



Tracking GHG emissions in a booming city - urban atmospheric monitoring in Recife, Brazil

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Work conducted/supported: F.R. Vogel, J. Staufer, G. Broquet, F. Baron, L. Bregonzio-Rozier, P.R. Amaral, L. Nunes, S. Souza, L.R. Oliveira, V. Felix, L. Zanutto, F. Velay-Lasry, M. Chiappero and P. Ciais

Thanks to the LSCE groups (RAMCES, ATC, SATINV and MOSAIC) for their support



The future of urban emissions

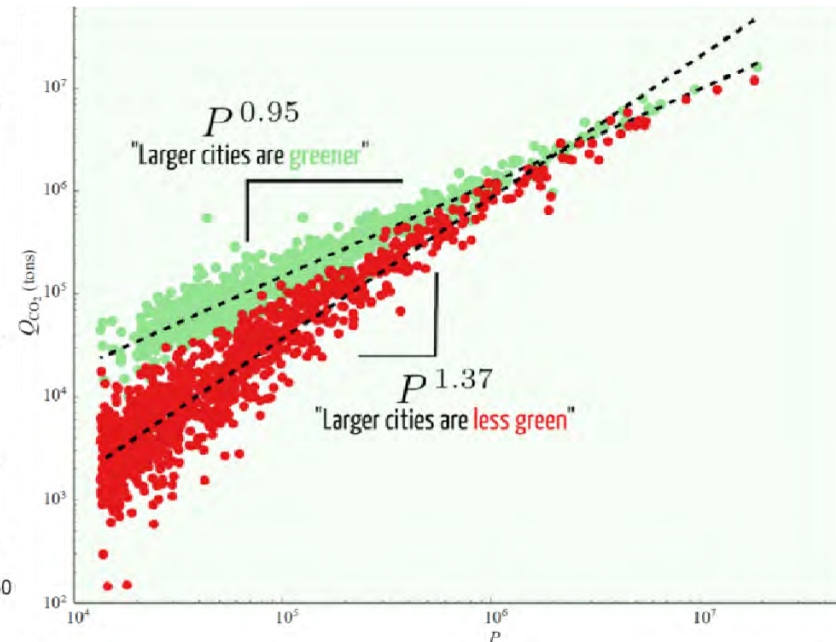
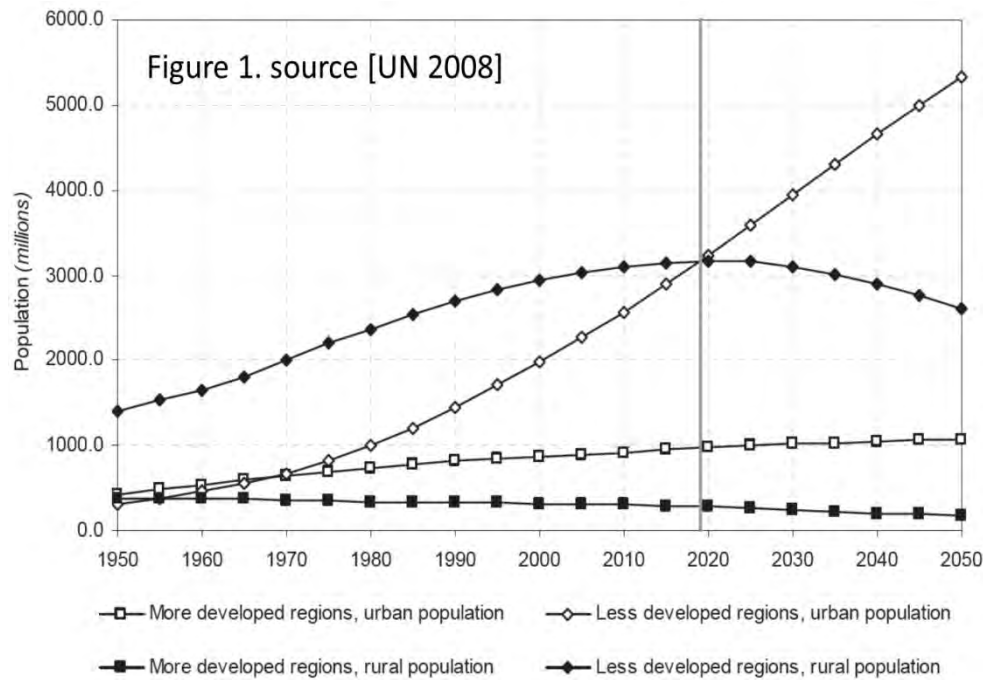


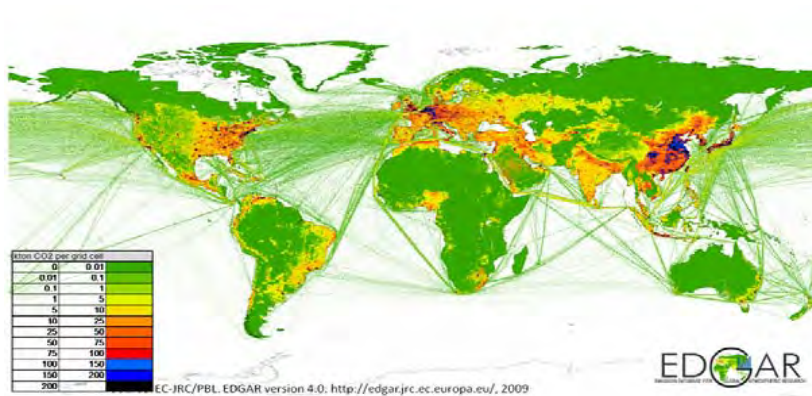
Figure 2. Emissions (Q) versus total population (P) in the US. Different urban area definitions (red, green) [Louf and Barthelmy, 2014]

The urban population will rise...

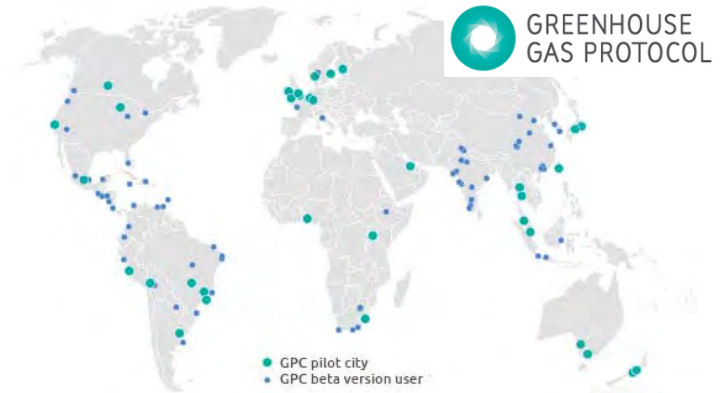
... but will the per capita emissions rise – stagnate – decrease?



Relevance of urban scale for GHGs



Cities are **major sources** of greenhouse gases (and pollutants)



Cities are **active stakeholders** and have ambitions reduction target and mitigation effort



Development of techniques within many projects and now also **experience with routinely operated monitoring network and inversion**

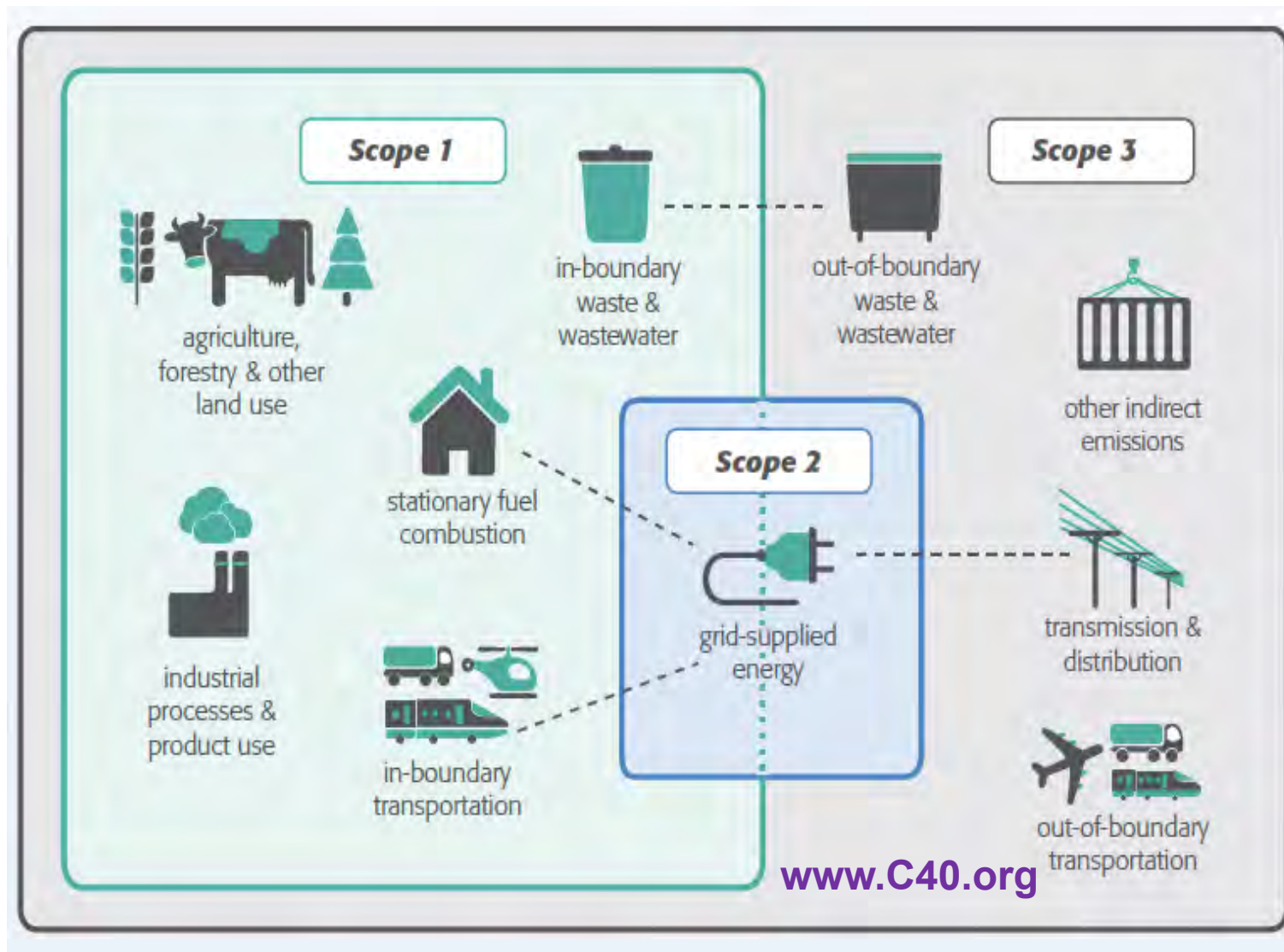


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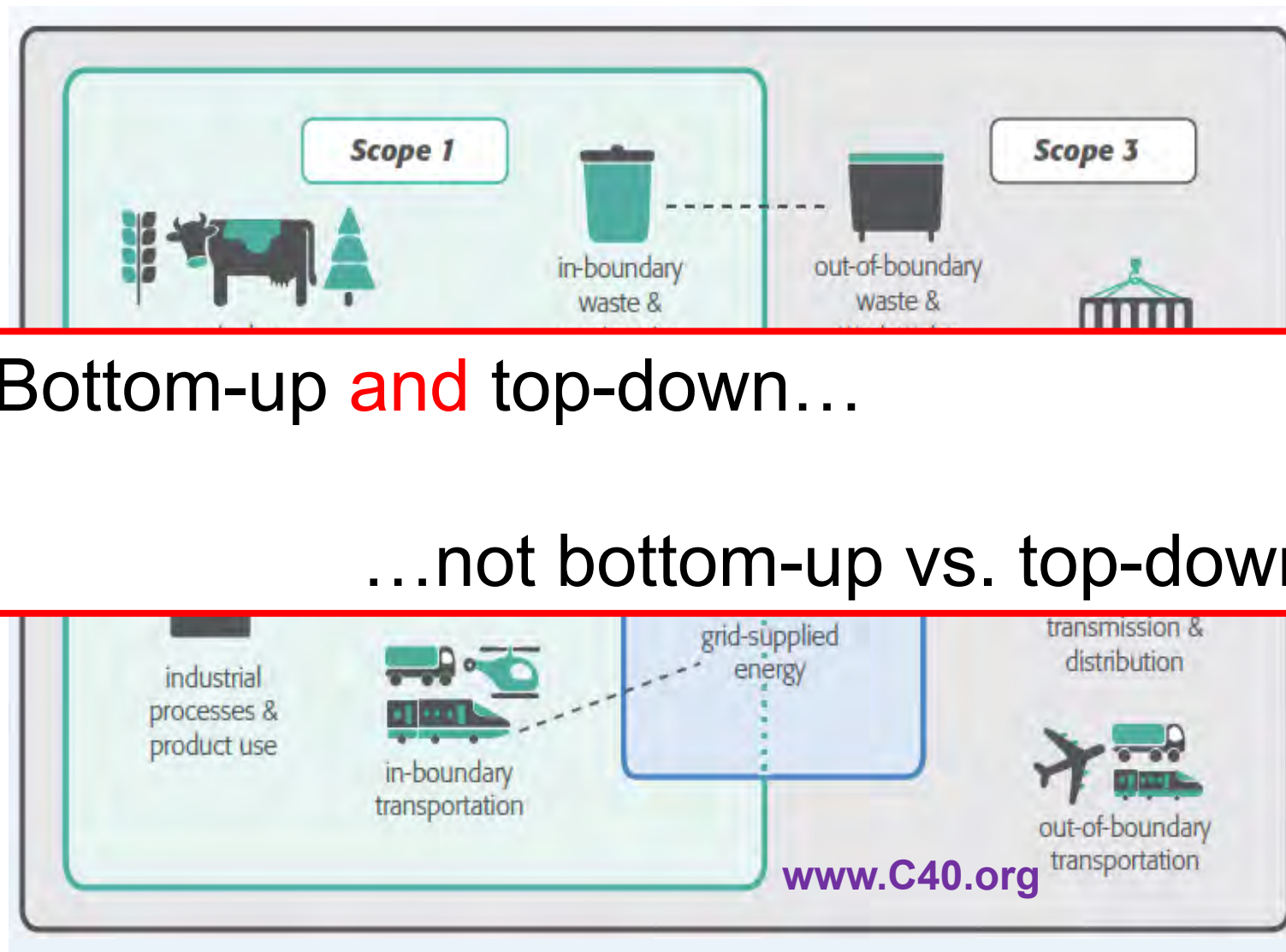
2nd ICOS science conference, September 27th, 2016, Helsinki, Finland



Tools to assess GHG emissions



Tools to assess GHG emissions



Bottom-up **and** top-down...

