MERRA & US Reanalysis
Plans & Activities

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Overview

- National Perspective
  - Past and ongoing re-analyses
  - Potential projects
  - CCSP deliverable

- MERRA
  - GEOS-5 System
  - Processing Plans
  - Status
Atmospheric Reanalyses

- NASA Data Assimilation Office
  - Early 1985 – 1993 reanalysis, GEOS-1
  - Not much impact - NCAR/NCEP product came out soon after

- NCAR/NCEP Reanalysis 1 and 2
  - Covered 1948 – present; v2 corrects a few significant problems
  - T62, 28 levels
  - Products disseminated effectively; huge impact

- North American Regional Reanalysis
  - Based on operational regional eta model – 32km
  - Covered 1979 – 2003; dissemination underway
Ongoing Atmospheric Reanalyses

- **Climate Data Assimilation System - CDAS**
  - Extension in real time of NCAR/NCEP global reanalysis
  - Still useful, although coarse and outdated
  - Current operational analysis beginning to be used for many purposes

- **Regional Climate Data Assimilation System – R-CDAS**
  - Extension in real time of North American Regional Reanalysis
  - Eta being superseded by WRF model?

- **What’s the problem (all circa 2002 or so)?**
  - All of these, while extremely valuable, had/have serious flaws
  - No overall National coordination/oversight
  - No coherent NOAA program
The Workshop concluded that the U.S. must establish a National Program for Ongoing (Iterative) Analysis of the Climate System to provide a retrospective and ongoing physically consistent synthesis of earth observations in order to:

- Design and guide operation of observing systems
- Produce and sustain the growing climate record
- Reconcile disparate climate observations and characterize analysis uncertainty
- Establish initial conditions for climate prediction
- Validate prediction and projection models on all time scales
- Provide long time series of global and regional (North American) climatic analyses for all types of prediction and projection verification

- Workshop report distributed (Arkin et al. 2003)
- See workshop web site (http://www.joss.ucar.edu/joss_psg/meetings/climatesystem/) for pdf version of report and background information from the workshop.
Elements of a Comprehensive Ongoing Analysis

- Enhancing and managing the observational database
  - Archeology, new sensors, continuity and feedback

- Ongoing analysis
  - Document impact of continuing observing system changes
  - Provide feedback to observing system developers/operators

- Periodic reanalyses
  - **R1979** -- Post 1979 -- goal of continuous climate record, improved hydrological cycle
  - **R1950** -- Post 1950 -- emphasis on continuity and low-frequency signal, interannual-to-decadal variability
  - **R1850** -- Post 1850 -- best and longest consistent analysis, surface NH oriented, climate change
  - Continental-scale regional reanalysis at very high spatial resolution

- Stewardship and dissemination
  - Ensure that the products are useable

- Research
  - Develop improved methods and products
  - Intended to solve problems identified within program
Planned and Potential Reanalysis Activities in the U.S.

- **Modern Era Reanalysis for Research and Applications (MERRA)**
  - Funded NASA GMAO effort

- **Surface Input Reanalysis for Climate Assessment (SIRCA)**
  - Initial testing underway; funding needed [Gil Compo]

- **NCEP/EMC is interested in a reanalysis to support its Climate Forecast System**
  - Focused on satellite era
  - No real funding or progress so far

- **Integrated Earth System Analysis Project**
  - Evolved from proposed US Ongoing Analysis Project
  - Proposed by Randy Dole/Anjuli Bamzai to Climate Change Science Program [CCSP]
  - Presented to NRC Climate Research Committee
  - Tepid reception by CCSP so far

- **Analysis of Record proposed by NWS – overlap with NARR**

- **Arctic System Reanalysis**
  - Proposal for IPY -- coupled atmosphere-sea-ice-ocean-terrestrial-30km, north of 45°N
CCSP Deliverable
CCSP Implementation Plan SWG
Chairs: Siegfried Schubert and Marty Hoerling

A state-of-science synthesis report that:

(a) Summarizes the present status of current reanalysis efforts.

(b) Discusses key research findings on the strengths and limitations of the current reanalysis products for:

(1) Describing past climate variations and trends
   [reducing uncertainties; improving models used for climate projections]

(2) Attributing causes of climate variations and trends
   [regional climate variations; high-impact climate events events; rapid climate shifts; signature of external forcing]

The temporal focus: 1948-present.

• Proposed lead agency: NOAA
• Supporting agencies: NASA, DOE, (NSF)
Long-term Trends in the NCEP/NCAR Reanalysis
Glenn H. White
EMC/NCEP/NWS/NOAA

Precipitation, Evaporation
1948-Apr 1999

Global Mean (mm/day)

12 Month Running Mean

number of observations/2.5deg

90S 90N

ECMWF Reanalysis Workshop
19–22 June 2006
What causes major drought in the United States? What can we expect in the future?

