Applying Modern Meteorological Tools to the Study of Ball Lightning (Kugelblitz)

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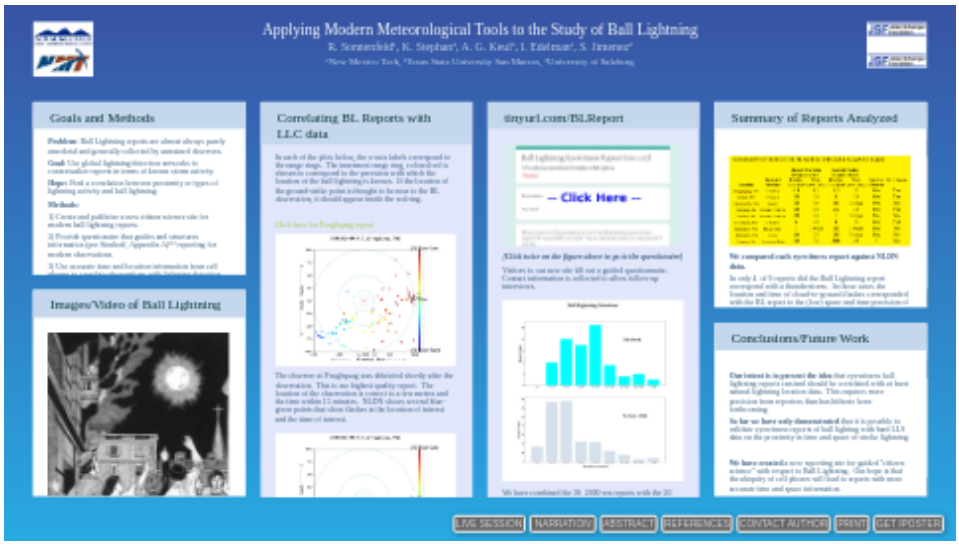
Abstract

Rakov and Uman pointed out (Lightning: Physics and Effects, 2003) that despite 5000 published reports of ball lightning (BL) and a scientific literature comparable in volume to the literature on conventional lightning, we still have no idea of what mechanisms create or power BL. Lightning characterization technology advances can and should be applied to BL studies. Keul and Diendorfer (2018) have correlated BL reports with European lightning-detection network data, but no such attempt has been made for US BL reports up to now. Using 31 BL reports from a now-defunct US website, we have attempted correlations with National Lightning Detection Network (NLDN) and radar data archived at the National Climactic Data Center. Of the 31 reports, 5 objects were indoors and 25 were reported to coincide with thunderstorms. Time information accurate to 30 minutes (1 sigma) and location information accurate within one to ten km was available from nine of the reports, and for these we obtained both NLDN and composite radar data covering the time frames indicated by the reports. For three of the nine reports, we found NLDN located strikes plausibly within the distance and time frames of the observer reports – thus qualifying as nearby (possibly causal) lightning. However, for the report for which the location of the ball was known within meters, the nearest lightning was 2.3 km away. 23 reports only associate BL with a storm within 25 km. Should it continue to hold in the face of more evidence, the relative lack of correlation of BL and nearby lightning suggests that the production of BL is associated more with static or changing electric fields in the vicinity of thunderstorms, than with the lightning plasma channel itself. While these results by themselves are limited, we are optimistic that one can learn more about the link between natural and ball lightning by fusing more precise eyewitness reports with lightning location and other archival meteorological data. To this end, we have launched a website to guide citizen scientists in future ball lightning reports. The site may be reached via https://tinyurl.com/BLReport.

Applying Modern Meteorological Tools to the Study of Ball Lightning



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GOALS AND METHODS

Properties of Ball Lightning (BL) which must be explained:

Per Rakov and Uman[d]

(i) Association of with thunder storms or CG lightning.

(ii) Reported shape, diameter and duration and relative constancy of these over its lifetime.

(iii) Occurence in both open air and enclosed buildings/aircraft

(iv) Motion inconsistent with hot gas.

We plan to attack item (i) and collect information in (ii)--(iv).

Problem: Ball Lightning reports are almost always purely anecdotal and generally collected by untrained observers.

Goal: Use global lightning detection networks to contextualize reports in terms of known storm activity.

