Next Generation Monthly Products for Terra

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Outline

• Globally Gridded CERES Instantaneous and Time-Averaged Products
  – What CERES gridded products are available?
  – How do I know which one is best for my research?

• CERES Temporal Interpolation
  – How does it work?
  – How successfully do we remove temporal sampling errors?
  – What products are currently available?
CERES Temporal Interpolation and Spatial Averaging (TISA)

Goals

• Produce climate quality monthly and daily means
  – Must maintain calibration

• Eliminate temporal sampling errors

• Retain consistency among TOA fluxes, cloud properties and surface fluxes

• Produce synoptic maps of TOA, surface, and atmospheric flux
Where TISA Fits Into CERES Processing

CERES Instrument Data → Geolocate & Calibrate 1 → ERBE-Like Inversion 2 → ERBE-Like Averaging 3 → ERBE-Like Products

Clouds & TOA Flux 4 → Grid TOA & SRB 9 → Monthly TOA & SRB 10 → TOA and Surface Products

SARB 5 → Grid Geo Data 11 → Monthly Mean SARB 10 → Synoptic & Monthly TOA, Surface, and Atmospheric Products

Grid SARB 6 → Time Interpolate SARB 7 → Monthly Mean SARB 10
Start with Gridded CERES Observations
One hour of CERES TOA SW Fluxes
<table>
<thead>
<tr>
<th>CERES Data Product</th>
<th>TRMM</th>
<th>Terra</th>
<th>Aqua</th>
<th>ERBElike Product</th>
<th>TOA and Surface Product</th>
<th>Atmosphere Product</th>
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</thead>
<tbody>
<tr>
<td>ES9 (ERBElike Monthly Regional Averages)</td>
<td>Ed2</td>
<td>Ed2</td>
<td>Ed2</td>
<td>X</td>
<td></td>
<td></td>
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<tr>
<td>SFC (Monthly Gridded TOA/Surface Fluxes and Clouds)</td>
<td>Ed2B</td>
<td>Ed2C</td>
<td>Ed1B</td>
<td>X</td>
<td></td>
<td></td>
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<tr>
<td>FSW (Monthly Gridded Radiative Fluxes and Clouds)</td>
<td>Ed2C</td>
<td>Ed2C</td>
<td>Beta1</td>
<td></td>
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<td></td>
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<tr>
<td>SYN (Synoptic Radiative Fluxes and Clouds)</td>
<td>Beta</td>
<td>Beta2</td>
<td>2005</td>
<td></td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>
Organize Regional Data by Time
One day of CERES TOA SW Fluxes at 10:30 LT
Interpolate Fluxes and Clouds over Month
Regional Time Series of Flux from Terra over ARM SGP
Create Temporally Interpolated and Averaged Data Products
TOA SW Flux Terra FM-1 July 2001
### CERES Monthly Gridded Average Data Products

<table>
<thead>
<tr>
<th>CERES Data Product</th>
<th>TRMM</th>
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<tr>
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<td>Ed2</td>
<td>Ed2</td>
<td>Ed2</td>
<td>X</td>
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<td></td>
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<tr>
<td><strong>ES4</strong> (ERBElike Monthly Geographical Averages)</td>
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<td>Ed2</td>
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<td></td>
</tr>
<tr>
<td><strong>SRBAVG</strong> (Monthly TOA/Surface Averages)</td>
<td>Ed2B</td>
<td>Ed2C</td>
<td>2005 Beta1</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>AVG</strong> (Monthly Regional Radiative Fluxes and Clouds)</td>
<td>2005 Beta1</td>
<td>2005 Beta2</td>
<td>2005 Beta1</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ZAVG</strong> (Monthly Zonal and Global Radiative Fluxes and Clouds)</td>
<td>2005 Beta1</td>
<td>2005 Beta2</td>
<td>2005 Beta1</td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### CERES Monthly Mean Products

