

Goddard Space Flight Center

Land Information System

The Impact of Soil Moisture and Snow Assimilation on North American Land Data Assimilation System (NLDAS) Drought Metrics

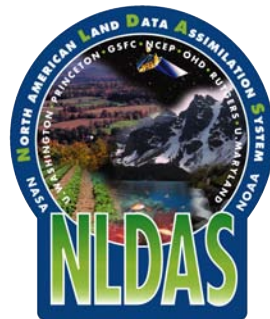
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¹Hydrological Sciences Laboratory, NASA/GSFC, Greenbelt, Maryland

²SAIC at Hydrological Sciences Laboratory, NASA/GSFC, Greenbelt, Maryland

³Environmental Modeling Center, NCEP/NOAA, Camp Springs, Maryland



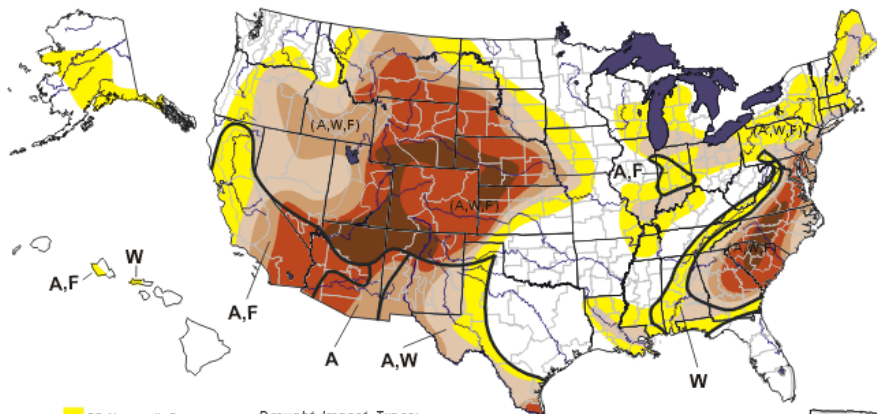
Outline

- 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

July 30, 2002
Valid 8 a.m. EDT



- 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
 (N 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>

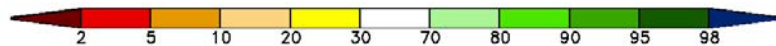
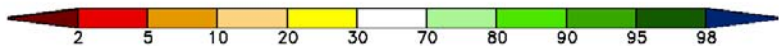
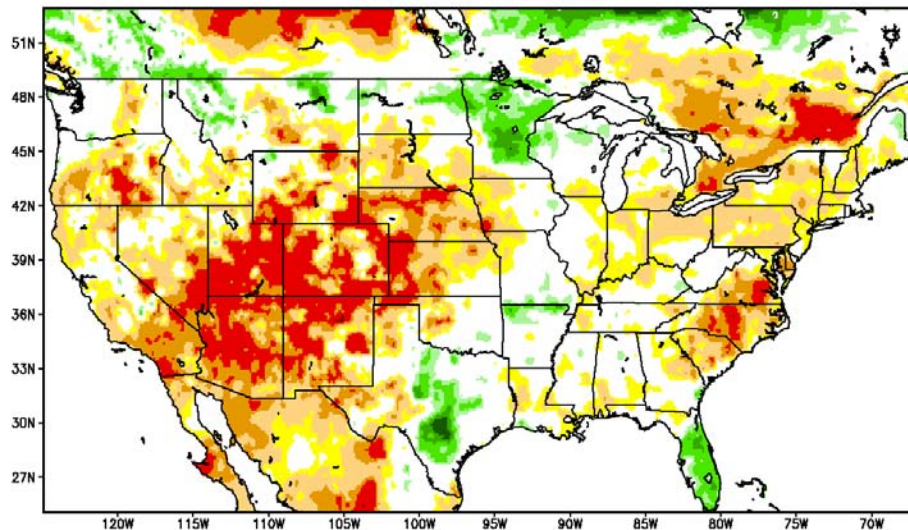
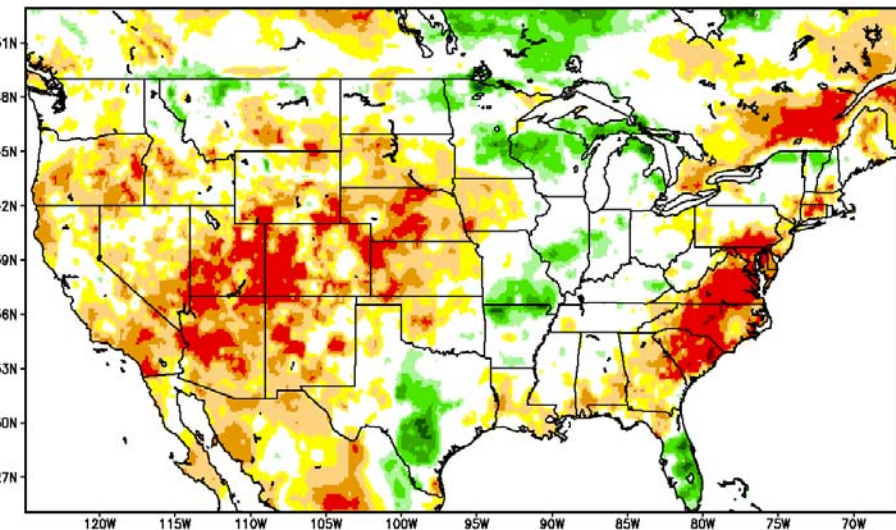


Released Thursday, August 1, 2002

Author: Rich Tinker, CPC/NWS/NOAA

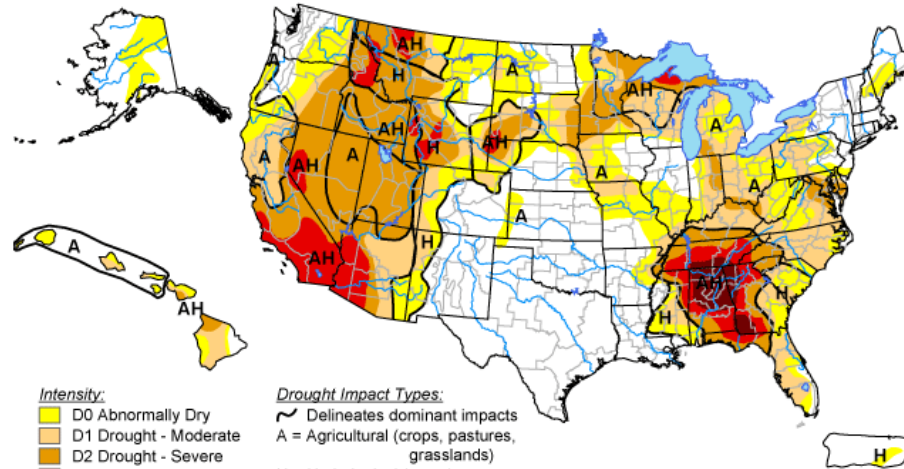
NASA Mosaic – Past Month Total Column Soil Moisture Percentile
Valid: JUL 30, 2002

NCEP Noah – Past Month Total Column Soil Moisture Percentile
Valid: JUL 30, 2002



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)

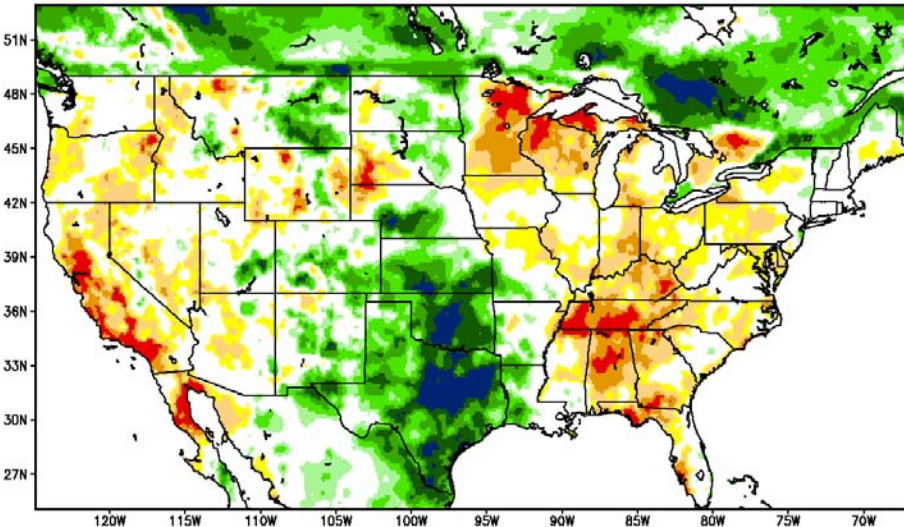
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<http://drought.unl.edu/dm>

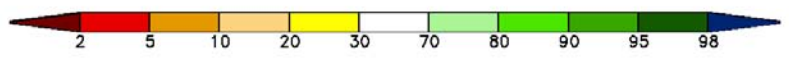
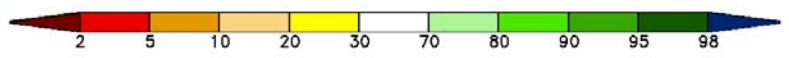
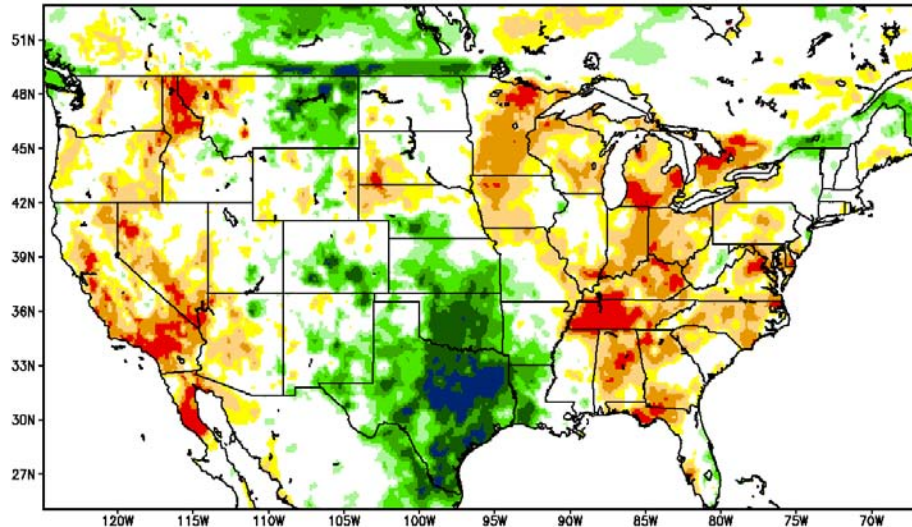


