Overview and Status

Some early results

Monitoring (time permitting)

Presented by Michael Bosilovich, GSFC, January 5, 2009
NASAs Modern Era Retrospective-analysis for Research and Applications (MERRA)

- Retrospective-analyses use a fixed Global Atmospheric Model and Data Assimilation System to analyze the historical satellite and conventional data records into a continuous global gridded data set including a multitude of ancillary weather and climate diagnostics.

- MERRA uses the latest release of the GMAO Global Earth Observing System Data Assimilation System (GEOS-5) and will analyze the period from 1979 – present, assimilating satellite radiances and conventional observations.

- A NASA contribution to CCSP Synthesis and Assessment Product 1.3: Re-analyses of historical climate data for key atmospheric features. Implications for attribution of causes of observed change.
MERRA will analyze radiances from these satellites, and also several satellite retrieved data products as well as conventional observations (e.g. sondes).
The Changing Observing System

1973 – 77K Obs every 6hrs
07-Jan-1973 12UTC All data: 77098 observations

1979 – 325K Obs every 6hrs
07-Jan-1979 12UTC All data: 325765 observations

1987 – 550K Obs every 6hrs
02-Aug-1987 12UTC All data: 550502 observations

2006 – 4.2M Obs every 6hrs
07-Jan-2006 12UTC All data: 4217655 observations
NASA’s Modern Era Retrospective-analysis for Research and Applications (MERRA)

► Objective: To improve the water cycle representation in reanalyses, and support NASA Earth science and application activities

► 1979-present (continuing as it is feasible)

► $\frac{1}{2}^\circ$ horizontal resolution (72 model levels, sfc-strat)

► 1 hourly surface and 2D diagnostic data

► 6 hourly 3-Dimensional atmospheric analysis

► >150 Tbs online storage, many portals

► Production Began May 2008 (complete Fall-2009)


► Data - http://disc.sci.gsfc.nasa.gov/MDI SC/

► Discussion - http://merra-reanalysis.blogspot.com/
MERRA Validation

- Experiment Review, Nov 2007
- Included Short Experiments at native resolution (9 months was the longest)
  - Long experiment with coarse resolution (Scout)
- Radiation, clouds, precipitation, surface temperature, UTH, general circulation
- Data sources: SRB, CERES, MODIS, GPCP
- Increments (e.g. P-E), Indian Monsoon
MERRA Production Status

Nearly 17 years complete shipping to DISC

MERRA Production Streams

Updated Sat Jan 3 19:20:09 UTC 2009

► This figure is updated regularly at:
http://gmao.gsfc.nasa.gov/research/merra/progress-events.php
Effect of Water Vapor Analysis

Global mean P–E

- MERRA
- MERRA sc
- ECinterim
- JRA–25
- NCEP2
- ERA–40 and ops

P–E (mm/day)

Time (year)
MERRA Precip Taylor Diagrams

See also: Bosilovich et al (2008, JAMC)
Zonal Mean Specific Humidity

ERA 40

JRA25
Basin-scale Precipitation

- CPC US ¼ gridded gauge data
- Daily, Jan 1 – Sep 30 2004
- Consider all of the Mississippi River Basin domain
- Comparison with CEOP Multi-Models in Poster session
Jan-Sep 2004
Daily MRB
Precipitation

- MRB is in the heart of a data rich region for analyses
- Precipitation is independent (not assimilated)
- In general, Models have different characters
- Most overestimate high rain events
- BMRC excessively dry summer
- GEOS5 slight under estimate, but otherwise comparable with the best
Following A. Betts et al. compare soil wetness with LCL and precipitation to estimate land/atm coupling.

