REQUEST FOR A SPECIAL PROJECT 2026-2028

MEMBER STATE: The Netherlands

Principal Investigator[1]: Prof. dr. A. Pier Siebesma

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Project Title:

Pseudo-Global Warming Experiments of Shallow Cumulus Convection

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** ………….	
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 X ☐	NO ☐

Computer resources required for project year:		**2026**	**2027**	**2028**
High Performance Computing Facility	[SBU]	39 Million	*	*

[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.

Accumulated data storage (total archive volume)[2] [GB]	2 Tb	*	*

EWC resources required for project year:	2026	2027	2028
Number of vCPUs [#]			
Total memory [GB]			
Storage [GB]			
Number of vGPUs[3] [#]			

Continue overleaf.

Principal Investigator: Pier Siebesma

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Extended abstract

Summary

Marine shallow cumulus is the most abundant cloud type on our planet and a prime source of climate feedback uncertainty, due to our lack of knowledge how this cloud type responds to global warming. From satellite observations it has become clear that these clouds often organised in clusters of various sizes and shapes. Recent research has shown that these mescoscale cloud structures are partly the result of spontaneous self-organization emerging from the small turbulent scales but are also partly shaped by the large-scale conditions. This requires high-resolution simulations on very large domains with suitable open boundary conditions. As part of a previous ECMWF special project project "EUREC4A-MIP" we have succesfully simulated a 10-day period from the EUREC4A field campaign for 2 nested simulations: one at a resolution of 600 m over a domain of 1440x1200 km^2 and a another at an even higher resolution of 150 m over a domain of 520x320 km^2. In this new ECMWF special project "Pseudo-Global Warming Experiments of Shallow Cumulus Convection" we propose to simulate perturbed runs over the same period with a 4K-warming of the Sea surface Temperature (SST) by using the so-called Pseudo Global Warming (PGW) technique. These model experiments will provide answer what the cloud radiative effect will be of organized shallow cumulus clouds when subjected to global warming.

Motivation

In a previous special project : ***"EUREC4A-MIP"*** we have realized to produce turbulence resolving Large eddy Simulations using open lateral boundary conditions on very large domains that represent realistic cloud mesoscale structures such as observed during the EUREC4A Field Campaign (Lung 2025). These simulations are part of a international model intercomparison project EUREC4A-MIP for which we (the authors) are the Co-Pi's. Further information we refer to https://eurec4a.eu/motivation.

As a the next step we propose in this special project to simulate 4K Sea Surface Temperature (SST) warming experiments where the lateral boundary field are perturbed using a Pseudo Global Warming (PGW) method. These runs will provide information on how realistic shallow cumulus fields will respond to global warming .

Methodology

In the last 3 years we developed a new implementation for open boundary conditions in our LES model DALES which runs now stable and provides smooth transitions from the coarser model to the finer model provided that the jump in resolution is not larger that a factor of 4 and that the boundary fields are frequently updated

The configuration that we have developed for simulating the EUREC4A period is visualized in Figure 2 where the cloud albedo for three embedded models is visualized for a snapshot at the end of a simulation of 24 hours of February 2nd 2020. The other box marks the boundary of HARMONIE that runs at a resolution of 2.5 km. Harmonie receives lateral boundaries from ERA5. The next nest is DALES that runs at a resolution of 625m on a domain of around 1500 X1500 km^2. The final nest is another DALES instance that runs at a turbulence resolving resolution of 156m on a domain of 300x500 km^2.

