# Initiating Oil Spill Drift Model with Thickness Variations

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## Introduction

Oil spill contingency and preparedness planning requires near-real-time and relevant information about a potential oil slick. Oil slicks can cover several square kilometres at sea and forecasting the drift from a large spill might result in even more uncertainties in the drift and fate of the oil. For several decades, Synthetic Aperture Radar (SAR), has been used to detect oil slicks at sea. Oil slicks can be detected because of its damping effect of the small-scale roughness [1]. With the launch of Sentinel-2 satellites, the use of optical satellite data for detecting and classifying oil slicks has increased. Oil slicks might have a different appearance and slightly different spectral signature compared to the surrounding sea and can thus be detected in optical satellite imagery given appropriate sun glint conditions [2]. Following an oil slick detection in either SAR or optical, information about thickness related to actionable oil is of essence. Only a small fraction of the slick contains thick actionable oil, and this is of special interest. Therefore, initiating the drift model based on varying thickness levels should provide more realistic results for the oil spill forecast. Information about the relative oil slick thickness can be extracted from optical using the visual appearance of oil and connecting it to the Bonn Agreement Oil Appearance Code or by using the infrared channel [2]. For SAR, the relative oil slick thickness can be obtained through the damping ratio, which is a contrast between the backscatter from clean sea and oil. This has been shown, in previous studies and laboratory experiments, to be a proxy to relative oil thickness [3]. This study demonstrates how to initiate the drift model from oil masks with thickness variations extracted from both SAR and optical. This way information about the thickest parts of the oil can be incorporated into the forecast, thus focusing efforts in a potential clean-up scenario.

## Study Area and Data Set

For this study, we are using two Sentinel-1 and two Sentinel-2 scenes from the Java Sea (see Figure 1) that covers an oil spill event that took place in 2019 [4] shown in Table 1. Figure 2 shows the VV-intensity images, where the dark patches are oil slicks spilled from the platform. The damping ratio is automatically calculated from the VV-intensity image by estimating the average clean sea profile and dividing this by the image (sigma-0). The damping ratio has been shown, with some limitations, to be a proxy for relative oil thickness. Internal variations across the slick can be seen in the bottom panel of Figure 2. Sentinel-2 scenes are shown in Figure 3, where we have calculated the ratio, SWIR/BLUE, which represents short-wave-infrared divided by the blue spectral channel.

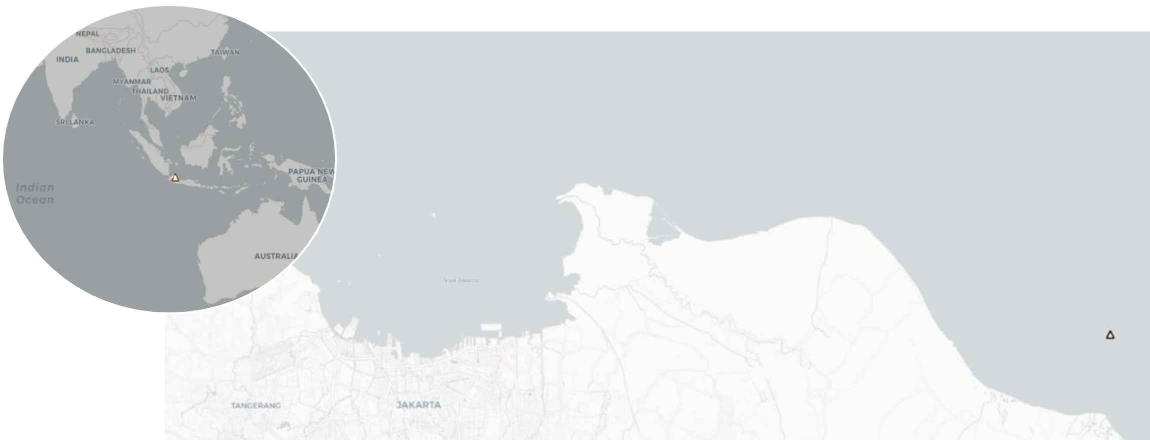


*Figure 1  Overview of the area where the oil spill occurred (from white marker) in 2019.*

According to [5], this parameter shows good contrast between both the oil and clean sea, and between thin and thicker oil, since thick oil is “warmer” than thin oil (sheen) in the infrared channel. The left panel of Figure 3 shows the manually drawn mask (thin and thick oil) using SWIR/BLUE, that has been extracted by visual inspection of the parameter.

