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The new magnetic observatory at Choutuppal, Telangana, India

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ABSTRACT
Hyderabad Magnetic Observatory (HYB) of CSIR-NGRI, has 50 years of uninterrupted and stable recording of magnetic variations. These observations have contributed to global data, which is the basis of the main field model of the Earth's magnetic field, as well as several studies of low-latitude magnetic phenomena, and regional induction anomalies. With upgraded instruments, HYB became an INTERMAGNET observatory in 2009. With rapid urbanisation and introduction of Hyderabad Metro Rail project in the vicinity, it was imperative to establish an alternate observatory to continue the geomagnetic data series.

The campus of the former Choutuppal Geo-electric observatory provided a suitable location. Preliminary observations in 2012 and continuing observations thereafter, have led to provisional recognition of Choutuppal (CPL) as a magnetic observatory by International Association of Geomagnetism and Aeronomy (IAGA). Assessment of the quiet magnetic environment, minimising effects of temperature fluctuations in the construction of a primary variometer room, and stabilisation of power supply and internet connectivity have been achieved over the last three years.An evaluation of baselines, data quality and stability at CPL in comparison with HYB, is presented here.

Keywords: Magnetic observatory, Variation measurement, Absolute measurement, Baselines, Choutuppal, IAGA workshop 2014.

HISTORY OF MAGNETIC MEASUREMENTS AT HYB AND CPL

Hyderabad Magnetic Observatory, HYB (1964-present) and Choutuppal Geoelectric Observatory (CPL) (1967-1991) were set up in the center of the Indian peninsula and Ettaiyapuram Observatory (ETT) was set up at equatorial latitudes at the southern tip of the Indian peninsula (*Sanker Narayan, 1964; Sanker Narayan et al,1966, 1967; Sanker Narayan et al, 1978*) with the intention of studying concurrent low latitude magnetic phenomena at all frequency ranges. The geo-electric measurements at CPL were based on orthogonal 500m electric dipoles and magnetic pulsations were measured with solid core induction coils. Both quick run and ultra quick run photographic records were generated using highly sensitive galvanometers. Equatorial pulsation data and earth current measurements at CPL also contributed significantly to contemporary knowledge about the propagation and seasonal characteristics of magnetic pulsations (*Sarma et al, 1969; Sastry et al, 1982;*) and induction coil measurements of magnetic pulsations in 1969 (*Sarma et al, 1969; Sastry et al, 1990*).

HYB is situated just outside the influence of the quiet-day equatorial electrojet and is free from anomalous oceanic or geological induced effects and provides an ideal low-latitude location to monitor ionospheric and magnetospheric signals. With continuous recording and reporting of reliable and quality data over the last fifty years, HYB has emerged as an ideal, inland, low-latitude, international Key Magnetic Observatory, acknowledged by the International Association of Geomagnetism and Aeronomy (IAGA). The long data series has been used as input to main field model computations along with data from observations all over the world. Significant contributions to studies of low-latitude geomagnetic phenomena from daily magnetic variation, as well as magnetic pulsations and earth current measurements have been made from these datasets (*Srivastava, 1966; Srivastava and Abbas, 1977; Srivastava and Prasad, 1979; Srivastava et al, 1982; Sastry et al, 1982; Rao and Sarma, 2003; Rabiu et al, 2007, 2012; Rabiu & Nagarajan, 2007; Arora et al, 2014*).

Hourly values of magnetic variation as well as analyses of equatorial magnetic pulsations were reported from HYB and CPL (*CSIR-NGRI Report, 1972*).From 1972 hourly values are published in Indian magnetic data volumes and uploaded to WDC Kyoto (*Svendsen et al, 1990*).With digital instruments and technical support from Niemegk Observatory, GFZ, HYB produced 1-min data since 2008. The absolute measurements continued to be made using a DI fluxgate magnetometer and proton precession magnetometer. HYB became an INTERMAGNET observatory in 2009. Barely three years later, due to activities associated with Metro rail construction in the neighbourhood, within a distance of 500 m, deterioration of data quality at HYB was expected. An alternate magnetic observatory needed to be established, in order to continue the valuable 50-year data series, without interruption. To this end magnetic measurements commenced at Choutuppal in 2012. This paper is a commentary on the initiation and development of the new observatory and an evaluation of the new data series.

