A Reanalysis Synthesis of EOS Observations to support the National Climate Assessment

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Overview

- Initial NCA Project
  - Reanalysis Assessment
  - New Products
  - High-Res Proof of Concept

- Reanalyses and Climate Applications
  - Regional Climate Variability
  - National Climate Assessment
  - Climate Monitoring

- MERRA2 and Beyond
  - Rationale for a sequel
  - Recent development


JJA Precipitation Anomalies (mm/day)
NASA and Reanalysis

NASA’s strategic goal

“Advance Earth System Science to meet the challenges of climate and environmental change”

• Approach: characterize, understand, predict using NASA’s observations and so acquire deeper scientific understanding of the components of the Earth system and their interactions.

• Role of Reanalyses in NASA’s mission:
  • Long-term synthesis of data for a physically consistent climate research-quality data sets
  • Initial and boundary conditions for predictions
  • Validation and verification references, and internal and external constraints to models
Initial Project Summary

- Developed Assessment of MERRA and Reanalyses for US summertime regional climate (Project Report, 2012; Bosilovich 2013, JAMC)
- Tested and Delivered several MERRA-based data products
  - NCA Regional Time Series Data
  - MERRA-Land and MERRAero
  - Enhanced Ocean Flux Product
- Tested $\frac{1}{4}^\circ$ Reanalysis system in EOS period
  - Computationally expensive (short duration)
  - Little or no improvement in precipitation stats
Summer MERRA – Gauge Correlation

- Skill is regional
- Large scale influence (e.g. ENSO) can be resolved
- Mesoscale and Land-Atm interactions need study
- Bosilovich (2013)
Motivation for the Follow-on

- New data available for Reanalysis (MLS, OMI, GPSRO, IASI to name a few)
- Aerosol data assimilation incorporated
- 2013 NCA Report includes substantial discussions on extreme events and uncertainties
  - Can reanalysis play a more significant role in regional climate assessment?
- Collaboration with the INCA team for advanced metrics in reanalysis evaluation
Current and Planned Activities

- Develop MERRA2
  - 1979-onward, $\frac{1}{2}$ degree resolution
  - Latest data, updated data
  - Updated data assimilation and background model

- Explore Reanalyses for Climate Data Indices
  - Implement CDO routines for Extremes – making data available and documented online
  - Collaborate with INCA team

- Uncertainty in Regional Climate
  - Collaborate with obs4MIPS and ana4MIPS
Indices Computed and Availability

- Current MERRA-Based Indices
  - Processed using Climate Data Operators (CDO)
  - RX5day, RX1day – Max 5,1 daily precipitation in a month or season
  - 95th, 90th and 75th Percentile Precipitation
  - Heat (Cold) Wave Duration Index
  - Warm (Cold) Spell Duration Index
  - Growing Season Length
  - Some assorted data processed for input

- Data at NCCS Portal: Some pre-generated images will be linked near the MERRA Atlas

- Exploring interactive display of the data with the GESDISC Giovanni team
Max Daily Precip in a Season

- Largest precip occurrence each season at each grid point
- Hurricane Season (Jun-Nov) shows increases along East Coast and SE US
- MERRA represents the variability of the extreme precipitation well
Compositing the most extreme years to show the supporting large scale environment

- Low pressure in tropical Atlantic, with weaker westerly flow
- SST Shows warm Atlantic, including off the east coast and La Niña Pacific pattern
Warm/Cold Spell Duration

- Relies on daily mean temperature above (below) the 90\textsuperscript{th} (10\textsuperscript{th}) percentiles for the day over three days
Daily Composites of Extremes

- Choose days when mean T2m exceeds 90\textsuperscript{th}%
- JAN days in the Northeastern US
- Strong southerly flow ahead of low pressure to the west

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MERRA2 Evolution

- MERRA system will be obsolete in a few years
- Precipitation bias correction for land forcing and aerosol deposition
- Aerosol data assimilation interactive radiation - Black and Organic Carbon, Dust, Sea Salt
- Substantial revisions to the boundary layer in the background model
- Updated observational data (e.g. IASI, GPSRO)
- Tropical Cyclone Relocation
- Water Vapor Mass Increment Correction
  - Constrains the water vapor increment to be very small when averaged globally
Sweeper (2 degree) Experiment

