Environment and Climate Change Canada | Environnement et Changement climatique Canada

Monitoring facility-scale CO_2 emission changes from space

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AGU PUBLICATIONS

Geophysical Research Letters

2017 and 2021 papers demonstrated method with OCO-2

RESEARCH LETTER
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Quantifying CO_2 Emissions From Individual Power Plants From Space

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Key Points:
- The combustion of coal for electricity generation accounts for more than 40% of global anthropogenic CO_2 emissions
- Orbiting Carbon Observatory 2 observations can be used to quantify CO_2 emissions from individual coal power plants, in selected cases
- This work suggests that a future constellation of CO_2 imaging satellites could monitor fossil fuel power plant CO_2 emissions to support climate policy

Supporting Information:
- Supporting Information S1

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Abstract In order to bett
emissions are needed at all sp
Orbiting Carbon Observatory
show that in some cases, CO_2
individual middle- to large-siz
estimates for U.S. power plan
of the approach to internatior
of future CO_2 imaging satellit
plants to support the implem

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Advances in quantifying power plant CO_2 emissions with OCO-2

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Overview of Method and Equations

- Identify background and enhancement in OCO-2 XCO_2
- Fit observed OCO-2 XCO_2 enhancements to 2D Gaussian plume model
- Optimize wind direction by iterating fit with small adjustments to wind direction to maximize correlation coefficient (R)
- Determine emission estimates, varying some parameters yielding an ensemble of estimates for quantifying uncertainties

$$V(x,y) = \frac{F}{\sqrt{2\pi}\sigma_y(x)u} e^{-\frac{1}{2}\left(\frac{y}{\sigma_y(x)}\right)^2}$$

$$\sigma_y(x) = a \cdot \left(\frac{x}{x_o}\right)^{0.894}$$

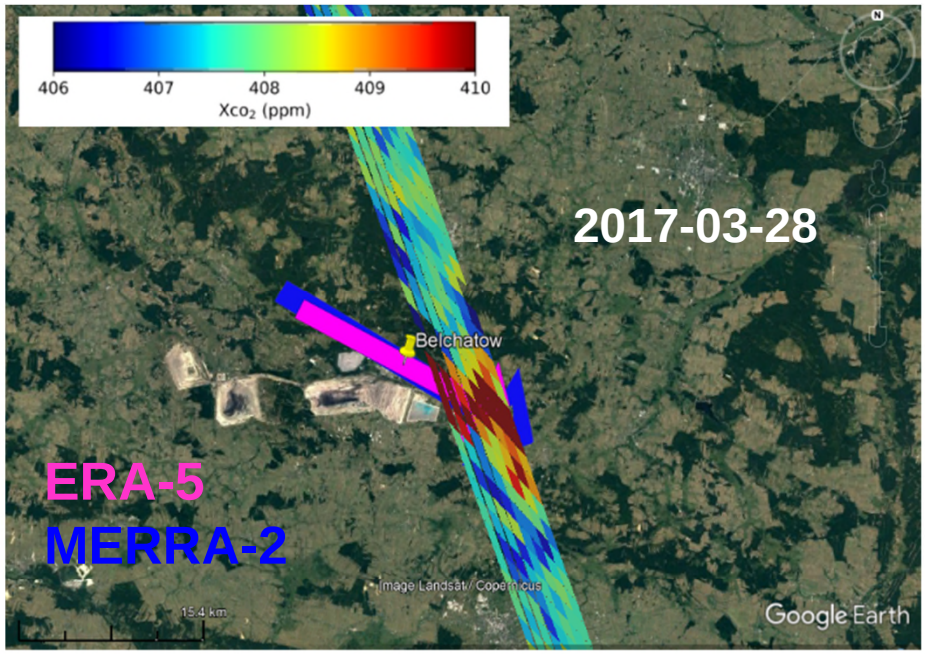
V is the CO_2 vertical column (g/m^2) downwind of the point source
x is along wind distance (m) (x_o = 1000 m is a characteristic length)
y is across wind distance (m)
F is emission rate (g/s)
u is the wind speed (m/s)
σ_y is the standard deviation in the wide direction (measure of the plume width) (m)
a is the atmospheric stability parameter

