8.2 THE FLOATING MONTH DROUGHT INDEX – A NEW DROUGHT MONITORING TOOL

Richard R. Heim Jr.*
NOAA National Climatic Data Center, Asheville, North Carolina

ABSTRACT

Dozens of drought indices have been developed over the 20th century which measure specific aspects of drought (from water supply and water demand to impacts) or have specific applications. In some cases, these indicators may yield inconsistent or conflicting results. A new drought index (the Floating Month Drought Index, or FMDI) was developed to address these inconsistencies. The FMDI initiates a drought based on unusually dry conditions (≤ 30th percentile) over 3 consecutive months. The dry spell ends when the total precipitation for the spell period no longer falls below the dry threshold, or the precipitation for the past 3 months was unusually wet (≥ 70th percentile). The FMDI computes the precipitation percentile for the current month and current N-month dry spell, the length and starting year/month of the current dry spell, and the Dx dry spell category based on USDM categories (and similar statistics for wet spells). The FMDI thus provides an objective decision-support tool for integrating the multiple time scales of drought.

1. Introduction – Why an FMDI?

Drought is a recurring phenomenon that has plagued civilization throughout history. Its nature makes drought a difficult phenomenon to define and measure. Consequently, drought indices evolved during the 20th century from simple precipitation-based indices to more complex water balance models which assessed the total moisture status. At the end of the century, the U.S. Drought Monitor (USDM) was developed to incorporate the various existing drought indicators, drought impacts information, and input from local field experts. A set of objective blends was created to integrate appropriately-scaled indices which assessed short-term and long-term moisture conditions. However, even with this comprehensive suite of drought monitoring tools, drought assessment still is sometimes difficult. In some cases, these indicators may yield inconsistent or conflicting results. For example, hydrological indicators may show wet conditions while agricultural indices reflect drought conditions. Or, as another example, the long-term objective blend may indicate drought conditions in an area (resulting from dryness spanning potentially a six- to 60-month period) while the short-term objective blend indicates wet conditions (resulting from unusually heavy precipitation over a period spanning potentially one to six months), or vice versa. In cases like this, how does one determine if unusual short-term wetness is sufficient to end long-term drought (or vice versa)?

The Floating Month Drought Index (FMDI) integrates moisture conditions over time to provide an answer to this type of question. It was developed as a new tool to be added to the suite of existing drought indicators, not to replace any of them. The FMDI was inspired by, and has adopted elements of, the U.S. Drought Monitor (USDM) (Svoboda et al., 2002), U.S. objective blends, and Australian drought index (BOM, 2009; Foley, 1957; Gibbs and Maher, 1967).

* *Corresponding author address:* Richard Heim, NOAA National Climatic Data Center, 151 Patton Avenue, Asheville, NC 28801; e-mail: Richard.Heim@noaa.gov.

2. Data and Methodology – How is the FMDI Computed?

The FMDI is computed monthly and is based on precipitation percentiles. It has a near-real time component and a back-stepping component (similar to the Palmer Index [Palmer, 1965]), and it requires serially complete data. It provides:

- the precipitation percentile for the current month
- the length (number of consecutive months, N) and begin year/month of current dry spell
- the precipitation percentile for the current N-month dry spell
- the Dx dry spell category (based on USDM Dx categories) for the current month (see Figure 1)
- the length (number of consecutive months) and begin year/month of the current wet spell
- the precipitation percentile for the current N-month wet spell
- the Wx wet spell category (based on a wet analog to the USDM Dx categories) (see Figure 2).

In this analysis, the FMDI was computed for climate division data covering the period 1895-2009, but it could be computed for any data set which is serially complete and covers a sufficiently long period to enable computation of precipitation percentiles.

2.1 Dry Spell

A dry spell begins when three consecutive months each have precipitation ≤ 30th percentile and the total precipitation for the three consecutive dry months falls beyond the cutoff (≤ 30 percentile).

