CMSAF AVHRR-based CDR of TOA radiative fluxes (CLARA-A3): results and validation

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1. Introduction

- What is CLARA? “CM SAF cLoud, Albedo and RAdiation dataset from AVHRR data” (≈similar to Patmos-X):
  - Polar orbiting: NOAA and MetOp
  - FCDR from NOAA (Heidinger, 2010)
  - L3 products on 0.25°x0.25°
  - Currently released versions:
    • CLARA-A1 (1982-2009)
    • CLARA-A2 (1982-2015)

- Some of the modifications in the upcoming version CLARA-A3:
  - Inclusion of the AVHRR-1 sensor (TIROS-N, NOAA-6,-8,-10): extension of time range to 1979-2020, which is 42 years
  - Updated FCDR: new calibration for visible channels (latest PATMOS-x coefficients)
  - Updated cloud treatment algorithms (NWC SAF / PPS v.2018; Karlsson et al.)
  - Addition of new product “TOA radiative fluxes” → this presentation
2. Results

- Example: daily mean RSF (15/6/2008)
2. Results

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2. Results

March

Mean=95.73 W/m²

June

Mean=93.50 W/m²

September

Mean=93.13 W/m²

December

Mean=104.40 W/m²
• **Global Monthly Mean RSF:**

![Graph showing Global monthly absolute flux of CLARA-A3 RSF and other data records](image)

Systematic seasonal biases, e.g. from ERA5 w.r.t. CERES and CLARA-A3:
underestimated amplitude of annual cycle
• **Global Monthly Mean RSF:**

• Deseasonalized

**Trends (W/m²/dec):**

*Full series:*
- ERA5: -0.0769
- CLARA-A3: -0.2318

*Since 2000:*
- ERA5: -0.2024
- CLARA-A3: -0.9645
- CERESSYN: -0.6451
- CERESEBAF: -0.7023
2. Results

March

June

September

December
- **Global Monthly Mean OLR:**
Global Monthly Mean OLR:

- Deseasonalized

Trends (W/m²/dec):

**Full series:**
- ERA5: -0.1125
- HIRS: +0.1461
- CLARA-A3: +0.6321

**Since 2000:**
- ERA5: +0.2295
- HIRS: -0.0679
- CLARA-A3: +0.3800
- CERESSYN: +0.2825
- CERESEBAF: +0.2839
3. Validation

- **Longwave: Outgoing Longwave Radiation**:
  - **Bias**:
    - Daily mean OLR
    - Monthly mean OLR
  - **RMSE (bias corrected)**:
    - Daily mean OLR
    - Monthly mean OLR

- **Shortwave: Reflected Solar Flux**:
  - **Bias**:
    - Daily mean RSF
    - Monthly mean RSF
  - **RMSE (bias corrected)**:
    - Daily mean RSF
    - Monthly mean RSF
3. Validation

- **Daily mean OLR:** 365 bias maps/year, each with global bias and RMSE:

  - **Bias of CLARA-A3 TOA OLR radiation w.r.t. CERES-SYND-Ed4.1 (20080612)**
    - ME = -0.81 W/m²; MAE = 3.41 W/m²
  - **Bias of CLARA-A3 TOA OLR radiation w.r.t. CERES-SYND-Ed4.1 (20080613)**
    - ME = -0.77 W/m²; MAE = 3.34 W/m²
  - **Bias of CLARA-A3 TOA OLR radiation w.r.t. CERES-SYND-Ed4.1 (20080614)**
    - ME = -0.70 W/m²; MAE = 3.27 W/m²
  - **Bias of CLARA-A3 TOA OLR radiation w.r.t. CERES-SYND-Ed4.1 (20080615)**
    - ME = -0.72 W/m²; MAE = 3.32 W/m²

RMSE = 4.34 W/m²
RMSE = 4.40 W/m²
MAE = 3.32 W/m²
ME = -0.72 W/m²
3. Validation

- **Monthly mean OLR**: 12 bias maps/year, each with global bias and RMSE:
Global daily bias of CLARA-A3 OLR w.r.t. other data records

