

REPLY TO THE REVIEWER-1

We sincerely thank the reviewer for constructive criticisms and valuable comments, which were of great help in revising the manuscript. Accordingly, the revised manuscript has been systematically improved with new information. Our responses to the referee's comments are given below.

Text in Black color: Comments by Reviewer

Text in Blue color: Reply to the Comments

Text in Green color: Existing text in the Manuscript.

Comment (1): Firstly, 1 second data is not 'in lieu of' (as claimed on page 1, line 15), but an addition to 1 minute data; the latter remains being the primary product of any INTERMAGNET observatory.

Corrected the sentence and included "in addition to the traditional 1 minute data" in text as suggested. Lines: 17-18.

Comment (2): Secondly, the authors claim that 1 second data is more compatible with measurements from LEO satellites (line 17) and contributes to the development of space weather forecasts (line 19). The authors do not give any evidence of these claims. I am not aware of examples that would support these claims and I had hoped the authors could educate us in this respect.

Corrected the language in the abstract and few parts of the text are rewritten. Provided evidences to the reported claims in the text. Lines: 20-27. Our intention in this paper is to highlight the possible studies by using the 1 sec data and the relevant claims were mentioned above in the current version.

There is increasing demand from the global geomagnetic community for the recording of 1 second vector and scalar magnetic data in addition to the traditional 1 minute data, which would be more useful for (i) understanding the global scale ultra-low frequency (ULF) waves and sudden impulses (Chulliat et al. 2009; Agapitov and Cheremnykh, 2013); (ii) synchronizing the ground observatory data with low-Earth orbiting satellites for the development of high resolution magnetic models (Matzka et al. 2010; Love and Chulliat, 2013; Stolle et al. 2016); (iii) development of real-time space weather applications using the geomagnetic pulsation indices (Nosé et al. 2012; Xu et al. 2013); (iv) studying the ionospheric magnetic fields, Sq field, equatorial electrojet and lower-middle atmospheric dynamics (Chulliat et al. 2016) and (v) investigations on high-latitude magnetospheric-ionospheric physics with magnetometer networks (i.e., IMAGE, CANOPUS, GMC, etc.), (Chulliat et al. 2009b).

Comment (3): Similarly, on page 2, line 16 to 19 the authors give examples for relevant science areas. However, all these science goals are easily achievable with standard equipment like FGE magnetometers.

All the data and our analysis are generated by FGE magnetometers. The manuscript revolves around conditions of installation and transmission of data with respect to old and new models of FGE magnetometers.

Comment (4): What is the purpose of Fig. 5?

The relevance of Figure 5 is now added in the manuscript. Lines: 7-9, Page: 10.

The purpose of Figure 5 is to report the observed night time horizontal field variations from GEOMAG-02MO with the established 3-component Fluxgate Magnetometer (DTU Space, Denmark) by using Spectral decomposition technique. It is evident from Figure 5 that the dynamic spectra obtained from

GEOMAG-02MO showing similar response of signal as observed in FGE, highlighting the variations recorded at GEOMAG-02MO are closely in agreement with FGE.

Comment (5): A major problem of the manuscript is that it presents technical data and screenshots of commercially available products. These figures and tables likely come together with these commercial products in the form of advertisement material or manuals.

The screenshots provided in the manuscript are from the commercial product, MAGREC-4B which was configured for the first time with the 3-component GEOMAG-02MO with GSM-90F1. To achieve this, standard script files were modified to accommodate the formats of the output data of a new FGE for optimum archival and display.

Comment (6): We learn very little about the source of these figures and the validity of the experimental procedures and analysis methods on which they are based (e.g. Figs 4, 6).

Figure 4 represents the basic frequency-noise response of the new GEOMAG-02MO FGE sensor, generated at controlled conditions at manufacturing location. The manuscript includes the description of the noise characteristics and the improvements made by Geomagnet, Ukraine, for bringing the Observatory grade 1 second magnetometer compared to earlier GEOMAG-02M (see Reda and Neska, 2016). The best technical specifications of the GEOMAG-02MO are also mentioned in Table-01.

The plots shown in Figure 6 illuminate the various stages of development of the new FGE installation and the parameters associated with it.

Comment (7): Also, it is not possible to evaluate the information collected and presented by the authors. For example, the temperature stability of their enclosure design cannot be evaluated since only 1day of temperature data is presented. We wonder how stable the temperature in the variometer enclosure is in the long term, say during weeks or even a year.

