

COMPARISON OF PERFORMANCE OF THREE DIFFERENT MODIS AOD ALGORITHMS USING HAND-HELD SUN PHOTOMETER MEASUREMENTS AT THE HONG KONG INTERNATIONAL AIRPORT

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Abstract

Two MODIS AOD algorithms are being used at the Hong Kong Observatory (HKO) for aerosol and visibility monitoring, namely, the standard 10-km resolution product from NASA and the 1-km resolution product developed by Li (PhD thesis, 2002). A new algorithm at 10-km resolution developed by Kim (JGR, 2007) has recently been tried out. The performance of the three algorithms in retrieving AOD near the south China coast is studied in this paper by comparing their outputs with the measurements of a hand-held sun photometer at the Hong Kong International Airport. The period of study is cloud-free days in the autumn of 2008 and the spring/early summer of 2009. The accuracy of the sunphotometer measurements is first established by comparison with AERONET AOD data. It is found that, among the three MODIS AOD algorithms, the 10-km resolution algorithm of Kim (2007) appears to have the best performance. The slope of the best-fit straight line for the data points between the AOD outputs of Kim's algorithm and the sun photometer measurements is the closest to unity and the correlation coefficient is high (above 0.9). Moreover, the AOD values so determined have good correlation with the AERONET AOD data. Further studies for an extended period will be performed with more comprehensive ground-based measurements.

INTRODUCTION

Visibility is an important weather element in the provision of meteorological services. For instance, at the Hong Kong International Airport (HKIA) at Chek Lap Kok, the visibility may drop below 5000 m or even to around 1000 m when west to northwesterly sea breeze brought haze from the inland areas. MODIS AOD map is a useful tool for monitoring the aerosols over southern China and thus helpful in the forecasting of low-visibility weather.

A couple of MODIS AOD algorithms are in use at the Hong Kong Observatory, namely, the standard Collection 4 algorithm and a high-resolution (1 km) algorithm developed by Li (2002). Their performance at HKIA has been studied in Chan (2007) by comparing with the AOD determined from the backscattered power obtained by a Doppler Light Detection And Ranging (LIDAR) system and the visibility data provided by a forward scatter sensor. The comparison results are in general satisfactory. However, in a more vigorous sense, the kind of Doppler LIDAR in use at HKIA has not been fully calibrated against known aerosol concentration profiles in terms of the backscattered power signal. As such, though comparison with LIDAR-based AOD has been made, the quality of MODIS AOD data as obtained from the above two algorithms has yet to be established.

A hand-held sunphotometer (Microtops II) has been used at HKIA since October 2008. It is regularly calibrated and provides independent measurements for assessing the quality of satellite-based AOD data. Moreover, another MODIS AOD algorithm, namely, by Kim et al. (2007) has been introduced. This paper studies the performance of the above three MODIS AOD algorithms near the south China coast by comparison with the hand-held sunphotometer measurements conducted at HKIA.

SUNPHOTOMETER AND ITS ACCURACY

The sunphotometer in use is a hand-held device that employs the following five wavelengths to measure AOD: 340, 500, 675, 870 and 1020 nm. It is equipped with five accurately aligned optical collimators, with a full field view of 2.5 degrees. Each channel is fitted with a narrow-band interference filter and a photodiode suitable for the particular wavelength range. AOD is determined assuming the validity of the Bouguer-Lambert-Beer law. The optical depth due to Rayleigh scattering is subtracted from the total optical depth to obtain AOD. According to the manufacturer, the uncertainty of the AOD measurement is ± 0.01 . The sunphotometer is regularly calibrated at the factory every year.

To assess the accuracy of the sunphotometer measurement at HKIA, the AOD data so obtained are compared with those from the two AERONET stations in Hong Kong as operated by the Hong Kong Polytechnic University (PolyU), namely, at Hok Tsui (a background site to represent the countryside environment, about 36 km to the east-southeast of HKIA) and PolyU campus (a site within the city centre, about 26 km to the east of HKIA). The AERONET (AErosol RObotic NETwork) is a network of ground-based sun photometers which measure atmospheric aerosol properties (<http://aeronet.gsfc.nasa.gov/>). The study period is from October 2008 to May 2009. The comparison results are shown in Figures 1 and 2. Throughout the whole paper, total least square fits are used in the scatter plots. This kind of fitting has been used in the previous AOD studies, e.g. in Chan (2009).

