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Aerosol Properties in Central Kalimantan Due to Peatland Fire

Sheila Dewi Ayu Kusumaningtyas*, Edvin Aldrian, Muhammad Arif Rahman, Ardhasena Sopaheluwakan

Indonesia Agency for Meteorology Climatology and Geophysics (BMKG), Jakarta 15138, Indonesia

ABSTRACT

The optical properties of aerosol could describe the potential source of prevalent pollutants of certain area. With the annual occurrences of biomass burning over the peat swamp forest, the study of aerosol characters in Central Kalimantan province becomes important. Aerosols from Aerosol Robotic Network (AERONET) data network combine with some environmental parameters, i.e., rainfall, visibility, surface humidity and hotspot number are investigated. Here we use the data from 2012 to 2014 collected from AERONET in Palangkaraya. We found a strong relationship between aerosol properties and environmental parameters (rainfall, hotspot number, visibility). Variability of aerosol properties such as aerosol optical depth (AOD), Angstrom exponent number, and its fine mode are consistent with the dry period between August and October when most fire episodes occur. In fact, the increase of aerosol loading occurs mostly when the monthly rainfall reaches below 150 mm month^{-1} (dry period), as the cut off number of our analyses. Considerable reduction of visibility below 500 m occurs whenever AOD is above 3.0. During observation period, we found that aerosol sources at this location originate from dust, marine aerosol, continental and urban aerosol, and biomass burning. The biomass burning aerosol gave a substantially high AOD values that reach almost 6.0 and fine feature as an indication of highly concentrated smoke from peatland source. Moreover, smouldering combustion from peat land is characterized by high value of single scattering albedo observed in the location.

Keywords: Aerosol optical depth; Peatland; Smoulder haze; Kalimantan; Biomass burning.

INTRODUCTION

Aerosol is one of the significant atmospheric pollutants primarily emitted from vegetation fires (Andreae and Merlet, 2001). Aerosol negatively impacts human health (Janssen *et al.*, 2011), degrades visibility (Field *et al.*, 2009; Han *et al.*, 2012; Langridge *et al.*, 2012), and influences climate systems (Boucher, 2015). Aerosol also contributes the largest uncertainty in estimating and interpreting the Earth's changing energy budget by scattering and absorbing solar radiation (Boucher, 2015). These processes are known as aerosol direct effect. However, indirect effect refers to the increase in available cloud condensation nuclei, due to an increase in anthropogenic aerosol concentration, and thus cloud albedo – the first indirect effect (Houghton *et al.*, 2001; Lazaridis, 2011). Nowadays, more investigations on aerosol concentration and properties through ground based, satellite, aircraft etc has been conducted in order to address the impact of aerosols to radiative forcing, climate and public health, ecological impacts, the future economic and political entities (Toledano *et al.*, 2007).

One of the ground-based aerosols monitoring system that offers standardization for a ground-based regional to global scale aerosol monitoring and characterization network as well as data archive is the Aerosol Robotic Network (AERONET) (Holben *et al.*, 1998). The AERONET has established more than 250 operational sites across the world to measure the Aerosol Optical Depth (AOD/τ) which is used in local investigations to characterize aerosols, assess atmospheric pollution and make atmospheric corrections to satellite remotely sensed data (Dubovik *et al.*, 2000).

Aerosols properties vary remarkably in different regions and time (Xin *et al.*, 2007; Asmat *et al.*, 2012). This is due to inhomogeneity in aerosol sources and their short lifetime of aerosols (from hours to weeks) (Liu *et al.*, 2013; Boucher, 2015). For example, composition and the size modes of Asian aerosols differ from those in Europe, America, and Africa since they are dominated by soot and organic aerosols generated from coal for transportation and energy, biomass burning and dust storms (Lelieveld *et al.*, 2001; Streets *et al.*, 2001; Huebert *et al.*, 2003; Li, 2004; Seinfeld *et al.*, 2004; Salinas *et al.*, 2009). Local land cover type and regional meteorology influence the atmospheric aerosol environment at a given location (Schafer *et al.*, 2008). Aerosol properties

* Corresponding author.
Tel.: 62-21 4246321 ext. 1812; Fax: 62-21 65866236
E-mail address: sheila.dewi@bmkg.go.id

resulting from biomass burning in South America and Africa might be different from Asia which mostly originated from peatland (Gras *et al.*, 1999; Matsueda and Inoue, 1999; Sawa *et al.*, 1999; Fujii *et al.*, 2014), while fire in South America and Africa likely occurred in Boreal Forest and savannah (Eck *et al.*, 1998; Holben *et al.*, 2001). In addition, human activities influence the aerosol environment by releasing amount of particulate and gas species to the atmosphere through land cover change, combustion of fossil fuel for transportation and energy (Artaxo *et al.*, 1994; Holben *et al.*, 2001).

