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IMPACT OF FOREST FIRES IN SUMATRA AND KALIMANTAN TO ATMOSPHERIC POLLUTION DURING PERIOD OF 2010-2015

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ABSTRACT

Tropical deforestation in developing countries Indonesia pollutants and GHG emissions contribute significantly. Pollutant emissions caused by forest fires comprising CO, SO_2 and dust (PM10). This paper will be analyzed estimates of pollutant emissions in both Kalimantan and Sumatra using the estimation method based on amount of material burned. Estimates of the emissions and dispersion of pollutants such as particulates, sulfur dioxide, carbon monoxide was investigated. Distribution and concentration of pollutants used time series of monthly data and spatial map based on satellite data. Extensive data obtained from the 2010-2014 forest fires data from the ministry of the environment and forestry (KLHK) and forest fire data period 2015 from LAPAN. Pollutant concentration data used AIRS on satellite data, OMI satellite and MERRA during the period 2010-2011 and in 2014-2015, adjusted to the data in situ vast wildfires that have for both regions. The results of estimation of pollutant emissions in Sumatra shows emissions from forest fires for the period of 2010 greater than in 2011, reaching 9 tons of CO per year, while emissions from fires and plantations during 2011 was higher than in 2010 with a very high value of 150 Tons / year for pollutants CO. In Kalimantan, emissions from forest fires during 2010-2011 CO emissions highest in West Kalimantan 11.13 tons / year and South Kalimantan 12.14 tons of CO per year. Emissions from fires and plantations in South Kalimantan reached 32.11 tons / year.

***Keywords**: deforestation, satellite, pollutant CO, Kalimantan, Sumatera*

INTRODUCTION

Forest fires in Sumatra and Kalimantan is a national disaster that happens every year and increase the volume of forest fires is increasing from year to year [1]. Tropical deforestation in developing countries, including Indonesia contributed to green-house gas emissions and pollutants [2,3]. Particularly carbon dioxide, the main driver of global warming [1,3]. Primary forest also caused the loss of biodiversity due to habitat destruction of tropical forests is a unique [4] The United Nations Food and Agriculture Organization (UNFAO) Forest Resources Assessment 2010 report the rate of forest loss in Indonesia became 0.31 Mega Hectare per year from 2000 to 2005 and 0, 69 Mega ha per year from 2005 to 2010 [1.5]. Indonesia's second Communication to the UN Framework Convention on Climate Change in 2009 reported a loss rate of 1.1 Mega Ha of forest per year from 2000 to 2005 [2]. Most of the burning forests and cause smog so thick in Indonesia is a type of peatland forests by land area is estimated at 20.6 million hectares, or about 10.8 percent of Indonesia's land area. Estimated at more than 0.40 Mega ha per year of forest loss from 2009 to 2011 reported by the Indonesian Ministry of Forestry [6]. The variation in the estimate points to the need for thematic consistency and data spatiotemporal improvement in bringing transparency to change the dynamic of this important area. Most of the burning forests and cause smog so thick is the type of peatland forests. Peatland area in Indonesia is estimated at 20.6 million hectares, or about 10.8 percent of Indonesia's land area. And of the total, about 7.2 million hectares (35% are on the island of Sumatra). Degradation of peatlands causes a decrease in ground water levels and leads to increased oxidation and drainage of peat which can cause fires [7]. Over the function of forests and peat in the plantation sector (palm) be the crucial issues are the main cause for the fire peat in 2015.

During the period 2000–2010, the annual world rate of forest conversion to agricultural land was approximately 13 million hectares. For the period 1990–2005, Indonesia was responsible for approximately 23% (1.9 million Ha/year) of deforestation worldwide (the highest deforestation rate in the world), and slowed to 0.68 million ha/year between 2005 and 2010 [8,9]

Papers related to forest fires in Kalimantan and Sumatra, namely Sumaryati et al, In Central Kalimantan the impact of forest fire on declining air quality due to increasing of PM10 concentration occurred in July–November 2015 with an average concentration rising of 129 µg/m3 [10]. Shuai Yin et al, the estimated results show that from 2015 to 2016 the monthly anthropogenic CO in Kalimantan and Sumatera increased 0.26 Mt. in September and 0.25 Mt in October [11]. Elania Aflahah et al, the 2015 forest fires in Kalimantan followed a monsunal nature and were influenced by El Nino events [12].

This paper will examine the estimated emissions and determine the distribution of pollutants that result from land and forest fires in Kalimantan and Sumatra. Emission estimation method used by the burned forest area, equipped with a spatial map of the area of forest fires in the two regions based on satellite data from MERA and AIRS satellites. It is hoped that this paper will contribute to the community, especially PEMDA/ the local government.

METHODS

1. Pollutant Emission Estimation

In this paper secondary data on forest fire area from the Ministry of the Environment and the National Aeronautics and Space of Indonesia (LAPAN) are used to determine the estimated emissions produced, followed by satellite data to analyze the distribution of the highest pollutant emissions from forest fires in the Sumatra and Kalimantan regions.

