Universität Bremen

Institute of Environmental Physics
Faculty 1 - Physics / Electrical Engineering
University of Bremen

Towards robust CH_4 emission inversions: Aiming again for permafrost regions?

Work done and next steps

Santiago Parraguez Cerda
Laboratory for Modelling and Observation of the Earth System (LAMOS)

✉ sanparra@uni-bremen.de

37th TM Meeting
03-04 September 2026
Heraklion, Greece

Summarizing the parametric regularization

Applied to TROPOMI WFMD v2.0

Motivation

≈ 180,000,000 per year

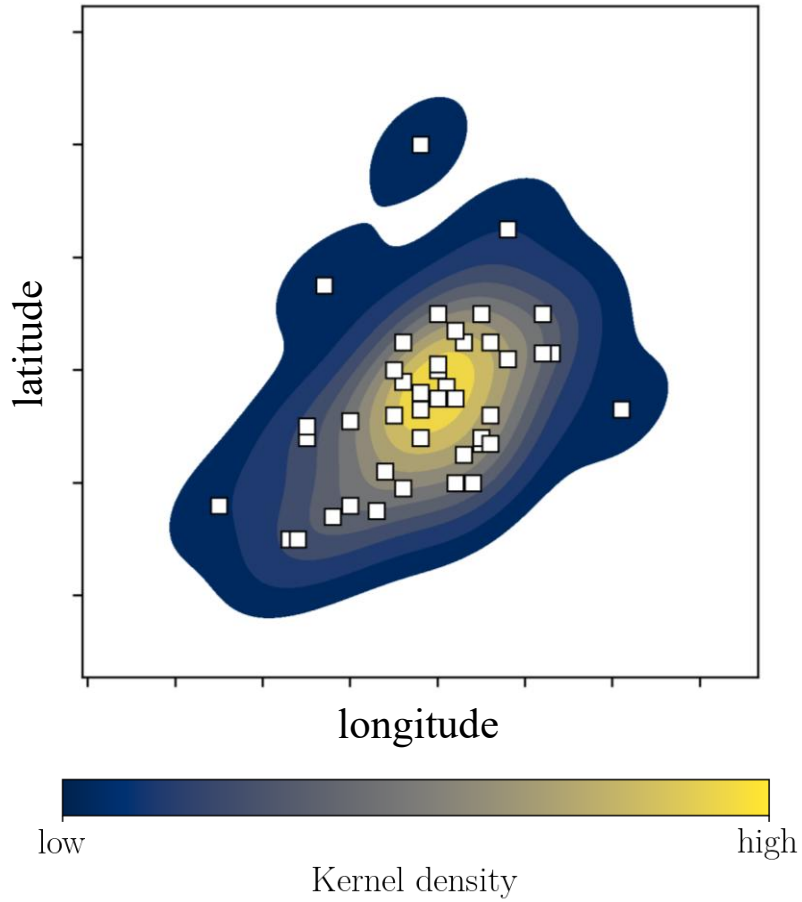
≈ 2,000 per year

$$J(x) = \gamma \cdot \sum^{n} \frac{(Model - TROPOMI)^2}{\sigma^2} + \sum^{m} \frac{(Model - Stations)^2}{\sigma^2} + \ldots$$

Constant regularization factor

Addressing imbalances in dataset size and spatial distribution of atmospheric observations to improve inversions

