Etude des émissions de CO_2 urbaines par l'approche atmosphérique

Journée valorisation scientifique AIRPACA
9 décembre 2016

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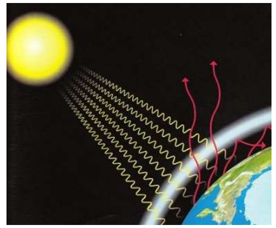
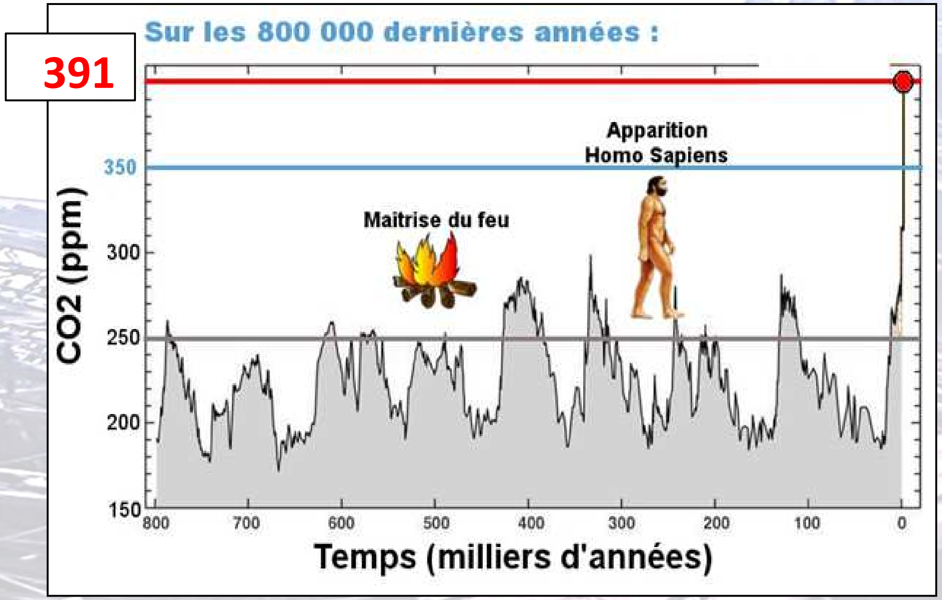
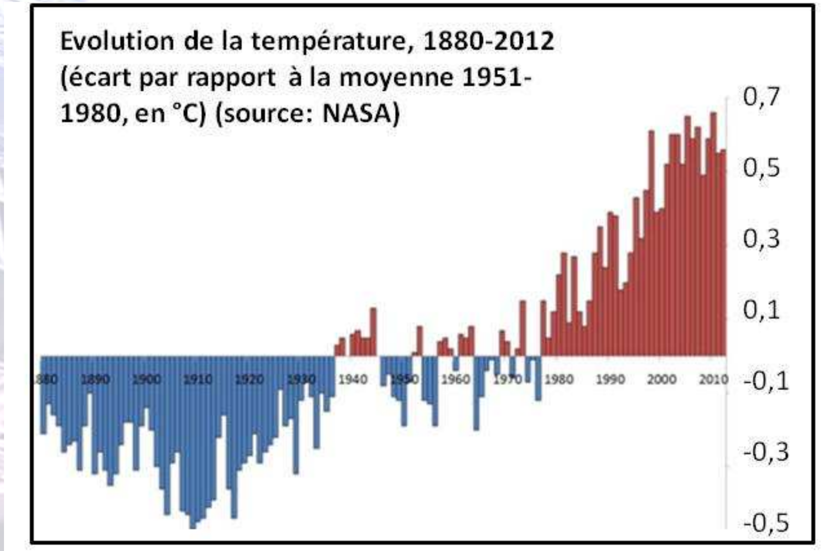
Pourquoi s'intéresser au CO_2 ?

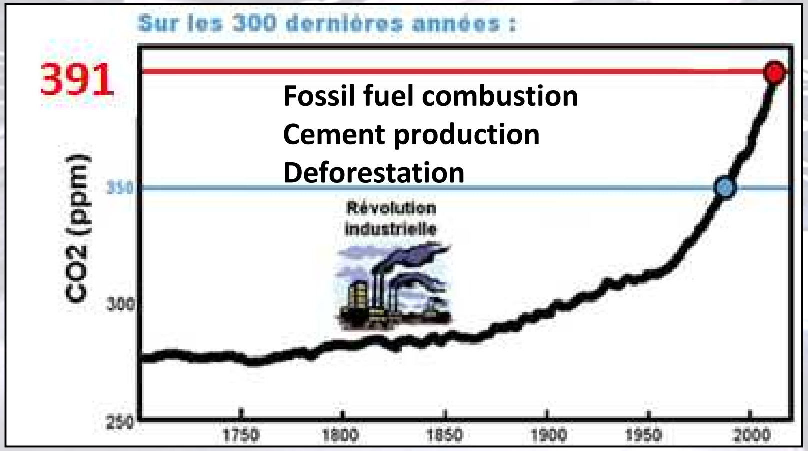


"It is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century."

GIEC (IPCC) 2013





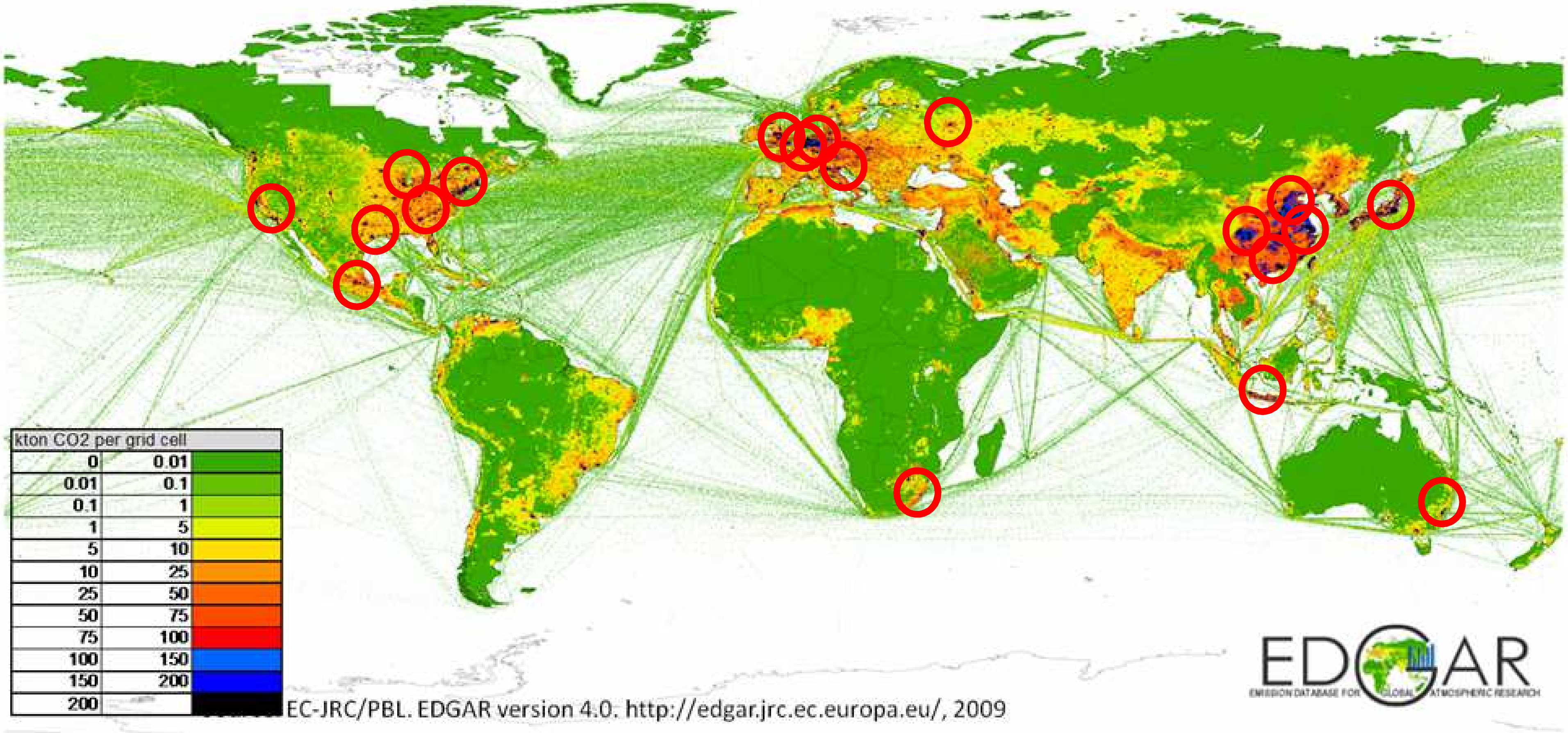


GIEC 2013 projections:
=> +0.3 to + 4.8°C in 2100

Objective: keep it under 2°C => control our CO2 (GHG) emissions

Why studying urban CO_2 emissions ?

More than 75% of global fossil fuel CO_2 emissions come from urbanized and industrialized areas - in the first line: MEGACITIES



⇒ **Quantifying CO_2 emissions of the biggest cities and of power plants can be easier than measuring them everywhere over the globe**

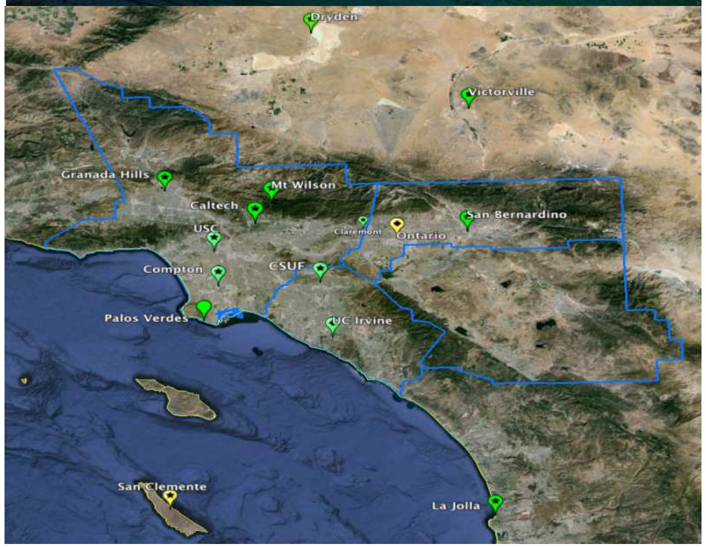
⇒ **BUT REGIONAL EMISSIONS UNCERTAINTIES ARE VERY LARGE or UNKNOWN**

Scientific/political needs for improving/verifying emissions estimates from cities

Since 2009 => Increasing number of city scale in-situ CO_2 networks & emission survey programs

INFLUX (Penn State University): Indianapolis

MEGACITIES CARBON PROJECT (NASA/JPL): Los Angeles (in link with Paris, São Paulo…)

