

A Data mining approach for Monsoon prediction using Satellite image data

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Abstract

The onset of monsoon is eagerly awaited in the Indian sub-continent as it has deep impact in the economic and social domain. It has been monitored and studied in great depth. With the advent of satellite imagery, it's now possible to monitor the different parameters which affect or gets affected by the monsoon in a more global scale. In this paper, the onset of monsoon is predicted based on the features extracted from satellite images using data mining approach.

1. Introduction

The prediction of rainfall is one of the major studies in meteorological science. In India, where 75% of agriculture is dependent on rainfall as its main source of water, the amount and time of precipitation holds high importance and can affect the entire economy of nation. Other than in agriculture, the study of rainfall is also required in the fields of aviation, shipping, fishing, cyclone prediction, drought management, power consumption etc. Hence the onset of monsoon is eagerly awaited by all.

Rainfall measurements have been taken in India for more than 50 years. The ground based measurements like radar, wind speed, pressure and humidity are highly localised and do not help much in providing long range prediction of rainfall. In the recent years, with the development of weather satellites, the monitoring of weather in a more global scale is feasible and long range monsoon prediction has become possible. In this paper we propose a method for medium to long range prediction of monsoon onset using a data mining technique based on satellite images.

In section I a brief is given on the different satellite images used for the paper and the source of those images. Section II explains the technique used for cloud detection. The detail on different features that are extracted and the dataset that is obtained is given in section III. Section IV explains the monsoon onset prediction algorithm and finally the features that can be

incorporated into the system to improve the efficiency are discussed.

2. Cloud detection in satellite image

A Satellite image is not a photograph of earth taken from space. They are the pictorial representation of various electromagnetic radiations measured by sensors on the satellite. A photograph is taken normally in the visible spectrum. Satellites take images in visible as well as outside this spectrum, like in the infra red, far infra red and near infra red etc. The infra red (IR) spectrum sensor measures the different thermal radiation (10.5 - 12.5 μ m) coming from earth (day and night). They are useful in differentiation land, sea, thick and thin clouds. IR images also help in calculating the cloud height, CTT (Cloud Top Temperature), an important parameter in identifying rain bearing clouds and SST (Sea Surface Temperature), another important parameter in the study of monsoon. Water Vapour Wind (WVW), which represents the humidity, is studied in the near infra red spectrum (5.7 - 7.1 μ m). The visible spectrum image (0.55 - 0.75 μ m) is useful in determining overall cloud coverage, thin clouds, fog, pollution, smoke etc [7]. Based on the type of spectrum and the type of satellite (Geostationary or polar orbiting), the resolution of image varies from 2km to 8km.

Cloud detection in satellite images is the pre-processing step of all satellite imagery. Their accurate detection is difficult as clouds can easily be confused by sand, snow or ice covered surfaces. Many studies and developments have been made in this field with varying techniques, technologies and success rates. Most of the cloud detection techniques in satellite imagery make use of the high reflectance of cloud in the visible (VIS) spectrum and/or the low temperature in the infra red (IR) spectrum. As mentioned in [8], cloud detection methods can be categorized into two.

The first category utilizes the difference in the reflectivity of thick clouds, thin clouds, land, and water

in the Visible spectrum during day time and the difference in the temperature radiance of cloud and other entities in the Infra red spectrum during both day and night. Based on this technique, seven different types of clouds can be identified in satellite image [9]. The second category utilizes the texture of clouds to identify and classify clouds. A variety of techniques based on pattern recognition and/or maximum likelihood estimation method and the use of Artificial Neural Network (ANN) come under this category. But the results based on the second category are comparatively poor, as clouds (especially low clouds) have very complex shapes and it's not easy to typecast them based solely on their texture.

For our system, we would use a technique similar to what Xiaoning Song, Yingshi Zhao and Zhenhua Liu used in their work [10]. Cloud is detected using the spectral characteristics of cloud in the visible and infra-red spectrum. Cloud has high reflectance in the visible spectrum and low radiation temperature in the infra red (thermal) spectrum [11]. Cloud can be detected in the thermal infra-red band based on the low temperature of the cloud top, but this fails in case of thin clouds, however thin clouds show high reflectivity in the visible spectrum (but can be used only in daytime). The trick here is in identifying the correct threshold. The thick cloud and thin cloud edges are determined by infrared band.