Hope: Find a correlation between proximity or types of lightning activity and ball lightning.

Methods:

1) Create and publicize a new citizen science site for modern ball lightning reports.

2) Provide questionaire that guides and structures information (per Stenhoff, Appendix A)[b] reporting for modern observations.

3) Use accurate time and location information from cell phones to correlate observations with lightning detection networks.

Prior Work:

We are not the first to try to add some science to anecdotal reports.

Keul[e] has correlated eyewitness reports in Europe with European LLS's.

Shmatov tried to analyze a window with a circular hole purportedly formed by ball lightning.

Stephan[f] had a report in which the BL object appeared to cause fluorescence in nearby window glass, and he was able to extract from that an optical power in the ultraviolet.

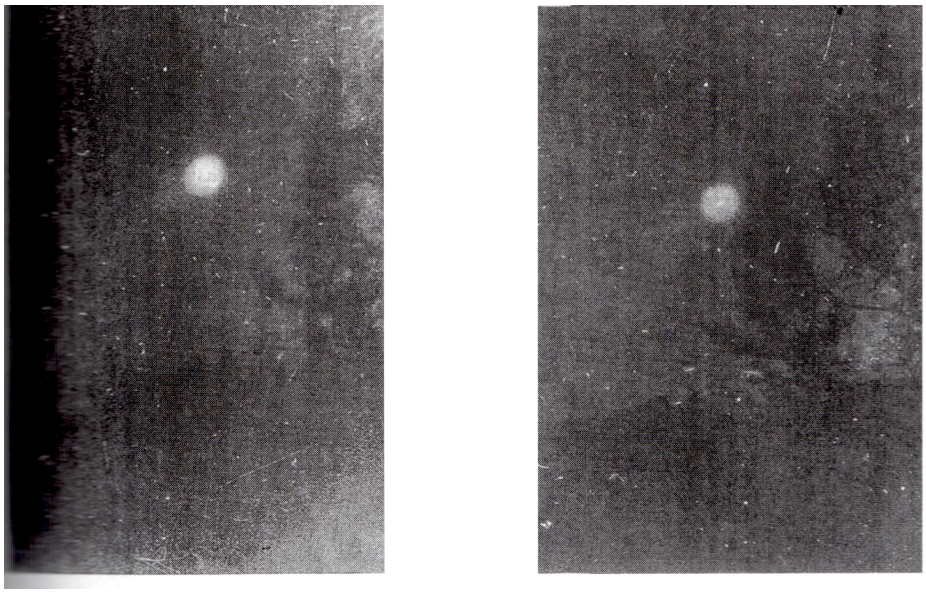
While our initial data set for this work came from a reporting site active on America Online in the 1990's (previously discussed by Keul[c]), we found no current centralized reporting site focusing on American cases.

For this reason we have started one.

IMAGES/VIDEO OF BALL LIGHTNING

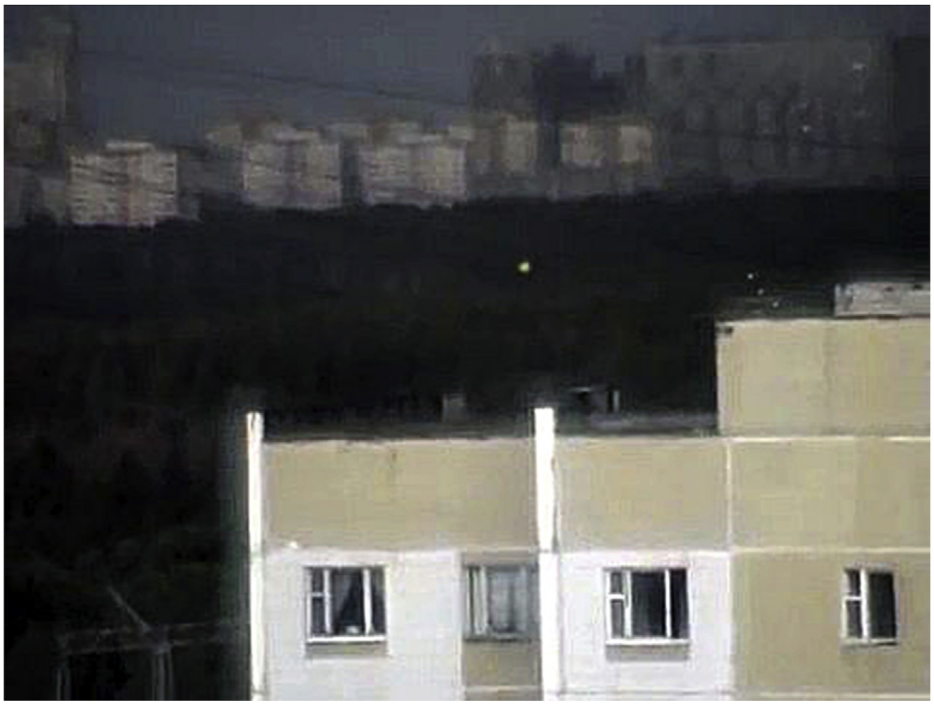
from Francois Arago, Meteorological Essays (1841)

