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

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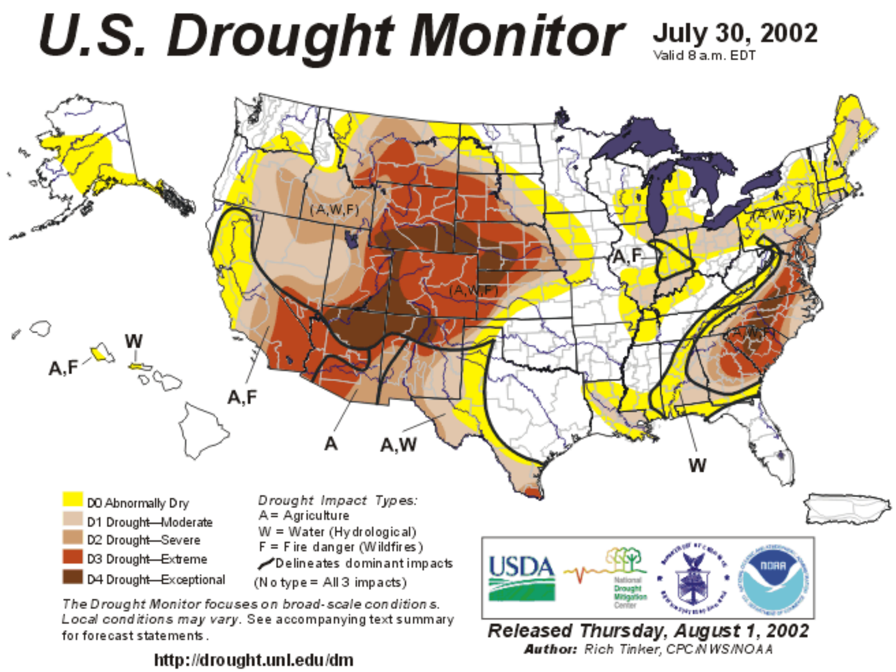
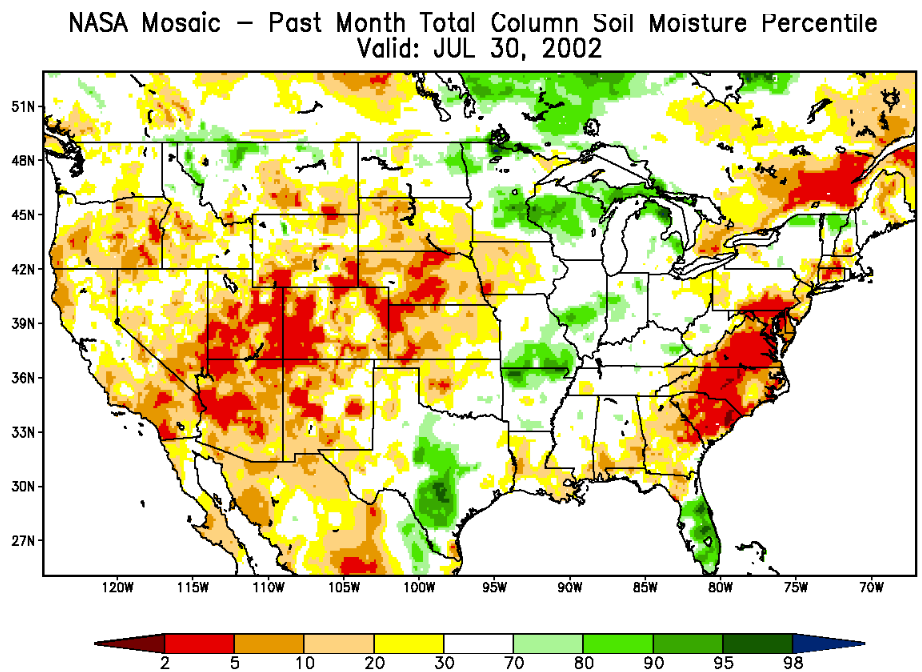
Outline

- NLDAS Drought Monitoring Background
  - 3 NOAA/MAPP DTF Case Studies: Comparisons with USDM
- 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

Jul 2002


U.S. Drought Monitor
July 30, 2002
Valid 8 a.m. EDT
(A,W,F)
A,F
W
A
A,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
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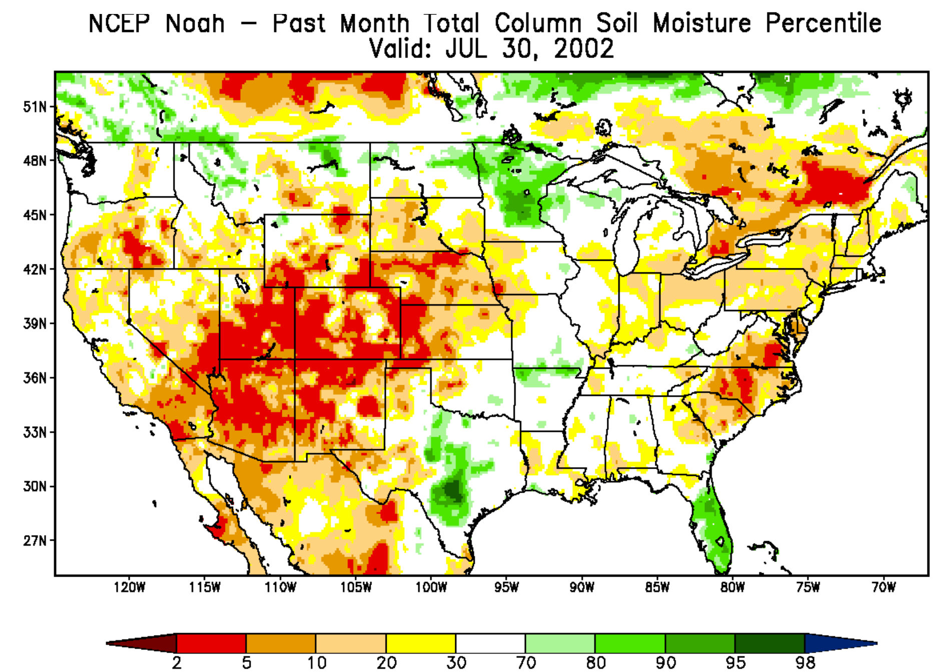
2 5 10 20 30 70 80 90 95 98