Global mean bias of Daily Mean OLR:

- Bias w.r.t. ERA5 has a systematic seasonal pattern, not visible in biases w.r.t. CERES and HIRS.
• **Global mean bias** of Daily Mean OLR:

- Deseasonalized
• **Global mean bias** of Daily Mean OLR:

• Deseasonalized
• Weekly running average

*Overall: good: within +/-1% w.r.t. HIRS*
- **Global mean bias** of Daily Mean OLR:
  - Deseasonalized
  - Weekly running average

Discontinuities related to changes in orbital configuration?
Orbital discontinuities

Between the discontinuities are gradients from small to large temporal spread of observations.
- Global mean bias of Daily Mean OLR:
  - Deseasonalized
  - Weekly running average
• **Global mean bias** of Monthly Mean OLR:

  - Deseasonalized

- Monthly pattern same as daily.

- Stable w.r.t. HIRS
- **Global mean bias** of Monthly Mean OLR:

- Deseasonalized

Monthly pattern same as daily.

Stable w.r.t. CERES SYN/EBAF
• Global RMSE (bias-corrected) of Daily Mean OLR:

• Weekly running average
• **Global RMSE (bias-corrected)** of Daily Mean OLR:

• **Weekly running average**

Discontinuities due to changed orbital configuration.
• **Orbital configuration** of CLARA-A3:

Discontinuities due to changed orbital configuration:

- Single-orbit periods (either morning or afternoon)

- Discontinuities between satellites and hence local solar time
• **Global RMSE (bias-corrected) of Daily Mean OLR:**

• **Weekly running average**

Discontinuities due to changed orbital configuration:

- Single-orbit periods (either morning or afternoon)
- Discontinuities between satellites and hence local solar time
• **Global RMSE (bias-corrected) of Monthly Mean OLR:**

  On monthly scale, impact of orbital configuration is much smaller.
• **Global RMSE (bias-corrected) of Daily Mean OLR:**
• Global RMSE (bias-corrected) of Monthly Mean OLR:

• Max 2 missing days per month
• Global RMSE (bias-corrected) of Monthly Mean OLR:

• Max 2 missing days per month
- **Global RMSE (bias-corrected) of Monthly Mean OLR:**

  - Max 2 missing days per month

*Strange artifacts in CERES Ed4.1*
3. Validation

• **Longwave: Outgoing Longwave Radiation:**
  - Bias:
    - Daily mean OLR
    - Monthly mean OLR
  - RMSE (bias corrected):
    - Daily mean OLR
    - Monthly mean OLR

• **Shortwave: Reflected Solar Flux:**
  - Bias:
    - Daily mean RSF
    - Monthly mean RSF
  - RMSE (bias corrected):
    - Daily mean RSF
    - Monthly mean RSF
Global daily bias of CLARA-A3 RSF w.r.t. other data records

ERA5 has a systematic seasonal bias w.r.t. CERES and CLARA-A3.
Global mean bias of Daily Mean RSF:

Deseasonalized

ERA5 has a systematic seasonal bias w.r.t. CERES and CLARA-A3. This is removed by deseasonalizing.
• **Global mean bias** of Daily Mean RSF:

• Deseasonalized

• Weekly running average

ERA5 has a systematic seasonal bias w.r.t. CERES and CLARA-A3. This is removed by deseasonalizing.
• **Global mean bias** of Daily Mean RSF:

• Deseasonalized
• Weekly running average

ERA5 has a systematic seasonal bias w.r.t. CERES and CLARA-A3.

This is removed by deseasonalizing.

