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Hail Detection Using Dual Polarization Weather Radar

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FULBRIGHT

Abstract

This poster highlights how active remote sensors such as weather radar are completely useful for hail detection given its feature and the information they produce. Hail detection is already well studied by the atmospheric scientific community and dual polarimetric variables values for hail signature are presented according to those advances. Then, a supervised classification technique is showed to illustrated how machine learning can be integrated to radar information for automatic hail detection. However, this fuzzy logic algorithm has the capability to distinguish between meteorological and non-meteorological echoes. This automatic information might help forecasters from National Weather Services – NWS to issue early warnings about hail.

Introduction

The glossary of meteorology of the American Meteorological Society, defines weather radar as "**any radar** that is suitable or can be used for the detection of **precipitation** or **clouds**" (AMS, 2020).
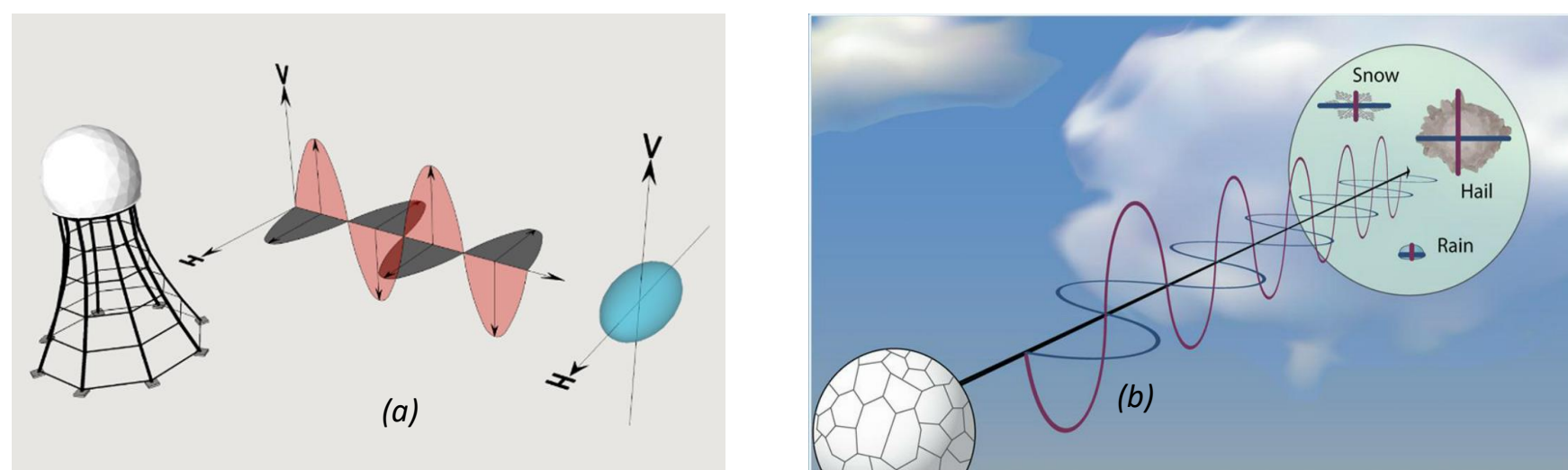

Figure 1. a) Horizontal and vertical polarization used in weather radar (Cao et al, 2012). b) Shape detection of meteorological targets using dual polarization weather radar (NWS, 2020).

