CARBO COUNT ITY

Measuring Greenhouse Gases Emissions from Cities

eit Knowledge & Innovation Community Climate-KIC

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TNO innovation for life

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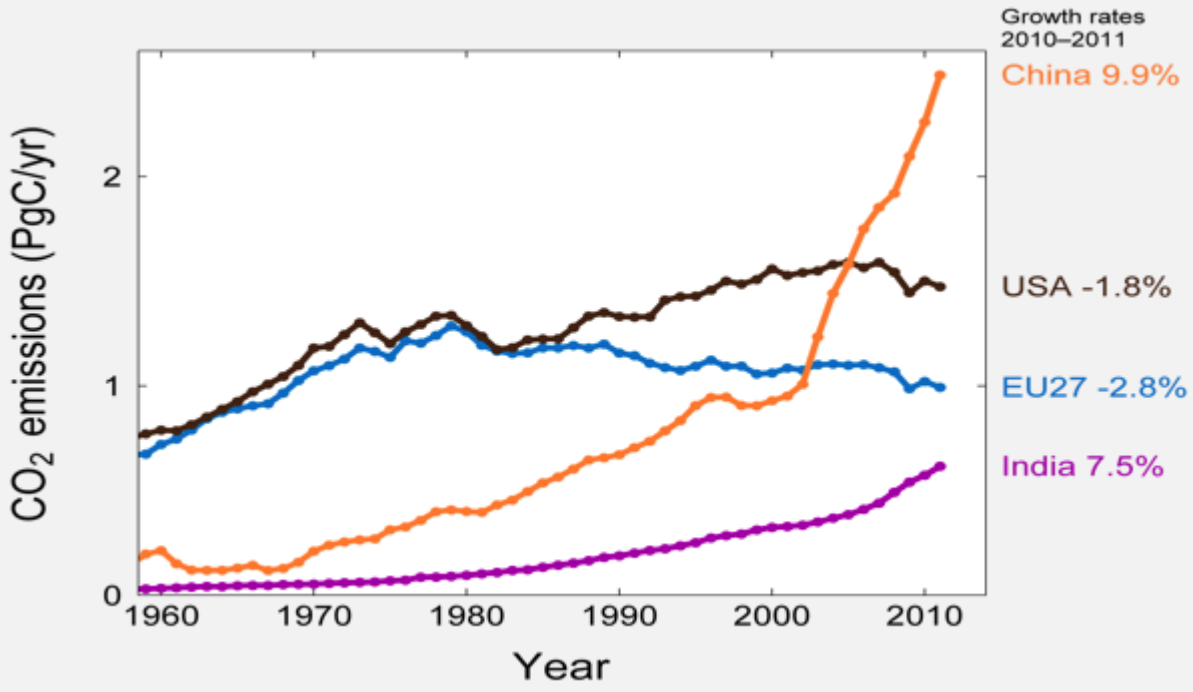
SOFIE SINO-FRENCH INSTITUTE FOR EARTH SYSTEM SCIENCE

Cities and Greenhouse Gases

Fastly growing emissions in emerging economies

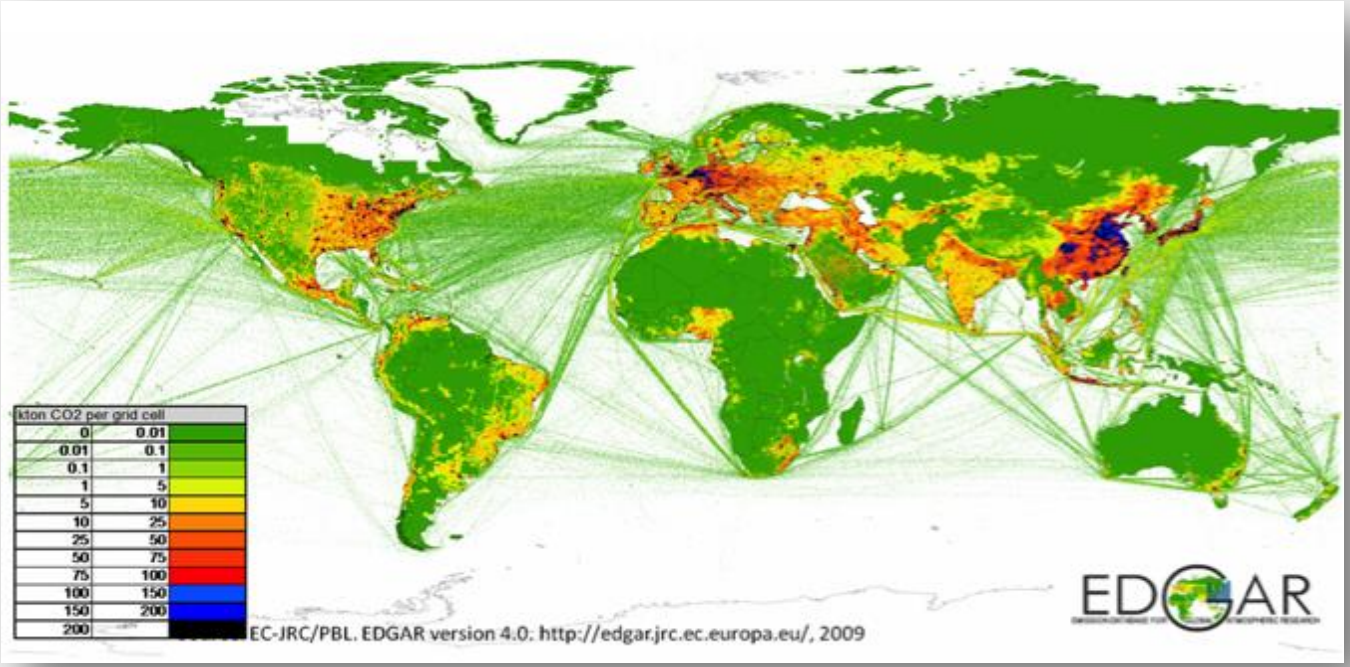
- Top four emitters in 2011 covered 62% of global emissions
- China (28%), United States (16%), EU27 (11%), India (7%)



