POLARIMETRIC RAINFALL RETRIEVAL WITH A C-BAND RADAR IN MINAS GERAIS, BRAZIL

R.V. Calheiros*[1], C. Beneti[1], C. Oliveira[1], M. Lima[1], L. Calvetti[1], A. Held[1], G. Held[1] and A. Paiva Neto[2]
[1]SIMEPAR, Paraná Meteorological System, Curitiba, Brazil
[2]CEMIG, Minas Gerais Power Company, Belo Horizonte, Brazil

1. INTRODUCTION

Improved rainfall estimates enhance the potential of radar for many outstanding applications, as is the case with flood forecasting. Polarimetric techniques, which undergo an ever-growing implementation, carry the promise of providing rainfall estimates which are significantly more accurate. In Brazil in 2011, a C- band polarimetric radar was deployed at Morro do Elefante (19° 56.7'S, 44° 26.1'W), to provide operational support for hydropower generation and flood forecasting for the densely populated metropolitan area of Belo Horizonte, Minas Gerais State.

In a first study, a limited set of this radar data was used to estimate rainfall with both a generic tropical R(Z) in the original radar set up and a polarimetric R(Z, ZDR) algorithm. CDF curves from the rainfall estimates were shown to stratify significantly both in range and daily interval.

These results corroborate the findings by Calheiros and Zawadzki (1987) and Calheiros and Gomes (2011) showing the importance of those stratifications for hydrological applications, in particular rate of flow, for the Bauru radar operating in an area contiguous to that of the Monte do Elefante radar coverage.

Work developed in continuation is presented in this paper involving a substantially larger amount of radar data, from which the 3-month December 2013 to February 2014 (DJF) period corresponding to the rainiest season on the radar coverage area was selected. A Z(R) relationship, which was derived for the radar coverage area using a rain gage network under the radar umbrella following the methodology of Calheiros and Zawadzki (1987), and a R(Z, KDP) algorithm for the C-band from Crisologo et al (2014), were selected for the work. Both were used to retrieve rainfall, together with the generic tropical Z(R) relationship presently operational with the radar.

**Corresponding author address:* Roberto V. Calheiros, Research Collaborator, SIMEPAR – Parana Meteorological System, Curitiba, Brazil; email: rv_calheiros@hotmail.com

The three different rainfall retrievals were checked against a rainfall climatology based on the rain gage network. Radar and gage data are described in the next section followed by sections on Processing and Results; a section on Comments and Conclusions close the paper.

2. DATA

Radar data used were volume scans every 7.5 min from December/2013 to February/2014. PPI at 0.5° elevation, and CAPPI at 3.27 km AMSL, taking into proper account ground clutter and bright band contamination, provided the data basis.

While data was acquired up to 250 km range, data processing was limited to 150km for derivation of the Z-R relationship. Rain gage data were provided by a set of 22 stations within the 150 km effective radar range, out of the CEMIG (Minas Gerais state hydropower company) network of 44 automatic stations in the 250 km full coverage.

Time resolution of the gage data was 15 min and data were from the same period as radar data. The CEMIG rain gage network is shown in the zoom of the radar area position which is in the upper left corner of Figure 1. Also, gage data from the National Institute of Meteorology (INMET) network of 9 automatic stations within or at the 150 km radar range, out of 20 stations for the full 250 km range were used in the study. Gage data were from DJF (December, January and February), for the CEMIG network from the 2009-2014 period and for the INMET network from the 2007-2014 period.

3. PROCESSING

Probability P(R´>=R) was computed for the Rio de Pedras station rainfall with 15 min time resolution, from the CEMIG network. The Rio de Pedras station is located at the Alto Rio das Velhas basin, a drainage area of specific operational interest to CEMIG, within a region of relative climatological rainfall homogeneity and at a radar range where no significant range effect was detected, and was then selected for this work.

For the radar reflectivity ZH data were integrated into 5 km x 5 km cell in the 3,27 km CAPPI and then the absolute probability

$$\mathrm{P}(\mathrm{Z}' \geq \mathrm{Z}, \mathrm{Z}_0) = \mathrm{P}(\mathrm{Z}' \geq \mathrm{Z}|\mathrm{Z}_0)\mathrm{P}(\mathrm{Z}_0).$$

was computed. The resulting CDF were matched (Calheiros and Zawadzki, 1987) and a file of Z, R pairs were generated. A power law relationship was adjusted to the Z, R curve, in log scale, for the 32-44 dBZ interval.

