Attenuation Documentation

Andrew Lowry
Climate Research Group

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1 Introduction

This code calculates the attenuation of Z_{hh} and Z_{dr} caused by passage of the radar beam through precipitation, and corrects Z_{hh} and Z_{dr} for this attenuation. There is no additional output from this function, although changes are made to the Z_{hh} and Z_{dr} variables.

This algorithm uses self-consistency methodology developed from Bringi & Chandrasekar 2001 and Park et al. 2005 Pts. I & II. Bringi & Chandrasekar 2001 outline the algorithm and Park et al. 2005 presents considerations for X band radar.

2 Algorithm - Code

This section will describe the algorithm in attenuation_calc.m

Step 1

Input the data for Z_{hh}, Z_{dr}, ρ_{hv} and ϕ_{dp} and load the noise profile from the configuration file. Determine the signal to noise ratio (SNR), using the SNR threshold set in the configuration file. Calculate the range vector for the data.

Step 2

Set the constants to be used later in the algorithm:

$0.025 \leq \alpha \leq 0.575$	see Park et al. 2005 Pt. II.
$b = 0.780$	see Park et al. 2005 Pts. I & II.
$p = 0.051$	see Eq. 1 in Park et al. 2005 Pt. II.
$q = 0.486$	see Eq. 1 in Park et al. 2005 Pt. II.

Step 3

For each radial in the data, loop through the range gates to determine the start and end of each rain cell. The start of a rain cell is determined where 5 consecutive gates have both SNR > 5 and $\rho_{hv} > 0.7$. In practice this is done using a convolution along each radial of 9 gates and taking the start of the rain cell to be where this convolution is ≥ 5. The end of a rain cell is determined in a similar manner, except a convolution of 5 gates is used and the end of the rain cell is where this is ≤ 1. The data is padded prior to the convolution so that the output is the same size as the data. This step produces a 2 x n vector indicating the start and end locations of any rain cells along the radial, where n is the number of rain cells.

Step 4

Iterate over each rain cell along the radial and perform the attenuation algorithm for reflectivity. For each rain cell also loop over the range of α from Step 2. First calculate

$$I(r_s, r_e) = 0.46b \int_{r_s}^{r_e} \left[Z'_{hh}(s)\right]^b ds \tag{1}$$

where r_s and r_e are the start and end of the rain cell respectively, and Z'_{hh} is the uncorrected reflectivity in linear units ($mm^6 m^{-3}$). Then calculate

$$I(r, r_e) = 0.46b \int_{r}^{r_e} \left[Z'_{hh}(s)\right]^b ds \tag{2}$$

and

$$A_h(r) = \frac{\left[Z'_{hh}(r)\right]^b \left(10^{0.1b\alpha\Delta\phi_{dp}} - 1\right)}{I(r_s, r_e) + \left(10^{0.1b\alpha\Delta\phi_{dp}} - 1\right) I(r, r_e)} \tag{3}$$

where $\Delta\phi_{dp} = \phi_{dp}(r_e) - \phi_{dp}(r_s)$. Then calculate a derived version of ϕ_{dp}

$$\phi_{dp}^{cal}(r; \alpha) = 2 \int_{r_s}^{r} \frac{A_h(s; \alpha)}{\alpha} ds \tag{4}$$

and minimise the error of ϕ_{dp}

$$\text{Error of } \phi_{dp} = \sum_{i=1}^{N} \left|\phi_{dp}^{cal}(r_i; \alpha) - \phi_{dp}(r_i)\right| \tag{5}$$

where i denotes the range gate index from r_s to r_e. Eq. (5) is the difference between the measured and filtered ϕ_{dp} and that derived from Eq. (4). The value of α that minimises Eq. (5) is then used with Eq. (3) to calculate the corrected reflectivity

$$10\log_{10}\left[Z_{hh}(r)\right] = 10\log_{10}\left[Z'_{hh}(r)\right] + 2\int_{r_s}^{r} A_h(s) ds \tag{6}$$

Step 5

Calculate the attenuation corrected differential reflectivity. First calculate the corrected differential reflectivity at the end of the rain cell (r_e)

$$Z_{dr}^{cor}(r_e) = \begin{cases} 0 & \text{when} \quad Z_{hh}(r_e) \leq 10 \text{ dBZ} \\ p10\log_{10}\left[Z_{hh}(r_e)\right] - q & \text{when} \quad 10 < Z_{hh}(r_e) \leq 55 \text{ dBZ} \\ 2.3 & \text{when} \quad Z_{hh}(r_e) > 55 \text{ dBZ} \end{cases} \tag{7}$$

where $10\log_{10}[Z_{hh}(r_e)]$ is the corrected reflectivity in Eq. (6) in dBZ. Then using Eq. (7) calculate γ_{opt}

$$\gamma_{opt} = \frac{1}{\alpha_{opt}} \frac{|Z'_{dr}(r_e) - Z^{cor}_{dr}(r_e)|}{\phi_{dp}(r_e) - \phi_{dp}(r_s)} \tag{8}$$

where $Z'_{dr}(r_e)$ is the measured differential reflectivity at the end of the rain cell. Then using Eq. (8) calculate the attenuation corrected differential reflecting

$$Z_{dr}(r) = Z'_{dr}(r) + 2\gamma_{opt} \int_{r_s}^{r} A_h(s)ds \tag{9}$$