Goddard Space Flight Center

Land Information System

The Impact of Soil Moisture and Snow Assimilation on NLDAS Drought Metrics

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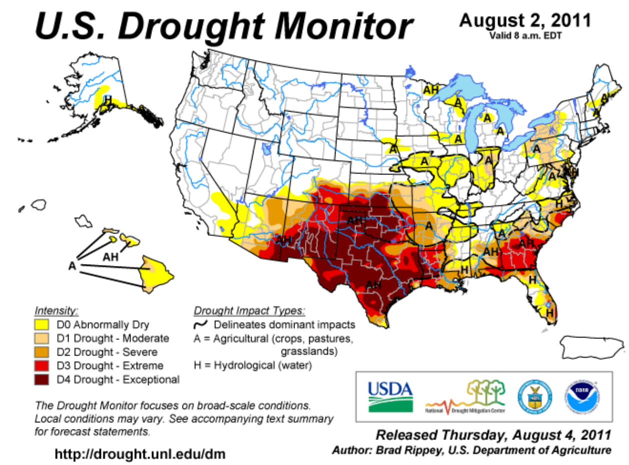
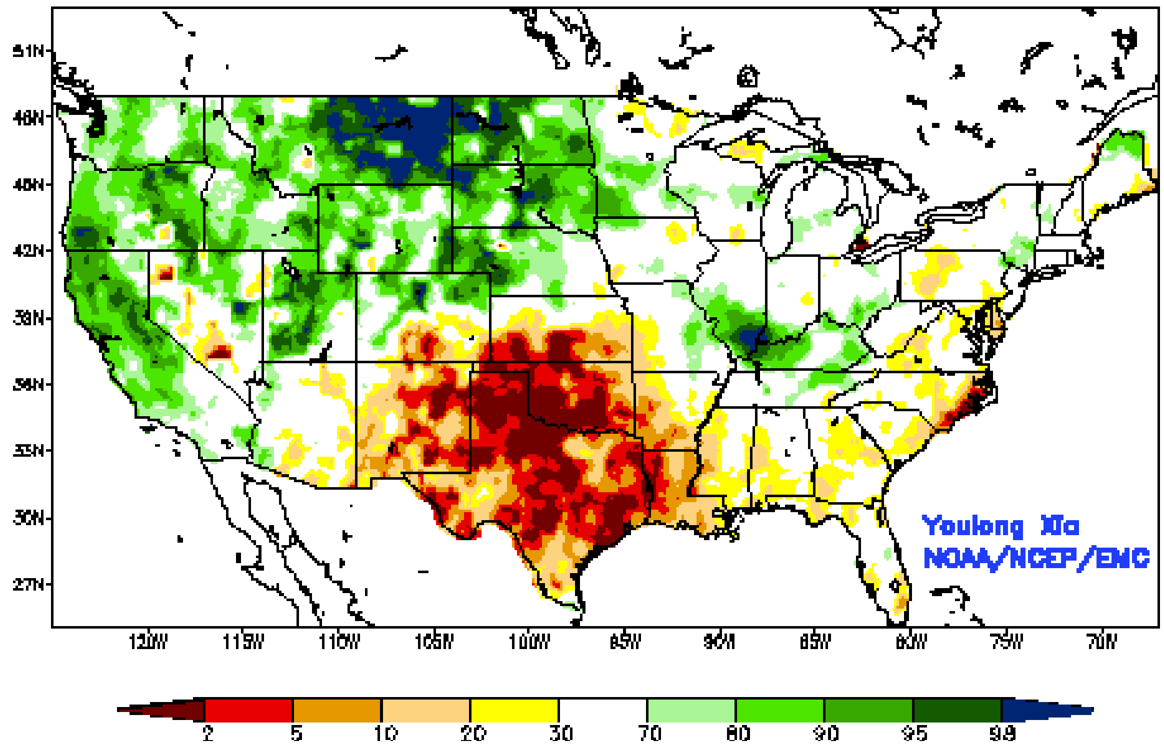
Outline

- NLDAS Drought Monitoring Background
  - Comparisons with USDM
  - NLDAS-based objective blends
- Soil Moisture Assimilation
  - Evaluation vs. in situ Soil Moisture and Streamflow
  - Impacts on Drought Metrics
- Snow Assimilation
  - Evaluation vs. in situ SWE/Depth and Streamflow
  - Impacts on Drought Metrics

Aug 2011



Ensemble-Mean – Past Month Total Column Soil Moisture Percentile
NCEP NLDAS Products Valid: AUG 01, 2011



Princeton VIC – Past Month Total Column Soil Moisture Percentile
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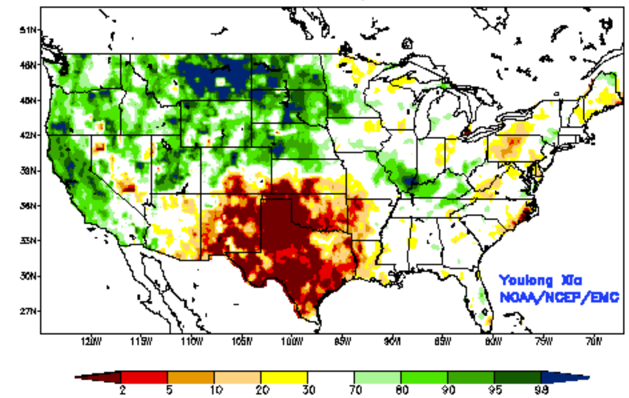
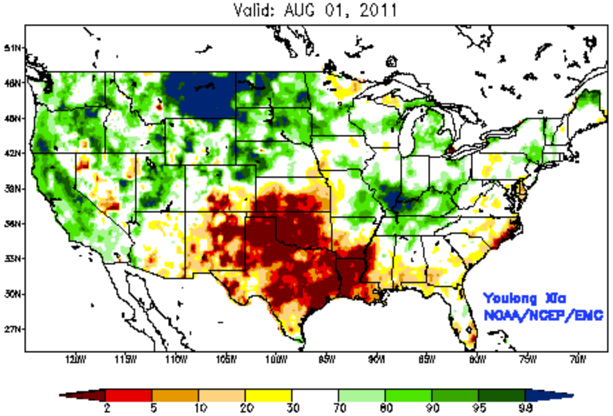
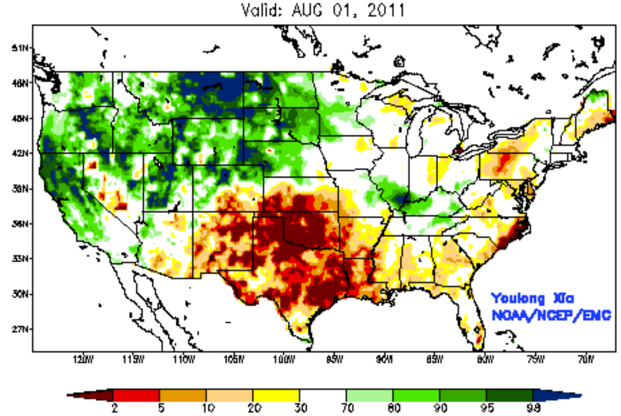


NASA Mosaic – Past Month Total Column Soil Moisture Percentile
Valid: AUG 01, 2011



