Effect of lightning and precipitation on the Global Electric Circuit source

ECE 460, 4th Year Project

DigiPen Institution of Technology

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1 Abstract

There is a global electric circuit in the earths atmosphere. The purpose of this project is to find out what is the source that is driving the global electric circuit. So far most study are rely on a combination of multi-year's data. Im working on two data-sets: IMERG precipitation and WWLLN measures lightning strokes both of them have a time resolution up to 30min after prepossess. By using matlab comparing these two data-sets I conclude that thunderstorms have an important effect on the fair weather electric field.

2 Introduction

The global electrical circuit (GEC) is electrical currents in the atmosphere.[1] The purpose of this project is to explore the source and sink of Earths global electric circuit. To achieve this goal, a GEC Balloon will be launched and collect the data of fair weather vertical electric field and current density. The balloon will go up 30+ km in height. With the high altitude of the balloon. It will have clean measurements due to it is above the weather, orographic and other[1]. The part Im working on is to study the contemporaneous global thunderstorm activity and to use the property to compare with the data that will be collected by the balloon in the future. For now comparing with VOSTOK which is a dataset of electric field.

2.1 Back ground Information and related work

The most famous study related to what Im doing is the The Carnegie Curve.[2] The Carnegie Institution of Washington have sent out seven cruises to measure the earths fair weather atmospheric electric field. This project concludes that Earths fair weather atmospheric electric field variation is following UT time and independent of location. The difference of which parameter reaches a maximum around 19UT and minimum around 03UT, where the plot is referred to the Carnegie Curve. [2]

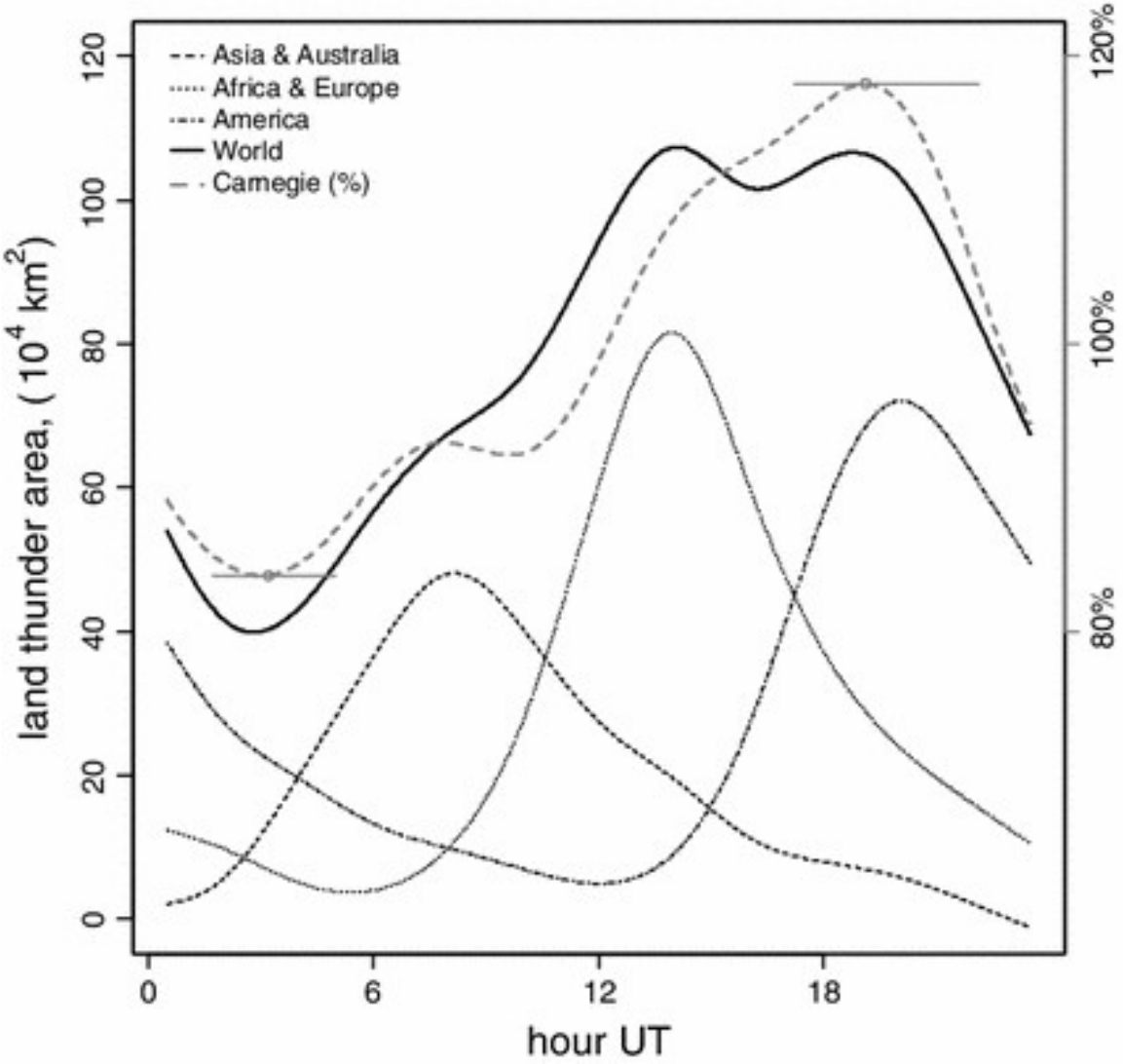

Figure 1: Classic carnegie curve

Instead of IMERG, liu et al. have used a subset of IMERG product called TRMM(Tropical Rainfall Measuring Mission)[3]. This is the first study that used ten years of data to qualify the thunderstorm that occurs on the globe with much higher accuracy. Moreover, their result supports Wilsons idea which is both thunderstorms and electrified shower clouds contribute to the DC global circuit by negative charge from precipitation.[3]

2.1.1 Similarity and Difference

My project is to analyze the IMERG precipitation data[4] and WWLLN[5]] lightning data with a different model, to see if the result agrees with the previous research or not. No study has used the IMERG data to verify the source of Global electric circuit By revealing the relationship between precipitation and lightning, we can separate thunderstorms from charged clouds. comparing to what LIU et al.s study.[3] With the balloon data in the future, we can do a day by day break down instead of just the ten year of combination. This research could lead us toward what is happening in each different day.

3 Methods, Techniques, and Design:

3.1 Overview

To accomplish the goal for research, Matlab was used to process both the IMERG precipitation and WWLLN lightning data. Primary tasks were needed to perform including re-grid both the IMERG data and WWLLN data. Validate the matching between each cell. combination of those two datasets using different models were analyzed by statistical tools. The primary task is to find out what is driving the global electric circuit. The thunderstorm or electrified shower clouds.

