CERES TSI/SYNI/AVG STATUS

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Outline

• Product Introduction
• Model vs. Observed (Agreement?)
• TSI <31 day per month bug (Fixed !)
• Global Mean TOA Flux (Net Balance ?)
• Validation Spatial Subset
  – Hourly, Daily, Monthly & Station Averages
  – UVB and PAR
• Beta4_AVG “content survey”
• PAR compared with SeaWiFS product
• Atmosphere radiation budget
  – AVG Product and NCAR/NCAR Reanalysis
SYNI Product What is it?

Global Hourly
- 1 x 1deg Equal Area Grid N=44012

Fu-Liou Radiative Transfer
- Broadband SW,LW
- TOA, surface and atmosphere

TSI Input product for SYNI
- CERES (~12 hourly)
- MODIS (~12 hourly)
- Geostationary (3 hourly)
  - Normalized to CERES for TOA Fluxes
  - Geostationary radiances calibrated to MODIS
  - Cloud Properties
    - Fraction, height, optical depth, phase, particle size

Other major input products for SYNI
- GEOS4 Temperature & Humidity
- SMOBA Ozone
- MODIS and MATCH AOTs, MATCH constituents / OPAC properties
- Daily Microwave Snow & Ice
Fu-Liou Code for SYNI

- Gamma weighted 2-Stream (SW), 2/4 Stream (LW) pristine multi-stream correction to COART
  - Treats sub-computational scale Inhomogeneous clouds (S. Kato)
- Correlated k: 29 Bands: 15 SW, 14 LW, 3 of 14 LW in WN
- Enhanced output of PAR and UVA, UVB (W. Su)
- Shortwave: (0.17 - 4.0 or inf) μ [2500-57000 cm-1]
  - HITRAN 2000 (H₂O) w/(O₂, CO₂, CH₄) @ Fixed concentration
- Longwave (0-2850 cm-1) (3.5 μ – Infinity)
  - H₂O, CO₂, O₃, N₂O, CH₄, CFCs, H₂O continuum
- Optical Properties: spectral (β, ω, g)
  - Water Cloud (Y. Hu)
  - Ice Cloud (Q. Fu 1996, Dge)
  - Aerosol Optical Properties (OPAC, Tegen&Lacis, d’Almedia)
- Major Revisions
  - 10 visible SW bands reworked for O₃ and rayleigh in 1995
  - Near-Ir 0.7-1.3 μ subdivided into 4 bands in 2005
- Online Version http://www-cave.larc.nasa.gov/cave
Daytime Longwave Correction
FM1 Trends as function of SW minus LW value

Correction Ratio always positive: Increasing mean OLR by about 1%

Bright/Cold scenes correction decreases with time

Dark/Warm scenes correction increases with time
Beta4 “AVG” July 2004
TOA Model – Observed [Wm^{-2}]

Tuned Minus Observed SW TOA

Untuned Minus Observed SW TOA

Tuned Minus Observed LW TOA

Untuned Minus Observed LW TOA

GlbAvg= 0.17

GlbAvg= 0.66

GlbAvg= -0.73

GlbAvg= -0.96
UNtuned-Observed
SW TOA [Wm⁻²]
July 02

Global Mean Shortwave TOA Reflected Monthly Mean

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Albedo</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>0.92</td>
<td>0.001</td>
</tr>
<tr>
<td>CERES</td>
<td>7.27</td>
<td>0.007</td>
</tr>
<tr>
<td>GEO</td>
<td>0.94</td>
<td>0.002</td>
</tr>
<tr>
<td>Interp</td>
<td>0.65</td>
<td>0.0009</td>
</tr>
</tbody>
</table>

Combined Daytime

~12 hr/day

Interpolated

~7 hr/day

CERES Flux
~1 hr/day
MODIS Multispectral Clouds

Geostationary NB/BB Flux
~3 hr/day
Vis/Ir Clouds
UNtuned - Observed LW TOA [Wm\(^{-2}\)] July 02

