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Rainfall Estimation Using Polari metric Weather Radar by Measuring Reflectivity

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Abstract - *Study of various physical processes related to water cycle, which is of interest to scientific communities of meteorology, hydrology, environment, ecology, agriculture etc., often require reliable precipitation measurements. This paper presents the comparative analysis of Global Precipitation Measurement (GPM) Ku- band Precipitation Radar's (KuPR) attenuation corrected reflectivity values with Next- Generation Radar (NEXRAD) KAMX reflectivity values at different elevation angles. The NEXRAD KAMX and GPM KuPR reflectivity volume scans are projected on to a common Cartesian grid to minimize the uncertainties and the data sets with different resolutions are interpolated to a horizontal grid of spatial resolution 0.1o x0.1o approximately 11x11km and to have a better agreement both the data sets are quality controlled by considering the reflectivity values greater than 20 dBZ and are cross validated by calculating RMSE (Root Mean Square Error), MAE (Mean Absolute Error) and CC (Correlation Coefficient).*

Key Words: GPM, KuPR, NEXRAD, Polarmetric variables, Range resolution, spatial resolution

1. INTRODUCTION

Many hydrologic simulation studies, weather related to climatic change scenarios, flood forecasting, or water management, depend heavily on the availability of good-quality precipitation estimates. Difficulties in estimating precipitation arise in many remote parts of the world where ground -based measurement networks (rain gauges or weather Radar) are either sparse or non-existent.

The quantitative information on the spatial and temporal distribution of precipitation is essential for hydrologic and climatic applications. However, accurately measuring precipitation has been a challenge, because of its high variability in space and time. There are three major types of techniques of precipitation measurement they are: (1) surface-based in-situ precipitation gauges, (2) weather Radars and (3) space-based meteorological satellites [1].

The ability of measuring high-resolution precipitation data in space and time has been increased due to the development of Weather Radars. Polarimetric Weather Radars are capable of distinguishing non-meteorological echoes from meteorological echoes and they significantly improve Precipitation Estimates by identifying rain echoes from other hydrometeor types. Weather Radar is a powerful tool for validating PR data that provides physical insight into the development and interpretation of space-borne Weather Radar algorithms and observations.

This paper mainly focuses on comparative analysis of Dual-Polarization Radar reflectivity values with the attenuation corrected reflectivity values of space- borne Ku- band Precipitation Radar

2. LITERATURE REVIEW

Irje Yixin Wen et al., [3] this paper provides a quantitative assessment of Tropical Rainfall Measuring Mission (TRMM) precipitation radar (PR) and S-band Polarimetric Radar (KOUN) reflectivity measurements in which NASA's resolution volume- matching technique is used to match and compare simultaneous TRMM PR and KOUN reflectivity observations. t Template sample paragraph .Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, sc, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable.

Steven M. Bolen et al., [2] in this paper simultaneous comparison of data collected from the TRMM PR and the S-band Polarimetric Ground Radar (GR), operated by the National Center for Atmospheric Research, is carried out in which comparison between GR and PR data performed on a point-by-point basis in three dimensions via scatter diagrams.

E Amitai et al., [4] in this paper Probability Density Functions (PDFs) based on TRMM PR rainfall rate observations and National Oceanic and Atmospheric Administration (NOAA) Next- Generation Quantitative Precipitation Estimation (QPE) high resolution national mosaic product (Q2) of single and combined overpasses were compared.

3. SYSTEM DESCRIPTION

NEXRAD KAMX is a Weather Surveillance Radar (WSR) located at Miami (Florida) with 25.610o N, -80.41306o W latitude and longitude specifications respectively [5]. It is a dual polarization Radar which provides the Polarimetric variables such as reflectivity (Z), differential reflectivity (ZDR), radial velocity, spectrum width, differential phase (ϕDP) and correlation coefficient.

The GPM KuPR is a Ku- band space- borne Precipitation Radar to map the precipitation and provides the 3 dimensional observations of reflectivity and rain and also provides accurate rainfall measurements over land and ocean [6].

