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Research paper

Development of a cloud cover reader from whole sky images

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Abstract

Since the cloud amount in the sky is one of major variables to decide amount of sunshine or solar irradiance. A traditional method is eye-observation and it is widely used up to now. It requires one of observers at observation site for 24 hours due to the hourly observation. Another disadvantage is that there is individual difference and error between observers. Some of leading countries about weather observation have been trying to develop a cloud automatic observation system to replace the eye-observation. As a result, several methods have developed to replace the cloud observers, which have some restriction such as measurement range, accuracy and reliability. The conventional approach distinguishes between clouds and sky regions by RGB color and the ratio of each color in the image, but our proposed method extracts the cloud region using the optical properties of clouds and sky. The suggested method is applied to a randomly selected one day for 24 hours. The result shows that the amount of cloud compatible with the results of the existing observations be abele to obtained, and further quantified data can be obtained.

Keywords: *eye observation of cloud; automatic observation system; color space; optical attribute of cloud; optical attribute of cloud.*

1. Introduction

Clouds in the atmosphere are one of the important factors in the temperature change by reflecting the radiant energy of the sun and reflecting the radiant energy of the earth surface. Especially, it is important information for agriculture and industries that utilize solar energy because solar radiation directly affects solar radiation and sunshine. There are several automatic measuring instruments such as ceilometer using laser and radiometer. They can measure cloud height and thickness but those measuring range are restricted to their vertical direction. Hence, the human eye-observation method is widely used in the world. Observation of clouds includes cloudiness (total cloudiness, partial cloudiness) or cloud amount, cloud height and cloud type. Cloudiness is the amount of cloud which is defined as the value of area occupied by clouds from 0 to 10 when the observation area is taken as 10. The total cloud amount is the ratio of all types of clouds covering the sky at the observation site, and the partial cloud amount is the ratio of the clouds covering the sky at each altitude layer such as upper layer, middle layer, and lower layer. It is because the layer classification is that the type of cloud is different for each layer, and the composition of cloud is determined by weather conditions. Therefore, it is possible to predict weather conditions by knowing the type of cloud. Total cloud amount can be calculated not only the solar radiation energy at the surface of the earth but also the reflected earth's radiant energy at the surface of the earth, so it is an important variable in the field of utilizing solar energy. Therefore, WSI (Whole Sky Imager) and TSI (Total Sky Imager) are invited to improve the calculation of the cloud amount, but few studies related to it have been conducted domestically [1, 2]. Metrological Administration in Korea has been trying to automatize the cloud observation, but it is still on-going project to apply in the practical observation site or field. A common approach to distinguish between sky and cloud is to use the RGB component and the ratio of each color component obtained from the image. In this method, the radiation spectrum of sun is irregular according to the optical mass of the atmosphere, so the application of the method is limited because the ratio of the color component changes with time or the position of the sun. In this paper, we propose a Universal Covered-Cloud Reader Solution (UCCRS) based on the improvements of the performance and problems of the automatic weather observation system by applying the optical property of sky and cloud. The results of the proposed algorithm are consistent with the human perceptible cloud area from the sample images and it is possible to replace the human eye cloud observation.

2. Measurement of cloud covered in sky

2.1. Current approach to get total cloud amount

Until now, the cloud observations in the Korea are based on eye observations, but because of dependency on observers, there is lack of consistency and lack of time continuity because observation is made at a fixed period (usually 1 hour). Various researches have been developing on an automatic cloud observation system to replace the observing expert. However, since the system which can be applied to the measuring site has not been developed, the output of automated system was used as reference data of the eye observation result until recently. One of main approach is image processing technic such as k-nearest-neighbor method to get the cloud type [3], and another method is color analysis of the whole sky image [4]. The boundary detection between sky and cloud is difficult to get a usable result to analyze the whole sky image since the arbitrary shape and gradation of concentration at the boundary of the cloud and the sky. In this project, through the color analysis, we try to distinguish cloud and sky from cloud to cloud. This is the same that observers distinguish between clouds and sky in color from the observation range. Although the automation of the cloud observation is technically possible to replace only considering the economic efficiency when the observation error is smaller than the eye observation, the system developed until now is not more advantageous than the eye observation. The reason for this is that observation of clouds by information processing of acquired still images is not more advantageous than observation by observer's viewpoint, knowledge and experience. It is believed that the currently observing system is able to obtain images with higher quality than the observer's view, but the results are worse than the observer's results. Therefore, it is required to improve the system by researching and analyzing the human factor of the observer and intelligent system that develops the algorithm applying the observer's knowledge and experience. The final goal of this study is to improve the automation system by analyzing the human factor of the observer. The systems developed so far initially observe the whole sky area observed with a fisheye lens and the analyzing area should the whole-sky since the observing result is different due to the random distribution of the cloud and irregular pattern if the analyzing area is different.

