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Hourly Forecast of Global Irradiation Using GMS Satellite Images

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ABSTRUCT

This paper describes the methods for forecasting solar irradiance by using Geostationary Meteorological Satellites(GMS) images. As the first attempt the authors forecasted the cloud albedo for a basic study of irradiance estimation by estimating driving drift vector of clouds using GMS images. A new procedure is also proposed for removing the effect of ground albedo, which disturbs cloud movement analysis. This time, Annual forecastable probability was estimated as 81.3% for one hour ahead, 71.0% for two hours ahead and 59.3% for three hours ahead.

Keywords: irradiation, albedo, forecast, Geostationary Meteorological Satellites(GMS), the drift vector of clouds

1. Introduction

In recent years there have been environment protection to introduce of solar power systems and aggressive introduction and diffusion to the public is advanced. When the amount of introducing of photovoltaic systems increase, they have a effect on the power dispatching plan. However, if the irradiance for several hours ahead can be forecasted, it is useful for the power dispatching plan. By the way, the main cause of an irregular change in the irradiation at the ground level is the effect of the clouds, therefore the methods of estimating the solar irradiation by using the GMS images may be very useful. The utilization of cloud images has been already proposed by several organizations[1),2),3),4)].

This study shows the methods for estimating the irradiation by using the GMS images. Firstly, the authors have developed a method for deriving the drift vector of clouds from the images and forecasting a cloud albedo at certain pixels. The cloud albedo was forecasted as a basis study of estimating the irradiation.

This time, the authors used GMS images, which are resolved into 1800×1800 pixels with 64 gradations of brightness, and size of a pixel covers 1.25×1.25 km^2 approximately and covered a region between 20°S and 70°N in latitude and between 70°E and 160°E in longitude. The wavelength that is the visible portion of the spectrum by GMS radiometer hardly concern absorption of the atmosphere. Therefore, the reflection of irradiation from the object only was considered. The GMS images were affected by the relationship of relative position between a sun and an object. The albedo observed by the GMS images could be suitable a statistical analysis using different images. Fig.1 shows the four spots from which data using this analysis extracted.

2. Methodology

2.1 Classification of the ground albedo

The albedo observed by the GMS images are constituted of the cloud and ground albedo on the assumption that the simple atmosphere model composed by the clouds and ground. The ground albedo was obtained by connecting the minimum value of the GMS-observed albedo for a term of previous 7days. The ground albedo from January 1 to 31 in 1999 are shown in Table.1.

2.2 Calculated the cloud albedo

The cloud albedo was derived to subtract the ground albedo from the observed albedo. However, the cloud albedo is varied with the cloud transmittance by thickness, altitude and ratio of cloud and so on. Fig.2. shows the transmittance of stratocumulus and altocumulus. It is understood that a transmittance is wrong even if obviously it is based on the kind of the cloud. This time, the value of threshold was assumed observed albedo 38, 40 and 42. If the observed albedo was beyond the value of threshold, it was classified into cloud albedo. The cloud albedo is calculated at the simple liner model if cloud albedo is less than it. Fig. 3. shows the distribution of the observed cloud. The simple liner model is as follows:

$$\rho_c = \rho_p \qquad : \quad T_c < \rho_p$$
$$\rho_c = \rho_p - \frac{T_c - \rho_p}{T_c - \rho_g} \times \rho_g \qquad : \quad T_c > \rho_p$$

where Tc: the value of threshold, ρ_g : ground albedo, ρ_p : observed albedo, ρ_c : cloud albedo. This equation assumed that the cloud transmittance changed linearly.

2.3 The methods of calculating the driving drift vector of clouds

Three kinds of GMS images, observed images, an image several hours ago and an image after several hours from the observed images, are used for estimating the clouds motion. The driving drift vector of clouds are represented to calculate a correlation between image several hours ago and observed image. The region to calculate a correlation set up totals 10 kinds by making 5 pixels each change from 5×5 pixels to 50 ×50 pixels. Fig.4 shows the example of the driving drift vector of clouds.