Maps of accumulated rainfall for DJF were elaborate for:

a) The INMET rain gage network, taken as an average for DJF along the 2007-2014-year period,
b) The CEMIG rain gage network, taken as an average for DJF along the 2010-2014-year period,
c) The radar rainfall from the default generic tropical Z=250R$^{1.25}$ relationship presently operational in the CEMIG radar,
d) The radar rainfall from the local Z-R relationship from this work, and
e) The radar rainfall from the R(Z, KDP) algorithm employed by Crisologo et al (2014) expressed below:

$$\mathrm{R}(\mathrm{Z}, \mathrm{KDP}) = w.R(KDP) + (1-w).R(Z)$$

$$\text{with} \begin{cases} 0, & \text{for } KDP \leq 0.5 \\ 2KDP - 1, & \text{for } 0.5 < KDP < 1 \\ 1, & \text{for } KDP \geq 1 \end{cases}$$

where:

$R(Z) = 56.3\, R^{1.6}$ and

$R(KDP) = 129(|KDP|/f)^{0.85}\,\mathrm{sign}(KDP)$.

All maps were elaborated covering the full 250 km radar range.

4. RESULTS

The curves and maps resulting from the processing are presented in the sequence.

The CDF for the Rio de Pedras station and the radar are associated in the same Figure 2 illustrating the process of obtaining the Zi,Ri pairs.

Figure 3 is a plot of the Zi,Ri with the adjusted power law curve.

Figure 4 comprises a set of figures (a) to (e) reproducing the maps described in Section 3 of this paper, following the same order of the listing.

5. COMMENTS AND CONCLUSIONS

The radar-rainfall relationship derived in this work is comparable to the relationship used for hydrological purposes with the Bauru radar which is situated in a contiguous area from the same Brazilian region (Calheiros and Gomes, 2011).

Due to the apparent range effects in the radar 2013/2014 DJF accumulation maps, derivation of the local Z-R was restricted to the 150 km range in an attempt to mitigate those effects.

While a thorough quantitative analysis is required to robustly substantiate the impact of the applied algorithms on the rainfall retrievals, in general it is noticed that the accumulated rainfall map elaborated with the generic tropical relationship presently used as a default relationship with the CEMIG radar underestimated the accumulated rainfall, when compared to corresponding gage accumulated maps taken as reference.

On the other hand, the corresponding accumulated rainfall maps from both the local R(Z) and the R(Z,KDP) algorithms show accumulations closer to the reference gage maps.

Also, the local relationship seems to perform better than the R(Z, KDP) polarimetric algorithm for the specific accumulations maps elaborated in this work.

When comparing the maps it should be taken into account that the maps for the gage networks are averages of accumulated DJF values for a relatively long period, e.g. 7 summers for the INMET network and 5 summers for the CEMIG network, while radar maps are from one DJF period.

For the derivation of the local relationship, however, this is methodologically taken into account (Calheiros and Zawadzki,1987). It should also be considered in the comparisons that the rain gage networks feature, mainly, either a relatively small number of gages, as is the case with the INMET network, or spatial coverage discontinuities due to clustering of gages, occurring with the CEMIG network.

Further work includes the exploration of other algorithms in addition to the above mentioned quantification issue.

REFERENCES

Calheiros, R. V., Zawadzki, I., 1987: Reflectivity-Rain Rate Relationships for Radar Hidrology in Brazil, Journal of climate and Applied Meteorology, **26**, 118-132.

Calheiros, R. V. and Gomes, A.M., 2011: Impact of Z-R Relationship on Flow Estimates in Central São Paulo, International Association of Hydrological Sciences - IAHS-AISH Publication, Red Book Publ.351, England, UK.

