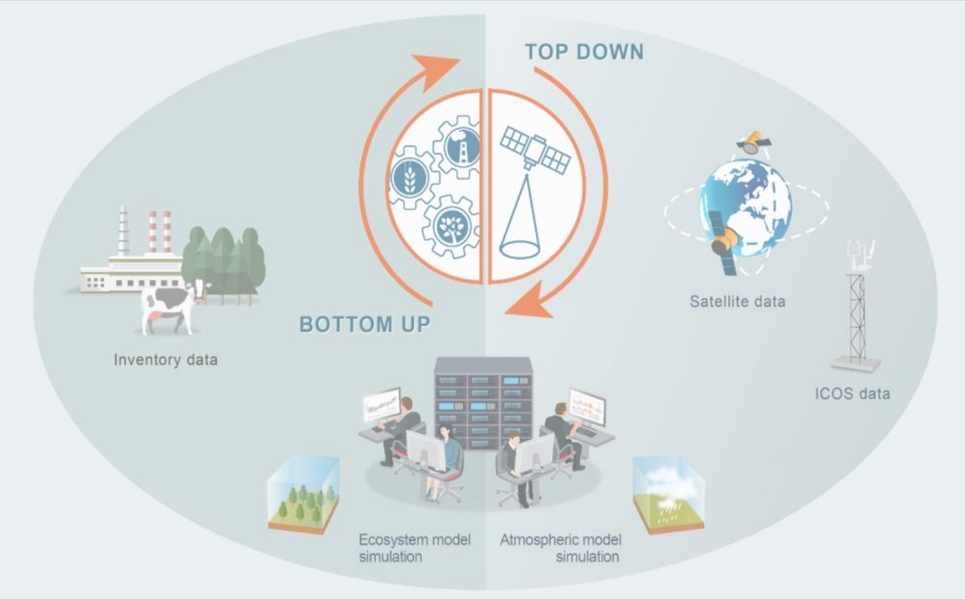
VERIFY General Assembly

PhD thesis paper - Mounia MOSTEFAOUI supervised by Hervé Le Treut
with Philippe Ciais, Philippe Peylin and Matt McGrath

May 9th-11th, 2022

Synthesis of GHG trends over the last three decades across Africa



Summary

- Fossil CO_2 emissions
- LULUCF CO_2 emissions and removals
- CH_4 anthropogenic fluxes
- N_2O total emissions
- GHG synthesis

Research questions

- What are the current GHG budgets over Africa from different sources?
- What are the differences between those estimates?
- What are the trends?

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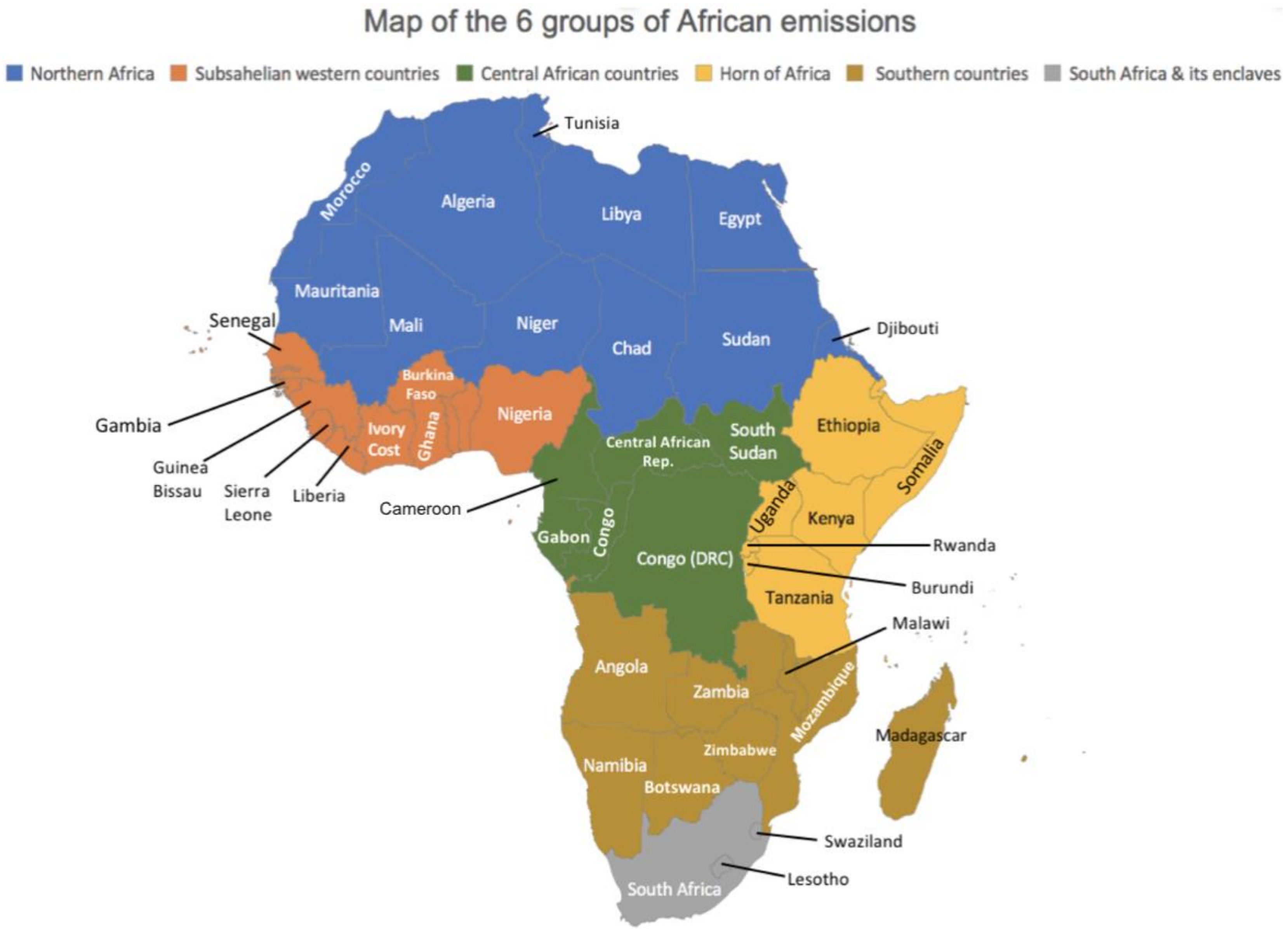
METHODS AND DATASETS

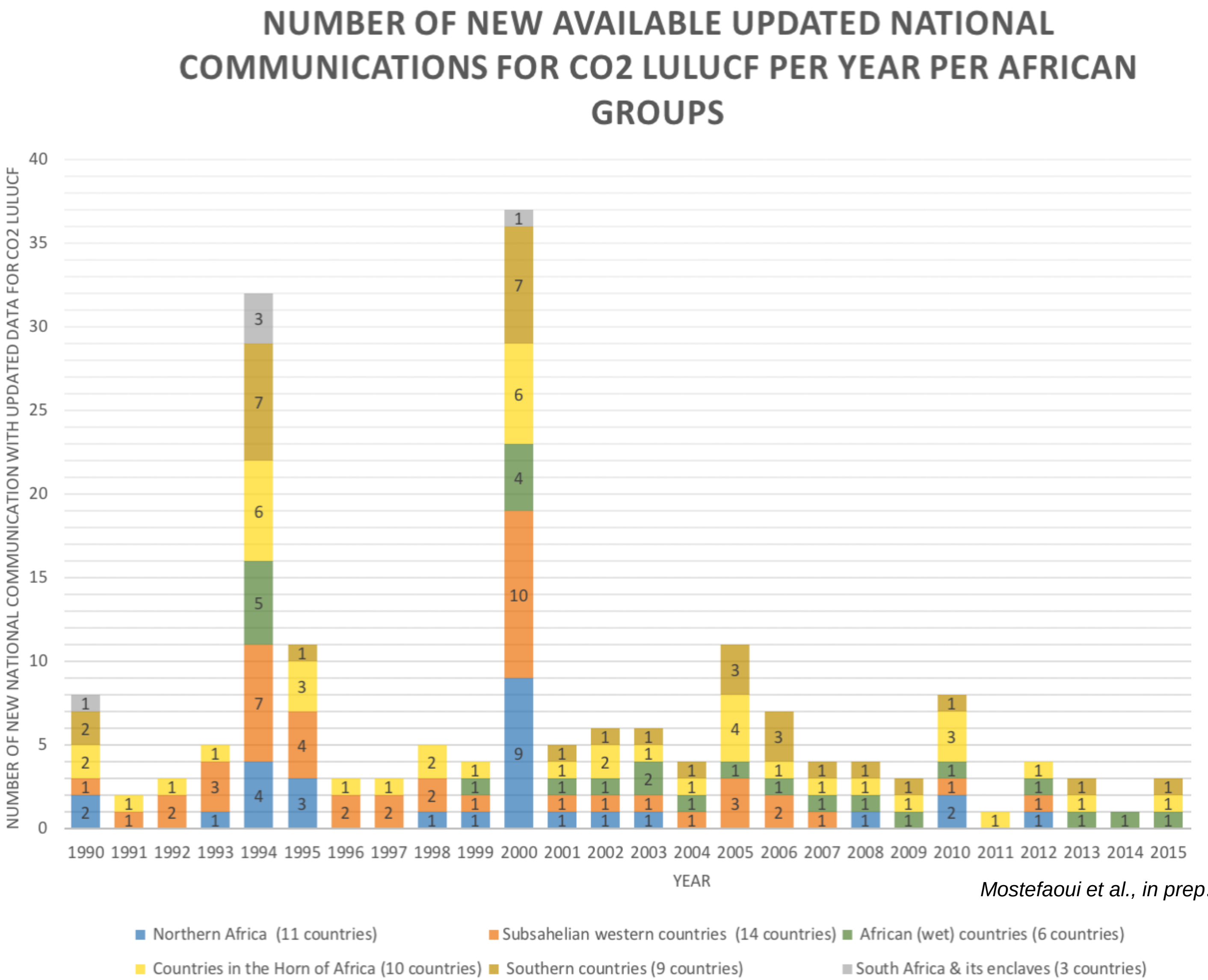


- Groups by geographical and eco-climatic areas.
- South Africa specific.

Methods and datasets - List of BU and TD methods

Dataset type/name	Method	CO_2	CH_4	N_2O	Spatial resolution (degrees)	Optimization	Time period covered in the present work
Inversions							
CAMS (GCB 2019)	TD	×			Global: 3.75°×1.875°	Variational	2000-2018
CarbonTracker Europe (CTE) (GCB 2019)	TD	×			Global : 3°× 2° Regional: 1°× 1°	Ensemble Kalman filter	2000-2018
Jena CarboScope	TD	×			Global : 4°× 5°	Conjugate gradient	2000-2018
Global Methane Budget ensemble (*see 22 products details in the supplementary table ST1)	TD		×		from 1° × 1 ° to 6° × 4°		2000-2017* (*variations from 2003-2015, 2000-2015, 2010-2017: see detailed period coverage for each dataset in the supplementary section.)
PyVAR	TD			×			1998-2017
TOMCAT-INVICAT	TD			×	5.6° × 5.6°	4DVAR	1998-2015
MIROC4 - ACTM (JAMSTEC)	TD			×		Bayesian statistics	1998-2016
DGVMs							
TRENDYv9* (*see supplementary table for the 14 products)	BU	×			0.5°× 0.5° (land surface) or 1° x 1°		1990-2019
Other BU inventories							
PRIMAP-hist	BU	×	×	×			1990-2019
GCP (CDIAC)	BU	×			0.1°× 0.1°		1990-2019
UNFCCC	BU	×					1990-2015
GFEDv4	BU		×		0.25° × 0.25°		1997–2016

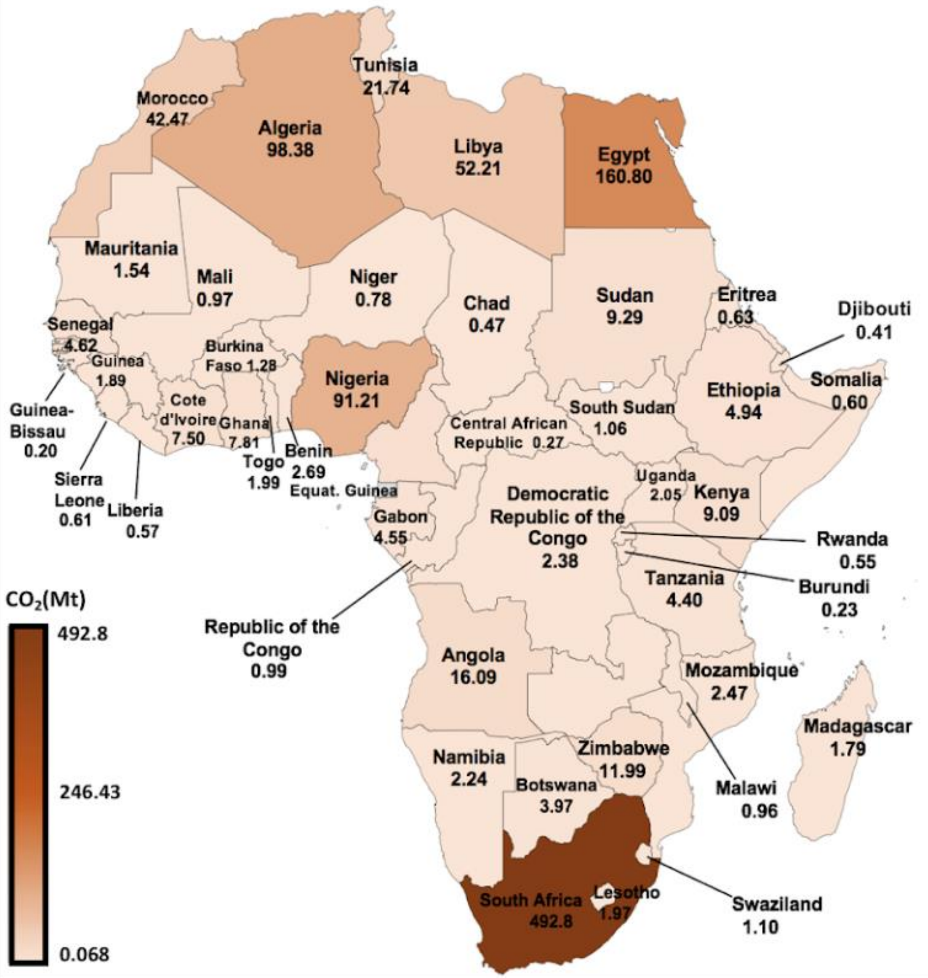
METHODS AND DATASETS



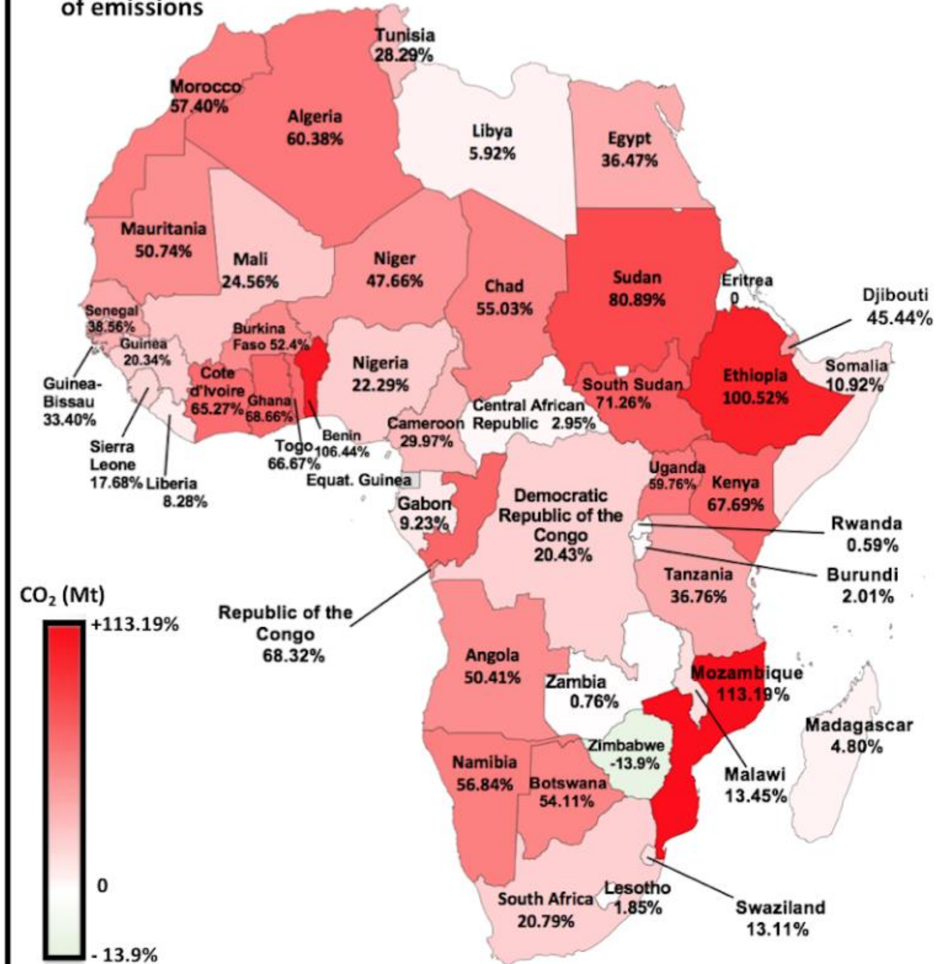
- Non-Annex I <=> reports not required every year.
- Some years with numerous updates, other sparse.

MAPS OF FOSSIL CO_2 ANTHROPOGENIC EMISSIONS FOR AFRICAN COUNTRIES

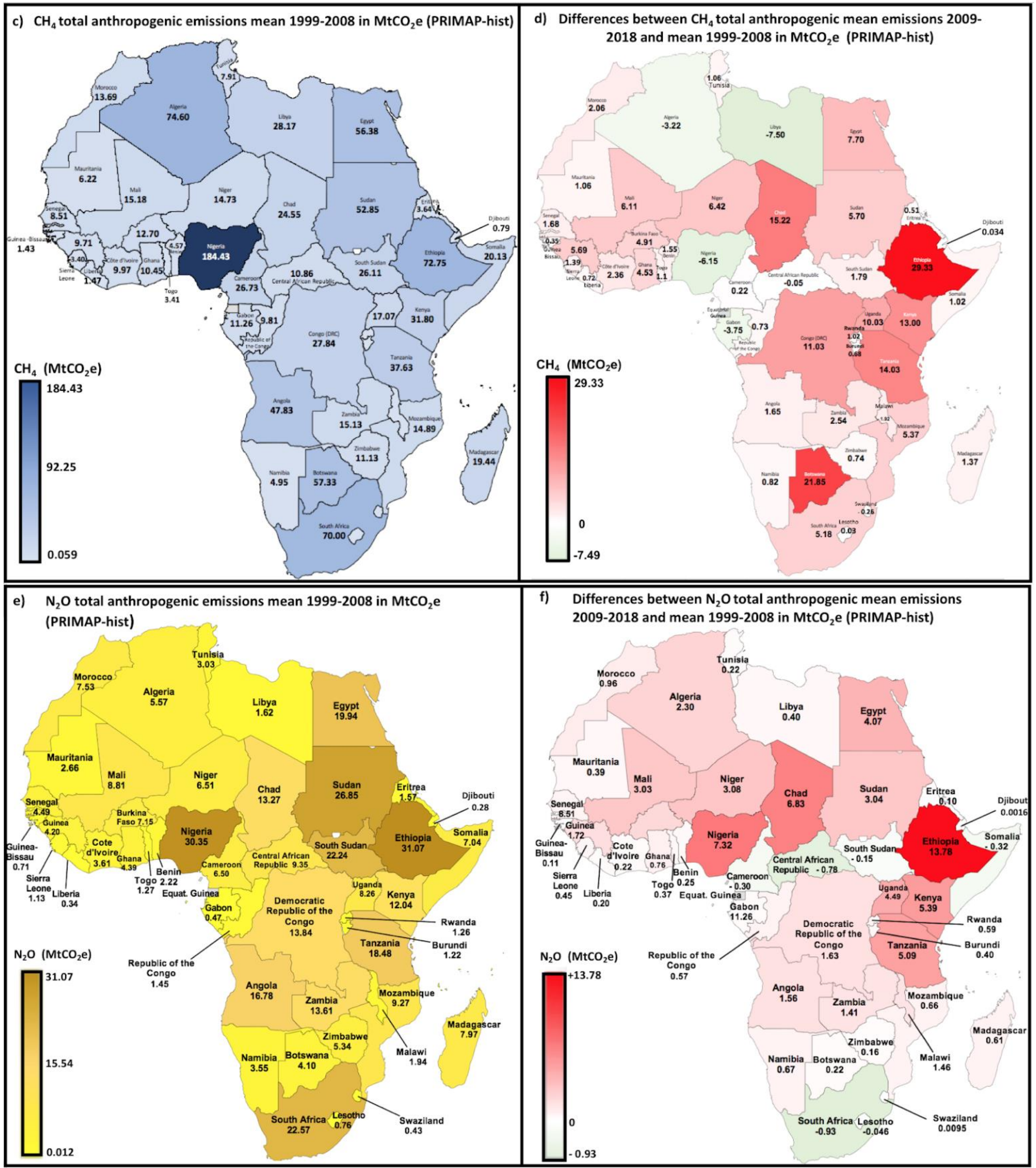
a) CO_2 total anthropogenic emissions mean 1999-2008 in Mt (PRIMAP-hist)



b) Differences between CO_2 total anthropogenic mean emissions 2009-2018 and mean 1999-2008 in percentage (PRIMAP-hist) divided by average value of emissions



Mostefaoui et al., in prep.

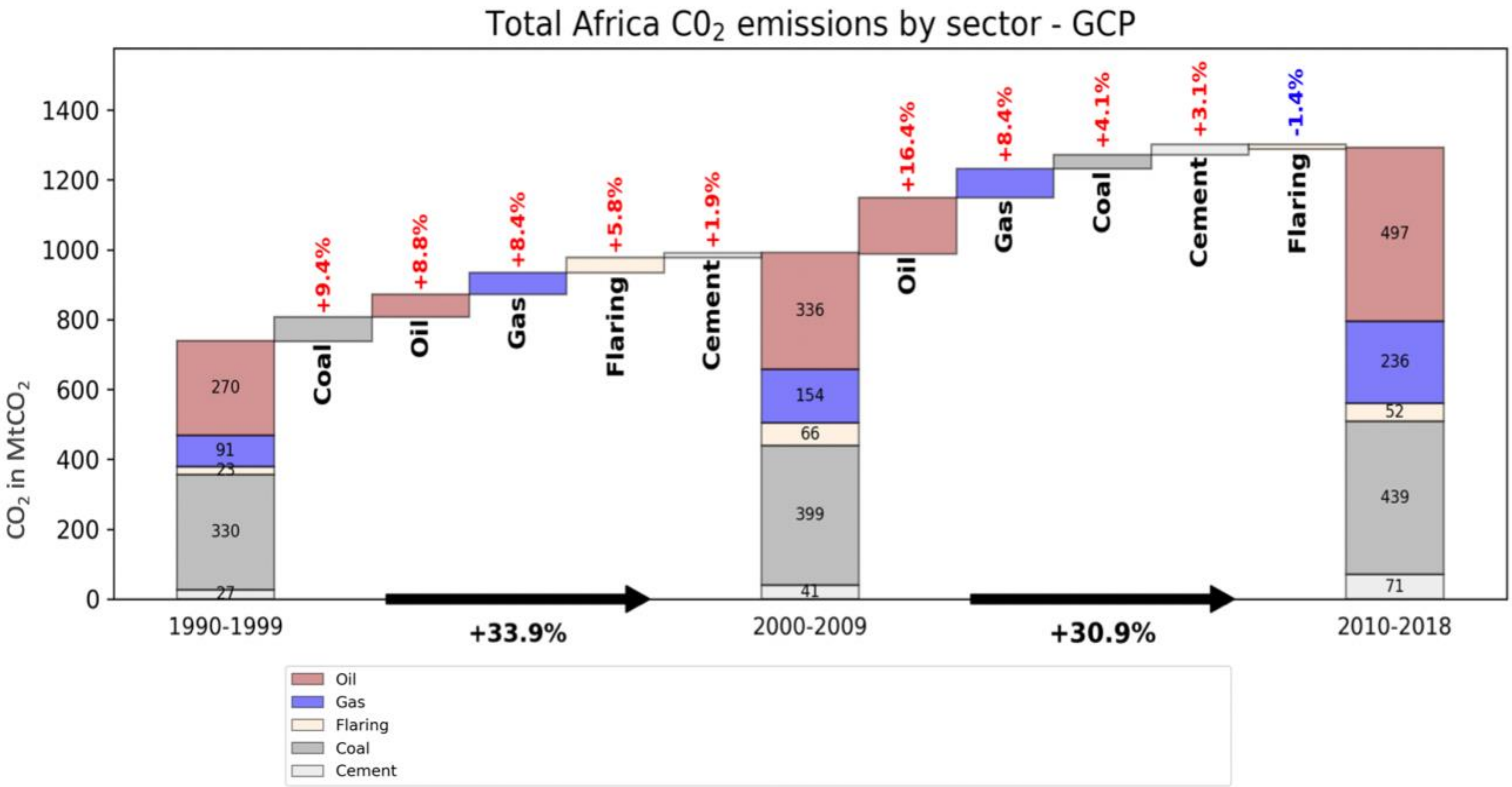


MAPS OF THE ANTHROPOGENIC CH_4 AND N_2O EMISSIONS FOR AFRICAN COUNTRIES

Mostefaoui et al., in prep.

AFRICAN FOSSIL CO_2 EMISSIONS

Synthesis of African mean anthropogenic fossil CO_2 emissions (CDIAC) over three decades. Contribution of each sector to the change.

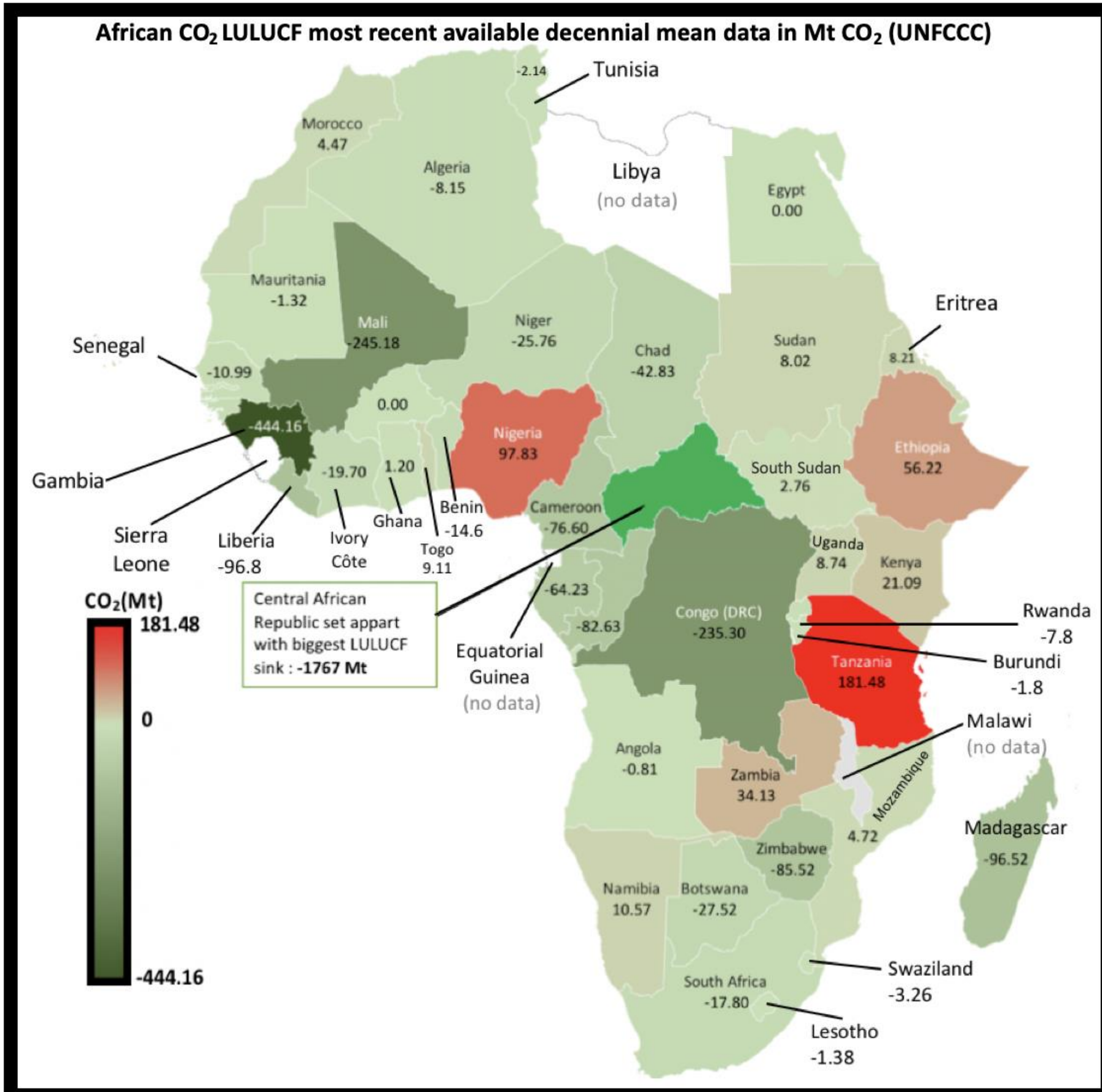


Mostefaoui et al., in prep.

- Rapid increase of fossil CO_2 emissions in Africa that doubled since 1990.
- Fossil CO_2 in Africa are dominated by an increase of **coal** emissions for the decennial 1990-98 compared to 1999-2008 (+9.4%) and by **oil** for the decennial 1999-2008 compared to 2008-2017 (+16.4%).

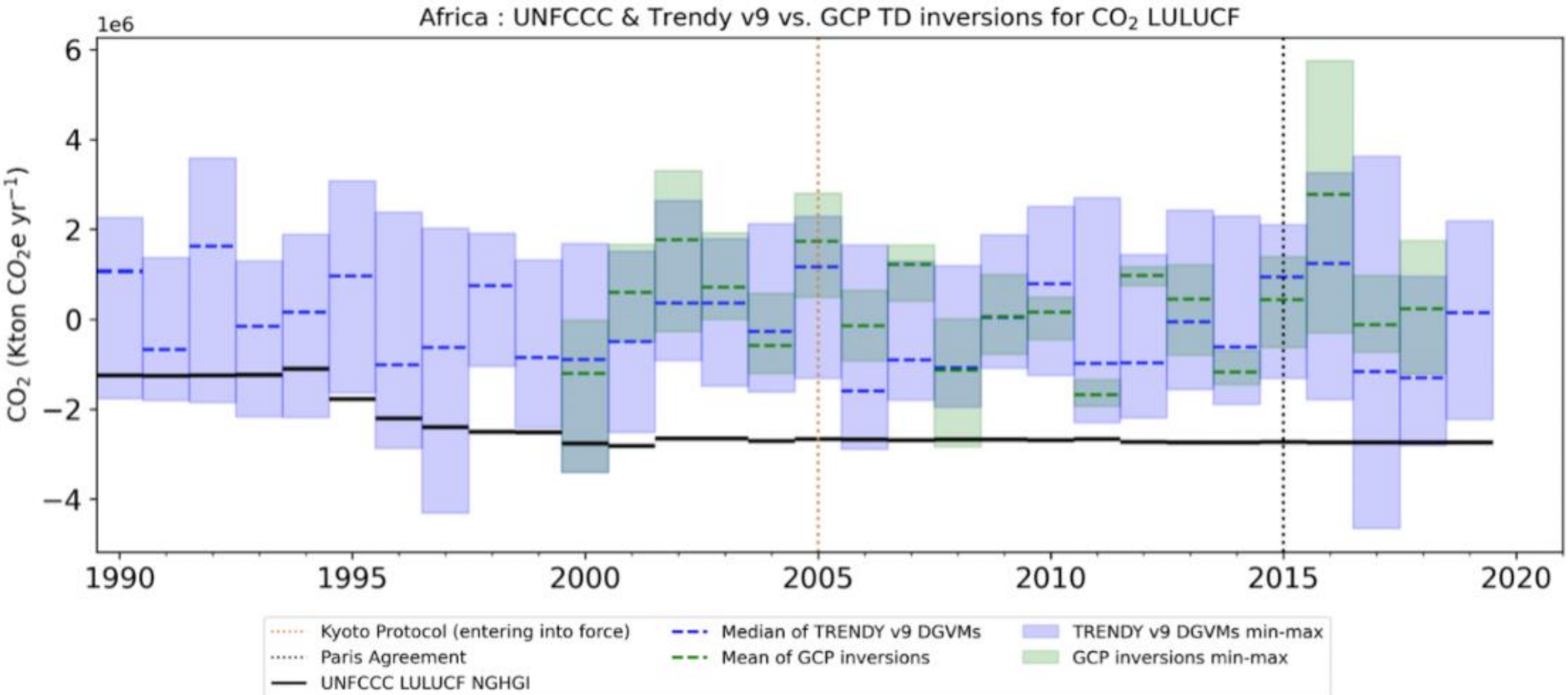
MAP OF AFRICAN LULUCF CO_2 EMISSIONS AND REMOVALS

- Most countries are sinks, except 10.
- Biggest sink in Central Africa.
- 2006 IPCC GL about "managed land" may differ.



Mostefaoui et al., in prep.

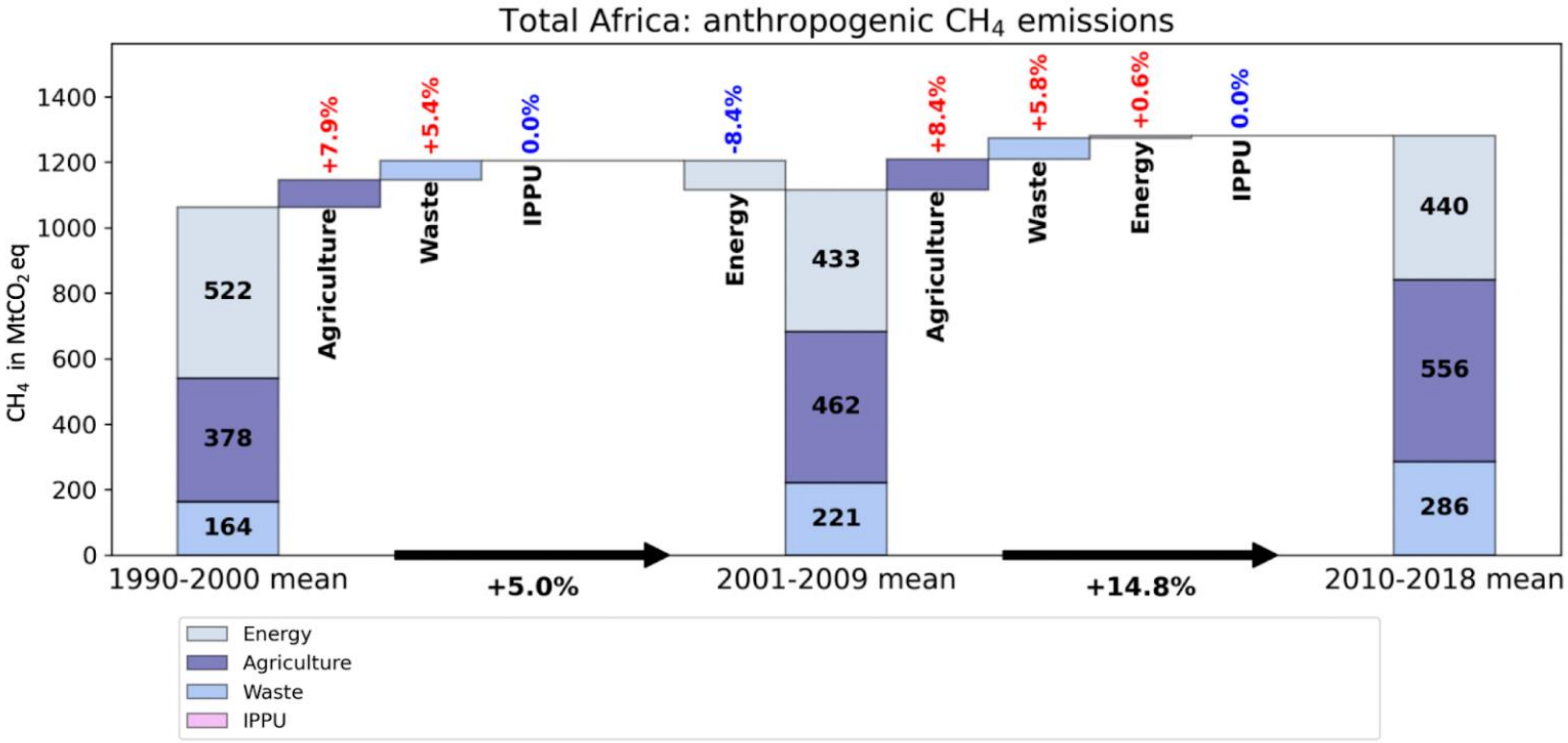
CO_2 LULUCF EMISSIONS: UNFCCC VS. DGVMS AND TD METHODS



Mostefaoui et al., in prep.

- **Mean of overlapping time period (2000-2018) :**
  - Mean GCP inversions : **+ 0.27** Gt CO_2 e.yr^{-1} (min : - 0.8 Gt CO_2 e.yr^{-1} ; max : 1.3 Gt CO_2 e.yr^{-1})
  - Mean Trendy v9 : **- 0.29** Gt CO_2 e.yr^{-1} (min : - 2 Gt CO_2 e.yr^{-1} ; max : 2.1 Gt CO_2 e.yr^{-1})
  - Mean UNFCCC : **- 2.71** Gt CO_2 e.yr^{-1}

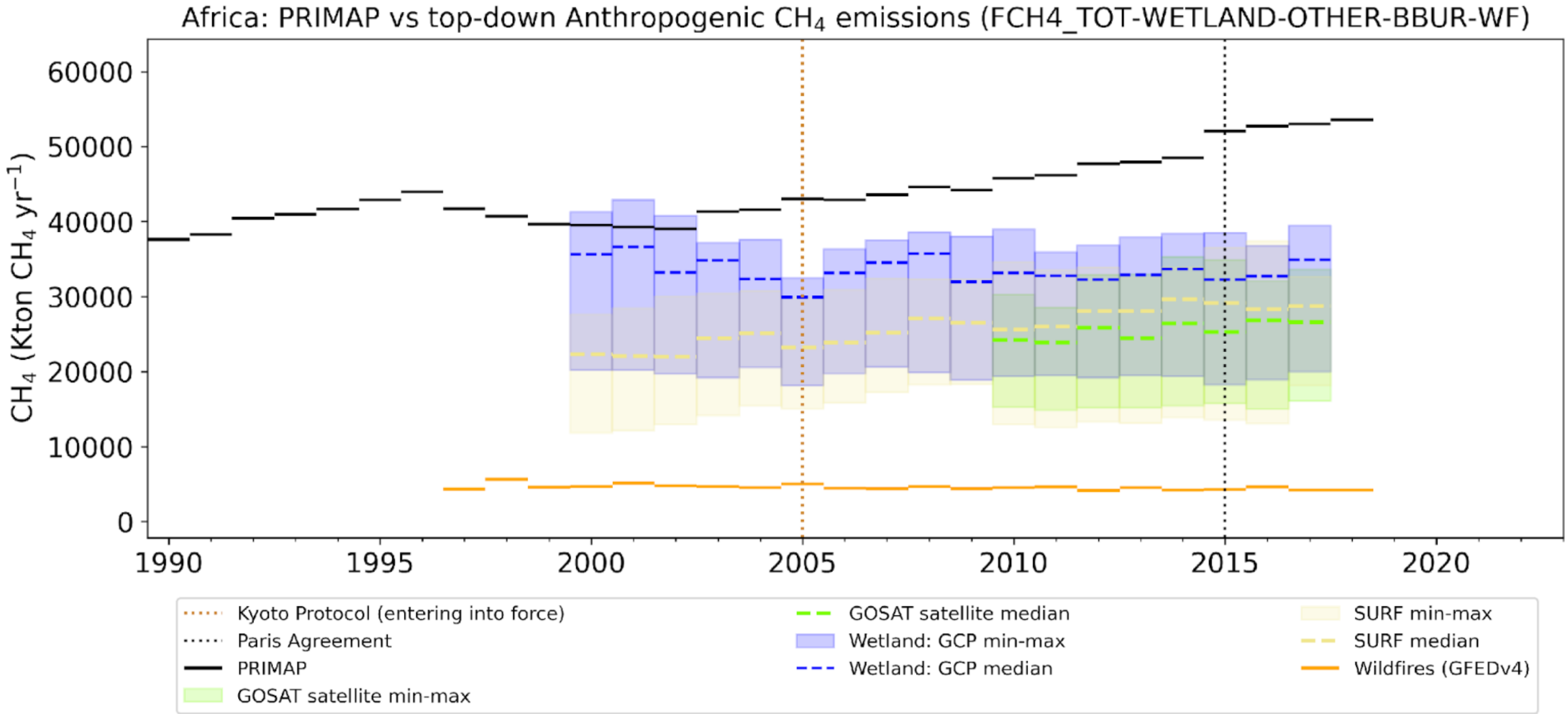
CH_4 ANTHROPOGENIC FLUXES



Mostefaoui et al., in prep.

- **Emissions increase from 2001-2009 to 2010-2018 :**
  - 1116 Mt CO_2 eq. -> 1282 Mt CO_2 eq.
    - All sectors (except IPPU) contribute to the **+ 14.8%** increase.
    - Mainly from **Agriculture** : 433 Mt CO_2 eq. -> 440 Mt CO_2 eq. (+7.9% of the increase) and Waste (+5.8% of the increase).
- Regions shifts from 2001-2009 to 2010-2018
  - 2 main contributors : **Northern Africa + Sub Sahelian western Africa**
  - African shift : **Energy -> Agriculture** as main emitting sector in 30 years => due to North Africa trend mainly.

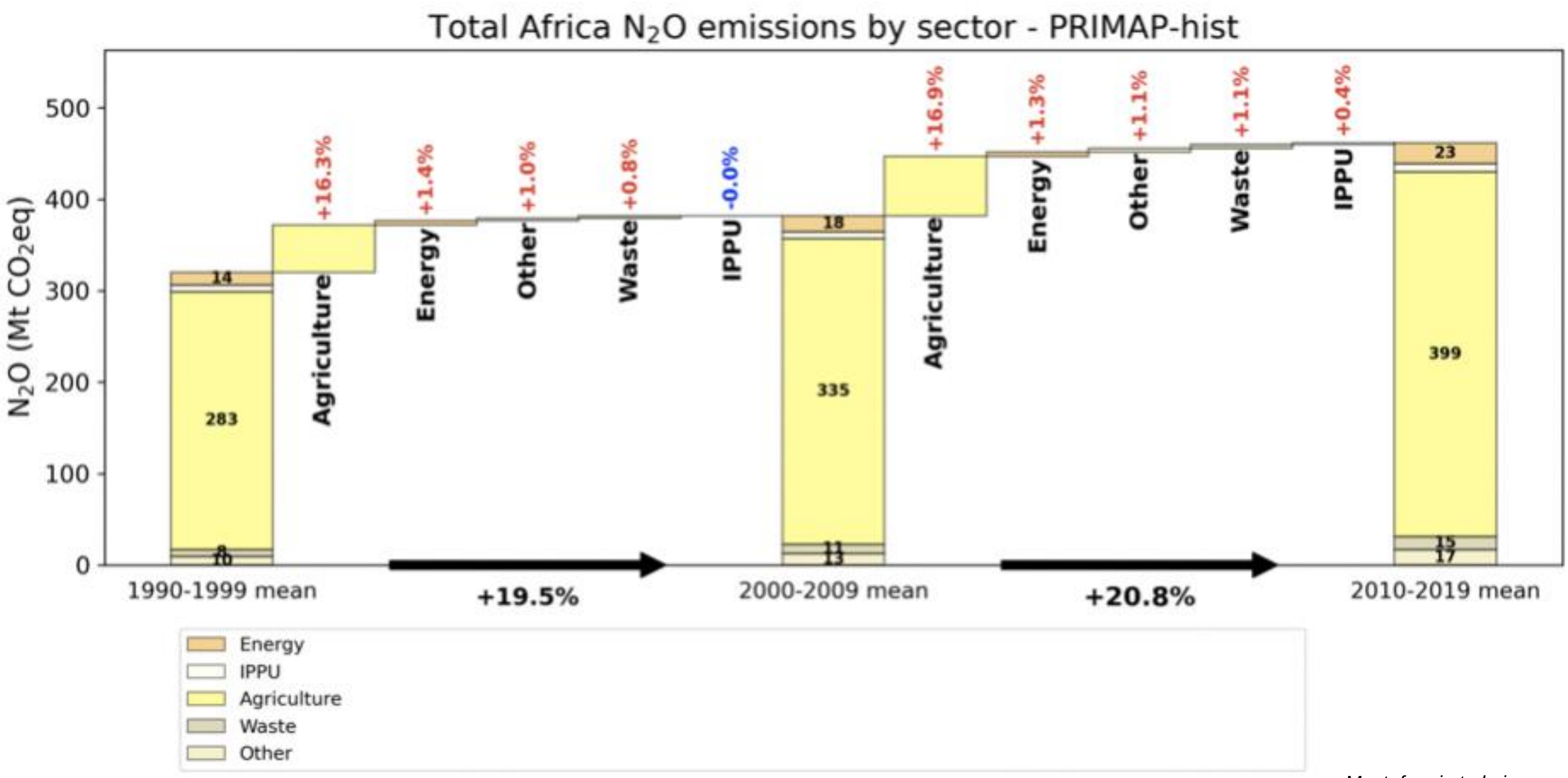
ANTHROPOGENIC CH_4 TD VS BU ESTIMATES



- BU method (PRIMAP) & 2TD global inversions with withdrawal of wildfire emissions (GFEDv4). *Mostefaoui et al., in prep*

- **Mean of overlapping time period (2010-2017) :**
  - Mean GOSAT inversions : 25 627 kton $CH_4 .yr^{-1}$ (min : 15 359 kton $CH_4 .yr^{-1}$; max : 32 886 kton $CH_4 .yr^{-1}$)
  - Mean Surface : 28 254 kton $CH_4 .yr^{-1}$ (min : 13 962 kton $CH_4 .yr^{-1}$; max : 34 339 kton $CH_4 .yr^{-1}$)
  - Mean PRIMAP-hist : **49 728** kton $CH_4 .yr^{-1}$
  - Mean wetlands : 33 075 kton $CH_4 .yr^{-1}$ (min : 19 231 kton $CH_4 .yr^{-1}$; max : 37 676 kton $CH_4 .yr^{-1}$)
  - Mean wildfires : 4 404 kton $CH_4 .yr^{-1}$