2.2. Universal cloud covers reader solution

The cloud observation is performed by pre-processing of extracting the observation area from the obtained whole sky image, and by converting it into CMYK color space based on the RGB analysis and extracting the cyan component to correct the cloud area. By mixing green and blue in the RGB color space, a luminescent component can be produced. Human vision can perceive color, but does not have an ability to analyze perceived color. Nevertheless, when you analyze the solar radiation spectrum, you can see that the amount of blue and green radiation is larger than that of other wavelengths. Therefore, although the human eye recognizes the blue sky by Rayleigh scattering, which has a very high wavelength dependency, it does not have the ability to analyze the color of the blue sky, but the computer can utilize the green information as a useful identifier. Generally, green with wavelength longer than blue, which is adjacent wavelength, is less scattered. The intensity of the green component spectrum on the surface is still the same as that of the blue series. In addition, the intensity of the blue and green series is weak in the spectrum during the sun rising or sunset, but scattering blue and green in pure sky are stronger than the color component, so the sky can be identified. In other words, the reading pixel or area in the original raw image through the observation window is a pure sky region if lager Cyan components contour is selected in Cyan component or map. The cloud area is white due to Mie scattering which scattered light of all wavelengths. Also, the sky area is blue by Rayleigh scattering, which has a larger scattering effect as the wavelength is shorter. Therefore, the intensity of R in the sky region has a minimum value, and the intensity of RGB in the cloud region is relatively similar.

2.2.1 Extraction of observation window

Since the observation of cloudiness by the eyes is not limited to the observer's eyeball or neck movements, it is practically the same in the image obtained with the 180 degree fisheye lens and the observation range. In order to analyze the whole sky image, it starts from the process of removing the obstacle around the image. Depending on the characteristics of Korean terrain, which has more than 80% of mountain area, the surrounding part of ground based whole sky image consists of obstacles such as ridge, forest and trees and buildings. The search for the skyline is simple due to the characteristics of the image but artifacts like buildings cause problems that are light reflections on the surface depending on the position of the sun, and building lighting. An artifact removal process is added and it processes at once because artifacts rarely change. This process of removing the obstacle around the image is defined as observation window as shown Fig.1 that is the whole sky image at Daejeon regional weather station in Korea.

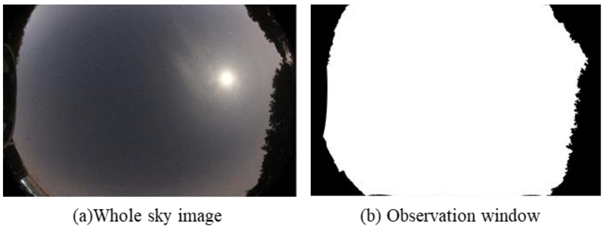


Fig. 1: Observation window extraction from the obtained image

Figure 1(a) shows a night pre-observation image of a 4th-generation automatic observation system. Preliminary studies have shown that the color and texture of the exterior wall of the building influences the observation during the daytime, and lighting at the building is affected to observation of cloud during the night. Figure 1(b) shows the observation window with the artifact as the building removed. The observation window is superimposed on the whole sky image to be analyzed.

2.2.2 Robust cloud cover reader algorithm

The whole sky image as shown in Figure 2, has been taken at same site as Figure 1 on the 3rd of Jan. 2018 at 12:00. The superimposed whole sky image with RGB color analysis has been performed and each color component has an index which is changed from '0' to '255'. The next step is normalizing process of RGB component to transform the RGB color space to CMYK system as shown in Figure 3. Each component has a value from '0' to '1' and the component of cyan which can be seen more clear the cloud form in the sky than that of RGB. That means Cyan values or indexes and CMYK color space suitable for the cloud observation since each C component of Green, Blue and Cyan is '1' in CMYK.

