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Linear and non-linear enhancement for sun glint reduction in advanced very high resolution radiometer (AVHRR) image

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Abstract. Cloud detection over water surfaces is difficult due to the sun glint effect. The mixed pixels between both features may introduce inaccurate cloud classification. This problem generally occurs because of less contrast between the glint and the cloud. Both features have almost the same reflectance in the visible wavelength. The piecewise contrast stretch technique shows preservation capability on the reflectance of the cloud. The result of a band ratio was smoothed by applying the Sobel edge detection to provide better cloud feature detection. The study achieved an accuracy of about 77.5% in cloud pixels detection.

1. Introduction

Polar and geostationary satellites are typically used for cloud study. However, their altitude and inclination had made them prone to the sun or sky glint effect. The glint effect always appears bright in the visible band of satellite images. Studies by [1] described the sun glint region on Advanced Very High Resolution Radiometer (AVHRR) image is presented by the reflectance of 850nm band that exceeding 0.2 acquired at the altitude of 800km and the inclination of 98.7 degree. Besides, the 0.64- and 0.84-µm AVHRR bands used for differentiating the cloud pixels with pixels of surface background experience the sun glint pixels that are consistently occurred at the sea surface [2]. It becomes major challenge in the application of AVHRR images for oceanography and climate studies.

AVHRR is comes from series of operational satellite that able to supply data for many years until the future [3]. Moreover, AVHRR also provide many types of spatial coverage which are Local Area Coverage (LAC), Global Area Coverage (GAC), High Resolution Picture Transmission (HRPT) and Full Resolution Area Coverage (FRAC) that is significant to various applications. Due to this problem, image interpretation process is restricted and false information will acquired especially in oceanography application [4] and atmospheric properties study [5]. Until now, many methods for sun glint correction have been applied as mentioned by [4].

Many tests have been carried out to perform the cloud detection neither, over the land nor water surfaces. Yet, the visible wavelength tests over the homogenous water surface are suffered from sun and sky glint problems. As a result, the cloud reflectance is altered by the glint reading caused false cloud detection test due to less contrast of the image. The glint occurred when the reflected sun angle is between 0° and 36° when the satellite sensor captured the images. Over the glint area, the pixels is tended to declare as cloudy pixels when band ratio test is carried out but threshold test of thermal channel is use as an alternative to verify the cloud pixels. Figure 1 shows the glint effect over the ocean during daytime. This paper highlights on reducing of sun glint effect using

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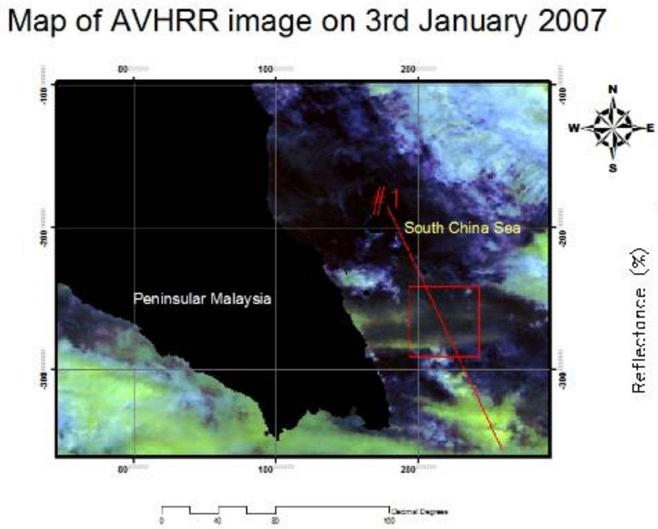
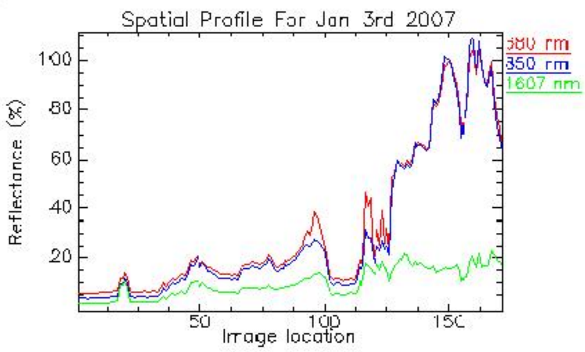
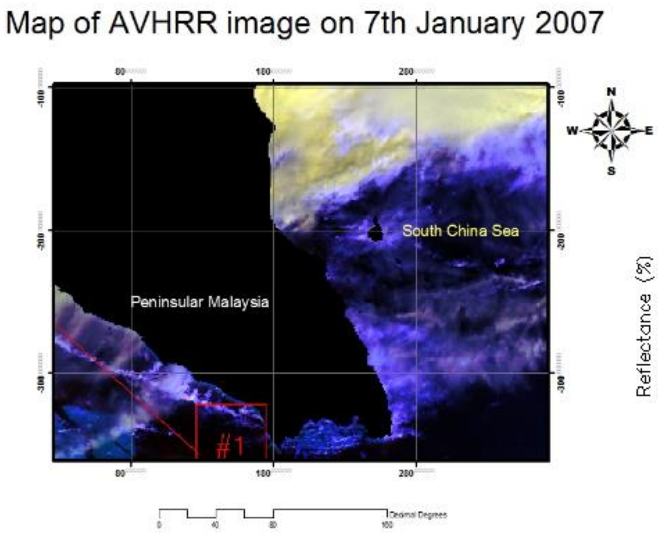
image enhancement to perform cloud detection. This research was motivated by the need to differentiate the cloud pixels over homogenous water surface with less glint effect. The enhancement is important in order to enhance the contrast from adjacent pixels. However, the sky glint effect in the satellite images is not discussed detailed in this paper. With the valid reflectance, cloud detection over homogenous water surface can be carried out with large spatial satellite coverage. The enhancement techniques are able to perform high contrast between the pixels hence provided accurate cloud detection with reduction of glint effect. This paper discussed the technique for sun glint reduction. Section 2 briefly discussed the enhancement and edge detection technique to perform reliable cloud detection result. Section 3 discussed on the result acquired for the experimental images.



