Assessing CO_2 emissions from Paris megacity:

First lessons from our atmospheric CO_2 network, carbon isotopes and co-emitted species. Observation strategy for future urban CO_2 networks.

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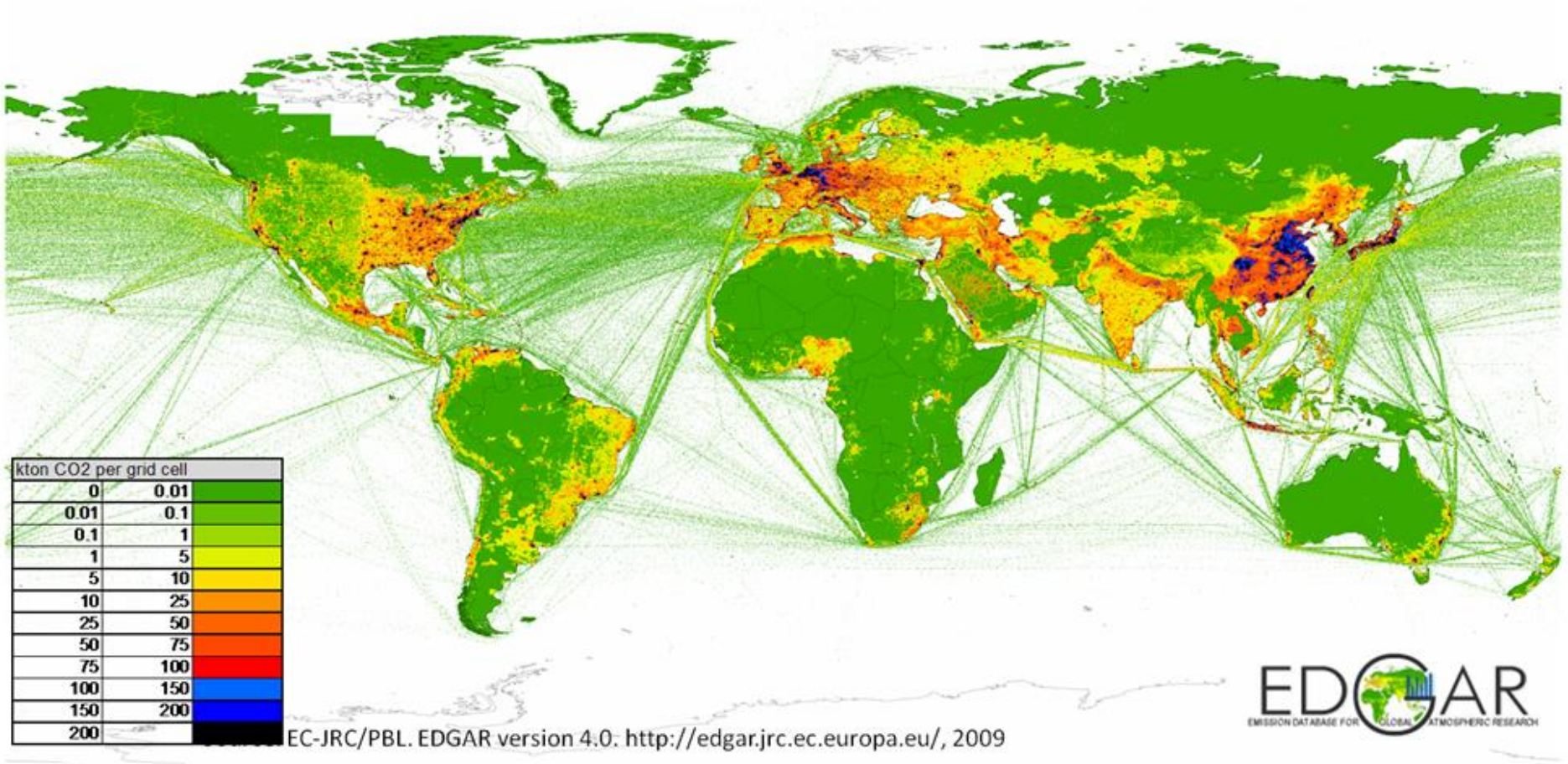
Urbanized and industrialized areas account for more than 70% of global FF CO_2 emissions

(source: FAO, IEA, IPCC)

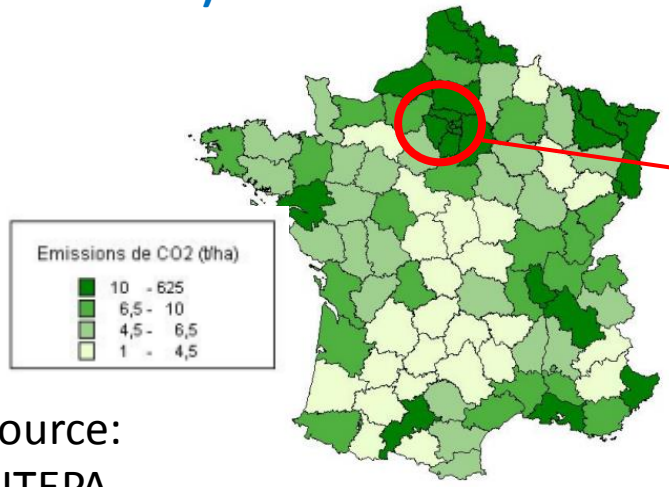


The case of Paris conurbation

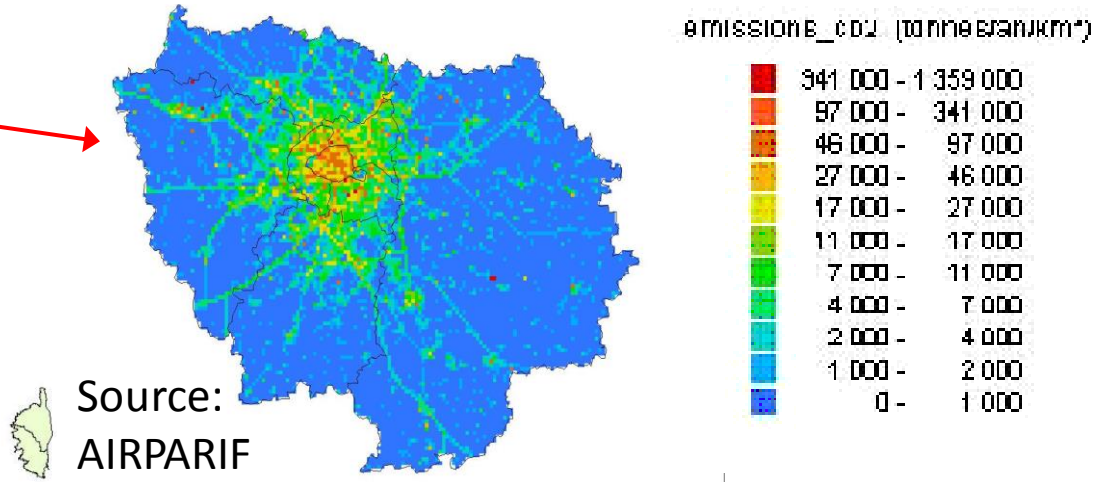
The Eiffel tower, a station of the CO_2-Megaparis project (ANR - LSCE)

- ❑ The 2nd megacity in western Europe
- ❑ Paris region: 13% of CO_2 French emissions
- ❑ Only 2% of the national territory
- ❑ High resolved inventory from AIRPARIF
- ❑ Uncertainties poorly known

90% of the population of Paris region are concentrated in 20% of its area



Source: CITEPA

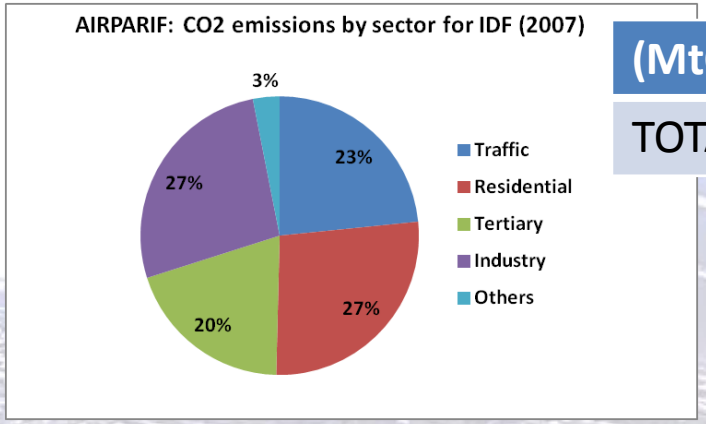


Source: AIRPARIF

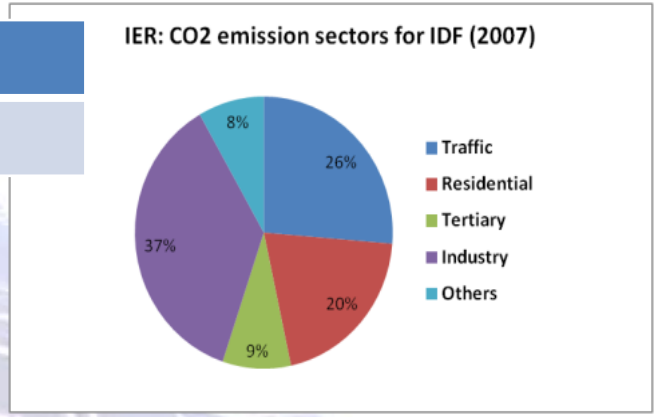
Intercomparaison of high resolved inventories