Global Mean Longwave TOA Untuned -Obs

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>-0.99</td>
</tr>
<tr>
<td>CERES</td>
<td>-1.62</td>
</tr>
<tr>
<td>GEO</td>
<td>-3.14</td>
</tr>
<tr>
<td>Interp</td>
<td>-0.77</td>
</tr>
</tbody>
</table>

Combined LW 24 hr/day

Interpolated ~14 hr/day

CERES Flux ~2 hr/day MODIS Multispectral Clouds

Geostationary NB/BB Flux ~8 hr/day IR only Clouds
Beta4 SYNI

UNtuned *minus* “Observed” TOA

- Longwave Correction applied to observed CERES/GEO TOA
- Rev1 Shortwave Correction

<table>
<thead>
<tr>
<th>Instrument</th>
<th>FM1 15mth</th>
<th>FM2 2mth</th>
<th>FM3 3mth</th>
<th>FM4 3mth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longwave</td>
<td>-1.0 (11.6)</td>
<td>-1.1 (11.6)</td>
<td>0.4 (11.4)</td>
<td>0.2 (11.3)</td>
</tr>
<tr>
<td>Shortwave</td>
<td>0.6 (16.5)</td>
<td>0.7 (16.6)</td>
<td>0.8 (17.7)</td>
<td>1.0 (17.4)</td>
</tr>
<tr>
<td>Window</td>
<td>0.2 (5.4)</td>
<td>0.1 (5.32)</td>
<td>0.7 (5.4)</td>
<td>0.3 (5.3)</td>
</tr>
</tbody>
</table>

Note: April (30 day) months omitted due to Beta4 TSI Observed ClrSky OLR bug
TSI Beta4 Bug

<30 Day/Month Clear Sky OLR Bug

TSI 200204 Outgoing Longwave
Clear Sky Monthly Mean

Mean = 202.30

TSI 200204 Outgoing Longwave
Total Sky Monthly Mean

Mean = 235.37

Corrected Re-Run

TSI 200204 Outgoing Longwave
Clear Sky Monthly Mean

Mean = 262.09

TSI 200204 Outgoing Longwave
Total Sky Monthly Mean

Mean = 238.19
Net TOA Balance Components
OBSERVED and
MODEL Tuned
Single Month of July 2004 (FM1)

<table>
<thead>
<tr>
<th>July 2004 FM1 [Wm$^{-2}$]</th>
<th>Obs</th>
<th>Model Tuned</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOA Insolation</td>
<td>330.45</td>
<td></td>
</tr>
<tr>
<td>TOA SW Up</td>
<td>91.65</td>
<td>91.80</td>
</tr>
<tr>
<td>OLR</td>
<td>242.41</td>
<td>241.7</td>
</tr>
<tr>
<td>TOA SW&amp;LW Net</td>
<td>-3.60</td>
<td>-3.03</td>
</tr>
</tbody>
</table>

Toa Insolation

- Obs SW UP
  - GlbAvg = 91.65
- Tuned SW UP
  - GlbAvg = 91.80

- OBS LW UP
  - GlbAvg = 242.41
- Tuned OLR
  - GlbAvg = 241.68

OBS TOA SW&LW NET

- GlbAvg = -3.60
- Tuned TOA SW&LW NET
  - GlbAvg = -3.03

[Wm$^{-2}$]
Beta4 SYNI
Global Monthly Mean TOA
2000-2005
Jan, Apr, Jul, Oct
April has TSI CSOLR bug
Spatial Subset Validation

• 170 grid boxes out of 44012
  – Planned as part of CAVE website (Edition release)

• Selected according to.......
  – Surface validation sites
    • CAVE
      – ARM, SURFRAD, BSRN CMDL
      – BB SW&LW
    • Aeronet sites
  – Variety of IGBP types
    • Crude global representation
Surface Downward Longwave Comparison to Surface Validation sites

Remember these are point to grid-box comparisons
Surface Upward Longwave Comparison to Surface Validation sites
Surface Downward Shortwave Comparison to Surface Validation sites
Surface Upward Shortwave Comparison to Surface Validation sites
Surface
Upward
Shortwave
Comparison to
Surface
Validation sites