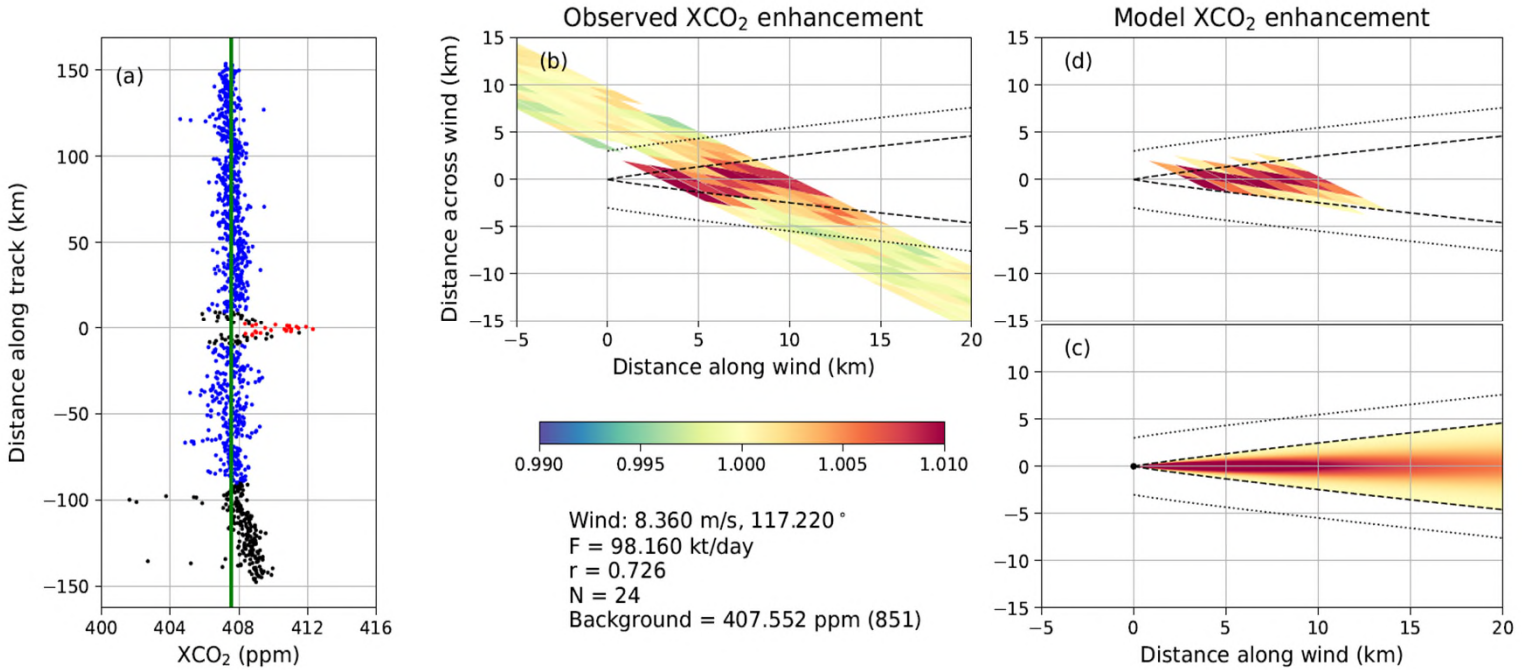
$$\varepsilon = \sqrt{\varepsilon_w{}^2 + \varepsilon_b{}^2 + \varepsilon_e{}^2 + \varepsilon_r{}^2}$$

Wind Background Enhancement Rise

Bełchatów Power Plant

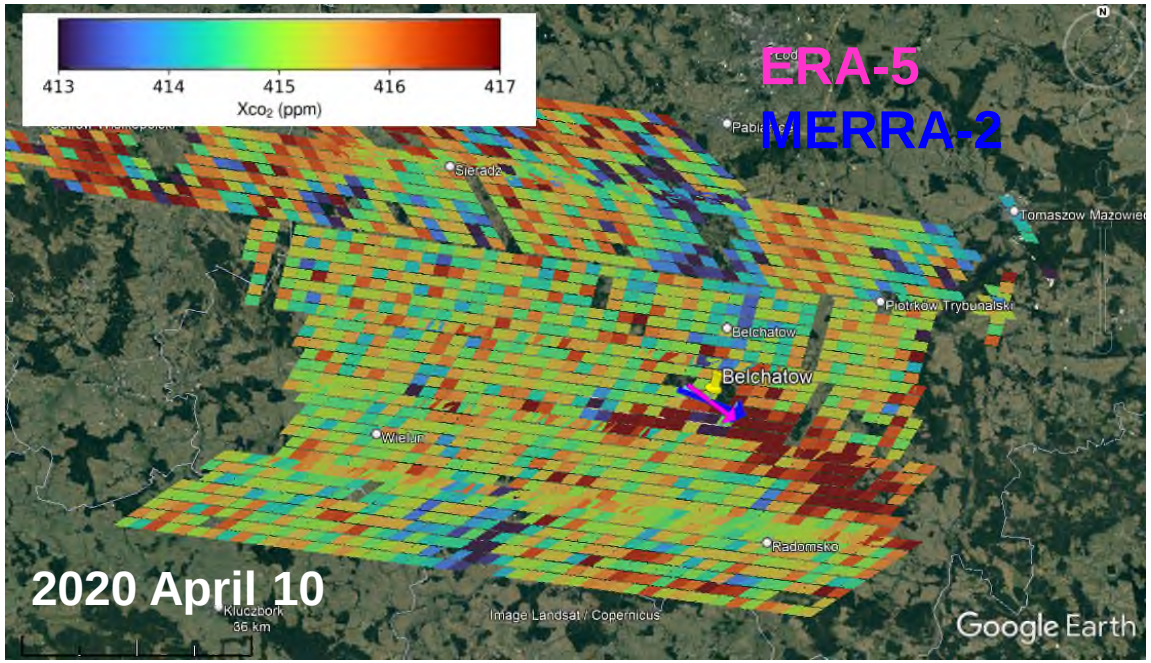
- Largest fossil fuel power plant in Europe
- 5th largest in the world (5102 MW)
- Reported emissions for 2017 are 37.6 $MtCO_2$, average of 103.0 $ktCO_2$/day