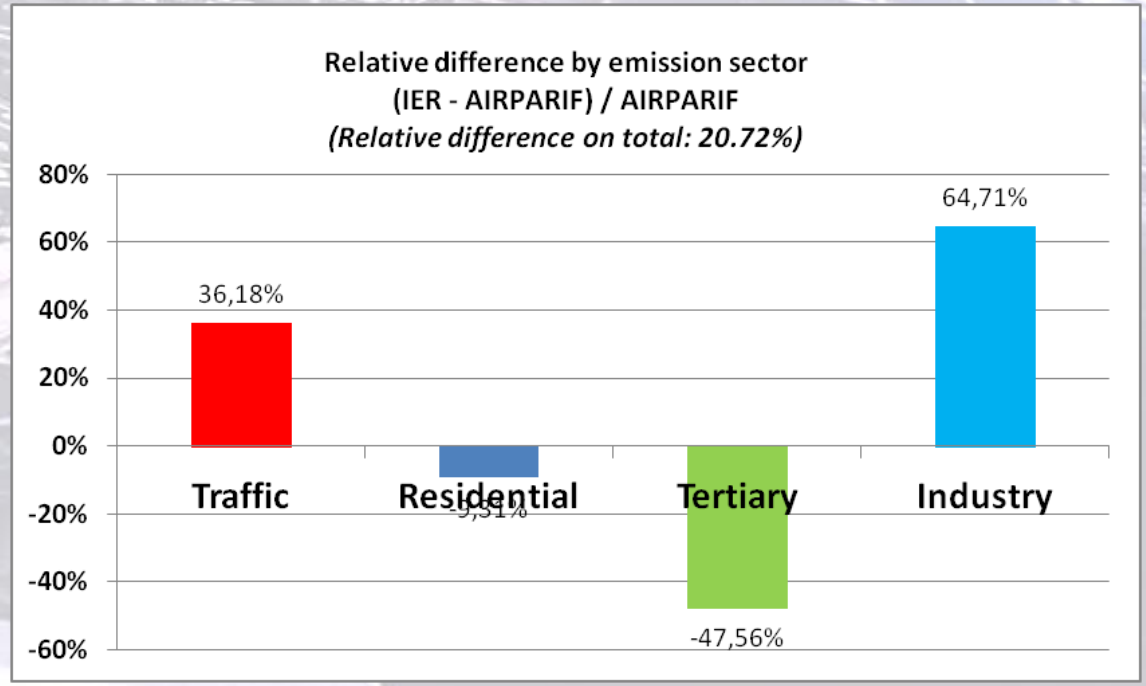
AIRPARIF Paris/ IER Stuttgart : 1x1 km^2, 1h (2008)

© *Dieudonné et al, 2013*



($MtCO_2$/yr)	AIRPARIF	IER
TOTAL	52,1	62,9

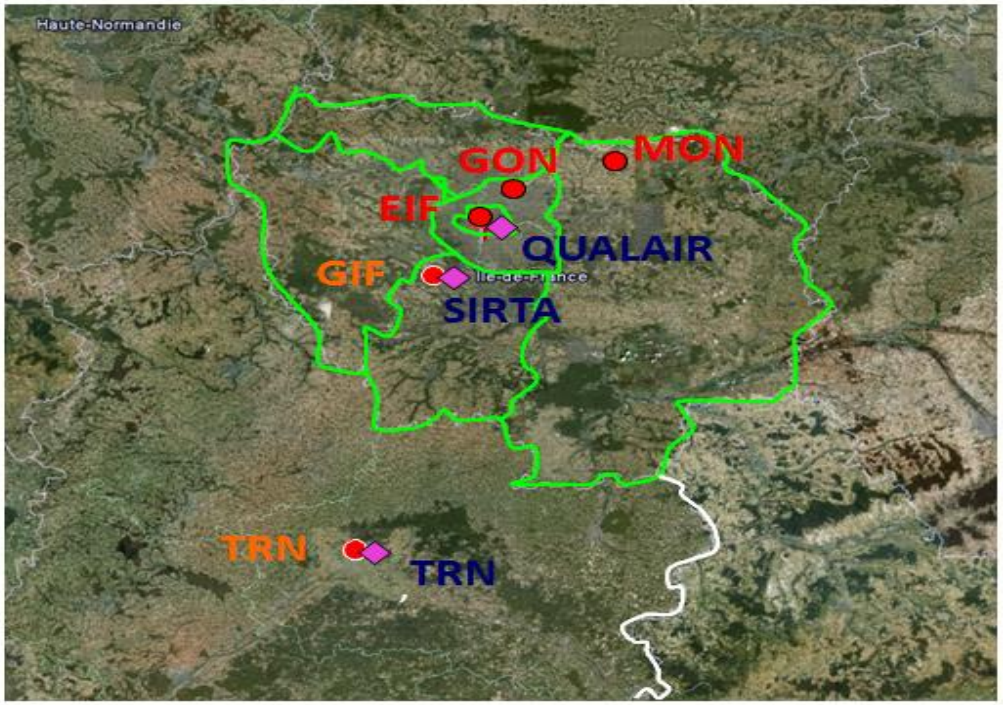




The CO_2-Megaparis network

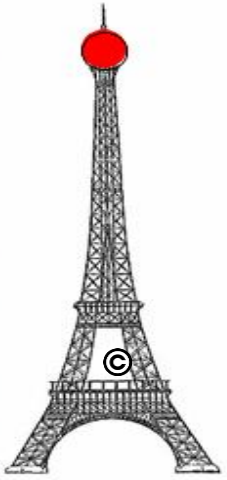
CO2 & CO (red: CO2-MEGAPARIS, orange: RAMCES-ICOS)

ABL height



NE

SW



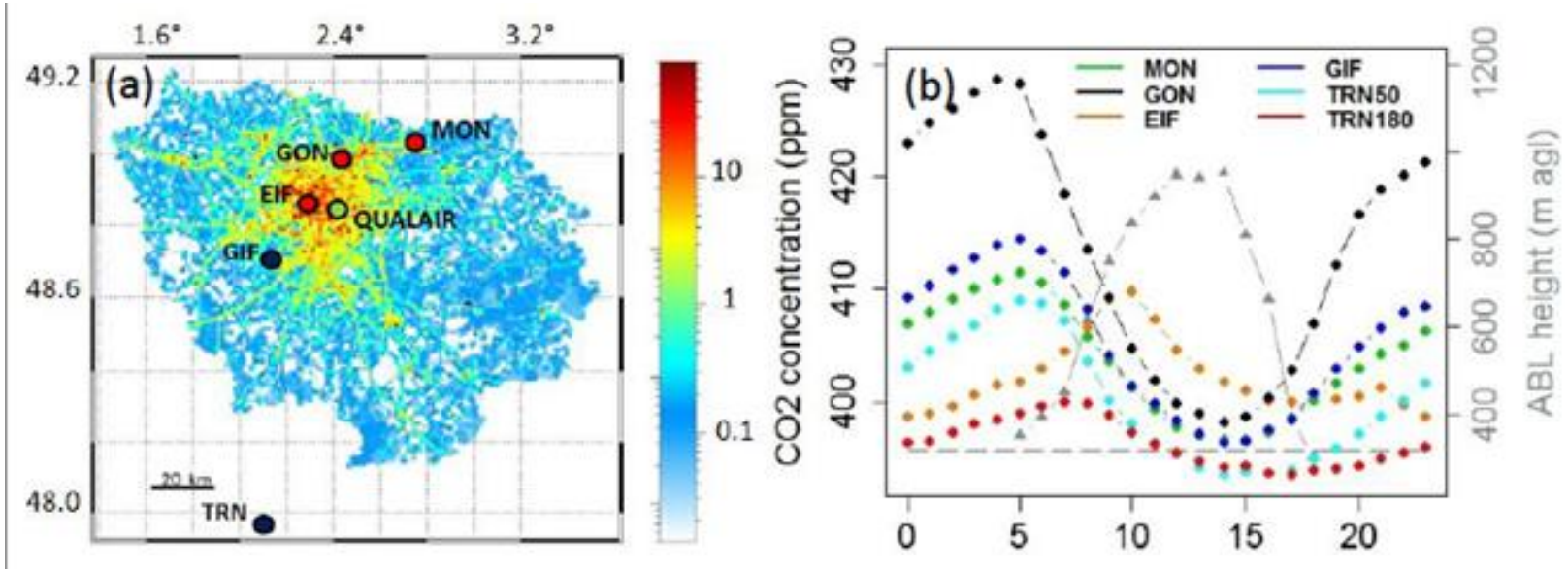
Model G1302 (CO_2/CO/H_2O)

Xueref-Remy et al, tbs

July 2010- August 2011	EIF	MON	GON	GIF	TRN
Accuracy CO_2	0.128ppm	-0.039 ppm	-0.071 ppm	GC = Reference	GC = Reference
Repeatability CO_2	0.382ppm	0.101 ppm	0.065 ppm	0.05 ppm	0.06 ppm

CO_2 diurnal cycle

- The strength of the signal increases with the urbanization level
- There is a strong coupling with the boundary layer cycle (especially at EIF)

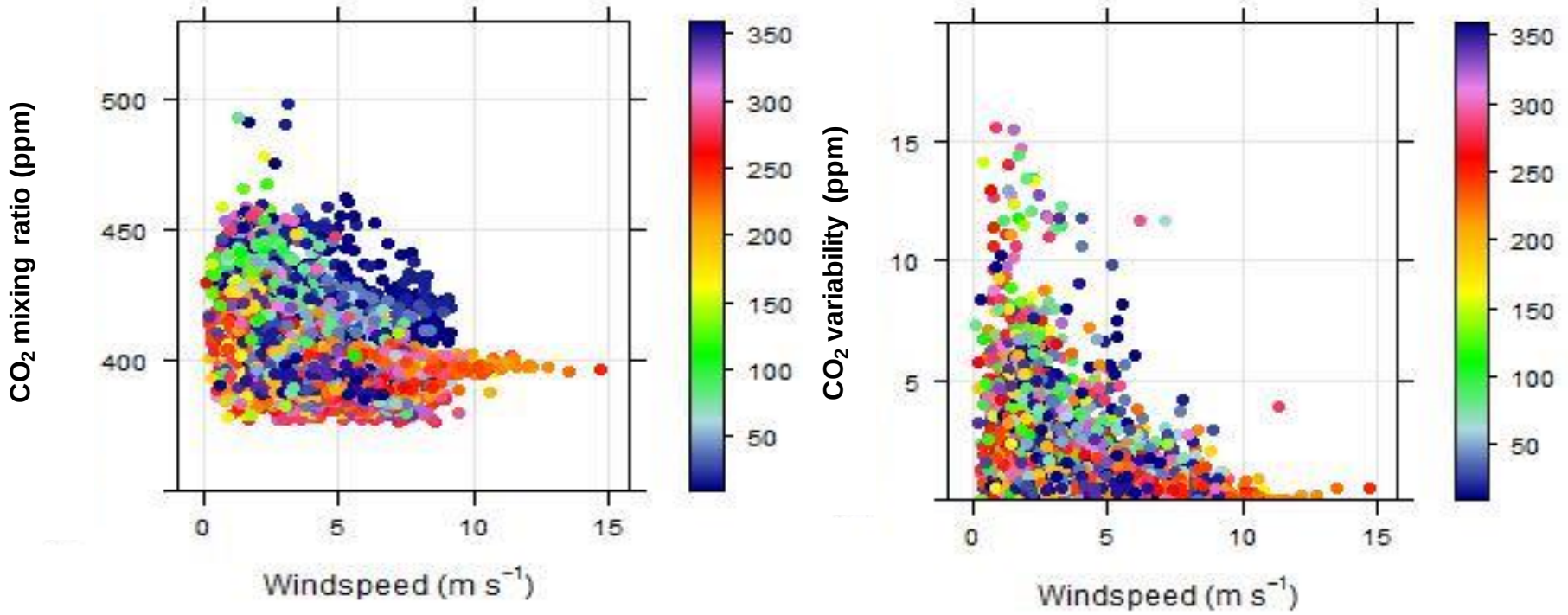


Xueref-Remy et al, BIPM 2015

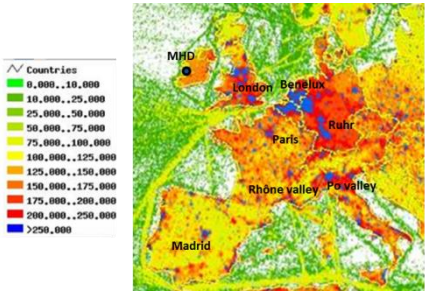
Windspeed as a key factor

- Dilution of the plume
- Decrease of the variability (at low windspeed, mainly linked to the emissions variability)