Vegetation fires became a serious problem in Southeast Asia in recent decades. Indonesia is prone to the impact of global and regional climate perturbation that might enhance air and surface dryness condition. During the extreme El Nino episode, the regional climate will be affected by low moisture and extremely dry (Aldrian *et al.*, 2003) further enhancing the prospects of regional forest fire (Heil *et al.*, 2007). Although regional fires are for certain human induced, there is a clear inter-relationship between prevailing seasonal weather conditions and forest fires.

In Indonesia, fires from peatlands and deforestation are the most common compared to any other countries in Asia (Hayasaka *et al.*, 2014). Central Kalimantan, Indonesia, in particular, has undergone dramatic ecological and social changes over the past decades. According to Wetlands (2004) report, 3,010,640 hectare or 52.18% from the total area of Central Kalimantan is peat lands. However, millions of hectares of forest are quickly and rampantly logging. The peat swamps are drained and converted for agricultural use. This drained peat lands are at greater risk of fire and such a risk would be amplified when severe dryness sets in (Heil and Goldammer, 2001; Someshwar *et al.*, 2010). According to our calculation, on average the Central Kalimantan province itself accounts for 40% of whole hotspot number from Kalimantan according to hotspot data 1997–2009. Numbers of hotspots indicate the high possibility of fire occurrences, however the real impact of fire will be the aerosol content as indicated by the AOD number. The measurement of aerosol particle concentration through Sun-photometer provides information of the on-going air quality reduction due to the forest fire. The in situ observation of aerosol is costly when compared to the wide coverage that remote satellites can provide. However, our the study area is a humid tropical area with high cloud coverage and hence it possess a heavy hindrance to remote satellite observability (Reid *et al.*, 2013) Ground-based measurements via Sun-photometer or sky radiometers on the other hand, offer a more reliable way to perform remote measurements of aerosol concentrations such as those from biomass burning but this kind of measurement lack the wide coverage that satellites can provide.

This present study aims to characterize the aerosol physical and optical properties in Central Kalimantan by utilizing the AERONET data from 2012 to 2014. The AOD, Angstrom Exponent (AE/α), and other derived inversion products of AERONET together with the meteorological data (total rainfall, visibility, humidity, and hotspot from MODIS satellite) have been assessed to understand the aerosol environment during the measurement.

METHODS

Palangkaraya is the capital city of Central Kalimantan province. The province is near equatorial line and considered as lowland area (27 m altitude). The city has flat and small hill areas. By size, it is a middle size city (220,962 inhabitants at the 2010 Census) surrounded mostly by forests, including protected forests, nature conservation areas and lowland peat swamp forest ecosystems. Palangkaraya has an equatorial climate type that is humid (average of 83.21%) and receive quite a substantial amount of annual rainfall (average of 2.868 mm) with annual rainfall pattern of two peaks and troughs that marked the wet and dry seasons. According to the definition of local meteorological office, the dry season occurs between July and October where average rainfall reaches below 150 mm month^{-1}. The cut off number are defined by the Indonesian Meteorological office as the indicator of the dry monsoon onset.

The Palangkaraya AERONET site as shown in Fig. 1 is one of the in-situ aerosol observation sites in Indonesia which started in 19 July 2012.This station is part of the ground-based AERONET (Holben *et al.*, 1998). The photometer is installed on the roof of the Tjilik Riwut Meteorology Station at Tjilik Riwut Airport Palangkaraya, Central Kalimantan - Indonesia at latitude 2.23° and longitude 113.94°. Direct Sun measurements are collected daily with a CIMEL Electronique CE-318A automatic Suntracking photometer.

AOD or τ_a is the main product of these measurements, while other associated optical and physical parameters such as the AE or α (Angstrom, 1929) and its derivative as well as its fine and coarse mode counterparts can be subsequently retrieved from these measurements. The inversion algorithm is used to retrieve aerosol volume size distribution in the range of 0.05 to 15 µm together with information for refractive index, single scattering albedo and asymmetry factor. The AERONET data are available in three categories: cloud-contaminated (level 1.0), cloud-screened (level 1.5), and cloud-screened and quality assured (level 2.0) following the methodology of Smirnov *et al.* (2000). For Palangkaraya site, from level 1.5 to level 2.0 there is a substantial reduction of the amount of data by about 50% approximately. In this study we only use data level 2.0 to ensure the data quality. However, poorer quality data may be mixed in with the mostly reasonable quality AOD.

Based on the optimal method for PW retrievals from sun photometry observations by Schmid *et al.* (2001) and the relatively large uncertainty in the modified Langley V_o, Holben *et al.* (2001) estimated the uncertainty as approximately ±10%. The estimate is further supported by informal comparisons, according to Holben *et al.* (2001), to retrievals of PW from raman lidar, microwave radiometer, other sun photometer methods and radiosondes.

Analyses of this paper utilize aerosol parameters from AERONET observation and the selected environmental parameters from weather data in the same place as the AERONET instrument. Environmental parameters include rainfall, hotspot number, visibility and humidity data. The

Fig 1. The sun photometer installed on the roof of the Tjilik Riwut Meteorology Station at Tjilik Riwut Airport Palangkaraya, Central Kalimantan – Indonesia.

hotspot numbers are derived from MODIS satellite observation that represents the total number of the province.

