Shortwave surface radiation budgeting network for spatio-temporal observation of cloud inhomogeneity fields

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HD(CP)² High definition clouds and precipitation for advancing climate prediction

TROPOS Leibniz Institute for Tropospheric Research

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Overview

Clouds and precipitation are formed by complex non-linear processes that are least understood and is arguably the foremost problem to be addressed for improving the climate prediction. The German initiative "**H**igh **D**efinition **C**louds and **P**recipitation for advancing **C**limate **P**rediction" - HD(CP)² conception involve modules focused on modeling, observations and synthesis was a major step towards advancing our understanding on this problem. The observational module (O) is aimed at proving specific data products capturing the spatio-temporal variability of water vapour, temperature, and cloud and precipitation properties. The four sub-modules include: O1 (Supersites), O2 (Full domain), O3 (Integration) and O4 (Prototype Experiment). The project O4 "HD(CP)² Prototype Experiment" (HOPE) was designed to provide critical model evaluation at the scale of model simulation and further provide information on sub-grid scale variability and microphysical properties that are subject to parameterizations even at high resolution simulations. In HOPE measurements, five work packages focused on land-surface exchange processes (WP1), planetary boundary layer studies (WP2), aerosol and cloud microphysics (WP3), cloud morphology (WP4) and radiative closure studies (WP5). The present work is part of WP5 with the following goals:

- To observe the spatio-temporal variability of cloud induced downwelling shortwave fluxes at the surface using ground based autonomous pyranometers (~ 100 nos.) equipped with micro-sensors of relative humidity and air temperature during HOPE campaign.
- Use 3D Monte-Carlo radiative transfer code, MC-UNIK (Macke et al., 1999) to close the radiative flux measurements from other collocated ground based observations or LES model simulations and further quantify the effect of cloud inhomogeneity on cloud radiative forcing (Scheirer and Macke, 2003).

