CLASSIFICATION OF CONVECTIVE AND STRATIFORM CELLS IN METEOROLOGICAL RADAR IMAGES USING SVM BASED ON A TEXTURAL ANALYSIS

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ABSTRACT

This contribution deals with the discrimination between stratiform and convective cells in meteorological radar images. This study is based on a textural analysis of the latter and their classification using a Support Vector Machine (SVM). First, we applied different textural parameters such as energy, entropy, inertia and local homogeneity. Through this experience, we identified the different textural features of both the stratiform and convective cells. Then, we used an SVM to find the best discriminating parameter between the two types of clouds. The main goal of this work is to better apply the Palmer and Marshall Z-R relations specific to each type of precipitation.

KEYWORDS

Meteorology, clouds, stratiform, convective, texture, SVM.

1. INTRODUCTION

Clouds are formed according to two processes: the convection and the progressive uplifting of the air mass (stratification).

The convective uplifting is due to the air instability. It is often vigorous and abrupt. The produced clouds are characterized by a large vertical extension and a limited horizontal extension. These clouds are generally designated by the term “cumulus”. They could be developed in different troposphere levels, where the instability exists.

The synoptic uplifting is the result of dynamic processes in the stable atmosphere, in a stratified flow. This gradual uplifting, producing clouds systems with uniform texture, could cover thousands of square kilometers. These clouds are generally designated by the term “stratus”.

The discrimination between these two types of clouds (stratiform and convective) is very important for applying the specific Palmer and Marshall Z-R relations for weather forecasting. [1]

Numerous researchers have been interested to solve this problem. In 2000, Michael Biggerstaff and Steven Listemaa developed an improved algorithm for the partitioning of radar reflectivity

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into convective and stratiform rain classifications. Their algorithm starts with output from the current operational version of the Tropical Rainfall Measuring Mission (TRMM) convective/stratiform scheme for the ground–based validation sites and corrects the output based on physical characteristics of convective and stratiform rain diagnosed from the three-dimensional structure of the radar reflectivity field. The modified algorithm improved the performance of echo classification by correcting two main sources of error. Heavy stratiform rain, originally classified as convective, and the periphery of convective cores, originally classified as stratiform. [2]

In 2005, Maria Franco *et al.* used the vertical profile of reflectivity (VPR) characteristics of the stratiform and convective rain combined with the algorithms by Sanchez – Diezma et al (2000) and Steiner et al (1995) to discriminate between the two kinds of precipitation. [3]

In 2006, Capsoni *et al.* based on the knowledge of the local yearly cumulative distribution function P(R), they studied the space-time evolution and the impact on electromagnetic waves propagation through the atmosphere of the stratiform and convective precipitation. Moreover, they modified the EXCELL rain cell model. [4]

In 2012, Xu Wang *et al.* used fuzzy logic to discriminate between convective and stratiform precipitation in Doppler weather radar. Based on the differences of radar reflectivity distribution morphology between stratiform and convective precipitation, they selected four recognition parameters, which were maximum reflectivity factor, altitude of echo top, vertical reflectivity gradient and vertical reflectivity gradient. [5]

Our approach is to use SVM to discriminate between convective and stratiform precipitation using textural features. We considered four textural parameters, which were energy, entropy, inertia and local homogeneity. Then we used SVM to identify which parameter could distinguish the best between the two types of precipitation.

2. DATA

The data were collected in Dakar (Senegal), Setif (Algeria) and Bordeaux (France). The observed images contain convective and stratiform cells. Our database consists of 400 images collected during 1999 in Dakar, 2000 observed in Bordeaux (France) and 5000 recorded in Setif (Algeria). We present in figure 1 a sequence of 20 images collected on August 13, 1999 in Dakar

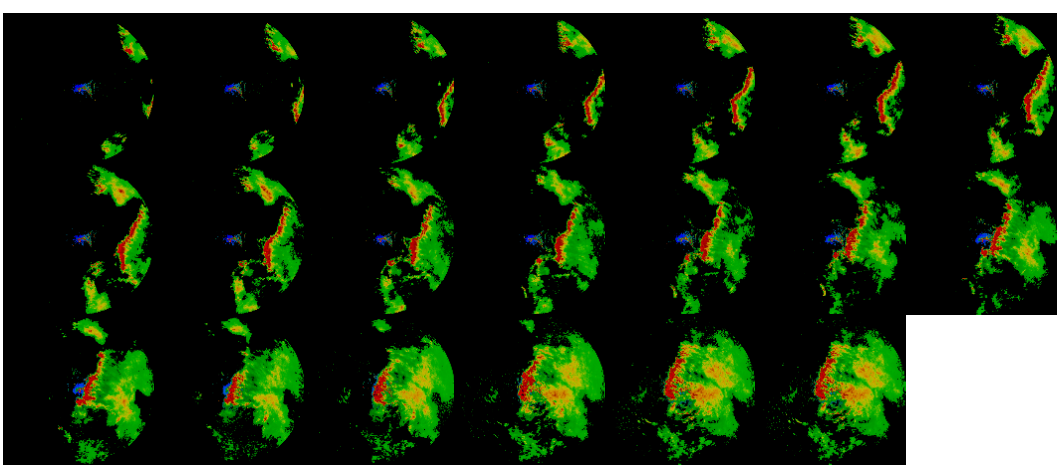

Figure 1. Sequence of meteorological radar images of Dakar.