Parametric regularization factor: Kernel Density Estimation



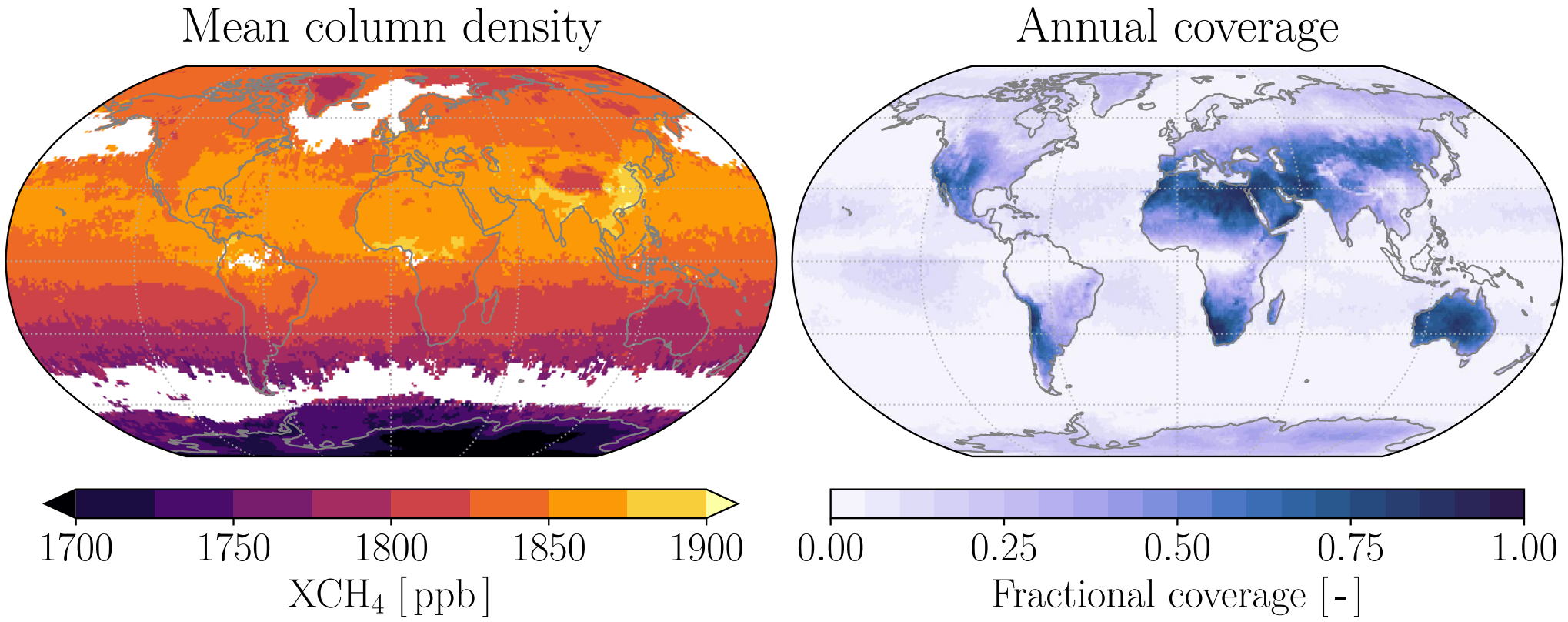
Regularization calculated based on time and space

$$\gamma_i^2 = \sum \exp\left(-\frac{d_{ij}^2}{2h^2}\right)$$

