**AFRICAN CENTRE OF EXCELLENCE IN DATA SCIENCE**

# WEATHER RADAR DATA PROCESSING ANALYSIS AND ADJUSTING RADAR BASE RAINFALL ESTIMATES BY RAIN GAUGE OBSERVATIONS USING DATA MINING IN RWANDA

By

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**A dissertation submitted in partial fulfilment of the requirements for the degree of Master of Science in Data in Science in Data Mining in the African Centre of Excellence in Data Science, College of Business and Economics (CBE), University of Rwanda**

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**September, 2021**

## Declaration

I declare that this dissertation entitled **Weather radar data processing analysis and adjusting radar base rainfall estimates by rain gauge observations using data mining in Rwanda** is the result of my own work and has not been submitted for any other degree at the University of Rwanda or any other institution.

NIZEYIMANA RWAKAGEYO Valens

Signature…

Date 13/08/2021

## Approval sheet

This dissertation entitled. **Weather radar data processing analysis and adjusting radar base rainfall estimates by rain gauge observations using data mining in Rwanda** written and submitted by **NIZEYIMANA RWAKAGEYO Valens**.in partial fulfilment of the requirements for the degree of Master of Science in Data Science majoring in **Data Mining**, is hereby accepted and approved. The rate of plagiarism tested using Turnitin is 18 % which is less than 20% accepted by the African Centre of Excellence in Data Science (ACE-DS).

Supervisor

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Head of Training

## Dedication

This work is dedicated to my family, my lovely wife UWAMAHORO Odile, my daughter Ineza RWAKAGEYO Meghan, my son GWIZA RWAKAGEYO Tylan, my lovely parents, whose words of encouragement and prayers strengthened me to my academic achievement, brothers and sisters have never cleared out my side and are exceptionally extraordinary to me.

I also dedicate this thesis to numerous companions who have backed me through the used methods; I will continuously appreciate their contribution.

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## Abstract

Radar reflectivity data and rain gauge data are broadly utilized in precipitation gauges for flood warning, water administration, in numerical climate forecast models, and for checking of extreme climate in common. The quantitative precipitation estimates (QPE) of the radar take advantage of the relationship between radar reflectivity and precipitation watched.

Data mining is a wide field and has numerous factors and methods in its problem-solving weapons store. Be that as it may, the need of surface precipitation information destinations makes the adjustment of temporal radar determination in 5’ or 10’ cannot be given in numerous nations particularly in Rwanda. Precipitation information in Rwanda are commonly accessible in every day aggregation so that it is troublesome to make connections between the reflectivity of radar and precipitation watched. The aim of this research is to urge methods obtaining of adjustment of hourly Quantitative precipitation estimation, convert dBZ to QPE, adjustments QPE functions, aggregate 6 minutes QPE to 1hr, aggregate Adjusted QPE to daily, aggregate QPE 1hr to daily, Plot Aggregated QPE for 1hr, plot QPE for Rwanda particularly for evaluating strongly precipitation pointing at flood warnings. This radar application is distant more requesting than the subjective utilize of radar, e.g. for just taking after and extrapolating echoes in time and space. The characteristics of the third generation of Rwanda Meteorology dual polametric weather radar are examined. This incorporates calibration, clutter end and the check methodology received for ideal profile redress., The profile rectification points to dispense with the impact of clutter concealment and protecting on the climate: i.e. permits to extrapolate from districts, where the radar can "see" precipitation to - ordinarily - lower districts where protecting disposes of genuine climate echoes and clutter produces extra, manufactured echoes.

This research concludes by depicting many of the inclinations and downsides of the application of data mining methods and gadgets to Quantitative Precipitation Estimation, it takes note a few possible obstacles in its execution and at the end, it gives recommendations for future investigations in the application of data mining to empower choices related to Quantitative Precipitation Estimation.

**keywords:** Radar, Automatic weather stations, Quantitative Precipitation Estimation, rainfall, Attenuation, clutter, Reflectivity, Doppler, Clutter, attenuation, Adjustments, Aggregation, dual polar

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## List of symbols and acronyms

AWS: Automatic weather stations

Dbz: stands for decibel relative to Z

FTP: File transfer Protocol

Radar: Radar Detection and Ranging

MDV: Meteorological data volume

MAM: March to May

Aws: Automatic weather station

ADD: additive error model

MUL: multiplicative error model

MIX: mixed error model

MFB: mean field bias

KED: kriging with external drift

NCAR: National Center for Atmospheric Research

RAL: The Research Applications Laboratory

ARC: Arc Radar Company

OFC: Optical Flow Constraints

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# CHAPTER I: GENERAL INTRODUCTION

## I.1 Introductions

Rwanda is located in central Africa, to the east of the Democratic Republic of the Congo, at the co-ordinates 2°00′S 30°0′E.At 26,338 square kilometres (10,169 sq mi) , Uganda to the north, Tanzania to the east, and Burundi to the south, Rwanda is the world's 149th-largest country. The entire country is at a high altitude: the lowest point is the Rusizi River at 950 metres (3,117 ft) above sea level Rwanda is located in Central/Eastern Africa, and is bordered by the Democratic Republic of the Congo to the west It lies a few degrees south of the equator and is landlocked. The capital, Kigali, is located near the centre of Rwanda.

Rwanda is rapidly placing itself as a natural hub for technological and industrial advancement on the continent. This is evident by first dual weather radar worked under Rwanda meteorology agency Maranyundo weather radar is an Arc C250P C-band polarimetric doppler weather utilize by Rwanda meteorological Agency found at the latitude of 02°09'29.07" S, longitude of 30°06'44.43" E and the altitude of 1616 m [1].

The relationship between reflectivity and rain rate has been examined broadly since the early days of radar meteorology, as said numerous experimental Z-R connections have been created and utilized to change over radar measurement s into rainfall estimates [2].

The weather radar gives high-resolution spatial distribution, which exceptionally valuable to fulfill the lack of rain gauge sites. Be that as it may, the capacity in quantitative precipitation estimated (QPE) is still a concern since of radar's limitation [3, 4].

The setup presented in Maranyudo weather radar used the Marshall-Palmer relationship

$Z = a R^b$, where Z is the reflectivity figure and R describe rainfall concentrated. The coefficients utilized are a = 300, b = 1.4 in Maranyundo weather radar station

The source error of weather radar is Clutter, precipitation variability, attenuation, beam blocking [5 ,6]. The radar error can causes an issue for qpe calculations since a single clutter point will deliver a huge sum of wrong QPE value when the clutter reflectivity is changed overal into qpe rate and coordinates timely. In this way, clutter must be removed before computing the precipitation rate.

Clutter expulsion method comprises computing using different algorithms for clutter outline from different MDV volumes containing "clear air" data, 30 to 40 volumes are used to make the map and plots. The middle reflectivity values for these clear-air checks are computed at that point put away as a map clutter remover in MDV arrange. The clutter outline is utilized to evacuate clutter. As it were reflectivity which surpasses the middle esteem by a indicated sum (ordinarily 2 or 4 dB) will be held. For more details [7] and Fig. 1 are helpful.

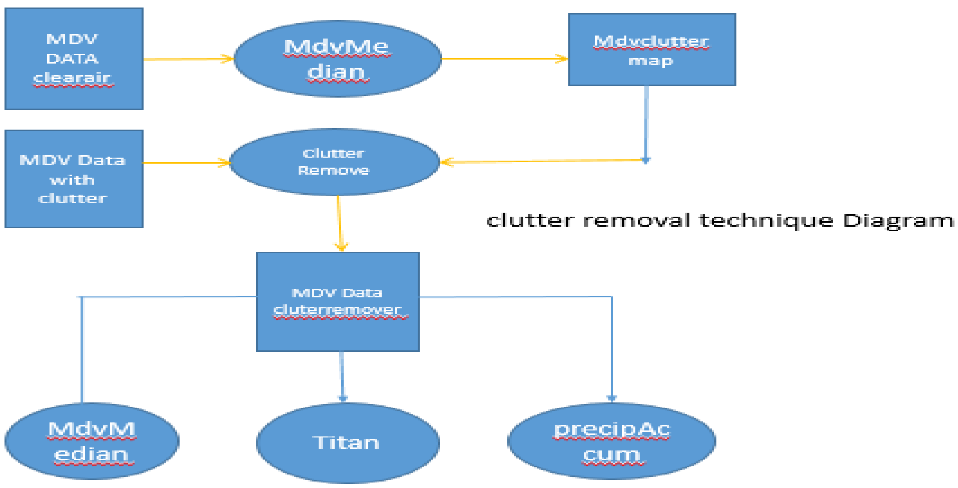


Figure 1:Clutter removal technique Diagram

The Maranyundo weather radar highlights a specific application, Precipitation Accumulation utilize to compute precipitation rate Figure.2 shows the chart utilizing Precipitation Accumulations. A single check rate is computing to start with, at that point a running storing up sums for 1hour, 3-hour, and 24-hour items are performed as mentioned earlier and explained in

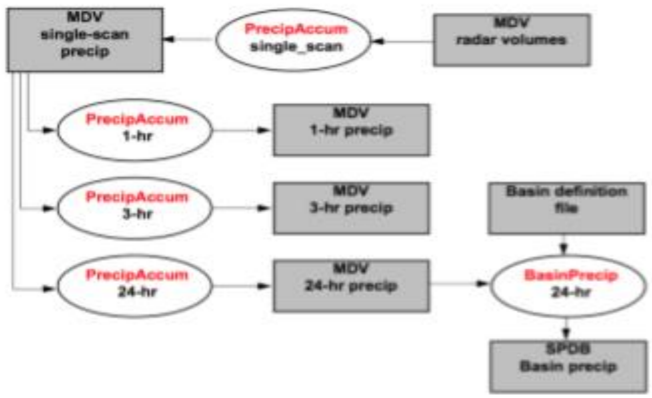


**Figure** 2: Precipitation estimation application

Rwanda meteorological weather radar computes a single-scan significance, a 1-hour and 24-hour running collection entireties precipitation. A two-dimensional mdv record with the surface precipitation gauges in millimeters of rain is made by the application, Each 5 minutes, the radar performs 11 azimuthal filters of 360° around a vertical axis at beam elevation angles of 0.5°, 1.5°, 2.5°, 3.5°, 4.5°, 6.0°, 8.0°, 11.0°, 15.0°, 22.0° and 32.0° with greatest run 250 km. The precipitation values can be removed and balanced with surface gauge perceptions. The data from the radar are chronicled in a data format Meteorological Data Volume (mdv).

With Data mining we will extracted and manipulated ,recognize, and extract valuable data from big data from radar and aws to produce valuable data from the records put away in their databases, information stores, and information warehouses. However, the weather radar data is still more complicated especially the measurement of rainfall rate and amount is critical to a wide range of applications including space and atmospheric sciences, environmental and agricultural research, hydrology, and water resources management. A normal rain gauge network have numerous impediments because of the spatial and transient inconstancy of precipitation. Over the past two decades, the utilization of weather radar has incredibly changed quantitative precipitation estimation (QPE) based on weather radar perceptions are utilized increasingly for water administration, and for observing of extreme climate In common.

Digitized climate radar data can give useful information, regarding the spatial distribution of rainfall, but this data may contain error such as the following clutter, the relationship used to computer rainfall rate from the radar reflectivity assumes standard conditions (eg drop size), atmospheric conditions may cause anomalous propagation of the radar beam and indicate rainfall where there is none, different approaches to address explicit blunders and ancient rarities in radar-based quantitative precipitation gauges decided in this examination.

Alternatively, I might need to adjust our radar QPE in any case of the blunder source by utilizing ground truth since the rain gauge were correct and used them as ground "Truth" how ever radars and raingauges really measure different things, the sample volume of a rain gauges is very small compared to that of a radar, typical rain gauges have openings on the order8 to 12 inch across(0.03 to 0.7 m2 sampling area) the typical area covered by a single pulse of a radar is 150 m long(corresponding to a pulse duration of 1 us)and perhaps 10000 m across (for a $1^{O}$ beam width at a range of 57 km from the radar). Thus the sample area of a radar is more than 2 million times larger than the sample area of a rain gauge.

