HiSPARC Cosmic Ray Research Project Report- Pip Rudge

Abstract:

The research discussed in this report uses data collected from HiSPARC Detector located around Europe to investigate how the latitude of the Earth affects cosmic rays and what might have caused any changes found. To begin with I read articles about cosmic radiation and the HiSPARC detector to gain the vital background information I needed to complete this research project. Then I conducted preliminary data analysis and compared how the difference between the number of cosmic rays detected during the day and night varied with latitude and found a correlation. I then normalised the number of events detected at 10 different stations to find whether the voltage of each detected produced a major difference to the number of cosmic rays detected. I later conducted more preliminary data analysis and compared how the total number of cosmic rays varied at different latitudes. I then conducted mass data analysis on 3 months of data – June, July & August. I plotted latitude against the number of cosmic ray events on many graphs and used a statistical test to find a correlation and its significance. This research will show the correlation I found between these two variables but more in depth research is needed to come to an absolute conclusion for the reason behind why latitude influences cosmic rays.

Introduction:

Cosmic Rays:

Cosmic Rays are high energy radiation composed primarily of high-energy protons and atomic nuclei which can produce showers of secondary particles that penetrate the Earth's atmosphere. [1] The Earth is constantly bombarded by cosmic radiation which scientists know little about making them a significant part of current scientific research. The first serious experiments were in 1912, when Victor Hess went up in a balloon to measure the rates of these particles. The sources of these particles in terms of physics processes and production locations are still not well known; one of the reason many research projects have been set up to find out more about these mysterious particles. [4]

HiSPARC:

HiSPARC is one of the projects set up to investigate the secondary cosmic rays colliding with the Earth. It's a project in which secondary schools and academic institutions join together and form a network to measure cosmic rays with extremely high energy. The grid of HiSPARC detectors, of which Birmingham University is a member, allows for measurement of cosmic rays characteristics, like energy and time of arrival. [3]

Research:

I used data gathered by many detectors from different countries; often detectors were situated in the Netherlands, as that is where the HiSPARC project first originated. [2] In this report I will look at the effect of latitude on the number of cosmic ray events detected by the HiSPARC detectors and find a possible explanation for any effect found.

Context:

My project, on how latitude affects the number of cosmic rays, can help to identify areas where more cosmic radiation is likely and people who are most at risk. During my background reading I found a study suggesting increased exposure to cosmic rays might lead to an increased risk of cancer. My study identifies that higher latitudes are likely to have an increased number of cosmic ray events. Therefore people living in an area at higher latitude can take the right precautions to help reduce this risk.

Aim/ Objectives & Hypotheses:

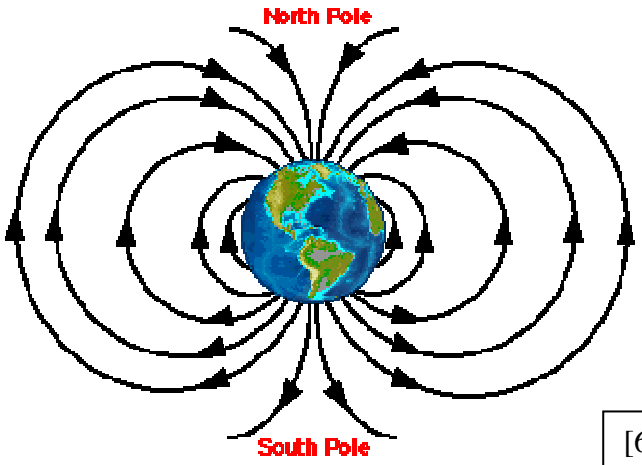
Aim – To find if a difference in latitude affects the number of cosmic ray events detected and if so, what causes it.

Hypothesis 1 – As the latitude increases the number of cosmic ray events detected will increase.

I chose this hypothesis because of my preliminary data analysis using a weeks worth of data to investigate the effect of different latitudes on cosmic ray events. I conducted a statistical test to find a correlation of 0.654 suggesting the latitude and numbers of cosmic ray events are correlated so I conducted mass data analysis to improve the reliability of my results.