The method of calculating pollutant emissions (consisting of SO_2, PM10 and CO) from forest fires uses the Seiler and Crutzen (1980) equation, which is calculated based on the amount of burning material from the forest fire area data. The first step is to calculate the amount of material burned as in the formula 2.1-2.3. The method of calculating pollutant emissions consisting of SO_2, PM10, and CO from fires uses the Seiler and Crutzen equation, which is calculated based on the amount of burning material from the area of forest and land fires [13]. The first step is to count the burning material with the following formulation:

$M_C = A x\ \rho x\ \alpha\ x\ \beta\ x\ \rho_C$ 1-1

$M_N = A x\ \rho x\ \alpha\ x\ \beta x\ \rho_N$ 1-2

$M_S = A x\ \rho x\ \alpha\ x\ \beta\ x\ \rho_C$ 1-3

With:
A = Extensives forest burner (Ha)
ρ = The biomass forest (ton dry matter/ha)
α = The biomass fraction above ground to the total biomass
β = Biomass fraction is burned on the ground
ρ_C = The carbon in dry matter (ton C/ton dm)
ρ_N = Levels of nitrogen in dry matter (tonN/ton dm)
ρ_S = The level of sulphur at dry matter (ton S/ton dm)

Next step calculated pollutant emissions (SO_2, NOx, and CO) with the following equation and Crutzen, 1980) [13]

E_{CO} = M_C x EF_{CO} x 18/12 1-4

E_{NO} = M_N x EF_{NO} x 30/12 1-5

E_{N2O} = M_N x EF_{N2O} x 44/28 1-6

E_{SO2} = M_S x EF_{SO2} x 64/32 1-7

With:
E_{CO}, E_{NO}, E_{N2O}, E_{SO2} = CO, NO, N_2O, and SO_2 emission
M_C, M_N, M_S= material burned for C, N, dan S
EF_{CO}, EF_{NO}, EF_{N2O}, EF_{SO2} = emission factor for CO, NO, N_2O, SO_2

While the emission factors used are:

Table 1. The emission factors

Emission Factor CO (Ton/ton)	Emission Factor PM10 (Ton/ton)	Emission Factor SO_2 (Ton/ton)
0.0068	0.001	0.00043

Based on the factors the issue then we will gain in value for the emission of each pollutant parameter, with the formulation as follows:

E= M x EF …………… (1-8)

2. Timeseries data and spatial pollutant maps based on Satellite data

To obtain spatial maps of pollutants, satellite data is used, namely dust concentration data (PM210) Dry Deposition bin-1 downloaded from MERRA-2 satellite version v5.12.4. Carbon monoxide (CO) concentrations for both the total column and volume mixing ratio were downloaded from the AIRS version v006 satellite, and the OMI satellite version v003. SO_2 concentration data (total column) used, downloaded from OMI satellites. The selected temporal resolution is daily and spatial resolution 0.25 ° x 0.25 °.

RESULTS AND DISCUSSION

This paper focus to analyze the estimated emissions of CO, SO_2 and PM10 pollutants in the atmosphere of Sumatra and Kalimantan during the period 2010-2011 and 2014-2015. In addition to calculating the estimated pollutant emissions above, this paper will also analyze MERRA satellite model data to determine spatial maps, time series and monthly concentrations of CO, SO_2, and PM10 pollutants in both regions (Figure 3-Figure 5). The time-series data (time series) and spatial maps of the three pollutants are presented in Figure 6 - Figure 8 below. Secondary data used is the total area of burnt land in Sumatra and Kalimantan, then an estimate of emissions is carried out using the formula equation 1-8.

1. Estimation of CO, SO_2 and PM10 (dust) Emissions in Kalimantan and Sumatra

The estimation results of SO_2, CO and PM10 pollutant emissions in Sumatra and Kalimantan in 2010-2011 and 2014-2015 are presented in Figure 1 - Figure 2 below. Based on Figure 1 time-series, PM10 dust concentration is known to be the highest monthly PM10average in 2010 and 2011, which occurred in July. CO concentrations maximum in 2014 is in March and October, while in 2015 had maximum pollutant concentrations in October. Maximum SO_2 concentrations in March-April and November. Time series data show that dust concentration in 2011 had an average concentration of $1.4x10^{-5}$ kgm^{-2} higher than in 2010 of $4x10^{-6}$ kgm^{-2}. Table 2 and Table 3 Present pollutant emissions are originating from fires and land fires during the 2010-2011 period in Kalimantan.

Table 2. Pollutant emissions from forest and land fires in Kalimantan in 2010 (Tones/year)

Province	CO-forest	CO- land	SO_2- forest	SO_2- land	PM10- land
Kalimantan Barat	11.13	1.64	0.70	0.70	1.64
Kalimantan Tengah	2.04	2.04	0.13	0.13	0.30
Kalimantan Selatan	1.06	1.06	0.07	0.07	0.16

Table 3. Pollutant emissions from forest and land fires in Kalimantan in 2011 (Tones / year)

Province	CO-forest	CO-land	PM10-forest	PM10-land	SO_2-forest	SO_2- land
Central Kalimantan	1.80		0.26		0.11	
South Kalimantan	12.14	32.11	1.79	4.72	0.77	2.03
West Kalimantan		1.23		0.18		0.08

Table 4 Pollutant emissions from forest and land fires in 2010 on Sumatra island

Province	CO-forest	CO-land	PM10 -forest	PM10-land	SO_2 -forest	SO_2 -land
D.I. NAD (ACEH)	0.41		0.06		0.03	
Nort Sumatera	6.53	8.89	0.96	1.31	0.41	0.56
West Sumatera	4.57	4.69	0.67	0.69	0.29	0.30
R i a u	2.12		0.31		0.13	
J a m b i	0.20		0.03		0.01	
Lampung	8.65		1.27		0.55	
South Sumatera		0.33		0.05		0.02

