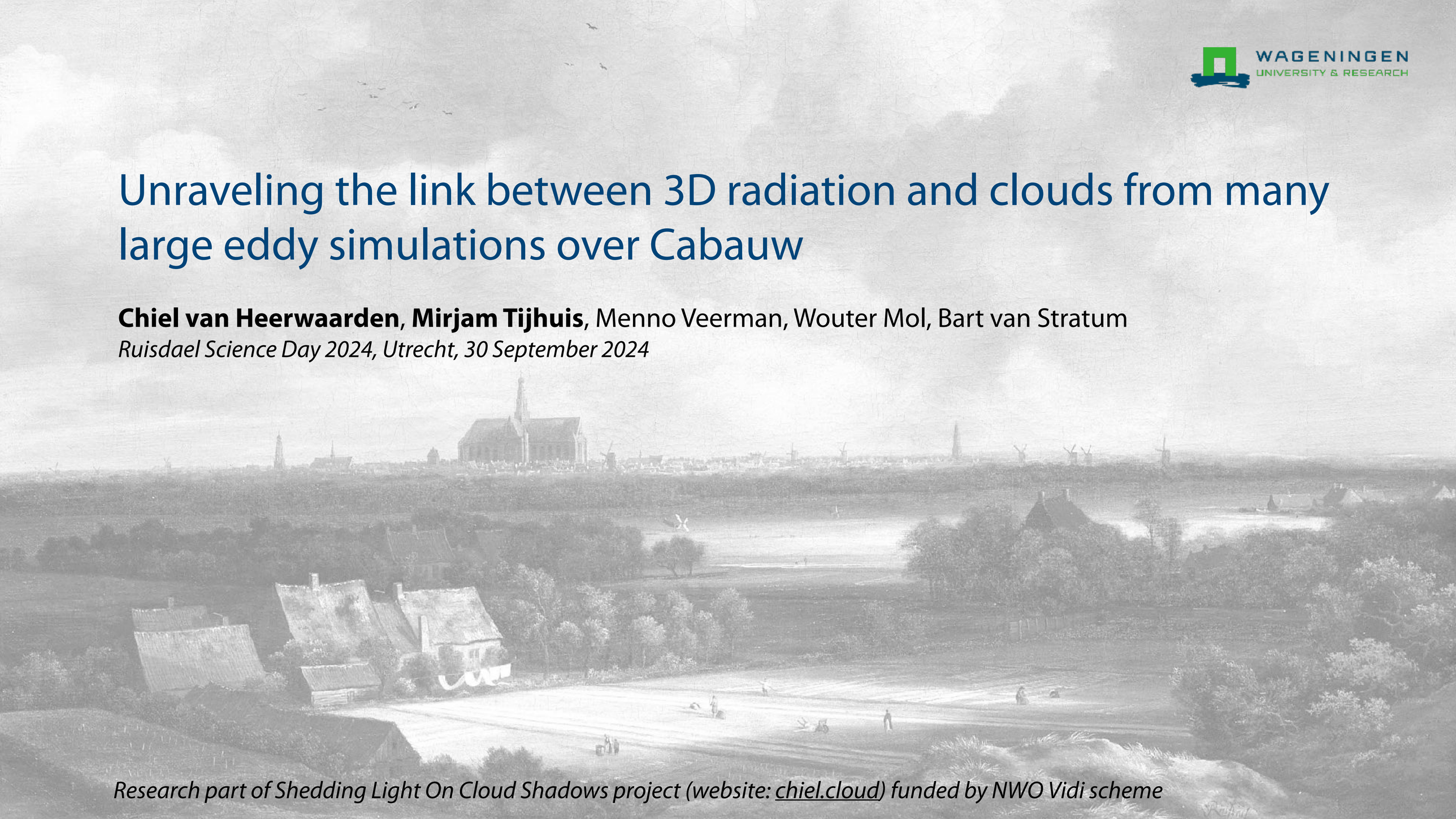
Unraveling the link between 3D radiation and clouds from many large eddy simulations over Cabauw

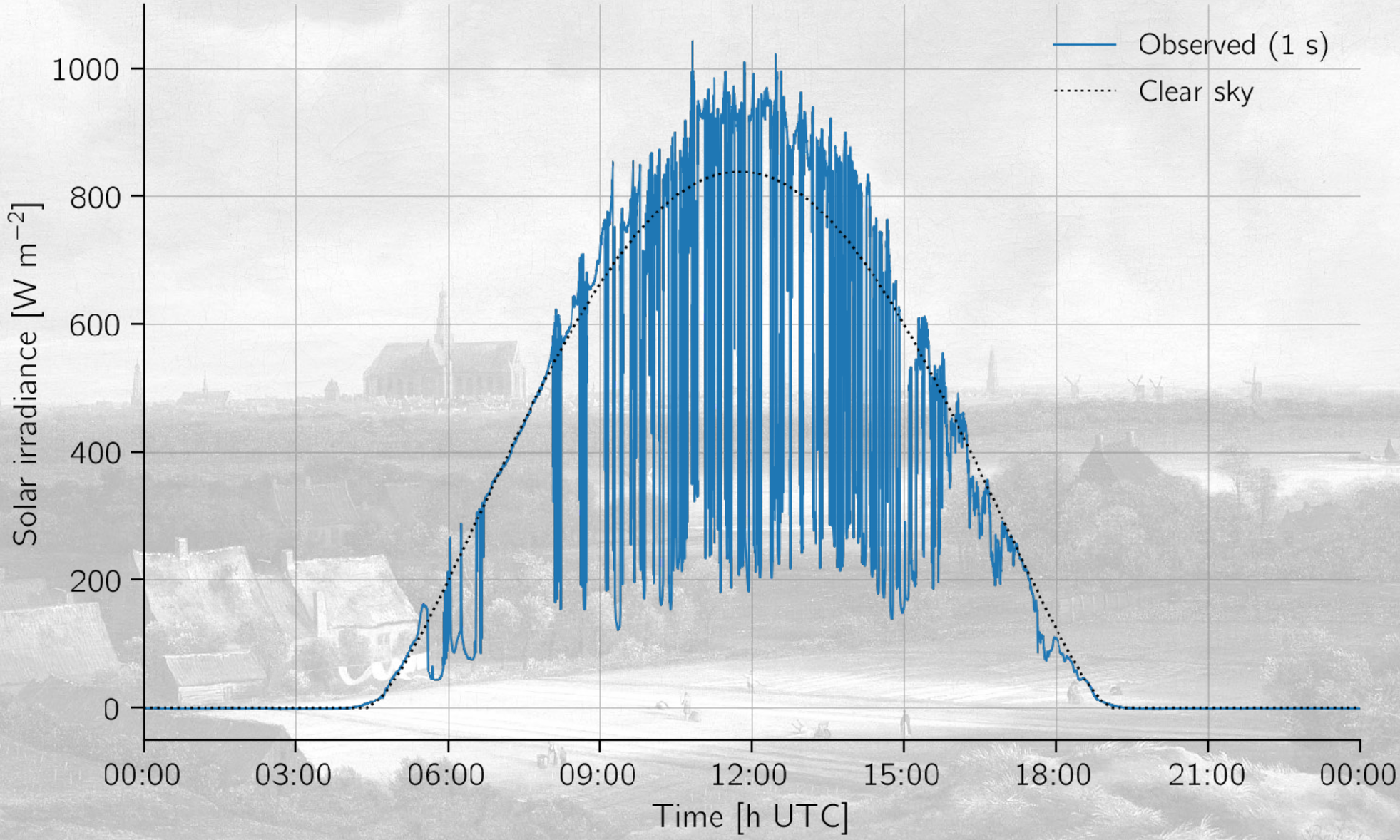
Chiel van Heerwaarden, **Mirjam Tijhuis**, Menno Veerman, Wouter Mol, Bart van Stratum