Hypothesis 2 – The reason for the latitude's effect on the number of cosmic ray events is due to the Earth's magnetic field.

I chose this hypothesis because during background reading I found two possible explanations were the suns radiation and the Earth's magnetic field. [7] I thought the magnetic field would be the most likely cause because as the latitude increases from the equator the magnetic field becomes perpendicular to the Earth's surface making it easier for the cosmic rays to penetrate. However, closer to the equator, at a lower latitude, the magnetic field it parallel to the Earth's surface making it more difficult for the cosmic rays to penetrate.



[6]

Methods:

Reading:

Initially I read many articles related to my project in order to gain important background knowledge on the subject matter and improve my data analysis ability.

Core articles:
- "The Sun" by N.G. Schultheiss
- "Solar Winds" by N.G. Schultheiss
- "Introduction Cosmic Radiation" by N.G. Schultheiss

Data analysis help:
- Teacher-student guidelines
- Useful information on statistical analysis
- How to analyse data ppt.
- "Data Processing - Periodic Data" by N.G. Schultheiss

Practice Data Analysis:

I then practiced analysing how the number of cosmic ray events changes with: winter-summer variation, day-night variation and the effect of pressure on cosmic rays. I analysed a week of data from one station until I felt confident in my data analysis ability. I decided to base my research project around day-night variation because the results from my preliminary data showed there was a difference. Data for the night included: number of events recorded from 2200 to 0300. For the day: 1000 to 1500.

Data Analysis - difference between number of night & day events and latitude:

For my initial research I chose to investigate the difference between the number of day and night events (day – night) rather than the total number of events in the day and night. This is because different detectors have slightly different voltages and I thought that depending on the voltage, and therefore sensitivity of each detector, more or less rays may be detected so a correlation may not be found. I thought that using the difference between day and night events will overcome this problem. [5]

It was suggested by Dr. Maria Pavlidou that I could include how a change in latitude affects cosmic rays in my report therefore I decided to conduct preliminary data analysis to see if there was a significant difference to enable me to do this. Firstly, I analysed data collected over seven days from the station with the highest latitude (Denmark, Aarhus - 56.1674°) and I found that there were more events during the day than night. However, when analysing data from the station with the lowest latitude (Netherlands, Eindhoven, Weert - 51.2636°) I instead found there were more events during the night than day. This difference prompted me to begin mass data analysis.

I analysed 1 week of data from 15 stations at a range of latitudes and plotted a graph to show how the difference in the number of cosmic ray events at day and night

is affected by the latitude of the station and decided to do a statistical test to see whether my results were statistically significant.
Stations Analysed:

Name & Number of station	**Latitude**
Netherlands, Eindhoven, Weert – 8303	51.26364162
Netherlands, Leiden, Terneuzen – 3401	51.32342574
UK, Bristol – 13001	51.45827434
Netherlands, Eindhoven, Tilburg – 8103	51.561525
Netherlands, Leiden, Middelharnis – 3201	51.75387017
Netherlands, Leiden, Zwijndrecht – 3104	51.843736
Netherlands, Utrecht – 1008	52.08209249
Netherlands, Leiden – 3001	52.16904147
Netherlands, Amsterdam, Science Park – 501	52.3559285
Netherlands, Amsterdam, Zaanstad – 102	52.449408
Netherlands, Amsterdam, Kennemerland – 303	52.49433401
Netherlands, Amsterdam, Hoorn – 601	52.6474122
Netherlands, Groningen – 4001	53.24999351
Denmark, Aarhus – 20003	56.16561085
Denmark, Aarhus – 20002	56.16743287

Data Analysis – total number of day & night events and latitude:

I found it difficult to create a hypothesis for why latitude might influence the difference between the number of cosmic ray events during the night and day. Therefore, I sought help from Cristina Lazzeroni who is knowledgeable about HiSPARC and she suggested I use the total number of events during the day & night rather than the difference between them. She also proposed that the voltage would not make a significant difference but I could normalise the data to investigate it myself. This caused me to research what effect the sensitivity of each detector had on the number of cosmic rays detected by normalising the data.