Released Thursday, August 9, 2007
Author: Brian Fuchs, National Drought Mitigation Center

NASA Mosaic – Past Month Total Column Soil Moisture Percentile
Valid: AUG 07, 2007

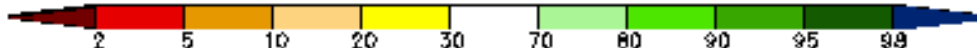
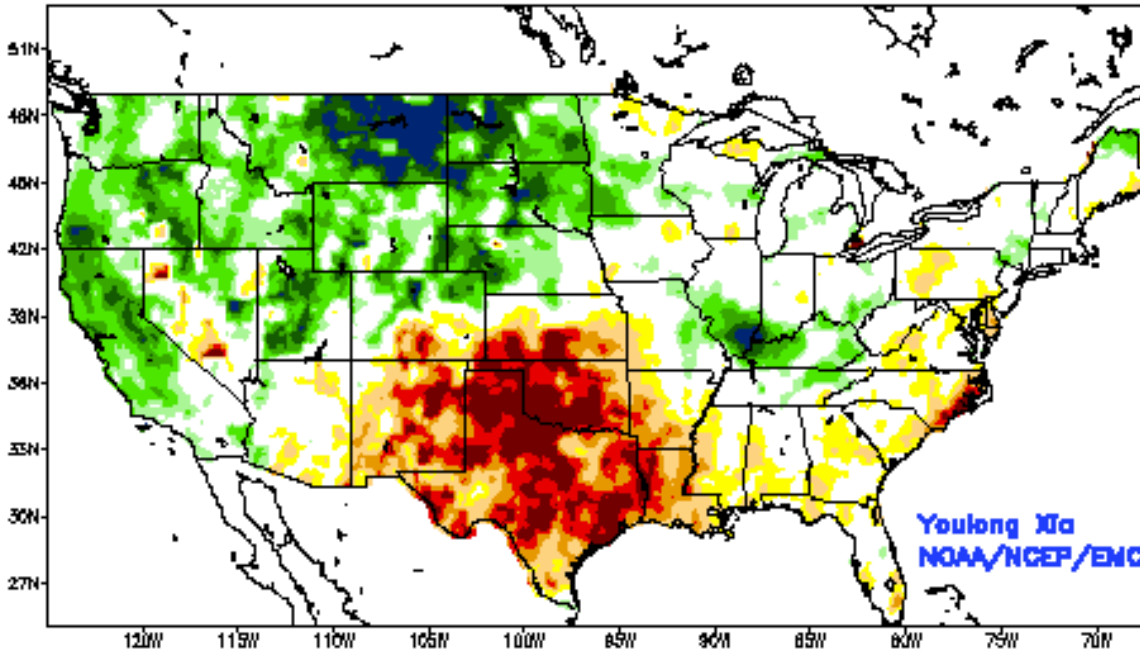


NCEP Noah – Past Month Total Column Soil Moisture Percentile
Valid: AUG 07, 2007



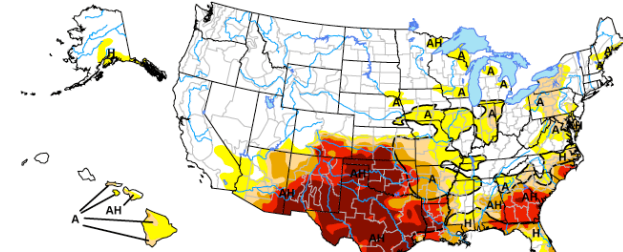
Aug 2011

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



U.S. Drought Monitor August 2, 2011

August 2, 2011
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)

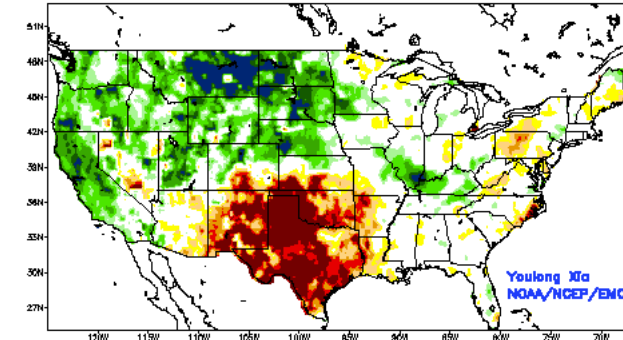


The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

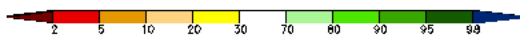
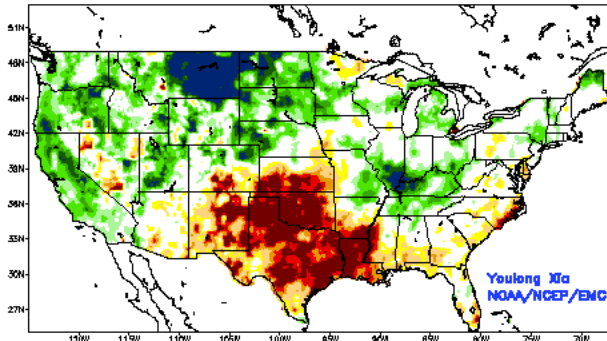
Released Thursday, August 4, 2011
 Author: Brad Rippey, U.S. Department of Agriculture

<http://drought.unl.edu/dm>

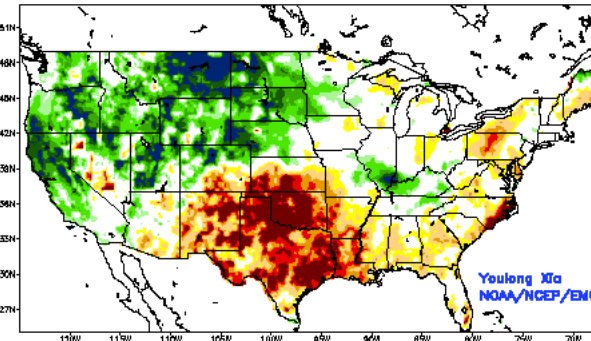
Princeton VIC - Past Month Total Column Soil Moisture Percentile
Valid: AUG 01, 2011



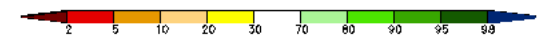
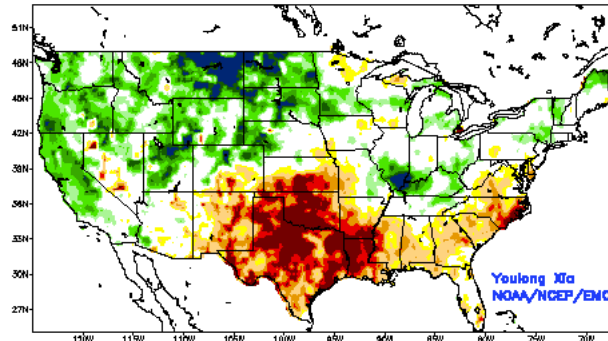
NASA Mosaic - Past Month Total Column Soil Moisture Percentile
Valid: AUG 01, 2011



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



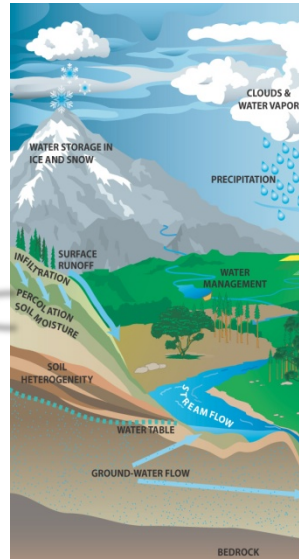
OHD SAC - Past Month Total Column Soil Moisture Percentile
Valid: AUG 01, 2011



Soil Moisture Data Assimilation

Experimental Setup:

- Domain: CONUS, NLDAS
- Resolution: 0.125 deg.
- Period: 1979-01 to 2012-01
- Forcing: NLDAS Phase 2
- LSM: Noah 3.3



Data Assimilation:

- ESA ECV soil moisture (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)

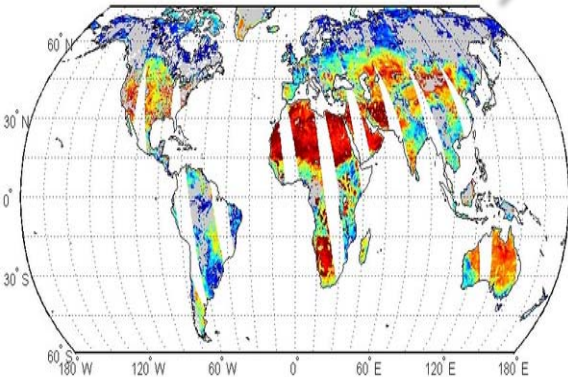


Figure 3: Daily soil moisture based on Aqua/AMSR-E. Future observations will be provided by SMAP.

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).

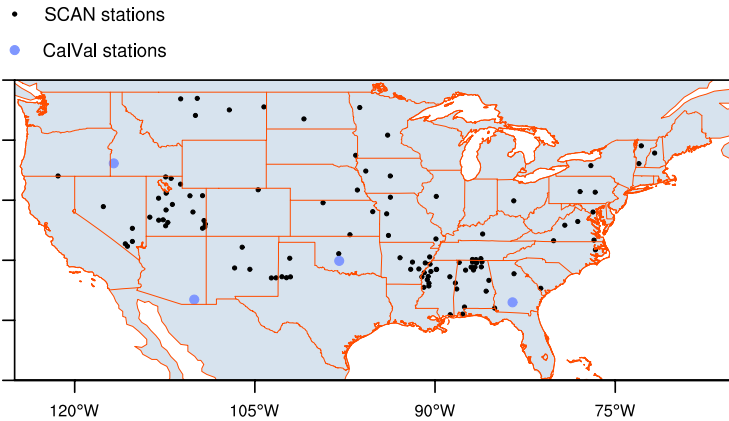
Snow depth:

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



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.

