Estimation of solar radiation and Photosynthesis Active Radiation using automatic capturing Digital Fisheye Camera

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Abstract: The system which presumes the amount of incoming solar radiation and photosynthesis active radiation (PAR) over land surfaces has been developed using the sky image taken by Automatic-capturing Digital Fisheye Camera (ADFC) in arbitrary time and place.
The surface solar radiation under the clear sky condition is estimated first by a set of empirical equations taking account of the effects of atmospheric turbidity, pressure, precipitable water vapor, and surface reflectance at given place and time.
For the cloudy sky condition, the surface solar radiation is estimated using an attenuation parameter indicating the effects of reflection and absorption by the clouds. The attenuation parameter is obtained by analyzing the sky images based on the intensity and brightness of each pixel. By multiplying the attenuation parameter to the radiation under the clear sky condition, the surface solar radiation was successfully estimated every half hour with high correlation with observed data (correlation coefficient 0.85-0.91) at two terrestrial sites throughout the year.
This system will be utilized for such studies as the quantification and verification of attenuation of radiation by various clouds, the advanced estimation of surface radiation from satellite, and scaling up of surface meteorological data to satellite scale resolution using the system for multi-point observation.

1. Background and objectives

As input data of the global model analysis for grasping quantitatively the change between space-time of a terrestrial ecosystem (for example, phenology, carbon balance, etc.), satellite remote sensing data is used widely. On the other hand, the ground verification data set which can be used for this satellite data verification is restricted. In order to correspond to such a situation, Tsuchida, et. al is developing ground verification data set network Phenological Eyes Network for satellite remote sensing (henceforth, PEN).

Phenological eyes network (PEN) for validation of remote sensing data has measured ground surface and atmosphere parameters at the ASIAFLUX sites using Automatic-capturing Digital Fisheye Camera (ADFC), HemiSpherical Spectro -Radiometer (HSSR) and SunPhotometer (SP), which contributes to the carbon and energy flux studies for global change. ADFC images are mainly used for a phenological study, sky condition and leaf area index. HSSR is for studies of vegetation spectral parameters and a photosynthetically active radiation. Atmospheric parameters are measured by SP for an atmospheric correction to acquire surface parameters.

The objective of this study is to presume an amount of radiation and the amount of photosynthesis active radiation from the ADFC images

Yoshikado has proposed a method of presuming the amount of global solar radiation from a cloud shape and the amount of cloud by visual observation. A decreased part obtained by the parameter in the amount of cloud and the cloud shape was multiplied by the presumed amount of radiation at the time of fine weather, and the amount of radiation is presumed. Thereby, about 0.8 correlations accuracy is acquired.However, a system to calculate radiation and PAR from the information on the amount of cloud which may be obtained from a digital image does not exist.

This research aims at proposing the amount of radiation of an observation region, and the technique of presuming PAR (30-minute average) from the digital sky image taken by ADFC. This result is useful to offer the relation of the meteorological data ADFC-satellite data in consideration of the resolution between space-time.

2. Observation area and instruments

2.1 Observation area

In this research, the data of two investigation grounds of the University of Tsukuba (TGF: grass land) and the Gifu examination ground (TKY: deciduous broad-leaved forest) was used.

2.2Automatic-capturing Digital Fisheye Camera

Nikon Coolpix 4500 was used for the digital camera.This camera was equipped with the exclusive fish-eye lens, and it put into the small waterproof case to which the dome was attached.
The signal wire and a power supply line, remote operation and data transfer are packed into one LAN cable, and it takes out to the case exterior, and makes it possible to detach an operation system several 10m (a maximum of 100m or more) from a camera (SPC31A-CP4300 SPC31A-CP4500).
A personal computer Linux or windows is used for photography. According to the set-up schedule, data transfer is performed in that PC (Figure 1.ADFC).

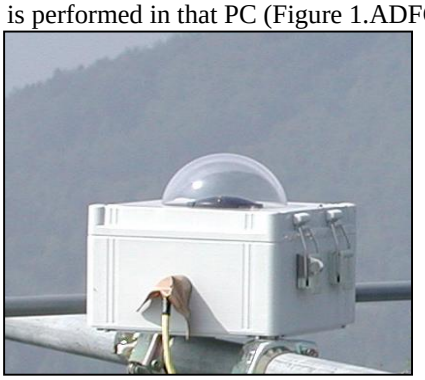

Figure1 ADFC

2.3. Dataset

Two ADFC dataset, TKY and TGF were used, which covers more than one year were used.
By this technique, since it aimed at presuming radiation and PAR of a 30-minute average, about ADFC, the data based on [average] time was used as a central value for 30 minutes among the data taken at intervals of 2 minutes. The data from 7:00 a.m. to 5:00 p.m. was made applicable to analysis.
About the TKF site, the 30-minute average field measurement meteorological value of radiation (W/S2) and PAR (umol/m2/s) obtained by tower observation of the National Institute of Advanced Industrial Science and Technology was used. At TGF site, only radiation dataset was used as there is no long-term observation of PAR.

