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Application of Poincare Plot Analysis in Geomagnetism

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ABSTRACT

Poincare plot is a nonlinear method. It is a graphical representation of the correlation between consecutive RR intervals. It is a graph where each RR interval is plotted against the next RR interval. It is an emerging quantitative visual technique, where, the shape of the plot is categorized into functional classes. The inter-relationships of the geomagnetic components D (declination), H (horizontal), Z (downward) at four Indian geomagnetic observatories Alibag (ALB), Hyderabad (HYD), Pondicherry (PON), and Visakhapatnam (VIZ) from January 1995 to December 1997 is determined. Towards this purpose, the places which have certain common characteristics are analyzed using Poincare plot analysis.

KEYWORDS: Poincare Plot – Standard deviation - RR intervals - Geomagnetic components – Monthly Sq variation.

INTRODUCTION:

Significant contribution to research in geomagnetism started from India as back as in 19th century with the pioneering work of Brown and Chambers and Moos.**[1].** The geographical location of India plays a pivotal role with the latitudinal coverage existing from equator to the focus of the low latitude Sq current system.

Variations in the natural magnetic field are measured at the Earth's surface and elsewhere in the Earth's magnetosphere (for example, at the geostationary orbit).**[2].** These are field changes with periodicities from about 0.3 second to hundreds of years. (These boundaries are set to distinguish geomagnetic variations from the quasipermanent field and higher - frequency waves). Many of these observed variations from-very short periods (seconds, minutes, hours) to daily, seasonal, semiannual, solar-cycle (11-years), and secular (60–80 years) periods - arise from sources that either are external to the Earth (but superposed upon the larger, mainly dipolar field) or internal to the Earth (the magnetic-dipole and higher - harmonic trends and variations on the scales of hundreds and even thousands of years). The daily and seasonal motions of the atmosphere at ionospheric altitudes cause field variations that are smooth in form and relatively predictable, given the time and location of the observation. During occasions of high solar–terrestrial disturbance activity that give rise to aurorae (northern and southern lights) at high latitudes, very large geomagnetic variations occur that even mask the quiet daily changes.**[3].** These geomagnetic variations are so spectacular in size and global extent that they have been named geomagnetic storms and substorms, with the latter generally limited to the polar regions.**[5].**

Solar-terrestrial-physics associated studies were mainly utilizing long series of geomagnetic field observations at the Indian Observatories and also worldwide network of geomagnetic data. The Geomagnetic Observatory data were also used for studies on Interplanetary Magnetic Field (IMF) associations, Solar flare effects etc. The continuously recorded data from the Institute gives an opportunity to decipher the long-term secular changes as well as the daily variations of the magnetic components that is basically the reflection of the ionospheric and magnetospheric changes occurring over the region.**[4].** Thus, the variations in the geomagnetic field can be used as a diagnostic tool for understanding the internal structure of the Earth as well as the dynamics of the upper atmosphere and magnetosphere.

POINCARE PLOT:

Poincare plot is a nonlinear method. It is a graphical representation of the correlation between consecutive RR intervals. It is a graph where each RR interval is plotted against the next RR interval. It is an emerging quantitative

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visual technique, where, the shape of the plot is categorized into functional classes.**[8].**

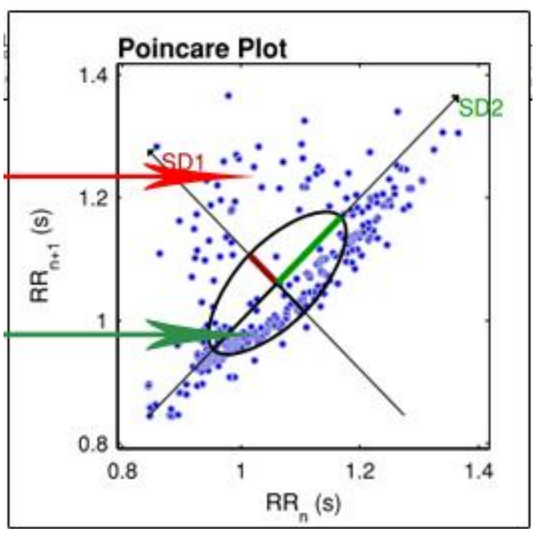
The Poincare Plot is an XY graph whose x's and y's are two consecutive RR intervals. The graph is modeled by an ellipse that is fitted on the line of symmetry at 45◦ to the x-axis.**[6].**
SD1— the standard deviation of the points perpendicular to the line of symmetry.
SD1 describes the short-term variability.

