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Atmospheric Measurement Techniques Discussions

Interactive comment on "A performance assessment of the World Wide Lightning Location Network (WWLLN) via comparison with the Canadian Lightning Detection Network (CLDN)" *by* D. Abreu et al.

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Response to Anonymous Referee 1

We thank the referee for his or her helpful comments. In the following we present the referee's original comments in italics and our responses in plain text.

General Comments

This paper is a very nice summary of previous comparisons between WWLLN and

regional networks and it adds to the information on the previous knowledge of the WWLLN by a new comparison between WWLLN and the CLDN. It is a technically sound paper that provides nice discussion on various findings of detection efficiency, location accuracy, timing accuracy, and peak current thresholds for WWLLN.

Scientific Issues/Comments

Main suggestions/issues: 1. Grid box criterion – a number of shared events could be excluded by your grid box cutoff. You discuss this a bit on p 1871, lines 18-23. But is it possible to do a quick search to determine how many actual events fall under these criteria? For example, only use your cutoff spatial grid on CLDN events, and look for any shared WWLLN events within your time window. (You could limit WWLLN events to a slightly larger box if needed, so that you don't get coincident events that happened half-way around the world.) Then report how many additional shared events you get with that method. Then you can do the reverse – limit WWLLN events to only those inside the grid, and look to see how many CLDN events are shared within your time window of those events. I understand that you have to make a hard boundary to count how many events are included in each network, but this additional quick look could allow you to better elaborate on how many of the events are not shared simply because their shared partner lay outside the hard boundary region.

We agree that some shared events may be excluded by using the same grid box for both the WWLLN and the CLDN. We do note in the paper that expanding the CLDN region by 50 km (the size of a typical storm system) on each side of the original grid box might reduce the number of unshared or outlier events by matching WWLLN strokes close to the boundary of the WWLLN grid box with CLDN strokes just outside it. We did try to obtain the additional CLDN data to do exactly this earlier in our study, but were unsuccessful and so are unable to make this calculation.

Using the same grid box for both networks, we find that 19,128 of the 20,605 WWLLN strokes are shared with the CLDN, leaving 1477 unshared WWLLN strokes. Of these,

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1466 are within 50 km and 1 hour of CLDN strokes, consistent with the size and duration of a typical storm system, and so likely to be valid lightning strokes detected by WWLLN but missed by CLDN. We have examined the 1477 unshared events more closely and found that 309 of them are within 20 km (chosen as approximately three standard deviations in the mean spatial offset between shared events; see Table 2, formerly Table 1) of at least one of the boundaries of the grid box and 209 events are within 10 km. So it is possible that these unshared WWLLN strokes have matching CLDN strokes that lie outside the grid box for which we have data. Assuming that all 309 strokes are in fact shared (but mis-categorized because of our fixed grid boundary) would give a total of 19,128 + 309 = 19,437 valid shared strokes, and a detection efficiency of 2.9%, just slightly higher than the 2.8% obtained.

We have added some of this text to the last paragraph in Section 3.

2. Day/Night Detection Efficiency – you use +/- 12 hours around local noon/midnight, but you neglect to mention if that is about right for local sunrise/sunset during that time of year in that region of Canada. I would suspect that Canada gets more daylight than nighttime in the summer. You may want to take that into account in you day/night DE calculation by using a solar zenith angle cutoff instead of a local time +/- 12 hours cutoff. You may want to also not push your cutoff up to the boundary of day/night, since then the WWLLN sferics will have to cross the terminator in their propagation, so it confuses the issue a bit. In any case, the day/night difference is apparent in your data, so you may not need to change the plot, just add a little discussion along these lines.

We agree with this point and have added the following discussion to Section 3:

"A better approach for evaluating the diurnal dependence of the detection efficiency would use the solar zenith angle and define 'day' and 'night' such that they do not include twilight. The 12-hour windows used in this study blur the day/night boundary, and as the season examined was summer at mid-latitudes, the window centered on local midnight includes significant periods of solar illumination. Thus, a stronger contrast in

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detection efficiency between day and night would be expected with the use of a solar zenith angle cutoff."

Minor issues: 1. P. 1863, line 15-16. All the WWLLN papers (Lay,Rodger,Jacobsen) should not be cited here for regional networks, since they address the WWLLN, which is global. It is better to cite them after mentioning WWLLN, such as on p 1864, line 1.

We have removed the WWLLN references from this sentence and moved them to the first sentence in Section 2.2.

2. p 1864 line 19: All networks have a peak current threshold, although it is lower for regional networks like CLDN. They must have a goal of 90% Det. Eff. of strokes with a peak current greater than some value (maybe 5kA or so?). Is there any way to find that information for CLDN?

The peak current threshold for the CLDN is 5 kA (Burrows et al., 2002). This information has been added to the text here and also in the Conclusions section.

3. P 1868 line 29: Are the multiple shared events from the same CLDN flash, or from separate strokes?

Based on a calculation of the distance between the CLDN strokes that are shared with the same WWLLN stroke, none of the multiple shared events appear to be from the same CLDN stroke, however, all but two of them seem to be part of the same storm system. This information has been added to the text.

