Co-ordinated by ECMWF

CO_2 Human Emissions

THE EUROPEAN CO2 HUMAN EMISSION (CHE) PROJECT

A precursor to the Copernicus CO2 Service

Gianpaolo Balsamo

With contributions from Richard Engelen, Anna Agusti-Panareda, Joe McNorton, Nicolas Bousserez, Margarita Choulga and the CHE consortium

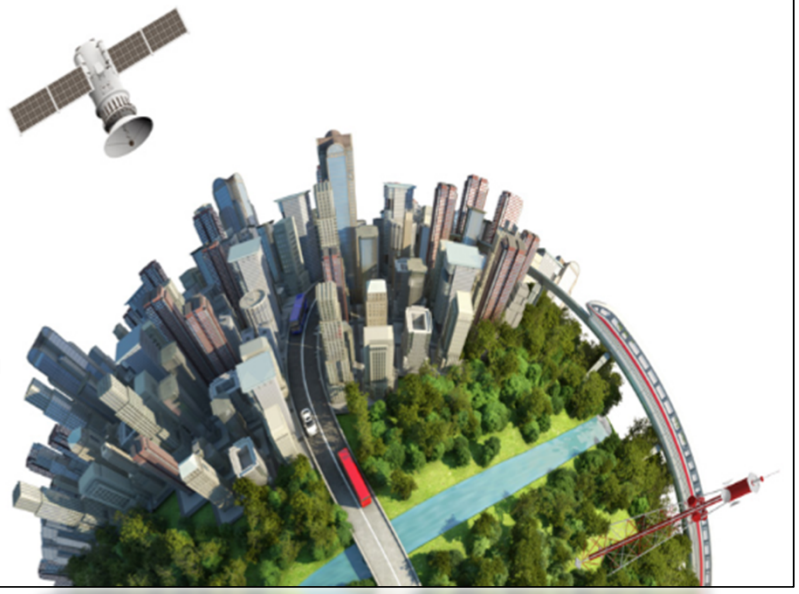
MONTREAL
16/7/2019 – International Surface Working Group #3

CHE-CO2 Human Emission Project (& its numbers)

Aim:
Build European monitoring capacity for anthropogenic CO_2 emissions

How:
CO_2 emission estimation system driven by Earth observations (remote sensing and in situ) combined with enhanced modelling system

Why:
To support the Paris Climate Agreement and its implementation



Project Duration:
39 month

Project Funding:
3.75 ME (1.25 ME/year)

Consortium Numbers
22 partners Institutes

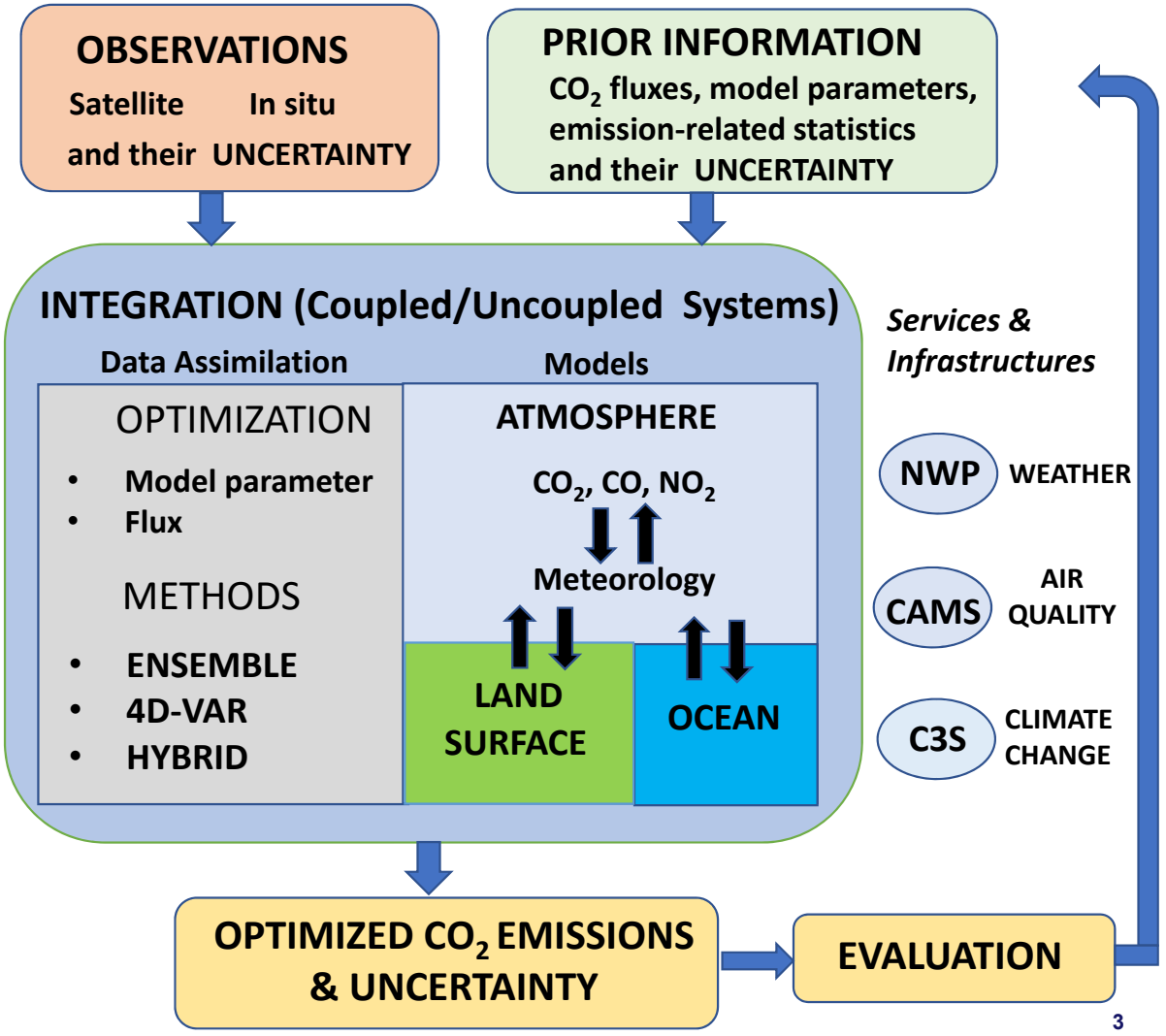
Work Content Numbers
7 work-packages:
5-Science development,
1-International liaison,
1-Management & Coms
7 Milestones
45 Deliverables

344.25 Person Month
(Eq 8.8 FTE)

3 Project Reviews
(M15, M27Tech, M39)

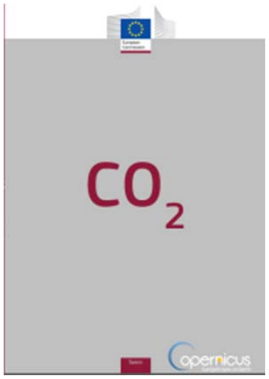
CHE System

1. **Protocols** of processing chain: from observations to inter-comparisons of methods and bottom-up/to-down estimates.
2. **Multiple scales** from global, national to plume scale (library of simulations)
3. **Uncertainty** estimation throughout processing chain
4. **Use of in situ observations and other co-emitting tracers to separate anthropogenic signal.**
5. Synthesis of results to design an **operational prototype**



Thanks to Anna Agusti-Panareda

High Level Requirements for CHE System



Accuracy

200-400 ton/year

km & daily scales

Space & Time Resoltuion

1.Detection of emitting hot spots such as megacities or power plants.

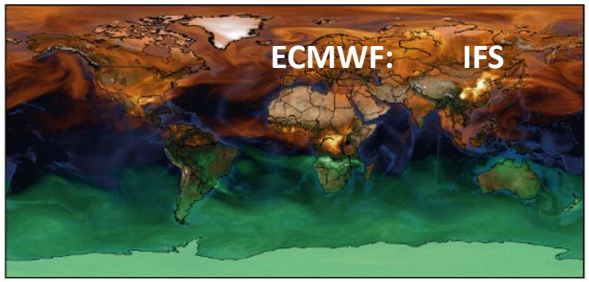
2.Monitoring the hot spot emissions to assess emission reductions/increase of the activities.

3.Assessing emission changes against local reduction targets to monitor impacts of the NDCs.

