Application of the National Water Model for Drought Monitoring

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Applying the National Water Model for Drought Monitoring

NOAA's National Water Model (**NWM**) offers fine spatial and temporal analyses and predictions of hydrologic variables relevant to drought monitoring and forecasts. The NWM is still under development as new versions are being released. We present results exploring the potential for NWM soil moisture (**SM**) and streamflow nowcasts to inform drought monitoring.

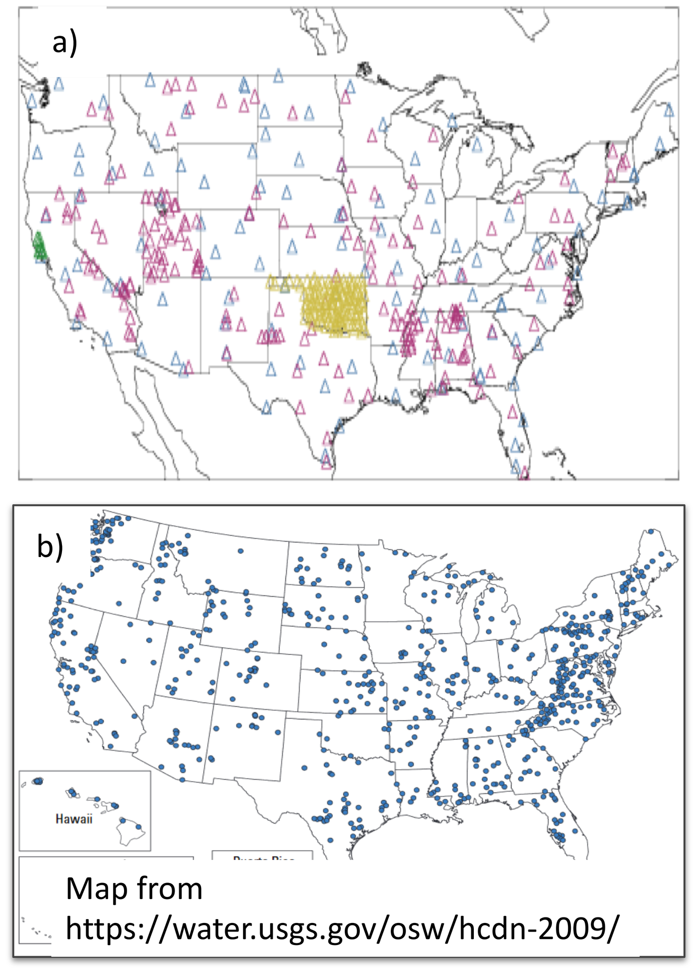

Figure 1: Locations of in situ (a) soil moisture sensors and (b) streamflow gauges.

Data used

We evaluate the NWM's potential for drought monitoring through comparison of a 26-year retrospective NWM version 2.0 simulation with in situ observations. NWM SM is compared against in situ SM sensors from two national networks (Figure 1a, and Table 1), and NWM streamflow is compared against streamflow from the USGS Hydro-Climatic Data Network (**HCDN**) gauge network (Figure 1b; HCDN-2009). NWM SM is further compared to that of other land surface models from the North American Land Data Assimilation System, version 2 (**NLDAS2**) , which serve as an appropriate benchmark for performance since they are currently used to inform the US Drought Monitor (**USDM**).

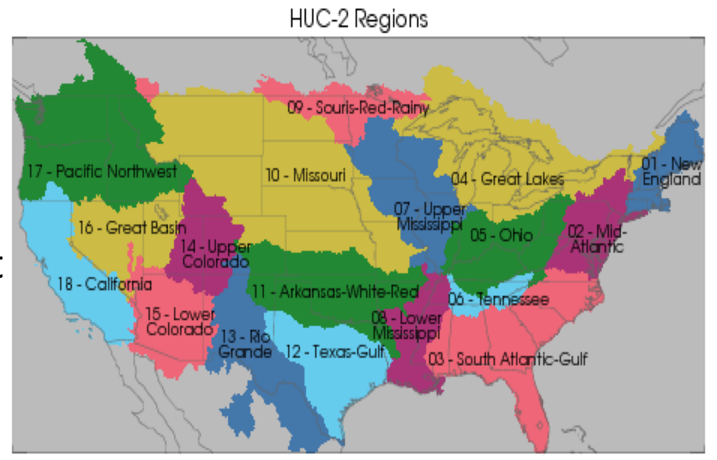

Figure 2: Boundaries and names of of 2-digit HUCs.