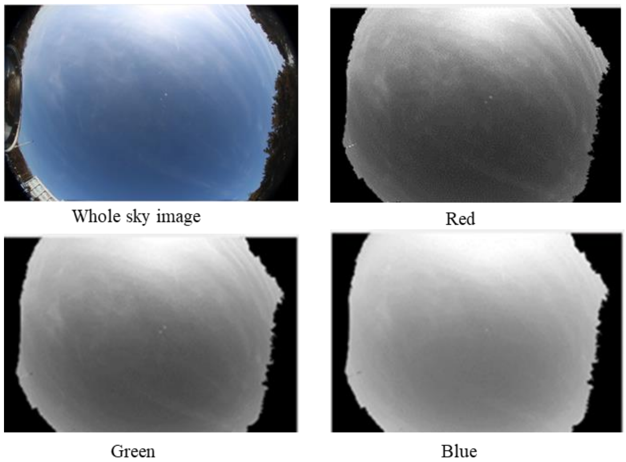


Fig. 2: RGB color analysis of the obtained whole sky image

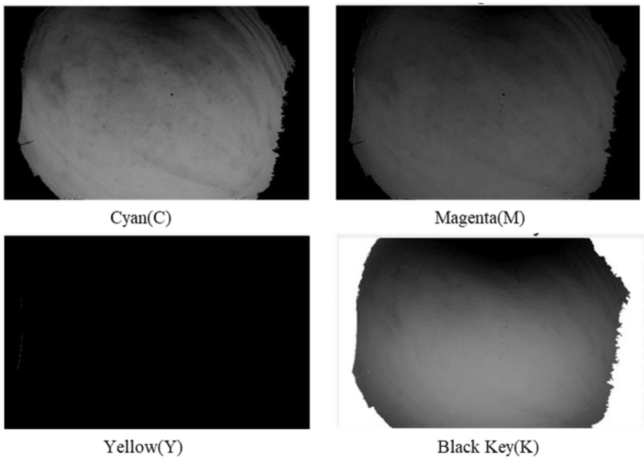


Fig. 3: Cyan, Magenta, Yellow, and Black key component in CMYK

The well-known RGB to CMYK conversion equations are following. The R, G, B values are divided by 255 to normalize value between '0' and '1'.

$$R_n = R/255$$
$$G_n = G/255$$
$$B_n = B/255$$
$$K = 1 - \max(R_n, G_n, B_n)$$
$$C = (1 - R_n - K) / (1 - K)$$
$$M = (1 - G_n - K) / (1 - K)$$
$$Y = (1 - B_n - K) / (1 - K)$$

Then, the index of Cyan is adjusted that the index values are modified new values such that 1% of data is saturated at low and high index of Cyan, like a grayscale image enhancing processing. Figure 4 is the proposed algorithm output and the covered cloud in Daejeon area was 32% at the noon on the 3rd of Jan, 2018.

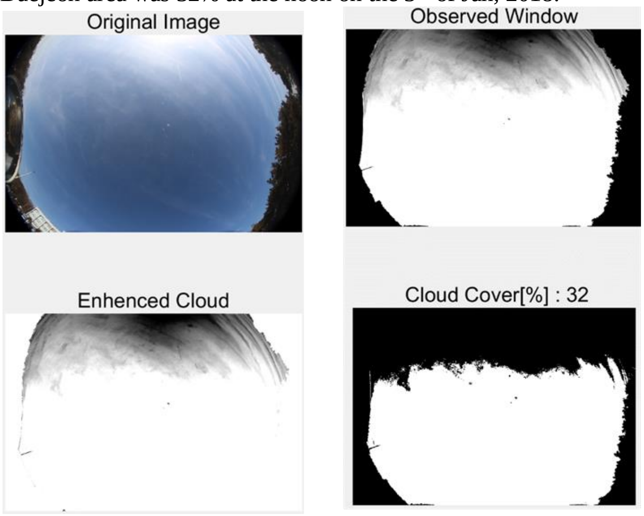


Fig. 4: The output of robust cloud cover reader algorithm

The output might be acceptable and reasonable to cloud observation experts. The block diagram of preprocessing and UCCRA are shown in Figure 5 and Figure 6.