The LCL is not sensitive to soil wetness over the Ohio, and a bit more over the Missouri.
Cloud forcing to Precipitation

Cloud Albedo, a SW cloud forcing diagnostic (Betts et al)

MERRA underestimates the maximum range of both ISSCP observations and ERA40 over the Missouri.
Global Energy Flows W m⁻²

1. Reflected Solar Radiation
   - 102
   - 101.9 W m⁻²
   - 96.2

2. Reflected by Clouds and Atmosphere
   - 79
   - 72.2

3. Analysis Increment
   - 12.4

4. Reflected by Surface
   - 23
   - 24.0

5. Absorbed by Surface
   - 161
   - 173.2

6. Absorbed by Atmosphere
   - 78
   - 72.0

7. Evaporation
   - 80
   - 74.9

8. Net absorbed
   - 0.9
   - 13.7
   - 13.8 W m⁻²

9. Toa Net
   - 2.6

10. Outgoing Longwave Radiation
    - 238.5 W m⁻²
    - 242.6

11. Atmospheric Window
    - 40

12. Greenhouse Gases
    - 333

13. Back Radiation
    - 333

14. Surface Radiation
    - 393.2
    - 396

15. Net absorbed
    - 0.9
    - 13.7
    - 13.8 W m⁻²

Background from Trenberth, Kiehl and Fasullo (2008, BAMS Accepted)
• All reanalyses get similar patterns as observation.
• The difference between observations can be a reference for the uncertainty in reanalyses.
• For all reanalyses, strongest error happens over tropical convective regions.
• MERRA TOA LW flux bias mean and standard deviation are moderate among reanalyses.

From Junye Chen
• LW-SW Joint Frequency Distribution (JFD) shows the relationship of LW and SW under different atmospheric states.
• The shape and location of MERRA LW-SW JFD is closer to CERES observation, while the MERRA pattern is a little stretched.
• From Junye Chen
**Trends in the Water and Energy Cycles**

- Global P trend mostly over Ocean, and corresponds to Qv Increments
- Atm Latent heating variations anti-correlated to heating increments
Global surface net imbalance is improving in time, mostly changing over Ocean.

The Ocean net imbalance is decreasing in incoming SW radiation and increasing LE.
Vertically-Integrated Water Vapor Budget for July 1993

\[ \frac{\partial q_v}{\partial t} = E - P - \nabla \cdot q_v + \frac{\partial q_v}{\partial t}_{\text{ANA}} \]

- Complete budgets are available including all tendencies and analysis increments
- Water (all phases), Ozone, KE, Enthalpy, Included
- Also, land-only budgets
- Tremendous effort by Max Suarez, Larry Takacs, and Randy Koster
Much fewer observations early in the record, still weather can be reasonable.
MERRA analyzed center is south of observed
Contaminated ERS1 data is used
Resolution still too coarse for small TCs
Scout SBUV Assimilation Statistics, Mar 1992

All ozone data (Global)

Data counts: Used (p) Passive Not used

Data residuals: rms(O-B) rms(O-A) mean(O-B) mean(O-A)

Normalized cost: \( \frac{J_0(O-B)}{p} \) \( \frac{J_0(O-A)}{p} \)
Ozone response to questionable data

Increments

Ozone
Flawed sounding: Azores

1979-1980: A persistent sounding west of Portugal is very different from others nearby.

The result is a persistent counter-increment that affects energetics and moisture budgets.
MERRA On-Line Atlas

- Updated regularly with monthly comparisons versus existing reanalyses and some global observed data sets
- More comparisons being added and will be redone at the completion of MERRA
- Beta Version: Comments Welcome

Example figures from the Atlas

500mb Eddy Height vs JRA25

Precipitation Taylor Diagram, All Reanalyses using GPCP as the reference
MERRA Documentation

- GEOS5 Model and Assimilation Document, Rienecker et al., 2008: NASA/TM-2008-104606, V27

- MERRA File Specification, Suarez et al. (Outlines the output data format, and information on variables)

- MERRA Validation, Bosilovich et al. (Results of the GEOS5 Validation Experiments, prior to beginning MERRA production)