11TH COSMIC RAY INTERNATIONAL SEMINAR
CRIS 2018
"ENTERING THE ERA OF MULTI-MESSENGER ASTRONOMY"

MEASUREMENTS OF HIGH ENERGY COSMIC RAYS AND CLOUD PRESENCE: A METHOD TO ESTIMATE CLOUD COVERAGE IN INFRA-RED IMAGES TAKEN FROM SPACE AND GROUND

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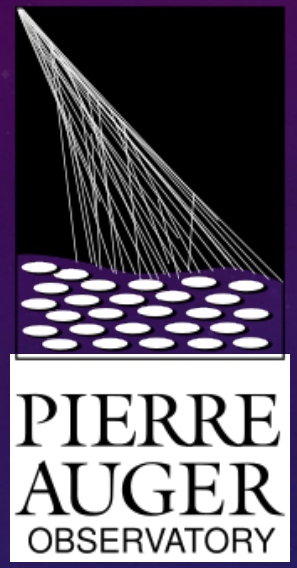
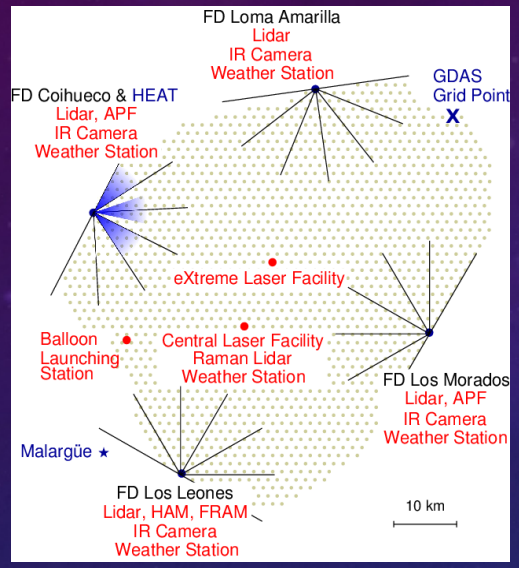
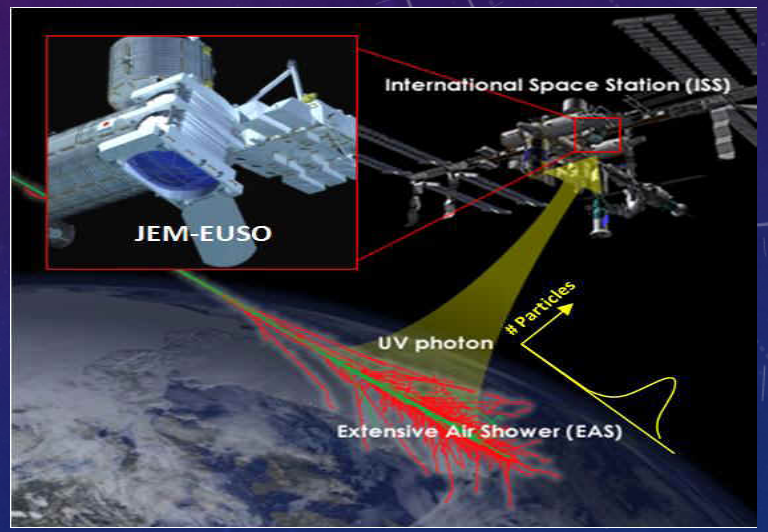
CLOUDS AND VERY ENERGETIC COSMIC RAY DETECTION

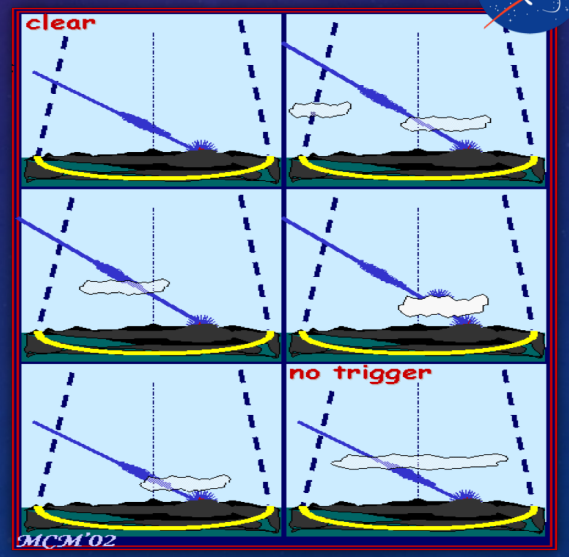
Ultra-High Energy Cosmic Rays can be detected indirectly by ground and space based experiments measuring Cherenkov and fluorescence light in night-time







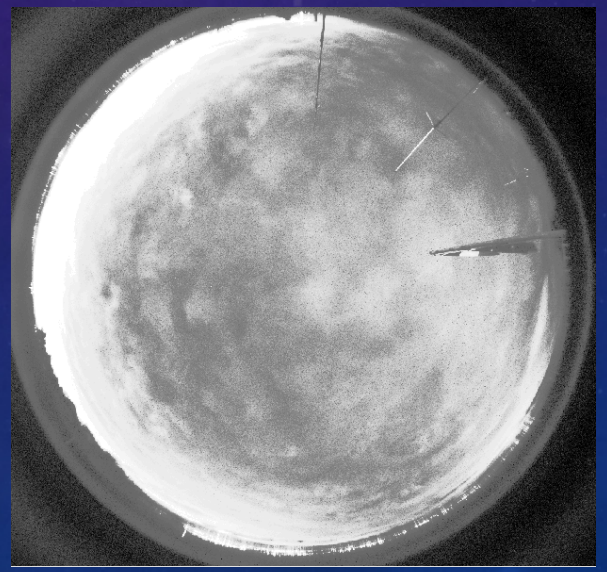
- Clouds can affect the detection
- Atmospheric Monitoring System
  - Infra-red cameras

