Towards an operational observing system to monitor fossil CO_2 emissions

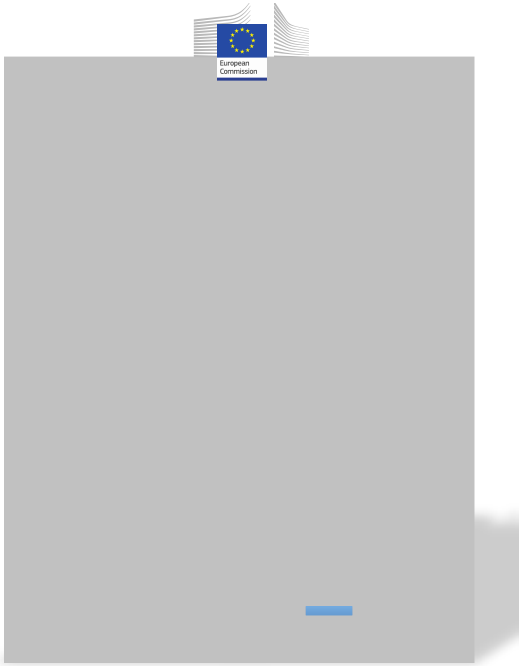
Y. Meijer[(1)], P. Ciais[(2)], M. Drinkwater[(1)], P. Ingmann[(1)],
A. Loescher[(1)], B. Sierk[(1)], and P. Silvestrin[(1)]

[(1)]ESA, Noordwijk, The Netherlands
[(2)] LSCE, Paris, France

"CO_2 report"
Towards a European Operational Observing System to Monitor Fossil CO_2 Emissions

In preparation of the COP21 meeting in Paris,
the EC initiated a report to monitor fossil CO_2 emissions

The report provides an implementation plan toward an independent European operational observing system, which would be a supporting tool to assess international climate commitments on CO_2 emissions



Experts & authors:
P. Ciais, D. Crisp, H. van Denier der Gon
R. Engelen, M. Heimann, P. Rayner,
G. Janssens-Maenhout, and M. Scholze

European Commission

Report available via:
http://www.copernicus.eu/main/towards-european-operational-observing-system-monitor-fossil-co2-emissions

Questions addressed in CO_2 report

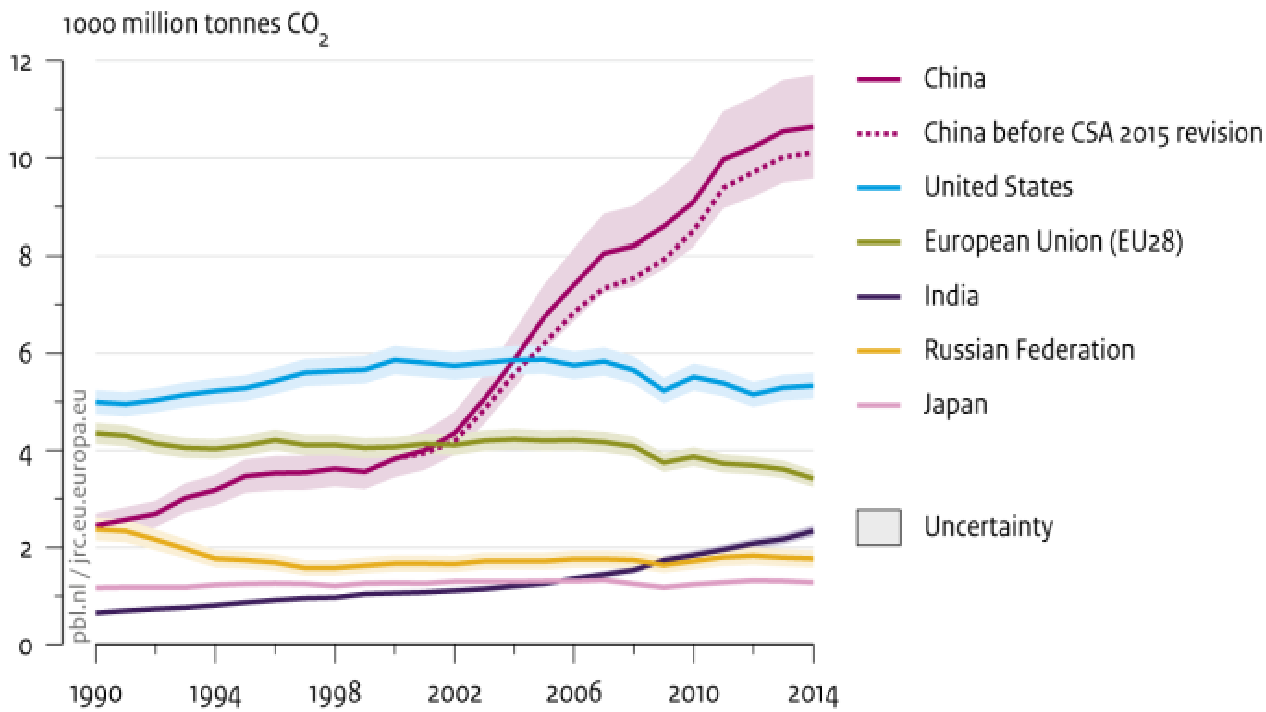
1. What are the **critical uncertainties** and limitations of **current inventories** of fossil CO2 emissions based on fuel use statistics?
2. How could inventories be improved using independent **space-borne measurements of atmospheric CO2**?
3. What are the **current capabilities** of space-borne and in-situ ground-based measurements of atmospheric CO2 in Europe and worldwide?
4. How should these **capabilities be optimized into an operational system** for independent monitoring of fossil CO2 emissions and for improving current estimates at the global, European and country scales?
5. What are the critical elements and a **possible road map** for setting up such a system enabling first pre-operational CO_2 emission quantification capacities **around 2025** and full operational exploitation at the **horizon of the 2030s**?

