Surface Atmosphere Radiation Budget (SARB) working group update

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Work done after the fall 2018 CERES meeting

• Revision of SYN1deg products (Edition 4.0 to Edition 4.1).
• Producing Edition 4.1 EBAF-surface
• Producing the difference of TOA and surface irradiances between clear-sky cloud removed and clear-sky observation sampled (Loeb’s talk).
• MATCH aerosol optical thickness evaluation under partly cloudy conditions.
• Evaluation of MERRA2 and new GMAO skin temperatures, temperature profiles, and humidity profiles.
• Analysis of sea ice albedo depending on age of ice
• Comparison of deep blue and dark target aerosol optical thickness (Rutan’s talk)
• Evaluation of daily mean computed TOA and surface irradiances by 2- and 4-steram models (Ham’s talk)
• Changing MOA format (binary to HDF)
Outline of this talk

• Edition 4.1 SYN1deg and EBAF flux, aerosol, and cloud changes from Edition 4.0
• MATCH aerosol validation under partly cloudy conditions
• Evaluation of GMAO products, GEOS-5.4.1, MERRA, MERRA2, FP
  • How skin temperature bias affects surface flux computations
• Sea ice albedo
• Working in progress
  • Revision of Fu-Liou code k-distribution (with a help from Lusheng Liang)
  • C3M with Ed4 clouds and new versions of CALIPSO and CloudSat products
Edition 4.1 SYN1deg

- Edition 4.1 SYN1deg has been processed from March 2000 through September 2018 with
  - MATCH with Collection 6.1 Terra and Aqua (from July 2002)
  - Revised Himawari-8 cloud code
  - Tuning TOA fluxes to the latest TSI
  - Collection 5 MODIS from March 2000 through February 2016
  - Collection 6.1 MODIS after March 2016
  - New surface albedo history map with Collection 6 (not 6.1) MODIS BRDF product
Edition 4.1 EBAF-surface

• March 2018 is the final month of Edition 4.0
• Edition 4.1 EBAF-surface from March 2000 through September 2018 will be released soon.
Issues affecting edition 4.0 EBAF-surface

• Large changes occur in polar night cloud fraction after March 2016 due to MOIDS instrument issues

• A bug in the MODIS aerosol algorithm (Terra and Aqua dark target and deep blue) causes large differences in the aerosol optical thickness over land between collection 5 and collection 6.1.

• These problems do not affect observed TOA irradiances, but affect computed surface irradiances.
  • The effect of small compared with clear-sky adjustment but significant enough to introduce a discontinuity in clear-sky surface downward shortwave fluxes.

• Edition 4.0 EBAF-surface is available from March 2000 through March 2018.

• Edition 4.1 EBAF-surface will replace Ed4.0 for the entire record.
Edition 4.1 EBAF-surface

• Nighttime polar cloud fraction bias correction (60° to poleward) is applied from July 2003 through the end of the record to correct Terra cloud fraction.
  • Terra polar nighttime cloud fraction is adjusted to match Aqua nighttime cloud fraction.

• New Himawari 8 clouds is processed with correct input including corrected collocation of IR and VIS from July 2015.
  • Himawari-8, GOES-16, and GOES-17 are processed with the same cloud code.

• MODIS collection 6.1 aerosol optical thickness (and new surface albedo history map) is used for the entire time period.
**Terra & Aqua Ed4.1 vs Ed4.0 Changes**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>ED4.0</th>
<th>ED4.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>MODIS-collection</td>
<td>Terra-MODIS 6.7, 8.6 µm striping, March 2016 to March 2018</td>
<td>MODIS C6.1 resolved the Terra-MODIS 6.7, 8.6 µm striping</td>
</tr>
<tr>
<td>MATCH-Edition</td>
<td>Large discontinuity between MODIS C5 &amp; C6.1 AOD inputs</td>
<td>Uses MODIS C6.1 AODs as input for entire CERES record</td>
</tr>
<tr>
<td>MODIS Clouds</td>
<td>Impacted Terra cloud properties</td>
<td>Terra cloud properties corrected beginning in Feb 2016</td>
</tr>
<tr>
<td>GEO Clouds</td>
<td>Him-8, GOES-16,17, Met-8,11 cloud codes with bugs</td>
<td>Consistent cloud code using MATCH Ed4.1, begin July 2015</td>
</tr>
<tr>
<td>Surface fluxes</td>
<td>The clear-sky SW down surface flux was impacted by MODIS C5 &amp; C6.1 AOD discontinuity</td>
<td>SYN surface fluxes, computed using consistent GEO cloud code with MATCH Ed4.1 and tuned fluxes to correct GEO TOA flux</td>
</tr>
</tbody>
</table>