- Wind rotation of -2.0° applied, gives very good model-data correlation (R = 0.726)
- Estimate 98.2 ± 12.1 $ktCO_2$/day with ±9.6 $ktCO_2$/day due to wind speed uncertainty

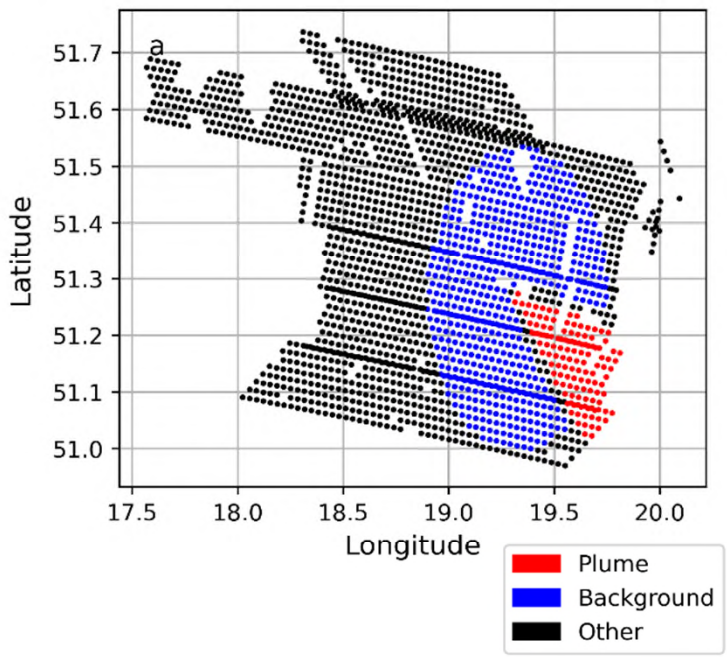
Quantifying CO_2 Emission Changes at Bełchatów