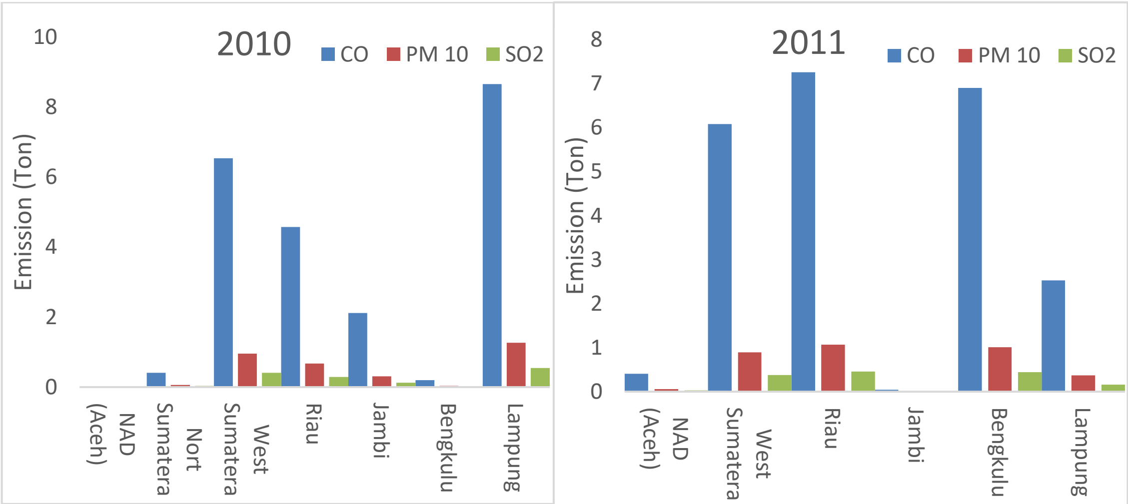
(Data source: Ministry of Environment and Forestry)

Table 5 Pollutant emissions from forest and land fires in 2011 on Sumatra island

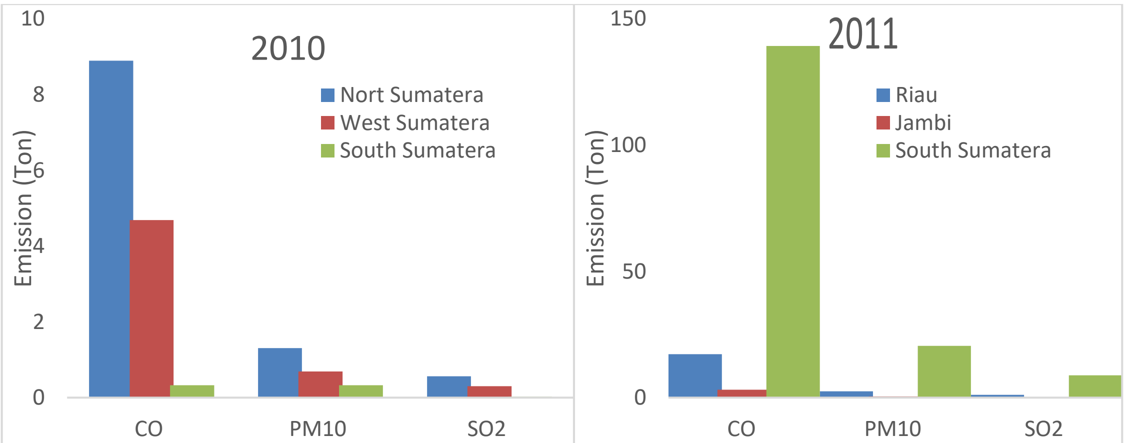
Province	CO-forest	CO-land	PM10-forest	PM10-land	SO_2-forest	SO_2-forest
Nort Sumatera	0.41		0.06		0.03	
Riau	6.08	17.22	0.89	2.53	0.38	1.09
Jambi	7.26	3.10	1.07	0.46	0.46	0.20
Bengkulu	0.04		0.01		0.00	
South Sumatera	6.90	**139.20**	1.01	20.47	0.44	8.80
Lampung	2.53		0.37		0.16	

(Data source: Ministry of Environment and Forestry).

While we can see Table 4 and 5 above present pollutant emissions originating from forest and land fires during 2010-2011 in the Sumatera area. The results of the calculation of estimated pollutant emissions in Sumatra show that the main contributor to emissions from land and forest fires is from CO pollutants, with the estimated value of emissions reaching nearly 10 tons of CO pollutants in 2010. Figure 1 below shows that CO emissions in 2011 in the South Sumatra region emitted the highest CO pollutants reaching 140 tons / year. This shows that the South Sumatra region is a land area, with a very severe fire emergency on Sumatra Island. In the other words, South Sumatra is an area prone to burning forests.



