Analysis of cloud properties in the Matsuyama plain using downward solar radiation dataset from a Geostationary Satellite

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Abstract

The purpose of this study is to analyze the downward solar radiation dataset from a geostationary satellite in the Matsuyama plain and to investigate the impact of land use and the geographical landscape variation on clouds. Matsuyama has different geographical features including a plain, which shows contrasting land uses for urban and rural areas. The satellite dataset was validated by data observed in the field. In this study decrease ratio of solar radiation (DRSR) was used as an index of cloud thickness because solar radiation generally decreases when sky is covered by clouds. The following are the main outcomes. DRSR is likely to be higher in mountainous areas rather than plain areas. DRSR of noncoastal areas have a significantly higher value than coastal areas in the afternoon. In summer, urban DRSR are larger than rural area in the afternoon, but the magnitude is almost same in the winter.

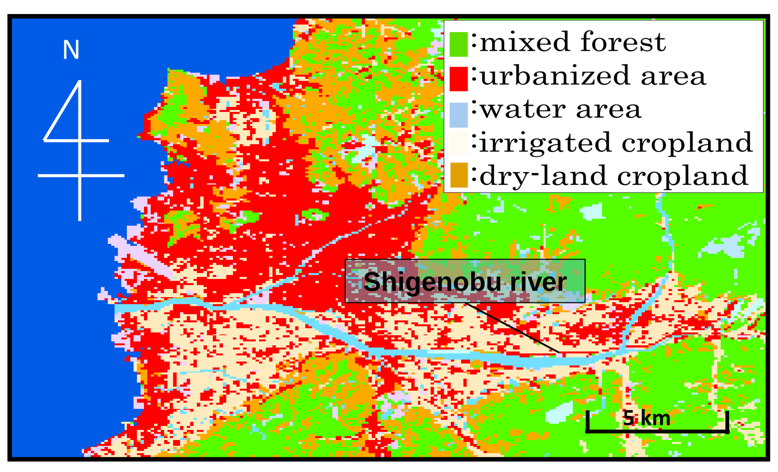


Fig.1 Land use category of National Land Numerical Information and location of observations

