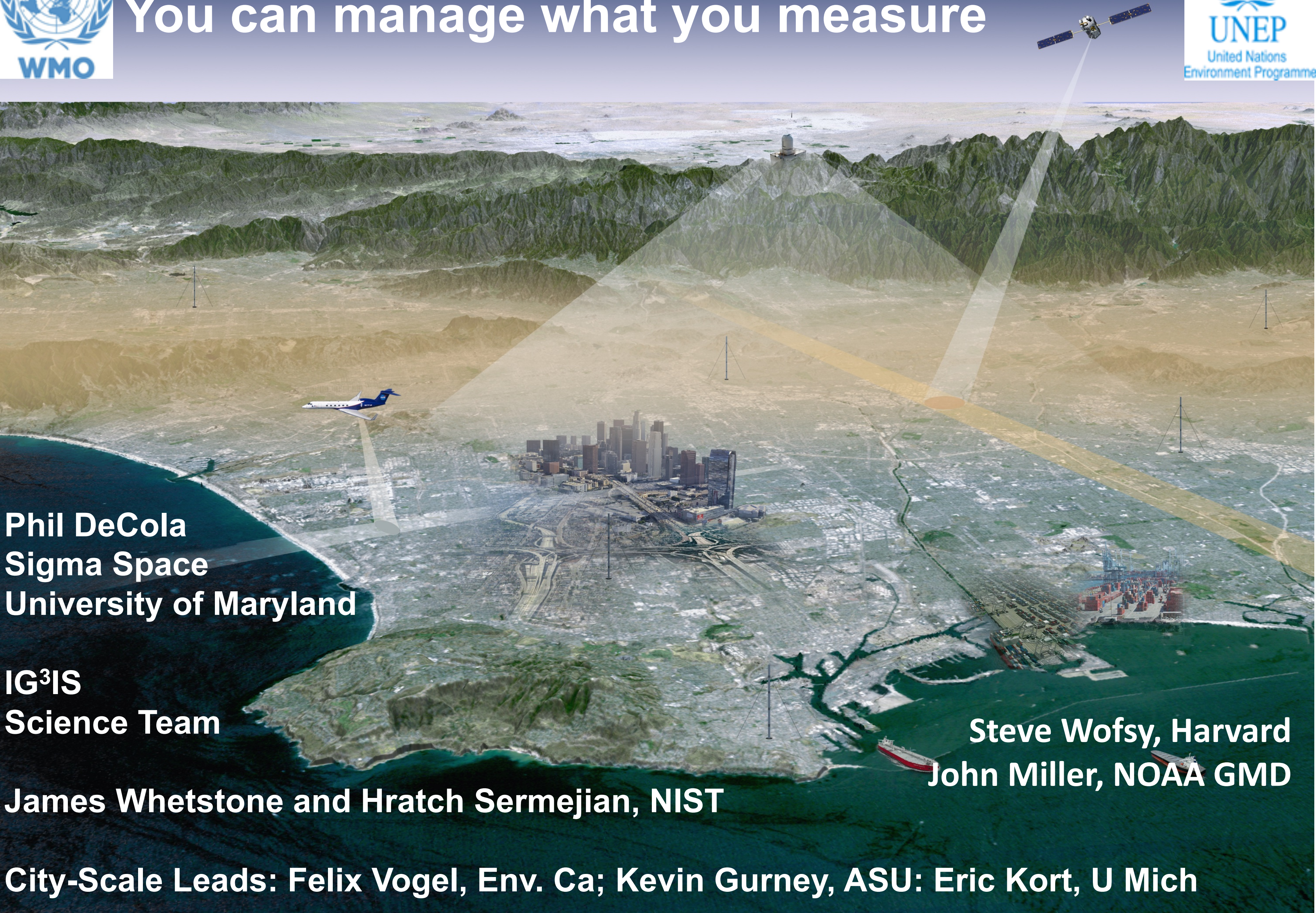
Integrated Global GHG Information Services (iG³IS): You can manage what you measure



Phil DeCola
Sigma Space
University of Maryland

IG³IS
Science Team

James Whetstone and Hratch Sermejian, NIST

Steve Wofsy, Harvard
John Miller, NOAA GMD

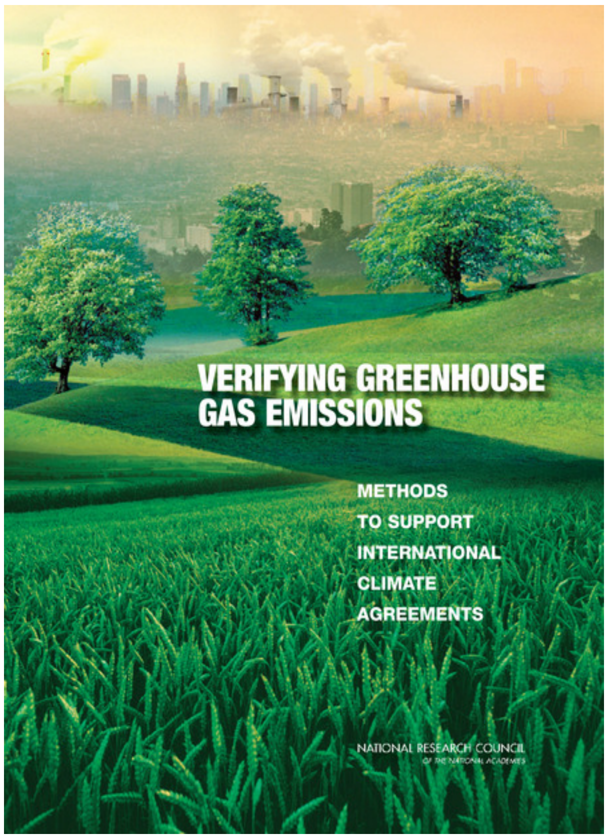
City-Scale Leads: Felix Vogel, Env. Ca; Kevin Gurney, ASU: Eric Kort, U Mich

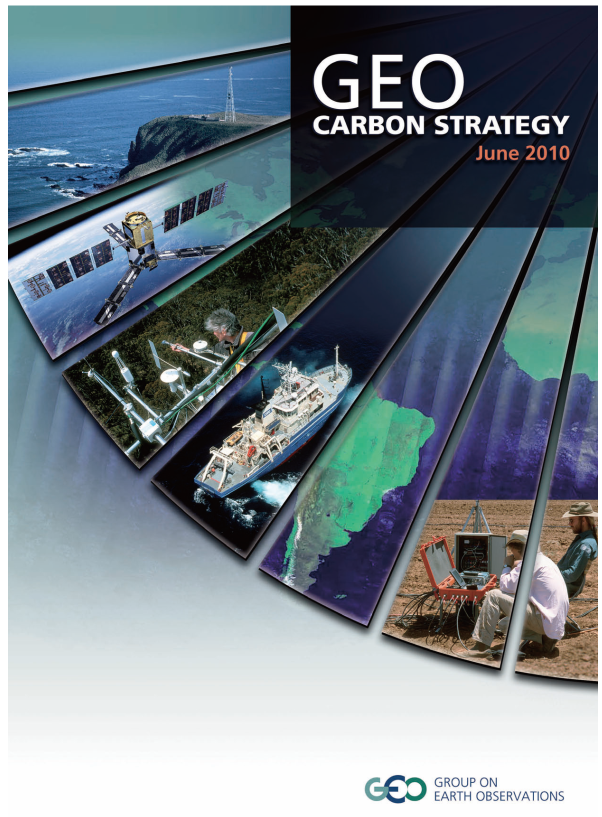
Translational medicine is a rapidly growing discipline in biomedical research and aims to expedite the discovery of new diagnostic tools and treatments by using a multi-disciplinary, highly collaborative, **"bench-to-bedside" approach**.

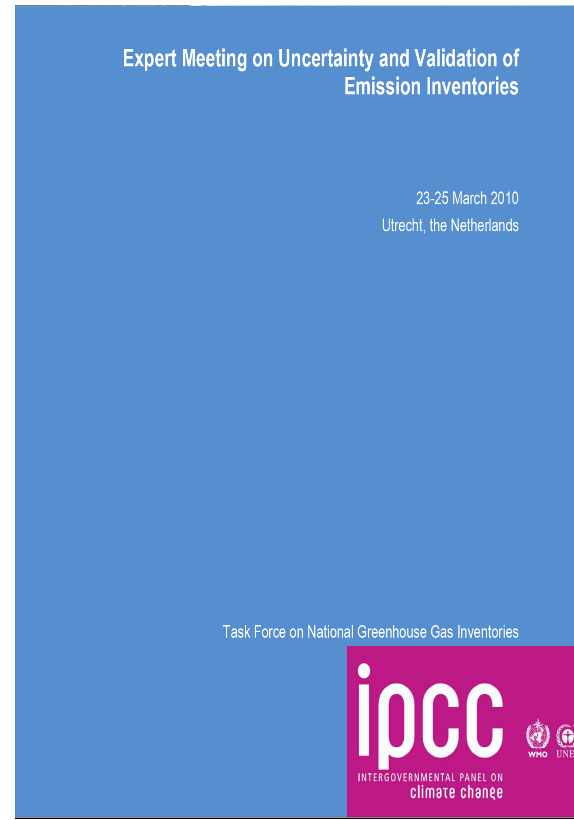
The IG^{3}IS concept is a similar :
"Translation Atmospheric Sciences" **approach**
Build confidence today that atmospheric science-based information services **can be**, and **in fact, need to be** part of the end-to-end solutions

GHG monitoring and reporting in 2010:
atmospheric "top-down" and inventory "bottom-up"

Can atmospheric measurements and models "verify" inventories?







Paris Agreement and GHG Monitoring: Evolving from Top-Down versus Bottom-Up Paradigm

Then (2009)

Binding Multi-national Treaty Commitments

"we will verify your reported emissions"

A grand top-down GHG Information System

Advocates: Science Community!!!

Now (2016)

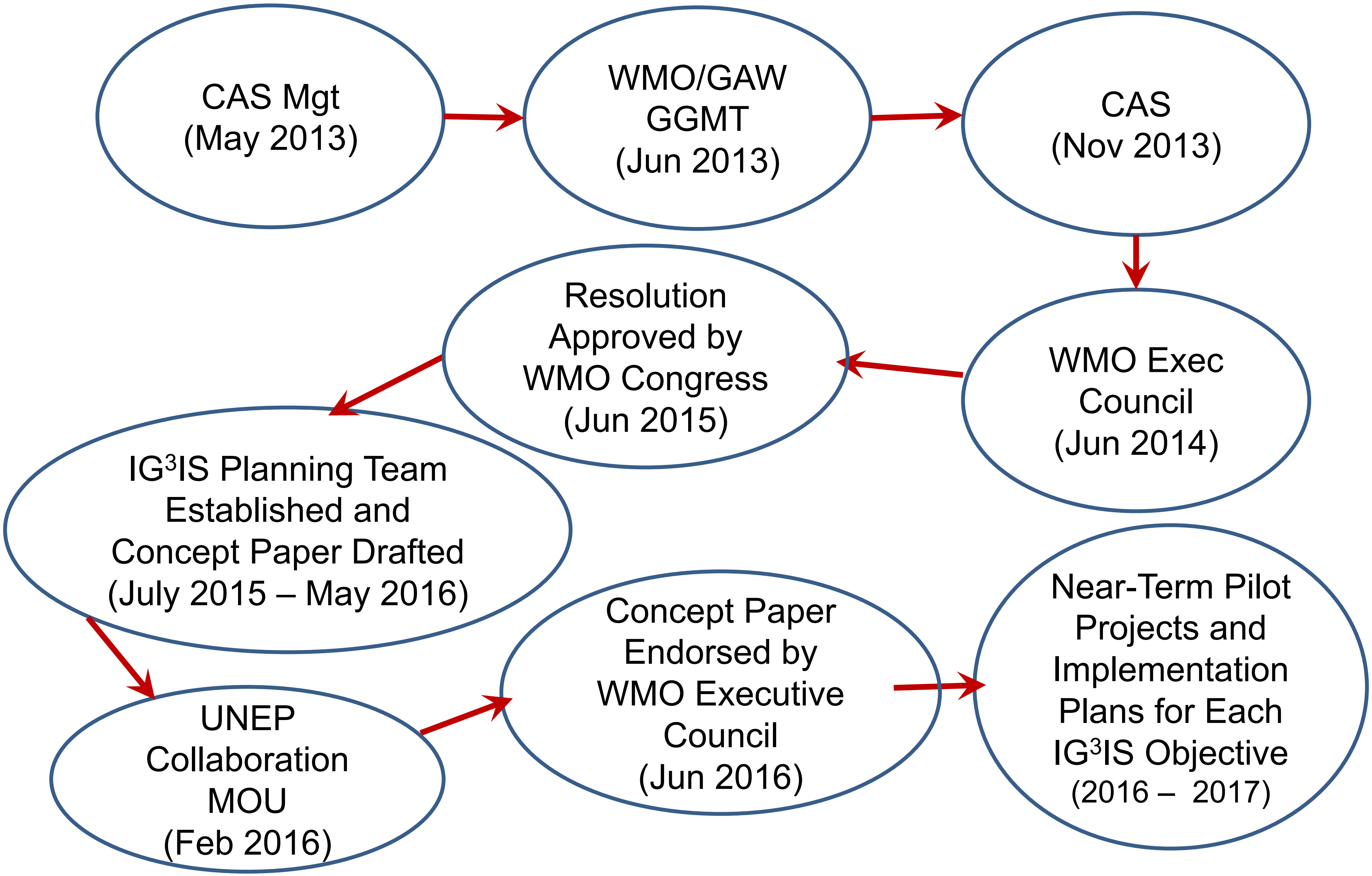
Nationally Determined Contributions

"we will help you improve your data"

Federation of focused monitoring systems

Advocates: WMO (191 countries),UNEP,
Cities (eg, C40), NGOs, Industry (eg, Oil Companies)

IG^{3}IS programmatic evolution within WMO



The Integrated Global Greenhouse Gas Information System (IG^3IS)

- Combine (unified approach) atmospheric measurements with socioeconomic inventory data to *better quantify and attribute greenhouse gas emissions.*
- IG^3IS will serve as an international coordinating mechanism and establish and propagate *consistent methods and standards* (**BIPM/GAW** partnership).
- *Stakeholders are entrained from the beginning* to ensure that information products meet user priorities and deliver on the foreseen value proposition.
- Success-criteria are that the information *guides additional and valuable emission-reduction actions*.
- IG^3IS must mature *in concert with evolution of policy and technology.*

IG³IS Implementation: Products and Objectives

Products

- ***Pilot projects*** **to build user-base and improve skill,**
- ***Document good-practice*** **implementation guidelines**

Objectives

Support of Paris Agreement:

- ***Improved national inventory reporting*** by making use of atmospheric measurements for all countries
- Timely and quantified trend assessment in ***support of countries' NDC tracking and "Global Stocktaking"*** (TBD)

Key sub-national efforts and new mitigation opportunities:

- GHG monitoring in ***large urban source areas*** (megacities)
- Detection and quantifying ***large unknown CH_4 emissions***

Executive Summary
1.0 Motivation and Overview
1.1 Motivation for an IG^{3}IS
1.2 **IG^{3}IS Principles**
1.3 **IG^{3}IS Objectives**
2.0 IG^{3}IS Governance, Management and Support
3.0 Objective 1: IG^{3}IS in Support of National Inventory Preparation
(Dominik Brunner; Alistair Manning, Shamil Maksyutov)
2.1 Overview
2.2 Customer-based Information Requirements, Current Capabilities and Gaps
2.3 Measurement Network Design
2.3.1 Measurement Network Development
2.4 Model development
2.5 Communications and Technical Support for Inventory Builders
2.6 Capacity Building and Outreach
4.0 Objective 2: Detect and Quantify Anthropogenic Methane Emissions
(Daniel Zavala, Rod Robinson, Gaby Petron)
3.1 Overview
3.2 Customer-based Information Requirements, Current Capabilities and Gaps
3.3 Measurement Network Design and Modeling Framework
3.4 Communications and Technical Support for Inventory Builders
3.5 Capacity Building and Outreach

5.0 Objective 3: IG^{3}IS in Support of City-Scale Mitigation Efforts
(Jocelyn Turnbull, Felix Vogel, Kevin Gurney)
4.1 Overview
4.2 Customer-based Information Requirements, Current Capabilities and Gaps
4.2.1 Urban typology
4.2.2 High spatial and temporal resolution bottom-up inventories
4.3 Measurement Network Design
4.4 Modeling Framework
4.4.1 Data processing and management routines
4.5 Demonstration experiments
4.6 R&D for novel/other observing and modelling systems to pre-operational status
4.7 Capacity Building and Outreach
6.0 Objective 4: IG^{3}IS in Support of the Global Stock Take
(Philippe Ciais, Frederick Chevalier, Florin Vladu)
5.1 Overview
5.2 Extension of Global Carbon Atlas Approach
7.0 IG^{3}IS Inverse Modeling Cross Cutting Activities – Decision-Scale TransCom
(Thomas Lauvaux, Sander Houweling, plus Dominik, Alistair, Shamil others)
8.0 IG^{3}IS Atmospheric Measurement Strategy: Tiered Suite of Observations
9.0 IG^{3}IS Research and Development Activities
10.0 IG^{3}IS Partner, Stakeholder and Sponsor Coordination
11.0 Execution of the Implementation Plan

12.0 Summary/Conclusion

An Integrated Global Greenhouse Gas Information System (IG³IS)

by Phil DeCola[1] and WMO Secretariat[2]

Atmospheric composition measurements in the latter half of the twentieth century showed increasing global concentrations of greenhouse gases. These measurements were the initial cause of concern about global warming and climate change. Today, as nations make pledges to reduce their greenhouse gas (GHG) emissions, concentration measurements of carbon dioxide (CO_2) and other GHGs will unequivocally determine whether the actions taken are having the desired effect. Thus, WMO has initiated the development of an Integrated Global Greenhouse Gas Information System (IG³IS) to help guide valuable GHG emission-reduction actions in response to climate change. This new System will establish and build confidence in the role of atmospheric composition measurements as an essential part of climate change mitigation efforts. This article discusses the need for and development of atmospheric composition measurements and the role of IG³IS.

Climate change a global concern

In 1992, participants of the United Nations Conference on Environment and Development (the "Rio Earth Summit") adopted the United Nations Framework Convention on Climate Change (UNFCCC), an international treaty aimed at combatting climate change. The ultimate objective of the Convention is to stabilize greenhouse gas (GHG) concentrations "at a level that would prevent dangerous anthropogenic (human-induced) interference with the climate system." It further states "such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner." There are now 197 Parties to the Convention. But, what was the motivation and basis for this impressive global action?

The UNFCCC was established upon a bedrock of scientific evidence and understanding, consisting particularly of long-term observations of Earth's atmospheric chemical composition and its change over time. Consistent and accurate measurements show rapidly rising concentrations of GHGs, such as carbon dioxide. These measurements also unambiguously attribute the rise to human activities, and link the increasing GHG concentrations to global warming and negative climate impacts.[3]

Since the eighteenth century Industrial (or energy) Revolution, human activities have caused a steady increase in concentrations of GHGs such as CO_2, methane (CH_4) and nitrous oxide (N_2O), and mean global temperatures have been rising in response. Concentrations of CO_2 have risen by more than 40% from pre-industrial levels and continue to rise at an increasing rate. They are now higher than they have been in at least about four million years, when global average temperatures were 2 to 3 °C hotter than in the nineteenth century and sea levels were 7 to 25 metres higher than today.[4] Current levels of CH_4 are 2 ½ times

[1] Sigma Space Corporation and Department of Atmospheric and Oceanic Sciences, University of Maryland

[2] Oksana Tarasova, Chief, Atmospheric Environment Research Division

[3] IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (Core Writing Team, R.K. Pachauri and L.A. Meyer, eds.). IPCC, Geneva, 151 pp.

