Ground Clutter Documentation

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April 27, 2016

1 Introduction

This code calculates the likelihood that a radar pixel is either precipitation or ground clutter. It then adds a precipitation and ground clutter field to the MATLAB struct with the names "precip_mask" and "gc_mask" respectively.

This algorithm uses a fuzzy logic methodology similar to that employed in precipitation type classification algorithms, but restricts itself to whether a pixel is ground clutter or not. This algorithm is developed from ideas in Gourley et al. 2007 and Rico-Ramirez & Cluckie 2008. Primarily this approach uses the algorithm described in Gourley et al. 2007. However we use more radar variables and derived variables, and employ a signal to noise ratio (SNR) threshold from Rico-Ramirez & Cluckie 2008.

2 Before Calling gc_calc.m

Prior to calling the function gc_calc.m you must calculate the normalised density functions for precipitation and ground clutter using the same radar settings as your data. The important radar settings are pulse width, pulse repetition frequency and rotation speed. You must develop these density functions from sufficient scans such that the density functions converge to their final form. Sometimes this can be just a few scans, but in any case the more scans the better. These density functions are passed into gc_calc.m through the configuration file.

3 Algorithm - Code

This section will describe the algorithm in gc_calc.m

Step 1

Load the density functions for precipitation and ground clutter from the configuration file. There are density functions for the two categories (precipitation and ground clutter) for each of the six input variables: $\sigma(Z_{dr})$, $\sigma(Z_{hh})$, $\sigma(\phi_{dp})$, $\sigma(\rho_{hv})$, ρ_{hv} and V. These density functions are sampled over domains that ensure $> 99\%$ of the density is captured.

Step 2

Calculate the area that is under both the ground clutter and precipitation density functions for each of the 6 density functions, using

$$A_i = \int_{x_s}^{x_e} \min_{x_s<x<x_e} \left[\hat{f}_i(x)\right] \tag{1}$$

where $\hat{f}(x)$ is calculated by,

$$\hat{f}(x) = \frac{1}{\sigma\sqrt{2\pi}} \sum_{i=1}^{n} e^{-\left[\frac{1}{2}\left(\frac{X_i - x}{\sigma}\right)^2\right]} \tag{2}$$

In (2) X_i is the ith observation of the input variable and x is the independent variable. σ is calculated using Silverman's rule ($\sigma = 1.06\mathrm{SD}n^{-1/5}$) and SD (Standard Deviation) is computed from the actual distribution. $\hat{f}(x)$ produces a smoothed histogram, which are the density functions. A_i in (1) is then used to calculate the weight (W_i) assigned to each input variable using

$$W_i = \frac{1}{A_i} \sum_{i=1}^{6} \frac{1}{A_i} \tag{3}$$

The result is that where there is less overlap between the precipitation and ground clutter density functions, the corresponding weight for that input variable is larger.

Step 3

Input the radar data and a noise profile using the same settings as the radar data. Then calculate the signal to noise ratio (SNR). The SNR is used to eliminate pixels close to the edge of precipitation cells, which can increase the values of the input variables. Therefore pixels where SNR $<$ 5 dBZ are not included in the standard deviation calculations, i.e. $\sigma(Z_{dr})$, $\sigma(Z_{hh})$, $\sigma(\phi_{dp})$ and $\sigma(\rho_{hv})$. From the resolution of the azimuth in the input data, a neighbourhood of 1.1km x 3° is calculated. The data is left in polar form to minimise smoothing from interpolation to a Cartesian grid. Then the standard deviation of Z_{dr}, Z_{hh}, ϕ_{dp} and ρ_{hv} is calculated for each radar pixel ($y_{a,b}$) using

$$\sigma(y_{a,b}) = \sqrt{\frac{1}{N-1}\left[\sum_{i=1}^{N}(y_i^2) - N\sum_{i=1}^{N}\left(\frac{y_i}{N}\right)^2\right]} \tag{4}$$

where N is the number of pixels in the neighbourhood that exceed the SNR threshold. In practice this is done by setting pixels below the SNR threshold to zero and taking the convolution in 2D over the neighbourhood for y and y^2 in (4).

Step 4

For each of the six variables ($\sigma(Z_{dr})$, $\sigma(Z_{hh})$, $\sigma(\phi_{dp})$, $\sigma(\rho_{hv})$, ρ_{hv} and V) lookup the density function value for each radar pixel for both precipitation and ground clutter. In practice this is done using spline interpolation of the density function.

Step 5

Calculate the aggregation value (Q_j) for precipitation and ground clutter using

$$Q_j = \frac{\sum_{i=1}^{6} \hat{f}(x)_i \cdot W_i}{\sum_{i=1}^{6} W_i} \tag{5}$$

The maximum aggregation value for each radar pixel determines if that pixel is precipitation or ground clutter, i.e. if $Q_{pre} > Q_{gc}$ then the pixel is classified as 'precipitation'.

Step 6

To avoid the misclassification of classes, thresholds are applied to each pixel where it is clear from the radar measurements that a given class should not be assigned. These thresholds are shown in Table 1.

Table 1: Empirical thresholds to suppress erroneous class assignments for precipitation and ground clutter

Variables	Thresholds	Suppressed Class Assignment
ρ_{hv}	< 0.7	Precipitation
Z_{hh}	5 dBZ	Precipitation
$\sigma(\phi_{dp})$	100°	Precipitation
V	5 m/s	Ground Clutter

Step 7

De-speckle the precipitation class in a 3 x 3 region surrounding each pixel. If the central pixel is precipitation and fewer than 3 of the neighbouring pixels are also precipitation, then the precipitation class is suppressed for the central pixel.