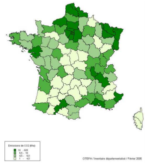


52 MtCO2/an

12000km²

...and also in Europe: The CO2-MegaParis project

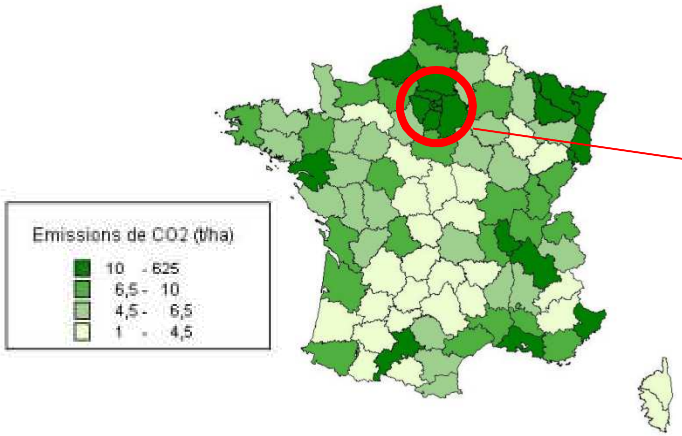
(projet ANR blanc 2009-2013)



308 MtCO2/an

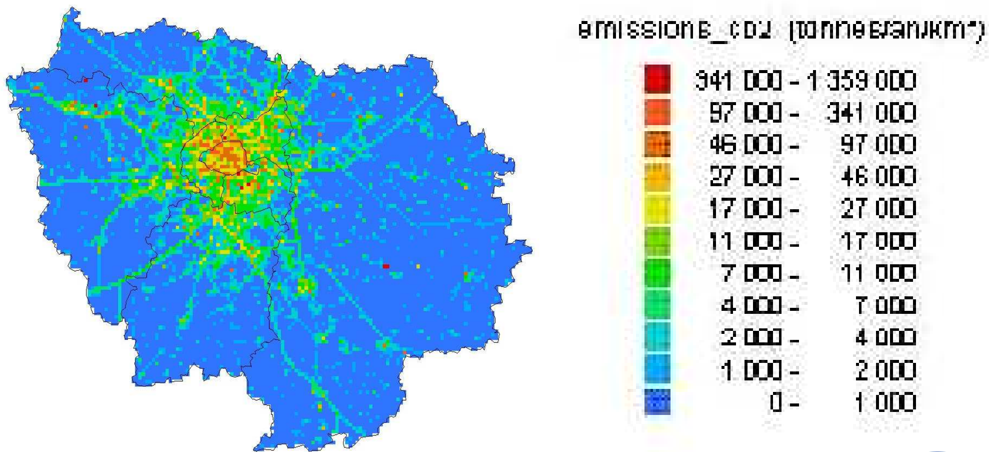
551000km²

- Paris is the 2nd megacity in Western Europe (and ~20th at the global scale)
- Plan Climat Energie - Ville de Paris (baisse émissions CO2 -25% 2020; -75% 2050 / ref 2004)
- The region Ile-de-France emits ~13% of national CO_2 emissions for 2% of the territory*
- No independant verification of inventories and uncertainties unknown



CO_2 emissions per region (CITEPA)

90% of the population of IDF are concentrated in 20% of its area



HR CO_2 emissions for Ile-de-France (AIRPARIF)

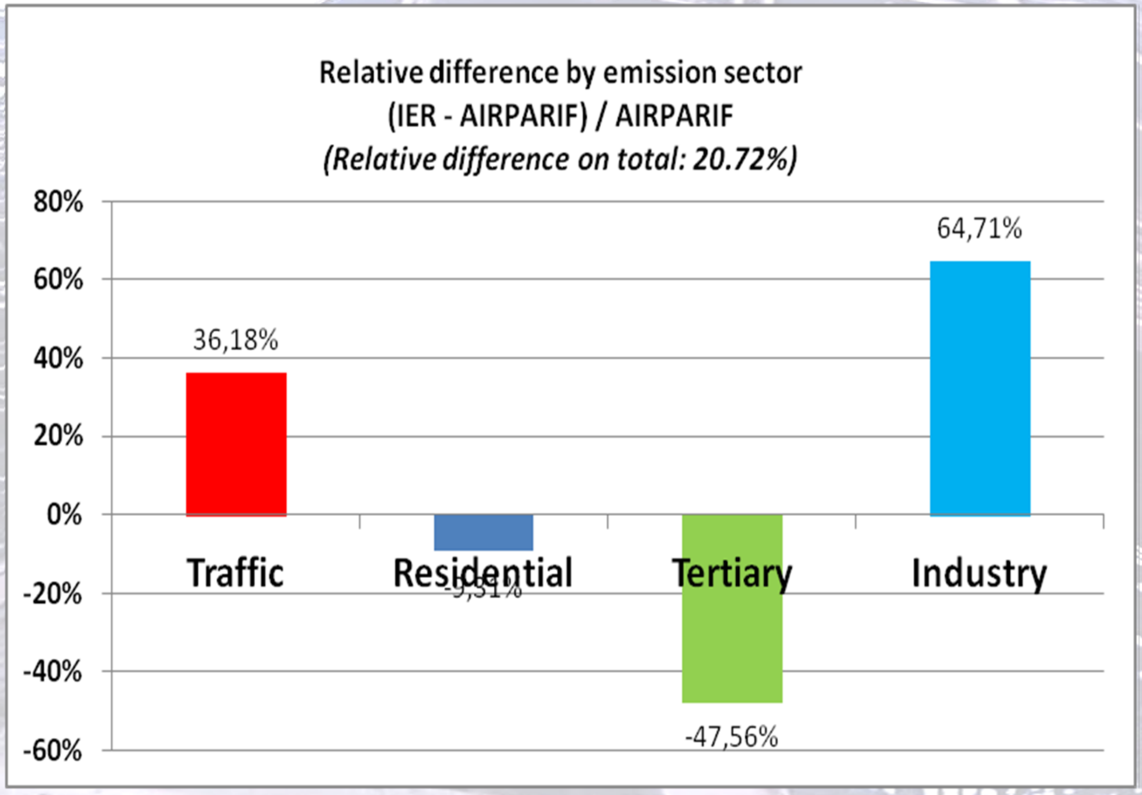
(**source: inventories of AIRPARIF & CITEPA*)

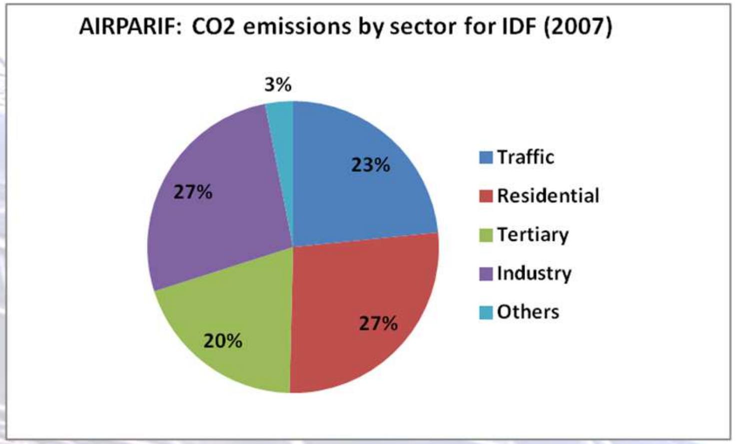
1- Intercomparaison of high resolved inventories

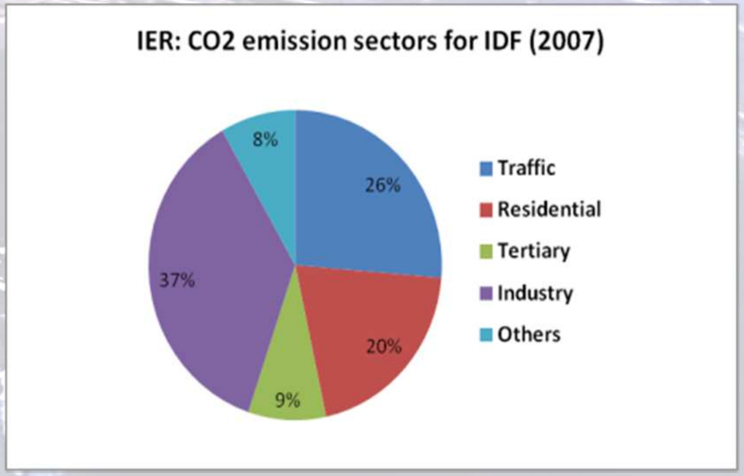
AIRPARIF Paris/ IER Stuttgart : 1x1 km², 1h (2008)

Dieudonné et al, AGU 201

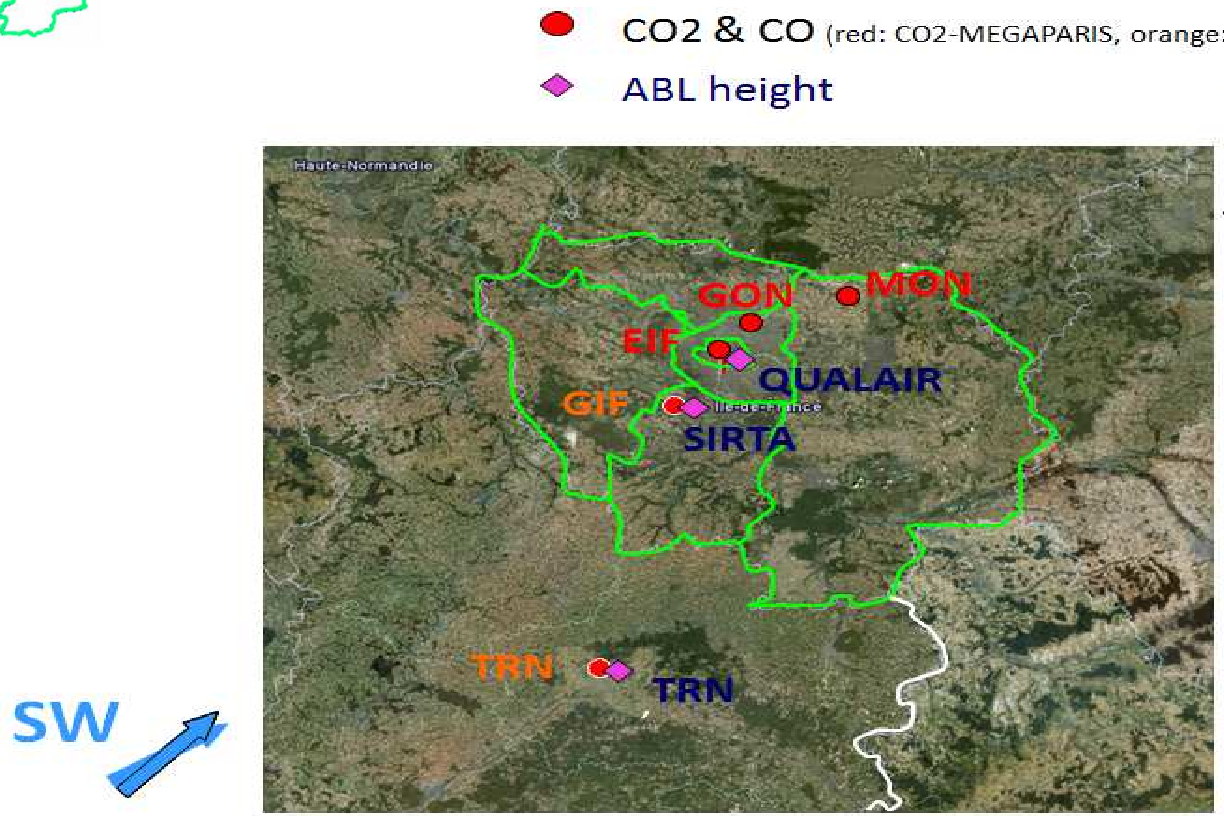
Sector	$Mt(CO_2)/yr$ IER	AIR
All	**62.86**	**52.07**

