Co-ordinated by ECMWF

CO2 Human Emissions

CO2 HUMAN EMISSIONS

Synthesis of results 2018-2020 & next steps

Gianpaolo Balsamo, for CHE coordination

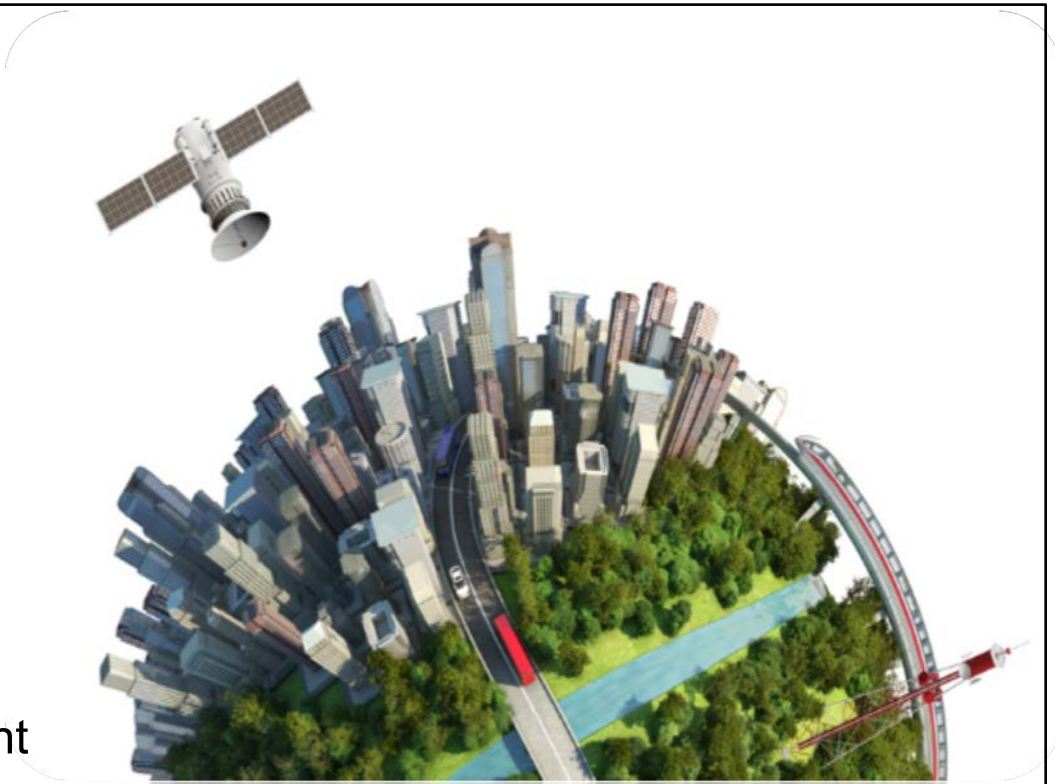
10.9.2020 ESA-CCI Coloc 2020

CHE project (2017 - 2020) – Month 35 of 39 ☺

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



ECMWF AIRBUS CMCC DLR Empa EUMETSAT iLab European Commission cea
Lund University NILU SPASCIA SRON ThalesAlenia Space TNO innovation for life UEA University of Leicester Wageningen University & Research

Project Duration:
39 month (35)

Project Funding:
3.75 M€ (1.25 M€/year)

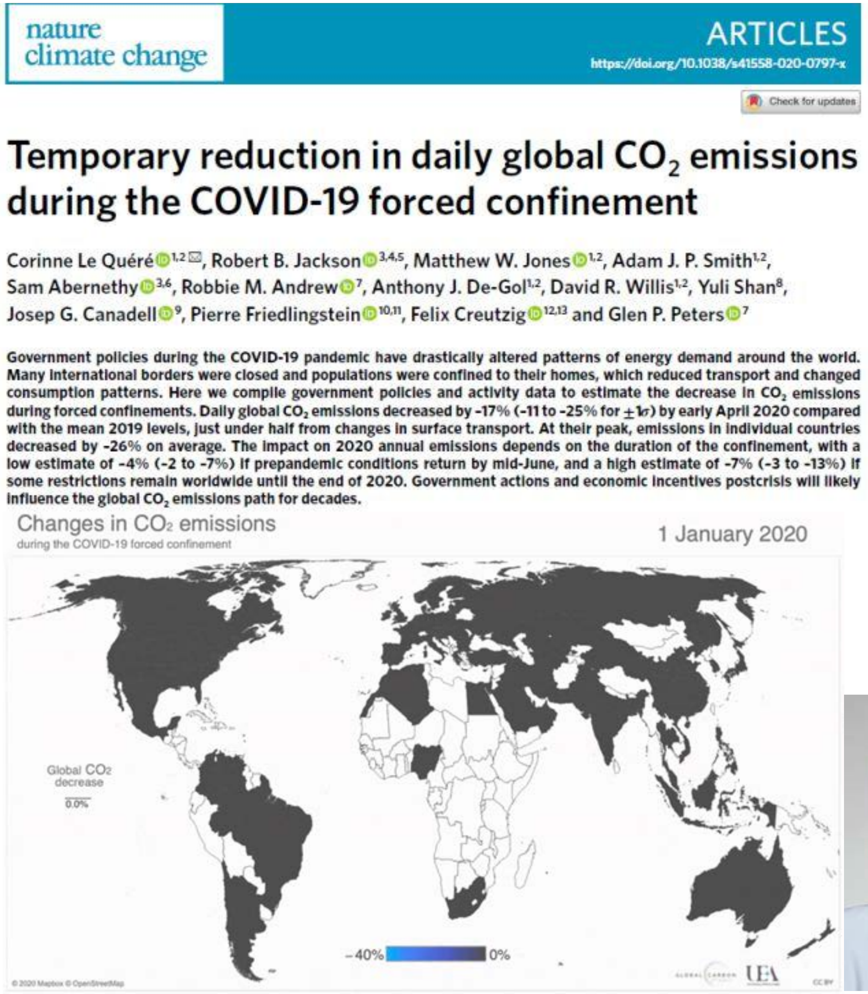
Consortium Numbers
22 partners Institutes

Work Content Numbers
7 work-packages:
5-Science development,
1-International liaison,
1-Management & Coms
7 Milestones (6)
45 Deliverables (29)

344.25 Person Month
(Eq 8.8 FTE)

CHE efforts…both a Sprint & a Marathon…

Already about 10 publications within CHE, documenting efforts on CO_2 monitoring & verification progress: short-term & long-term


nature climate change

ARTICLES

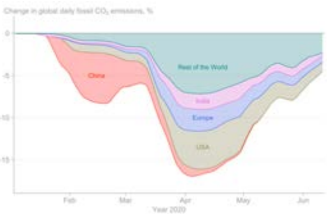
https://doi.org/10.1038/s41558-020-0797-x

Check for updates

Temporary reduction in daily global CO_2 emissions during the COVID-19 forced confinement

Corinne Le Quéré[1,2], Robert B. Jackson[3,4,5], Matthew W. Jones[1,2], Adam J. P. Smith[1,2], Sam Abernethy[3,6], Robbie M. Andrew[7], Anthony J. De-Gol[1,2], David R. Willis[1,2], Yuli Shan[8], Josep G. Canadell[9], Pierre Friedlingstein[10,11], Felix Creutzig[12,13] and Glen P. Peters[7]

Government policies during the COVID-19 pandemic have drastically altered patterns of energy demand around the world. Many international borders were closed and populations were confined to their homes, which reduced transport and changed consumption patterns. Here we compile government policies and activity data to estimate the decrease in CO_2 emissions during forced confinements. Daily global CO_2 emissions decreased by –17% (–11 to –25% for $\pm1\sigma$) by early April 2020 compared with the mean 2019 levels, just under half from changes in surface transport. At their peak, emissions in individual countries decreased by –26% on average. The impact on 2020 annual emissions depends on the duration of the confinement, with a low estimate of –4% (–2 to –7%) if prepandemic conditions return by mid-June, and a high estimate of –7% (–3 to –13%) if some restrictions remain worldwide until the end of 2020. Government actions and economic incentives postcrisis will likely influence the global CO_2 emissions path for decades.




BAMS

ISSUES EARLY ONLINE RELEASE COLLECTIONS FOR AUTHORS ABOUT

Article Contents

Abstract

Footnotes

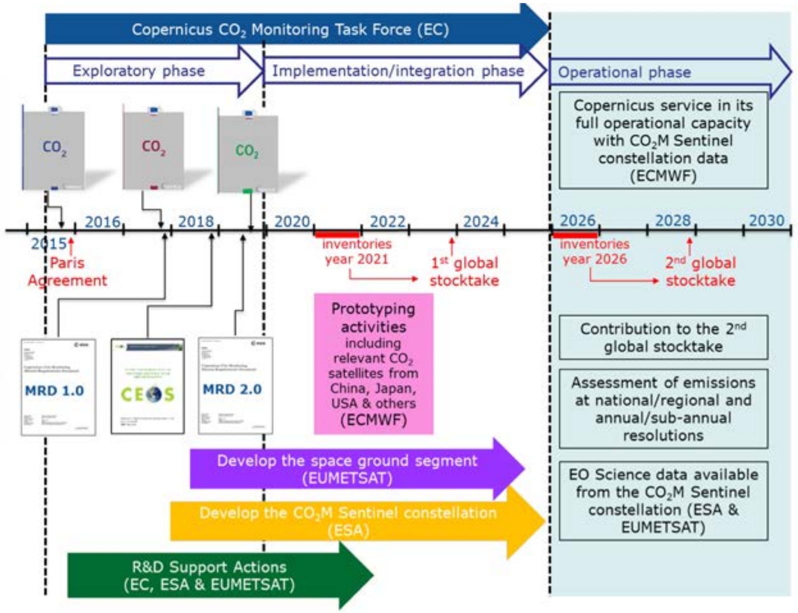
RESEARCH ARTICLE | 10 FEBRUARY 2020

Towards an operational anthropogenic CO_2 emissions monitoring and verification support capacity

G. Janssens-Maenhout; B. Pinty; M. Dowell; H. Zunker; E. Andersson; G. Balsamo; J.-L. Bézy; T. Brunhes; H. Bösch; B. Bojkov D. Brunner; M. Buchwitz; D. Crisp; P. Ciais; P. Counet; D. Dee; H. Denier van der Gon; H. Dolman; M. Drinkwater; O. Dubovik; R. Engelen; T. Fehr; V. Fernandez; M. Heimann; K. Holmlund; S. Houweling; R. Husband; O. Juvyns; A. Kentarchos; J. Landgraf; R. Lang; A. Löscher; J. Marshall; Y. Meijer; M. Nakajima; P.I. Palmer; P. Peylin; P. Rayner; M. Scholze; B. Sierk; J. Tamminen; P. Veefkind