The remaining bias is due to non-systematic biases in CLARA-A3.
Orbital configuration of CLARA-A3:

Non-systematic biases in CLARA-A3:

- Single-orbit periods (either morning or afternoon)
- Discontinuities between satellites and hence local solar time
- **Global mean bias** of Daily Mean RSF:

- Deseasonalized
- Weekly running average
• Global mean bias of Daily Mean RSF:

• Deseasonalized
- **Global mean bias** of Daily Mean RSF:

- **Deseasonalized**
• **Global mean bias** of Daily Mean RSF: 93% of months are within mean +/- 2W/m² (about +/-2%)

• Deseasonalized Trend of bias: -0.1547 W/m²/dec
• Global mean bias of Daily Mean RSF:

• Deseasonalized
- Global RMSE (bias-corrected) of Daily Mean RSF:

- Weekly running average
- **Global RMSE (bias-corrected) of Daily Mean RSF:**

- **Weekly running average**

![Graph showing global daily bc-RMSE between CLARA-A3 RSF and other data records]

- Global daily bc-RMSE between CLARA-A3 RSF and other data records
  - CERES-SYN
- **Orbital configuration** of CLARA-A3:

No mid-morning orbit available (NOAA-17, MetOp)

Orbital drift of afternoon satellite towards evening
• Orbital configuration of CLARA-A3:

- No mid-morning orbit available (NOAA-17, MetOp)
- Orbital drift of afternoon satellite towards evening

Next CLARA update includes VIIRS
• **Global RMSE (bias-corrected) of Daily Mean RSF:**

• Weekly running average

No mid-morning orbit available (NOAA-17, MetOp)

Orbital drift of afternoon satellite towards evening
• Global RMSE (bias-corrected) of Monthly Mean RSF:

On monthly scale, same effects but less pronounced.

No mid-morning orbit available (NOAA-17, MetOp)

Orbital drift of afternoon satellite towards evening

Strange artifacts in CERES Ed4.1
• Global RMSE (bias-corrected) of Daily Mean RSF:

• Weekly running average

Strange artifacts in CERES Ed4.1
4. Future outlook

- Full data record of **CLARA-A3** has just been generated. After validation, release is foreseen around Q1 2023; an ICDR will also be developed.
- Update **CLARA-A3.5** will include VIIRS instrument (S-NPP and NOAA-20) without any code changes (i.e. to be used as extension to CLARA-A3).
- Potential code updates will be done as part of **CLARA-A4** (within CMSAF), or as stand-alone data record (within RMIB), including:
  - Use of new CERES ADM's Ed4 (currently being implemented and tested at RMIB)
  - Use of new Narrowband-to-broadband regressions (based on reflectances with updated calibration coefficients, and updated scene types).
Thanks for your attention!
Strange artefacts in CERES-SYN (RSF):

Bias of CLARA-A3 TOA RSF radiation w.r.t. CERES-SYNNM-Ed4.1 (200106)

RMSE_{bc} = 9.16 W/m²
RMSE = 9.21 W/m²
MAE = 4.85 W/m²
ME = -0.93 W/m²
• Strange artefacts in CERES-EBAF (RSF):

Bias of CLARA-A3 TOA RSF radiation w.r.t. CERES-EBAF-Ed4.1 (200106)

RMSE-bc=7.84 W/m²
RMSE=8.37 W/m²
MAE=4.91 W/m²
ME=-2.93 W/m²
• Strange artefacts in CERES-SYN (OLR):

Bias of CLARA-A3 TOA OLR radiation w.r.t. CERES-SYNM-Ed4.1 (200106)

RMSE_{bc}=4.18 \text{ W/m}^2
RMSE=4.41 \text{ W/m}^2
MAE=2.76 \text{ W/m}^2
ME=-1.40 \text{ W/m}^2
• Strange artefacts in CERES-SYN (OLR):
• **Global spatial coverage** of each RSF daily mean (%).
Global spatial coverage of each RSF daily mean (%).
- **Global spatial coverage** of each RSF daily mean (%).

- Missing areas are filled with ERA5.

- If entire day is missing (i.e. 0% coverage), then no filling is done.
4. Validation

- **ERA5** annual mean OLR: