Assessing Radiative Closure of the EarthCARE ACM-RT product with Surface Observations

Hartwig Deneke[1], Carola Barrientos Velasco[1], Rainer Hollmann[2], Anja Hünerbein[1], Andreas Macke[1]

[1] Leibniz Institute for Tropospheric Research (TROPOS), Leipzig, Germany

[2] German Service (DWD), Offenbach, Germany

EarthCARE Science and Validation Workshop
Frascati, Italy, 13.-17. Nov. 2023

Leibniz Association

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

DWD

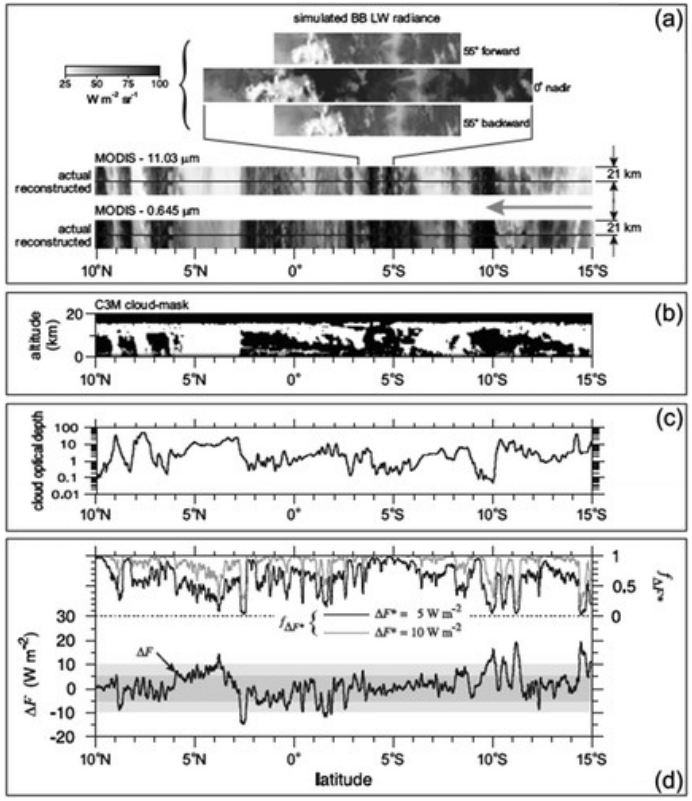
TROPOS
Leibniz Institute for Tropospheric Research

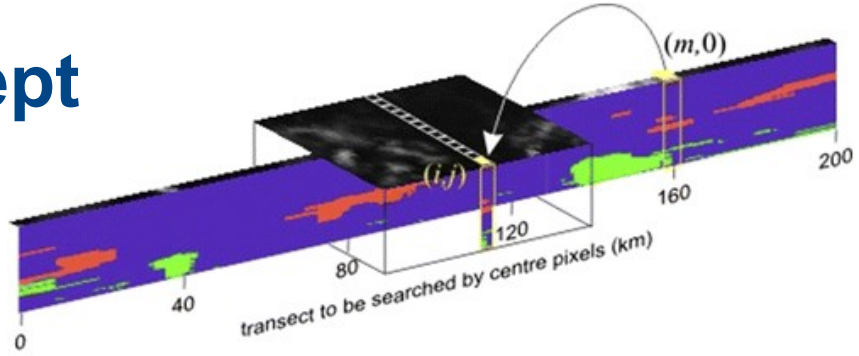
Motivation

- Closure of atmospheric properties and radiative fluxes key science objective of EarthCARE mission
- Target accuracy of +/- 10 W/m^2 on 100 km^2 scale for radiative fluxes at top-of-atmosphere => validation by BBR instrument
- However: radiative fluxes at the surface essential for understanding energy flows in our climate system
- Closure assessment at surface more challenging:
  - *High variability in surface irradiance induced by clouds*
  - *Point-like nature of ground-based measurements*