The lack of detail and reliability in most ball lightning photos to date lead us to choose this etching as the first image of the poster. Stenhoff (1999)[(b)] published 27 still photographs, several of which were specifically instructive of how to spot artifacts, and all but one of which could be explained by natural lightning, streetlamps with a long exposure, incendiary devices, or power line arcs. The photo below is the most convincing still photo in Stenhoff's collection.



"A luminous ball 30 cm in diameter traveling at 2--4 m/s with about the brightness of a 100W bulb was observed 30 minutes before dawn crossing Undudun Lake in Russia."

The two photos were taken at an estimated distance of 250 m with 0.5 second exposures and are separated by 3 seconds in time. A badly resolved tree branch at the right of the image shows that the object has moved in the intervening seconds. (The small white spots in the photo are film blemishes)



from Nikitin et al. (2018)[a]

The little dot roughly centered in the picture is the ball lightning. It was captured simultaneously by three cell phone cameras, allowing the 200 meter wandering path it traversed during its two minute life to be calculated by triangulation. Despite the lack of detail, it is one of the most convincing photos of this phenomena because of its long life, multiple observers, and meandering

path. On the other hand, some researchers are speculating that this was merely a drone flight.

The Nikitin publication cited above includes links to the videos used in the analysis. (See below)

If the video below does not play, you can download it directly here:

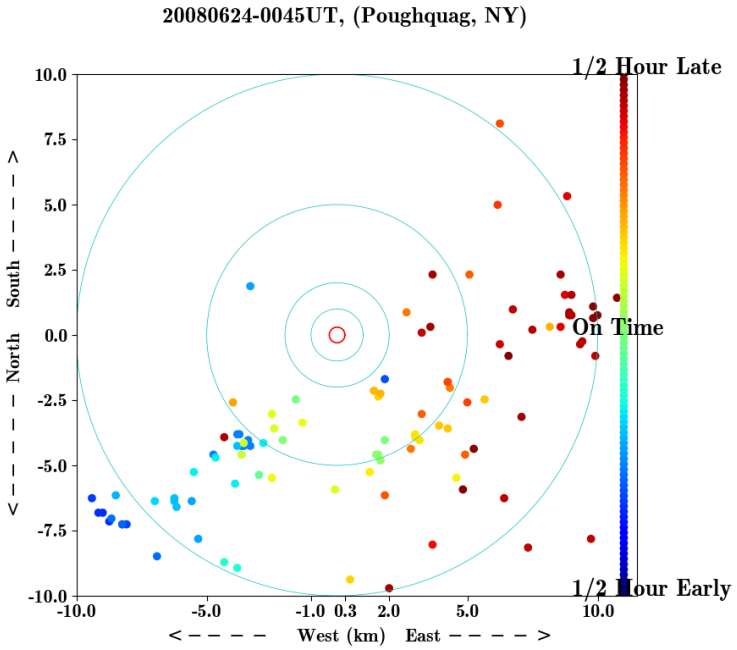
Video of Nitino Ball Lightning reported event (http://kestrel.nmt.edu/~rsonnenf/BL/Mitino_Krasnogorsk_27.07.15.mp4)

One video of this event is attached here:

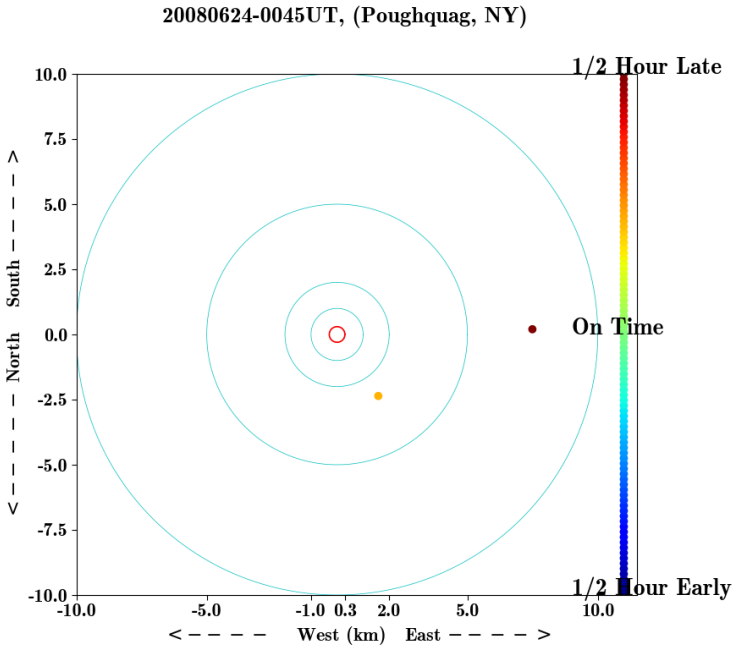
CORRELATING BL REPORTS WITH LLS DATA

In each of the plots below, the x-axis labels correspond to the range rings. The innermost range ring, colored red is chosen to correspond to the precision with which the location of the ball lightning is known. If the location of the ground-strike point is thought to be near to the BL observation, it should appear inside the red ring.

Click here for Poughquag report (http://kestrel.nmt.edu/~rsonnenf/BL/rpts/BallLightningReports9s.html#2)

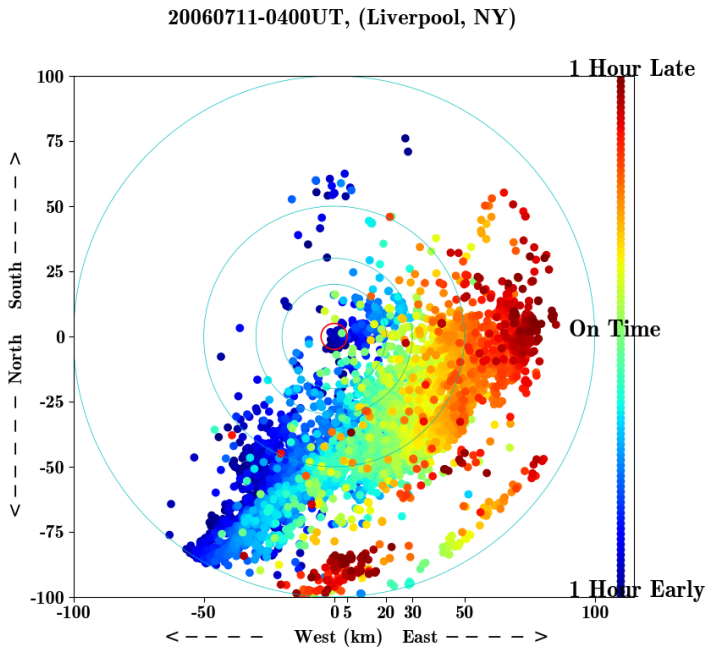


The observer at Poughquag was debriefed shortly after the observation. This is our highest quality report. The location of the observation is correct to a few meters and the time within 15 minutes. NLDN shows several blue-green points that show flashes at the location of interest and the time of interest.