...not bottom-up vs. top-down

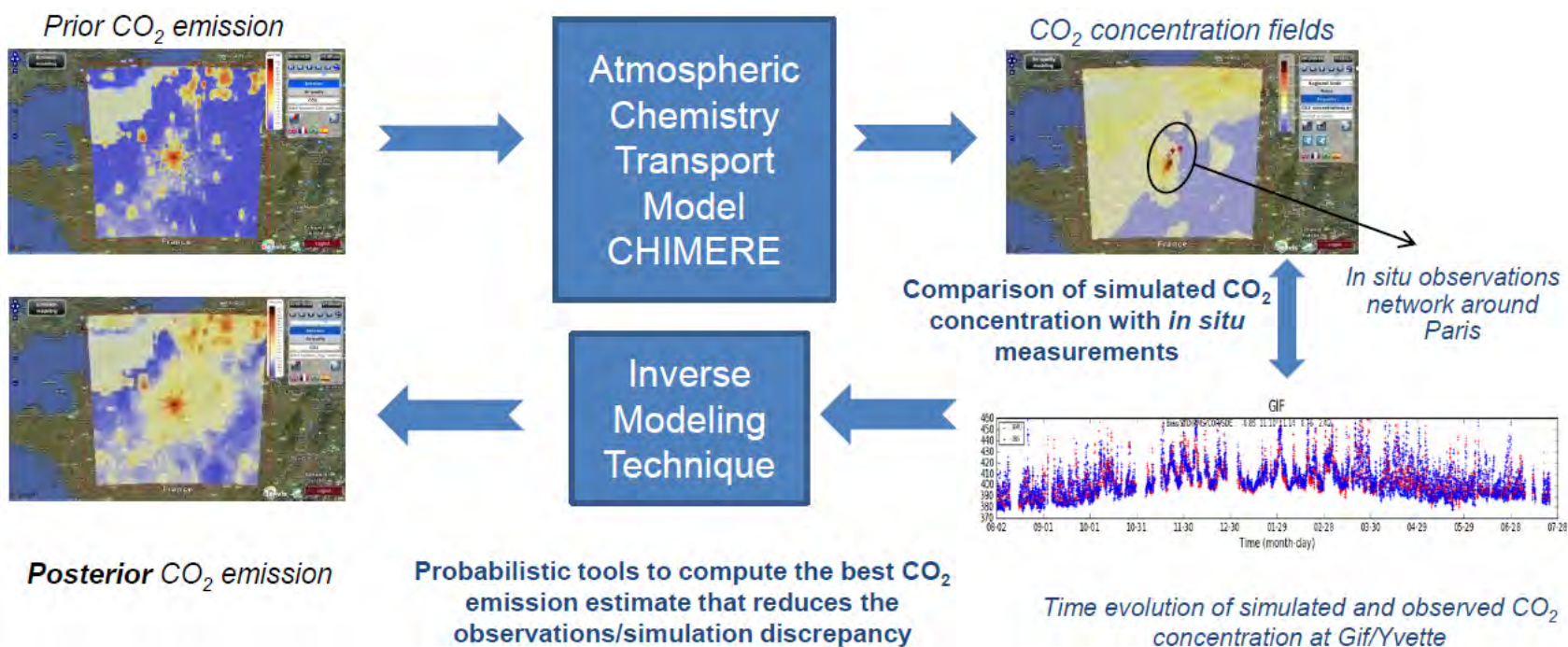


Inversion system simplified

Emission inventory/model

Transport model

Observation system



Atmospheric studies lead by LSCE

CO2 - MEGAPARIS

Paris, France



CarboCountCity



Recife, Brasil

LOCATION

Mexico City, Mexico



“Proof-of-concept”



“Demonstration”



“Scalability”



LOCATION



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led by LSCE



Low Carbon City Lab

local.climate-kic.org

eit Climate-KIC

LoCaL Climate Finance For Cities

STAKEHOLDERS Engage with us

PROJECTS What we do

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Low Carbon City Lab

Unlocking the climate action potential of cities

Actions

LoCaL aims to reduce 1 Gt of CO₂ annually and leverage € 25 billion worth of climate finance for cities by 2050. The platform's partners provide cities with better tools for assessing greenhouse gas emissions, planning, investing and evaluating progress. Our activities include:

- Assessing
- Planning

“Proof-of-concept”



“availability”

“INTEGRATION”



Atmospheric studies lead by LSCE

CO₂ - MEGAPARIS

Paris, France



CarboCountCity



Recife, Brasil

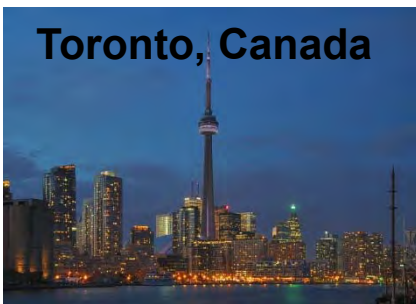
LOCATION

Mexico City, Mexico



Key “hands-on” scientific collaborations (e.g. PhD students, SOFIE, LoCal)

Toronto, Canada



Shenzhen, China



Frankfurt, Germany



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Exporting CarboCountCity to South America

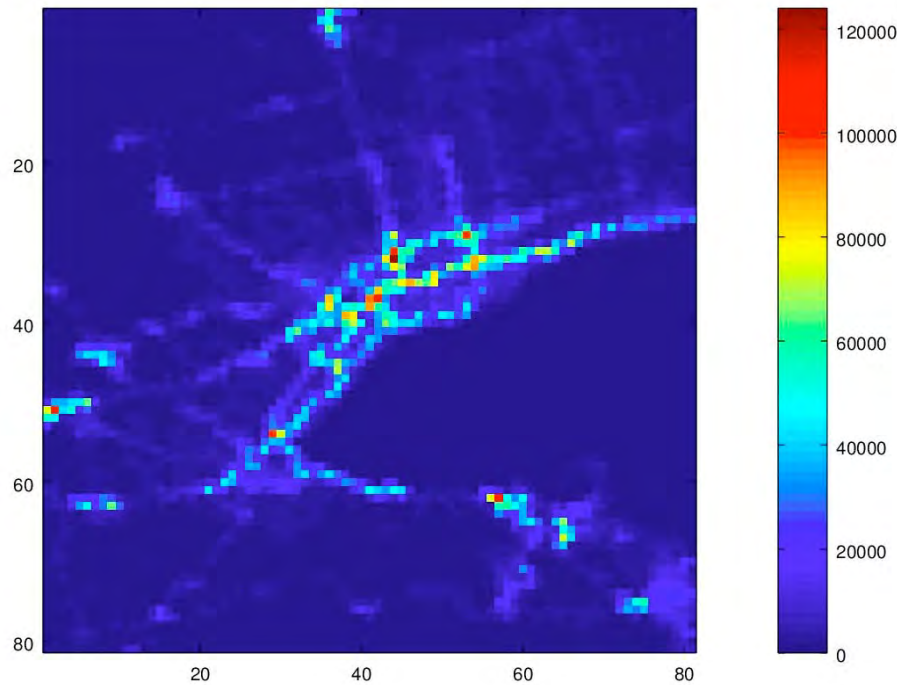


Key figures:

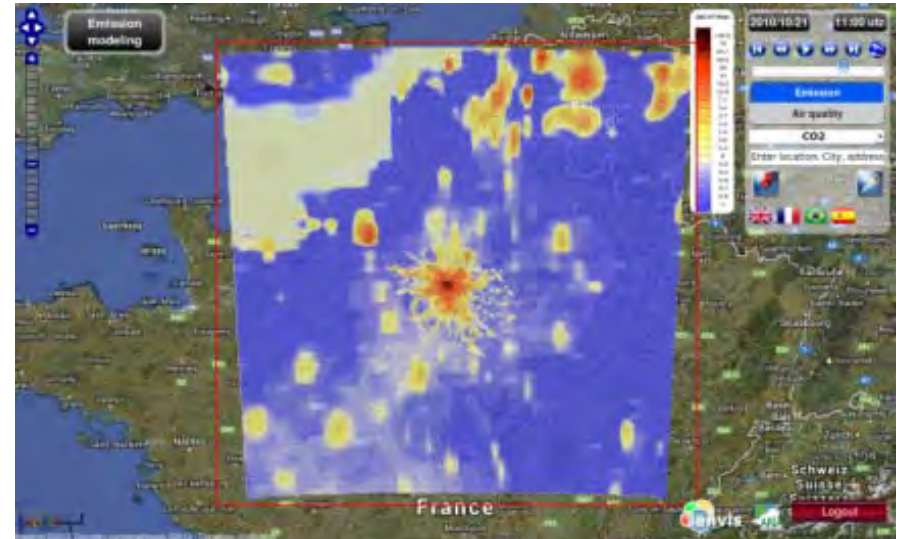
- Tropical city – 8°3'S, 24°54'W
- Inhabitants 1.6M (city), 3.8M (metro), 6th largest city in Brazil
- High density (7000-8000/km²) similar to Istanbul
- 1%/a growth since 1980 ca. → 300k-400k/decade



Emission inventories for cities - towards common techniques



Toronto, Canada, 0.02°x0.02°
Based on air quality inventory
Collaboration LSCE, ECCC,
UoToronto

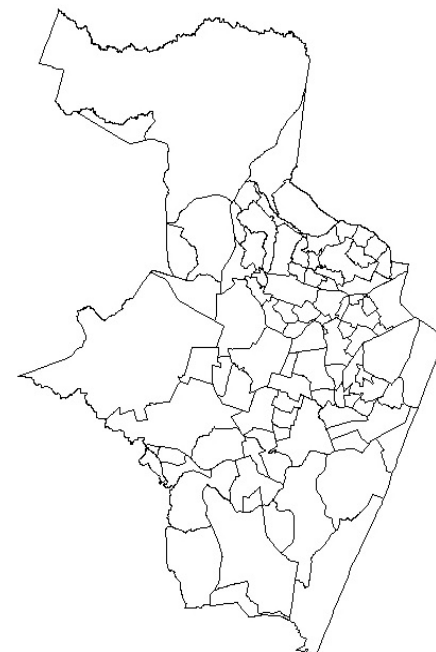
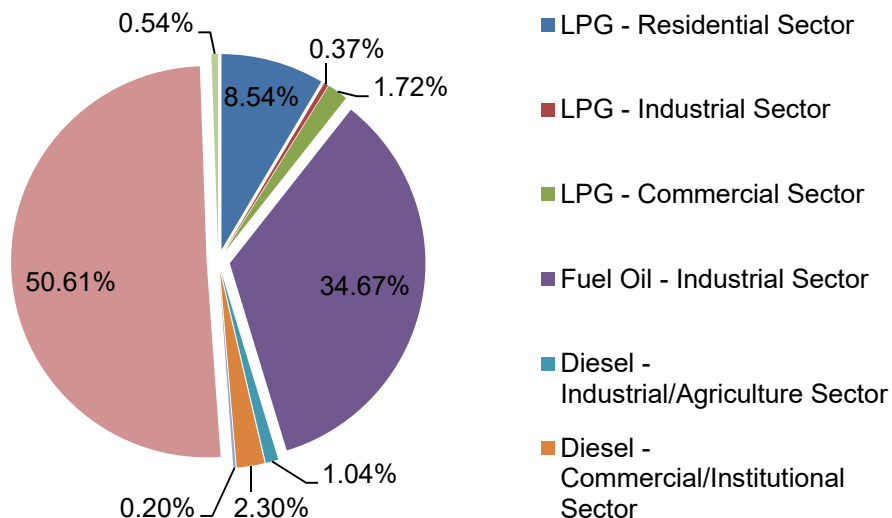