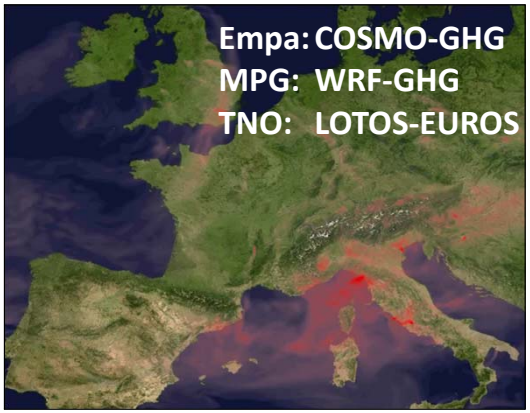
4.Assessing the national emissions and changes in 5-year time steps to estimate the global stock take.

Embracing multi-scale, from local to global

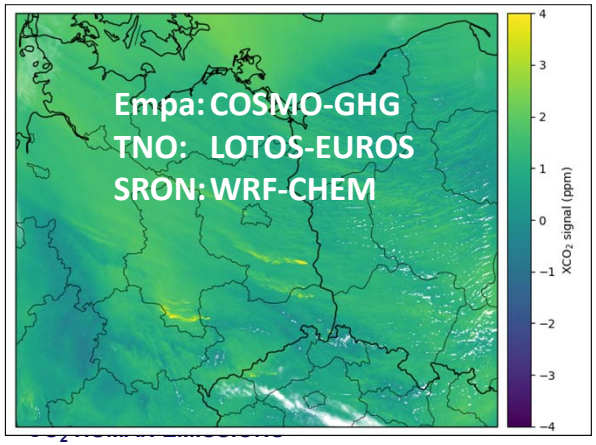
Global **~ 9km** resolution, ECMWF



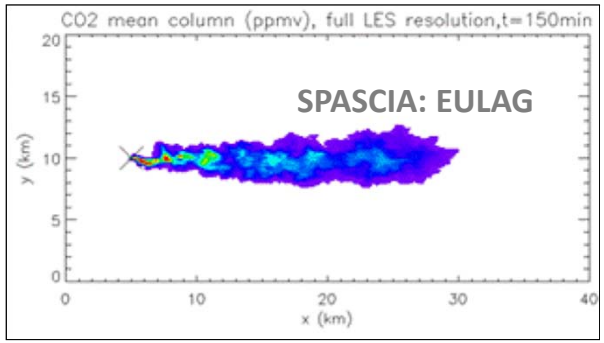
Europe ~ 5 km, Empa, TNO, MPG



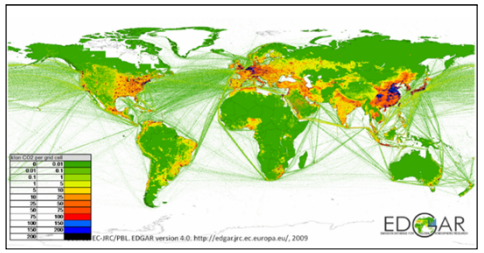
Regional ~ 1 km, Empa, TNO, SRON

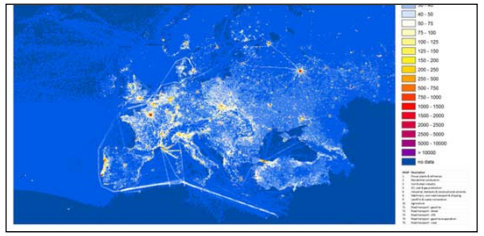


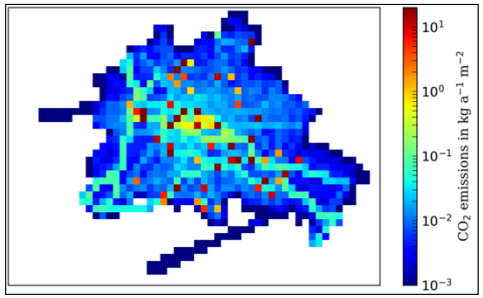
Point source ~ 100 m, SPASCIA



Global, Regional City emissions

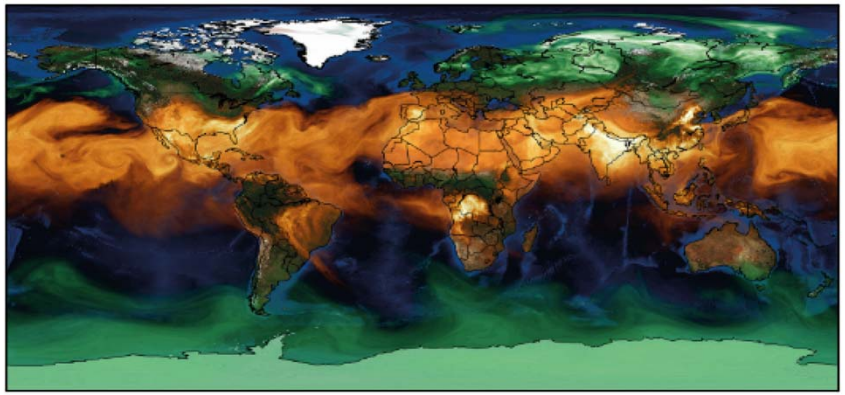


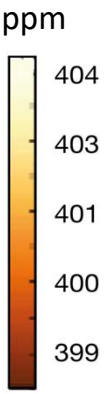




Reference global runs for CO_2 linking with VERIFY

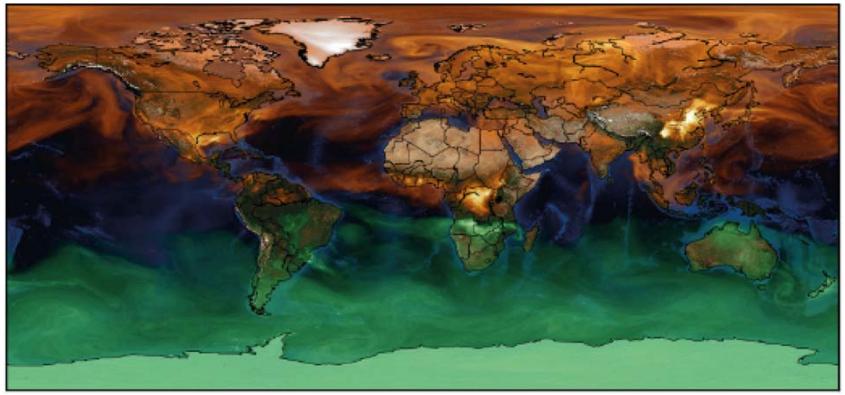
15 Jan 2015

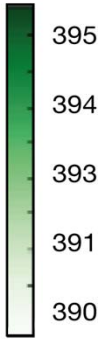




Above global mean

15 Jul 2015





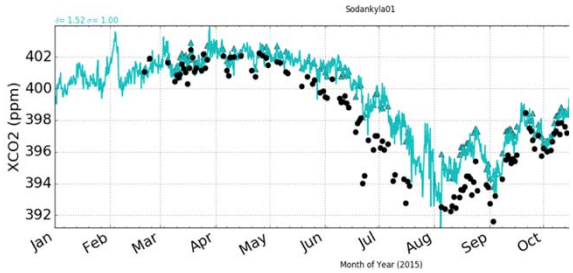
Below global mean

*CO_2 concentration from global runs on **9 km 3-hourly** . For 2015 freely available from CHE project website.*