Details of experiment & data quality control

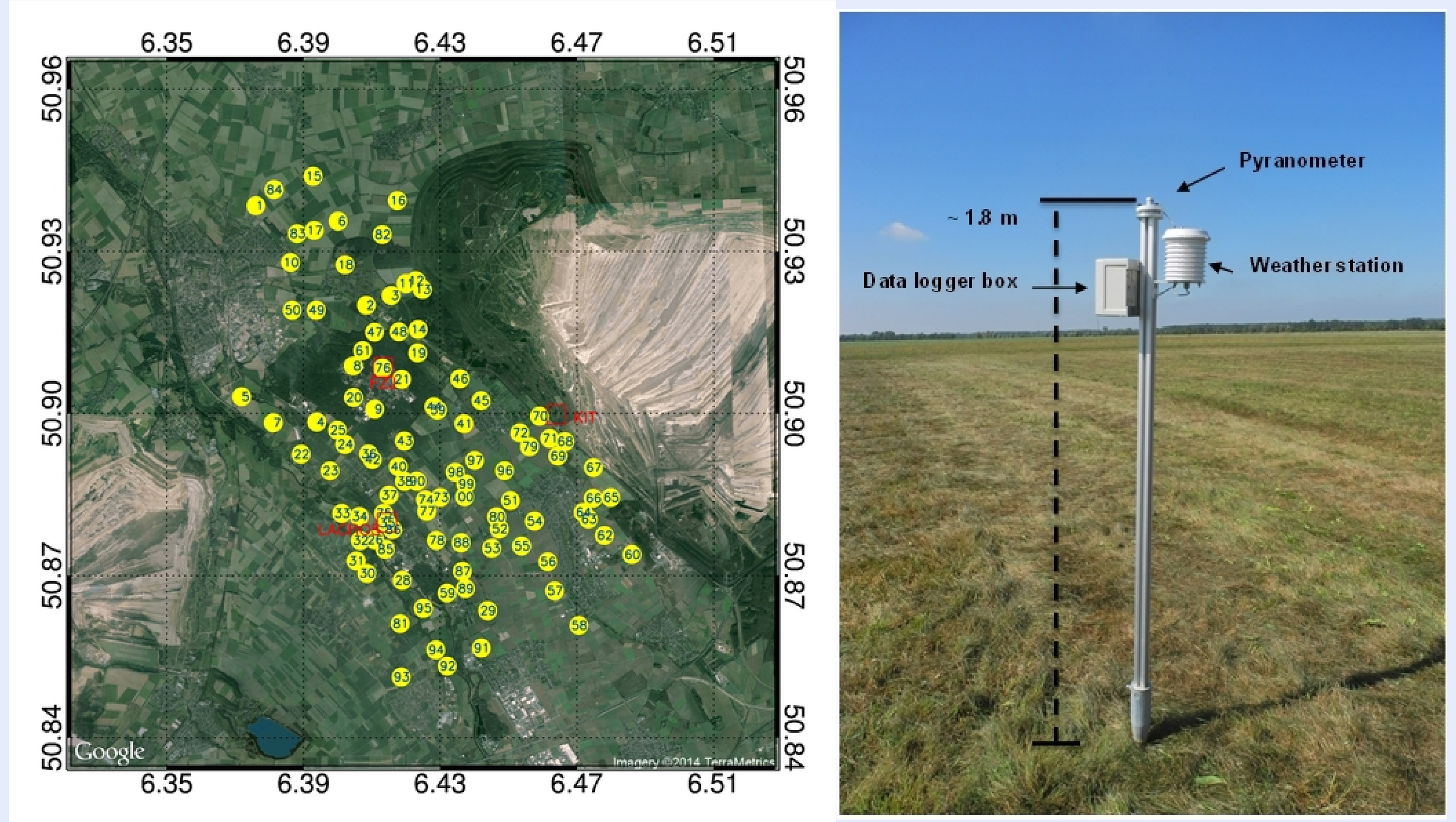


Figure 1: ***Pyranometer network during HOPE-Juelich campaign (left side). Each yellow circle represents a pyranometer station in the field (right side).***

HOPE-Juelich campaign

(April – July, 2013)

Spatial domain: 10 x 12 km² (99 stations)

Datasets:

- Shortwave downwelling irradiance at surface (in W m⁻²; Model: EKO ML-020VM)
  Sensitivity range: 6.3 - 7.7 µV/Wm⁻²
- relative humidity (RH; Model: DKRF 4001-P)
  Range: 0 ... 100 % RH
- air temperature (in K; Model: DKRF 4001-P)
  Range: -20 ... +80 deg. C
  Accuracy: +/- 0.4 deg. C @ 25 deg. C

Temporal resolution:
10 Hz observations averaged to 1 Hz data

Screening procedure

Data from the pyranometer network can possibly be influenced by various factors which may be either observable or non-observable many a times. So, we adopt a two way quality checking of the radiation measurements viz., by observations and statistical screening.

Observable factors: tilt/level imbalance, cleanliness of the pyranometer glass dome, and calibration uncertainty.

Non-observable factors: instrument malfunctioning, resting of birds, movement of insects, possible water condensation on/in the glass dome, and background shadowing.

The observable factors are mostly nullified by our observations during the battery replacement every week, where the data flags were assigned to the entire previous week data of each corresponding station. We adopt a statistical screening to identify the stations which are malfunctioning. In this approch, we classify each data point as *good*, *suspected outlier* and *outlier*. If a particular station data for the entire day has more than 50% data falling under '*outlier*' cateogory, then we consider that station as malfunctioning. The quality screening of data from meteorological sensors completely rely on the above statistical screening.

