Satellite monitoring of urban CO2 emissions: optimizing the selection of cities and meteorological conditions

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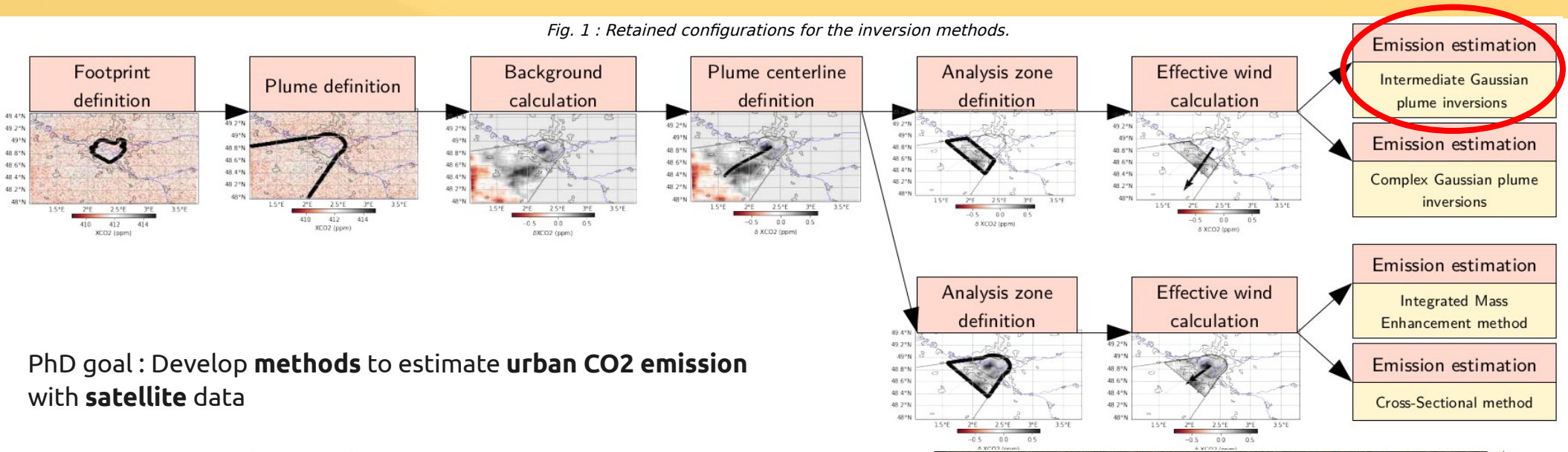
Inversion process

Fig. 1 : Retained configurations for the inversion methods.



PhD goal : Develop **methods** to estimate **urban CO2 emission** with **satellite** data

Study of **computationally-light** methods to estimate urban CO2 emissions:

- selection of the methods with synthetic data (test-case over Paris);

- analysis of the **sensitivity of the error** with synthetic data (31 cities);

- application to OCO-3 data.

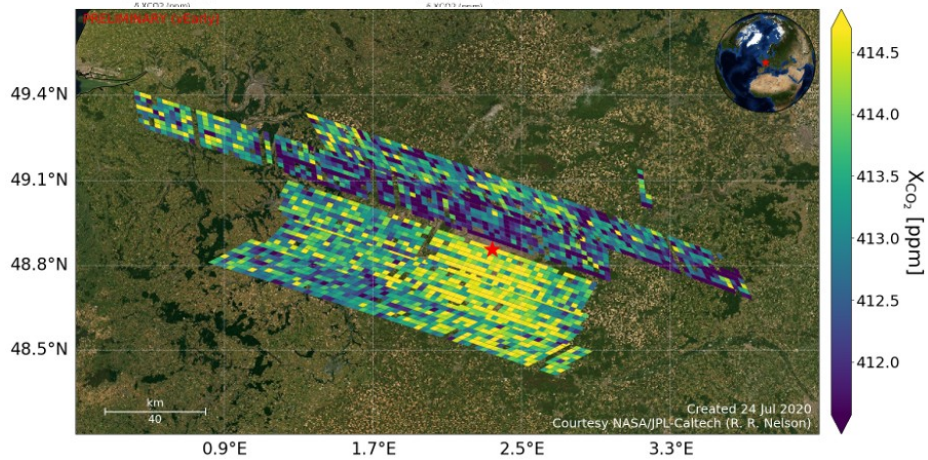


Fig. 2: XCO2 data from OCO-3 SAM over Paris on April 13th 2020.

Results of the first study (test-case over Paris)

First study : Evaluation of the **emissions estimation methods** and their **preprocessing steps**.