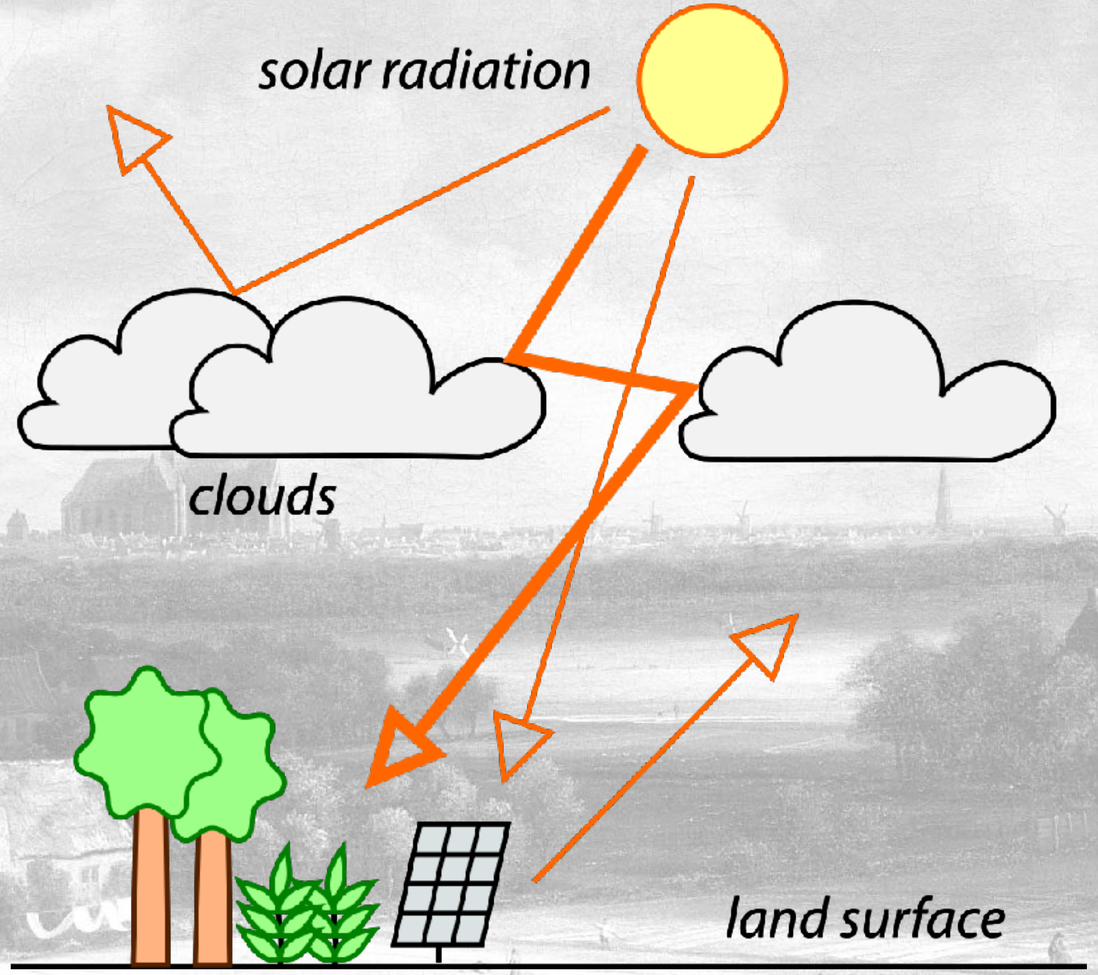
Ruisdael Science Day 2024, Utrecht, 30 September 2024



Research part of Shedding Light On Cloud Shadows project (website: chiel.cloud) funded by NWO Vidi scheme

August 11, 2018, Cabauw, NL (BSRN KNMI)