[4] Salawitch et al., 2017: Paris Agreement: Beacon of Hope, ISBN DOI 978-3-319-46939-3 at Springer Climate

https://public.wmo.int/en/resources/bulletin

Summary
"Translation Science"

Build confidence today that science-based information services need to be part of the solutions:

- Define the detailed good-practice guidelines for each objective area
- Develop near term pilot projects for each objective area

- Actively entrain users, partners and sponsors through all stages of development
- Coordinate with partners UNFCCC, IPCC, GCOS, GFCS, GEO, WCRP, and others

Level of sophistication of urban stakeholder needs

Complexity of solution

Identify major emitters and anomaly detection	Quantification of total GHG emissions	Assessment of GHG emissions per sector	Tracking annual and long-term emission changes	Understand short-term emission changes and spatial patterns	Process understanding of emissions and tracking of mitigation impacts
Inventory validation (A1)	Inventory or emission model (A2)	Sector-specific inventory or emission model (A3)	Continuously updated inventory or emission model (A4)	Temporally and spatially disaggregated inventory or emission model (A5)	Process-based emission model using real-time emission data
Mobile surveys (B1)	Mass-balance (B2) Radon tracer method (B3)	Multi-tracer ratio observations (B4)	Radon tracer method (B5) Multi-tracer observations (B6)	Mobile surveys (B7) Repeated mass-balance	Dedicated field campaigns (
Remote sensing (C1)	DAS using short-term observations (C2)	*DAS using dense observations(C3)* *DAS using multi-species data*	DAS using long-term observations (C4)	*DAS using dense observations (C5)*	FFDAS DAS using multi-species

Demonstrated skills

Theoretically tested skills

Future potential skills

DAS = data assimilation system

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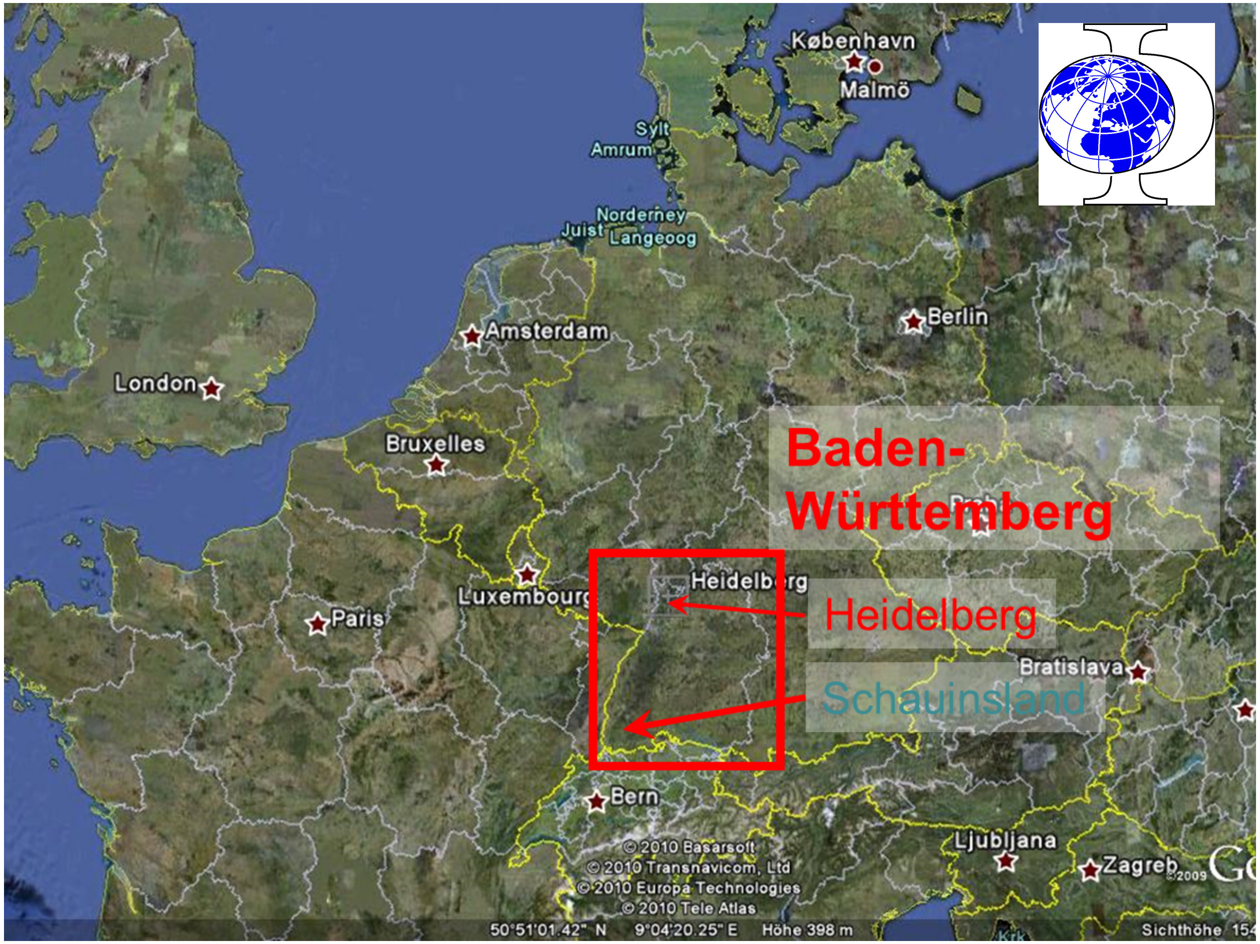
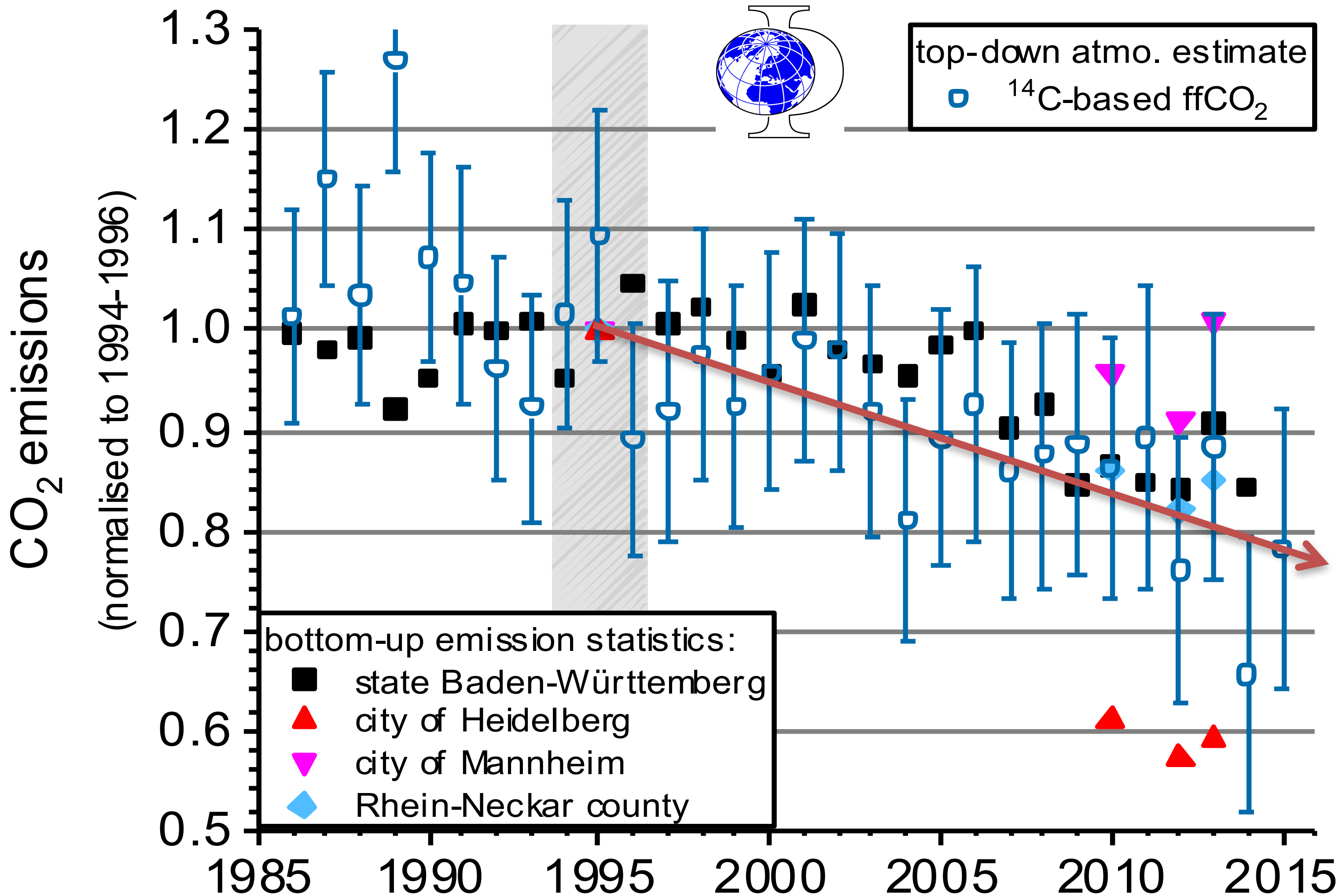
How bottom-up statistics trends compare to top-down?

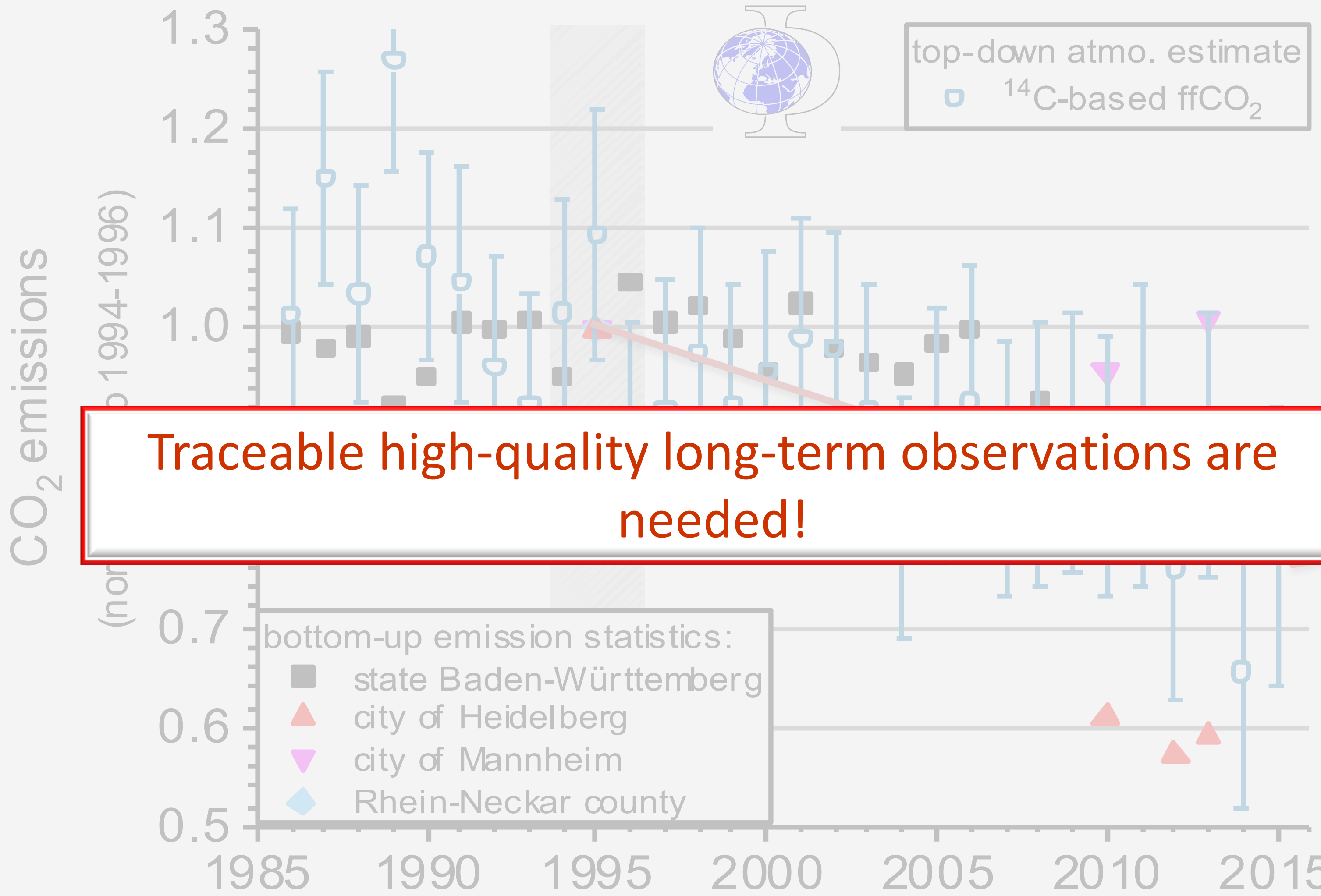


Courtesy: S. Hammer and I. Levin



Courtesy: S. Hammer and I. Levin

Emission data from: Statistisches Landesamt Baden-Württemberg



Traceable high-quality long-term observations are needed!

Courtesy: S. Hammer and I. Levin

Emission data from: Statistisches Landesamt Baden-Württemberg

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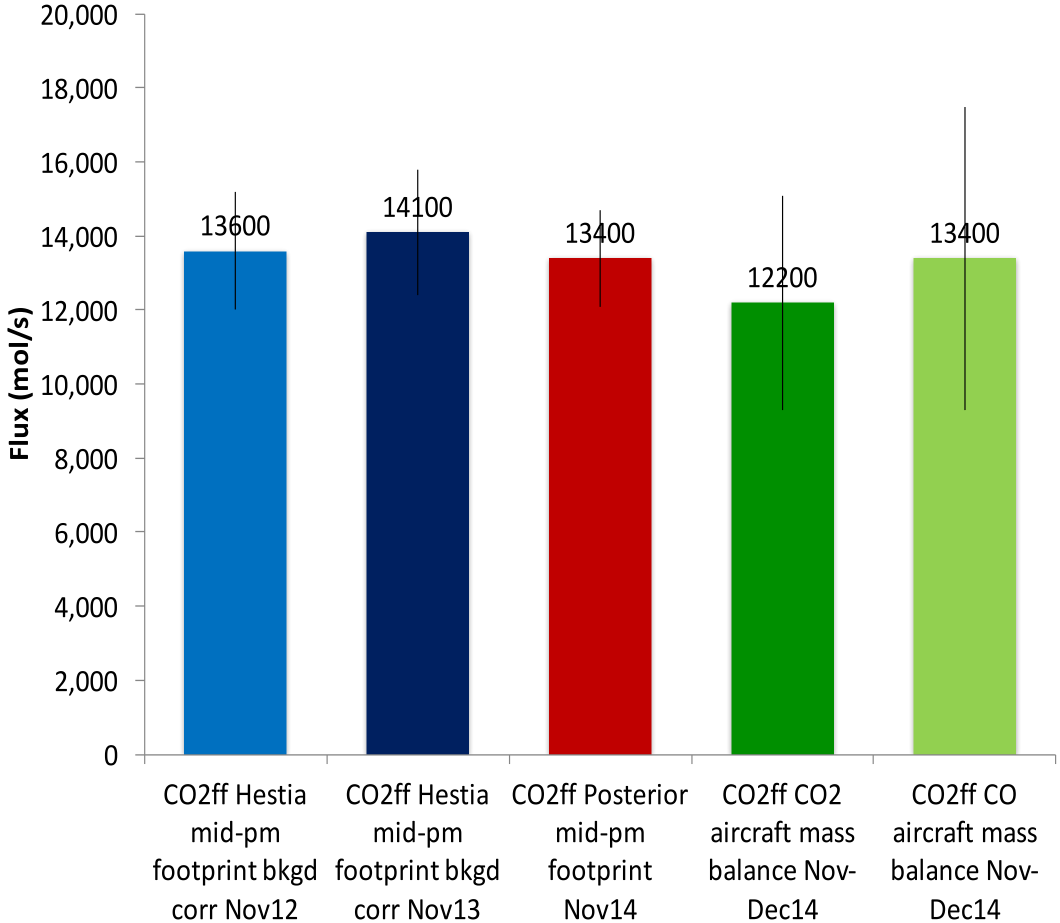
Indianapolis CO_2ff flux comparison



Turnbull et al, ICDC10 presentation

Comparison of whole city, winter, fossil fuel CO_2 flux

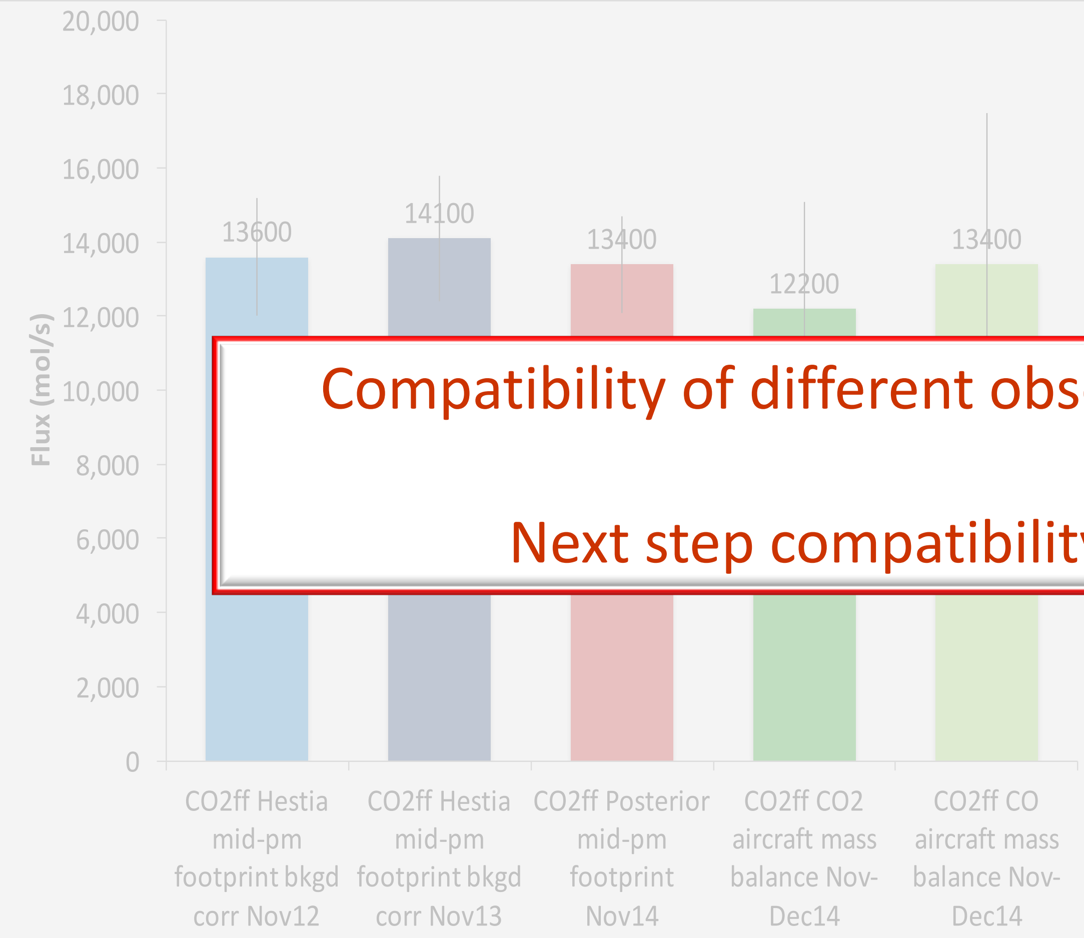
- Hestia high resolution bottom-up data product
- Atmospheric inversion based on in situ tower CO_2 data and WRF/LPDM
- Mass balance using downwind aircraft measurements

- Flask measurements used to convert total CO_2 or CO to CO_{2ff} for aircraft and inversion
- Matched times and footprint
- Corrected to the same background

Excellent agreement across top-down and bottom-up methods

13,300 mols/s ± 6%

Indianapolis CO_2ff flux comparison



Turnbull et al, ICDC10 presentation

Comparison of whole city, winter, fossil fuel CO_2 flux

- Hestia high resolution bottom-up data product
- Atmospheric inversion based on in situ tower CO_2 data and WRF/LPDM
- Mass balance using downwind aircraft

al CO_2 or

Compatibility of different observations are needed!

Next step compatibility of methods…

Excellent agreement across top-down and bottom-up methods

13,300 mols/s ± 6%

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How to start from scratch – Recife, Brazil

1. Build emission inventory
2. Establish modelling system
3. Setup measurement system
4. Analyse data

CPRH Agência Estadual de Meio Ambiente

'can you do this in Recife?'