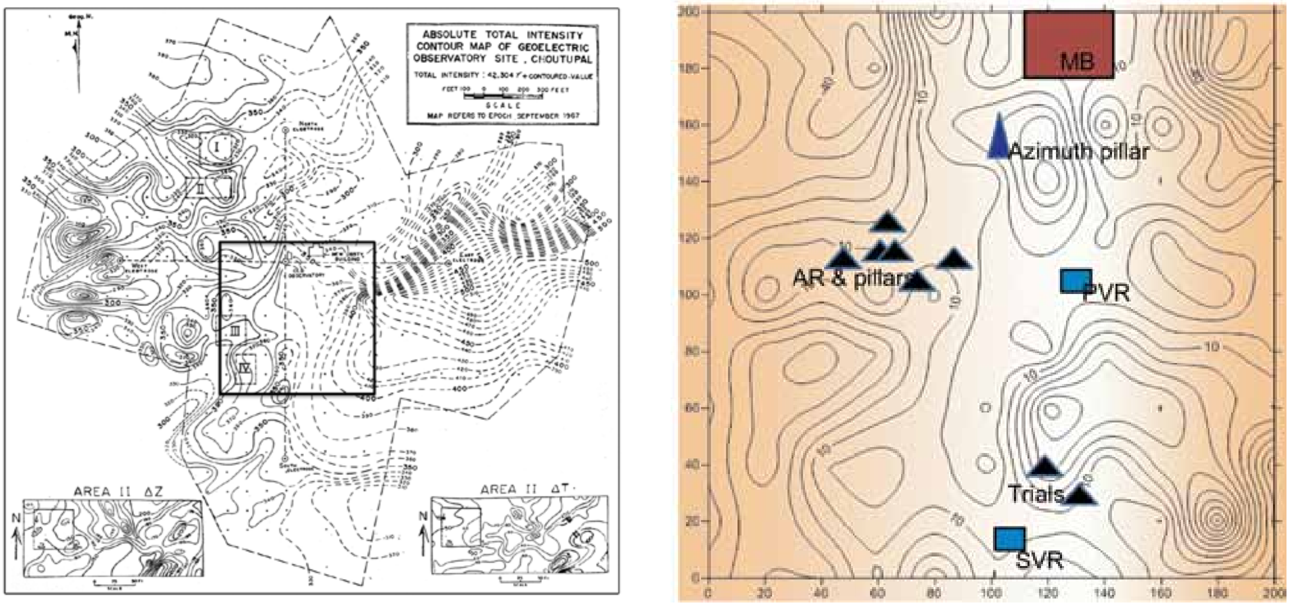

Figure 1. a) Contour map of the magnetic anomaly survey of the entire campus conducted in 1967; the black outlined square is the designated area for the new observatory. b) The area designated for the new magnetic observatory was re-surveyed in 2012 and locations of the different buildings and pillars are indicated within the 200mx200m area.

CHOUTUPPAL CAMPUS AS AN ALTERNATIVE LOCATION

The 0.4 sq km campus of the erstwhile geo-electric observatory in Choutuppal, situated 60 km due east of HYB, in geologically similar Archaean granite-gneiss terrain and semi-arid conditions, located more than 5 km away from any major road network, was a natural choice for setting up the new observatory. Preliminary measurements, as well as a magnetic survey were carried out to confirm the suitability of the new location for a medium term observatory. Within the approximately star shaped layout of the Choutuppal campus, the northern part is devoted to hydrogeological experiments; towards the south a geothermal observatory has been established. A 200 m x 200 m area in the central part was demarcated with the Main Building at its north-central periphery. The outline of the area is superimposed on the contour map of the magnetic anomaly survey of the entire campus, conducted in 1967 (Figure 1a; *Sanker Narayan et al, 1967*). Such an area is sufficiently far away from the boundary of the campus to ensure that local activities outside the campus may not have significant contribution to the measurements.

A detailed magnetic survey was made of the demarcated area in November 2012. Three areas were identified where the changes in magnetic field were within 12 nT; these were designated to be the sites of Primary Variometer Room (PVR), Secondary Variometer Room (SVR) and Absolute Room with the Absolute pillars, shown in Figure 1b. The ongoing trial measurements were located close to the site of the SVR to enable uninterrupted recording during the period of construction.

Trial measurements of magnetic variation data were started in early 2012, about 200 m south of the Main Building, away from internal roads and pathways, where two stable pillars were constructed for the DI measurements and the scalar magnetometer; the instruments were protected with wooden boxes. For the variometers, two pits were dug into the underground about 1m in depth and lined with marble and Styrofoam, in which the fluxgate sensor and data loggers were installed. The pillars and pits were covered with sheds of natural materials for protection against rain and direct sun. Solar panels were used to power the system. Absolute measurements were made about once in 15 days during the year, care being taken to make measurements early in the morning or late in the evening so that temperatures during measurements were mostly around 30°C.