RESULTS AND DISCUSSION

Palangkaraya has the equatorial semi monsoonal type of climate (Aldrian and Susanto, 2003). Annual rainfall ranges between 1892 and 4508 mm (Fig. 2). During the dry season, the prevailing south-easterly to southly winds carried in smoke from the fires in south of Palangkaraya, where peatlands are located. The dry season is usually marked with recurring biomass burning for mainly land clearing activities. As a result, smoke particulate will be prominent and will be the major supply of aerosol loading. The amount of biomass smoke highly depend on daily rainfall occurrence since only natural rainfall could actually clear the air from smoke haze.

Following the annual rainfall pattern, high aerosol loading occurs during the dry period, when most forest fires occur. There is a strong relationship between rainfall variability and the hotspot number along with the aerosol depth. The increase of aerosol loading occurs mostly when the monthly rainfall reaches below 150 mm month^{-1}. According to the rainfall variability data, thus only 2012 and 2014 meet that cut off number with a high peak of aerosol loading following the hotspot number increase. The AOD at wavelength 500 nm or τ_{500} are presented in Fig. 3(a) along with the rainfall variability and hotspot number in the province. From that figure actually there are three peaks of fire occurrence in the August to October in every year. However there is one major peak recorded in 2012 and another in 2014, both would be the central focus of this study. Those two episodes are the worst ones during the entire AERONET observation. There are, however, some delays in the relationship between lowest rainfall period and the peak of highest hotspot at sub monthly time scale. According the Global Fire Emissions Database or GFED (Giglio *et al.*, 2013), there were two major fire episodes in Indonesia in 1997 and 2006. In the central Kalimantan province there were 32952 hotspots recorded in 1997 and 30866 in 2006. Those numbers are more than 15 times of the average from other years. For comparison, total hotspots in 2012, 2013 and 2014 were 1493, 913 and 4163, respectively. Those hotspots mainly occurred between August and October with a peak in September.

Figs. 3(b) and 3(c) shows the relationship of AOD and local visibility and number of hotspot in the province during the burning episodes in 2012 and 2014. The visibility is inversely correlated with both hotspot number and AOD or aerosol loading. Visibility was reduced due to scattering and absorption of solar radiation by particles and gaseous pollutants (Han *et al.*, 2012). In this case, aerosol particles play an important role on atmospheric radiation transmission. The higher the aerosol loading was, the stronger the impact on atmospheric transitivity, due to scattering and absorption of incoming direct and diffuse solar radiation, would be (Jacobson, 2004; Seinfeld and Pandis, 2006; Solomon *et al.*, 2007). The required visibility for the airport operation is above 2 km. High aerosol loadings during burning episodes resulted in several days of low visibility which lead to airport closure hence affecting the local transport industry. Moreover, in 2014, there are other days with low visibility that might be caused by other local sources of haze at nearby locations. High aerosol loading during burning episodes resulted in the closure of the airport and gave additional impact to the transportation industry. In 2014, there are days with low visibility that may be caused by other local source of haze in nearby locations. From that figure, whenever the AOD above 3.0 then there is a considerable reduction of visibility below 500 m. Beside the transportation industry, there may be other environmental problem such as health issue (e.g., Vadrevu, *et al.*, 2014) and other economic losses due to lower visibility caused by aerosol loading during burning season. As already described previously, in 2012 there was high AOD near 6 in the peak of burning season.

There is a significant and strong correlation between the surface humidity and the total column precipitable water

