# OCO-2 $XCO_2$ retrievals using the FOCAL algorithm

**M. Buchwitz, M. Reuter, S. Noël, H. Bovensmann, J. P. Burrows,**
**Institute of Environmental Physics (IUP), University of Bremen, Bremen, Germany**

## Abstract

Satellite observations of the column-averaged dry-air mole fraction of $CO_2$, denoted **$XCO_2$**, combined with inverse modelling, permits to obtain information on natural and anthropogenic $CO_2$ sources and sinks (e.g., [1-7, 10-12]).

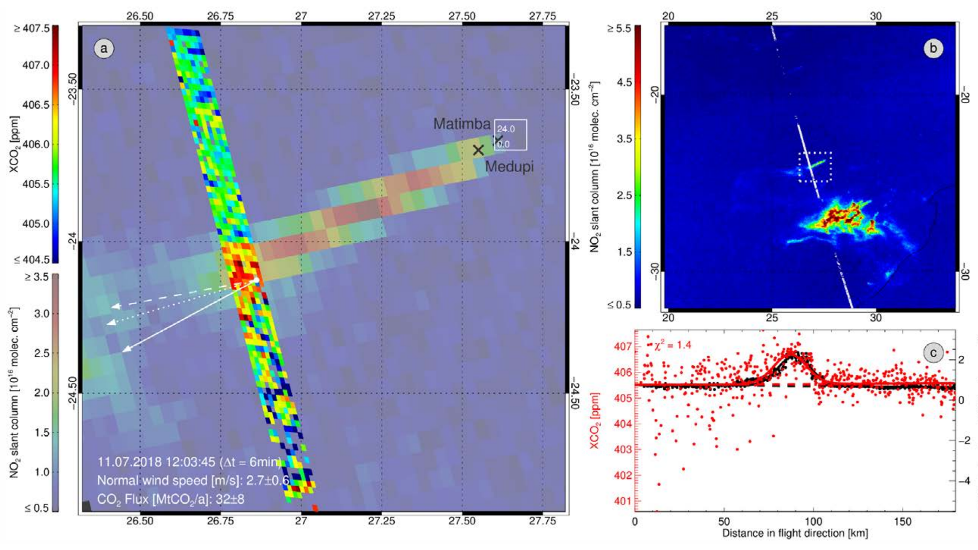
The planned future European Copernicus anthropogenic $CO_2$ Monitoring (**CO2M**) mission, a Copernicus Sentinel High-Priority Candidate Mission (HPCM), will likely be implemented as a constellation of satellites with small ground pixels (approx. 2x2 km$^2$) and wide swath (> 200 km) as needed for $XCO_2$ imaging [1-3, 10-12]. In addition to $XCO_2$, CO2M will also provide a number of other parameters, which are highly beneficial to meet the CO2M objectives, such as methane ($XCH_4$) and $NO_2$ columns.

CO2M will cover similar spectral bands as **NASA's OCO-2** satellite mission however with a much wider swath resulting in about one order of magnitude more observations per satellite compared to OCO-2. Using co-funding from different sources including CHE and VERIFY the University of Bremen started working on the development of a new very fast but still very accurate algorithm (**FOCAL**) for the retrieval of $XCO_2$ from OCO-2 [8, 9] and to generate $XCO_2$ data products for CHE and VERIFY.

