Preliminary study of the estimation of CH_4 emissions from the Bordo Poniente landfill using a Gaussian Plume Model

EM27/SUN Telecon

August 24, 2023

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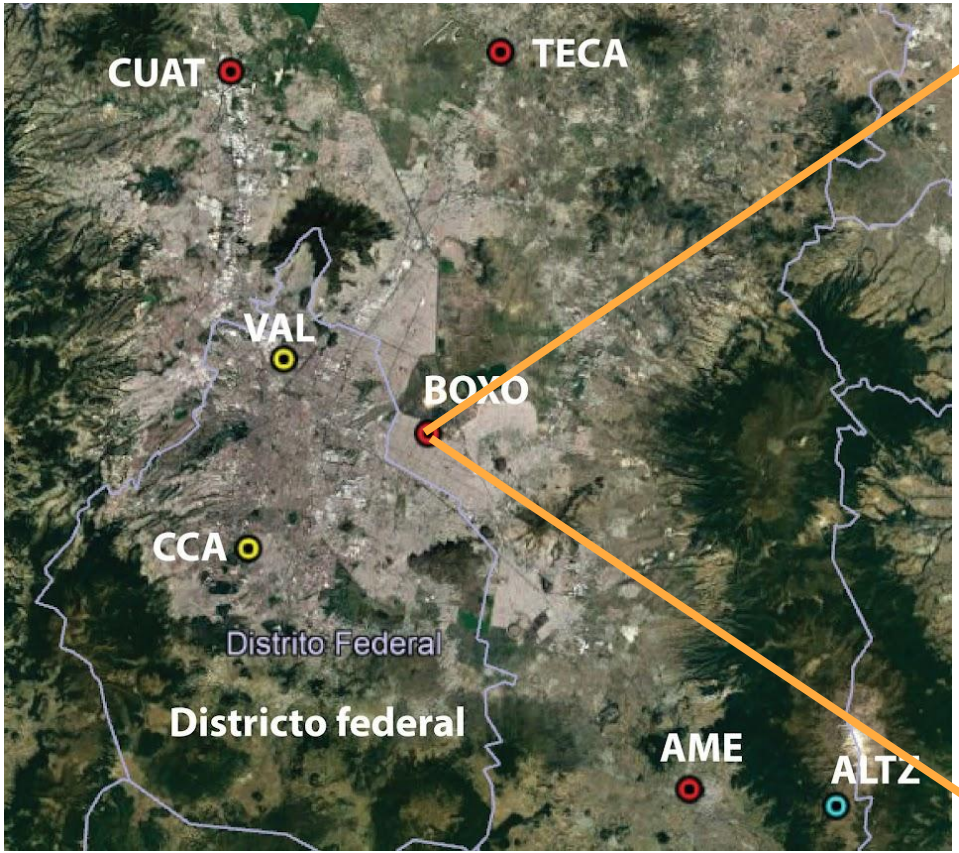
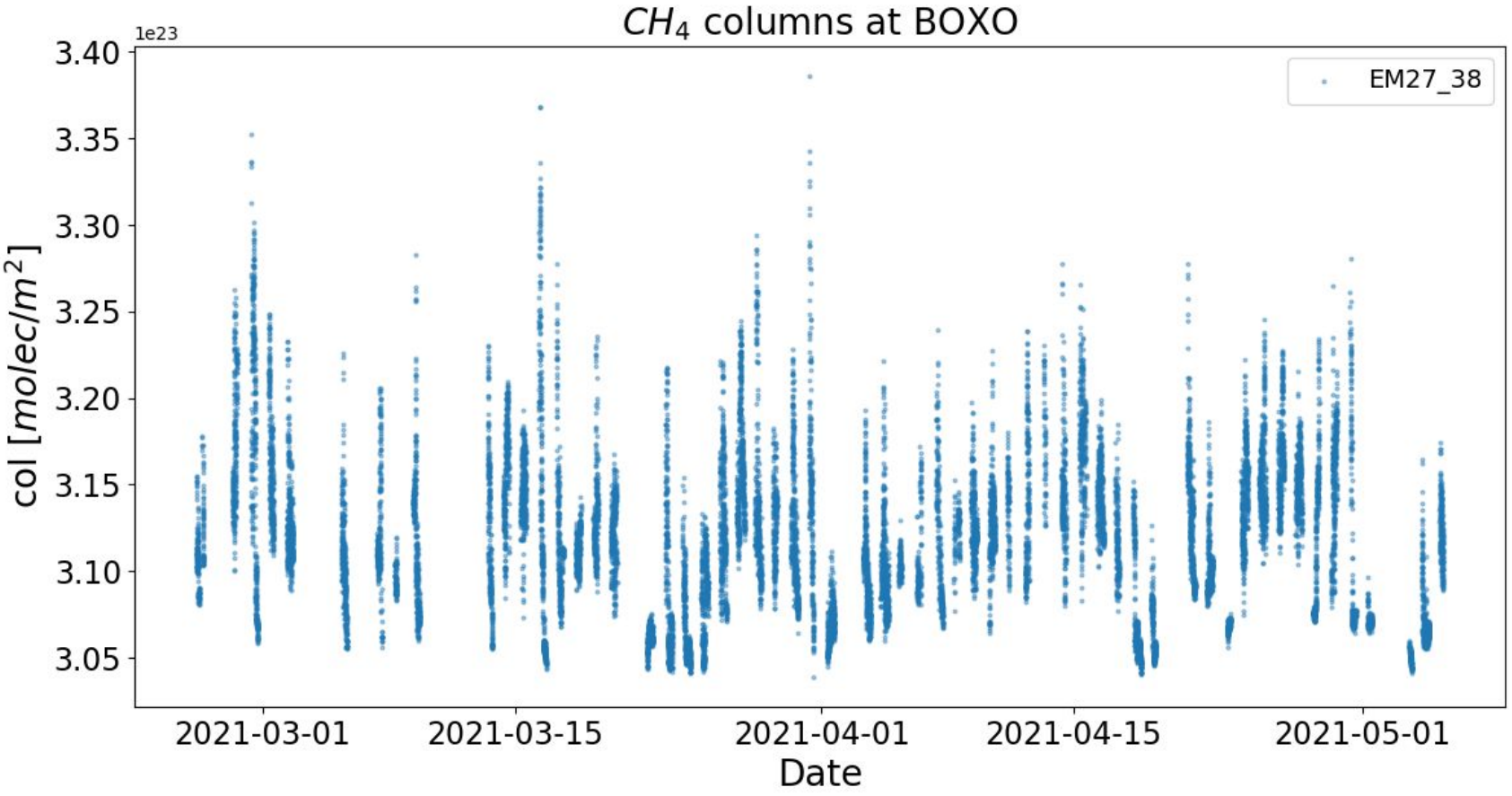
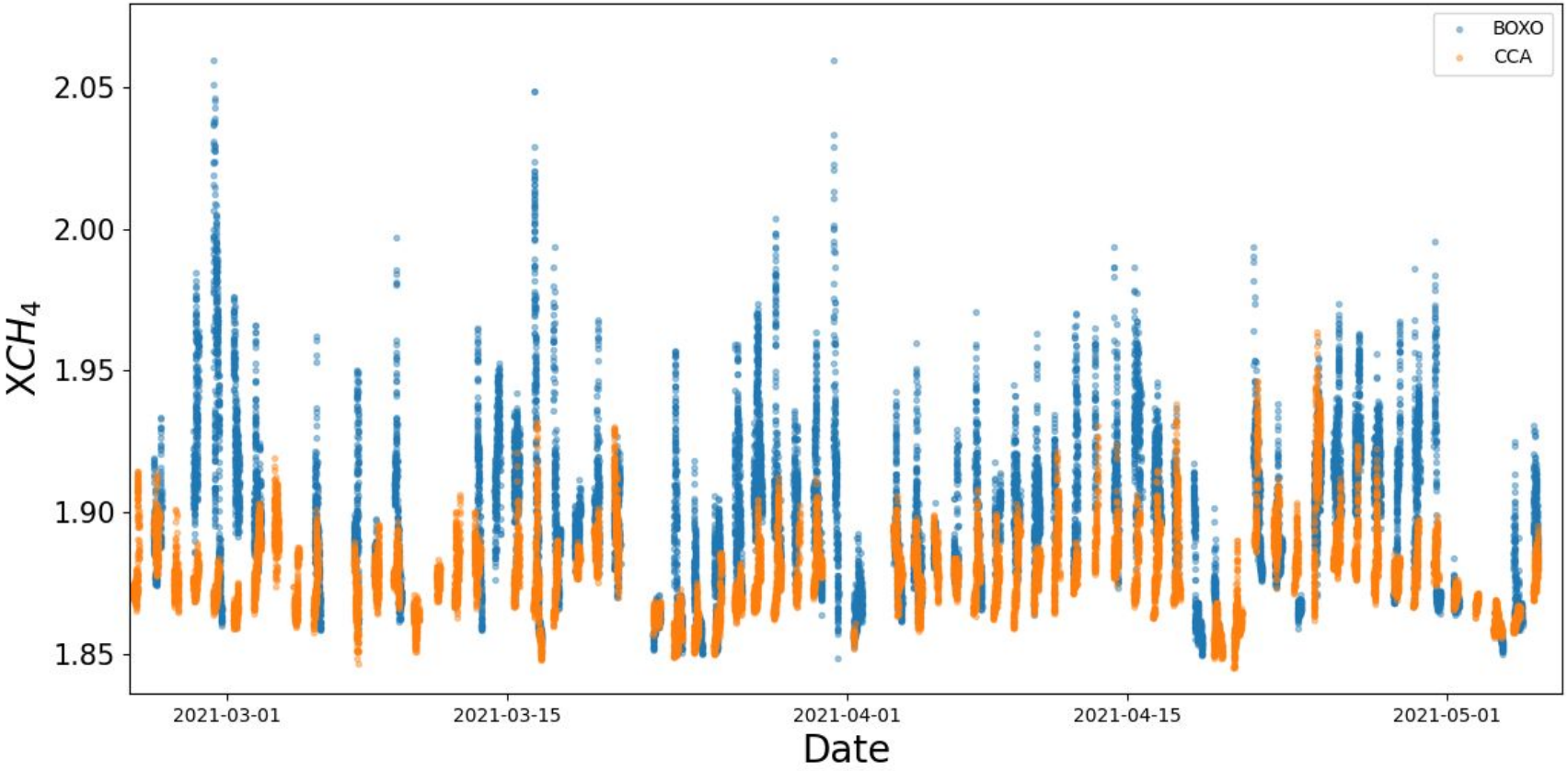
MERCI-CO_2


