Validation of BBR TOA broadband irradiance (BMA_FLX_2B) by high altitude airborne observations during PERCUSION

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How can we use airborne broadband irradiance observations for EarthCare's BBR validation?

- HALO (High Altitude and Long Range) research aircraft operated during PERCUSION in high altitude ~14.5 km
  - → Upward broadband irradiance at flight level → requires atmospheric correction for TOA fluxes
  - → Parameterization of $F^{\uparrow}(TOA)$ based on radiative transfer simulations
- Case studies illustrate the different field of view for BBR and HALO observations
- Statistical analysis: Bias in thermal-IR $F^{\uparrow}(TOA)$ → detailled analysis required to identify reasons

1. Broadband AirCrAft RaDiometer Instrumentation (BACARDI) on HALO

- Up- and downward solar and thermal infrared (TIR) irradiance, $F^{\downarrow}_{sol}$, $F^{\uparrow}_{sol}$, $F^{\downarrow}_{ter}$, $F^{\uparrow}_{ter}$
- 2x Kipp&Zonen pyranometer (CMP 22) solar 0.2 – 3.6 µm
- 2x Kipp&Zonen pyrgeometer (CGR-4) TIR 4.5 – 42 µm
- Fixed mounting to aircraft, passive ventilation
- 10 Hz sampling frequency

Corrections

(Luebke et al., 2022 and Ehrlich et al., 2023)

→ Temperature dependence of sensitivity
→ Sensor time response
→ Attitude correction for $F^{\downarrow}_{sol}$
→ **Thermal offset correction**

2. PERCUSION 2024 campaign

- Aug. 2024: Cape Verde (Tropics) 9 EC overpasses
- Sep. 2024: Barbados (Tropics) 9 EC overpasses
- Nov. 2024: Europe (high latitude) 10 EC overpasses
- Flight altitude >14km
- Tropics: often still clouds above HALO

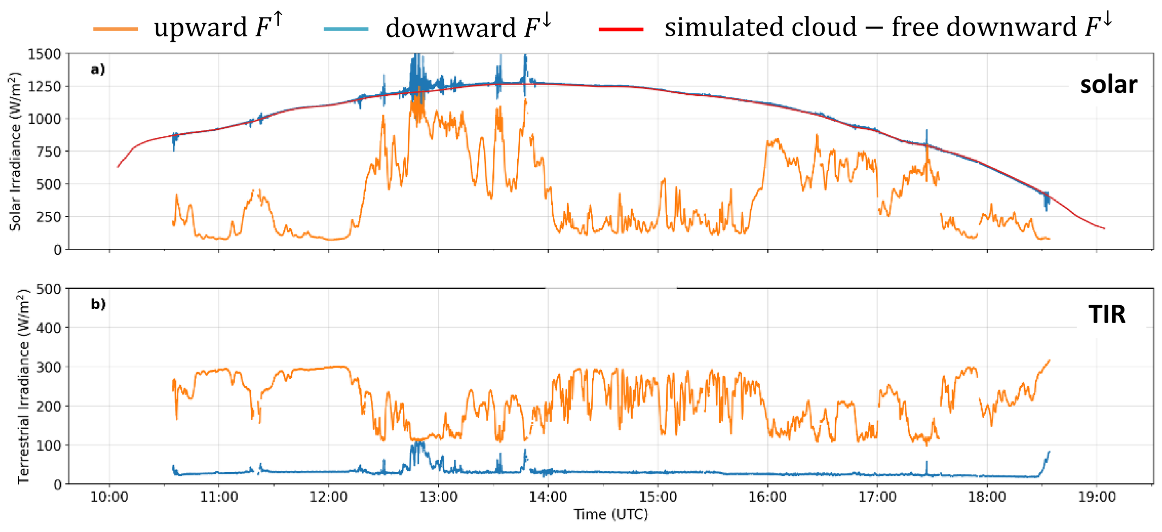

Fig. 1: Time series of solar (top) and TIR irradiance (bottom) for RF 18 Aug. 2024 .

