GEOS-5 Atmospheric Analyses for Climate Studies

Michele Rienecker, Max Suarez, Ron Gelaro
Julio Bacmeister, Ricardo Todling, Emily Liu
Michael Bosilovich, Siegfried Schubert, Man Li Wu

&
GMAO

Presentation at CERES Science Team Meeting
May 7, 2008
Overview

• The GEOS-5 system

• Observing System - changes for G5-CERES

• Validation

• Climate Variability
GEOS-5 Atmospheric DAS
(Supported by NASA MAP Program)

AGCM
- Finite-volume dynamical core (S.J. Lin)
- Moist physics (J. Bacmeister, S. Moorthi and M. Suarez)
- Physics integrated under the Earth System Modeling Framework (ESMF)
- Generalized vertical coord to 0.01 hPa
- Catchment land surface model (R. Koster)
- Prescribed aerosols (P. Colarco)
- Interactive ozone
- Prescribed SST, sea-ice

Assimilation
- Apply Incremental Analysis Updates (IAU) to reduce shock of data insertion (Bloom et al.)
- IAU gradually forces the model integration throughout the 6 hour analysis period
- Allows for 1 hourly diagnostic output

Analysis
- Grid Point Statistical Interpolation (GSI from NCEP)
- Direct assimilation of satellite radiances data using JCSDA Community Radiative Transfer Model (CRTM)
- Variational bias correction for radiances

\[
\left( \frac{\partial q}{\partial t} \right)_{total} = dynamics(adiabatic) + physics(diabatic) + \Delta q
\]

- Total “observed change”
- Model predicted change
- Correction from DAS

- 03Z 06Z 09Z 12Z 15Z 18Z 21Z 00Z 03Z

- Raw analysis (from GSI)
- Background (model forecast)
- Assimilated analysis (Application of IAU)
- Initial States for Corrector
- Analysis Tendencies for Corrector
- Corrector Segment (1- and 3-hrly products)
MERRA Production

- 2-year spin up at 2-degree resolution
- 1-year spin up at \(\frac{1}{2}\) degree
- Proposed Objective: Focus on the water cycle

**Preview/Validation runs:**
- Jan, Apr, Jul, Oct 2004
- July-August 1987
- Jan, Jul 2001
- Jan 2006

**2 degree (scout) runs** ⇒ preliminary look at data and spin-up of satellite bias estimates.
<table>
<thead>
<tr>
<th>DATA SOURCE/TYPE</th>
<th>PERIOD</th>
<th>DATA SUPPLIER</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Conventional Data</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiosondes</td>
<td>1970 - present</td>
<td>NOAA/NCEP</td>
</tr>
<tr>
<td>PIBAL winds</td>
<td>1970 - present</td>
<td>NOAA/NCEP</td>
</tr>
<tr>
<td>Wind profiles</td>
<td>1992/5/14 - present</td>
<td>UCAR CDAS</td>
</tr>
<tr>
<td>Conventional, ASDAR, and MDCRS aircraft reports</td>
<td>1970 - present</td>
<td>NOAA/NCEP</td>
</tr>
<tr>
<td>Dropsondes</td>
<td>1970 - present</td>
<td>NOAA/NCEP</td>
</tr>
<tr>
<td>PAOB</td>
<td>1978 - present</td>
<td>NCEP CDAS</td>
</tr>
<tr>
<td>GMS, METEOSAT, cloud drift IR and visible winds</td>
<td>1977 – present</td>
<td>NOAA/NCEP</td>
</tr>
<tr>
<td>GOES cloud drift winds</td>
<td>1997 – present</td>
<td>NOAA/NCEP</td>
</tr>
<tr>
<td>EOS/Terra/MODIS winds</td>
<td>2007/7/01 - present</td>
<td>NOAA/NCEP</td>
</tr>
<tr>
<td>EOS/Aqua/MODIS winds</td>
<td>2002/9/01 - present</td>
<td>NOAA/NCEP</td>
</tr>
<tr>
<td>Surface land observations</td>
<td>1970 - present</td>
<td>NOAA/NCEP</td>
</tr>
<tr>
<td>Surface ship and buoy observations</td>
<td>1977 - present</td>
<td>NOAA/NCEP</td>
</tr>
<tr>
<td>SSM/I rain rate</td>
<td>1987/7 - present</td>
<td>NASA/GSFC/DAAC</td>
</tr>
<tr>
<td>SSM/I V6 wind speed</td>
<td>1987/7 - present</td>
<td>RSS</td>
</tr>
<tr>
<td>TMI rain rate</td>
<td>1997/12 - present</td>
<td>NASA/GSFC/DAAC</td>
</tr>
<tr>
<td>QuikSCAT surface winds</td>
<td>1999/7 - present</td>
<td>JPL</td>
</tr>
<tr>
<td>ERS-2 surface winds</td>
<td>1996/3/19 – 2001/1/17</td>
<td>CERSAT</td>
</tr>
<tr>
<td><strong>Satellite Data</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOVS (TIROS N, N-6, N-7, N-8)</td>
<td>1978/10/30 – 1985/01/01</td>
<td>NCAR</td>
</tr>
<tr>
<td>(A)TOVS (N-9; N-10; N-11; N-12)</td>
<td>1985/01/01 - 1997/07/14</td>
<td>NOAA/NESDIS &amp; NCAR</td>
</tr>
<tr>
<td>ATOVS (N-14; N-15; N-16; N-18; N-19)</td>
<td>1995/01/19 - present</td>
<td>NOAA/NESDIS</td>
</tr>
<tr>
<td>EOS/Aqua</td>
<td>2002/10 - present</td>
<td>NOAA/NESDIS</td>
</tr>
<tr>
<td>SSM/I V6 (F08, F10, F11, F13, F14, F15)</td>
<td>1987/7 - present</td>
<td>RSS</td>
</tr>
<tr>
<td>GOES sounder Tg</td>
<td>2001/01 - present</td>
<td>NOAA/NCEP</td>
</tr>
<tr>
<td>SBUV2 ozone (Version 8 retrievals)</td>
<td>1978/10 - present</td>
<td>NASA/GSFC/Code 613.3</td>
</tr>
</tbody>
</table>

