

AN INTEGRATED OIL SPILL PLANNING, MONITORING AND FORECASTING SYSTEM FOR THE ARABIAN GULF

Alexis Culot¹, Nylan Ramnauth¹, Jean Bouchat¹, Thomas Dobbelaere¹,
Pierre Defourny¹, Essam Heggy^{2,3,4} and Emmanuel Hanert¹

¹UCLouvain, Earth and Life Institute, Louvain-la-Neuve, Belgium

² Viterbi School of Engineering, University of Southern California, Los Angeles, CA, USA

³ Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA

⁴ Qatar Environment and Energy Research Institute, Hamad Bin Khalifa University, Doha, Qatar

ABSTRACT

An integrated method for oil spill planning, monitoring and forecasting is presented. First, the method identifies sea areas from where an oil spill is most likely to reach a sensitive coastal infrastructure. Then, we use a SAR oil spill detection algorithm to identify and monitor oil spills over the areas presenting the largest risk. Finally, we use an oil spill dispersal model to forecast the drift of the detected oil spills. A preliminary version of this system is presented for Qatar's territorial waters in the central Arabian Gulf.

1. INTRODUCTION

Oil exploration, transportation and processing have significantly increased in recent decades to meet an ever-increasing energy demand. These developments led to an increase in marine oil pollution [1]. In addition to being environmental disasters, oil spills are also a threat for coastal facilities as they can e.g. impede maritime traffic, clog desalination plants intakes and cause damage to fishing and aquaculture. The Persian/Arabian Gulf (the Gulf) is one of the most oil-polluted sea in the world. It is a major passage for oil tankers, with 20,000-30,000 tankers movements per year. The Gulf also includes 34 major oilfields that are exploited by 800 wells and 40 major oil terminals. On average, 100,000-160,000 tons of oil are accidentally or intentionally released in the Gulf annually. To mitigate the consequences of oil pollution, it is important to detect oil spills as early as possible and predict which areas are most likely to be impacted. Orbital synthetic-aperture radar (SAR) images are the most effective products to monitor oil spills over large areas [2]. While the timeliness and short revisit period of current SAR imagery makes building automated oil spill detection system possible, it still requires to preidentify specific high-risk areas to optimize the revisit period. Once detected, an oil spill can be used as input data for an oil-spill dispersal model to simulate its future drift (to predict where it will go) and its past drift (to predict where it came from). In this study, we present an integrated system

that combines oil spill detection in predefined high-risk sea areas and the subsequent simulation of their past and future drift.

2. METHODS

The oil spill detection and forecasting system described in this study is based on 3 main components: (1) Identification of high-risk sea areas, (2) automatic SAR early detection and (3) oil spill dispersal forecasting.

2.1. Identification of high-risk areas for response planning

We identify offshore areas presenting the highest risk for an oil spill released there to reach a key coastal infrastructure by simulating the dispersal of oil particles *backward in time* from those coastal infrastructures. Those simulations are carried out for each day of the year and over 5 consecutive years. We hence obtain an ensemble of trajectories starting from the coast and moving backward in time. By meshing the sea surface with a 1km grid, we can compute the number of trajectories intersecting each grid element. By dividing that number by the total number of trajectories originating from the coastal infrastructure, we obtain the probability for an oil spill released in an offshore grid element to reach the coastal infrastructure. The resulting probability spatial distribution can then be combined with a maritime traffic density map (taken as a proxy of oil pollution risk) to estimate the exposure of coastal infrastructures to oil spills produced by maritime traffic.

2.2. SAR oil spill detection and monitoring

We detect oil spills from ESA Sentinel-1 SAR images. The first step consist in preprocessing the Ground Range Detected (GRD) SAR images with the "Sentinel Application Platform" (SNAP). The main preprocessing steps are speckel filtering,

beta-nought and sigma-nought calibration and land-sea-mask generation. The images can then be used in the detection algorithm. It is based on an adaptive thresholding method that can separate objects of interest, here the oil slicks, from the background. However, some objects (called "look-alikes") can be wrongly identified as oil slicks [3]. To differentiate them from oil spills, a series of characteristics from the detected objects is extracted and then used to differentiate oil spills from look-alikes. These characteristics are separated into four classes: geometrical, physical, contextual or textural [2]. The training dataset is composed of 1112 SAR images and their detection masks representing the sea surface, land, oil spills, look-alikes and boats [4, 5]. A second dataset is composed of SAR images captured by Sentinel-1 and acquired through the Alaska Satellite Facility. For this project, we consider the the VV amplitude band of Level-1 Ground Range Detected (GRD) products. This polarization is known to be the most favorable for oil spill detection [6].