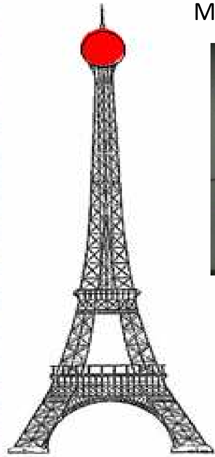






2- The regional in-situ CO_2&CO network





Model G1302 (CO_2/CO/H_2O)

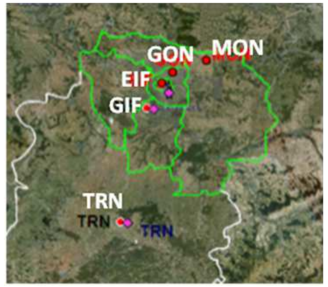
© Xueref-Remy et al, tbs

MON	GON	EIF	GIF	TRN
CO2-Megaparis	CO2-Megaparis	CO2-Megaparis	ICOS	ICOS
CRDS Picarro G1302	CRDS Picarro G1302	CRDS Picarro G1302	Gaz chromatography	Gaz chromatography
CO_2, CO	CO_2, CO	CO_2, CO	CO_2, CO and others!	CO_2, CO and others!
5s	5s	5s	5mn	5mn

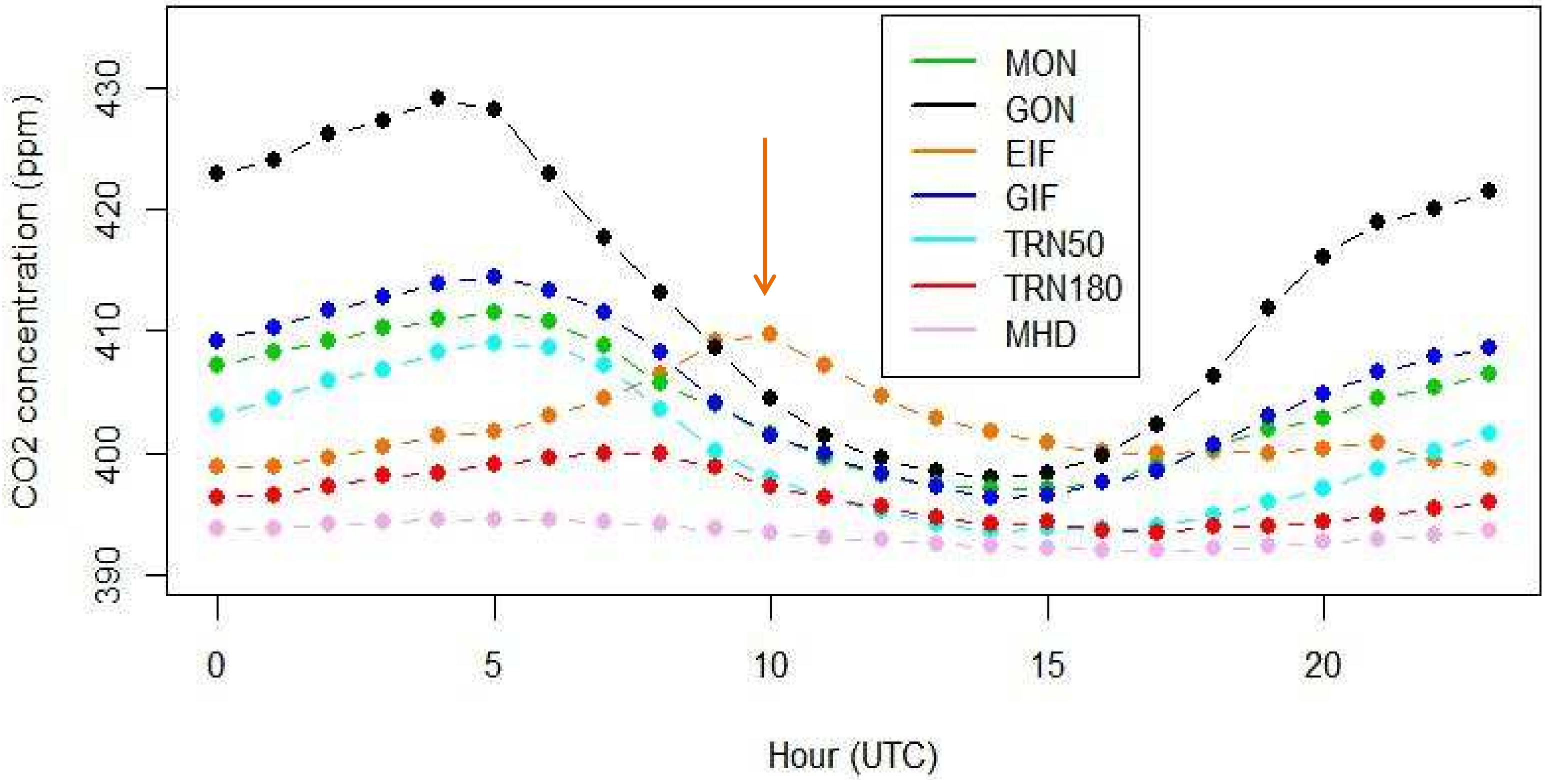
+ 3 aerosols Lidars (355 nm, 15m, 5mn)

Diurnal cycles

Amplitude night-day: 5 to 30 ppm
Gradient between stations: <1 to 25 ppm



© *Xueref-Remy et al, tbs*

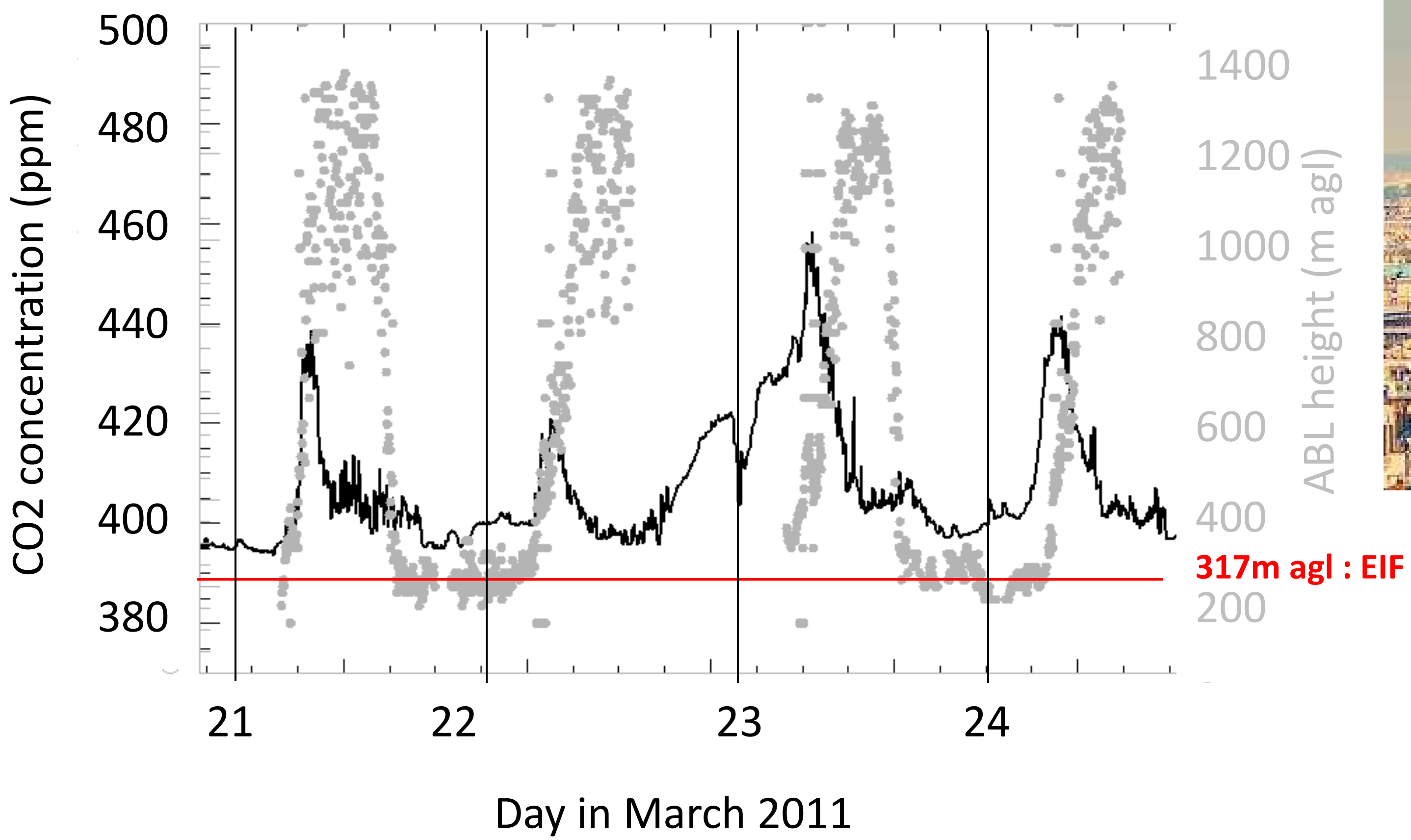


Xueref-Remy et al, ACP 2016, subm.

