GHGSAT-D/WAF-P Quality Assessment Summary

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AMENDMENT RECORD SHEET

The Amendment Record Sheet below records the history and issue status of this document.

ISSUE	DATE	REASON
draft	09/07/2021	First Draft
1.0	22/03/2022	First Issue addressing ESA feedback

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LIST OF THE ACRONYMS

C&A: Cloud and Aerosols sensor

GHGSat-D: Greenhouse Gas Satellite – Demonstrator or Claire

GHGSat: Greenhouse Gas Satellite

SFL: Space Flight Laboratory

SWIR: Short Wave Infrared

VNIR: Visible and Near Infrared

WAF-P: Wide-Angle Fabry-Perot imaging spectrometer

1. EXECUTIVE SUMMARY

In this study the quality assessment of methane CH4 concentrations/plumes utilizing the high resolution (50 m) retrievals CH4 from the GHGSAT satellite on some specific targets that are related to the anthropogenic emissions are presented.

The Greenhouse Gas Satellite – Demonstrator satellite (identified as GHGSat-D or Claire satellite), is a microsatellite built by UTIAS Space Flight Laboratory (SFL) for GHGSat Inc. as greenhouse gas monitoring demonstrator satellite, with the objective to measure methane (CH4) abundances in a field of view of approximately 12 km x 12 km and spatial resolution of less than 50m.

The satellite is equipped with an advanced miniature hyperspectral SWIR imaging spectrometer for monitoring targeted greenhouse gas emitters such as area fugitive sources (tailing ponds and landfills) and stacks (emissions such as flaring and venting). A secondary instrument will measure clouds and aerosols in order to enhance retrievals from the primary instrument. The satellite payload includes in fact two different sensors:

- a 2D Wide-Angle Fabry-Perot ("WAF-P") imaging spectrometer that measures vertical column densities of CO2 and CH4;
- a Clouds & Aerosols ("C&A") sensor that measures interference from clouds and aerosols in the field of view of the WAF-P.

The WAF-P spectral range is in the short-wave infrared (SWIR) at 1600-1700 nm, with multiple bands in a proprietary configuration.

The C&A spectral range is in the visible and near-infrared (VNIR) at 400-1000 nm, with 325 bands at 1.9 nm spectral resolution.

Claire has a primary body measuring 20x20x42cm with an additional 7x18x42cm mezzanine on one side. The mass of CLAIRE is < 15 kg, payload included.

Claire's orbit is sun-synchronous at an altitude of approximately 500 km, resulting in a site revisit period of approximately 14 days.

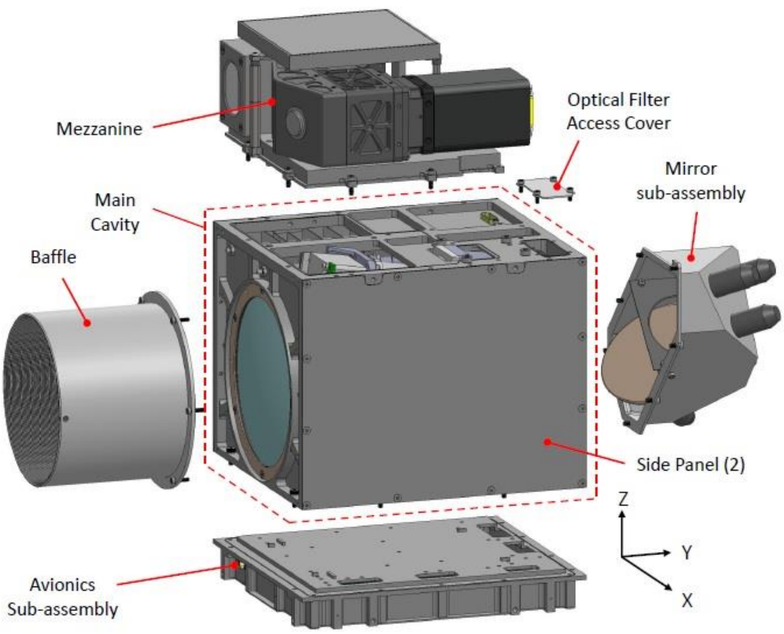


Figure 1 – GHGSAT-D (Claire) Payload Schema

GHGSAT-D instrument can measure atmospheric methane columns from solar backscatter in the shortwave infrared (SWIR) with near-uniform sensitivity down to the surface.

There is considerable interest in using these measurements to quantify methane emissions: the data show that these measurements can successfully map regional methane emissions but have limited ability to resolve individual methane point sources, even with imaging capabilities, because the sources tend to be relatively small and spatially clustered (e.g., oil/gas fields, livestock operations, landfills, coal mine vents).

In the oil and natural gas industry, methane is released when natural gas is flared or vented. Methane is also released in small leaks, called fugitive emissions, from valves and other equipment used in drilling and production. Methane emissions are strictly related to waste management, when it comes to solid waste disposal, also result from the decay of organic matter in municipal solid waste landfills, some livestock manure storage systems, and certain agro-industrial and municipal wastewater treatment systems. The big hydropower dams, especially the big plants built in tropical areas, are causes of GHG emissions from reservoirs stem primarily from the decomposition of organic matter that is either flooded, transferred to the reservoir via runoff and river input, or produced within the reservoir as aquatic plant and algal biomass.

Atmospheric methane (CH4) is the second most important anthropogenic greenhouse gas after carbon dioxide and contributes significantly to changes in radiative forcing and climate change.

1.1 Mission Quality Assessment Matrix

Product Information	Product Generation	Ancillary Information	Uncertainty Characterisation	Validation
Product Details	Sensor Calibration & Characterisation Pre-Flight	Product Flags	Uncertainty Characterisation Method	Reference Data Representativeness
Availability & Accessibility	Sensor Calibration & Characterisation Post-Launch	Ancillary Data	Uncertainty Sources Included	Reference Data Quality
Product Format	Retrieval Algorithm Method		Uncertainty Values Provided	Validation Method
User Documentation	Retrieval Algorithm Tuning		Geolocation Uncertainty	Validation Results
Metrological Traceability Documentation	Additional Processing			

Key
Not Assessed
Not Assessable
Basic
Intermediate
Good
Excellent
Information Not Public

Figure 2 – GHGSAT-D mission Quality Evaluation Matrix

2. MISSION ASSESSMENT OVERVIEW

2.1 Product Information

Product Details	
Product Name	*GHGSAT*
Sensor Name	• *WAF-P* • *C&A (additional sensor in support of the WAF-P)*
Sensor Type	• *2D Wide-Angle Fabry-Perot imaging spectrometer (in the short-wave infrared (SWIR) at 1600-1700 nm, with multiple bands)* • *Clouds & Aerosols sensor (in the visible and near-infrared (VNIR) at 400-1000 nm, with 325 bands at 1.9 nm spectral resolution)*
Mission Type	*Technological Demonstrator, shall be followed by 2 new satellites*
Mission Orbit	*Sun Synchronous, altitude 500 km, inclination 97.3 deg.*
Product Version Number	*v1*
Product ID	*GDSW1_XXXXXXXXXXXXXX_XXXXXXXXXXX_COLN01*
Processing level of product	*Level-1 and Level-2; additional info as Layer-3 and Layer-4*
Measured Quantity Name	*L-1: Surface Reflectance* *L-2: Abundance dataset CH4* *L-3: Uncertainty* *L-4: Quality Flag*
Measured Quantity Units	*L-1: sr^-1* *L-2: ppb* *L-3: ppb* *L-4: integer*
Stated Measurement Quality	*13.2% as CH4 standard deviation*
Spatial Resolution	*c.a. 50 m per pixel*
Spatial Coverage	*Approx. 12 km x 12 km*
Temporal Resolution	*Measurement temporal resolution: 20 sec. Revisit period of approximately 14 days*
Temporal Coverage	*Since June 2016 (launch), still in operation*
Point of Contact	https://www.ghgsat.com/contact/, info@ghgsat.com
Product locator (DOI/URL)	*DataMaster (web interface that GHGSat uses to deliver its products)* https://datamaster.ghgsat.com/DMweb/login.go
Conditions for access and use	Commercial Data, conditions defined by contract
Limitations on public access	N/A (Conditions defined by contract)
Product Abstract	Numerical values: PRODUCT_TYPE_1: Surface Reflectance PRODUCT_TYPE_2: Abundance Dataset - CH4 PRODUCT_TYPE_3: Concentration Map - CH4 PRODUCT_TYPE_4: Quality flag

Availability & Accessibility	
Compliant with FAIR principles	*Yes*
Data Management Plan	*Not available to users*
Availability Status	*Data available via catalogue.* *Possibility to order specific acquisitions.*

Product Format	
Product File Format	*.tiff*
Metadata Conventions	*v1*
Analysis Ready Data?	*Yes, available on request Level-3 and Level-4 data*

User Documentation		
Document	*Reference*	*QA4ECV Compliant*
Product User Guide	*GHGSAT Data Description GHG-1507-7004-a (08/2020)*	*No*
ATBD	GHGSAT Toolchain Manual GHG-1292-6001-a (26/03/2020)	Yes

Metrological Traceability Documentation	
Document Reference	*System Validation Report* • *GHGSat-DGHG-1501-6100-d (24/10/2017)*
Traceability Chain / Uncertainty Tree Diagram Available	*Yes, partially*

2.2 Product Generation

Sensor Calibration & Characterisation – Pre-Flight	
Summary	A ground test campaign was performed prior to launch: a series of measurements were conducted to test the forward model that includes the instrument and the radiative transfer through the atmosphere. For the laboratory measurements, gas cells with fixed total pressure P and mixing ratio X of each GHG (in a buffer of dry nitrogen) were used as a surrogate for the atmosphere. The setup for this test involved shining a light source whose spectrum covers our spectral bandpass through a gas cell and illuminating the instrument with the transmitted light.
References	*System Validation Report* • *GHGSat-DGHG-1501-6100-d (24/10/2017)*

Sensor Calibration & Characterisation – Post-Launch	
Summary	The InGaAs detector that we use for GHGSat-D has over 300,000 pixels, all with different offset, gain, and dark current characteristics. Moreover, the offset, gain, and dark current have been observed to change over time. The characterization of a camera pixel's offset and dark current is accomplished by taking observations of a (dark) ocean scene at different exposure times, whereas characterization of the gain is accomplished by taking observations of a (uniform) desert scene. This characterization approach has several limitations: ocean scenes not being truly dark and desert scenes not being truly homogenous being just two of them.
References	*System Validation Report* • *GHGSat-DGHG-1501-6100-d (24/10/2017)*

Retrieval Algorithm Method	
Summary	Methane column concentrations are retrieved from the resulting spectra using a 100-layer, clear-sky radiative transfer model in an inverse modelling framework: the inversion retrieves the total column concentrations Ω(x,y) of methane across the scene, based on HITRAN absorption line spectra and U.S. Standard Atmosphere vertical profiles. The column mass enhancement ΔΩ(x,y) = Ω(x,y) – Ωb then characterizes the plume relative to the local background column concentration Ωb, which is inferred from a scene-wide methane column retrieval.
References	• *GHGSat Toolchain Manual (GHG-1292-6001, 26 March 2020)* • *Varon, D. J.; McKeever, J.; Jervis, D.; Maasakkers, J. D.; Pandey, S.; Houweling, S.; Aben, I.; Scarpelli, T.; Jacob, D. J. Satellite discovery of anomalously large methane emissions from oil/gas production. Geophys. Res. Lett. 2019, 46, 13507– 13516, DOI: 10.1029/2019GL083798* • *Rodgers, C. D. Inverse Methods for Atmospheric Sounding: Theory and Practice; World Scientific, 2000; Vol. 2*

Retrieval Algorithm Tuning	
Summary	The error depends strongly on wind speed, with larger errors for low wind speeds. There is a strong sensitivity and dependence from the plume rate (necessity to be more times greater than the detector threshold).

References	• *GHGSat Toolchain Manual (GHG-1292-6001, 26 March 2020)* • *McKeever, J.; Durak, B. O. A.; Gains, D.; Varon, D. J.; Germain, S.; Sloan, J. J. GHGSat-D: Greenhouse Gas Plume Imaging and Quantification from Space Using a Fabry–Perot Imaging Spectrometer. American Geophysical Union 2017 Fall Meeting, New Orleans, LA, 2017, Dec 11–15, 2017*

Additional Processing	
Additional Processing 1	
Description	Geophysical variables such as column densities and parameters about surface reflectance such as albedo2 are estimated by the toolchain from level 1B data. That data product is given on an instrument-specific processing grid and not on a grid having a simple relation to a standard geographic coordinate system. Therefore, according to the usual remote sensing terminology, this data product can be most accurately described as a level 2 product, although in practice the toolchain output still has to be manually geo-referenced and converted to a defined output format, which is the GHGSat "NMSO" format based on GeoTIFF with extra metadata files in a custom ASCII format and PNG previews. This level 2 product can then be used to estimate source emission rates using dispersion modelling.
Reference	*GHGSat Toolchain Manual (GHG-1292-6001, 26 March 2020)*

2.3 Ancillary Information

Product Flags	
Product Flag Documentation	*Reported in the metadata file related to the specific product.*
Comprehensiveness of Flags	*Yes, only quality flag is reported (1, 'Good'), (2, 'Nodata'), (3, 'Bad fit')*

Ancillary Data	
Ancillary Data Documentation	*The ancillary data necessary for the processing (telemetry data, calibration files, spectroscopy data and radiative transfer model info) are reported in the GHGSAT Toolchain Manual GHG-1292-6001-a (26/03/2020).*
Comprehensiveness of Data	*Yes*
Uncertainty Quantified	*Yes*

2.4 Uncertainty Characterisation

Uncertainty Characterisation Method	
Summary	*For a measurement system like the GHGSat instrument, an error budget is essentially a breakdown of the various contributions to the measurement*

	errors. This budget has been generated with the end-to-end (e2e) simulation toolchain (a forward model of the system that includes the instrument and atmospheric radiative transfer). simulations typically use sinusoidally varying patterns or simulated emissions plumes. *An e2e simulation consists of a simulated observation that generates an image sequence followed by a retrieval. The retrieval essentially finds the model parameters and CH4 field that match the data best (Errors in the retrieved CH4 fields arise from several phenomena: Instrument noise, Sampling and interpolation errors causing albedo gradients, Spurious signals in the simulated images, inaccuracies in the model parameters used).*
Reference	*System Validation Report* • *GHGSat-DGHG-1501-6100-d (24/10/2017)*

Uncertainty Sources Included	
Summary	*The following sources of errors have been identified and characterized:* • *Offset non-uniformity including camera striping;* • *Ghosting;* • *Stray light;* • *Gain non-uniformity;* • *Persistence.*
Reference	*System Validation Report* • *GHGSat-DGHG-1501-6100-d (24/10/2017)*

Uncertainty Values Provided	
Summary	*The errors are expressed in terms of the standard deviation (SD) of the retrieved methane values within a region of interest in the retrieval field: the SD has been divided by the mean (background) column, so the reported quantity is a unitless percentage typically around 13.2 %.*
Reference	*System Validation Report* • *GHGSat-DGHG-1501-6100-d (24/10/2017)*
Analysis Ready Data?	*No*

Geolocation Uncertainty	
Summary	*The geolocation of the retrieved column enhancements is accurate to within ~30 m*
Reference	*McKeever, J.; Durak, B. O. A.; Gains, D.; Varon, D. J.; Germain, S.; Sloan, J. J. GHGSat-D: Greenhouse Gas Plume Imaging and Quantification from Space Using a Fabry–Perot Imaging Spectrometer. American Geophysical Union 2017 Fall Meeting, New Orleans, LA, 2017, Dec 11–15, 2017*

2.5 Validation

Validation Activity #1	
Independently Assessed?	No: this is the official validation results provided by GHGSAT.

