WHITE PAPER

Advancing Global Methane Monitoring: A Breakthrough Partnership between Chinese National Satellites and Canadian Commercial Satellites

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1 SUMMARY / KEY FINDINGS

This white paper presents the first collaborative integration between GHGSat Inc. (GHGSat) and the Shanghai Institute of Technical Physics, Chinese Academy of Sciences (SITP) in comprehensive methane monitoring, combining observations from the GHGSat constellation and the Chinese satellites with the Advanced Hyperspectral Imagers (AHSIs) in one of the most important energy producing regions in the world throughout 2023. Scheduled for release at COP29, this breakthrough partnership demonstrates a significant advancement in international climate cooperation, leveraging complementary space assets for enhanced climate monitoring and setting a model for future global collaboration.

- Through systematic analysis of more than 500 satellite scenes (229 from GHGSat and 323 from AHSI aboard four Chinese satellites), using independently developed retrieval algorithms respectively, we achieved monitoring coverage of over 130 thousand square kilometers and successfully identified more than 2,400 methane emission events. This achievement demonstrates how combining different operational strategies - GHGSat's targeted measurements and AHSI's large coverage - can significantly enhance detection capabilities.
- This study represents the first successful integration of Chinese national satellites and Canadian commercial satellites for global methane monitoring, marking a historic milestone in international climate collaboration. The complementary observation strategies - with GHGSat providing high-frequency temporal coverage and AHSI delivering comprehensive spatial coverage - demonstrate how international partnerships can achieve superior monitoring effectiveness.
- With a combined fleet of twelve satellites (eight from GHGSat constellation and four Chinese national satellites) and over 500 scenes, this partnership represents one of the largest coordinated deployments of national and commercial satellites in methane monitoring to date, thereby accelerating international collaboration in climate action.
- Our findings demonstrate the strong complementarity between advanced technological approaches - the convex-grating spectrophotometry of AHSI and the Fabry-Pérot interferometer of GHGSat. Both systems deliver exceptional detection capabilities, with extensive coverage and precise emission quantification. Together, they have successfully detected and measured emission rates from minor sources to major sources exceeding 5,000 kg/hr.
- Through the identification of three spatially coincident detections between both systems, we have established an effective approach for cross-validation and temporal analysis of emission sources. This integration enables more accurate annual emission estimates and demonstrates the potential for developing rapid alert systems for emission events.
- The study establishes an innovative framework for "tip and cue" operations between advanced satellite systems. This operational synergy, combined with

the complementary capabilities of both systems, sets a new benchmark for future global methane monitoring efforts.

2 INTRODUCTION

The greatest challenge in global methane monitoring is the current inability to detect and quantify emissions comprehensively and rapidly enough for effective mitigation. This challenge stems from a fundamental dilemma: achieving both extensive spatial coverage and frequent temporal sampling has proven impossible for any single satellite system. This limitation severely impedes global efforts to reduce methane emissions, particularly from dispersed emitters.

While satellites offer unprecedented capabilities in methane detection, individual systems face inherent constraints. Commercial satellites such as GHGSat's can provide targeted, repeated observations with high sensitivity but struggle to cover vast geographical areas. National satellites can often achieve broader spatial coverage but may miss the temporal dynamics of intermittent emissions due to limited scales. This technical bottleneck has become increasingly critical as countries and companies seek to meet their methane reduction commitments.

This white paper represents the first collaborative study between GHGSat and SITP using the GHGSat constellation and Chinese Advanced Hyperspectral Imager (AHSI) satellites. By integrating different satellite systems, we demonstrate how to overcome the spatial-temporal coverage dilemma. We validate this approach in this 2023 study in a region where extensive oil and gas operations provide an ideal test case for comprehensive methane monitoring.

2.1 Mission Overview – GHGSat Methane Constellation

GHGSat is a Canadian business established in 2011 to monitor greenhouse gas emissions from industrial facilities worldwide. GHGSat's vision is to use satellites to become the global leader for the remote sensing of greenhouse gas emissions from any industrial source in the world, enabling user organizations in the energy, resource, power generation, agricultural, waste management, and sustainability sectors to better understand, control, and reduce their emissions. GHGSat's commercial constellation currently consists of 11 satellites: GHGSat-C1 launched in September 2020, GHGSat-C2 launched in January 2021, GHGSat-C3 to -C5 launched in May 2022, GHGSat-C6 to -C8 launched in April 2023, and GHGSat-C9 to -C11 launched in November 2023.

Eight of these satellites (GHGSat-C1 through -C8) were fully commissioned and available in 2023 for the work described in this white paper.

