Haze in urban areas from peatland fires in Sumatra based on simulation using HYSPLIT

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Abstract. Peatland fires which were occurred in September and October 2015 have caused air pollution in six provinces in Indonesia i.e. Riau, Jambi, South Sumatra, South Kalimantan, Central Kalimantan, and West Kalimantan. The Ministry of Health of Indonesia reported that in those six provinces, the Standard Index of Air Pollution (ISPU) reached the very dangerous level (>400) which caused public health problems. This study performed a simulation using HYSPLIT to generate haze trajectory from peatland fires in Sumatra in October 2015. Initial points for the simulation were hotspots which have occurred in order from two to five days in the same location. This study analysed haze dispersion in three urban areas: Pekanbaru, Jambi, and Palembang. The results indicated that in the period of 20-25 October 2017 haze in Pekanbaru originated from the mainstream of the Indragiri or Indragiri Hulu in which the source points were located in four villages in two sub districts: Rengat and Kuala Cenaku. In the period of 23-25 October 2017, haze from Muaro Jambi and Tanjung Jabung Timur in the Jambi Province reached Pekanbaru. In addition haze in Palembang and Jambi in the period of 18-25 October 2015 came from the three districts in South Sumatra namely Ogan Komering Ilir, Musi Banyuasin, and Banyuasin where the initial points were located in 10 villages in 9 sub districts.

1. Introduction

Haze and pollutants from forest and land fires caused high a Air Pollution Standard Index (ISPU) level in September and October 2015 in Sumatra and Kalimantan. Ministry of Health Indonesia (2015) reported that in the period of September to October 2015, monthly ISPU reached a very hazardous level (>400) in 6 provinces: Riau, Jambi, South Sumatra, South Kalimantan, Central Kalimantan, and West Kalimantan [1]. ISPU level in Riau, Jambi, South Sumatra, Central Kalimantan and West Kalimantan was 1074, 435, 957, 1987, 917 respectively in September 2015. In October 2015, the ISPU level in Riau, Jambi, South Sumatra, Central Kalimantan and West Kalimantan has reached 602, 514, 478, 2230, 622 respectively [1]. One of the indicators for forest and land fires is the hotspot. In September 2015, the number of hotspot was high which reached 1371 in Riau, 2529 in Jambi, 3900 in West Kalimantan, 12327 in Central Kalimantan. In October 2015, hotspots in South Sumatra was 12319 [1].

The three provinces in Sumatra: Riau, Jambi, and South Sumatra had negative impacts of forest and land fires in October 2015. Hotspot data were obtained from the Ministry of Environment and Forestry. Figure 1 illustrates that the number of hotspots in Riau, Jambi, and South Sumatra in the period of 19-25 October 2015. The number of hotspots at the district level in Riau, Jambi, and South

Sumatra is illustrated in figure 2. In the Province of Riau, most of the hotspots were found in Indragiri Hilir or downstream Indragiri (11 points) and Indragiri Hulu or mainstream Indragiri (15 points) whereas in Jambi, hotspots frequently occurred in Muarojambi (27 points) and Tanjungjabung Timur (20 points). South Sumatra had a large number of hotspots compared to Riau and Jambi where the highest frequency of hotspots in 19-25 October 2015 period was discovered in Ogan Komering Ilir (92 points).

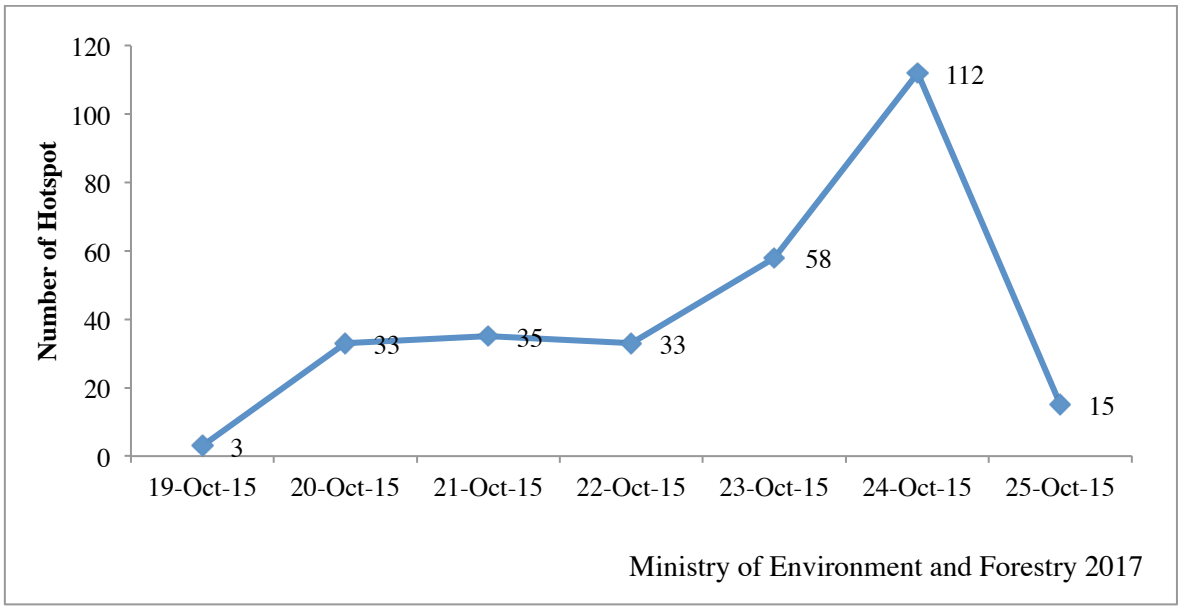


Figure 1. Number of hotspots in Riau, Jambi and South Sumatra in the 19-25 October 2015 period

