Shedding light on cloud shadows

Measuring and simulating surface solar irradiance under broken clouds

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

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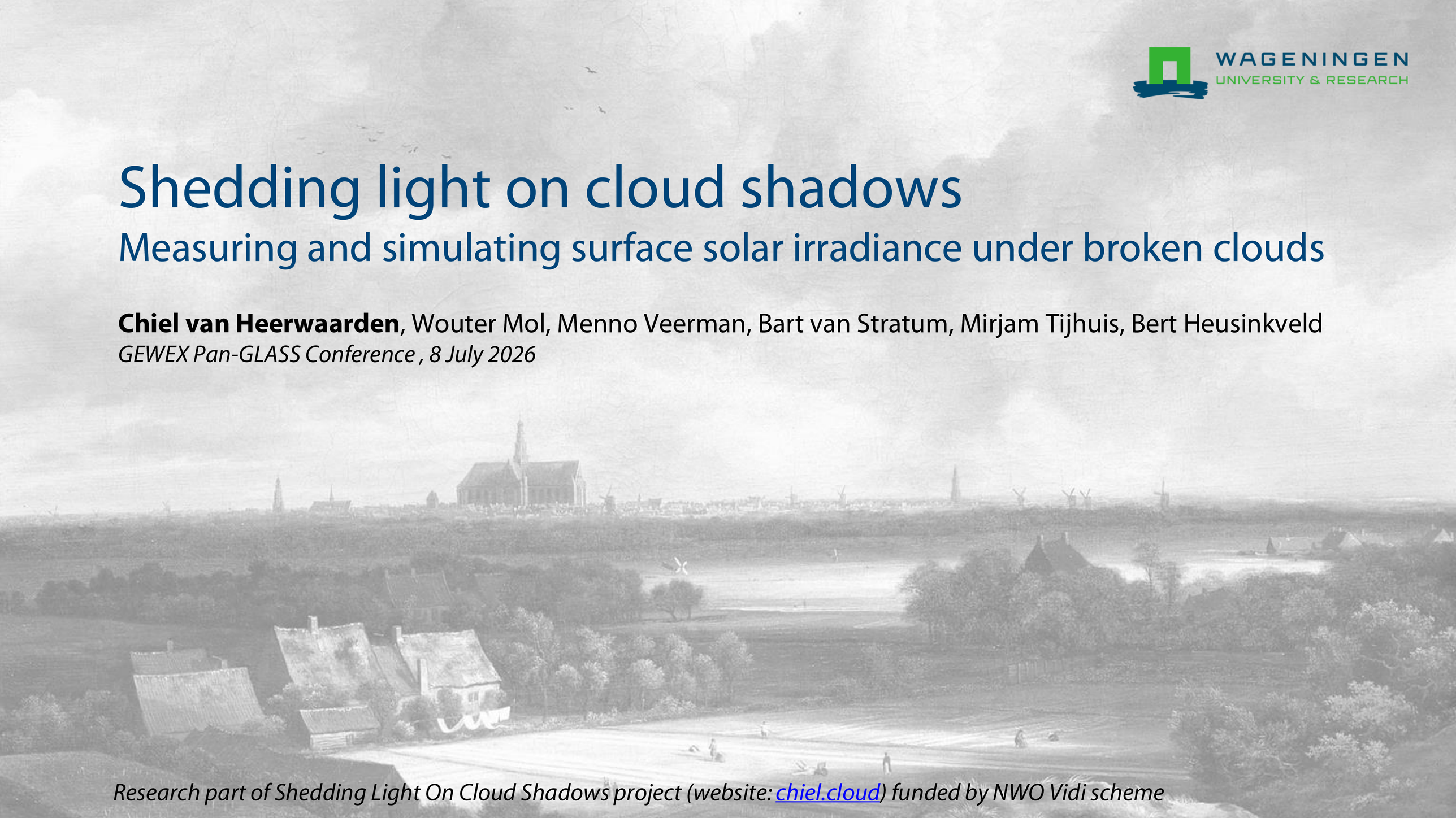
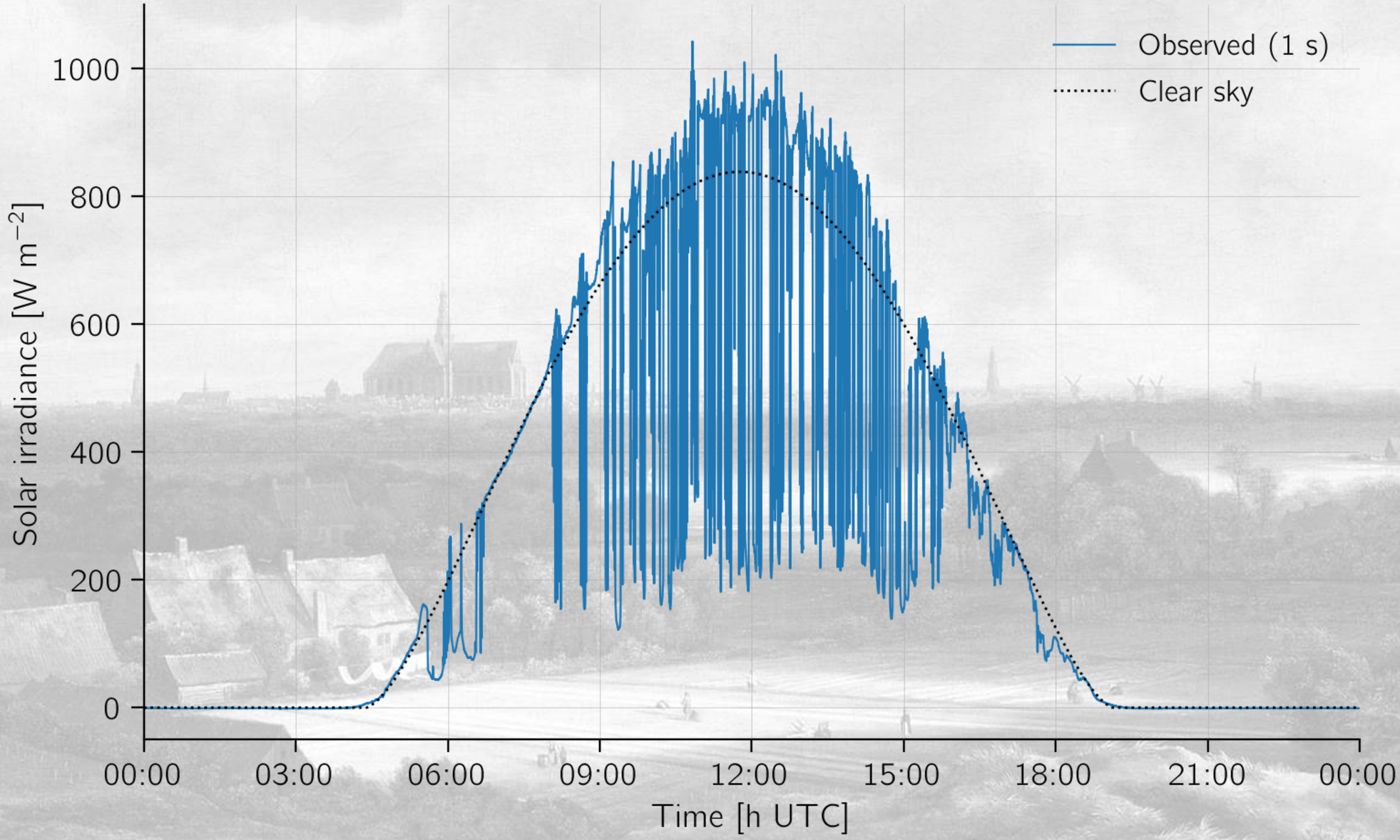
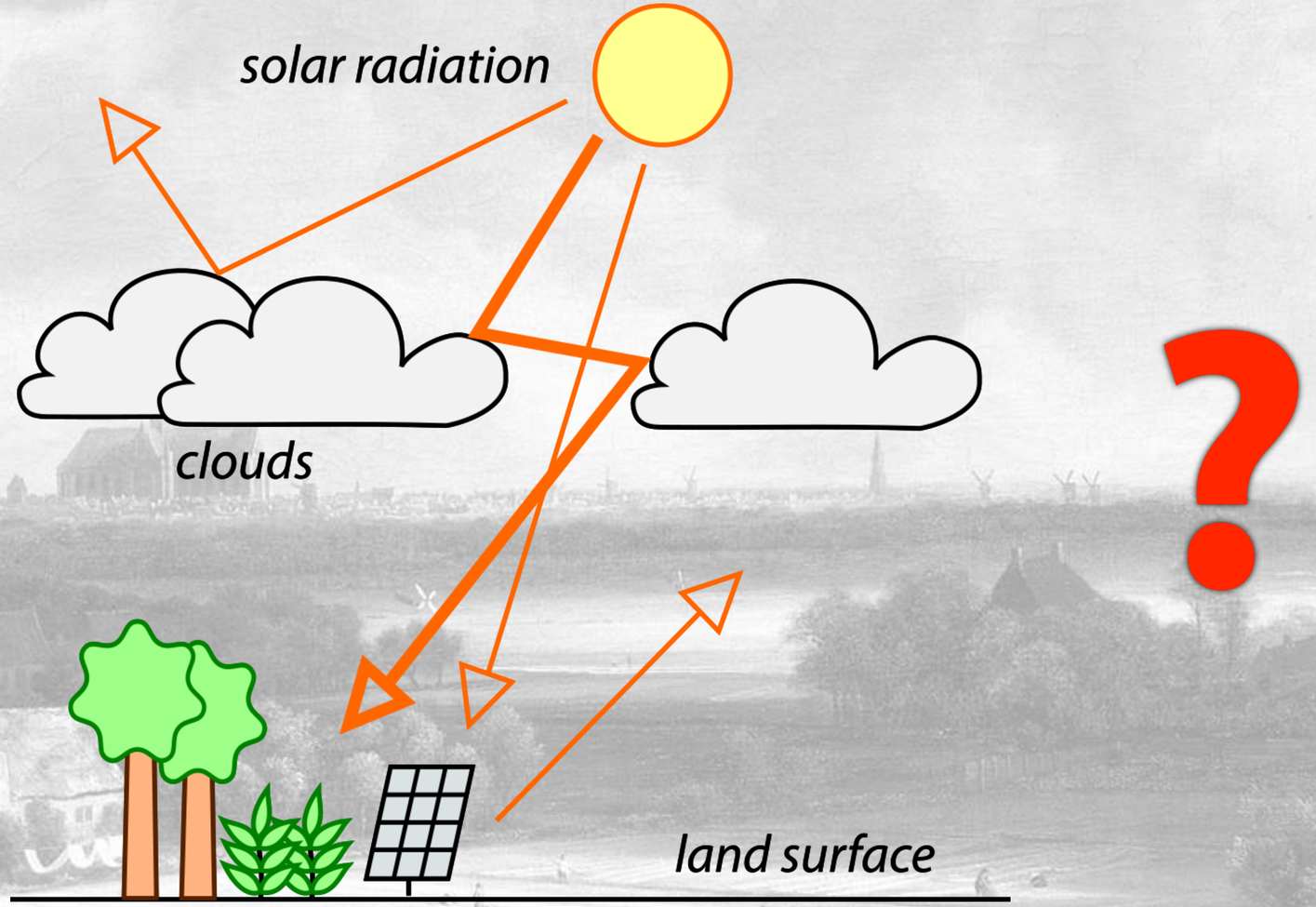