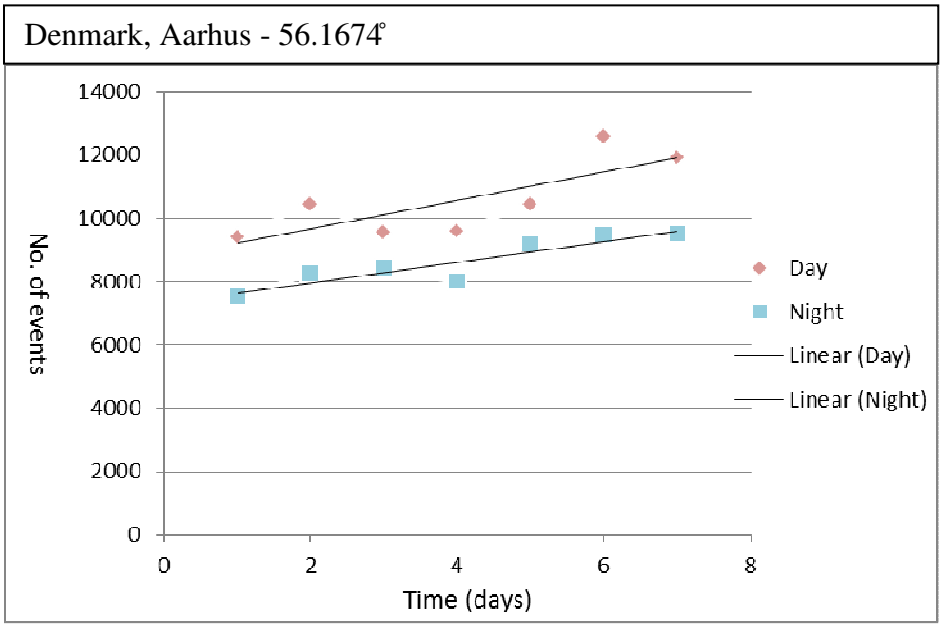
I used a collection of stations at very similar latitude which should've had similar, if not identical, data. 5 station in: Netherlands, Amsterdam, Science Park. I plotted the average number of events per day against average voltage of each detector.

Then I found the gradient of the line of best fit; it is used in an equation to find the normalised values and should've been similar to the gradient of the graph of the other sets of stations in close proximity that I analysed. However, the first gradient I found was 65.68 whereas the second gradient was -0.00440. These completely different gradients caused me to continue with the assumption that the voltage did not affect the number of events substantially. From this I was now able to compare the total number of night events to day events and create a hypothesis.

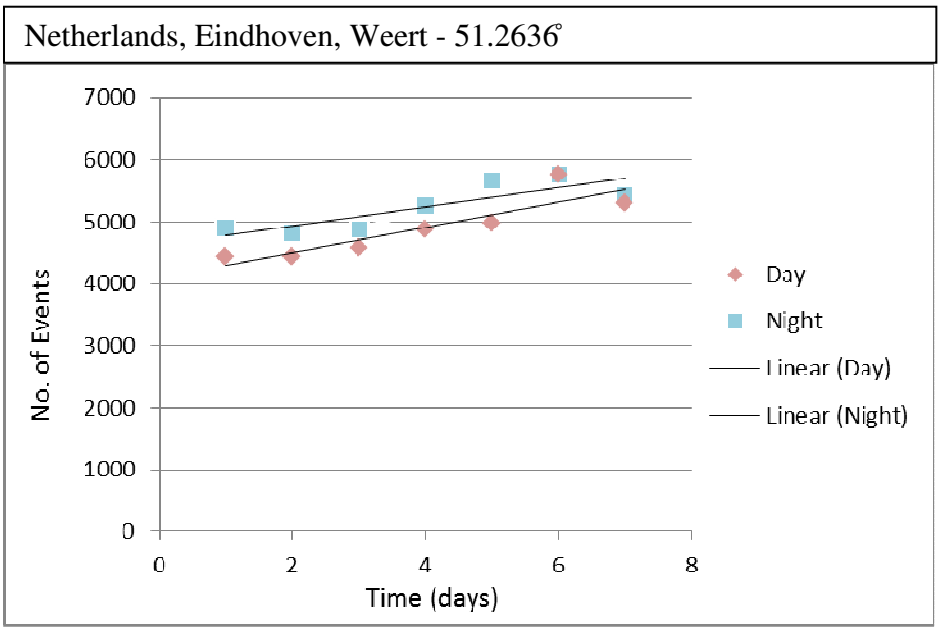
I then decided to conduct preliminary analysis of data from stations at a range of latitudes for one week and plotted a graph to show how the total number of cosmic ray events at day and night is affected by the latitude and found a correlation.

