# Three Dimensional Radiative Transfer Effects in Numerical Weather Prediction and Large Eddy Simulations – Methods and Impact on Cloud Evolution and Precipitation

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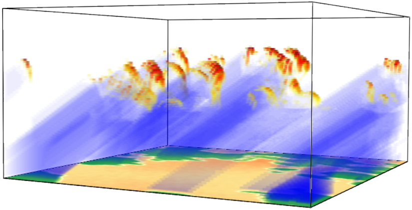
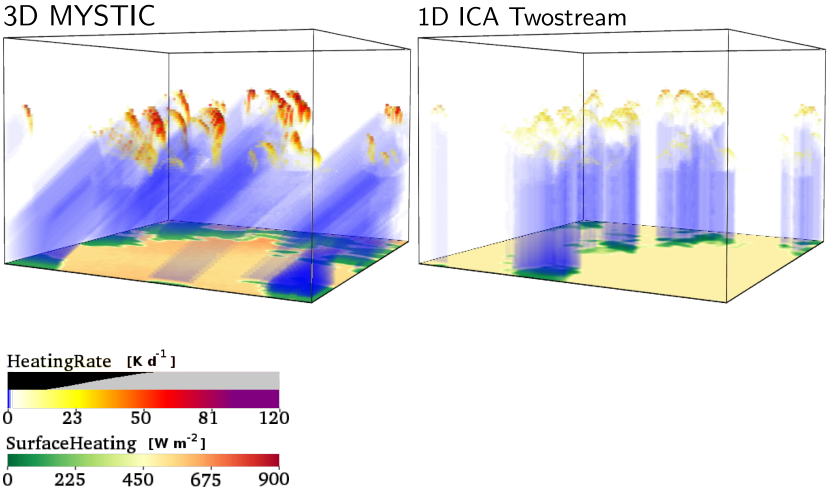


# Comparison to MYSTIC

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Computations done with libRadtran (Library for Radiative Transfer, libradtran.org)

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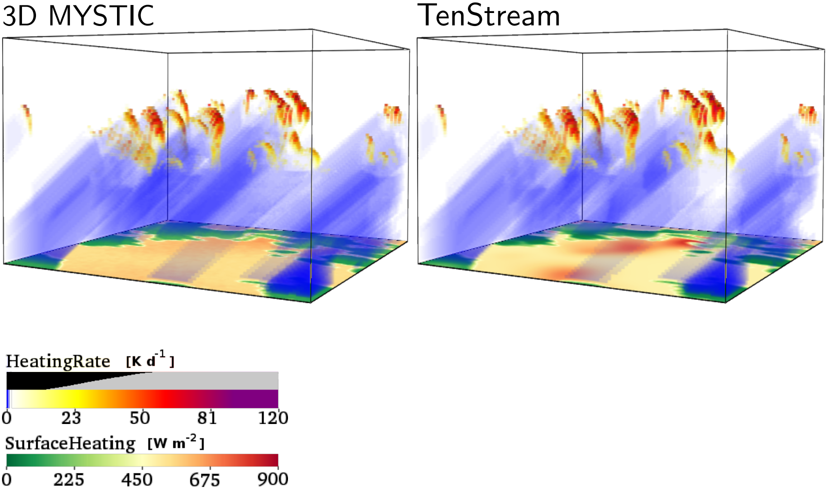


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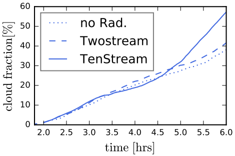
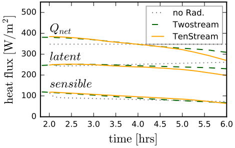
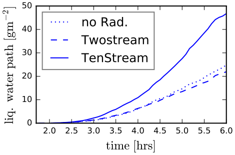
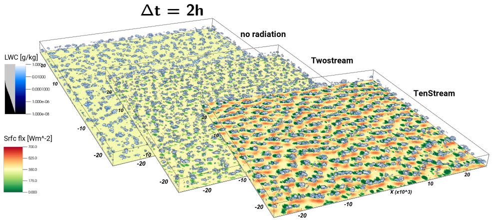


