SPECIAL PROJECT PROGRESS REPORT

All the following mandatory information needs to be provided. The length should *reflect the complexity and duration* of the project.

Reporting year 2022………………………………………………………..…

Project Title: European emissions of CO2 and CH4 inferred from model inversion system and their comparison with annual national inventory reports ……………………………………………………………….……

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Computer Project Account: spitgraz …………………………………………………………………….……

Principal Investigator(s): Francesco Graziosi……………………………………….……

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Affiliation: University of Urbino Carlo Bo ……………………………………………………………………….……

Name of ECMWF scientist(s) collaborating to the project (if applicable) ……………………………………………………………………….……

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Start date of the project: 01/04/2021…………………………………………….……

Expected end date: 31/12/2023………………………………………………… ……….……

Computer resources allocated/used for the current year and the previous one
(if applicable)
Please answer for all project resources

		Previous year		Current year	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	4,000,000	-	4,000,000	7,000,000
Data storage capacity	(Gbytes)	2500	300	25000	5000

Summary of project objectives (10 lines max)

The aim of this project is to check the consistency between CO2 and CH4 bottom-up national emission inventories and concentration measured in the atmosphere. Moreover, changes in emissions of CH4 and CO2, due to the lock down COVID-19 pandemic, will be investigate over Po basin. For this purpose, a model inversion techniques will be used to estimate the magnitude and trend over 10 years period, of emissions sources of CH4 and CO2 over the European domain. In order to do this, we will use a combination of atmospheric measurements, Lagrangian Particle Dispersion Model (LDPM) in conjunction with a Bayesian inversion algorithm

Summary of problems encountered (10 lines max)

Initial technical problems, e.g. transferring data to/from ECMWF, compiling and achieving acceptable model performance at ECMWF CCA cluster.

Summary of plans for the continuation of the project (10 lines max)

Perform tests to evaluate the atmospheric transport model performances, focusing on mountain monitoring stations. Driven transport model with high resolution wind field. Carry out inversions sensitivity tests. Once determinate the reference setting to the inversion system, we will extend the inversions to all period investigated.

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List of publications/reports from the project with complete references

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Summary of results

Introduction

In order to estimate emissions of the most important greenhouse gases (GHGs), in particular CO2 and CH4, at different spatial scales using a top-down approach, we used the most up-to-date atmospheric measurements, appropriately distributed over the central western part of the European continent combined with inverse models that link emissions with concentrations using air mass transport models. The aim, supported by the World Meteorological Organization, is to promote the development of top-down modelling as a verification tool for the bottom-up approach, and foster links between the scientific world, policymakers and the regulatory world. In the inverse modelling approach, a first hypothesis emission map is therefore introduced in order to optimise the emission map, taking into account the uncertainties of the first hypothesis field to minimize the discrepancies between the real GHG measurements gas and the modelled ones.

Accurate estimates of national GHG emissions, mainly due to the energy sector, are of particular importance for understanding the effectiveness of the actions taken to achieve the reduction targets that the country must achieve to comply with international agreements on climate.

National GHG emission estimate obtained with the top-down approach have been compared with national inventory data, obtained through a bottom-up methodology, and with the EDGARv6.0 database. Considering the uncertainty associated with the estimate, we obtained an overall fair agreement with both. For the estimates obtained at higher spatial resolution, different locations of emission point sources, in correspondence with large urban and industrial centers are highlighted, as well as the lack of locations in similar areas.

Method

The timeseries of atmospheric CO2 and CH4 concentration values used in our study are obtained from measuring stations belonging to two of the main international measurement networks in Europe, ICOS (https://www.icos-cp.eu/) and WDCG (https://gaw.kishou.go.jp/). Although the measuring stations adopt different measuring instruments (e.g. gas chromatography, optical spectroscopy), they guarantee comparability between the time series (using a single calibration scale) and high accuracy of the measured data (high reproducibility guaranteed by the standards imposed by the networks). For this study, we considered time series of high-frequency measurements (≤ 3 hours), excluding measurements from weekly or daily flask. Indeed, the information of hourly atmospheric variability is necessary to discretize the spatial variability of emissions.
The measuring points used (Table 1) in the inversion process are: CMN (Monte Cimone, Italy), JFJ (Jungfraujoch, Switzerland), MHD (Mace Head, Ireland), PRS (Plateau Rosa, Italy), PUY (Puy-de-Dôme, France) and TAC (Tacolneston, UK).