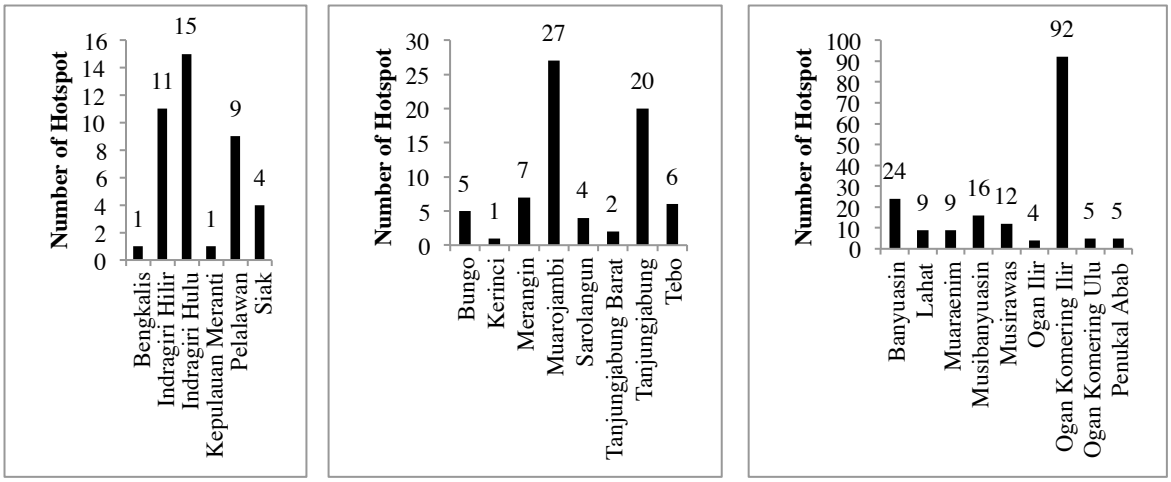


Figure 2. Number of hotspots in the 19-25 October 2015 period, which are located in districts of (a) Riau, (b) Jambi and (c) South Sumatra

Peatland fire is difficult to control compared to those in mineral areas because the fires smolder under the surface of peatlands and their spreading is difficult to detect because only white smoke is

visible [2]. Haze and smoke from peatland fires produce high carbon emissions which are harmful to human health and contributes significantly to global warming. A study by Huijnen *et al*. (2016) reported that the average CO_2 emissions rate produced by Indonesia's forest and land fires reach 11.3 T_g each day during September to October 2015 [3]. BBC News (2015) reported that in late October 2015 at the forest fire epicenters in Kalimantan and Sumatra, Pollutants Standards Index (PSI) readings have exceeded 2,000 [4]. This situation caused respiratory illnesses, the close of schools, and flight cancellations.

Haze and pollutant from forest and land fires caused public health problems not only in the district where the fires occurred but also in the urban area located far from fire locations. Haze as negative impact of peatland fires which was felt by people in urban area came from surrounding districts or even provinces. This study analysed haze dispersion in three urban areas in Sumatra: Pekanbaru, Jambi and Palembang in October 2015. The source locations of haze in those urban areas were identified based on the simulation results using Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT). Haze trajectory showed the path of haze movements from the place of peatland fires toward urban area. This information is important for decision makers in minimizing the negative impacts of peatland fires.

2. Literature review

HYSPLIT was used to determine the concentration of five major pollutants in the Province of Riau, Indonesia, in 2006 and 2007 [5]. Those five major pollutants included PM10 (Particulate matter less than or 10 μm in size), SO2, NO2, CO and O3. The study indicated that the concentration of PM10 during a haze episode was significantly different when compared to its concentration in non-haze conditions and the distribution of PM10 was greatly influenced by the direction of the wind.

The smoke event simulation of forest fires on March 7th 2014 in Sumatera-Indonesia was performed using a WRF-Chem with the Fire Inventory from NCAR (FINN) fire emissions dataset [6]. The results indicated that smokes moved southwest covering the Province of Riau. Furthermore, the simulation has discovered that the source of the smoke also came from Malaysia [6]. The simulation was supported by the authorized use of the satellite image from the Moderate Resolution Imaging Spectroradiometer (MODIS) of NASA's Aqua satellite.

A study on Trajectory and Concentration PM10 in Banjarbaru (South Kalimantan Province) and Palangka Raya (Central Kalimantan Province) was undertaken from September to October 2015 period [7]. The GDAS (Global Data Assimilation System) output was used to result the Dynamics of PM10 using The HYSPLIT model. This study indicated that the distribution of PM10 was greatly influenced by the direction of the wind and topography. Furthermore, the study reported a large difference between the concentration of PM10 Palangka Raya and Banjarbaru.

Haze trajectory from peatland fires in South Sumatra in October 2015 has been generated in [8]. HYSPLIT model and the package Opentraj, which is available in the open source software R, were used in the simulation to obtain haze dispersion with hotspot sequences as the initial points of trajectory. This study showed that haze from fires in South Sumatra affected not only people in this province but also in neighboring provinces namely Jambi and Riau. The haze also reached West Sumatra, North Sumatra and moved to the Indian Ocean. The haze clusters were also identified in this study using the K-Means clustering algorithm. Clustering on the dataset with 119,808 haze positions resulted in two dense clusters with the height average of 65.06 m AGL and 22.21 m AGL. Dense clusters covered about 27% to 29% members of all haze trajectories.

Haze trajectory patterns from peatland fires has been also studied in [9] with the Province of Riau as the study area. This study discovered as many as 4,887 movement locations of haze which moved towards the northeast and northwest of the Riau Province in July, September and October 2015. Those haze locations were originated from the sources located in four districts in Riau: Rokan Hilir, Indragiri Hulu, Siak, and Kampar. The source and position of the haze was the location of hotspot sequences, which occurred consecutively 2 to 5 days in a certain location. The largest cluster contains 3,702 locations of haze locations with the lowest height of haze of 23.554 m AGL. The spread of haze

in 10 districts and cities in the Province of Riau, 4 districts in North Sumatra, 3 states in Malaysia, as well as around the Strait of Malacca.