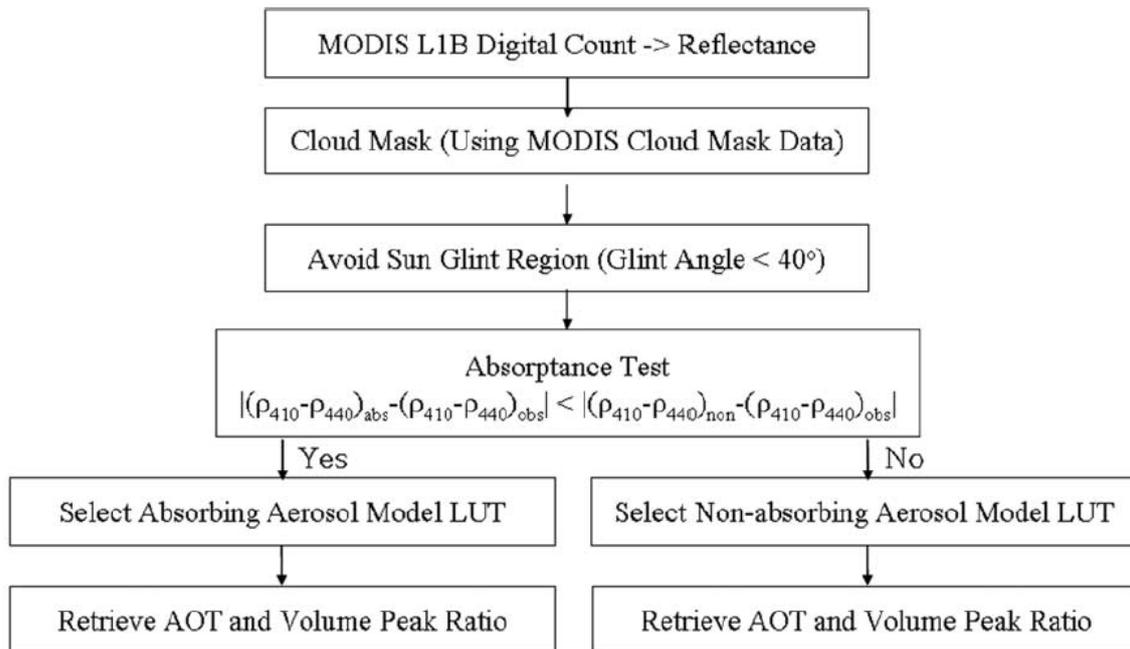
It could be seen from Figures 1 and 2 that, in general, the sunphotometer data are well correlated with the AODs from the two AERONET stations. Among the two scatter plots, the comparison with PolyU data is better, namely, the slope of the least square linear fit is closer to unity and the correlation coefficient is higher. This may be due to the fact that the air condition at HKIA is closer to that of an urban site than that of a countryside site.

THE THREE MODIS AOD ALGORITHMS UNDER STUDY

As mentioned in the Introduction section, two MODIS AOD algorithms have been used in real time at HKO. The first one is the standard Collection 4 algorithm of MODIS, providing AOD map at a spatial resolution of 10 km. The second one is developed in Li (2002) with a higher spatial resolution of 1 km. This method assumes a dark vegetation background, which may be better fulfilled at the rural areas over southern China than the highly developed city centres.

The third algorithm is discussed in Kim et al. (2007) as applied to southern China, with a spatial resolution of 10 km. In this method, the aerosols are classified according to a 4-channel algorithm (4CA). This 4CA adopts the look-up table (LUT) approach for computational efficiency. MODIS channels 1 and 2 are used to retrieve the aerosol optical properties while channels 8 and 9 are used to determine whether the aerosol absorbs radiation or not. The LUT is then computed by using a radiative transfer model assuming absorbing and non-absorbing aerosol types.

To classify aerosols into the four major types, two important decisions on the size and radiation absorptance of the aerosol must be made. The difference between channel 8 and 9 reflectance is smaller for the absorbing aerosol model than the non-absorbing aerosol model. Comparing the reflectance differences between channel 8 and 9 with those values for the absorbing or non-absorbing model, the radiation absorptance of the aerosol is determined. As a next step, AOD can be retrieved by using MODIS channel 1 and 2 reflectance for the appropriate aerosol model. For easy reference, a flow chart of the classification of the aerosol types and the calculation of AOD (or aerosol optical thickness, AOT) is given below. Further technical details could be found in Kim et al. (2007).



