Temporal Distribution and Characteristic Analysis of Oil Spill in Balikpapan Bay

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Abstract. Balikpapan Bay has an oil spill case that attracts many people because it is considered a serious environmental problem and is detrimental to the environment. One of the cases that occurred was the leak of an oil pipeline in Balikpapan Bay due to the wrong anchorage of a ship that occurred on March 31, 2018. Detection of oil spills for three months using Sentinel 1-A satellite data to determine the distribution and analysis of the same oil characteristics from the source of pipe leaks in the Gulf of Balikpapan. The multi-temporal distribution of oil spills in Balikpapan Bay in March, April, and May 2018 has a significant difference in the upstream and mouth of the bay due to a pipe leak on March 31, 2018. Characteristics of upstream oil spills represented by stations 4 and 5 have the anisotropy value is lower than at the mouth of the bay which is represented by stations 1 and 2. The characteristics of the oil spill in Balikpapan Bay have differences before and after the oil spill due to pipe leakage as indicated by the decrease in the anisotropy value.

1. Introduction
Kalimantan is an oil production island in Indonesia. Kalimantan has many oil refineries and other mining activities both on land and sea. One area that has a lot of oil drilling activity in Kalimantan is Balikpapan Bay. Balikpapan Bay is a very narrow bay in the upper and lower reaches of the part of the high seas of the Makassar Strait. The upstream of Balikpapan Bay has many drilling locations which impact the territorial waters. Balikpapan Bay has an oil spill case that attracts many people because it is considered a serious environmental problem and is detrimental to the environment. One of the cases that occurred was an oil pipe leak in Balikpapan Bay due to the wrong anchorage of a ship that occurred on March 31, 2018. To find out the distribution pattern and characteristics of an oil spill due to a pipe leak, it can be detected using remote sensing. Remote sensing can assess oil contamination [1]. An approach aimed at improving the detection/identification of oil spills at sea using satellite imagery as the main source of information has been developed [2].

The distribution of oil spills is not easily lost because it depends on the bay drain time. So that in this project, satellite data processing for Multi-temporal was carried out in March, April, and May 2018. Detection of oil spills for three months to determine the distribution and analysis of the same oil characteristics from the source of pipe leaks in Balikpapan Bay. This is very important because Balikpapan Bay has high marine pollution and is added to the occurrence of large oil spills so that the impact on the marine environment will be very dangerous. Therefore, this project was carried out to determine the distribution and analysis of the character of the oil spill to help with marine environmental problems in Balikpapan Bay.
2. Materials and Method

2.1. Description of the study sites
This study uses data from the Sentinel 1A satellite imagery taken from the Copernicus ESA website. Data was taken for March, April and May 2018 for the Balikpapan Bay area with coordinates 116°30'00"-117°00'0" E and 1°30'00"-1°45'0" S. Data was taken for 3 months with the distribution of data 1 taken on March 1, 2018, used as normal conditions before the pipe leak incident in Balikpapan Bay. Second data is data on April 6, 2018, which is used as the closest incident data because the pipe leak occurred on March 31, 2018. While data 3 is data after the incident of pipe leakage which was taken on May 12, 2018. For the analysis of the characteristics of the oil spill, 6 locations represent oil spills in Balikpapan Bay from upstream to downstream.

![Balikpapan Bay study area and station location](image)

**Figure 1.** Balikpapan Bay study area and station location
2.2. Data process
This study uses an oil spill detection method from satellite data using SNAP software with Profile plot analysis to determine the characteristics of an oil spill and ArcGIS software for visualization. The method used goes through several stages as follows,

**Figure 2. Stages of data processing**

The first stage is importing data, retrieving data from the Copernicus ESA website. The second stage is the process before data processing using SNAP to find out the optimal multi look number and window size on Lee Sigma for data processing.

**Figure 3. Stages of data processing preparation**

S-1 Tops Split is the stage to determine the desired target location, namely by choosing the right sub wash and burst for the target location. Sub wash: IW1 and Bursh: 1-4. S-1 Tops Split is a step to calibrate data using two polarizations VV and VH. Select the menu to save the complex output. S-1 Top Deburst is a step to remove horizontal lines in Sentinel image. In the Sentinel 1A image, some lines make the Sentinel 1A image look disjointed. Multilooking is a step to improve image interpretation and produce application products with pixel sizes of 3x4, and 6. Multi-temporal Speckle Filter is a step for speckle filters on 7x7, 9x9, and 11x11 data. Terrain Correction is a step to compensate for this distortion so that the geometric representation of the image will be as close to the real world as possible.

