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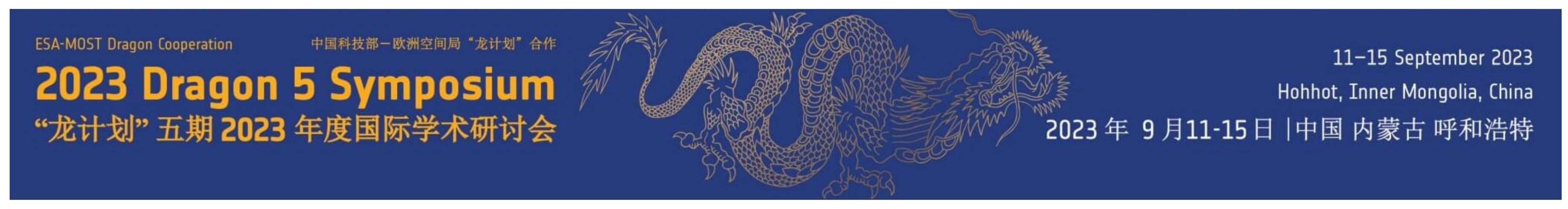

Detection of Anthropogenic Emission Signatures from Space

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Key Points

- We use OCO-2, OCO-3 and TanSat satellites to detect anthropogenic CO_2 emission signatures from space
- We analyze co-emitted NO_x emissions from S5P/TROPOMI NO_2 observations
- NO_x-to-CO_2 emission ratios are also analyzed
- Future satellite missions such as the Copernicus CO2M, TanSat-2 and the GOSAT-GW will provide simultaneous CO_2 and NO_2 observations

Data and Methodology

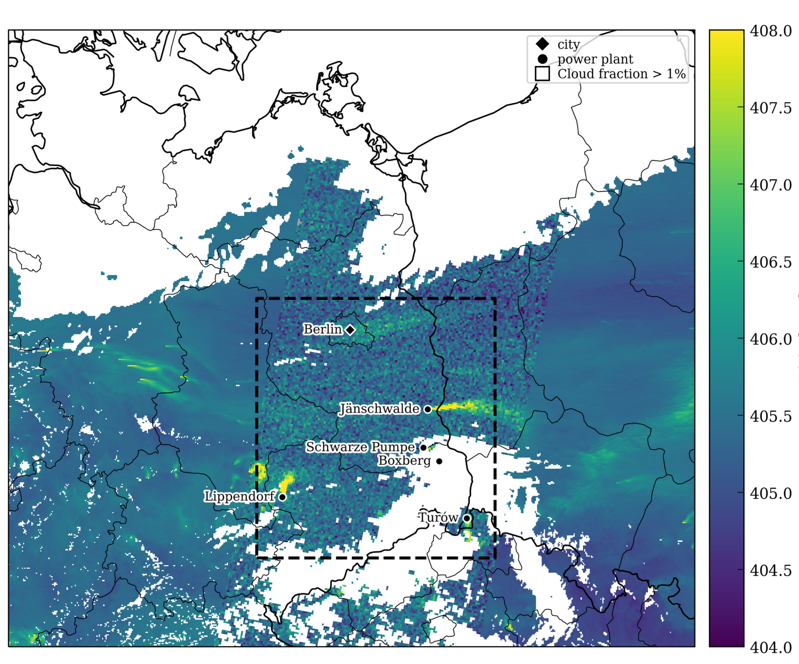
We use carbon dioxide (CO_2) data from NASA's CO_2 monitoring missions Orbiting Carbon Observatory (OCO) -2 and -3 as well as from China's first CO_2 satellite mission, TanSat. TanSat XCO_2 data are derived by the Institute of Atmospheric Physics Carbon dioxide retrieval Algorithm for Satellite remote sensing (IAPCAS).

The TROPOspheric Monitoring Instrument (TROPOMI) is the sole satellite instrument onboard the Copernicus Sentinel-5 Precursor (S5P) satellite. As nitrogen oxides ($NO_x = NO + NO_2$) are often co-emitted with CO_2, these data can be used to facilitate the identification and analysis of the CO_2 plumes. For example, TROPOMI NO_2 data can used to identify the emission plume, to derive the plume width and to analyze the NO_x-to-CO_2 emission ratio.