PERFORMANCE OF THE THREE ALGORITHMS

To study the performance of the three algorithms, the MODIS AOD values so determined for the grid point nearest to HKIA are compared with the sunphotometer measurements at the airport. The study period is, again, from October 2008 to May 2009. The comparison results could be found in Figures 3 to 5.

It could be seen from Figures 3 and 4 that, for the standard Collection 4 algorithm and the Li's 1 km algorithm, the comparison results are not so satisfactory. Though in general the MODIS AOD so determined and the sunphotometer measurement are correlated, the slope of the linear fit is far away from unity and the correlation coefficient is low (around 0.5 only). This brings up the question about whether these two algorithms are applicable to southern China for more quantitative monitoring of aerosols and visibility.

On the other hand, the Kim's algorithm appears to produce MODIS AOD values that are better correlated with the sunphotometer measurements. The comparison result is shown in Figure 5. The slope of the linear fit is close to unity and the correlation coefficient is higher (above 0.9). Though the algorithm is originally developed for northern China and Korea, it appears to be also applicable to the climate of southern China as well.

FURTHER CHECK OF THE ACCURACY OF KIM'S ALGORITHM

In order to study further the performance of Kim's algorithm in Hong Kong, the MODIS AOD values near Hok Tsui and PolyU campus are also extracted for comparison with the AERONET data. The comparison results are shown in Figures 6 and 7. The correlations are generally satisfactory, with the linear fits having slopes close to unity and the correlation coefficients being above 0.9. It is interesting to note that the y-intercepts of the linear fits in Figures 6 and 7 are less than 0.1, whereas the corresponding value in the comparison with sunphotometer measurement (Figure 5) is larger than 0.1 in magnitude. It is not sure if there is a bias in the sunphotometer measurement. The equipment manufacturer has been contacted in this regard but there is not yet any conclusion about the occurrence of the relatively larger value of y-intercept in the linear fit in Figure 5.

CONCLUSIONS

The sunphotometer measurements at HKIA are first established in this paper by comparison with AERONET data. They are then used to study the performance of three MODIS AOD algorithms, namely, the standard Collection 4 algorithm of NASA, the 1-km resolution algorithm of Li (2002) and the recent algorithm by Kim et al. (2007). The last algorithm is found to have the best performance by comparison with the sunphotometer measurements. The linear fit to the data points in the scatter plot has a slope close to unity and the correlation coefficient is high (above 0.9). The AOD values from Kim's algorithm also compare well with the AERONET data. The study period in the present paper is less than one year. More data are being collected with the sunphotometer to study the performance of the three MODIS AOD algorithms for a longer period and find out any annual and seasonal variation of the algorithm performance.

ACKNOWLEDGEMENT

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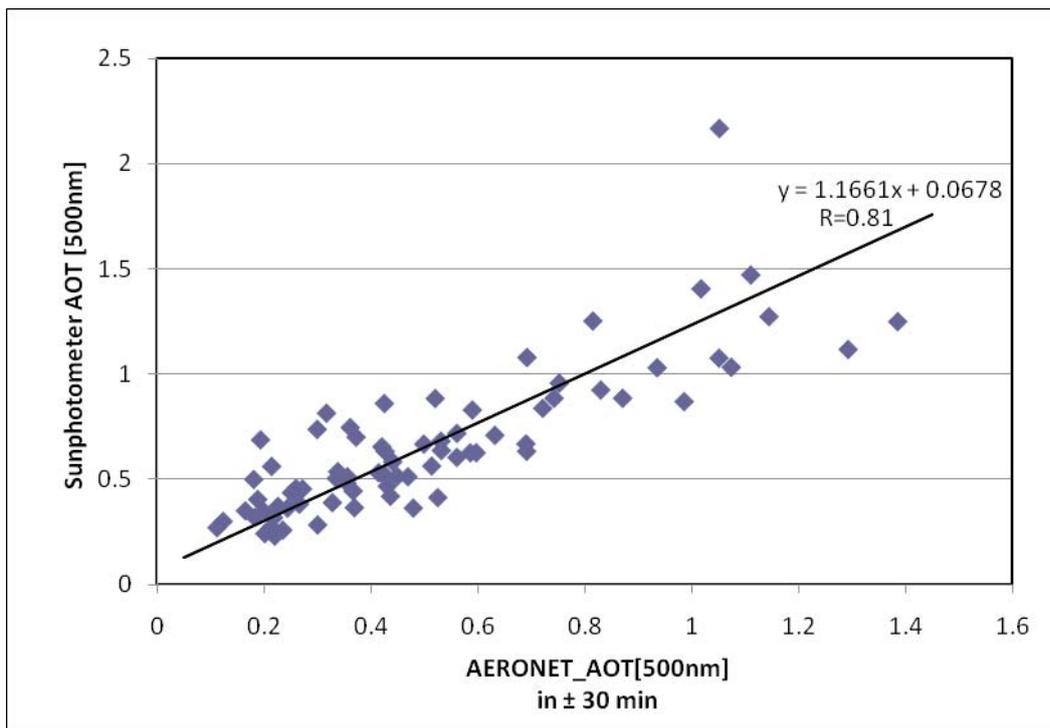