2.2 Mission Overview – Chinese Hyperspectral Satellites

We analyzed 323 scenes of spaceborne imaging spectrometry to detect, and quantify methane plumes using the Advanced Hyperspectral Imagers (AHSIs) aboard the Gaofen-5-02, Gaofen-5-01A, Ziyuan-1-02D, and Ziyuan-1-02E satellites. The primary task of each payload here is to search for both known and unknown emission sources without any priori spatial knowledge, enabling comprehensive mapping of emission patterns in the target region. The AHSIs aboard Gaofen-5-02 and Gaofen-5-01A satellites were deployed as part of the Chinese High-resolution Earth Observation System (CHEOS), while those on Ziyuan-1-02D and Ziyuan-1-02E satellites were implemented under the National Medium- and Long-Term Development Plan for Civil Space Infrastructure (2015-2025). Notably, the AHSI represents a significant technological advancement as the first spaceborne hyperspectral sensor to integrate convex-grating spectrophotometry with an enhanced three-concentric-mirror (Offner) configuration, marking a crucial innovation in Earth observation capabilities. Each imager achieves 30-m spatial resolution across a 60-km swath, with wavelength coverage from 400 to 2500 nm at 10-nm spectral resolution. The signal-to-noise ratio exceeds 200 near methane absorption bands. The detection threshold for methane emissions reaches 100-200 kg/h, with a methane concentration detection precision of 20-30 ppb. These imagers are the first-generation hyperspectral imagers that use convex grating to disperse spectrum in China and are designed and built by the Shanghai Institute of Technical Physics, Chinese Academy of Sciences.

	GHGSat	**AHSI**
Number of available satellites in 2023	8	4
Altitude (km)	490-521	705-778
Swath width (km)	12	60
Measured area per observation (km^2)	200-435	3690-3871
Ground Sampling Distance (m)	25-30	30

Table 1: Overview of satellites used in this study. GHGSat observations have adjustable length, with (standard, extended) modes having approximately (200,345) km^2 areas, respectively. In 2023, only the standard mode was used in the region under study.

3 SPATIAL COVERAGE OF SATELLITE OBSERVATIONS

The spatial monitoring coverage in 2023 from the two satellite systems are illustrated in Figure 1 and Figure 2. GHGSat capacity has been allocated mainly to perform repeat measurements in areas with persistent emissions. On the other hand, the AHSI satellites have been tasked in a more evenly distributed manner. This is an example of complementarity of different operational strategies.

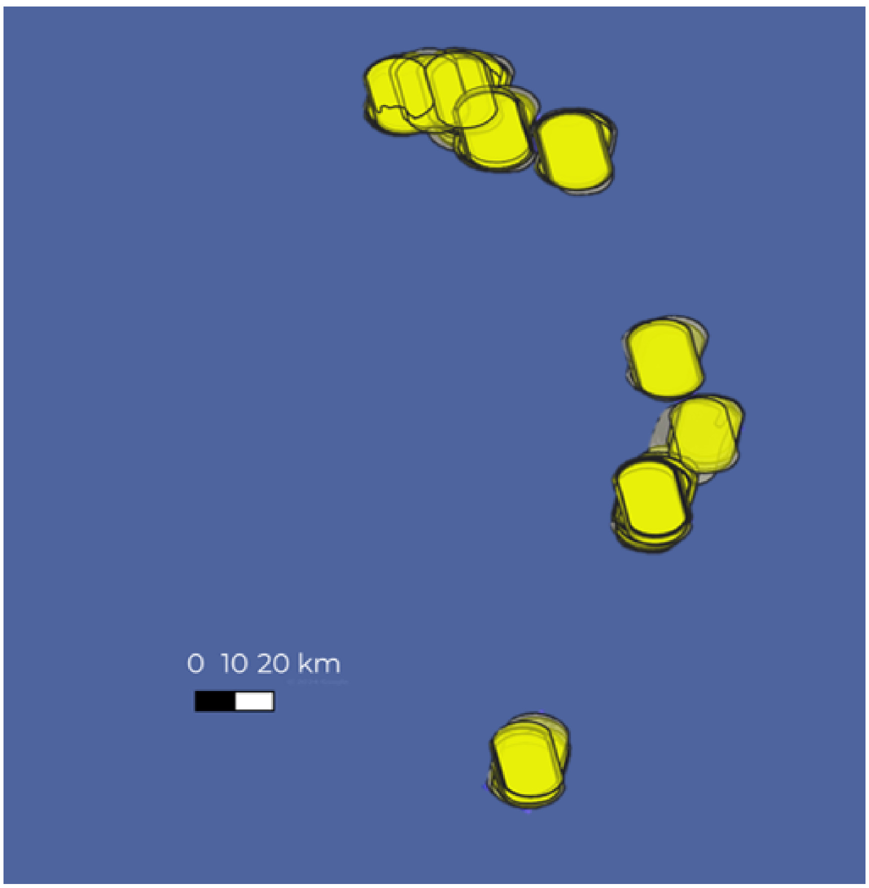

Figure 1: Footprints of all 2023 observations by the GHGSat constellation.