Here we use the cross-sectional flux method to calculate emission estimates and a related method to calculate NO_x-to-CO_2 emission ratio [1, 2]. We also calculate the XCO_2 anomalies (with respect to the daily latitudinal background) defined as

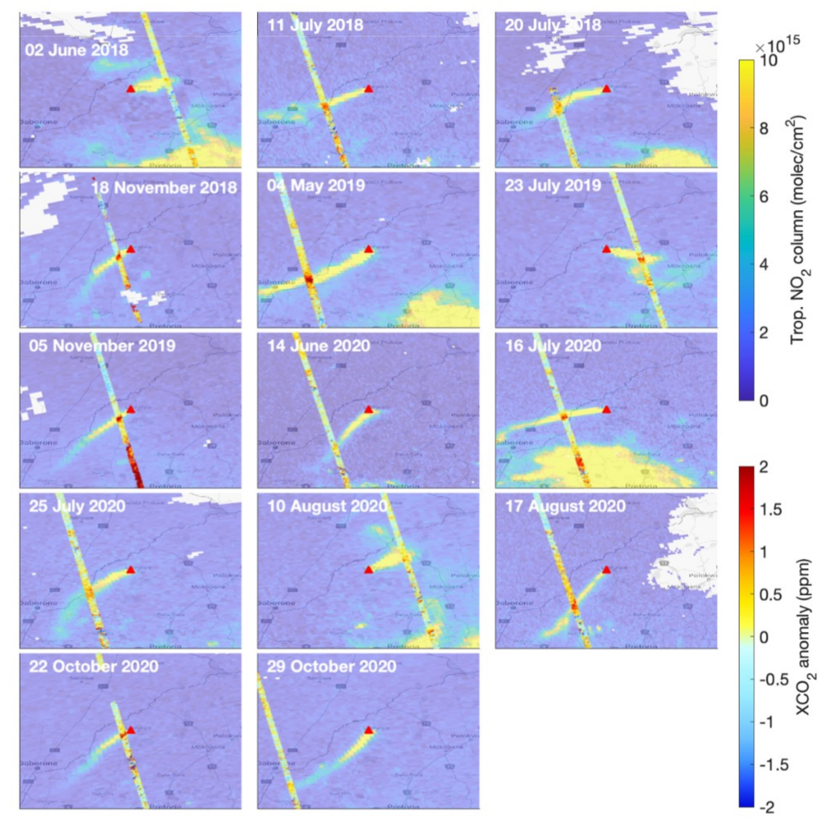
$$XCO_2^a(x,y,t) = XCO_2(x,y,t) - XCO_2^{bg}(t).$$

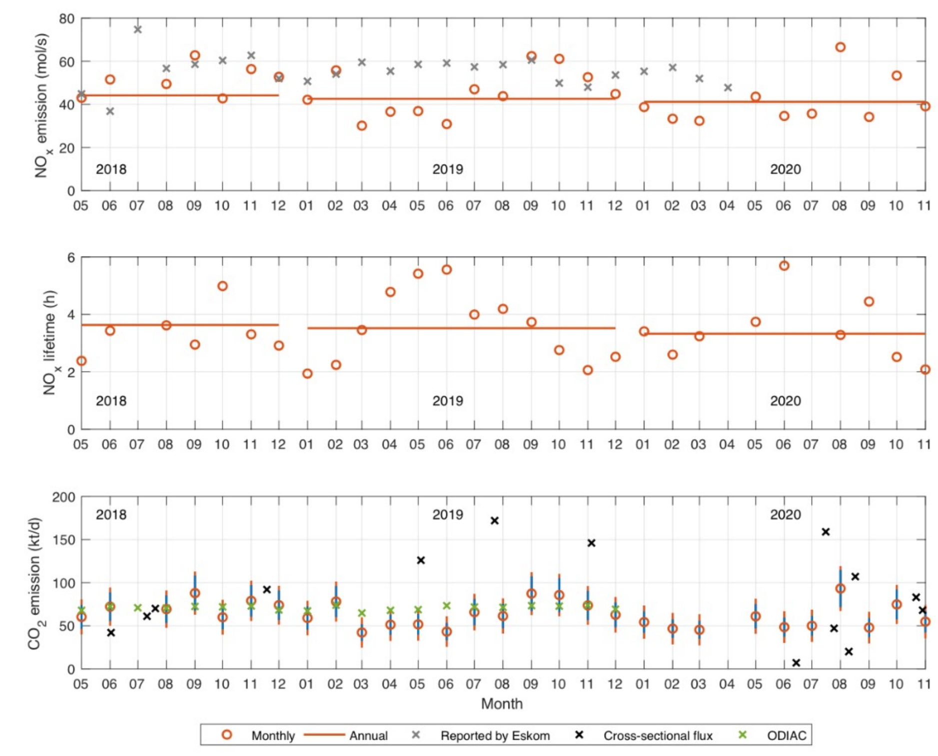
Future satellite missions such as the Copernicus CO_2 Monitoring Mission (CO2M), TanSat-2 and the GOSAT-GW will provide simultaneous CO_2 and NO_2 observations with wider swath than the current missions (Figure below)



Simulated CO2M observations. Figure by Gerrit Kuhlmann, Empa.