- Upward irradiance responds to the presence of clouds
- Agreement between the observed and simulated solar $F^{\downarrow}$
- Confirms statistical analysis of $F^{\downarrow}$ based on EUREC4A data

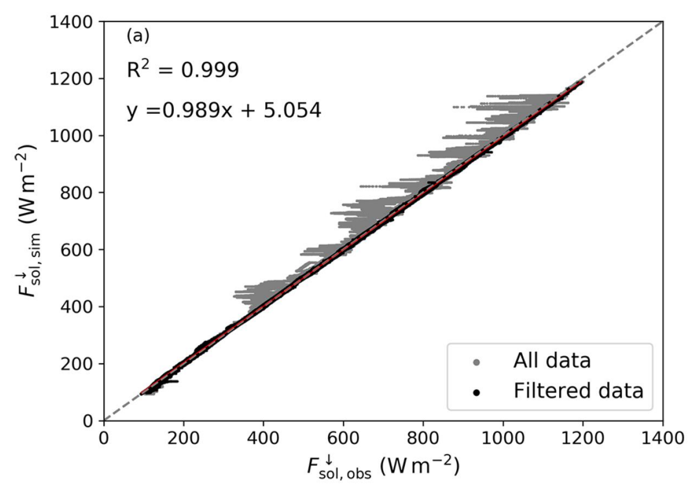

Fig. 2: Comparison of simulated and observed downward solar irradiance $F^{\downarrow}$ of 12 EURECA4A flights. Filtered data (black dots) excludes clouds above HALO and flight maneuvers, (from Ehrlich et al. 2023).

- EC sections are representative for entire campaign
- BACARDI Field of View (FOV) = depends on cloud top altitude

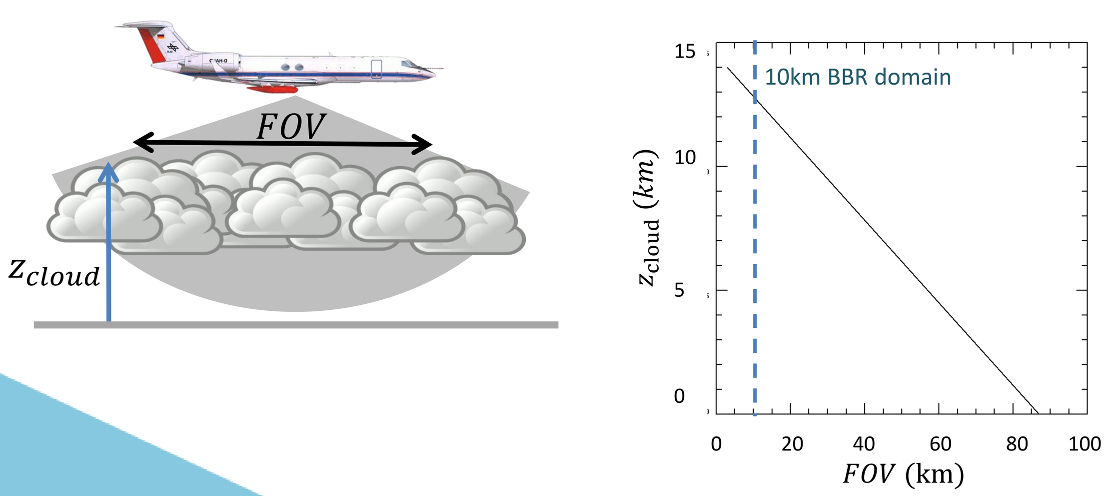

Fig. 3: FOV at different cloud top altitudes for a HALO flight altitude of 14.5 km.

3. TOA vs. Flight Altitude

- Radiative transfer simulations (libRadtran)
  - Solar: two-stream, reptran medium, sza=0-85°, 0.29-3.6 µm
  - TIR: disort2, reptran medium, 3-100 µm
  - Varying clouds 0 - 12 km (deep convective type)
- Tropics: 2 month radiosonde profiles (Barbados)
- High Lat: 1 month radiosonde profiles (Torshavn)

