SPECIAL PROJECT PROGRESS REPORT

All the following mandatory information needs to be provided. The length should *reflect the complexity and duration* of the project.

Reporting year	2024
Project Title:	Towards a computationally efficient parameterization for surface shortwave 3D radiative effects in cloud resolving models
Computer Project Account:	spnlstra
Principal Investigator(s):	Bart van Stratum, Mirjam Tijhuis, Chiel van Heerwaarden
Affiliation:	Wageningen University and Research
Name of ECMWF scientist(s) collaborating to the project (if applicable)	-
Start date of the project:	01/01/2024
Expected end date:	31/12/2026

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

(if applicable)
Please answer for all project resources

		Previous year		Current year	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	n/a	n/a	26500000	0
Data storage capacity	(Gbytes)	n/a	n/a	760	0

Summary of project objectives (10 lines max)

Within the SLOCS project (https://chiel.cloud/Projects/SLOCS) and PhD of Mirjam Tijhuis, we aim to understand and more accurately simulate surface solar irradiance. More specifically, the PhD of Mirjam Tijhuis focusses on understanding 3D radiative effects and developing a computationally efficient parameterization to include the surface 3D radiative effects in cloud resolving models.

To achieve these goals, we use a combination of high-frequency radiation observations, and simulations with the MicroHH large-eddy simulation (LES) model. MicroHH can calculate radiative transfer using either the two-stream approximation or an online GPU-based ray tracer, contains all the physics for simulating realistic weather, and is coupled to ERA5 and CAMS using the $(LS)^2D$ Python package developed by our group (van Stratum et al., 2023).

Summary of problems encountered (10 lines max)

None. Most of our recent simulations required the GPU-based ray tracer in MicroHH, or involved model development. As such, this work was mostly done on other computer systems, and we have not yet started using the ECMWF facilities.

Summary of plans for the continuation of the project (10 lines max)

1. Development and validation parameterisation of surface 3D radiative effects.
In Tijhuis et al. (2023), we demonstrated the feasibility of parameterizing surface 3D radiative effects by post-processing the surface radiation from 1D radiation calculations. In the next years, we aim to generalize this parameterization for a wider range of cloud types and include and test the parameterization online in LES.

2. Improve representation of clouds in real-life LES.
As outlined in the results below, we developed the capability of nesting MicroHH with open boundary conditions in ERA5. We plan to simulate several months of real-life weather using both periodic boundary conditions or nested open boundaries, to study the impact of different boundary conditions on the representation of clouds and surface radiation.

List of publications/reports from the project with complete references

- Tijhuis, M., van Stratum, B. J. H., and van Heerwaarden, C. C.: The impact of coupled 3D radiative transfer on surface radiation and cumulus clouds over land, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2024-1519, 2024.

Summary of results

1. The impact of coupled 3D radiative transfer on surface radiation and clouds.
By performing LES simulations with both 1D (two-stream) and 3D (ray tracer) radiation, we studied the impact of 3D radiation on the development of clouds and surface radiation. The simulations showed that including 3D radiation results in cumulus clouds that are larger and contain more liquid water, without affecting the mean cloud fraction. In addition, 3D radiation and its influence on clouds results in a decreased domain averaged direct radiation and increased diffuse radiation. However, combined, the net change in global radiation was found to be small at less than 1 W/m2. This work is currently under review in the publication listed above.

2. Nested LESs with open boundary conditions.
In the past, most simulations of real-life weather in LES used doubly periodic boundary conditions. In a recent publication, we demonstrated both the benefits and limitations of such a periodic model setup (van Stratum et al., 2023). One of our findings was that the representation of more complex cloud structures – formed by e.g. cloud organisation or mesoscale variability – was quite poor. To overcome these problems, we have implemented open boundary conditions in MicroHH, and

developed a modelling infrastructure that nests MicroHH in ERA5. An example is shown in Figure 1. We are using this new model setup in ongoing work to study the influence of doubly periodic vs. nested open boundary LESs on the representation of clouds and surface irradiance.