3.2 Datasets

The IMERG precipitation data and WWLLN lightning data were used in this study. The dataset will be explained in detail down below.

3.3 IMERG precipitation data

Integrated Multi-satellitE Retrievals for GPM, (IMERG) is The global precipitation measurement mission. An international satellite mission launched by NASA and JAXA on 27 February 2014 that sets new standards for precipitation measurements worldwide using a network of satellites united by the GPM Core Observatory[4][6]. The data has been generated every half hour with a 6-hour latency from the time of data acquisition. Here, the dataset which is gridded to a 0.1 degree by 0.1-degree grids was used in the study. The region covers 90 degrees N - 90 degree S (60 degrees N - 60 degree S full)[7]The Research / Final Run of the data is available after 2.5 months of the scan. This dataset was not the raw data collected by satellite, but was intercalibrated, merged and interpolated between multiple satellites estimates. [6]
The source of this dataset is from NASA PPS(Precipitation Processing system) FTP under HDF5 format.[8]As in Figure 2, we can see that we are using the precipitationCal field. This data stands for Multi-satellite precipitation estimate with gauge

calibration and in a unit of mm/hr. As we can see here, the size is 1800 * 3600. That is for -90 to 90 latitude and -180 to 180 longitude. So this data set has a cell that is corresponding to every 0.1 by 0.1-degree grid on the earth, and cell[0][0] is on the southwest point of the global grid.

```
Dataset 'precipitationCal'
    Size:  1800x3600
    MaxSize:  1800x3600
    Datatype:   H5T_IEEE_F32LE (single)
    ChunkSize:  1800x145
    Filters:  deflate(6)
    FillValue:  255.688477
    Attributes:
        'DimensionNames':  'lon,lat'
        'Units':  'mm/hr'
        'units':  'mm/hr'
        'coordinates':  'lon lat'
        '_FillValue':  -9999.900391
        'CodeMissingValue':  '-9999.9'
        'DIMENSION_LIST':  H5T_VLEN
```

Figure 2: HDF5 structure of IMERG data

Below in Figure 3. Here is a sample plot of IMERG data on Oct22 2017. I've made this plot with parsing the IMERG data and using show() function in Matlab. One thing worth to point out is as we can see above over 60 and -60 latitude there is some straight cutting edge which is due to missing of some satellite data.

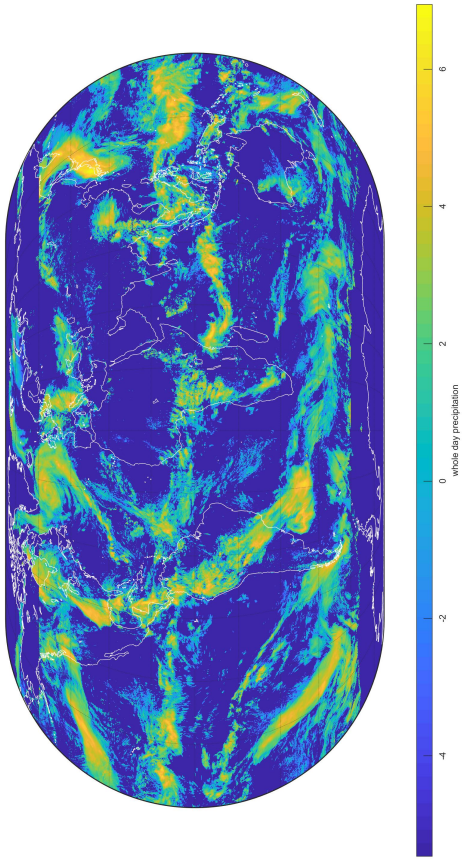

Figure 3: IMERG data plot on Oct22 with log base 10 scale

3.4 WWLLN lightning data

World Wide Lightning Location Network (WWLLN) measures the lightning events worldwide [5].This sensor network working at VLF(3 - 30kHz) can detect an impulsive signal from lightning discharges called sferics. For each lightning stroke, it will need at least 5 WWLLN sensors based on the time of group arrival to calculate the location. Sensors have enclosed the lightning will have a better accuracy over the ones that are not[5]. Refers to WWLLN the detection efficiency for strokes about 30 kA is approximately 30% globally.[5]
The data is in a CSV format which includes the year/month/day; hr/min/sec; latitude; longitude; error and number of stations. To scale the WWLLN and IMEEG data, the WWLLN data were re-grid into a 0.5 by 0.5-degree grid where the lightning counts in each cell could be add up to perform statistical analysis. in Figure 3. Here is a sample plot of WWLLN data on Oct22 2017. Ive made this plot with parsing the WWLLN data and using geoshow() function in Matlab. This data plot is consistent with the scheme that Ive had with IMERG on that day.

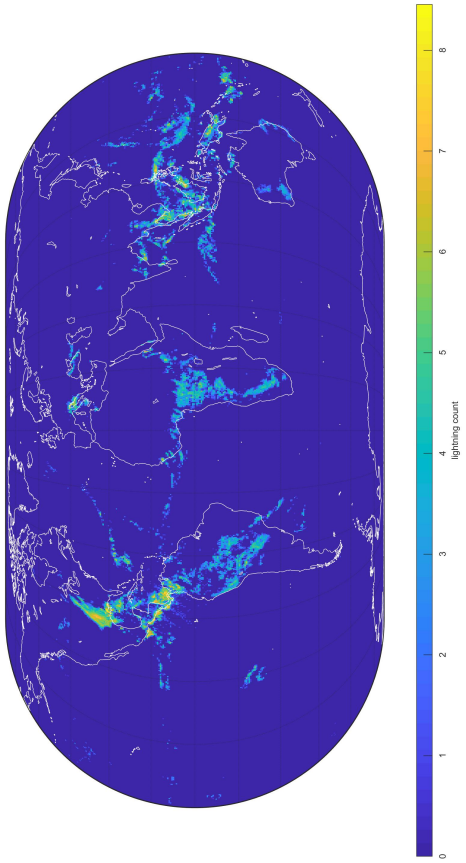

Figure 4: WWLLN data plot on Oct22 with log base 10 scale

3.5 VOSTOK ez data

VOSTOK ez dataset is the electric field data measured at VOSTOK station at Antarctic Plateau. This area has a time interval around local noon in summer that has negligible influence factor such as dust and moisture on the data recorded. This data set also have people working on manually removing the solar wind noise, however, the time overlay with WWLLN data we have remove noise. Thus, the few days of low noise data in Feb 2015 were used in this study.[9]