Crisologo, I., Vulpiani, G., Abon, C. C., David, C. P. C., Bronstert, A. and Heistermann, M., 2014: Polarimetric Rainfall Retrieval from a C-Band Weather Radar in a Tropical Environment (The Philippines). Asia-Pacific Journal of Atmospheric Sciences, 50, 595-607

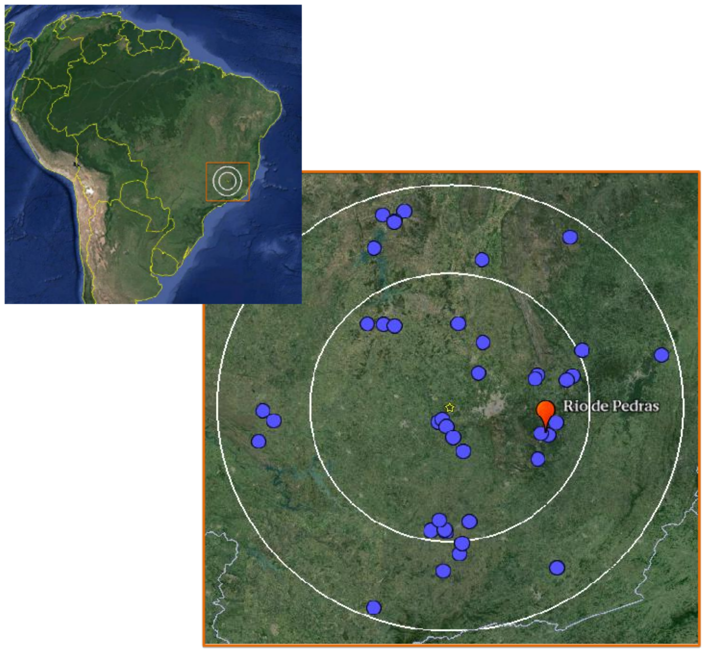


Figure 1: Radar coverage area to 150 km and 250 km and the CEMIG network (blue dots). The Rio de Pedras station is indicated in red.

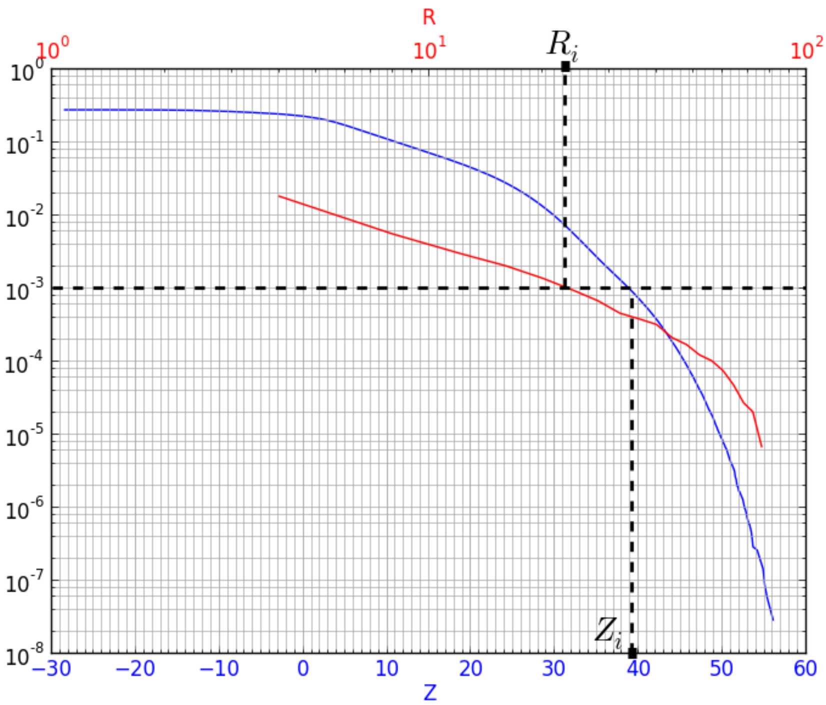


Figure 2: CDF for Z and R (display from 4 mm/h). Probabilities as in Calheiros and Zawadzki (1987).