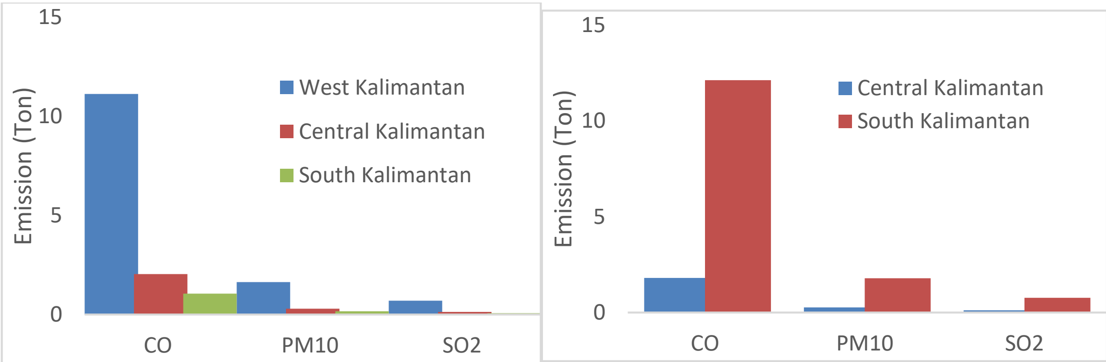
(a) Forest Fire



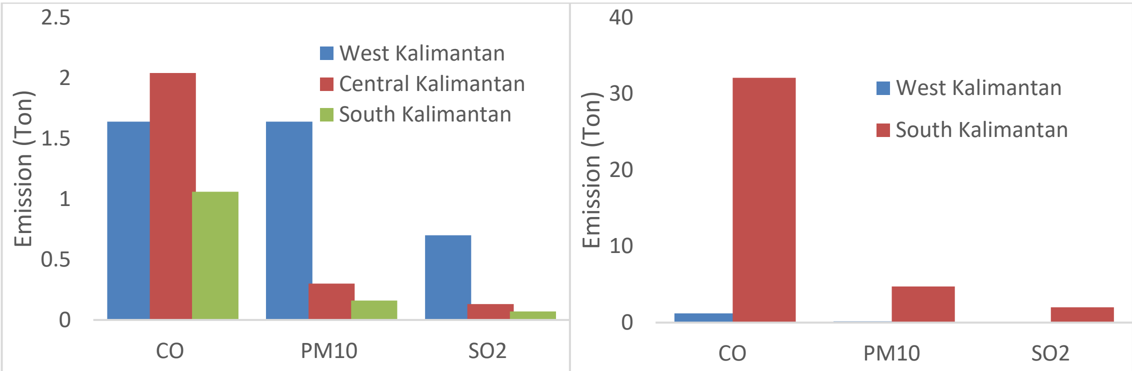
(b) Land fire (soil and plants)

Figure 1. Estimated air pollution emissions from (a) forest fires and (b) land fires during the 2010-2011 period in Sumatra

Figure 2 below shows that in Kalimantan during 2011, the estimated value of pollutants from land fires (soil and plants) was higher than from forest fires. Furthermore, to calculate emissions of forest and land fire pollutants for the period of 2015 were calculated based on data sourced from Satellite Utilization center (LAPAN).



(a) Forest fire



(b) Land Fire (soil and plants)

Figure 2. Estimated air pollution emissions from (a) forest fires and (b) land fires during the 2010-2011 period in Kalimantan

The next step is to calculate the estimated pollutant emissions from forest fires in the Kalimantan and Sumatra regions in the 2014-2015 period. The results of the calculation of pollutant emissions are presented in Table 6 below.

Table 6 Pollutant emissions from peatlands and forest fires in Kalimantan & Sumatra in 2015

Province	CO *Mineral* (Ton)	CO Peatland (Ton)	PM10 *Peatland (Ton)*	PM10 mineral *(Ton)*	SO_2 *Peatland (Ton)*	SO_2 mineral (Ton)
South Sumatera	***17797.1***	11992.5	1763.6	2617.2	758.3	1125.4
Riau	8362.8	5437.3	799.6	1229.8	343.8	528.8
Jambi	7948.2	3301.8	485.6	1168.9	208.8	502.6
Lampung	5128.3	412.7	60.7	754.2	26.1	324.3
Bangka Belitung	3806.5	196.6	28.9	559.8	12.4	240.7
West Sumatera	1152.5	574.1	84.4	169.5	36.3	72.9
Nort Sumatera	1427	81.4	12.0	209.9	5.1	90.2
Bengkulu	4522	18.4	2.7	66.9	1.2	28.8
NAD (Aceh)	281.5	70.8	10.4	41.4	4.5	17.8
Riau Islands	165.98			24.4		10.5
Central Kalimantan	***16074.1***	10924.3	2363.8	1606.5	1016.5	690.8
West Kalimantan	6108.4	7575.2	898.3	1114	386.3	479.0
South Kalimantan	1523.1	10569.6	224.0	1554	96.3	668.4
East Kalimantan	2287.6	9483.7	336.4	1394.6	144.7	599.7
Nort Kalimantan	69.4	1235.7	10.2	181.7	4.4	78.1

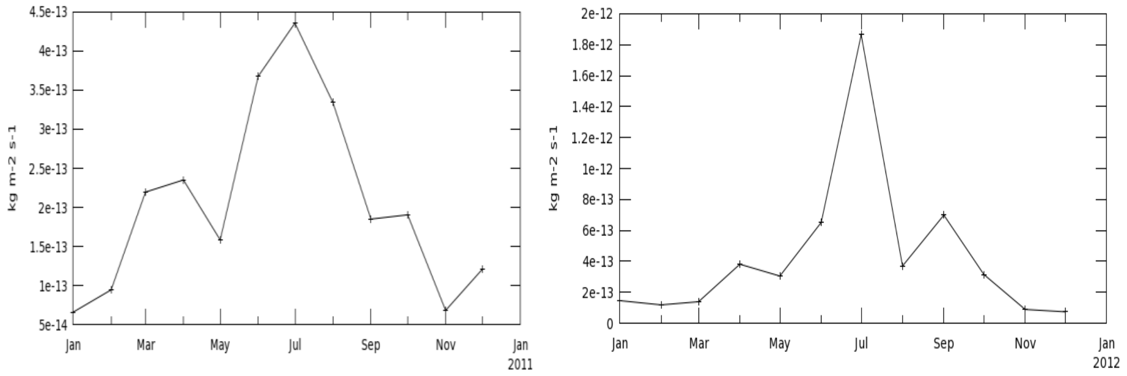
Source data: (Satellite Utilization centre LAPAN)

Based on Table 6, the results of estimated pollutant emissions in 2014-2015 in Sumatra and Kalimantan are analyzed based on 2 types of forest fires, namely peat forest areas and mineral soils. Furthermore, the two types of burnt land are calculated on the area of the burnt area, based on satellite data sourced from the Satellite Data Center LAPAN. Furthermore, the emission calculation is done using the method in equation 1. After that, the emission calculations for CO, PM10 and SO2 are carried out. Estimation result show that in 2015 CO emissions in South Sumatra showed the highest value of 17797.1 tons / year from peatlands. Another contributor to high pollutant emissions in South Sumatra is PM10. According to Rizki et al, the concentration of particulate matter (PM10) in the South Sumatra / Jambi region has increased to 400 µg / m3, thus worsening the air quality in this city. PM10 is a particulate/dust compound that is mostly produced from forest and land fires [14].