https://www.che-project.eu/news/che-tier-1-co2-global-nature-run

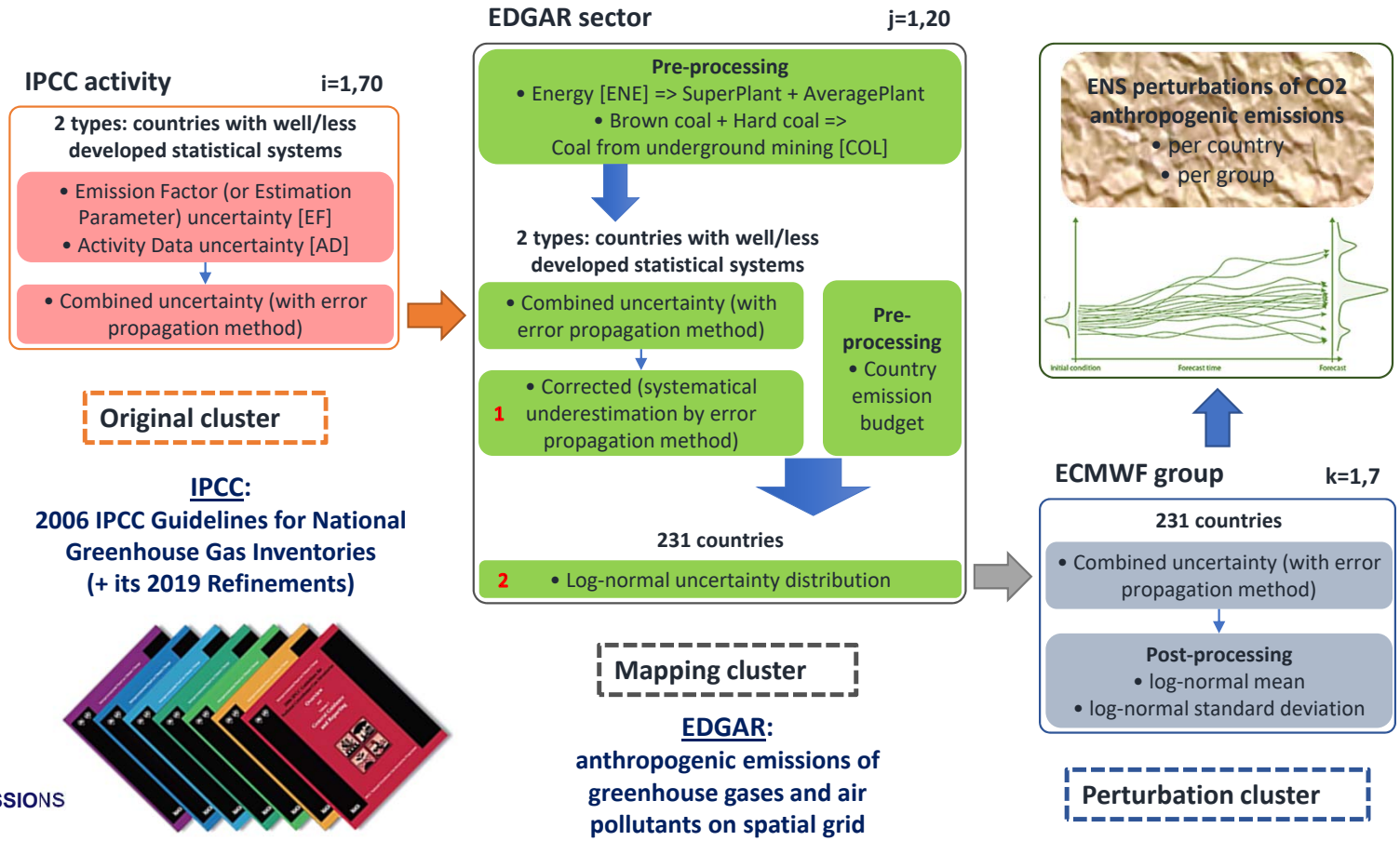
CO_2 HUMAN EMISSIONS

CO_2 concentration at Sodankyla (Finland)



Thanks to Anna Agusti-Panareda

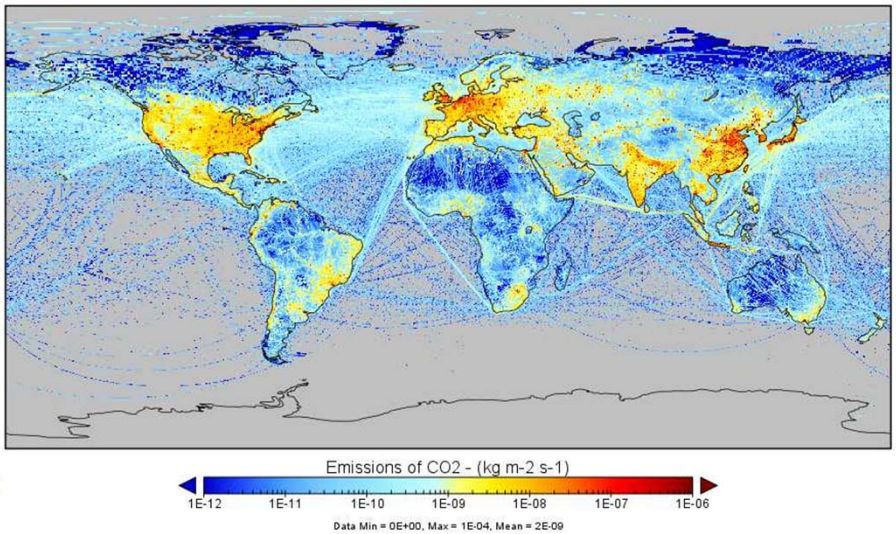
IPCC data chain & consolidation CHE

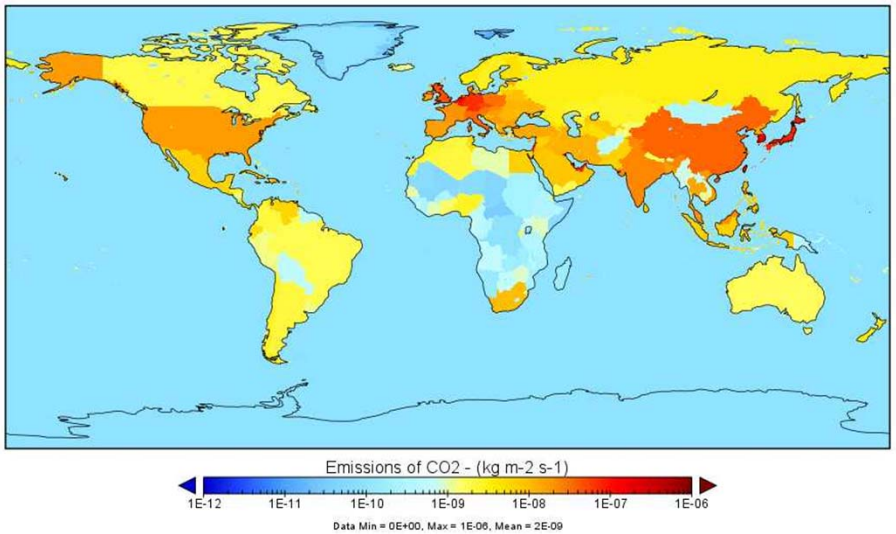


Thanks to Margarita Choulga

CHE Outlook: Are we able to detect large CO2 emission changes?

Experiment	Nationally Aggregated Emissions	Resolved Emissions
Standard	None	All
Smoothed	All	None
Smoothed_excl_sp	All Except Super Power Stations	Super Power Stations
Smoothed_excl_pp	All Except Energy Sector	Energy Sector

