<u>LATE</u> REQUEST FOR A SPECIAL PROJECT 2024–2026

MEMBER STATE: Germany

Principal Investigator[1]: Swen Metzger

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Project Title: Application and validation of a computationally efficient and mass-conserving cloud cover module that considers the aerosol—cloud continuum for NWP, including fog, haze and optical thin clouds

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** N/A	
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2024	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for project year:		**2024**	**2025**	**2026**
High Performance Computing Facility	[SBU]	2.000k	10.000k	8.000k
Accumulated data storage (total archive volume)[2]	[GB]	4TB	10TB	20TB

EWC resources required for project year:		**2024**	**2025**	**2026**
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.

Principal Investigator: Swen Metzger

Project Title: **Application and validation of a computationally efficient and mass-conserving cloud cover module that considers the aerosol—cloud continuum for NWP, including fog, haze and optical thin clouds**

Extended abstract

Within the Copernicus Atmosphere Monitoring Service (CAMS2_35), a computationally efficient gas-aerosol partitioning module (Metzger et al., 2012, 2016, 2018, 2023) has been recently integrated in the Integrated Forecasting System, IFS-COMPO (Flemming et al., 2017, Rémy et al., 2019, 2022, Williams, et al, 2022). From the next operational cycle (CY49R1) onwards, IFS-COMPO represents numerous aerosols, trace and greenhouses gases, and treats aerosol hygroscopic growth (HGF) more explicitly. HGF plays an important role in the computation of various aerosol properties since water is mixed in the aerosol particle, increasing its mass and size and decreasing its density under humid conditions affecting the aerosol direct radiative effects, gas/aerosol partition, aerosol lifetime, as well as aerosol acidity (Metzger et al., 2024, Rémy et al., 2024, Williams, et al, 2024). Despite these recent significant improvements, the full potential w.r.t. HGF are not fully captured yet with CY49R1, since aerosol indirect effects are not of focus of CAMS and can therefore not be considered. However, it is well known that aerosols can affect through HGF (i.e., aerosol water) cloud formation, as well as haze, fog and optical thin clouds (e.g., Metzger and Lelieveld, 2007). Unfortunately, CAMS2_35 does not cover any spin-offs from the 'near-operational' tasks, in terms of progress in scientific terms. Investigations of the benefit of any aerosol—cloud interaction approach are beyond the scope of CAMS. Therefore, we consider this special project, which aims to provide us with needed computational resources to execute such science-related aspects.

This special project is about an application and validation of a computationally efficient cloud cover module, which is mass-conserving, and which allows to consider the aerosol—cloud continuum, including fog, haze and optical thin clouds, for climate and NWP scales. The routine calculates the area fraction of a grid box covered by stratiform and convective (sub grid-scale condensing) clouds and diagnoses the initial cloud water and cloud ice mass from the aerosol composition and associated water mass, depending on aerosol hygroscopic growth (Metzger and Lelieveld, 2007). The routine has been written in 2004 by S. Metzger for use in the non-hydrostatic limited-area atmospheric model – formally known as the Local Model (LM) of the German Weather Forecast Service (DWD) and now called COSMO, since maintained and developed by the Consortium for Small-scale Modeling (COSMO) – as part of the EC funded ANTISTORM EC(Nest)-project. But a derivate of the original routine also has been applied in the EMAC chemistry-climate model and applied to evaluate e.g., the Metop PMAp version 2 AOD product, as well as solar irradiance day-ahead forecasting as part of the EoCoE project (Cumpston et al., 2017). Results of an initial evaluation are displayed in Figure 1, showing the differences of MSG cloud fraction minus the original ECHAM5 scheme versus the MSG cloud fraction minus the new cloud cover scheme coupled to an aerosol model that can provide the aerosol water content at high humidity (up-to saturation).

The fractional cloud cover (clc) is determined from the aerosol water content that depends on the chemical composition and mass of the atmospheric aerosol particles and relative humidity. An in-cloud water and ice content of sub grid-scale clouds is determined from the aerosol water mass and the freezing point depression caused by the dissolved particulate matter. The threshold for the cloud water/ice mass is the saturation specific humidity, while the aerosol water mass is limited by the available water vapor. The quantities define the grid-volume mean cloud water/ice. Assumptions are made on the mass and number distributions of the particulate matter, in case no explicit coupling exists with an aerosol model. The module can thus be also applied at pure NWP scale by using an aerosol climatology rather than a detailed aerosol package. We intend to apply and validate the computationally efficient and mass-conserving cloud cover module both with and without a detailed aerosol package using IFS and considering multi-year simulations. The model results will be evaluated with various ground-station and satellite observations, including BSRN, CERES, Eye2Sky, EarthCARE data. Special attention will be given to the ability in improving day-ahead forecasting of solar irradiance properties, such as the global horizontal irradiance (GHI) and the direct normal irradiance (DNI) which are needed by the solar power community and therefore part of the CAMS Radiation Service (e.g., Azam et al., 2021, Schroedter-Homscheidt et al., 2016, 2018).