SD2—the standard deviation of the points along the line of symmetry.
SD2 describes the long-term variability.**[7].**

Computerized analysis entails fitting an ellipse to the plot, with its centre coinciding with the centre point of the markings. The line defined as axis2 shows the slope of the longitudinal axis, whereas axis1 defines the transverse slope, which is perpendicular to axis2. In addition, the ratio SD1/SD2 is computed.**[9].**

The parameters quantified on the plot are shown in the fig:1, an example of a Poincare plot.

Figure 1: POINCARE PLOT



If an ellipse is fitted to the plot, the dimensions of that ellipse can be measured.

Short-axis of fitted ellipse is called SD1.
Long-axis of fitted ellipse is called SD2.
Poincare ratio is SD1/SD2.

OBJECTIVE:

We use Poincare plot analysis for the identification of the characteristics of monthly Sq variations for geomagnetic components D, H and Z for a time series at four Indian geomagnetic observatories, namely, Alibag(ALB), Hyderabad(HYD), Pondicherry(PON) and Visakhapatnam(VIZ). Our objective is to identify the characteristics of monthly variations for the components, D, H and Z for the years 1995, 1996 and 1997.

DATA USED:

This research work is based on the data of Indian geomagnetic observatories only. Data for monthly variations of the geomagnetic components D, H and Z, from January 1995 to December 1997, for Alibag, Hyderabad, Pondicherry and Visakhapatnam observatories have been obtained from the volumes of Indian Magnetic data.

The monthly Sq variations for geomagnetic components D, H and Z for a time series of 36 months from January 1995 to December 1997 at four Indian geomagnetic observatories, namely, Alibag (ALB), Hyderabad (HYD), Pondicherry (PON) and Visakhapatnam (VIZ) is considered.

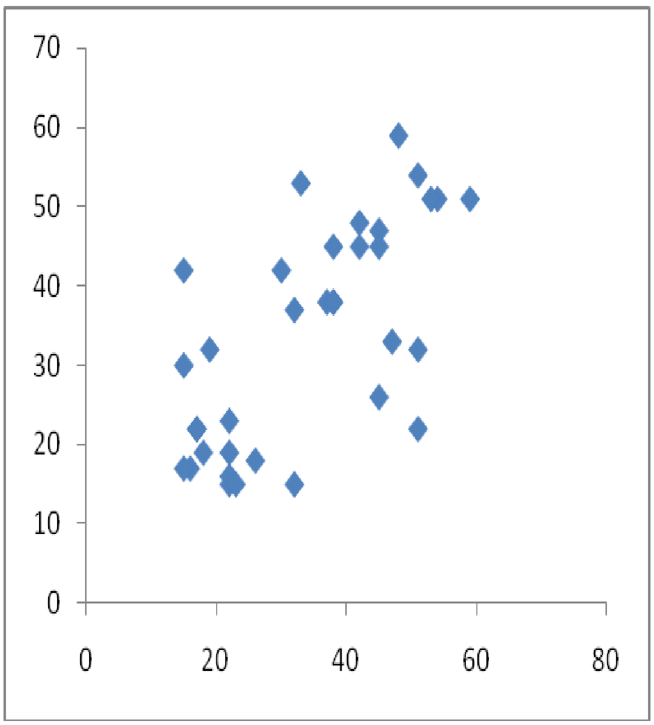
TABLE 1: LOCATION OF OBSERVATORIES:

No.	STATION	GEOGRAPHIC	DIPOLE
1.	ALIBAG (ALB)	Latitude 18° 37' N Longitude 72° 52' E	9.7° N 145.6°
2.	HYDERABAD (HYD)	Latitude 17° 25' N Longitude 78° 33' E	9.7° N 148.9°
3.	PONDICHERRY (PON)	Latitude 11° 55' N Longitude 79° 55' E	2.4° N 151.7°
4.	VISAKHAPATNAM (VIZ)	Latitude 17° 41' N Longitude 83° 19' E	07.8° N 155.8°

The inter-relationships of the geomagnetic components D (declination), H (horizontal), Z(downward) at four Indian geomagnetic observatories Alibag (ALB), Hyderabad (HYD), Pondicherry (PON), and Visakhapatnam (VIZ) from January 1995 to December 1997 is determined.Towards this purpose, the places which have certain common characteristics are analyzed using Poincare plot analysis.

APPLICATION OF POINCARE PLOT ANALYSIS TO GEOMAGNETIC Sq VARIATIONS:

POINCARE PLOT FOR COMPONENT D AT ALIBAG DURING THE PERIOD OF STUDY: FIG:2



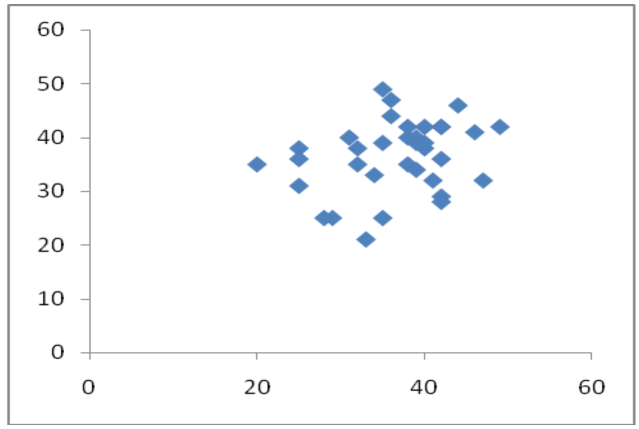
Mean value = 33.30556

SD1= 7.860155

SD2=17.7996

Ratio=SD1/SD2=0.441592

POINCARE PLOT FOR COMPONENT H AT ALIBAG DURING THE PERIOD OF STUDY: FIG:3



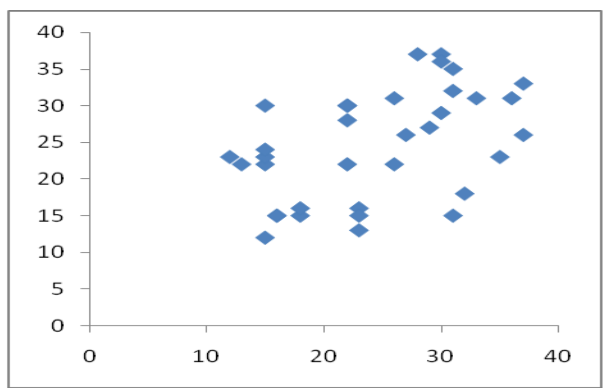
Mean value = 36.11111

SD1= 5.597157

SD2=8.374494

Ratio=SD1/SD2=0.668358

POINCARE PLOT FOR COMPONENT Z AT ALIBAG DURING THE PERIOD OF STUDY: FIG:4



Mean value = 24.38889

SD1= 5.362531

SD2=9.075281

Ratio=SD1/SD2=0.590894

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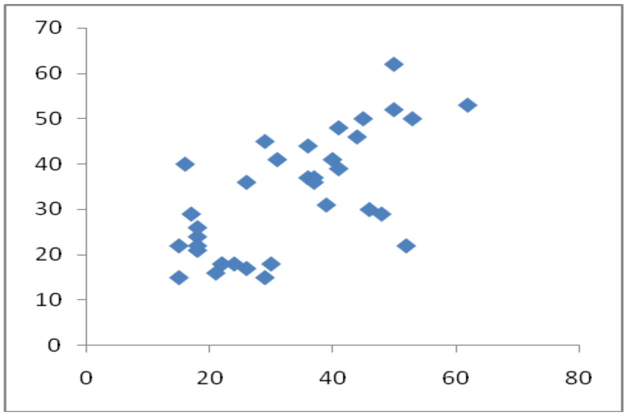
POINCARE PLOT FOR COMPONENT D AT HYDERABAD DURING THE PERIOD OF STUDY: FIG:5