*Table 1: Satellite data used for this study.*

| Sensor | Type | Date |
|---|---|---|
| Sentinel-2 | Optical | 03-08-2019 |
| | | 08-08-2019 |
| Sentinel-1 | SAR | 31-08-2019 |
| | | 07-09-2019 |

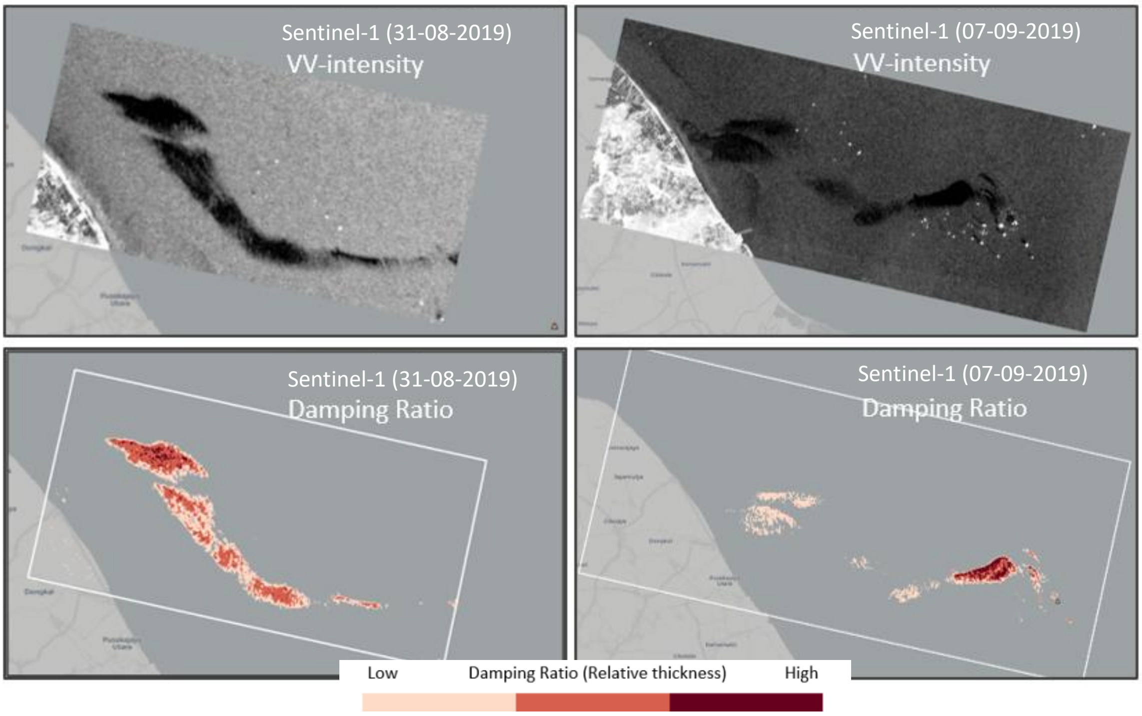


*Figure 2 Top: VV-Intensity images of the Sentinel-1 scenes containing oil slicks (dark features). Bottom: damping ratio calculated from the VV-Intensity data. Contains modified Copernicus Sentinel data 2019, processed by KSAT.*