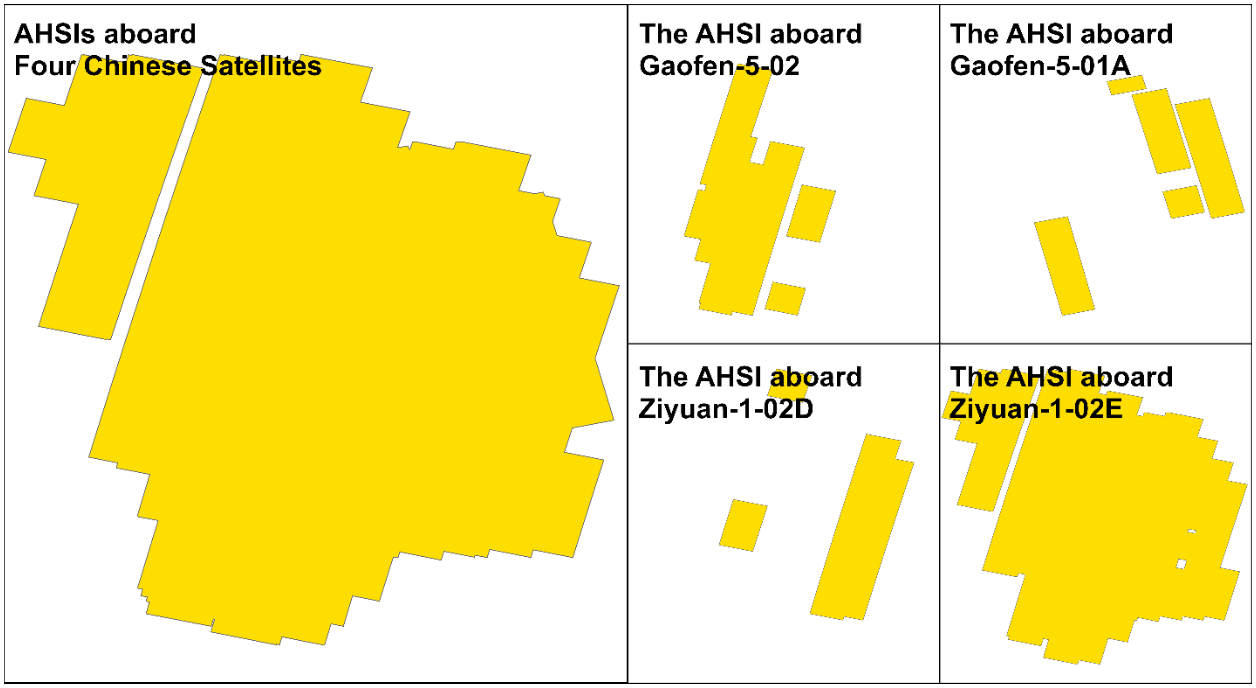

Figure 2: Footprints (shaded in yellow) of all 2023 observations by the AHSI satellites in the region.

This complementarity can also be seen in Table 2, which shows the higher area coverage from the Chinese satellites vs GHGSat's constellation. Furthermore, it shows that the areas observed by GHGSat have been measured an average of ~20 times in the year, whereas this ratio is less than 10 for the Chinese system.

	GHGSat	**AHSI**
Number of observations in 2023	229	323
Average area covered per observation	207 km^2	3690-3871 km^2
Total aggregate area of all observations	47.3×10^3 km^2	1198.4×10^3 km^2
Aggregate area measured at least once	2.4×10^3 km^2	133.0×10^3 km^2

Table 2: Coverage statistics for each satellite system, 2023.

4 DETECTED EMISSIONS

Here we present the locations (Figure 3, Figure 4) and emission statistics (Table 3, Figure 5, Figure 6) from the plumes detected by the two satellite systems.

Here, the difference in coverage strategy between the two systems is again apparent. While there are very few imaging plans for AHSIs targeting emission sources focused by GHGSat satellites, AHSI satellites have seen widespread key emissions in areas without any priori knowledge unobserved by the GHGSat constellation. This shows the potential for collaborative tip and cue operations – GHGSat could reallocate some capacity to monitor additional locations for the sources that AHSIs have identified.

	GHGSat	AHSI
Number of plumes detected	2427	14
Average emission rate	1659 kg/hr	5384 kg/hr

Table 3: Plumes detected in 2023 by the two satellite systems in the region under study.