Bull. Amer. Meteor. Soc. (2020)

https://doi.org/10.1175/BAMS-D-19-0017.1

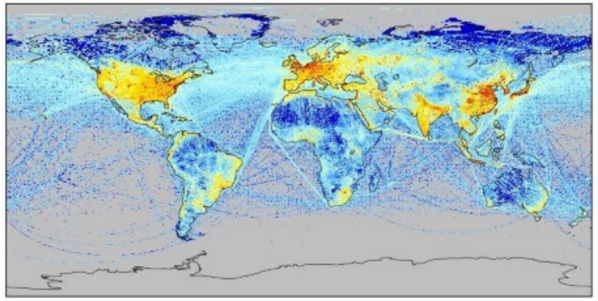


Global system based on ECMWF IFS

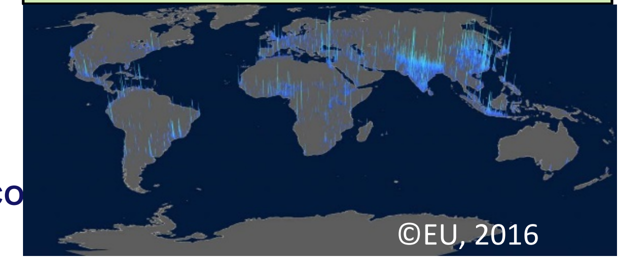
INPUT DATASETS

IFS FORECAST MODEL & DATA ASSIMILATION

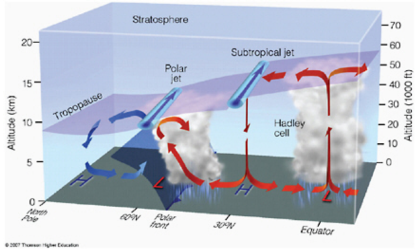
EMISSION INVENTORIES WITH TEMPORAL/VERTICAL PROFILES & UNCERTAINTIES (JRC EDGAR,TNO/BSC, CAMS81)



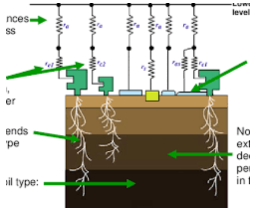
VEGETATION & URBAN MAPS (ESA-CCI, JRC GHSL)
OCEAN FLUXES (CMEMS)

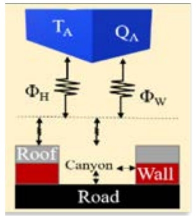


IFS ATMOSPHERIC TRANSPORT

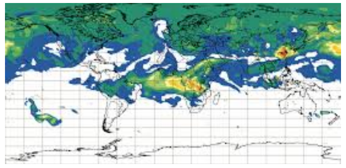


URBAN & VEGETATION MODEL, LAND SURFACE DATA ASSIMILATION

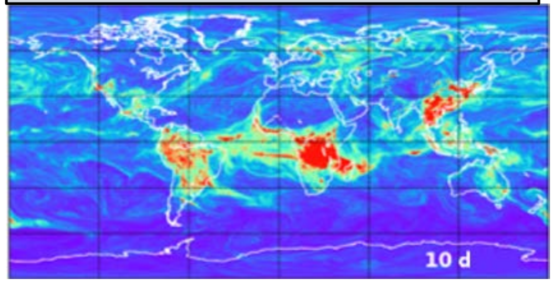




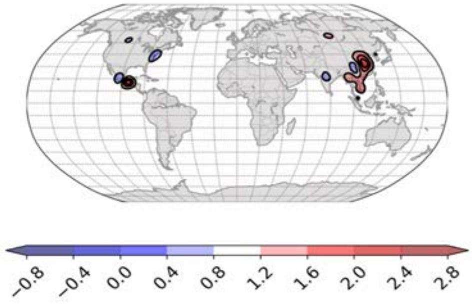
CAMS REACTIVE SPECIES (NOx, CO, CH4)



ENSEMBLE APPROACH (uncertainty propagation)



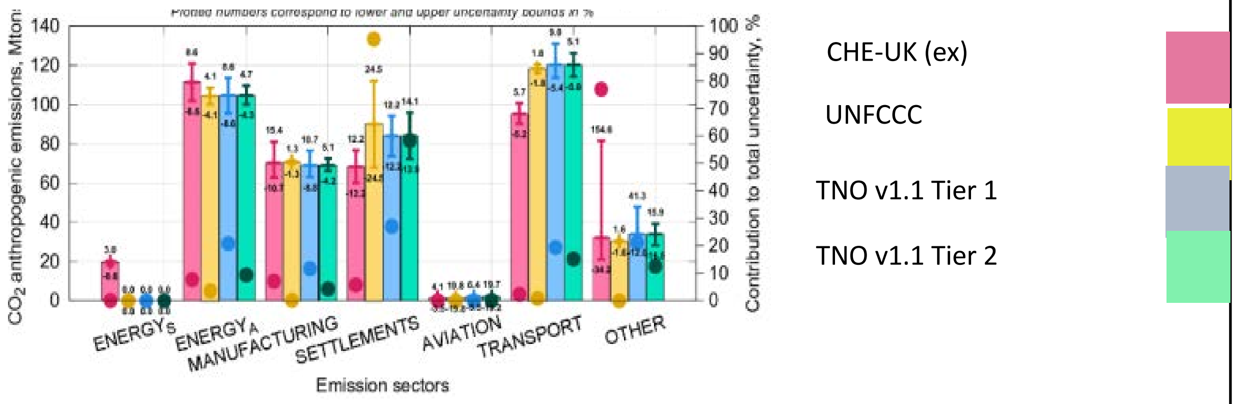
4DVAR ATMOSPHERIC ANALYSIS & INVERSION CAPABILITY



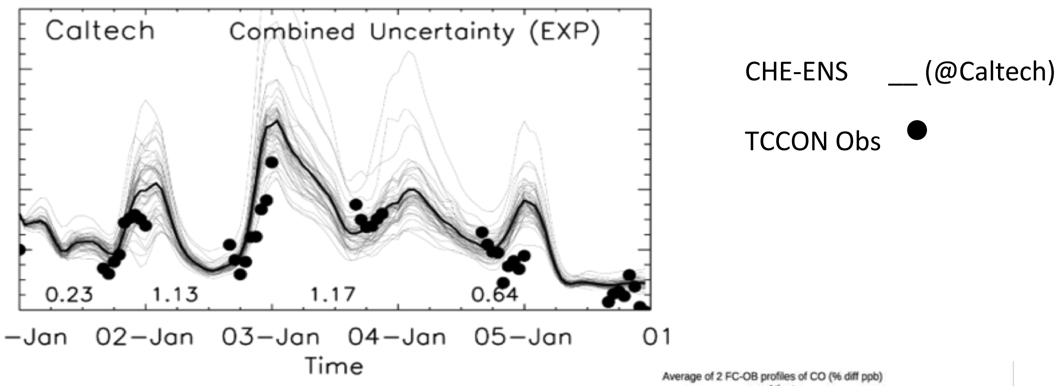
Thanks to Anna Agusti-Panareda ECMWF

CHE: 3 achievements to prepare the Global- MVS

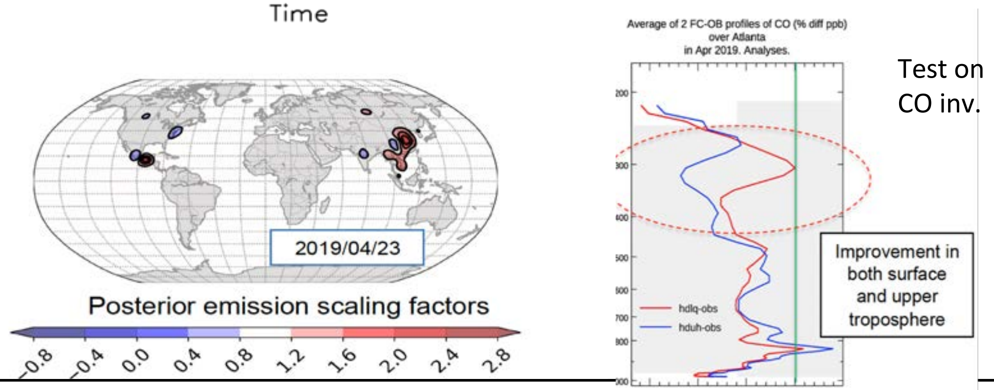
CO_2 Anthropogenic Sectors Mapping:
CO_2 Global Fossil-fuel emissions from
IPCC / UNFCCC / JRC-EDGAR
gridded & clustered in 7 groups for IFS
Choulga et al. 2020 (in discussion)



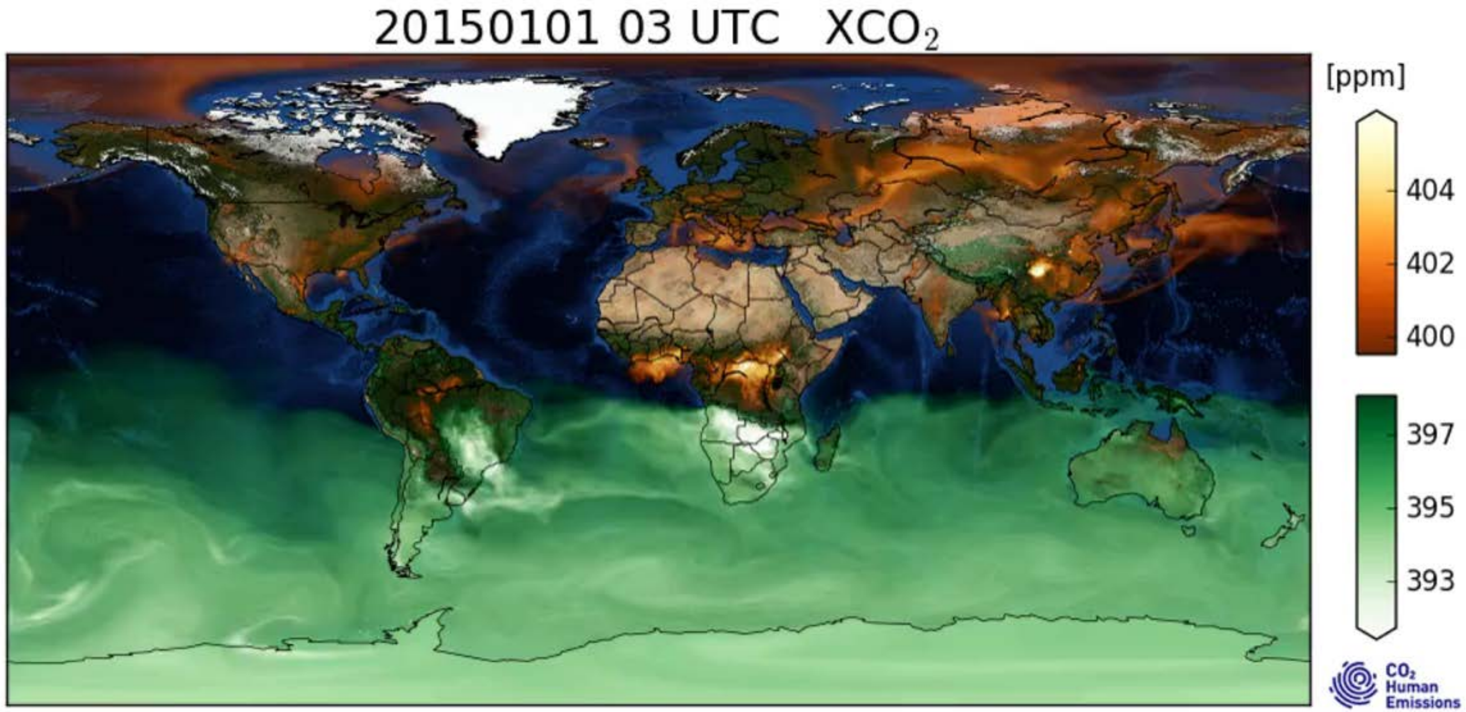
CO_2 Ensemble-based Modelling:
CO_2 emissions and concentrations
represented using HRES & ENS
to characterise Uncertainties
McNorton et al. 2020 (final accepted)
Agustì-Panareda et al. 2019, 2020 (in prep.)



