LATE REQUEST FOR A SPECIAL PROJECT 2025–2027

MEMBER STATE: Denmark……………………………………………………………………………………

Principal Investigator[1]**:** Carl Svenhag………………………………………………………………………………

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Other researchers: Ulas Im

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Project Title: Integration and Climate Implications of Extended Aerosol Nucleation and Precursor Vapours in OpenIFS/AC c48r1 under the CleanCloud Project.

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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.		
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2026	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for project year:		**2025**	**2026**	**2027**
High Performance Computing Facility	[SBU]		45 000 000	
Accumulated data storage (total archive volume)[2]	[GB]		10 000	

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

Despite significant advances, Earth System Models (ESMs) still struggle to accurately capture the microphysical processes governing aerosol-cloud interactions (ACI) due to their immense computational demands. As a result, parameterizations are often simplified to maintain a balance between accuracy and efficiency, potentially overlooking critical processes involving ultrafine particles which is an aspect that remains largely unexplored in current ESM frameworks. This project aims to develop and evaluate improved representations of new functions for aerosol new-particle-formation (NPF) and precursor gas chemistry in OpenIFS/AC cycle48r1 that explicitly account for the role of ultrafine aerosols. Thereby reducing structural uncertainties in CMIP-class models and advancing the accuracy of climate predictions. This is part of the model development intended for the Horizon Europe funded CleanCloud project (Grant Agreement 101137639).