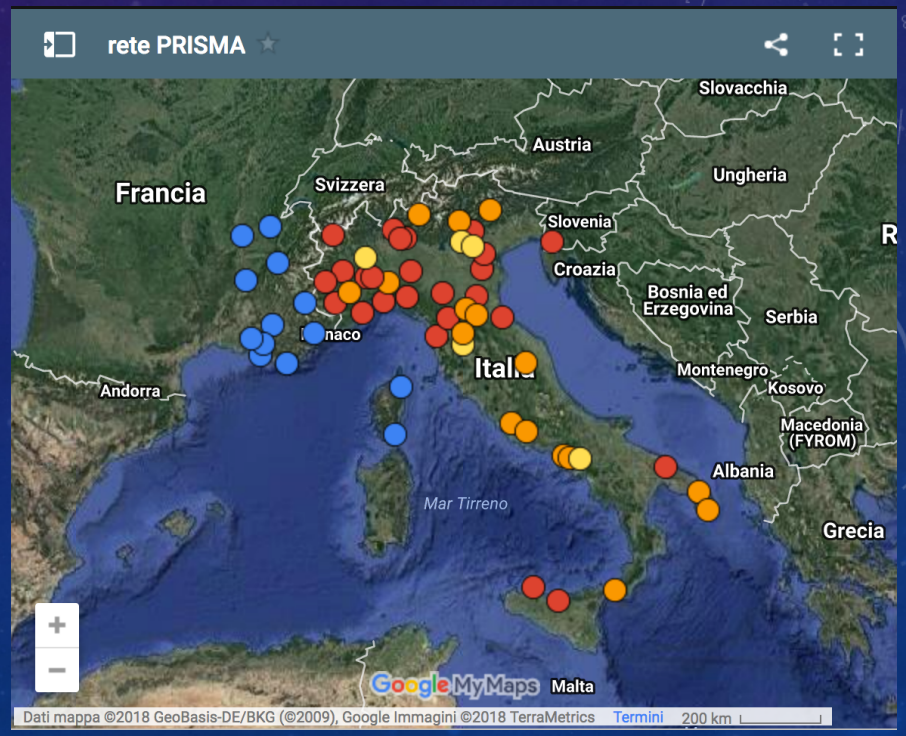


CLOUDS AND METEOR DETECTION FROM GROUND

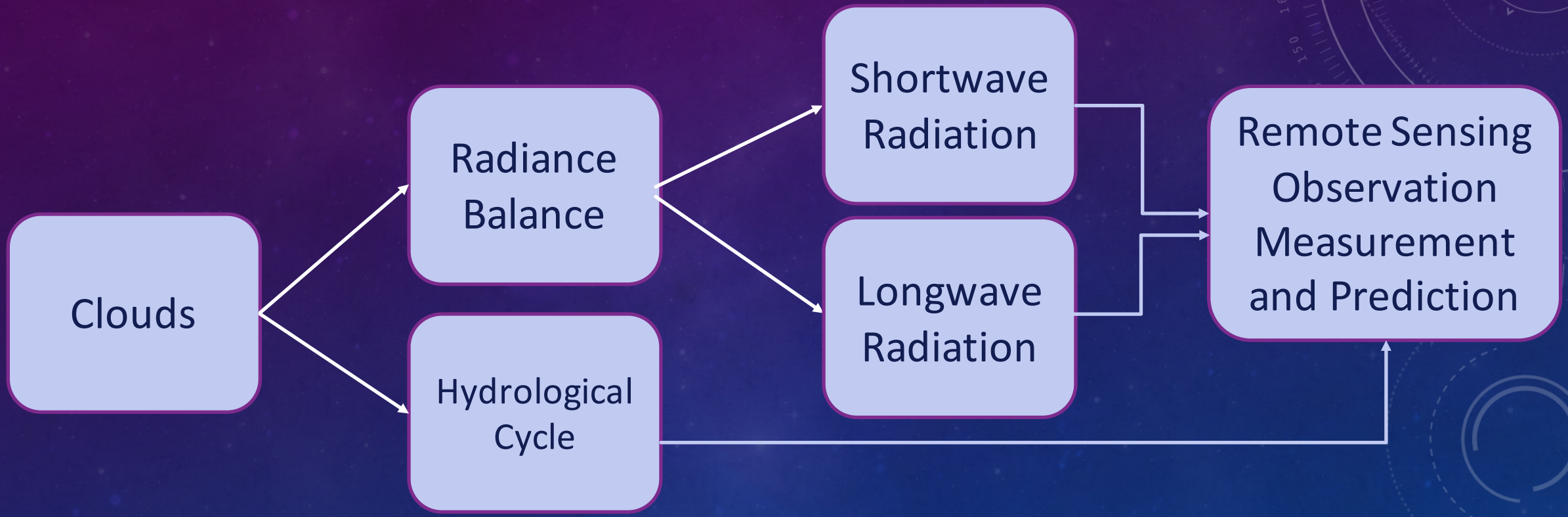
Italian all-sky camera network PRISMA: (http://www.prisma.inaf.it/)

- observation of bright meteors and their orbits (the so-called bolides and fireballs)
- recovering the meteorites
- cloud coverage





CLOUDS AND METEOROLOGY



Clouds play a critical role on the atmospheric radiation balance and hydrological cycle.

CLOUD FEATURES

- **Clouds** generally show higher **reflectance** and lower **temperature** values than the underlying **earth surface**;
- Simple visible and **infrared** window **threshold** approaches are generally reliable in cloud detection but not always sufficient;
- Some cloud types such as thin **cirrus** and **low-level** stratus at night, and small-scale **cumulus** are difficult to detect because of **insufficient contrast** with the surface **radiance**;
- Cloud edges increase difficulty since the instrument field of view is not completely **cloudy or clear**.

STATE OF THE ART

- Most Cloud Detection methods can be roughly divided as follows:

Radiometric Feature Based

Multiple Bands Based

Multiple Images Based (Different Dates)

Contextual Pixel and Texture Feature Based

Object based Classification for Cloud Detection

Machine Learning and Deep Learning Methods for Cloud Detection

STATE OF THE ART

- Satellite Imagery products such as MODIS , AATSR, SENTINEL-3, provide Cloudiness Mask, extracted as a results of both radiative and atmospheric properties analysis, the cloudiness mask are with different spatial resolution depending on the camera sensor;
- The masks are obtained by a big amount of info from several bands
- Different contests do not have this availability
- The objective of our method is to extract a cloudiness mask as accurate as possible by using only BT information

PROPOSED METHOD

- Our goal is to provide a general purpose method for cloud extraction on several remote sensing imagery products such as AATSR, MODIS, SENTINEL-3;
- The overall scheme of the method is as follows:

Image Histogram Analysis for Main K Modalities detection

Pixel Clustering (K-Means) with respect to Gray Level Intensity feature

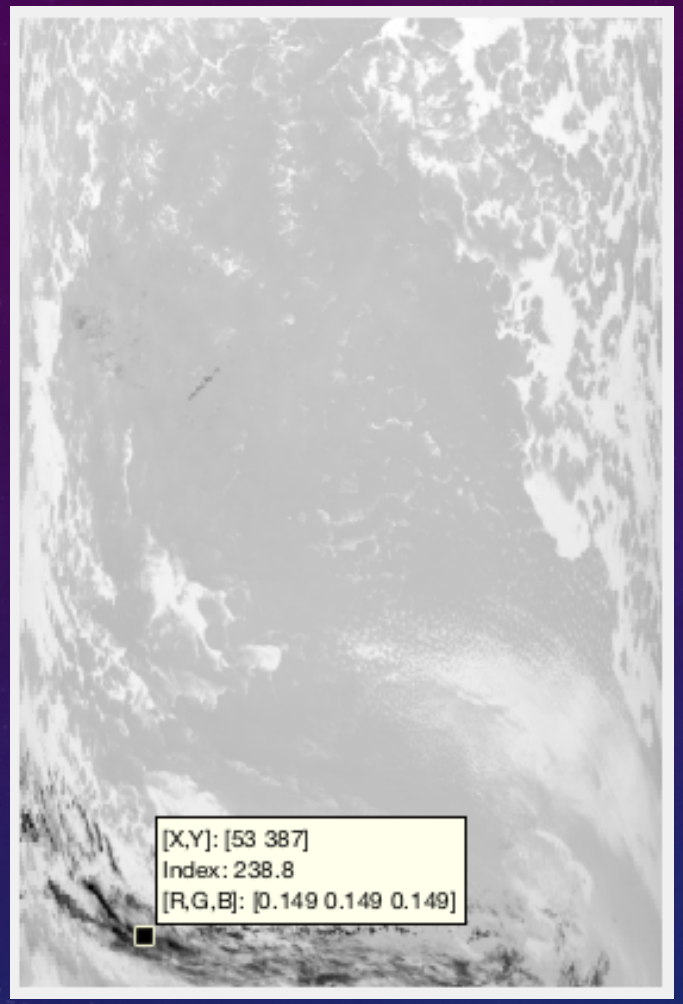
BT Mapping with respect to the clustering

