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IMAGE-BASED ATMOSPHERE CORRECTION USING DARK PIXEL SUBTRACTION TECHNIQUE IN PENANG ISLAND, MALAYSIA

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ABSTRACT

Lack of study has found in emphasizing the appropriate chosen of atmospheric models with specific atmospheric condition. This study is attempting to answer whether selection of atmospheric models is based on regional atmospheric condition or geographic location. The proposed method is a combination of the radiative transfer equation and dark target subtraction technique. Two important atmospheric parameters in the radiative transfer equation which are visibility and aerosol loading are estimated from the image itself to be as an input in atmospheric modelling. ATCOR-2 was used to perform different atmospheric models (maritime and urban) which can represent regional climatic condition in Penang Island, Malaysia. By relating the determined aerosol optical thickness with visibility values, urban model at the visible (blue band) on image 2005 showed a high correlation coefficient which is r^2 = 0.8896. It has been shown that determined the aerosol is highly correlated to the visibility range from 10 to 50 km. Study also found that optical satellite remotely sensed image data (Landsat TM blue band) can be used to determine the visibility value through the darkest pixel atmospheric correction algorithms.

Keywords: *aerosol loading; visibility; wavelength; atmospheric model*

1. INTRODUCTION

The correction of atmospheric effects is very essential because visible bands of shorter wavelengths are highly affected by atmospheric scattering especially of Rayleigh scattering. The most challenge is to obtain accurate values for those parameters and limited availability of the atmospheric correction parameters in the analyses. The atmospheric correction process is included in atmospheric models and the objective of an atmospheric correction is to eliminate the atmospheric and illumination effects to retrieve proper physical parameters of the earth's surface for example surface reflectance, emissivity, and temperature (Arnis Asmat, 2009; Richter, 2011; Wan Noni Afida et al, 2012). Atmospheric aerosol model plays an important indicator of visibility distance range because it will influence the objects that can be seen.

To describe the combined earth/atmosphere behaviour with respect to the reflected solar radiation, the values is converted into apparent reflectance (Richter, 2011; Chander et al, 2009) also known as top-of-atmosphere (TOA) reflectance. The equation is as follow;

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$$\rho \text{ (apparent)} = \frac{\pi d^2 L}{E \cos \theta_s} \quad (1)$$

Where d is the earth-sun distance in astronomical units, $L = c_0 + c_1 DN$ is the at-sensor radiance, c_0, c_1, DN, are the radiometric calibration offset, gain, and digital number. E and θ_s are the extraterrestrial solar irradiance and solar zenith angle.

2. DATA AND MATERIAL

2.1 Data Acquisition

Archived TM Landsat 5 is obtained from Malaysian Remote Sensing Agency (ARSM) for the Penang Island. Detailed description showed in Table I. The image was subsetted into the region of interest. The image was geocorrected from ARSM.

Table 1: Description of Landsat 5 TM Images for Penang Island

Images Description	Acquisition Year
	2005
Site	Penang Island
Sensor Type	Landsat 5 TM
Date	02-02-2005
Latitude/longitude	05°25'N 101°15'E
Resolution	30m
Cloud cover (%)	35.8

2.2 Study site

The study area is focusing at city area located at the eastern part of Penang Island. Penang Island also known as a second largest city in Malaysia and most populated with approximately 720,000 peoples (Tan et al, 2010). It lies between latitudes 05°25'N and longitudes 101°15'E and the island is surrounded by the sea with the area is approximately 1030 km^2 (Sirat et al, 2010). The temperature range is 22-33°C and humidity range is about 64-91 % that provided from Malaysian Meteorological Department.

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3. RESEARCH METHODOLOGY

3.1 Atmospheric Model

Atmospheric parameters were used as an input in determining the aerosol values in ATCOR-2. To begin the model, it is prerequisite to identify the location region that reflects the regional climatic condition of study site. To determine which model is appropriate to be used in atmospheric correction**,** two types of atmospheric models are tested which are urban and maritime models.

Maritime model aerosol is composed of a sea-salt component and a continental component without larger particles (dust like). Urban aerosol is also found as a mixture of the rural aerosol (80 %) with carbonaceous aerosol (20 %) (Richter, 2011). The models were selected based on the regional atmospheric condition and geographical location (Wan Noni Afida et al, 2012).

3.2 Visibility Distance

Visibility is a meteorological guessing that calculates the opacity of the atmosphere at certain time and place (Richter, 2007) and was measured the utmost distance that a person can see a prominent object. In this study, the range of visibility was set to estimate aerosol loadings from 10 to 50 km for both sites, of which is the iterative procedure by the adding value of 5 km between the range (Wan Noni Afida et al, 2012).

3.3 Dark Pixel Subtraction Technique

In order to estimate the aerosol loading, dark pixel subtraction technique is adopted (Hadjimitsis & Clayton, 2008; Hadjimitsis, 2009; Hadjimitsis & Clayton, 2009; Hadjimitsis, 2010). 30 samples of mean reflectance values of a 1x1 pixel window were derived. Identification of the minimum pixel is normally corresponds to dark water body and 30 samples were derived (Wan Noni Afida et al, 2012). Figure 1 shows the dark pixel sampling over water body.

The combination of radiative transfer equation and dark target subtraction technique was applied during sampling of aerosol loading. Once the atmospheric path radiance is computed from dark points at the wavelength range, it is possible to compute the aerosol contribution to the path radiance and then aerosol optical thickness from the radiative transfer equation (Hadjimitsis, 2009; Hadjimitsis & Clayton, 2009).