The dry spell ends when: (a) the total precipitation for the months from the beginning anchor year-month to the current month no longer falls beyond the cutoff (≤

30th percentile), or (b) the precipitation for the past three months is extremely wet (3-month total precipitation ≥ 70th percentile).

2.2 Wet Spell

A wet spell begins when three consecutive months each have precipitation ≥ 70th percentile and the total precipitation for the three consecutive wet months falls beyond the cutoff (≥ 70 percentile).

The wet spell ends when: (a) the total precipitation for the months from the beginning anchor year-month to the current month no longer falls beyond the cutoff (≥ 70th percentile), or (b) the precipitation for the past three months is extremely dry (3-month total precipitation ≤ 30th percentile).

Figure 1. Dry spell percentiles and corresponding USDM categories: D0 = Abnormally Dry, D1 = Moderate Drought, D2 = Severe Drought, D3 = Extreme Drought, D4 = Exceptional Drought.

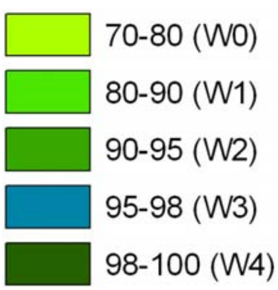

Figure 2. Wet spell percentiles and corresponding categories: W0 = Abnormally Wet, W1 = Moderate Wet Spell, W2 = Severe Wet Spell, W3 = Extreme Wet Spell, W4 = Exceptional Wet Spell.

2.3 Modification for Exceptionally Dry Seasons

If there is no seasonality in precipitation, then (for every month) the monthly normal precipitation = 1/12 of the annual normal:

$$P_{norm}(\text{month}) = 1/12 * P_{norm}(\text{annual}) \quad (1)$$

If a month is normally very dry, then it should not be counted as a drought or wet spell trigger. The solution is to find a threshold X such that:

$$P_{norm}(\text{month}) < X * 1/12 * P_{norm}(\text{annual}) \quad (2)$$

The FMDI was computed for the 344 climate divisions in the contiguous United States for every month from January 1895 through July 2009 using six different threshold values for X (no threshold [X=0], 10%, 30%, 50%, 70%, 90%). These FMDI values were correlated over the January 1931-July 2009 period (January 2000-July 2009 for the USDM) against several drought indices (four Palmer indices [PMDI, PHDI, PDSI, Z Index], the Standardized Precipitation Index [SPI] at seven time scales [1-, 2-, 3-, 6-, 9-, 12-, 24-months], and the USDM with the Dx categories converted to a percentile equivalent). The results are shown in Table 1. The Z Index and 1-month through 3-month SPI should be excluded from consideration for determination of the X threshold due to the FMDI trigger methodology. The threshold having the highest correlations for most of the remaining indices is X = 30%.

INDEX	No Threshold (0) 1/1931-7/2009	Threshold 10% 1/1931-7/2009	Threshold 30% 1/1931-7/2009	Threshold 50% 1/1931-7/2009	Threshold 70% 1/1931-7/2009	Threshold 90% 1/1931-7/2009
PMDI	0.713	0.713	0.717	0.708	0.684	0.615
PHDI	0.658	0.659	0.665	0.662	0.646	0.592
PDSI	0.688	0.688	0.690	0.679	0.655	0.588
Z Index	0.619	0.618	0.612	0.598	0.573	0.505
SPI – 1	0.555	0.554	0.542	0.519	0.492	0.426
SPI – 2	0.651	0.649	0.635	0.607	0.572	0.487
SPI – 3	0.759	0.758	0.741	0.706	0.663	0.558
SPI – 6	0.715	0.715	0.712	0.696	0.667	0.579
SPI – 9	0.659	0.660	0.665	0.664	0.651	0.591
SPI – 12	0.607	0.608	0.617	0.623	0.618	0.578
SPI – 24	0.464	0.465	0.477	0.490	0.497	0.499
USDM	0.520*	0.520*	0.519*	0.516*	0.505*	0.478*

Table 1. Correlations of the FMDI with other drought indices, for all months and all climate divisions, for several values of the multiplication factor X (X=0, 0.1, 0.3, 0.5, 0.7, 0.9). *Correlations are for the period January 1931-July 2009, except January 2000-July 2009 for the USDM.