CUAT
TECA
VAL
BOXO
CCA
Distrito Federal
Districto federal
AME
ALTZ

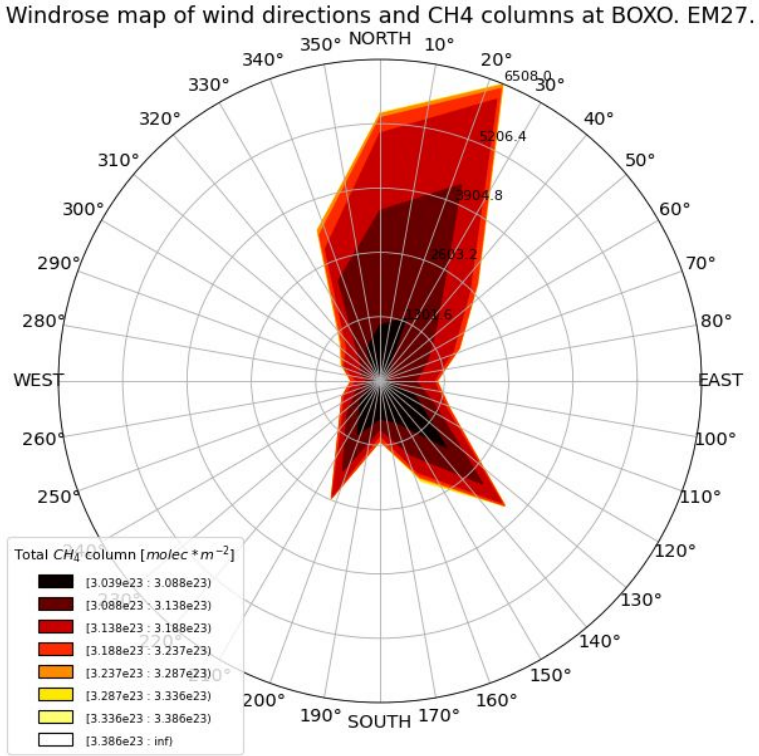
MERCI-CO_2

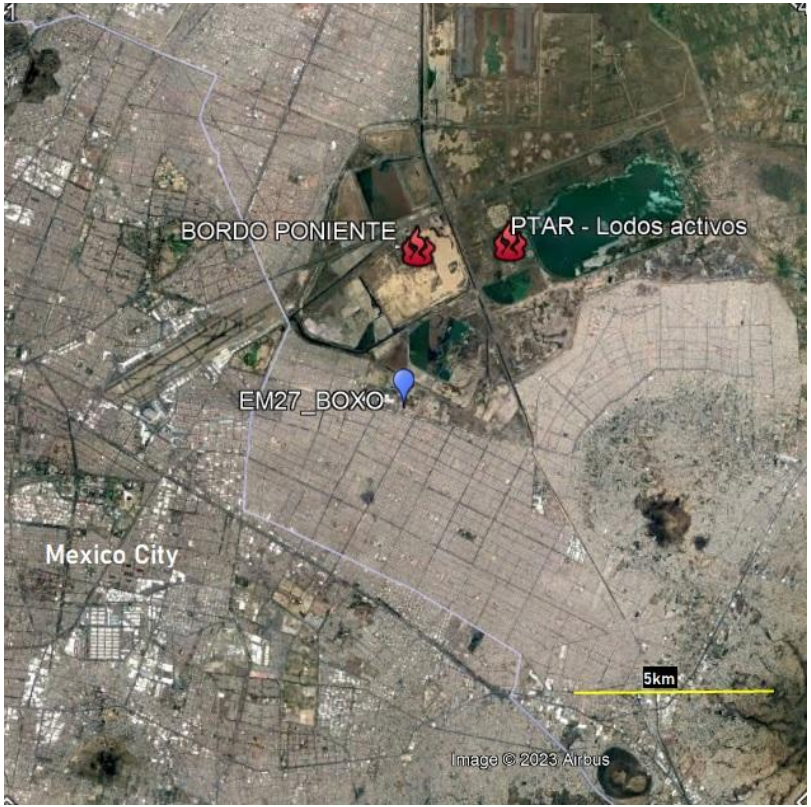

CH_4 columns at BOXO
1e23
3.40
3.35
3.30
3.25
3.20
3.15
3.10
3.05
