CROSS-VALIDATION OF CSU-CHIVO RADAR AND GPM DURING RELAMPAGO

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ABSTRACT

This paper describes the deployment and features of CSU-CHIVO radar during the RELAMPAGO campaign in Argentina. Intercomparison with GPM-DPR is done using Volume Matching. Vertical profile analysis of storms is also shown and a list of GPM overpasses and summary of the tallest storms during the campaign are also included. The results show that CHIVO agree well with GPM in terms of reflectivity and microphysical structure of clouds and show the value of CHIVO for ground validation.

Index Terms— GPM, DPR, Remote Sensing, Weather Radar, Precipitation Measurement, Ground Validation, RELAMPAGO

1. INTRODUCTION

RELAMPAGO (Remote sensing of Electrification, Lightning, And Mesoscale/microscale Processes with Adaptive Ground Observations) was an international field campaign funded by NSF, NASA, NOAA, MinCyT, FAPESP. It took place in Argentina near Sierras de Cordoba with an Intense Observing Period (IOP) from November 1st to Dec 15th of 2018 [1]. It was aimed at measuring various weather parameters that will allow a better understanding of Convective Initiation, Severe Weather and Upscale Growth in sub-tropical South America. The region, amid the Sierras in Argentina, permits the formation of significant amount of severe weather events such as super cells, MCS, heavy rain and large hail. A dense network of weather sensors was deployed all over the Cordoba region which includes CHIVO C-band radar, disdrometers, hail pads, weather station, among others.

During the campaign, GPM made several passes over the Cordoba region with significant weather occurring for few cases. That give the opportunity to use Dual Precipitation Radar (DPR) onboard GPM to analyze the structure of storms during the campaign. DPR has two radars collecting precipitation data at two different bands concurrently, Ku and Ka, which allow for gathering information on precipitation globally [2].

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This combination of severe events and a dense network of sensors in the same region is a significant opportunity to analyze the effects of severe conditions using C-band radar, which is known to have a better sensitivity but greater attenuation than S-band [3]. We study three different C-band radars that were deployed in the region of interest, some of t them are: Colorado State University C-band Hydrological Instrument for Volumetric Observation (CSU-CHIVO), First Radar Meteorologico Argentino (RMA1) and Atmospheric Research Measurement C-band Scan Precipitation Radar 2 (ARM-CSPR2). In the future we will include additional radar observations available in the program. In addition to collecting data during the IOP, an extended period of observation lasting from December 15th to January 31st during which CHIVO, RMA1 and ARM-CSAPR2 radars were still in operation and observing intense weather. The dense network of in situ sensors deployed in the region (disdrometers, gages, hail pads) provides a ground point of view of the storm and facilitates the interpretation of radar products. The following figure shows the location of the radars.

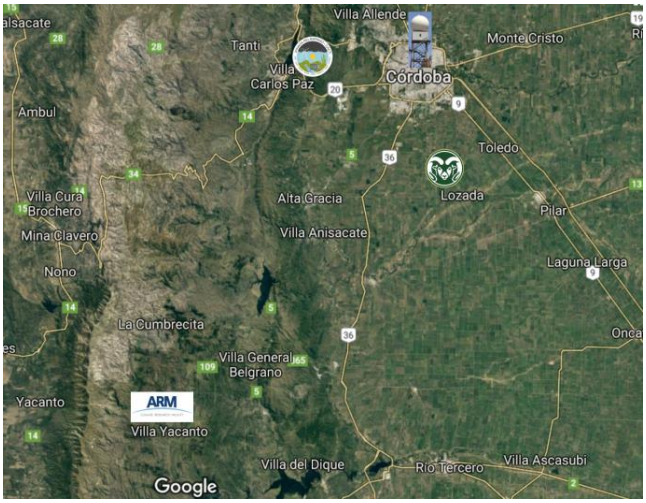

Figure 1. Location of Radars during RELAMPAGO, CSU logo means CHIVO, ARM is the location for CSAPR2 , RELAMPAGO means Obs. Center in Villa Carlos Paz and radar in Cordoba City is the RMA1 site (Radar Meteorologico Argentino)

RELAMPAGO domain is known for having some of the tallest storms studied in detail. For some intense cases, cloud top reaches more than 20 km, going beyond the stratosphere. Table I lists the events with tallest storms during the campaign, including the extended period.