Cities and Greenhouse Gases

Cities global emissions of CO2

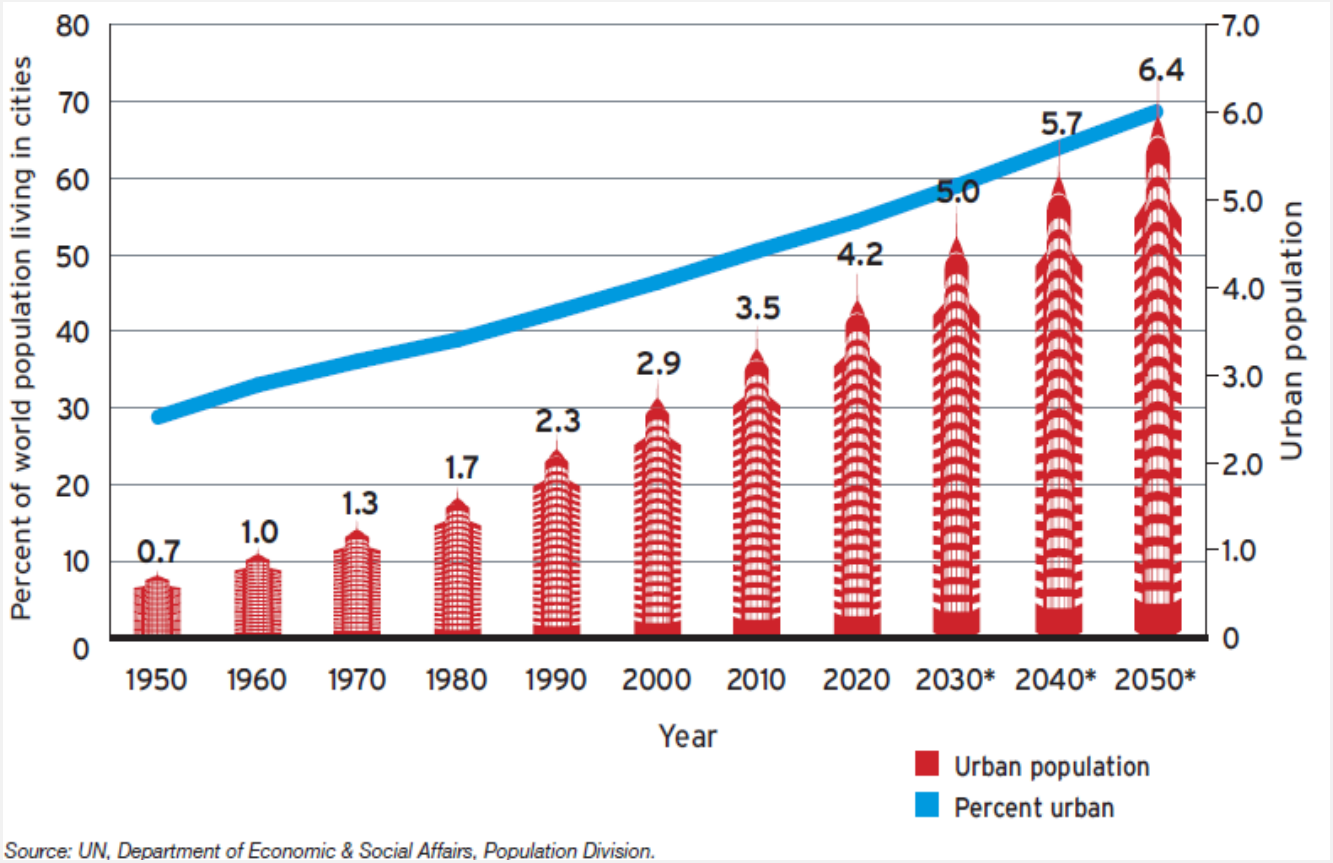
- Cities are major sources of greenhouse gases (and pollutants)
- Megacities are responsible for 80% of the human-caused emissions of CO_2
- According to the UN, in 2050 urban areas will concentrate almost ¾ of world population



Cities = Nexus for designing emission reduction policies

Cities and Greenhouse Gases

Cities global emissions of CO2



Source: UN, Department of Economic & Social Affairs, Population Division.

Cities = Nexus for measuring the effectiveness of concrete GHG mitigation action

Cities and Greenhouse Gases

Cities global emissions of CO2

The 50 Largest Cities, C40 Cities, and Top 10 GHG Emitting cities[4]

Population (Millions)	GHG Emissions (M tCO_2e)	GDP (billion $ PPP)
1. China: 1,192	1. USA: 7,107	1. USA: 14,204
2. India: 916	2. China: 4,058	**2. 50 Largest Cities: 9,564**
3. 50 Largest Cities: 500	**3. 50 Largest Cities: 2,606**	**3. C40 Cities: 8,781**
4. C40 Cities: 393	**4. C40 Cities: 2,364**	4. China: 7,903
5. USA: 301	5. Russian Federation: 2,193	5. Japan: 4,354
6. Indonesia: 190	6. Japan: 1,374	**6. Top 10 GHG Cities: 4,313**
7. Brazil: 159	**7. Top 10 GHG Cities: 1,367**	7. India: 3,388
8. Russian Federation: 142	8. India: 1,214	8. Germany: 2,925
9. Top 10 GHG Cities: 136	9. Germany: 956	9. Russian Federation: 2,288
10. Japan: 128	10. Canada: 747	10. United Kingdom: 2,176

Source: See Annex D. Data for the urban agglomeration associated with each C40 city is used in calculations to maintain consistency with the 50 largest cities, 2005.

