CERES Surface and Atmospheric Radiation Budget (SARB)

Overview part of CERES/ARM Science Team Meeting Nov. 2004

T. P. Charlock (NASA LaRC)
Fred G. Rose (AS&M) - algorithm
David A. Rutan (AS&M) - CAVE validation and calculation facility
Zhonghai Jin (AS&M) - coupled radiative transfer
Lisa H. Coleman, Thomas E. Caldwell, Scott Zentz (SAIC) - Data Management Team
Seiji Kato (H.U.) - modifications to operational radiative transfer
David Fillmore & Bill Collins (NCAR) - MATCH
Wenying Su (H.U.) - surface UV algorithm & balloon broadband

CRS footprint [SYN gridded] product has [will have] fluxes
at surface, 500-200-70 hPa, and TOA, cloud & aerosol forcing
[and surface UVA, UVB]
CERES Surface and Atmospheric Radiation Budget (SARB)

CRS (footprint)/SYN (gridded) product has fluxes at surface, 500-200-70 hPa, & TOA, cloud & aerosol forcing

Inputs: SSF (TOA flux, clouds, aerosols), NWP meteorology, MATCH, aerosol assimilation, NCEP O3
Langley Fu-Liou 2 stream SW
2/4 LW with Kratz-Rose window
Kato gamma-weighted \( \tau \)

Adjustments (tuning) to PW, UTH, skin T, aerosol \( \tau \),
cloud LWP/IWP, cloud fraction,& cloud height

A priori uncertainties assigned to each adjustable parameter

Minimum sum of squares of normalized differences between

(1) computed TOA fluxes & adjusted inputs
and
(2) observed TOA fluxes & initial inputs
MODIS pixels (~1km) give cloud properties in larger broadband CERES footprint

Viewing geometry of Surface and Atmosphere Radiation Budget (SARB)

Output levels at 500 hPa, 200 hPa, and TOA not drawn

70 hPa (altitude ~18 km)

cirrus

Vertical profile of fluxes (SARB) from Langley Fu-Liou code with MODIS clouds and GEOS sounding

stratus

Surface

~20-50 km
Input data for computing SARB vertical profile at ~2,000,000 footprints/day

Absolutely no ground-based radiometric data are used for input

NCEP O3(z)
Mostly from SBUV/2

70 hPa (altitude ~18 km)

MODIS ~1km pixels provide
Cloud properties (almost always)
Aerosol AOT (sometimes)
Land skin temperature (if clear)

GEOS4 T(z), q(z), surface wind
Wind speed affects ocean surface albedo

MATCH aerosols
Always used for SSA & g
Used for AOT if no MODIS AOT

Surface

~20-50 km

Large CERES footprint for TOA flux
CERES CRS: Surface and Atmosphere Radiation Budget (SARB) Product

- Tuned fluxes at all 5 levels
  - All-sky & Clear-sky, Up & Down,
  - SW and LW
- Surface & TOA also have Untuned fluxes
  - Fluxes with aerosols
  - Pristine fluxes (no aerosols)

Aerosol forcing for all-sky & clear-sky

Tuning does NOT yield a perfect match to TOA observations.

Parameters adjusted when clear:
- Skin temperature, aerosol AOT,
- precipitable water (PW)

Parameters adjusted when cloudy:
- LWP/IWP, cloud top temperature,
- cloud fractional area within footprint

~20-50km Terra
CERES SARB Aerosol Optical Thickness ($\tau_\lambda$): Daylight on 15 July 2001

Orange: Instantaneous MODIS (MOD04) Kaufman algorithm

Purple: Time interpolation from MODIS Daily Gridded Product

Blue: MATCH (which uses MODIS as one input)
Model for Atmospheric Transport and Chemistry (MATCH; Fillmore, Collins, Rasch) generates, transports, assimilates MODIS $\tau_\lambda$, and removes species with wet & dry processes.

