Terra CRS Results and Status  
CERES/GERB Science Team Meeting  
NCAR, Boulder 29 March 2004

Surface and Atmosphere Radiation Budget (SARB) group:  
T. P. Charlock (NASA LaRC)  
Fred G. Rose (AS&M)  
David A. Rutan (AS&M) – validation and “CAVE” URL  
Zhonghai Jin (AS&M) - coupled radiative transfer  

Lisa H. Coleman, Thomas E. Caldwell, Scott Zentz (SAIC)  
- Data Management Team

Seiji Kato (H.U.) – his Gamma Weighted 2-stream is latest code advance  
David Fillmore and Bill Collins (NCAR) - MATCH

Wenying Su (H.U.)- developing surface UV in gridded “SYN” product

Access to CAVE on line surface and CERES validation,  
point and click Fu-Liou and COART calculations:  
www-cave.larc.nasa.gov/cave/ or goggle “CERES CAVE”
Tuesday: Joint meeting of TISA/SOFA/SARB Working Groups

TISA: Temporal Interpolation and Spatial Averaging (Young)
SOFA: Surface-Only Flux Algorithms (Kratz)
SARB: Surface and Atmosphere Radiation Budget

Agenda: Development of the gridded “SYN” (3-hourly)

Dave Young - TISA input for SYN
Fred Rose - SARB broadband radiative transfer for 3-hourly flux
Wenying Su - New CERES surface UV for bio-medical applications
Zhonghai Jin - Spectral properties of cryosphere
Wenying Su - Ultra-long Duration Balloon (ULDB) report

Reserve - Anand Inamdar on water vapor greenhouse
CERES CRS: Surface and Atmosphere Radiation Budget (SARB) Product

Tuned fluxes at all 5 levels
- All-sky & Clear-sky both Up & Down
- SW, LW, 8-12.5um non-CERES Window
- Surface & TOA also have Untuned fluxes & Pristine (no aerosol) fluxes for SW&LW aerosol forcing (includes cloud effect)
- Emulated 8-12um CERES Window at TOA
- Photosynthetically Active Radiation (here as 437.5-689.6nm) at surface
- Tuning does NOT yield a perfect match to TOA observations.

- Parameters adjusted when clear:
  - Skin temperature, aerosol AOT, lower & upper tropospheric humidity

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

Instantaneous, geolocated at surface, ungridded
MODIS pixels (~1km) give cloud properties in larger broadband CERES footprint.

Viewing geometry and vertical profile of SARB fluxes

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

70 hPa (altitude ~18 km)

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

Impact of cirrus to flux at X is missed in this example. Next footprint to left sees cirrus but misplaces it from X.
Input data for computing SARB vertical profile at ~2,000,000 footprints/day

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

NCEP O3(z)
Mostly SBUV/2

GEOS4 T(z) and q(z)
Wind speed affects ocean surface albedo
Land skin temperature when cloudy

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

Large CERES footprint (geolocated at surface) for TOA flux

MODIS pixels (~1 km) provide
cloud properties (almost always)
aerosol AOT (sometimes)
land skin temperature (when clear)

Surface

70 hPa (altitude ~18 km)

~20-50 km
Initial surface albedo for cloudy footprints (1 January 2001).

Land: Based on look up table of the whole month’s clear footprints
Ocean: Based on Jin’s Coupled Ocean Atmosphere Radiative Transfer
Google “CERES CAVE”: fruitful domain of David Rutan

- Ground data to validate retrievals
- To other web pages of this talk
- Run our codes on line

www-cave.larc.nasa.gov/cave/
Sources of Aerosol Optical Thickness (AOT): 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)
### Assignment of aerosol characteristics