2.4 The methods of forecasting the cloud albedo

When the cloud albedo on the spot (x_f, y_f) at an image $h_{t+n}(x,y)$ for several hours ahead was forecasted, the driving drift vector of clouds must be calculated first. The spot (x_p, y_p) at the image $h_{t-n}(x,y)$ for several hours behind was equal in the spot (x_f, y_f) at an image $h_{t+n}(x,y)$ for several hours ahead. It is decided that the spot (x_f, y_f) fills the next condition.

$$xf = xp = xo$$

$$yf = yp = yo$$

The driving drift vector of clouds $C_p = (C_{px}, C_{py})$ apply the reverse direction from the spot (x_o, y_o) at the observed image and the spot $(x'_o{}', y'_o)$ at the observed image was decided. The spot $(x'_o{}', y'_o)$ is as follows :

$$x'_o = x_o - C_{px}$$

$$y'_o = y_o - C_{py}$$

Therefore the cloud on it could be estimated to move the spot (x_f, y_f) at an image $h_{t+n}(x,y)$ for several hours ahead. Fig.5 shows the methods for estimating the cloud albedo.

3. Results

The forecast of cloud albedo was used a monthly images from January 1 to 31 in 1999. The four spots where was forecasted were chosen arbitrarily and the cloud albedo was forecasted by images from one hour ahead to three hours ahead. Fig.6 shows the graph of the result that forecasted whether the cloud albedo exist for several hours ahead. It was classify them according to size of images to calculate the correlation coefficients. The percentage of average was estimated 81.4% for one hour ahead, 71.0% for two hours ahead 59.3% for three hours ahead.

Fig.7. shows an example for hourly estimates. The root mean square errors (RMSE) for one hour ahead hardly change in every correlation

size. This means the forecast of cloud albedo doesn’t depend on the region of images to calculate the correlation coefficients. However, RMSE for three hours ahead change greatly. The average of RMSE for hourly estimates was 9.5 for one hour ahead, 11.2 for two hours ahead and 13.5 three hours ahead.

4. Conclusions

In this paper the method for forecasting the drift vector of clouds was presented. As a result, the technique that only a cloud albedo was extracted with the GMS images was suggested. The cloud albedo was forecasted by images from one hour ahead to three hours ahead. The methods of forecasting the cloud albedo for one hour ahead had no influence on the correlation region. The result that forecasted whether the cloud exist was 81.3% for one hour ahead, 71.0% for two hours ahead and 59.3% for three hours ahead. Therefore, the method of forecasting the cloud albedo is very useful for irradiance estimation. Hence, we must examine the simple model to decide the cloud albedo and it consider whether estimating the irradiation is actually possible.

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Table.1 A classification of the ground albedo