STANDARDISATION OF MAGNETIC DATA SERIES FROM CHOUTUPPAL CAMPUS

Standardisation of the new data series and evaluation of its suitability to continue the data series of HYB has been accomplished between 2012 and 2015. Trial measurements started with recording of continuous three component variation data with GEOMAG02M fluxgate sensor and electronics and Overhauser PPM. The quality of data was good with high signal-to-noise ratio. The measurements were continued, establishing satisfactory baseline stability and comparisons with HYB. A set of sample data from one day in 2013 is shown in Figure 2.

Temperature variations were monitored closely to plan

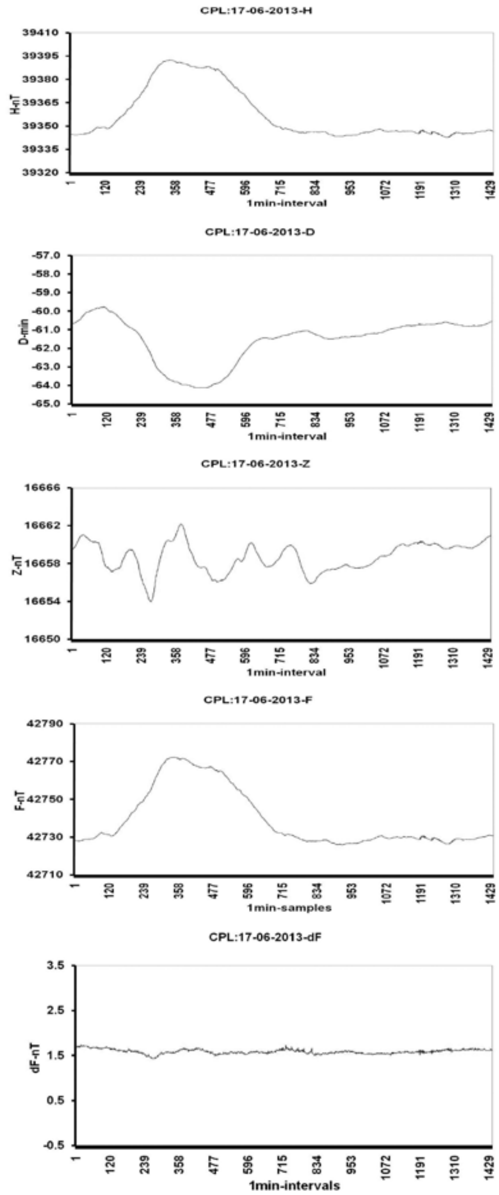

Figure 2. Sample data set showing the three component data, scalar data and ΔF, recorded in 2013.

for sufficient thermal insulation to keep daily variations to within 1°C in the semi-arid weather conditions of Choutuppal. As expected, the most important challenge of the Choutuppal measurements lay in controlling the temperature and its variations in the vaults where the variometers placed. The mean annual temperature is high at 26.7°C , with monthly and daily ranges of around 11°C. Despite best efforts at insulating the instruments, the sensor and logger experienced significant temperature swings, varying between 1 to 1.5°C daily and as much as 4°C annually, which affected the quality of the trial data. Daily temperature changes at CPL are significant when compared with HYB variometer where temperature fluctuations are within 0.1°Cas shown in Figure 3, top panel. The effect of temperature on fluxgate measurements is observed as a sag in the red line of ΔF for CPL compared to the blue line of HYB, in Figure 3, bottom panel. Efforts were continued to minimize temperature effects over 2013 and diurnal temperature effects in Choutuppal reduced to 1 nT or better.

Frequency of absolute measurements was increased to achieve baseline stability within 1 nT. One min variation data during 2012-2013, had some interruptions and jumps during the planning phase due to changes of pillars and instruments. These would stabilise later during 2014-15. The H,D,Z baselines (2012-2014) are shown in Figure 4. The baseline plots had some scatter, attributable to short and somewhat irregular record length. The jump in all the