Focus on a test-case with **synthetic data** :

High-resolution simulations of hourly atmospheric CO2 concentrations (WRF-Chem V3.9.1) for 5 month over Paris;

Using Origins.Earth inventory.

Aim : (i) **parametrization** of the inversions methods, (ii) **analysis of the sensitivity** of the error.

Paris test-case	without filtering (100% of data)	with Paris filtering (57% of data)
WRF-grid sampling	6% [-38%,+56%]	4% [-29%,+45%]
OCO-3 like sampling	3% [-43%;+60%]	5% [-37%;+53%]

Table 1 : Total error obtained without and with filtering of the data, following criteria defined over Paris test-case. Results are obtained with Intermediate Gaussian plume method.

Main conclusions :

- **Small bias** when rightly configured, but **significant spread**;
- Main error sources come from the **background** and **effective wind** estimations.

Two main factors for the precision of the results :

- **spatial variability of the wind direction** in the PBL;
- variability of the XCO2 signal outside of the plume.

→ Those two factors result in a **seasonal dependency** of the error.

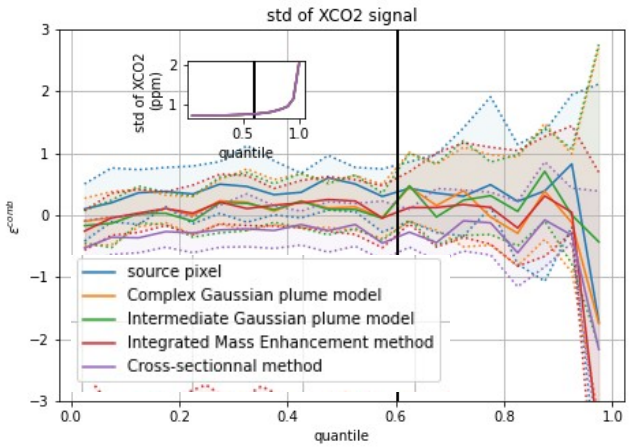


Fig. 3 : Error sensitivity to the spatial variability of the wind in the PBL and to std of the XCO2 signal

Context

Question : What is the **influence** of the different **characteristics of a city** (size, compacity,..) and of the **meteorological conditions** on the error on the emission estimation?

Synthetic data simulation :

- model OLAM ([Schuh et al. 2021]);
- spatial resolution : octahedral variable resolution grid, reprojected on 100x100km^2 images at 3x3km resolution for **31 cities worldwide**;
  → **optimistic sampling** compared to real satellite data
- temporal coverage : August 2015,
- CO_2 data : ODIAC for anthropogenic emissions, CarbonTracker2017 for biogenic emissions.

→ Calculation of the error distribution for all cities, analysis of the **sensitivity to meteorological conditions** and **city characteristics**.

Overlook on the sensitivity of the error

Paris test-case	without filtering (100% of data)	with Paris filtering (57% of data)
WRF-grid sampling	6% [-38%,+56%]	4% [-29%,+45%]
OCO-3 like sampling	3% [-43%;+60%]	5% [-37%;+53%]

31 cities (100x100km, 3x3km)	without filtering (100% of data)	with Paris filtering (53% of data)
OLAM sampling	-16% [-53%,+35%]	-5% [-34%,+30%]

Table 2 : Total error obtained without and with filtering of the data, following criteria defined over Paris test-case. Results are obtained with Intermediate Gaussian plume method.

Criteria found in with Paris test-case **relevant**.

→ can we find **better ones**?

