REQUEST FOR A SPECIAL PROJECT 2025–2027

MEMBER STATE: Italy……………………………………………………………………………………………..

Principal Investigator[1]**:** Dr. Francesco Graziosi (EC-JRC)…………………………………………….

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Other researchers: Giovanni Manca (EC-JRC), Delia Segato (EC-JRC)…………………………………………………………

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Project Title: Global emissions of methane inferred from atmospheric inversions modelling technique……………………………………………………………

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To make changes to an existing project please submit an amended version of the original form.)

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP** ECJRC………….	
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2025	
Would you accept support for 1 year only, if necessary?	YES X	NO ☐

Computer resources required for project year:		**2025**	**2026**	**2027**
High Performance Computing Facility	[SBU]	900.000	900.000	900.000
Accumulated data storage (total archive volume)[2]	[GB]	2500	2500	2500

EWC resources required for project year:		**2025**	**2026**	**2027**
Number of vCPUs	[#]			
Total memory	[GB]			
Storage	[GB]			
Number of vGPUs[3]	[#]			

Continue overleaf.

[1] The Principal Investigator will act as contact person for this Special Project and, in particular, will be asked to register the project, provide annual progress reports of the project's activities, etc.
[2] These figures refer to data archived in ECFS and MARS. If e.g. you archive x GB in year one and y GB in year two and don't delete anything you need to request x + y GB for the second project year etc.
[3]The number of vGPU is referred to the equivalent number of virtualized vGPUs with 8GB memory.

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Extended abstract

All Special Project requests should provide an abstract/project description including a scientific plan, a justification of the computer resources requested and the technical characteristics of the code to be used. The completed form should be submitted/uploaded at https://www.ecmwf.int/en/research/special-projects/special-project-application/special-project-request-submission.

Following submission by the relevant Member State the Special Project requests will be published on the ECMWF website and evaluated by ECMWF and its Scientific Advisory Committee. The requests are evaluated based on their scientific and technical quality, and the justification of the resources requested. Previous Special Project reports and the use of ECMWF software and data infrastructure will also be considered in the evaluation process.

Requests exceeding 10,000,000 SBU should be more detailed (3-5 pages).

Methane (CH_4) is the second most important anthropogenic greenhouse gas in the Earth climate system, with additional indirect impacts as it affects both tropospheric ozone and stratospheric water vapor. Atmospheric CH_4 has significantly increased since the preindustrial times and currently contributes to about 20% of the concentration-based radiative forcing (RF) [IPCC 2013]. There are both natural and anthropogenic sources of CH_4 emissions. Wetlands are the largest natural source and contribute between 30 and 40% to the total CH_4 emissions [Wania et al.,2010]. At the same time, wetlands are important carbon (C) sinks, since anoxic conditions favour C accumulation by limiting the microbial decomposition of plant residues. Climate change or anthropogenic impacts (e.g. draining) which altering environmental conditions may alter the wetlands' exchange of CO_2 and CH_4 with the atmosphere. The production of CH_4 in wetlands is due to microbial methanogenesis, which depends on temperature, water-table depth, and both the quality and quantity of organic matter [O'Connor et al., 2013]. Climate change is going to affect these main drivers, leading to possible increment of CH_4 emissions from wetlands. Because of the multiple feedbacks between climate and the drivers of CH_4 emissions, wetlands have the potential to substantially amplify human-induced climate change and are therefore ecosystems of major concern for prediction of future climate trajectories. The aim of this project is to investigate the relation between these main drivers and the CH_4 wetland fluxes. We plan to estimate the CH_4 emission fluxes using inverse model approach. The inverse modeling system estimates surface CH_4 emissions through the use of observed atmospheric CH_4 concentrations, a transport model, prior estimates of CH_4 emissions, and estimates of atmospheric CH_4 removal (primarily by the hydroxyl radical) [Bergamaschi et al., 2013].
For this, we will use 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. The TM5 chemistry transport model will be driven by ECMWF ERA5 meteorological fields at 1° x 1° latitude longitude horizontal resolution and 137 vertical layers. Simulations are performed at the same horizontal resolution of the ERA-5 meteorological input, and at 34 vertical layers, defined as a coarsening of ECMWF's 137-layer definition. The temporal resolution of the data processed for TM5 is hourly for the surface fields, and 3-hourly for 3D fields; at run time, linear interpolation in time is used to obtain the values at the model time step. The model system generates the 3D methane model fraction fields taking into account a priori information on emissions from wetlands, rice, biomass burning, other (mainly anthropogenic) sources, and atmospheric photochemical sinks in the troposphere (reacting with OH) and in the stratosphere (OH, Cl and O1(D)). The output of the inversions is a timeseries optimized surface fluxes of CH_4. The a posterior fluxes are deviations from a priori fluxes that provide better agreement with observations when used as input in the chemistry transport model TM5-MP. The CH_4 fluxes will be estimated for four different emission categories: wetlands, rice fields, biomass burning and others (mainly