3. TEXTURAL ANALYSIS OF CLOUDS

The textural features of the radar images of Setif, Bordeaux and Dakar have been calculated by using the histogram approach. The analysis of cloud cells is based on four parameters, namely, energy, entropy, inertia and local homogeneity. Let (x_{ij}) be the grey level of each pixel of the radar image (with i=1,…,N and j = 1,…,N), n_x, the number of pixels at grey level (x) and N_T, the total number of pixels in the image. Its relative frequency is given by:

$$P(x) = {n_x}/{N_T} \quad (1)$$

The textural parameters are then defined as:

Table 1. Mathematical formulas of textural parameters

Parameter	Mathematical formula
Energy	$E = \sum\sum x_{ij}^2$
Entropy	$S = \sum\sum x_{ij} \cdot \log(x_{ij})$
Inertia	$I = \sum\sum (i-j)^2 \cdot x_{ij}$
Local homogeneity	$HL = \sum\sum \left[\frac{1}{(1+(i-j)^2)}\right] \cdot x_{ij}$

First, we made up a database. To do, we considered that the convective cells are represented by a reflectivity factor superior to 42 dBZ, and the stratiform cells are described by a reflectivity factor between 5 dBZ and 40 dBZ. We constituted cloud cells with 4×4 pixels.

Next, we calculated the four textural parameters and we classified them depending on their reflectivity factor. The figures 2.a, 2.b, 2.c and 2.d show respectively the histograms of the four textural parameters, energy, entropy, inertia and local homogeneity.

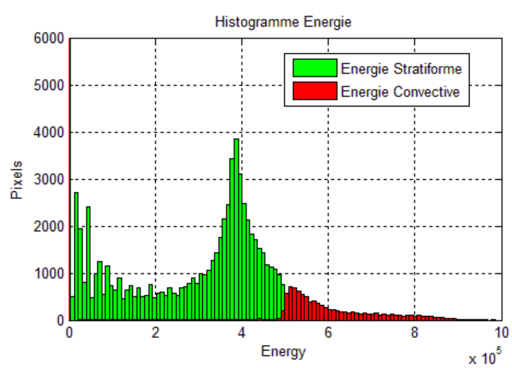

Figure 2.a. Energy histogram

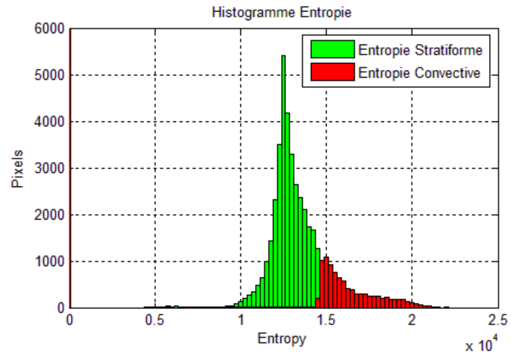

Figure 2.b. Entropy histogram

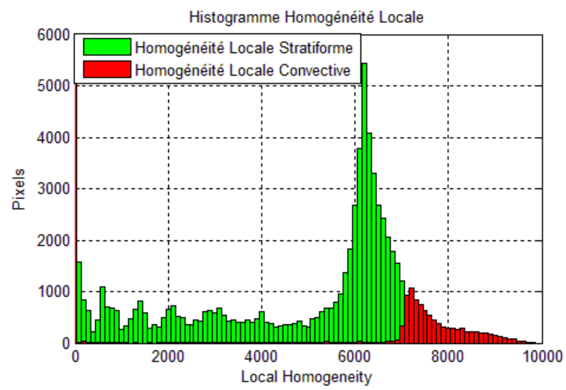

Figure 2.c. Inertia histogram

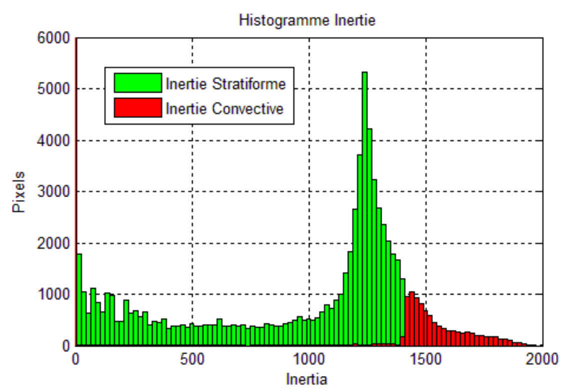

Figure 2.d. Local homogeneity Histogram

4. SVM CLASSIFICATION

Support Vector Machines (Commonly known as SVM) are a set of supervised learning techniques intended to solve discrimination and regression issues. They treat non-linear discrimination and reformulate the classification problem as a quadratic optimization problem.

They could be used to solve discrimination problems (i.e. to decide to which class should a sample belong), or a regression problems (i.e. to predict the numerical value of a variable).

The concept of the SVM is to find the best hyperplan between the two classes (stratiform and convective). The hyperplan is a separator line that separates the stratiform class from the convective class. The figure 3 shows an example of an hyperplan.

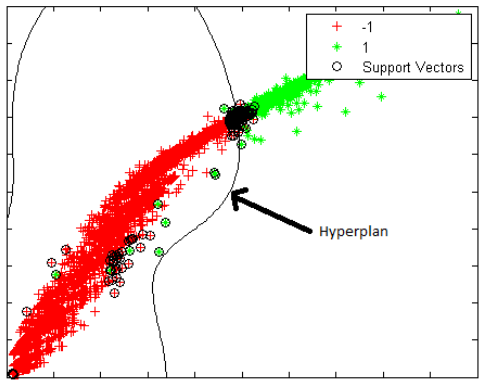

Figure 3. Hyperplan between two classes

The second step of our approach is to use an SVM to find out which one of the four textural parameters distinguishes the best between the convective and stratiform cells of a meteorological radar image. We used an SVM with “RBF” kernel function with default parameters

$$(C = 1 \text{ and } sigma = 1)$$

The table 2 gives the correlation factor between the train base and the test base of the SVM for the four textural parameters (energy, entropy, inertia and local homogeneity).

Table 2. Correlation factor between the train base and the test base of the SVM.

Parameter	Energy	Entropy	Inertia	Local homogeneity
Correlation factor	97.01%	76.29%	96.02%	88.58%

According to the table 2, the two parameters (energy and inertia) are the most pertinent for the discrimination between the convective and the stratiform cells of meteorological radar images. The combination of the two parameters in an SVM gives 95.24% of good identification.

For example, we present in figures 3.a and 3.b the classification result of one image recorded in Dakar.

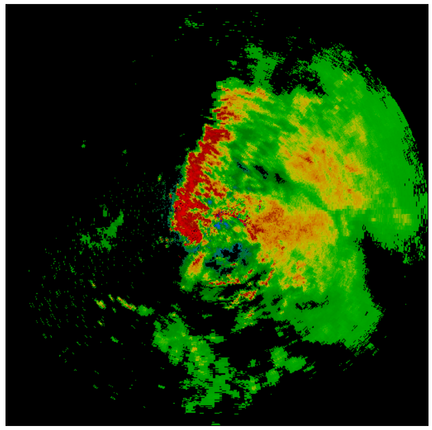

Figure 3.a. None-classified image

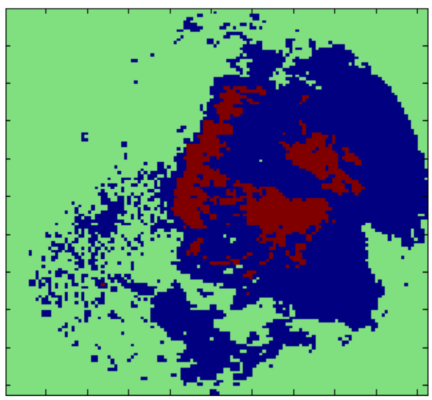

Figure 3.b. Classified image

The output image of the classifier represents the convective cells in red and the stratiform cells in blue. The ratio of good identification is 97%. This shows the efficiency of the proposed approach in the discrimination between the precipitation cells. Note that this approach has not been previously proposed.

5. SVM CLASSIFICATION

The aim of our study is to discriminate between stratiform and convective cells in radar images. This discrimination is very important to optimize the choice of the best Z-R Palmer relation to be used for quantitative rainfall estimation. The texture-based approach presented in this paper allow the classification of the stratiform and convective cells in a meteorological radar image without ambiguity. The proposed approach correctly identifies isolated convective and stratiform cells. The two parameters energy and inertia show the efficiency of this approach by a ratio of good identification of around 97%. It is also proven that the combination of good parameters in an SVM doesn't give necessarily a better result.

Next, the objective will be to see how this method can help to improve the precipitation estimation. This method will be tested on other sites where different climates prevail.

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