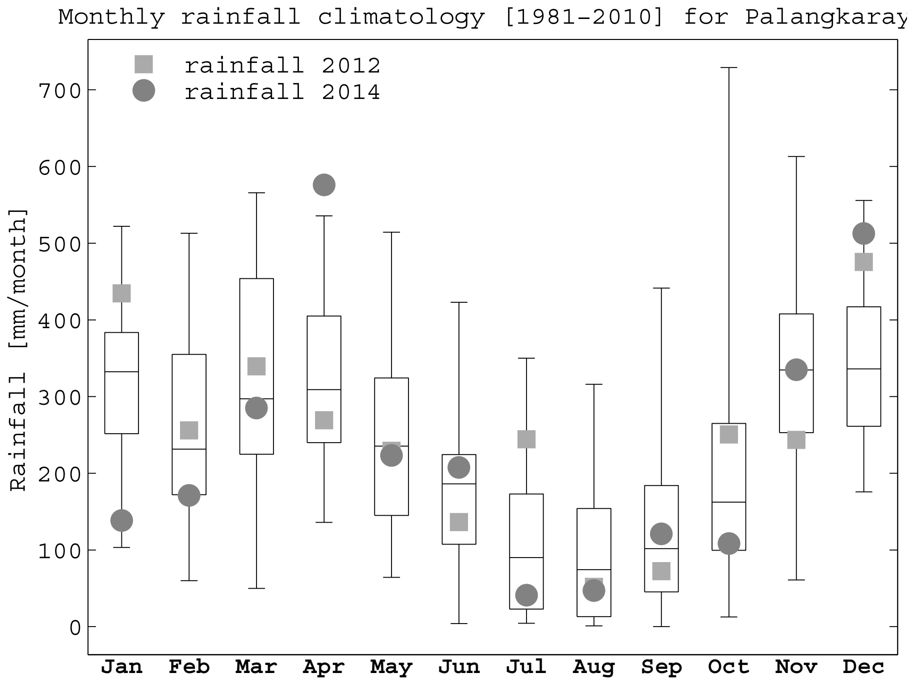

Fig. 2. Cumulative monthly rainfall climatology at the site between 1981–2010 and monthly rainfall variability in 2012 and 2014.

content (PW) as shown in Fig. 4(a) with R^2 value 0.343 (n = 715, p < 0.0001). The correlation holds well except for a certain period between March and June 2014 and November and December 2014. The scatter plot indicates an even stronger evidences with few outliers. Most of those months are within the wet period or peak of the equatorial type of climate. At normal atmospheric conditions, most of the water content lies at the surface due to. Thus the surface ground level humidity shall correlate well with PW. In similar fashion the mid atmosphere may have more PW than at the surface when there is squall line or front. Days with high precipitable water are likely to have a northwesterly flow component, therefore suggesting the monsoonal wet flow of mid layer air. Daily average PW exhibits large daily variability and some seasonality with higher values in two annual peaks of rainfall variability and fall during the dry period of August to October. The range of PW values from less than 2.79 cm to almost 5.6 cm, which indicates a typical humid tropical climate. Correspondingly, the surface humidity values range from 66 to 96%. Interestingly, PW is also highly correlated with the AOD (R^2 = 0.295, n = 438, p < 0.0001), while rainfall and hotspot number (R^2 = 0.295, p < 0.0001). The relationship between daily averages of PW and AOD at 500 nm or τ_{a500} (Table 1) shows strong correlation. Significant correlations with AOD and rainfall are consistent with the intra-annual variability of aerosol optical properties, synoptic air masses and associated amount of precipitable water. Large number of hotspot corresponds with dry condition as indicated with low RH and PW. According to Holben *et al.* (2001) not every site exhibits strong relationship between PW and AOD. For example strong relationships are established in US Atlantic coast (Smirnov *et al.*, 2000), Thompson Canada, Cuiba Brazil and Mongu Zambia during primary burning season (Holben *et al.*, 2001).

Fig. 4(b) shows the variability of AOD with the AE during observation period in Palangkaraya. The AE is derived from the first derivative (negative slope) of AOD at wavelength between 440 and 870 nm. The observed AOD levels are moderate considering that Palangkaraya's aerosol environment in the middle of an island with many burning activities throughout the year with slightly higher values during the dry season (Aug–Oct) during the peak of dry season. The daily average's AOD mean is of the order of ≈0.39 with a median of ≈0.20 which indicates high levels of aerosol loading. Those numbers indicate the AOD distribution as a typical lognormal behavior with a clear differentiation between the mean and the median. There were only few fire episodes during the three years of observation. The AE varies mostly between 1 and 2 while the AOD varies mostly below 0.5. High AE values near 2.0 correspond to fine mode aerosols and low values near zero indicate the dominance of coarse mode aerosols. The daily average's AE is of the order of ≈1.26 with a median of ≈1.34, which indicates a fine mode particle regime. Those statistical values are quite similar, which would indicate a non-normal AE distribution, which illustrates an obvious dominance of the fine mode regime over the coarse mode part for the entire observation period with most α > 1.0. During the burning season in 2014 (Aug–Oct) there is an increase of AE values in the peak of burning season and return to lower after passing the peak of burning season. The higher AE values are, the finer the aerosol size. The maximum AOD values reach up to near 6 in 2012 as an indication of a high concentration of smoke near the AERONET site. Since the data series are derived from