4. P 1870, lines 11-14. I would say that the D-layer increases absorption of the wave, not that the D-layer must be penetrated before reaching the E-layer, since that doesn't say anything about what happens to the wave while penetrating that cause it to be different when it reaches the receiver.

We have changed this sentence to the following:

"During the day, however, solar radiation enhances the ionization of the ionosphere,

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producing the D-region, which increases the absorption of the VLF sferic energy upon each transit of the layer."

5. P1873, lines 12-14. Could one factor in this difference be that, for some reason, there is a higher fraction of ICs in NZ lightning?

Having a high percentage of WWLLN unshared events means that many strokes detected by the WWLLN were not detected by the NZLDN. If there were a higher fraction of ICs (for some reason) in NZ lightning, the NZLDN should detect more lightning strokes than the WWLLN. This is because ICs produce a peak current that is very low compared to CGs, resulting in the WWLLN detecting fewer lightning strokes than the NZLDN due to its higher peak current threshold compared to local lightning networks. So this does not explain why WWLLN detected such a high percentage of strokes that were not detected by the NZLDN.

6. P 1873, line 28. Perhaps lower DE could be due to the fact that LASA detects many more ICs than the other regional networks that WWLLN has been compared to? ICs are typically lower in peak current, so WWLLN would be less likely to detect them because of its peak current threshold.

We agree with this comment and have added the following sentence to the text:

"This may explain the low detection efficiency observed in that study, as cloud lightning strokes typically have a low peak current and so the WWLLN is less likely to detect them due to its relatively high peak current threshold (see Fig. 6)."

7. In the summary, could you include the detection efficiency of WWLLN for certain peak current thresholds?

We have calculated the detection efficiency of the WWLLN using a series of values for the peak current threshold and have added a table (new Table 1; the previous Table 1 has been renumbered as 2) reporting these results. The following text has been added to paragraph 5 of Section 3:

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Table 1. The stroke detection efficiency of the WWLLN as a function of peak current threshold.

Peak Current Threshold (kA)	Number of Shared CLDN-WWLLN Events	Number of CLDN Events	WWLLN Detection Efficiency (%)
120	439	579	75.8
100	933	1302	71.7
80	1995	3027	65.9
60	4530	7960	56.9
40	10,241	26,725	38.3
20	18,187	160,545	11.3
0	19,128	677,406	2.8

"In Table 1, the stroke detection efficiency of the WWLLN as a function of peak current threshold is summarized. This threshold is the minimum value of the peak current, so that the number of events in each entry includes all events whose peak current is greater than the given threshold. The detection efficiency clearly increases with the peak current threshold, having a value of 11.3% for $\pm$20 kA increasing to 75.8% for $\pm$120 kA."

We have also modified the relevant text in the Abstract and referred to these results in the Conclusions.

Technical corrections:

1. p. 1864, line 15 - give frequency range for LF 2. p. 1864, line 16 - give freq. range for VLF

We have added the frequency ranges and modified the text slightly as the CLDN sensors use both LF and VLF bands:

"Unlike the WWLLN, which functions solely in the Very Low Frequency band (VLF; 3-

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30 kHz) to detect sferics, CLDN sensors use both VLF and the Low Frequency band (LF; 30-300 kHz) to detect ground waves. Attenuation is higher in the LF band, so the CLDN receivers must be placed a few hundred kilometers apart, much closer than the sensors of the WWLLN (see Section 2.2)."

3. p. 1866, line 1 (also p 1870, line 21)- you should probably use 'sferic' instead of 'sky wave', since you just spent a few sentences describing a sferic, but not calling it a sky wave.

All occurrences of 'sky wave' have been replaced by 'sferic'.

4. P. 1869, lines 11-16. This discussion is confusing - I think it is much clearer if you just press forward to Figure 6 and describe the results from that figure. They are much easier to understand.

As suggested, we have deleted the following sentence:

"Figure 4 confirms this hypothesis, where below the magnitude of 20 kA, the fraction of the entire CLDN data set with peak currents in this range is much greater than that of the shared events. In contrast, outside the $\pm$20 kA range, this relation is reversed."

We have also moved the sentence that followed this to the end of the second paragraph in Section 3:

"Note that there exists a greater fraction of negative lightning strokes than positive as expected (Rakov and Uman, 2003)."

5. P. 1871, line 16. The word 'although' doesn't fit here. It implies that the second part of the sentence should be contrary to the first part, while, in reality, they are not necessarily related, and definitely not contrary to each other.

This sentence has been revised to:

"This is also the conclusion assumed for the outlier events in this study."

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And the first sentence in the paragraph has been revised to:

"The remaining 11 unshared events are considered "outliers"; these comprise a negligible 0.05% of the WWLLN events detected."

6. P. 1873, lines 22-23. I don't understand what you are saying here. Please clarify.

We have tried to clarify the text as follows:

"Finally, Jacobson et al. (2006) obtained similar results to those achieved in this study using five months of data from the Los Alamos Sferic Array (LASA) in Florida. They found a WWLLN detection efficiency of 0.8% (compared to 2.8% acquired here), and observed that 1.3% of the WWLLN strokes were outlier events (compared to 0.05% in our study). Theirs is the only study, in addition to ours, that reported single WWLLN strokes shared with multiple local network strokes."

Interactive comment on Atmos. Meas. Tech. Discuss., 3, 1861, 2010.