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WP4 COORDINATING EFFORTS ON ATTRIBUTING CO_2 EMISSIONS FROM IN-SITU MEASUREMENTS

2nd General Assembly

Frédéric Chevallier
CEA/LSCE
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Julia Marshall,

Gregoire Broquet, Hugo Denier van der Gon, Jean-Matthieu Haussaire, Penelope Pickers, Ignacio Pisso, Elise Potier, et al.

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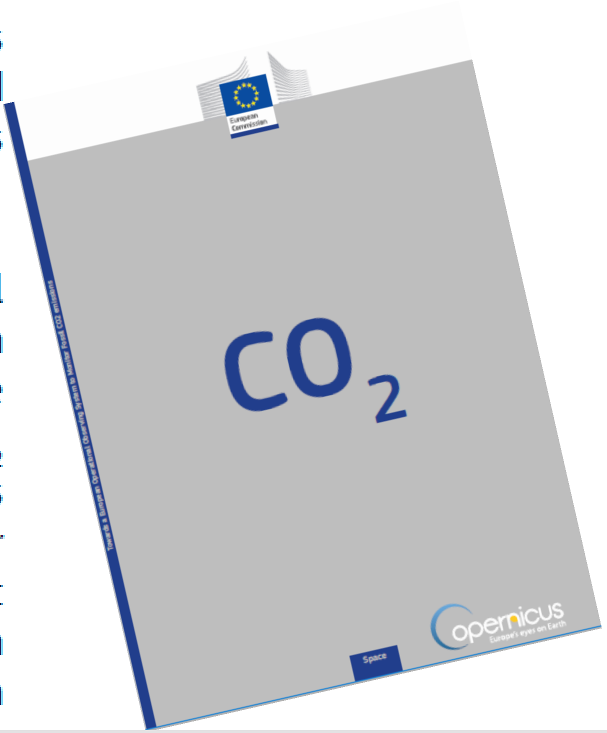
CO_2 Human Emissions

Roadmap from the 2015 CO_2 report

The abovementioned limitations can be overcome by collecting two types of atmospheric measurements:

- Dense atmospheric CO_2 measurements, with detailed, high resolution, coverage of emissions hotspots. With their global and high revisit coverage, satellite observations of column integrated CO_2 (XCO_2) at high spatial resolution can meet this requirement, e.g., using space-borne sensors with imaging capabilities (**Chapter-3**).

- In-situ measurements of specific tracers in the atmosphere that allow the separation of fossil CO_2 from other sources. The best of these tracers is ^{14}C (radiocarbon) in atmospheric CO_2, which is nearly a direct tracer of emissions (Turnbull et al., 2014) but is so far expensive to measure because of its very low abundance. Fossil fuels do not contain any radiocarbon: when CO_2 from their combustion is released to the atmosphere, it dilutes with CO_2 from other sources that contain ^{14}C, which creates a measurable depletion of the ^{14}C isotope composition in air masses containing fossil CO_2. The accuracy at which the fossil fuel component of atmospheric CO_2 can be determined from ^{14}C measurements of CO_2 in air samples is about 1 ppm with Accelerator Mass Spectrometry. Carbon monoxide is also a tracer of combustion processes. In many environments, it is a reas
though subject to uncertainty in
differences in fuel type and con



We recommend to build urban monitoring networks for selected European large cities. Results from city-scale inversions of CO_2 data from urban networks will be used to evaluate independently satellite-based city-scale emission estimates. ^{14}C measurements should be deployed a set of approximately 50 atmospheric CO_2 monitoring stations across the European continent, with higher density over regions with high emissions. Results from regional- and continental-scale inversions of in-situ ^{14}C and CO_2 measurements will be used to evaluate independently satellite-based emission estimates.

WP Objectives

- Explore the practical implications of distinguishing between anthropogenic vs. biogenic CO_2 fluxes when using CO_2 satellite imagery.
  - Do we need accompanying surface measurements?
  - Anthropogenic = fossil fuel emissions, and also non-fossil waste burning, biofuels, etc.
- Focus on the optimization of the space-time sampling of $^{14}CO_2$, CO and APO at the surface.
  - Network design
  - 4 regional modelling frameworks (EMPA, CEA/LSCE, MPI-BGC, NILU)
  - 1 inventory provider (TNO)
  - 1 expert in APO (UEA) and 1 expert in surface flux measurements and citizen data (CMCC)
  - + link with WP3 (ULUND)

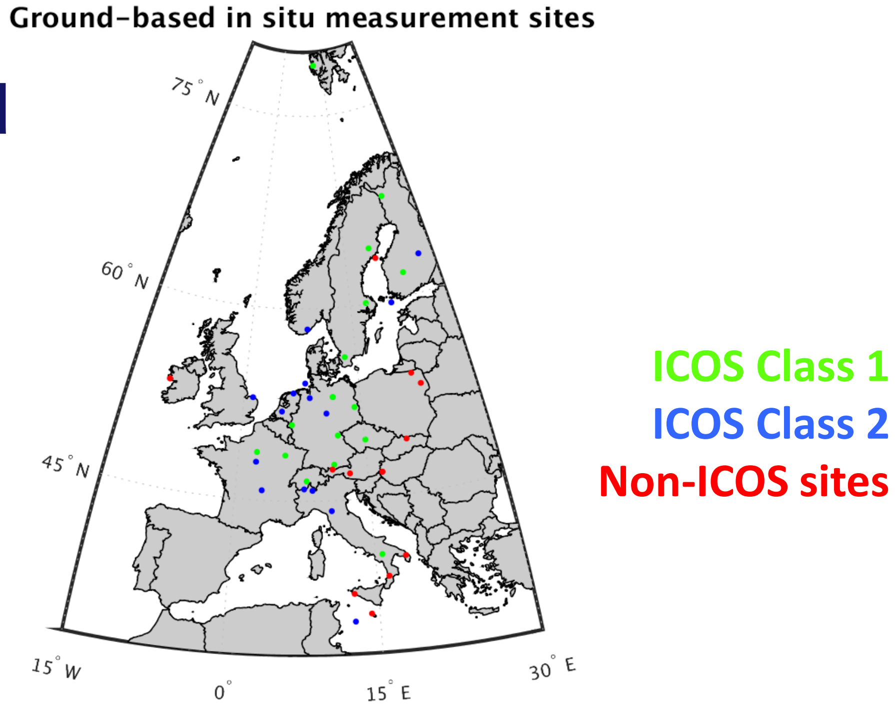
Survey of existing European in-situ network (D4.1, lead MPI-BGC)