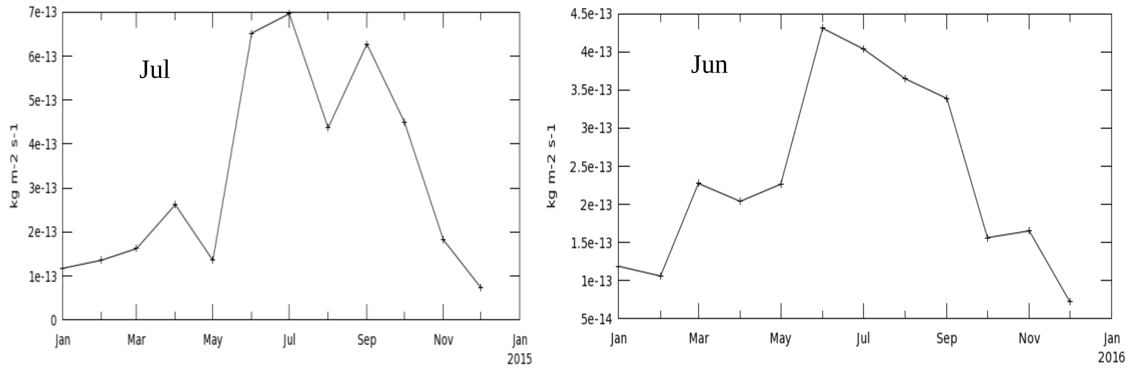
Furthermore, high CO emissions were emitted from peat fires in Central Kalimantan with a total emission of 16074.1 tons/ year. While the highest CO emissions were contributed by mineral land fires in the Central Kalimantan region, amounting to 10924.3 tons / year. As validation, the distribution of CO pollutants was analyzed in figure 6b which shows the CO concentration maps in 2014-2015. In Sumatra, CO concentrations due to forest fires in 2014 were highest in Riau with concentrations of 3.5x1018mol/cm2. From table 6: the 2015 the distribution of CO showed concentrated concentrations in the South Sumatra region reaching a value of 6x 1018mol / cm2, while in Riau there was no significant increase in CO concentrations. The forest fires that occurred in 2015 extend to the Kalimantan region. Especially in the Palangkaraya area with concentrations reaching 6x 1018 mol / cm2. Indonesian fire activity and smoke pollution in 2015 show Sumatera Fire activity (hotspot) increased in late August and by early September [15].

2. Timeseries pollutants PM10, CO and SO_2 in Kalimantan and Sumatra use satellite data

Furthermore, to observe when the air pollutants experience maximum peak concentrations (mole fraction of columns) analyzed satellite data sourced from AIRS satellites. Time series data observations were made during the period 2010-2011 and 2014-2015. Figure 3 (a) below presents the PM10 pollutant time series in the Kalimantan and Sumatra regions for the period 2010-2011, while Figure 3 (b) presents the PM10 pollutant time series in the Kalimantan and Sumatra regions during the 2014-2015 period. Time series data show that in 2010-2011 the maximum concentration of PM10 occurred in July, whereas in 2014-2015, the maximum concentration of PM10 in June and July.



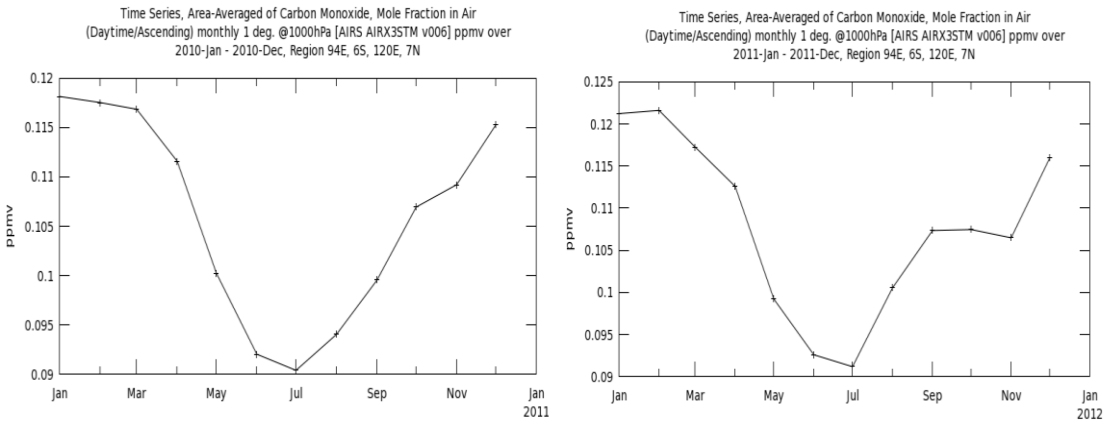
(a)



(b)

Figure 3.Timeseries PM10 from satelit MERRA thn 2010-2011 (a) and period 2014-2015 (b) in Kalimantan and Sumatera

In below, Figure 4-a shows the time series of CO pollutant concentrations in the Kalimantan and Sumatra regions during 2010-2011. Figure 4-b shows the time series of CO pollutant concentrations in the Kalimantan and Sumatra regions during 2014-2015[13].