col [$molec/m^2$]
EM27_38
2021-03-01
2021-03-15
2021-04-01
2021-04-15
2021-05-01
Date

MERCI-CO_2

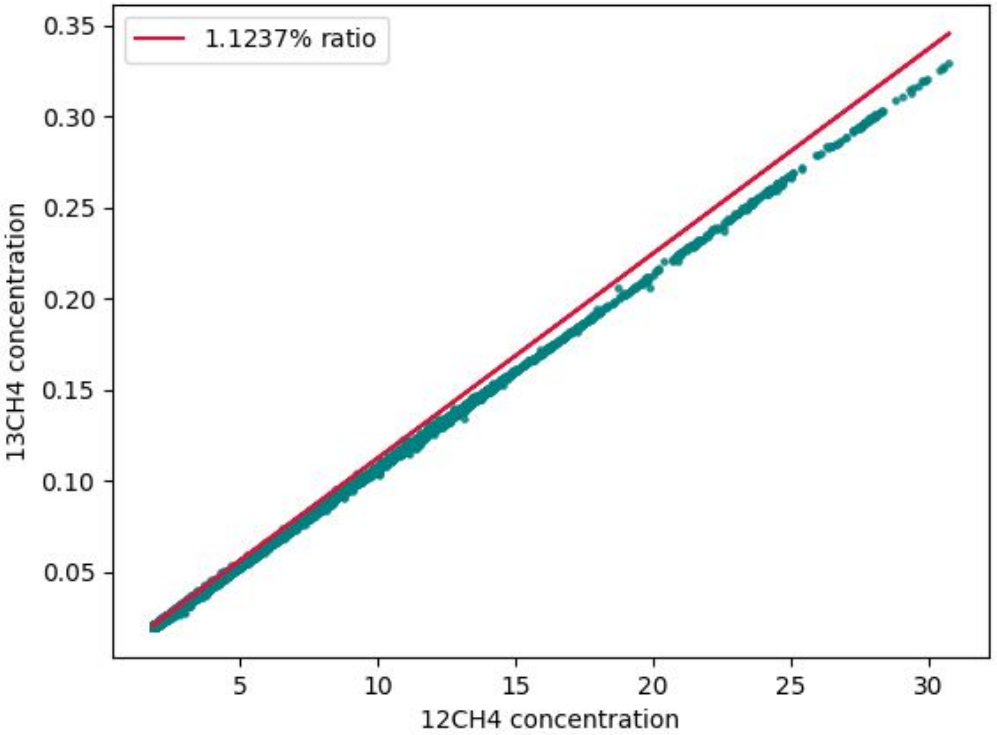

BOXO
CCA
2.05
2.00
1.95
1.90
1.85
XCH_4
2021-03-01
2021-03-15
2021-04-01
2021-04-15
2021-05-01
Date

