Mechanisms of surface solar irradiance variability under broken clouds

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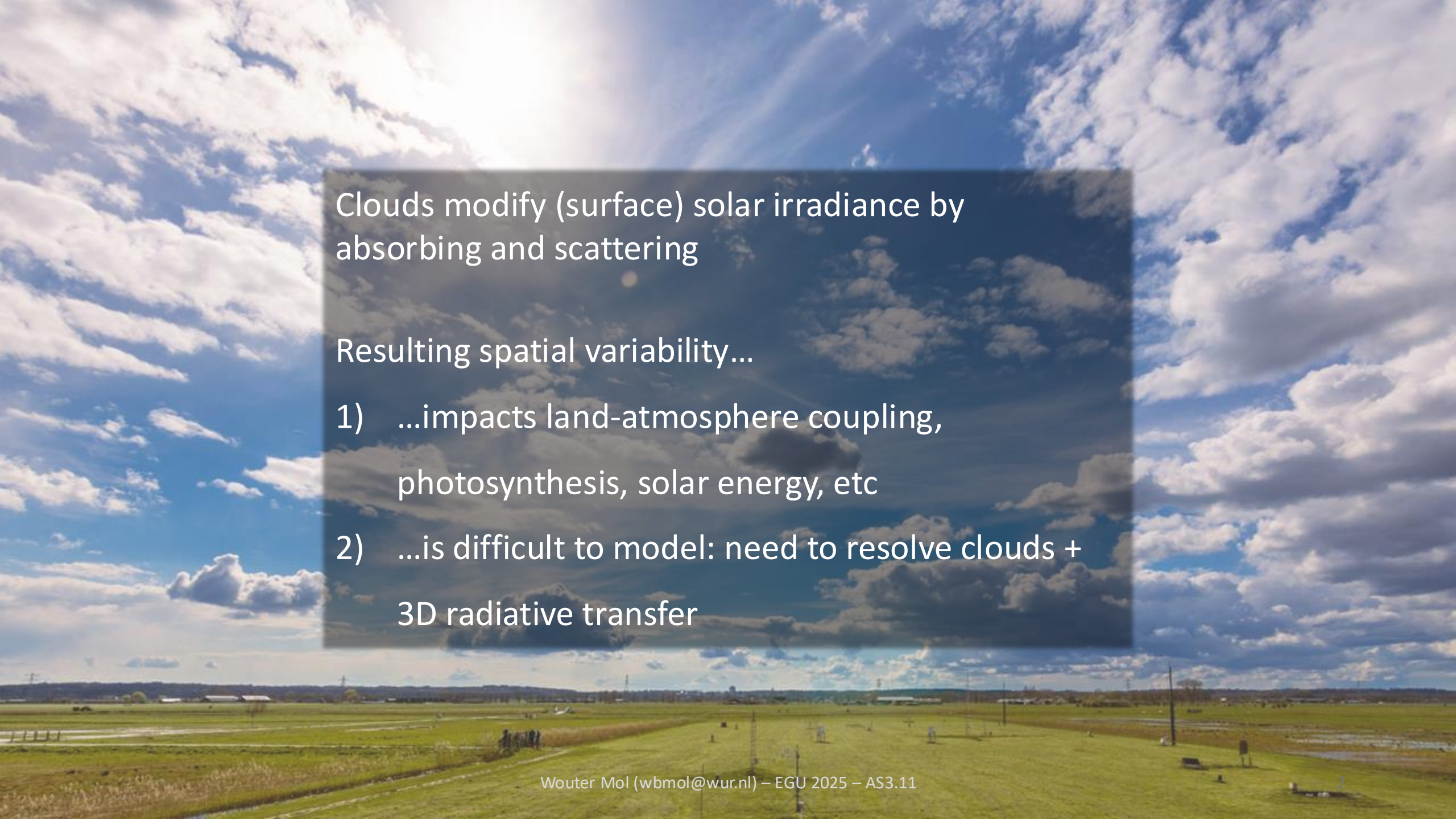
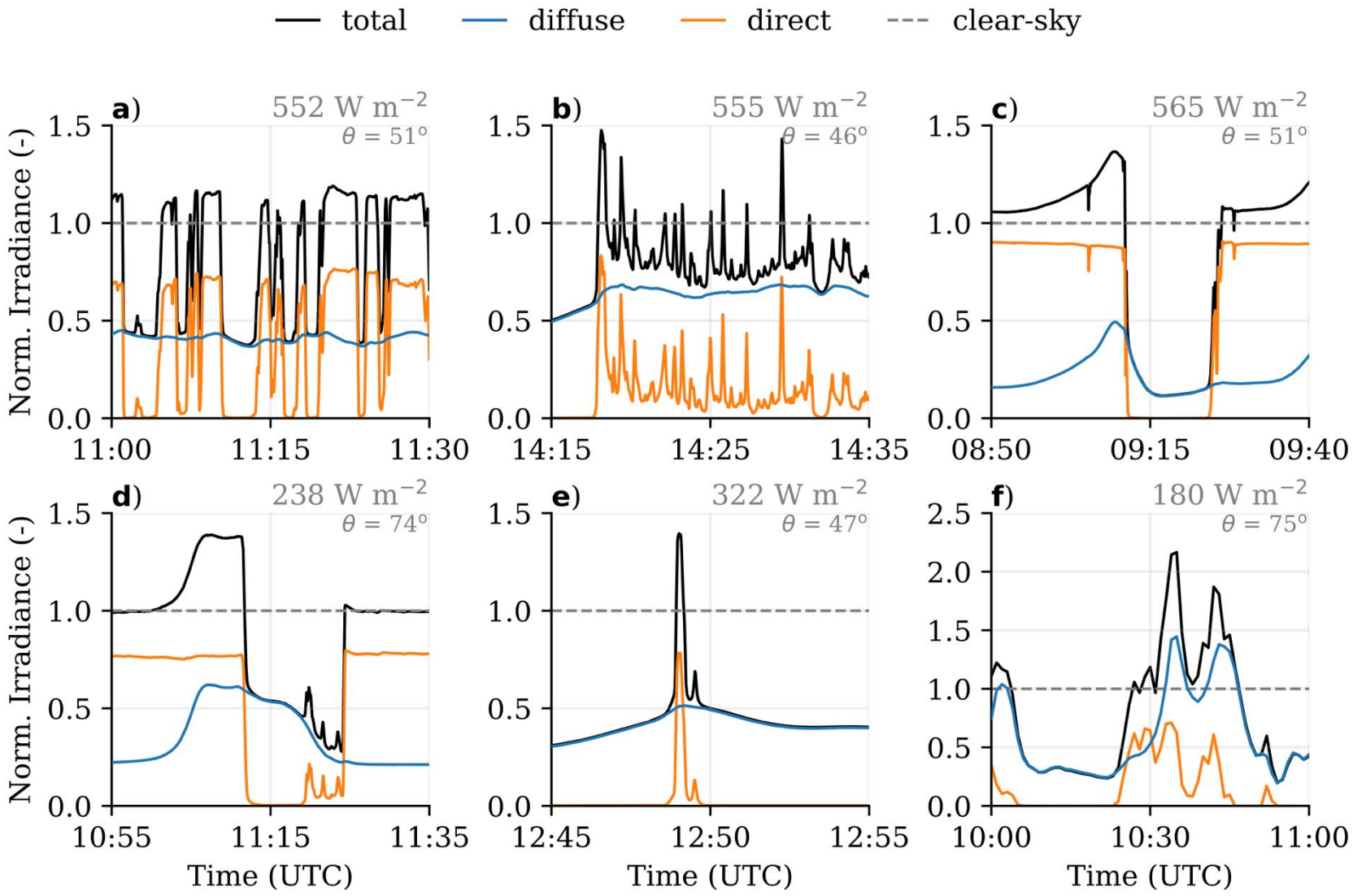