How to start from scratch – Recife, Brazil

1. Build emission inventory
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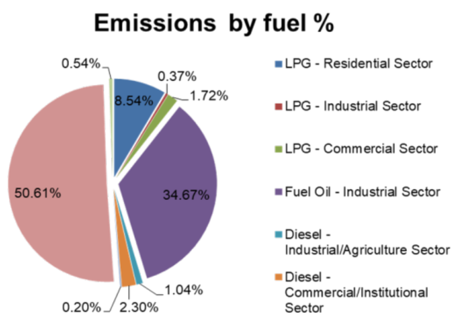
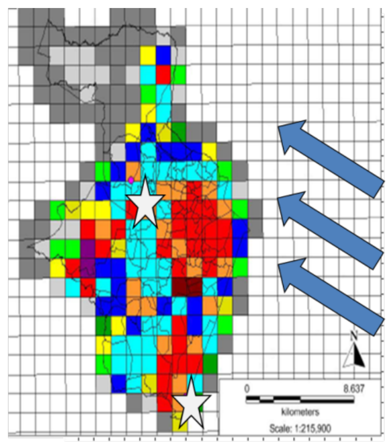
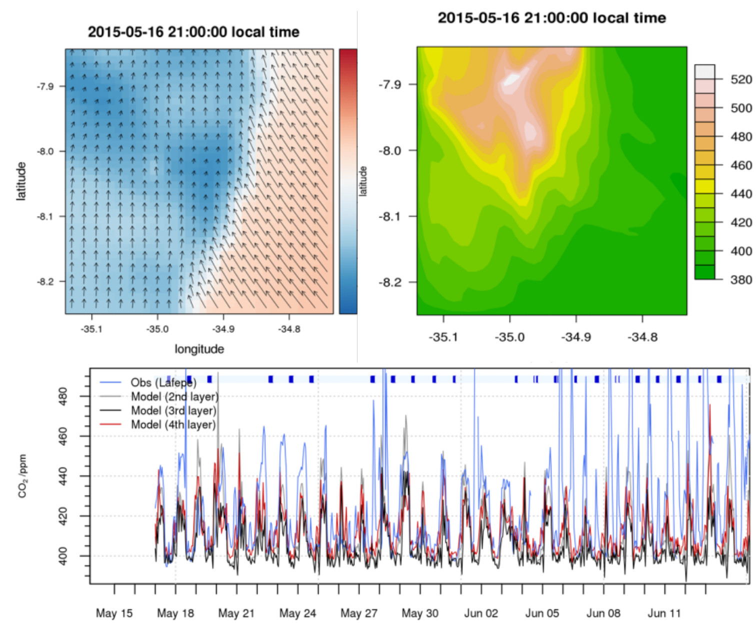
3. Setup measurement system
4. Analyse data

Use socio-economic data to create disaggregated emission prior





Total emissions
5.52±??? $MTCO_2/a$



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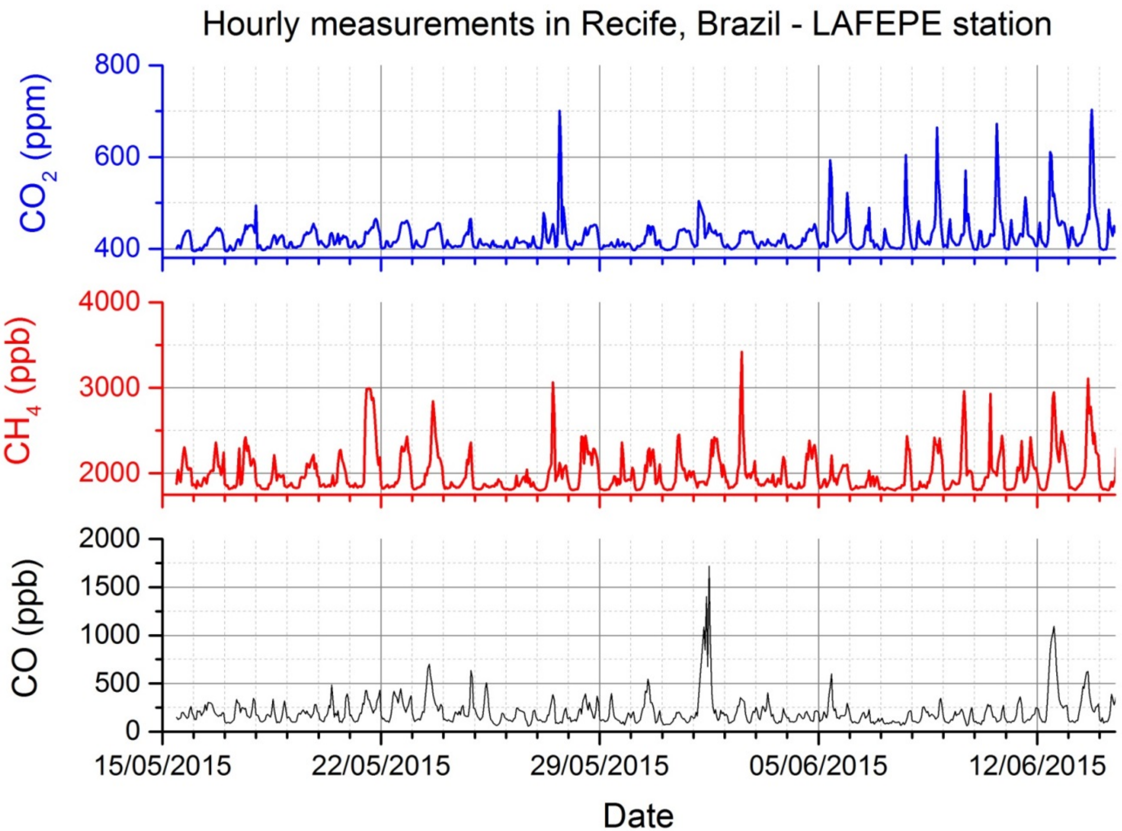

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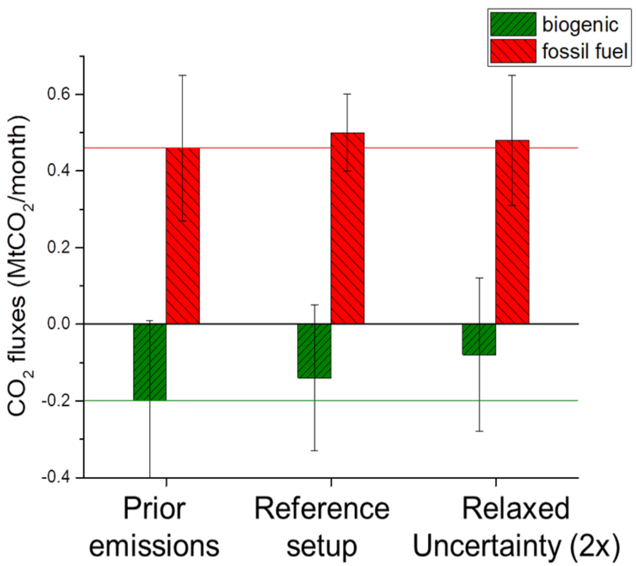
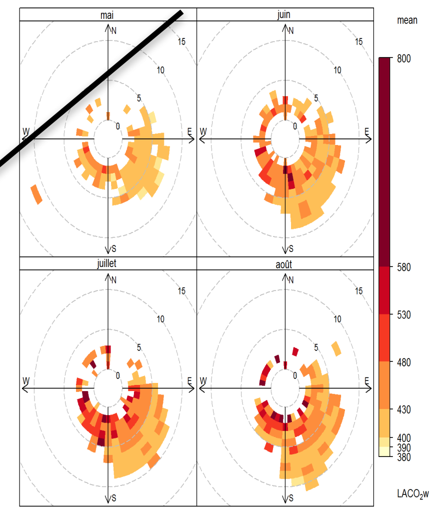


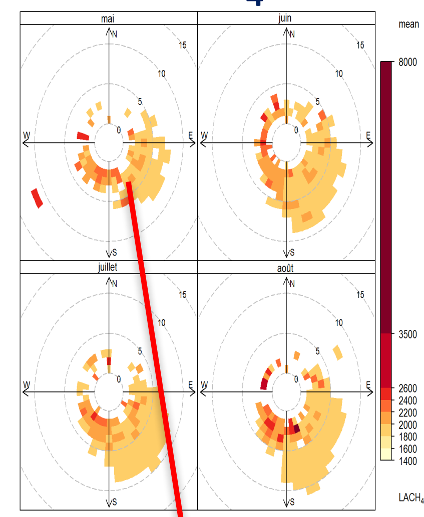
Inversion system for ΔCO_2

Posterior
6.0 ± 0.12 $MTCO_2$/a

CO_2



CH_4



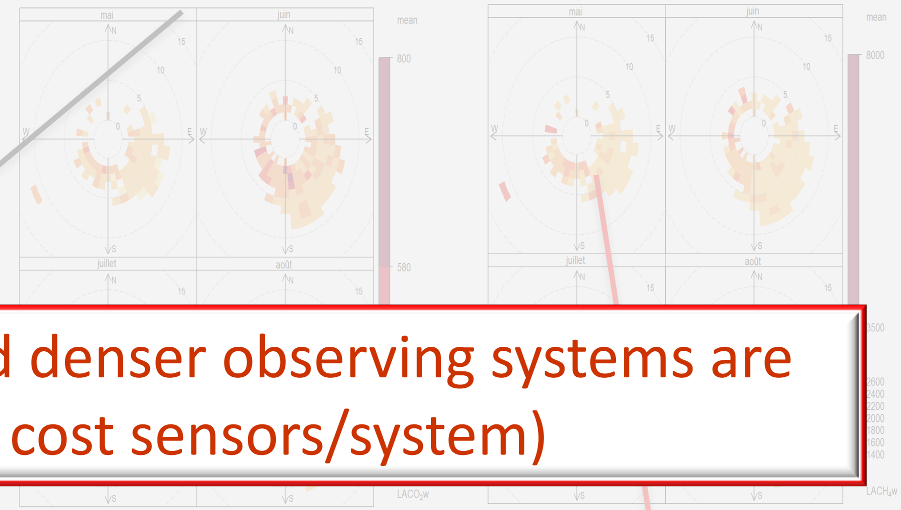
Mangrove

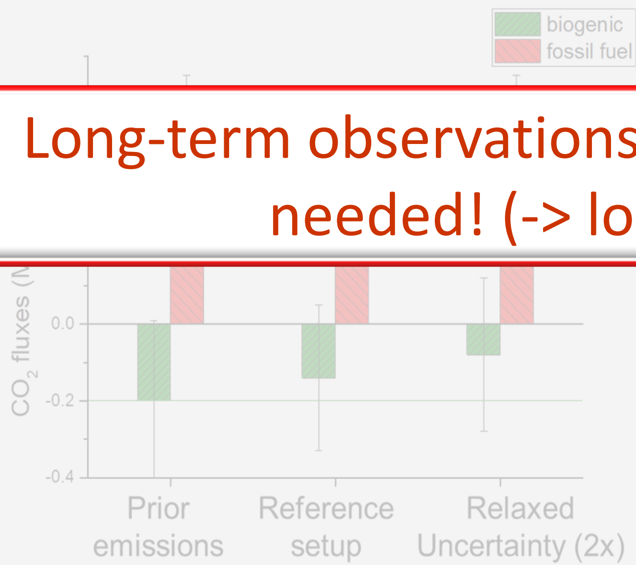
How to start from scratch – Recife, Brazil

1. Build emission inventory
2. Establish modelling system
3. Setup measurement system
4. Analyse data

Long-term observations and denser observing systems are needed! (-> lower cost sensors/system)

CO_2 CH_4





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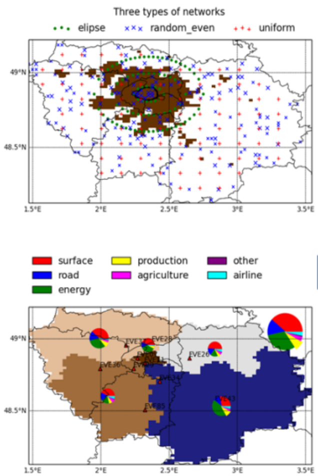
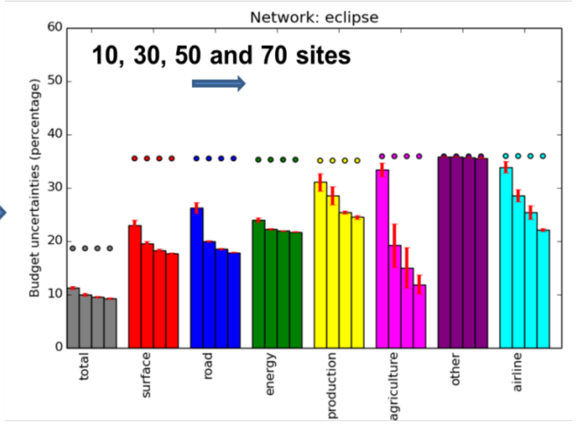
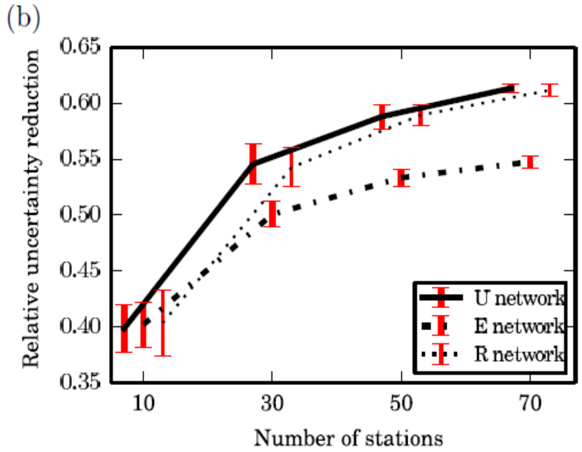


Inversion





What are the requirements for novel observing systems?

Many posters and new instruments at GGMT (and ICDC)

Summary
"Translation Science"

Build confidence today that science-based information services need to be part of the solutions:

- Define the detailed good-practice guidelines for each objective area
- Develop near term pilot projects for each objective area

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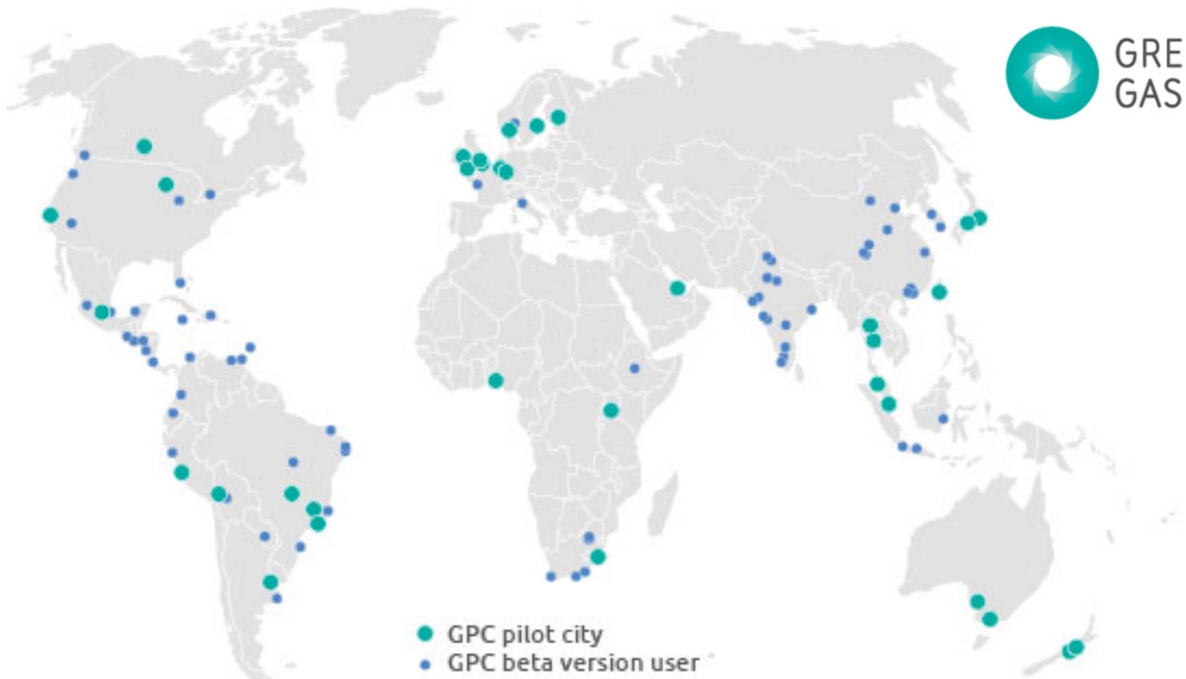
Why care about GHGs in cities?



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

GREENHOUSE GAS PROTOCOL

UNDER 2°
SECRETARIAT THE CLIMATE GROUP

THE WORLD BANK

eit Climate-KIC

ICLEI Local Governments for Sustainability

C40 CITIES CLIMATE LEADERSHIP GROUP

PIONEERED BY THE ROCKEFELLER FOUNDATION 100 RESILIENT CITIES

GLOBAL COVENANT of MAYORS for CLIMATE & ENERGY
THE WORLD'S LARGEST COALITION OF CITIES FIGHTING CLIMATE CHANGE
COMPACT of MAYORS
Covenant of Mayors for Climate & Energy

Why care about GHGs in cities?

Who can the stakeholders talk to?

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

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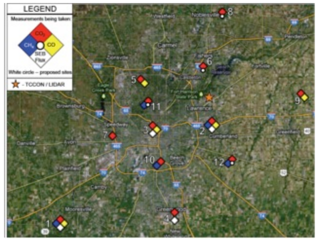
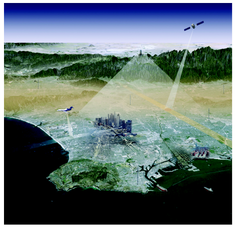
Atmospheric work in urban areas

LSCE | CNRS | CEA | Université de Versailles St-Quentin-en-Yvelines | Université Paris-Saclay | ARIA Technologies | ARIA do Brasil | CPRH Agência Estadual de Meio Ambiente | KIT Karlsruhe Institute of Technology | aer | HARRIS | Environment and Climate Change Canada | Institut Pierre Simon Laplace | Climate-KIC

Indianapolis Flux Experiment - INFLUX
NIST | PennState | Purdue University | ASU | Earth Networks | PICARRO | GNS | JPL





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

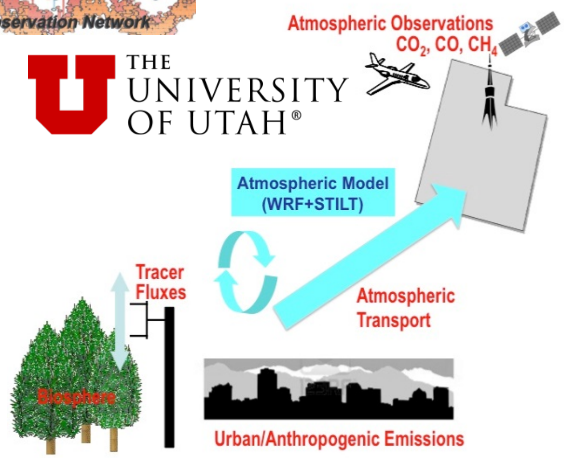
University of Toronto | Environment and Climate Change Canada | Environnement et Changement climatique Canada

JPL | California Institute of Technology | Scripps Institution of Oceanography | California Air Resources Board | Earth Networks | Arizona State University | University of Michigan | LSCE | Resources for the Future | USC University of Southern California | Berkeley Lab | SigmaSpace | Ames Research Center | INMETRO | Universidade de São Paulo

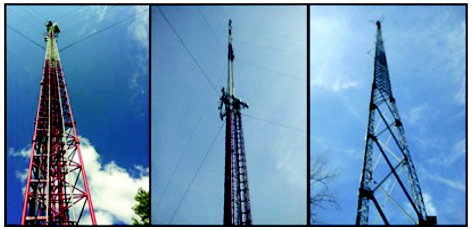
GURME
The WMO GAW Urban Research Meteorology and Environment Project

BEACO2N
The BErkeley Atmospheric CO2 Observation Network

The University of Utah



FLUXNET A Global Network
Integrating Worldwide CO2, Water and Energy Flux Measurements

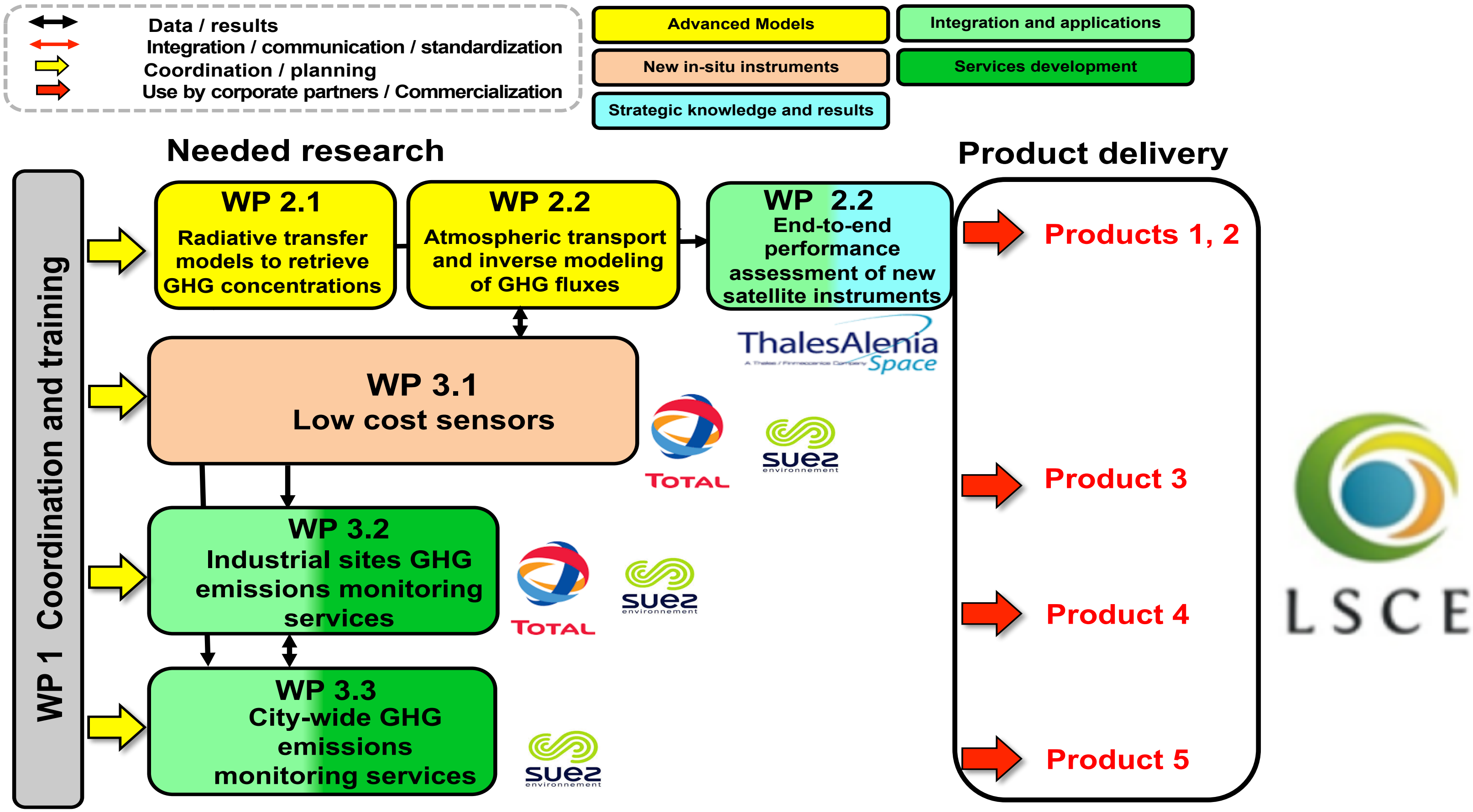


RINGO | Readiness of ICOS

Atmospheric work in urban areas

International coordination needed!