<table>
<thead>
<tr>
<th>SYN/AVG</th>
<th>SRBAVG</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Uses GEO-enhanced interpolation to produce global synoptic flux and cloud fields</td>
<td>• Takes advantage of improved CERES fluxes</td>
</tr>
<tr>
<td>• Atmospheric Fluxes</td>
<td>• Uses improved temporal interpolation to remove sampling effects</td>
</tr>
<tr>
<td>• Pristine/Clear Fluxes</td>
<td>• 1.0° grid</td>
</tr>
<tr>
<td>• Complete RT results</td>
<td>• TOA and surface fluxes</td>
</tr>
<tr>
<td></td>
<td>• Detailed cloud properties</td>
</tr>
<tr>
<td></td>
<td>• Product contains GEO and nonGEO monthly means</td>
</tr>
</tbody>
</table>
Study Type

- TOA flux only comparison
- Rough estimate of surface flux
- In situ Flux comparison over particular region
- Flux comparison with radiative transfer model
- Comparison with GCMs
- Cloud and aerosol properties comparison
- Cloud and aerosol radiative forcing estimate or comparison with other estimate
- Comparison of radiation, aerosol and cloud properties with model other than GCM (i.e. LES, CRM)
- Interpretation of radiation cloud and aerosol property variability
- Decadal study consistent with ERBE
- Angular dependent of radiance

Temporal

- Instantaneous
- Hourly
- 3hr Average
- Daily
- Monthly Average
- ANY of above

http://snowdog.larc.nasa.gov/cgi-bin/rose/wd
July SRBAVG Monthly Means

TOA SW

TOA LW

TOA Net

TOA LW CF

(1)Mean  (2)Std Dev: Watts per square meter,  (3)Num. Obs.: Unitless
TISA Product Update: SYN and AVG/ZAVG

• SYN: Spatially/Temporally averaged product on 1° x 1° global grid
  – 3-hourly synoptic TOA, atmospheric, and surface fluxes + cloud data

• AVG/ZAVG monthly averaged SYN parameters

• Terra Beta2 SYN/AVG/ZAVG
  – Beta version tested for Mar00, Jan01, Apr01, Oct01
  – wait until GEO SW finalized to begin production
Using Geostationary Imager Data for Temporal Interpolation

• Use geostationary data to define flux variations between CERES measurements
  – 3 hourly geostationary VIS and IR (8km) images
  – Algorithm needs to preserve CERES calibration
  • Algorithm needs to have consistent cloud properties with MODIS
Using Geostationary Imager Data for Temporal Interpolation

- G GEO SW
- Calibrate GEO visible radiances against MODIS
  - Geostationary VIS not calibrated
  - Calibrate over oceans to mitigate GEO spectral response function differences
  - Regress Co-located, Co-angled, Coincident radiances within 15 minutes
  - Validate by cross-calibrating GEO satellites
January 2003, GOES-8/Terra

Degradation rate = $365 \times 1.136 \times 10^{-4} = 4.15\% / \text{year}$
GGEJO Cloud Product

• Needed for SW interpolation & for monthly clouds
  – Necessary for ADM selection
• Uses IR/Vis retrievals (run as subset of CERES cloud algorithm)
• Uses CERES surface property maps and GEOS soundings
• 3-hourly Cloud Properties
  – Cloud Amount
  – Cloud Temperature
  – Cloud Height (using standard 4 CERES layers)
  – Optical Depth/Emittance (Daytime Only)
• The GGEJO Product is not publicly released
  – Only monthly mean properties available
• Monitor cloud properties over time to validate visible calibration
GEO - MODIS monthly mean cloud fractions
3 year timelines over oceans

(Based on coincident matches)
Daytime 60°N to 60°S Cloud Amount
Using Geostationary Data for Temporal Interpolation of TOA Fluxes

- Narrowband GEO data converted to flux using NB-BB relationship & CERES TRMM ADMs
  - Based on angles, geo-type, cloud amount, phase, optical depth and GEO satellite
- Final fluxes are normalized to CERES observations
  - Using matched coincident CERES fluxes and GEO derived BB fluxes at multi-regional scale
  - Interpolated SW fluxes not normalized with CERES flux at the same hourbox, since meteorology may change significantly between 3 hourly GEO measurements
  - Normalization applied to total-sky flux
  - Use CERES regional clear-sky albedo during GEO clear-sky events
  - Normalized fluxes have no functionality with solar zenith angle but there is some functionality with cloud amount
Using Geostationary Data for Temporal Interpolation of TOA Fluxes

