Identification and Classification of Cloud–dense areas in Infrared Weather Imagery using Intensity Contours

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Abstract—An alternative method to detect cloud density on geographic locations of the satellite infrared images for the prediction and nowcasting of weather and precipitation has been derived and tested. INSAT and METEOSAT satellite captured two different images were used for the analysis. Those images were covered different range and period of time; it shows the geographical areas of India and its nearest subcontinents. The techniques applied for cloud studyare density slicing and image contouring, the core idea behind the technique thatthe various intensity levels of gray in the monochromic images. Three basic steps involved in this task, Grayscale conversion, plot contour lines, provide labels.There are two contouring techniques appliedto carryout tests. After experiments the cloud dense areas are identified and classified into five categories. Those categories indicated by five colors, a circle like white region covered by red color spectacles that a cyclonic circulation formed on that location, same time a white region bounded by blue curves indicates no cloud on that particular surface

Keywords —Cloud Intensity, Density Slicing, Image Contouring, Infrared Vision, Weather Image

1. INTRODUCTION

Weather is the state of atmosphere at a place and time as concerns rain, wind, temperature etc., on meteorological perspective, most weather occurrences happen in the troposphere[1], just under the stratosphere. Meteorological conditions changes primarily due to temperature and moisture differs from one location to another location. The long-range difference (various times of a year) makes climates or seasons. These differences can occur due to the sun angle at any particular location, which differs by latitude from the tropics. These weather changes are making a crucial impact on lives of living hoods by the way of rain, heat wave, storm, cyclone, typhoon, hurricanes, snowfall etc.

The weather predicted by the approachessuch as numeric (mathematical) models, radiosondes and weather satellite images. From these methods, numeric model is very traditional technique of forecasting; now the meteorological department uses image-processing systems for weather predictions. The satellites were launched particularly for capturing earth surface to detect clouds formation, moisture density, and convective clouds.The idea behind weather imaging is maps, which startedto use in mid nineteenth century to formulatea theory on storm systems. IsothermsMaps shows the temperature gradients,which can help to locate weather fronts [2].At present, weather satellites are using to monitor the current weather of atmosphere. These satellites are polar (equator) orbiting, spinning at the speed of Erath and seem to be at the same location. These satellites send real-time captured image data to the ground stations. It observes the surface by using various channels of electromagnetic spectrum. The visible and infrared are the two widely used channels. The drawback of visible channel is that, it cannot be applied for the night hour's areas. However, that is not at all an obstacle in infrared vision.

2. WEATHER IMAGES

2.1 Infrared images

The infrared(thermal) images recorded by sensors called scanning radiometers tocalculate cloud heights and types,locate oceansurface features, and measure land and surface water temperatures. Infrared satellite imagery can be used effectively for tropical cyclones with a visible eyepattern, using the Dvorak technique, where the difference between the temperature of the warm eye and thesurrounding cold cloud tops can be used to determine its intensity (colder cloud tops generally indicate a moreintense storm)[3]. Infrared pictures show ocean tides or cyclones and map currents such as the Gulf Stream, which are valuable to the shipping industry. Farmersandanglers are attentive in knowing land and watertemperatures to protect their crops against frost or increase their catch from the sea, even an El Ninophenomenon can be spotted. Coloredand contouring techniques are used to convertgray-shaded infrared images to color for easier identification of preferred information.

TABLE 1: Visible and Infrared Spectrum properties

Spectrum	Frequency (H_Z)	Wavelength (m)
Visible	10^{15}	0.6 µm – 1.6 µm
Infrared	10^{13} - 10^{14}	3.9 µm – 13.4 µm

Table 1 indicates the common spectrum used for the most geostationary orbit satellites to make images available ofEarth surface and atmosphere. These spectrum has medium traveldistance but most suitable for the manual processing.

Visible Spectrum:
Clouds cover only during the daytime. Not suitable for night vision.

Infrared Spectrum:
3.9 µm – 7.3 µm (Water Vapor), 8.7 µm, – 13.4 µm (Thermal imaging)[4].