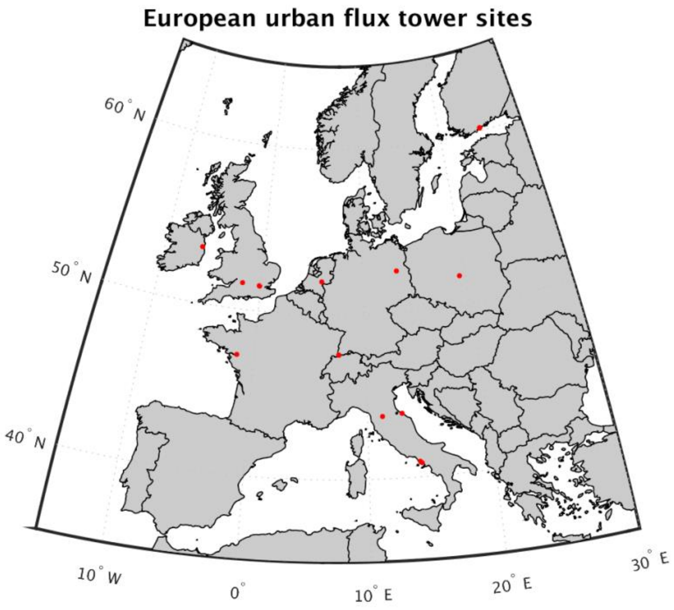
Documented existing *in situ* measurements, their frequency, and uncertainty for:

- carbon dioxide (CO_2)
- carbon monoxide (CO),
- the ratio of radiocarbon in carbon dioxide ($\Delta^{14}CO_2$)
- and atmospheric potential oxygen (APO)

Documented currently-operating urban flux tower sites in Europe, to support the planned work of CMCC to assess the use of these data to solve and/or validate the attribution problem.

- Potentially valuable for the definition of time factors





D4.2: High-resolution scenarios of CO_2 and CO emissions (lead TNO)

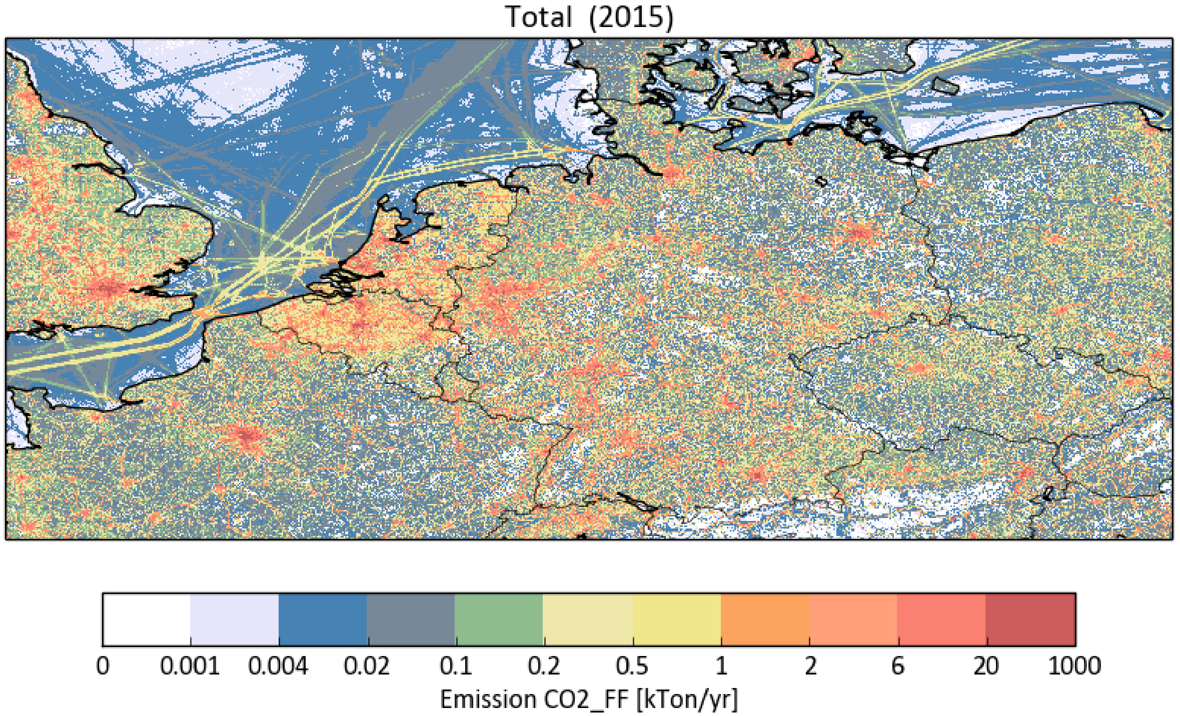
- **Task Objective:** Construction of ten 1×1 km^2 scenarios of CO_2 and CO emissions associated with anthropogenic activities in Europe over a full year (2015).

