Mixing Up a Drought Indicator Cocktail, Blended, not Stirred: A Combined Drought Indicator Approach

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USDM Forum
Keystone/Rapid City, SD, April 3-5, 2017

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Types of Drought

- **Meteorological**
- **Environmental/Ecological**
- **Agricultural**
- **Hydrological**
- **Socioeconomic**

- There are ***indices and indicators*** used to identify *all* of these types of drought at various thresholds
- There is ***no single definition*** of drought
- Thus, in most cases, there is ***no "one-size-fits-all"*** drought indicator or index

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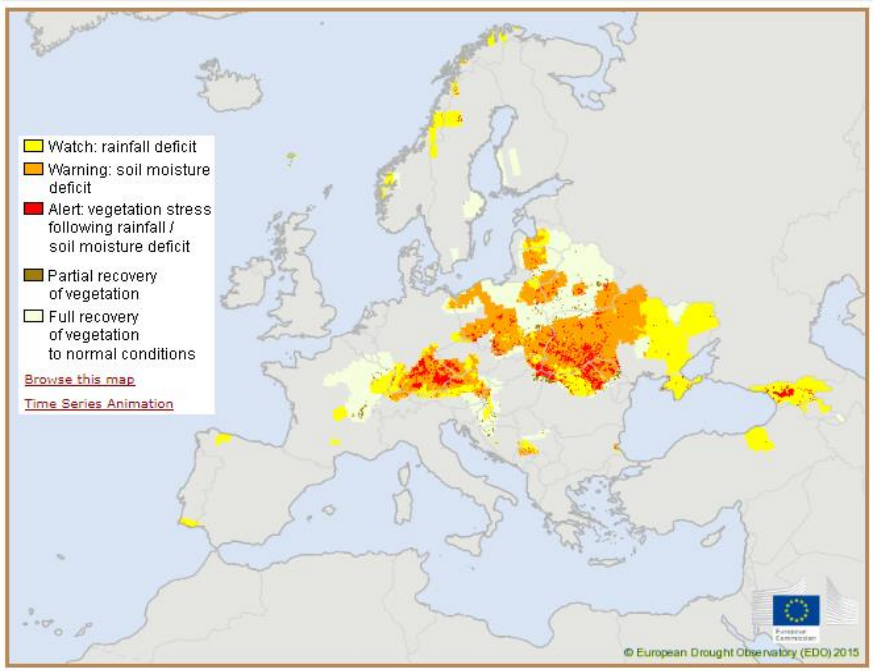
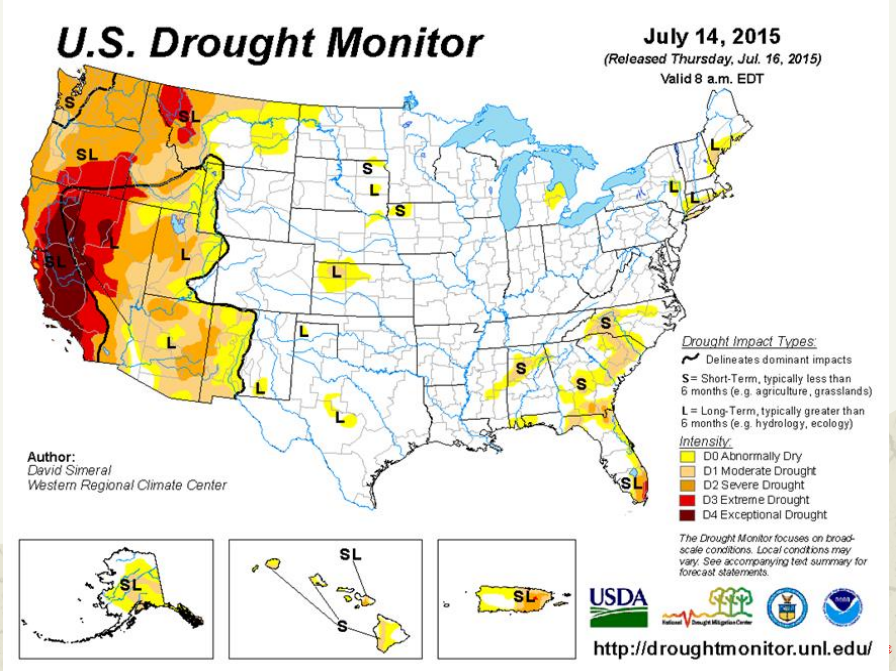
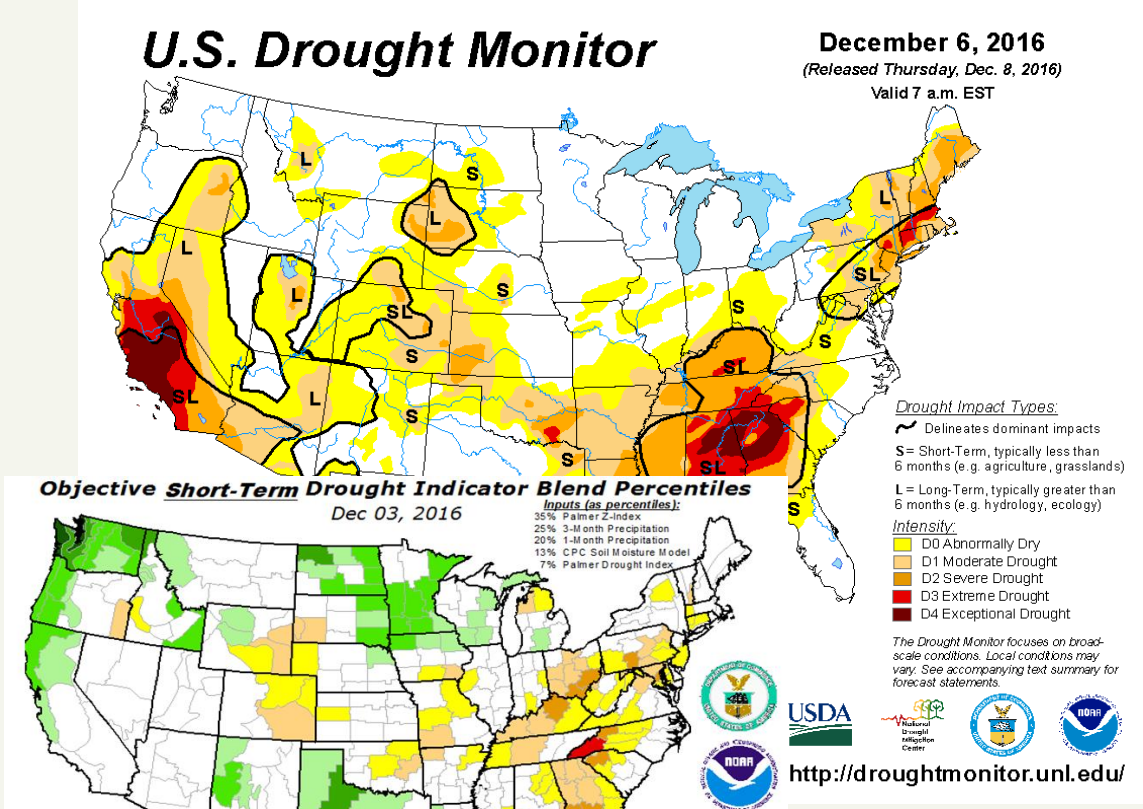
Approaches to Drought Assessment