I then proceeded with mass data analysis and analysed data from 01-07-2013 to 28-07-2013 from all 15 stations and conducted a statistical test to find a strong correlation.

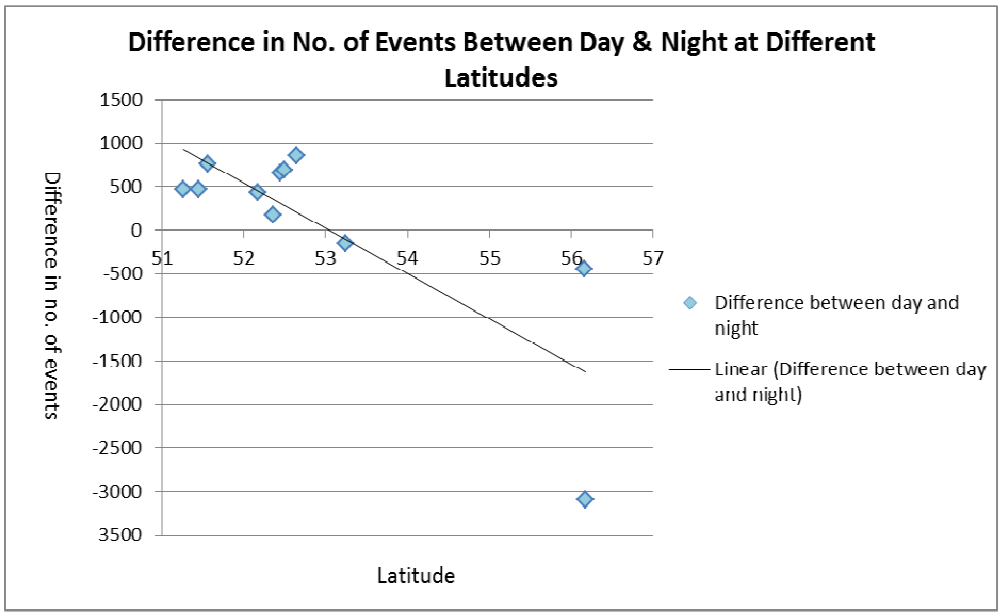
Results:



I analysed data collected over seven days from the station with the highest latitude (Denmark, Aarhus - 56.1674°) and I found that there were more events during the day than night. However, when analysing data from the station with the lowest latitude (Netherlands, Eindhoven, Weert - 51.2636°) I instead found there were more events during the night than day.