2.3. Oil spill drift modeling and forecasting

Once an oil spill is detected, we use the surface area covered with oil as the initial condition of an oil spill dispersal simulation. This is done with the OpenOil model, which is part of the OpenDrift trajectory modelling library developed at the Norwegian Meteorological Institute [7]. OpenOil is a Lagrangian model that represents an oil spill as an ensemble of particles that are transported by the 3D ocean currents, the waves and the wind. The oceanic model forcings are provided by the Copernicus Marine Environment Monitoring Service (CMEMS) and the atmospheric forcings come from the Global Forecast System (GFS) of the National Centers for Environmental Prediction (NCEP). Oil spills are subject to several weathering processes, such as evaporation, emulsifi-

cation and degradation, that change the oil chemical composition and physical characteristics. Oil dispersal simulations can be performed either forward or backward in time. The former represents the future evolution of the spill and indicates where the spill will go. The latter represents the past evolution of the spill and indicates where it came from. Both are useful in an operational system as they indicate where mitigation measures should be deployed and which vessel is the possible culprit of the pollution.

3. RESULTS

We have so far developed a prototype of this system by focusing on Qatar territorial waters, in the central part of the Arabian Gulf (Fig. 1). We have performed the oil spill risk assessment needed for the planning phase [8] and have identified two offshore areas where most of the shipping oil pollution exposure is concentrated (see grey rectangle and triangle Fig. 1a). They cover about 5,000 km², which is about 15% of Qatar's exclusive economic zone total area, but also extends out of it into Bahrain's coastal waters. The total size of those two areas can be entirely covered using one or two orbital SAR scenes, depending on the acquisition geometry (Fig. 1b). A combination of multiple SAR platforms in X and C bands for the defined areas can allow daily monitoring with a manageable data volume and reliable change detection to identify oil spills. Once an oil spill is detected, we can simulate its future trajectory (as illustrated in Fig. 1c) and hence estimate what volume of oil could reach a sensitive coastal infrastructure such as Ras Laffan's LNG terminal, and where oil mitigation measures should be deployed.

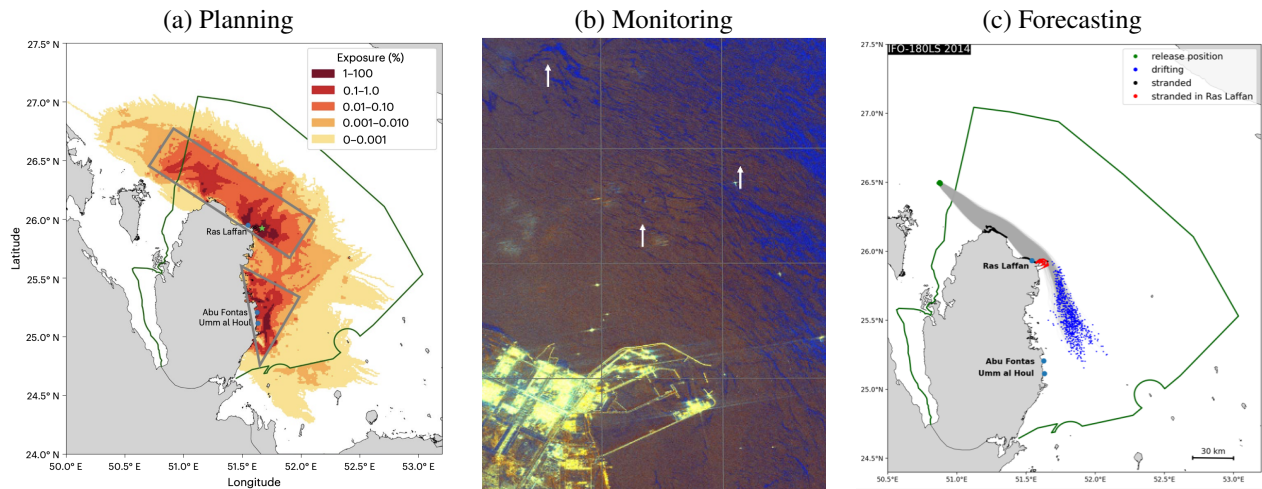


Fig. 1. Main components of the oil spill planning, monitoring and forecasting illustrated for Qatar coastal waters, in the central part of the Arabian Gulf.

4. REFERENCES

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