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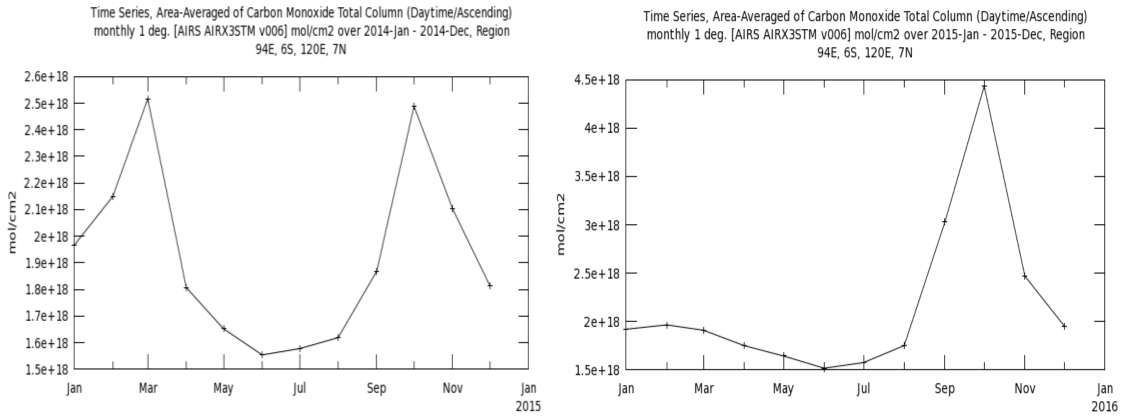
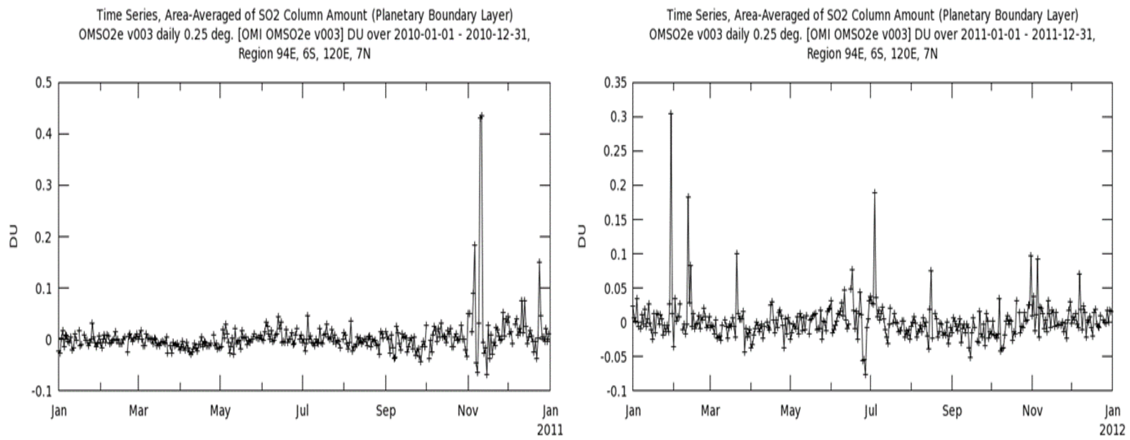


(b)

Figure 4. Timeseries mol fraction CO total column from AIRS satellite (a) period 2010-2011 and (b) period 2014-2015 in Kalimantan and Sumatra

Figure 4 shows that the total CO (carbon monoxide) mole fraction of columns from the AIRS satellite in 2010 and 2011 occurred in the same month, February, whereas in 2014, the total CO mole fraction occurred in March and October. The year 2015 showed the maximum CO mol fraction only in October. If analyzed, there was a very significant increase in CO concentrations from 2010-2011 compared to 2014-2015. CO concentrations during 2014-2015 reached 8.12x 10^{16} part per million volume (ppmv). Whereas during 2010-2011, CO concentrations were only 0.125 part per million volume (ppmv).

While the SO_2 pollutant time series in Kalimantan and Sumatra during the period 2010-2011 and 2014-2015 are presented in Figure 5 below.



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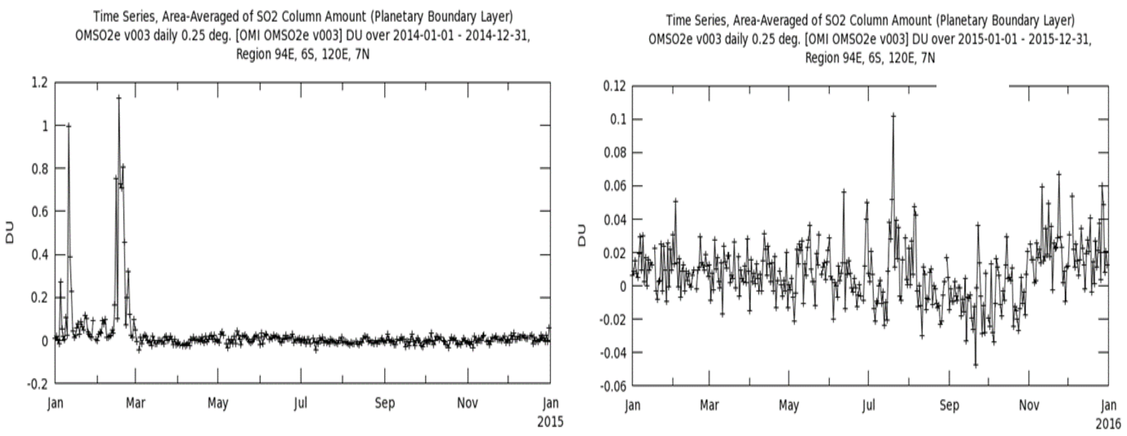