Explaining the variability

The special case of the top of the Eiffel tower

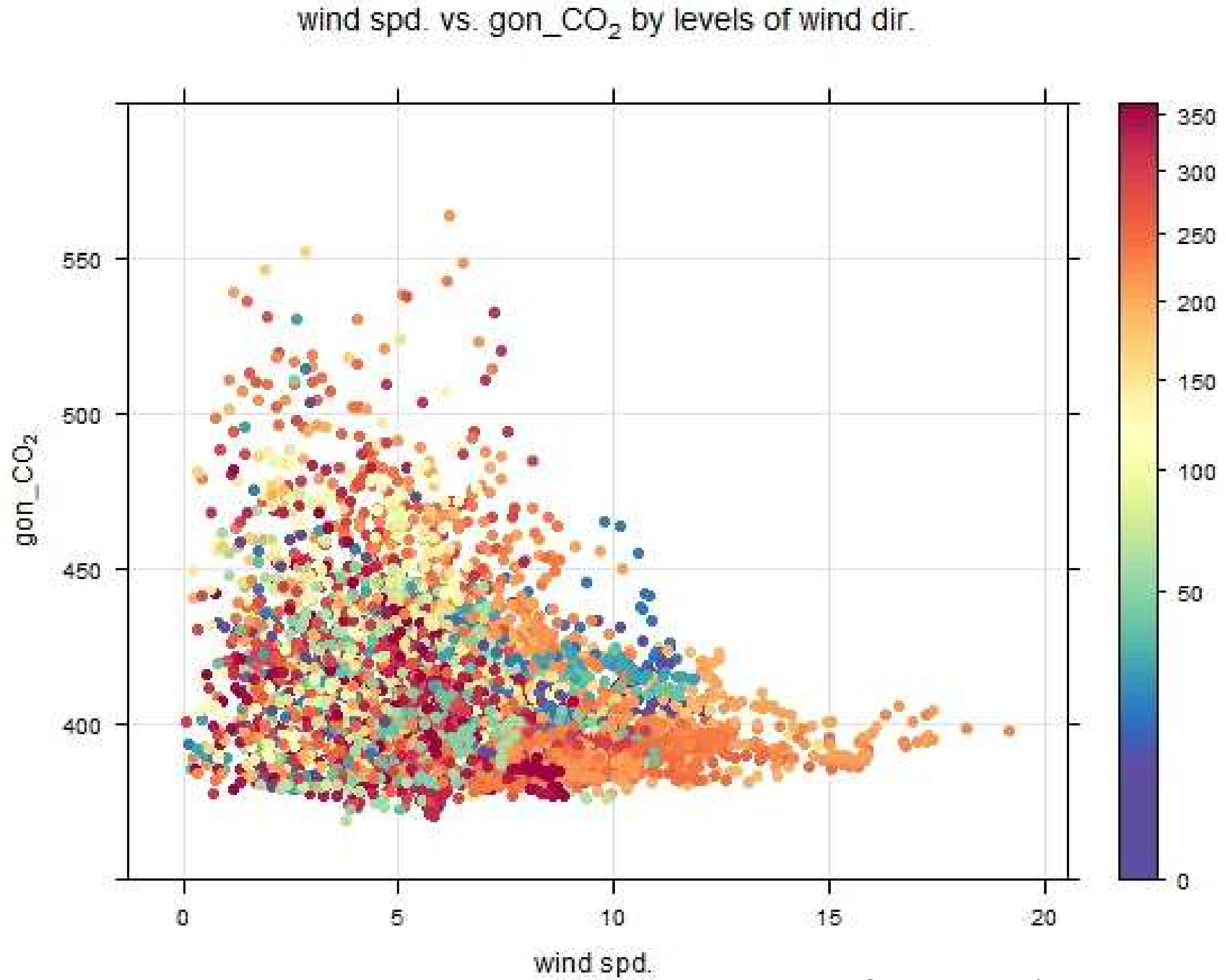
The CO_2 concentration at EIF is coupled with ABL dynamics



Xueref-Remy et al, FAO Roma 2011

Distinguer le signal régional du fond

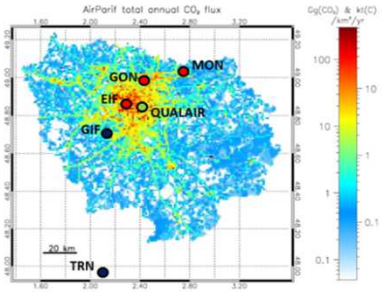
Asymptote (NOT a CO_2 regional background level !)

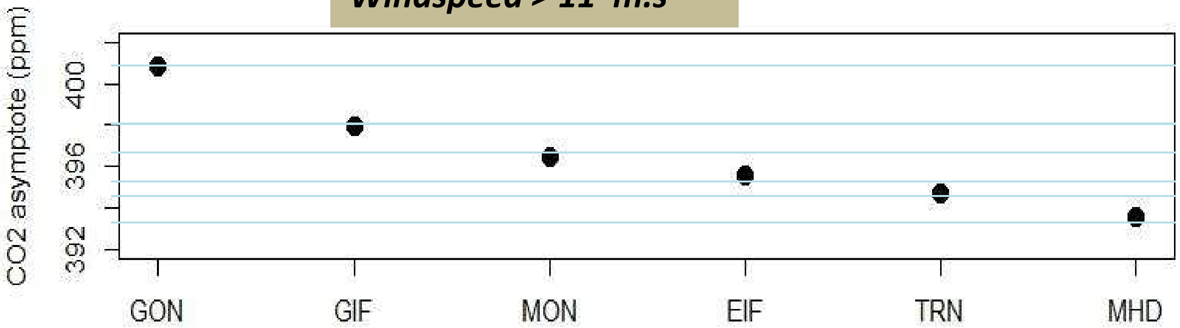


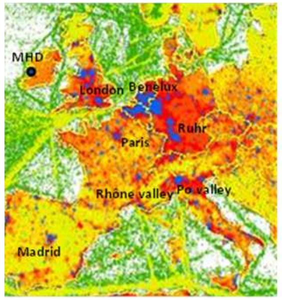
Xueref-Remy et al, ACP 2016, subm.

Upwind background assessment (afternoon hours)

Windspeed > 11 m.s^{-1}

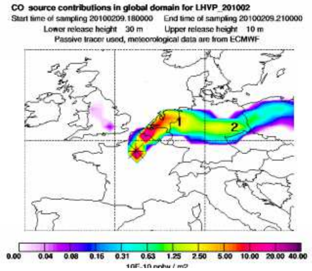




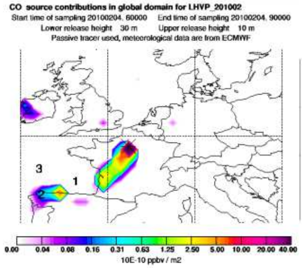


Windspeed = 3 to 11 m.s^{-1}

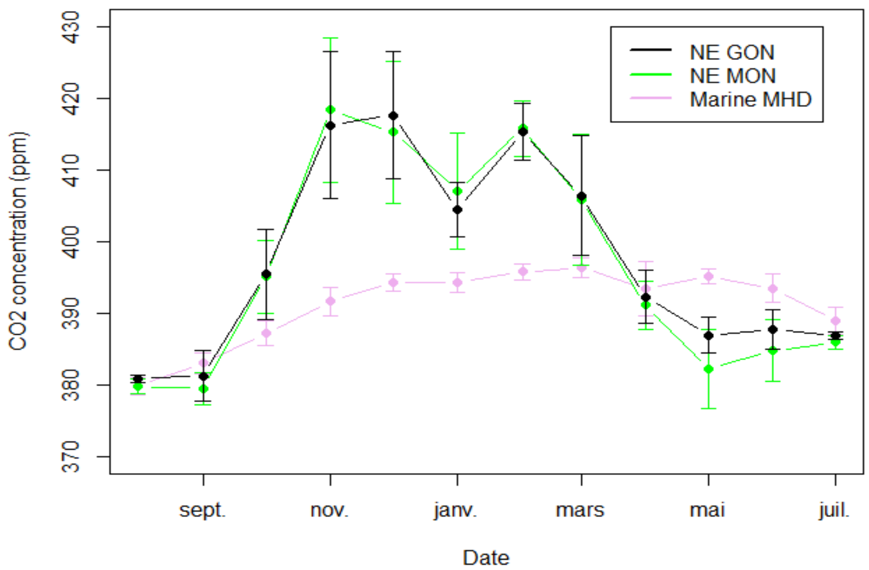
FLEXPART



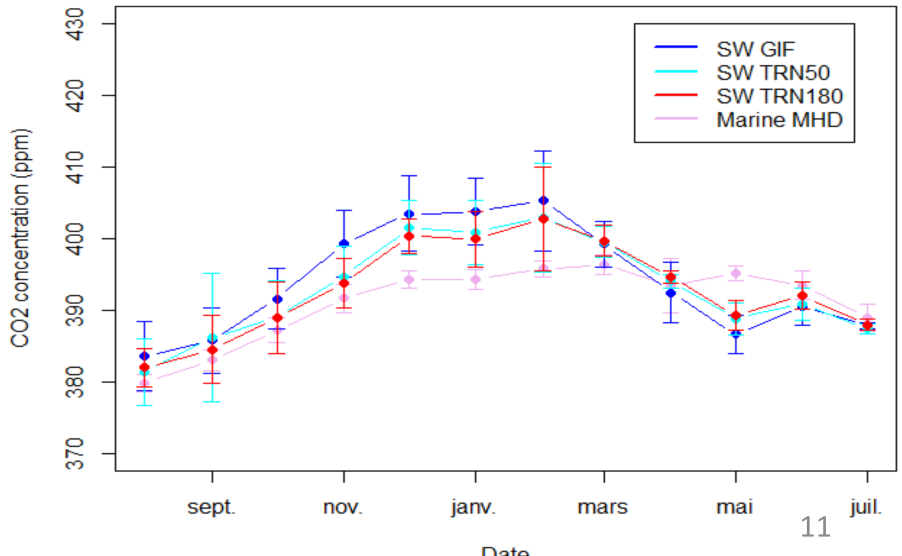
FLEXPART



NE sector CO2 background, comparison to MHD marine sector



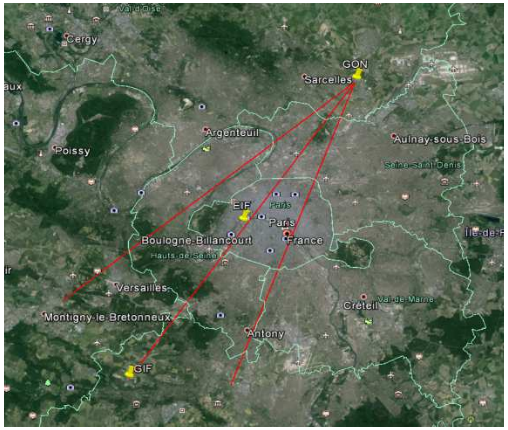
SW sector CO2 background, comparison to MHD marine sector

