Microphysical parameters retrieval of rainfall using Ka band radar profiler at central Andes of Peru

UNIVERSIDAD NACIONAL JOSÉ FAUSTINO SÁNCHEZ CARRIÓN

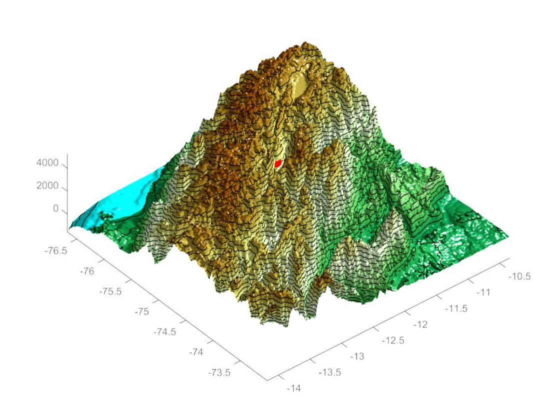
Jairo M. Valdivia[1,2], Yamina Silva[1] y Danny E. Scipión[1]

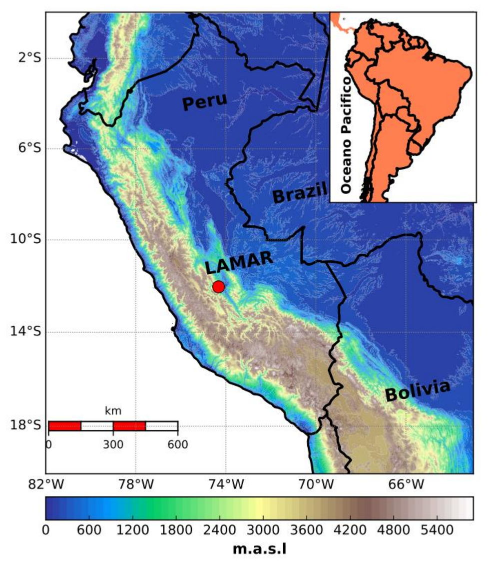
[1] Instituto Geofísico del Perú (IGP), [2] Universidad Nacional José Faustino Sánchez Carrión

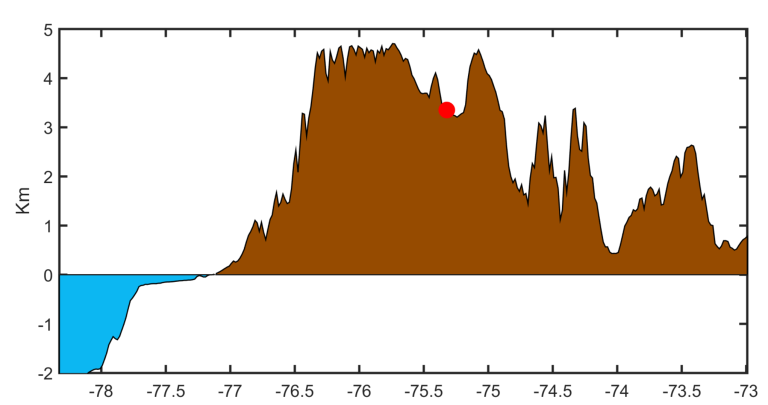
Introduction

In 2015, the Geophysical Institute of Peru implemented the Atmospheric Microphysics and Radiation Laboratory (LAMAR), Huancayo Observatory, at 3300 m.a.s.l.; in order to obtain atmospheric data to study the microphysical processes associated with water and energy balance. A Ka band cloud-profiling radar, MIRA-35c (by METEK) is one of the main instruments.

Figure 1. Location of Atmospheric Microphysics And Radiation Laboratory







Problems

- The different techniques for estimating precipitation differ from observed data.
- Original software of MIRA 35c has errors in the estimation of precipitation and did not have the drop size distribution (DSD) as a product.

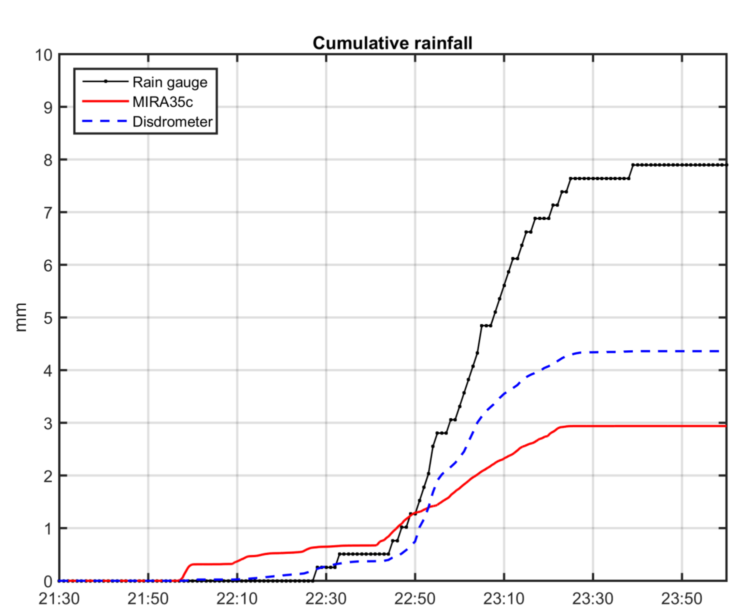


Figure 2. Comparison of rainfall measurements using rain gauge, disdrometer and MIRA 35c.