Figure 1: Scatter plot of the sunphotometer measurement at Chek Lap Kok against the AERONET data at Hok Tsui.

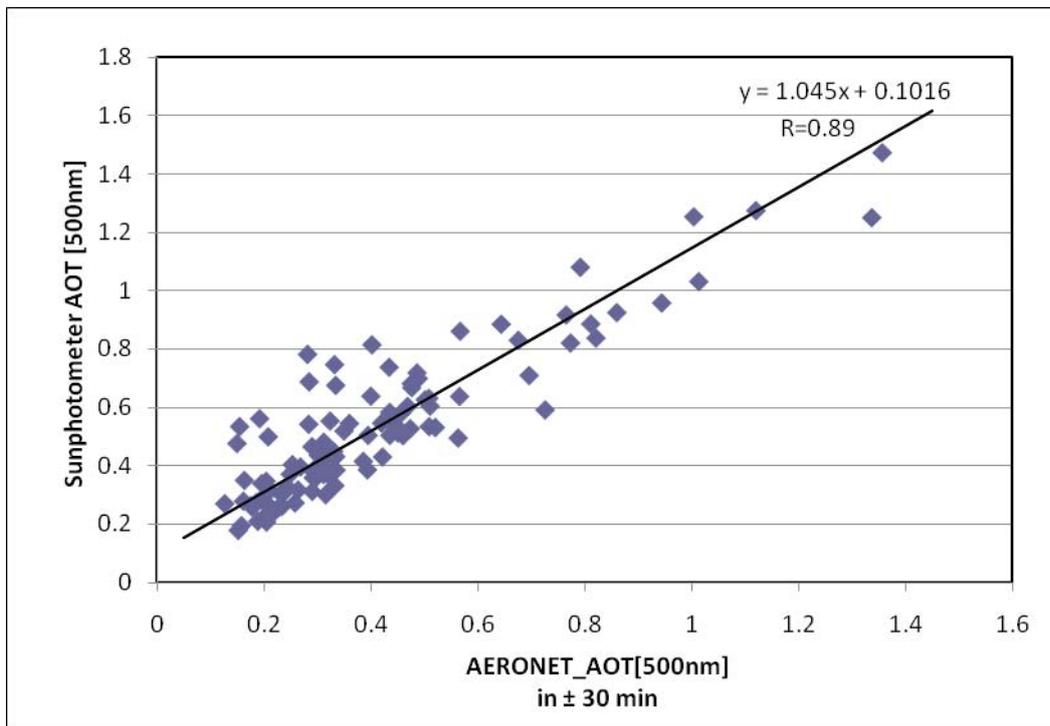


Figure 2: Scatter plot of the sunphotometer measurement at Chek Lap Kok against the AERONET data at PolyU.