CO_2 4D-Var-based Inversion:
Using the ACV infrastructure CO2
fluxes & concentration are corrected
Bousserez et al. 2020 (in prep.)



Global forecasts of CO_2 atmospheric values



User requirements from:

- EUMETSAT (S-4/-5)
- MicroCarb
- flight campaigns
- boundary conditions

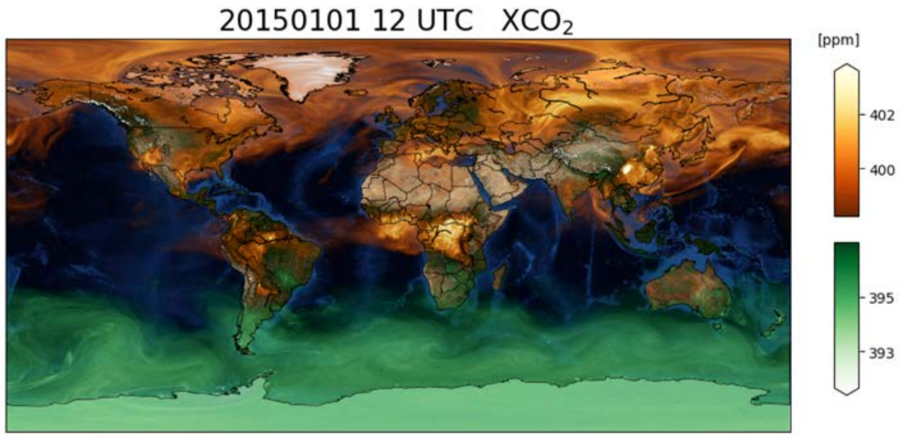
CO_2, CH_4, and linear CO at Tco1279 (~9km) L137 in ECMWF IFS

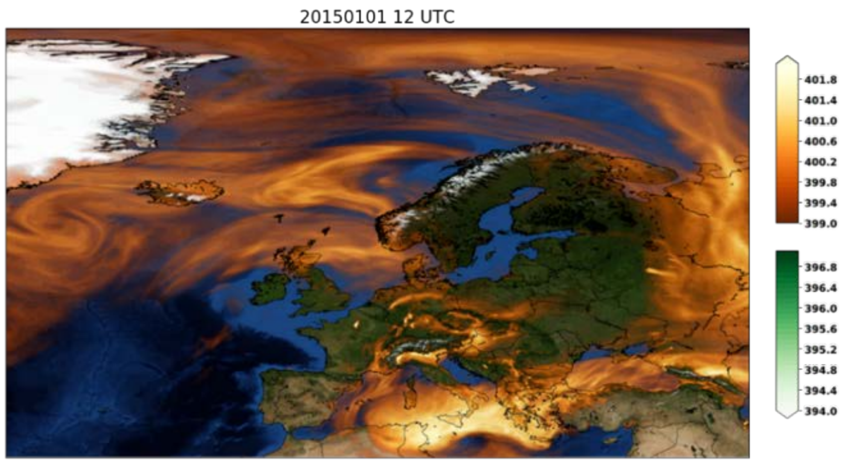
- CTESSEL NEE (+bias correction)
- EDGAR+CAMS81 anthropogenic emissions
- SOCAT Carbo-Scope, CMEMS ocean fluxes
- GFAS biomass burning
- IFS transport (Bermejo & Conde mass fixer)

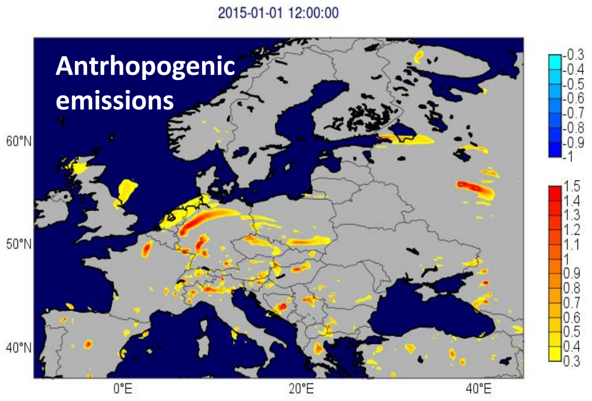
Developments are aligned with ECMWF's Earth system modelling strategy (e.g., strengthen IFS land surface modelling).

Thanks to Anna Agusti-Panareda ECMWF

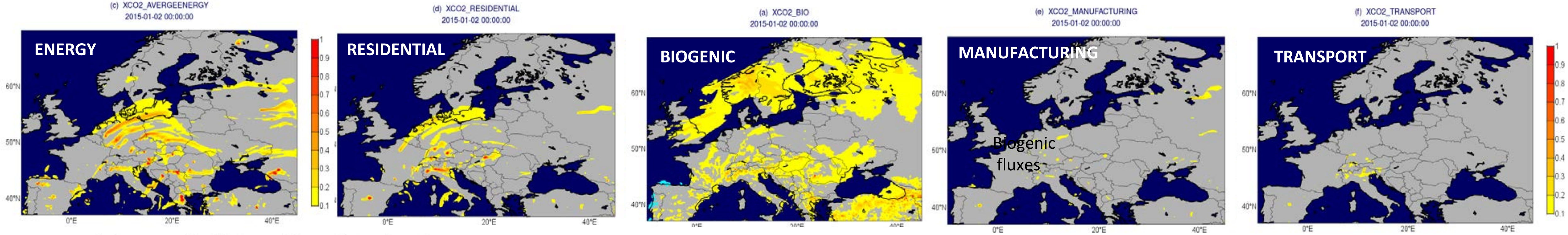
Global nature runs: tier-2 better than tier-1, biogenic show key role

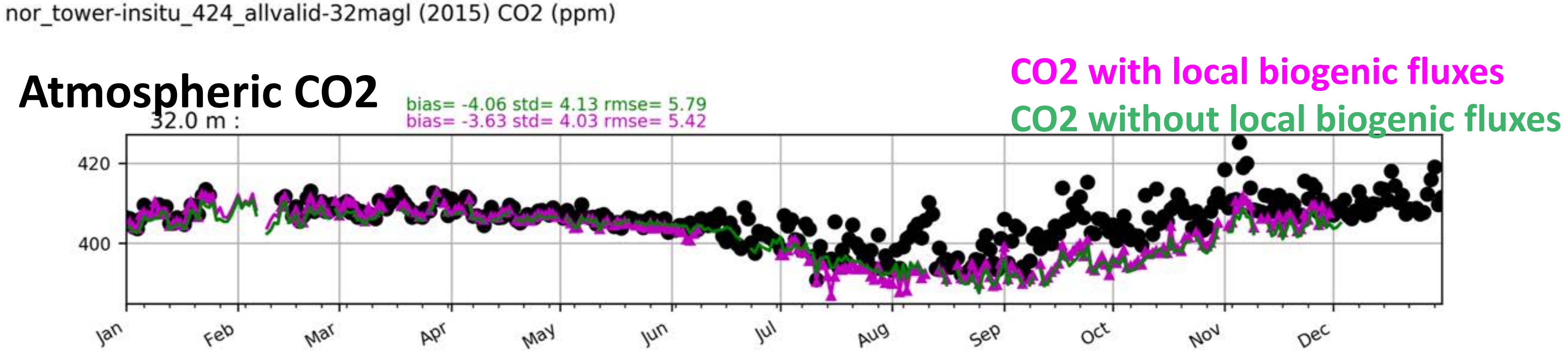


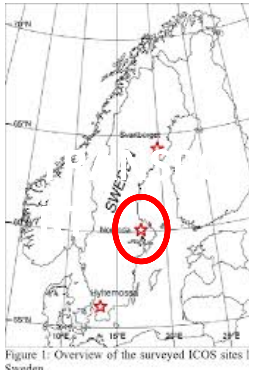


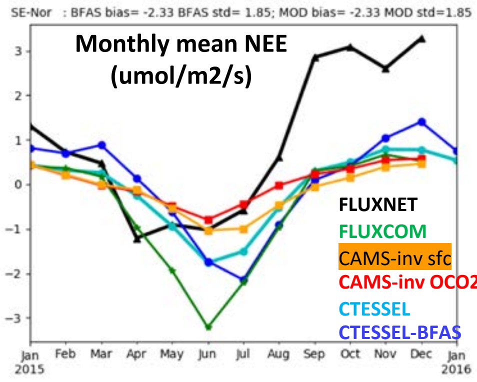


XCO_2 enhancement [ppm] associated with emission sectors and biogenic fluxes during 1-day FC