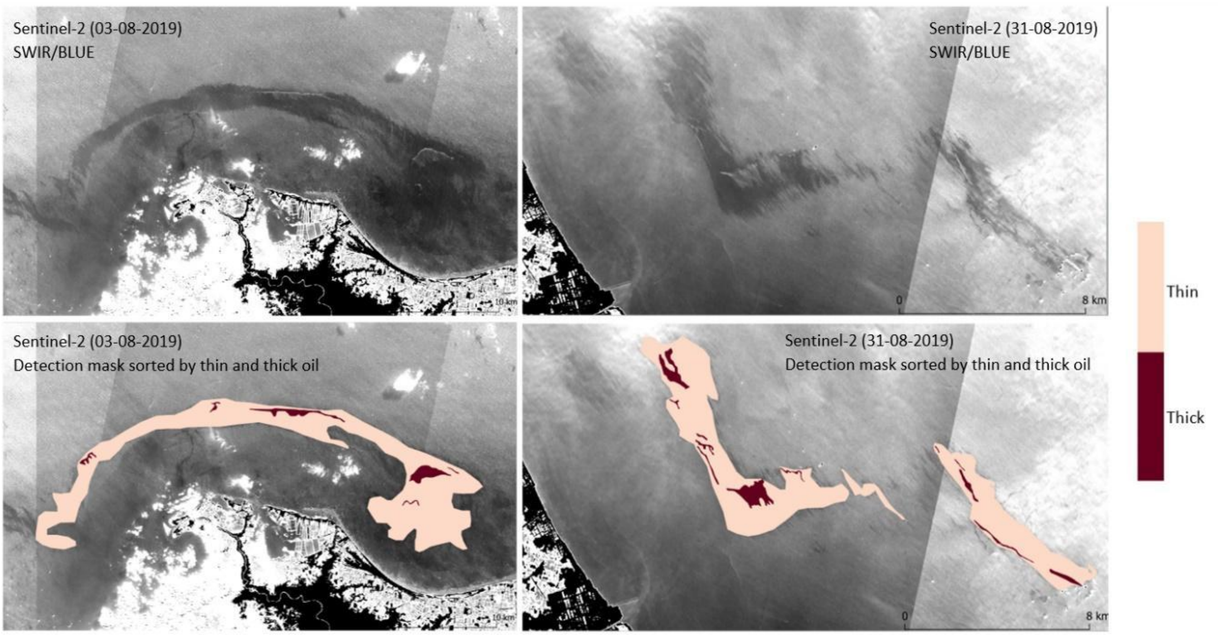


*Figure 3 Top: SWIR/BLUE from Sentinel-2. Bottom: Detection mask manual drawn from the left-most images, where light pink is thin oil and dark red represents thick oil. Contains modified Copernicus Sentinel data 2019, processed by KSAT.*

**Drift Model and Input Parameters**

In this study we are using the OpenDrift model (https://github.com/OpenDrift, [6]) to estimate the drift of the oil, with ocean current model from the global HYCOM model (hycom.org), and wind from the global NCEP GFS model as input. The physical processes of the OpenOil module of OpenDrift is described in [7], and application to another case study is described in [8]. OpenOil is coupled to the ADIOS oil library developed by NOAA, which is also available as an open source Python library.
For this study case we are using oil type *Jatibarang*, and we are comparing two different ways of initiating the drift model:

*1)* Weight number of particles and volume based thin (low damping ratio) or thick oil (high damping ratio).
*2)* Homogeneous distribution of the oil particles and volume for the entire oil slick mask.

In both cases the surface oil film thickness is updated during the model run, by summing the mass of oil within a grid with cells of approximately 1x1 km, and assuming equal spatial distribution within each grid cell.

**Results, Conclusion, Limitation, and Future Remarks**
The top- or left-most panels of Figures 4-6 illustrate how we initiated the model (T = 0) using two Sentinel-1 and one Sentinel-2 by thickness variations or by a homogenous distribution of oil particles in the entire slick mask. For Sentinel-2 (Figure 4), two thickness classes are detected based on visual interpretation of SWIR/BLUE. For Sentinel-1 (Figures 5 and 6), three thickness classes are semi-automatically extracted using thresholding of the damping ratio followed by smoothing and merging for easier initiating of the model by the different polygons.

