Review of manuscript 10.5194/egusphere-2024-704

The World Wide Lightning Location Network (WWLLN) over Spain

Summary This manuscript compares a VLF-based global lightning detection network (WWLLN) to an LF-based local lightning detection network operated by AEMET. The comparisons are made over several regions at the Iberian peninsula, during a 4-month interval in 2012, and also during intense storms on days in 2020, 2021, and 2022. In particular, the stroke detection efficiency (DE) and stroke location accuracy (LA) of WWLLN relative to AEMET strokes were derived. Secondary goals were to examine DE and LA variation with geography, and to compare WWLLN and AEMET strokes during three large storms. A prominent finding was the unexpectedly high (38%) WWLLN detection efficiency for Jan–Apr 2012, over the largest studied region surrounding Spain. This seems to be the first such comparison done for Europe.

Overall Assessment At 12 figures and 2 tables, the content of this manuscript is mostly observations, with limited analysis. Observations are reduced to standard statistical quantities and then briefly commented upon. As a contribution to the science literature, the importance of this work is limited by the use of older datasets, and discussion of implications of the results being speculative rather than critical and complete. Nevertheless, as a new comparison of two lightning detection networks, this work is publishable.

General Comments The finding of an unusual unexplained high DE of 38% around Spain may indicate an error. Adding to the puzzle, the DE in sub-regions, Fig 2 green and cyan boxes, was smaller. That requires an even higher DE outside the green and cyan boxes to give an average DE over the full region of 38%. Unfortunately, it is not convenient to check the analysis through independent calculations. Perhaps AEMET data had been over-filtered to eliminate weaker CG strokes. Figure 7 is helpful to address this, although there is not enough information about filtering to eliminate this possibility. There may be a problem with how DE is calculated (see comments about section 4).

A number of minor errors should be corrected. Several questions popped up, some due to incomplete descriptions, some some of which may suggest modifications that would improve the paper, and other questions may be outside the scope of this work. When this review was written, no other comments about this manuscript had been viewed; these comments were independently produced.

Abstract First sentence is good, but the following text has too much detail for an abstract. Consider deleting sentences after the first down into line 22. Then resume with: *This study finds the detection efficiency of WWLLN is around 38%* ... and continue with the remaining text in the abstract.

Tables

Caption on Table 1 declares a date range 2004–2022. However, datasets in the table are from 2003–2015, while publication references are from 2004–2018.

Table 1 has some historical interest, but could be shorter. Much of the contents is not relevant to WWLLN in 2012 or in the 2020s, because algorithms and network station distribution have changed greatly.

Figures

Figure 2: Text near line 565 describes the cyan region of Figure 2 as the boundary for study, but Figures 10–12 show strokes outside the Figure 2 region. Is the text wrong? Or do Figures 10–12 show strokes not considered in the analysis?

Figure 5A: horizontal axis label is wrong. West should be negative, but the label has west is positive.

Figure 8: shows a point above DE=1. Isn't that impossible? The method for calculating uncertainties cannot be correct, for an uncertainty bar extending above DE=1 is wrong. The smoothed blue line is difficult to see behind the red circles. If the blue line were plotted on top of the circles, both would be visible.

Section 1, Introduction

lines 69–75: The method for calculating DE seems to be incorrect (see comments for Section 4).

A CG stroke is not a vertical column above a point on Earth's surface. The path of a stroke often has a large horizontal displacement. Given this behavior of strokes, what is meant by stroke location? For a VLF stroke detection, this is an effective point for the transmitting antenna location. That point is unlikely to be the stroke contact point on the ground, and it is unlikely to be the effective location of an LF transmitting antenna. Stroke location is expected to be slightly different for different kinds of instruments and it is not defined or meaningful below some distance scale. These considerations mean that one must be careful in finding meaning in stroke accuracy, at small value, from different instruments.

Section 2, WWLLN

lines 91–93, 119–120: Fig 2 of 10.1029/2020GL091366 (Lightning in the Arctic) shows the history of the count of active WWLLN stations. The number of *active* stations is the important number for network performance, and is always less than the number of stations. Some stations are offline at any time due to network, power, or other technical issues.

lines 120–126: For a recent comparison over time, WWLLN detection efficiency compared to New Zealand lightning network is shown in Fig 1 of 10.1029/2019JD030975 (Global Distribution of Superbolts).

Here and elsewhere (lines 416–418, 671–673), is the idea that a higher density of nearby stations might cause DE to be higher. Even assuming station density is high and that DE is high, there is no analysis in the paper showing a cause-effect relation. The link between WWLLN station density around Spain and the apparently higher DE is purely speculation in this paper, and that should be made clear wherever this possible link is mentioned.