Situation	The albedo
Sea	12 ～ 18
Coast	19 ～ 24
Ground	25 ～ 30

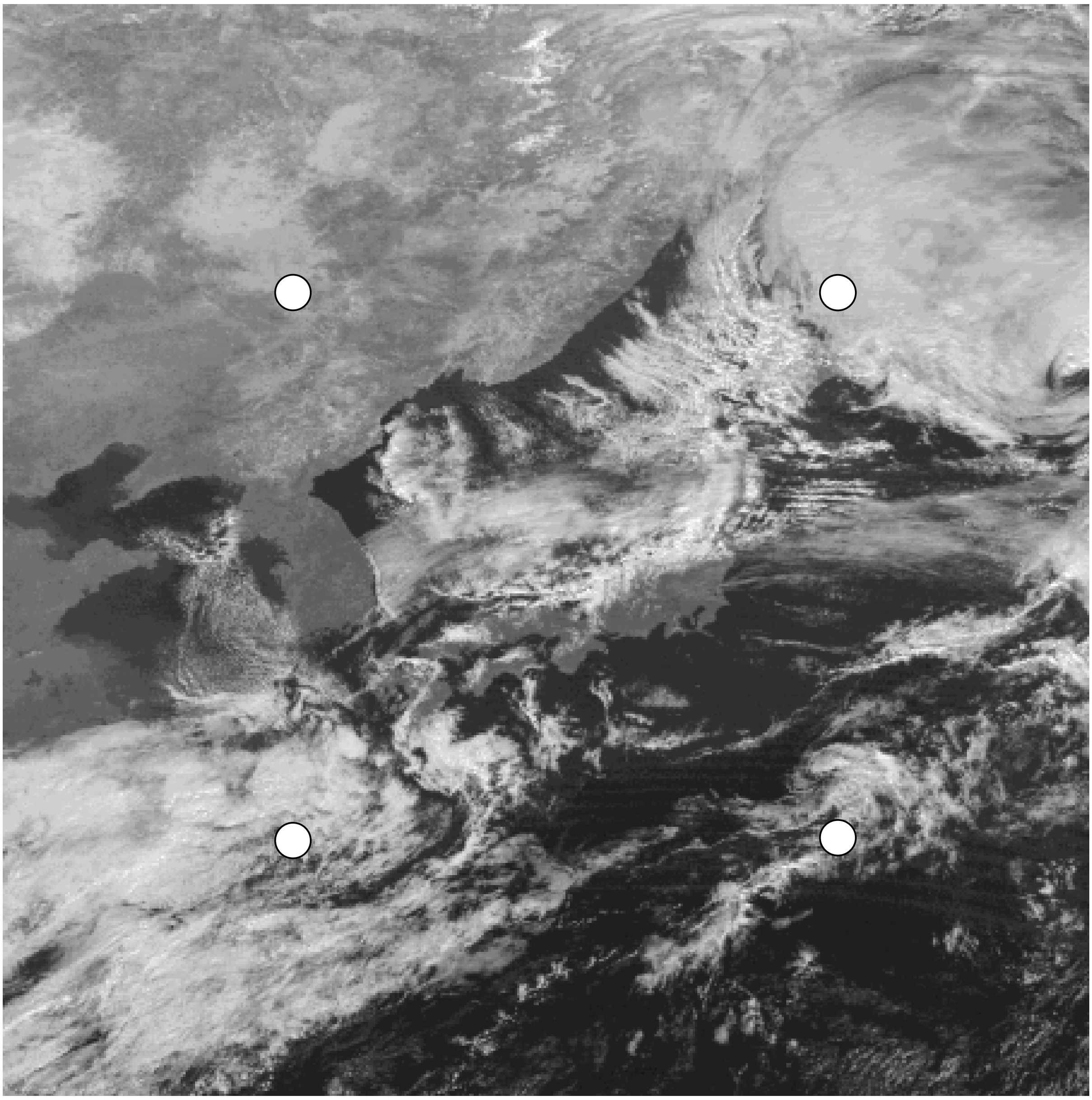

Fig.1. The example of the GMS image used for the forecast