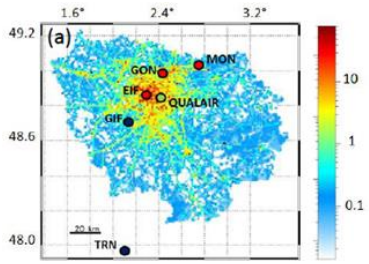
Example of GIF:



Xueref-Remy et al, tbs

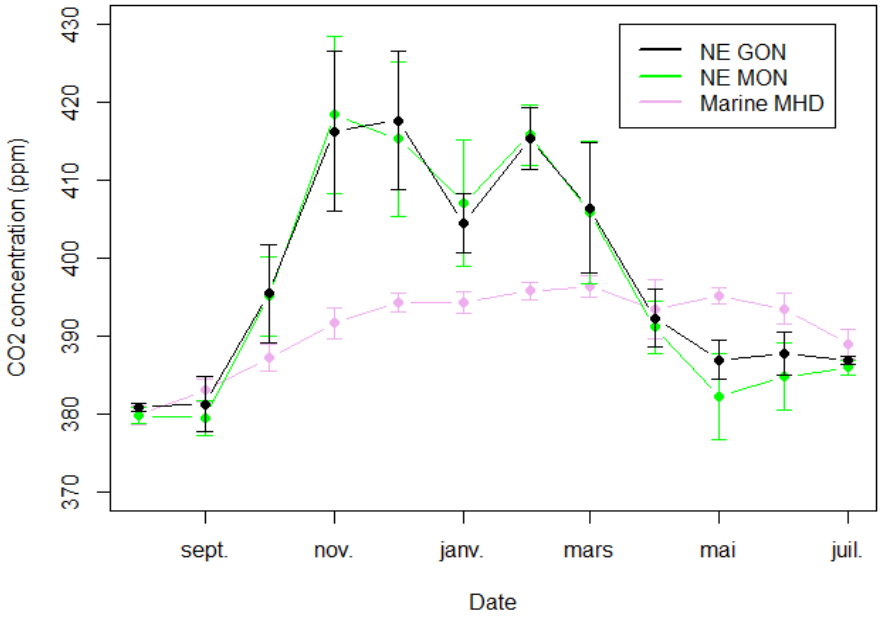


Assessing the plume:
regional background choice

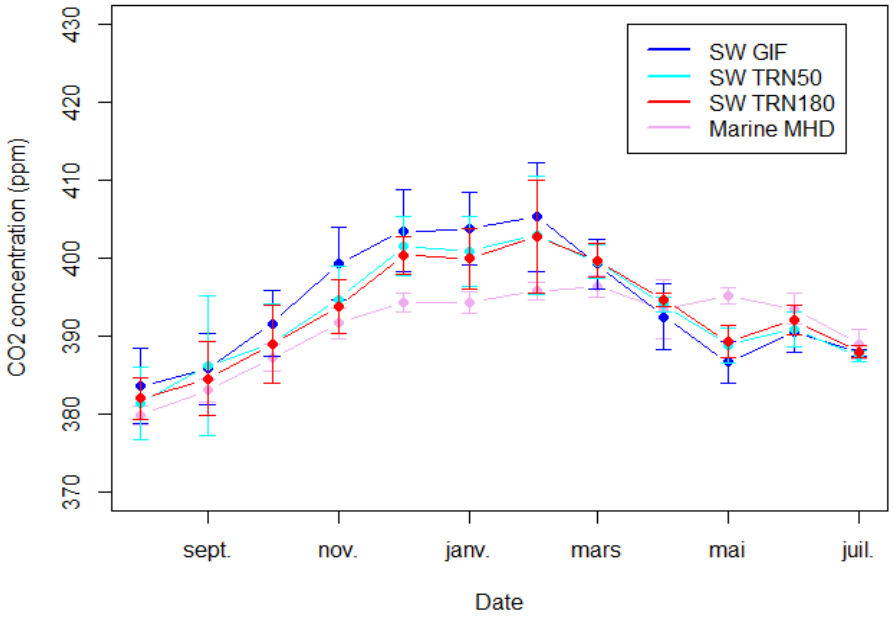


(see also Turnbull et al, 2015 for Indianapolis)

NE sector CO2 background, comparison to MHD marine sector



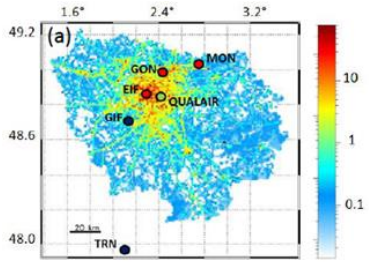
SW sector CO2 background, comparison to MHD marine sector



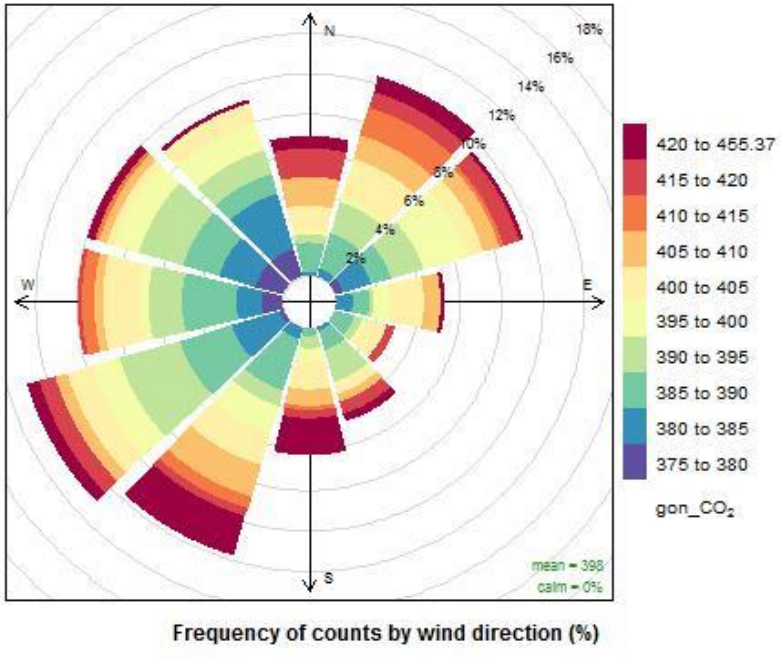
Xueref-Remy et al, tbs

Assessing the plume:

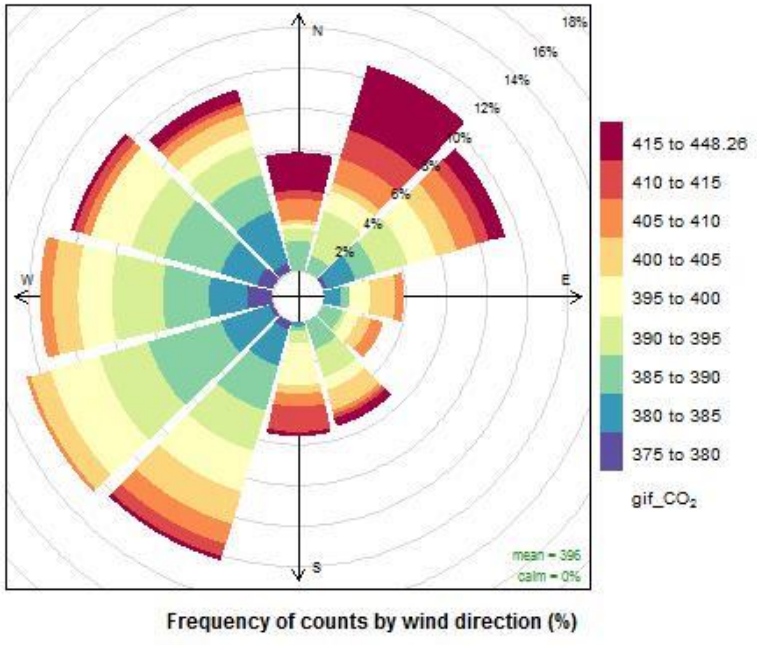
wind selection (direction and speed)



