Universität Bremen

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

Parametric weighting of satellite data: Towards robust CH_4 emission inversions

Some insights on the impact of weighting the TROPOMI WFMD XCH4 product

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36th TM Meeting
03-04 November 2025

GLOBAL METHANE BUDGET 2010-2019

	Bottom-up view (BU)	Top-down view (TD)
TOTAL EMISSIONS	669 (512-849)	575 (553-586)
CHANGE IN ATMOSPHERIC ABUNDANCE	36	21* (19-33)
TOTAL SINKS	633 (507-796)	554 (550-567)
Fossil fuel production and use	120 (117-125)	115 (100-124)
Agriculture and waste	211 (195-231)	228 (213-242)
Biomass and biofuel burning	28 (21-39)	27 (26-27)
Combined wetland & Inland freshwaters	248 (159-369)	165 (145-214)
Other natural emissions (geological, oceans, termites, wild animals, permafrost, vegetation)	63 (24-93)	43 (40-46)
Sink from chemical reactions in the atmosphere	602 (496-747)	521 (485-532)
Sink in soils	31 (11-49)	35 (35-36)

EMISSIONS AND SINKS

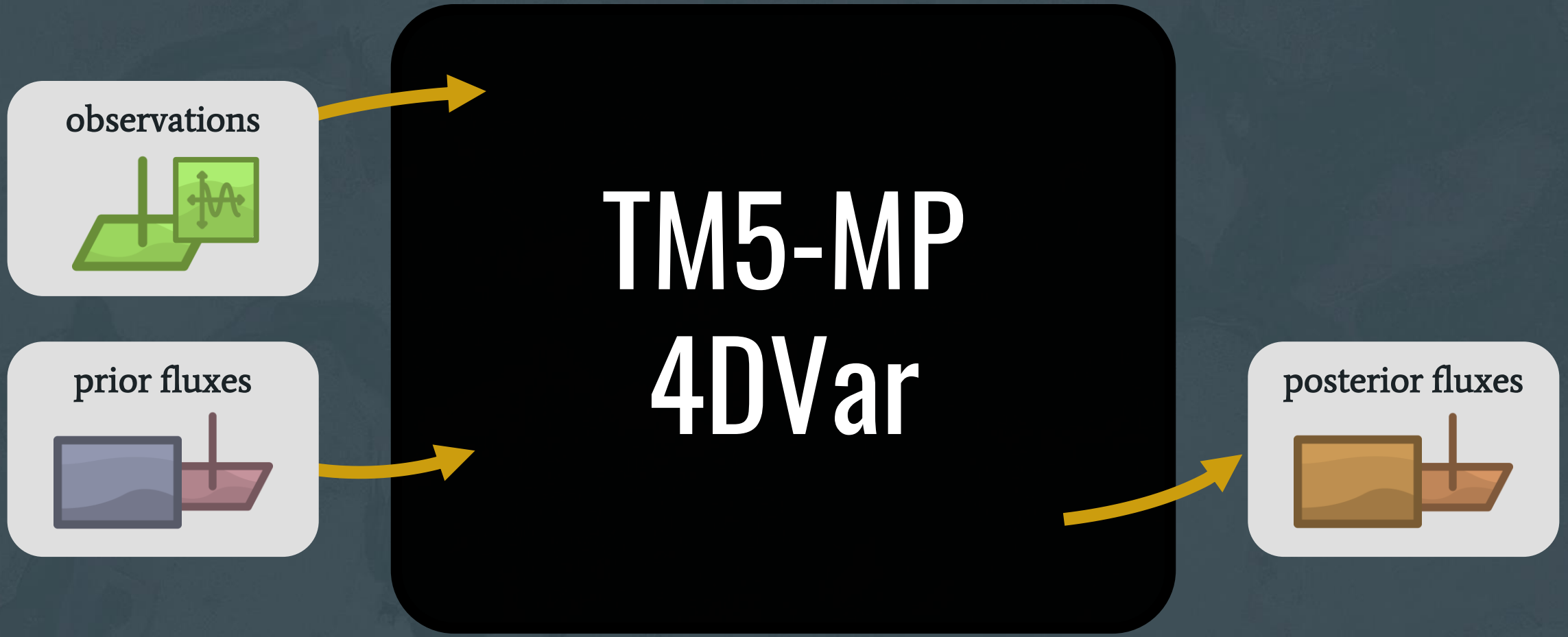
In teragrams of CH_4 per year (Tg CH_4 / yr) average over 2009-2019

The observed atmospheric growth rate is 20.9 (20.1-21.7) Tg CH_4 / yr. The difference with the TD budget imbalance reflects uncertainties in capturing the observed growth rate.

