CRS, the CERES Footprint-scale
Surface and Atmosphere Radiation Budget (SARB)
Clouds and the Earth’s Radiant Energy System (CERES)
Science Team Meeting (GISS, New York City, 27-29 October 2008)

T. P. Charlock (NASA LaRC)
Fred G. Rose (SSAI) speaks later on SYNI, the “Synoptic” SARB
David A. Rutan (SSAI) Surface validation with CAVE
Zhonghai Jin (SSAI) Coupled Ocean Atmosphere Radiative Transfer (COART)
Wenying Su (SSAI) UV, PAR algorithms and comparison with GCMs
Seiji Kato (LaRC) Co-I talk on “super” SARB with Calipso/CloudSAT
Thomas E. Caldwell, Lisa H. Coleman (SSAI) - Data Management
David Fillmore (Boulder) provides MATCH aerosol assimilation

**Bold font** marks co-authors who could not attend meeting

SARB/SOFA Working Group Tuesday Morning:
Discussion/validation of SYN Beta4 (gridded & diurnal, CERES+geostationary)

[www-cave.larc.nasa.gov/cave/](http://www-cave.larc.nasa.gov/cave/) or google “CERES CAVE”
Easy to use subsets of data, on line radiative transfer, ocean albedo tables…
Ungridded SARB vertical profile at ~2,000,000 CRS footprints/day

Langley Fu-Liou radiative transfer: Kato 2005 SW upgrade, Kratz-Rose LW window

70 hPa (altitude ~18 km)

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

NCEP O3(z)
Mostly from SBUV/2

GEOS4 T(z), q(z), surface wind
Jin ocean surface albedo = f(wind)

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

Large CERES footprint for TOA flux

Surface

~20-50 km

David Fillmore

MINNIS modis

GSFC NWP

Modis Atmosphere Team

Matthews

Loeb

Priestley

Wielicki
Aqua CRS Ed2B and Ed2C (Jul02-Dec06) within 25 km of ARM SGP sites  
Daytime-Only analysis below  
All rows in table have 71191 samples (mean cloudiness 48%)

<table>
<thead>
<tr>
<th></th>
<th>Observed (W/m**2)</th>
<th>Untuned Bias</th>
<th>Untuned RMS</th>
<th>Tuned Bias</th>
<th>Tuned RMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOA SW up</td>
<td>268</td>
<td>4</td>
<td>26</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>OLR</td>
<td>255</td>
<td>-2</td>
<td>9</td>
<td>-1</td>
<td>5</td>
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<tr>
<td>SW SFC down</td>
<td>589</td>
<td>8</td>
<td>101</td>
<td>15</td>
<td>102</td>
</tr>
<tr>
<td>SW SFC up</td>
<td>115</td>
<td>-20</td>
<td>48</td>
<td>-17</td>
<td>47</td>
</tr>
<tr>
<td>LW SFC down</td>
<td>345</td>
<td>-12</td>
<td>19</td>
<td>-12</td>
<td>19</td>
</tr>
<tr>
<td>LW SFC up</td>
<td>444</td>
<td>-8</td>
<td>30</td>
<td>-6</td>
<td>28</td>
</tr>
</tbody>
</table>

54639 samples report clouds (mean cloudiness then 63%).  
Tuning assigns a priori uncertainties to cloud parameters and TOA fluxes,  
then solves for minimum least squares adjustment. Similar for clear sky.

Observed cloud parameters from Minnis MODIS SSF:  
MODIS    Tuned    RMS  (N = 54639)

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Cloudiness (%)</td>
<td>63.8</td>
<td>63.8</td>
</tr>
<tr>
<td>Cloud top temperature (K)</td>
<td>264</td>
<td>264</td>
</tr>
<tr>
<td>Cloud optical depth</td>
<td>12.1</td>
<td>11.5</td>
</tr>
</tbody>
</table>
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
Evaluation of Cloud Effect Profile in HadGAM1 GCM with TRMM SARB

Profiles of All-sky SW Downwelling

Black = CERES SARB
Grey = HadGAM1

From analysis of SW and LW profiles for all-sky and clear-sky fluxes...