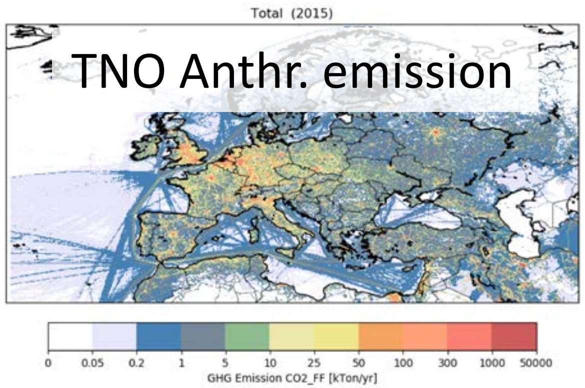






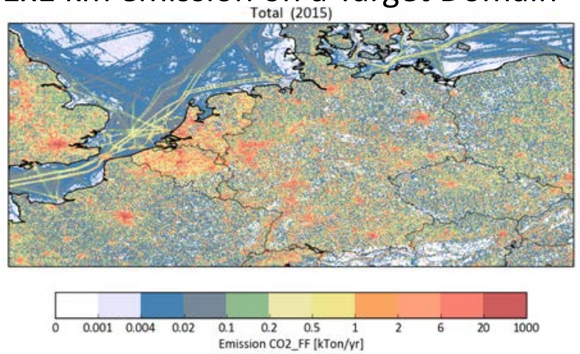


Linking Global to Regional/Local-scale runs: the value of resolution



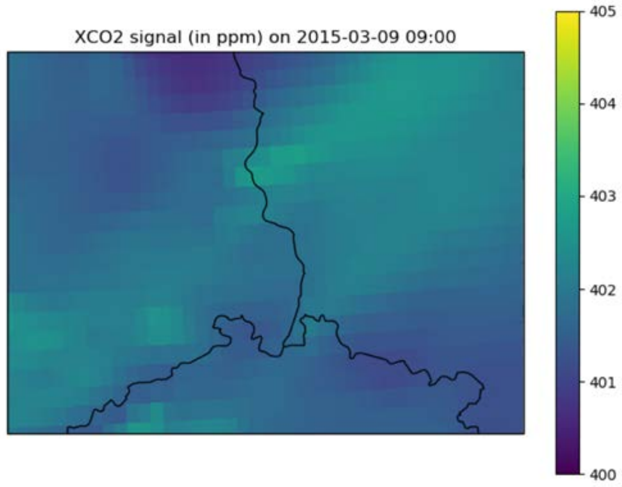
5x5 km emission over Europe

1x1 km emission on a Target Domain

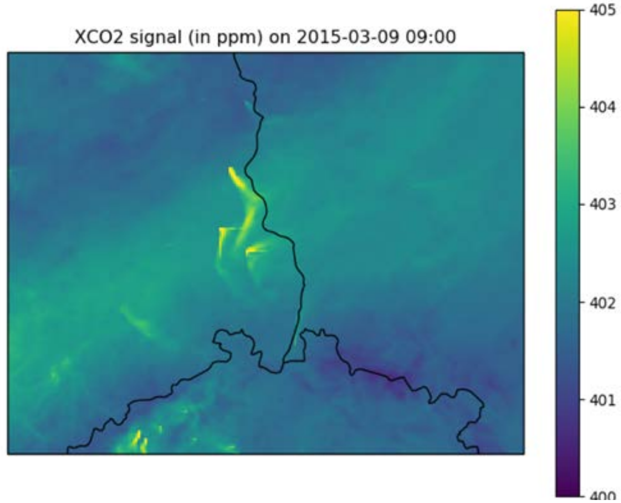


https://doi.org/10.5194/acp-2019-696

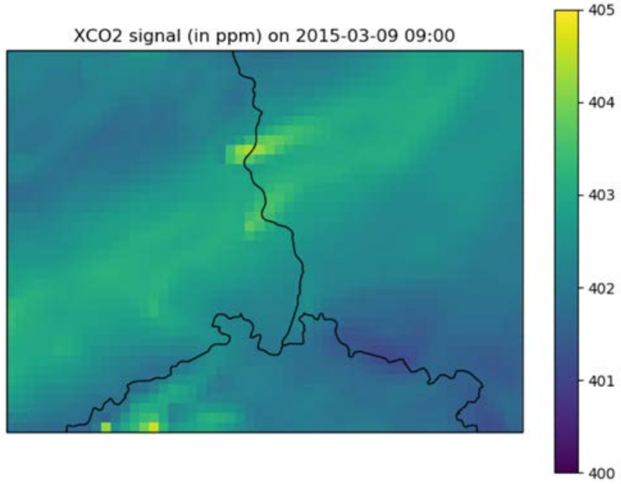
Tier-1 (CAMS), 9km, EDGAR emissions



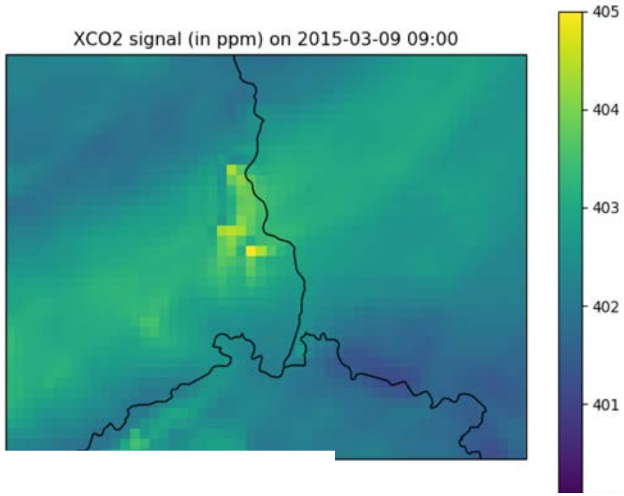
COSMO 1km, TNO emissions



Point sources will need km-scale!



COSMO 5km, EDGAR emissions



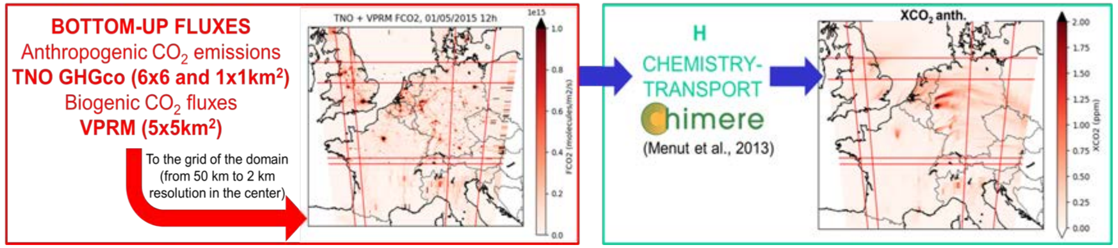
COSMO 5km, TNO emissions

Thanks to Ingrid Super, Hugo Denier van der Gon, TNO

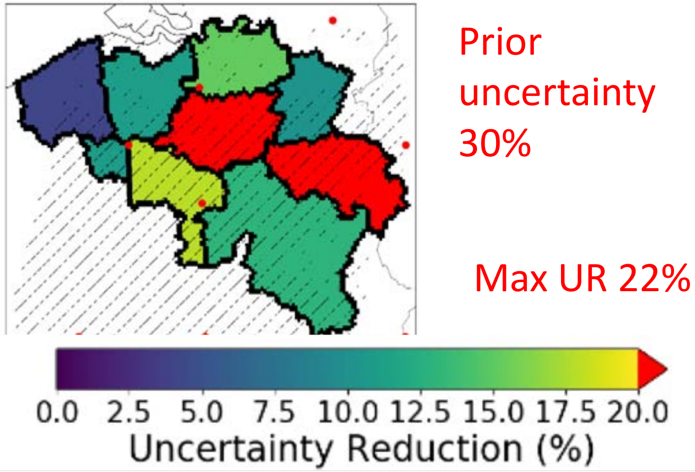
Thanks to Jean-Matthieu Haussaire, Dominik Brunner, EMPA

Learning how to assimilate CO_2 Co-Emissions & design Obs-Net

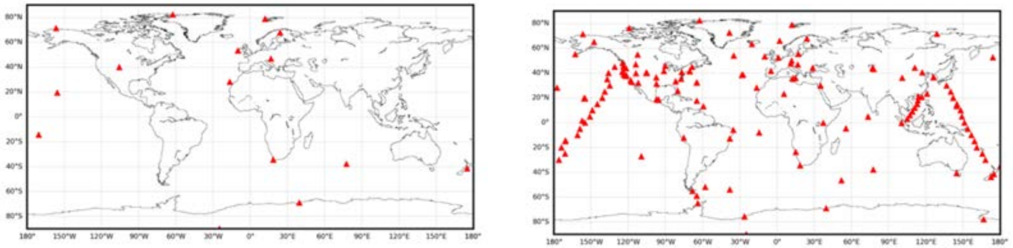
Assimilation of CO and CO_2 observations in winter (2015-01-05)



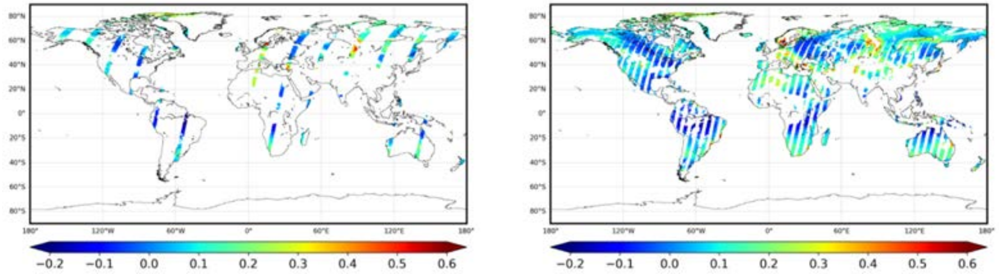
Uncertainty reductions over Belgium between prior and posterior **daily CO2 anthropogenic budgets**



Testing CCFFDAS with 15 vs 141 in-situ sites



Testing CCFFDAS with 1 vs 4 satellites



		Other sector					Electricity generation sector				
		Emission rate uncertainty (MtC/week)									
Scenario	Description	AUS	BRA	CHN	DEU	POL	AUS	BRA	CHN	DEU	POL
1	surface 15 sites	9.03	16.70	177.31	12.18	4.70	0.28	0.17	2.36	0.43	0.23
2	surface 141 sites	4.57	8.21	8.29	2.60	2.10	0.28	0.17	2.36	0.43	0.23
3	1 satellite (default)	0.30	0.42	3.43	0.97	0.38	0.27	0.17	2.21	0.43	0.23
4	4 satellites	0.25	0.29	2.38	0.79	0.33	0.26	0.17	2.07	0.43	0.23
5	default with ocean	0.29	0.41	2.93	0.94	0.37	0.27	0.17	2.20	0.43	0.23
6	default with repr. error	0.35	0.68	4.68	1.36	0.62	0.28	0.17	2.28	0.43	0.23
7	default with nat. inventory	0.03	0.16	1.84	0.08	0.05	0.04	0.06	1.43	0.07	0.05
		Annual average weekly emission rate (MtC/week)									
-	national inventory	0.90	1.67	17.73	2.43	0.73	1.15	0.22	16.36	1.76	0.83

Uncertainty reductions with simplified scenarios

Thanks to Frederic Chevallier & LSCE/CEA

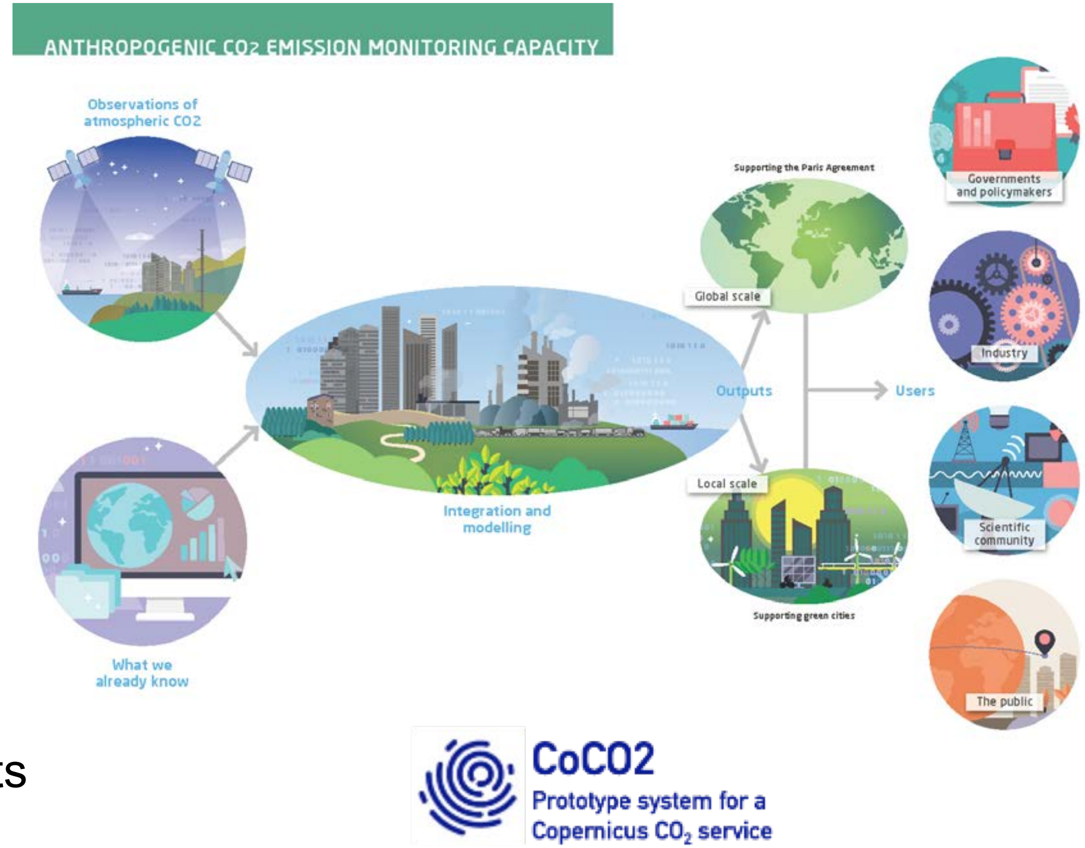
Thanks to Thomas Kaminski & Marko Scholze (iLab/Lund)