Fig.2 Locations of different geographical and land use points

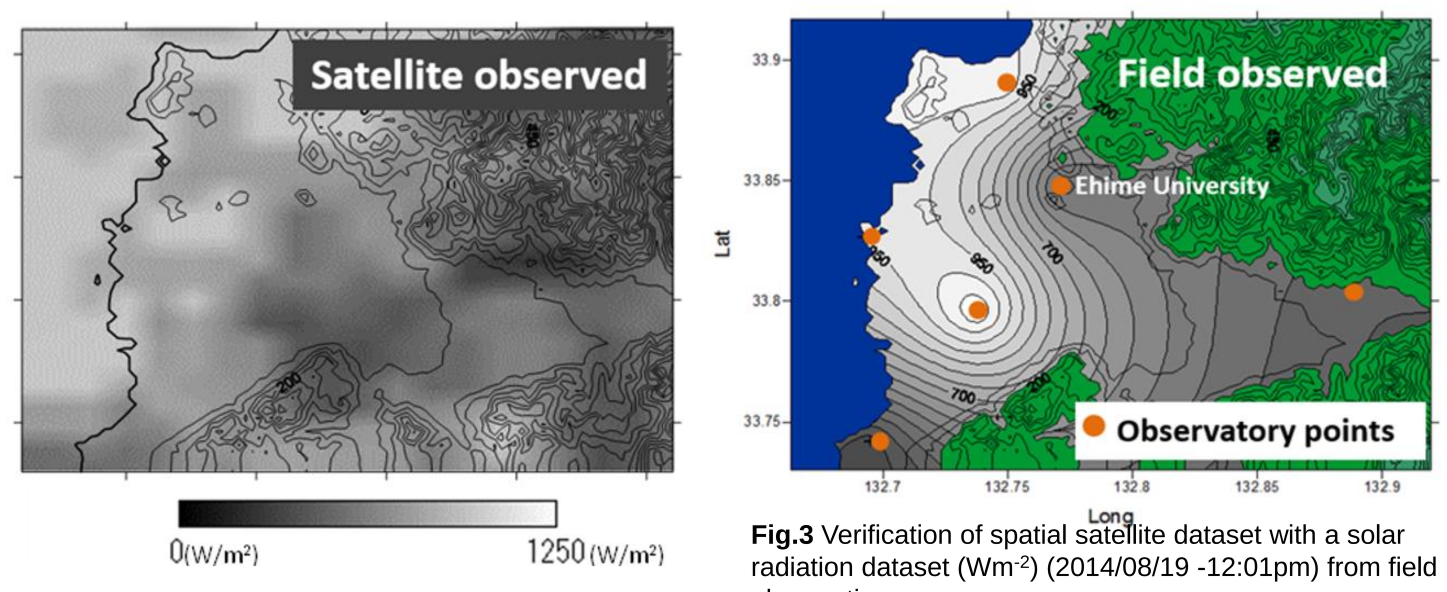


Fig.3 Verification of spatial satellite dataset with a solar radiation dataset (Wm^{-2}) (2014/08/19 -12:01pm) from field observations

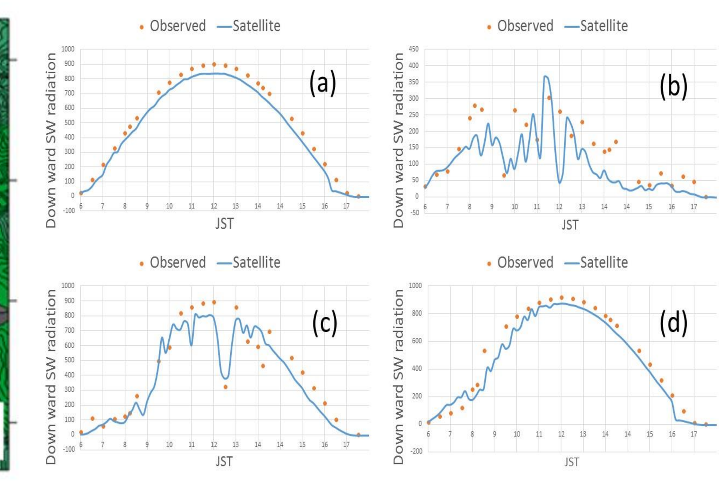


Fig.4 Diurnal course of downward short wave radiation from satellite data and the instrument observed data at Ehime University (33.847° N,132.772° E).

Site Description and Data set

Matsuyama is located in the northwestern part of Shikoku Island, Japan. It is a plain, which is almost triangular in geometry. The Matsuyama plain is mainly an alluvial fan which was formed by the material deposited through the flooding of the Shigenobugawa River and its territorials. The plain area runs about 20 km from east to west and is about 17 km from north to south with a total area of about 100 km². The population of the plain is approximately 5,200,000, most of which is concentrated in the northern part. The plain has become more urbanized since the 1980s. The Shigenobugawa River generally divides the plain into urban and non-urban area. The northern part of the river is densely populated, whereas the southern part consists almost entirely of rice paddy fields. The plain is surrounded by mountains to the east and south. To the north and west is the inland sea coastal area as shown in Fig.1.

The key dataset used in this study is downward short wave (SW) radiation from geostationary satellite developed by Takenaka et al.[4]. The dataset (semi-real time with high-spatial resolution) is estimated from Multi-functional Transport Satellite-1 Replacement (MTSAT-1R) using radiative transfer calculations and neural network technique. Six sensors (CMP3, PREDE Pyranometer) were installed in different parts of the Matsuyama plain including Ehime University as shown in **Fig.3**. The temporal and spatial satellite datasets were validated by comparing it with field-observed data. A good correlation between satellite and observed dataset were found in both spatial and temporal datasets. **Fig.3** and **Fig.4** show the spatial and temporal verification of the satellite dataset respectively.