<table>
<thead>
<tr>
<th>MATCH aerosol type</th>
<th>CRS aerosol optics</th>
<th>scale height</th>
</tr>
</thead>
<tbody>
<tr>
<td>dust (0.01-1.0 µm)</td>
<td>1. dust (0.5 µm) Tegen-Lacis</td>
<td>3.0 km</td>
</tr>
<tr>
<td>dust (1-10 µm)</td>
<td>2. dust (2.0 µm) Tegen-Lacis</td>
<td>1.0 km</td>
</tr>
<tr>
<td>dust (10-20 µm)</td>
<td>2. dust (2.0 µm) Tegen-Lacis</td>
<td>1.0 km</td>
</tr>
<tr>
<td>dust (20-50 µm)</td>
<td>2. dust (2.0 µm) Tegen-Lacis</td>
<td>1.0 km</td>
</tr>
<tr>
<td>hydrophilic black carbon</td>
<td>3. soot (OPAC)</td>
<td>3.5 km</td>
</tr>
<tr>
<td>hydrophobic black carbon</td>
<td>3. soot (OPAC)</td>
<td>3.5 km</td>
</tr>
<tr>
<td>hydrophilic organic carbon</td>
<td>4. soluble organic (OPAC)</td>
<td>3.8 km</td>
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<tr>
<td>hydrophobic organic carbon</td>
<td>5. insoluble organic (OPAC)</td>
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<tr>
<td>sulfate</td>
<td>6. sulfate (OPAC)</td>
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<tr>
<td>sea salt</td>
<td>7. sea salt (OPAC)</td>
<td>0.5 km</td>
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</table>

Input from MATCH (Fillmore and Collins) 15 July 2001
Contributing Projects

- **ARM – Atmospheric Radiation Measurement**
  The Department of Energy’s Atmospheric Radiation Measurement (ARM) project supplies CAVE a number of surface observations at 23 different locations. There are 21 sites in and around Kansas and Oklahoma, and two on the islands of Nauru and Manus in the Tropical West Pacific Ocean.

- **BSRN – Baseline Surface Radiation Measurement**
  The BSRN project is an international effort to obtain long-term high-quality surface observations of downwelling broadband radiation. We are downloading data for 4 sites around the globe.

- **CMDL – Climate Monitoring & Diagnostics Laboratory**
  The National Oceanic & Atmospheric Association (NOAA) CMDL supplies a high-quality data set of primarily downwelling radiation from a number of remote sites around the globe.

- **SURFRAD – Surface Radiation Budget**
  SURFRAD supplies a complete set of radiation and surface meteorology from 6 sites located within the US. These sites provide a reliable data set of both upwelling & downwelling radiation, and located in a diverse set of surface vegetation types.

- **Independent Sites**
  INDOEX – Indian Ocean Experiment

www-cave.larc.nasa.gov/cave/
All-sky Untuned Wm-2: Terra Ed2A (ValR2 for review) and TRMM Ed2B (released)

TRMM (low latitude) Edition 2B instantaneous snapshots

VIRS (sea) and MATCH (uses AVHRR) aerosols

Terra (global) Edition 2A instantaneous snapshots

MODIS (sea and land) and MATCH aerosols; better SW code

Surface (SFC) observations as 30-minute (half hour) intervals

~40 CAVE sites (ARM, BSRN, SURFRAD, COVE)

<table>
<thead>
<tr>
<th></th>
<th>Terra Observed (Wm-2)</th>
<th>N</th>
<th>Bias (Wm-2)</th>
<th>TRMM Observed (Wm-2)</th>
<th>N</th>
<th>Bias (Wm-2)</th>
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<tbody>
<tr>
<td>LW down SFC</td>
<td>290</td>
<td>7727</td>
<td>-5</td>
<td>358</td>
<td>5571</td>
<td>-2</td>
</tr>
<tr>
<td>LW up SFC</td>
<td>360</td>
<td>5556</td>
<td>-3</td>
<td>425</td>
<td>3992</td>
<td>-3</td>
</tr>
<tr>
<td>SW down SFC</td>
<td>488</td>
<td>3939</td>
<td>9</td>
<td>451</td>
<td>3244</td>
<td>29</td>
</tr>
<tr>
<td>SW up SFC</td>
<td>114</td>
<td>2756</td>
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<td>92</td>
<td>2348</td>
<td>-13</td>
</tr>
<tr>
<td>LW up TOA</td>
<td>222</td>
<td>8028</td>
<td>1</td>
<td>253</td>
<td>6122</td>
<td>-2</td>
</tr>
<tr>
<td>SW up TOA</td>
<td>271</td>
<td>3879</td>
<td>2</td>
<td>215</td>
<td>3355</td>
<td>-6</td>
</tr>
</tbody>
</table>

