Universität Bremen

Institut für Umweltphysik (IUP)
Fachbereich 1 - Physik / Elektrotechnik
Universität Bremen
Institute of Environmental Physics
Faculty 1 - Physics / Electrical Engineering
University of Bremen

On CH_4 inversions using TROPOMI, and how to better combine different measurements (maybe…)

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

Rasmus Nüß, Nikos Daskalakis, Arjo Segers, Oliver Schneising,
Michael Buchwitz, Mihalis Vrekoussis, Maria Kanakidou

35th International TM5 Meeting
21-22 October 2024
Wageningen, The Netherlands

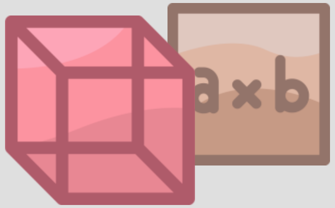
Overview

1. Motivation
2. Observations and measurements
3. Background
4. Simulations with adaptative factor

1. Motivation

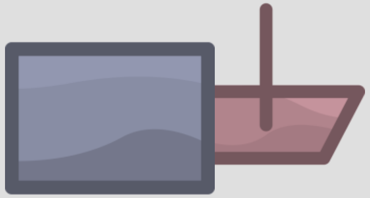
Inverse modelling pillars

TM5-MP

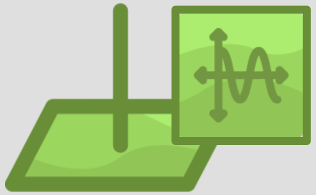


4DVAR

prior estimate



observations



Objective

To robustly harmonize data from different sources with uneven amount of observations for inversions

…like TROPOMI and the NOAA network

WHY? CURRENT?

PROBLEM? APPROACH?

