The Role of 1D and 3D Radiative Transfer on the Formation of Cloud Streets

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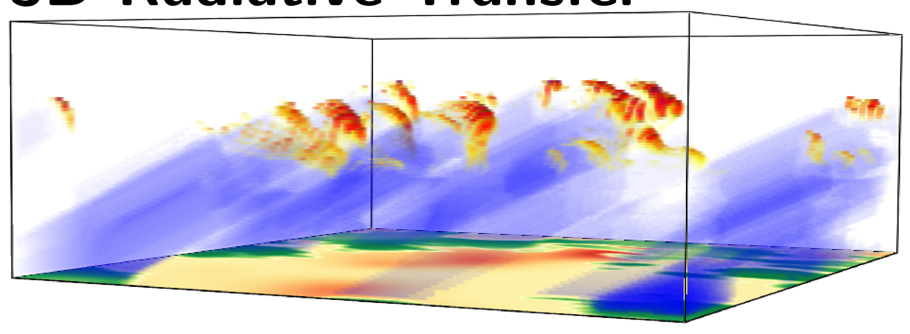
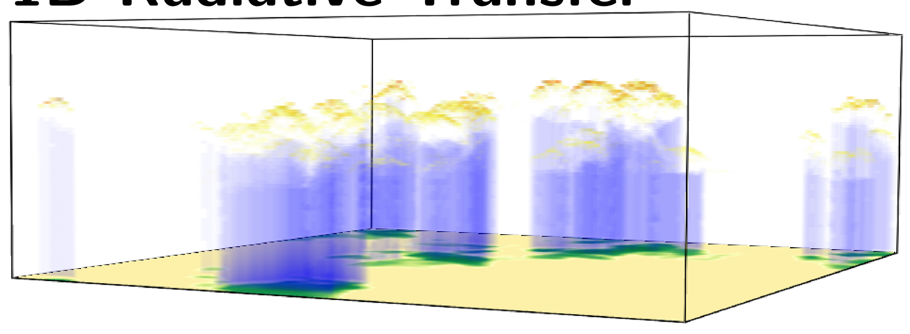
1. Convective Organization Depending on Radiative Transfer Solver