At this stage, 3 scenarios for multi looking are carried out, namely 3, 4, and 6, and the optimal multi look number is obtained, namely 3. Lee Sigma's stage also uses 3 window size scenarios, namely 7x7, 9x9, and 11x11, and obtained optimal results at a window size of 9x9. Multi look number 3 and window size 9x9 are used for the data processing stage. Data processing is carried out in stages as shown in the following diagram,
Figure 4. Stages of data processing

Polarimetric Decomposition is a step to separate data into groups by using zones defined in the H / Alpha field with window size 5. RGB Decomposite is a step to separate data into 3, namely red, green, and blue in the H-Alpha field. With the H-a Alpha profile, red is filled with entropy, green is filled with anisotropy, and blue is filled with alpha. After the processing is complete, the results of the terrain correction are analyzed using Profile plots for each parameter of anisotropy, entropy, and alpha at 6 focused locations. The results of data processing are exported with the ENVI or GeoTiff extension for further processing. The next process is the visualization and closure of land data (land masking) using ArcGIS software. At this time a filter is also carried out for the value of the oil spill to be displayed. After that, an analysis of the results obtained was carried out.

3. Result and Discussion

3.1. Balikpapan Bay Oil Spill Distribution

The distribution of oil spills in Balikpapan Bay for March, April, and May 2018 has a different pattern. The distribution pattern of the oil spill in Balikpapan Bay is strongly influenced by water conditions and current patterns in Balikpapan Bay. The distribution of this oil spill is the result of anisotropy parameters with a range of values from the Profile plot, namely 0.20 – 0.50.
Figure 5. Map of the distribution of the Balikpapan Bay oil spill March 1, 2018

The map of the distribution of the oil spill in Balikpapan Bay in March 2018 before the leak of the oil pipeline showed that there was already oil around the coast and also upstream of Balikpapan Bay. In March, before the pipe leak, there was no oil spill at the mouth of the bay.
The map of the distribution of the oil spill in Balikpapan Bay in April 2018 shows that the oil that was already around the coast and also upstream of Balikpapan Bay in the previous month was still there and was increasing due to pipe leaks. In April, shortly after the pipe leak, it was seen that at the mouth of the bay there was an oil spill. Seen in the upper part of the bay there is oil that is decreasing and increasing but oil that remains trapped upstream of the bay. The distribution of oil spills is mostly in the area of pipe leaks and spreads to the south of the bay to the Labangka area. This data was taken 6 days after the incident, it appears that not all of the oil spills have piled up at the mouth of the bay but have spread to the south of the bay.

Figure 6. Map of the distribution of the Balikpapan Bay oil spill April 6, 2018

The map of the distribution of the oil spill in Balikpapan Bay in April 2018 shortly after the leak of the oil pipeline shows that the oil that was already around the coast and also upstream of Balikpapan Bay in the previous month was still there and was increasing due to pipe leaks. In April, shortly after the pipe leak, it was seen that at the mouth of the bay there was an oil spill. Seen in the upper part of the bay there is oil that is decreasing and increasing but oil that remains trapped upstream of the bay. The distribution of oil spills is mostly in the area of pipe leaks and spreads to the south of the bay to the Labangka area. This data was taken 6 days after the incident, it appears that not all of the oil spills have piled up at the mouth of the bay but have spread to the south of the bay.
The map of the distribution of the Balikpapan Bay oil spill in May 2018 shows that the oil that was already around the coast and also upstream of Balikpapan Bay in the previous month was still there and the upstream part was increasing due to pipe leaks. In May, after the pipe leak, there were no oil spills at the mouth of the bay. It can be seen in the bay that there is less oil before it enters the upstream and at the end of the upstream that approaches the mainland, more and more oil remains trapped. The distribution of the oil spill has decreased a lot, both in the pipe leak area and in the south bay area to the Labangka area. This data was taken a month after the incident, it appears that the oil spill has disappeared from Balikpapan Bay and its distribution in the southern area of the bay has also decreased.

3.2. Characteristic Analysis
The characteristic analysis is an analysis method of oil spill detection parameters from satellite data that is used to determine the characteristics of the oil. The parameters analyzed are anisotropy, entropy, and also alpha. For each of these parameters, Profile plot analysis was carried out for 6 stations which were used as focus areas. The results of the characteristic analysis are shown in the appendix.
The characteristic analysis used as a reference is when a pipe leak occurred which caused an oil spill in April 2018. Meanwhile, the reference for oil from upstream activities was taken from data 1 in March 2018.

