Developing an AVHRR-based CDR of TOA radiative fluxes within the CMSAF Project

Akkermans, T., Clerbaux, N., Ipe, A., Baudrez, E., Velazquez, A., Moreels, J.

29th CERES Science Team Meeting – May 2018

<tom.akkermans@meteo.be>
Overview

1. Introduction: CM-SAF, CLARA, radiative flux products
2. Developing the CDR: details of algorithm
3. Results and validation with CERES datasets
4. Conclusions and outlook
1. Introduction

What is CM SAF?

- Climate products from (weather) satellites
- Part of EUM ground segment
- Products target the energy and water cycles*
- 3 types of products:
  - EDR = Environmental Data Record
  - ICDR = Interim Climate Data Record
  - TCDR = Thematic Climate Data Record
- Global/regional products
- Polar and geo satellites
- User’s oriented programme: help desk, web user ordering system, users training events, ...
- Operational: annual quality ass., Review, operation reviews, ...
- Guidance from a steering group, visiting scientist programme, ...

(*) The energy and water cycles:
- TOA and surface radiation
- Cloud properties
- TCWV + profiles
- HOAPS retrieval (SSMI)
- Precipitation
- Aerosol
- Surface albedo, LST, latent/sensible heat fluxes

Tom Akkermans

Developing an AVHRR-based CDR of TOA radiative fluxes within the CMSAF Project
1. Introduction

Meteosat instruments used in CMSAF for TOA radiation products:

- Broadband radiometer: GERB *(channels TOT+SW, 44x44km)*

Current TOA radiation products in the CMSAF:

- MVIRI/SEVIRI ed01 data record *(Urbain et al., 2017)*:
  - Long data record 1982-2015
  - GERB used “offline”
  - Released January 2017
  - Resolution 0.05°x0.05°

- GERB/SEVIRI ed02 data record *(Clerbaux et al., 2017)*:
  - Feb. 2004 - April 2015
  - Drift corrected
  - All sky and clear sky fluxes
  - Just released, 21 Sept. 2017
  - Resolution 0.1°x0.1°
What is CLARA? “CM SAF cLoud, Albedo and RAdiation dataset from AVHRR data” (=Similar to Patmos-X)

- Only polar orbiting satellites NOAA and MetOp
- FCDR from NOAA (Heidinger et al.,2010)
- Currently released versions:
  - CLARA-A1 (Karlsson et al.,2013): 1982-2009 i.e. 28yr
  - CLARA-A2 (Karlsson et al.,2017): 1982-2015 i.e. 34yr; +improved FCDR
- Some of the modifications in upcoming version CLARA-A3:
  - Inclusion of AVHRR-1 sensor (TIROS-N, NOAA-6, -8, -10): extension of time range to 1978-2019 i.e. 42yr
  - Updated FCDR, from Fiduceo project (http://www.fiduceo.eu)
  - Updated cloud treatment algorithms (NWCSAF/PPS v.2018; Karlsson et al.)
  - Addition of new product “TOA radiative fluxes” -> this presentation
2. Development of algorithm

**PART 1**
- **Land use map**
  - 1. USGS
  - 2. IGBP
- **AVHRR NB reflectances**
- **Cloud mask**
  - 1. Binary (classic)
  - 2. Probabilistic

**AVHRR**
- **NB-to-BB**
  - BB reflectance
  - BB radiance

**ADM’s**
- BB flux
- BB albedo

**PART 2**
- **Spatial aggreg. regridding 0.25°**
  - 1. Simple/fast: reproject pixel centre
  - 2. Complex: reproject pixel area

**PART 3**
- **Diurnal cycle modeling**
  - Per pixel: match observed albedo with modelled diurnal cycle (5' bins) + interpolate

**PART 4**
- **Daily mean**
- **Monthly mean**
Narrowband-to-broadband conversion:
- Default: H&J, 1995 (ERBE)
- Currently in development: regression AVHRR-CERES
2. Development of algorithm

• CERES -> AQUA orbit: 700km, period 99’

• AVHRR -> NOAA19 orbit: 850km, period 102’ (slower)

Chances of having simultaneous observations will be highest with coinciding orbital plane (=similar local solar time): hence focus on these months to gather data:

• 01/2012 (NOAA19xAQUA)
• 01/2008 (NOAA18xAQUA)
• 01/2005 (NOAA17xTERRA)
Within coïnciding orbital plane:

- **AVHRR -&gt; NOAA19 orbit:**
  850km, period 102’ (slower)
- **CERES -&gt; AQUA orbit:**
  700km, period 99’ (faster)

At least once every 48 hours, the faster AQUA catches up with the slower NOAA19: close to this point, observations by both satellites have:

- Minimal time lag
- Similar viewing geometry = coangular/collocated match
2. Development of algorithm

Example of AVHRR-CERES coangular/collocated matches:

- Sun glint angle <25°: automatic exclusion of pixels
- 3D viewing angle difference >6°: automatic exclusion of pixels
- Swath width difference (2300km vs 2900km)

Number of AVHRR pixels per CERES pixel
2. Development of algorithm

- AVHRR pixels with pixel centre inside CERES SSF pixel are considered:
  - Elliptical deformation of CERES pixel along scanline is explicitly modelled, incl. impact of viewing angle and earth curvature.

- Temporal (<300s) and angular (<3°) constraints in collocation algorithm.