anthropogenic). The a priori emission fields will be built from different emission category fields. The global wetland CH_4 emissions will be obtained using the process-based Dynamic Global Vegetation Model (DGVM) LPJ-wsl [Zhang et al., 2018]. However, we will conduct tests in order to evaluate more updated wetland CH_4 emission fields. The biomass burning emissions will be taken from GFAS [Kaiser et al., 2012], as available from the CAMS fire emission service from 2003 onwards.
The CH_4 emissions from anthropogenic sources will be retrieved from EDGARv8 database. Natural CH_4 fluxes fields, such as ocean, wild animals, termites, and soil sinks, will be retrieved from climatological model simulation fields (e.g. Lambert and Schmidt, 1993 , Sanderson et al., 1996).
In this study we plan to use both, CH_4 surface base observations and satellite measurements.
Indeed, even if the measurements from the ground based CH_4 network accurately track the global atmospheric CH_4 budgets and their trends, adding the global satellite CH_4 observations to the inversion system, allows to increase the coverage of the detected sources improving the quantification of the CH_4 fluxes magnitude from emitted areas. The monthly timeseries optimized surface fluxes of CH_4 for the four source category will be obtained from the model inversions, at spatial resolution of 1° x 1° latitude longitude degree resolution, over the period of 2018-2023. This will allows us to investigate the relationship between wetlands emissions and the driving paraments during the period investigated. Special attention will be dedicated to evaluate the effect of the El Niño–Southern Oscillation (ENSO) phenomenon to the CH_4 fluxes. The surface based observations will be retrieved from NOAA Earth System Research Laboratory (ESRL) and integrated carbon Observatory System (ICOS) database. In addition, the XCH_4 retrievals from Greenhouse Gases Observing Satellite (GOSAT) and Copernicus Sentinel-5P TROPOspheric Monitoring Instrument (TROPOMI) will drive the inversions.
The inversion procedure consists of two inversion steps. As the first step, we will perform 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), covering the period from 2018 to 2023. This first inversion stream will generate the 3D optimized methane mole fraction fields, which will be ingested as initial concentration fields by the second iteration inversions. ElThe second step consists in a yearly (plus 6 months of spin-up and 6 months of spin-down) high resolution (1° x 1° latitude longitude and 34 vertical layer) inversion runs covering all the investigated period. We will perform two different high resolution inversion streams, 1) using surface based measurements from NOAA only, and 2) adopting satellite retrievals from satellite and surface based measurements. For the last high resolution inversion stream, a bias correction will be applied.

Project plan

During the first year of the project a setup of the model cascade will be performed focusing in one year of inversion (e.g. 2019). During this period we will examinate the input data (e.g. observation networks, XCH_4 measurement from different satellites, a prior emissions fields), with the aim to find the best model setting of inversion system, which allow us to better constraint the global CH_4 fluxes. Moreover, a series of sensitivity tests will conducted in order to determine the stability of the results respect the input data variability.
The second year will be focused on extending the best model setup to all investigate period, and conducting statistical analysis of driver paraments.
The third year will be dedicated to analysis the relations between the CH_4 emission fluxes, calculated by the inversions, and the driver parameters. Technical report or scientifical publication is expected to be achieved from this study.

The amount of SBU's requested are mainly needed to perform the high resolution inversions, and the amount of the space disk request are required to write the output of the model system .

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