NCEP Noah – Past Month Total Column Soil Moisture Percentile
Valid: AUG 01, 2011



OHD SAC – Past Month Total Column Soil Moisture Percentile
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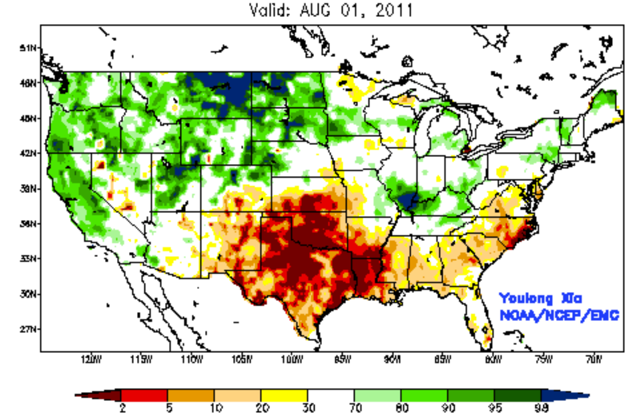
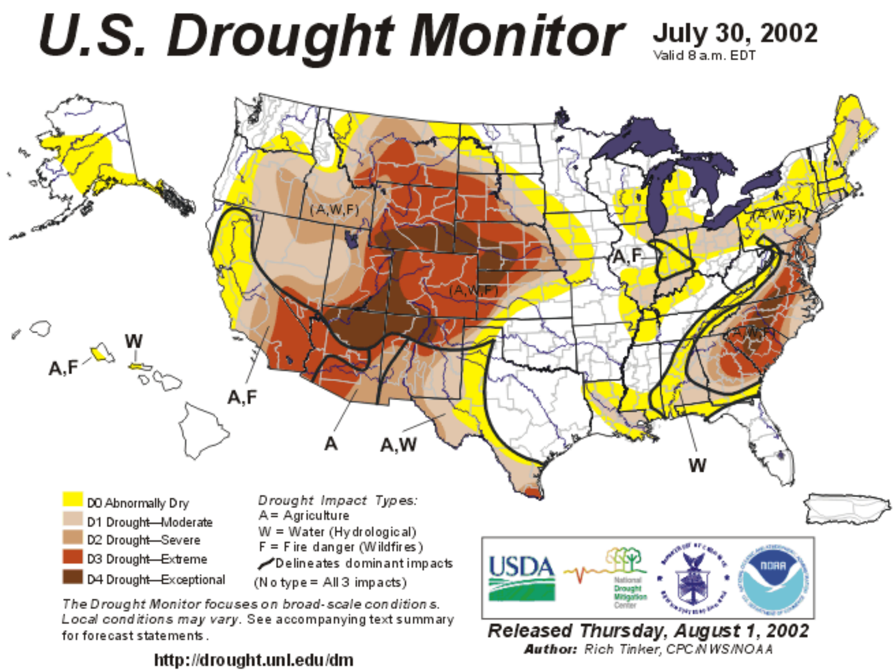
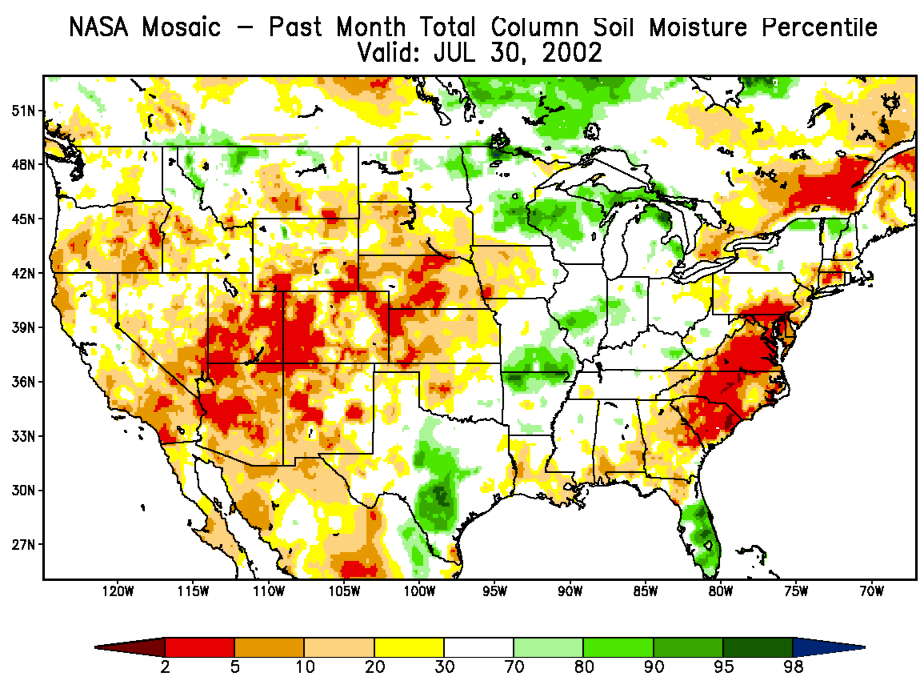


Jul 2002



U.S. Drought Monitor
July 30, 2002
Valid 8 a.m. EDT
(A,W,F)
(A,W,F)
(A,W,F)
(A,W,F)
A,F
W
A,F
A,F
A
A,W
W
D0 Abnormally Dry
D1 Drought—Moderate
D2 Drought—Severe
D3 Drought—Extreme
D4 Drought—Exceptional
Drought Impact Types:
A = Agriculture
W = Water (Hydrological)
F = Fire danger (Wildfires)
Delineates dominant impacts
(No type = All 3 impacts)
The Drought Monitor focuses on broad-scale conditions.
Local conditions may vary. See accompanying text summary
for forecast statements.
http://drought.unl.edu/dm
USDA
Released Thursday, August 1, 2002
Author: Rich Tinker, CPC/NWS/NOAA



NASA Mosaic – Past Month Total Column Soil Moisture Percentile
Valid: JUL 30, 2002
51N
48N
45N
42N
39N
36N
33N
30N
27N
120W
115W
110W
105W
100W
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90W
85W
80W
75W
70W
2
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30
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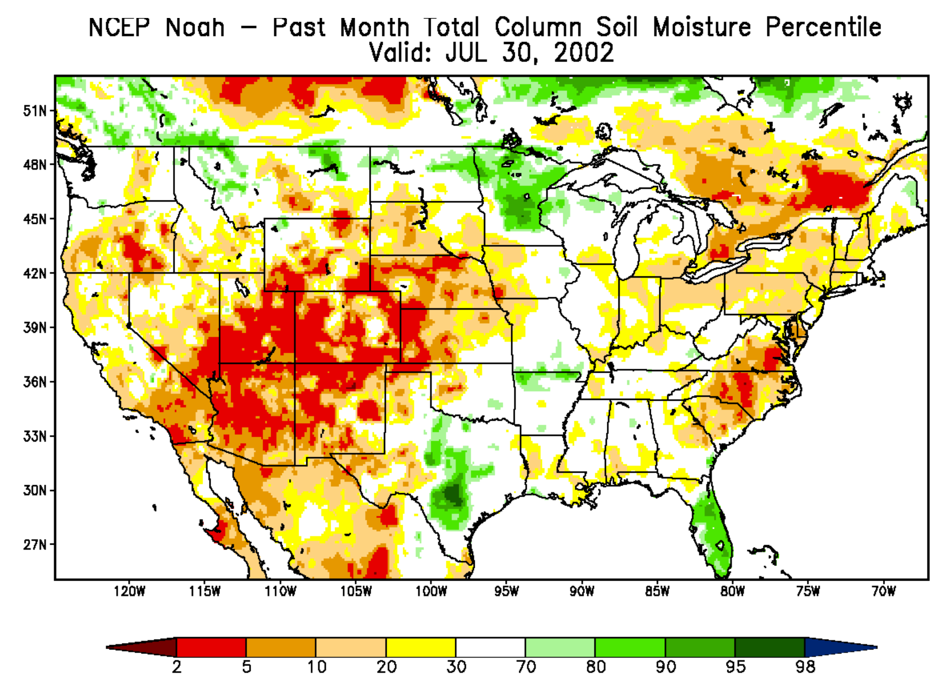
98



NCEP Noah – Past Month Total Column Soil Moisture Percentile
Valid: JUL 30, 2002
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42N
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33N
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120W
115W
110W
105W
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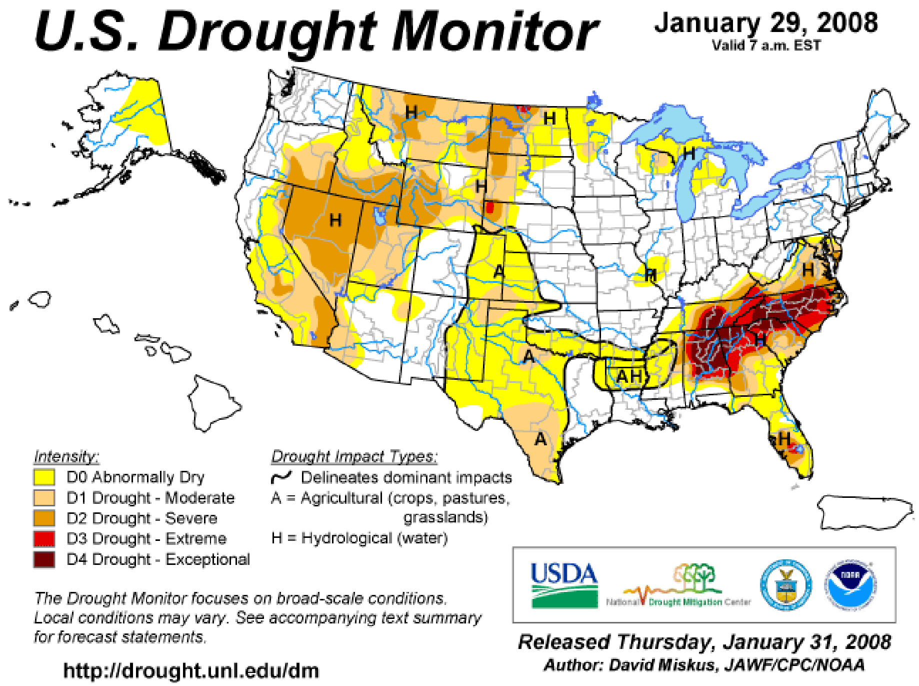
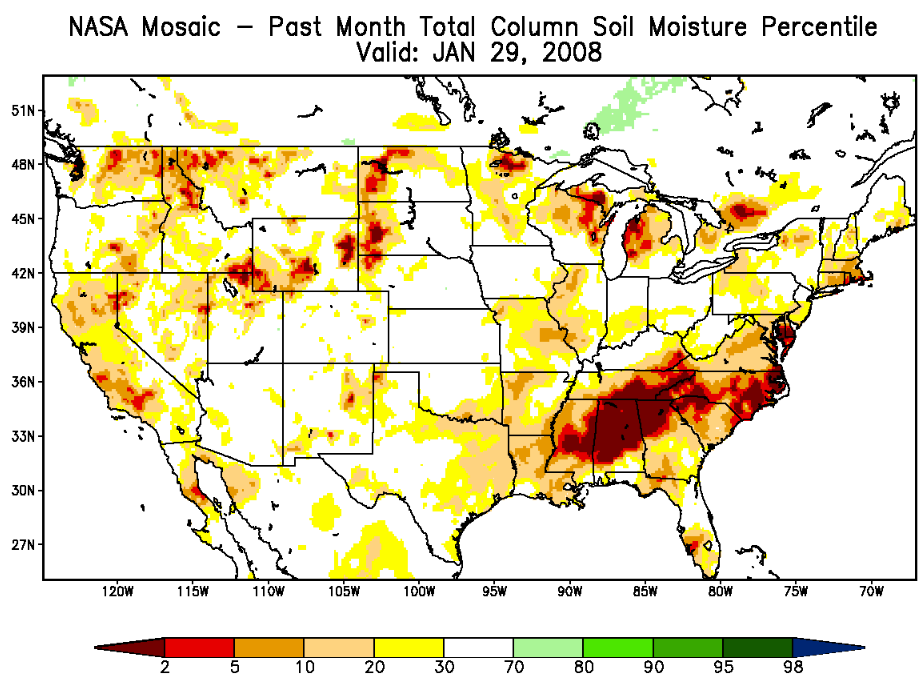
Jan 2008



