IWGGMS 20

The 20th International Workshop on Greenhouse Gas Measurements from Space

Neutral Tropical African CO_2 Exchange Estimated From Aircraft and Satellite Observations

Session 5: Regional-to-Global Fluxes

Friday, May 31, 2024

Benjamin Gaubert, B. B. Stephens,
NASA OCO-2 MIP team, NASA ATom CO_2 team

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The African Carbon Budget

Variability and recent trends in the African terrestrial carbon balance

P. Ciais[1], S.-L. Piao[2], P. Cadule[1], P. Friedlingstein[1], and A. Chédin[3]

Net terrestrial C sink of 0.15 PgC yr^{-1} in the 1990s (Ciais et al., 2009)

The carbon balance of Africa: synthesis of recent research studies

By P. Ciais[1,*], A. Bombelli[2], M. Williams[3], S. L. Piao[4], J. Chave[5], C. M. Ryan[3], M. Henry[2,6], P. Brender[1,6] and R. Valentini[2,7]

Net carbon balance of African ecosystems [...] is a sink of the order of 0.2 PgC yr^{-1} with a large uncertainty around this number (Ciais et al., 2011)

https://doi.org/10.5194/bg-11-381-2014

Article | Peer review | Metrics | Related articles

Research article | 28 Jan 2014

A full greenhouse gases budget of Africa: synthesis, uncertainties, and vulnerabilities

R. Valentini, A. Arneth, A. Bombelli, S. Castaldi, R. Cazzolla Gatti, F. Chevallier, P. Ciais, E. Grieco, J. Hartmann, M. Henry, R. A. Houghton, M. Jung, W. L. Kutsch, Y. Malhi, E. Mayorga, L. Merbold, G. Murray-Tortarolo, D. Papale, P. Peylin, B. Poulter, P. A. Raymond, M. Santini, S. Sitch, G. Vaglio Laurin, G. R. van der Werf, C. A. Williams, and R. J. Scholes

RECCAP-1: Regional Carbon Cycle Assessment and Processes (Valentini et al., 2014): Africa is a **small sink of CO_2: 0.61 +/- 0.58 PgC yr^{-1}** in the 2000s (Large IAV and uncertainties noted)

Global Biogeochemical Cycles

RESEARCH ARTICLE
10.1029/2023GB008016

Special Section:
Regional Carbon Cycle Assessment and Processes-2

The African Regional Greenhouse Gases Budget (2010–2019)

Yolandi Ernst[1], Sally Archibald[2], Heiko Balzter[3,4], Frederic Chevallier[5], Philippe Ciais[5], Carlos Gonzalez Fischer[6], Benjamin Gaubert[7], Thomas Higginbottom[8], Steven Higgins[9], Shakirudeen Lawal[10], Fabrice Lacroix[11,12], Ronny Lauerwald[13], Mauro Lourenco[2,14], Carola Martens[15,16], Anteneh G. Mengistu[17], Lutz Merbold[18], Edward Mitchard[19], Mthokozisi Moyo[2], Hannah Nguyen[20], Michael O'Sullivan[21], Pedro Rodríguez-Veiga[22,23]

RECCAP-2 (Ernst et al., 2024): Carbon sink capacity is decreasing, switching from a small sink in RECCAP1 to a small source in RECCAP2 at **0.16** PgC yr^{-1}

The unexpected Northern Tropical African (NTA) source

ARTICLE

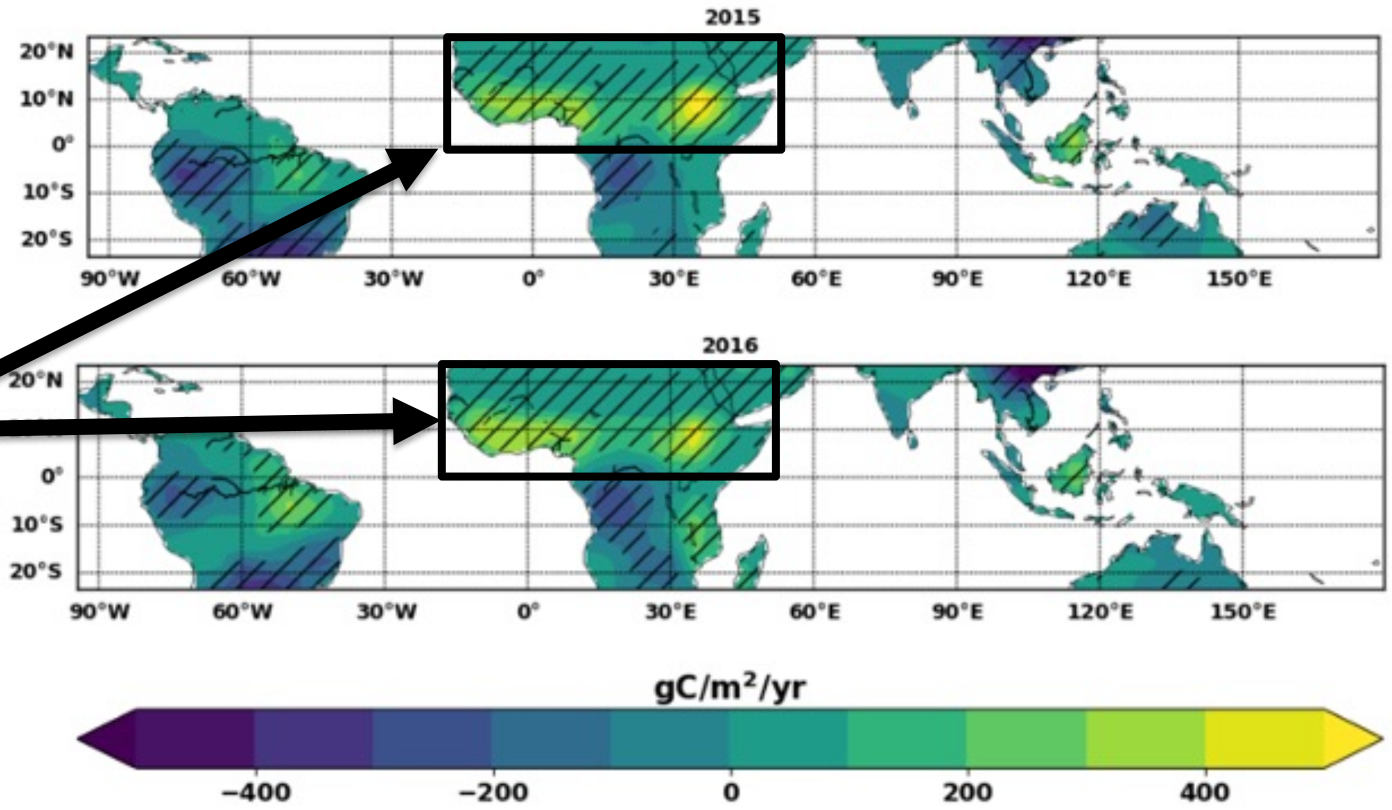
https://doi.org/10.1038/s41467-019-11097-w OPEN

Net carbon emissions from African biosphere dominate pan-tropical atmospheric CO_2 signal

Paul I. Palmer[1,2], Liang Feng[1,2], David Baker[3], Frédéric Chevallier[4], Hartmut Bösch[5,6] & Peter Somkuti[5,6]

"The largest emissions are found over western Ethiopia and western tropical Africa during March and April when it is **hottest and driest**"

Annual land flux is a **source** of around **1.5 PgC yr^{-1}** (2015-2016)



Supplementary Figure 9: Annual mean distribution of CO2 fluxes (gC/m2/yr) over tropical continents inferred from OCO-2 XCO2 data, 2015–2016.

	GOSAT/ACOS	GOSAT		OCO-2				
	UoE	UoE	UoE	LSCE	CSU	Mean	Median	Std
2015	0.60	0.69	1.89	1.54	1.91	1.33	1.54	0.64
2016		1.45	2.02	1.34	2.54	1.84	1.74	0.56

NTA (TransCom 5b) annual means flux (PgC yr^{-1}), adapted from Table 1 (Palmer et al., 2019)

Orbiting Carbon Observatory-2 (OCO-2) model intercomparison project (MIP)

12 models x 5 experiments: 54 available inversions

1. In-Situ (IS)
2. Ocean Glint (OG)
3. Land Nadir Land Glint (LNLG)
4. Land Nadir Land Glint In-Situ (LNLGIS)
5. LNLGOGIS

v7 MIP: OCO-2 inversions indicate a **source** in northern tropical Africa (TransCom 05b) in (November–March)

v9 MIP: Annual land flux is a **source** of around **1.26 +/- 0.58 PgC yr^{-1}** (2015-2018, v9 MIP)

v10 MIP: Annual land flux (LNLG) is a **source** of around **0.89 +/- 0.88 PgC yr^{-1}** (2015-2020, v10 MIP)

The 2015–2016 carbon cycle as seen from OCO-2 and the global in situ network

Sean Crowell[1], David Baker[2], Andrew Schuh[2], Sourish Basu[3,4], Andrew R. Jacobson[3,4], Frederic Chevallier[5], Junjie Liu[6], Feng Deng[7], Liang Feng[8,9], Kathryn McKain[3,4], Abhishek Chatterjee[10,11], John B. Miller[4], Britton B. Stephens[13], Annmarie Eldering[6], David Crisp[6], David Schimel[6], Ray Nassar[12], Christopher W. O'Dell[2], Tomohiro Oda[10,11], Colm Sweeney[4], Paul I. Palmer[8,9], and Dylan B. A. Jones[7]

v7 MIP: Crowell et al., 2019

Four years of global carbon cycle observed from the Orbiting Carbon Observatory 2 (OCO-2) version 9 and in situ data and comparison to OCO-2 version 7

Hélène Peiro[1], Sean Crowell[1], Andrew Schuh[2], David F. Baker[2], Chris O'Dell[2], Andrew R. Jacobson[3,4], Frédéric Chevallier[5], Junjie Liu[6], Annmarie Eldering[6], David Crisp[6], Feng Deng[7], Brad Weir[8,9], Sourish Basu[10,11], Matthew S. Johnson[12], Sajeev Philip[13,a], and Ian Baker[14]

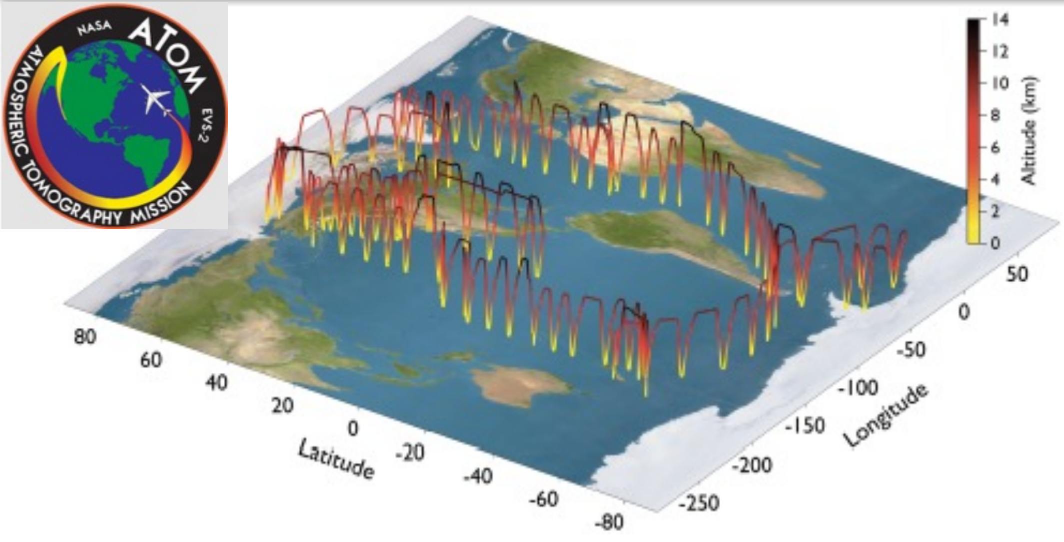
v9 MIP: Peiro et al., 2022

National CO_2 budgets (2015–2020) inferred from atmospheric CO_2 observations in support of the Global Stocktake

Brendan Byrne[1], David F. Baker[2], Sourish Basu[3,4], Michael Bertolacci[5], Kevin W. Bowman[1,6], Dustin Carroll[7,1], Abhishek Chatterjee[1], Frédéric Chevallier[8], Philippe Ciais[8], Noel Cressie[5,1], David Crisp[1], Sean Crowell[9], Feng Deng[10], Zhu Deng[11], Nicholas M. Deutscher[12], Manvendra K. Dubey[13], Sha Feng[14], Omaira E. García[15], David W. T. Griffith[12], Benedikt Herkommer[16], Lei Hu[17,18], Andrew R. Jacobson[17,18], Rajesh Janardanan[19], Sujong Jeong[20], Matthew S. Johnson[21], Dylan B. A. Jones[10], Rigel Kivi[22], Junjie Liu[1,23], Zhiqiang Liu[24], Shamil Maksyutov[19], John B. Miller[17], Scot M. Miller[25], Isamu Morino[19], Justus Notholt[26], Tomohiro Oda[27,28], Christopher W. O'Dell[2], Young-Suk Oh[29], Hirofumi Ohyama[19], Prabir K. Patra[30], Hélène Peiro[9], Christof Petri[26], Sajeev Philip[31], David F. Pollard[32], Benjamin Poulter[3], Marine Remaud[8], Andrew Schuh[2], Mahesh K. Sha[33], Kei Shiomi[34], Kimberly Strong[10], Colm Sweeney[17], Yao Té[35], Hanqin Tian[36,37], Voltaire A. Velazco[12,38], Mihalis Vrekoussis[39,26], Thorsten Warneke[26], John R. Worden[1], Debra Wunch[10], Yuanzhi Yao[36], Jeongmin Yun[20], Andrew Zammit-Mangion[5], and Ning Zeng[28,4]

v10 MIP: Byrne et al., 2023

NASA Atmospheric Tomography Mission (ATom)

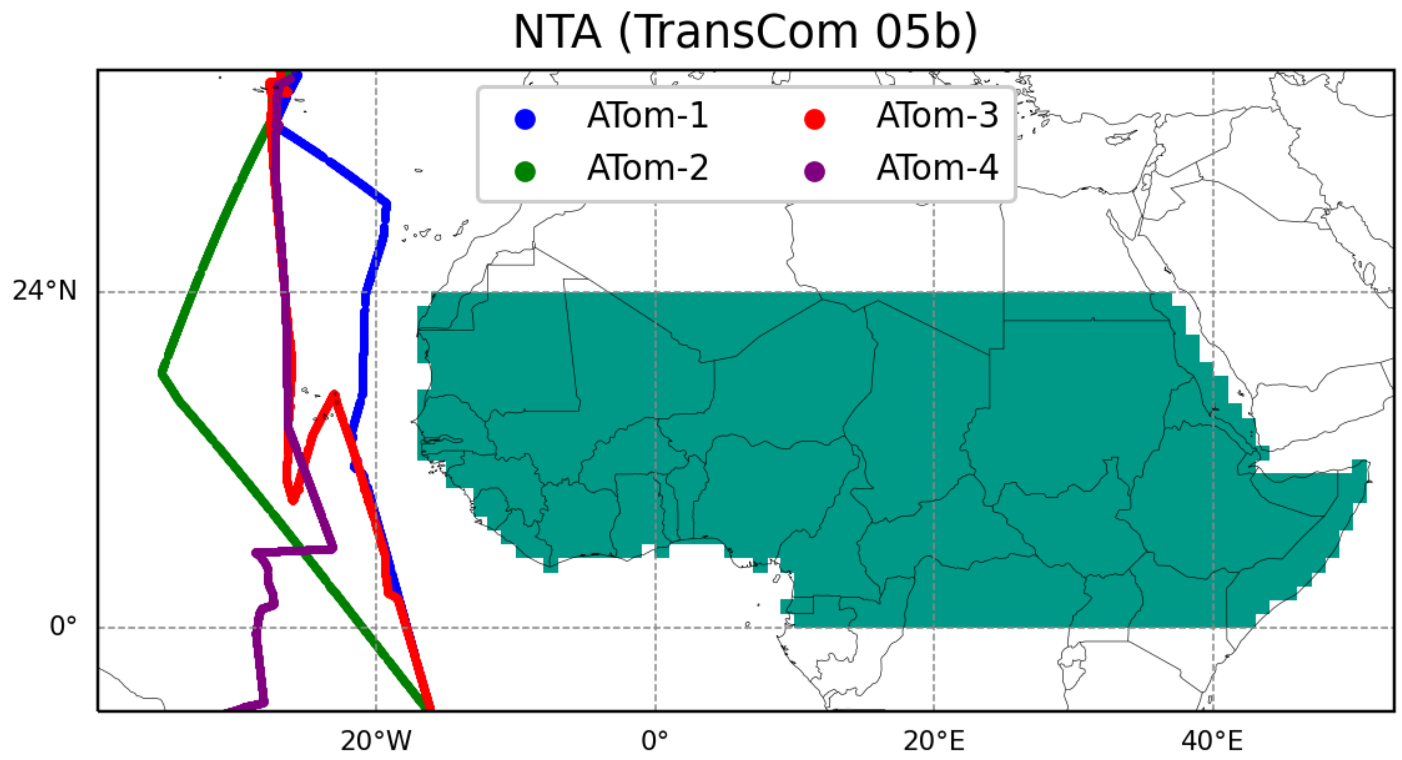


Thompson et al. BAMS, 2022

4 aircraft campaigns:

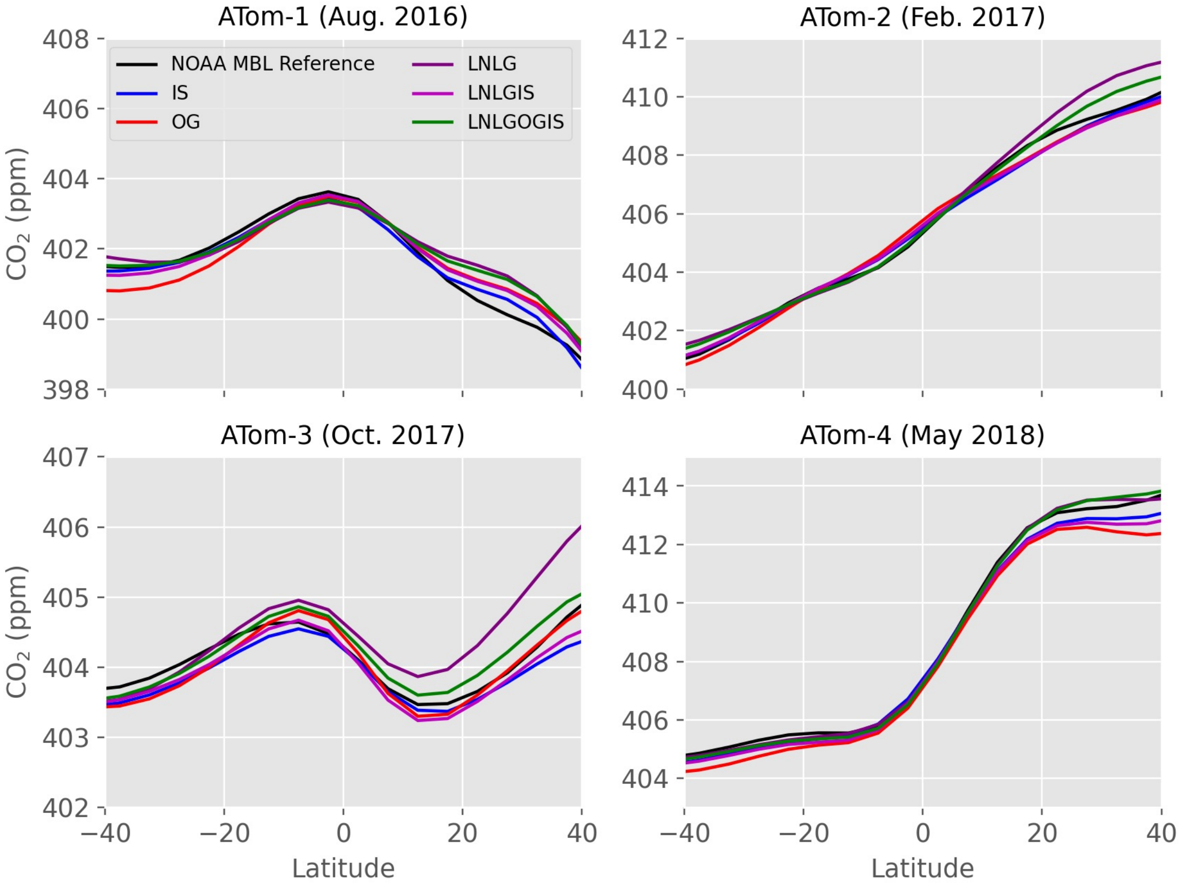
ATom-1: August 2016
ATom-2: February 2017
ATom-3: October 2017
ATom-4: May 2018

ATom surveyed downwind of Tropical Africa in 4 seasons



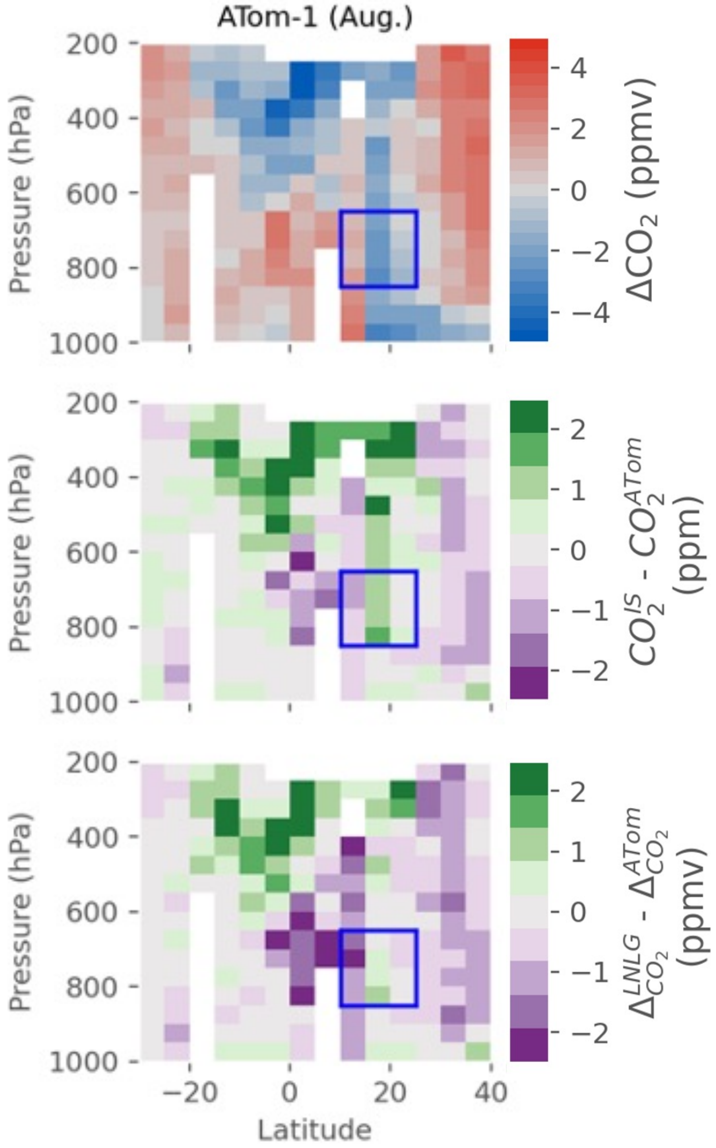
NOAA Marine Boundary Layer reference

Metric to look at ATom signals: subtract the latitudinal gradient of CO_2

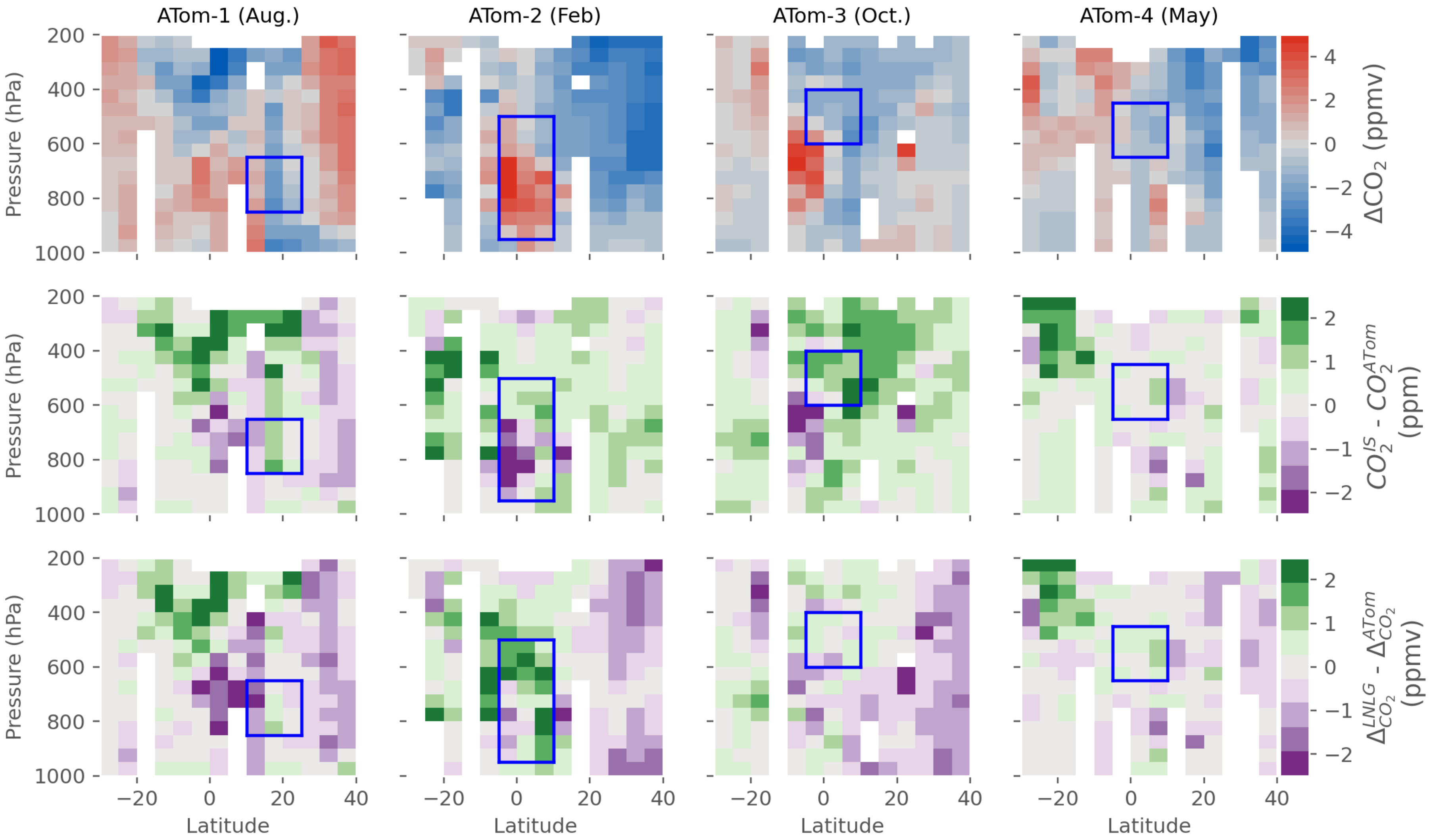


Surface in-situ: Weekly NOAA MBL / 5° Latitude

$$\Delta CO_2 = CO_2\ \text{(ATom)} - CO_2\ \text{(NOAA–MBL)}$$



ATom vs. v10 MIP



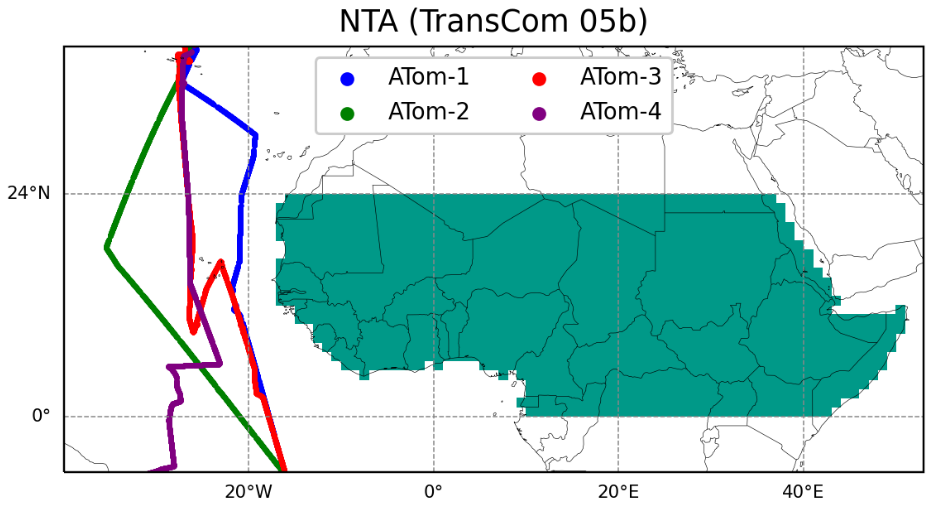
ATom data average in 5° Latitude and 100 hPa pressure bin.

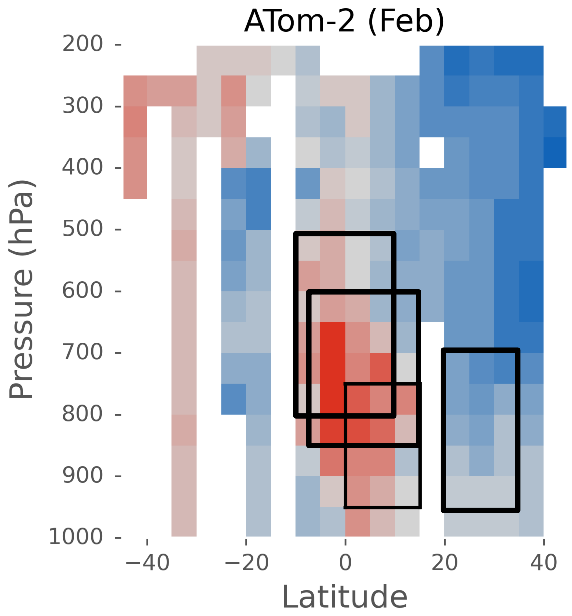
ΔCO_2 is calculated for ATom and MBL obs. or ATom and MBL inverse models

Atom emergent constraint: NTA flux monthly mean vs. Posterior ΔCO2

ATom-2 example (February 2017)

NTA flux monthly mean



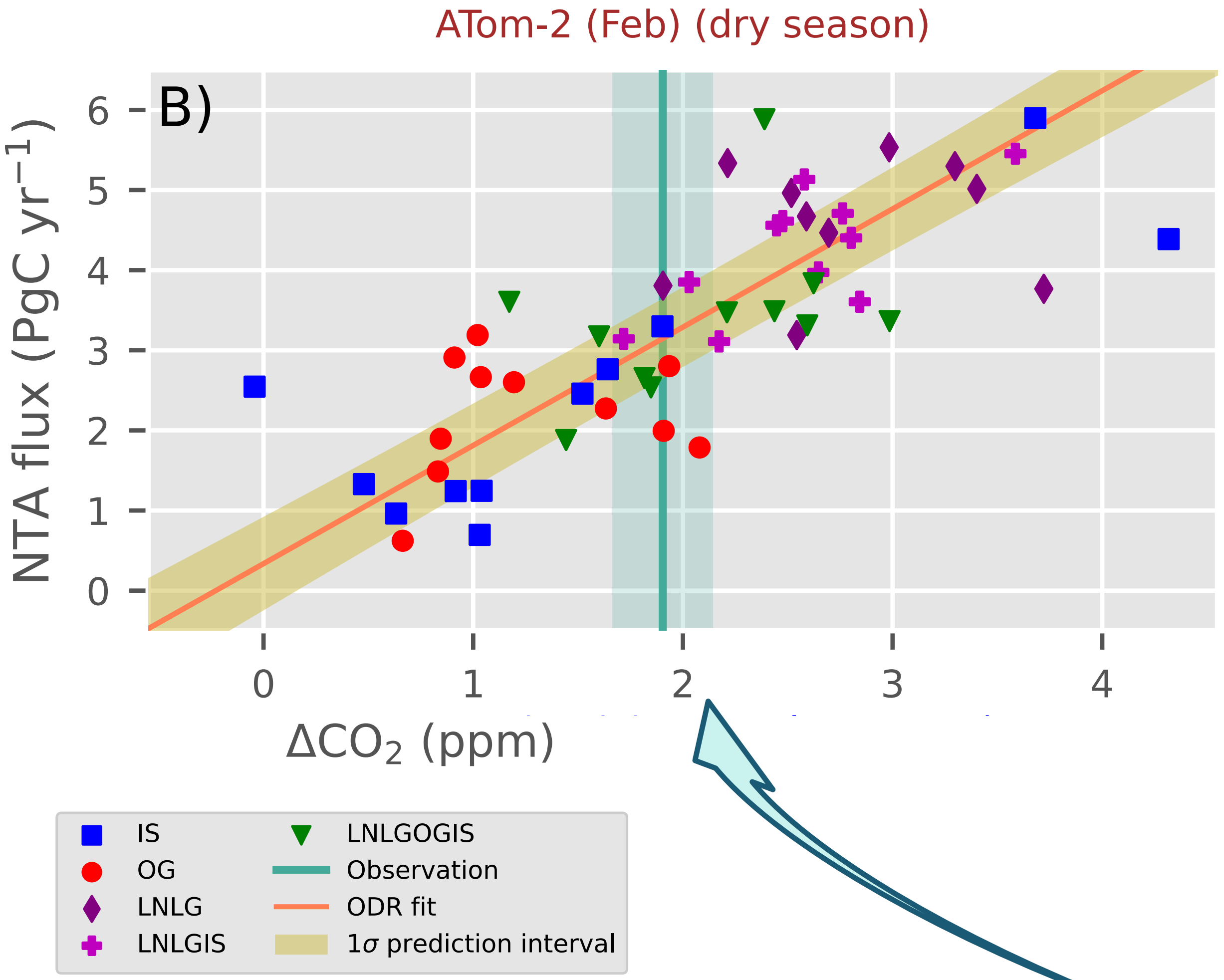


Calculate correlation
r(NTA NBE, Posterior model ΔCO_2)

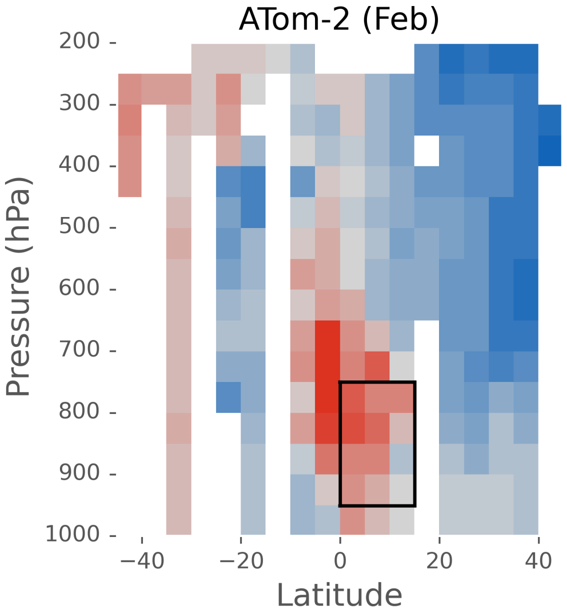
Posterior ΔCO_2 for each inversions

Boxes: minimum width of 15 degrees and minimum height of 300 hPa

Atom emergent constraint: NTA flux monthly mean vs. Posterior ΔCO2



1 box (Highest correlation)

