

CLLOUD COVER ESTIMATION USING MULTITEMPORAL HEMISPHERE IMAGERIES

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ABSTRACT:

The solar radiation is the origin of energy for the photosynthesis and forest productivities. On the other hand, clouds constantly appear, move and disappear all the time and influence atmospheric and radiation conditions at the same time. Therefore, to understand cloud parameters which consist of cloud covers, its distributions and types etc. for a short time interval can help us to estimate solar radiation or photosynthetically active radiation (PAR) with high accuracy.

Authors have been observed and measured various parameters related with photosynthesis and carbon exchange for tropical rain forest in Borneo Malaysia so far. Concerning to the cloud conditions, we also monitor the whole sky using the commercial digital camera with the fisheye converter lens and can obtain hemisphere imageries about every two minutes interval.

As the experimental study about cloud parameters, in this paper, we present 1) the observation system of whole sky conditions, 2) how to analyze the obtained hemisphere imageries and 3) the method to estimate cloud cover and understand cloud distribution with sun position. Here, we use Sky Index which is calculated using visible RGB image taken by digital camera. This index is useful to separate whole sky area to clouds and the blue sky areas. Then multi-temporal cloud covers can be estimated from the Sky Index generated by multi-temporal hemisphere imageries.

Through this study, we also could recognize the efficiency to understand cloud cover, cloud distributions and types by using hemisphere imageries and Sky Index. As the continuous works, we examine the relationship between the solar radiation and cloud conditions such as cloud covers, distribution and types.

1. INTRODUCTION

The solar radiation is the origin of energy. Thus estimating solar radiation at the surface is needed in not only atmospheric science but various fields such as the photosynthesis, carbon exchange, energy budget, water cycling and productivities of forest and agriculture. On the other hand, clouds control total incoming irradiance at the surface. On the condition of the clear sky, which means cloudless, it possible to estimate solar radiations using cosine of sun zenith angle and some existing models (Charles et al., 2000). However in reality, the clouds constantly appear, move, change shapes and disappear, that influence to the atmosphere and radiation environment at the same time. Therefore, in order to estimate the global radiation in short time interval and with high accuracy, it is necessary to understand the effects of clouds as input parameters. Especially cloud cover, which is defined as the ratio of cloud area to whole sky area at the observed point, and cloud distribution in whole sky are the strong impact to the global radiation that consists of direct, diffuse and reflected solar radiations.

We have been observed and measured various parameters related with photosynthesis and carbon exchange for tropical rain forest in Borneo Malaysia (Yoshimura et al., 2001), which is carried out on the project entitled 'Mechanisms of Atmosphere-Ecosphere Interaction in Tropical Forest Canopy' (Nakashizuka et al., 2001). Clouds in tropical rainforest area are moving at multi layers. Here is little chance of cloudless in whole sky all day long through a year. Therefore, as regards the observation of cloud conditions in this project, we setup the

camera system which takes whole sky image at the top of tree tower. Our purpose of this study is to estimate cloud covers and understand cloud distributions multi-temporally by using hemisphere imageries. We present, in this paper, the whole sky observation system, the methods to detect clouds from the hemisphere image and understand the distribution of clouds, and cloud cover estimation by using clouds detection imageries. As for the method of clouds detection, we used Sky Index, which is generated by using blue and red channels of original RGB images, and extracted the clouds area clearly. In the future works, we will examine the relationship between the global radiation and cloud conditions which consist of cloud covers and distribution estimated as the results of this study.

2. WHOLE SKY OBSERVATION

2.1 System of whole sky camera

The system and observation for taking multi-temporal hemisphere images are described. This system consists of the commercial digital camera installed with the fisheye lens and the remote control cord. The details are explained as follows.

Digital camera: Used digital camera is Nikon COOLPIX5000 which has color CCD with effective pixels of 2658 x 1970. The image sizes are selectable from 2560 x 1920, 1600 x 1200, 1280 x 960, 1024 x 768, and 640 x 480. The file formats of image quality are uncompressed TIFF (RAW) and compressed

JPEG at four levels as Hi, Fine, Normal and Basic. The image files are saved to Compact Flash card in the camera.

Fisheye lens: The model of used fisheye lens is Nikon Fisheye Converter FC-E8. The angle of view area is about 183 degrees covered to hemisphere. FC-E8 has Equidistant Projection that means the centre of lens is correspond to zenith, and zenith angles are in proportion to distances from the centre point of zenith. One of the other projections for fisheye lens is Orthographic Projection that shows sine of zenith angles are in proportion to distance from the centre point of zenith. Figure 1 illustrates Equidistant and Orthographic Projections of the fisheye lens.