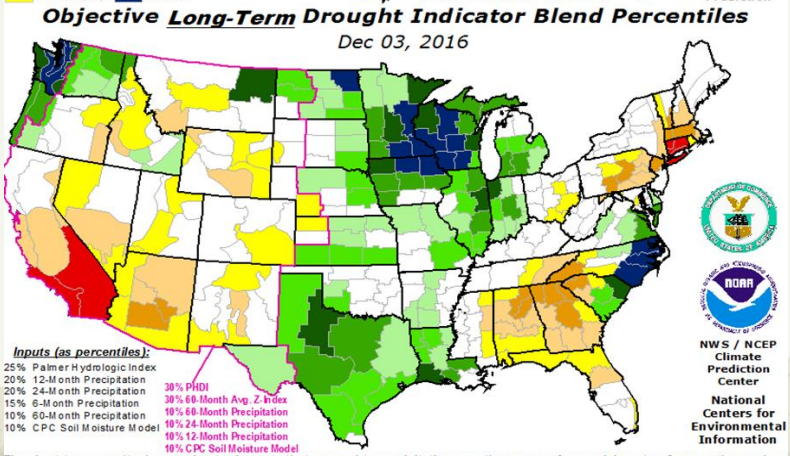
- Single index or indicator (parameter)
- Multiple indices or indicators
  - Assessed stand-alone
- *Composite (or "hybrid") Indicator*
  - *Blended approach*





- The **U.S. Drought Monitor (USDM) and Objective Blend Drought Indicators (OBDI)** were early (perhaps the earliest?) examples of multi-indicator/CDI approaches in the U.S./world *(Svoboda et al. 2002, BAMS)*





The short-term map (top) approximates impacts that respond to precipitation over the course of several days to a few months, such as agriculture, topsoil moisture, unregulated streamflows, and most aspects of wildfire danger. The long-term map (bottom) approximates impacts that respond to precipitation over the course of several months to a few years, such as reservoir content, groundwater depth, and lake levels. HOWEVER, the relationship between indicators and impacts can vary significantly with location and season. THIS IS PARTICULARLY TRUE OF WATER SUPPLIES, which are additionally affected by source, and management practices.

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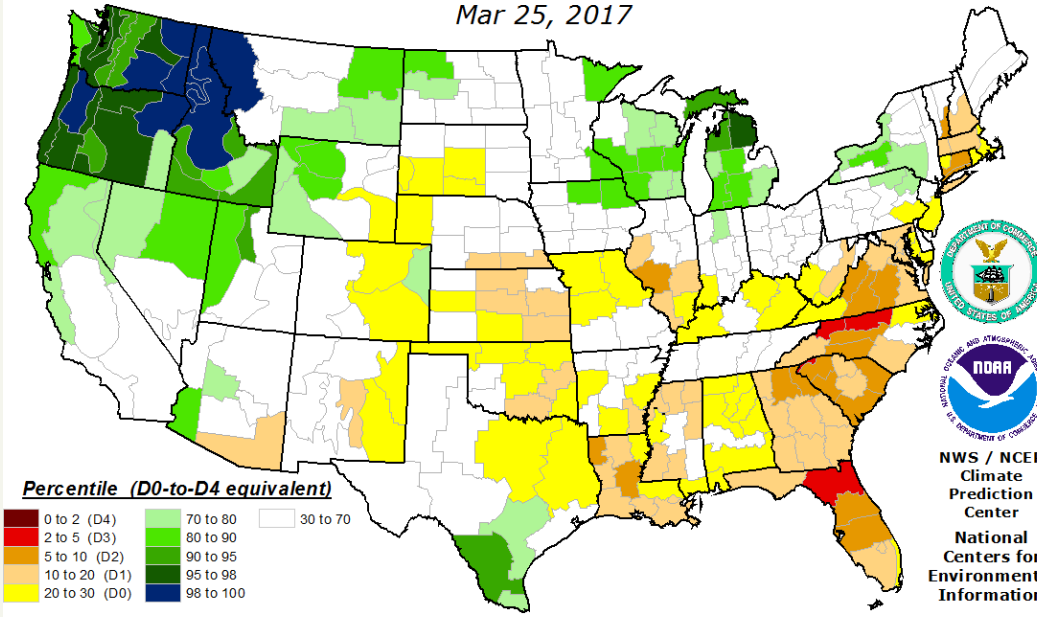
Objective Short-Term Drought Indicator Blend Percentiles

Mar 25, 2017



Percentile (D0-to-D4 equivalent)

0 to 2 (D4)	70 to 80	30 to 70
2 to 5 (D3)	80 to 90	
5 to 10 (D2)	90 to 95	
10 to 20 (D1)	95 to 98	
20 to 30 (D0)	98 to 100	

NWS / NCEP Climate Prediction Center

National Centers for Environmental Information

Inputs (as percentiles):

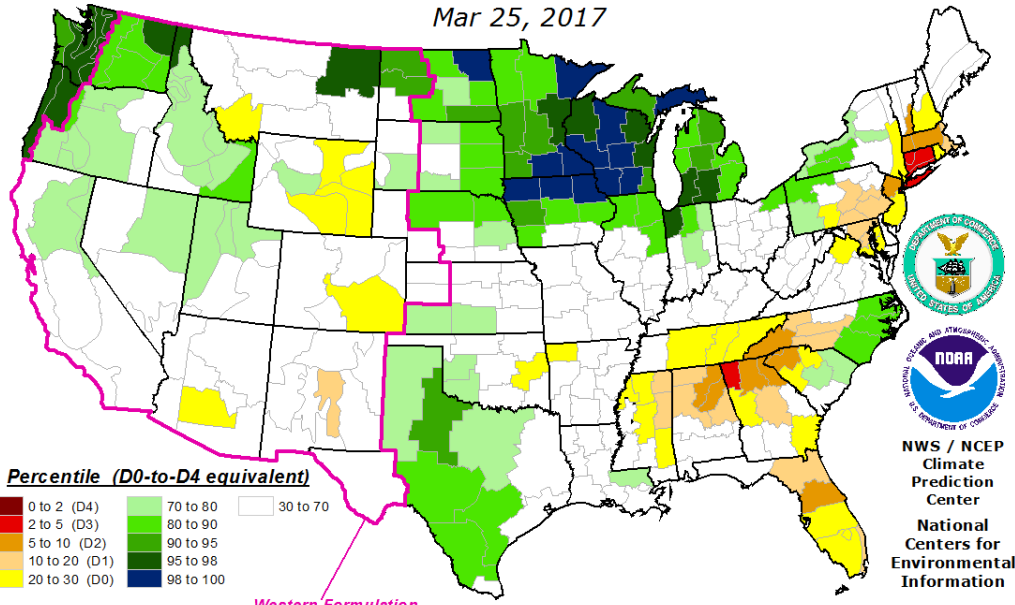
35% Palmer Z-Index
25% 3-Month Precipitation
20% 1-Month Precipitation
13% CPC Soil Moisture Model
7% Palmer Drought Index