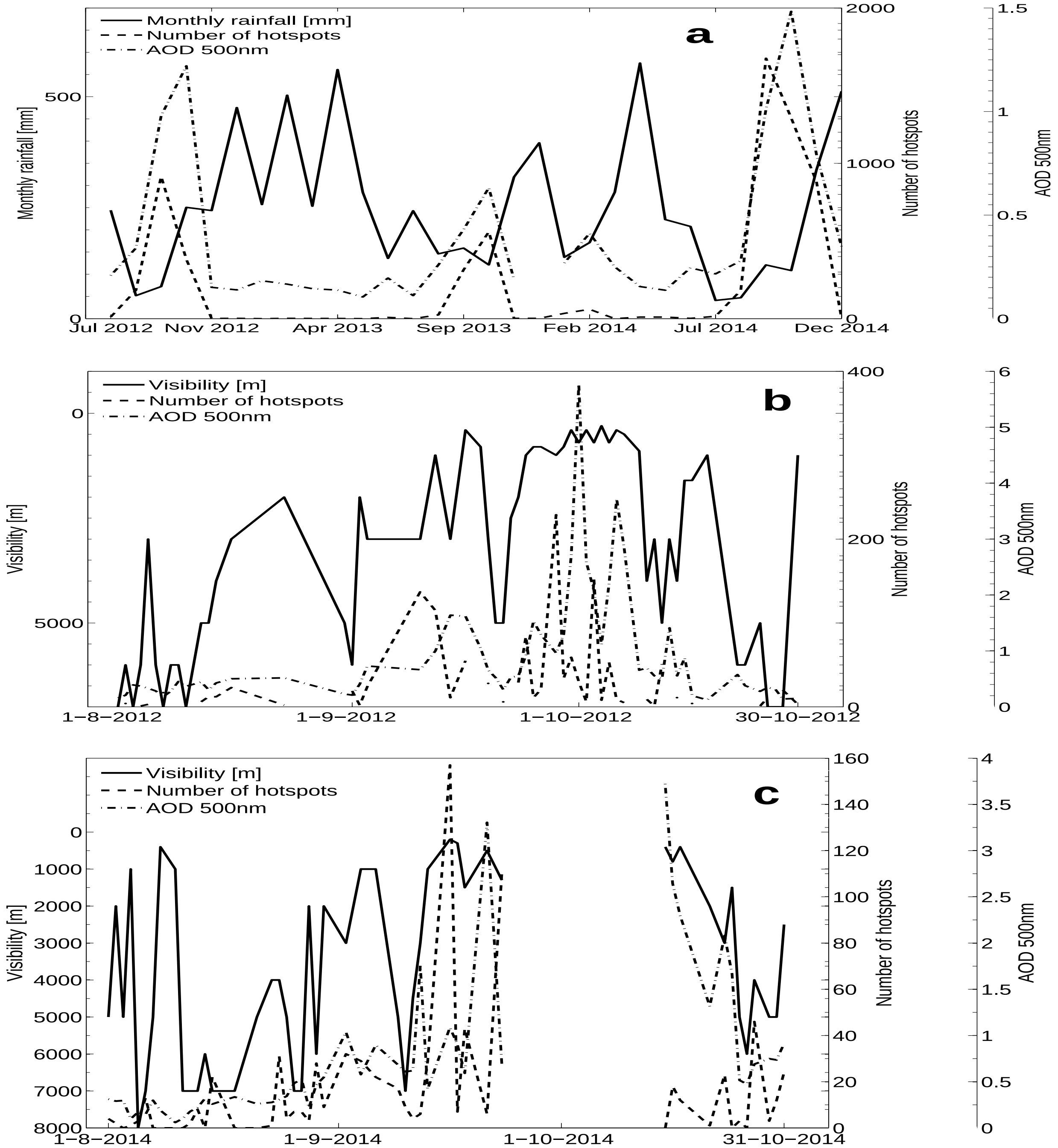

Fig. 3. Monthly AOD, hotspot and rainfall relationship. AOD at wavelength 500 nm (a) and Visibility versus AOD and hotspot in 2012 (b) and 2014 fire episodes (c), notice gap of data during peak of fire in 2014.

AERONET data level 2.0, which are already cloud screen and quality checked, the number is quite trustworthy. With such a high value of AOD, the only possible fuel source might be from peatlands which are known to release considerable amount of smoke up to 8 to 9 times higher than from non peatland source (Heil *et al.*, 2007).

The last feature is the fraction of fine and coarse particle as shown in Fig. 4(c). From a bimodal distribution, O'Neill *et al.* (2001a, b) were able to extract the fine (τ_f) and coarse (τ_c) mode AOD from the spectral shape of the total AOD ($\tau_a = \tau_f + \tau_c$). Their scheme, known as the spectral deconvolution algorithm (SDA), depends essentially on the fact that the coarse mode spectral variation is approximately neutral (O'Neill *et al.*, 2003). The coarse mode distribution often appears bimodal while the fine mode is typically a single and fairly symmetrical mode (Dubovik and King, 2000). Once the fine mode fraction (FMF) ($\eta = \tau f/\tau a$) is known, then fine mode equivalent of AOD and AE can be readily extracted. As shown in Fig. 4(d), the dominant of fine mode aerosol (FMF > 0.5) are present during the entire observation period as indicator of urban aerosols or biomass burning aerosols, which could be attributed to local