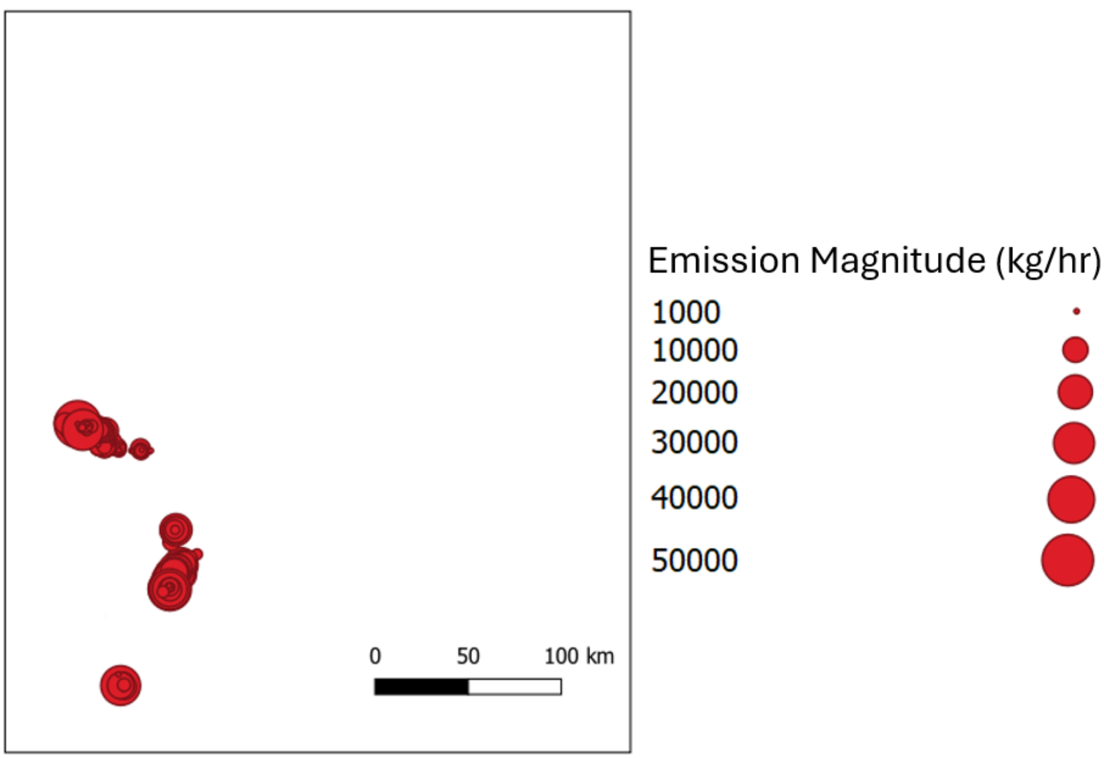

Figure 3: Geographical distribution of plumes detected by GHGSat satellites in the region in 2023.Marker size is scaled with emission rate.