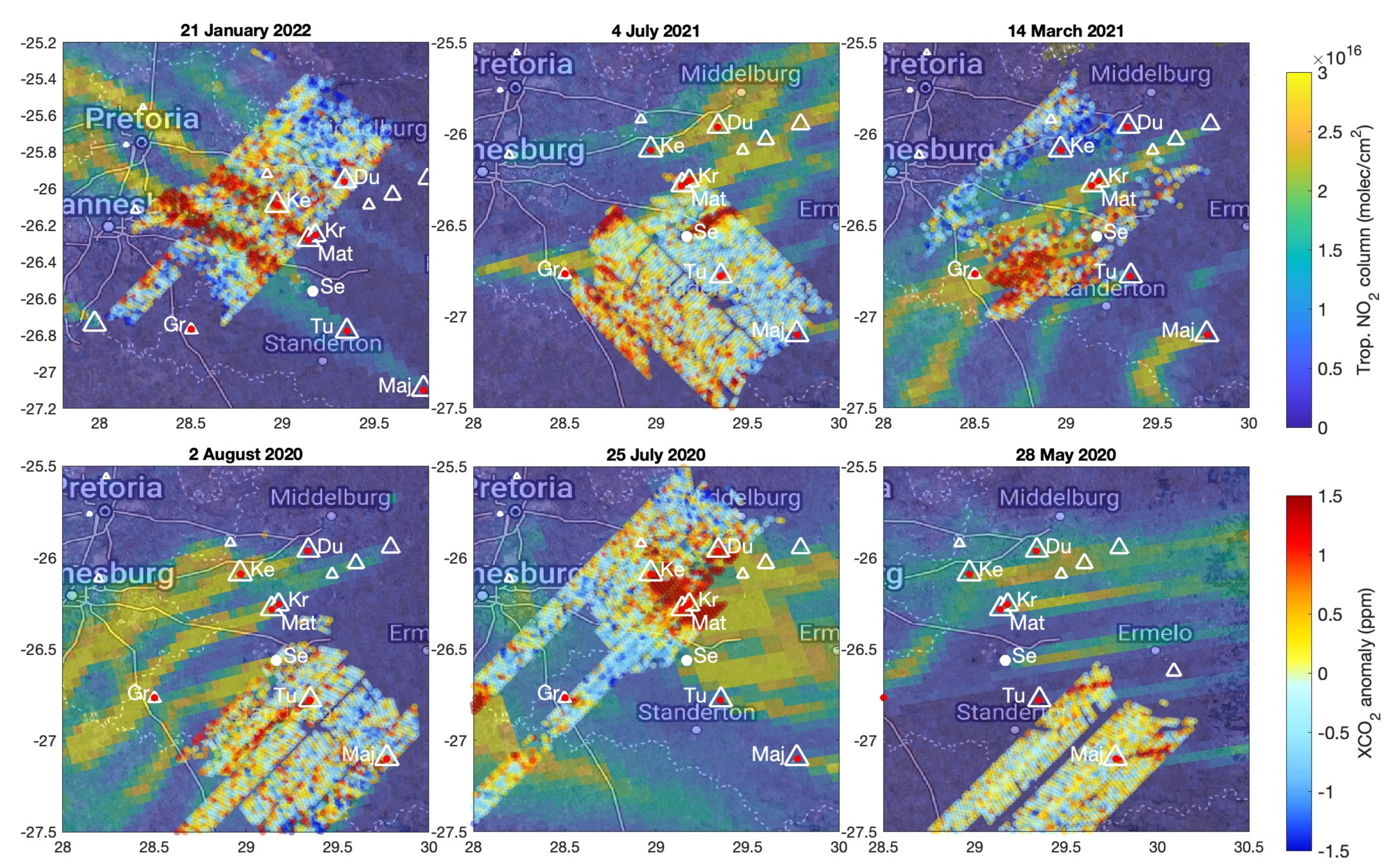
OCO-2

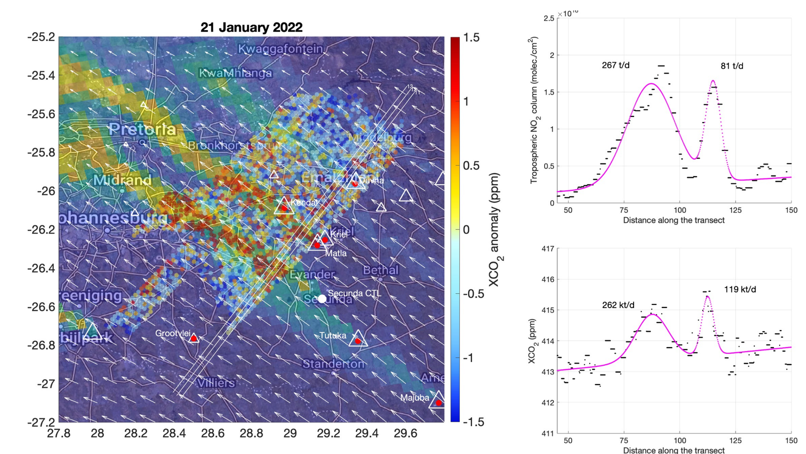


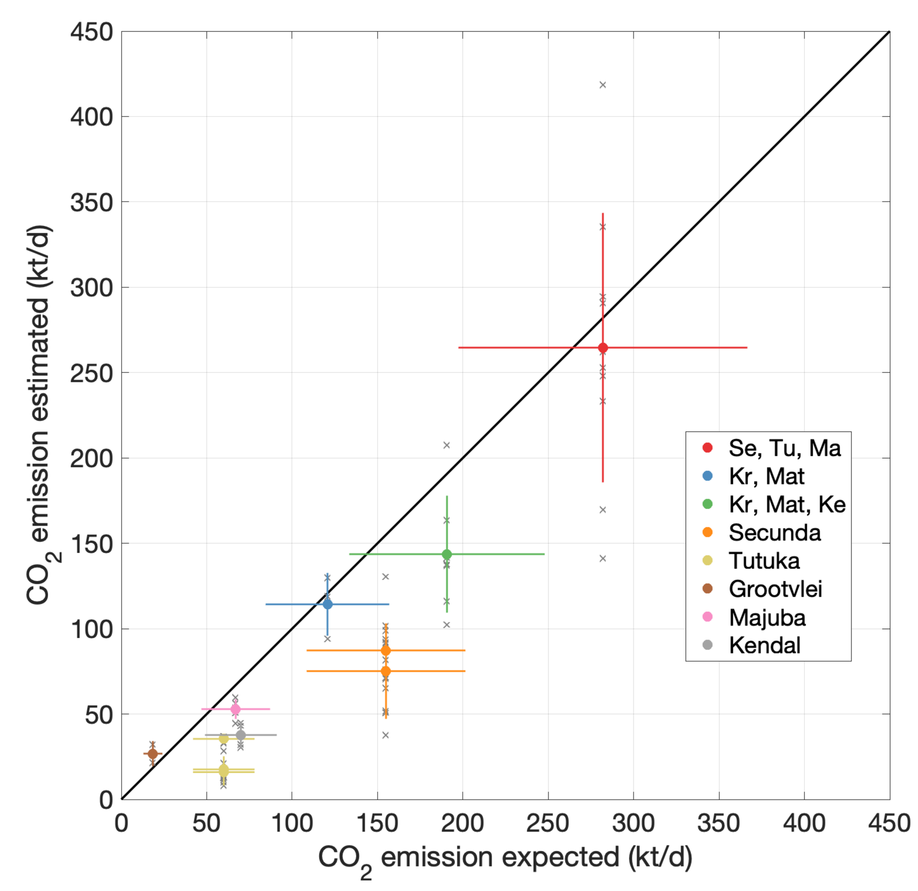


Left: OCO-2 and S5P/TROPOMI observations near Matimba power station (red triangle) in South Africa between May 2018 and November 2020. **Right:** The mean emission ratio of $(2.6 \pm 0.6) \times 10^{-3}$ is obtained for Matimba Power Station. The annual CO_2 emissions for Matimba are ~60 kt/d. The emission estimates are consistent with existing inventories such as ODIAC. More details [1].