Critical uncertainties in CO_2 inventories

Emissions on the rise

Are CO_2 emissions still rising? YES, but the trend is stalling

CO_2 emissions from fossil-fuel use and cement production in the top 5 emitting countries and the EU



Source: EDGAR 4.3 (JRC/PBL, 2015) (1970-2012; notably IEA 2014 and NBS 2015); FT2014 (2013-2014): BP 2015; GGFR 2015; USGS 2015; WSA 2015

Critical uncertainties in CO_2 inventories   Emission uncertainties on the rise

- During the last decade, emerging countries have become the largest emitters
- The global emissions uncertainty is increasing with time : we are losing our anchor
- No reliable information about spatial & temporal patterns

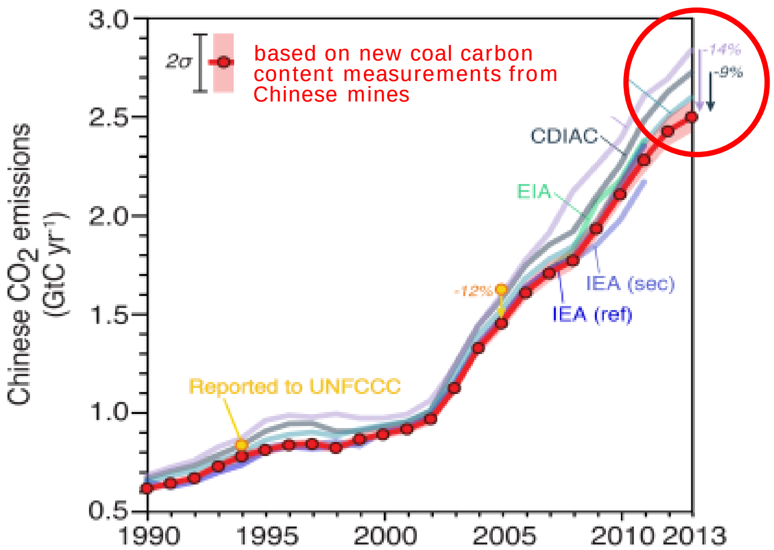
→ this is a limitation to mitigation policy

In Aug 2015, a study revised China's emission downwards by 14% based on new coal emission factors

In Nov 2015, China's coal consumption statistics were re-evaluated upwards by 20%

This illustrates the large uncertainty of emissions, which is critical to interpret emission reduction pledges

A 14% correction of China emissions translates into adjusting the global land sink by ~30% in the global budget of CO_2 !