Research part of Shedding Light On Cloud Shadows project (website: chiel.cloud) funded by NWO Vidi scheme

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




solar radiation
clouds
land surface

Aim and objectives of *Shedding Light On Cloud Shadows (2019-2025)*

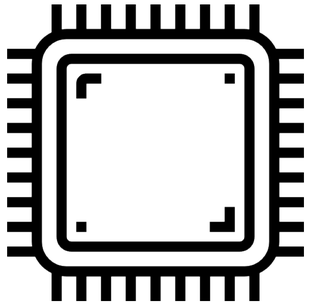
Quantify and understand variability in surface solar irradiance caused by clouds

***1. Observing** variability*

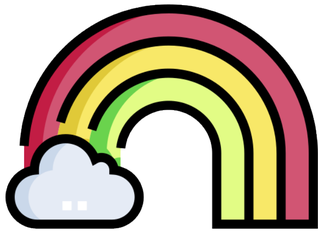
***2. Simulating** variability*

***3. Understanding** variability*

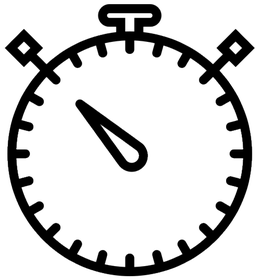
Observations: new cheap instrument for quantifying solar irradiance variability in the field



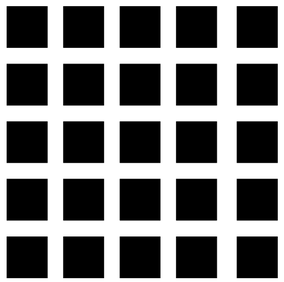
new sensor techniques



18 wave lengths
UV - visible - near-infrared



10 samples per second



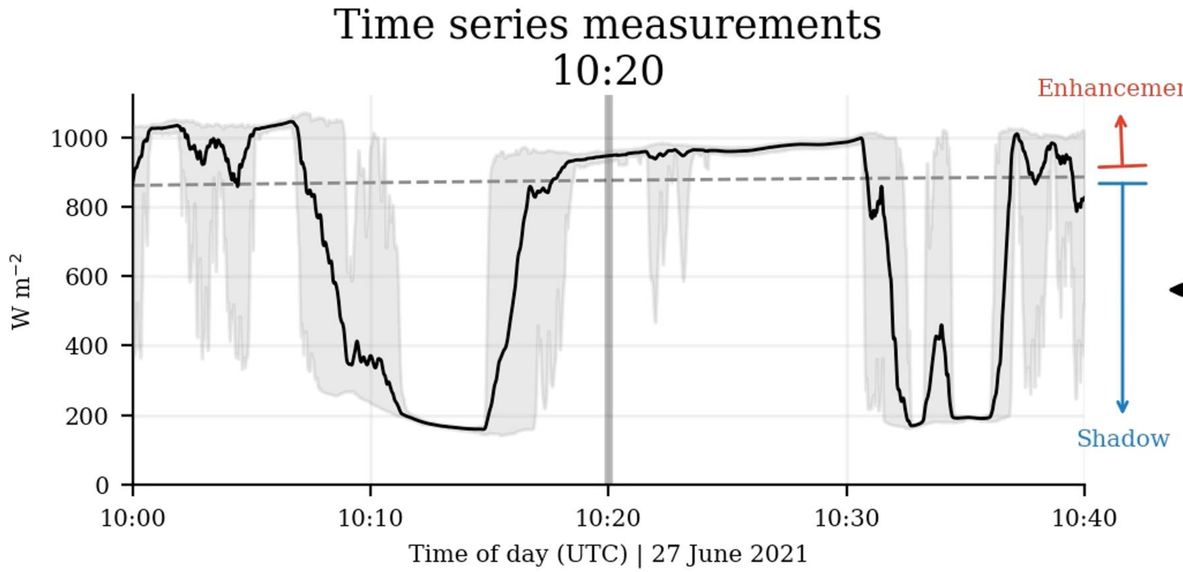
50 m spacing

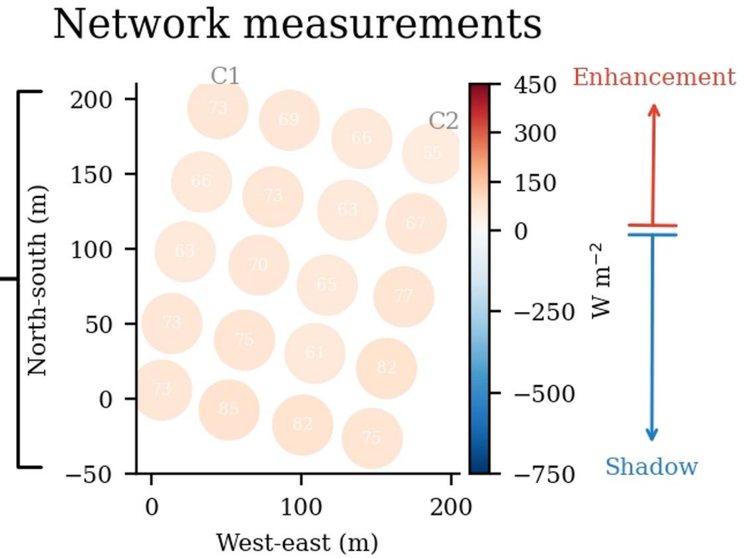
FESSTVaL / LIAISE / CloudRoots campaigns