- Water Vapor Mass Conservation stabilizes TPW
- Global E/P balance – Increments are small
- Regional increments would still be locally influential
Summary

- Developing climate index routines and verification with MERRA
  - Access through GSFC NCCS and exploring Giovanni
- Looking forward MERRA2 validation and production
  - *Currently processing Spin-up periods*
- Interested in testing and verifying additional indices in collaboration with the NASA INCA team
Supplementary Information
MERRA

• GEOS-5 ADAS, 2008 version – GEOS-5.2.0
  • 1/2° × 2/3° × 72L
  • 1979-present; cont. as a ~2-week delayed NRT climate analysis
• MERRA-Land as an update to the land-surface collection

• Web site (FAQ, blog, issues found/resolved) http://gmao.gsfc.nasa.gov/merra
  • MERRA Atlas (http://gmao.gsfc.nasa.gov/ref/merra/atlas/)
• Data online through the GES DISC (http://disc.sci.gsfc.nasa.gov/mdisc/)
  • > 2.2 PB distributed to date – Several access options
  • International by Volume: Canada, Japan, Germany, Spain, Taiwan, UK
• MERRA is online at PCMDI’s ESG for CMIP5 model evaluations (other reanalyses have been included lately)

• MERRA Special Collection in J. Climate
  • GMAO’s Overview paper – Rienecker et al. (2011)
  • 20 papers
MERRA On-line Resources

• http://gmao.gsfc.nasa.gov/merra
  • MERRA Atlas
    http://gmao.gsfc.nasa.gov/ref/merra/atlas/
  • MERRA-Land as an update to land-surface collection
  • Extremes
  • MERRA is online at PCMDI’s ESG for CMIP5 model evaluations
• Data Access: GES DISC
  http://disc.sci.gsfc.nasa.gov/mdisc/
MERRA2 – New Data in the Modern Climate Record From 1979 – Present

- MERRA2 includes the latest satellite observing systems
  - NPP: ATMS, CrIS, OMPS
  - MetOp-A/B: IASI, ASCAT, GOME2, AMSU, MHS
  - OSCAT, GPS-RO, SSMI (v7)
  - Reprocessed AMV
  - SBUV-v8

MERRA2 will begin from 1979 and carry on for several years to come, adding some of the latest observations and significant updates to the data assimilation and global model.
MERRA2 - Improved Analysis and Model

- **Aerosol Analysis**
  - Includes Black and Organic Carbon, Dust, Sea Salt
  - Interactive with modeled radiative fluxes

- **Water Vapor Conservation**
  - Surface pressure and water vapor (ANAQ) analyses are penalized for global imbalances
  - The result is that unphysical changes in total mass are ameliorated
  - Improved balance between global Precipitation (P) and Evaporation (E)
MERRA-driven component reanalyses

**Underway:**
- CO₂ (AIRS, AVHRR, MODIS)
- Aerosols (MODIS, MISR)
- Ocean (JASON, Argo, in situ)
- Sea-ice (ice concentration)
- Ocean biology (SeaWIFS, MODIS)
- Land surface (AMSR-E, ASCAT, SMOS, MODIS, GRACE)

**Analyzed Sea-ice conc. 2/20/2007**

**AERONET**

Baseline Assimilation

**AOT (500 nm) at Bonanza Creek Assimilation of MODIS data**

Linear trends of HC300, 1993–2009 from GMAO Ocean Reanalysis (°C/decade) constrained by MERRA

Improvements in soil moisture skill (R) from data assimilation (2007-2010)
Summer MERRA – Gauge

JJA Pr MERRA Correlation to CPC

NCA CONUS Regions

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Climate Monitoring

- Temperature can be robust
- Biases remain; no surface temperature analysis
Heat Wave Duration Index

- 5K above climatology for 5 day stretches
- Not exactly warming, but affected by warming
- Identifying an appropriate daily temperature data set for comparisons
Max vs Mean Precip Composite Anomaly
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System Development

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