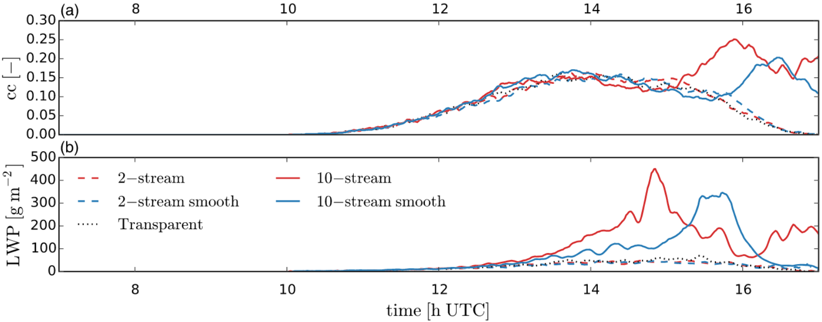




**wind** $\mathbf{u} = \mathbf{0}\,\mathbf{m/s}$, **sza**$\theta = \mathbf{60}^\circ$

- 3D radiation produces larger, higher and thicker clouds
- const. influx of moist air increases cloud lifetime (2x)
- more efficient moisture flux into the cloud layer

Jakub, F. and Mayer, B. (2017) The role of 1-D and 3-D radiative heating in the organization of shallow cumulus convection and the formation of cloud streets (ACP) https://doi.org/10.5194/acp-17-13317-2017

# Shallow cumulus during a diurnal cycle




## Internship of Menno Veerman

- DALES shallow convection simulations with a diurnal cycle
- **organization** with secondary circulations vs. popcorn convection
- Interactions between **radiation**, **clouds** and the **surface** lead to considerable changes in cloud size distribution and updraft efficiency

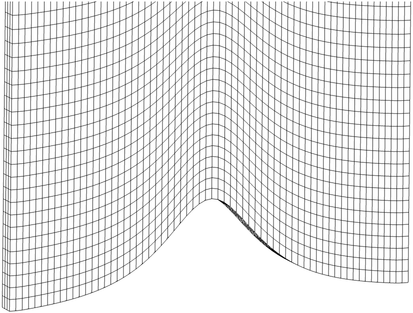
Veerman, M. A. et al (2020). Three-dimensional radiative effects by shallow cumulus clouds on dynamic heterogeneities over a vegetated surface. (JAMES) https://doi.org/10.1029/2019MS001990

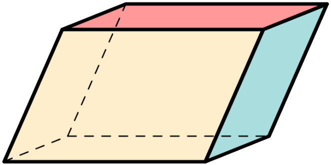
# WRF LES with mountains

stationary cumulus above Stellihorn (Wallis) (CC wikipedia)

# WRF LES with mountains

Orography realized with ground following $\sigma$-coordinates:

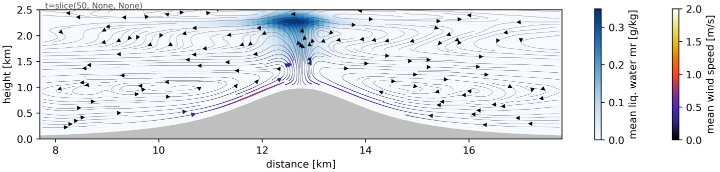




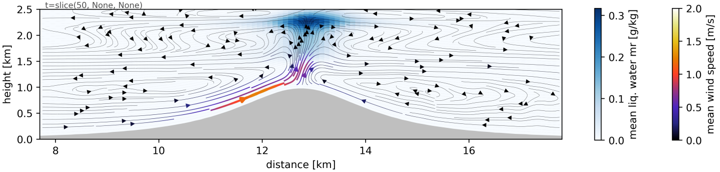
**Masterthesis of H. Böttcher**

- solve propagation of radiation through distorted meshes, by projecting “outgoing“ faces onto “incoming“ faces along sundirection and integrating lambert-beer extinction through partial volumes
- approximation: parallelepiped – opposite faces are parallel