The oil drift model is run with an internal time step of 60 minutes, and Figure 4-6 shows the locations and thickness after e.g., 24 h and 72 h (see Figure 4 and 5), or 6h and 48 h (see Figure 6). The colors represent the surface oil film thickness (with colorbar to the right) calculated by averaging surface oil amount in bins of 100x100m

Comparing left vs. right (Figure 4) or top vs. bottom (Figures 5 and 6) panels in the three figures, some differences can be observed in both the locations of the overall cloud of oil particles and the thickest oil patches. From Figure 5, the location of the thickest areas is completely different when comparing the top-center vs. top-bottom, and top-right vs. bottom-right figures. Having initiated the model with the additional thickness information extracted from the satellite imagery, we are able to point out where a potential clean-up operation should start. The same observations apply for Figure 6, but Figure 4 only shows slight differences between the two scenarios.

Initiating the model with thickness variations might have less impact if the spatial and temporal scales of the drift are large compared to the thickness variations within the slick, and we therefore believe this is more important for short-term forecasting of potential actionable oil.

A lot of effort was put into extracting thickness variations from Sentinel-2 (using SWIR/BLUE) and thresholding, smoothing, and merging of the damping ratio values from Sentinel-1. Some work is needed to make this process fully automatic in future. In conclusion, using both location, slick extent, and thickness variations from satellite images as inputs to the drift model we can (in theory) increase confidence on the prediction of the slick extent and track the actionable oil. This is information that would be relevant in a potential recovery operation. For this study, we do not have the ground truth of where the oil was heading, and the presented results only demonstrate the concept and potential.