SM data aggregation to 2-digit HUCs

Point measurements of SM are not always representative of a large area. For this reason, in addition to showing statistics at point locations, we also aggregate model statistics across 2-digit Hydrologic Unit Code (**HUC**) regions (Figure 2). Most HUCs contain more than 10 stations.

Dataset	Grid spacing	Soil layer depths	Temporal availability
NWM	1 km SM, 250 m routing	1-10, 10-40, 40-100, 100-200	1993-2018
NLDAS2-Noah	1/8 degree	1-10, 10-40, 40-100, 100-200	1979-present
NLDAS2-VIC	1/8 degree	1-10, others vary across CONUS	1979-present
NLDAS2-Mosaic	1/8 degree	1-10, 10-40, 40-100, 100-200	1979-present
NLDAS2-SAC	1/8 degree	Conceptual upper/lower layer; rescaled to Noah layers as in Xia et al. 2015	1979-present
SCAN	N/A (point data)	5, 10, 20, 50, and 100 cm	Variable (2000 on)
USCRN	N/A (point data)	5, 10, 20, 50, and 100 cm	Variable (~2010 on)
USDM	Built from data at varying grid spacings.	Typically representative of root zone (~0-40 cm) or total column (~0-200 cm) SM.	1999-present (weekly)
USGS HCDN	N/A (point data)	N/A	Varies; many at least 1950-present

Table 1: Datasets used in this study, and their resolution and vertical levels

Drought-relevant skill scores

We use a contingency table metric, the Critical Success Index (**CSI**), to assess how well the NWM captures the occurrence of anomalously low SM and streamflow values. Daily SM and streamflow values are compared against daily percentiles calculated from the period of overlap with observations, which varies for the SM stations but covers the full 26-year period for the streamflow gauges. The percentile thresholds (30th, 20th, 10th, 5th, 2nd) align with the thresholds used to delineate various levels of drought by the USDM.