TABLE I
List of tallest storms during RELAMPAGO that CHIVO captured

Date	Time	Mission
2018/11/10	21 – 23 UTC	IOP 04, Severe
2018/12/14	00 – 05 UTC	IOP 17, Upscale
2019/01/25	18 – 23 UTC	Extended Period

CHIVO is a C band commercial grade weather radar which has dual polarization capability and uses a Sigmet Digital Receiver and RVP900 Signal Processor to compute products such as reflectivity, ZDR, PHIDP, KDP. During the RELAMPAGO field campaign CHIVO was deployed for about 3 months of continuous operation with good performance. Fig. 2 shows CHIVO in Lozada site south of Cordoba City. Fig. 3 shows one of the tall severe storms during the campaign. The attenuation corrected moments and HydroClass were obtained using DROPS 2.0 [4].

Figure 2. CSU C-Band radar deployed near Alta Gracia – Argentina during RELAMPAGO

This paper is organized as follows. Section 2 shows the procedures that are used to perform the intercomparison between CHIVO and GPM-DPR. Results and Conclusions are showed in Section 3 and 4 respectively.

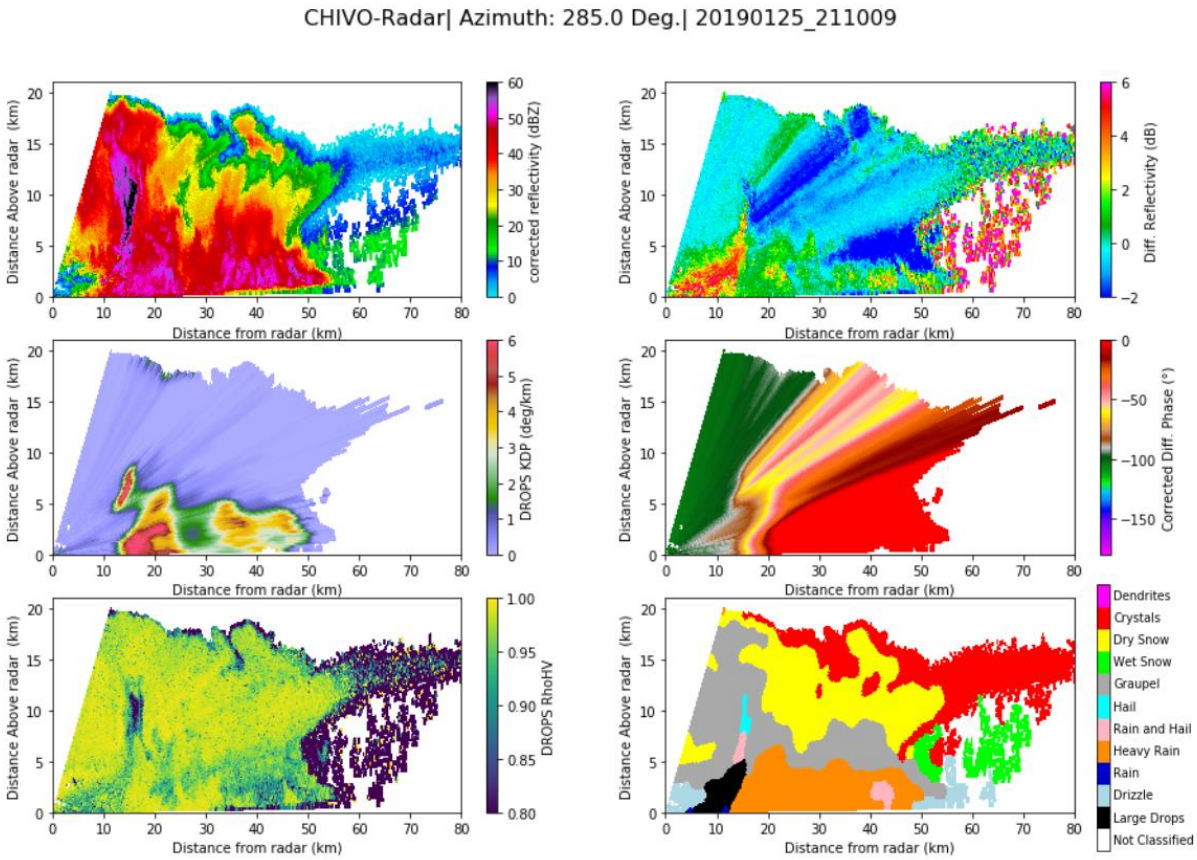

Figure 3. CHIVO moments when Jan .25th storms was over the radar

2. METHODOLOGY

Intercomparison between C-band radars in Tropical South America and GPM-DPR was presented initially in [5] . There, the authors proposed a methodology to perform a comparison between a C-Band radar and DPR that consider effects of attenuation on reflectivity. A similar procedure is used in this study.