AR

**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

AR

**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

AR

**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

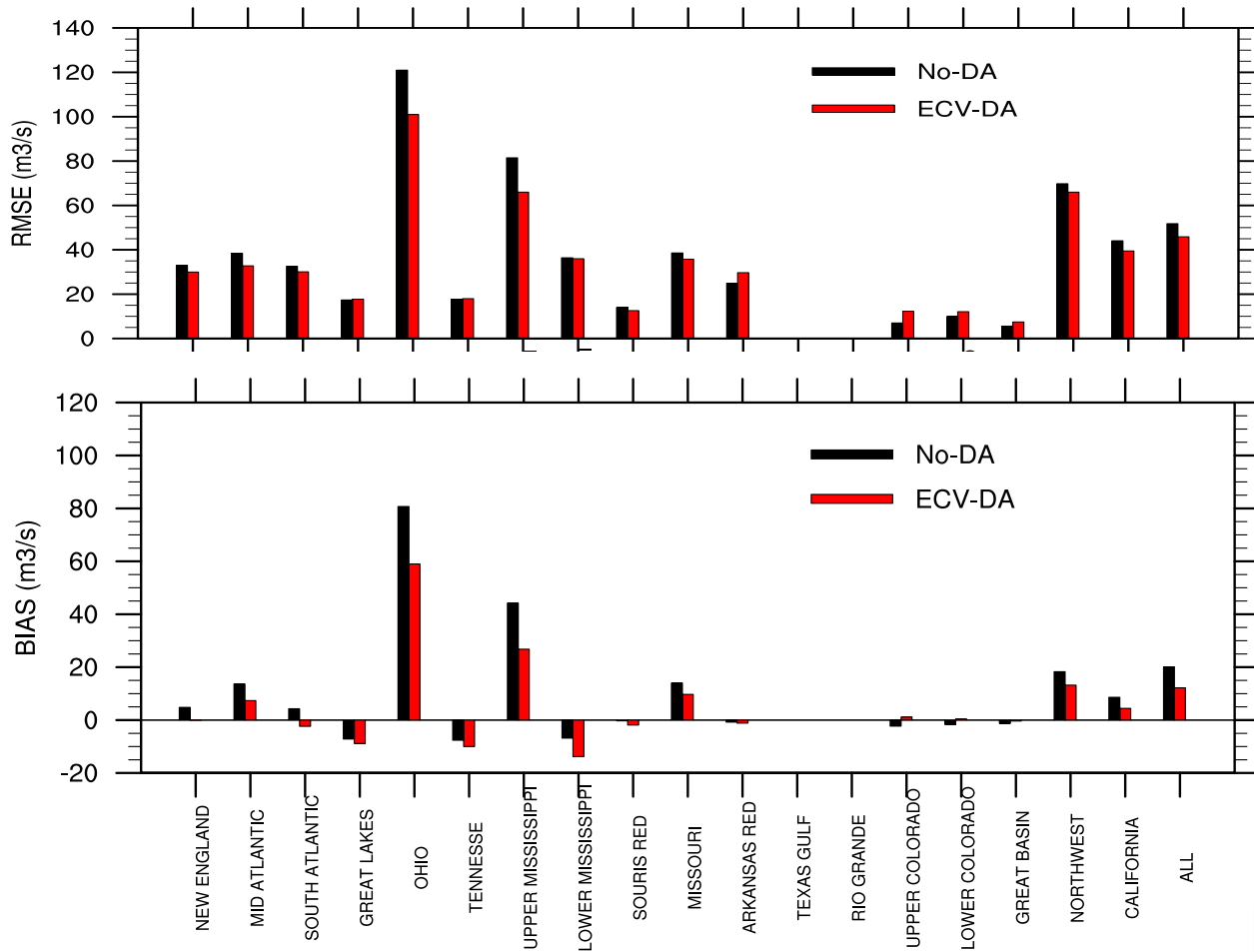
ubRMSE (m3/m3)

0.048 +/- 0.003

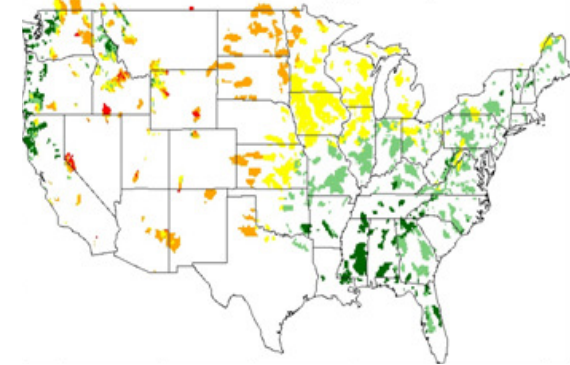
0.046 +/- 0.003

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 (m ³ /s)	51.8 +/- 1.0	45.9 +/- 1.0
Bias (m ³ /s)	20.1 +/- 1.0	12.2 +/- 1.0

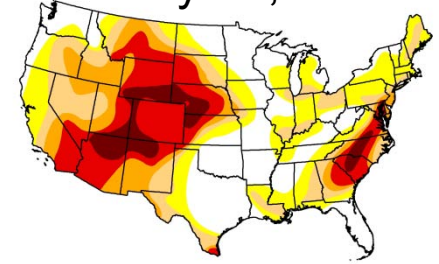
Improvements to the streamflow simulations are observed in most basins except Arkansas-red, Upper Colorado, Lower Colorado, and Great Basin.

Comparison against USDM

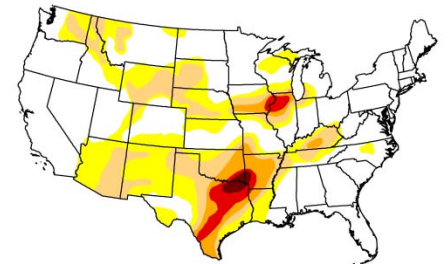
No-DA

ECV-DA

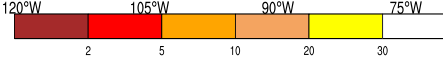
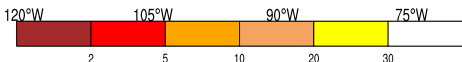
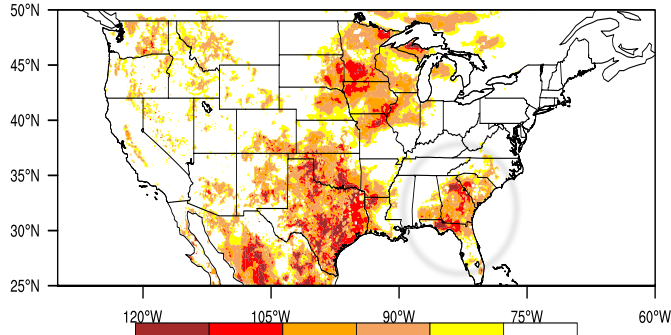
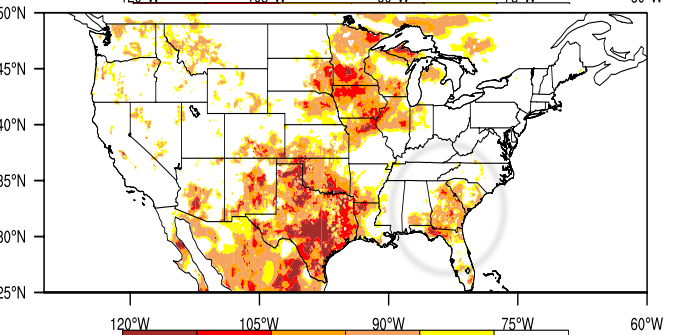
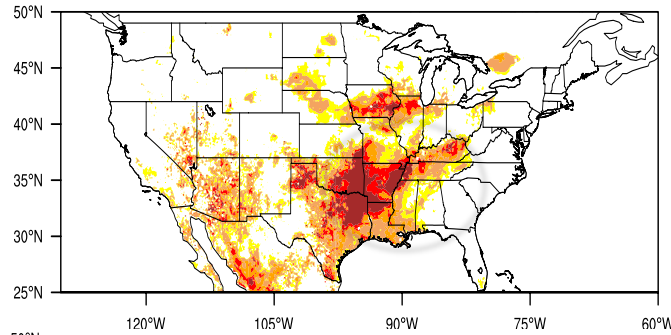
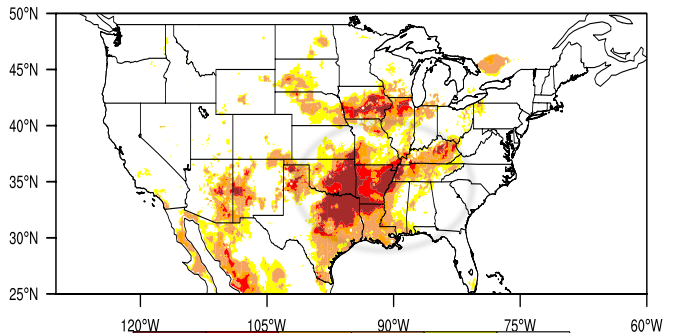
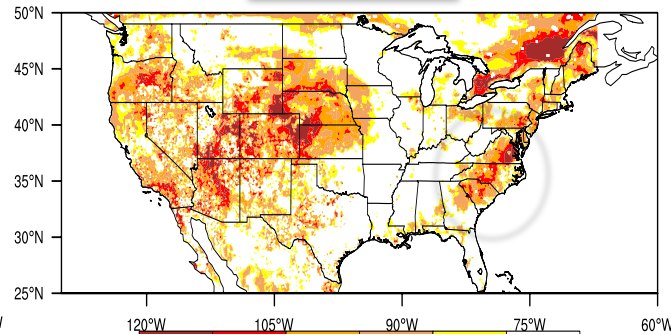
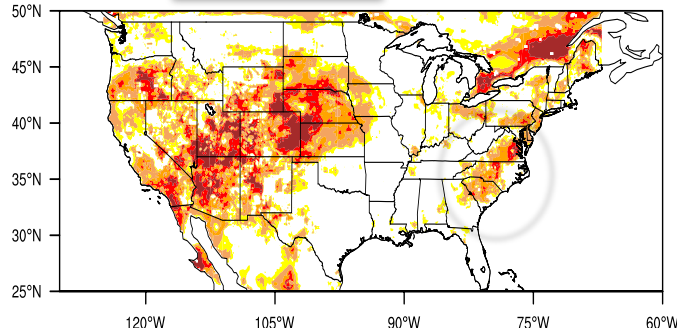
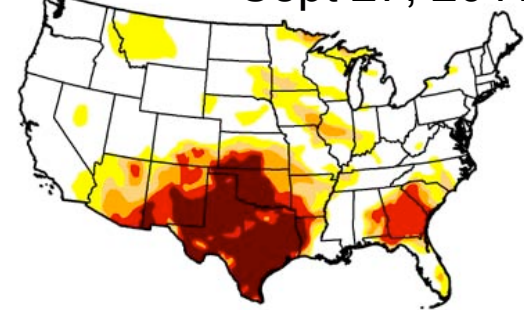
July 30, 2002