- Emission and attenuation by higher atmosphere

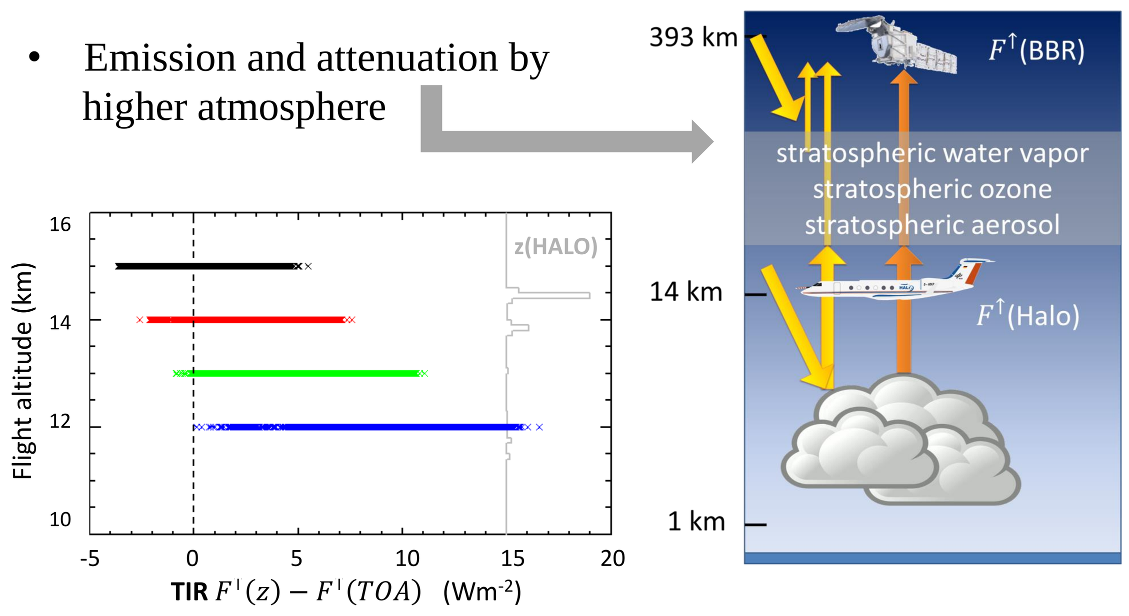

Fig. 4: TIR upward irradiance $F^{\uparrow}$ bias for different flight altitudes in tropical conditions.

Parameterization of TOA irradiance

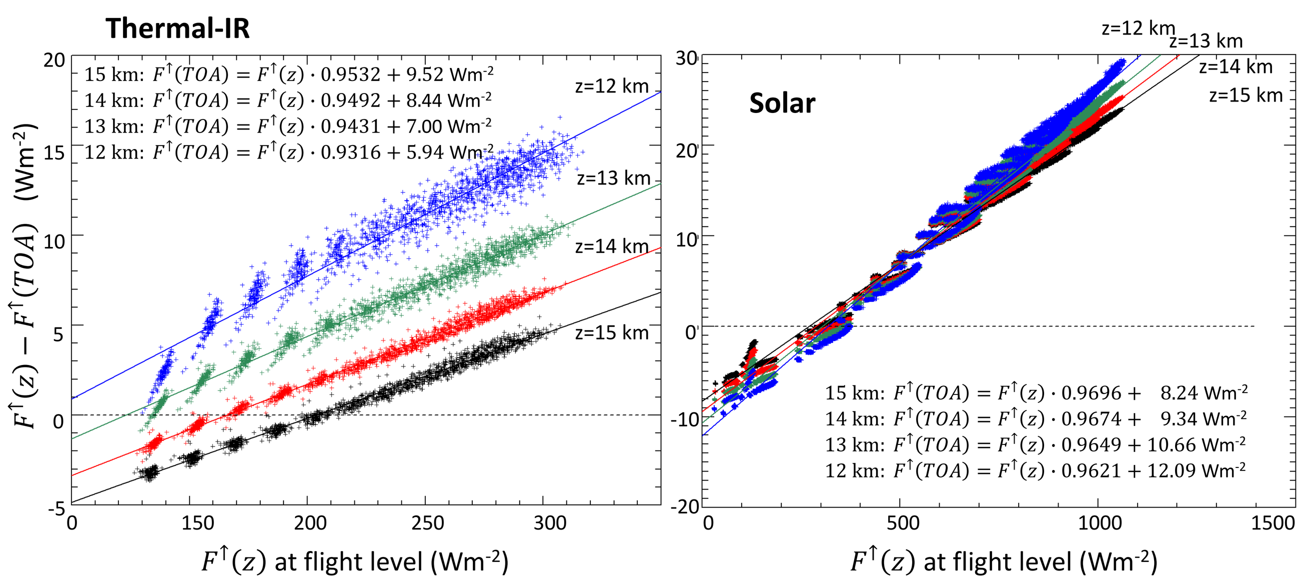

Fig. 5: Bias of upward irradiance $F^{\uparrow}(z) - F^{\uparrow}(TOA)$ for different flight altitudes in tropical conditions. A linear parameterization is given to calculate $F^{\uparrow}(TOA)$ from measured $F^{\uparrow}(z)$.

