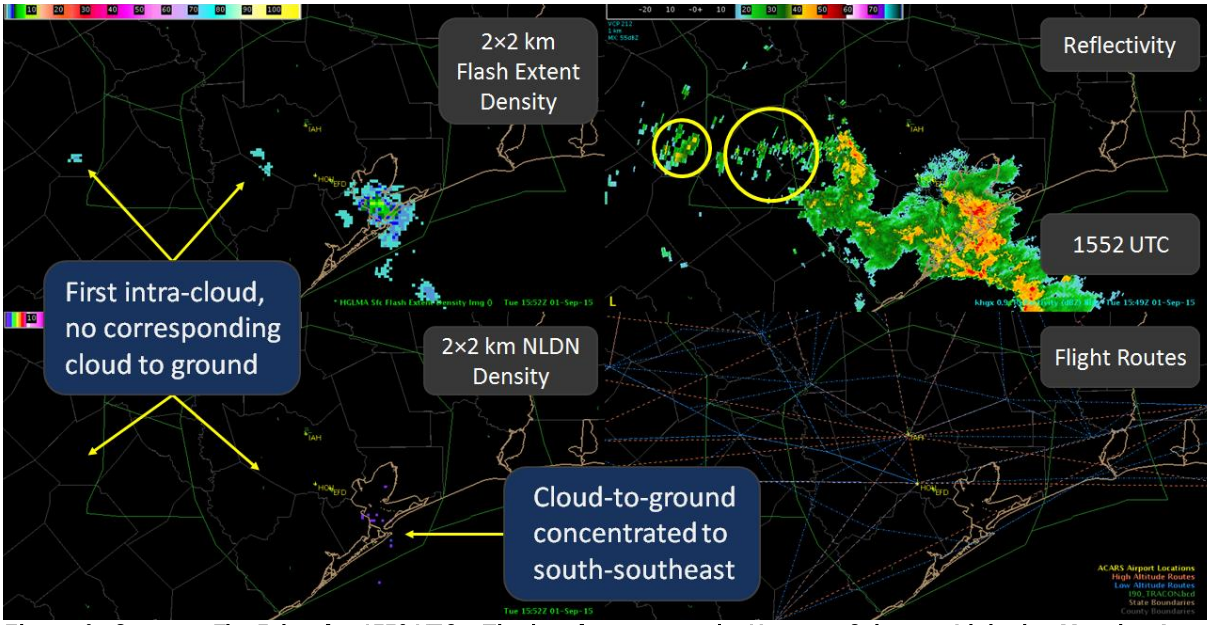

Figure 6: **Same as Fig. 5, but for 1552 UTC. The key features are the Houston-Galveston Lightning Mapping Array observing intra-cloud flashes to the west of Houston Bush Intercontinental Airport (IAH – relevant storms circled in yellow in the radar reflectivity) and that the National Lightning Detection Network flashes are concentrated over Galveston Bay.**