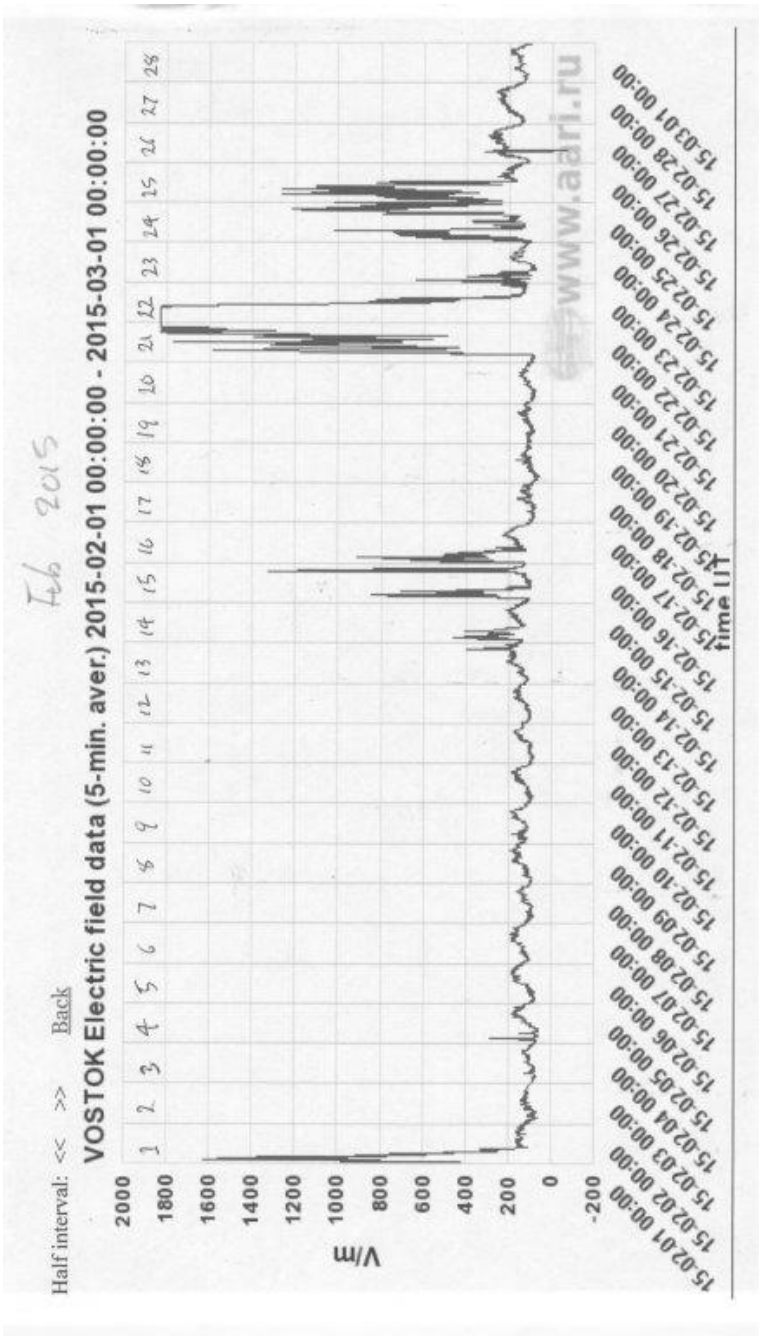

Figure 5: VOSTOK data Feb 2015

Figure 5 shows the plot for VOSTOK data on Feb 2015. As we can see in the plot from 5th to 12th there is no spike and really little noise. So we are using these 8 day as a reference to prepare IMERG and WWLLN data to perform analysis on.

3.6 Analysis

For data analysis, I've accomplished the following steps.

3.6.1 Task been done

- **Regrid Imerg and WWLLN**
  Regriding Imerg and WWLLN data to a scale of 0.5 * 0.5-degree cell over the globe. Imerg data comes with a 0.1 * 0.1 degree cell and WWLLN data comes not gridded. So I'm regarding both of the data set
- **Heatmap for verification**
  I'm using the heatmap to verify that the dataset after regrid lines up with each other also confirm that the orientation is still correct
- **VOSTOK plots**
  I'm using VOSTOK data (fair weather electric field measured at the ground station) plot against Imerg + WWLLN combination to see the relation of fair weather electric field vs. precipitation + lightning

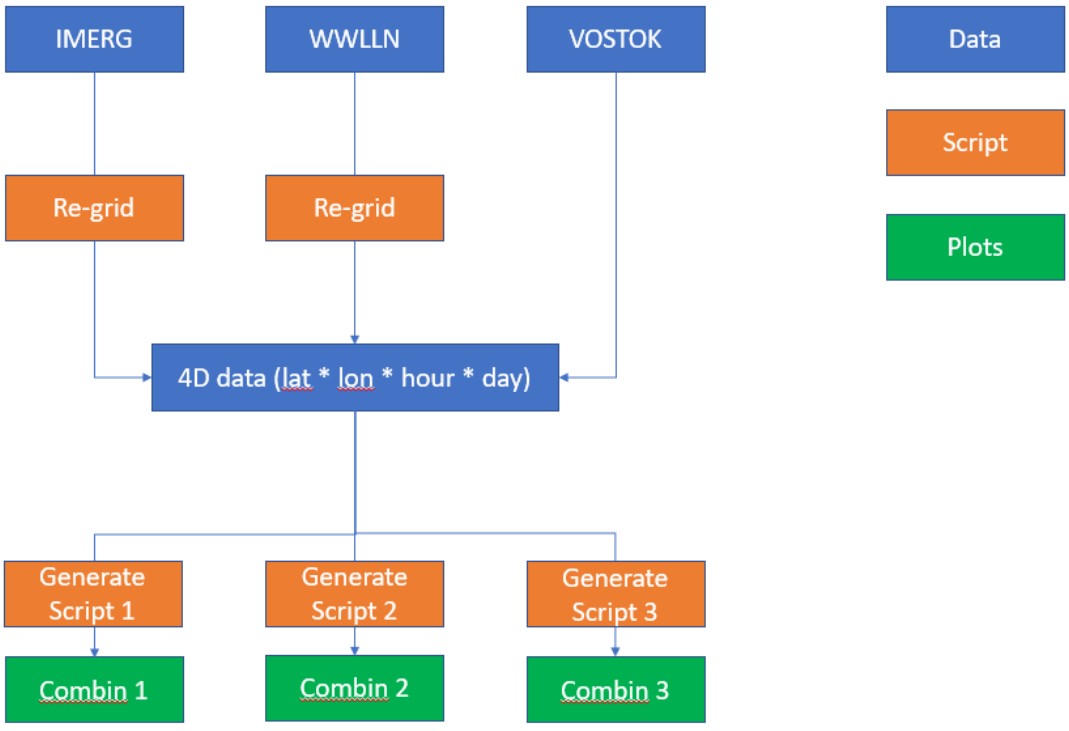

Figure 6: Software structure

Figure 6 is a software flow figure. The raw data input is Imerg, WWLLN, and VOSTOK. For Imerg I'm regriding 0.1 * 0.1 degree cell to a 0.5 * 0.5 degree cell. WWLLN raw data is not gridded so grid it to a 0.5 * 0.5 cell. VOSTOK data is already a global average so no need to grid it. After grid step all the data have been stored in a .mat file which contains two 4D double variable and one 2D double variable(VOSTOK). This structure can be easily port to use with different generating script. For my generating script, I have a different combination of Imerg and WWLLN from 0 lightning up to 10 lightning and 0 mm/hr precipitation up to 100mm/hr precipitation.