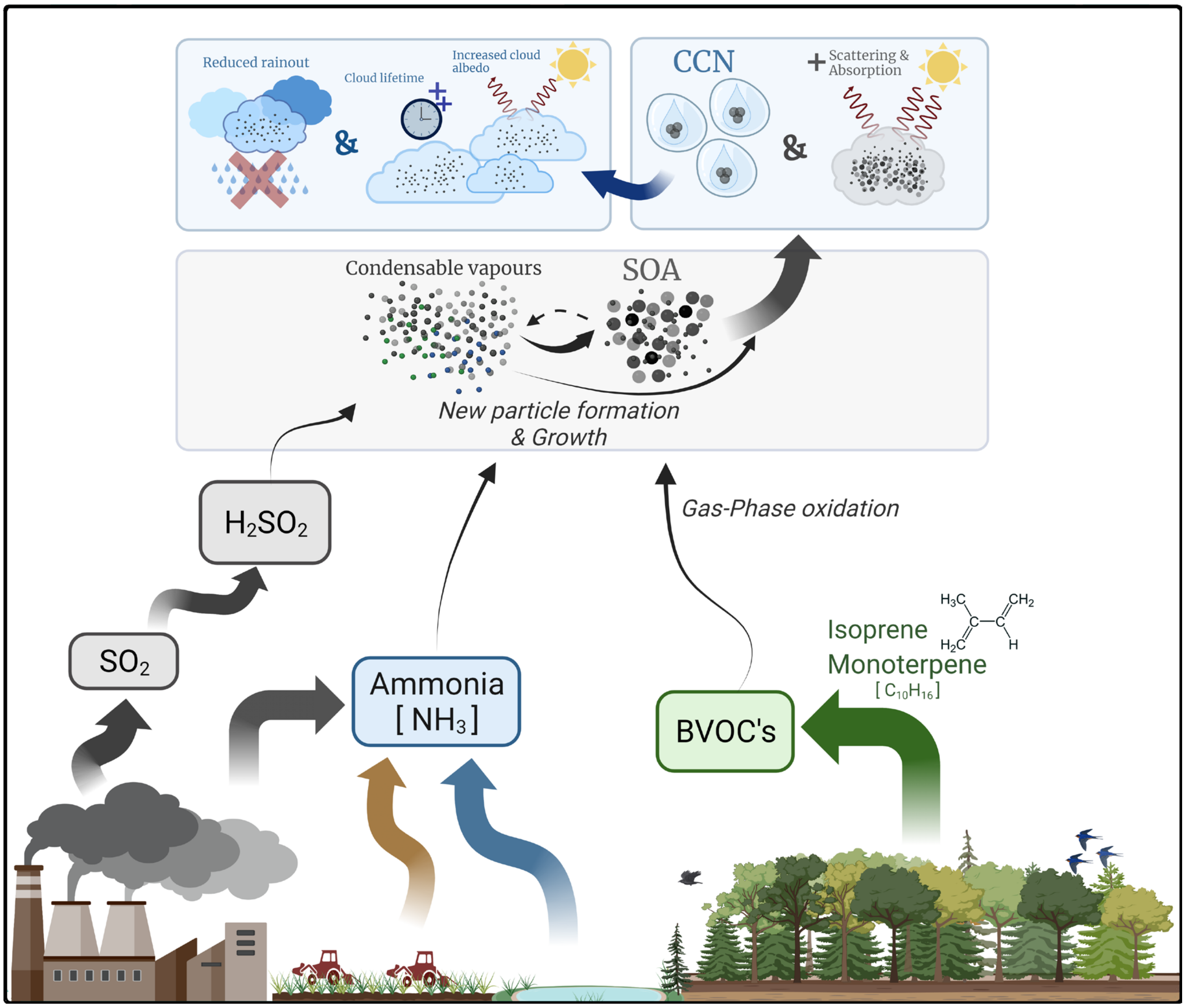

Figure 1: Conceptual figure of compounds contributing to aerosol new particle formation and growth into sizes affecting the radiative balance and clouds. Illustration by Carl Svenhag.

This work will implement a new particle formation look-up table scheme for sulfuric acid–ammonia nucleation, developed by Yazgi and Olenius (2021) based on the detailed aerosol cluster dynamics code ACDC (Olenius, 2021). The model configuration will be OpenIFS/AC coupled with the TM5 chemistry and HAM-M7 aerosol physics. The aerosol dynamics model M7 is the designated aerosol module for the EC-Earth4 CMIP7 version of OpenIFS, which this work aims to build upon. The NPF implementation extends the approach developed by Svenhag et al. (2024, 2025), where the method was successfully applied in the EC-Earth3 model. Figure 2 illustrates the variability in particle formation rates between the new look-up table (*CLUST,* in a high and low version) and previous (*control/Riccobono*) parameterizations of the nucleation rate from Svenhag et al. (2024). Implementing this new NPF parameterization in OpenIFS/AC is expected to enhance the representation of boundary-layer aerosol formation, as OpenIFS/AC currently lacks the organic nucleation pathway included in EC-Earth3. At present, OpenIFS/AC only accounts for the sulfuric acid–water nucleation mechanism following Vehkamäki et al. (2002). With progress in development of additional aerosol precursor species to OpenIFS/AC, we are aiming to analyze the outcomes of a similar implementation of BVOCs to OpenIFS as shown in Bergman et al. (2020) with aerosol nucleation and condensations from *extremely low volatile organic compounds* (ELVOCs) and *semi volatile organic compounds* (SVOCs), where NPF parameterizations are adapted from Riccobono et al. (2014).

Table 1.

Simulation plan OpenIFS/AC:		**5 Years:**
Control run	Default settings	PD / PI
New NPF scheme	CLUST lookup-table	PD/ PI
New Precursor chemistry	BVOC chemistry + condensation	PD/ PI
NPF scheme + Precursor chemistry	All additional parameterizations	PD/ PI

In this study, we will quantify the impact of new particle formation (NPF) on the global effective radiative forcings and assess potential model sensitivity to the updated NPF and chemistry parameterizations. Additionally, we will evaluate these results against an observational dataset including multi-year in-situ aerosol measurements of particle number size distributions (PNSD) collected at ground-based stations distributed across diverse geographical regions. These stations span a range of altitudes, climates, and environments, from rural to urban settings, providing a comprehensive basis for model evaluation. The global direct and indirect radiative effects associated with the new parameterization through aerosol–radiation and aerosol–cloud interactions will be quantified, in reference to EC-Earth3 results shown in Figure 3 from Svenhag et al. (2024). Additionally, the ERF contributions from the new parameterizations will be calculated and discussed using the PD versus PI simulations.