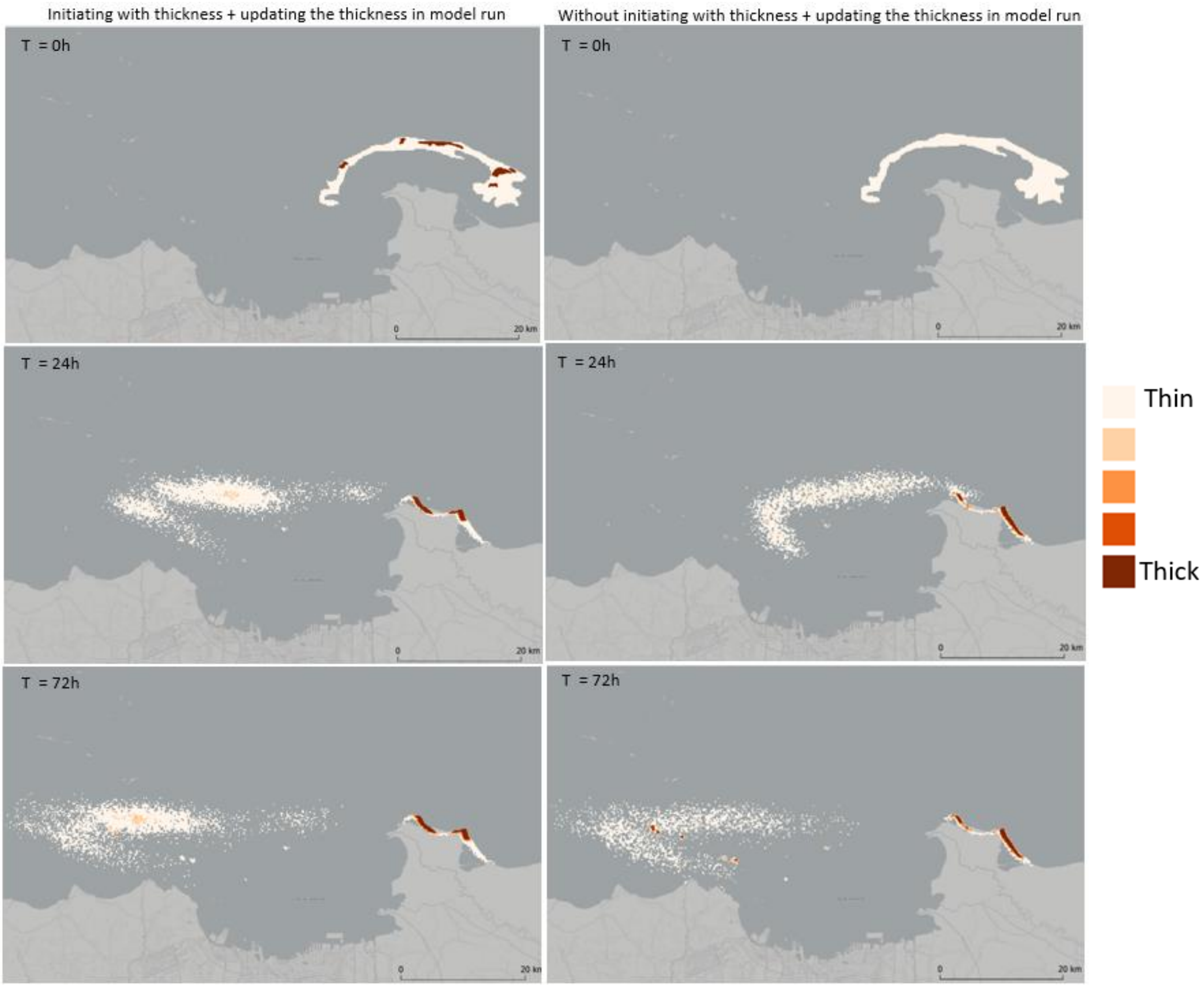


*Figure 4 Output oil film thickness from the drift model initiated with oil slick masks from the Sentinel-2 scene acquired 3/8/2019.*