NEXRAD KAMX is a ground- based Weather Radar and GPM KuPR is a space- based Precipitation Radar. NEXRAD KAMX is a S- band Radar which operates at frequency range 2- 4 GHz with range and spatial resolution of 250m. GPMKuPR operates at 13.5 GHz which is higher than that of the operating frequency of NEXRAD KAMX, having the higher spatial resolution of 5km at nadir and lower range resolution of 125m than that of the NEXRAD KAMX as shown in Table I and Table II which gives the technical specifications of NEXRAD KAMX and GPM KuPR respectively. In the present study the simultaneous observations of passage of Hurricane Fred near South Eastern Florida by NEXRAD KAMX and GPM KuPR are used.

Table -1: TECHNICAL SPECIFICATIONS OF NEXRAD KAMX

Parameters	**Specifications**
Operating frequency band	S band
Wavelength	10.5cm
Peak power	750kw
Polarization	Dual-pol
Maximum reflectivity range	460km
Range resolution	250m
Beam width	0.95degrees
Power gain	45.5dB
Number of scans	9-14

TABLE II: TECHNICAL SPECIFICATIONS OF GPM KUPR

Parameters	**Specifications**
Swath width	245km
Range resolution	125/250m
Spatial resolution	5km at nadir
Beam width	0.71degrees
Transmitter	128 solid state amplifiers
Peak transmit power	1013watts
Pulse repitition frequency	4100 to 4400Hz

Pulse width	Two 1.667µs pulses
Beam number	49

4. DATABASE

In the present study the volume scan observations by NEXRAD KAMX along with the simultaneous observations from the GPM KuPR are used. The NEXRAD KAMX level II data are downloaded from National Centre for Environmental Information (NCEI) site and level 2A KuPR attenuation corrected reflectivity values were downloaded from Precipitation processing System (PPS). Figure 1 shows the location of the KAMX Radar and its observational radius along with the GPM KuPR observations. The black solid circle indicates the significant precipitation coverage within a and Root Mean Square Error (RMSE) and Correlation 250km Radar radius and the area between the two solid straight lines indicates the swath coverage of GPM KuPR. However both the instruments have different viewing angle and resolutions hence the interpolation of data to a common coordinate system is necessary.

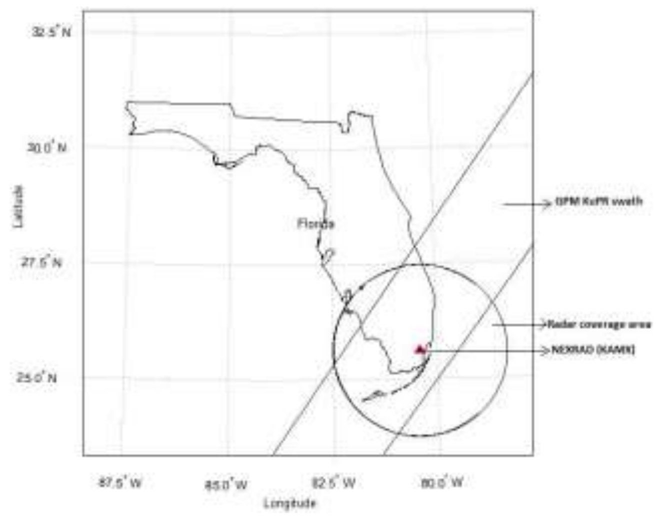

Fig -1: Name of the figure

Figure 1: Location of the NEXRAD (KAMX) along with the radius of coverage and the GPM KuPR near surface swath coverage.

5. DATABASE

To compare NEXRAD reflectivity values with attenuation corrected reflectivity values of GPM KuPR, the present methodology which is explained below is adopted.

The GPM KuPR attenuation corrected reflectivity data that are downloaded as described in Section IV will be in geo spatial Cartesian coordinate system with coordinates latitude, longitude and altitude. The NEXRAD reflectivity data that are downloaded will be in polar coordinate system with co-ordinates range, azimuth and elevation are converted to geo spatial Cartesian coordinate system same as GPM KuPR.

The KAMX and GPM KuPR reflectivity volume scans are projected on to a fixed Cartesian grid of 79^o W -82^o W and 24^o N -27^o N to minimize navigation mismatches.

To compare data sets at different elevation angles the latitude, longitude and altitude information of GPM KuPR are converted to polar coordinates such as range, azimuth and elevation.

The data sets with different resolutions as described in the Section III are interpolated to a fixed resolution grid by considering the maximum reflectivity value and assigning the same value to each horizontal grid of resolution 0.1^o x0.1^o approximately 11x11km.