1. Motivation

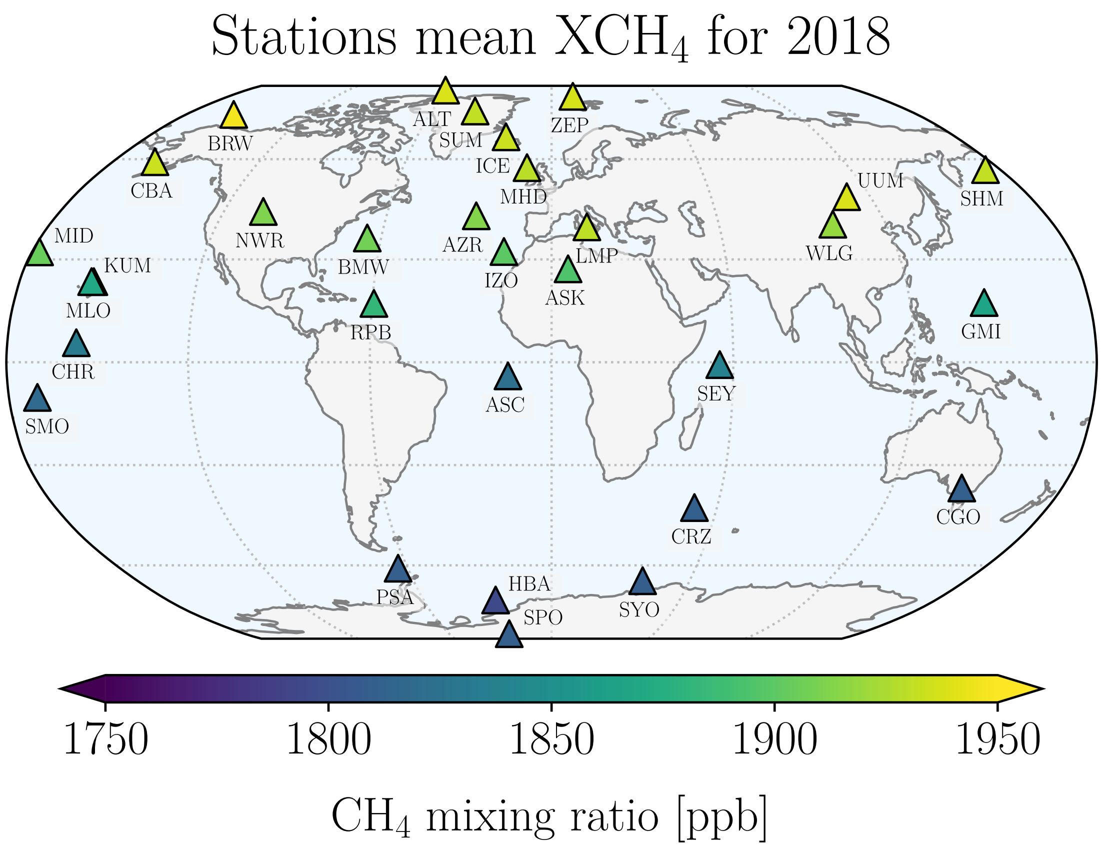
2. Observations and measurements

Ground measurements: NOAA

High precision, in-situ measurements

Global background network, less affected by sources

Sparse temporal coverage

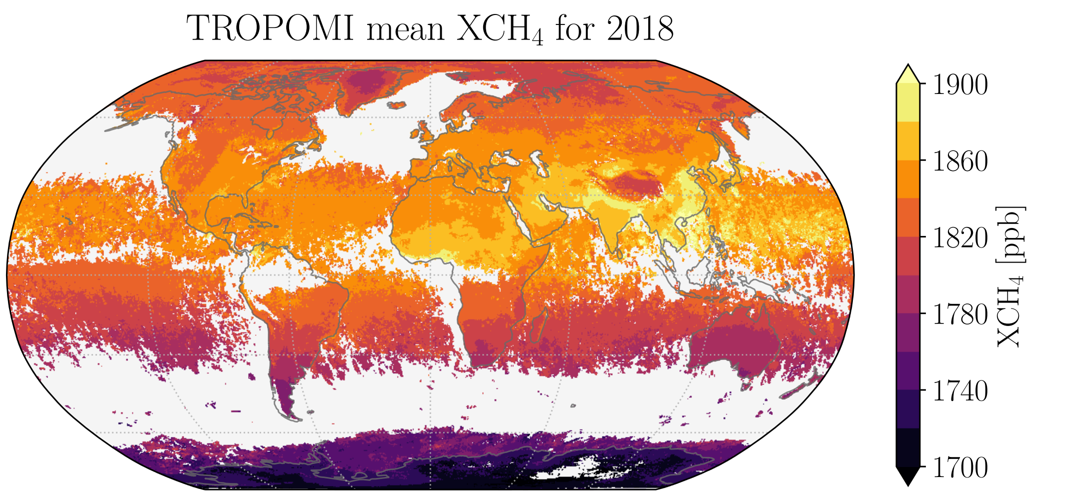


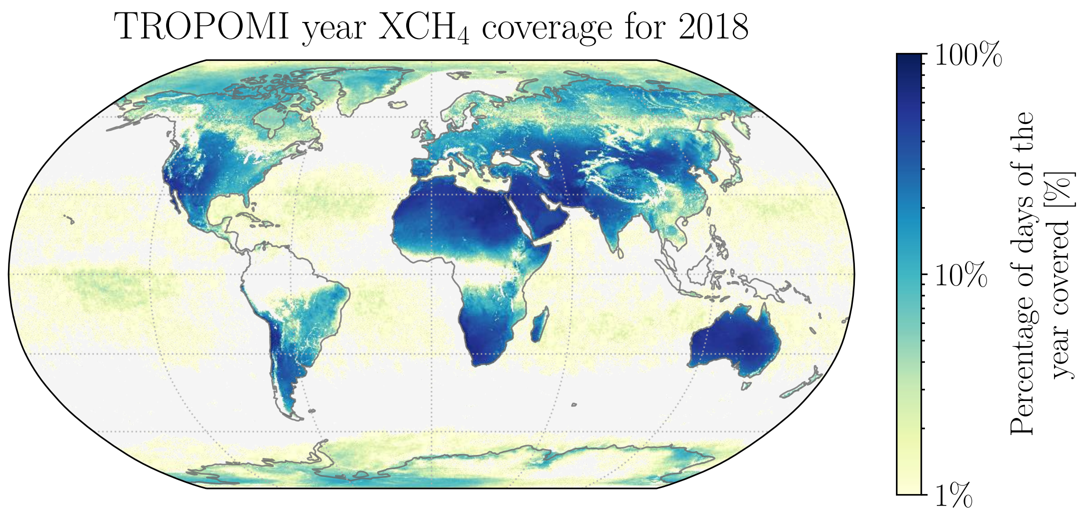
Remote observations: TROPOMI

High resolution data
(up to 7.0×5.5 km^2)

Global daily coverage since 2018
(kind of)

WFMD product covers high latitudes [1]





[1] Schneising et al. (2023). Advances in retrieving XCH4 and XCO from Sentinel-5 Precursor: improvements in the scientific TROPOMI/WFMD algorithm. In *Atmos. Meas. Tech.*

TROPOMI

Atmospheric total column

General constrain over atmosphere

142,000,000 pixels per year

NOAA