G5-CERES: restricted input data streams
MERRA FILE COLLECTIONS

• MERRA products are organized into 24 collections, each consisting of a series of daily HDF files.

• All distributed data products have slightly degraded precision and are compressed with gzip.

• All data within each collection have the same horizontal, vertical, and temporal resolution.

• Data are produced on three horizontal grids:
  - Native ----------- (1/2 by 2/3 w/ FV conventions)
  - Reduced ------- (1½ by 1½ Dateline-edge, Pole-edge)
  - Reduced FV -- (1 by 1¼ w/ FV conventions)

• In the vertical, 3-D data can be at:
  - 72 model layers
  - 42 pressure levels

• Temporal resolution can be:
  - 1- or 3-hour averages
  - 3- or 6-hourly instantaneous
MERRA FILE COLLECTIONS

ANALYZED FIELDS \( (u,v,t,q,O_3,p) \) [2]
NATIVE, INSTANTANEOUS, 6-HOURLY MODEL AND PRESSURE LEVELS

INVARIANTS [2]

ASSIMILATED FIELDS [1]
REDUCED, INSTANTANEOUS, 3-HOURLY PRESSURE LEVELS

3-D DIAGNOSTIC FIELDS [8]
REDUCED, TIME-AVERAGED, 3-HOURLY PRESSURE LEVELS

2-D DIAGNOSTIC FIELDS [5]
NATIVE, TIME-AVERAGED, HOURLY

PRODUCTS FOR OFFLINE CHEMISTRY TRANSPORTMODELS [6]
VARIOUS RESOLUTIONS FREQUENCIES AND GRIDS
Comparisons
What is the impact of removing data for G5-CERES?
Zonal mean temperature comparison

G5-MERRA

GEOS-5

ECMWF

Δ

G5-CERES
Zonal mean temperature comparison

G5-MERRA

G5-CERES

Δ
Zonal mean zonal wind comparison

G5-MERRA

G5-CERES

Δ
Zonal mean specific humidity comparison

G5-MERRA

G5-CERES

Δ
Precipitation comparison

G5-MERRA

G5-CERES

GEOS-5

GPCP

Δ
Validation
Including ERA-40, JRA-25
Precipitation c.f. GPCP (mm/day)
January 2004

GEOS 5 - GPCP
\(aave = 0.077, sd = 1.495\)

CMAP - GPCP
\(aave = -0.00, sd = 1.059\)

NCEP-R1 - GPCP
\(aave = 0.113, sd = 1.828\)

JRA-25 - GPCP
\(aave = 0.371, sd = 1.832\)