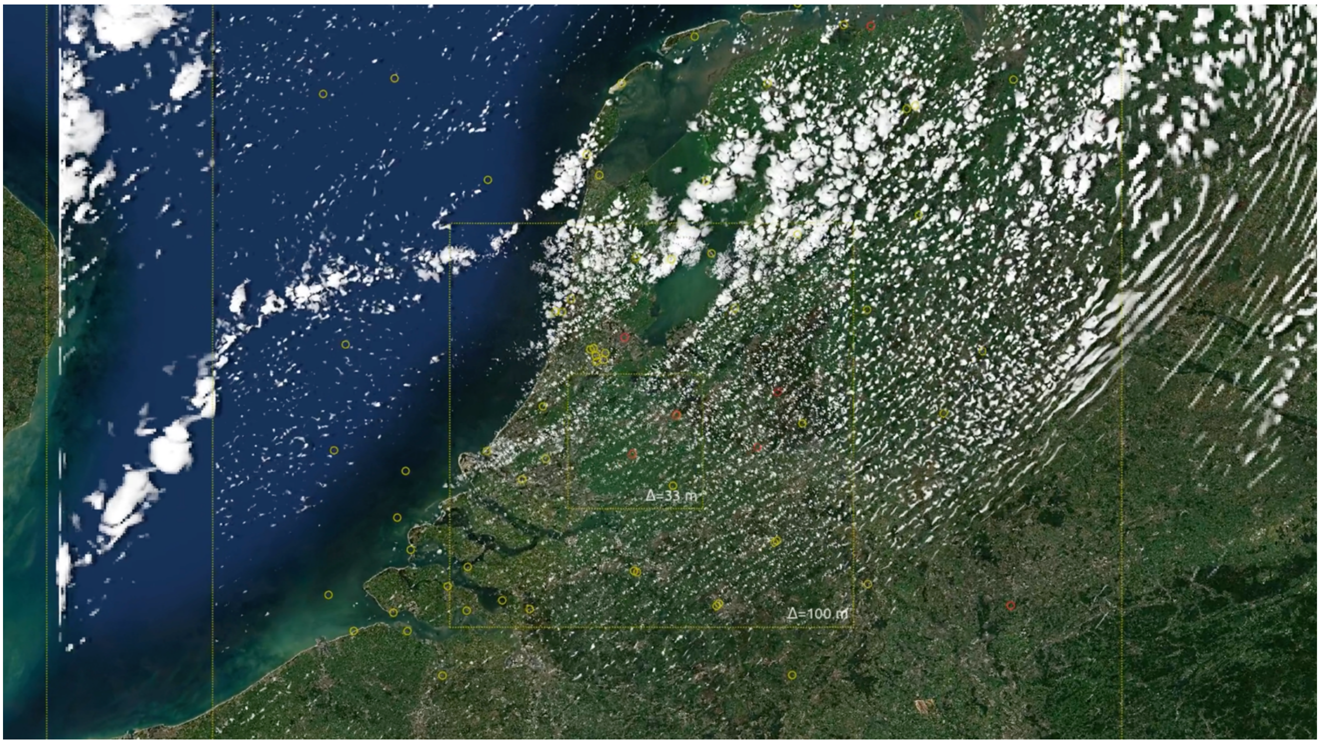

Figure 1. Example of nesting MicroHH in ERA5, for 15 August 2016. In this setup, four LES domains with a horizontal resolution of (900 m, 300, m 100 m, and 33 m) were used, with the outer domain receiving the lateral boundary conditions from ERA5. The full animation is available at https://vimeo.com/903271032

References

B.J.H. van Stratum, C.C. van Heerwaarden, & J. Vilà-Guerau de Arellano (2023). *The benefits and challenges of downscaling a global reanalysis with doubly-periodic large-eddy simulations.* Journal of Advances in Modeling Earth Systems. (10.1029/2023MS003750)

M. Tijhuis, B.J.H. van Stratum, M.A. Veerman, and C.C. van Heerwaarden (2022): *An Efficient Parameterization for Surface Shortwave 3D Radiative Effects in Large-Eddy Simulations of Shallow Cumulus Clouds.*. J. Adv. Model. Earth Syst., (10.1029/2022MS003262)