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Observing Oil Releases from Platforms Using Synthetic Aperture Radar

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INTRODUCTION

Synthetic aperture radar (SAR) is used for operational surveillance of ocean areas and oil spill detection [1]. Oil spills are frequently detected around oil platforms due to the releases of so-called produced water (PW) (see, e.g., [2]), which is water containing low concentrations of oil that can form surface slicks similar to other oil spills. PW releases are legal within given limits. Understanding the signatures of produced water and how they are related to, e.g., the relative oil volume and/or concentration can be helpful for the operational services. For example, distinguishing a "normal" release of produced water from an "abnormal" release (elevated amounts) in a SAR image is currently an unsolved problem. Very little research on these topics have been done before.

The objective of this study is to investigate the characteristics of produced water SAR signatures and how they depend on, e.g., the properties of the release (oil volume, concentration), environmental conditions and sensor properties.

PROJECT BACKGROUND & DATA COLLECTION

- Produced water is water from the reservoir that has been separated from the oil and gas at the platform, but that still contains small concentrations of oil.
- Release of produced water is legal for concentrations up to 30 mg/L (Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) requirement.)
- Although the concentration of oil in PW is low, the releases can form surface slicks that are clearly detectable by SAR.
- In Norwegian waters, platforms are monitored daily using satellite SAR. Differentiating between low concentration releases of produced water and larger releases of oil is a challenge for the detection services.

Figure 1: The oil platform Brage located in the North Sea, about 120 km northwest of Bergen, Norway. Image is courtesy of Wintershall/Morten Berentsen.

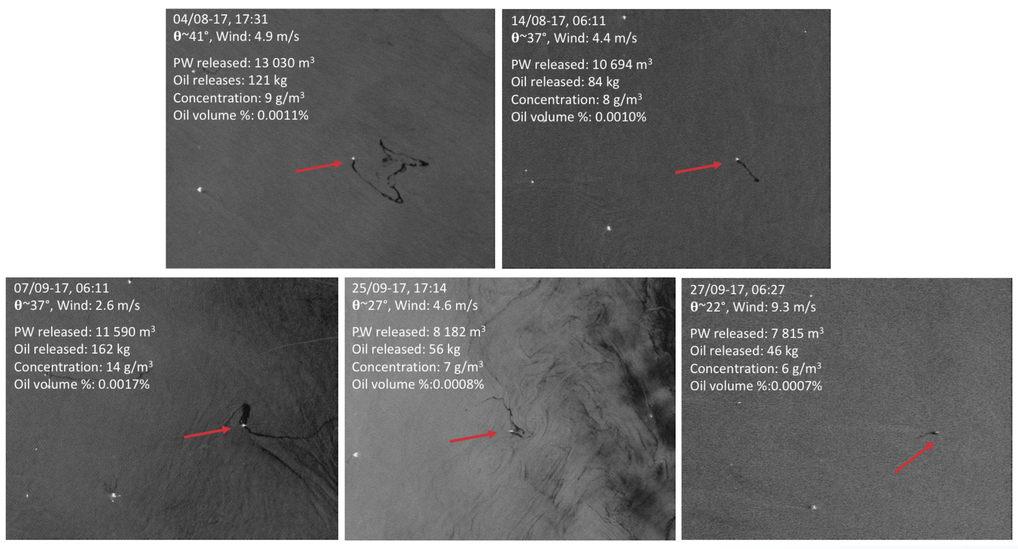

Figure 2: Radarsat-2 Fine Quad-polarization scenes with detections of oil slicks close to Brage (indicated with red arrow). Information on acquisition time, incidence angle (θ), wind conditions, and release properties are included for each scene. RADARSAT-2 Data and Products ©MDA LTD. (2017) – All rights reserved.