Jan 3, 2006



Sept 27, 2011

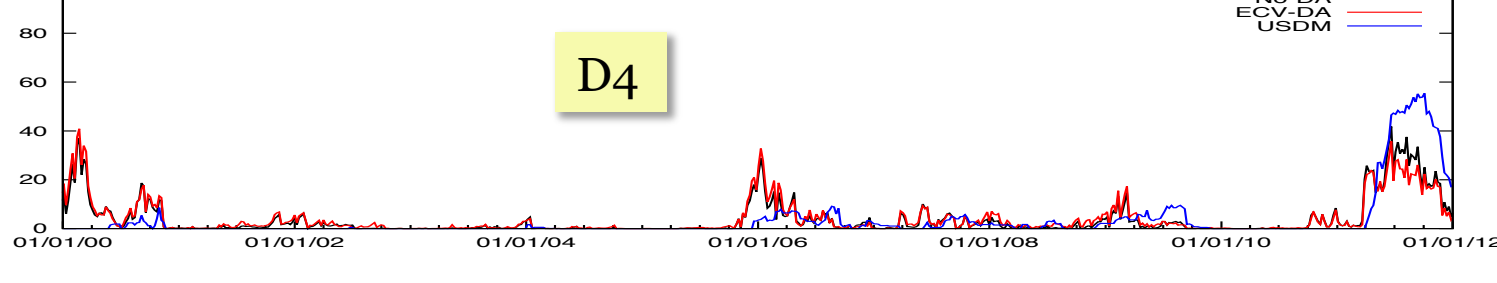
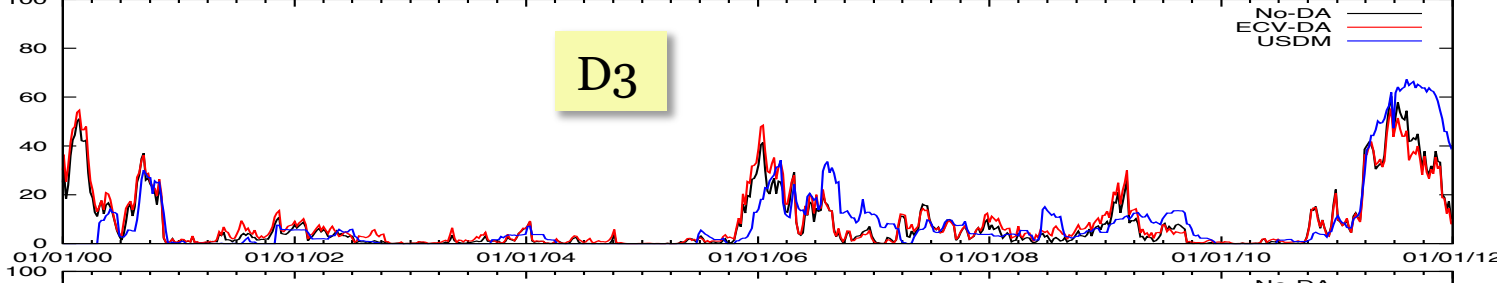
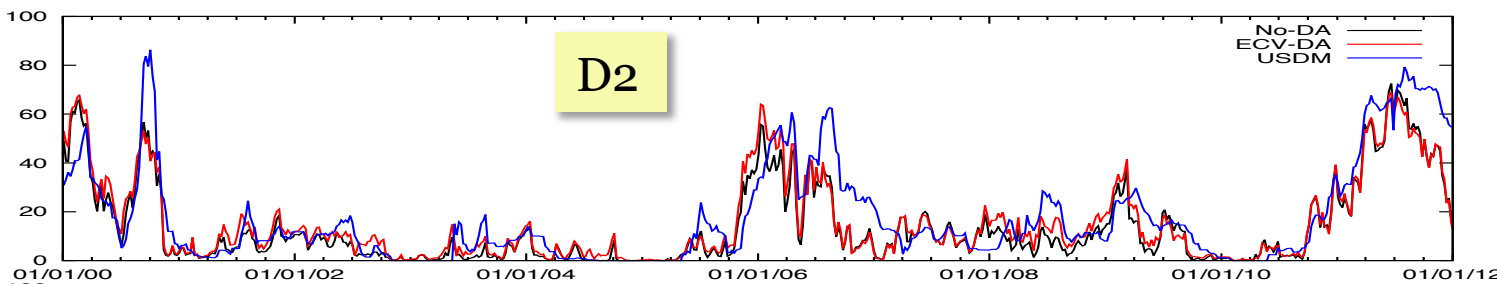
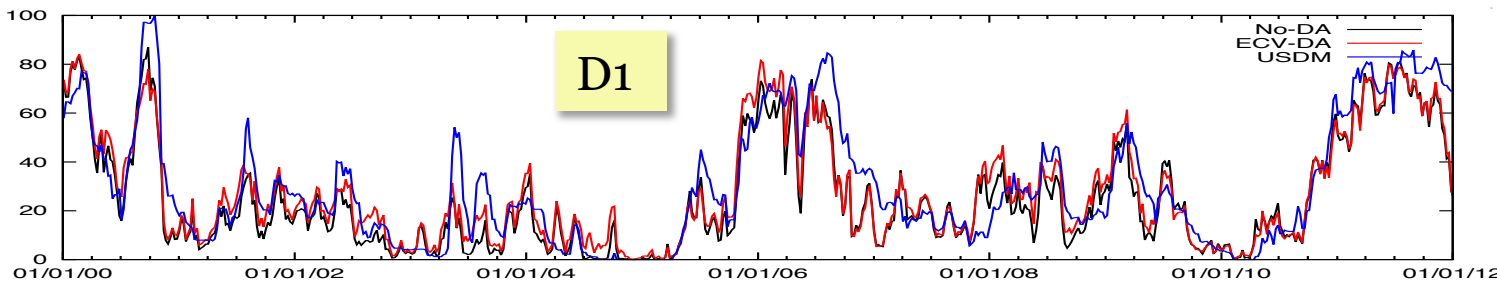
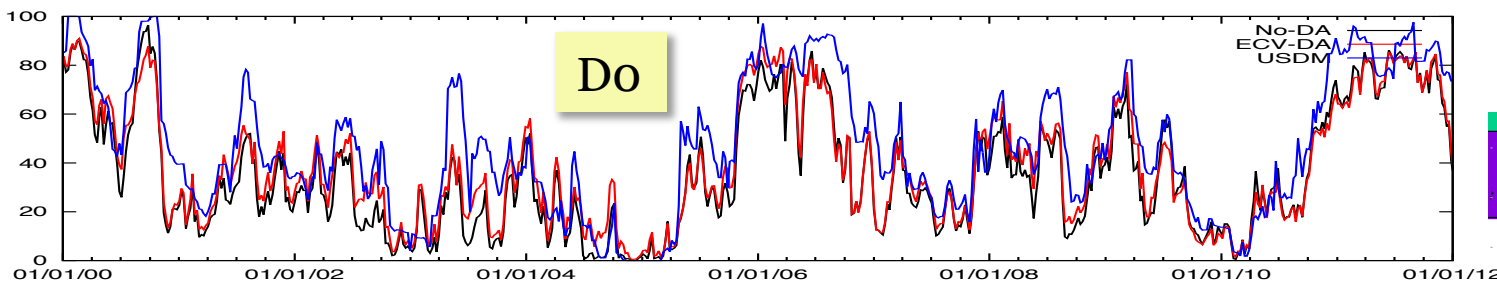
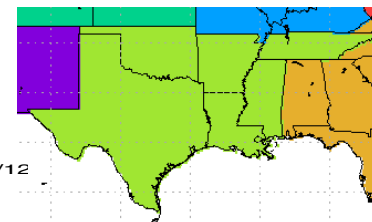