Methods

The microphysical parameters retrieval method is in analog to the methodology described by Peters *et al.* (2005):

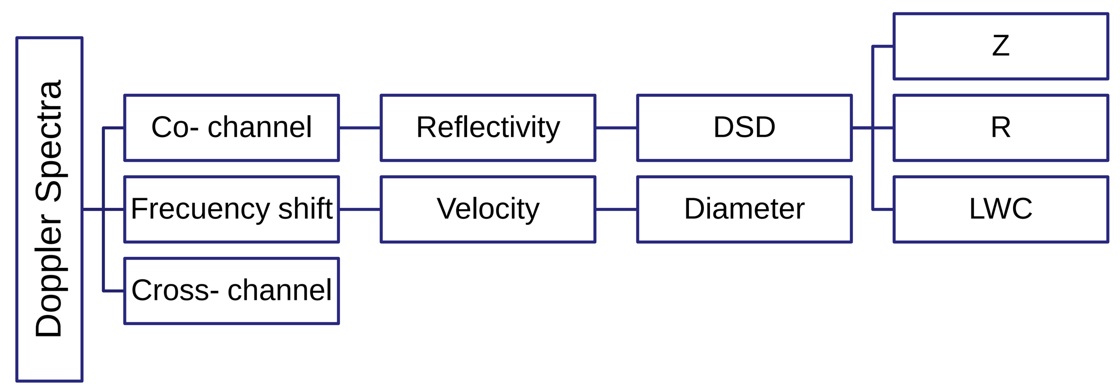


Figure 3. Flow diagram for rainfall. microphysical parameters retrieval.

The spectral reflectivity $\eta(f)$ as function of Doppler frequency f is obtained by

$$\eta(f,r) = p(f,r).C.r^2$$

where C is radar constant. The DSD is given by,

$$N(D,r)\Delta D = \frac{\eta(D,r)}{\sigma(D)}\Delta D$$

where $N(D,r)$ is the spectral density of drops at height r and $\eta(D,r)$ is the spectral backscattering cross section volume. The back scattering cross section of a single particle, $\sigma(D)$, is calculated using Mie scattering theory, (Bohren and Huffman, 1983).

Drop diameter is calculated using the Gunn and Kinzer (1949) equation:

$$D(v,r) = \frac{1}{0.6}\ln\frac{10.3}{9.65 - v/\delta(r)}$$

The height dependence of the terminal fall velocity due to change in air density, $\delta(r)$, is approximated as a second-order polynomial (Foote and Du Toit, 1969).

From DSD different rain parameters are calculated:

$$Z = \int N(D)D^6 dD$$

$$LWC = \rho_w(\pi/6)\int N(D)D^3 dD$$
$$R = (6x10^5\,\pi)\int N(D)v(D)D^3 dD$$

Correction Algorithm for wet antenna attenuation:

In rainfall events the backward power is severely attenuated by the water in the antenna. We do not know how much is exactly the attenuation, but we can measure the error related about it.

To estimate the wet antenna attenuation, we use the influence of rainfall on noise power as reference (see Fig, 4). Attenuation is estimated computing a exponential function with the least error.

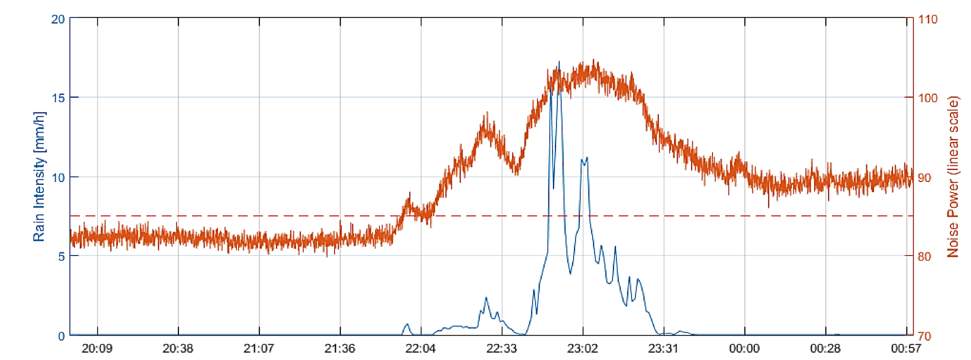


Figure 4. Rain intensity of disdrometer (blue) and radar internal noise level (orange), in dashed lines the value 86 of the noise.