Method

Decrease Ratio of Solar Radiation (DRSR)

Solar radiation generally decreases when sky is covered by clouds. Thus in this study reduction of solar radiation was used as an index of cloud presence. Decrease of solar radiation due to the blockage of cloud was calculated using the following concept. An ideal time series dataset was created by selecting the maximum values of each time series for every month. The ideal time series data resembles solar radiation on a virtually perfectly sunny day (without any clouds). The time series dataset of target day is then subtracted from the ideal time series dataset and normalized by ideal SW to get decrease ratio of solar radiation (DRSR). The higher the DRSR, the higher the cloud coverage and the cloud thickness, while the lower the DRSR, the lower the cloud coverage and the cloud thickness

$$\mathrm{DRSR} = \frac{\text{ideal SW} - \text{target day SW}}{\text{ideal SW}}$$

The relation between thickness and DRSR

To know the relationship between cloud thickness and DRSR, a ceilometer (CL31, Vaisala) and (CMP3) pyranometer were set up at Ehime University, on the top of the Faculty of Engineering building. Backscatter intensity by ceilometer was vertically integrated (represent thickness of cloud) and then compared to DRSR by pyranometer (**Fig.5**). The graph shows a reasonable linear relation between cloud thickness and DRSR using a pyranometer. Hence, DRSR has equitable relation with thickness of the cloud.

To compare the monthly temporal DRSR of different areas, various points were selected according to their geographical locations and land use as shown in **Fig.2**. where 'C' represents the coastal locations, 'M' represents mountainous (Peak of four mountains in the study area) locations, 'R' represents rural locations, 'U' represents urban locations; Urban and rural points are chosen same as the Moriwaki et al.[2] (Table 1) study. 'R' and 'U' also represent non-coastal locations. The temporal results are then verified with the temporal and spatial variation DRSR contour graph. To compare DRSRs, we analyze partially sunny days (days with percentage of sunshine, time per day is between 50 and 80) in sunny months (September and January). The sunshine percentage was calculated using the sunshine time data from the Japan Meteorological Agency in Matsuyama. 11 days out of September and 15 days out of January were partially sunny. The days were selected using the sunshine time data from the Japan Meteorological Agency in Matsuyama. The effects of solar radiation were seen between 6:00AM until 6:00PM in September. Difference of DRSR were also calculated to see the variation pattern of cloud in two different places

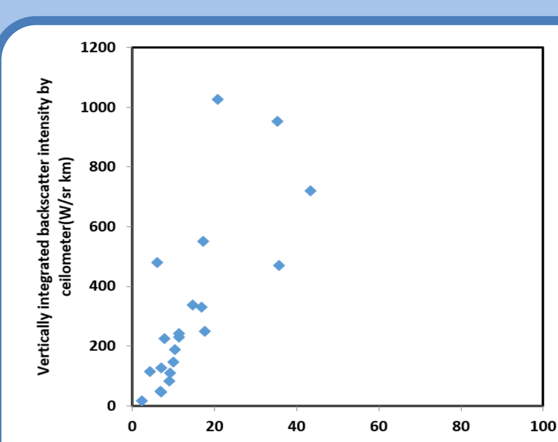


Fig.5 Comparison of vertically integrated back scatter intensity by ceilometer and DRSRs by pyranometer