The manuscript centers around documenting the crucial initial stages of development and establishment of a Magnetic observatory expected to produce good quality of data in the long term. It is true that in some examples only a short duration of data has been presented as a representation of the evolving stages of improvements of the setup and thereby of the data. CPL observatory itself is barely 3 years old. The new FGE was commissioned just about a year earlier and the improvements during this time are being showcased in the manuscript. In the revised version we are providing one complete month of observed variations and the temperature stability of the enclosure design are shown in Figure 12. The Figure 12 of earlier submitted version is now replaced with the new figure and labeled with the same figure number.

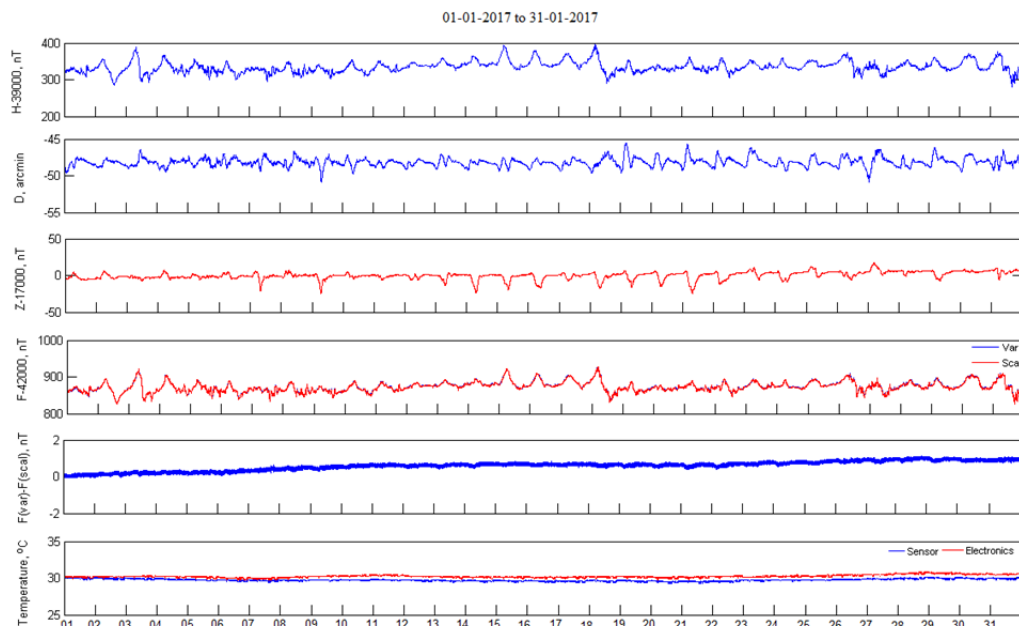
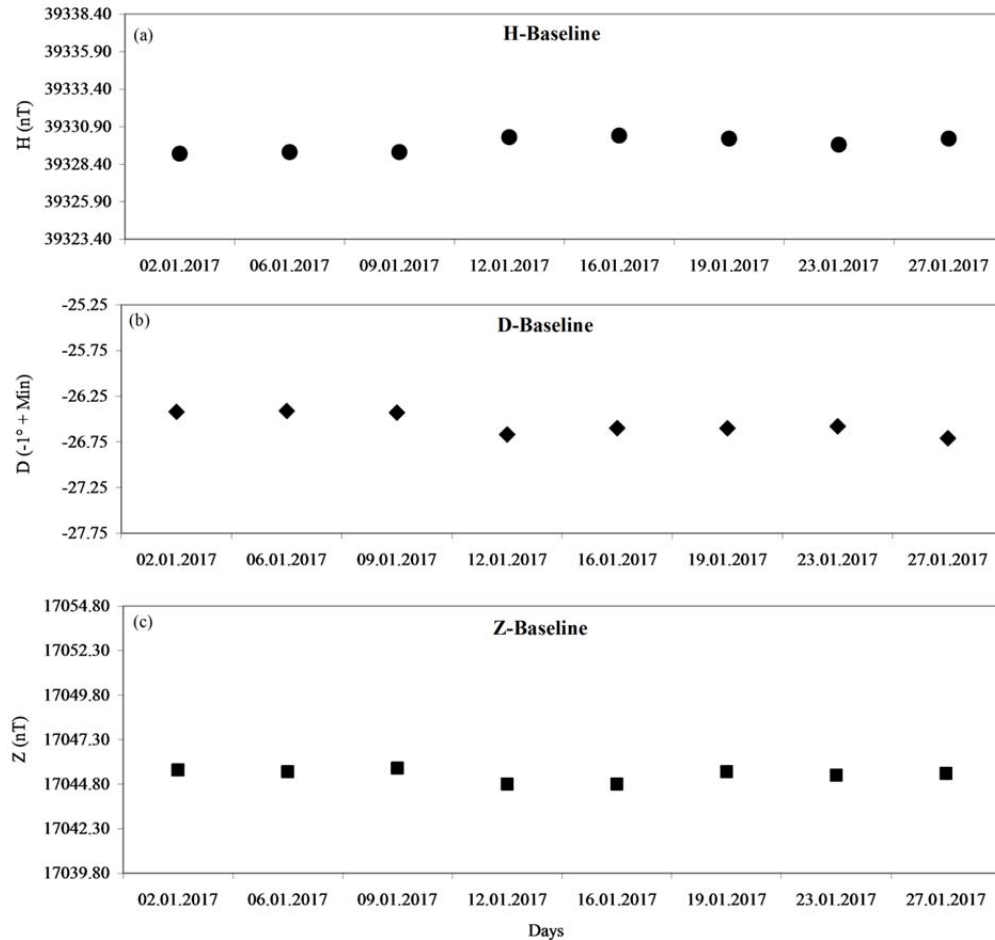


