A global CO fire emissions assessment and its connection with drought events

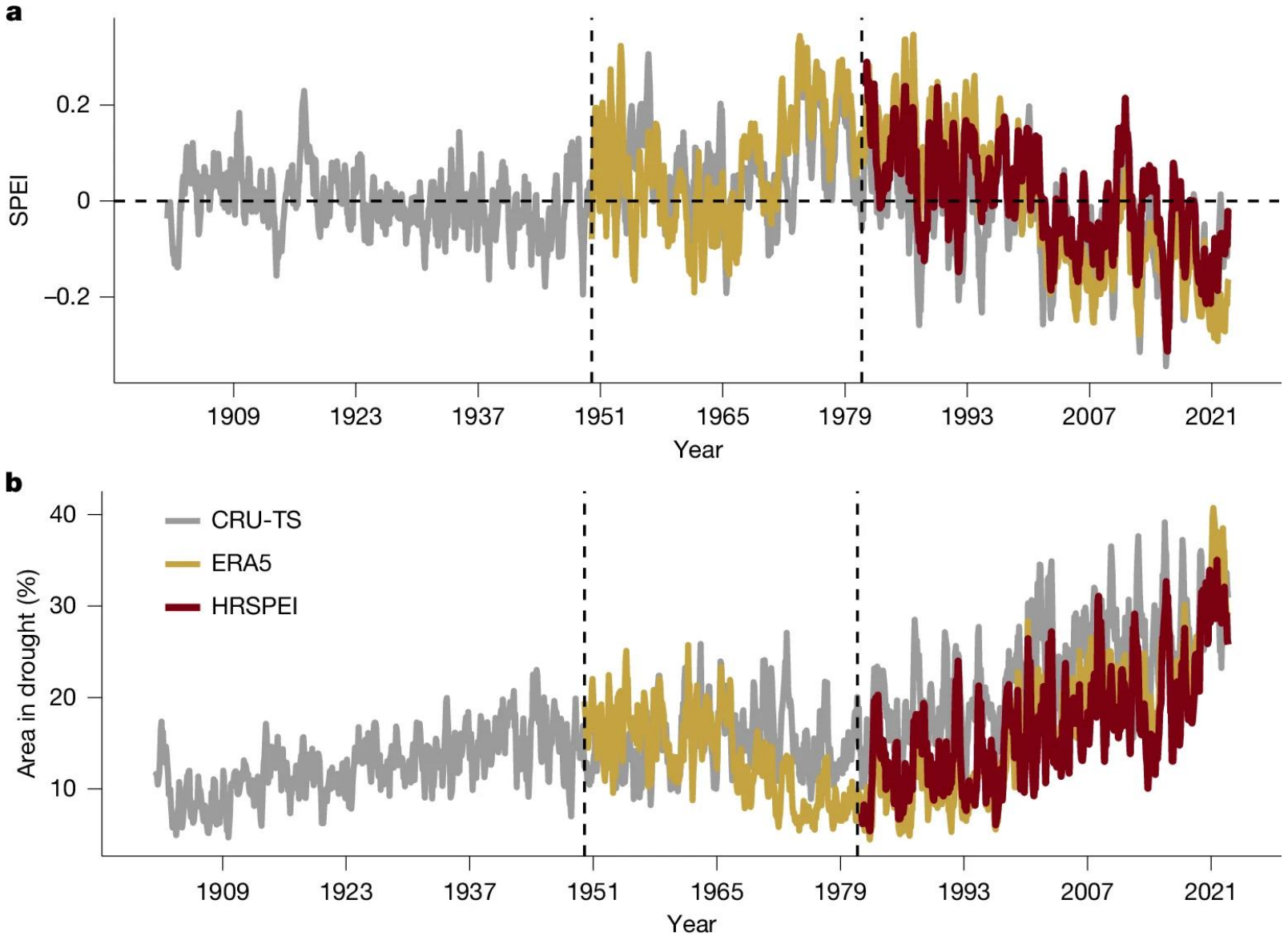
Helene Peiro, Ivar van der Velde, Guido van der Werf, Sander Houweling, Pieter Rijsdijk, Anne-Wil van der Berg, and Ilse Aben

SRON SPACE RESEARCH ORGANISATION NETHERLANDS

NWO

1. Introduction

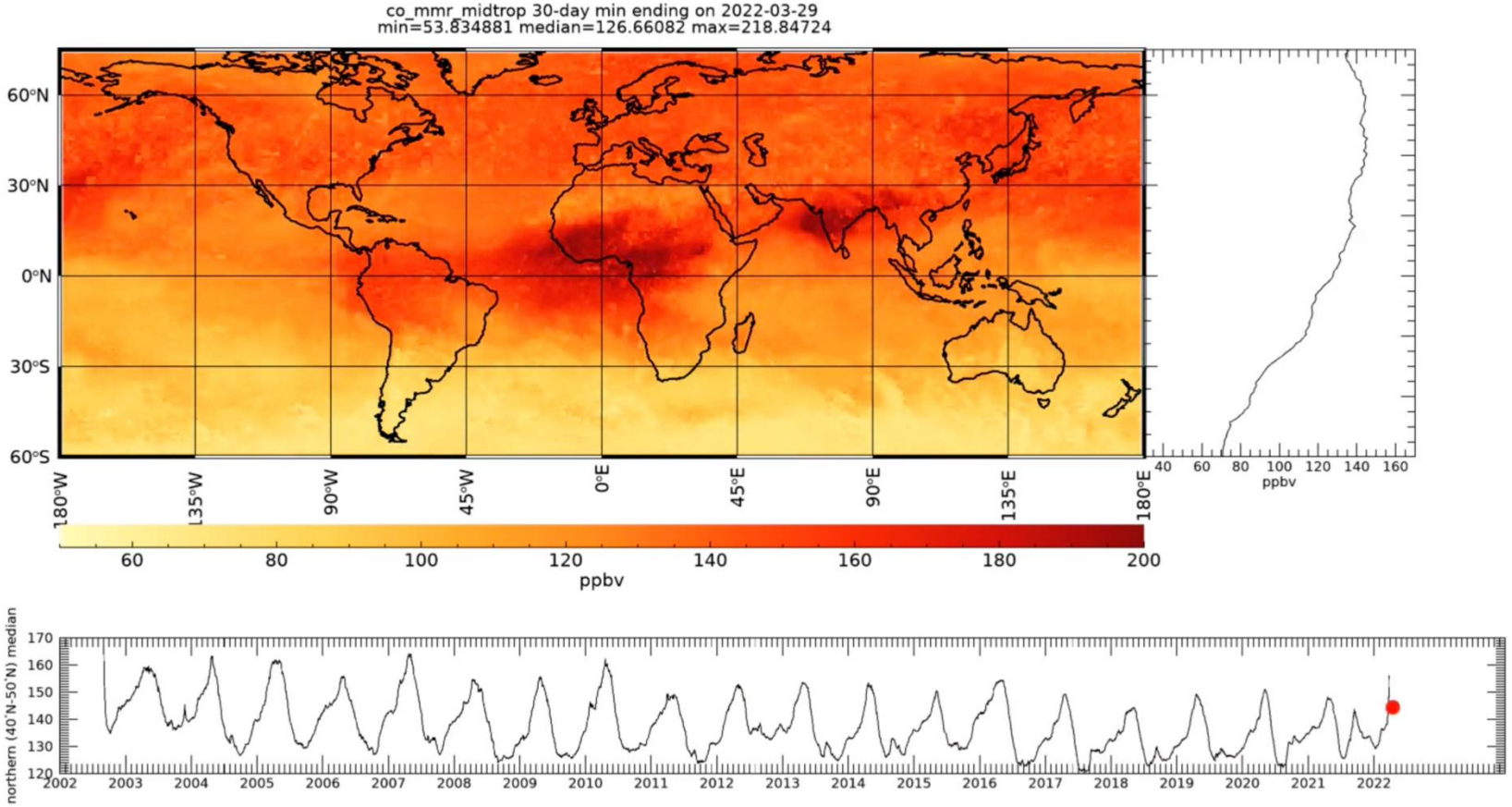
Drought index: SPEI (Standardised Precipitation Evapotranspiration Index, Vicente-Serrano et al., 2010)



- Increasing trend globally during the period 1981-2022 in :
  - drying conditions
  - Area affected by drought

Gebrechorkos et al., 2025

1. Introduction

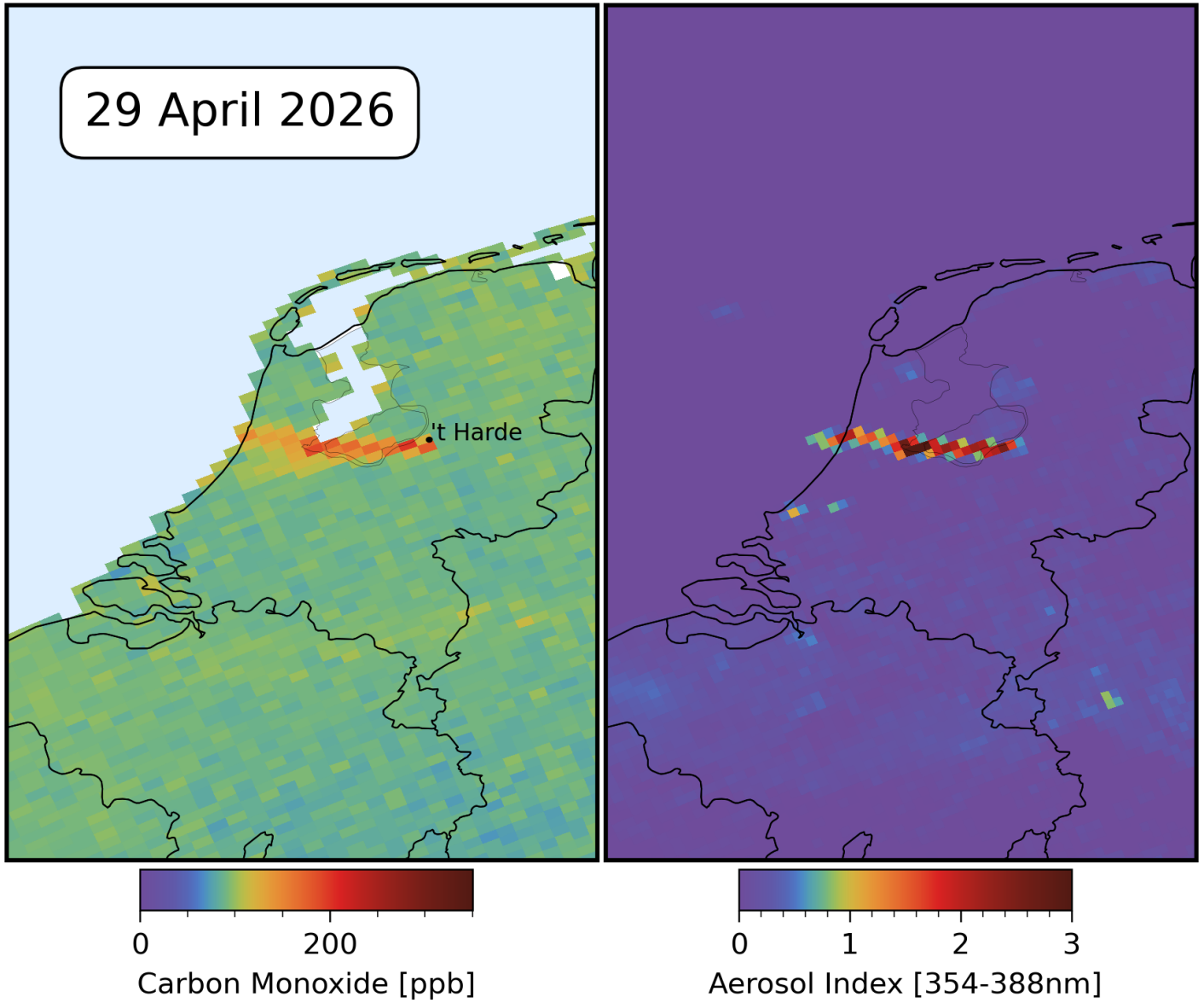


https://airs.jpl.nasa.gov/resources/239/airs-global-carbon-monoxide-over-20-years-2002-2022/

- Since 2000, decreasing trend of CO concentration
  - Improved combustion
  - Less fire in savannahs
- **The declining trend is slowing down** during Northern Hemisphere fire seasons (Buchholz et al., 2022).