U.S. Drought Monitor
January 29, 2008
Valid 7 a.m. EST
Intensity:
D0 Abnormally Dry
D1 Drought - Moderate
D2 Drought - Severe
D3 Drought - Extreme
D4 Drought - Exceptional
Drought Impact Types:
Delineates dominant impacts
A = Agricultural (crops, pastures, grasslands)
H = Hydrological (water)
The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.
http://drought.unl.edu/dm
USDA
National Drought Mitigation Center
Released Thursday, January 31, 2008
Author: David Miskus, JAWF/CPC/NOAA



NASA Mosaic — Past Month Total Column Soil Moisture Percentile
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33N
30N
27N
120W
115W
110W
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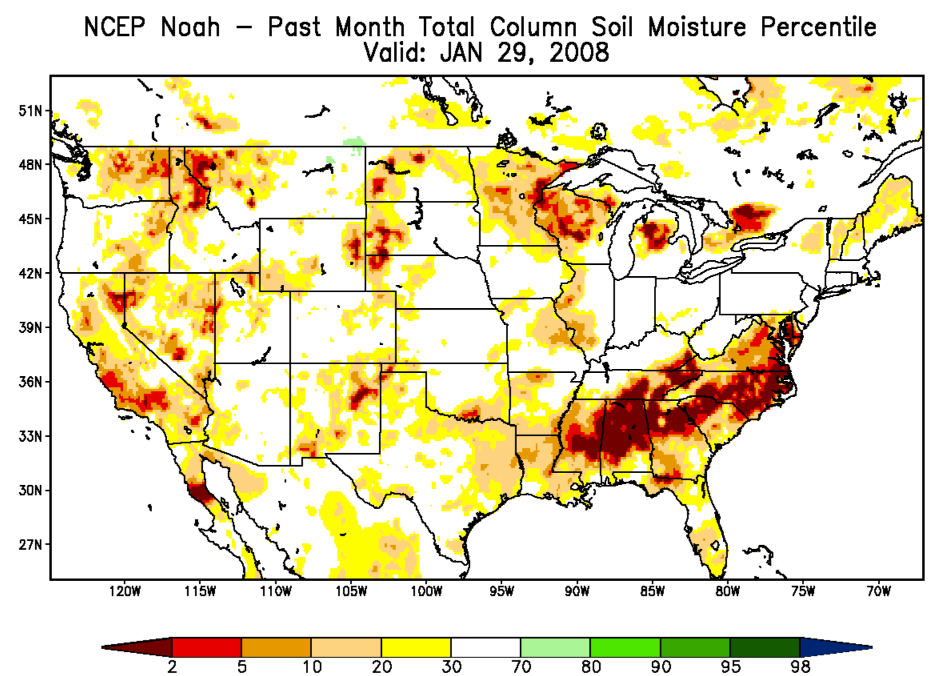

NCEP Noah — Past Month Total Column Soil Moisture Percentile
Valid: JAN 29, 2008
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48N
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120W
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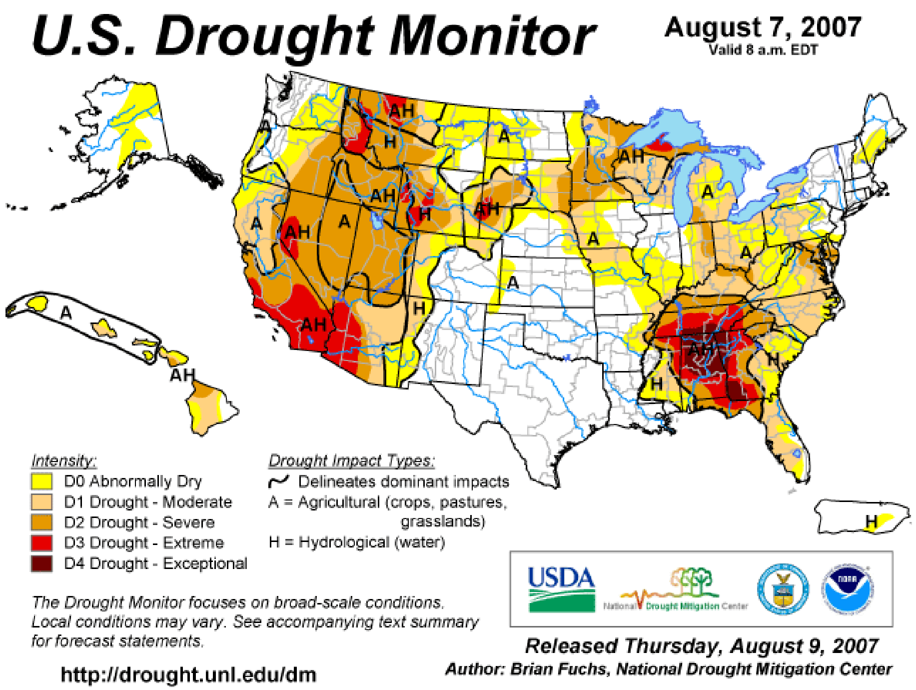
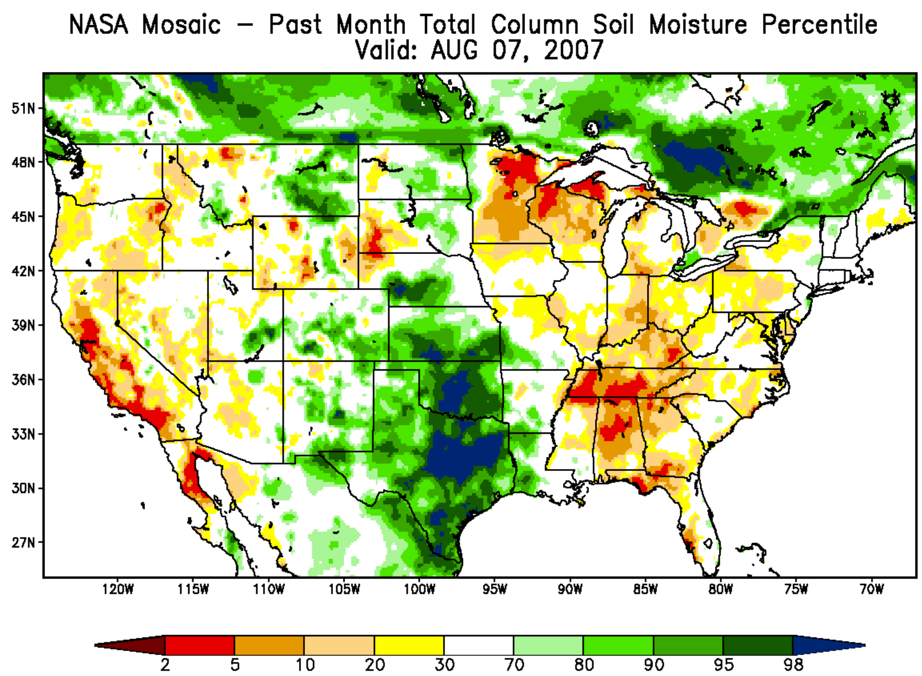
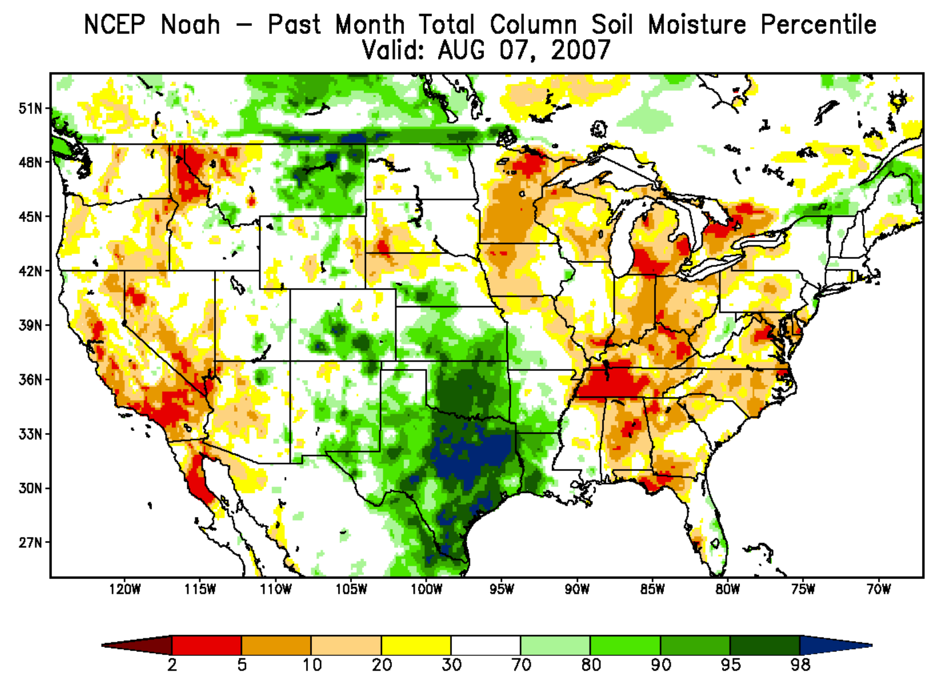
Aug 2007