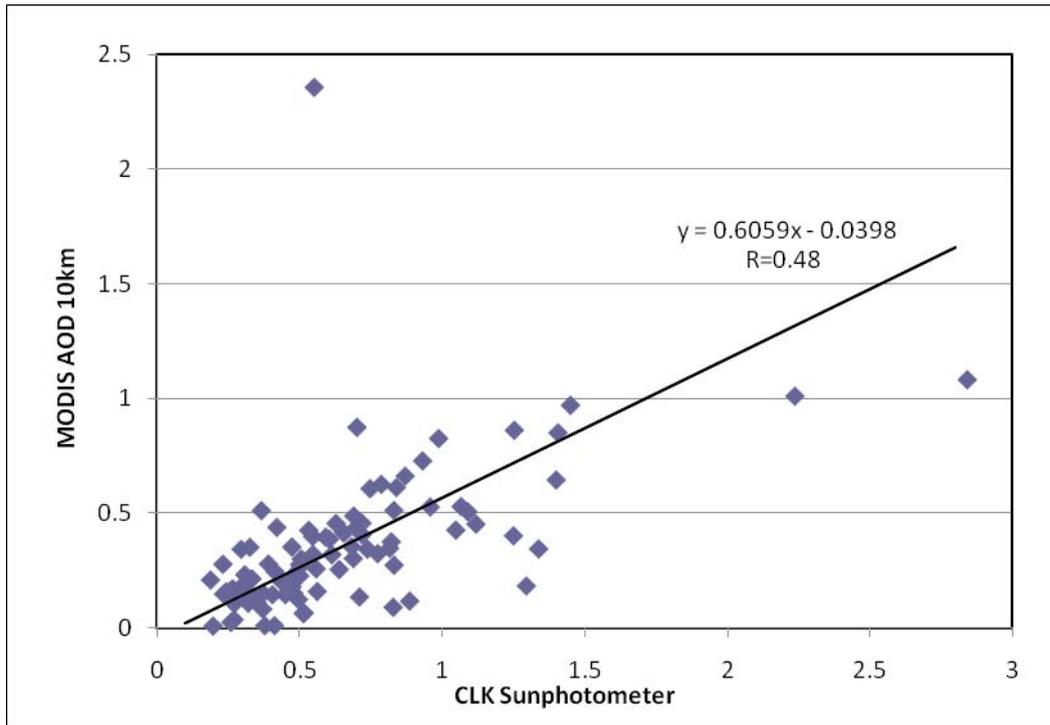


Figure 3: Scatter plot of the MODIS AOD based on Collection 4 algorithm against the sunphotometer measurements at Chek Lap Kok.