NCEP Noah – Past Month Total Column Soil Moisture Percentile
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48N
45N
42N
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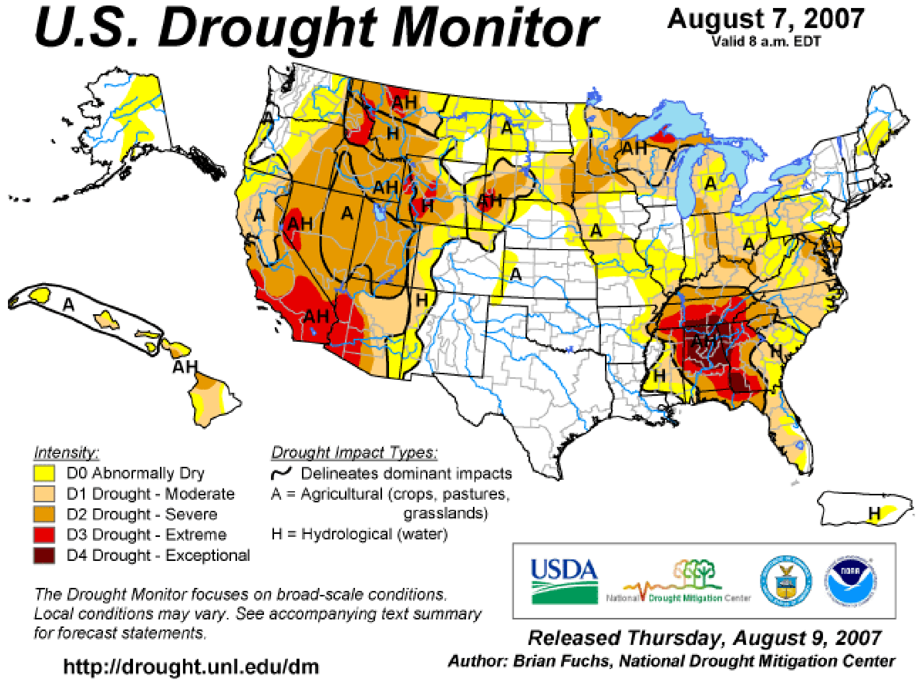
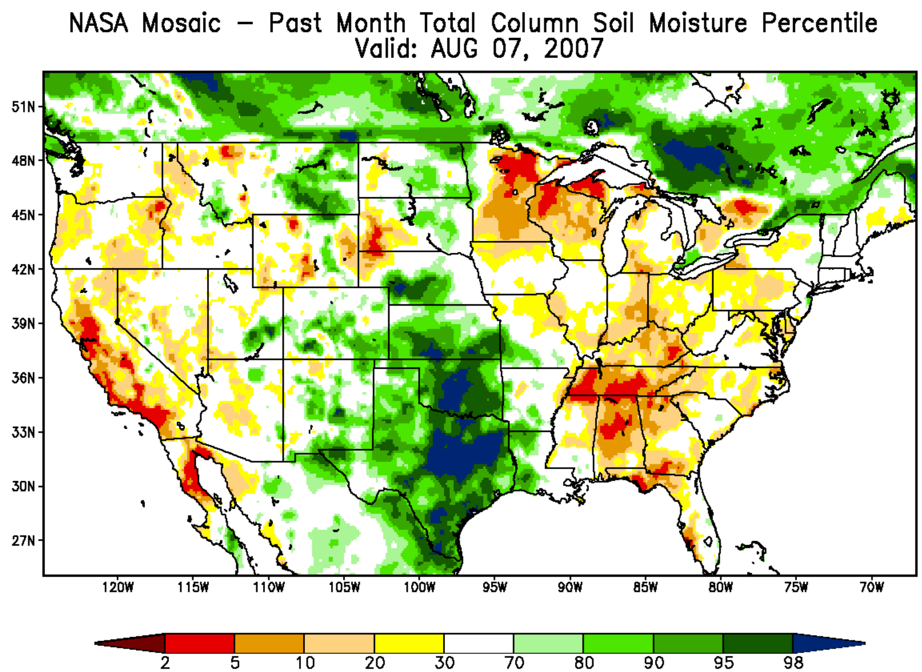
2 5 10 20 30 70 80 90 95 98

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
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45N
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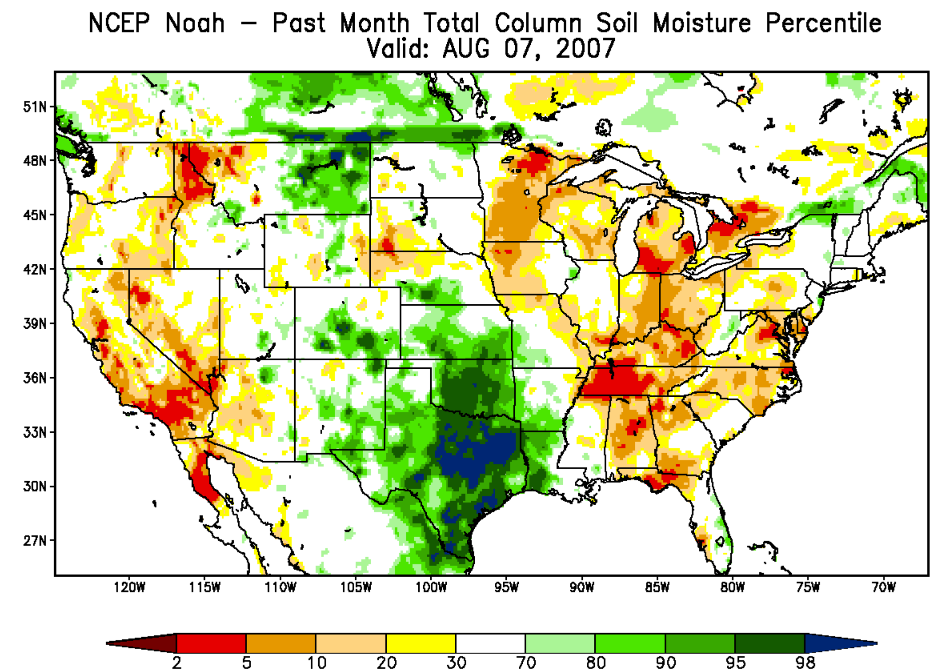
2 5 10 20 30 70 80 90 95 98