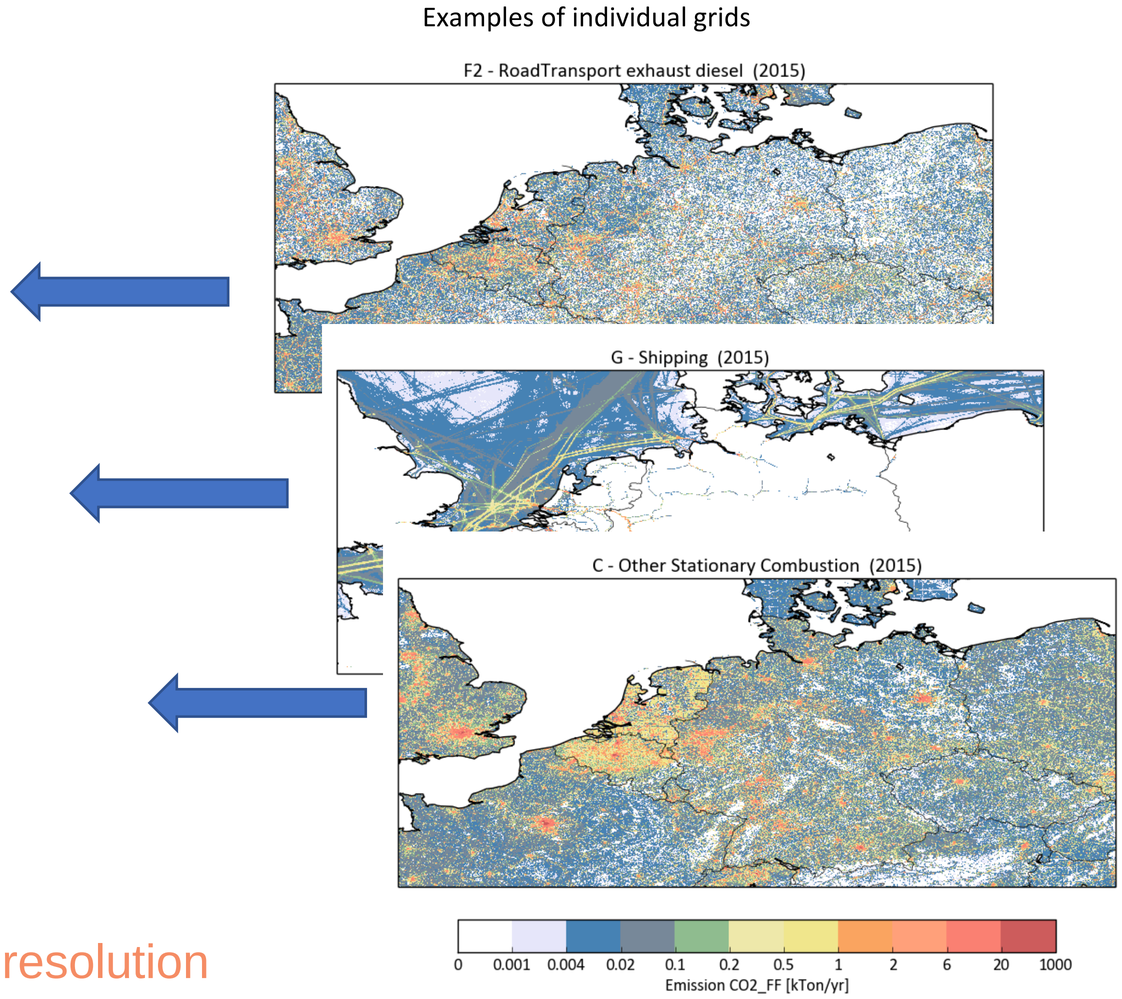
- Closely related to WP2 and the production of a new European emission inventory at 6×6 km^2 for year 2015 which is the basis for the 1×1 km^2 zoom version for WP4. The baseline 1×1 km^2 inventory was delivered to the partners on 28 January 2019.

- Quantification of uncertainties in 4 key parameters for this baseline: activity data, emission factors, spatial distribution proxies and temporal distribution proxies.
  - Each of these key parameters has an uncertainty function, which is being included in a covariance matrix. Within a Monte Carlo simulation TNO creates an ensemble (N=10) by drawing random samples from this matrix and calculates emission maps for each ensemble member. This creates a set of possible solutions in the emission space, reflecting the uncertainties in the underlying parameters.

- Deliverable report D4.2 submitted for review 08/03/2019; family of grids ready end of March.

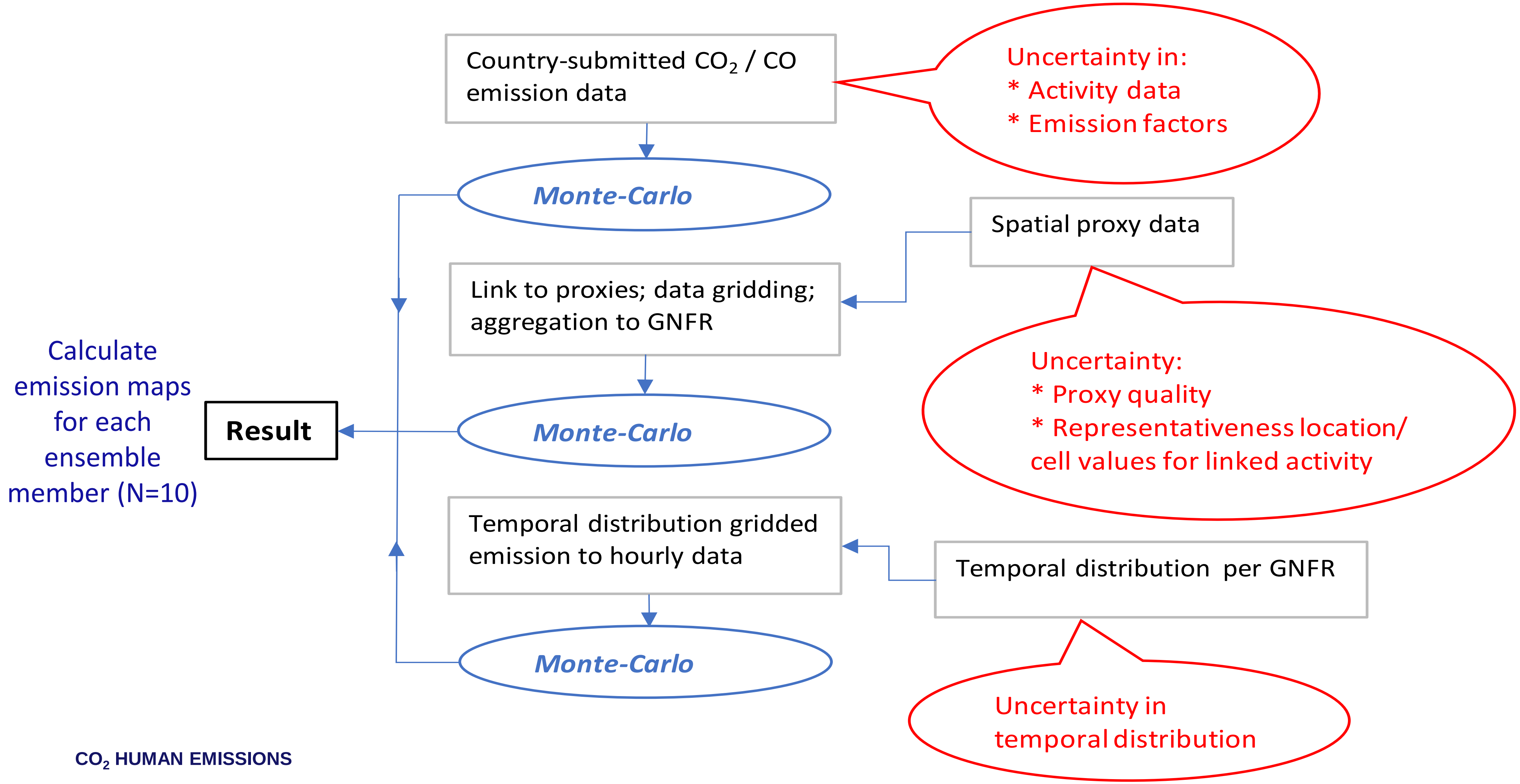
D4.2 (lead TNO)