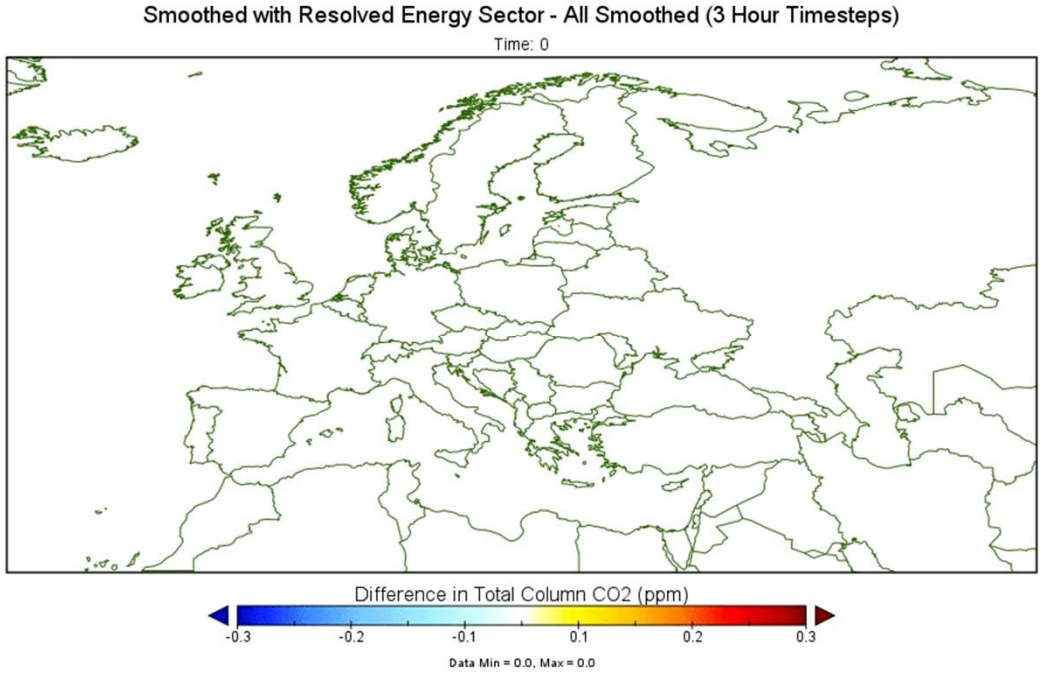


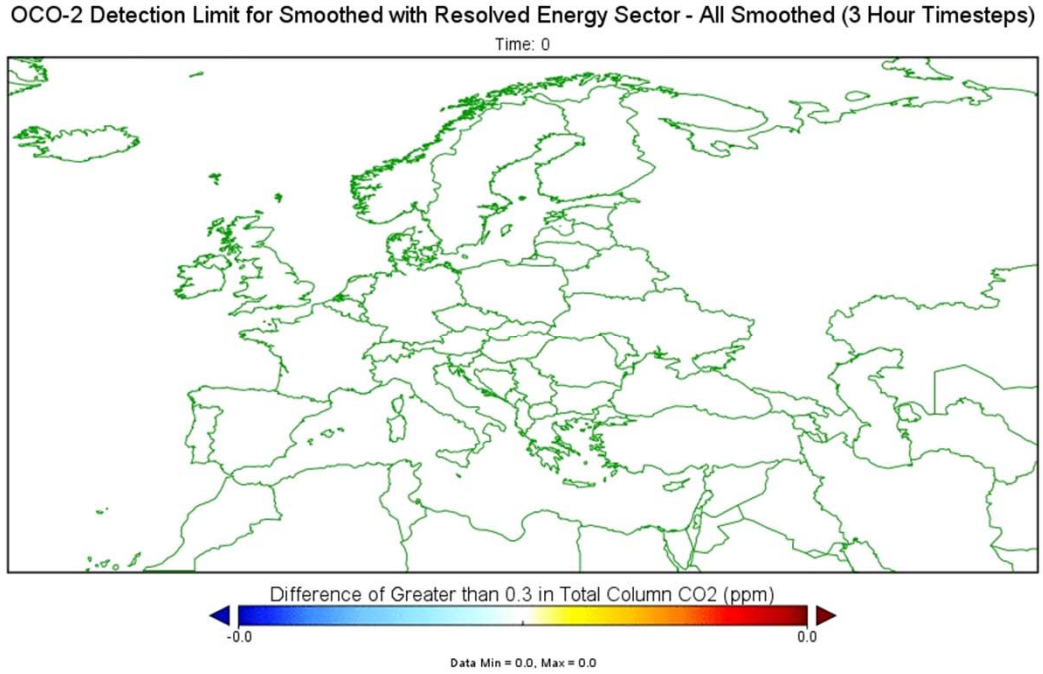


Sensitivity to point source power stations (Europe)

Spatially resolved power stations generate local area differences, beyond emission points of over 5 ppm in the 25km model.

Several plumes are detectable using 0.3 ppm as a threshold, that have a lifetime of over 1 day.



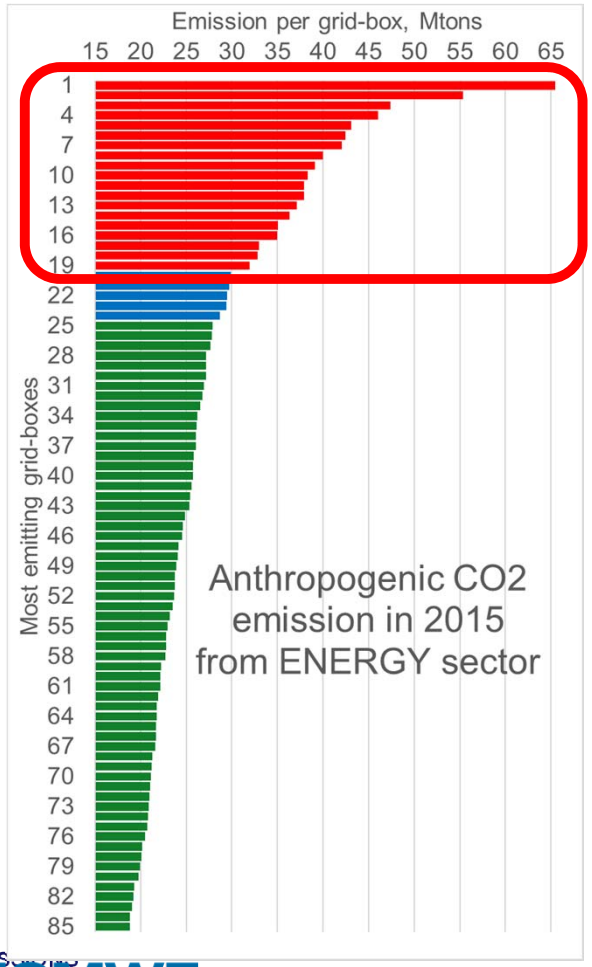


Thanks to Joe McNorton, Margarita Choulga, Nicolas Bousserez

Focusing on energy “super-power” plants

Check of the super emitting points helped to spot country mask inaccuracies!

(Kuwait – ENE budget was 10 times less as it should be)