Spatial and temporal observations

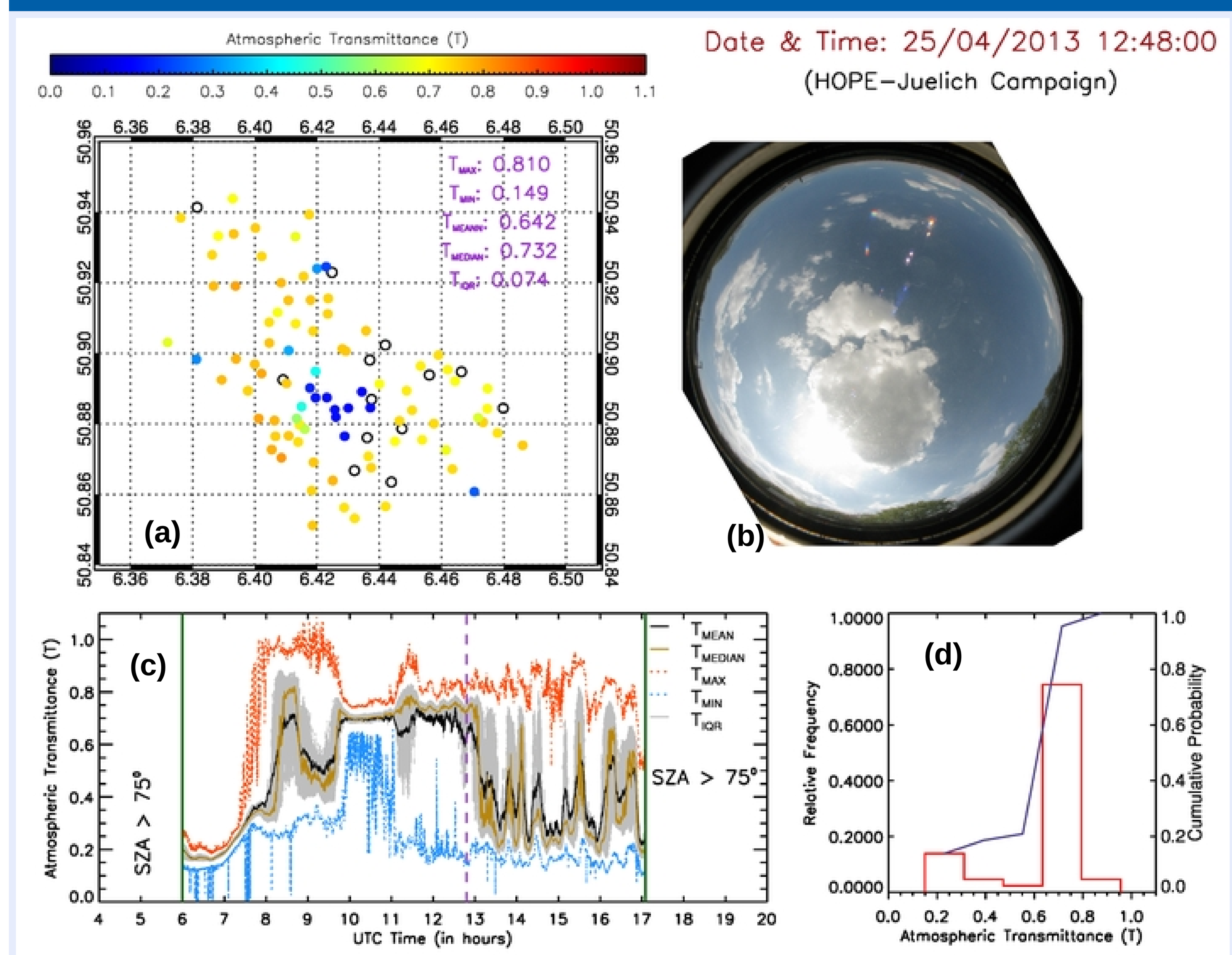


Figure 2: **(a)** ***Spatial variability of atmospheric transmittance on April 25, 2013. Open black circles in between represent the stations with missing data.*** **(b)** ***Sky image at the time of observation.*** **(c)** ***Diurnal variability of atmospheric transmittance (bottom-left side) for SZA < 75⁰. Dashed dark orchid line represent the time of spatial measurements shown in the other three sub-figures.*** **(d)** ***Probability density function (PDF) and cumulative probability of atmospheric transmittance at the time of observation.***