TROPOS

EarthCARE Closure Concept

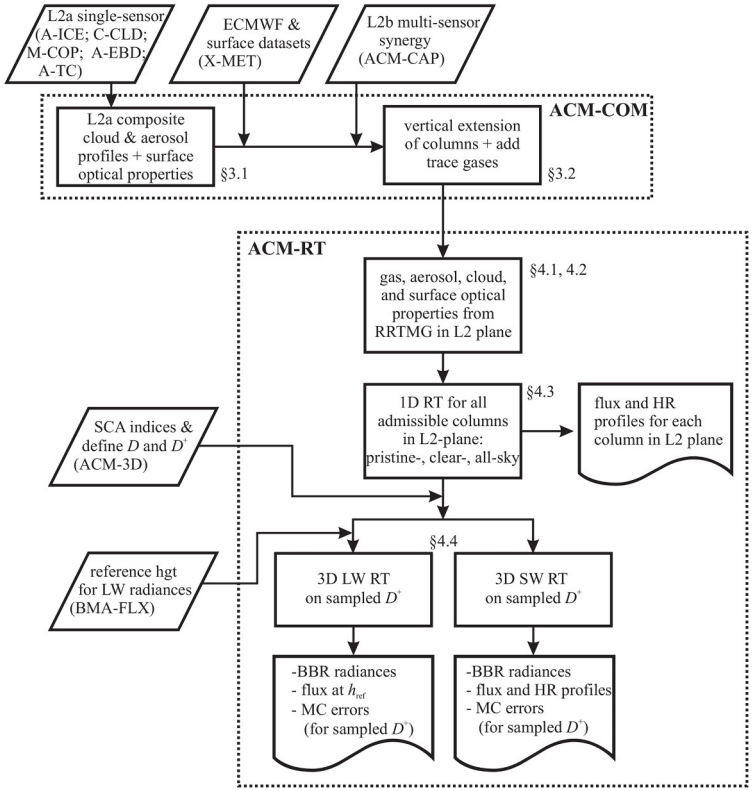


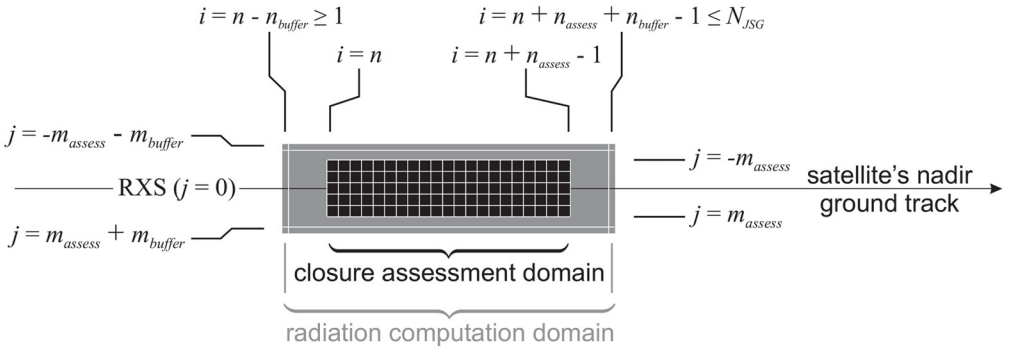


- Aerosol and cloud retrievals, 3D scene construction as input for 1D/3D radiative transfer models
- Validation with BBR observations
- Target accuracy at TOA: 10 *W/m²*

Figs.: EarthCARE closure concept and scene reconstruction. *Source: Illingworth et al., BAMS, 2015, doi:10.1175/BAMS-D-12-00227.1*.