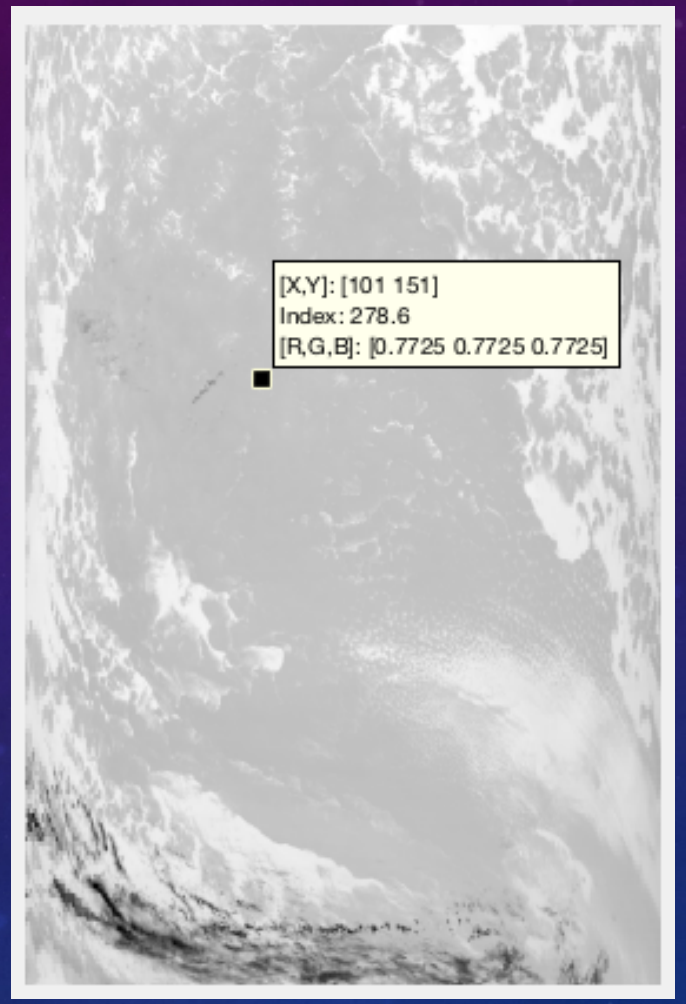
Simple and straightforward Cloud Segmentation

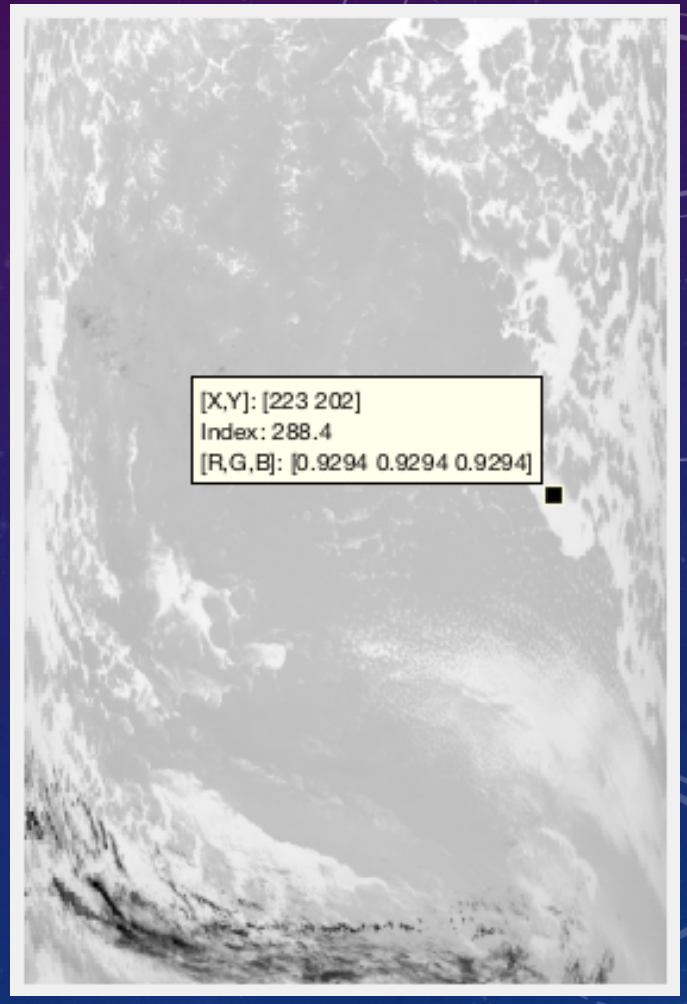
BT BRIGHTNESS TEMPERATURE - IMAGE

- BT Image pixel shows Brightness Temperature value. The proposed method aims at the identification of cloudy pixel by considering only BT pixel value;
- Generally, cloudy pixels show BT value higher (or at most equal) than sea surface, soil, vegetation;

BT BRIGHTNESS TEMPERATURE - IMAGE



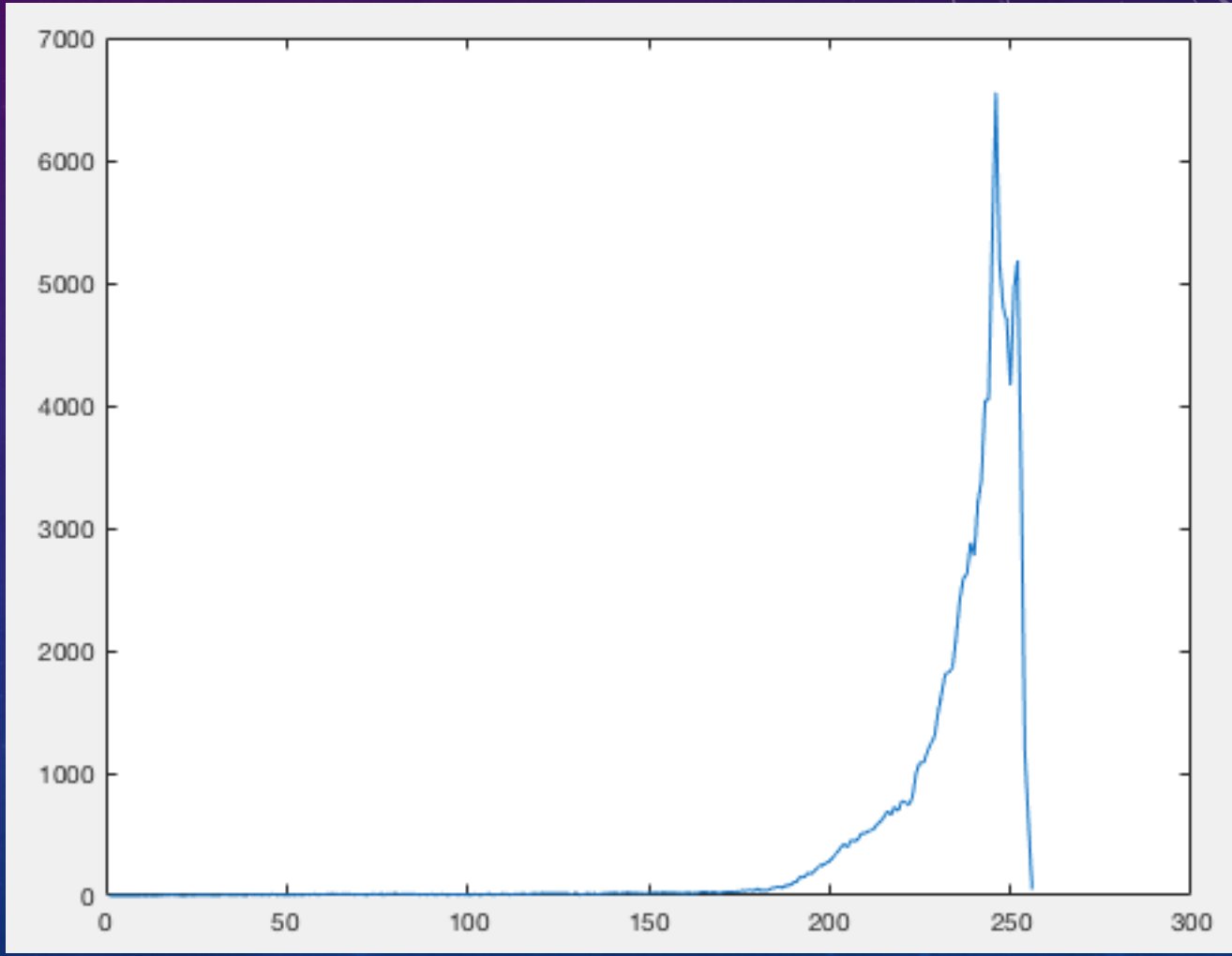




The **Brightness Temperature** values change with respect to different macro-categories (High, low, middle Cloud, Sea, Vegetation); High cloud pixel (left image) and low cloudy pixel (central image) usually show lower Brightness Temperature values than Sea Surface pixels (right side pixel). The Images are from MODIS, they were taken using the infrared window (11 µm) on 03/22/2017 - 17:04:05 UTC.