Table 1 – List of monitoring stations used in the inversion system.

Monitoring stations	**WMO Code**	**Country**	**Latitude** (nortth: +; south: −)	**Longitude** (east: +; west: −)	**Altitude** (m a.s.l.)
Monte Cimone	CMN	Italy	44,193	10,701	2165
Jungfraujoch	JFJ	Switzerland	46,547	7,985	3580
Mace Head	MHD	Ireland	53,327	-9,904	8,4
Plateau Rosa	PRS	Italy	45,935	7,707	3480
Puy-de-Dôme	PUY	France	45,772	2,966	1465
Tacolneston	TAC	United Kingdom	52,518	1,139	56

Inverse Modelling

The approach that we used for this study combines the high-frequency trace gas observations with an atmospheric particle dispersion model and a Bayesian inversion. To simulate transport to the receptor sites, we used trajectories obtained with the 3-D FLEXPART v-10.4 dispersion model (Pisso et al., 2021, Stohl et al., 1998; 2005) run every three hours for 20 days backward driven by operational three-hourly meteorological data at 1°x 1° resolution from the European Centre for Medium-Range Weather Forecasts (ECMWF). This allowed us to obtain the sensitivity of the receptor to the source, also defined as the source receptor relationship (SRR) which in a particular grid cell is proportional to the particle residence time in that cell and measures the simulated mixing ratio that a source of unit strength (1 kg s^{-1}) in the cell would produce at the receptor (Stohl et al., 2009). Fig 1 shows an example of footprint retrieved from the simulation of CMN JFJ and PRS stations on 03 02 at 22.00 hrs.

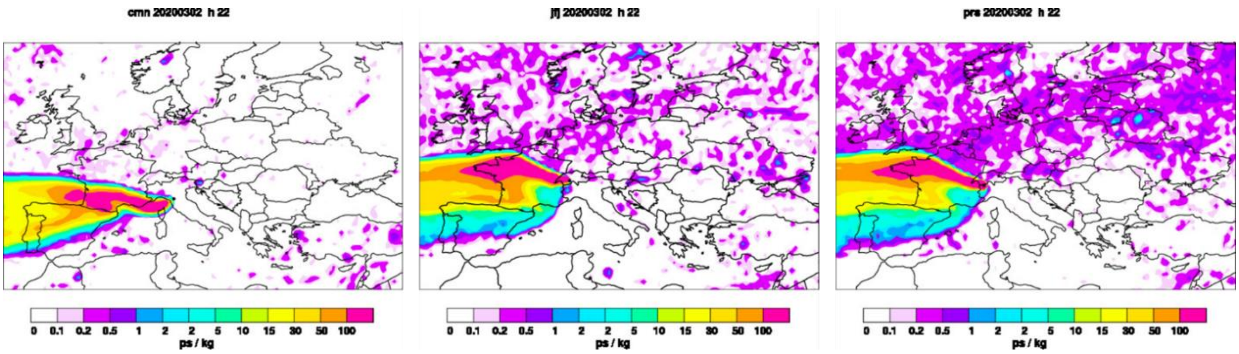


Fig 1 Footprint calculated for the station CMN (left), JFJ (centre) and PRS (right), on 2020 03 02 at 22.00 hrs.

Multiplying the emission sensitivity by the emission flux taken from an appropriate emission inventory (the *a priori* emission field), the simulated mixing ratio at the receptor to be compared with the observations is obtained. Finally, the a posteriori emission field is obtained through the Bayesian inversion method developed by l by Thompson and Stohl (2014).

Preliminary results

- CO_2

Figure 2 shows the CO2 emission values in the CWE in the year 2018 calculated through modelling inversion (INV), and the values reported in the two databases (UNFCC and EDGARv6.0). In 2018, the CO2 emission value in the CWE reported in the EDGARv6.0 database is higher than the value in the UNFCCC inventory of 0.85 Pg/yr. The CO2 emission value calculated through the inversion method is 2.73 ± 0.63 Pg/yr. This value is 0.55 Pg/yr higher than the emission value reported in the UNFCCC inventory and 0.31 Pg/yr lower than the value reported in the EDGARv6.0 database. From this analysis we observe that the INV estimates are closer to the values calculated by EDGARv6.0 than those reported in the UNFCCC inventory, although both values reported in the two databases fall within the error bar. Looking at the individual areas, we see substantial agreement between the estimate from INV and that reported in EDGARv.6.0, except for the DE and UK region, where the estimated values are closer to those reported in the UNFCCC database.