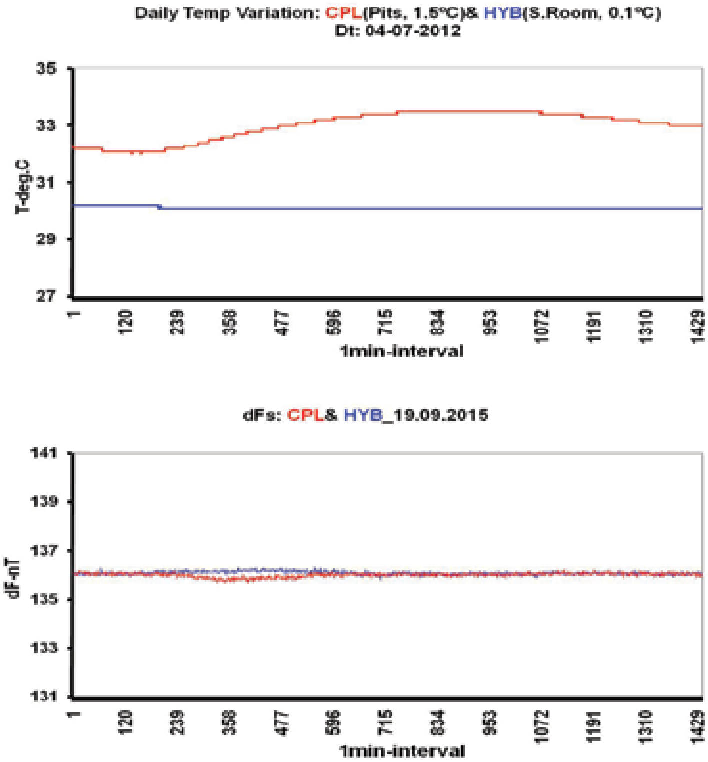

Figure 3a. Average daily temperature variation in HYB and CPL, b. Effect of temperature on ΔF –comparison between CPL and HYB.

components at the beginning of 2014 is attributable to a change in instrument.

The total field scalar data, at 5s sampling of the HYB Overhauser was increasingly affected by noise generated by construction activities of the Metrorail, shown in Figure 5 bottom panel. The top panel of Figure 5 shows the superimposed curves of F(HYB) and F(CPL) at 5s sampling interval, on 31 May 2013. The noise in the HYB data is clearly seen. The difference curve in the bottom panel further highlights the noise of the HYB PPM data. Average daily variation in total field between the two locations is about 2nT.

The trends of variation data of HYB and CPL were compared by obtaining histograms of their first differences, as independent check of quality of data at each location. First differences are obtained by subtracting each minute value from the previous one; first differences of a representative month of data from the years 2012, 13, 15 for each component are shown in Figure 6.

Histograms of differences at HYB and CPL in red and blue respectively show elongated Gaussian distributions for the three cases for three components. From a statistical standpoint, daily variation in H, would comprise of small differences ~0.0 -0.1 nT during 6 hours of night time. Daily variations averaging 60 nT over 8 hours of daytime (0800-1600) would result in large number of differences in 0.1-0.2 nT range (60nT/8x60min=0.12). More rapid changes before and after the noon peak, and disturbances, would provide some of the larger differences. Variations in D and Z are half the amplitude and show correspondingly less smooth Gaussian distributions. Similar distributions have been obtained for both HYB and CPL, over several months, attesting to the stability and close similarity of variations at the two observatories.

CONSTRUCTION OF PRIMARY VARIOMETER ROOM AND ABSOLUTE PILLARS

The construction of Primary Variometer and Absolute Room was started in June, 2013. The dimensions of the former were 12ft by 16 ft and 12 ft in height. It is constructed in the form of a buried vault with just 2 ft above surface. The dimensions of the Absolute Room, built above ground are 16 ft by 8 ft and 11 ft in height; the pillars are 40 inch above ground with 7.5 ft below ground for long term stability. The construction material used was tested non-magnetic sandstone sourced from about 120 km away. Instead of regular bricks, stone constructions with ceilings reinforced by wooden planks were used. The PVR is double walled. The roof is fitted with thick layers of Styrofoam. The primary digital fluxgate magnetometer and recording unit were installed in the primary variometer room in