Direct anthropogenic fluxes | Natural fluxes | Natural and indirect anthropogenic fluxes

GLOBAL CARBON PROJECT

Inverse modelling of emissions (top-down method)



Motivation

≈ 180,000,000 per year

≈ 2,000 per year

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

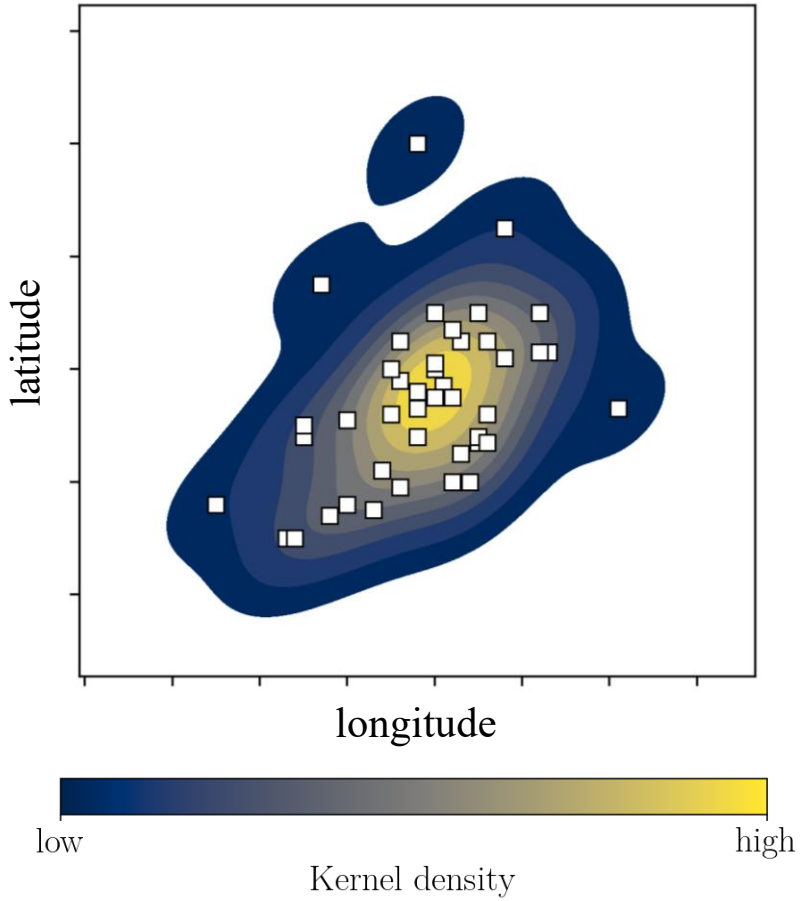
Addressing imbalances in dataset size and spatial distribution of atmospheric observations to improve inversions

Parametric regularization factor

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

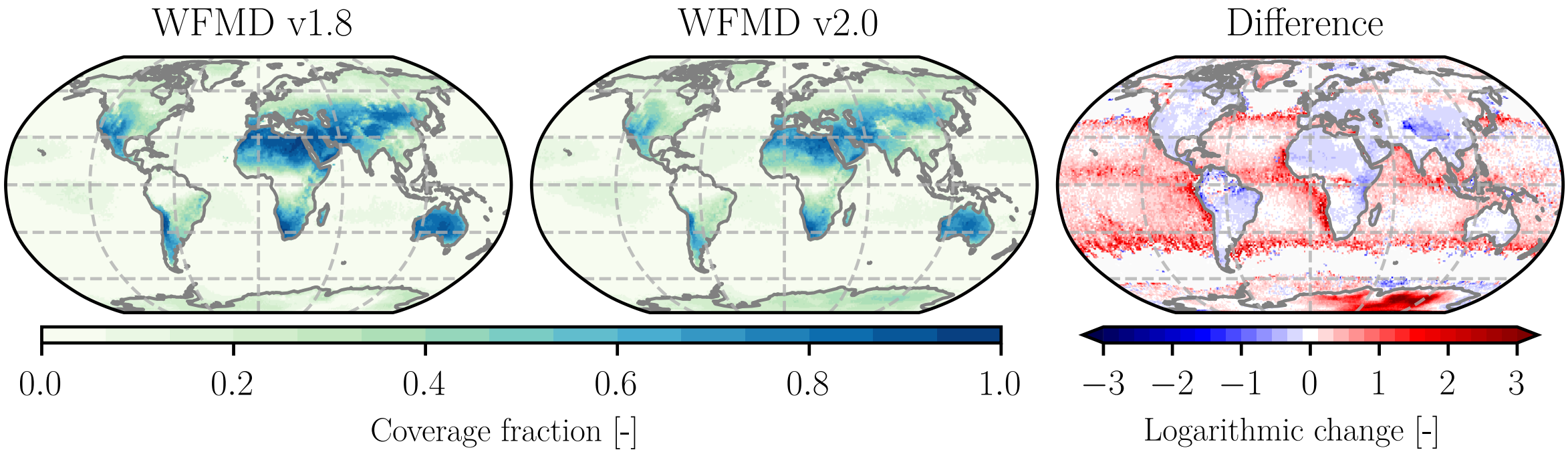
- Kernel Density Estimation or Parzen–Rosenblatt window method [2]
- Estimation based on both time and distance