D0 - Abnormally Dry
D1 Drought - Moderate

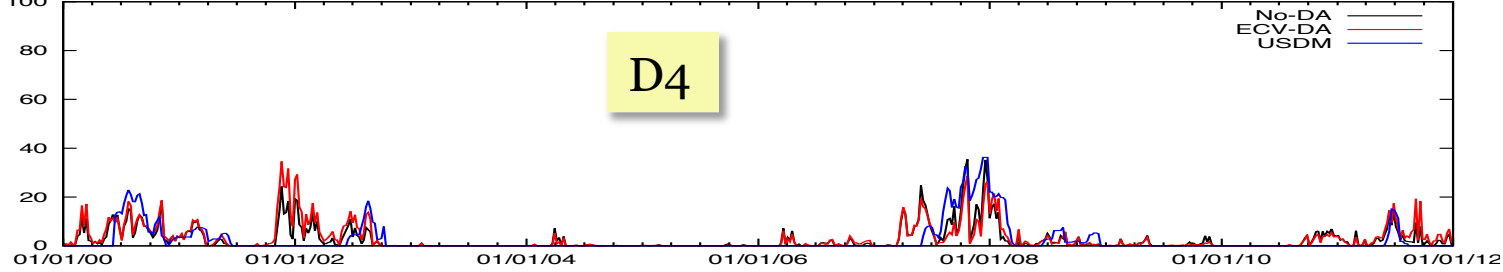
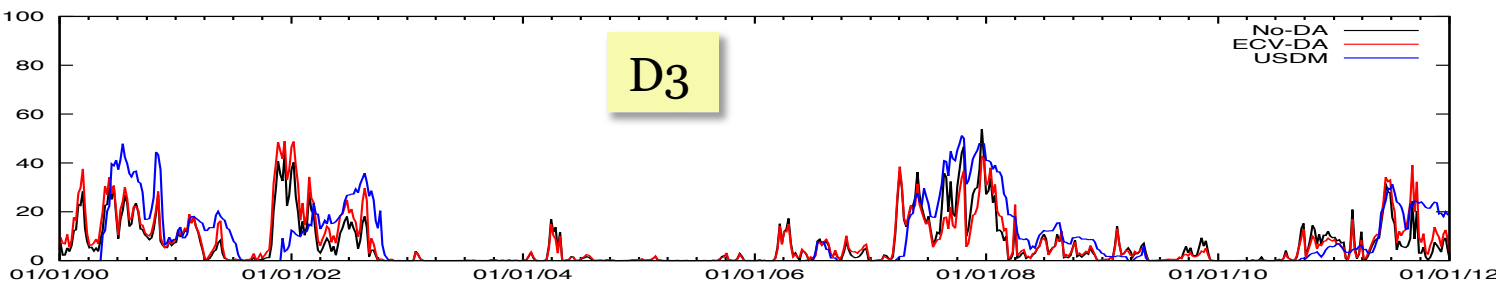
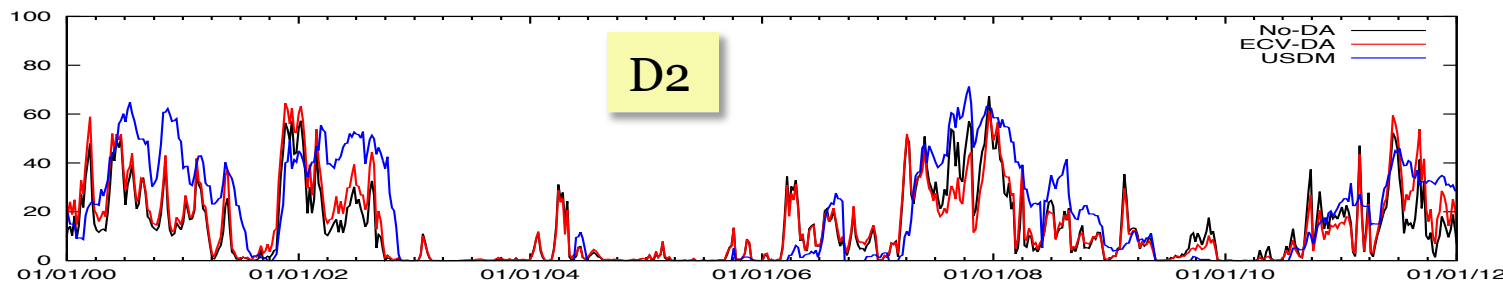
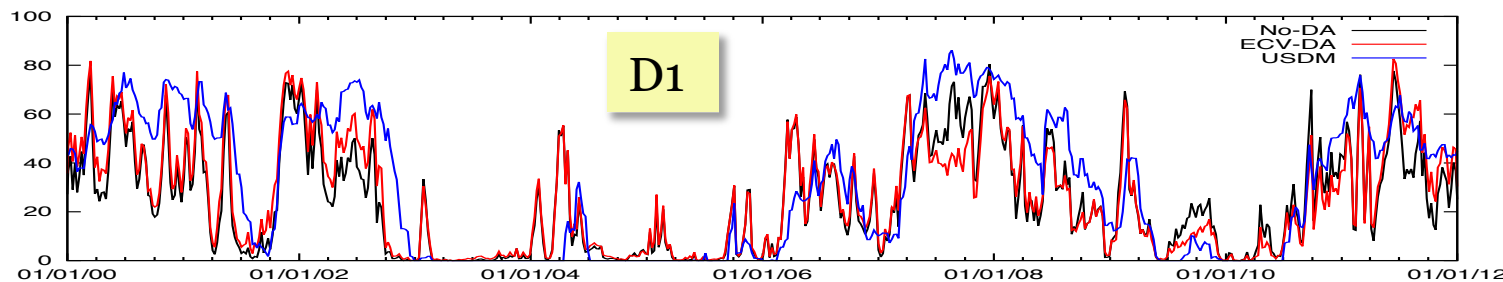
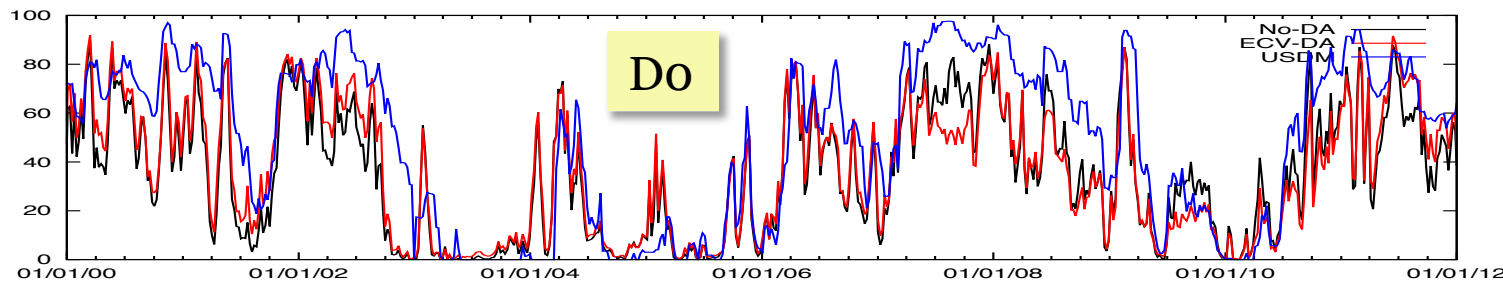
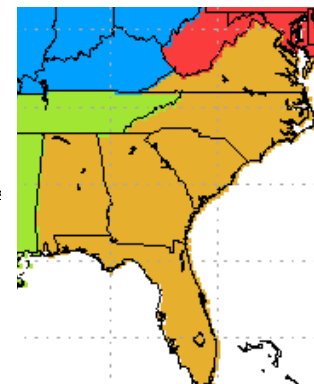
D2 Drought - Severe
D3 Drought - Extreme

D4 Drought - Exceptional

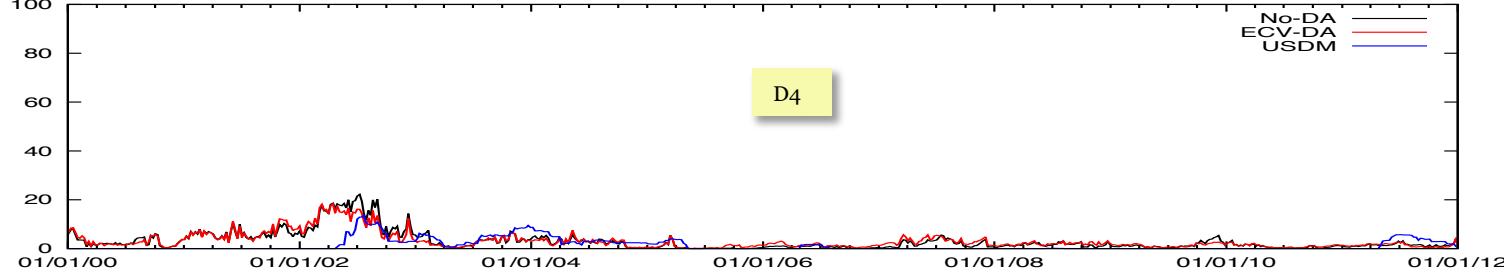
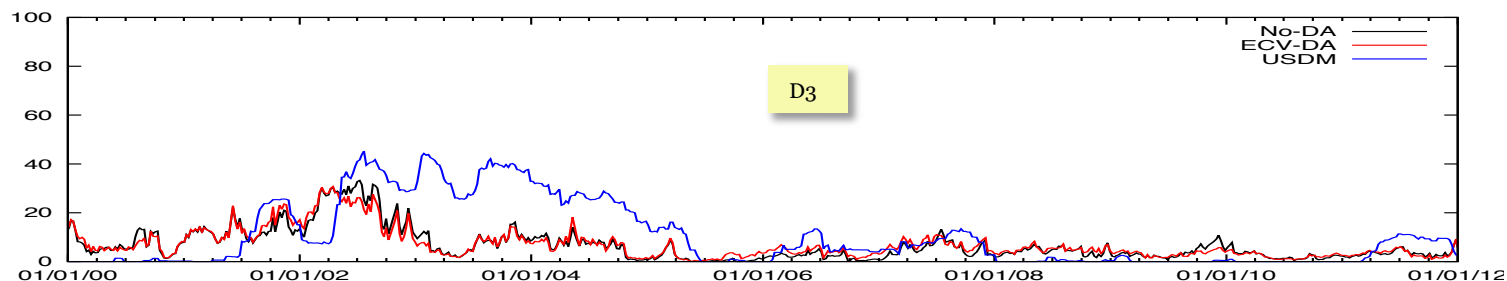
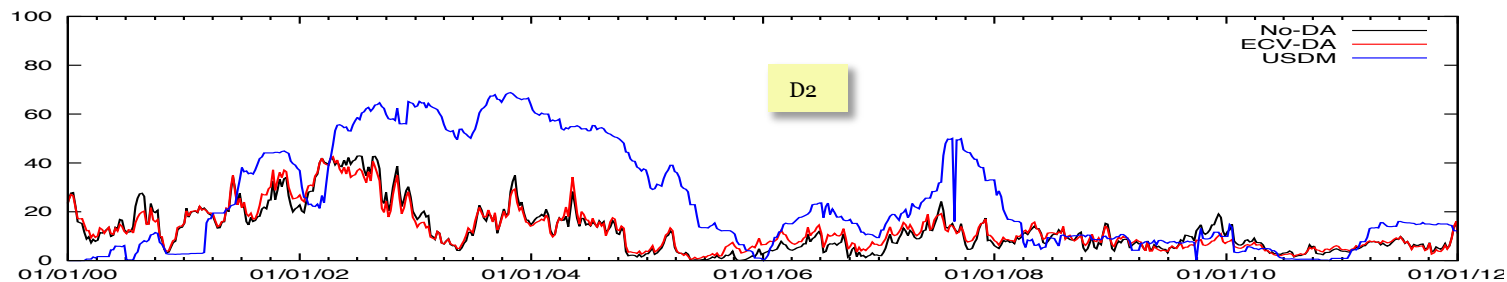
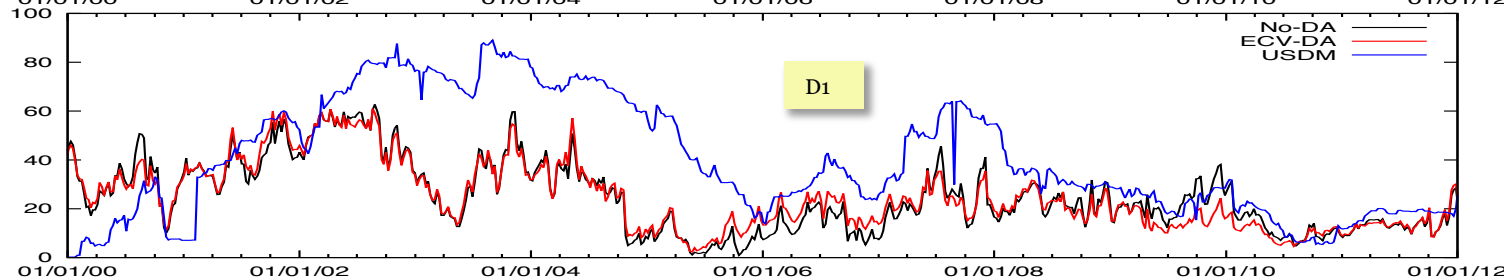
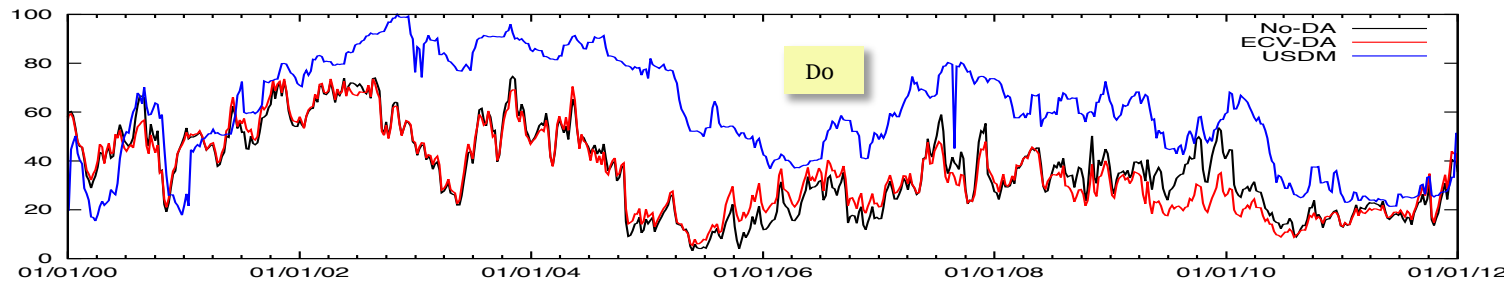
South