The concentration of CO and CO_2 from peat fires in the Province of Riau were generated by using the HYSPLIT model [10]. The study discovered that on July 9th , July 22nd , July 26th , August 30th and October 21st , 2015, the concentration of high pollutants have spread in some districts in the Province of Riau including Rokan Hilir, Bengkalis, Meranti Island, Indragiri Hulu, and Siak. The average concentration of pollutants in these locations was 11.1471 μg/m^3 for CO and 88.5882 μg/m^3 for CO_2 [10]. As many as 45525 (95%) haze trajectory locations which contained pollutant concentration has spread starting from Riau to Nanggroe Aceh Darussalam.

3. Method

3.1. Study area and data

Data used in this study were hotspot sequences during October 12-15, 2015 in the Provinces of Riau, Jambi, and South Sumatra, which have been generated in the previous study [11]. Table 1 illustrates the period of the hotspot and the study area. Hotspot datasets were obtained from FIRMS MODIS Fire/Hotspot, NASA. Furthermore, this study used district border digital maps from Statistics Indonesia. Haze simulation using HYSPLIT required meteorological datasets. This study used the global meteorological datasets CDAS from Air Resources Laboratory National Oceanic and Atmospheric Administration (ARL NOAA). The datasets determined the height (meter Above Ground Level/m AGL) and pressure (hectopascal/hPa) attributes. Those monthly datasets were stored in the type .gbl file with the format with the file name as RP(year)(month). Figure 3 indicates the initial points of haze simulation in three provinces: Riau, Jambi, and South Sumatra.

Table 1. Hotspot sequence and the study area

Period of hotspot sequence	Study area
20-22 October 2015	Riau
23-25 October 2015	Riau
18-20 October 2015	Jambi
20-22 October 2015	Jambi
23-25 October 2015	Jambi
18-20 October 2015	South Sumatra
20-22 October 2015	South Sumatra
21-23 October 2015	South Sumatra
22-23 October 2015	South Sumatra
23-25 October 2015	South Sumatra

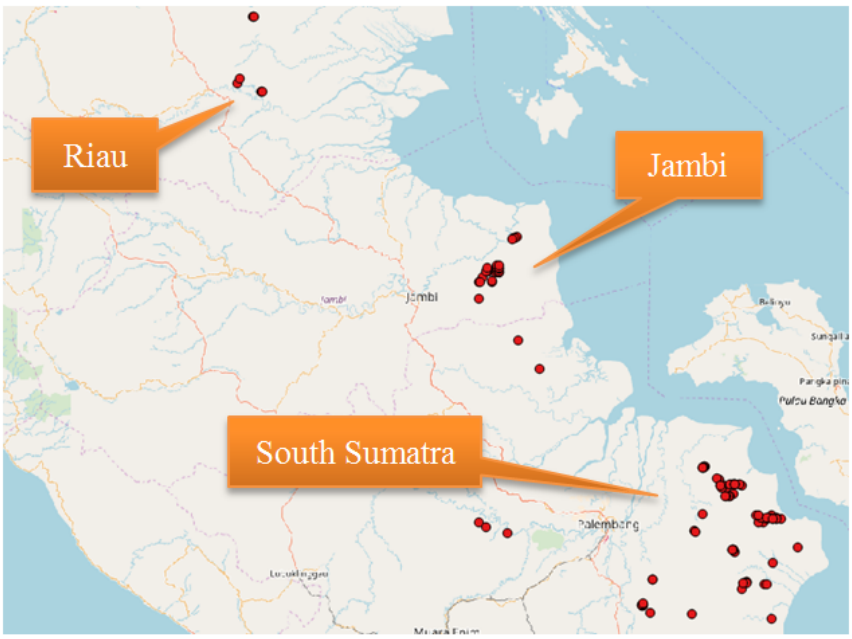


Figure 3. Initial points of haze simulation.

3.2. Simulation using HYSPLIT

The course or the route of the Haze caused by peatland fires was generated by using the HYSPLIT model. Data preprocessing and the simulation was performed on R studio. Opentraj was utilized which is available in the package Openair in the statistical tool R to create and analyze data of the air path. Several functions have been frequently used in Opentraj are ProcTraj, Df2SpLines, Df2SpLinesDf, PlotTraj, PlotTrajFreq, and RasterizeTraj, where one of the most important functions is ProcTraj which runs HYSPLIT to track the locations of the haze movements. Table 2 illustrates the number of haze locations in the urban area in Sumatra.

Table 2. The Urban area affected by haze in October 2015

Period of Hotspot Sequence	Location of hotspot Sequence	Urban areas affected by haze (number of haze locations)
20-22 October 2015	Riau	Pekanbaru (39)
23-25 October 2015	Riau	Pekanbaru (217)
18-20 October 2015	Jambi	Jambi (2)
20-22 October 2015	Jambi	Pekanbaru (4)
23-25 October 2015	Jambi	Pekanbaru (171)
18-20 October 2015	South Sumatra	Palembang (154), Jambi (101)
20-22 October 2015	South Sumatra	Palembang (28), Jambi (51), Pekanbaru (12)
21-23 October 2015	South Sumatra	Palembang (17), Jambi (272), Pekanbaru (2)
22-23 October 2015	South Sumatra	Palembang (60), Jambi (102)
23-25 October 2015	South Sumatra	Palembang (39), Jambi (64)

4. Results and discussion

4.1. Haze in Pekanbaru

Haze in Pekanbaru which occurred in October 2015 came from several districts in Riau, Jambi and South Sumatra. As many as 39 haze locations in 20 – 22 October 2015 and 217 haze locations in 23 – 25 October 2015 have been discovered in Pekanbaru where the initial points of those haze routes was located in Upstream Indragiri Riau, as illustrated in Table 3. Initial points were hotspots in sequence that were used in the simulation as starting locations for the haze trajectory. Those initial points were located in four villages in Indragiri Hulu: Rantau Mapesai, Sungai Guntung Tengah, Sungai Guntung Hilir and Pulau Gelang.