OCO-3

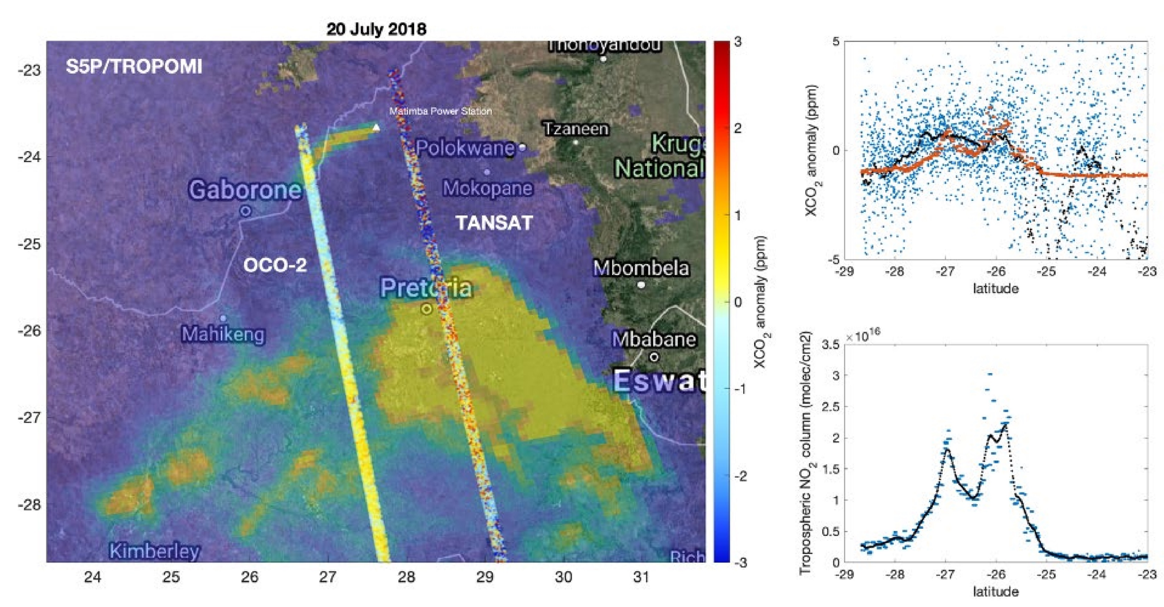


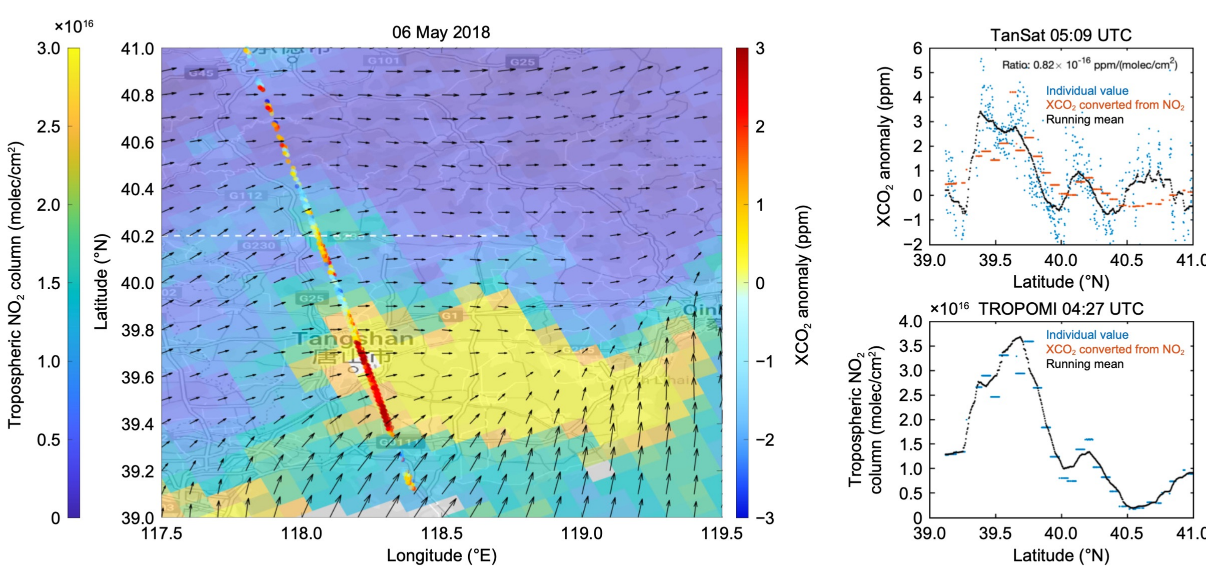




Left: Six OCO-3 SAMs analyzed in this study over the Highveld region, South Africa. The TROPOMI NO_2 tropospheric column fields are overlaid by the OCO-3 XCO_2 anomalies. **Top right:** Cross-sectional NO_x and CO_2 flux calculated along the transects indicated (white lines). **Bottom right:** Summary of the CO_2 emissions from all the cases analyzed. More details [2].

