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	2024………………………………………………..……
Project Title:	Extend and improve CH4 flux inversions at global and European scale based on ERA5 reanalyses ………………………………………………………..…… ………………………………………………………….……
Computer Project Account:	ECJRC……………………………………………..……
Principal Investigator(s):	Dr. Francesco Graziosi (EC-JRC)……………………..…… ………………………………………………………….……
Affiliation:	European Commission, Joint Research Centre (EC-JRC) Directorate for Energy, Mobility and Climate Clean Air and Climate Unit ……………………………………………………..……
Name of ECMWF scientist(s) collaborating to the project (if applicable)	………………………………………………………….…… ………………………………………………………….……
Start date of the project:	2022………………………………………………..……
Expected end date:	2024…………………………………………………….….

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)	3.200.000	3.754.748	850.000	176.754
Data storage capacity	(Gbytes)	1500	1300	1500	1300

Summary of project objectives (10 lines max)

Extend and improve estimates of global CH4 emissions. Assess the global methane emissions applying global inversion system (TM5-4DVAR). The purpose of the special project was improve the understanding of the methane (CH_4) source and sink processes investigating CH_4 fluxes trough atmospheric model inversion system. To do this, we calculate the global CH_4 fluxes using TM5-4DVAR inversion system over the period from 2018 to 2021. The inversions were driven by both, surface based observations and space born observations. The atmospheric inversion system adopted in this study allows to determine the monthly fluxes from 4 different emission categories : rice fields, wetlands, biomass-burning and anthropogenic sources.

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Summary of problems encountered (10 lines max)

No major problems encountred……………………………………………………………………………………………
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Summary of plans for the continuation of the project (10 lines max)

Extend the application of the TM5-4DVAR inversions up to 2022 with the aim to assess the methane emissions from global domain. Perform a set of sensitivity tests to determine the best model setting to retrieve the wetlands methane fluxes. Increase the spatial resolution of the inversions grid fluxes to 1° x 1° latitude longitude horizontal resolution.

List of publications/reports from the project with complete references

Report in preparation.

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Summary of results

If submitted **during the first project year**, please summarise the results achieved during the period from the project start to June of the current year. A few paragraphs might be sufficient. If submitted **during the second project year**, this summary should be more detailed and cover the period from the project start. The length, at most 8 pages, should reflect the complexity of the project. Alternatively, it could be replaced by a short summary plus an existing scientific report on the project attached to this document. If submitted **during the third project year**, please summarise the results achieved during the period from July of the previous year to June of the current year. A few paragraphs might be sufficient.

To improve the knowledge of the global CH_4 source and sinks process we investigate the CH_4 fluxes using atmospheric inversion cascade, based on atmospheric chemical transport model (TM5), atmospheric observations and 4DVAR inversion system. The preliminary results reported here are generated adopting the TM5-4DVAR inversion system [Bergamaschi et al., 2013; Meirink et al., 2008; Segers and Houweling, 2017a;

2017b]. This model chain is based on the atmospheric transport model TM5 [Krol et al., 2005] and its adjoint and uses a 4DVAR variational technique that iteratively minimises the cost function. To estimate the global CH4 fluxes for the period 2018 2021 three different inversion simulation were conducted. The TM5 chemical transport model was driven by ECMWF ERA5 meteorological fields at 1 ° lat 1 ° lon grid resolution and 137 vertical layers. The model generate the 3D CH_4 mole fraction fields taking in to account the a priori information on emission from wetlands, rice fields, biomass burning and anthropogenic sources, and atmospheric sinks in the troposphere (reacting with OH) and in the stratosphere (OH, CL and O1(D)).

The inversion system ingests the surface based measurements and satellite retrievals as observational constraints to optimise fluxes in the grid cells taking into account the four source categories. The inversion procedure consists of two inversion steps. As the first step, we performed an yearly inversions (including 6-months of spin up and 6 months of spin down) at coarse resolution (6° x 4° latitude longitude and 25 vertical levels) using surface based measurements from NOAA Earth System Research Laboratory (ESRL) [Segers and Houweling, 2017a; 2017b], covering the period from 2018 to 2021, extending one year from the previous report.

This first inversion stream generates the 3D optimized methane mole fraction fields, ingested as initial concentration fields by the second iteration inversions.

The second step consists in a yearly (plus 6 months of spin-up and 6 months of spin-down) high resolution (3° x 2° lat lon and 34 vertical layer) inversion runs covering all the investigated period. We performed two different high resolution inversion streams, 1) using surface based measurements from NOAA only (named S1), and 2) adopting satellite retrievals (from GOSAT satellite) and surface based measurements from NOAA (named S2). For the last high resolution inversion stream (S2), a bias correction is applied.