EarthCARE ACM-RT Product

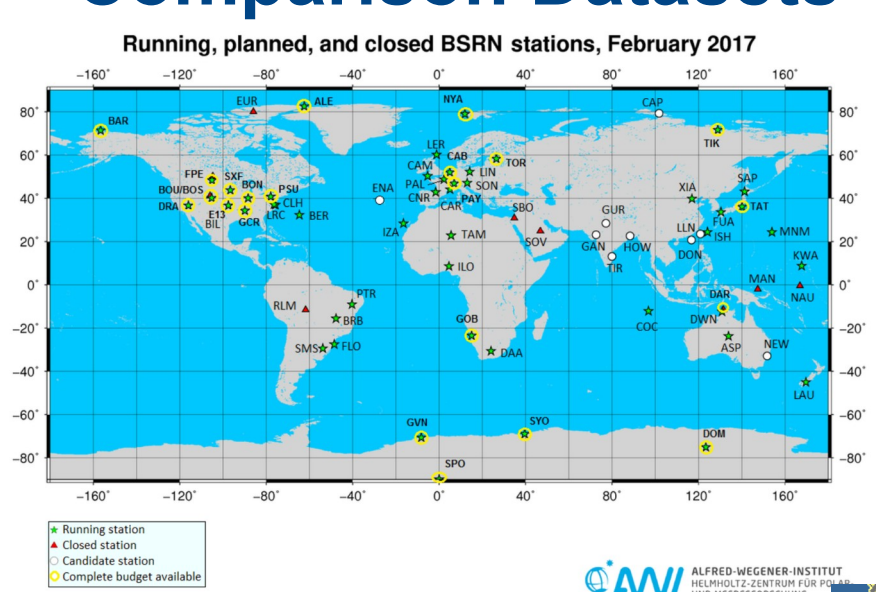


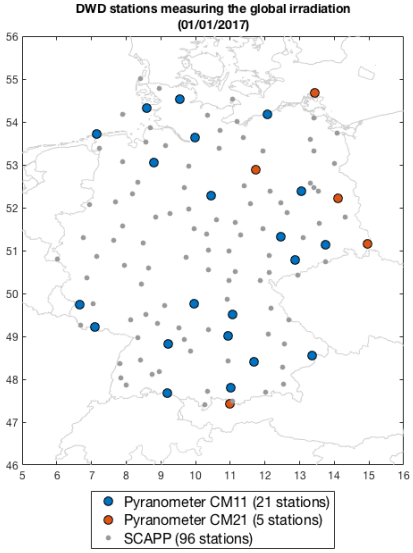


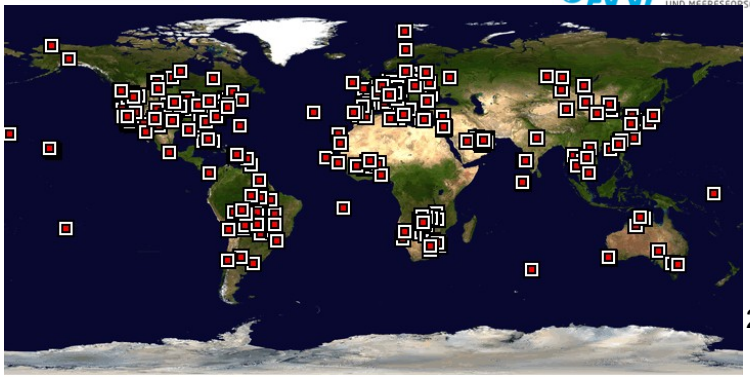
Figs.: (left) Flowchart of the ACM-RT processor. (top) Planned 21 x 5 km^2 closure assessment domain. *Source: Cole et al., AMT, 2023, doi:10.5194/amt-16-4271-2023.*

