Reply to Referee #2

The manuscript presented by Li et al. investigates an optimal design (size and placement) of an EM27 total column CH_4 network in Africa.

This is an excellent manuscript, very well written, concise and easy to follow. The proposed method employs a Bayesian framework building on previous network design studies such as Kaminski and Rayner (2017). The design involves two steps, first finding an optimal number of sites from an ensemble of candidate sites, then identifying the optimal combination of sites for this number maximising the uncertainty reduction for a selected target quantity (e.g. total African CH_4 emissions). The method is sound, well-motivated, and formally outlined in a clear way. The results of the study are convincing and relevant. I particularly like the approach of not randomly searching for locations, but starting from a pre-defined set of candidate sites potentially offering the infrastructure for setting up and operating such an instrument. Cloud cover is a severe limitation for this type of measurements, but is quite carefully included in the analysis.

The manuscript is already in a very good state. I thus have only a few minor points and small corrections:

We thank the reviewer for the thoughtful evaluation of our manuscript and for the helpful suggestions. We have carefully considered each comment and provide our detailed responses below.

1. Line 68: Please consider adding two recent network design for CO_2 and CH_4: 1. Villalobos et al. (https://doi.org/1088/1748-9326/adc41e), 2) Thanwerdas et al. (https://doi.org/10.5194/egusphere-2025-5804), which were similarly exploring the suitability of existing infrastructure.

Response: We have added citations of these two recent works on network design in Line 70.

2. Line 152: The choice of a different year for the inventories (2023) and meteorology (2025) is certainly not ideal for natural fluxes correlated with meteorology such as wildfires and wetlands. I don't expect this to severely impact the results but this was clearly not an optimal choice when designing the study.

Response: We agree that matching the inventory and meteorological years would have been preferable. The manuscript has been revised to acknowledge this limitation and to clarify the expected implications for the network optimization. In particular, the temporal inconsistency may introduce some uncertainty in the exact magnitude of the estimated benefits and in individual site choices, while the comparative evaluation of candidate configurations remains internally consistent. The corresponding clarification has been added in Lines 162-167.

Lines 162-167: The reference year of the inventories therefore differs from that of the meteorology used for the transport simulations (2025). This temporal mismatch is not ideal, particularly for meteorology-sensitive natural sources such as wetlands and fires, and may affect the absolute uncertainty reductions or the placement of individual sites. However, because all candidate networks are evaluated consistently using the same prior and transport framework, the main relative spatial priorities and overall methodological conclusions are expected to remain broadly robust.

3. Line 234. Up to this equation, this is all standard Bayesian formalism. It would be nice if it could be stated more clearly how the proposed network design approach differs from previous studies.

Response: We have revised the methodological overview to clarify that the calculation of posterior uncertainty reduction follows the conventional Bayesian principles. The main distinction of the present study lies instead in how this formalism is embedded within the network-design framework and applied to the African case. Specifically, the framework evaluates all candidate-site combinations across a range of network sizes, allowing the number of additional stations and their spatial configuration to be determined jointly rather than prescribing the network size in advance. It also incorporates site-specific cloud-driven data availability and restricts the candidate pool to locations identified as realistically deployable based on consultation and assessment of local hosting and operational capacity. These features make the framework more directly applicable to practical network planning and phased implementation. This clarification has been added to Lines 117–125.

Lines 117–125: The framework quantifies the reduction in emission uncertainty provided by atmospheric observations and identifies cost-efficient network designs under specified observational and deployment constraints. Posterior uncertainty reduction is calculated using the conventional Bayesian principles, while the network-design component evaluates all candidate-site combinations across a range of network sizes to determine both an optimal number of additional stations and their optimal spatial configuration. Site-specific cloud-driven data availability is incorporated, and the candidate pool is restricted to locations considered realistically feasible for EM27/SUN deployment based on consultation and assessment of local hosting and operational capacity. The framework can therefore inform both practical network planning and phased implementation.

4. Line 242: Incomplete sentence. Please add "is" between "n*" and "determined"

Response: Done.