Individual maps by sector combined yield the new high resolution 1×1 km^2 emission grid for WP4. (Point sources at exact location). This dataset is the basis for the family of 10 grids

Uncertainties HR gridded CO_2 and CO emission data: Method used



I. Uncertainties in activity data and emission factors

- For activity data (incl. biomass[1]): Average from National Inventory Reports (NIRs)
- For CO_2 emission factors (incl. biomass[1]): Average NIRs
- For CO emission factors: Literature range[2] (EEA Guidebook, BREFs)

[1]Biomass low coverage in NIRs

[2]Indicated range assumed for 95% confidence interval

Sector		Range found in reported uncertainties (%)		
		Activity data	Emission factors	
			CO2	CO down/up
Public power		2 - 6	2 - 5	30-50 / 50-200
Industry		3 - 4	2 - 6	20-70 / 40-300
Other stat. comb.	Fossil	4 - 10	2 - 14	30-90 / 40-150
	Biomass	10 - 20[1]	5 - 10[1]	70-90 / 300-800
Road transport (incl. bio)		3 - 5	2 - 5	30-60 / 40-250
Other mobile sources		5 - 10	2 - 4	50-70 / 200-300
Distribution		Normal	Normal	Logn. & norm.

II. Uncertainties in spatial proxy use

Uncertainty in spatial distribution:

- European Pollutant Emission Register (EPRTR) point source location and emission **Neglected for now**
- Proxy quality (e.g. population, roads, industrial areas) **Neglected for now**
- Proxy representativeness for linked activity, at individual cell level:
  1. Spatial pattern
  2. Cell values

Combined in 1 numerical indicator

Spatial uncertainty of 60 most important Sector – Proxy combinations estimated:

Low uncertainty, e.g.

- Household gas use – Population

Medium uncertainty, e.g.

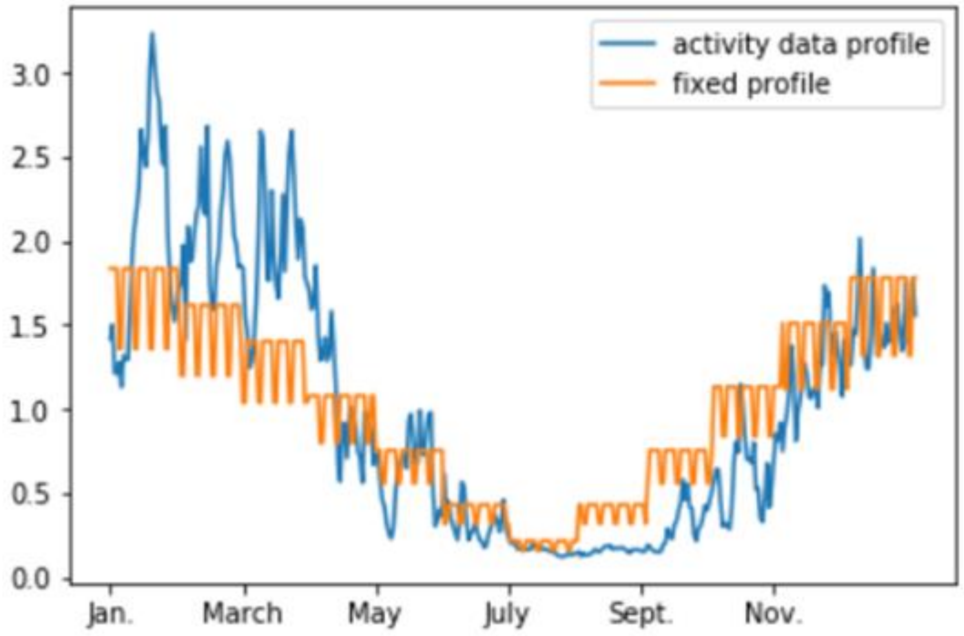
- Iron & steel industry – Older proprietary plant capacity databases

High uncertainty, e.g.

- Gas refining – CORINE general industrial area
- Residual emissions – Default proxy (e.g. population)

III. Uncertainties in temporal variations

- Fixed monthly, daily and hourly fractions per source sector (GNFR definition) based on long term averages
- In reality, temporal distribution is more irregular and shows large regional differences
- Uncertainty has been assessed by comparing fixed fractions to observations
- E.g. residential combustion in the Netherlands (below)



This comparison suggests an uncertainty of 20 – 50% in the averaged monthly and daily fractions

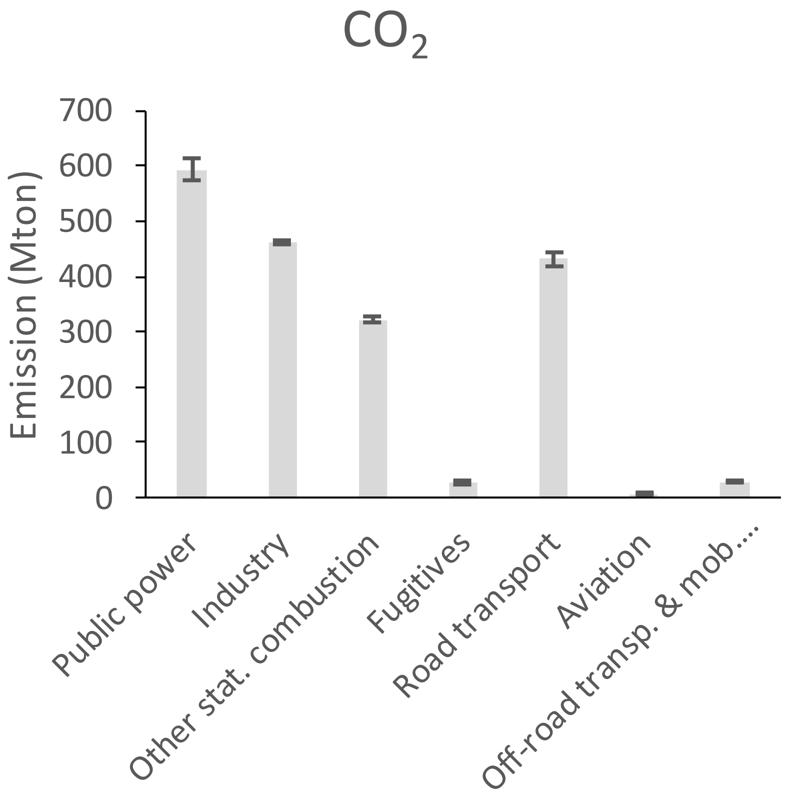
All GNFR sectors were analysed in a similar manner