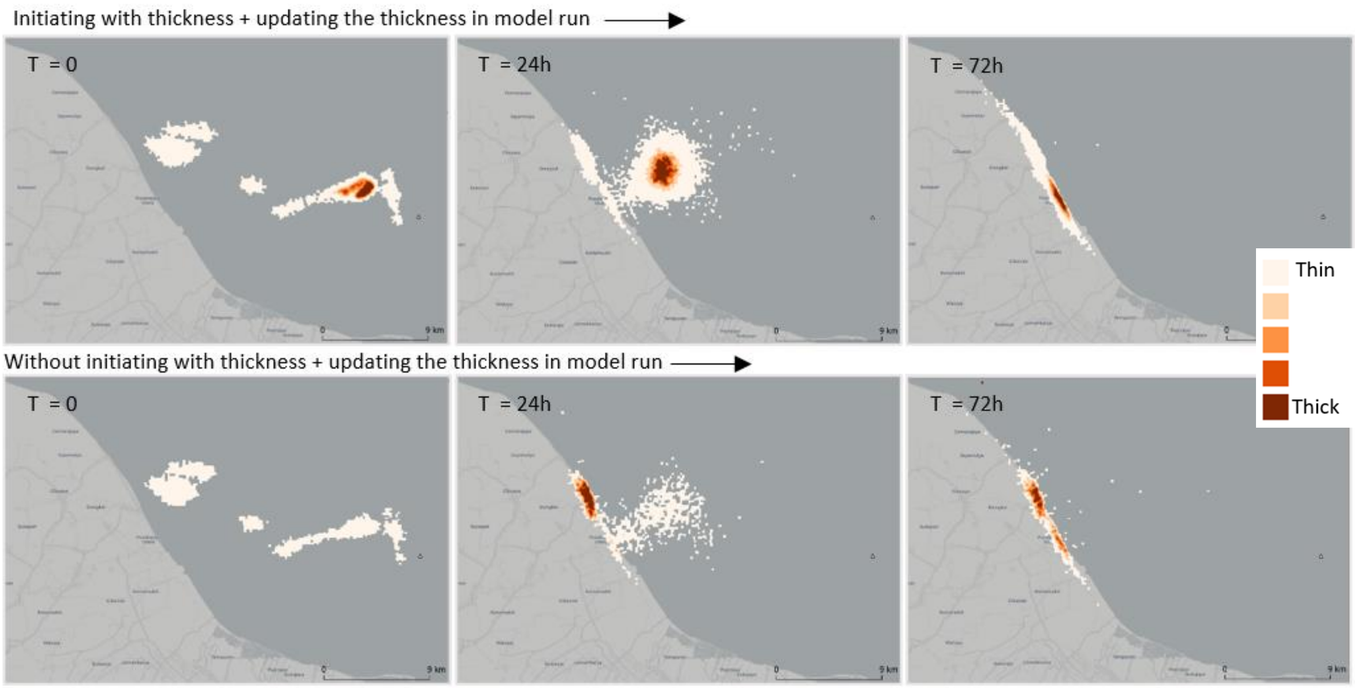


*Figure 5 Output oil film thickness from the drift model initiated with oil slick masks from the Sentinel-1 scene acquired 7/9/2019.*

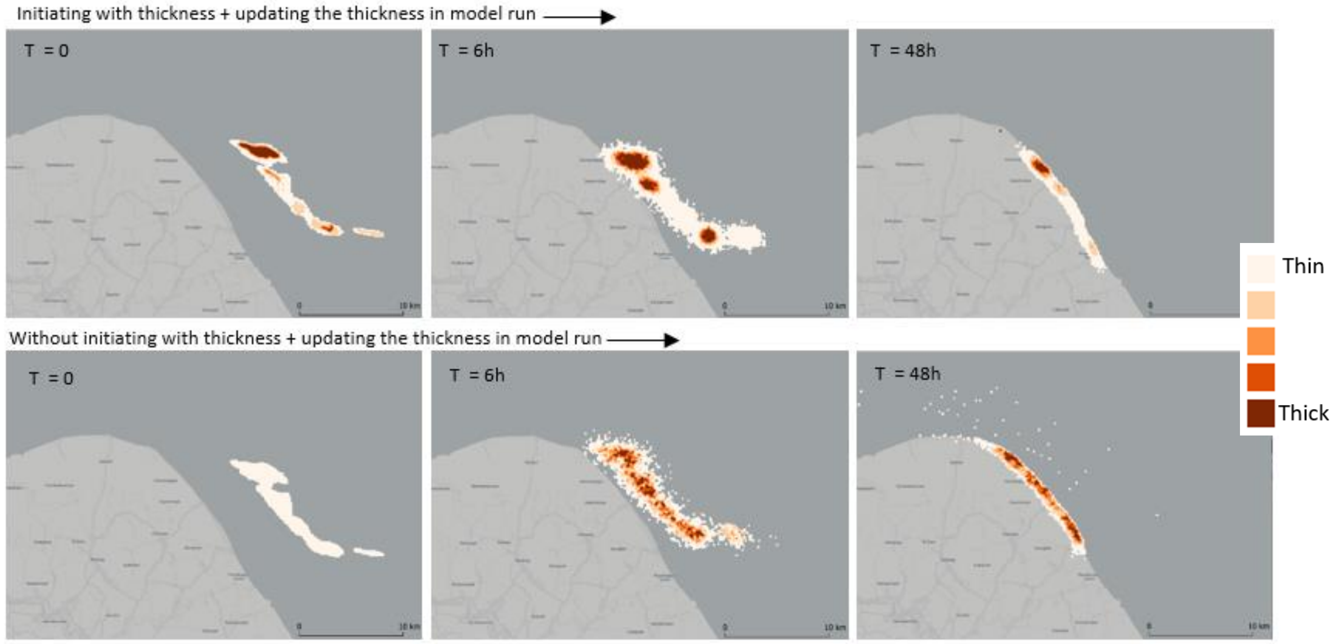


*Figure 6 Output oil film thickness from the drift model initiated with oil slick masks from the Sentinel-1 scene acquired 31/8/2019.*

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