5. Figure 2: The middle x-axis label of the upper figure should be corrected. It currently reads "9 Operational + 4 Plan Sites plan".

Response: Done.

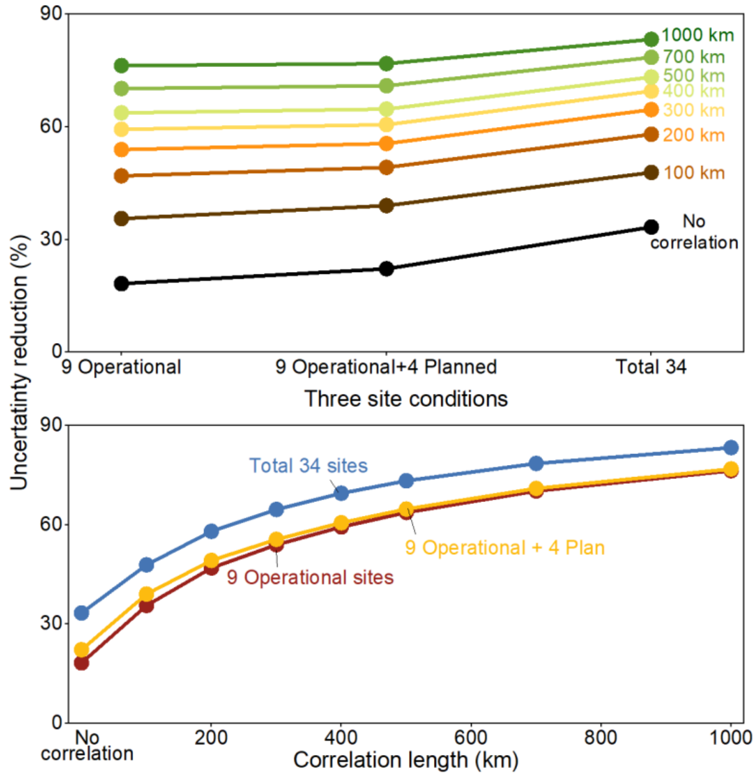

Figure 2. The impact of assumed prior error correlation length on uncertainty reduction. Tests on three basic site conditions, including 9 operational sites only, 9 operational and 4 planned sites, and a network with total 34 sites.

6. Table S2 in the supplement: The table provides an overview the existing, planned, and candidate sites. Since this list is important, it should be stated more clearly in the manuscript how these planned and candidate sites were chosen. It is unclear, for example, which organization / project has planned the four sites. Also the selection of candidate sites needs some more explanation. What kind of sites are these? Why are they suited for EM27 deployment?

Response: The description of the site pool has been clarified in both the main text (Lines 218-227) and Table S2. The four planned sites are locations already included in funded EM27/SUN deployment plans and are being prepared in coordination with the relevant project partners and prospective local host institutions. The other candidate sites are not confirmed future stations. They represent potentially deployable locations identified through consultation with project partners, taking into account the prospective availability of local institutional support and basic research infrastructure. The candidate pool was further designed to improve the geographical coverage of major African methane-emission and ecosystem regions and to fill gaps in the footprint coverage of the existing and planned network. Their inclusion therefore reflects both scientific relevance and preliminary operational feasibility.

Lines 218-227: For the African case study, the pool consists of nine existing stations, predominantly located along the continental periphery, four planned African sites outside the current operational network, and 21 additional candidate sites, yielding 34 potential locations in total (Table S2). The candidate locations were identified through consultation with project partners and selected to balance scientific relevance with preliminary deployment feasibility. Specifically, they were chosen to improve coverage of major African methane-emission regions, including areas with high prior emissions, while also considering the prospective availability of local institutional support and basic research infrastructure, such as universities, observatories, or field stations capable of hosting, operating, and maintaining an EM27/SUN instrument. Their inclusion in the candidate pool does not imply a confirmed deployment commitment, and final installation would require further site-specific logistical and technical assessment.

Table S2. The XCH_4 site pool in Africa in this study, with spatial distribution presented in Fig. 3.