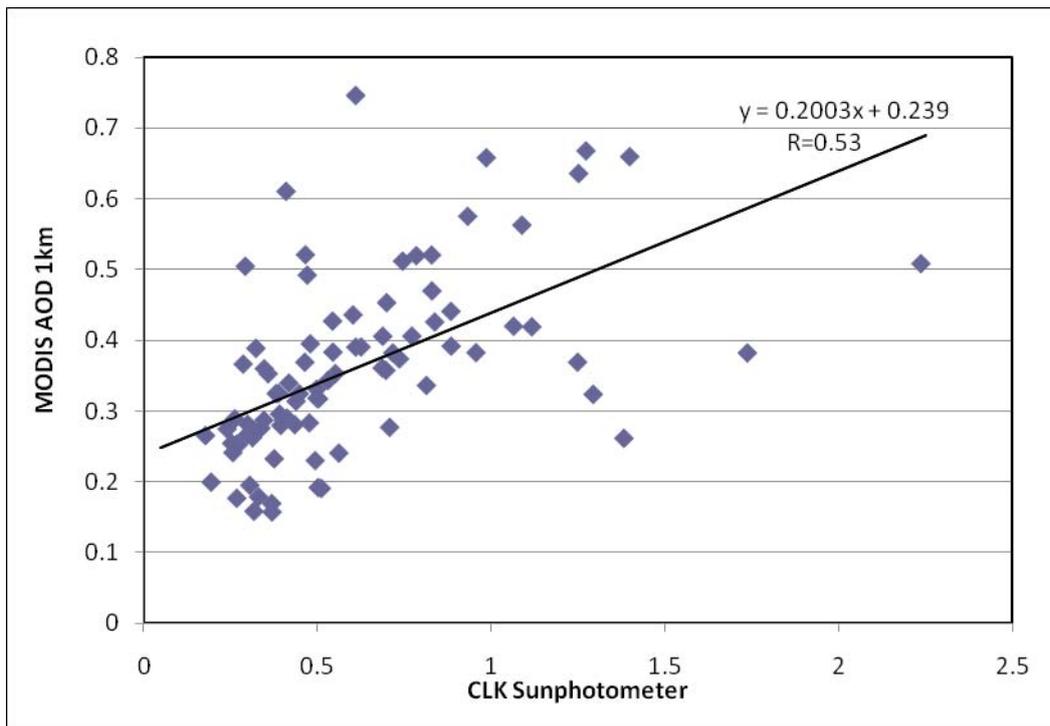


Figure 4: Scatter plot of the MODIS AOD based on Li's algorithm against the sunphotometer measurements at Chek Lap Kok.

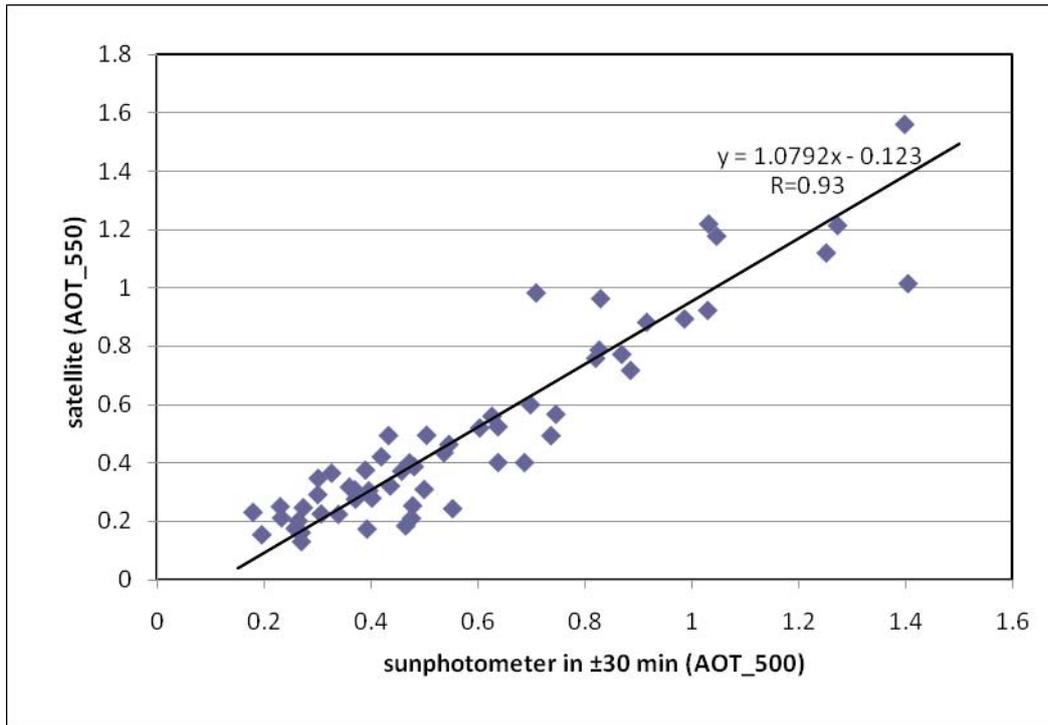


Figure 5: Scatter plot of the MODIS AOD based on Kim's algorithm against sunphotometer measurement at Chek Lap Kok.