As I consider this "discrepancy" as an added substance or multiplicative mistake is some way or another self-assertive - regularly, it's a blend of both. I will measure this blunder at different areas (i.e. rain gages), and I can go ahead and develop redress areas for our climate radar QPE. The objective of this ponder is to develop balanced precipitation field based on various leveled spatial demonstrate combining radar information and AWS information and create a new data sets by providing spatially continuous estimates of rainfall at small temporal sampling intervals.

This now serves as the primary rainfall observing system, with the usage of rainfall gauge measurements for bias corrections, and for merging with the radar estimates.

Dual-polarization techniques offer advantages for weather radar applications, including QPE. Dual-polarization radar QPE is one of the most important accomplishments of this study. This thesis will describe the foundations of radar rainfall estimation, particularly from the perspective of dual-polarimetry techniques call a weather radar data processing and analysis chain. The radar QPE system, including its implementation, ground validation, and performance evaluation, will also be presented in detail

## I.2 Statement of the Problem

- ✓ Many of the algorithms used for rainfall measurements using reflectivity and dual polarization parameters have not been developed for east Africa especially in Rwanda but for the sub-tropics and mid-latitudes. These algorithms have to be adapted for the Rwanda region using the radar and rain gauge stations. Furthermore, the initial step is to create a weather radar data processing analysis chain to evaluate the error in radar precipitation measurement and adjust the bias to correct the radar algorithms used for rainfall measurements, and afterward this can be used as reference in other east Africa country for radar rainfall measurements and adjustments.
- ✓ The climate radar information are at that point put away and are not utilized.

## I.3 Objectives

The main objective of this study was to adapt the radar processing analysis chain to create quantitative Precipitation estimation (QPE) in Rwanda. To attain the objective, the specific goals are to:

- ✓ Convert radar measurements into rainfall estimates using data processing algorithms.
- ✓ Combine rain gauges and radar data together and perform data quality control.
- ✓ Create algorithms for adjustments, adjustment of hourly Quantitative precipitation estimation, adjustments QPE functions, aggregate 6 minutes QPE to 1hr, aggregate Adjusted QPE to daily, aggregate QPE 1hr to daily, convert dBZ to QPE, Plot Aggregated QPE for 1hr, plot QPE, read radar Cartesian.
- ✓ Determine the projected Quantitative Precipitation Estimation change over Rwanda.
- ✓ Enhance the availability access and utilization of radar data in climatological Applications, hydrologist, research by integrating radar data into other existing meteorological datasets for analysis and applications and make them accessible to users/clients in friendly format.

- ✓ Characterise the error of our radar QPE at a rain gauge area by the error between rain gauge observation and radar QPE at that very location and construct correction fields for our weather radar QPE.

## I.4 Hypothesis of the Study

Quantitative Precipitation Estimation (QPE) and adjustments radar by rain gauge can be a way to understand radar measurements into rainfall estimates using weather radar data processing analysis chain to Justification of the radar problems and understand extreme events such as the floods, landslide, storm and frequent droughts that have far reaching socio-economic impacts to the country.

## I.5 Justification of the problem

Quantitative Precipitation Estimation QPE is a method to obtain the rainfall estimates. The rainfall is important to different sectors and this can be obtained by using QPE. Data from QPE is critical to guarantee flood security, water administration of the nation that depends on the precipitation. In expansion, one of the components that contribute to expanded defenselessness of communities is need of adequate data on rainfall, which could be obtained by Quantitative Precipitation Estimation and adjustments by utilizing climate radar information and rain gauge perception. It is expected that this consider will fill the gaps by extending the data on the QPE, QPE alter over Rwanda and then comes about will serve as preface for future arranging and choice making as well as progression and organization of Flooding and Nowcasting.

### I.6 Area of Study

The 250 km radius around radar station locate in Maranyundo in east of Rwanda comprises the total study area including 21 stations LSI and 38 REMA station of automatic weather station (AWS), the total study area was used for real rainfall estimation .

# CHAPTER II: LITERATURE REVIEW

A comprehensive literature study has been conducted and speculations were synthesized accordingly. The outcomes about of the literature study are presented and examined in this chapter.

## II.1 An improved QPE algorithm for the South African Weather Service's S-Band Doppler Radar at Irene

Weather radar frameworks can be utilized to assess precipitation in ranges where no gauges are accessible. In spite of the fact that its estimations are backhanded, it remains the most excellent elective to assess precipitation on high temporal and spatial determination in East Africa as well as Rwanda.

With the usage of the South African Flash Flood Guidance system (SAFFG) and the establishment of the modern S-band Doppler radar frameworks, much accentuation has been put on the execution from radar based Quantitative Precipitation Gauges (QPE) .A methodology used by the Bureau of Meteorology (BoM) was selected to upgrade and improve the existing radar precipitation field [8].

As a beginning point, a precipitation classification calculation has been presented which isolates convective from stratiform precipitation with the expectation to assign double Z-R relations to the two distinctive precipitation sorts.

A strategy for smoothing the amassing of precipitation, which is based upon Optical Flow Constraints (OFC), has moreover been presented into the QPE calculation.

The recently calculated precipitation field will be compared against hourly and every day ARS and AWS information, as well as the existing Thunderstorm Identification Tracking and Nowcasting (TITAN) precipitation algorithm.

The TITAN framework is the current operational framework utilized by SAWS forecasters and the SAFFG show. Comes about appear that there's a decrease within the overall error as well decrease within the over-estimation of precipitation for the S-band radar at Irene when utilizing double Z-R relationships. The results are further improved when the rainfall field is morphed with the assistance of OFC vectors. Results for a selected period during the summer rainfall season of 2010/11 will be presented.

### II.2 Quantitative precipitation estimation with weather radar using a data- and information-based approach.

The author proposed and outlined a data-driven approach in an information-theoretic framework to evaluate the gauge. The results relations are communicated by observational discrete likelihood disseminations specifically inferred from data instead of fitting. The advantage to supply joint verbalizations nearly rain rate and the related estimation instability [9].

The system information besides permits union of any type of information considered valuable and the questionable quality of quantitative precipitation estimation (QPE).

This system, we explore the data picks up and misfortunes related with different information and practices regularly connected in QPE as mentioned earlier [9].

The conclusion from the author show that he conducted six tests utilizing four a long time of data from 6 laser optical disdrometers, 2 small scale rain radars customary rains gauges, Each test addresses a typical address related to QPE, to begin with, we measure the data approximately ground precipitation contained in different operationally accessible predictors. The weather radar demonstrates as a most critical source of data, which can be encourage made strides when recognizing the reflectivity ground precipitation connections or radar (Z-R relations) by season and winning synoptic circulation design. Moment, to explore the impact of information test measure on quantitative precipitation estimation instability utilizing diverse information based prescient models. It appears that the usage of reflectivity and month of the year as a twofold indicator demonstrate is the most excellent trade-off between strength of the demonstrate and data gain.

The author Examined the content information in spatial position by understanding and using site-specific Z-R relations [10]. The related data gains are only check and especially lower than when distinguishing Z-R relations based on time of the year or synoptic circulation pattern [10].

The author measures the missing data when fitting and employing a deterministic Z-R connection, because it is standard practice in operational radar based QPE applying

The results uncover that impressive extra data is gained by utilizing observations from lower elevations by maintaining a strategic distance from data misfortunes caused by continuous precipitation microphysical forms from cloud tallness to ground. This underlines both the significance of vertical rectifications for precise QPE and of the specified MRR acknowledgments.

Interior 5th test assess the substance information of radar because it were rain gage information since it were and a combination of both as a work of the evacuate between the target and marker rain gage. The comes around appear up that station-only QPE beats radar-only QPE up to a oust of 7 to 8.

### II.3 Radar Rainfall Estimation in Morocco: Quality Control and Gauge Adjustment

This investigate centered on exploring the effect of gage adjustment on the rainfall estimate from a Moroccan C-band climate radar. The radar reflectivity experienced a quality check some time recently arrangement to recover the precipitation sum. The method comprised of clutter recognizable proof and the rectification of flag weakening. From that point, the radar reflectivity was changed over into precipitation profundity over a period of 24 h. An evaluation of the precision of the radar.

The case was conducted on December 16, 2016 uncovered considerable enhancements within the precipitation structure and escalated with reference to African Precipitation Climatology adaptation 2 (ARC2) precipitation.

# CHAPTER III: METHODOLOGY

## III.1 Introduction

In this chapter we will be looking at the ways through the assistance of which the distinctive steps included within the investigate can be streamlined and can be put viably into hone. At the same time it moreover makes a difference in understanding and applying of diverse methodological standards through the assistance of which inquire about can be conducted and the steps that are fundamental for it. It is critical to mention here that the nature of strategy connected and utilized is subordinate upon the kind of inquire about that's conducted. The nature of methodological standards connected shifts in terms from utilization whether it is quantitative or subjective and changes in technique are joined in like manner [11].

## III.2 Data Collection

The information utilized for this work was produced by radar Doppler located at Maranyundo Mountains in east of Rwanda and 59 rain gauge across the country. The taking after strategies were embraced at this organize of the inquire about: Data Cleaning, Data Selection, and Data Transformation.

## III.3 Data Cleaning

Climate data cleaning comprises of two processes: the substitution of lost values and the substitution of incorrect values. These processes ought to be performed simultaneously to get the most excellent result because the sources of lost climate information may be that the instrument was broken, that there was a break in the transmission of the climate information, and the Errors in climate data regularly are caused by ineffectively calibrated instrumentation.

The issue of data cleaning at that point gets to be an issue of replacing values by introductions between observations over a few stations (spatial interpolation) and interpolations between observations over time (temporal interpolation).

after converting dbz to rainfall in netcdf missing values might have been coded with a number 9999,a reliable format for the data demonstrate was created which took care of lost data, finding copied data, and weeding out of awful data. Finally, the cleaned data were changed into a arrange reasonable for data mining

### III.4 Data Selection

At this arrange, data pertinent to the investigation was chosen on and recovered from the dataset. Due to the nature of the Cloud Frame, information where all the values are the same and the tall rate of lost values within the daylight information both were not utilized within the investigation

### III.5 Data Transformation

This is typically known as data consolidation. The chosen data is transformed into shapes suitable for data mining within the organize. The data record was a Comma separated values (csv) record organize and the datasets were normalized to decrease the impact of scaling on the data.

### III.6 Weather radar Data

Weather has got data and they are categorized into different types.

#### III.6.1 Meteorological data volume (MDV)

The meteorological data (MDV) organize for gridded information was created by the Inquire about Research facility at NCAR. There is not open information standard accessible at the time was consider reasonable in term s of information embodiment and inner compression.

The mdv advanced as information arrange one of kind to Research, its well organize for information, with great meta data bolster. information imported from and sent out to organization exterior RL is as often as possible in designs such as GRIB and HDF5. To the degree conceivable, converters have been created to permit change between MDV and these other information designs, an XML /binary form of MDV in beneath advancement as mentioned earlier [7].

### III.6.2 Meteorology data volume (MDV) concepts

MDV is a universally useful information record design for putting away two and three dimensional gridded data. MDV may be a single time organize each MDV information set contains information for single time, Time looking and recovery is taking care of by a time based record naming tradition. MDV gives capabilities to dealing with numerous information areas in a single record. For illustration, one mdv record might contain radar information with region of reflectivity and radial speed or show data with temperature, humidity and wind speed as independent fields within (x,y) measurement, MDV underpins various projection types ,include Lamber Conformal Conic, stereographics, the basic scope longitude matrix(otherwise called as Simple Cylindrical) and polar coordinate for radar information.

### III.6.3 Meteorological Data Volume Diagram

Within the vertical estimation, MDV maintain different vertical arrange types, counting height in Kilometer or ft, weight level, signal levels for numeric models and rise points .

Data areas may be spoken to as Four byte coasting point, two and one byte scaled integrability and 4 byte RGBA picture pixels, Inner compression is bolstered ,with each plane of each field exclusively compressed .The data organize is extensible in that it gives space and get to privileges for discretionary nonexclusive 'Chunk' information characterized by the mdv client, chunk information permit data clients to connect to the information set extra data that is not well for capacity within the data header or information areas. AS illustration, the router header for adherent information other highlight of the mdv record arrange incorporate a compatible I/O structure as mentioned earlier [7, fig 3].