This map approximates impacts that respond to precipitatic a few months, such as agriculture, topsoil moisture, unregu most aspects of wildfire danger. The relationship between can vary significantly with location and season. Do not interpr

This map is based on preliminary climate division dat final data may differ. See the detailed product suite de

Objective Long-Term Drought Indicator Blend Percentiles

Mar 25, 2017



Percentile (D0-to-D4 equivalent)

0 to 2 (D4)	70 to 80	30 to 70
2 to 5 (D3)	80 to 90	
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10 to 20 (D1)	95 to 98	
20 to 30 (D0)	98 to 100	

NWS / NCEP Climate Prediction Center

National Centers for Environmental Information

Inputs (as percentiles):

25% Palmer Hydrologic Index
20% 24-Month Precipitation
20% 12-Month Precipitation
15% 6-Month Precipitation
10% 60-Month Precipitation
10% CPC Soil Moisture Model

Western Formulation Inputs (as percentiles):

30% Palmer Hydrologic Index
30% 60-Month Average Z-Index
10% 60-Month Precipitation
10% 24-Month Precipitation
10% 12-Month Precipitation
10% CPC Soil Moisture Model

This map approximates impacts responding to precipitation over the course of several months to a few years, such as reservoir content, groundwater, and lake levels. HOWEVER, THE RELATIONSHIP BETWEEN INDICATORS AND WATER SUPPLIES CAN VARY MARKEDLY WITH LOCATION, SEASON, SOURCE, AND MANAGEMENT PRACTICE. Do not interpret this map too literally.

This map is based on preliminary climate division data. Local conditions and/or final data may differ. See the detailed product suite description for more details.

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DROUGHT INDICATOR BLEND AND COMPONENT PERCENTILES -- March 25, 2017

Climate Division						Drought Blends		Individual Blend Components										
								Precipitation						Palmer Z-Index	Palmer Drought Index (PDI)	Palmer Hydro. Drought Index (PHDI)	5-Year Average Z-Index	CPC Soil Moisture Model
ID #	U.S. CD #	State #	State CD #	State Name	CD Name	Short Term	Long Term	1-Month	3-Month	6-Month	1-Year	2-Year	5-Year					
0101	1	1	1	Alabama	Northern Valley	25.4	15.6	19.7	23.5	10.2	8.4	46.4	59.6	48.8	21.4	11.7	51.4	11.6
0102	2	1	2	Alabama	Appalachian Mountain	28.0	6.2	25.0	24.5	8.7	1.3	24.8	46.9	54.9	12.6	3.7	34.4	5.8
0103	3	1	3	Alabama	Upper Plains	28.8	11.2	27.1	33.7	4.5	8.0	31.1	46.0	45.1	32.6	19.3	33.1	5.8
0104	4	1	4	Alabama	Eastern Valley	28.3	5.6	30.6	40.1	6.7	1.5	23.0	49.7	43.4	4.7	2.4	30.2	4.7
0105	5	1	5	Alabama	Piedmont Plateau	24.6	18.2	10.1	60.2	25.8	12.0	50.3	58.1	23.4	19.1	7.3	30.8	15.1
0106	6	1	6	Alabama	Prairie	40.4	41.6	18.9	62.3	32.4	22.3	49.3	53.0	44.4	58.5	67.2	30.8	22.1
0107	7	1	7	Alabama	Coastal Plain	27.6	54.9	8.0	71.6	40.1	32.7	71.6	70.0	15.4	47.4	63.2	59.1	24.4
0108	8	1	8	Alabama	Gulf	22.1	58.0	6.6	72.7	50.3	42.9	70.0	76.4	6.1	30.9	61.9	63.3	20.9
0201	9	2	1	Arizona	Northwest	44.8	52.5	28.4	65.1	77.8	87.5	83.3	66.6	25.5	52.4	59.1	5.0	73.3
0202	10	2	2	Arizona	Northeast	53.7	53.4	29.6	73.1	75.8	80.2	82.6	59.1	43.6	59.1	65.0	0.4	80.2
0203	11	2	3	Arizona	North-Central	74.4	56.2	46.4	77.7	77.8	84.0	68.1	53.2	72.9	76.1	79.0	4.1	80.2
0204	12	2	4	Arizona	East-Central	54.2	42.3	24.0	74.9	71.3	69.4	65.9	32.1	44.8	65.2	69.5	1.2	69.8
0205	13	2	5	Arizona	Southwest	84.9	68.9	53.3	87.8	84.6	77.2	63.5	69.3	85.2	86.5	85.9	31.7	84.9
0206	14	2	6	Arizona	South-Central	46.6	28.1	32.6	71.3	63.5	58.6	52.9	43.8	33.3	46.6	41.4	0.7	53.5
0207	15	2	7	Arizona	Southeast	19.1	36.4	14.4	41.9	55.1	67.0	66.9	50.8	3.5	38.7	46.7	9.5	54.7
0301	16	3	1	Arkansas	Northwest	41.6	22.8	59.6	36.4	12.6	19.3	82.4	33.8	54.0	5.6	5.6	25.7	14.0
0302	17	3	2	Arkansas	North-Central	31.2	43.6	38.9	15.8	5.7	53.2	93.7	68.1	54.4	29.0	28.2	64.0	10.5
0303	18	3	3	Arkansas	Northeast	37.8	43.5	41.9	20.8	7.2	48.6	89.0	74.9	60.4	23.9	22.5	59.9	29.1
0304	19	3	4	Arkansas	West-Central	28.9	32.2	35.9	23.9	3.0	20.5	90.5	67.8	44.3	18.3	18.5	54.5	3.5
0305	20	3	5	Arkansas	Central	32.9	43.5	38.5	21.7	9.7	44.0	87.7	59.1	53.0	29.9	33.1	42.9	18.6
0306	21	3	6	Arkansas	East-Central	26.2	35.8	26.7	18.2	18.6	34.1	72.3	62.5	47.7	22.8	27.5	49.6	14.0
0307	22	3	7	Arkansas	Southwest	30.9	57.7	23.5	30.1	25.7	60.8	93.8	80.7	45.1	35.6	46.2	72.1	18.6
0308	23	3	8	Arkansas	South-Central	28.4	50.8	16.7	30.5	23.1	54.3	85.4	67.3	43.2	38.6	49.6	59.6	18.6
0309	24	3	9	Arkansas	Southeast	16.6	39.9	8.6	24.0	16.7	46.4	77.3	78.4	27.8	19.6	23.0	67.4	12.8
0401	25	4	1	California	North Coast Basin	87.7	67.6	79.8	91.2	92.5	92.1	88.7	35.0	69.8	99.8	99.8	6.3	97.7
0402	26	4	2	California	Sacramento Basin	79.0	71.2	77.6	97.4	98.7	96.6	90.3	45.8	41.2	95.3	96.1	9.8	97.7
0403	27	4	3	California	Northeast Interior Basin	72.1	76.5	72.1	100.0	100.0	99.7	96.3	49.9	27.2	93.3	95.7	18.4	97.7
0404	28	4	4	California	Central Coast Basin	78.2	62.2	68.2	93.9	91.6	91.0	85.1	27.8	42.5	96.0	96.7	0.3	96.5
0405	29	4	5	California	San Joaquin Basin	68.4	64.2	54.2	95.8	97.1	93.3	88.0	22.7	27.0	96.4	96.5	0.0	93.0
0406	30	4	6	California	South Coast Basin	56.4	48.0	34.6	80.3	81.3	81.9	54.4	4.4	29.3	75.1	79.4	0.0	73.3
0407	31	4	7	California	Southeast Desert Basins	53.6	38.1	40.3	83.0	83.5	81.8	67.1	34.4	25.5	66.8	48.5	0.2	68.6