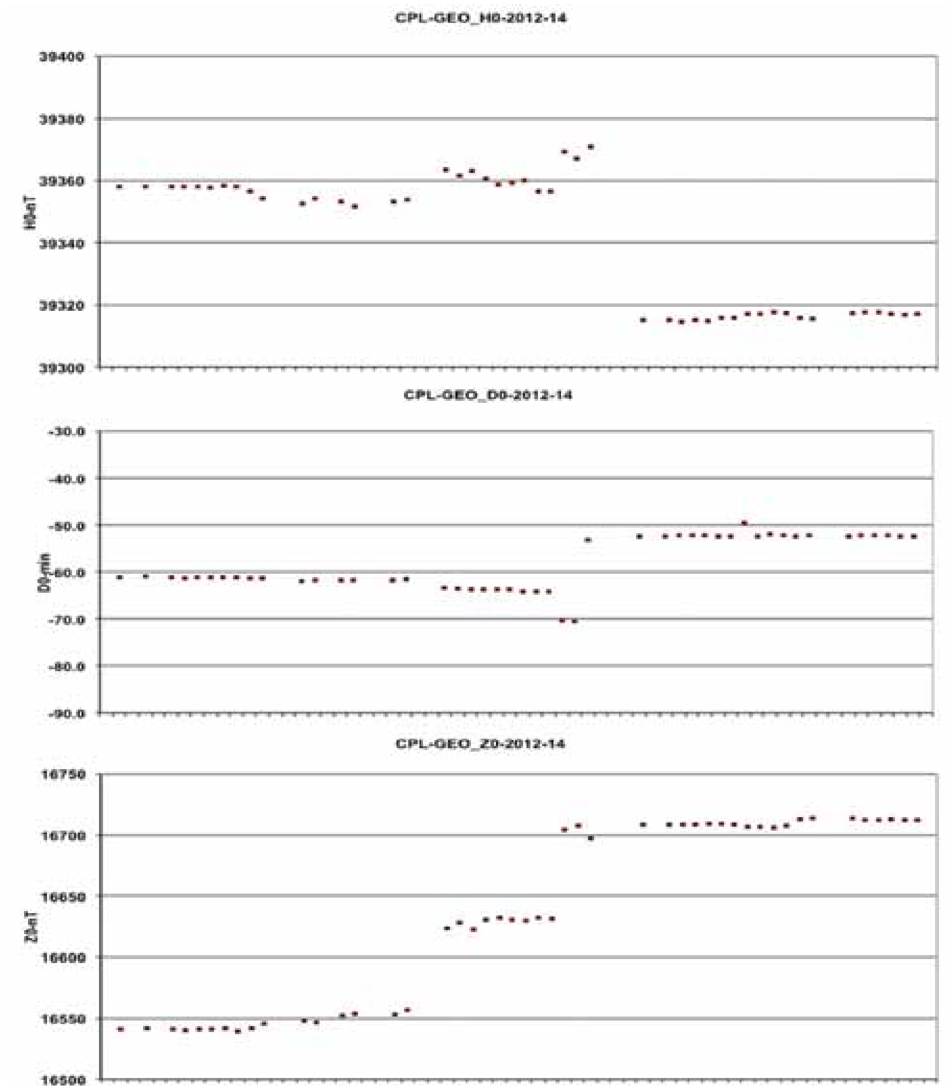

Figure 4. H,D,Z baselines, 2012-13

February 2014. However, issues of irregular power supply, fluctuations in solar powered backup and installation of dedicated internet connectivity had to be resolved. The primary variometer measurements have been uninterrupted since January 2015. The electronics and computers were housed in the control room of the main building. Solar panels of is it >3 kW capacity was installed to power the recording system independently; as Choutuppal experiences 90% sunny days, this is sufficient for uninterrupted clean power supply. Prior to supply of solar power, sharp voltage fluctuations and deviations from the standard 50 Hz supply played havoc with the electronics, which had to be rectified painstakingly. Dedicated internet lines were setup. In a remote area where both power supply and internet are very uncertain, completion of these activities took a lot of time and investment. Efforts to improve power supply and internet continued. In mid 2014, the new observatory at Choutuppal was provisionally assigned the IAGA code, CPL. The baselines and ΔF for the first half of 2015 show the significant improvements compared to 2012, as seen in Figure 7.

Seven absolute pillars were constructed, 2 positioned within the demarcated Absolute Room and five outside. An azimuth pillar was constructed south-west of the Main Building, about 300 m from the Absolute pillars. Azimuth was determined by geodetic (Stellar)and DGPS observations made by the Survey of India (SOI) and Indian Institute of Geomagnetism (IIG) as well as NGRI GPS team and relative positions of all 7 pillars were determined and the azimuth correction for each was assigned. From the coordinates the azimuths of baselines between the pillars and azimuth pillar were estimated. The measurements from the different methods agreed within 30 second of each other. D observations were carried out on each pillars to find out the pillar differences, which shows a range of 2.5 minutes. The results of the azimuth computation are given in Table 1.