Terra here 6 months in 2001  TRMM here 8 months in 1998
All-sky Untuned Wm-2: Terra Ed2A (ValR2 for review) and TRMM Ed2B (released)

TRMM (low latitude) Edition 2B instantaneous snapshots

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<th>TRMM</th>
<th></th>
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<tr>
<td></td>
<td>Observed</td>
<td>N</td>
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Surface insolation bias for new Terra (9 Wm-2) is much better than old TRMM (29 Wm-2).

But surface reflection is highly biased in Terra and TRMM.
Terra Ed2A (ValR2 for review) Untuned Bias/RMS for All sky and Clear sky
January, February, March, April, July and October 2001

Bias = Mean (Calculation - Observation)

RMS = (1/N)*\( \sqrt{\sum (\text{Calculation} - \text{Observation})^2} \)

Surface (SFC) observations as 30-minute (half hour) intervals

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<table>
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<th>All sky</th>
<th>Clear sky</th>
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<tr>
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Terra Ed2A (ValR2 for review) Untuned Bias/RMS for All sky and Clear sky

January, February, March, April, July and October 2001

Bias = Mean (Calculation - Observation)

RMS = \((1/N)*(\text{SQRT} \sum (\text{Calculation} - \text{Observation})^2)\)

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RMS is huge (82 Wm-2) for all-sky SW downwelling at the surface. The surface radiometer is located at a single point in the big ~20-50km footprint. The distance to the centroid (relative position of the surface radiometer) changes every day; so does the footprint size and viewing geometry.
We retrieve surface albedo for clear CERES footprints ~20-50km.

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

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

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

Overcast: \( \Delta(\text{Sfc.Alb.}) \) 0.1 \( \sim \Delta(\text{Ins.}) \) 30 Wm-2

500 hPa at ~6km
50% of Rayleigh scattering to surface comes from above 5 km

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

Cloud base 2km
Bias for untuned clear-sky surface insolation is very small when averaged over 40 sites for 6 months. RMS error is 25 Wm-2. Mean aerosol forcing to insolation is -25 Wm-2.
Mean bias for untuned clear-sky downwelling LW at the surface is -8.70 Wm-2 in the new Terra Ed2A (ValR2) using GEOS4. The old Terra Beta5 using ECMWF was better for downwelling LW.
The bias in downwelling LW at the surface is reduced for all-sky conditions in the new Terra Ed2A (ValR2) using GEOS4, but the earlier version (Beta5 using ECMWF) was slightly better. Is GEOS4 too moist near the surface?
Both the new Ed2A (ValR2) using GEOS4 and the old Beta5 using ECMWF have small biases for clear-sky upwelling LW at the surface. Over land, the skin temperature for clear footprints is taken from the Cloud WG, which uses MODIS.
## Impact of Constrainment (Tuning) at TOA for Terra Ed2A (ValR2)

January, February, March, April, July and October 2001

Bias = Mean (Calculation - Observation)

\[ \text{RMS} = \frac{1}{N} \sqrt{ \sum (\text{Calculation} - \text{Observation})^2 } \]

Surface (SFC) observations as 30-minute (half hour) intervals

~40 CAVE sites (ARM, BSRN, SURFRAD, COVE)

<table>
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<tr>
<th>All sky fluxes</th>
<th>Untuned</th>
<th>Tuned (Constrained)</th>
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<tr>
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</tr>
<tr>
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<tr>
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<td>9</td>
</tr>
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</tr>
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</table>

Clear tuning: Adjust PW, UTH, skin temperature, land albedo/ocean AOT
Cloudy tuning: Adjust cloud fraction, optical depth, altitude
**Impact of Constrainment** (Tuning) at TOA for Terra Ed2A (ValR2)

January, February, March, April, July and October 2001

Bias = Mean (Calculation - Observation)