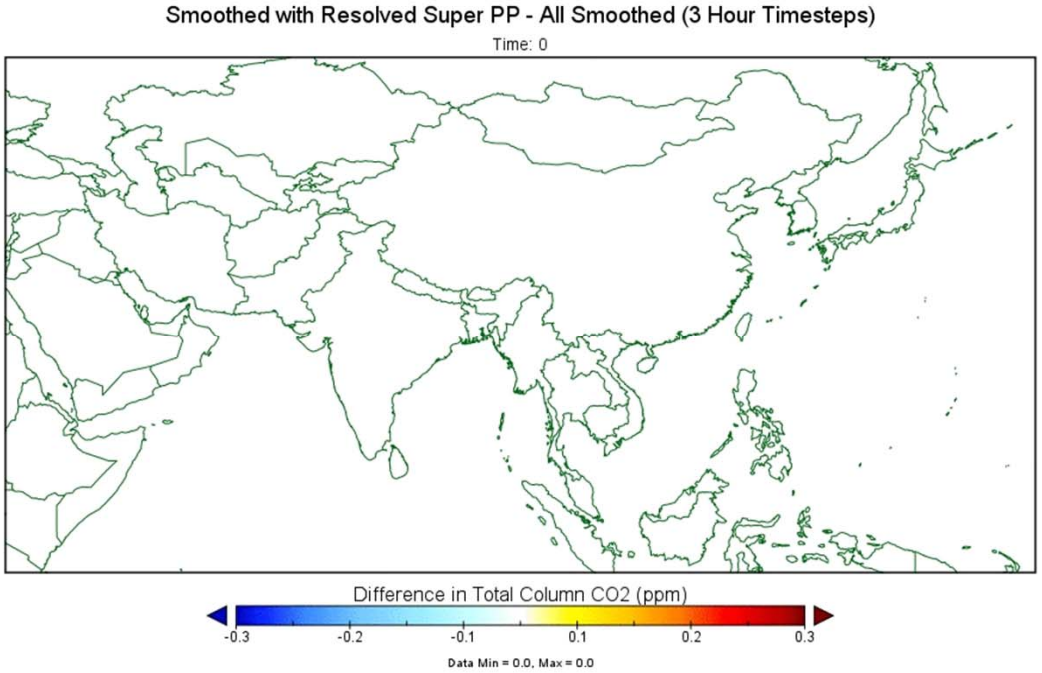


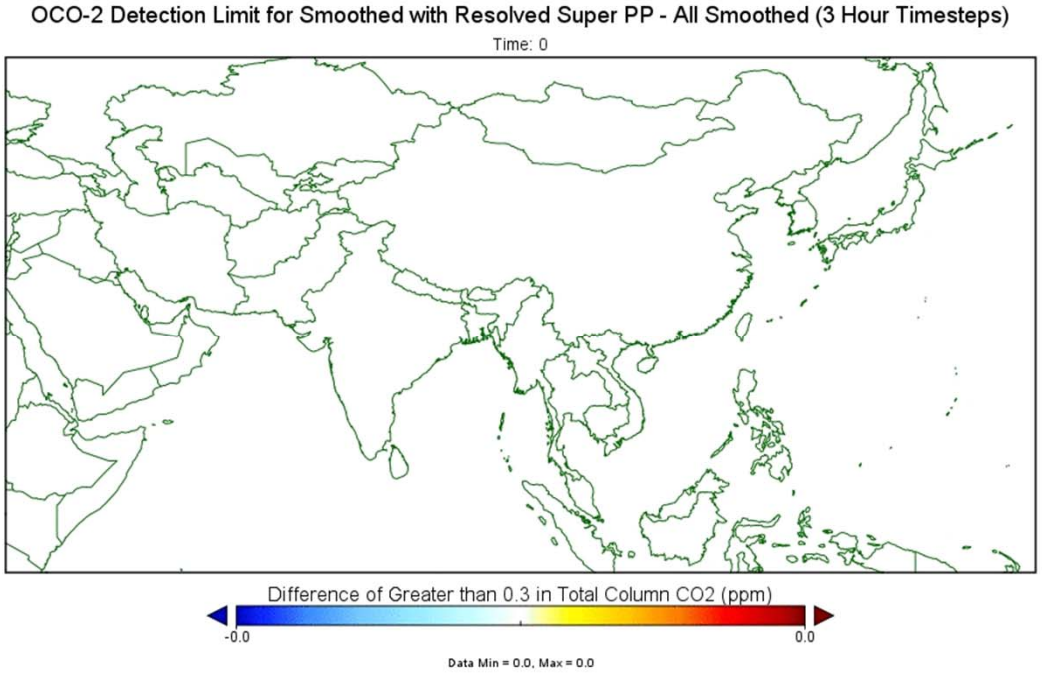
Based on step in emissions per grid-box in 2015 TXT emission file for EDGAR Power industry (ENE) sector the top 19 most emitting ones were used - values > 30 Mtons/year as clustered/labelled as “super-power plants”

Rank	Latitude, º	Longitude, º	CO2 emission 2015, Mtons	Country totals, Mtons
1	24.2	120.4	65.5	Taiwan [TWN] 65.5
13	31.2	120.5	37.1	China [CHN] 37.1
2	55.9	37.7	55.3	Russia [RUS] 188.7
3	60.3	28.6	47.4	
4	55.7	52.4	46,0	
8	54.7	20.5	40.0	
5	24.1	82.7	43.1	India [IND] 220.8
9	11.5	79.4	39.1	
12	24.0	82.6	37.9	
16	21.9	83.4	35.0	
17	22.3	82.6	33.0	
18	21.0	85.0	32.8	
6	36.7	126.2	42.5	Korea [KOR] 112.7
10	36.8	126.6	38.3	
19	37.7	128.1	32.0	
7	-26.2	29.1	42.0	South Africa [ZAF] 42.0
11	35.4	139.6	38.0	Japan [JPN] 38.0
14	29.4	48.2	36.4	Kuwait [KWT] 36.4
15	-32.3	150.9	35.0	Australia [AUS] 35.0
Total	**5.7 % of global ENERGY sector**			

Sensitivity to point source for “super-power” stations (Asia)

Spatially resolved super power stations generate local differences over 1 ppm in the 25km model.
These differences are expected to be larger at increased model resolution.
The detection limit of 0.3 ppm is reached at grid boxes local to the source and plumes are detectables.

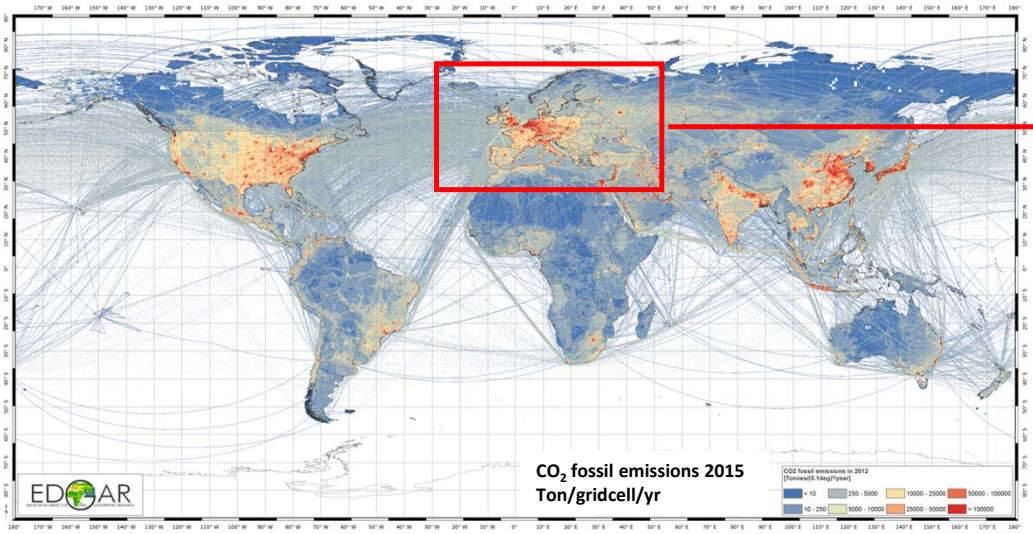




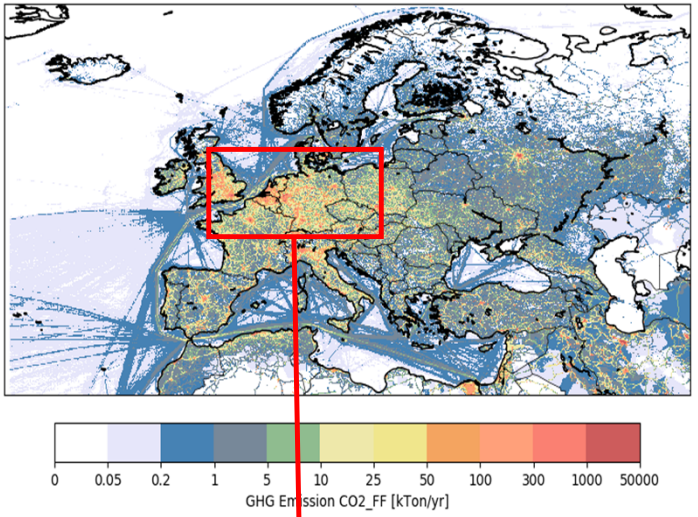
Thanks to Joe McNorton, Margarita Choulga, Nicolas Bousserez

High-resolution anthropogenic CO_2 emission inventories for different scales for 2015 and 2030