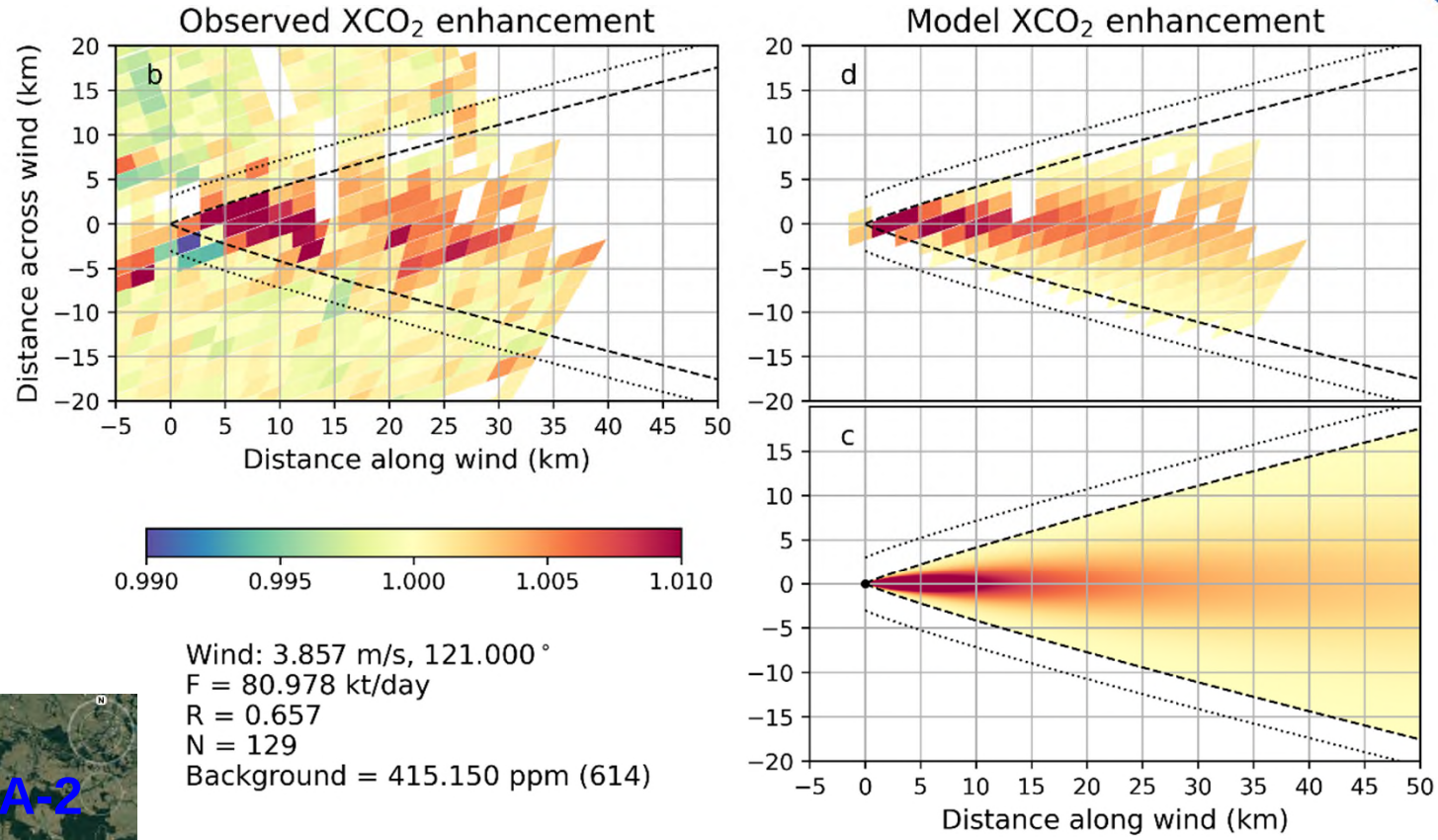


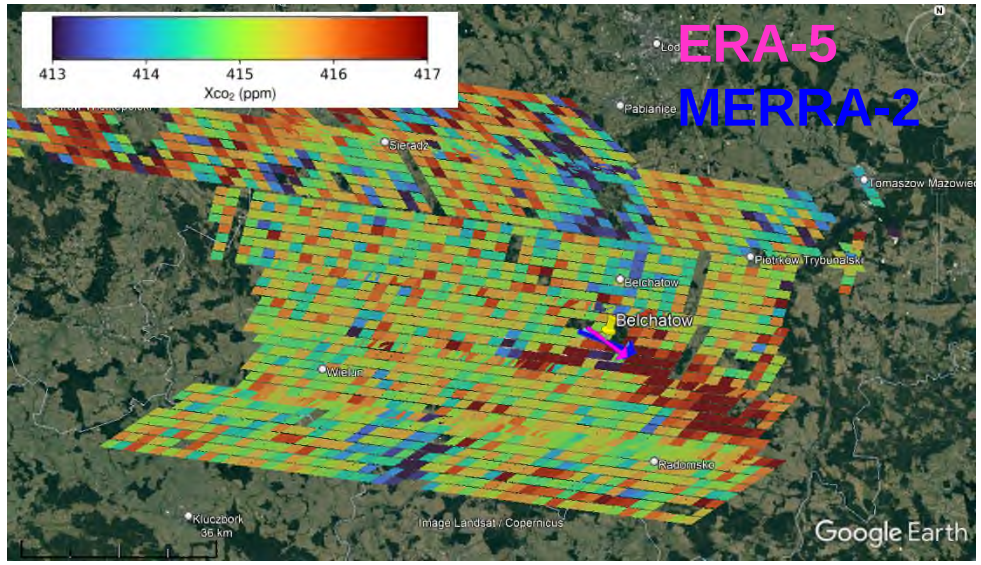
Overpass	Mission	Power Generated at overpass time (MW)*	Expected emissions ($ktCO_2$/day)
2017-03-28	OCO-2	4755	103.0
2020-04-08	OCO-3	3615	78.3
2020-04-10	OCO-3	3601	78.0
2020-04-17	OCO-3	3230	70.0
2021-06-18	OCO-3	3666	79.4
2021-06-19	OCO-3	3724	80.7
2021-06-20	OCO-3	1971	42.7
2021-10-08	OCO-3	2785	60.3
2021-10-09	OCO-3	1784	38.6

- Multiple OCO-3 v10 Snapshot Area Maps (SAMs) of Bełchatów power plant in 2020-2021 now available
- We can compare our emissions estimates derived from OCO-2/OCO-3 to those expected based on hourly power generation available from the European Network of Transmission System Operators for Electricity Transparency Framework