### III.6.4 MDV File format overview

The information for each time is portion into 2 records (a) and XML information record and

(b) a double data buffer record

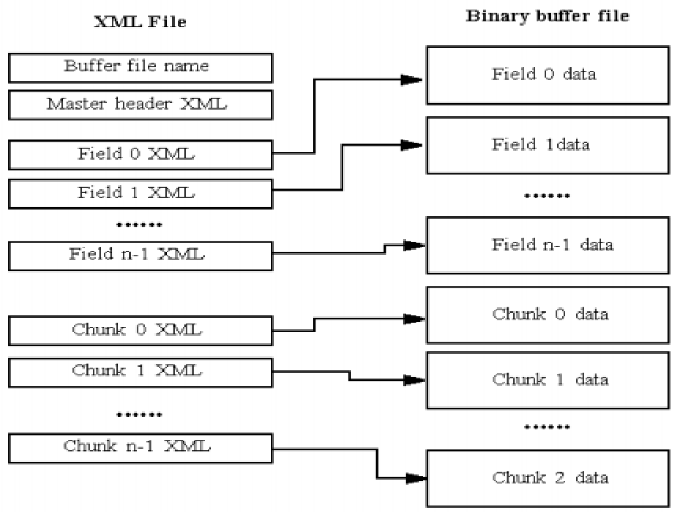


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Figure 3:mdv File structure

Include within the XML meta data information are byte offsets and lengths for the field information within the binary buffer record, when the information set is examined, the XML is studied to begin with and the Meta data at that point distinguishes the information range within the buffer record

### III.6.5 Binary data types

Byte requesting for information sorts with a length of more than 1 byte, the requesting of the bytes is critical in translating information.

Record naming traditions For meteorological information volume one of the foremost critical properties, mdv record has information for a single time. MDV records are named concurring to the time of the information put away within the record. As a common run the show.

### III.6.6 The X-Y grid

MDV information sets are two Dimension or three Dimension frameworks utilize by Maranyundo weather radar. They lattice dividing is standard in X and Y, such as a normal lat-long network (Basic Round and hollow) or Lambert Conformal.

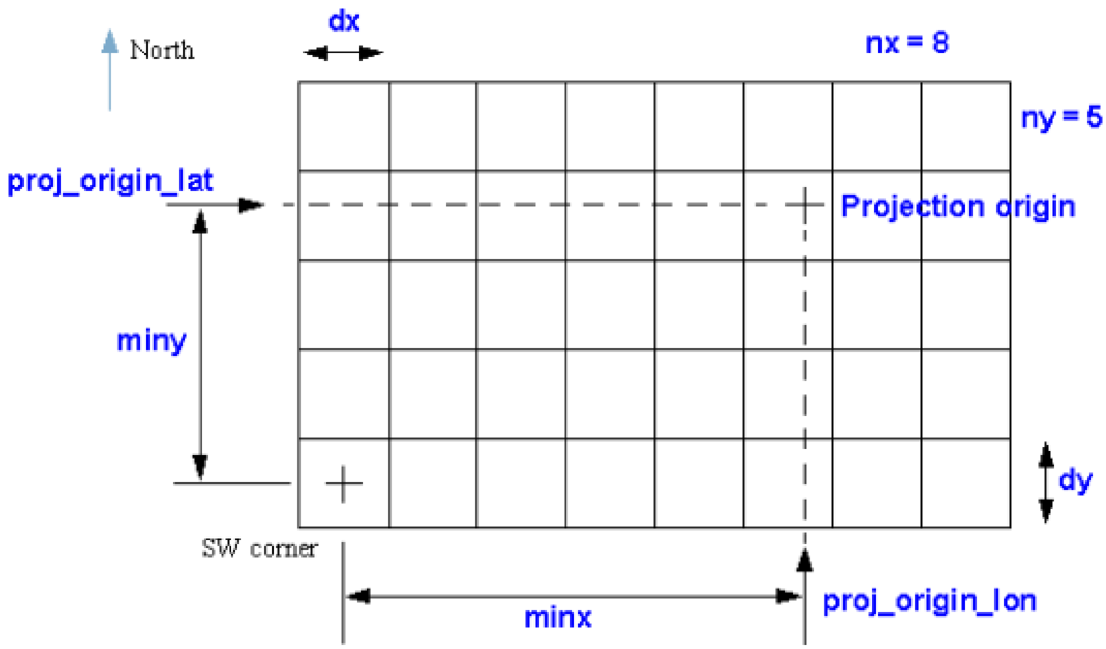
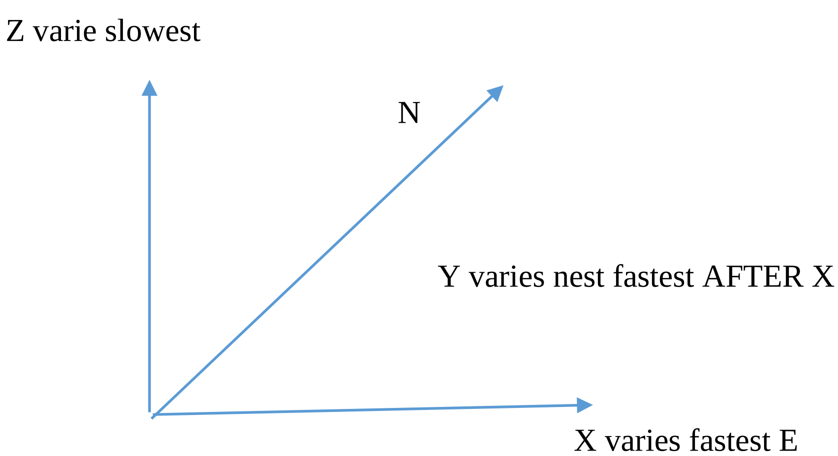



Figure 4: MDV X and Y grid

### III.6.7 Data capacity order

The information components is put away in an cluster, stuffed in X-Y-Z requesting, meaning that X shifts the speediest, Y another and Z slowest




The primary byte within the cluster is at the SW corner of the network and at the least vertical level. To begin unloading the information, start at the SW corner of the network and at the most reduced vertical level. Meteorological radar parameters and units to be utilized.

Table 1:Meteorology radar parameter and units

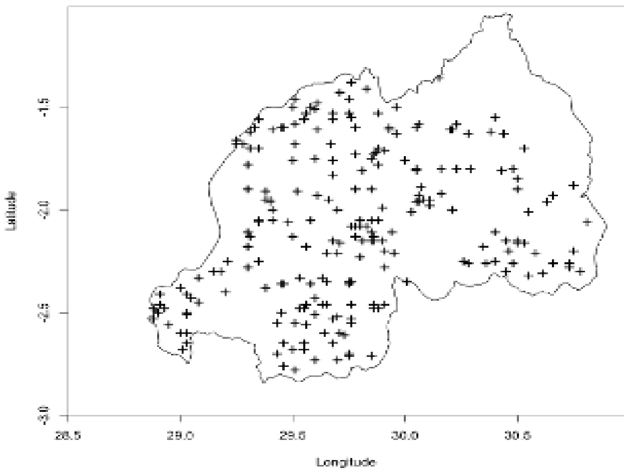
| **Symbol** | **Parameter** | **units** |
|---|---|---|
| Ze | Equivalent or effective radar reflectivity | mm6 m–3 or dBZ |
| Zdr | Differential reflectivity | dBz |

Table 2:Precipitation parameter and units and Rainfall Rate

| **dBZ** | **Precipitation Description** | **Rainfall Rate (mm/hour)** |
|---|---|---|
| >57 | Very heavy rain and hail; large hail possible | 180 or more |
| 50-57 | Very heavy rain; hail possible | 114 - 179 |
| 44-50 | Heavy rain | 56 - 113 |
| 38-44 | Moderate to heavy rain | 28 - 55 |
| 30-38 | Light to moderate rain | 5 - 27 |
| 18-30 | Light precipitation | 1 - 4 |

### III.7 Automatic weather Station data (AWS)

The observed precipitation datasets utilized in this study were collected from automatic weather station managed by Rwanda Meteorological agency. The dataset were made for precipitation and temperature independently It is basic to note that the Sanctions gridded data covers the entire Rwanda but for the reason of this inquire about, LSI and Rema aws stations will be considered.



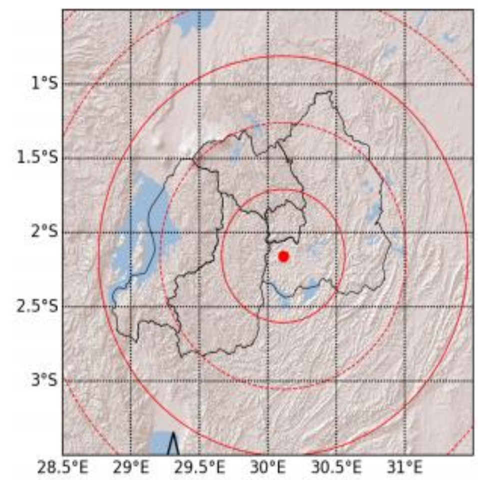




Figure 5:Weather stations location on map

Figure 6: radar location point

The Rwanda meteorology radar utilizes TITAN/CIDD radar item era and show computer program, which has been refined through decades of inquire about and operational utilize around the planet, for both standard and polar metric radar products. The Circular segment C250P has been executed for considering precipitation inconstancy and Quantitative Precipitation Estimation (QPE) for water asset administration, agriculture, urbanisation. It is an perfect operational framework for observing serious and perilous climate in real-time, as well as for post-event inquire about and examination of extreme and perilous climate and cloud and precipitation formation.

Information from 2017-10-04 – 2019-05-13 may be an perfect put to watch conceivable intelligent between precipitation and groundwater. Two precipitation information sets are arranged in this ponder, one based on a combination of climate radar information and rain gage information whereas the other is based completely on radar data.

### III.8 Description of the methods

Distinctive strategies combining radar and rain gage information have been actualized to get the finest quantitative precipitation estimation (QPE) from reflectivity information. The precipitation estimation from radar was obtained employing a convention reflectivity to precipitation rate (Z–R) exponential relationship [12].

$Z = a R^{b}$ where

- Z = reflectivity (dBZ),
- R = rainfall rate (mm h−1) at the rain Gauge for this study the parameters a= 300 and b =1.4 and the Maximum value (Hail threshold) =
- Hail threshold = 60 and Minimum value to be taken account
- (Low dBZ threshold) = Low dBZ threshold = 20

A few strategies require the comparison between a rain gage estimation and a comparing radar esteem. the spatial inspecting issue is of significant significance when radar a genuine gauges are compared or combined with gage point estimations [13].

### III.8.1 Mean field bias correction (MFB)

The suspicion here is that the radar gauges are influenced by a uniform multiplicative mistake. This mistake can be due for illustration to a awful electronic calibration or an wrong coefficient a within the Z-R relationship. The alteration figure is evaluated as a cruel field predisposition:

$$C_{MFB} = \frac{\sum_{i=1}^{N} G_i}{\sum_{i=1}^{N} R_i} \quad (1)$$

Where N is the number of valid radar-gauge pairs, Gi and R are the gauge and radar values associated with haute.

### III.8.2 Range-dependent adjustment (RDA)

This method accept that the R/G proportion could be a work of the remove from the radar. Run dependences are basically delivered by the expanding tallness of the estimations, pillar broadening and constriction impacts. The extend subordinate alteration is basically based on the BALTEX alteration strategy, the connection between R/G communicated in log-scale and run is approximated by a second order polynomial whose coefficients are decided employing a slightest squares fit. log CRDA =ar2+br+c where r is the remove from the radar. The extend subordinate multiplicative calculate CRDA is determined from the polynomial fit.

### III.8.3 Brandes spatial adjustment (BRA)

This spatial strategy was proposed by Brandes[14], A adjustment calculate is calculated at each rain gage location. All the variables are at that point add don't he entirety radar field. This strategy takes after the Barnes objective investigation plot based.