NCEP Noah – Past Month Total Column Soil Moisture Percentile
Valid: AUG 07, 2007
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45N
42N
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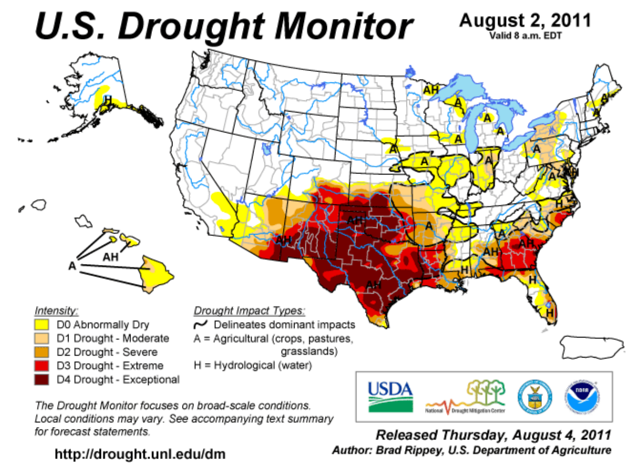
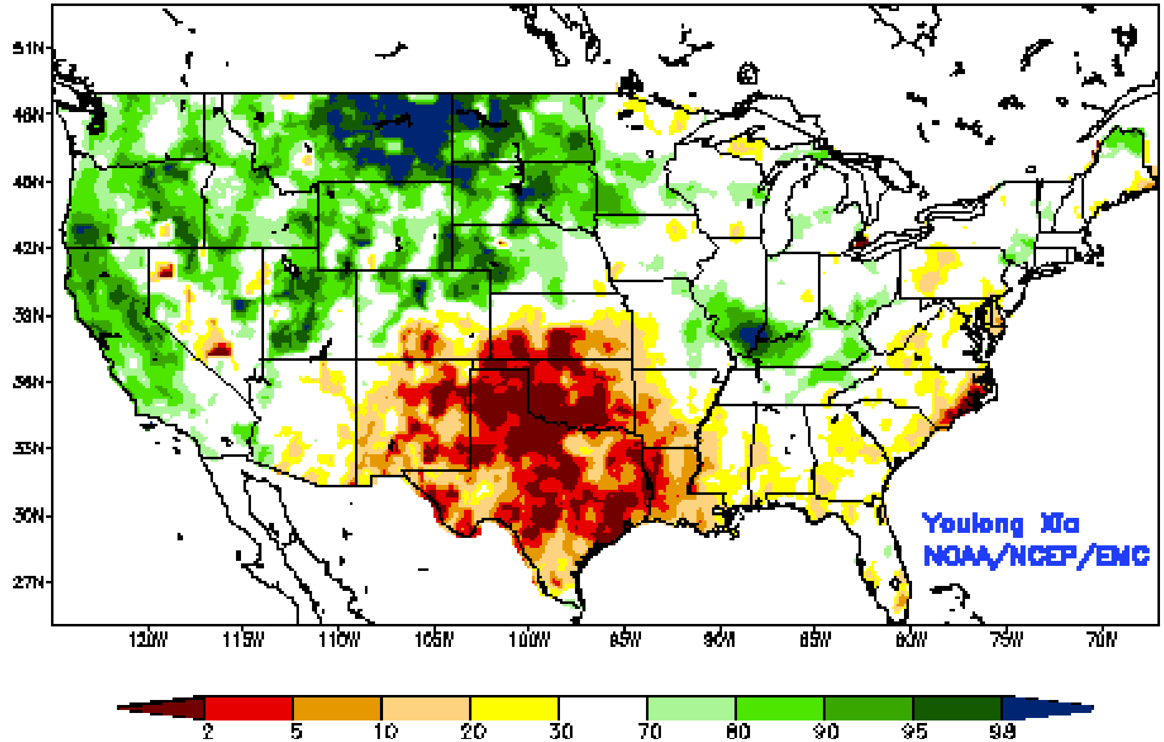
2 5 10 20 30 70 80 90 95 98

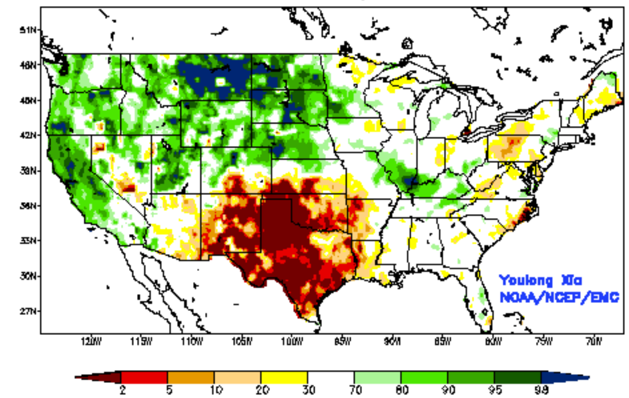
Aug 2011



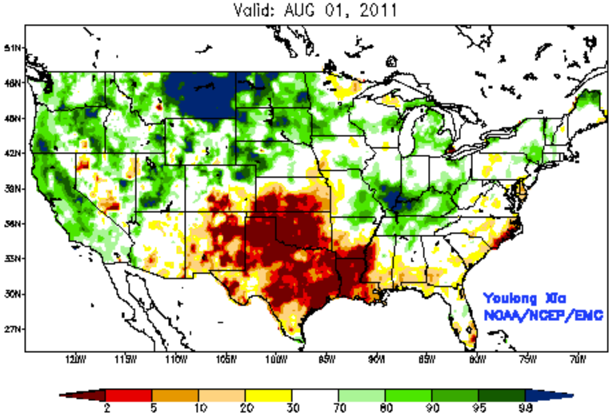
Ensemble-Mean – Past Month Total Column Soil Moisture Percentile
NCEP NLDAS Products___ Valid: AUG 01, 2011



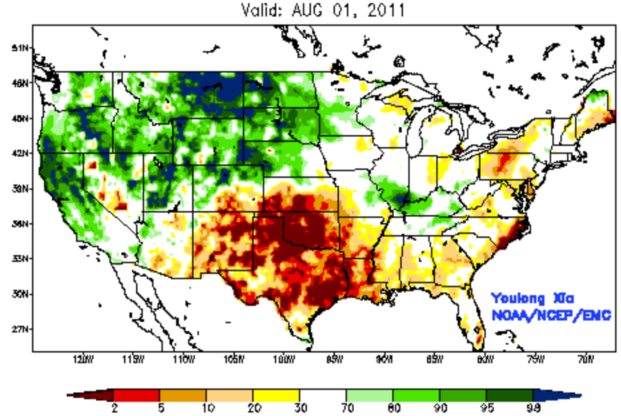
Princeton VIC – Past Month Total Column Soil Moisture Percentile
Valid: AUG 01, 2011



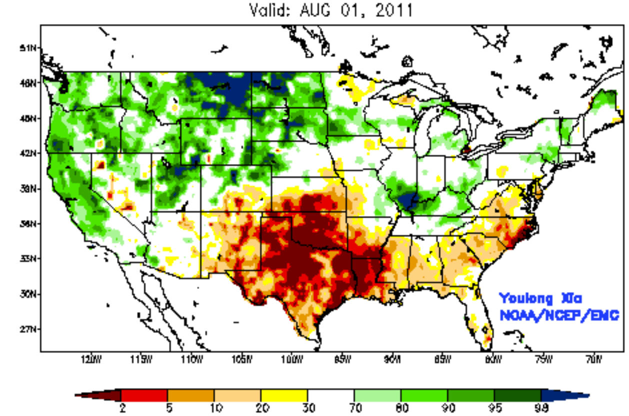
NASA Mosaic – Past Month Total Column Soil Moisture Percentile
Valid: AUG 01, 2011



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



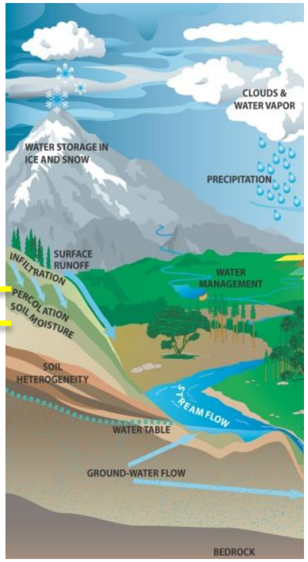
OHD SAC – Past Month Total Column Soil Moisture Percentile
Valid: AUG 01, 2011



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



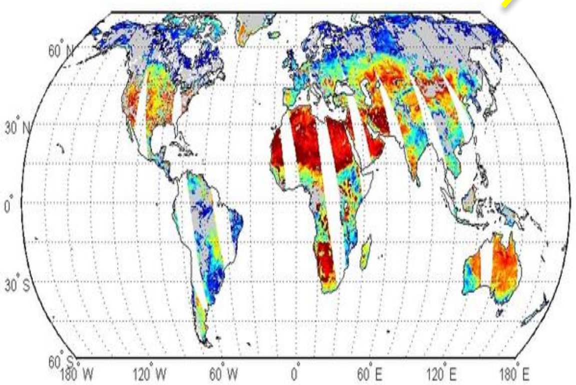


Figure 3: Daily soil moisture based on Aqua/AMSR-E. Future observations will be provided by SMAP.