# WRF LES with mountains




**1D**

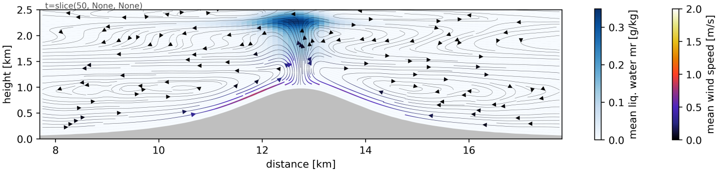



**1D**

slope

corrected

# WRF LES with mountains

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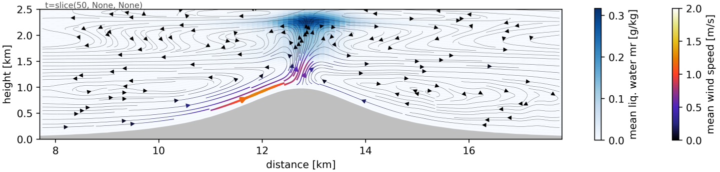
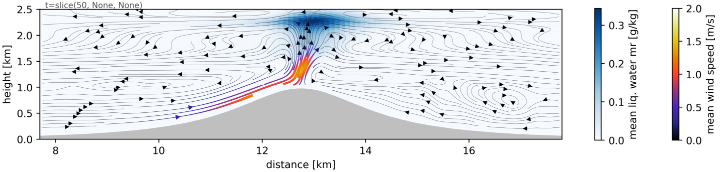
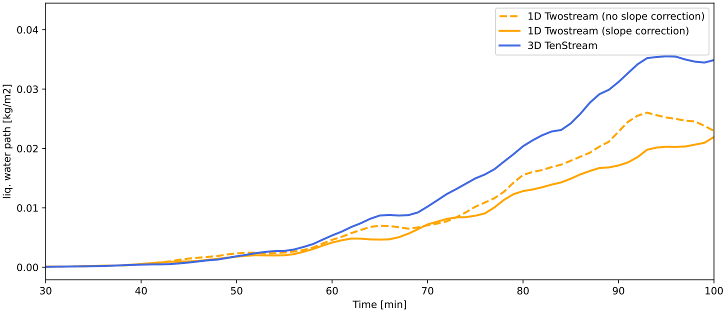



**1D**
slope
corrected




**3D**
TenStream

# WRF LES with mountains

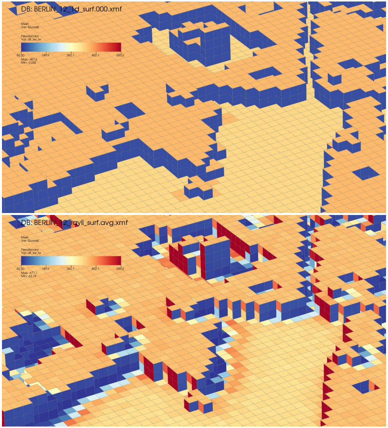



continued illumination of mountain top leads to

- stronger updrafts
- enhanced cloud development
- earlier onset of rain

# Palm-LES within urban canopies

Net surface irradiance (sw + lw)




**1D Twostream** neglects:

- illumination and emission of walls
- blocking of radiation from the sun
- scattering between surfaces
- RMSE **65.4%** bias -**7.62%**

**MonteCarlo**

- raytracing as benchmark
- full interaction in short- and longwave

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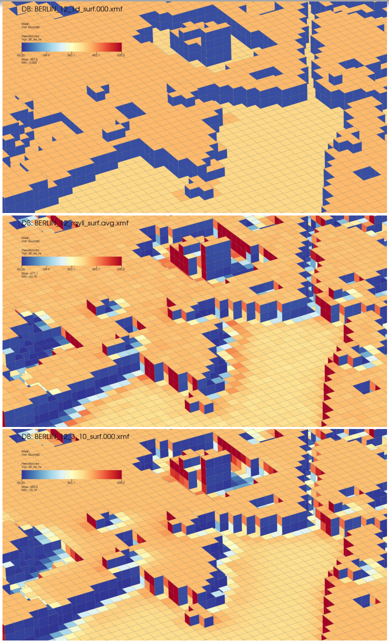


