New Algorithm to Separate Cloud and Drizzle

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Introduction

- A new method to detect, estimate and separate cloud and drizzle echoes from vertically pointing Doppler spectra radar data.
- A parametric model is developed using the recorded radar Doppler spectra data to retrieve the signal spectral moments.
- Goodness of fit parameters are defined that specify features of the Doppler spectrum. If the detection parameters exceed pre-determined thresholds, the signal contains a mixture of cloud and drizzle.
- A drizzle map is specified and processed to reduce uncertainty due to turbulence and to accommodate the location of the cloud base. At the locations where cloud and drizzle co-exist, the model is modified to include drizzle and cloud spectral parameters.
- A similarity-based classifier is implemented to identify which echoes are associated with cloud or drizzle.

Methodology

1. Parametric time domain method (PTDM)

- If *N* echoes contained in the received signal, the radar power spectrum *S(v)* can be written as

$$S(v) = \sum_{i=1}^{N} S_i(v) + p_n$$

$$S_i(v) = \frac{P_i}{\sqrt{2\pi}\sigma_i} \exp\left[-\frac{1}{2}\left(\frac{v - \bar{v}_i}{\sigma_i} \right)^2 \right]$$

- The spectral moments of the signals can be obtained by minimizing the negative log-likelihood

$$L(\mu) = \ln(\det(\mathbf{R}(\mu))) + trace\left(\hat{\mathbf{R}}\mathbf{R}^{-1}(\mu)\right)$$

$$\mu = \left[\bar{v}_1, \sigma_1, P_1, \ldots, \bar{v}_N, \sigma_N, P_N, p_n\right]$$

where $\hat{\mathbf{R}}$ and $\mathbf{R}(\mu)$ are the covariance matrix from recorded power spectrum and the model covariance matrix, respectively.

2. Goodness of fit parameters

- $Tr_{\text{var}} = std\left\{diag\left(\hat{\mathbf{R}}\mathbf{R}^{-1}(\mu)\right)\right\}$ with its value close to zero indicating a good fit.