Existing inventories for Paris
AIRPARIF, IER and TNO
Here AIRPARIF 2km x 2km



Emission inventories for cities - towards common techniques

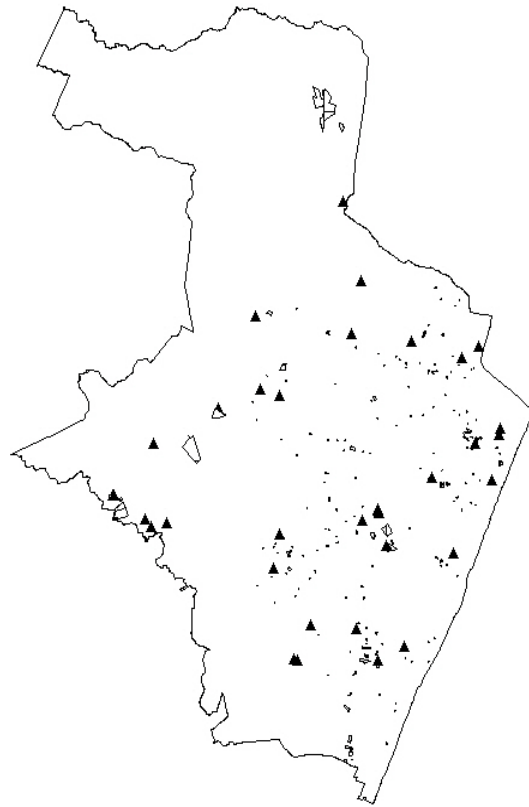
Emissions by fuel %



| Sector | Power Source | tCO ₂ Emissions |
|-------------|-------------------------|----------------------------|
| Residential | Natural Gas | 3,151.97 |
| Residential | Liquefied Petroleum Gas | 131,810.54 |
| Commercial | Natural Gas | 8,391.53 |
| Commercial | Liquefied Petroleum Gas | 26,616.05 |
| Commercial | Diesel | 35,518.47 |
| Industrial | Natural Gas | 781,408.76 |
| Industrial | Diesel | 16,119.09 |
| Industrial | Fuel Oil | 535,354.37 |
| Industrial | Liquefied Petroleum Gas | 5,649.94 |



Emission inventories for cities - towards common techniques

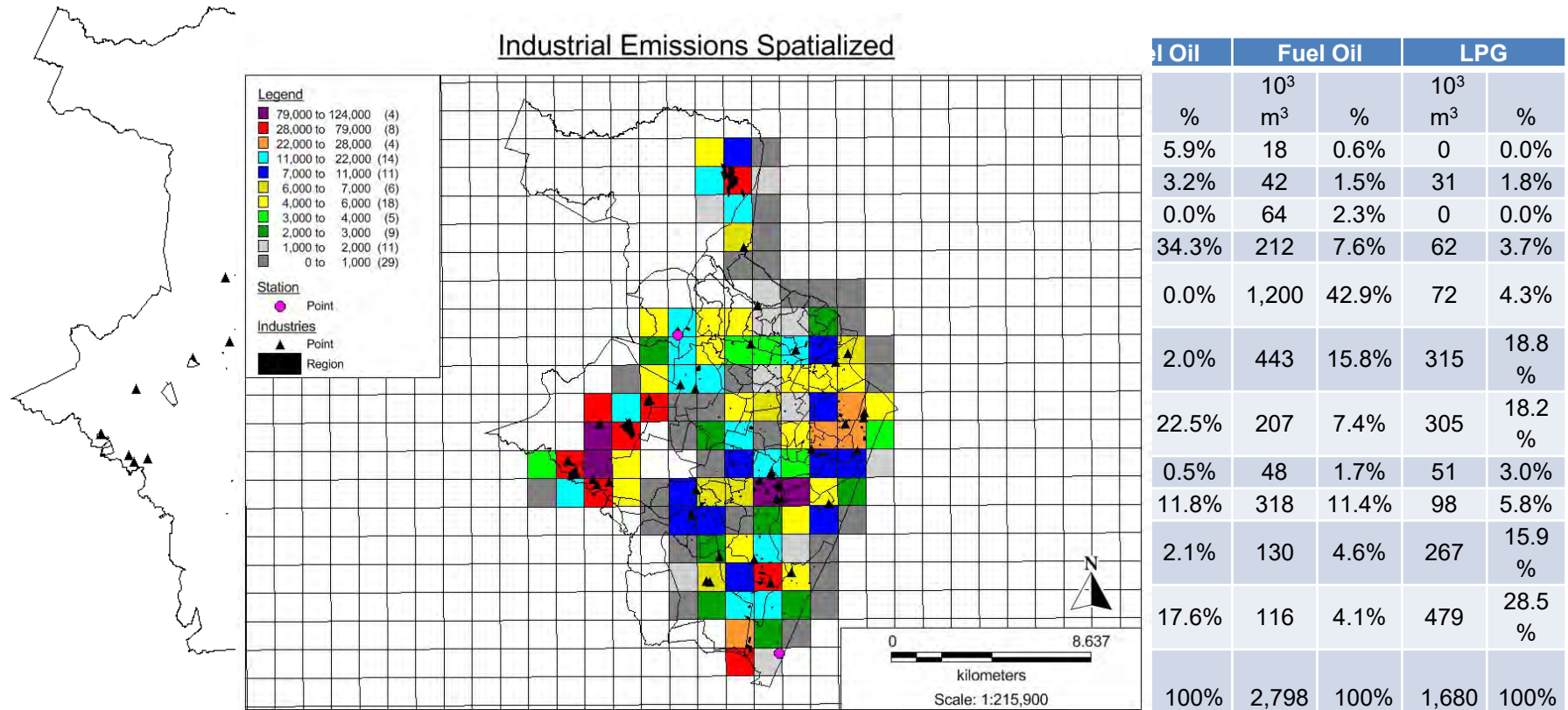


| Industrial Consumption by Sector (2013 year) | Natural Gas | | Diesel Oil | | Fuel Oil | | LPG | |
|--|--------------------------------|-------|--------------------------------|-------|--------------------------------|-------|--------------------------------|-------|
| | 10 ⁶ m ³ | % | 10 ³ m ³ | % | 10 ³ m ³ | % | 10 ³ m ³ | % |
| CEMENT | 35 | 0.3% | 80 | 5.9% | 18 | 0.6% | 0 | 0.0% |
| PIG-IRON AND STEEL | 1,159 | 10.5% | 44 | 3.2% | 42 | 1.5% | 31 | 1.8% |
| IRON-ALLOYS | 25 | 0.2% | 0 | 0.0% | 64 | 2.3% | 0 | 0.0% |
| MINING/PELLETIZATION | 720 | 6.5% | 467 | 34.3% | 212 | 7.6% | 62 | 3.7% |
| NON-FERROUS/OTHER METALLURGICAL | 1,070 | 9.7% | 0 | 0.0% | 1,200 | 42.9% | 72 | 4.3% |
| CHEMICAL | 2,315 | 20.9% | 27 | 2.0% | 443 | 15.8% | 315 | 18.8% |
| FOODS AND BEVERAGES | 781 | 7.1% | 306 | 22.5% | 207 | 7.4% | 305 | 18.2% |
| TEXTILES | 355 | 3.2% | 7 | 0.5% | 48 | 1.7% | 51 | 3.0% |
| PAPER AND PULP | 919 | 8.3% | 161 | 11.8% | 318 | 11.4% | 98 | 5.8% |
| CERAMICS | 1,538 | 13.9% | 29 | 2.1% | 130 | 4.6% | 267 | 15.9% |
| OTHERS | 2,148 | 19.4% | 240 | 17.6% | 116 | 4.1% | 479 | 28.5% |
| TOTAL INDUSTRIAL | 11,065 | 100% | 1,361 | 100% | 2,798 | 100% | 1,680 | 100% |

Industrial sources in the Recife area



Emission inventories for cities - towards common techniques



Industrial sources in the Recife area



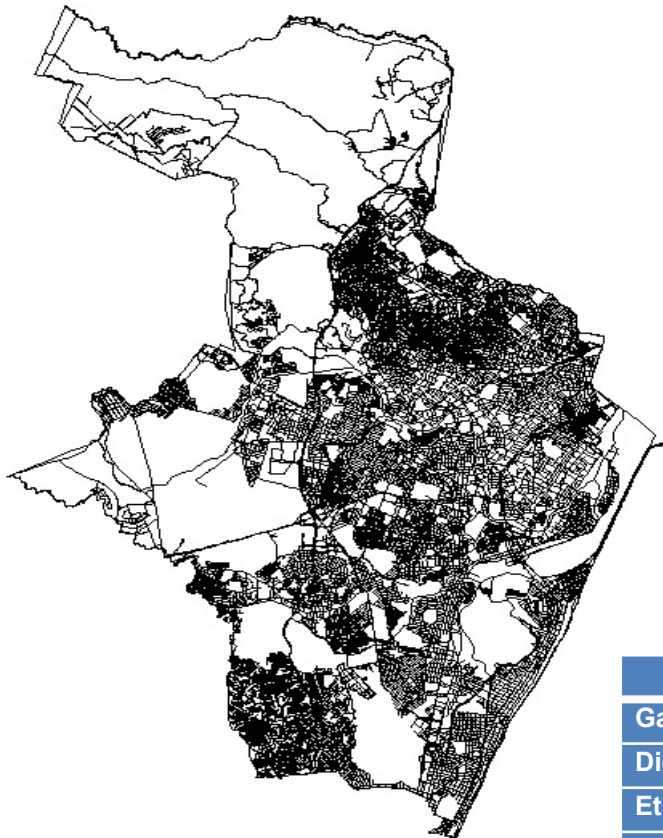
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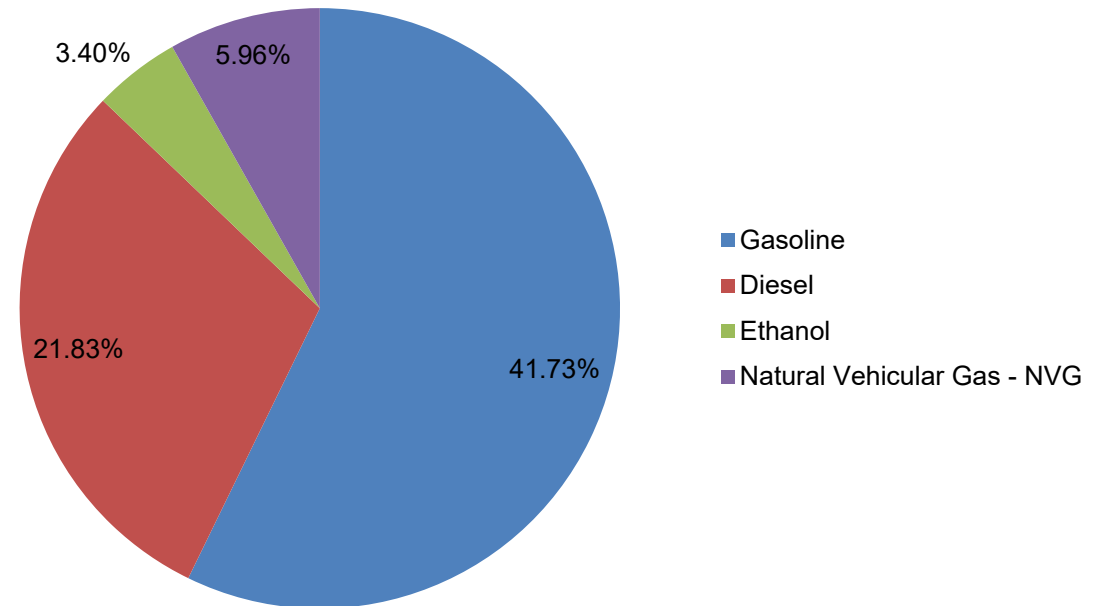