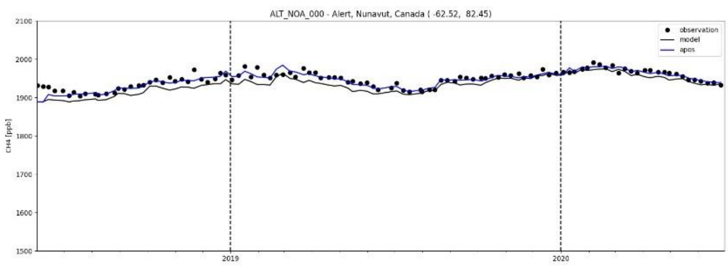
During the last year of activity, we increased the resolution of meteorological data up to 1° x 1° latitude longitude horizontal resolution and 137 vertical levels. Moreover, we refined the bias correction system, increasing the time resolution of the bias correction fields applied in the inversions, improving the accuracy of the inversion results. Furthermore, we increased the model sensitivity, adding non-remote sites observations to the measurement network adopted in the inversion cascade. However, in order to avoid local contaminations, not reproduced by the model, we selected the measurements ingested by inversion system. Indeed, for the stations with in situ measurements in the boundary layer, the model assimilated measurements in the early afternoon (between 12:00 and 15:00 LT) and for mountain stations only nighttime measurements were assimilated (between 00:00 and 03:00 LT), in similar manner of Bergamaschi et al., [2015].

In addition to the previous report, the inversions at high resolution are conducted using surface based measurements and the Copernicus Sentinel-5 Precursor satellite using the Tropospheric Monitoring Instrument TROPOMI observations over the global domain. To do this, the TROPOMI observations are post processed in to 1° x 1° latitude longitude horizontal resolution.

Currently we are focusing on comparative analysis between CH_4 fluxes obtained by the S1 inversions, S2 inversions based on GOSAT data and S2 inversions using TROPOMI observations.

Furthermore, we are conducting tests to increase the horizontal resolution of the inversions, reaching the 1° x 1° latitude longitude resolution over the global domain.

The fig 1 shows an example of CH_4 mixing ratio timeseries from Alert in Canada (ALT), Ascension Iland in United Kingdom (ASC), Terceira Island in Portugal (AZR) and Tudor Hill, Bermuda of United Kingdom (BMW), obtained through the S2 inversions using TROPOMI data. The model inversions ingested as input the CH_4 mixing ratio observed from monitoring stations (“obs”), the a priori mixing ratio (“model”) obtaining the a posterior runs (“apos”).



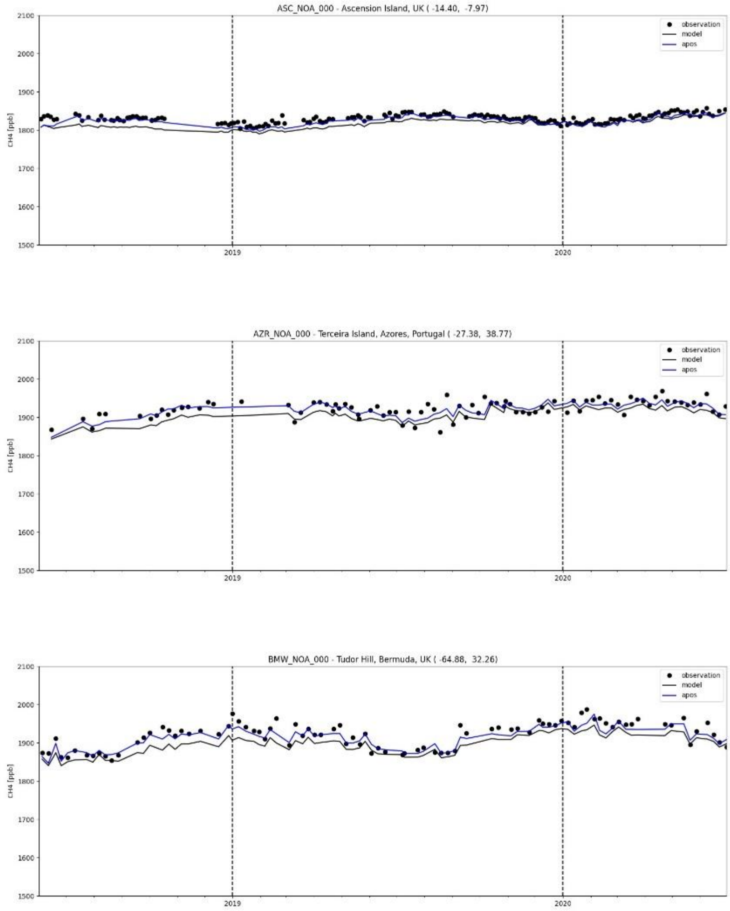


Figure 1. Methane mixing ratio timeseries of Alert in Canada (ALT), Ascension Iland in United Kingdom (ASC), Terceira Island in Portugal (AZR) and Tudor Hill, Bermuda of United Kingdom (BMW) of observations "obs", a priori simulation "model" and a posteriori run "apos", obtained by the S2 inversions using TROPOMI data.

References

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