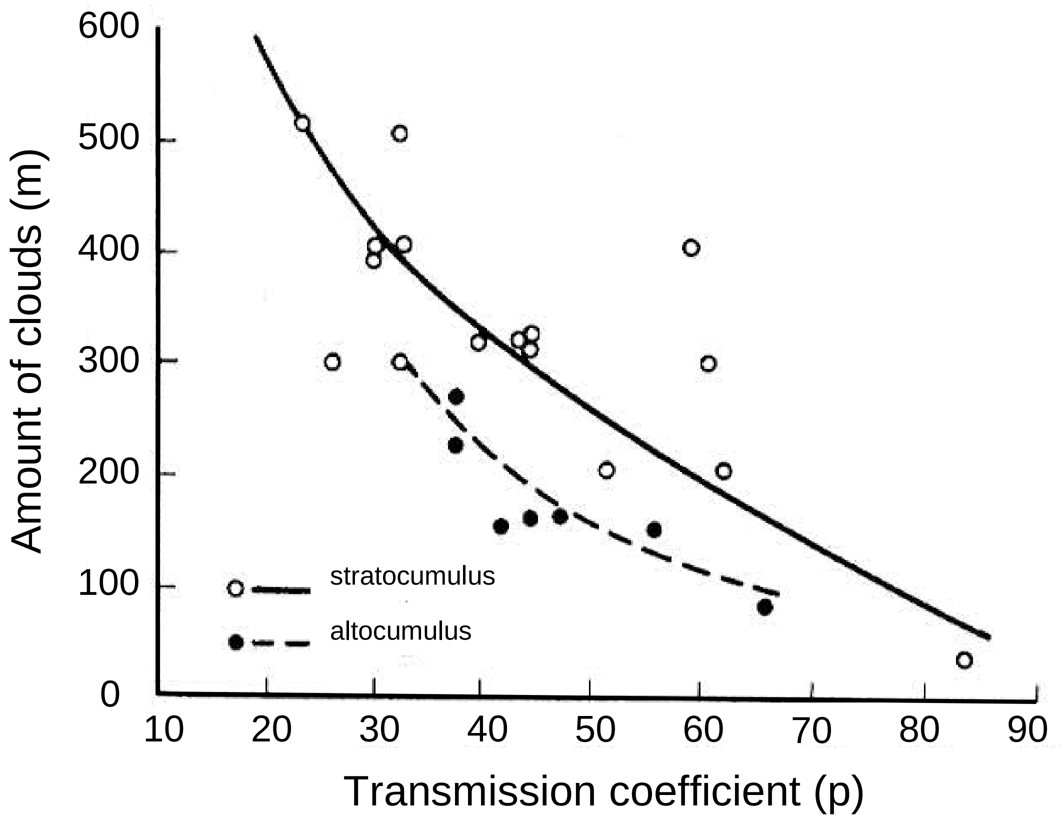

Fig.2. The transmittance of stratocumulus and altocumulus

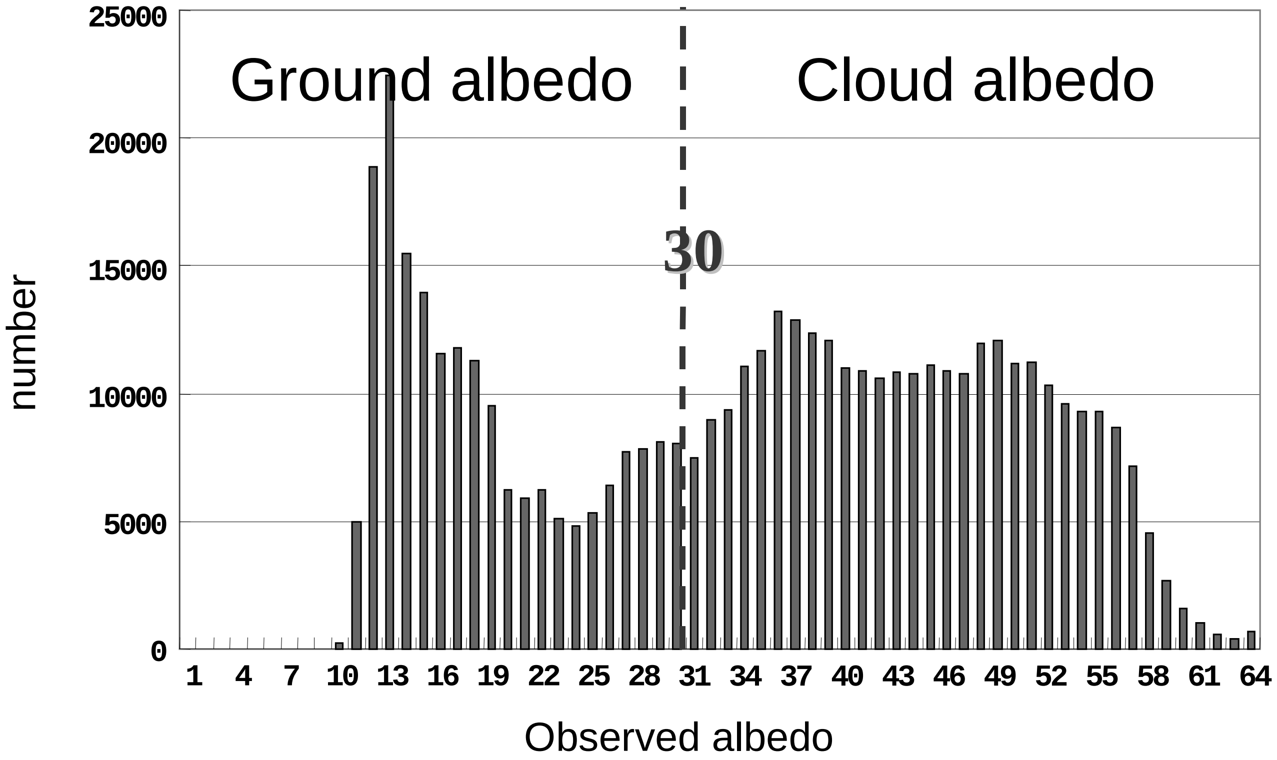