Reference Data Representativeness	
Summary	Controlled releases of CH4 have been performed in July 2017, on facility near Cold Lake, Alberta and summer of 2018. Several coincident measurements have been planned and performed in summer 2016, July 2017, August 2018
Reference	*System Validation Report* • *GHGSat-DGHG-1501-6100-d (24/10/2017)*
Reference Data Quality & Suitability	
Summary	For controlled releases, the method is limited by the amount of CH4 that is able to be released by facility operators, as well as by the wind speed at the time of release. The CH4 release rates would be many times the detection limit of GHGSat-D so that retrievals could be optimized using an obvious and undeniable signal. The value of coincident measurements is limited by the combined uncertainties of both ground and satellite measurement methods.
Reference	*System Validation Report* • *GHGSat-DGHG-1501-6100-d (24/10/2017)*
Validation Method	
Summary	*GHGSat is validating system performance through a series of such tests, including:* • *Controlled / metered releases from test sites;* • *Coincident ground/space measurements of certain sources, such as a coal mine vent in Australia, oil sands tailings ponds, and oil & gas wells in Canada & US; and* • *Measurement of well-characterized emissions sources, such as thermal generating stations.*
Reference	*System Validation Report* • *GHGSat-DGHG-1501-6100-d (24/10/2017)*
Validation Results	
Summary	*GHGSat has conducted a thorough investigation of a retrieved CH4 emission plume from the Lom Pangar Dam, Cameroon. This analysis confirms the plausibility of the measurement result, comparing results to both end-to-end instrument re-simulations as well as the best available emission estimates (degassing flux) based on measured CH4 concentration levels in the water upstream and downstream of the dam.*
Reference	*System Validation Report* • *GHGSat-DGHG-1501-6100-d (24/10/2017)*

Validation Activity #2	
Independently Assessed?	Yes
Reference Data Representativeness	
Summary	*The dataset analysed in this report refers to 10 acquisitions over 8 specific targets (oil and gas infrastructures, landfills, and hydroelectric dam).*
Reference	*This report*
Reference Data Quality & Suitability	
Summary	*The products analysed are referred to big infrastructures and targets that are clearly big methane emitters. The emissions are quite evident in the*

	products, even if: • *in some products the amount of the plume is not so intense if referred to the background;* • *unwanted GHGSAT-related features seem to be present in some products, representing an additional source of errors.*
Reference	*This report*
Validation Method	
Summary	*The strategies used for the verification and the validation of the dataset are: 1) the intercomparison of the GHGSAT plumes with the recalculated plumes from the L2 products; 2) the intercomparison of products with the CAMS inventory emissions.*
Reference	*This report*
Validation Results	
Summary	*The quality of the data is overall quite good: emission plumes are clearly identified, and the amounts are in line with the results provided by GHGSAT. Features different from plumes are anyway presents and can induce confusion or additional wrong identifications.* *Clouds and humidity seem to have an impact on the quality of the product.* *Offset and gain non uniformity are the cause of presence of features in some cases of the same order of magnitude of the main emissions in the products.* *In few cases ghosting effects seems be manifested in circular features in the products.*
Reference	*This report*

3. DETAILED ASSESSMENT

3.1 Methodology

In this section the results of the quality assessments of the GHGSAT-D data are presented. Two methodologies have been adopted for the assessments of the data:

1) The emissions rates of GHGSAT-D provided by the GHG maps have been compared with the derivation of emissions from the products, to estimates and compare the presence of emitters, the peak values of the emitters, the difference from the background and the evidence of emission events from other "events."

2) The intercomparison of the observations with high resolution CH4 forecasts (~9km) produced by the Copernicus Atmosphere Monitoring Service (CAMS) to provide an effective way to link satellite measurements and emission inventory data.

3.2 Analysis of results

The Table 1 shows the overall results found during this analysis. The third column of Table 1 refers to successfully result of the intercomparison of GHGSAT product with the recalculated emission derived by the product itself, the fourth columns to the presence of noise and artefacts on the recalculated emission, and the fifth column refers to the presence of an intercomparison with CAMS data.

Geographic Area	Emission Source	Intercomparison with CH4 Emissions	Noise, Issues, Features	CAMS Emission
Turkmenistan#1	Oil&Gas infrastructure	Yes	Yes	Yes
Turkmenistan#2	Oil&Gas infrastructure	Yes	No	Yes
Pakistan#1	Landfill	Partially Appreciable	Yes	Partially
Pakistan#2	Landfill	Yes	No	Partially
US (Texas)	Oil&Gas infrastructure	Yes	Yes	Partially
US (New Mexico)	Oil&Gas infrastructure	Yes	No	No
Turkmenistan	Oil&Gas infrastructure	Yes	Yes (clouds)	Yes
Russia	Oil&Gas infrastructure	Partially Appreciable	Yes	Partially
Argentina	Landfill	Yes	Yes (clouds)	Not Assessed
Cameroon	Hydroelectrical Dam	Noisy	Yes	Partially

Table 1 – Summary of the results per analysed product

The red colour highlights products affected by noise, issues and features and those ones that have been not intercompared with CAMS. Products highlights in yellow have been partially intercompared, due to low detectable values of the emissions or because partially noisy.

Starting from the list of products provided, the first analysis has been focused on the intercomparison of the CH4 excess column and plumes derived by the abundance dataset.

Figure 3 – Turkmenistan, Oil and Gas Mary Infrastructure site

In the figure above the satellite image Oil and Gas Mary Infrastructure site have reported.

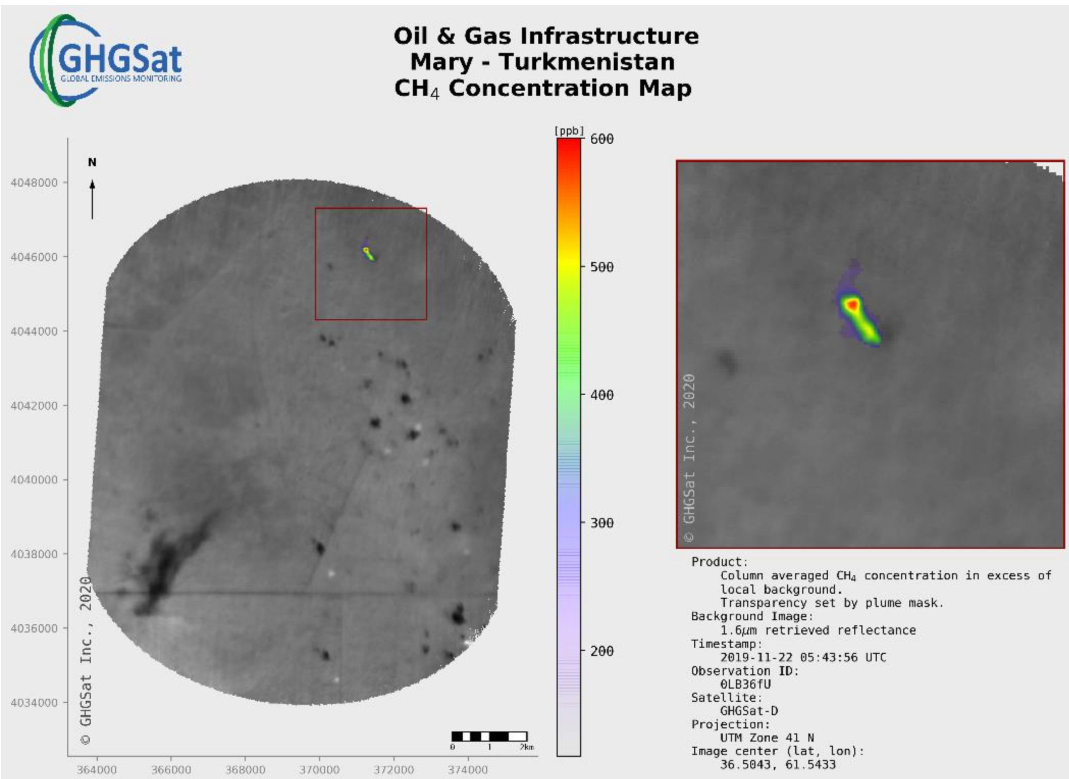


Figure 4 – GHGSAT-D Emission over Turkmenistan, Oil and Gas Mary Infrastructure site

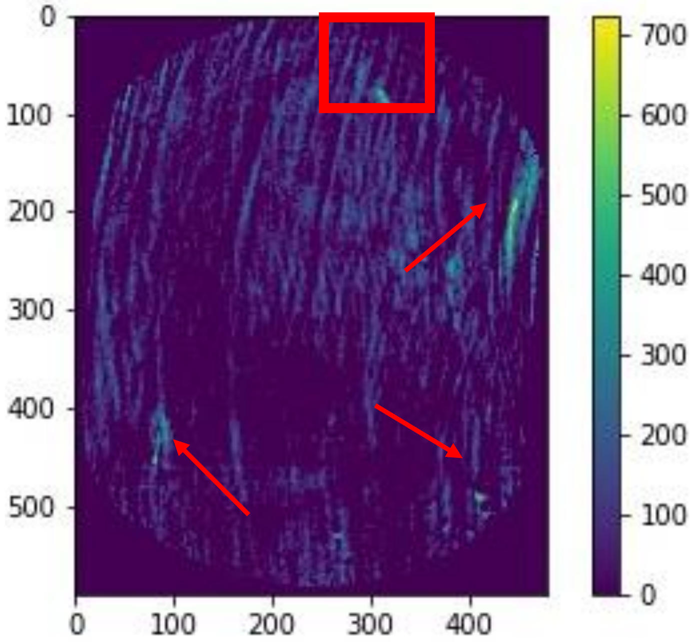


Figure 5 – Emission recalculated over Oil and Gas Mary Infrastructure site

The intercomparison of GHGSAT plume emission and the recalculated emission shows a good agreement (c.a. 600 ppb). In the products are present at least 2 “not identified” points in the lower part and one “additional” feature mistakable with point emissions and plumes. In this product the additional features (speckles) could be related to non-uniformity offset or bad-pixels screenings.

In the second product on the same area acquired in a different date, multiple emissions have been detected: the main emission well visible in the upper part of the region, and three little plumes in the central area. By the intercomparison with the recalculated emission, the main emission is clearly visible and the intercomparison on the peak value is 900 vs 1000 ppb.

The emissions in the central area are barely notable if compared with the background and features in the products: the amount of the emissions is consistent (300/400 ppb) with the recalculated products. This product seems partially affected by gain non-uniformity that appears in the stripes in the figure. The two red arrows highlight two spots mistakable with emissions.