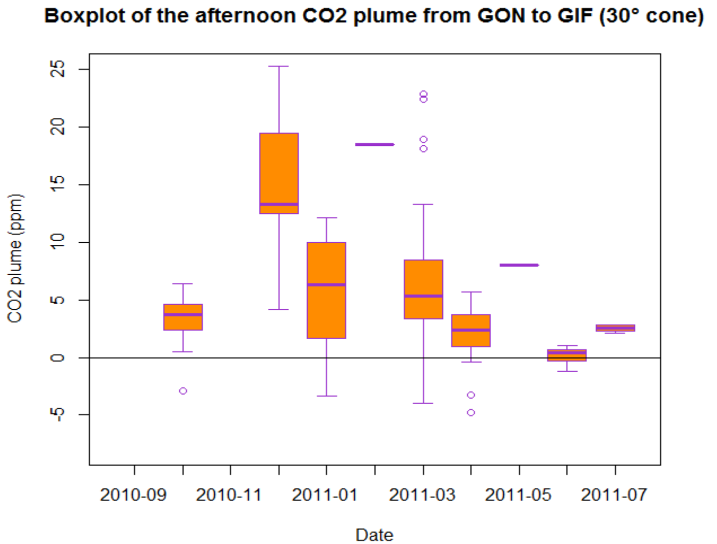


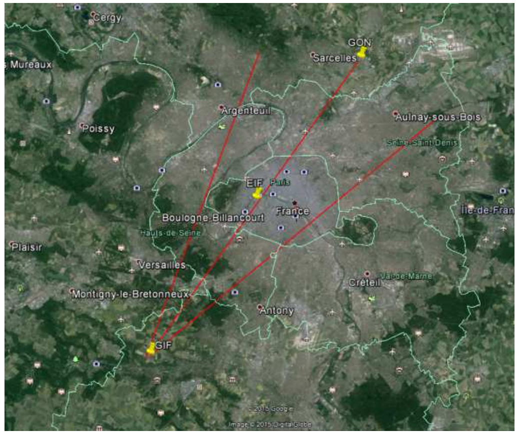
Xueref-Remy et al, 2016

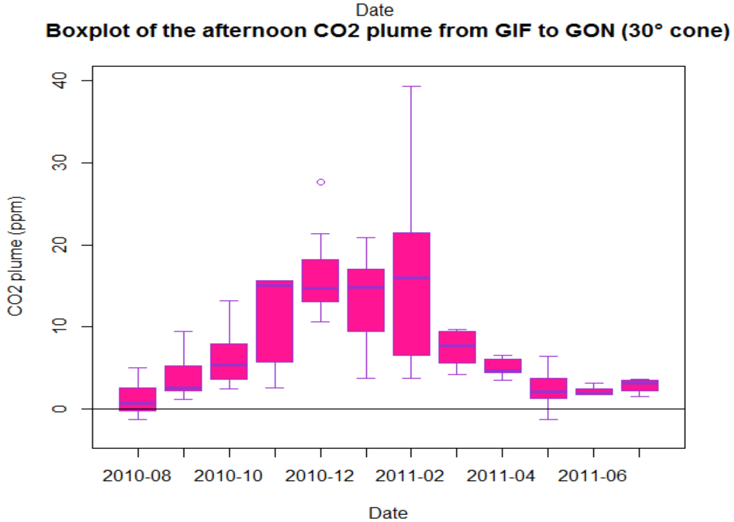
Paris CO_2 seasonal plume in the mid-afternoon:
Ex. GON minus GIF & GIF minus GON

Wind selection:
3-8 $m.s^{-1}$ & 30° cones (ie +/-15°)





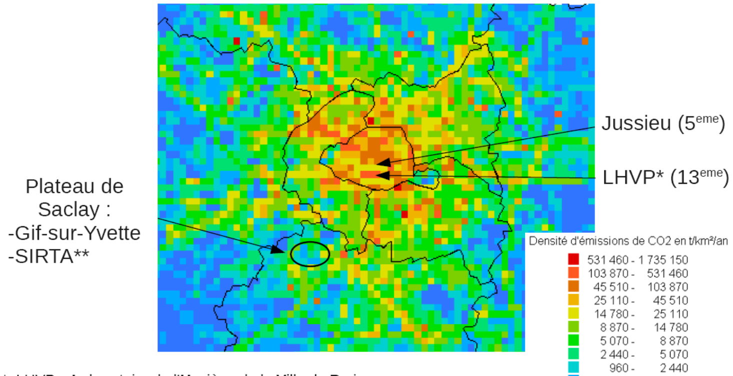




Xueref-Remy et al, AGU 2015

Assessing the relative role of the different emission sectors

$^{14}CO_2$ winter campaign in Feb 2010 (MEGAPOLI / CO2-Megaparis)



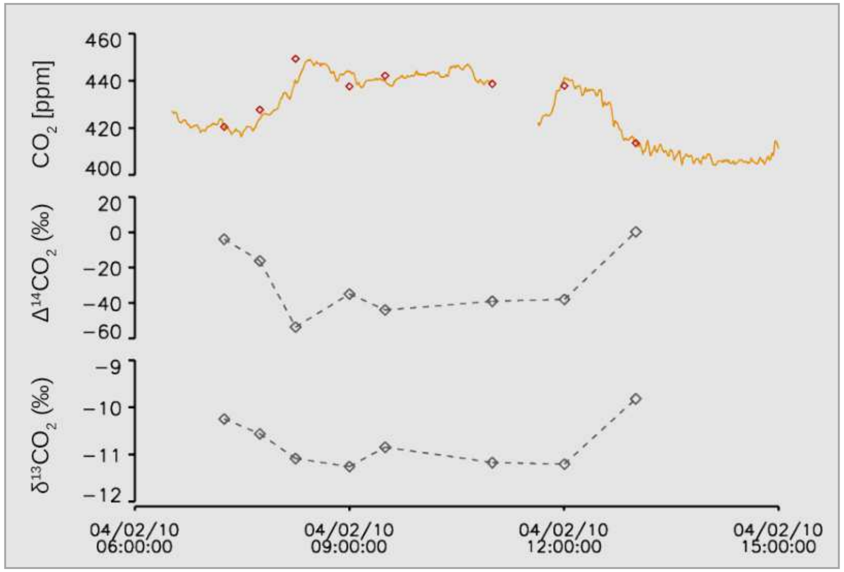
* LHVP : Laboratoire de l'Hygiène de la Ville de Paris
** SIRTA : Site Instrumental de Recherche par Télédétection Atmosphérique

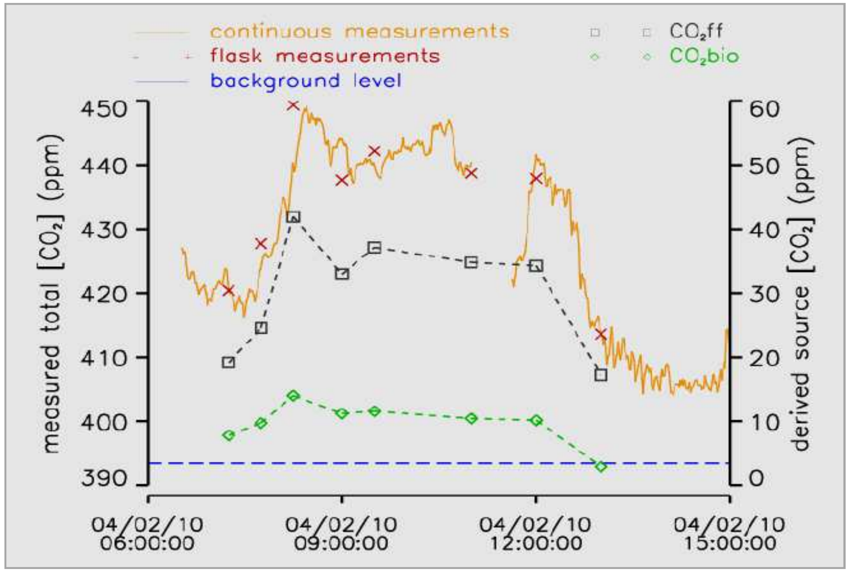
$$CO_2ff = CO_2meas \cdot \frac{\Delta^{14}CO_2bg - \Delta^{14}CO_2meas}{\Delta^{14}CO_2bg + 1}$$

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

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

Levin et al, 2001
Lopez et al, ACP, 2013





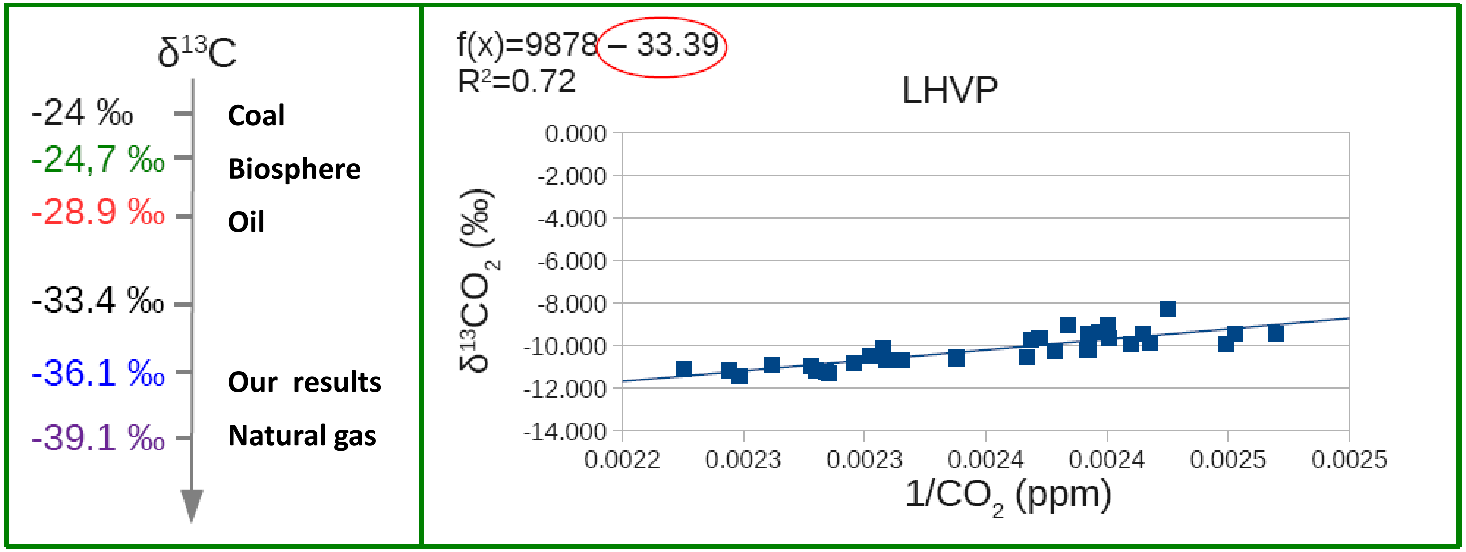
	LHVP (ppm / %)	Sources
CO_2 ff	**30 ppm / 75 %**	**Natural gas and oil**
CO_2 bio	**10 ppm / 25 %**	**Human and biospheric respiration + Biofuels**

Assessing the role of the different emission sectors:

$^{13}CO_2$ Keeling plot

$$\delta^{13}CO_2meas = \frac{CO_2bg(\delta^{13}CO_2bg - \delta^{13}CO_2s)}{CO_2meas} + \delta^{13}CO_2s$$

