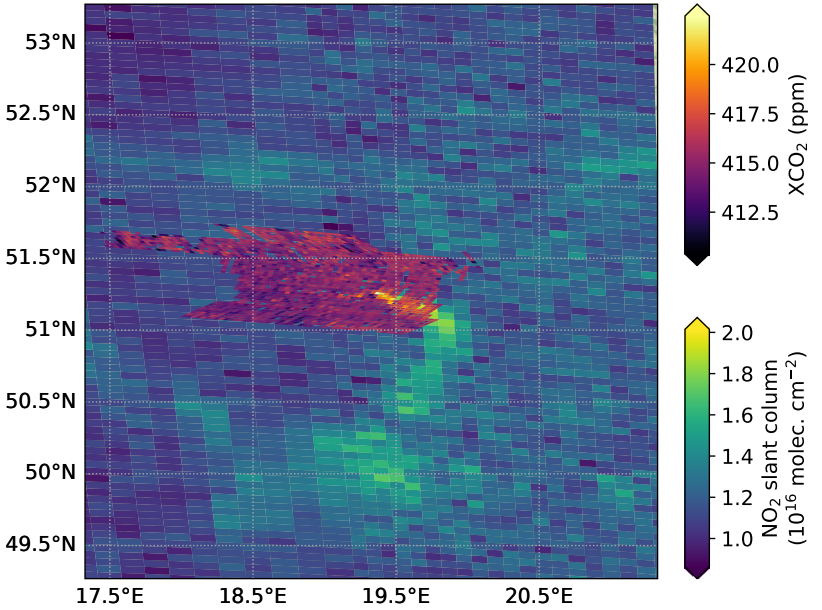
17th International Workshop on Greenhouse Gas Measurements from Space (IWGGMS 17) - June 14 – 17, 2021
Session 4.2c: Observations to quantify hot spots and local/urban emissions

Deriving CO_2 emissions of point sources from OCO-3 XCO_2 and S5P NO_2 data

B. Fuentes Andrade, M. Buchwitz, M. Reuter, H. Bovensmann, J.P. Burrows,
Institute of Environmental Physics, University of Bremen, Germany

- Carbon dioxide (CO_2) is the most important anthropogenic greenhouse gas leading to climate change. Almost 90% of the anthropogenic CO_2 emissions come from the combustion of fossil fuels, mostly emitted from localized sources.

- Satellite observations are needed to verify and complement the national greenhouse gas inventories (Paris Agreement).



- We are developing methods to obtain CO_2 emission information of localized sources (*e.g.* power plants and cities) using OCO-3 XCO_2 SAMs and NO_2 slant columns from TROPOMI.

- This will also serve as a preparation for the future CO2M mission, which will retrieve both XCO_2 and NO_2 slant columns.

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Blanca Fuentes Andrade
Institute of Environmental Physics (IUP)
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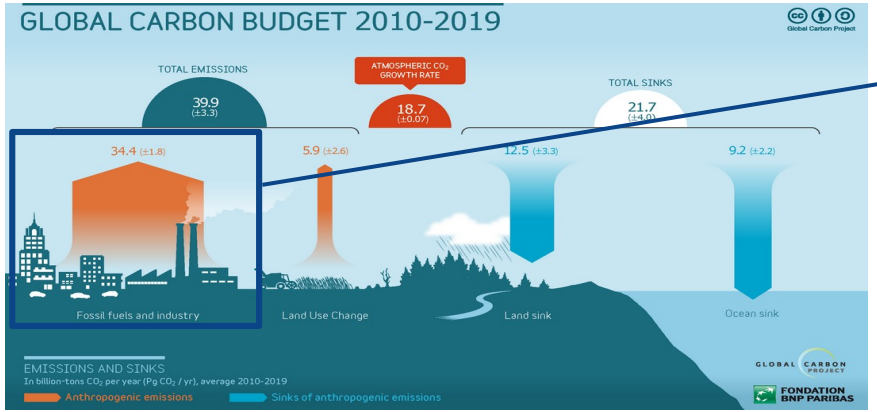
Motivation



Friedlingstein et al. 2020: Global Carbon Budget 2019. Earth System Science Data.

CO_2 and NO_2 originate from the combustion of fossil fuels

CO_2

XCO_2 enhancements due to the anthropogenic emissions from point sources are usually small compared to the large background values.