Many stations nearby is offered as a possible explanation for the high DE around Spain. However, there are other considerations for stations near a storm that work against this explanation: (1) close strokes can saturate the receiver, distorting the waveforms; (2) close strokes have less frequency dispersion, making it harder to extract the time of group arrival; (3) when several nearby stations see a distant stroke, much of the information is redundant; (4) nearby strokes have more high frequency content that is noise in the VLF analysis—these high frequencies decay quickly with distance. In the stroke location algorithm, stations closer than 300 km to a stroke are not used.

lines 136–145: Some details in the list are wrong. No power or peak current estimates are produced in the WWLLN stroke analysis. Instead, stroke VLF (5–18 kHz) energy and uncertainties, in Joules, are output. Stations used for energy calculation are restricted to be in the range 1000–8000 km from the located stroke.

lines 157–158: Only stroke VLF energy is provided by WWLLN. An approximate linear relation between stroke VLF energy and peak current is sometimes used to estimate peak current. Of course, once a WWLLN stroke is matched to an AEMET stroke, peak current is available from the AEMET data.

lines 167–168: *(DE and LA) must be considered as global value, since they correspond to the detected lightning strokes, independently of their current peak amplitude.* If I understand what this sentence should mean, global is a confusing word to use here. Possible rewording: *(DE and LA) values were calculated from all the matched lightning strokes, independently of their peak current.*

line 185: DE in the early days of WWLLN was about 1%, but DE at these early times in the development of the network are not relevant for this study (2012 and 2020–2022). For 2012, WWLLN global DE was probably above 10%. For 2012, the median number of active stations on any day was 55. The total number of stations, 69, is a less useful number.

Section 3, AEMET

line 294: Are AEMET stroke times rounded to the nearest second or truncated to the second? For instance, if a stroke was originally time-stamped at 01:23:45.678901 at microsecond accuracy, is that stroke's AEMET time published as 01:23:45 or 01:23:46? The method used affects DE.

lines 299–301: The description for how AEMET IC and CG strokes were separated is incomplete. How exactly was this done? How sensitive are DE calculations to the criteria used to separate strokes types?

Section 4, WWLLN performance in Spain

lines 406–411: The calculation of WWLLN DE relative to AEMET appears to be incorrect, in a way that over-estimates DE. The correct DE calculation is to count the number of AEMET strokes that match a WWLLN stroke, then divide by the total number of AEMET strokes. This ratio is the fraction of AEMET strokes also detected by WWLLN—a detection efficiency. The method in the manuscript finds the number of WWLLN strokes that match an AEMET stroke, then divides that by the total number of AEMET strokes. It is a ratio of WWLLN strokes to AEMET strokes, and is not a detection efficiency. It over-estimates DE because it is possible for several WWLLN strokes to match with one AEMET stroke, especially within a 1 second matching time window. Because WWLLN cannot detect the same AEMET stroke more than once, the numerator of the ratio becomes larger than it should be, and DE is over-estimated.

lines 420–423: Although there is a resemblance, this is not a Rayleigh distribution. The tail is too heavy; Rayleigh falls fast, as $\exp(-x^2)$. This distribution is also too narrow around its median value. Graphing a few Rayleigh distributions and comparing with the histogram shows this easily. Statistical methods, such as χ^2 goodness-of-fit, would confirm this numerically.

lines 549–553: The claim of DE/LA differences in the two geographic regions seems plausible, but there is no evidence or a clear line of reasoning that explains how geography relates to DE/LA differences. For example, a study of the WWLLN stroke energies or the AEMET peak currents in the two regions could explore whether different stroke energy distributions explain the DE differences. The assertion that there are more intense atmospheric phenomena occurring in this region should have a reference. There is only speculation here, with the goal stated in the abstract, lines 25–26, not being met.

Section 4 Conclusions

lines 662–663: Number of stations in 2012 compared with now: what matters is number of active stations, not number of stations. Both have grown over the years. A correct statement is that based on WWLLN growth, it is reasonable to assume that the 2012 DE is a lower bound to the present DE in Spain. However, if the AEMET network has also improved enough, then WWLLN DE relative to AEMET might even be lower now than in 2012.

line 688: How does one decide that there is good agreement between AEMET and WWLLN? This seems like a subjective evaluation, which is ok. But it should be clear this is an opinion rather than a rigorous finding.

typos/grammar

- Line 23: considerable→considerably
- Column heading in Table 2: change Est-West→East-West
- Line 284: his→its
- Line 295: Jan 1, 2120–Apr 20, 2012 should be Jan 1, 2012–Apr 20, 2012
- Line 319 change son→soon