CoCO2 project (2021 – 2023) approved ☺

Aim:
Consolidate a Copernicus CO2 pre-operational prototype for the 1st Global Stock Take (GST-1)

How:
CO_2 emission estimation system driven by Earth observations (remote sensing and in situ) combined with modelling to build an information products portfolio

Why:
To support the Paris Agreement in its operational implementation phase



Project Duration:
36 month

Project Funding:
9.00 M€ (3.00 M€/year)

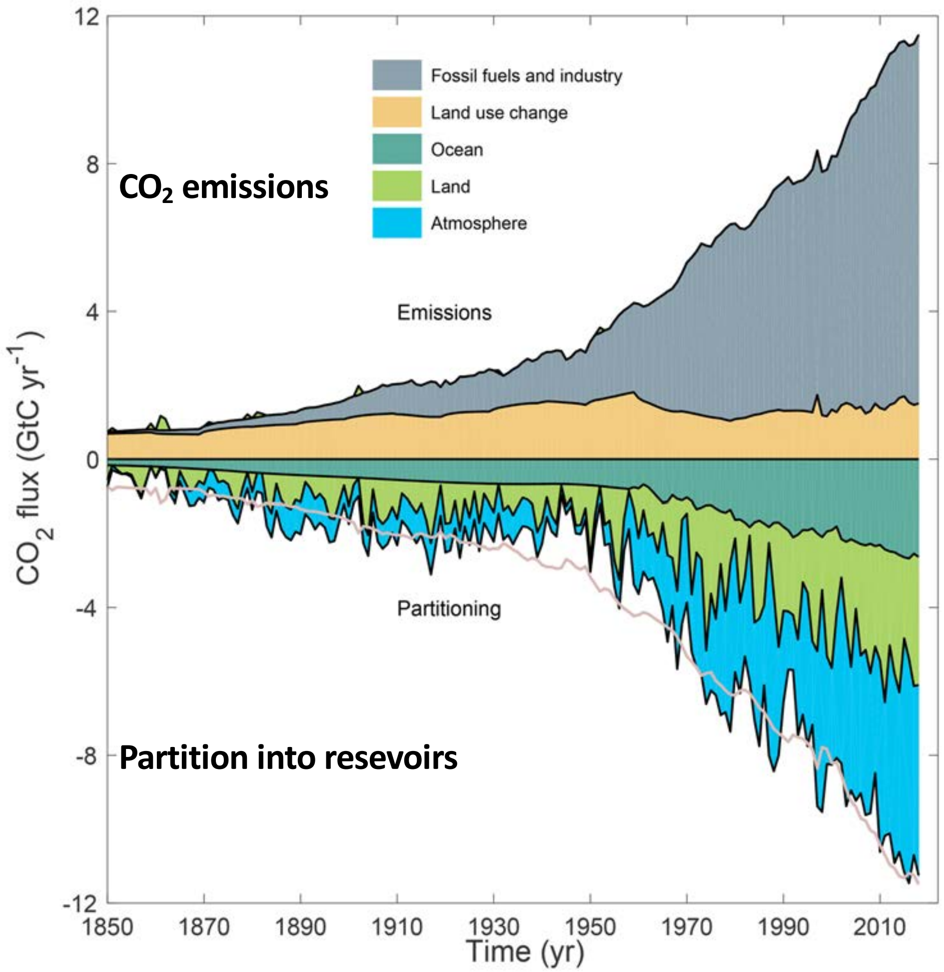
Consortium Numbers
25 partners Institutes

Work Content Numbers
9 work-packages:
4-Science development,
1-Prototype integration,
1-Observations & Nat. link,
1-Information Products,
1-Coordination & Outreach
1-Ethics
25 Milestones
67 Deliverables

920 Person Month
(Eq 25.5 FTE)

Global Carbon budget – in CHE & COCO2

GLOBAL CARBON PROJECT







Global Carbon Budget, Friedlingstein et al., 2019

Integrated Forecasting System (IFS) Approach

7 CO2 emissions groups in CHE → CoCO2 urban
Monthly maps → maps+modelling

Currently GLCC → C3S Land-Use in CoCO2
No-change → Annual change

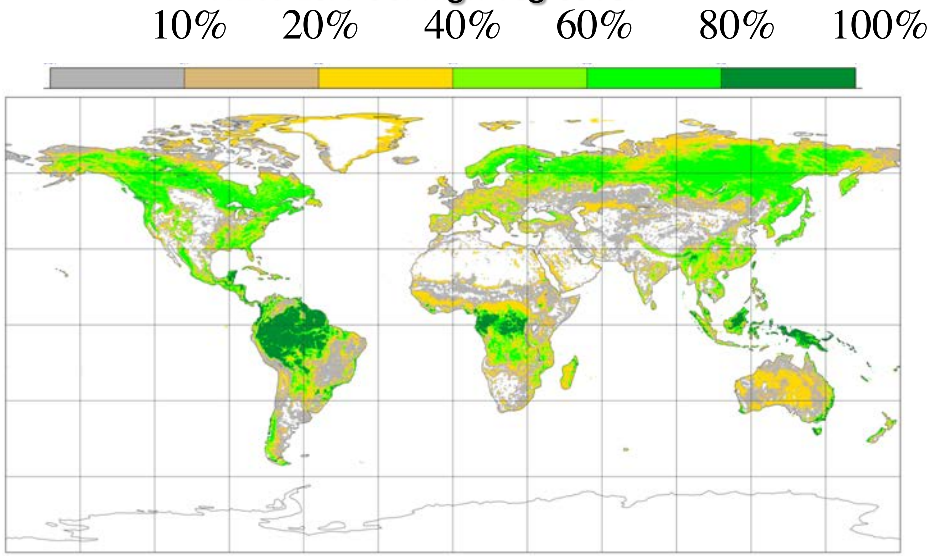
Currently in CHE → **CMEMS CO2 in CoCO2**
Monthly maps

Currently CHTESSEL-Ags → CTESSEL+ C3S LC
BFAS → BFAS+Var CoCO2

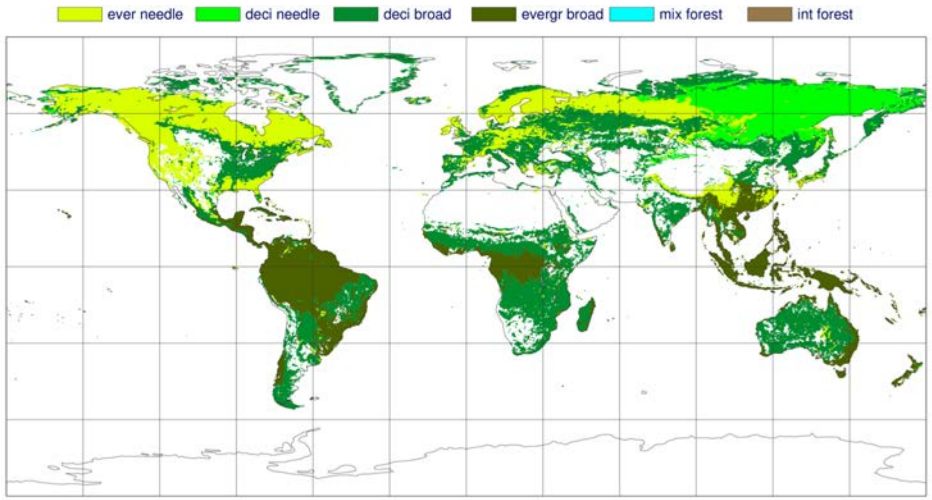
Currently CO2 CAMS → Greater interactions
No Radiation or DA interaction → 7 emission groups tracers