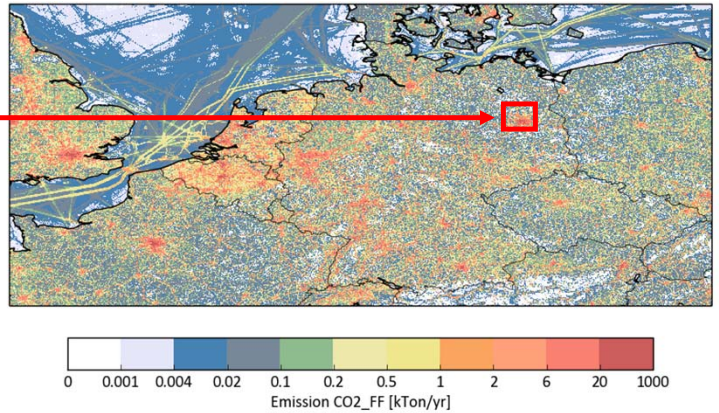
EDGARv4.3.2 Global 0.1° x 0.1°



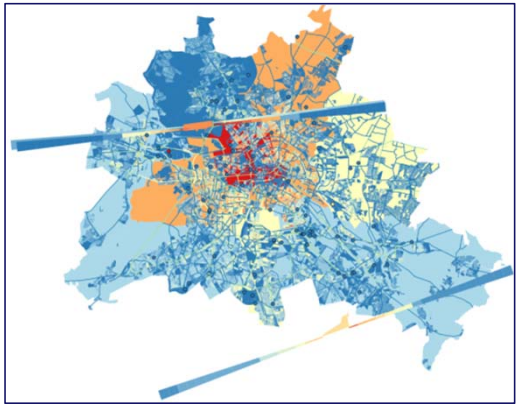
TNO-GHGco Europe, approx. 6 km x 6 km



TNO-GHGco zoom: approx. 1 km x 1 km

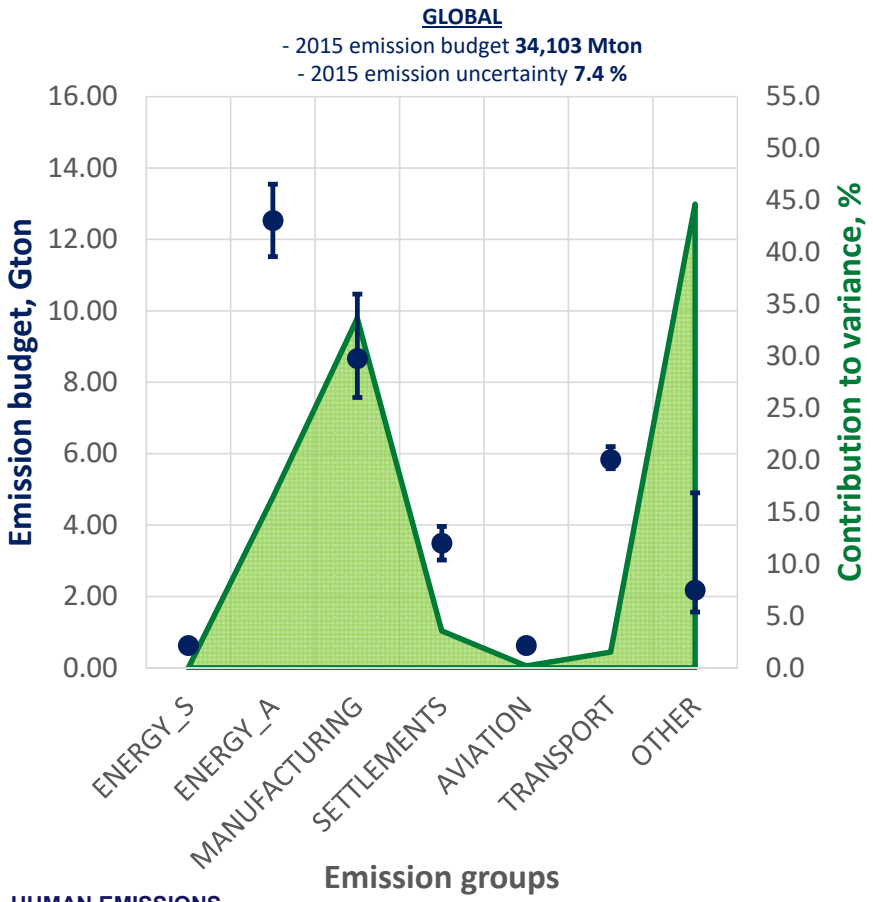


Senate of Berlin
point, area + line sources
at 1 km x 1 km



Thanks to Jean-Matthieu Haussaire et al.

CO2 Human Emissions global budget for 2015



Gr. №	Group name	Note	E-s, Mton
1	**ENERGY_S**	**Power industry** - super emitting power plants	**13,704**
2	**ENERGY_A**	**Power industry** - average emitting power plants	
3	MANUFAC-TURING	**Combustion for manufacturing**	**6,183**
		Iron and steel production	234
		Non-ferrous metals production	91
		Non energy use of fuels	10
		Non-metallic minerals production	
		Chemical processes	
4	SETTLE-MENTS	**Energy for buildings**	**3,322**
		Solvents and products use	61
		Solid waste incineration	137
5	AVIATION	Aviation cruise	815
		Aviation climbing&descent	
		Aviation landing&takeoff	
6	TRANS-PORT	**Road transportation**	**5,530**
		Shipping	819
		Railways, pipelines, off-road transport	255
7	OTHER	Agricultural soils	99
		Oil refineries and Transformation industry	1,917
		Fuel exploitation	258
		Coal production	48

Thanks to Greet Maenhout and Margarita Choulga, Source: JRC EDGAR Team

Connecting CO_2 Inventories to Ensemble simulations (local)

Initial Concentration
Informed from high resolution (~9km) nature simulation

CHE Emissions
Perturbed inventory estimates based on uncertainties

Meteorology transport
Introduce tracers to current EPS framework

Perturbed Ensemble Simulations

Three simulation types:

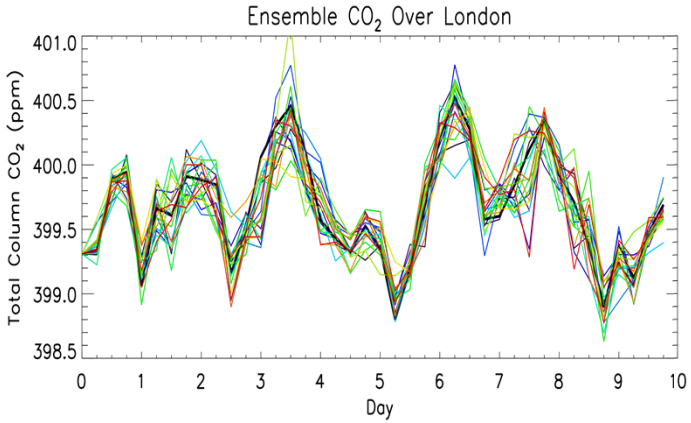
Meteorology	Emissions	Resulting Information
Perturbed	Fixed	Transport Error
Fixed	Perturbed	Transport Jacobian
Perturbed	Perturbed	Transport Jacobian with Noise

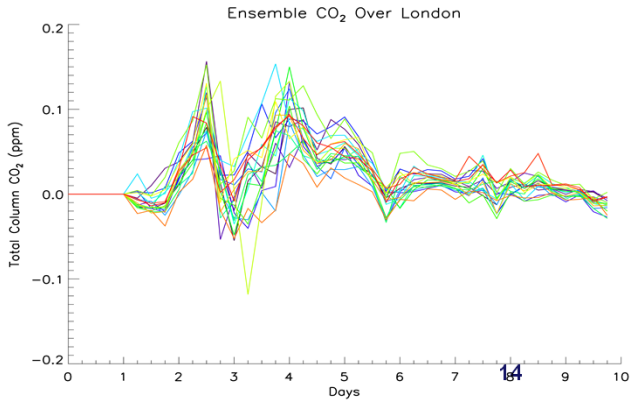
Ensemble-based Inversion System
Test multiple inversion systems to estimate sector/national posterior fluxes

Example of ensemble spread over London:

Fixed anthropogenic emissions and perturbed meteorology

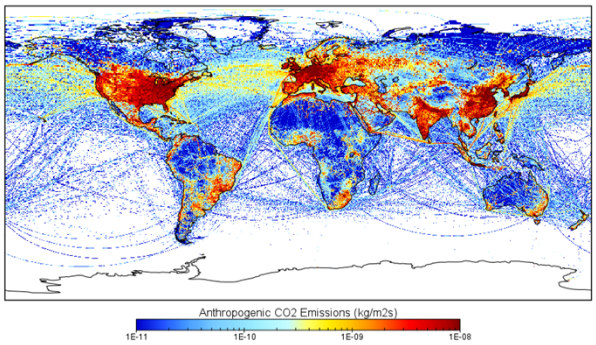
Fixed Meteorology and perturbed emissions



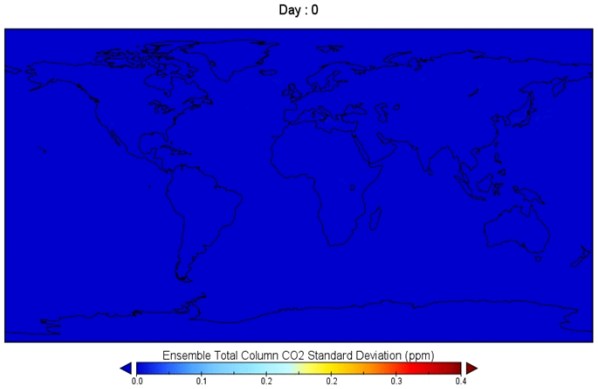


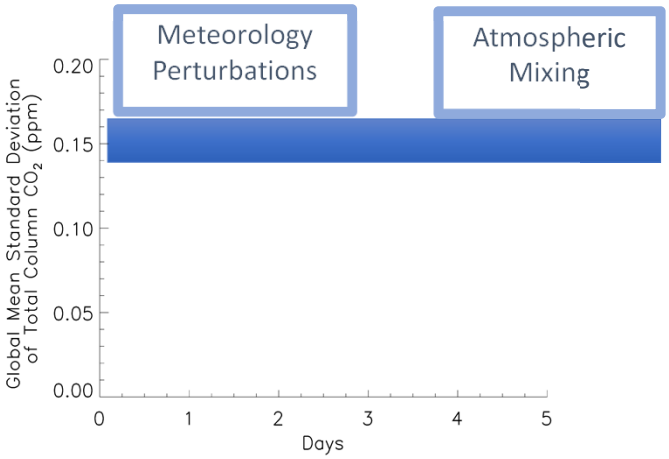
Thanks to Joe McNorton, Margarita Choulga, Nicolas Bousserez