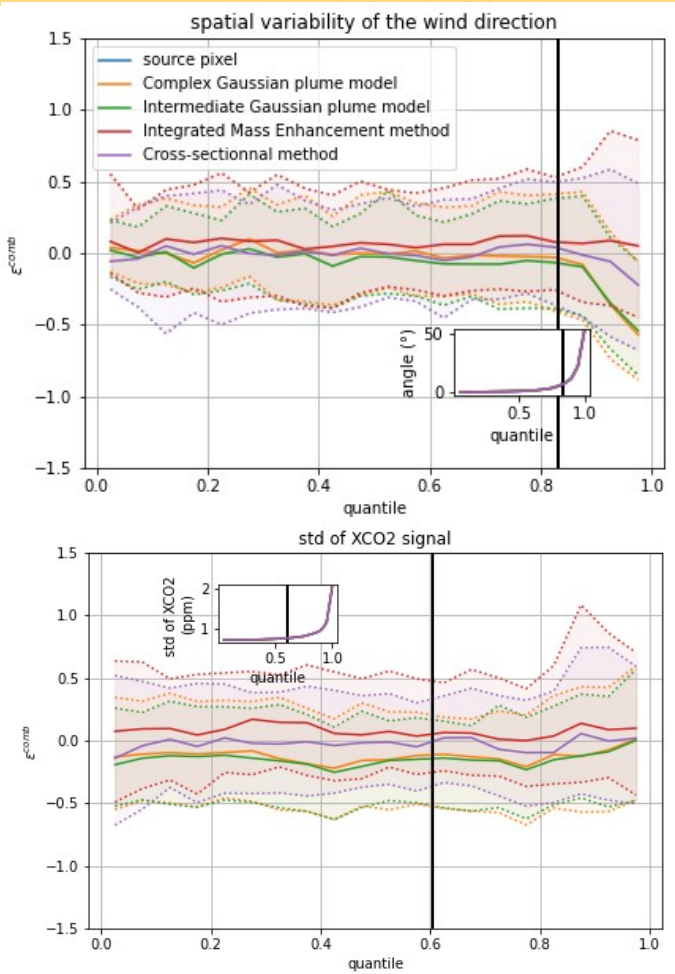


Fig. 4 : Error sensitivity to the spatial variability of the wind in the PBL and to std of the XCO2 signal.

Method to define the criteria

2 analysis

1. which **cities and weather situations** should be **favoured**?

   → give keys to decide **whether or not to acquire an image**.

2. once the image is taken and the inversion performed, how do we know if we can **trust the result**?

   → gives keys to **sort out the inversions**.

Criteria definition

separation of the dataset into **100 samples**;

application of a **decision tree learning method** to the 100 subsamples:

- depth of the tree 2 (separation in max 4 subsets),
- keep criteria that lead to subsets of the total dataset with a bias<10% and IQR<70%;

study of the **stability of the criteria** on the 100 resulting trees.

Results for the criteria optimization

Which cities and weather situations should be favoured?

Criteria in **79 cases out of 100** :

- **emission** levels in the city
- spatial **variability of the wind** direction.

→ **Stability** of the criteria but not so much of the threshold.

How do we know if we can trust the result?

Criteria in **68 cases out of 100**:

- **variability of the XCO2 signal** outside the plume.

→ Stability of the criteria, but precision of the threshold should be less than 0.01ppm.

We only retain the criteria of the first analysis:

	without filtering (100% of data)	with Paris filtering (53% of data)	with DT filtering (47% of the data)
OLAM sampling	-16% [-53%,+35%]	-5% [-34%,+30%]	-6% [-33%,22%]

Table 3 : Total error obtained with the different filtering strategies.

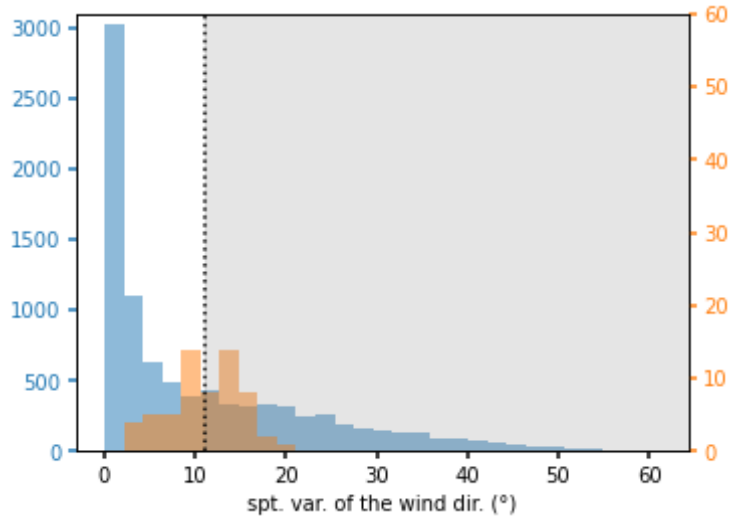


Fig. 5 : Distributions of the spatial variability of the wind direction of the dataset (blue) and the thresholds found with the decision trees (orange).