TROPOS

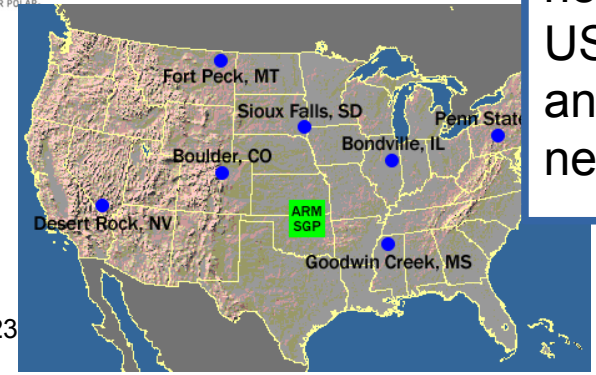
Comparison Datasets







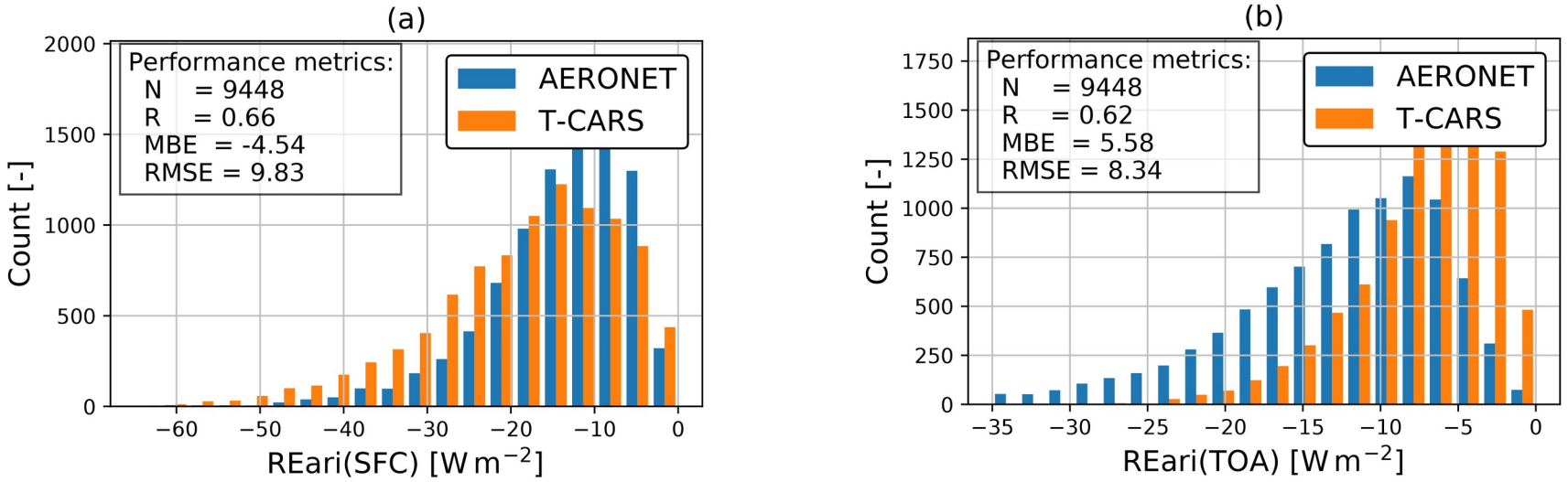
2023



Figs.: Instrumental networks to be used for planned EarthCARE evaluation activities. This includes the global Baseline Surface Radiation Network (BSRN) and NASA's AERONET network, as well as regional networks including the US SURFRAD network and the meteorological network of DWD.