NO_2 is a suitable tracer for recently emitted CO_2

NO_2

It has a much shorter lifetime than CO_2 and therefore its enhancements in the vertical column densities due to anthropogenic emissions largely exceed background values.

NO is co-emitted with CO_2 in the combustion of fossil fuels and it rapidly reacts with O_3 to form NO_2.

Co-located and in temporal proximity observations of CO_2 and NO_2 allow us to detect the emission plume and its shape

Atmos. Chem. Phys., 19, 9371–9383, 2019
https://doi.org/10.5194/acp-19-9371-2019

Atmospheric Chemistry and Physics
EGU

Reuter et al., 2019

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

Maximilian Reuter[1], Michael Buchwitz[1], Oliver Schneising[1], Sven Krautwurst[1], Christopher W. O'Dell[2], Andreas Richter[1], Heinrich Bovensmann[1], and John P. Burrows[1]
[1]Institute of Environmental Physics, University of Bremen, Bremen, Germany
[2]Colorado State University, Fort Collins, CO, USA

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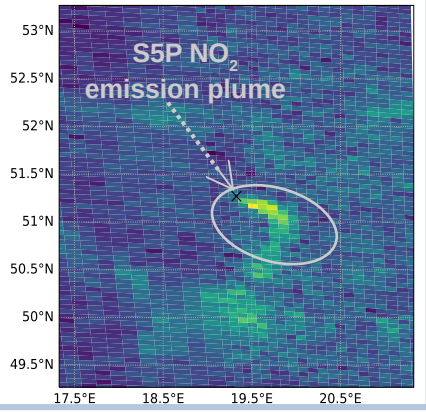
Datasets

NO_2 data

NO_2 slant columns retrieved by TROPOMI on S5P with DOAS (Differential Optical Absorption Spectroscopy) from IUP Bremen.

Swath of about 2600 km and spatial resolution of 3.5 x 7 km² at nadir.

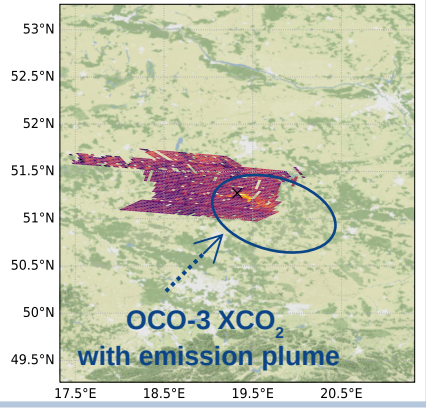


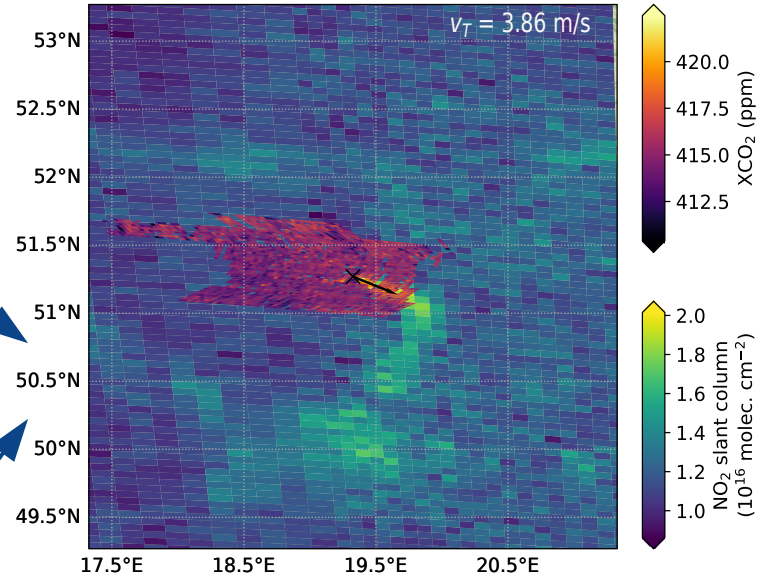
XCO_2 data

OCO-3 level 2 XCO_2 from NASA.

Snapshot Area Maps (SAMs).

Spatial resolution 1.6 x 2.2 km².