Data Assimilation:

- 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).

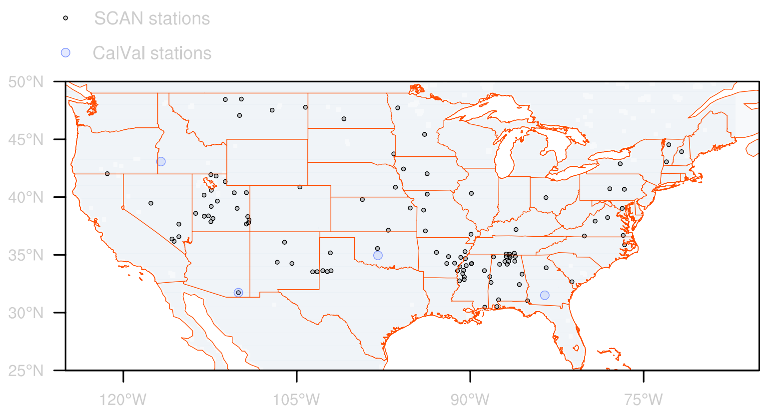
Snow depth:

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 (ECV) : Evaluation of soil moisture fields



ARS CalVal (surface soil moisture)	Open loop (no DA)	Soil moisture DA
Anomaly R	0.74 +/- 0.01	**0.76 +/- 0.01**
Anomaly RMSE (m3/m3)	0.034 +/- 0.001	**0.030 +/- 0.001**
ubRMSE (m3/m3)	0.041 +/- 0.002	**0.037 +/- 0.002**

Statistically significant improvements in surface soil moisture and root zone soil moisture as a result of soil moisture DA

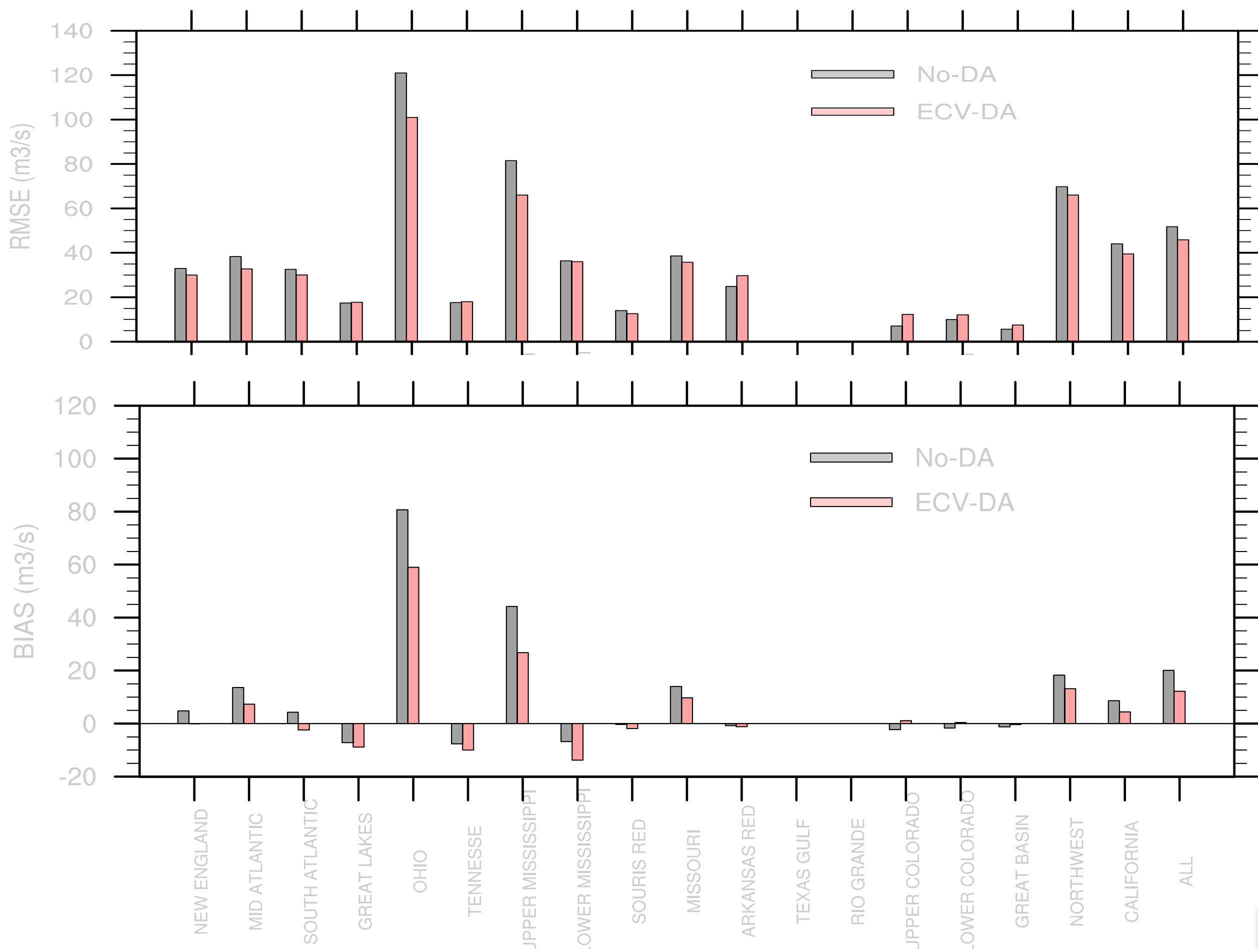
Anomaly R increases, Anomaly RMSE reduces and unbiased RMSE reduces with soil moisture assimilation.