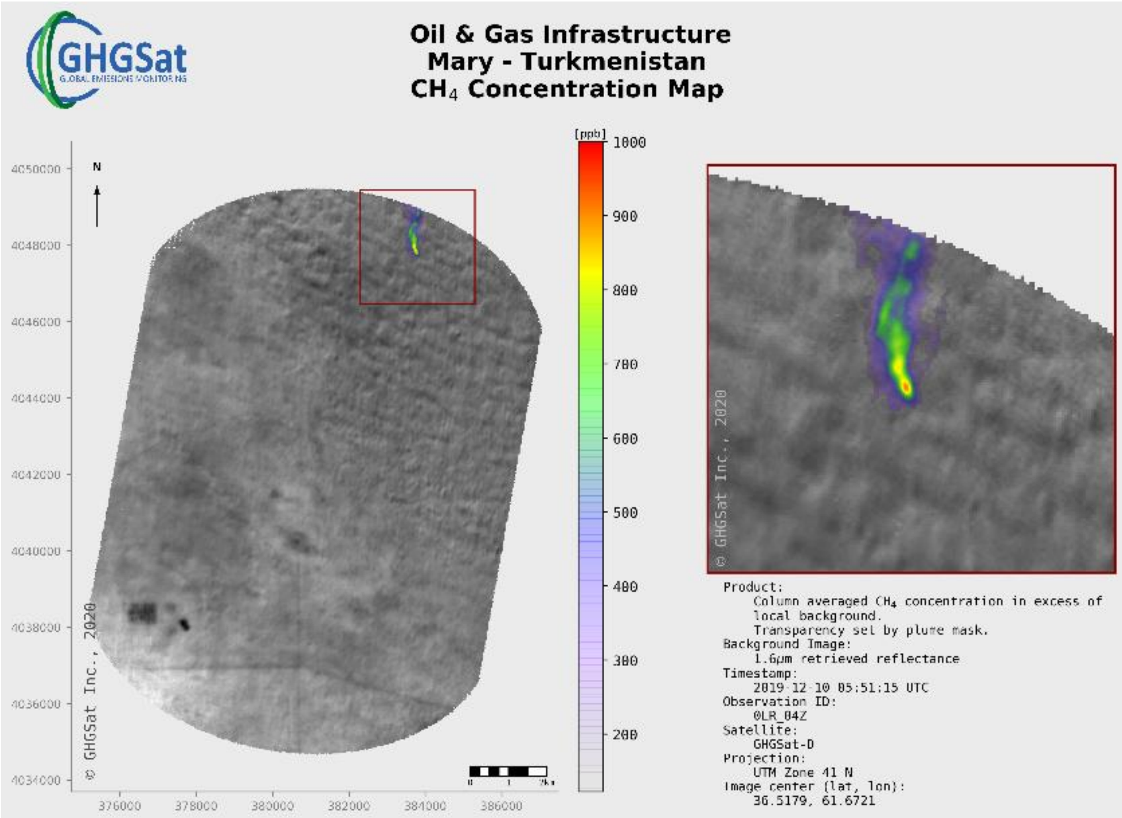
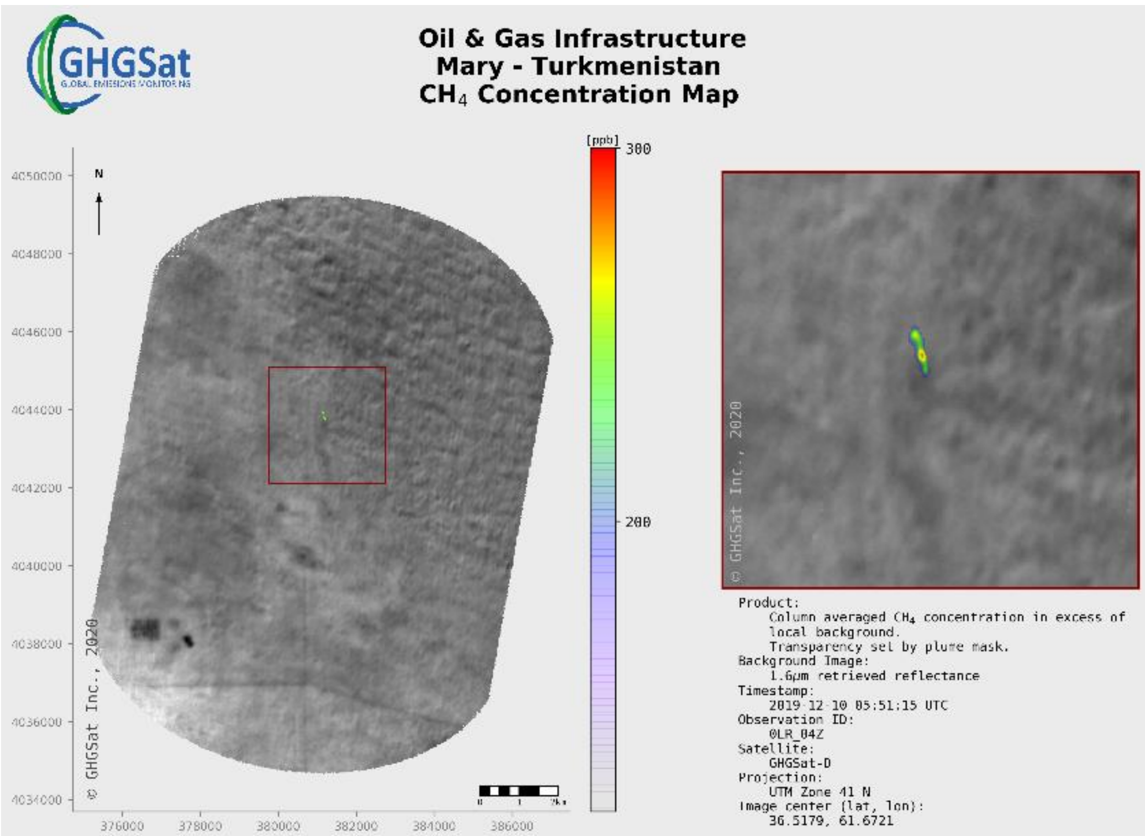


Figure 6 – GHGSAT-D Emission over Turkmenistan, Oil and Gas Mary Infrastructure site



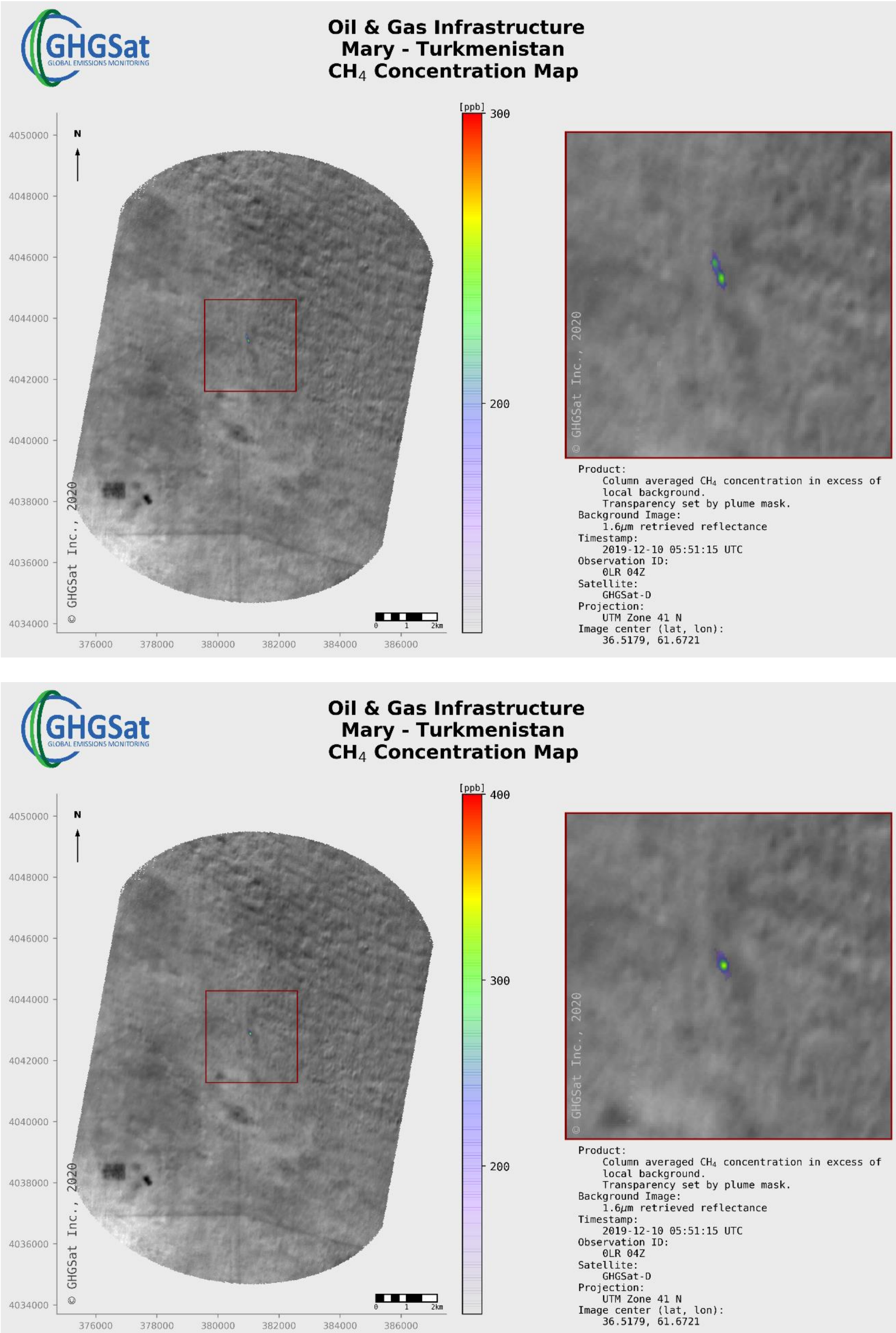


Figure 7 – GHGSAT-D 3 Multiple Emissions over Turkmenistan, Oil and Gas Mary Infrastructure site

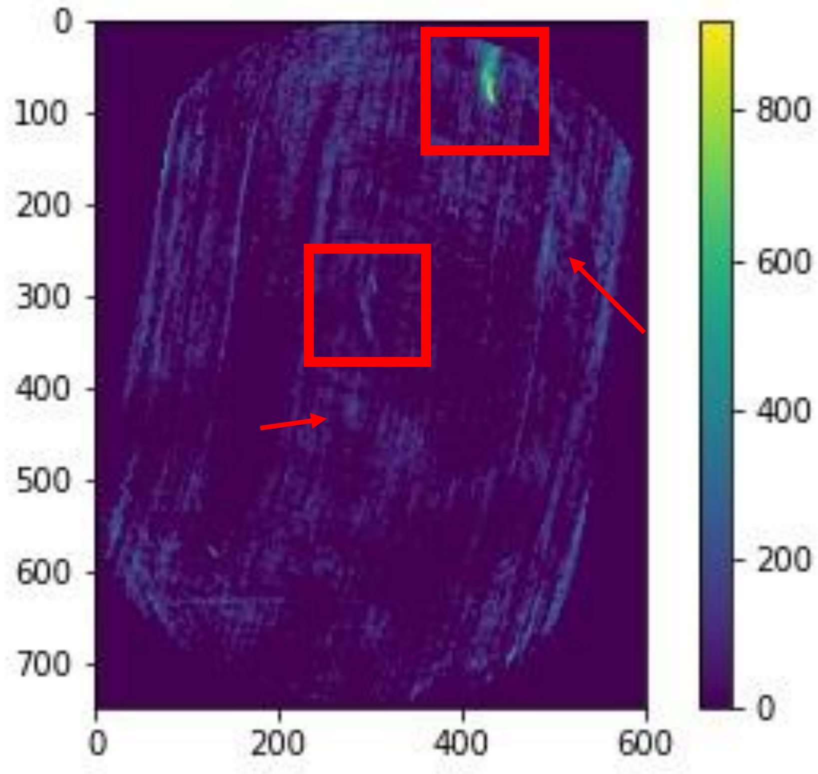


Figure 8 – Multiple Emissions recalculated over Oil and Gas Mary Infrastructure site

In the figure below the satellite image Lom Pangar Dam site (Cameroon) has been reported.

Figure 9 – Cameroon, Lom Pangar Hydroelectric Infrastructure site

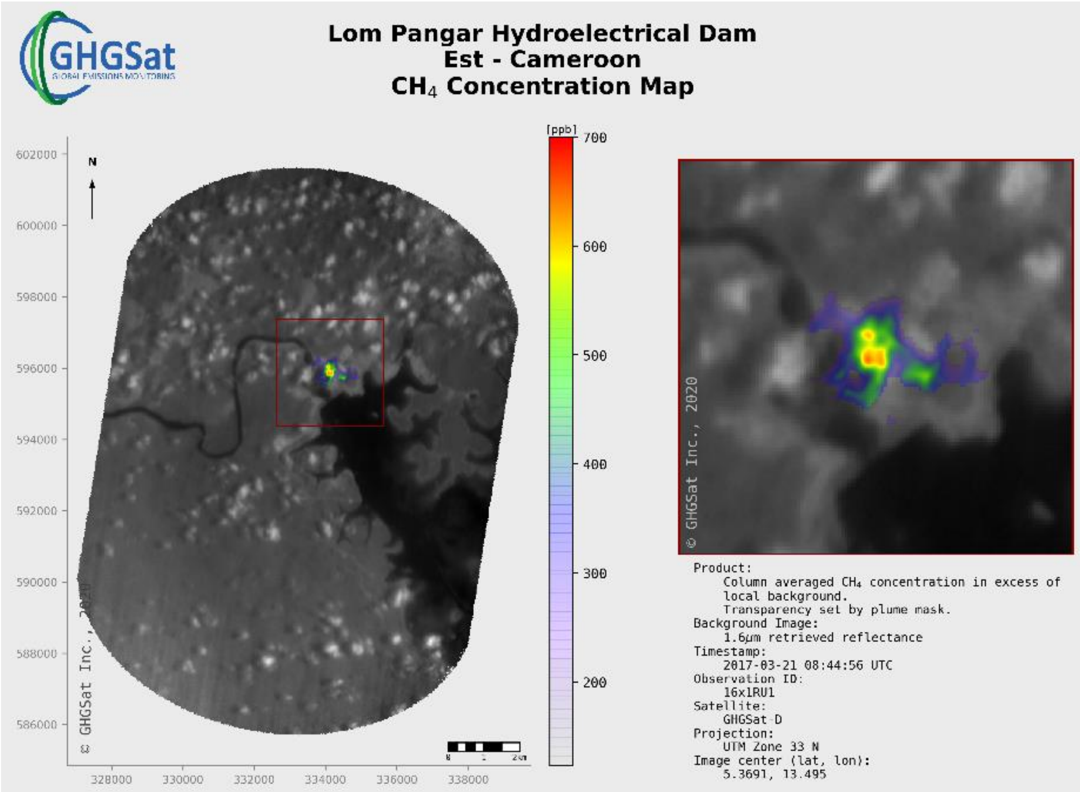


Figure 10 – GHGSAT-D Emissions over Cameroon, Lom Pangar Hydroelectric Infrastructure site

In this product acquired over a hydroelectric dam, there is the coincidence of the peak emission (700 ppb). The product is difficult to analyse: too many features are present and comparable with the main emission, probably related to the clouds. The product seems affected by stay-light effect (darkening visual effect) and gain/offset in the stripes.