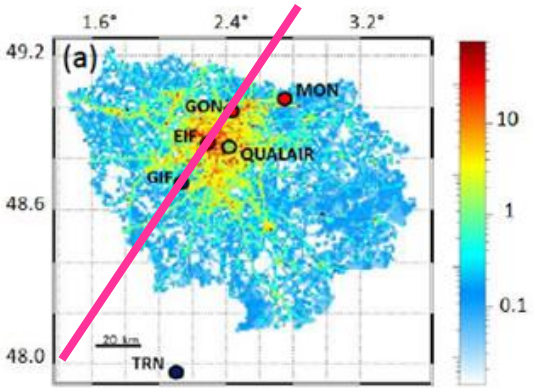
GON



GIF

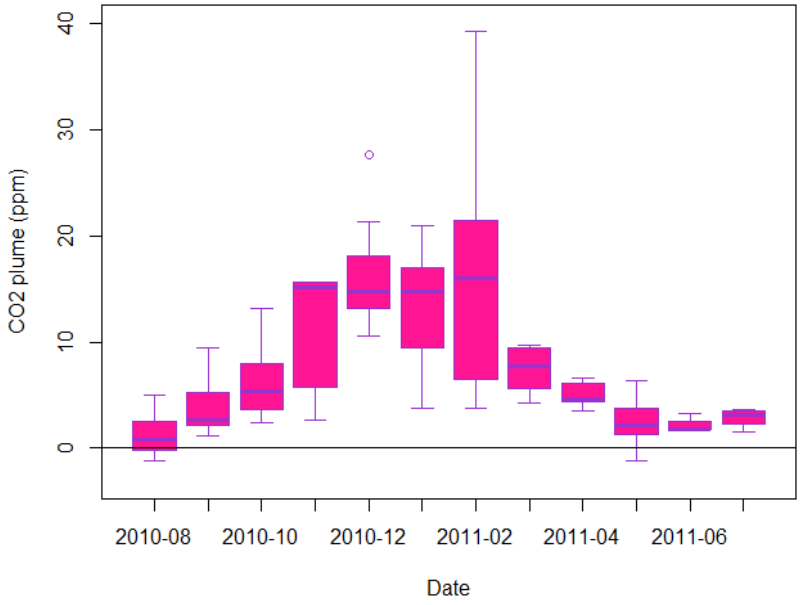


Paris megacity CO_2 plume

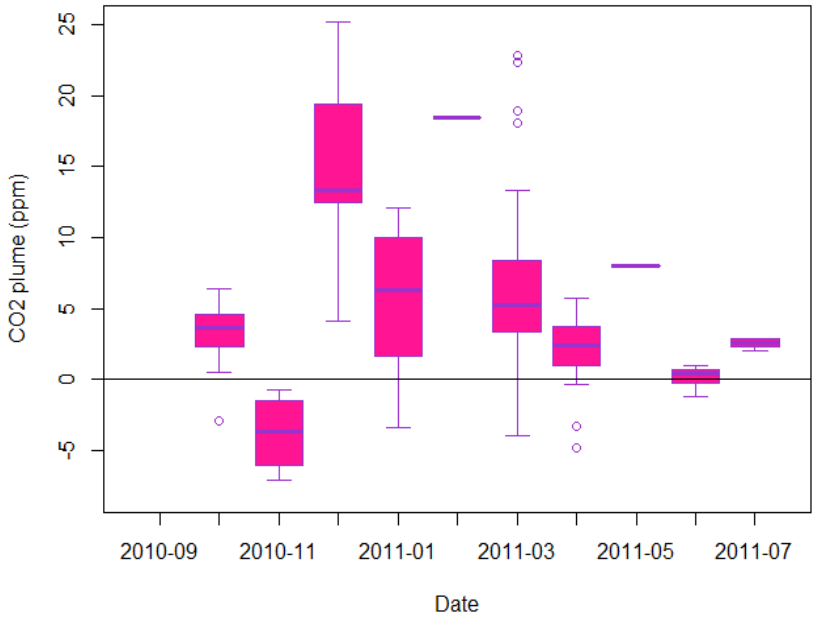


- Background signal: upwind station data
- Wind cone: +/-15° along the axis of 2 stations
- Windspeed: >3 $m.s^{-1}$

GIF to GON



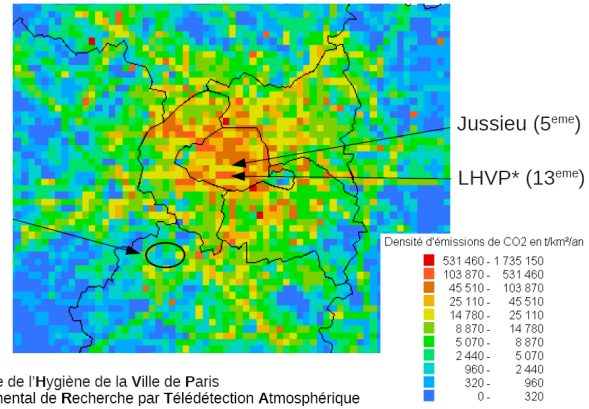
GON to GIF



Xueref-Remy et al, tbs

Assessing the relative role of the different emission sectors

$^{14}CO_2$ winter campaign in Feb 2010

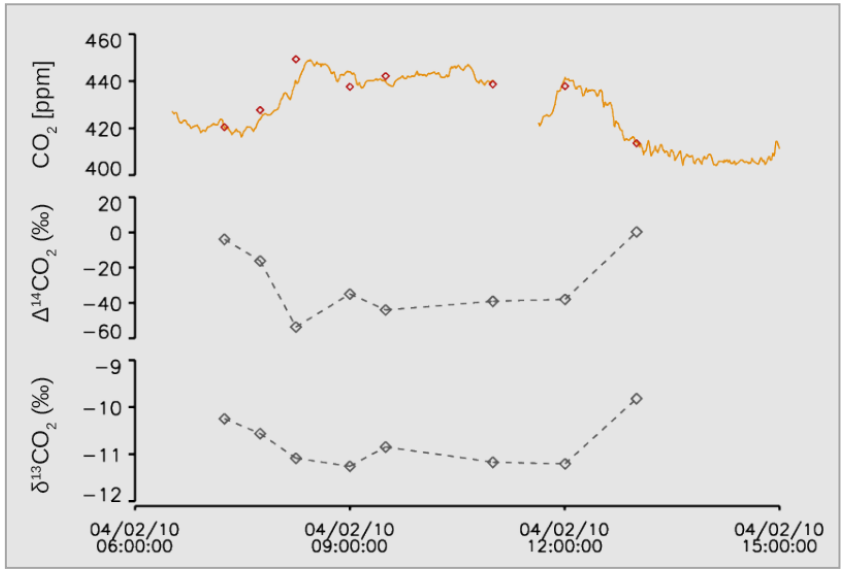


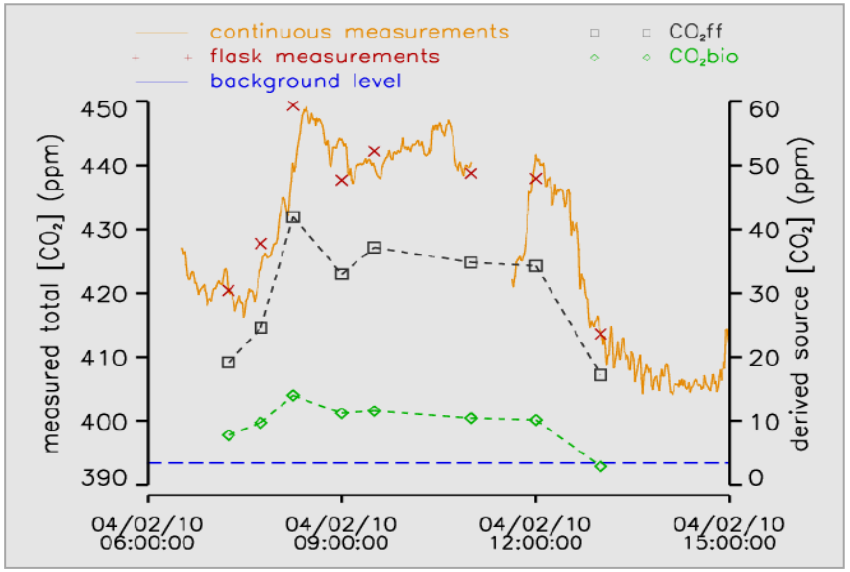
* LHVP : Laboratoire de l'Hygiène de la Ville de Paris
** SIRTA : Site Instrumental de Recherche par Télédétection Atmosphérique

$$CO_2ff = CO_2meas \cdot \frac{\Delta^{14}CO_2bg - \Delta^{14}CO_2meas}{\Delta^{14}CO_2bg + 1}$$

$$\Delta^{14}CO_2bio = \Delta^{14}CO_2bg$$

$$\Delta^{14}CO_2ff = -1$$





	LHVP (ppm / %)	Sources
CO_2 ff	30 ppm / 75 %	Natural gas and oil
CO_2 bio	10 ppm / 25 %	Human and biospheric respiration + Biofuels

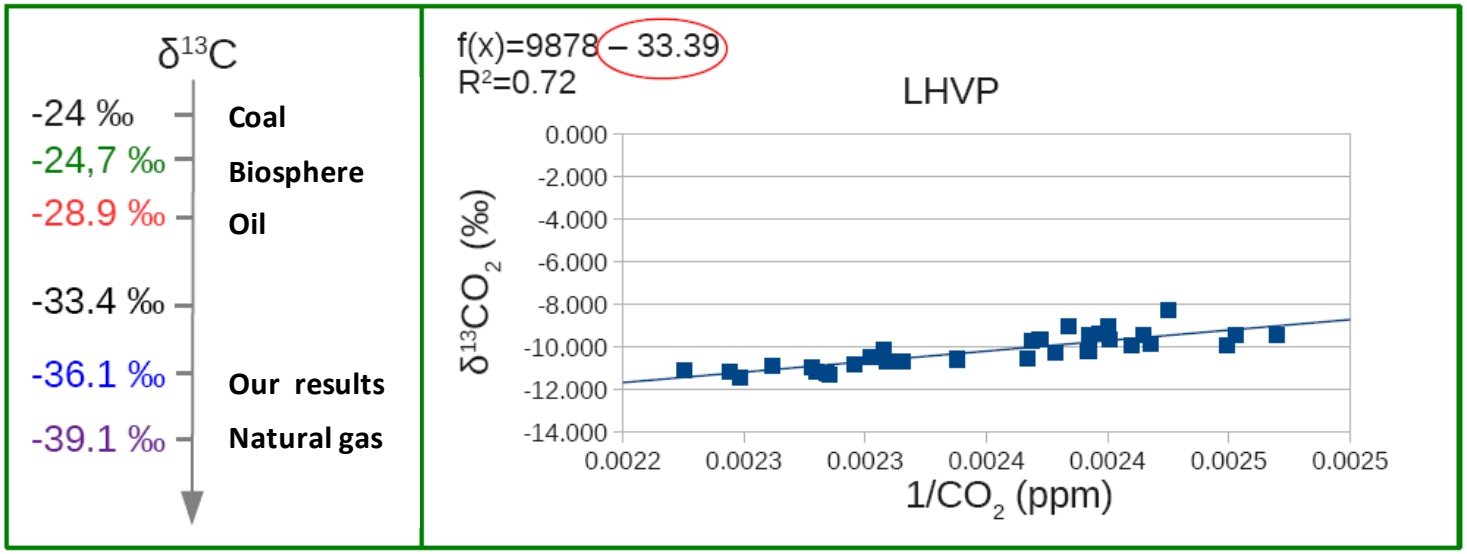
Lopez et al, ACP, 2013

Assessing the role of the different emission sectors:

$^{13}CO_2$ Keeling plot

$$\delta^{13}CO_2 meas = \frac{CO_2 bg(\delta^{13}CO_2 bg - \delta^{13}CO_2 s)}{CO_2 meas} + \delta^{13}CO_2 s$$