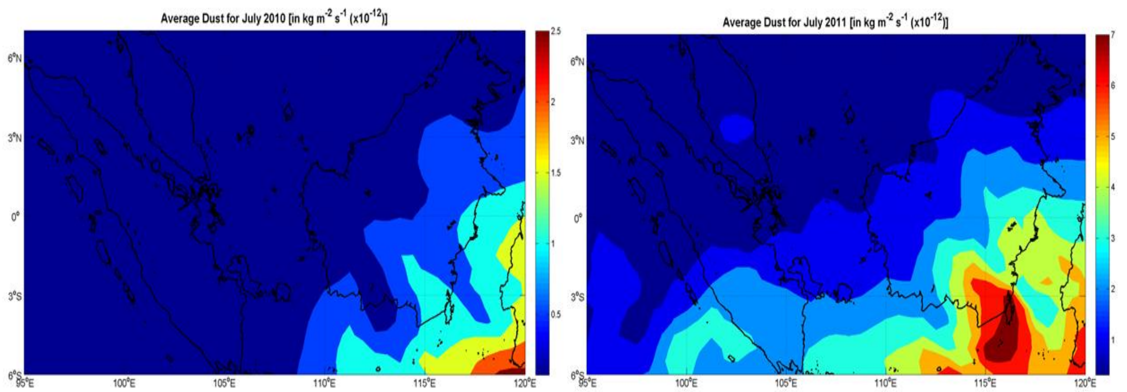
(b)

Figure 5. Time series SO2 concentrations during (a) in 2010-2011 and (b) in 2014 and 2015 in Kalimantan and Sumatra

Figure 5 shows that the total SO_2 mole time series of the 2010 period occurred in November 2011. The maximum SO_2 mole time series was in February, whereas in 2014, the total CO mole fraction occurred in March, and the maximum CO mole fraction occurred in August in 2015.

3. Spatial maps of pollutants CO, SO_2 and PM10 in Kalimantan and Sumatra use satellite data

To analyze the distribution map of three pollutants (CO, SO_2 and PM10), MERRA satellite data is used, which are presented in Figures 4-6. Figure 4 shows the distribution of PM10 dust during 2010-2011 and 2014-2015. Based on satellite data in the form of a spatial map of dust concentration (PM10), it is known that the highest dust concentration in Sumatra compared to Kalimantan, as presented in Figure 4. The results of satellite data show that the distribution of PM10 pollutants is higher in the Aceh and Malacca Strait regions. The distribution map of PM10 concentration increased from 2010 to 2011 with a concentration value $6x10^{12}$ $kgm^{-2}s^{-1}$.



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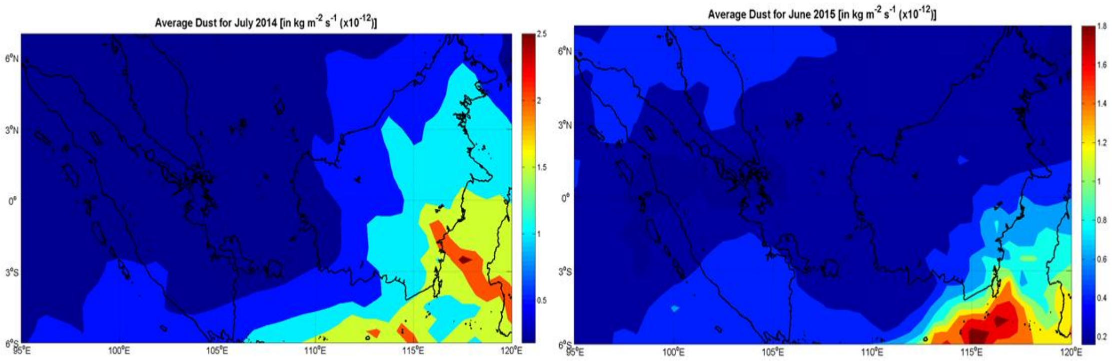
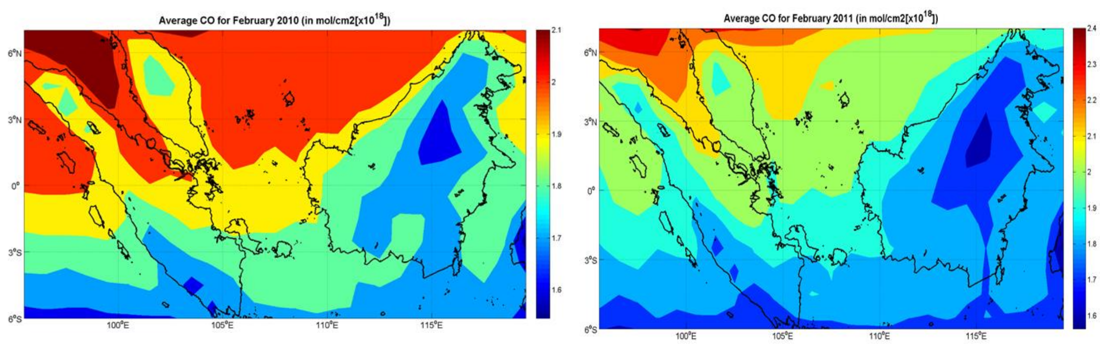


(b)

Figure 6. Spatial maps of PM10 concentrations (a) in 2010-2011 and (b) in 2014-2015 in Kalimantan and Sumatra.

Figures 6a and Fig.6b show dust concentrations in the Kalimantan and Sumatra regions for the 2010-2011 and 2014-2015 periods. The dust concentration data (PM10) used, was downloaded from the MERRA-2 satellite version v5.12.4. Temporal resolutions chosen are monthly and spatial resolution of 0.5 ° x 0.625 °. The data code for downloading MERRA-2 data with the above resolution is M2TMNXADG. MERRA satellite monitoring results show that the highest dust concentration in the South Kalimantan region is 7.0 x 10-12 kgm-1s-1. For Sumatra, the dust concentration in the 2010-2015 period showed lower concentra-tions compared to Kalimantan.