As such models advance, application to ocean research may include aerosol deposition to ocean surface and adjustment of atmospheric correction $\tau_\lambda$ to satellite Chl.
Coupled Ocean Atmosphere Radiative Transfer (COART)

Explicit scattering in both air & sea (i.e., aerosols and phytoplankon)

Model and Observation Comparison For Ocean Surface Albedo at COVE (3-1-00 to 3-1-01)

TOA CRS vs. SARB (All Sky) 21-06-04

Similar plots are made for a number of cloud and surface conditions.

y axes: model
x axes: observations
color: population

Shortwave

Longwave

Bias = 0 Wm$^{-2}$
RMS = 8 Wm$^{-2}$

Bias = 0 Wm$^{-2}$
RMS = 4 Wm$^{-2}$

Bias = 0 Wm$^{-2}$
RMS = 11 Wm$^{-2}$

Bias = 10 Wm$^{-2}$
RMS = 25 Wm$^{-2}$

N $\sim$ 1,000,000

N $\sim$ 2,000,000
Surface sites in CAVE surface validation program

- **ARM (22 Sites)**
  - SGP(20) & TWP(2)

- **SURFRAD (7 Sites)**
  - BON, DRA, FPK, GWN, PSU, TBL, SXF

- **CMDL (7 Sites)**
  - BAR, BER, BOU, KWA, SAM, MLO, SPL

- **BSRN (12 Sites)**
  - ASP, DAA, FLO, GVN, LAU, LIN, NYA, PAY, SBO, SYO, TAM, TAT

- **Other Sites (6 Sites)**
  - SSV, COV, KAS, SIR, VAS, CAB

Surface sites in CAVE surface validation program
## SARB Surface Flux Validation
(Terra, 20 Months of CRS Ed2A)

### Downward Tuned Surface Flux Biases (Model-Obs)(W/m²)

<table>
<thead>
<tr>
<th></th>
<th>All Sky</th>
<th>Clear Sky</th>
<th>SFC Aerosol Forcing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LW</td>
<td>SW</td>
<td>LW</td>
</tr>
<tr>
<td>ARM/SGP</td>
<td>-9</td>
<td>+8</td>
<td>-10</td>
</tr>
<tr>
<td>Island Sites</td>
<td>-4</td>
<td>+33</td>
<td>-4</td>
</tr>
<tr>
<td>Polar Sites</td>
<td>-2</td>
<td>+10</td>
<td>-7</td>
</tr>
<tr>
<td>SURFRAD</td>
<td>-6</td>
<td>+13</td>
<td>-8</td>
</tr>
<tr>
<td>Coastal</td>
<td>+1</td>
<td>+15</td>
<td>+2</td>
</tr>
<tr>
<td>Validation Sites</td>
<td>-5 (24)</td>
<td>+13 (93)</td>
<td>-9 (18)</td>
</tr>
</tbody>
</table>

### Upward Tuned TOA Flux Biases (Model-Obs)(W/m²)

<table>
<thead>
<tr>
<th></th>
<th>All Sky</th>
<th>Clear Sky</th>
<th>TOA Aerosol Forcing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LW</td>
<td>SW</td>
<td>LW</td>
</tr>
<tr>
<td>ARM/SGP</td>
<td>+1</td>
<td>-0</td>
<td>0</td>
</tr>
<tr>
<td>Island Sites</td>
<td>-0</td>
<td>+4</td>
<td>-3</td>
</tr>
<tr>
<td>Polar Sites</td>
<td>+2</td>
<td>+2</td>
<td>-1</td>
</tr>
<tr>
<td>SURFRAD</td>
<td>+1</td>
<td>-0</td>
<td>-1</td>
</tr>
<tr>
<td>Coastal</td>
<td>+1</td>
<td>+9</td>
<td>0</td>
</tr>
<tr>
<td>Validation Sites</td>
<td>+1(5)</td>
<td>+2 (12)</td>
<td>-1(3)</td>
</tr>
</tbody>
</table>

* Difference model run with clouds and aerosols and model run with clouds, no aerosols.
Mismatch of surface albedo and surface insolation in SARB.

We retrieve surface albedo for clear CERES footprints ~10-100km.

Surface insolation measured at a point is affected by surface albedo.