Source: *Cities and Climate Change: an urgent agenda*, World Bank, 2010

Efforts

Cities have began to take action on climate change

- Global Methane Initiative (http://www.globalmethane.org): business opportunities related to CH_4 emissions reduction
- Network of 63 megacities, chaired by the New York City Mayor Michael Bloomberg, with the agenda reducing greenhouse gas emissions. (http://live.c40cities.org)
- Association of local governments, whose members include 12 mega-cities, 100 super-cities, 450 large cities
- The European Covenant of Mayors, voluntarily committing to exceed the European Union 20% CO2 reduction objective by 2020.
- The U.S. Conference of Mayors' endorsed a Climate Protection Agreement to reduce emissions in their cities to 7% below 1990 by 2012.
- Carbon Disclosure Project: working with C40 on standardized reporting and validation of cities GHG emissions

International cooperation

A worldwide standard is needed for cities to monitor their emissions, comply with rules and regulations, and participate to carbon markets

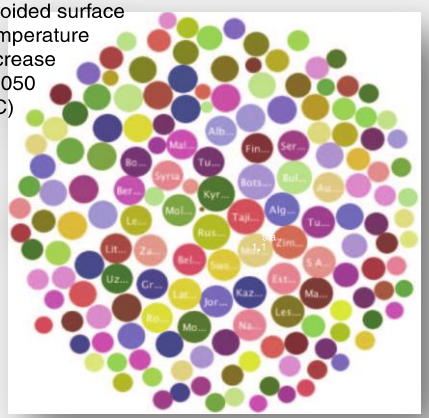
Efforts

Cities have began to take action on climate change

- Co-benefits of reducing cities GHG emissions on climate, air quality and food security

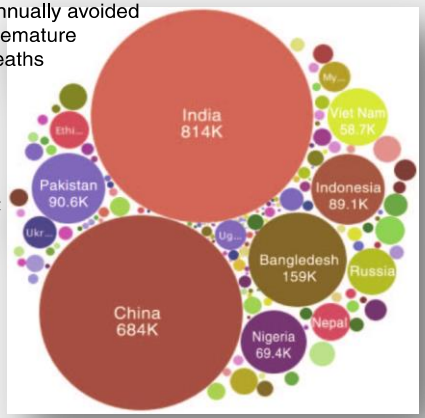
Avoided surface temperature increase ~2050 (°C)

A



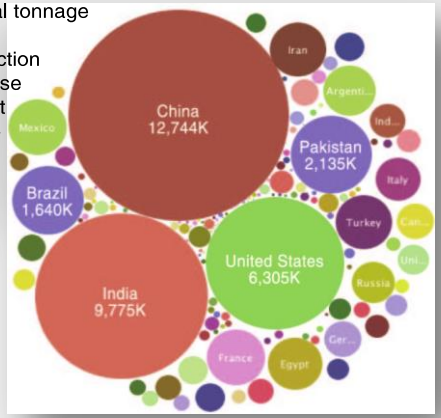
Annually avoided premature deaths

C



Annual tonnage crop production increase (wheat +rice+ maize +soy)

E



Simultaneously Mitigating Near-Term Climate Change and Improving Human Health and Food Security

Drew Shindell,[1]* Johan C. I. Kuylenstierna,[2] Elisabetta Vignati,[3] Rita van Dingenen,[3] Markus Amann,[4] Zbigniew Klimont,[4] Susan C. Anenberg,[5] Nicholas Muller,[6] Greet Janssens-Maenhout,[3] Frank Raes,[3] Joel Schwartz,[7] Greg Faluvegi,[1] Luca Pozzoli,[3]† Kaarle Kupiainen,[4] Lena Höglund-Isaksson,[4] Lisa Emberson,[2] David Streets,[8] V. Ramanathan,[9] Kevin Hicks,[2] N. T. Kim Oanh,[10] George Milly,[1] Martin Williams,[11] Volodymyr Demkine,[12] David Fowler[13]

Barriers

- Currently, emissions are estimated from activity data and energy use statistics, not directly measured :
  - Labor intensive work to obtain detailed data for a country, region, city
  - Paper-based reporting – no independent verification
- As a result, emissions estimates of cities are highly uncertain
  - Most cities do not have a pollutant / GHG emission inventory

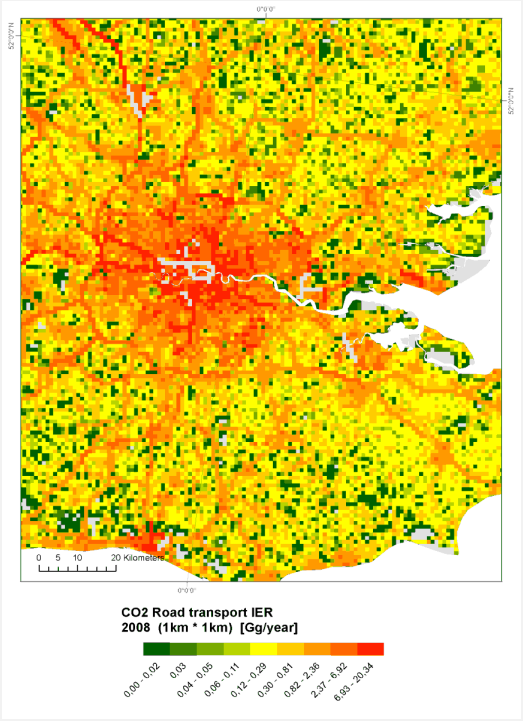
Barriers

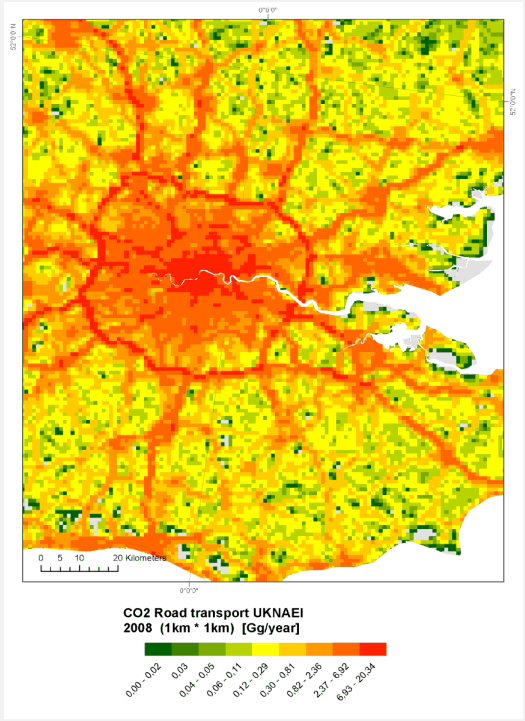
- Comparison of different inventories over the Paris region