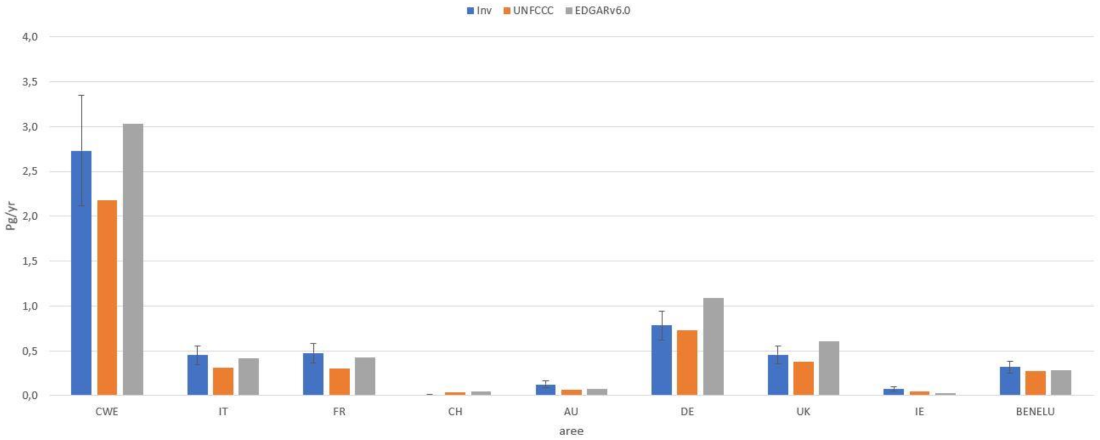


Figure 2- CO2 emission values (expressed in Pg/yr) in the year 2018 from individual areas within CWE derived from inversion (INV, blue bars) and comparison with those reported in the UNFCCC (orange bars) and EDGARv6.0 (grey bars) databases.

Figure 3 shows the CO2 emission distribution over the study domain obtained by the inversion (left) (average over the period 2018-2020) and reported on the EDGARv6 database (right) (2018).

We see that the largest CO2 emission fluxes correspond to industrial and more densely populated areas, such as BENELU, the Po Valley and large European metropolises. A comparison with the UNFCCC inventory is not shown because this does not contain the information on the distribution of emissions.