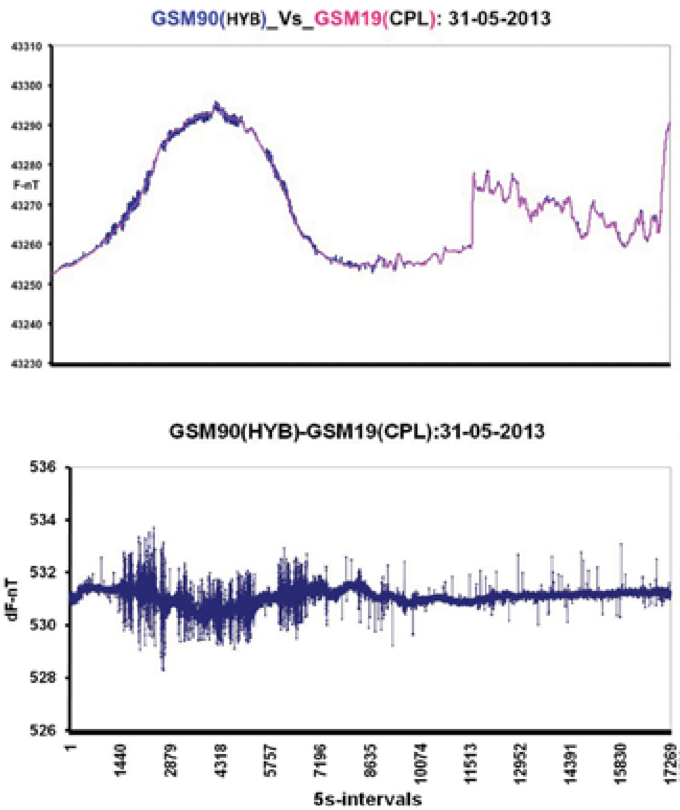

Figure 5. Noise in HYB Overhauser data

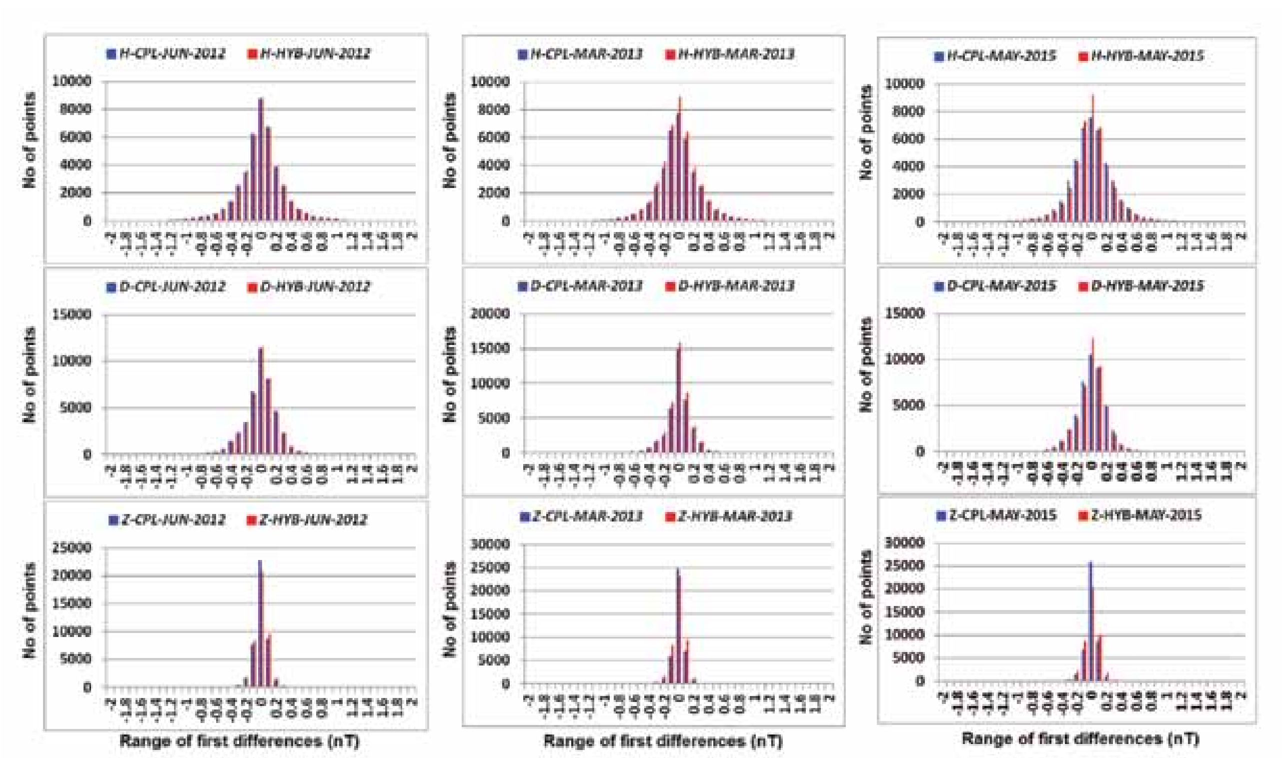

Figure 6. Comparison of first differences of three component data from HYB and CPL shows very similar nature of data distribution.