Climate Division | Drought Blends | Individual Blend Components | Precipitation | Palmer Z-Index | Palmer Drought | Palmer Hydro | 5-Year Average | CPC Soil

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Calculating a CDI

Introduction:

- Using the output indice data calculated from the climate station data and/or satellite sources, ***each station and/or grid will have a history*** calculated based on a ranking percentile approach ***for each input parameter and an overall weighted percentile for the CDI*** that combines the indicators
- We have ***used Microsoft EXCEL to generate the input and CDI values for a station-based*** method using climate-based station data
- ***Grid cell calculations are stored in a database (SQL Server)*** and Python is used to help automate and script the monthly updates and CDI calculations

Calculating a CDI

Comparison of the *station vs. gridded* approaches:

- **Station-based** approach is site specific and ***distribution is not uniform***. Must then interpolate/extrapolate to cover large areas….
- The **gridded** approach will produce a CDI value for ***every cell over a given area***, so interpolation of the data is not required
  - ***Distribution is uniform***
  - The results can still be interpolated/smoothed in a GIS and will produce a smoother surface if so desired
  - May require more processing power
- The CDI ***weighting and the ranking for all of the other calculations are the same*** using both approaches (station vs. gridded) the only difference is in the amount of data being processed (potentially many, many, many more grid cells!)

Prototype MENA Combined Drought Index (CDI) initial satellite-derived input components ***(all at 5km resolution)*** and weightings**:

Standardized Precipitation Index 2-mo (CHIRPS2): 40%

Evaporative Stress Index (ESI): 20%

Soil Moisture (Land Information System): 20%

Normalized Difference Vegetation Index (NDVI-anom): 20%

***These are only initial, non-validated expert judgement inputs and weightings that need to be validated to determine how they match the conditions, impacts and reality of the situation the ground at the local level….feedback and other statistical + data mining techniques will help fine tune the CDI**

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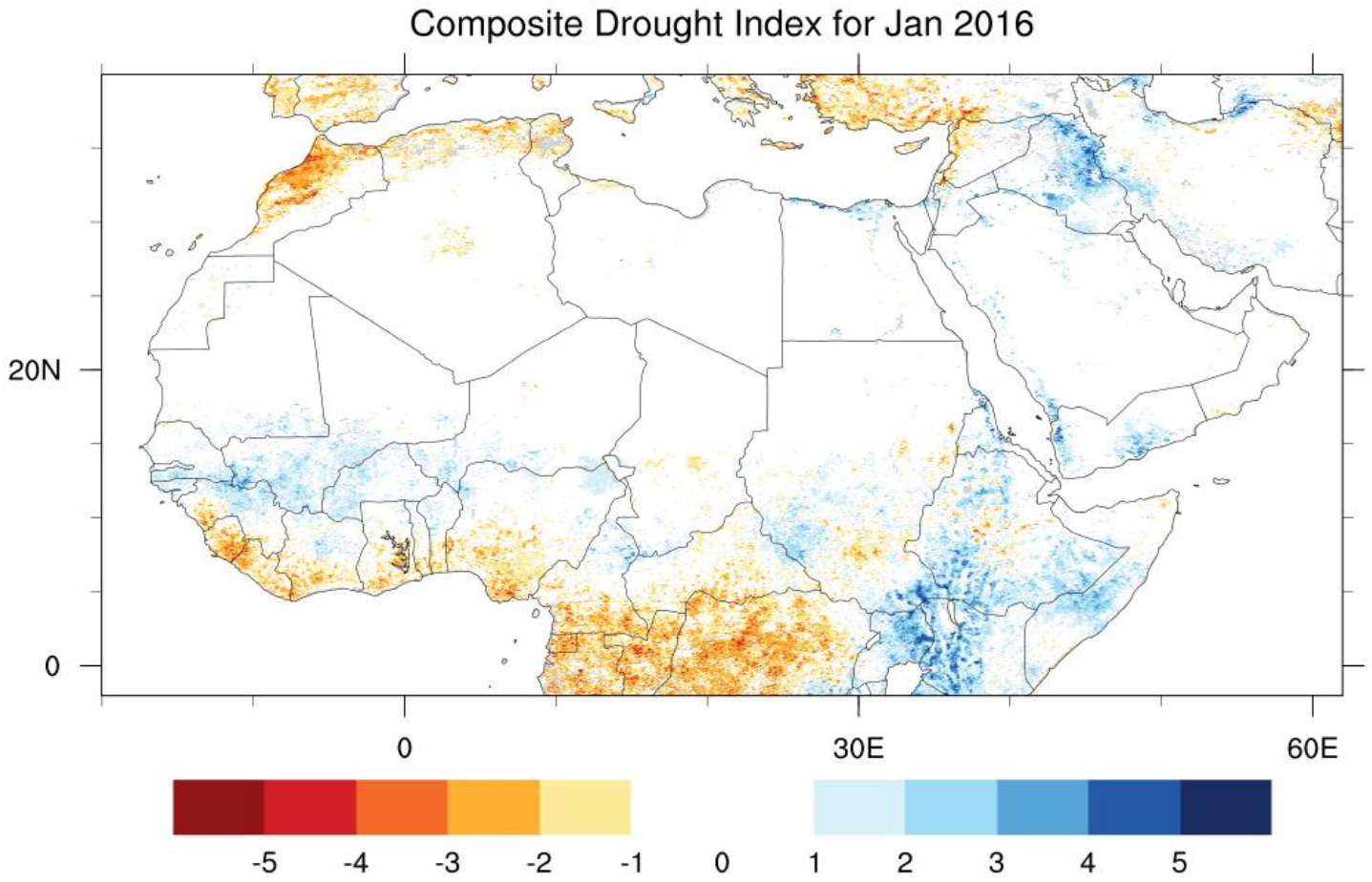

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Water for Food
DAUGHERTY GLOBAL INSTITUTE
at the University of Nebraska

