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ORIGINAL PAPER

Automatic day time cloud detection over land and sea from MSG SEVIRI images using three features and two artificial intelligence approaches

Mourad Reguiegue[1] · **Fatima Chouireb**[1]

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Abstract A fuzzy logic and neural network approaches are proposed to generate a cloud mask for Meteosat Second Generation Spinning Enhanced Visible and Infrared Imager (MSG SEVIRI) images. MSG images are classified into land/sea clear sky or cloudy. A spatial and temporal properties of three solar channels (0.6, 0.8 and 1.6 μm), and three thermal infrared channels (3.9, 6.2 and 10.8 μm) are used for this aim. The proposed methods were tested and evaluated using seventy-two MSG images taken at different times and dates. The fuzzy logic method leads to cloud detection accuracy of 84.41%, and the neural network achieved an average accuracy of 99.69%. Our proposed methods detected not only thick clouds but also thin and the less bright clouds. To give more support to our results, we made a comparison between the proposed approaches and the cloud mask product which is one of the applications integrate into software package Satellite Application Facility to NoWCasting and Very Short Range Forecasting (SAFNWC/MSG) by the European Organisation for the Exploitation of Meteorological Satellites EUMETSAT applied on the same MSG data. The high average accuracy achieved by our neural network proposed method (and more less for fuzzy logic) demonstrates its effectiveness and robustness and also the utility to benefit of using the artificial intelligent techniques in remote sensing imagery applications.

Keywords MSG SEVIRI · Cloud detection · Neural network · Fuzzy logic · CMa · EUMETSAT

✉ Mourad Reguiegue
m.reguigue@lagh-univ.dz

Fatima Chouireb
f.chouireb@lagh-univ.dz

1 Laboratoire des Télécommunications, Signaux et Systèmes LTSS, Université Amar Telidji de Laghouat, BP 37G, Route de Ghardaïa, 03000 Laghouat, Algérie

1 Introduction

The cloud is one of most important factors which influence climate, it plays a key role in the radiative balance in the atmosphere, and it is in charge for about 23% of the earth albedo [1].

Either to estimate the earth's energy budget or in weather prediction, we needed a global view to determine the location and amount of cloud coverage in the sky [2,3].

The study of cloud has been improved with the use of geostationary satellites such as Meteosat First Generation (MFG) [4] or Meteosat Second Generation (MSG). The MSG system is under cooperation between the European Space Agency (ESA) and the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) [5]. Observation of the earth's full disk is insured with the Spinning Enhanced Visible and Infrared Imager (SEVIRI). Every 15 min, the MSG satellite provides a series of 12 images obtained in different frequency bands (spectral channels), 11 of them provide measurements with a resolution of 3 km at the sub-satellite point and the twelfth, so-called high resolution visible (HRV) channel provides measurements with a resolution of 1 km. These data provide useful information about the content of the atmosphere like: cloud cover, snow cover, water vapor and measurement of land and sea surface temperature [6].

In the aim to eliminate the need for human observers and keep up with the advanced technologies, automatic methods have rapidly evolved in order to facilitate the detection of clouds. Thus, accurate automatic detection of clouds from remote sensing images is an important step for climatological

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applications [7]. In the last few years, considerable researches have been conducted to get cloud detection and classification with high accuracy. Most of the techniques based on satellites images algorithms, use the thresholding mechanism [8–10] or statistical procedures [11–13]. In the other hand, artificial intelligence techniques are increasingly being used in areas of prediction and classification, these algorithms are robust and very flexible since they can learn, solve problems and take decisions as the human brain [14]. In these methods, we can use expert's knowledge in a supervised mode to label the training data, which leads us to get better results.

Different artificial intelligent approaches for cloud detection and classification exist, such as: fuzzy logic systems [4,15–18], neural networks [3,6,7,16,19] as well as other algorithms in artificial intelligent literature.

It is important to note that there are many cloud discrimination algorithms applied to different types of satellite images, such as the Moderate Resolution Imaging Spectroradiometer (MODIS) cloud mask [20,21], Function of Mask (Fmark) for cloud detection in Landsat imagery [22] and cloud mask product (CMa) for MSG data.

In this paper, we use fuzzy logic and neural network techniques for automated cloud detection from MSG SEVIRI images without any ancillary data (atlas/sea, elevation atlas, etc.).

We are able to improve the accuracy of our cloud mask when benefiting from three features extracted for each pixel in visible/infrared imaging and taking into account its spatial as well as temporal context, more details are given in Sect. 2.

To enrich this work, we compare our obtained results with cloud mask product (CMa) by EUMETSAT, developed for Satellite Application Facility on support to Nowcasting context (SAFNWC).

This paper is organized as follows: the data used in this work is described in Sect. 2 and Sect. 3 outlines the classification methodologies, followed by the results and evaluation in Sect. 4, and finally the conclusion and discussion are given in Sect. 5.

2 Data

2.1 Training and evaluation dataset

The training dataset consists of 144 (24 images in each of the 6 spectral channels) MSG-3 (Meteosat 10) images taken at different dates and times (in different seasons also) from year 2013, each one is of size 512 × 512 pixels covering the Spain and North Africa region.

We label a set of areas in each image corresponding to cloudy/land, clear sky/land, cloudy/sea and clear sky/sea; this selection has been realized by a meteorological analyst (see Fig. 1).

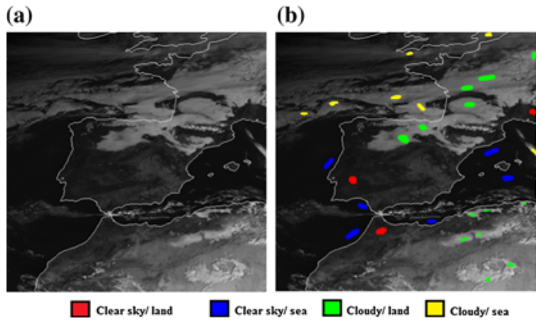

Fig. 1 **a** MSG-3 VIS 0.6 µm image for the Spain and North Africa region, 05/12/2013 at 0900 UCT; **b** the same image with samples of four classes labeled by meteorological analyst

Table 1 Labeled pixels from the MSG-3 training data

Class	Labeled pixels	
	Over land	Over sea
Clear sky	29,759	29,700
Cloudy	18,658	20,125
Total	48,417	49,825

The Table 1 illustrates the distribution of labeled data for land and sea.

For the step of evaluation, seventy-two MSG images (each one has six spectral channels, which mean a total of 432 images) have been used to evaluate our proposed methods. This dataset was obtained from all months of three years 2013, 2014 and 2015.

2.2 Extraction of features

Three features have been extracted from all training MSG images by using 3 × 3 window around each pixel applied to Visible VIS, Near Infrared NIR and Infrared IR images: two spatial features which are mean (μ) and standard deviation (σ) of brightness temperature in infrared images (IR 3.9, IR 10.8 and Water Vapor WV 6.2 µm), mean and standard deviation of visible count in visible and near infrared images (VIS 0.6, VIS 0.8 and NIR 1.6 µm) and one temporal feature applied only to visible images (VIS 0.6 and VIS 0.8 µm) which is the mean difference from clear sky background. The labeled data used in training process, which consists of 98,242 pixels selected in region of study, is represented by a features extraction matrix of size 98,242 × 14; because we have a total of 14 composed spatial and temporal features data (2 from temporal feature and 12 from spatial features). The present study is limited to day time cloud detection, for this purpose we have used these six spectral channels which contain more information of cloud for day time [6], and even better for cloud detection accuracy when 50% of them are in solar channels (0.6, 0.8 and 1.6 µm), with the IR 3.9 µm