Fig. 3. The distribution of the observed cloud

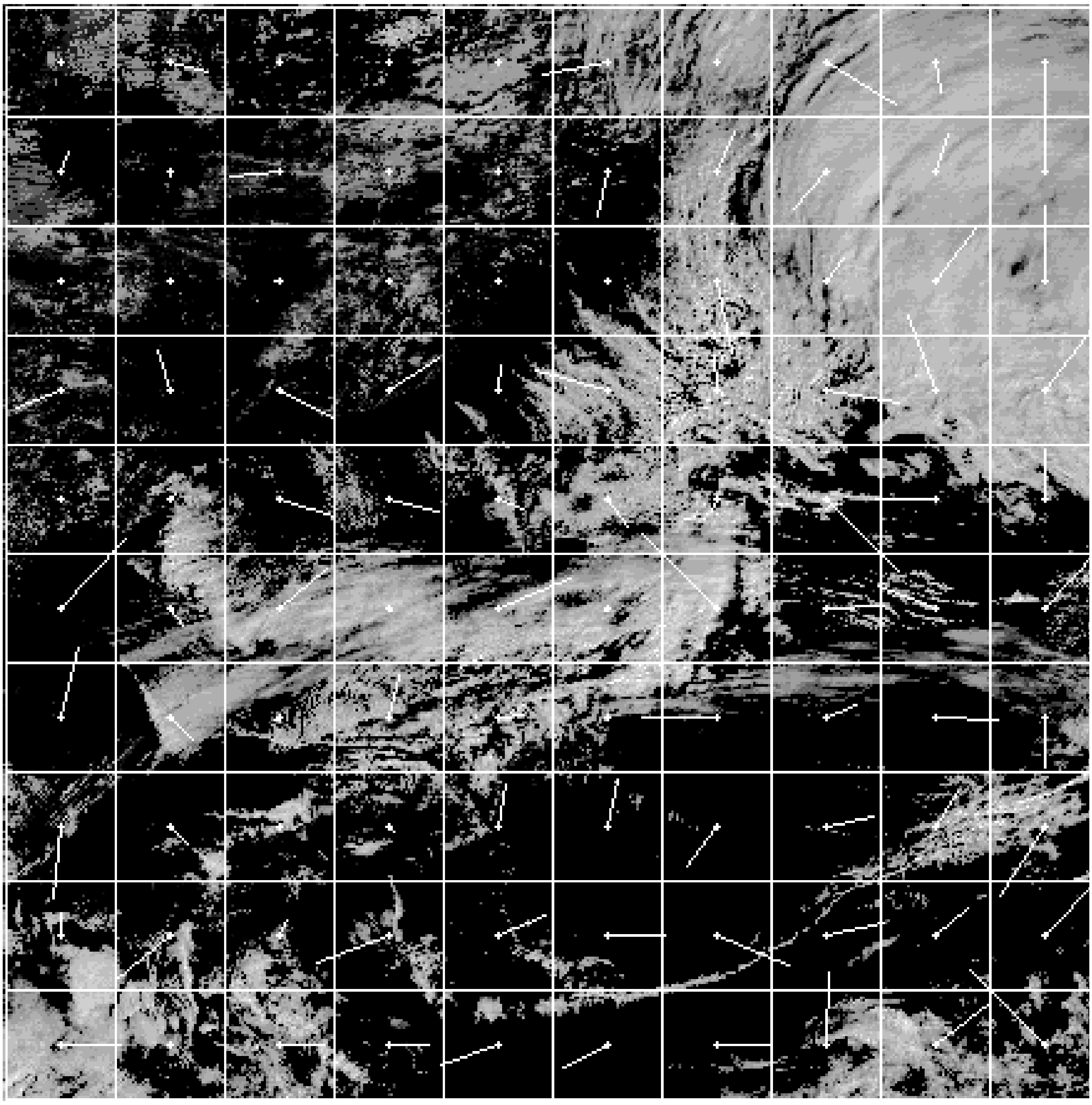

Fig.4 The example of the driving drift vector of clouds.