**Clear sky:** surface albedo impact on insolation is small. Relevant albedo scale is ~10km.

**Cloudy sky:** surface albedo impact on insolation can be large. Relevant albedo scale is ~2 X cloud base height.

500 hPa at ~6km

50% of Rayleigh scattering to surface comes from above 5 km

Overcast: $d(\text{SfcAlb}) \approx 0.1 \sim d(\text{Ins}) \approx 30 \text{ Wm}^{-2}$

Not a problem at COVE sea platform, where we know the surface albedo.
COVE

CERES Ocean Validation Experiment

Rigid sea platform
Continuous
Long-term
Well calibrated
AERONET aerosol
NOAA wind and waves
BSRN surface radiation
looks DOWN at sea

At COVE:
SW up (time mean)
approximately equals
SW up (space mean)

Various short/medium term measurements:
SP1A for upwelling
SW spectral radiance
Ocean optics (ODU)
Surface Insolation at COVE
Year 2001 (Terra CRS Edition 2A)

<table>
<thead>
<tr>
<th></th>
<th>Observed</th>
<th>Bias</th>
<th>Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>All-sky</td>
<td>536</td>
<td>-8</td>
<td>214</td>
</tr>
<tr>
<td>Clear-sky</td>
<td>662</td>
<td>-2</td>
<td>14</td>
</tr>
</tbody>
</table>

Bias = (Retrieved - Observed)
CAVE Homepage

http://www-cave.larc.nasa.gov/cave
SW uses HITRAN 2000 (Rose-Kato)

On line Fu-Liou radiative transfer

Google “CERES CAVE” www.cave.larc.nasa.gov/cave/
On line Coupled Ocean Atmosphere Radiative Transfer (Zhonghai Jin)

SW spectral radiances and fluxes

Coupled Ocean and Atmosphere Radiative Transfer (COART)

This is a tool for you to calculate the radiances and irradiances (flux) at any levels in the atmosphere and ocean. Specify the input parameters simply by clicking the buttons and changing the default numbers in the table. More information here.

Select calculation type and Output levels:

- Spectral fluxes (irradiances) (up and down) (W/m²·um) at a single wavelength: 9.55 um
- Spectral fluxes (W/m²·um) at multiple wavelengths from 0.4 um to 0.7 um at every 0.05 um.
- Integrated fluxes (W/m²) from 3.4 um to 0.7 um in spectral resolution of 0.01 um. Filter: Flat (No filter) -
- Broadband shortwave (0.25–4 µm) fluxes (W/m²). (It's under working, not implemented yet!)
- Radiances (W/m²·um/Sr) at wavelength: 0.55 um.
- Radiances (W/m²·um/Sr) at multiple wavelengths from 0.40 um to 0.50 um at every 0.15 um.
- Want to include the Water-leaving radiance output? 
- Yes
- Radiance output directions: at Zenith (deg) 30.0 OR All computational zenith angles
- Azimuth (deg): 30.0 OR at every 30.0 (deg) from 0.0 to 360.0

*Note: Computation time is not related to the number of output angles here. How the angles are defined?

Output at: FTA, Surface, 1.0 km above surface, and 1.0 m below surface, OR All levels in atmosphere.

Solar Zenith Angle Calculations

Julian Day: 30
GMT (hour): 8.550
Latitude (deg N): 36.91
Longitude (deg E): 75.71

When checked, ignore Time and Location above and input your Solar Zenith Angle (deg):

Atmosphere

Select an atmospheric model: Mid-Latitude Summer

When checked, use reduced number of atmospheric layers to save computation time (not recommended for UV).
On line Coupled Ocean Atmosphere Radiative Transfer

Select aerosol optical properties

Select wind speed chlorophyll phase function
CLAMS: Chesapeake Lighthouse and Aircraft Measurements for Satellites  July 2001  CERES-MODIS-MISR-GACP

(Bill Smith Jr.’s Flying Circus)
Comparison of modeled and aircraft measured spectral albedo over COVE.
Broadband ocean albedo (color contours) versus wind speed (vertical axes) and cosSZA (horizontal axes) using the LUT.
Change in Tegen and Lacis dust properties

- Significantly less absorption
- More backward scatter in visible.
### Instantaneous All Sky Mean(RMS) All Wm⁻²