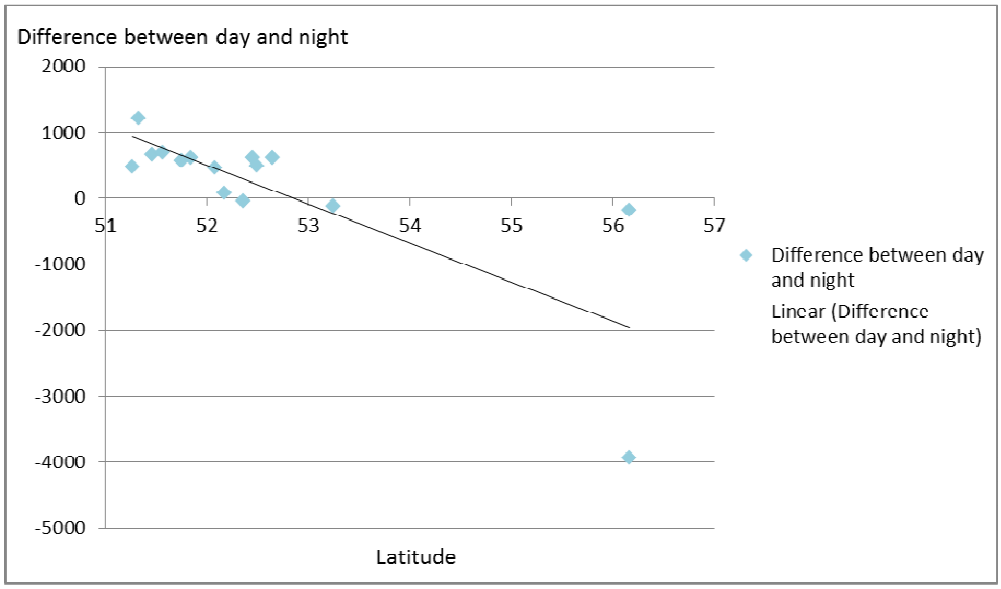


I analysed 1 week of data from 15 stations at a range of latitudes and plotted a graph to show how the difference in the number of cosmic ray events at day and night is affected by the latitude.



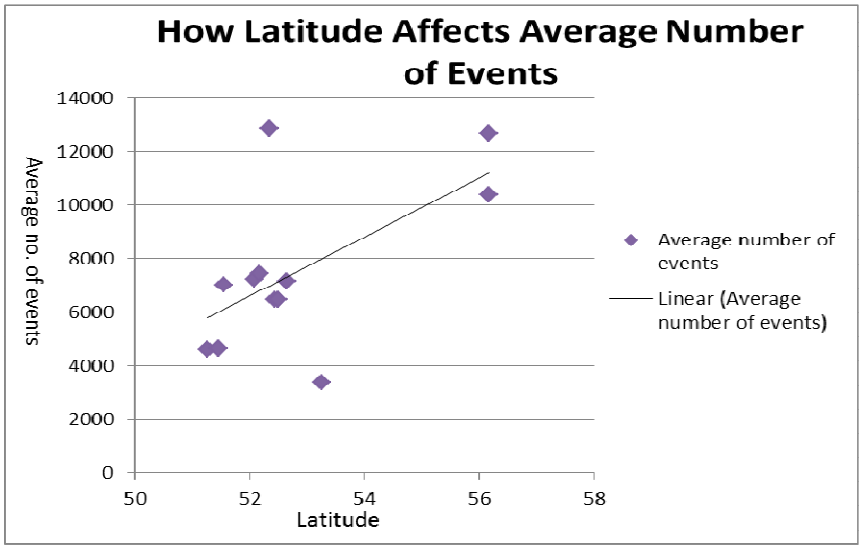
I conducted a statistical test to find whether the results are statistically significant and found a correlation of -0.795549223. The correlation is close to -1 meaning latitude and difference between the number of day and night events are anti-correlated quantities with high significance.

I then analysed data from 01-07-2013 to 28-07-2013 from all 15 stations.



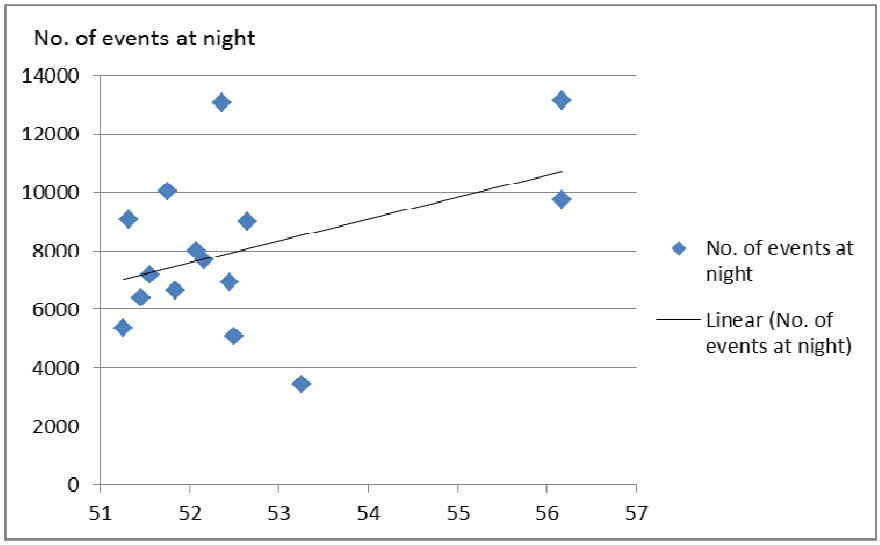
I conducted a statistical test to find whether the results are statistically significant and found a correlation of -0.767375362, the correlation is close to -1 meaning latitude and difference between number of day and night events are anti-correlated quantities with high significance.

