



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

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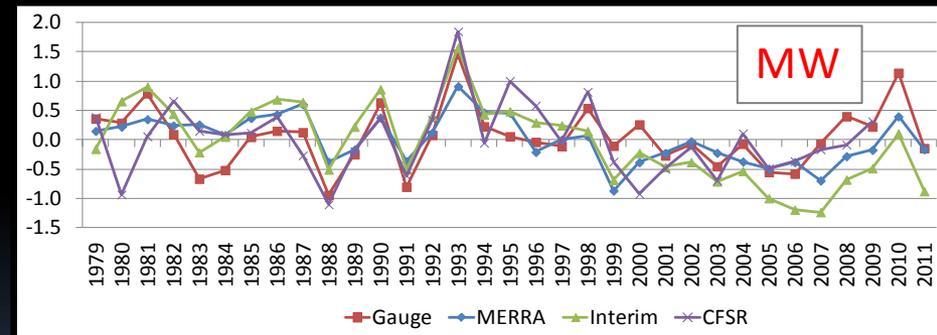
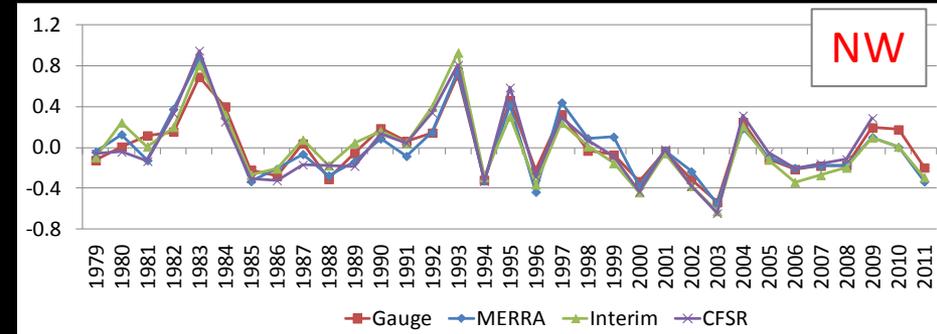
and Michele Rienecker*

NASA National Climate Assessment Indicators Team
Meeting
April 8-9, 2014

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)



Project Page:

<http://gmao.gsfc.nasa.gov/projects/NCA/>

NASA and Reanalysis

NASA's strategic goal

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

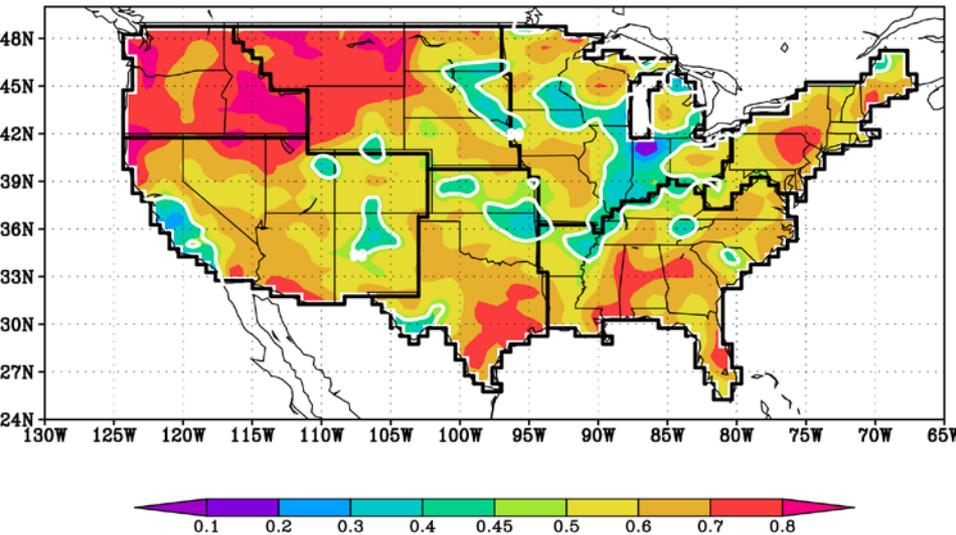
- Approach: characterize, understand, predict using NASA's observations and so acquire deeper scientific understanding of the components of the Earth system and their interactions.
- **Role of Reanalyses in NASA's mission:**
 - Long-term synthesis of data for a physically consistent climate research-quality data sets
 - Initial and boundary conditions for predictions
 - Validation and verification references, and internal and external constraints to models

Initial Project Summary

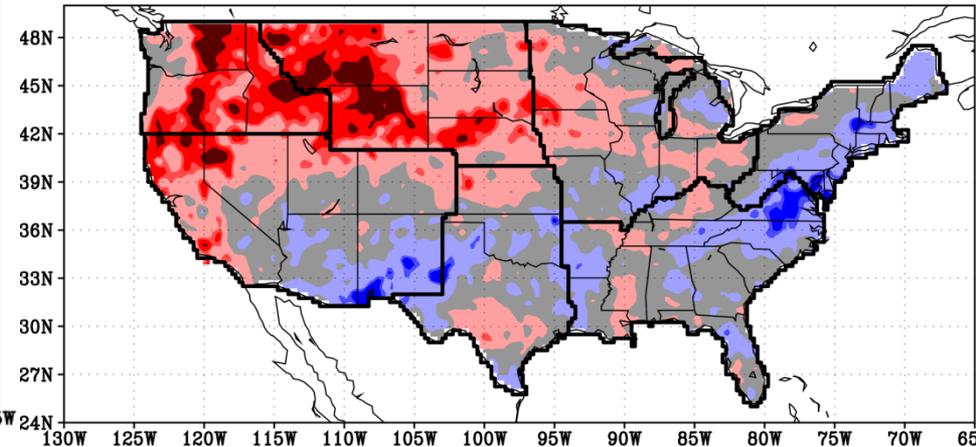
- Developed Assessment of MERRA and Reanalyses for US summertime regional climate (Project Report, 2012; Bosilovich 2013, JAMC)
- Tested and Delivered several MERRA-based data products
 - NCA Regional Time Series Data
 - MERRA-Land and MERRAero
 - Enhanced Ocean Flux Product
- Tested $\frac{1}{4}^\circ$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