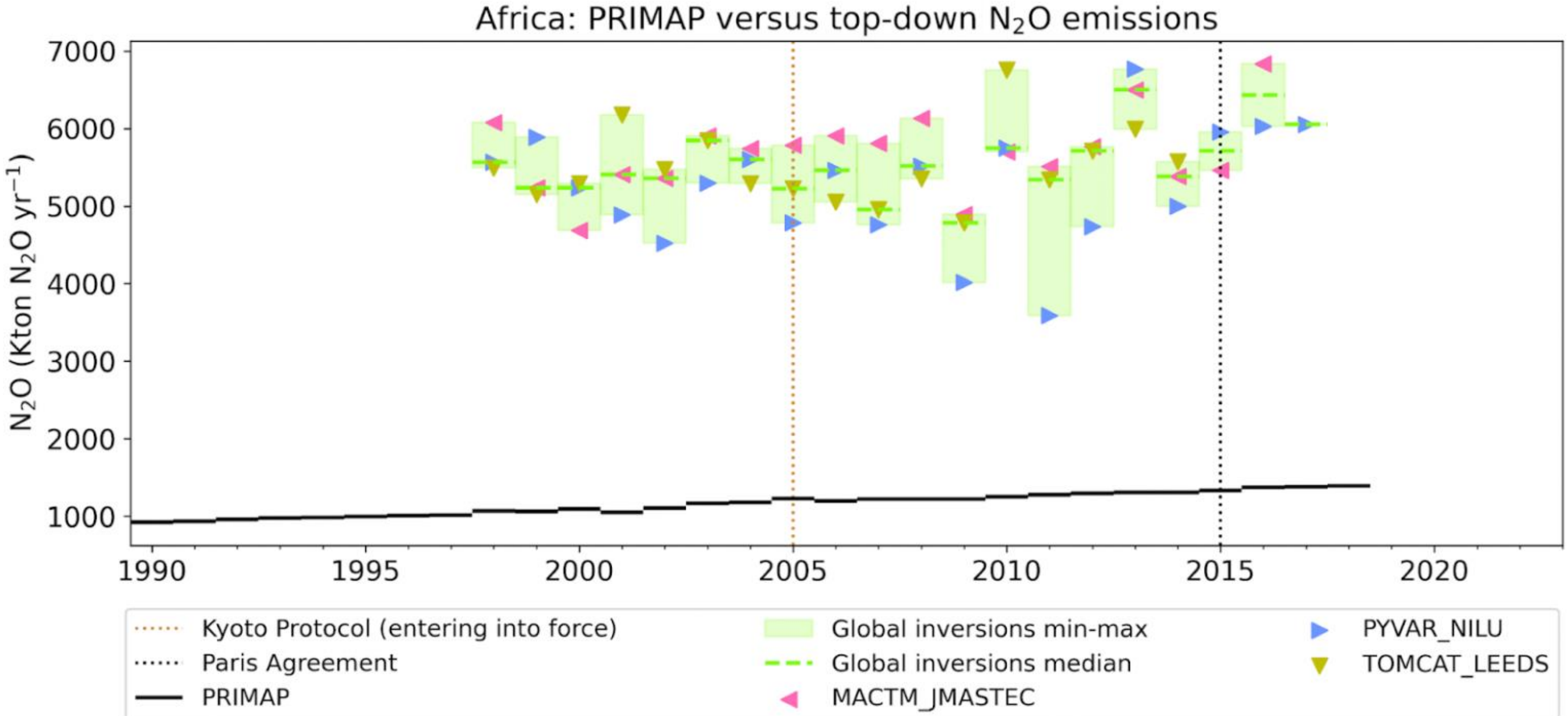
AFRICAN ANTHROPOGENIC N_2O EMISSIONS



Mostefaoui et al., in prep.

- African total anthropogenic N_2O emissions between mean 2000-2009 and 2010-2019 mean increased from **382 Mt CO_2 eq**. to **461 Mt CO_2 eq.** (**+ 20.8%**).
- Slightly bigger increase than for the previous decade (**+ 19.5%).**

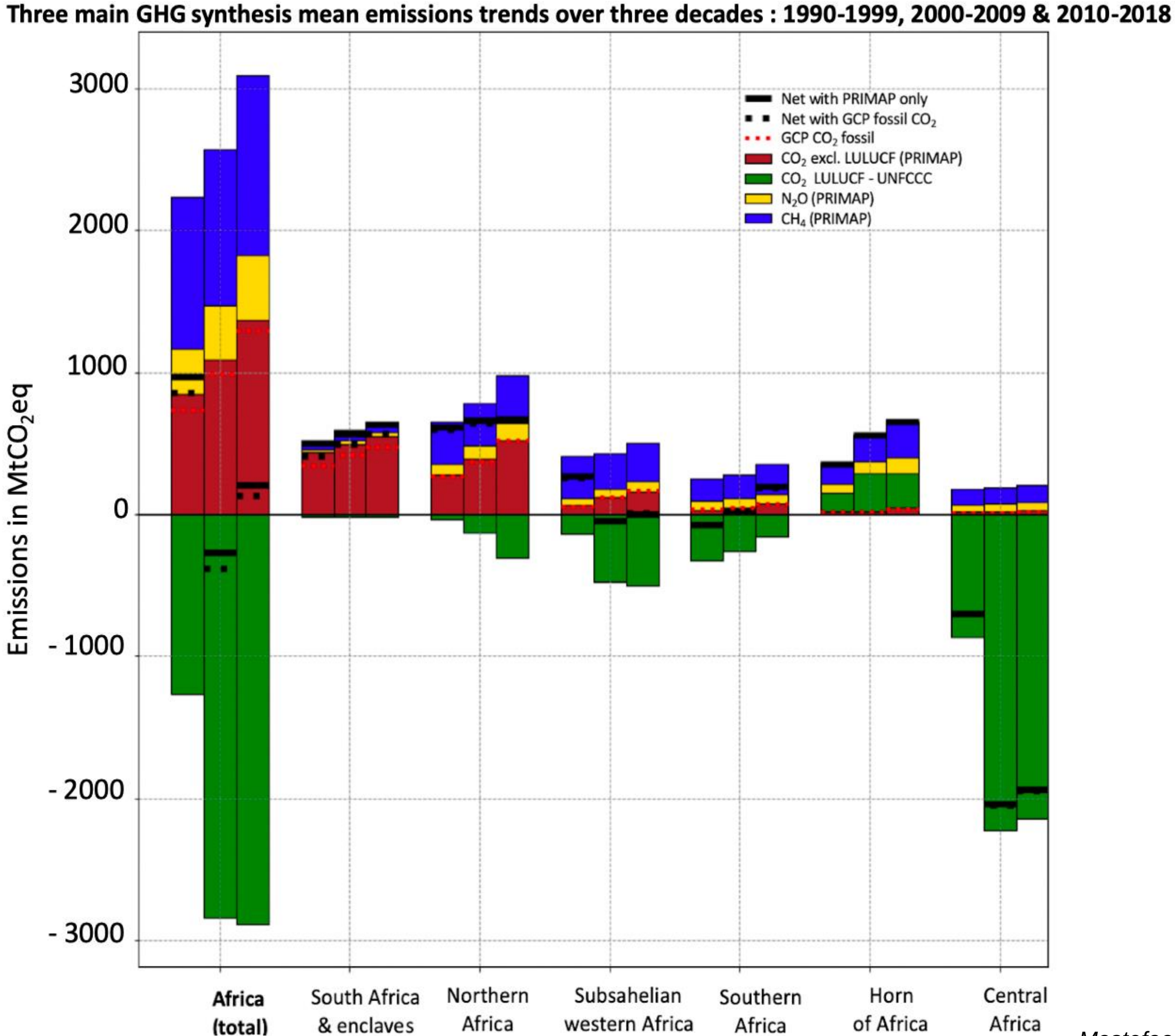
N_2O PRIMAP VS. ATMOSPHERIC INVERSIONS (TOTAL FLUX)



- **Mean of overlapping time period (1998-2017) :**
  - Mean Global inversions : **5 552** kton $N_2O.yr^{-1}$ (min : **4 781** kton $N_2O.yr^{-1}$; max : **6 498** kton $N_2O.yr^{-1}$)
  - Mean PRIMAP-hist : **1 220** kton $N_2O.yr^{-1}$
- N_2O TD increase trend consistent but always much higher than BU estimates.
- Importance to separate natural N_2O emissions from total TD estimates.
- Even if withdrawing reconstructed N_2O natural estimates, inversions > BU values, Ciais et al. 2022.

Mostefaoui et al., in prep.

SYNTHESIS FOR THE THREE MAIN GHG



Mostefaoui et al., in prep.

- 1999-2008 : **- 166 $MtCO_2e$**
- 2009-2018 : **+ 127 $MtCO_2e$**
- 1990-1999 : **+ 1000 $MtCO_2e$**

- Differences between **CO_2 GCP and PRIMAP get smaller with time.**

CONCLUSION

- Africa as a continent **5th worldwide** emitter regarding fossil CO_2.

- **African quickly growing population and industrial potential =>** huge future impact on climate change.
  - Depending on pathways : between **10% - 18% of global emissions in 2050.**

- But monitoring featured with high spread among different methods : uncertainties.
  - Most of African national pledges < level of disagreements between methods.

- Discrepancies for all scientific independent methods to date => still an interesting result.

- Calls for investment in monitoring tools and research funding.
  - Should be done rapidly to change the game and enable a reliable verification.

Thank you for your attention.