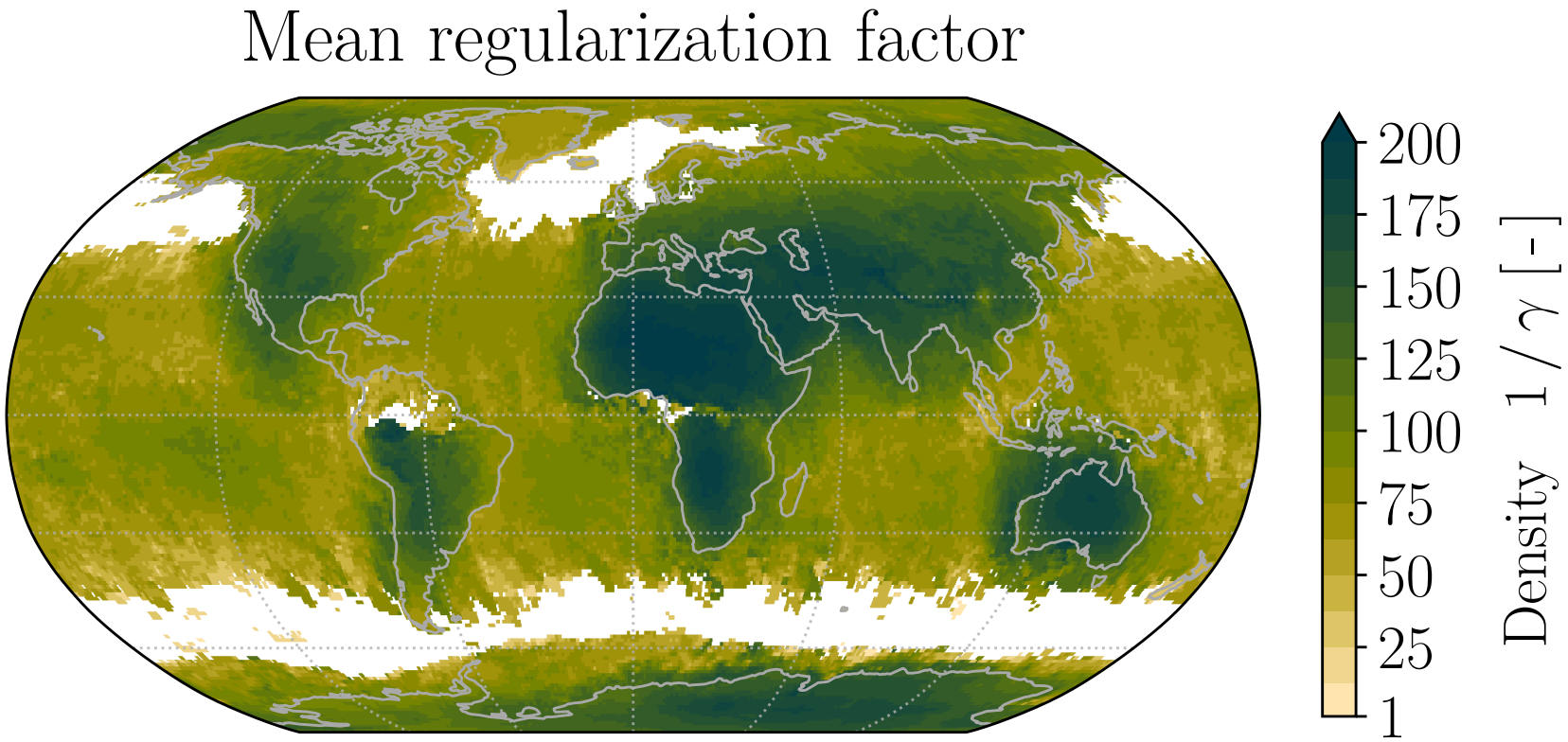
$$J(x) = \sum^{n} \frac{(Model - TROPOMI)^2}{\gamma^2 \cdot \sigma^2} + \sum^{m} \frac{(Model - Stations)^2}{\sigma^2} + \cdots$$