Different inventories	EDGAR V4 (JRC)	IER 2005 (U Stuttgart)	AIRPARIF2005 (local City data)	Max – Min
Resolution	0.1° x 0.1°	1min x 1min	1km x 1km	
Annual budget of Ile-de-France (TgC)				
Residential	6.75	5.36	5.65	**31%**
Road	8.50	6.03	3.63	**60%**
Industry	5.19	4.61	3.02	**42%**
Total	24.65	16.39	12.34	**50%**

Barriers

- Comparison of the road CO_2 emissions near London between two inventories show enormous differences





Top-down meets bottom-up

Direct measurement of emissions

* Collection of GHG atmospheric data over cities

  * Inversion of GHG concentration into fluxes using atmospheric inversion technology imported from weather prediction, capable to deliver improved maps of GHG emissions

Top-Down

Measurement systems for atm/land/etc

*

Modeling

Regional GHG sources and sinks

* Assessment of the inversion accuracy of the data + complementarity

*

Verification/ Compliance

Improved Cities Emissions *

Bottom-up

Regional Authorities

Accounting systems

Carbon Footprint of companies/ cities/ etc

* Extraction and packaging of information relevant to decision-making processes,

Vision

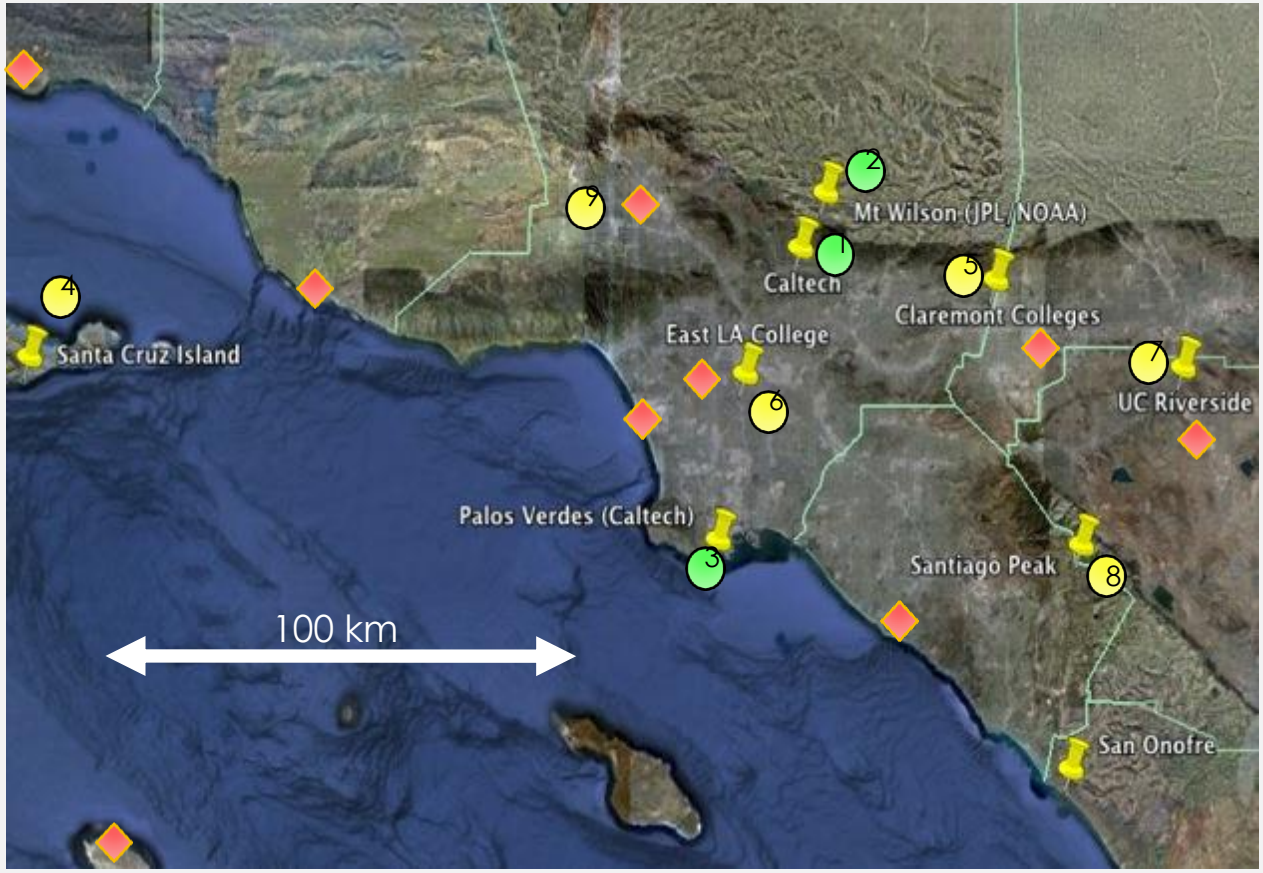
Direct measurement of emissions

- A **global monitoring system** for urban CO_2 can offer actionable information to attribute & validate mitigation policy effects
- We need to and can start now with **Pilot Projects** between cities
  - Sustained (5yr), transparent data exchange & comparative analysis
  - Address scientific challenges
  - Demonstrate confidence by validating effects of specific policies
  - Capacity building (infrastructure & knowledge, including developing cities)

Vision

Los Angeles Network

Wind profilers



Carbocount-City

Demonstrate that cities GHG emissions can be assessed

- Duration: 3 years project. 2013-2015. Co-funded by the European Institute of Technology (Climate KIC)
- Objective: set up a demonstrator of a new service for measuring and GHG emissions of two cities
- Product: a cost-effective service that will deliver improved emission maps of urban CO2 and CH4 fluxes with sectorial attribution and uncertainties.
- Customers and users: cities authorities having to establish and report emission inventories

Strategy

Improve **existing bottom-up inventory-based GHG emissions** with continuous **top-down atmospheric measurements** of GHG concentrations.