OCO-3 v10 Bełchatów 2020-04-10



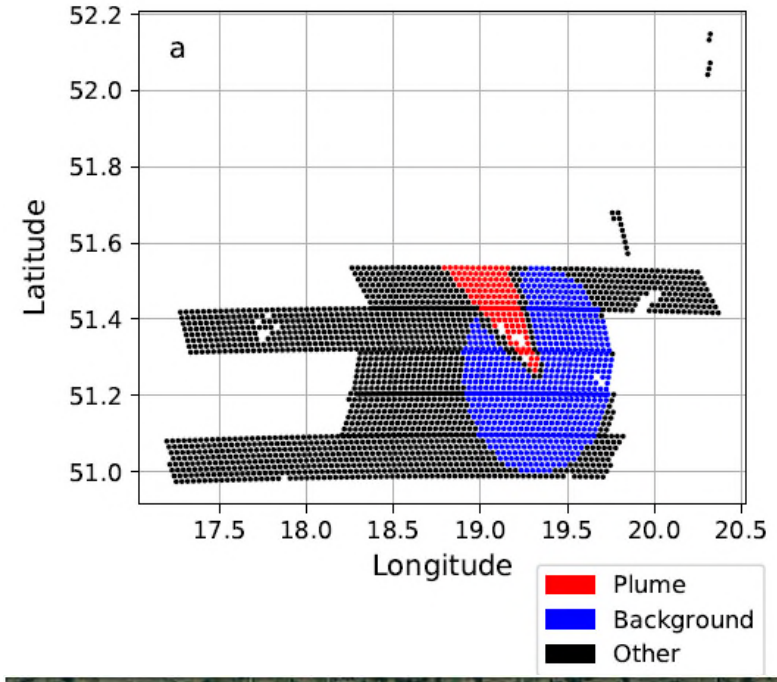


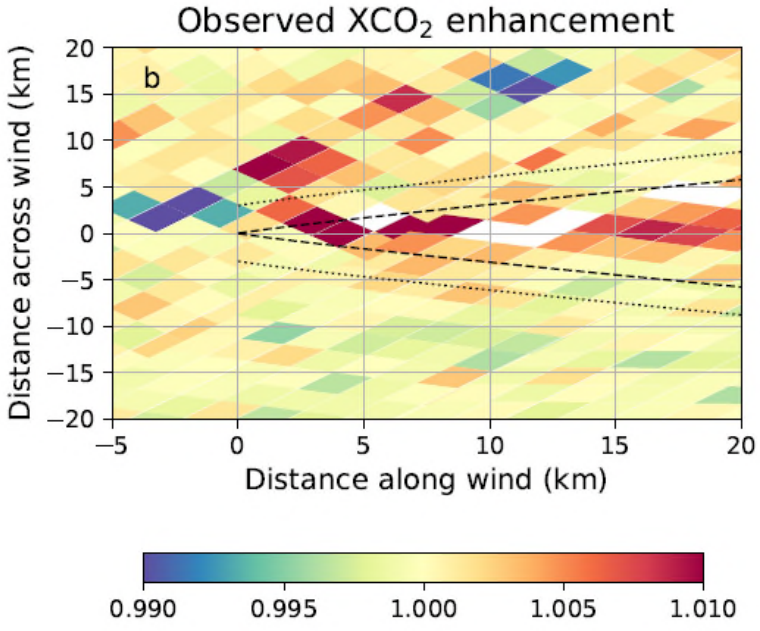


OCO-3 background is average of footprints taken within a specified radius from the source, excluding a sector corresponding to the plume and a narrow buffer zone.

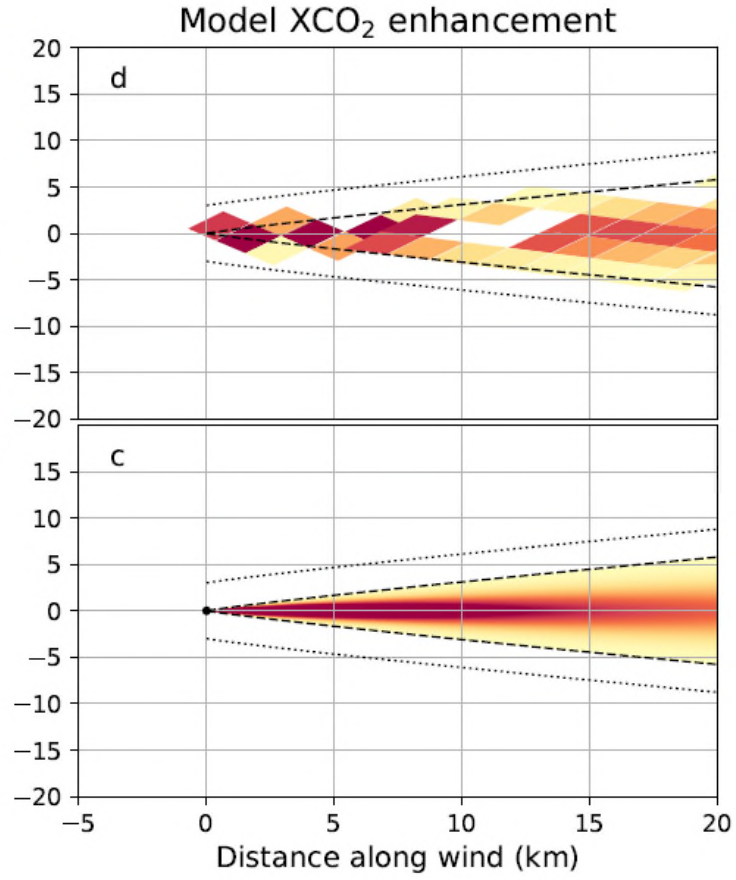
78.0 kt/day (Power Generation) **81.0±8.3** kt/day (OCO-3) with wind uncertainty of 8.2 kt/day

