MONITORING SURFACTANTS POLLUTION POTENTIALLY RELATED TO PLASTICS IN THE WORLD GYRES USING RADAR REMOTE SENSING

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ABSTRACT

Plastics within the ocean have been found to be colonised by microorganisms that, as a by-product of their metabolism, produce surfactants. Short capillary waves on the sea surface can get dampened due to the increased surface elasticity of these surfactants. Radar satellites are sensitive to surface roughness and can therefore detect the dampening of these waves. This research investigates areas inside the Atlantic, Pacific and Indian Ocean gyres using ESA Sentinel-1 and DLR TerraSAR-X data. We found out that we can observe several surfactant instances in the gyres and these are not correlated to medium or high level of chlorophyll. We can exclude that they have origin in biogenic slicks. Among other possible unknown origins, we hypothesise that these surfactants are produced from plastic concentrations within the ocean.

***Index Terms*—** SAR, Plastic, Surfactants,

1. INTRODUCTION

Plastic pollution within ocean waters has seen a growth of research within the past decade. Buoyant plastics have been found to create garbage patches within ocean gyres, most notably the Great Pacific Garbage Patch. However, evidence of plastic pollution has also been found within the Atlantic Ocean gyre and the Indian Ocean gyre.

More recently, it has been shown that the polarimetric information in SAR images can be utilized to identify surfactants, and therefore oil spills [1][2]. Within areas of oil slicks, non-Bragg scattering is dominant, conversely, Bragg scattering is dominant in slick-free sea surfaces [2]. Additionally, polarimetric decomposition parameters such as entropy values and average alpha angle are significantly higher within oil slicks on the sea surface compared to those of an ambient sea surface [3]. It has been observed [4] that surfactants in the ocean can also be produced by microbes, some of which reside on plastic debris. Therefore, the same polarimetric information can be utilized to identify slicks related to plastic pollution.

2. METHODOLOGY

Many studies have reported the colonization of plastic debris by bacterial phyla. A range of microbes have been found residing on plastic debris found in ocean waters, including: alphaproteobacterial, roseobacteria and gammaproteobacterial groups [5], rhodobacterales, rhizobiales, streptomycetales, cyanobacteria, actinobacteria and betaproteobacteria, small flagellates, dinoflagellates (Ostreopsis sp. and Coolia sp.) and vegetative cells of Alexandrium taylori [6].

Synthetic Aperture Radar (SAR) is capable of monitoring continuously with the ability to penetrate cloud cover and good resistance to weather conditions. SARs sensitivity to surface roughness makes it particularly valuable in monitoring oceans, where it has primarily been used to retrieve wind speeds and currents of the sea surface. However, SAR has also been used to detect oil pollution. This detection process is often related to the dampening of short capillary waves from oil spills, which produces a reduction of roughness of the sea surface. Substances that dampen surface waves by changing surface tension are called surfactants [7].

High microbial activity in water has been observed to produce by-product substances that accumulate as surfactants on the water surface. High concentrations of surfactants can be accumulated by eddies [8]. Surfactant biofilms are capable of forming over the ocean surface and therefore decrease the surface elasticity. Additionally, these biofilms reduce the surface tension of water. If winds are not too strong, these surfactant biofilms are capable of a reduction in small gravity and capillary waves on the sea surface [9]. As a consequence of the latter, small-scale surface roughness of the sea can be reduced.

The hypothesis that this research follows is that we can use SAR to detect the effect of surfactants produced by microbes colonising the plastic. Due to the influence of differing surfactants concentrations on surface waves, Bragg-scattering will be affected [10]. These areas of surfactants are easily visible in SAR images during low to medium wind speeds (up to 8m/s) due to the dampening of small capillary waves and reduction in sea surface roughness.

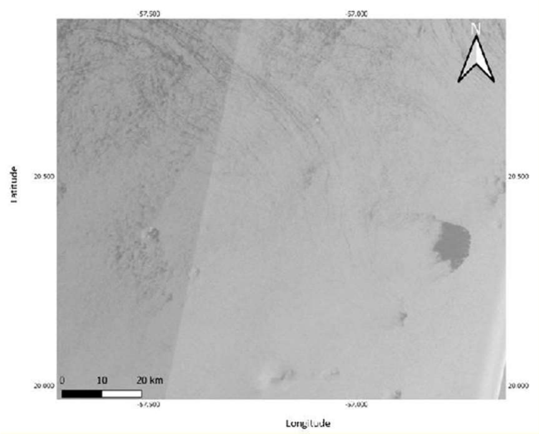

Figure 1. SAR image of the Atlantic Ocean acquired 12 June 2014. (Sentinel-1, Credits: ESA).

2.1 Testing hypotheses

In this work we want to test the hypotheses that the dark stripe features we observe in the gyres are surfactants and are not produced by algal blooms.