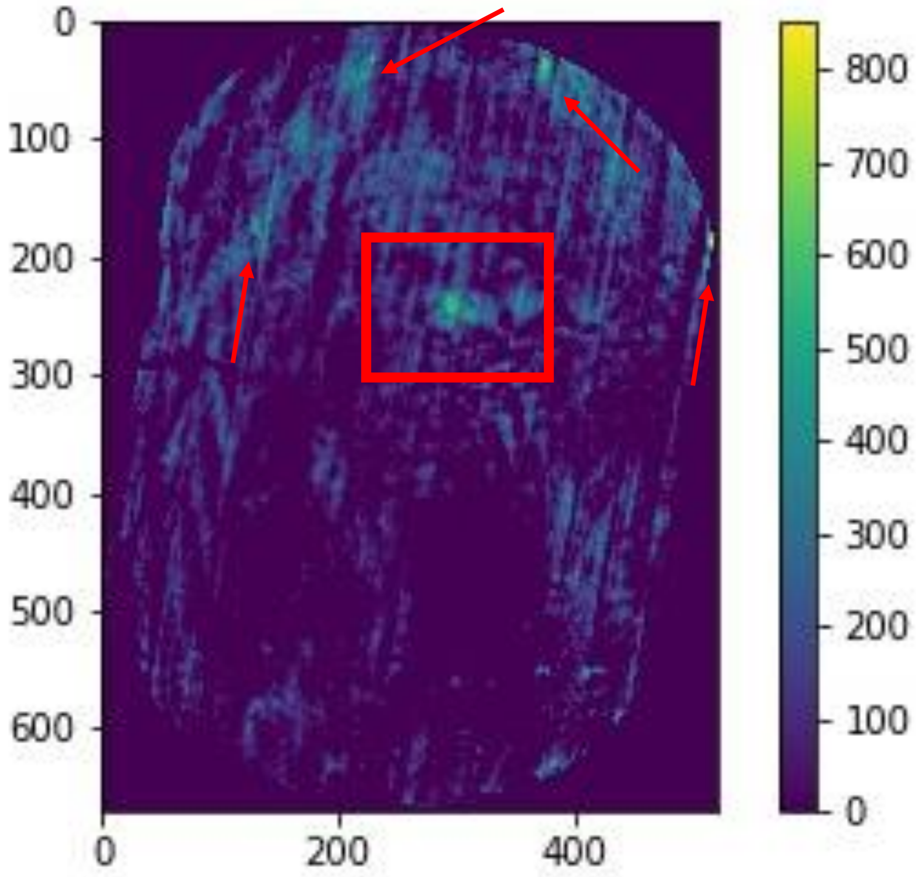


Figure 11 –Emissions recalculated over Lom Pangar Hydroelectric Infrastructure

In the Buenos Aires product, the emission from the landfill in the right lower part of the product is clearly visible (1000ppb of peak). Even if the landfill emission is identified univocally, however in the upper part are present features probably related with the presence of humidity (lakes) and biomasses. The stripes are present, with same order of magnitude of the main emission, probably related to gain/offset non uniformity.

Figure 12 – Argentina, Buenos Aires Landfill Infrastructure site

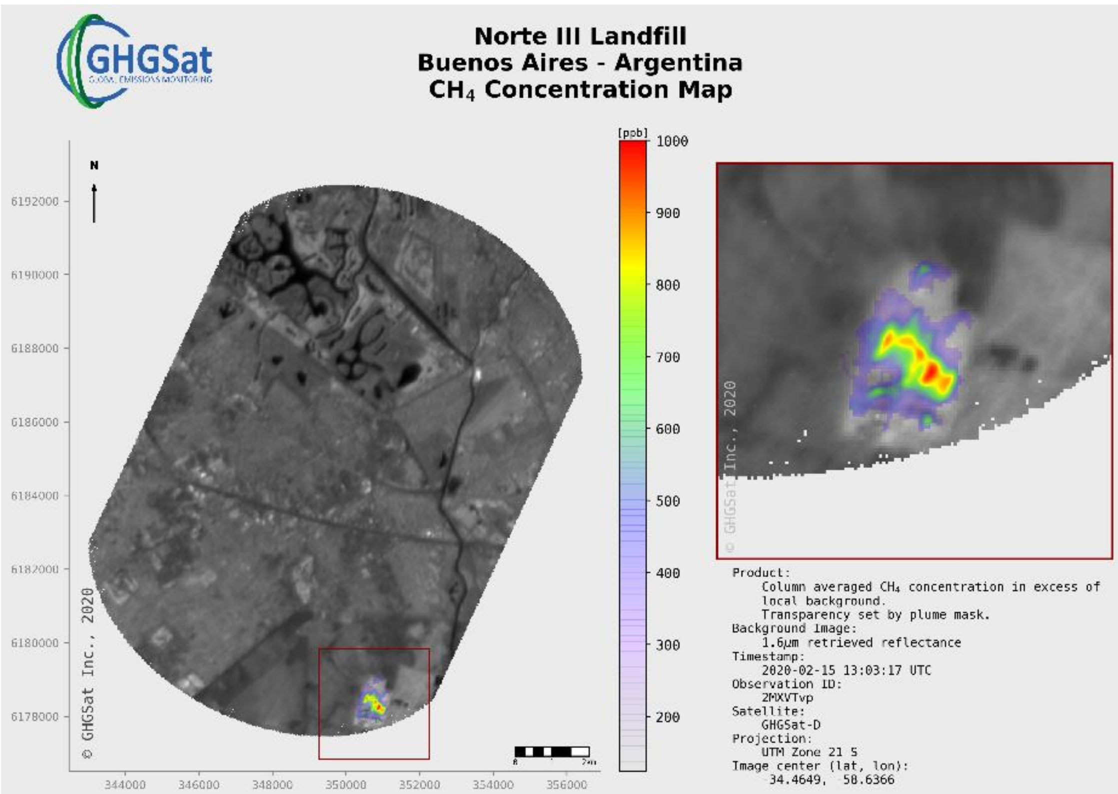


Figure 13 – GHGSAT-D Emissions over Argentina, Buenos Aires site

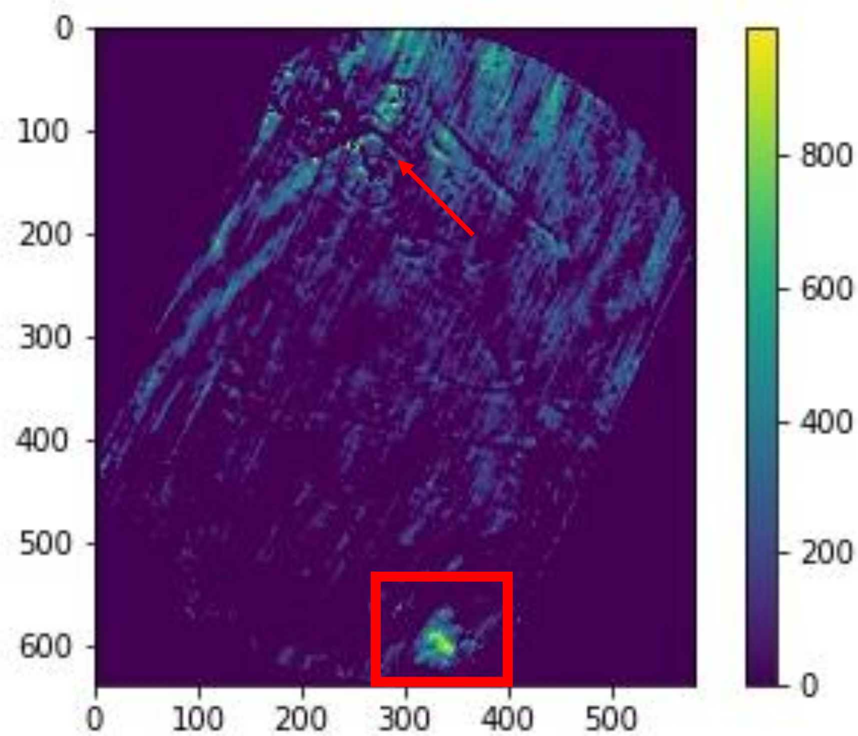


Figure 14 – Emissions recalculated over Buenos Aires Landfill Infrastructure

In the product related to the Russian Oil and Gas infrastructure, there is the corrispondence of the main emission at 400 ppb in the central area, but there are too many features of the same order of magnitude of the emission indicated with the red arrows. This product is clearly problematic, probably affected by gain/offset non uniformity, but also probably by ghosting, which manifetstation is the round pattern in the lower part of the figure.

Figure 15 – Russia, Oil and Gas Yamal-Nenets Infrastructure site

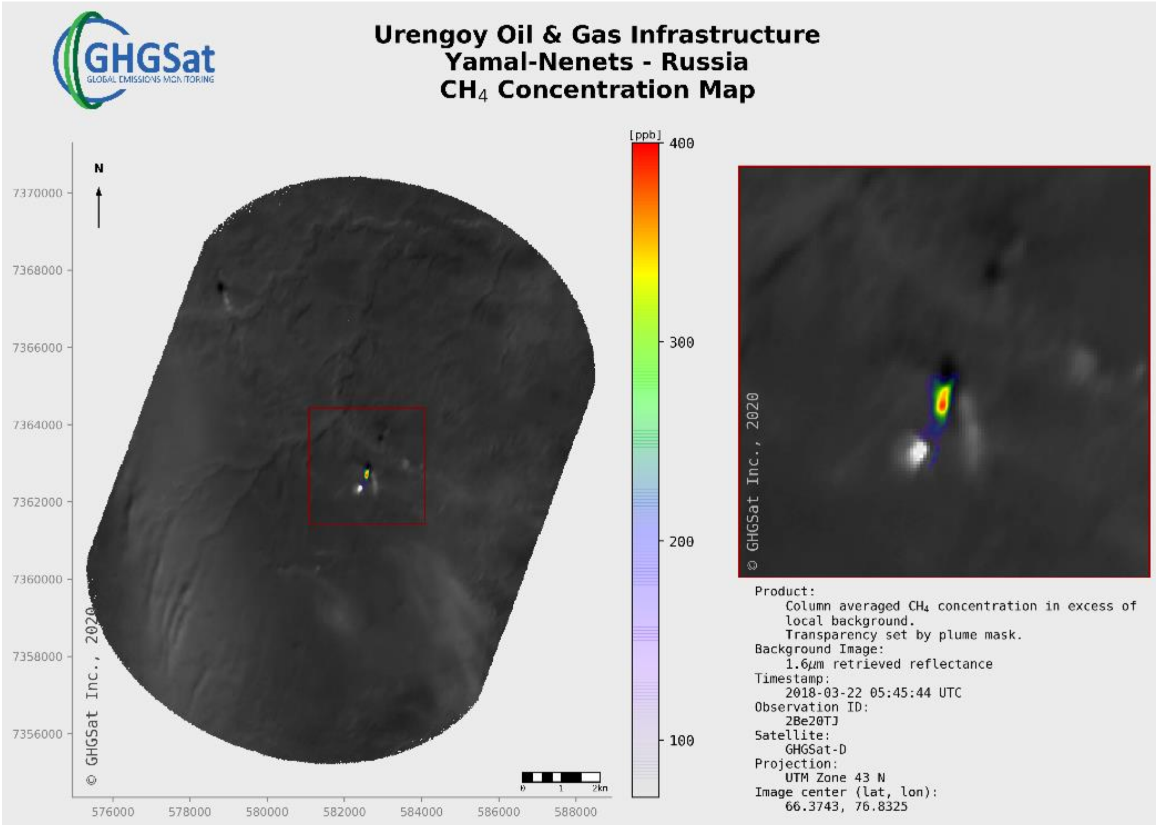


Figure 16 – GHGSAT-D Emissions over Russia, Oil and Gas Yamal-Nenets Infrastructure site

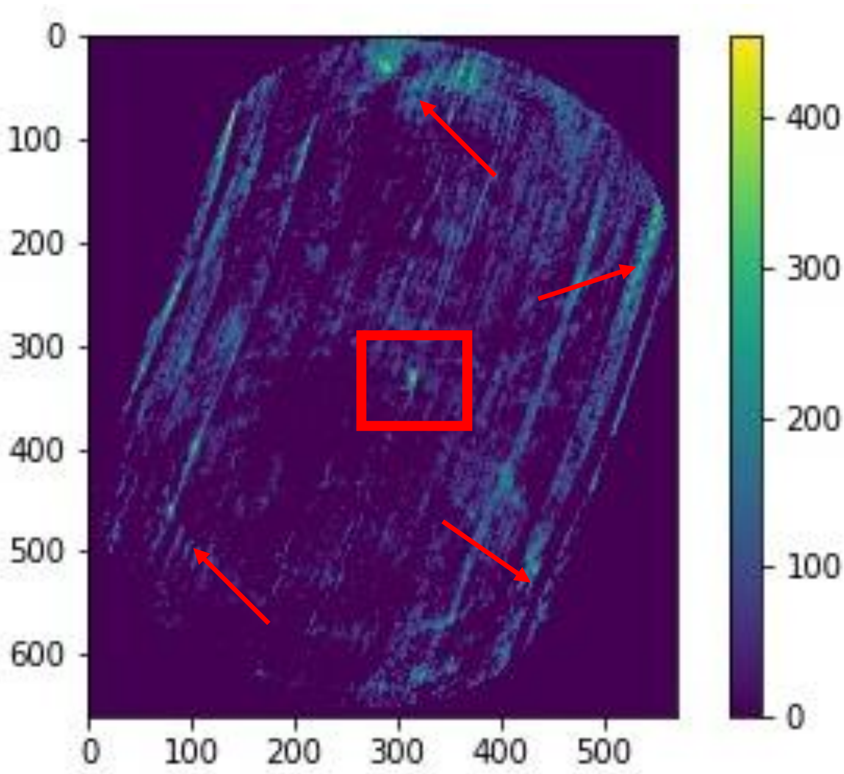


Figure 17 – Emissions recalculated over Russia, Oil and Gas Yamal-Nenets Infrastructure site

There are two products over the Pakistan Landfill acquired in two different dates: the first product shows a good agreement with the emission recalculated, with a peak of 1100 ppb.

In this first product there are again features related to the presence of probably biomass close the river, and stripes generated by the offset/gain non uniformity.