HISTOGRAM ANALYSIS

- BT image histogram describes the range of the pixel with respect to the elements inside the image such as low, middle and high cloud, sea and land;
- An image histogram usually shows neglectable fluctations giving rise to peaks that do not correspond with meaningful information of the image from a “macrocategory” viewpoint
- To extract the most meaningful information from the image histogram we adopt a straightforward downsampling

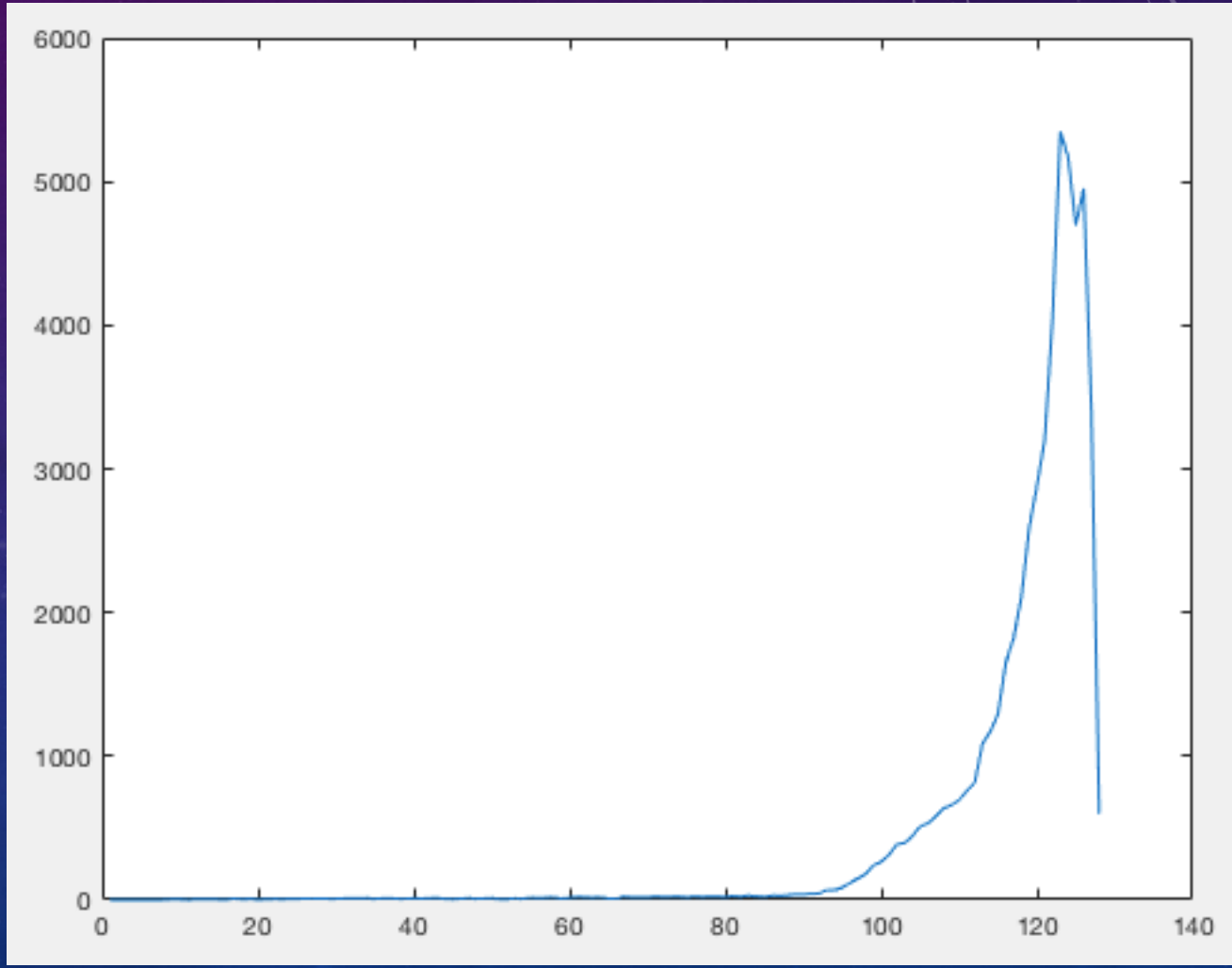


HISTOGRAM ANALYSIS

- Histogram downsampling allows to detect the most meaningful peaks of the “curve”

- A direct correspondence between the number of the most important peaks and the number of the macrocategories inside the BT Images is given

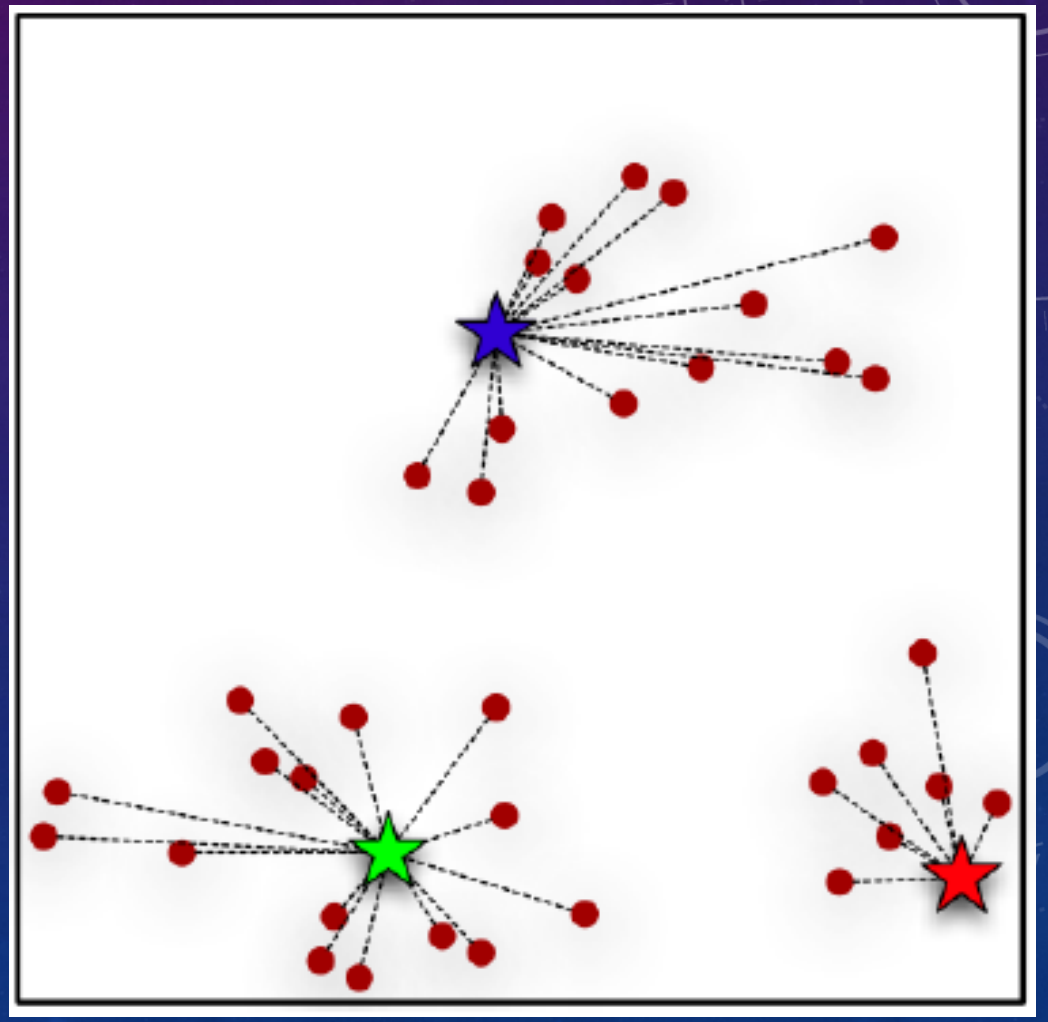
K (number of clusters of the image) = Number of meaningful peak of the BT Histogram