3D Radiative Transfer



- TenStream solver[2;3]
- cloud-side illumination
- displaced surface shadow

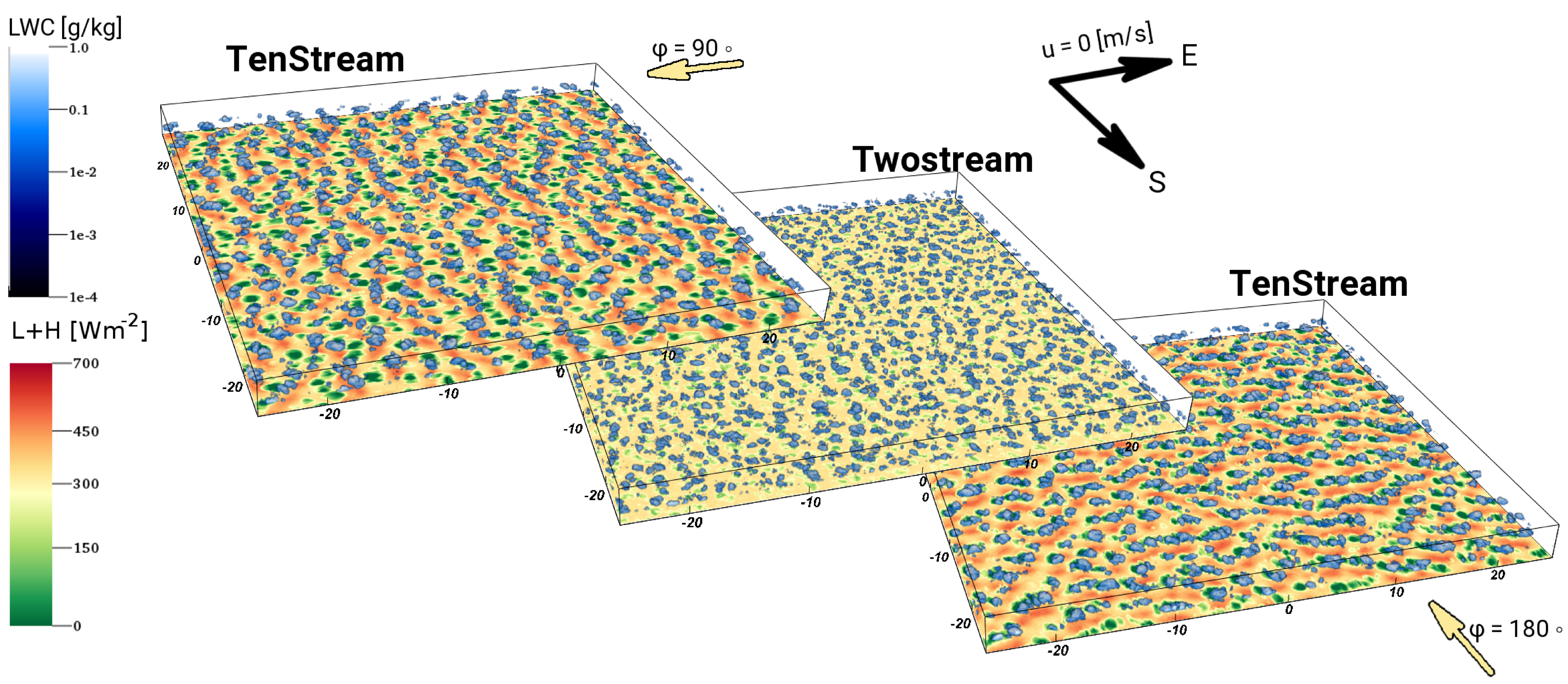
1D Radiative Transfer



- δ-eddington two-stream solver
- independent column approx.(ICA)
- shadow directly beneath cloud

Virtual photographs of UCLA-LES simulations, as seen from a cruising altitude of 15 km. The simulations either use 3D or 1D Radiative-Transfer calculations and show differences with respect to cloud size distribution and the organization in cloud streets, the cloud fraction though remains the same (27 %).
Both visualizations are performed with MYSTIC (physically correct MonteCarlo renderer in libRadtran[4;5]).