Point measurement

Constrain near-surface concentrations

1,200 measurements per year

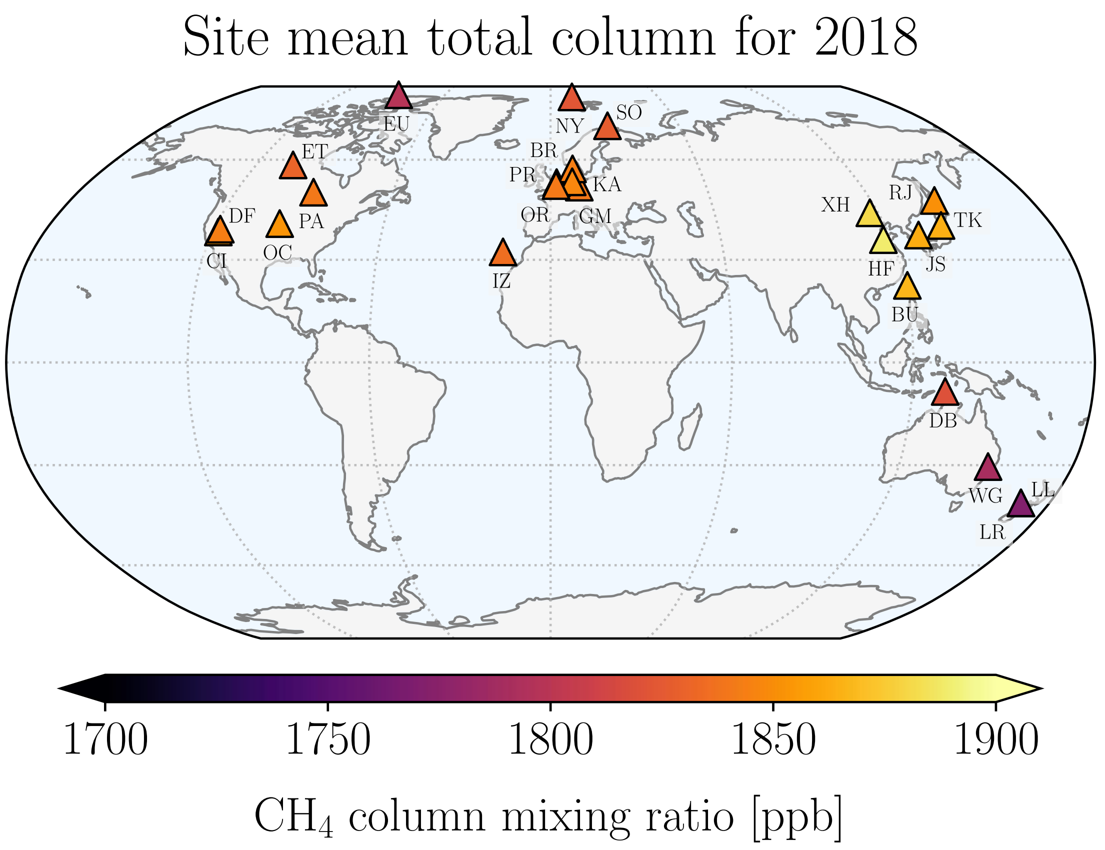
WHY

Ground measurements:
TCCON

Ground-based total column observations

Accurate and precise,
widely used for validation

Sites not globally distributed



1. Motivation
2. Observations and measurements

3. Background

Cost function

$$\min_{x} J(x) = J_{bg}(x) + \sum_{k} J_{obs}(x)$$

- Aim to find the background state x to minimize our cost function

Cost function

$$J_{obs}(x) = \sum_i \frac{(F(x_i) - y_i)^2}{\sigma_i^2}$$

- Aim to find the background state x to minimize our cost function
- Sampling model F at the time and point of observations y
- Variance σ^2 comprises both model sampling error and observation error