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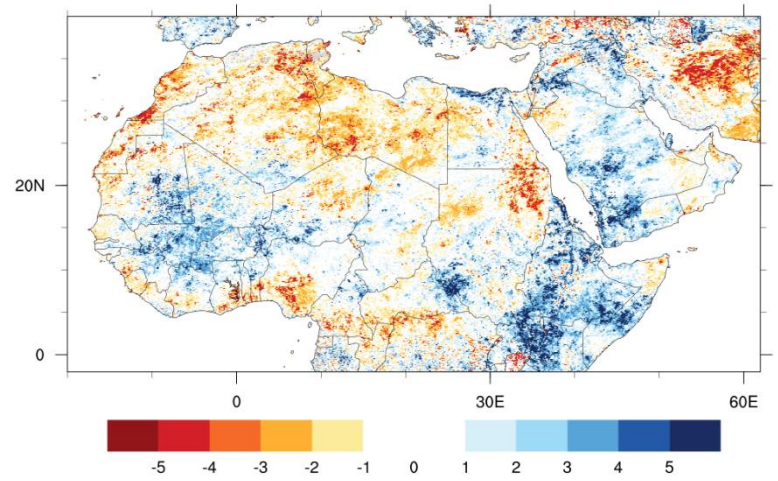
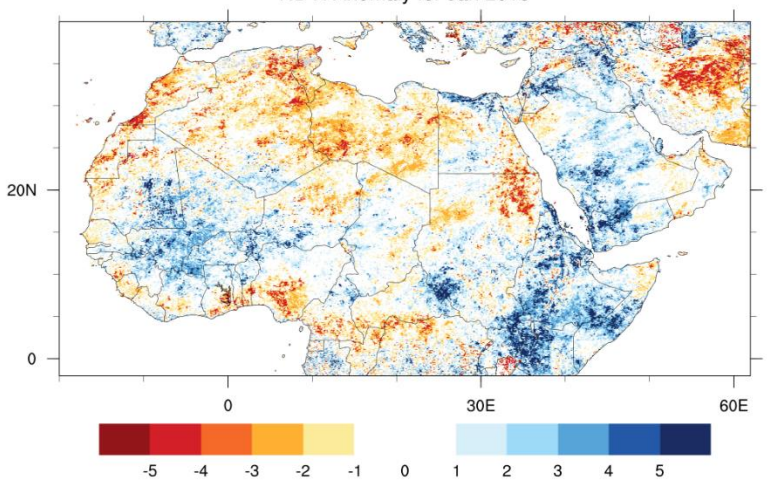
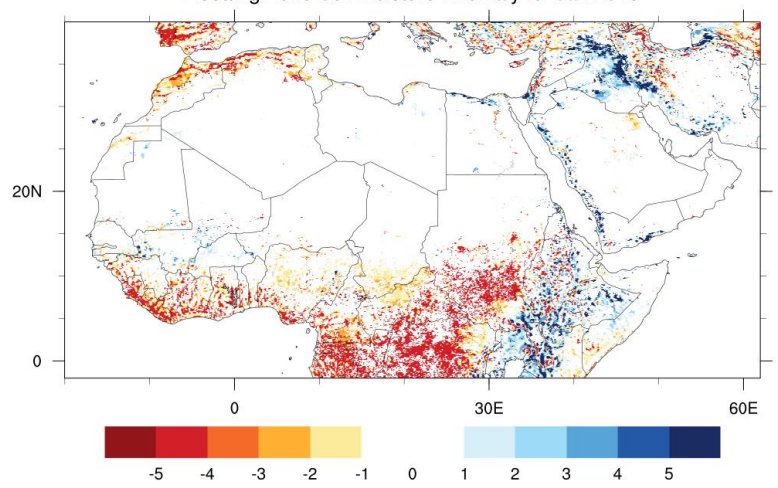
Land Surface Temperature Anomaly for Jan 2016



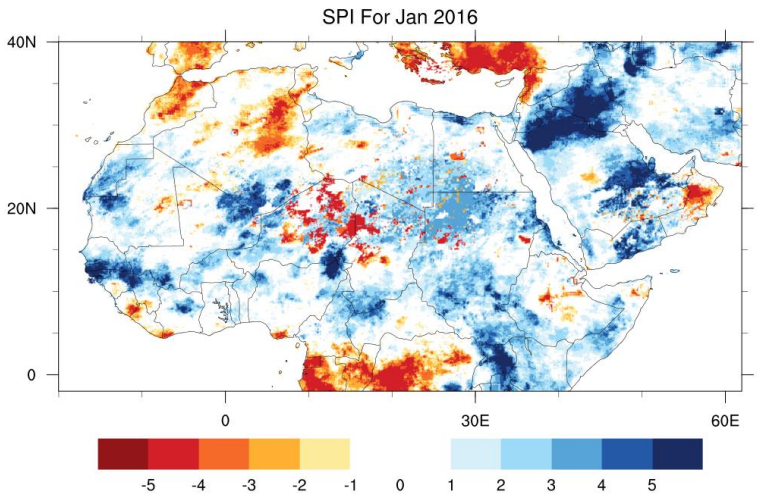
NDVI Anomaly for Jan 2016



Rootting Zone Soil Moisture Anomaly for Jan 2016



SPI For Jan 2016



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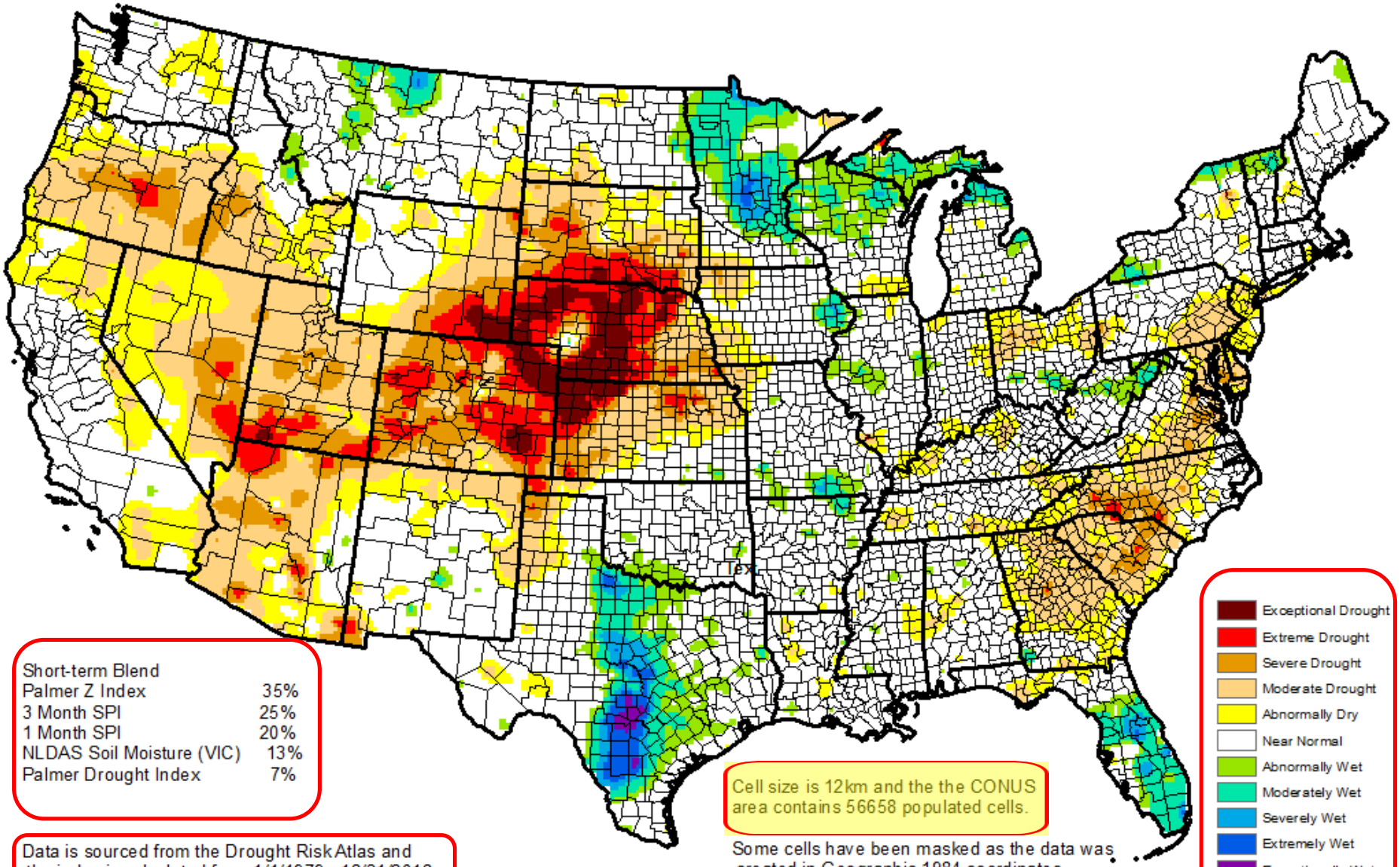
Short-term Blend July 2002