Observations of CO concentrations from space: TROPOspheric Monitoring Instrument (TROPOMI)

- measures daily total column of CO
- CO = good tracer for fires



2. Methodology

Top-down emissions

TM5

- 4D-Var algorithm
- Global 3°x2° resolution
- Ensemble of 5 inversions for each fire prior used
- All sources optimized:
  fire= 3 days
  nat and ant=monthly

Natural emissions from TM5 full chemistry (Huijnen et al., 2006)

Fire emissions from GFED41s, GFAS, or GFED5

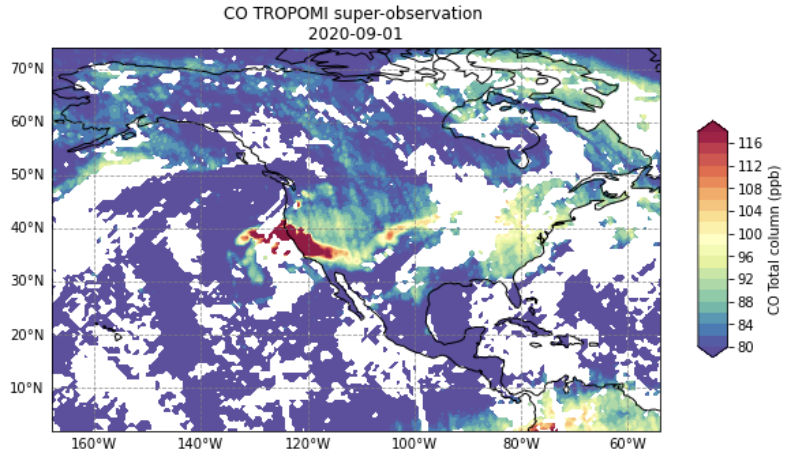
Anthropogenic emissions from CAMS-GLOB-Ant v5.3

Optimized GFAS emissions

Optimized GFED41s emissions

Optimized GFED5 emissions

TROPOMI satelllite super-observations (here CO at 0.5°)



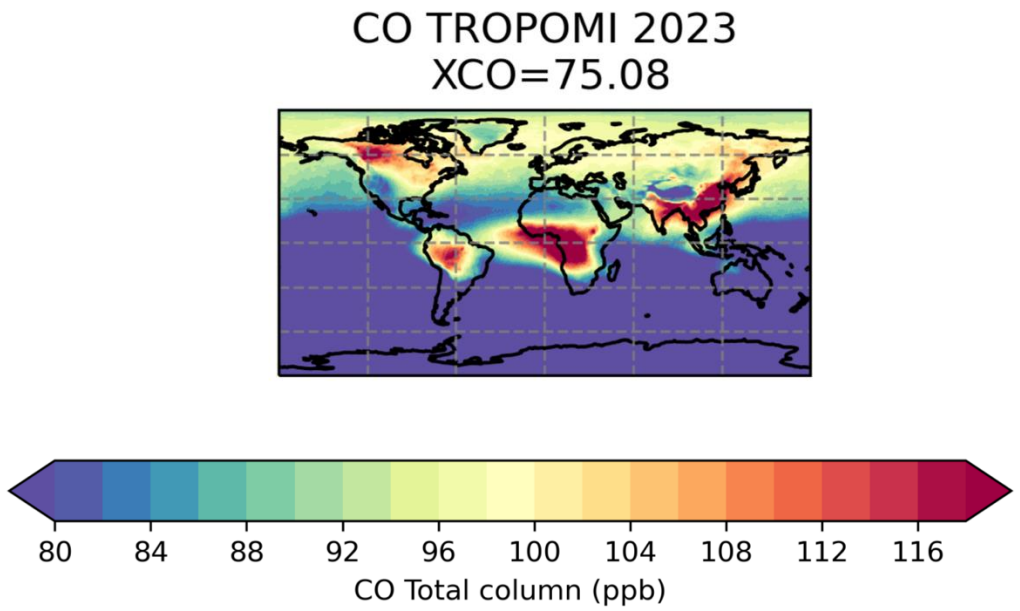
2. Methodology

For each year, an ensemble of inversions were performed based on the following setups:

		set1	set3	set4	set5	set6
Prior uncertainty (%)	Nat (TM5)	50	50	10	50	80
	Ant (CAMS)	10	50	10	10	10
	Fire (…)	80	250	250	250	250

3. Results

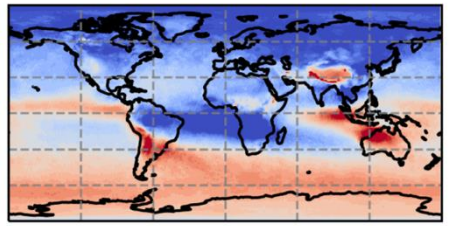
1. Inversion abilities to fit the data



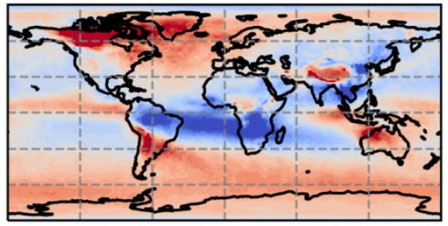
3. Results

1. Inversion abilities to fit the data

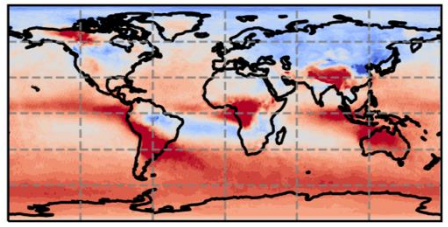
CO GFAS - TROPOMI
Delta XCO=-2.68



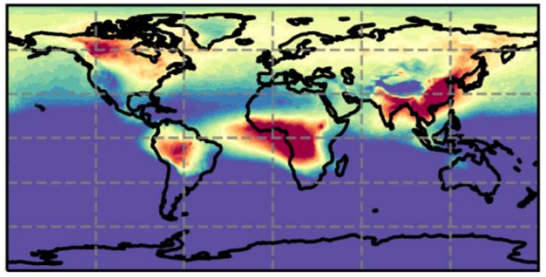
CO GFED41s - TROPOMI
Delta XCO=0.85

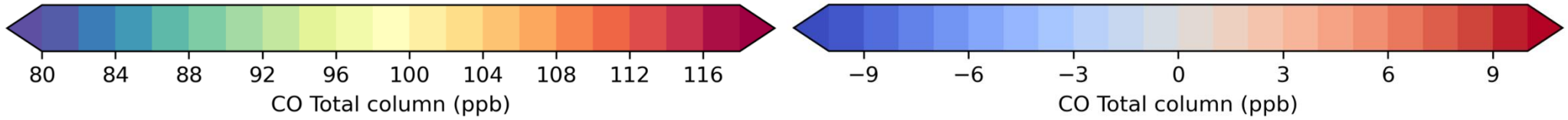


CO GFED5 - TROPOMI
Delta XCO=2.76



CO TROPOMI 2023
XCO=75.08



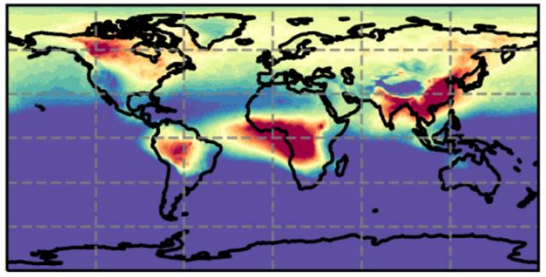


3. Results

1. Inversion abilities to fit the data

Ensemble mean

CO TROPOMI 2023
XCO=75.08



CO GFAS - TROPOMI
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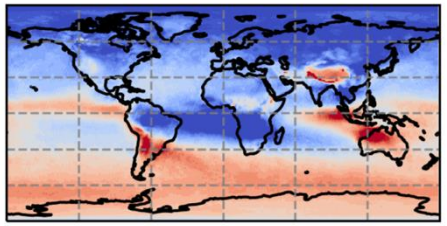
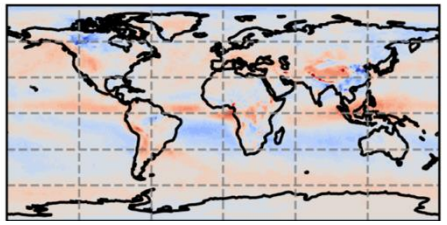
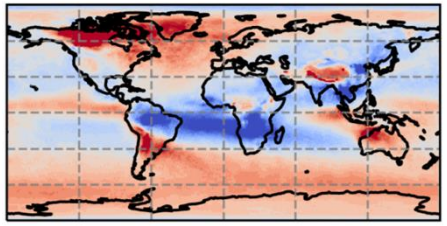


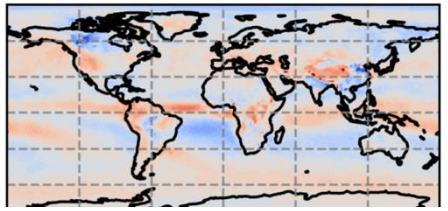
GFAS posterior - TROPOMI
Delta XCO=-0.01



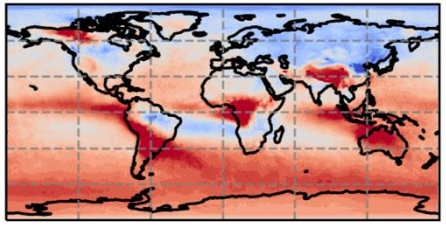
CO GFED41s - TROPOMI
Delta XCO=0.85



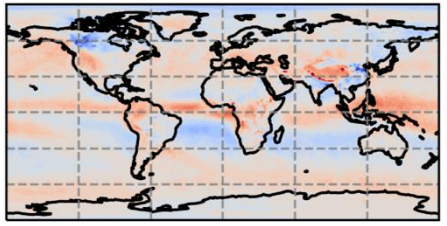
GFED41s posterior - TROPOMI
Delta XCO=-0.13