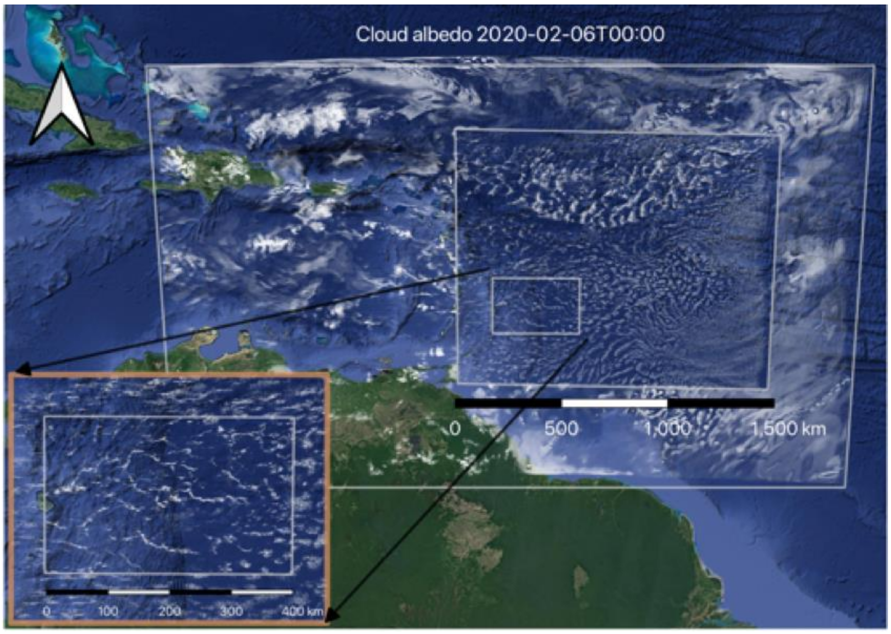

Figure 2: A snaphot of a 24 hr cloud resolving three-way nested simulation of the subtropical Atlantic Ocean. The three nested simulations include in order of domain size from large to small: HARMONIE (2.5km resolution)), DALES 625m resolution) and DALES (156,25m).

In the previous EUREC4A-MIP project we successfully simulated 10 day periods with DALES and evaluated the results with observations from EUREC4A. In this new project, the 10 day present day simulations will be repeated with a 4K warmer ocean Sea Surface Temperature (SST) driven by the same ERA5 boundaries plus a perturbation signal derived from centennial global climate runs using the Pseudo Global Warming (PGW) technique. For more detailed information on the set up of the simulations, the required output we refer to the EUREC4A website (https://eurec4a.eu/motivation). This way we will be able to simulate a consistent future weather realisation and will allow us to asses cloud radiative response. This will be the first time that we will be able to quantify the cloud radiative response of realistic mesoscale shallow cumulus cloud conditions. This is of prime importance since the uncertainty of the cloud feedback due to these type of clouds in climate models remains to largest source of uncertainty in climate sensitivity of climate models.

Justification of the Computer Resources

Dales simulations have been executed as the HPC of the ECMWF for a long time and the model exhibits a perfect weak scaling behaviour on multiple nodes. The typical DALES run requires 2 10^{-6} sec per grid point per time step per core on the ATOS machine of ECMWF. The typical time step of the model is 1 sec.

For the runs in phase 1 this implies that a simulation of 1 day on a domain of 300 by 500 km with a resolution of 100 m requires around 1.000 000 SBU's and at present while the costs for 600m run on the larger domain are 700.000 SBU's, somewhat cheaper due to the longer timestep. So the 2 simulations would require around 17 million SBU's. However in addition we anticipate to include test simulations and a sensitivity experiment (i.e. increasing the concentration of the cloud condensation nuclei (CCN) to assess to possible influences of aerosols) . The test runs require 5 million SBU's and the sensitivity run on aerosols another 17 Million SBU. That requires a total of 39 million SBU's.

We only require resources for one year (2026) as we will have the present day simulations already finalised and we have produced the perturbed boundary conditions already

Embedding

The proposed model runs are of crucial importance for the modelling efforts of EUREC4A to investigate our simulation capability of the rich observed modes of cloud organisation. It is part of an international model intercomparison project endorsed by CFMIP and GASS where a number of Storm Resolving Models (SRMs)will participate (ICON-LAM, HARMONIE and AROME) as well as a number of Large Eddy Models (LEMs) such as DALES, ICON-LES and Meso-NH. We will also make use of the DYAMOND runs of high resolution global models for this same period including the IFS. This will provide an opportunity to compare a range of model resolutions that completely resolve, partly resolve or fully parameterise cumulus convection and will provide new insights in how to deal with shallow cumulus convection in the grey zone and how they these simulations will respond to a future warming perturbation using the Pseudo_Global Warming (PGW) technique.

References

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