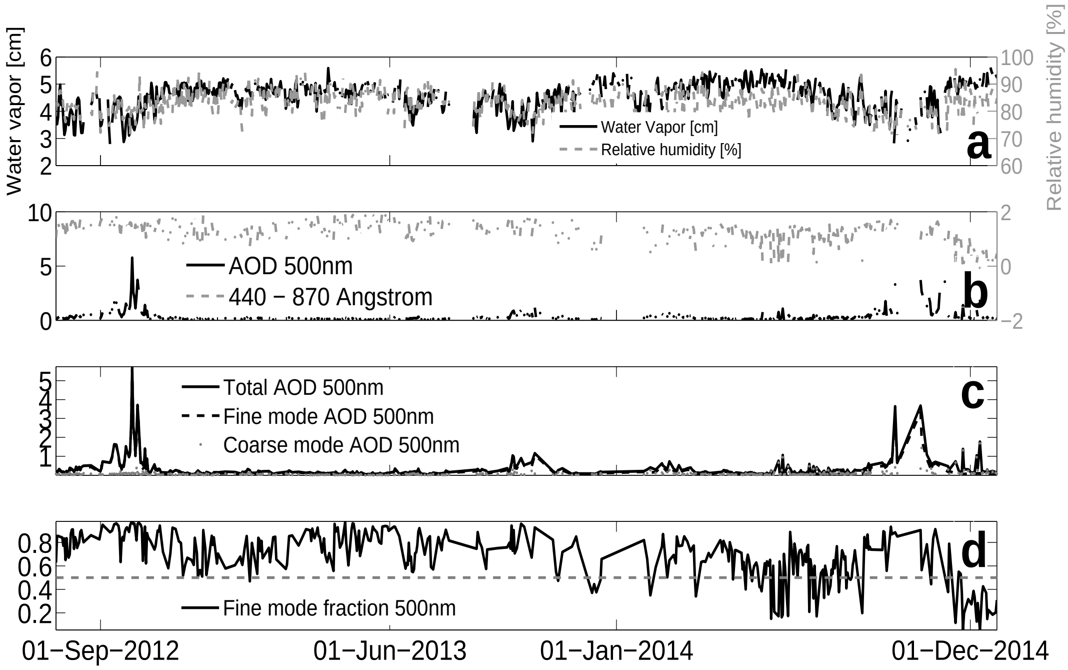

Fig. 4. Relationship between surface humidity (RH) and the total column water vapor content (a), Variability of AOD at 500 nm versus AE calculated using wavelength 440 and 870 nm (b) and Fine and coarse mode time series (c, d). Please use (d) to see detail view of fine mode fraction in (c).

Table 1. Correlation values among aerosol and environmental parameters (top right values are correlations, while the bottom left values are data sizes).

Correlation size	Rainfall	AOD	AE	Visibility	Hotspot	PW	surface RH
Rainfall		0.101	0.138	0.184	0.121	0.471	0.331
AOD	30		0.00031	0.236	0.745	0.051	0.037
AE	30	438		0.035	0.034	0.16	0.029
visibility	30	438	438		0.609	0.029	0.565
Hotpot	30	30	30	30		0.295	0.649
PW	30	519	519	715	30		0.342
surface RH	30	519	519	30	30	715	

sources, most probably from fossil fuel burnings (vehicle and aircraft activity at the site or airport business) and other nearby urban source. There is dominant fraction of coarse mode, when FMF < 0.5, during 2014 episode from non urban and non biomass burning sources. Another feature of FMF is the variability, which is quite wide especially in 2014 with many low FMF values, which are rarely found in 2012 or 2013. There is intermittent flow of smoke over the region from biomass burning. Interestingly there is an episode of large aerosol particle flow during November and December 2014 or during the burning episode.

In order to understand the source of aerosol, the combination of both information from AOD and AE could be used to distinguished aerosol type using a scatter plot. Fig. 5, shows large portion of particles between the $0 < \tau_{a500} < 1.0$ and $\alpha > 1.5$ or a clear fine mode regime. The α is commonly used as an indicator of the predominant aerosol size and eventually the source, because the spectral shape of the extinction is related to the particle size (Eck *et al.*, 1999; Cachorro *et al.*, 2000b; Schuster *et al.*, 2006). The second largest concentration of particles can be found between AOD levels of the order of $1.0 < \tau_{a500} < 4.0$ with associated $\alpha > 1.0$. Furthermore, there is one data that reach τ_{a500} near 6.0 which indicates a very high concentration of peat aerosol loading. The range of variability observed on the coarse mode AOD ($0.1 < \tau_c < 0.4$) and the relative low AE ($\alpha < 0.3$) all suggest the presence of cirrus cloud contamination within the particle size distribution. Since we are using cloud screen data level 2.0 there are only few of this type of data. From the scatter plot, it can be seen that aerosol in Palangkaraya consist of mixed aerosol (dust, marine, urban and biomass burning).