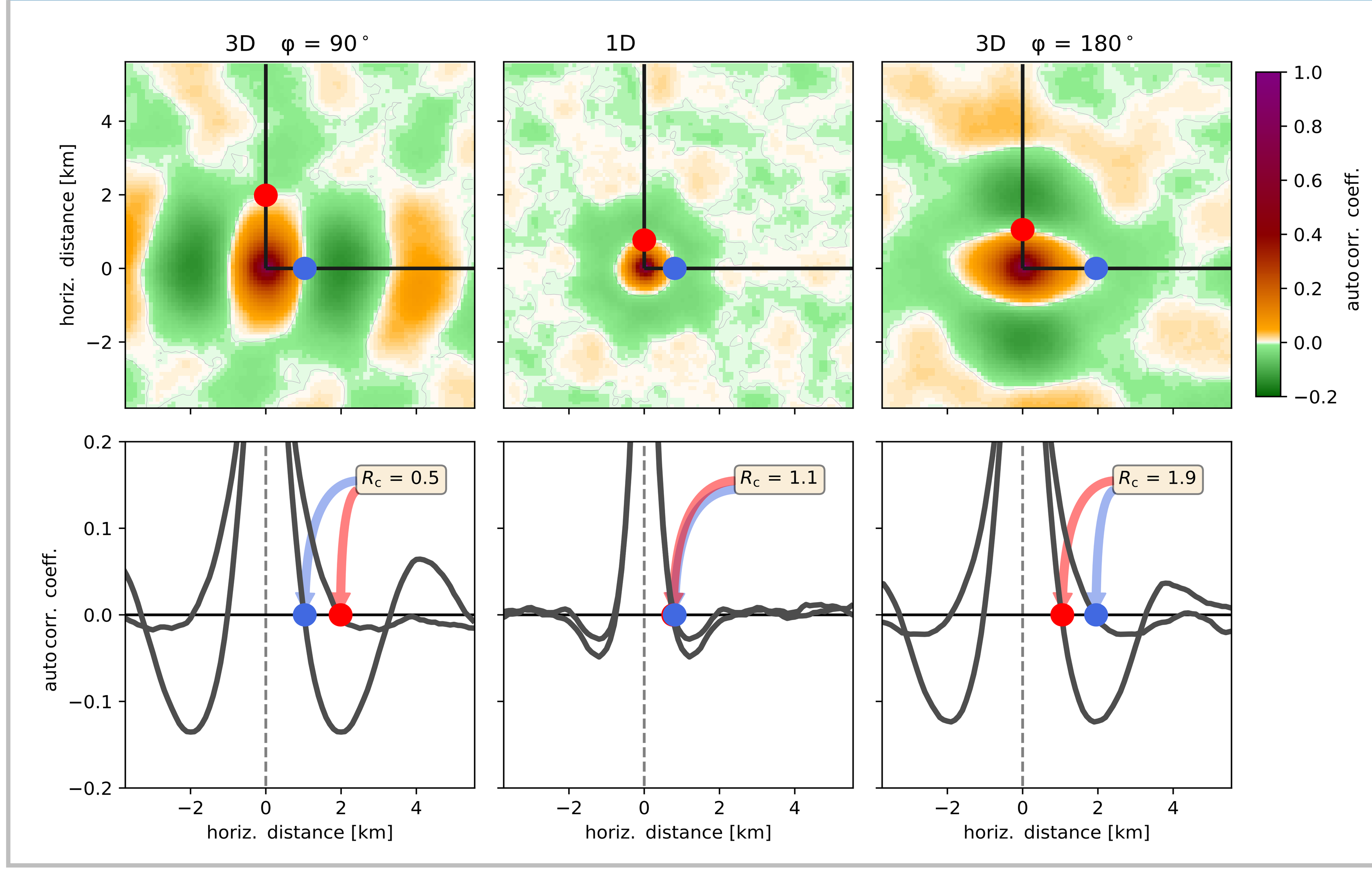
2. Orientation of Cloud Streets Depends on Solar Azimuth φ



Volume rendered perspective on LiquidWaterContent (LWC) and latent and sensible heat flux (L,H).
Cloud-Streets form perpendicular to the sun's incident angle.

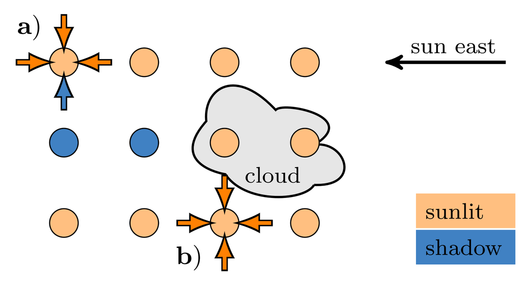
- solar zenith $\theta = 60°$
- solar azimuth $\varphi = 90°$ (East); $180°$ (South)
- horizontal wind $u = 0\,\mathrm{m\,s^{-1}}$
- surface: $C_{\mathrm{skin}} = 1$ cm water column