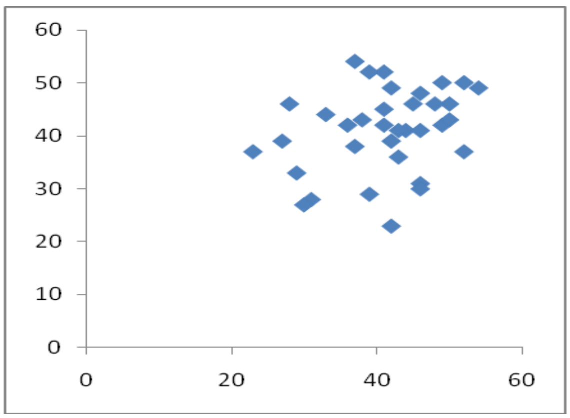
Mean value = 32.61111

SD1= 7.3984

SD2=16.83987

Ratio=SD1/SD2=0.439338

POINCARE PLOT FOR COMPONENT H AT HYDERABAD DURING THE PERIOD OF STUDY: FIG:6



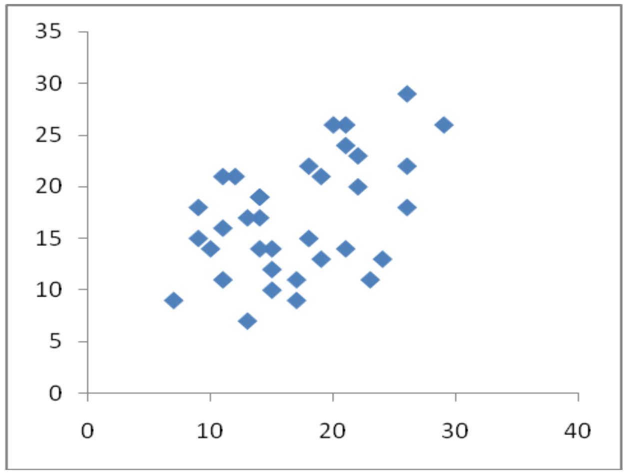
Mean value = 40.61111

SD1= 6.482945

SD2=9.742559

Ratio=SD1/SD2=0.665425

POINCARE PLOT FOR COMPONENT Z AT HYDERABAD DURING THE PERIOD OF STUDY: FIG:7



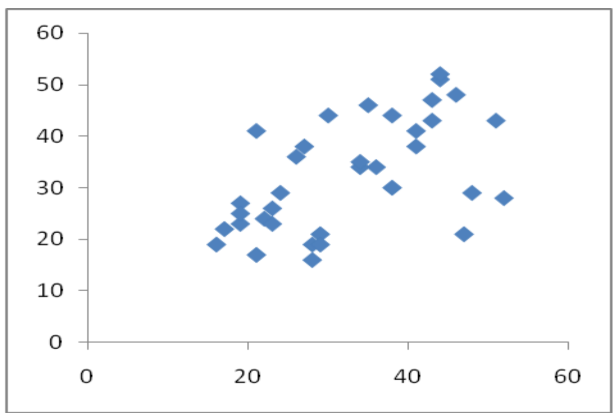
Mean value = 17

SD1= 4.037275

SD2=6.739043

Ratio=SD1/SD2=0.599087