When normalising the data the first gradient I found was 65.68, whereas the second gradient was -0.0044. These completely different gradients caused me to assume that the number of events was not affected substantially by the voltage. This meant I could investigate the total number of night & day events at different latitudes. I conducted preliminary data analysis of the same 15 stations and plotted a graph to show the how the total average number of cosmic ray events is affected by the latitude.



I found a correlation of 0.654017927 suggesting the latitude and number of events is correlated but not significantly so.

I analysed data only from night to reduce the influence from the suns radiation. If there is a correlation in these results then it is likely to be due to the influence of the Earth's magnetic field not the sun's radiation.



I found a correlation of 0.4248 suggesting the two are correlated but not significantly and further research would be needed to come to a solid conclusion.

I plotted a graph of the number of events each day against latitude for 7 stations for 3 months – June, July and August. The spread of the number of events seen on the graph shows the lines are overlapping but there is still a difference between each one. This is a clear way to show that latitude does appear to effect the number of cosmic ray events.

Discussion:

Overall I would describe this project as a success. I have proven my first hypothesis however; my second hypothesis is in need of further research into the effect of the sun's radiation before I can make any conclusions. Although I haven't proven or disproven my second hypothesis, my project has created a basis for further research on this topic.

This project has taught me that there are many different factors influencing cosmic rays which can be explored and I've only researched one aspect. I've also learnt that the quantity of research needed to fully explore the topic and reach a concrete conclusion is immense and I would need many more weeks to find out if latitude affects the number of cosmic rays due to the influence of the Earth's magnetic field. I've learnt many data handling techniques such as standard deviation, normalisation and statistical tests, all of which will help with any future projects I undertake.

My research project acts as a solid foundation for further research into this area therefore we can take forward my data analysis and graphs to help other researchers understand the link between latitude and cosmic rays and possibly find a reason for this link.

From my research I can conclude that the number of cosmic ray events changes with different latitudes because I analysed a wide range of data – 3 months – and found a strong correlation in my results. However, I cannot conclude the reason for this change. The Earth's magnetic field may be an influence however, until more research is done I cannot be certain.

There are many reasons for research on any aspect of cosmic rays. My project, on how latitude affects the number of cosmic rays, can help to identify area where more cosmic radiation is likely and the people who are most at risk. During my background reading I found studies suggesting increased exposure to cosmic rays might lead to increased risk of cancer. My study identifies that higher latitudes are likely to have an increase number of cosmic ray events. Therefore people living in area at higher latitude can take the right precautions to help reduce this increased risk.

Reference:

[1] - http://en.wikipedia.org/wiki/Cosmic_ray

[2] - http://www.bristol.ac.uk/physics/research/particle/public/

[3] - http://www.birmingham.ac.uk/Documents/college-eps/physics/schools/hisparc-project-advert-2.pdf

[4] - http://www.bristol.ac.uk/physics/research/particle/public/hisparc

[5] - *Talk with Dr. Maria Pavlidou*

[6] - http://www.unc.edu/depts/oceanweb/turtles/geomag.html

[7] - *An introduction to cosmic radiation & HiSPARC. Author: Gerard Osinga. Original Dutch text by: Cor Heesbeen, Connie Morsing, Jef Colle†,Charles Timmermans.* P15