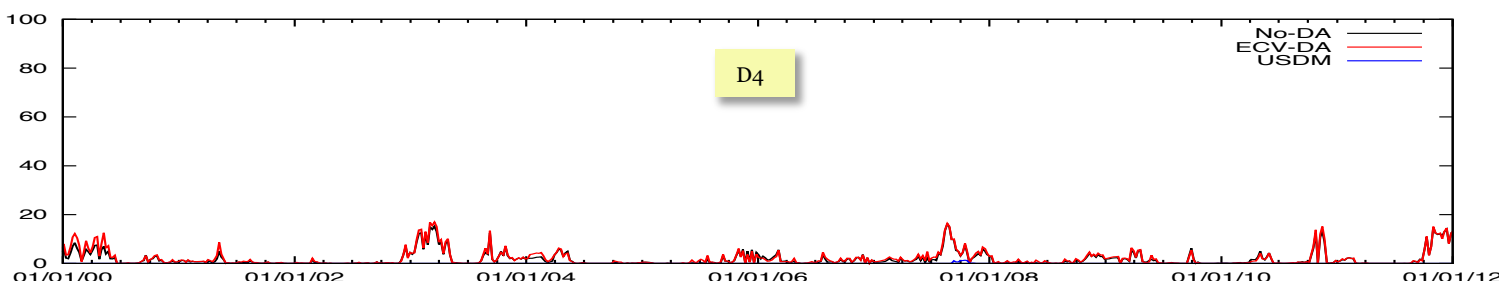
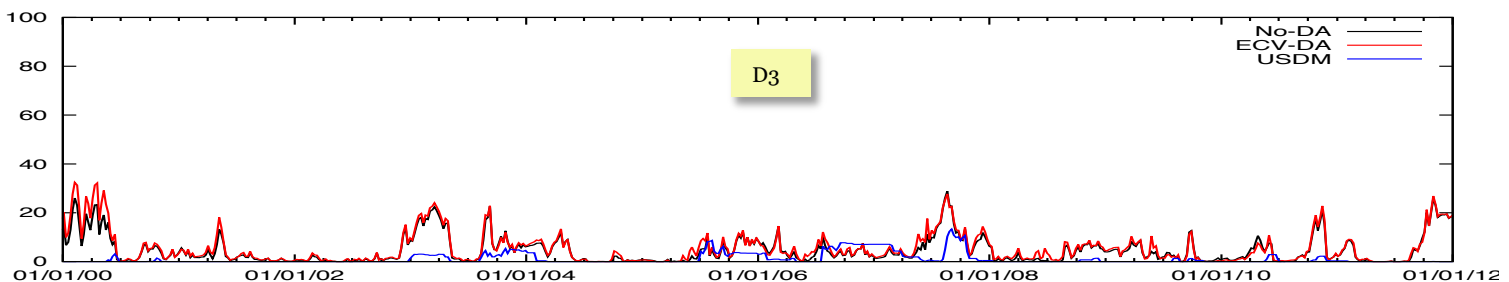
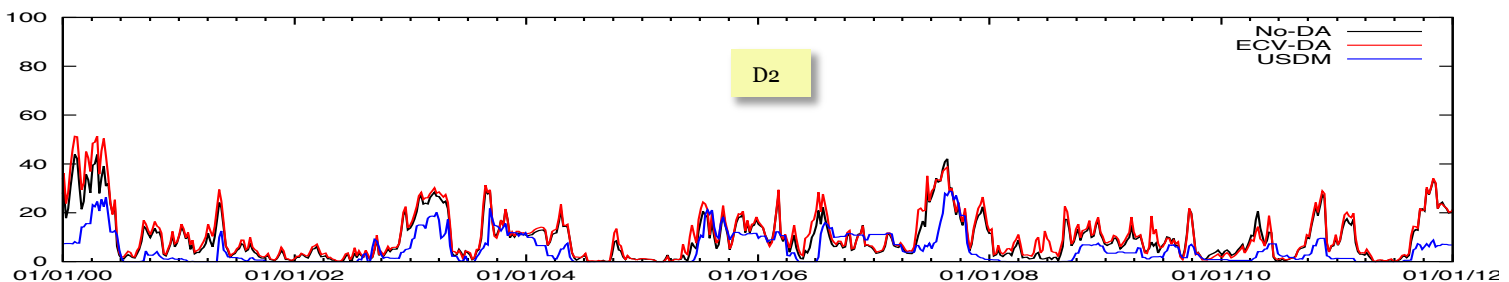
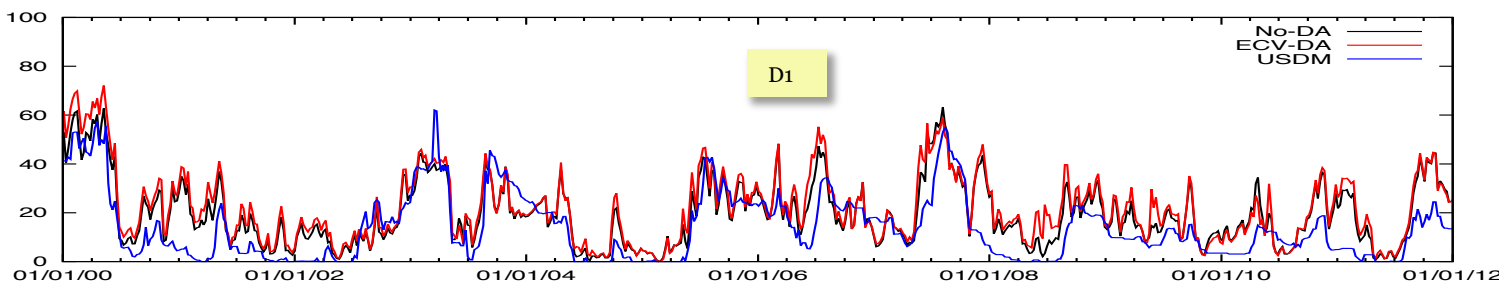
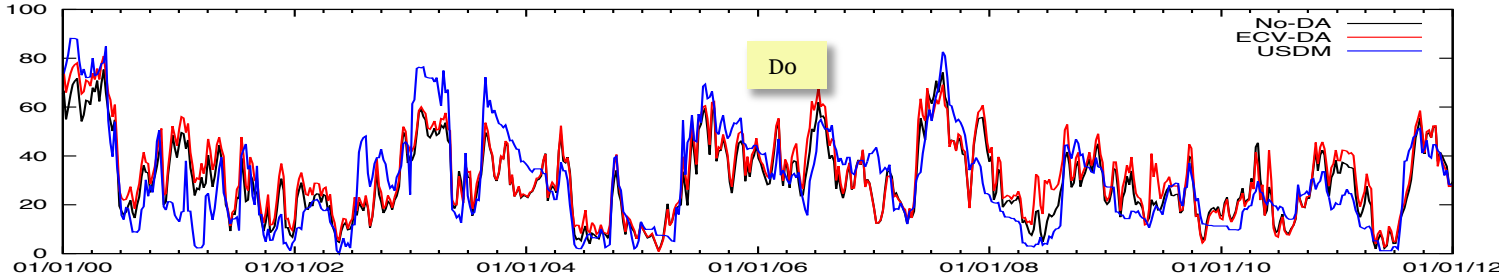
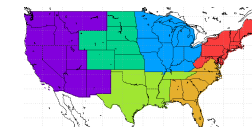
Southeast



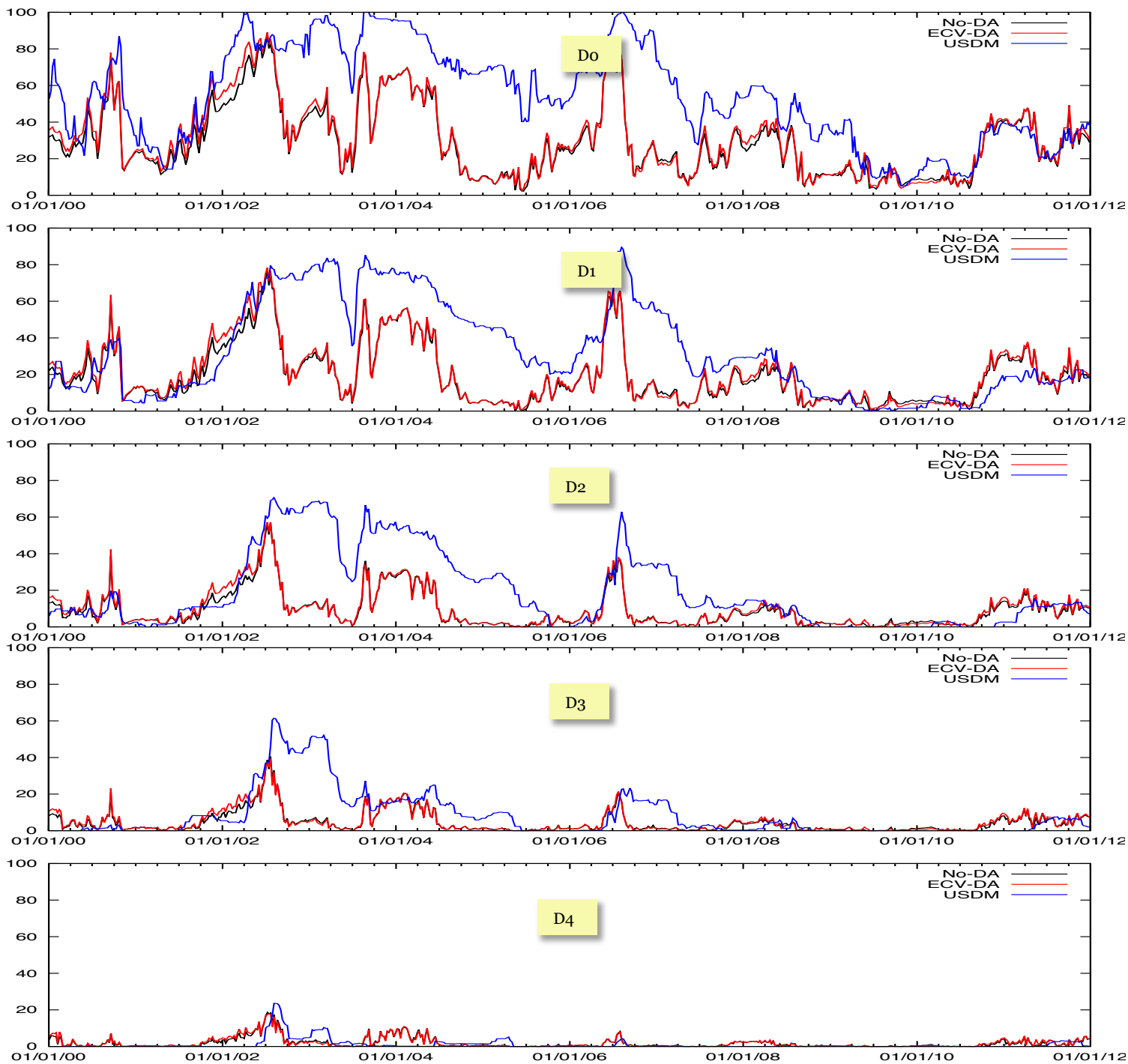
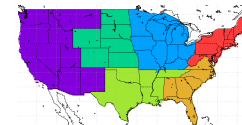
West