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%

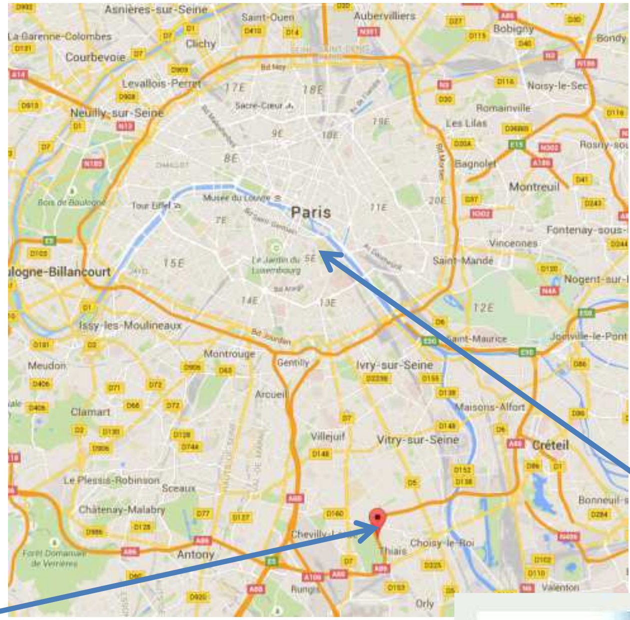
Residential and industrial sectors

Oil: 30%

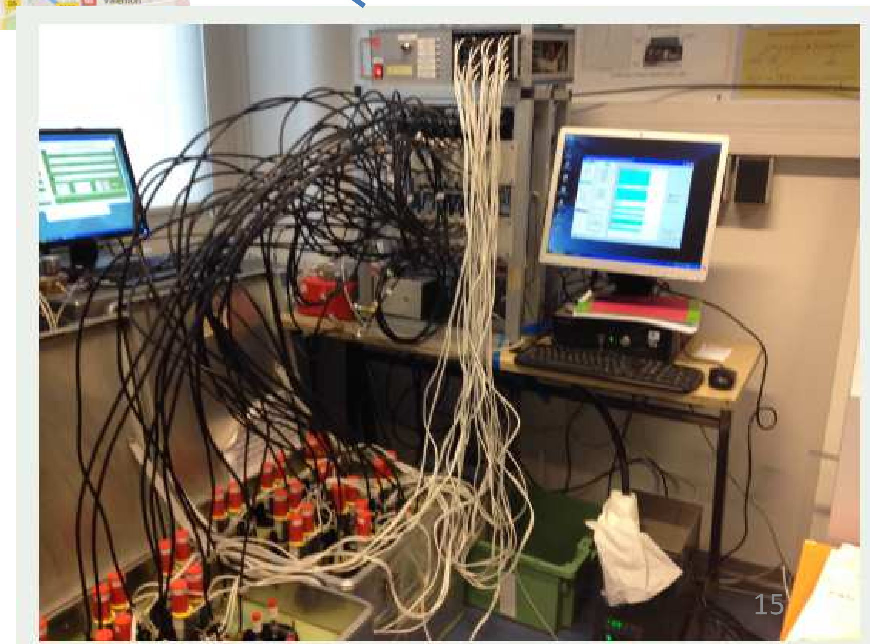
Traffic sector

3…- CO_2 emissions sectors: developping a multi-tracers approach

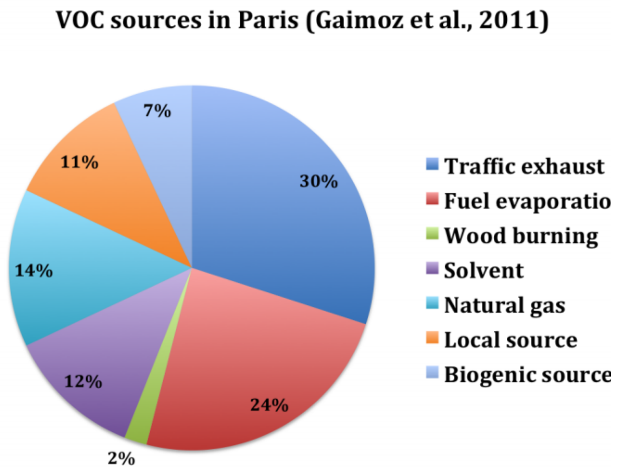
Tunnel campaign (Primequal-ZAPA project with AIRPARIF)

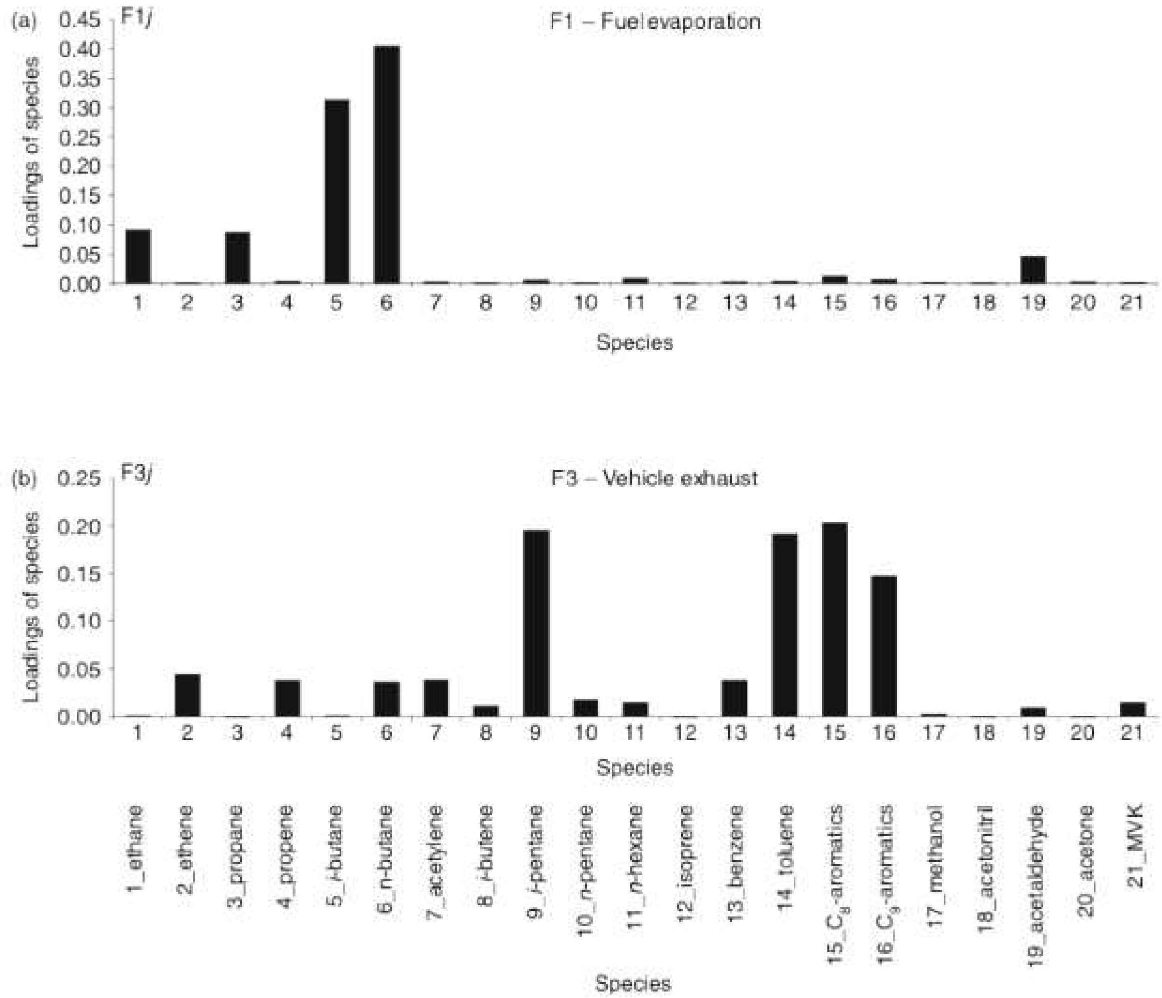


Campaigns at QUALAIR/JUSSIEU
***Multi-CO2 project, IPSL**
***OCAPI-Paris 2030 with IPSL, AIRPARIF and INERIS**



VOCs source profiles in Paris

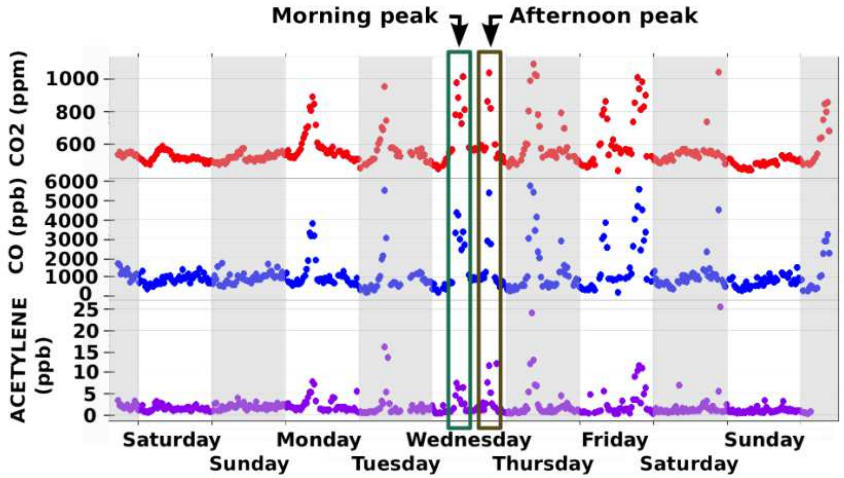




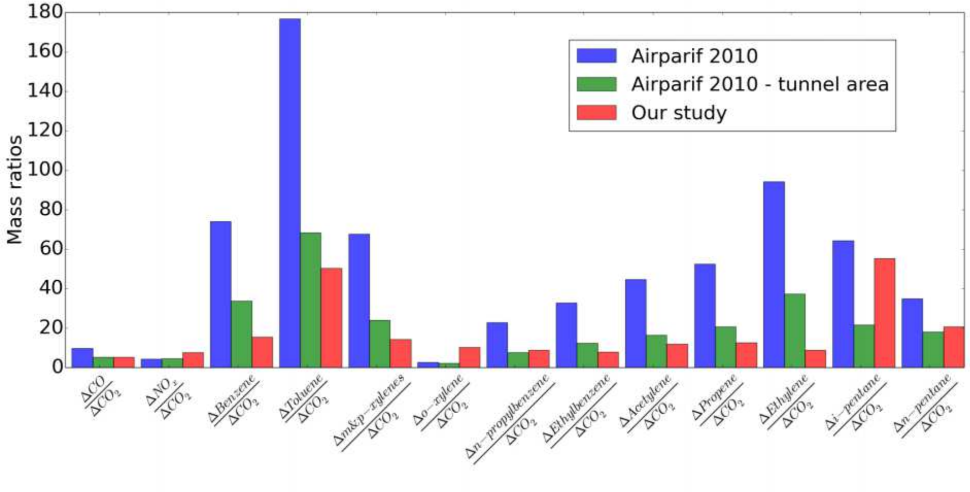
Source : Gaimoz et al., 2011.

Tunnel campaign => assess emission ratios to CO_2 for the traffic sector

Primequal-ZAPA project, September 2012, Tunnel de Thiais (A86)

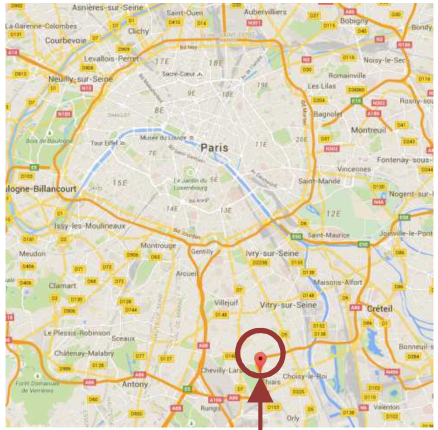


- Workdays : diurnal pattern with two concentration peaks.
- Concentration peaks ⇌ rush hours.



Data from inventory : traffic only.

Ammoura et al, ACP, 2014



Conclusions:

- ❑ **Caractérisation des rapports pour le trafic.**
- ❑ **Intérêt comparaison inventaire HR**
- ❑ **Vérification de l'inventaire => La matrice de spéciation des COVs AIRPARIF doit être révisée / normes actuelles.**

Campagne Multi-CO_2 (Jussieu)

Atmosphère ouverte, pics marqués & corrélés entre espèces par vent faible.