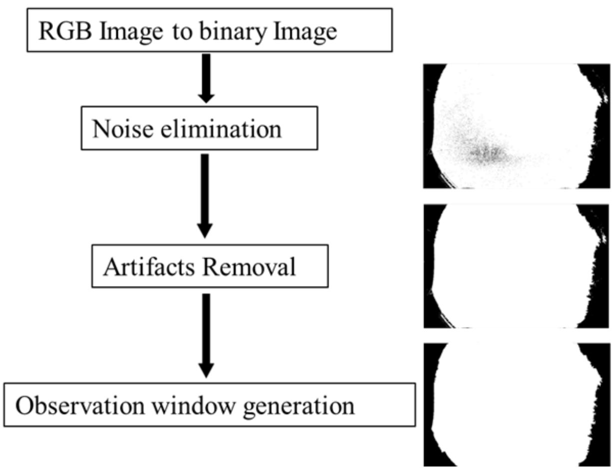


Fig. 5: Block diagram of the pre-processing (right side images are taken after finishing left side processing).

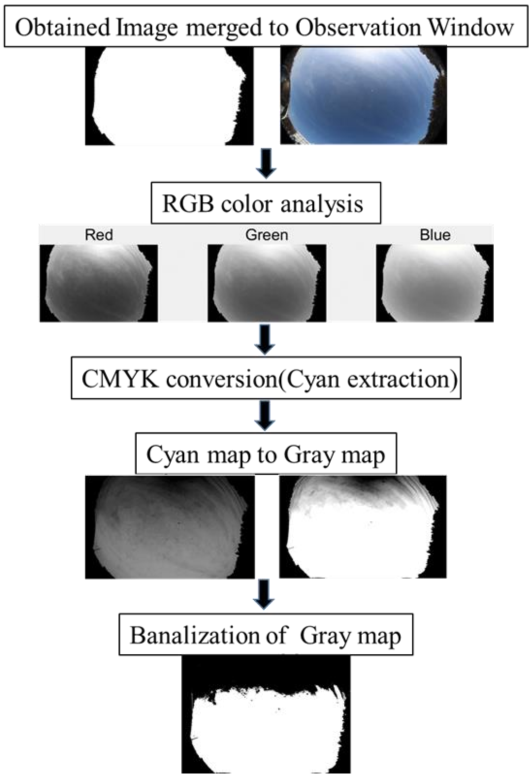
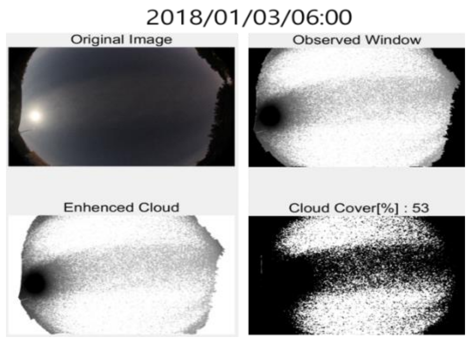
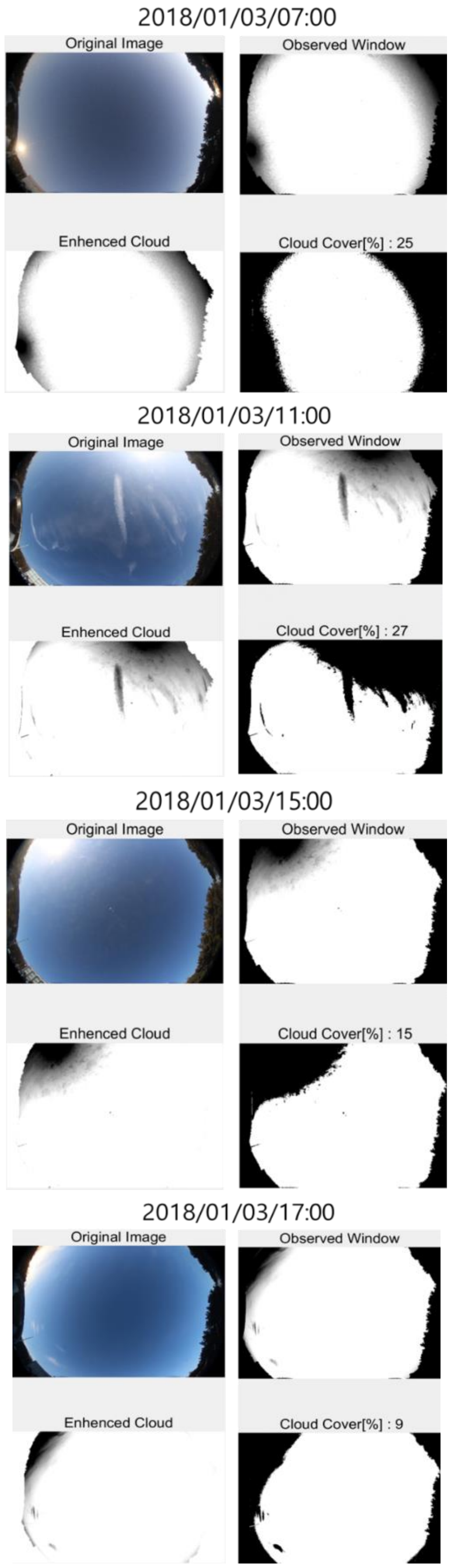