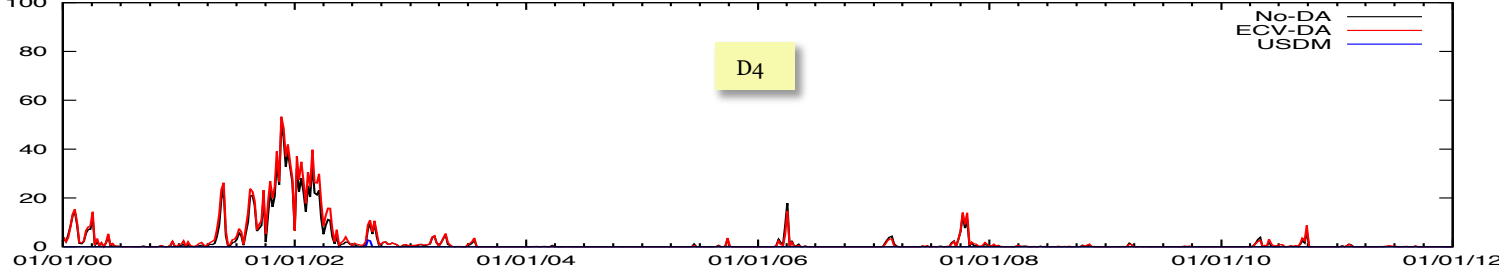
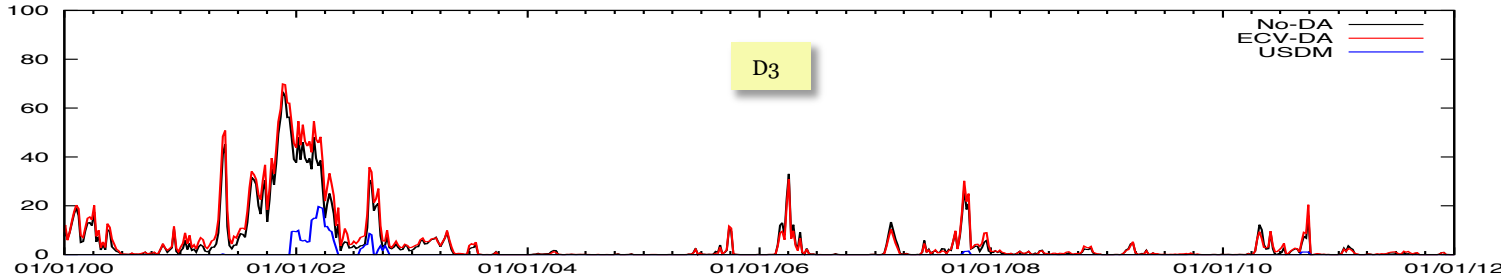
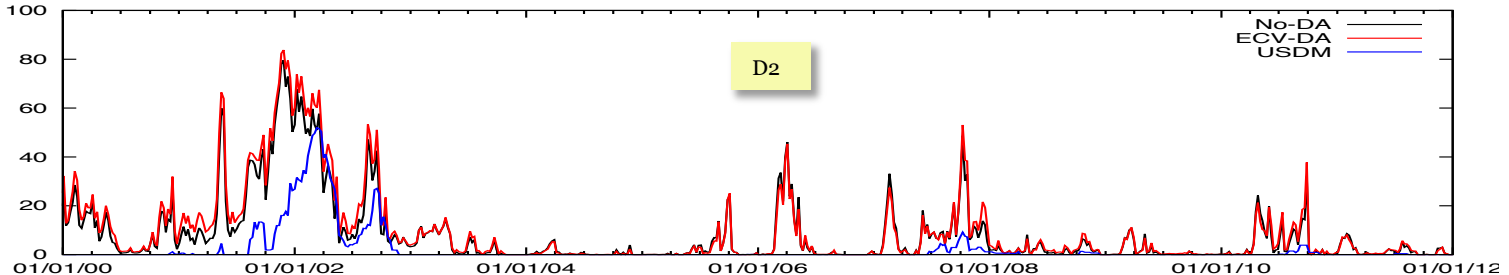
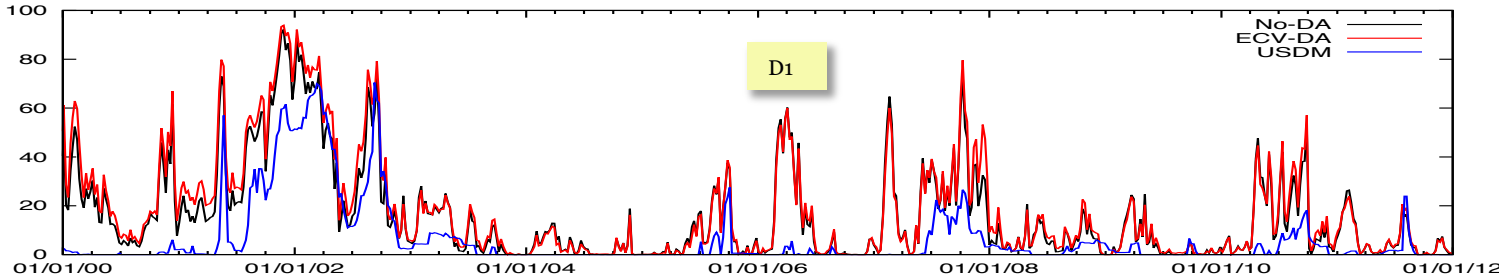
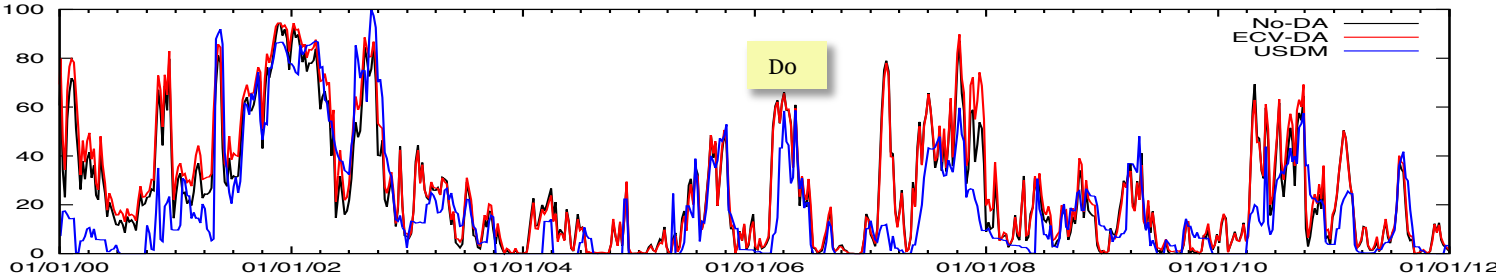
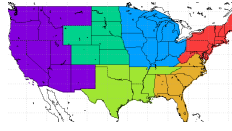
Midwest



Highplains



Northeast



Snow Data Assimilation

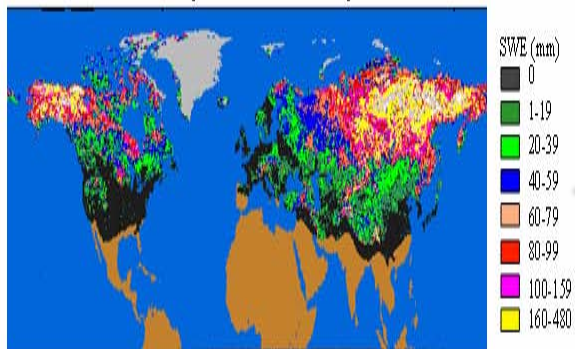
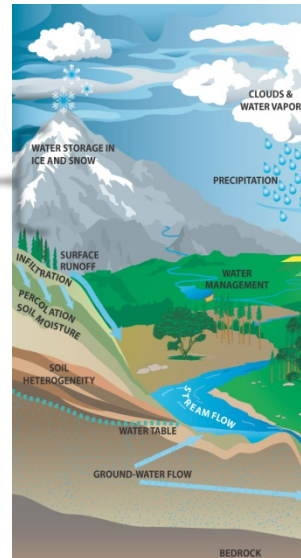