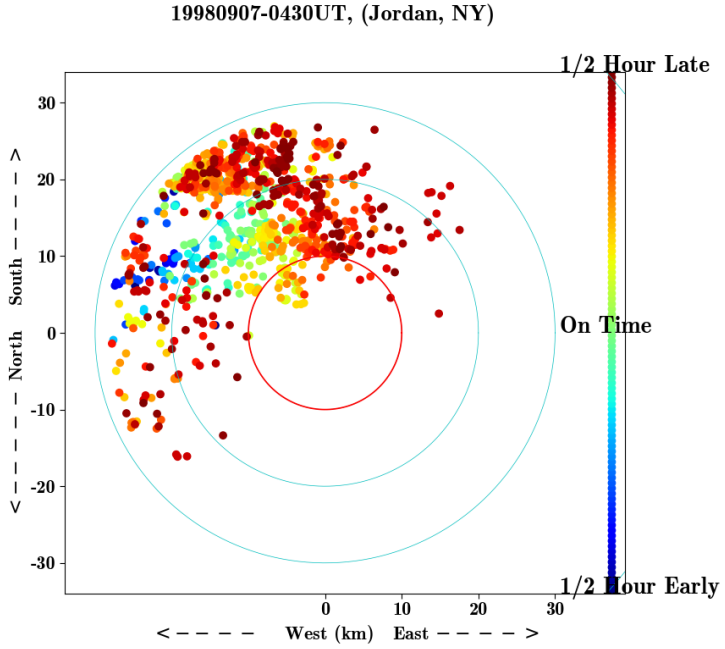
Another plot of the Poughquag data shows only positive flashes, as some observers have reported a correlation with positive flashes. These are all small, 6-20 kA. They might well be K-changes and not +CGs at all.

Click here for Liverpool report (http://kestrel.nmt.edu/~rsonnenf/BL/rpts/BallLightningReports9s.html#7)

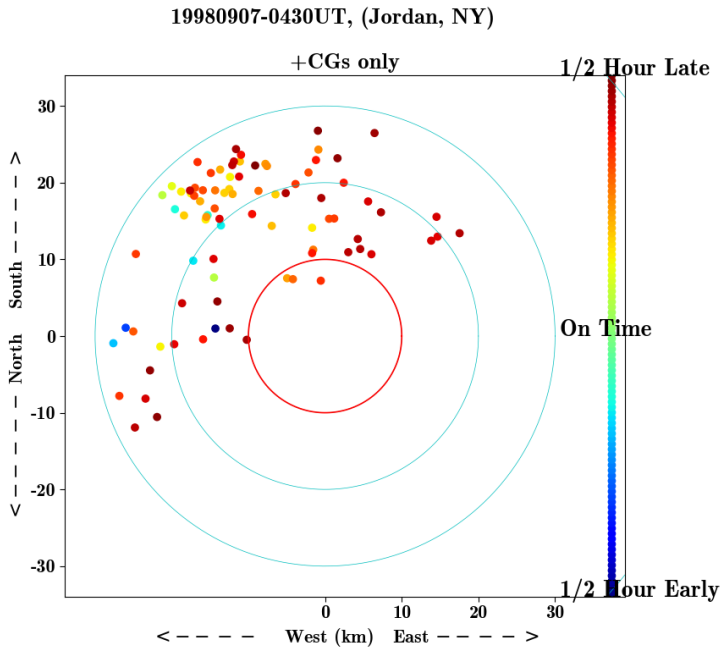


This plot of Liverpool data shows that there are several flashes within the 5-km range ring and "on time" that could have sourced the BL.

Click here for Jordan report (http://kestrel.nmt.edu/~rsonnenf/BL/rpts/BallLightningReports9s.html#3)