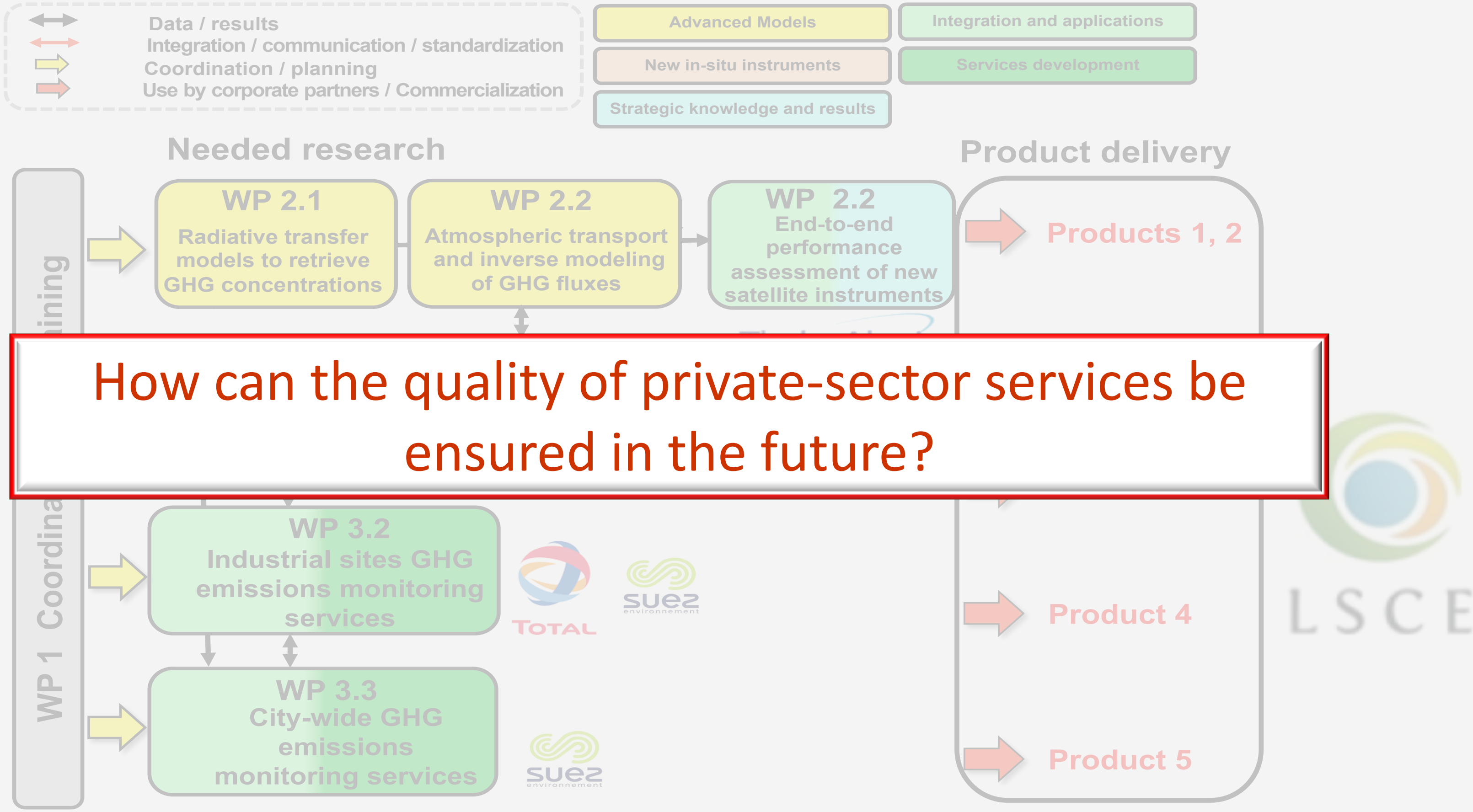
Climate/environmental services by companies



Chaire industrielle TRACE started 2017/18: P. Ciais

Positions available - Email: contact-trace@lists.lsce.ipsl.fr

Climate/environmental services by companies



How can the quality of private-sector services be ensured in the future?

Chaire industrielle TRACE: P. Ciais

Positions available Email: contact-trace@lists.lsce.ipsl.fr

Objectives for IG^{3}IS in Support of City-Scale Mitigation Efforts

Implementation plan to be submitted for EC-70

1. Customer-based Information Requirements, Current Capabilities and Gaps
2. Urban typology
3. High spatial and temporal resolution bottom-up inventories
4. Measurement Network Design
5. Modeling Framework
6. Data processing and management routines
7. Demonstration experiments
8. R&D for novel/other observing and modelling systems to pre-operational status
9. Capacity Building and Outreach

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9. Capacity Building and

WMO

UNEP

Level of sophistication of urban stakeholder needs

Complexity of solution

Identify major emitters and anomaly detection	Quantification of total GHG emissions	Assessment of GHG emissions per sector	Tracking annual and long-term emission changes	Understand short-term emission changes and spatial patterns	Process understanding of emissions and tracking of mitigation impacts
Inventory validation (A1)	Inventory or emission model (A2)	Sector-specific inventory or emission model (A3)	Continuously updated inventory or emission model (A4)	Temporally and spatially disaggregated inventory or emission model (A5)	Process-based emission model using real-time emission data
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Demonstrated skills

Theoretically tested skills

Future potential skills

DAS = data assimilation system

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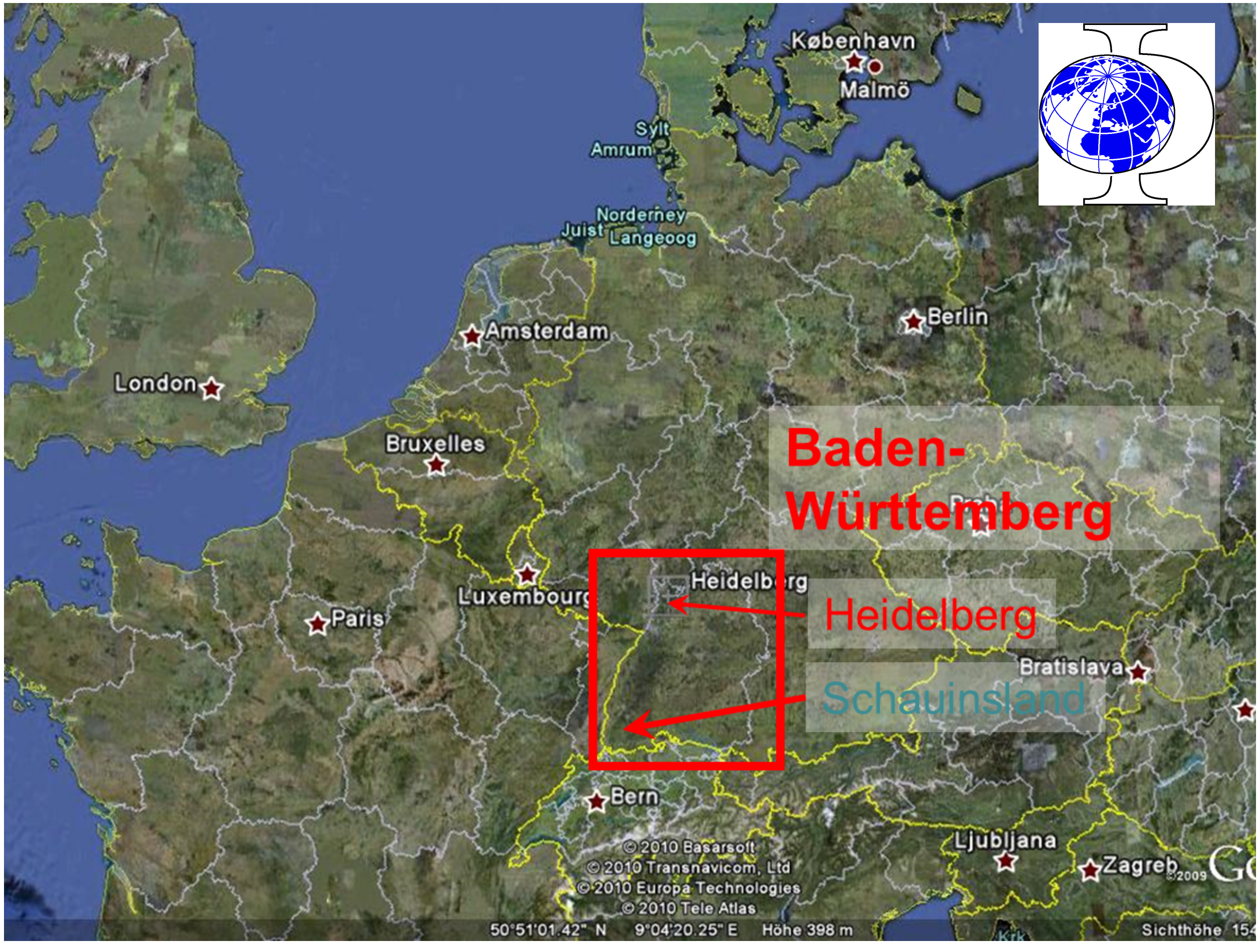
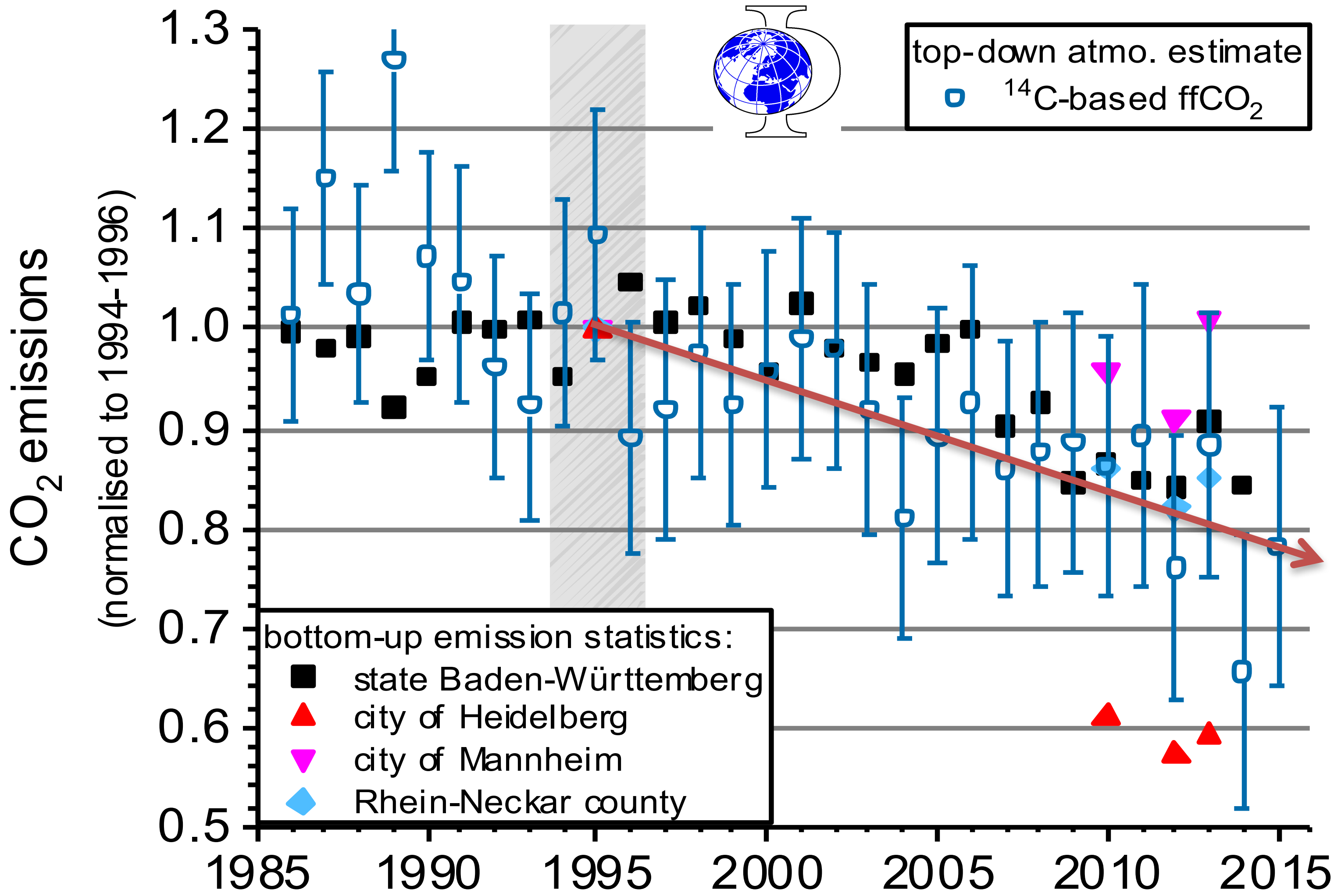
How bottom-up statistics trends compare to top-down?

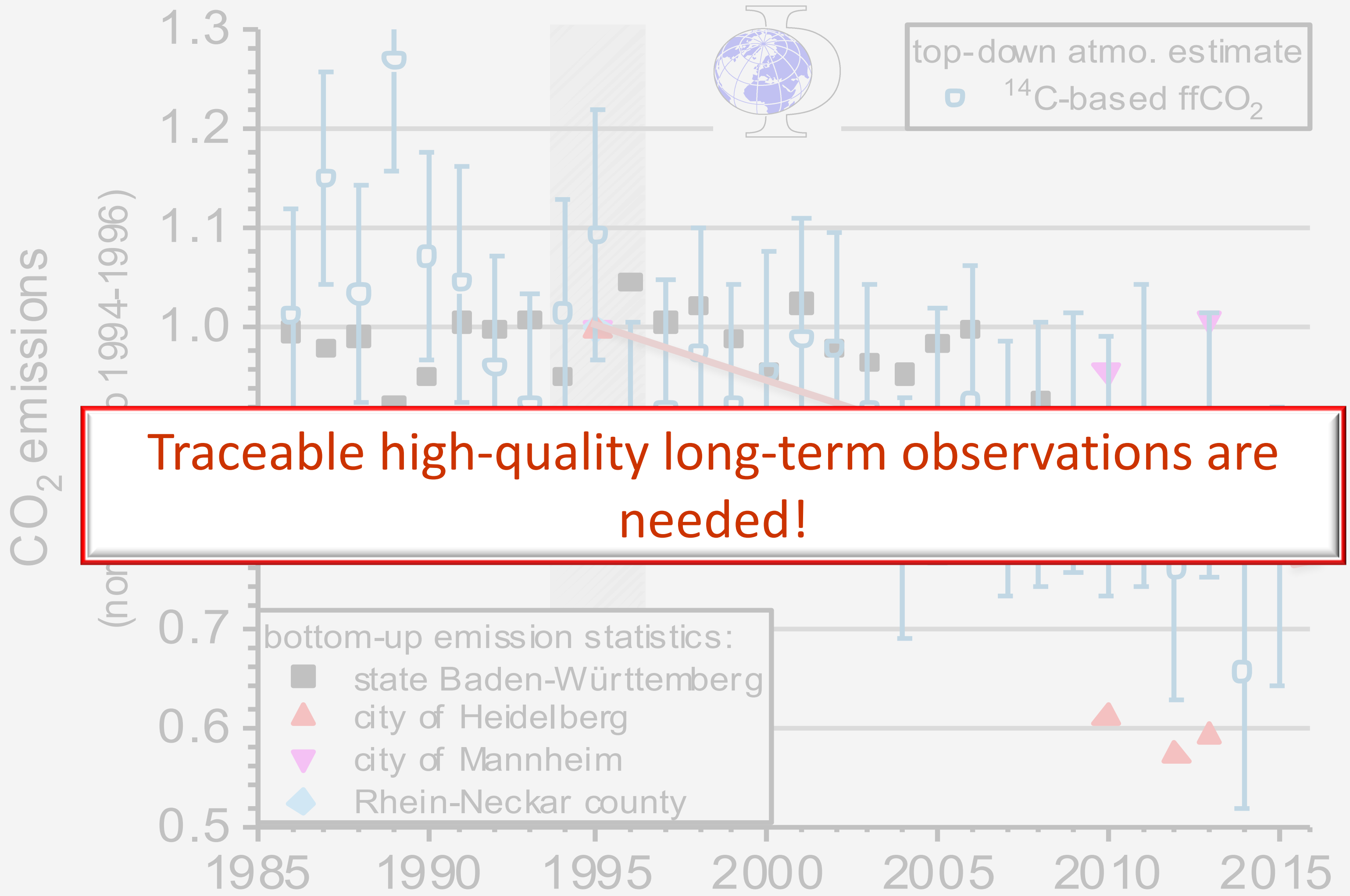


Courtesy: S. Hammer and I. Levin



Courtesy: S. Hammer and I. Levin

Emission data from: Statistisches Landesamt Baden-Württemberg



Traceable high-quality long-term observations are needed!

Courtesy: S. Hammer and I. Levin

Emission data from: Statistisches Landesamt Baden-Württemberg

Level of sophistication of urban stakeholder needs

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How to start from scratch – Recife, Brazil

1. Build emission inventory
2. Establish modelling system
3. Setup measurement system
4. Analyse data

CPRH Agência Estadual de Meio Ambiente

'can you do this in Recife?'