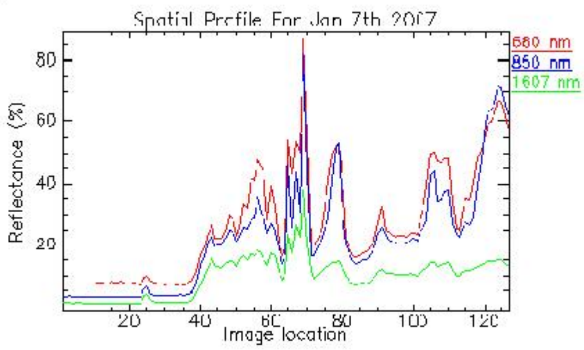
(a)(i)



(a)(ii)



(b)(i)



(b)(ii)

Figure 1. Illustration of sun glint in AVHRR imagery. (a)(i) Subset of AVHRR-17 image of the South China Sea showed sun glint on right hand side. (a)(ii) Plotted of true colour image (band 1,2and 3) along transect line. (b)(i) Sun glint at Malacca Strait showed on left hand side. (b)(ii) Plotted of true colour image along transect line

2. Materials and Method

Five scenes of LAC AVHRR satellite imageries are used as experimental for this study. The sun glint contaminated pixels is identified between the cloudy pixels by linear and nonlinear contrast enhancement. Image for 3rd, 6th, 7th, 8th and 10th of January 2007 are used for this study with 15000 pixels involved excluded land. Remote sensing software package and ArcGIS are used to process the images and perform the output. MOD035 cloud data product is used for the validation purposed. The calibration of this satellite imagery is referred to NOAA KLM user guide.

In satellite imagery, cloud appeared brighter with low temperature from the underlying surface in visible and infrared wavelength [6] [7].However, the brightness of the cloud is contaminated with the glint pixels during the images were captured. As a result, the cloud detection is not very accurate over the water bodies. In order to reduce the uncertainties, contrast enhancement techniques are proposed to differentiate the two adjacent pixels that consists almost the same reflectance value. Atmospheric correction is neglected in image processing. Figure 2 shows the flowchart of the methodology used in this study.