SCAN (surface soil moisture)	Open loop (no DA)	Soil moisture DA
Anomaly R	0.60 +/- 0.02	**0.71 +/- 0.02**
Anomaly RMSE (m3/m3)	0.044+/- 0.002	**0.041 +/- 0.002**
ubRMSE (m3/m3)	0.054 +/- 0.003	**0.052 +/- 0.003**

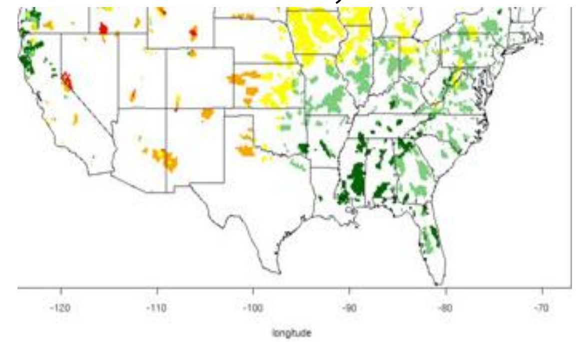
SCAN (root zone soil moisture)	Open loop (no DA)	Soil moisture DA
Anomaly R	0.60 +/- 0.02	**0.62 +/- 0.02**
Anomaly RMSE (m3/m3)	0.037+/- 0.002	**0.037 +/- 0.002**
ubRMSE (m3/m3)	0.048 +/- 0.003	**0.046 +/- 0.003**

Acknowledgements: Rolf Reichle and Gabrielle de Lannoy (NASA GMAO) for the quality controlled SCAN data and Mike Cosh (USDA ARS) for the ARS CalVal data

Soil moisture DA (ECV): Evaluation of streamflow



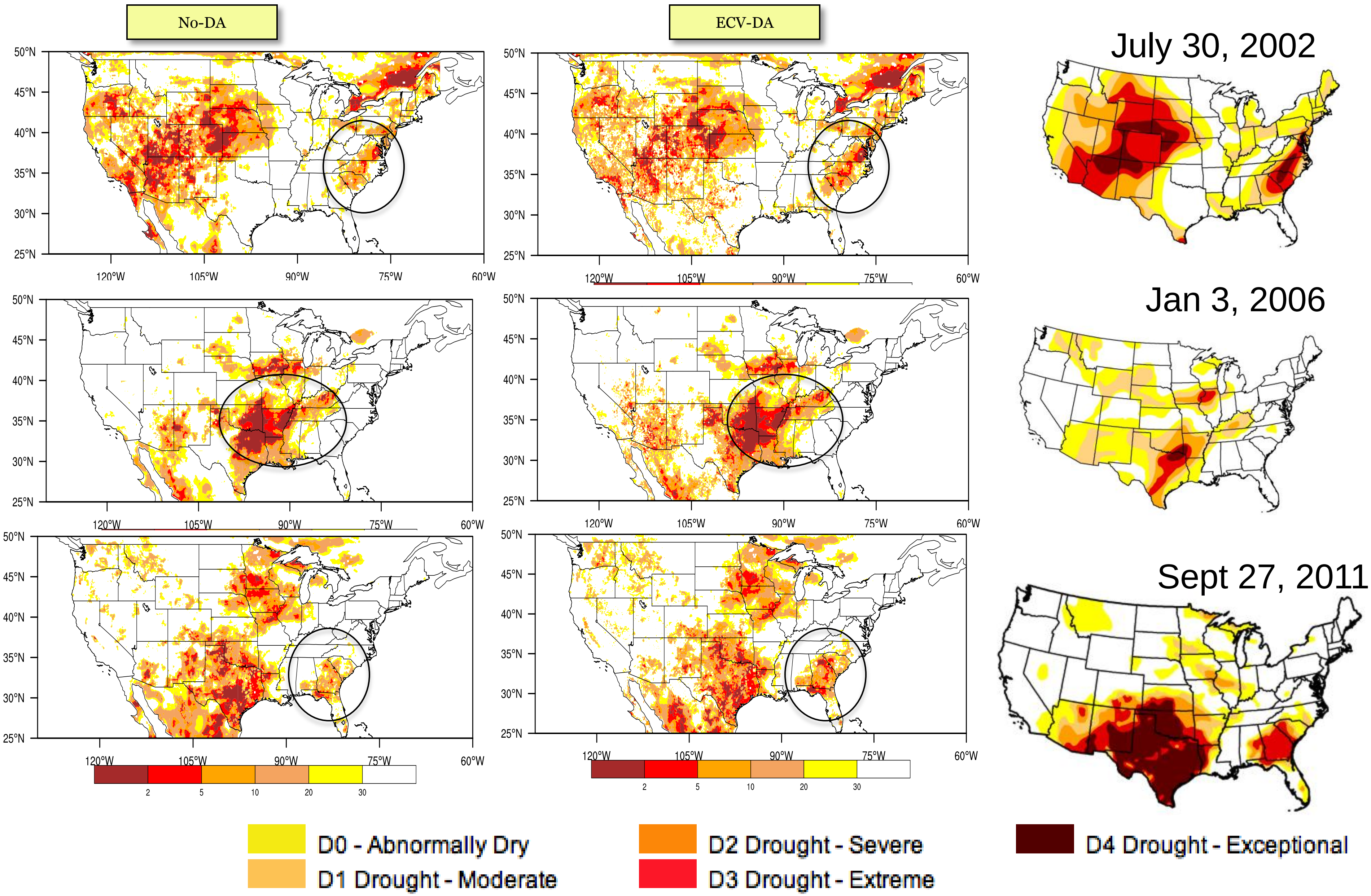
961 unregulated basins as in Xia et al., 2012

