The Radiation Fluxes of NCEP/Climate Forecast System Reanalysis Validated with CERES-ERBE

S-K Yang, Y-T Hou, C.S. Long, T. Wong, and D. Rutan

Acknowledgement: W. Ebisuzaky, H-T Lee, and CFSR production team
CERES STM,
Newport News, VA, Apr 27-29, 2010
Why this Reanalysis:

For generating re-forecasts, for the calibration of the NCEP operational Climate Forecast System, CFS

Outline:

• CFSR Intro –
  CFSR(R), Model- streams –Ob data
  radiation modules
  Data source

• Flux Comparison with CERES-EBAF data

• Tropical 20NS Time Series - ERBE

• Remarks
Analysis & Model Attributes

- Couple Atmos-ocean-land models (NCEP+MOM4+NOAH)
- Coupled Analysis System (GSI + GODAS + GLDAS)
- Assimilate Satellite Radiance
- Atm model resolution T382, ~38km, Atm Layer: T64, top at 0.26hPa.
- Ocean: 0.25° at Equ, ext to 0.5° beyond trop. 40 layer, to 4737m
- Land: 4 soil level
- Sea Ice: 3 level
- Convection: S. Arakawa-Schubert (Pan and Moorthi)
- Radiation RRTM, SW/LW, computation freq. – hourly
- Variational CO₂, Strato Aerosol (SAMII, Sato ‘93)
# NCEP Operational SW Radiation vs. CFSRR RRTM SW Radiation

<table>
<thead>
<tr>
<th>Description</th>
<th>NCEP (GFS-Chou)</th>
<th>RRTM (CFSRR-Iacono, 2000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>- 8 uv+vis, 1-nir;</td>
<td></td>
<td>5 uv+vis, 9-nir bnds</td>
</tr>
<tr>
<td>- 38 k-dis terms;</td>
<td></td>
<td>112 cor-k terms</td>
</tr>
<tr>
<td>- O₃, H₂O, CO₂, O₂;</td>
<td></td>
<td>O₃, H₂O, CO₂, O₂, CH₄</td>
</tr>
<tr>
<td>Advantages:</td>
<td>- Comp. Efficient;</td>
<td>Accu. (use ARM’s data)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>clr-sky - 10-30 w/m^2 reduction</td>
</tr>
<tr>
<td></td>
<td></td>
<td>all-sky - adv. scheme</td>
</tr>
<tr>
<td>Disadvantages:</td>
<td>- large errors;</td>
<td>Comp. slow, 4 times</td>
</tr>
<tr>
<td></td>
<td>clr-sky - und est;</td>
<td>slower than oprtnl sw</td>
</tr>
<tr>
<td></td>
<td>cld-sky - ovr est;</td>
<td></td>
</tr>
</tbody>
</table>
### Operational CFS GFDL-LW Radiation vs. CFSR RRTM-LW Radiation

<table>
<thead>
<tr>
<th>Description</th>
<th>GFDL (Fels-Schwartz.)</th>
<th>RRTM (Mlawer et al. ‘97)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- 15 bands;</td>
<td>16 bands</td>
</tr>
<tr>
<td></td>
<td>- trans tbl look-up;</td>
<td>140 cor-k terms</td>
</tr>
<tr>
<td></td>
<td>- $O_3, H_2O, CO_2$;</td>
<td>$O_3, H_2O, CO_2, O_2, CH_4$ CO, 4 CFCs</td>
</tr>
<tr>
<td>Advantages/Disadvantages:</td>
<td>- comp efficient;</td>
<td>better comp efficient</td>
</tr>
<tr>
<td></td>
<td>- no aerosols;</td>
<td>aerosol effect capable</td>
</tr>
<tr>
<td></td>
<td>- fixed $CO_2$ only;</td>
<td>varying $CO_2$ capable</td>
</tr>
<tr>
<td></td>
<td>- fixed sfc emis;</td>
<td>varying emis capable</td>
</tr>
<tr>
<td></td>
<td>- random sfc emis;</td>
<td>max-random overlap</td>
</tr>
<tr>
<td></td>
<td>- random cld ovlp;</td>
<td>improved accuracy</td>
</tr>
<tr>
<td></td>
<td>- larger errors;</td>
<td>at upper stratosphere</td>
</tr>
<tr>
<td></td>
<td>- simple cld opt prop;</td>
<td>advanced cld opt prop</td>
</tr>
<tr>
<td></td>
<td>- simple cld opt prop;</td>
<td></td>
</tr>
</tbody>
</table>
CFSR Data and Documentation

- CFSR Site: [http://cfs.ncep.noaa.gov/cfsrc](http://cfs.ncep.noaa.gov/cfsrc)
- NOAA Operational Model Archive Distribution System (Nomad5) [http://nomad5.ncdc.noaa.gov](http://nomad5.ncdc.noaa.gov)
- 33 Radiation-Cloud variables *(107 total, Monthly PGB06)*
- *Saha et al. 2010-* > BAMS
Comparison with CERES-ERBE