Emission inventories for cities - towards common techniques

Road map of Recife



Road Traffic - Emissions by fuel %



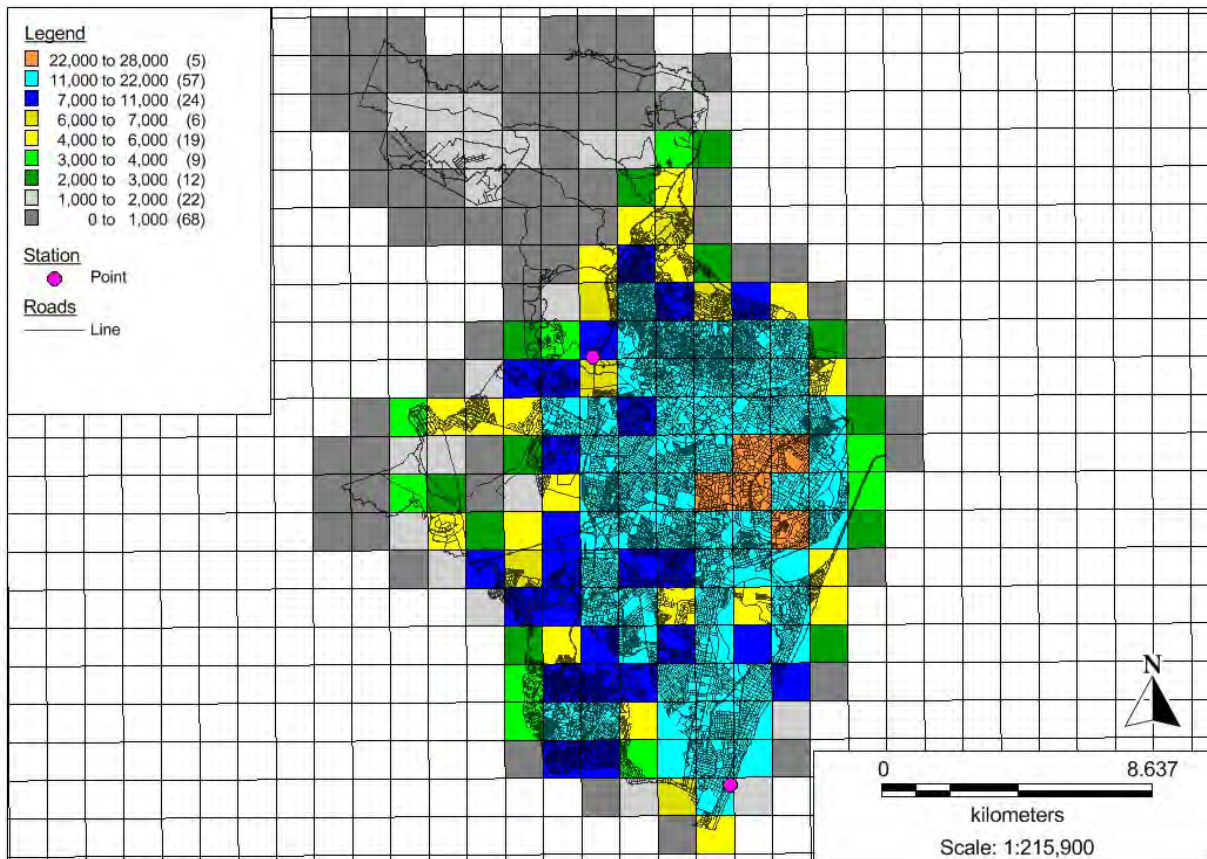
| Power Source | tCO ₂ Emissions |
|-----------------------|----------------------------|
| Gasoline | 833.496,29 |
| Diesel | 436.062,53 |
| Ethanol | 67.977,76 |
| Natural Vehicular Gas | 119.095,22 |



Emission inventories for cities - towards common techniques

Traffic Emissions Spatialized

Road m



by fuel %

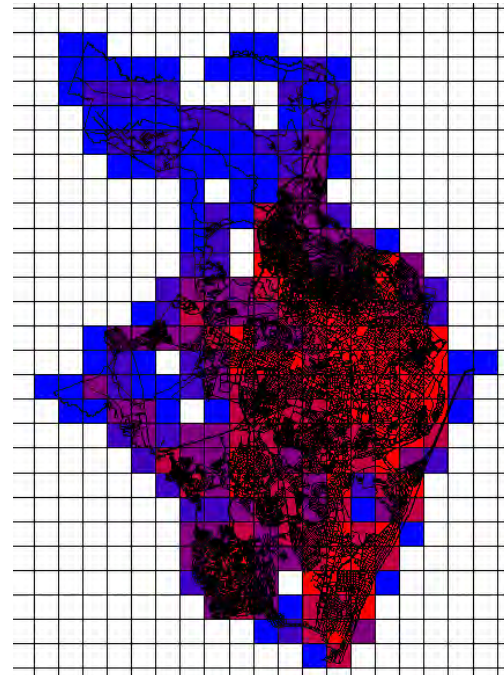
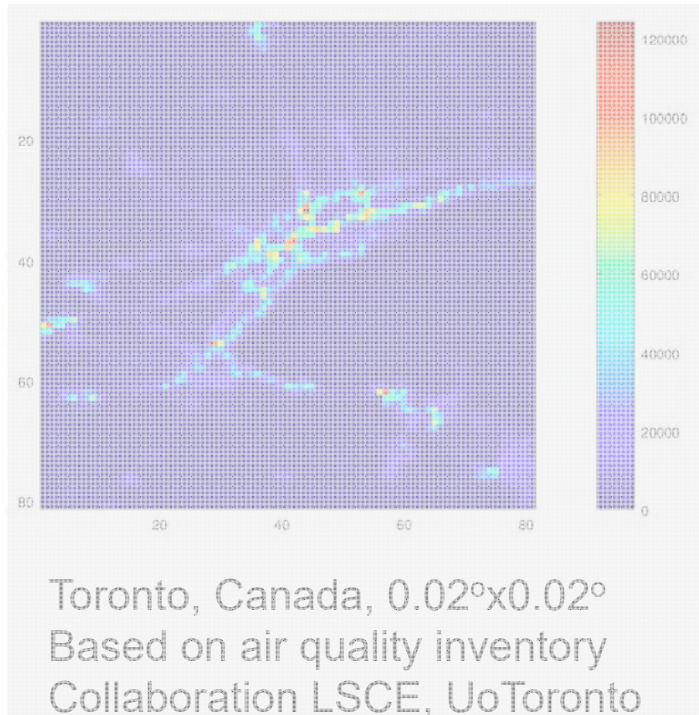
- Gasoline
- Diesel
- Ethanol
- Natural Vehicular Gas - NVG

| | |
|-----------------------|--|
| Diesel | |
| Ethanol | |
| Natural Vehicular Gas | |

| Emissions | |
|-----------------------|------------|
| Gasoline | 833.496,29 |
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Emission inventories for cities - towards common techniques



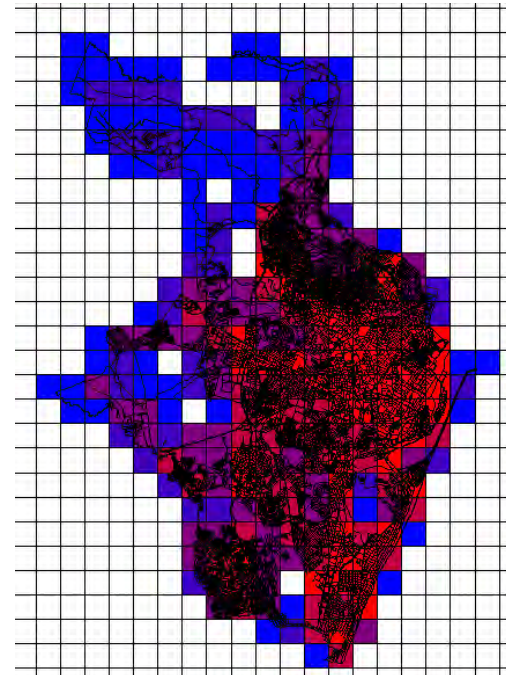
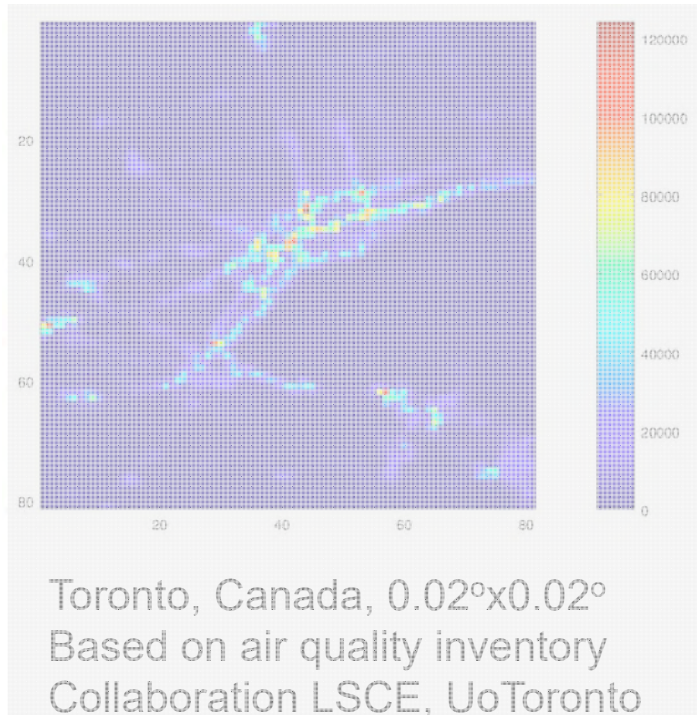
Recife, Brazil, 1km x 1km,
based on IPCC and GPC
Collaboration LSCE, ARIA tech.



5.52 MtCO₂



Emission inventories for cities - towards common techniques



Recife, Brazil, 1km x 1km,
based on IPCC and GPC
Collaboration LSCE, ARIA tech.

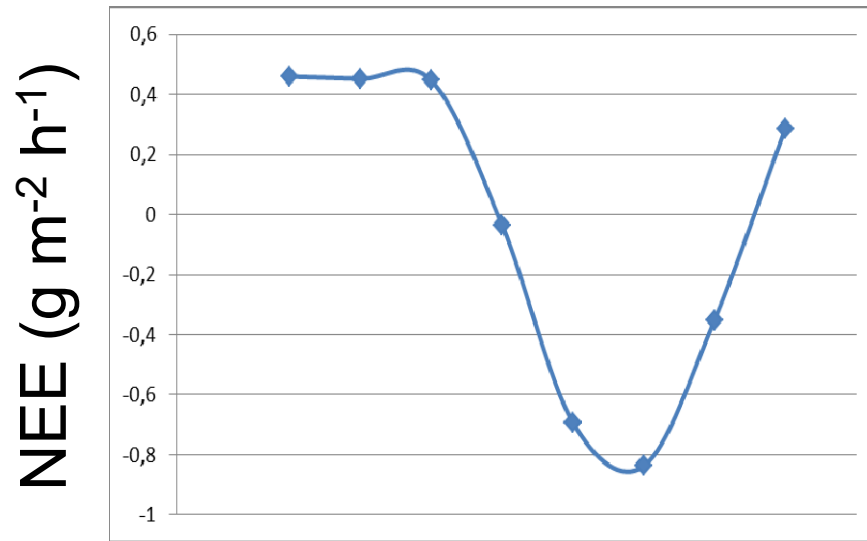


5.52 MtCO₂ +/- ???



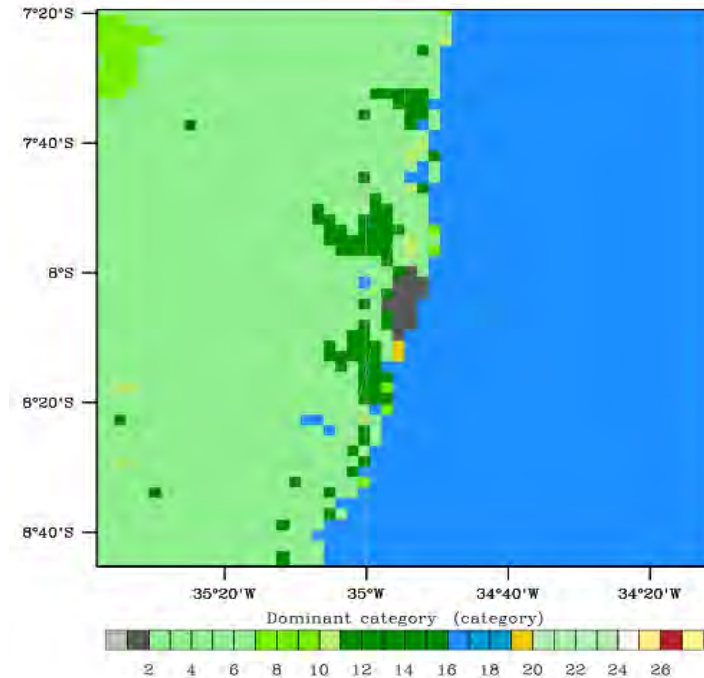
Simplified biogenic inputs

ORCHIDEE
(based on long-term climatology)



Mean daily cycle

Land-use data within the domain



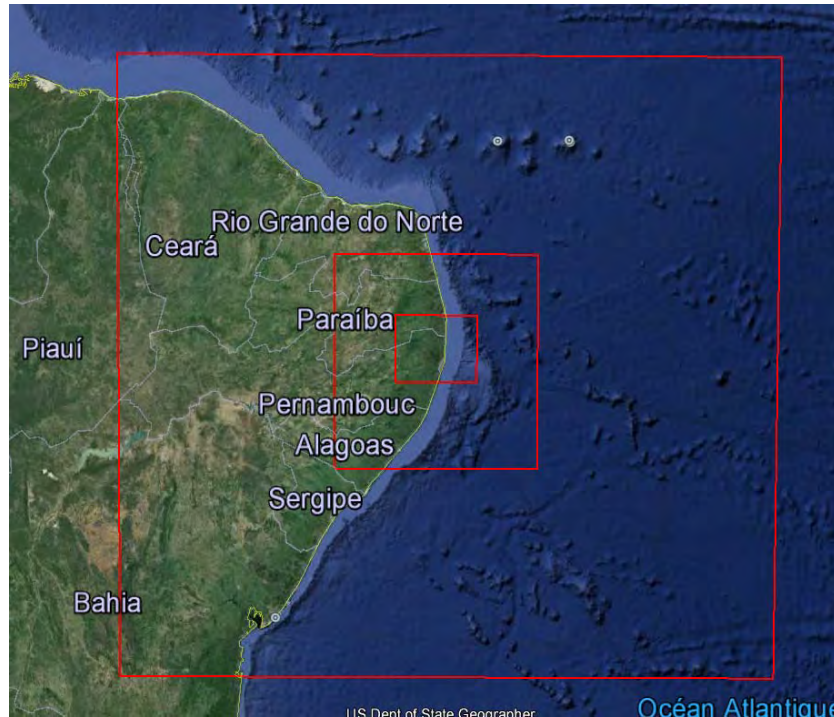
Thanks to the MOSAIC team

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Atmospheric modelling



- NCEP-WRF for meteorological forcing
- Horizontal resolution: 27km, 9km, 3km
- Transport model CHIMERE
- Lowest model layers: 5m, 25m, 50m, 90m
- CO₂ boundary conditions from MACC2

