Institutional and scientific challenges for a carbon monitoring system

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CO_2 Territorial emissions in 2014 ($MtCO_2$)

Fragmented landscape: society

Societal dimension

Citizens

Municipalities

Private sector

Governmental institutions

NGOs

High-level decision making

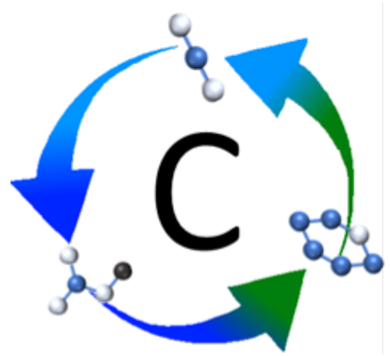
Science

GEO-C's role: identify and collaborate with the end-users across societal sectors

Ecosystems **Oceans** **Atmosphere** **Gases** **Aerosols** **Human activities** **Natural processes**

Scientific dimension of Earth Observations

Fragmented landscape: science



Carbon Cycle

Climate Change

Ecosystems Oceans Atmosphere Gases Aerosols **Human activities** Natural processes

Very diverse scientific domains that need specialized approaches

NEON
FLUXNET
eLTER
GOOS
SOCAt
Blue Planet
ARGO
IG^{3}IS
GAW
IAGOS
USGS
TCCON
ICOS
ACTRiS
NIES
AnaEE
CEOS
JAXA

Biomass Inventories

... and many others!

GHG-Inventories

correspondence

A post-Paris look at climate observations

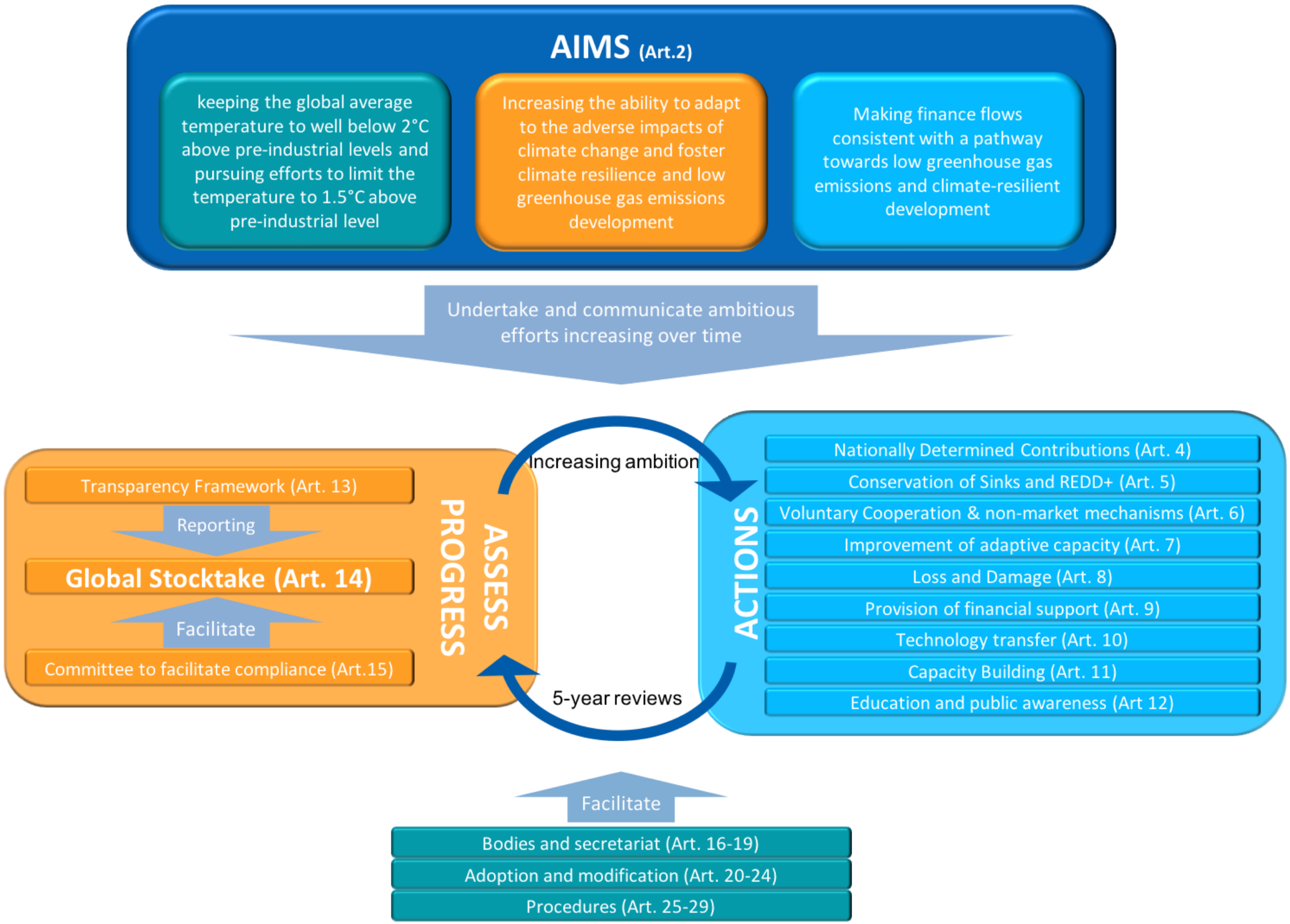
To the Editor — The Paris Agreement[1] of the United Nations Framework Convention on Climate Change in December 2015 was

variables (ECVs) have been defined: they aim to describe key aspects of the behaviour and composition of the land, oceans and

reminder to the observing community to deliver the data that will underpin progress. ❐

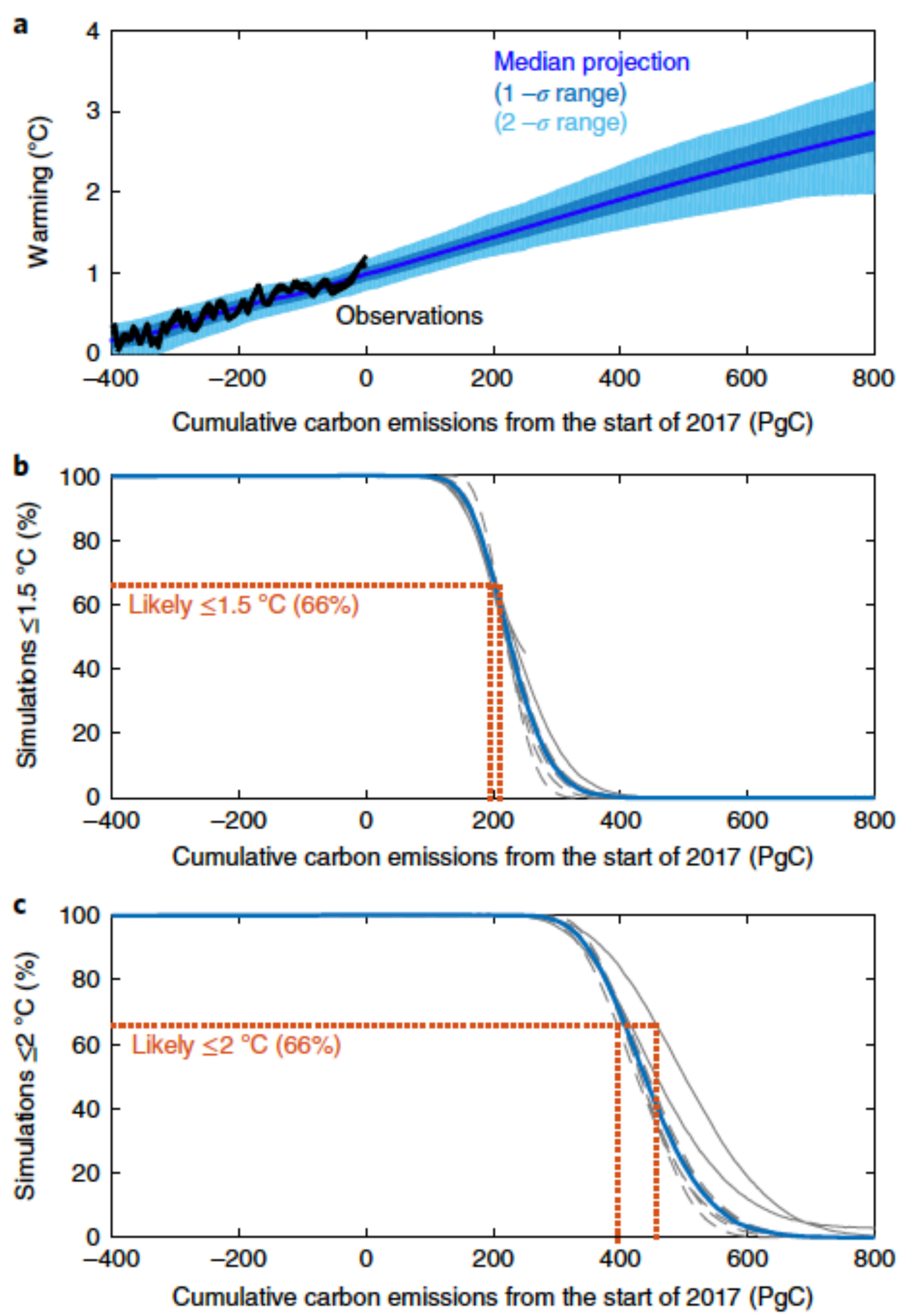
- Renewed emphasis on fossil emission sources
    - Requires rethinking of strategy (scaling)
    - Observation networks
- Firm robust limits (1.5/ 2 ^{0}C), or 200 Pg C