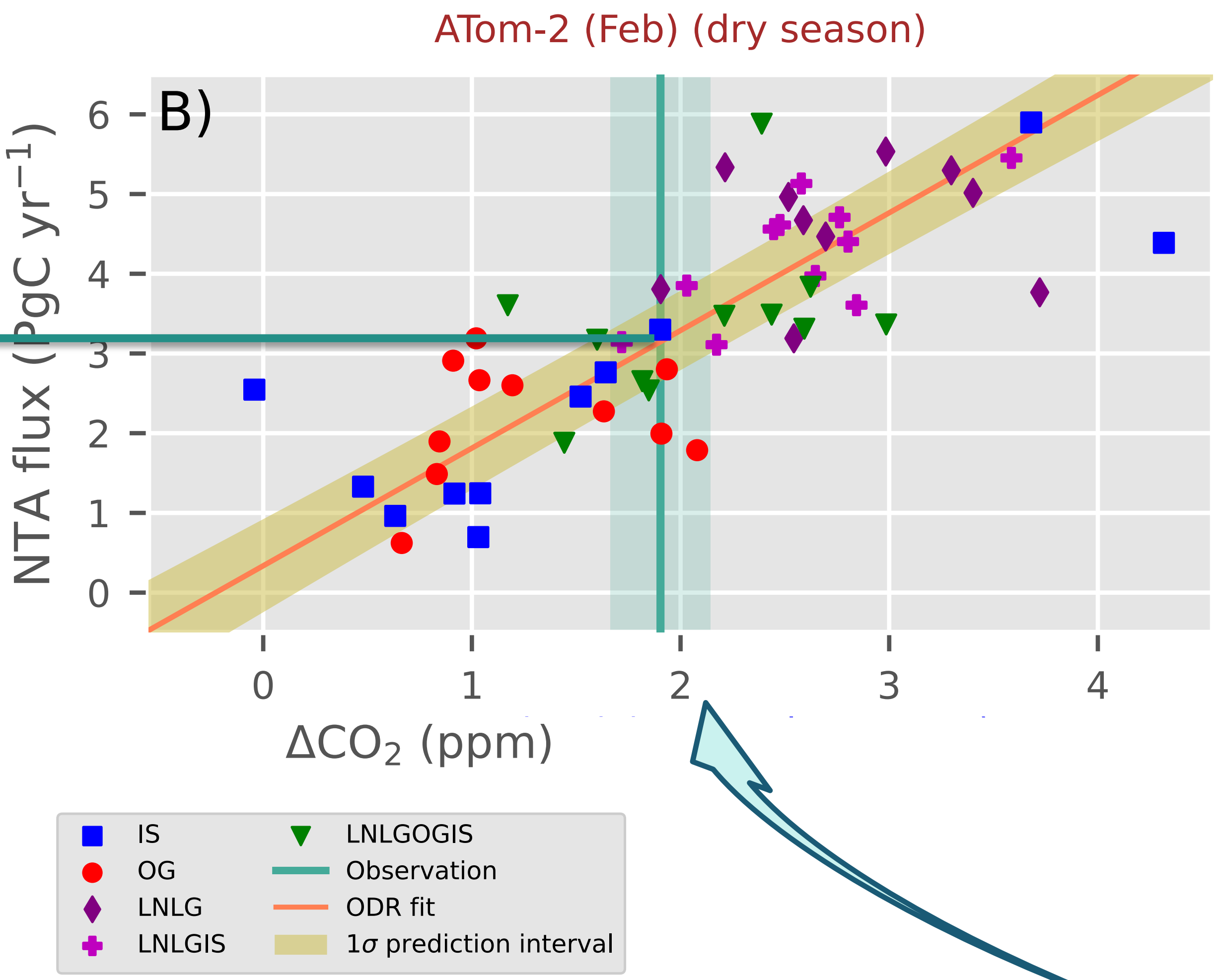


Posterior ΔCO_2 for each inversions

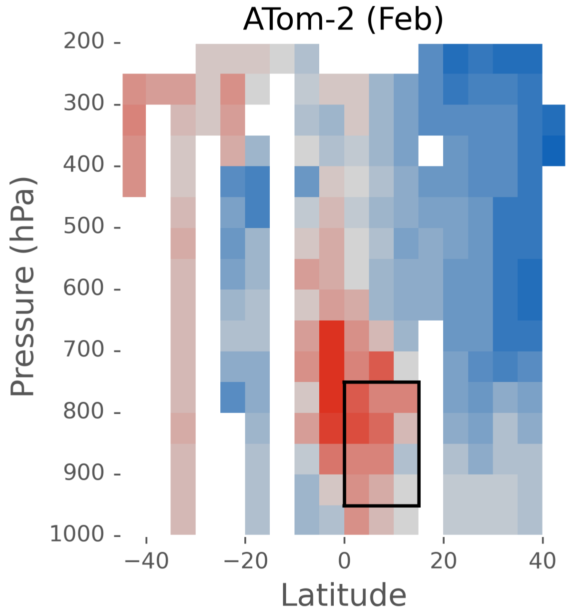
+ Observed ΔCO_2

Atom emergent constraint: NTA flux monthly mean vs. Posterior ΔCO_2

Emergent Constraints NTA NBE land flux: ATom-2: 3.15 +/- 0.6 PgC/yr



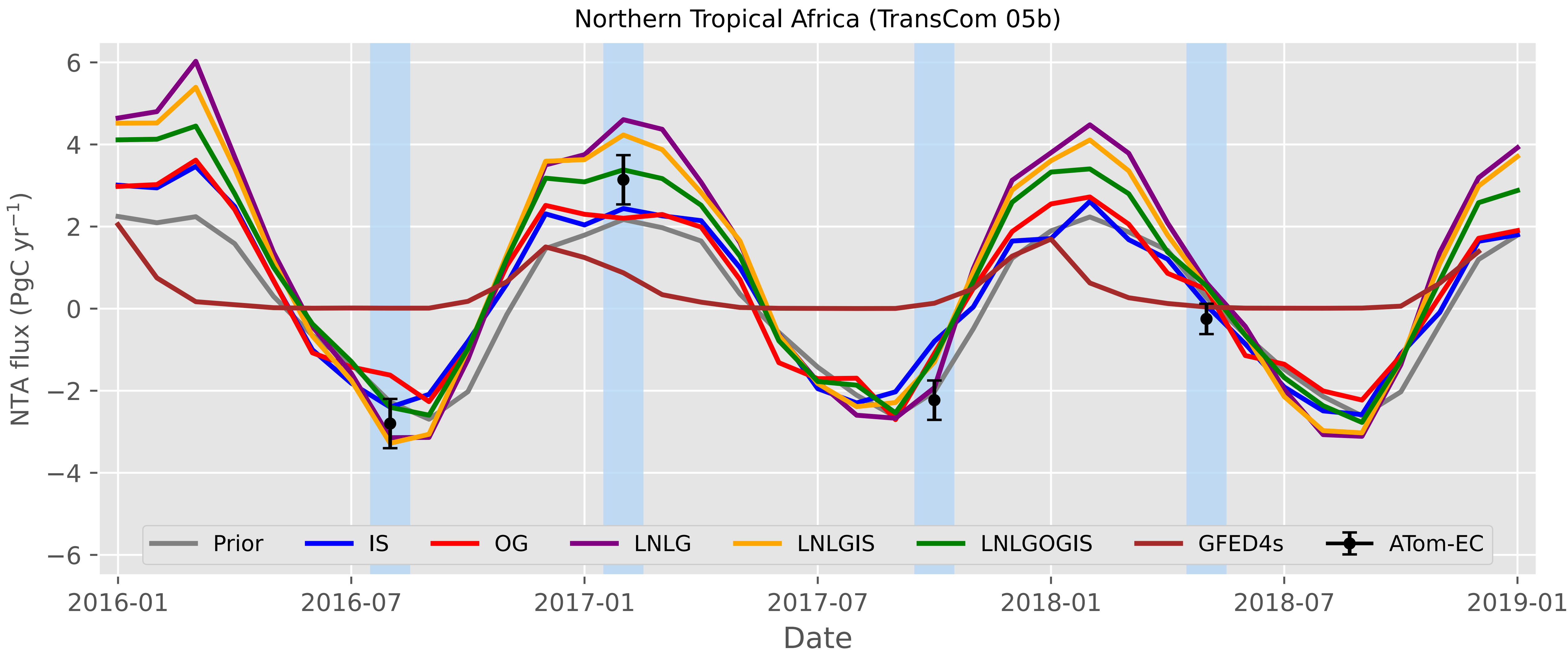
1 box (Highest correlation)



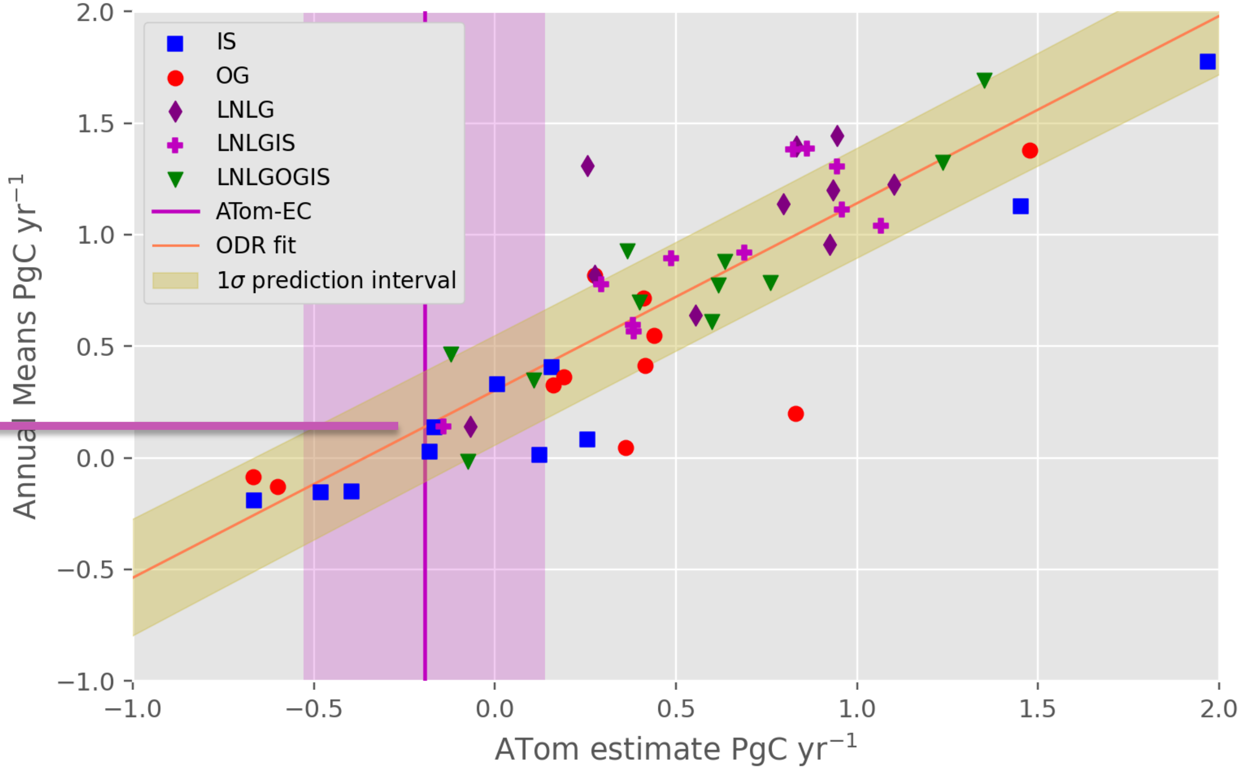
Posterior ΔCO_2 for each inversions

\+ Observed ΔCO_2

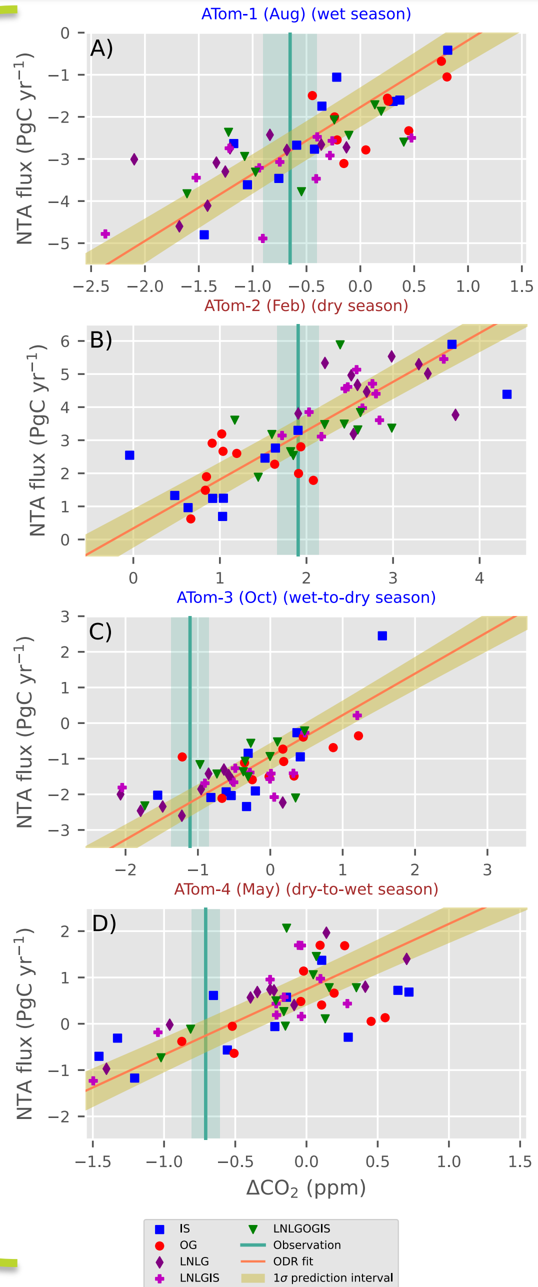
Atom emergent constraint: monthly time series



2016–2018 Mean Flux Estimates



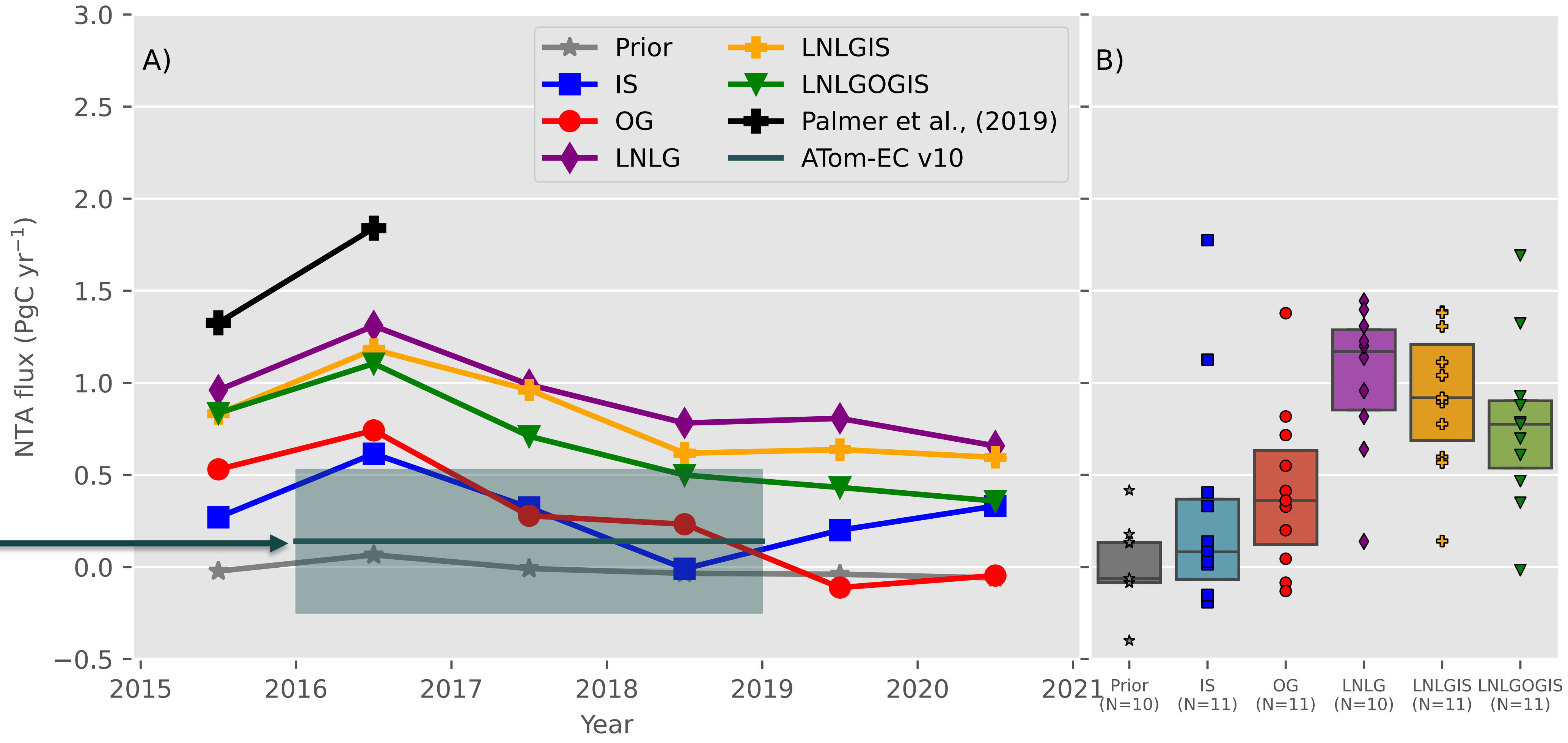
0.14 +/- 0.39 PgC yr^{-1} (2016-2018)



4-ATom estimates

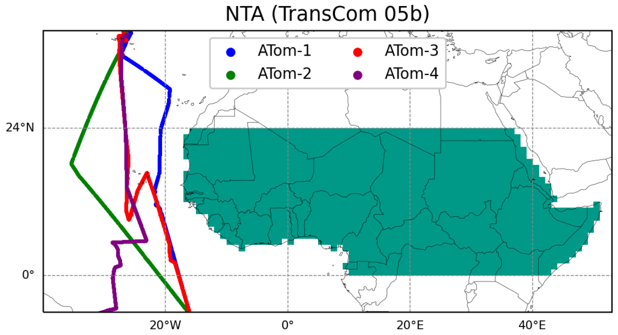
2016-2018 Mean Flux Estimates

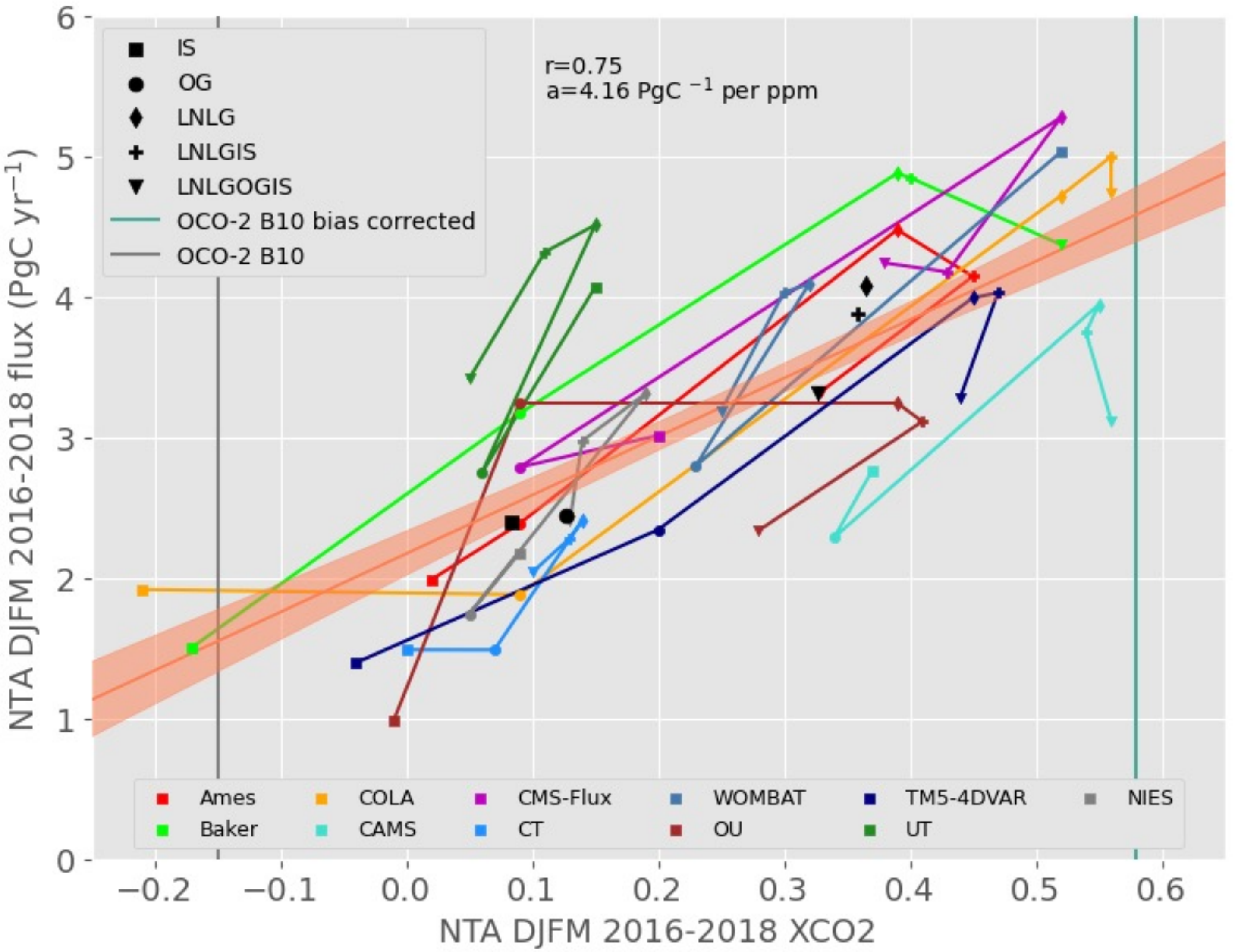
0.14 +/- 0.39 PgC yr^{-1} (2016-2018)