Winter 2010 (Lopez et al, ACP 2013):



Correction to substract the biospheric contribution: $\delta^{13}Cbio = -24.7$ ‰

→ **$\delta^{13}Cff = -36.1 \pm 2.7$ ‰**

Gas: 70%

Residential and industrial sectors

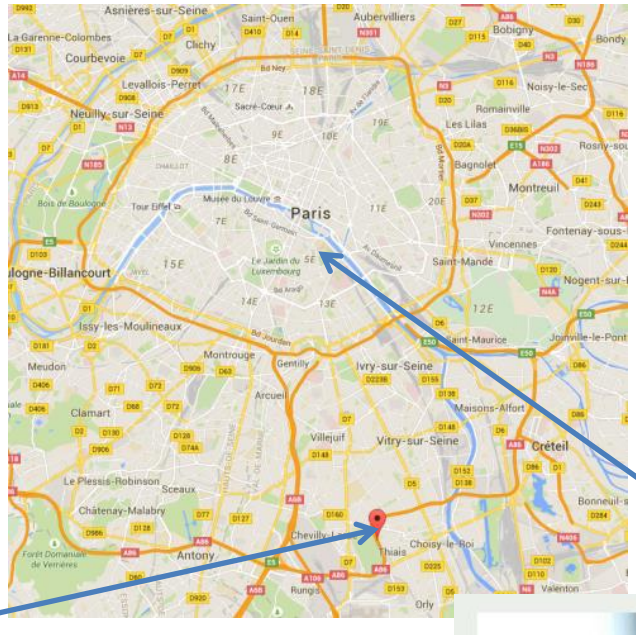
Oil: 30%

Traffic sector

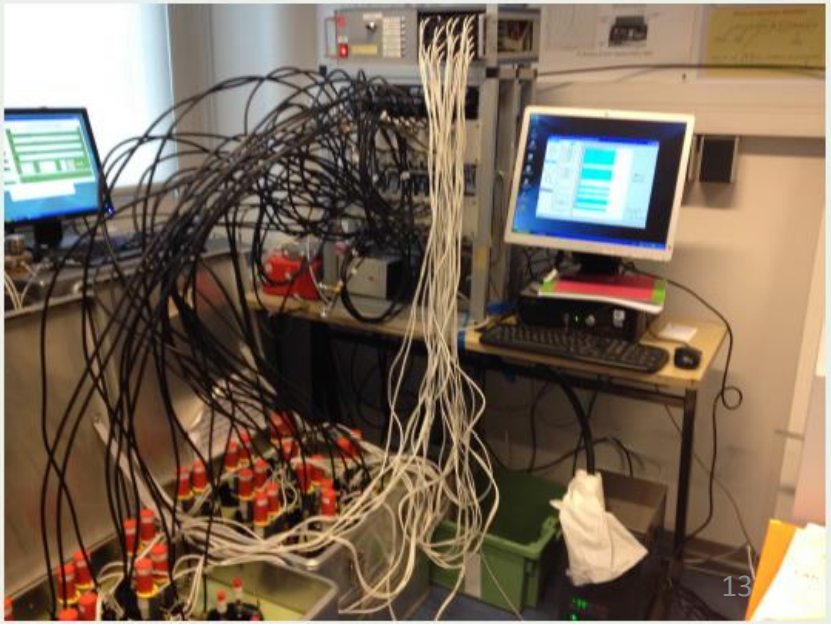
Specific efforts on the multi-tracers approach

Lamia Ammoura's phD work

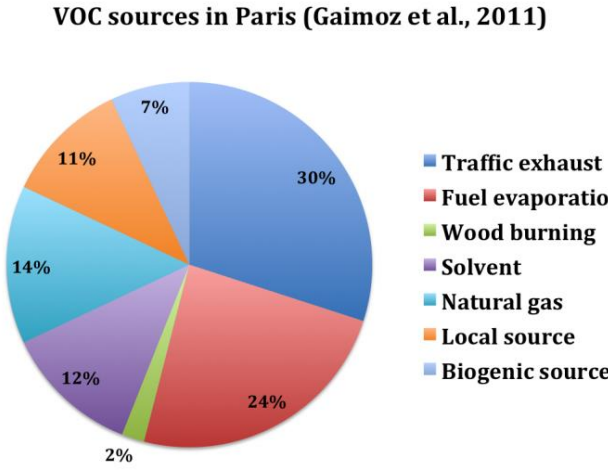
Tunnel campaign (Primequal-Zapa project with AIRPARIF)

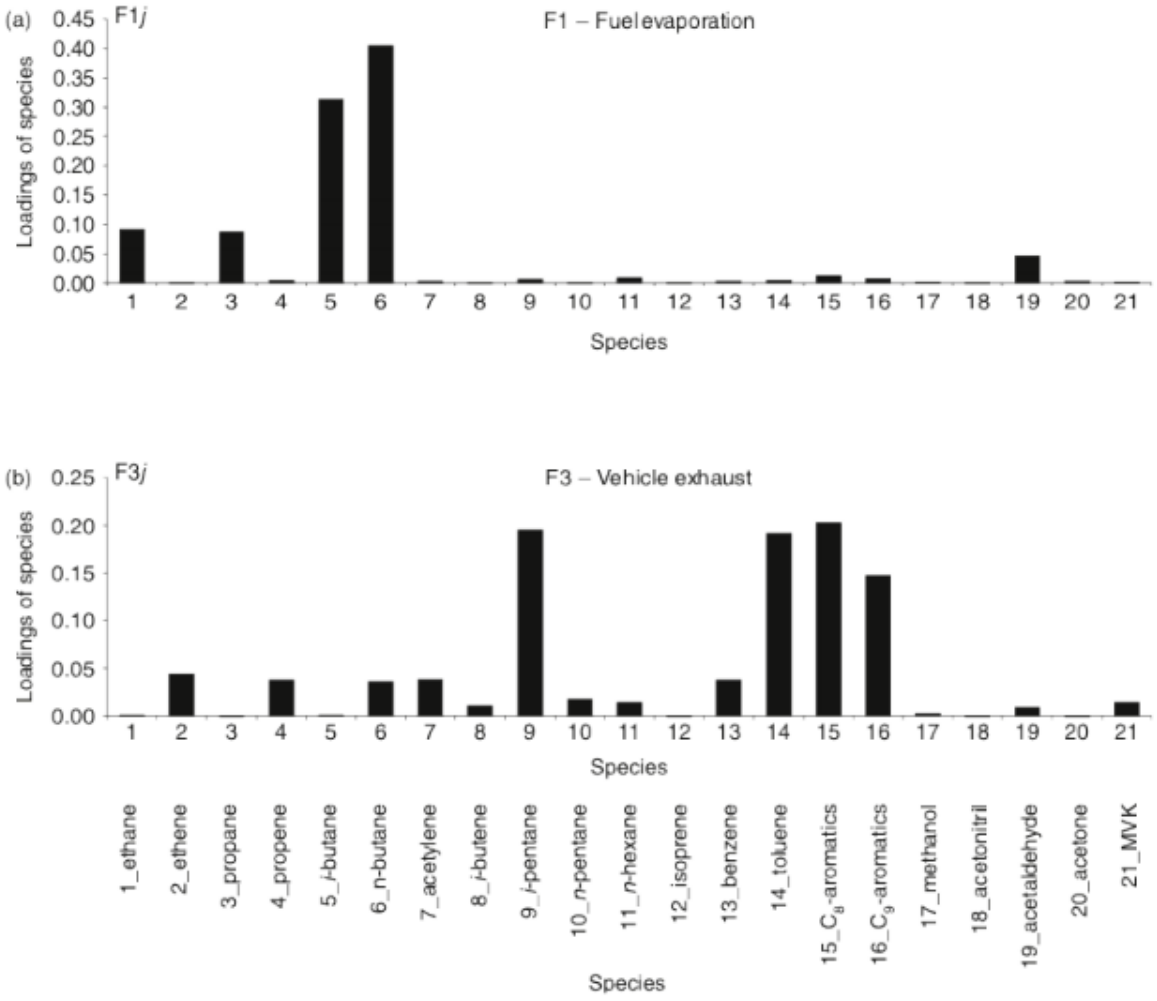


Jussieu campaign (Multi-CO2 project, IPSL)



VOCs source profiles in Paris

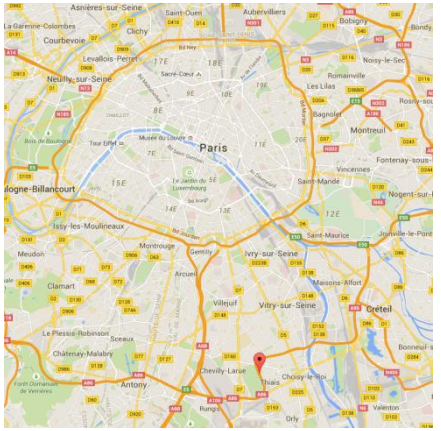


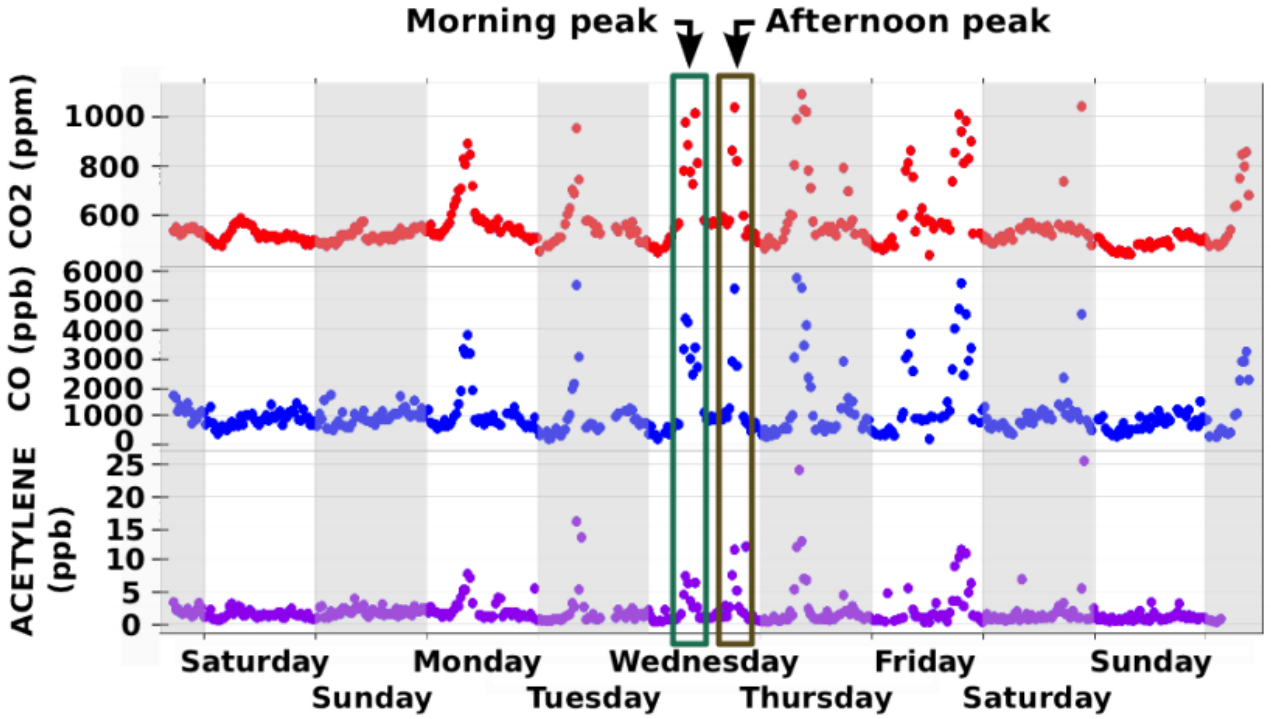


Source : Gaimoz et al., 2011.