The Paris agreement



The five year cycle

17-18 or 35-41 years

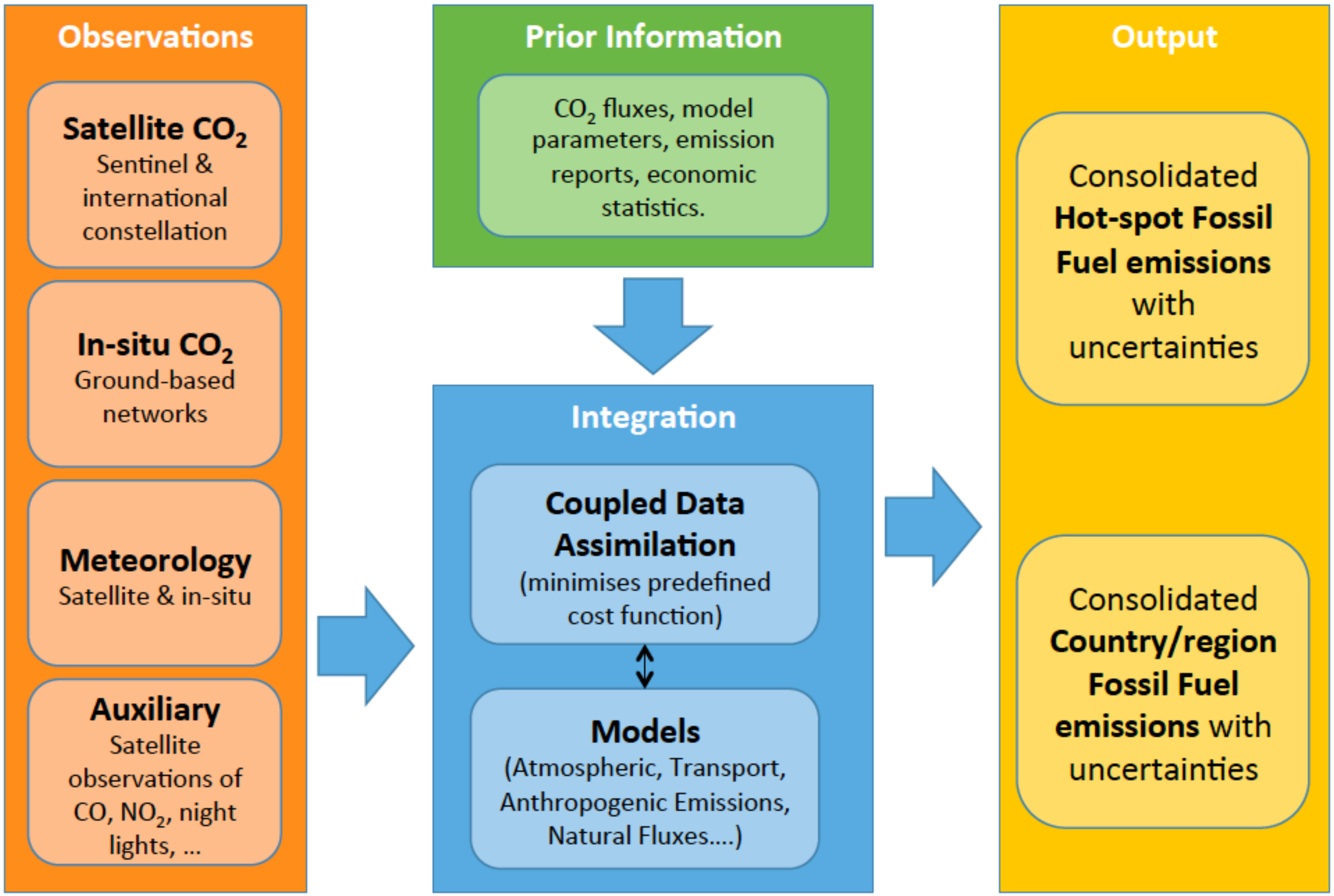


Clark et al., last week
Nat. Geosc.

Challenges

- What has changed since Paris?
- Some issues with mesoscale models
- Where uncertainties meet regional budgets: future satellite requirements
- Closed country budgets?
- Can we deliver in time and how?

The system of systems



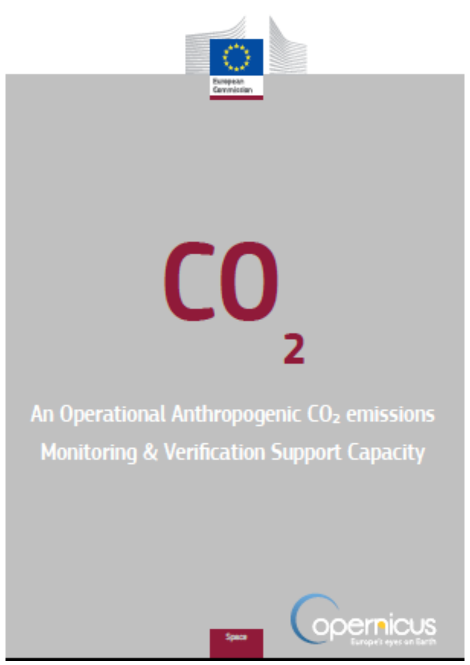
What is needed?

Detection of hot spot. A hot spot is defined as a small area surrounded by a strong CO_2 concentration gradient, because the area contains a large emitting CO_2 source. This can be a large power plant, a megacity or any other activity characterized by strong CO_2 emissions with different time evolution.

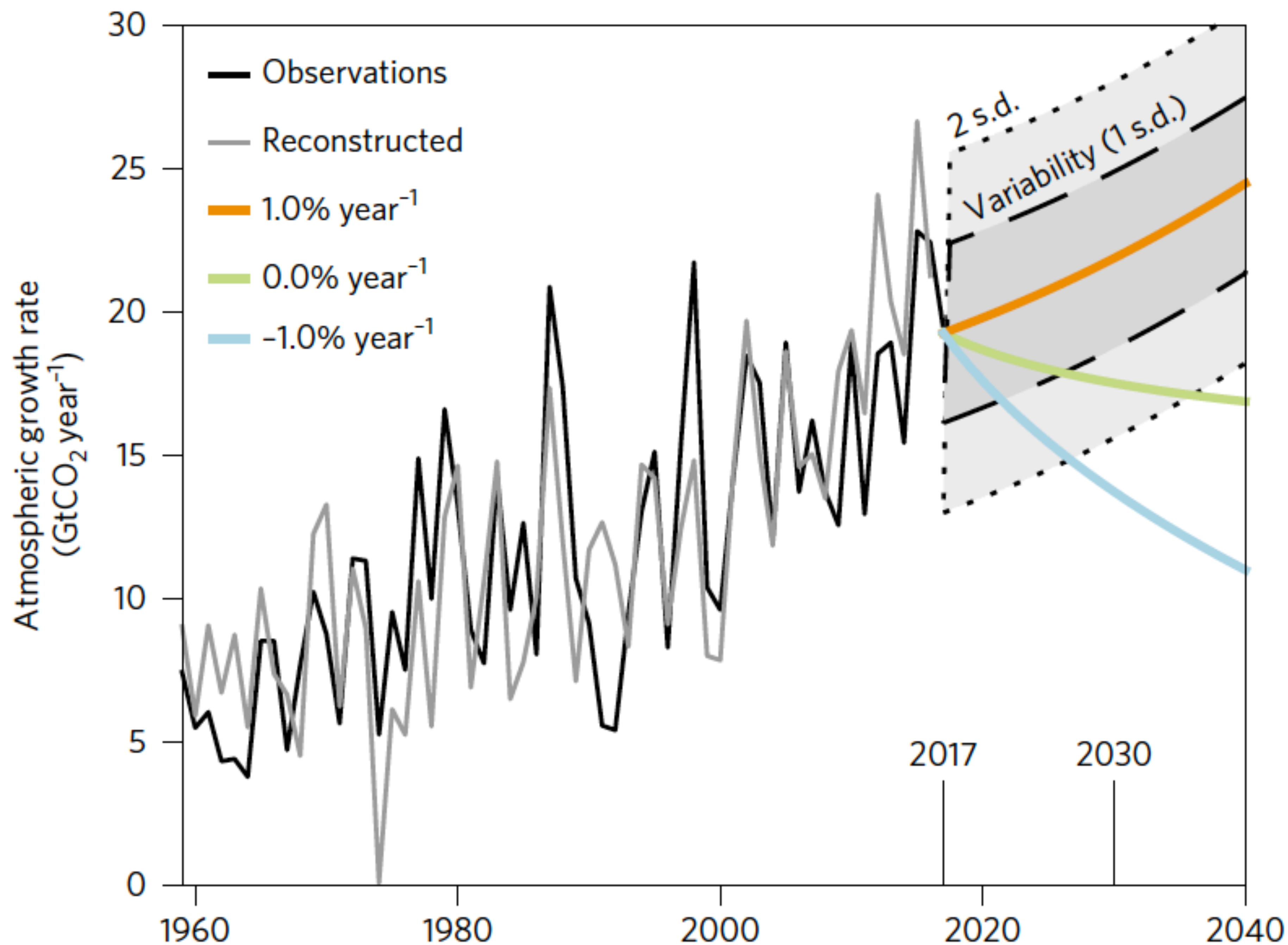
Monitoring the emissions of the hot spot. Consecutive measurements are needed to link the measured emission level to previous measurements and to monitor local emission reductions of the activities within the hot spot. The accuracy of the measurements must ensure the capability to attribute CO_2 emissions anomalies relative to the CO_2 concentration background level.