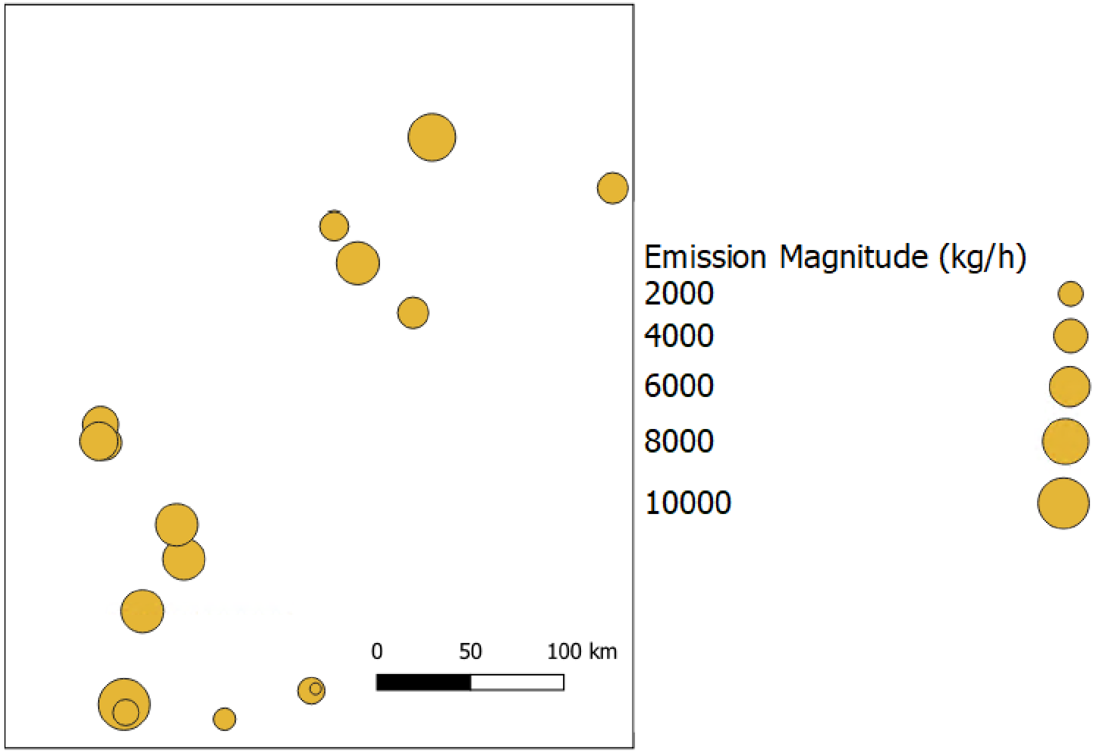

Figure 4: Geographical distribution of plumes detected by AHSI satellites in the region in 2023. Marker size is scaled with emission rate.

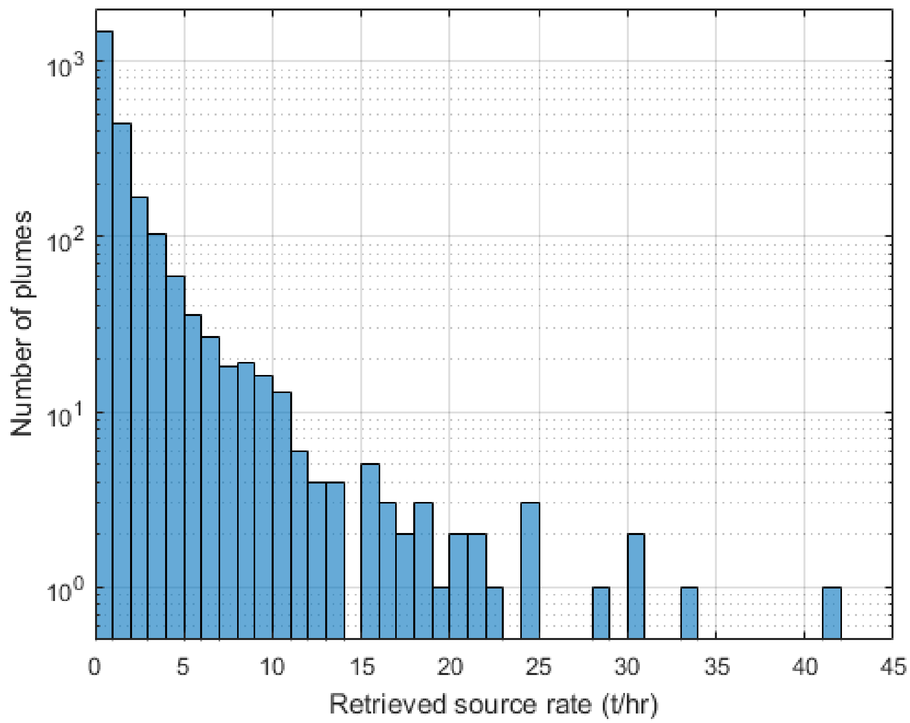

Figure 5: Histogram of emission rates from plumes detected and quantified by the GHGSat constellation.