Country	Site	Lat	Lon	Status
France	La Réunion#	-21.0833	55.3917	Operational FTIR sites · (# are sites within TCCON network) · (* are sites operated by the Laboratory for Climate and Environmental Sciences) · (Gobabeb is operated by the Karlsruhe Institute of Technology) · (Jinja is operated by the University of Leicester)
Cyprus	Nicosia#	35.1410	33.3800	
UK	Ascencion#	-7.9667	-14.4000	
Spain	Izaña#	28.3090	-16.4990	
Côte d'Ivoire	LAMTO*	6.2244	-5.0278	
Maroc	AMV*	33.4062	-5.1033	
France	Amsterdam I. *	-37.7976	77.5725	
Namibia	Gobabeb	-23.5622	15.0409	
Uganda	Jinja	0.4165	33.2070	
Congo	Yangambi	0.8100	24.5000	Planned sites (Deployment funding secured or committed)
Congo	Mbandaka	0.0500	18.3000	
Dem. Rep. Congo	Nouabele-Ndoki	2.7000	17.0000	
South Africa	Spioenkop	-28.7132	29.5086	
Cameroon	Dja-Somalomo	3.3738	12.7331	Candidates (With prospective local hosts and existing or potential research infrastructure)
Algeria	Tamanrasset	22.47	5.31	
Chad	Ndjamena	12.1265	14.9997	
Tanzania	DaresSalam	-6.7808	39.20369	
Cameroon	Ntui	4.4000	11.6200	
Senegal	Niakhar	14.5000	-16.4000	
Senegal	Dahra	15.3600	-15.4800	
Benin	Djougou	9.6500	1.7333	
Benin	Dangbo	6.6014	2.5465	
Ethiopia	Assosa	10.1000	34.6000	
Ethiopia	Gondar	12.6000	37.4500	
Djibouti	Arta	11.5000	42.8000	
Rwanda	Kigali	1.9617	30.0642	
Botswana	Maun	-19.9022	23.5283	
Egypt	Nile	27.8800	30.8900	
Burundi	Bujumbura	-3.3600	29.3700	
Zambia	Kalene	-11.1755	24.1917	
Gabon	Lope	-0.2000	11.6000	
Central African Rep.	Bangui	5.2000	18.4000	
South Africa	Kimberley	-28.7300	24.7540	
South Africa	Wits	-24.5530	31.0970	

* Planned sites are locations included in funded deployment plans. Candidate locations were identified through consultation with project partners based on the prospective availability of local institutional support and research infrastructure.

7. Line 378: Seasonal transport patterns also play a role here.

Response: We have added the impact from atmospheric transport patterns in this sentence as shown below.

Lines 394-397: Despite this common pattern, the optimal number of additional sites required to satisfy the marginal gain criterion (ε=0.6% in default setting) varies across sectors and between months (Fig. 4), reflecting differences in the spatial heterogeneity and seasonal redistribution of emission sources, as well as in atmospheric transport patterns.

8. Line 453: It should probably be "system parameters" not "system parameter"

Response: Done.

9. Line 493: The last section should probably be called "Discussion and Conclusions" since there is no final Conclusion section.

Response: Done.

10. Line 501: The sentence emphasises that the global configuration avoids the need for lateral boundary conditions. However, I don't see any difference from a regional study employing e.g. backward Lagrangian transport simulations over 10-20 days as often done. The footprints computed in this way would be very comparable to those computed with LMDZ. I thus suggest adding a sentence instead emphasising that the approach could equally well be applied in combination with backward Lagrangian transport simulations (which would likely be cheaper and could be run at higher resolution).

Response: We have revised this passage to clarify that the global LMDZ configuration is one possible implementation of the framework in Lines 524-527. The text now states explicitly that the network-design approach is not tied to a specific transport model and could also be applied using backward Lagrangian simulations, which may offer lower computational cost and higher spatial resolution for regional applications.

Lines 524-527: This setup provides a consistent representation of large-scale transport pathways without requiring lateral boundary conditions, while the network-design framework is not tied to a specific transport model and could also be coupled with backward Lagrangian simulations to reduce computational cost and enable higher-resolution regional applications.