A Fuzzy Approach to Masking Cloud Systems Over Land

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Abstract – Identification of cloud systems over continental regions is a difficult task given on the one hand the variability in space and time of the radiative properties of the land surface and on the other the non-homogeneous character of the background. Cloud systems also possess radiative characteristics, which change according to the type and shape of the particles that make the cloud. In the present work we have used NOAA-AVHRR and VEGETATION imagery and the aim is to identify cloud systems over Portugal and then build a cloud mask. For this purpose we have developed an unsupervised fuzzy technique whose main advantage lies on the possibility of coherently defining different cloud masks depending for instance on the required degree of confidence that no cloud-contaminated pixels fail to be detected.

Keywords: NOAA/AVHRR, VEGETATION, cloud mask, land surface, fuzzy algorithm

1. INTRODUCTION

The use of satellite information to detect cloud systems has been increasing in the recent years because satellite imagery provides the only means of obtaining quantitative information about clouds over wide areas and on a continuous basis.

Besides allowing the detection and removal of cloud systems on a reliable and automated way, satellite-based cloud masks (*e.g.* Saunders and Kriebel, 1988; Dybbroe *et al.*, 1999) also play an important complementary role since they allow identifying cloud free pixels. For instance a good and accurate high-resolution cloud mask is a pre-requisite for the retrieval of surface temperature sea-ice extent, snow cover, surface albedo, land cover, vegetation types and burnt areas.

Rather than delineating cloud-free pixels with a high confidence, the aim of the developed scheme is to reject all pixels whose radiative signatures are not conformal to those considered as characteristic of land surface areas.

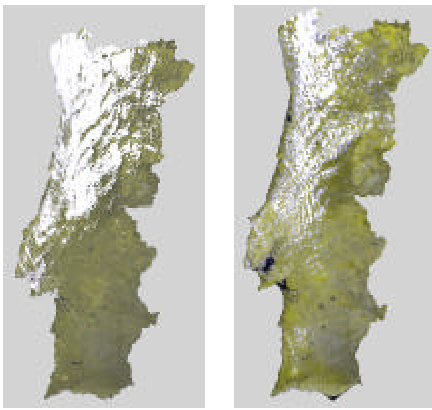
Accordingly, the aim of the present work is to use NOAA-AVHRR and VEGETATION imagery and attempt to identify cloud systems over Portugal in order to build a cloud mask. For this purpose, a subtractive clustering fuzzy method (Chiu, 1994) was applied to estimate cluster centres possessing the characteristics of clear sky pixels and pixels with a very low degree of membership to those clusters were then classified as clouds.

2. DATA

The dataset consists of images from May to August 2000 from NOAA / AVHRR and SPOT 4 / VEGETATION satellites.

The NOAA dataset consists of images of the "early afternoon" orbit containing count values of the five AVHRR channels (red, near-infrared, mid-infrared and 2 thermal infrared, respectively). The images were geometrically corrected, geocoded to the size of 1.1 km and resampled to the UTM WGS 84 North, zone 29 projection. Data were defined on a 548×292 pixel matrix covering Continental Portugal, a small part of Spain and of Atlantic Ocean, but the study area was restricted to the territory of Continental Portugal (Fig. 1a).

In what respects to VEGETATION, the data consist of daily images from early morning containing count values of the spectral bands B0, B2, B3 and SWIR (*i.e.*, blue, red, near-infrared and short wave infrared, respectively). The images were also geometrically corrected, geocoded to the size of 1 km and georeferenced using geographic coordinates. Data were defined on a 606×416 pixel matrix covering a similar area to the NOAA images and again the study area was confined to the territory of Continental Portugal (Fig. 1b)



(a) (b)

Figure 1. Examples for June 10 of a) RG (channels 2, 1) NOAA image from 15:49 summer local time and b) RGB (channels B3, B2) VEGETATION image from 10:30.

3. CLOUD MASKING

Cloud screening is a rather complex task because the radiative properties of cloud systems strongly depend on the cloud type, the viewing angle and the illumination conditions, the characteristics of the surface background, the atmospheric state and the season of the year, among other factors. Cloud screening is especially difficult over land because in most cases the reflectance and the brightness temperature of the background highly varies in space and time due to their strong dependence on soil and vegetation types, fraction of vegetation cover and topography.

The rationale behind the developed approach took into account that the images that are useful for land surface analysis are characterised by a low amount of fully or partly cloudy pixels; therefore there is a large number of clear sky pixels that allow a proper characterisation of the radiative properties of the surface background. This aspect is of extreme importance because otherwise there will be no assurance that the clusters identified are characteristic of the land surface and/or that the computed values of the cluster centres are not biased by the presence of pixels not belonging to land. In case there are an enough number of clear sky pixels, their characteristic properties in terms of reflectance and brightness temperature may be determined by means of clustering techniques (*e.g.* Yager and Filev, 1994a, 1994b; Chiu, 1994). On the other hand one may rely on fuzzy logics (Zadeh, 1965) to set up the criteria for rejecting pixels that appear to be not close enough to those considered as clear sky.