Edited to removing mainly coastal sites
1. Georg von Neumayer
2. Manus
3. Nauru
4. Tateno
5. E12 sgp (some suspect data)
UNtuned TOA

ALL Beta5 SITES

UNTuned TOA SW UP(Hourly)

N= 2580778.
Mean (StdDev)
OBS SW TOA Up 102.8 (138.1)
UNTUNED SYNI SW TOA Up 102.0 (137.5)
Y-X -0.811 (19.70)
RMS( 19.72)

UNTuned TOA SW UP(Daily)

N= 106284.
Mean (StdDev)
OBS SW TOA Up 103.1 (68.81)
UNTUNED SYNI SW TOA Up 102.3 (67.71)
Y-X -0.756 (10.56)
RMS( 10.69)

UNTuned TOA SW UP(Monthly)

N= 3506.
Mean (StdDev)
OBS SW TOA Up 102.8 (59.14)
UNTUNED SYNI SW TOA Up 101.9 (58.14)
Y-X -0.868 (7.09)
RMS( 7.14)

UNTuned TOA SW UP(SITE AVG)

N= 167.
Mean (StdDev)
OBS SW TOA Up 102.8 (14.38)
UNTUNED SYNI SW TOA Up 101.9 (13.01)
Y-X -0.901 (4.45)
RMS( 4.53)

UNTuned TOA LW UP(Hourly)

N= 2582231.
Mean (StdDev)
OBS LW TOA Up 230.0 (47.49)
UNTUNED SYNI LW TOA Up 229.6 (46.69)
Y-X -0.351 (12.46)
RMS( 12.46)

UNTuned TOA LW UP(Daily)

N= 106862.
Mean (StdDev)
OBS LW TOA Up 230.1 (43.14)
UNTUNED SYNI LW TOA Up 229.8 (42.61)
Y-X -0.367 (8.28)
RMS( 8.29)

UNTuned TOA LW UP(Monthly)

N= 3507.
Mean (StdDev)
OBS LW TOA Up 230.0 (31.21)
UNTUNED SYNI LW TOA Up 229.6 (30.52)
Y-X -0.352 (3.36)
RMS( 3.37)

UNTuned TOA LW UP(SITE AVG)

N= 167.
Mean (StdDev)
OBS LW TOA Up 230.0 (31.21)
UNTUNED SYNI LW TOA Up 229.6 (30.52)
Y-X -0.352 (3.36)
RMS( 3.37)
### Beta5 SYNI FM1&FM2 (STS Subset)
2000:2005/Jan, Apr, Jul, Oct
TOA and Surface Flux Comparison [Wm$^{-2}$]