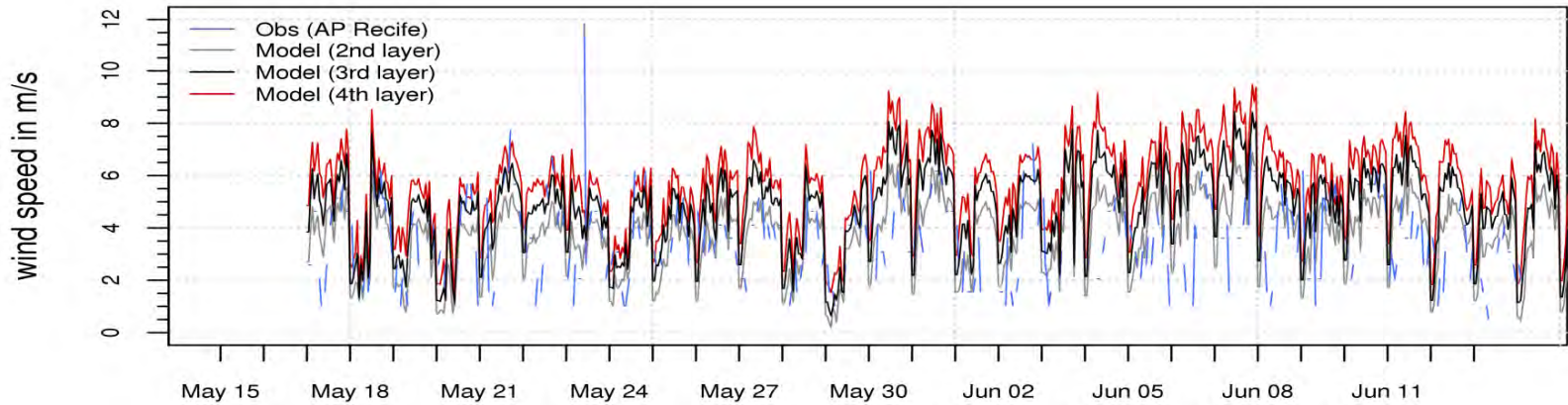
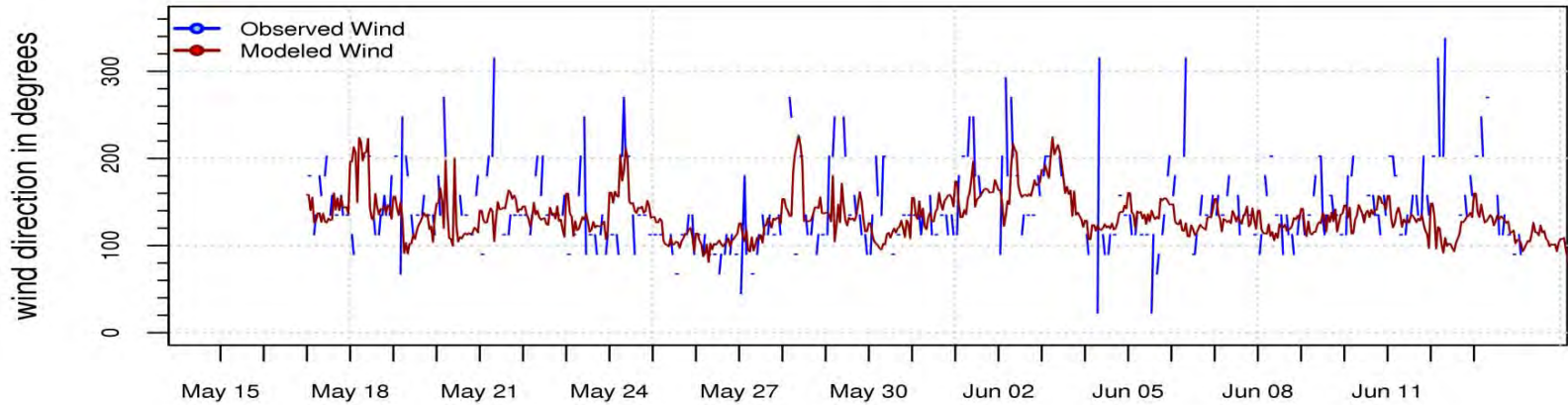
Nested domain

| | 0-6 | 6-12 | 12-18 | 18-24 | 0-6 |
|-------|-----|------|-------|-------|-----|
| Run 1 | → | | | | |
| Run 2 | | → | | | |
| Run 3 | | | → | | |
| Run 4 | | | | → | |

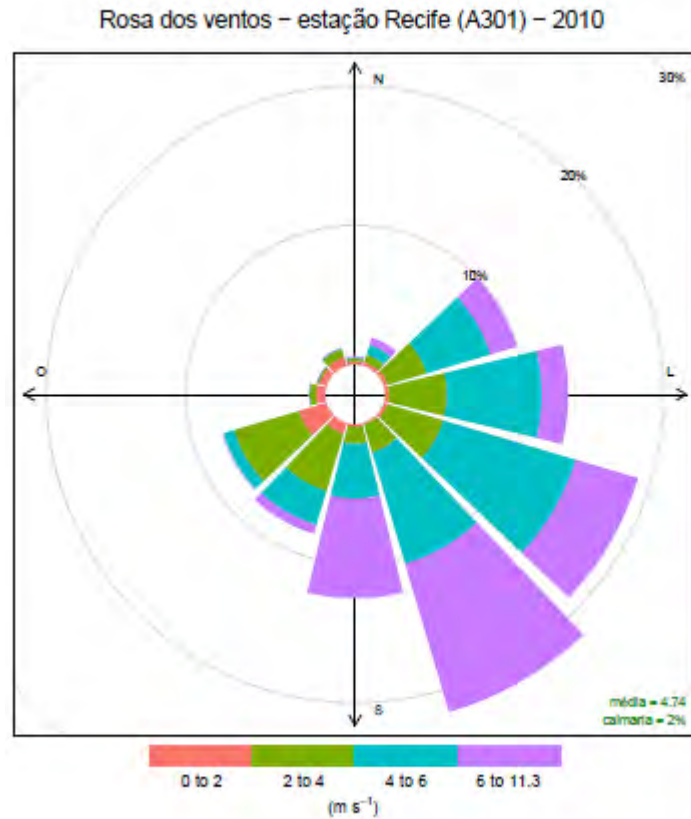


Atmospheric modelling

Observed vs Modeled Wind, Airport Recife



Wind roses as tool to design observational network



Recife urban monitoring program



- Upwind station
- Inlet tube to collect air installed on a lamppost at 30 m;
- Perfectly situated to catch “clean air” from the sea



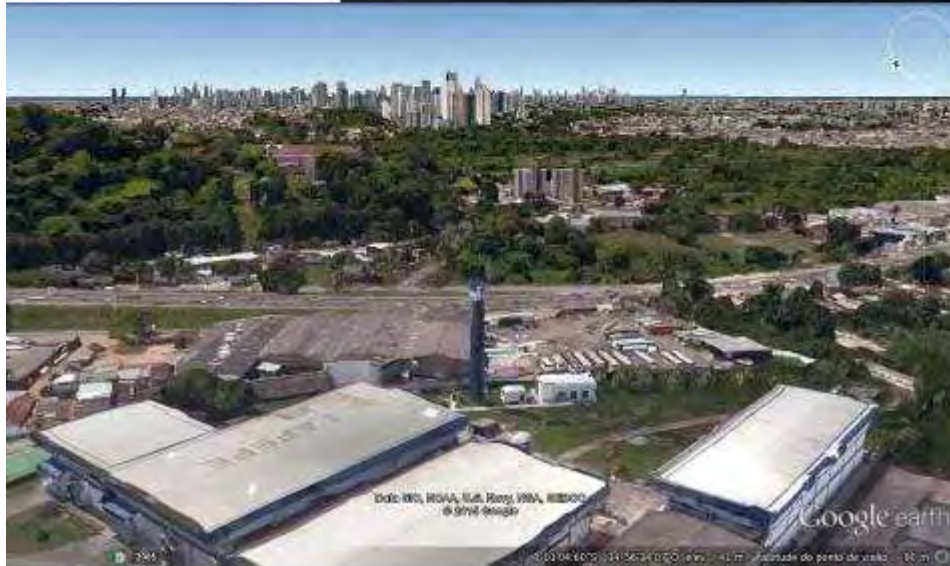
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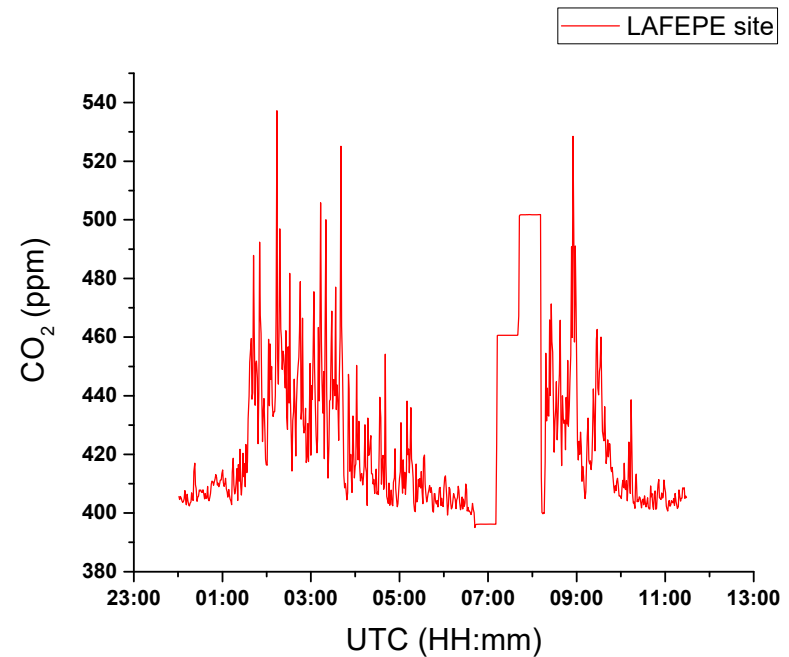
Recife urban monitoring program



- Downwind station
- Inlet tube to collect air installed on a water tower at 30 m;
- Well situated to catch “polluted air” coming from the city (South and center area mainly)



Recife urban monitoring program



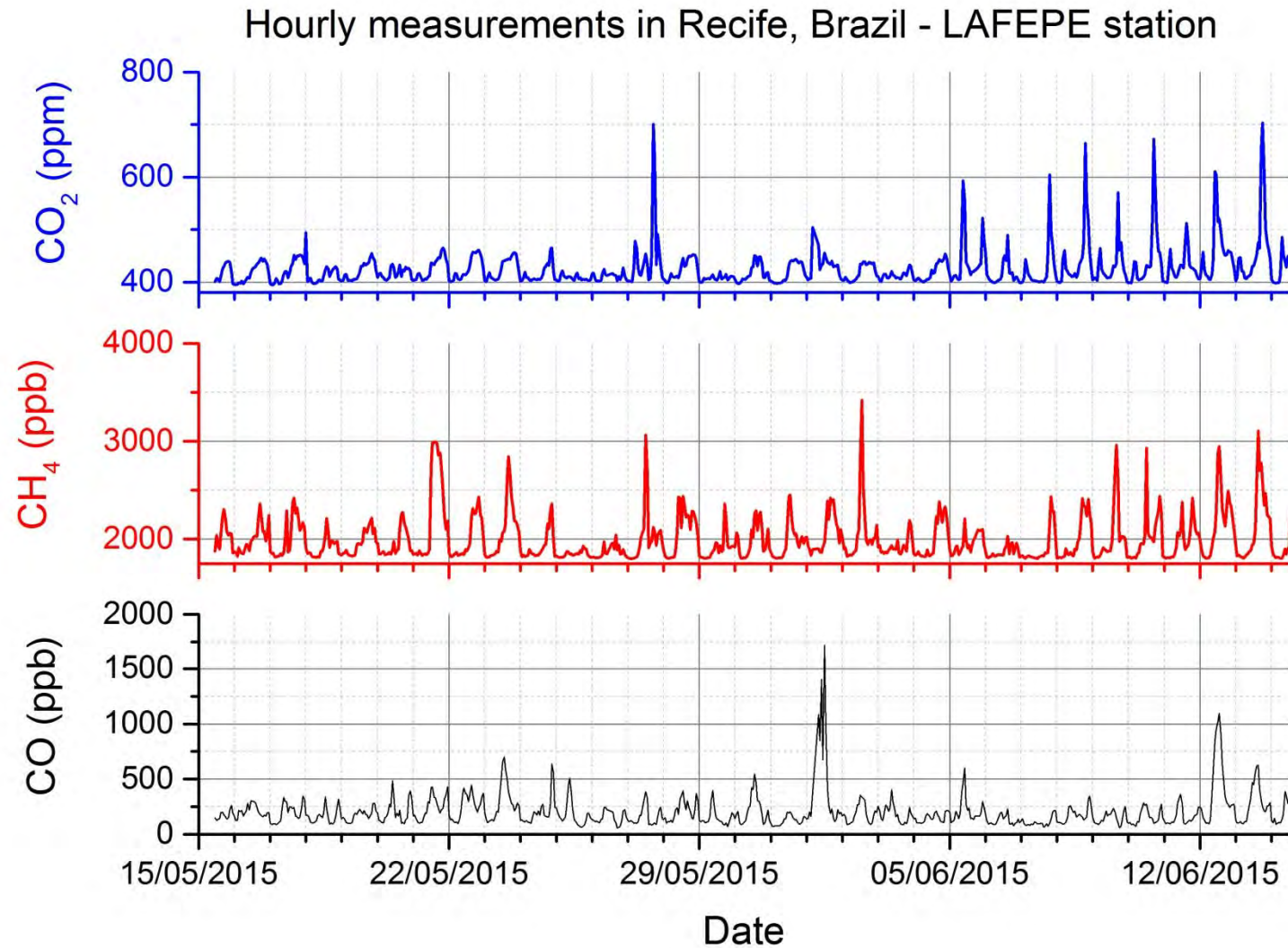
- Weekly calibrations using 3 reference gases (390ppm to 510ppm)
- Daily target measurements
- Performance CO₂ repeatability better than 0.1ppm