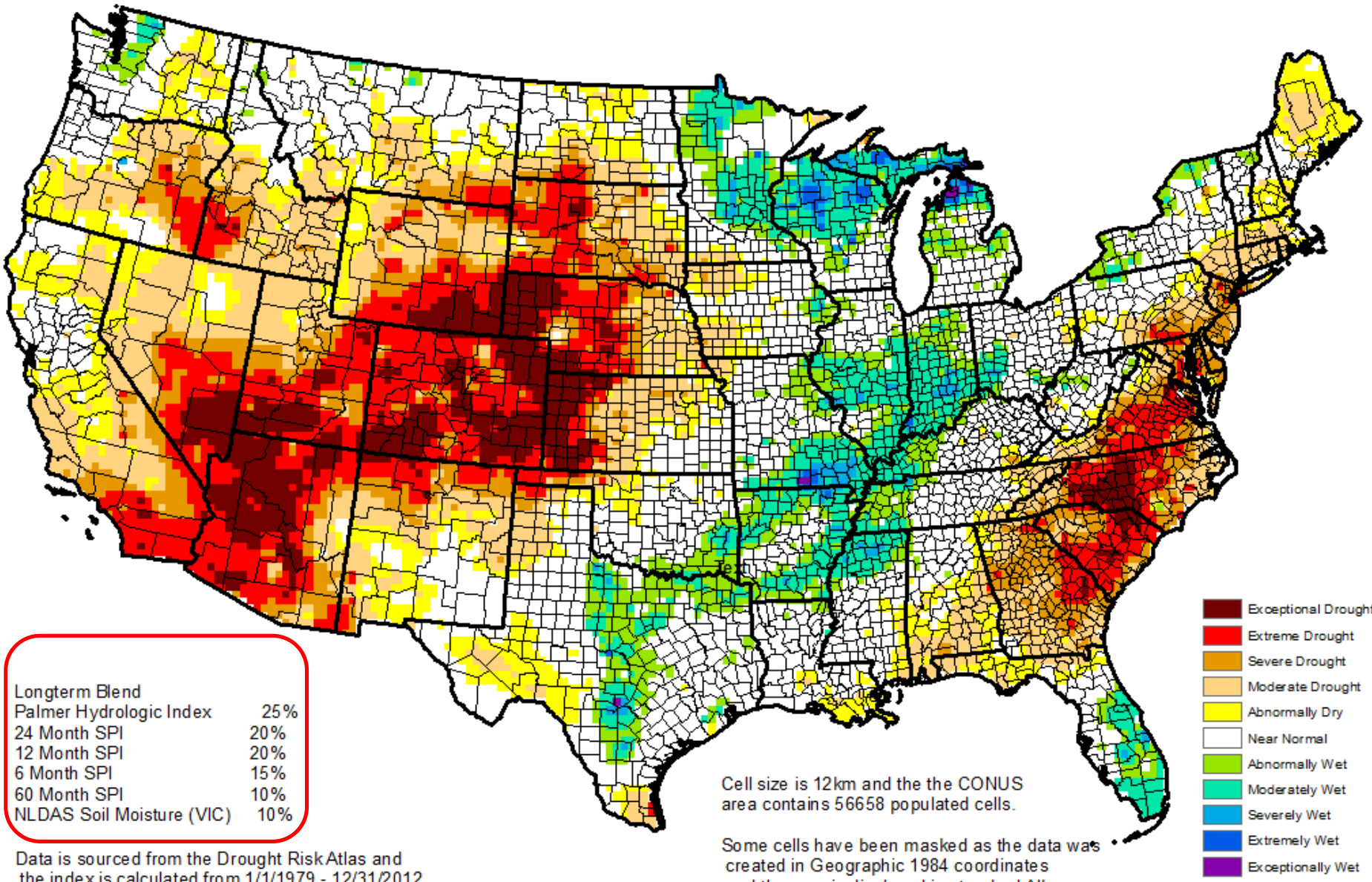
Short-term Blend	
Palmer Z Index	35%
3 Month SPI	25%
1 Month SPI	20%
NLDAS Soil Moisture (VIC)	13%
Palmer Drought Index	7%

Data is sourced from the Drought Risk Atlas and the index is calculated from 1/1/1979 - 12/31/2012 based on the availability of NLDAS data.

Cell size is 12km and the the CONUS area contains 56658 populated cells.

Some cells have been masked as the data was created in Geographic 1984 coordinates and the map is displayed in standard Albers

Long-term Blend July 2002



Longterm Blend	
Palmer Hydrologic Index	25%
24 Month SPI	20%
12 Month SPI	20%
6 Month SPI	15%
60 Month SPI	10%
NLDAS Soil Moisture (VIC)	10%

Data is sourced from the Drought Risk Atlas and the index is calculated from 1/1/1979 - 12/31/2012 based on the availability of NLDAS data.

Cell size is 12km and the the CONUS area contains 56658 populated cells.