Summer MERRA – Gauge Correlation

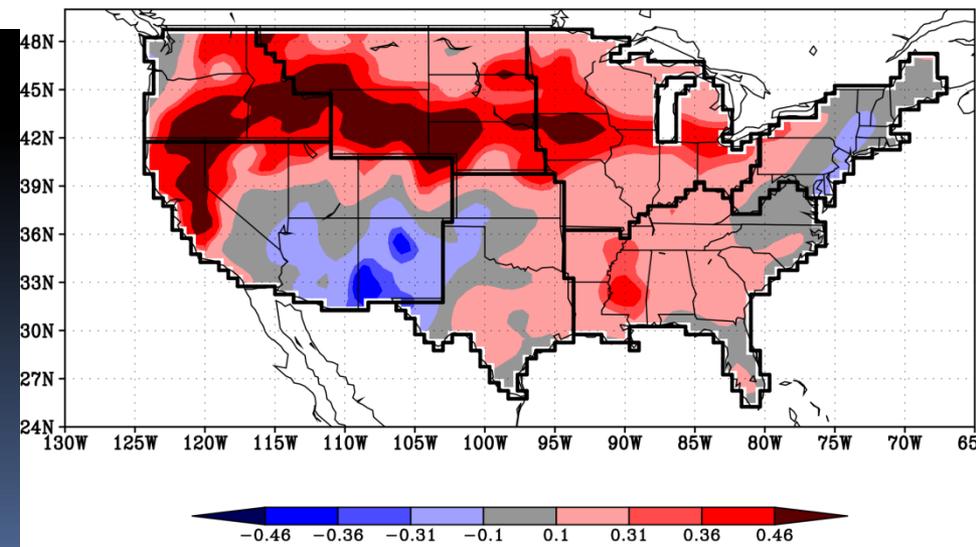
JJA Pr MERRA Correlation to CPC



CPC Gauge JJA Pr Correlation to MAM ENS034



MERRA JJA Pr Correlation to MAM ENS034



- 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

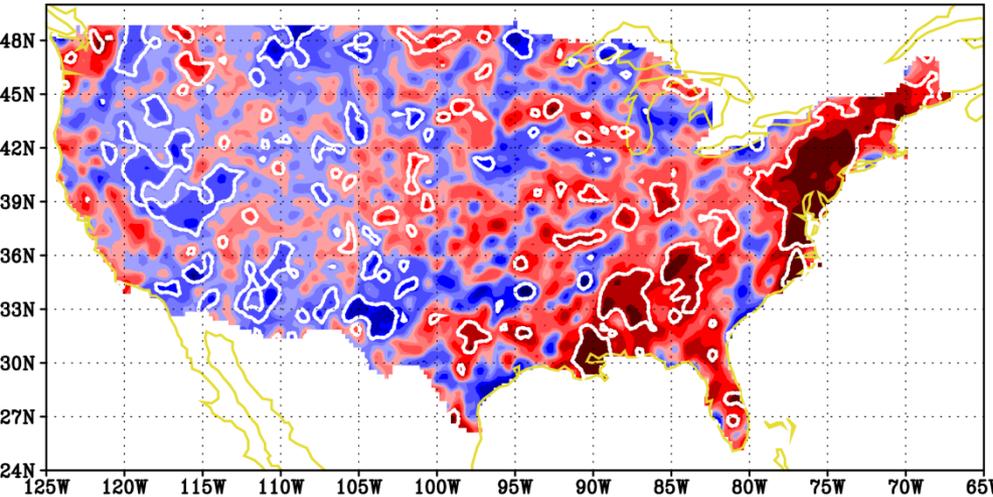
- Develop MERRA₂
 - 1979-onward, 1/2 degree resolution
 - Latest data, updated data
 - Updated data assimilation and background model
- Explore Reanalyses for Climate Data Indices
 - Implement CDO routines for Extremes – making data available and documented online
 - Collaborate with INCA team
- Uncertainty in Regional Climate
 - Collaborate with obs₄MIPS and ana₄MIPS

Indices Computed and Availability

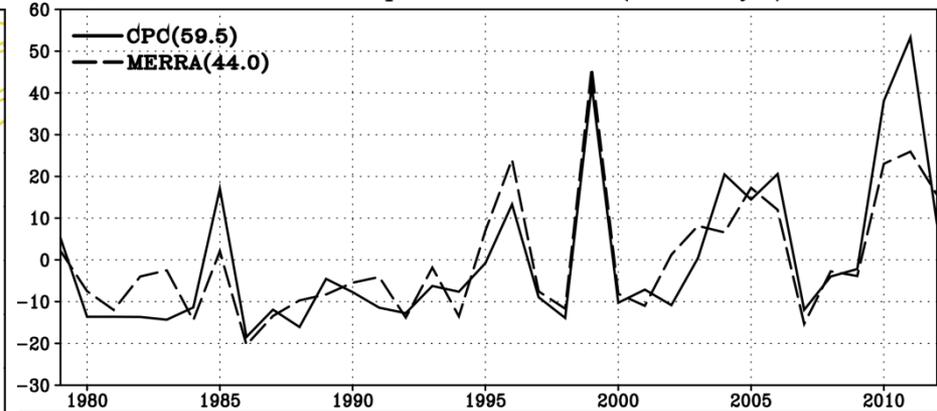
- Current MERRA-Based Indices
 - Processed using Climate Data Operators (CDO)
 - RX5day, RX1day – Max 5,1 daily precipitation in a month or season
 - 95th, 90th and 75th Percentile Precipitation
 - Heat (Cold) Wave Duration Index
 - Warm (Cold) Spell Duration Index
 - Growing Season Length
 - Some assorted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

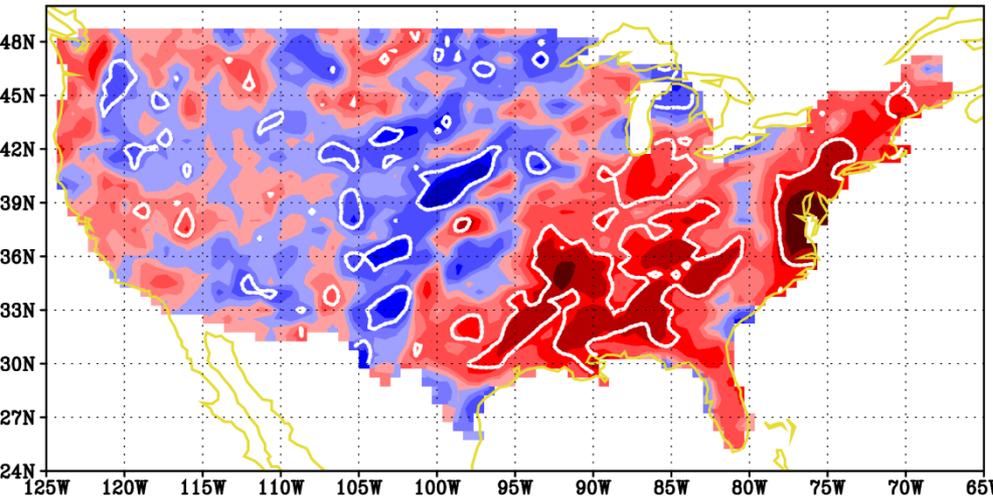
CPC Gauge Max Daily Pr Trend HUR (mm/day 10yr⁻¹)



Seasonal Max Precipitation Anom (mm day⁻¹) hur NA



MERRA Max Daily Pr Trend hur (mm/day 10yr⁻¹)

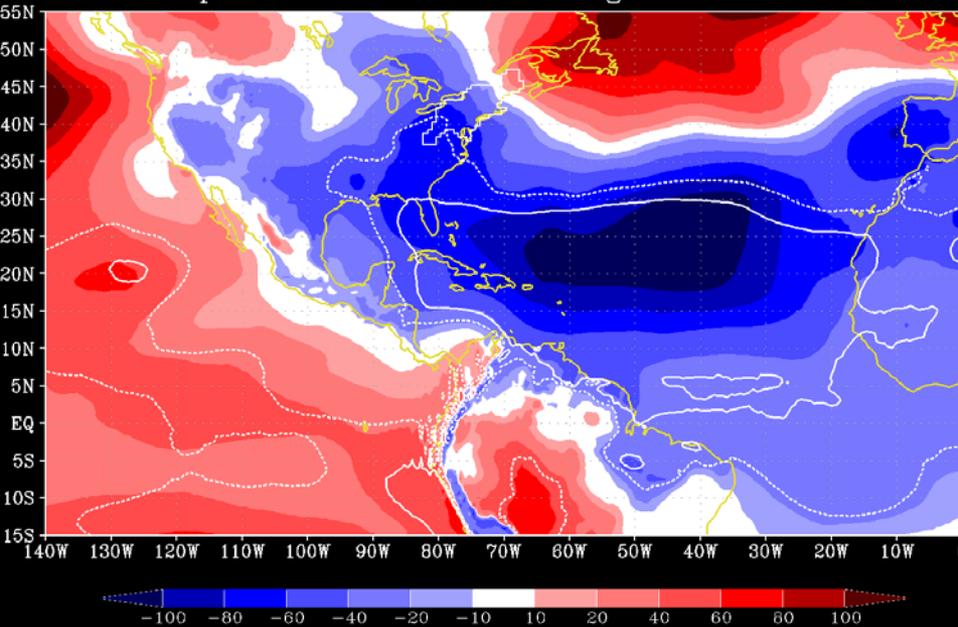


- Largest precip occurrence each season at each grid point
- Hurricane Season (Jun-Nov) shows increases along East Coast and SE US
- MERRA represents the variability of the extreme precipitation well