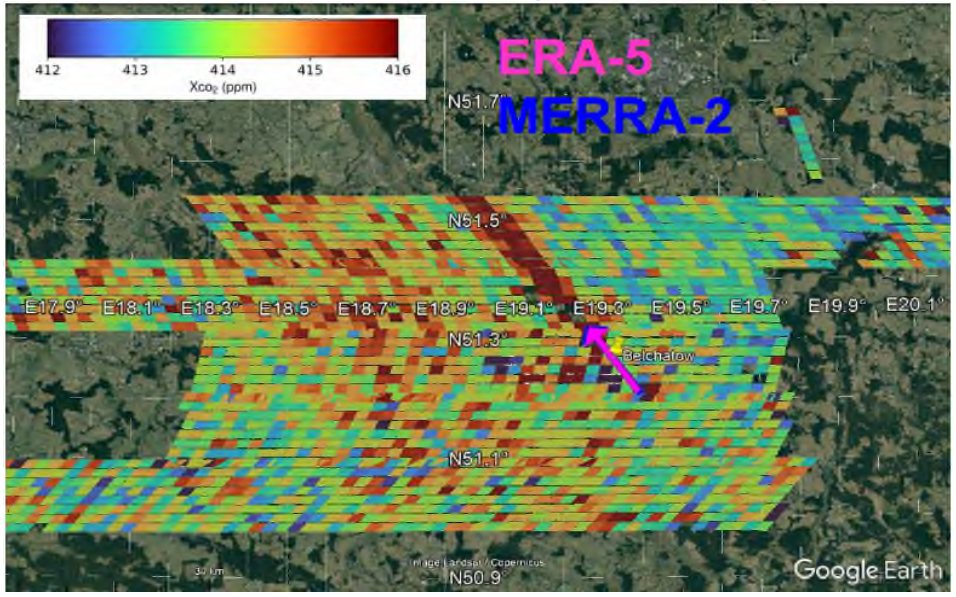
OCO-3 v10 Bełchatów 2021-06-18





Wind: 5.777 m/s, -36.718 °
F = 101.163 kt/day
R = 0.715
N = 121
Background = 414.038 ppm (676)