The presence of coarse mode particles such as dust is characterized by particles with largest value of AOD with small values of AE (Holben *et al.*, 2001). In this site, dust was found in the region of $0.4 < \tau_{a500} < 1$ with the relative low AE ($\alpha < 0.5$). According to Smirnov *et al.* (1998), dust events are characterized by atmospheres turbidity, with a very similar AOD for all wavelengths, giving as a result a low α. The AOD value below 0.2 with $0.5 < \alpha < 2$ indicate

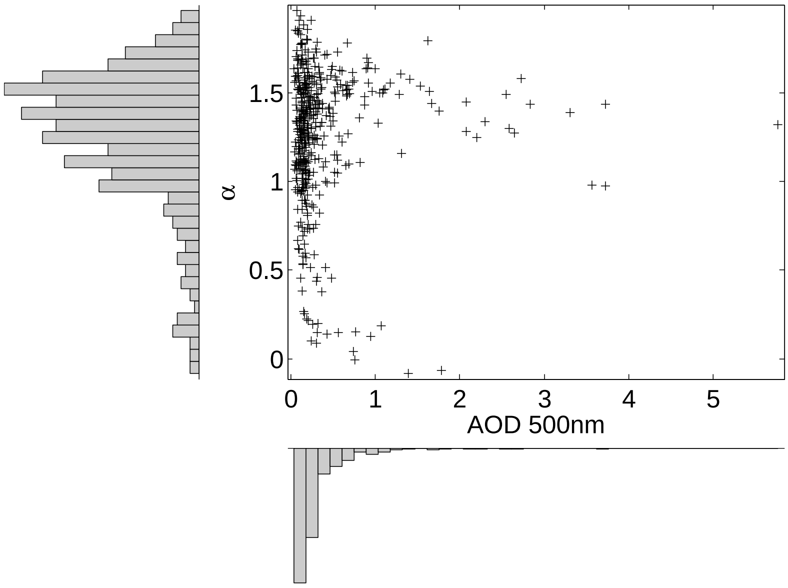

Fig. 5. Scatter plot of AOD versus AE for the period 2012–2014 along with each histogram.

the presence of marine aerosol (Salinas *et al.*, 2009). Coastal sites should have marine aerosol with α < 1 (Smirnov *et al.*, 2002). The pure marine aerosols should be located in the region with AOD (440 nm) below 0.15 and α < 0.6 in the AOD–α scatter plot (Toledano *et al.*, 2007). We use in our study, however, the 500 nm AOD. The presence of marine aerosol in Palangkaraya is caused by its location near the coastal area (about 136 km away) that still receives sea breeze from the sea southward. There is a period with α > 1 and 0.2 < AOD < 0.6 as an indication of continental and urban aerosols. According to Asmat *et al.* (2012) the continental and urban aerosols mainly consist of fine particles where the AOD is very variable and present high α. Asmat *et al.* (2012) and Salinas *et al.* (2009) found that continental and urban aerosols has the AOD value between 0.2 and 0.4 in nearby location in Kuching and Singapore respectively. Another type of aerosol found was biomass burning aerosol with values of AOD > 1 and α > 1.

For size distributions analysis, Figs. 6(a) and 6(b) shows retrievals obtained from a total of 58 and 49 photometric observations from 2012 and 2014, respectively. The AOD distribution shows a typical lognormal behavior with a clear differentiation between the mean and the median. Skewness and kurtosis are both small but positive indicating a slightly peaked distribution with a long tail which appears as a consequence of a typical large AOD. Skewness for 2012 and 2014 are 2.685 and 2.088, respectively, while their kurtosis for 2012 and 2014 are 11.6293 and 6.966, respectively. From those parameters, signatures of both burning seasons are quite similar. However, the peak of burning season in 2014 is missing. In comparison with the size distribution of all observation period, there are large differences in lower end of AOD to these burning seasons. There is a shift toward higher concentration of aerosol during the burning season.

Furthermore, we also assess the inversion product such as the single scattering albedo (SSA). The SSA is an important parameter specifying the impact of aerosols on radiative forcing. This properties could determine the amount of solar radiation backscattered to space (cooling effect) and how much of it is absorbed by the aerosol layer (heating effect) (Salinas *et al.*, 2013). Here, we use the level 2.0 SSA retrieval at 440 nm. During observation period, there were only 20 retrievals. Histogram of SSA is presented in Fig. 6(c). The average value and standard deviation were 0.94 and 0.051 respectively. Similar high SSA value was found by Salinas *et al.* (2013) who studied the SSA in Kuching during burning season in 2010, which was 0.93 in 440 nm. Schafer *et al.* (2008) also found that region affected by biomass burning of tropical forest vegetation like in Southern forest of Amazon has the average value of SSA 0.92 in 550 nm. They argued that such a high average SSA indicates the underground smoldering. The magnitude of SSA are influenced by aerosol aging, differences on combustion type (surface flaming or underground smoldering) and fuel source moisture content (Salinas *et al.*, 2013; Schafer *et al.*, 2008). Most of the Palangkaraya's land is covered by peat, which will smolder underground when burning and resulting in higher SSA. Nonetheless, from Fig. 6(c), there was event with lower SSA value which is 0.74. Low SSA might indicated the presence of freshly emitted smoke which is typically highly absorbing with substantial spectral variability. Particles like biomass burning aerosol which contain soot/ash are highly absorptive thus decrease the SSA. Analyses during observation period identified that there is no such statistically significant seasonal trend of SSA.