Assessing emission changes against local reduction targets. This concerns the monitoring of the implemented emission reduction strategies on the hot spots, which all add up to achieve NDC targets. In the EU this requires the monitoring, at the most appropriate time scale, of not only the point source facilities (which are under the Emissions Trading System) but also the megacities with peak emissions of transport and buildings.

Assessing the national emissions and changes with 5 year time steps. This requires the entire screening of the full area covered by the country, in order to account for changes in emission patterns with new or occasional hotspots.

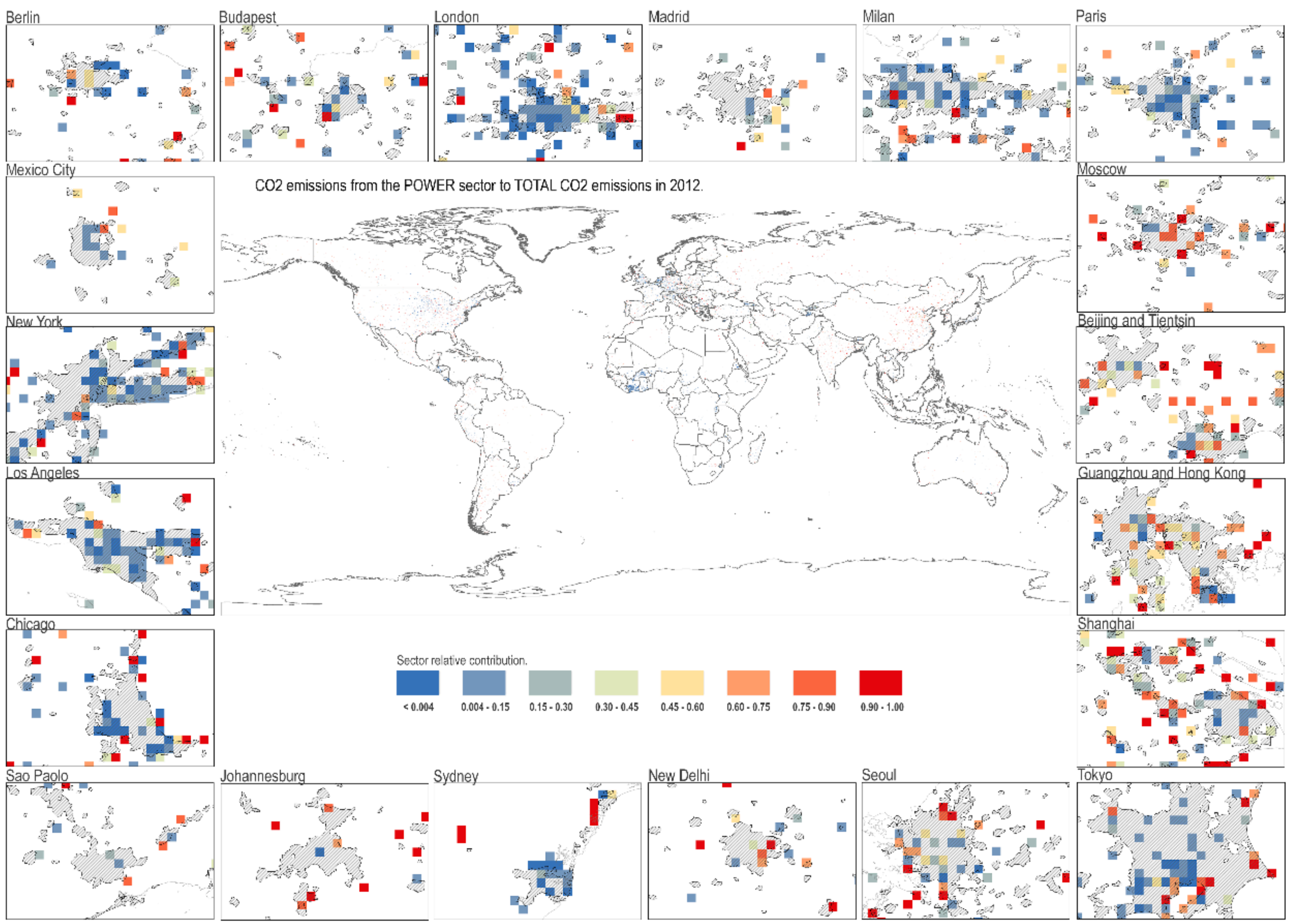


Can we observe any reduction?