U.S. Drought Monitor
August 7, 2007
Valid 8 a.m. EDT
Intensity:
D0 Abnormally Dry
D1 Drought - Moderate
D2 Drought - Severe
D3 Drought - Extreme
D4 Drought - Exceptional
Drought Impact Types:
Delineates dominant impacts
A = Agricultural (crops, pastures, grasslands)
H = Hydrological (water)
The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.
http://drought.unl.edu/dm
USDA
National Drought Mitigation Center
Released Thursday, August 9, 2007
Author: Brian Fuchs, National Drought Mitigation Center


NASA Mosaic – Past Month Total Column Soil Moisture Percentile
Valid: AUG 07, 2007
51N
48N
45N
42N
39N
36N
33N
30N
27N
120W 115W 110W 105W 100W 95W 90W 85W 80W 75W 70W
2 5 10 20 30 70 80 90 95 98


NCEP Noah – Past Month Total Column Soil Moisture Percentile
Valid: AUG 07, 2007
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42N
39N
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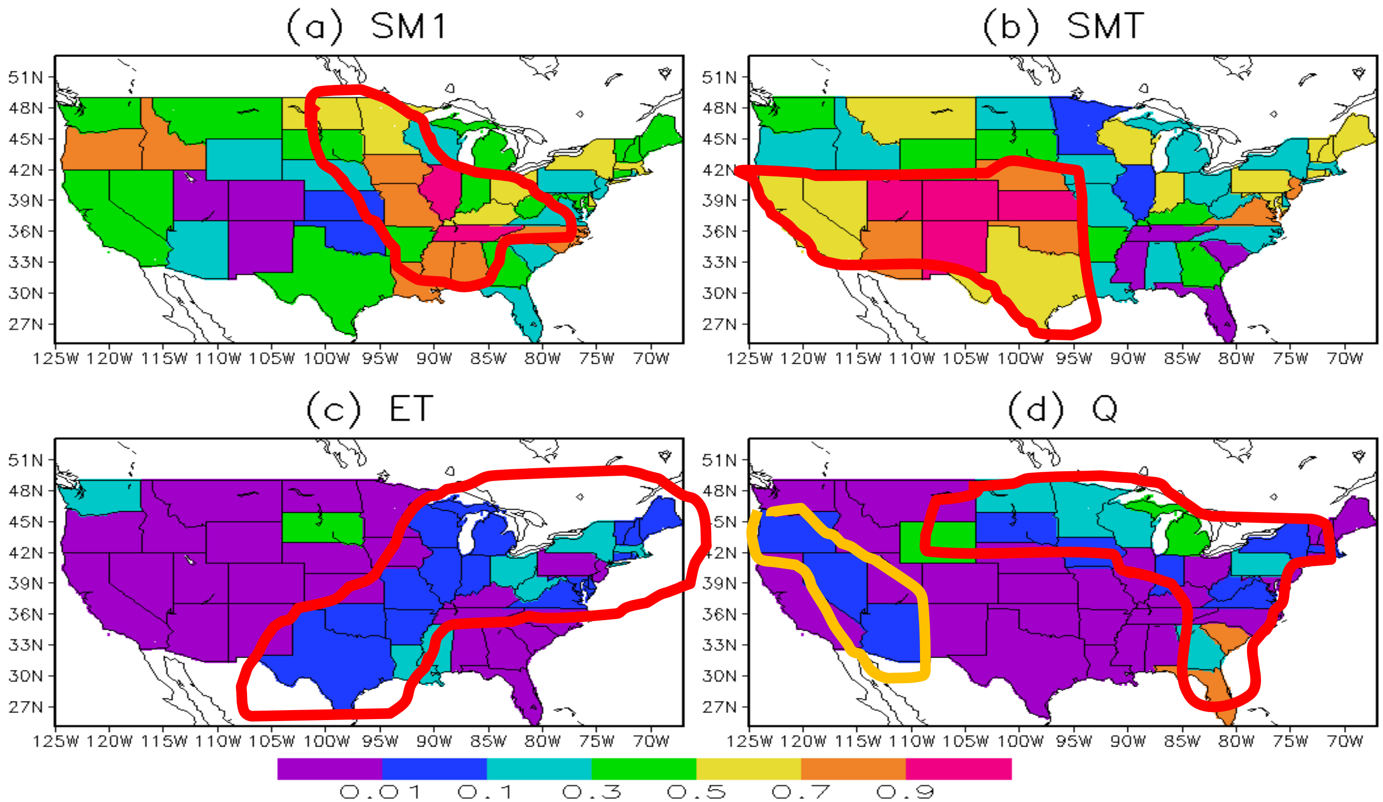
33N
30N
27N
120W 115W 110W 105W 100W 95W 90W 85W 80W 75W 70W
2 5 10 20 30 70 80 90 95 98

Uncertainties, Relationships, and Optimal Blends of Ensemble-Mean NLDAS Drought Indices

Youlong Xia, Michael B. Ek, David Mocko, Christa Peters-Lidard, Justin Sheffield,
Jiarui Dong, and Eric F. Wood

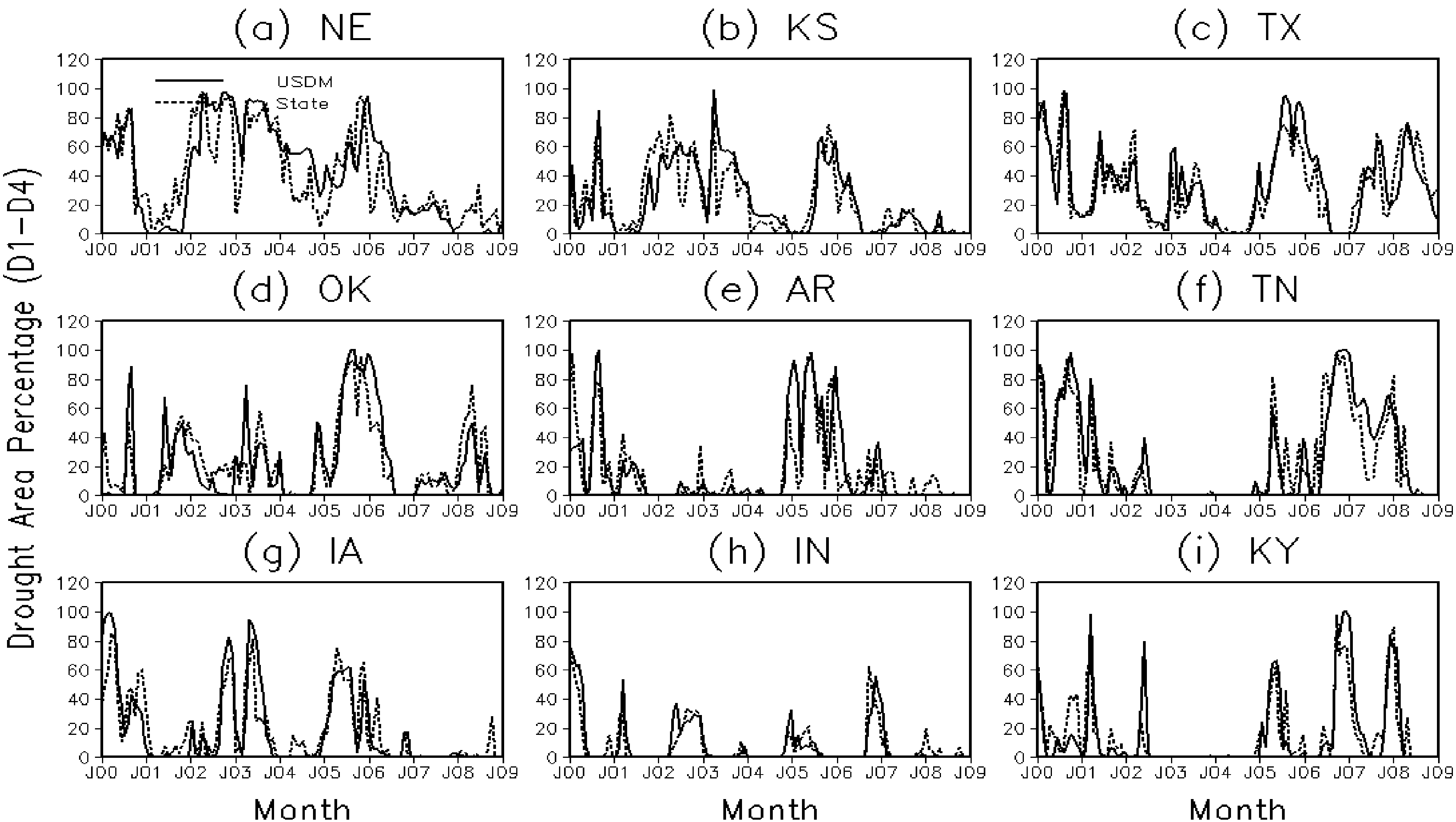
To be submitted to JHM Special Collection, 2012

Normalized weight coefficients on NLDAS output variables optimized to match USDM state drought areas