It should be noted that, for the Z Index and 1-month through 3-month SPI, the strongest correlations with the FMDI occur where there is no seasonality and the weakest correlations occur for a strong seasonal check (see Table 1). This is expected because the FMDI methodology requires strong precipitation departures at the one- to three-month time scales to trigger or end moisture spells. A strong seasonal check will exclude from the trigger process more months which occur during the dry season.

Figure 3 illustrates the difference in August 2009 FMDI index values for two values of the X threshold: X=0 (no seasonality, Figure 3a) and X=0.3 (Figure 3b). In areas where the precipitation climatology shows minimal change from month to month (typical of Köppen “f” type climates), the FMDI index values are identical. For areas with a pronounced seasonality in precipitation climatology (such as Köppen dry summer, or "s" type, climates of the west coast or Köppen dry winter, or "w" type, climates of the central Plains), the FMDI values can be different.

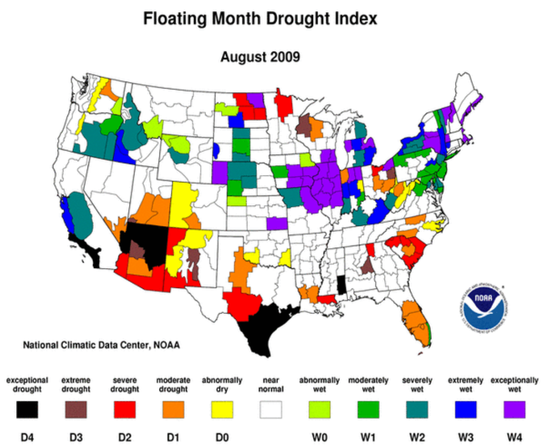

Figure 3a. FMDI for August 2009 computed using no seasonality (X=0).

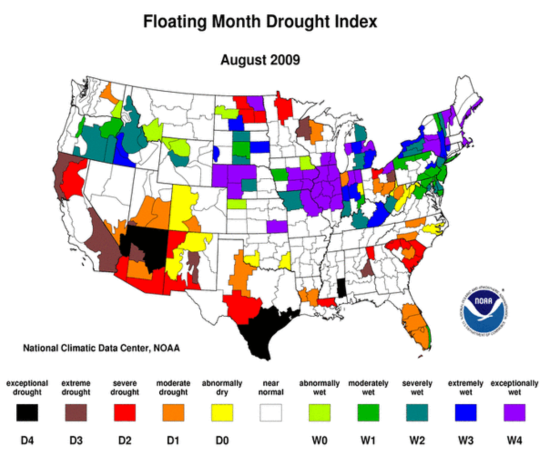

Figure 3b. FMDI for August 2009 computed using seasonality factor of X=0.3.

3. Applications

3.1 Use of the FMDI in Operational Drought Monitoring

The greatest strength of the FMDI lies in its ability to determine if short-term precipitation is sufficient to end a long-term dry spell. The USDM author is frequently confronted with the situation where an ongoing drought has lasted so long that longer-term indicators (such as the long-term objective blends and 60-month, 36-month, and/or 12-month SPI or precipitation anomalies) still show very dry conditions but shorter-term indicators (such as the short-term objective blends and 2- or 3-month SPI or precipitation anomalies) show very wet conditions. The author's decision, based on these data and other drought indicators, impacts information, and recommendations from local experts in the field, may involve some degree of subjective judgment. The FMDI provides an objective tool for this decision.