Percent Area of the Missouri Basin Experiencing Severe to Extreme Drought
January 1895–March 2004

Based on data provided by the National Climatic Data Center, NOAA

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1930s Dust Bowl

Lake Meade 2003
R1979

Focus: the best comprehensive, consistent, high-resolution global data with a strong emphasis on improving the hydrological cycle and related physical processes.

Utilize latest state-of-the-art data assimilation system Link 4DDA and model development

• Improve/assess model performance esp. hydrological cycle
• Extend assimilation techniques (e.g. precip/cloud) to use historical data
• Improve ocean surface fluxes
• Develop DAS techniques that are “moisture friendly”
• Improve stratosphere, assimilate constituents, aerosols
• Support efforts to “clean-up” satellite radiance data
• Assess impact of resolution in model and analysis
New R1979 Efforts in the U.S.

- **NOAA/NCEP NARR completed**
  - [http://wwwt.emc.ncep.noaa.gov/mmb/rreanl/](http://wwwt.emc.ncep.noaa.gov/mmb/rreanl/)
  - 1979-2003
  - Available from NCDC and JOSS

- **NASA/MERRA production starts fall 2006**
  - 1979-present
Modern Era Reanalysis for Research and Applications (MERRA)

GMAO

System Configuration

- Satellite Era, 1979 – Present
- $1/2° \times 2/3° \times 72L$
- Top: 1 Pa
- NASA GEOS-5 GCM
- Finite Volume Dynamical Core
- Physics integrated under the Earth System Modeling Framework (ESMF)
- Catchment Land Surface
- NCEP/GMAO Gridpoint Statistical Interpolation (GSI)
- Prescribed aerosols; assimilated, interactive ozone
- Assimilation of GPROF rain-rate from SSM/I and TMI
MERRA Processing Streams
ICs from 2° Sweeper

- Two ways to handle 77 – Conventional obs from early 70s, or climate IC from 77-82
- Minimum 15 years then for Sweeper to provide land ICs
GEOS-5 DAS & MERRA - status

- Incremental Analysis Update (IAU)
  - reduces shock of data insertion
- Moist physics model development and tuning in DAS mode
- Data sets assembled and pre-processed as required
- Background error statistics generated and tuned for GEOS-5 (vs GFS)
- Tuning balance constraint statistics
- Currently undertaking a data-sweep
- 1/2° system in parallel test phase; 2° system used for 2001 tests
- External User Group will evaluate validation data sets (2001; 2004)
AMIP: DJF   200 MB   U vs ERA-40

GEOS-5
0.05 / 3.49

CAM-3
1.72 / 3.89

AM-2
-0.68 / 3.11
AMIP DJF  PP  vs  GPCP

GEOS-5  
.24 / 1.49

CAM-3  
.40 / 1.44

AM-2  
.22 / 1.22
Residual Circulation
Impact of IAU
January Residual circulation streamfunction
June 2001 Precipitation – GPCP (mm/day)

MERRA RPM: Mean = -0.0728723 Std = 2.19619

CMAP: Mean = 0.132038 Std = 0.974549

NCEP R1: Mean = 0.359343 Std = 2.11395

ERA-40: Mean = 0.95458 Std = 3.3008

NCEP R2: Mean = 0.828587 Std = 2.71224

JRA-25: Mean = 0.53398 Std = 2.18725
2° MERRA tests

Zonal Mean Temperature for January 2001

GEOS-5

NCEP OPS

Δ

ERA-40

Δ
2° MERRA tests

Zonal Mean Temperature for April 2001

GEOS-5

NCEP OPS

Δ

GEOS-5

ERA-40

Δ
1/2° tests

Zonal Mean Temperature for January 2006

GEOS-5

NCEP OPS

ECMWF OPS

Δ

Δ
1/2° tests

Zonal Mean U for January 2006

GEOS-5

NCEP OPS

ECMWF OPS

Δ
MERRA: Issues encountered

- CRTM does not support early satellite data or SSU -- RTTOVS not yet fully included -- workaround is to use GLATOVS
- Precipitation shock, online ozone assimilation, stratosphere and tracer applications led us to adopt IAU
- Calibration issues for SSM/I precipitation estimates (TMI merged product)
- Precipitation assimilation
- Need to tune the model physics in assimilation mode
- Super-ob’ing of non-radiance data
- SST - which product?

Schedule

- Production planned to begin Sept 2006
- 2-year duration for production