- Over- and underestimation of $F^{\uparrow}(TOA)$ possible
- Mostly depending on the general irradiance level
- Cloud, solar zenith angle and atmosphere dependence is less important
- Unresolved variabilities: stratospheric ozone, aerosol

4. Example Case of 7 Sept. 2024

- BMA_FLX_2B: assessment resolution (21 km x 10 km average)

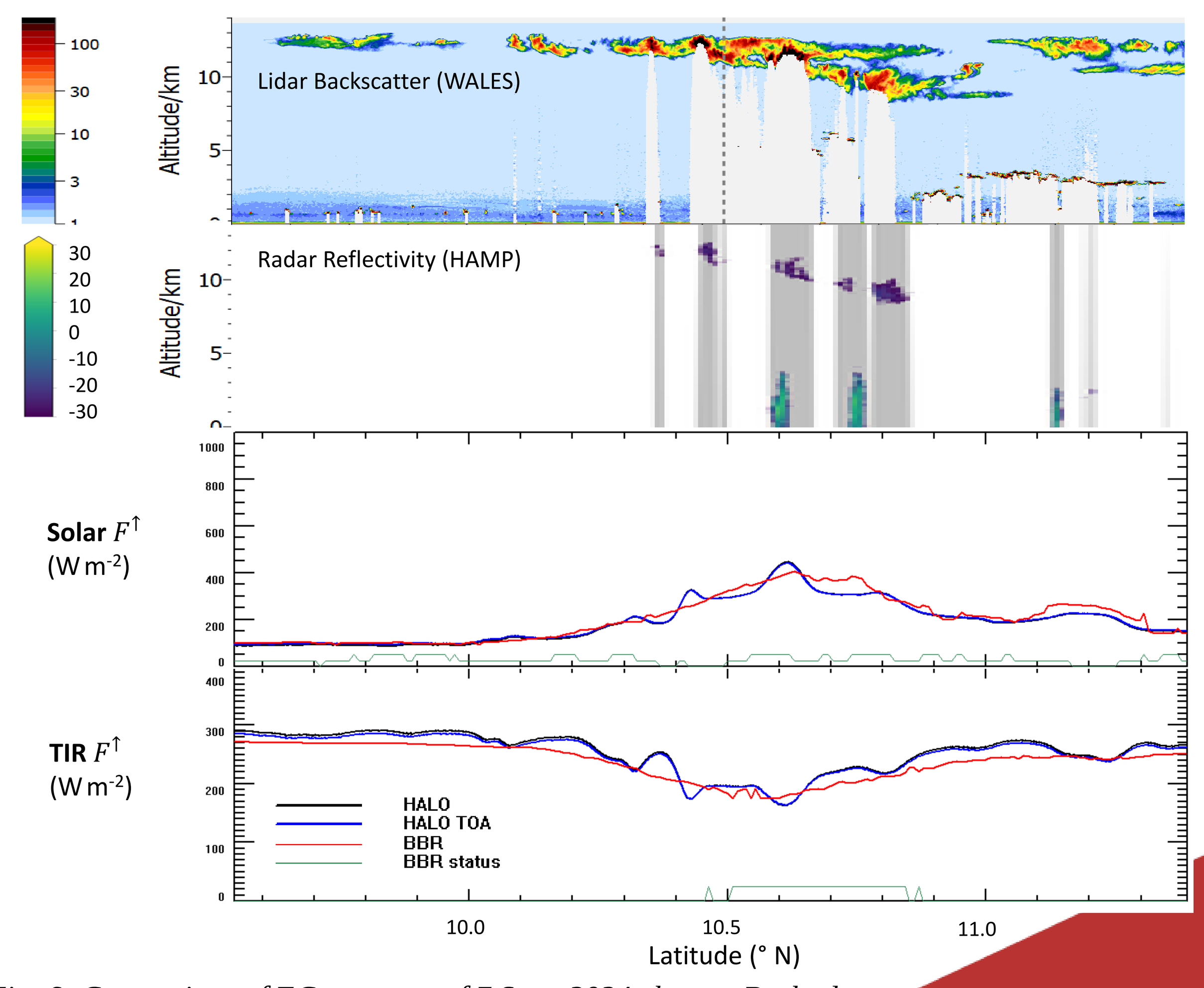

Fig. 6: Comparison of EC overpass of 7 Sept. 2024 close to Barbados. Top: Lidar backscatter and Radar reflectivity measured by WALES and HAMP on HALO. Bottom: BMA_FLX_2B combined TOA fluxes compared to HALO BARCARDI data.