solar radiation
clouds
land surface

Aim and objectives of *Shedding Light On Cloud Shadows (2019-2024)*

Quantify and understand
variability in surface solar irradiance
caused by clouds

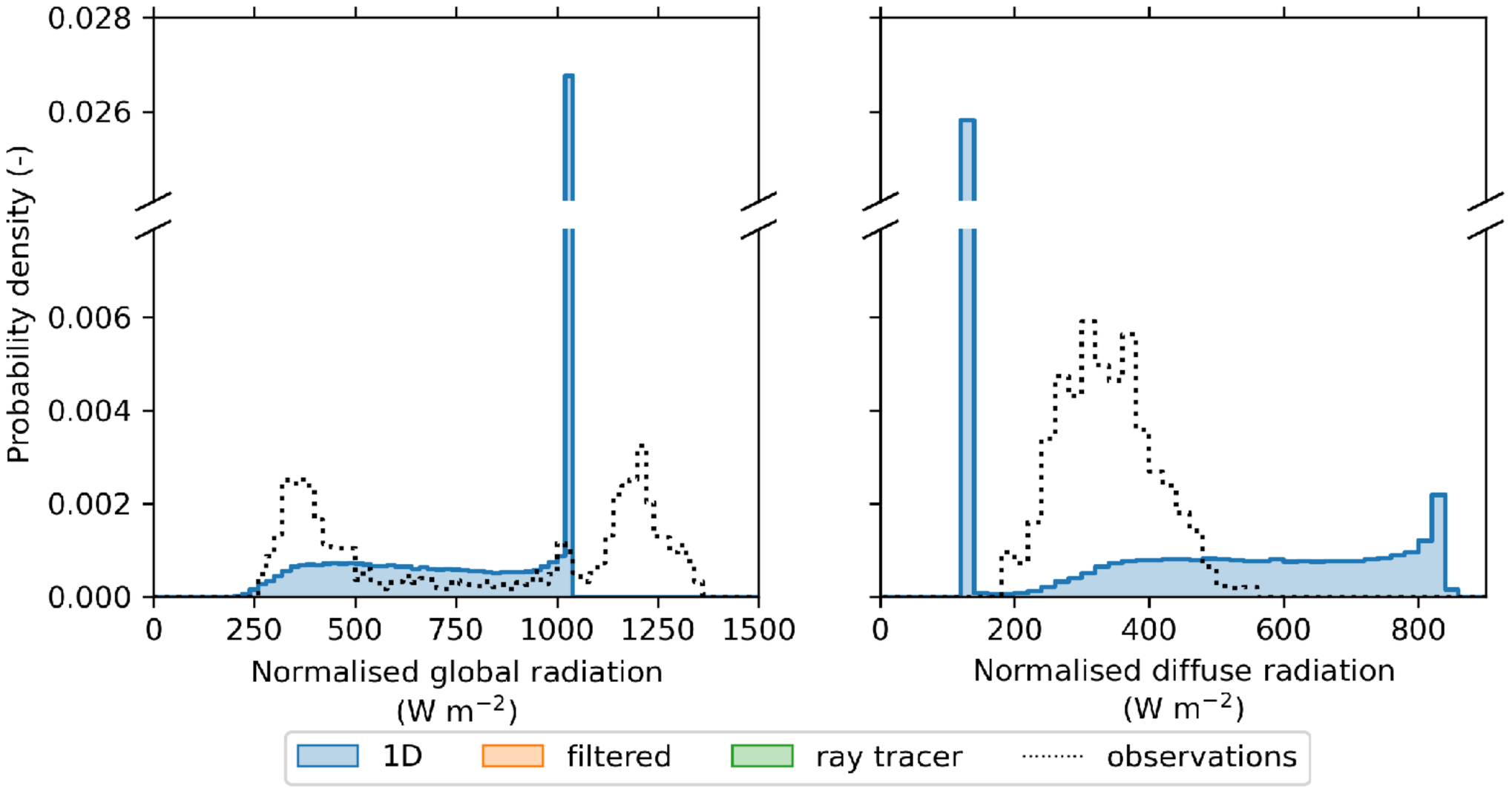
***1. Observing** variability*

***2. Simulating** variability*

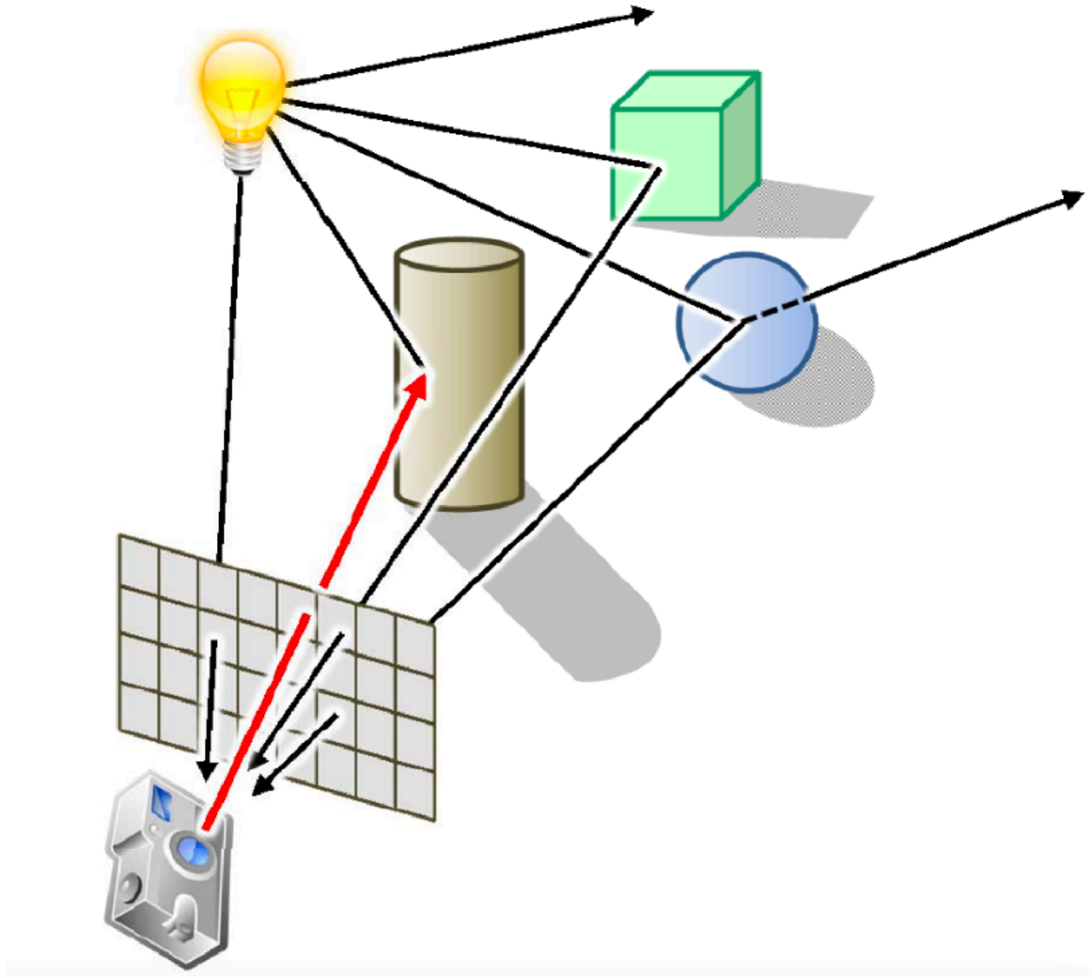
***3. Forecasting** variability*

Overview of project output on chiel.cloud

Simulation: state-of-the-art cloud resolving models have unrealistic PDFs of solar irradiance