Carbocount-City

Demonstrate that cities GHG emissions can be assessed

- The project is designed to mobilize research institutes, together with corporate partners, SMEs and cities authorities
- Cities: Paris and Rotterdam
- International collaboration: Los Angeles, Indianapolis

eit Climate-KIC

The two pilot cities

Paris and Rotterdam

Paris
- Largest city in France
- Population 10 M
- 60 MtCO2
- 30% within 10 km radius from the center, 60% within 20 km
- 30% road traffic and 40% residential

Rotterdam
- 2nd largest city in the Netherlands
- Largest port in Europe.
- Population 616,000
- 25 MtCO2
- 90% power plants and refineries

- The methodology is designed to be scalable and adaptable to any other city
- Research collaboration with Los Angeles area partners organizing a large scale campaign (see Poster)

Move forward

A user driven implementation

1. **Measuring the atmosphere** An operational operational atmospheric network of 9 ground based sensors deployed at fixed stations
2. **Surveyor campaigns** search and find CH4 fugitive emissions
3. **Inverse modeling**, correct emission inventories using atmospheric measurements
4. **Urban winds and enhanced data potential.** urban meteorology and multi-scale dispersion modeling to separate local from city emissions
5. **Trust but verify.** Regular aircraft campaigns to check on the performances of the modeling system;
6. **Consult users and receive early feedbacks from stakeholders**

Critical technologies

1- Transfer innovative methods from research labs to service application
2- Cost / quality of atmospheric measurements, and number of stations

Opportunities

1- Partners with strong experience
2- Growing interest of SMEs for GHG inversion
3- Global interest of cities for emission measurements
4- Small market opportunities

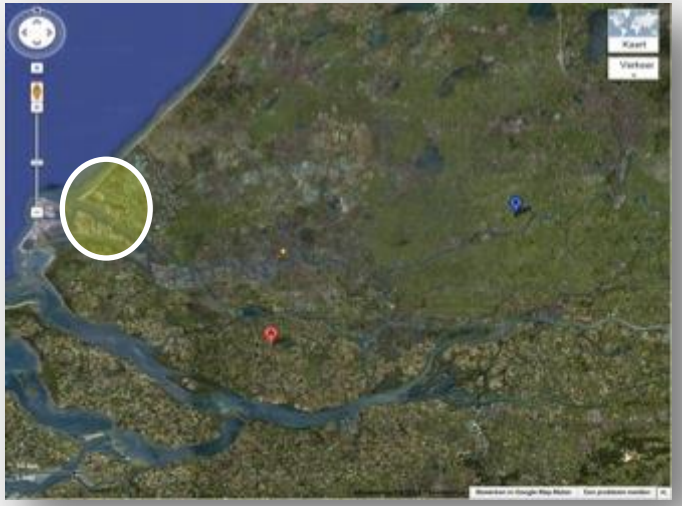
Measuring the atmosphere

Stations installed across dominant wind direction

- 6 GHG measurement stations sites in Paris, sensors under installation
- 2 GHG measurement stations in Rotterdam, one under localization

- Install monitors
- Calibration of the working standards (with gases)
- Analyse first results
- Compare & cross check between cities

Paris network (9 stations, 3 pre-existing)
See I. Xueref-Remy's presentation



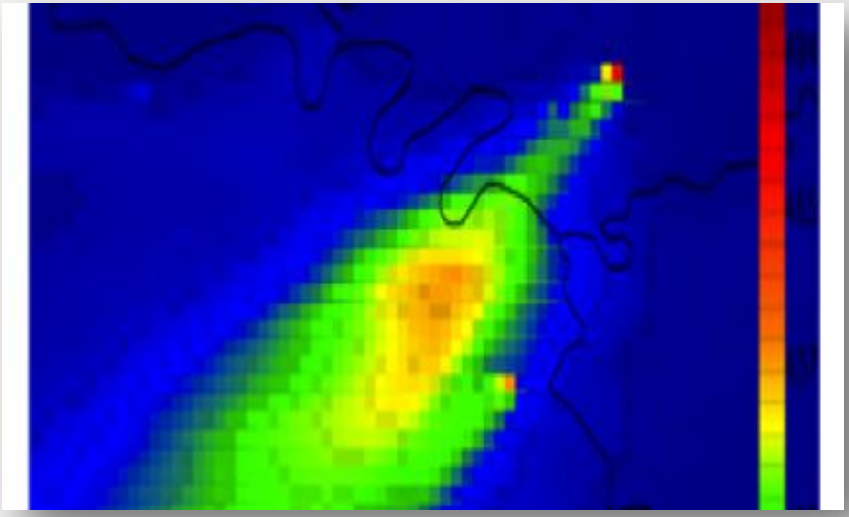
Rotterdam network (3 stations)
Being established by TNO

Measuring the atmosphere

Stations installed across dominant wind direction

- Paris, Rotterdam, London are « plume cities »
- Los Angeles, Grenoble, Mexico are « dome cities »

Paris network
See I. Xueref-Remy's presentation



Simulated plume of CO2 emissions

Measuring the atmosphere

How does an urban station looks like

Boston University
Image courtesy
Nathan Phillips

Eiffel Tower
CO2-megaparis
project

Surveyor campaigns

Spotting methane fugitive sources

- Picarro, a leading high-precision instrument manufacturer
- Two campaigns performed in 2013

The picture shows a schematic of the instrumental setup for Picarro Surveyor using a G2132-i methane analyzer to detect natural gas leaks.

Through measuring the lower atmosphere's methane concentration, leaks in the distribution of the natural gas can be detected even through asphalted roads and at traffic speed.

Surveyor campaigns

Identify hot-spot of emissions

- Fugitive Methane Emissions due to Natural Gas leaks

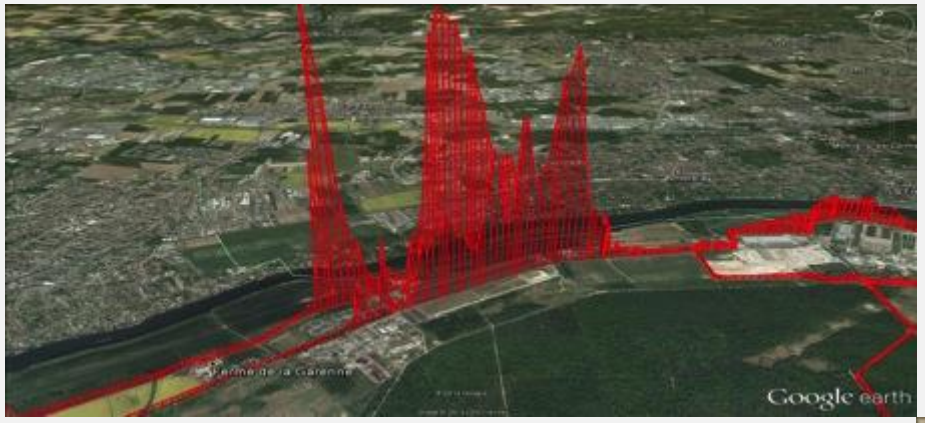
Above:
Methane leak in the gas compressor station near Cuvilly (17. December 2012)

Right:
Natural Gas leak in the city of Paris (22. May 2013)

Peaks are not to scale, but correspond to Methane concentrations higher than 3 ppm.

Surveyor campaigns

Methane hot-spots outside cities



- Other sources of Methane emissions

Above:
Methane emissions in the surroundings of a Waste Water Treatment Plant near Conflans-Saint-Honorine
(17. December 2012)

Right:
Methane emissions in the surroundings of a landfill near Claye-Souilly
(16. December 2012)

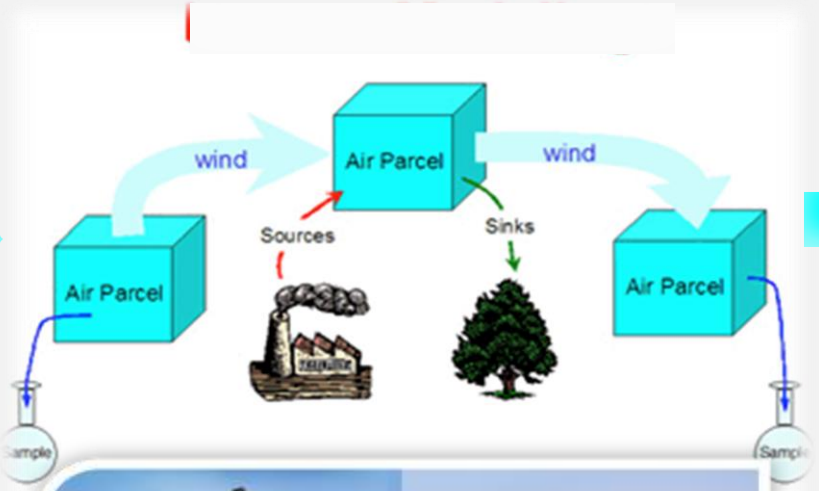
Peaks are not to scale, but correspond to Methane concentrations higher than 3 ppm.

Inverse modelling

Find emissions from concentration measurements

- Advanced data assimilation techniques developed by LSCE researchers for global CO_2 fluxes now applied to cities emissions
- An inversion model is in place over Paris at 2 km spatial resolution

Stations upwind



Stations downwind

First guess of emissions

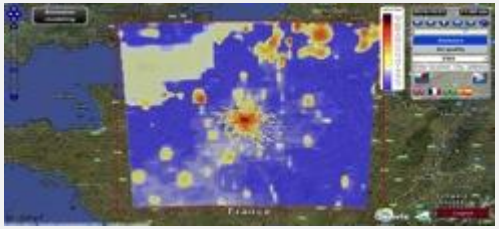
Corrected emissions

Inverse modelling

Find emissions from concentration measurements

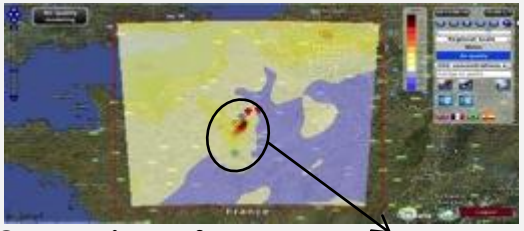
- The quality of the inversion model result depends on :
  - Existing inventories used as first guess
  - How many stations capture the urban CO2 plume structure
  - How well can winds be simulated (see next)
  - How representative is a station from cities emissions vs. local emissions (see next)

First guess CO2 emission



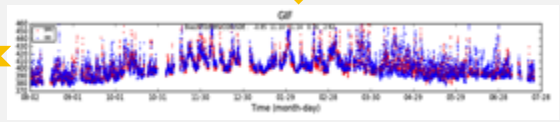
Atmospheric Transport Model CHIMERE

CO2 concentration fields



Comparison of simulated CO2 with measurements

In situ observations network around Paris

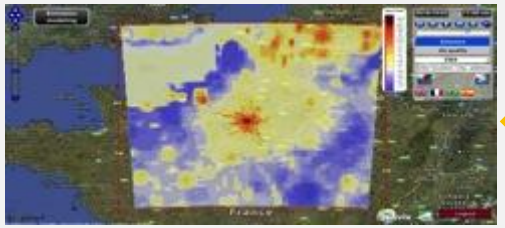


Time evolution of simulated and observed CO2 concentration at Gif/Yvette

See I. Xueref-Remy's presentation For measurement time series

Inverse Modeling Technique

Mathematical and probabilistic tools to compute the best CO2 emission estimate that reduces the observations/simulation discrepancy