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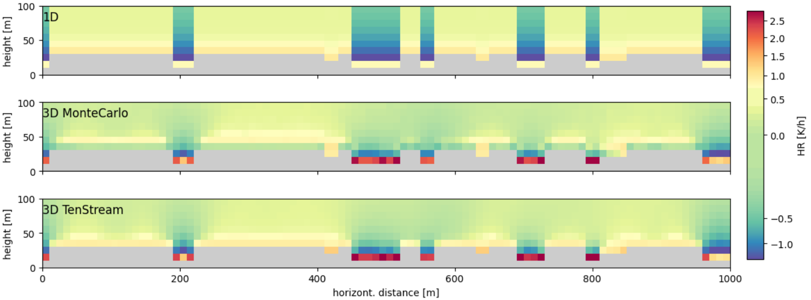
**TenStream**

- numerical diffusion leads to smoothing of shadows
- all details of radiance field not captured with 10 streams
- RMSE **5.8%** bias -**0.62%**

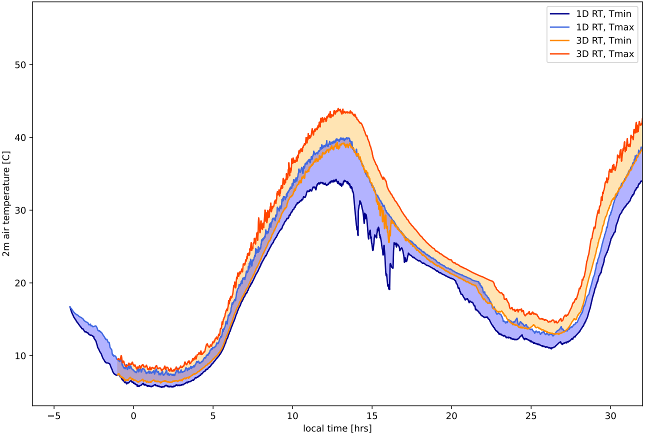
# Palm-LES within urban canopies




## Net atmospheric heating rates (sw+lw)

- heating and cooling rates particularly different in narrow canyons
- **1D Twostream** RMSE **576%** bias **114%**
- **3D TenStream** RMSE **129%** bias **13%**

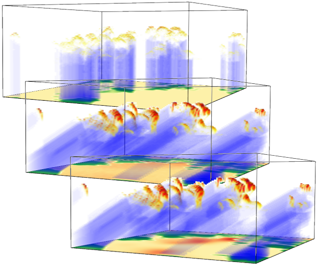
# Palm-LES within urban canopies

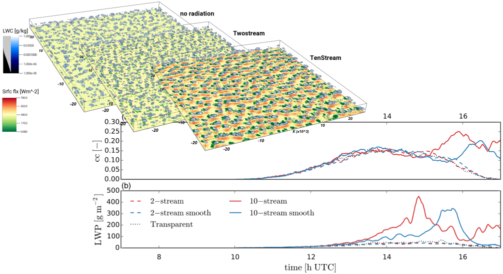


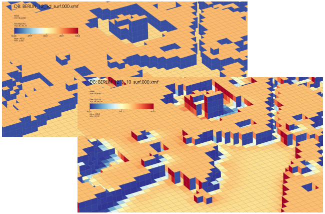

## Diurnal cycle

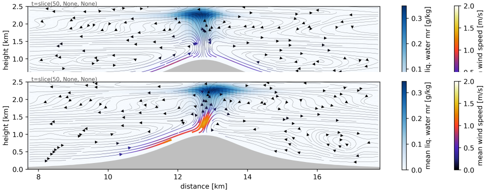
- 3D radiative transfer leads to 2m temperature increase by 5°C
- *preliminary results

# Thank you!









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