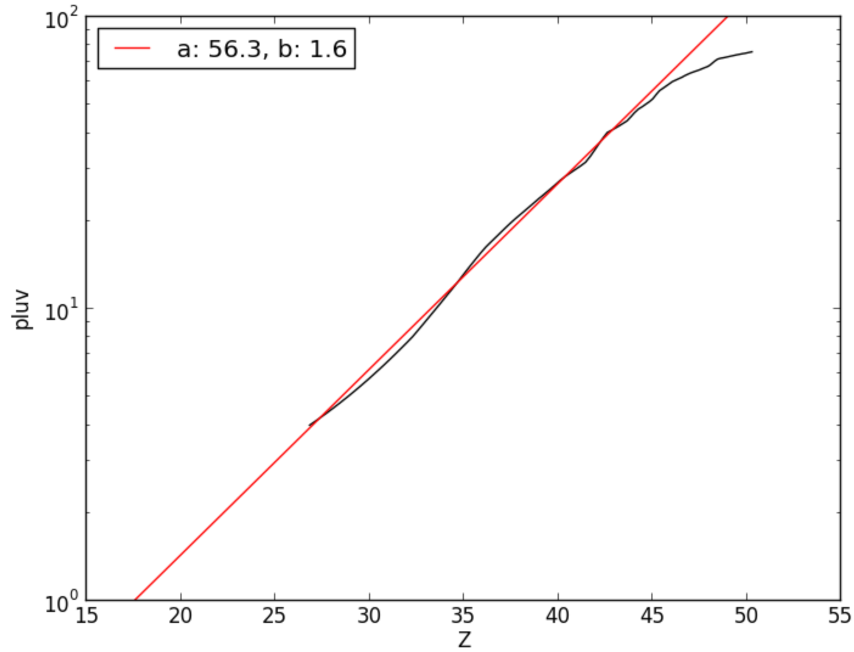


Figure 3: Z-R conversion relationship as a power law adjustment to the curve from the Z,R pairs defined by the same Z and R probability level (displayed from 4 mm/h).

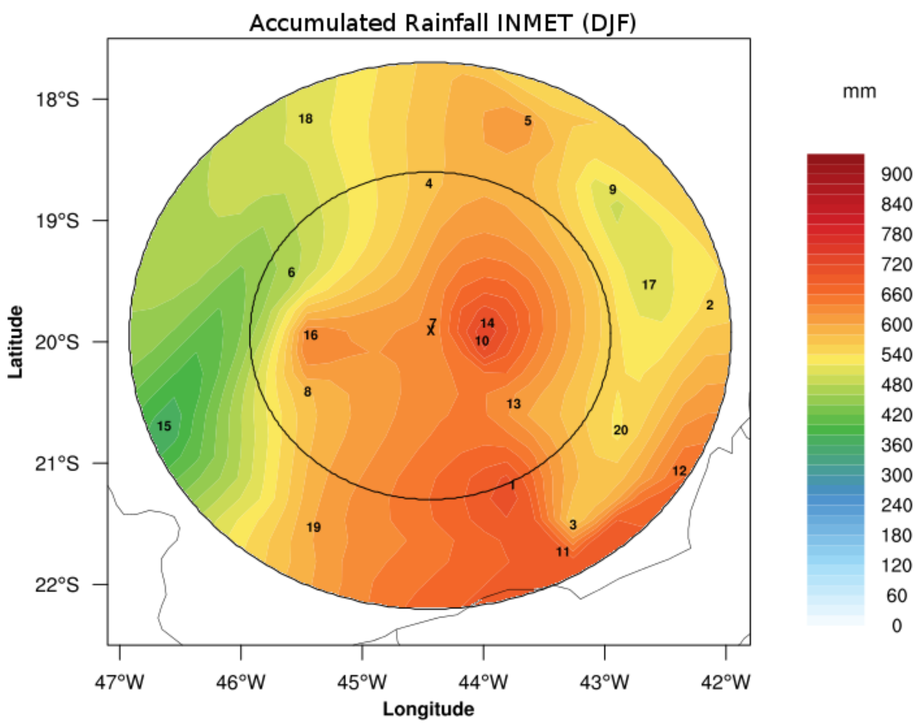


Figure 4(a): Accumulated rainfall for DJF averaged over seven summer seasons, from the rain gauge network of INMET (Brazilian weather service) as depicted in the map.

