SPECIAL PROJECT PROGRESS REPORT

Progress Reports should be 2 to 10 pages in length, depending on importance of the project. All the following mandatory information needs to be provided.

Reporting year	July 2017 – June 2018 (project started Jan 2017)
Project Title:	Towards Cloud-Resolving Climate Simulations
Computer Project Account:	spnlcrom
Principal Investigator(s):	Daan Crommelin, Pier Siebesma, Gijs van den Oord, Fredrik Jansson
Affiliation:	Centrum Wiskunde & Informatica (Crommelin, Jansson), KNMI and TU Delft (Siebesma), Netherlands eScience Center (van den Oord)
Name of ECMWF scientist(s) collaborating to the project (if applicable)	N/A
Start date of the project:	1/1/2017
Expected end date:	31/12/2019

Computer resources allocated/used for the current year and the previous one

(if applicable)

Please answer for all project resources

		Previous year (2017)		Current year(2018)	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	10M	6.15M	15M	6.8M
Data storage capacity	(Gbytes)	5000	18	100 000	2.6TB ($SCRATCH) 7.9TB (tape archive)

Summary of project objectives

(10 lines max)

The overarching goal of this project is to come to a better understanding of cloud-climate feedbacks, leading to reduced uncertainty in climate sensitivity estimates. To achieve this, we pursue a computational strategy of developing 3-dimensional superparameterization (3dSP) by embedding 3-d convection-resolving Large Eddy Simulation (LES) models in each grid column of a global model (OpenIFS). The LES models are embedded as a two-way nesting (or two-way coupling): the global model column state drives the LES model, and the LES feeds back to the global model. The nested LES models replace traditional convection parameterization schemes in the global model columns. We work with DALES, the Dutch Large Eddy Simulation model, as the convection-resolving LES.

The computer resources of this special project are intended for performing simulations with the coupled (OpenIFS-DALES) 3dSP model for test cases including a cold air outbreak case (previously subject of the WGNE Grey Zone project).

Summary of problems encountered (if any)

(20 lines max)

To couple OpenIFS and DALES, we currently use the AMUSE framework (www.amusecode.org). AMUSE makes it possible to build a Python interface to existing code written in e.g. C or Fortran. The coupling of the two models is handled by a master script written in Python, which communicates with OpenIFS and DALES through the AMUSE framework.

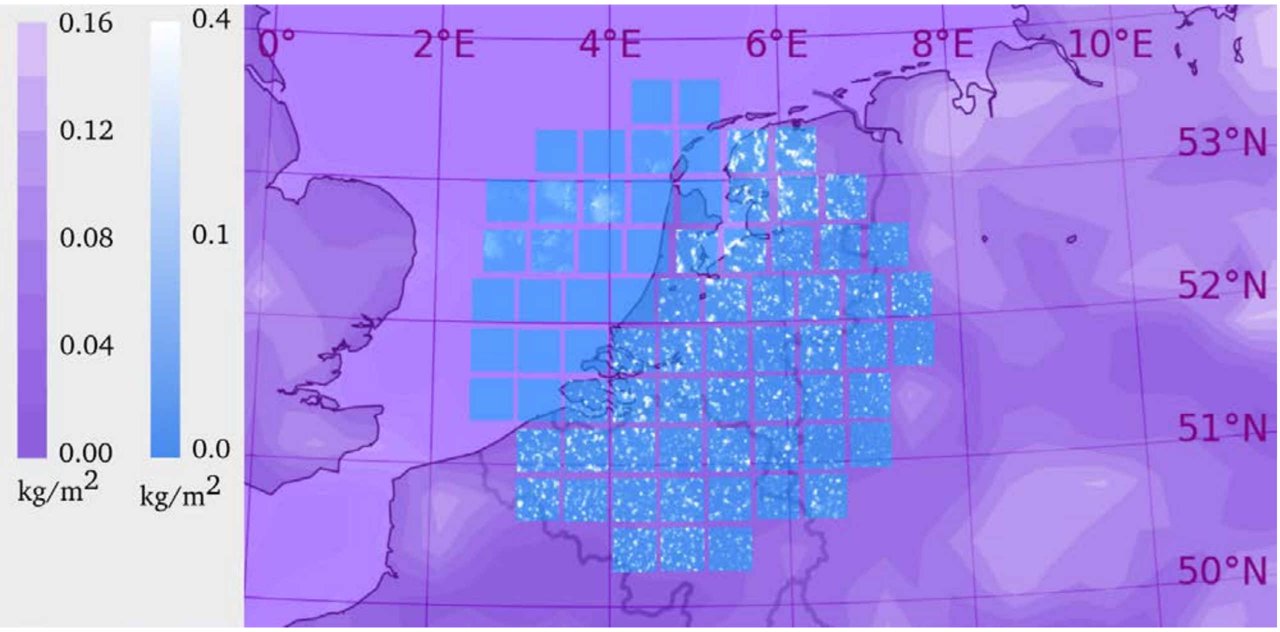
In 2017 we found out that AMUSE does not work well with the Cray MPI which is installed on the ECMWF Cray, the reason being that when AMUSE spawns worker processes it launches them using MPI_Comm_spawn(), which the Cray MPI does not support. We solved this problem with a work-around where all workers are launched at the start of the simulation in a regular MPI job, after which the appropriate MPI communicators are created. This works for us, since we know ahead of time how many workers are needed for a particular simulation.