Results

The algorithm of attenuation correction indicates that the attenuation can reach 9 dB (Fig. 5)

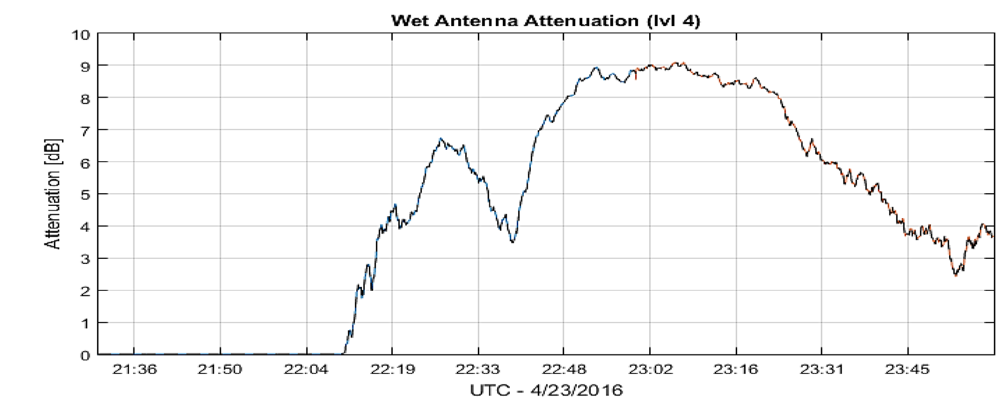


Figure 5. Attenuation estimates for an event of rainfall. April 23, 2016.

Using Doppler spectra the DSD was retrieved (Fig. 6), and we used the DSD to calculate rainfall rate, liquid water contain and reflectivity (Fig. 7).

To evaluate the rainfall rate, we analyzed a month of data and it was compared with a rain gauge as daily and hourly data. The absolute errors was 2.4 mm and 1.2 mm respectively. In both cases the mean error is around of 12%

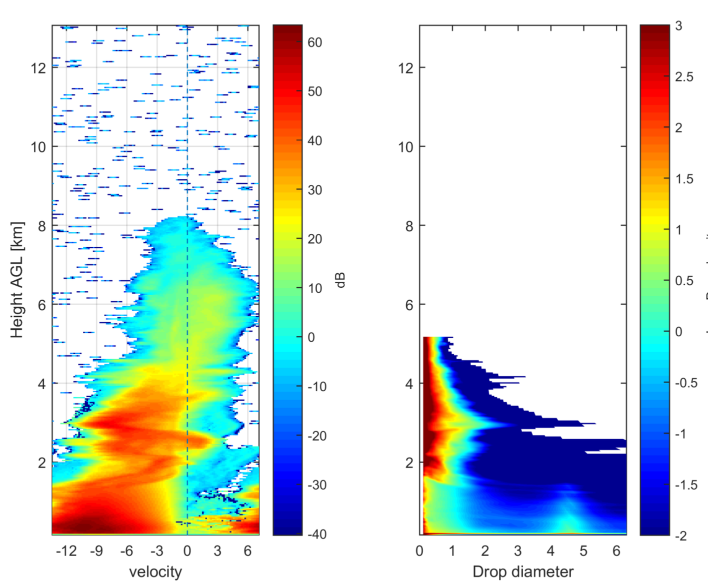


Figure 6. Mean Doppler spectra (left) and mean DSD (right). Apr. 04, 2016.

