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	2023……………………………………………………….… …
Project Title:	European emissions of CO2 and CH4 inferred from model inversion system and their comparison with annual national inventory reports ………………………………………………………….…… ………………………………………………………….………
Computer Project Account:	spitgraz ………………………………………………………….………
Principal Investigator(s):	Francesco Graziosi……………………………….……. ………………………………………………………….………
Affiliation:	University of Urbino Carlo Bo ………………………………………………………….………
Name of ECMWF scientist(s) collaborating to the project (if applicable)	………………………………………………………….……… ………………………………………………………….………
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	7,000,000	4,000,000	-
Data storage capacity	(Gbytes)	25000	5000	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, compiling and achieving acceptable model performance at the Atos 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. Comparing the inversion results with a different inversion system results.……
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List of publications/reports from the project with complete references

Report Stima delle emissioni dei gas serra a differenti scale spaziali mediante modellistica inversa e confronto con gli inventari nazionali per valutare l'efficacia delle politiche europee nel contrastare i cambiamenti climatici. Rif.RSE 21010315 **(Autori** F. D'Assisi Apadula, A. Lanza (RSE S.p.A.), M. Maione, F. Graziosi (UniUR Carlo BO - DISPEA)………
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Summary of results

Introduction

Surface based high frequency observations, distributed around the European geographical domain, in conjunction with atmospheric transport model and inversion system are adopted to provide the emission estimation of the fluxes of carbon dioxide (CO2) and methane (CH4). The so-called, top-down approach, can be used in order to enhance accuracy, cost-efficiency and transparency of the process to assess progress towards the national emissions reduction targets, carried out with bottom up approach. For this reason, climate scientists employ atmospheric observations to determine atmospheric emissions and support national bottom-up emission inventories, providing independent data of emission values on quasi-real time and generate spatial and temporal distribution of emission fluxes with a level of accuracy compliant with policy needs. In our work, national GHG emission estimate obtained with the top-down approach have been compared with national inventory data, and with the EDGARv6.0 database. Considering the uncertainty associated with the estimate, we obtained an overall fair agreement with both.

Method

The timeseries of atmospheric CO2 and CH4 concentration values used in our study are retrieved 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

High frequency observations, in combination with atmospheric transport model and Bayesian inversion system, are adopted to asses the emissions of CO_2 ad CH_4 over the European domain.

We simulate the transport of particles, in backword mode, starting from the measurement sites. For this purpose, 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). The CO_2 particles were considered as passive tracer, meanwhile the CH4 particles reacted with OH field in order to simulate the atmospheric sink of methane. Post processing the output of atmospheric transport model allowed us to obtain the sensitivity of the receptor to the source, also defined as the source receptor relationship (SRR) . The SRR 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 average footprint retrieved using 1 year of backward simulations of all the stations.

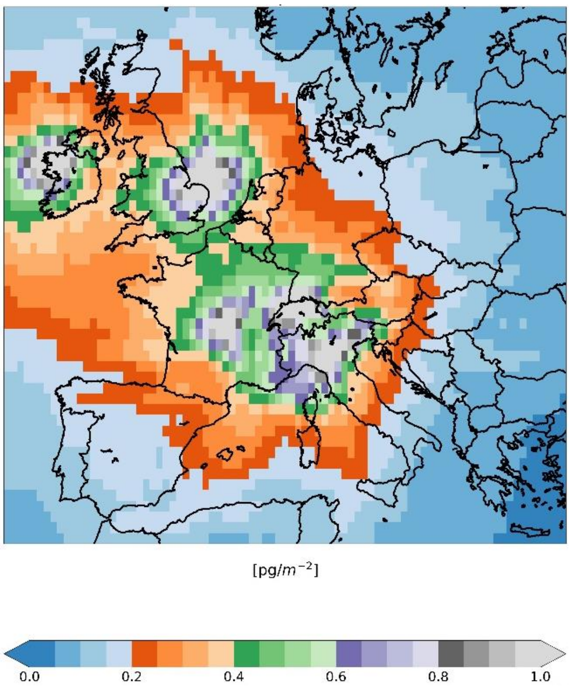

Fig 1 One year average footprint obtained using 1 year of backward FLEXPART model simulations of the stations used in the inversions.

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

- CH_4

Figure 2 shows the CH_4 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 CH_4 emission value in the CWE reported in the EDGARv6.0 database is larger than the value in the UNFCCC inventory of 1.1 Tg/yr. The CH_4 emission value calculated through the inversion method is 12.9 ± 3.1 Tg/yr. The CWE inversion estimate is1.8 and 0.8 Tg/yr larger then the UNFCCC and EDGARv6.0 emissions respectively.
Based on this comparison 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 of the inversion estimate. Looking at the main individual areas, we see substantial agreement between the estimate from INV and that reported in both of database, except for the BENELU, whereas larger percentage discrepancy are obtained for the small countries, (i.e CH and AT) mainly due to the errors related border definition.

