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Geoscientific Instrumentation Methods and Data Systems Discussions
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Interactive comment on "Time-stamp correction of magnetic observatory data acquired during unavailability of time-synchronization services" *by* Pierdavide Coïsson et al.

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Thank you for evaluating positively this work. The comments and remarks you raised were all relevant and we followed them to improve the manuscript and correct it.

Comment: *This study is very useful and interesting for geomagnetic observatories and data users. The authors propose the method which correct time-stamp using time-series of other observatories or the second acquisition system with GPS synchronization. This might be good method to ensure or correct the time-stamp of data from observatories with un-manned acquisition system or those without the second acquisi-*

tion system.
However, I think that quantitative discussion about accuracy and precision of time correction value is insufficient. It is necessary to show accuracy and precision of the time correction value using time-series which have GPS synchronization at both of the LZH and the reference stations. The accuracy and precision may depend on position of reference observatories or time of analysis. I would recommend the article for acceptance after dealing with the issue of accuracy and precision.

Answer: We agree with the reviewer comment, that it is necessary to control the effectiveness of the method during times when both compared datasets have a correct time-stamp. This was done in this work for the period between 1 January and 7 March 2013, before the interruption of the GPS PPS. The results can be seen in Figures 3 and 4, that start on 1 January. In the case of the co-located instruments, the computed time lags in this period are almost always 0 s and in rare cases 1 s (average 0.1 s, standard deviation 0.3 s on X Y and Z component). In the case of the comparison with Kakioka, the spread of data is larger and it depends on the local time at the observatories, the best results are obtained on X component at 5:30 UTC when an average of -3 s and standard deviation of 11 s. A table containing the whole statistics has been added in the supplementary information.

Moreover, Figure 2 shows all the cross-correlations between each pair of observatories, when only LZH was having a failing GPS synchronization. This figures shows that the cross-correlation peak is large, centred near 0, but the estimated lags can be larger than 10 s, especially for magnetic component that are not presenting a sharp peak in the cross-correlation (Y, Z, F).

Since we understand that it is not explicit in the text of the article, we included in the abstract the date when the GPS PPS was interrupted, 7 March 2013 and inserted in section 2.2 that the period over which we computed the time lag started on 1 January 2013 and we added the results of the statistics: "During the period between 1 January 2013 and 7 March 2013, when the GPS synchronization of LZH observatory was still operational, the cross-correlation of one hour X values around 5:30 UTC resulted in an average time lag of -3 s with a standard deviation of 11 s."

SPECIFIC COMMENTS:

Comment: *1) I have a concern about cross-correlation using local signals. In my understanding, when the time series at LZH and LZ2 are cross-correlated, signals from road traffic are also computed. I guess that there might be a time lag if the sensors of LZH and LZ2 is not on the line perpendicular to the road. For example:*

- *Sensor of LZH is 50 m away from that of LZ2 to North.*
- *There is a road going north and south.*
- *A car go to north with 10 m/s. In above case, there will be the computed time lag of 5 s, even though LZH and LZ2 have GPS synchronization. In addition, what does the oscillation of Z component mean in Figure 2? Do each narrow peaks represent car signals?*

Answer: This comment is important and indeed signals from moving trucks are delayed according to the relative geometry of the road and sensors. If the only source of local noise is road trafic, the delay of detection in each site has to be taken into account. In the specific case of LZH observatory, the two instruments are located within the same room, at a distance of about 3 m. Near LZH sensor building there is a small agricultural road whose traffic is only one among various sources of spikes. Most of recorded spikes last just a couple of seconds, as it can be seen in Figure 1 and they are the ones producing the narrow peak on Z component. Other instruments in the observatory produce a different kind of signal: many times per day regular oscillations that last few minutes are generated, also seen in Figure 1. The short spikes are usually more pronounced on the Z

component, thus the cross-correlation present a narrow peak, while the oscillating signals produce oscillations also in the cross-correlations function with peaks corresponding to multiples of the period of these signals. We also found in LZH data perturbations lasting up to about 1 minute, that could be related to moving vehicles, but we could not verify it. We are anyway confident that the issue of a moving source is not affecting this particular analysis.
To better explain LZH perturbations, the sentence "In particular, at Lanzhou observatory, quite frequent magnetic perturbations are observed, some due to nearby road traffic and other due to geophysical experiments running on the same site." has been changed: "at Lanzhou observatory, quite frequent magnetic perturbations are observed of various durations, from a few seconds up to a couple of minutes. The longest are due to nearby road traffic and to geophysical experiments running on the same site."
It has also been specified "the second acquisition system available in Lanzhou inside the same room".