- In the fall of 2017, a project focusing on SAR observation of produced water was started up. The platform Brage (Fig. 1) was selected as a test site for the project.
- The project is a cooperation between UiT and industry partners including
  - *Wintershall:* operator of the Brage platform,
  - *Norwegian Clean Seas Association for Operating Companies (NOFO):* responsible for oil spill response on behalf of the oil companies, and
  - *Kongsberg Satellite Services (KSAT):* delivers the operational oil spill detection service for Norwegian waters.
- The first data collection took place August-October 2017, and focused on acquiring Radarsat-2 (RS-2) Fine Quad-pol. (FQ) data.
- In addition, in situ measurements of the PW releases and weather observations at the platform were provided by Wintershall.
- Out of 13 acquired scenes, five contained visible slicks, see Fig. 2.
- For the remaining scenes, high wind (mainly above 8 m/s) was probably an important factor preventing the detection of slicks.
- The PW slicks are most often detected in low-medium wind conditions, as shown in Fig. 3, where detections by KSAT around Brage over the course of about one year is plotted.
- The produced water contains very low concentrations of oil (see, Fig. 2), and will have a limited effect on the dielectric constant (ε) of the observed surface (see, Fig. 4). Hence, damping of small-scale waves is probably the main detection mechanism.

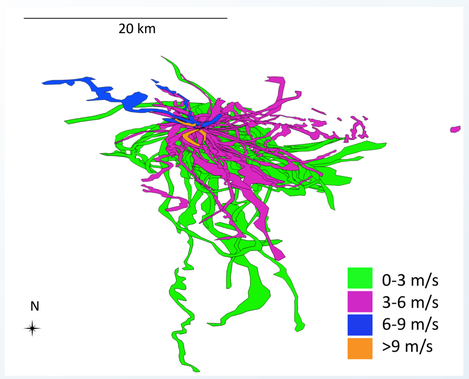

Figure 3: Detections over Brage from October 2016 to September 2017 for various wind speed regimes. Figure based on detections and information from KSAT.

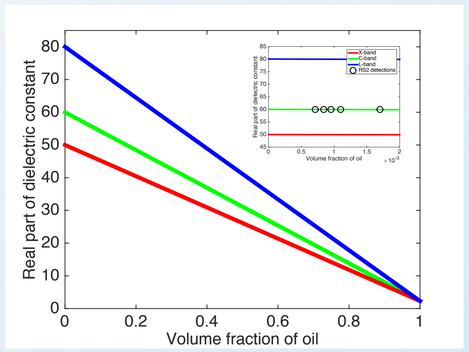

Figure 4: Real part of the dielectric constant as function of volume fraction of oil in oil-water mixtures for various SAR frequency bands (see [3] for details on calculations).

PRELIMINARY RESULTS

RS-2 FQ data and damping ratio:

- The damping ratio (DR) is used to quantify the slick-sea contrast, and is here calculated as the ratio between the VV intensity in clean sea and in the oil slick. Results are shown in Fig. 5.

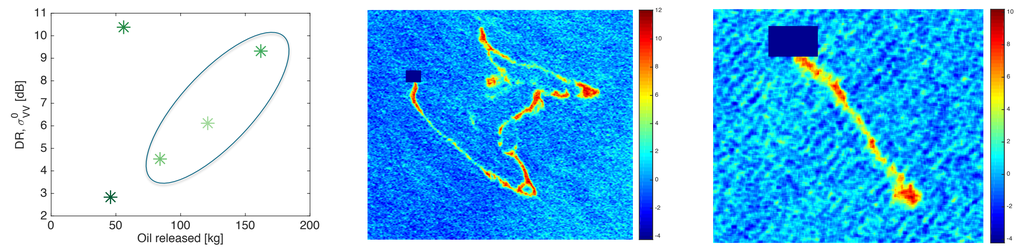

Figure 5: Left: DR vs. oil volume released. Scenes with similar incidence angle and wind speed are indicated with an ellipse. Middle and right: plot of DR [dB] for the top two scenes in Fig. 2. The platform is masked out to enhance contrast (blue box).