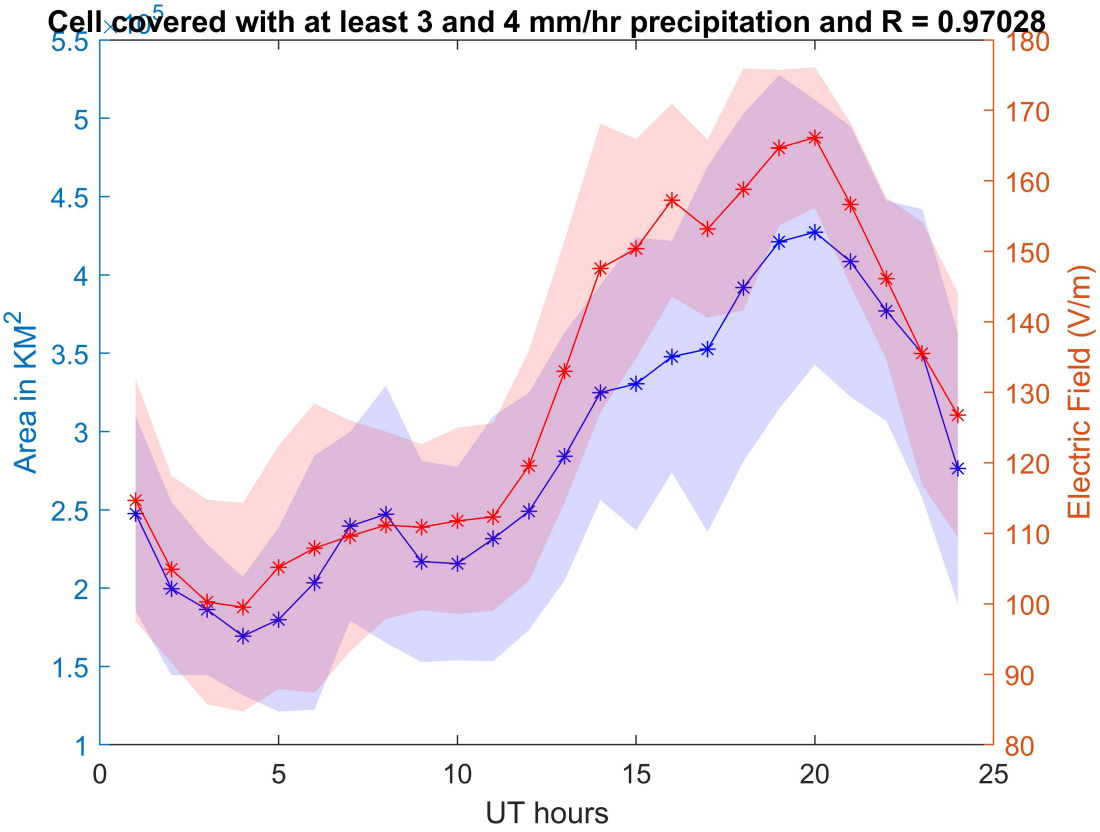

Figure 7: 4 mm/hr prec with 3 lightning

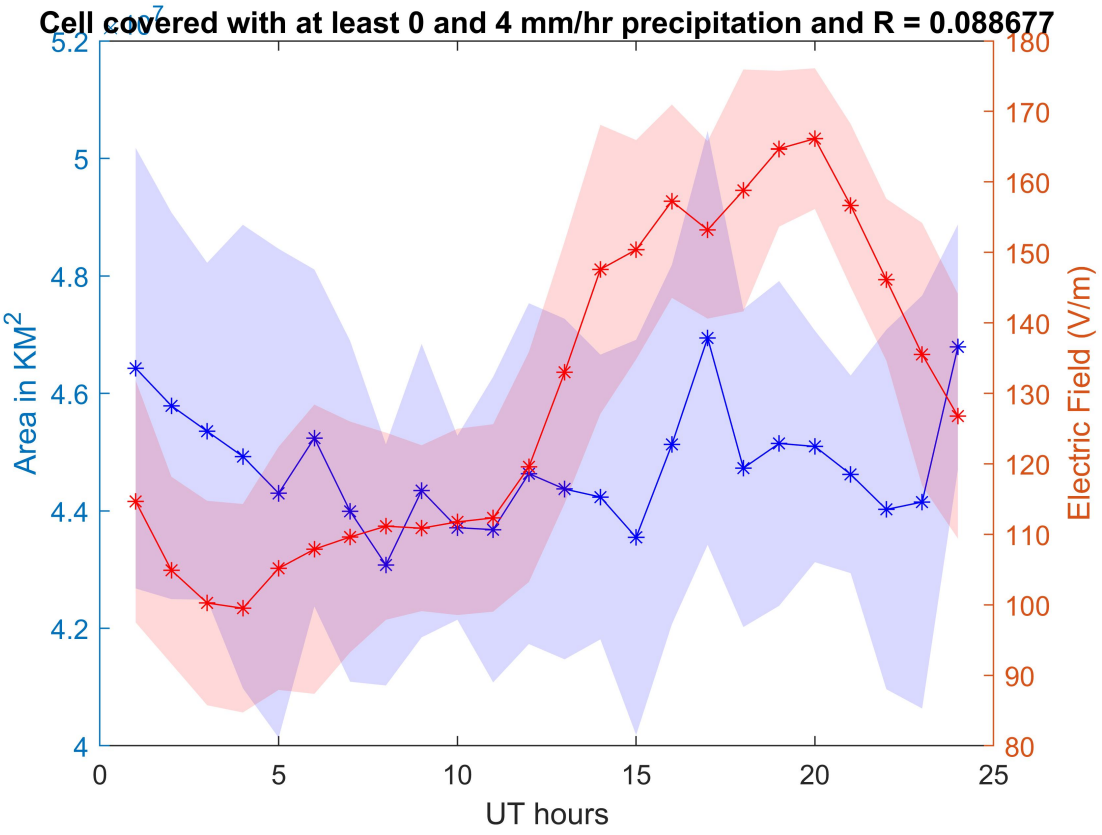

Figure 8: 4 mm/hr prec with 0 lightning

Figure 7 and figure 8 are both using the 8 day that over lays with VOSTOK low noise data in Feb 2015. I first add all 8 day up and divide by 8 to find the mean which is the solid line in this case then the shading area is the variance. Beside the 8 day in combined together, I've also got day by day break down as well. Some example can be seen in the appendix.