Table 3. Haze locations in Pekanbaru from Riau Province.

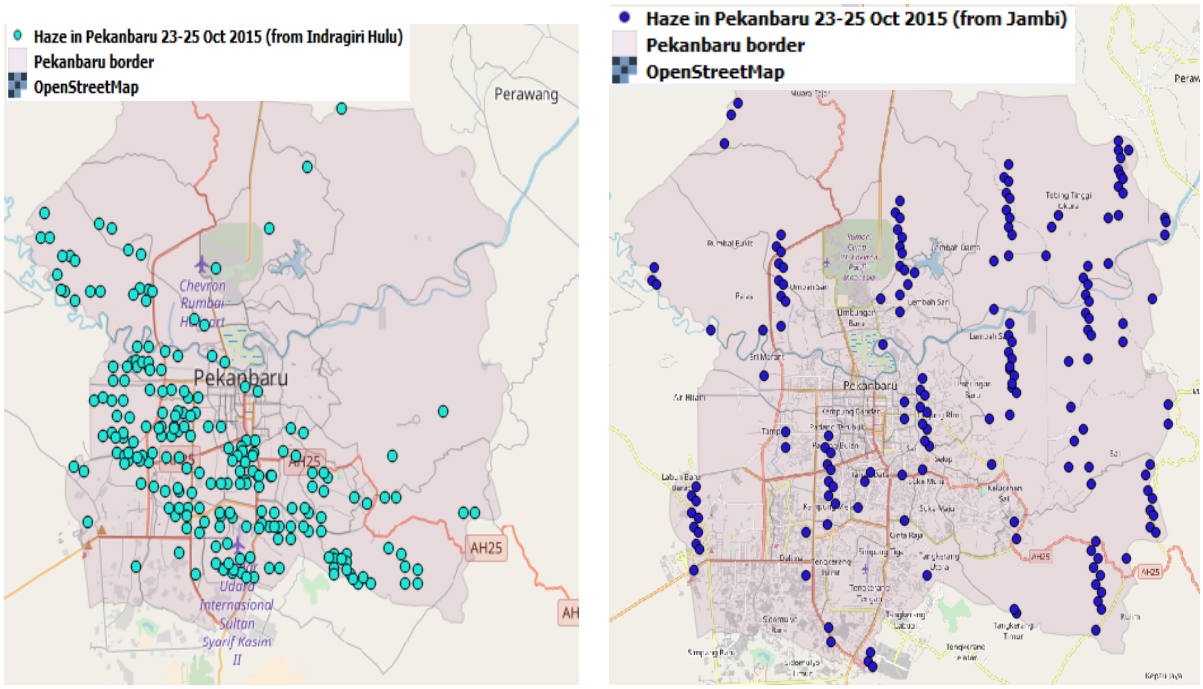
Initial point of simulation in Riau						Haze location (Number of haze locations)
Longitude	Latitude	Sequence Period	Village	Subdistrict	District/City	
102.59	0.1	20-22 Oct 2015	Rantau Mapesai	Rengat	Indragiri Hulu	Pekanbaru (39)
102.5	-0.31	20-22 Oct 2015	Sungai Guntung Tengah	Rengat	Indragiri Hulu	Pekanbaru (39)
102.51	-0.28	20-22 Oct 2015	Sungai Guntung Hilir	Rengat	Indragiri Hulu	Pekanbaru (39)
102.6	0.1	23-25 Oct 2015	Rantau Mapesai	Rengat	Indragiri Hulu	Pekanbaru (217)
102.64	-0.36	23-25 Oct 2015	Pulau Gelang	Kuala Cenaku	Indragiri Hulu	Pekanbaru (217)
102.65	-0.36	23-25 Oct 2015	Pulau Gelang	Kuala Cenaku	Indragiri Hulu	Pekanbaru (217)

Haze in Pekanbaru did not only come from the villages in Riau but also from Jambi. Table 4 indicates that as many as 171 haze locations have been discovered throughout Pekanbaru in the 23-25 Oct 2015 period. Initial points of those haze trajectories were located in two villages in Tanjung Jabung Timur and four villages in Muaro Jambi. Figure 4 shows haze locations in Pekanbaru in the period of 23-25 Oct 2015 with the initial points in Indragiri Hulu, Riau and Muaro Jambi, Jambi.

Table 4. Haze locations in Pekanbaru and Jambi from Jambi Province.

Initial point of simulation in Jambi						Haze location (Number of haze locations)
Longitude	Latitude	Sequence Period	Village	Subdistrict	District/City	
104.08	-1.45	18-20 Oct 2015	Jebus	Kumpeh	Muaro Jambi	Jambi (2)
104.08	-1.44	18-20 Oct 2015	Jebus	Kumpeh	Muaro Jambi	Jambi (2)
104.2	-1.24	18-20 Oct 2015	Hutan	Hutan	Tanjung Jabung Timur	Jambi (2)
104.03	-1.45	18-20 Oct 2015	Kelurahan Tanjung	Kumpeh	Muaro Jambi	Jambi (2)
103.99	-1.49	18-20 Oct 2015	Seponjen	Kumpeh	Muaro Jambi	Jambi (2)
103.97	-1.52	18-20 Oct 2015	Petanang	Kumpeh	Muaro Jambi	Jambi (2)
103.98	-1.52	18-20 Oct 2015	Sungai Bungur	Kumpeh	Muaro Jambi	Jambi (2)
104.02	-1.45	20-22 Oct 2015	Kelurahan	Kumpeh	Muaro Jambi	Pekanbaru (4)