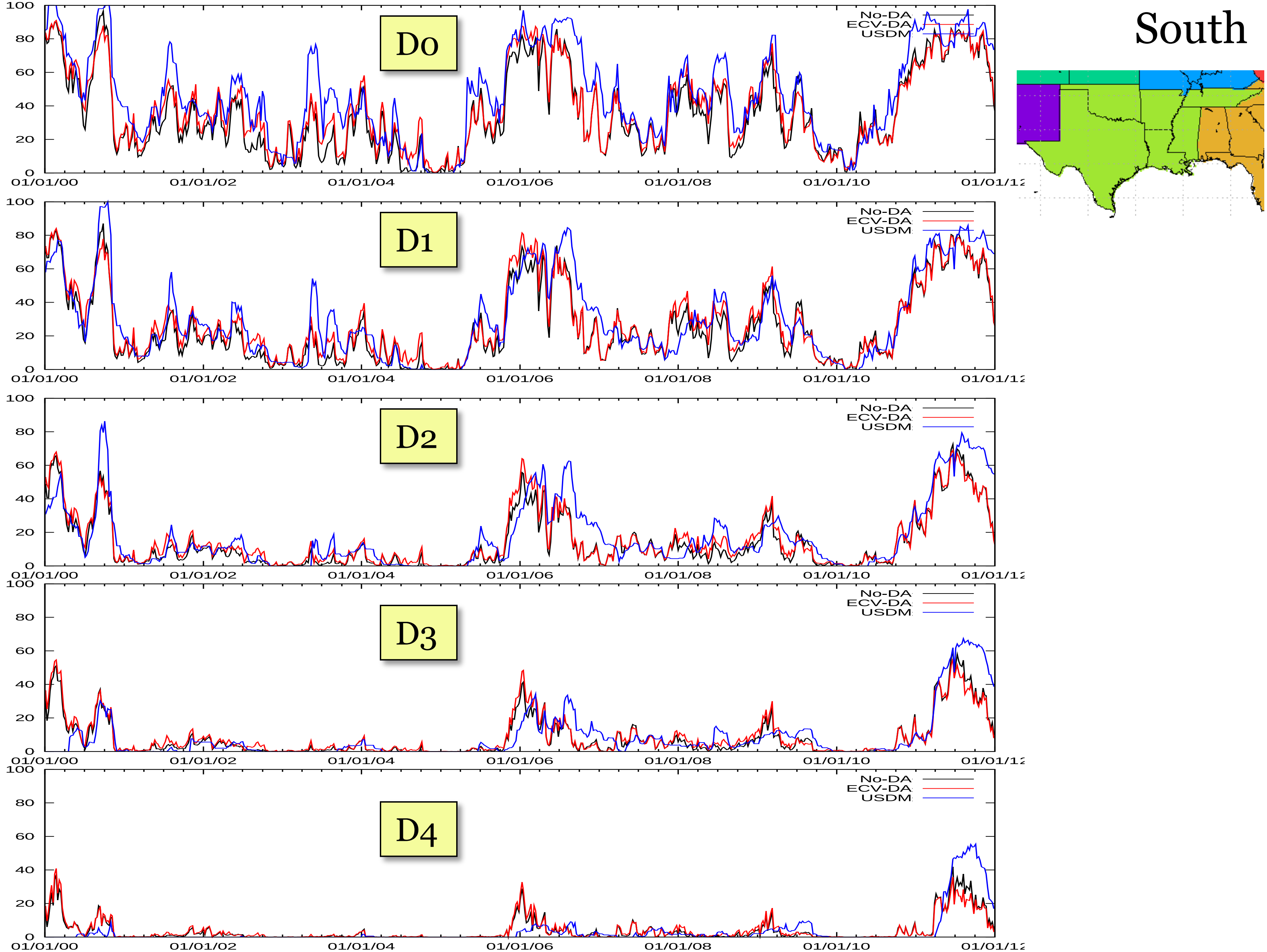


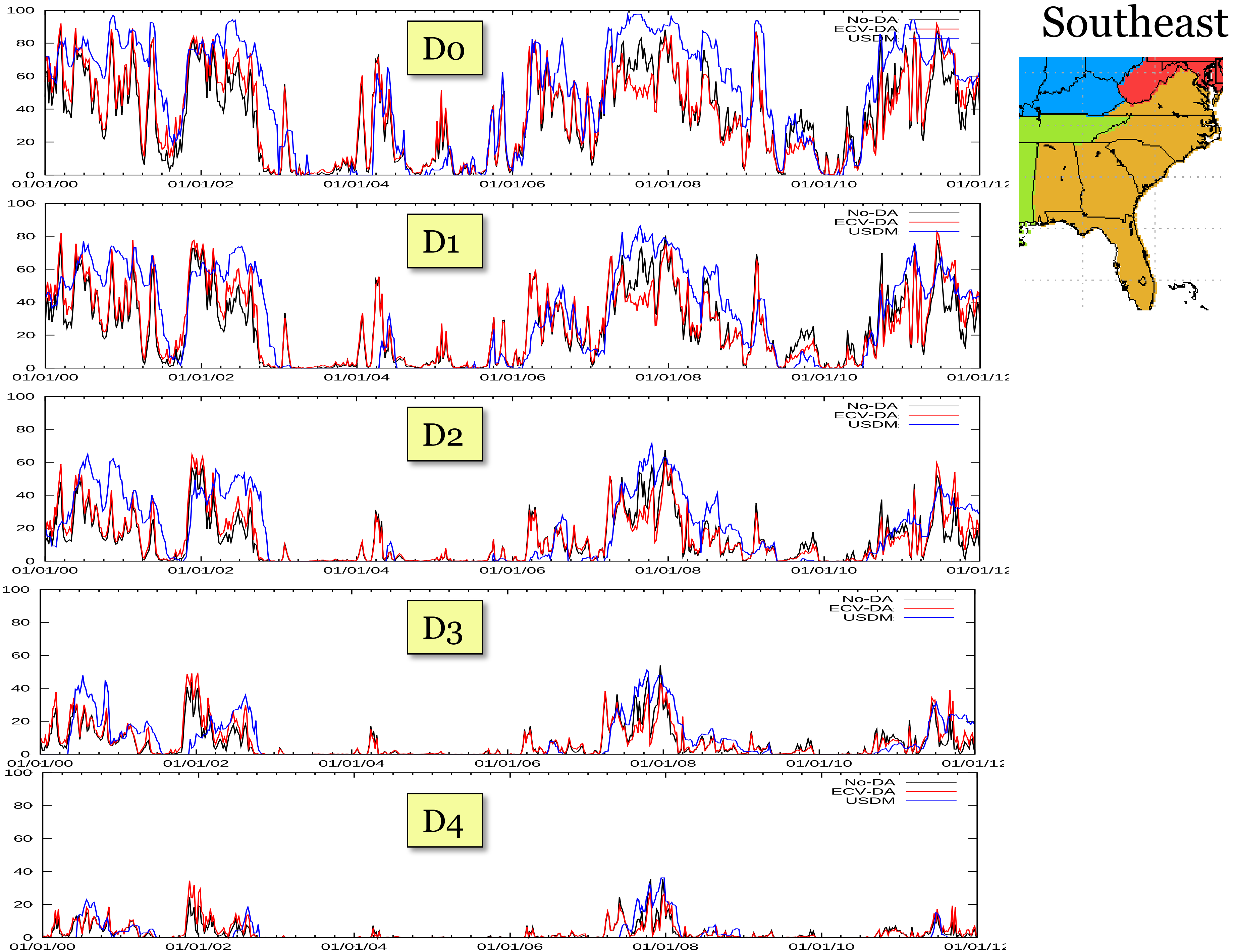
Streamflow (USGS)	Open loop (no DA)	ECV DA
RMSE (m3/s)	51.8 +/- 1.0	**45.9 +/- 1.0**
Bias (m3/s)	20.1 +/- 1.0	**12.2 +/- 1.0**

Improvements to the streamflow simulations are observed in most basins except Arkansas-red, Upper Colorado, Lower Colorado, Great basin.