As we can see here in figure 7 the correlation factor r is significantly higher than figure 8. This appears always to be the case, which indicates that lightning is the effect the GEC by a lot more than just perception.

Note here the y axis is area. Since I'm using 0.5 degree by 0.5 degree cell. Each cell will have a difference in area respect to latitude (longitude also has an effect by it is negligible). The cell that are close to equator will have a larger area covered. So I'm using cos of latitude to calculate a coefficient to normalize every cell to roughly the same area as the cell near equator.

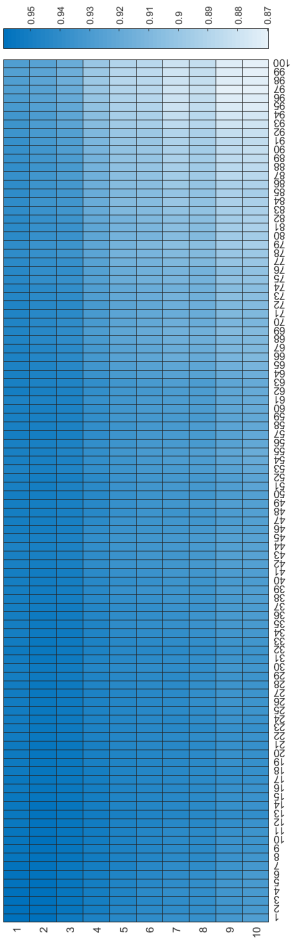

Figure 9: r value heatmap

Figure 9 shows that as long as there is 1 or 2 lightning with precipitation in the same cell. The correlation value r will remains high. But with increasing amount of precipitation or lightning count doesn't help on the correclation with VOSTOK dataset.

4 Conclusion and future plan

According to the preliminary result, lightning is the most critical factor that is driving the GEC. With precipitation and lightning happens at the same time this could also be a thunderstorm that is happening at that cell. Other things worth to point out is that the electric field around ut 13 to ut 20 is faster than the lightning and precipitation. Compares to the primary result from Liu et al., my plots have similar amplitude and phase especially around ut 13 to ut 20 where the electric field comes before thunderstorms. Shortly, I will work on getting the land vs. ocean plot, multi-year analysis(2015 - 2018), multi-year heat-maps and seasons and regional analysis.