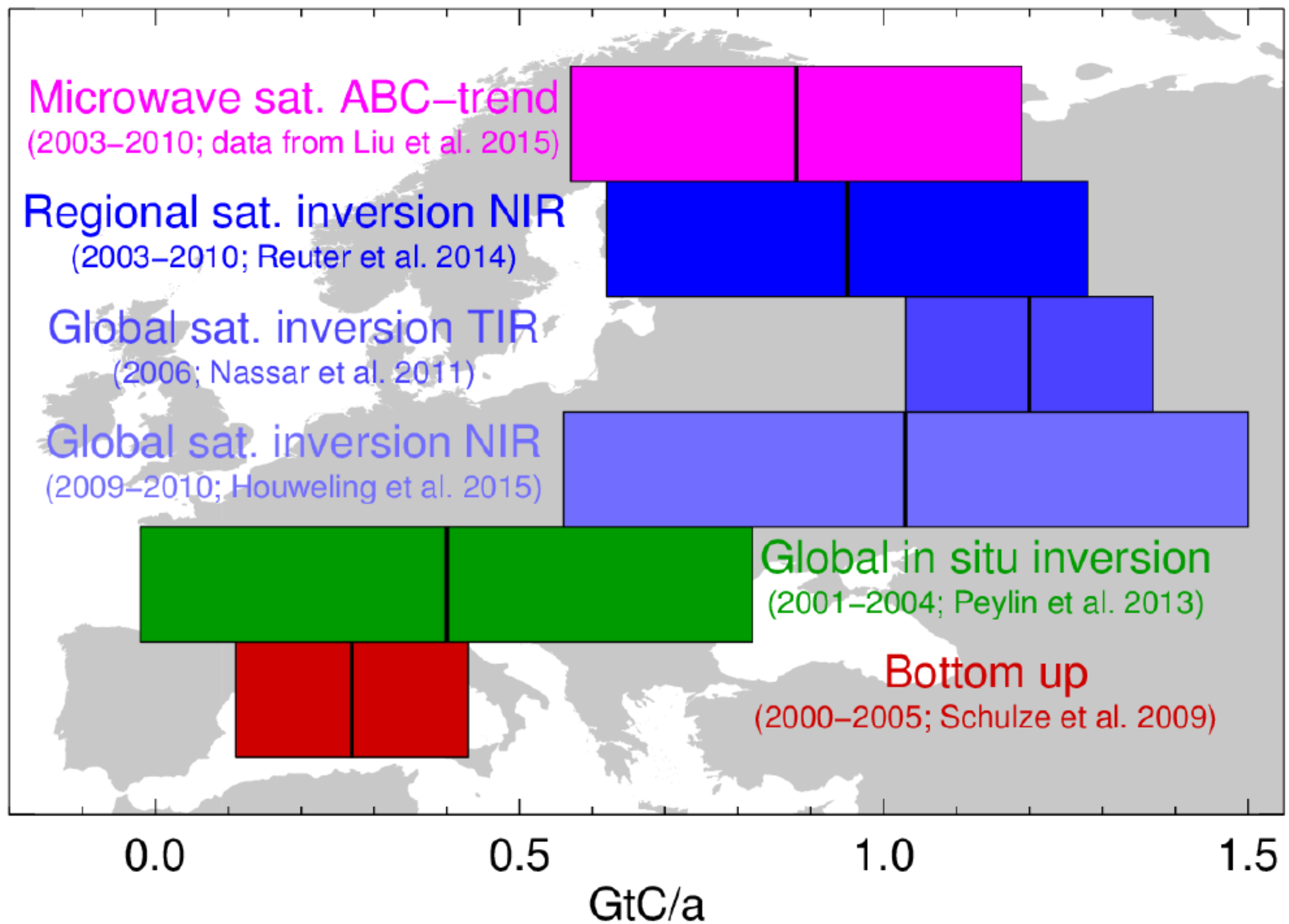
Peters et al., 2017

Emission hotspots



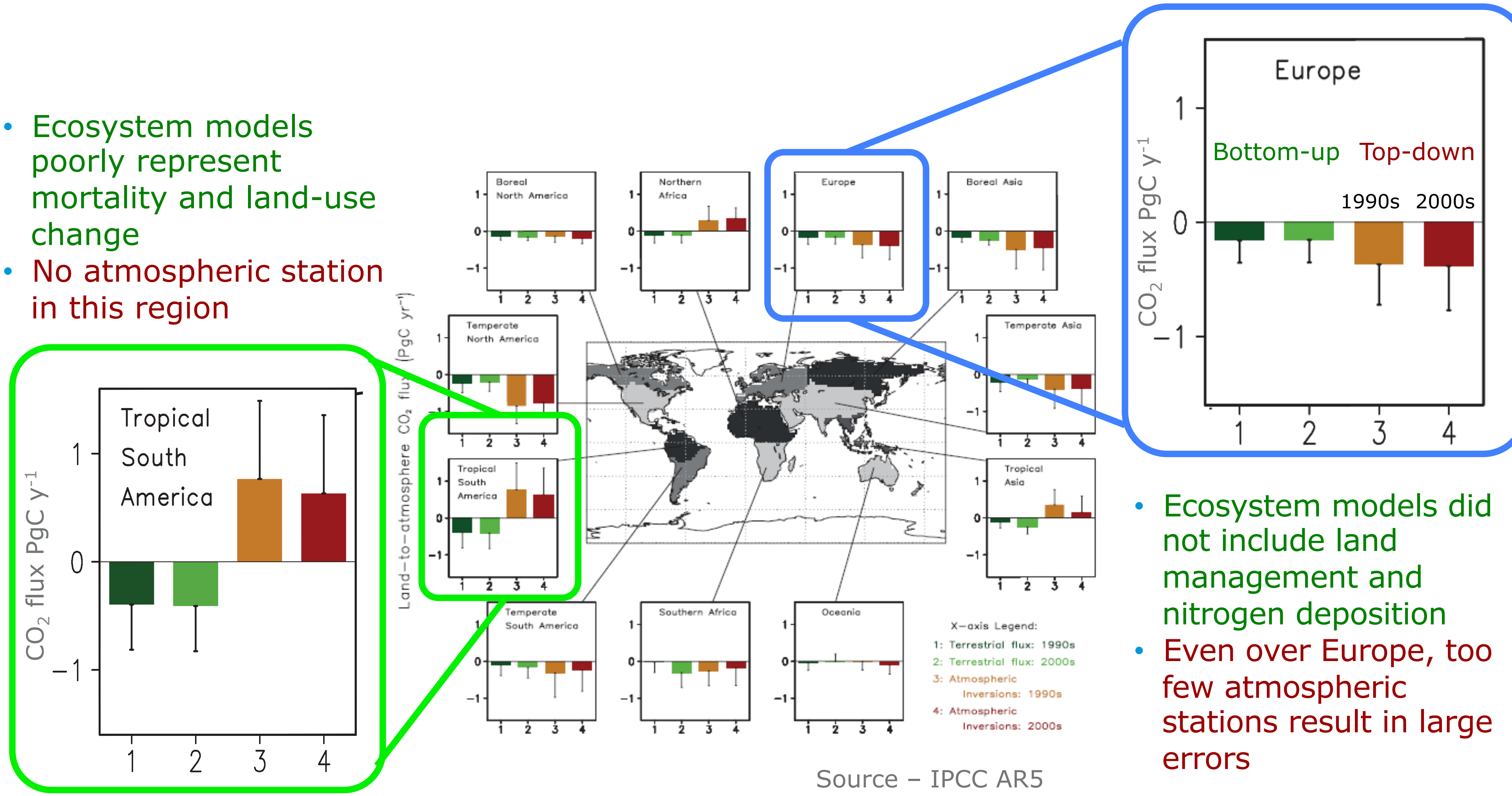
Graphic Greet Maenhout

How good are we at that?



(un)closed budgets at the continental scale

- Ecosystem models poorly represent mortality and land-use change
- No atmospheric station in this region