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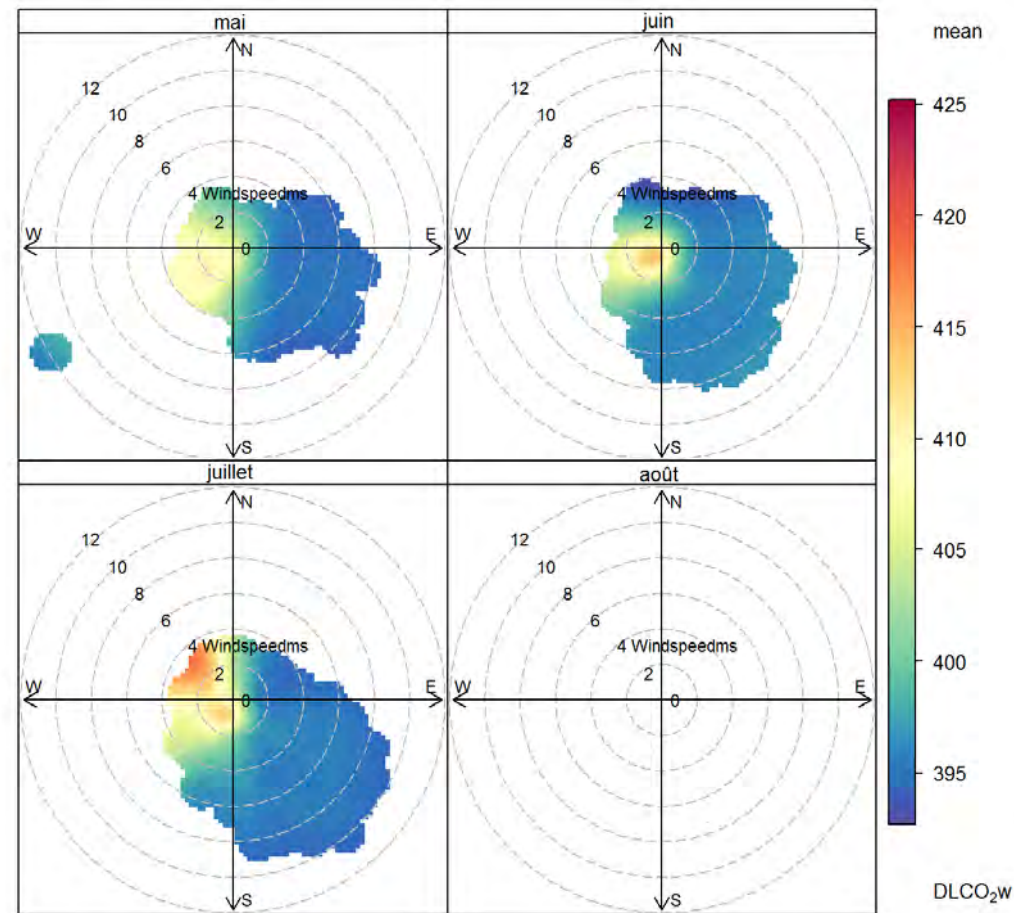


Recife urban monitoring program



Recife urban monitoring program

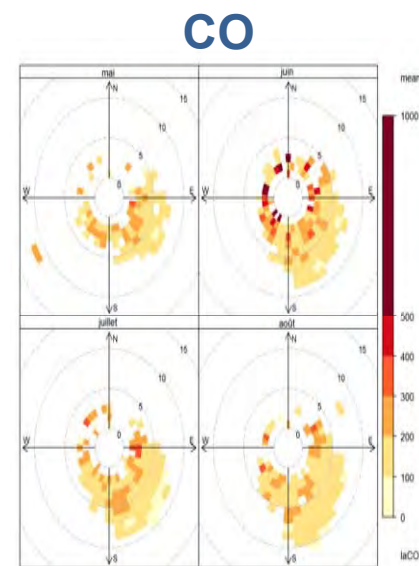
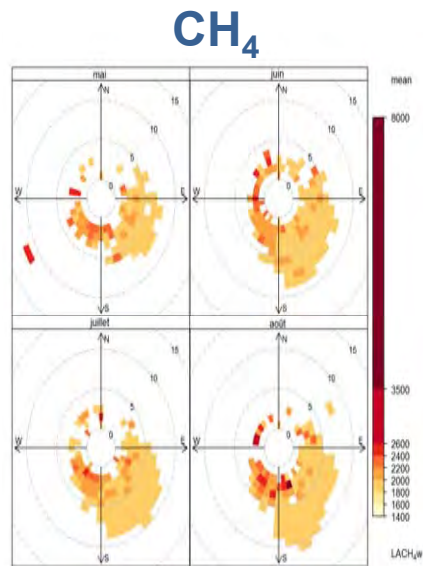
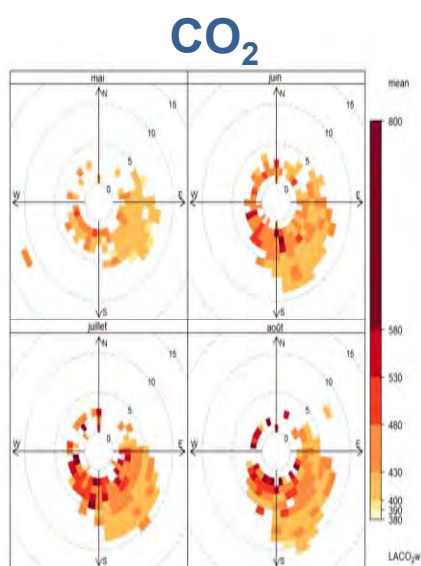
Dona Lindu
"Coastal station"



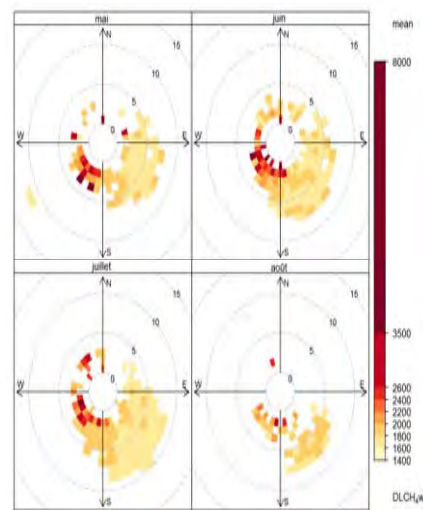
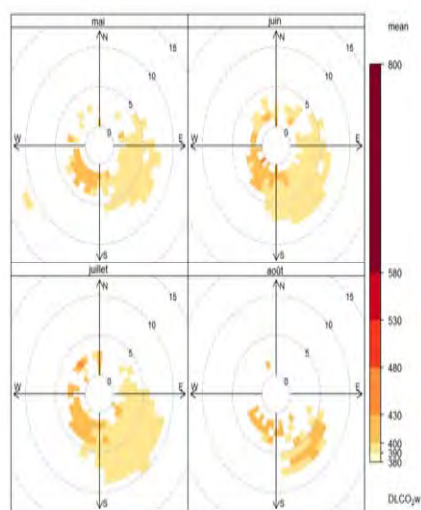
- Combine information of wind direction and concentration to understand source regions!



Recife urban monitoring program



Lafepe

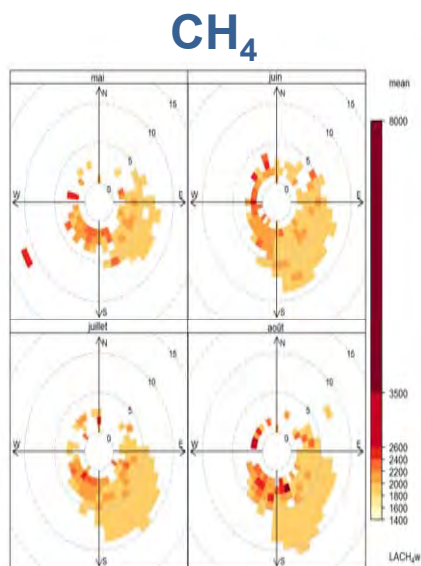


Dona Lindu

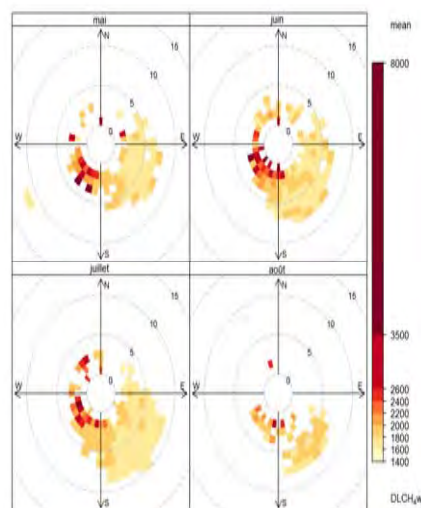


Recife urban monitoring program

Lafepe



Dona Lindu



Mangrove park Recife



Large span for potential Mangrove emissions:
 $4\text{mgCH}_4\text{m}^{-2}\text{d}^{-1} - 82\text{mgCH}_4\text{m}^{-2}\text{d}^{-1}$

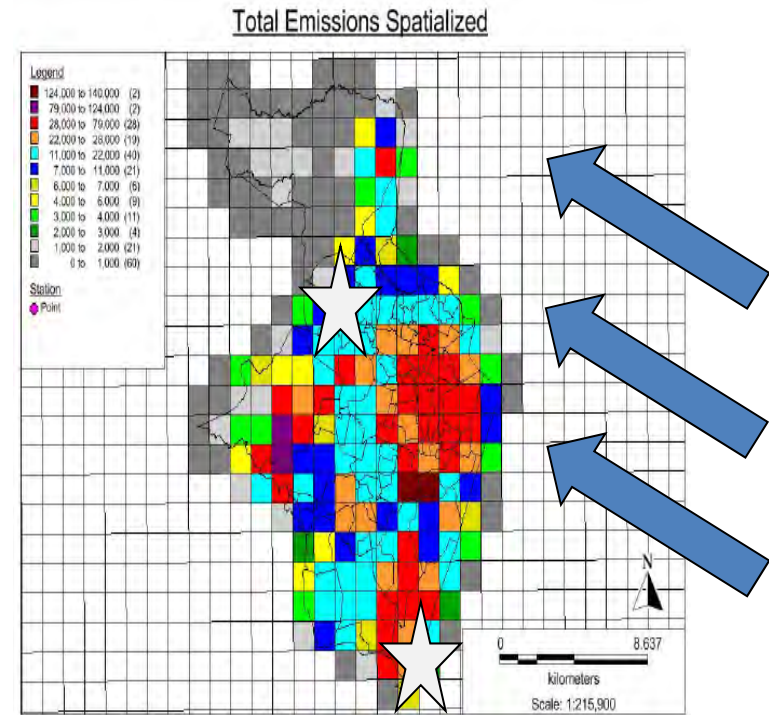
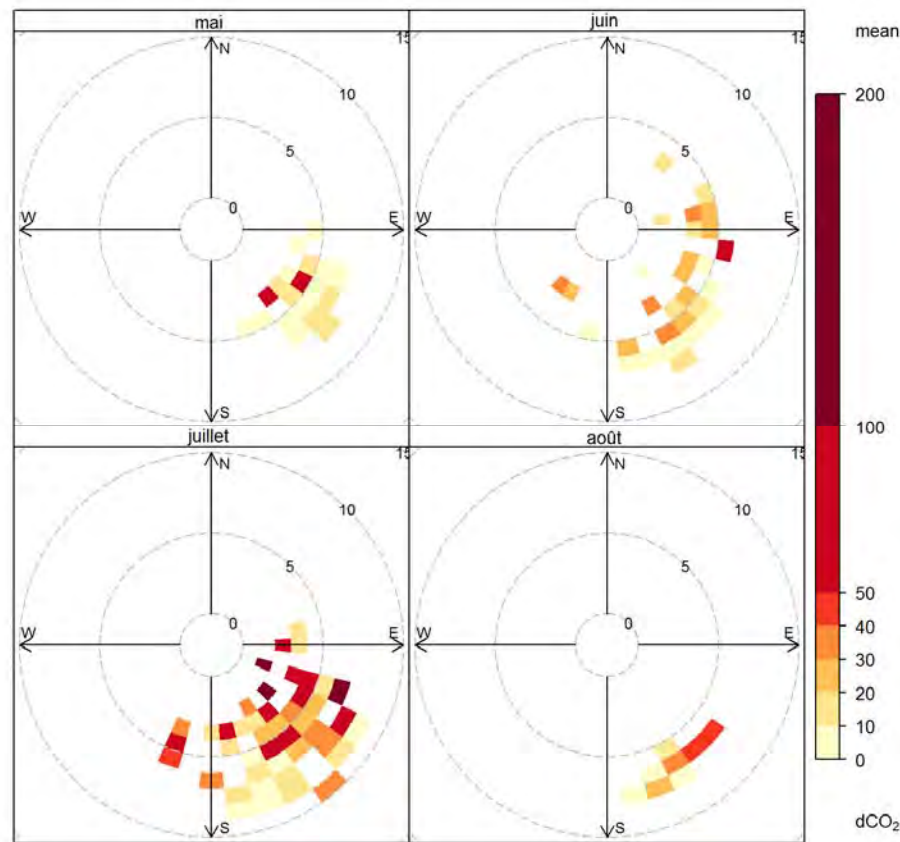
Sotomayor et al. Puerto Rico