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References

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6 Appendix

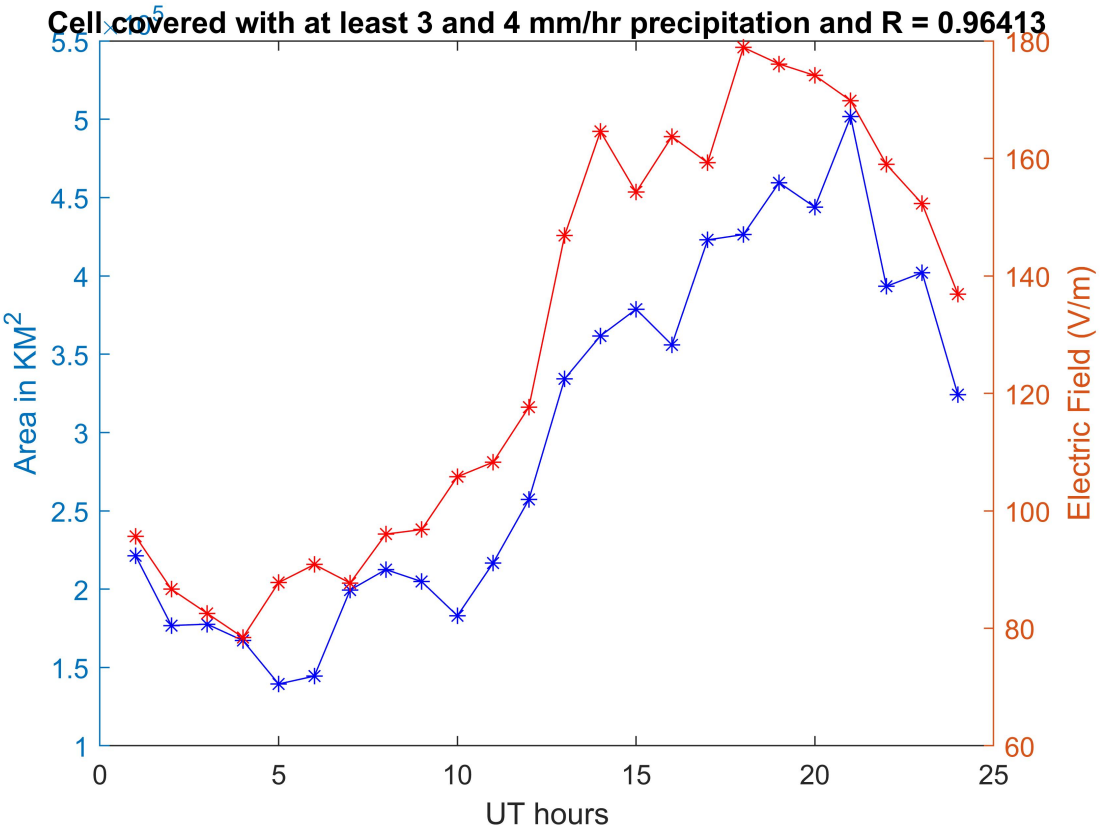

Figure 10: precipitation 4mm/hr lightning count 3 day1

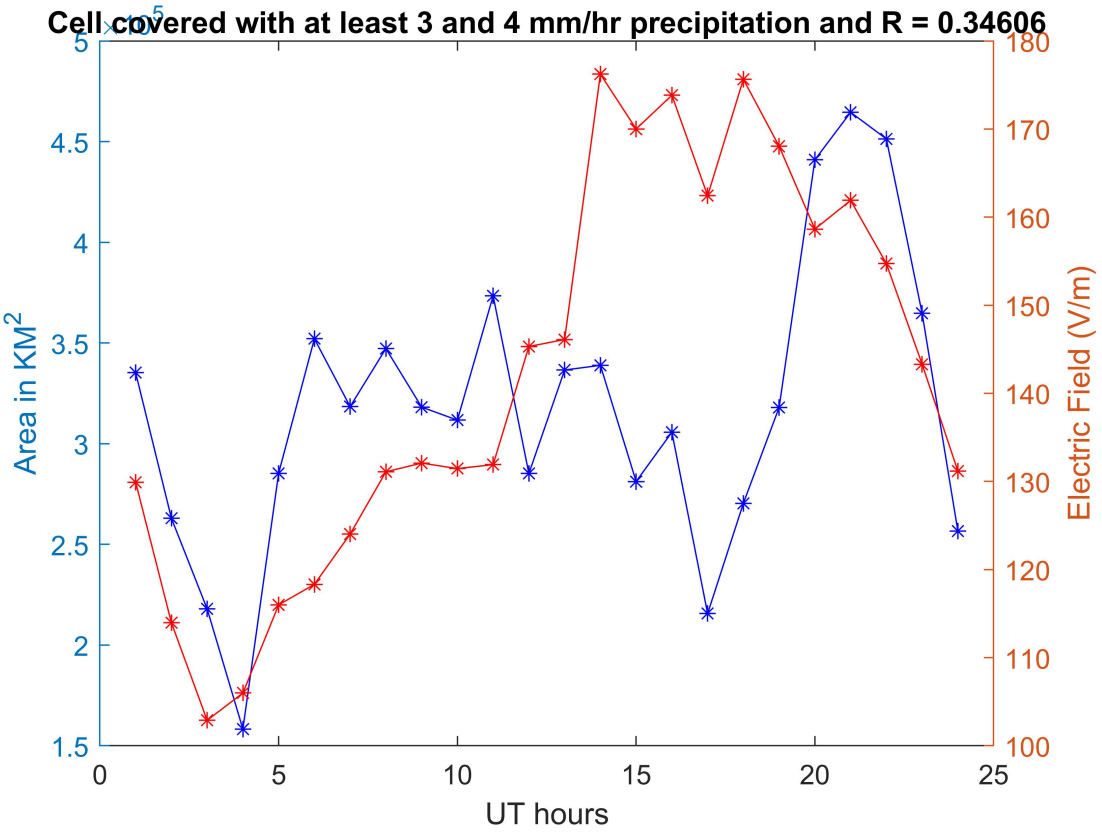

Figure 11: precipitation 4mm/hr lightning count 3 day2