Above 200 hPa: HadGAM1 produces more clouds than CERES

From 200-500 hPa: HadGAM1 underestimates average cloud height

Below 500 hPa: HadGAM1 and CERES generally agree for cloud effects

SURFACE ALBEDO
Terra CRS Edition 2B and MODIS 5km MCD32C2 versus Measurements at 14 land surface sites during four months in 2001

CERES footprint ~ 30km
MODIS product 5km
Ground tower ~ 10m

Here MODIS product is scaled up to approximate CERES footprint.

SARB surface albedo is then ~2% darker than MODIS.
CERES retrieval of surface albedo catches the large interannual variability at Fort Peck:

Cloud forcing and aerosol forcing are useful diagnostic quantities.

What about Surface Albedo Forcing in Edition 3?

A tool to assess the causes of long-term variations to TOA albedo, (i.e., in regions with seasonal snow cover).
GTSRT Calculation at Fort Peck, Montana

GTSRT is a test SW calculation with 18 SW bands.

March 2000 to June 2005

Surface Albedo Forcing = (Regular calculation) - (Calculation with zero surface albedo)
Forcing to SFC
All-sky Down (W/m**2)

GTSRT Calculation at Fort Peck

Surface Albedo
Aerosol
Cloud

March 2000 to June 2005

Surface Albedo Forcing = (Regular calculation) - (Calculation with zero surface albedo)
Surface albedo explains half of the variance at Fort Peck.

Surface Albedo Forcing = (Regular calculation) - (Calculation with zero surface albedo)
Cloud forcing explains most of the variance of transmission at Fort Peck.

Surface Albedo Forcing = (Regular calculation) - (Calculation with zero surface albedo)
Correlation of Observed TOA Albedo with Calculations (Deseasonalized)

Barrow, Alaska

Surface albedo and cloud forcing are more confused when footprint mixes land and ocean.

Deseasonalized TOA Albedo Terra SSF Ed2B

Surface Albedo Forcing = (Regular calculation) - (Calculation with zero surface albedo)
A Global Test for One Day…

Zonal Mean TOA Albedo at Aqua Overpass (20060513)

Untuned SARB calculations done two ways

- CRS Ed 2C (production run)
- Zero Surface Albedo (run with surface albedo = 0.001)

Solid = All sky

Dashed = Clear sky
Forcing to Zonal Mean TOA Albedo at Aqua Overpass (20060513)

Untuned SARB Calculations

**Cloud Forcing** in CRS Ed 2C (production run)

**Cloud Forcing** in Zero Surface Albedo (run with surface albedo = 0.001)

Surface Albedo Forcing = (All sky Ed 2C) - (All sky Zero Surface Albedo)
Introduce Surface Albedo Forcing in Edition 3

Tool to assess the causes of long-term variations to TOA albedo,
(i.e., in regions with seasonal snow cover).

Complement to aerosol forcing in areas with substantial surface albedo.

Easy: just compute for zero surface albedo.

And related to surface albedo forcing (a broadband quantity):

We are also considering to retrieve Antarctic snow grain sizes with MODIS in Edition 3 (Jin et al.).

More general algorithm for larger grain sizes in NH would require re-tooling and experimentation.

Bias of Calculated SW at TOA (all-sky, ice-free ocean)

For each field, compute monthly average, deseasonalize, then form bias.

Untuned SW calculation uses no CERES broadband data over ice-free ocean. This compares the original calculations (Ed2) to original observations (Ed2), to official revised observations (Rev1), and to further test modifications to observations (Beta15).
Bias of Calculated SW at TOA (all-sky, ice-free ocean)

For each field, compute monthly average, deseasonalize, then form bias.

Untuned SW calculation uses no CERES broadband data over ice-free ocean.

For both Terra and Aqua, these original SARB CRS Edition 2 calculations have less bias and less trend with Rev1 modifications to SSF Edition 2 observations, and even less when compared with Beta 15 modifications to observations.
Bias of Computed All-sky OLR
Deseasonalized Monthly Footprint Means over Full Globe

Untuned calculations for OLR and window (WN) use no CERES data.

Beta 15 modifications to observed OLR use 11 scene types, differ for day and night.

Terra SSF Ed2 daytime OLR drifts. There is still some drift in daytime OLR with Beta 15.