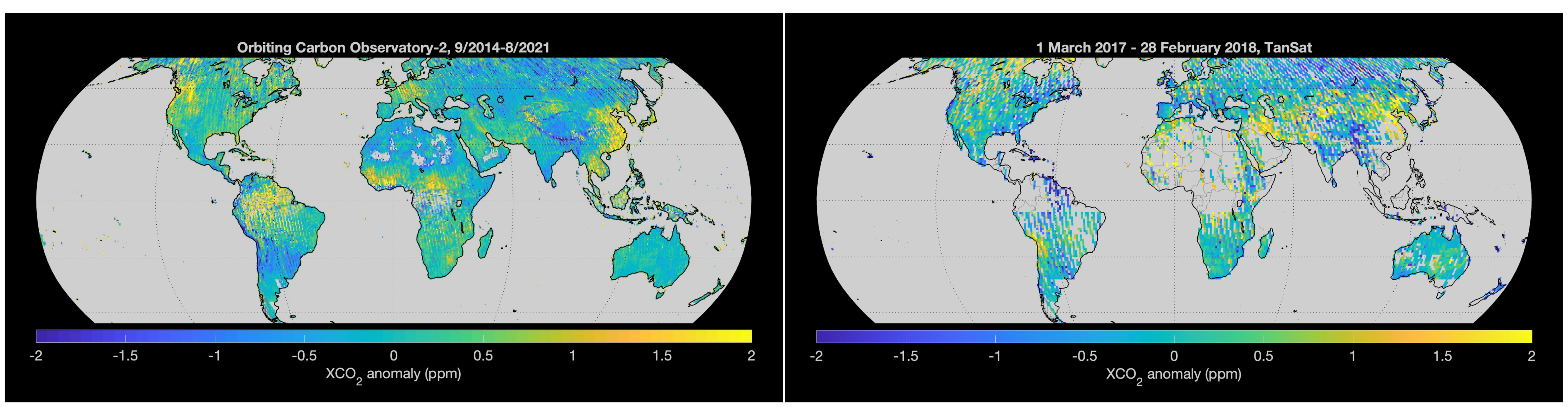
TanSat





Left: Detection of anthropogenic plumes using TanSat, OCO-2 and Sentinel 5P satellites in Highveld area in South Africa, where several power plants are located. We illustrate the cross-sections of the plumes along the TanSat track as a function of latitude. **Right:** TROPOMI NO_2 observations overlapped by TanSat XCO_2 observation near Tangshan (China) on 6 May 2018. ERA5 wind fields are shown as arrows. TanSat observes CO_2 enhancements of 3–4 ppm from Tangshan. More details [3].

Global XCO_2 anomalies



Global OCO-2 (left) and TanSat (right) XCO_2 anomalies. Positive anomalies are seen over most industrialized areas such as China, Europe, USA, Middle East and South Africa. They are also seen in regions of Africa and South America with frequent and intense forest fires.

Take Home Message

- OCO-2/3, TanSat and S5P/TROPOMI are important tools for monitoring anthropogenic emission sources from space

References:

[1] Janne Hakkarainen, Iolanda Ialongo, Tomohiro Oda, Monika E. Szeląg, Christopher W. O'Dell, Annmarie Eldering, and David Crisp: Building a bridge: Characterizing major anthropogenic point sources in the South African Highveld region using OCO-3 carbon dioxide Snapshot Area Maps and Sentinel-5P/TROPOMI nitrogen dioxide columns, Environmental Research Letters, vol. 18, no. 3, doi:10.1088/1748-9326/acb837, 2023.

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[3] Dongxu Yang, Janne Hakkarainen, Yi Liu, Iolanda Ialongo, Zhaonan Cai, and Johanna Tamminen: Detection of anthropogenic CO2 emission signatures with TanSat CO2 and with Copernicus Sentinel-5 Precursor (S5P) NO2 measurements: first results, Advances in Atmospheric Sciences, doi:10.1007/s00376-022-2237-5, 2022.