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	2021 (01 January 2021 - 30 June 2021)
Project Title:	Extend and improve CH_4 flux inversions at global and European scale
Computer Project Account:	spjrc4dv
Principal Investigator(s):	Dr. Ernest Koffi (EC-JRC)
Affiliation:	European Commission Joint Research Centre (EC-JRC) Directorate for Energy, Transport and Climate Air and Climate Unit
Name of ECMWF scientist(s) collaborating to the project (if applicable)	……………………………………………….…… ……………………………………………….……
Start date of the project:	01 January 2021
Expected end date:	31 December 2021

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)			150000	33822 (29 June 2021)
Data storage capacity	(Gbytes)			1500	

Summary of project objectives (10 lines max)
- Extend and improve estimates of global CH_4 emissions
- Further develop, test and apply coupled FLEXPART-COSMO / TM5 4DVAR inverse modelling system ("FLEXVAR") with high spatial resolution.

Summary of problems encountered (10 lines max)

no major problems

Summary of plans for the continuation of the project (10 lines max)
- finalization of FLEXVAR model development
- application of FLEXVAR to estimate European CH_4 emission, including a comprehensive set of sensitivity experiments

List of publications/reports from the project with complete references
- various (non-public) internal reports on FLEXVAR system
- publication about FLEXVAR system in preparation

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.

Further development and testing of coupled FLEXPART-COSMO / TM5 4DVAR inverse modelling system ("FLEXVAR")

Building on the development of the coupled FLEXPART-COSMO / TM5 4DVAR inverse modelling system ("FLEXVAR") performed during the previous special project ("Improve European and global CH_4 and N_2O flux inversions", 2018-2020, PI: Dr. Peter Bergamaschi), various further developments have been performed:

- a new approach to estimate / parameterize the model representation error based on meteorological data (from COSMO-7 model) at the monitoring stations has been implemented and tested. This new approach results in generally somewhat better statistical performance of the station data (posteriori model simulations vs. observations) compared to the parameterization of the model representation error based on the difference between prior model simulations and observations.

- a new approach to describe the boundary conditions ("baseline") for the limited domain model FLEXPART has been implemented, based on the "particle dumps" of the FLEXPART trajectories (particle positions at termination of the back trajectories) and 3D CH_4 concentration fields from global TM5-4DVAR inversions (with European zoom). This approach can be used as alternative to the scheme of Rödenbeck et al. [2009]. The two schemes yield somewhat different baselines (and consequently somewhat different posterior emissions), which is currently analysed in more detail.

- The conjugate gradient / Lanczos algorithm has been implemented to estimate the posteriori uncertainties, including aggregated uncertainties, e.g., for total emissions from countries (taking into account the estimated posterior covariance).

- The emission interface has been extended to allow the use of recent emission inventories (e.g., EDGARv6.0) as prior emission estimates.

Figure 1 shows as example a FLEXVAR inversion for 2018 using EDGARv6.0 (2018) as prior and a comprehensive observational data set of 20 European atmospheric stations.
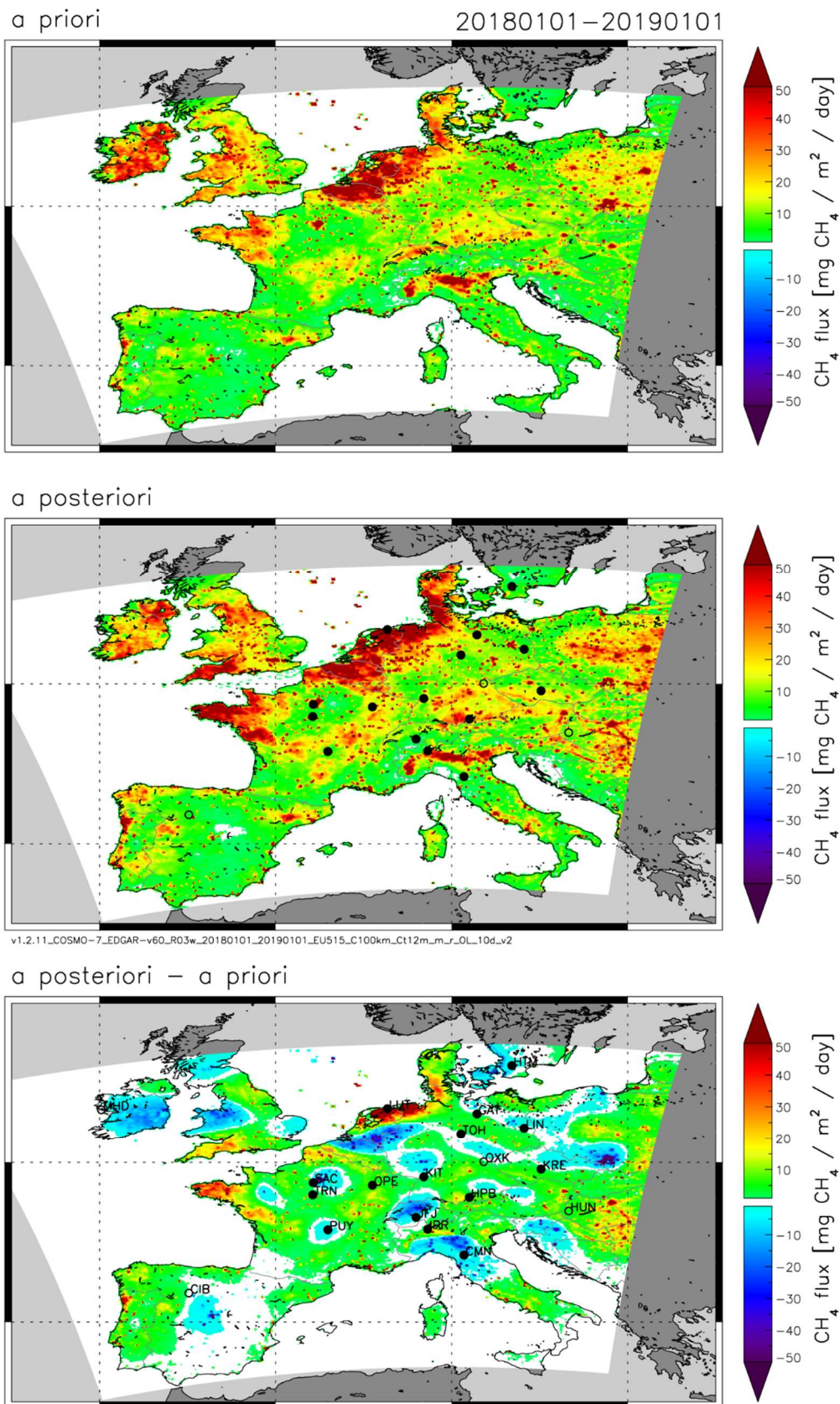
Figure 1: Inverse modelling of European CH$_4$ emissions with high-resolution FLEXVAR inverse modelling system. The FLEXVAR system uses FLEXPART-COSMO-7 back trajectories at a resolution of about 7 km × 7 km. Top: a priori emissions (EDGARv6.0; no natural emissions used in this test inversion). Middle: a posteriori emissions. Bottom: difference between a posteriori and a priori. Black circles show locations of measurement stations used in the inversion; filled circles: stations with quasi-continuous measurements; open circles: discrete air sampling sites.