Bias of 0.4% is ~1 W/m**2
Bias of Simulated Terra OLR and Window (WN)

"Trend" in Terra daytime OLR bias is less in daytime WN. Trend is probably not explained by constant CO2, CH4, N2O, and CFC in SARB Edition 2 radiative transfer. Edition 3 code will account for changes in CO2 for LW.
Aqua WN biases with Edition 2 SSF are erratic.

Aqua biases for day OLR and day WN are both flat with Beta 15.
Terra (previous slide) biases for day OLR and day WN still increase with Beta 15.
Aqua and Terra relative biases (%) for WN are larger than for OLR.
Bias of Calculated SW at TOA (CLEAR-sky, ice-free ocean)

Clear ocean SW is the toughest field to observe. For Beta 15, bias are \( \sim 0\% \) for most of Terra versus \( \sim -2\% \) for Aqua.

NH winter of 2005-2006 has large Terra bias for SW over clear ocean. It is due to an input error: Aerosol Optical Thickness (AOT) is too high. Terra CRS Ed2B (but not Terra Ed2F or Aqua 2B2C) allows MODIS Daily Average AOT as a source; we’ve interpolated that field incorrectly earlier in Aqua CRS Ed2A.
How do we validate Aqua CRS Edition 2C, the 2006 successor to Edition 2B?

Compare CRS Ed2B vs surface data and CRS Ed2C vs. surface data for a common “season” (May to December).

CRS Ed2C starts in May 2006.

Use 2006 for Ed2C and 2002-2005 for Ed2B.

Surface and Satellite Data (<25km from 17 CAVE sites) having fairly consistent reporting in this period:


<table>
<thead>
<tr>
<th></th>
<th>All sky</th>
<th>Clear sky</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untuned SW up TOA</td>
<td>7.86</td>
<td>-0.92</td>
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<tr>
<td>Tuned SW up TOA</td>
<td>1.55</td>
<td>-0.18</td>
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<tr>
<td>Untuned SW down SFC</td>
<td>9.73</td>
<td>-0.99</td>
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<tr>
<td>Tuned SW down SFC</td>
<td>18.24</td>
<td>-1.80</td>
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<td>Untuned SW up SFC</td>
<td>-26.18</td>
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<td>Tuned SW up SFC</td>
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<td>Untuned OLR</td>
<td>-1.53</td>
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<tr>
<td>Tuned OLR</td>
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<tr>
<td>Untuned LW down SFC</td>
<td>-8.09</td>
<td>-0.07</td>
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<tr>
<td>Tuned LW down SFC</td>
<td>-8.36</td>
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<tr>
<td>Untuned LW up SFC</td>
<td>-5.84</td>
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<tr>
<td>Tuned LW up SFC</td>
<td>-4.75</td>
<td>-0.27</td>
</tr>
</tbody>
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** 2 of 17 sites lack surface measurements of upwelling radiation

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<thead>
<tr>
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<th>Clear sky</th>
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<tbody>
<tr>
<td>Untuned SW up TOA</td>
<td>26.06</td>
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<td>Tuned SW up TOA</td>
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<td>Untuned SW down SFC</td>
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<td>Untuned SW up SFC</td>
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<td>Untuned OLR</td>
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<td>4.65</td>
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<tr>
<td>Tuned LW up SFC</td>
<td>25.00</td>
<td>-0.36</td>
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</tbody>
</table>

** 2 of 17 sites lack surface measurements of upwelling radiation
Significant error in Terra CRS Ed2B during NH winter for clear-sky ocean SW
Caused by software that Ed2F leap frogs

Aqua CRS Edition 2C and Terra CRS Edition 2F are satisfactory
(Collection 5 MODIS, starting in May 2006)

Climatological aerosol profiles in Terra CRS Ed2F for May-Dec06
- cannot verify adverse impact to broadband

Comparison with successive global TOA observations (Ed2, Rev1, Beta15)

Beta 15 still gives ~2% bias of all-sky SW over oceans
in Terra and Aqua

Untuned bias drifts with daytime Beta 15 all-sky OLR
in Terra but not in Aqua

Surface albedo forcing product suggested for Edition 3