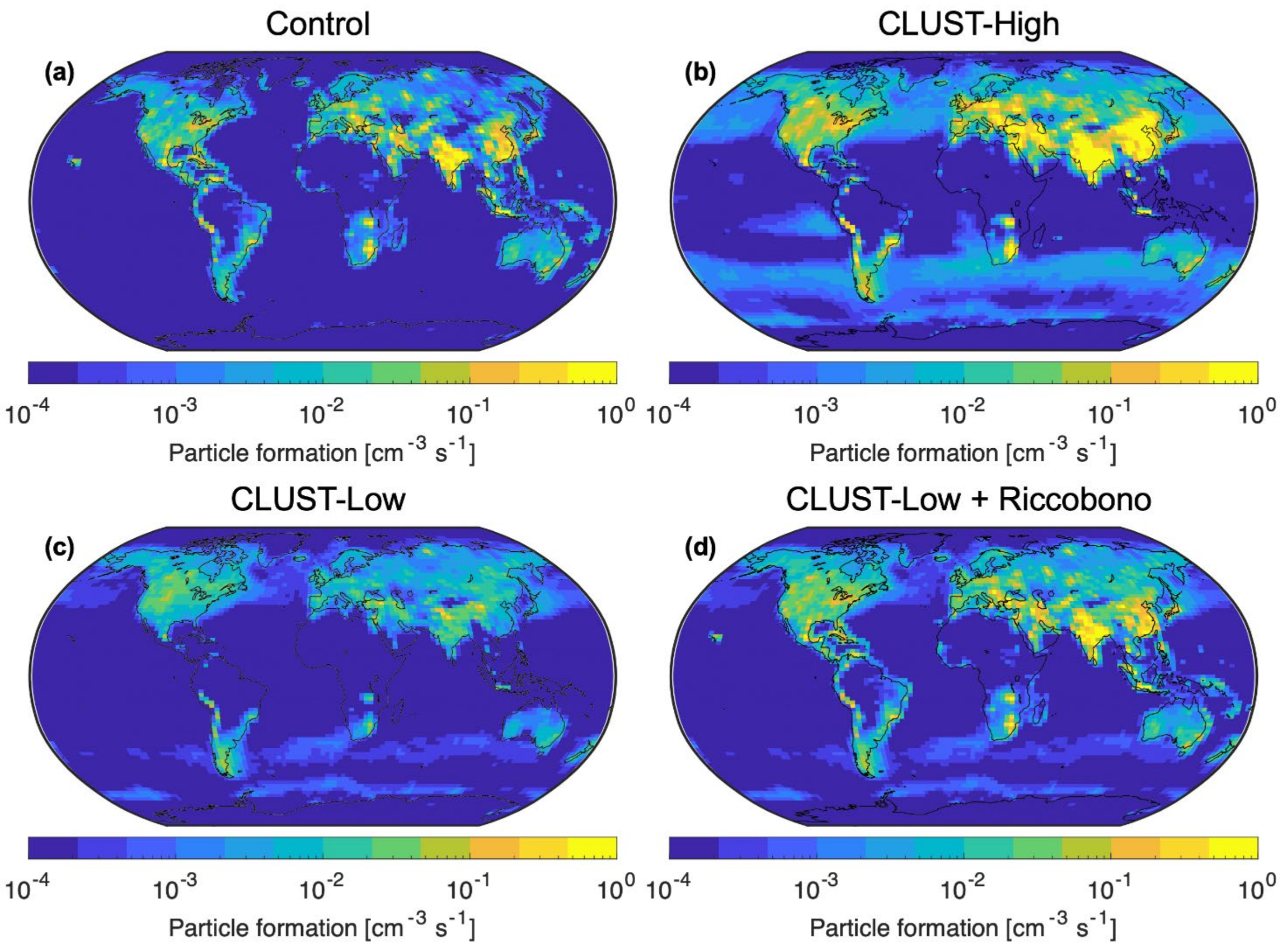

Figure 2: The EC-Earth3-AerChem 5-year near-surface mean of 5 nm diameter aerosol particle formation rate for the (a) control run, (b) CLUST-High (RICC2) case, (c) CLUST-Low (DLPNO), and (d) CLUST-Low+Riccobono. Figure from Svenhag et al. (2024).

The simulation framework for the ACI impact, effective radiative forcings (ERF), and sensitivity analysis consists of up to 8 six-year simulations (including a one-year spin-up) using *atmosphere-only (*fixed SST and sea-ice) and nudged meteorological fields. For Present-day (2010-2016) and Pre-industrial (1850-1856) simulations, shown in Table 1. Currently our configuration of OpenIFS/AC is running on 8 nodes with 1.65 SBU (~500,000 SBU / simulated year) on HPC2020.