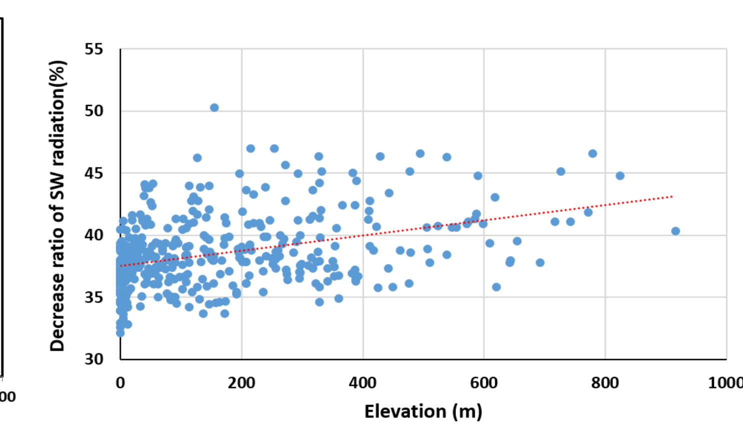
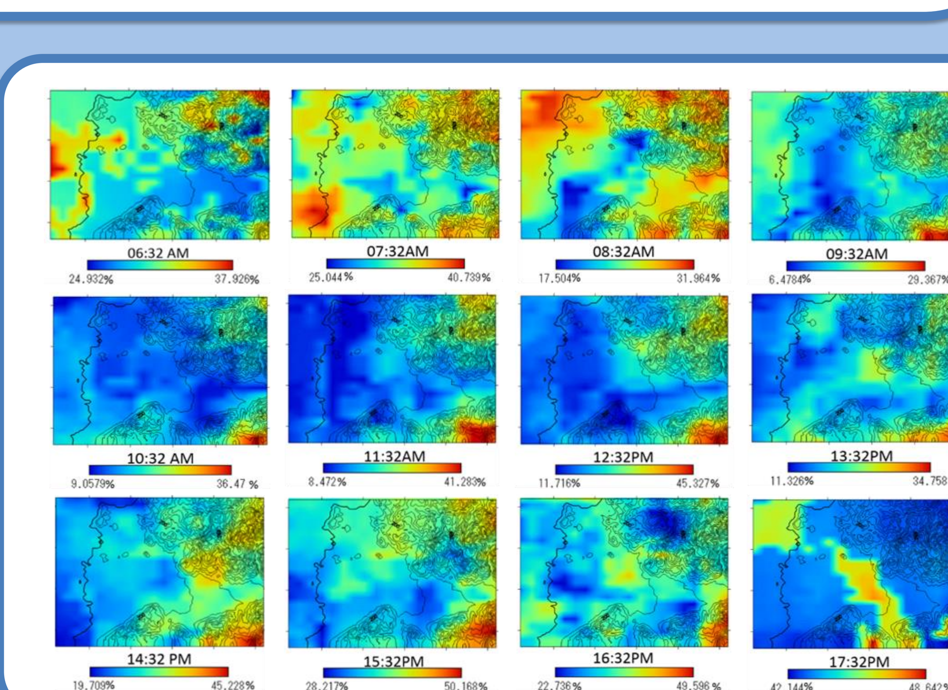
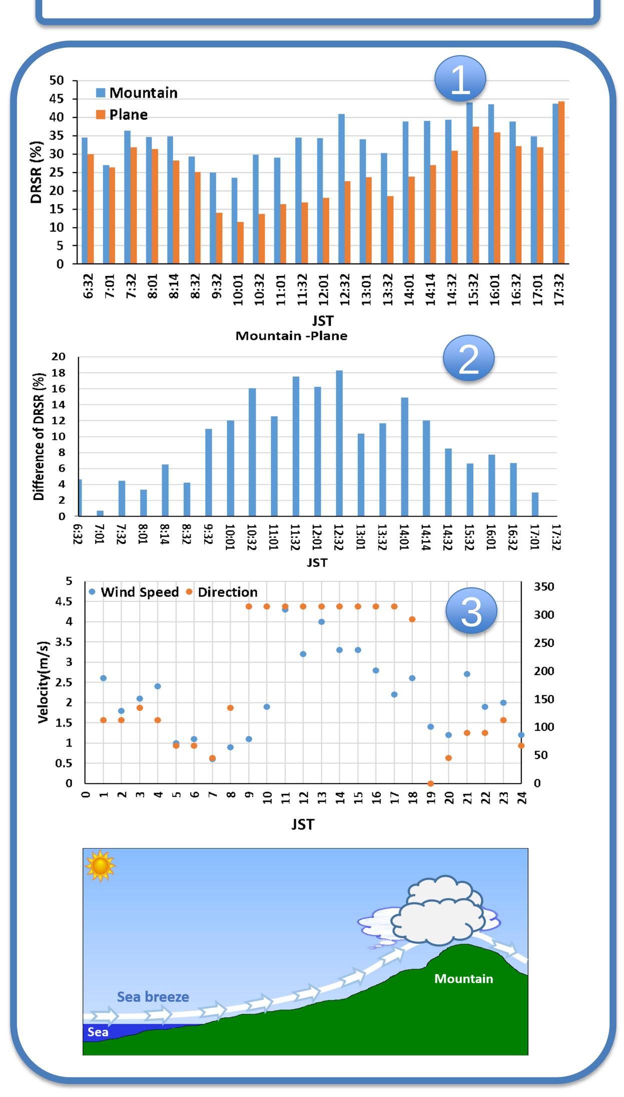