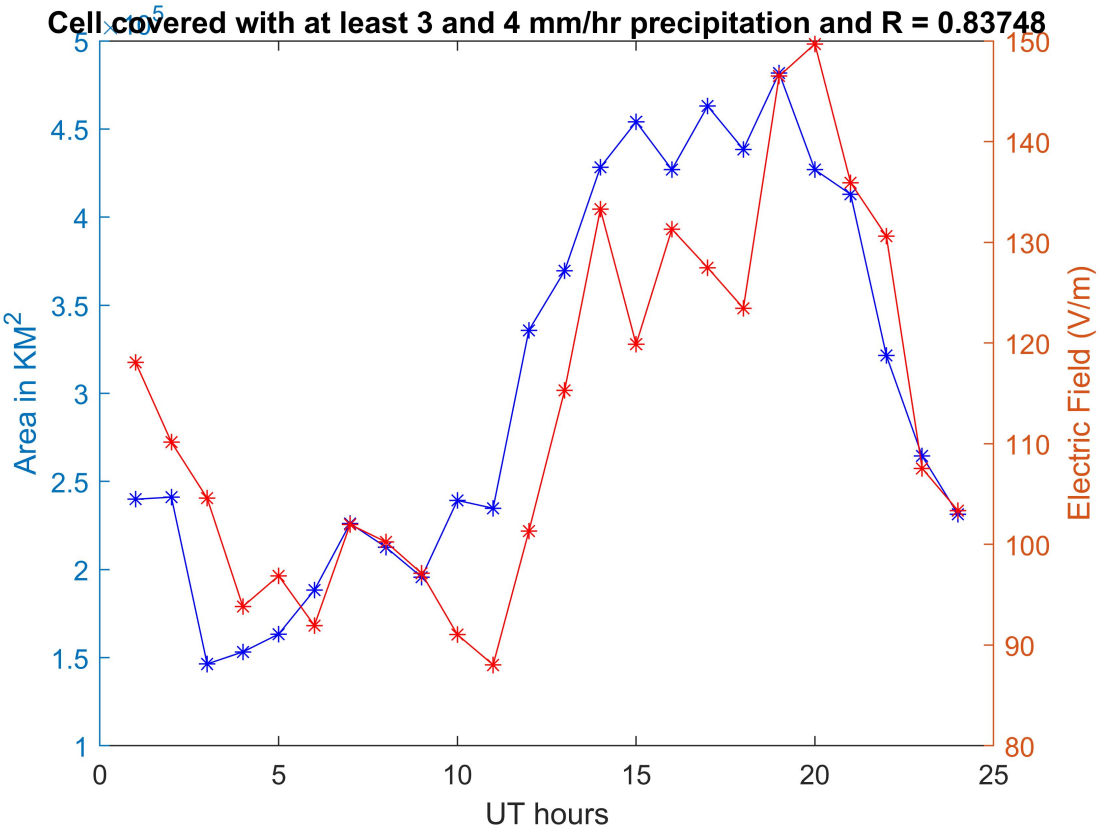

Figure 12: precipitation 4mm/hr lightning count 3 day3

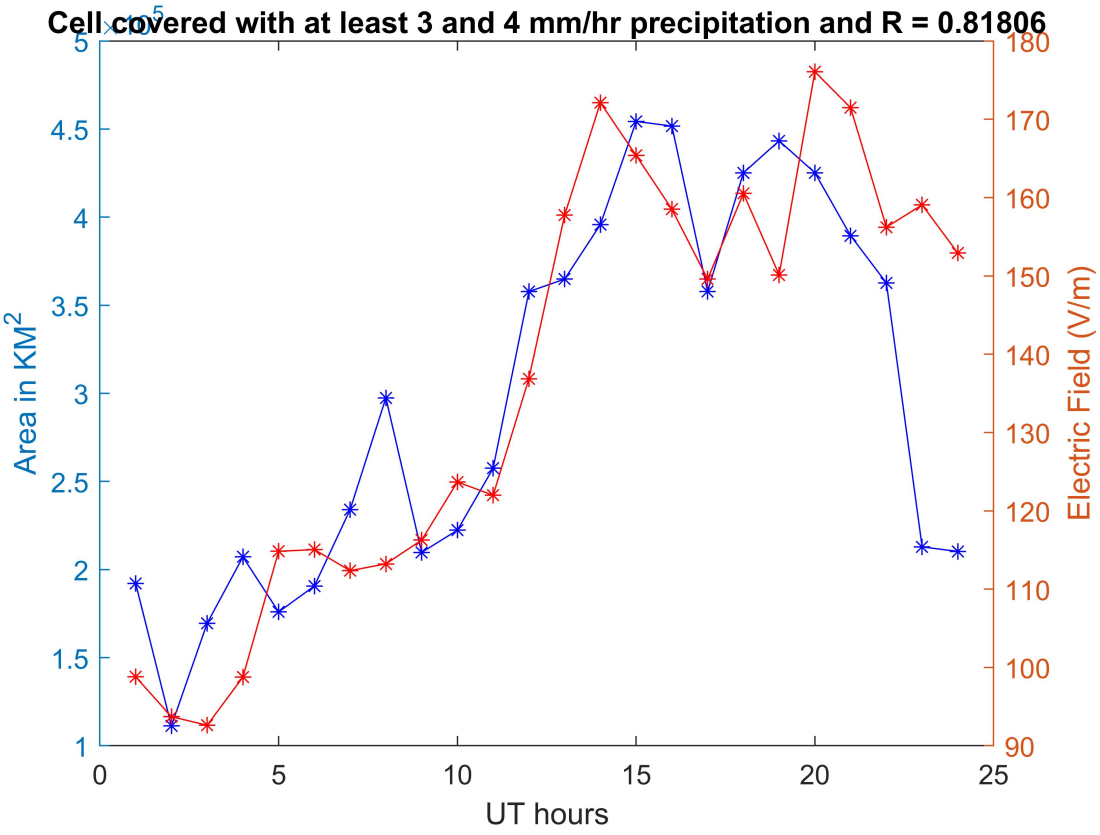

Figure 13: precipitation 4mm/hr lightning count 3 day4

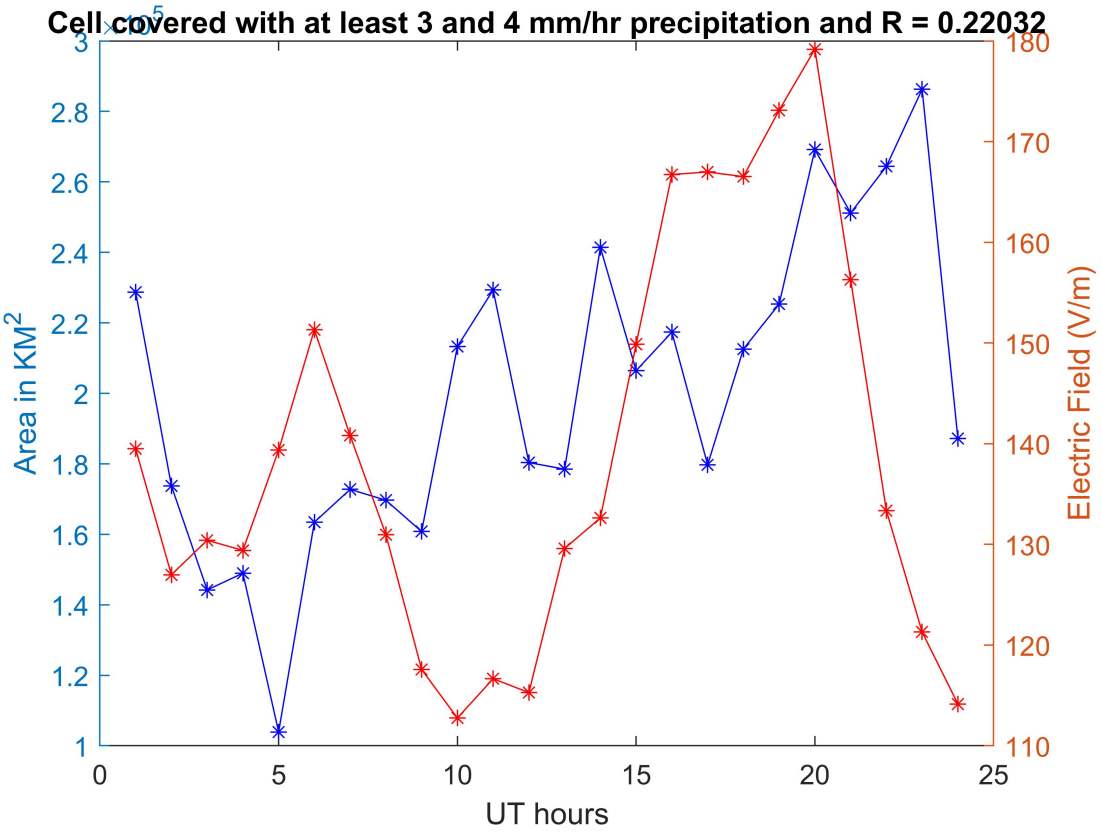

Figure 14: precipitation 4mm/hr lightning count 3 day5