Cost function

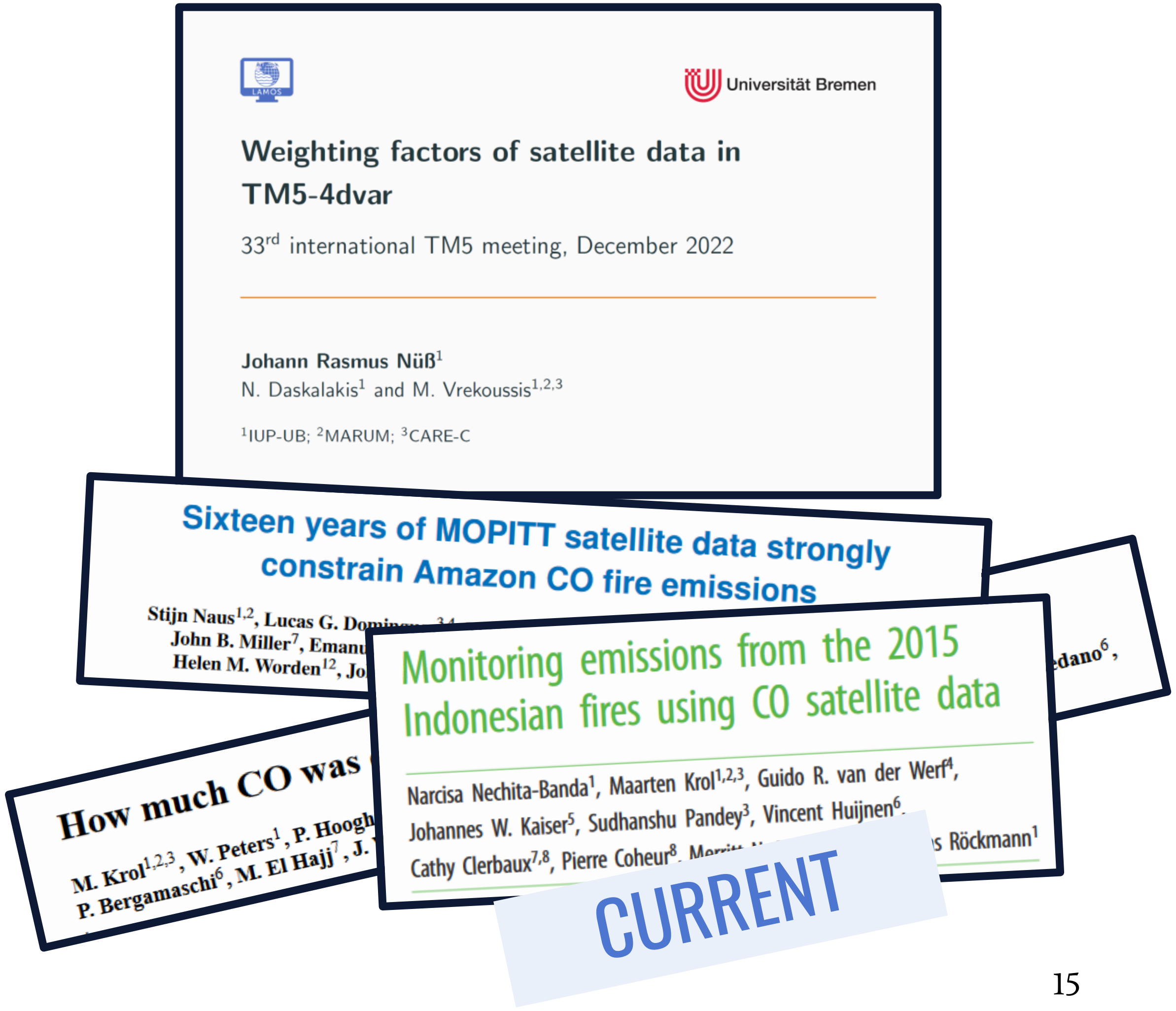
$$J_{obs}(x) = \frac{1}{I^2} \sum_i \frac{(F(x_i) - y_i)^2}{\sigma_i^2}$$

- Aim to find the background state x to minimize our cost function
- Sampling model F at the time and point of observations y
- Variance σ^2 comprises both model sampling error and observation error
- Inclusion of inflation factor I decreases weight of cost function

Inflation factor for TROPOMI

- Constant factor applied as variance inflation in previous works
- Factors used:
  - $I = \sqrt{50}$ or $I = \sqrt{150}$
- TROPOMI need higher inflation factor to compensate amount of pixels ($I = \sqrt{10000}$)
- Massive reduction ignores more isolated pixels

PROBLEM



Cost function

$$J_{obs}(x) = \sum_i \frac{(F(x_i) - y_i)^2}{I_i^2 \cdot \sigma_i^2}$$

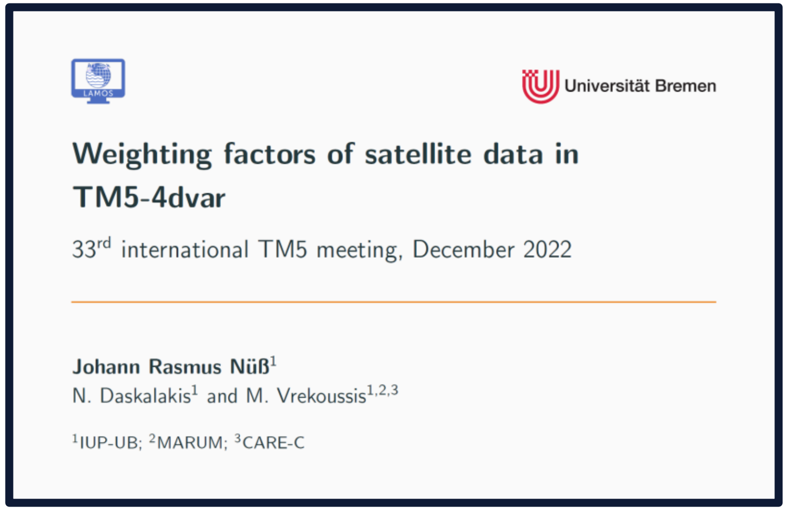
- Aim to find the background state x to minimize our cost function
- Sampling model F at the time and point of observations y
- Variance σ^2 comprises both model sampling error and observation error
- Inclusion of inflation factor I decrease weight of cost function
- Use of individual value for each observation based on spatial density of points