Fig. 6: Block diagram of robust cloud cover reader algorithm

3. Results

In order to verify the validity of the proposed system, various time in one day were selected and the cloud was observed as shown in Figure 7. Because the selected day is winter season, observation started at 6 o'clock in the morning and observing at 4 o'clock intervals. The results of the analysis are as follows: 7:00 am, 11:00 am, 3:00 pm, 7:00 pm, 11:00 pm, and observations at 6:00am and 5:00pm were added since the error occurred before and after the sunrise and the sunset. Advantage of the output can be the quantified of the cloud area relative to the effective observation area which is same as the human observation area. If the obtained raw image is compared with the enhanced cloud image, it can be seen that the black area in the enhanced cloud corresponds to the cloud area of the original image.





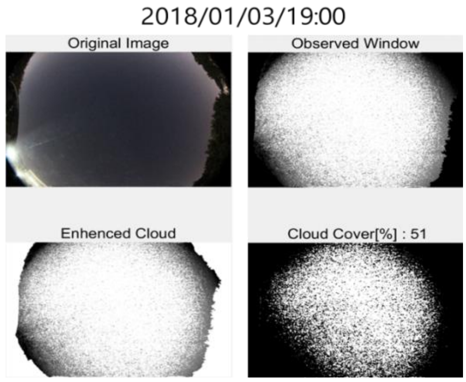


Fig. 7: Observation of covered cloud in the whole sky image at 6am, 7am, 11am, 3pm, 5pm and 7pm on Jan. 03, 2018.

An arising question is how to select of grey level threshold for some light cloud in “Observed Window” in Figure 4. The best way is utilizing knowledge and experience of cloud observer. However, ‘0.5’ was set as the threshold value from the engineering point of view in this study since the famous Otsu’s threshold selection method [5] was not working and the level of threshold should be discussing with cloud observation experts. The block diagram of UCCRA is shown in Figure 6. The term “R” or “reader” is used because the covered cloud value is accumulated the binary value of each pixel after binarizing of Cyan values in CMYK color space after RGB color analysis for each pixel from the acquired image. The one of advantages is that the covered cloud in sky can quantified more than the eye observation.

4. Conclusion and future work

The final goal of this study is the development of an automated system that will replace human beings in cloud observations. The cloud observation is divided into cloud cover, cloud height, and cloud type and the research scope of this study is cloud cover.

The methods used for the current cloud observations are intensities of R, G, and B, and those ratios such as the ratio of intensity of B and intensity of R [1, 2]. Recent study [6] has shown that the intensities of R, G, and B also change as the solar radiation spectrum observed on the earth surface changes irregularly as shown in figure 8. Therefore, since their ratio varies irregularly, existing methods using a fixed ratio cannot classify the sky and cloud regions precisely. However, the reported result of [1] shows that the intensity of B in pure sky has the highest value and the intensity of R has highest vale in cloud region. Another word, the intensity of B has the highest value and the intensity of R has the lowest value in the pure sky region. In another study [7], it was reported that when observing the solar radiation spectrum on the earth surface, the intensity of green is similar to the intensity of blue although it is not recognized in the eye as shown in Figure 9. By combining the above mentioned, we can derive the basic concept of the proposed robust cloud cover reader algorithm. The pure sky region has a relatively strong intensity of B and G, and is expressed as a region having a strong intensity of a Cyan component, which is a mixed color of two colors in CMYK color space. In addition, the cloud area is most clear in the R component map when analyzing the whole image in the RGB color space as shown in Figure 2. Therefore, the basic hypothesis of the proposed algorithm is that the pure sky region is represented by the C component map and negation of R component map, which does not violate the previously reported research results. Therefore, the proposed algorithm divides the pure sky and cloud regions by adding logically the Cyan component map and the negation of R component map.