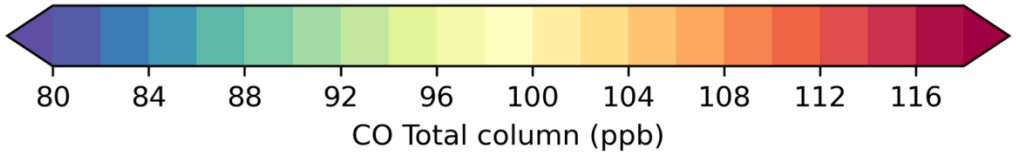


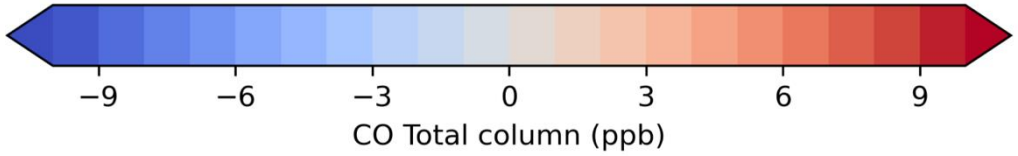
CO GFED5 - TROPOMI
Delta XCO=2.76



GFED5 posterior - TROPOMI
Delta XCO=0.22





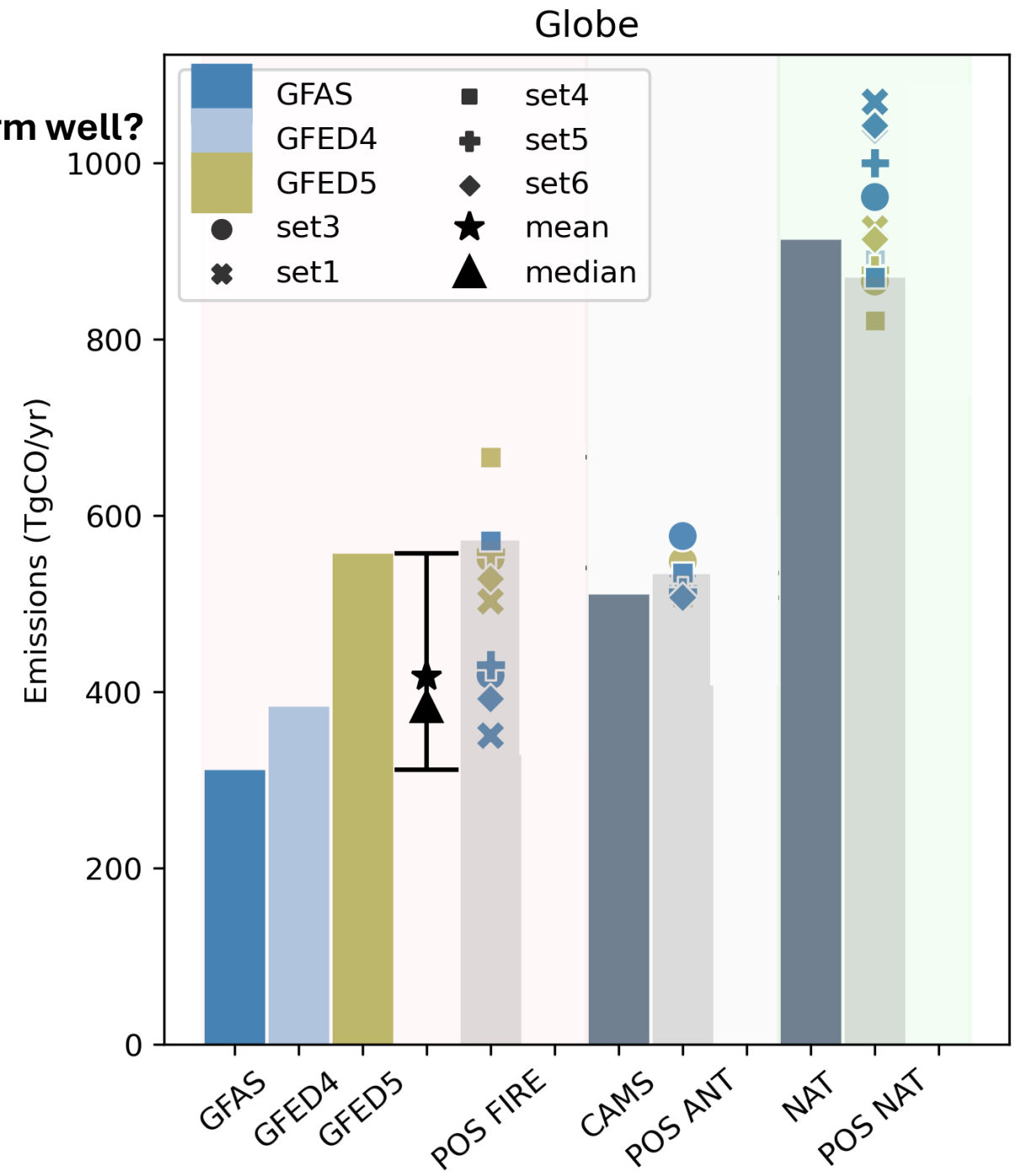


- Inversion better fits observations than TM5 prior emissions
- Sum of all sources are converging

3. Results

1. CO emission assessment – do all setups perform well?

CO emissions average over the period 2019-2024

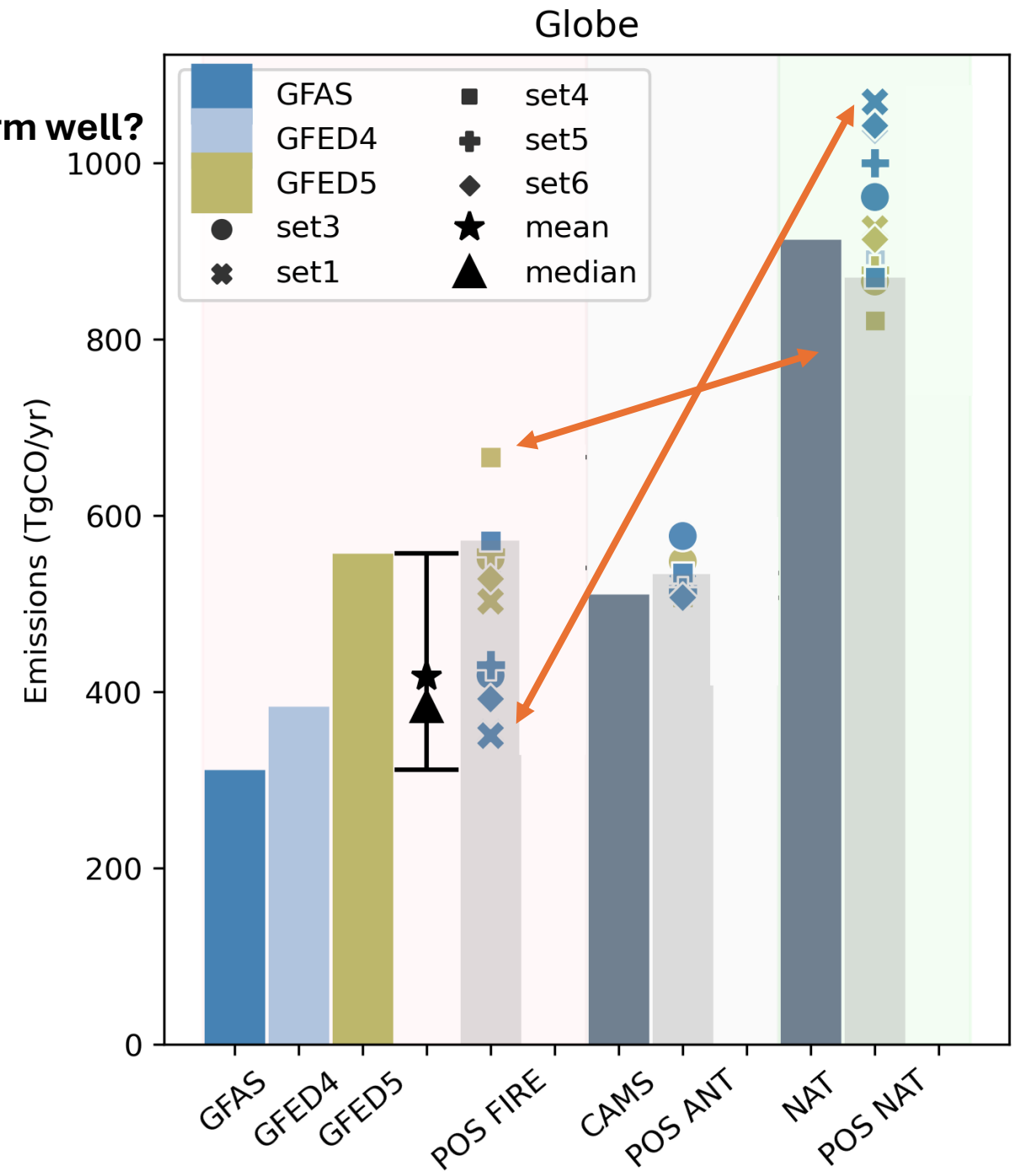


3. Results

1. CO emission assessment – do all setups perform well?

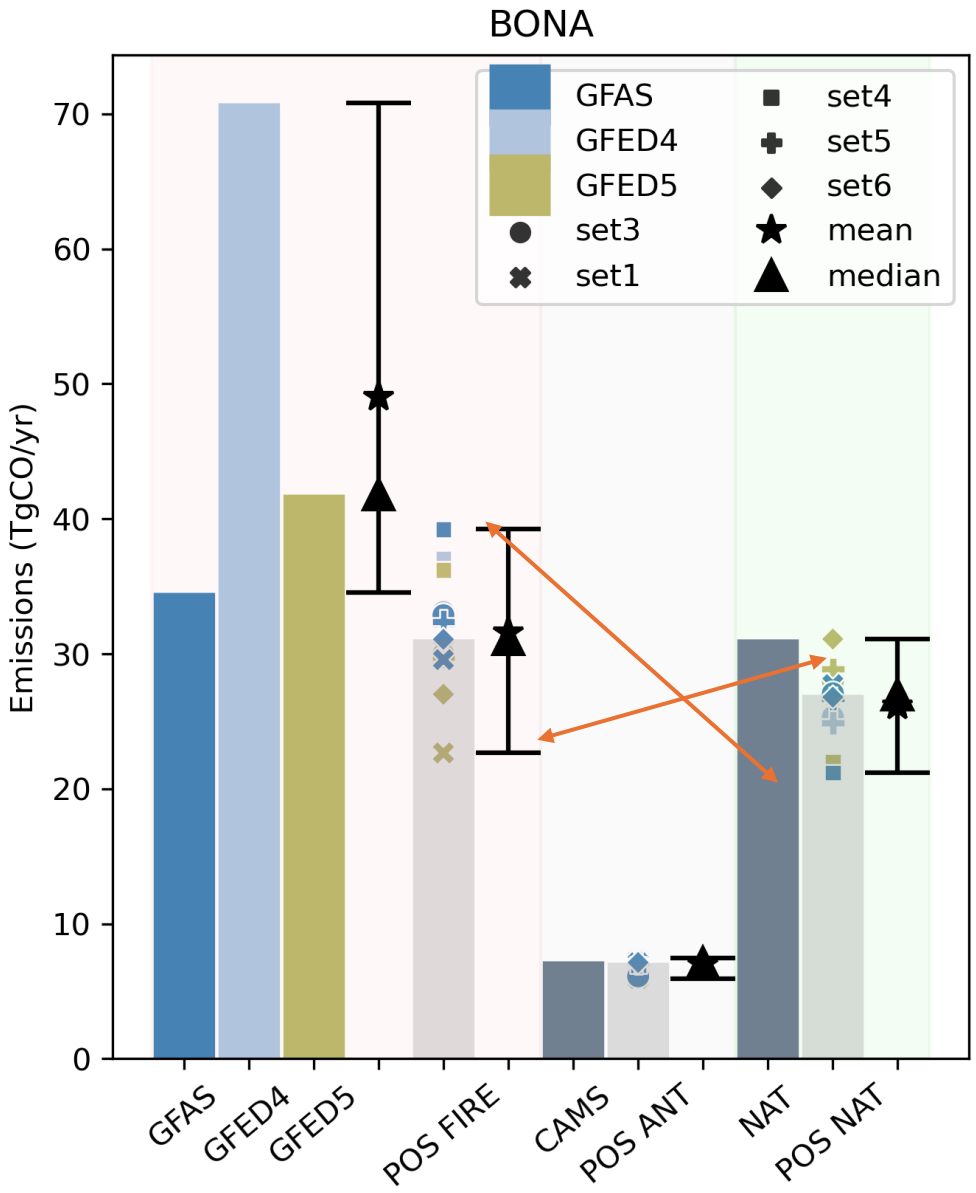
CO emissions average over the period 2019-2024