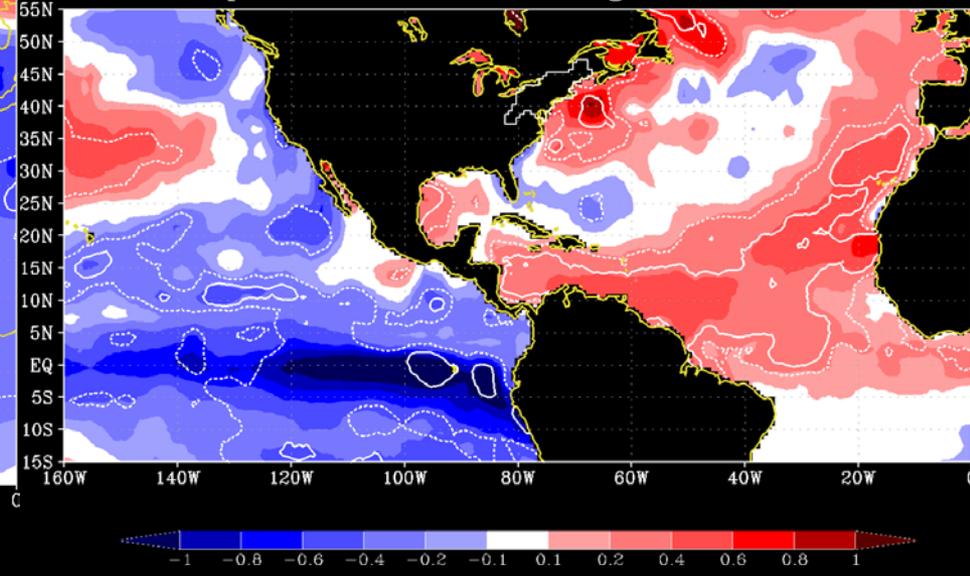


Max Precip SLP/Ts Composite Anomaly

Composite SLP for SON 10 High RX5DAY in NE

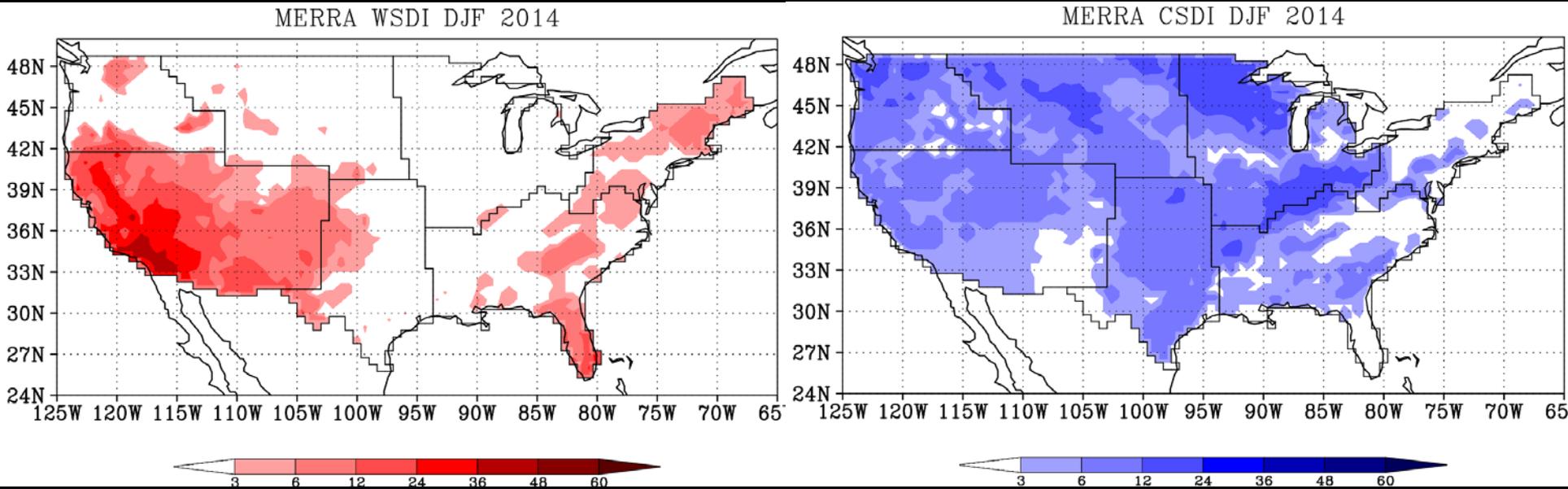


Composite Ts for SON 10 High RX5DAY in NE



- 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

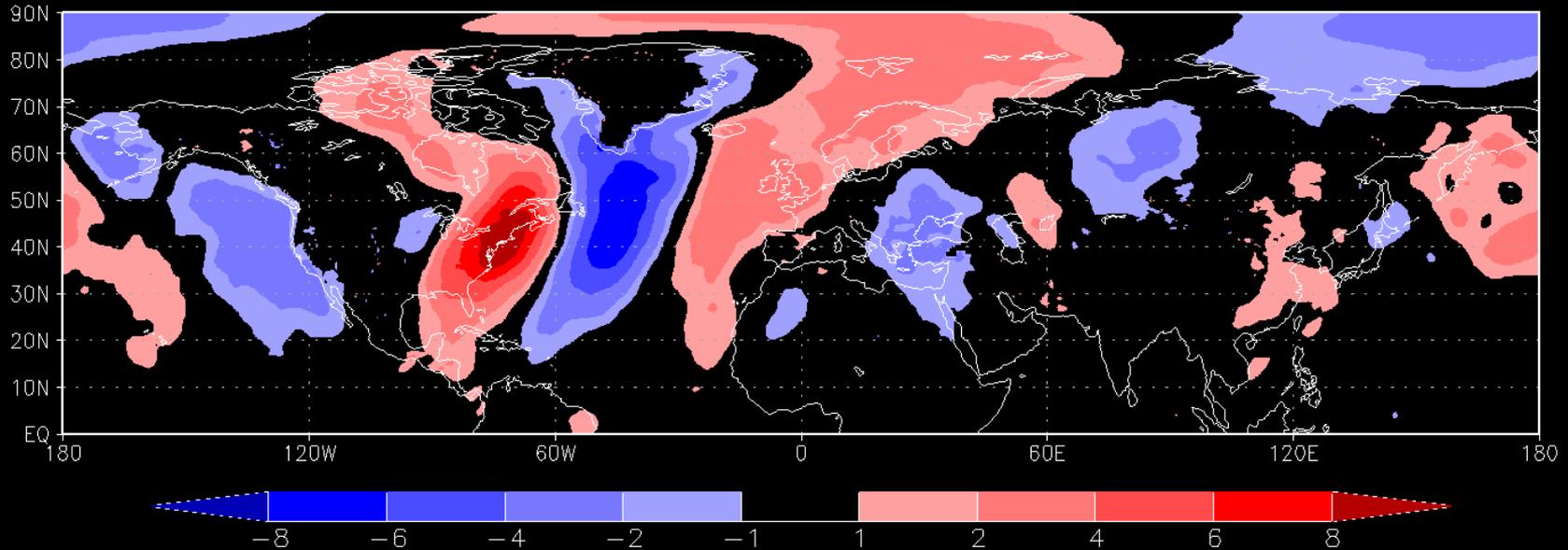
Warm/Cold Spell Duration



- Relies on daily mean temperature above (below) the 90th (10th) percentiles for the day over three days

