Using GLM Sub Flash Properties to Assess Convective State

Importance of Flash Area and Total Optical Energy

Lightning is a broadband emitter that is detectable across multiple frequencies. One of the challenges in using lightning "flashes" are that there are different definitions for a flash, which are entirely dependent upon the instrument making the measurement.

However, GLM provides two metrics which provide insight into the kinematic state of the parent cloud producing the lightning. These are flash area and flash energy.

Bruning and MacGorman (2013; right) provides theoretical basis for the use of flash area and flash energy in assessing convective state. In areas where there are weaker updrafts, larger flashes with more energy are generally found. Where there are strong, turbulent updrafts (e.g., supercell), smaller, less energetic flashes are observed.

The purpose of this poster is to demonstrate how this flash area and energy relationship spans multiple convective regimes and can help the forecaster assess the kinematic state of the cloud to aid in operational decision making.

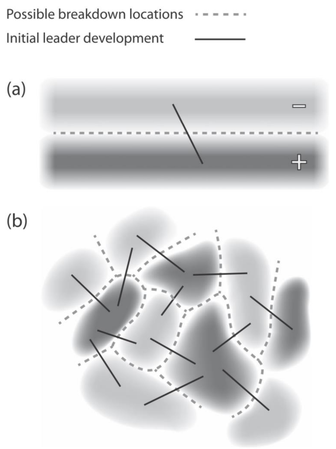


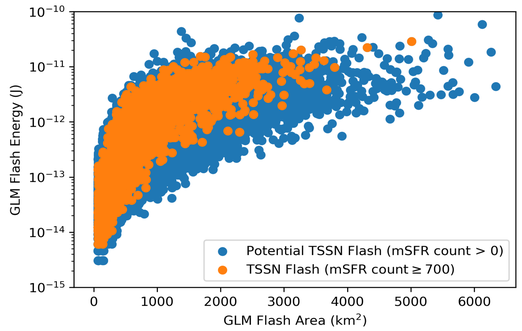
FIG. 1. Two idealized charge structures showing (a) extensive, horizontally stratified charge and (b) smaller pockets or blobs of charge. Dark gray blobs or regions are positive charge, while lighter gray is negative charge. Dashed gray lines indicate regions of large electric field where breakdown might begin. Solid black lines indicate where leaders would develop and propagate toward the center of the charge regions after initial breakdown.

Bruning and MacGorman 2013

https://journals.ametsoc.org/doi/full/10.1175/JAS-D-12-0289.1

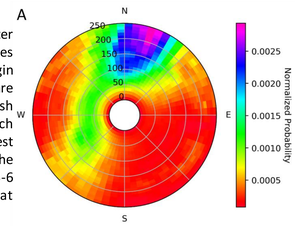
Thundersnow

Harkema et al. 2019: https://journals.ametsoc.org/doi/10.1175/WAF-D-19-0082.1

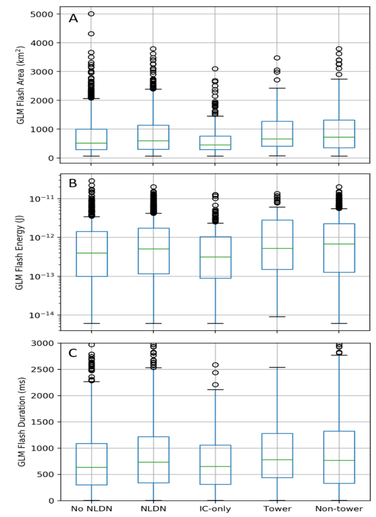


Relationship between GLM flash energy and flash area. Blue are GLM flashes with Merged Snowfall Rate values between 0 and 700, and orange represents TSSN flashes observed by GLM with a NESDIS Merged Snowfall Rate count of 700 or greater.

Polar plot of frequency of snowfall rates greater than 4.44 cm h^{-1} (1.75 in h^{-1}) for all TSSN flashes observed by GLM. The flash location is at the origin of the polar plot. The heaviest snowfall rates are located 10s of km downstream from the flash origination point. This supports previous research that the lightning is located outside of the greatest surface snowfall rates. Main reason for the displacement is that lightning is generated at 3-6 km, which means it takes at least an hour for that snowfall to make it to the surface.



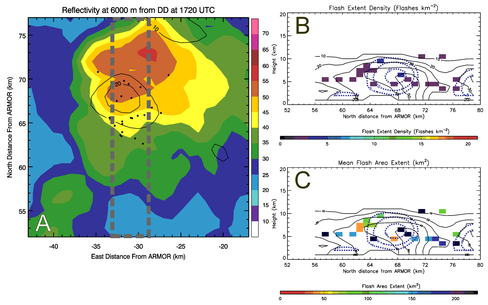
Harkema et al. 2020: https://journals.ametsoc.org/doi/abs/10.1175/WAF-D-19-0126.1

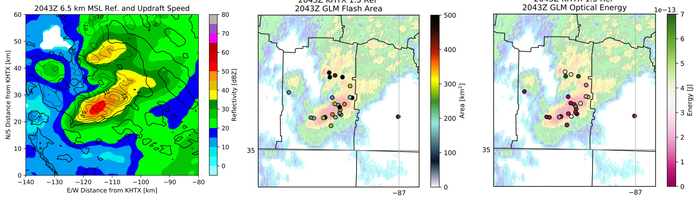


Differentiation of GLM flashes with regards to flash: a) area, b) energy, and c) duration based on NLDN matchup characteristics. There is a total of 1,081 GLM flashes did not correspond with any NLDN data while the remaining 1,095 GLM flashes corresponded with NLDN data. The 1,095 GLM flashes subcategorized as IC-only (N=356), Tower (N=152) and Non-tower (N=587) initiated.