5. Example Case of 14 Sept. 2024

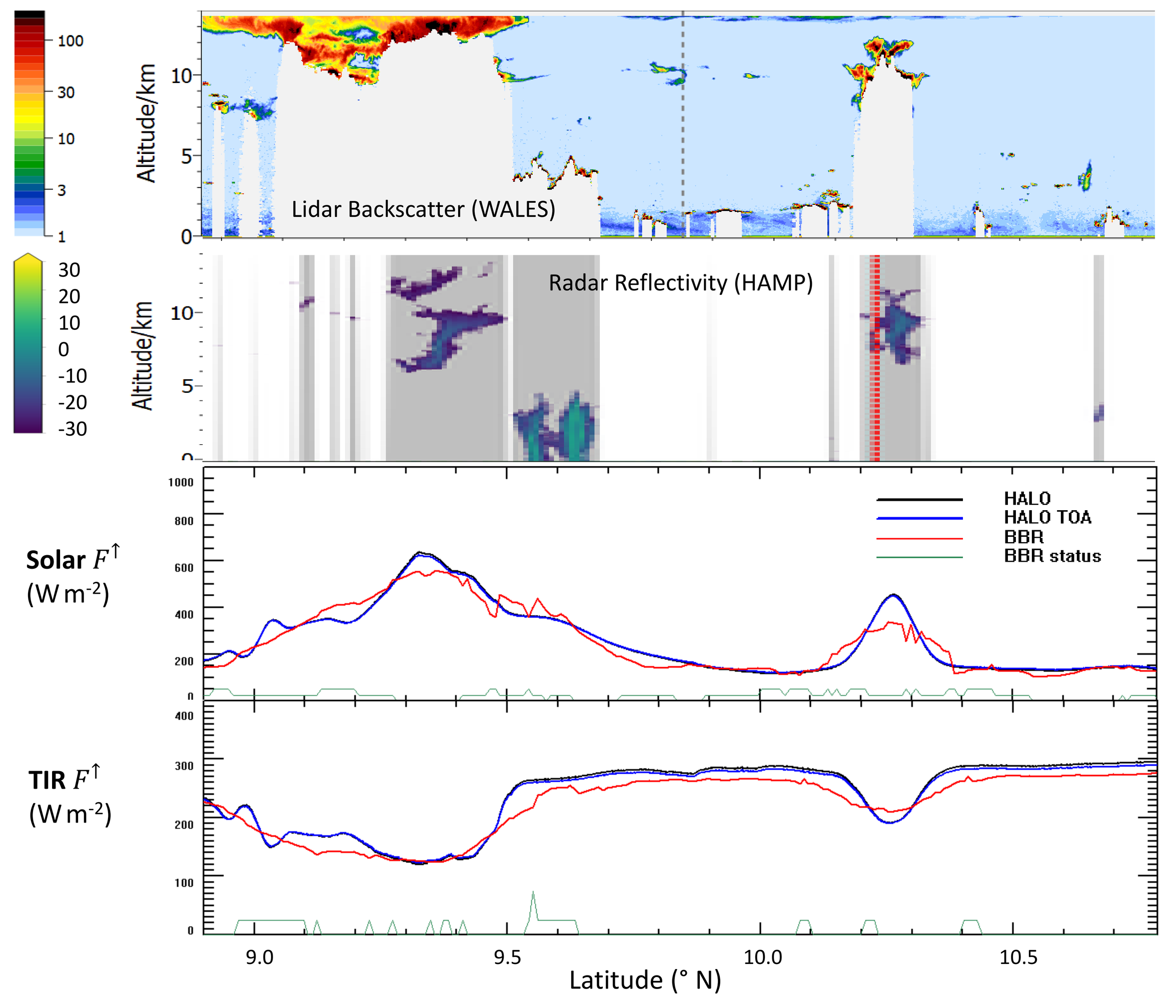

Fig. 7: Similar to Fig. 6 but for the EC overpass of 14 Sept. 2024 close to Barbados.