Daily Composites of Extremes

JAN V850 (m/s) Anomaly for NE US T2m 90pctl



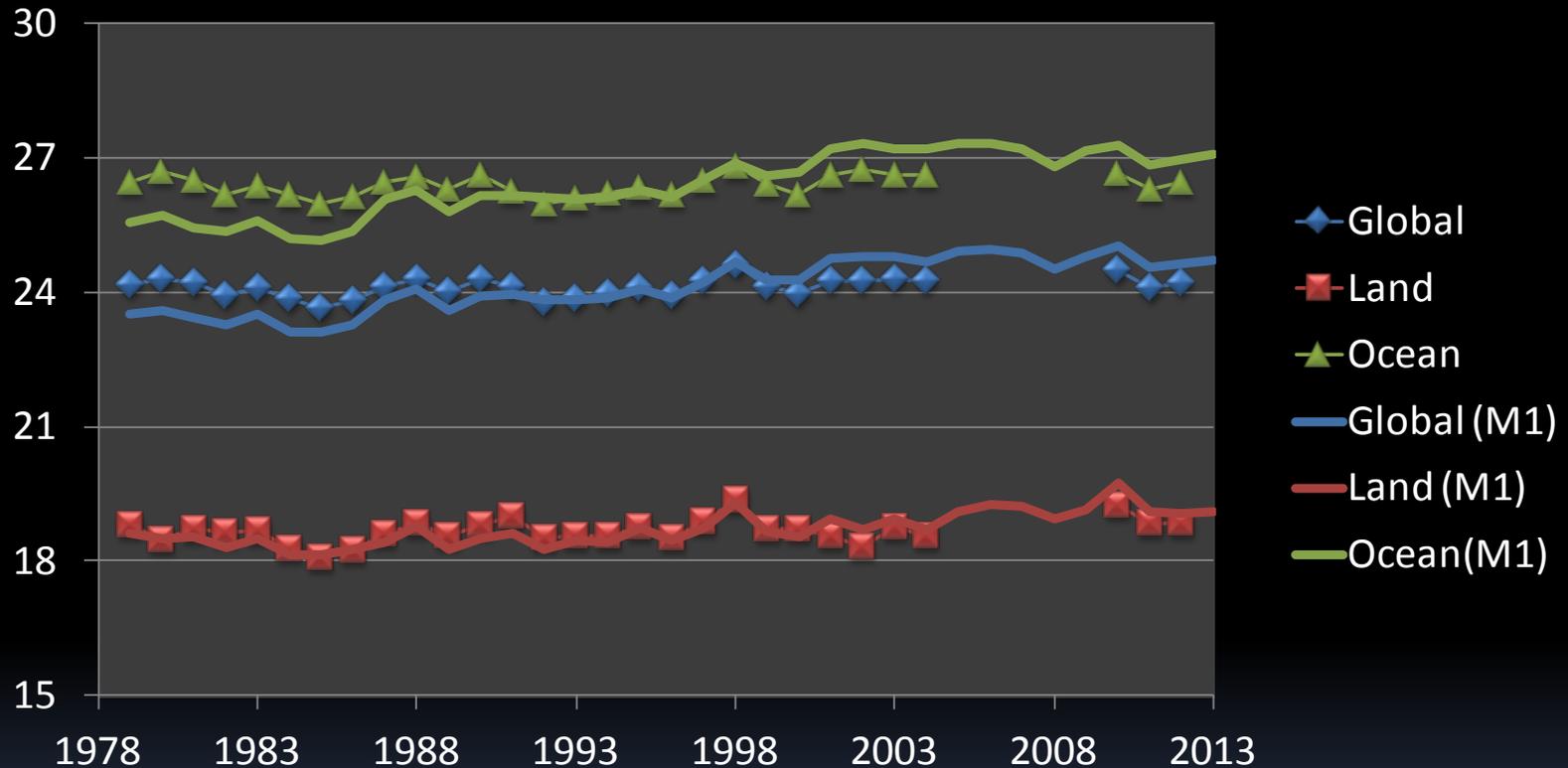
- Choose days when mean T2m exceeds 90th%
- JAN days in the Northeastern US
- Strong southerly flow ahead of low pressure to the west

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

M2 Sweeper Total Column Water (mm)



- 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

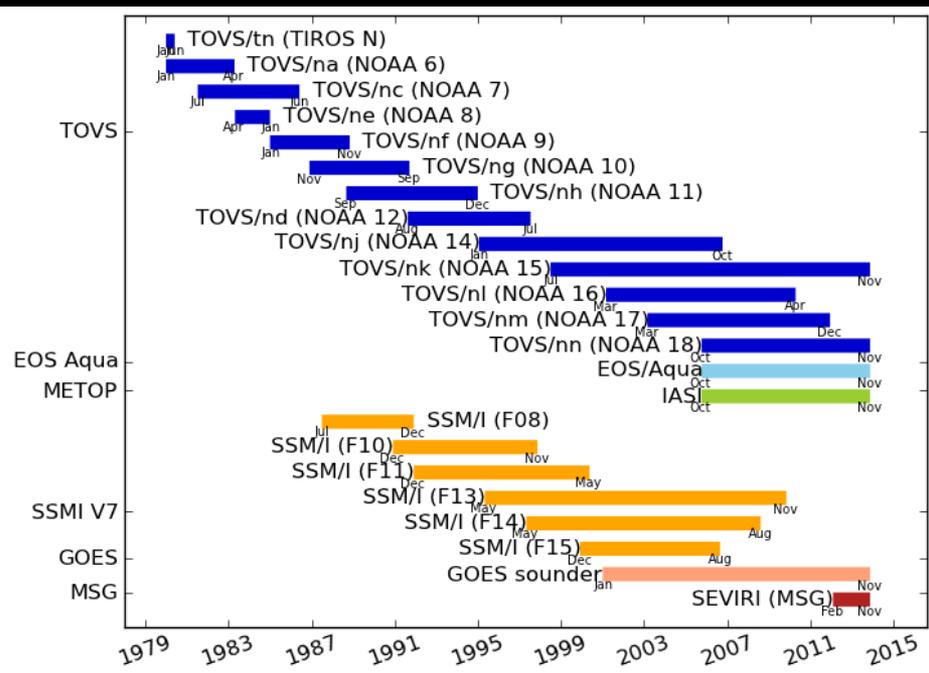
- **GEOS-5 ADAS, 2008 version** – GEOS-5.2.0
 - $1/2^\circ \times 2/3^\circ \times 72L$
 - 1979-present; cont. as a ~2-week delayed NRT climate analysis
 - **MERRA-Land** as an update to the land-surface collection
- Web site (FAQ, blog, issues found/resolved) <http://gmao.gsfc.nasa.gov/merra>
 - **MERRA 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
<http://gmao.gsfc.nasa.gov/merra/merra-land.php>
 - Extremes
<http://gmao.gsfc.nasa.gov/research/subseasonal/atlas/Extremes.html>
 - 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

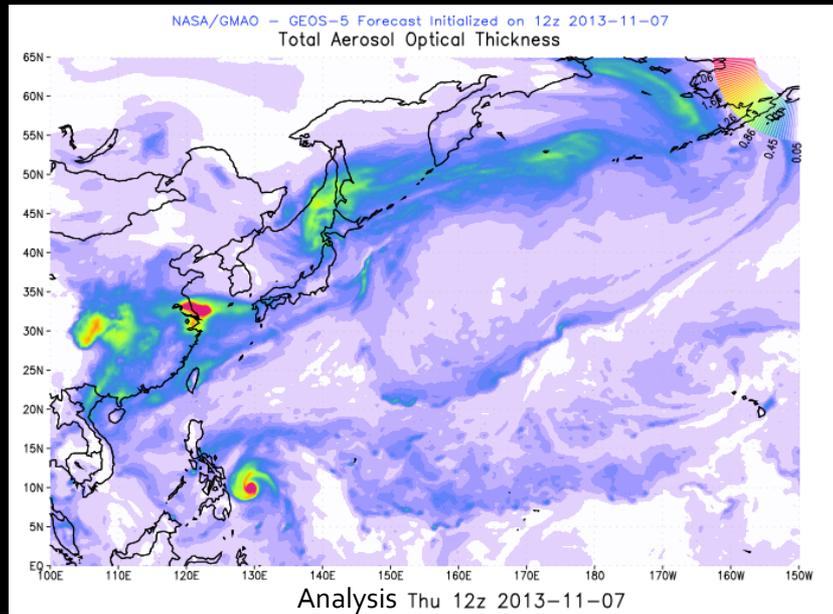
Satellite Radiances to be Assimilated



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 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 – Improved Analysis and Model