Source – Liu et al. Nature 2015

Critical uncertainties in CO_2 inventories

Summary

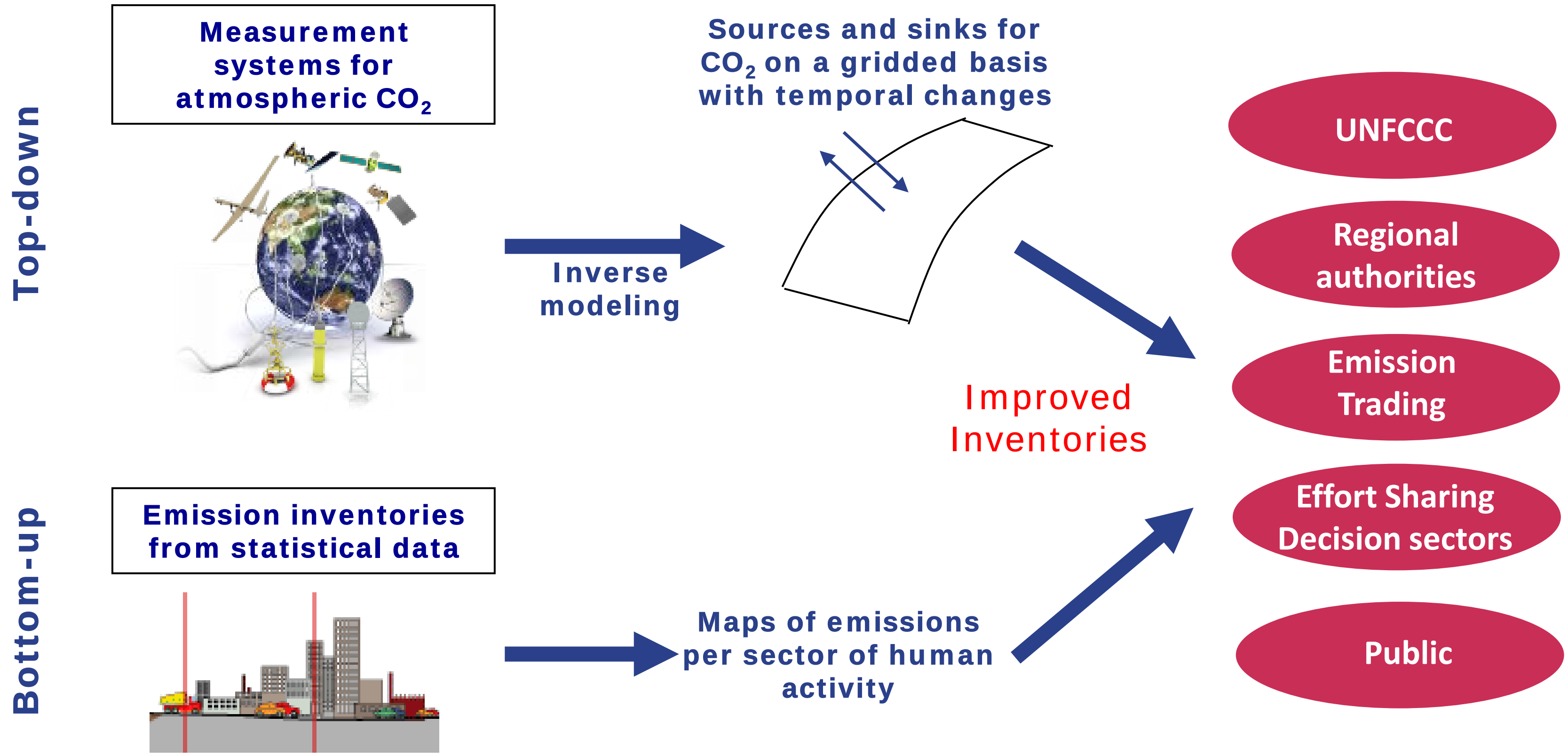
- Current emission inventories are based on self-reported statistical data by the emitters themselves
- Despite efforts to improve inventories, global fossil CO_2 emissions information is becoming more uncertain

Recognized limitations of inventories :

- Difficult to independently verify since they require most of the available information to be compiled
- They are limited in scale, given the limited granularity of economic data
- They require considerable infrastructure and technical capacity
- As a result, their quality is highly variable between countries

Current inventories seem to be not sufficient to quantify the effectiveness of climate policy