- Large emissions spread with posterior emissions
- Balance among all optimized sources between fire and secondary production



3. Results

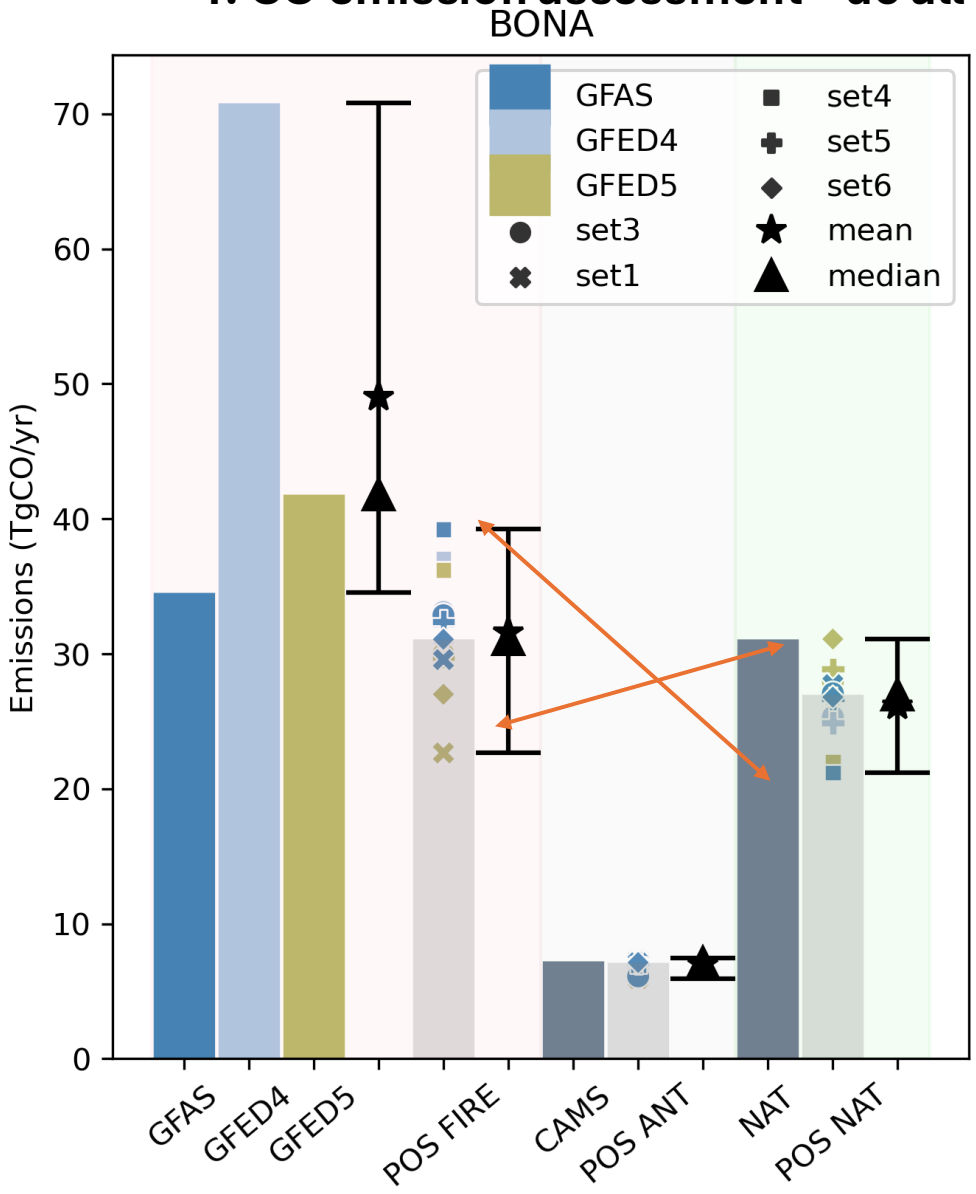
1. CO emission assessment – do all setups perform well?

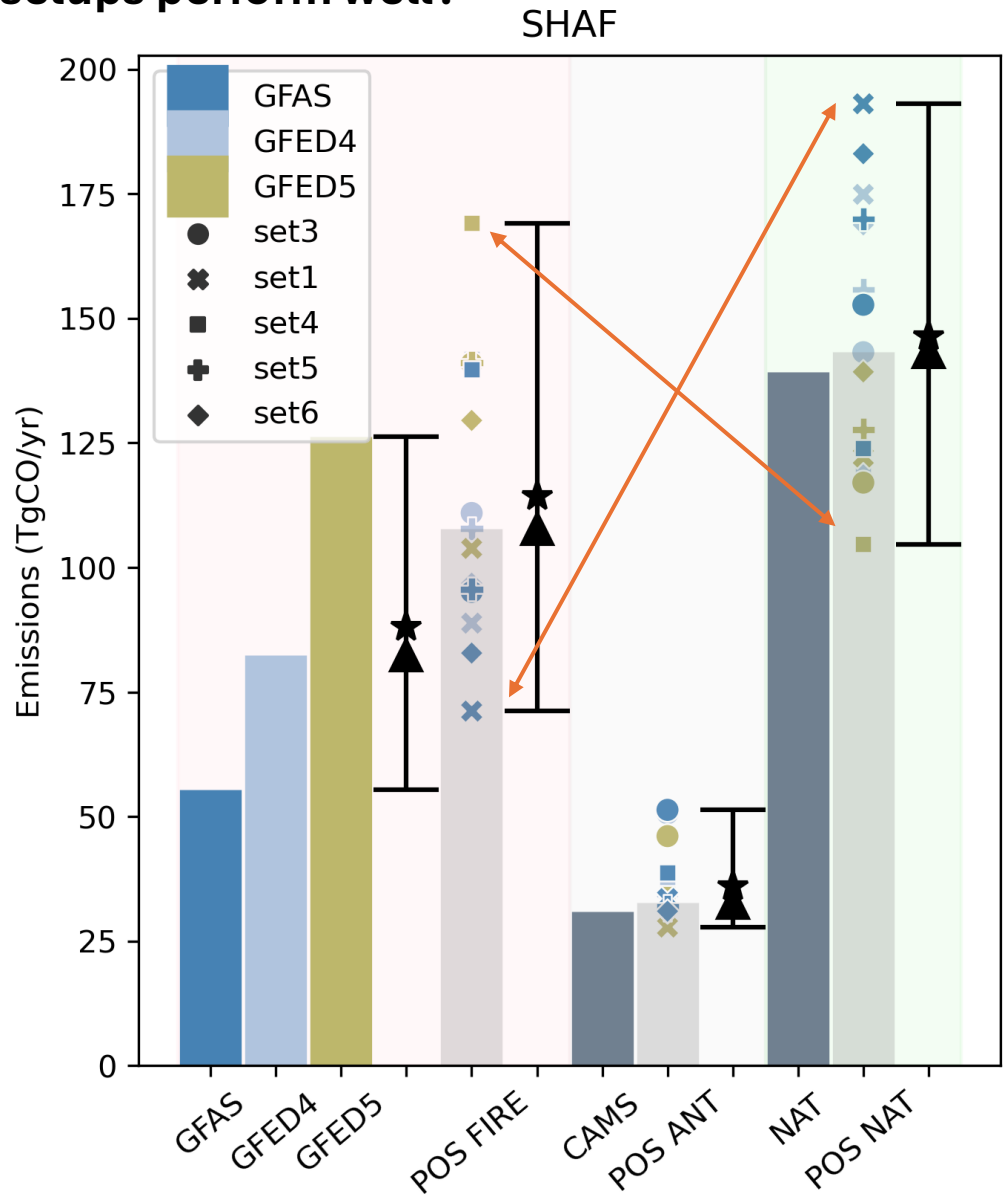


Balance also observed at regional scale

3. Results

1. CO emission assessment – do all setups perform well?





Even more accentuated in the tropics!!

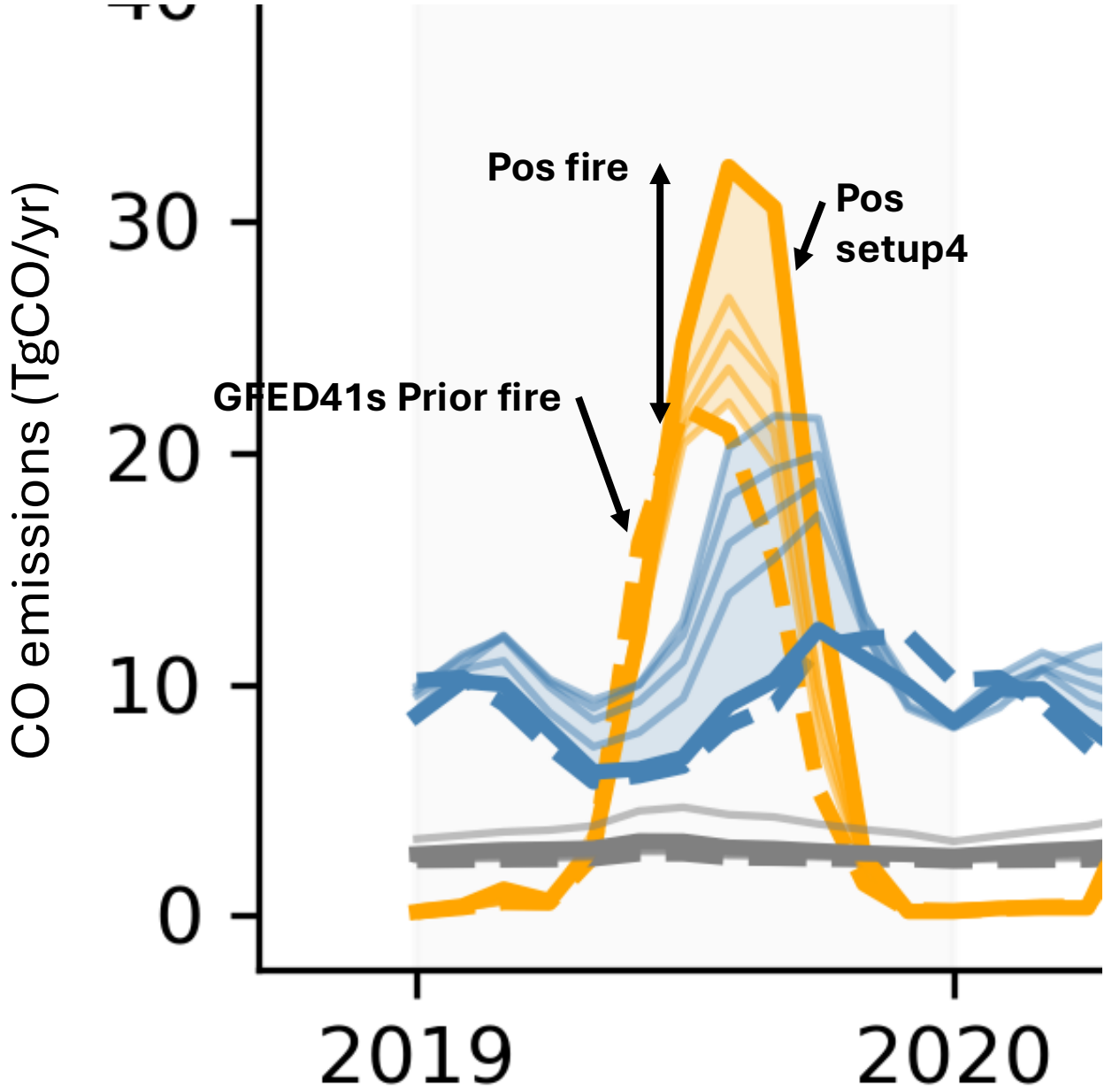
3. Results

Using GFED41s

1. CO emission assessment –
do all setups perform well?

→ Let's look at the monthly variation of fire, natural, and anthropogenic emissions