**Different Method has been used to adjust** the radar observation using radar data by

- additive error, spatially variable (AdjustAdd)The additive error model defines the error as the difference between the measurement and the truth.
- multiplicative error, spatially variable (AdjustMultiply) Multiplicative error model defines the error as the ratio between the two. Neither is wrong theoretically, but each needs to be evaluated .
- The mixed error, spatially variable .
- The multiplicative error, spatially uniform .

### III.8.4 Kriging with radar-based error correction

This strategy referenced as "conditional consolidating "in Sinclair and Pegram [15]. uses the radar field to assess the mistake related with the standard kriging strategy based on rain gages and to redress it. To begin with, radar values at each gage location are utilized to create a radar-based kriging field. This field is at that point subtracted from the initial radar field to get an blunder field. Finally, the blunder field is included to the gage based kriging field. The KRE strategy is generally basic and computationally efficient.

### III.8.5 The clutter mitigation

The Doppler channels, can cause changeless echoes, which may present serious predisposition in quantitative applications. In this way, an proficient recognizable proof and evacuation of clutter is required e.g. for hydrological ponders. Clutter expulsion can be based on inactive maps or energetic channels. Regularly, inactive clutter gets to be unmistakable more clearly in precipitation aggregation maps over periods of weeks or months. We recommend such aggregations to make inactive clutter maps which can in turn be utilized to expel the inactive clutter from an picture and fill the coming about crevices by insertion [16].

# CHAPTER IV:  RESULTS AND DISCUSSION

This Chapter summarizes the results gotten from the different methods utilized to achieve the specific objectives of the study utilizing data technology.

The results incorporate a quantitative Precipitation estimation based on radar data and raingauge data, adjust 1 hourly QPE using weather radar data and automatic weather radar station , read radar Cartesian, adjust hourly QPE, aggregate 6min QPE to 1hr, aggregate Adjusted QPE to daily, aggregate QPE 1hr to daily, Plot Aggregated QPE1hr, plot QPE , make radar data available inn easy format.

Maranyudo  Weather Raw data which is natural reflectivity products can as of now give valuable visual data almost the spatial distribution of precipitation areas using different  software  like TITAN  and configurable interactive Data Display(CIDD), Rview.

In any case, in arrange to utilize weather radar perceptions for quantitative considers (e.g. in hydrological displaying or for digestion into Numerical Climate Expectation models), the mdv information has been carefully handled in arrange to account for ordinary mistakes sources such as ground echoes (clutter), constriction of the radar flag, or instabilities within the Z/R relationship .

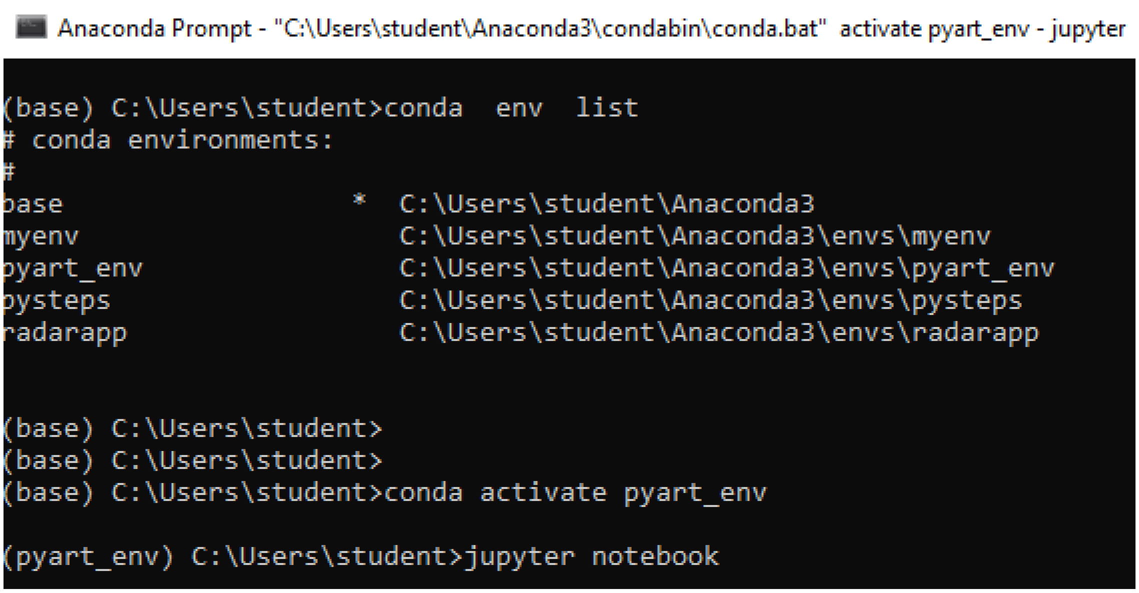
After got mdv information from the radar it was been essential to exchange the information from polar facilitates to Cartesian lattices and combine perceptions from distinctive radar areas in covering regions on a common lattice (composition).

And within the conclusion pictured the spatial rainfall distribution on a outline and measure the potential blunder (instability) of data-based precipitation estimation got and the comes about are displayed in Figures.

Differents steps has been taken after in arrange to form radar information valuable in a particular quantitative application environment. All steps together are regularly alluded to as a "radar data processing chain" Wradlib [17], R [18], Python [19], Json [20], panoply, Pyart [21], and was outlined to back us to setting up our own handling chain, suited to our particular necessities. Within the taking after, we'll give result of a normal handling chain, step-by-step.

### IV.1 Installation of a work environment

To start the algorithm environment, I started installing the anaconda with different packages the create environments called radar App as show bellow


```
Anaconda Prompt - "C:\Users\student\Anaconda3\condabin\conda.bat"  activate pyart_env - jupyter

(base) C:\Users\student>conda  env  list
# conda environments:
#
base                  *  C:\Users\student\Anaconda3
myenv                    C:\Users\student\Anaconda3\envs\myenv
pyart_env                C:\Users\student\Anaconda3\envs\pyart_env
pysteps                  C:\Users\student\Anaconda3\envs\pysteps
radarapp                 C:\Users\student\Anaconda3\envs\radarapp


(base) C:\Users\student>
(base) C:\Users\student>
(base) C:\Users\student>conda activate pyart_env

(pyart_env) C:\Users\student>jupyter notebook
```

**Figure 7:Envirnoments screen shot**

- ✓ .created a directory on my desktop and call it "RadarApp"in the directory where I put the subdirectories AWS_DATA, AWS_SCRIPT, RADAR_DATA, RADAR_SCRIPT. These directory contains the processed data and script.
- ✓ AWS_DATA: contains all AWS data ouput from automatic weather station

- ✓ AWS_SCRIPT: contains all scripts written in R, Python and dependency to process all Automatic Weather Stations data
- ✓ RADAR_DATA: contains all Cartesian weather radar data from radar and the ouput of the processes radar data
- ✓ RADAR_SCRIPT: contains all scripts written in R and python and dependency to process all radar data

### IV.2 Radar data and Radar Script

In this study the binary encoding of radar data was a major Problems potential radar clients Frequently, decoder computer program isn't effectively accessible but R, Python , Pyart, wradlib and different libraries ,CDT (Climate data tools) used in this study because its bolsters a handful of formats such as the MDV and NetCDF, csv, essential data sort utilized in could be a multi-dimensional cluster, the numpy.ndarray. Such an cluster might with a polar or Cartesian framework, or a arrangement of rain gage perceptions. Metadata are regularly overseen as Python word references. In arrange to perused the substance of a information record into a numpy cluster, we ordinarily utilize the Pyart module.

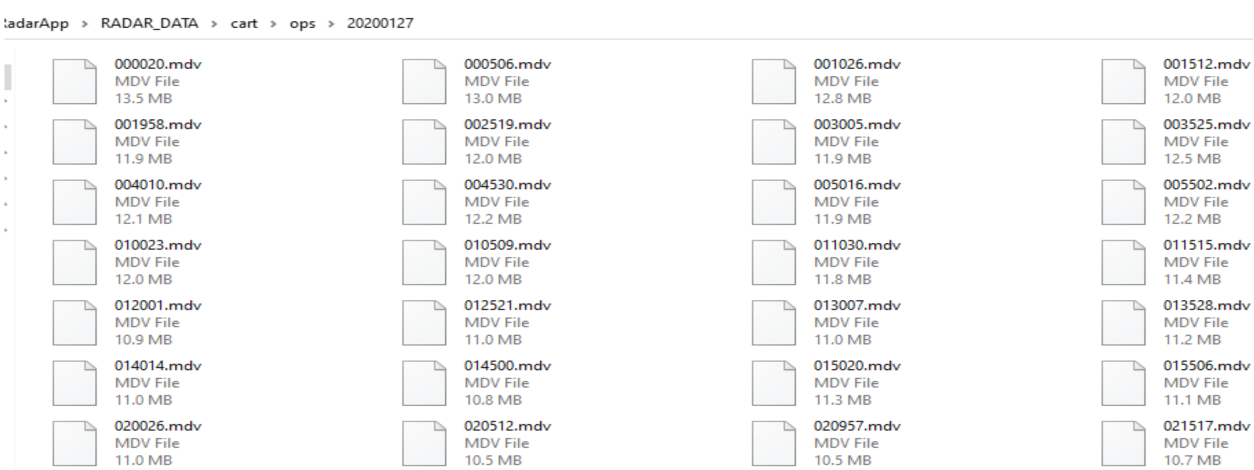



Figure 8:An Mdv 3 dimension data in Cartesian before reading it.

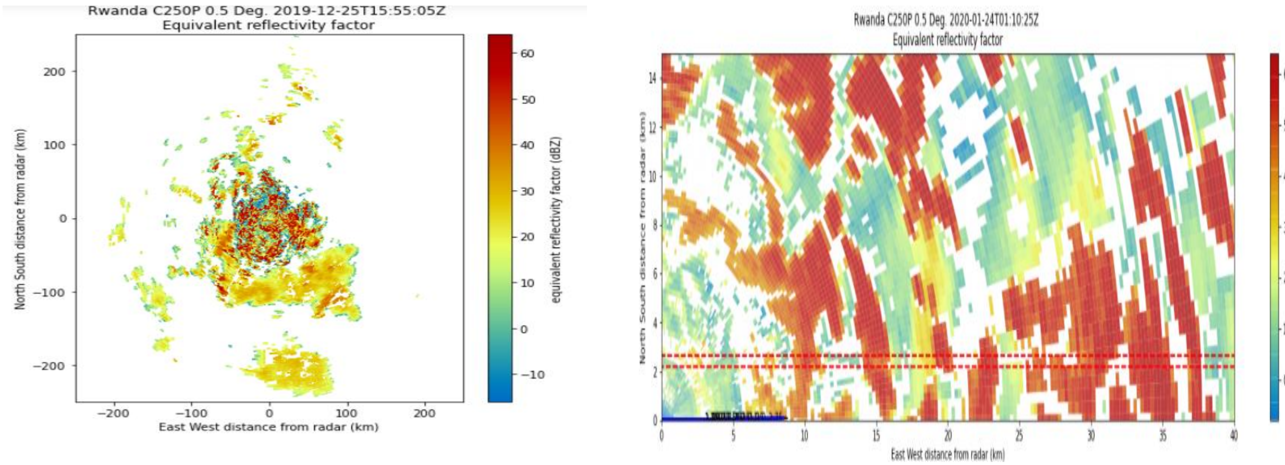
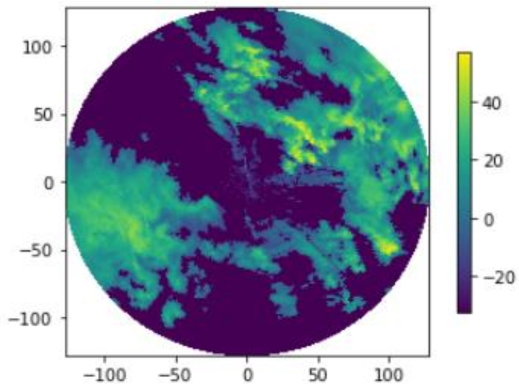



Figure 9:: Plotting mdv file and Plot RHI reflectivity factor

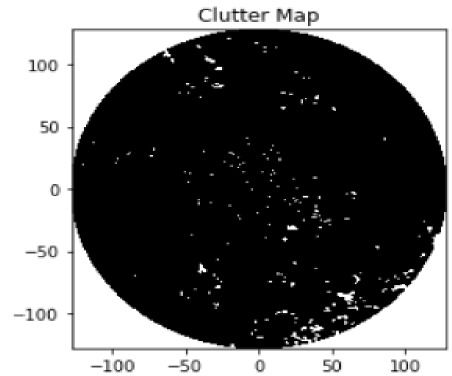
This figure shows the equivalent reflectivity factor in dbz from east west distance from radar in KM and North south distance from radar in Km and the second one is a plot of RHI reflectivity contour lines from mdv file in 2019/04/24 at 01 ‘13’’ 56 second .