In the fall of 2017 we ran into some additional difficulties due to physics-induced as well as software-related crashes of the coupled OpenIFS-DALES model. These problems were solved so that we arrived at a stable coupled model near the end of 2017. As a consequence we were not able to use all of the compute time allocated to our project for 2017. However, with a stable model now up and running we have used nearly half of our allocated compute time for 2018 in the period Jan-June 2018.

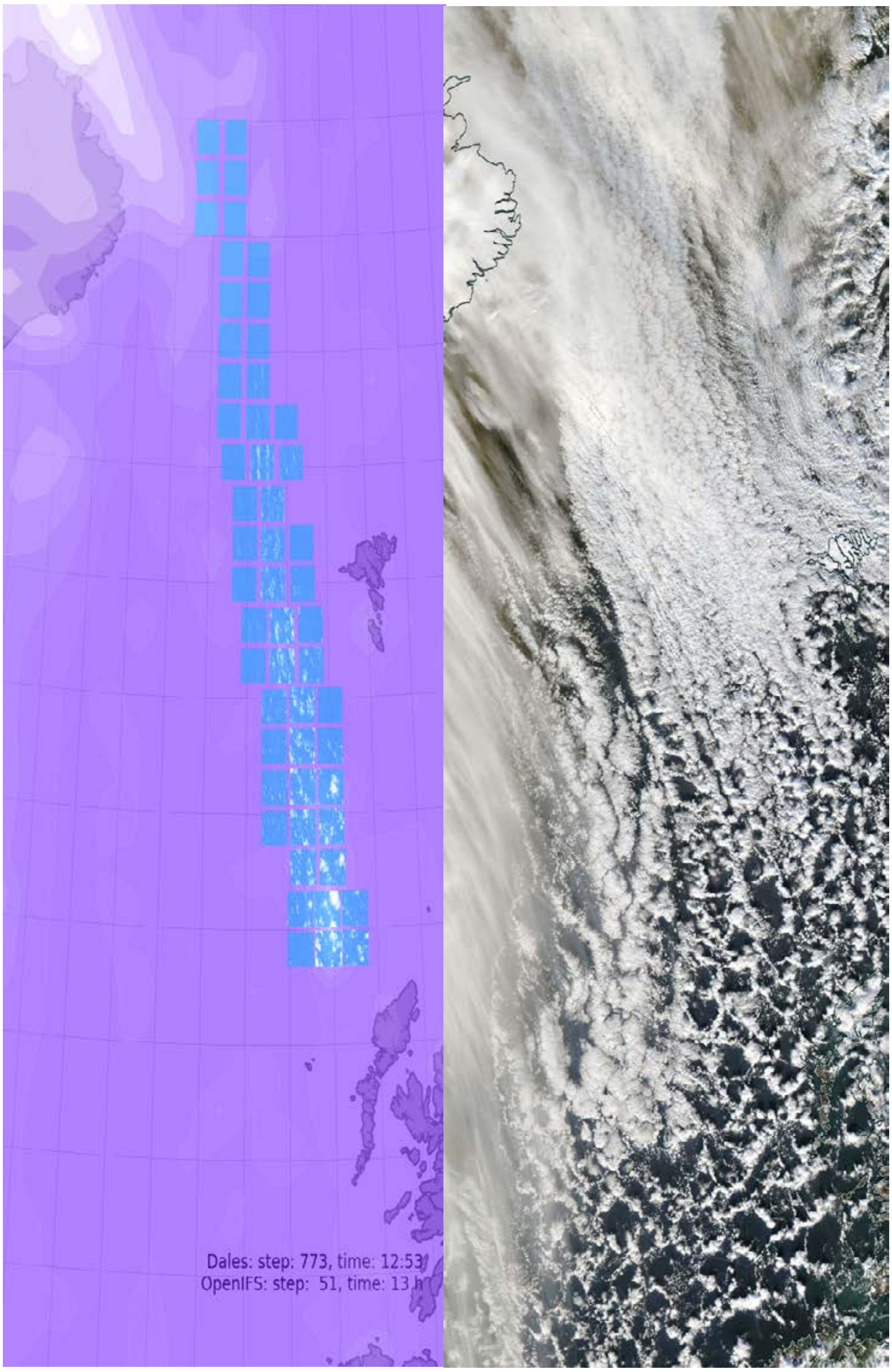
Summary of results of the current year (from July of previous year to June of current year)
This section should comprise 1 to 8 pages and can be replaced by a short summary plus an existing scientific report on the project