How to start from scratch – Recife, Brazil

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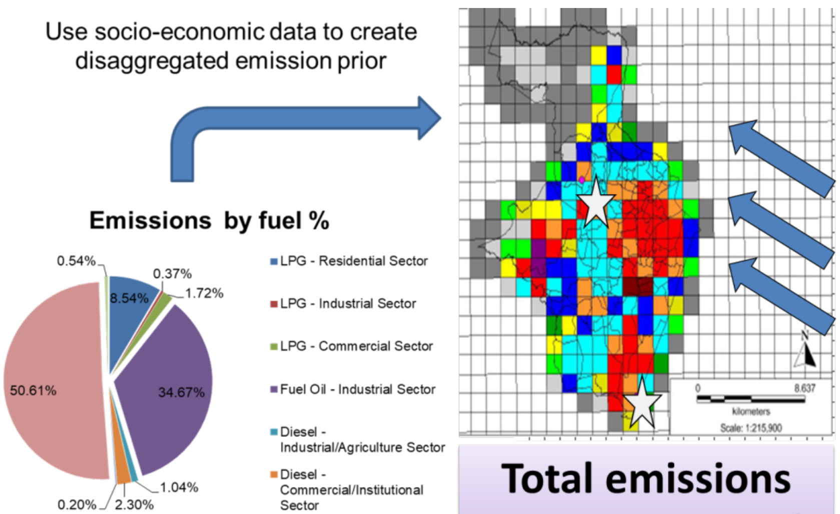
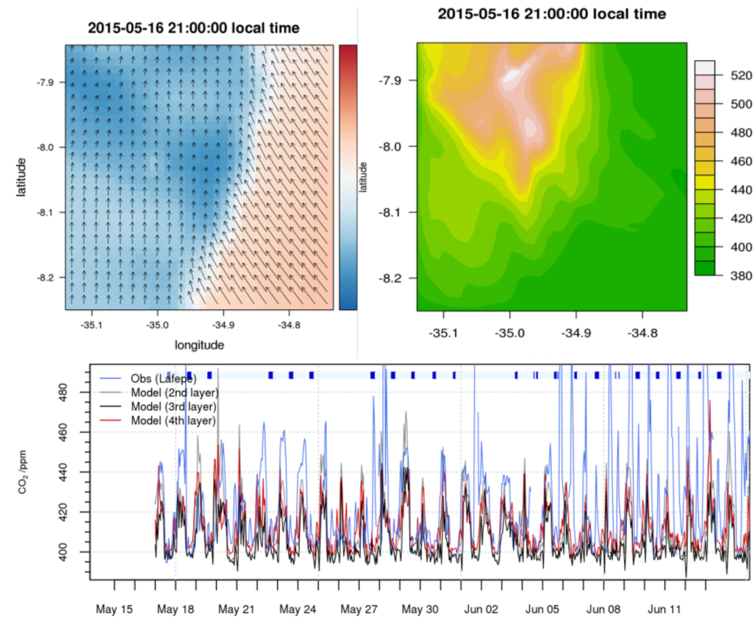


Total emissions
5.52±??? $MTCO_2$/a



[Vogel et al. in prep / Modelling ARIA tech, 2016]

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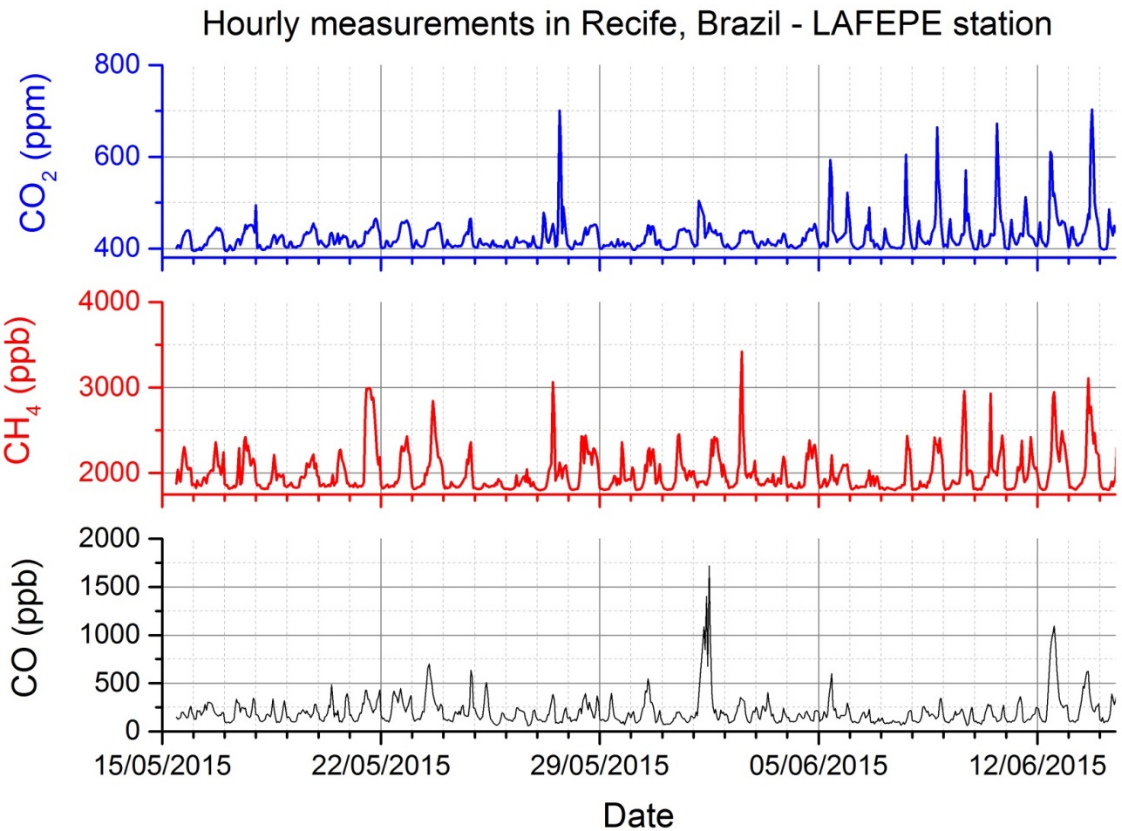

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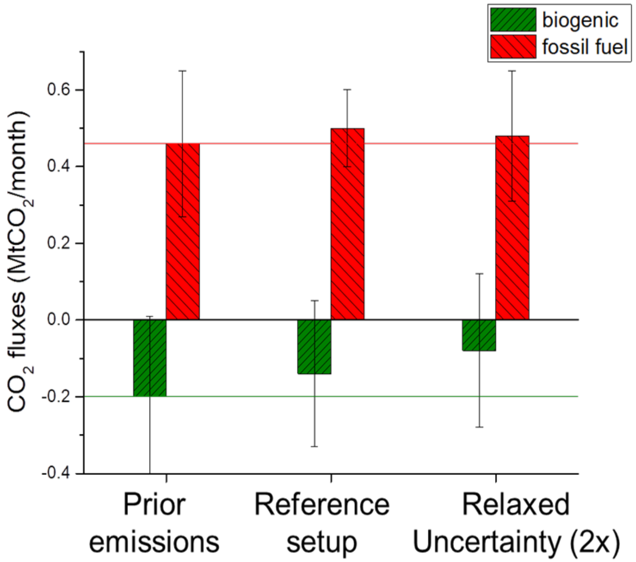
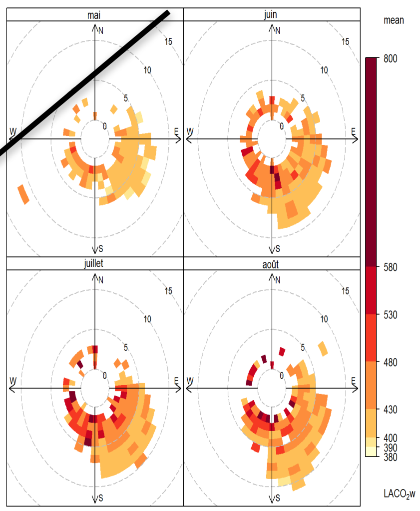


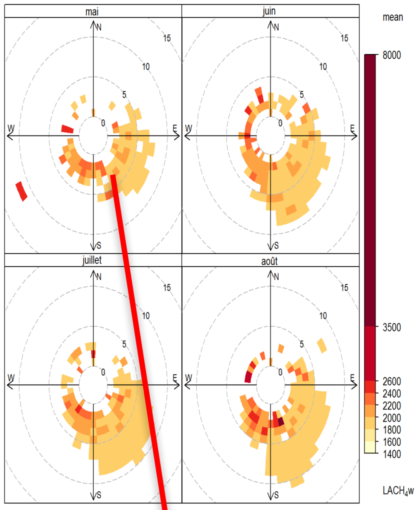
Inversion system for ΔCO_2

Posterior
6.0 ± 0.12 $MTCO_2$/a

CO_2



CH_4



Mangrove

How to start from scratch – Recife, Brazil

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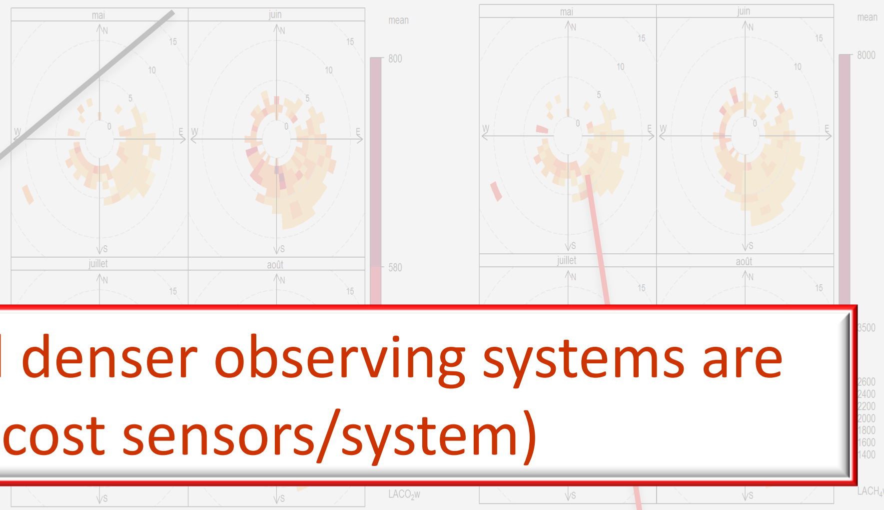
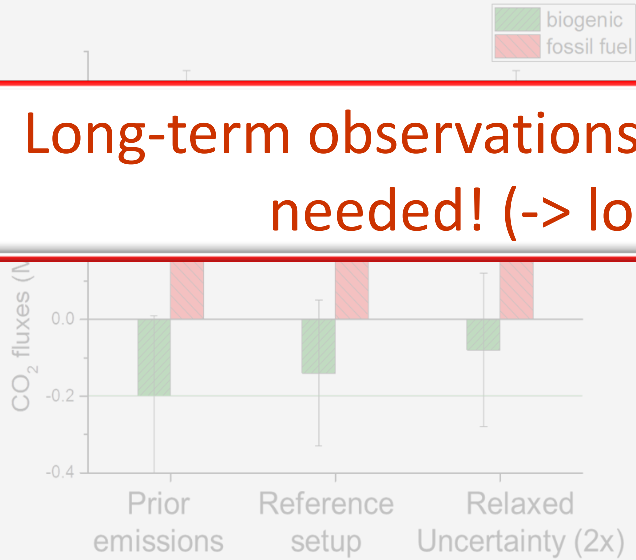
CO_2 CH_4





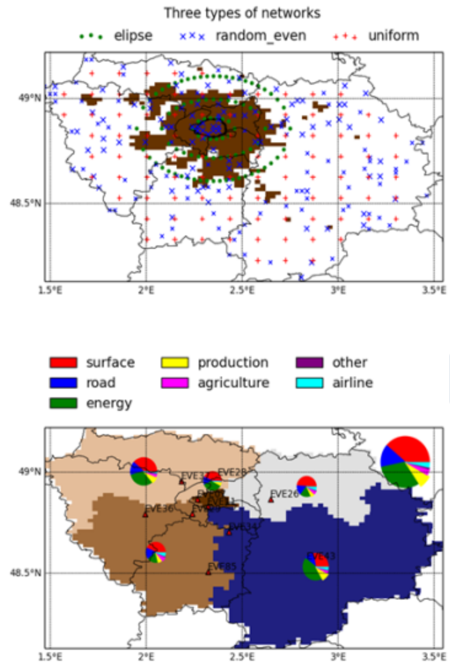
Long-term observations and denser observing systems are needed! (-> lower cost sensors/system)

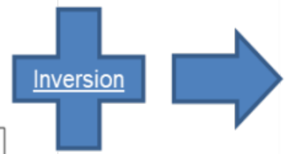
Inversion system for ΔCO_2

Posterior
6.0±0.12 $MTCO_2$/a

Mangrove

Lower cost medium precision sensors

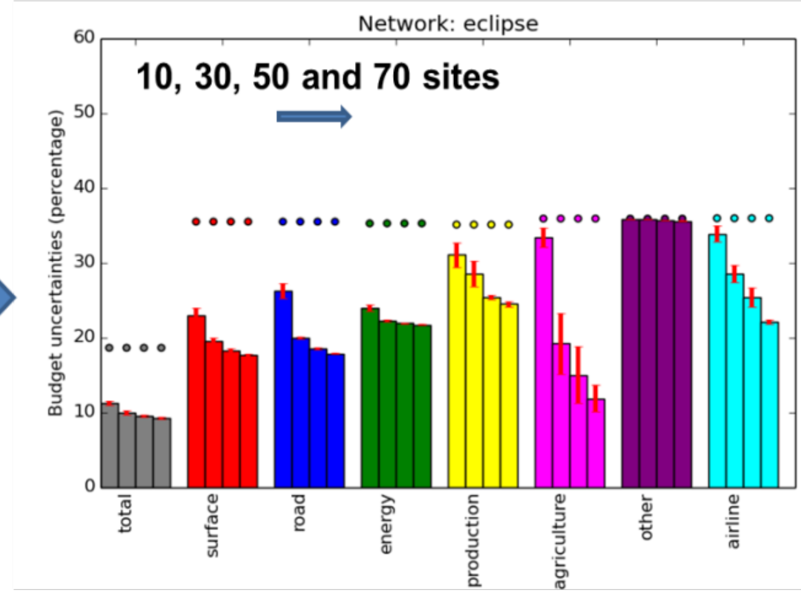




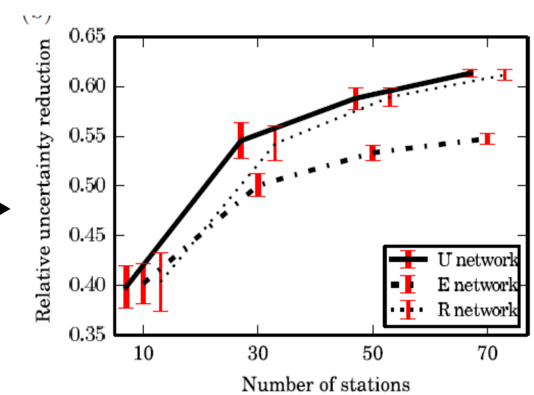
Atmos. Chem. Phys., 16, 7743–7771, 2016
www.atmos-chem-phys.net/16/7743/2016/
doi:10.5194/acp-16-7743-2016

Wu et al. 2016

Atmospheric Chemistry and Physics
Open Access
EGU



- Lower cost medium precision (LCMP) sensors allow much denser monitoring networks
- Dense networks allow better estimates of emissions for sectors and neighborhoods
- BUT LCMPs must be properly calibrated and QA/QC is crucial (1ppm)
- Also saturation can be reached (more is not always better!)



Canadian work – ECCC so far?

Level of sophistication of urban stakeholder needs

Complexity of solution

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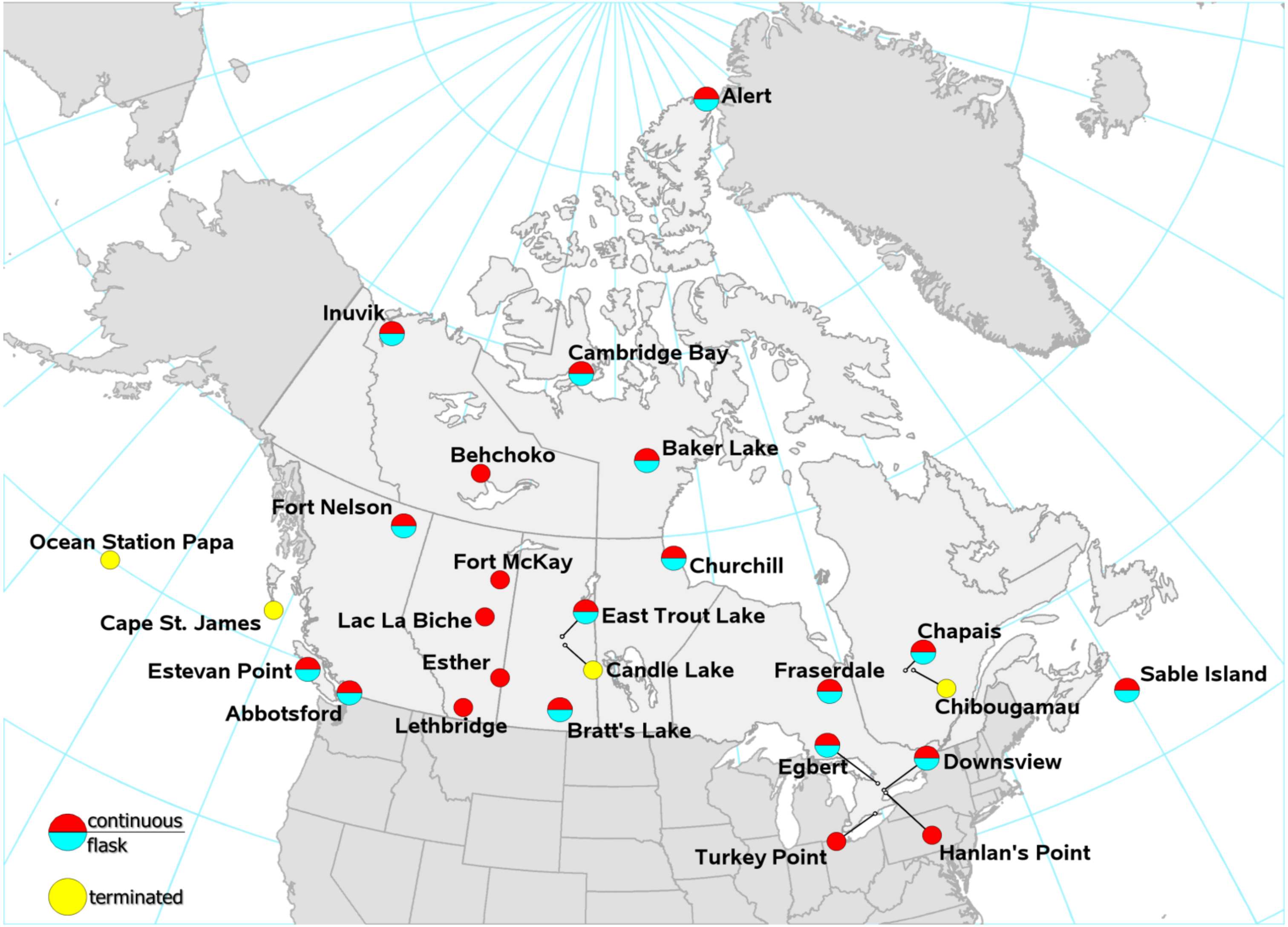
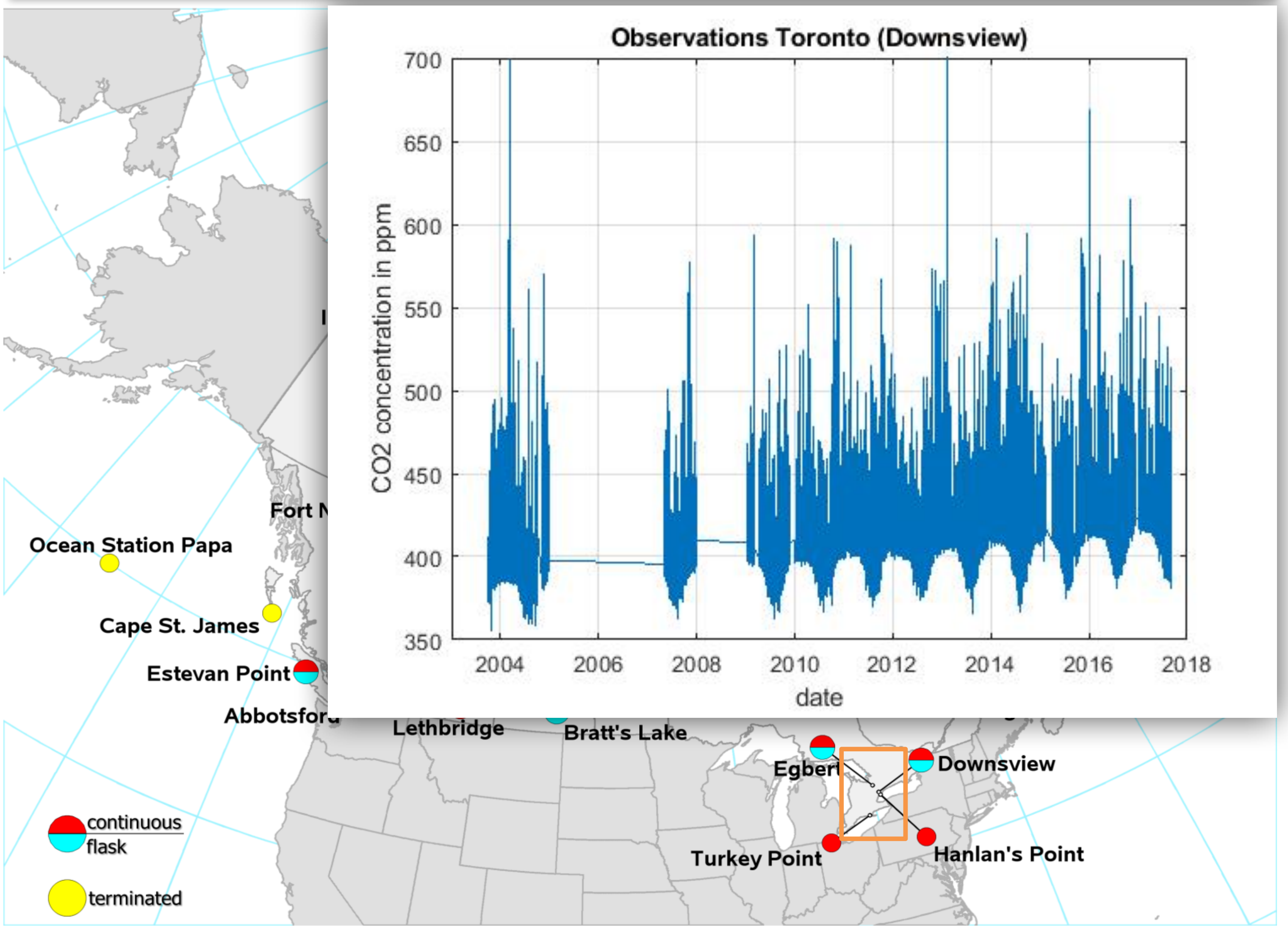
Demonstrated skills
Theoretically tested skills
Future potential skills

