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Analyzing nitrogen oxides to carbon dioxide emission ratios from space: A case study of Matimba Power Station in South Africa

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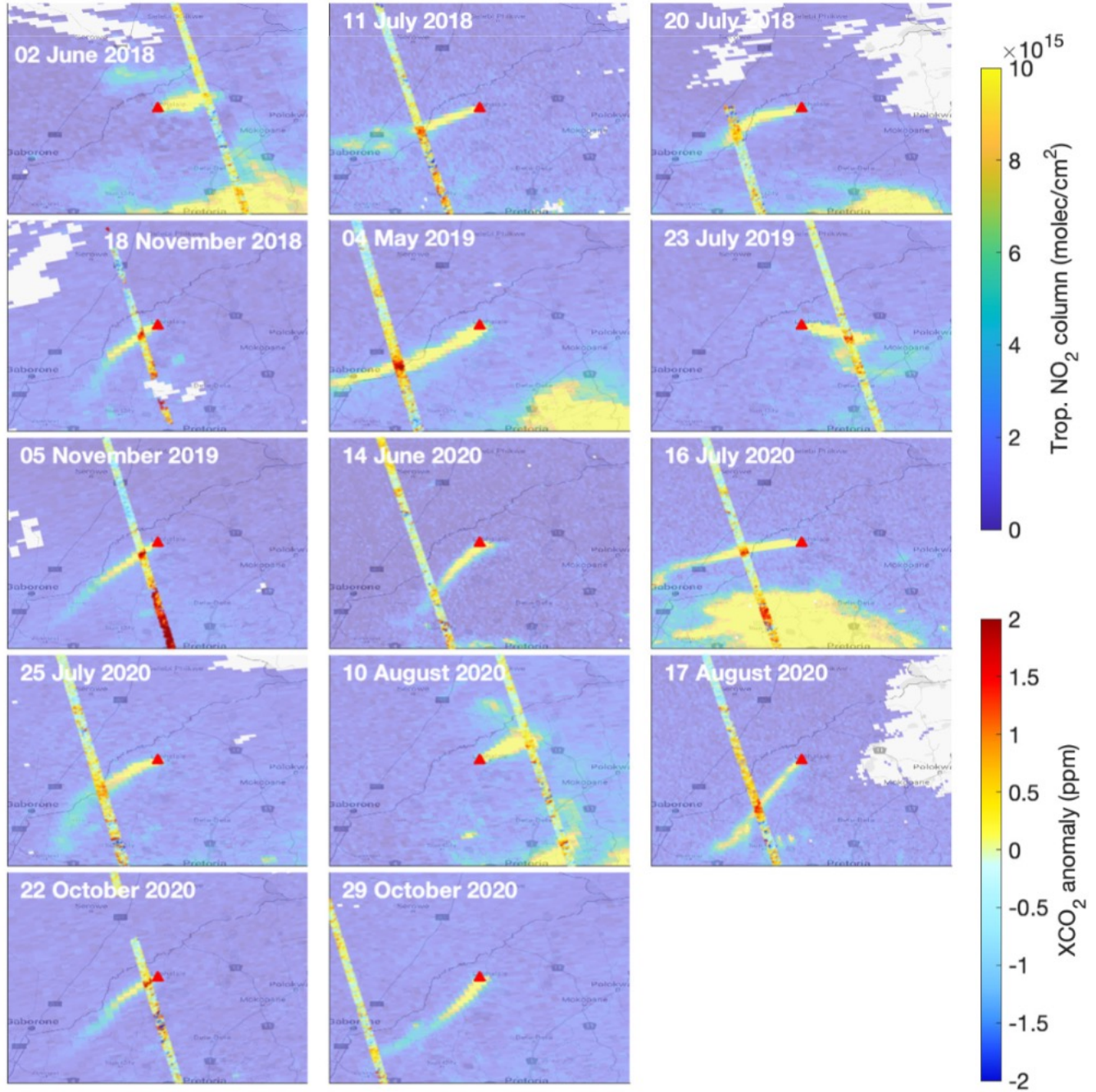
Highlights

- A new methodology to derive source-specific NO_x-to-CO_2 emission ratios.
- The method is applied for TROPOMI and OCO-2 satellite observations.
- The mean emission ratio of $(2.6 \pm 0.6) \times 10^{-3}$ is obtained for Matimba Power Station.
- The annual CO_2 emissions for Matimba are ~60 kt/d.
- The emission estimates are consistent with existing inventories such as ODIAC.