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

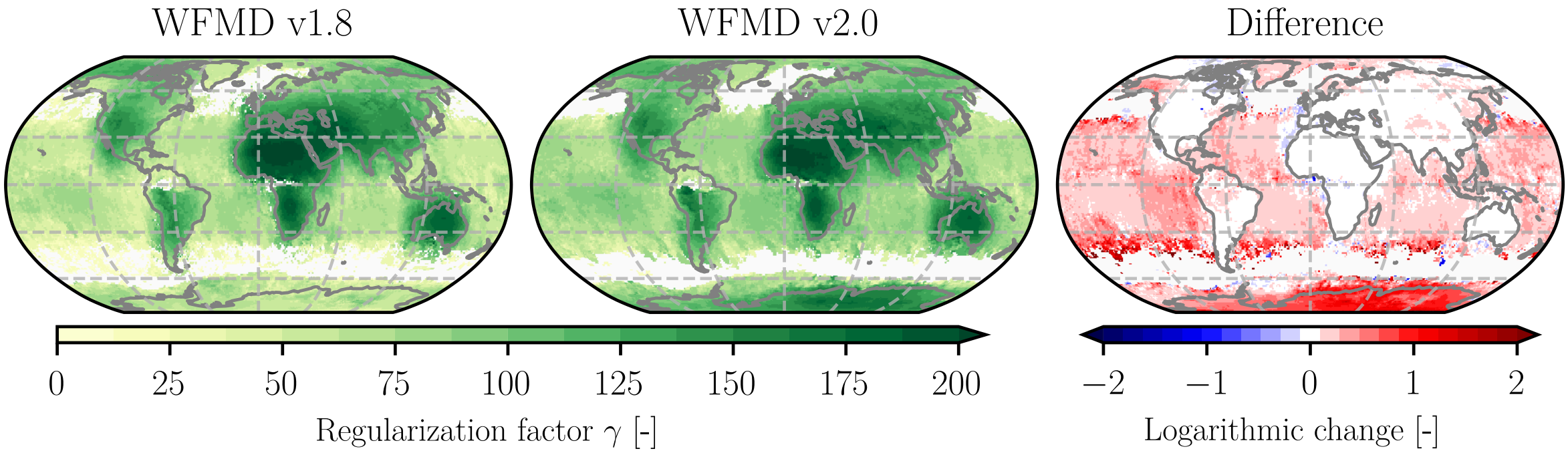


[2] Rosenblatt, M. (1956). Remarks on Some Nonparametric Estimates of a Density Function. In The Annals of Mathematical Statistics (Vol. 27, Issue 3, pp. 832–837). Institute of Mathematical Statistics.