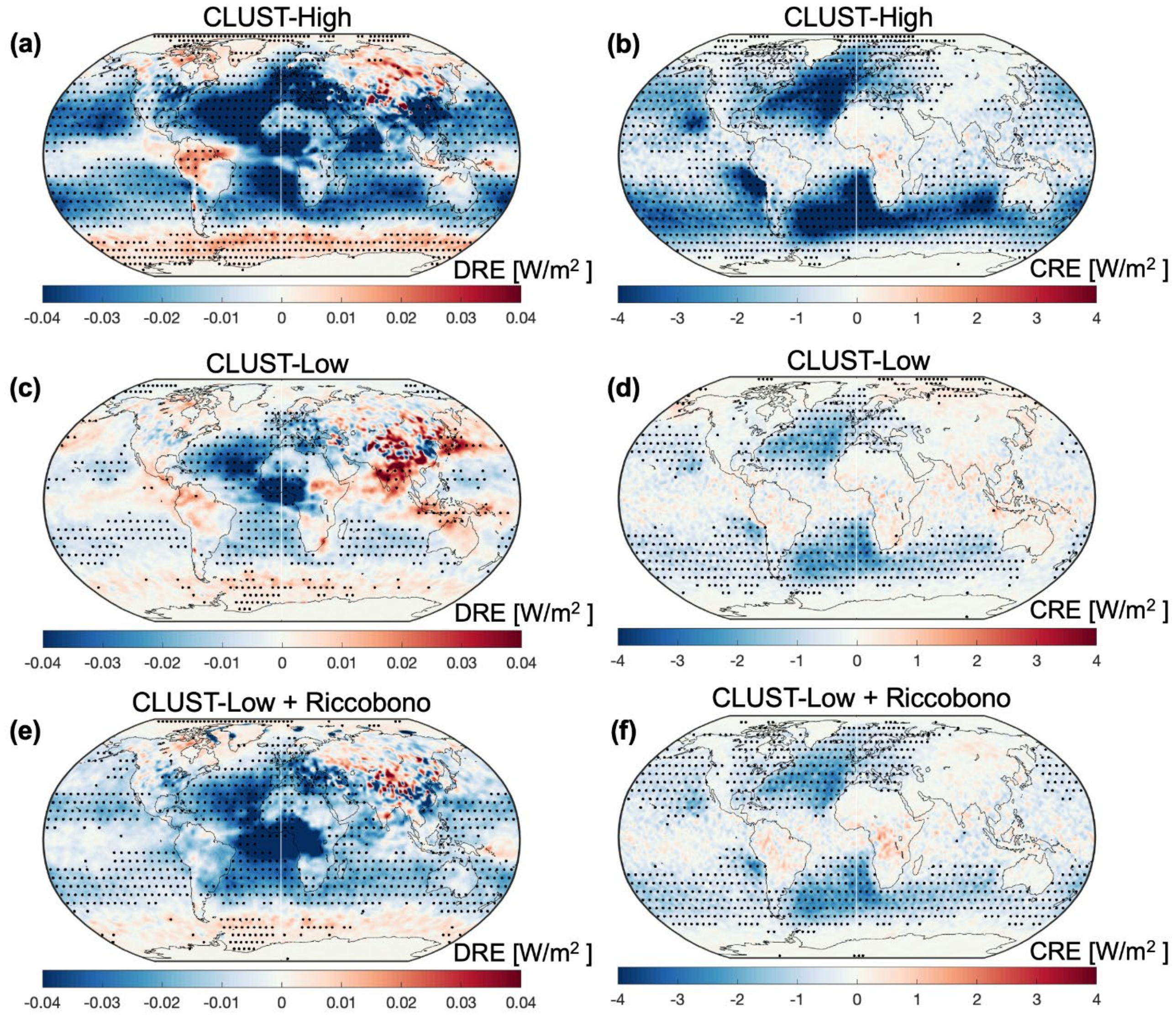

Figure 3: The EC-Earth3-AerChem global mean net TOA downward radiation modelled difference for the direct aerosol effect (DRE; a, c, e), and cloud radiative effect (CRE; b, d, f). Figure from Svenhag et al. (2024).

References

Bergman, T., Makkonen, R., Schrödner, R., Swietlicki, E., Phillips, V. T., Le Sager, P., and van Noije, T.: Description and evaluation of a secondary organic aerosol andnew particle formation scheme within TM5-MP v1.1, https://doi.org/10.5194/gmd-2021-49, 2021.

Olenius, T.: Atmospheric Cluster Dynamics Code Github Repository, https://github.com/tolenius/ACDC, 2021.

Riccobono, F., Schobesberger, S., Scott, C. E., Dommen, J., Ortega, I. K., Rondo, L., Almeida, J., Amorim, A., Bianchi, F., Breitenlechner, M., and et al.: Oxidation products of biogenic emissions contribute to nucleation of atmospheric particles, Science, 344, 717–721, https://doi.org/10.1126/science.1243527, 2014.

Svenhag, C., Sporre, M. K., Olenius, T., Yazgi, D., Blichner, S. M., Nieradzik, L. P., and Roldin, P.: Implementing detailed nucleation predictions in the Earth system model EC-Earth3.3.4: sulfuric acid–ammonia nucleation, Geoscientific Model Development, 17, 4923– 530 4942, https://doi.org/10.5194/gmd-17-4923-2024, 2024.

Svenhag, C., Roldin, P., Olenius, T., Wollesen de Jonge, R., Blichner, S. M., Yazgi, D., and Sporre, M. K.: Seasonal differences in observed versus modelled new particle formation at two

European boreal stations, Atmos. Chem. Phys., 25, 11483–11504, https://doi.org/10.5194/acp-25-11483-2025, 2025.

Vehkamäki, H.: An improved parameterization for sulfuric acid–water nucleation rates for tropospheric and stratospheric conditions, Journal of Geophysical Research, 107, https://doi.org/10.1029/2002jd002184, 2002.

Yazgi, D. and Olenius, T.: J-gain: Generator and interpolator for look-up tables of aerosol particle formation rates, https://github.com/tolenius/ J-GAIN, 2021.