- Underestimation of the fire prior
- Seasonality almost matches



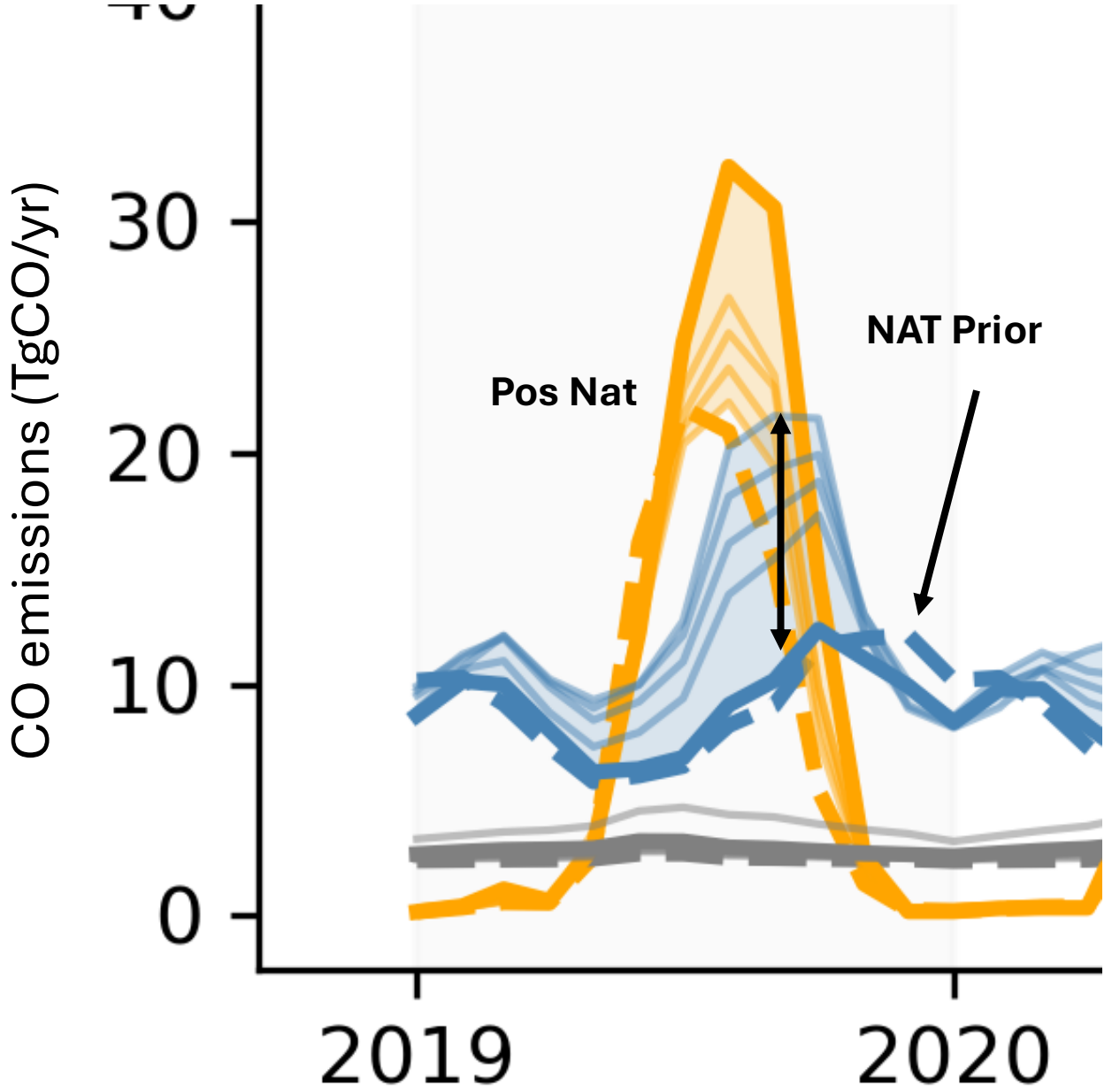
3. Results

1. CO emission assessment –
do all setups perform well?

→ Let's look at the monthly variation of fire, natural, and anthropogenic emissions

- Seasonality between prior and pos natural emissions do not match
- Pos natural emissions capture fire emissions

Using GFED41s



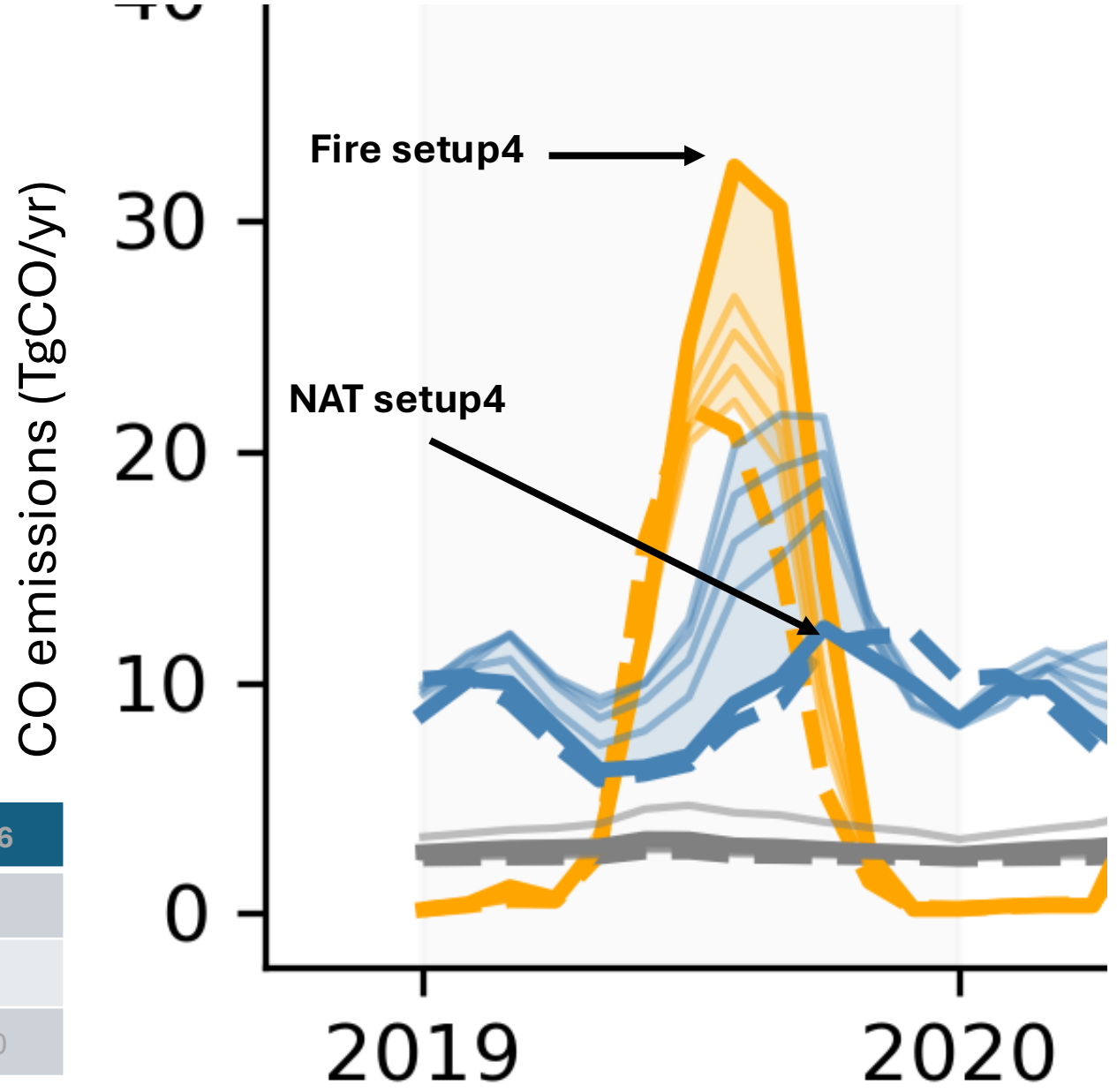
3. Results

Using GFED41s

1. CO emission assessment –
do all setups perform well?

- Seasonality between prior and pos natural emissions do not match
- Pos natural emissions seem to capture fire emissions
- Less pronounced for 1 inversion (setup4)

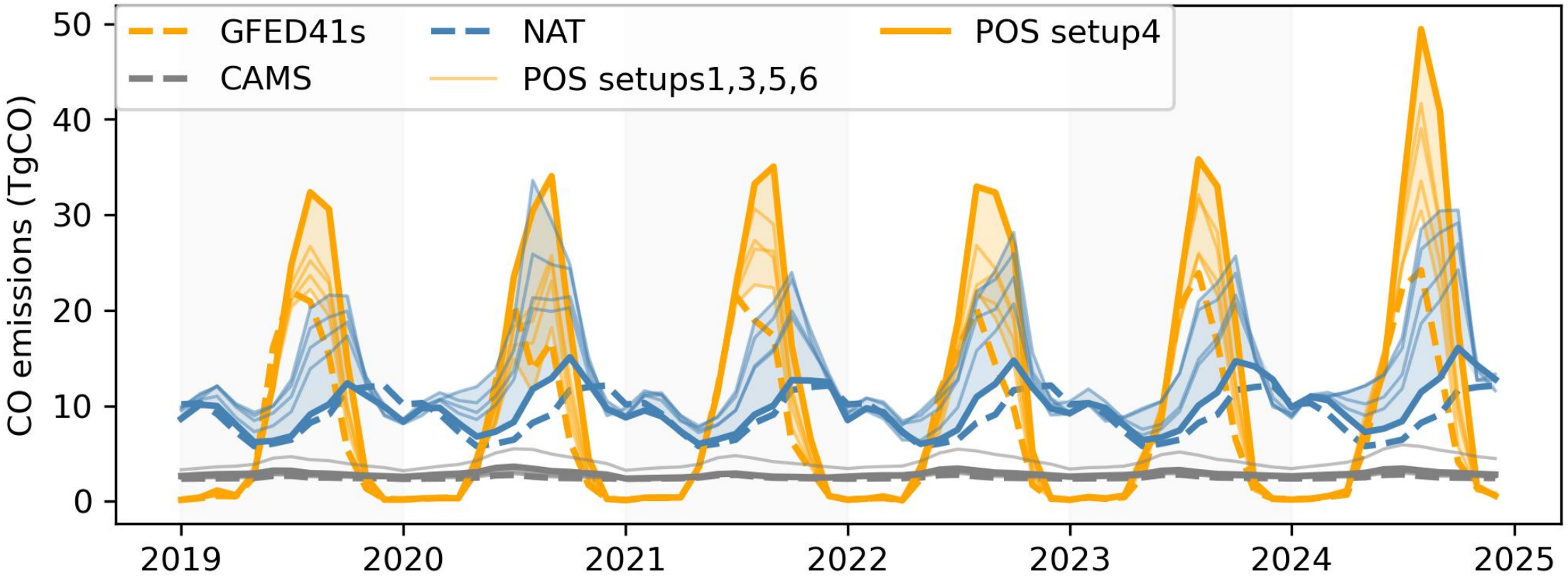
		set1	set3	set4	set5	set6
Prior uncertainty (%)	Nat	50	50	10	50	80
	Ant	10	50	10	10	10
	Fire	80	250	250	250	250