6. Statistical Evaluation

- All tropical flights during PERCUSION
- Conservative filtering for clouds above HALO (still not perfect?)
  - ±7.5 min around overpass time
  - 14 EC overpasses for comparison

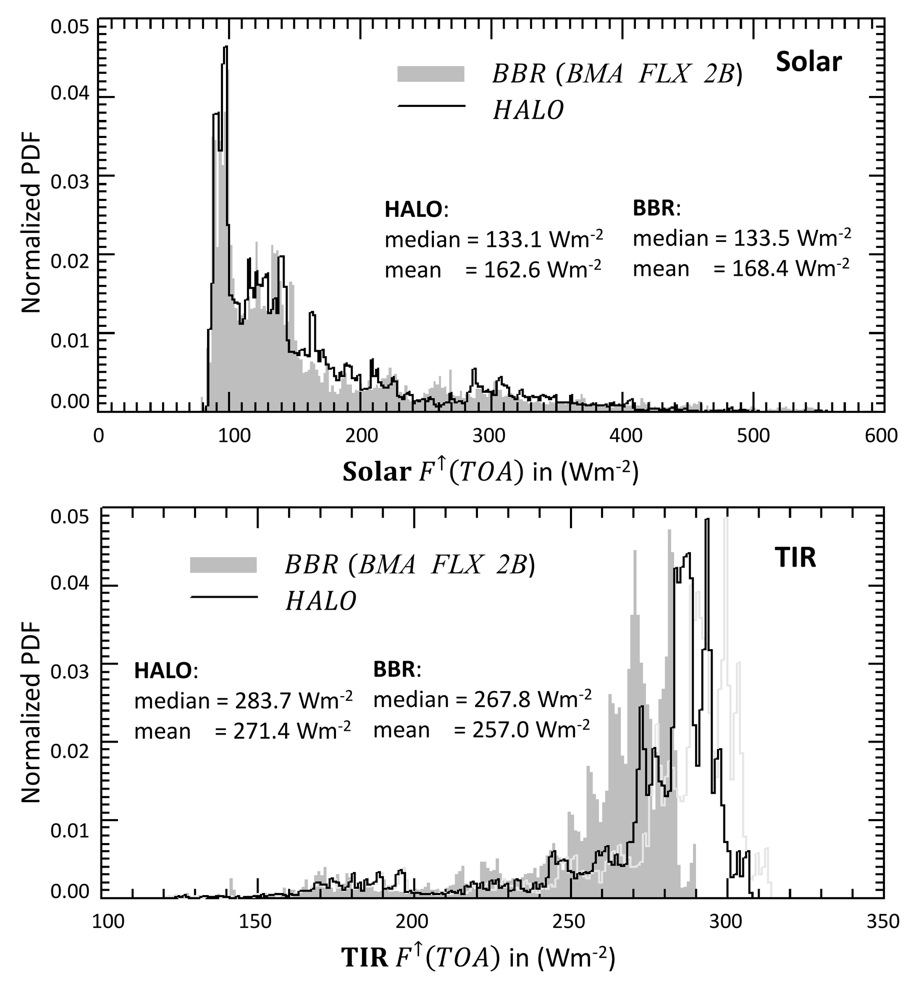

Fig. 8: Normalized frequency distribution of solar (top) and thermal IR (bottom) $F^{\uparrow}(TOA)$ for BBR and HALO observations during all PERCUSION flight in tropical conditions. The data are significantly reduced by filtering clouds above HALO.

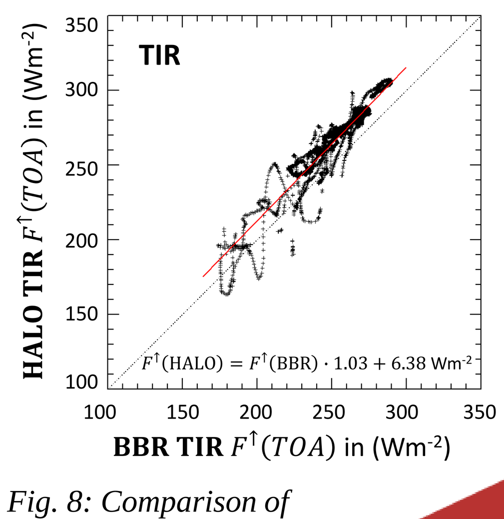

Fig. 8: Comparison of thermal-IR $F^{\uparrow}(TOA)$ for BBR and HALO.

- Bias in TIR $F^{\uparrow}(TOA)$ for warm surfaces?
- Still impact of stratosphere?
- Solar $F^{\uparrow}(TOA)$ matches within uncertainties

REFERENCES

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