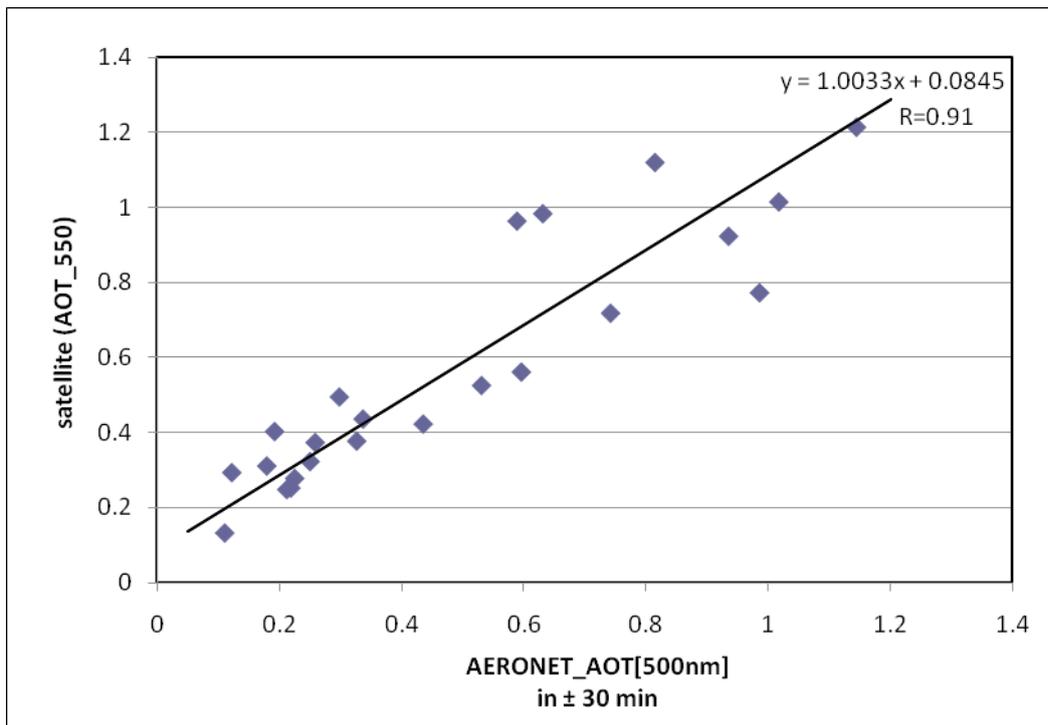


Figure 6: Scatter plot of the MODIS AOD based on Kim's algorithm against the AERONET data at Hok Tsui.

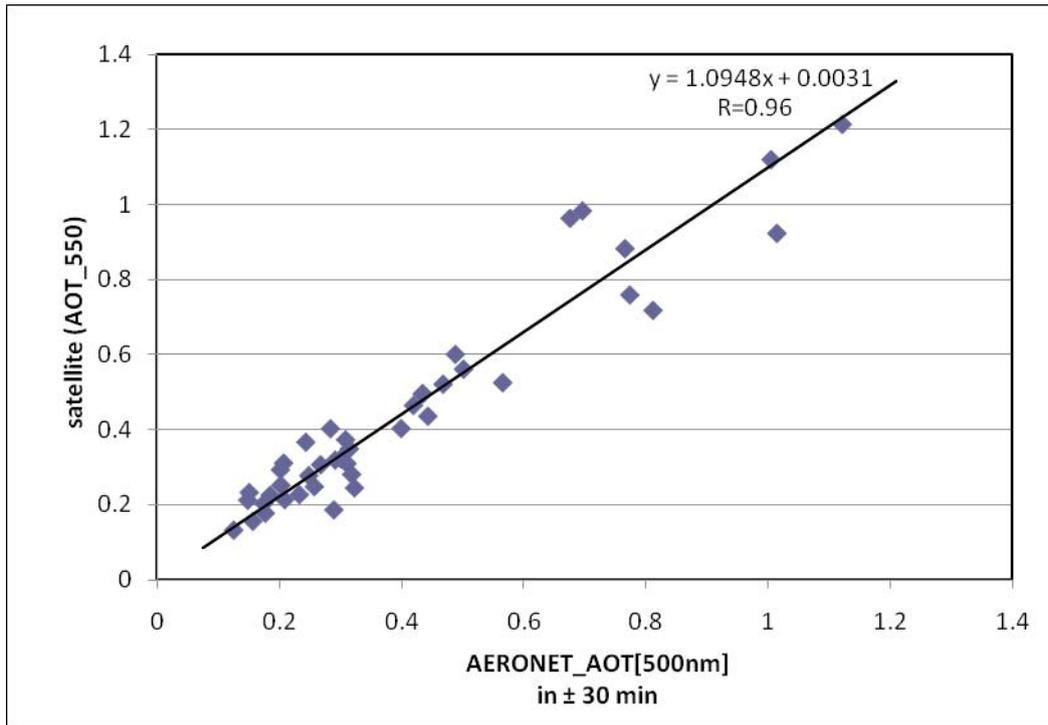


Figure 7: Scatter plot of the MODIS AOD based on Kim's algorithm against the AERONET data at PolyU campus.