Fig.6 Variation of DRSR with altitude, September 2013 (1:32pm)

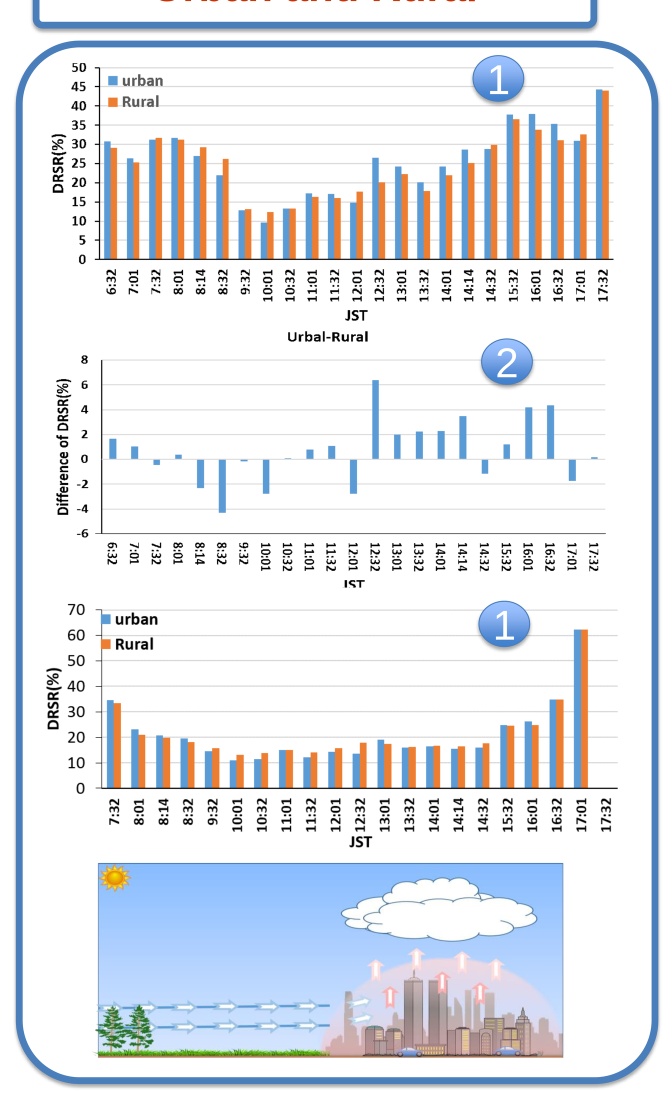


Results (Comparison between.......)