2.2 Cloud density

Weathersystem ishighlycomplex because the system includes numerouselements.Amongthem the cloud is a very important factor.Clouds are composed primarily of small water droplets and, if it is cold enough, ice crystals. Cloud appears with various shapes, different Grayscale and not clear boundaries in the remote sensing images [5].Cloud consists of different layers. The formation of such layer clouds is primarily due to the local meteorological conditions, in which increasing moist air-cools until it becomes sufficiently supersaturated with water vapour to allow condensation on submicron diameter atmospheric particles[6].Cirriform, waveform, cumuliform and,stratiform are the various kinds of clouds based on its density. Cirriform clouds are very wispy and feathery looking, waveform clouds occur in sheets or patches with wavy, rounded masses or rolls. Cumuliform clouds are usually puffy in appearance, similar to large cotton balls. Stratiform clouds are horizontal in nature, layered clouds that stretch out across the sky like a blanket [7].The basic classification implies three elementary categories i.e. high, middle and low clouds. Thus, it is possible to classify clouds based upon its density level, and it would be an accurate fact for the precipitation nowcasting. Volume ofclouds present in the atmosphere at a given locationcalculated as per the term $g/_{m^3}$. The same term applied for finding mass of air. The less intensity cloud may be fog or leads to drizzling, medium density clouds provides scattered rainfall up to 10 mm. the high density clouds may be a severe cyclone (hurricane, typhoon) and pouring more than 25mm rainfall.

3. METHODOLOGY

The weather images are analyzed for the prediction of both forecasting and nowcasting, and applied for statistical study. Consideration on flood, drought, cyclone and monsoon are done with the collection of satellite imageries. These image dataset are makes meteorologist and weather analyst to make decisions easily.

Density slicing and image contouring are most related methods known with different dimensions. Here, a single method used (contour) that explore infrared image, and map different color code for variability on density. The density slicing is the process of pixel classification based on intensity, but the contouring is the process that groups classified pixel categories and draws curves or plots stream of points.

3.1 Density Slicing

The term density slicing is the part of false color image processing. Allottingcolor on the pixels to the gray values based on the intensity levels i.e. the process of replacing gray level detail to specified color details. Here, each gray level has arranged with equalizing color pattern. Image noise can also be reduced by using density slicing.As a result of slicing, image can be segmented, or contouredinto slices of parallel grey level pixels.In weather image processing,analysis of satellite imagery to enhance the information gathered from an individual brightness band. It is done by dividing the range of brightness's in a single bandinto intervals, then allocating each interval to a color. [8].

$$f(x,y) = \begin{cases} 1, if\ f(x,y_i) < level_{n-1} \\ 0, if\ f(x,y_i) \geq level_1 \end{cases} \quad (1)$$

Where, *i*is pixel location, *n*maximum intensity level. At each pixel, graylevel details divided into categories for color allocation.The slicing process starts with $f(x,y_i) \geq level_1$condition which indicates *pixel data = 0 = white*.The peak intense *pixel data = 1 = black*. In-between, other white to black colors had categorized in equal intervals.