Dual polarization means that the radar can send pulses energy in **vertical** and **horizontal** orientations that brings the opportunity to infer information from the **targets** such as **size, shape** and **intensity** to **distinguish** among **meteorological** and **non-meteorological** echoes (NWS, 2020)
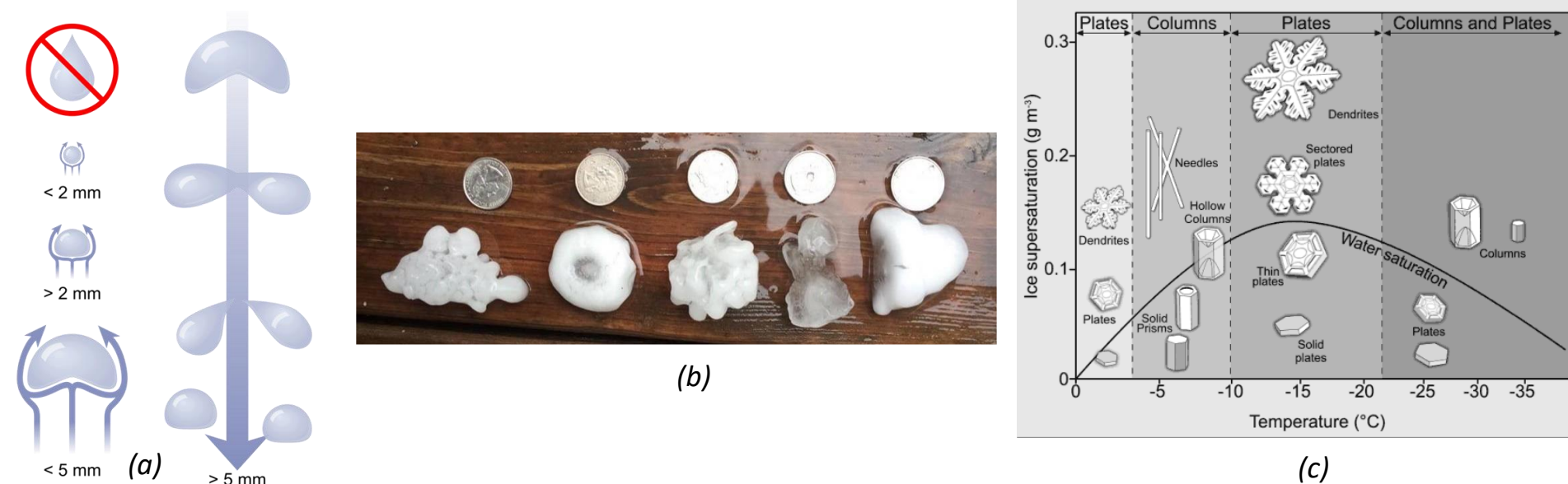

Figure 2. Shapes and sizes of a) droplets. b) hail (AEMET, 2019). c) Ice crystals – Snow (Emersic, 2020)

Methods

1. Weather radar generates **dual polarization** information. The **intensity** and **phase** of the horizontal and vertical pulses orientation coming from the backscattered target energy, supported on **signal processing algorithms**, create dual polarization **variables**.

Figure 3. National Severe Storm Laboratory Weather Radar in Norman, OK. (NSSL, 2020)

2. Interpretation of dual polarimetric variables is required to detect hail formation. There are multiple radar variables to achieve this:

- **Reflectivity (Z):** Amount of the backscattered energy related to **precipitation intensity**

- **Differential Reflectivity (Z_{DR}):** Comparison between horizontal and vertical backscattered energy related to **hydrometeor shape.**

- **Copolar Correlation (ρ_{HV}):** Comparison between horizontal and vertical backscattered signal phase related to **hydrometeor homogeneity.**
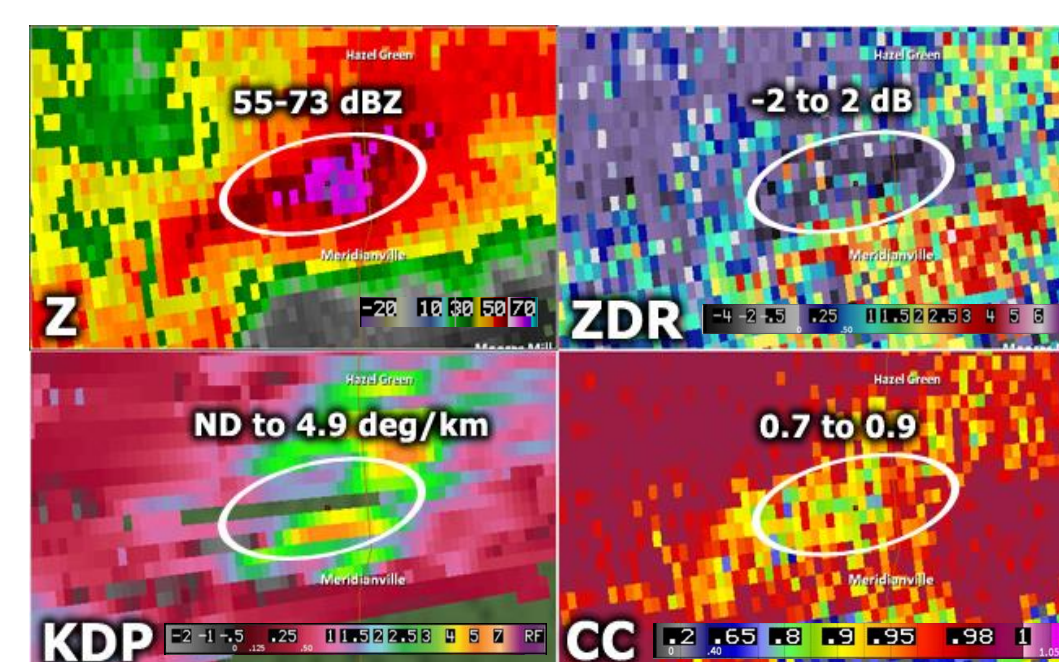