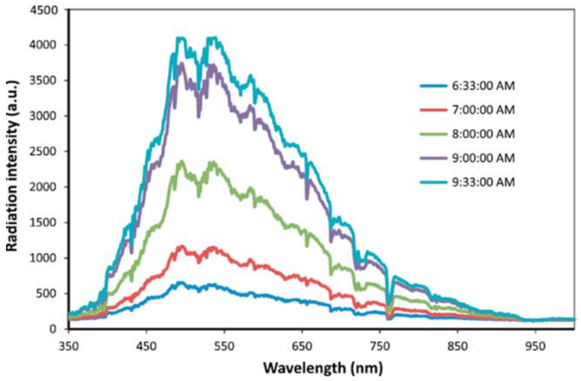


Fig. 8: Spectral irradiance variation versus time (A.Ms) on a clear sky measurement day. (Image source [6])

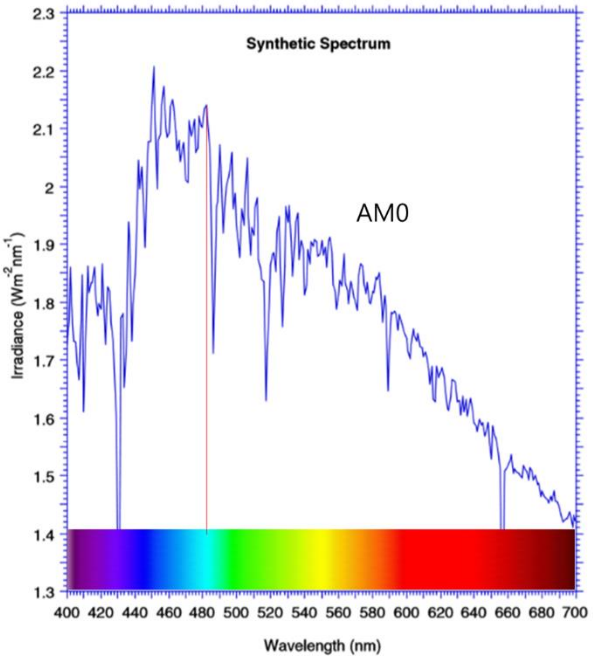


Fig. 9: Solar radiation spectrum on the earth surface (image source [7])

The results of the proposed algorithm showed satisfactory results in the almost case if whole sky images are obtained in a clean atmospheric environment, but especially in spring, high concentrations of fine dust or mist appears in the atmosphere cause observation errors in some cases. The main cause is that the color of cloud has a very bright white color when sun is behind the cloud. White has the maximum value of R, G, and B components. Then C component also has a high value and the cloud region is perceived as the pure sky region as shown in figure 10. The images used in the sample are the all-sky images acquired at noon on March 24, 2018, and the unprocessed original image shows that the entire sky is covered with clouds and the cloud cover is '100%', but the result of the proposed algorithm shows '73%' with '46%' of the dense cloud area and '26%' of the thin cloud area. These errors are considered to be lost when a color component that can distinguish achromatic color from achromatic color is found in the color space.

If the enhanced cloud in the figure 7 has black area and gray area, it can be explained as the black area is thick cloud region and the grey area is thin cloud region. It may helpful to get an accurate solar radiation energy on the earth surface.

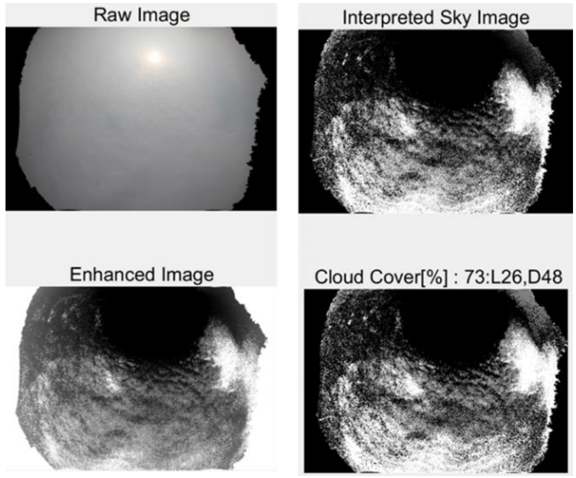


Fig. 10: Observation of covered cloud of the cloudy day in spring season at 12am, on Mar. 24, 2018.

If the obtained raw whole sky image is studied more to get various information such as the distance of the visibility, it is possible to get by processing data of the original raw image. One of ways is the contrast comparison at the sky region boundary.

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