Biosphere: importance of land use

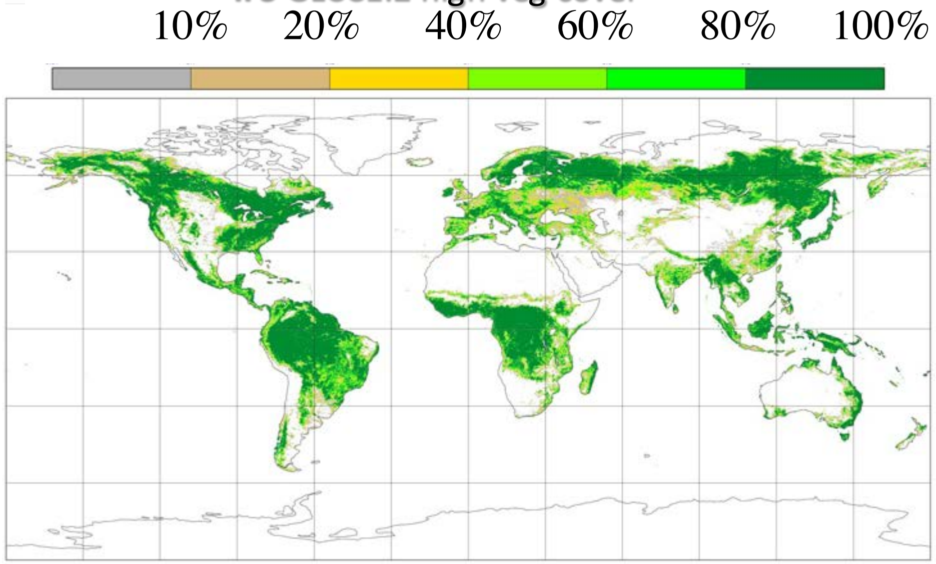
NEW ESA-CCI high veg cover



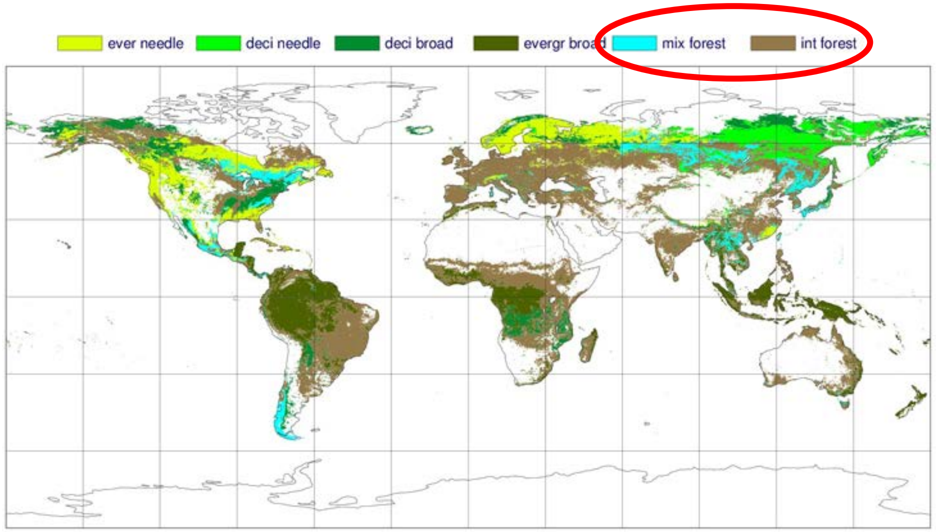
NEW ESA-CCI high veg type



IFS GLCC1.2 high veg cover



IFS GLCC1.2 high veg type



	Vegetation type	Percentage of land points	
Index		ESA-CCI	GLCC1.2
	Low vegetation		
1	crops	23.50%	18.00%
2	sh grass	38.70%	9.00%
7	ta grass	0.00%	12.80%
9	tundra	0.70%	6.00%
10	irr crops	1.90%	3.90%
11	semidesert	0.00%	11.60%
13	bog/marsh	0.00%	1.50%
16	ever shrub	5.10%	1.20%
17	deci shrub	4.70%	3.90%
	Remaining points	25.00%	31.40%
	High Vegetation		
3	ever needle	11.70%	5.40%
4	deci needle	4.70%	2.50%
5	deci broad	29.50%	5.60%
6	ever broad	18.20%	12.90%
18	mix forest	0.00%	3.00%
19	int forest	0.00%	24.70%
	Remaining points	35.60%	45.50%

In COCO2 much more focus on biosphere to uptake lesson of CHE on importance of Bio CO2

Thanks to Souhail Boussetta

Summary of CHE Development Streams

Lessons learnt within CHE allow define MVS prototype requirements:

- Modelling emissions & concentrations requirements
  - High-resolution global ensemble, improved conservation & transport, biosphere enhancement.
  - Learning from regional modelling experience, elevated source emissions, temporal disaggregation
- Mapping & Modelling accuracy requirements
  - Anthropogenic sources groups + point-source database for powerstations, stacks height.
  - Coordinated Land-Use/Land-Cover dataset at km-scale including relevant Urban-scale
  - Urban modelling description to further characterise CO2 temperature-based variability
- Multi-scale & Multi-source requirements for Data Assimilation
  - CO2 & Co-Emissions (NO2, CO) consistently treated to enable 4D-Var inversion capability
  - Regional/Local-scale enable account for spatial, vertical, different inventories in Hybrid Ens-4D-Var

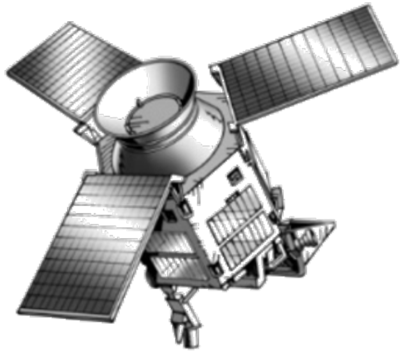
THANKS

Thank You on behalf of the CHE Team
Follow Us on the CHE Media Channel
https://mobile.twitter.com/che_project

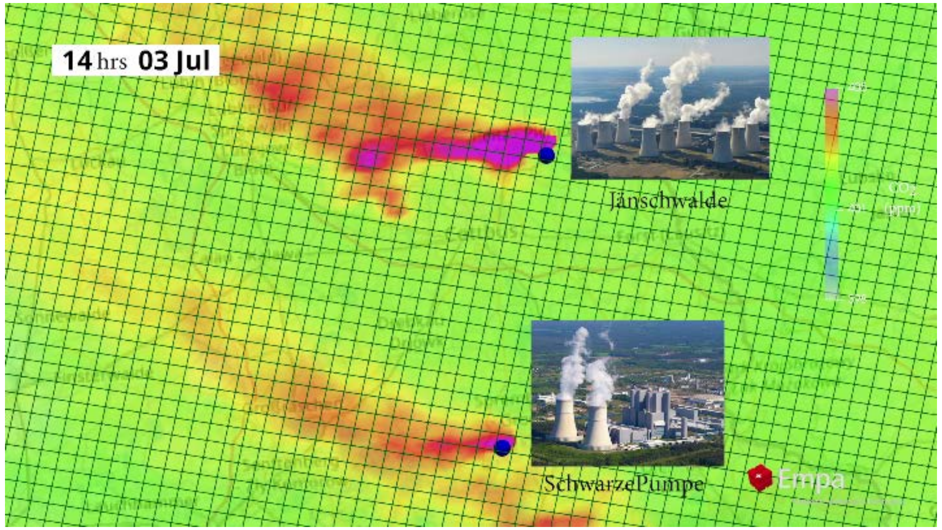
Preparing for the Copernicus CO_2 Monitoring mission

Mission requirements for XCO_2 & NO_2:

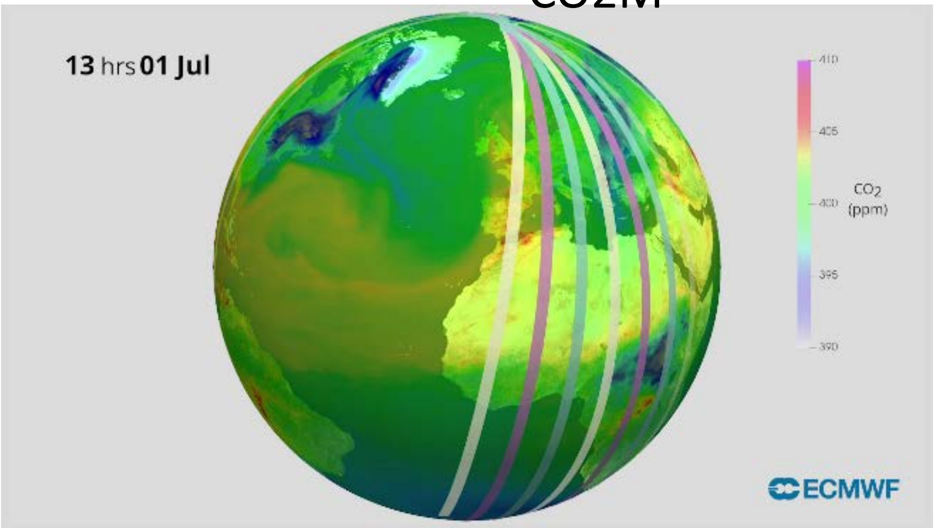
Spatial resolution **4 km²**
XCO_2 precision: **0.7 ppm (veg. scene, 50° SZA)**
NO_2 precision: **$1.5 \cdot 10^{15}$ molec/cm²**
Imaging swath **> 250 km**
Viewing modes: **nadir (land) & sun-glint (water)**



Ceci n’est pas une CO2M



CO_2 measured at 2x2 km² grid (credit: EMPA)



Examining plume inversions for hotspot emissions

ESTIMATION OF CO_2 EMISSION HOTSPOTS (POWER PLANTS, CITIES) USING SATELLITE DATA:

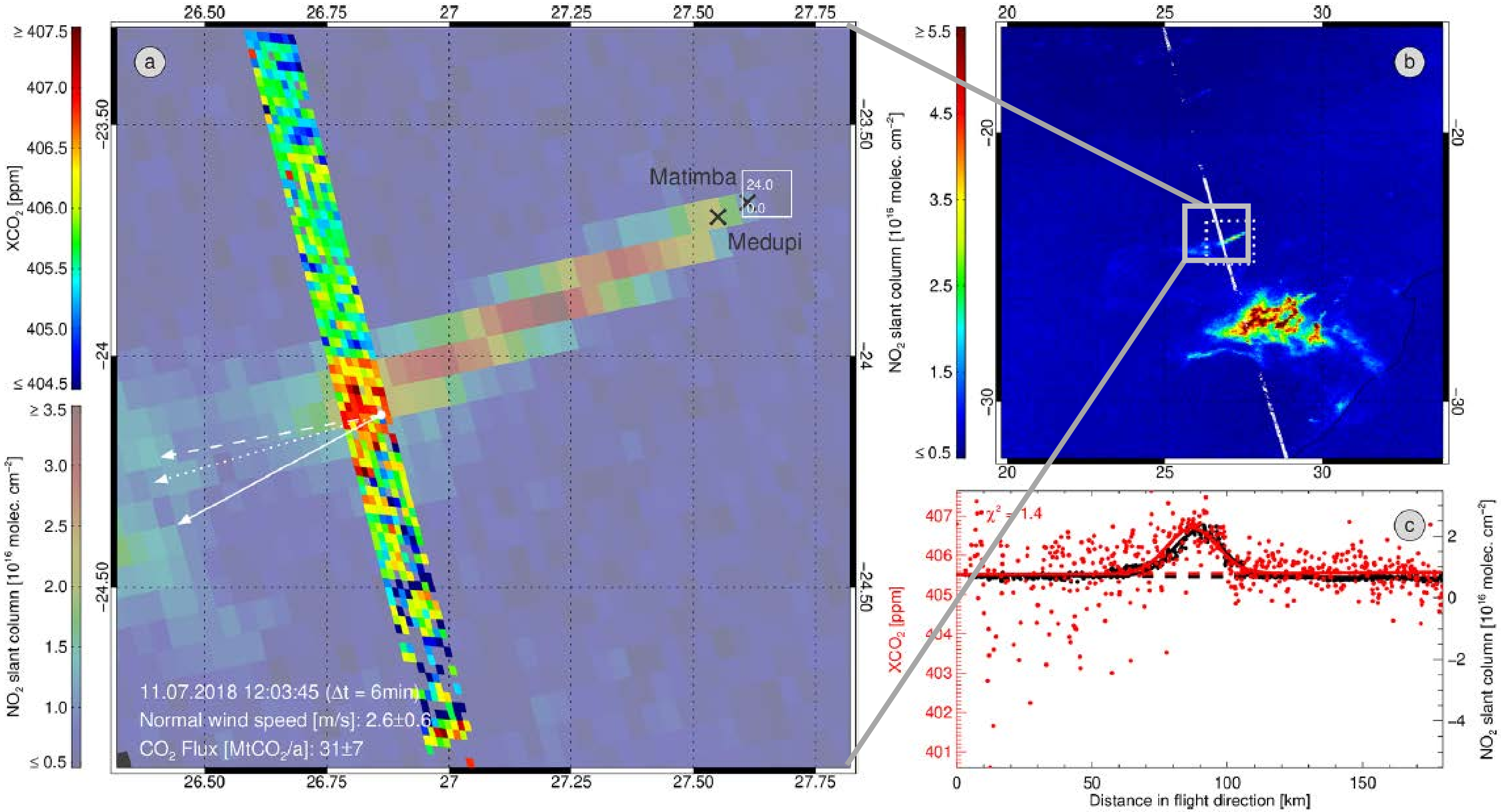
Example: Power plant (South Africa)