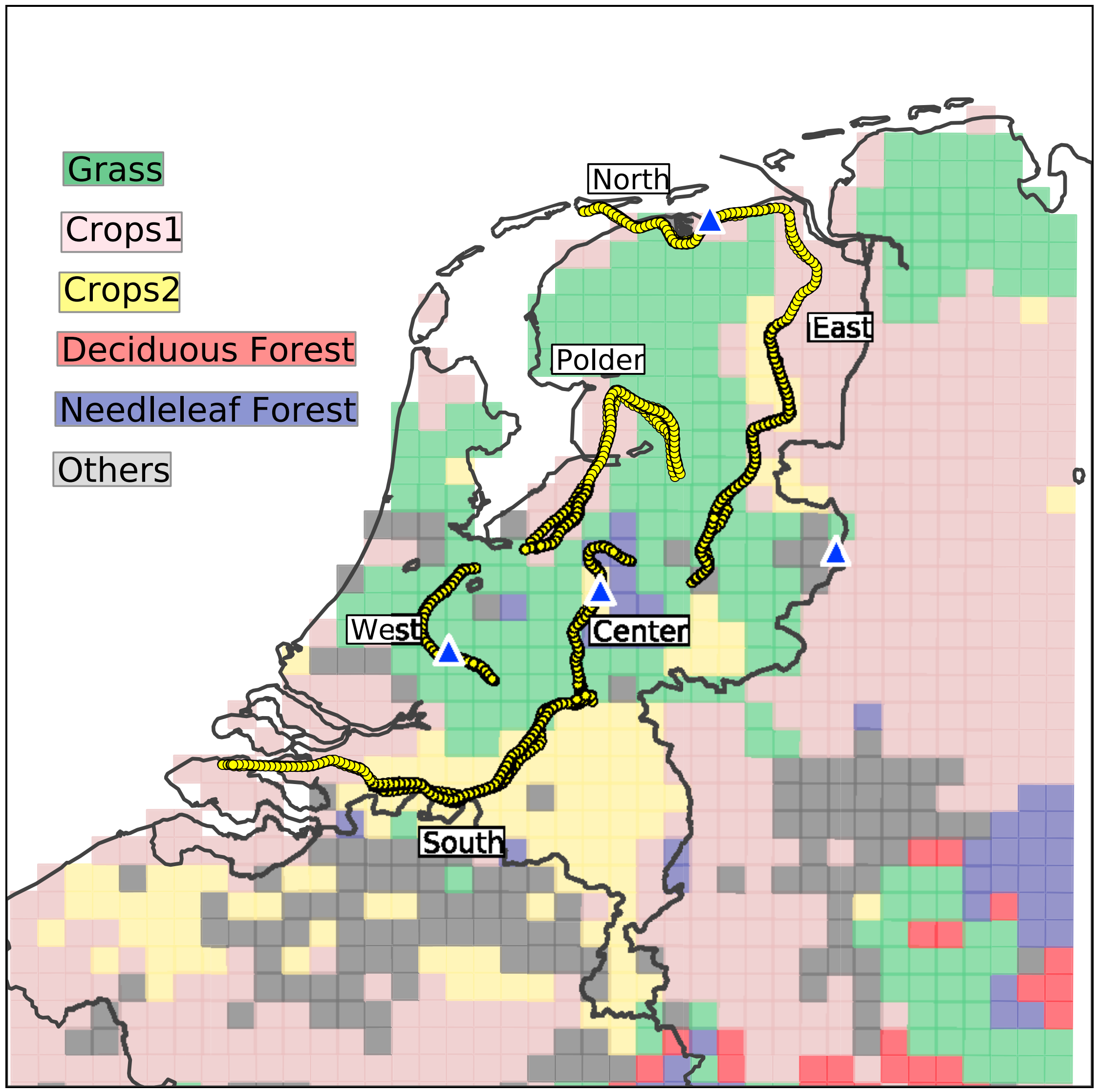


Source – IPCC AR5

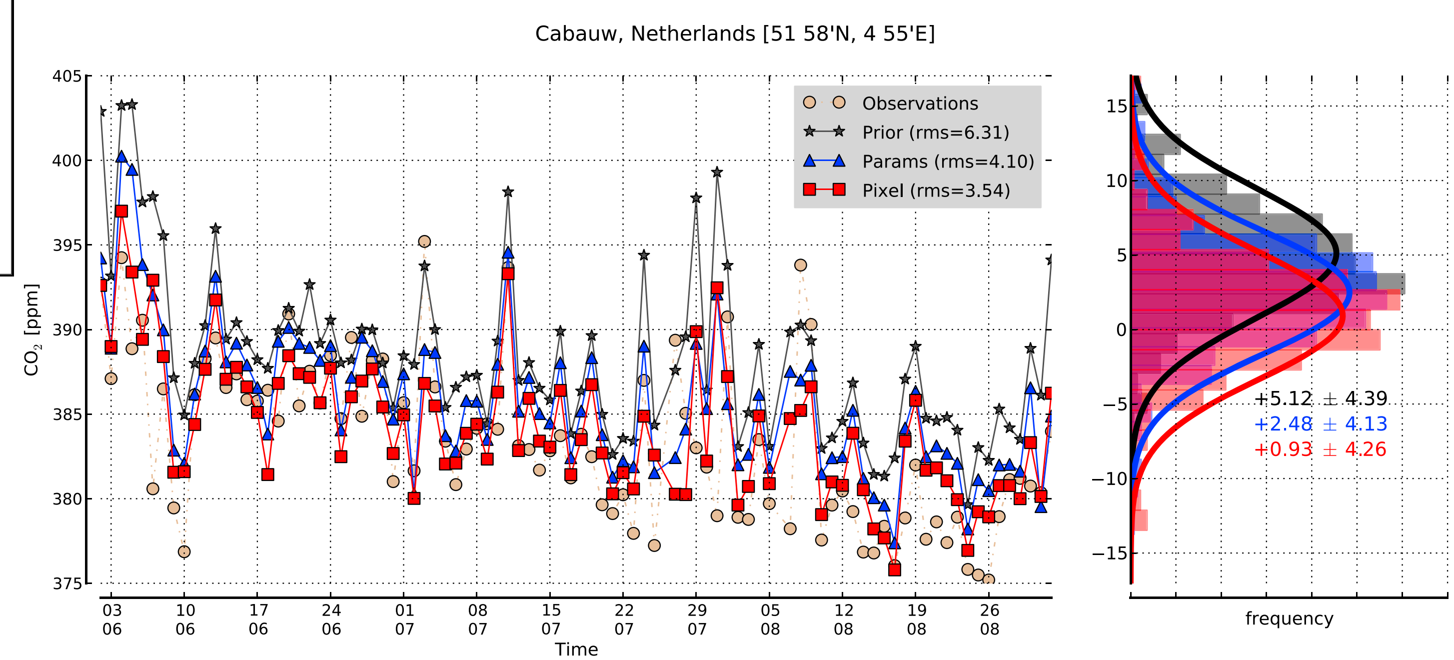
- Ecosystem models did not include land management and nitrogen deposition
- Even over Europe, too few atmospheric stations result in large errors

- Large discrepancies between bottom-up models and atmospheric inversions
- Tropics and high latitudes regions have almost no observation
- Large uncertainties ~100% on regional budgets !