Figure 12

Comment (8): Judging from the baselines presented in Fig. 13 (changes of 5 nT in Z and 8 nT in H, D is illegible, so we don't know), the quality of the variometer or the temperature stability of its enclosure must be poor. Please present convincing temperature data over the course of several months or a year. Please present stable baselines if you want to advocate your mode of operations and the instruments you use.

The baselines of December 2016 were admittedly affected by several interventions which were required for troubleshooting. Subsequently we have achieved better quality baselines. An example of good quality and stable baselines of H, D and Z components are shown in Figure 13 for January 2017. Figure 13 of earlier version is now replaced with the new Figure and continues with the same number.

Figure 13



Comment (9): Figures are illegible (Figs. 1, 6, 9, 10) or hardly legible (Figs. 11, 12, 13), invalidating any information that they might contain about the quality of the 1 second data presented here.

In the revised version of manuscript:

(i) Increased the font size in Figures 01, 09, 10 and 11.

(ii) The last bottom panel was removed in Figure 06.

(iii) Figures 12 and 13 are replaced with new Figures.

Comment (10): Please mention the Narod magnetometers (page 4, line 7).

Included in text as suggested. Lines: 22, Page 4.

Comment (11): Please use SI units (e.g., page 4, line 19).

Included "meters" and changed the values accordingly in the text.

Comment (12): A variometer oriented to magnetic north should not compensate the magnetic field at its Y sensor (page 5, line 29), because standard methods of calibration will then fail to orient the horizontal sensors correctly. What precautions/methods have been used in this respect to guarantee correct calibration at CPL?

GEOMAG-02MO sensor was installed initially keeping 'X' component close to magnetic north and 'Y' component close to Zero by leaving 'Y' in uncompensated mode. But in the text the word "Un" was missing. After reaching 'Y' close to zero, the 'X' and 'Z' total field values were noted and in the next step 'X' component of the sensor is oriented towards south direction keeping 'Y' close to zero and the corresponding total field values were noted. Similarly, the 'X' component of the sensor is oriented towards East and later in West direction, keeping 'X' close to zero and the corresponding total field values were noted. All these exercises will ensure the similar values in the 'Z' component in all the four directions to achieve perfect verticality. In other means the horizontal position of the sensor is also leveled equally in all the four directions.

The adopted installation procedure for GEOMAG-02MO at CPL Magnetic Observatory is discussed in detail below:

Step-1: Total: X= +39448.7
Y= +00001.3
Z= +16923.1 } "X" component in North direction and "Y" component close to Zero

Step-2: Total: X= -39463.2
Y= -00011.7
Z= +16927.4 } "X" component in South direction and "Y" component close to Zero

Step-3: Total: X= -00000.5
Y= -39523.1
Z= +16937.6 } "X" component in East direction and "X" component close to Zero

Step-4: Total: X= -00000.4
Y= +39545.7
Z= +16916.7 } "X" component in West direction and "X" component close to Zero

Average of Z component in North-South direction = +16923.1 + 16927.4 = 16925.3 (a)

Average of Z component in East- West direction = +16937.6 + 16916.7 = 16927.2 (b)

Mean of Z component from (a) and (b) = 16926.2

Again we leveled the sensor in all four directions (N, S, E and W) to achieve the mean value (i.e. 16926.2 nT), to ensure the sensor is vertically leveled. Finally the sensor brought back to "X" is in North direction and "Y" close to zero leaving in uncompensated mode.