Variable inflation factor

- Density of points estimation based on the distance
- Kernel Density Estimation or Parzen–Rosenblatt window method [2]

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

APPROACH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Weighting factors of satellite data in TM5-4dvar

33rd international TM5 meeting, December 2022

Johann Rasmus Nüß[1]
N. Daskalakis[1] and M. Vrekoussis[1,2,3]

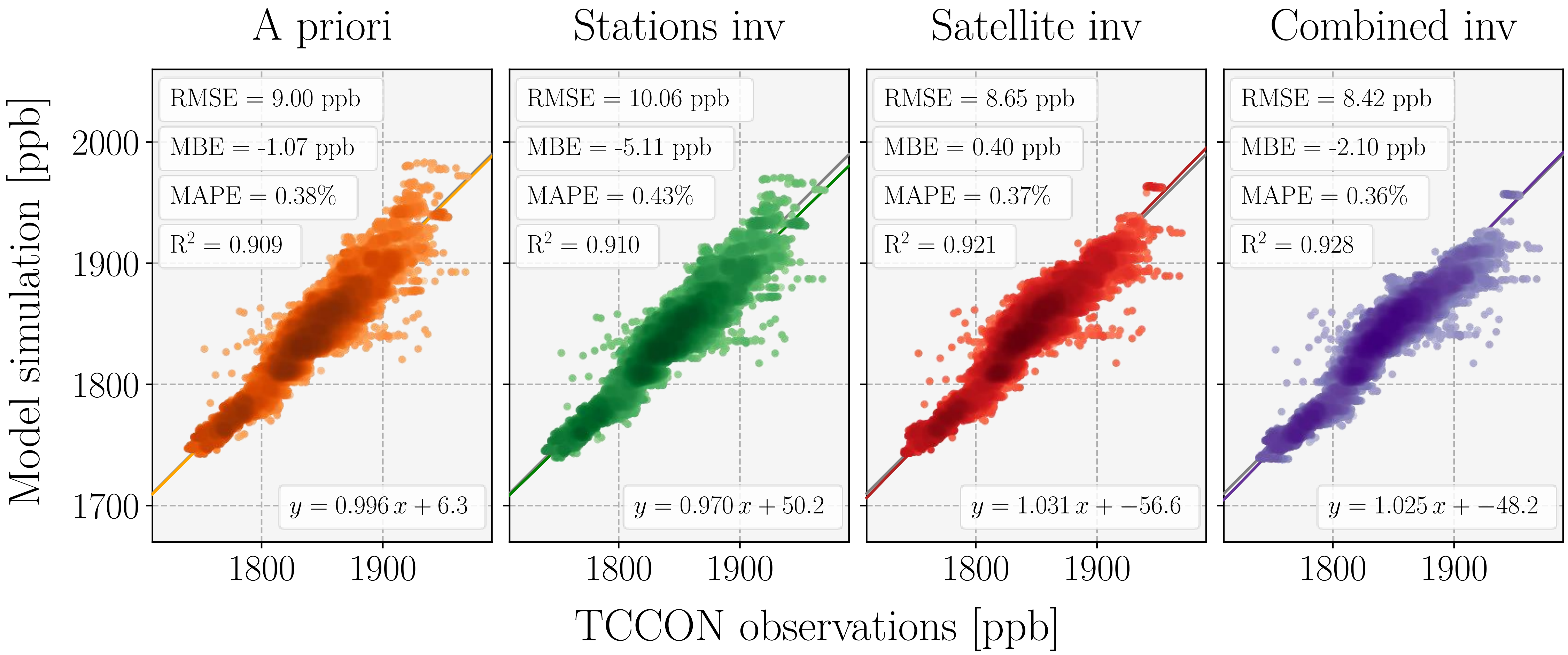
[1]IUP-UB; [2]MARUM; [3]CARE-C

[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.

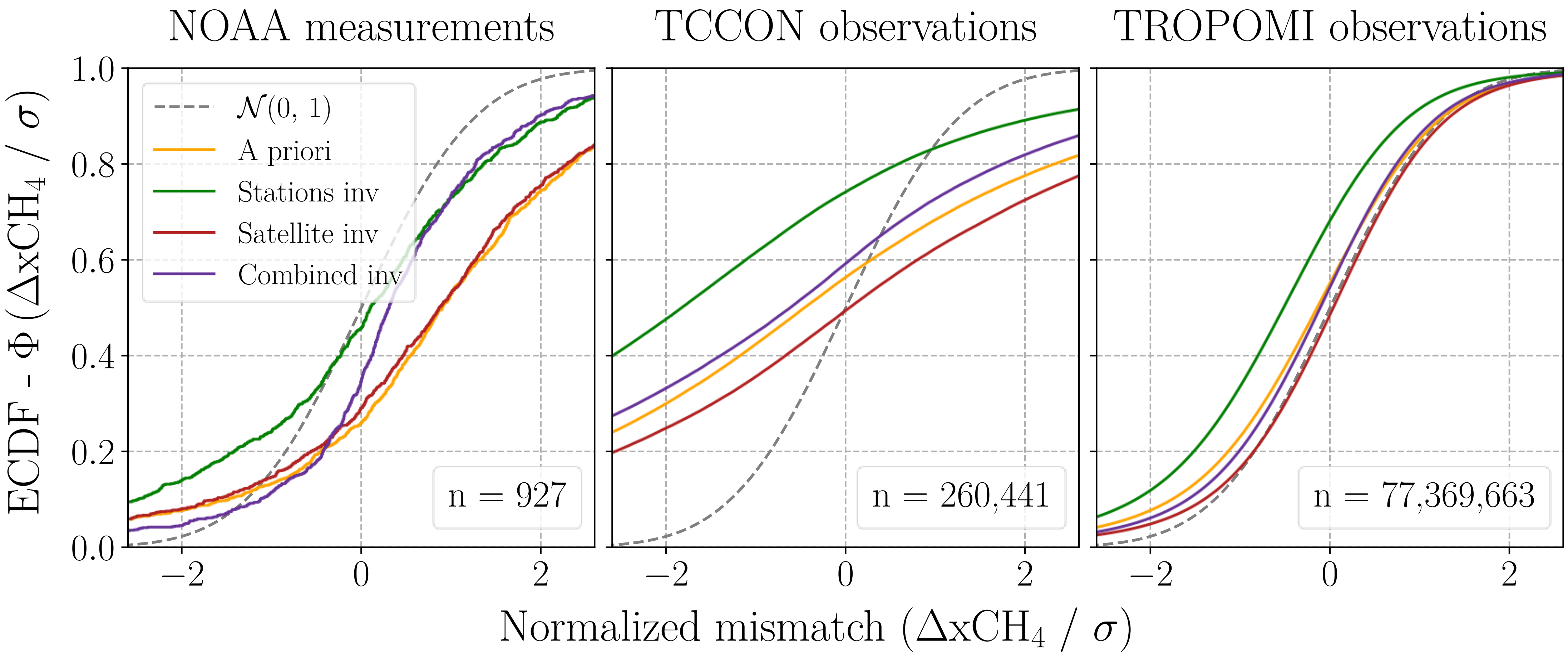
1. Objective
2. Observations and measurements
3. Background