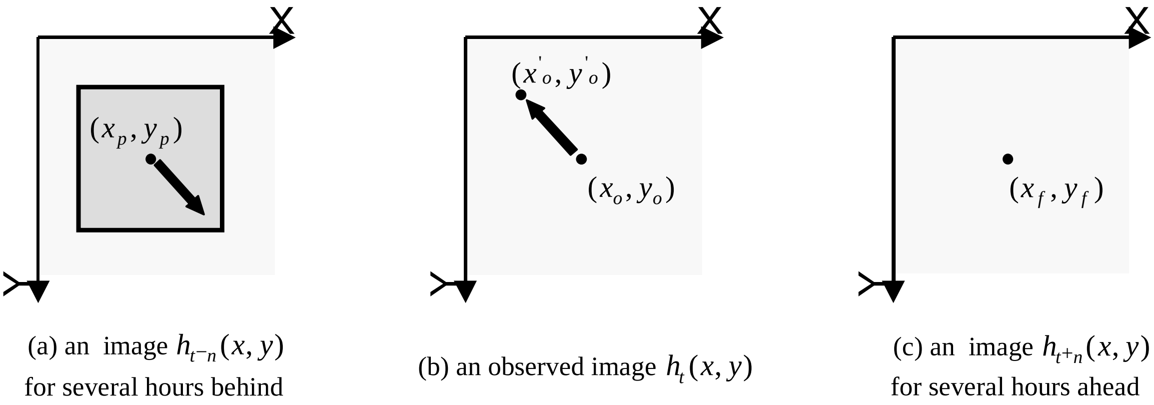

Fig.5 The methods for estimating the cloud albedo

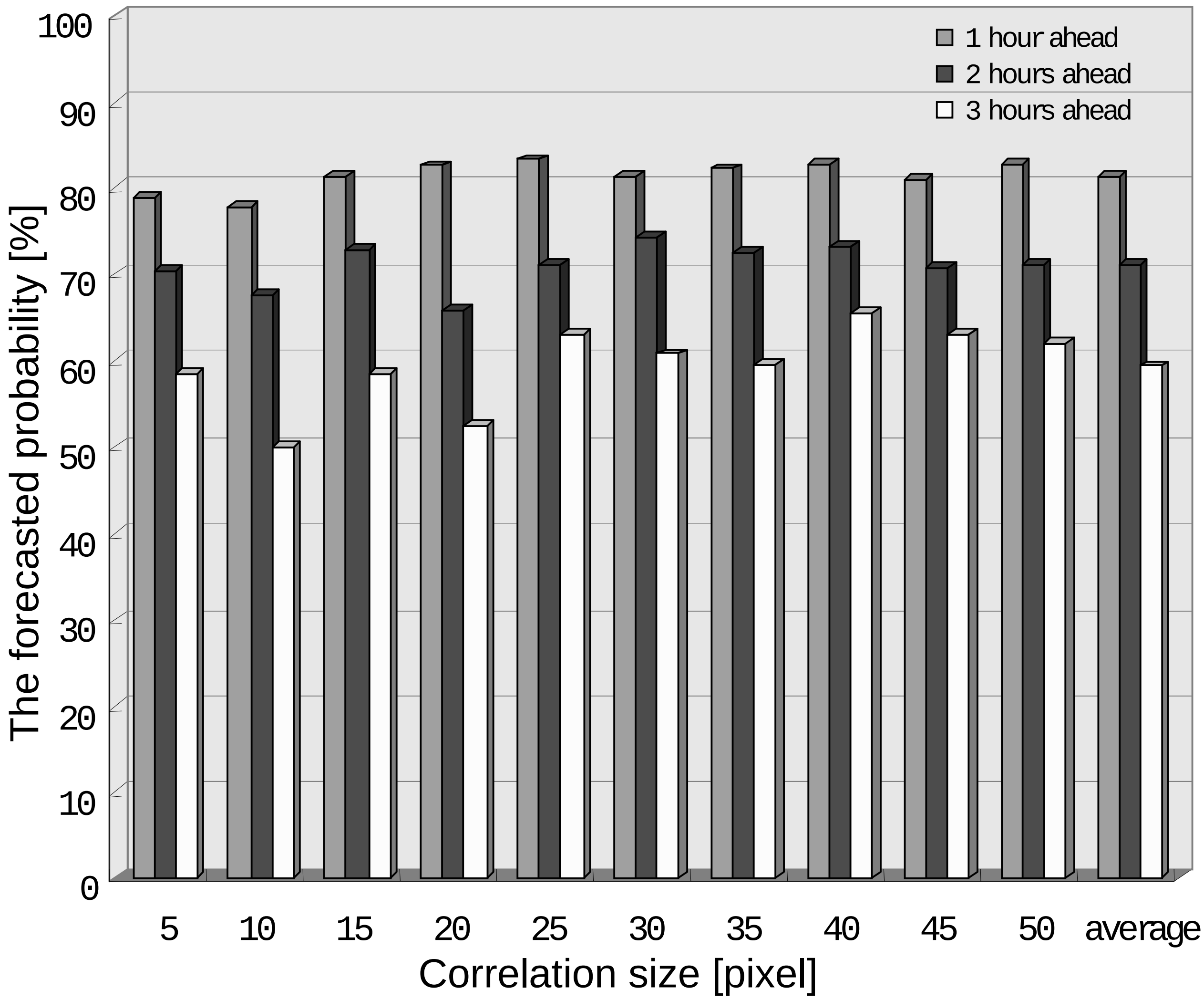

Fig.6 The graph of the result that forecasted whether the cloud albedo exist for several hours ahead.