Comparison against USDM




South
D0
D1
D2
D3
D4
No-DA
ECV-DA
USDM
0
20
40
60
80
100
01/01/00
01/01/02
01/01/04
01/01/06
01/01/08
01/01/10
01/01/12


Southeast
D0
D1
D2
D3
D4
No-DA
ECV-DA
USDM
100
80
60
40
20
0
01/01/00
01/01/02
01/01/04
01/01/06
01/01/08
01/01/10
01/01/12

Snow Data Assimilation

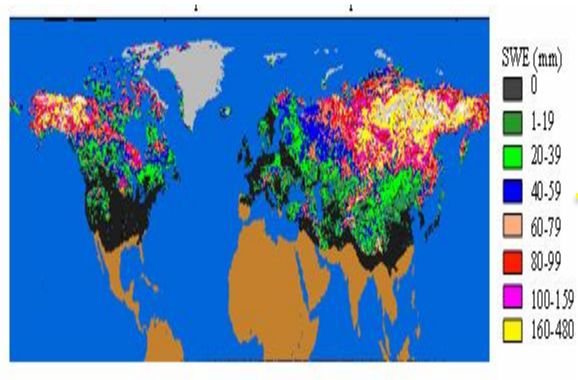
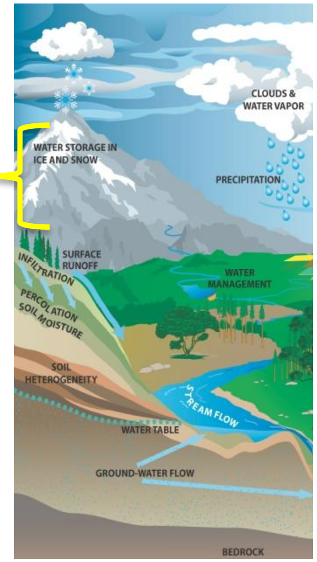


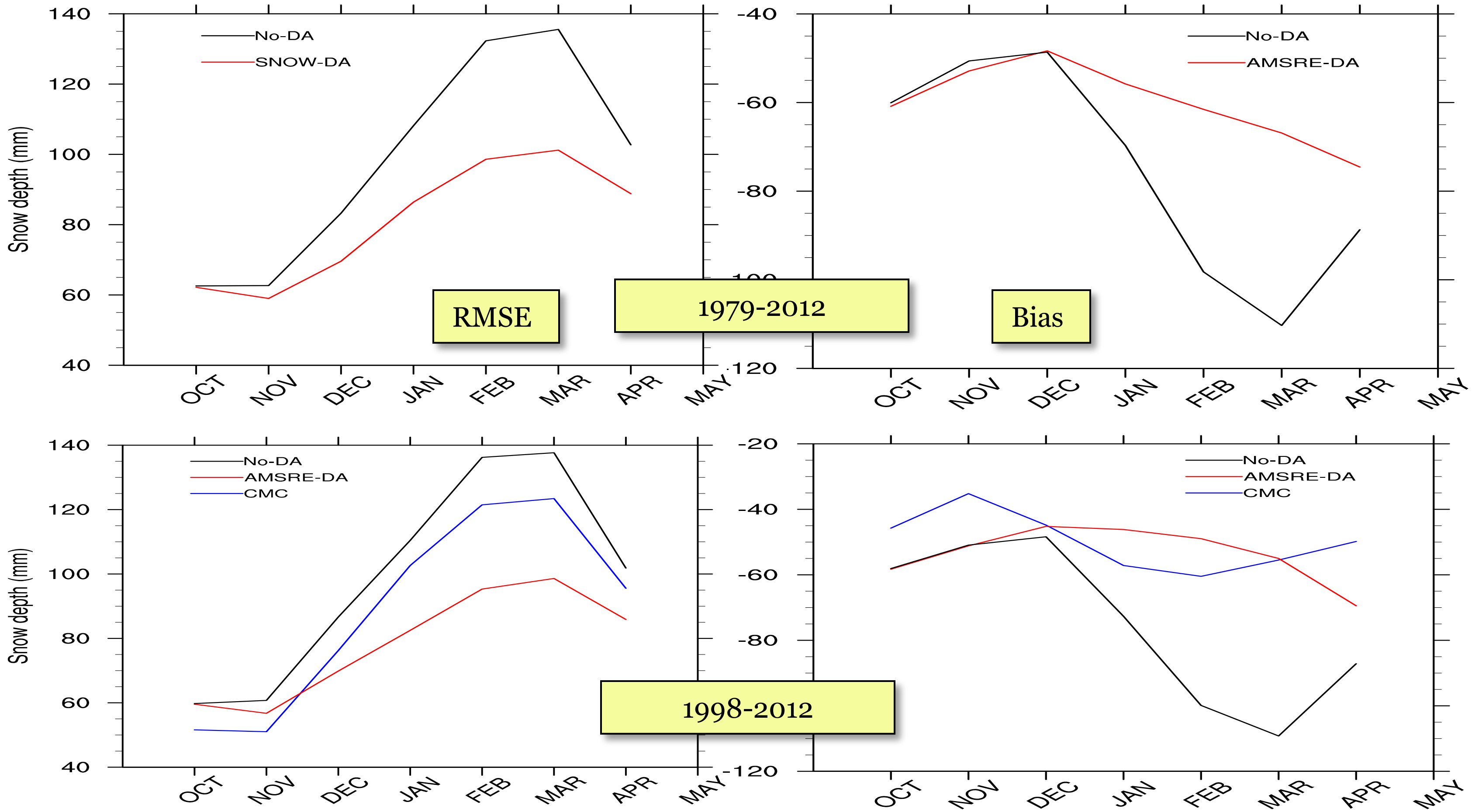
Figure 1: Snow water equivalent (SWE) based on Terra/MODIS and Aqua/AMSR-E. Future observations will be provided by JPSS/VIIRS and DWSS/MIS.



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 (SMMR+SSM/I+AMSR-E) : Evaluation of snow depth fields