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Concentration gradient afternoon (13h-15h)



ΔCO_2
(Lafepe – Dona Lindu)



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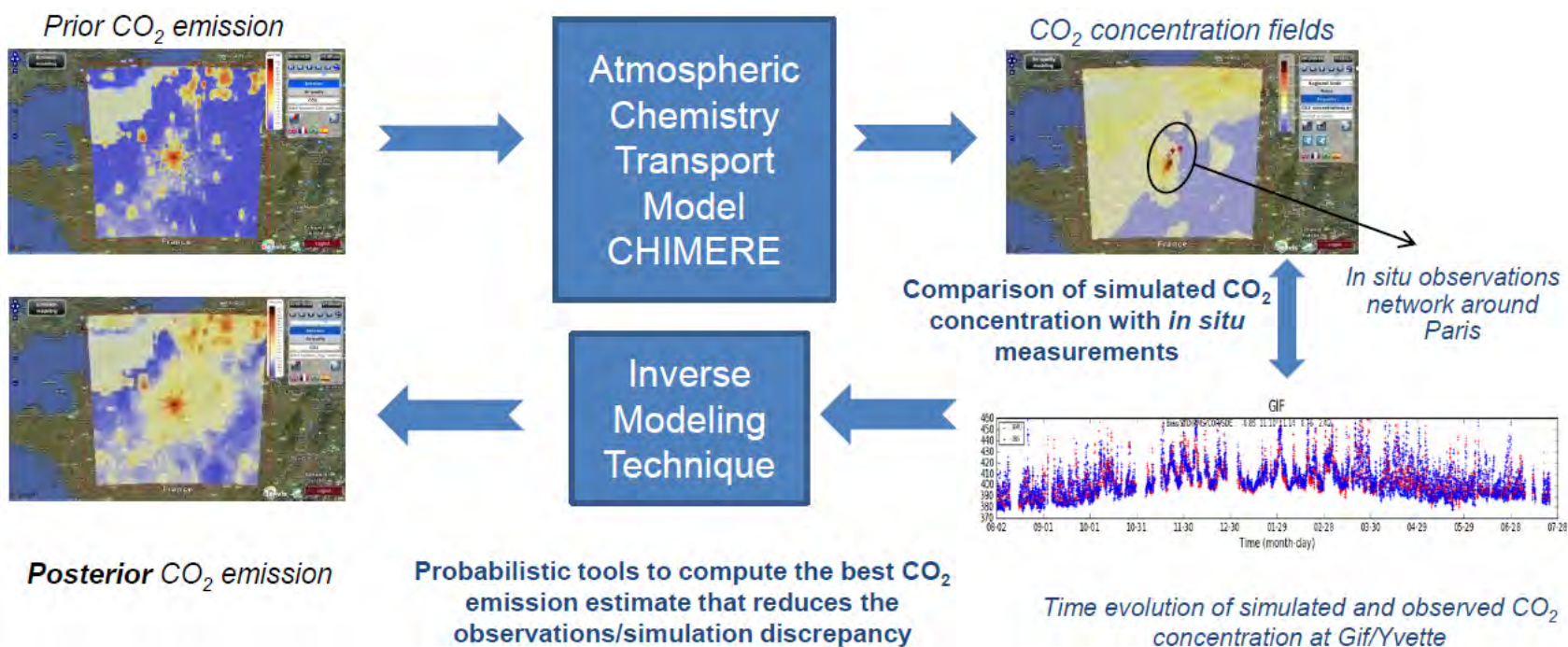


Inversion system simplified

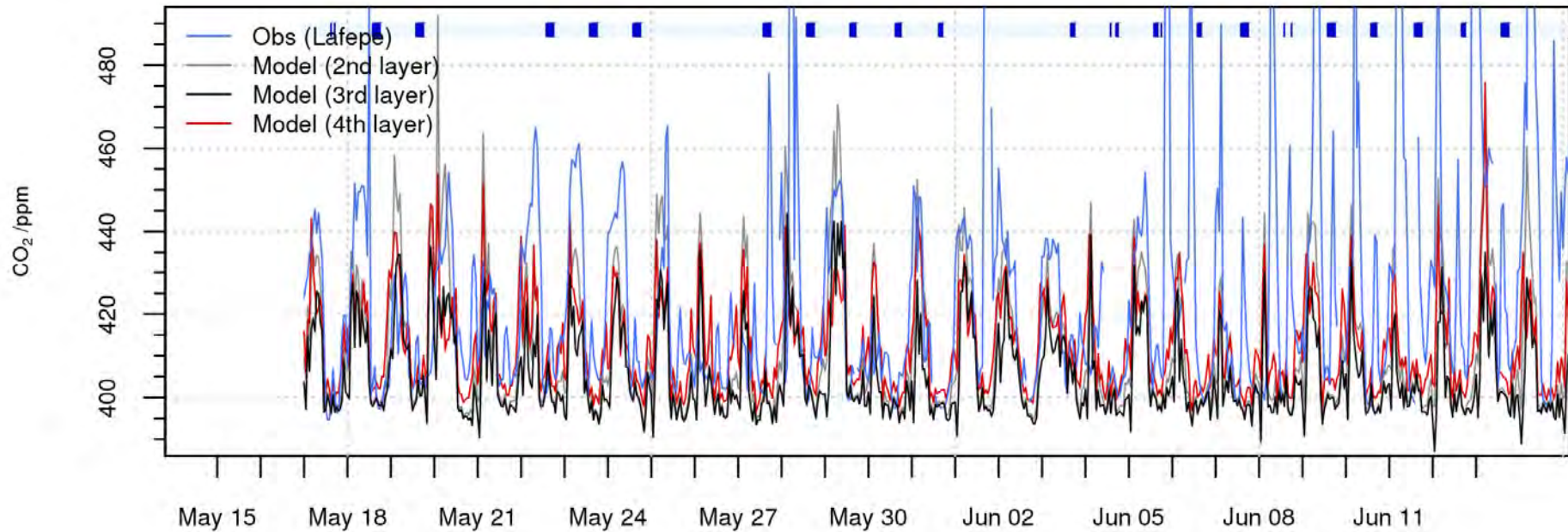
Emission inventory/model

Transport model

Observation system



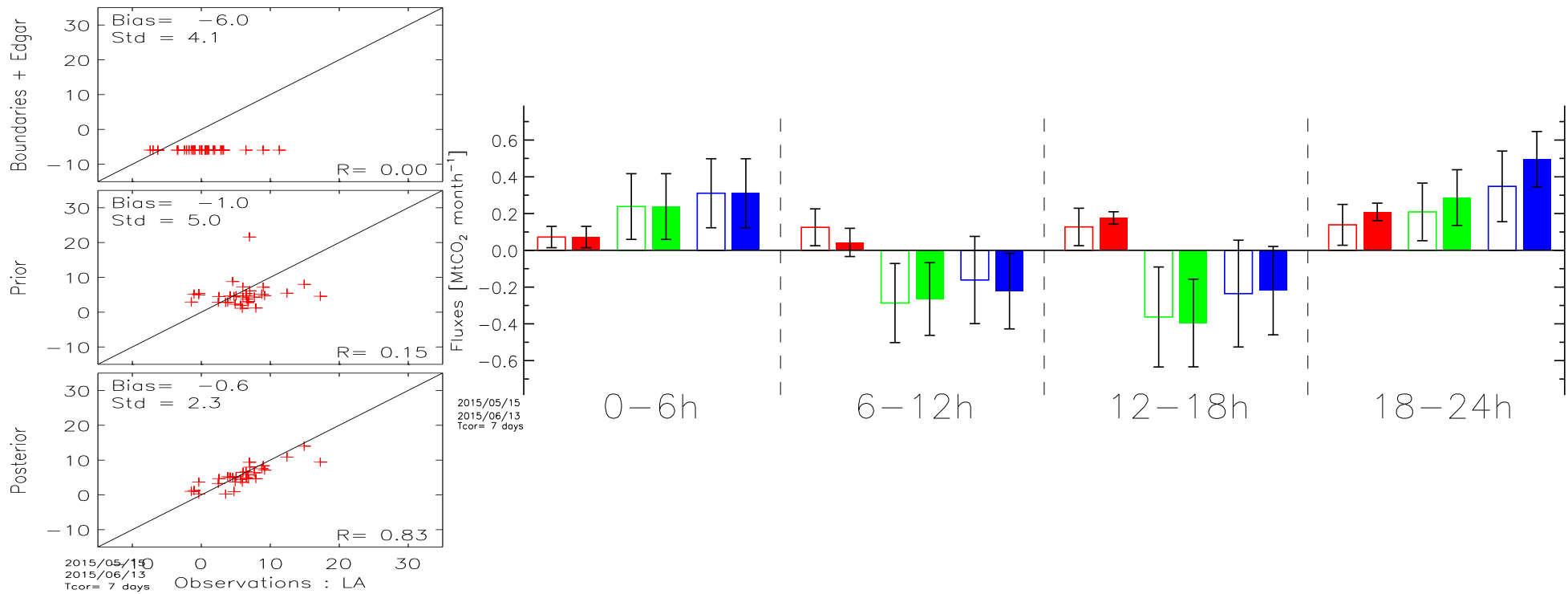
Inversion system Recife - first results



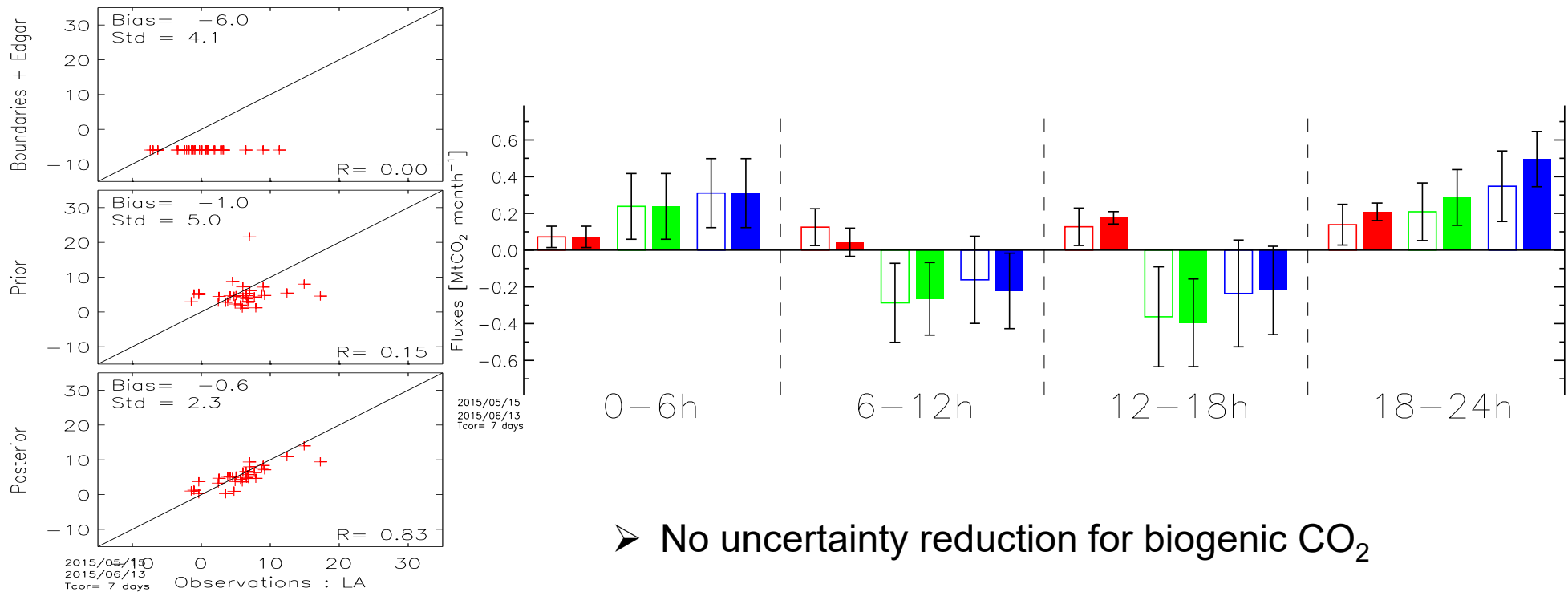
- Definition of wind sectors and minimal wind speed
- Data selected for the afternoon window
- Identification of appropriate model level