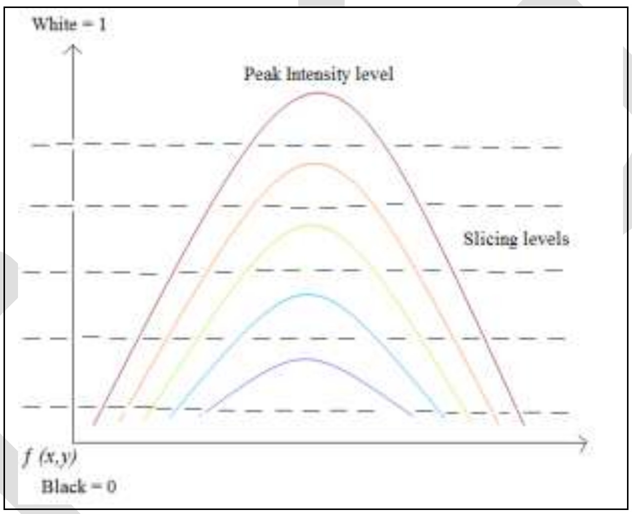


Figure 1: Density Slicing Graph with five color levels

The fig. 1 shows the graph that state about how an infrared image transformed into color contoured map. The *y*axis denotes intensity and *x*indicates pixel data. The lowest or *zero* value for black pixels, highest intensity level is white, and *one* represented for white pixels, in-between *0.5* may represent gray-100% color. Five different color curves plotted on the graph, it separates black to white pixels equally.

3.2 Image Contouring

Edges of a particular surface in the image, connectedto make a region boundary. This connecting activity is called a contour. These may be plotted over the boundaries or density variations on the image itself [9]. The contour may be open or closed.An open contour may be part of a region boundary, which is not projecting a boundary. Closed contours correspond to region boundaries, and the pixels in the region may be found by a filling algorithm. Here, open contours are done by single looping plots where closed contouring by looping plots by more than once. The edge detection is the most relevant ideology to contouring, because both are finding regional boundaries, in addition to that contours provides extra detail that about intensity. The canny edge detector applied for such operations [10].

A contour represented as a list of edges or by a curve, i.e. each curve segregated by its density on that particular location where the curve plotted [11].These contours are the outlines that implied by,

$$C = (v_{0,} v_{1,} \dots v_{n-1}) \quad (2)$$

where, *C* is contour Vector$v$ of *n* length.

$$|C| = \left(\sum_{i=0}^{n-1} |v_i|^2\right)^{\frac{1}{2}} \quad (3)$$

|C| is length of contours, and v is vector.

The image contours are follows density slicing, i.e. each contour line plottedbased on the density. The lines drawn as curves classified into different colors for different intensity in the image.

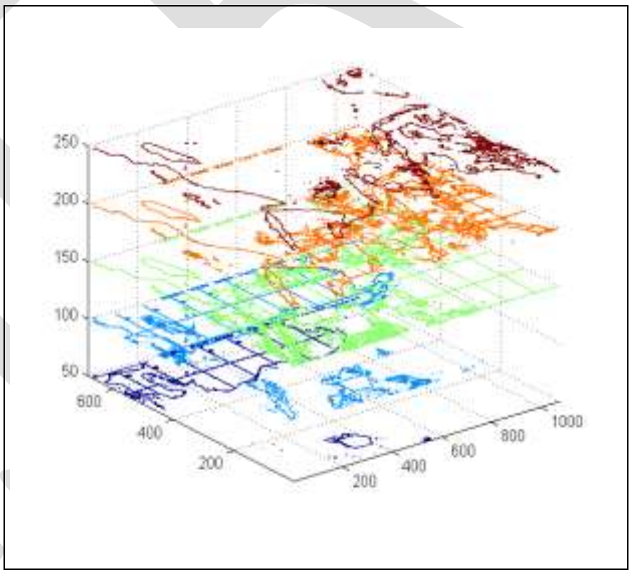


Figure 2:3-D graph for Infrared Image with different density levels.

The Fig.2 shows the three dimensional view about contoured layers of the infrared image ‘meteosat.jpg’.The*x* and *z* axis denotes pixel map, and *y* axis represents density of those pixels. The maximum intensity level is set as *250*and the minimum level as *50*.The infrared image had categorizedinto five layers according to their own gay level details.Each same valued pixel were connected by plotting curve between them, after to separate each layer, five different colors set for each of them.

4. PROCEDURE

Cloud density identification process consist of four tasks, in some cases it need one more task that to convert a RGB (Red Green Blue) infrared image to Grayscale monochromic image [12]. The Fig. 3 illuminates the entire procedure of the image analysis. Thus, satellite infrared images were taken for contour analysis as a first step of the process, and the consecutive second step is needed at some circumstances while using *RGB* image for the study. When the color thermal images used for density slicing or contouring, that image must be converted to Grayscale, because in the pixel analysis state, the matrix of image should be at least two dimensional.Third stage is to plot contour lines based on their intensity, and it is possible to provide annotation based on the contour plots or curves. The final steps are identification and classification of cloud with referring to the contour color layers.