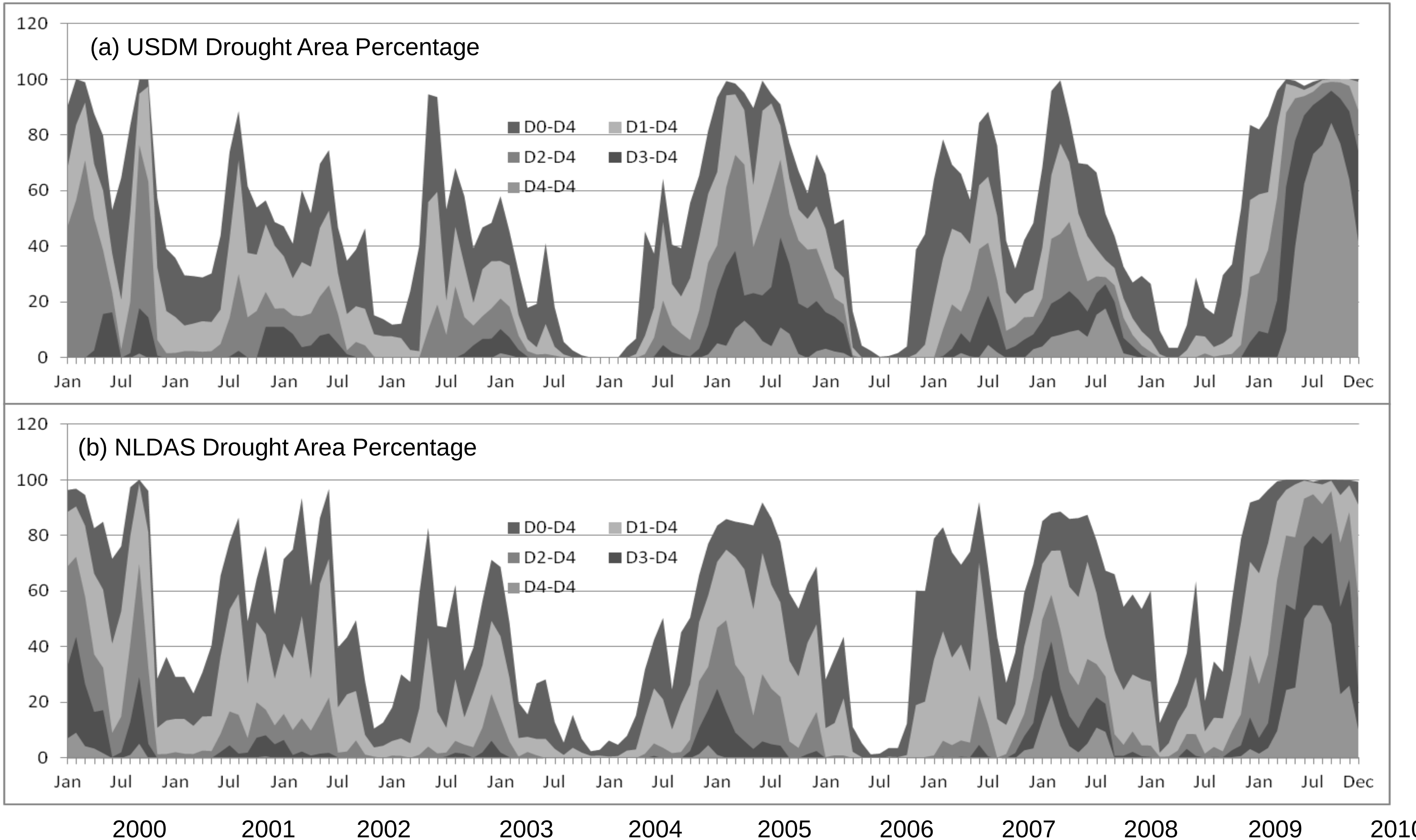
Reason: forest cover, weight percentage is larger for SM1 and than SMT.
NE is wet and SM1 can represent drought variation enough. Deeper soil water has small variation because of its wetness.

Uncertainties, Relationships, and Optimal Blends of Ensemble-Mean NLDAS Drought Indices



Comparison of USDM and NLDAS in the Best 9 States

Uncertainties, Relationships, and Optimal Blends of Ensemble-Mean NLDAS Drought Indices

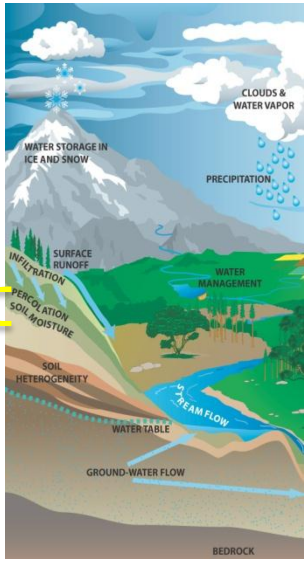


Texas Drought Area Percentage

Soil Moisture Data Assimilation

Experimental Setup:

- Domain: CONUS, NLDAS
- Resolution: 0.125 deg.
- Period: 1979-01 to 2012-01
- Forcing: NLDASII
- LSM: Noah 3.3



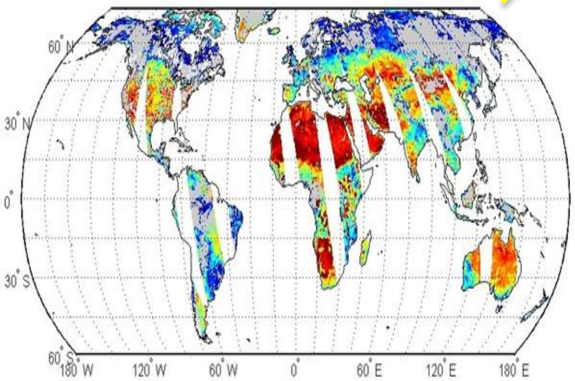


Figure 3: Daily soil moisture based on Aqua/AMSR-E. Future observations will be provided by SMAP.

Data Assimilation:

- AMSR-E LPRM (Owe et al., 2008; Peters-Lidard et al., 2011) 2002-2011
- ESA ECV (Liu et al., 2012; Wagner et al., 2012) 1978-2011

- Flags: light and moderate vegetation, precipitation, snow cover, frozen ground, RFI
- The observations are scaled to the LSM's climatology using CDF matching
- 12-member ensemble
- A spatially distributed observation error standard deviation (between 0.02-0.12 m3/m3)

Evaluation of NLDAS outputs

Soil moisture:

USDA Soil Climate Analysis Network (SCAN); 37 stations chosen after careful quality control (used for evaluations between 2000-2011)

Four USDA ARS experimental watersheds ("CalVal" sites) (used for evaluations between 2001-2011)

Streamflow:

Gauge measurements from unregulated USGS streamflow stations (1981-2011).

Snow depth:

Global Historical Climate Network (GHCN) – used for evaluations between 1979-2011.

Canadian Meteorological Center (CMC) daily snow depth analysis – used for evaluations between 1998-2011.

All model verifications and analysis generated using the Land surface Verification Toolkit (LVT; Kumar et al. 2012)

Soil moisture DA (LPRM) : Evaluation of soil moisture fields

Statistically significant improvements in surface soil moisture as a result of LPRM DA, for all metrics when compared with ARS data.

Marginal degradation in anomaly R for surface surface and root zone (statically insignificant) in comparisons with SCAN.

Marginal improvements in root zone estimates (again statistically insignificant) for anomaly RMSE when compared with SCAN.

The percentage change in water cycle variables introduced by DA is largest in subsurface runoff, ET and surface runoff – consistent with the findings of Sahoo et al. (2012), AWR.

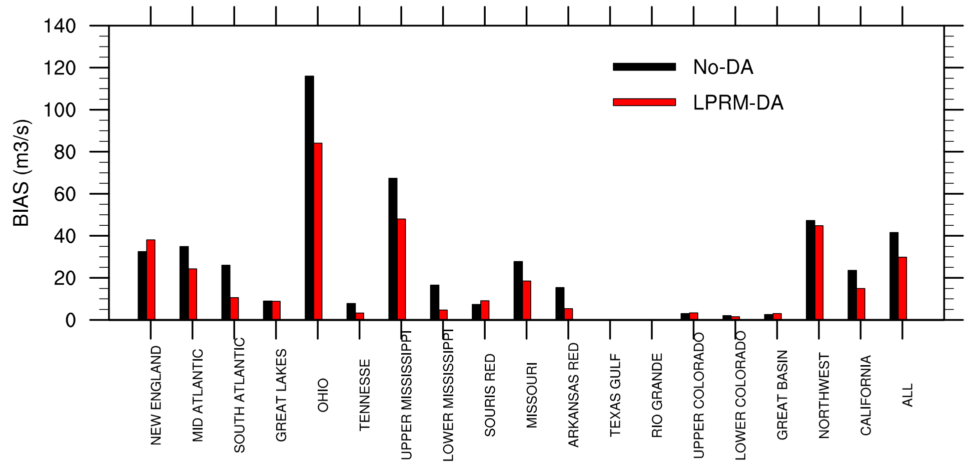
ARS CalVal	Open loop	LPRM DA
Anomaly R	0.74 +/- 0.01	**0.76 +/- 0.01**
Anomaly RMSE (m3/m3)	0.032 +/- 0.001	**0.028 +/- 0.001**
ubRMSE (m3/m3)	0.038 +/- 0.002	**0.033 +/- 0.002**

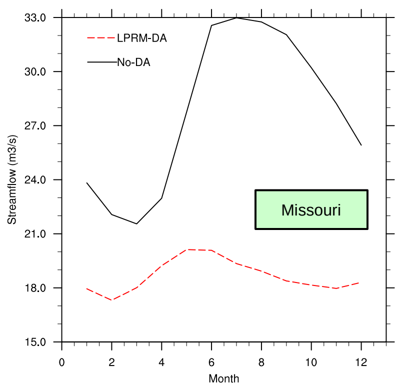
SCAN (surface soil moisture)	Open loop (no DA)	LPRM DA
Anomaly R	0.63 +/- 0.03	0.61 +/- 0.03
Anomaly RMSE (m3/m3)	0.038 +/- 0.002	0.038 +/- 0.002
ubRMSE (m3/m3)	0.044 +/- 0.003	0.045 +/- 0.003