Comment: *2) It is better to write magnetic coordinates of each observatory in Table 1, since the Sq currents are discussed in line 22 of page 3.*

Answer: The table has been modified to include both geomagnetic and geographic coordinates and the distance with respect to LZH.

Comment: *3) Please include enough information about making "A single daily correction value" in the section 2.2.1. Which data did you use, LZ2 or KAK? In the case of LZ2, there are 24 time lags per day. In the case of KAK, there is one time lag per day which have large dispersion. How did you calculate "A single daily correction value"?*

Answer: We used the data from the LZ2 instrument to compute the time-correction. The clock drift was sufficiently slow to be largely below 0.5 s during a single day, apart during the period April-July 2014 for which we decided not to produce defini-

tive data. During the month of faster clock drift, August 2013 1 s was accumulated in 4 to 5 days for a total of 7 s in a month. As the lags computed on Z component present a very smooth curve, it was possible to fit an hyperbolic tangent that follow closely the computed cross-correlation lags. The value of that curve at 12 UTC was used for the time-stamp correction. We recall that the aim of this correction is to provide 1-minute averages definitive data.
Some additional details have been added in the text : "A single daily correction value was used, based on the second instrument available in Lanzhou observatory. This correction value was calculated for 12 UT, following a smooth hyperbolic tangent fitted to the calculated hourly delays."

Comment: *4) Please describe the required time accuracy for making 1-minute definitive data, citing the INTERMAGNET Technical Reference Manual.*

Answer: INTERMAGNET Technical Reference Manual indicates that the data logger clock should have a drift below 5 seconds per month. With the time correction we applied we are well below this limit during the whole period when we applied the correction.
To avoid confusion, we followed the suggestion and indicated explicitly this value in the text : "This choice was possible since the drift of the clock was always well below the 5 seconds/month recommended by INTERMAGNET for computing 1 minute values. The corrected 1 s data files were averaged to compute 1 minute data files following the INTERMAGNET recommendations for data filtering."

TECHNICAL CORRECTIONS:

Comment: *Page 2, line 21: PSS → PPS*

Answer: The typo was corrected.

Comment: *Page 3, lines 12, 13: Is "longitude distance" a difference between longitude of LZH and that of other observatory? According to Table 1, the longitude distance of KAK is 36 degrees and the time difference of KAK is two hours.*

Answer: Thank you for pointing out this mistake: as the reviewer correctly pointed out, there are more than 2 hours local time difference between KAK and LZH. The text has been corrected accordingly.

Comment: *Page 4, Figure 2: To make it easier to discriminate the different lines in Figure 2, I recommend that you use some type of lines, e.g. dashed lines. It is difficult for me to distinguish some lines in Figure 2.*

Answer: We regret that this figure contains too many lines to provide an easy readability of all lines. We tried plotting some as dashed lines, but the result was not satisfactory. The value of the lag (position of the maximum of the cross-correlation) is indicated in the legend and the reason of including this figure was to show that there can be a large uncertainty on the estimate of the lag because of the width of the cross-correlation peak.
We did not modify this figure.

Comment: *Page 8, Figure 5: To make it easier to recognize these lines in Figure 5, I recommend that you change the markers of legend bigger or longer.*

Answer: Sorry for this inconvenience, the small dots were the default symbol appearing in figures generated without connection line between points. We modified the way the figure was realized (also following the suggestions of the other reviewer) and the new figure is easier to interpret, we kept only the temperature of the energy card (the other temperatures are from components in another building) and we included a line showing the temperature at the time of GPS failure.

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