Heusinkveld et al, AMT, 2023, https://doi.org/10.5194/amt-16-3767-2023

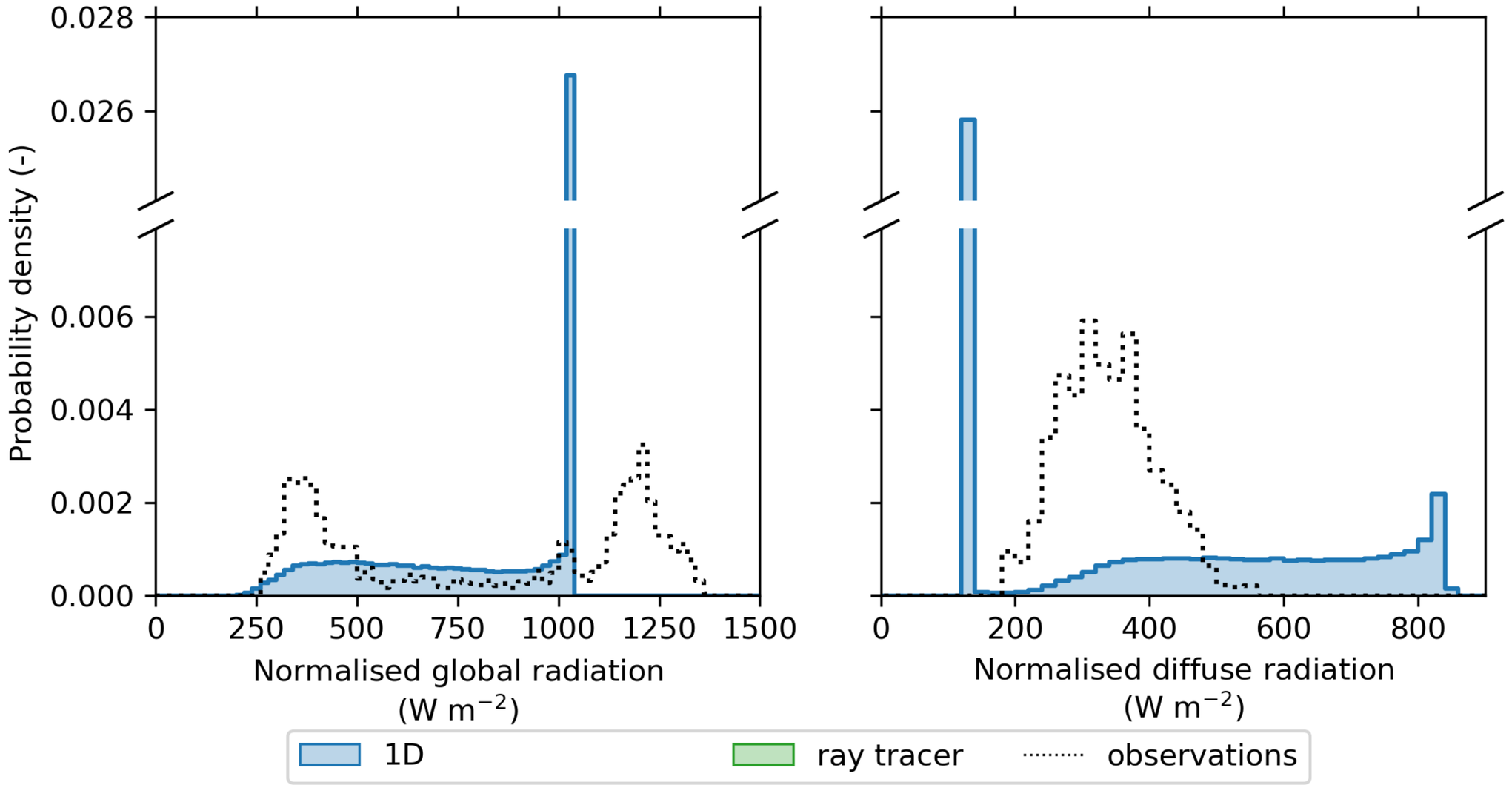
Observations of cloud shadows by boundary-layer clouds during FESSTVaL campaign in 2021

Mol et al. (2024)
https://doi.org/10.1002/qj.4712



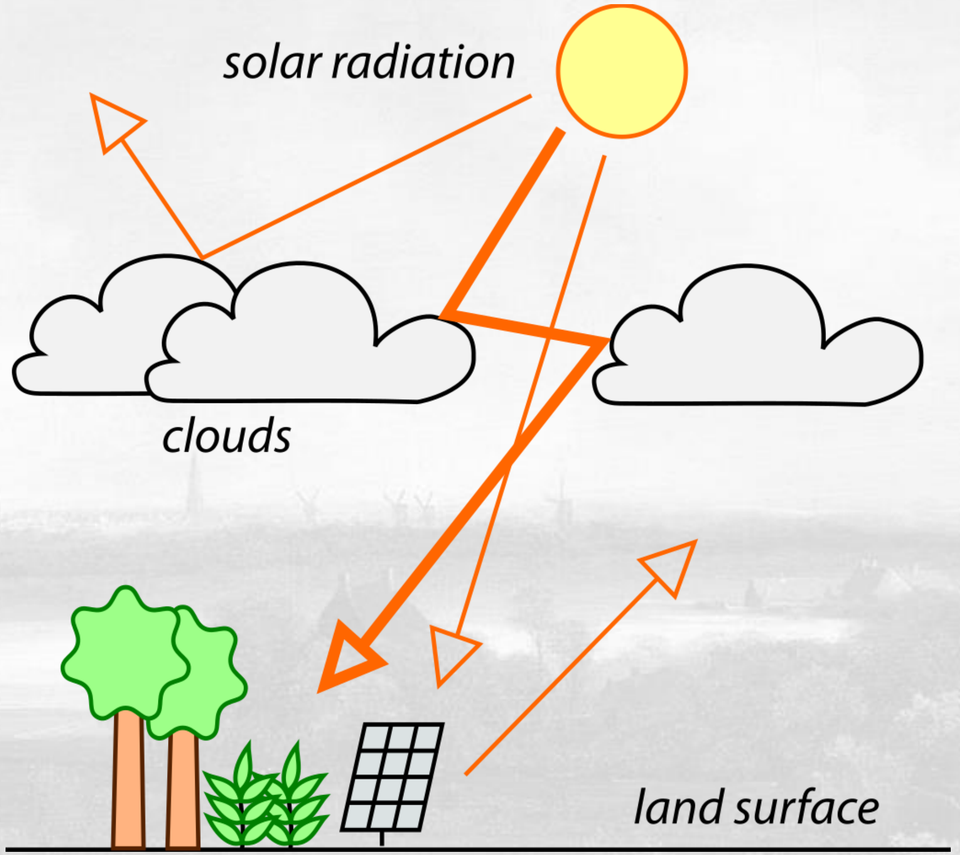


Simulation: state-of-the-art cloud-resolving models have unrealistic PDFs of solar irradiance