Tracers: CO & VOCs => assess emission ratios to CO_2

Ex: tunnel campaign (primequal-ZAPA project): traffic emission sector only

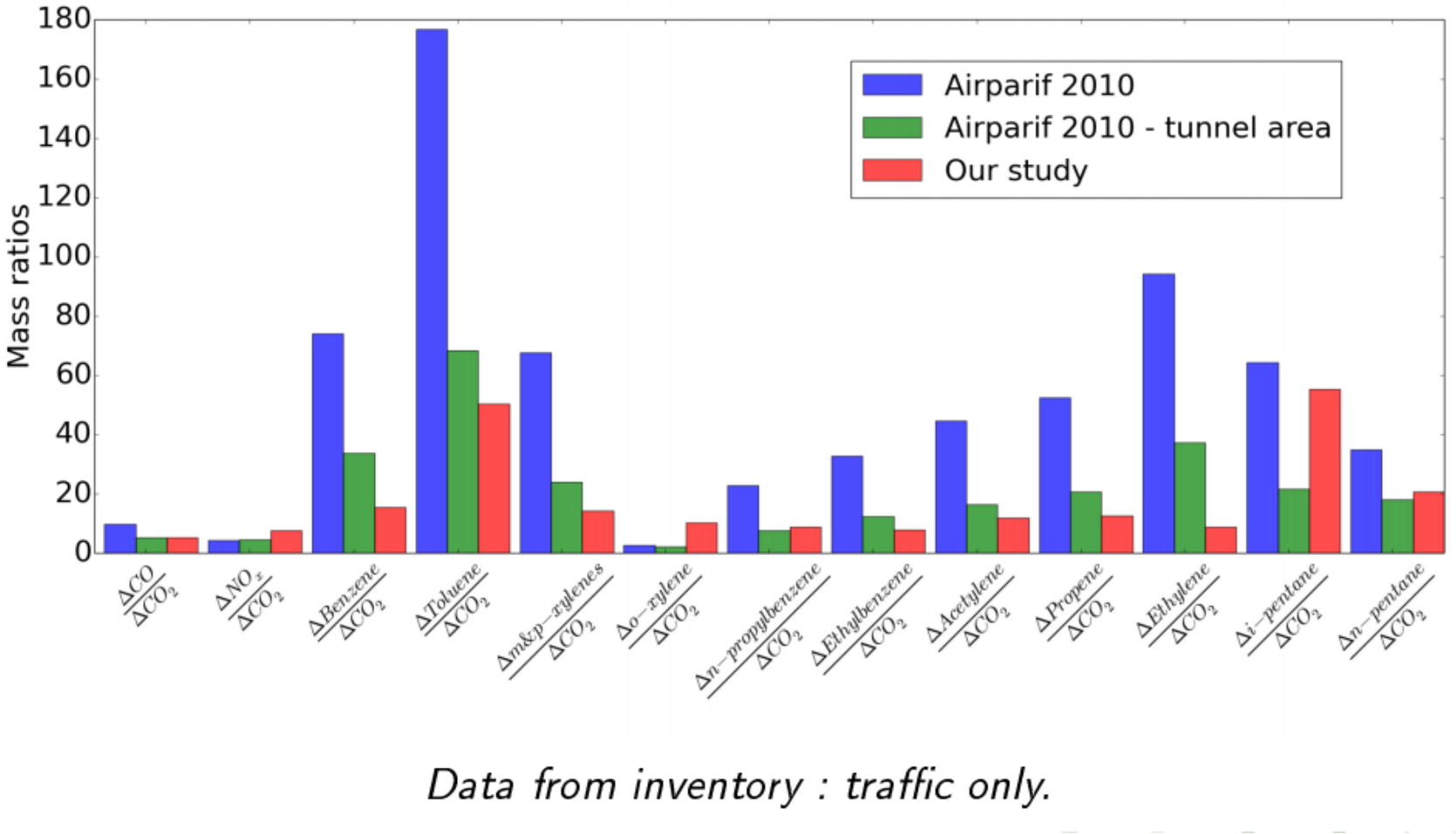




- Workdays : diurnal pattern with two concentration peaks.
- Concentration peaks ⇌ rush hours.

Ammoura et al, ACP, 2014

Comparison of our results to the AIRPARIF inventory



Data from inventory : traffic only.

Ammoura et al, ACP, 2014

IPSL/Multi-CO_2 campaign (Jussieu)

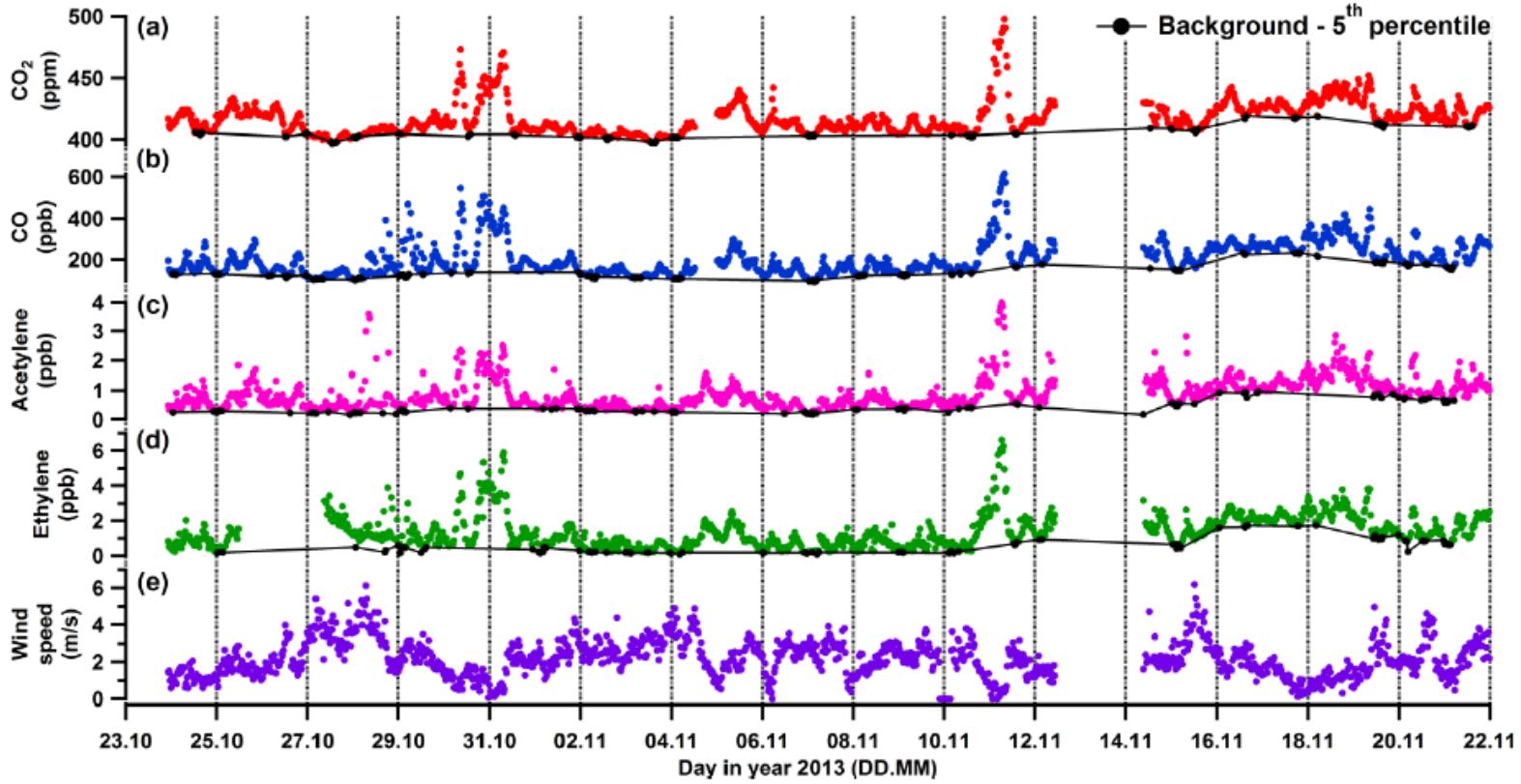


Fig.1: (a-d) Temporal variation of the mole fraction of selected compounds monitored during the Multi-CO_2 campaign (30 minutes time step). The black lines represent the background levels defined with the calculation of the 5th percentile (black disks). **(e)** Wind speed during the campaign. Time is given in UTC.

Ammoura et al, ACPD ,2015

Conclusions

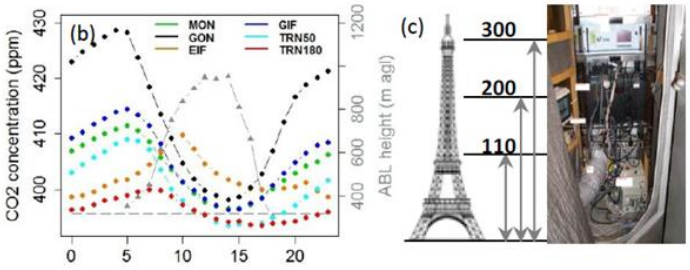
- The impact of Paris megacity on atmospheric CO_2 mixing ratio can be detected from our atmospheric observations
- Strong coupling with ABL height dynamics: need hABL monitoring, take into account the station elevation
- Need a good background: get it regional (at the border of the studied area)
- Need tracers of emissions to separate the FF vs the biospheric signals, and also discriminate the contribution of the different emission sectors: 14C, 13C, CO, NOx, VOCs, black carbon…
- Need meteorological fields at the stations (windspeed and wind direction)
- Work on the large urban concentration variability ongoing, especially the role of atmospheric dynamics processes (turbulence…) vs emissions variability (phD project submitted).