OCO-2 biases impact on flux inversions

- Linear relationship with higher posterior XCO2 resulting from higher fluxes (DJFM).
- The linear regression has an r^2 of 0.56 and a slope of 4.16 PgC yr^{-1} per ppm.
- This slope implies that a flux error of 1 PgC yr^{-1} could result from an XCO2 bias of +0.72 ppm if entirely within DJFM, or **+0.24 ppm if the bias persisted all year.**



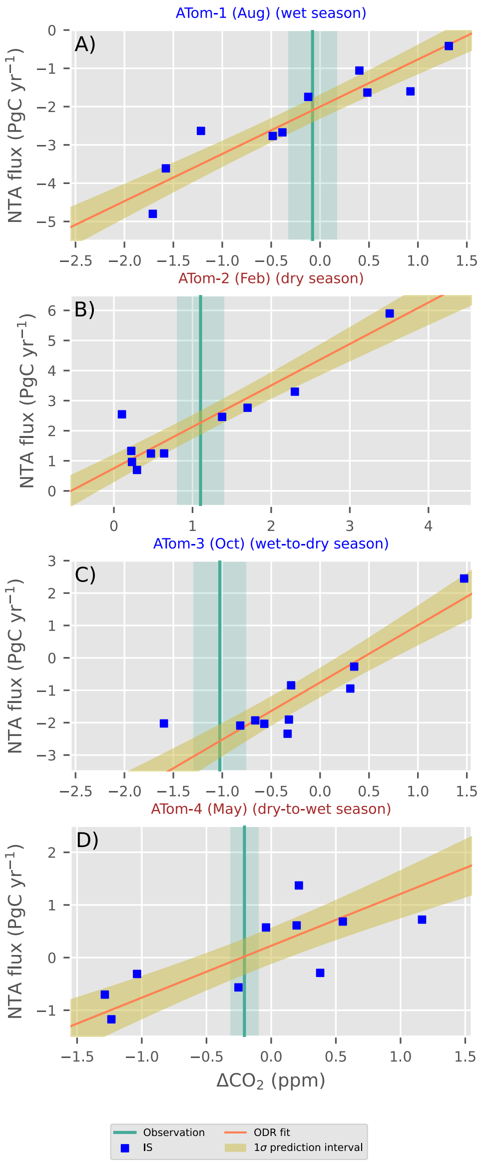


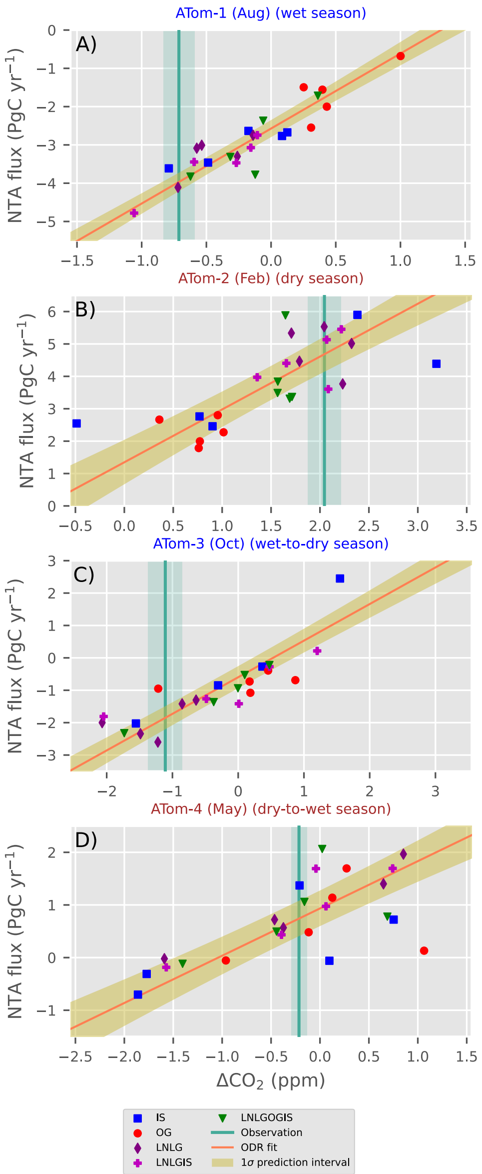
Atom emergent constraint:

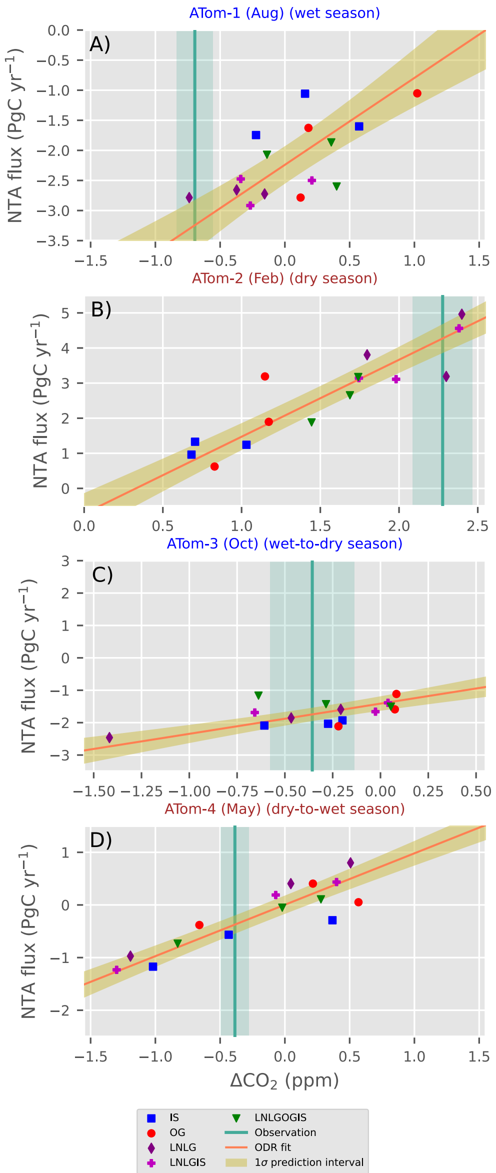
IS only

GEOS-chem only

TM5 only







Northern Tropical Africa (NTA) annual means (2016-2018)

- ✓ 0.14 ± 0.39 PgC yr^{-1} (N=54)
- ✓ 0.08 ± 0.33 PgC yr^{-1} (N=10, IS)
- ✓ 0.27 ± 0.36 PgC yr^{-1} (N=3x5, TM5 only)
- ✓ 0.8 ± 0.43 PgC yr^{-1} (N=5x5, GEOS-chem only)

Conclusions

❖ We evaluated inverse model calculations of northern tropical African CO_2 fluxes with aircraft measurements over the Atlantic Ocean.

- ✓ During the dry season (DJFM): NTA land fluxes are **overestimated** by the **LNLG experiment**, and **underestimated** by the **IS** and **OG** experiments.
- ✓ In other seasons (ATom 1, 3 and 4) clearly demonstrate the improved fluxes following **OCO-2 assimilation w.r.t IS only inversions.**
- ✓ Despite cloud coverage, OCO-2 based inversions do have a stronger sink during the wet season, in agreement with ATom emergent constraints

❖ We derived the **three-year annual mean flux estimate of 0.14 +/- 0.39 PgC yr^{-1} (2016-2018)**

- ✓ XCO2 bias of +0.72 ppm (DJFM), or +0.24 ppm if the bias persisted all year.
- ✓ The ATom emergent constraint is driven by aircraft in-situ observation

References:

Ernst et al.: The African Regional Greenhouse Gases Budget (2010–2019)
Gaubert et al.: Neutral Tropical African CO2 Exchange Estimated From Aircraft and Satellite Observations

OCO-2 bias correction