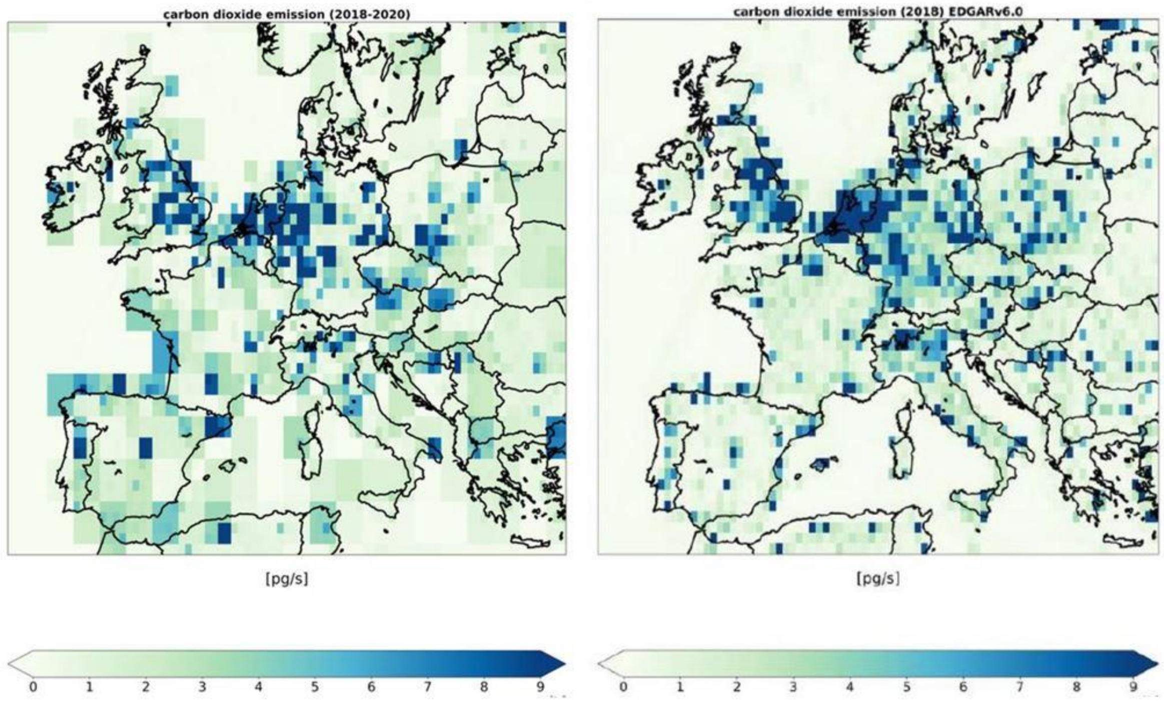
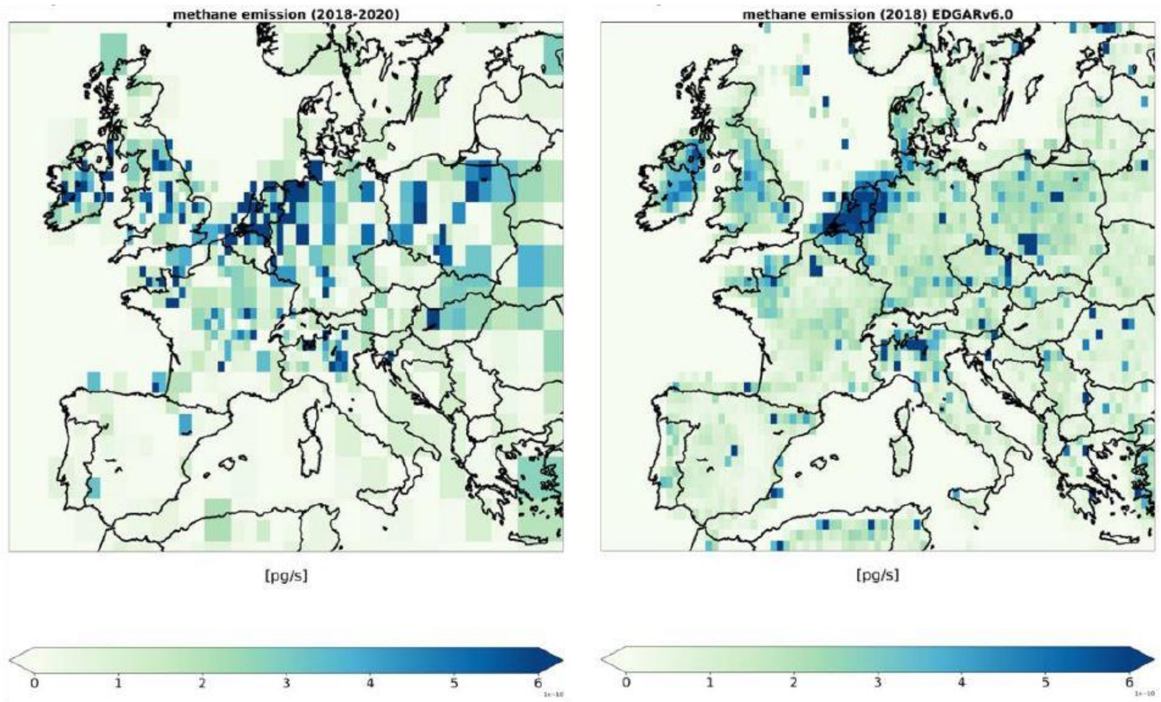


Figure 3 - CO2 emission map (average 2018-2020) derived from inversion (left) and derived from data in the EDGARv6.0 database for the year 2018 (right).

- CH4

Figure 4 shows the CH4 emissions distribution retrieved from the inversions over the period 2018-2010 (left) and reported in the EDGARv6.0 for the period 2018.



Additional resource are needed in order to move forward on the project.
Part of the preliminary results showed here were obtained using an external machine.

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