A Climatology of Quasi-linear Convective Systems in the U.S.

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Research supported by the National Science Foundation through AGS Award #1637225

Research Questions

Can we automate the detection of QLCSs with high accuracy?

Gallus et al. (2008) and Smith et al. (2012) hand-labeled (n=~10^3)

Where do QLCSs occur in the U.S.?

~10^6 available radar images to assess across 22 years

What percentage of severe reports are produced by QLCSs?

Match ~10^5 severe reports with ~10^6 radar images

Data and Methods

Data for 1996 through 2017 include:

→ NOWrad radar mosaics at 2 x 2 km, 15 min. resolution

→ SPC's SVRGIS, including reported severe hail (≥1"), severe nontornadic wind (≥58 mph), and tornadoes

QLCS classification:

→ Image classification problem

- Convolutional neural network
- Hand classified 3,000 samples of QLCS/ Non-QLCS radar signatures
- 93% testing accuracy

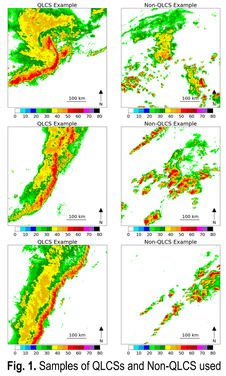

Fig. 1. Samples of QLCSs and Non-QLCS used to inform image classification approach.

QLCS Tracking:

→ See MCS tracking method in Haberlie and Ashley (2018a,b *JAMC*)

→ Extract t-storm clusters that are ≥40 dBZ and ≥100 km with ≥3:1 length-to-width ratio = **slices**

→ Spatiotemporal overlap to associate clusters in time = **swaths**

→ Cluster is QLCS if classified as a QLCS with 95% confidence during two consecutive hours

Determining QLCS-affiliated storm report:

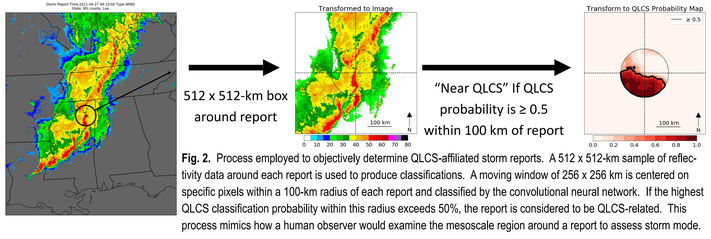

Fig. 2. Process employed to objectively determine QLCS-affiliated storm reports. A 512 x 512-km sample of reflectivity data around each report is used to produce classifications. A moving window of 256 x 256 km is centered on specific pixels within a 100-km radius of each report and classified by the convolutional neural network. If the highest QLCS classification probability within this radius exceeds 50%, the report is considered to be QLCS-related. This process mimics how a human observer would examine the mesoscale region around a report to assess storm mode.

Climatology

Annual Frequency

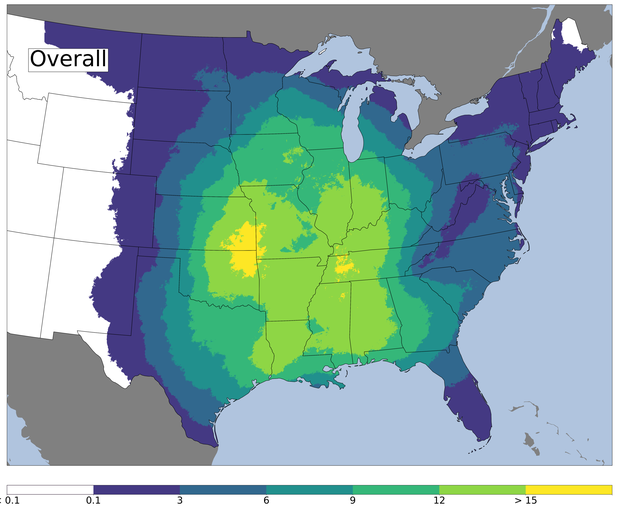

Fig. 3. Mean annual frequency of QLCSs, 1996-2017.

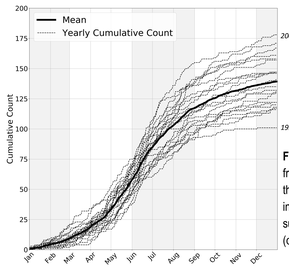

Fig. 4. Cumulative frequency diagram of the mean (bold) and individual yearly summative counts (dashed), 1996-2017.

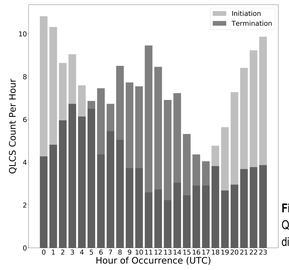

Fig. 5. Mean hourly QLCS initiation and dissipation counts.