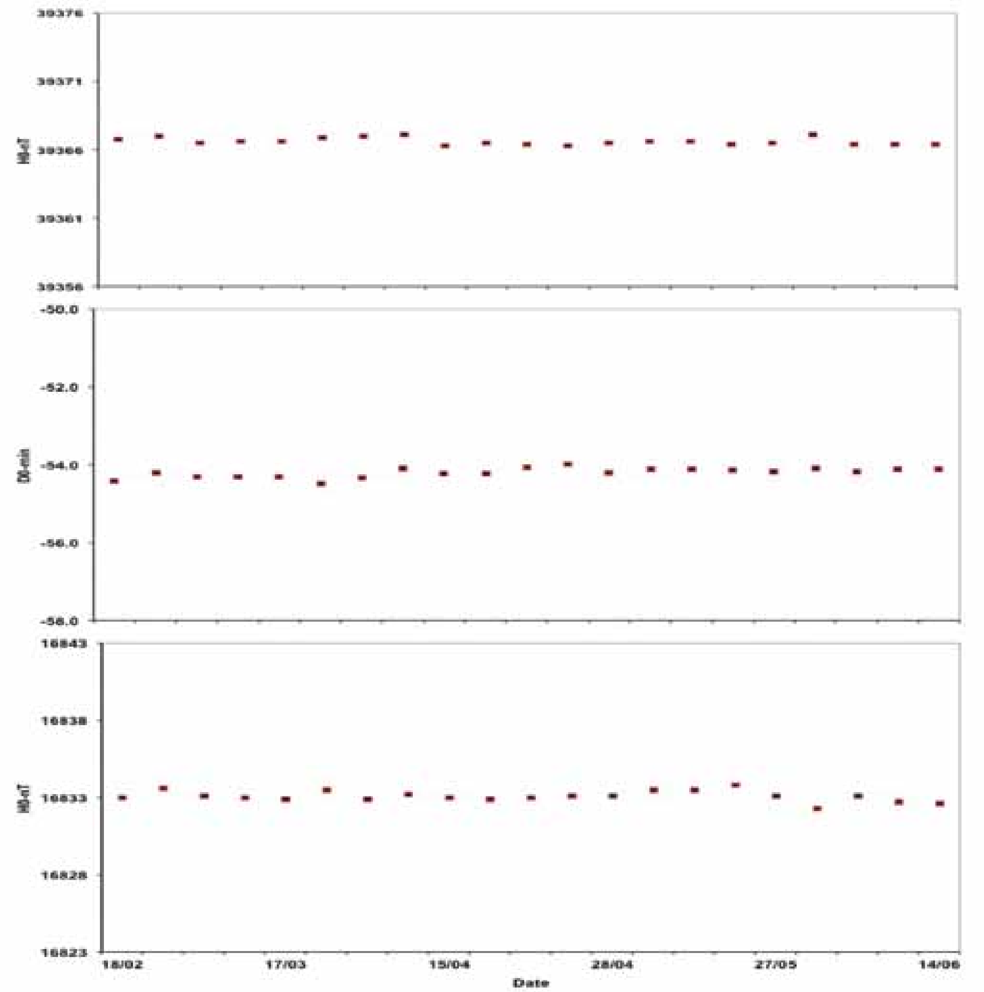

Figure 7. H,D,Z, Baselines of CPL, Feb to June, 2015

Table 1. Azimuth corrections for the absolute pillars

Pillar no	Azimuth Deg min sec	D corr (min)	dFcorr (nT)
1	42 22 31	0	0
2	41 07 19	-0.43	4.8
3	41 45 42	0.41	-2.4
4	38 15 35	0.55	18.6
5	39 35 58	-0.68	14.4
6	44 59 57	-1.78	-7.4
7	45 51 13	-1.28	-15.9

INTERCOMPARISON DURING XVI IAGA OBSERVATORY WORKSHOP, 2014

The XVI IAGA Observatory Workshop was held at CSIR-NGRI, Hyderabad, 7-16 October, 2014. About 60 observers attended the measurement sessions at CPL Observatory. Of these the measurements of the more experienced observers compare well with the baselines established for CPL. About 4 sets of declination-inclination observations were made by each observer, over 5 days. The observations were carried out on 7 absolute pillars. The appropriate declination correction was applied to each observation. A summary of the 3 best measurements of declination (D) and inclination (I) angles, of thirty four observers, are shown in the plots in Figure 8. It is seen that most measurements cluster about the mean between +/- 0.2 min for Dand +/- 0.3 min for