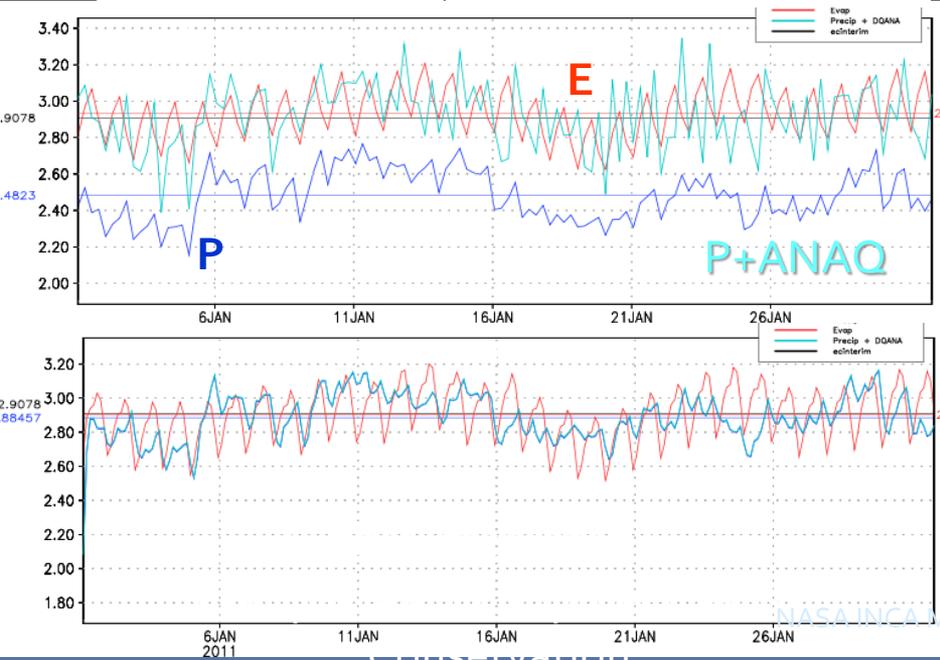


■ Aerosol Analysis

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

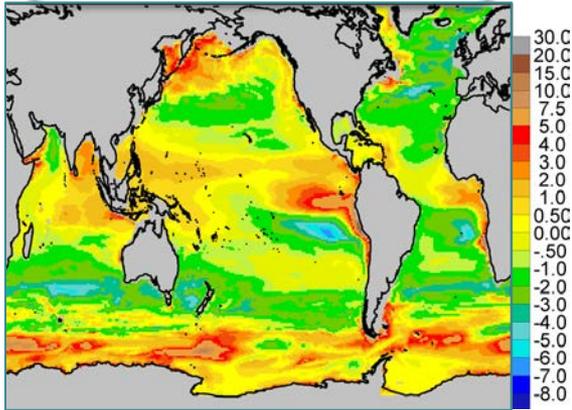
■ Water Vapor Conservation

- 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

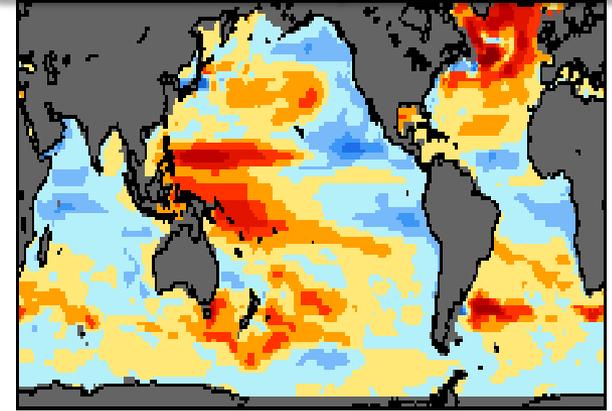
Annual Mean Air-sea CO₂ flux
from ocean model (NOBM)
forced with MERRA



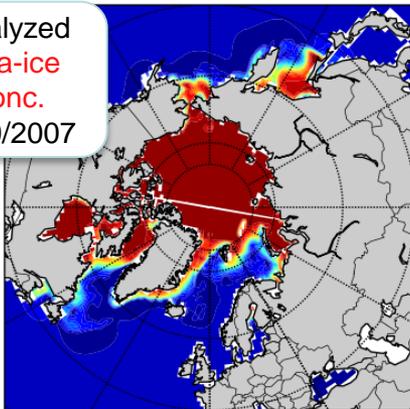
Underway:

- 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)

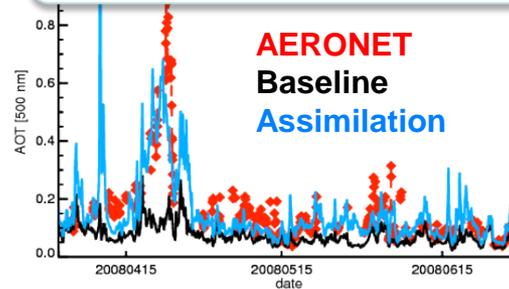
Linear trends of HC300, 1993–2009
from GMAO Ocean Reanalysis (°C/decade)
constrained by MERRA