3. A Quantitative Measure for Streakiness



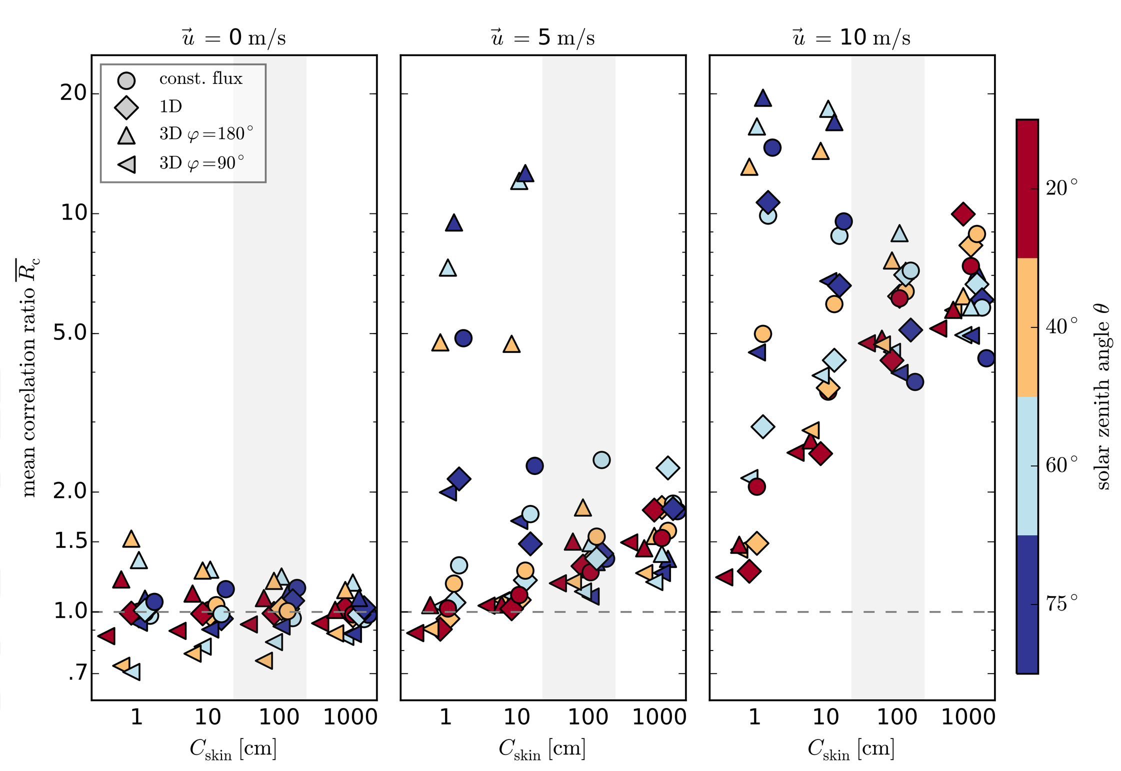
- Use 2D-AutoCorrelation of Cloud-Mask
- Search for zeroes along North-South and East-West transects
- Ratio of distances measures degree of organization:
  - $R_c < 1$: North-South
  - $R_c \approx 1$: random
  - $R_c > 1$: East-West

4. Hypothesis for Mechanism



A convective plume is fueled by moist and warm air from adjacent pixels and is thus more likely to rise near sun-lit areas (b) compared to areas in the vicinity of shadows (a).
This favors the organization of new clouds perpendicular to the solar incidence angle.

5. Results of Parameter Study



- Purely radiatively forced simulations (no wind) show to organize clouds perpendicular to the solar incident
- Simulations with sun in zenith (quasi 1D) clouds don't organize
- Ocean-like surfaces diminish radiative influence
- Wind induced cloud streets may be enhanced or suppressed through radiative feedback (dynamic surface heterogeneities)

References

[1] Jakub, Fabian, and Bernhard Mayer. "The Role of 1D and 3D Radiative Transfer on the Formation of Cloud Streets" (to be submitted).
[2] Jakub, Fabian, and Bernhard Mayer. "3D Radiative Transfer in Large-Eddy Simulations – Experiences coupling the TenStream solver to the UCLA–LES" GMD (2016).
[3] Jakub, Fabian, and Bernhard Mayer. "A Three-Dimensional Parallel Radiative Transfer Model for use in Cloud Resolving Models – the TenStream solver." JQSRT (2015).
[4] C. Emde et. al. "The libRadtran Software Package for Radiative Transfer Calculations" GMD (2015).
[5] Mayer, Bernhard. "Radiative transfer in the cloudy atmosphere." EPJ Vol. 1., 2009.