### IV.3 Clutter Removal

The clutter removal script has been developed and applied to remove clutter which can cause high reflectivities due to expansive scrambling cross segment Inactive clutter, in case not effectively evacuated by Doppler channels, can cause lasting echoes which might present extreme inclination in quantitative application. Hence, an effective recognizable proof and evacuation of clutter is obligatory e.g. for hydrological ponders. The Clutter evacuation can be based on inactive maps or energetic channels. Regularly, inactive clutter gets to be obvious more clearly precipitation amassing maps over periods of weeks or months




Reflectivity image




Clutter  map

Figure 10:Reflectivity and Clutter map

### IV.4 Attenuation correction

Attenuation by wet radome and by overwhelming precipitation can cause genuine underestimation of precipitation for C-Band. For our radar, circumstances with overwhelming precipitation require a rectification of weakening effects. The common approach utilized in this think about with single-polarized radars was being utilized a recursive gate-by-gate approach. Kraemer et al., 2008 for an presentation to this concept. Fundamentally, the particular constriction k of the primary extend door is computed by means of a so-called k-Z relationship. Based on k, the reflectivity of the moment range gate is adjusted and after that utilized to compute the particular constriction for the moment extend door and so on. [22]. Its fundamental downside is its susceptibility to instable conduct.

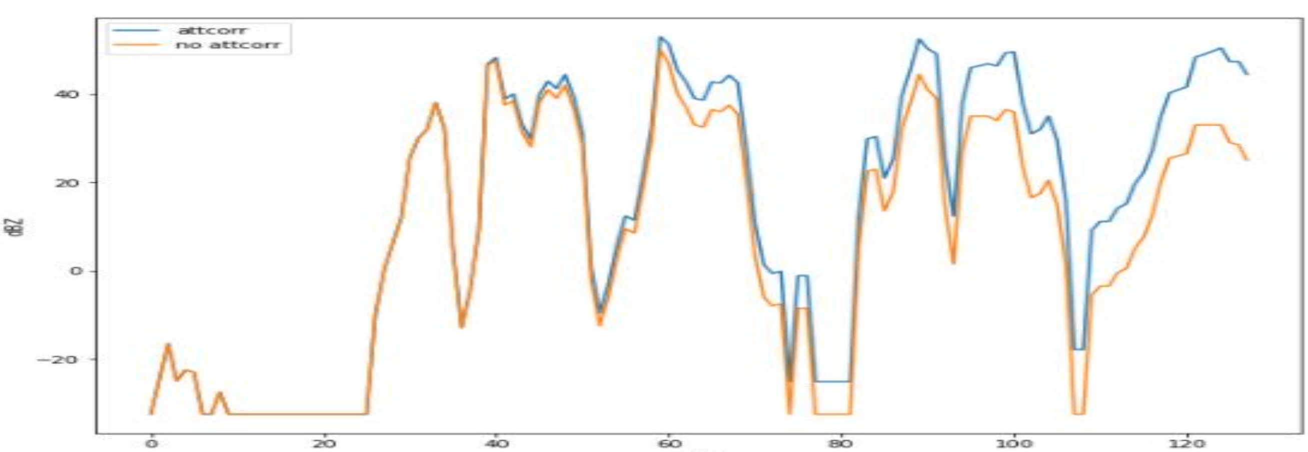


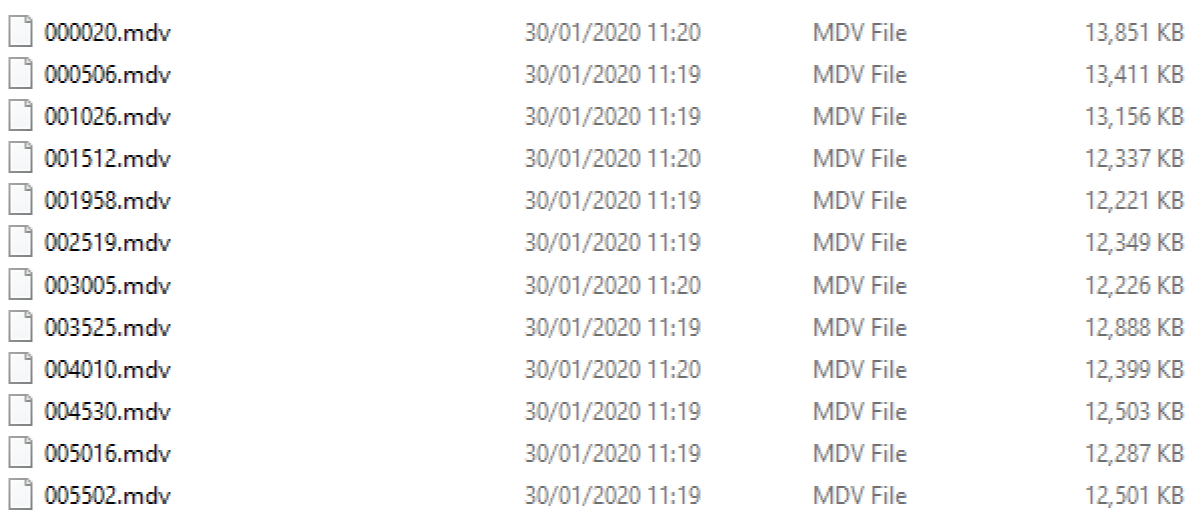

Figure 11: Attenuation correction graph

### IV.5 Converting Reflectivity to Rainfall

Convert dBz to quantitative precipitation estimate Qpe In this study we're developed an algorithm write in R and python to compute the Reflectivity (z and precipitation rate *R* which is presented in form of power law $Z=a.R^b$ the parameters used in this study is a= 300 b=1.4 using R and python, wradlib functions.

Different step has followed to convert the dbz (decibel of the reflectivity factor Z)to rainfall intensity (in the unit of mm/h)the Convert to reflectivity factor Z (unit**:**$mm^6/m^3$):

Convert to rainfall intensity (unit: mm/h**)** using the Marshall-Palmer Z(R) parameters then we Converted to rainfall depth **(**unit: mm**)** assuming a rainfall duration of five minutes



| | | | |
|---|---|---|---|
| 000020.mdv | 30/01/2020 11:20 | MDV File | 13,851 KB |
| 000506.mdv | 30/01/2020 11:19 | MDV File | 13,411 KB |
| 001026.mdv | 30/01/2020 11:19 | MDV File | 13,156 KB |
| 001512.mdv | 30/01/2020 11:20 | MDV File | 12,337 KB |
| 001958.mdv | 30/01/2020 11:19 | MDV File | 12,221 KB |
| 002519.mdv | 30/01/2020 11:19 | MDV File | 12,349 KB |
| 003005.mdv | 30/01/2020 11:20 | MDV File | 12,226 KB |
| 003525.mdv | 30/01/2020 11:19 | MDV File | 12,888 KB |
| 004010.mdv | 30/01/2020 11:20 | MDV File | 12,399 KB |
| 004530.mdv | 30/01/2020 11:19 | MDV File | 12,503 KB |
| 005016.mdv | 30/01/2020 11:19 | MDV File | 12,287 KB |
| 005502.mdv | 30/01/2020 11:19 | MDV File | 12,501 KB |

Figure 12:Radar Cartesians' data in mdv format

```
## Path to python.exe
#python.exe <- "C:/python37/python.exe"
##python.exe <- "C:/Users/Student/anaconda3/envs/myenv/python.exe"
python.exe <-  "C:/Users/student/Anaconda3/envs/pyart_env/python.exe"

#python.exe<-  "C:/Users/student/Anaconda3/python.exe"

python.script <- "C:/Users/student/Desktop/RadarApp/RADAR_SCRIPT"

#############
## Path to the folder containing the radar cartesian mdv files
dir.radar.mdv <- "C:/Users/student/Desktop/RadarApp/RADAR_DATA/cart/ops'

#############
## Path to the folder RADAR_SCRIPT
radar_script_dir <- "C:/Users/student/Desktop/RadarApp/RADAR_SCRIPT"

## Path to the folder RADAR_DATA
radar_data_dir <- "C:/Users/student/Desktop/RadarApp/RADAR_DATA/"
##############
## Start date (GMT time) to process in the format "YYYYMMDD:HH"
start_day <- '20200325:09'
## End  date (GMT time) to process in the format "YYYYMMDD:HH"
end_day <- '20200325:10'

##############
## Marshall-Palmer coefficients
ZR_coeff_a <- 300
ZR_coeff_b <- 1.4
## Maximum value (Hail threshold)
Hail_threshold <- 60
## Minimum value to be taken account (Low dBZ threshold)
Low_dBZ_threshold <- 20

# ZR_coeff_a <- 200
# ZR_coeff_b <- 1.6
# Hail_threshold <- 55
# Low_dBZ_threshold <- 10
```

Array precip:Longitude 2 of 800=28,3192degree Dataset:precip 20171029_000506 variable , precip,radar estimation rainfall and unit in mm ,Slice Lon,average over 800 indices I dimension X axis Latitude (degree)

**Figure 13:radar estimate rainfall**

Dependencies is : read_radarCartesian.py file which is a python script to read Radar data, extract and convert it

```python
import datetime
import numpy as np
import matplotlib.pyplot as plt
import pyart
import netCDF4
import sys
import os
import warnings
warnings.filterwarnings('ignore')

os.environ['PATH'] = sys.argv[3] + sys.argv[4] + os.environ['PATH']

def read_mdv_radarCart(filename):
    filemetadata = pyart.config.FileMetadata('mdv', field_names=['DBZ_F'],
                                            additional_metadata=None,
                                            file_field_names=True, exclude_fields=None)
    mdv = pyart.io.mdv_common.MdvFile(pyart.io.common.prepare_for_read(filename))

    # time dictionaries
    units = pyart.io.common.make_time_unit_str(mdv.times['time_begin'])
    time = pyart.config.get_metadata('grid_time')
    time['data'] = np.array([netCDF4.date2num(mdv.times['time_centroid'], units)])
    time['units'] = units

    # origin dictionaries
    origin_altitude = pyart.config.get_metadata('origin_altitude')
    origin_altitude['data'] = np.array([mdv.master_header["sensor_alt"] * 1000.], dtype='float64')

    origin_latitude = pyart.config.get_metadata('origin_latitude')
    origin_latitude['data'] = np.array([mdv.master_header["sensor_lat"]], dtype='float64')

    origin_longitude = pyart.config.get_metadata('origin_longitude')
    origin_longitude['data'] = np.array([mdv.master_header["sensor_lon"]], dtype='float64')
```

The output will be stored in Radar_data/QPE and this is now in netcedf format which will be ready by Climate data tools and PanoplyWin to create more plot from variable precipitation 2D plotting using Latitude as X axis and Longitude for Y axis and horizontal or vertical line plot along Latitude or longitudes axis.