Bełchatów Power Station, Poland

10/04/2020

OCO-3: 13:35 UTC

S5P: 12:37 UTC

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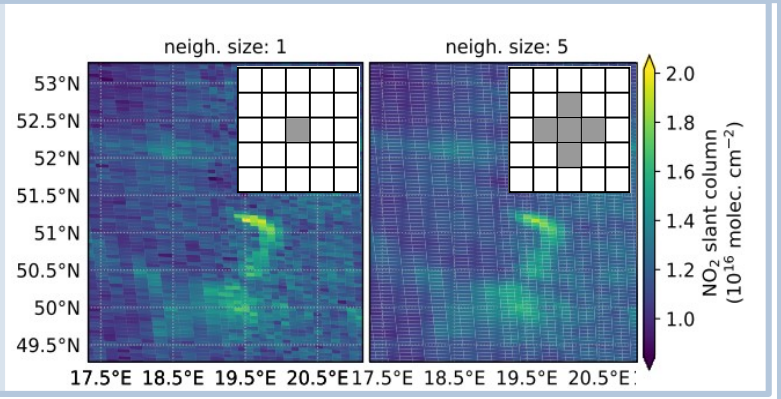
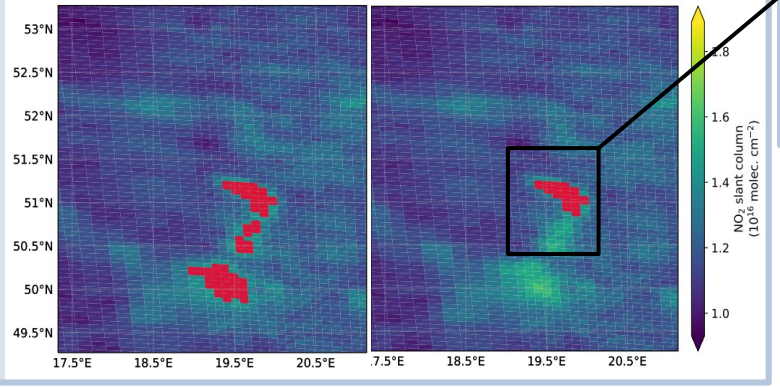
Method to estimate the emission flux

Plume detection (from NO_2 data)

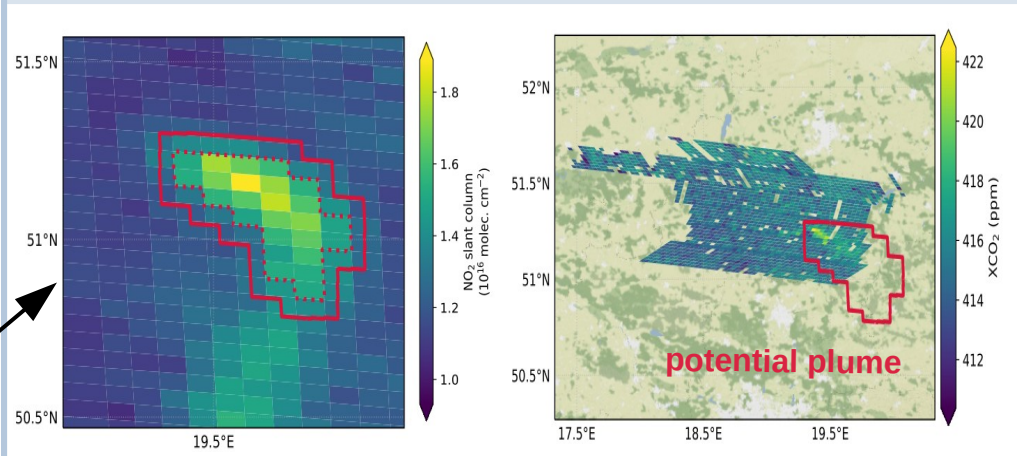
1. Spatial averaging



2. Enhance-ments selection and clustering



3. Extension of the borders of the plume



Atmos. Meas. Tech., 12, 6695–6719, 2019
https://doi.org/10.5194/amt-12-6695-2019

Atmospheric Measurement Techniques
EGU

Kuhlmann et al., 2019

Detectability of CO_2 emission plumes of cities and power plants with the Copernicus Anthropogenic CO_2 Monitoring (CO2M) mission