KMEANS CLUSTERING ALGORITHM

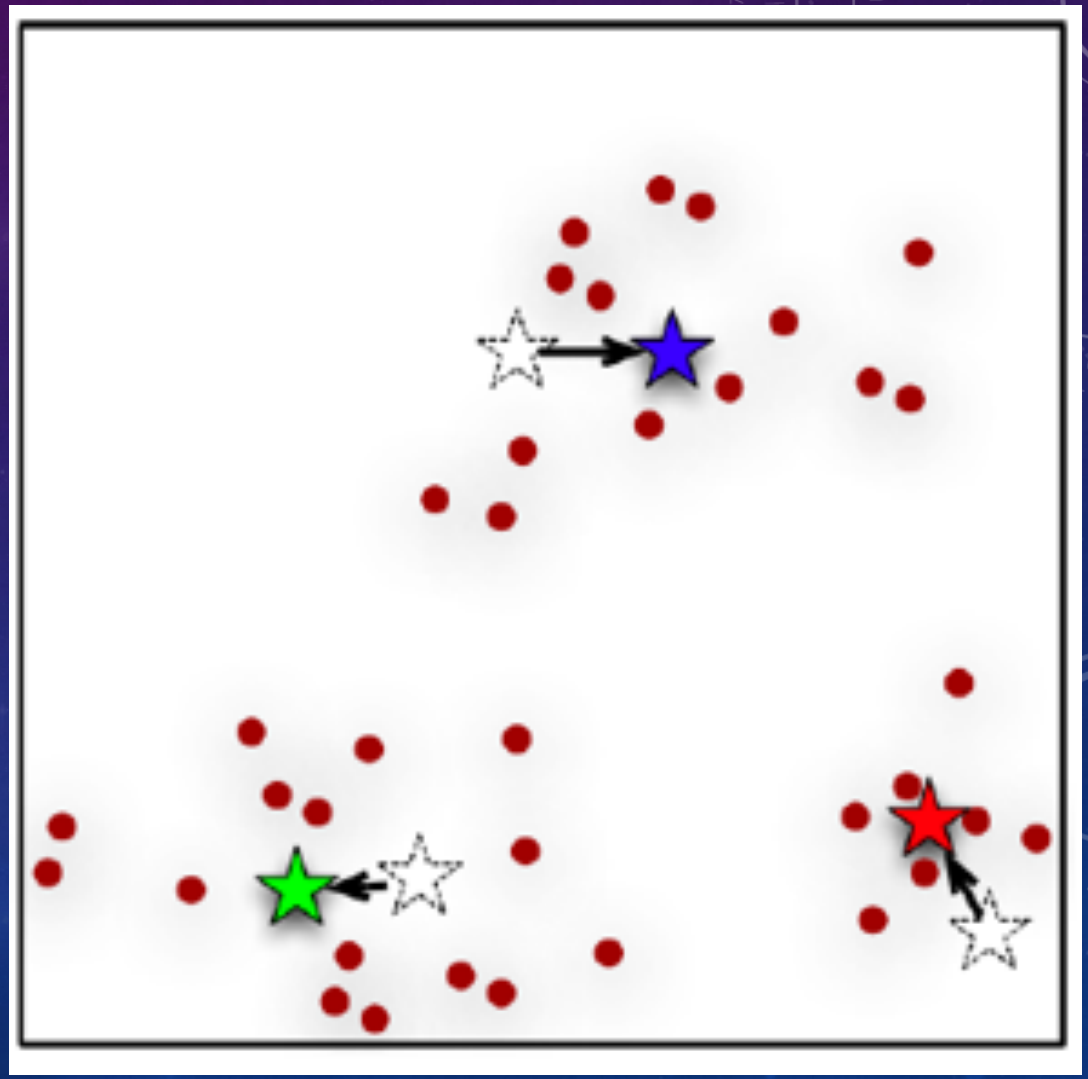
- Let's suppose data to be clustered into three clusters (K=3). K-means is an iterative algorithm and it does two steps: 1. Cluster assignment step 2. Move centroid step.

- In Cluster assignment step, the algorithm goes through each of the data points and depending on which cluster is closer, whether the red cluster centroid or the blue cluster centroid or the green; It assigns the data points to one of the three cluster centroids.



KMEANS CLUSTERING ALGORITHM

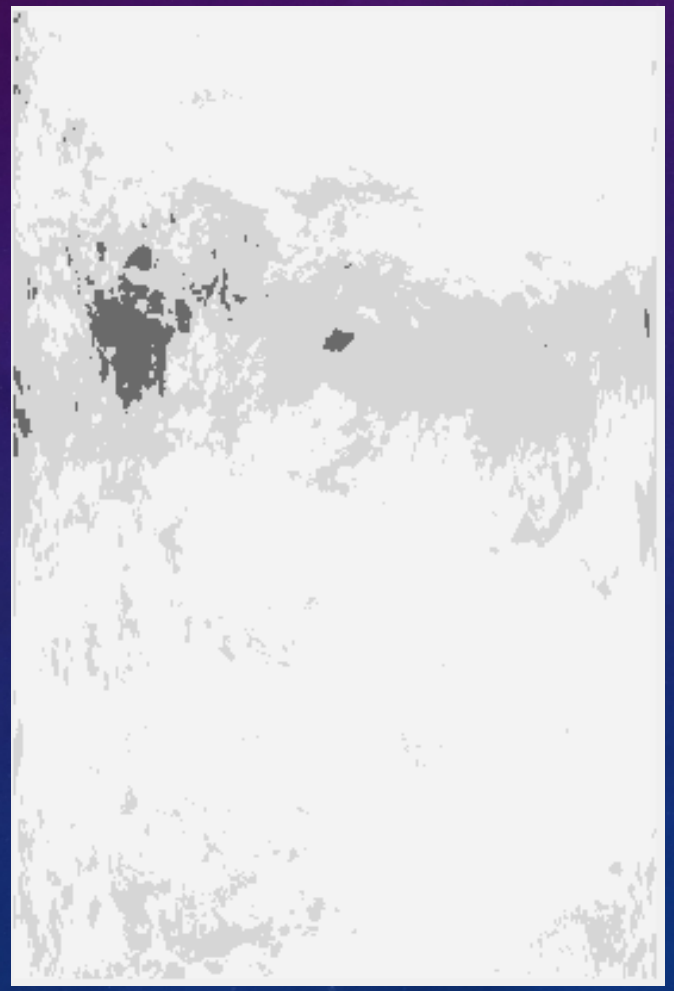
- In **MOVE** centroid step, **K-means** moves the **centroids** to the average of the points in a cluster. In other words, the algorithm calculates the average of all the points in a cluster and moves the centroid to that average location;
- This **process** is repeated until there is no change in the clusters (or possibly until some other stopping condition is met). **K** is chosen randomly or by giving specific initial starting points by the user.