- GEO LW
  - GEO satellites have onboard IR calibration
  - IR radiances are converted to Narrowband (NB) fluxes using limb darkening
  - Apply empirical NB-BB relationship which includes a water vapor term
  - Normalize GEO derived interpolated fluxes with CERES at coincident times
CERES Temporal Interpolation Algorithms

- **ERBE-like**
  - Assumes constant meteorology between observations
  - LW
    - Linear interpolation
    - Simple diurnal sine function modeling over land regions
  - SW
    - Interpolation performed using directional models of albedo
    - Only 12 simple scene types
    - Scene identification based on LW and SW fluxes

- **CERES nonGEO**
  - Same approach as ERBE-like
    - Uses new CERES directional models (~600 scene types)
    - Uses MODIS cloud properties for scene identification

- **CERES GEO**
  - Normalize 3-hourly GEO derived BB fluxes with CERES at coincident times
    - Uses geostationary data to define flux variations between CERES measurements
Temporal Interpolation of TOA LW Flux
January 1998  E. Sahara 24.5N 20.5E

[Graph showing temporal interpolation of TOA LW Flux with labels for Observations, ERBE TSA, and CERES TSA.]
GEO vs. nonGEO Monthly Mean Diurnal SW Flux
Equatorial Pacific Region

Mean Difference = 1.8 W/m²
Improved Next Generation CERES Products
Aug 2002 Clear-sky Albedo

ERBE like mean

ERBE like - nonGEO
Adding GEO Data Decreases Temporal Sampling Errors
TOA LW Flux Change  Terra FM-1 July 2001
(nonGEO - GEO)

Decrease: Yellow-red
Increase: Blue
Adding GEO Data Decreases Temporal Sampling Errors

2:30 - 9:30 LT LW FLUX  Terra FM-1 January 2001

PM Higher: Yellow-red

AM Higher: Blue
Adding GEO Data Decreases Temporal Sampling Errors

TOA SW Flux Change  Terra FM-1 July 2001

(nonGEO - GEO)

Decrease: Yellow-red
Increase: Blue
Adding GEO Data Decreases Temporal Sampling Errors
2:30 - 9:30 LT SW FLUX Terra FM-1 January 2001

PM Brighter: Yellow-red
AM Brighter: Blue
Validation

- **GERB**
  - Compare regional temporal interpolation with geostationary BB measurements onboard Meteosat-8

- **Comparing Interpolation from 2 CERES Satellites**
  - Can assess instantaneous errors or monthly means
  - March 2000 TRMM vs Terra
  - Terra vs Aqua

- **Surface Flux**
  - Compare surface fluxes derived from CERES measurements with surface radiometers
SRBAVG GEO and CAVE Monthly Surface Downwelling Longwave Flux Validation

• SRBAVG Model B (all-sky) LPLA (Gupta model)
  – Surface longwave fluxes independent from TOA
  – GEOS atmospheric state vertical profiles
  – GGEO (low) cloud base heights

• Monthly site surface fluxes from CAVE
  – ARM, SURFRAD, CMDL, and BSRN quality controlled surface radiometer networks
  – 3 years of monthly fluxes per station (Mar00 to Feb03)
  – 36 stations across the globe
Comparison with Surface-Based Measurements

ARM SGP CF   February 1998

Downwelling LW Flux   Region Number: 19163   Data Date: 02/1998

<table>
<thead>
<tr>
<th></th>
<th>ΔFlux Bias</th>
<th>ΔFlux RMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instantaneous</td>
<td>-0.05</td>
<td>19</td>
</tr>
<tr>
<td>Interpolated</td>
<td>-2.9</td>
<td>25</td>
</tr>
</tbody>
</table>
SRBAVG GEO and CAVE Surface Monthly Downwelling Longwave flux comparison

March 2000 to February 2003, 36 stations

- Bias: 2.1 Wm-2 or 0.7%
- RMS error: 11.4 Wm-2 or 3.6%

Biases likely where the GEOS profile is not representative of coastal, desert, or polar stations.
Remaining Issues