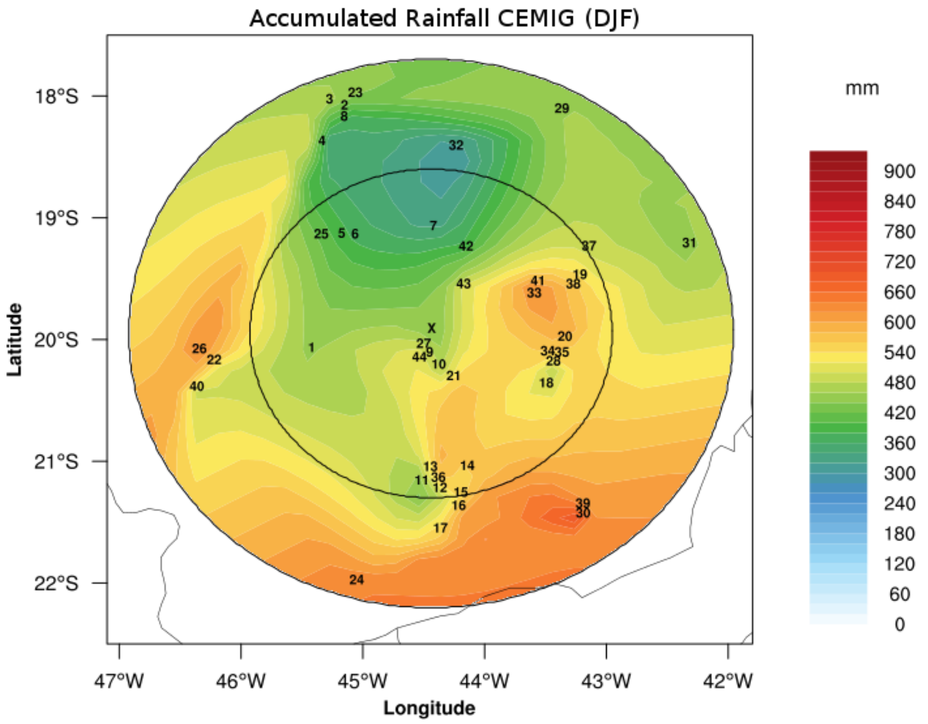


Figure 4(b): Accumulated rainfall for DJF averaged over five summer seasons, from the Minas Gerais state hydropower company, CEMIG, rain gauge network as depicted in the map.

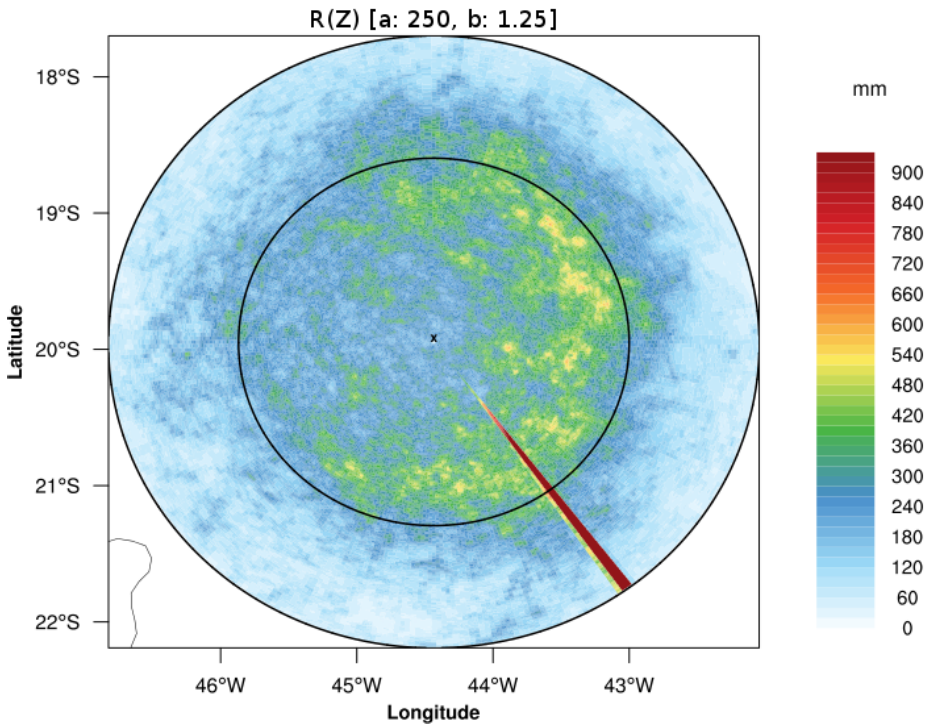


Figure 4(c): Accumulated radar rainfall for DJF December, 2013 to February, 2014 computed with the tropical relation $Z = 250\ R^{1.25}$ presently used by CEMIG, 0.5° PPI