Country scale budgets

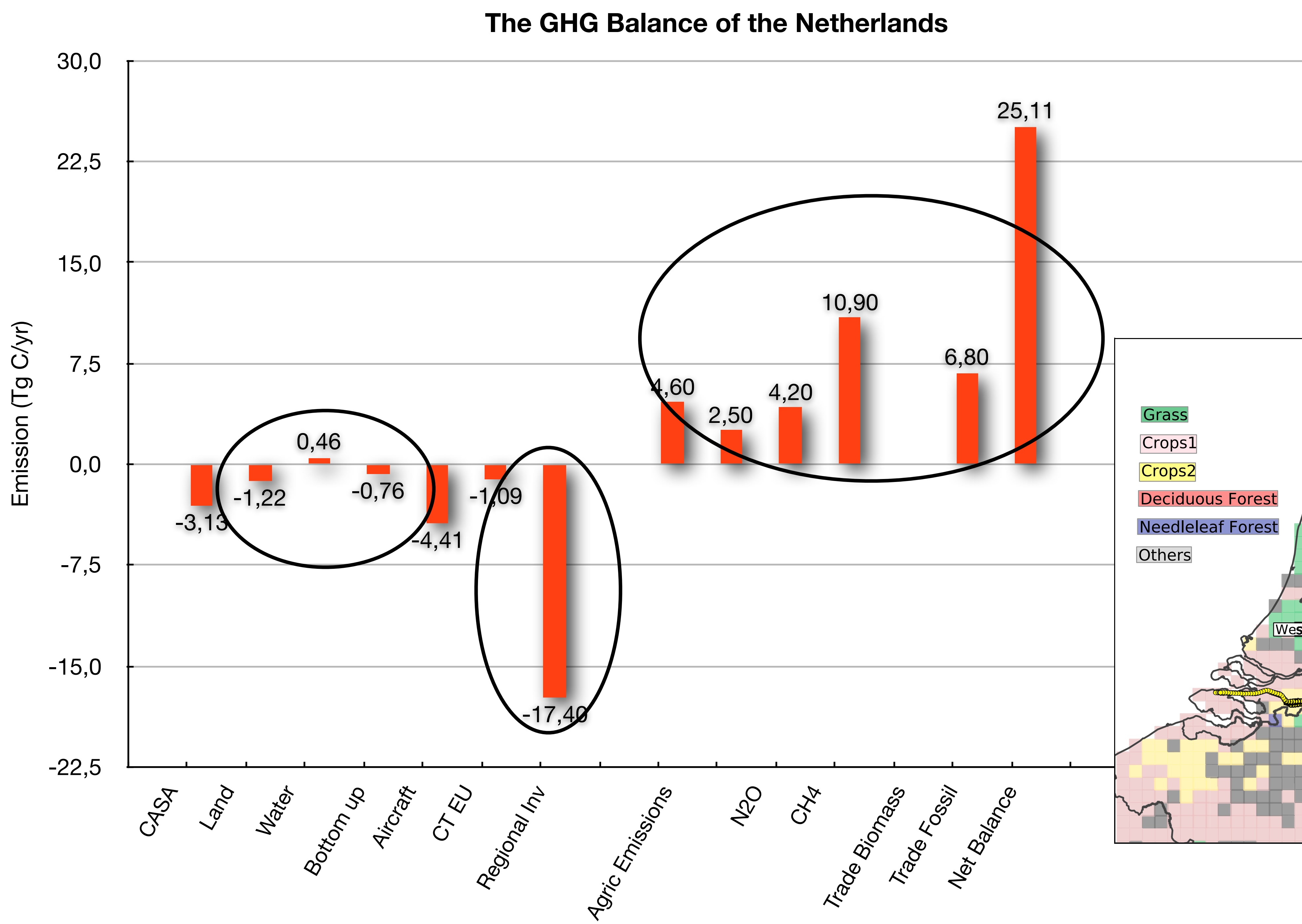


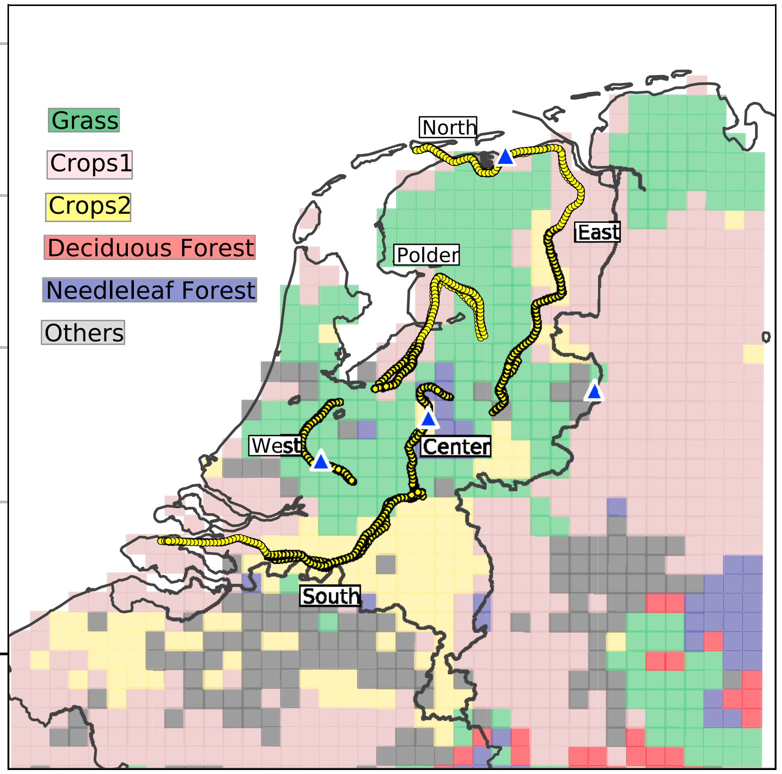
6 ecoregions
pixel and parameter inversion
ensemble Kalman filter
comparison with aircraft data



Meesters et al., 2012, JGR

Unclosed country scale balance





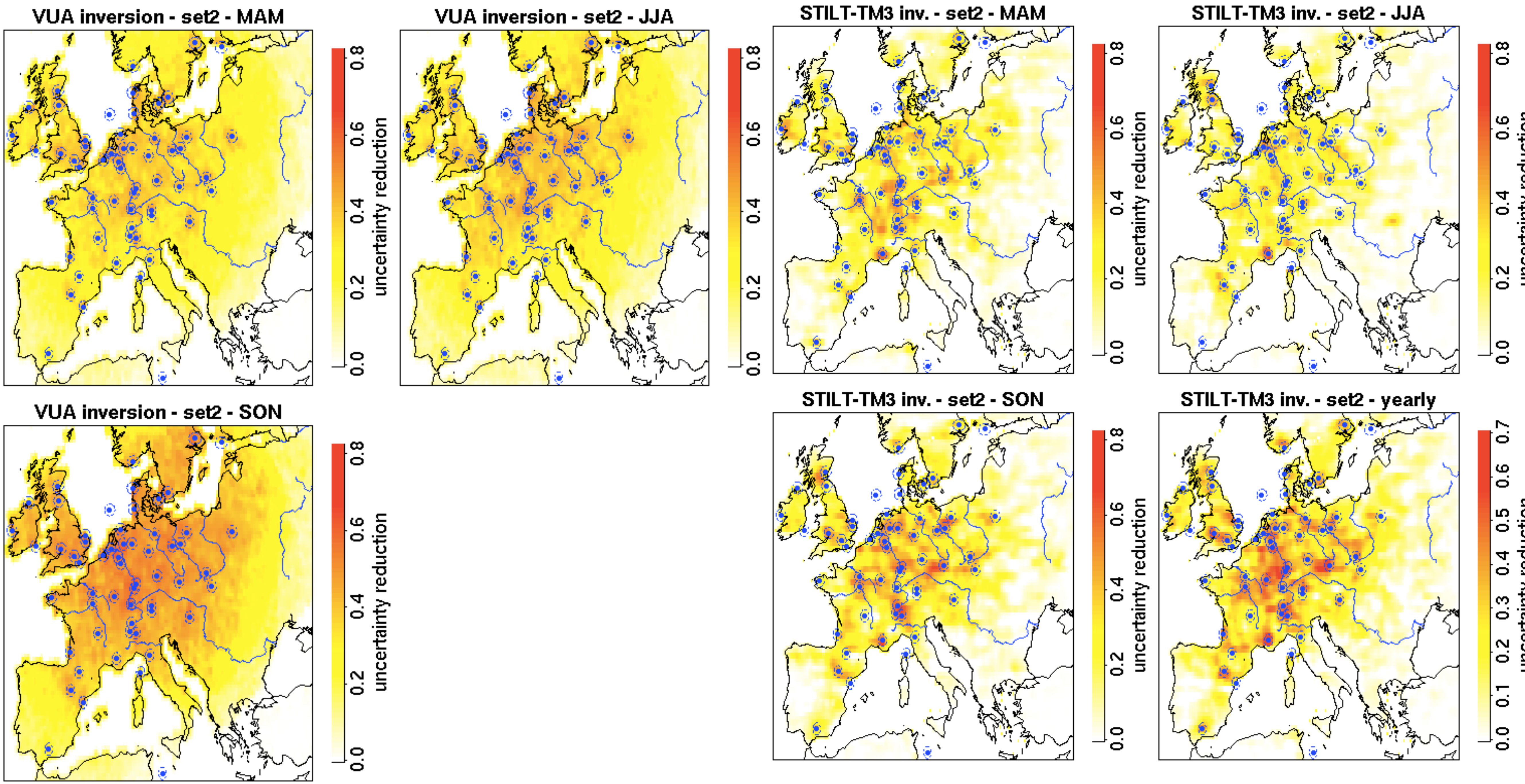
Trade date courtesy Glen Peters

Atmosphere: sources of error

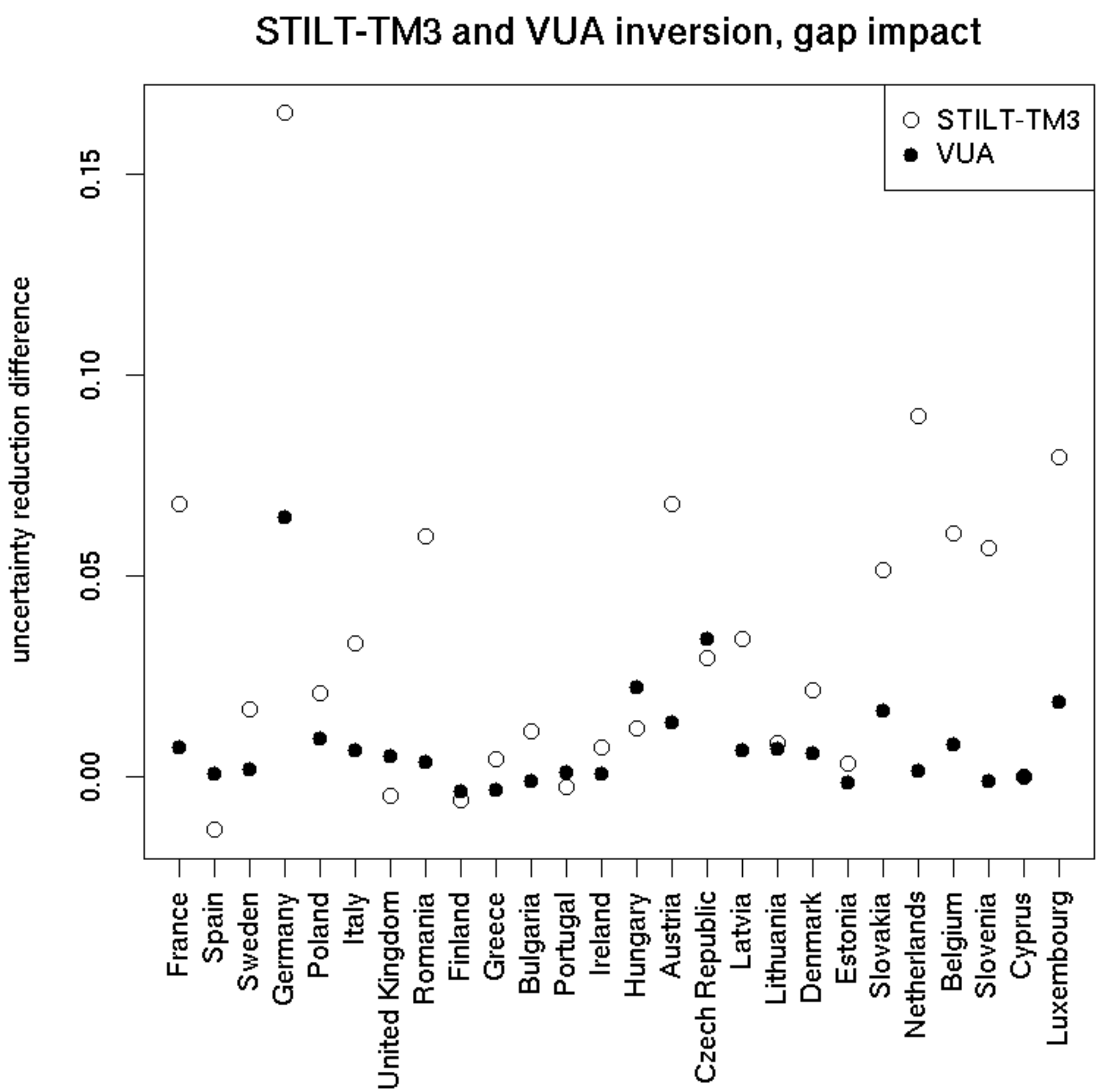
Source of uncertainty	Type or error	Size	Impact on observational strategy	Reference
Transport Model	Advection	~5 ppm (summertime)	avoid regions with complex flows	Lin and Gerbig, 2005
	PBL mixing	~3.5 ppm (summertime)	Vertical profiling, column observations	Gerbig et al., 2008
	Convection	No estimate		–
	Mesoscale processes	~2–3 ppm (summertime)	Avoid regions with mesoscale flows	Van der Molen and Dolman (2007), Tolk et al., 2008
Transport and Flux Model	Grid resolution	~1 ppm @ 200 km (summertime)	Choice of representative stations	Gerbig et al., 2003
Flux Model	Prior uncertainty	2-8 ppm*** (summertime)	network elements distributed according to prior uncertainties	P. Peylin, personal communicarion, 2008
	Aggregation	Depending on Aggregation and Model		Gerbig et al., 2006
Measurement	Precision, accuracy	0.1 ppm (targeted)	WMO	WMO