- **NO_2 plume detection and cross-section CO_2 flux estimation**
  Reuter et al (2019)

- **Gaussian plume model**
  Bo Zheng et al. (VERIFY), Nassar et al. (2017)

- **High resolution Eulerian transport model**
  Zheng et al. (2019),
  Ye et al. (2020)

- **Lagrangian transport model**
  Wu et al. (2020)



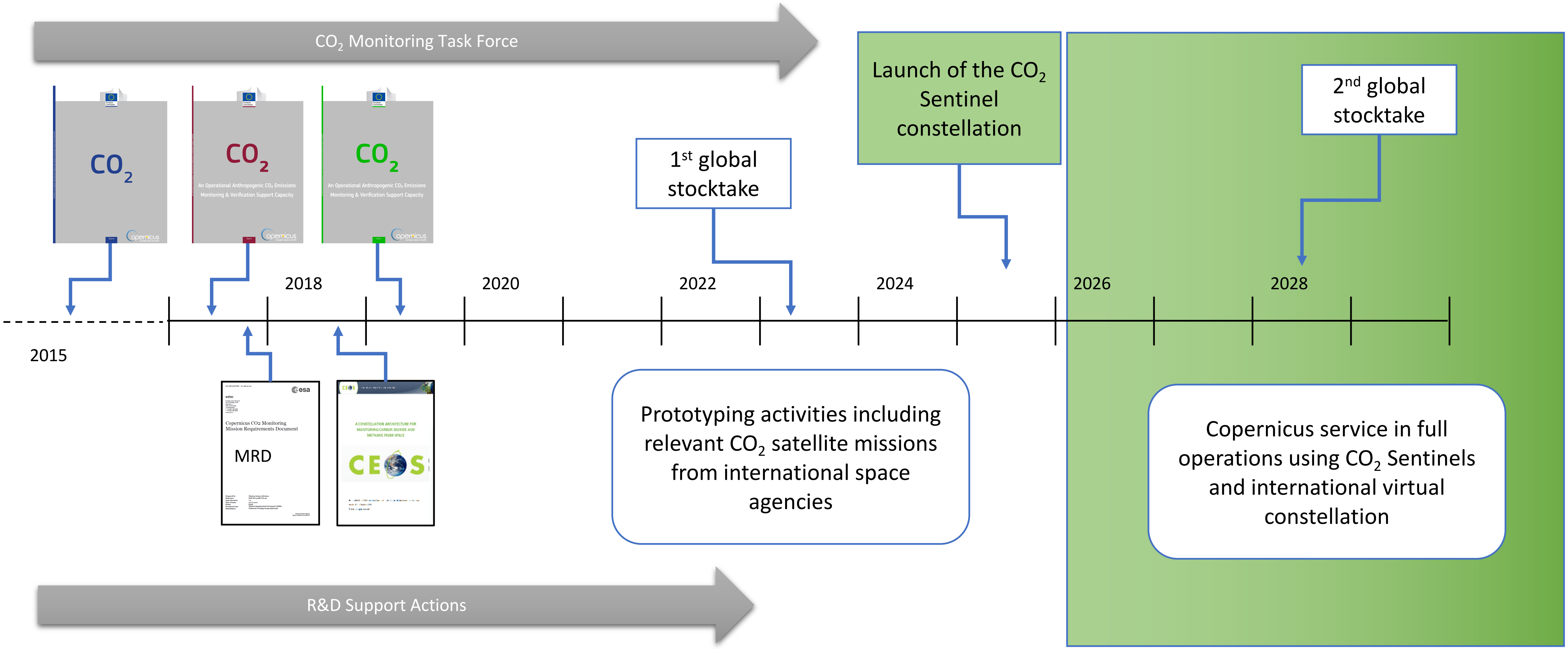
Reuter et al. (2019)

CHE is in the last 4-month run … to CoCO2

CHE will complete the remaining 16 deliverables (of 45 total). CHE will transfer Outcomes to CoCO2-H2020 starting in 2021

D1.3	Reconciliation of top-down and bottom-up estimates of the carbon balance
D1.4	Stakeholder report on the requirements for future space-based instruments to deliver products suitable for CO2 emission monitoring
D2.7	Impact of urban aerosols on satellite retrieved total column CO2
D2.8	LES Simulation Report
D3.5	Inversion strategy based on OSSEs
D3.6	Inversion strategy based on joint QND assessment
D4.4	Sampling Strategy for additional tracers
D5.2	**Final report on service elements for CO2 Earth Observation Integration**
D5.4	**Final report on service elements for CO2 Emission and Transport Models Integration**
D5.6	**Final report on service elements requirements for data assimilation methodology**
D5.8	**Final report on service elements requirements for uncertainty representation**
D5.9	**Report on synthesis of service elements for an integrated CHE monitoring infrastructure**
D6.3	**Strategic Research Agenda document 3**
D6.4	Report on workshops organised by CHE
D7.7	Final Dissemination and Exploitation Report

Roadmap towards Copernicus CO_2 service

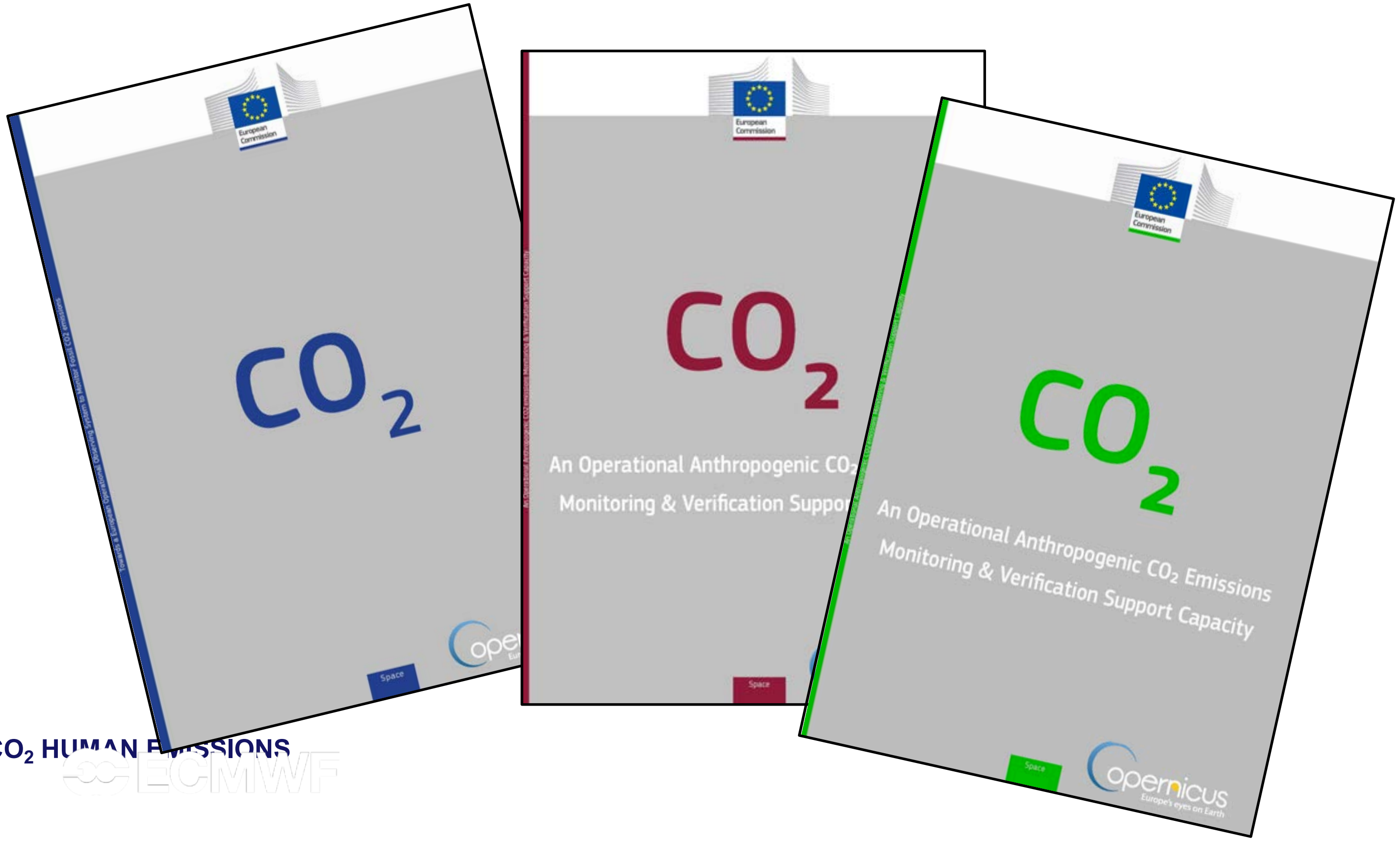


C CO2 Human Emissions | VERIFY | CoCO2 Prototype system for a Copernicus CO_2 service