4. Simulations with adaptative factor

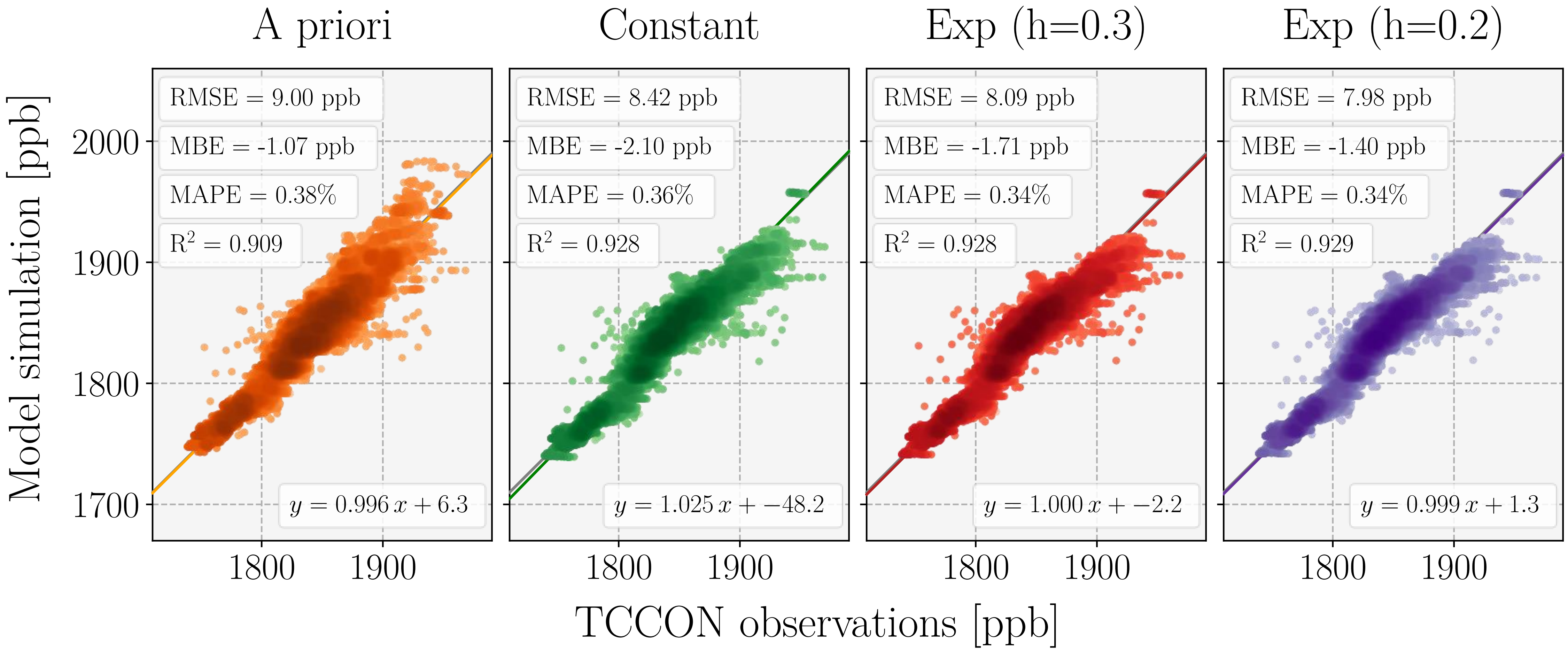
First simulation with a constant factor



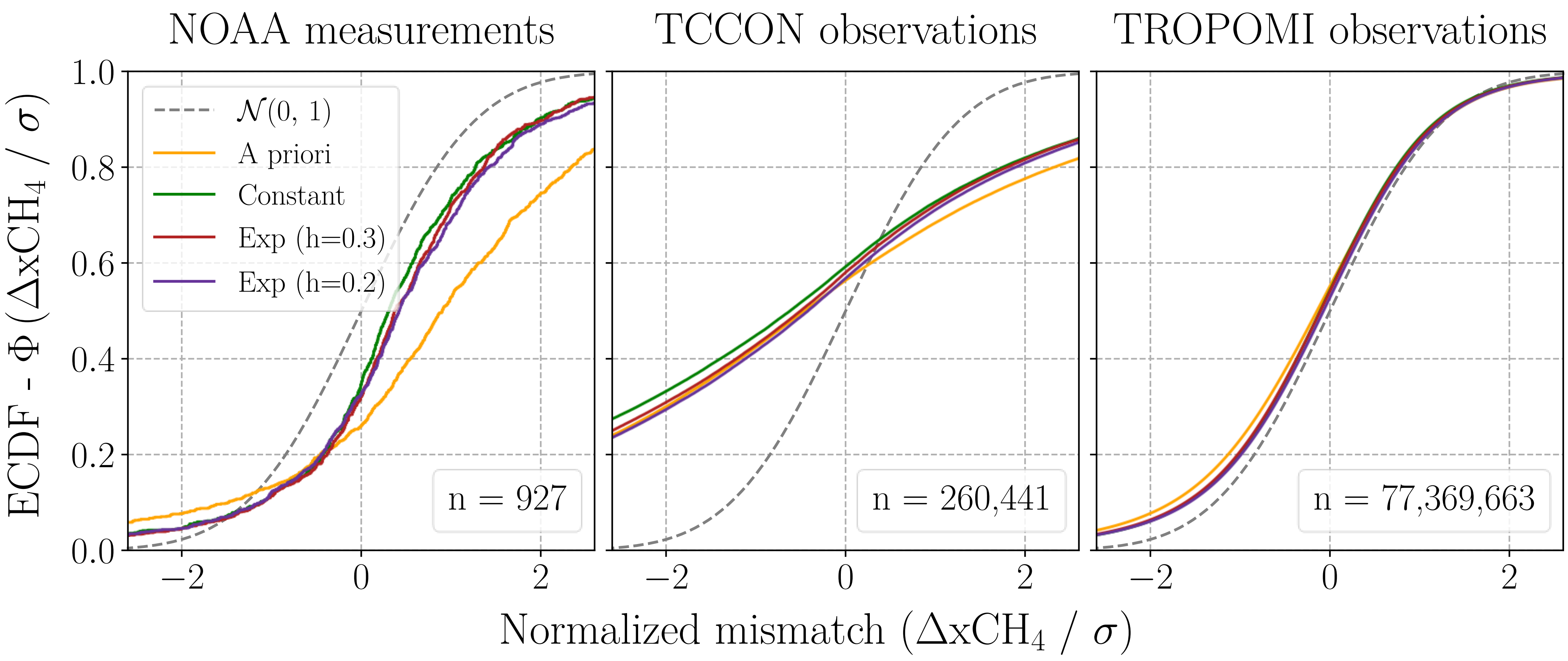
First simulation with a constant factor



Simulations with adaptative factors

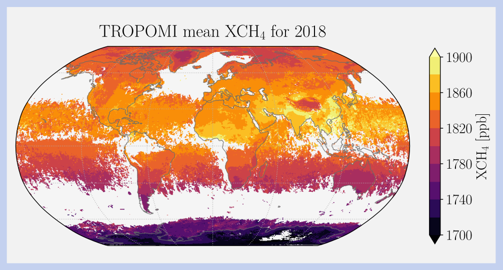


Simulations with adaptative factors



Summary

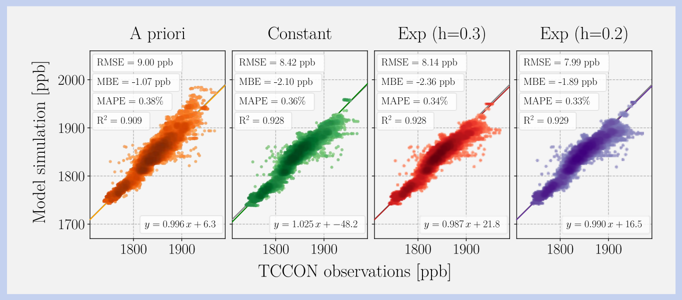
- TROPOMI provides added information but too many pixels