NCEP-R2 - GPCP
\(aave = 0.564, sd = 2.628\)

ECMWF_EC-OPS - GPCP
\(aave = 0.487, sd = 1.563\)
Precipitation c.f. GPCP (mm/day)
July 2004
TPW - SSM/I
Jan 2004
TPW - SSM/I
Jul 2004

GEOS-5 - ssmi
\[ \text{aave} = 0.282, \text{sd} = 1.187 \]

NCEP-R2 - ssmi
\[ \text{aave} = -0.33, \text{sd} = 4.390 \]

JRA-25 - ssmi
\[ \text{aave} = -0.42, \text{sd} = 1.721 \]

ECMWF_EC-OPS - ssmi
\[ \text{aave} = -0.57, \text{sd} = 1.362 \]
Jan 2004 TOA SW CLDFCN diff from CERES ERBE–like (W/m^2)

CERES Terra–Aqua
ave=-2.32 std=9.409

GEOS5 MERRA
ave=-0.18 std=20.38

EC–OPS
ave=-2.36 std=19.98

JRA–25
ave=2.429 std=26.53

NCEP/NCAR
ave=-17.3 std=27.04
Jan 2004 TOA LW CLDFCN (W/m$^{-2}$)

CERES ERBE-like
- ave=26.89 std=18.33

GEOS5 MERRA
- ave=24.42 std=18.95

EC-OPS
- ave=18.21 std=13.62

JRA-25
- ave=16.82 std=12.02

NCEP/NCAR
- ave=31.38 std=18.95
Jan 2004 TOA LW CLDFCN diff from CERES ERBE-like (W/m²)

**CERES Terra–Aqua**
- ave = -1.04 std = 3.148

**GEOS5 MERRA**
- ave = -2.65 std = 8.462

**EC–OPS**
- ave = -8.51 std = 8.061

**JRA–25**
- ave = -9.95 std = 8.815

**NCEP/NCAR**
- ave = 4.260 std = 10.82

[Color scale from -40 to 40]
G5P15-NCDC SoD July 2004

Surface Air Temp (K) (G5 T2M–Station) July 2004

Min Daily Surface Air Temp (K) (G5 T2M–Station) July 2004

Max Daily Surface Air Temp (K) (G5 T2M–Station) July 2004
T2m Variations over Antarctica
January 2004

Megadunes -83S -160W

Moody Nunatak 80.5S -125.0W

Climate Variability
and
Observing system impacts
300 MB Eddy Height vs EC OPS

<table>
<thead>
<tr>
<th>GEOS-5</th>
<th>EC OPS</th>
<th>G5 - EC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan 04 (neutral)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jan 06 (weak La Nina)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>04 - 06</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Jan 06 (weak La Nina)
300 MB Eddy Height vs EC OPS

GEOS-5
EC OPS
G5 - EC

Jul 04
Jul 06
04 - 06
TOA NET SW interannual variation (W/m²)

CERES ERBE-like

Merra

Merra–CERES

Jan 2004

Jan 2006

Jan 04–06
Precipitation (mm/day) Jan 2006-Jan 2004

Jan 06: weak La Nina
Jan 04: near neutral
Area Averaged Precipitation (mm/day)

- MERRA validation and spin-up runs
- Obs: GPCP, CMAP

Graph showing area-averaged precipitation over time for different models, including ERA40, NCEP R2, JRA25, NCEP R1, and Global.
Last changes

CRTM: re-calibrated coefficients for MSU and AMSU-A ch 14
Input data: re-calibrated channels for MSU (reducing inter-satellite biases)
Input data: updated PAOB data
Zonal mean temperature comparison

G5-MERRA

GEOS-5

ECMWF

Δ
Summary

- GEOS-5 analysis improves upon many features of existing reanalyses
- G5-CERES is comparable in quality to G5-MERRA
- Biases are generally smaller than climate signals
- Precipitation issues remain: trends; diurnal cycle

- 2-degree SCOUT run precedes 1/2-degree production to provide performance preview

- MERRA: Spin-ups and Scout streams underway
  - Expect to complete processing by Fall 2009

- G5-CERES: 2 streams
  - 1998 - 2008
  - Oct 2007 → (Near real-time stream)

MERRA & NCEP CFSRR
- Comparisons
- Observing system issues: sensitivity of the systems (different models, same analysis);
  performance of assimilation tools (bias corrections);
  feedback files from scout runs