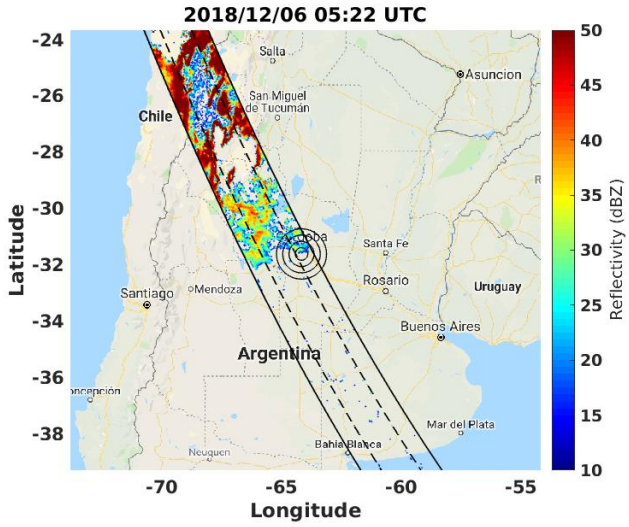

Figure 4. GPM overpass over Cordoba Region, solid lines mean Normal Swath and dashed line Matched Swath, rings mean CHIVO each one 25 km

Giving the kind of severe events that were captured during RELAMPAGO, attenuation correction is needed. The methodology presented in [6] is used to performed attenuation correction to the data. In addition, lower PPI sweeps are taken out of the comparison since they suffer ground clutter contamination. After performing the attenuation correction, the Common Volume methodology is applied to find the geometry that matches DPR and CHIVO [7]. The metrics that are used to measure the performance of the comparison are the Bias, Pearson Correlation Coefficient and Root Mean Square Error. They are described in the following formulas respectively:

$$BIAS = E[GR - DPR] \quad (1)$$

$$CORR = \frac{Cov(GR, DPR)}{\sigma_{GR}\sigma_{DPR}} \quad (2)$$

$$RMSE = (E[(GR - DPR)^2])^{1/2} \quad (3)$$

Where $E[.]$ is the expected value, $Cov(.,.)$ is the covariance between two random variables and σ the estimation of the standard deviation.

Table II shows a list of GPM overpasses during the campaign with significant weather. Dec. 6th case is analyzed in this paper since is the case with the most weather. Fig. 4 shows the aforementioned overpass, while Fig. 5 shows the reflectivity for CHIVO during the overpass.