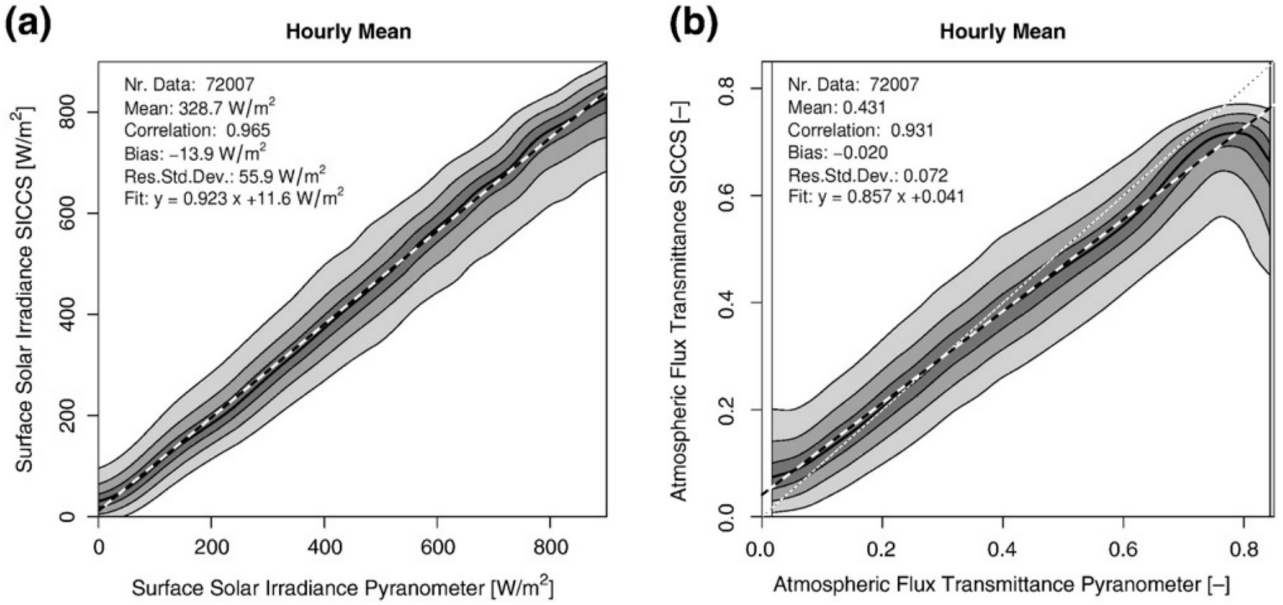
TROPOS

Past Activities focused on Aerosol



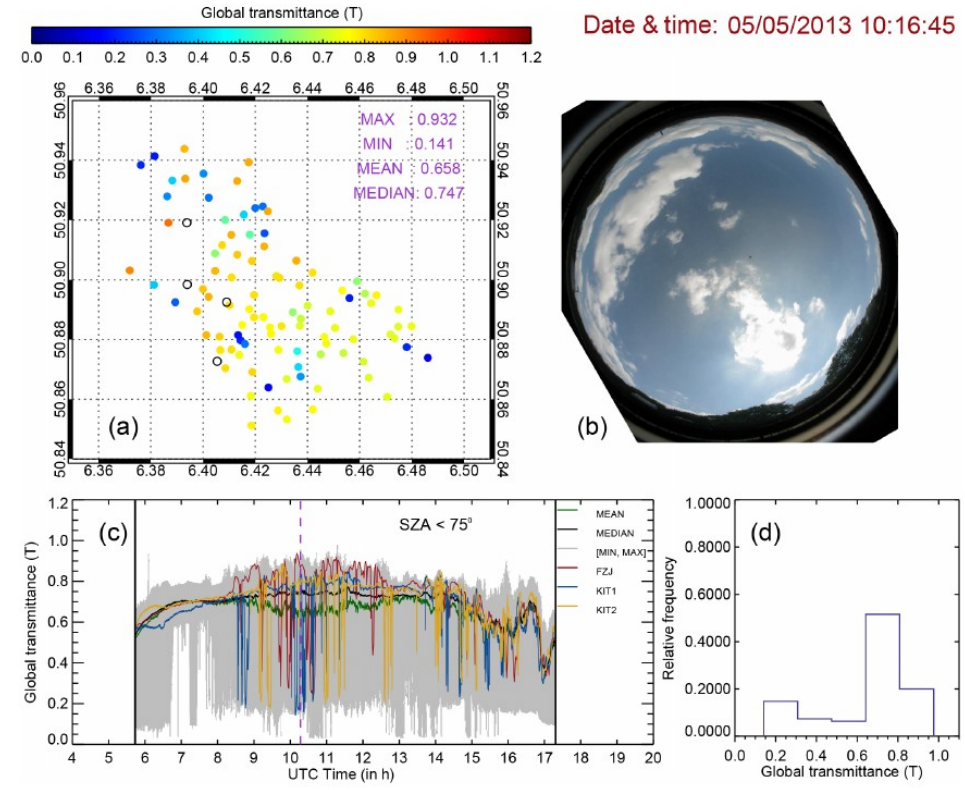
Figs.: Comparison of aerosol radiative effect derived from AERONET observations and simulated based on the CAMS reanalysis and explicit 1D radiative transfer (left) at the surface, and (right) at the top-of-atmosphere. *Source: Witthuhn et al., ACP, 2021, doi:10.5194/acp-21-14591-2021*.

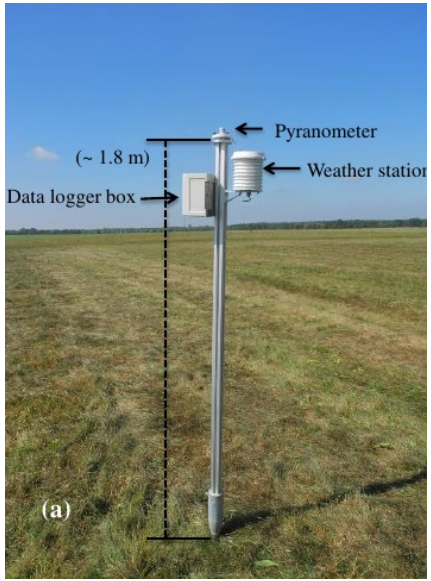
Past Activities focused on Clouds



Figs.: Comparison of hourly-averaged pyranometer observations and satellite retrievals in terms of (left) surface solar irradiance and (right) atmospheric transmittance. *Source: Deneke et al., RSE, 2008, doi:10.1016/j.rse.2008.03.012*.