In the second half of 2017 we completed the coupling of the OpenIFS and DALES models, with coupling via the Python interface using AMUSE. Furthermore, we solved several technical difficulties (as already mentioned in the previous section) so that we arrived at a stable coupled OpenIFS-DALES model towards the end of 2017.

We have run a number of simulations with the coupled model, in order to test and validate the model and to explore its behaviour (in particular, the simulated convection in and near the OpenIFS model columns where DALES is nested). We have focussed on three test cases: the Cold Air Outbreak (CAO) in the North-Atlantic, subtropical convection in the trade wind region east of Barbados, and convection over the Netherlands. The latter case gives the opportunity to compare simulation results with observations from the Cabauw measurement station in the center of the Netherlands.



The figure shows a snapshot from a superparameterized simulation with 72 DALES instances (blue boxes) over the Netherlands coupled to OpenIFS (purple background). Cloudiness (liquid water path) is shown in shades of white. OpenIFS was run with a T-511 grid. The extent of the DALES instances is 12.8 x 12.8 x 5 km, with the resolution 200 m in the horizontal direction and 25 m in the vertical. The simulation was started at midnight with ERA-Interim conditions, the image shows the state at 2012-04-13 11:35 UTC.



A preliminary result of the Cold Air Outbreak simulation, compared to a MODIS image, at 2010-01-31 12:53 UTC. The simulation was started at midnight initialized from ERA-Interim data. Hints of the cloud field breaking up into cells can be seen in the southern half of the superparameterized region.

List of publications/reports from the project with complete references

Because of the recent starting date (January 2017) of this project, there are currently no completed publications to report. However, preliminary results from the project were presented at the OpenIFS user meeting 2017, the workshop on “The Future of Cumulus Parametrization” at TU Delft 2017, the SURFSara SuperD event in Amsterdam 2017, the National eScience Symposium in Amsterdam 2017, and at the Netherlands Mathematical Congress 2018. At the SuperD event, we were awarded 2nd place in the SURFSara visualization competition 2017, for visualizations of the superparameterized model.

Two papers are currently being prepared:
“Creating a reusable cross disciplinary multi-scale and multi-physics framework: from AMUSE to OMUSE and beyond”, Inti Pelupessy, Simon Portegies Zwart, Arjen van Elteren, Henk Dijkstra, Fredrik Jansson, Daan Crommelin, Pier Siebesma, Ben van Werkhoven, Gijs van den Oord, Computing in Science and Engineering

“Superparameterization of clouds and convection in OpenIFS Cy40r1 with a 3D Large Eddy Simulation DALES 4.1”, for GMD.

Furthermore, an abstract for a talk has been submitted to the IEEE eScience Conference in Amsterdam 2018.

Summary of plans for the continuation of the project

(10 lines max)

- submit article on the technical description of the superparametrization setup
- document and publish the coupling code and AMUSE interfaces to DALES and OpenIFS
- further study and analysis of test cases, in particular the Cold Air Outbreak and the Barbados case
- further articles on scientific results from running the coupled models
- improve the performance of DALES and the coupler code (especially the communication with the models)