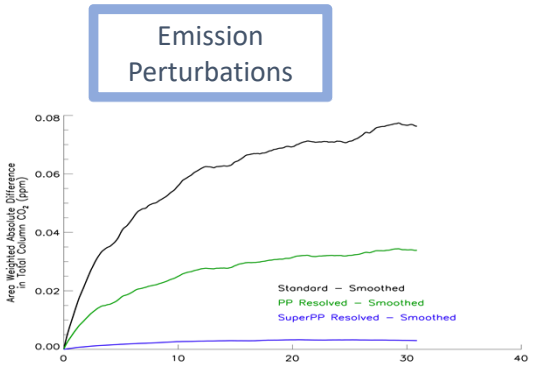
Connecting CO_2 Inventories to Ensemble simulations (global)



Starting from EDGAR Emissions and CAMS Atmospheric concentrations the first Ensemble simulations have been realised



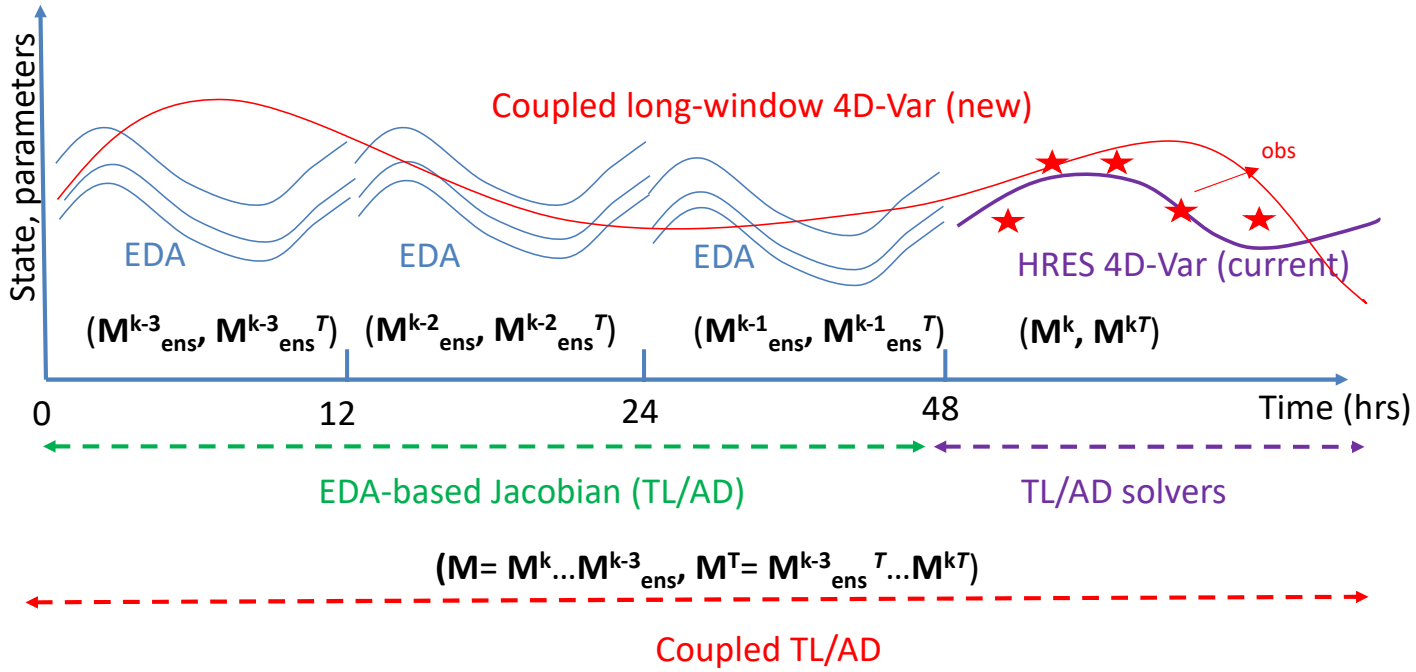




Model error spread takes ~2 days to spin-up. Emissions error spread ~30 days (from initial tests, 10% err)

Thanks to Joe McNorton, Margarita Choulga, Nicolas Bousserez

Ensembles Data Assimilation/Coupled 4D-Var for CO_2



- Same EDA-based least-square approximation of the transport Jacobian $\mathbf{M}^{k-i}_{ens}$ and same trajectory used at each outer-iteration (transport is linear).
- Emission posterior error covariances updated for each long-window 4D-Var cycle using Hessian information (Ritz pairs)→use only observations from current 12hrs 4D-Var window.
- Ability of the EDA-based system to propagate sensitivities depends on the degree of overlapping between EDA members across 4D-Var windows→requires testing.

Thanks to Nicolas Bousserez

CHE summary

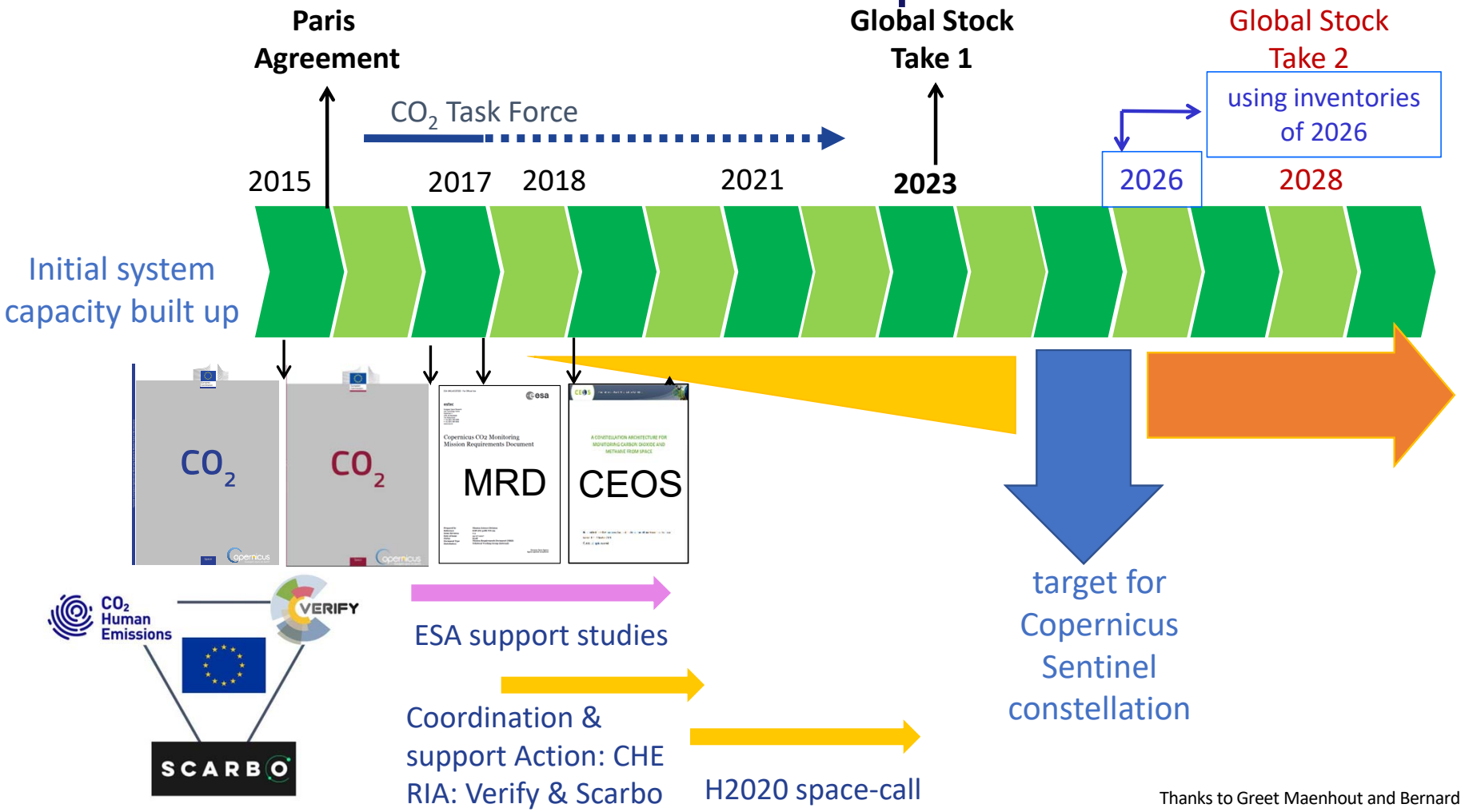
CO_2 Human Emission estimation using Earth Observations requires enhancing existing mapping modelling and data assimilation capabilities.