Background

- CO_2 emissions from point sources can be estimated using different methods, e.g., Gaussian plume model method (Nassar et al., 2016), Cross-sectional flux method (Reuter et al., 2019), see (Varon et al., 2018) for overview
- Satellite-based NOx emission estimation methods are based on statistical analysis
- Can we derive source-specific emission ratios of NOx to CO_2 directly from space-based data?
- We propose an approach based on scaling the observed ratio along the OCO-2 track with simulated data, to obtain the NOx-to-CO_2 emission ratio at the source.

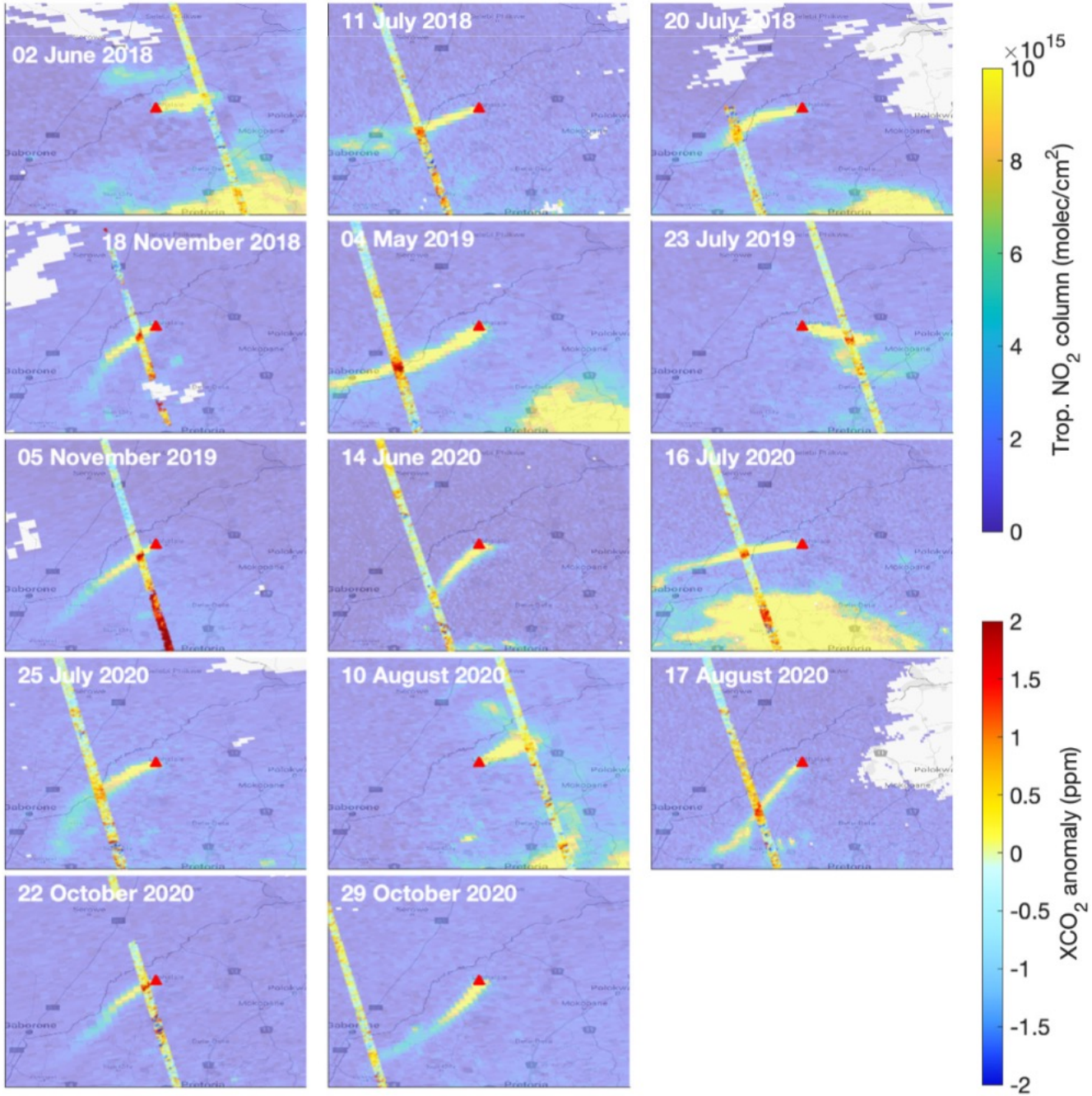
See the paper for details: https://doi.org/10.1016/j.aeaoa.2021.100110