Clouds modify (surface) solar irradiance by absorbing and scattering

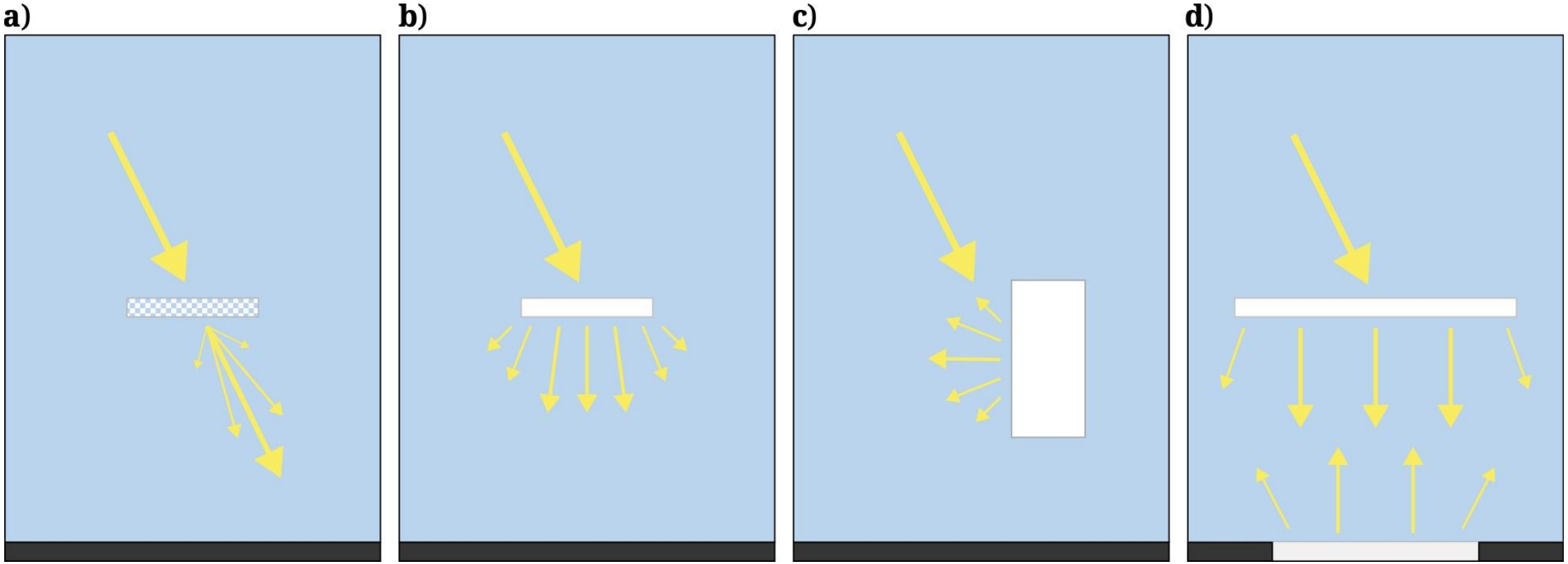
Resulting spatial variability…

1) …impacts land-atmosphere coupling, photosynthesis, solar energy, etc
2) …is difficult to model: need to resolve clouds + 3D radiative transfer

Surface solar irradiance under various cloudy skies



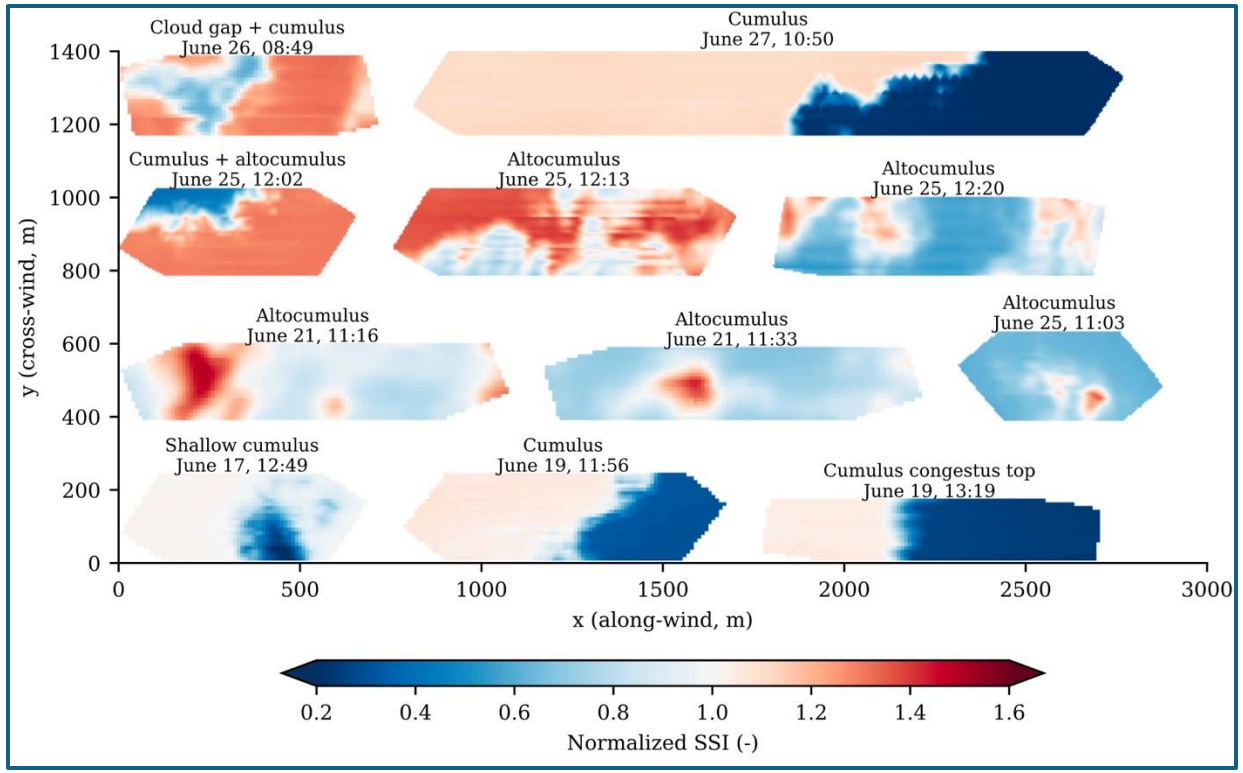
Goal:
capture the essence with only a few mechanisms