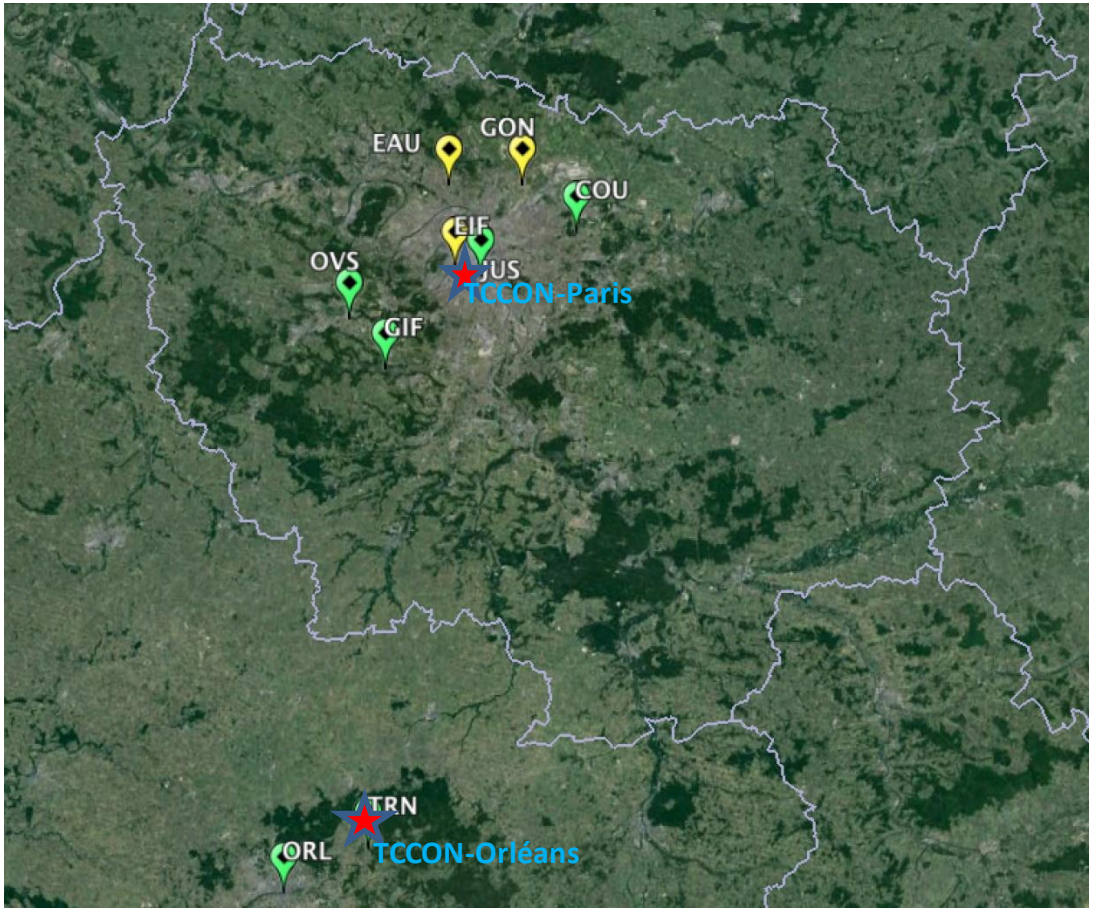
Paris GHG network in 2015

(Carbocount-city / IPSL / Ville de Paris/ ICOS)

- **ABL height covariation:**

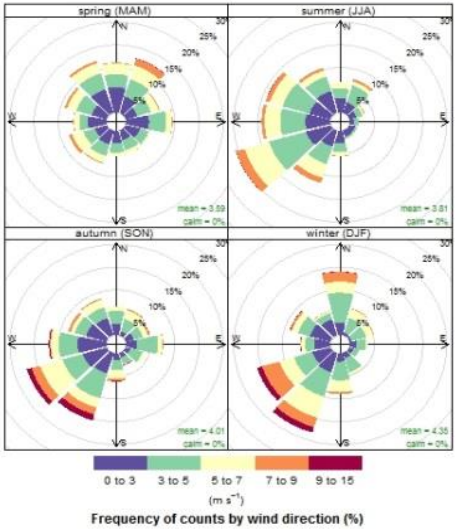
=> CO_2 profile at the Eiffel tower





- **Wind direction fluctuations :**

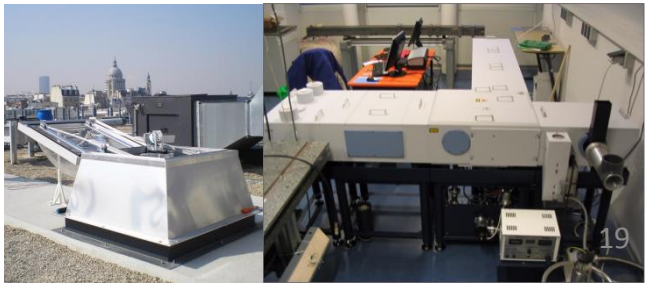
=> arches of circles on main wind paths



- **Link with satellite data:**

⇒ in-situ stations at TCCON sites & model

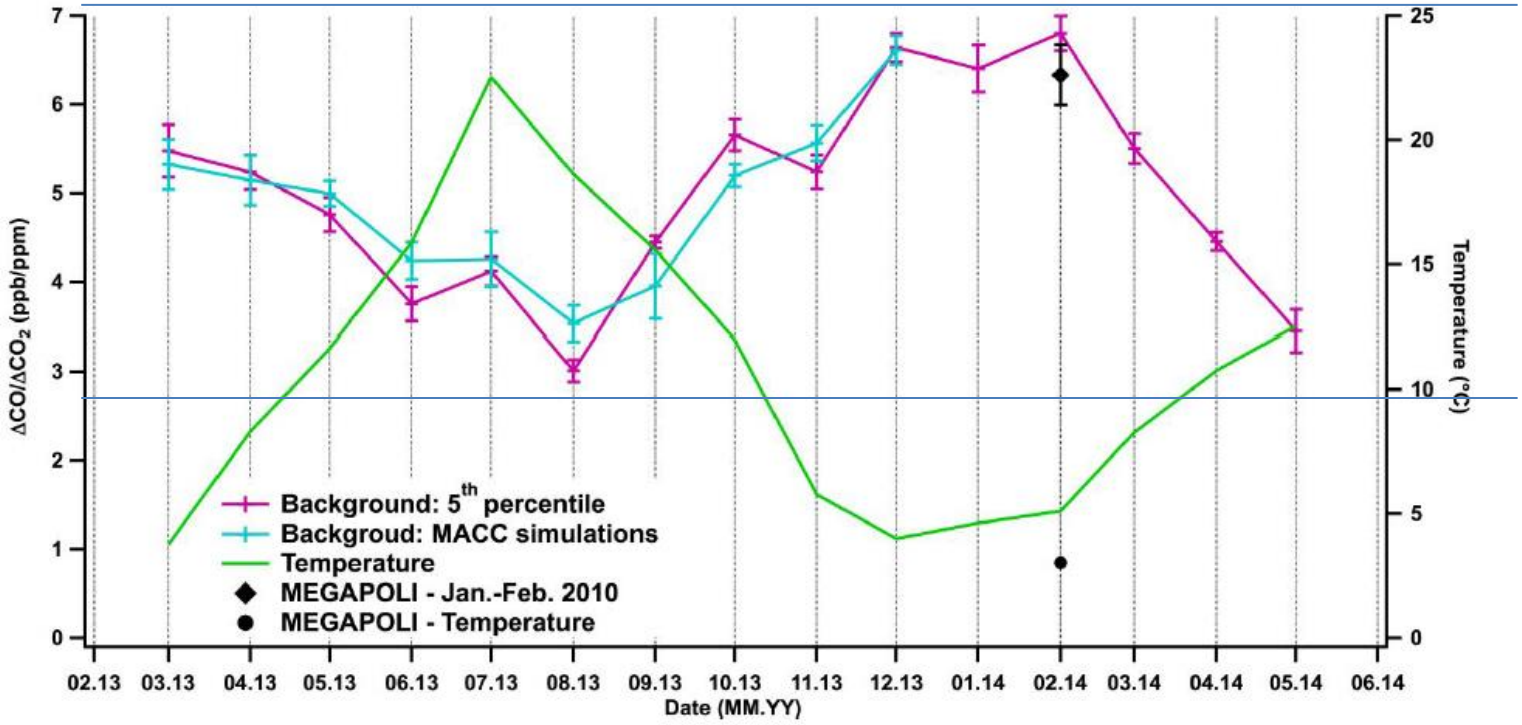
⇒ Regular tracers to come(14C…)



But! Even for the traffic sector,
we observe a large variability of the CO-CO2 ratio

Low speed period ($<$20 km.h^{-1})		High speed period ($>$ 50 km.h^{-1})	
$\Delta CO/\Delta CO_2$ (ppb/ppm)	Coefficient of determination r^2	$\Delta CO/\Delta CO_2$ (ppb/ppm)	Coefficient of determination r^2
8.44 $\pm$0.45	0.89	5.68 $\pm$2.43	0.45

Seasonal variation of the CO-CO2 ratio in Jussieu



AIRPARIF
Traffic
7,1 ppb/ppm

AIRPARIF
Heating
2,7 ppb/ppm

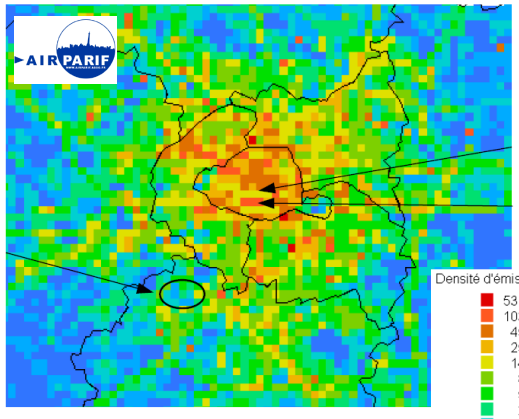
Fig.5: Monthly ΔCO to ΔCO_2 ratios in Paris. Results using background levels defined with the 5^{th} percentile are given in violet. The ones using the MACC simulations are in blue. Error bars on the ratios correspond to 1σ. The ratio from the MEGAPOLI-CO_2-Megaparis campaign and the corresponding average temperature are represented by a black disk. Temperature corresponding to the selected data for the ratio calculation averaged by month is represented in green as a proxy for season.