[1] Rosenblatt, M. (1956). Remarks on Some Nonparametric Estimates of a Density Function. In The Annals of Mathematical Statistics (Vol. 27, Issue 3, pp. 832–837). Institute of Mathematical Statistics.

TROPOMI XCH4 observations (WFMD v2.0)



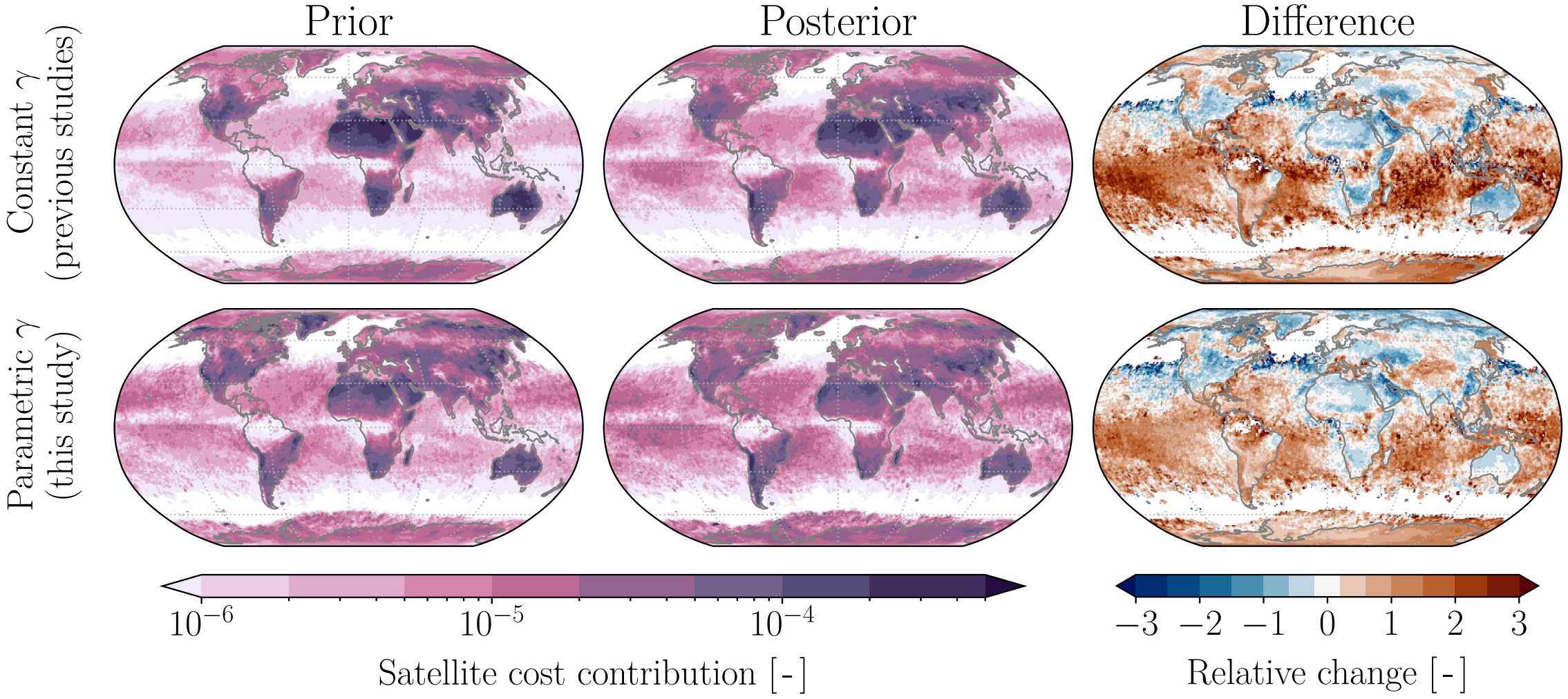
Obtained adaptive regularization factor



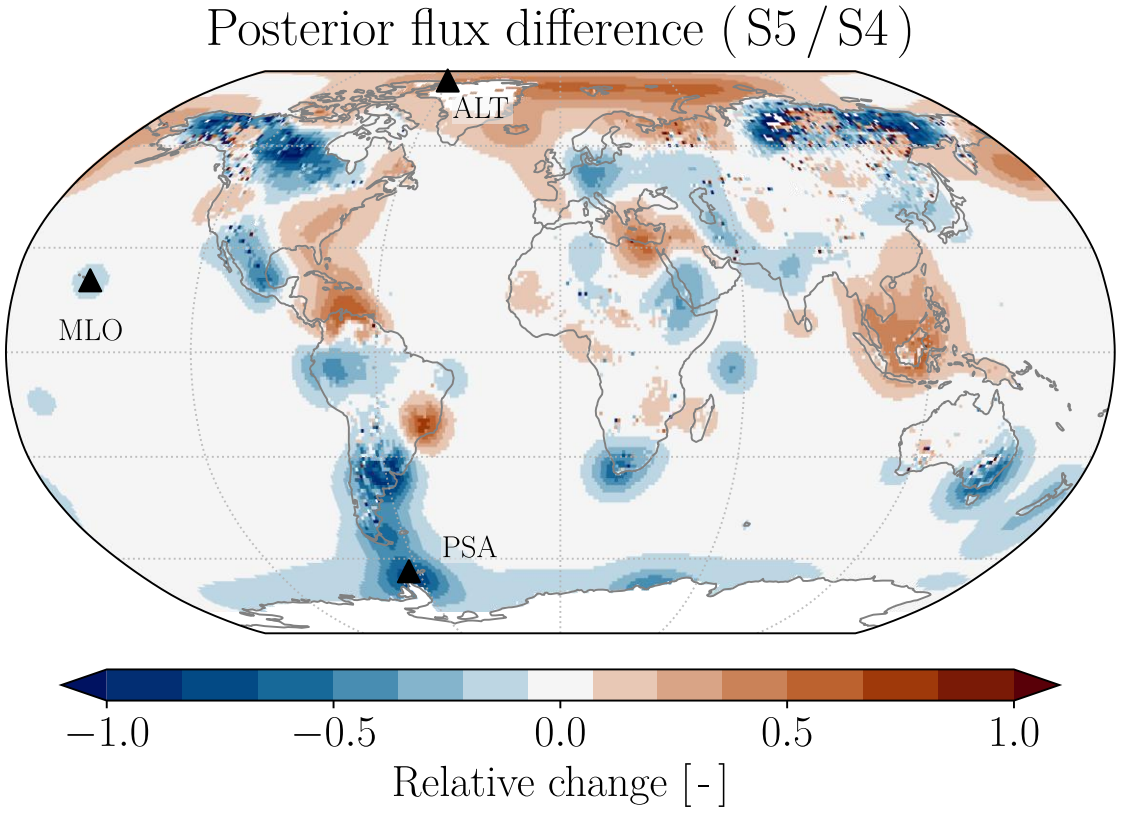
Simulations performed

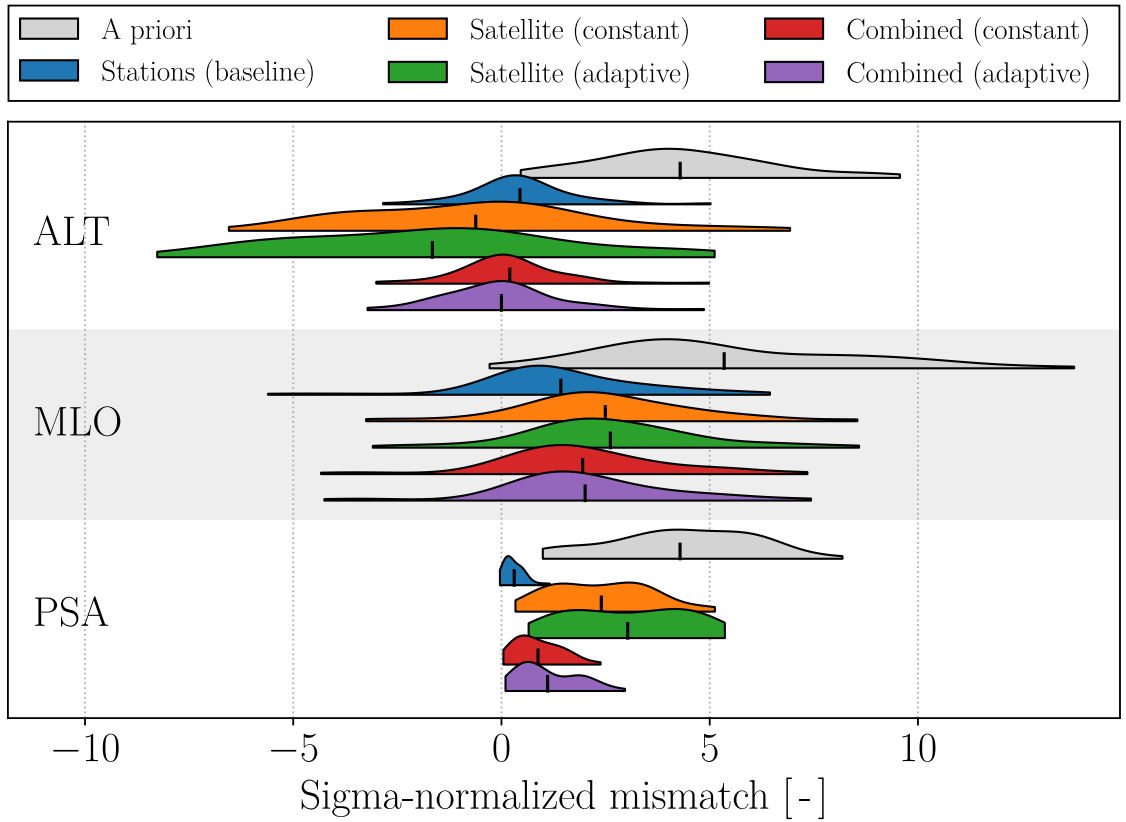
Code	Assimilated data	Regularization	Color
S0	none (a priori)	-	
S1	stations	-	
S2	satellite	constant	
S3	satellite	adaptive	
S4	NOAA stations and satellite	constant	
S5	NOAA stations and satellite	adaptive	

Difference in satellite cost contribution



Effect of an individual weighting on certain regions





EGUsphere preprint

More details in the preprint of this work...

https://doi.org/10.5194/egusphere-2026-3458

28 Aug 2026

Status: this preprint is open for discussion and under review for Geoscientific Model Development (GMD).

Towards robust inversions: Parametric weighting of high-resolution TROPOMI observations for global CH_4 emission estimates with TMVar (TM5-MP/4DVAR)

Santiago Parraguez Cerda, Johann Rasmus Nüß, Nikos Daskalakis, Arjo Segers, Oliver Schneising, Mihalis Vrekoussis, and Maria Kanakidou