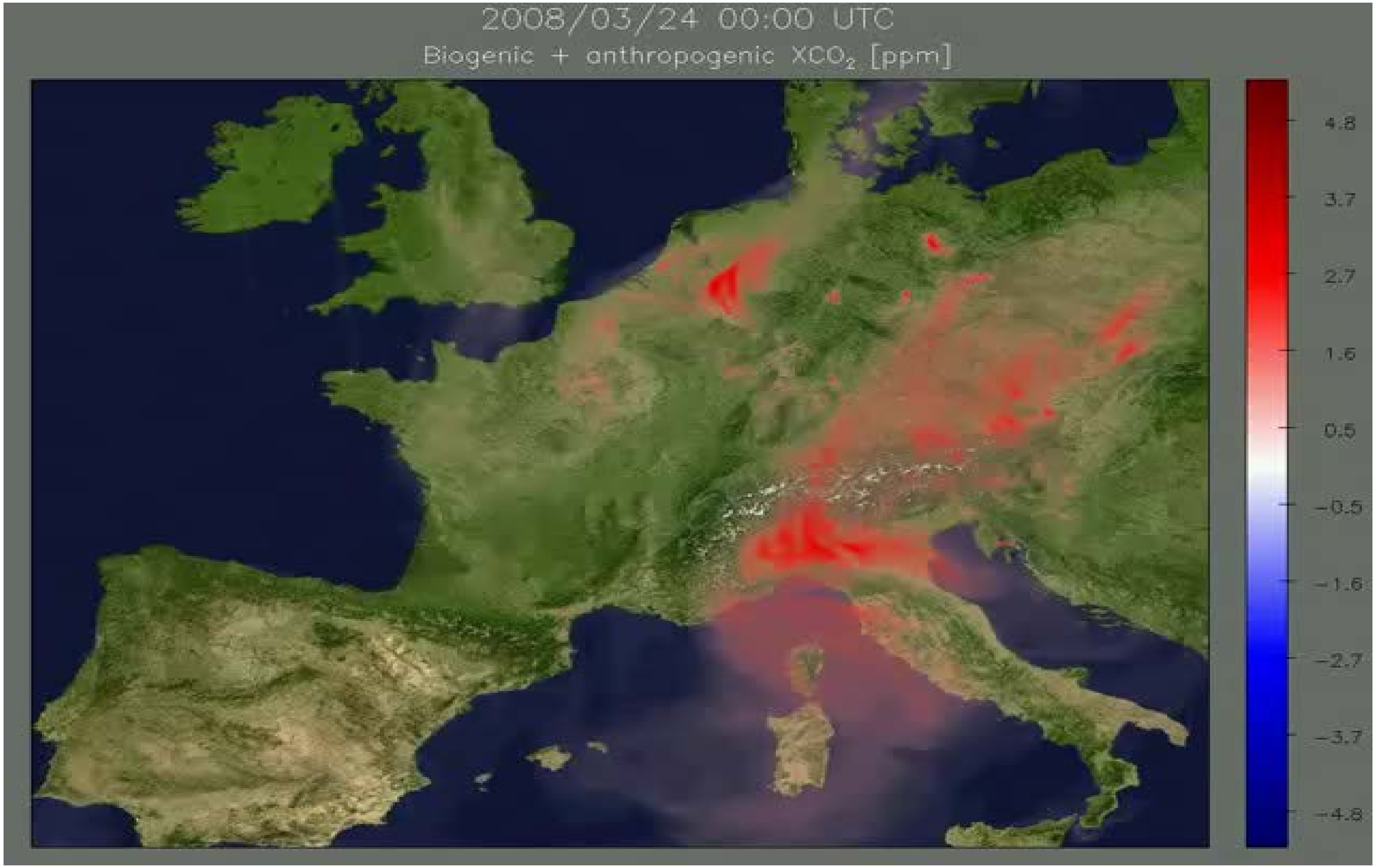
The top-down atmospheric approach Improving emission inventories



- CO_2 emissions of subnational governments / regions need also to be mapped within a regionally complete picture (covering all human activities)

The top-down approach requires high spatial resolution

Simulation of CO_2 emission plumes



Source : D Brunner, EMPA COSMO model

Summary

Independent quantification of fossil CO_2 emissions using inverse modeling and atmospheric measurements is feasible with current technology

Two **complementary** approaches :

- Dense sampling of emission hotspots, such as megacities, major industrial areas, and large power plants

  → *This can be achieved with satellites measuring column CO_2*

- Separate the fossil CO_2 component from the natural fluxes at regional scale, by measurements of additional trace species, such as radiocarbon (^{14}C in CO_2) and carbon monoxide

  → *This can be achieved in Europe by making ^{14}C measurements at existing CO_2 monitoring tall towers (ICOS and national in-situ networks)*

→ Need for increasing dense and spatial sampling of atmospheric CO_2 measurements to quantify emissions

The pillars of an operational system

An **operational observation system** to monitor fossil fuel CO_2 emissions consists of **four pillars**:

1. **Bottom-up inventories**; frequently updated and improved maps of emissions from
2. **Satellite** measurements of total column CO_2
   - Dense sampling: imagery
   - High spatial resolution: sample size smaller than < 3 km
   - Individual measurement precision of < 1 ppm
   - Systematic errors < 0.5 ppm
   - Global coverage of emission hotspots
3. **In-situ** tall towers networks
   - Very high precision continuous CO_2 measurements
   - ^{14}C sampling
4. **Inverse modeling** with operational capabilities
   - High resolution atmospheric transport models
   - Fossil fuel data assimilation system built upon existing Copernicus capabilities

Space based measurement capabilities

Space segment

Specific measurements of atmospheric CO_2 from space are needed for fossil **CO_2 emissions quantification**

- Discussion with the EC has started (a Task-Force to iterate the requirements is in place)
- Around 2025, **a pre-operational European carbon mission** delivering column CO_2 at high resolution and accuracy/precision with imaging capability should be in place
- By ~2030 a fully **operational system** with an expanded space segment based on the four pillars identified in the CO_2 should be in place
- This system will need to be complemented by a set of carbon missions (European and non-European) to ensure the frequent detection, quantification and monitoring of emissions
- To ensure success broad international support will be key to exploit **all available data** (European and non European) to the best extend possible

Roadmap to operational system

ESA proposed to its member states a **generic roadmap** for the evolution of the Copernicus space component

CO_2 monitoring is in the top priority list and used as first case to explore implementation, see **CO_2 Roadmap**

ESA and the European Commission jointly established by nomination a **CO_2 Monitoring Task Force** of experts (Task A on space component)

The system requires a broad international support and in the task force involves other space agencies

Annex 1a - CSC Evolution DRAFT CO2 Roadmap

	2015	
Oct.	**CO2 Report published by DG GROW**	COM
	2016	
Feb.	**Nomination of Task Force of experts**	COM/ESA
Jul./Sep	**Kick-off of EC/ESA End-to-end Architecture Studies** for CO_2 emissions monitoring system	COM/ESA
Apr. – Dec.	**Draft CO_2 Mission MRD**	COM/ESA
	2017	
Dec.	**Detailed technical requirements for the overall CO_2 System**	ESA/EUM/ECMWF
	2018	
	Phase A/B1	ESA
	2019	
	Phase B2	ESA
	2020	
	Instrument QM development	ESA
	2022	
	Procurement of recurrent units of CO_2 Mission	ESA
	2024/2025	
Jan.-Dec.	**First (Pre-) operational CO2 mission** launched	ESA
	2030	
Nov.	**Constellation of operational CO2** missions launched	ESA

Roadmap to operational system

Task Force (Task A) will advise on the pre-operational implementation of a space component for a global “CO_2 Emissions Monitoring System”

First meeting scheduled on 11–12 July

Name	Affiliation
Hartmut BOESCH	Dept. of Physics & Astronomy, Space Research Centre, University of Leicester, UK
Antonio BOMBELLI	CMCC - Euro-Mediterranean Centre for Climate Change, IT
Dominik BRUNNER	EMPA, Swiss Federal Laboratories for Materials Science and Technology, CH
Michael BUCHWITZ	Institute of Environmental Physics (IUP), University of Bremen, DE
Philippe CIAIS	Laboratoire des Sciences du Climat et de l'Environment (LSCE), FR
Richard ENGELEN	Chemical Aspects Section, Research Department, ECMWF, UK
Sander HOUWELING	SRON/IMAU, NL
Julia MARSHALL	Max-Planck-Institute for Biogeochemistry, DE
Marko SCHOLZE	Dept. of Physical Geography & Ecosystem Science, Lund University, SE
Greet JANSSENS-MAENHOUT	European Commission, Joint Research Centre, Institute for Environment and Sustainability, IT
David CRISP	Jet Propulsion Laboratory (JPL), California Institute of Technology (Caltech), US
Masakatsu NAKAJIMA	Japan Aerospace Exploration Agency (JAXA), JP
Yves BUHLER	EUMETSAT, DE

Take home

1. Limitations of current inventories to **assess and support the effectiveness of local and national mitigation policies** are evident
2. **Inverse modeling** with dense atmospheric CO_2 measurements allows to improve fossil fuel CO_2 emissions knowledge
3. Capabilities need to be developed within Copernicus to build the four pillars of an **operational** CO_2 emission **monitoring system by 2030**
4. System should support countries in **monitoring their efforts** to reduce CO_2 emissions down to the scale of major cities
5. This system will require frequently updated bottom-up emission maps, an operational Fossil Fuel Data Assimilation System and adequate space-based and in-situ CO_2 observations, being pre-operational with a **first satellite** CO_2 imagery mission launched **around 2025**
6. This system should be part of the **Copernicus program complemented by broad international cooperation**