The second product is instead very problematic: the minor emission is scarcely appreciable, and there are other features mistakable with methane emissions indicated with the red arrows. Calibration problems (gain/offset) are probably the cause of the presence of the additional features in the product.

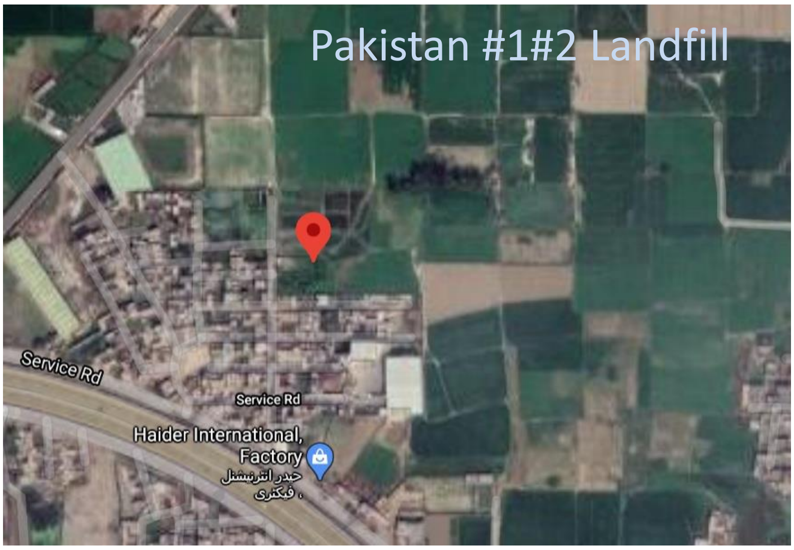


Figure 18 – Pakistan, Lakhodair Punjab Landfill Infrastructure site

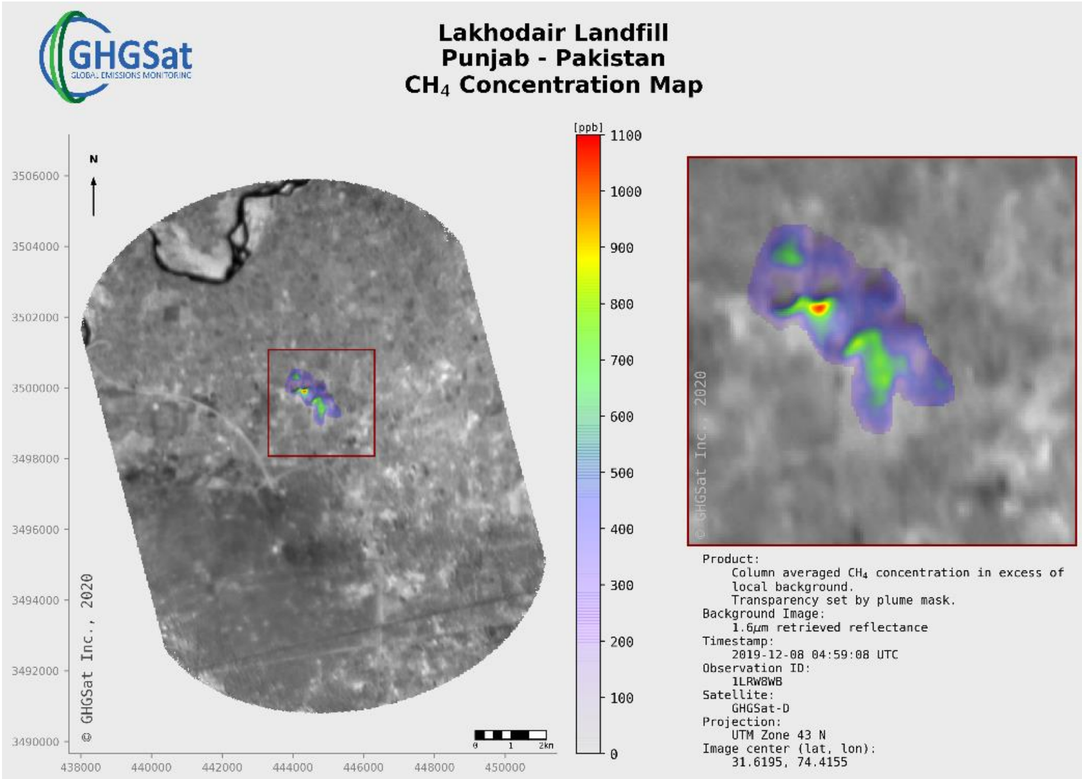


Figure 19 – GHGSAT-D Emissions#1 over Pakistan, Lakhodair Punjab Landfill Infrastructure site

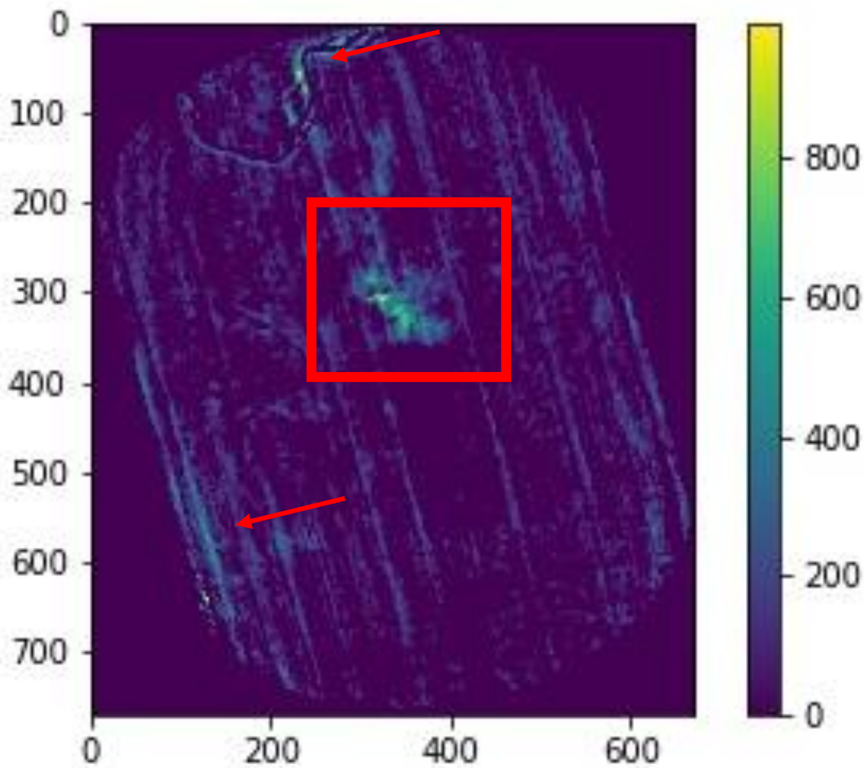


Figure 20 – Emissions recalculated over Pakistan, Lakhodair Punjab Landfill Infrastructure site

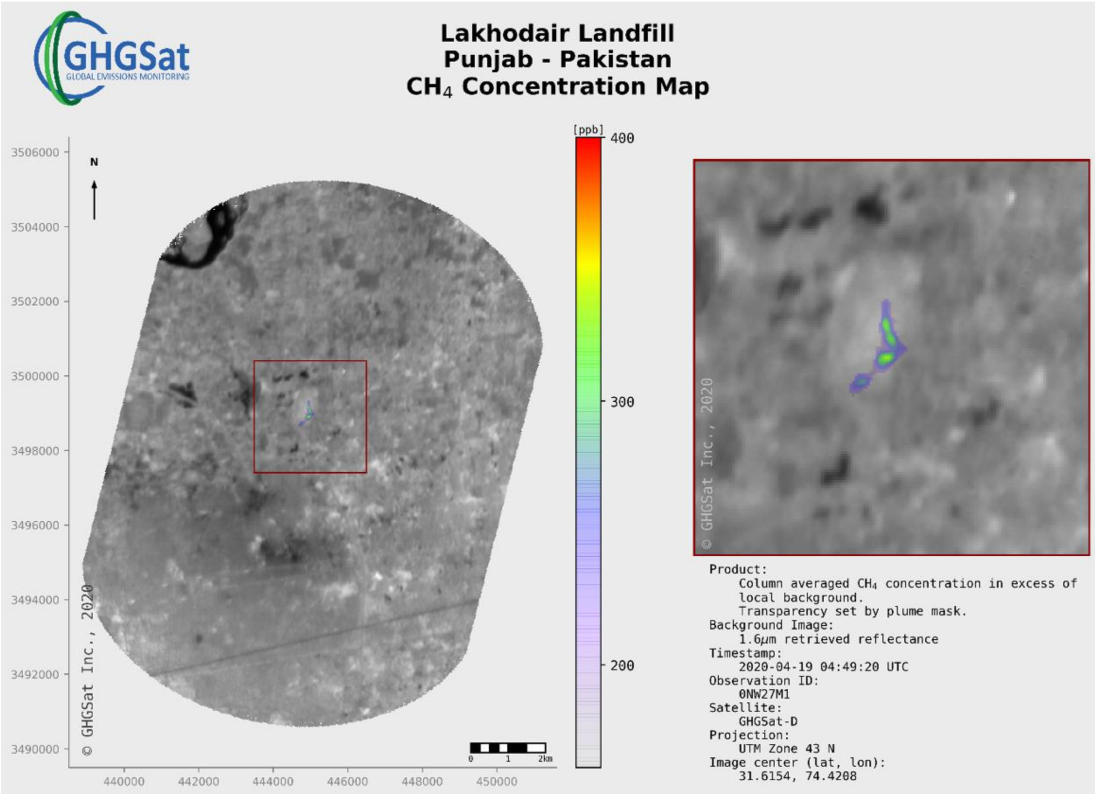


Figure 21 – GHGSAT-D Emissions#2 over Pakistan, Lakhodair Punjab Landfill Infrastructure site

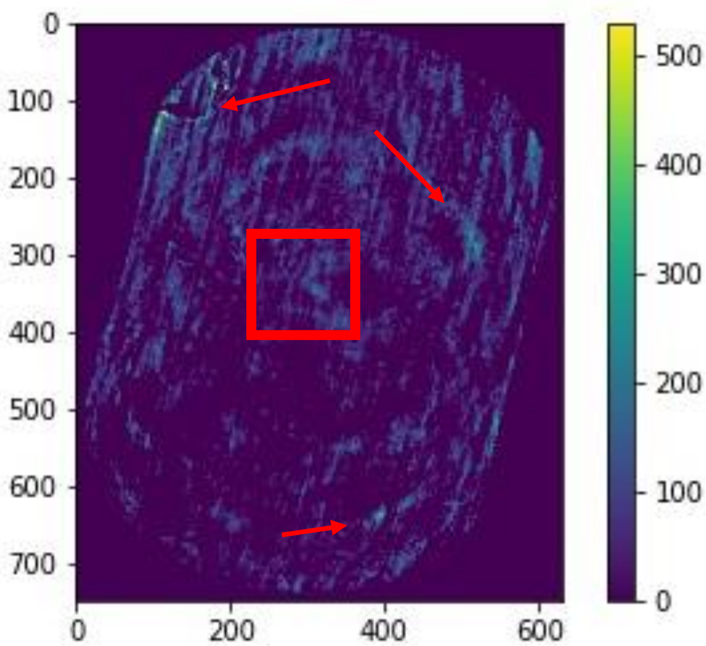
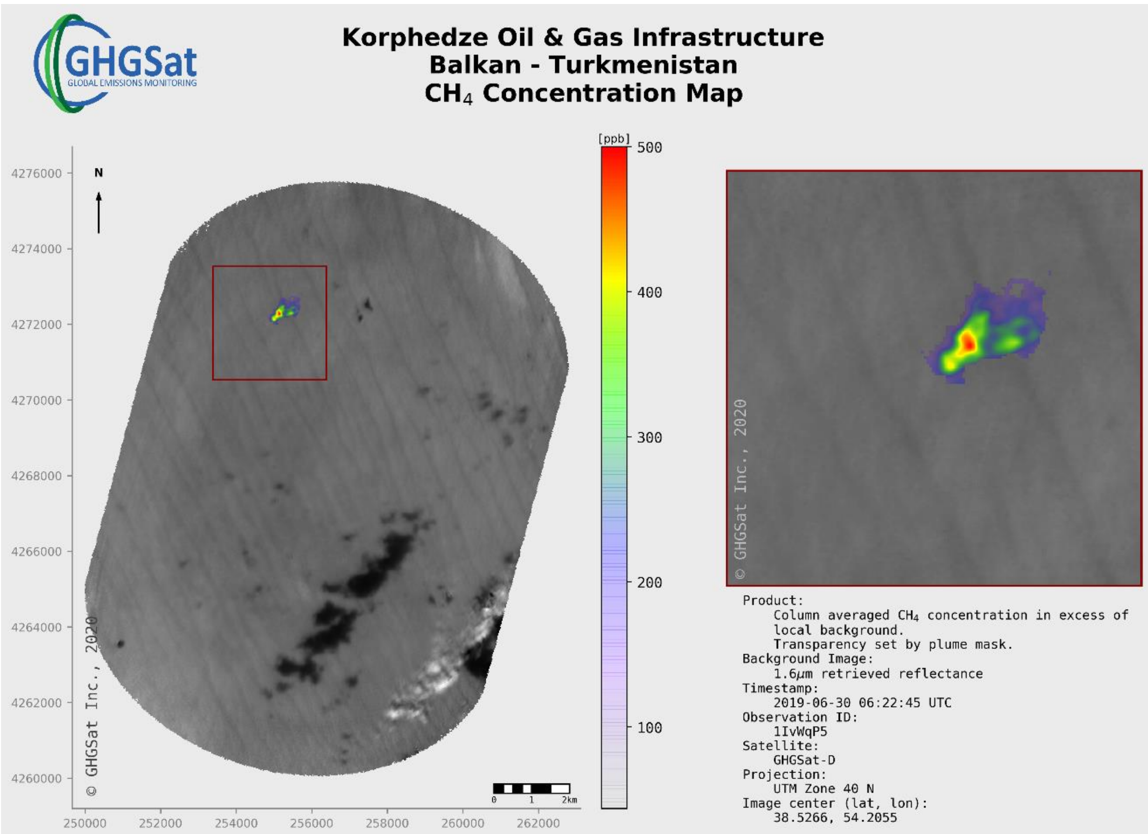


Figure 22 – Emissions recalculated over Pakistan, Lakhodair Punjab Landfill Infrastructure site

In this different site from Turkmenistan, two emissions are revelead.