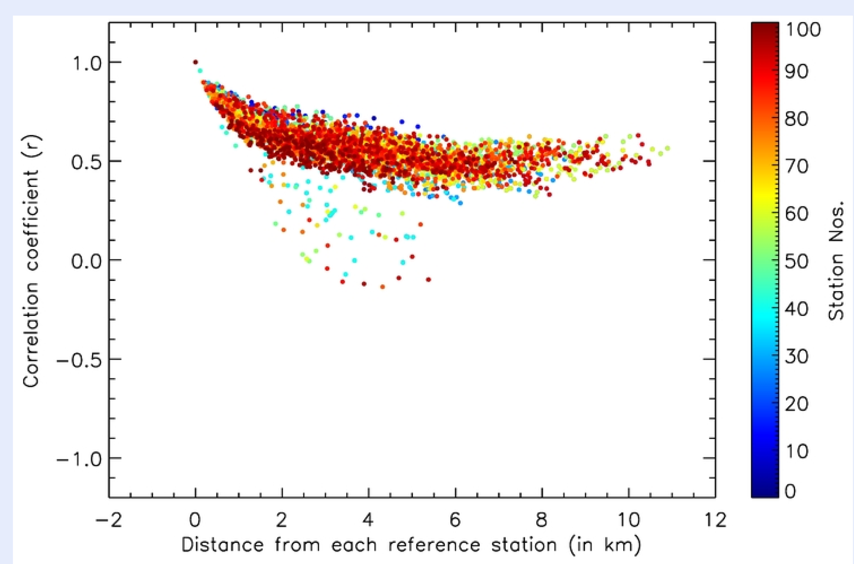


Figure 3: ***Spatial correlation of atmospheric transmittance as a function of distance for April 25, 2013. Considering each station as a 'reference', the correlation with other stations is computed on the entire day observations available at 1 second resolution. Colorbar represents the station reference numbers.***

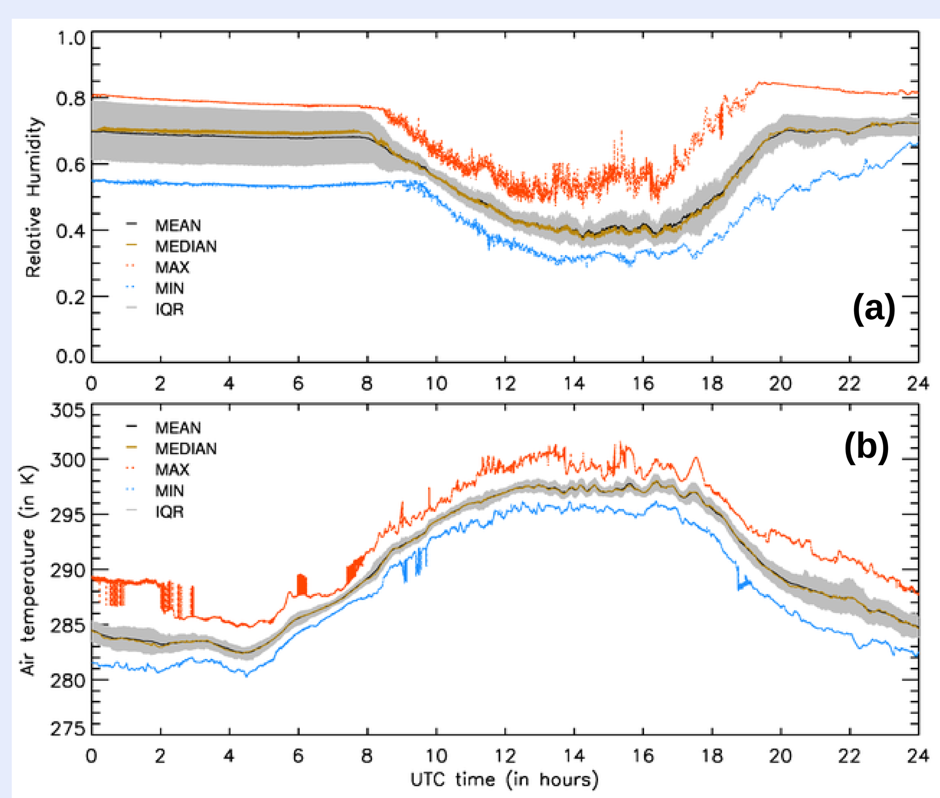


Figure 4: ***Diurnal variability of (a) RH and (b) ambient air temperature (in K) for April 25, 2013.***

