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	2025
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 & 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)	27 000 000	0	27 000 000	1 154 909
Data storage capacity	(Gbytes)	760	0	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)

We did not encounter any issues on the ECMWF HPC. More generally for the project, our work increasingly relies on the GPU-based ray tracer in MicroHH. As a result, much of the work we had planned to run on the ECMWF HPC has shifted to the SURF facilities in the Netherlands (Snellius), which offers a large number of NVIDIA A100 and H100 GPUs.

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

1. Development and validation parameterisation of surface 3D radiative effects.
This project has moved entirely to other HPCs because of the need for NVIDIA GPUs and will not be continued within this special project.

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

1. M. Tijhuis, B.J.H. van Stratum, and C.C. van Heerwaarden (2024): *The impact of coupled 3D shortwave radiative transfer on surface radiation and cumulus clouds over land*. Atmos. Chem. Phys., (10.5194/acp-24-10567-2024)

Summary of results

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 models like ERA5 or HARMONIE-AROME.

In the Ruisdael project (https://ruisdael-observatory.nl/), we compared this model setup to a range of other models and observations, which revealed several issues in our setup. We have been addressing these to improve the model's reliability and accuracy.

As an example, Figure 1 shows a comparison between Cabauw observations and a MicroHH simulation with open boundary conditions nested in ERA5. The complex cloudy conditions on this day were captured well by the nested setup, resulting in good agreement between the observed and modelled surface energy balance.

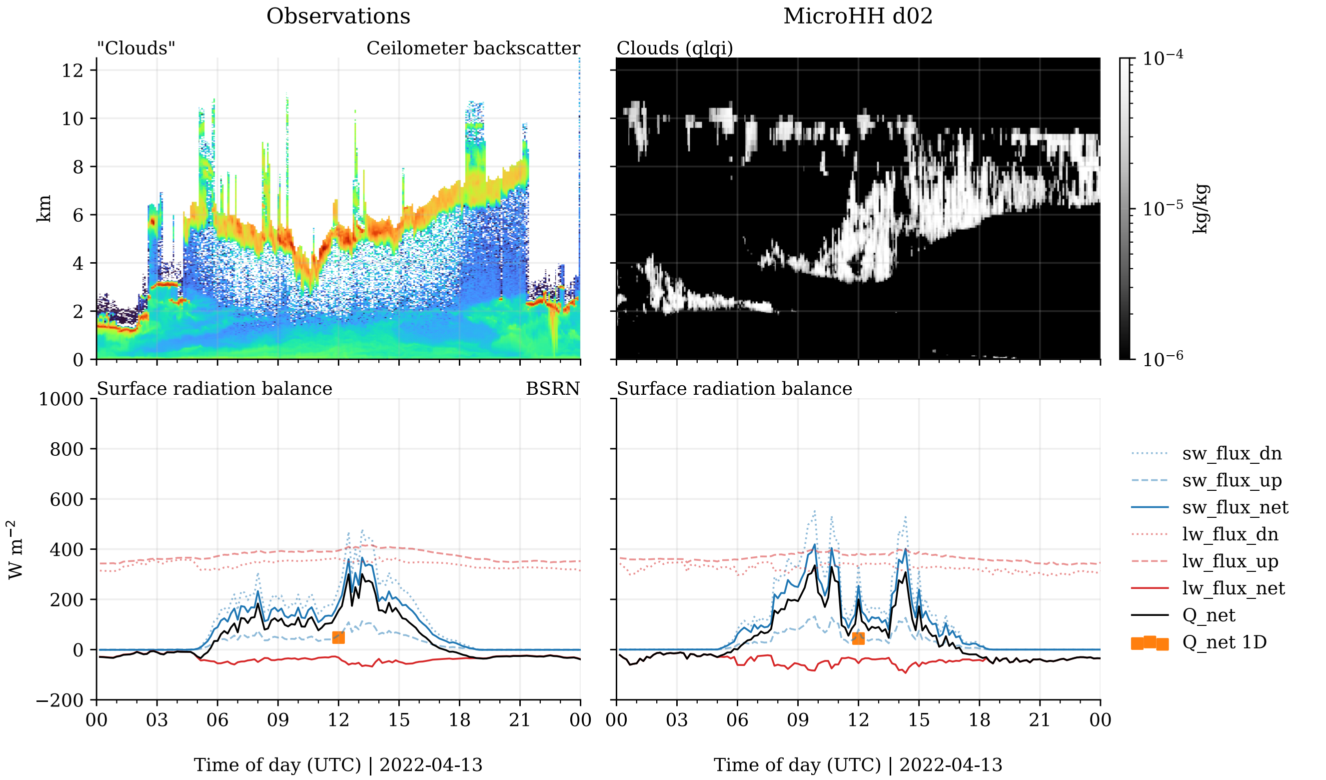

Figure 1: Comparison Cabauw observations (left) with MicroHH simulation (right).

In addition to the open boundary conditions, our work also focused on implementing a plant physiological extension (A-Gs + soil respiration) of our HTESSEL land-surface model, to enable the study of surface CO_2 exchange. Figure 2 shows a comparison of MicroHH (blue) and an IFS simulation (CATRINE project, red) against the observed CO_2 flux at the Loobos tower. Both MicroHH and IFS capture the daily cycle well, with CO_2 uptake by vegetation during the day and CO_2 release from soil respiration at night.

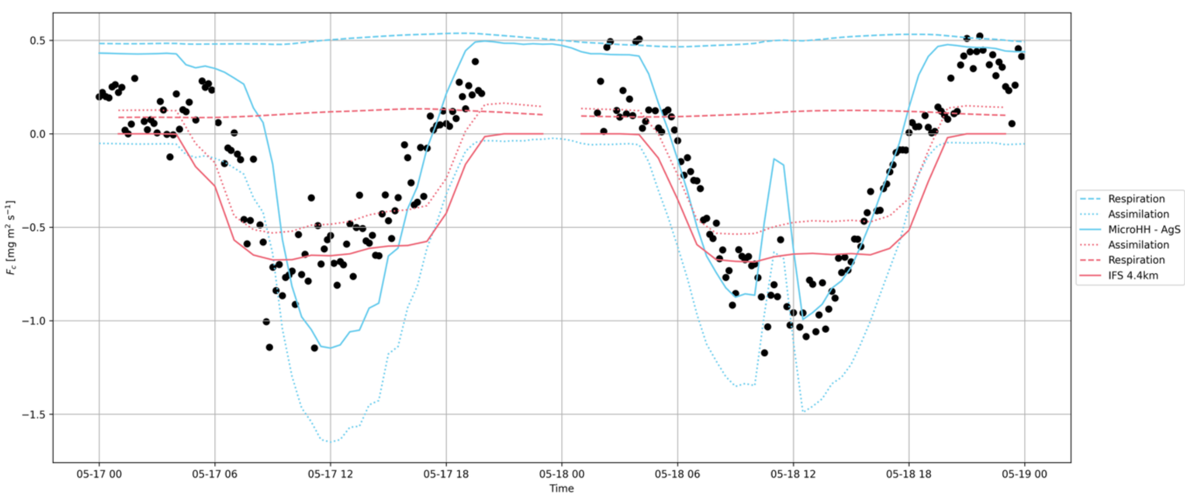

Figure 2: comparison surface CO2 flux between MicroHH, IFS, and Loobos observations

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)

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