• **CERES:**
  – TOA: EBAF, 1x1, Jul 2000 - Jun 2005
  – SFC: SARB, same period as TOA, from Dave R.
• **CFSR:** 0.5x0.5, Monthly, Re-grid to 360x180 from 720x361
• **ERBE:** Tropics 20NS TOA OLR/RSW, by Tak W.
Global TOA RSW

CFSR/CERES 200007:200506 Global TOA All/CS RSW

All-Sky

Clear-Sky

2001 2002 2003 2004 2005
# Global Annual* Means

<table>
<thead>
<tr>
<th></th>
<th>TOA OLR</th>
<th>TOA CS OLR</th>
<th>TOA RSW</th>
<th>TOA CSRSW</th>
<th>SFC SW DN</th>
<th>SFC SW UP</th>
<th>SFC DN</th>
<th>SFC LW DN</th>
<th>SFC LW UP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jul00-Jun05</td>
<td>CFSR</td>
<td>228.1</td>
<td>248.2</td>
<td>101.8</td>
<td>65.2</td>
<td>167.6</td>
<td>36.9</td>
<td>304.2</td>
<td>356.4</td>
</tr>
<tr>
<td></td>
<td>CERES (EBAF/SARB)</td>
<td>224.1</td>
<td>249.7</td>
<td>102.7</td>
<td>61.7</td>
<td>165.7</td>
<td>32.9</td>
<td>304.7</td>
<td>354.7</td>
</tr>
<tr>
<td></td>
<td><strong>Diff (RMSD)</strong></td>
<td><strong>4.1 (6.74)</strong></td>
<td><strong>-1.5 (6.12)</strong></td>
<td><strong>-0.9 (16.30)</strong></td>
<td><strong>3.5 (10.54)</strong></td>
<td><strong>1.9 (18.02)</strong></td>
<td><strong>4.0 (9.05)</strong></td>
<td><strong>-0.5 (10.3)</strong></td>
<td><strong>1.6 (10.14)</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Spatial Correlatn</strong></td>
<td><strong>0.9</strong></td>
<td><strong>0.87</strong></td>
<td><strong>0.72</strong></td>
<td><strong>0.88</strong></td>
<td><strong>0.76</strong></td>
<td><strong>0.91</strong></td>
<td><strong>0.92</strong></td>
<td><strong>0.92</strong></td>
</tr>
<tr>
<td>Jan85-Dec86</td>
<td>R1</td>
<td>237.1</td>
<td>267.8</td>
<td>115.3</td>
<td>54.9</td>
<td>207.5</td>
<td>333</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>ERBE</strong></td>
<td>234</td>
<td>266.7</td>
<td>102.7</td>
<td>53.1</td>
<td>184</td>
<td>349.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Dif</strong></td>
<td><strong>3.1</strong></td>
<td><strong>1.7</strong></td>
<td><strong>12.6</strong></td>
<td><strong>1.8</strong></td>
<td><strong>23.5</strong></td>
<td><strong>-16.5</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Surface Downward & Upward Shortwave

CFSR/CERES 200007:200506 Global SFC DN SW

CFSR/CERES 200007:200506 Global SFC UP SW
Surface Downward & Upward Longwave
Remarks

• CFSR 1979~2009 Data Available.
• Very good SW improvements from R-1/R-2, both TOA and SFC, in larger scales
• LW slight less accurate than R-1. Fewer Clouds in general for stronger CS OLR. difference in W. Tropical Pacific; Over Stratus off W. Coasts. Very good in anomalies
• Stratospheric Aerosol input file mis-match for Mt. Pinatubo Stratospheric ERB computation.
• Surface LW/, 60 deg ice-snow model affect ERB, Brighter SFC Albedo
Back Up Slides
This time series of the outgoing longwave radiation from the NCEP/Climate Forecast System Reanalysis project manifests the complexity of the earth system. The regular seasonality is overlaps the ENSO and subtle inter-decadal variations with occasional large inter-seasonal variations.

This product also reflects the cross-cutting collaborations among the experts of surface observations, satellite, modeling, assimilation, and climate analysts from STAR, CPC, EMC, and JCSDA.

The product is highly valuable for assessing tropical hazard, intra-seasonal variability, El Nino evolutions, as well as model and retrieval system biases that are essential for NOAA Missions.
SW CLEAR SKY HEATING AND FLUXES

TROPICAL PROFILE
COSZ = .500

MIDLAT SUMMER
COSZ = .500

SUBARCTIC WINTER
COSZ = .500

HEATING RATE IN K/DAY

SICMA LAYER

150

100

UPWARD FLUX AT THE TOP

W/m^2

150

100

550

500

450

DOWNWARD FLUX AT THE SURFACE

W/m^2

150

100

550

500

450

W/m^2

BLACK - AER. GMT
RED - NCEP. OPR
GREEN - NCEP. NEW
BLUE - NASA. CHOI
YELLOW - SPDL. SW
• **Sato et al. 1993**


  A global stratospheric aerosol database employed for climate simulations is described. For the period 1883-1990, aerosol optical depths are estimated from optical extinction data, whose quality increases with time over that period. For the period 1850-1882, aerosol optical depths are more crudely estimated from volcanological evidence for the volume of ejecta from major known volcanoes. The data set is available over Internet.