Gerrit Kuhlmann[1], Grégoire Broquet[2], Julia Marshall[3], Valentin Clément[4,5], Armin Löscher[6], Yasjka Meijer[6], and Dominik Brunner[1]
[1]Empa, Swiss Federal Laboratories for Materials Science and Technology, Dübendorf, Switzerland
[2]Laboratoire des Sciences du Climat et de l'Environment, LSCE/IPSL, CEA-CNRS-UVSQ, Université Paris-Saclay, Gif-sur-Yvette, France
[3]Max Planck Institute for Biogeochemistry (MPI-BGC), Jena, Germany
[4]Center for Climate Systems Modelling (C2SM), ETH Zurich, Zurich, Switzerland
[5]MeteoSwiss, Kloten, Switzerland
[6]European Space Agency (ESA), ESTEC, Noordwijk, the Netherlands

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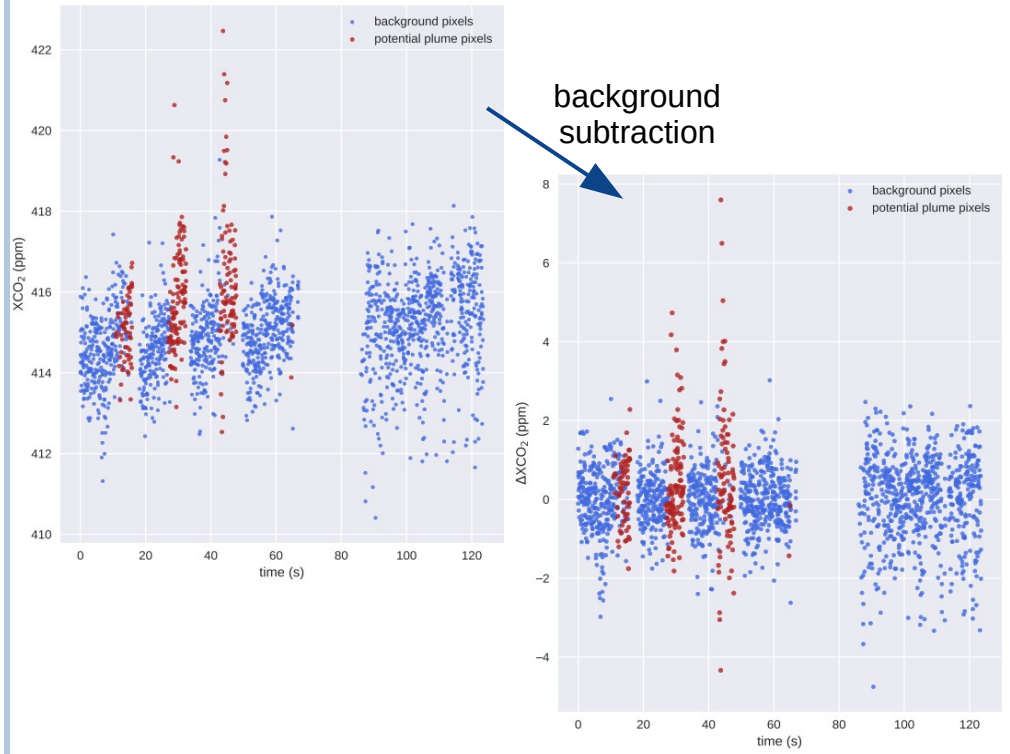
Method to estimate the emission flux

XCO_2 enhancements



Flux estimation

1. Definition of cross sections along track.
2. Wind information from ERA5 Reanalysis.
3. Filling in missing data: Gaussian approach.
4. Computation of cross sectional flux as:

$$\Phi_k = \frac{v_\perp \, n_e \, M_{CO_2}}{N_A} \sum \Delta l_i \left(\Delta XCO_2\right)_i$$

$v_\perp$: wind speed perpendicular to cross section,

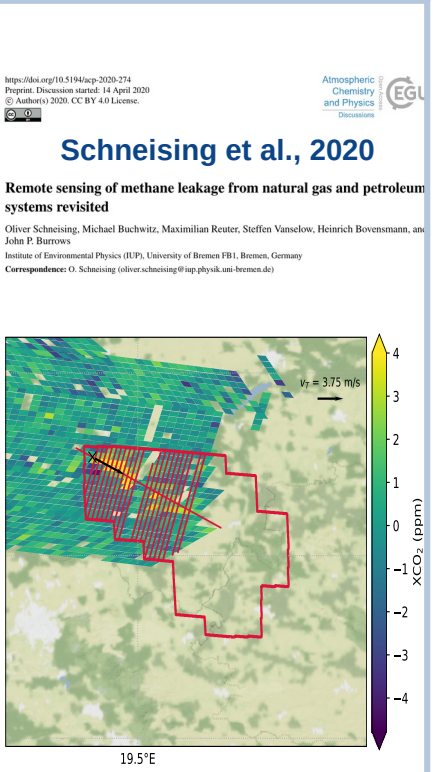
n_e: number of dry air particles per unit area,