3. Results

1. CO emission assessment – do all setups perform well?

Setup 4 better matches the seasonality of natural prior emissions in comparison to the other inversions



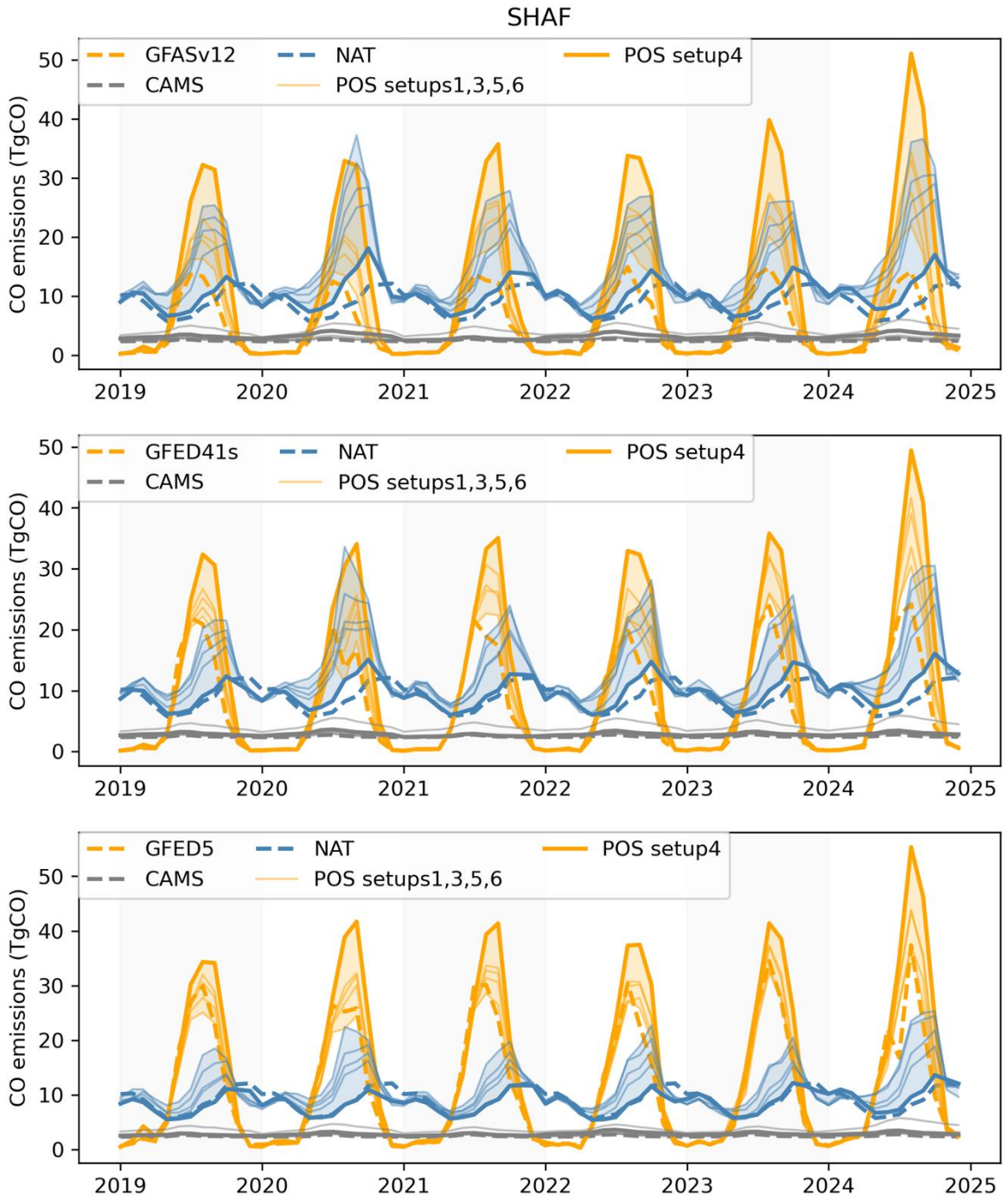
3. Results

1. CO emission assessment –
do all setups perform well?

GFAS

GFED41s

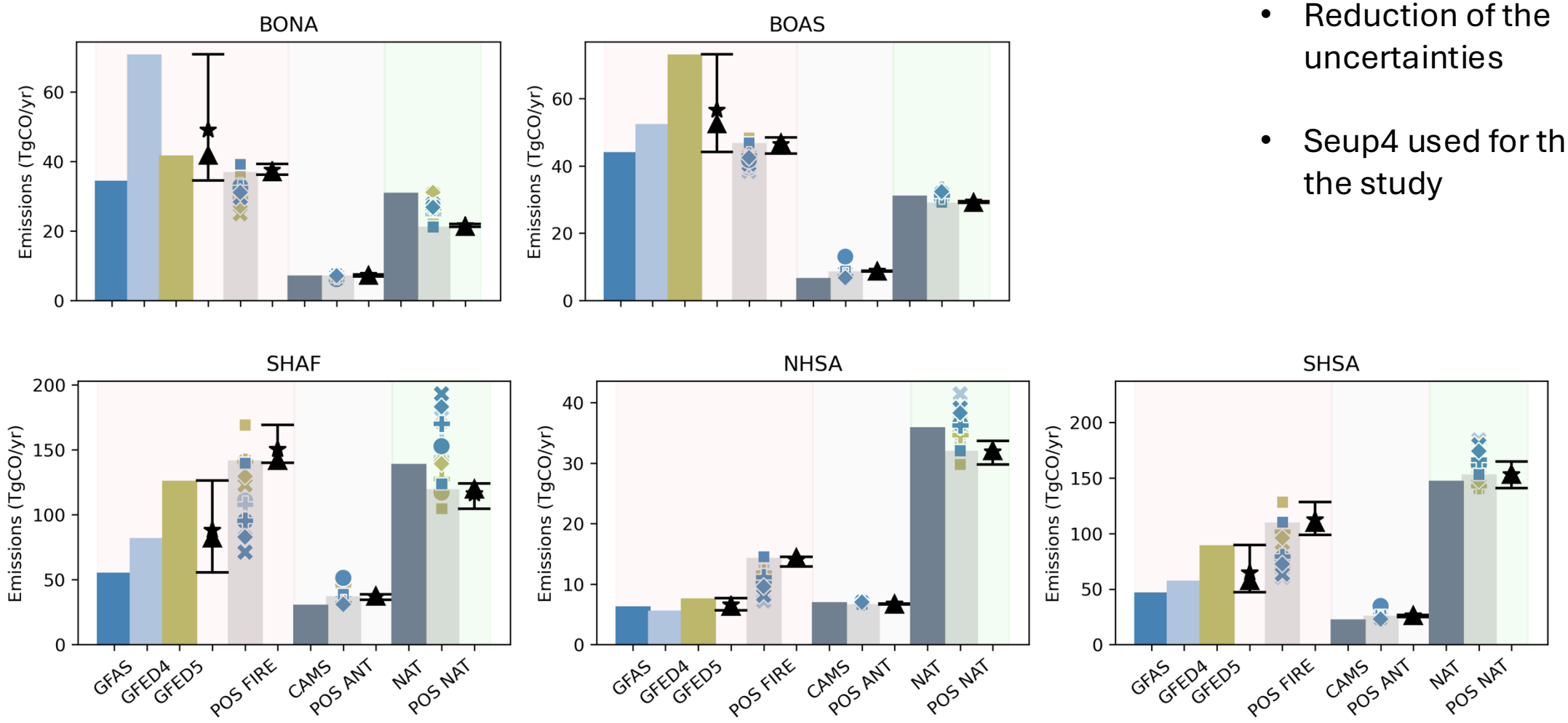
GFED5



GFED5 improves inversions in comparison to the other priors for SHAF

3. Results

1. CO emission assessment – do all setups perform well?

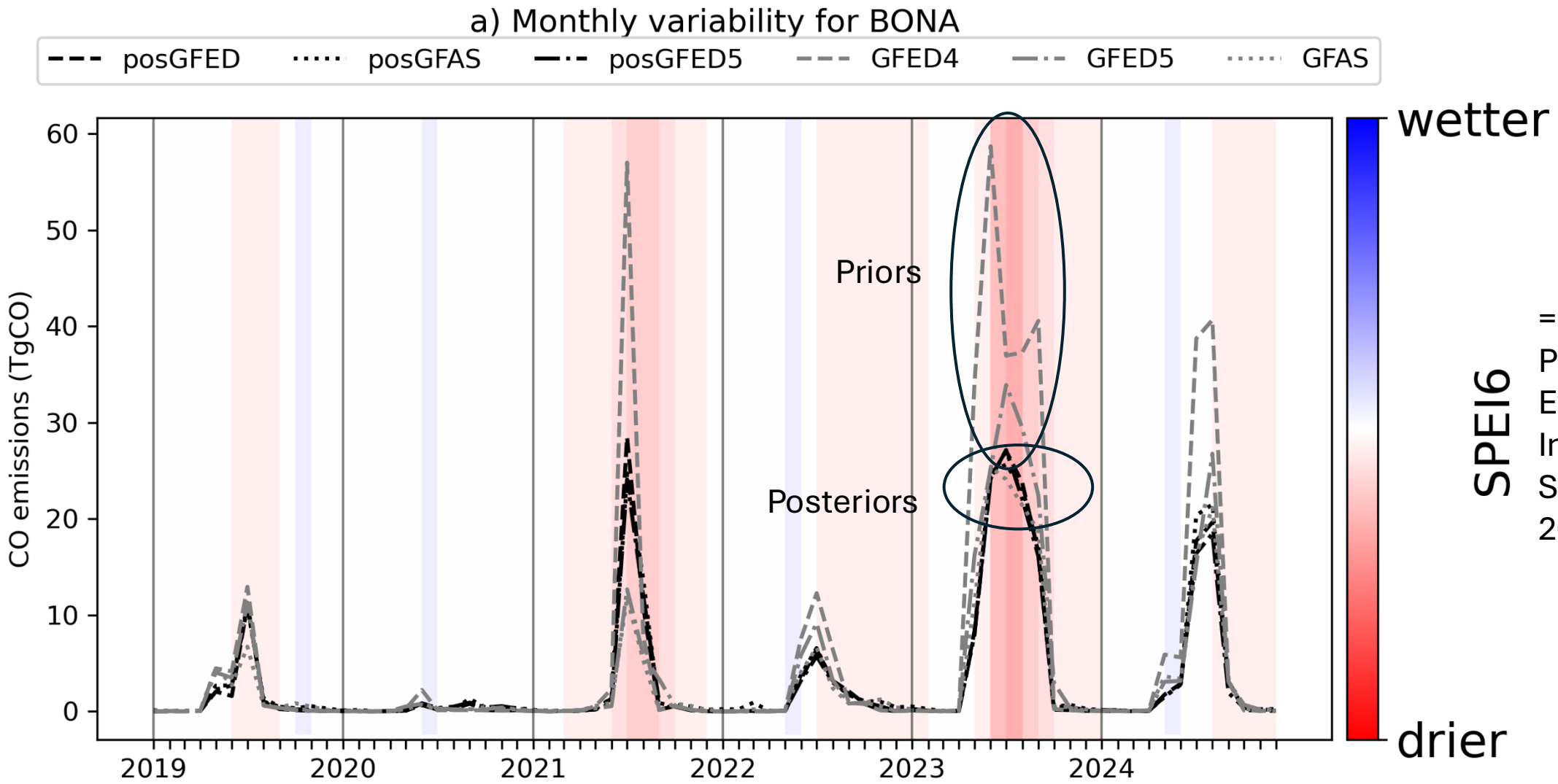


- Reduction of the uncertainties
- Seup4 used for the rest of the study

3. Results

Boreal Northern America

2. Assessing regional link between CO fire emissions and drought events:



= Standardised Precipitation Evapotranspiration Index (Vicente-Serrano et al., 2010)