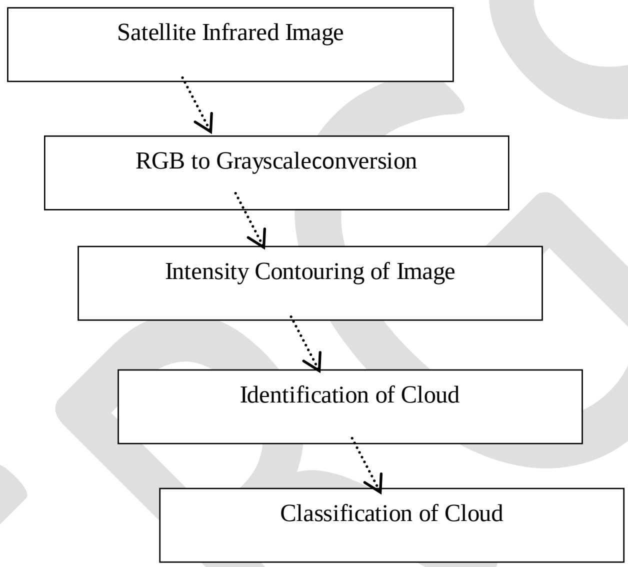


FigURE3: Theflow diagram for the cloud classification process.

TABLE 2: Contour Colors and Custom ranges

Color	Range
	250
	200
	150
	100
	50

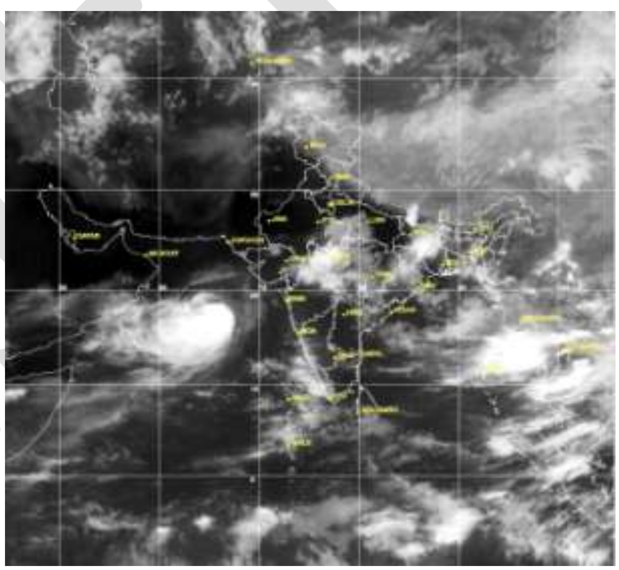
The table 2 shows that colors assigned for the contour lines and corresponding numerical range. These ranges are applied to segregate curves for analyses cloud variations on the imagery. The colors and ranges given on the table for analysis are fully user defined; those numbers did not show any relevance to the rainfall. The range denotes lowest intensity cloud to the highest on the atmosphere.

Two satellite infrared images captured by two different satellites INSAT (Indian National Satellite System) and METEOSAT (METEOrologySATellite), taken for experimentation from the public access websites of IMD (Indian Meteorological Department) and EUMETSAT (European Organisation for the Exploitation of Meteorological Satellites). Both the images are infrared thermal pictures namely "insat.jpg" and "meteosat.jpg". First image was Grayscale by default; second one was color thermal imagery. The images are labeled as '*A*' and '*B*' respectively and those images are different in size, captured date-time, capture satellite and covering area. The test images would be taken into Matlab application for the experimentation.