<table>
<thead>
<tr>
<th>TOA Model-Obs Bias (RMS)</th>
<th><strong>UN-tuned Longwave</strong></th>
<th>Tuned Longwave</th>
<th><strong>UN-tuned Shortwave</strong></th>
<th>Tuned Shortwave</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hourly</strong></td>
<td>-0.4 (12.5)</td>
<td>-0.4 (10.4)</td>
<td>-0.8 (19.7)</td>
<td>-0.9 (12.9)</td>
</tr>
<tr>
<td><strong>Daily</strong></td>
<td>(8.3)</td>
<td>(6.7)</td>
<td>(10.7)</td>
<td>(6.7)</td>
</tr>
<tr>
<td><strong>Monthly</strong></td>
<td>(4.5)</td>
<td>(3.4)</td>
<td>(7.1)</td>
<td>(4.3)</td>
</tr>
<tr>
<td><strong>Site Avg</strong></td>
<td>(3.4)</td>
<td>(2.5)</td>
<td>(4.5)</td>
<td>(3.1)</td>
</tr>
<tr>
<td><strong># Sites</strong></td>
<td>167</td>
<td>167</td>
<td>167</td>
<td>167</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tuned – Obs Bias (RMS)</th>
<th><strong>Downward Longwave Surface</strong></th>
<th><strong>Upward Longwave Surface</strong></th>
<th><strong>Downward Shortwave Surface</strong></th>
<th><strong>Upward Shortwave Surface</strong></th>
<th><strong>Upward Shortwave Surface</strong> edit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hourly</strong></td>
<td>-5.8 (23.5)</td>
<td>-3.5 (25.5)</td>
<td>4.2 (60.8)</td>
<td>-9.9 (35.0)</td>
<td>-6.23 (24.1)</td>
</tr>
<tr>
<td><strong>Daily</strong></td>
<td>-5.9 (16.5)</td>
<td>-3.5 (17.3)</td>
<td>4.3 (24.2)</td>
<td>-10.1 (21.7)</td>
<td>-7.12 (14.1)</td>
</tr>
<tr>
<td><strong>Monthly</strong></td>
<td>-5.8 (11.5)</td>
<td>-3.3 (13.5)</td>
<td>4.5 (10.4)</td>
<td>-10.8 (18.4)</td>
<td>-7.03 (9.9)</td>
</tr>
<tr>
<td><strong>Site Avg</strong></td>
<td>-4.6 (9.1)</td>
<td>-3.9 (11.5)</td>
<td>4.8 (7.9)</td>
<td>-10.2 (14.7)</td>
<td>-7.03 (9.5)</td>
</tr>
<tr>
<td><strong># Sites</strong></td>
<td>44</td>
<td>31</td>
<td>43</td>
<td>33</td>
<td>27 (no coast)</td>
</tr>
</tbody>
</table>
Spectral Diurnal Transmission Examples

Uses LaRC Fu-Liou code for UVA, UVB, PAR see JGR 2007 W.Su
Surface UV INDEX Comparison to seven SURFRAD Validation sites
UV INDEX equals erythermal action spectra over 215:380 nm in Wm$^{-2}$ times 40
Bondville:
Some surface UVB measurements are suspect?
IAV of Monthly Mean UV Index

Fort Peck
SYNI Beta4 FM1 2000:2005 /Jan, Apr, Jul, Oct:
Surfrad FPK

Monthly Diurnal Mean

[Graph showing UV index over time for Fort Peck with specific months highlighted]

Bondville
SYNI Beta4 FM1 2000:2005 /Jan, Apr, Jul, Oct:
Surfrad BON

Monthly Diurnal Mean

[Graph showing UV index over time for Bondville with specific months highlighted]
Daily Integrated UV Dosage (J m\(^{-2}\))

**TOMS Vs. SURFRAD(OBS)**

- **N = 707**
- **Avg. TOMS = 3001.6**
- **Avg. SURFRAD = 2514.5**
- **RMS = 916.9 (36%)**

**Beta4_SYNI Vs. SURFRAD(OBS)**

- **N = 707**
- **Avg. SYNI = 2383.6**
- **Avg. SURFRAD = 2514.5**
- **RMS = 546.4 (22%)**

Analysis courtesy: Wenying Su (NASA LaRC)
Surface PAR
Comparison to Sfc. SURFRAD Validation sites
PAR = 400:700nm Wm^-2
CERES “AVG” PAR
(Photosynthetic Active Radiation)
Compared to SeaWiFs
July 2004.
OCEAN ONLY!
But remember CERES does land as well
CERES "AVG" PAR
(Photosynthetic Active Radiation)
Compared to SeaWiFS
July 2004.
OCEAN ONLY!
But remember CERES does land as well

Let's look at a region with two locations, one with a positive and another with a negative bias.
Monthly Diurnal Mean Sfc. Transmission Broadband SW & PAR

We had seen monthly mean PAR bias compared to NOON overpass SeaWifs. Could diurnal cloud differences be the cause? (Yes) CERES TSI/SYNI/AVG gives better diurnal sampling.
Photosynthetically Active Radiation (PAR)
Global Monthly Avg (OCEAN Only)
CERES SARB Beta4_AVG Vs SeaWifs

- CERES "AVG" PAR
- SeaWifs PAR

PAR (Wm-2)