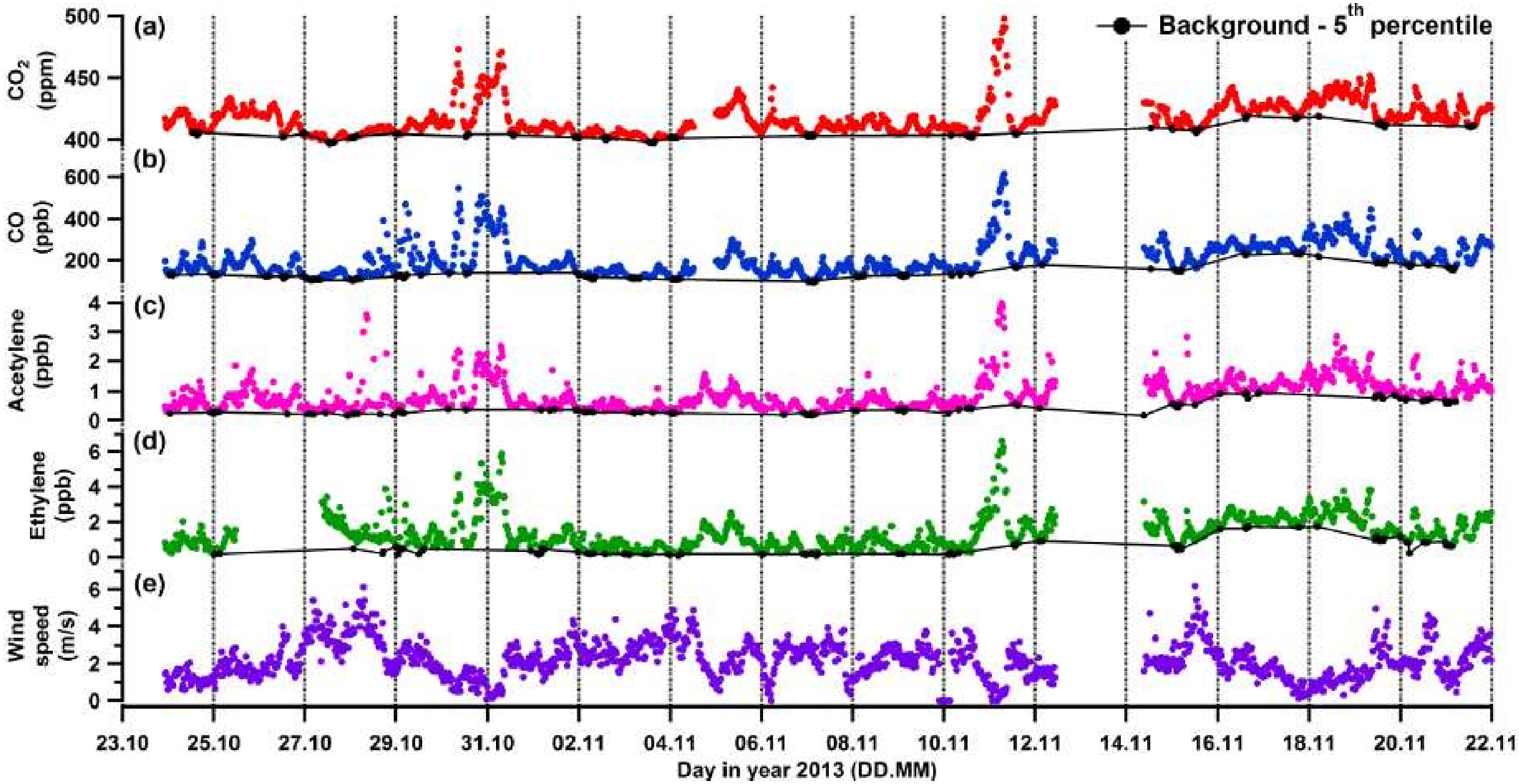
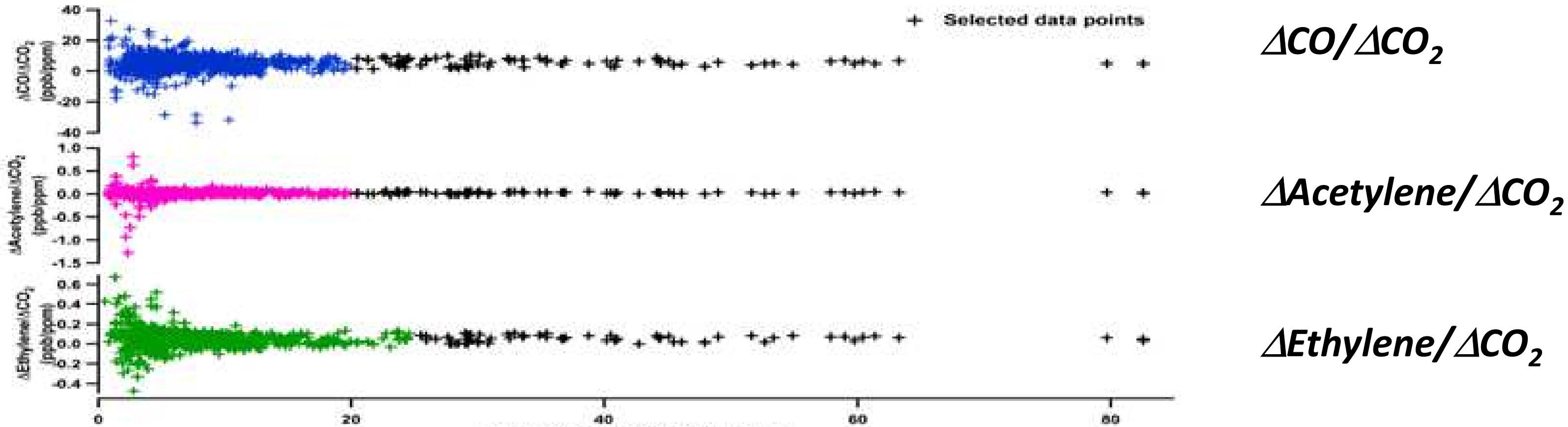


Fig.1: (a-d) Temporal variation of the mole fraction of selected compounds monitored during the Multi-CO_2 campaign (30 minutes time step). The black lines represent the background levels defined with the calculation of the 5^{th} percentile (black disks). **(e)** Wind speed during the campaign. Time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

Ammoura et al, ACP 2016

Méthode asymptotique pour déterminer les rapports (Ammoura et al, ACP 2016)



CO_2 peak amplitude minus background as the 5th percentile

Windspeed < 3 m/s, 1-3 days long => signature of the Paris emissions

ΔCO_2	-	**5.55 (0.24)**	**24.82 (2.13)**	52.55 (3.87)	11.18 (2.51)	**13.57 (2.34)**	9.27 (0.97)	49.81 (5.10)	32.07 (2.92)
ΔCO		-	3.48 (0.28)	**5.47 (0.39)**	1.32 (0.08)	**2.18 (0.15)**	1.15 (0.11)	6.56 (0.59)	3.19 (0.30)
ΔAcetylene			-	1.09 (0.06)	0.21 (0.01)	0.28 (0.02)	0.17 (0.01)	0.75 (0.10)	0.48 (0.04)
ΔEthylene				-	0.11 (0.01)	**0.19 (0.01)**	0.10 (0.01)	0.57 (0.04)	0.35 (0.02)
ΔPropene					-	0.72 (0.04)	**0.36 (0.03)**	1.87 (0.20)	**1.13 (0.09)**
Δi-pentane						-	0.44 (0.01)	1.73 (0.11)	0.89 (0.06)
Δn-pentane							-	2.66 (0.21)	1.14 (0.08)
ΔEthane								-	0.20 (0.01)
ΔPropane									-

Assessment of CO_2 and VOCs ratios in the urban atmosphere over Paris at the Fall 2013

(bold = in agreement with Winter 2011 ratios calculated during the MEGAPOLI/CO2-MEGAPARIS campaign)

Good correlation with CO_2 (R_2 > 0,8) with species emitted from combustion sources (trafic, gaz heating, wood burning….) but multiple sources for each gas, thus sources speciation difficult

=> need combination with other tracers (BC, levoglucosan, isotopes…)

Impact of wood burning on Paris CO_2 emissions and CO/CO2 ratio?

Large $\Delta CO/\Delta CO_2$ in winter: not in agreement with AIRPARIF inventory (3.1 ppb/ppm in January against 3.6 ppb/ppm in August)
Impact of wood burning? = 90% emissions of CO of the residential sector, not accounted for in the AIRPARIF CO2 emissions because not a fossil fuel.

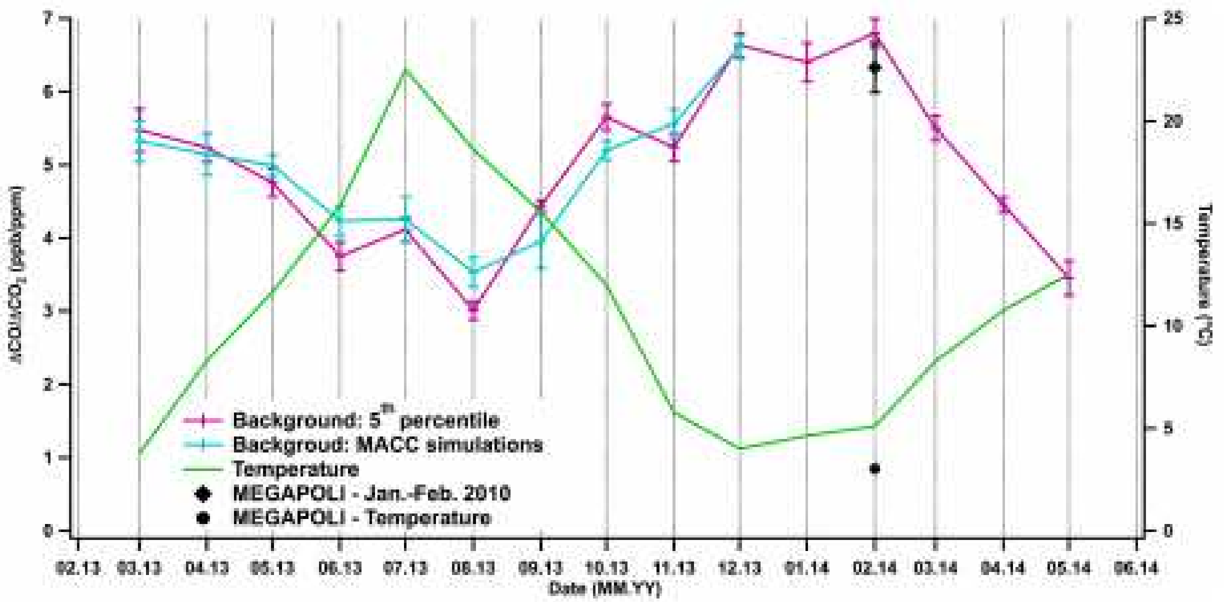
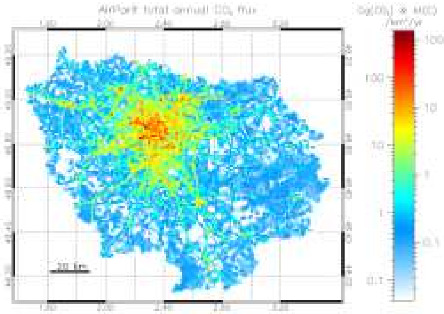
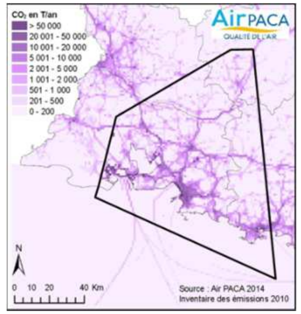


Figure 5. Monthly ΔCO to ΔCO_2 ratios in Paris. Results using background levels defined with the 5th percentile are given in violet. The ones using the MACC simulations are in blue. Error bars on the ratios correspond to 1σ. The ratio from the MEGAPOLI-CO_2-Megaparis campaign and the corresponding average 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.