Wind analysis





MERCI-CO_2



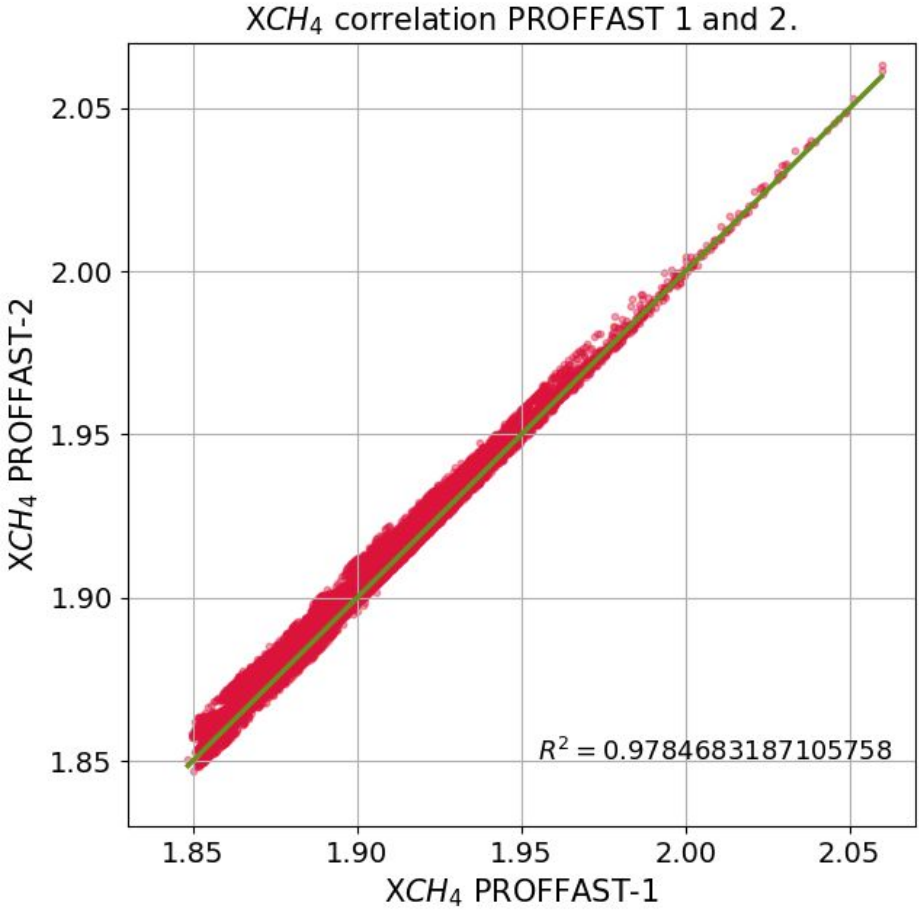
At BOXO there was a **G2201-i PICARRO,** that measured different isotopes of methane.

Some concentrations exceed the 1.1237% ratio of standard methane in the atmosphere.