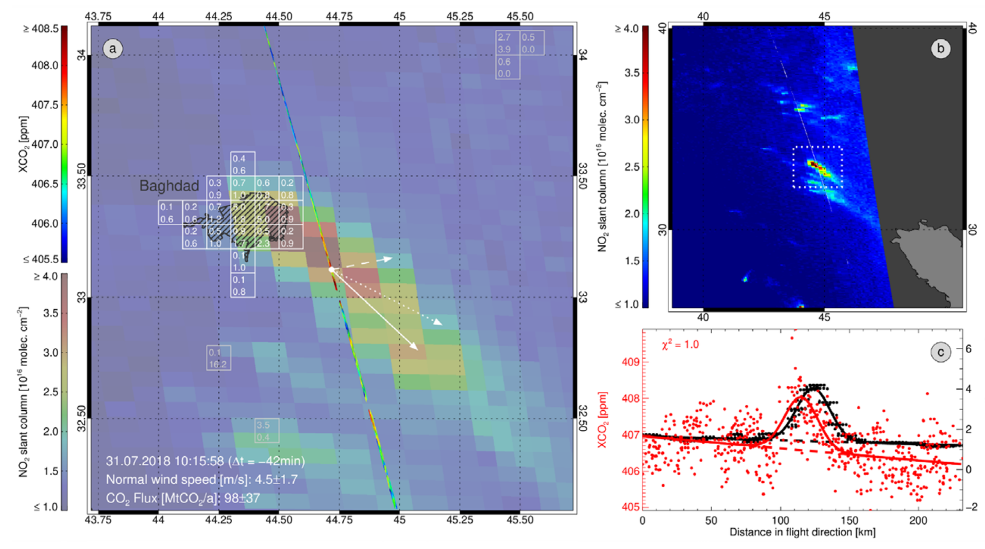
Here we present an initial global $XCO_2$ data set covering the years 2015-2016 including comparisons with TCCON ground-based observations, the CAMS model and OCO-2 $XCO_2$ data products from NASA generated using NASA's **ACOS** algorithm. We also present first results from using OCO-2 $XCO_2$ in combination with **Sentinel-5-Precursor (S5P) $NO_2$** to obtain information on anthropogenic $CO_2$ emission sources [10].

## Anthropogenic $CO_2$ emissions

We use OCO-2 $XCO_2$ in combination with S5P $NO_2$ to identify $XCO_2$ enhancements from localized $CO_2$ emission sources and we quantify the $CO_2$ cross-sectional flux w.r.t. OCO-2's orbit and compare with emission inventories [10]. Here 2 examples:



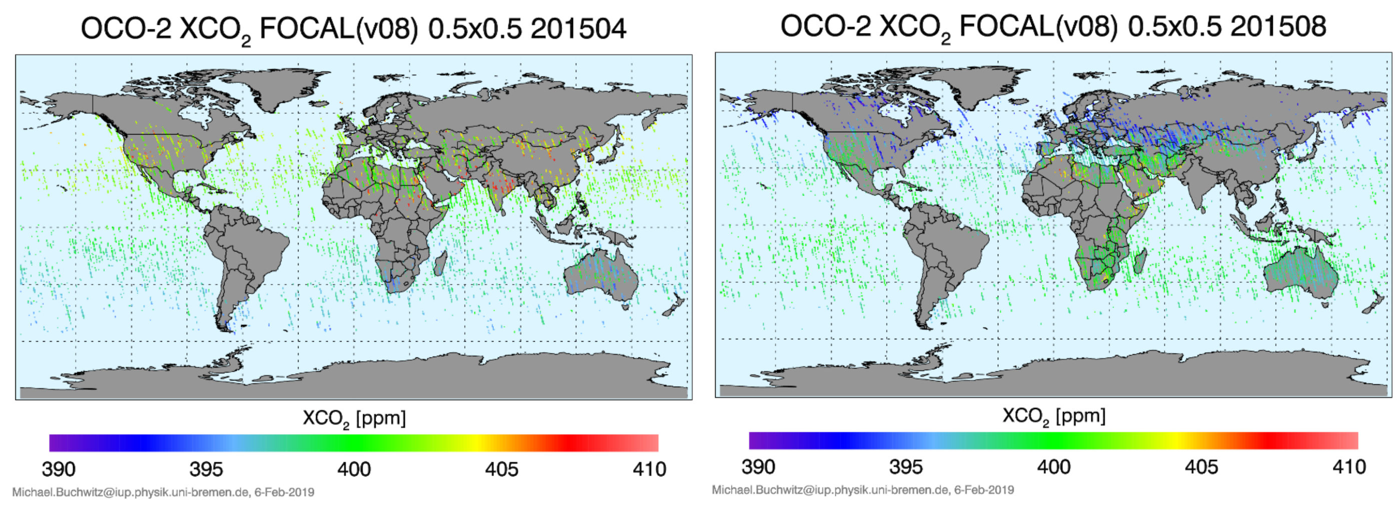
Medupi and Matimba power plants in South Africa on July 11, 2018.