Thanks to Richard Engelen ECMWF & CO_2 Task-Force

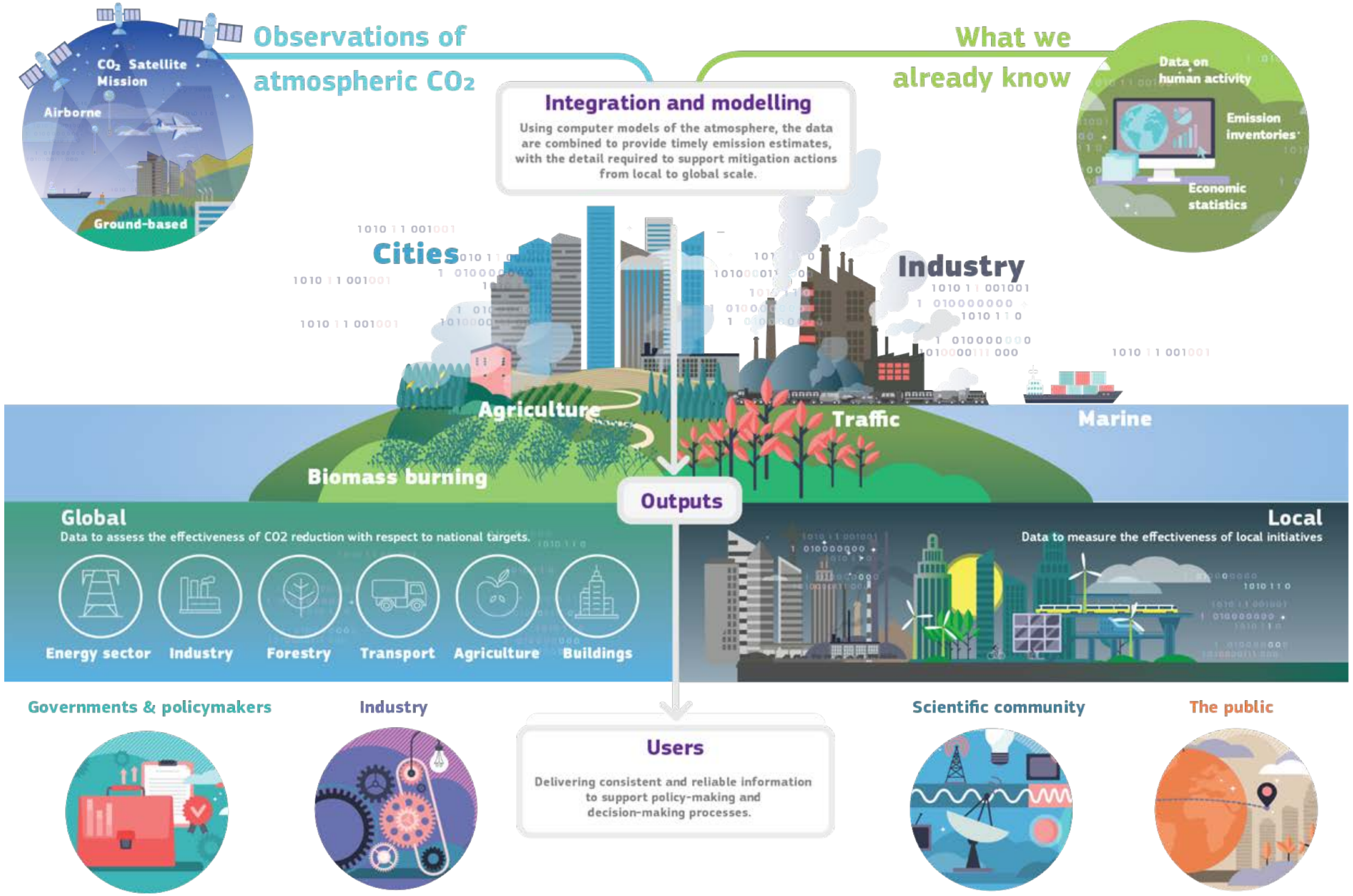
Anthropogenic CO2 emission monitoring

Recommendations by the European Commission CO_2 Monitoring Task Force for an Anthropogenic CO_2 Emissions Monitoring & Verification Support (MVS) capacity

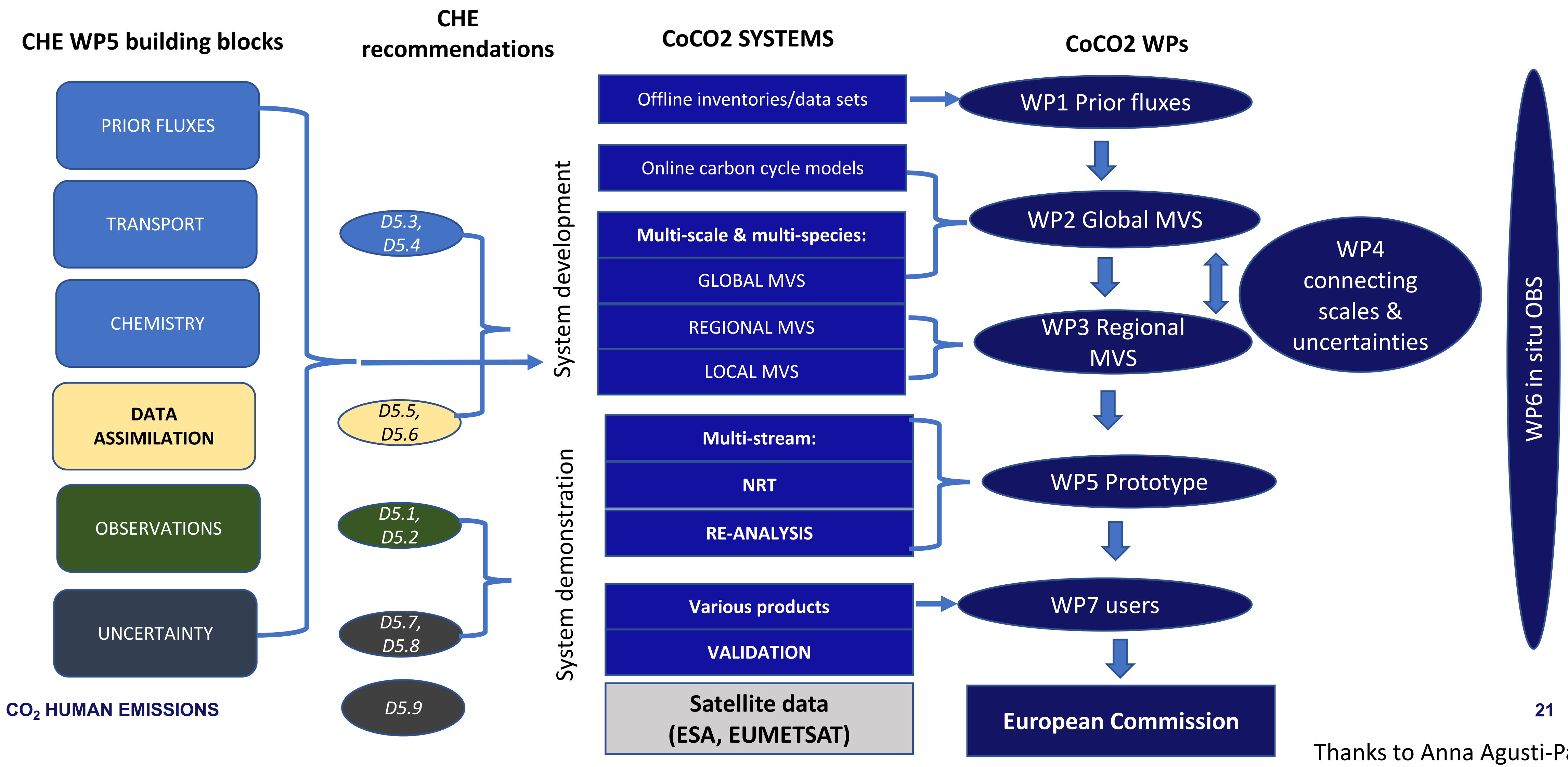


1. Detection of emitting hot spots such as megacities or power plants,
2. Monitoring the hot spot emissions to assess emission reductions of the activities,
3. Assessing emission changes against local reduction targets to monitor impacts of the NDCs,
4. Assessing the national emissions and changes in 5-year time steps to estimate the global stock take.

Proposed Copernicus MVS capacity



CoCO2: from system design to deployment

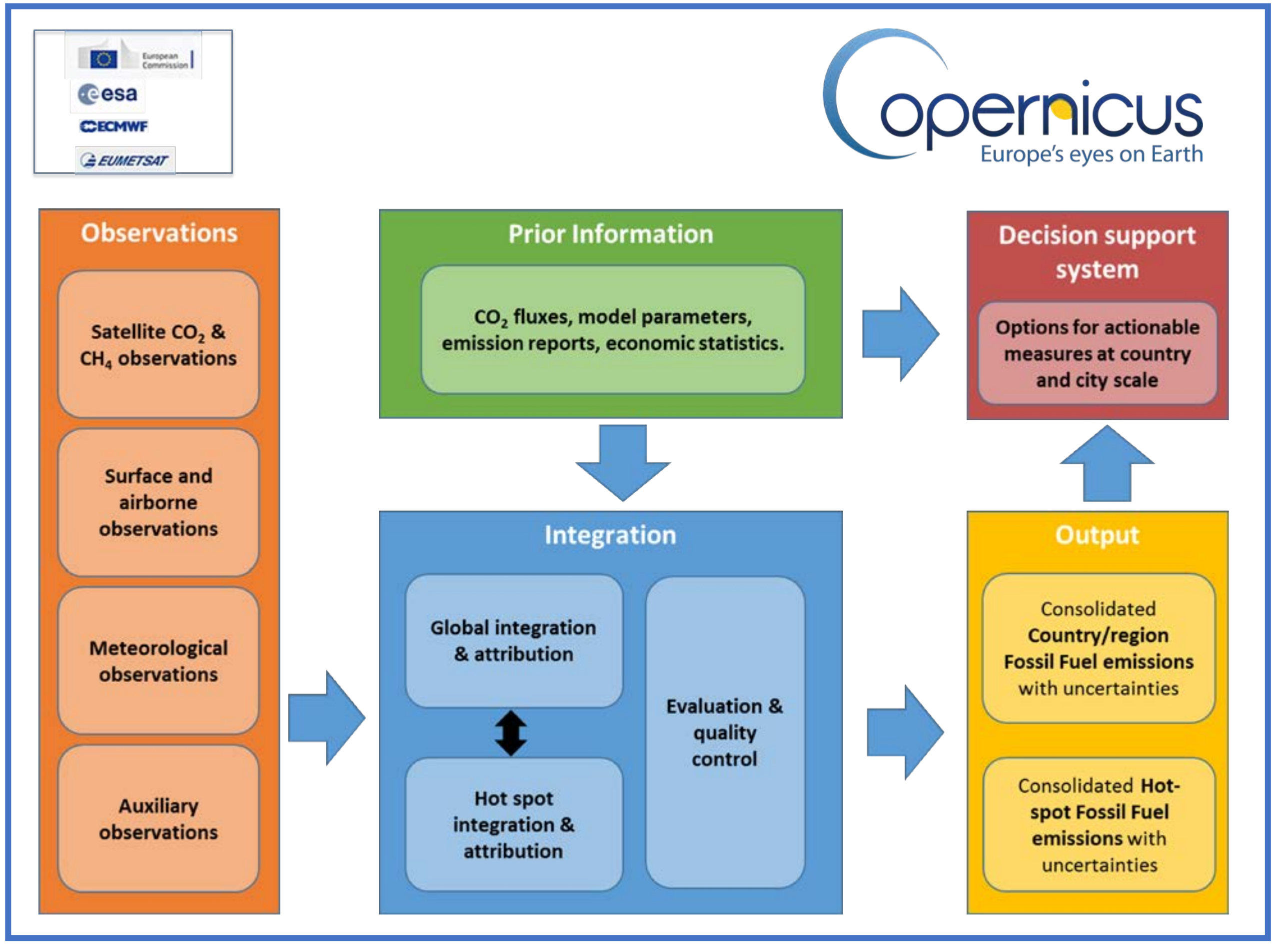


Thanks to Anna Agusti-Panareda

Developing a new CAMS service element

Atmosphere Monitoring Service
atmosphere.copernicus.eu

Climate Change Service
climate.copernicus.eu



Synergies with existing Copernicus services shall be exploited.

Especially the CAMS existing infrastructure and the plans for estimating emissions of CO and NO_2 fits very well with the planned CO_2 MVS.

Also linking with other services and national activities.

Thanks to Richard Engelen ECMWF