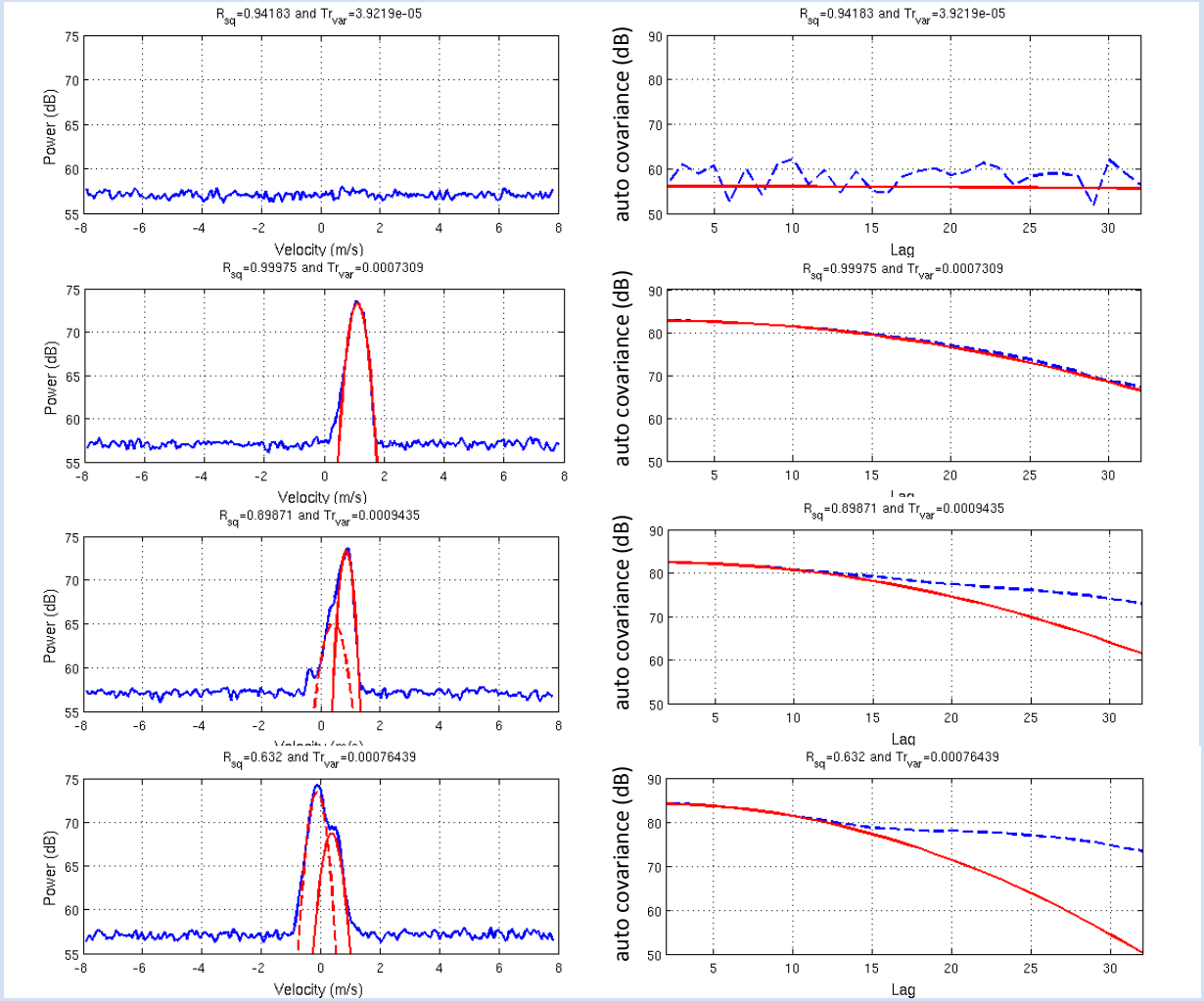
- R_{sq} is a fraction of the total signal variance explained by the model and the closer it is to unity, the better fit.