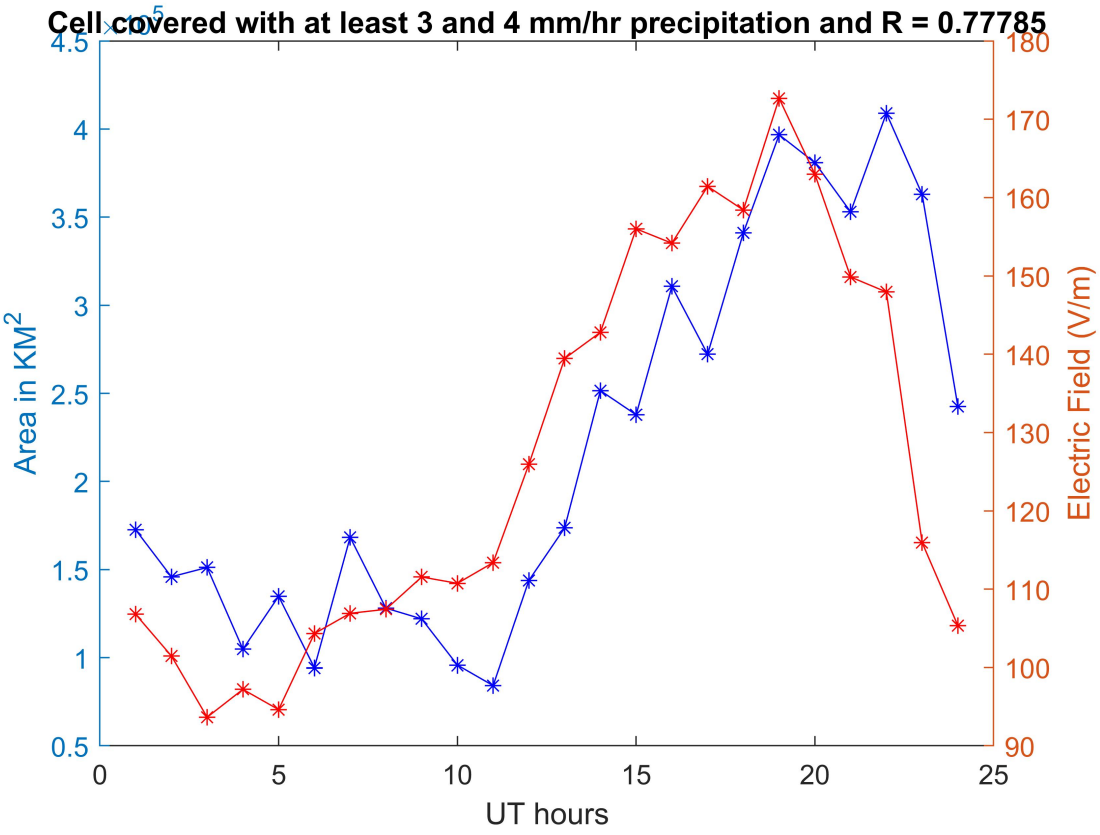

Figure 15: precipitation 4mm/hr lightning count 3 day6

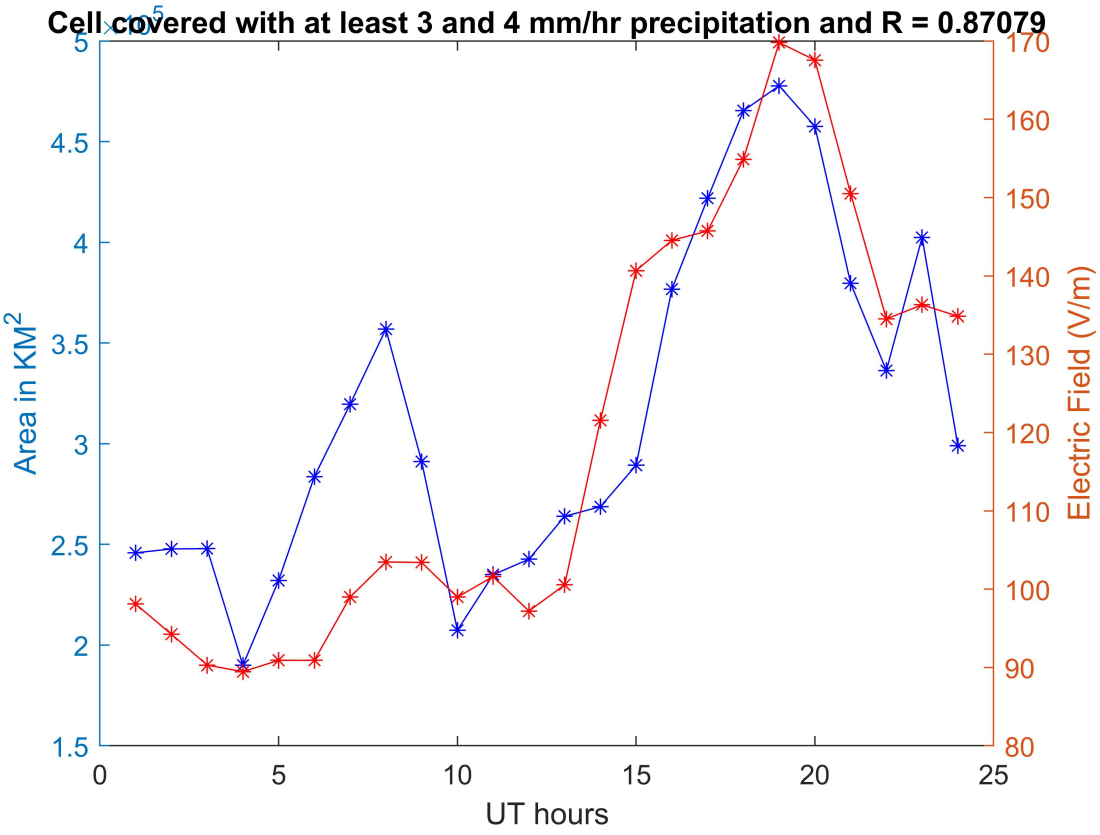

Figure 16: precipitation 4mm/hr lightning count 3 day7

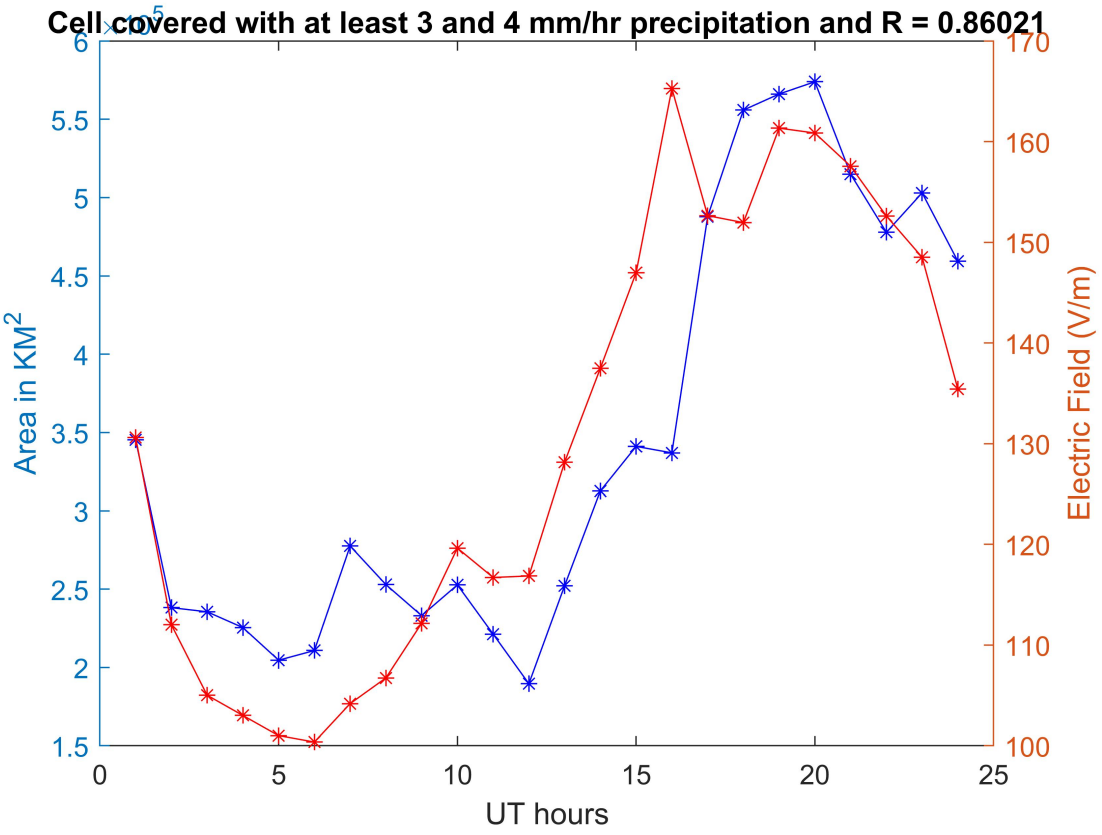

Figure 17: precipitation 4mm/hr lightning count 3 day8