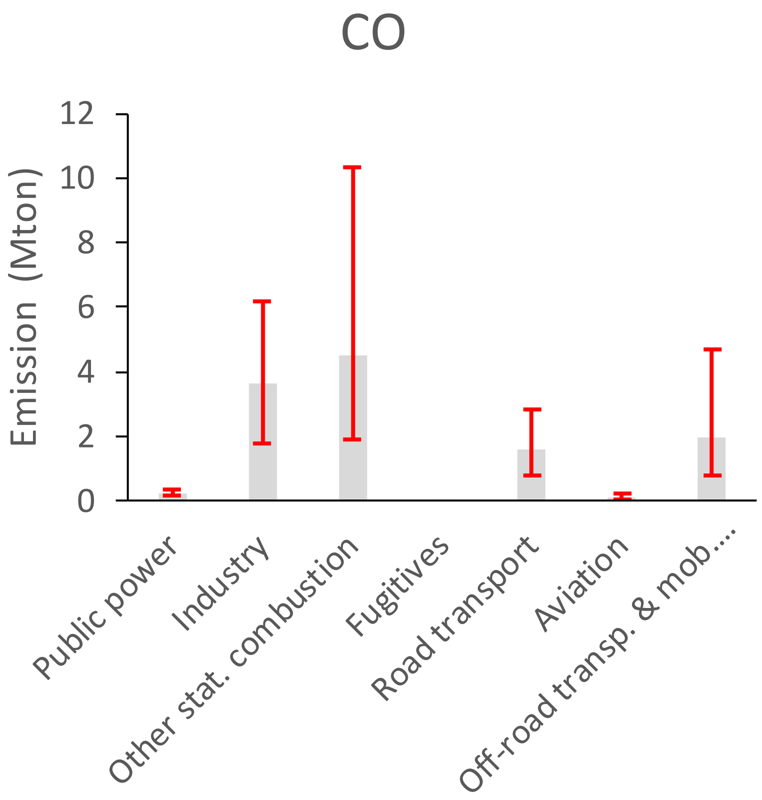
Result: uncertainty in total CO_2 and CO emissions per source sector

before adding uncertainty of spatial and temporal distribution

Shown error bars indicate range in 10 random draws

CO data preliminary due to difficult drawing from lognormal distributions



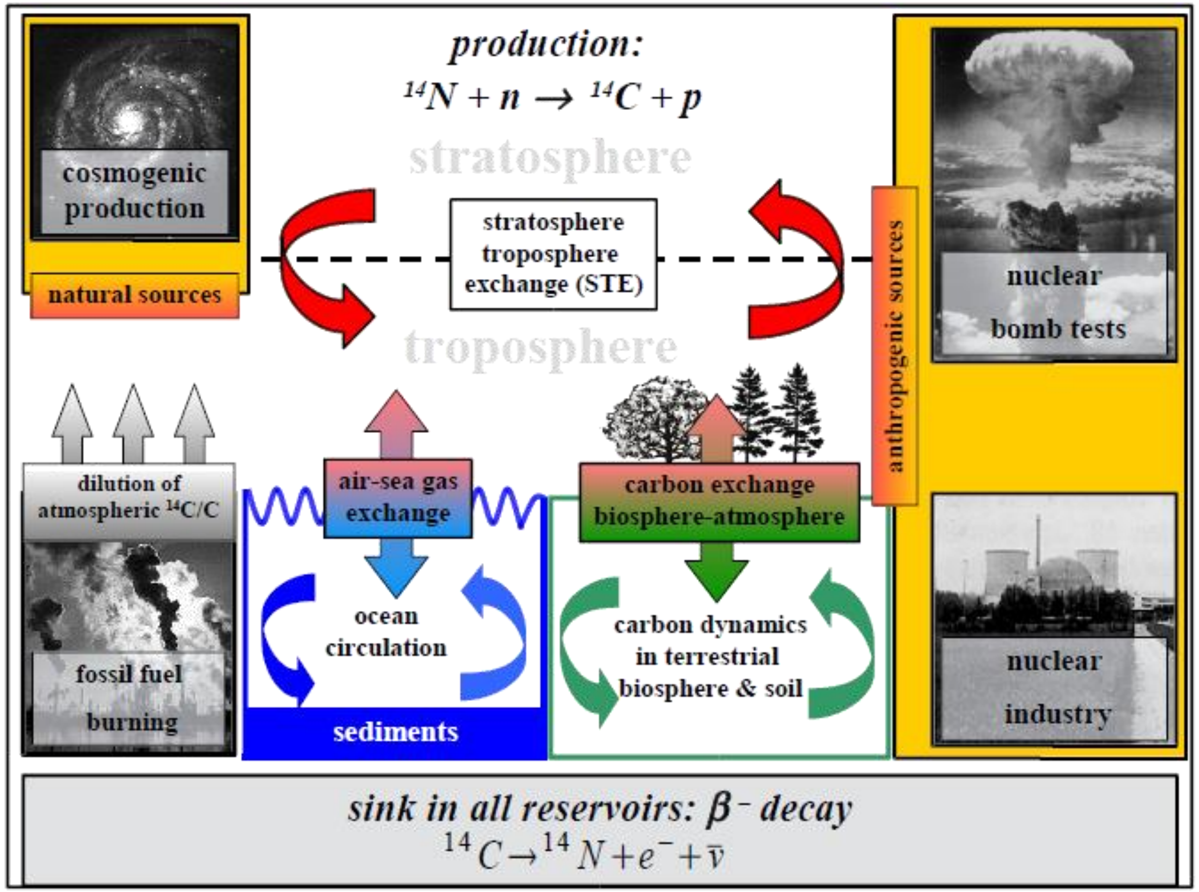


Budget for the whole domain

Note: Uncertainties increase substantially when spatial (gridcell level) and temporal uncertainty are added

$^{14}CO_2$ emissions (CEA/LSCE)

- **Simulation of C and ^{14}C cycles (Wang, 2016)**
  - Nuclear $^{14}CO_2$ emissions from yearly data in TBq/yr (Zazzeri et al., 2018).
  - Biogenic $\delta^{14}CO_2$ from extrapolation of products based on ORCHIDEE-MICT simulations (Wang, 2016). These coefficients will be applied to the new VPRM CO_2 biogenic fluxes.
  - Biofuel under the hypothesis of no lag between growth, harvest and burning.
  - Cosmogenic $^{14}CO_2$ neglected.
- **Inversion : control of the CO_2 fluxes**
  - → Ant., GPP, respiration and the corresponding $\delta^{14}CO_2$



(Wang, 2016)

Modelling APO: fossil fuels (UEA and TNO)

$$APO\ (per\ meg) = \frac{O_2}{N_2} - \alpha_L \times CO_2 = \left(\frac{ocean_{O_2} - ((\alpha_F - \alpha_L) \times ff_{CO_2}) + (\alpha_L \times ocean_{CO_2})}{S_{O_2}} - \frac{ocean_{N_2}}{S_{N_2}}\right) \times 10^6$$

- α_F = O_2:CO_2 ratios assigned, either directly using values from the literature (but not many exist) or from assigned H:C ratios for each TNO inventory fuel type, using values from the literature (based on the fact that for most fuels, H:C ratios and O_2:CO_2 ratios are strongly correlated).
- Assumptions: for each TNO inventory fuel
  - Sulphur and nitrogen content has negligible impact for most fuels.
  - Fuels are burnt completely, and any CO produced is short-lived in the atmosphere and converted to CO_2 relatively quickly (Keeling et al. 1988).
  - Energy production is nearly proportional to O_2 consumption across a wide range of fuels, based on relatively similar energetic efficiencies (NHHV, in kcal/mole) across different types of fuels (Keeling 1988)
- Assign uncertainties to O_2:CO_2 ratios that account for the above assumptions (work still ongoing).

Modelling APO: biosphere (UEA)

- Uncertainty in α_L (oxidative ratio of terrestrial biospheric exchange) will be assessed using existing European atmospheric O_2 and CO_2 data.

Used O_2 and CO_2 data from across Europe (ZOT, BIK, MHD, WAO, GOE), and excluded periods that were likely influenced by fossil fuel by using APO, leaving data that are representative of mostly natural sources.

- Diurnal and seasonal variability in α_L?

None found

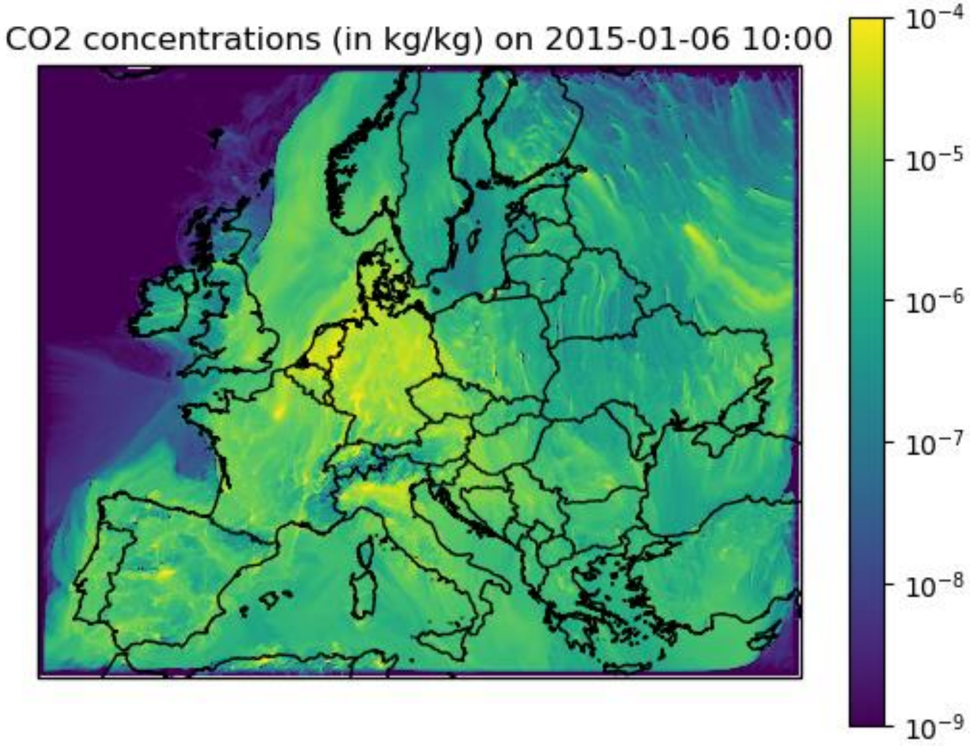
- Is $\alpha_L = -1.1$ valid for Europe?

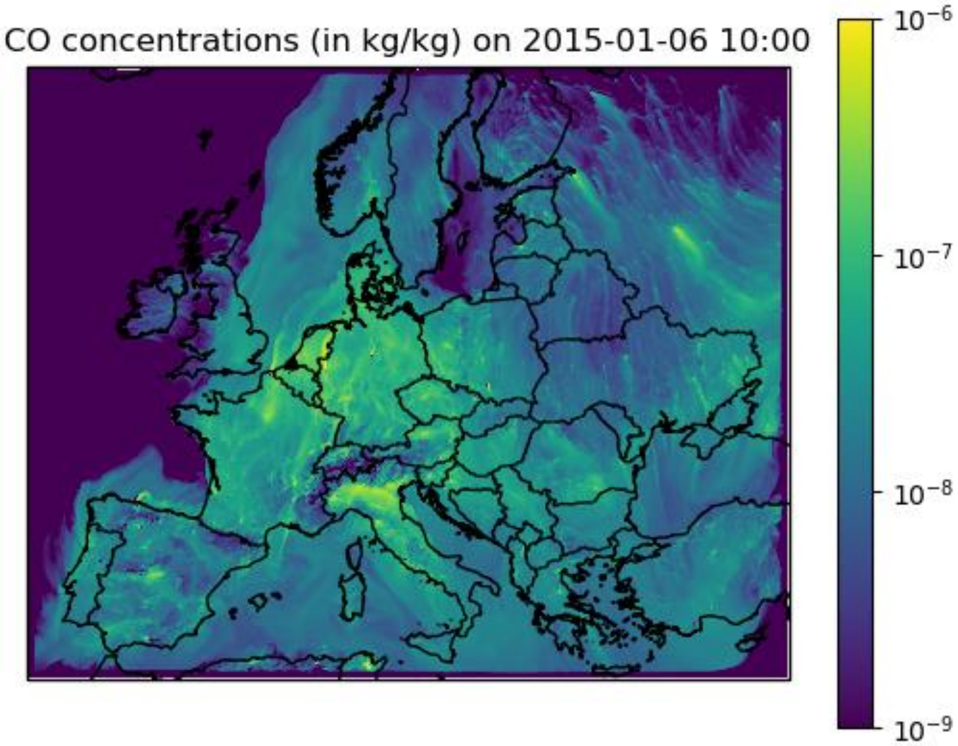
Use -1.07 +/- 0.04 mol/mol (1 sigma SD, normal distribution) instead of -1.1.

- Is there a gradient in α_L between north and south, or east and west?

None found, but geographical ranges of available datasets are limited (latitude: ~51-60 deg N; longitude: ~10 deg W to 90 deg E)

COSMO-GHG forward simulations (EMPA)



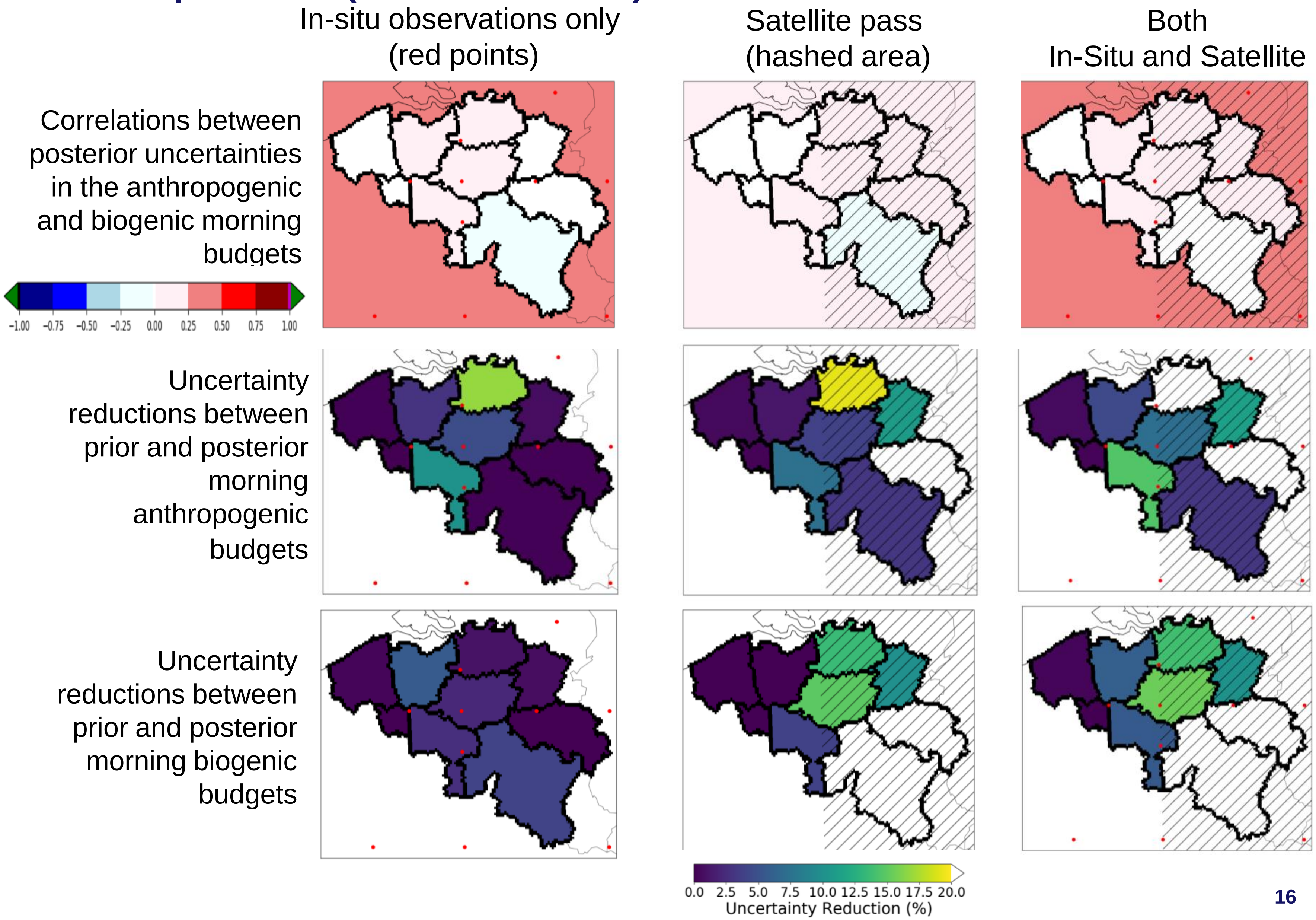


Modelling the Benelux plume (CEA/LSCE)