TROPOS Pyranometer Network





Figs.: Autonomous pyranometer network for resolving small-scale variability in solar irradiance. *Source: Madhavan et al., AMT, 2016, doi:10.5194/amt-9-1153-2016*.

Representativity of Single Stations

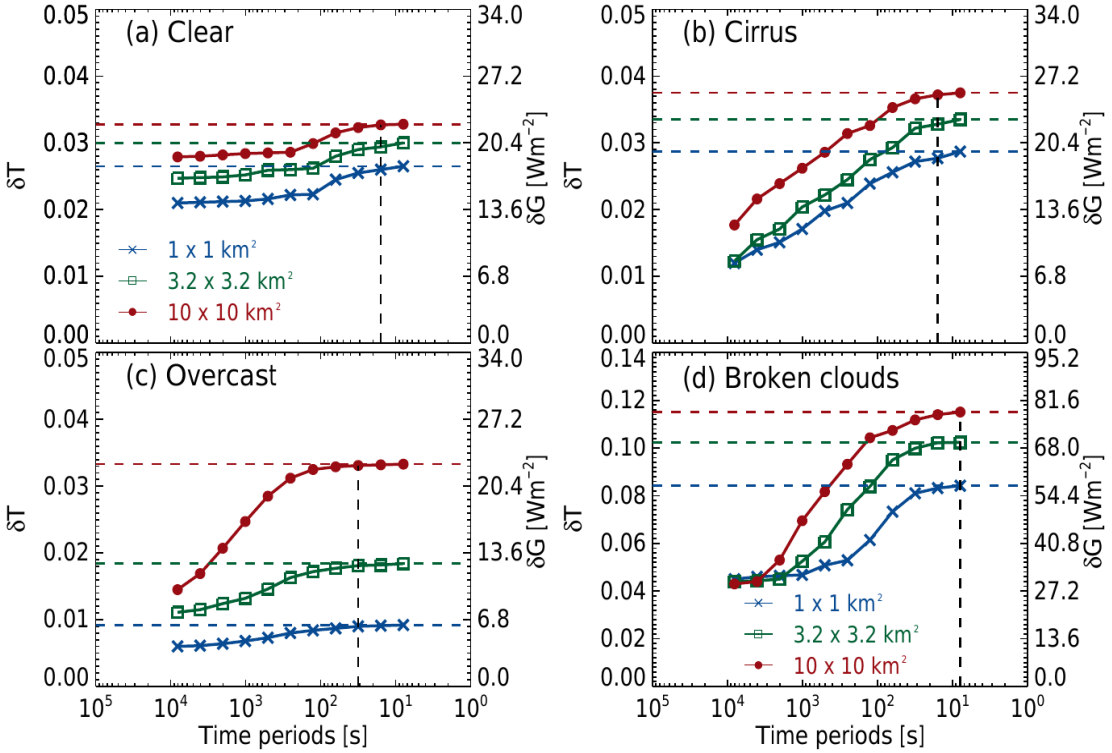


Fig.: Expected deviation of surface solar irradiance for single station and domain average, for 3 domain sizes, cloud situations, and different averaging times. *Source: Madhavan et al., ACP, 2017, doi:10.5194/acp-17-3317-2017.*

