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Mono and multi temporal approaches for detecting and quantifying industrial methane plumes using PRISMA hyperspectral satellite data

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Methane (CH4) is one of the most contributing anthropogenic greenhouse gases (GHGs) in terms of global warming. Since some years, satellites based CH4 product show ability to monitor large-scale variabilities and trends. In the same time, several works have proven the feasibility of quantifying anthropogenic methane plume at metric resolution using airborne hyperspectral imagers
[Frankenberg et al. 2016]. More recently, the launch of high spatial resolution (decametric) satellites such as PRISMA has already demonstrated the feasibility of providing methane map of anthropic plumes [Guanter et al. 2021]. This paper focuses on methodological improvement of gas plume segmentation and quantification from satellite hyperspectral data at high spatial resolution and applications to PRISMA data over Turkmenistan oil and gas site during two years (2020-2021) [Nesme et al. 2021].

First, the ISBR-OE method based on in-scene background radiance (ISBR) estimation and an Optimal Estimation (OE) approach is presented. One principle of the method is to estimate the background radiance by spatial and spectral search in the “free-methane” part of the image. It is useful to avoid radiative transfer model time-consuming calculations for atmospheric retrieval in particular in the OE quantification step. Flow rates of methane-emitting sources were quantified for different dates by using the images one by one in an independent way (mono-temporal approach).

In this paper, we focus on the plume segmentation: identification of the pixels affected by an industrial source. The ACE probability score, commonly used in image processing, is applied to compare the theoretical signature of the methane with the observed signature class by class. In the first instance, we worked on a single image. In mono-temporal case, this score leads to the plume but also to many false alarms when a single threshold is applied. For this reason, we developed an isolation method based on thresholding, morphological transformations, labelling and spatial study of regions. This helps to remove most of the false alarms and artefacts in the detection map caused in particular by roads, buildings or clay.

In the second instance, this paper introduces a multi-temporal (multi-T) approach. One of the advantages of satellite data is the revisit time period which is not always possible with airborne campaigns. This approach is based on the joint use of data from different dates. It is assumed that the reflectance varies slowly between two passes, unlike the atmosphere. A mean atmospheric correction is therefore applied to each image. The ACE score applied on the difference of the two images, increases the plumes contrast on the two images (with positive and negative scores). The use of a multi-T approach improves the quality of the detection map and decreases the false alarms rate: roads and buildings are no longer detected as pixels with a methane signature. So, the complex image processing used for the mono-temporal segmentation can be replaced by a simple thresholding in multi-T approach. Nevertheless, the use of multi-temporal approach for the quantification step requires high accuracy in the atmospheric correction process and to deal with natural reflectance temporal and directional variations.