Typical dual polarimetric values of hail according to NWS (2020)

- Z: 40 to 80 dBZ
- Z_{DR}:   -0,5 to 1,0 dB
- ρ_{HV}:   < 0,9
- K_{DP}:   ND to 5 deg/km

Figure 4. Hail signature using dual polarization variables (NWS, 2020)

3. Machine learning techniques are used for creating **Hydrometeor Classification Algorithms – HCA**. Weather radar generates information approximately every **five minutes** of all dual polarization variables over all coverage of radars (**Big Data**). This amount of information might be difficult to analyze by forecasters. Hence, automatic detection **facilitates** and **improve** hail detection.
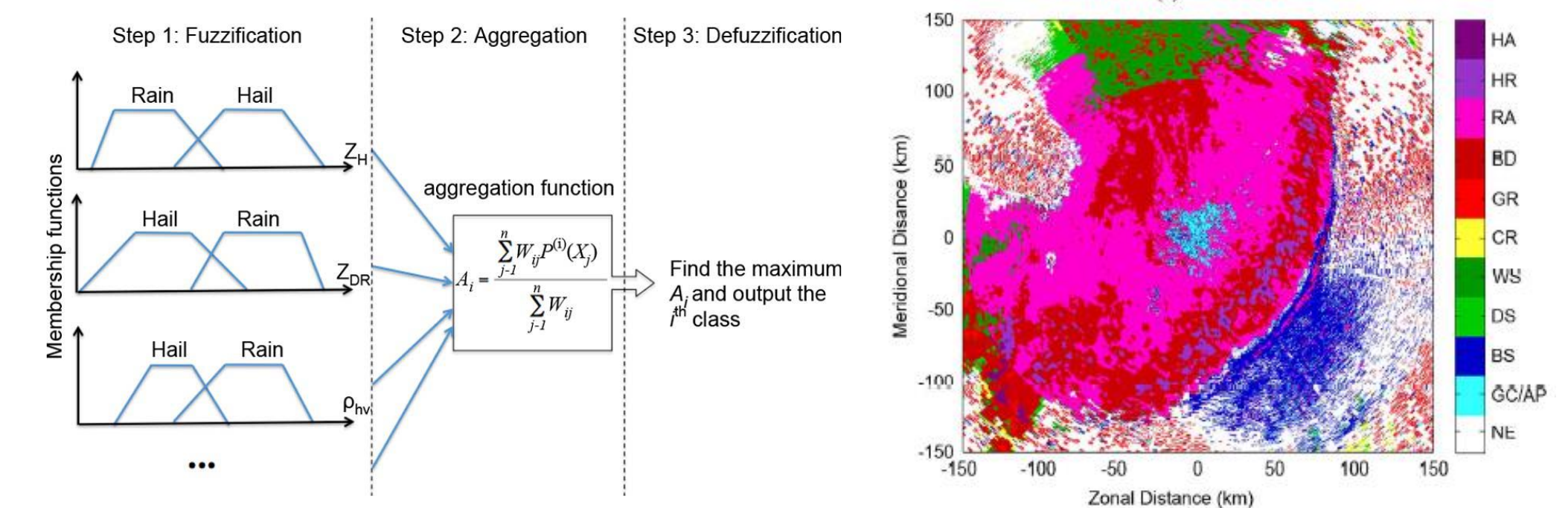

Figure 5. a) Fuzzy logic algorithm for HCA. b) Radar echo classification (Cao et al, 2012)

According to Cao et al, (2012) the HCA algorithm classifies into ten categories: "mixture of rain and **hail (HA)**, heavy rain (HR), light and moderate rain (RA), big drops (BD), graupel (GR), wet snow (WS), dry aggregated snow (DS), biological scatterers (BS) and ground clutter or abnormal propagation (GC/AP)"- (p.64)

Conclusion

Hail detection can be achieved by both machine learning algorithms or radar variables images interpretation made mainly by forecasters. Both ways are useful for societies in order to create resilience to severe weather, and in this case, about hail impacts.

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