TABLE II
List of GPM overpasses during RELAMPAGO with significant weather

Date	Time
2018/12/06	05:22 UTC
2018/12/20	10:40 UTC
2019/01/13	04:00 UTC

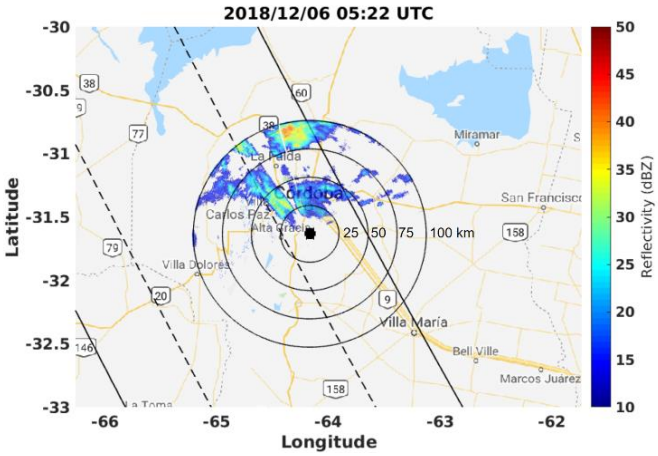

Figure 5. CHIVO Reflectivity

CHIVO scan strategy at the time of the overpass was RHI and PPI in 5 minutes interval. This provides a valuable dataset since vertical profile analysis can be done. For this study case, CHIVO RHI in 315° azimuth overlap significantly well with bin 39 of Normal Swath (NS) of GPM. Fig. 6 shows the location of the RHI and DRP track.

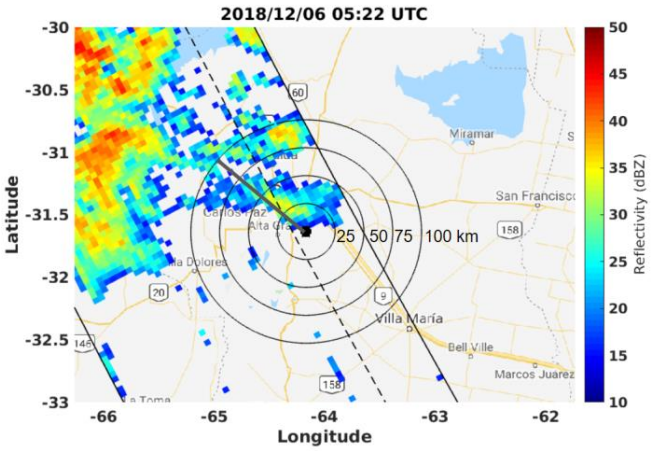

Figure 6. Dec. 6th Overpass, dashed line is along the track of bin 39 of DPR Normal Swath and solid line means CHIVO RHI in 315° azimuth

3. RESULTS

Fig. 7 shows vertical analysis for both GPM and CHIVO. Note the vertical structure of the storms shows similar patterns for both platforms. For instance, melting layer is located at the same height ~ 2.5 km and cloud top also coincides.