Coverage of the TROPOMI XCH4 WFMD products



Regularization factor for product versions

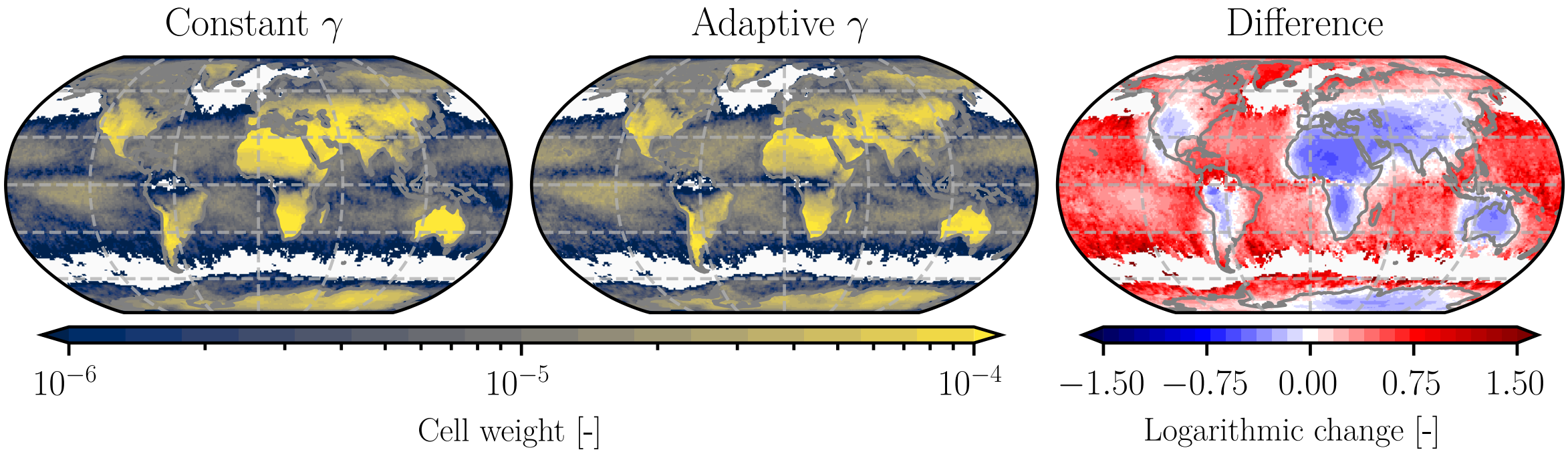


Inversions

using TROPOMI WFMD v2.0

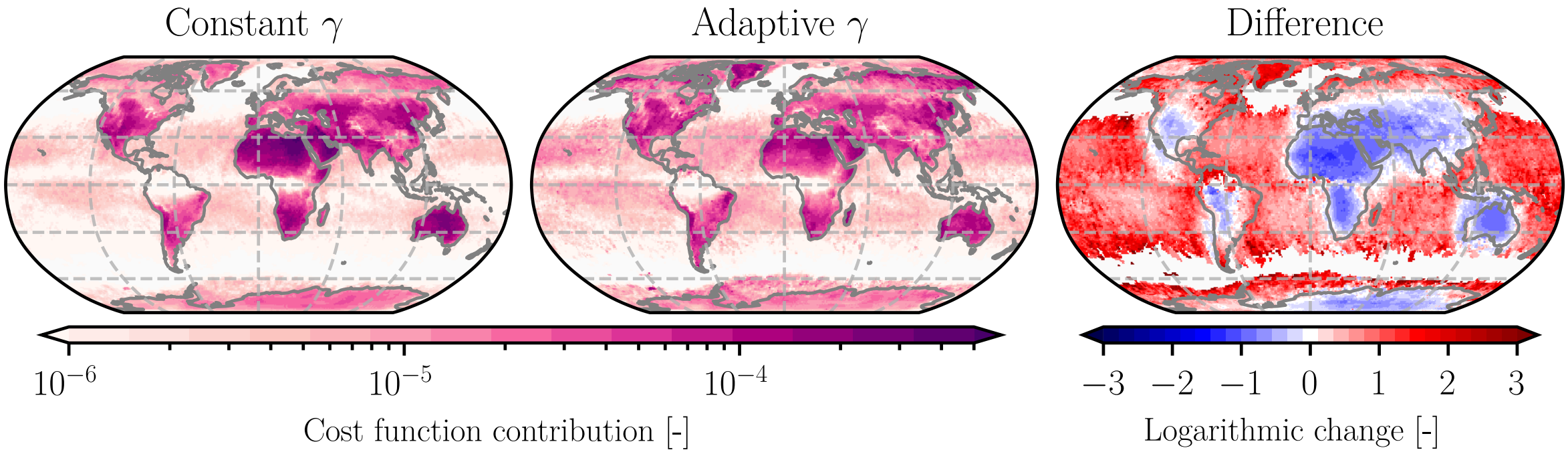
(and TM5-MP CB05 output as initial concentrations)