TROPOS

Effects of Satellite Resolution

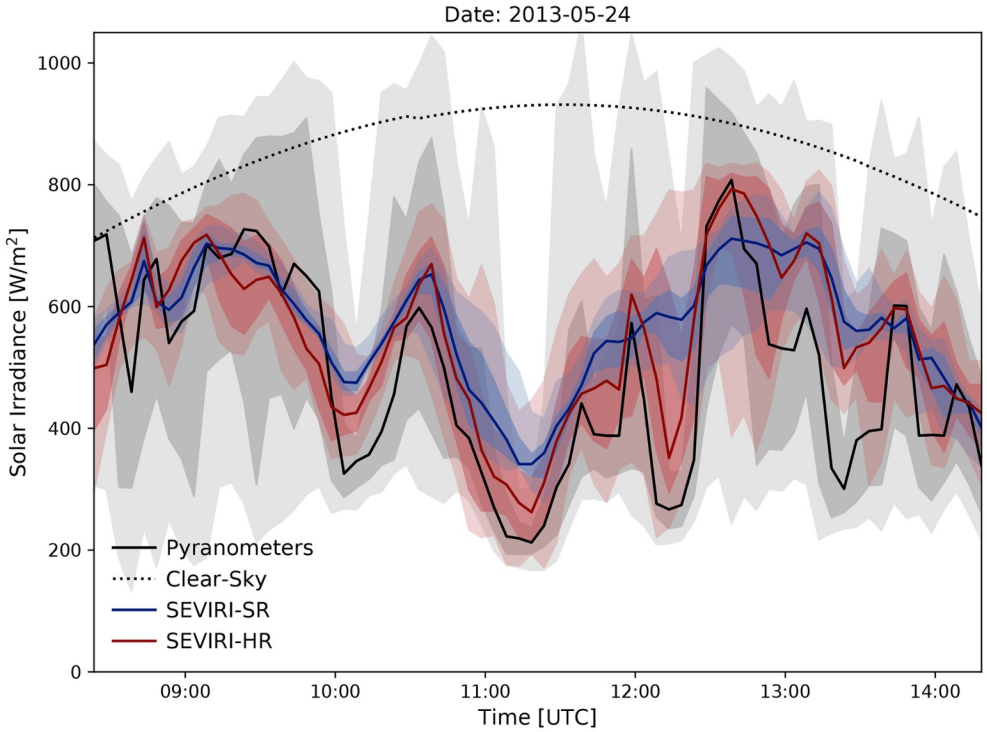
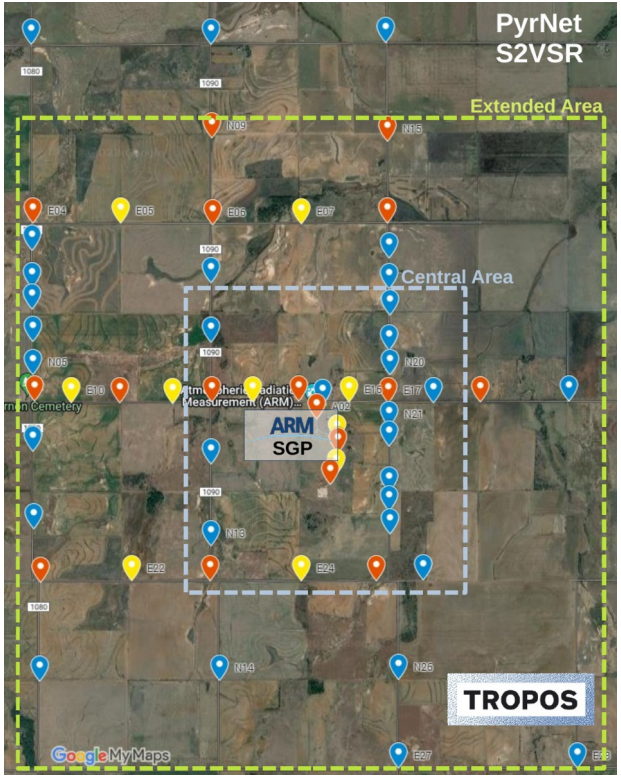


Fig.: Comparison of surface solar irradiance estimated from METEOSAT SEVIRI at standard (3x3km^2) and HRV (1x1km^2)resolution vs. ground-based pyranometer network. *Source: Deneke et al., AMT, 2021, doi:10.5194/amt-14-5107-2021.*