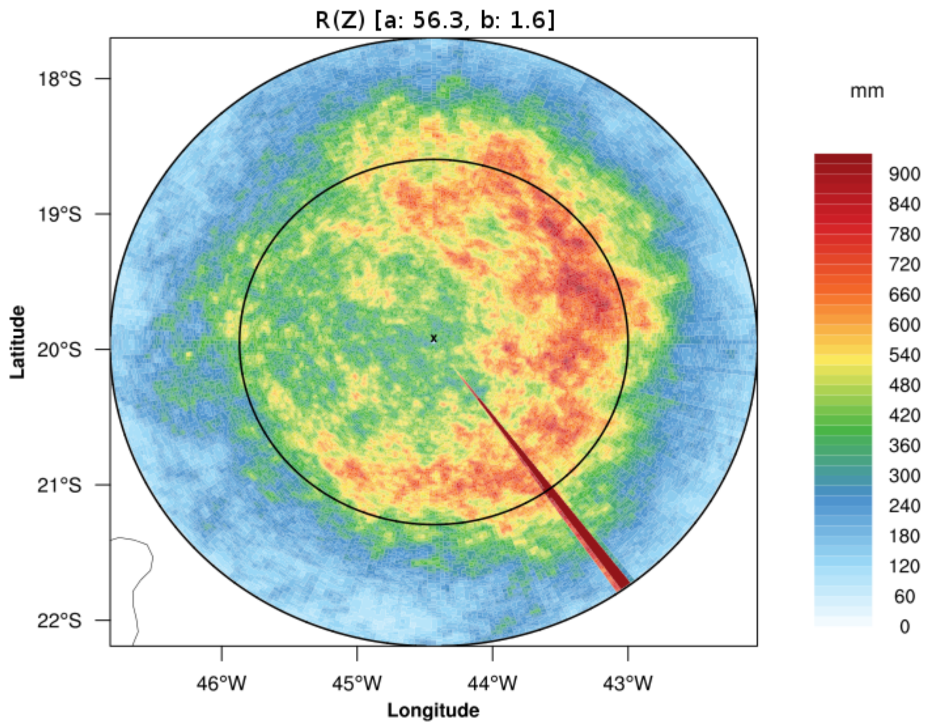
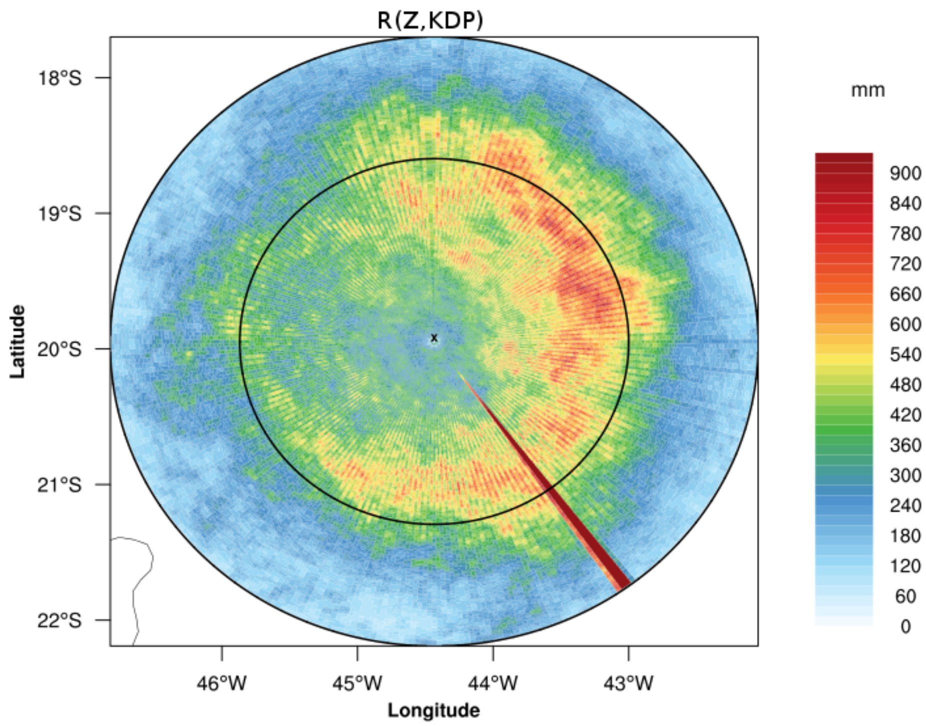


Figure 4(d): Accumulated radar rainfall for DJF December, 2013 to February, 2014 computed with the local relation $Z = 56\ R^{1.6}$, 0.5° PPI.



(every other ray is collected)

Figure 4(e): Accumulated radar rainfall for December/2013 to February/2014 computed with the polarimetric algorithm R(Z,KDP), 0.5° PPI.