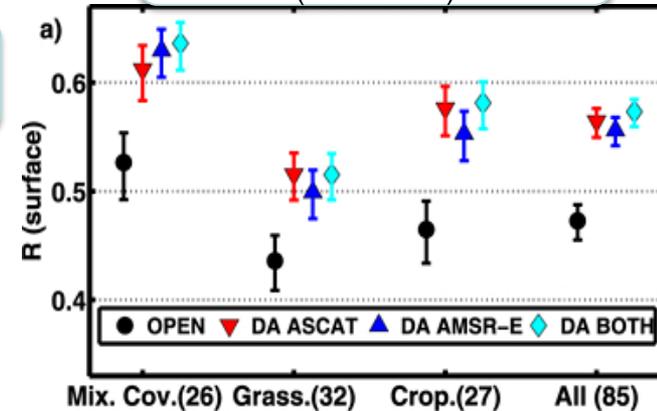
Analyzed
Sea-ice
conc.
2/20/2007



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

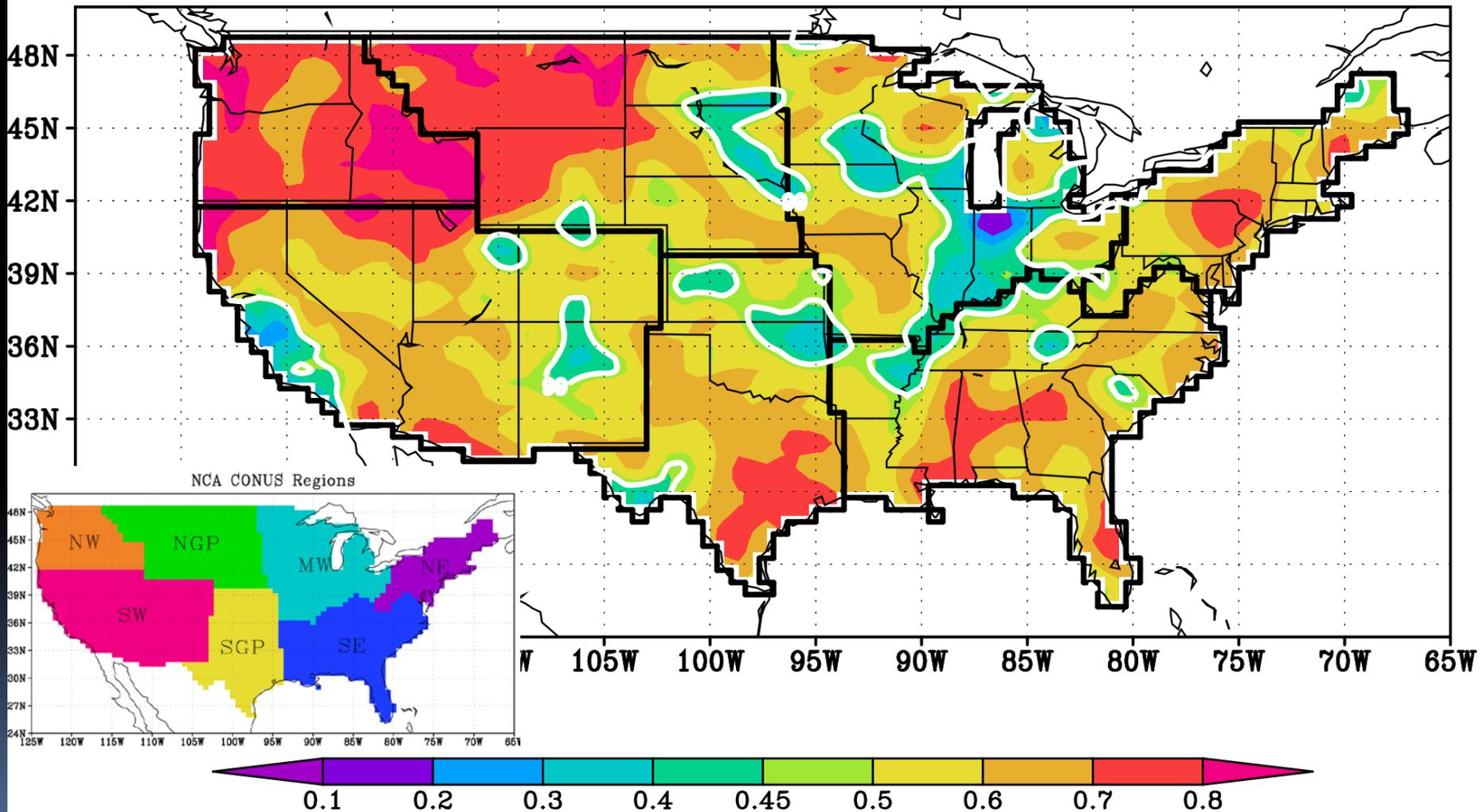


Improvements in soil moisture
skill (R) from data assimilation
(2007–2010)



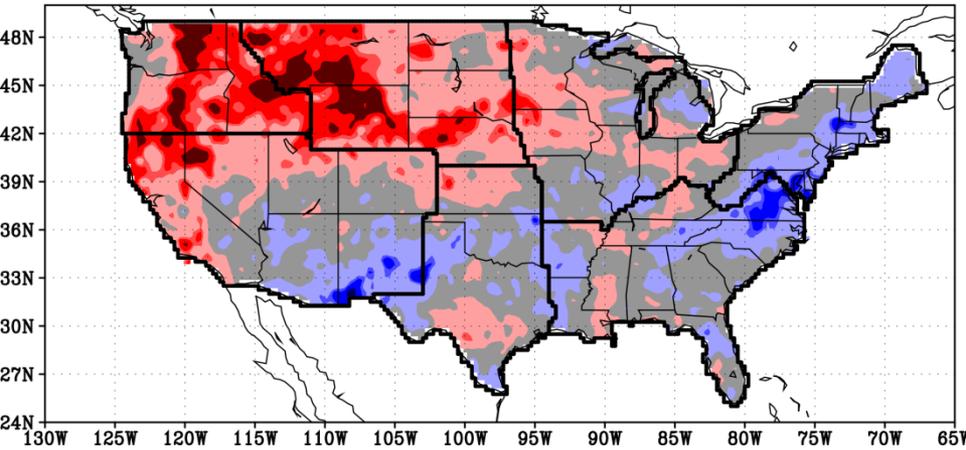
Summer MERRA – Gauge

JJA Pr MERRA Correlation to CPC

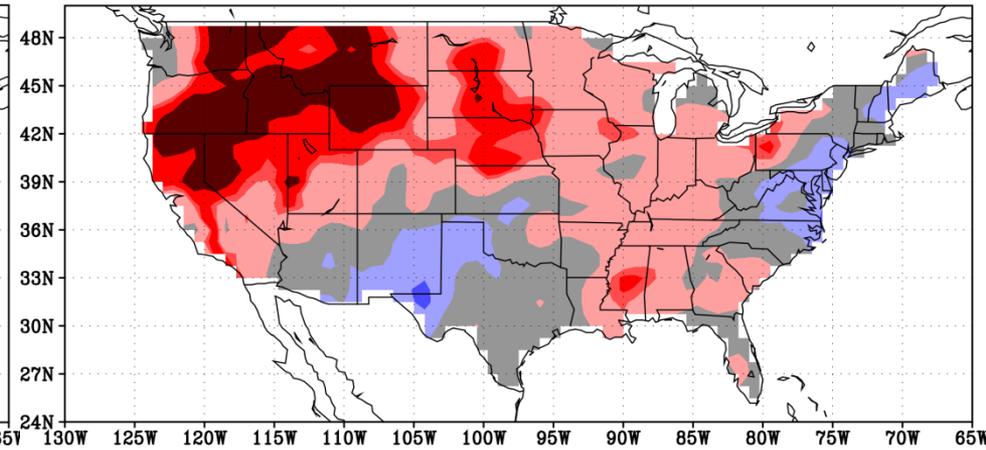


ENSO Connection

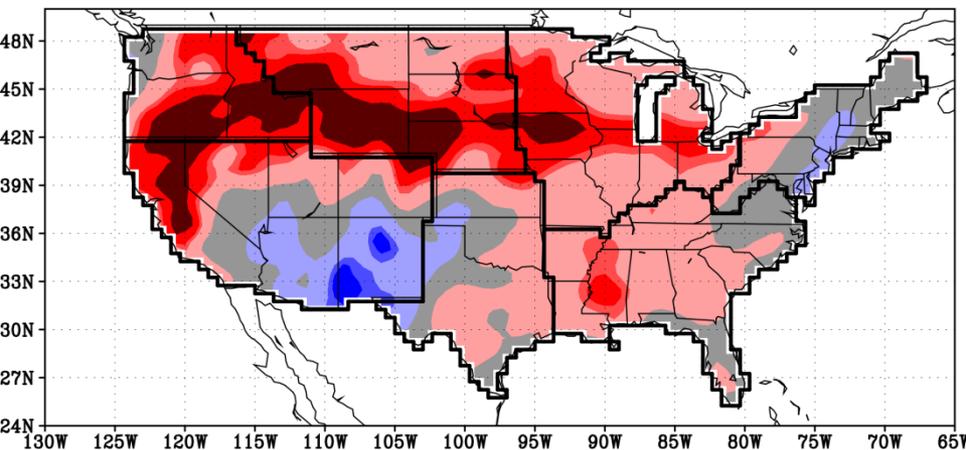
CPC Gauge JJA Pr Correlation to MAM ENSO34



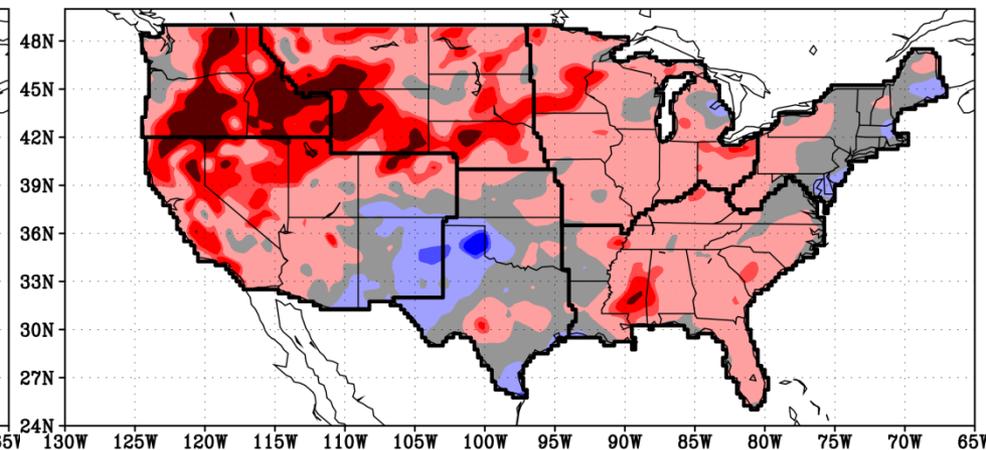
ERA Interim JJA Pr Correlation to MAM ENSO34