Average normalized cell weight when using TROPOMI

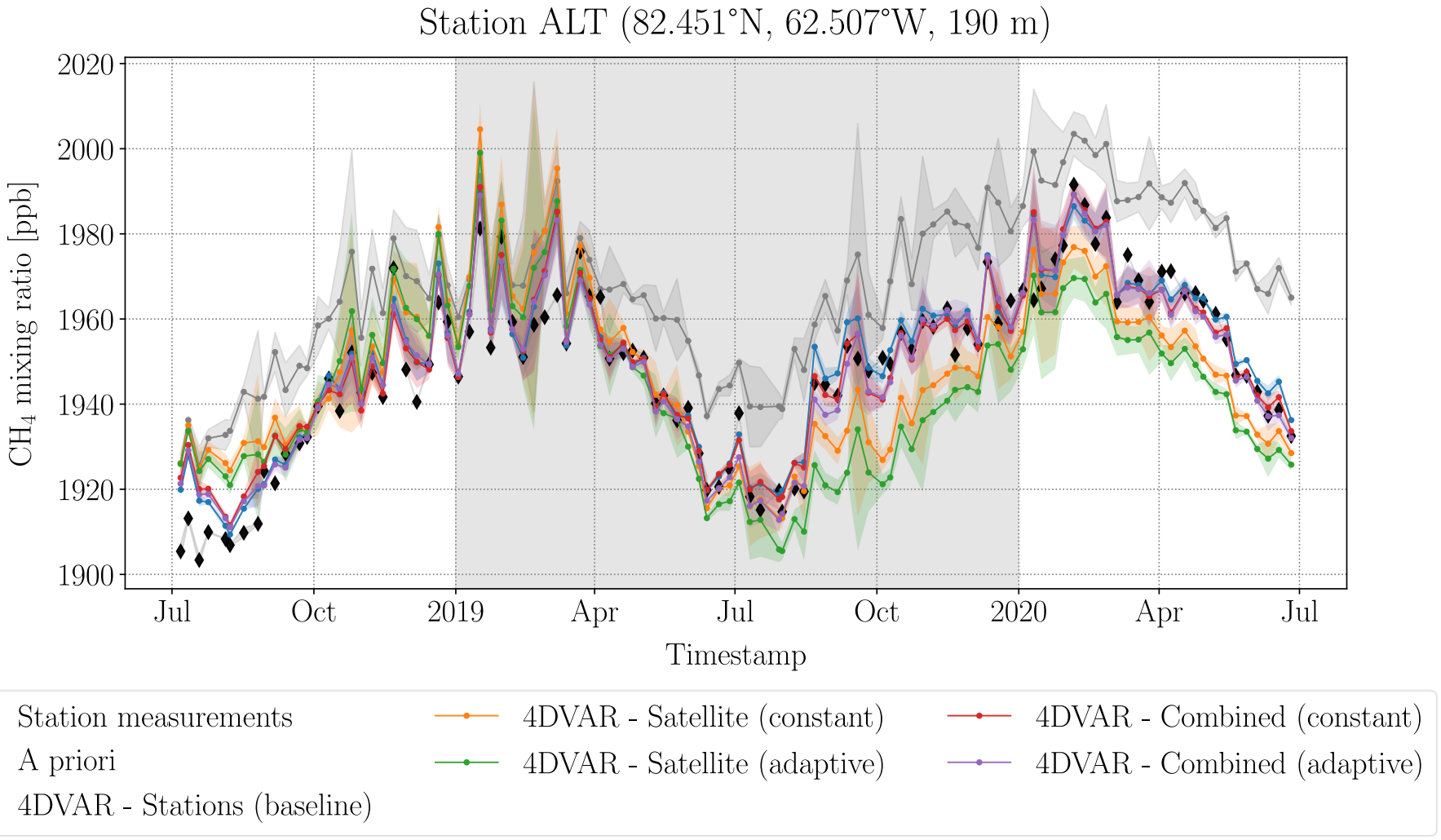


Coefficient of variation reduced from 1.62 to 1.30 ⟶ More homogeneous contribution