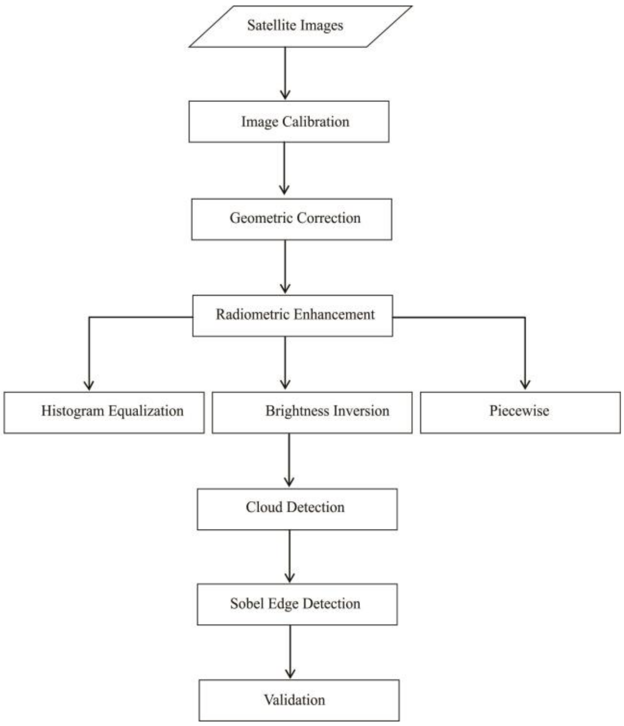


Figure 2. Flowchart of methodology.

2.1. Radiometric enhancement

There are many enhancement techniques to adjust the image contrast. For this study, linear and nonlinear radiometric enhancement is applied to the experimental images. This enhancement uses the individual pixels to enhance the images. Therefore, the pixels with consist of cloudy and glint pixels are enhanced separately to have better contrast [8].The linear contrast enhancement use is Piecewise linear contrast stretch (PIE) while brightness inversion (BI) and histogram equalization (HE) are representing nonlinear enhancement.

2.2. Spatial enhancement

The spatial enhancement is carried out to smooth the cloud detection result from band ratio technique. This enhancement takes into account the intensity contrast of individual and neighbouring pixels to enhance the image. Even though it will loses amount of data but it preserve the structure of the image. Edge detection is use to smooth the result of band ratio technique by identifying the discontinuities in the image. Band ratio test (band 2/band 1) is used to detect the cloud over the ocean. In the ocean, the reflectance of visible wavelength is low than the cloud [6][9][7]. For this paper, the Sobel non directional edge detection is applied because it is simple and able to detect the edge of the pixels with the orientations [10].

3. Experiment Result.

Five scenes of LAC AVHRR satellite imageries are used as experimental for this study captured between 11.00 am until 12.00pm local time. The study area is located near Peninsular Malaysia as

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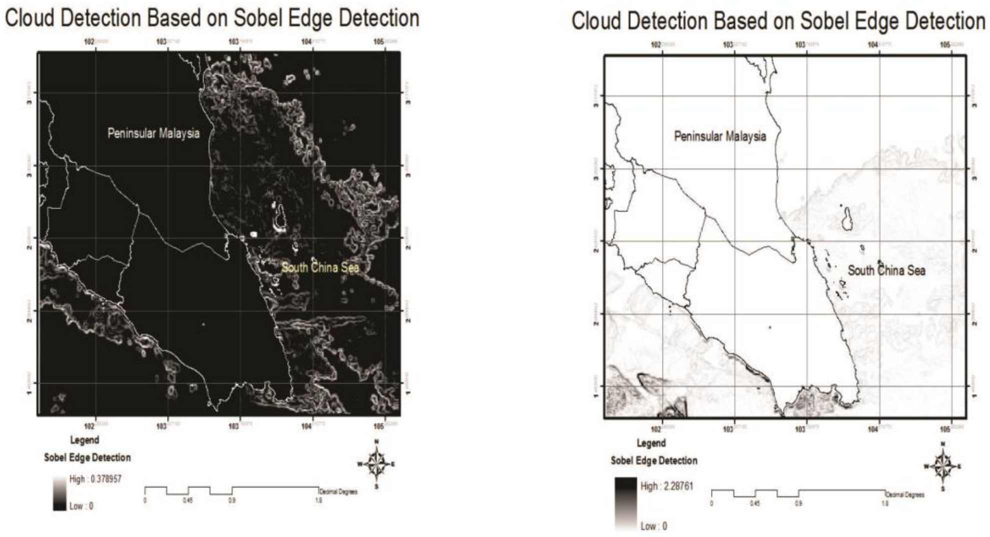
shows in figure 1. The sun glint contaminated pixels is identified between the cloudy pixels by linear and nonlinear contrast enhancement. Image for 3rd, 6th, 7th, 8th and 10th of January 2007 are used for this study with 15,000 pixels involved but excluded land. From the calculation performed, the pixels contained of cloud and glint is about 79%. Hence, enhancement technique is carried out to reduce the effect of the glint. The PIE enhancement technique gives better contrast in qualitative interpretation than the others techniques. This technique has stretched only certain value to increase the contrast between the clouds at the glint pixels. The statistic of the enhancement is shows in table 1. From the enhancement, about 2.5% of sun glint pixels are removed from the imagery.

Table 1: Statistic info of enhancement technique for images January 2007

Enhancement	Statistic	3rd Jan	6th Jan	7th Jan	8th Jan	10th Jan
	μ	32.95	15.68	31.09	24.47	26.26
Original image	σ	35.35	21.09	39.76	26.87	27.16
HE	μ	86.88	70.78	66.59	64.66	60.17
	σ	93.95	81.22	79.54	74.27	72.11
BI(Inverse)	μ	9.04	4.92	10.13	10.72	3.10
	σ	16.10	7.58	14.92	18.01	6.80
BI(Reverse)	μ	52.20	45.37	50.38	59.46	44.47
	σ	48.21	40.34	51.13	51.46	39.82
PIE	μ	32.92	15.63	31.06	24.34	26.22
	σ	35.39	21.11	39.84	26.79	27.18

The band ratio test is performed to detect the cloudy and glint pixels where the ratio is 0.69 to 1.17 while ratios less than 0.69 are for cloud free pixels. [9] had applied the technique and find that ratio 0.6 at the sea is classified a cloud free pixels while [11] found 0.8 ratio is cloud free pixels at the water. Based on the previous ratio, the ratio acquired form this study is believed shared by cloud and glint pixels. Besides, the study area is located at tropical region where the cloud covered is full during diurnal. Other than that, the result also may altered by the layer of the cloud with the cloud development during the time image was captured. Generally, cloud development is rapidly until the afternoon. Hence, the Sobel edge detection is applied to delineate the edge of cloud and glint pixels as shows in figure 3 hence improved the cloud detection.



(a) (b)

Figure 3. Map of Sobel edge detection for a) 3rd January 2007 and b) 7th January 2007

Based on figure 3, the line is represented the edge of cloud and the glint. The ratio obtained for the cloudy pixels is 0.93 to 1.17 over the ocean while the glint is 0.69 to 0.93. Nevertheless, the ratio of the cloud is intercept at 0.93 because the glint pixels are mixed with the cirrus cloud. As known, cirrus cloud over tropical is difficult to detect because of their thin and 'veil' characteristics. MODIS cloud product (MOD035) with 1 km spatial resolution was used to validate the result obtained from the experimental images. As mentioned before, the pixels contained of cloud and glint obtained is about 79% while the cloud pixels only are 77.5%. The difference of 2.5% is coming from the glint pixels successful identified in this study. Meanwhile, about 70.8% amount of only cloud pixels is acquired from MOD035 with 6.3% difference with combination of glint and cloud region where good quality of cloud amount is obtained. The individual tests and the additional information tests for MOD035 provided good quality product. Compared with this experimental study, only band ratio test is applied to detect the cloud. Besides, the difference between times of captured satellite images effect the difference amount of cloud obtained.

4. Conclusion

Since band ratio test cloud detection is mostly used by many researcher, the good quality of result may achieved by radiometric correction of satellite imageries. This test gives good result for cloud detection over the ocean than the land. The cloud ratio that close to 1 due to similar Mie Scattering effects in the visible and infrared channel is not valid for the land with high dense of vegetation. In this paper, the experimental using five sets of satellite imageries is enhanced using linear and nonlinear contrast enhancement. The Piecewise contrast is the best compared to the other enhancement. The cloud detection over homogenous water surface is improved with the enhancement and edge detection is applied to differentiate the cloud and the glint pixels. For the future, sky glint pixel should be taking into account to improve the accuracy besides the use of multi test for cloud detection after the radiometric enhancement. In addition, the spectral enhancement may apply before further process to differentiate between the features due to weather problems.

Acknowledgment

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