Methodology

Observations:

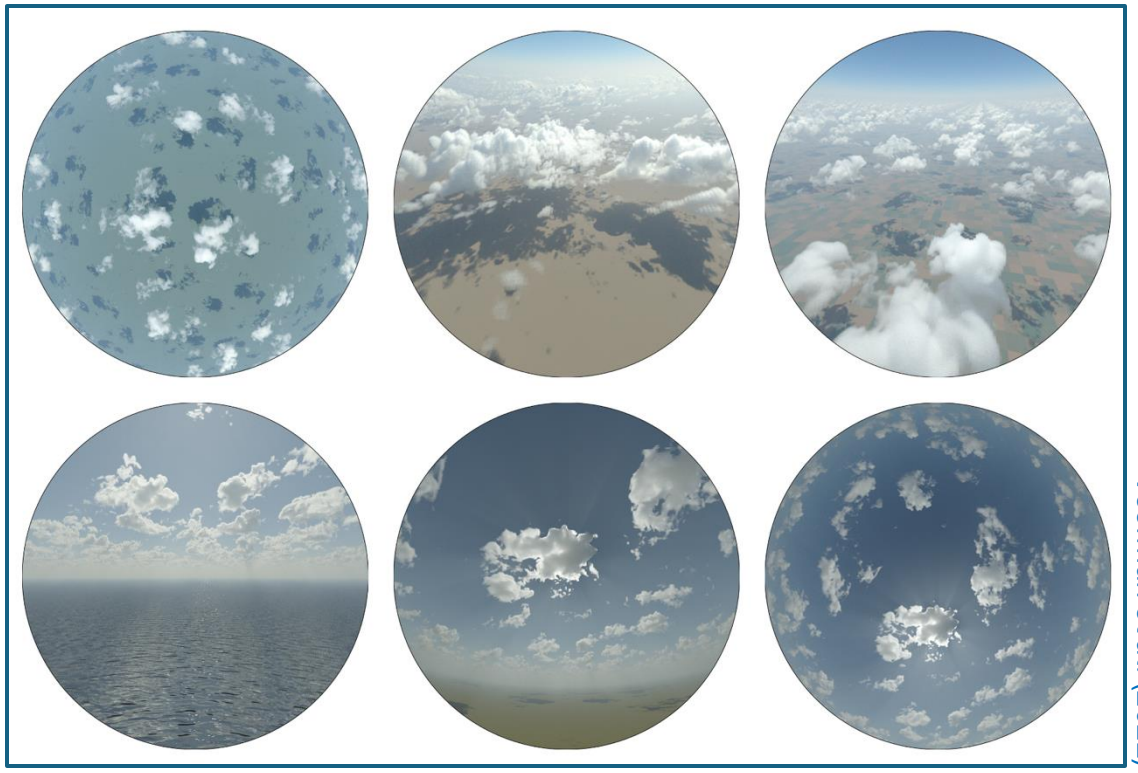
Small-scale spatial sensor network and long-term detailed time series



Mol et al. (2024)

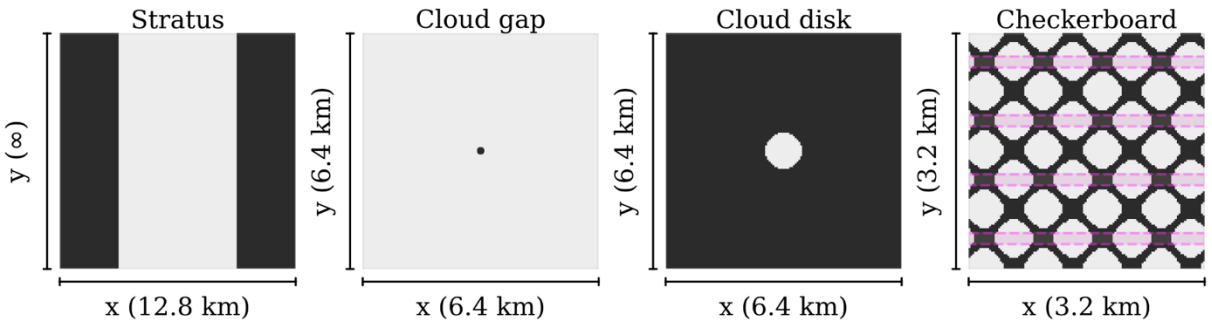
Simulations:

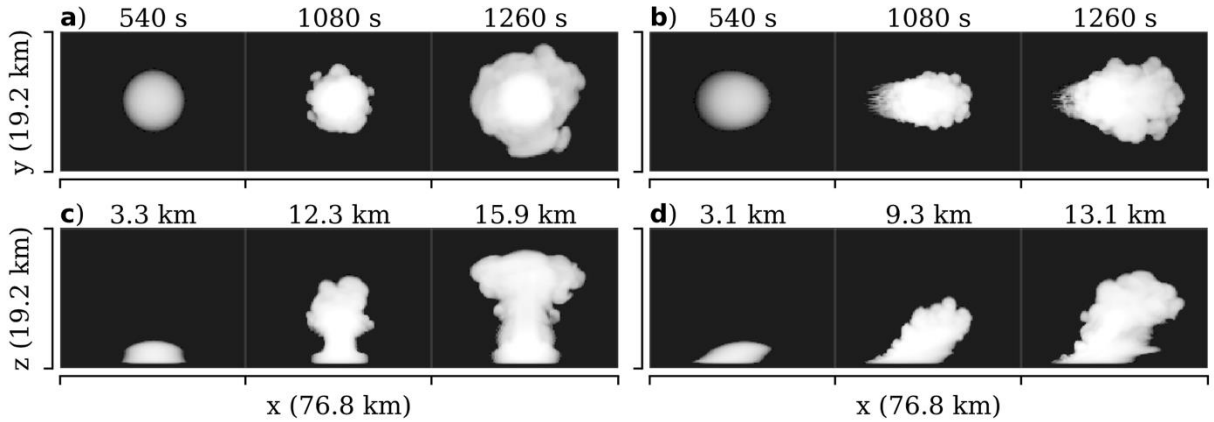
Cloud-resolving large-eddy simulation and 3D Monte Carlo ray tracing

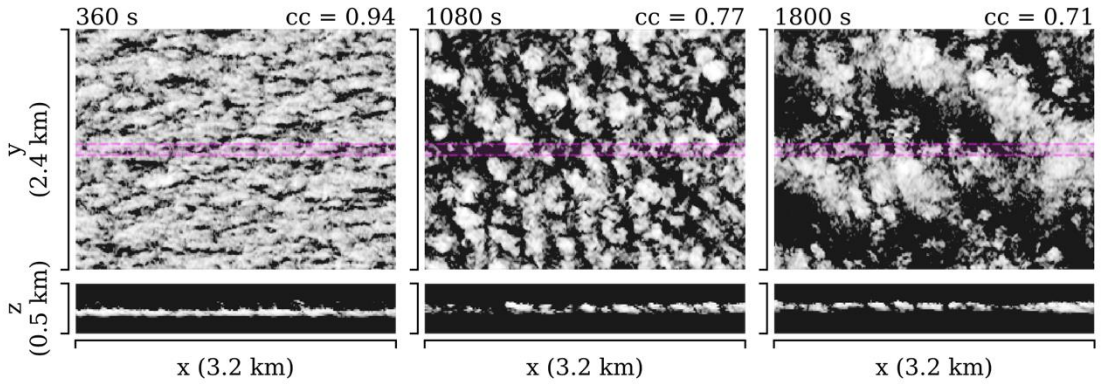


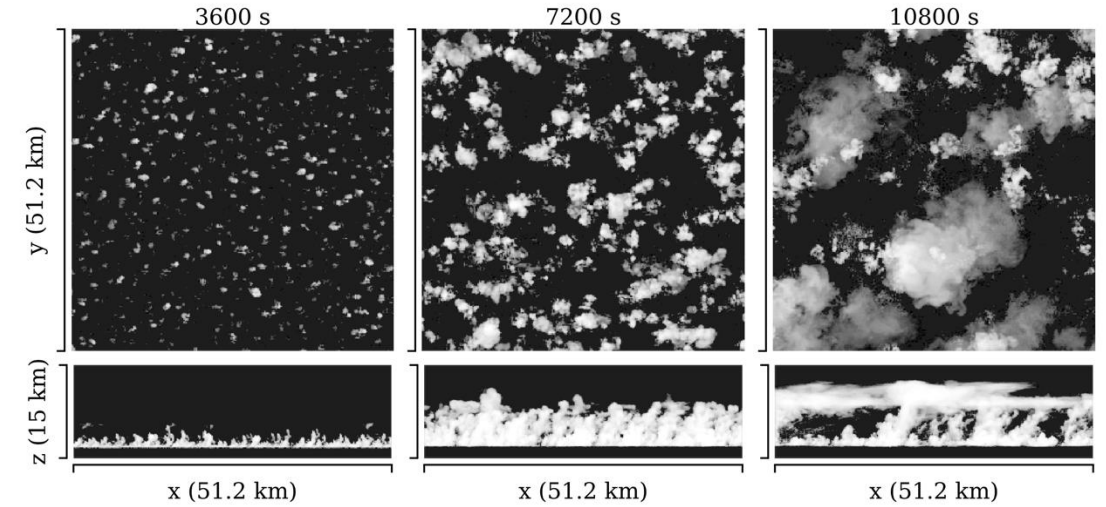
Veerman et al. (2022)