SCAN (root zone soil moisture)	Open loop (no DA)	LPRM DA
Anomaly R	0.50 +/- 0.02	0.48 +/- 0.02
Anomaly RMSE (m3/m3)	0.027 +/- 0.002	0.026 +/- 0.002
ubRMSE (m3/m3)	0.033 +/- 0.003	0.032 +/- 0.003

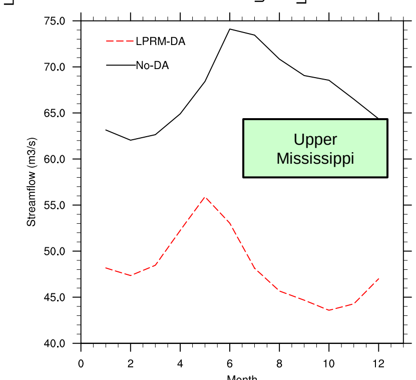
Soil moisture DA (LPRM): Evaluation of streamflow

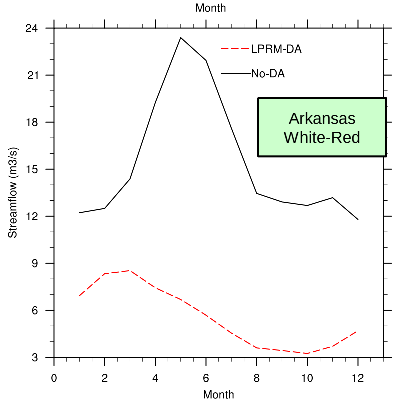
Streamflow (USGS)	Open loop (no DA)	LPRM DA
RMSE (m3/s)	51.0 +/- 4.0	**36.5 +/- 4.0**
Bias (m3/s)	41.6 +/- 4.0	**29.9 +/- 4.0**

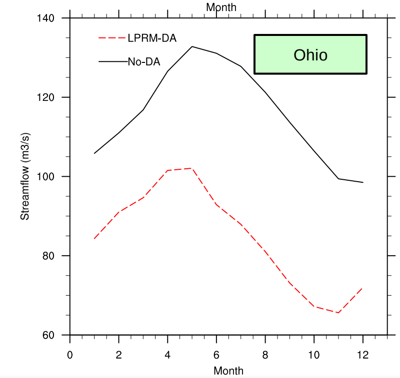




Average seasonal cycle of RMSE

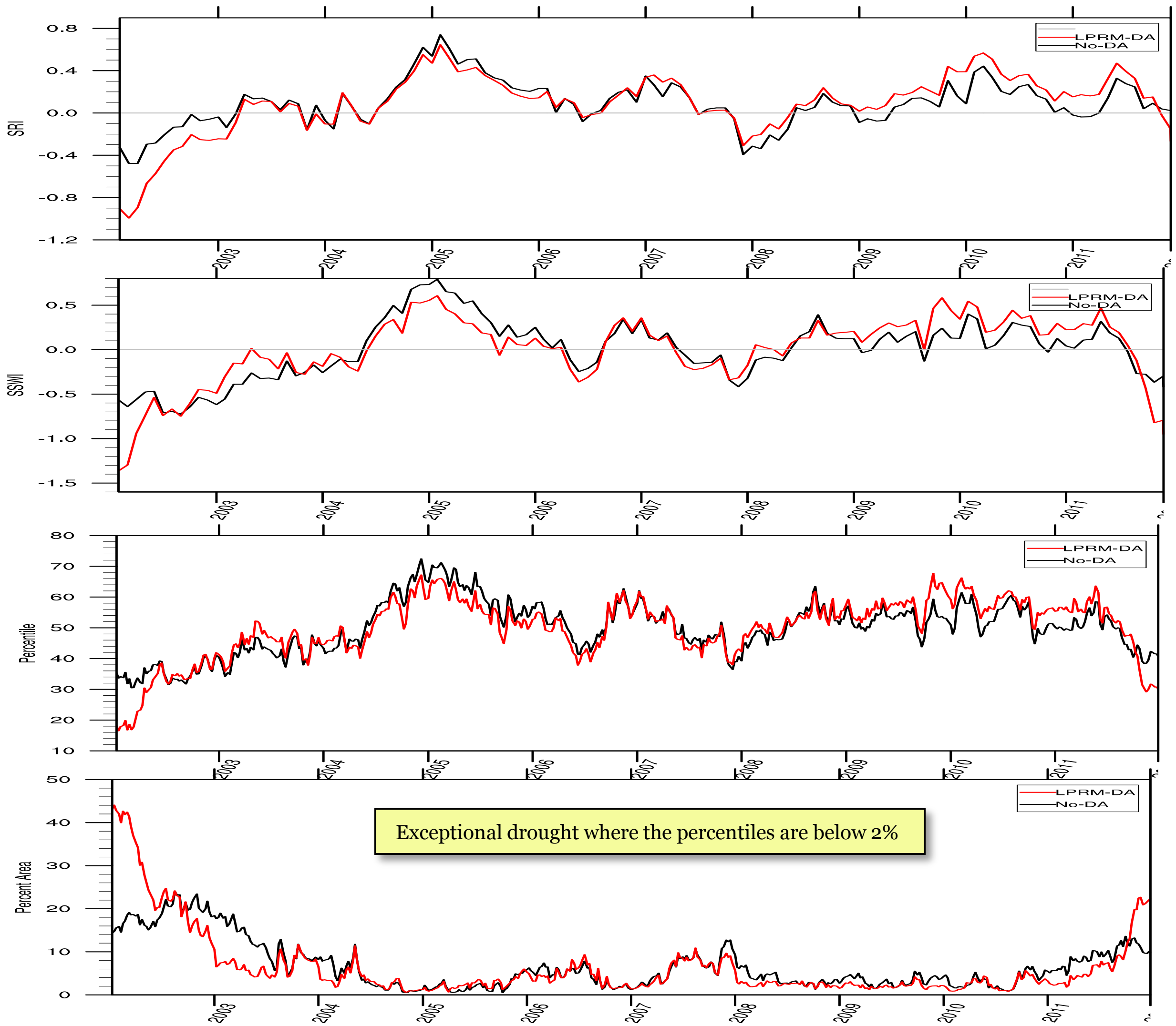






Significant improvements to the streamflow simulations are observed in most basins

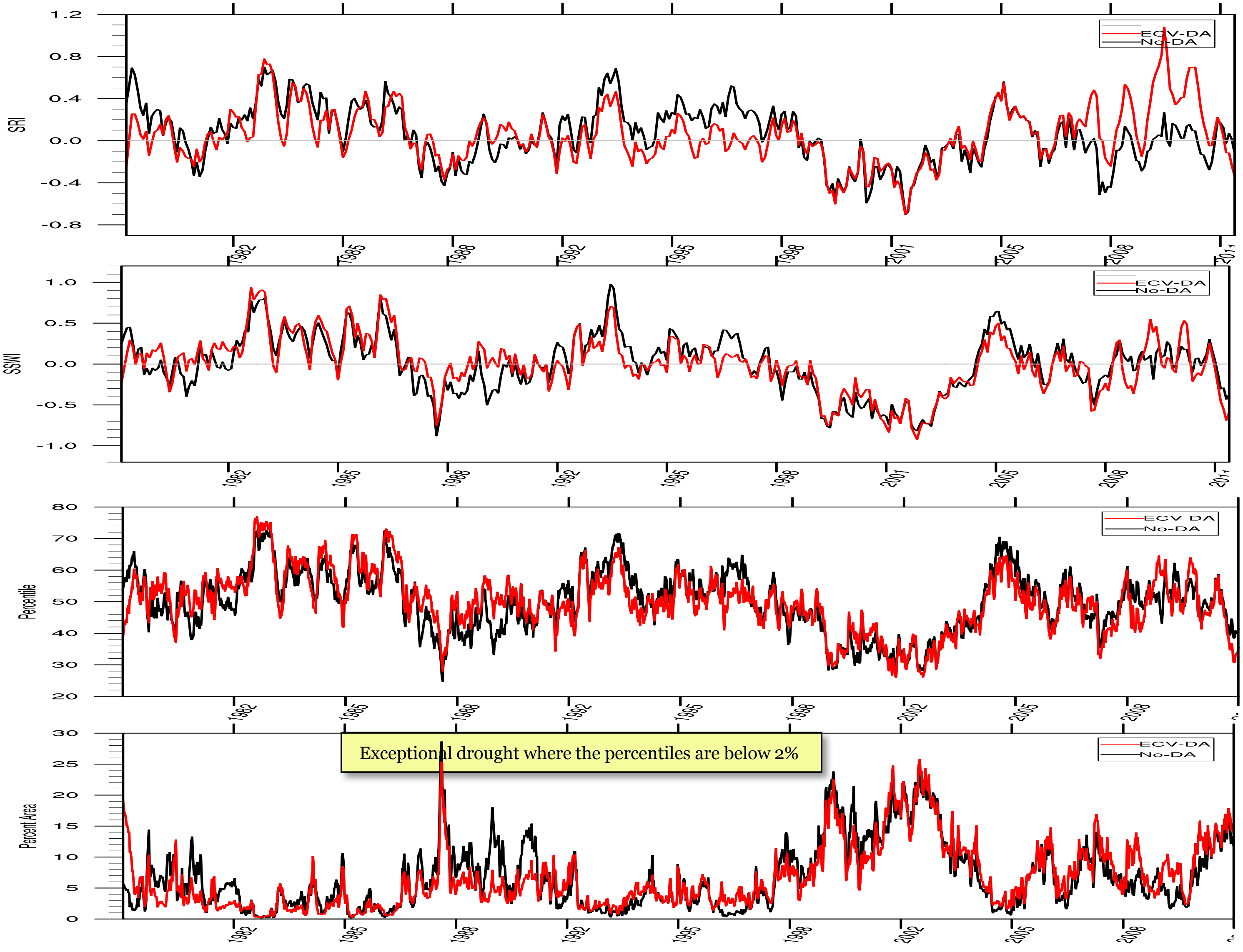
Soil moisture DA (LPRM): Drought indices (NLDAS domain average)



SRI, SSWI, and Soil Moisture Percentiles indicate that DA causes an increased drought in early 2000s and reduced drought 2008-2011. DA also simulates an increased onset of the 2011-2012 drought.