Initial point of simulation in Jambi						Haze location (Number of haze locations)
Longitude	Latitude	Sequence Period	Village	Subdistrict	District/City	
104.18	-1.25	23-25 Oct 2015	Tanjung Sungai Rambut	Berbak	Tanjung Jabung Timur	Pekanbaru (171)
104.19	-1.25	23-25 Oct 2015	Hutan	Huran	Tanjung Jabung Timur	Pekanbaru (171)
104.01	-1.45	23-25 Oct 2015	Kelurahan Tanjung	Kumpeh	Muaro Jambi	Pekanbaru (171)
104.02	-1.43	23-25 Oct 2015	Kelurahan Tanjung	Kumpeh	Muaro Jambi	Pekanbaru (171)
104.07	-1.46	23-25 Oct 2015	Gedong Karya	Kumpeh	Muaro Jambi	Pekanbaru (171)
104.08	-1.45	23-25 Oct 2015	Jebus	Kumpeh	Muaro Jambi	Pekanbaru (171)
104.08	-1.44	23-25 Oct 2015	Jebus	Kumpeh	Muaro Jambi	Pekanbaru (171)
104.08	-1.43	23-25 Oct 2015	Jebus	Kumpeh	Muaro Jambi	Pekanbaru (171)
104.08	-1.42	23-25 Oct 2015	Jebus	Kumpeh	Muaro Jambi	Pekanbaru (171)
104.09	-1.46	23-25 Oct 2015	Jebus	Kumpeh	Muaro Jambi	Pekanbaru (171)
104.09	-1.45	23-25 Oct 2015	Jebus	Kumpeh	Muaro Jambi	Pekanbaru (171)
104.09	-1.44	23-25 Oct 2015	Jebus	Kumpeh	Muaro Jambi	Pekanbaru (171)
104.09	-1.43	23-25 Oct 2015	Jebus	Kumpeh	Muaro Jambi	Pekanbaru (171)
104.09	-1.42	23-25 Oct 2015	Jebus	Kumpeh	Muaro Jambi	Pekanbaru (171)
103.97	-1.62	23-25 Oct 2015	Pematang Raman	Kumpeh	Muaro Jambi	Pekanbaru (171)
104.05	-1.52	23-25 Oct 2015	Kelurahan Tanjung	Kumpeh	Muaro Jambi	Pekanbaru (171)
104.05	-1.51	23-25 Oct 2015	Kelurahan Tanjung	Kumpeh	Muaro Jambi	Pekanbaru (171)
104.17	-1.26	23-25 Oct 2015	Hutan	Hutan	Tanjung Jabung Timur	Pekanbaru (171)



(a) (b)

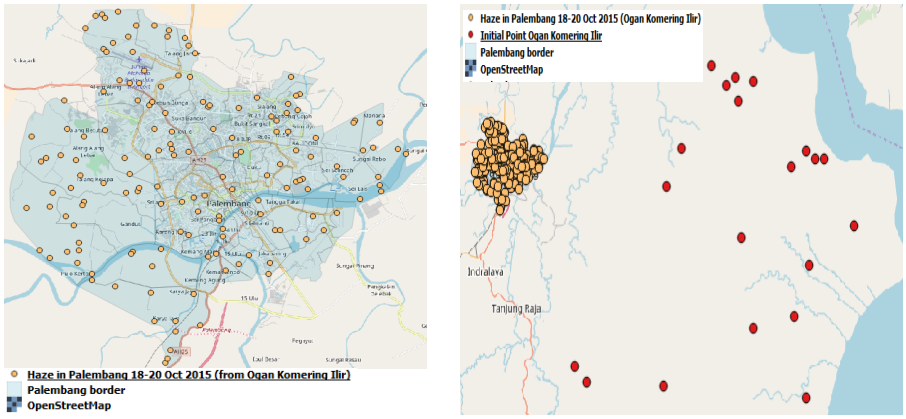
Figure 4. Haze locations in Pekanbaru in the period of 23-25 Oct 2015 with the initial points in (a) Indragiri Hulu, Riau and (b) Muaro Jambi, Jambi.

4.2. Haze in Palembang

This study performed the simulation using HYSPLIT to acquire the spreading of haze in South Sumatra. The simulation was done on 72 initial points during the 18 – 25 October 2015 period. The initial points were hotspots which occurred sequentially in three days: 18-20 October 2015, 20-22 October 2015, 21-23 October 2015, 22-23 October 2015 and 23-25 October 2015 representing strong indicators for peatland fires during those periods. Those initial points were located in four districts: Ogan Komering Ilir (67 initial points or 93.06%), Musi Banyuasin (2 points or 2.78%), Banyuasin (2 points or 2.78%), and Penukal Abab Lematang Ilir (1 point or 1.39%). The specific locations of those 72 initial points in the 18-20 October 2015, 20-22 October 2015, 21-23 October 2015, 22-23 October 2015 and 23-25 October 2015 period are displayed in table 5, table 6, table 8, table 9 and table 10, respectively. Table 5 displays the HYSPLIT model with a result of 154 locations of haze in Palembang in which the initial points of simulation have occurred in 9 villages in Ogan Komering Ilir: Cinta Jaya, Kayu Labu, Kuala Sungai Jeruju, Riding, Simpang Tiga Sakti, Sumber Hidup, Sungai Batang, Sungai Lumpur, and Ulak Kedondong, 1 village in Musi Banyuasin: Danau Cala, and 1 village in Banyuasin: Tanah Pilih. Figure 5 displays the haze locations in Palembang where the initial points are located in Ogan Komering Ilir, South Sumatra. In addition to Palembang, haze from Ogan Komering Ilir, Musi Banyuasin, Banyuasin South Sumatra moved to Jambi in the period of 18-20 October 2015. As many as 101 locations of haze were found in the urban areas of Jambi.

