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Satellite Characterization of Methane Point Sources by Offshore Oil and Gas PlatForms †

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Abstract: Reducing methane, which is the second most important anthropogenic greenhouse gas after carbon dioxide, has been shown to be a good opportunity to mitigate global warming in the short to medium time. Remote sensing is nowadays a useful tool for the identification of anthropogenic emission from methane point sources. In this work, we will demonstrate the capability of high-resolution satellites to detect point sources of methane. Specifically, this study focuses on emissions from offshore oil and gas platforms using sun-glint mode acquisitions, as these platforms represent a significant fraction of total emissions and pose a challenging issue due to the low radiation from water.

Keywords: remote sensing; methane; O&G; sun-glint

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1. Introduction

Methane (CH_4) is a potent greenhouse gas that has become the second most important anthropogenic contributor to global warming after carbon dioxide (CO_2) [1]. Its atmospheric concentration has more than doubled since pre-industrial times and has an 86 times greater global warming potential than CO_2 over a 20-year period [2]. In addition, methane is involved in the formation of tropospheric ozone, which is also a potent greenhouse gas. This leads to the production of air pollutants, such as surface ozone, that can harm human health, ecosystems, and crops [3]. Currently, remote sensing technologies, such as high-resolution satellites, are employed to detect and accurately quantify these emissions as part of efforts to mitigate their impact. Satellites equipped with sensors capable of measuring backscattered solar radiation in the short-wave infrared (SWIR) spectral region can detect variations in signals that are associated with the absorption of methane [2].

The oil and gas (O&G) industry is a significant contributor to anthropogenic methane emissions, primarily due to various design and operational factors. Equipment leaks, flaring during extraction and processing, and intentional venting are the main causes of methane emissions [3]. The current challenge is to prove the ability of satellites to detect emissions on offshore O&G infrastructure, which represent approximately 30% of O&G global production [4]. Detecting these offshore emissions from space is more difficult than in the onshore case, due to the high level of water absorption in the SWIR. This limitation reduces the amount of reflected light that can reach the sensor, which in turn affects the sensor capabilities to differentiate methane absorption in the SWIR from instrument background noise or roughness of the sea surface [5]. The way to overcome the weak reflectance of water is using satellites measuring in the sun-glint mode [5,6]. The sun-glint effect occurs in imagery when the angle of the sun reflection on the water's surface is directly towards the sensor. This phenomenon is dependent on the sea surface state, as well as the position of the sun and the viewing angle of the sensor [7].

In this work, we have explored the capability of satellite-based optical imagers for the detection of CH_4 plumes emitted from offshore O&G platforms using sun-glint mode acquisitions. We have used data acquired by PRISMA, Sentinel-2 and Landsat 8-9 missions to detect CH_4 plumes in offshore platforms.

2. Materials and Methods

2.1. Study Areas

To constrain and select potential methane emissions source areas, we used the TROPOspheric Monitoring Instrument (TROPOMI) (Astrium, Paris, France), which is on board the Sentinel 5 Precursor (S5-P) satellite and provides daily global methane measurements data with low resolution. This allowed us to map emissions and deduce trends at the global scale. However, we found that TROPOMI offshore does not provide as reliable data as onshore, because it currently does not have a good sun-glint configuration. For this reason, we decided to focus the study on offshore platform areas provided by databases [8].

Then, using this information, we identified the specific point sources of emissions with multispectral (Sentinel-2 and Landsat 8-9) and hyperspectral satellites (PRISMA) in offshore platforms areas in the Gulf of Mexico, Malaysia, India, and Africa.

2.2. Methane Emission Detection

In this work, we used both multispectral and hyperspectral satellites for methane plume detection. On one side, high-resolution multispectral satellites have few broad bands that provide sensitivity to methane detection. Sentinel-2 and Landsat 8-9 have a high revisit time that allowed us to monitor the areas of interest. To obtain CH_4 retrievals, we applied the multi-band–multi-pass (MBMP) method defined by Varon et al. [9]. On the other hand, high-resolution hyperspectral satellites such as PRISMA have multiple narrow bands that provide high sensitivity to methane detection. However, the images are acquired on request. To obtain CH_4 retrieval in the hyperspectral data, we used the matched-filter method [9].

2.3. Verification of Methane Plume

Detected plumes have been confirmed by identifying the emitting point source with a high-resolution image. In addition, we verified that the emission direction is aligned with the wind direction using the NASA GEOS-FP wind data [10].