Ray tracing to follow light from the sun through a cloudy atmosphere



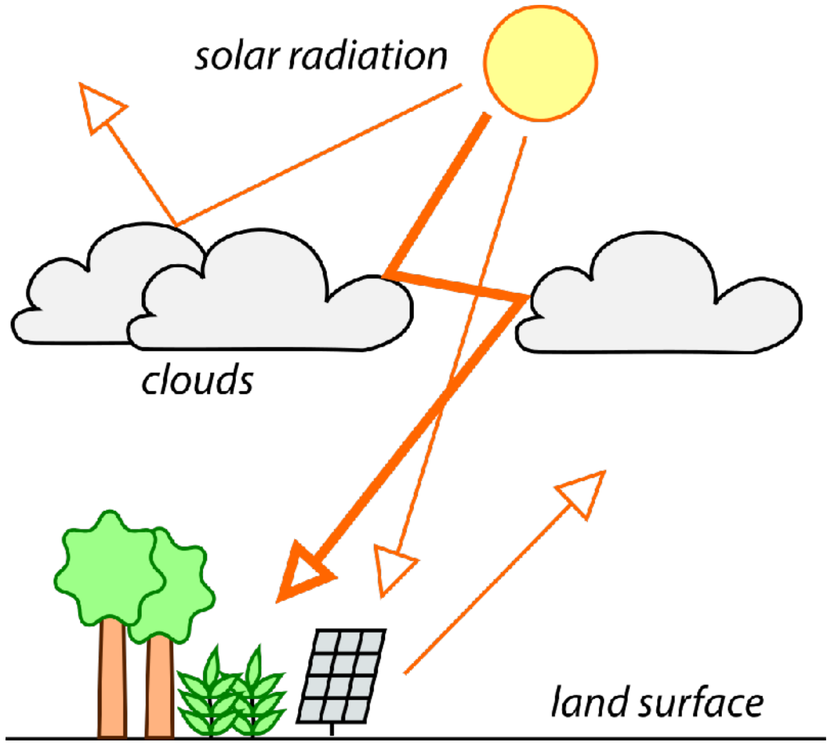


Figure from Retzlaff et al. (2017)

esiwace
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Movie by Menno Veerman (vimeo.com/channels/microhh)

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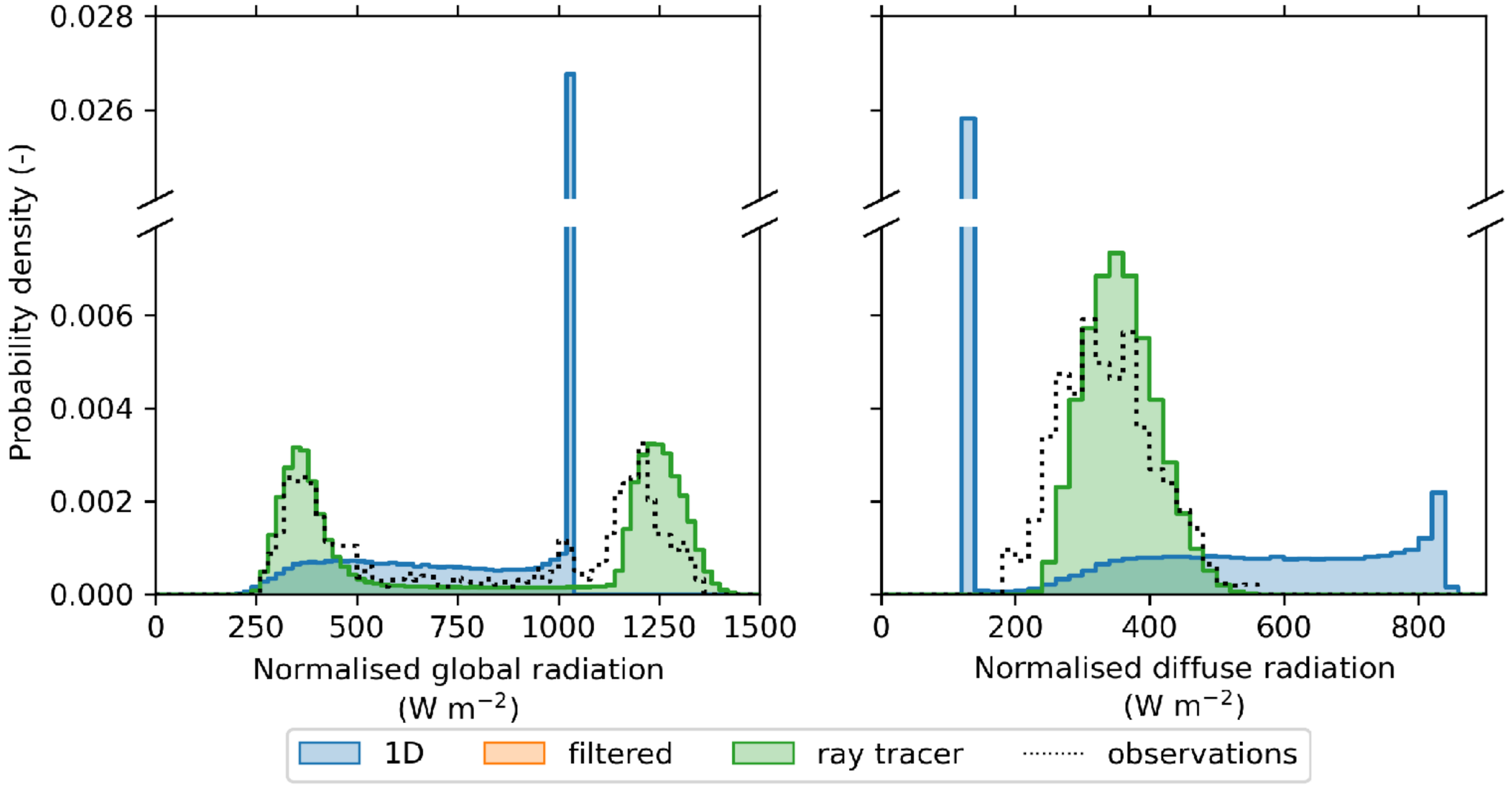
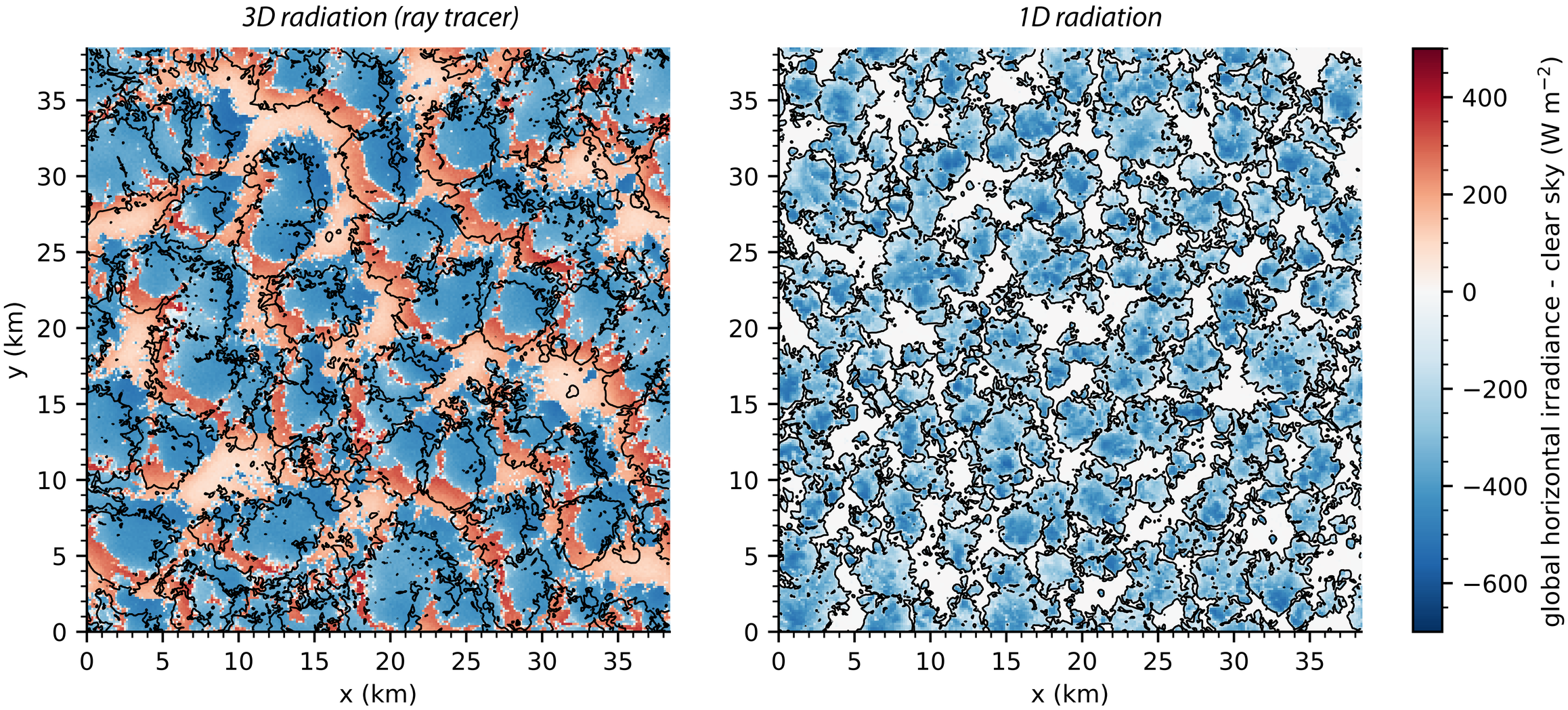
Simulations with ray tracing reproduce correct PDFs