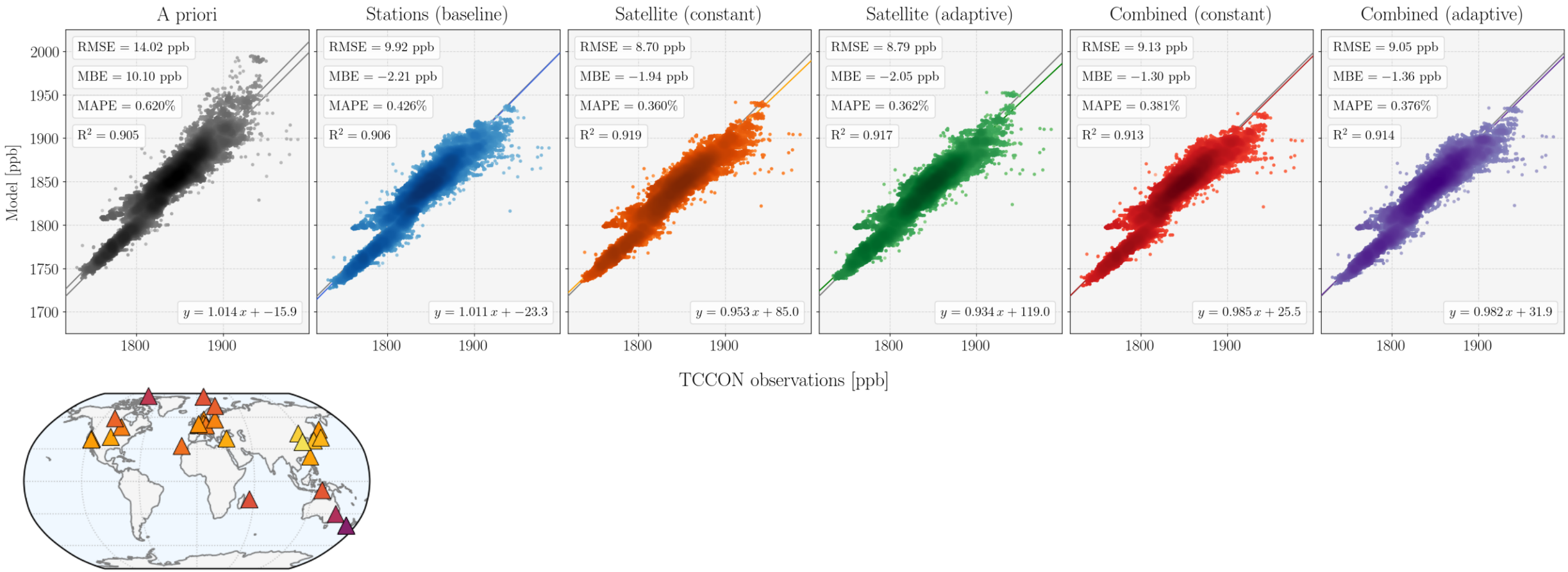
Normalized prior cost contribution of TROPOMI