Comparison of pyranometer network observations with MSG / SEVIRI high resolution channel TOA reflectances

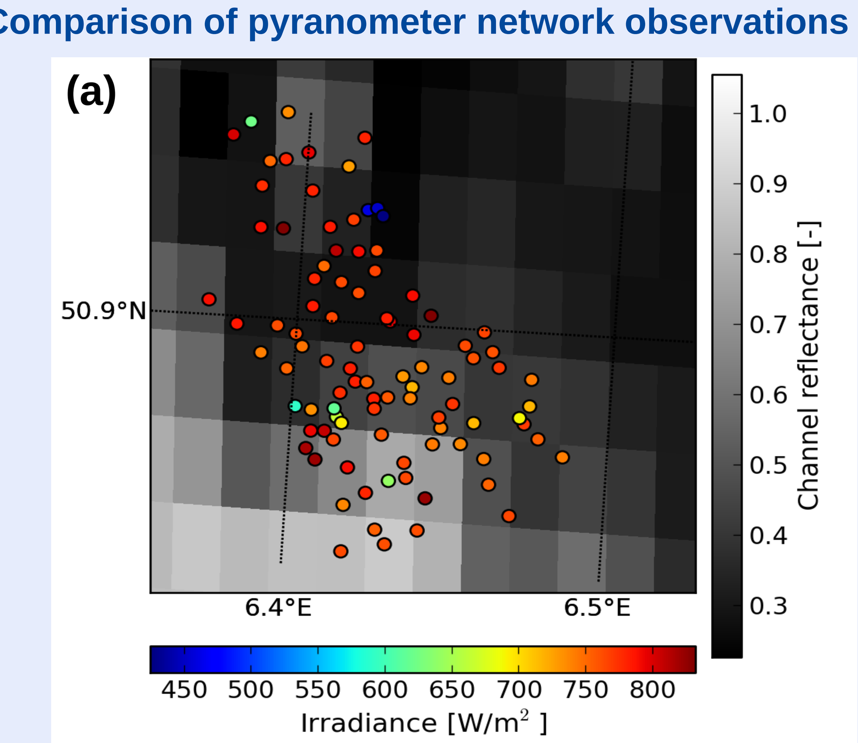
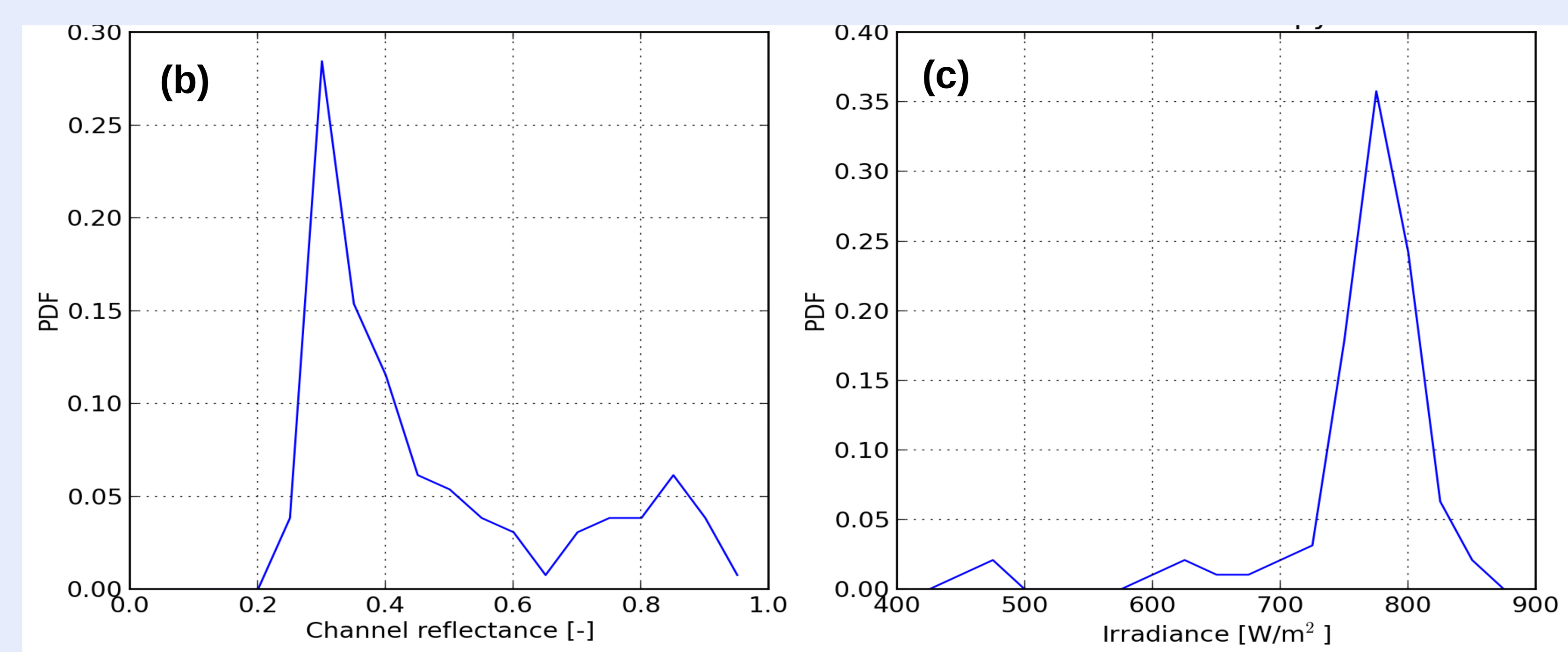