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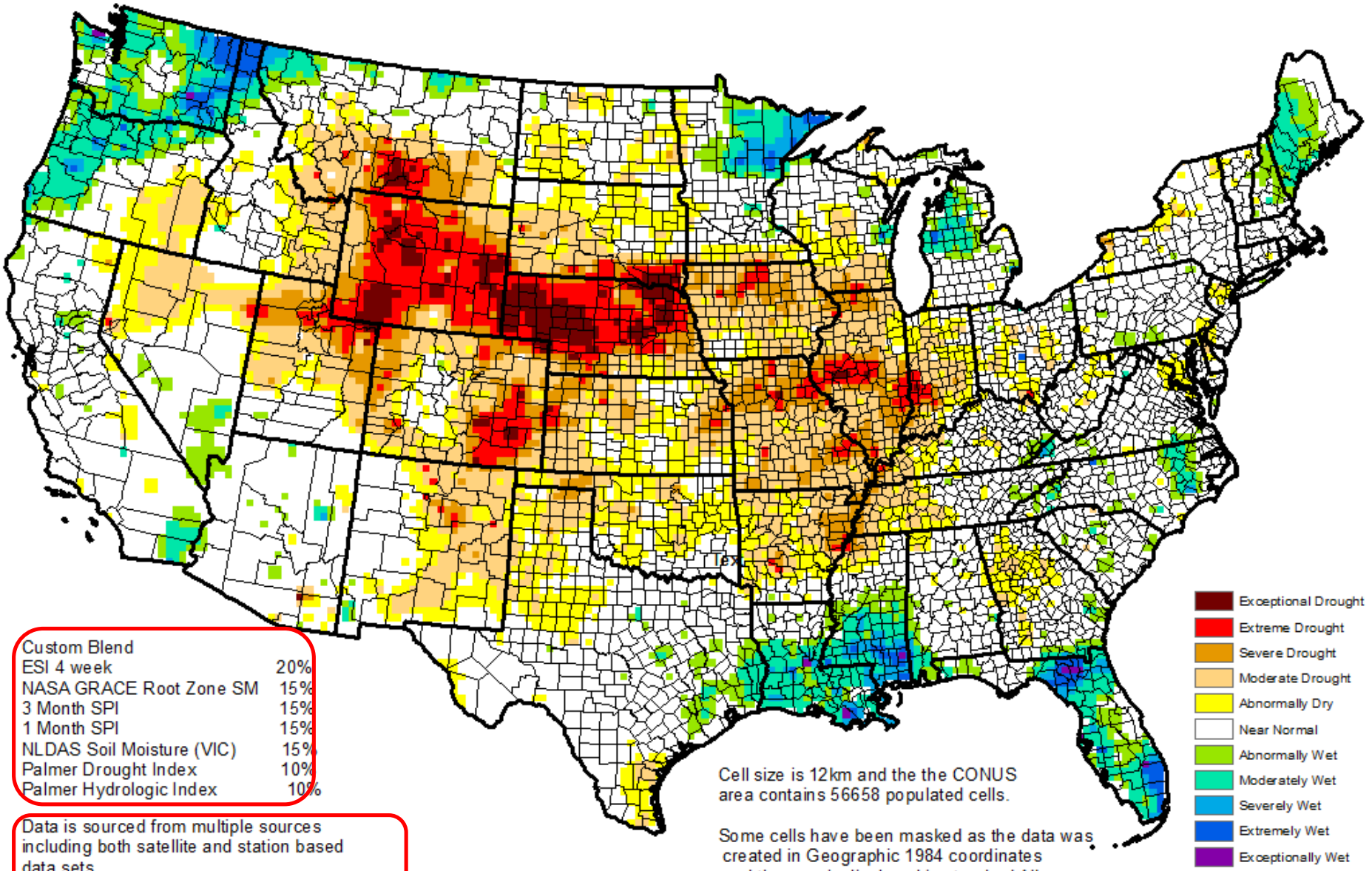
Custom Drought Blend August 2012



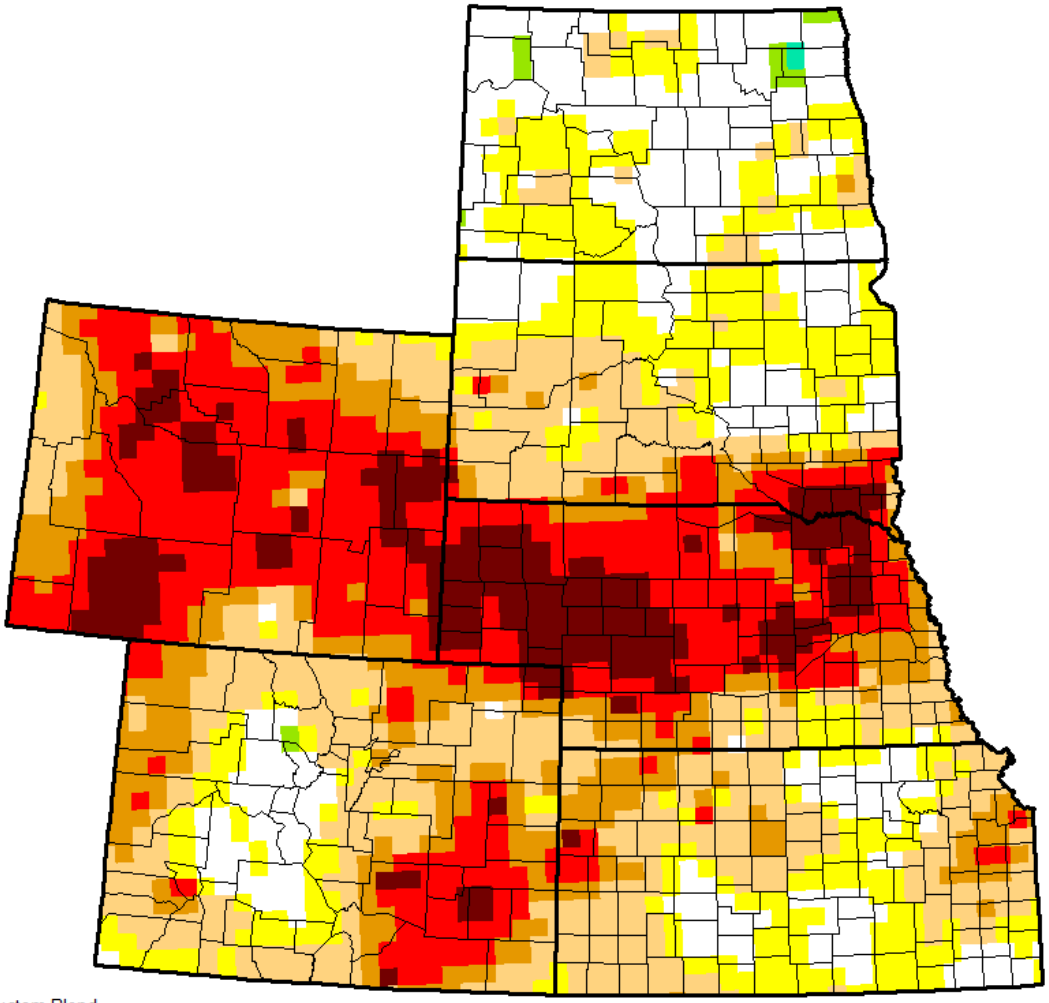
Custom Blend	
ESI 4 week	20%
NASA GRACE Root Zone SM	15%
3 Month SPI	15%
1 Month SPI	15%
NLDAS Soil Moisture (VIC)	15%
Palmer Drought Index	10%
Palmer Hydrologic Index	10%

Data is sourced from multiple sources including both satellite and station based data sets.
The history is based on 1/1/2003 to 12/31/2016 due to the satellite record.