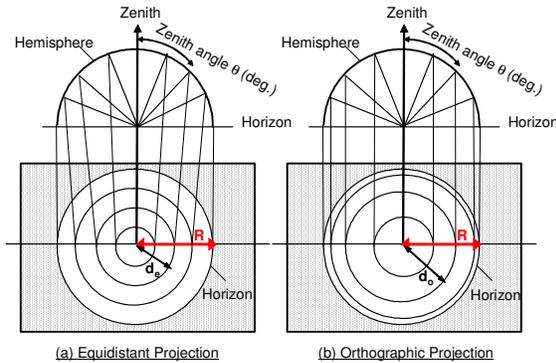


Figure 1. Projections of fisheye lens
 Left: Equidistant Projection, $\theta/90 = d_e/R$
 Right: Orthographic Projection, $\sin \theta = d_o/R$

As the areas of which the zenith angles are wider in hemisphere image taken by equidistant projection, these image areas where is especially near the horizontal line are shown as larger than the same areas in case of taking by orthographic projection. That means orthographic projection is useful for calculating the ratio of area. However, there is very little availability of these kinds of fisheye lens with orthographic projection. Therefore, it is necessary to do the cosine correction of zenith angle for each pixel in the hemisphere image taken by the equidistant projection when cloud cover is calculated.

Remote control cord: This cord, which is Nikon Remote Cord (MC-EU1), is used for taking pictures automatically at the same interval. It is able to set two minutes interval as the shortest. We set two minutes interval.

As the other accessory, ND filter with 0.9 optical density (transparency about 13%) is put between camera lens and the fisheye lens in order to decrease the strong sun light and defend CCD saturation.

2.2 Camera setup

This camera system is installed at the top of tower with 45 meters heights. The scene of sky area is almost hemisphere. Here, various meteorological observation systems are equipped in addition to the camera system.

The head of digital camera is fixed to north direction and levelled to horizon on tripod. As for the exposure control, we have priority aperture and set the aperture as f2.8 because the

image contrast is better than the image taken by the aperture more than f2.8 or shutter speed priority.

The image size and quality should be different from the purpose of use. The image with the full size and the uncompressed quality might be needed for the purpose of precision photogrammetry, but our use of images is to understand cloud distribution and estimate cloud cover in this study, therefore the image size and quality are set as 1024 x 768 and the compressed JPEG format respectively.

2.3 Hemispherical area on image

Given this camera system and setup described previously, the hemispherical area shown in the whole image is determined. Figure 2 shows the hemisphere area and image coordinates in 1024 pixels and 768 lines.

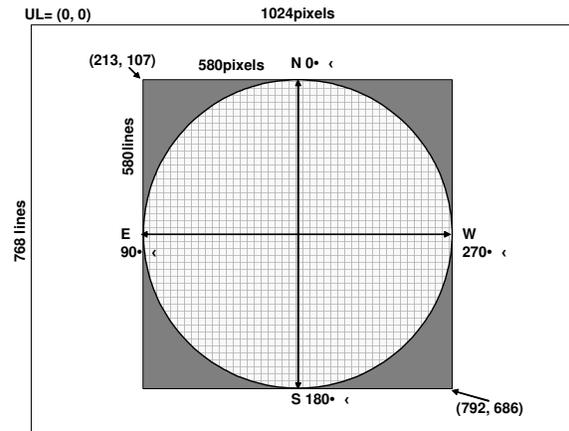


Figure 2. Hemispherical area and image coordinates

In this case, the radius of the circle filled with hemispherical area is corresponded to 290 pixels. One pixel corresponds to about 0.31 degrees of zenith angle.

3. METHODS OF CLOUDS DETECTION

As the pre-processing of hemisphere imageries, each image is clipped with 580 pixels by 580 lines, and then the masking image of sky area except for the others around horizon is generated (Figure 3).

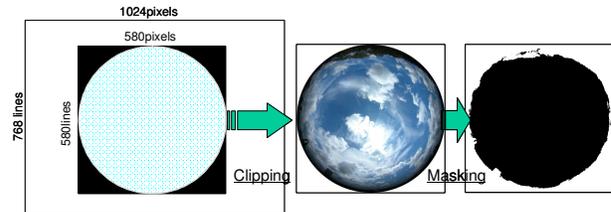


Figure 3. Pre-processing of hemisphere image

3.1 Detection of clouds area

Gabriela et al. (2002) used the simple ratio of red / blue from RGB image to extract feature in sky image. Here, we also use two channels of red and blue from the visible RGB image in order to separate the blue sky and cloud areas. The blue sky area in the RGB image has the high digital number in blue

channel and the low digital number in red channel. On the other hand, cloud areas show white or grey in the image that means the digital numbers of red and blue are almost same or close. Therefore, as one of the methods for separating to blue sky and clouds area, we use equation (1) and generate the index imageries that show the blueness of sky for all images. We call this index as Sky Index.