Figure 5: ***Comparison high resolution broadband channel (0.4 - 1.1 µm) TOA reflectance of METEOSAT SEVIRI satellite with shortwave downwelling irradiance (st surface) observations from pyranometer network during HOPE-Juelich campaign corresponding to 12:48 UTC time of observation on April 25, 2013. Also, PDFs of channel reflectance and surface irradiance measurements are shown in (b) and (c) for spatial comparison.***



Results

- Large spatial and temporal variability in cloud induced surface radiation fields is observed.
- Spatial correlation of atmospheric transmittance as a function of distance between different reference stations indicates that the cloud induced radiation at different time stamps is well captured.
- Spatial anti-correlation of spatial PDFs between the shortwave downwelling irradiance and TOA reflectance supports that lower the TOA reflectance, stronger is the cloud induced shortwave forcing or transmittance at the surface.

Outlook

- Multi-scale analysis of high density surface radiation fields to understand the optimal spatial and temporal resolutions for studying the cloud radiative effects is in progress.
- Spatio-temporal analysis between the cloud induced radiation fields obtained from the pyranometer network and METEOSAT SEVIRI satellite images of top of atmosphere high resolution broadband channel (0.4 - 1.1 µm) reflectances for the same domain of observation.
- Cloud induced radiative flux closure studies with MC-UNIK as *forward operator* for quantifying the effect of cloud inhomogeneity on cloud radiation budget.

References

Macke, A., D. L. Mitchell, and L. V. Bremen, 1999: Monte Carlo radiative transfer calculations for inhomogeneous mixed phase clouds. *Phys. Chem. Earth*, 24B, 237–241.

Scheirer, R. and A. Macke (2003): Cloud-inhomogeneity and broadband solar fluxes, *Journal of Geophysical Research*, 108(D19), doi:10.1029/2002JD003321

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