Simulated cloud fields: from simple to complex



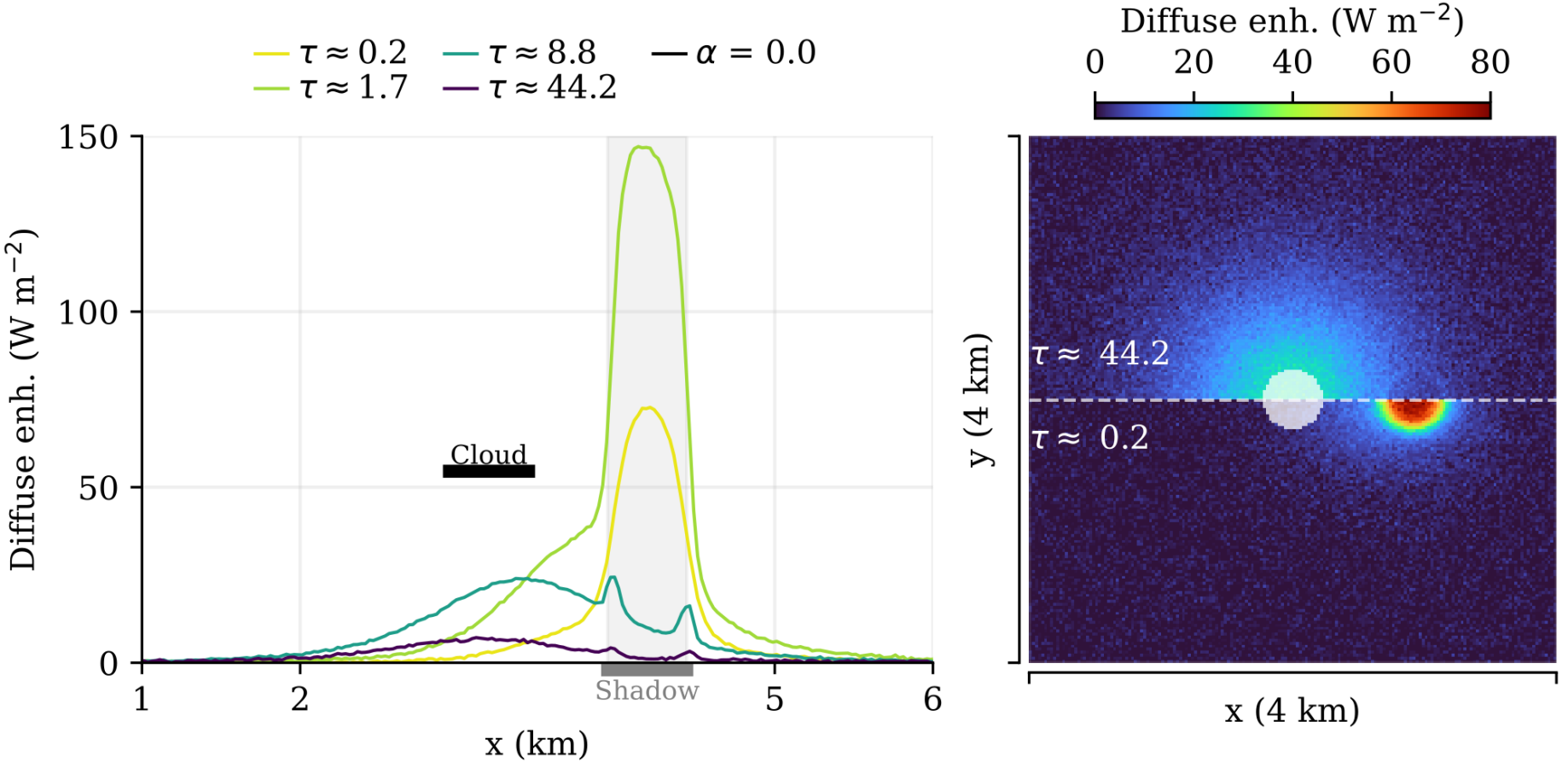




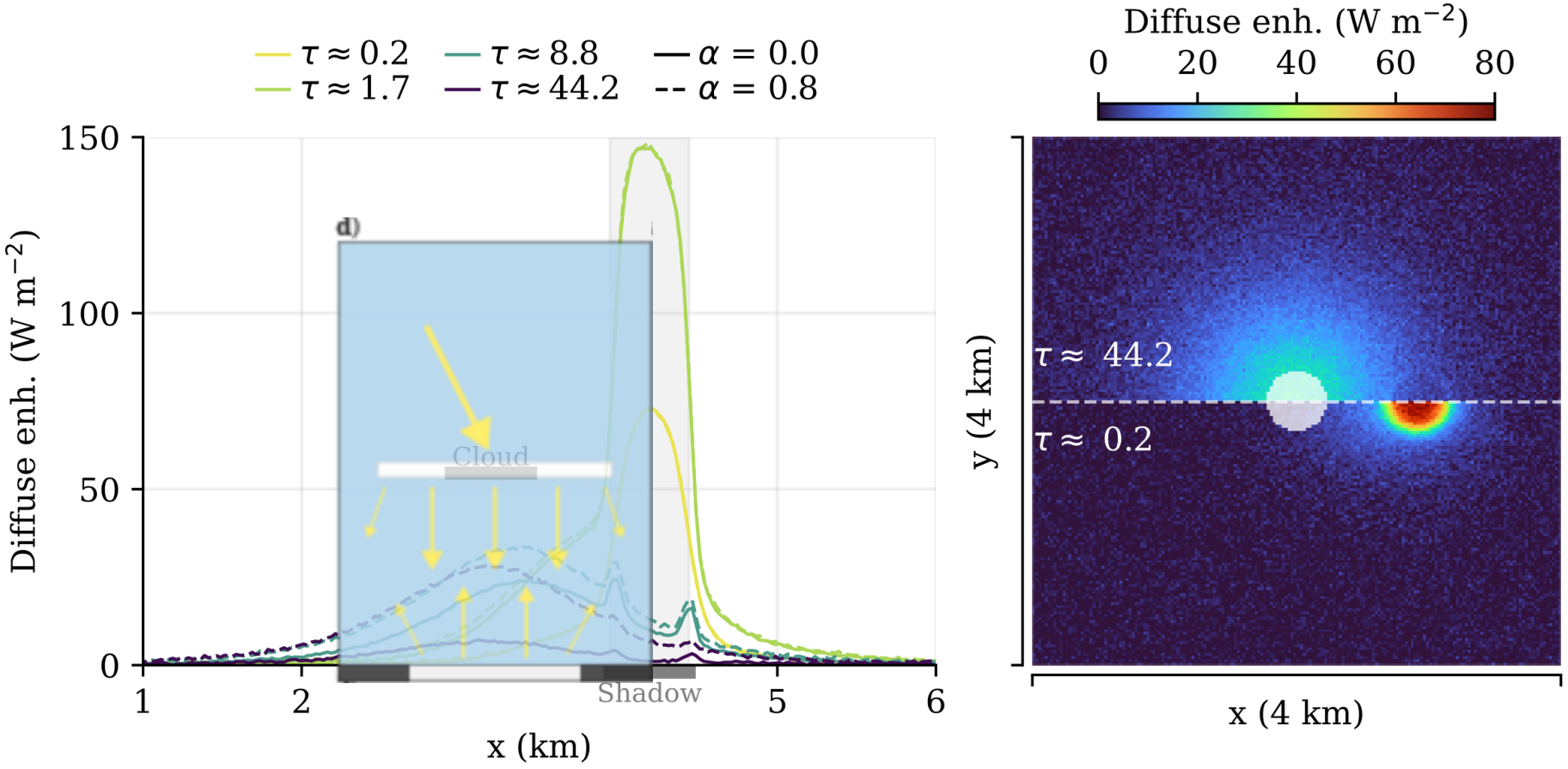


Forward vs *downward escape*

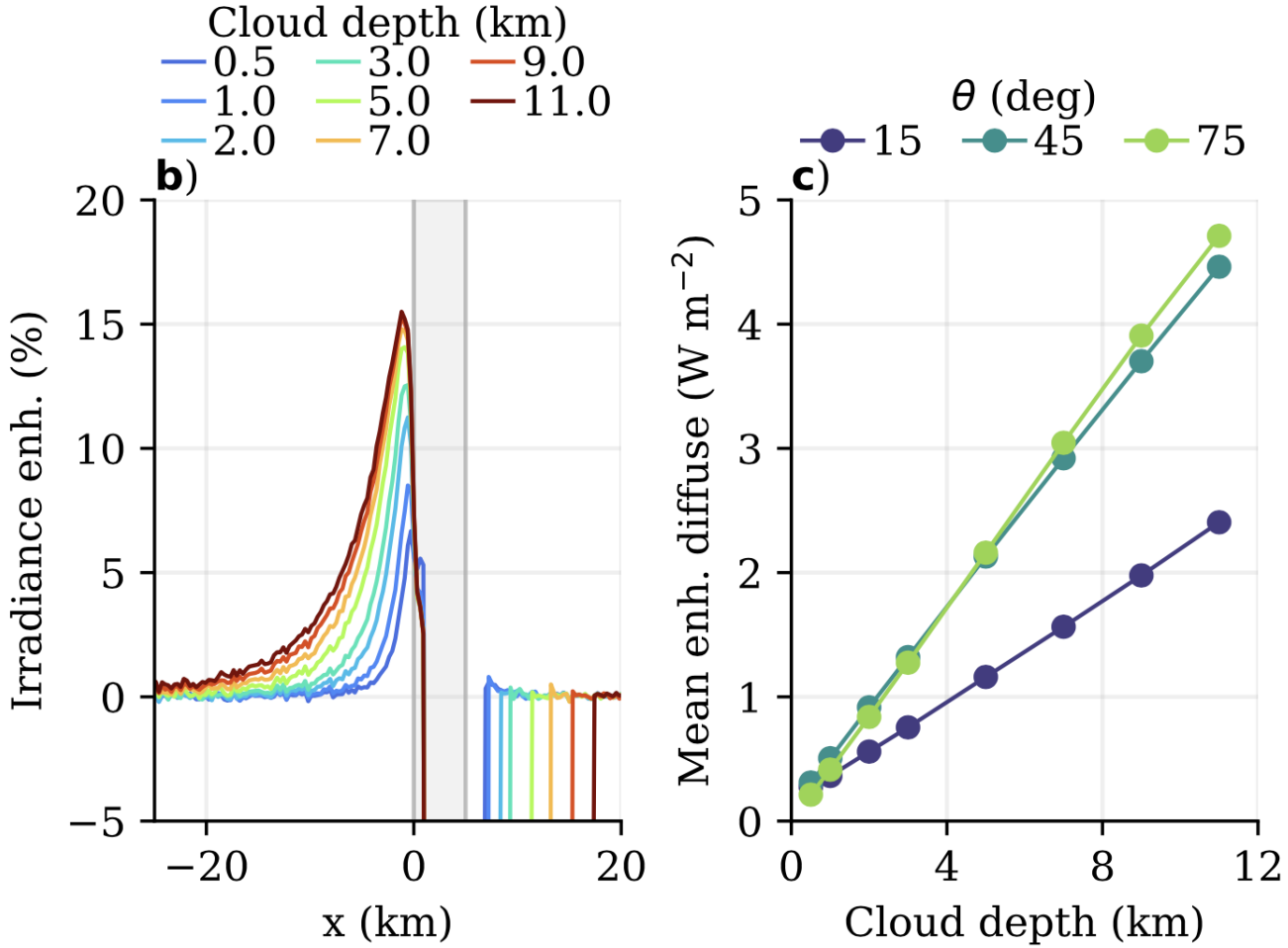
Transition at $\tau \backsimeq 5$ to 6