Note: The fitted distributions for SRI/SSWI/Percentiles in this analysis are computed by using 2002-2011 period.

Soil moisture DA (ECV) : Drought indices (NLDAS domain average)



SRI, SSWI, and Soil Moisture Percentiles indicate that DA indicates an increased drought in early 2000s and reduced drought 2008-2011. DA also simulates an increased onset of the 2011-2012 drought.

Snow Data Assimilation

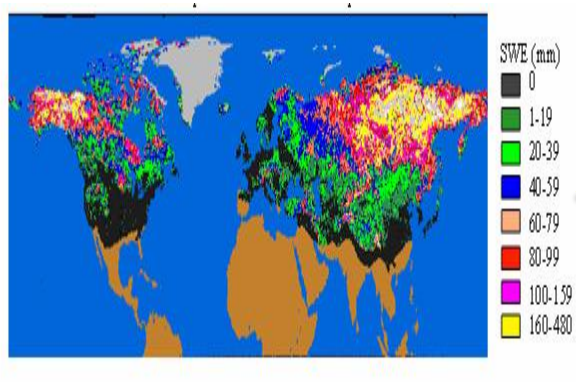
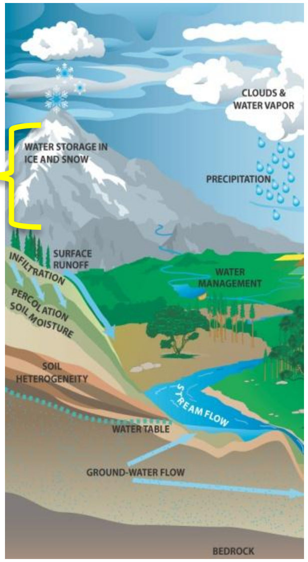


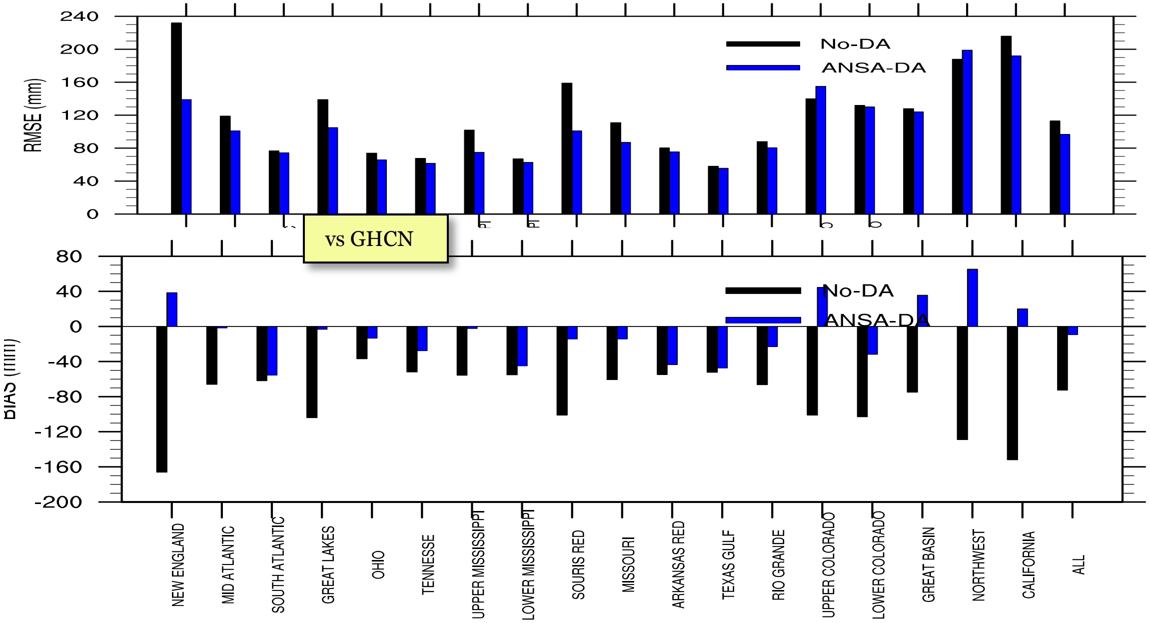
Figure 1: Snow water equivalent (SWE) based on Terra/MODIS and Aqua/AMSR-E. Future observations will be provided by JPSS/VIIRS and DWSS/MIS.



Data Assimilation:

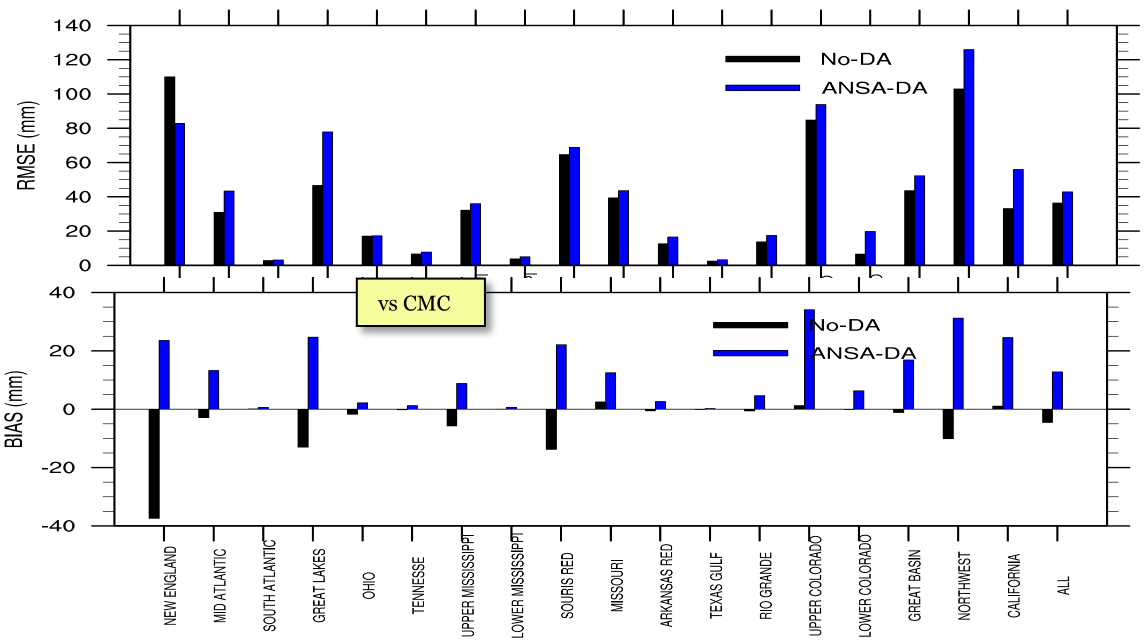
- SMMR (spans 1978-1987), SSM/I (spans 1987-2002) and AMSR-E (spans 2002-2011); SMMR and SSM/I retrievals are based on the Chang et al. (1987) and AMSR-E retrievals are based on the improved retrieval algorithm from Kelly et al. (2009).
- AMSR-E retrievals are further improved by combining the information from MODIS snow cover retrievals – a product known as ANSA (AFWA NASA snow algorithm; Foster et al. 2010).

Snow DA (ANSA) : Evaluation of snow depth fields



Snow depth (GHCN)	Open loop (no DA)	ANSA DA
RMSE (mm)	113 +/- 10.0	**72.6 +/- 10.0**
Bias (mm)	-96.6 +/- 10.0	**-92.9 +/- 10.0**

Snow depth (CMC)	Open loop (no DA)	ANSA DA
RMSE (mm)	**36.4 +/- 5.0**	42.9 +/- 5.0
Bias (mm)	**-4.58 +/- 3.0**	12.8 +/- 3.0

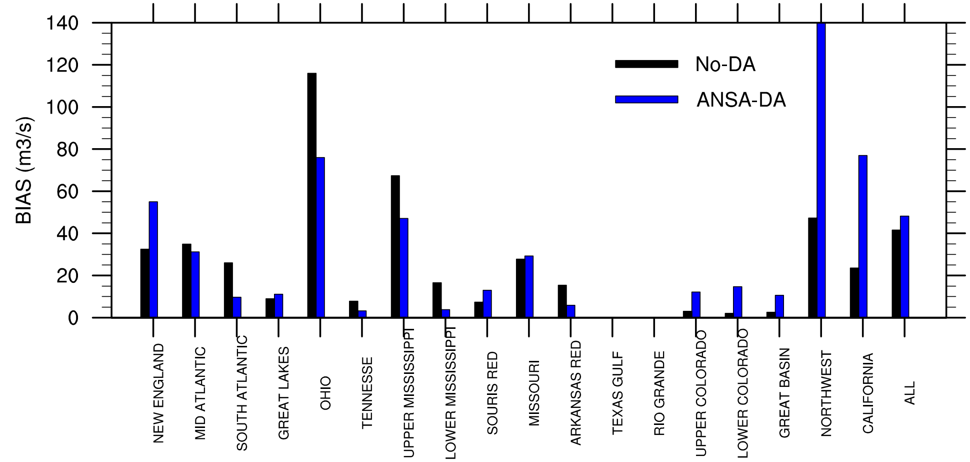


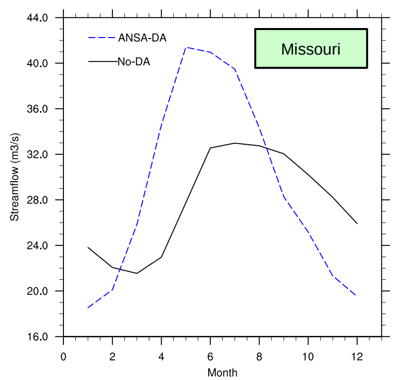
GHCN comparison indicates improvements across most basins, whereas CMC comparison indicates that improvements are limited to a few basins.