MERRA JJA Pr Correlation to MAM ENSO34



CFSR JJA Pr Correlation to MAM ENSO34

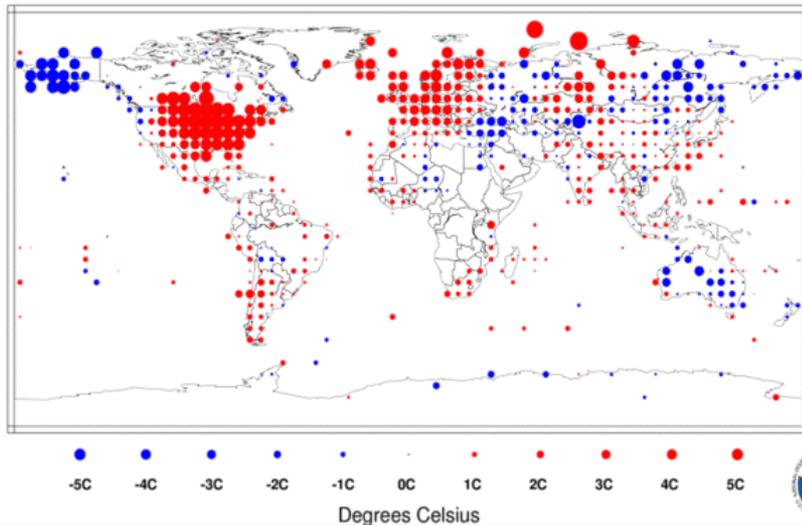


Climate Monitoring

Temperature Anomalies March 2012

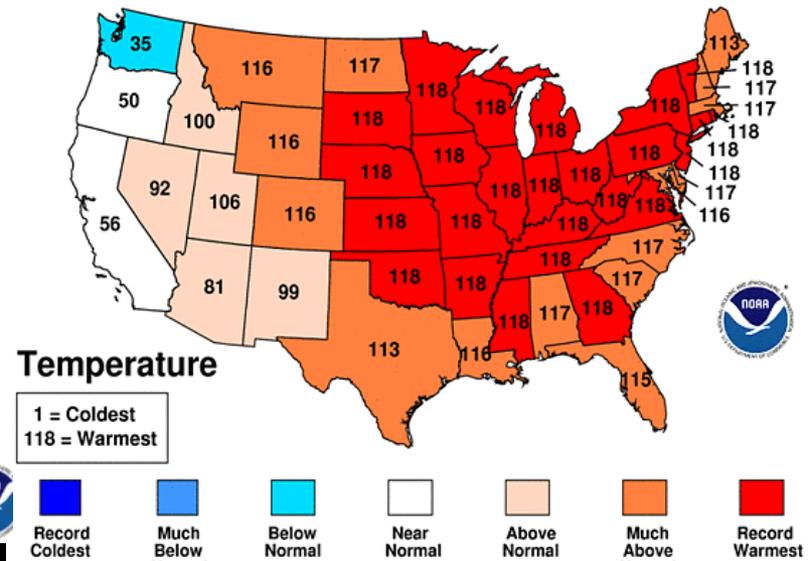
(with respect to a 1961-1990 base period)

National Climatic Data Center/NESDIS/NOAA



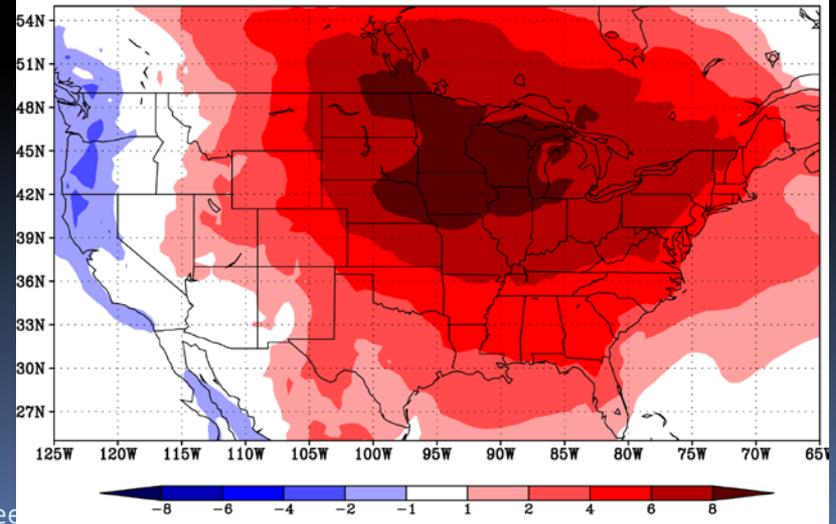
March 2012 Statewide Ranks

National Climatic Data Center/NESDIS/NOAA

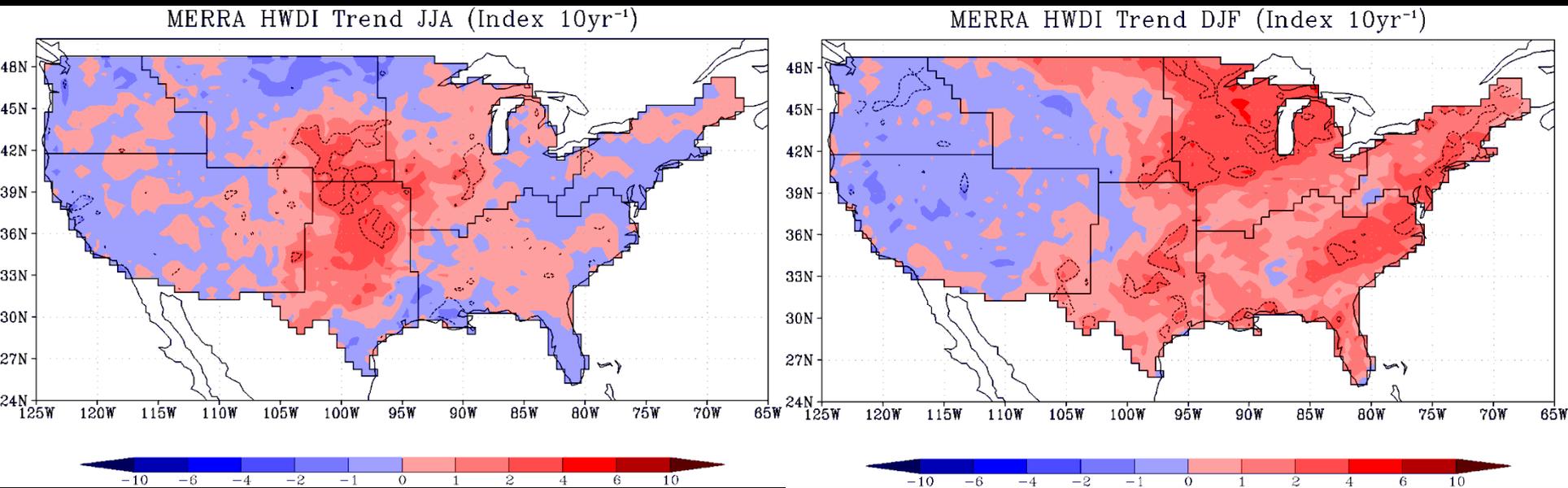


- Temperature can be robust
- Biases remain; no surface temperature analysis

MERRA March 2012 T2m Anomaly (K) (1979-2008 base)