Methodology

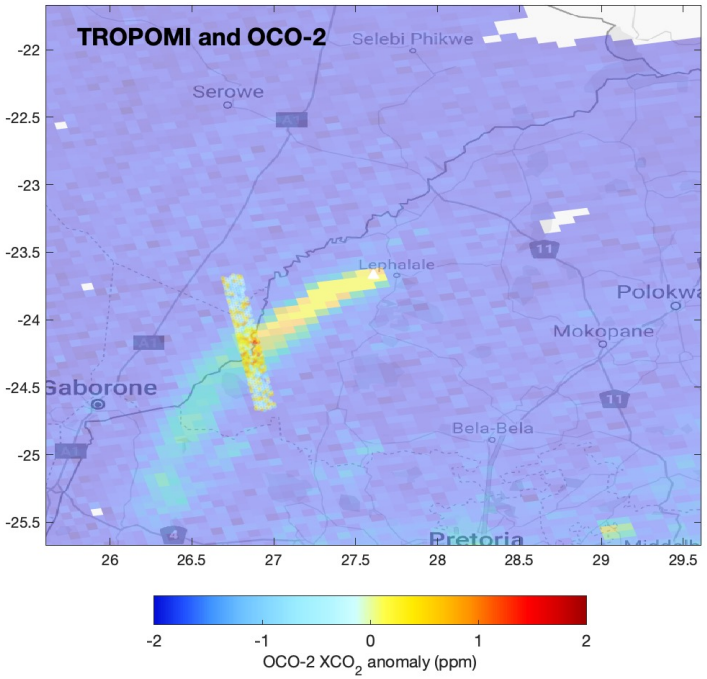
1. Select a place of interest and find plumes with both OCO-2 (CO_2) and TROPOMI (NO_2) data
2. Simulate CO_2 and NO_2 plumes using FLEXPART Lagrangian particle dispersion model
3. Calculate the CO_2-to-NO_2 ratio at the cross-section from observations and simulations and derive NO_x-to-CO_2 emission ratio at the source (see paper for details)
4. Calculate monthly NO_x emissions using data driven approach (e.g., exponentially-modified Gaussian, Beirle et al., Science, 2011)
5. Use NO_x-to-CO_2 emission ratio to scale NO_x emissions to CO_2 emissions