KMEANS ON REMOTE SENSING IMAGERY

INPUT BT IMAGE
01/15/2017 - 17:20

CLUSTERED IMAGE (KMEANS)



The clustered pixels with respect to K number of clusters are mapped with respect to a grayscale range normalized to [0,1];

In the image aside, the number of K = 3 because of the automatic detection of the most important peaks of the histogram;

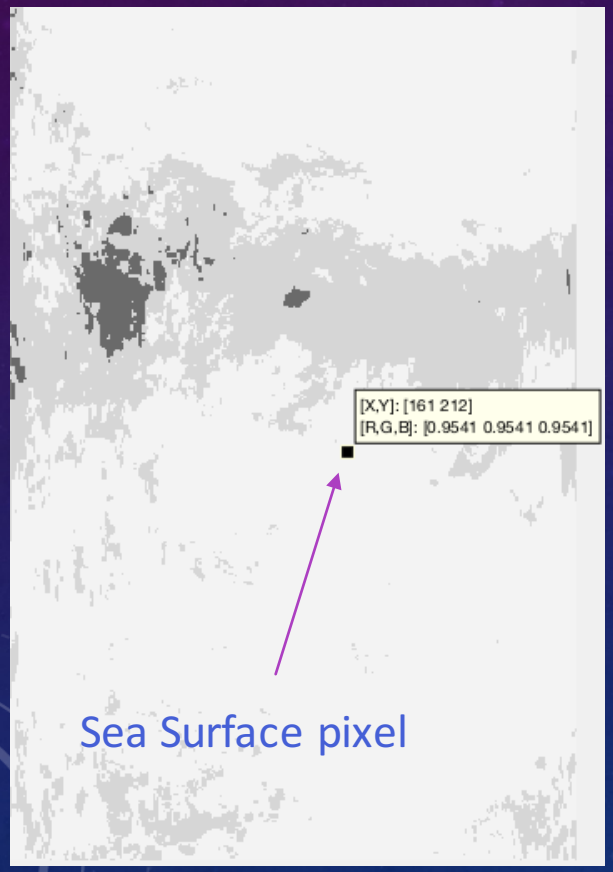
A further step is needed for an exclusive cloudy pixel segmentation;

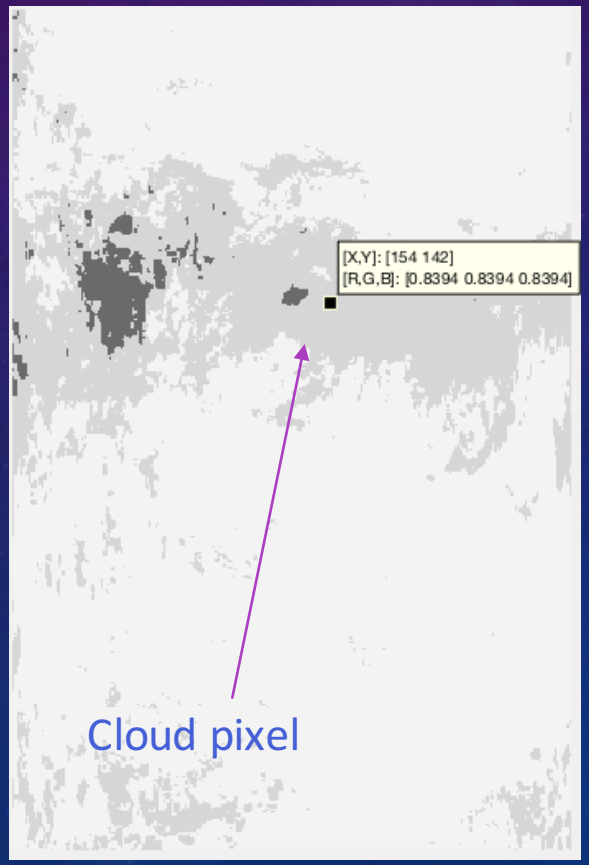
Kmeans allows to extract different pixel classes (Low, middle and high Cloud, Sea and Land);

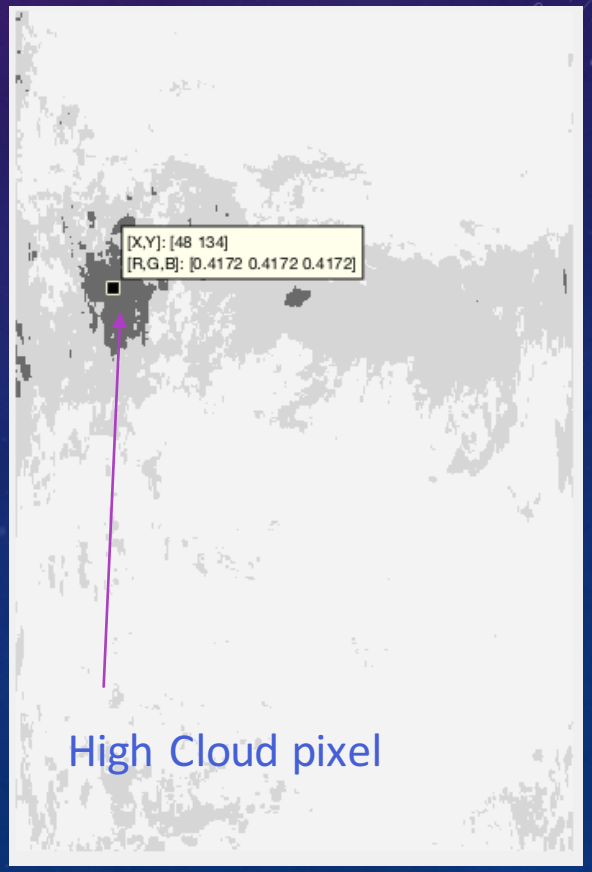
For cloud segmentation purpose a further mapping step is needed, then a straightforward cloud segmentation thresholding will be applied.

GRAY LEVEL MAPPING

- Clustered pixel value reveals the macro-category, the higher graylevel intensity corresponds with sea surface pixel whilst others correspond with High, Middle and Low Cloud pixels.
- In the next step, to make segmentation step a simple and straightforward thresholding, cloud pixels are connected in a single “class”







CLOUDINESS MASK

- All the pixel belonging to high, middle and low Cloud are connected, then the Image consists of two cluster pixels: Cloudy, Non Cloudy;
- Then a straightforward threshold is applied to segment clouds ;
- A pixel is cloudy if the intensity gray level is lower than the higher class pixel value;
- The binary cloudiness mask show pixels assuming value 0 (non cloudy) and 1 (cloudy pixel);
- **Remark**: The cloudiness mask is obtained by using **ONLY Brightness Temperature** information, whilst Cloud Masks with Satellite Products (such as MODIS) are detected through optical and infrared channels and using also radiative information

EXPERIMENTAL RESULTS - CLOUDINESS MASK (MODIS 36 BANDS)

Brightness Temperature Image (11µm)