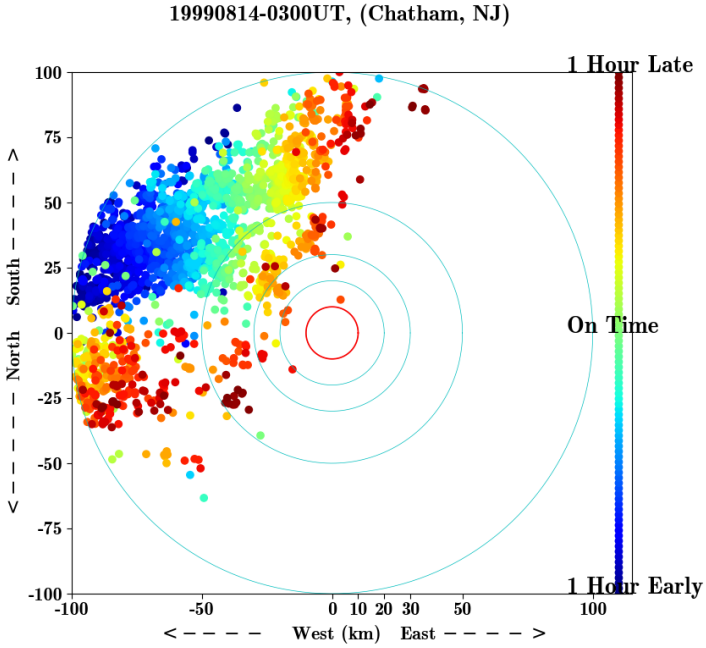


A storm in Jordan NY also corresponded with a BL observation.



There were also a number of +CGs near the observation site but all below 15 kA.

Click here for Chatham report (http://kestrel.nmt.edu/~rsonnenf/BL/rpts/BallLightningReports9s.html#5)



There are a few flashes within range in a one hour window. Opening up the window to two hours puts the storm directly on top of the observation point. This is consistent with eyewitness reports of an active but distant storm.

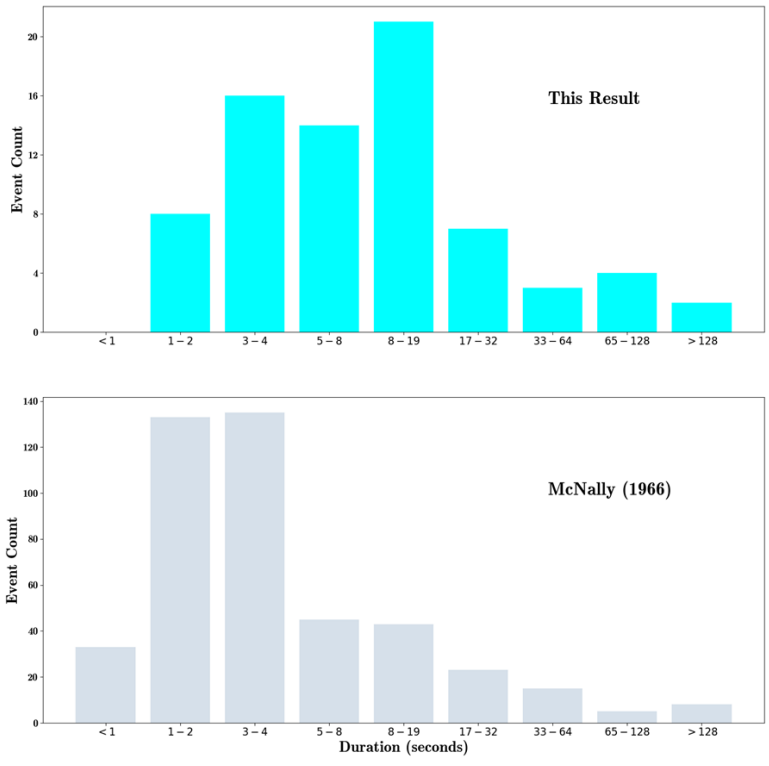
TINYURL.COM/BLREPORT

(http://kestrel.nmt.edu/~rsonnenf/BL/)

[Click twice on the figure above to go to the questionaire]