Table 1. Parameter values for the March 2018 oil spill

| Station | Anisotropy   | Entropy    | Alpha   | Description                        |
|---------|--------------|------------|---------|------------------------------------|
| 1       | 0.3 – 0.45   | 0.85 – 0.90| 30 – 38 | -                                  |
| 2       | 0.25 – 0.35  | 0.85 – 0.95| 30 – 38 | -                                  |
| 3       | 0.25 – 0.45  | 0.80 – 1.00| 35 – 45 | -                                  |
| 4       | 0.30 – 0.50  | 0.85 – 0.95| 30 – 48 | Oil from upstream activities       |
| 5       | 0.30 – 0.50  | 0.85 – 0.95| 25 – 43 | Oil from upstream activities       |
| 6       | 0.25 – 0.38  | 0.75 – 1.00| 38 – 50 | -                                  |

The characteristics of the upstream oil spill have higher anisotropy values ranging from 0.30 – 0.50; entropy values ranged from 0.85 – 0.95; and the low alpha degree values at station 5 ranged from 25 to 43 and at station 4 ranged from 30 to 48.

Table 2. Parameter values for the April 2018 oil spill

| Station | Anisotropy   | Entropy    | Alpha   | Description                        |
|---------|--------------|------------|---------|------------------------------------|
| 1       | 0.28 – 0.45  | 0.88 – 0.95| 34 – 45 | Oil from pipe leakage              |
| 2       | 0.22 – 0.44  | 0.90 – 0.98| 25 – 45 | Oil from pipe leakage              |
| 3       | 0.25 – 0.50  | 0.80 – 1.00| 20 – 45 | -                                  |
| 4       | 0.22 – 0.40  | 0.85 – 1.00| 35 – 48 | -                                  |
| 5       | 0.28 – 0.38  | 0.80 – 1.00| 32 – 48 | -                                  |
| 6       | 0.24 – 0.45  | 0.80 – 1.00| 30 – 45 | -                                  |

The characteristics of oil spills due to pipe leaks have lower anisotropy values ranging from 0.22 to 0.45; entropy values ranged from 0.88 – 0.98, and the value of the alpha degree at station 1 ranged from 34 to 45 and at station 2 ranged from 25 to 45.

Table 3. Parameter values for the May 2018 oil spill

| Station | Anisotropy   | Entropy    | Alpha   | Description |
|---------|--------------|------------|---------|-------------|
| 1       | 0.25 – 0.50  | 0.80 – 0.90| 30 – 45 | -           |
| 2       | 0.25 – 0.45  | 0.80 – 1.00| 38 – 40 | -           |
| 3       | 0.30 – 0.50  | 0.80 – 0.90| 27 – 42 | -           |
| 4       | 0.25 – 0.35  | 0.75 – 0.90| 38 – 50 | -           |
| 5       | 0.23 – 0.45  | 0.80 – 1.00| 30 – 55 | -           |
| 6       | 0.20 – 0.40  | 0.80 – 1.00| 35 – 50 | -           |

The characteristics of an oil spill one month after a pipe leak has a lower anisotropy value, ranging from 0.25 – 0.50; entropy values ranged from 0.75 – 1.00; and the alpha degree value at station 1 ranges from 34 to 45 and at station 2 ranges from 27 to 50.

The characteristics of the oil spill in March 2018 before the oil leak had a higher anisotropy than the oil spill after the leak and one month after that the characteristics of the oil spill had an even lower anisotropy value. It is indicated that the oil spill due to pipe leakage is mixed with other oil spills so that
the anisotropy value of oil throughout the station decreases to close to the anisotropy value of oil at the mouth of the bay due to pipe leakage. The entropy and alpha parameters did not change much. This can be used as evidence that the anisotropic change in the Multi-temporal distribution of the oil spill in Balikpapan Bay is an intrusion from the oil spill due to pipe leakage.

4. Conclusions
Multi-temporal distribution of oil spills in Balikpapan Bay in March, April, and May 2018 has a significant difference in the upstream and mouth of the bay due to pipe leaks on March 31, 2018. Characteristics of oil spills upstream represented by stations 4 and 5 have lower anisotropy values than those at the mouth of the bay represented by stations 1 and 2. Characteristics of oil spills in Balikpapan Bay have differences before and after an oil spill due to pipe leakage as indicated by the decrease in anisotropy values.

References
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