To have a better agreement the reflectivity values greater than 20 dBZ are considered for intercomparison and are cross validated quantitatively by computing Mean Absolute Error (MEA) and Root Mean Square Error (RMSE) and Correlation Coefficient (CC).

5.1 Cross -Validation Indices

To validate the intercomparison of reflectivity values of KAMX and KuPR quantitatively mean Absolute Error (MEA) Coefficient (CC) are computed and are expressed as in (1), (2) and (3).

$$MAE = \frac{\sum_{i=1}^{N} |R(i) - G(i)|}{N} \quad (1)$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N} (R(i) - G(i))^2}{N}} \quad (2)$$

$$CC = \frac{\sum_{i=1}^{N} (R(i) - \overline{R})(G(i) - \overline{G})}{\sqrt{\sum_{i=1}^{N} (R(i) - \overline{R})^2} \sqrt{\sum_{i=1}^{N} (G(i) - \overline{G})^2}} \quad (3)$$

where N is total number of samples, R􏰀􏰀􏰀􏰀is NEXRAD reflectivity value, G􏰀􏰀􏰀is GPM KuPR reflectivity value, R is

Arithmetic mean of NEXRAD reflectivity values, G is arithmetic mean of GPM KuPR reflectivity values. The MAE and RMSE are in units of dB for reflectivity comparisons [1].

6. RESULTS AND DISCUSSION

This section describes the comparative analysis of NEXRAD reflectivity values and GPM KuPR attenuation corrected reflectivity values at different elevation angles. The data sets of KAMX and KuPR, recorded during the passage of Hurricane Fred near South Eastern Florida where the simultaneous observations of both the instruments available on 30th August 2017 at times 7:23 and 7:20UTC respectively were downloaded.

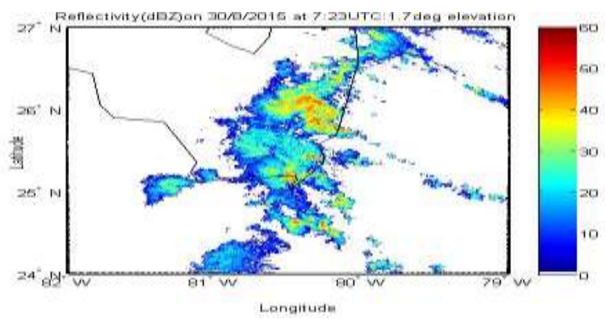

Figure 2: The NEXRAD reflectivity values recorded on August 30 2017 at 7:23UTC at 1.7° elevation

Figure 3 shows the attenuation corrected reflectivity values recorded by GPM KuPR on August 30 2017 at 7:20 UTC ranging from 0 to 60 dBZ at an elevation angle of 1.7°.

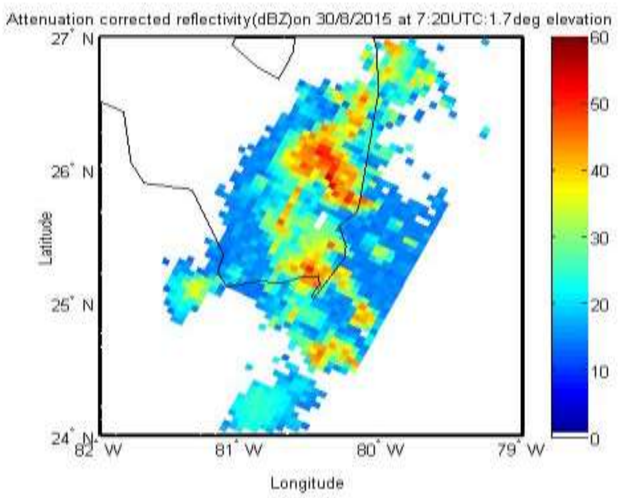

Figure 3. The GPM KuPR attenuation corrected reflectivity values recorded on August 30 2017 at 7:20UTC at 1.7° elevation

Figure 4 shows the reflectivity values recorded by NEXRAD KAMX on August 30 2017 at 7:23UTC ranging from 0- 60 dBZ at an elevation angle of 2.3°.