- Only CERES pixels with 100% surface type homogeneity
2. Development of algorithm

- NB-to-BB regression parameters for each CERES surface type
- Example: regressions for dark vegetation:

**Longwave:**

**Shortwave:**
Diurnal cycle modeling:
- Based on Young et al., 1998
- cfr. CO-method in TISA (Doelling et al., 2013)
2. Development of algorithm

Date: 20120902; Location: 30°N, -105°E

Observations

Local noon
2. Development of algorithm

Date: 20120902; Location: 30°N, -105°E

Derive climatological average diurnal albedo cycles for every CERES scene type in the pixel (in this case types #411 and #471):

OBSERVATION @ 17:20 UTC:
- Cloud cover: 14% [partly cloudy, 1-25%]
- Cloud phase: liquid
- Cloud optical thickness: 0.44 [0.1-2.5]

Observations

Diurnal cycle (colors):
- theoretical, per landuse

UTC time (hours)

Surface: dark desert
CERES scene type: 471

Surface: bright vegetation
CERES scene type: 411
Calculate weighted mean diurnal albedo cycle, depending on areal proportions of land cover:
Now we have the correct SHAPE of the diurnal cycle. To obtain the correct MAGNITUDE, we shift the weighted mean diurnal albedo cycle to match instantaneous observation (Young et al., 1998):

*Weighted mean diurnal cycle, shifted to match observation!*

*Weighted mean diurnal cycle, climatological average (!)*
Interpolate between the 4 observations following their 4 respective diurnal cycles (Young et al., 1998):

Observation Q 20:20UTC:
Cloud cover: 97% [mostly cloudy, 75-99%]
Cloud phase: ice
Cloud optical thickness: 4.6 [2.5-6.0]
2. Development of algorithm

Date: 20120902; Location: 30°N, -105°E

- SZA < 84° daytime
- SZA > 84° twilight
- SZA > 100° nighttime

Convert daytime albedo to flux

UTC time (hours)
2. Development of algorithm

PART 1

- Land use map
  1. USGS
  2. IGBP
- AVHRR NB reflectances
- Cloud mask
  1. Binary (classic)
  2. Probabilistic

- NB-to-BB
  - BB reflectance
  - BB radiance
- ADM’s
  - BB flux
  - BB albedo

PART 2

- Instantaneous swath grid

- Spatial aggreg. regridding 0.25°
  1. Simple/fast: reproject pixel centre
  2. Complex: reproject pixel area

PART 3

- Per pixel: match observed albedo with modelled diurnal cycle (5' bins) + interpolate

PART 4

- Diurnal cycle modeling
- Daily mean
- Monthly mean

- Tom Akkermans
Developing an AVHRR-based CDR of TOA radiative fluxes within the CMSAF Project
3. Results/validation

CLARA-A3 TOA SW radiation (201206)

Northern summer

Mean=97.90 W/m²
3. Results/validation

Northern autumn

CLARA-A3 TOA SW radiation (201209)

Mean=97.18 W/m²
3. Results/validation

Northern winter

CLARA-A3 TOA SW radiation (201212)

Mean = 110.05 W/m²
3. Results/validation

Northern summer

Bias of CLARA-A3 TOA SW radiation w.r.t. CERES-EBAF (201206)

ME = 2.84 W/m²; MAE = 5.10 W/m²
Developing an AVHRR-based CDR of TOA radiative fluxes within the CMSAF Project

3. Results/validation

Bias of CLARA-A3 TOA SW radiation w.r.t. CERES-EBAF (201209)

Northern autumn

ME = 3.00 W/m²; MAE = 4.61 W/m²
3. Results/validation

Bias of CLARA-A3 TOA SW radiation w.r.t. CERES-EBAF (201212)

Northern winter

ME = 2.72 W/m²; MAE = 4.86 W/m²
Developing an AVHRR-based CDR of TOA radiative fluxes within the CMSAF Project

Tom Akkermans

ADM: CERES-TRMM/-TERRA

2012-06

+2.84 W/m²

2012-09

+3.00 W/m²

2012-12

+2.72 W/m²

ADM: Suttles et al, 1988

2012-06

+0.25 W/m²

2012-09

+0.09 W/m²

2012-12

-0.40 W/m²
4. Conclusion

- Ongoing work; CLARA-A3 official release foreseen around end of 2021 (preliminary date)
- Until now, mainly the shortwave radiation is considered; the part with longwave radiation is under development (challenges due to absence of water vapor channel in AVHRR)
- Lot to learn from CERES processing; (opportunity to make use of the newest ADM’s?)
Thanks for your attention!
Extra slides
3. Results/validation

Bias of CLARA-A3 TOA SW radiation w.r.t. CERES-EBAF (201206)

Northern summer

ME=0.25 W/m²; MAE=3.42 W/m²
3. Results/validation

Northern autumn

Bias of CLARA-A3 TOA SW radiation w.r.t. CERES-EBAF (201209)

ME = 0.09 W/m²; MAE = 2.85 W/m²
Developing an AVHRR-based CDR of TOA radiative fluxes within the CMSAF Project

3. Results/validation

Bias of CLARA-A3 TOA SW radiation w.r.t. CERES-EBAF (201212)

Northern autumn

ME=-0.40 W/m²; MAE=3.22 W/m²

Map: Mollweide projection, 111x111km (GCS,W)