Currently running simulations



Comparison against TCCON observations



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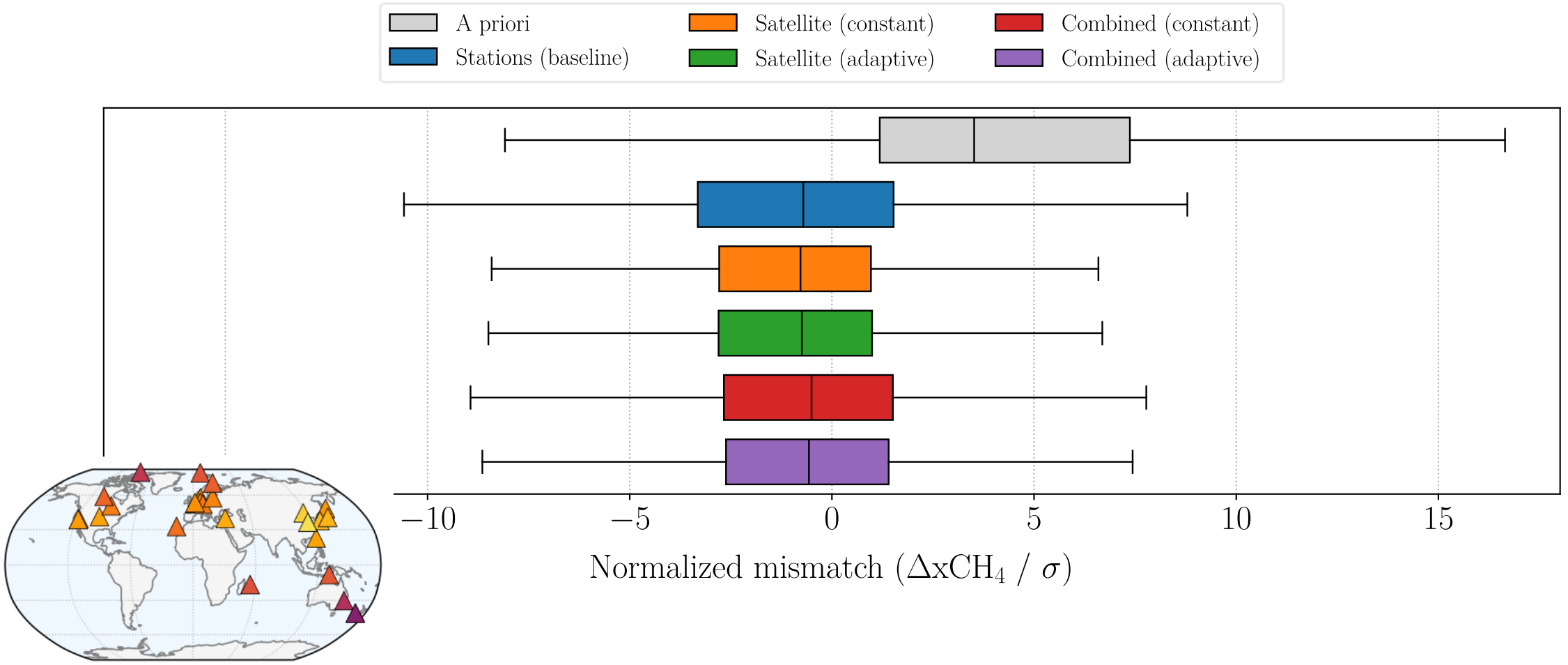
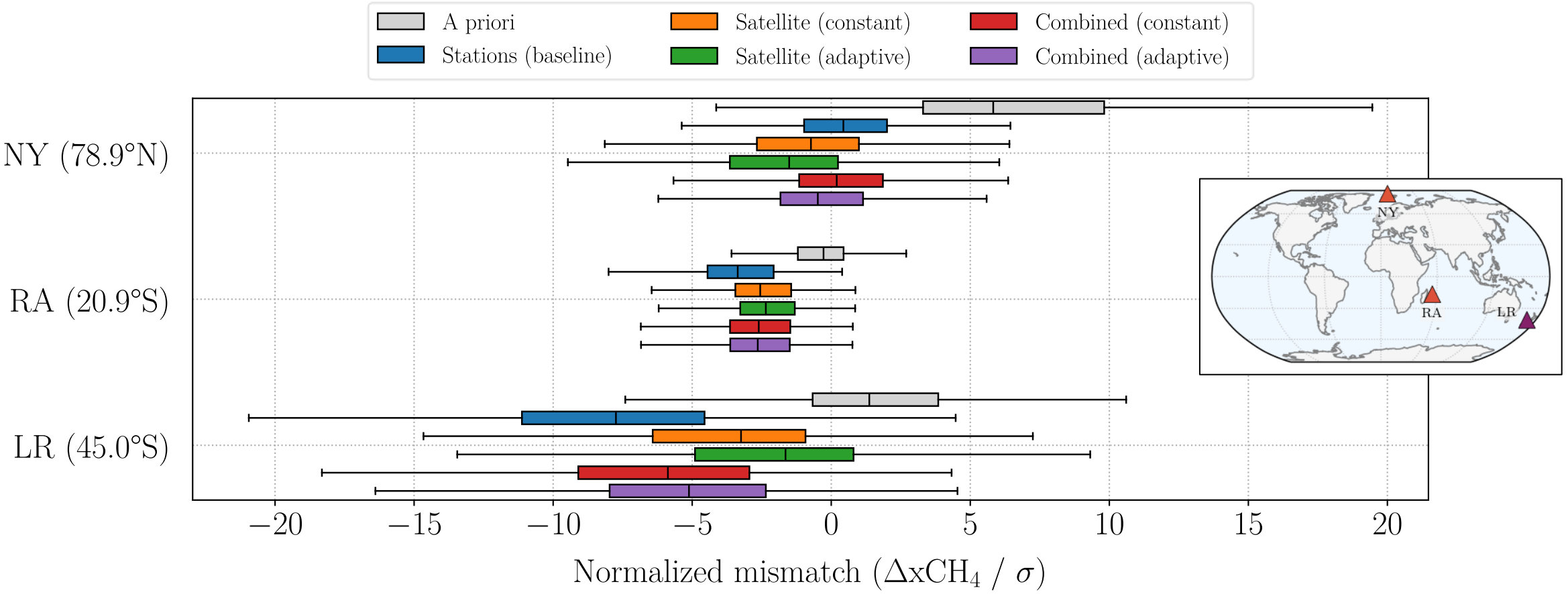


Comparison against TCCON observations



Concluding insights

- Parametric regularization can be (more) justified
- Easy to adjust to multiple dataset inversions
- Hard to determine the length parameter h
- More homogeneous cell weight distribution
- High impact on remote regions (mostly high latitudes)
- Might be unveiling other issues?
  - Observation biases and error
  - Model behaviors around the poles