Percent Difference CERES_AVG minus SeaWifs

Month
Beta4 “AVG”

- Survey of Cloud and Aerosol forcing variables
- Atmospheric Radiation Budget
  - Diabatic (SH + LE = ATM NET RAD)
  - Compare Subsidence and Radiative Cooling
Survey of Beta4 “AVG” Forcing Quantities (July 2004) [Wm⁻²]

Cloud Forcing of SWTOA NET
- GblAvg = -42.25
-180 -120 -60 0 60 120

AllSky Aerosol Forcing of SWTOA NET
- GblAvg = -3.41
-20 -15 -10 -5 0 5 10

Cloud Forcing of LWTOA NET
- GblAvg = 24.35
-10 0 10 20 30 40 50

AllSky Aerosol Forcing of LWTOA NET
- GblAvg = 0.54
-2.5 0 2.5 5 7.5 10

Cloud Forcing of TOA NET NET
- GblAvg = -18.00
-120 -60 0 60 120

AllSky Aerosol Forcing of TOA NET NET
- GblAvg = -2.87
-20 -15 -10 -5 0 5 10

Cloud Forcing of LW SFC NET
- GblAvg = 25.14
0 5 10 15 20 25

Aerosol Forcing of SFC NET NET
- GblAvg = 1.30
0 4 8 12 16 20 24 28 32

Cloud Forcing of SFC NET NET
- GblAvg = -19.76
-120 -90 -60 -30 0 30 60 90

Aerosol Forcing of SFC NET NET
- GblAvg = -5.57
-30 -25 -20 -15 -10 -5 0 5 10

ATM_LW&SW_NET_CLDFORC. 200407
- GblAvg = 1.76
-75.0 -56.2 -37.5 -18.8 0.0 18.8 37.5 56.2 75.0
Sensible(24) + Latent(78) + SW_ATM_Absorbed(67) = LW_ATM_Emitted(-169)
-OR-
Sensible&Latent(102) = Atm_Net_SW&LW(-102)
{Kiehl and Trenberth 1997}
Global Energy Flows \ W \ m^{-2} \ 

Sensible&Latent(97) = Atm\_Net\_SW&LW(-98) + Ocean(0.9): 
{Trenberth, Fasullo, Keiilh :2008}
Atmosphere Diabatic Radiation Budget

Atmosphere gains ..
Latent and Sensible Heat
Shortwave absorption

Atmosphere loses ...
Longwave cooling

On monthly global scale
the processes are nearly in equilibrium.

Zonal gradient drives global atmosphere circulation
Hadley cell
poleward heat transport

Kalnay et al., The NCEP/NCAR 40-year reanalysis project,
Source NOAA/OAR/ESRL PSD, Boulder, Colorado, USA
Comparison of
CLOUD FORCED Atmosphere Net Radiative Process
to
TOTAL Diabatic Processes 200407

• Clouds increase atmosphere radiative cooling in polar regions and reduce cooling in tropics

• Increasing atmosphere zonal heat transport

Zhang, Y.-C., and W. B. Rossow, 1997:
Estimating meridional energy transport by the atmospheric and oceanic general circulations using boundary fluxes,
J. Climate, 10, 2358-2373.

Kato S., Rose F., Rutan D., Charlock T.,
Zonal Height profile of OMEGA/Vertical Motion (Adiabatic) Radiational Cooling (Diabatic)
Zonal Temperature Tendencies for July 2004
Beta4_AVG Net Atmosphere SW&LW (Radiative/Diabatic) SOLID
NCEP OMEGA based (Vertical Motion/Adiabatic) DASHED

SFC to 500hPa

500 to 200hPa

200 to 70hPa

SFC to 70hPa
Summary

• Point to grid-box surface validation of Beta4_SYNI and Beta4_AVG are encouraging.
• Diurnal effects of GEO clouds and fluxes are consistent and add value.
• Atmosphere Net budget closes to within 5% of Ncar/Ncep Reanalysis.
• A Full 12 month year will be processed and analyzed before an Edition decision is made.