The aerosol size distribution during the burning seasons was a bimodal type of distribution (Fig. 7). These distributions were derived from the algorithm by Dubovik *et al.* (2000), which utilized measurements of spectral τ_a and almucantar sky radiance distributions from a CIMELS Sun-sky radiometer (Eck *et al.*, 2001). Here the peak of the season in September to October is displayed together with the aerosol size distribution during the pre-burning season in

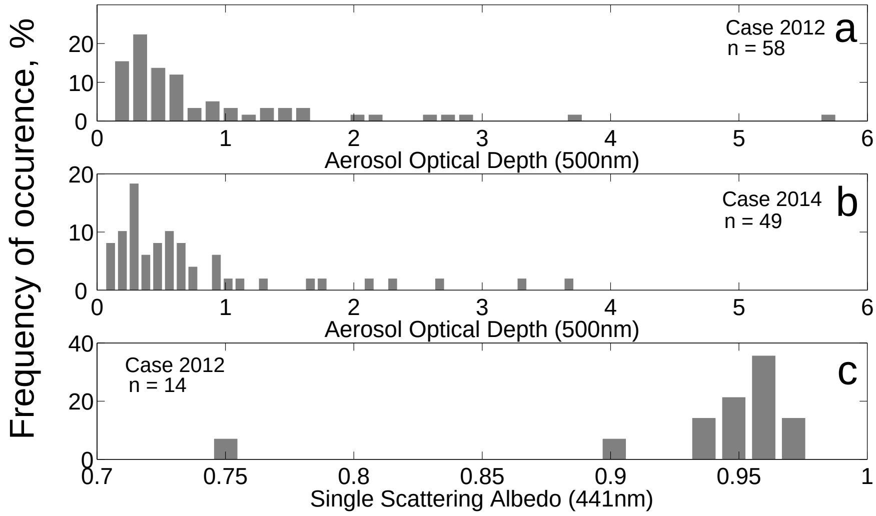

Fig. 6. Histogram of AOD during fire episode 2012 and 2014 (a, b) and Histogram of SSA (c), with each respective bin length 0.143, 0.91 and 0.01. Skewness for 2012 (a) and 2014 (b) are 2.685 and 2.088, while their kurtosis are 11.6293 and 6.966, respectively.

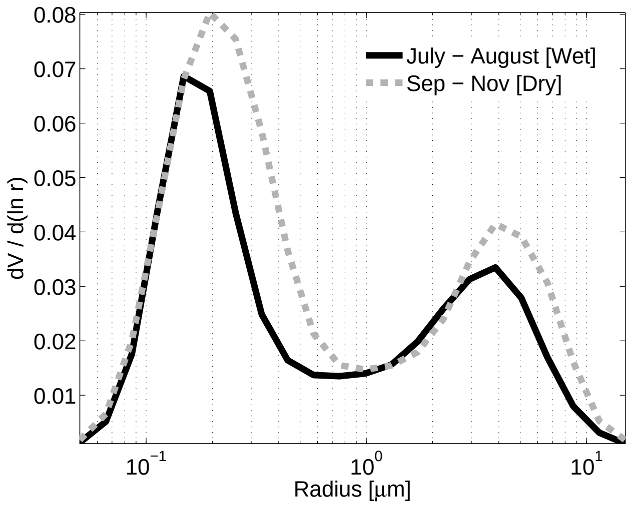

Fig. 7. Aerosol size distribution during fire episode and wet period.

July to August. The aerosol size distribution of fine particle for Palangkaraya shows a large increase in September and November 2012 due to region wide burning. The size distribution typology changes slightly between two periods. The lower size gets lower, while the higher size gets higher from the pre-burning into the burning season. Another feature is the increase of lower size aerosol during the peak season due to smoke aerosol from biomass burning. During the pre-burning season there are already smoldering smokes from nearby area as indicated with populated size distribution at the lower size aerosol.

CONCLUSIONS

The Palangkaraya AERONET site is the first of three AERONET sites established in Indonesia at the central of Kalimantan province and the almost 3-year data series presented here allows for the first time a study of the AOD and α. This study presents the characteristics of local aerosols detected from a land based measurement as part of the AERONET network. The observation of this AERONET site is interesting for some reasons. The peat swamp areas and the marine aerosol source south of the site somehow contribute to the aerosol characteristics as observed by the instrument. High AOD values in Palangkaraya occur during the dry period, when most forest fires occur. Hotspots as the main indicator of fires mainly appear between August and October. Exceptionally high AOD values up to 6.0 are attributed to the high concentration aerosol from peatland fire source with heavy smolder haze. AOD and rainfall show significant correlations which are consistent with the intra-annual variability of aerosol optical properties, synoptic air masses and associated amount of precipitable water. The inversion by product of AERONET or SSA of this site indicates a clear signature of smolder underground due to peatland burning. Meanwhile, persistent fine particle aerosols are present during the entire observation due to local activities of the airport and surroundings.

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