Table 5. The Haze locations in Palembang and Jambi , the Province of South Sumatra during the period of 18-20 October 2015.

Initial point of simulation in South Sumatra					Haze location (Number of haze locations)
Longitude	Latitude	Village	Subdistrict	District/City	
105.7	-2.98	Simpang Tiga Sakti	Tulung Selapan	Ogan Komering Ilir	Palembang (154), Jambi (101)
105.48	-2.77	Sungai Batang	Air Sugihan	Ogan Komering Ilir	
105.75	-2.94	Simpang Tiga Sakti	Tulung Selapan	Ogan Komering Ilir	
105.43	-2.72	Sungai Batang	Air Sugihan	Ogan Komering Ilir	
105.35	-2.64	Sungai Batang	Air Sugihan	Ogan Komering Ilir	
105.57	-2.76	Sungai Batang	Air Sugihan	Ogan Komering Ilir	
105.51	-2.75	Sungai Batang	Air Sugihan	Ogan Komering Ilir	
105.52	-2.81	Sungai Batang	Air Sugihan	Ogan Komering Ilir	
105.33	-2.93	Sungai Batang	Air Sugihan	Ogan Komering Ilir	
105.78	-2.96	Simpang Tiga Sakti	Tulung Selapan	Ogan Komering Ilir	
105.81	-2.96	Simpang Tiga Sakti	Tulung Selapan	Ogan Komering Ilir	
105.28	-3.03	Riding	Pangkalan Lapam	Ogan Komering Ilir	
105.53	-3.16	Simpang Tiga Sakti	Tulung Selapan	Ogan Komering Ilir	
105.91	-3.13	Simpang Tiga Sakti	Tulung Selapan	Ogan Komering Ilir	
105.76	-3.23	Simpang Tiga Sakti	Tulung Selapan	Ogan Komering Ilir	
105.57	-3.39	Ulak Kedondong	Cengal	Ogan Komering Ilir	
105.71	-3.36	Sungai Lumpur	Cengal	Ogan Komering Ilir	
105.27	-3.54	Kayu Labu	Pedamaran Timur	Ogan Komering Ilir	
105.01	-3.53	Sumber Hidup	Pedamaran Timur	Ogan Komering Ilir	
105.75	-3.57	Kuala Sungai Jeruju	Cengal	Ogan Komering Ilir	
104.97	-3.49	Cinta Jaya	Pedamaran	Ogan Komering Ilir	
103.97	-2.98	Danau Cala	Lais	Musi Banyuasin	
104.21	-1.87	Tanah Pilih	Banyuasin II	Banyuasin	



(a) (b)

Figure 5. The visualization of Haze locations in Palembang during the period of 18-20 October 2015 (a) without the initial points (b) with the initial points in Ogan Komering Ilir, South Sumatra.

The simulation using HYSPLIT was performed on 10 initial points in the period of 20-22 October 2015. Those initial points were located in four villages in Ogan Komering Ilir: Simpang Tiga Sakti (4 points), Sungai Batang (4 points), Sungai Ketupak (1 point), and Cinta Jaya (1 point). The haze from Ogan Komering Ilir South Sumatra was also felt by the people in Pekanbaru Riau. As displayed in table 6, there were 28 haze locations in Palembang, 51 haze locations in Jambi, and 12 haze locations in Pekanbaru.

Table 6. Haze locations in Palembang, Jambi and Pekanbaru from the Province of South Sumatra during the 20-22 October 2015 period

Initial points of simulation in South Sumatra					Haze location (Number of haze locations)
Longitude	Latitude	Village	Subdistrict	District/City	
105.72	-2.96	Simpang Tiga Sakti	Tulung Selapan	Ogan Komering Ilir	Palembang (28), Jambi (51), Pekanbaru (12)
105.46	-2.76	Sungai Batang	Air Sugihan	Ogan Komering Ilir	
105.34	-2.64	Sungai Batang	Air Sugihan	Ogan Komering Ilir	
105.52	-2.75	Sungai Batang	Air Sugihan	Ogan Komering Ilir	
105.5	-2.82	Sungai Batang	Air Sugihan	Ogan Komering Ilir	
105.78	-2.95	Simpang Tiga Sakti	Tulung Selapan	Ogan Komering Ilir	
105.67	-2.98	Simpang Tiga Sakti	Tulung Selapan	Ogan Komering Ilir	
105.51	-3.15	Simpang Tiga Sakti	Tulung Selapan	Ogan Komering Ilir	
105.6	-3.34	Sungai Ketupak	Cengal	Ogan Komering Ilir	
104.96	-3.49	Cinta Jaya	Pedamaran	Ogan Komering Ilir	

4.3. Haze in Jambi

Haze in Ogan Komering Ilir South Sumatra affected not only the people in Palembang but also the people in Jambi. The number of haze locations in Jambi from Ogan Komering Ilir South Sumatra in the period of 18-25 October 2015 is summarized on table 7. Hotspots in sequence wereoccurred in four sub districts in Ogan Komering Ilir: Air Sugihan, Cengal, Tulung Selapan in the period 18-25 October 2017. Specific positions of initial points which were represented by the hotspot in sequences are listed on Table 5, Table 6, Table 8, Table 9 and Table 10 during the period of 18-20 October 2015, 20-22 October 2015, 22-23 October 2015, 23-25 October 2015 respectively. The spread of haze from the results of the simulation using HYSPLIT are displayed in figure 6 and figure 7.

Table 7. The number of haze locations in Jambi from South Sumatra during the 18-25 October 2015 period.