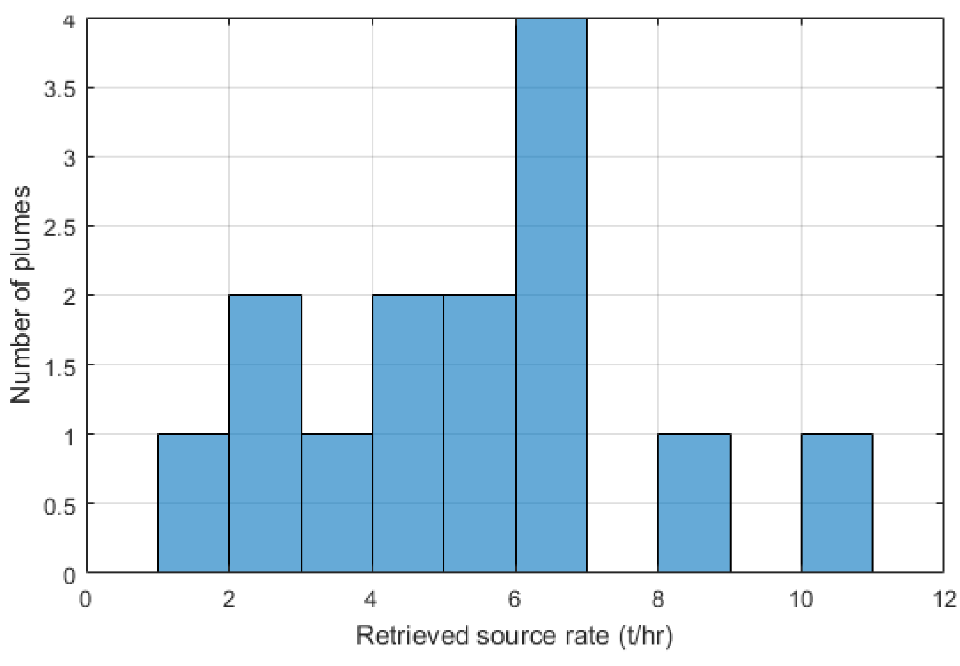

Figure 6: Histogram of emission rates from plumes detected and quantified by the AHSI satellites

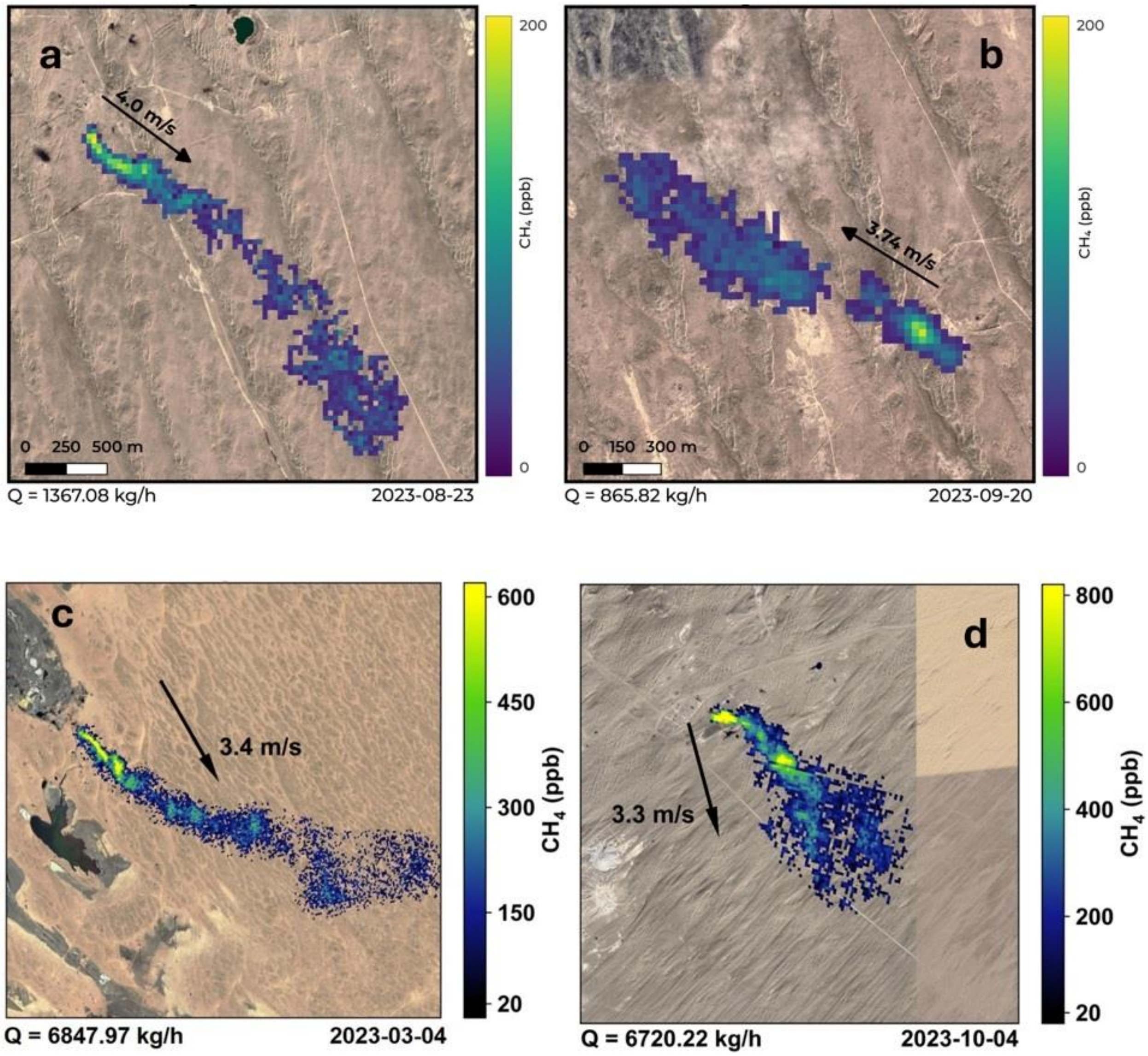

Figure 7: Representative examples of methane plumes in the region from the GHGSat constellation (a and b) and the AHSI satellites (c and d).