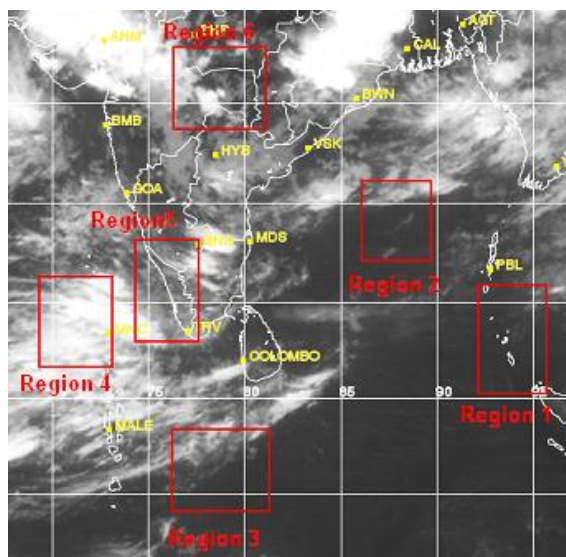


Figure 1: six regions used for extraction.
(Courtesy IMD)

3. Features extracted from Satellite Image

For this study we would be using the Infra Red, visible and water vapour images from INSAT-3A and Kalpana-1 for the months of April, May and June.

Rather than measuring the entire Indian sub-continent disc region, for the prediction purpose we would extract features from 6 satellite image regions; the region near Andaman and Nicobar Islands, the Lakshadweep Islands, the area nears Kerala, the Bay of Bengal, the Indian Ocean, and the mid regions of India as shown in Figure 1. The following features would be extracted from the image data set:

- **Sea Surface Temperature (SST):** This would be extracted from the IR images of INSAT-3A and Kalpana-1. Care is needed to ascertain that the temperature readings are taken from region void of clouds. SST is a key parameter controlling climate in the Indian subcontinent. In the case where clouds are present in the image, the average temperature for the season is set as default.
- **Cloud Top Temperature (CTT):** This is extracted from IR images of clouds present in the region. Colder clouds have higher probability of causing precipitation. In the case of absence of Clouds in the selected region the CTT is taken as IR intensity at the region.
- **Cloud density:** Cloud density or thickness can be estimated based on the intensity of visible radiation reflected and the temperature of the cloud. Thick clouds have higher chance of being rain bearing. When clouds are not present, the value is considered as 0. A high intensity in the visible spectrum and a low CTT (both based on thresholds) will warrant a 1 else 0.
- **Water vapour or humidity:** this is extracted from the water vapour wind (WVW) image. Higher the humidity, higher is the probability of precipitation.

Since the Thermal and visible images are represented as 8-bit greyscale image, each of the above parameters can be represented by values between 0 and 255. The values would be extracted by taking the histogram of each region and based on the parameter the intensity value over the majority area is considered. The extracted features for each hour of the day, for all the six regions will be represented as a single record. The data set consists of previous seven years of image data for the months of April, May and June; out of this four year data would be used as training dataset and the remaining 3 year for testing.

Table 1 shows the expected dataset created by the extraction process. Cells showing 0 for cloud density and CTT are for thin clouds or their absence. 0 SST are for regions over land. The final column, “Onset Days

Left” is the result field of the data set showing the number of days to the onset of monsoon for that year. In 2006 the onset was declared as 26th May.

Table 1: Sample Dataset extracted from six regions

Region→	Region 1				Region 2				Region 3				Region 4				Region 5				Region 6				Onset Days left
← Date (YYMMDD)	SST	CTT	Cloud density	Humidity	SST	CTT	Cloud density	Humidity	SST	CTT	Cloud density	Humidity	SST	CTT	Cloud density	Humidity	SST	CTT	Cloud density	Humidity	SST	CTT	Cloud density	Humidity	
20060425	56	80	0	100	60	0	0	10	55	0	0	20	50	0	0	25	55	0	0	25	0	0	0	20	31
20060426	95	110	0	130	75	0	0	20	90	0	0	25	60	0	0	35	90	0	0	30	0	0	0	18	30
20060427	98	120	1	90	95	0	0	25	90	0	0	28	55	0	0	25	90	0	0	28	0	0	0	10	29
20060428	95	125	1	110	85	0	0	25	98	0	0	35	58	0	0	20	98	0	0	20	0	0	0	18	28
20060429	97	110	0	125	80	0	0	25	89	0	0	28	60	0	0	25	89	0	0	25	0	0	0	25	27

4. Monsoon onset prediction algorithm

The entire prediction system consists of two stages. The first stage consists of creation of the dataset by extraction of parameters from 4 years of image data. The second stage is the prediction stage where the current (or test) IR and Visible image is provided and compared against the parameter values in the data set calculated in the first stage.