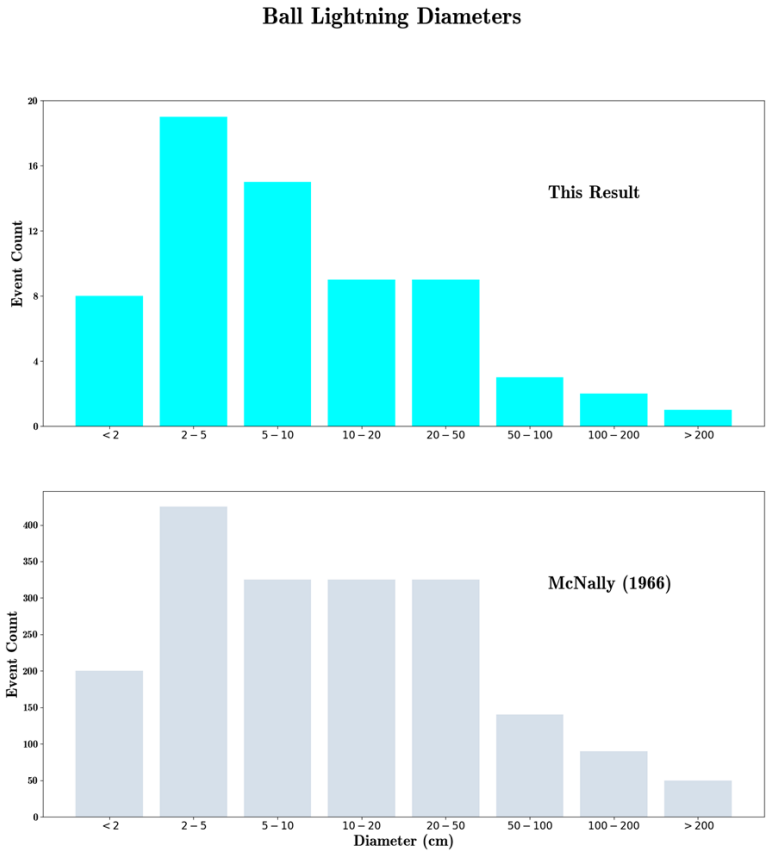
Visitors to our new site fill out a guided questionnaire. Contact information is collected to allow follow-up interviews.

Ball Lightning Durations



We have combined the 36 2000-era reports (the Beatty reports cited here[c]) with the 20 reports collected since our site went live

in September to check basic BL reporting statistics. The reported durations are somewhat longer than in McNally's much larger data set.



A comparison of sizes of our reports with McNally's shows a relative similarity.

Contents

-- Or Click Here --

(http://kestrel.nmt.edu/~rsonnenf/BL/rpts/BallLightningReports9.html)

SUMMARY OF REPORTS ANALYZED

SUMMARY OF REPORTED FLASHES CHECKED AGAINST NLDN

Location	Reported Weather	Report Precision (1 sigma values) Position *Error (km)*	Report Precision (1 sigma values) Time *Error (min.)*	Nearest Flashes (1 sigma values) Position *Error (km)*	Nearest Flashes (1 sigma values) Time *Error (min.)*	Agree w/ Observer	BL + Tstorm
Poughquag, NY	*T-Storm*	0.1	15	2.3	3	Yes	Yes
Jordan, NY	*T-Storm*	10	30	8	10	Yes	Yes
Quarryville, PA	*Sunny*	10	60	50	3 days	Yes	No
Chatham, NJ	*Distant T-Storm*	10	30	21	10	Yes	Yes
Fishers, IN	*Distant T-Storm*	10	30	1	4 days	No	No
Liverpool, NY	*T-Storm*	5	30	4	5	Yes	Yes
Mulkiteo, WA	*Heavy Rain*	1	1 week	50	1 week	Yes	No
Memphis, TN	*Clear*	10	30	30	9 days	Yes	No
Conroy, IA	*Previous Rain*	10	30	200	20	?	No

We compared each eyewitness report against NLDN data.

In only 4 of 9 reports did the Ball Lightning report correspond with a thunderstorm. In those cases the location and time of cloud-to-ground flashes corresponded with the BL report to the (low) space and time precision of the reporter.

In this data set, reporter only identified their city or town. The "location precision" was then based on inspection of maps and the distance to a town that would have a different name. Time was usually not reported to an accuracy better than 30 minutes.

It is interesting that for the case in which the Ball Lightning report is very clear and the time/location is known to 15 minutes and 100 meters that the nearest flash is 2.3 km away. While a correlation between lightning and ball lightning is known from many sources, our small data set does not suggest that it is as simple as a by product of a nearby flash.

CONCLUSIONS/FUTURE WORK

Our intent is to present the idea that eyewitness ball lightning reports can/and should be correlated with *at least* natural lightning location data. This requires more precision from reporters than has hitherto been forthcoming.

So far we have only demonstrated that it is possible to validate eyewitness reports of ball lighting with hard LLS data on the proximity in time and space of stroke lightning.