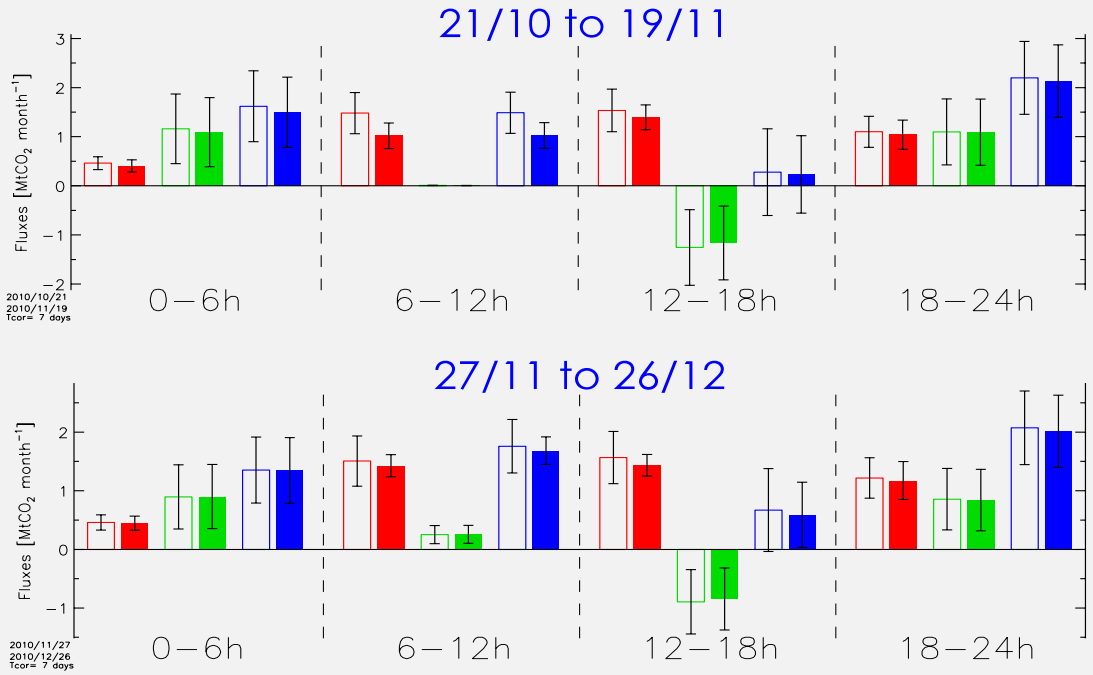


Optimized CO2 emission

Inverse modelling

First results

- 30-day rescaling of the 6-hour mean emissions in Ile de France from AIRPARIF
  - On-going analyses of a 1-year inversion



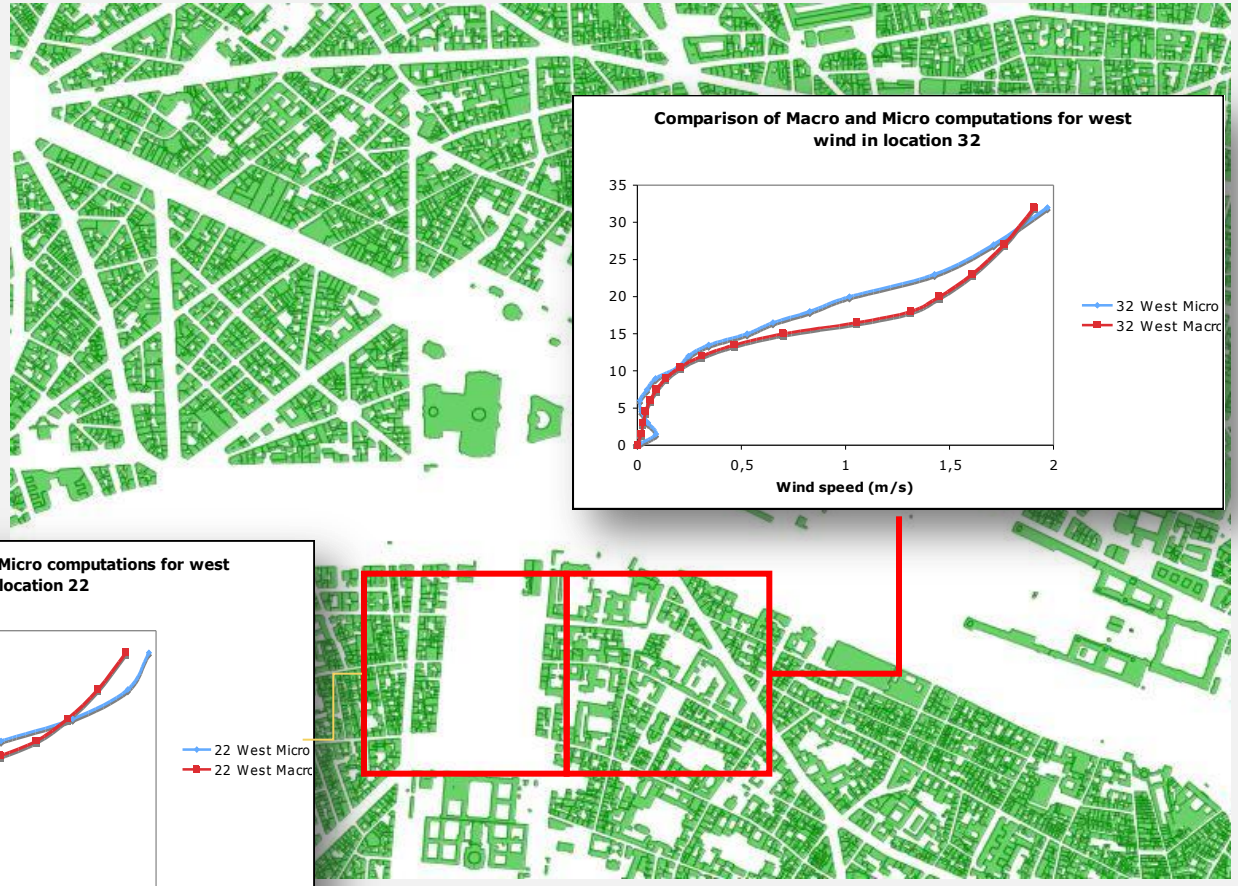
30-day budget of CO2 fluxes in the Ile de France region red=FF; green=NEE; blue=Total