Comment (13): From reading the text, I don't understand the filter procedure described in paragraphs 2.2, 3.1 and 3.2. Looking at the figures helps little to understand the situation at CPL since the axes labels are too small to be readable and I don't know the time scales of Figs. 9 and 10. Please make clear what part of text is a general description of the commercial products on the one hand (and avoid writing too much about them, if possible) and what part of the text is describing the settings you chose for CPL (and please explain why they were chosen, how they were realised and what the results are).

The Figures 09 and 10 have been improved in the current version. Paragraph 2.2 describes the noise characteristics of different components of GEOMAG-02MO and the solutions offered for the reduction of non-orthogonality of components of the newly available GEOMAG-02MO sensor. The details, which are not so far commercially available to the public domain, are being presented through this manuscript.

Sections 3.1 and 3.2 illustrate the examples of data acquisition and processing of the new FGE at CPL.

Comment (14): A cut off frequency of 0.005 Hz (200 seconds?) is mentioned in paragraph 3.1. Is this used in CPL and why was it chosen? The plot in Fig. 4 suggests that the signal is essentially zero at 0.2 Hz. My major concern here is that this is still part of the INTERMAGNET 1 second standard pass band and that the signal should not be altered here.

The cutoff frequency of 0.005 Hz is not the part of INTERMAGNET 1 second standard. But we made an attempt to see the differences in the noise removed in the data after applying the INTERMAGNET 1 second standard cutoff frequency of 0.2 Hz (Figure 09a) and 0.005 Hz (Figure 09b) for CPL Observatory. It is evident from Figure 09a that the noise in the Z component (last bottom panel) was not completely removed with cutoff frequency 0.2 Hz and still shows the clear signatures of noise in the data set. With the cutoff frequency of 0.005 Hz (Figure 09b, last bottom panel), the noise in the Z component was completely removed. An example showing various cutoff frequencies is illustrated in Figure 10. For low-latitude Observatories especially in India, the influence of temperature, increase in industrialization and habitation are the critical constraints for recording the good quality noise free data, for which more stringent filtering may be required. Our intention is to investigate the optimum filter required for our data based on our processing efforts with various filters. The occasional noise in the data will be removed by applying different cutoff frequencies or flagging the data by removing the data and substituting their values with the "missing value" to INTERMAGNET.