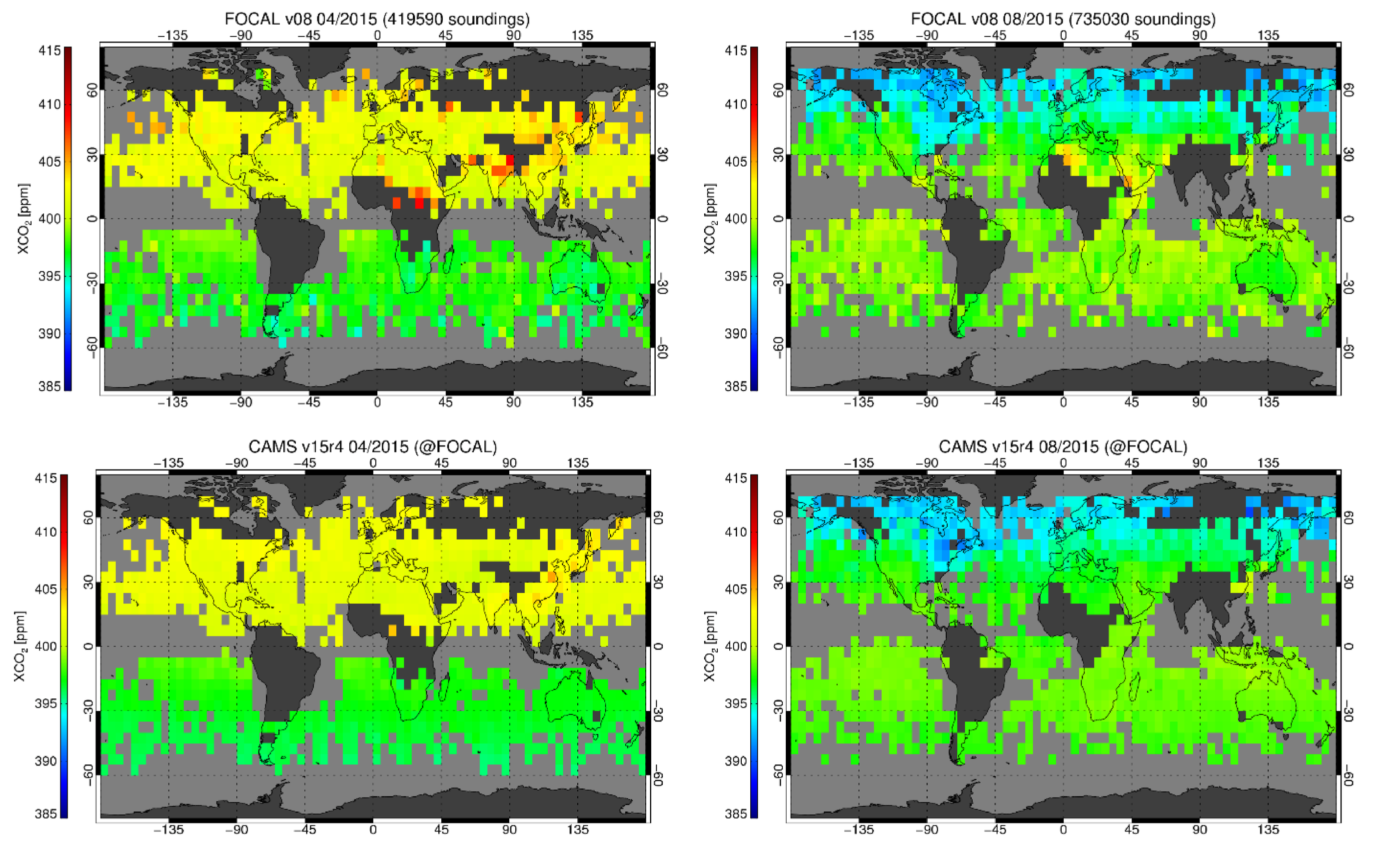
Bhagdad on July 31, 2018.