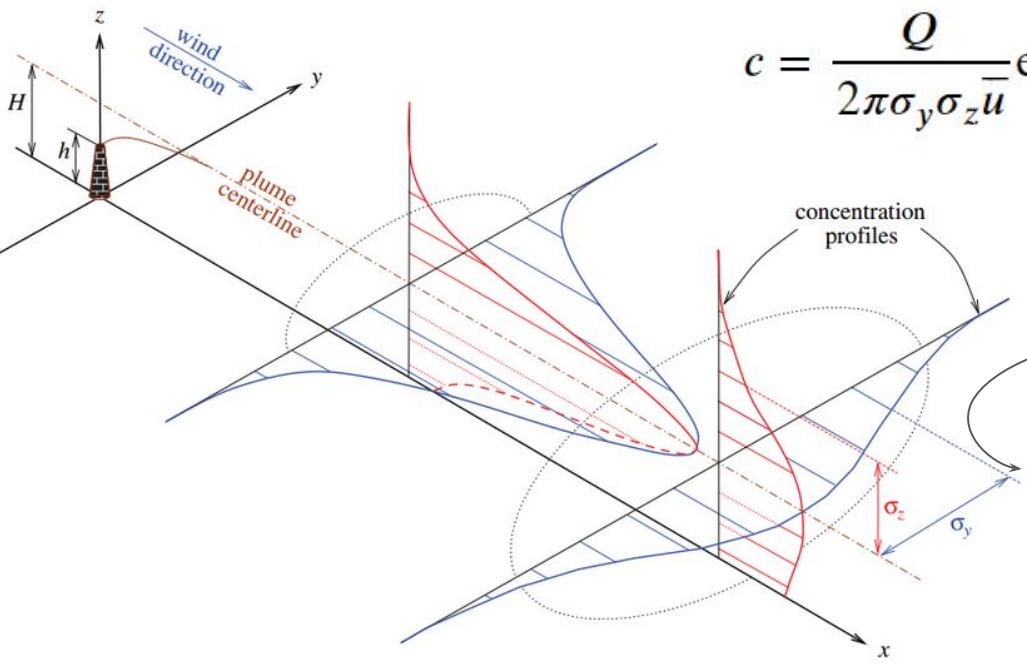
MERCI-CO_2

The data used for the model (applied only at BOXO) was processed with **PROFFAST-2**

Which correlate very well with the data processed with PROFFAST-1



The Gaussian Plume Model



$$c = \frac{Q}{2\pi\sigma_y\sigma_z\bar{u}}\exp\left[-\frac{1}{2}\left(\frac{y_r}{\sigma_y}\right)^2\right]\exp\left[-\frac{1}{2}\left(\frac{h_e - z_r}{\sigma_z}\right)^2\right]$$ [1]

$$col = \frac{Q}{\sigma_y ws\sqrt{2\pi}}\exp\left[-\frac{1}{2}\left(\frac{y_r}{\sigma_y}\right)^2\right]$$

Vertical component already measured

$$\sigma_y = \alpha x$$

True for calm winds

$$col(x,y) = \frac{Q}{ws\ \alpha\ x\sqrt{2\pi}}\exp\left[-\frac{1}{2}\left(\frac{y}{\alpha x}\right)^2\right]$$

[1]Zannetti, P. (1990). Gaussian Models. In: Air Pollution Modeling. Springer, Boston, MA. https://doi.org/10.1007/978-1-4757-4465-1_7

Why Gaussian Plume Model (GPM)?

- ➔ GPM is based on continuous and constant sources
- ➔ Landfills do not change their emissions on small periods of time
- ➔ In combination with EM27/SUN the vertical component is already measured, so reflection with the ground and the boundary layer is not a problem.
- ➔ Wind data (wind speed and wind direction) is easy to get and reliable.

Simple inverse problem

$$\mathbf{col}(x, y) = \mathbf{KQ}$$

$$\mathbf{col} = \begin{pmatrix} col_1 \\ col_2 \\ \vdots \\ col_n \end{pmatrix} \quad K = \begin{pmatrix} \frac{\partial col(r_1)}{\partial Q}_1 & \frac{\partial col(r_2)}{\partial Q}_1 & \cdots & \frac{\partial col(r_n)}{\partial Q}_1 \\ \frac{\partial col(r_1)}{\partial Q}_2 & \frac{\partial col(r_2)}{\partial Q}_2 & \cdots & \frac{\partial col(r_n)}{\partial Q}_2 \\ \vdots & \vdots & \ddots & \vdots \\ \frac{\partial col(r_1)}{\partial Q}_m & \frac{\partial col(r_2)}{\partial Q}_m & \cdots & \frac{\partial col(r_n)}{\partial Q}_m \end{pmatrix} \quad \mathbf{Q} = \begin{pmatrix} Q_1 \\ Q_2 \\ \vdots \\ Q_n \end{pmatrix}$$