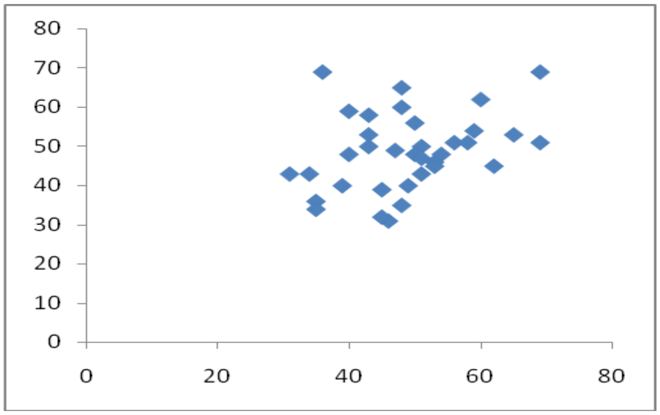
POINCARE PLOT FOR COMPONENT D AT PONDICHERRY DURING THE PERIOD OF STUDY: FIG:8



Mean value = 32.25

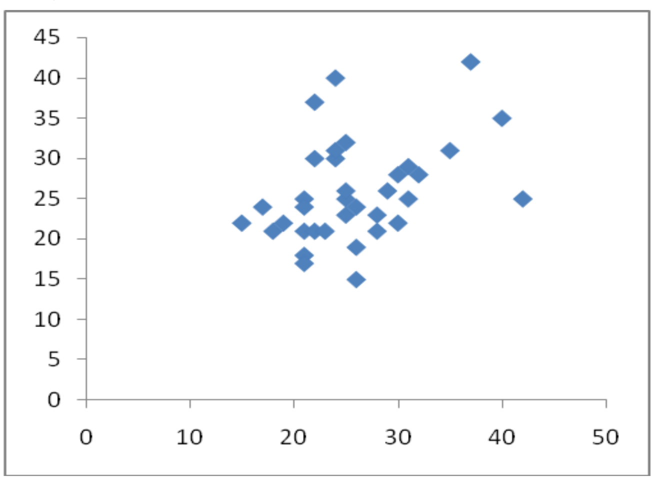
SD1= 7.025202
SD2=13.28601
Ratio=SD1/SD2=0.528767

POINCARE PLOT FOR COMPONENT H AT PONDICHERRY DURING THE PERIOD OF STUDY: FIG:9



Mean value = 48.27778
SD1= 7.894612
SD2=11.59935
Ratio=SD1/SD2=0.680608

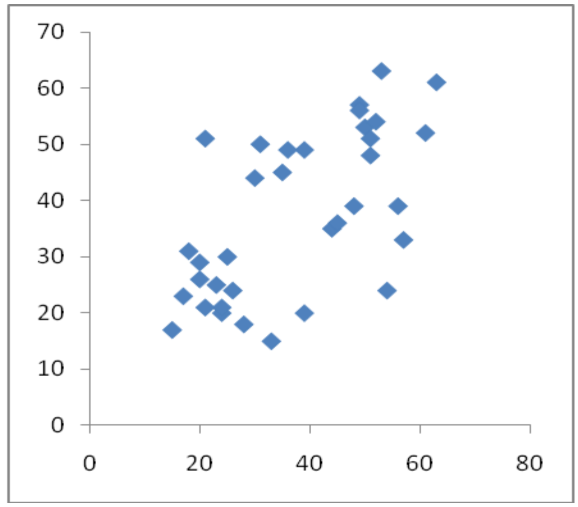
POINCARE PLOT FOR COMPONENT Z AT PONDICHERRY DURING THE PERIOD OF STUDY: FIG: 10