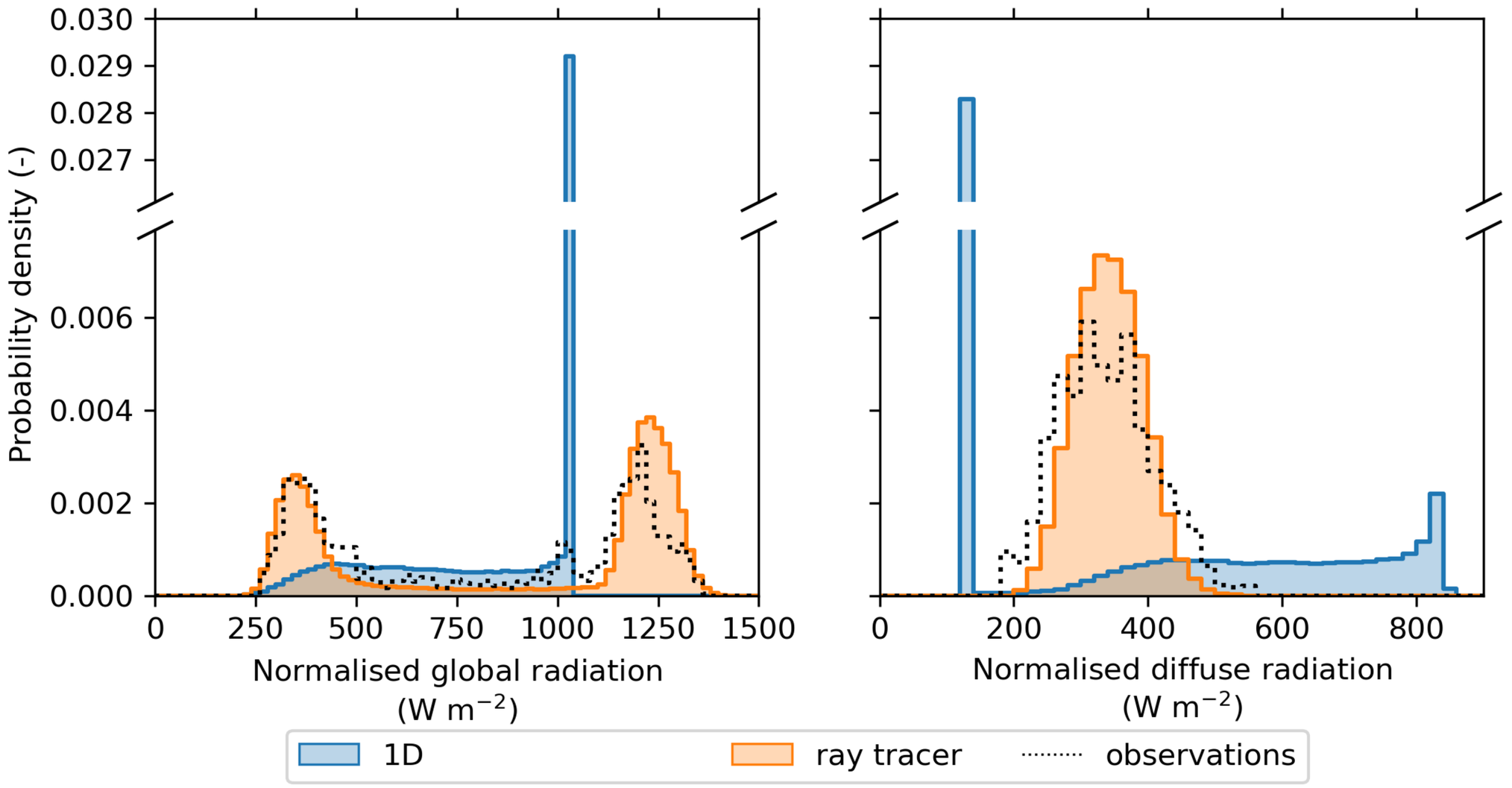
Simulation: study cloud shadows and reproduce observations in a virtual laboratory

- 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)**
- Simulation of many cases over Cabauw