3. Results

3.1. Multiespectral Results

Using Sentinel-2 and Landsat 8-9, we have detected several methane plumes from an offshore O&G platform. Figure 1 shows a strong emission detected by Sentinel-2 from an offshore O&G platform in Malaysia on 23 April 2023. This plume was emitted while the platform was flaring the gas, and the flux rates values were 23 ± 8 t/h. On the other side, we confirm that at the time of the emission, the wind speed was 2.9 m/s in a northwesterly direction. In addition, other offshore point source emissions have been detected in infrastructures in the Gulf of Mexico, Africa and India. Multiple plumes have been detected on these platforms in recent years, venting significant quantities of methane into the atmosphere. The study has shown that most of these emissions were from unlit gas flaring platforms.

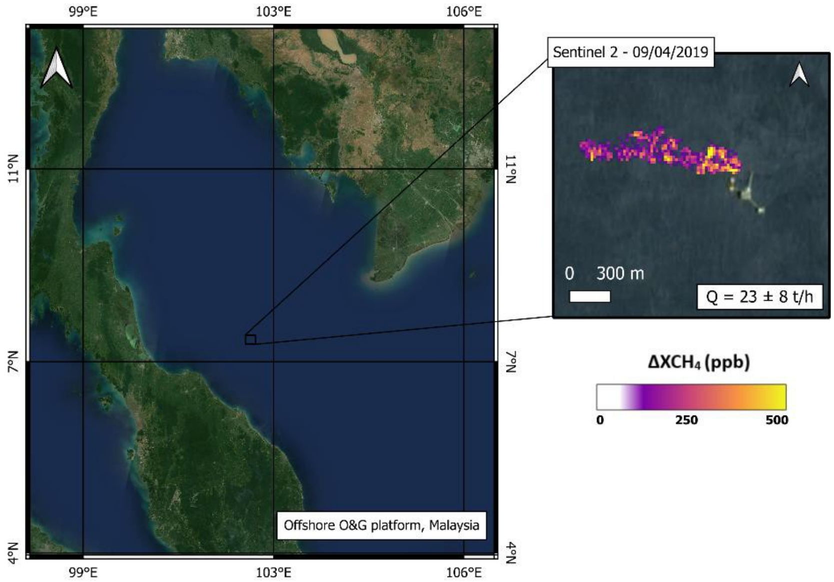

Figure 1. The right panel shows a methane emission from offshore O&G platform detected by Sentinel-2 satellite on 9 April 2019. The map on the left panel indicates the location of the platform in Malaysia.

3.2. Hyperspectral Results

Figure 2 shows a CH4 plume detected by PRISMA on the same O&G platform in Malaysia as in Figure 1, but on 24 April 2023. This could mean that this platform is emitting persistently over time. In this case, the wind speed was 3.8 m/s in the southwest direction, and the flux rates values were 5 ± 2 t/h.

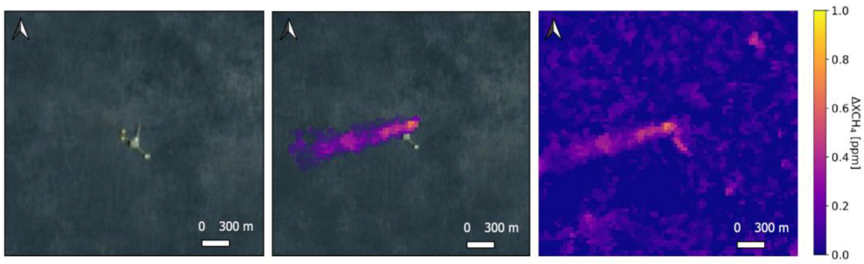

Figure 2. Methane emission from offshore O&G platform in Malaysia detected by PRISMA on 24 April 2023. Visualization of O&G platform using Sentinel-2 image (**left**), methane plume with background Sentinel-2 image (**center**) and methane retrieval using matched-filter (**right**).

4. Conclusions

The increase in CH_4 emissions in recent decades is a major environmental concern due to its growing impact on climate change. Satellite-based imaging has proven to be highly effective in detecting and quantifying these emissions. The use of high-resolution satellites has significantly improved our ability to understand these emissions. Identifying the root causes of these emissions in offshore O&G platforms is crucial, as many of them could be prevented.

On the other hand, this work demonstrates that detecting CH_4 emissions using the sun-glint mode is possible from space, which can help to mitigate emissions from the O&G industry.

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Data Availability Statement: Data are contained within the article.

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Conflicts of Interest: One of the authors, I.I.-L., is affiliated with the United Nations. Similarly, the author, L.G., is affiliated with the Environmental Defense Fund.

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