• SW Normalization
  – Remove dependency with cloud amount

• Final Validation
  – GERB
  – Aqua vs Terra

• Terra and Aqua SYN Product

• SRBAVG Additions
  – Daily means
  – ISCCP-like Cloud types based on optical depth and height
Global Mean Fluxes
SRBAVG Monthly Mean Flux and Cloud Property Images

(soon to be available on the web)

SW ERBE Jan86

SHORTWAVE RADIATION
ERBS + NDA49, 2.5 DEG SCANNER, JANUARY 1986
GLOBAL MEAN: (60S-60N = 104.1); (90S-90N = 108.5) W/m²

SW nonGEO Jan01

NON_GEO Total-sky TOA Shortwave Flux
Terra FM1 January 2001

Global
60N-60S
30N-30S
NON_GEO
96.92
91.16
101.88

NON_GEO/SRBAVG FILE: CER/SRBAVG1_Terra-FM1-MODIS_Edition2C_013023.200101
Global All-sky Longwave

![Graph showing Global All-sky Longwave data from August 2000 to February 2003. The graph compares different observational campaigns: ERBE, ERBE-NON_GEO, NON_GEO, and GEO.](image)

<table>
<thead>
<tr>
<th>ALL-SKY LW</th>
<th>Avg</th>
<th>Difference</th>
<th>Avg</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERBE</td>
<td>239.0</td>
<td>ERBE-NON_GEO</td>
<td>1.3</td>
</tr>
<tr>
<td>NON_GEO</td>
<td>237.7</td>
<td>NON_GEO-GEO</td>
<td>0.6</td>
</tr>
<tr>
<td>GEO</td>
<td>237.1</td>
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</table>
3 Year Global Mean TOA Fluxes

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td><strong>All-sky</strong></td>
<td>ERBE-like</td>
<td>nonGEO</td>
</tr>
<tr>
<td>OLR</td>
<td>239.0</td>
<td>237.7</td>
</tr>
<tr>
<td>SW</td>
<td>97.9</td>
<td>96.1</td>
</tr>
<tr>
<td>NET</td>
<td>4.4</td>
<td>7.5</td>
</tr>
</tbody>
</table>
Summary

• There are 3 main data product groups
  – ERBElike
  – Surface + TOA products (SFC/SRBAVG)
  – Complete atmospheric radiative products (SYN/AVG/ZAVG)
• CERES attempts to model meteorology between CERES measurements using narrowband GEO data
  – Large-scale diurnal sampling errors removed
  – Maintains CERES absolute calibration and consistent cloud properties
  – Goal: regional monthly mean fluxes within 1 Wm\(^{-2}\)
• SRBAVG GEO SW due out soon
  – SYN products to follow later in year
Backup Slides
TISA Product Update: SFC

- Spatially averaged product on 1° x 1° global grid
  - Derived from SSF (CERES footprint data)
  - Instantaneous gridded

- Terra Edition 2C complete Mar00 to Dec03
  - Data Quality Summaries delivered
  - Processing to continue to Oct04

- Aqua Edition 1B SFC complete Jul02 to Aug03
  - Data Quality Summaries delivered
  - Processing to continue Jun04
TISA Product Update: FSW

- Spatially averaged product on 1° x 1° global grid
  - Derived from CRS (CERES footprint data + SARB)
  - Instantaneous gridded

- Terra Edition 2C complete Mar00 to May02
  - Data Quality Summaries delivered

- Aqua Beta1 complete Jul02 to Sep02
TISA Product Update: SRBAVG

- Spatially/Temporally averaged product on 1° x 1° global grid
  - Monthly mean TOA and surface fluxes + cloud data
  - nonGEO product includes only CERES fluxes with accompanying MODIS cloud properties
  - GEO product includes 3 hourly GEO derived BB fluxes and GEO cloud properties

- Terra Edition 2C complete Mar00 to Feb03
  - GEO LW included, GEO SW set to default

- Terra Edition 2D
  - will contain the GEO SW when algorithm is finalized
  - Will contain Terra snow directional models

- Aqua Edition 1B to wait until GEO SW finalized