Dark Regions correspond with Clouds

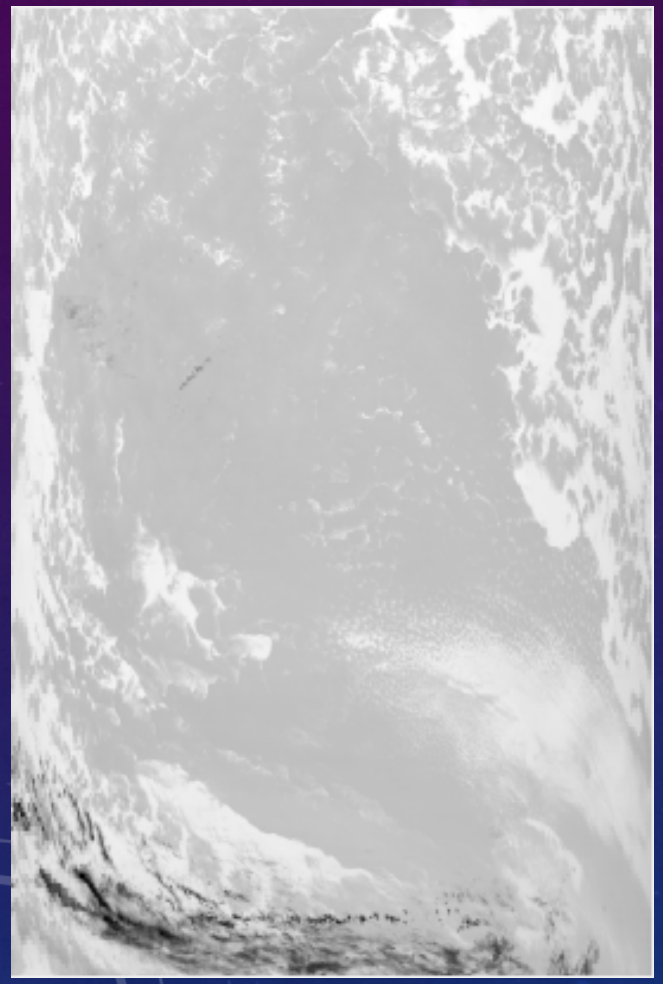
Cloudiness Mask

Cloud Mask shows pixel assuming value 1 (cloudy) and 0 (non cloudy)

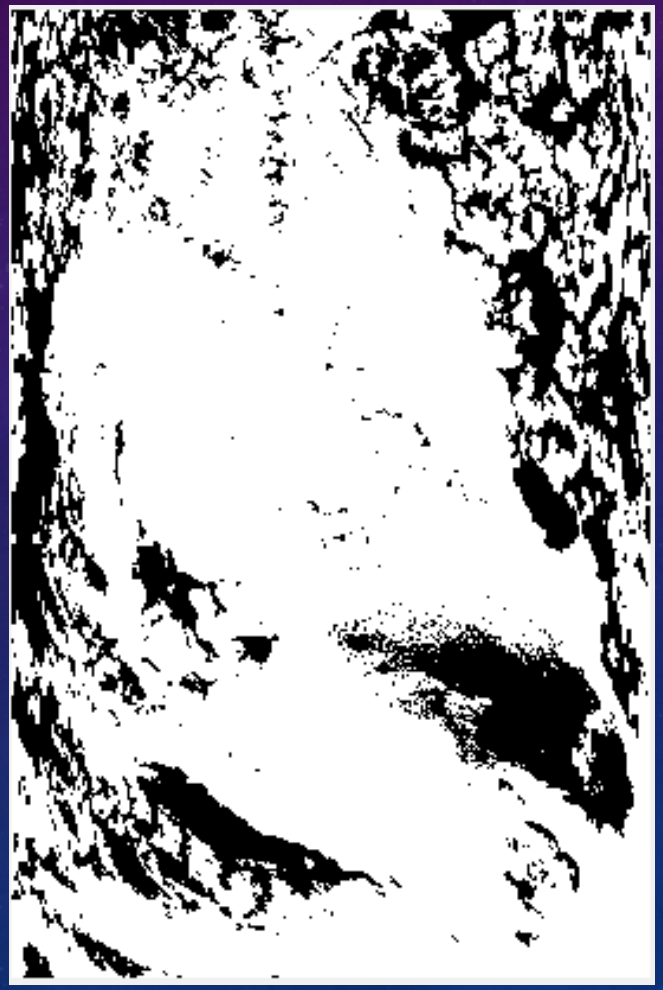
Ground-truth

EXPERIMENTAL RESULTS – CLOUDINESS MASK (MODIS 36 BANDS)