Seasonality

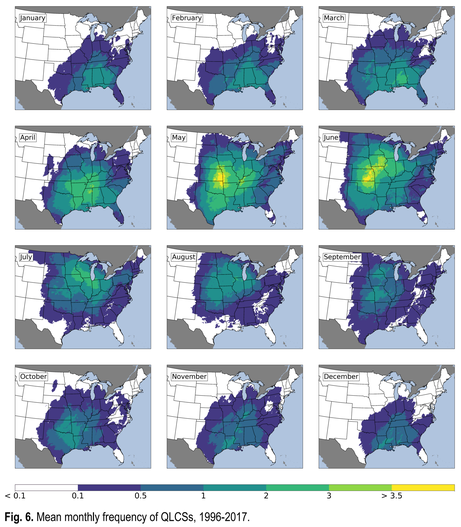

Fig. 6. Mean monthly frequency of QLCSs, 1996-2017.

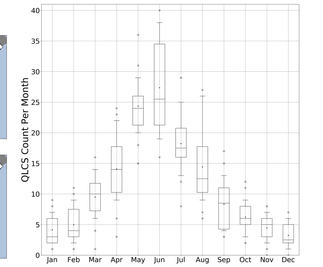

Fig. 7. Box-and-whisker plot of monthly QLCSs, 1996-2017. The box represents the interquartile range, horizontal line the median, dot the mean, whiskers are values between the 5th and 95th percentiles, and open circles are outliers.

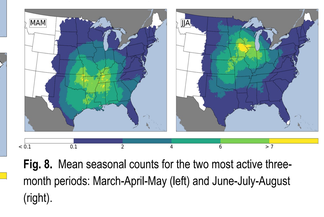

Fig. 8. Mean seasonal counts for the two most active three-month periods: March-April-May (left) and June-July-August (right).

QLCS Storm Reports

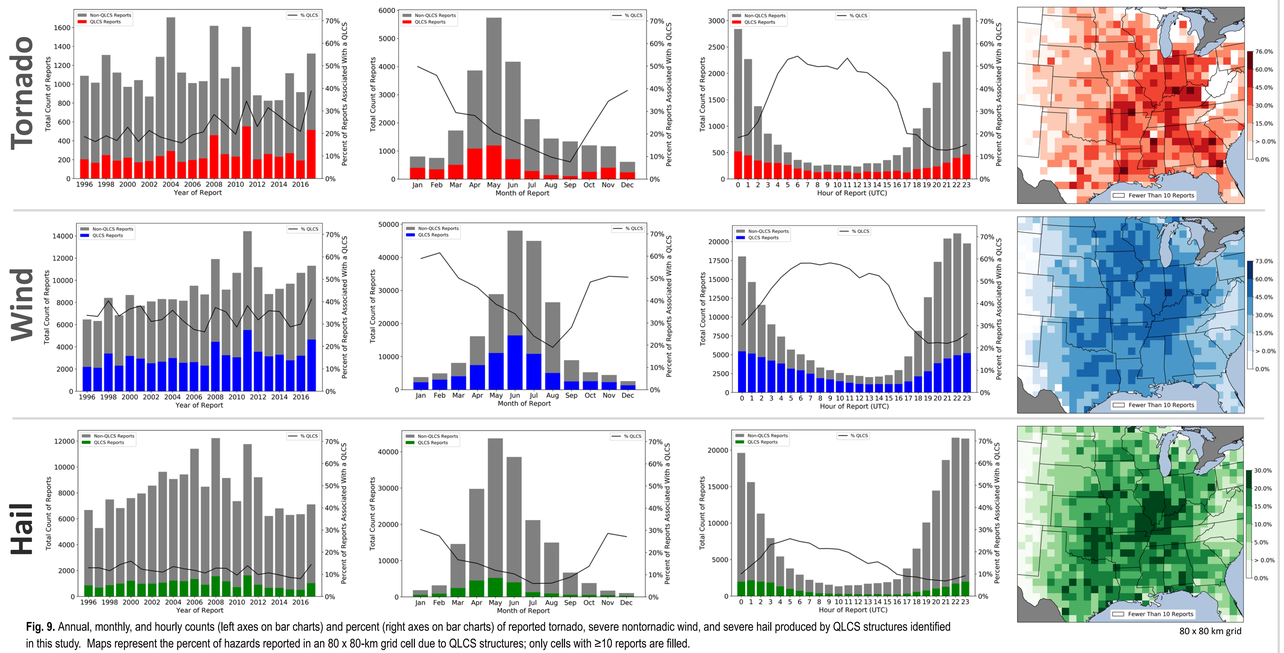

Fig. 9. Annual, monthly, and hourly counts (left axes on bar charts) and percent (right axes on bar charts) of reported tornado, severe nontornadic wind, and severe hail produced by QLCS structures identified in this study. Maps represent the percent of hazards reported in an 80 x 80-km grid cell due to QLCS structures; only cells with ≥10 reports are filled.

Conclusions

→ Image classification has high testing accuracy supported by subjective validation and summary statistics

→ 3,064 QLCSs tracked over 22-yr period; mean of 139 yr^{-1} with primary corridor east of I-35 in the central/lower Mississippi and Ohio Valleys; QLCS max is located in southeast Kansas, with a mean of 16 yr^{-1}

→ Maximize in late-spring / early summer, with a notable drop off from June to July

→ QLCSs are responsible for spatiotemporal variable proportion of severe reports

→ Max QLCS severe report attribution (40-60%) is in western Ohio River and central Mississippi River Valleys

→ In some locations, >50% of tornadoes are associated with QLCSs

→ Percent of QLCS-affiliated tornado and wind reports maximize during overnight and cool-season