Results from existing Network of 5 stations

Urban winds

Modeling wind profile in cities streets

Wind profiles obtained with micro-SWIFT (3 m resolution) and SWIFT with urban canopy new option (500 m resolution)



Courtesy of Aria Technologie

Enhancing the data potential

Microscale flow and local sources

- Micro-scale flow and GHG dispersion modelling in the area surrounding GHG stations (Gif, Gonesse and Jussieu)
- Vector data describing buildings and emission are created or extracted from existing database.
- GHG concentrations computed at a resolution of 3m. This will be compared to the 2km-spatial average concentration.
- Spatial representativeness of the station output can be quantified before being used in the inverse regional model

Courtesy of Aria Technologie

Enhancing the data potential

Separate the influence of local sources

- CO_2 in your street
- Ground concentration of CO_2 near the Jussieu station – model Micro-SWIFT-SPRAY

Courtesy of Aria Technologie

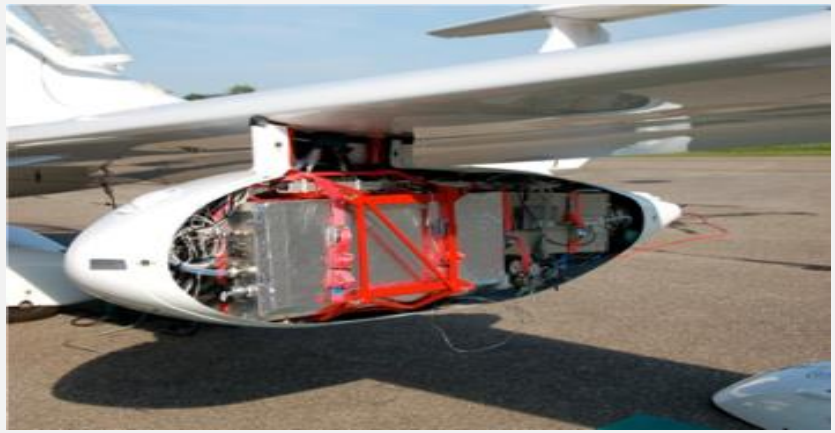
Trust but verify

Aircraft campaigns are independent evaluation data

Now ready to fly …

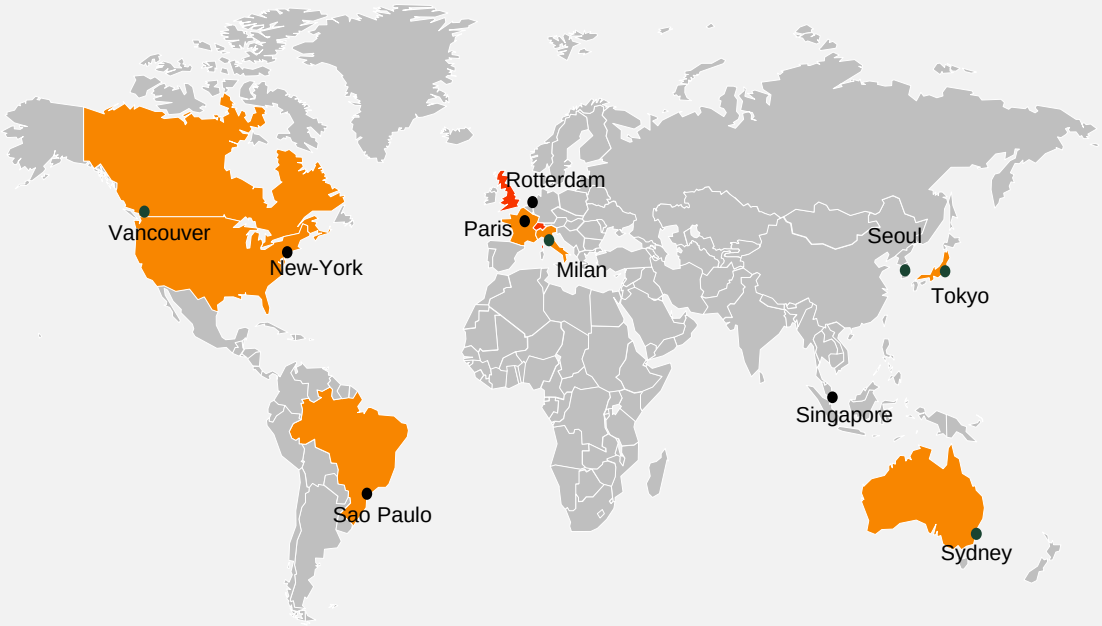
- Touring Motor Glider equipped with CH4, CO and CO2 sensors
- Aircraft ready and in standby for Rotterdam campaign on Monday (7th of Oct)
- Paris flight plan submitted and approved
- Waiting for authorisation from DGAC to perform campaign around Paris

- Representativeness of ground-based measurements is not well known
- Surface stations must be complemented by airborne measurements that will help to check the model for the dilution of CO2 emissions in the boundary layer
- Measurement of vertical profiles of CO2 and CH4 concentrations
- **3 aircraft campaigns over each city per year**



Feedback from users

Ongoing dialogue with cities in the world



Thank you for your attention

Questions about this presentation

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