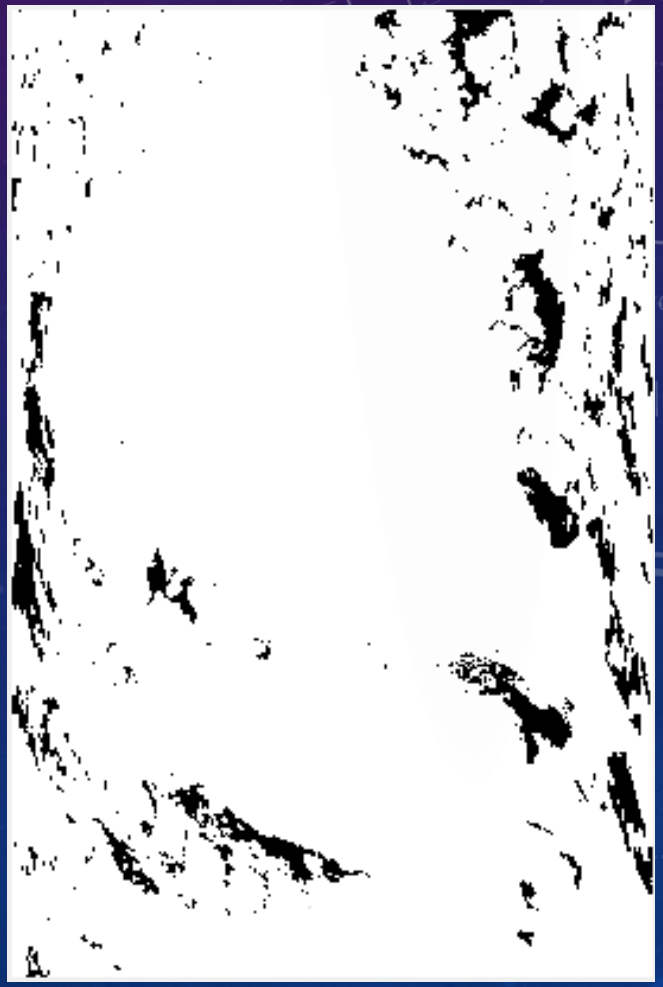
Brightness Temperature Image



Cloudiness Mask

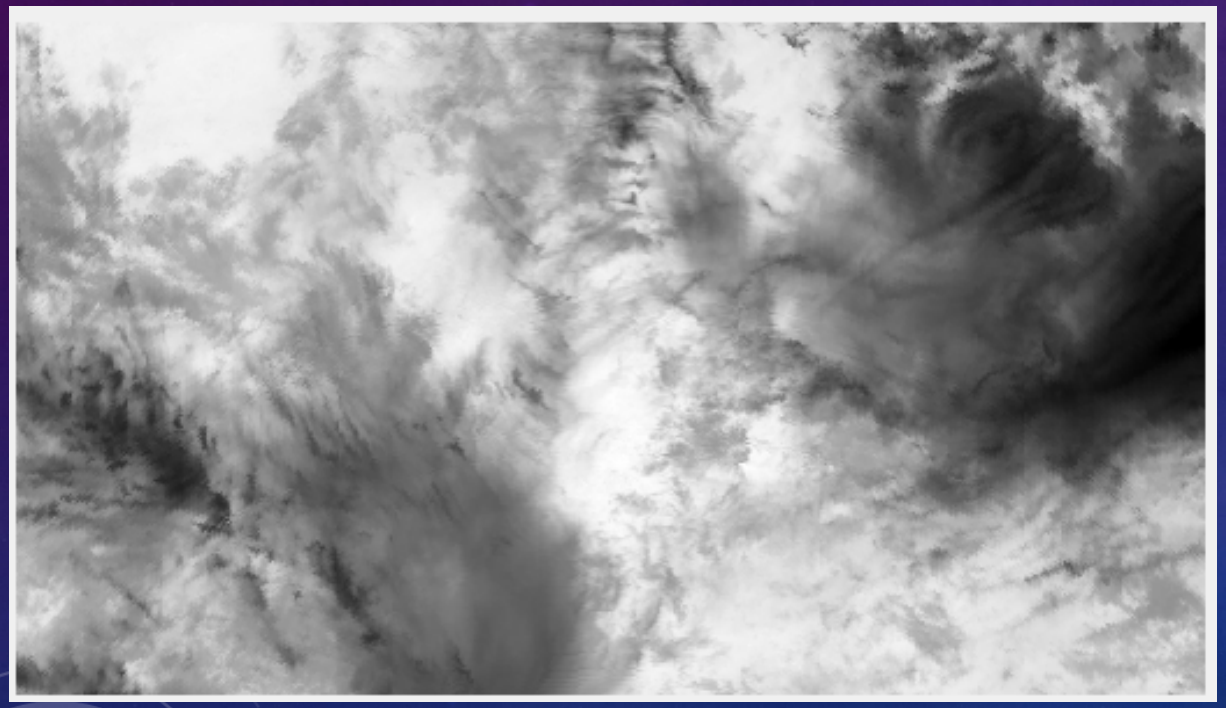


Ground-truth

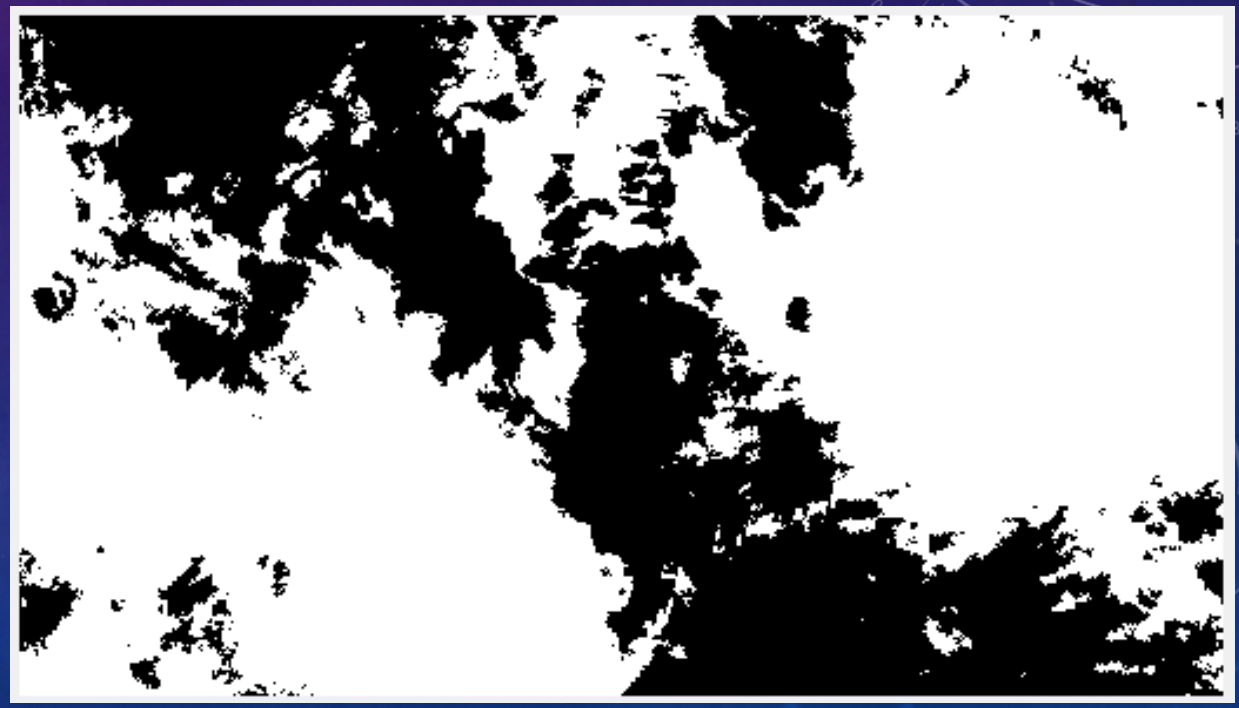


EXPERIMENTAL RESULTS – CLOUDINESS MASK (AATSR)

Brightness Temperature Image



Cloudiness Mask



QUALITY METRICS

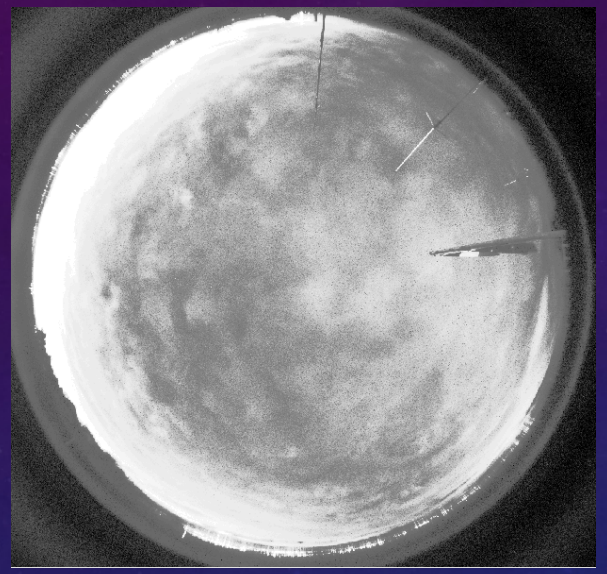
$$\text{Precision} = \frac{True\ Positive}{True\ Positive + False\ Positive}$$

$$\text{Recall} = \frac{True\ Positive}{True\ Positive + False\ Negative}$$

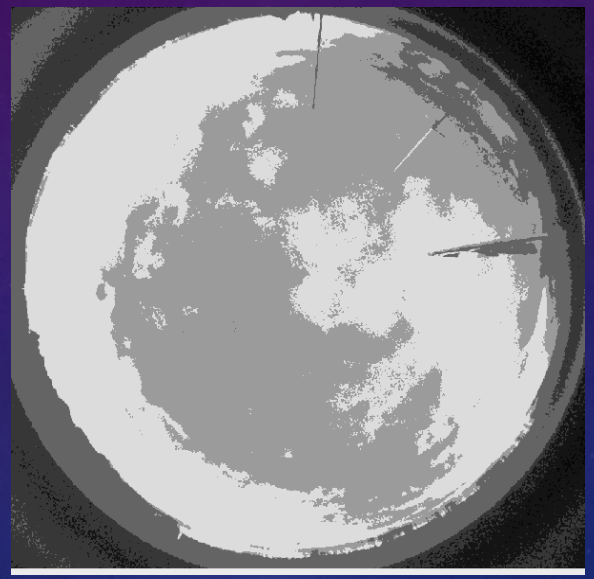
PRODUCT/IMAGE	PRECISION	RECALL
MODIS 03.22.2017 – 04:05	100%	75%
MODIS 01.15.2017 – 17:20	80%	86%
MODIS. 03.22.2017 - 09.05	96%	86%
MODIS 01.15.2017 – 17:40	96%	73%

EXPERIMENTAL RESULTS

Despite a ground-truth is not available, the method is also applied on ALLSKY overnight Images to extract a preliminary cloudiness mask



INPUT ALLSKY IMAGE FROM PRISMA PROJECT



CLUSTERED IMAGE WITH RESPECT TO THE MOST IMPORTANT MODES

BINARIZED IMAGE

Prisma Project Credits ….

CONCLUSIONS AND FUTURE WORKS

- The proposed method allows to achieve good performance in terms of cloud detection accuracy on several remote sensing imagery products (MODIS, AATSR, SENTINEL-3);
- As quality metrics show, the method slightly lacks accuracy in thinner clouds because of misclassification of Kmeans clustering, depending on the gray level intensity inside the BT images;
- In future works a further experimentation is needed for improving the overall accuracy in cloud detection;
- The idea behind the future works is to adopt several clustering methods and combining the results with a voting mechanism.