Figure 23 – Turkmenistan, Korphedze Oil and Gas Infrastructure site

The intercomparisons show the presence of the two emissions in line with the values of the GHGSAT-D product, in the same area anyway a spot is present, and in the lower part the clouds interfere with the retrieval of the emissions showing a granular pattern. Ghosting effect seems present in the circular/shadowed pattern in the figure.



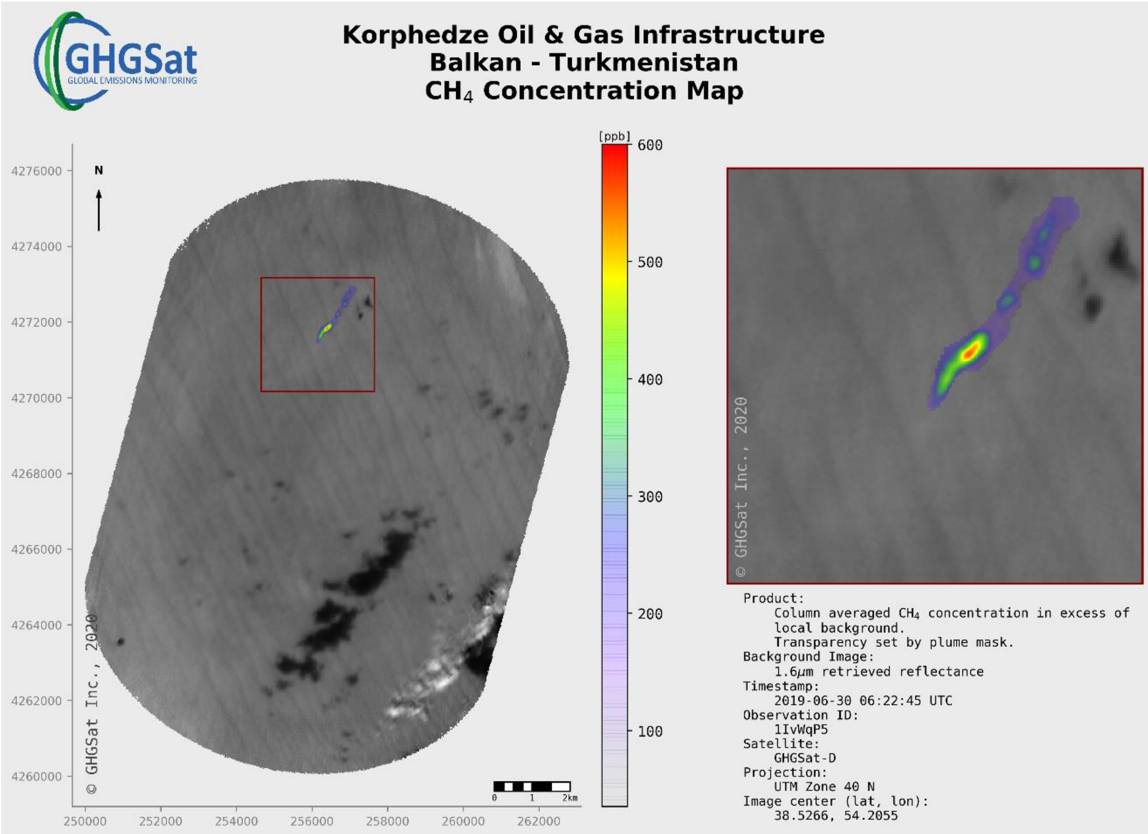


Figure 24 – GHGSAT-D Emissions over Turkmenistan, Korphedze Oil and Gas Infrastructure site

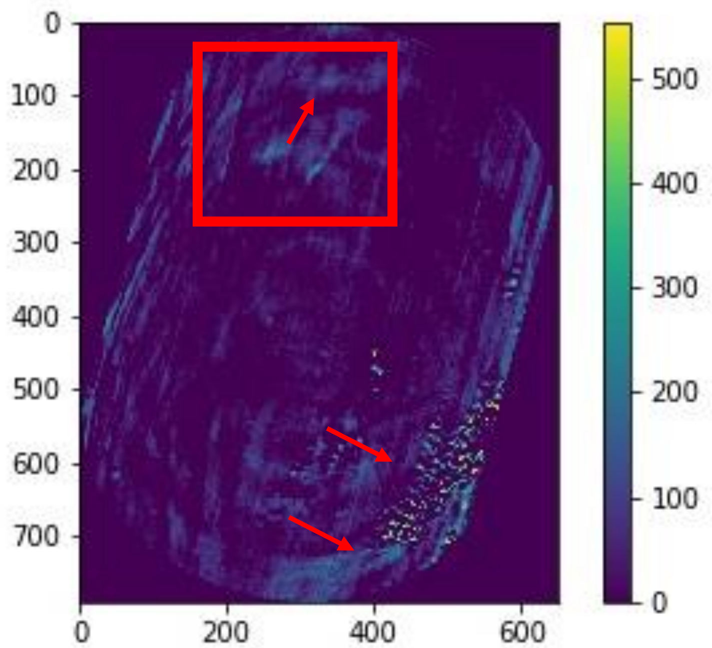


Figure 25 – Emissions recalculated over Turkmenistan, Korphedze Oil and Gas Infrastructure site

The product sensed on the oil and gas infrastructure in New Mexico is clearly visible (there is a difference of peak values of c.a. 100 ppb). Features related to gain or offset non uniformity are probably still present, but the high value of the peak emission (c.a. 1000 ppb) appears evident and distinguished from other features of the product.

Figure 26 – New Mexico, Permian Basin Oil and Gas Infrastructure site

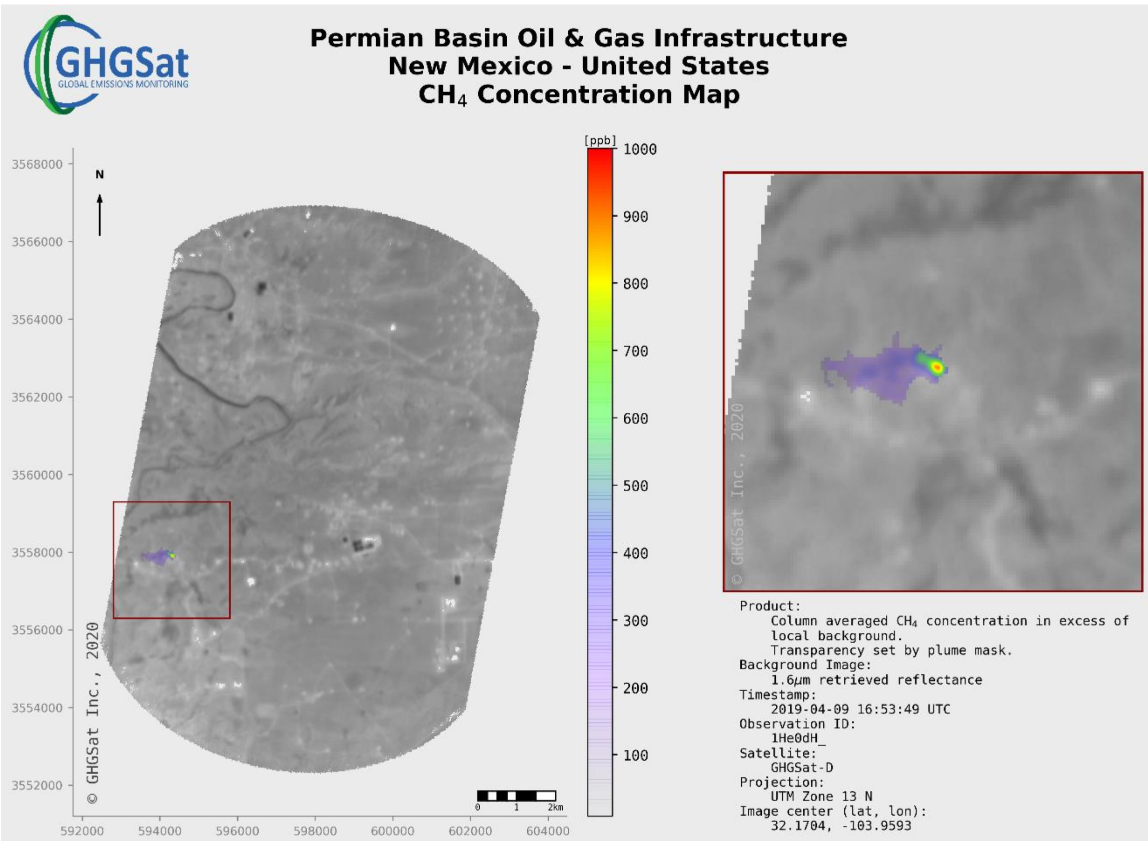


Figure 27 – GHGSAT-D Emissions over New Mexico, Permian Basin Oil and Gas Infrastructure site

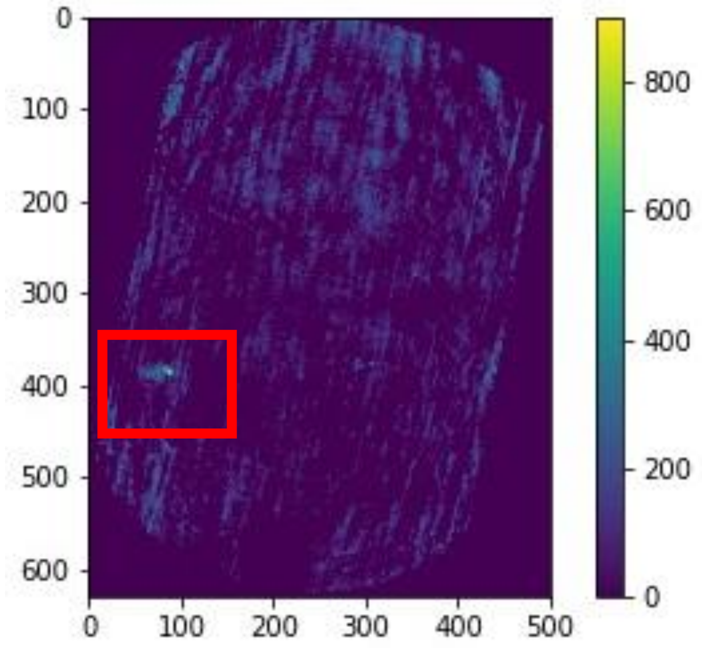


Figure 28 – Emissions recalculated over New Mexico, Permian Basin Oil and Gas Infrastructure site

The last product acquired over Texas Oil and Gas infrastructure, demonstrates the presence of the main emission in centre of the scene, but there are a lot of features (in the left part of the scene is comparable and slightly higher than the main emission). The straylight effect are probably manifested in the shadowed area, but there are probably effects related to the non-uniformity of gain or offset.

Figure 29 – Texas, Permian Basin Oil and Gas Infrastructure site

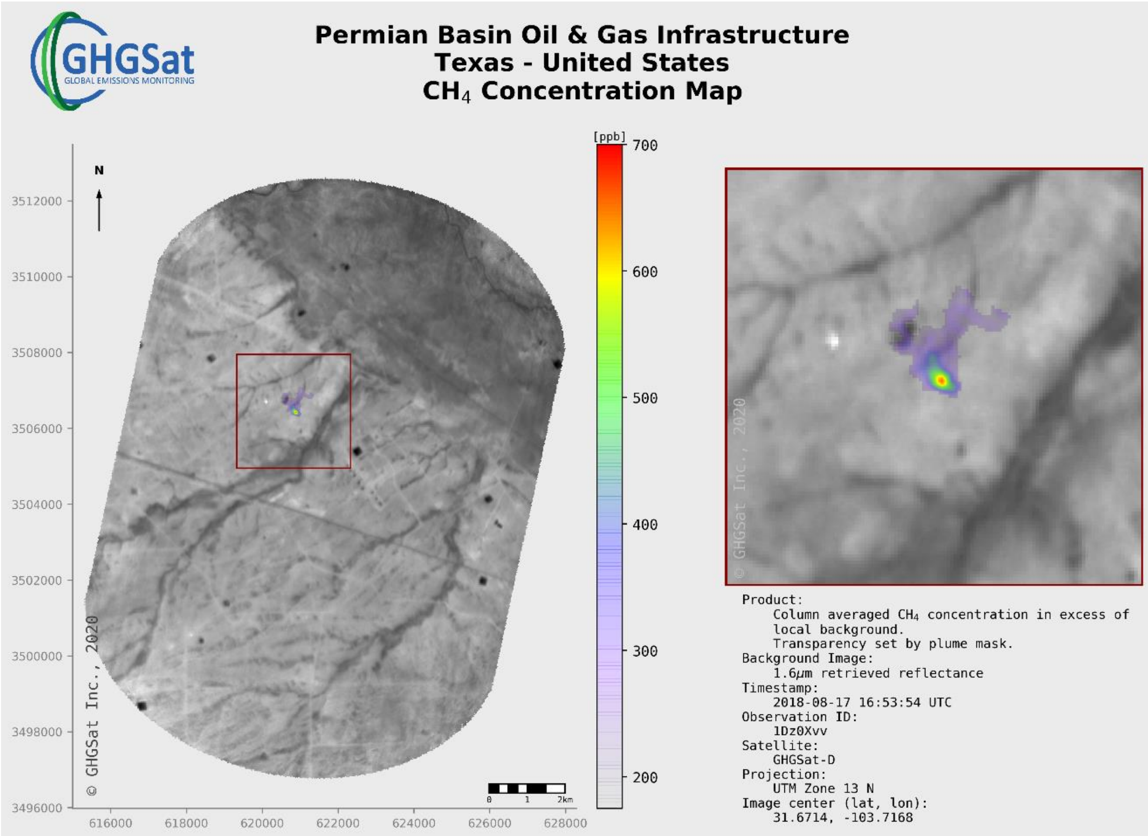


Figure 30 – GHGSAT-D Emissions over Texas, Permian Basin Oil and Gas Infrastructure site

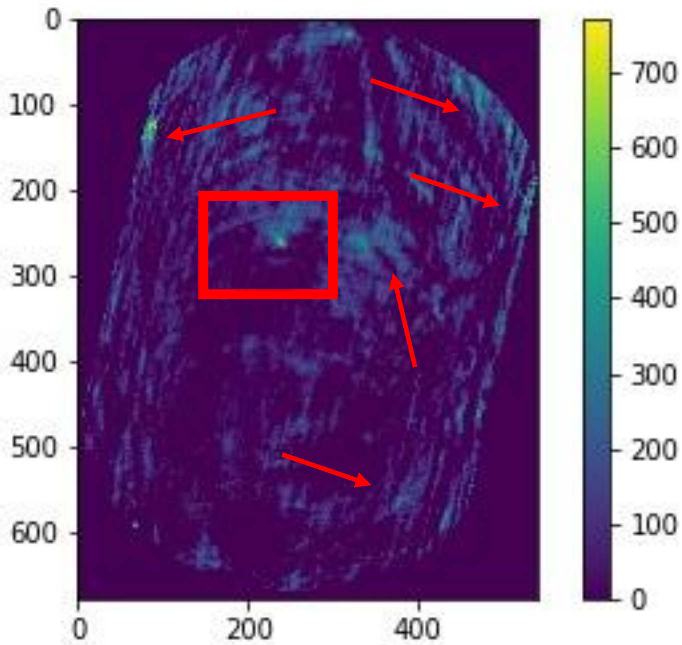


Figure 31 – Emissions recalculated over Texas, Permian Basin Oil and Gas Infrastructure site

3.2.1 Intercomparisons with CAMS emissions

CAMS provides gridded distributions of European and global anthropogenic emissions, as well as global natural emissions.