TROPOS

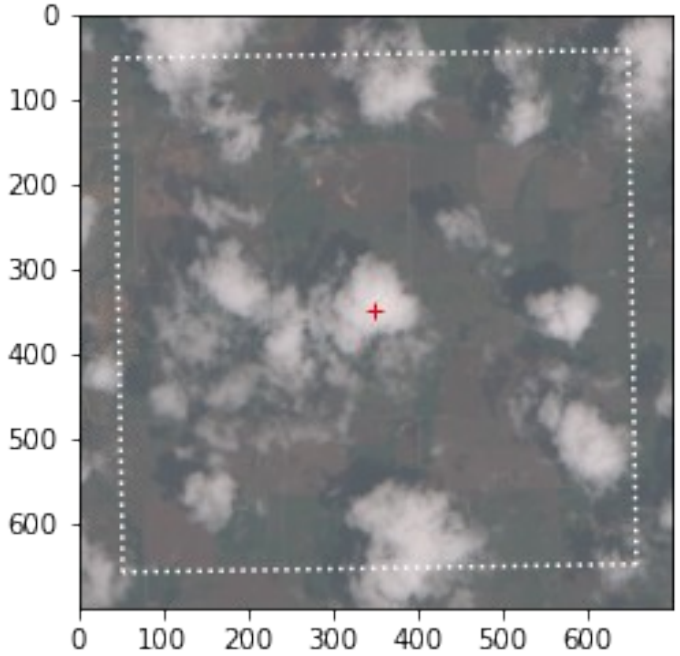
S2VSR Campaign @ ARM SGP Site

- Small-Scale Variability of Solar Radiation (S2VSR) Campaign
- Centered on ARM SGP Central Facility, supported by ARM
- Aim: resolve variability within 2x2 km^2 GOES-ABI (infrared) satellite pixel, study 3D cloud effects
- 12-week period: Jun. - Aug. 2023
- Collaboration with J. Redemann / C.Flynn (both OU)



TROPOS

Complementary S2VSR Observations



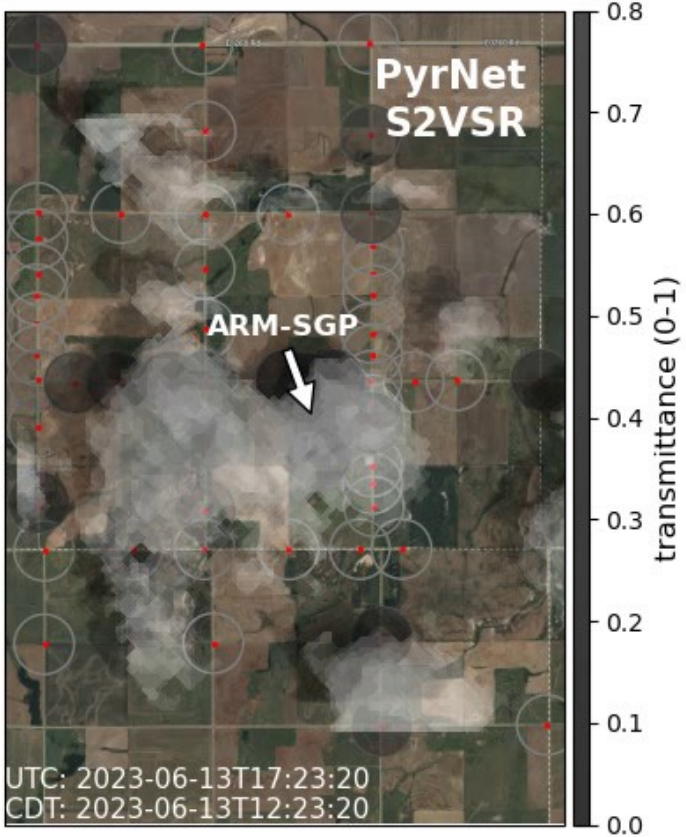


Fig.: Copernicus Sentinel-2 RGB image acquired on 2023-06-13 at 10m spatial resolution (left). Time-matched COGS cloud field at 50m res. (right).

ACTRIS Radiation Measurements by TROPOS on Cape Verde / Mindelo

Figs.: Radiation station recently established by TROPOS on the roof of the Ocean Science Centre Mindelo, following BSRN recommendations and including spectral measurements (0.4.2.5um) (photos by R. Hengst).

Conclusions and Outlook I.

- Planned activities shall extend EarthCARE's closure assessment to surface radiation based on ACM-RT product
- Global and regional operational networks will be used as primary source of reference data (primarily BSRN&AERONET)
- Small-scale variability of clouds limits representativity of single point-like surface observations
  - Averaging of multiple stations & overpasses required
  - Challenge: quantification of (situation-dependent) expected deviation of single-station obs. and ACM-RT fluxes

TROPOS

Conclusions and Outlook II.

- Dedicated field campaign using dense network of radiation sensors (*how many?*) would enable more rigorous closure assessment for cloudy skies
- Complementary cloud observations such as stereo-photogrammetry to assess EarthCARE scene construction
- Recent S2VSR campaign as blueprint?
- Feasibility depends on predictability of EarthCARE ground track!

Fig.: NOAA mobile MESONET station.

https://www.nssl.noaa.gov/tools/fofs/

TROPOS