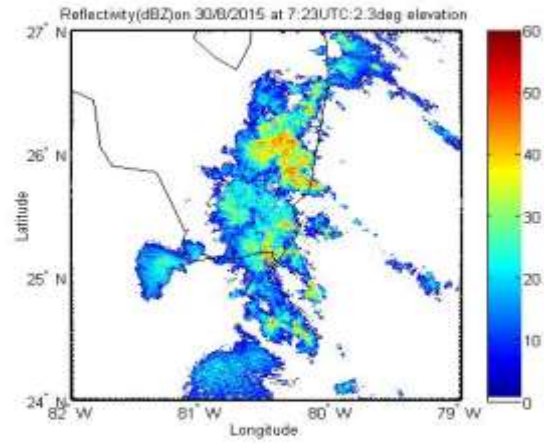

Figure 4: The NEXRAD reflectivity values recorded on August 30 2017 at 7:23UTC at 2.3o elevation

The attenuation corrected reflectivity values recorded by GPM KuPR on August 30 2017 at 7:20 UTC ranging from 0 to 60 dBZ at an elevation angle of 2.3 o is shown in Figure 5

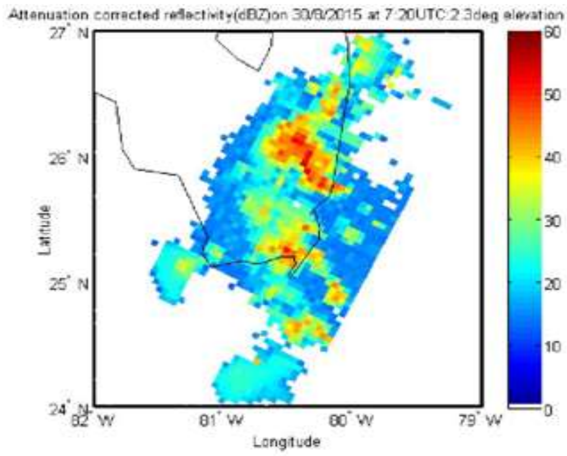

Figure 5: The GPM KuPR attenuation corrected reflectivity values recorded on August 30 2017 at 7:20UTC at 2.3o elevation.

6.1 Matched Resolutions

The reflectivity values of KAMX and GPM KuPR with different spatial resolutions such as 250m and 5km respectively are interpolated to 2Dimensional horizontal grid of resolution 0.1 ° x0.1° approximately 11x11km as described in Section V for latitude ranging from 24°N to 27°N (3°) and longitude ranging from 79°W to 82°W(3°).

The interpolated grid of 0.1° x0.1 ° to match the resolutions of KAMX and the KuPR reflectivity values ranging from 0 to 60dBZ at an elevation angle of 1.7 ° is shown in Figure 6.

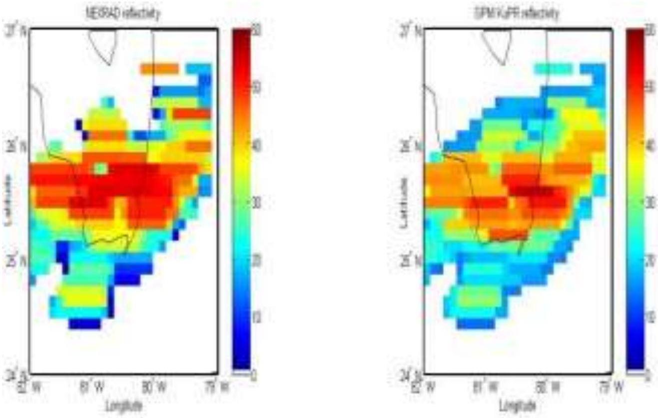

Figure 6: Interpolated grid of 0.1o x0.1o to match the resolutions of KAMX and the KuPR at 1.7 o elevation

Figure 7 shows the interpolated grid of 0.1o x0.1o to match the resolutions of KAMX and the KuPR reflectivity values ranging from 0 to 60dBZ at an elevation angle of 2.3 Degree.