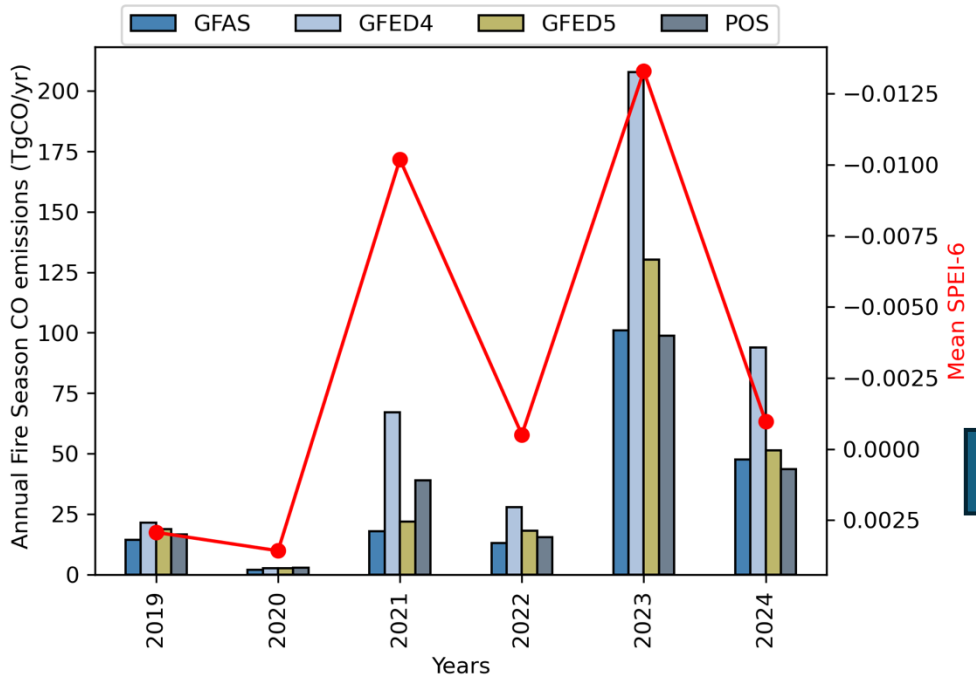
→ Lower CO fire emissions uncertainty and emissions with posterior than with priors

3. Results

Boreal Northern America

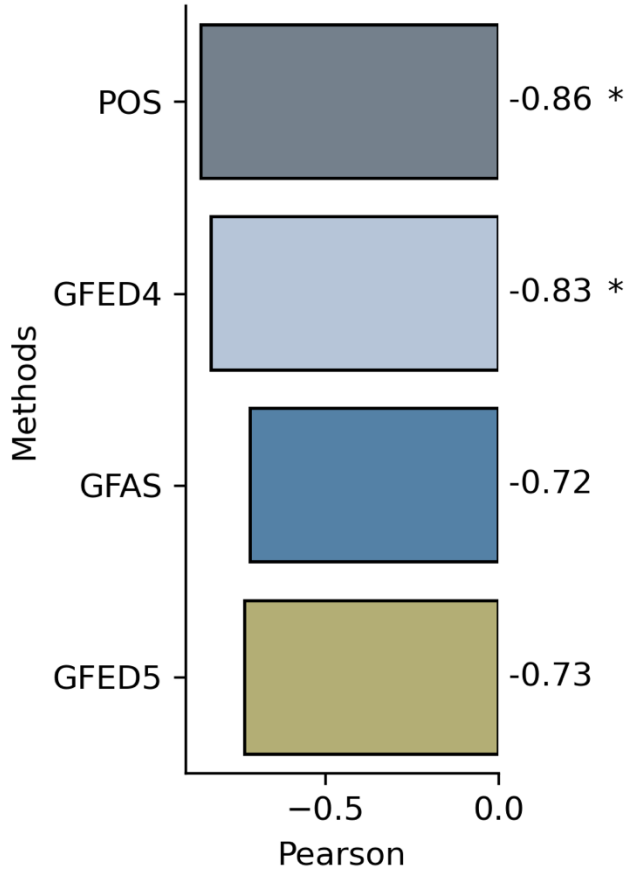
2. Assessing regional link between CO fire emissions and drought events:

b) Annual CO emissions and SPEI6



→ Fire emissions of the northern America boreal forests are more sensible to drought events

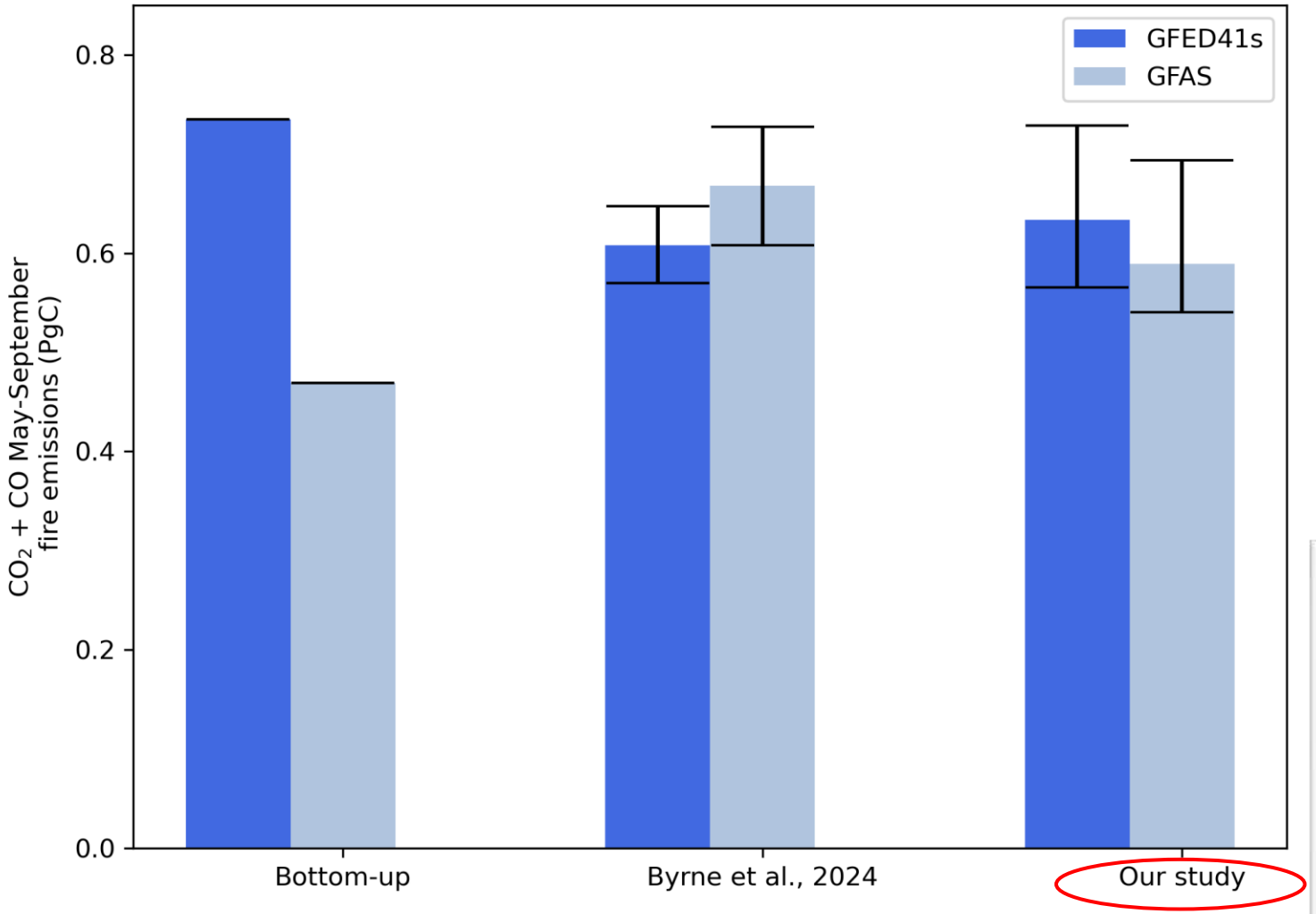
c) Emissions and SPEI-6 correlation



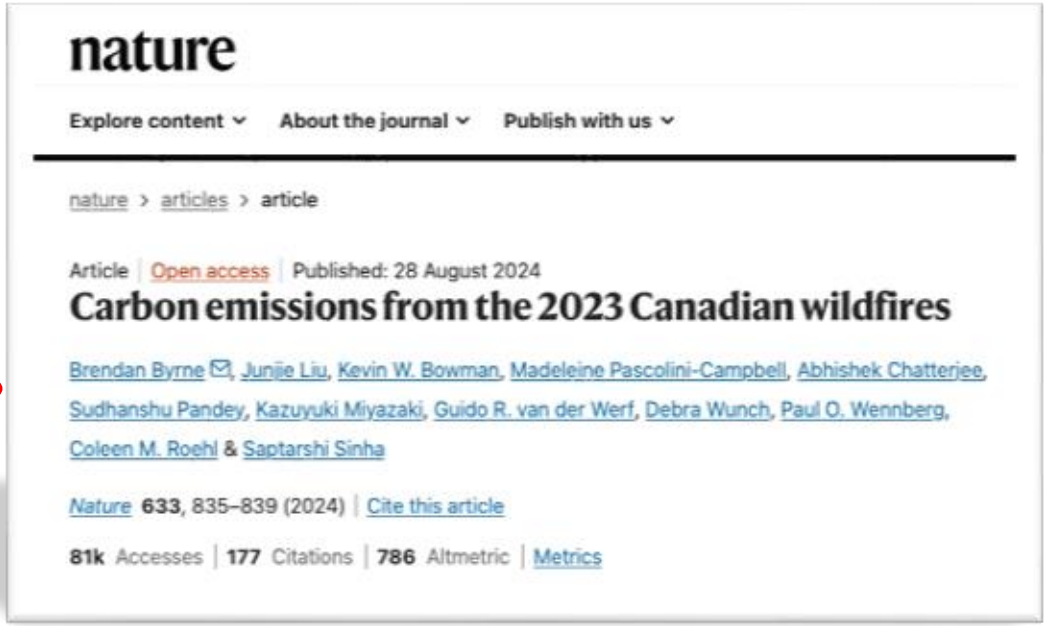
→ Strong negative Pearson correlation = strong link between CO fire emissions and drought events

3. Results

3. Evaluation



→ Results agreement with independent study of Byrne et al., (2024)



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Carbon emissions from the 2023 Canadian wildfires

Brendan Byrne ✉, Junjie Liu, Kevin W. Bowman, Madeleine Pascolini-Campbell, Abhishek Chatterjee, Sudhanshu Pandey, Kazuyuki Miyazaki, Guido R. van der Werf, Debra Wunch, Paul O. Wennberg, Coleen M. Roehl & Saptarshi Sinha