**Diagram Details:**
- **Terra & Aqua Ed4.1 vs Ed4.0 Changes**
- **Parameter:** Clouds, Surface Fluxes, MATCH Aerosols
- **Timeline:** 2000 to 2018
- **Key Dates:**
  - Feb 16 Terra Anomaly
  - Mar 17
  - Apr 18
- **Clouds Impact:**
  - EBAF
  - SYN1deg
  - SSF1deg
- **Surface Fluxes Impact:**
  - Terra & Aqua Ed4.1 vs Ed4.0
- **MATCH aerosols:**
  - C5, C6, C6.1
  - 4.0, 4.1

**Notes:**
- MODIS Collection
- MATCH aerosols
Ed 4.1 Sfc EBAF : Correction applied back to 2003

Time series of nighttime LW down bias correction averaged over nighttime Arctic and Antarctic

Actual bias correction is applied at a 1°×1° grid resolution

Correction is based on the nighttime cloud fraction correction applied to Terra cloud fraction correction

Assumption: nighttime monthly mean Terra cloud fraction over cryosphere is equal to the monthly mean nighttime Aqua cloud fraction
Summary of downward longwave flux bias correction

• Correction for monthly 1°×1° gridded all-sky and clear-sky surface and TOA LW fluxes due to the difference in temperature and specific humidity between AIRS and GEOS-5.4.1, using radiative kernels of Thorsen et al. (2018).

• Correction for monthly 1°×1° gridded all-sky surface LW fluxes for regions between 60° and 90° due to the difference in nighttime cloud fraction between Terra and Aqua, using radiative kernels of Thorsen et al. (2018).

• Correction for monthly 1° zonal all-sky LW fluxes based on the cloud fraction viewed from the surface derived from CALIPSO and CloudSat and MODIS and GEO-derived low-level cloud fraction, using radiative kernels of Thorsen et al. (2018).
Ed4.1 and Ed4.0 SYN1deg and EBAF-surface comparison
Aerosol optical thickness change

SfcEbfaf Ed4.0  SfcEbfaf Ed4.1y

Ed 4.0

AOT clear tune - untune

Ed4.1 – Ed4.0

Aerosol optical thickness over land

μ = 0.158  μ = 0.148  Δμ = 0.011  ρ = 0.973

σ = 0.009  σ = 0.010  0.002 / decade  -0.006 / decade  ρ_anomaly = 0.764

N = 64800  G1b mean(sd): 0.0088 (0.024)  MnMx: -0.127/0.200  N = 64800  G1b mean(sd): 0.019 (0.017)  MnMx: 0.0010/0.144
Clear-sky adjustment vs. SW difference due to aerosol difference

Adjustment is much larger than the TOA shortwave difference due to aerosol optical thickness difference. Difference over land is very small because clear-sky surface albedo is derived from CERES observations.
Clear-sky downward surface shortwave flux difference

EBAF Ed4.0 and Ed4.1 flux difference over land is largely due to aerosols.
Clear-sky downward shortwave flux change over land

SFC_SW_DN_CLR_TU Land

\[ \mu = 245.48 \quad \mu = 246.19 \quad \Delta \mu = -0.71 \quad \rho = 1.000 \]

SFC_SW_DN_CLR_TU Land Anomaly

\[ \sigma = 0.698 \quad \sigma = 0.653 \quad -0.139 \text{/decade} \quad 0.193 \text{/decade} \quad \rho_{\text{anomaly}} = 0.867 \]
Regional difference

![Graphs showing irradiance, irradiance anomaly, and aerosol optical thickness over time with statistical measures and correlation coefficients.](image)

March 2017
C5 to C6
## Ed4.0 and Ed4.1 global mean irradiances

<table>
<thead>
<tr>
<th></th>
<th>All-sky</th>
<th>Clear-sky</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ed4.1</td>
<td>Ed4.0</td>
</tr>
<tr>
<td>TOA SW insolation</td>
<td>340.0</td>
<td>340.0</td>
</tr>
<tr>
<td>SW down</td>
<td>186.6</td>
<td>187.0</td>
</tr>
<tr>
<td>SW up</td>
<td>23.3</td>
<td>23.4</td>
</tr>
<tr>
<td>SW net(^1)</td>
<td>163.3</td>
<td>163.7</td>
</tr>
<tr>
<td>LW down</td>
<td>345.0</td>
<td>345.0</td>
</tr>
<tr>
<td>LW up</td>
<td>398.3</td>
<td>398.3</td>
</tr>
<tr>
<td>LW net(^1)</td>
<td>-53.4</td>
<td>-53.4</td>
</tr>
<tr>
<td>SW+LW net</td>
<td>110.0</td>
<td>110.3</td>
</tr>
</tbody>
</table>

\(^1\) Net is defined as downward – upward
MATCH aerosols

• Evaluate MATCH aerosols under partly cloudy conditions
  • When MODIS-derived aerosols are not available, temporally and spatially interpolated MODIS-derived aerosols are used in flux computations.
  • Water up-take as a function of relative humidity for hygroscopic aerosols (sulfate, sea salt, and soluble) is included.