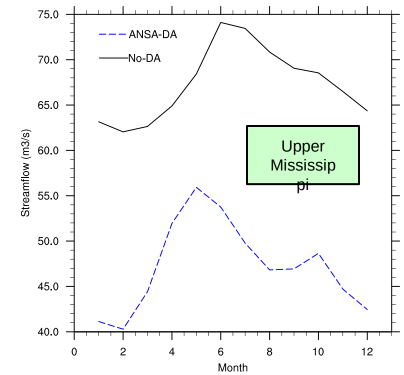
CMC comparison also indicates that ANSA-DA overcorrects the underestimation of snow depth estimates in the no-DA simulation.

Snow DA (ANSA): Evaluation of streamflow

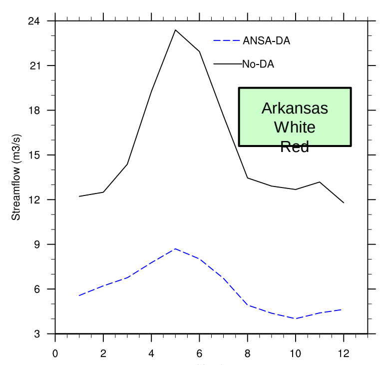
Streamflow (USGS)	Open loop (no DA)	LPRM DA
RMSE (m3/s)	**50.8 +/- 4.0**	66.1 +/- 4.0
Bias (m3/s)	**41.2 +/- 4.0**	48.2 +/- 4.0

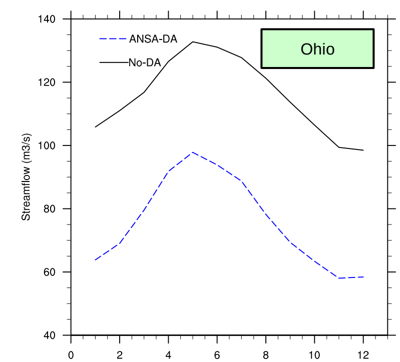






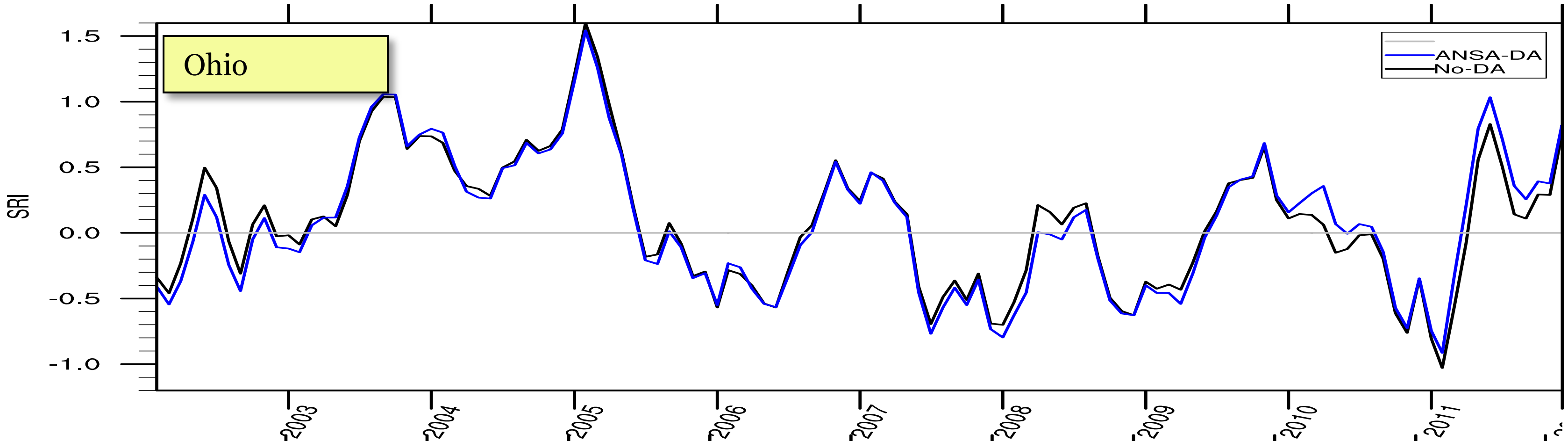
Average seasonal cycle of RMSE

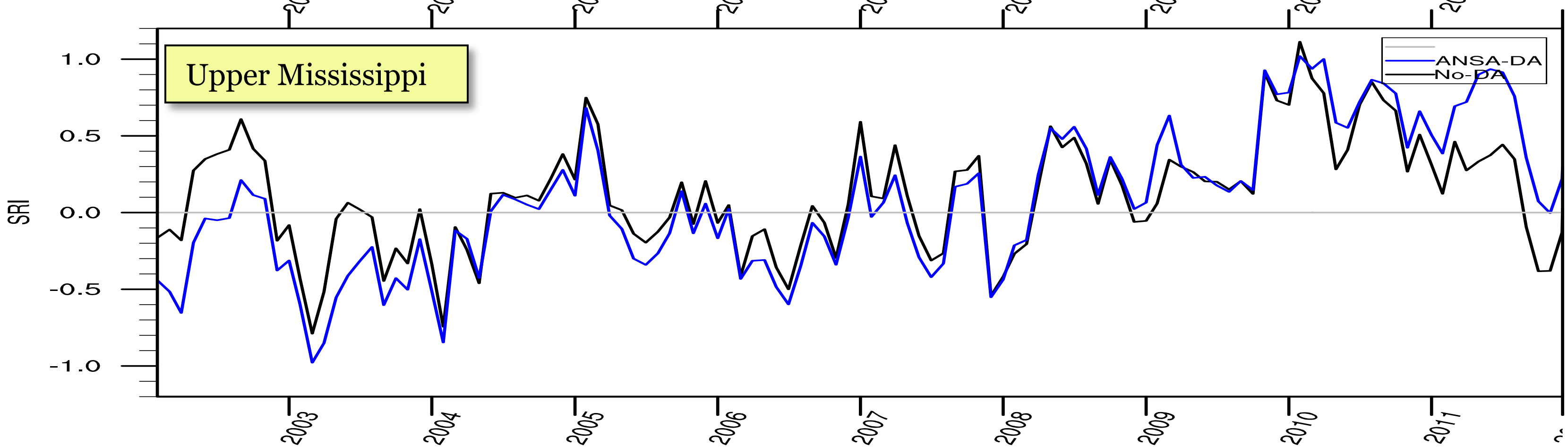




Significant improvements to the streamflow simulations are observed in Ohio, Upper Mississippi,
Significant degradations in Northwest and California.

Snow DA (ANSA) : Drought indices (basin averages)





Over both basins, DA estimates increased drought in early 2000s and reduced drought 2009-2011.

Note: The fitted distributions for SRI in this analysis are computed by using 2002-2011 period.

Summary

- LPRM AMSR-E Soil moisture assimilation can improve soil moisture, streamflow and evapotranspiration (not shown, see Peters-Lidard et al., 2011)
- Soil moisture assimilation has a significant effect on drought metrics such as
- Bias-corrected AMSR-E Snow depth assimilation improves snow depth and streamflow. Other results (not shown) show some potential for MODIS/SCA, especially in snow transition regions or spring snowmelt.
- Snow assimilation has a significant effect on drought metrics such as

Next Steps

- **Call to join "Objective/Optimal Blends of Multiple Drought Indices in the United States" - an Initiative**
- **Co-organizer:** Christa Peters-Lidard (NASA), Michael Ek (NCEP), and Youlong Xia (NCEP)
- **Contact Point:** Youlong Xia (NCEP): Youlong.Xia@noaa.gov, David Mocko (NASA): David.Mocko@nasa.gov
- **Goal:** To develop objective/optimal blends of multiple drought indices to support U.S. operational drought monitoring and prediction, in particular to support U.S. Drought Monitor (USDM) and CPC's Experimental Objective Blends of Drought Indicators
- **Objectivity:** Objective and reproducible (repeatable)
- **Expected delivery product:**
- one package including optimization algorithm, suggested drought indices used, and optimal weight coefficients (subjective to drought indices and state) which is able to be used for improving CPC's objective blends of Drought Indicators
- One reference drought index (USDM-based) for research community
- Long-term (30 years or longer) drought index reconstruction (USDM-based)

Additional References

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