The CAMS emissions are based on various existing data sets (e.g., nationally reported emissions, EDGAR, ECLIPSE and CEDS), which ensures good consistency between the emissions of greenhouse gases (spatial resolution 0.1 x 0.1 deg.). The emissions are provided on a monthly basis and for this reason a qualitative assessment can be performed.

The qualitative intercomparison between the emissions rate and the CAMS datasets, shows that the emission map matches with the site of methane emission: there is no correspondence only on New Mexico site. In the Figures 32-38 the CAMS maps are compared with GHGSat-D observations, with the red arrows pointing to the emissions (no arrow is present in Figure 35 due to the lack of correspondence between satellite measurements and CAMS map). The blue dots geo-localize the emission structures.

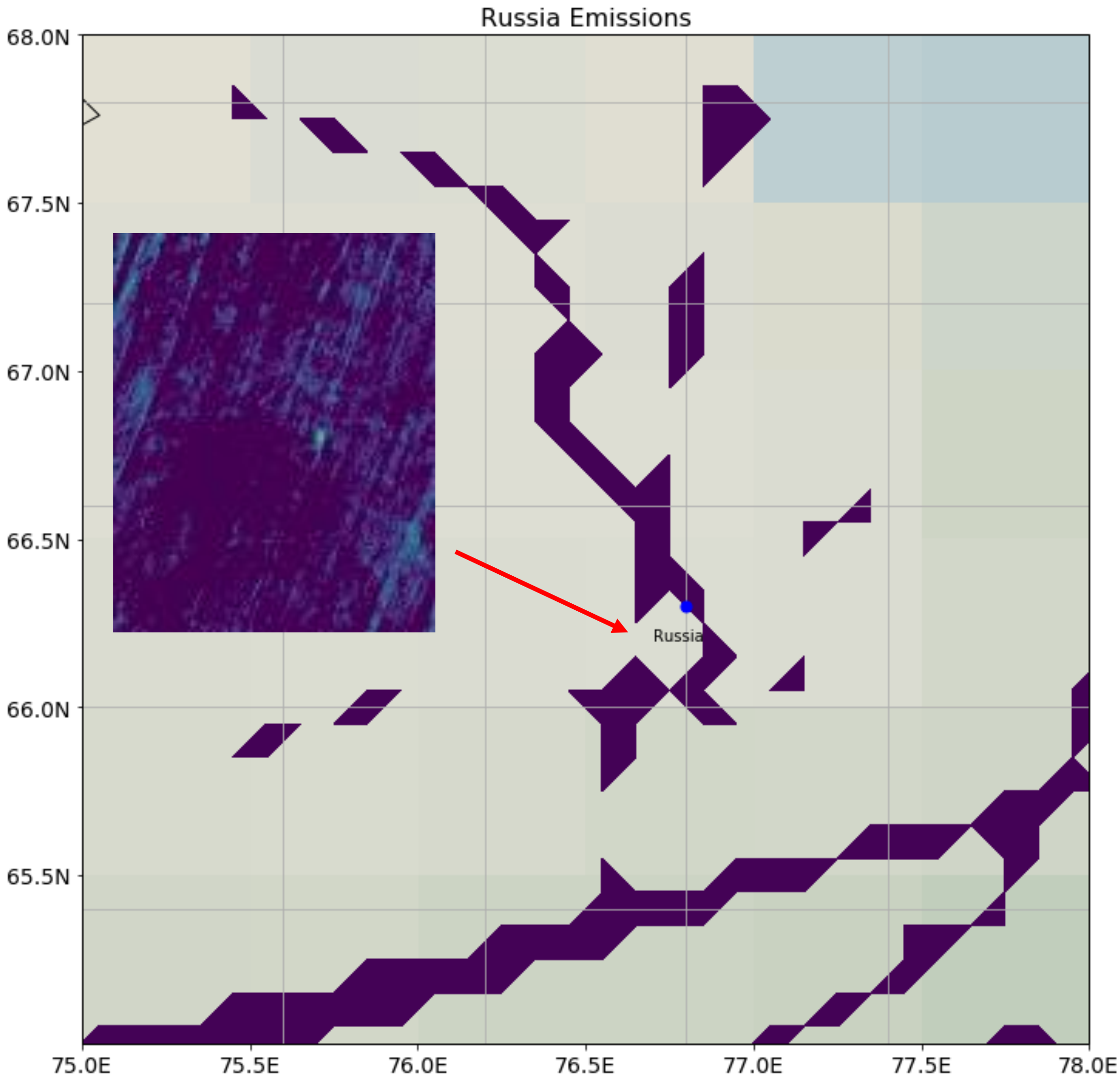


Figure 32 – CAMS Emissions over Russian Oil and Gas Infrastructure site

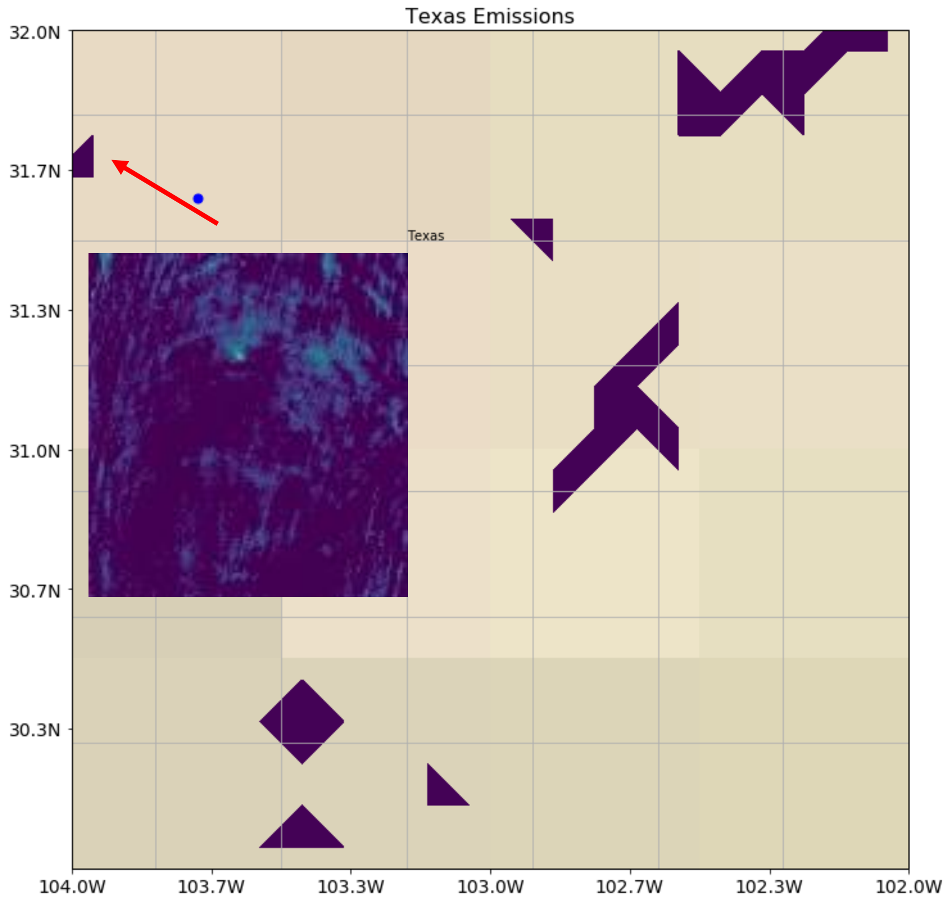


Figure 33 – CAMS Emissions over Texas Oil and Gas Infrastructure site

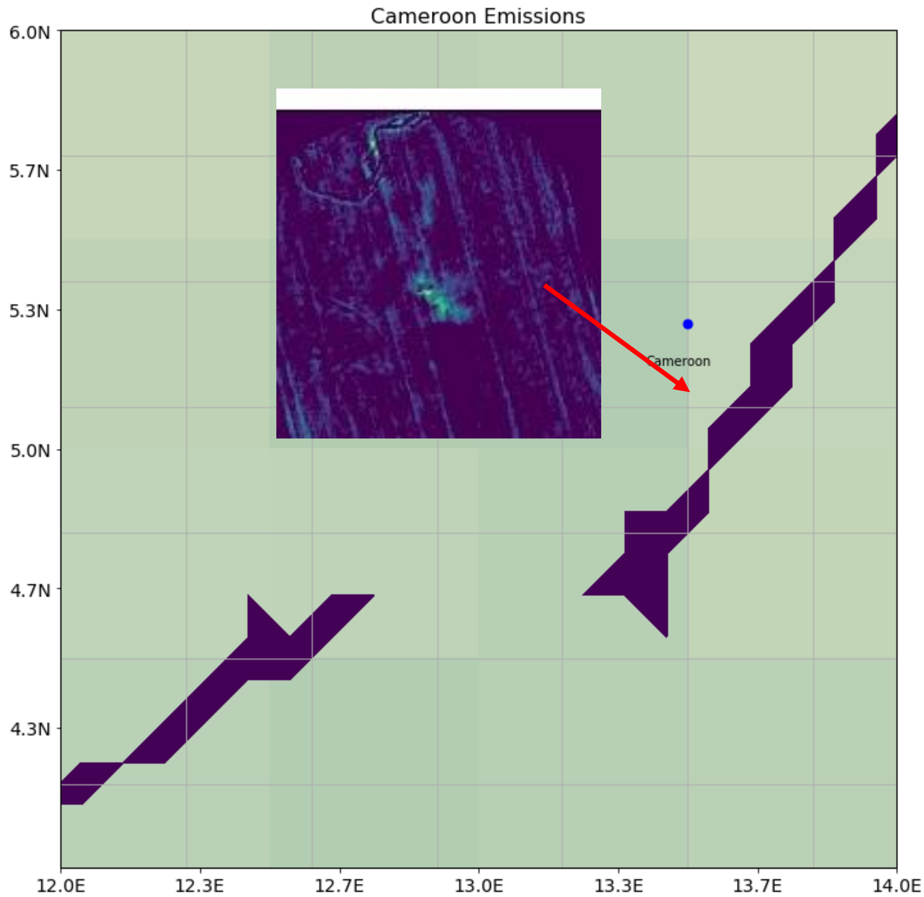


Figure 34 – CAMS Emissions over Cameroon Hydroelectric Infrastructure site

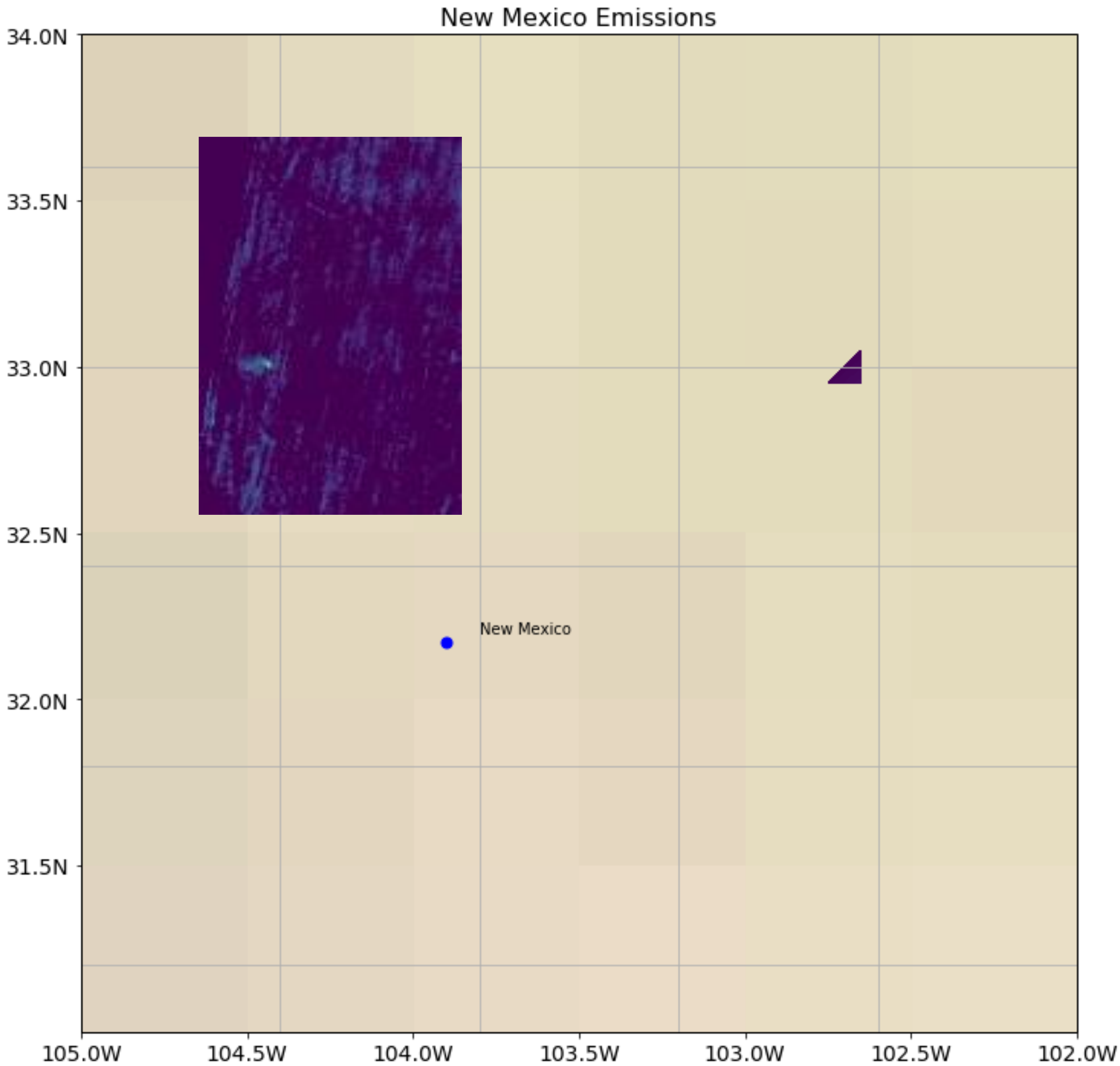


Figure 35 – CAMS Emissions over New Mexico Oil and Gas Infrastructure site

In this product over New Mexico seems there is not correspondence with the CAMS emissions.