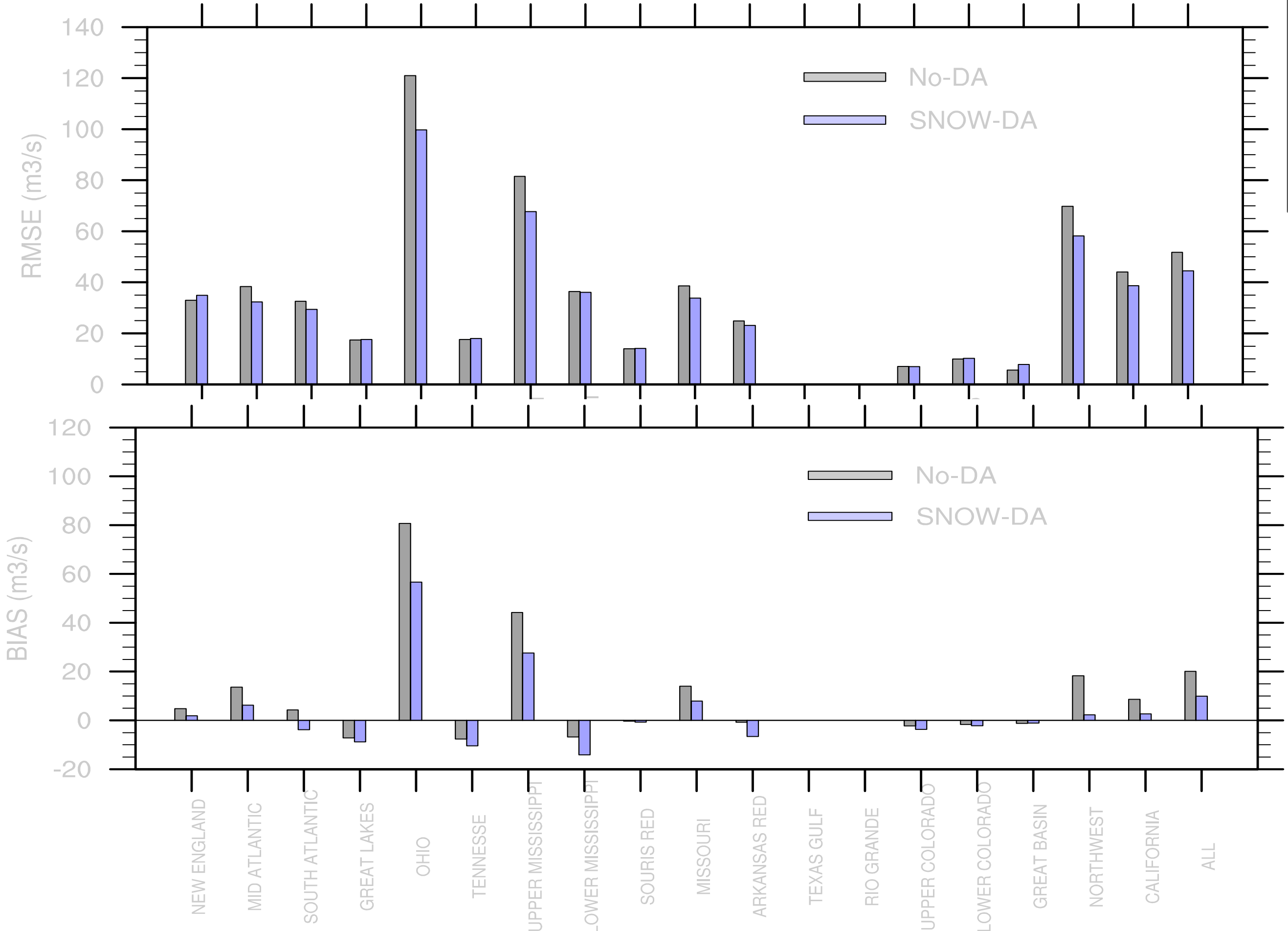


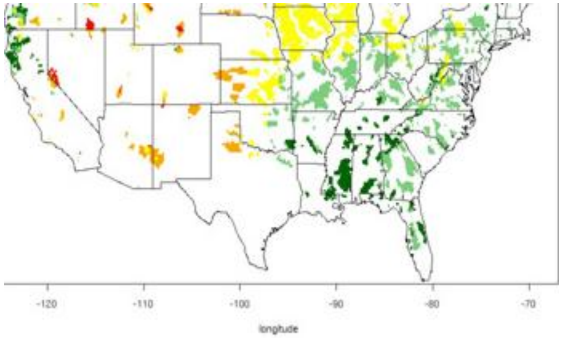
Snow depth (GHCN)	No-DA	SNOW-DA	CMC
RMSE (mm)	151.0 +/- 5.0	**114.0+/- 5.0**	135.0 +/- 5.0
Bias (mm)	-80.0 +/- 5.0	**-48.9 +/- 5.0**	-53.2 +/- 5.0

The assimilation of gauge-corrected snow EDR provides significant improvements to the snow depth fields, primarily over the peak winter and spring melt periods.

The gauge corrected AMSR-E data shows similar skill to that of CMC

Snow DA (SMMR+SSM/I+AMSR-E): Evaluation of streamflow over 961 small basins (grouped by USGS hydrologic units)

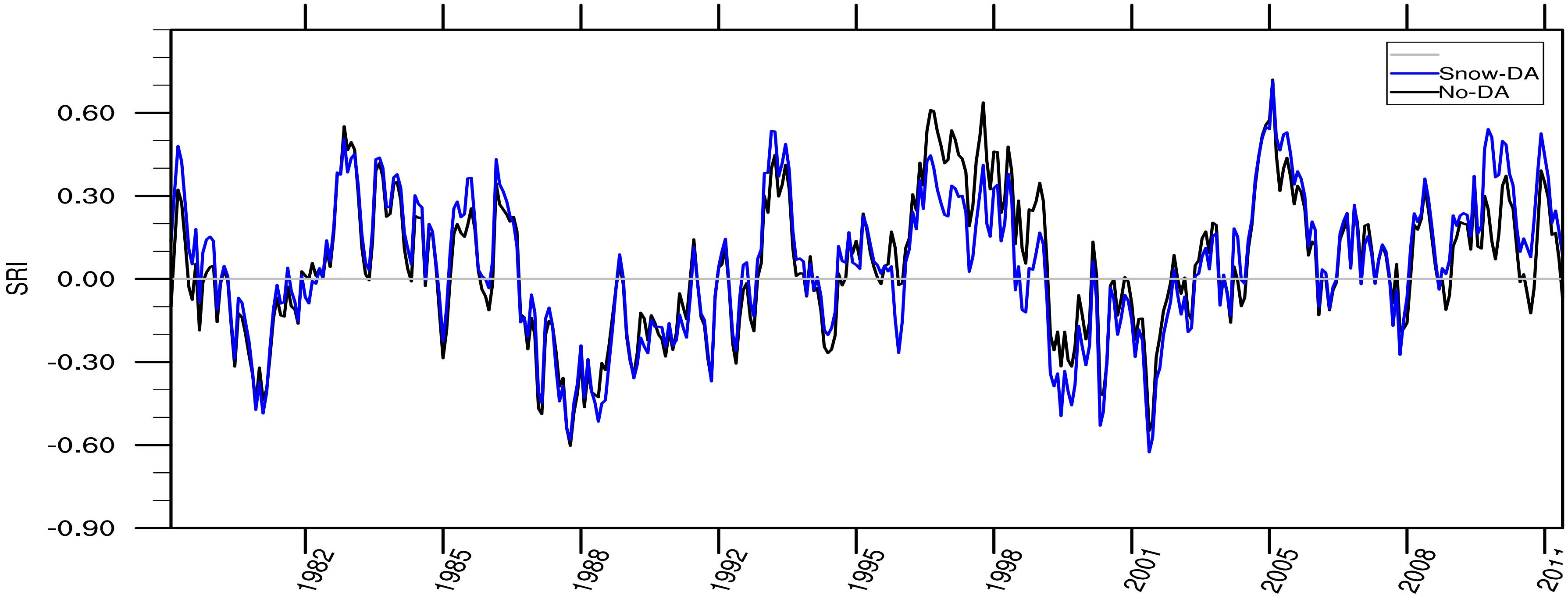




Streamflow (USGS)	Open loop (no DA)	SNOW-DA
RMSE (m3/s)	51.8 +/- 1.0	**44.5 +/- 1.0**
Bias (m3/s)	20.1 +/- 1.0	**9.9 +/- 1.0**

Significant improvements to the streamflow simulations are observed over most major basins, except over New England.

Snow DA : Impact on SRI Drought Index for CONUS



Summary

- Soil moisture assimilation can improve soil moisture, streamflow and evapotranspiration (not shown, see Peters-Lidard et al., 2011)
- Soil moisture assimilation can change area in D0-D4 threshold percentiles used to diagnose drought

- 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 Surface Runoff Index (SRI)

Additional References

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