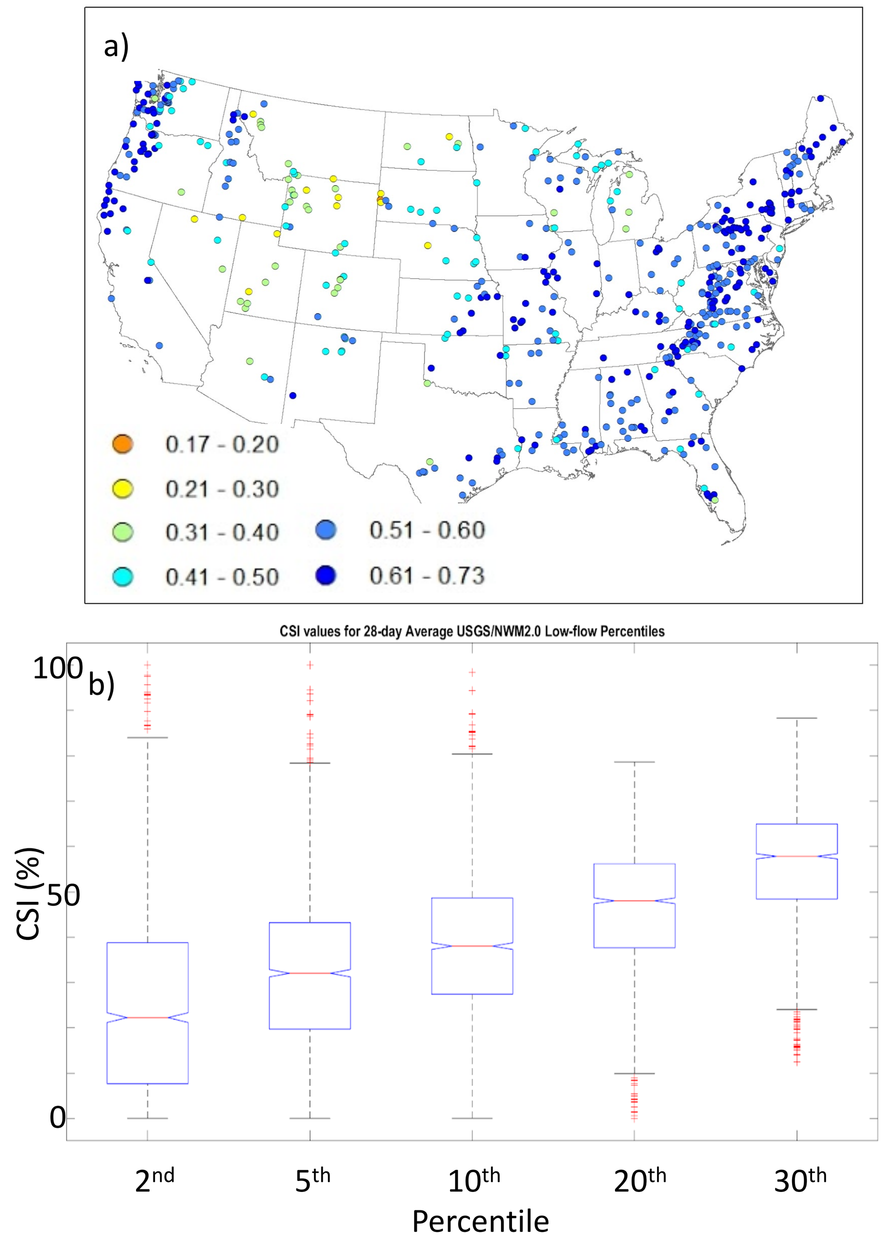

Figure 4: CSI for streamflow below (a) the 30th percentile at gauges (%/100) and (b) aggregated across CONUS, where bars (whiskers) show mean (standard deviation) of CSI for different percentiles.