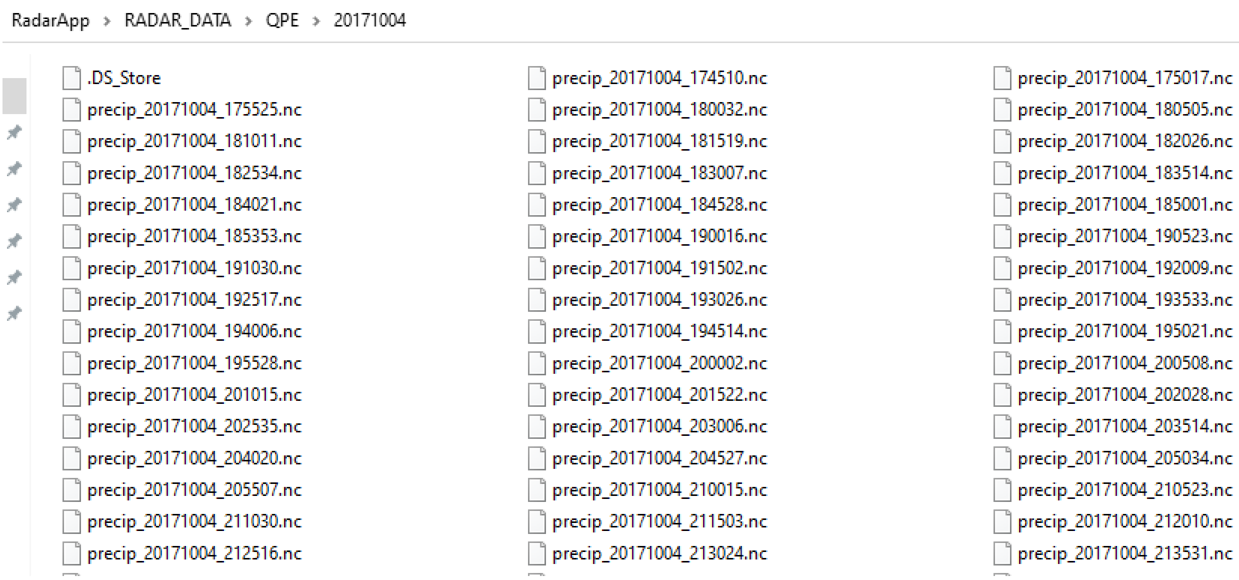



**Figure 14:QPE result from radar mdv data in ntcedf format**

## IV.6 Aggregate 6 min QPE to 1 hour results

The algorithm to aggregate 6 minute Quantitative Precipitation Estimation to 1hour have been developed , a minimum number of available 6min QPE to aggregate but If the available QPE files are below this number no aggregation will be made.

Minimum number of radar scan <- 2 The precipitation at 20 hr are the aggregated precipitation from 20:00:00 to 20:59:59 using library ncdf4, Parallel Library, for each Library, do Parallel Library this will change data from 5minutes to 1hr, as you see on Figure below

min_scan <- 8: this means that at least we need 8 scan to aggregate the data to 1hr. if we have less that 8 scan the data will not be aggregated

min_scan <- 8 to run the script source the script in R the output has been saved in "Aggregated_QPE_1hr" directory. this will be in netcdf and will be used for the adjustment.

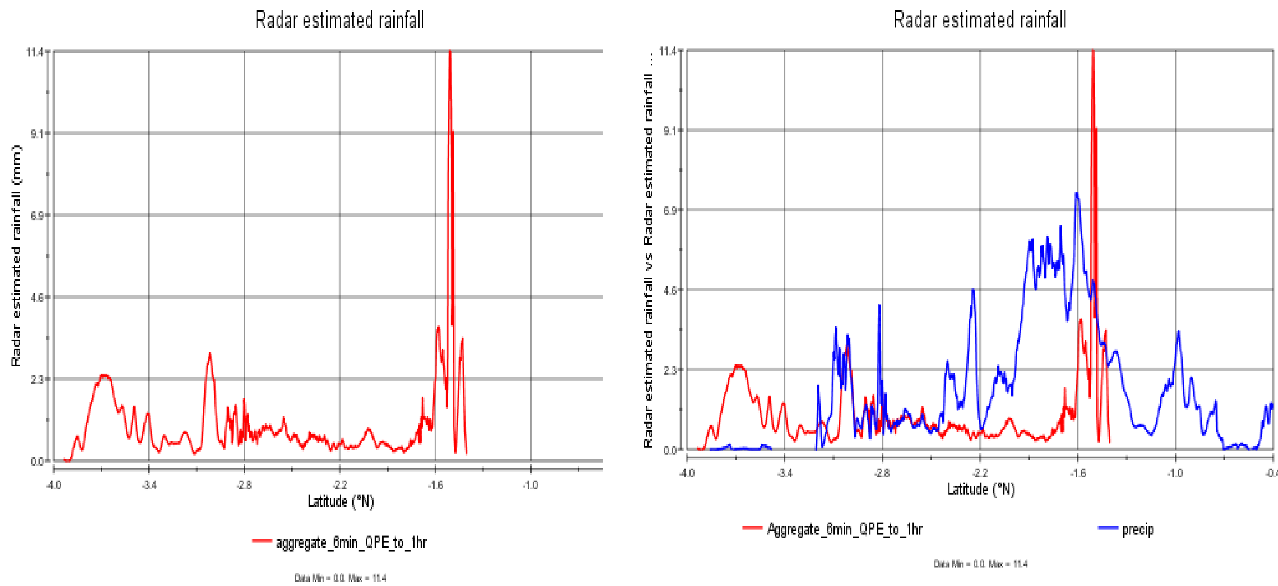



Figure 15:radar estimate rainfall

## IV.7 Aggregated QPE daily

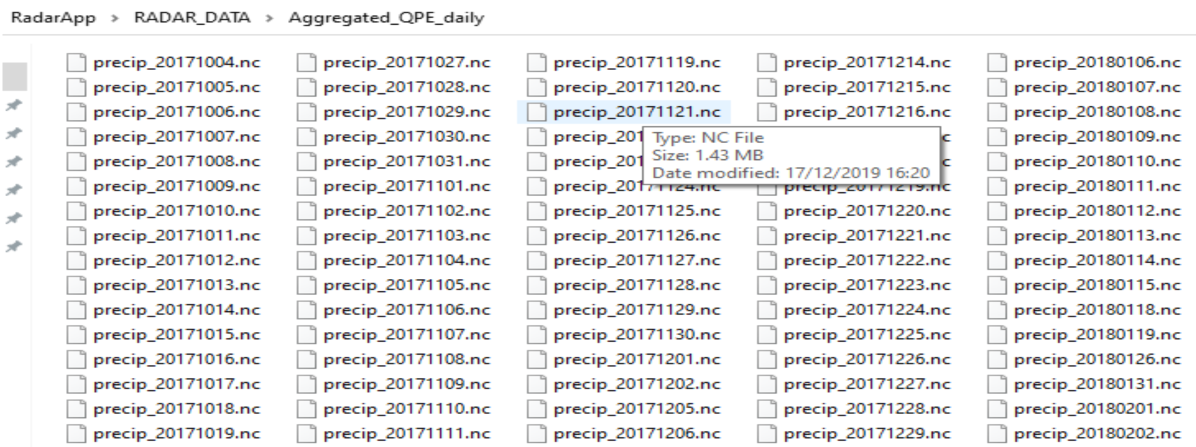
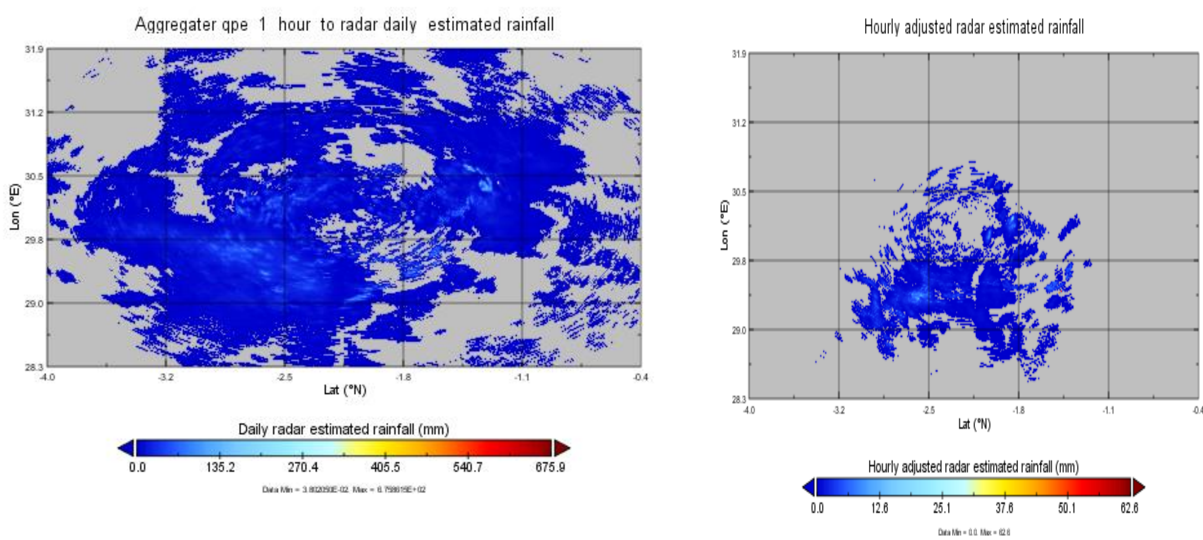



**Figure 16:Aggregater qpe daily data in ntcedf**




Create a 2d plot using lat for X axis and long fo Y axis

Figure 17:Aggregater qpe to daily radar estimated rainfall

### IV.8 Adjustment by rain gauge observation

In this study ,I Adjusted hourly Quantitative Precipitation refers to utilizing rain gauge perceptions on the ground to redress for mistakes within the radar-based precipitation assessing. give an fabulous outline of alteration methods. A commonplace approach is to measure the mistake of the radar-based precipitation appraise at the rain gage areas, expecting the rain gage perception to be exact. The blunder can be expected to be added substance, multiplicative, or a blend of both. Most approaches accept the blunder to be heterogeneous in space. Thus, the mistake at the rain gage areas will be introduced to the radar bin (or grid) areas and after that utilized to alter (redress) the crude radar precipitation gauges. with dependence of an adjust QPE functions script wrote in r.