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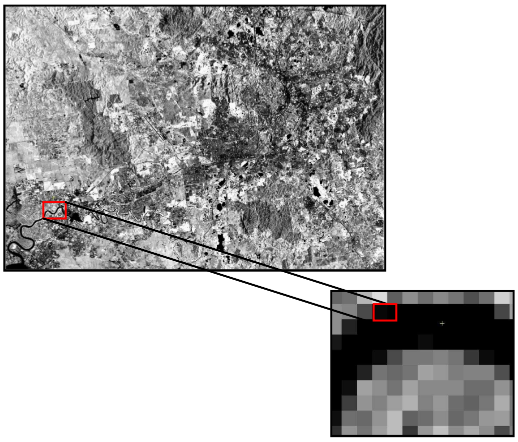

Figure 1: Dark pixel sampling over water body

4. RESULT AND ANALYSIS

Table 2 shows the estimation of urban aerosol loading in Penang Island year 2005. Overall pattern that can be shown from the result is decreasing of urban aerosol loading when the visibility was set to be higher for visible (blue) wavelength.

Table 2: Apparent reflectance of urban aerosol loading

Visibility range (km)	Apparent reflectance
10	0.319
15	0.283
20	0.263
25	0.258
30	0.254
35	0.249
40	0.246
45	0.245
50	0.244

Table 3 shows the estimation of maritime aerosol loading in Penang Island year 2005. Overall results show that the apparent reflectance of maritime aerosol loading increased when the

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visibility range goes up from 10 km to 50 km. The highest maritime aerosol loading was recorded at 50 km. The results were found opposite with aerosol estimated at urban aerosol.

Table 3: Apparent reflectance of maritime aerosol loading

Visibility range (km)	Apparent reflectance
10	0.205
15	0.218
20	0.224
25	0.229
30	0.230
35	0.233
40	0.234
45	0.236
50	0.236

Surface reflectance would improved by the aerosol scattering while aerosol absorption would decreased the visible brightness of brighter surfaces. Consequently, the capability of object that can be seen would reduced when the reflectance increase by the influence of aerosol. Figure 2 shows the correlation of urban aerosol with visibility range. By relating the determined aerosol optical thickness with visibility values, a logarithmic regression were fitted with correlation coefficient model was r^2 = 0.8896.

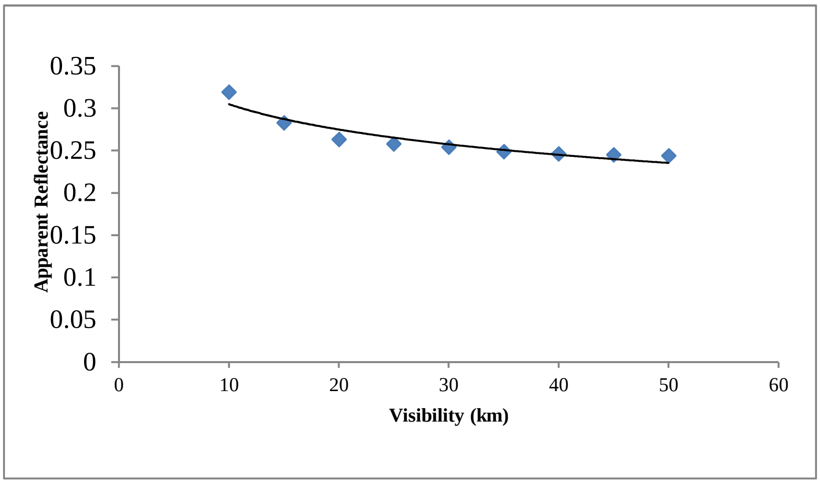

Figure 2: Urban aerosols with visibility range in Penang Island

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The results show an agreement pattern with Forster's aerosol optical thickness versus visibility and from Tanré's model. In visible band, the impact of short wavelength is mostly from Rayleigh scattering because the absorption by water vapour or other gases is very weak and thus can be ignored (Asrar, 1989; Elachi, 1987).

The maritime model was not suitable for Penang because (Richter, 2011) added that maritime aerosol type would be a reasonable option for locations that close to the sea if the wind was approaching from the ocean**.** However, maritime model does not account for fresh sea spray that exist in lower altitudes (10 – 20 meters) above the sea surface and which is strongly dependent on wind speed (Carr, 2005).

The urban model was chosen for both sites because the sources of particles such as vehicle emissions, industrial emission and domestic biomass burning were contributed to increase of aerosol in atmosphere (Keywood et al, 2003). Since the urban atmospheric model was chosen, the possible component that is dominant in the aerosol was sulfate aerosols resulting from combustion and built-up activities (Richter, 2007).

5. CONCLUSIONS

Results presented in this study have demonstrated that determination of suitable atmospheric model outlined for different types of urban is based on the regional climate condition.

The proposed method which is combinations of the radiative transfer equation and dark target subtraction technique shows how to determine the atmospheric parameters at certain area of interest from the image itself. The method is based on the use of the darkest pixel atmospheric correction theory for selecting the suitable ground reflectance value for the selected dark object (Wan Noni Afida et al, 2012).

Generally, the results proposed technique demonstrate the potential of earth observation to support the determination of aerosol loading in different geographical areas in which dark inland water bodies are located such areas in the city such as Kuala Lumpur and Penang Island area.

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