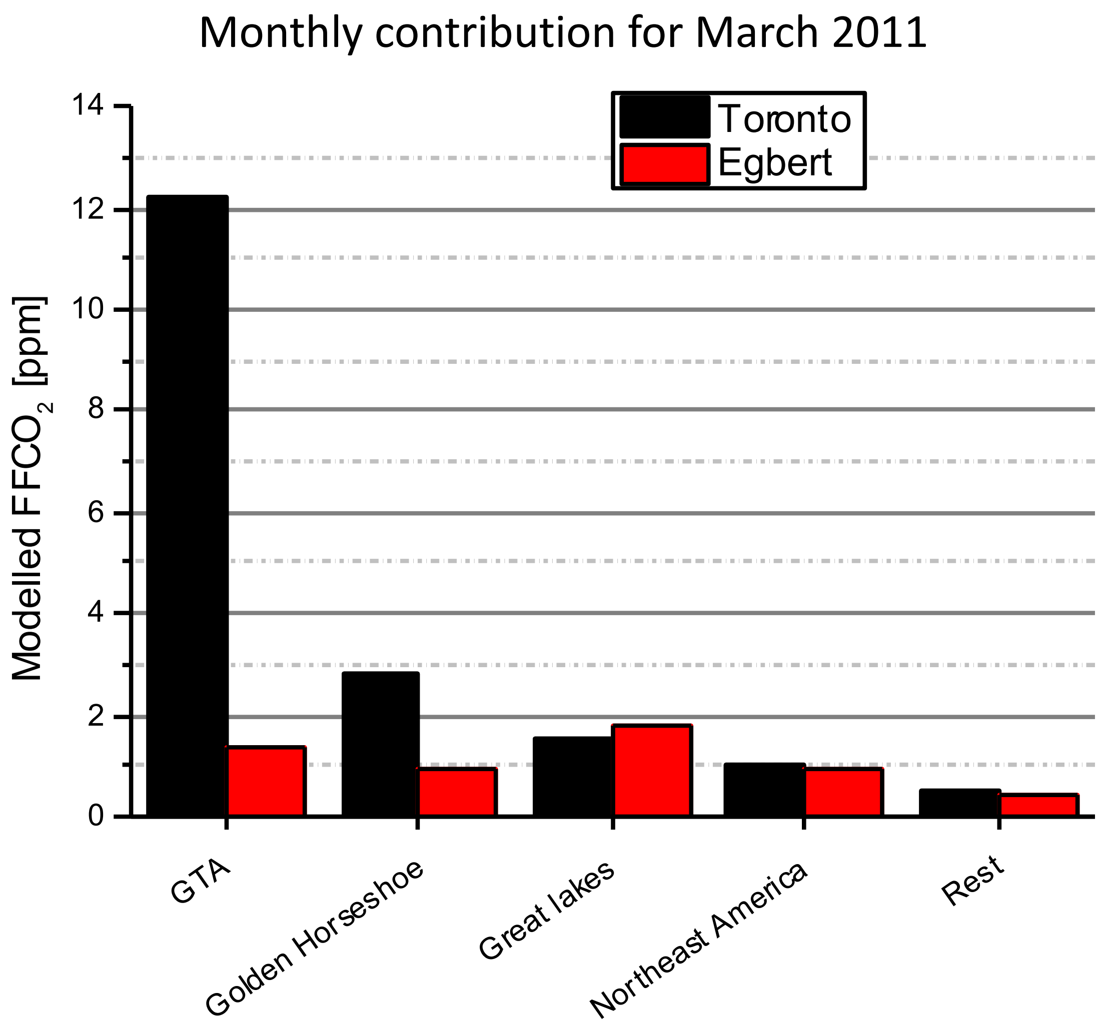
DAS = data assimilation system

ECCC GHG monitoring network



ECCC GHG monitoring network

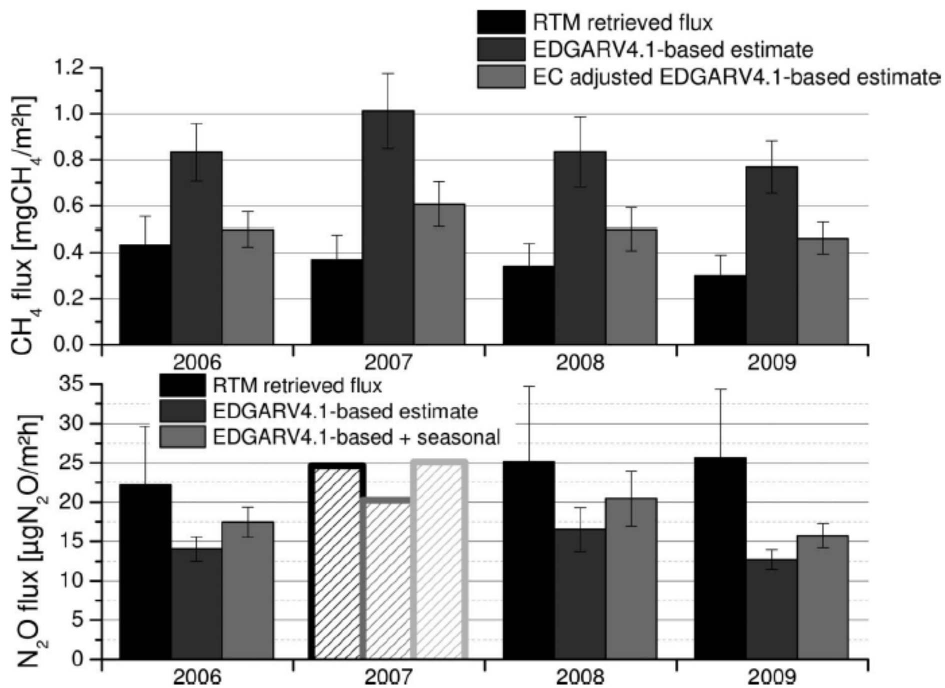


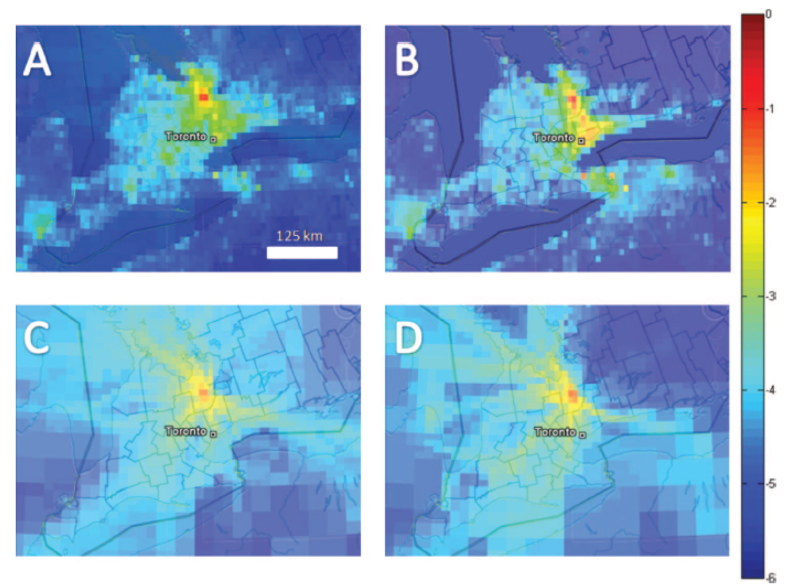


- ➢Observations at the “sister site“ in Egbert captures most of the signal of the regional and continental domain
- ➢$\Delta FFCO_2$ (CO_2 at Toronto minus CO_2 at Egbert) could be used to “zoom in“ on metropolitan emissions of the Greater Toronto Area/Golden Horseshoe

Canadian work – so far:

To cite this article: F.R. Vogel , M. Ishizawa , E. Chan , D. Chan , S. Hammer , I. Levin & D.E.J. Worthy (2012) Regional non-CO_2 greenhouse gas fluxes inferred from atmospheric measurements in Ontario, Canada, Journal of Integrative Environmental Sciences, 9:sup1, 41-55, DOI: 10.1080/1943815X.2012.691884



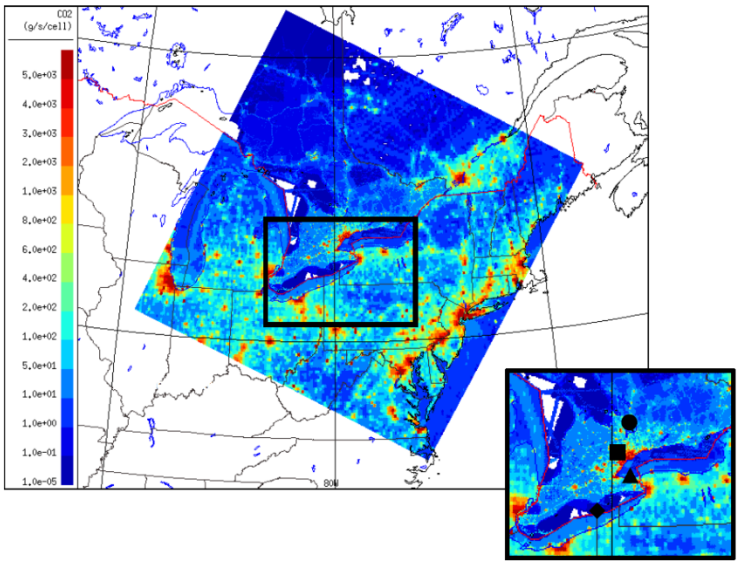


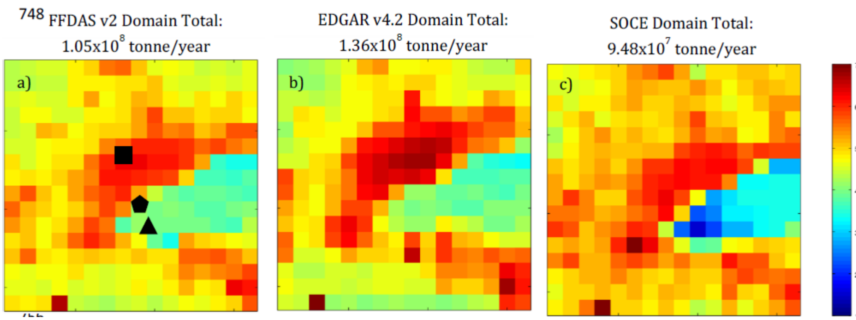
Assessment of regional emissions of CH_4 and N_2O – (will be expanded to look at decadal trend and processes)

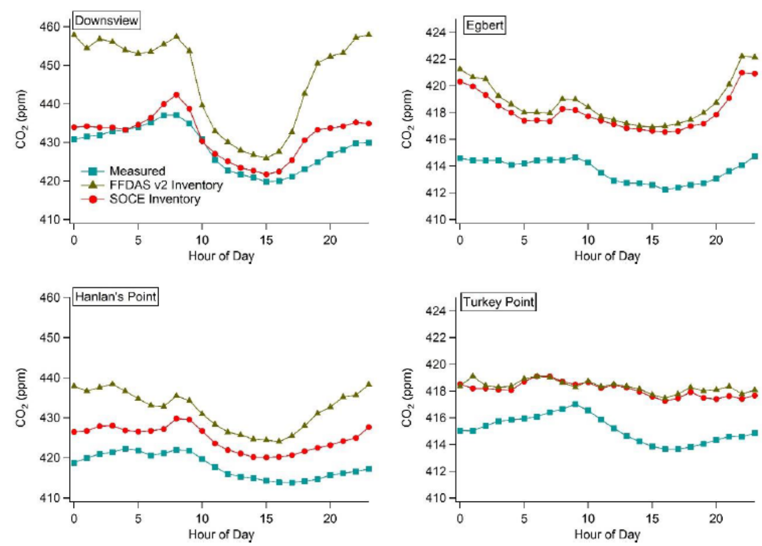
Canadian work – so far:

Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2017-678
Manuscript under review for journal Atmos. Chem. Phys.
Discussion started: 26 July 2017

Atmospheric Chemistry and Physics
Discussions







+ Assessment of regional emissions of CO_2

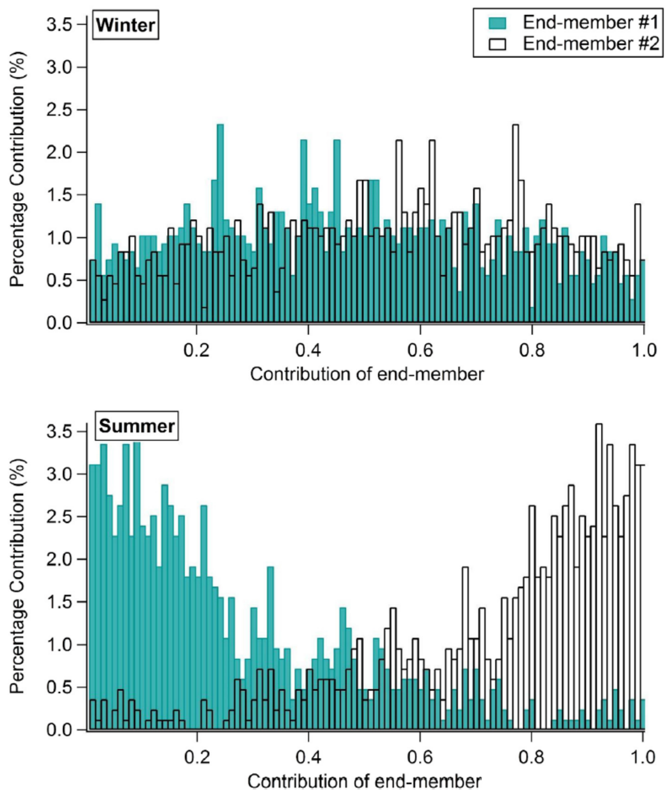
+ temporal emission factors

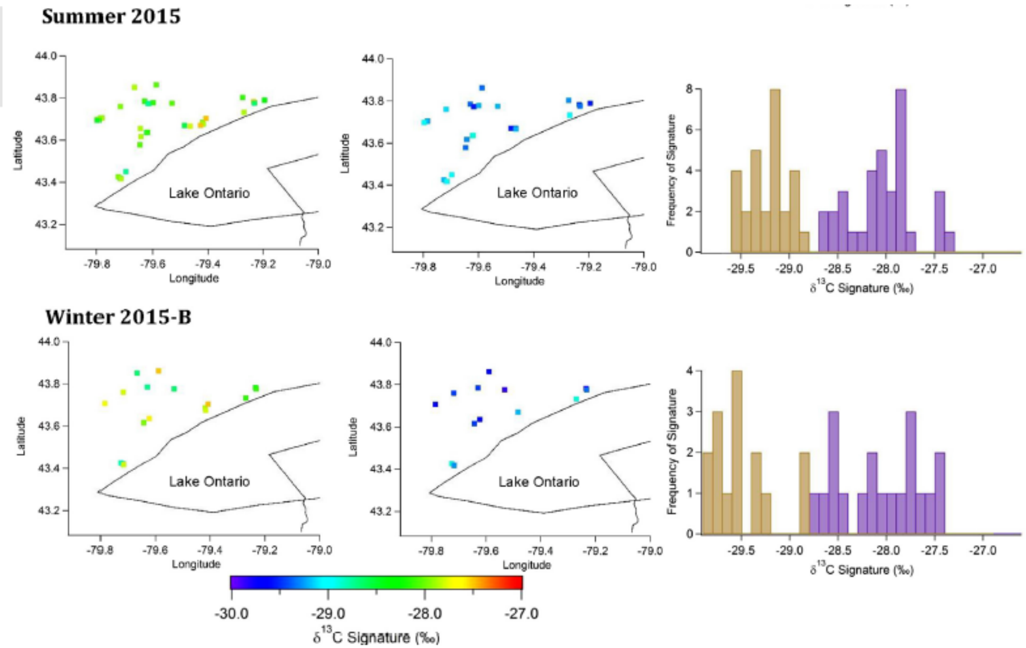
+ sectorial emission inventory

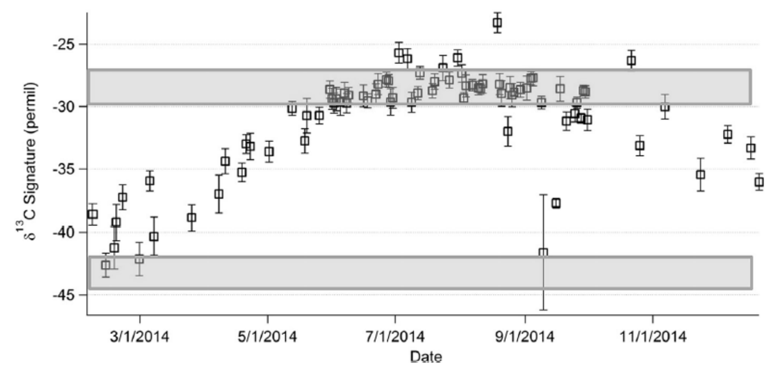
+ prototype modelling system

Canadian work – so far:

ELSEVIER
Contents lists available at ScienceDirect
Applied Geochemistry
journal homepage: www.elsevier.com/locate/apgeochem

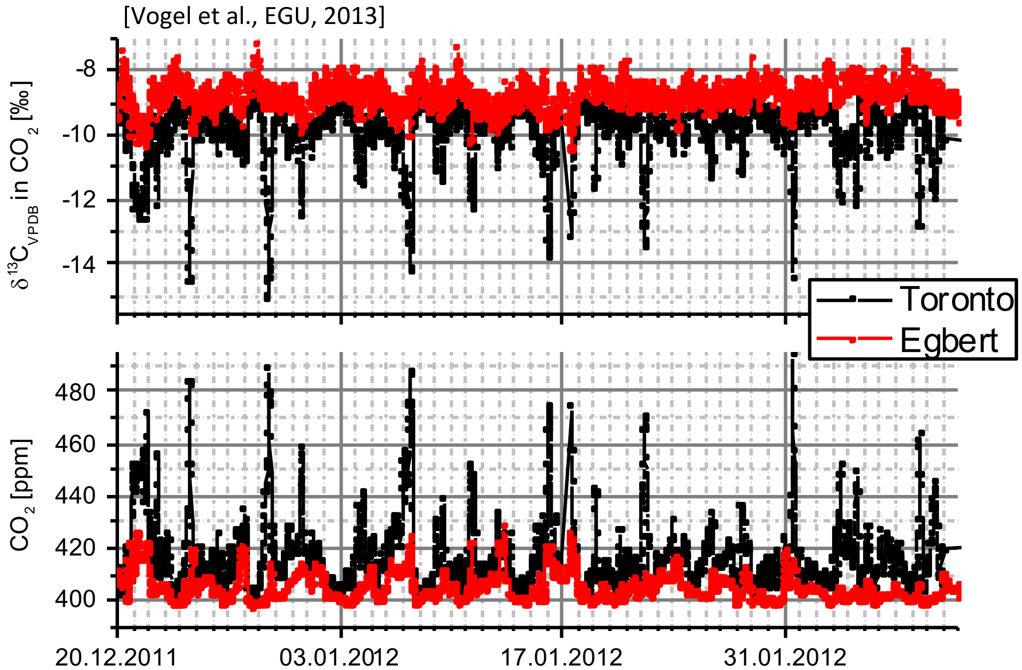




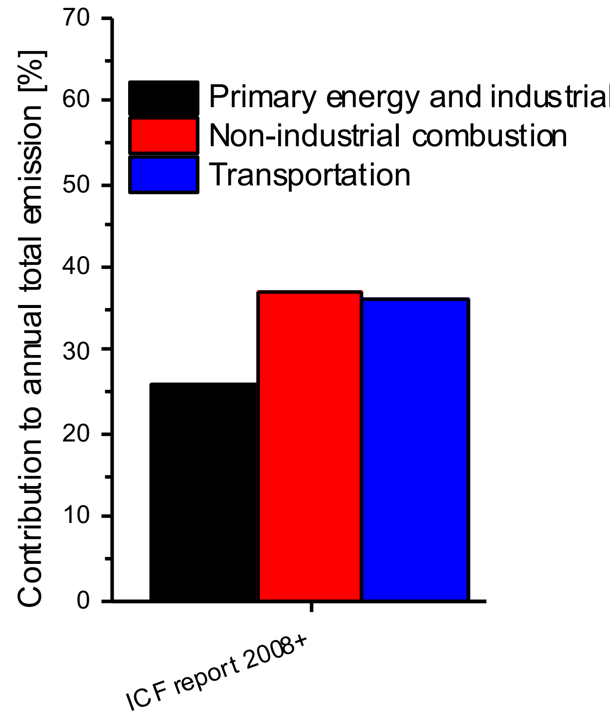


+ Continuous observations of $^{13}CO_2$ and $^{14}CO_2$
+ Fuel specific emission inventory
+ Sector specific modelling system prototype

Atmospheric observations



Bottom-up statistic (Toronto/GTA)



Night-time observation: -42.1±0.7‰

Contribution to $FFCO_2$:

Natural gas: 80±7%

Liquid fuels: 20±7%

Night-time ICF-based: -40.4‰ to -43.8‰

Contributions to $FFCO_2$:

Natural gas: 77%

Liquid fuels: 23%

Canadian work – next steps?