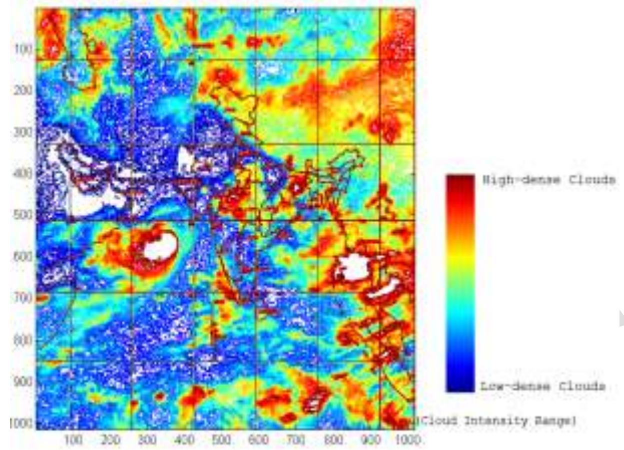
5. RESULTS AND DISCUSSIONS

After carrying out tests, images had Grayscale conversion, subsequently that converted into bi-colored image sliced with intensity pattern, a new map created that illustrates an outline of given image with variety of color curves (contours), and finally high dense clouds were noted with the label of range 250. The contouring was done in two types, single contouring and contouring with fifty loops.

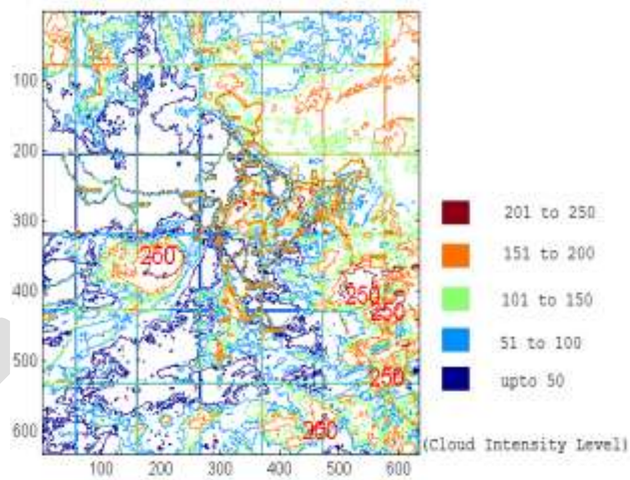
Whensingle contouring of image '*A*' done, a map was shown that there were 5 heavy cloud areas were detected on INSAT image, which was represented by the customized range 250 that was marked on the map (fig.4-c) with red color.The Fig. 4-b makes the results much easier as it draws closed contours i.e. a white region surrounded by dark red shows a depression or low pressure area or a cyclone. At the same time, a closed region surrounded by dark blue make us to conclude that high pressure or clear sky without any clouds present. Image '*B*' had one more step added to '*A*' that Grayscale conversion, then it contours on the map with five colored curves. Fig.5-c express two well-marked cloud dense areas on the location 200(y axis) – 600(x axis) and 100(y axis) – 600(x axis). The tiny cloud dense locations were detected on the Fig.5-d with open contour labels; it shows twenty four high-dense (250) categorizedclouds were spotted on the map.



(4-a)

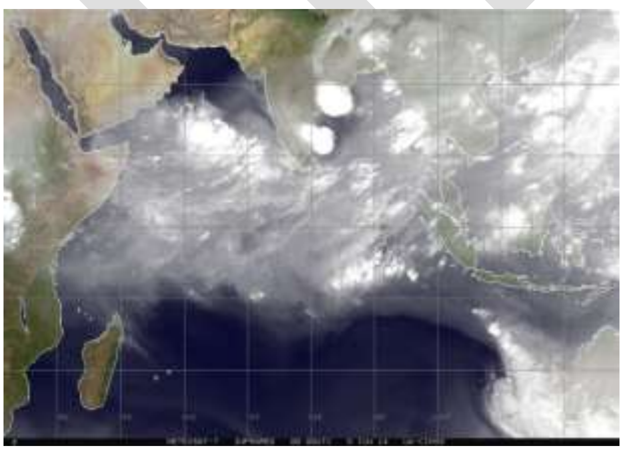


(4-b)