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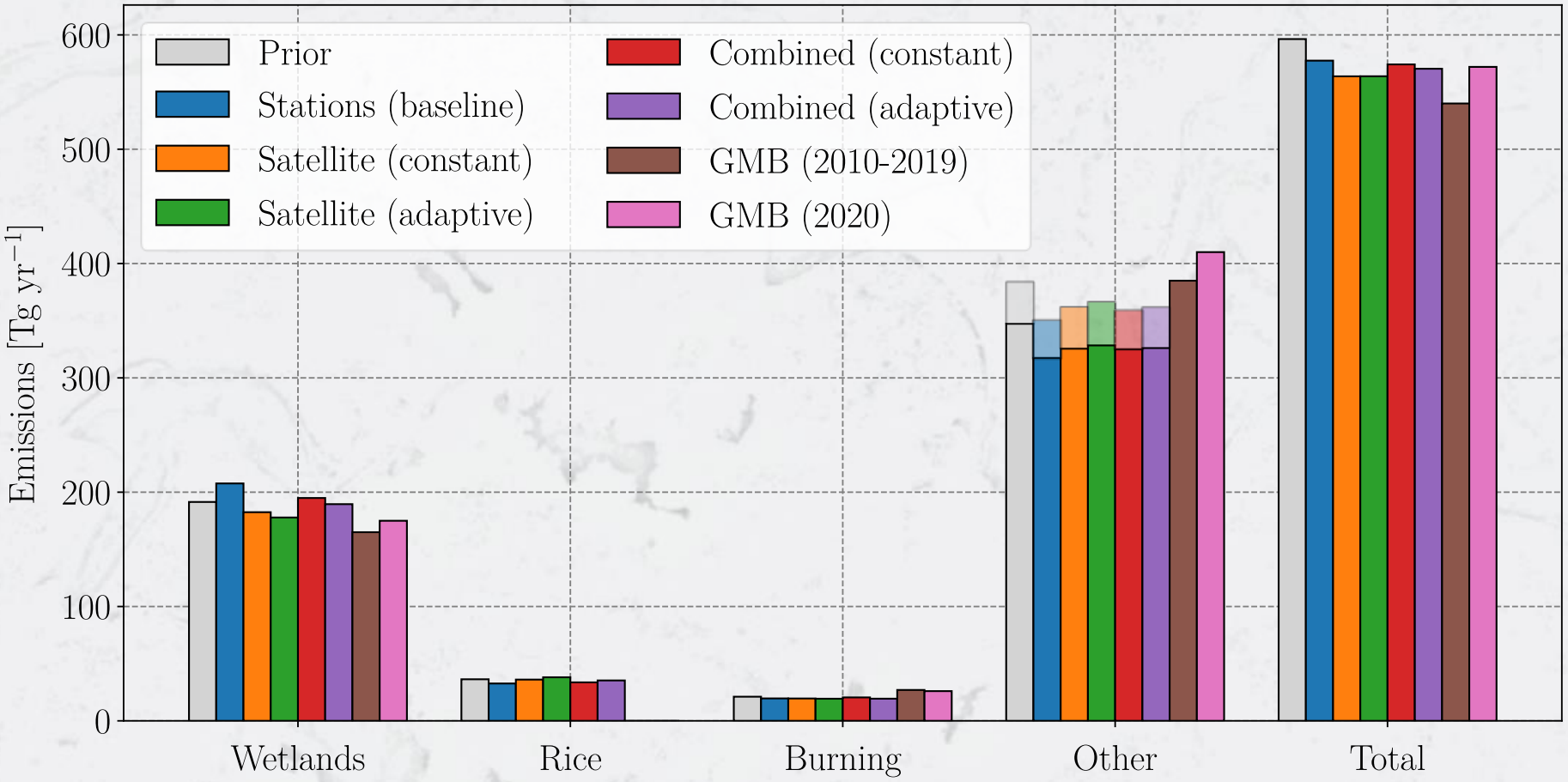
Methane prior budget used

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 fluxes for 2019

emissions – soil uptake



*Global Methane Budget (GMB)

Posterior fluxes for 2019

emissions – soil uptake

Global Methane Budget*

[Tg/year]	A priori	Only stations	TROPOMI (constant)	TROPOMI (adaptive)	Combined (constant)	Combined (adaptive)	GMB* (2010-2019)	GMB* (2020)
Wetlands	191.45	207.85	183.44	179.73	195.70	193.23	165	175
Biomass Burning	21.11	19.80	19.33	19.27	20.56	19.51	27	26
Rice	36.35	32.82	35.79	38.03	33.26	35.11	-	-
Others (Anthro+)	347.43	317.74	325.07	326.86	320.58	324.24	385	410
Total	596.35	578.21	563.63	563.89	570.11	572.09	540	572