Therefore, a threshold test was applied to all pixels appearing to be contaminated by clouds and/or cloud shadows in order to insure that pixels to be classified by means of the subtractive clustering algorithm do belong with a high degree of confidence to clear land surfaces.

Due to spectral differences between AVHRR and VEGETATION, the threshold test applied to the images was not the same for both sensors.

In the case of AVHRR, any pixel fulfilling at least one of the following conditions was removed:

Reflective test: $(Ch(1)+Ch(2))/2 > R$

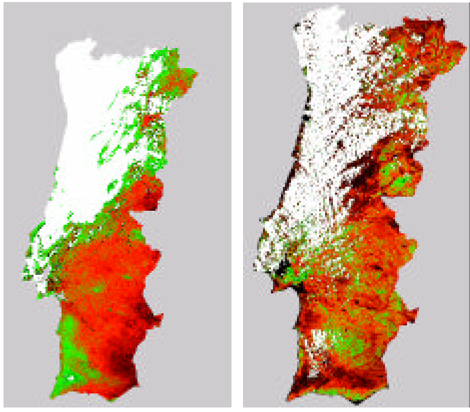
Thermal test: $Ch(5) < T$

where values of R and T were adjusted by visual inspection of several cloudy images and set to count values 100 and 196, respectively.

In what respects to VEGETATION, removal of all pixels under suspicion of being contaminated was performed following Champeaux *et al.* (2002). These authors have defined a pixel as cloudy if $B0 \geq 220$ and $\mathrm{SWIR} > 180$. In order to be sure that we have removed all cloudy contaminated pixels using an even more restrictive criterion:

$$B0 \geq 180 \text{ and } \mathrm{SWIR} > 180$$

After removing the potentially contaminated pixels, a subtractive clustering algorithm (Chiu, 1994) was applied to the remaining pixels of the images (Calado and DaCamara, 2002), allowing to compute the membership values of each pixel to the identified land clusters (Fig. 2).



(a) b)

Figure 2. Examples of results obtained for June 10 (see Fig. 1) for a) NOAA and b) VEGETATION, after applying the subtractive clustering algorithm (red [green] channels are membership values to cluster I [II]; pixels in white represent pixels that were removed by the threshold test);

For each image, the possibility of a given pixel belonging to land was evaluated by maximizing the respective memberships to the clusters identified by the subtractive clustering algorithm (Fig. 3).

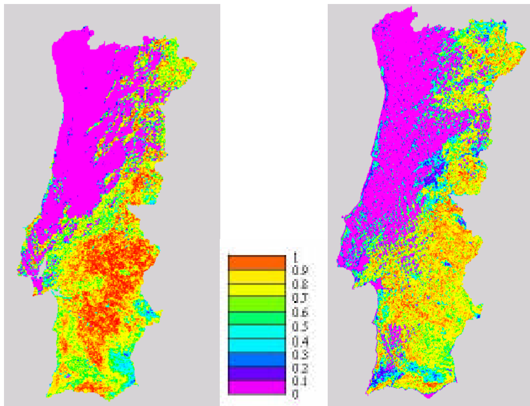
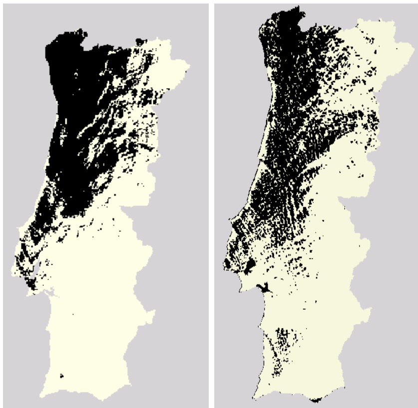


Figure 3. June 10 pseudo-colour images of membership to land of each pixel for a) NOAA and b) VEGETATION

Finally, defuzzification of results was performed by visual inspection. Therefore in every image of the NOAA and VEGETATION datasets all pixels with a membership to land lower than 0.03 were classified as contaminated and therefore masked (Fig. 4).



(a) (b)

Figure 4. Results obtained for June 10. Cloud mask for the threshold of 0.03 for a) NOAA image; b) VEGETATION image.

4. CONCLUDING REMARKS

Obtained results appear to be quite good if one takes into account that the main goal was to completely remove all cloudy pixels. We believe that an advantage of the procedure is the ability of the clustering method to adapt to the particular radiative characteristics of the land surface for a given image.

The developed fuzzy procedure is by its own nature very flexible giving the user the freedom to choose the thresholds that are deemed as the more adequate according to the type of study being performed. Furthermore, the technique seems to be adaptable to different types of sensors.

5. REFERENCES

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