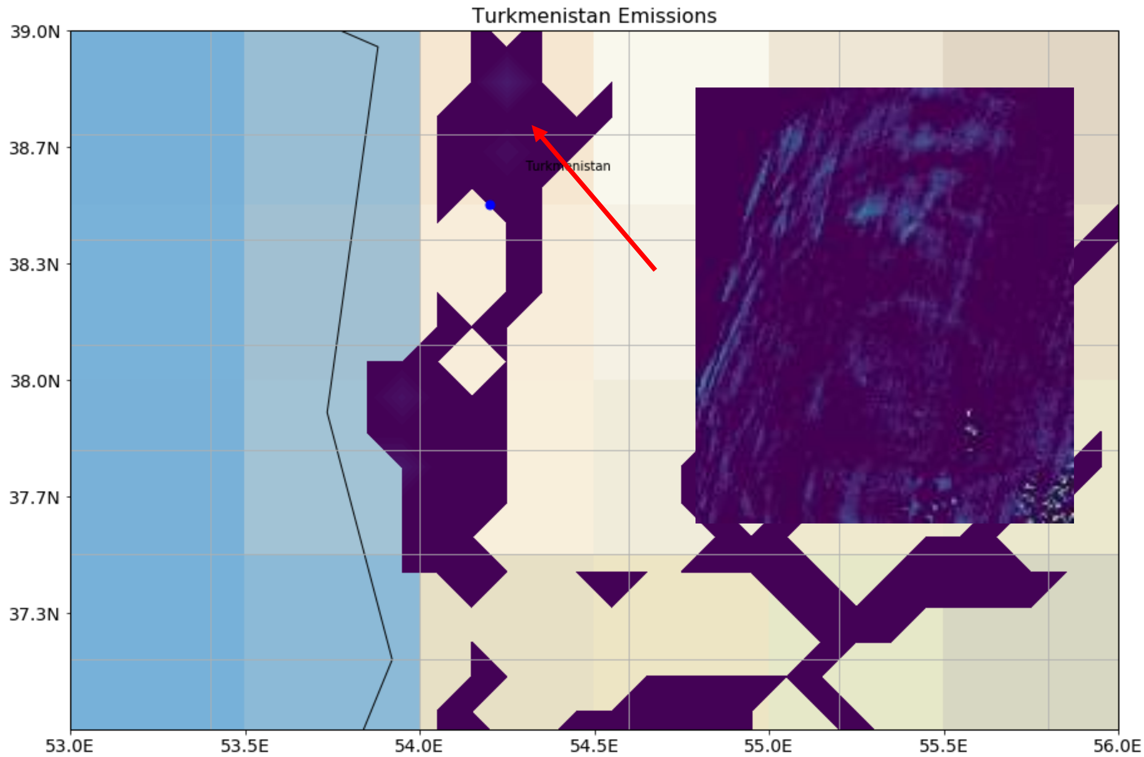


Figure 36 – CAMS Emissions over Turkmenistan Oil and Gas Infrastructure site

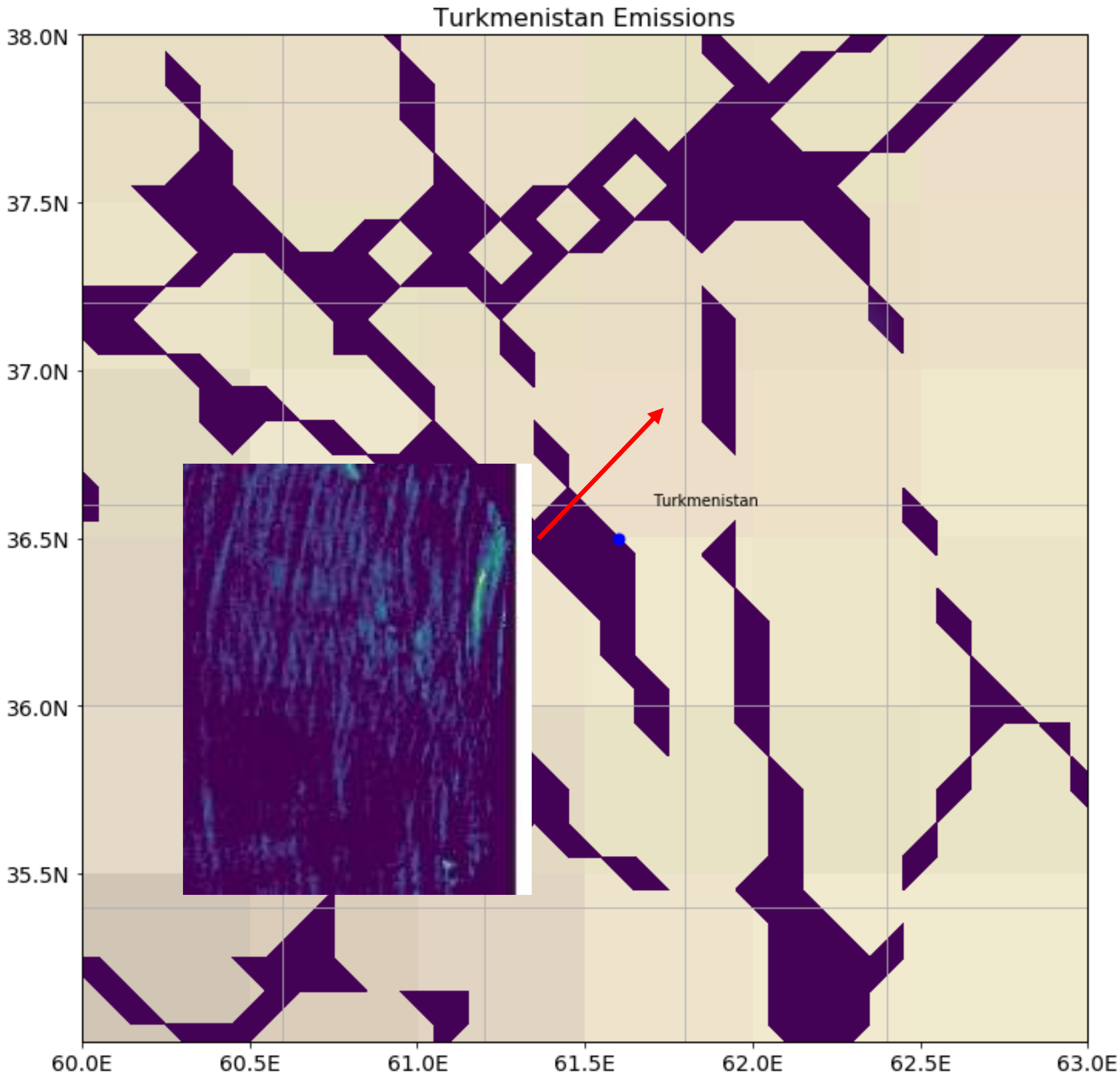


Figure 37 – CAMS Emissions over Turkmenistan Oil and Gas Infrastructure site

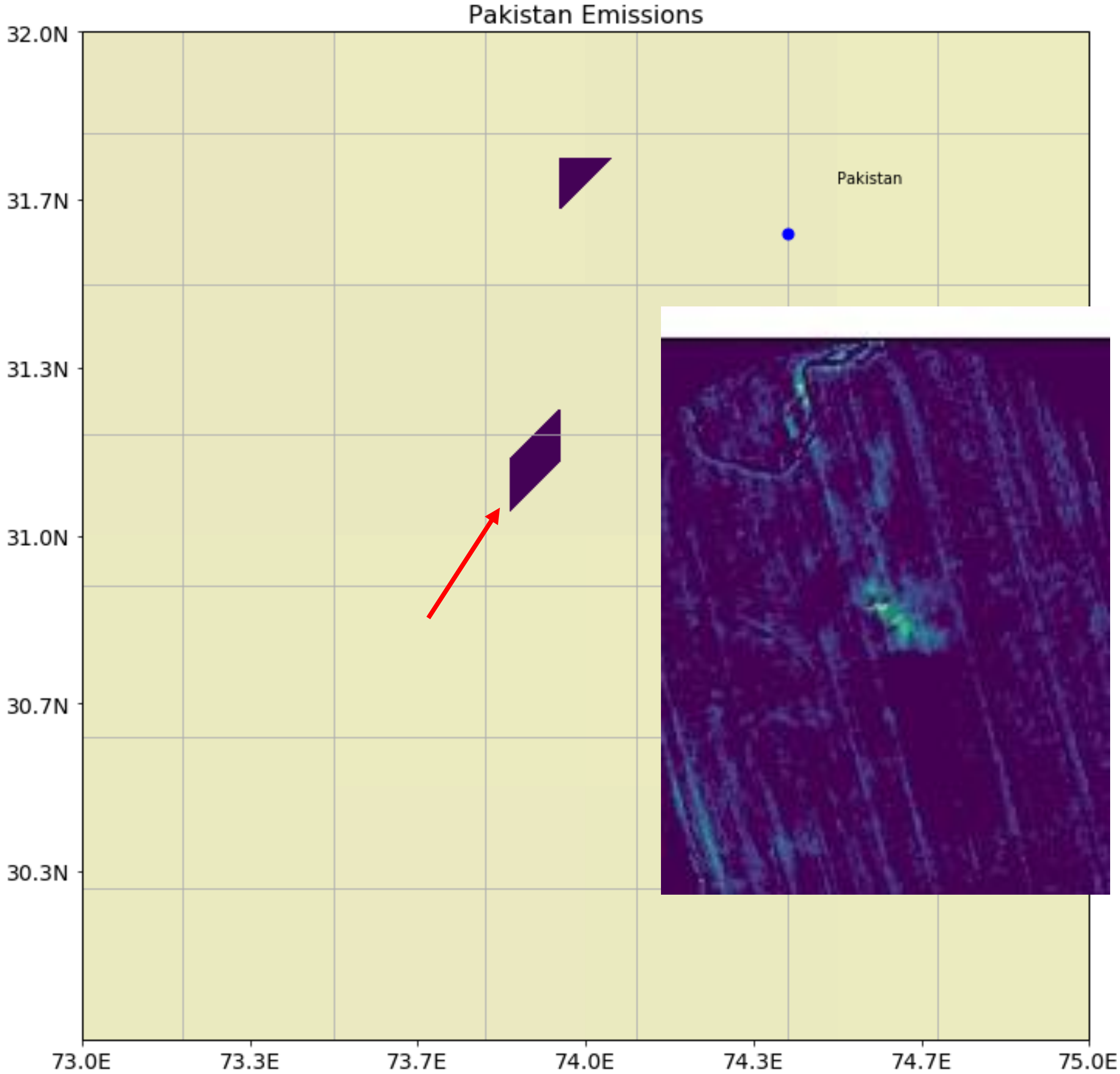


Figure 38 – CAMS Emissions over Pakistan Landfill Infrastructure site

4. CONCLUSION

Methane (CH4), the second most important manmade greenhouse gas (GHG) after carbon dioxide (CO2), is responsible for more than a third of total anthropogenic climate forcing. It is also the second most abundant GHG accounting for 14 percent of global GHG emissions. Methane is considered a “short-term climate forcer,” meaning that it has a relatively short lifespan in the atmosphere, approximately 12 years. While methane is in the atmosphere for a shorter period of time and is emitted in smaller quantities than CO2, its ability to trap heat in the atmosphere, which is called its “global warming potential,” is 21 times greater than that of CO2.

Methane is emitted during the production and transport of coal, natural gas, and oil. Emissions also result from the decay of organic matter in municipal solid waste landfills, some livestock manure storage systems, and certain agro-industrial and municipal wastewater treatment systems.

The performed assessment has been based on the intercomparison between the GHGSAT-D methane emissions and the recalculated emissions from the data provided; and the intercomparison with the CAMS emissions datasets.

The GHGSA-D instrument has demonstrated the capacity to reveal emissions, with some limitations related to the calibration strategy: in the dataset provided, there are in fact many features that can be correlated to the uncomplete correction of errors.

In the next study on C1 satellite, considering the different calibration strategy adopted, a clearer methane emissions identification is expected.