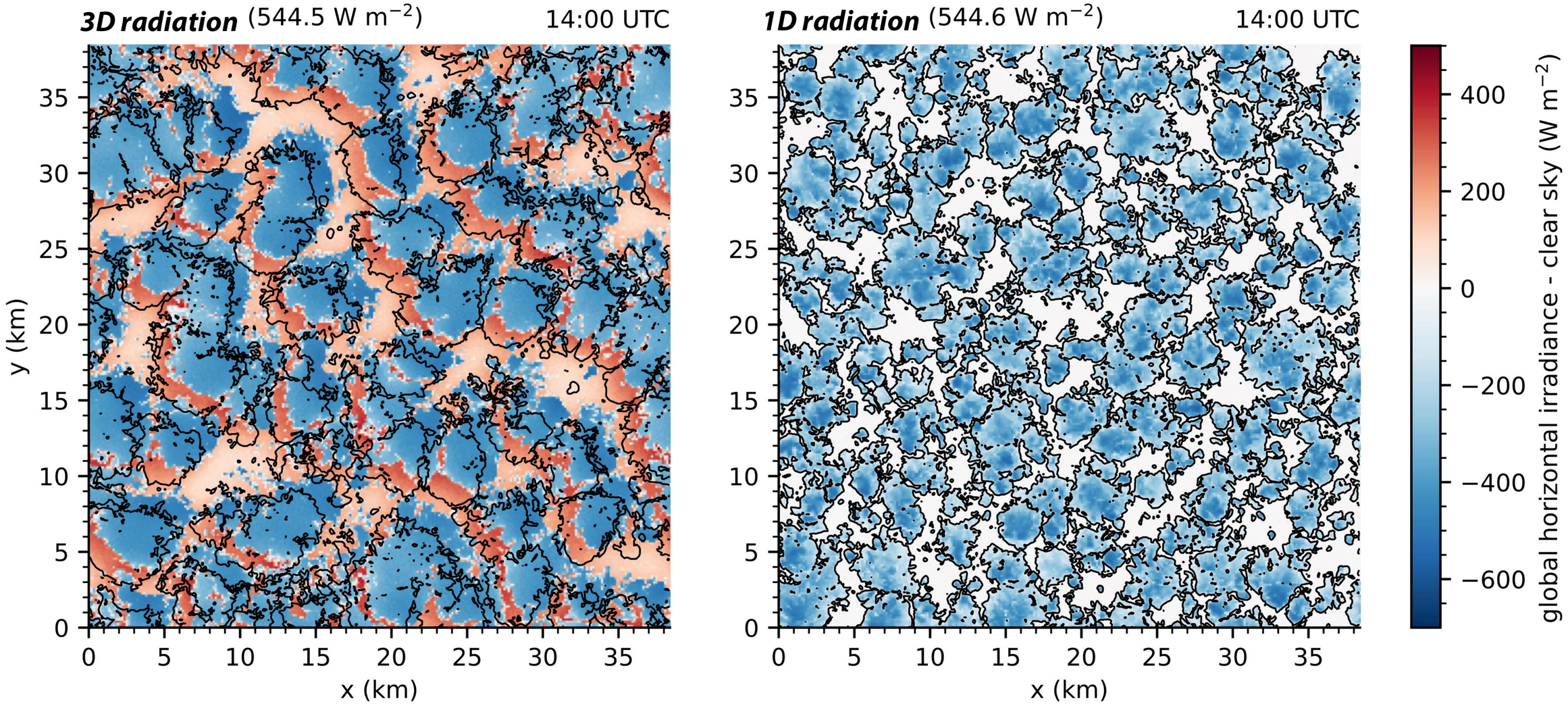
Movie by Menno Veerman

Simulations with ray tracing reproduce correct PDFs



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

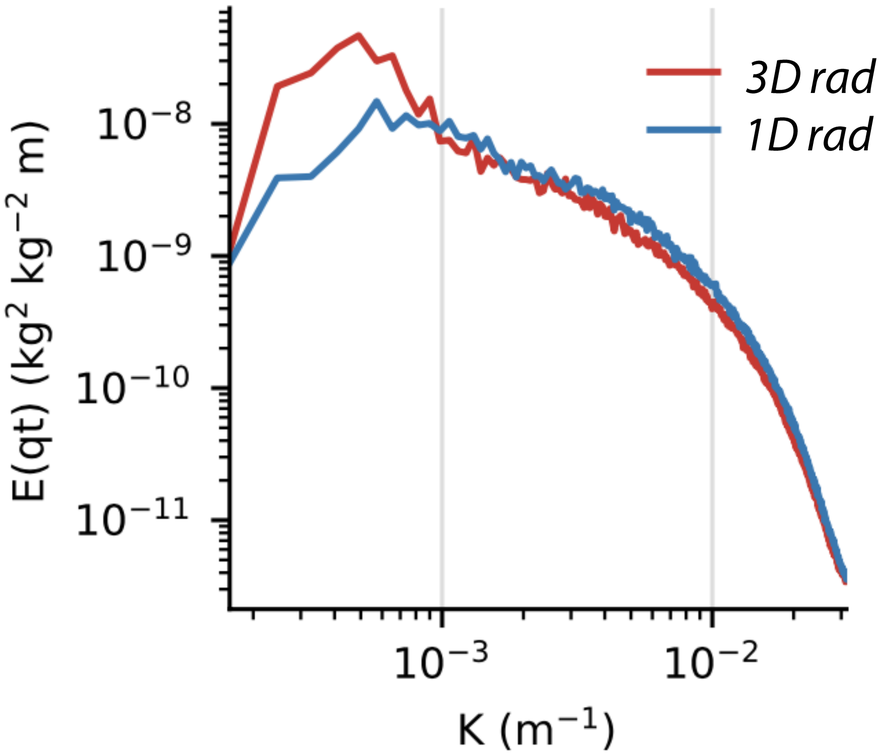
3D radiation modifies the boundary layer, resulting in stronger plumes and larger clouds



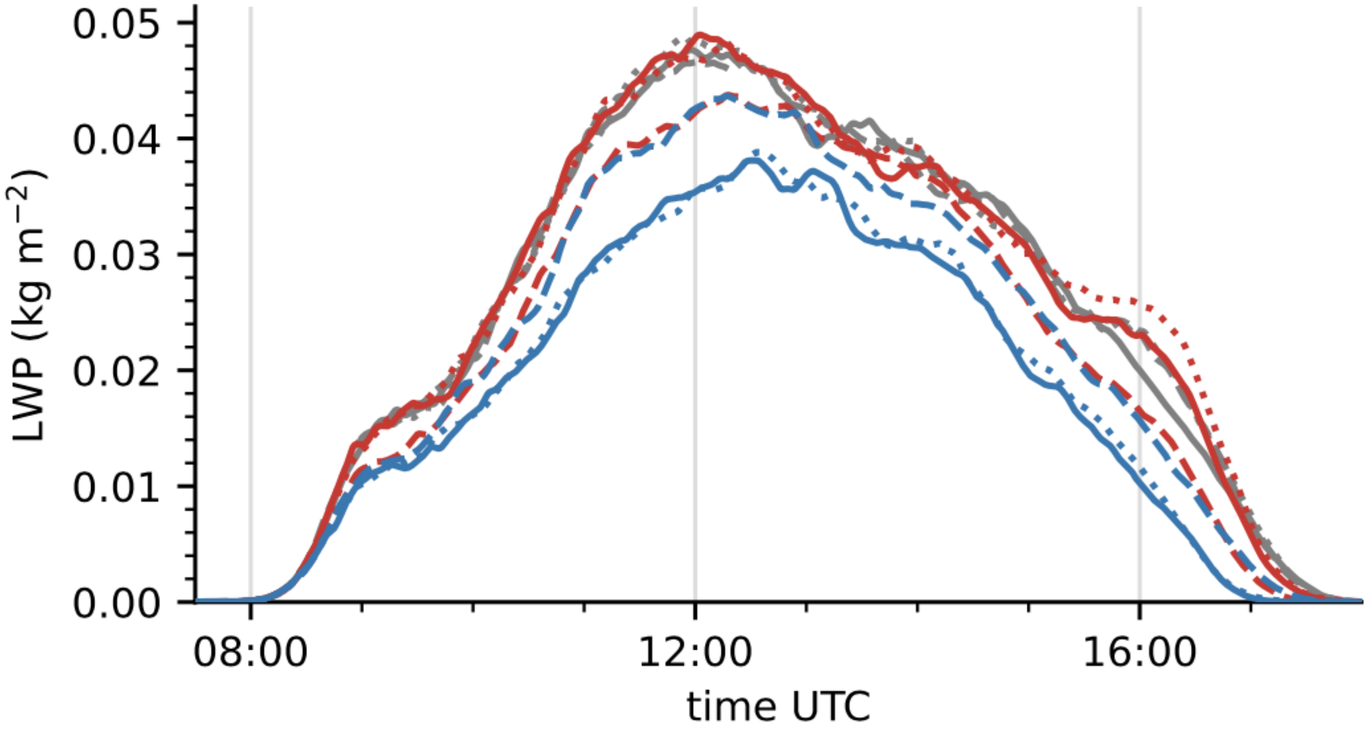
Veerman et al, GRL, 2022, https://doi.org/10.1029/2022GL100808, animations on chiel.cloud/projects/SLOCS