Input: Image dataset

Output: Monsoon Prediction

Begin

1. Set size of K-Array =0,
MaxDistK-Array=999999,
MinDistK-Array=999999
2. Extract all the 4 parameters from all the 6 regions of the IR and visible images
3. Repeat step 3 for each record of dataset
 - a. Calculate Euclidean distance
 - b. If distance less than MaxDistK-Array
 1. While size of k-array less than 7
 - i. Insert Record into KArray
 - ii. Increment size of K-Array by 1

Else

i. Replace record with
MaxDist in K-Array with
new record.

2. Update MaxDistK-Array value

c. If distance less than MinDistK-Array

1. Update MinDistK-Array value

4. Calculate the average of “Onset days left” of the seven records in K-Array

End

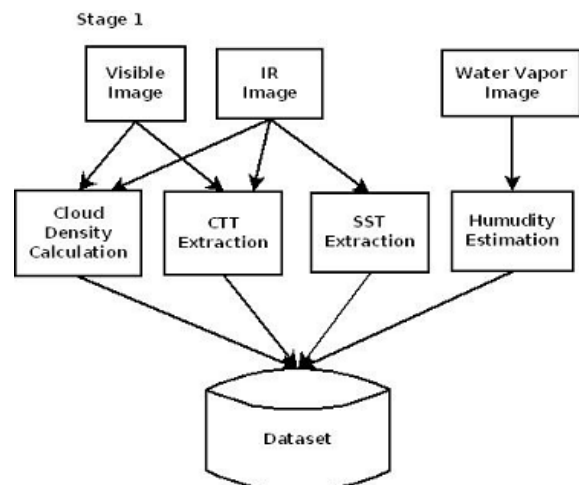


Figure 2 Block diagram of feature extraction stage

For the prediction of monsoon, we would be using Data mining technique, K- Nearest Neighbour algorithm. It is used with along with Euclidean distance estimation method for matching purpose. The K nearest neighbour value is taken as $k = 7$.

Euclidean distance =

$$\sqrt{(q_1 - p_1)^2 + (q_2 - p_2)^2 + (q_3 - p_3)^2 + \dots + (q_n - p_n)^2}$$

i.e.
$$= \sqrt{\sum_{i=1}^n (q_i - p_i)^2}$$

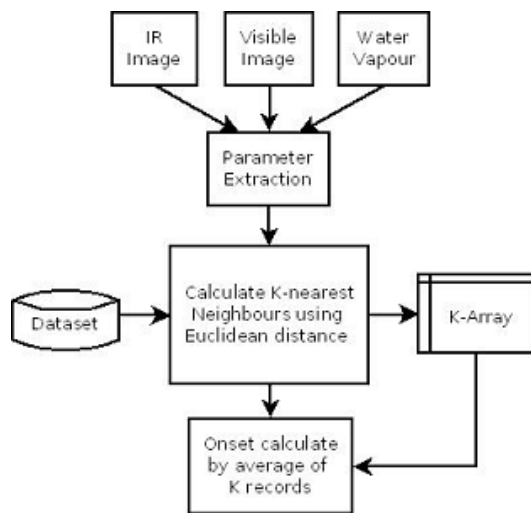


Figure 3: Block diagram of prediction stage

5. Discussion

The objective of this paper was to explain a new technique for the prediction of monsoon onset using satellite image data of previous years. The proposed system can predict onset 10-30 days in advance. There are lot of other factors which gets affected or affects the monsoon onset. The efficiency of the technique can be improved by adding those additional parameters like Outgoing long wave radiation (OLR), Quantitative Precipitation Estimate (QPE) and atmospheric pressure. Also more regions for comparison can be added.

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