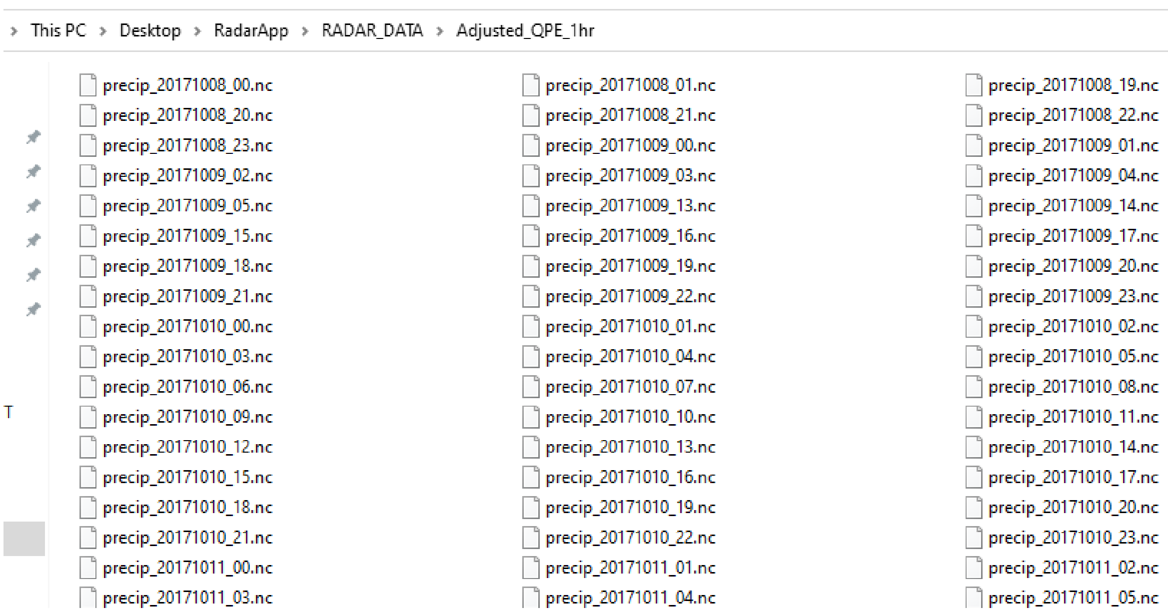



Figure 18:Adjustment radar by rain gauge observation

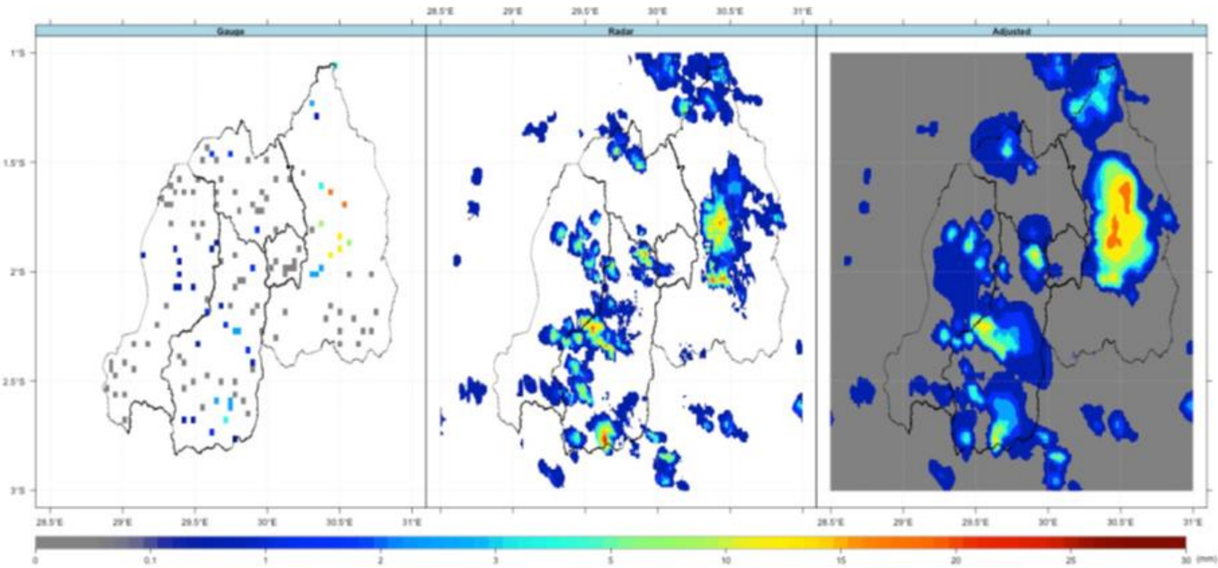


Figure 19:Adjustment figure show radar vs gauges

This figure show the Hourly rainfall depths for 2017-09-28 16:00 at local time. Results are shown for the automatics rain gauges (left), radar radar-based rainfall estimation, and the adjusted rainfall using adjustment method the output as show the Fig 21 an hourly adjusted radar estimate rainfall result with few clutter and bias.

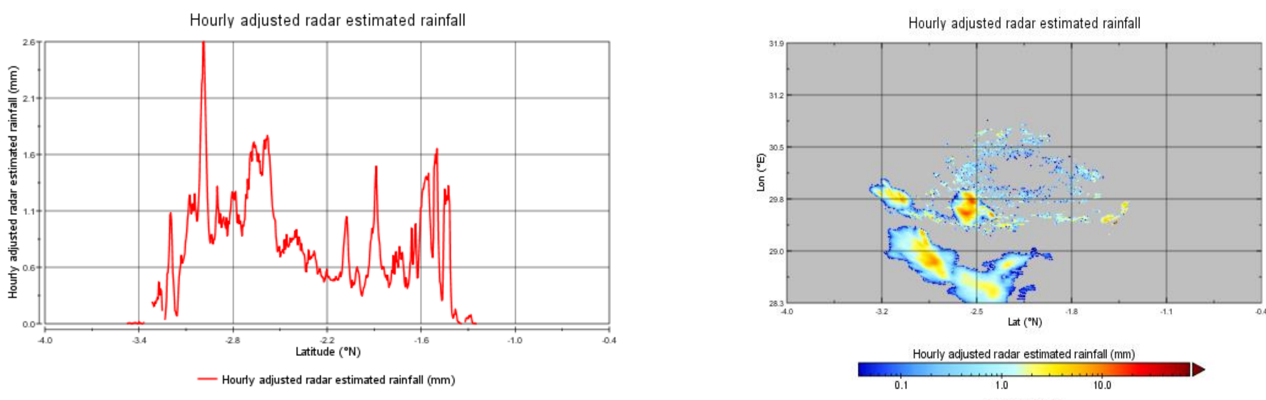



Figure 20:hourly-adjusted radar estimated rainfall

Adjust QPE to daily.R this will convert hourly to daily as show in the figure above.

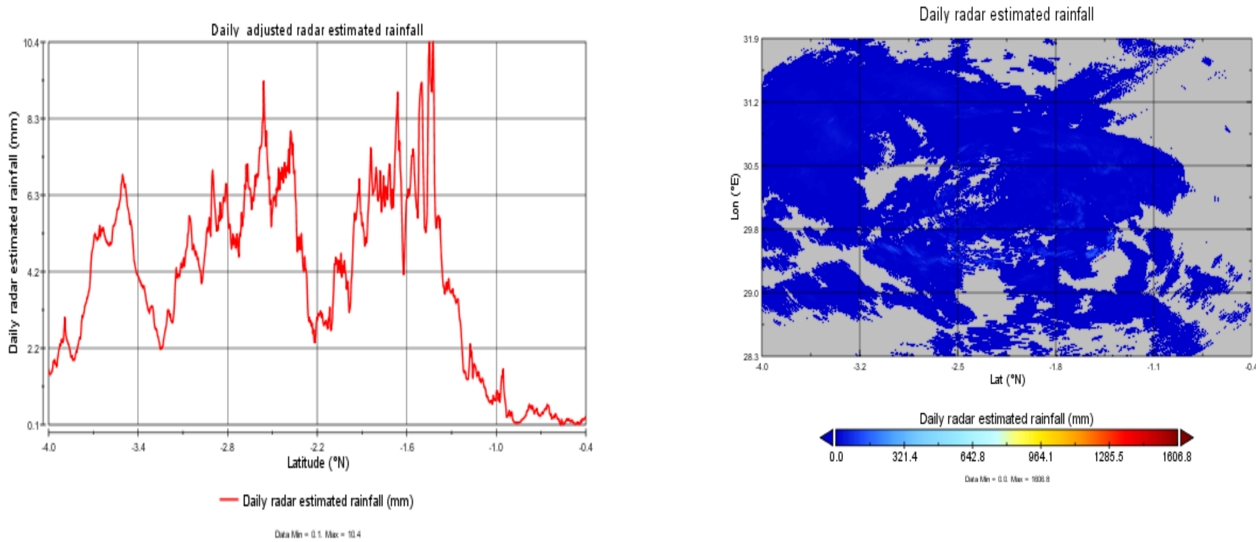



Figure 21:Daily radar estimate rainfall (mm)

## IV.9 PPI Marayundo weather radar

A local PPI from the Marayundo weather radar produced from an mdv file using Pyart , matplotlib

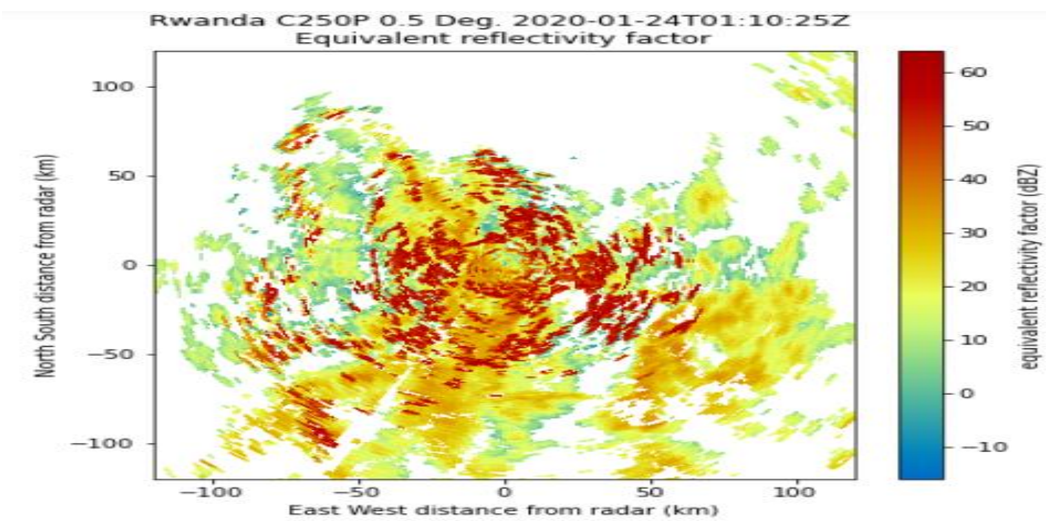



Figure 22:Plan position indicator using mdv file

This PPI plot of a MDV file using a RadarDisplay object. When checking in PPI mode, the radar holds its height point steady but shifts its azimuth point. The returns can at that point be mapped on a flat plane. In case the radar pivots through 360 degrees, the filter is called a "observation filter". In case the radar turns through less than 360 degrees, the check is called a "segment check". The metadata object can be assessed by means of keywords. The data protest contains the real data, in this case a polar grid with 360 azimuth points and 128 run canisters.

### IV.10 Automatic Weather Station (AWS) script

Different script has been developed like extract time series, plot spatial map, plot time series, precip Adjust Radar ,Time series. This figure 22 shows the plot Time Series of a daily total precipitation from Rutsiro aws stations from 15 August 2019 August to 25 December 2020 the highest Rainfall rate was 129.0 mm.

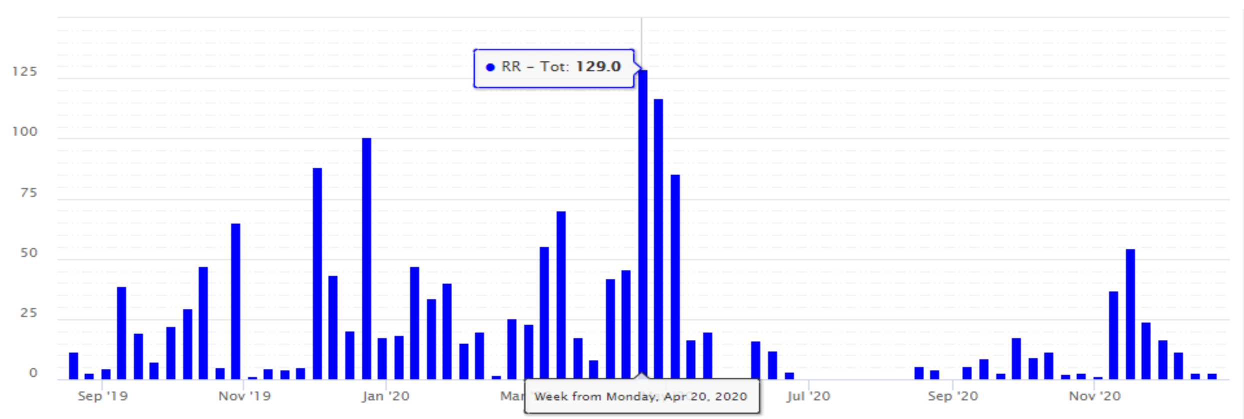
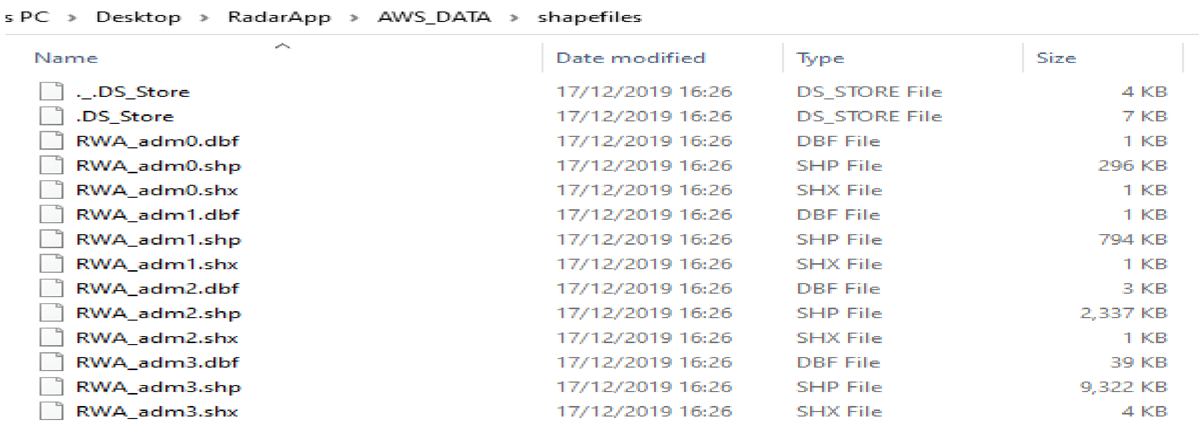