Larger moisture structures and wetter clouds due to 3D radiation-driven surface flux patterns

specific humidity at cloud height (14 LT)

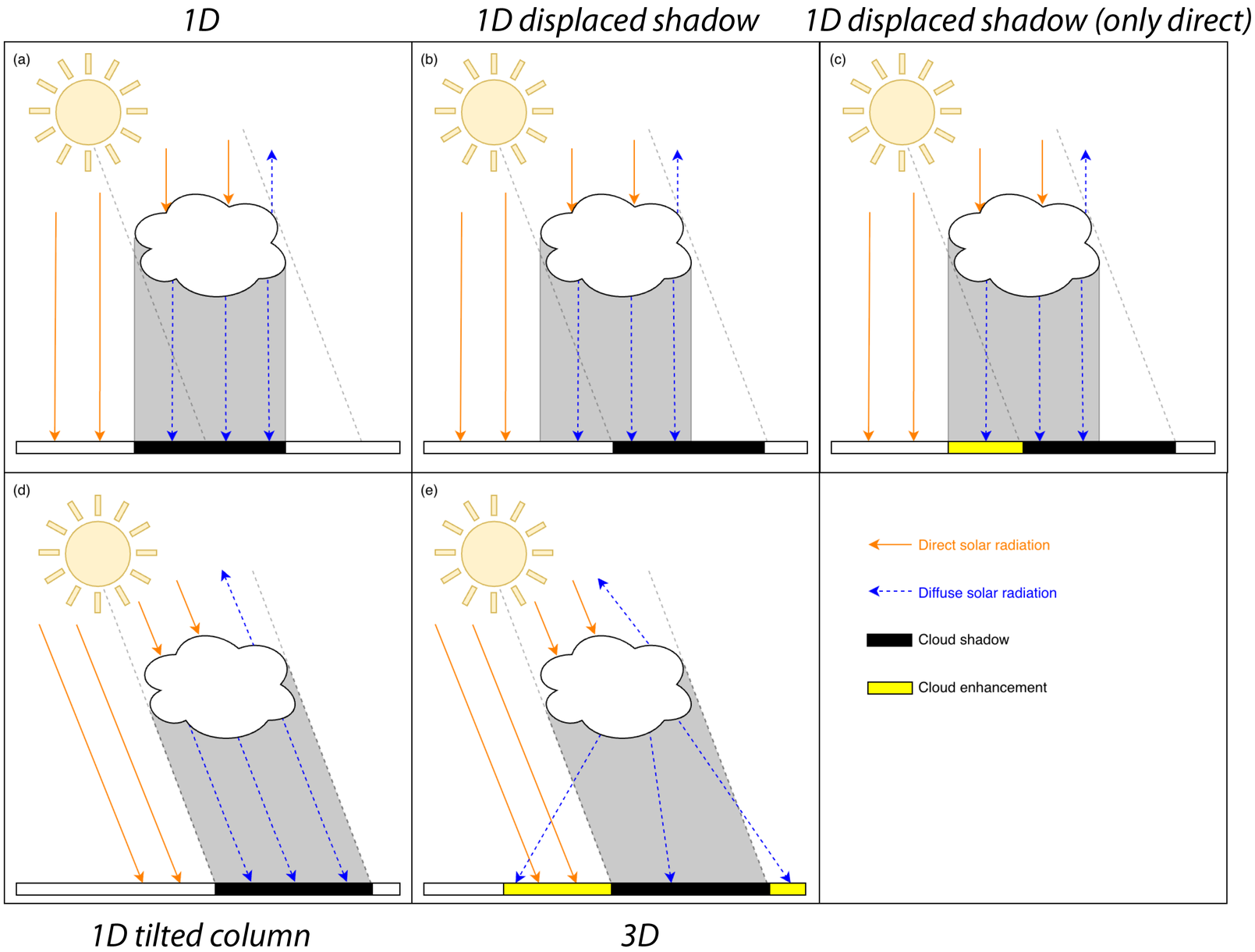


liquid water path

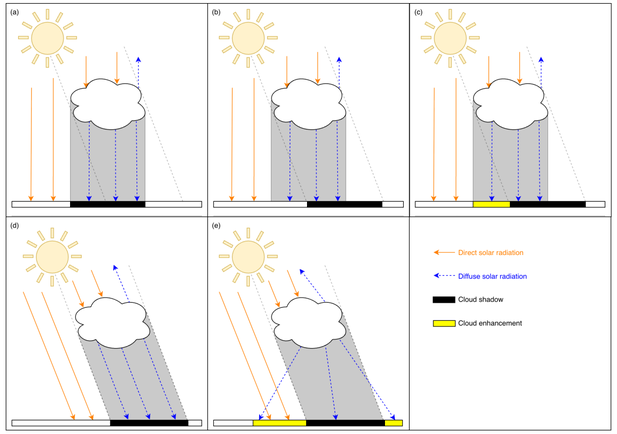


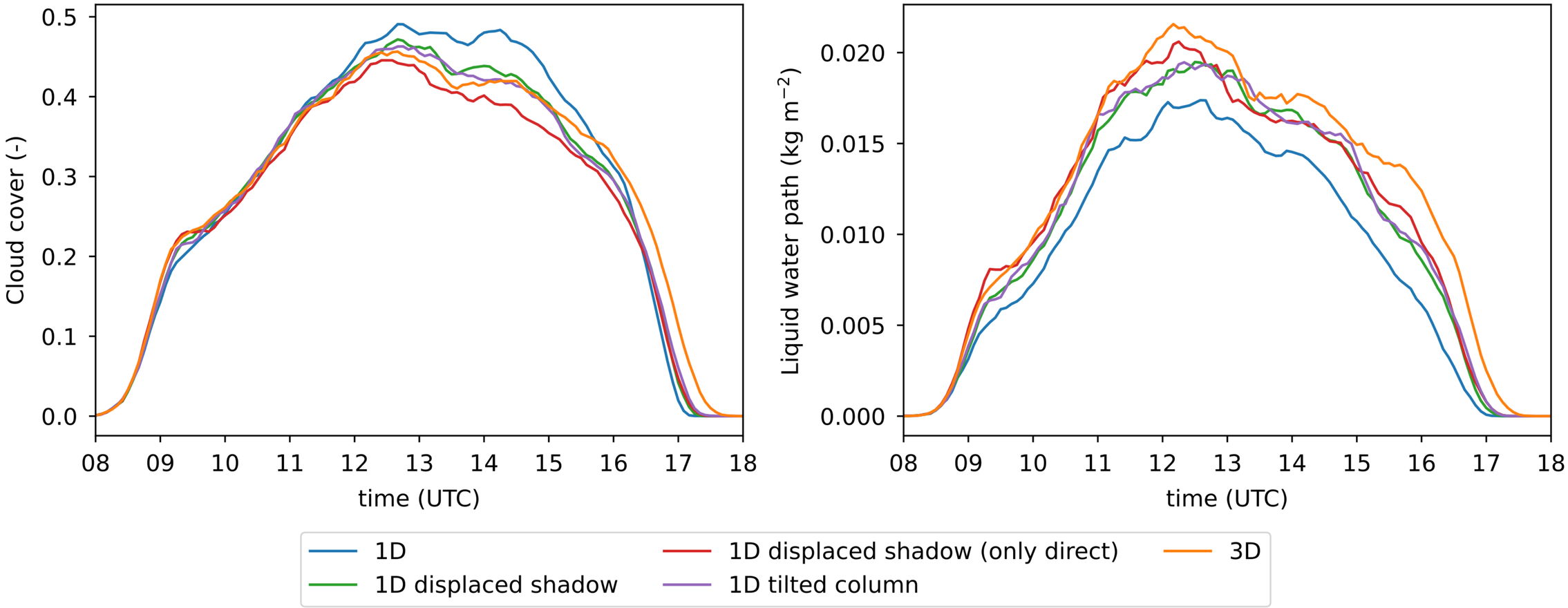
Dashed lines represent horizontally averaged surface fluxes

Which aspect of 3D radiation matters most?



Shadow displacement is the most important change from 1D to 3D





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