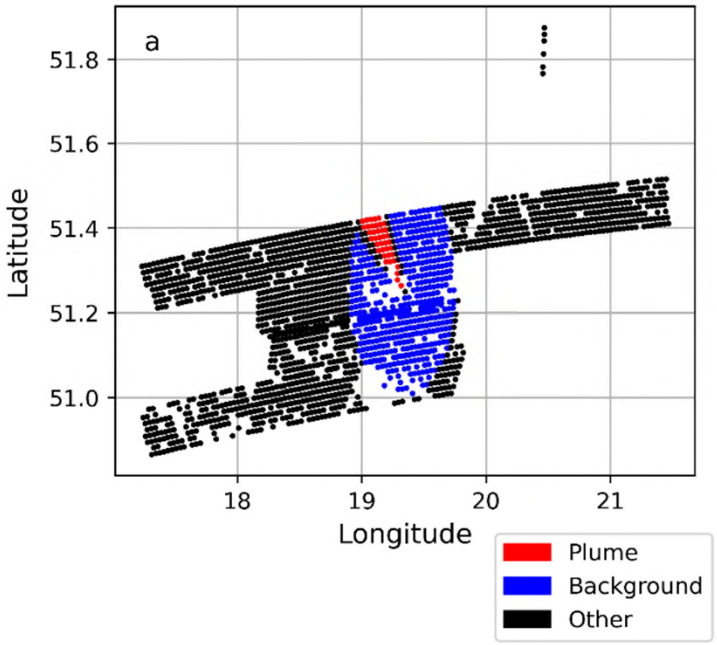


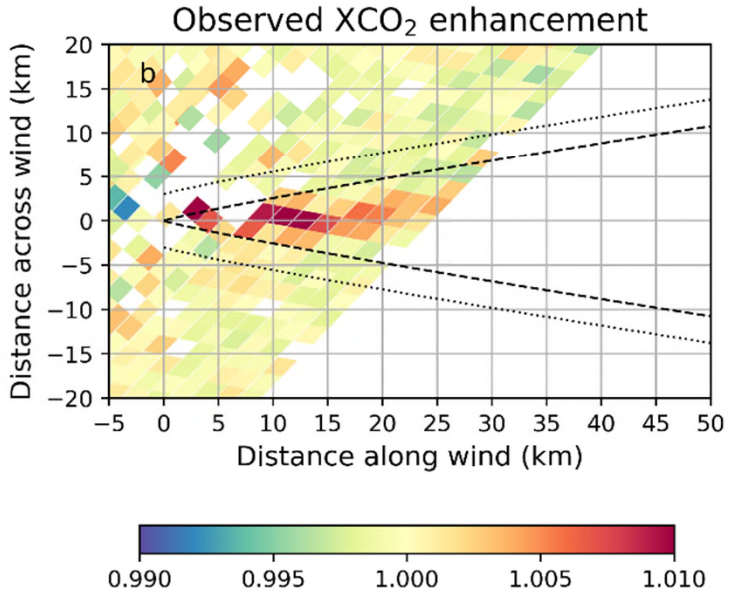


79.4 kt/day (Power Generation) **101.1±4.3** kt/day (OCO-3)
with wind uncertainty 4.0 kt/day

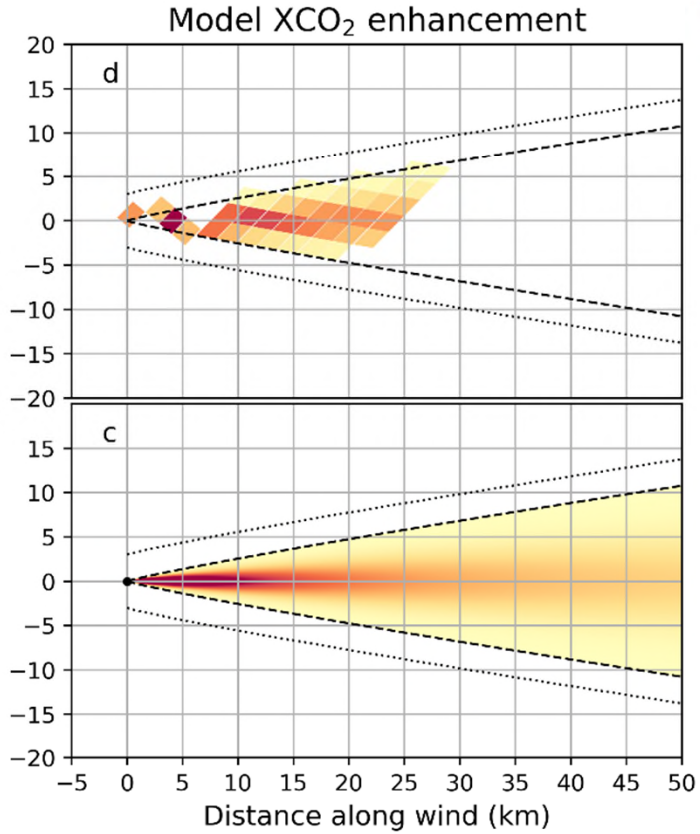
Strong symmetric plume, moderate wind speed, good correlation.
Asymmetric background may be source of discrepancy.

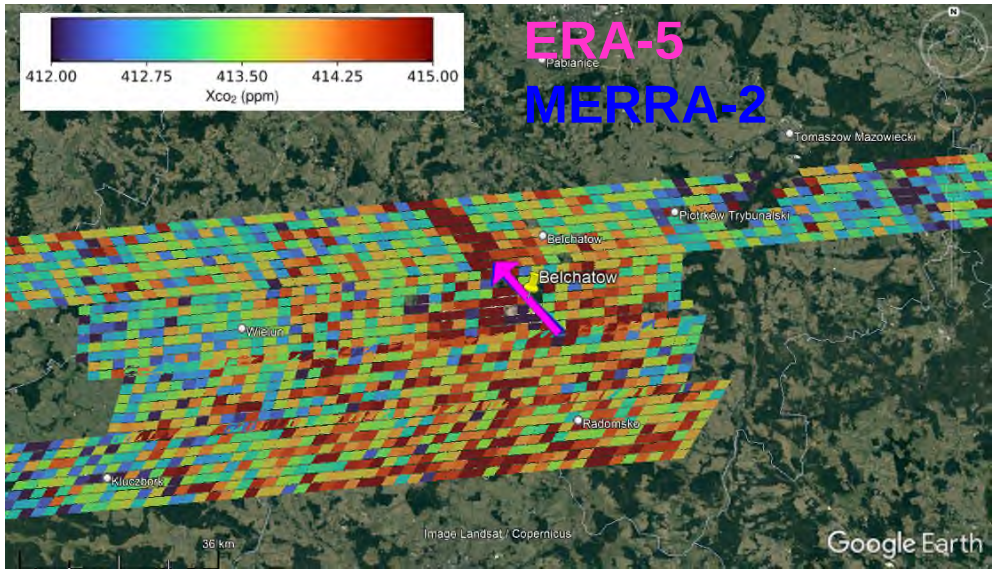
OCO-3 v10 Bełchatów 2021-06-19





Wind: 6.550 m/s, -42.639°
F = 79.748 kt/day
R = 0.703
N = 39
Background = 413.912 ppm (488)