Figure 23: Rutsiro aggregation precipitation total for sept 2019 to December 2020 plot_Time_Series

### IV.11 Automatic weather station data extraction

Extraction: the scripts developed to be used to extract the data and put them in way they will be used

- **Extract hourly precipitation Adjust Radar**:



s PC > Desktop > RadarApp > AWS_DATA > shapefiles

| Name | Date modified | Type | Size |
|---|---|---|---|
| ._.DS_Store | 17/12/2019 16:26 | DS_STORE File | 4 KB |
| .DS_Store | 17/12/2019 16:26 | DS_STORE File | 7 KB |
| RWA_adm0.dbf | 17/12/2019 16:26 | DBF File | 1 KB |
| RWA_adm0.shp | 17/12/2019 16:26 | SHP File | 296 KB |
| RWA_adm0.shx | 17/12/2019 16:26 | SHX File | 1 KB |
| RWA_adm1.dbf | 17/12/2019 16:26 | DBF File | 1 KB |
| RWA_adm1.shp | 17/12/2019 16:26 | SHP File | 794 KB |
| RWA_adm1.shx | 17/12/2019 16:26 | SHX File | 1 KB |
| RWA_adm2.dbf | 17/12/2019 16:26 | DBF File | 3 KB |
| RWA_adm2.shp | 17/12/2019 16:26 | SHP File | 2,337 KB |
| RWA_adm2.shx | 17/12/2019 16:26 | SHX File | 1 KB |
| RWA_adm3.dbf | 17/12/2019 16:26 | DBF File | 39 KB |
| RWA_adm3.shp | 17/12/2019 16:26 | SHP File | 9,322 KB |
| RWA_adm3.shx | 17/12/2019 16:26 | SHX File | 4 KB |

**Figure 24:automatic weather station shape file**

Here these files contain the coordinates. if we have other more station to add, we can fill the information as it is in the files above, change the sensors and also the information accordingly. The problem in LSI when I change the ID, I have to put also the ID in the following cell before that station. if I add a new station I have to put it below other stations and fills accordingly.

- ftpserver: this is the files contain all information with regards to data server server.
- LSI Automatic Weather Station,this folder contains the processed data for LSI AWS network
- compressed_data: contains the data
- info and inside is AWS : in this folder there is all information of the station
- data_10min: in this folder there is all data for 10 minutes (raw data not yet quality controlled)
- data_10minQC: in this folder there is all data for 10 minutes quality controlled
- data_1hr: in this folder there is all data from 10 minutes to 1hour quality controlled
- data_1hr: from one hour to daily

- data_dekad: from daily to dekad

the script will go to server get the data put them in 10min do QC, aggregate to 1hour, 1day, dekad if data is enough and write the info.

- **extract hourly precipitation adjusts Radar**

This algorithm extract hourly **precipitation for adjusted** the radar data using coordinates files the figure 24 show as the result extracted data based on longitude and latitude ,date and the identification of automatic weather stations.

| id | station_name | longitude | latitude | elevation | Sector | District | Type |
|---|---|---|---|---|---|---|---|
| 310 | Kinazi | 29.9066 | -2.1987667 | 1515 | Kinazi | Ruhango | AWS S |
| 311 | Nyabimata | 29.4374 | -2.6871333 | 2161 | Nyabimata | Nyaruguru | AWS S |
| 312 | Kaduha | 29.5341667 | -2.3216111 | 1879 | Kaduha | Nyamagabe | AWS S |
| 320 | Bakokwe | 29.7664 | -1.9348667 | 1466 | Kabacuzi | Muhanga | AWS H |
| 309 | Mayange | 30.1223056 | -2.1960833 | 1433 | Mayange | Bugesera | AWS S |
| 314 | Rutsiro | 29.3856333 | -1.95945 | 2043 | Gihango | Rutsiro | AWS S |
| 315 | Kanombe | 30.1495278 | -1.9715556 | 1412 | Kanombe | Kicukiro | AWS S |
| 305 | Kirehe | 30.6675278 | -2.2790556 | 1658 | Kirehe | kirehe | AWS S |
| 304 | Ndego | 30.7113889 | -2.01425 | 1366 | Ndego | Kayonza | AWS S |
| 303 | Kayonza | 30.51144 | -1.900278 | 1575 | Kayonza | Kayonza | AWS S |
| 302 | Ngarama | 30.2405 | -1.5450667 | 1503 | Ngarama | Gatsibo | AWS S |
| 317 | Gikomero | 30.2183889 | -1.8875278 | 1882 | Gikomero | Gasabo | AWS S |
| 306 | Rutongo | 30.06025 | -1.820417 | 1865 | | Rulindo | AWS S |
| 308 | Rulindo | 29.92322 | -1.722139 | | | | |
| 313 | Ngororero | 29.6339 | -1.85515 | 1803 | Ngororero | Ngororero | AWS S |
| 321 | Muhembe | 29.5367333 | -1.8281333 | 1893 | Muhanda | Ngororero | AWS H |
| 322 | Ntaruka | 29.7558333 | -1.4763333 | 1881 | Ntaruka | Burera | AWS H |
| 319 | Mukunguri | 29.9286333 | -2.1519333 | 1375 | Kinazi | Ruhango | AWS H |
| 301 | Bigogwe | 29.4275665 | -1.627056 | 2392 | Bigogwe | Nyabihu | AWS H |
| 323 | Sebeya | 29.3254333 | -1.7017833 | 1791 | Nyundo | Rubavu | AWS H |
| 324 | Iwawa | 29.1479167 | -1.9274444 | 1466 | iwawa | Rutsiro | AWS H |
| 326 | Gihinga | 29.96725 | -2.2866944 | 1340 | Nyarugenge | Bugesera | AWS H |

Figure 25: AWS station information

| ID | Bugesera | Burera | Gakenke | Gasabo | Gatsibo | Gicumbi | Gisagara | Huye | Kamonyi | Karongi | Kayonza |
|---|---|---|---|---|---|---|---|---|---|---|---|
| LON | 30.15013 | 29.82655 | 29.78424 | 30.14221 | 30.4454 | 30.11389 | 29.84351 | 29.7088 | 29.9024 | 29.39398 | 30.64194 |
| DATE/LAT | -2.23963 | -1.46623 | -1.69853 | -1.89145 | -1.61907 | -1.62163 | -2.61752 | -2.52464 | -2.00945 | -2.14094 | -1.84499 |
| 20180801 | 4.043 | 9.166 | 19.132 | 18.386 | 3.216 | 10.02 | 8.046 | 15.692 | 23.508 | 15.479 | 5.559 |
| 20180802 | 0.486 | 5.775 | 9.237 | 2.013 | 0.072 | 5.73 | 25.638 | 25.814 | 2.605 | 9.018 | 1.758 |
| 20180803 | 1.202 | 6.708 | 7.921 | 3.805 | 1.162 | 9.68 | 9.751 | 12.328 | 3.609 | 6.461 | 1.669 |
| 20180804 | 1.974 | 6.93 | 10.764 | 7.4 | 3.275 | 13.282 | 6.221 | 10.243 | 4.003 | 8.544 | 1.87 |
| 20180805 | 0.093 | 3.857 | 5.425 | 2.075 | 0.037 | 5.611 | 5.086 | 9.407 | 1.468 | 4.505 | 0.761 |
| 20180806 | 0.063 | 3.473 | 4.803 | 1.672 | 0.03 | 5.018 | 4.421 | 8.453 | 1.252 | 3.817 | 0.649 |
| 20180807 | 0.613 | 4.556 | 5.815 | 10.153 | 1.63 | 9.943 | 5.936 | 9.922 | 1.669 | 6.638 | 3.998 |
| 20180808 | 0.092 | 3.971 | 5.274 | 2.329 | 0.034 | 5.639 | 4.591 | 9.039 | 1.482 | 4.142 | 0.698 |
| 20180809 | 0.09 | 3.97 | 5.588 | 2.047 | 0.041 | 5.616 | 4.911 | 9.233 | 1.478 | 4.405 | 0.86 |
| 20180810 | 0.111 | 4.099 | 5.564 | 2.375 | 0.035 | 5.693 | 5.294 | 9.935 | 1.584 | 4.606 | 0.752 |

Figure 26:Daily district radar data extracted

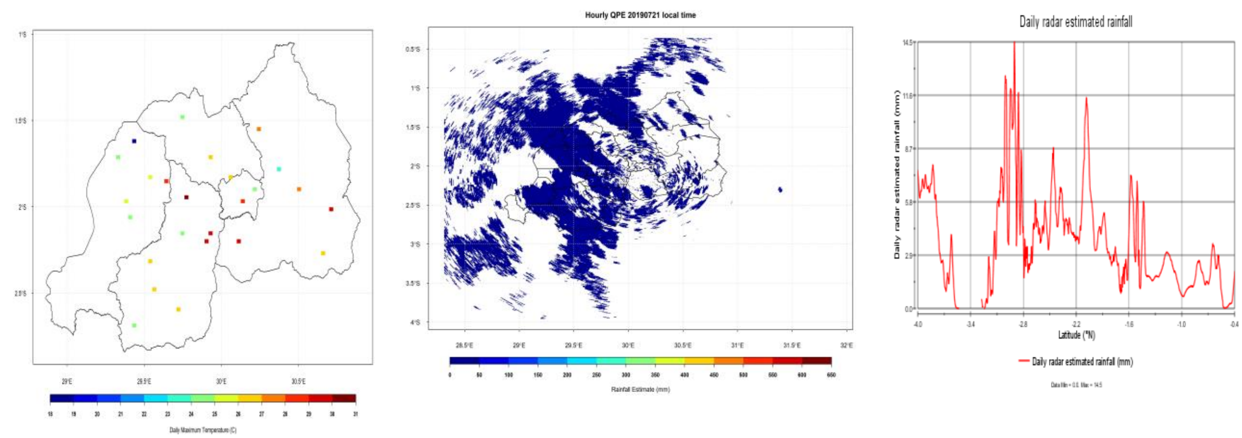



Figure 27:QPE products using radar and aws

# CHAPTER V: CONCLUSION AND RECOMMENDATION

This Chapter comprises two main parts namely Conclusion and Recommendations respectively.

## V.1 Conclusion

This study was to decide the radar data processing analysis chain and Adjustment of radar data by rain gauge observations using data mining to improve the rainfall estimates from radar The study utilized anaconda ,python, R,,wradlib, pyart, graphical statistical methods to assess the radar data processing analysis and adjustment to get the occurancy Quantitative Precipitation Estimation and radar data visualization.

To evaluate the aptitude of the models in recreating the climate radar data and aws data in Rwanda, correlation, absolute mean error, KID, difference plots analysis were used. The clutter removal have been used and rain gauges have been used to make accurate rainfall measurement s at a specific points within the radar field of views . Computation and graphical measures were utilized to survey the execution of ZR algorithms in reenacting QPE in Rwanda.

## V.2 Recommendations

It is prescribed that advance study should be carried out to examine the QPE inconstancy over Rwanda. We suggest such aggregations to form inactive clutter maps which can in turn be utilized to evacuate the inactive clutter from an image and fill the coming about holes by interpolation. It is also recommended to conduct a detailed study on weather radar data processing chain analysis to get an occurancy Z- R relationship over Rwanda for superior utilization of weather radar information and climate administrations. Different method chosen models were considered beneath this study, it is suggested that encourage research ought to be conducted evaluating the execution of all models and adjustment, aggregation measure should be undertaken. Due to the complex nature of Rwanda, it is emphatically recommended that more considers may well be done on weather radar and automatic weather station since can give quantitative data on precipitation with great determination for research and decision maker.

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## APPENDICES

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