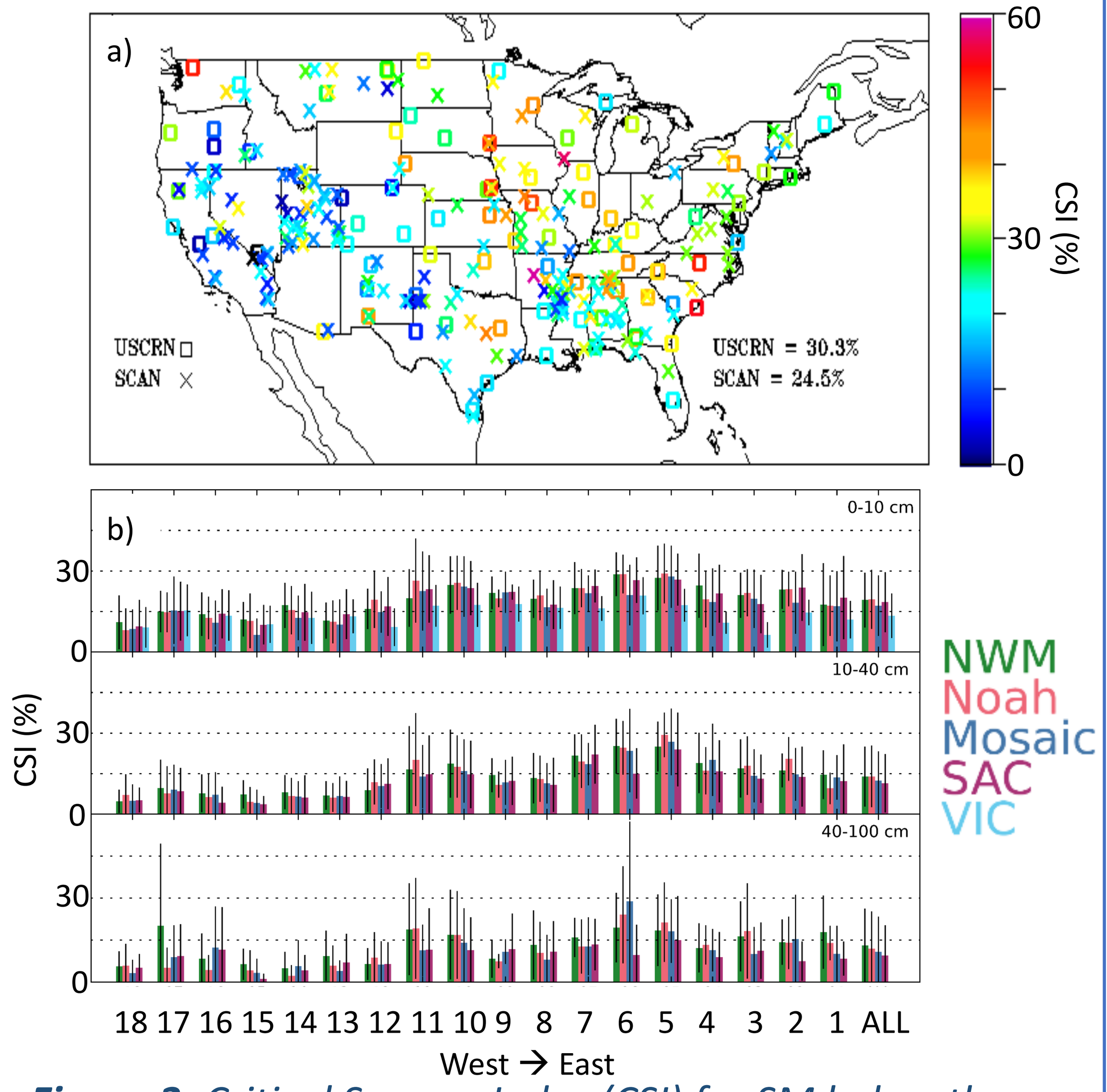

Figure 3: Critical Success Index (CSI) for SM below the 20th percentile in (a) 10-40 cm layer at stations and (b) aggregated across the 2-digit HUCs, where bars (whiskers) show mean (standard deviation) of CSI.

NWM SM CSIs for the 20th percentile (corresponding to Moderate Drought, D1, in the USDM) vary widely from station to station (Figure 3), with values between 40 and 60% across much of the central and midwestern states, and much lower values (<20%) in the desert southwest. This pattern is also apparent when the scores are aggregated by HUCs, with the Ohio and Tennessee HUCs (5 and 6) having the highest scores, and lowest scores in California (18); CSIs decrease in the deeper soil layers. The NWM's CSIs are in general statistically indistinguishable from the NLDAS models' scores.

NWM streamflow CSIs for the 30th percentile (abnormally dry conditions) are generally between 50 and 70% for most locations along the eastern seaboard and Pacific Northwest, with lower values in the northern central US and western interior states (Figure 4). CSIs decrease for more extreme thresholds. Although the maps show values for different thresholds, in general CSIs for streamflow are somewhat higher than CSIs for SM, and the locations with the best performance varies a bit by variable.

Historical Droughts in the NWM

Another relevant question is whether and how well economically significant historical droughts are represented by the NWM. Comparison of time spent in each SM percentile and drought category across the US (Figure 5) reveals many historical periods where the NWM indicates significantly drier than normal soils, consistent with SCAN SM sensors and the USDM; we note that the USDM incorporates information from sources other than SM through human input and thus we would not expect perfect agreement. Both the 2011 Texas drought and 2012 Great Plains drought show increases in the drought categories, and maps of the NWM SM during these times paint a heterogeneous picture of drought severity.