Inversion system Recife - first results



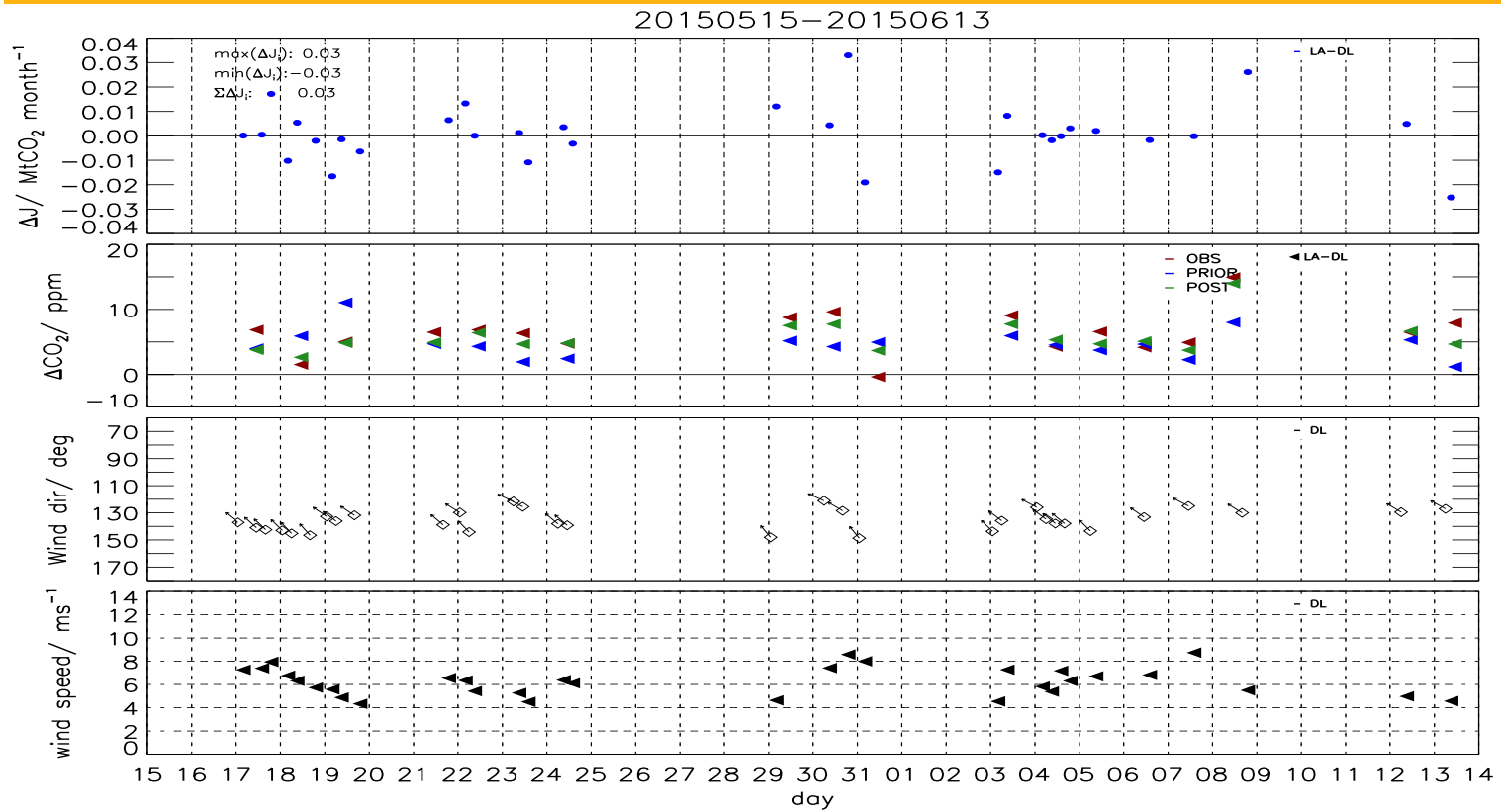
Inversion system Recife - first results



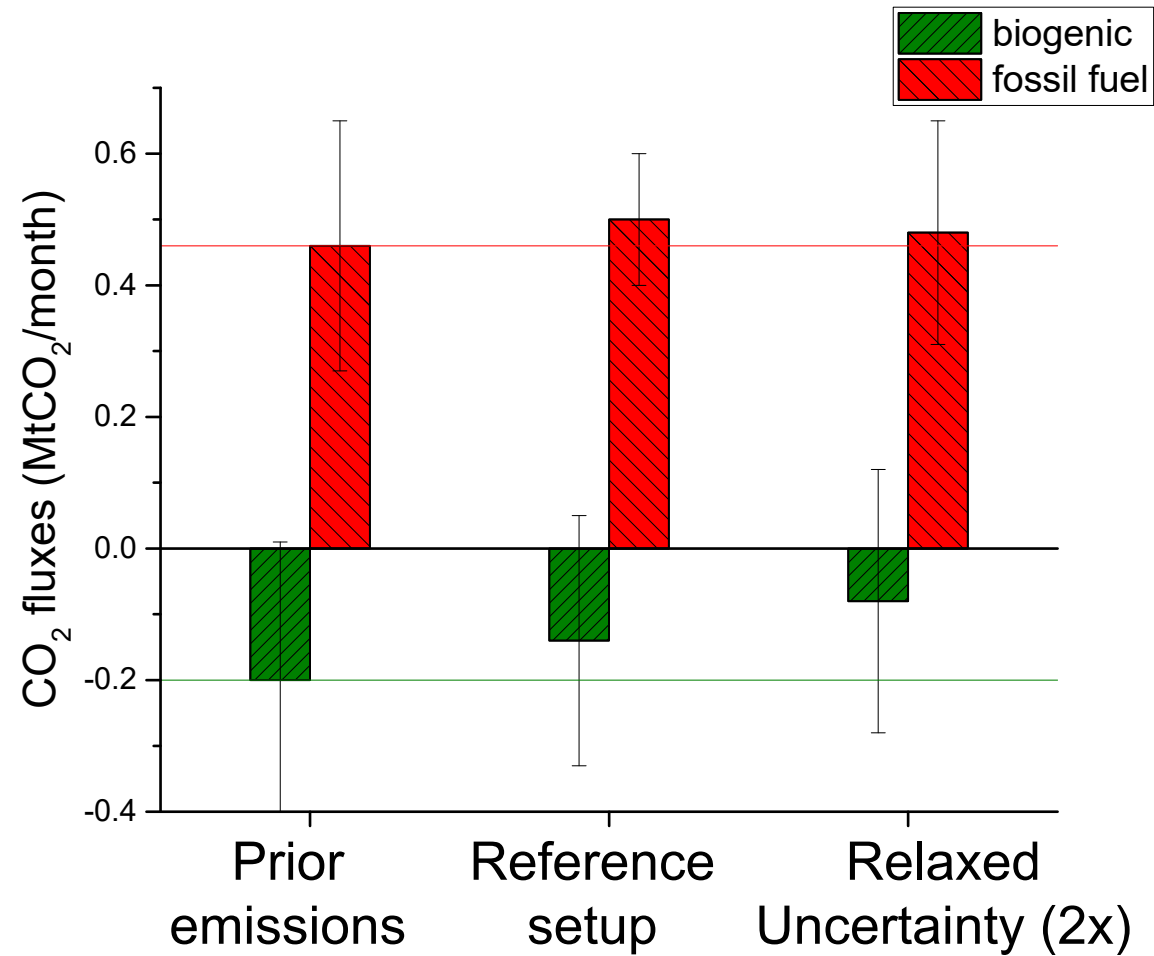
- No uncertainty reduction for biogenic CO₂
- No uncertainty reduction in the morning
- Large uncertainty reduction during daytime
- More balanced biosphere
- More FFCO₂ emissions



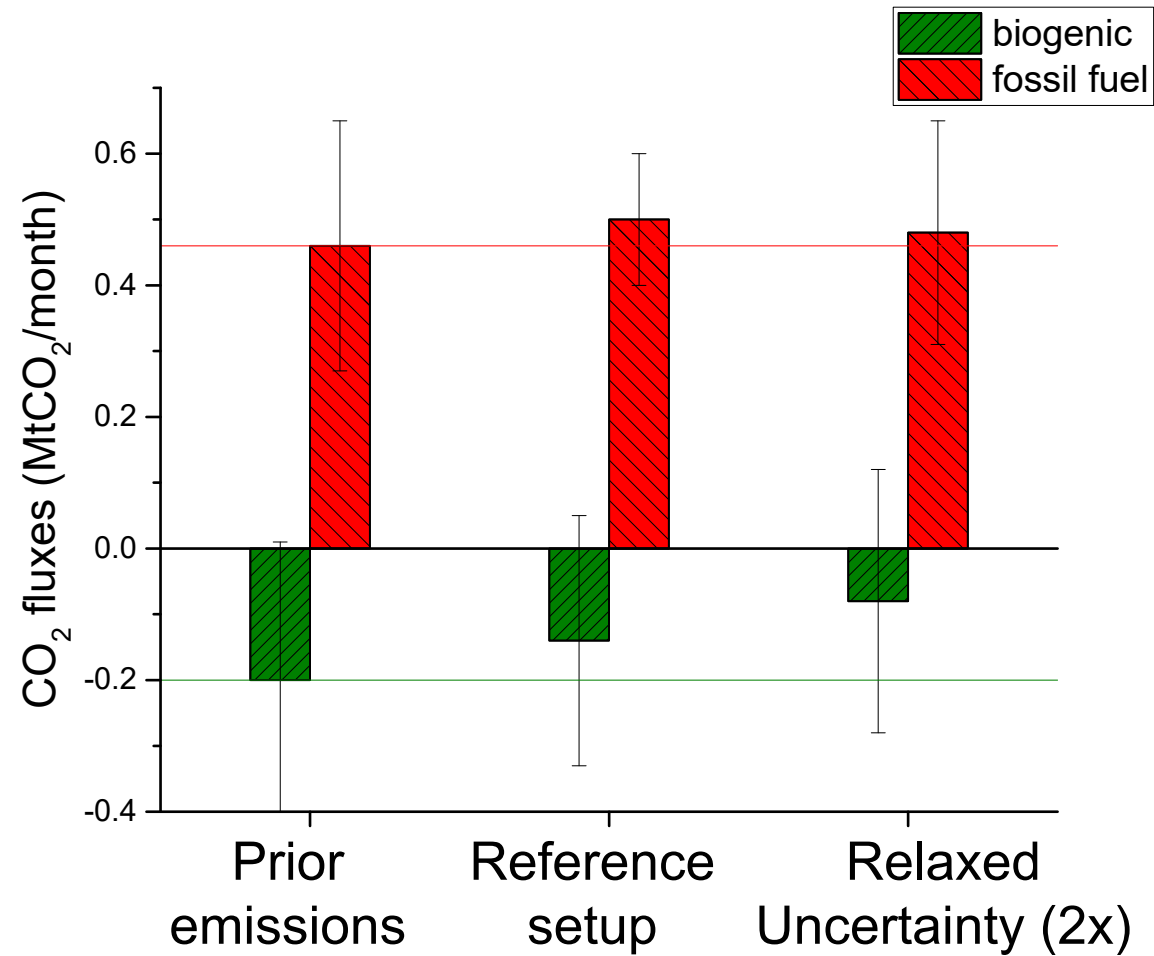
Inversion system Recife - first results



Inversion system Recife - first results



Inversion system Recife - first results



- More sensitivity tests conducted for: intake height, assimilation time-window, correlation of fluxes, ...



Summary

- Spatialized emission inventory constructed from statistical data (cookbook to be released in 2016)
- Successfully installed network and trained local staff
- CO₂ (and CO) concentrations in “expected” range and linked to sources
- Very high CH₄ concentrations at both sites – Mangrove and canals
- Forward modelling completed (and automated)
- First inversion conducted and first results on fossil fuel CO₂ emissions and bio fluxes (more work planned for 2016)
- Project continuation within LOCATION and IG3IS core activities



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Thank you



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