Representation of radar Doppler spectra and goodness of fit parameters

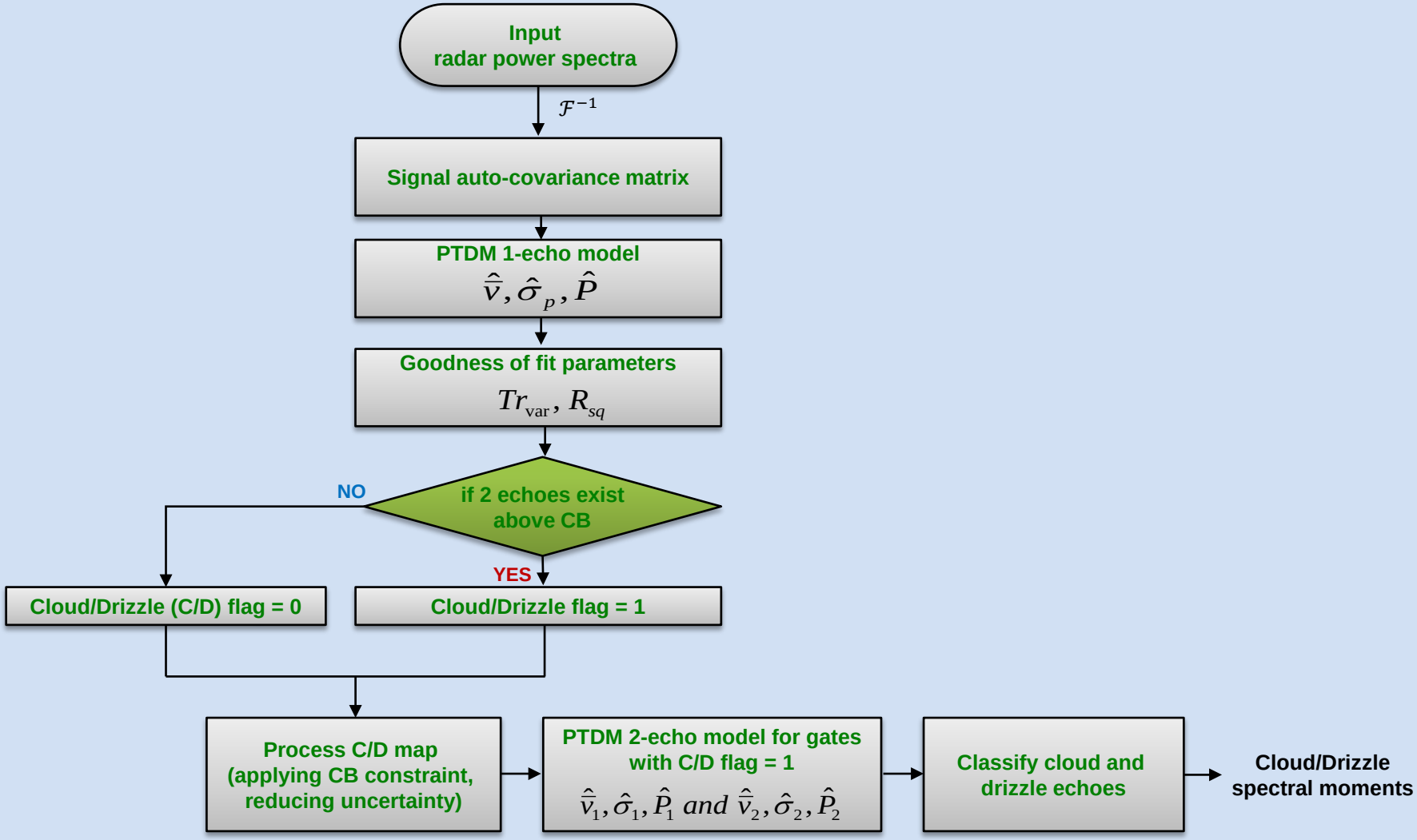
noise only

Gaussian spectrum

bimodal spectra

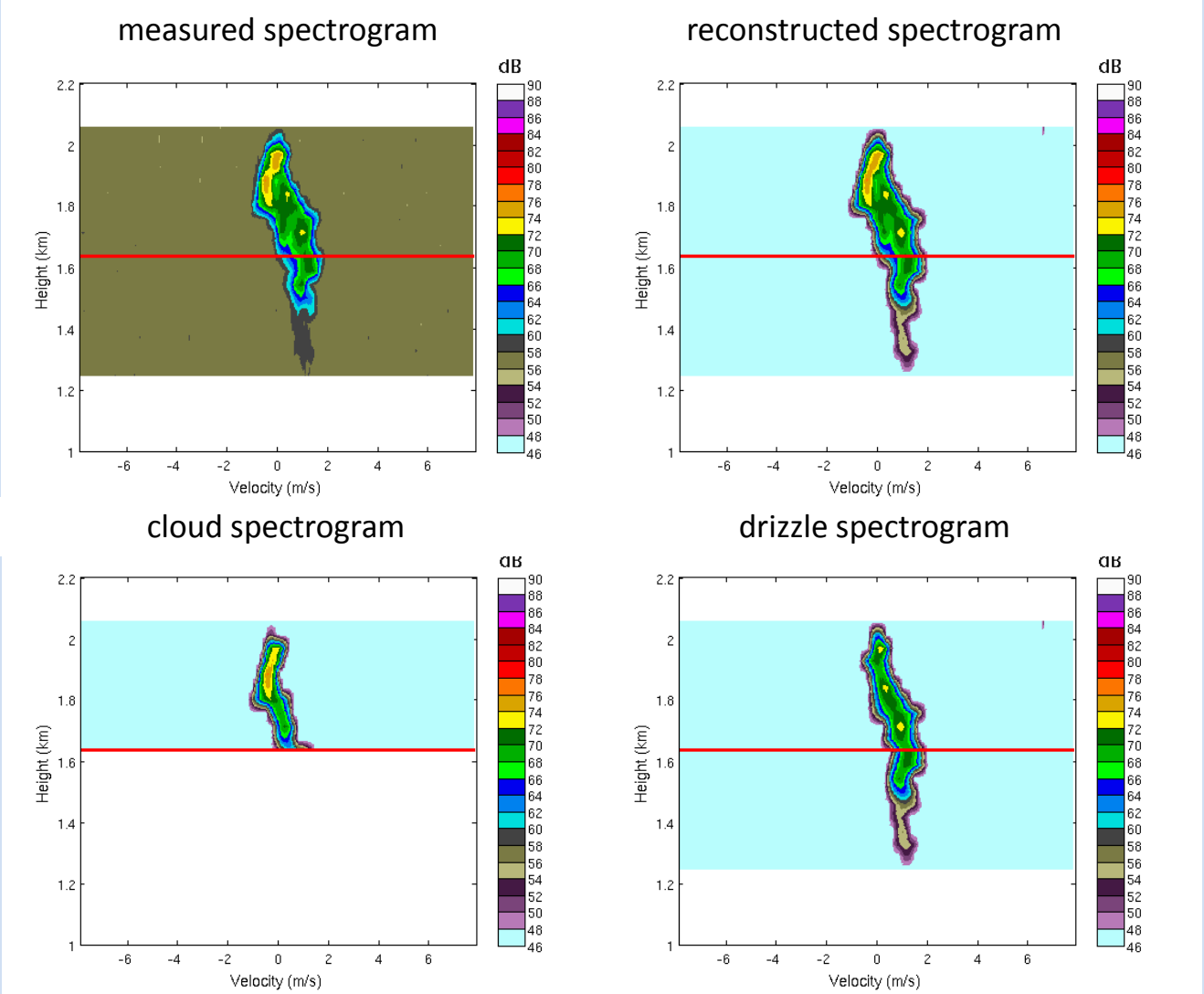


Cloud/Drizzle separation procedure diagram



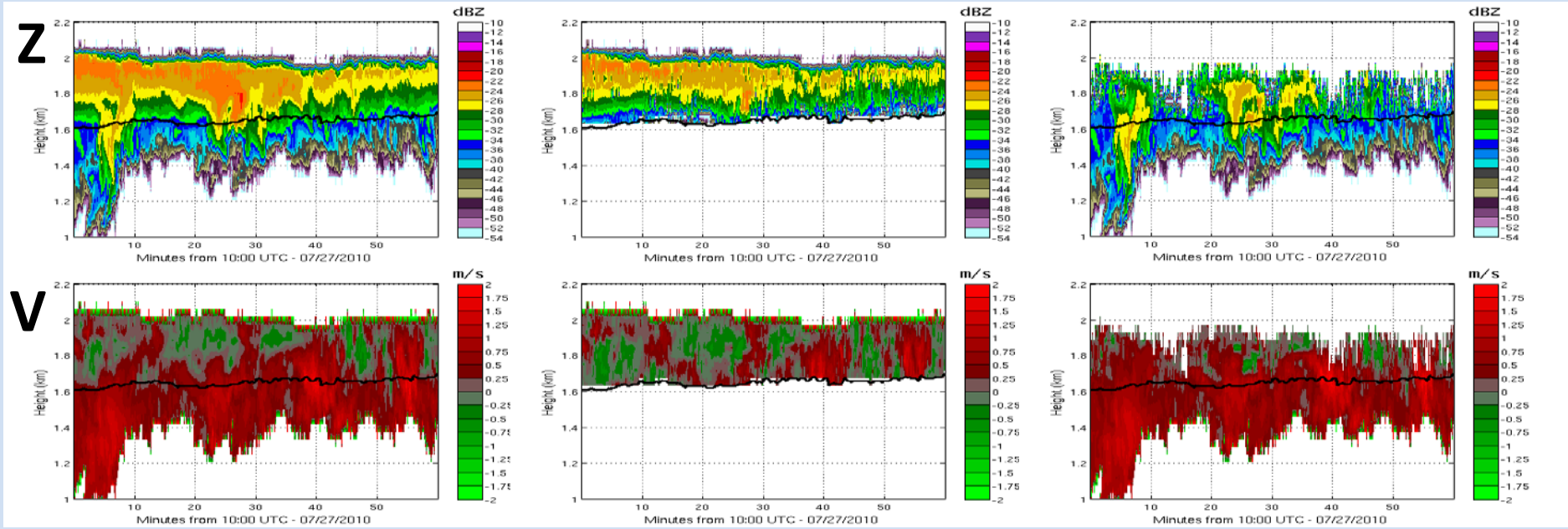
Azores data analysis

Example of cloud/drizzle decomposition



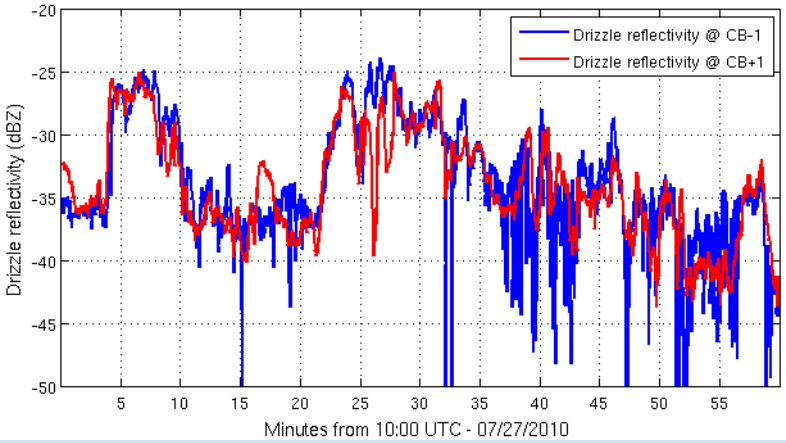
Radar Doppler spectrogram collected at 10:23:04 UTC on 27 July, 2010 by the W-band ARM cloud radar (WACR) on Graciosa Island in the Azores. The red line is the cloud base (CB).