M_{CO2}: molar mass of CO_2,

N_A: Avogadro constant,

ΔXCO_2: XCO_2 enhancement in ppm for each pixel i along k-th cross section,

Δl_i: length of pixel i along k-th cross section.



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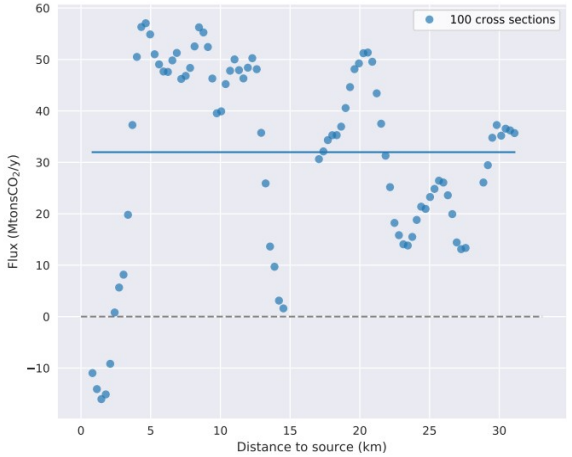
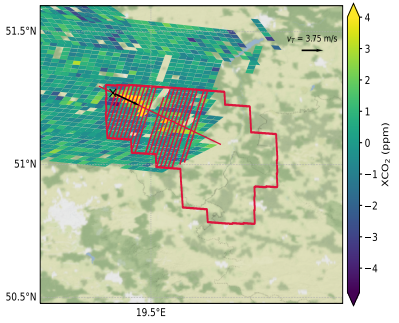
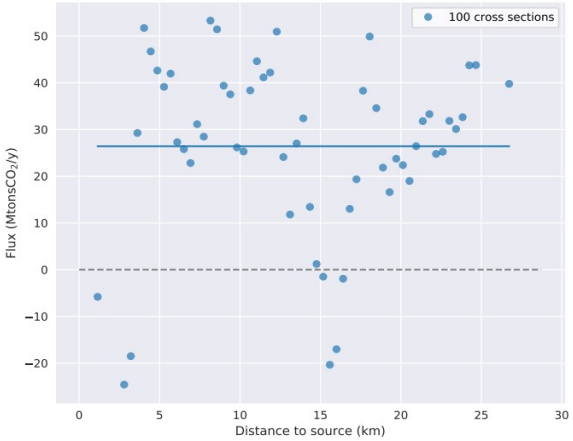
Results for the Belchatów Power Station (Poland)



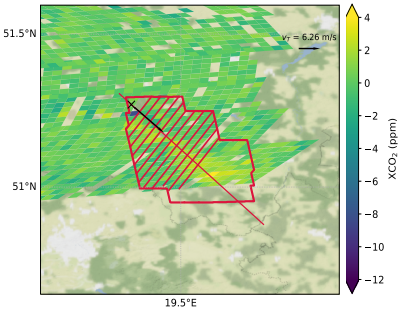
10/04/2020
OCO-3: 13:35 UTC
S5P: 12:37 UTC



First estimation of the flux: 32 ± 19 $MtonsCO_2$/year



17/04/2020
OCO-3: 09:42 UTC
S5P: 12:06 UTC



First estimation of the flux: 27 ± 18 $MtonsCO_2$/year

- **Significant variation** of the cross-sectional flux as a function of the distance from the source (to be investigated).
- Flux estimation is approximately **at overpass time**, not an annual average.
- Uncertainty via **standard deviation** (preliminary, to be improved).
- **Annual emissions***: 37.6 $MtonsCO_2$ in 2017, according to the E-PRTR (European Pollutant Release and Transfer Register).

*Typical uncertainty, at a 95% level of confidence, is less than 10% of full scale.

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