Inverse problem

It was also considered an **optimal estimation and a Tikhonov constraints** and a constant methane background, so the final inverse problem consist in:

$$\mathbf{col}(x, y) = \mathbf{K}\,(\mathbf{Q} + \mathbf{B})$$

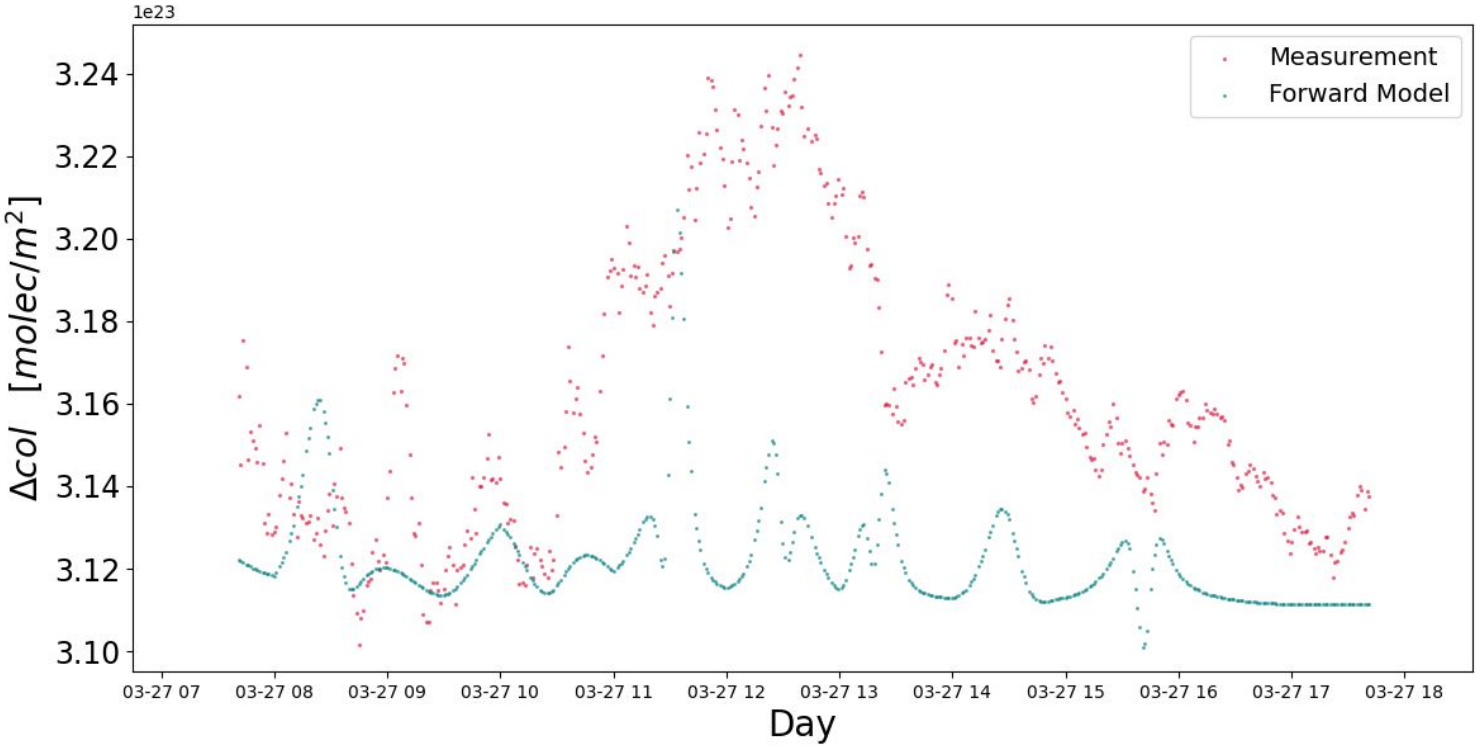
$$\mathbf{G} = \left(\mathbf{K}^T\mathbf{K} + \alpha\mathbf{R} + \beta\mathbf{I}\right)^{-1}\mathbf{K}^T$$

$$\mathbf{I} = \begin{bmatrix} 1 & 0 & \dots & 0 \\ 0 & 1 & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & 1 \end{bmatrix}$$

$$\mathbf{K} = \begin{bmatrix} \frac{\partial col(r_1)}{\partial Q}_1 & \frac{\partial col(r_2)}{\partial Q}_1 & \cdots & \frac{\partial col(r_n)}{\partial Q}_1 & 1 \\ \frac{\partial col(r_1)}{\partial Q}_2 & \frac{\partial col(r_2)}{\partial Q}_2 & \cdots & \frac{\partial col(r_n)}{\partial Q}_2 & 1 \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ \frac{\partial col(r_1)}{\partial Q}_m & \frac{\partial col(r_2)}{\partial Q}_m & \cdots & \frac{\partial col(r_n)}{\partial Q}_m & 1 \end{bmatrix}$$