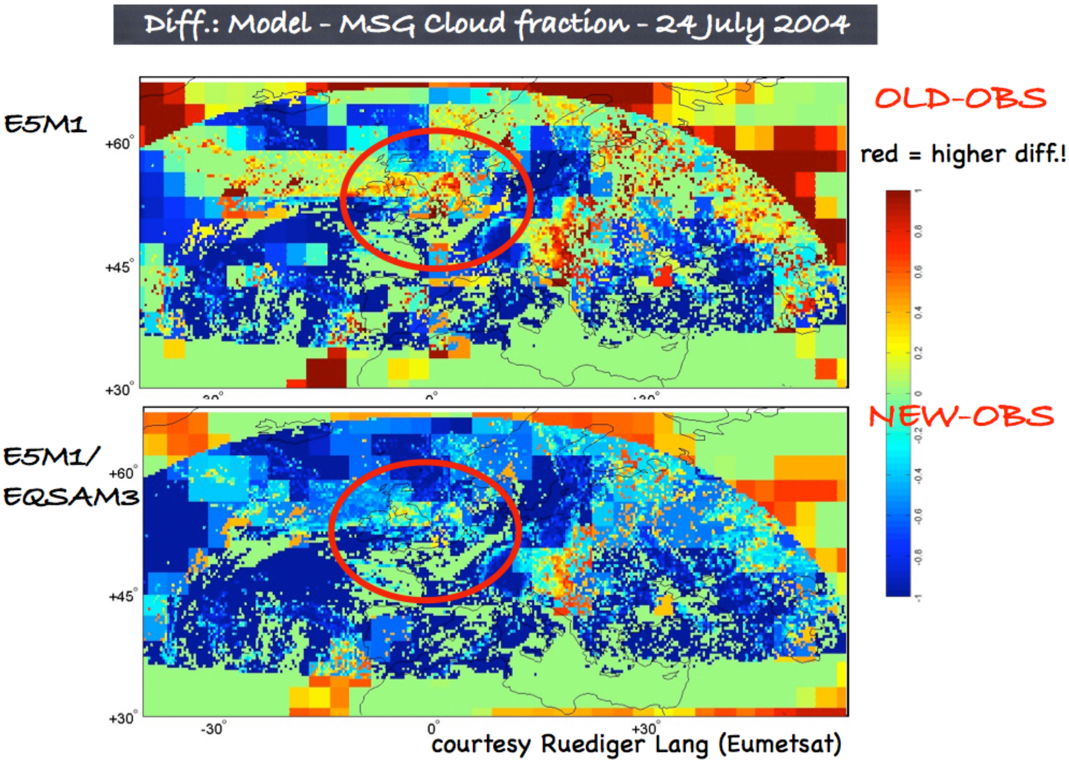

Figure 1. Comparison of the difference of MSG cloud fraction minus the original ECHAM5 scheme (top) and the MSG cloud fraction minus the new cloud cover scheme coupled to an aerosol water model (bottom).

Computational expenses

We envisage two different types of simulations: (i) For the first type of experiment, we consider an NWP set-up using IFS with aerosol climatology, while for (ii) we consider a CAMS2_35 set-up using IFS-COMPO as currently used for the Scouting experiments (multi-year simulations, 2003-2020) with a lower resolution (T255L137). The total billing units for the latter are estimated for a one-task hindcast simulation to be approx. 800 SBU; producing approx. 250 GB of data on the MARS archive. No additional costs are expected for the inclusion of the proposed computationally efficient cloud cover module, but multi-year runs are needed for a long-term evaluation to gain proper statistics. Various shorter sensitivity experiments (several one-month simulations) will be needed to re-define the required parameters for the two experiment types. Overall, a total of approx. 20.000 kSBU with ~20 TB of data storage will be probably needed for the simulations planed for each year (Table 1).

Table 1. Simulations planned for project year:		**2024**	**2025**	**2026**
IFS, NWP set-up	[exp]	24 monthly	5 x 18 years	5 x 18 years
IFS-COMPO, CAMS2_35 set-up	[exp]	24 monthly	5 x 18 years	5 x 18 years

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