- Implementation of adaptive inflation factor on TMVar

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

- Some improvements on inversions comparing with TCCON



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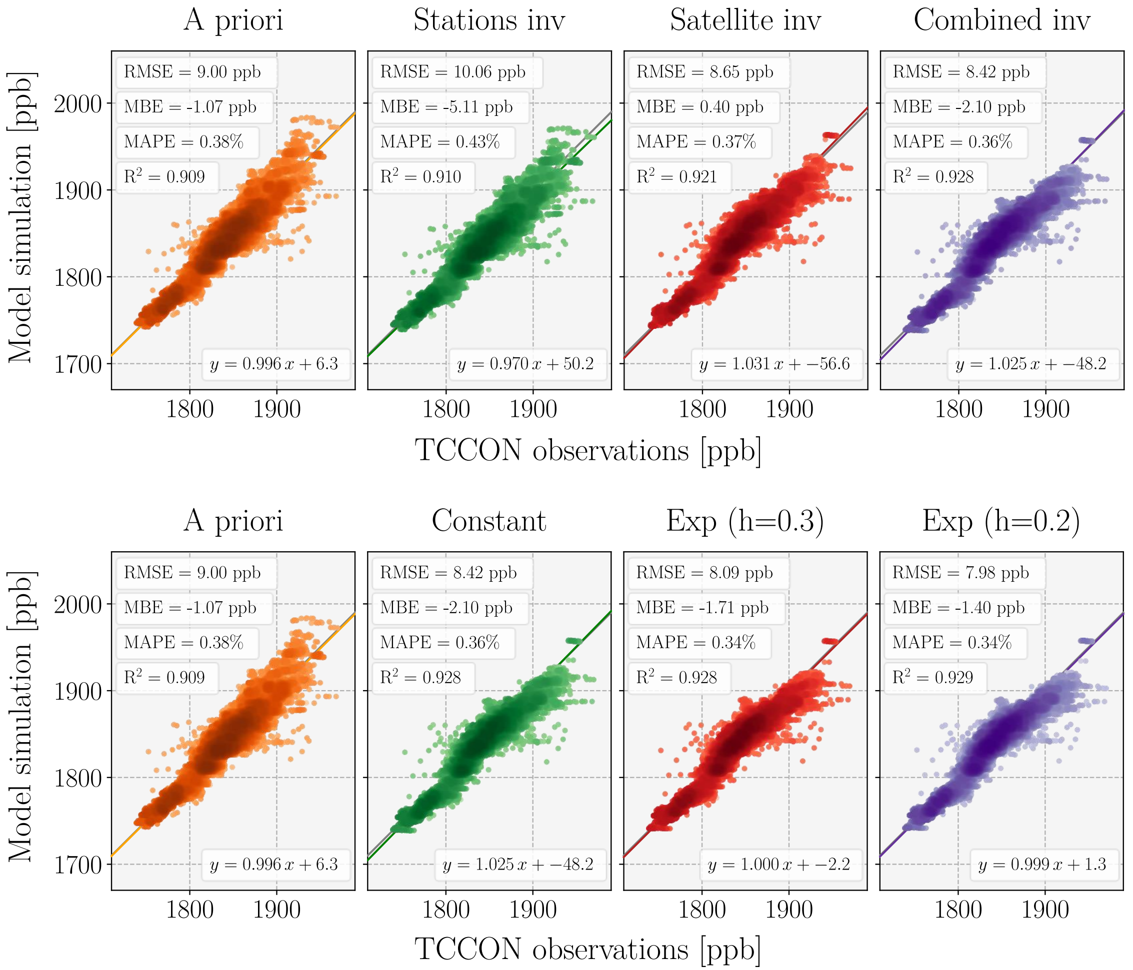
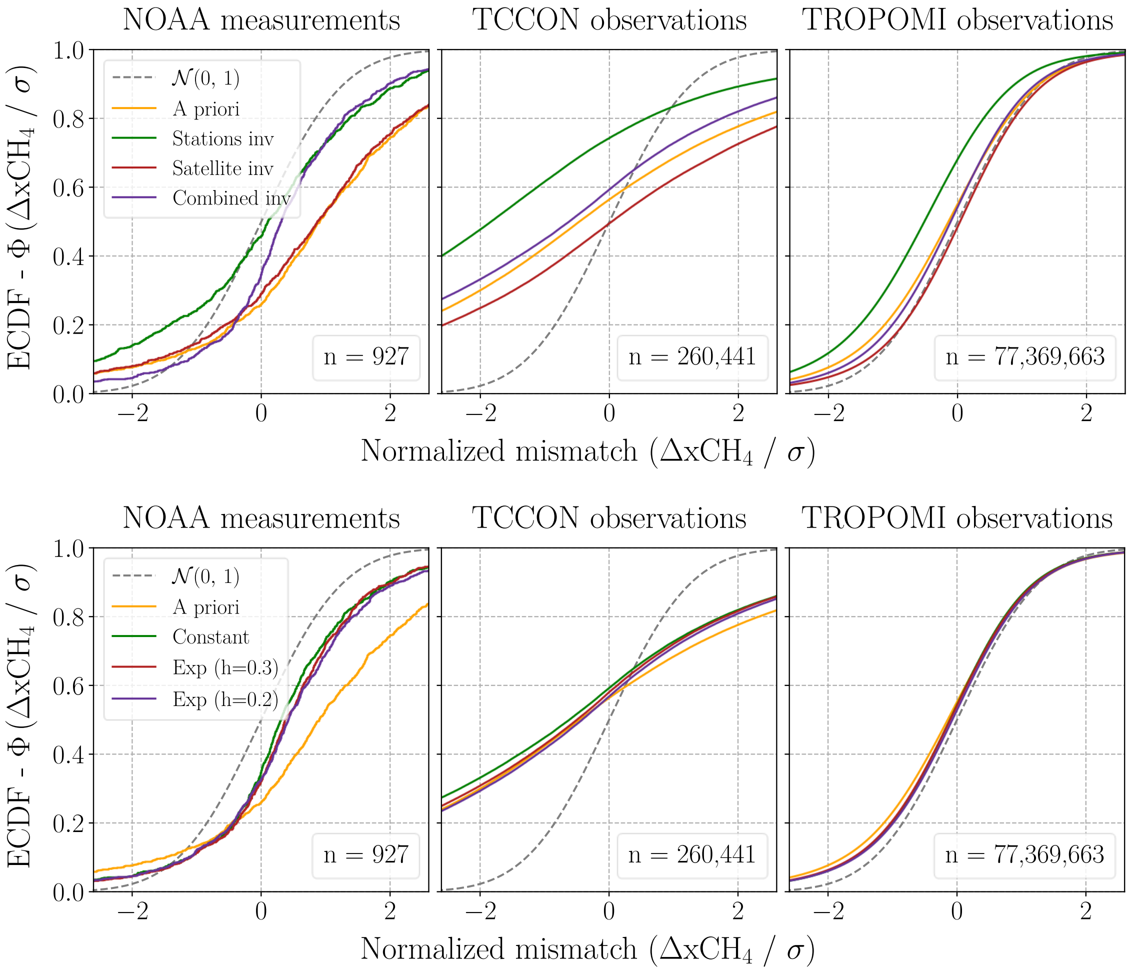
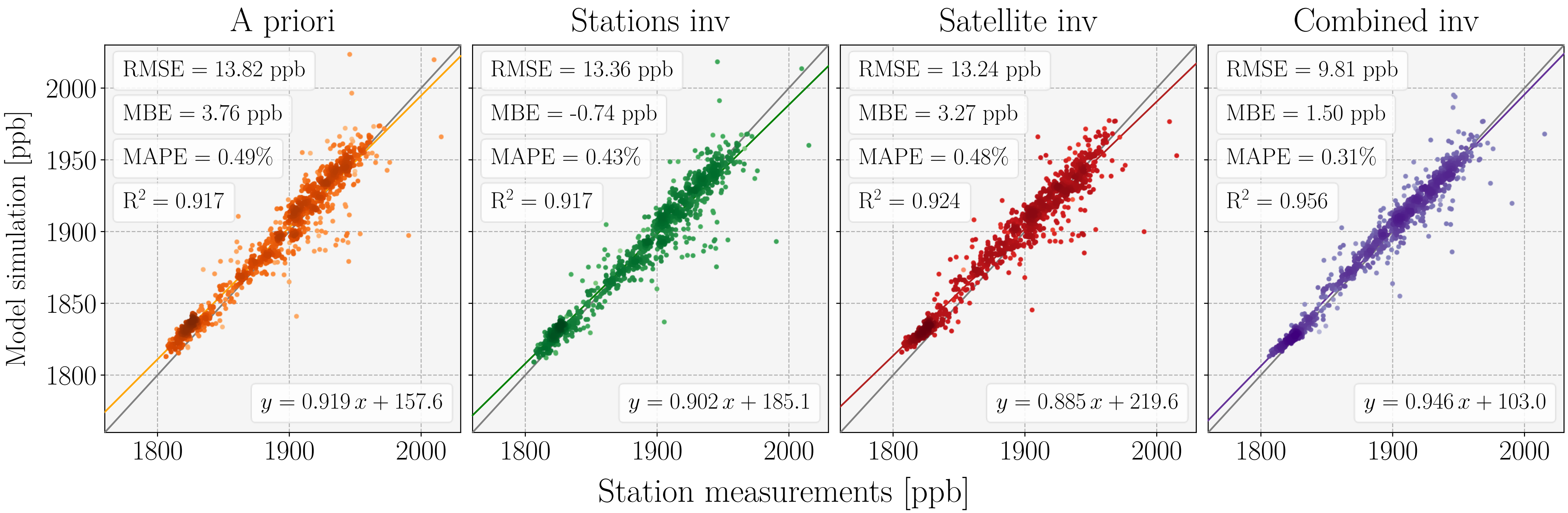
Comparison of results