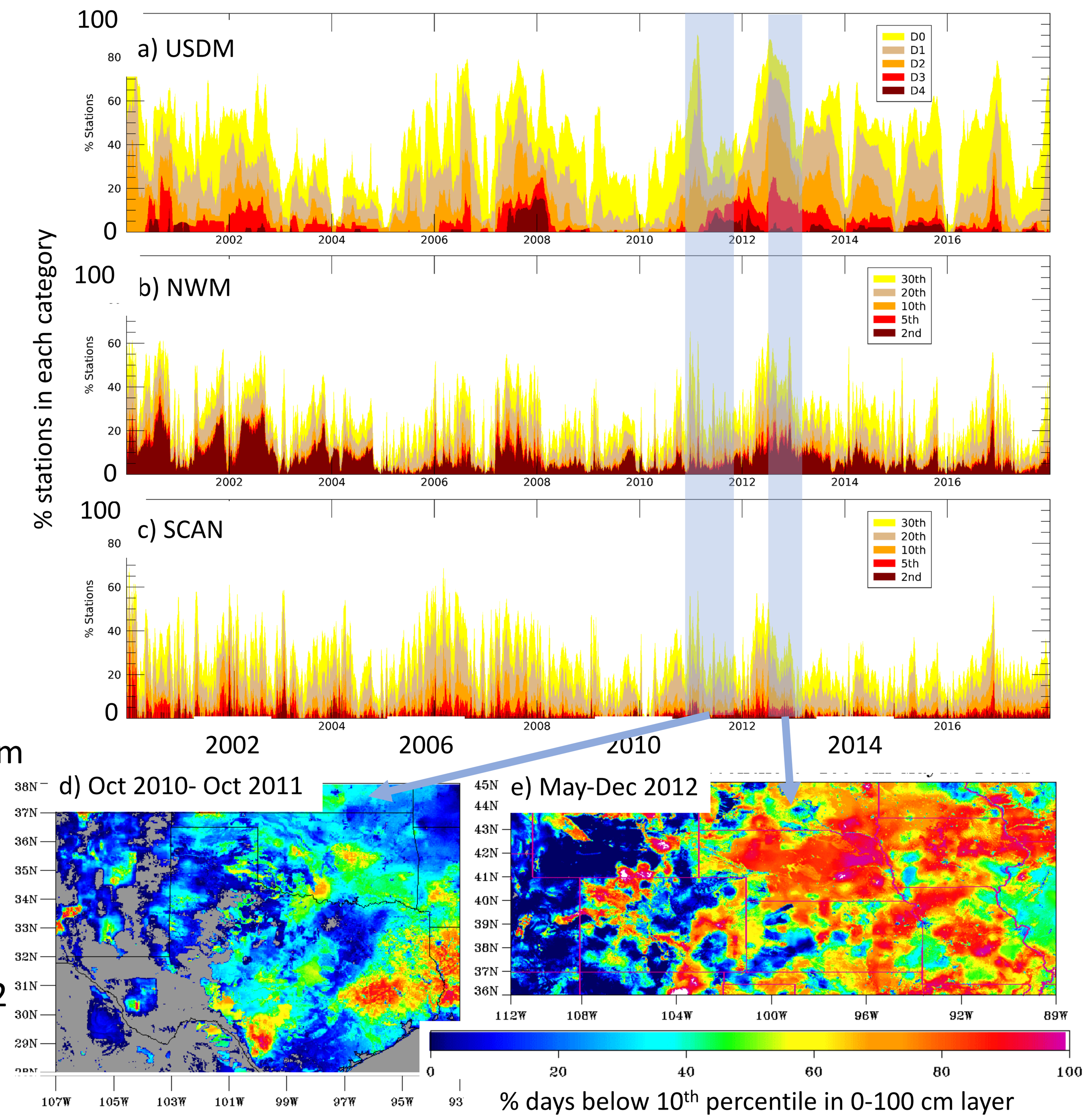

Figure 5: Time series of the percent of stations (or gridpoints nearest stations) in each category in a) USDM, b) NWM, and c) SCAN. Percentage 0-100 cm SM is below its 10th percentile for d) 2011 Texas drought and e) 2012 Great Plains drought.

Key Takeaway Messages

- NWM soil moisture and streamflow are being evaluated as products to potentially inform the US drought monitor, including targeted drought-specific evaluation.
- Our results so far indicate the NWM tends to agree most closely with NLDAS2-Noah in SM percentiles: This agreement is not surprising given NWM using Noah-MP (i.e., the Noah model with additional/improved physics options e.g. multi-layer snow) as its land surface model.
- The NWM SM has two potential advantages over NLDAS2 for drought monitoring: decreased latency and high resolution.
- Prototype streamflow products show promise in some parts of the country. Largest benefit will be in underserved (ungauged) locations.

References

HCDN-2009: *Lins, H.F., 2012, USGS Hydro-Climatic Data Network 2009 (HCDN–2009): U.S. Geological Survey Fact Sheet 2012–3047, 4 p., available only at https://pubs.usgs.gov/fs/2012/3047/.*

USDM: *The U.S. Drought Monitor is jointly produced by the National Drought Mitigation Center at the University of Nebraska-Lincoln, the United States Department of Agriculture, and the National Oceanic and Atmospheric Administration. Map courtesy of NDMC.*

Xia et al. 2015*: Xia, Y., M. B. Ek, Y. Wu, T. Ford, and S. M. Quiring, 2015: Comparison of NLDAS-2 Simulated and NASMD Observed Daily Soil Moisture. Part I: Comparison and Analysis. J. Hydrometeor., 16, 1962–1980, https://doi.org/10.1175/JHM-D-14-0096.1.*