2.4 The method of presuming radiation from ADFC

In this research, first, presumptions clear day radiation by the technique which Kondo proposed.
An amount of radiation is presumed by considering the parameter obtained from the average value of the effective pixel of ADFC as attenuation, and carrying out multiplication to it.
2.4.1 Presumption of a fine weather amount of radiation
By the technique of calculating the presumed amount of radiation of the clear day which Kondo and proposed, the presumed amount of radiation of a top of atmosphere is calculated first, and the multiplication of a attenuation by the atmosphere is carried out to it.
The parameters which are needed for this technique are photography time and a photography place (latitude longitude), Turbidity coefficient, atmospheric pressure, Albedo, and Precipitable Water Vapor: (PWV). These parameters assumed that it was a value without year change under fine weather conditions.
Values of parameters are listed bellow.
Turbidity coefficient: 0.05, Precipitable Water Vapor PWV: 0.3,
In addition, about atmospheric pressure, it presumed from altitude.
Moreover, about the albedo value, in consideration of land covering conditions, it set up with 0.15 at the TKF site, and set up with 0.12 at the TGF site.
About PAR, very high correlation (r2=0.9896) is obtained between radiation and PAR from the TKF metrological

data set. PAR is estimated by multiplying conversion factor (0.3733) to this estimated radiation.
The conversion coefficient of the natural daylight illuminant (about [whole sky radiation in the daytime,] 6500K) was used conversion (W/M2)-umol/m2/s of the unit of radiation-PAR (Inada).

2.4.2 The parameter obtained from an ADFC images

The technique of making a parameter the maximum of DN value of RGB and the minimum difference to each pixel is proposed. The parameter proposed is MAX {DNRed, DNGreen, DNBlue} - MIN {DNRed, DNGreen, DNBlue}.
This parameter is henceforth called simple chroma saturation.
Moreover, the number of the average of DN value of each RGB, chroma saturation, brightness, and saturation pixels was calculated separately.
Image was taken in Fine mode (2272x1704). But there is no apparent difference in this research; the size was resampled into 566 X 425.
Since the photography conditions of the image were summarized to appendix 1.

2.4.3 The presumed method of an amount of radiation

The formula which presumes radiation is defined as follows.

Presumed amount of radiation = clear day presumption amount-of-radiation x ADFC parameter

here,
ADFC parameter: Brightness x simple chroma saturation
The average value of the effective pixel of an image discusses brightness and simple chroma saturation.
Brightness and simple chroma saturation were standardized from radiation of the clear day in order to calculate the absolute value of an amount of radiation. The definition of clear sky condition is that the apparent semi diameter of the sun is constant at all season and time.
The number of pixels with which the pixel value of DNRed, DNGreen, and DNBlue becomes 250 or more, respectively was extracted (as saturation pixel), and this value considered it as 900-pixel or more a picture of 1500 pixels or less to 566x425 pixels.

3 Result and discussion

3.1 Clear day presumption amount of radiation
The estimate equation of the clear day presumption amount of radiation which Kondo proposed, and the validity of the parameter used this time was evaluated.
Fig. 2 shows relation between presumed radiation and survey radiation at TGF site in 2004.

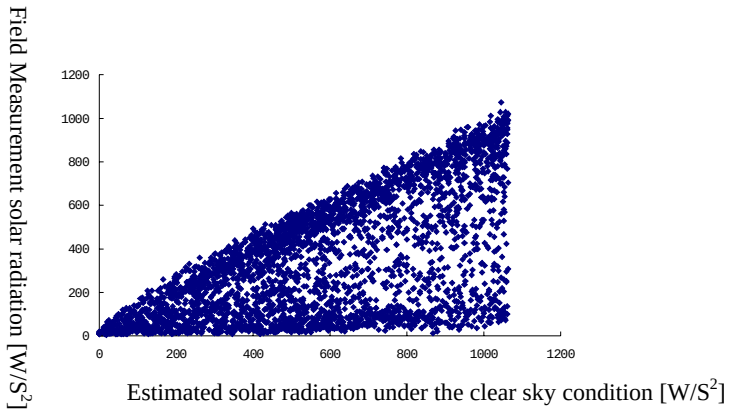

Fig2. Relation between presumed radiation and survey radiation at TGF site in 2004.

[W/S2]. On the other hand, radiation of survey decreases as it becomes cloudy weather. That is, it can be said that this figure showing a degree to the attenuation of radiation of a y-axis.
It can be said that the formula of clear day solar radiation which Kondo proposes is reproducing the fine weather amount of radiation of field observation.

3.2 ADFC parameter

As a result of investigating time series change of each parameter, it turned out that there is a showing [DN value of simple chroma saturation]-rapidly high value case.
Then, when the brightness in such a case was investigated, a DN value of 15 or more upward tendency was seen by the image. Although photography conditions are constant, since the increase was looked at by brightness under a certain influence, we decided to except from calculation to a time series when the increase in the brightness of order is 15 or more among the data sets of a time series.
Fig. 3 shows the relation between brightness and survey radiation. Survey radiation changes to a linear with a low value, and brightness shows the saturation tendency after that.
On the other hand, simple chroma saturation is an index which shows sky blue (Figure 3).

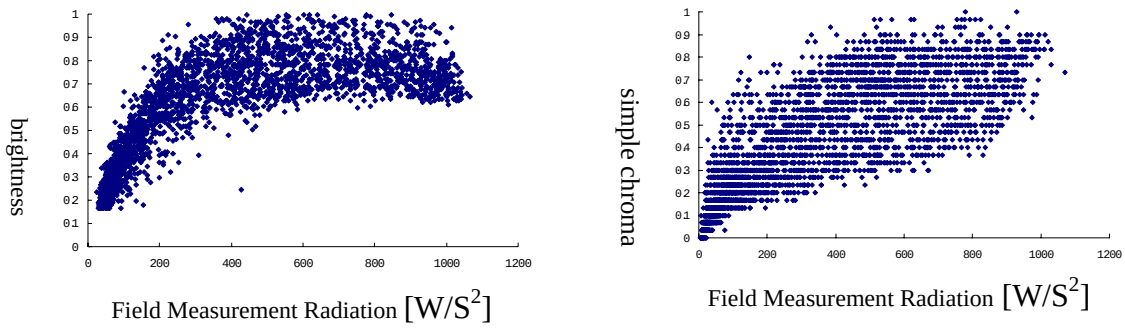

Figure 3 Brightness-radiation (Left) Simple-Chroma-radiation (Right)

3.3 Presumption of an amount of radiation

Radiation was presumed from the ADFC image and presumed amount of radiation of the TKF site in 2004, and the TGF site, and it compared with radiation of survey. A result is shown in figure.4.

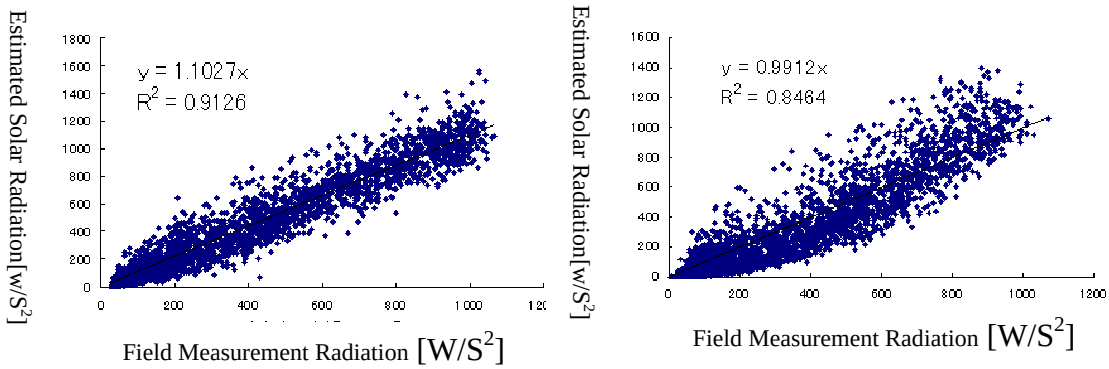

Figure 4. Estimated solar radiation-radiation(field) TKF(Left), TGF(Right)

TKF site correlation coefficient: 0.9126, the RMSE 103.8222932 [W/S2],
TGF site correlation coefficient: 0.8464, the RMSE 126.9677431 [W/S2].

4. Conclusion

The amount of radiation of calculation by using the clear day presumption amount of radiation x (time average of simple chroma saturation (DN value) / simple chroma saturation DN value), the amount of radiation was able to be presumed from the ADFC image in the accuracy of the correlation coefficients 0.9126 (TKF site) and 0.8464 (TGF

site).
Furthermore, presumption of PAR was also considered from the relation of PAR and radiation by survey.
Correlation of the radiation and PAR by a weather survey and an ADFC camera (abbreviation about 5km in radius) was able to be shown with this technique. It can be said that this result secured the field metrological measuement in the spot.
By having secured ground measurement, it will become possible that connecting a ground observation result to satellite observation.

Acknowledgement

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Appendix 1. Parameter used for camera photography

For the exposure mode:	sky M (Manual)1/250or1/500 F2.6
ISO	100
White balance	Sunlight
Light measurement system	Fixed to center
Gray level correction	Standard
Chroma saturation adjustment	0 Standard
Quality-of-image mode	FINE
Picture size	2272×1704
Edge enhancement	OFF
Exposure control Exposure fixation	OFF
Exposure compensation	0

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