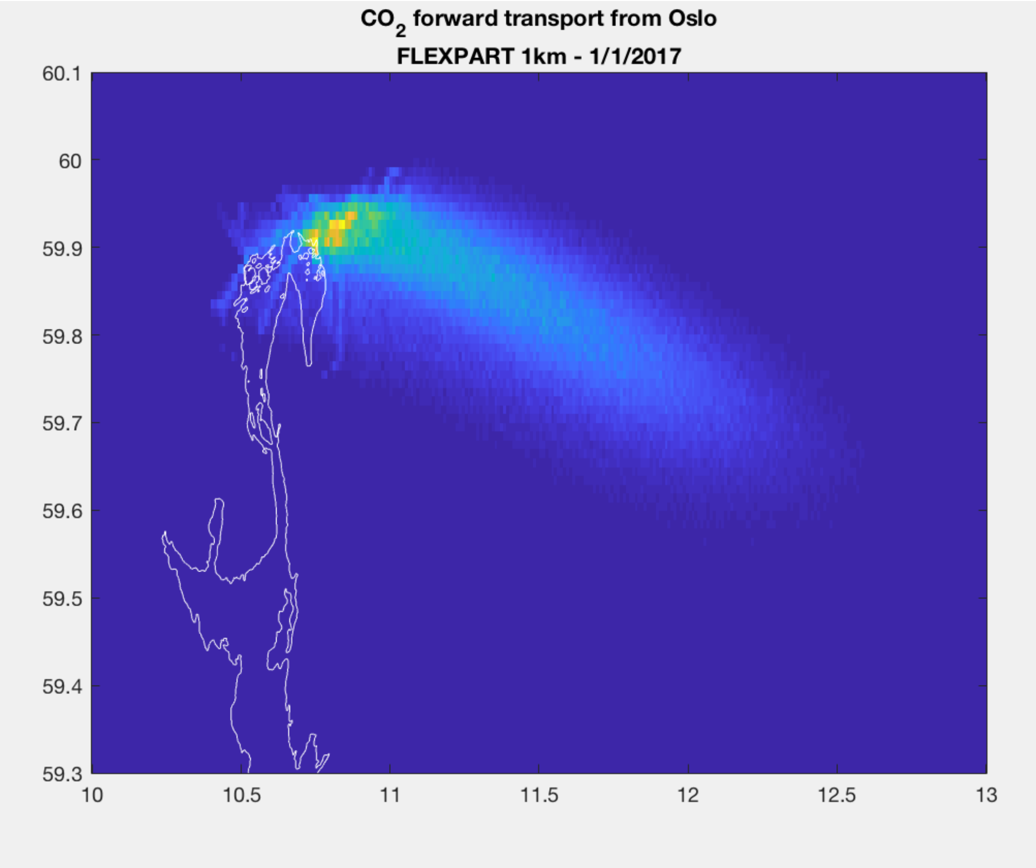
Impact of the assimilation of satellite and in-situ observations

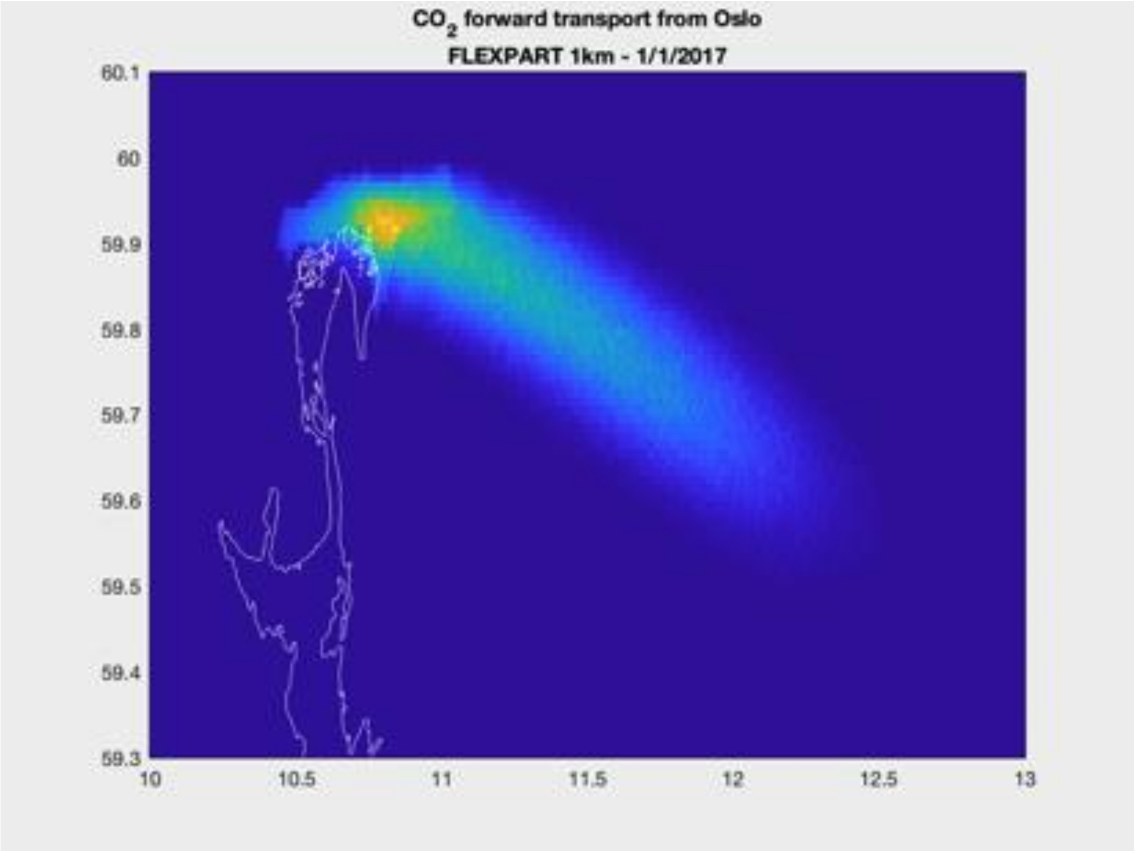
- The satellite pass mainly decreases the uncertainty for the regions within its field of view
- The uncertainty reduction is usually < 25%

- Negative correlations associated to relatively high posterior uncertainties are indicative of difficult separation between the different flux components, but they remain small here.



Modelling the Oslo downwind plume of CO_2 (NILU)





FLEXPART simulation at 1 km horizontal resolution during 3 hours starting 2017-01-01 at 00:00. With the URBES inventory (a). With the ODIAC inventory (b).

Main plans for the rest of Y2

- D4.3: Attribution problem configurations (report, lead MPG, M21)
  - Prior ocean APO flux estimates
  - Finalize set-ups for CO_2, CO, ^{14}C and APO (model configurations, input data, statistical hypotheses)
- First consolidated OSSEs

Frédéric Chevallier
CEA/LSCE
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