• Interpolated aerosols affect EBAF clear-sky flux corrections
AOD comparison with AERONET

Map shows AERONET sites grouped for validation.
## AOD comparison

<table>
<thead>
<tr>
<th>Group</th>
<th>MATCH mean</th>
<th>AERONET mean</th>
<th>Bias</th>
<th>RMS difference</th>
<th>Number of hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>China &amp; S. Korea (8 sites)</td>
<td>0.50</td>
<td>0.55</td>
<td>0.05</td>
<td>0.39</td>
<td>63844</td>
</tr>
<tr>
<td>Central Africa (6 sites)</td>
<td>0.46</td>
<td>0.54</td>
<td>-0.07</td>
<td>0.26</td>
<td>35820</td>
</tr>
<tr>
<td>West Africa (6 sites)</td>
<td>0.26</td>
<td>0.26</td>
<td>0.10</td>
<td>0.20</td>
<td>72673</td>
</tr>
<tr>
<td>Brazil (7 sites)</td>
<td>0.29</td>
<td>0.26</td>
<td>0.03</td>
<td>0.24</td>
<td>67706</td>
</tr>
<tr>
<td>India &amp; Bangladesh (8 sites)</td>
<td>0.47</td>
<td>0.52</td>
<td>-0.05</td>
<td>0.29</td>
<td>48584</td>
</tr>
</tbody>
</table>
Evaluation of GMAO products

• Compare skin temperature from reanalysis products with skin temperature derived from MODIS when clear-sky is identified by CALIPSO and CloudSat
  • CERES footprint and GMAO grids selection criteria
  • Ground track within CERES footprints is clear
  • No clouds are reported in collocated GMAO grids

• Understand how skin temperature biases affect surface irradiance computations
Evaluation of skin temperature

Near surface air temperature validation
Effect on downward longwave irradiance
Day night skin temperature comparison

Time Series of \{\text{Reanalysis} - \text{MODIS } T_{\text{skin}}\} over Africa

North Africa

Central+South Africa

\textbf{G520–MODIS G541–MODIS MERRA2–MODIS ERAI–MODIS ERA5–MODIS}
Clear-sky daytime OLR comparison, Jan., March, and July 2008
Land surface emissivity

**Zhou IASI 10.8um Jul**

- **N**: 259200
- **Emis 10.8um**: Mean (StdDev) 0.990 (0.008)

**Zhou IASI - Minnis Modis**

- **N**: 259200
- **Emis 10.8um**: Mean (StdDev) 0.001 (0.009)
Skin temperature bias
G-5.4.1 minus MODIS $T_s (\Delta T_s)$ for 2007-2010

January, April, and October 2010 daytime cloud fraction bias
Edition 4.0 MODIS – (CALIPSO+CloudSat)
Update on sea ice map

• [http://nsidc.org/data/nsidc-0051](http://nsidc.org/data/nsidc-0051), Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave Data
• IGBP = NISE (used in Ed4 production)
• CWG sea ice map from cloud working group
• Comparison using 2017 data
Difference between Sea Ice Concentrations (SICs) from NSIDC-51, IGBP, and CWG

SIC Maps
Difference between Sea Ice Concentrations (SICs) from NSIDC-51, IGBP, and CWG

SIC Difference Maps and Distributions

IGBP - NSIDC-51

CWG - NSIDC-51

Distributions of difference

FM-3 2017, IGBP vs NSIDC-51

FM-3 2017, CWG vs NSIDC-51
Summary

• Edition 4.1 EBAF-surface from march 2000 through September 2018 is produced and evaluated.
  • Significant change in shortwave surface fluxes over land especially for clear-sky conditions due to changes in the aerosol optical thickness. The difference is larger before February 2017.
  • Change in nighttime surface longwave fluxes over polar regions due to changes in polar cloud mask. Minor changes occur through February 2016 and significant changes occur from March 2016 onward.
  • Significant surface shortwave and longwave flux changes occur after July 2015 over western Pacific due to changes in cloud properties derived from Himawari-8.

• Edition 4.1 SYN1deg is produced with MODIS collection 6.1 aerosols.
• Need to revise land emissivity data in order to retrieve skin temperature and compute upward surface longwave fluxes for Edition 5.
Publications


backups
Ed 4.0 Sfc_Ebaf: No correction prior to March 2016
Maps of DLF Correction for 4 months of 2017 where magnitude of Aqua minus Terra Polar nighttime cloud fraction correction in Ed4.0 was at its peak.
Skin temperature comparison over the Arctic (Mostly over Greenland)
Skin temperature comparison over the Antarctica

Clear according to CC and the respective dataset; Snow surface