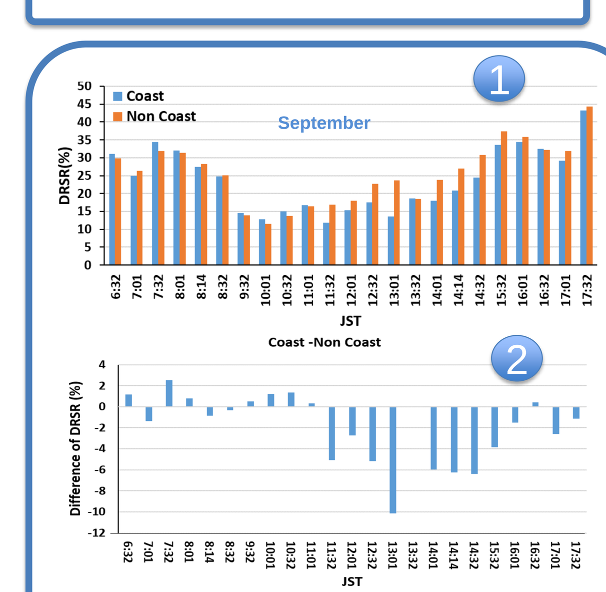
Mountain and Plane areas

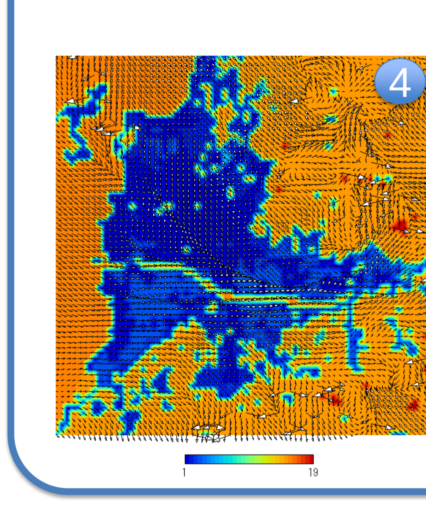


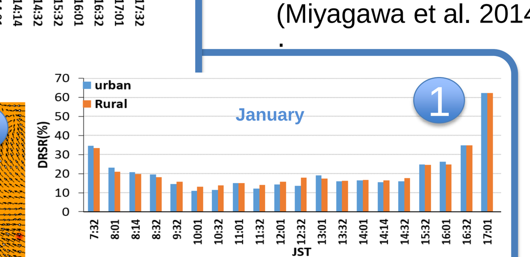
Urban and Rural

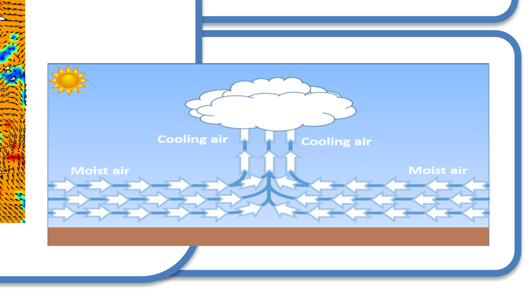


Costal and Non-coastal









1. Solar radiation rate from 6:32 am to 17:32 pm
2. Difference of downward SW radiation reduction rate between 6:32 am to 17:32 pm
3. Diurnal changes of wind velocity and direction at Matsuyama meteorological observatory
4. Convergence of wind in the Matsuyama plain (Miyagawa et al. 2014)

Conclusions

Downward SW radiation satellite dataset was used for the analysis of clouds over different geographical features and land use patterns. The study concludes that the thickness of cloud increases with increases in altitude. The comparison between mountainous and plain areas suggest that the thickness of clouds is likely to be higher in mountainous areas than plain areas. The comparison between coastal areas and noncoastal areas suggest that non-coastal areas have a significantly higher thickness than coastal areas in the afternoons. Another comparison between rural and urban areas suggests that in summer, urban clouds are thicker than rural clouds in the afternoons but in winter, the thickness is almost the same.

Acknowledgments

Sincerest thanks to Dr. Hideaki Takenaka, Center for Environmental Remote Sensing, Chiba University for providing geostationary satellite dataset. This research was supported by a JSPS Grant-in-Aid for Scientific Research (C) (15K06236) and by the Strategic Information and Communications R&D Promotion Programme (SCOPE) of the Ministry of Internal Affairs and Communications of Japan.