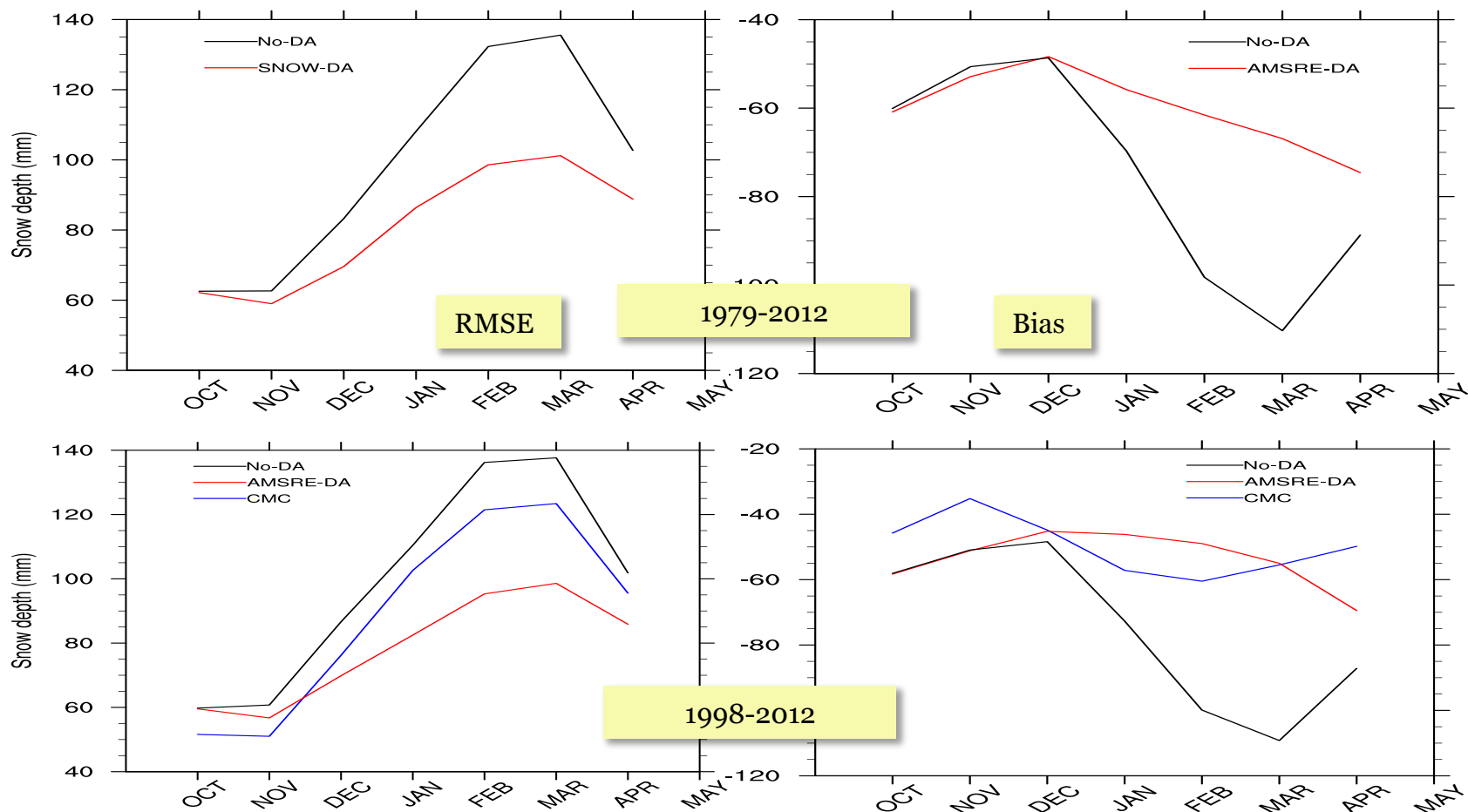
Figure 1: Snow water equivalent (SWE) based on Terra/MODIS and Aqua/AMSR-E. Future observations will be provided by JPSS/VIIRS and DWSS/MIS.



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

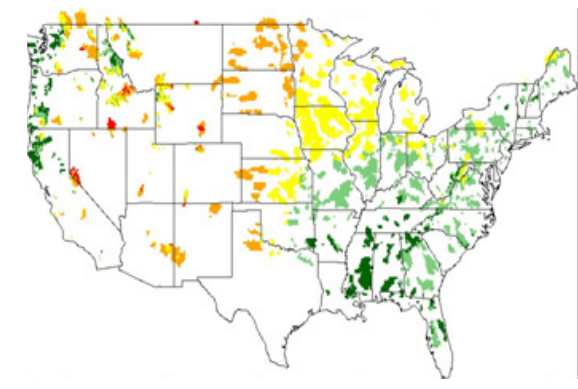
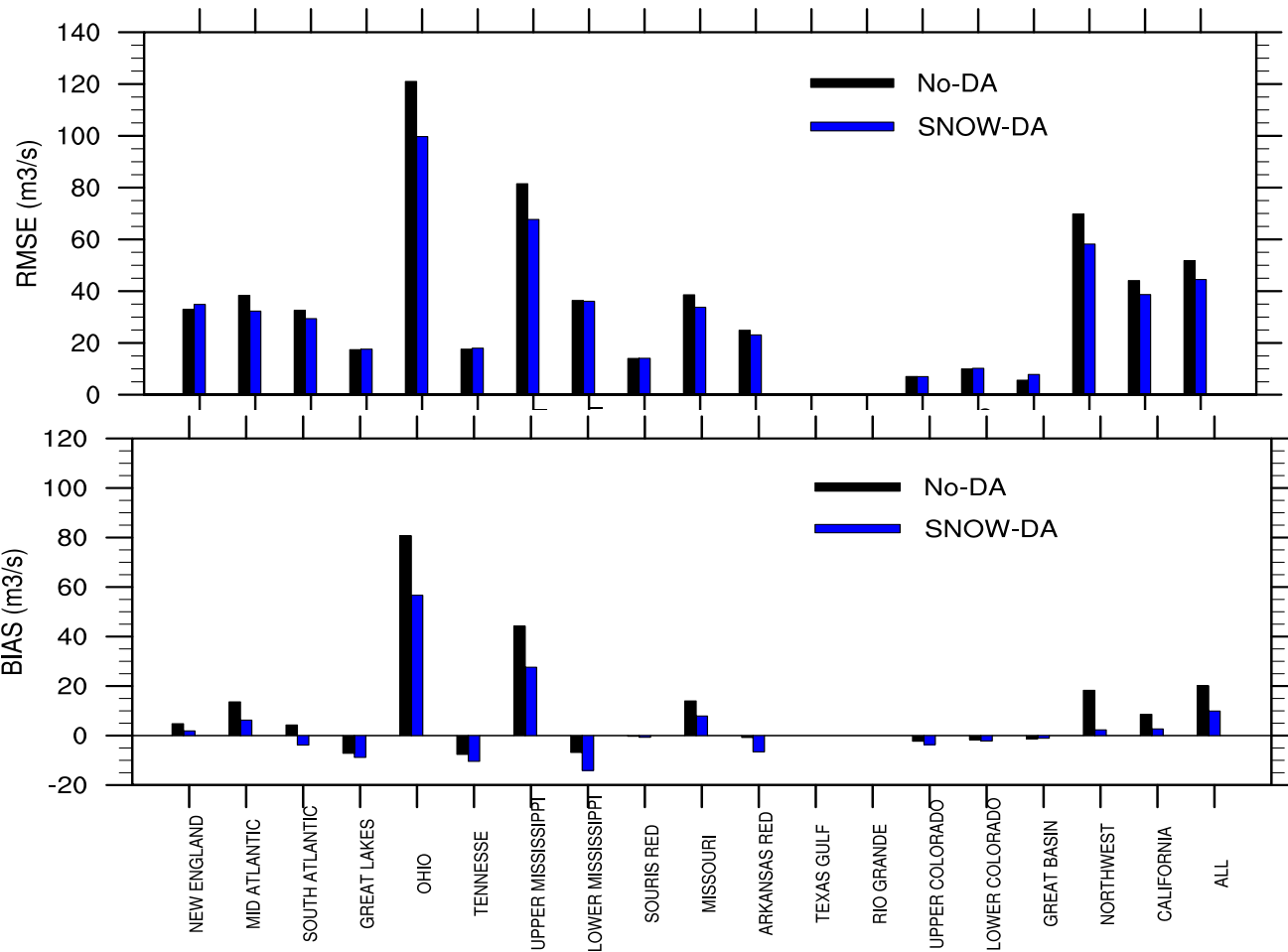


Snow depth (GHCN)	No-DA	SNOW-DA	CMC
RMSE (mm)	151.0 +/- 5.0	114.0 +/- 5.0	135.0 +/- 5.0
Bias (mm)	-80.0 +/- 5.0	-48.9 +/- 5.0	-53.2 +/- 5.0

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.

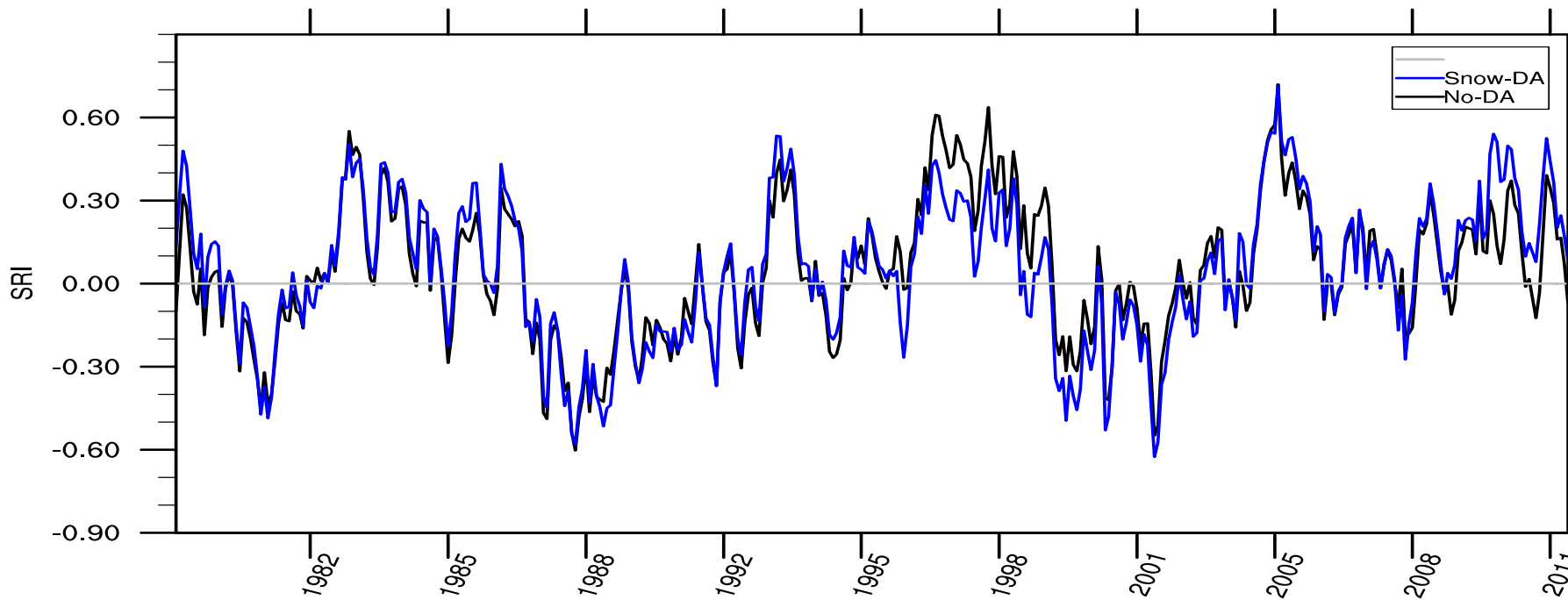
Snow DA (SMMR+SSM/I+AMSR-E): Evaluation of streamflow over 961 small basins (grouped by USGS hydrologic units)



Streamflow (USGS)	Open loop (no DA)	SNOW-DA
RMSE (m ³ /s)	51.8 +/- 1.0	44.5 +/- 1.0
Bias (m ³ /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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