In the example shown in Figure 4, the August 29, 2009 long-term objective blend (Figure 4a) shows ongoing dry conditions over most of California, Oregon, and Washington, while the short-term objective blend (Figure 4b) shows wet conditions in eastern Oregon and near-normal conditions across most of California. Since the west coast has a dry summer precipitation climatology, wet anomalies during the summer should be given less weight than winter precipitation anomalies. The August 2009 FMDI (Figure 3b) indicates that the dry spell in much of California had not ended. The USDM author depicted continuing D0-D2 conditions across California on the September 1 USDM map (Figure 4c).

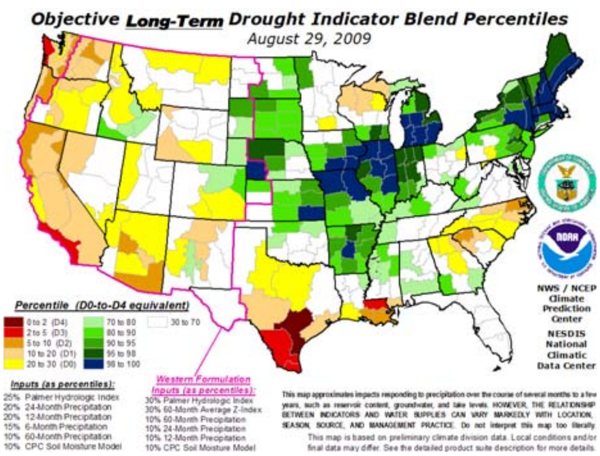

Figure 4a. U.S. long-term objective blend map for the week (August 29, 2009) corresponding to the end-of-August FMDI.

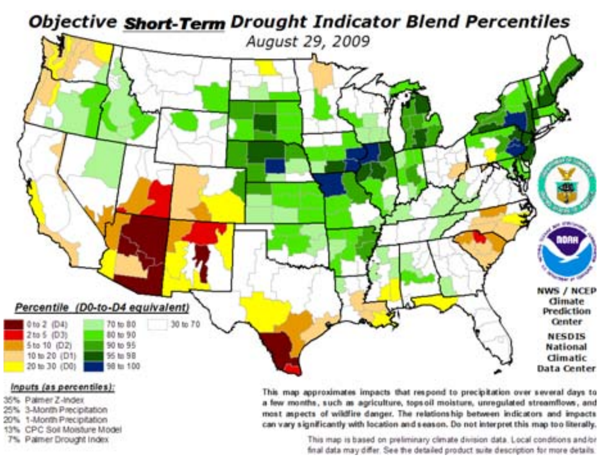

Figure 4b. U.S. short-term objective blend map for the week (August 29, 2009) corresponding to the end-of-August FMDI.

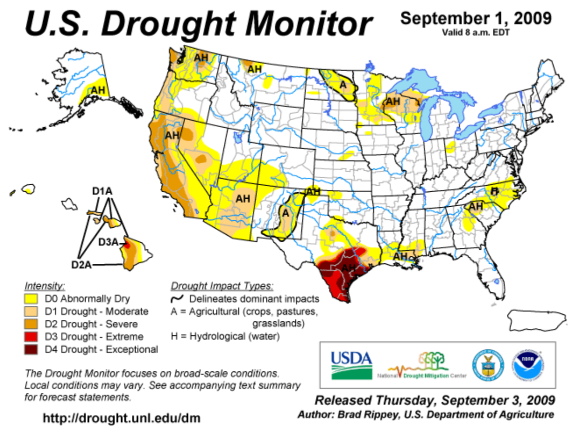

Figure 4c. U.S. Drought Monitor (USDM) map for September 1, 2009 (the weekly map closest to the end of August 2009).

Figure 5 illustrates the duration component (Figure 5a) and corresponding intensity component (Figure 5b) of the FMDI for October 2009.