CHE project builds on existing infrastructure and expertise in Europe (C3S and CAMS) with a strong consortium and links to the wider scientific community.

CHE aims at integrating CO2 Monitoring into Coupled Earth System Modelling and Data Assimilation at global kilometre-scale resolutions.

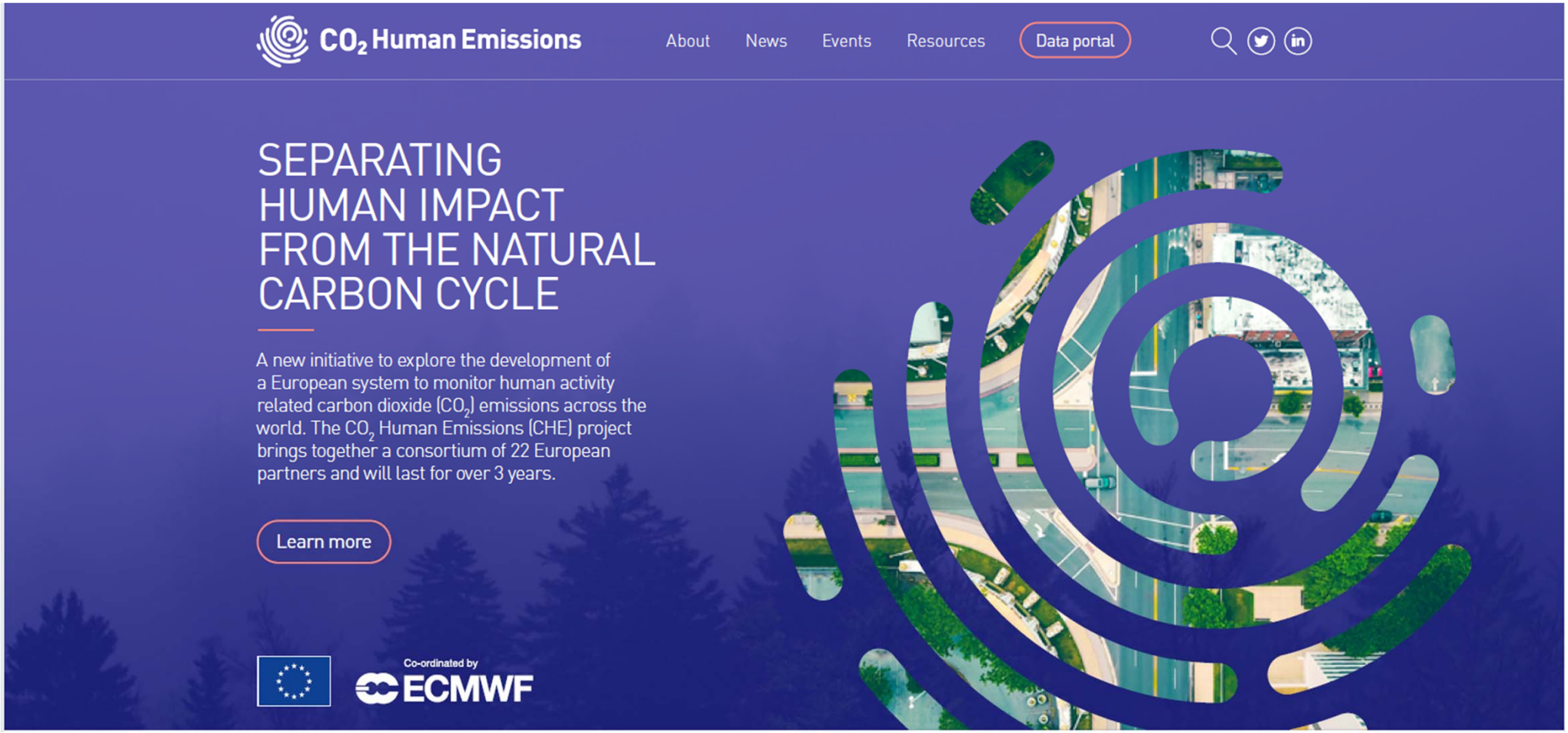
CHE will provide a further strong motivation to improve Land surface LSM/LDAS including Anthropogenic aspects (urban areas).

CHE outlook towards a Copernicus CO2 Service

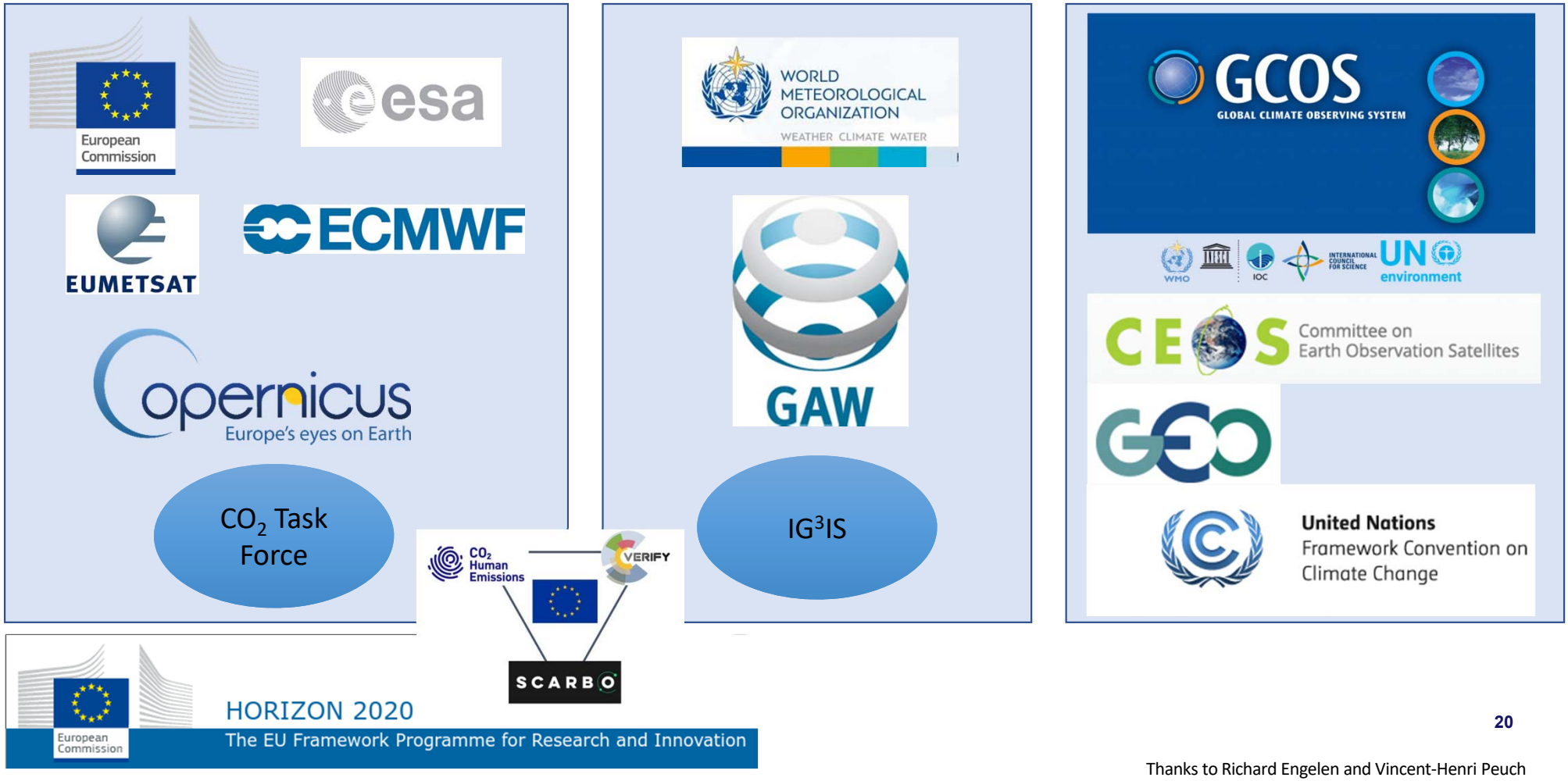


Thanks to Greet Maenhout and Bernard Pinty

Learn more about CHE on https://www.che-project.eu



CHE actors and governance framework



Thanks to Richard Engelen and Vincent-Henri Peuch