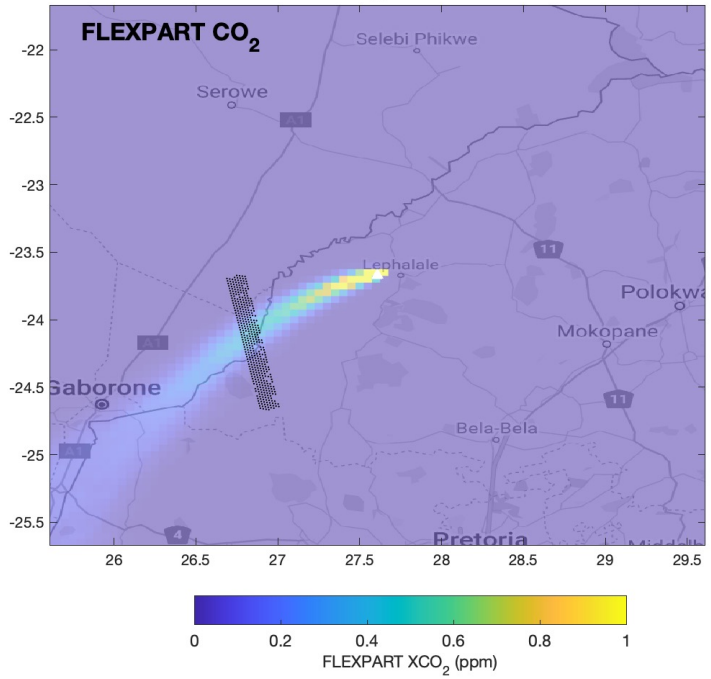
Results

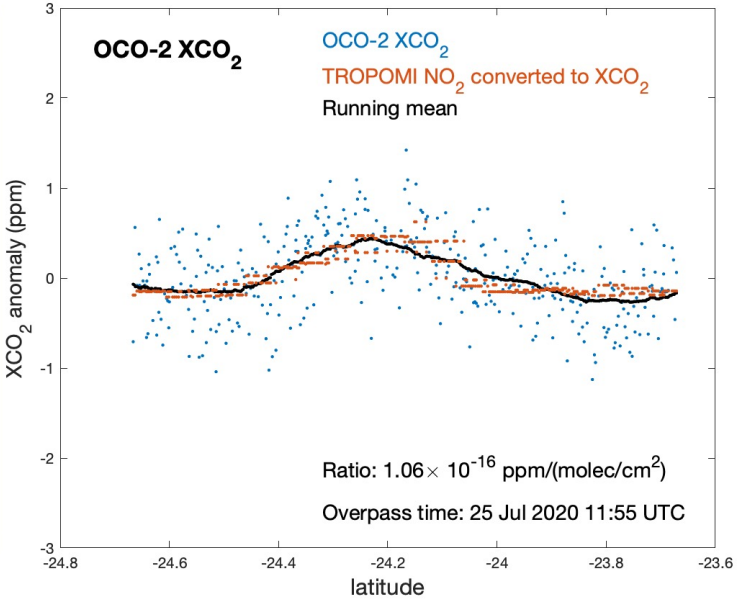
- For Matimba power station in South Africa we found 14 collocated plumes between May 2018 and November 2020