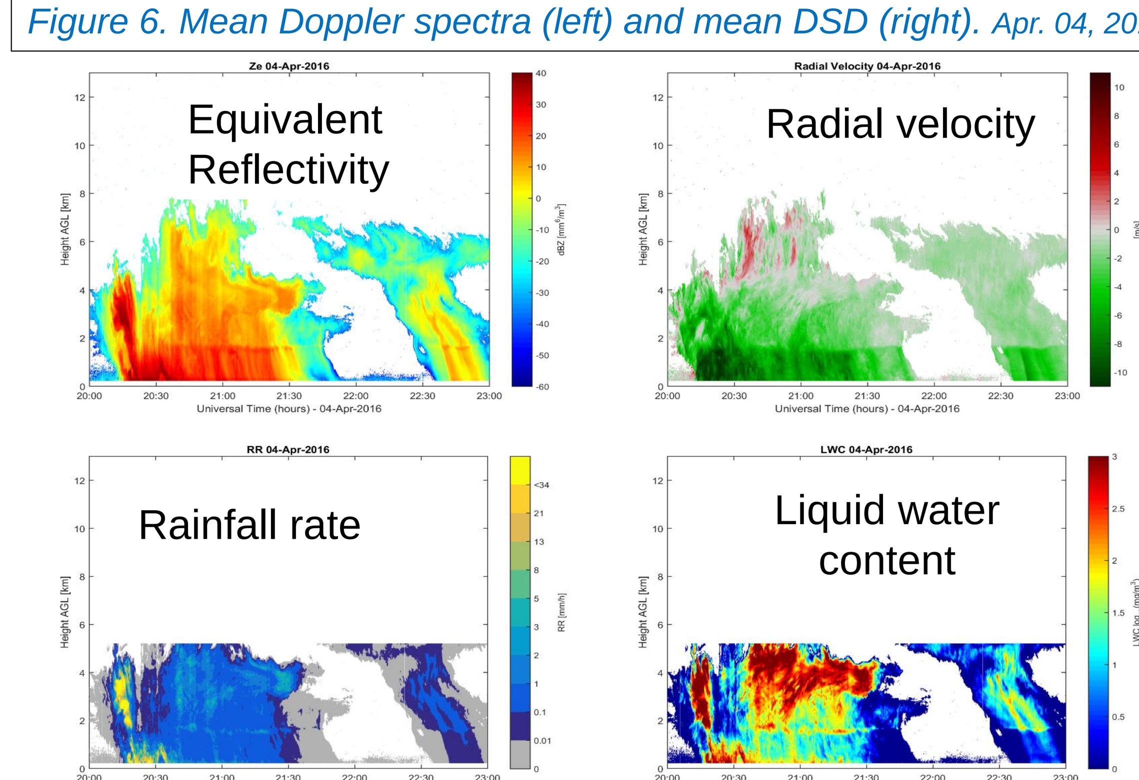


Figure 7. Some retrieved microphysical parameters of rainfall. Apr. 04, 2016.

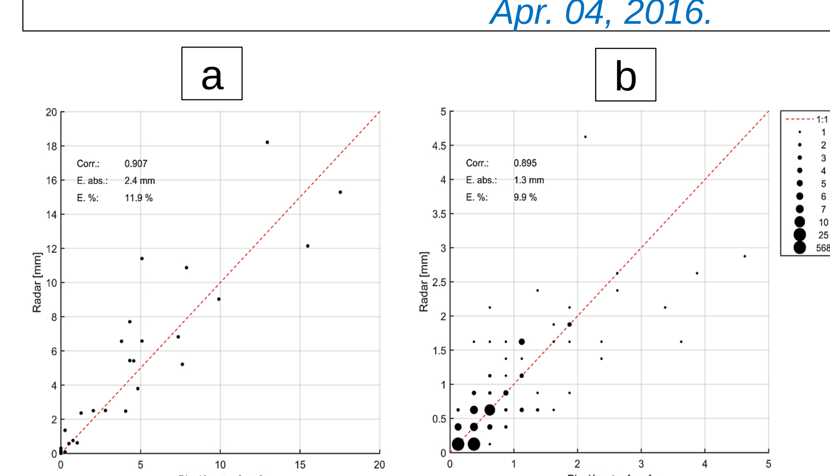


Figure 8. Scatter plots. Rain gauge vs. MIRA 35c of cumulative rainfall of a month of data. a) Diary data, b) Hourly data.

Conclusions

- In this work we have used the Doppler spectra to obtain DSD, and then the different microphysical parameters of rainfall.
- Wet antenna attenuation correction is necessary to estimate the precipitation, and a algorithm was developed.
- The radar cumulated rain presents variations in small time scales that tend to compensate in long periods (a day or more). This is because the correction algorithm is not representing the attenuation in the best way, more studies are required.

MIRA 35c specifications:

- Ka band @34.85GHz ~ 8.6 mm
- Monostatic – pulsed – magnetron
- Beam width 0.6°
- Doppler
- Polarimetric (co- & cross-)
- Time resolution, 5.3 s
- Range resolution, 31 m
- Range, 0.2 – 13 km

a

b

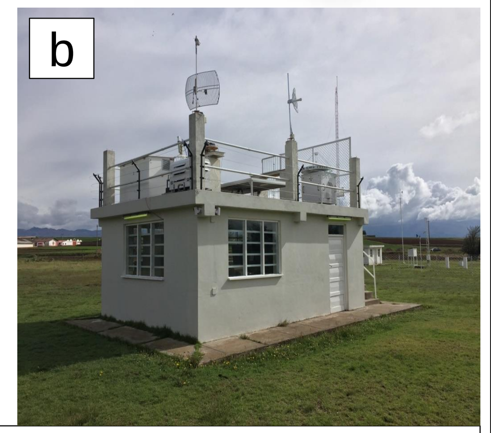


Figure 9. a) MIRA 35c. b) Radar location photography at Huancayo Observatory

Bibliography

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Acknowledgement:

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