SPECIAL PROJECT FINAL REPORT

All the following mandatory information needs to be provided.

Project Title:	EUREC4A-MIP
Computer Project Account:	spnlsieb
Start Year - End Year :	2024 – 2024 (1 year)
Principal Investigator(s)	Prof. dr. A. Pier Siebesma
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The following should cover the entire project duration.

Summary of project objectives

(10 lines max)

The main objective of this project is to generate and evaluate a realistic simulation with the turbulence resolving Dutch Atmospheric Large Eddy Simulation model DALES using open boundary conditions for a period of 10 days at a large domain of 520x320 km2 at a resolution of 150m over the subtropical North-Atlantic ocean. This simulated area and period coincides with the EUREC4A field campaign that took place in the period jan-feb 2020, East off the coast of Barbados and the simulations results are evaluated with observation of this field campaign. The simulations are part of a larger model intercomparison project EUREC4A-MIP. The 150m resolution simulation is part of a triple nested configuration: the model HARMONIE-AROME is nested in ERA5 and simulates at a 2.5 km resolution and provides lateral boundary conditions for a coarse resolution version (600m resolution) of DALES that runs over a domain of 1440x1200 km2 and provides the lateral conditions for the 150m resolution version.

Summary of problems encountered

(If you encountered any problems of a more technical nature, please describe them here.)

The initial plan was to use embed the DALES run using lateral boundary fields generated by the Limited Area Model COSMO. Unfortunately all high DALES simulations crashed due to over-explosive convection that was imported from the COSMO model. We refer to the section “Summary of Results” for further results.

Experience with the Special Project framework

(Please let us know about your experience with administrative aspects like the application procedure, progress reporting etc.)

All the administrative aspects and procedures were clear.

Summary of results

Two long simulations with open boundary conditions were finally produced with DALES for a 10-day period over the EUREC4A domain, a course simulations with a resolution of 600 m over a domain of1440x1200 km2 and embedded a high-resolution DALES with a 150 m resolution simulation over a 520x320 km2 domain. The simulations required respectively $5x10^6$ SBU's (coarse resolution run) and $10x10^6$ SBU's (fine resolution run). An additional $2x10^6$ SBU's has been used for merging, input production and visualisation).

The initial plan was that the Storm-Resolving Model COSMO would provide output that could serve as lateral and initial boundary conditions for the course resolution (600m) DALES model. However, all simulations where DALES was embedded in COSMO eventually became unstable and crashed. Intensive testes and esearch led to the conclusion that the reason for this was that the COSMO lateral boundary fields imposed too strong vertical velocity fields, probably due to the fact that the COSMO (2.5 km resolution) simulations were executed without an active shallow cumulus convection parameterization scheme leading to too strong vertical velocity fields and temperature profiles that are too unstable. This triggers "convective bombs" in the DALES simulations with unrealistic strong convection and crashes in the simulation. Repeating the simulations while being embedded in HARMONIE-AROME (a model that operates with an active shallow convection scheme at 2.5 km) resolved the issue and resulted in stable runs with realistic convective cells. This unforeseen complication has resulted in a number of extra simulations with COSMO-boundaries that were also computational expensive due to the small time-stepping as a result of the unrealistic high vertical velocities in DALES. This led to as pending of $20x10^6$ SBU's and prohibited to do extra Pseudo-Global Warming (PGW) simulations that were originally foreseen in this project.

The results of these simulations have been compared with other simulations over the same period and domain with periodic boundary conditions and further evaluated with observation that were made during the EUREC4A field campaign. A few main conclusions are:

- All simulations are capable of reproducing the observed diurnal cycle in cloudiness and precipitation as observed during EUREC4A.
- The DALES simulations with periodic boundary conditions created too intermittent cloud patterns varying too shallow to too deep as compared with observations and the simulations with open boundary conditions. This is likely due to the fact that the simulations with the periodic boundary conditions are too unbounded compared with the simulations with open boundary conditions
- The inherited cloud structures of the coarse DALES simulations (600m) break up in finer fragments in the fine DALES simulations (150m) but without a drop in cloud fraction.
- A significant drop in cloud fraction is observed between the HARMONIE simulations (2.5km) and the DALES simulations. This drop is explained by the lack of thin cloud layers that are present in HARMONIE-AROME but not produced by the coarse (and fine) DALES simulations

A full report of the results can be found in a manuscript entitled: *"The influence of open boundary conditions on cloud organization in atmospheric large eddy simulations"* which has been submitted to the Journal of Advances in Modeling Earth Systems and is currently under review. The output results of the simulations will also be used in an anlysis as part of a model intercomparison study. The required output can be found at https://eurec4a.eu/mip .

A next step in the EUEC4A-MIP project will be the simulation and analyseses of Pseudo Global Warming (PGW) simulations of the present runs. These will provide answers how robust these organised mesoscale shallow cumulus patterns are with respect to global warming perturbution. A separate new special project will be submitted for realisong these PGW-simulations with DALES and HARMONIE.

List of publications/reports from the project with complete references

F.Liqui Lung, C. Jakob, F. Jansson and A.P. Siebesma: "*The influence of open boundary conditions on cloud organization in atmospheric large eddy simulations"* J. of Advances in Modeling Earth Systems (2025) (Under Review)

Future plans

A next step in the EUEC4A-MIP project will be the simulation and analyseses of Pseudo Global Warming (PGW) simulations of the present runs. These will provide answers how robust these organised mesoscale shallow cumulus patterns are with respect to global warming perturbution. A separate new special project will be submitted for realisong these PGW-simulations with DALES and HARMONIE.