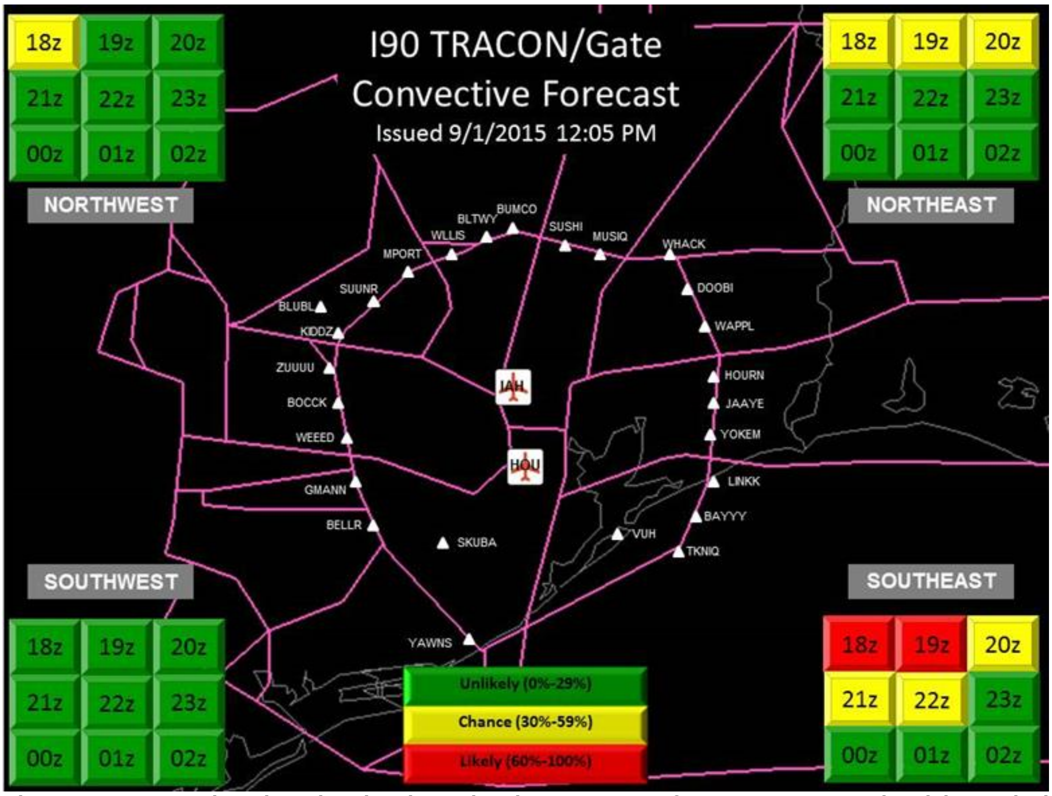

Figure 7: Same as Fig. 4, but showing the updated TRACON gate forecast at 12:05 PM local time. The key changes are the increase in convective likelihood in the southeast and the first indications of convection in the northern gates.

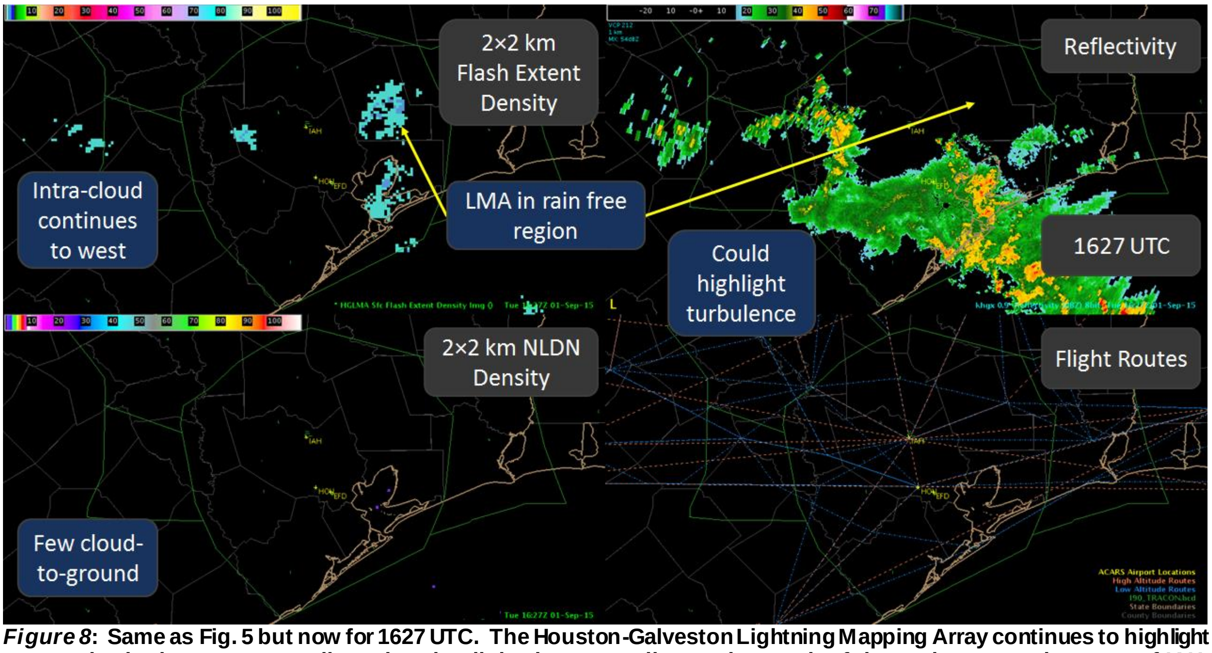

Figure 8: Same as Fig. 5 but now for 1627 UTC. The Houston-Galveston Lightning Mapping Array continues to highlight convection in the west as well as showing lightning extending to the north of the main convection east of IAH.