Period of hotspot sequences	Sub district in Ogan Komering Ilir South Sumatra where initial points are located	Number of initial points	Number of haze locations in Jambi (initial point in Ogan Komering Ilir South Sumatra)
18-20 October 2015	Air Sugihan, Cengal, Pangkalan Lapam, Pedamaran, Pedamaran Timur, Tulung Selapan	21	101
20-22 October	Air Sugihan, Cengal, Pedamaran,Tulung Selapan	10	51

Period of hotspot sequences	Sub district in Ogan Komering Ilir South Sumatra where initial points are located	Number of initial points	Number of haze locations in Jambi (initial point in Ogan Komering Ilir South Sumatra)
21-23 October 2015	Air Sugihan, Cengal, Pedamaran, Tulung Selapan	13	272
22-23 October 2015	Air Sugihan, Cengal, Pampangan, Pedamaran, Tulung Selapan	10	102
23-25 October 2015	Air Sugihan, Cengal, Pampangan, Pangkalan Lapam, Tulung Selapan	13	64

Table 8. Haze locations in Palembang, Jambi and Pekanbaru from the Province of South Sumatra Province during the 21-23 October 2015 period.

Initial point of simulation in South Sumatra					Haze location (Number of haze locations)
Longitude	Latitude	Village	Subdistrict	District/City	
105.66	-2.94	Simpang Tiga Sakti	Tulung Selapan	Ogan Komering Ilir	Palembang (17), Jambi (272), Pekanbaru (2)
105.45	-2.77	Sungai Batang	Air Sugihan	Ogan Komering Ilir	
105.5	-2.75	Sungai Batang	Air Sugihan	Ogan Komering Ilir	
105.74	-2.95	Simpang Tiga Sakti	Tulung Selapan	Ogan Komering Ilir	
105.42	-2.71	Sungai Batang	Air Sugihan	Ogan Komering Ilir	
105.34	-2.65	Sungai Batang	Air Sugihan	Ogan Komering Ilir	
105.53	-2.75	Sungai Batang	Air Sugihan	Ogan Komering Ilir	
105.56	-2.75	Sungai Batang	Air Sugihan	Ogan Komering Ilir	
105.49	-2.82	Sungai Batang	Air Sugihan	Ogan Komering Ilir	
105.78	-2.96	Simpang Tiga Sakti	Tulung Selapan	Ogan Komering Ilir	
105.52	-3.15	Simpang Tiga Sakti	Tulung Selapan	Ogan Komering Ilir	
105.6	-3.34	Sungai Ketupak	Cengal	Ogan Komering Ilir	
104.97	-3.48	Cinta Jaya	Pedamaran	Ogan Komering Ilir	

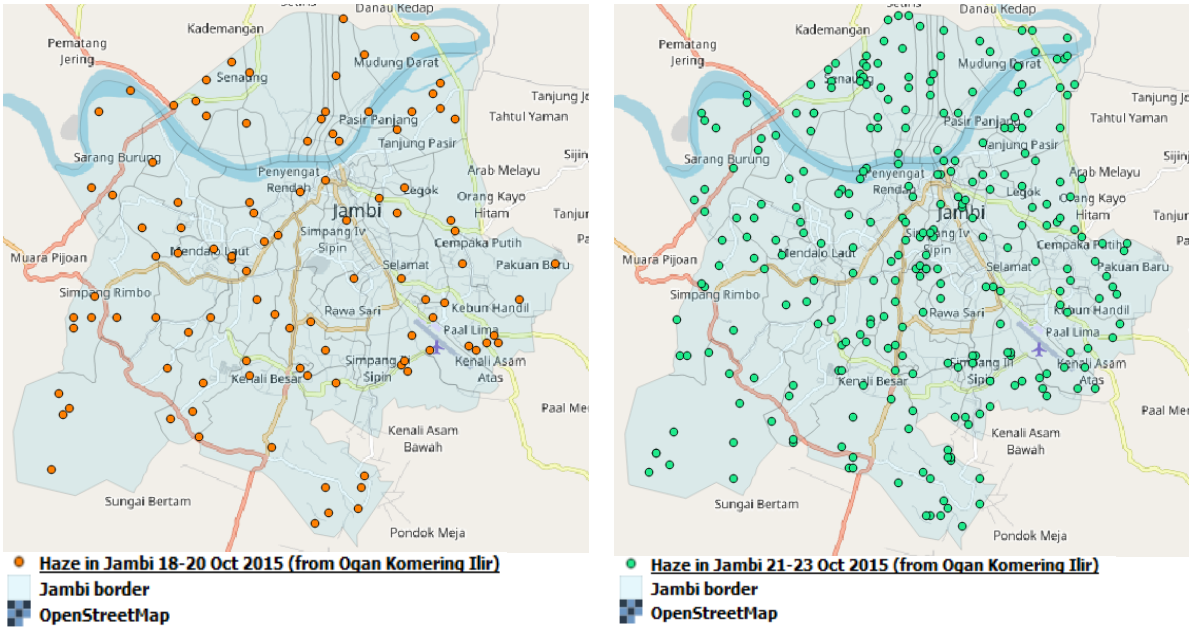
Table 9. Haze locations in Palembang and Jambi from the Province of South Sumatra during the period of 22-23 October 2015.