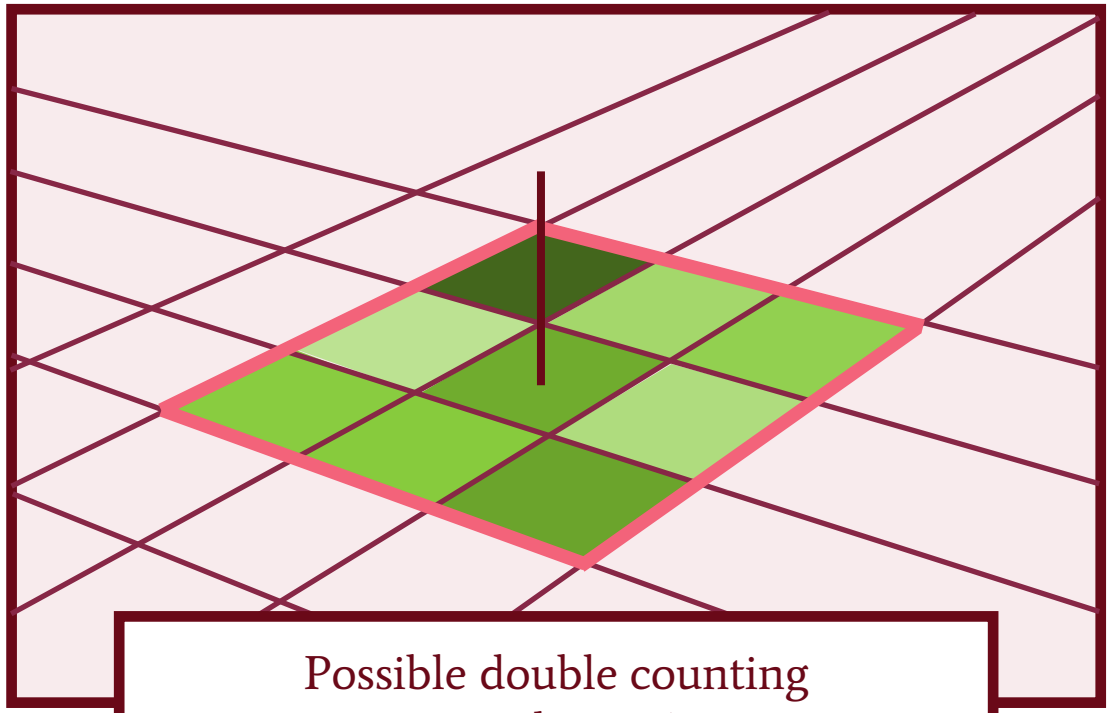
Abstract. Satellite observations play a central role in monitoring atmospheric methane (CH_4), a potent greenhouse gas. Recently launched instruments such as TROPOMI provide unprecedented spatial coverage, however, heterogeneous sampling with both dense and sparsely covered regions poses challenges for inverse modeling systems. This uneven sampling can cause very densely observed areas to dominate the inversion and lead to vanishing gradients in sparsely covered regions

Next simulations setup

- Merging with super-observations
- Application to multiple instruments
- Decadal inversion and analysis of permafrost emissions (maybe as separated category)