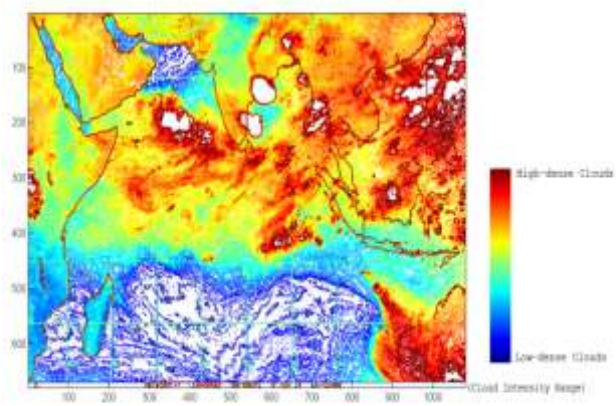


(4-c)

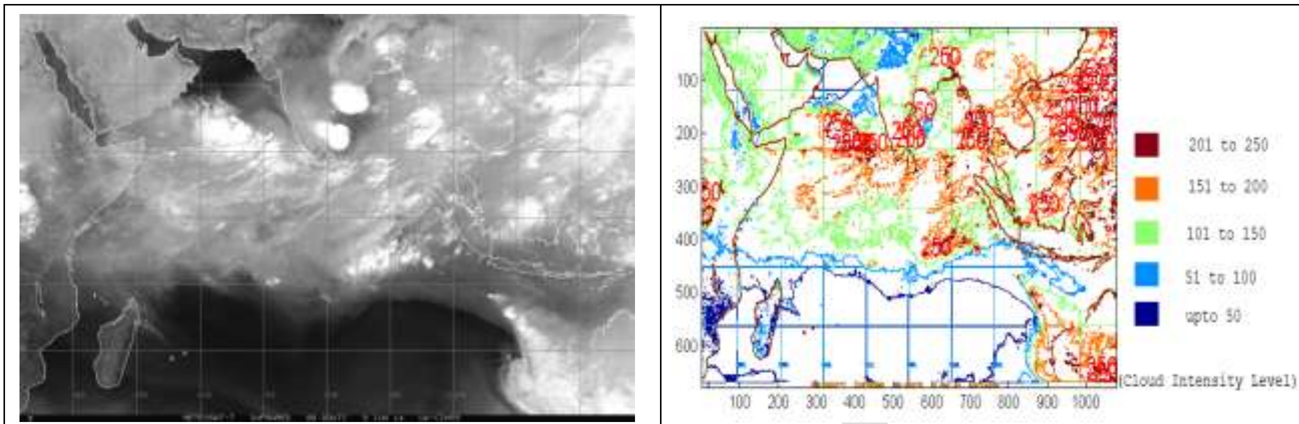
Figure 4:(a) INSAT Infrared Image (b) Map with 50 contour loops (c) Single contoured map with high cloud dense areas annotated.



(5-a)



(5-c)



(5-b) (5-d)

Figure 5: (a) EUMSAT Color Infrared Image (b) Grayscale converted Infrared image (c) Image after 50 Contours (d) Single contoured and Cloud level labeled map.

6. CONCLUSION

Satelliteimages are analyzed for weather predictions. This paper discussesan alternate way for precipitation nowcasting by analyzing cloud density. The infrared satellite images were used for study. Two different images from two satellites were taken for experiment. The technique behind this analysis is image contouring a part of density slicing. Image contouring done by two ways, open and closed.After experiments, to conclude that, by using closed contours techniqueit is possible to identify well-marked low pressures, cyclones and depressions. When using single contours, predict cloud dense locations and also annotate cloud density levels on the image.With these techniques the cloud were identified and classified into five categories. In future, improving this concept can be elaborated for the purpose of weather forecasting and automated rainfall annotations to specified sub-areas represented on the imagery.

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