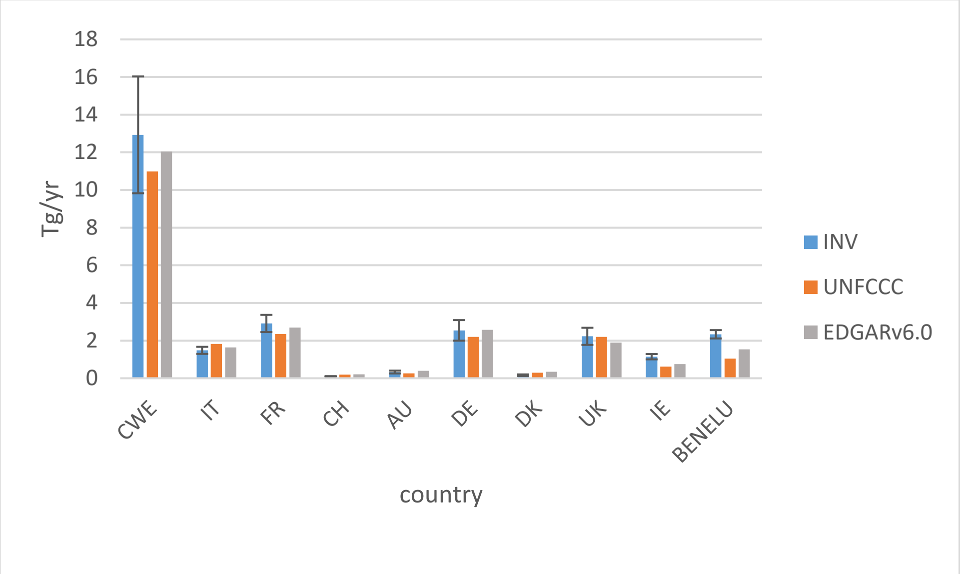

Figure 2- CH_4 emission values (expressed in Tg/yr) in the year 2018 from individual areas within CWE derived from inversion (INV, blue bars), the UNFCCC (orange bars) and EDGARv6.0 (grey bars) databases.

CH_4 emission distribution.

We performed the CH_4 inversions from 2018 to 2021, using EDGARv6.0 (year 2018) as a priori emission field and the four stations reported previously. Figure 4 shows the CH4 emissions distribution retrieved from the inversions over the period 2018-2021 (left) and reported in the EDGARv6.0 for the period 2018.

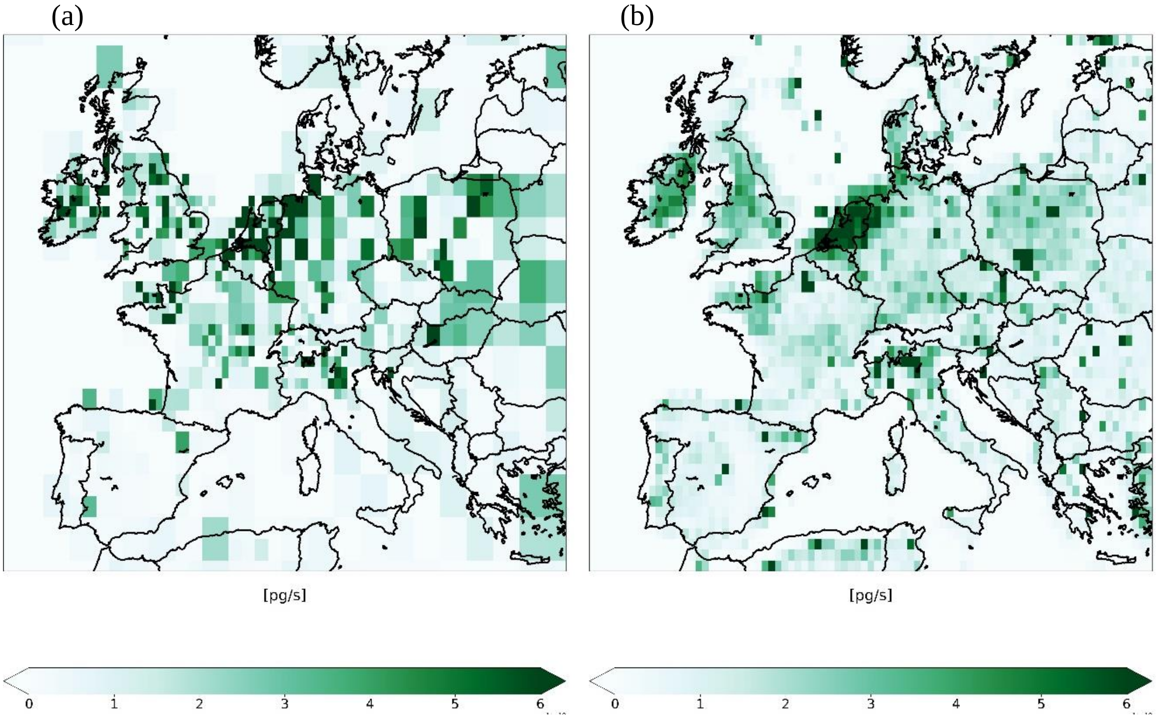
(a)
(b)

Fig 4 2018-2021 average methane emissions retrived from the inversion (a), metahne emissions distribution reported in the EDGARv6.0 database.

Part of the preliminary results showed here were obtained using an external machine.