$$\text{Sky Index} = (\text{DN}_{\text{Blue}} - \text{DN}_{\text{Red}}) / (\text{DN}_{\text{Blue}} + \text{DN}_{\text{Red}}) \quad (1)$$

where DN_{Blue} = digital number of blue channel
 DN_{Red} = digital number of red channel

Here, we examined the relationship between the indexes and sampling pixels in various areas in order to refer the value of the boundary with blue sky and clouds (Table 1)

Table 1. Sky Indexes at sampling pixels

	Sampling area / Colors	DN (Red)	DN (Blue)	Sky Index
2003/2/1 at 9:48	Clear sky / Blue	26	123	0.65
	Clear sky / Light blue	42	134	0.52
	Stratocumulus / Grey	93	131	0.17
	Cirrus / Light grey	140	189	0.15
2003/2/1 at 12:21	Clear sky / Light blue	45	120	0.46
	Clear sky / Light blue	60	127	0.36
	Cirrus / grey	83	116	0.17
	Cumulus / grey	79	111	0.17
	Cumulus /White	176	211	0.09
2003/2/1 at 14:00	Clear sky / Light blue	58	134	0.40
	Cumulus / Dark grey	64	95	0.20
	Cumulus / Dark grey	81	113	0.17
	Cumulus / Light grey	169	207	0.10
	Cirrus / Light grey	157	192	0.10

According to Table 1, the Sky Indexes of clear sky area show high values almost more than 0.3, on the other hand, cloud areas have low index values less than around 0.2. The value of the boundary is supposed to be between 0.2 and 0.3.

3.2 Cloud distribution in hemisphere coordinates

On the assumption that the fisheye lens dose not have any distortions, the relationship between the image coordinates (Xi,Yi) taken by Equidistant Projection and the hemisphere coordinates consists of zenith angle and direction (θ, ϕ) is expressed by following equations.

$$\begin{aligned} X_i &= (R-1)+R*\sin(\phi-180) *\theta/90 \\ Y_i &= (R-1)+R*\cos(\phi-180) *\theta/90 \end{aligned} \quad (2)$$

$$\theta = ((X_i - (R-1))^2 + (Y_i - (R-1))^2) *90/R$$

when $0^\circ \leq \phi < 180^\circ$,

$$\phi = 180 - \arccos((Y_i - (R-1)) / R*(90/\theta)) / \pi * 180$$

when $180^\circ \leq \phi < 360^\circ$,

$$\phi = 180 + \arccos((Y_i - (R-1)) / R*(90/\theta)) / \pi * 180 \quad (3)$$

where θ ; Zenith angle, ϕ ; Direction angle (units; degrees)
($0^\circ \leq \theta \leq 90^\circ, 0^\circ \leq \phi \leq 360^\circ$)

R; the radius of circle filled with hemisphere area
(Xi, Yi); Pixel, Line of one specified image coordinates when the origin is the upper left of the image shown in fig.3(middle).

The grid surfaces which are allocated by Zenith and Direction angles using equations (2) and (3) are generated. In this way, it is possible to understand cloud distribution viewed from the observation point by overlaying the grid surfaces of hemispherical coordinates to the clouds detection images.

3.3 Procedure of cloud cover estimation

Used fisheye lens has the equidistant projection, so that the numbers of pixels dose not correspond to the area which we can see in hemisphere from the observed point. Therefore, the cosine correction of zenith angles must be done for each pixel to estimate cloud cover. The procedure to calculate the ratio of the detected clouds to the whole sky area describes as follows:

- 1) Generating grid allocated the value of cosine zenith angle
- 2) Summation of values of cosine zenith angle corresponded to all pixels in the masking image in fig.3 (right)
- 3) Summation of values of cosine zenith angle corresponded to pixels which is detected as cloud area
- 4) Calculating the ratio of 3) to 2) as cloud cover

4. RESULTS AND DISCUSSION

4.1 Clouds detection

Figure 4 shows the original RGB images and the Sky Index images, which are illustrated with the contours of 0.1 interval's Sky Index.