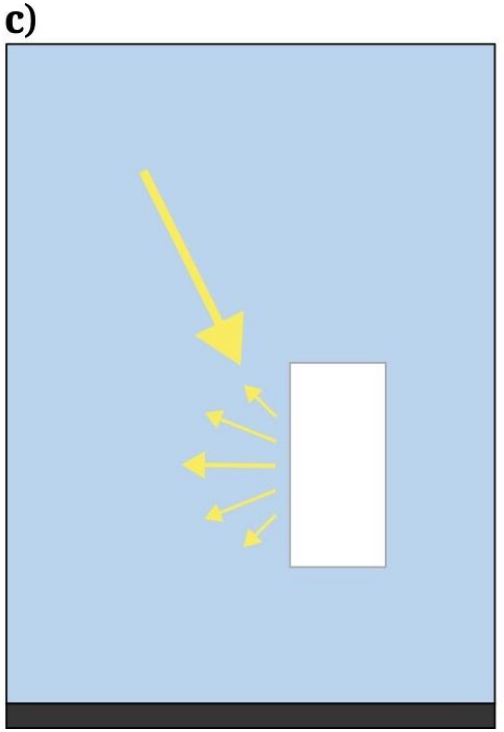


Surface albedo enhances the effect of *downward escape*

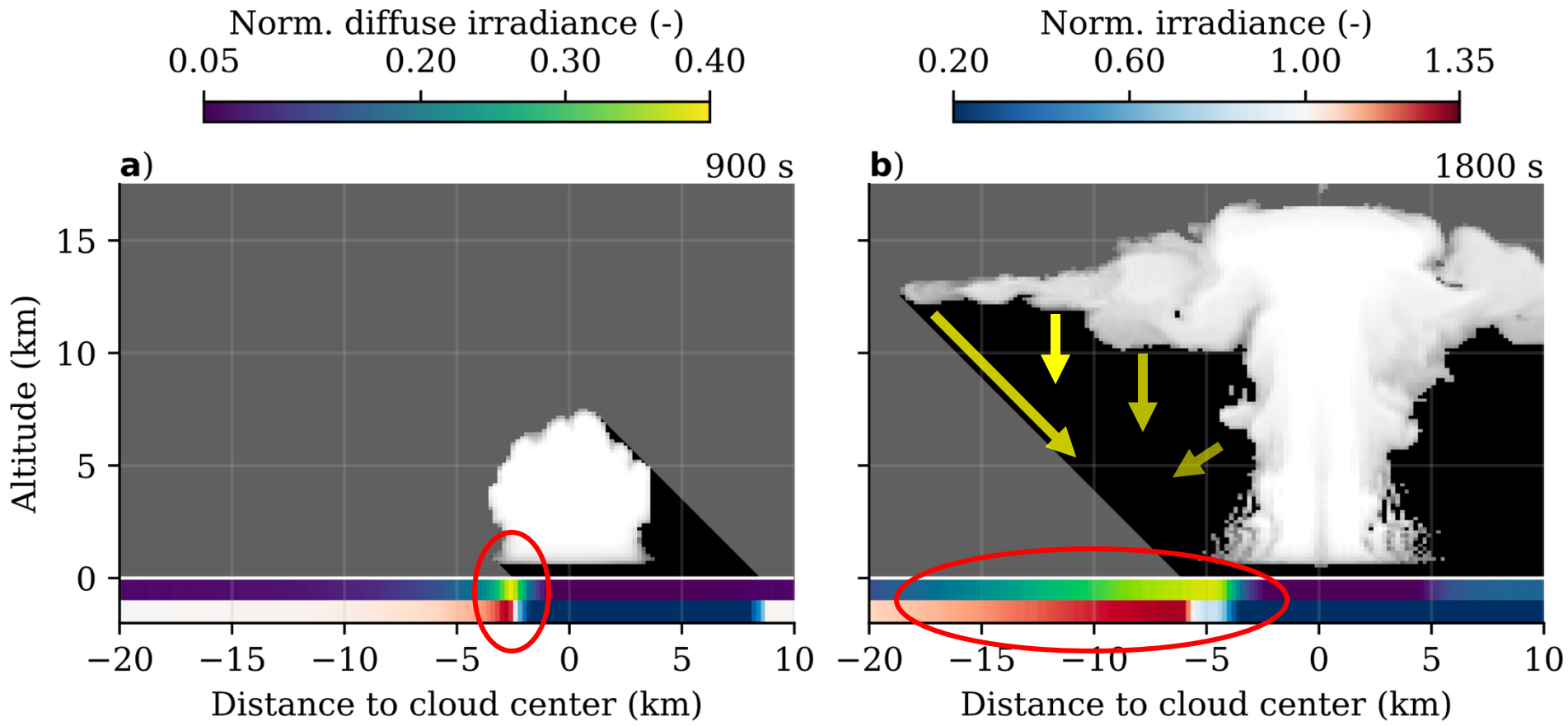


Side escape enhances SSI at the sunlit side of clouds
(not a cloud reflection!)





Combination of mechanisms as cloud geometry increases in complexity