Level of sophistication of urban stakeholder needs →

Complexity of solution ↓

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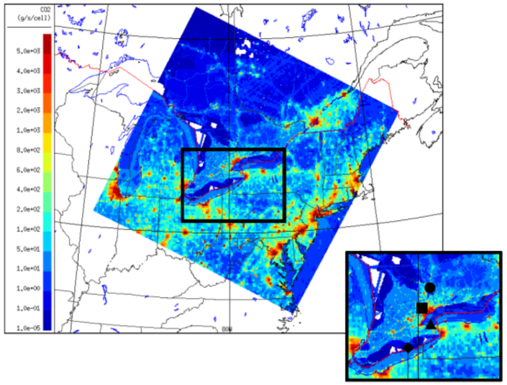
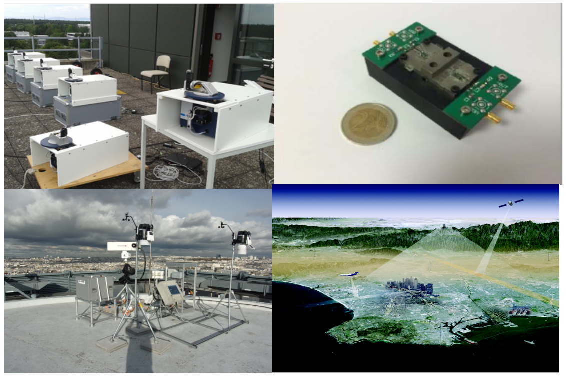
Canadian work – ideas beyond next steps

1. ECCC testbed city



- ✓ Develop modelling tools
- ✓ Test novel observing systems
- ✓ Establish processing routines
- ✓ Fully adapted framework



20 LCMP instruments for GTA

Canadian work – ideas beyond next steps

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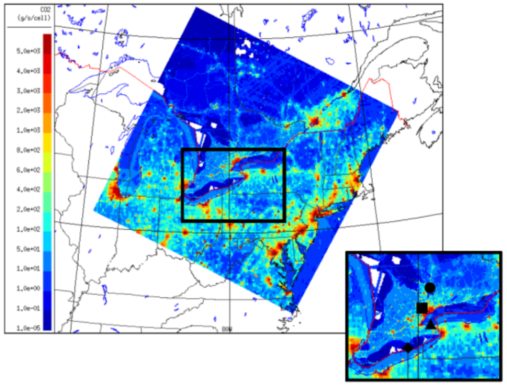

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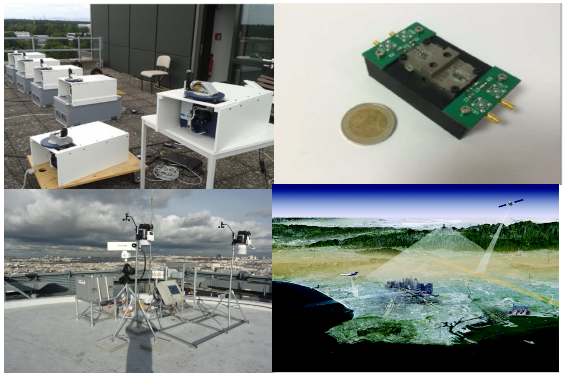
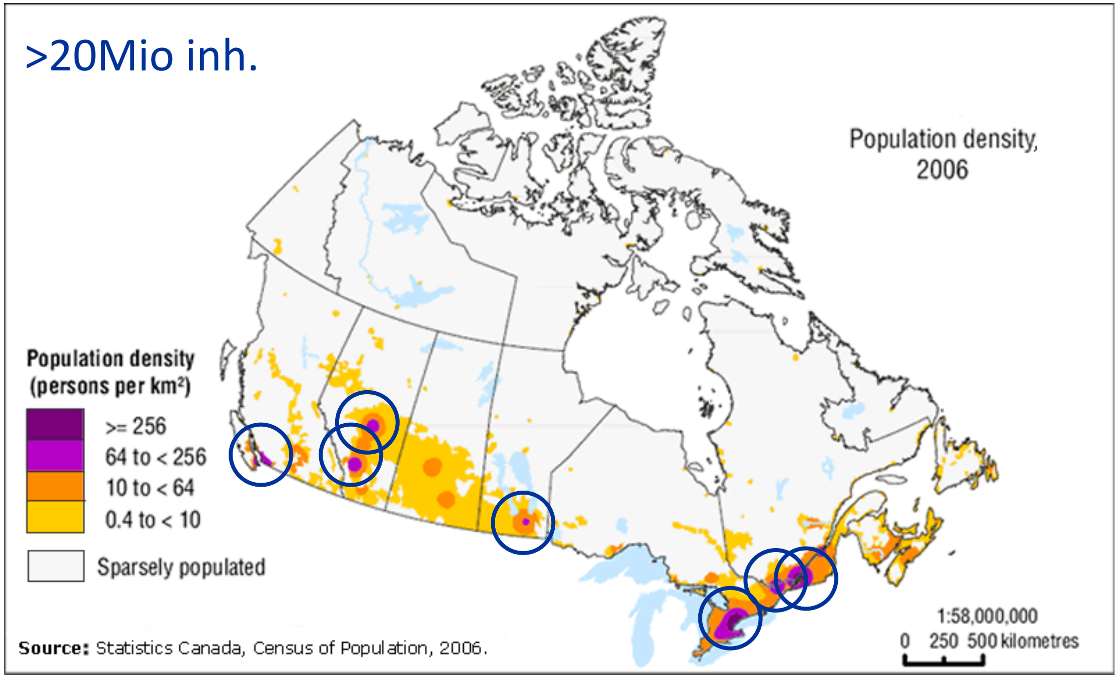


20 LCMP instruments for GTA

2. Canadian urban research federation (CURF)

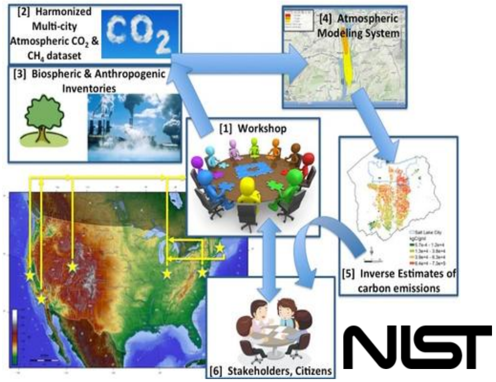


- ➢ Establish background network and WMO traceability
- ➢ Test low-cost sensors and provide grants for depl.
- ➢ Provide protocols, guidance, routines to community
- ➢ Canada-wide database of urban GHG emissions
- ➢ Interface to NIR group, policy makers and internat.

Upcoming events relevant for IG3IS and CRD

A

Gaithersburg, Nov. 2017



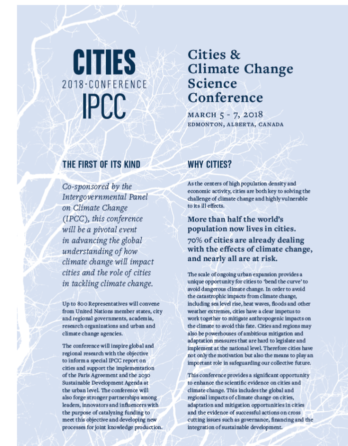
Geneva, Nov./Dec. 2017

Lead author meeting IG3IS

World Meteorological Organization

Weather • Climate • Water

Edmonton, Mar. 2018



CITIES
2018 · CONFERENCE
IPCC

Cities & Climate Change Science Conference

MARCH 5 - 7, 2018
EDMONTON, ALBERTA, CANADA

THE FIRST OF ITS KIND

Co-sponsored by the Intergovernmental Panel on Climate Change (IPCC), this conference will be a pivotal event in advancing the global understanding of how climate change will impact cities and the role of cities in tackling climate change.

Up to 800 Representatives will convene from United Nations member states, city and regional governments, academia, research organizations and urban and climate change agencies.

The conference will inspire global and regional research with the objective to inform a special IPCC report on cities and support the implementation of the Paris Agreement and the 2030 Sustainable Development Agenda at the urban level. The conference will also forge stronger partnerships among leaders, innovators and influencers with the purpose of catalyzing funding to meet this objective and developing new processes for joint knowledge production.

WHY CITIES?

As the centers of high population density and economic activity, cities are both key to solving the challenge of climate change and highly vulnerable to its ill effects.

More than half the world's population now lives in cities.

70% of cities are already dealing with the effects of climate change, and nearly all are at risk.

The scale of ongoing urban expansion provides a unique opportunity for cities to 'bend the curve' to avoid dangerous climate change. In order to avoid the catastrophic impacts from climate change, including sea level rise, heat waves, floods and other weather extremes, cities have a clear impetus to work together to mitigate anthropogenic impacts on the climate to avoid this fate. Cities and regions may also be powerhouses of ambitious mitigation and adaptation measures that are hard to legislate and implement at the national level. Therefore cities have not only the motivation but also the means to play an important role in safeguarding our collective future.

This conference provides a significant opportunity to enhance the scientific evidence on cities and climate change. This includes the global and regional impacts of climate change on cities, adaptation and mitigation opportunities in cities and the evidence of successful actions on cross cutting issues such as governance, financing and the integration of sustainable development.

B

Ottawa, Oct. 2017

Canadian photonics research for environmental monitoring

ipac INTERNATIONAL PHOTONICS ADVOCACY COALITION

Webinar, Jan. 2018

Réalité Climatique

The Climate Reality Project CANADA

Dronten, NL, Feb. 2018

summer school

MEthane goes MObile

MEMO²

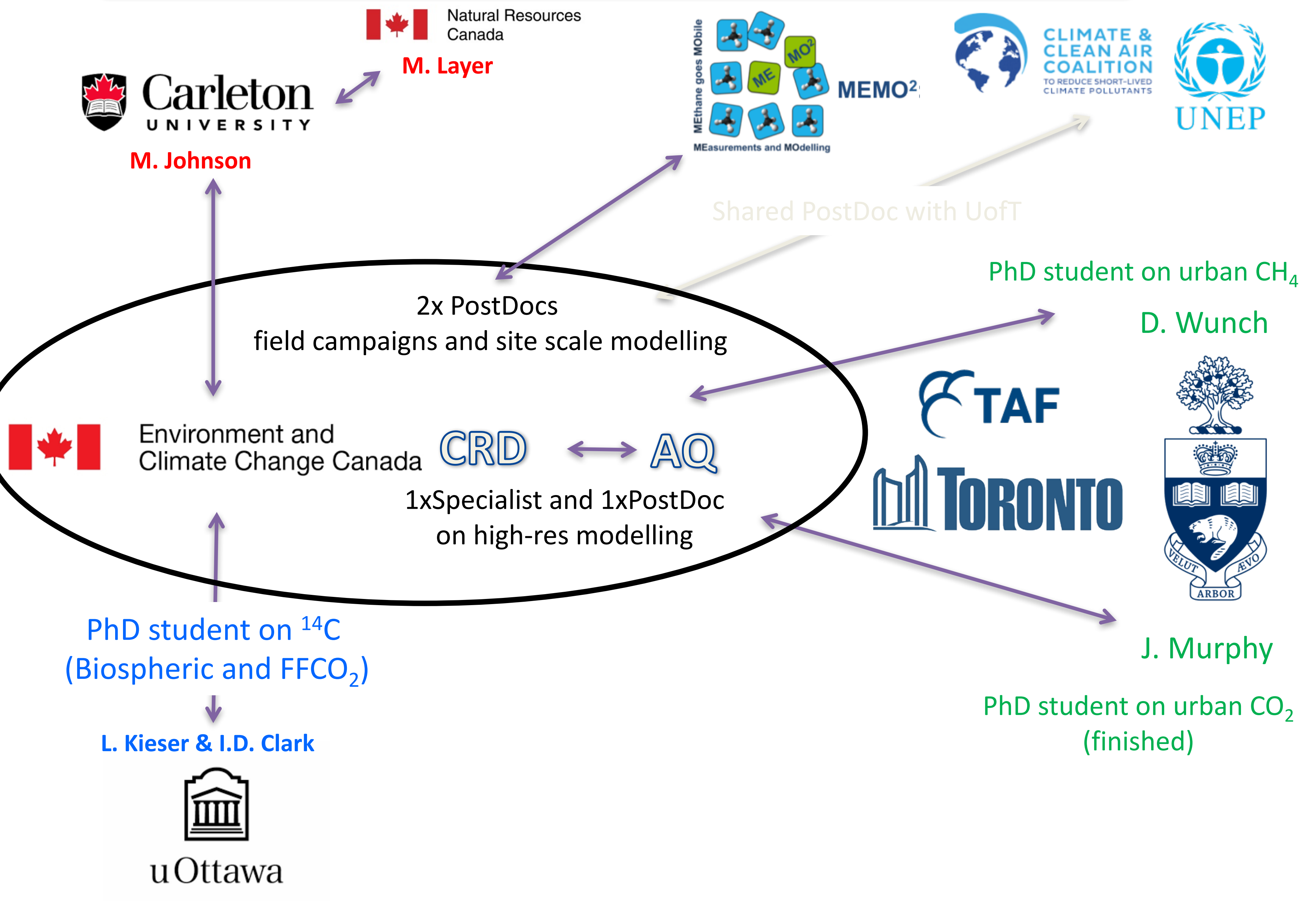
MEasurements and MOdelling

“Research enabling services”

1. Finding the right stakeholders can
   - raise awareness of the work done in the atmospheric GHG community
   - demonstrate relevance of long-term high-quality monitoring (programs)
   - open doors for research funding, but also ensuring quality in private sector projects
   - pose new challenges and maybe leads to new scientific findings
   - help “bending curves”

2. Research needed/done within IG3IS also benefits larger atmospheric GHG community
   - gaps in our knowledge on local scale GHG variability will be identified
   - best practices help reduce common mistakes and Urban typology
   - define requirement for novel (lower-cost) GHG observing systems
   - link the work in the atm. GHG community done at different scales

Ecosystem to advance CRD and IG3IS?



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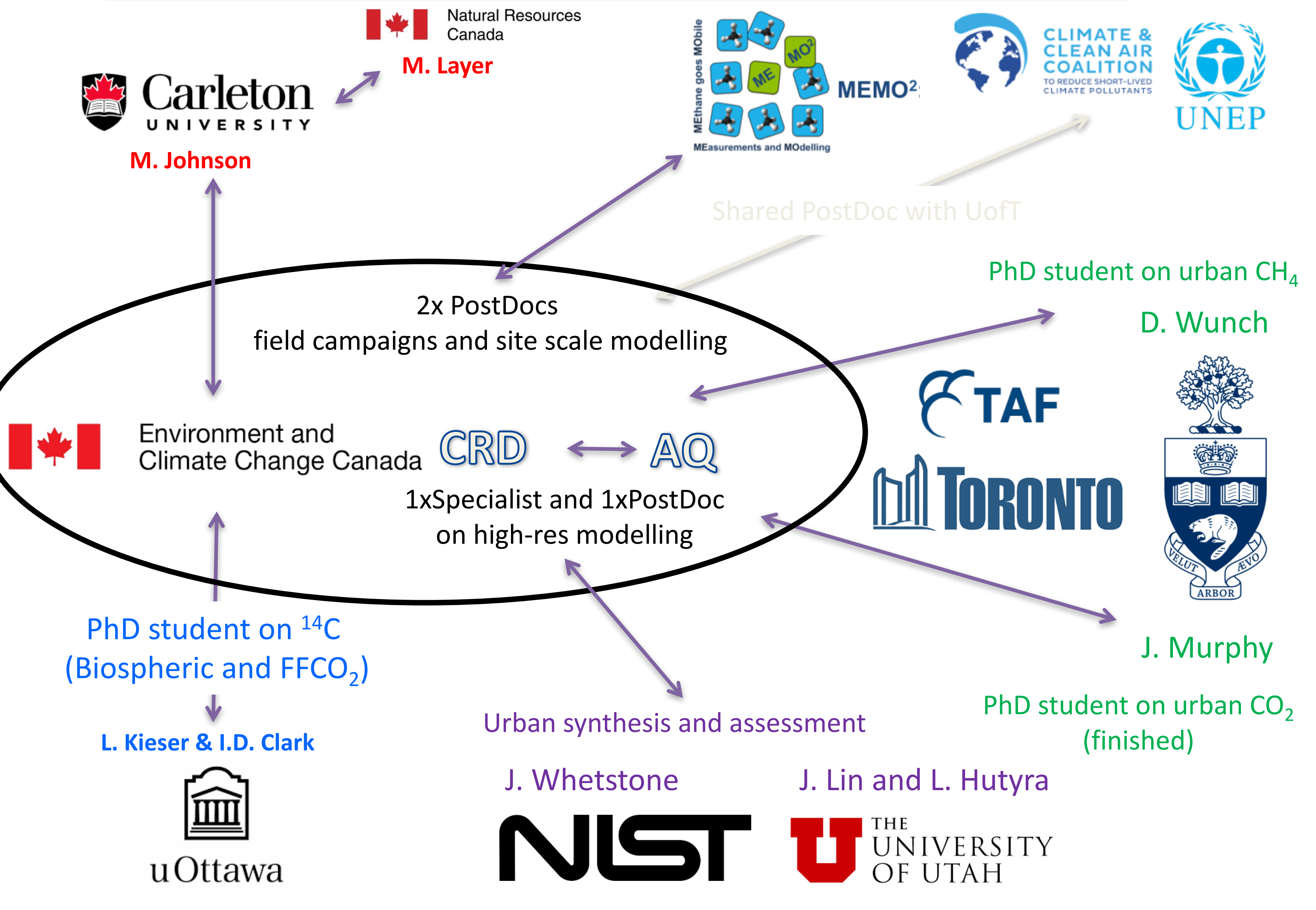
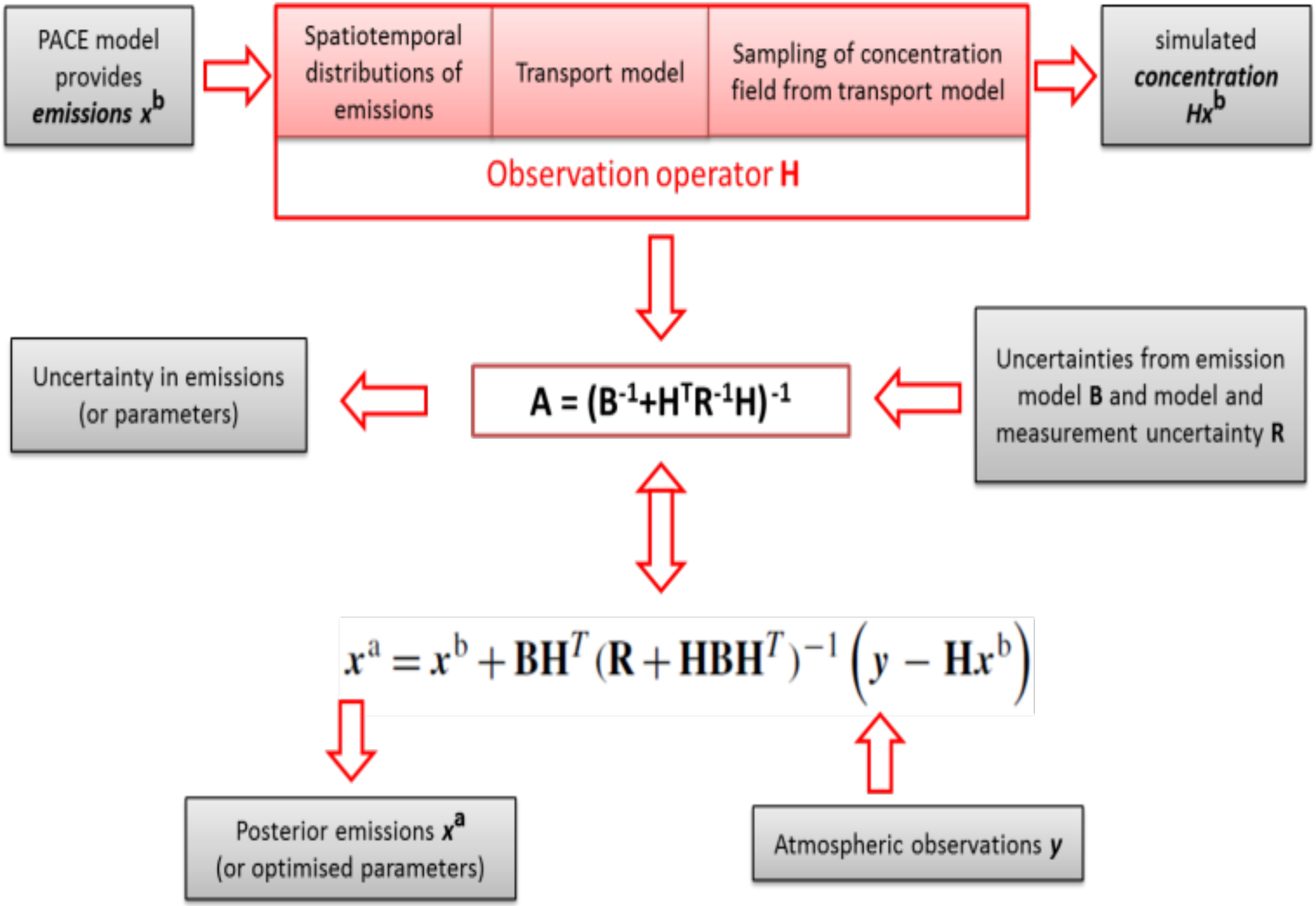
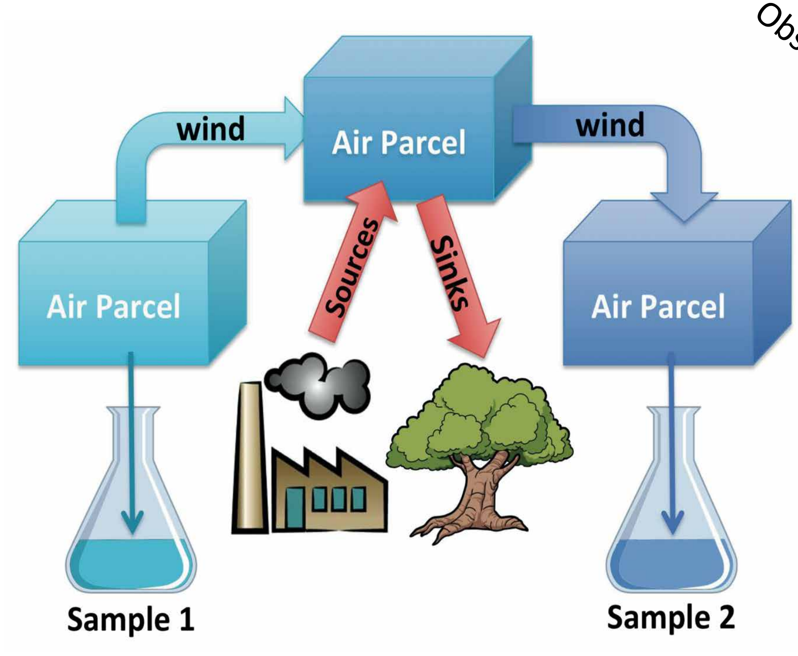