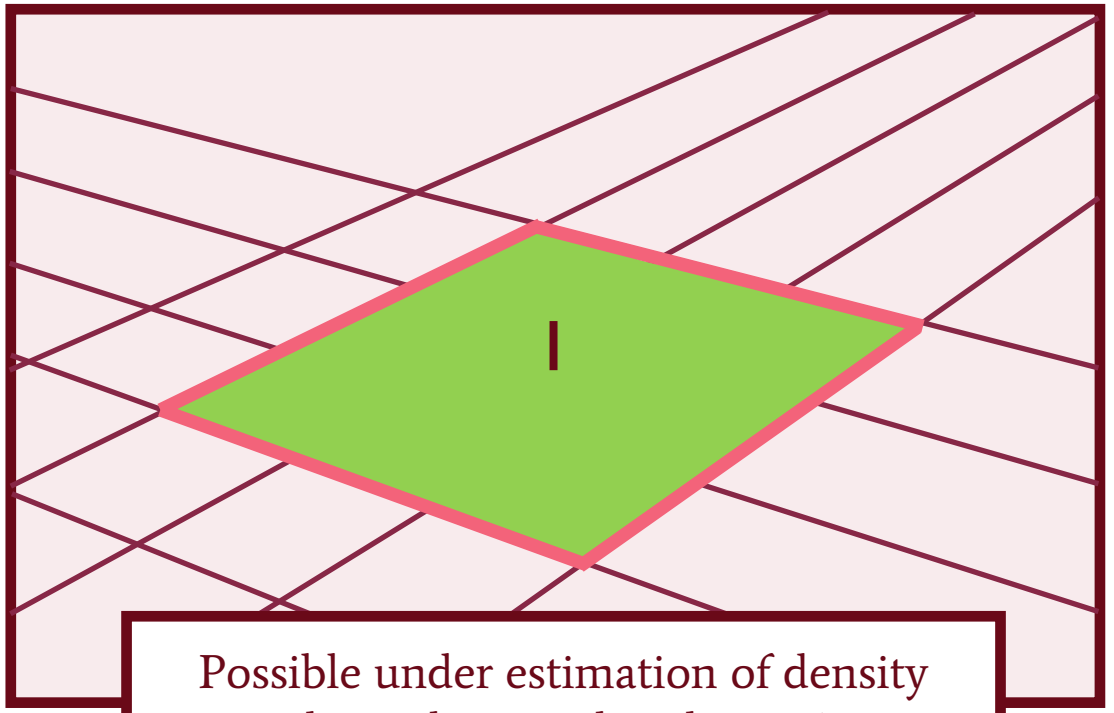
Merging with super-observations

Mean regularization for super-observation



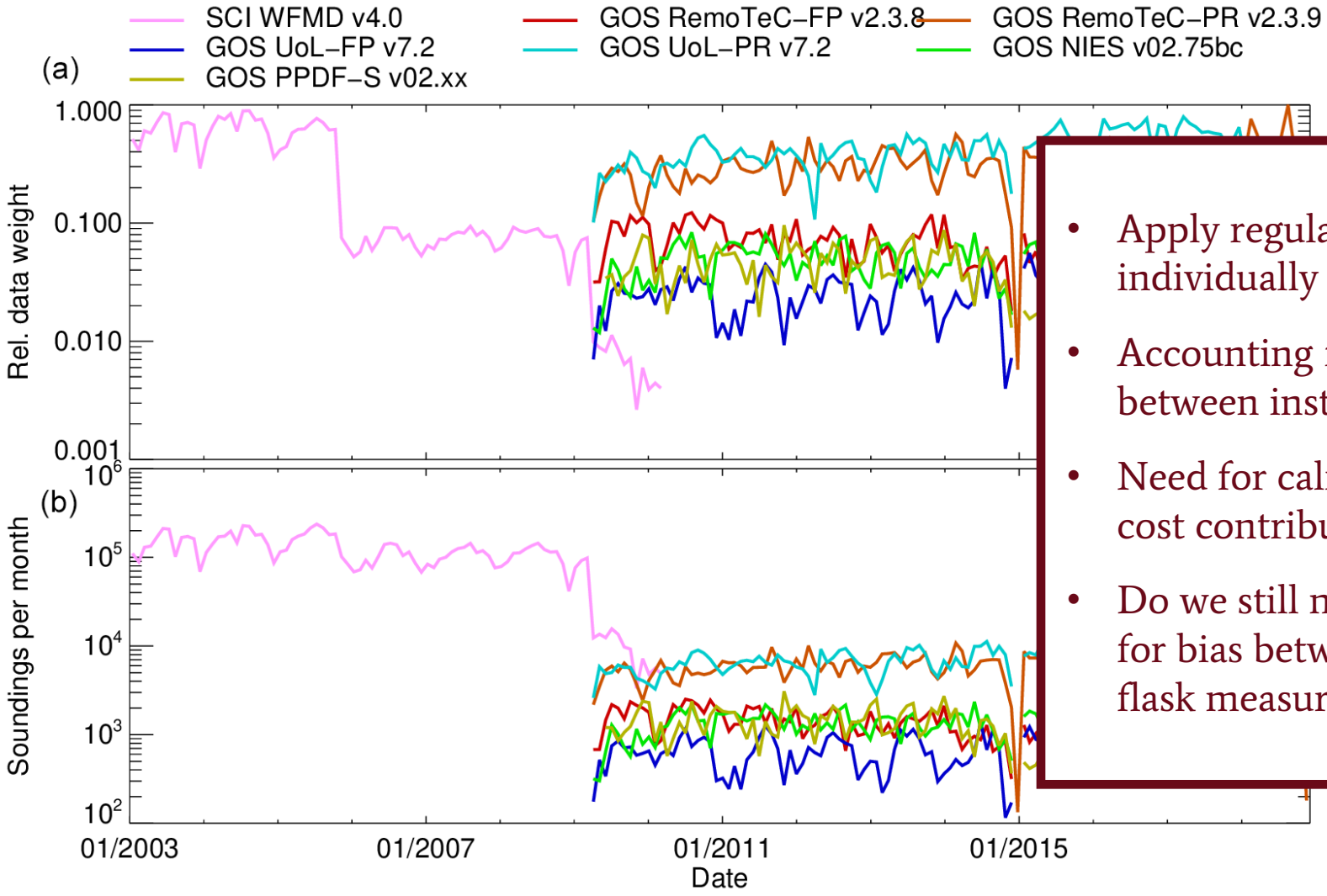
Possible double counting correlations?

Super-observation as individual sounding



Possible under estimation of density depending on distribution?

Application to multiple instruments



- Apply regularization individually per instrument
- Accounting for biases between instruments?
- Need for calibration of initial cost contribution?
- Do we still need to account for bias between satellite and flask measurements?