Ammoura et al, submitted to ACPD

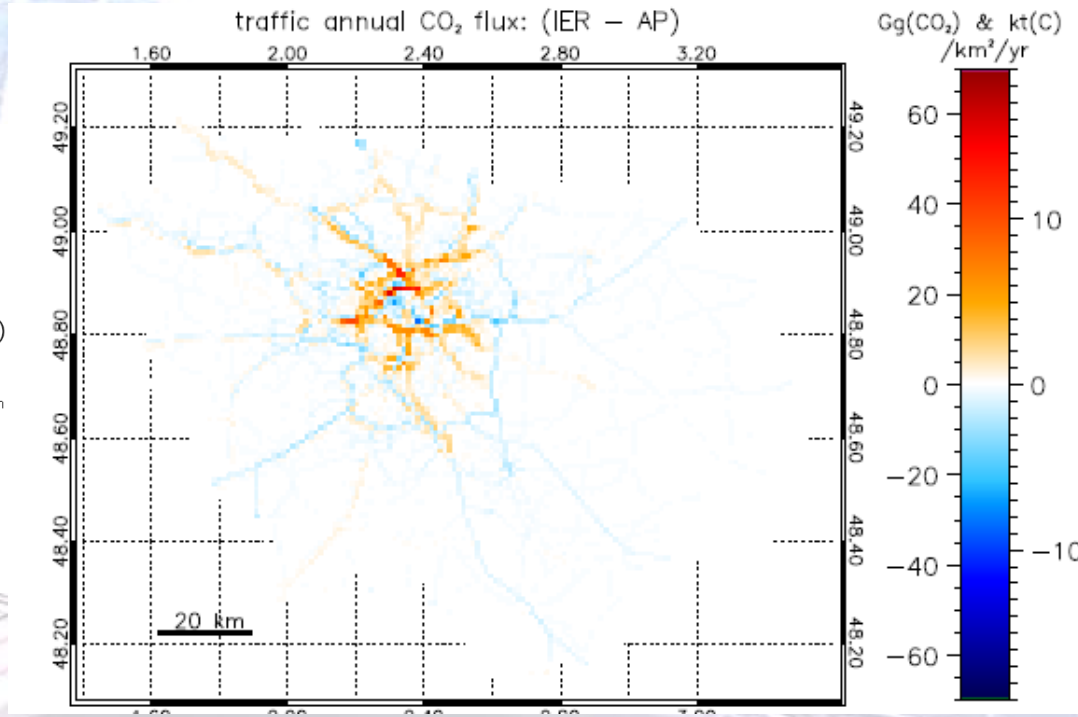
Example for the traffic sector

Spatial differences

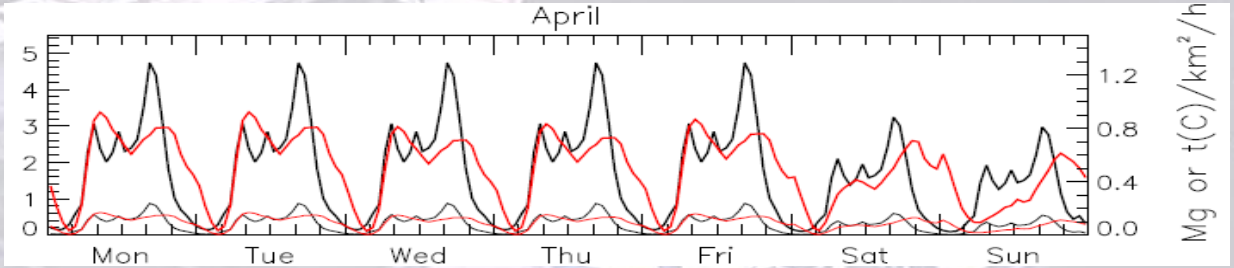
A very large spatial variability



* LHVP : **L**aboratoire de l'**H**ygiène de la **V**ille de **P**aris
** SIRTA : **S**ite **I**nstrumental de **R**echerche par **T**élédétection **A**tmosphérique



Temporal differences

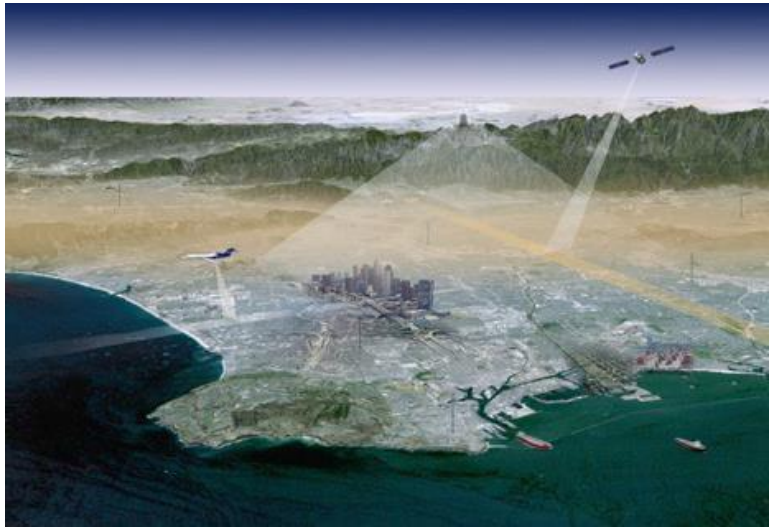


@ Dieudonné et al, 2013

Motivation

- Large uncertainties on urban CO_2 emissions
- Even larger uncertainties by emission sector
- In some megacities, no emission inventory at all
- Political need for improving / verifying emissions & their trends

=> Since 2009: Pilot atmospheric studies emerged in Los Angeles, in Indianapolis…



The MEGACITIES project in L.A.
(NIST - JPL/NASA)
including new satellite data from OCO-2

INFLUX project towers in Indianapolis
(NIST, UC)

Asymptot method

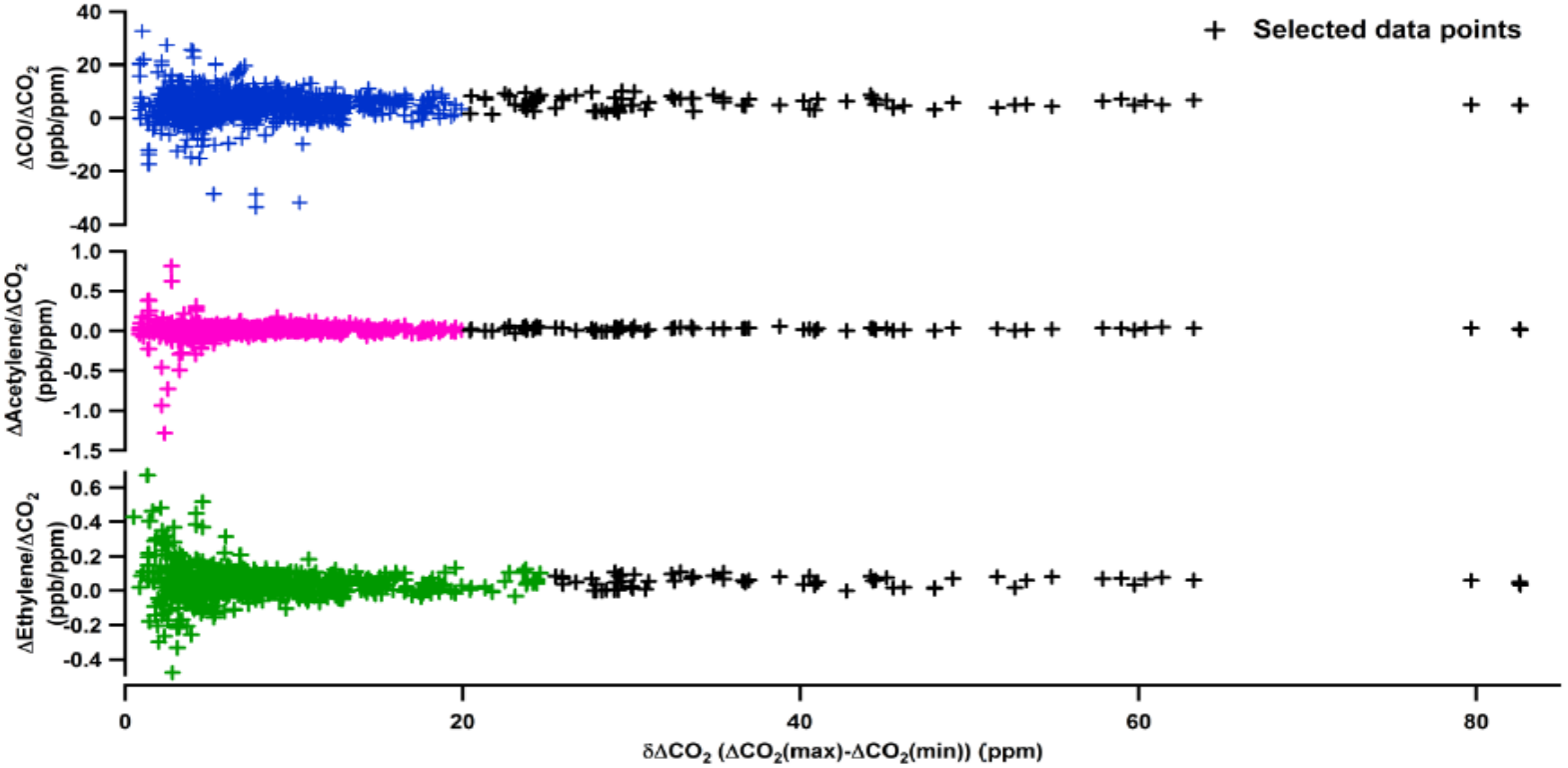


Fig. 3: Selected ratios to ΔCO_2 plotted versus the local CO_2 offset ($\delta\Delta CO_2$) from the measurements acquired during the Multi-CO_2 campaign. Black data points were selected to determine the equation of the horizontal asymptote using the criteria described in Section 3.3.2 (the used criteria depend on the considered species).

Ammoura et al, ACPD, 2015