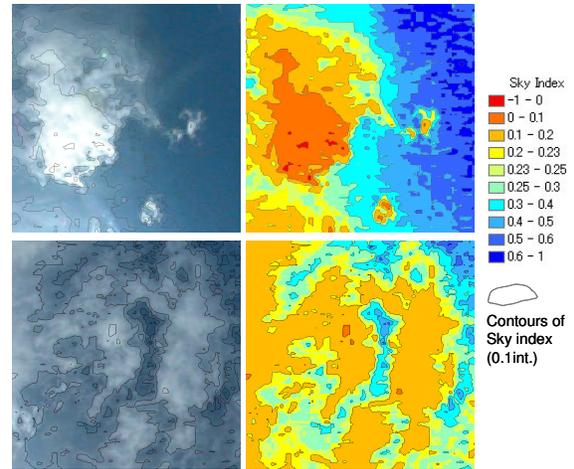


Figure 4. Comparison with RGB (left) and Sky Index (right) images taken at two different times on 7th February, 2003

These two samples are taken at 12:23 (uppers) and 8:56 (lowers) on 7th of February 2003. Two Sky Index images (fig.4 right) are classified to ten classes by considering Table 1. As for between 0.2 and 0.3 of Sky Index, three classes are set as 0.2-0.23, 0.23-0.25 and 0.25-0.3 (see the legend in fig.4). By visual interpretation, it is seemed that the boundaries of the blue sky and clouds are shown around between 0.2 and 0.25. These trends are looked in the others of Sky Index images. Therefore, we define the value of boundary as 0.23, and then apply the other images to detect cloud areas in this case.

Figure 5 shows the comparison with the hemisphere RGB image, its Sky Index and clouds detection images as one example taken at 12:53 on 1st of February, 2003.

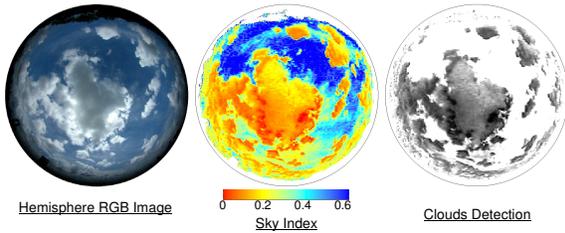


Figure 5. RGB, Sky Index and Clouds detection images

The clouds detection image was generated by the definition that the values of less than 0.23 show clouds area. The grey scale shows the brightness of clouds (the darker area shows the brighter cloud). Comparing with both RGB and clouds detection images, it shows the clear extraction of clouds area.

4.2 Cloud distribution and cloud cover

After generating the clouds detection images, the grid surfaces of the zenith and the direction angles are overlaid in order to visualize the cloud distribution. Figure 6 illustrates examples of cloud distributions on hemisphere coordinates with sun orbit on 7th of February, 2003.

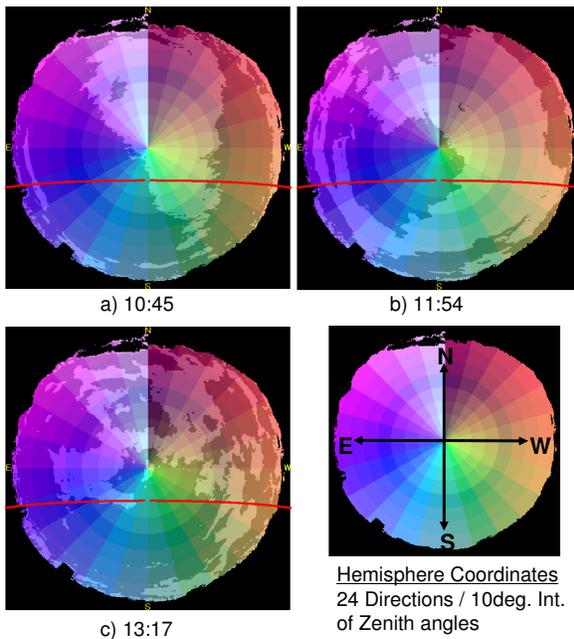


Figure 6. Cloud distributions on hemisphere coordinates

Furthermore, the results of cloud cover estimations were 0.55, 0.40 and 0.64 for a) 10:45, b) 11:54 and c) 13:17 in fig.6 respectively. According to the cloud distribution of fig. 6 a), the detected clouds are distributed almost eastern half side and near the horizon of western side, it looks cloud cover is more than 0.6 or 0.7, but estimated cloud cover is 0.55. This is represented efficiently about the cosine correction of zenith angle. We also

can recognize different pattern of cloud and distributions from Figure 6 visually.

5. CONCLUSION

Clouds have directly the strong impact to the solar radiation environment. Accordingly, understanding the cloud condition is indispensable for estimating global radiation consists of direct, diffuse and reflected radiations. We have observed cloud conditions in whole sky in order to grasp cloud distribution and estimate cloud covers in short time interval. In this paper, the whole sky observation and the methods how to detect clouds area from hemisphere imageries using commercial digital camera and estimate cloud cover based on image analysis.

Results of this study will be useful for automatic estimation of cloud cover and visualization of cloud distribution at the real time.

As the continuous works, we will examine how cloud cover and distributions influence to global radiation. Furthermore we will set more than two observation sites in order to estimate cloud volume and spatial distribution of clouds in regional area.

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