[2] Reuter et al. (2020) https://doi.org/10.5194/amt-13-789-2020

Future simulations

- Combining parametric regularization and super-observations
- Multi-instrument inversions
- Using pp-blocks for (above) decadal trends
- Analyzing permafrost regions
  - Separate category from permafrost distribution with high spatial and temporal correlation
  - Spread current bottom-up estimate totals and remove it from current wetlands?

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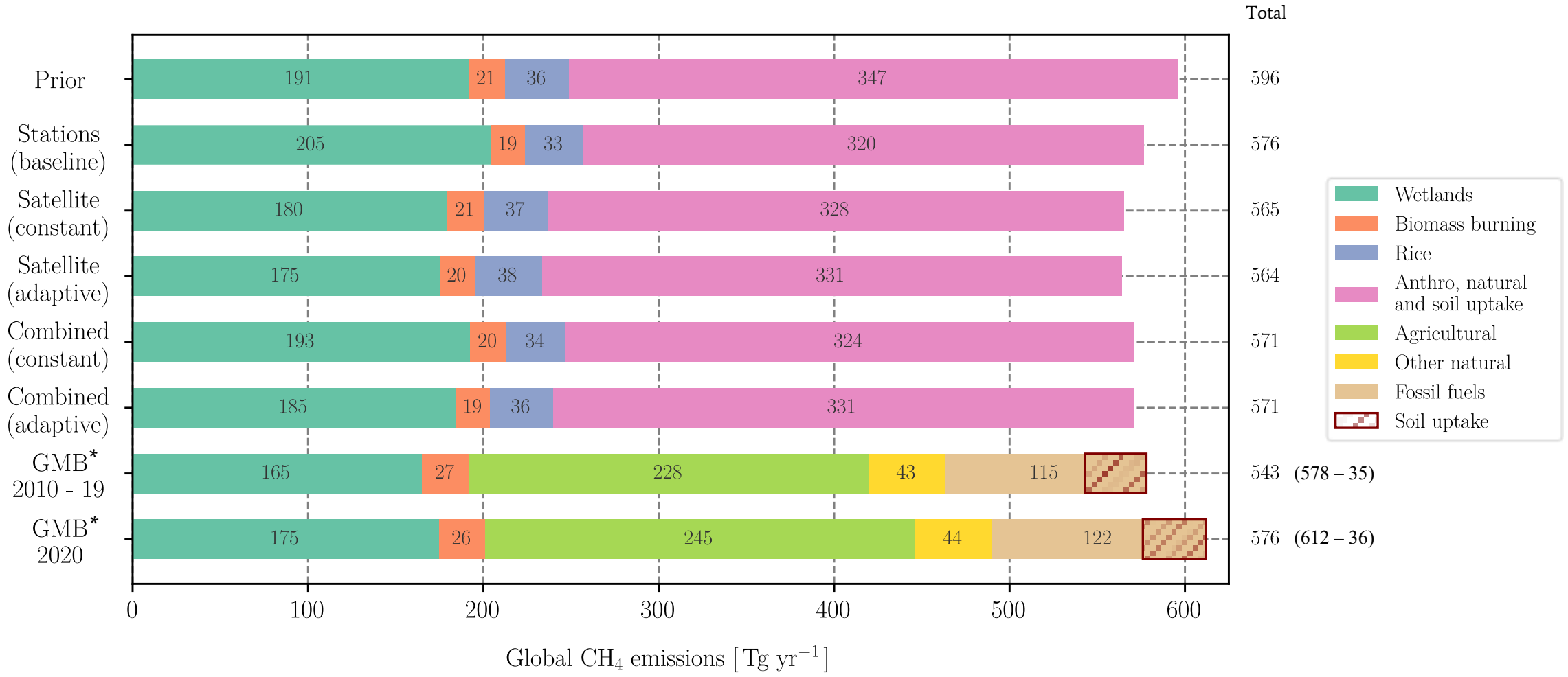
Methane prior emissions used

Table 1
Methane sources and sinks taken into account as prior emissions.

Type	Source	Reference	Temp. resolution
Anthropogenic	all sources	EDGAR v7.0 (Crippa et al., 2021)	monthly
Biomass burning	wildfires	GFAS v1.2 (Di Giuseppe et al., 2018)	daily
Natural	wetlands	LPJ-wsl (Zhang et al., 2023)	monthly
	oceans	Lambert and Schmidt (1993) climatology	-
	wild animals	Olson climatology	-
	termites	Doubalova and Sindelarova (2018) climatology	-
	geological	not included	
	soil uptake	Ridgwell et al. (1999) climatology	-

Posterior estimated CH_4 budget (2019)



*Global Methane Budget (Saunois et al., 2025)

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