For images where dark stripe features were present (as seen in Figure 1), variables were tested to confirm that these were indeed produced from surfactants. At higher wind speeds, typically above $8ms^{-1}$, reduced appearance of sea surface slicks can be found [11]. Daily wind speed is routinely estimated by using scatterometers and it is available from the ESA Copernicus Climate Data Store.

Areas with and without visible features (dark stripes) were selected for statistical testing.

The F-tests and T-tests were used to determine any significant differences in the variable variances and means between locations with visible features and those without.

Ocean colour data, collected from NASAs Ocean Biology Processing Group was used to determine the concentration of chlorophyll-*a* within the SAR images. This allowed for areas of high biogenic activity to be accounted for as they can produce surfactant look-alikes.

2.2. Data processing

Dual-polarimetric Sentinel-1 SAR data, provided by ESA, was processed using the Sentinel Application Platform (SNAP). These images were calibrated and a multilook of 4 was used to reduce noise. TerraSAR-X data, provided by DLR, was also provided. This data offered SAR images of the Indian Ocean, Atlantic Ocean, Pacific Ocean and Hudson Bay.

Hudson Bay was selected as a control site as it has an average 0.22 ± 0.23 plastic particle per litre of surface water [14]. Which is low when compared with more 'dirty' aquatic environments tested: The Atlantic Ocean, Indian Ocean and Pacific Ocean.

3. RESULTS

Possible surfactant features were identified in the Atlantic, Indian and Pacific Ocean, as seen in Figures 2., 3., and 4.

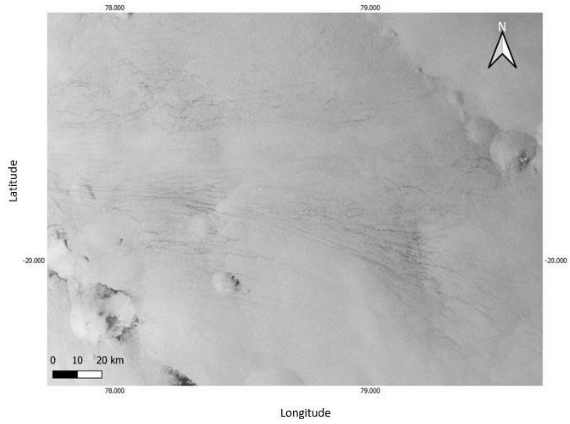

Figure 2. SAR image of the Indian Ocean acquired 08 February 2018. (Sentinel-1, Credits: ESA).

Wind speed data was tested for the selected coordinate locations. In the Atlantic, Indian and Pacific Ocean, all tested locations with visible features had wind speeds of < 8m/s, the wind speed found to fade surface films into underlying waters. Due to the limitation of space here we only present a few examples of the tested wind speeds can be seen in Figure 5 and Figure 6. In the presentation we will include all the graphs.

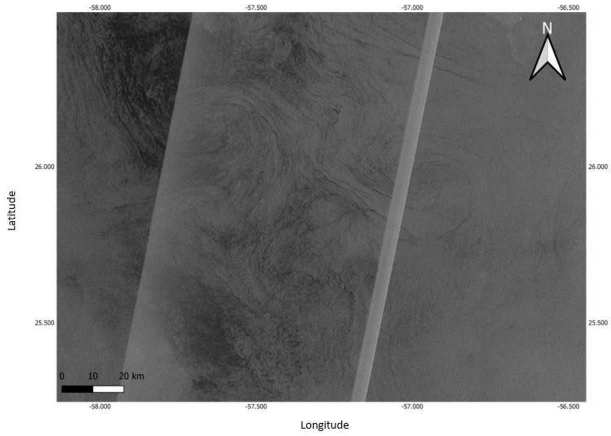

Figure 3. SAR image of the Atlantic Ocean acquired 12 June 2014. (Sentinel-1, Credits: ESA).

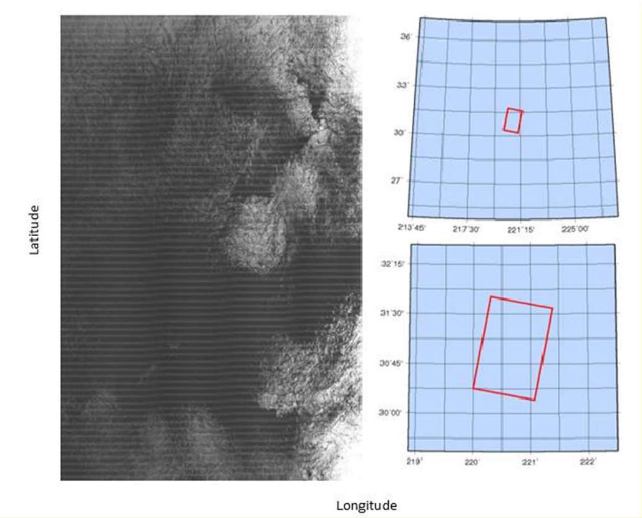

Figure 4. SAR image of the Pacific Ocean acquired 16 June 2013. (TerraSAR-X, Credits: DLR).