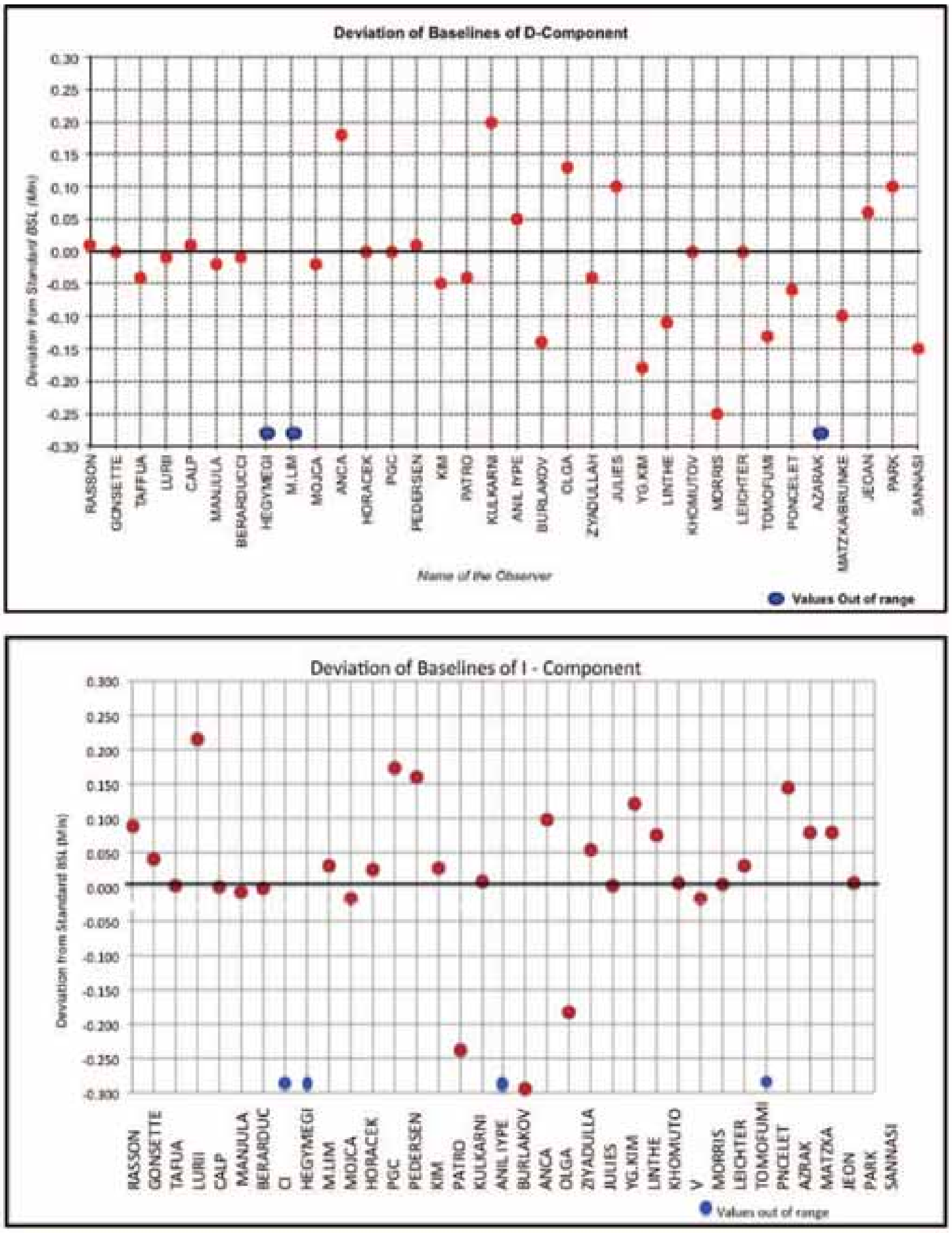

Figure 8. D and I observations during IAGA Workshop, October 2014.

I. Comparisons with measurements made by AUTODIF were also found to be satisfactory (*Arora and Veenadhari, 2014*). This was an additional affirmation of the stability of the environment, enabling accurate magnetic variation measurements at the recently established observatory CPL. Procedures for permanent assignment of the IAGA code are underway.

SUMMARY

HYB observatory has reported stable baselines and values of low-latitude variation, with suspended La Cour systems, as well as upgraded digital fluxgate magnetometers for 50 years. Due to external electromagnetic effects generated by the introduction of Metro rail about 500m from the observatory, it was decided to commence alternate recordings. A digital fluxgate magnetometer and Overhauser were installed for trial measurements at CPL, about 60 km from HYB, in 2012. The initial variations were compared and found satisfactory. Temperature fluctuations were further minimized to obtain long term stability of baselines at CPL. In 2014, the 3-axis Fluxgate Magnetometer Model FGE, assembled and calibrated by DTU, Space, Denmark with digital recording made by GFZ Potsdam was installed in the double walled, semi-underground primary variometer house at CPL. Both sets of data were reduced to obtain stable baselines in 2015.

Performance of the variometers was compared with observations at HYB over the period 2012-2015. Presentation of the on going data comparisons validates the establishment of this observatory. In future, this data will serve as an extension of the HYB data series.

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