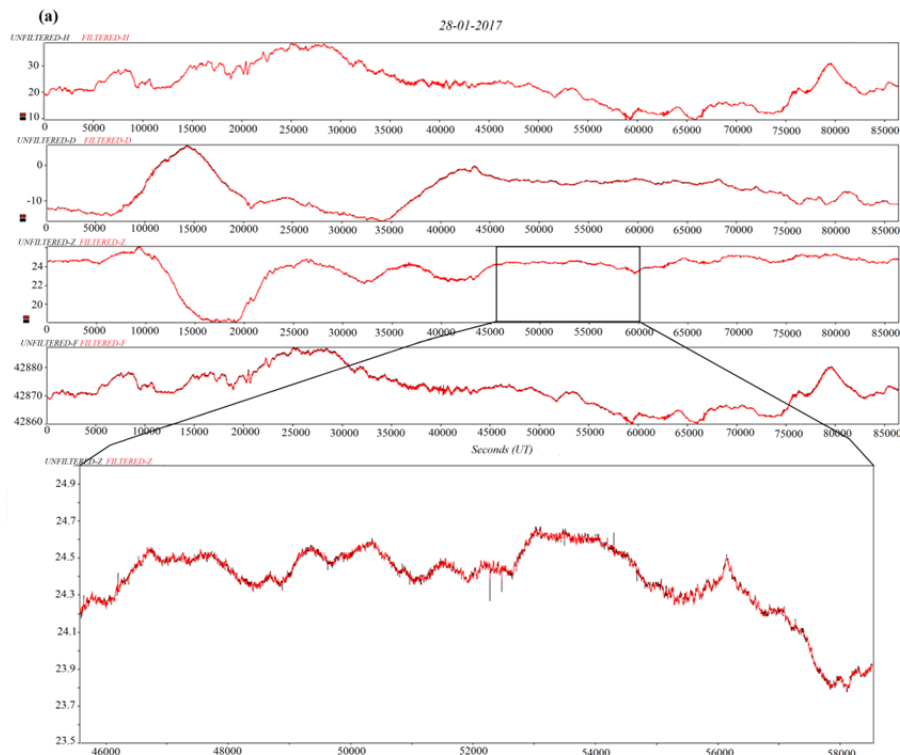


Figure 9a

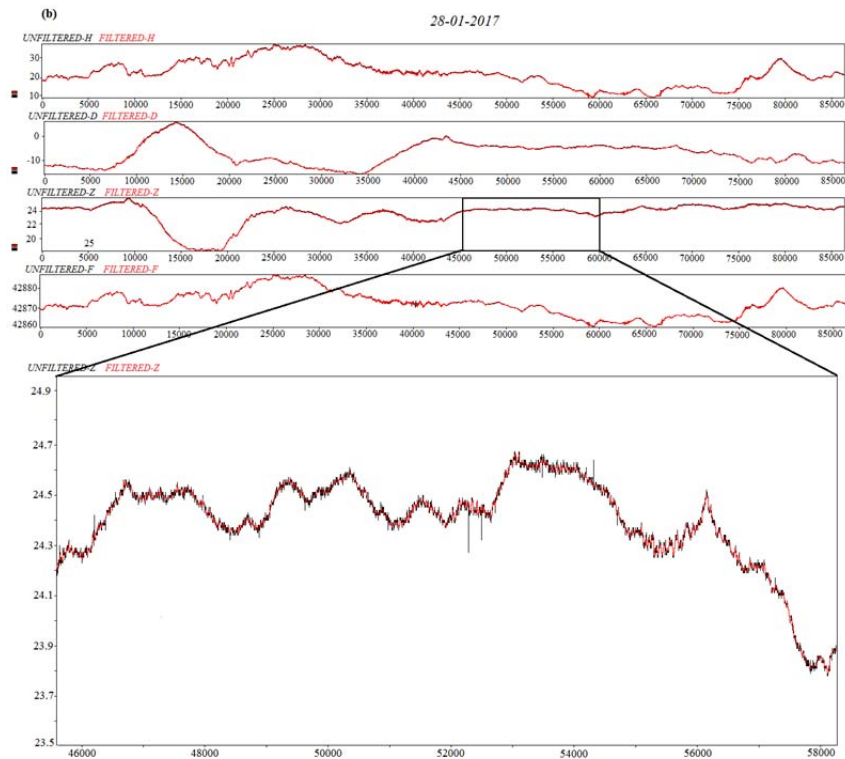


Figure 9b

Comment (15): General remarks to the data processing: I would expect that the de-spiking is performed at a primary sampling rate (100 Hz), and not at the 1 Hz sampling rate. Also, my feeling is that the filtering used here is just smearing out spikes rather than removing them.

The despiking is performed at 1 Hz sampling rate. In the revised version, two cut off frequencies 0.2 Hz and 0.005 Hz are shown as example for one day (i.e. 18/08/2017) in Figures 9a and 9b with regards to removal of spikes at low-latitude Observatory, CPL.

Comment (16): Finally, I am in doubt about the use of the Magrec 4 data logger here. It looks like the time stamping and the filtering is already done by the variometer (which has a digital output), thus main features of the Magrec remain unused and it is questionable why using such a sophisticated data logger for the simple task of saving and transferring data.

GEOMAG-02MO variometer doesn't offer filtering the data directly during the time of recording but connected to GPS for time stamping of the data. The filtering software is available to the community as an additional tool.

As discussed already, MAGREC-4B data logger is integrating the 3 component vector data from GEOMAG-02MO and Scalar data from GSM-90F1. Further, the INTERMAGNET Gaussian filter applied on 1 second data for minute means in IAGA 2002 format. MAGREC-4B plays a vital role in storing the GSM90-F1 data, as it doesn't have any internal memory and also identifies the time stamping differences between the fluxgate magnetometers, if any. It also provides backup data for GEOMAG-02MO, sent / received commands between the host PC and instruments, latest acquired data and their changes, short and long-term real-time plots of acquired and filtered data, logs of different events and errors of the recording systems and the information about the unexpected shutdown of the systems in any case.

Comment (17): I don't see a proper analysis and discussion of socio-economic-political factors in the manuscript and would remove this part from the conclusion. Where there any low-latitude aspects in the manuscript that would justify the title of the paper?

CPL is a Magnetic Observatory established in low latitude region of India, which implies that the amplitudes of Z component are relatively small, at the same time anthropogenic noise in Z component is large, combined effects of high temperature and humidity are significant. Socio-economic factors dictate that ideal conditions for operation of Magnetic Observatory are extremely difficult to achieve. Under such circumstances we have utilised natural non-magnetic material and low cost construction methods to attempt to produce 1 sec magnetic data of international standards. The manuscript documents various aspects of our evolving efforts for the same. It is hoped that it may provide a framework for scientists facing similar issues.

The revised version of manuscript highlights the above mentioned points in the conclusion section.

Comment (18): The English needs considerable improvement

In the revised manuscript, the English is improved.