<table>
<thead>
<tr>
<th></th>
<th>LW Up</th>
<th>TOA</th>
<th>SW Up</th>
<th>TOA</th>
<th>LW Down Sfc</th>
<th>SW Down Sfc</th>
<th>LW Up Sfc</th>
<th>SW Up Sfc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edition 2A</td>
<td>Untuned</td>
<td>Tuned</td>
<td>Untuned</td>
<td>Tuned</td>
<td>Untuned</td>
<td>Tuned</td>
<td>Untuned</td>
<td>Tuned</td>
</tr>
<tr>
<td></td>
<td>+1(8)</td>
<td>+1(5)</td>
<td>+4(22)</td>
<td>+2(9)</td>
<td>-4(25)</td>
<td>-4(25)</td>
<td>+12(85)</td>
<td>+13(87)</td>
</tr>
<tr>
<td>Edition 2B</td>
<td>+1(8)</td>
<td>+1(5)</td>
<td>+6(22)</td>
<td>+2(8)</td>
<td>-4(25)</td>
<td>-5(25)</td>
<td>+13(85)</td>
<td>+17(87)</td>
</tr>
</tbody>
</table>

### Instantaneous Clear Sky Mean(RMS) All Wm⁻² [clear - imager CF = 0.0]

<table>
<thead>
<tr>
<th></th>
<th>LW Up</th>
<th>TOA</th>
<th>SW Up</th>
<th>TOA</th>
<th>LW Down Sfc</th>
<th>SW Down Sfc</th>
<th>LW Up Sfc</th>
<th>SW Up Sfc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edition 2A</td>
<td>Untuned</td>
<td>Tuned</td>
<td>Untuned</td>
<td>Tuned</td>
<td>Untuned</td>
<td>Tuned</td>
<td>Untuned</td>
<td>Tuned</td>
</tr>
<tr>
<td></td>
<td>-1(6)</td>
<td>-1(5)</td>
<td>+3(8)</td>
<td>+1(3)</td>
<td>-9(19)</td>
<td>-9(19)</td>
<td>+1(32)</td>
<td>+1(31)</td>
</tr>
<tr>
<td>Edition 2B</td>
<td>+1(8)</td>
<td>+1(5)</td>
<td>+6(22)</td>
<td>+2(8)</td>
<td>-4(25)</td>
<td>-5(25)</td>
<td>+13(85)</td>
<td>+17(87)</td>
</tr>
</tbody>
</table>

### Instantaneous Overcast Sky Mean(RMS) All Wm⁻² [overcast - imager CF = 1.0]

<table>
<thead>
<tr>
<th></th>
<th>LW Up</th>
<th>TOA</th>
<th>SW Up</th>
<th>TOA</th>
<th>LW Down Sfc</th>
<th>SW Down Sfc</th>
<th>LW Up Sfc</th>
<th>SW Up Sfc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edition 2A</td>
<td>Untuned</td>
<td>Tuned</td>
<td>Untuned</td>
<td>Tuned</td>
<td>Untuned</td>
<td>Tuned</td>
<td>Untuned</td>
<td>Tuned</td>
</tr>
<tr>
<td></td>
<td>+0(9)</td>
<td>+1(4)</td>
<td>+10(31)</td>
<td>+1(12)</td>
<td>-5(24)</td>
<td>-6(25)</td>
<td>+15(90)</td>
<td>+25(97)</td>
</tr>
<tr>
<td>Edition 2B</td>
<td>+1(9)</td>
<td>+1(4)</td>
<td>+12(29)</td>
<td>+2(9)</td>
<td>-5(24)</td>
<td>-6(25)</td>
<td>+17(90)</td>
<td>+30(96)</td>
</tr>
</tbody>
</table>

LW – Day and night footprints.
SW – Day time only (not a 24 hour average).
Change in Surface Albedo

Surface Albedo Mar 2000 Ed2B–Ed2A

Mean = 0.00
Stddev = 0.02
Count = 44012
SARB vs. MODIS Albedo Jul 2001

SARB

MODIS

Overhead Sun Surface Albedo
Click “Balloon” from CAVE URL

Wenying Su’s deployment of Haeffelin modified radiometers

Failed launch from Alice Springs, Australia