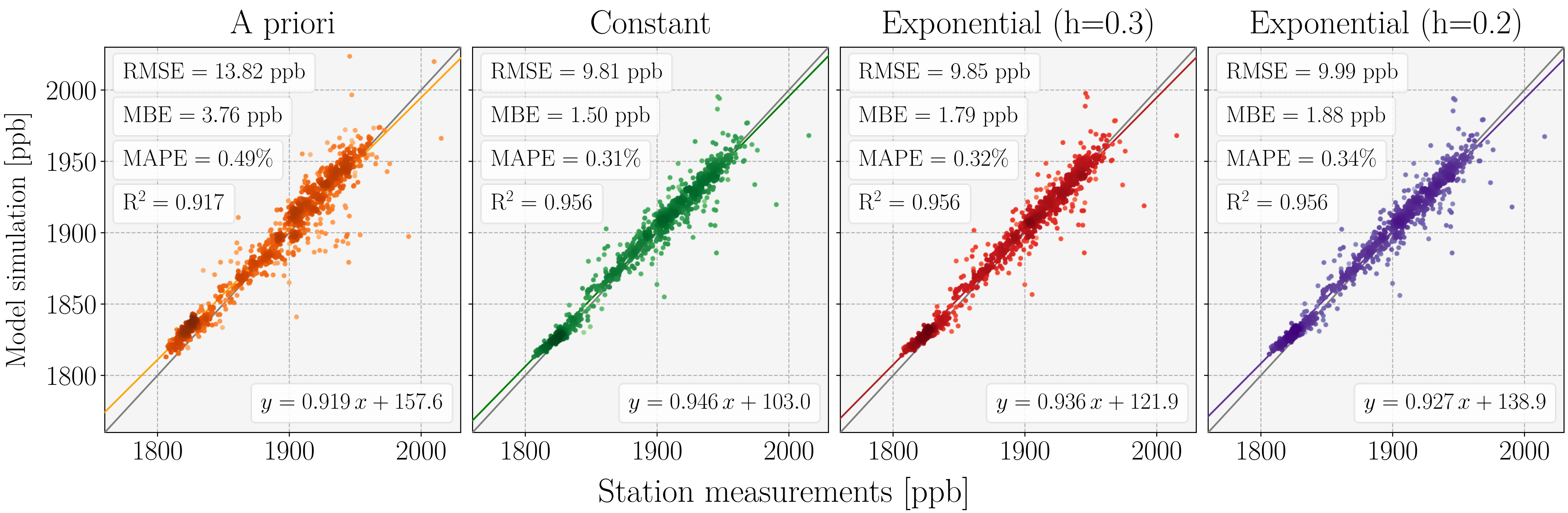




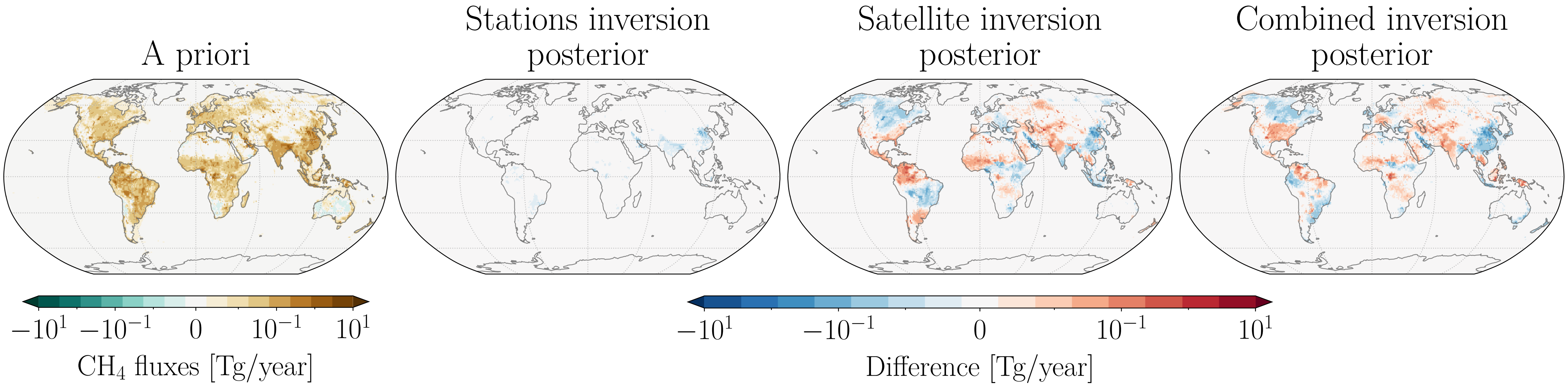
First simulation with a constant factor



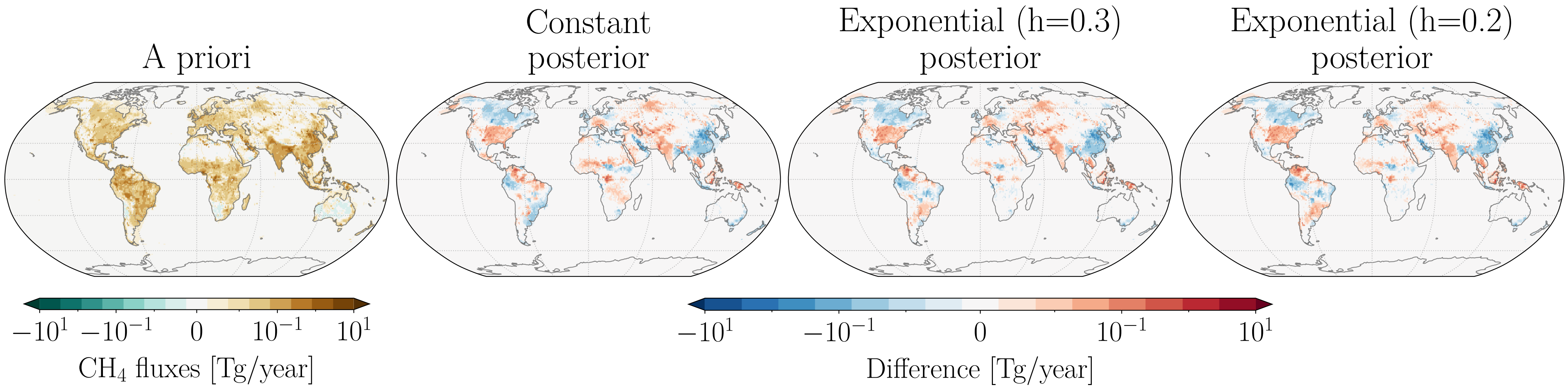
Simulations with adaptative factor



Emissions for base simulation



Emissions for simulation with adaptive factor



Total emissions per simulation

	A priori	Only stations	Only TROPOMI	Constant inflation	Exponential (h=0.3)	Exponential (h=0.2)
Total annual emissions [Tg/year]	585.61	572.11	584.51	575.50	575.39	577.97