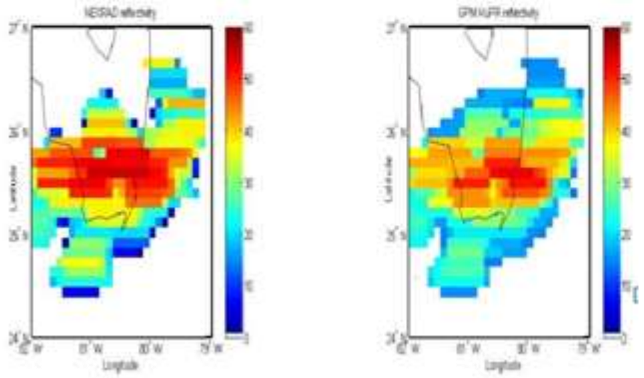

Figure 7. Interpolated grid of 0.1° x0.1° to match the resolutions of KAMX and the KuPR at 2.3 ° elevation

6.2 Intercomparison of reflectivity values of NEXRAD KAMX and GPM KuPR at different elevation angles

The reflectivity values of NEXRAD KAMX and GPM KuPR greater than 20 dBZ are considered for intercomparison to have a better agreement. The scatter plot is plotted to determine the correlation between KAMX and KuPR reflectivity values and are cross validated as described in Section V.

The scatter plot of NEXRAD KAMX reflectivity values in dBZ along x axis and GPM KuPR attenuation corrected reflectivity values in dBZ along y axis at an elevation angle of 1.7 ° with a correlation coefficient of 0.9853 is as shown in Figure 8.

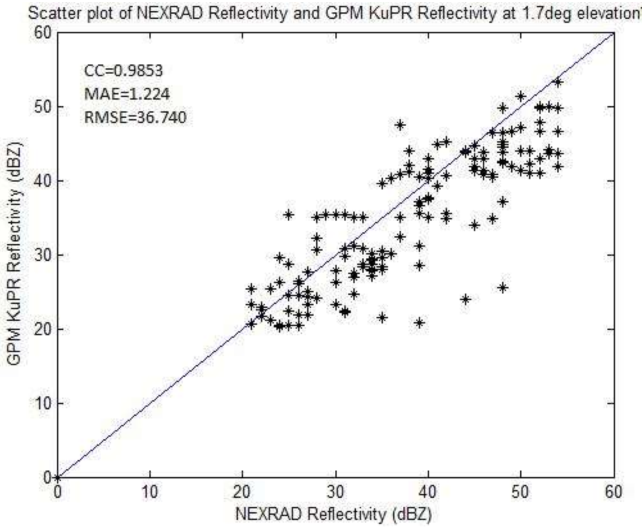

Figure 8. Scatter plot of NEXRAD KAMX versus GPM KuPR at 1.7° elevation

The scatter plot of NEXRAD KAMX reflectivity values in dBZ along x axis and GPM KuPR attenuation corrected reflectivity values in dBZ along y axis at an elevation angle of 2.3 ° with a correlation coefficient of 0.9914 is as shown in Figure 9.

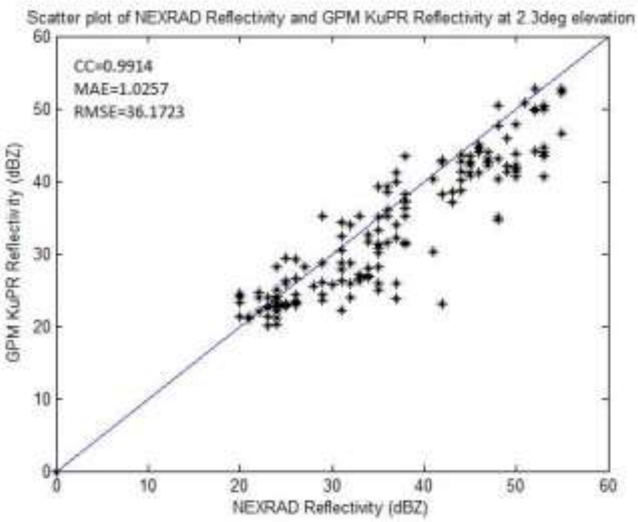

Figure 9: Scatter plot of NEXRAD KAMX versus GPM KuPR at 2.3 degree elevation

7. CONCLUSIONS

The NEXRAD KAMX reflectivity data and GPM KuPR reflectivity data recorded on August 30th 2017 during the passage of Hurricane Fred near South Eastern Florida with different volume scans are projected on to a common coordinate system and the data sets with different resolutions are interpolated to 0.1o x0.1o spatial grid. The reflectivity values at 1.7o and 2.3o elevation angle are compared and cross validated with the correlation coefficient 0.9853 and 0.9919 respectively, among which the reflectivity values at an elevation angle 2.3o provides the better agreement.

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