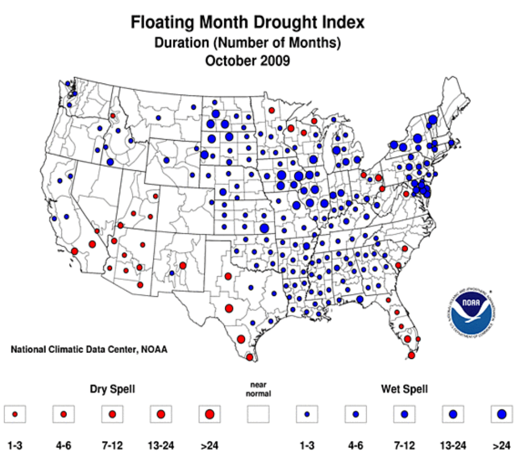

Figure 5a. Duration (number of months) of October 2009 FMDI dry spells (red circles) and wet spells (blue circles). The size of the circle is scaled to the duration.

3.2 Use of the FMDI for Historical Perspective of Local Drought Conditions

Like total precipitation, the SPI, the Palmer drought indices, and other indicators, time series of the FMDI can be computed for specific areas to show the historical variation of moisture anomalies over a specified period. Figure 6 compares the January 1900-August 2007 FMDI to the corresponding Palmer Drought Index (PMDI) for Middle Tennessee (climate division 3). The Palmer index graph shows smoother transitions from month to month because the FMDI plots percentile values ≥ 70 for months with a wet spell, ≤ 30 for months with a dry spell, and = 50 for months without a wet or dry spell.

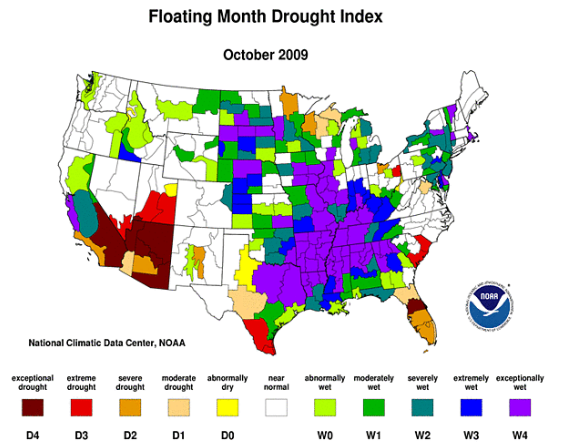

Figure 5b. Intensity of October 2009 FMDI dry spells and wet spells.

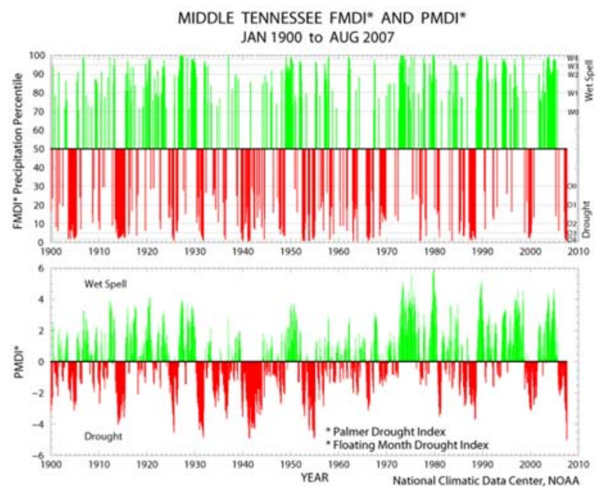

Figure 6. The FMDI and PMDI for Middle Tennessee for January 1900-August 2007.

3.3 Use of the FMDI for Historical Perspective of National Drought Conditions

The FMDI can be aggregated over large areas to provide regional or national temporal assessments of drought conditions. Figure 7 compares the percent area of the contiguous U.S., from January 1900 through October 2009, experiencing moderate to exceptional dry spells (Figure 7a) and moderate to exceptional wet spells (Figure 7b), based on the FMDI, to the same variables based on the PMDI (Figure 7c). Both indicators capture the prolonged and extensive drought episodes of the 1930s, 1950s, and early 2000s, as well as the national droughts of shorter durations. Similarly, both the FMDI and PMDI describe the extensive wet spells of the early 1900s, 1940s, early 190s, and late 1990s, as well as shorter duration national wet spells.