Figure 7 is an analysis of carbon monoxide (CO) concentrations for both the total column and volume mixing ratio used from the AIRS version v006 satellite. Temporal resolutions chosen are monthly and spatial resolution of 1 ° x 1 °. The data code for downloading AIRS data with the above resolution is AIRX3STM. Figure 5 (a) shows the CO spatial concentration map in 2011 showing high concentrations reaching 1.98 Mol / cm2 in South Sumatra and West Kalimantan and Central Kalimantan. From the spatial map it can be ascertained that forest fires during 2011 contributed to the CO which was quite high in both regions. Figure 5b in the region of South Sumatra (Riau and Jambi) the level of CO concentration reaches 6x1018 Mol/cm2. This is confirmed by the statement Shuai Yin et al, the estimated results show that from 2015 to 2016 the monthly anthropogenic CO increased 0.26 Mt. in September and 0.25 Mt in October [11].



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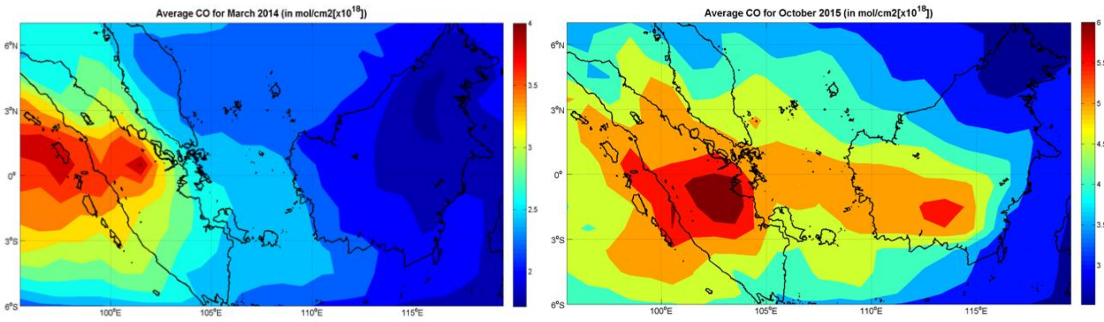
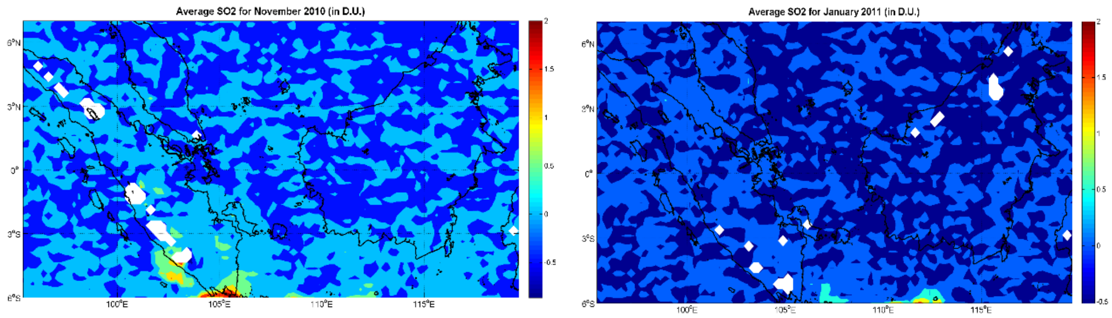


(b)

Figure 7. Spatial map of CO concentrations in 2010 - 2011 (a) and CO concentrations in 2014-2015 (b) in Kalimantan and Sumatra

From Figure 8 below presents SO2 concentration data (total columns) downloaded from the OMI satellite version v003. Temporal resolutions chosen are daily and spatial resolution of 0.25 ° x 0.25 °. From Figure 8 it is known that the SO2 concentration in 2010 shows the value of reaching 2.0 DU (Dobson Unit).



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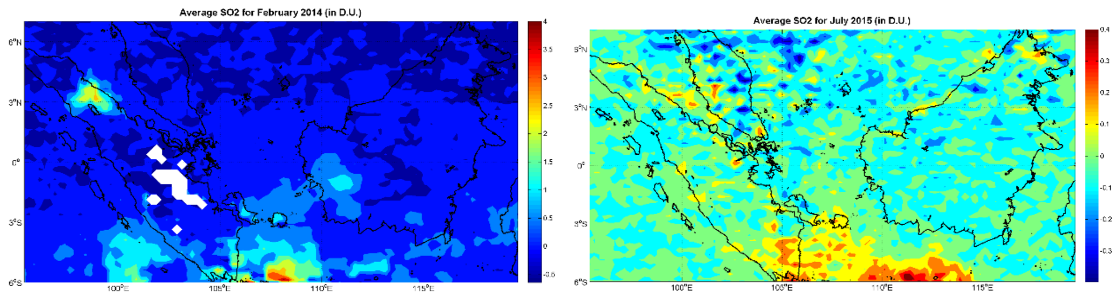

(b)

Figure 8. Spatial map of SO_2 concentrations in 2010 - 2011 (a) and CO concentrations in 2014-2015 (b) in Kalimantan and Sumatra

CONCLUSION

During the incidence of forest and land fires in Kalimantan and Sumatra in 2010 - 2015, it was concluded that the area of forest and land that experienced the largest fires occurred in 2015. The area receiving the most pollutant emissions from forest and land fires in Sumatra is South Sumatra. Meanwhile, the Kalimantan region receives the most significant emissions of forest and land fires in Central Kalimantan/ Palangkaraya.

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