## FOCALv08 $XCO_2$

OCO-2 $XCO_2$ is sparse due to narrow swath, small ground pixels and strict quality filtering:

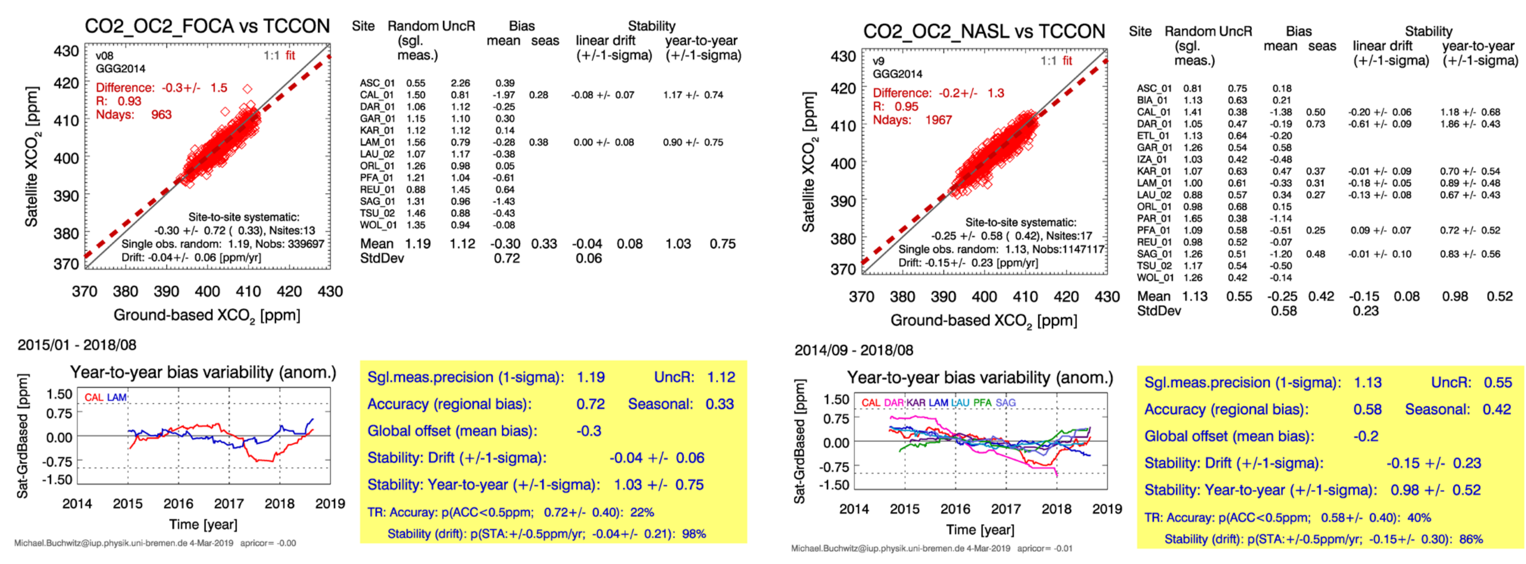



Large-scale pattern (5°x5°): Comparison with CAMS:

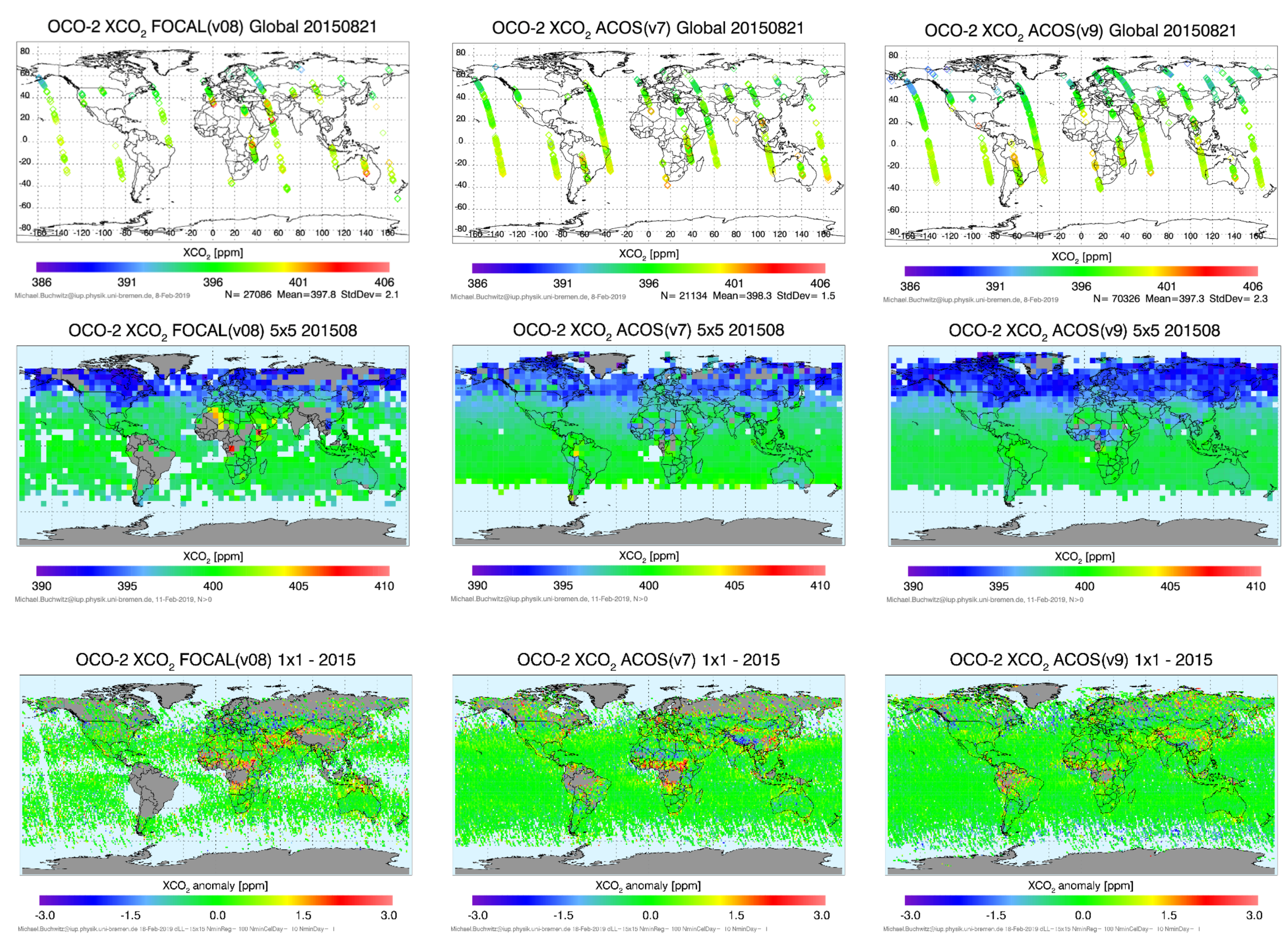


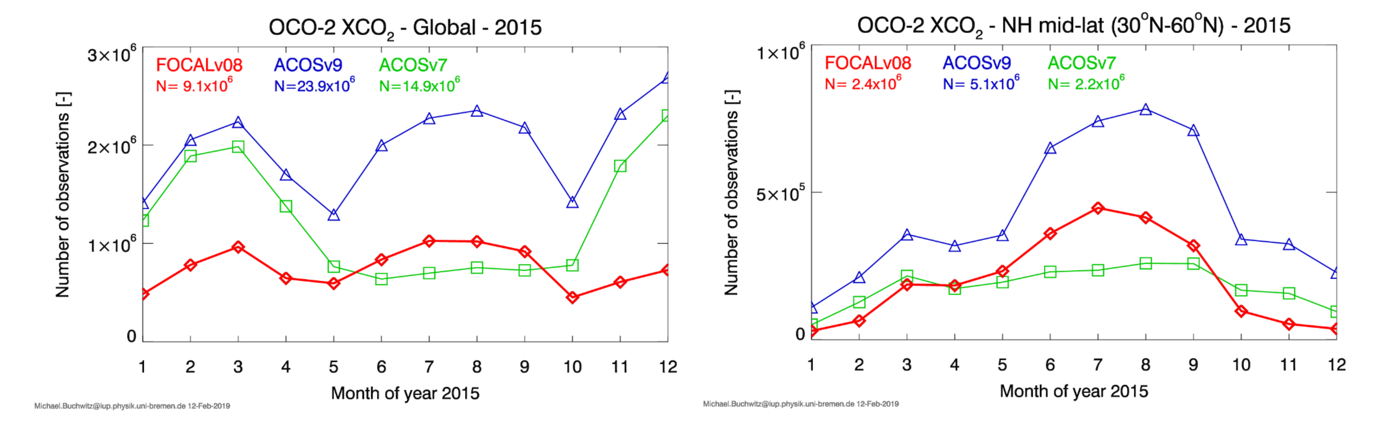
Systematic and random errors: Comparison with TCCON:

**OCO-2 FOCAL v08** | **Latest OCO-2 NASA v9 (Lite)**



Comparisons with initial & latest NASA products:






## Selected references

[1] Bovensmann, H., et al., **A remote sensing technique for global monitoring of power plant $CO_2$ emissions from space and related applications**, Atmos. Meas. Tech., 3, 781-811, 2010.

[2] Broquet, G., et al., **The potential of satellite spectro-imagery for monitoring $CO_2$ emissions from large cities**, Atmos. Meas. Tech., 11, 681-708, 2018.

[3] Buchwitz, M., et al., **Carbon Monitoring Satellite (CarbonSat): assessment of atmospheric $CO_2$ and $CH_4$ retrieval errors by error parameterization**, Atmos. Meas. Tech., 6, 3477-3500, 2013.

[4] Buchwitz, M., et al., **Copernicus Climate Change Service (C3S) Global Satellite Observations of Atmospheric Carbon Dioxide and Methane**, Adv. Astronaut. Sci. Technol., 2018.

[5] Buchwitz, M., et al., **Computation and analysis of atmospheric carbon dioxide annual mean growth rates from satellite observations during 2003-2016**, Atmos. Chem. Phys., 18, 17355-17370, 2018.

[6] Reuter, M., et al., **Decreasing emissions of NOx relative to $CO_2$ in East Asia inferred from satellite observations**, Nature Geoscience, pp.4, 2014.

[7] Reuter, M., et al., **How much $CO_2$ is taken up by the European terrestrial biosphere?**, Bull. Amer. Meteor. Soc., 665-671, 2017.

[8] Reuter, M., et al., **A Fast Atmospheric Trace Gas Retrieval for Hyperspectral Instruments Approximating Multiple Scattering - Part 1: Radiative Transfer and a Potential OCO-2 $XCO_2$ Retrieval Setup**, Remote Sens., 9, 1159, 2017.

[9] Reuter, M., et al., **A Fast Atmospheric Trace Gas Retrieval for Hyperspectral Instruments Approximating Multiple Scattering - Part 2: Application to $XCO_2$ Retrievals from OCO-2**, Remote Sens., 9, 1102, 2017.

[10] Reuter, M., et al., **Towards monitoring localized $CO_2$ emissions from space: co-located regional $CO_2$ and $NO_2$ enhancements observed by the OCO-2 and S5P satellites**, Atmos. Chem. Phys. (submitted), 2019.

[11] Pillai, D., et al., **Tracking city $CO_2$ emissions from space using a high resolution inverse modeling approach: A case study for Berlin**, Germany, Atmos. Chem. Phys., 16, 9591-9610, 2016.

[12] Pinty B., et al., **An Operational Anthropogenic $CO_2$ Emissions Monitoring & Verification Support capacity - Baseline Requirements, Model Components and Functional Architecture**, doi: 10.2760/39384, European Commission Joint Research Centre, EUR 28736 EN, 2017.

Universität Bremen

***www.iup.uni-bremen.de/carbon_ghg***

***Contact:*** ***buchwitz@uni-bremen.de***

***Acknowledgement:*** This research received funding from the European Commission via H2020 projects CHE & VERIFY, coordinated by ECMWF & LSCE/CEA, respectively.