For three of the nine reports, we found NLDN located strikes plausibly within the distance and time frames of the observer reports -- thus qualifying as nearby (possibly causal) lightning.

However, for the report for which the location of the ball was known within meters, the nearest lightning was 2.3 km away. Should it continue to hold in the face of more evidence, the relative lack of correlation of BL and nearby lightning suggests that the production of BL is associated more with static or changing electric fields in the vicinity of thunderstorms, than with the lightning plasma channel itself.

We have created a new reporting site for guided "citizen science" with respect to Ball Lightning. Our hope is that the ubiquity of cell phones will lead to reports with more accurate time and space information.

The site has attracted some interest whenever an article on Ball Lightning is published. From our initial 50 reports, we get results for size that are surprisingly comparable to published literature given the imprecision of this field. Our duration reports are skewed to longer durations. Since 95% of our "new" reports are in fact from decade old memories, the duration numbers may no longer be very accurate.

We suggest that one of the more promising routes for harder evidence is for lightning researchers with high speed cameras to use longer captures and try to follow strokes all the way to their ground-strike points to look for nascent ball phenomena.

With funding, **we will investigate/propagate** a cell phone App which will capture a short video stream along with time, location and orientation stamps.

ABSTRACT

Rakov and Uman pointed out (Lightning: Physics and Effects, 2003) that despite 5000 published reports of ball lightning (BL) and a scientific literature comparable in volume to the literature on conventional lightning, we still have no idea of what mechanisms create or power BL. Lightning characterization technology advances can and should be applied to BL studies. Keul and Diendorfer (2018) have correlated BL reports with European lightning-detection network data, but no such attempt has been made for US BL reports up to now. Using 31 BL reports from a now-defunct US website, we have attempted correlations with National Lightning Detection Network (NLDN) and radar data archived at the National Climactic Data Center. Of the 31 reports, 5 objects were indoors and 25 were reported to coincide with thunderstorms. Time information accurate to 30 minutes (1 sigma) and location information accurate within one to ten km was available from nine of the reports, and for these we obtained both NLDN and composite radar data covering the time frames indicated by the reports. For three of the nine reports, we found NLDN located strikes plausibly within the distance and time frames of the observer reports -- thus qualifying as nearby (possibly causal) lightning. However, for the report for which the location of the ball was known within meters, the nearest lightning was 2.3 km away. 23 reports only associate BL with a storm within 25 km. Should it continue to hold in the face of more evidence, the relative lack of correlation of BL and nearby lightning suggests that the production of BL is associated more with static or changing electric fields in the vicinity of thunderstorms, than with the lightning plasma channel itself. While these results by themselves are limited, we are optimistic that one can learn more about the link between natural and ball lightning by fusing more precise eyewitness reports with lightning location and other archival meteorological data.

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REFERENCES

References

(a) Anatoly I. Nikitin, Alexander M. Velichko, Tamara F. Nikitina, Ilya G. Stepanov, *Analysis of the unique case of ball lightning observation in Mitino, the northwest district of Moscow*, Journal of Atmospheric and Solar-Terrestrial Physics 179 (2018) 97–104 https://doi.org/10.1016/j.jastp.2018.07.001

(b) Mark Stenhoff, *Ball Lightning (An Unsolved Problem in Atmospheric Physics)* Kluwer Academic Publishers (1999).

(c) Keul, A.G. & Stummer, O. (2014). McNally, Rayle, Beaty: US ball lightning – a continuous phenomenon? International Journal Unconventional Electromagnetics and Plasmas, 6, 1-2, 81-87.

(d) Rakov, V.A. and Uman, M.A.: Lightning, Physics and effects (Chapter 20), Cambridge University Press, Cambridge, 2003.

(e) Keul, A.G. & Diendorfer, G. (2018). Assessment of ball lightning data by correlated LLS data. 34th International Conference on Lightning Protection, 2-7 September 2018 Rzeszow, Poland.

(f) Karl D. Stephan, Rozlyn Krajcik, Rolf J. Martin, Fluorescence caused by ionizing radiation from ball lightning: Observation and quantitative analysis, Journal of Atmospheric and Solar-Terrestrial Physics 148 (2016) 32–38 https://doi.org/10.1016/j.jastp.2016.08.005