Mean value = 25.80556

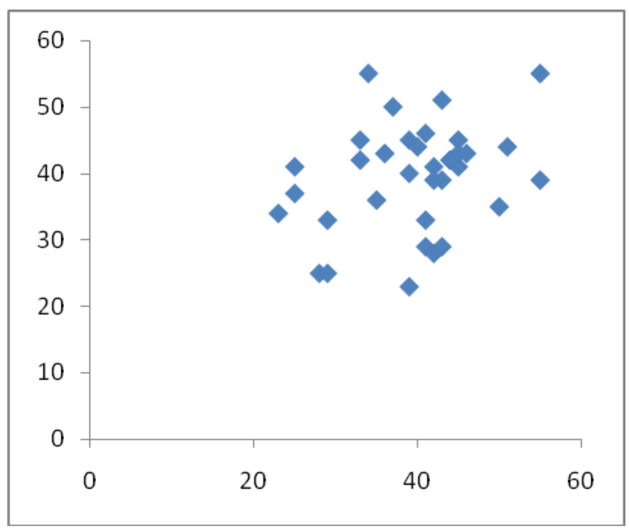
SD1= 4.767064
SD2=7.218837
Ratio=SD1/SD2=0.660365

POINCARE PLOT FOR COMPONENT D AT VISAKHAPATNAM DURING THE PERIOD OF STUDY: FIG: 11



Mean value = 37.13889
SD1= 8.720232
SD2=18.40429
Ratio=SD1/SD2=0.473815

POINCARE PLOT FOR COMPONENT H AT VISAKHAPATNAM DURING THE PERIOD OF STUDY: FIG: 12



Mean value = 39.02778
SD1= 6.587868
SD2=9.756236
Ratio=SD1/SD2=0.675247

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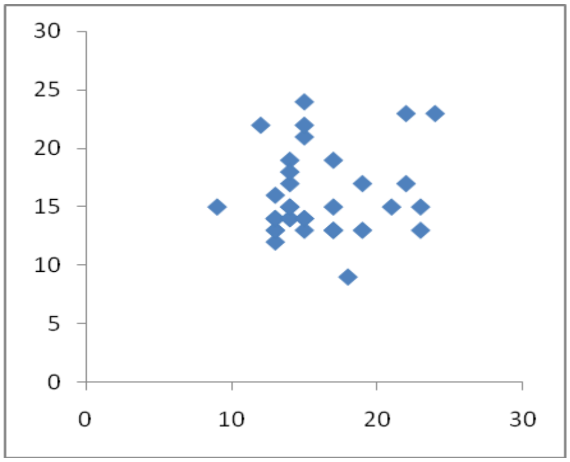
POINCARE PLOT FOR COMPONENT Z AT VISAKHAPATNAM DURING THE PERIOD OF STUDY: FIG: 13



Mean value = 15.97222
SD1= 3.297123
SD2=3.830176
Ratio=SD1/SD2=0.860828

FINDINGS OF THE STUDY:

It is analyzed that at Alibag and Hyderabad the components D, H and Z show same range of variation. At Hyderabad and Pondicherry the geomagnetic components D, H and Z show marginally enhanced variation whereas Visakhapatnam stands apart.

CONCLUSION:

The daily variation in the magnetic field at the Earth's surface during geomagnetic quiet periods (Sq) is known to be associated with the dynamo currents driven by winds and tidal motions in the E-region of the ionosphere known as atmospheric dynamo. Besides the atmospheric dynamo, other sources of electric field and currents at equatorial region contribute to Sq variations on different components of geomagnetic field observed at the ground level. Daily range of the geomagnetic field is an important parameter measuring the magnitude of diurnal variation. Being dependent on the daily maximum and minimum field values, the parameter fluctuates from day to day in accordance with the variability of both these values. A continuous recording of any of the components of the geomagnetic field typically exhibits two types of variations: a smooth, regular variation, known as Sq, the solar quiet day variation and a rapid irregular fluctuation. The Sq variations are the most regular of all the geomagnetic field variations. Here geomagnetic quiet day (Sq) variations have been analyzed through the application of Poincare Plot Analysis.

The application of Poincare Plot Analysis for pattern recognition and classification have been used for numerous applications in astronomy, meteorology, cartography, satellite data analysis, artificial intelligence etc., Here it is used to study the identical pattern of geomagnetic variations at Indian observatories. Generally, for a huge volume of data in a complicated analysis this technique yields accurate results. As a result of this study, it is expected that future usage of this technique may be appropriate for exploring some new results in geomagnetism.

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