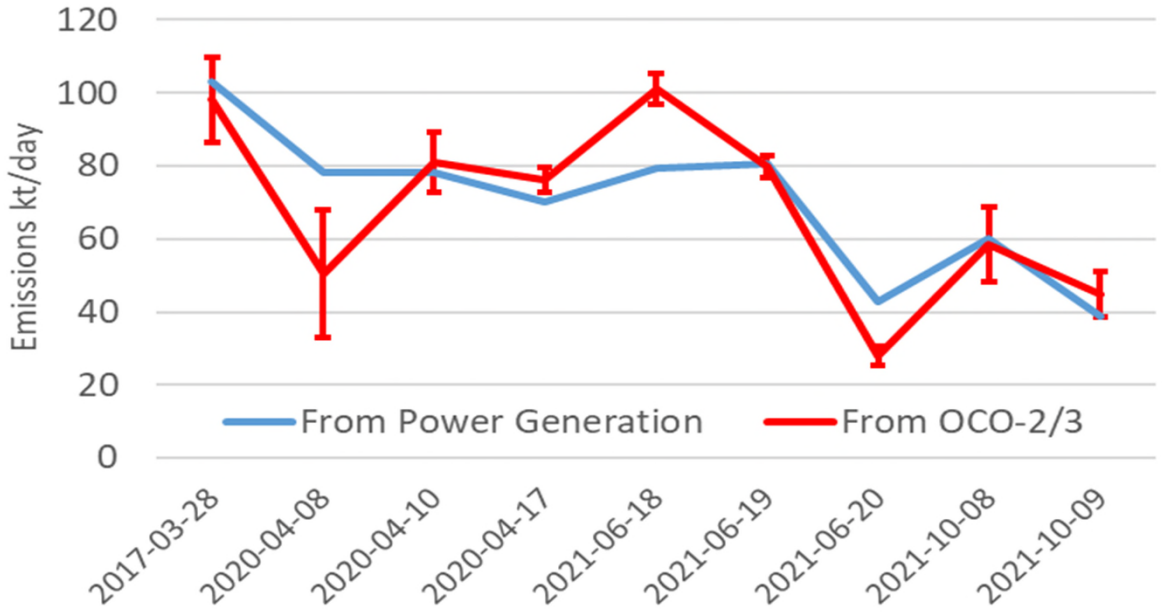


80.7 kt/day (Power Generation) **79.8±3.0** kt/day (OCO-3).
Background uncertainty of 2.7 kt/day is largest source.

Moderate wind speed, reasonable background, symmetric plume, good correlation and excellent agreement.

Quantifying CO_2 Emission Changes at Bełchatów

Overpass	Mission	Power Generated at overpass time (MW)*	Expected emissions ($ktCO_2$/day)	OCO mission emission estimate ($ktCO_2$/day)	Expected & observed % change	Correlation	Footprints in plume (background)
2017-03-28	**OCO-2**	**4755**	**103.0**	**98.2 ± 11.7**	**Baseline**	**0.726**	**24 (851)**
2020-04-08	OCO-3	3615	78.3	50.5 ± 17.6	-24 / -49 %	0.636	240 (466)
2020-04-10	OCO-3	3601	78.0	81.0 ± 8.3	-24 / -18 %	0.657	129 (614)
2020-04-17	OCO-3	3230	70.0	76.3 ± 3.4	-32 / -22 %	0.332	91 (476)
2021-06-18	OCO-3	3666	79.4	101.1 ± 4.3	-23 / +3 %	0.715	121 (676)
2021-06-19	OCO-3	3724	80.7	79.8 ± 3.0	-22 / -19 %	0.703	39 (488)
2021-06-20	OCO-3	1971	42.7	28.0 ± 2.6	-59 / -71 %	0.544	81 (549)
2021-10-08	OCO-3	2785	60.3	58.5 ± 10.3	-41 / -40 %	0.471	115 (529)
2021-10-09	OCO-3	1784	38.6	44.7 ± 6.3	-62 / -54 %	0.280	141 (426)



*Hourly power generation at facility unit level from entso-e

Estimated CO_2 emissions are consistent with trend expected from reported power generation for ~7 of 9 points in timeseries, demonstrating the ability to quantify short-term emission changes to support policy.

Conclusions

- NASA's OCO-2 and OCO-3 have enabled quantification of CO_2 emissions from large and medium-sized power plants in select cases, but narrow swath and limited coverage are key limitations.

- Despite these limitations, we have demonstrated the ability to quantify emission reductions of a few percent from a large power plant

- Our findings suggest a role for space-based monitoring of facility-scale CO_2 emission reductions in support of the Paris Agreement and capabilities for this application will continue to improve as the constellation of satellites expands with CO2M, GOSAT-GW, GeoCarb and other imaging missions