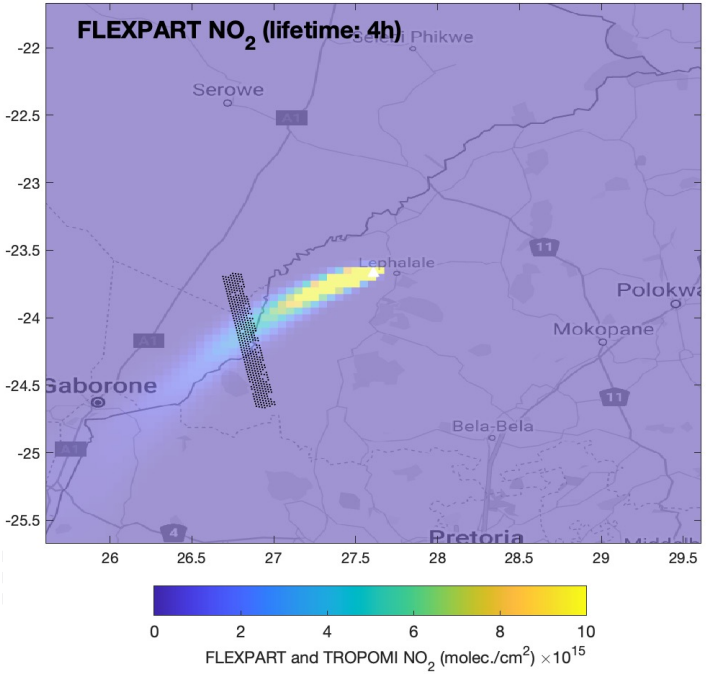


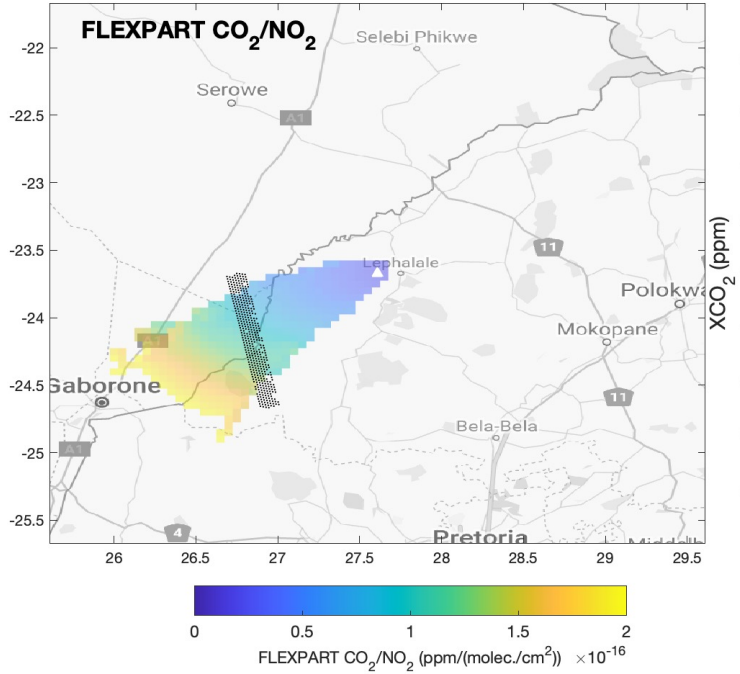
25 July 2020

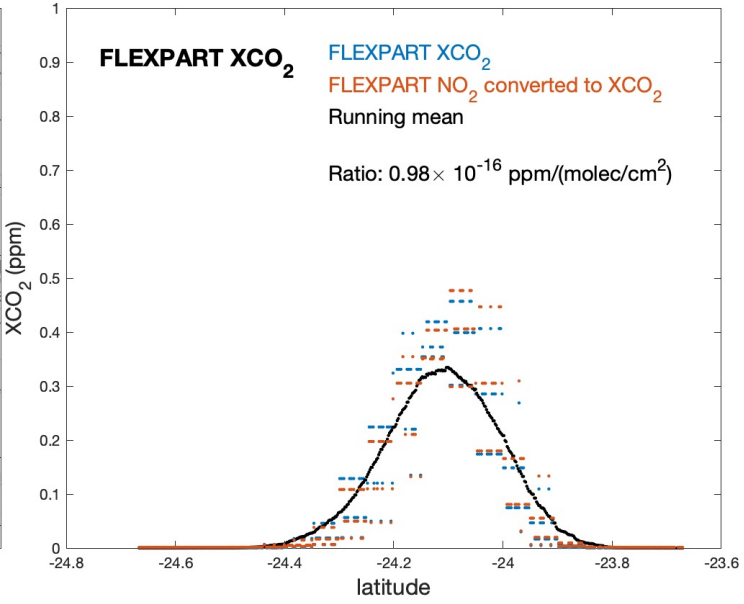

TROPOMI and OCO-2
Selebi Phikwe
Serowe
Lephalale
Polokwane
Mokopane
Gaborone
Bela-Bela
Pretoria
OCO-2 XCO2 anomaly (ppm)


FLEXPART CO2
Selebi Phikwe
Serowe
Lephalale
Polokwane
Mokopane
Gaborone
Bela-Bela
Pretoria
FLEXPART XCO2 (ppm)


OCO-2 XCO2
OCO-2 XCO2
TROPOMI NO2 converted to XCO2
Running mean
Ratio: 1.06× 10-16 ppm/(molec/cm2)
Overpass time: 25 Jul 2020 11:55 UTC
XCO2 anomaly (ppm)
latitude


FLEXPART NO2 (lifetime: 4h)
Selebi Phikwe
Serowe
Lephalale
Polokwane
Mokopane
Gaborone
Bela-Bela
Pretoria
FLEXPART and TROPOMI NO2 (molec./cm2) ×10^15


FLEXPART CO2/NO2
Selebi Phikwe
Serowe
Lephalale
Polokwane
Mokopane
Gaborone
Bela-Bela
Pretoria
FLEXPART CO2/NO2 (ppm/(molec./cm2)) ×10^-16


FLEXPART XCO2
FLEXPART XCO2
FLEXPART NO2 converted to XCO2
Running mean
Ratio: 0.98× 10-16 ppm/(molec/cm2)
XCO2 (ppm)
latitude

Results

- Annual and monthly NO_x emission estimated using wind rotation and EMG fitting
- Annual NO_x emissions are about 40 mol/s (lifetime about 4h)
- Average NO_x-to-CO_2 ratio is $(2.6 \pm 0.6) \times 10^{-3}$
- CO_2 annual emissions about 60 kt/d
- The emission estimates are consistent with existing inventories such as ODIAC