5 SPATIALLY COINCIDENT DETECTIONS

Of the 14 plumes detected by the AHSI satellites in 2023, three of them are within a short distance (comparable to the imaging resolution) of at least one GHGSat-detected plume. This is a strong indication that the emitter facility is the same. This type of spatial coincidence can potentially be exploited to combine data from multiple satellites to study single-site emissions trends, and ultimately to obtain better estimates of annual totals. An example of such a detection "cluster" is shown in Figure 8, and the time series of the estimated emission rates from the same collection of plumes is shown in Figure 9.

Independent measurements from convex-grating systems aboard AHSI satellites and Fabry-Pérot instruments aboard GHGSat satellites showed strong agreement in quantifying methane emissions. In this one key case, 16 GHGSat observations aligned with an AHSI detection of the same source, with emission rates closely matching despite different observation times and techniques. This consistency across independent platforms contributes to validation of both detection methods.

The two satellite systems reveal complementary aspects of emission dynamics. Combining observations from both platforms captures rapid temporal variations and sustained emission patterns, enabling detailed characterization of source behavior. The integrated dataset provides deeper insights into emission mechanisms and their temporal evolution - achievements beyond the capability of any single system.

These coincident observations demonstrate the value of integrating data from different satellites. The proven ability to cross-validate measurements opens new possibilities for automated monitoring and coordinated observations. As satellite methane detection technology advances, these early successes guide the development of more effective global monitoring strategies.