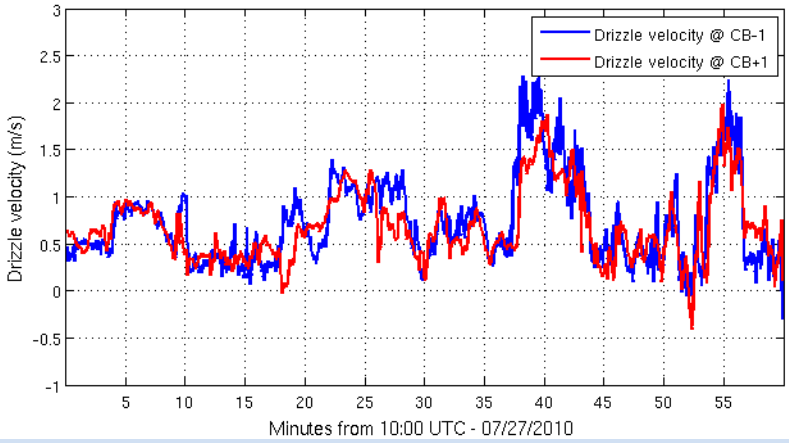
Azores data analysis: July 27 2010 case



Data collected by ARM WACR on 27 July 2010 from 10:00:04 UTC to 11:00:01 UTC in the Azores. Measured reflectivity and velocity (left column), retrieved reflectivity and velocity for cloud (middle column) and for drizzle (right column). The black line is the cloud base.

Algorithm verification





Comparison of retrieved drizzle reflectivity one gate above cloud base (CB +1) and one gate below (CB-1) (a). (b) as (a) but velocity.

Summary

- The new method works with a single radar power spectra profile and performs well in most scenarios.
- Drizzle reflectivity can be obtained accurately without the need of a compensation factor when cloud and drizzle echoes overlap heavily.
- The applications of the technique include inference of the vertical air motion, the particle size distribution of the drizzle and the dynamical and microphysical processes during the transition from cloud to drizzle.

Thank you and Questions?