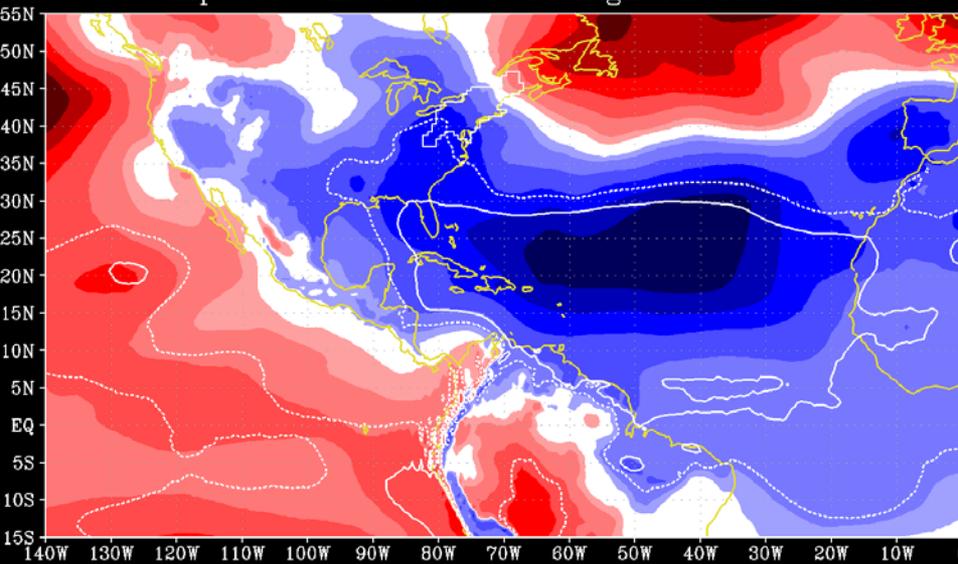
Heat Wave Duration Index



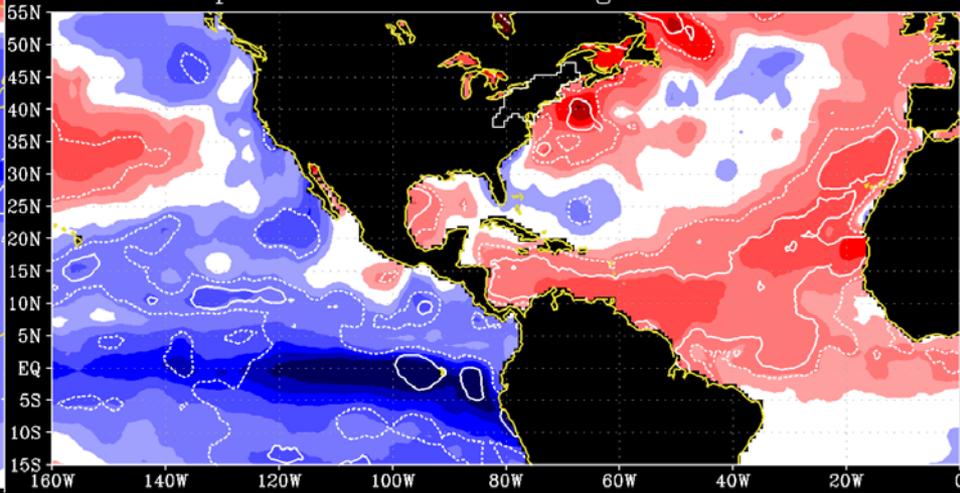
- 5K above climatology for 5 day stretches
- Not exactly warming, but affected by warming
- Identifying an appropriate daily temperature data set for comparisons

Max vs Mean Precip Composite Anomaly

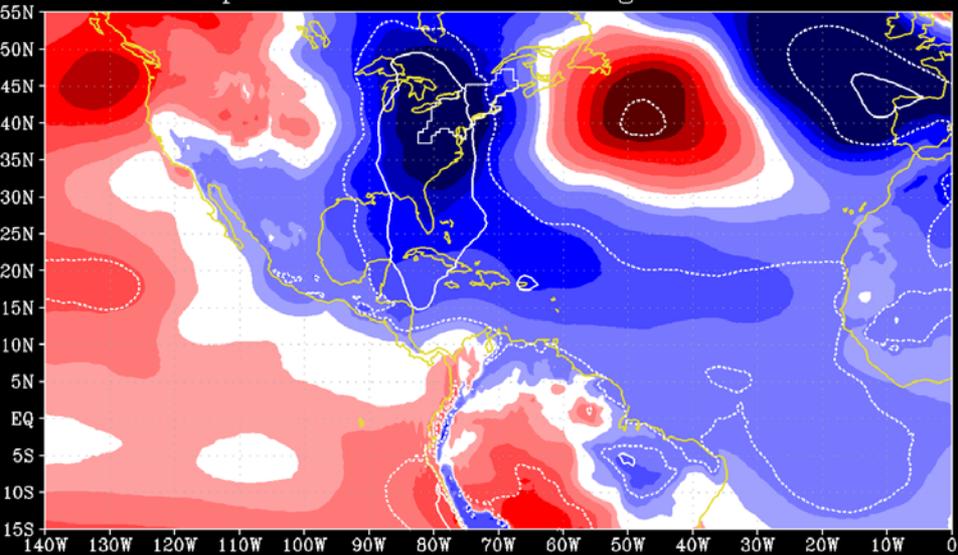
Composite SLP for SON 10 High RX5DAY in NE



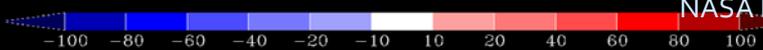
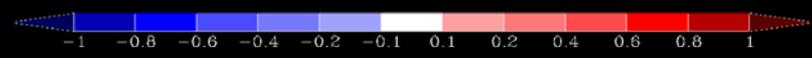
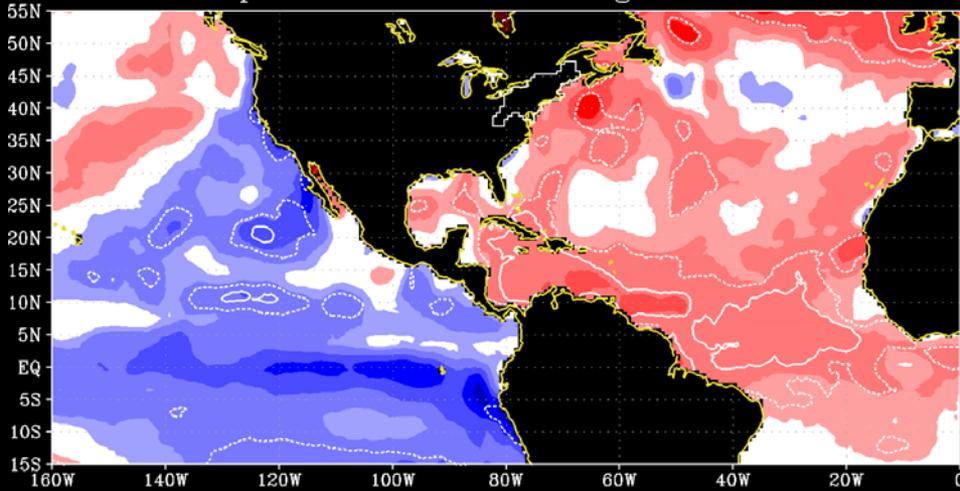
Composite Ts for SON 10 High RX5DAY in NE



Composite SLP for son 10 High Prec in NE



Composite Ts for son 10 High Prec in NE



MERRA Acknowledgements

System Development

GMAO: Ricardo Todling, Max Suarez, Julio Bacmeister, Emily Liu, Meta Sienkiewicz

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NCEP, NESDIS, NCAR, NCDC, RSS (SSMI radiances and wind speed), JPL (QuikSCAT), CERSAT (ERS winds); TRMM project; GSFC SBUV team

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