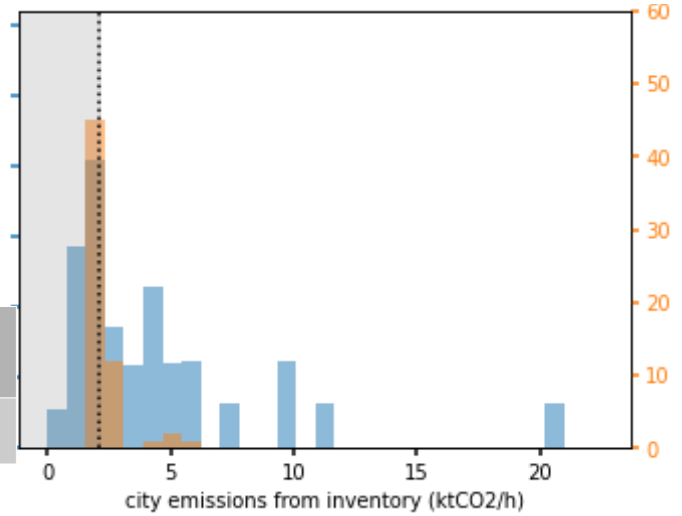


Fig. 6 : Same as figure 12 but for the emissions within the city..

Resulting error with the filtered data

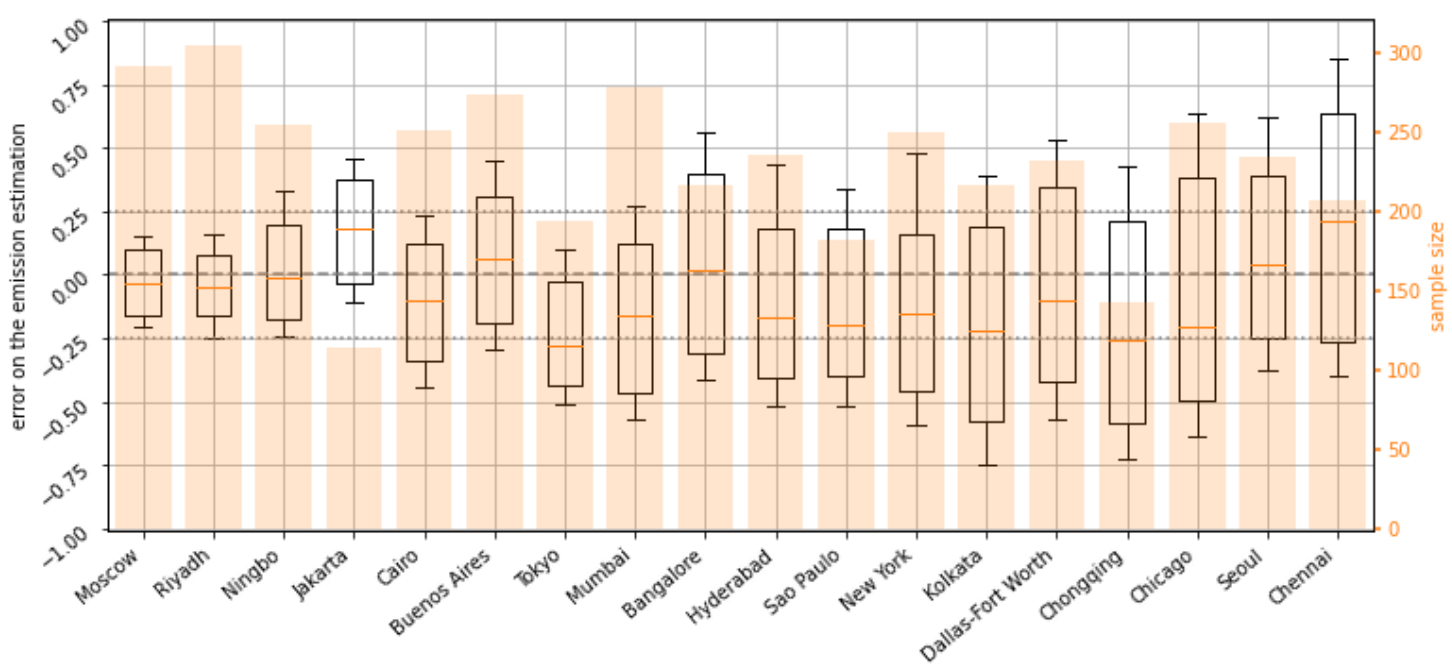


Fig. 7 : Total error distribution obtained for the cities simulated with OLAM using GP2 method.

Only 17 cities left (out of 31) after application of the criteria.

→ **Some cities and atmospheric conditions** are **more pertinent** to target than others for satellite inversion with light methods.

Criterion on the quality of the inversion were not found to be pertinent.

Conclusion

Results :

- Study on synthetic data show **promising results** for urban CO2 measurement with satellite.

  Not all cities are pertinent.

  Not all meteorological conditions are pertinent.

Next steps :

1. Application to OCO-3 data.
2. Add criteria to **control the match between the plume and wind directions** (wind product error).

Thank you for your attention!