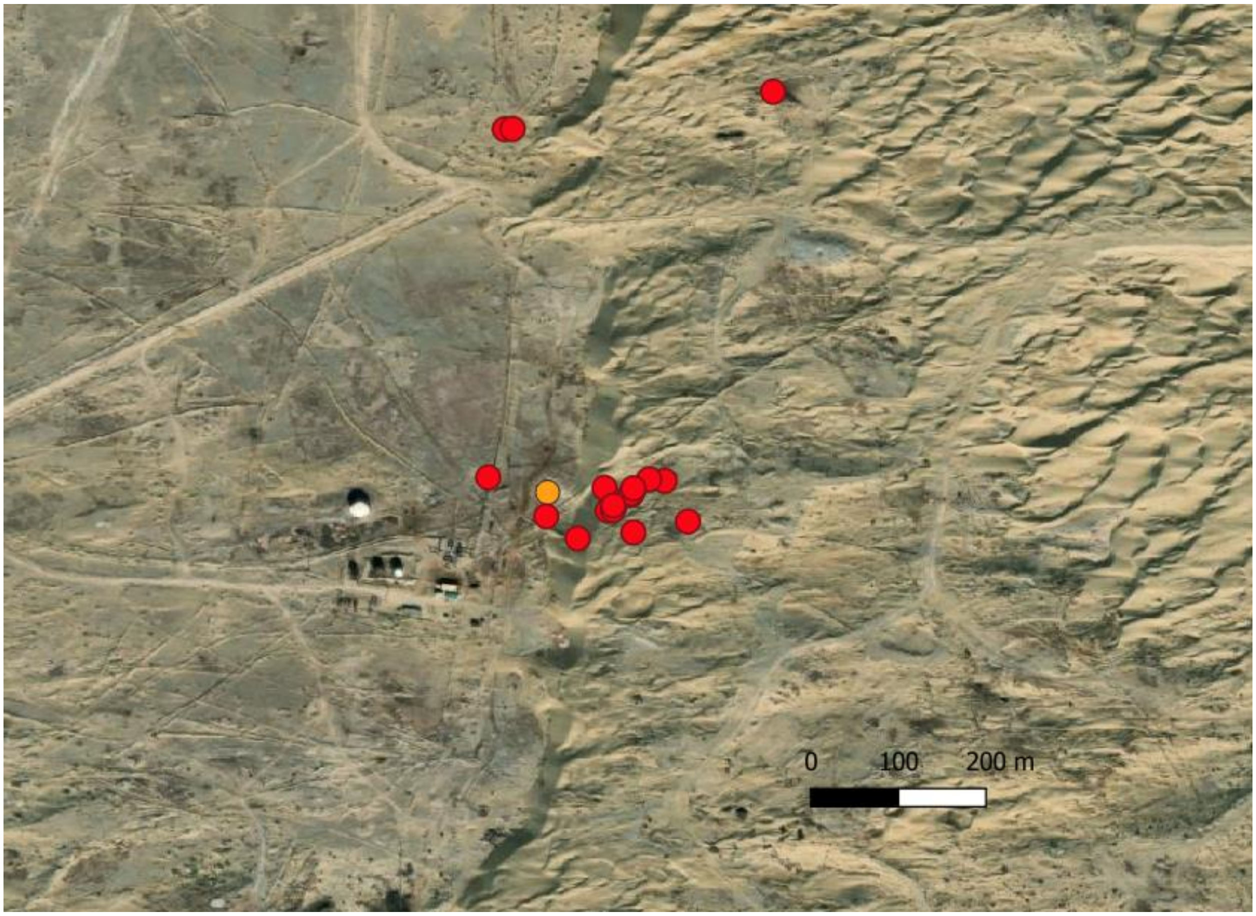

Figure 8: Example of a "cluster" of detected plumes within a small area. Here, 17 GHGSat-detected plumes (red markers) are located within 200 metres of a plume detected by an AHSI satellite (orange marker).

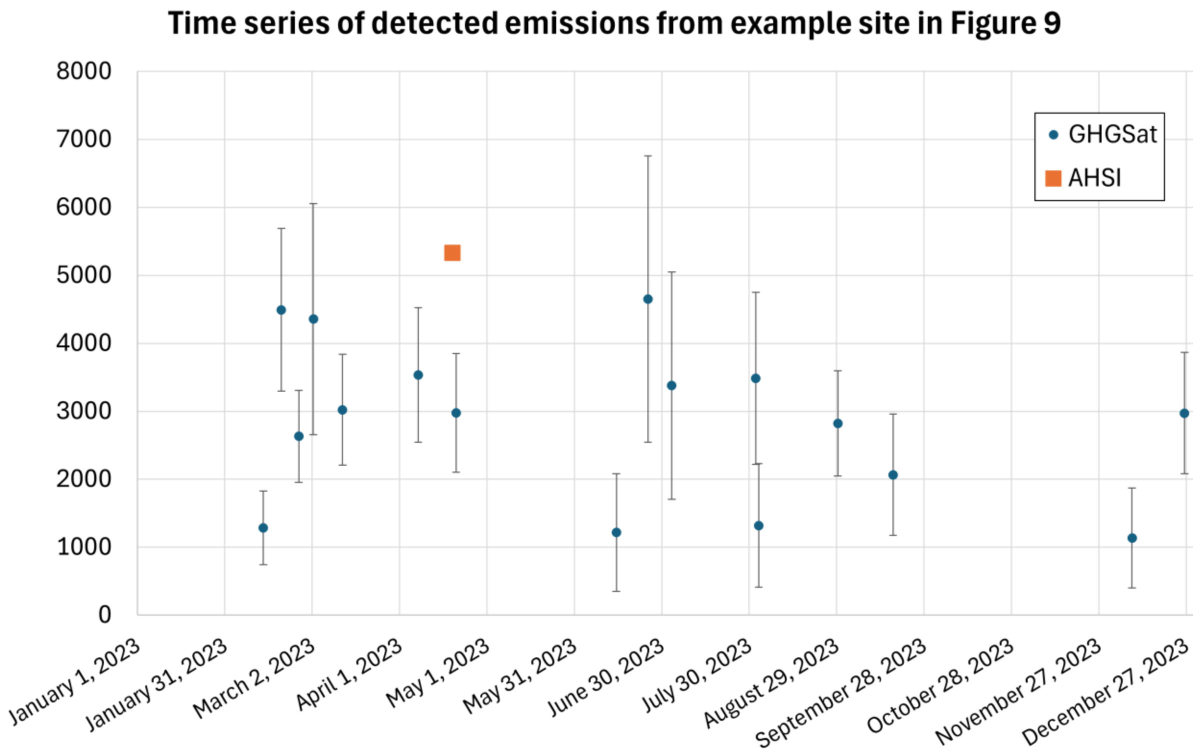

Figure 9: This time series shows how multiple satellites can be combined to increase temporal sampling density for specific sites.

6 Future Work

The exploratory work performed for this white paper raises confidence that data sets from both satellite constellations can be used together to enable a greater fraction of global emissions to be detected, enable better site attribution and potential for prompt mitigation of emissions, and maximize spatiotemporal coverage.

Future work should consider one or more of the following:

- Real-time joint detection framework, including for example alert mechanisms and cross-validation with coincident observations
- Strategic global coverage enhancement, including for example coordinated spatiotemporal planning and tipping & cueing between the two constellations
- New technology development, including for example improved methods for emissions quantification from different types of sources and improved methods for site-level emissions quantification for both intermittent and persistent sources

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