Gerbig et al., 2009

Mesoscale inversions



Uncertainty reduction at country scale

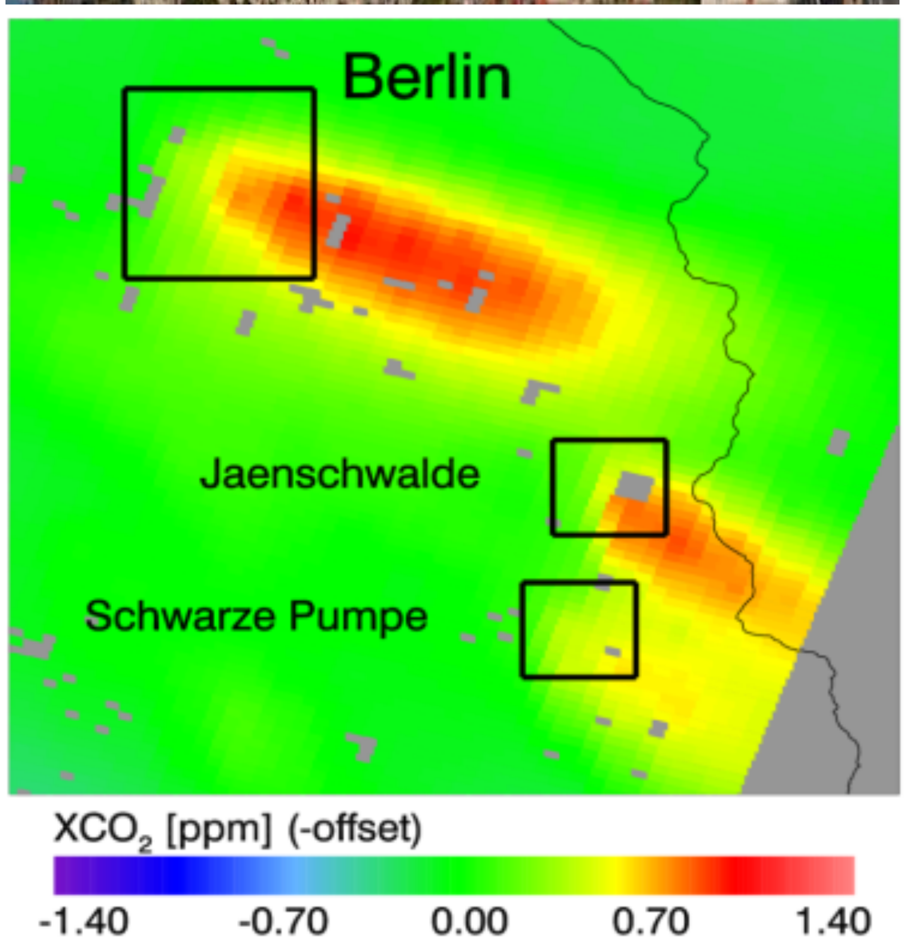


No “observations’ in Germany

Impact wider than just surrounding areas

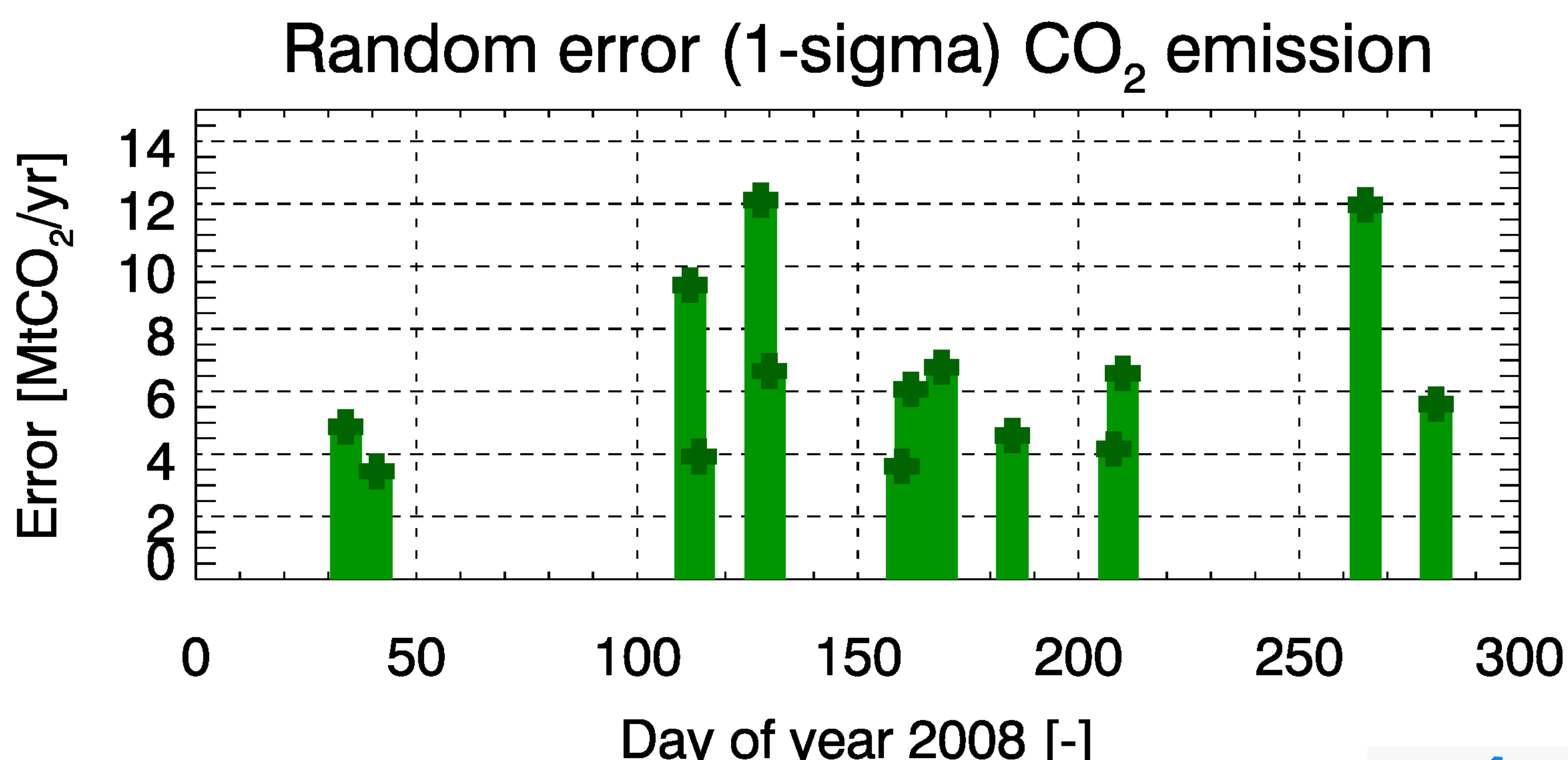
But also large model differences

Estimating CO_2 fluxes at local-scale

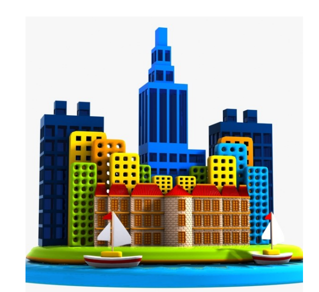


Berlin

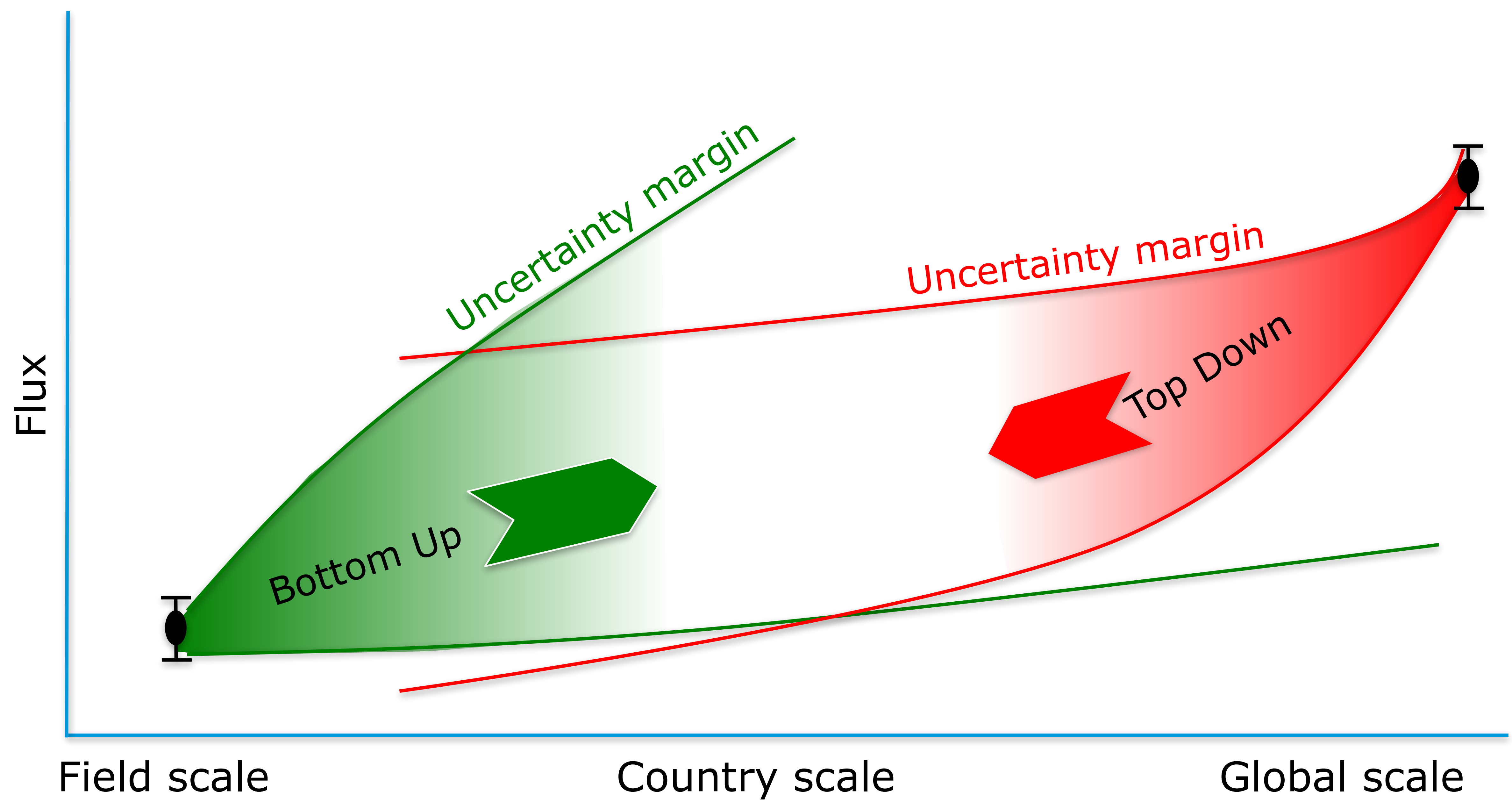
- Reported emission of 46 Mt CO_2 per year
- Targeted uncertainty 7 Mt CO_2/yr (single overpass estimate)



Bovensmann et al

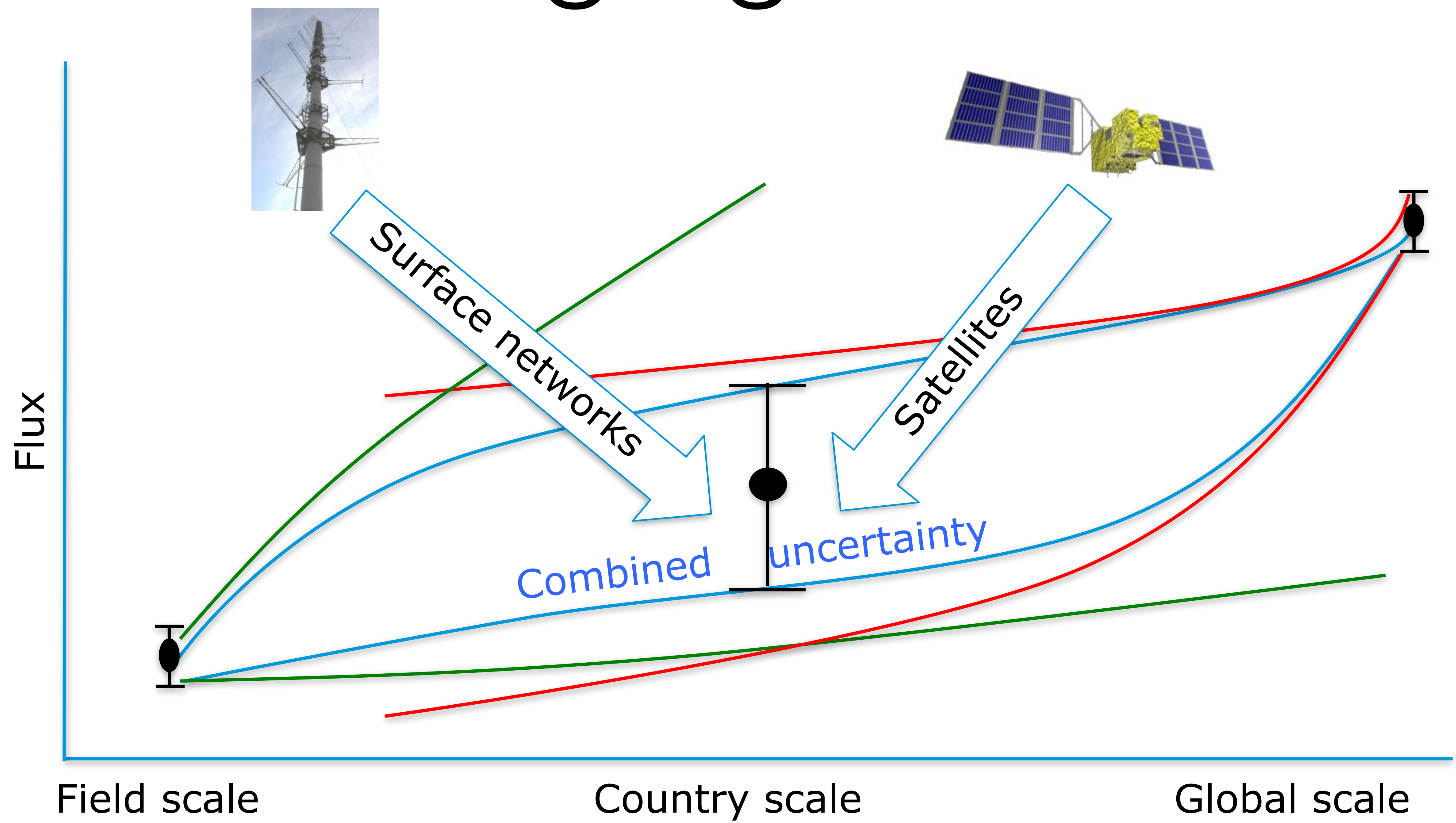


Bridging scales



Slide Sander Houweling

Bridging scales



Needs

- To be able to detect reductions in fossil fuel we need to refocus (observations, models)
    - Extend *in situ* observations through ICOS, and ^{14}C efforts and use in inversions models
    - Provide harmonised bottom up data for countries within Europe and outside
- Substantial errors in setup, *a priori* structure of the mesoscale inversions (very little real inversions)
    - Do HR mesoscale inversions (set up model inter comparisons à la Eurocom)
- At the country scale the uncertainties are enlarged, but this may provide the key to future development: e.g. VERIFY
    - Identify bottlenecks, uncertainties etc. through thorough analysis of bottom up and top down