Application of the National Water Model (NWM) for Drought Monitoring: An Overview of CPC Activities

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https://water.noaa.gov/about/nwm
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- produced real-time analysis (06/2019-present) and a 26-year (1993-2018) retrospective simulation for v2.0, which allows for drought monitoring
  - Streamflow, surface runoff, soil moisture, evaporation, snow, and other parameters.
An NWM Project

• Project
  • Application of the National Water Model for Drought Monitoring (09/2017-08/2020)

• Team
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• Key results
  • Evaluated the NWM v1.2 and 2.0 retrospective simulations using in-situ observations
    • Soil moisture:
      • Positively biased at most CONUS locations
      • Variability and <=10th percentile events: comparable to the NLDAS-2 model suite
    • Streamflow:
      • Wet biased across much of the CONUS
      • Low-flow streamflow (<=10th percentile): acceptable performance in Pacific Northwest and southeast US

Hughes et al. 2020 (in prep)
1) Its retrospective period (1993-2018) is relatively short
   - will be remedied in v2.1, which starts from 1979 for the retrospective simulation

2) It uses different precipitation forcings for the retrospective and real-time periods
   - Retrospective: NLDAS-2
   - Real-time: HRRR/RAP/MRMS/MPE

*Hughes et al. 2020 (in prep)*
1. Evaluated the NWM v2.0 retrospective simulation using the USDJ
2. Studied an outstanding issue of the NWM v2.0 for drought monitoring
   - Precipitation mismatch between the retrospective and real-time analysis
1. Evaluated the NWM v2.0 retrospective simulation using the USDM
   • Processed the NWM v2.0 data (1993-2018) by interpolating the native model data (3-hourly, 1km) to daily means at NLDAS-2’s lat-lon grid
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   • Processed the NWM v2.0 data (1993-2018) by interpolating the native model data (3-hourly, 1km) to daily means at NLDAS-2’s lat-lon grid
   • Evaluated the NWM soil moisture using contingency table based metrics
     • NWM soil moisture percentiles are converted to D0-D4 in order to compare with the USDM
     • Focus on their common period: 2000-2018
1.1 An Evaluation of the NWM using the USDM: *Evaluation*

**Frequency of drought occurrence (D0-D4)**

**USDM:** considerably more frequent drought occurrence in the western (W) US and southeastern (SE) US.
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**NWM**
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**False Alarm Ratio (FAR)**: low FAR in the W US and SE US, high FAR in the Midwest, northeastern US and Pacific northwest
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**Q**: Can we attribute these differences to the NWM deficiencies?  
**A**: No, we cannot.
1.2 An Evaluation of the NWM using the USDM: Caveats

We need to use caution when using the USDM to evaluate land surface models (LSMs), because it is not a fair apple-to-apple comparison:

1. They use different base periods to quantify drought anomalies.
   - The USDM uses century-long data and captures both short-term and long-term droughts, whereas LSMs are subject to the length of their available simulations.

2. The USDM integrates a multitude of drought indices, whereas LSMs usually use a single variable (e.g. soil moisture) to indicate drought conditions.

*<50% detection rate in the western US and southeastern US*
The VIC_LIVNEH simulation (1915-2011, Livneh et al. 2013) is used to help interpret the NWM vs. USDM differences, while keeping in mind that it uses a different LSM from the NWM:

1. When a century-long base period is used, the VIC_LIVNEH captures long-term droughts in the W US and SE US.

2. With a century-long base period, the VIC_LIVNEH still considerably differs from the USDM, in part due to the differences in the drought indicators they use.
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Frequency of drought occurrence (D0-D4)

USDM decomposition into short-term and long-term drought components
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Frequency of drought occurrence (D0-D4)

USDM

NWM

USDM (short-term)

USDM (long-term)

USDM decomposition into short-term and long-term drought components

short-term drought (<6 mons)

long-term drought (>6 mons)
1.3 An Evaluation of the NWM using the USDM

An approach to remedy the USDM vs. NWM inconsistency

A key reason for the USDM vs. NWM inconsistency:

- long-term droughts are insufficiently captured in the NWM because of its relatively short duration
1.3 An Evaluation of the NWM using the USDM
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Integrate the NWM with the USDM long-term drought component using their joint probability (Hao and AghaKouchak 2014) to produce a preliminary merged NWM product.
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How well does the merged product do?

NWM vs. USDM

<50% detection rate in the western US and southeastern US
1.3 An Evaluation of the NWM using the USDM

An approach to remedy the USDM vs. NWM inconsistency

Merging the USDM long-term drought component with the NWM:
- substantially improves drought detection rate
- reduces false alarm ratio.

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2. An Outstanding Issue of the NWM v2.0

Retrospective vs. real-time P forcing inconsistency

NWM analysis vs. NLDAS-2 precipitation comparison (06/20/2019-06/19/2020):

- NWM is noticeably wetter than NLDAS-2 across much of the CONUS (7.1%).
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Retrospective vs. real-time P forcing inconsistency

NLDAS-2

NWM

\[
\frac{(\text{NWM} - \text{NLDAS-2})}{\text{NLDAS-2}} \times 100(\%)
\]

7.1%

HUC2 mask (Darren Jackson, NOAA/PSL)
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- Such NWM underestimation is due to a typical caveat of using the USDM to evaluate land surface models (LSMs), and thus cannot be attributed to the NWM deficiencies alone.
  - The USDM uses a century-long base period to estimate drought anomalies and thus captures both short-term and long-term droughts, whereas LSMs are subject to the length of their simulations.
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   - The USDM vs. NWM inconsistency can be remedied by merging the NWM with the USDM long-term drought component.
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- The NWM v2.0 uses different precipitation \((P)\) forcings for its retrospective simulation and real-time analysis, which impacts its quantification of real-time drought anomalies.

  - The \(P\) differences vary with region, season and weather event, with the NWM analysis being \(~7.1\%\) wetter than NLDAS-2 for the annual mean in the CONUS.
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Looking Forward

Future NWM versions are expected to have continued improvements in drought monitoring capability

- Longer retrospective simulation (e.g. v2.1 starts from 1979)
- Upgrades in forcings and model physics
- Domain expansion