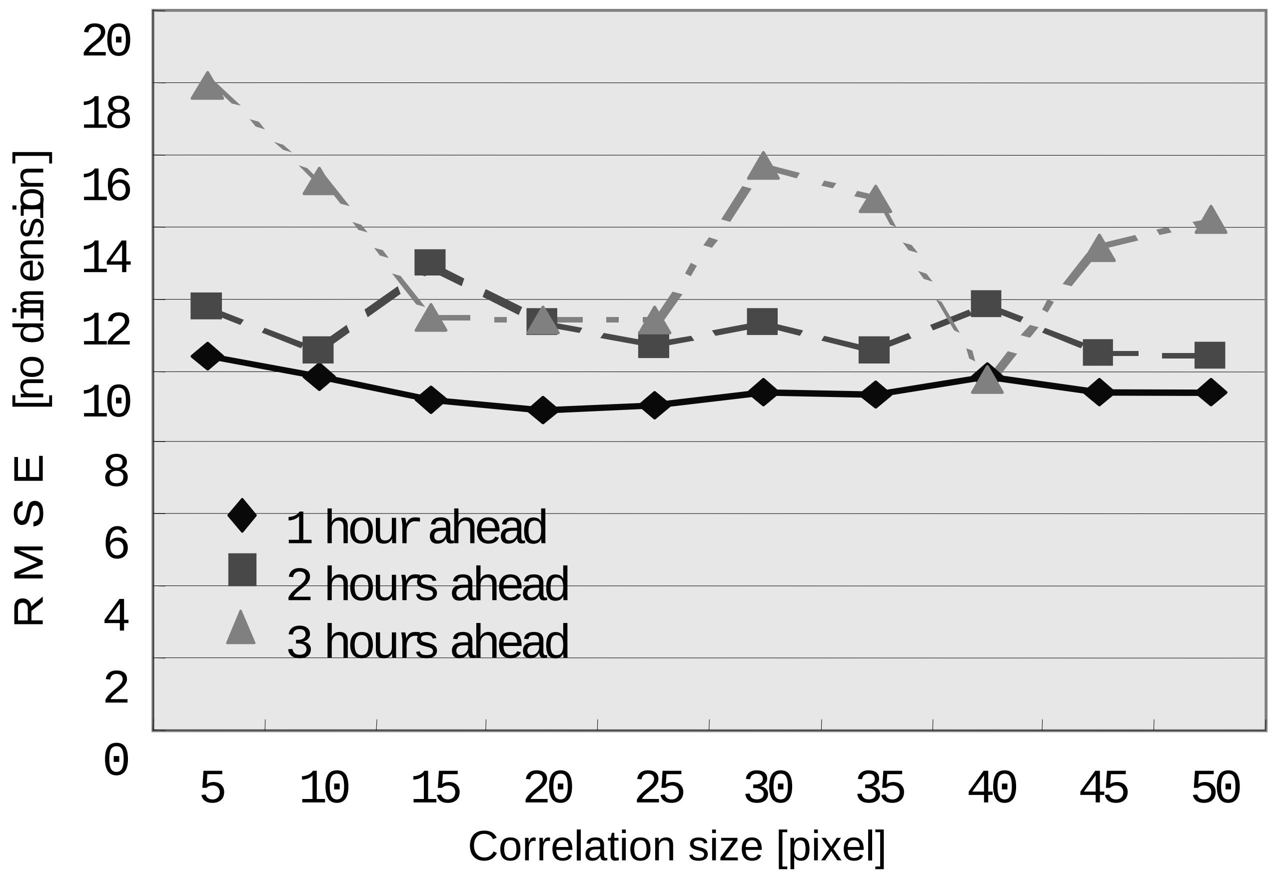

Fig.7. An example for hourly estimates