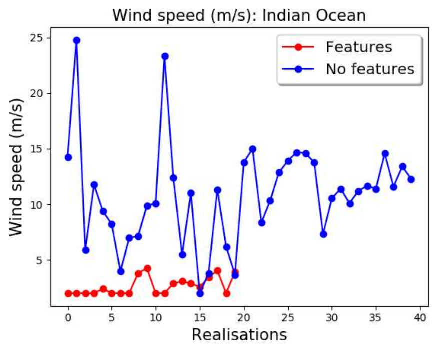

Figure 5. Wind speed data of visible features vs no features over separate realisations within the Indian Ocean.

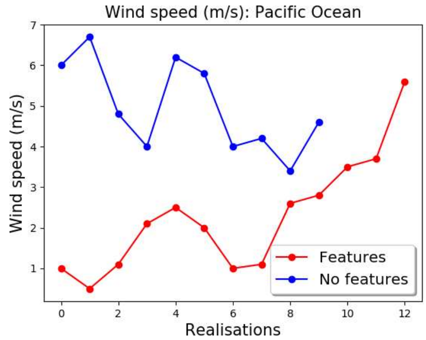

Figure 6. Wind Speed data of visible vs no features over separate realisations within the Pacific Ocean.

The statistical testing found a significant difference of wind speeds between visible features and no features, which further strengthens that the dark stripes seen within the tested images are indeed from surfactants. Therefore, lack of dark stripes in locations tested for no visible features suggested two conclusions: 1) There is a lack of surfactants within the tested location; 2) Wind speeds are high enough to incorporate surface films into the underlying waters causing them to fade from view in the images.

After the surfactants were identified, the chlorophyll-*a* concentrations were tested at each location to understand if these were produced by algal blooms. In the Atlantic, Indian and Pacific Ocean, all tested locations had low chlorophyll-*a* concentrations (below 0.134mg^{-3} maximum concentration within all 3 oceans), where it is not expected that chlorophyll is producing these biogenic surfactant features within the images. An example of the tested chlorophyll values can be seen in Figure 7 & 8.

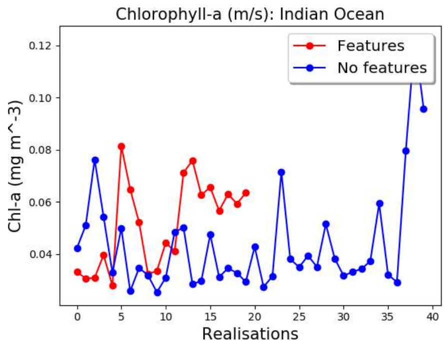

Figure 7. Chlorophyll-*a* data of visible features vs no features over separate realisations within the Indian Ocean.

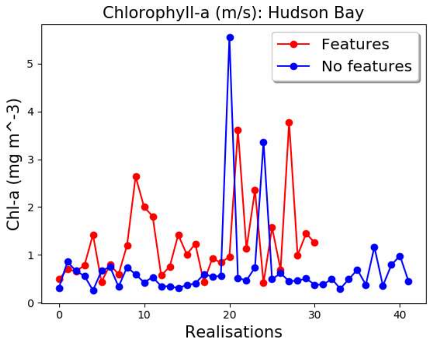

Figure 8. Chlorophyll-*a* data of visible features vs no features over separate realisations within Hudson Bay.

In the Hudson Bay, we did not identify any surfactant-like feature that was not correlated with high chlorophyll, as seen in Figure 7.

With chlorophyll-*a* concentrations within the Atlantic, Indian and Pacific oceans being so low, it is not expected that chlorophyll is producing biogenic surfactants visible in the SAR imagery. Due to chlorophyll not appearing to be the determining factor within the visibility of these surfactants, their presence must be related to other factors.

4. CONCLUSIONS

SAR images of the Atlantic, Indian and Pacific Ocean showed dark stripes within the imagery. Testing of coordinates from each ocean has shown that these dark stripes are visible at wind speeds < 8m/s. This is evidence that these dark stripe features are most likely produced from surfactant films on the water surface. Further testing has proven that these surfactants were not produced by a chlorophyll-*a* biogenic means and therefore must be produced from another source. Due to the occurrence of ocean garbage patches within these locations and the prevalence of surfactant-producing microbes that inhabit plastic pollution, this corroborates the idea that these dark features are produced by an unknown source of surfactants, which we hypothesise is plastic pollution within the marine environment.

5. ACKNOWLEDGEMENT

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