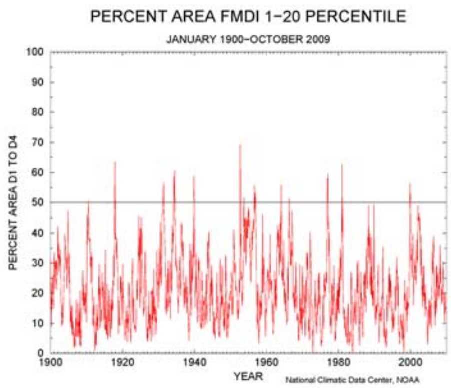

Figure 7a. Percent area of the contiguous U.S. experiencing moderate to exceptional dry spells (D1-D4), based on the FMDI, from January 1900-October 2009.

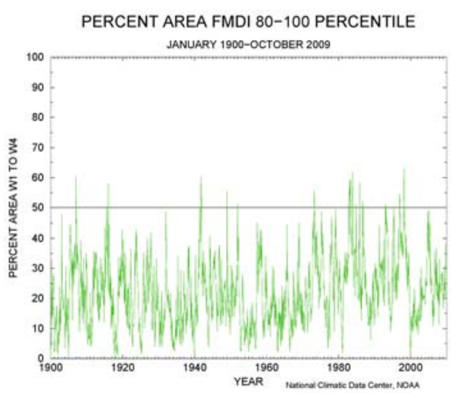

Figure 7b. Percent area of the contiguous U.S. experiencing moderate to exceptional wet spells (W1-W4), based on the FMDI, from January 1900-October 2009.

4. Summary and Conculsions

This paper has described the creation of a new drought index, the Floating Month Drought Index (FMDI), which expresses moisture supply (precipitation) in a percentile form compatible with the U.S. Drought Monitor (USDM) and U.S. objective blends. The FMDI provides an objective tool to assess drought (and wet spell) status when multiple other drought indicators provide inconsistent or conflicting results. In addition to intensity, the FMDI provides duration information for the dry and wet spells. It can be utilized to assess temporal variations in wet and dry conditions locally and for larger regions.

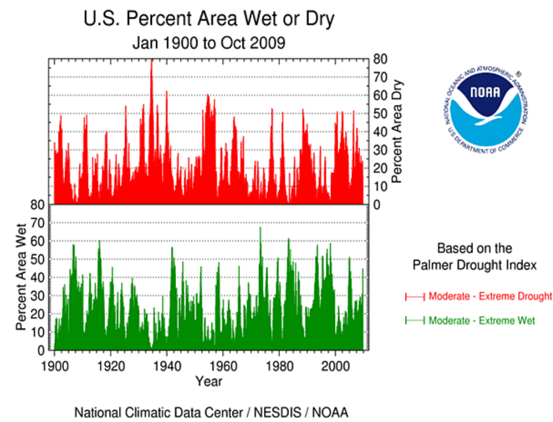

Figure 7c. Percent area of the contiguous U.S. experiencing moderate to exceptional drought and wet spells, based on the Palmer Drought Index, from January 1900-October 2009.

5. References

Commonwealth of Australia Bureau of Meteorology (BOM), 2009: Climate Glossary - Drought. http://www.bom.gov.au/climate/glossary/drought.shtml

Foley, J.C., 1957: Droughts in Australia: review of records from earliest years of settlement to 1955. Bureau of Meteorology, *Bulletin No. 43*, Commonwealth of Australia, Melbourne.

Gibbs, W.J. and J.V. Maher, 1967: Rainfall deciles as drought indicators. Bureau of Meteorology, *Bulletin No. 48*, Commonwealth of Australia, Melbourne.

Palmer, W.C., 1965: Meteorological drought. *Research Paper No. 45*. U.S. Weather Bureau. [NOAA Library and Information Services Division, Washington, D.C. 20852]

Svoboda, M., et al., 2002: The Drought Monitor. *Bulletin of the American Meteorological Society*, 83, 1181-1190.