Initial point of simulation in South Sumatra					Haze locations (Number of haze locations)
Longitude	Latitude	Village	Subdistrict	District/City	
105.69	-2.95	Simpang Tiga Sakti	Tulung Selapan	Ogan Komering Ilir	Palembang (60), Jambi (102)
105.44	-2.76	Sungai Batang	Air Sugihan	Ogan Komering Ilir	
105.53	-2.75	Sungai Batang	Air Sugihan	Ogan Komering Ilir	
105.33	-2.65	Sungai Batang	Air Sugihan	Ogan Komering Ilir	
105.48	-2.82	Sungai Batang	Air Sugihan	Ogan Komering Ilir	
105.76	-2.96	Simpang Tiga Sakti	Tulung Selapan	Ogan Komering Ilir	
105.52	-3.15	Simpang Tiga Sakti	Tulung Selapan	Ogan Komering Ilir	
105.6	-3.35	Sungai Ketupak	Cengal	Ogan Komering Ilir	
105.03	-3.33	Jungkal	Pampangan	Ogan Komering Ilir	

Initial point of simulation in South Sumatra					Haze locations (Number of haze locations)
Longitude	Latitude	Village	Subdistrict	District/City	
104.14	-3.05	Air Itam Timur	Penukal	Penukal Abab Lematang Ilir	
104.96	-3.48	Cinta Jaya	Pedamaran	Ogan Komering Ilir	

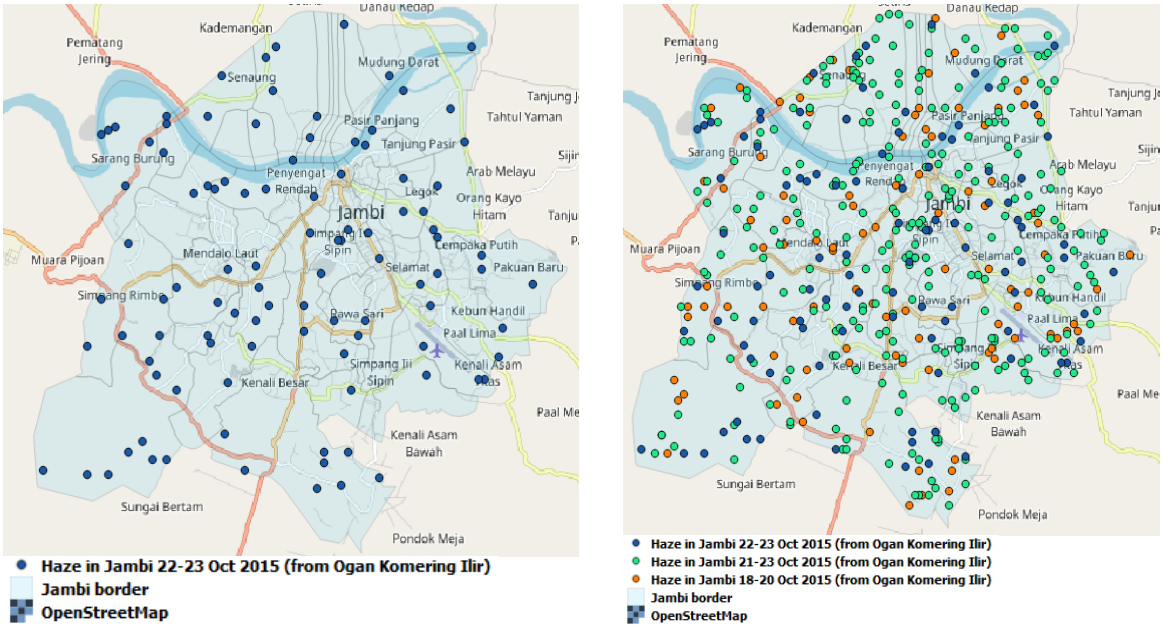
Table 10. Haze locations in Palembang and Jambi from South Sumatra Province in the period of 23-25 October 2015.

Initial point of simulation in South Sumatra					Haze location (Number of haze locations)
Longitude	Latitude	Village	Subdistrict	District/City	
105.67	-2.94	Simpang Tiga Sakti	Tulung Selapan	Ogan Komering Ilir	Palembang (39), Jambi (64)
105.72	-2.95	Simpang Tiga Sakti	Tulung Selapan	Ogan Komering Ilir	
105.44	-2.76	Sungai Batang	Air Sugihan	Ogan Komering Ilir	
105.53	-2.75	Sungai Batang	Air Sugihan	Ogan Komering Ilir	
105.33	-2.65	Sungai Batang	Air Sugihan	Ogan Komering Ilir	
105.47	-2.82	Sungai Batang	Air Sugihan	Ogan Komering Ilir	
105.76	-2.96	Simpang Tiga Sakti	Tulung Selapan	Ogan Komering Ilir	
105.29	-3.04	Ridih	Pangkalan Lapam	Ogan Komering Ilir	
105.51	-3.15	Simpang Tiga Sakti	Tulung Selapan	Ogan Komering Ilir	
105.58	-3.35	Sungai Ketupak	Cengal	Ogan Komering Ilir	
105.03	-3.33	Jungkal	Pampangan	Ogan Komering Ilir	
105.72	-3.36	Sungai Lumpur	Cengal	Ogan Komering Ilir	
104.01	-3.01	Rantau Keroya	Lais	Musi Banyuasin	
104.97	-3.47	Cinta Jaya	Pedamaran	Ogan Komering Ilir	
104.34	-2.05	Tanah Pilih	Banyuasin II	Banyuasin	



(a) (b)

Figure 6. Haze locations in Jambi with the initial points in Ogan Komering Ilir, South Sumatra in (a) the period of 18-20 October 2015 and (b) 21-23 October 2015



(a) (b)

Figure 7. Haze locations in Jambi with the initial points in Ogan Komering Ilir, South Sumatra in (a) the period of 21-23 October 2015 and (b) 18-23 October 2015.

5. Conclusion

This study has generated routes of haze which were caused by peatland fires in October 2015. Hotspots in sequence represented indicators as the cause of fire. Those hotspots were used as initial points for the simulation using HYSPLIT model. Starting points were located in some villages in

three provinces in Sumatra: Riau, Jambi, and South Sumatra. The results showed that haze from those starting points found not only in the villages where the fires occurred but also in urban areas which were located far from the villages. During the 18 – 25 October 2015 period, fires were located in the Ogan Komering Ilir, South Sumatra.

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