- As the incidence angle (θ) and wind speed (WS) vary between acquisitions, all scenes are not directly comparable. Three scenes with similar θ (37°-41°) and WS (2.6-4.9 m/s) are indicated with an ellipse in Fig. 5.
- For these scenes, there seem to be an increase in DR with oil volume released.
- However, only a few data points are available, and the oil volume is currently only provided once every 24 hours. Hence there is some uncertainty in the oil volume present at the time of the SAR acquisition.
- Although the PW releases contain low concentrations of oil, there are clear internal variations in the DR, which may be related to areas with varying oil thickness or concentration.

RS-2 FQ data and co-pol. ratio:

- The co-pol. ratio, i.e., the ratio between mean HH intensity and mean VV intensity, is independent of small scale roughness and can be used to evaluate changes in the dielectric properties [4].
- Fig. 6 shows that the difference in co-pol. ratio values between clean sea and oil slicks seems to increase with the oil volume in the release. Hence, the dielectric properties may be affected, at least for larger volumes of oil.
- As the starting concentration of the produced water is too low to be expected to affect the ε (see, Fig. 4), this may indicate that the oil component of the PW concentrates at the surface.

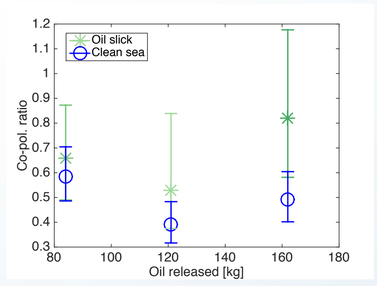

Figure 6: Co-pol. ratio vs. oil volume released for the scenes with similar θ and WS. Vertical lines are plotted between the 5th and 95th percentile in blue and green for clean sea and oil slick, respectively.

RS-2 FQ vs S-1 IW:

- For two of the RS-2 FQ scenes, Sentinel-1 (S-1) Interferometric Wide Swath (IW) scenes were acquired simultaneously at the same θ.
- The DR and the Coefficient of Variation (CV) for the two scene pairs are shown in Fig. 7 and Table 1, respectively.
- An increase in the DR as the oil volume increases is observed for both sensors, but is smaller in S-1 than for RS-2.
- In the oil slicks, RS-2 has larger CV than S-1, i.e., more internal variation, which could indicate that RS-2 contains more information about internal zones and variations.
- For clean sea areas, the CV for the two sensors are similar.
- As only one channel is used to calculate DR and CV, resolution is the main difference between RS-2 and S-1 scenes here. DR and CV were recalculated after additional multilooking were applied to the RS-2 data to emulate lower resolution, but this had little effect on the values and between-sensor differences.
- In the future, a more thorough emulation of more comparable resolutions, noise floor etc. will be carried out to further investigate these differences.

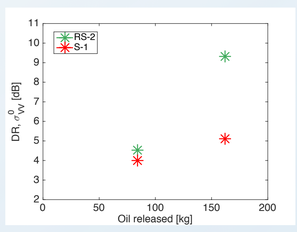

Figure 7: DR vs. oil volume released for the two RS-2/S-1 scene pairs.

Table 1: CV for the two RS-2/S-1 scene pairs.

	RS-2 Oil/sea	S-1 Oil/sea
14/08/17	0.32 / 0.23	0.27 / 0.24
07/09/17	0.23 / 0.25	0.17 / 0.25

CONCLUSIONS AND FUTURE OUTLOOK

- Preliminary results show a possible increase in damping ratio as oil volum (and concentration) in the PW release increases.
- A larger variation in slick-sea contrast and larger internal variation is found in high-resolution RS-2 FQ data compared to in S-1 IW data.
- This preliminary study will be expanded in the future to include a larger data set and more comparable remote sensing and in situ information.
- The data collection continues in 2018, collecting both high-resolution multi-polarization data and lower-resolution single/dual-polarizaion data.
- Increased emphasis is put on collecting more detailed in situ information with higher temporal resolution to allow a more in-depth study of the SAR data and the relation to oil release properties.

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