Bayesian Linear Unbiased Estimator



The atmosphere is a powerful integrator of surface fluxes



Observing scope 1 emissions

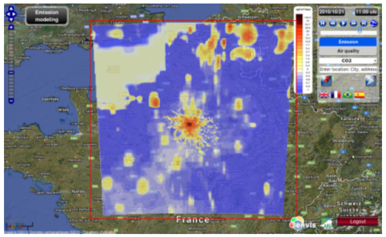
… but to use its power, reliable high-quality measurements are necessary

Atmospheric measurements were already proven to be effective to quantify regional CO_2 and CH_4 fluxes at all scales: global, continental, regional, country, local.

But we do not always have a **dense sampling of the atmosphere in space and time to identify specific source categories**

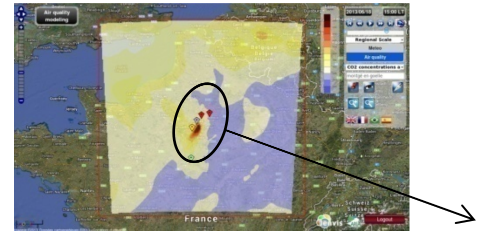
Data assimilation framework

Prior CO_2 emission



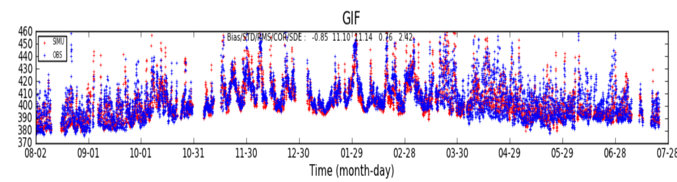
Atmospheric Chemistry Transport Model CHIMERE

CO_2 concentration fields



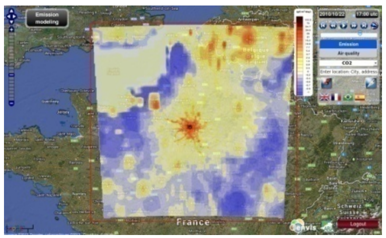
In situ observations network around Paris

Comparison of simulated CO_2 concentration with *in situ* measurements



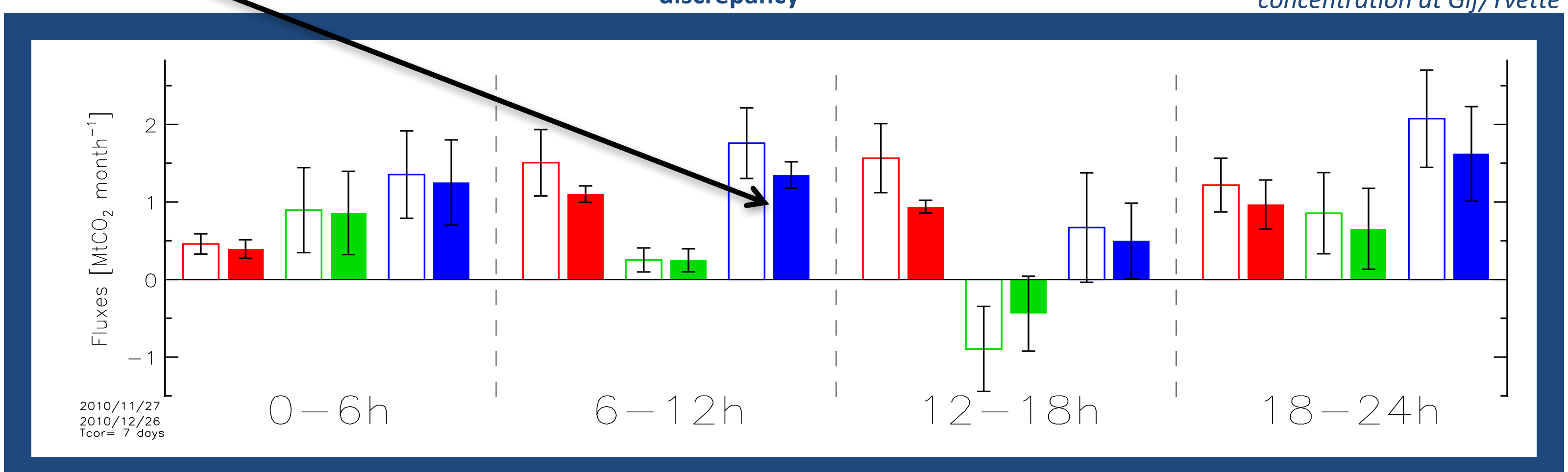
Time evolution of simulated and observed CO_2 concentration at Gif/Yvette

Inverse Modeling Technique



***Posterior** CO_2 emission*

Probabilistic tools to compute the best CO_2 emission estimate that reduces the observations/simulation discrepancy



[Breon et al.2015]

Fossil fuel + Bio = Total

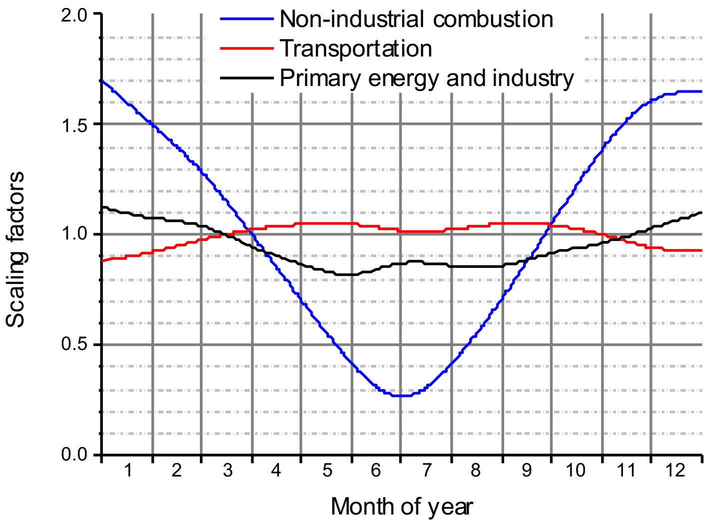
Source apportionment – what is contributing to GTA emissions?

Carbon-13

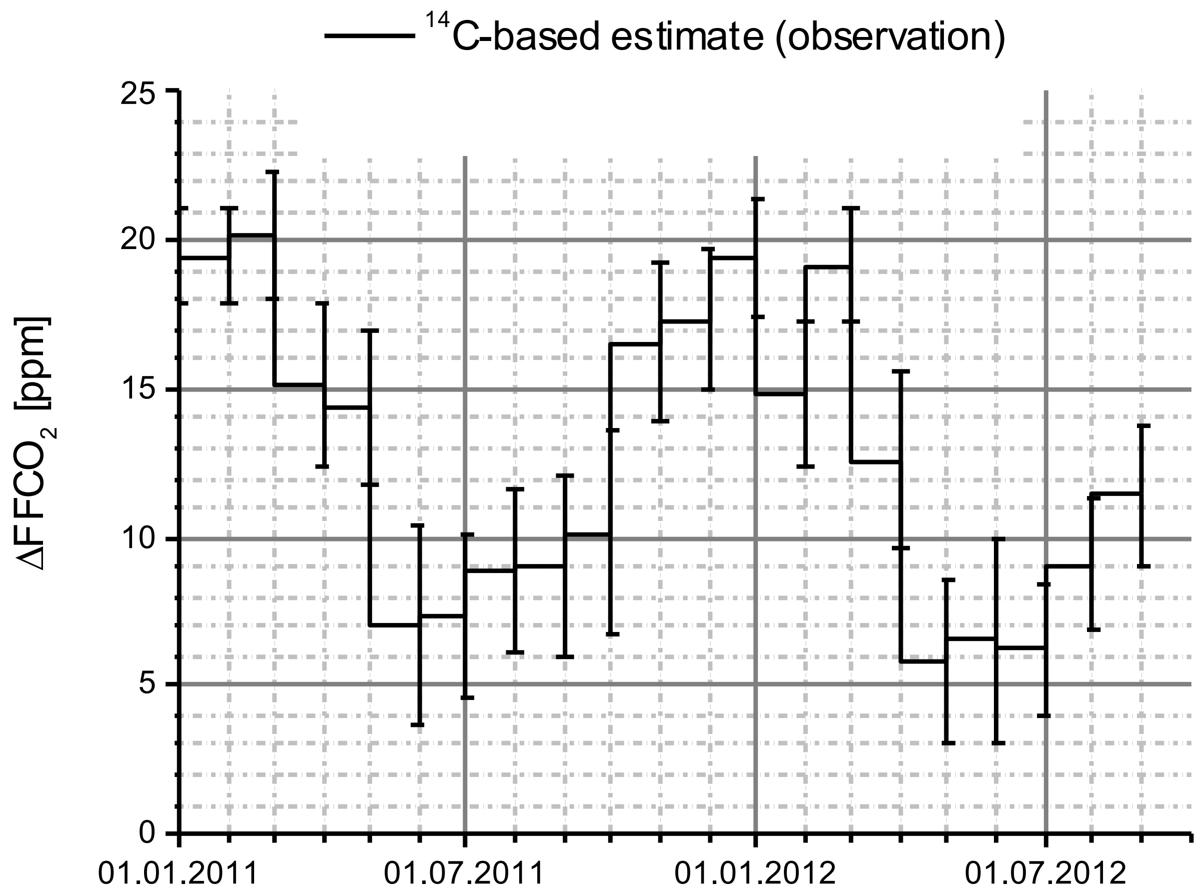
-40‰ to -48‰

-27‰ to -28‰

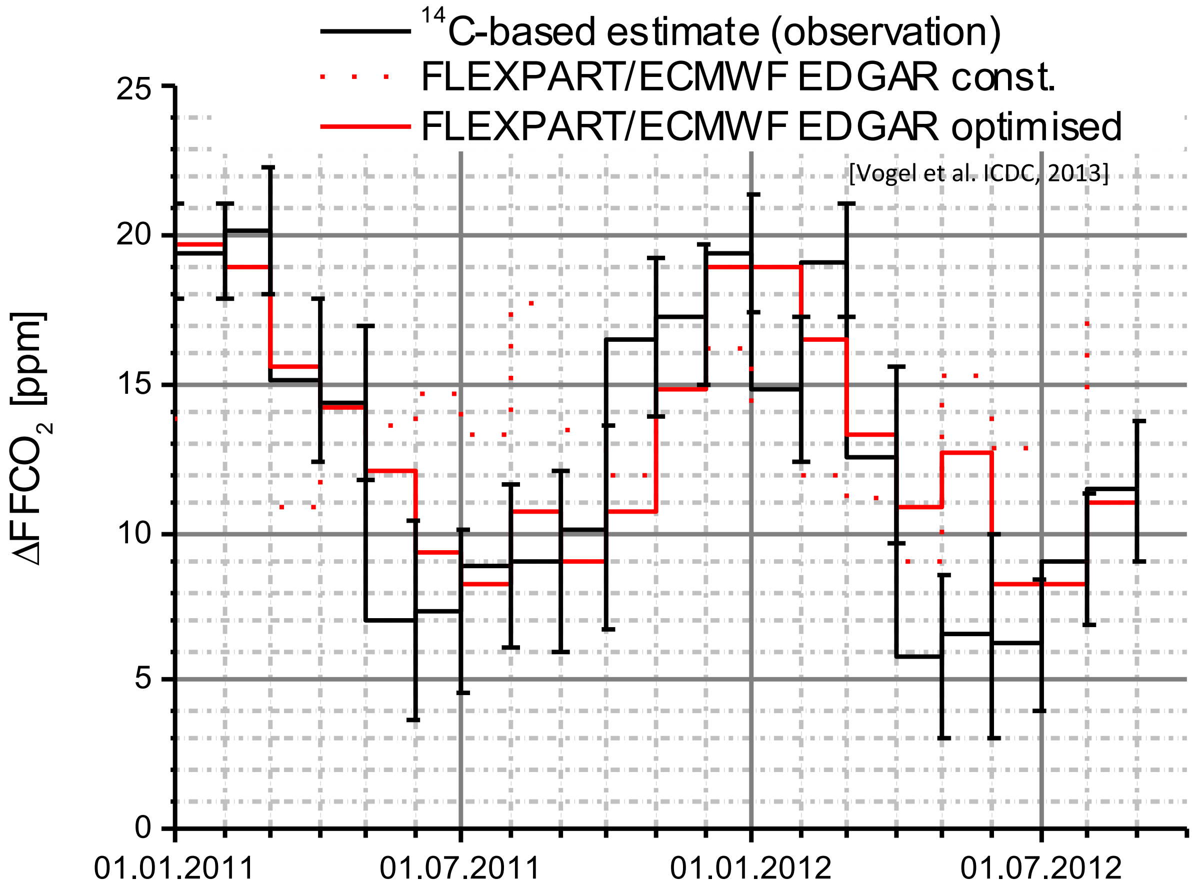
-24‰ to -27‰



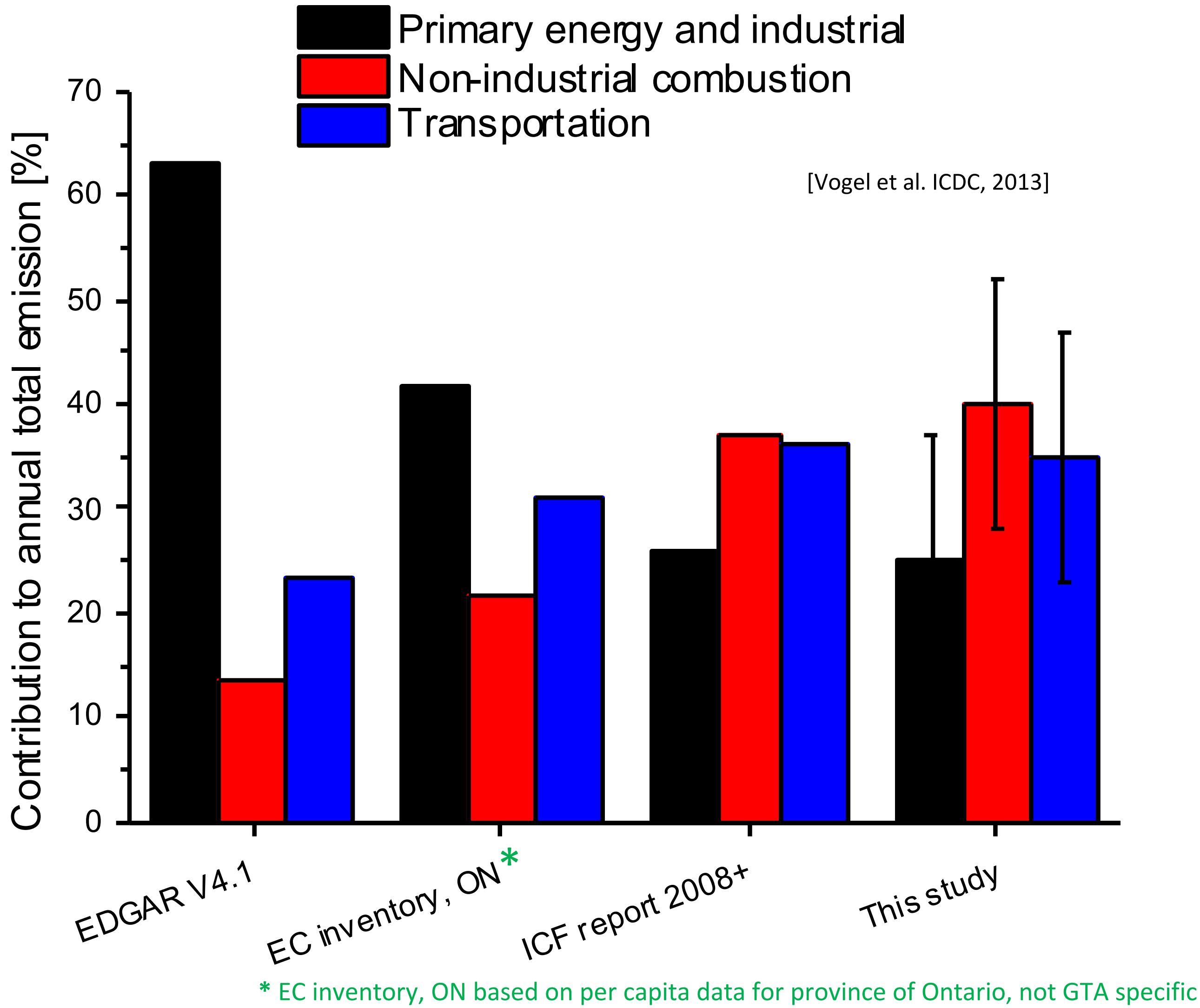
- Different emission sectors use different fuel-types (gas, coal, oil) approach #1
- Different emission sectors have different seasonal patterns approach #2



- Seasonal cycle in concentration due to changing anthropogenic emissions
- Potentially changing atmospheric transport



- ➢ Overall GTA emissions are 9% lower than predicted in prior emissions
- ➢ Retrieve an estimate of primary energy and industry, non-industrial combustion and transportation contribution



- Atmospheric observations support ICF report estimates for contributions