Nature **633**, 835–839 (2024) | Cite this article

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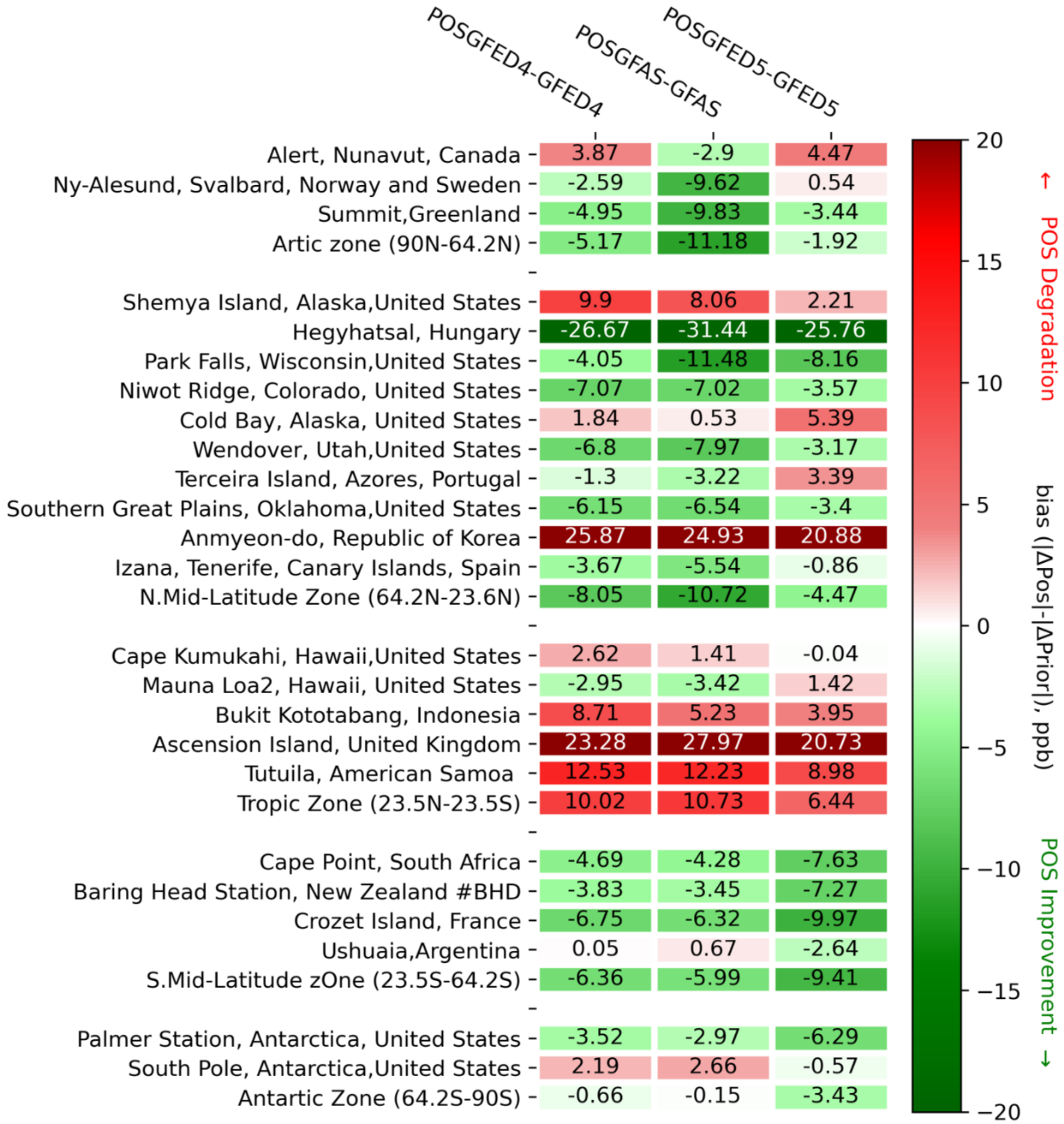
3. Results

3. Evaluation

→ Evaluation against surface flask measurements

→ Better performance with posterior emissions than with prior emissions



Conclusions

Submission soon in ACP

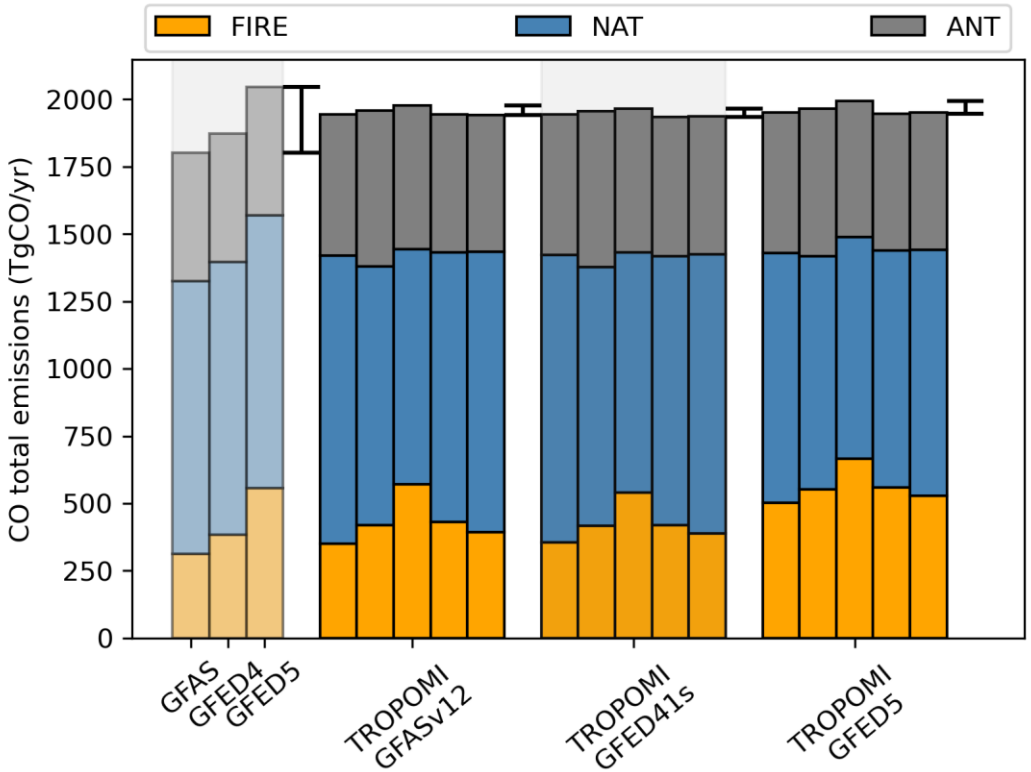
A global CO fire emissions assessment and its connection with drought events

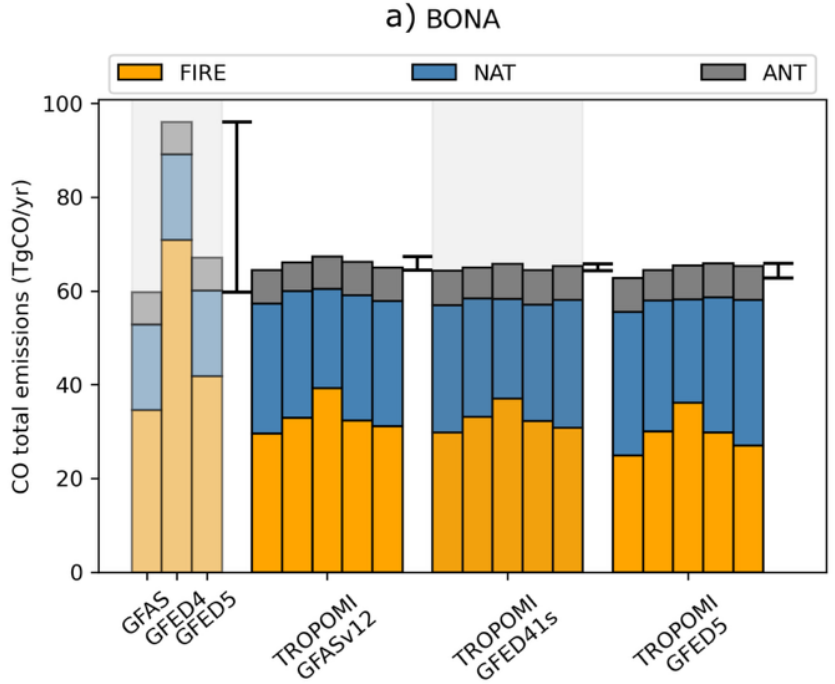
Helene Peiro[1], Ivar R. van der Velde[1], Guido van der Werf[2], Sander Houweling[1,4], Pieter Rijsdijk[1,3,4], Anne-Wil van der Berg[2], and Ilse Aben[1,4]

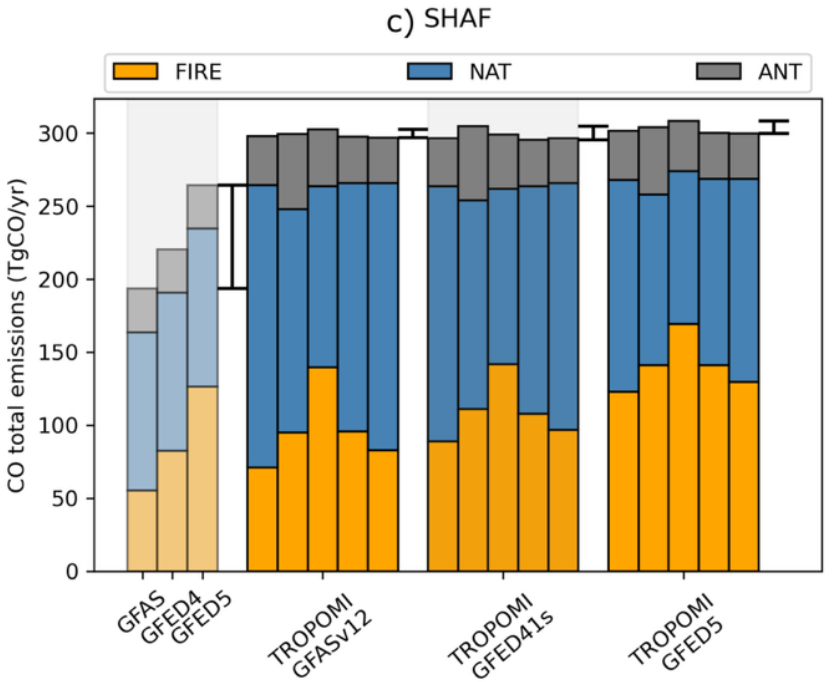
[1]SRON Space Research Organisation Netherlands, Leiden, the Netherlands
[2]Meteorology and Air Quality group, Wageningen University and Research, Wageningen, the Netherlands
[3]Satellite Observations department, Royal Netherlands Meteorological Institute, De Bilt, the Netherlands
[4]Department of Earth Sciences, Vrije Universiteit, Amsterdam, the Netherlands

Correspondence to: Helene Peiro (h.peiro@sron.nl)

- 1st assessment of long period and global analysis of TROPOMI CO inversion
  - Posterior emissions are globally larger than priors but with some exception region-to-region
- Regional carbon monoxide emissions – drought relationship
  - 1st assessment of regions of interest for further investigation
  - Stronger link between droughts and CO fire emissions in comparison to bottom-up
  - Some northern hemispheric regions show the strongest link, while not a clear link for some regions in the Tropics (other factors involved, like human activity, time ignition,..)


FIRE
NAT
ANT
CO total emissions (TgCO/yr)
0
250
500
750
1000
1250
1500
1750
2000
GFAS
GFED4
GFED5
TROPOMI GFASv12
TROPOMI GFED41s
TROPOMI GFED5


a) BONA
FIRE
NAT
ANT
CO total emissions (TgCO/yr)
0
20
40
60
80
100
GFAS
GFED4
GFED5
TROPOMI GFASv12
TROPOMI GFED41s
TROPOMI GFED5


c) SHAF
FIRE
NAT
ANT
CO total emissions (TgCO/yr)
0
50
100
150
200
250
300
GFAS
GFED4
GFED5
TROPOMI GFASv12
TROPOMI GFED41s
TROPOMI GFED5