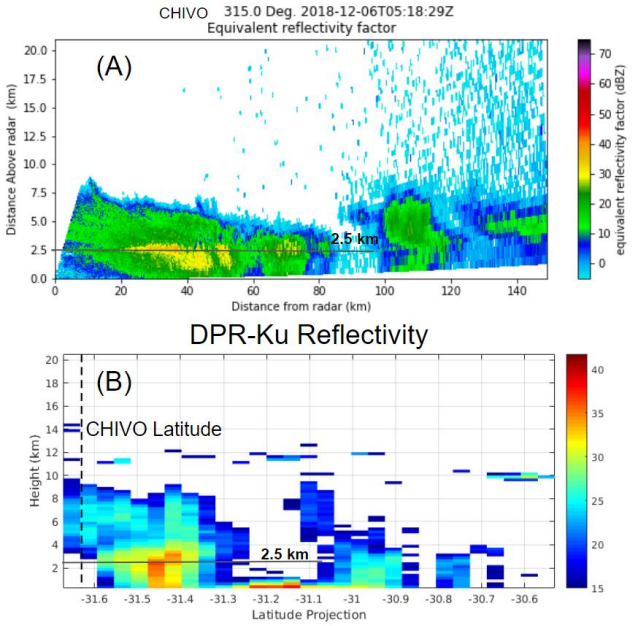

Figure 7. (A) CHIVO RHI, (B) GPM-DRP along 39 bin of Normal Swath

Fig. 8 shows the results of reflectivity cross-comparison between CHIVO and DPR for Dec. 6th overpass at 5:22 UTC. Low elevation sweeps were removed since the radar is close to the foothills of Sierra de Cordoba and ground clutter contamination shows to affect significantly the comparison. Note Bias is less than 0.5 dB and correlation is almost 90%.

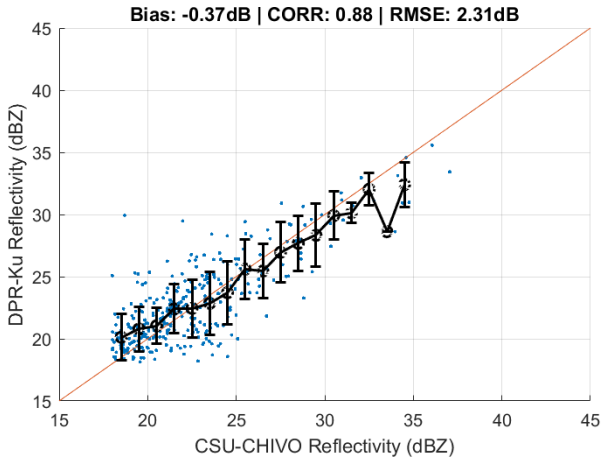

Figure 8. CHIVO and DPR reflectivity comparison for Dec. 6th case at 5:22 UTC

4. CONCLUSIONS

The results show that the CSU-CHIVO compare well with GPM-DPR with a high correlation to within 88% and bias within 1 dB. Also, results show the value of CHIVO for ground validation of GPM.

ACKNOWLEDGMENT

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REFERENCES

[1] S. Nesbitt, P. Salio, R. Trapp, R. Roberts, A. Varbel, F. Dominguez, L. Mchando, and C. Saulo, "Understanding Processes and Improving Predictions of Hydrometeorological Extremes in Subtropical South America: Proyecto RELAMPAGO-CACTI," in *AMS 98th Annual Meeting*, 2018.

[2] A. Y. Hou, R. K. Kakar, S. Neeck, A. A. Azarbarzin, C. D. Kummerow, M. Kojima, R. Oki, K. Nakamura, and T. Iguchi, "The global precipitation measurement mission," *BAMS*, no. May, pp. 701–722, 2014.

[3] V. N. Bringi and V. Chandrasekar, *Polarimetric Doppler Weather Radar: Principles and applications*. Cambridge University Press, 2001.

[4] H. Chen and V. Chandrasekar, "Validation of NASA's Global Precipitation Measurement mission with a high-resolution ground radar network," in *URSI Asia-Pacific Radio Science Conference (URSI AP-RASC)*, 2016, pp. 836–839.

[5] I. Arias and V. Chandrasekar, "CROSS VALIDATION OF GPM AND GROUND-BASED RADAR IN LATIN AMERICA AND THE CARIBBEAN," in *IGARSS*, 2018, pp. 3891–3893.

[6] S. Lim and V. Chandrasekar, "A Robust Attenuation Correction System for Reflectivity and Differential Reflectivity inWeather Radars," *IEEE Trans. Geosci. Remote Sens.*, vol. 54, no. 3, pp. 1727–1737, 2016.

[7] S. M. Bolen and V. Chandrasekar, "Methodology for aligning and comparing spaceborne radar and ground-based radar observations," *J. Atmos. Ocean. Technol.*, vol. 20, no. 5, pp. 647–659, 2003.