Severe Convection

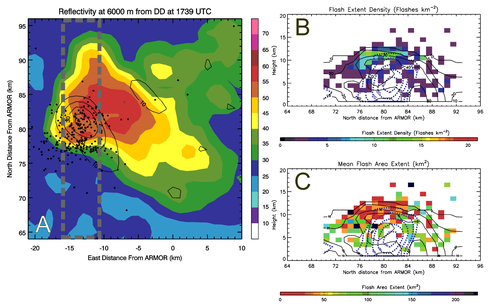
Pre updraft intensification



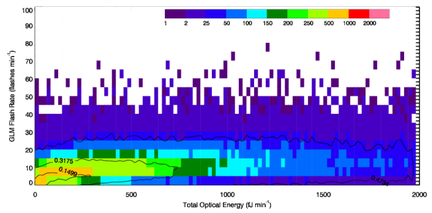


Updraft, flash size and flash rate relationships developed using lightning mapping arrays can plausibly be extended to GLM. Smaller, lower energy flashes are located near updraft regions, larger, higher energy flashes are in stratiform/anvil regions.
--Conrad et al. 2020, JGR, accepted, pending revision

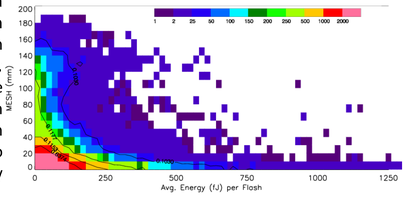
Post updraft intensification



Schultz et al. 2017:
https://journals.ametsoc.org/doi/full/10.1175/WAF-D-15-0175.1

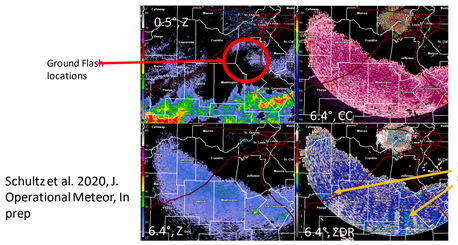


Using total energy alone may not be a viable signal for storm intensification (above) because of a broad spectrum of total energy per flash. However, when one normalizes the accumulated energy by the GLM flash rate, a more distinct relationship can be gleaned and directly related to other observed metrics fro intensity (e.g, right, MESH shown here).

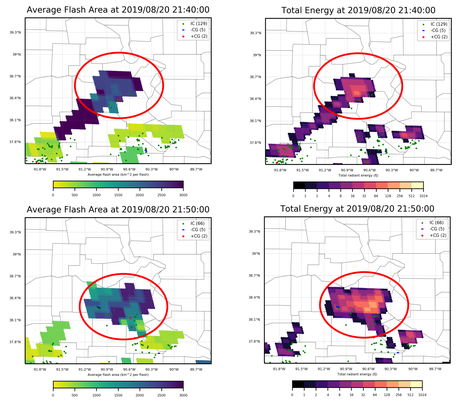


Schultz et al. 2020, JGR, in prep.

Safety



Schultz et al. 2020, J. Operational Meteor, In prep



An extreme bolt from the blue event on 20 August 2019 near St. Louis. Large lightning flashes propagated from a convective region of a decaying MCS rearward into an upper level stratiform region. Several +CG flashes were observed 10s of km outside of surface precipitation. The GLM flash area and energy information provided information on the propagation path and location of the largest observed total optical energy. Slight offsets were observed between GLM and the NLDN, which is due to parallax.

Volcanic Plumes

Andrews et al. 2020, Scientific Reports, accepted, pending revision

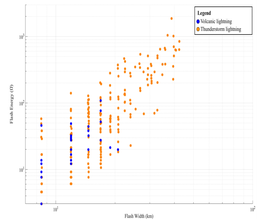
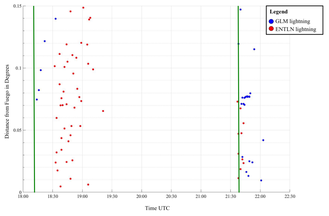


Figure 3. A comparison of GLM flash width (km) vs. flash energy (fJ) during the 3 June 2018 Fuego eruption, where the blue symbols indicate volcanic lightning and the yellow symbols indicate a thunderstorm located to the Northwest of the volcano.

Figure 2. GLM (blue) and ENTLN (red) through time within a 30 km radius of the Fuego vent. The first vertical, green line represents the start of the explosive eruption, the second line shows the interpreted initiation of column collapse, and/or the onset of the large PDC.



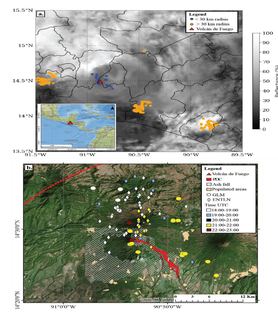


Figure 1. (a) GOES channel 1 (0.47 micron) reflectance with GLM lightning data overlaid (blue < 30 km from vent, orange > 30 km from vent). Lower reflectance in the area of the blue dots is associated with the ash plume while higher reflectance in other areas with orange dots is associated with 'ash-free' convective clouds. (b) GLM (circles) and ENTLN (diamonds) data by time displayed over Esri world imagery during the 3 June 2018 Volcán de Fuego eruption. The dashed red line is an approximation of the ash plume using MODIS true color imagery at ~19:00 UTC. A Copernicus EMS map and vector data was used to obtain PDC extent, ash fall and populated areas.