Tijhuis et al, JAMES, 2023, https://doi.org/10.1029/2022MS003262

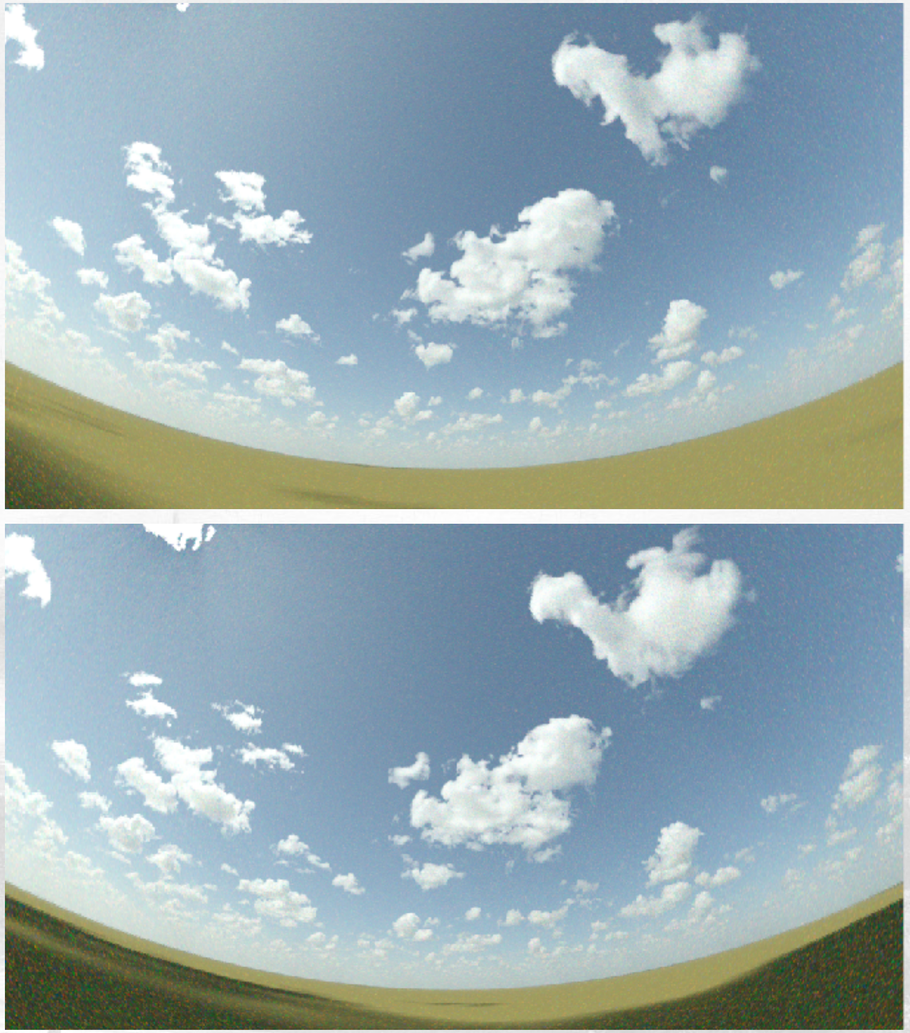
3D radiation gives surface patterns of observation, and makes clouds larger and wetter



Veerman et al, GRL, 2022, https://doi.org/10.1029/2022GL100808, animations on vimeo.com/channels/microhh

Simulation: study cloud shadows and reproduce observations in a virtual laboratory

- Large-eddy simulations set up against ERA5 and CAMS
  - $(LS)^2D$ tool (https://github.com/LS2D/LS2D, or via PyPI)
- MicroHH GPU large-eddy simulation
  - (https://github.com/microhh/microhh)
- RTE+RRTMGP radiation model
  - (https://github.com/earth-system-radiation/rte-rrtmgp-cpp)
- Radiation computations with different complexity
  - 1D independent columns (the status-quo in weather and climate)
  - 3D with GPU ray tracer (the SLOCS project)
- 12 selected days in Cabauw with shallow clouds



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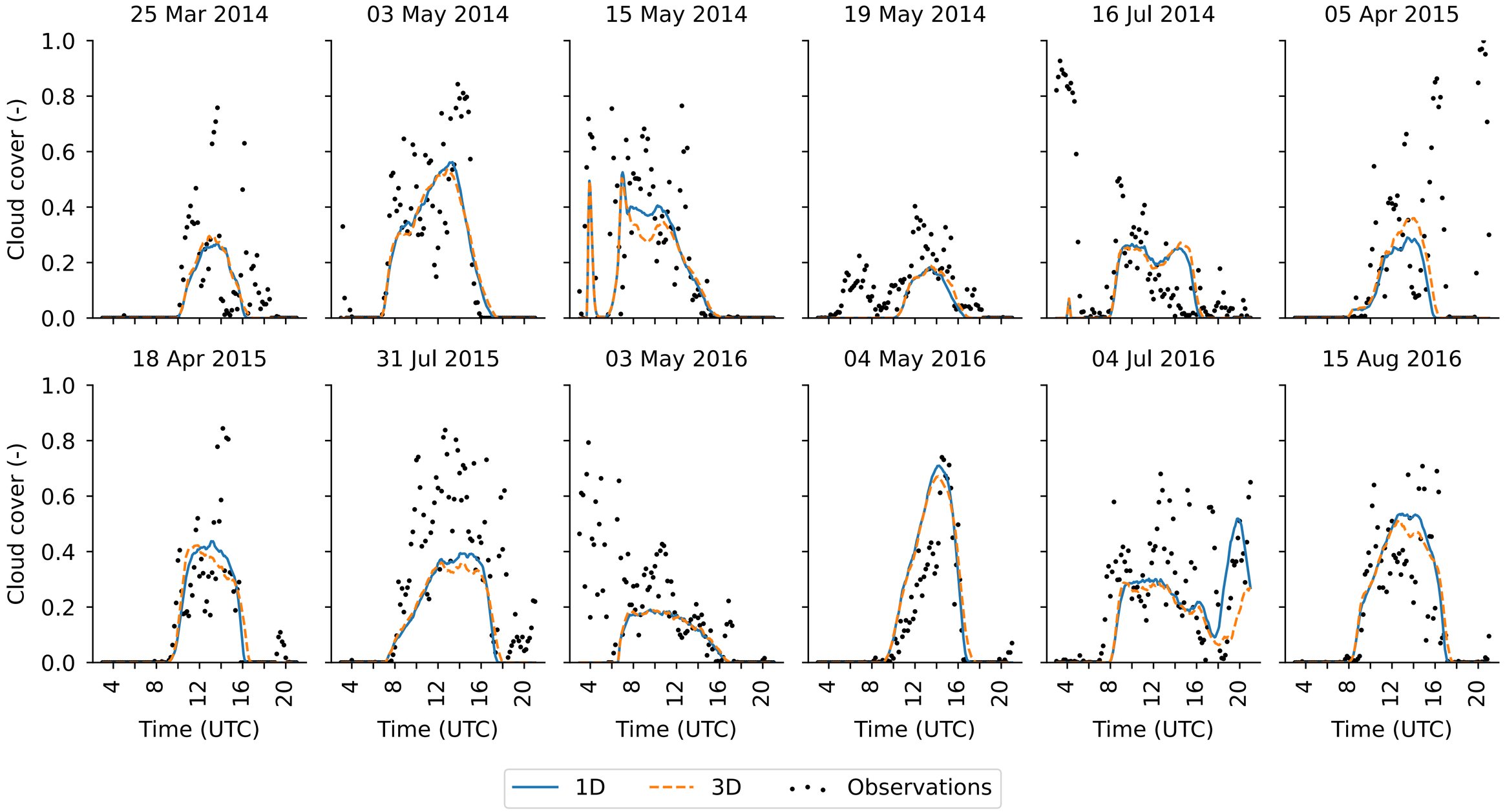
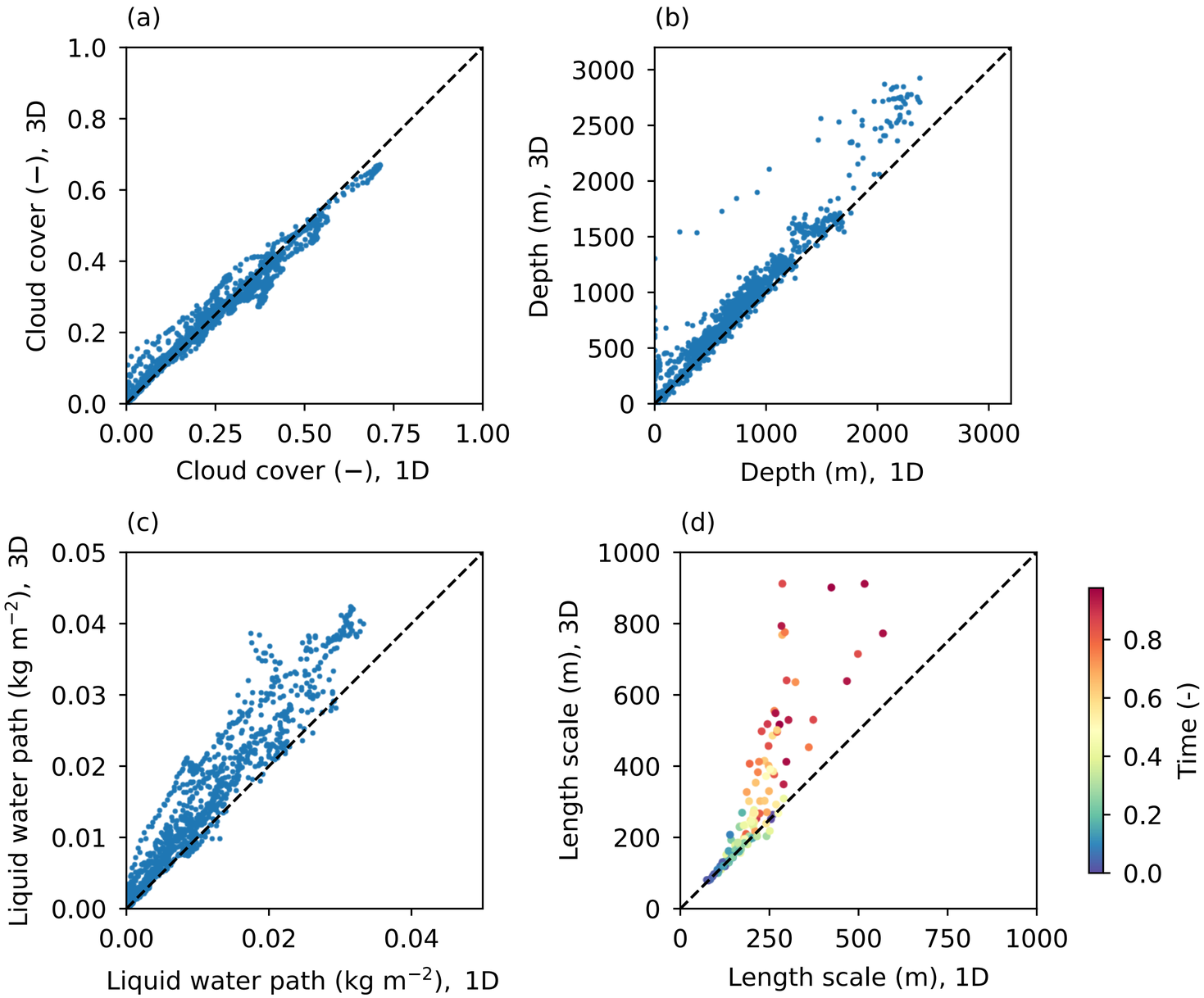
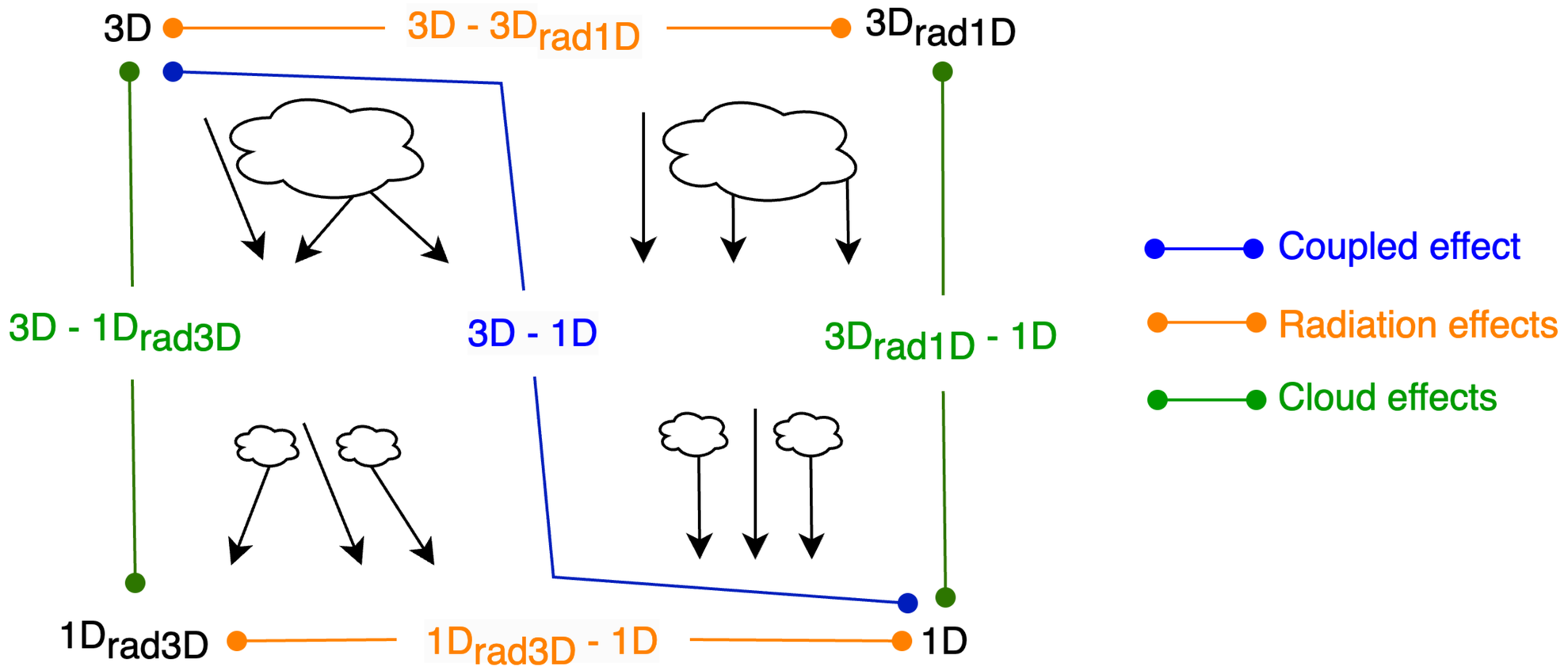


Tijhuis et al, ACP, 2024, https://doi.org/10.5194/acp-24-10567-2024

Similar cloud cover, but wetter and larger clouds with 3D radiation



Disentangling the role of cloud feedbacks in the total difference between 3D and 1D



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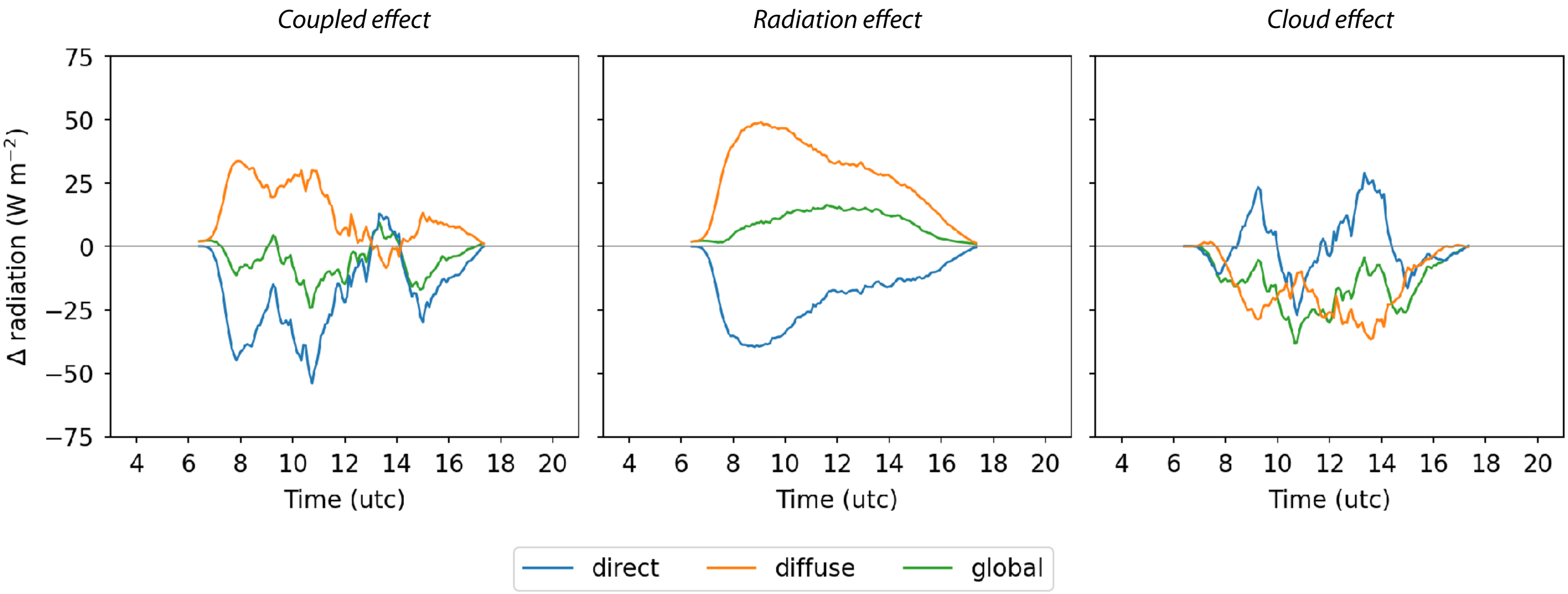
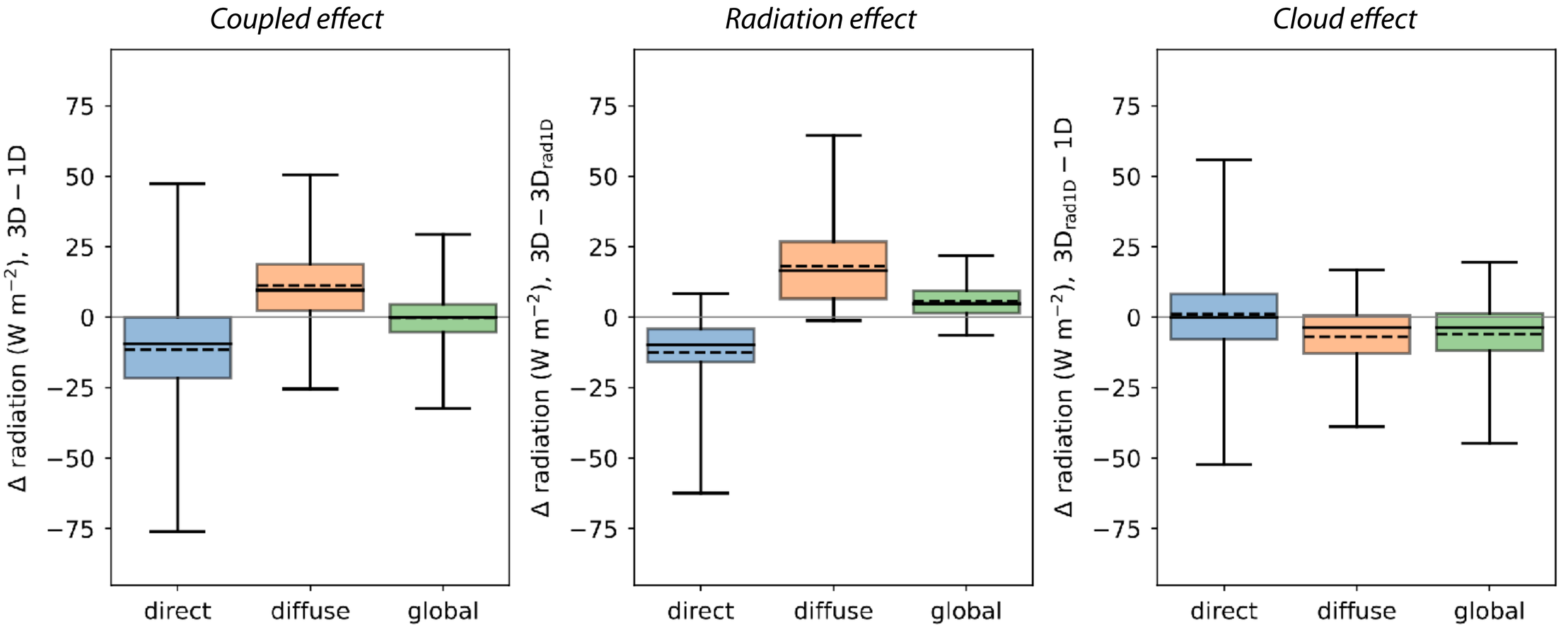
Wetter clouds compensate extra global radiation in 3D radiation computations



Cloud feedbacks counter global radiation changes due to 3D effects



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Unraveling the link between 3D radiation and clouds

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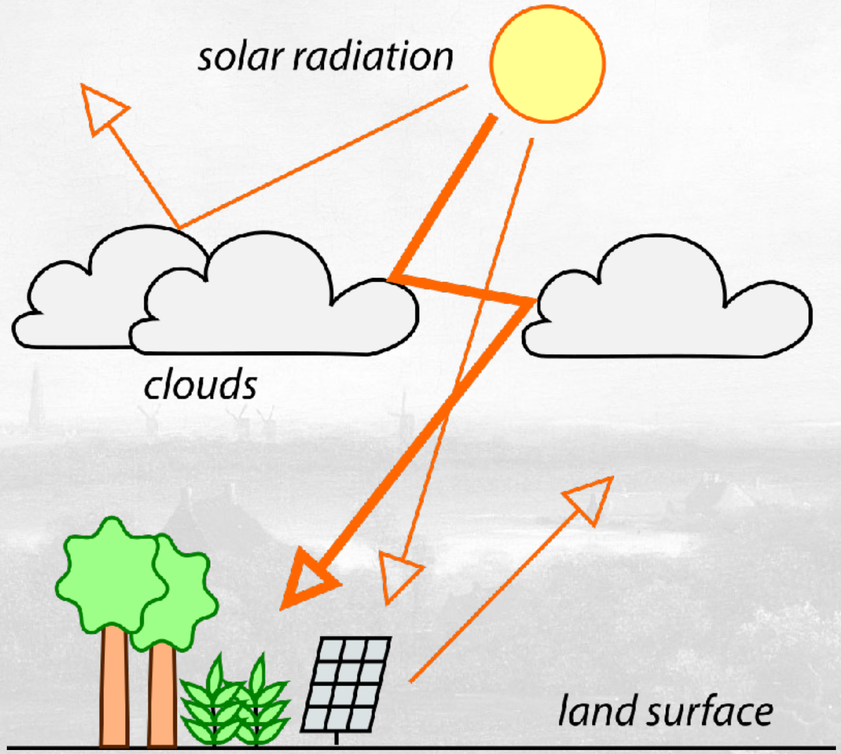
Conclusions

- GPU computing enables coupling LES with ray tracer
- 3D radiation makes clouds wetter and larger
- Wetter and larger clouds do not modify the global radiation
- Why net zero is a mystery to be solved…



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