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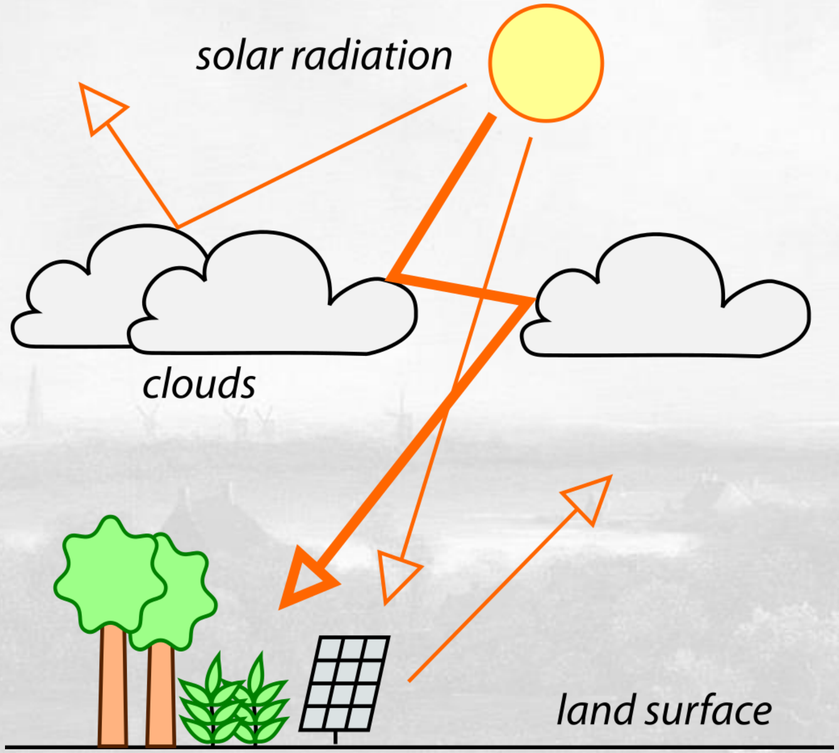
Chiel van Heerwaarden (chiel.vanheerwaarden@wur.nl)

Conclusions

- New instrument measure cloud shadows and enhancement patterns
- 3D simulations with online ray tracing reproduce field observations
- Coupled 3D radiation leads to larger and wetter clouds
- Cloud-induced spatial surface flux patterns modify boundary layer
- Shadow displacement is most important 3D effect
- All data, software, and instruments publicly available (see website)



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