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</tr>
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</table>

By design, constrainment (or tuning) reduces the RMS error, and generally the bias, with respect to TOA observations. It has little impact on the mean bias at the surface. The comparison with surface radiometric data is a totally “cold” test for CERES SARB.
Gross, global scale evaluation at TOA only

Table of raw mean TOA parameters for CRS Terra Edition 2
SW statistics are daylight-only means
Other statistics are 24-hour means

<table>
<thead>
<tr>
<th></th>
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<th></th>
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</thead>
<tbody>
<tr>
<td>SW reflected in Wm-2</td>
<td>252.6</td>
<td>239.7</td>
<td>223.4</td>
<td>243.8</td>
</tr>
<tr>
<td>Untuned bias (std. dev.)</td>
<td>7.3 (23.2)</td>
<td>5.0 (23.0)</td>
<td>5.7 (22.4)</td>
<td>6.1 (23.8)</td>
</tr>
<tr>
<td>Tuned bias (std. dev.)</td>
<td>1.1 (10.9)</td>
<td>0.6 (10.6)</td>
<td>2.0 (10.4)</td>
<td>0.6 (10.3)</td>
</tr>
<tr>
<td>OLR in Wm-2</td>
<td>223.1</td>
<td>222.0</td>
<td>229.1</td>
<td>222.7</td>
</tr>
<tr>
<td>Untuned bias (std. dev.)</td>
<td>0.1 (8.0)</td>
<td>0.4 (8.7)</td>
<td>0.2 (8.1)</td>
<td>0.3 (8.5)</td>
</tr>
<tr>
<td>Tuned bias (std. dev.)</td>
<td>0.2 (4.5)</td>
<td>0.5 (4.8)</td>
<td>0.2 (4.3)</td>
<td>0.4 (4.5)</td>
</tr>
<tr>
<td>Window 8-12µm in Wm-2</td>
<td>57.3</td>
<td>57.6</td>
<td>61.1</td>
<td>58.1</td>
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<tr>
<td>Untuned bias (std. dev.)</td>
<td>0.7 (3.6)</td>
<td>0.6 (3.7)</td>
<td>0.6 (3.8)</td>
<td>0.5 (3.5)</td>
</tr>
<tr>
<td>Tuned bias (std. dev.)</td>
<td>0.7 (2.3)</td>
<td>0.6 (2.6)</td>
<td>0.6 (2.4)</td>
<td>0.5 (2.4)</td>
</tr>
<tr>
<td>LW broadband radiance in Wm-2sr-1</td>
<td>72.9</td>
<td>72.6</td>
<td>75.0</td>
<td>72.8</td>
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<tr>
<td>Untuned bias (std. dev.)</td>
<td>-0.2 (2.6)</td>
<td>-0.1 (2.8)</td>
<td>-0.1 (2.6)</td>
<td>-0.1 (2.8)</td>
</tr>
<tr>
<td>Tuned bias (std. dev.)</td>
<td>-0.2 (1.5)</td>
<td>-0.1 (1.6)</td>
<td>-0.1 (1.4)</td>
<td>-0.1 (1.5)</td>
</tr>
</tbody>
</table>
Bias in Daytime OLR (Untuned calculation - Observed) 1 October 2001

scale -15 to +15 Wm-2

Bias for 24-hour OLR is 0.53 Wm-2 (1.14 Wm-2 for footprints with less than 5% cloud)
Bias in Reflected SW at TOA (Untuned calculation - Observed)  

1 October 2001

scale -50 to +50 Wm-2

Biases over the ocean:  Overcast (10.4 Wm-2)  Partly cloudy (5.1 Wm-2)  Clear (0.1 Wm-2)
SW bias (Untuned - Observed) for Ocean Only versus Clear Percentage (1 Oct 2001)

Lots of overcast and bias
**Overcast Ocean**: Untuned SW (y) vs. Observed SW (x) for 15 July 2001

Seiji’s Gamma weighted 2-stream reduces RMS error:

**Beta 5** (old SW code)

bias/rms = 6/34 Wm-2

**ValR2/Ed2a** (new SW code)

bias/rms = 11/26 Wm-2

Tuned bias/rms = 0/14 Wm-2

Tuned bias/rms = 2/10 Wm-2
Partly Cloudy Ocean: Untuned SW (y) vs. Observed SW (x) for 15 July 2001

**Beta 5** (old SW code)

bias/rms = -2/22 Wm-2

**ValR2/Ed2a** (new SW code)

bias/rms = 7/22 Wm-2
Assumed single scattering albedo for dust is too small. This causes huge biases for SW over deserts.
COVE  Ken Rutledge

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)
SW for all-sky conditions of CERES multi-angle Field of View (FOV) Terra overpasses at COVE from 7.8.01 to 8.2.01. Observations, model biases, and modeled forcings.

<table>
<thead>
<tr>
<th>CERES FOV Average (several snapshots on each of 18 days)</th>
<th>N FOVs</th>
<th>TOA Wm-2</th>
<th>Surface Wm-2</th>
<th>Direct Wm-2</th>
<th>Diffuse Wm-2</th>
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<tbody>
<tr>
<td>Observations</td>
<td>282</td>
<td>180</td>
<td>812</td>
<td>546</td>
<td>267</td>
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<tr>
<td>Model (MODIS $\tau$)</td>
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<td>RMS error</td>
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<td>21</td>
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<td>101</td>
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<td>Model (AERONET $\tau$)</td>
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<td><strong>Day Average (1 sample = mean of snapshots during 1 day)</strong></td>
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<td>Model (MODIS $\tau$)</td>
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<td>Model Forcings (MODIS $\tau$)</td>
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<td>Aerosol forcing to clear sky</td>
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<td>Aerosol forcing to all sky</td>
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<td>-31</td>
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This off line test uses CERES Programmed Azimuth Pattern for Scan.
This routine production uses along-track CERES scans. SW biases are large. Is this due to sunglint? LW is biased because of the SST and sounding reported over this coastal site.
Tuning over COVE does reduce the bias for surface insolation.
Concluding remarks on Terra Edition 2A / ValR2

CRS Terra ValR2 is acceptable for release as Terra Edition 2A

Bias in surface insolation is much reduced from 1998 TRMM Edition 2B

While aerosol forcing is generally interesting, it’s a disaster with dust. Our dust absorbs too much. Our retrieved surface albedo over desert is not realistic. Dust absorption will be reduced in the next version.

TOA SW bias is slightly higher than TRMM because Terra covers the overcast-laden baroclinic zones.

Bias for surface downwelling LW is larger than TRMM. This may be due to GEOS4 soundings (vs. ECMWF in TRMM).
Launch #1 (from Alice Springs) crashed. We prepare for #2.

Click “Balloon” from CAVE URL

Wenying Su’s deployment of Haeffelin modified radiometers

This slide and next show what can be done with TRMM SARB.

Cloud forcing to LW “convergence” (Surface to 500hPa) April 1998

All sky LW convergence is generally negative.

Gridded “FSW Beta3” = hourly mean of ungridded “CRS Ed2B”

Gridding here does not account for diurnal effects, but should give reasonable estimate for LW during this month.
Cloud Forcing to LW Convergence (Surface-500hPa)
crude mean = 7 Wm-2
range -50 to +50 Wm-2

Much of the LW cooling occurs in the lower troposphere.

Clouds (above) account for little of the gross mean cooling (the all-sky convergence below), but clouds strongly affect the geographical variation.

Relationship to dynamics and latent heating on the next page…

All Sky LW Convergence (Surface-500hPa)
crude mean = -117 Wm-2
range -170 to -70 m-2
Cloud Forcing
LW Conv  Sfc-500hPa
crude mean = 7 Wm-2
range  -50 to +50 Wm-2

Omega at 700 hPa
red = ascent
NCEP/NCAR  April 98

Precipitation expressed
as Diabatic Heating
mean = 89 Wm-2
range  0 to 500 Wm-2

All Sky
LW Conv  Sfc-500hPa
crude mean = -117 Wm-2
range  -170 to -70 m-2