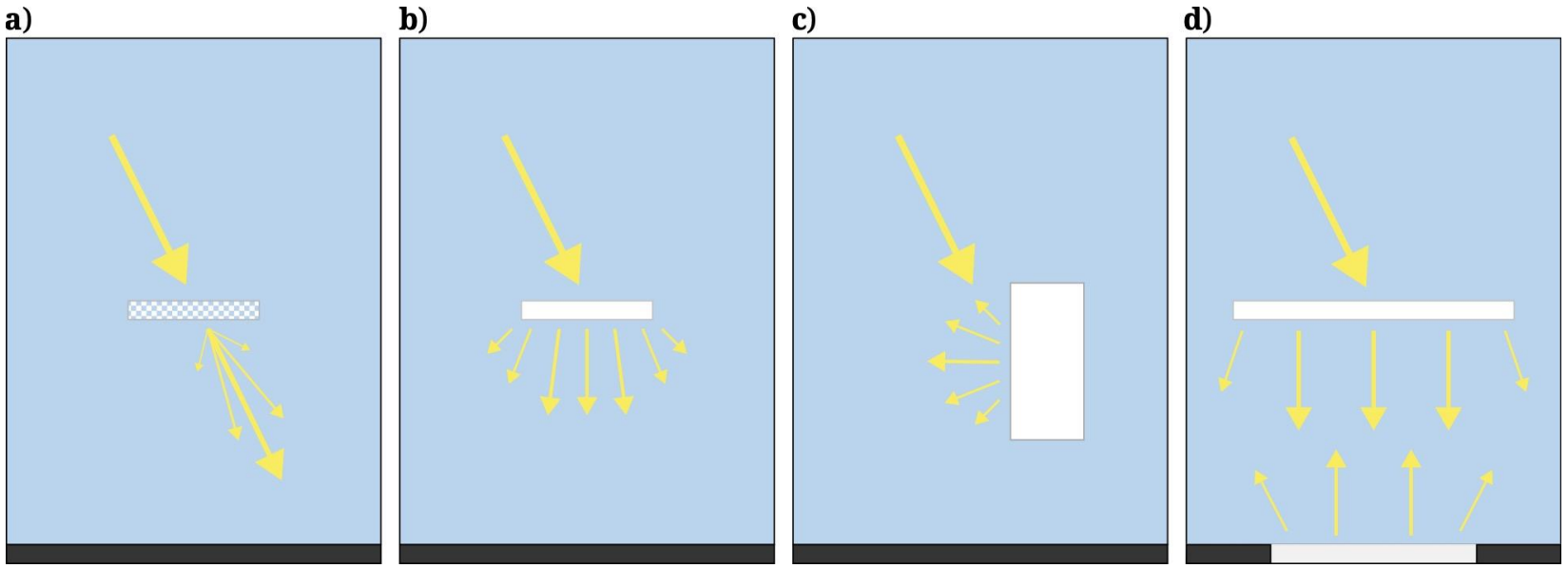


Summary

"Mechanisms of surface solar irradiance variability under broken clouds"
https://acp.copernicus.org/articles/25/4419/2025/

Four key mechanisms explain observed patterns of surface solar irradiance:

Forward escape | Downward escape | Side escape | Albedo enhancement



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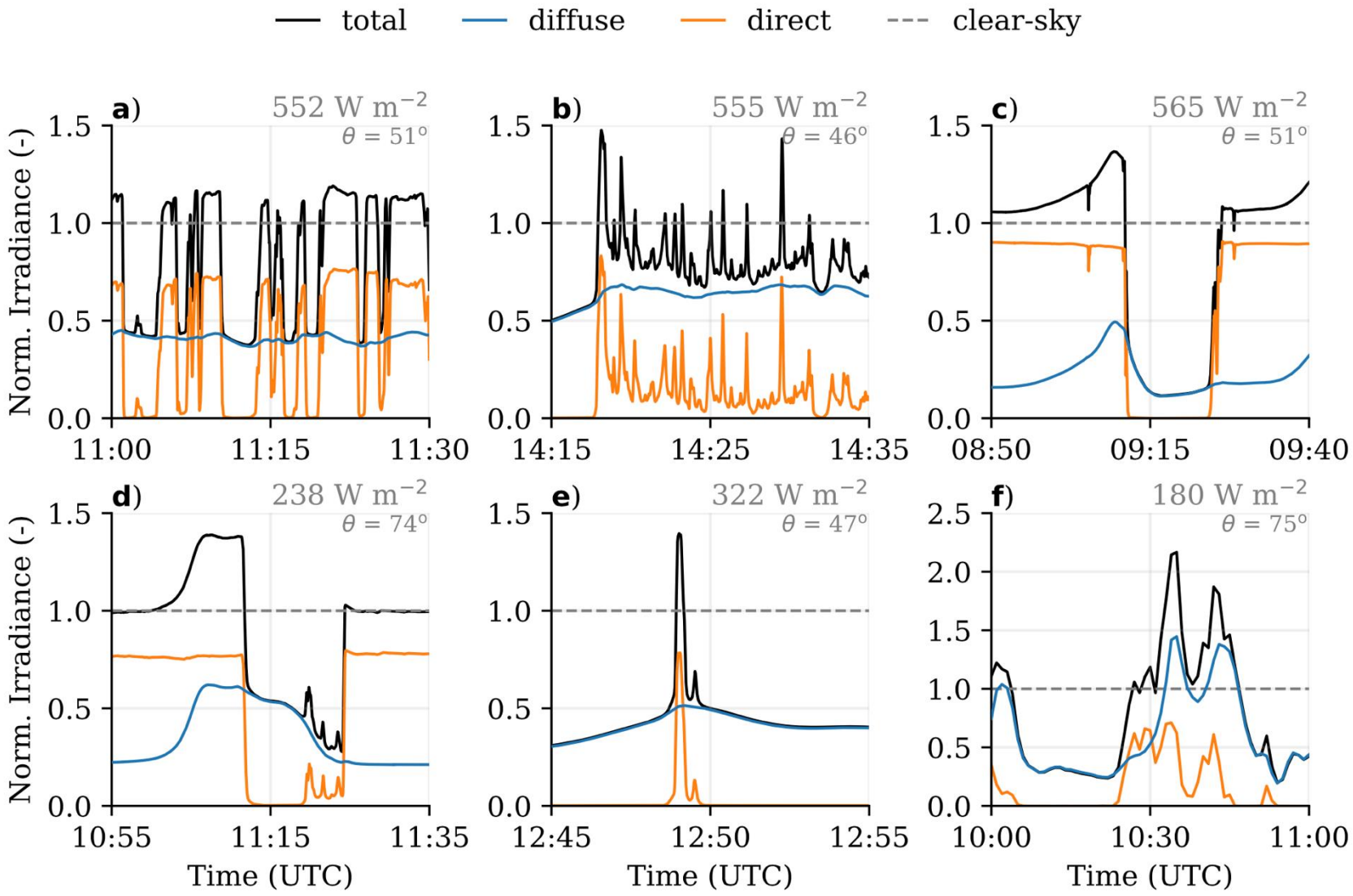
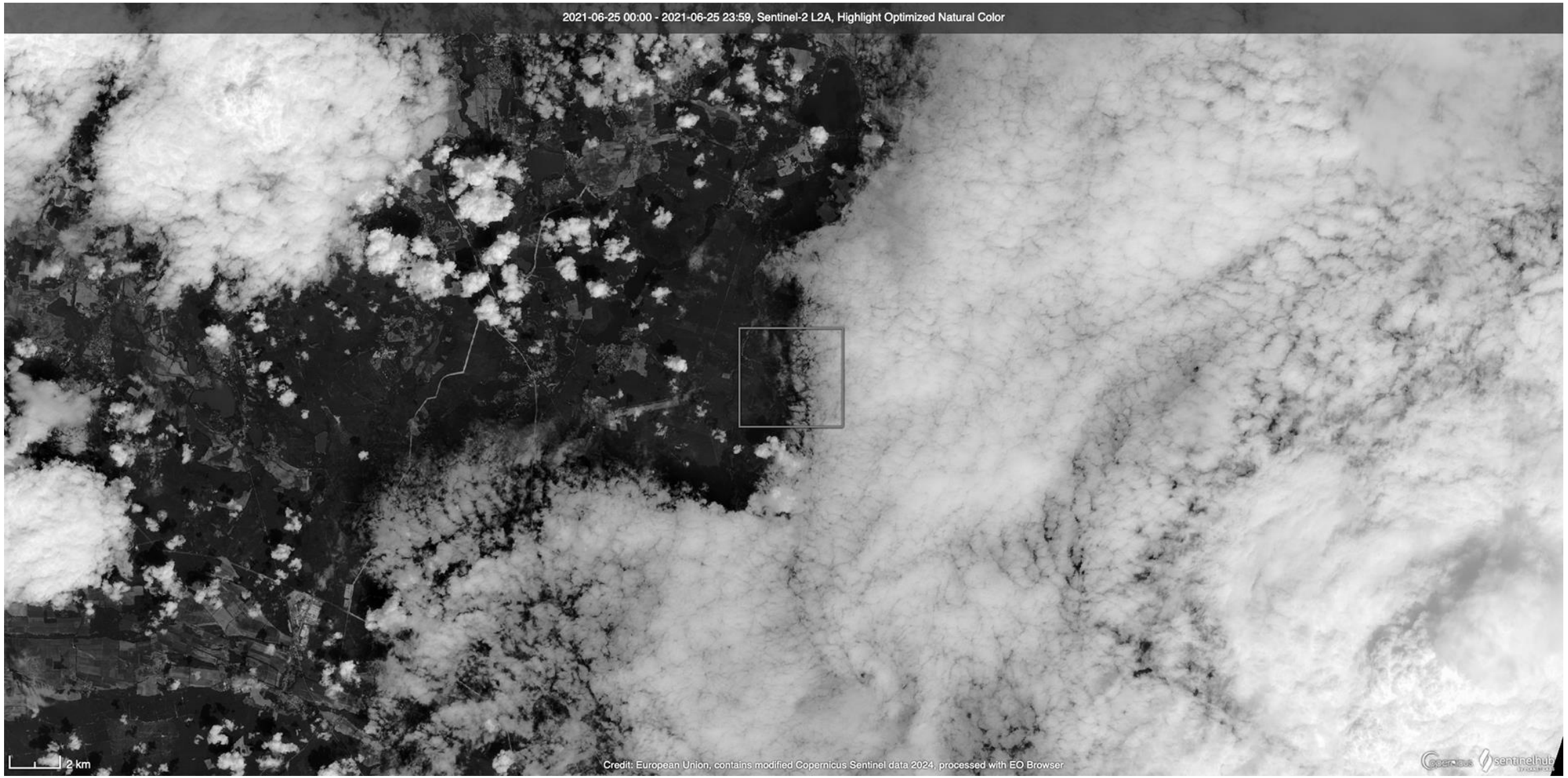
Surface solar irradiance under various cloudy skies




2021-06-25 00:00 - 2021-06-25 23:59, Sentinel-2 L2A, Highlight Optimized Natural Color
2 km
Credit: European Union, contains modified Copernicus Sentinel data 2024, processed with EO Browser