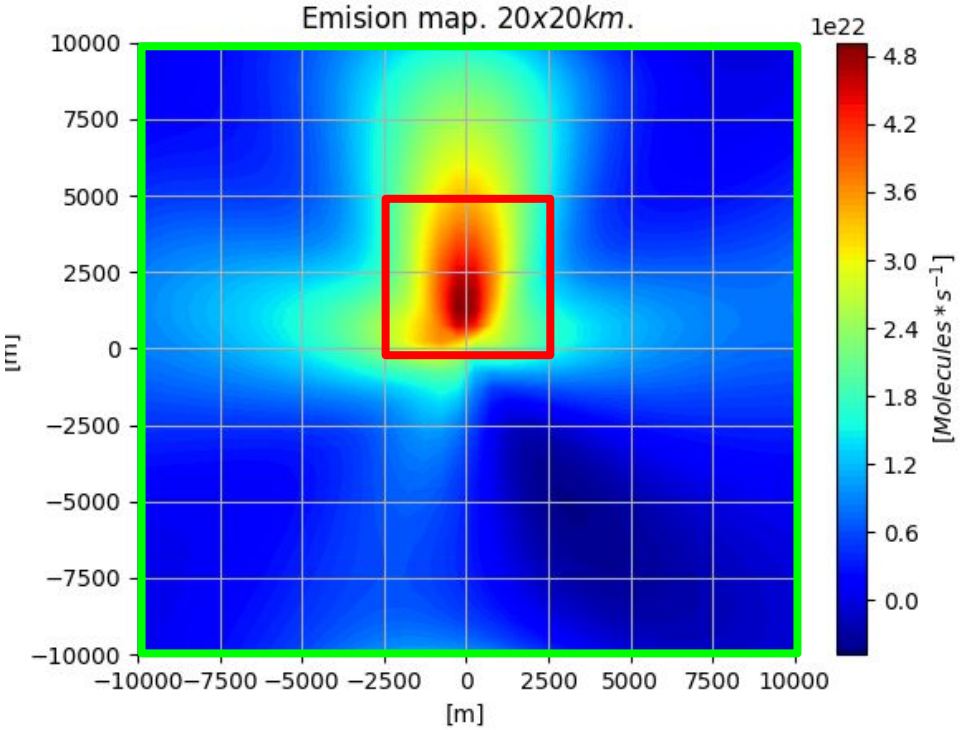
$$\mathbf{R} = \begin{bmatrix} 2 & -1 & 0 & \cdots & 0 & 0 & 0 & 0 \\ -1 & 4 & -1 & \cdots & 0 & 0 & 0 & 0 \\ 0 & -1 & 4 & \cdots & 0 & 0 & 0 & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & \cdots & 4 & -1 & 0 & 0 \\ 0 & 0 & 0 & \cdots & -1 & 4 & -1 & 0 \\ 0 & 0 & 0 & \cdots & 0 & -1 & 2 & 0 \\ 0 & 0 & 0 & \cdots & 0 & 0 & 0 & 0 \end{bmatrix}$$

Inverse problem



One day comparison between measurements and the forward model.

Emission comparison



Region	This study	Inventory[1]
	9859.2 Ton/year	114,199.615 Ton/year For total solid waste disposal
	1338.7 Ton/year	55,707.225 Ton/year For total solid waste disposal

[1]Scarpelli, Tia R; Jacob, Daniel J.; Octaviano Villasana, Claudia A.; Ramírez Hernández, Irma F.; Cárdenas Moreno, Paulina R.; Cortés Alfaro, Eunice A.; García García, Miguel Á.; Zavala-Araiza, Daniel, 2020, "Gridded inventory of Mexico's anthropogenic methane emissions", https://doi.org/10.7910/DVN/5FUTWM

Summary

- ➔ GPM in combination with EM27/SUN data suppose a promising method to estimate emissions from methane on local scale.
- ➔ Background methane is important for consideration.
- ➔ A larger period than three months might would offer better caption of the seasonality.
- ➔ Other emission sources could bias the emissions values from permanent sources (leaks of gas can modify column value from landfills) as Mexico City is a region with multiple sources of methane.

THANK YOU!