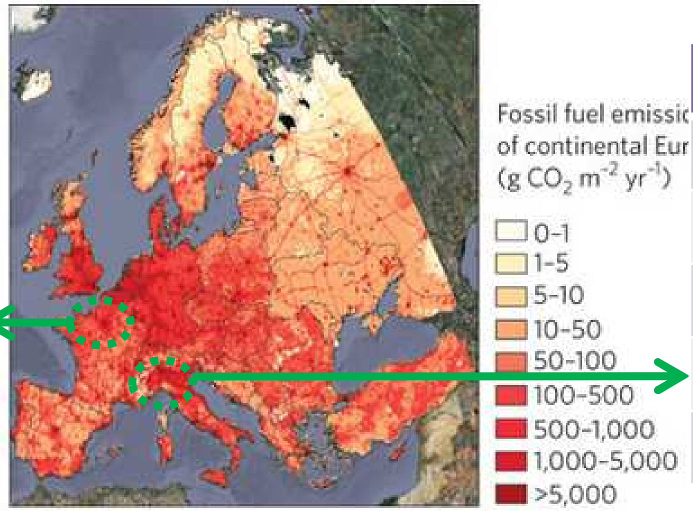
Ammoura et al, ACP 2016

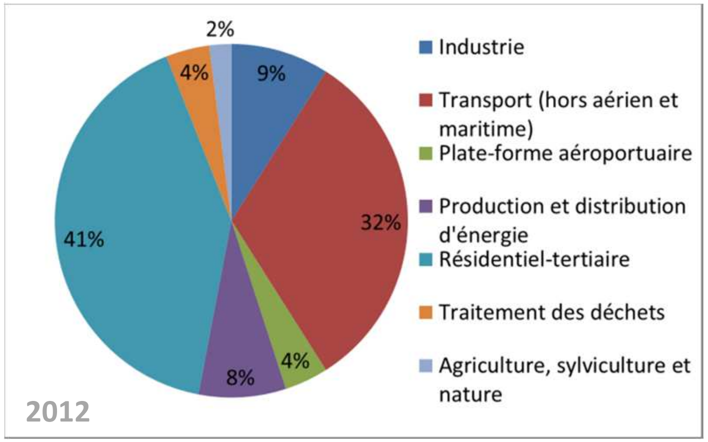
2- De Paris à Aix-Marseille…
…toujours de fortes émissions anthropiques de CO_2
La PACA, région très exposée au changement climatique (GIEC, 2013)

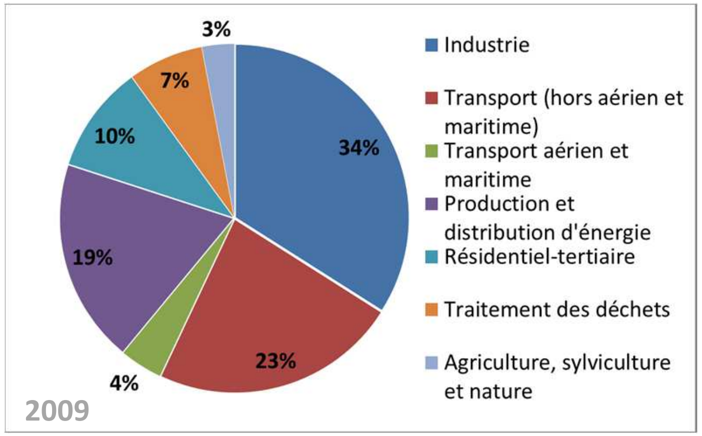




Paris & IDF	Aix-Marseille & PACA
12M habitants	5M habitants
41 MteqCO_2	36 MteqCO_2
13% émissions nationales	10,5% émissions nationales
Plaine	Zone côtière & Relief escarpé
Gaz naturel, pétrole	Charbon, pétrole, gaz naturel







Projet AMC/OT-MED (Aix-Marseille Carbon Pilot Study) 2016-2019

MIO – AIRPACA – IMBE – OHP - LSCE

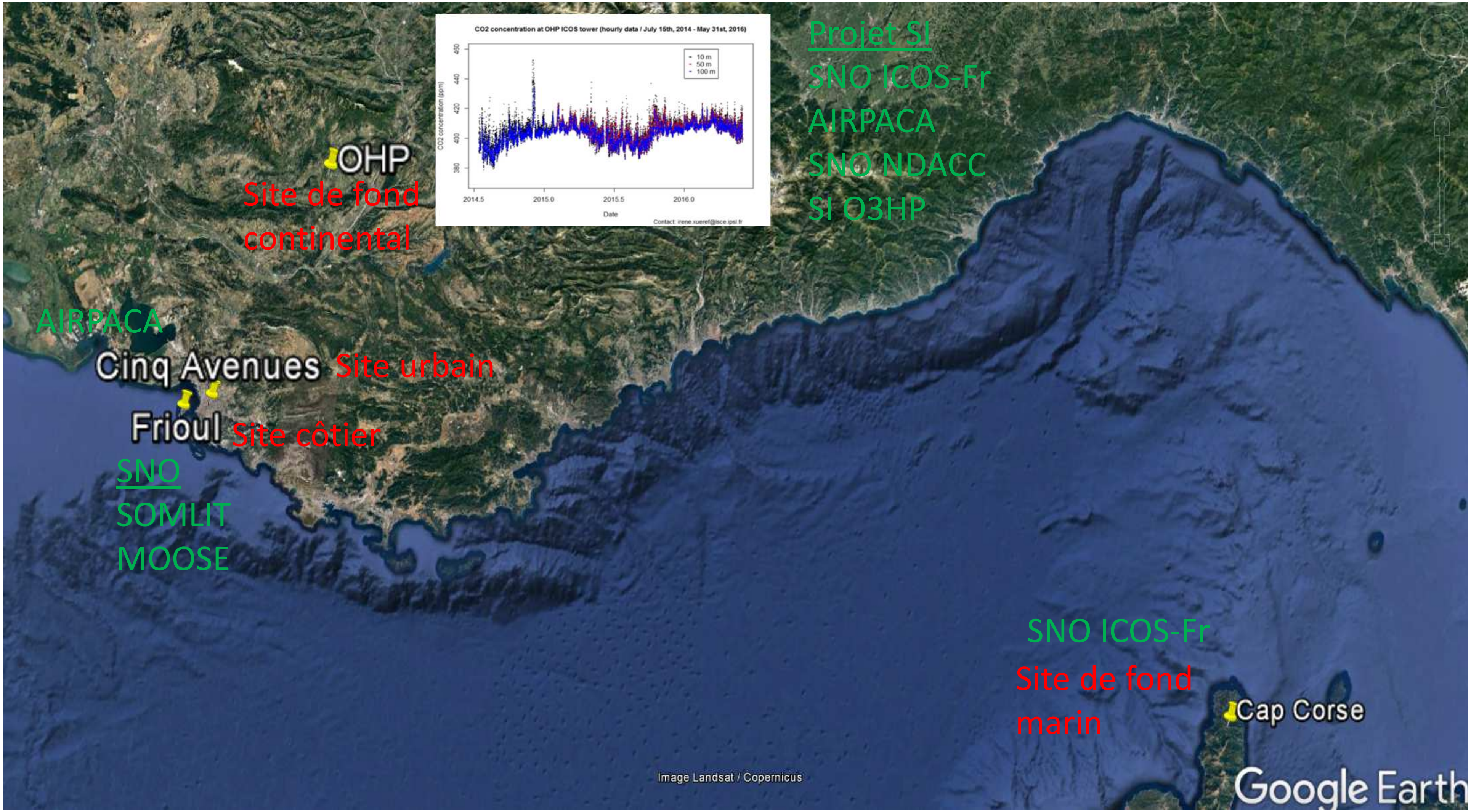
Développements & outils:

- Mini-réseau régional d'observation du CO2 (ICOS + AIRPACA + MIO
  Sites :OHP, Cinq Avenues, Endoume/Frioul, Cap Corse
- Modèle atmosphérique régional à haute résolution pour le CO2 + OSU-Pytheas, MIO, AIRPACA (POSTDOCTORANT)
- Campagne de terrain (CO, $^{14}CO_2$) (Janvier-juillet 2017)
- Comparaison observations/modèle

Résultats attendus:

- Caractérisation des contributions des différents secteurs d'émissions au CO_2 mesuré
- Première estimation indépendante de l'inventaire d'émissions de CO_2 d'AIRPACA
- Impacts sur écosytèmes terrestres (suivi CO_2 et O_3 simultanément)+IMBE
- Impacts sur milieu marin (échange CO_2 atmosphère-mer = f(ΔCO_2air-mer)+MIO

Réseau CO_2 régional PACA



Projet de thèse avec AIRPACA

Analyse des jeux d'observations

- **Raccorder tous les sites sur l'échelle internationale de calibration (WMO)**
- **Homogénéiser les protocoles de calibration et de traitement des données des 4 sites**
- **Etudier et comparer la variabilité du CO_2 aux échelles diurnes, synoptiques et saisonnières des quatre sites**
- **Comprendre l'impact de la ville de Marseille sur le CO2 atmosphérique (local/régional vs transport de plus longue distance) par l'approche de gradient testée sur le réseau parisien.**
- **Analyse isotopique ^{14}C => discrimination des sources de CO2 fossile vs les flux biosphériques (campagne multi-sites janvier - juillet 2017)**
- **Etudier les corrélations entre le CO_2, le CO_{2FF} et les espèces co-émises disponibles (CO, NO_x, carbone suie, lévoglucosan, COVs…) => identification des sources de CO2 urbaines**
- **Comparaison aux inventaires d'émissions AIRPACA**

=> Sources de financements envisagées: Doc2Amu - Région-ADEME

Lettre d'intention AMIDEX
Projet en montage à déposer le 1er mars

- Objectifs sur la caractérisation des sources de CO2 similaires mais sur période plus longue (méthodes observationnelles et modélisation)
- Renforcement en mesures de $^{14}CO_2$
- Financer la calibration en CO2 de Cinq Avenues
- Financer l'achat d'analyseurs CO2
- Permettre un suivi du CO2 atmosphérique sur plusieurs années (meilleure représentativité)
- Liens avec études impacts couche de surface marine (flux de carbone => chimie des carbonates et pompe biologique)