Cell size is 12km and the the CONUS area contains 56658 populated cells.

Some cells have been masked as the data was created in Geographic 1984 coordinates and the map is displayed in standard Albers

Custom Drought Blend August 2012



Custom Blend	
ESI 4 week	20%
NASA GRACE Root Zone SM	15%
3 Month SPI	15%
1 Month SPI	15%
NLDAS Soil Moisture (VIC)	15%
Palmer Drought Index	10%
Palmer Hydrologic Index	10%

Data is sourced from multiple sources including both satellite and station based data sets.
The history is based on 1/1/2003 to 12/31/2016 due to the satellite record.

- Exceptional Drought
- Extreme Drought
- Severe Drought
- Moderate Drought
- Abnormally Dry
- Near Normal
- Abnormally Wet
- Moderately Wet
- Severely Wet
- Extremely Wet
- Exceptionally Wet

Cell size is 12km and the the CONUS area contains 56658 populated cells.

Some cells have been masked as the data was created in Geographic 1984 coordinates and the map is displayed in STP 2500

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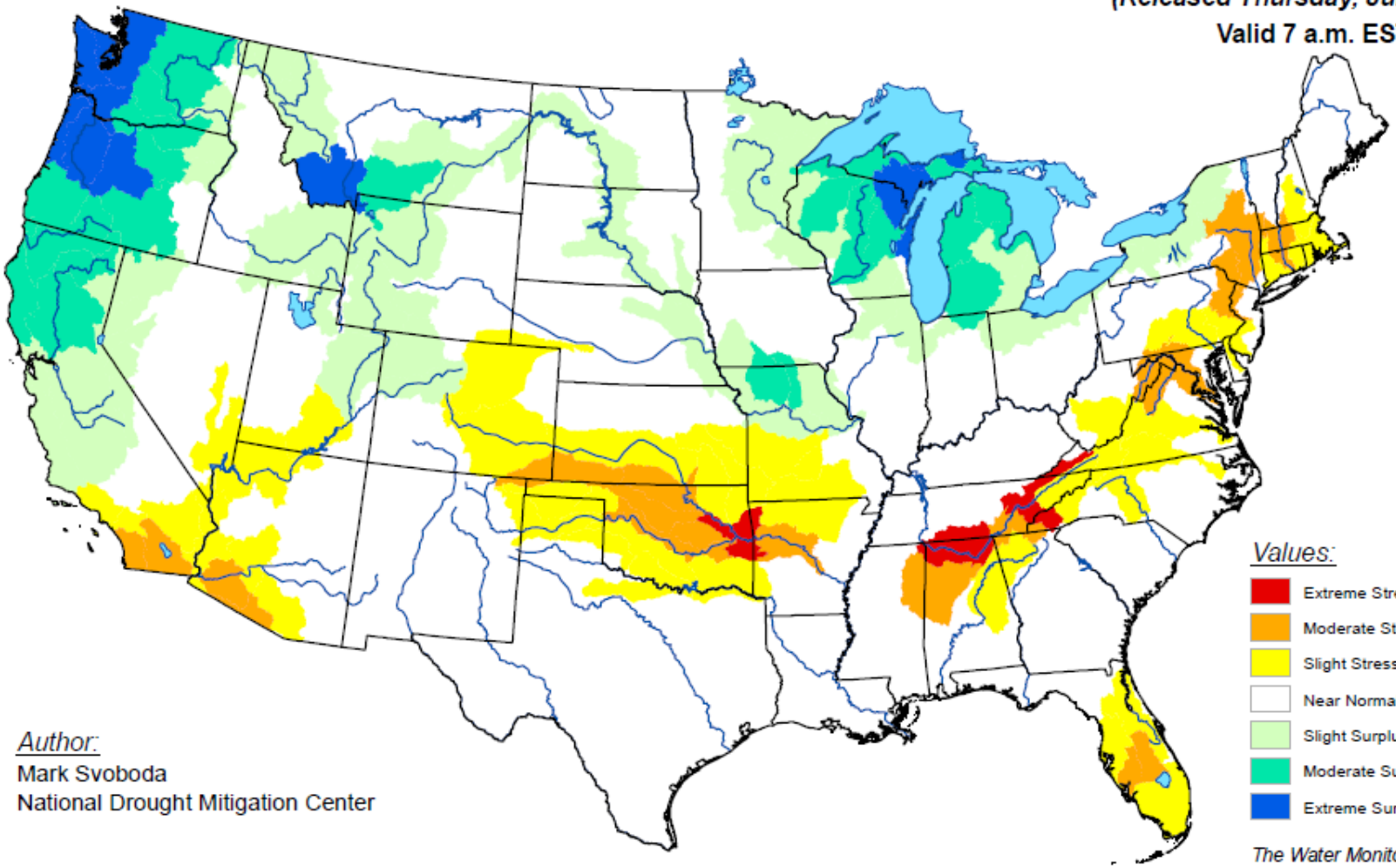
U.S. Water Monitor

July 14, 2020

(Released Thursday, Jul.16, 2020)

Valid 7 a.m. EST



Values:

- Extreme Stress (5th percentile)
- Moderate Stress (10th percentile)
- Slight Stress (20th percentile)
- Near Normal
- Slight Surplus (80th percentile)
- Moderate Surplus (90th percentile)
- Extreme Surplus (95th percentile)

Author:

Mark Svoboda

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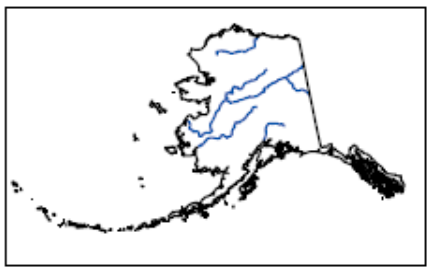
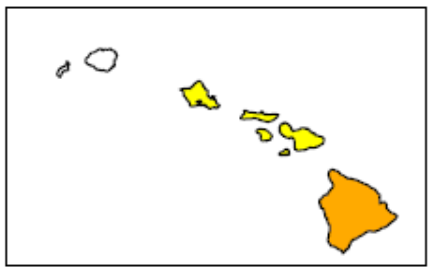
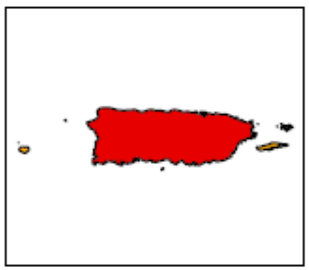
The Water Monitor focuses on broad-scale reservoir, surface and groundwater conditions. Local conditions may vary. See accompanying text summary for forecast statements.

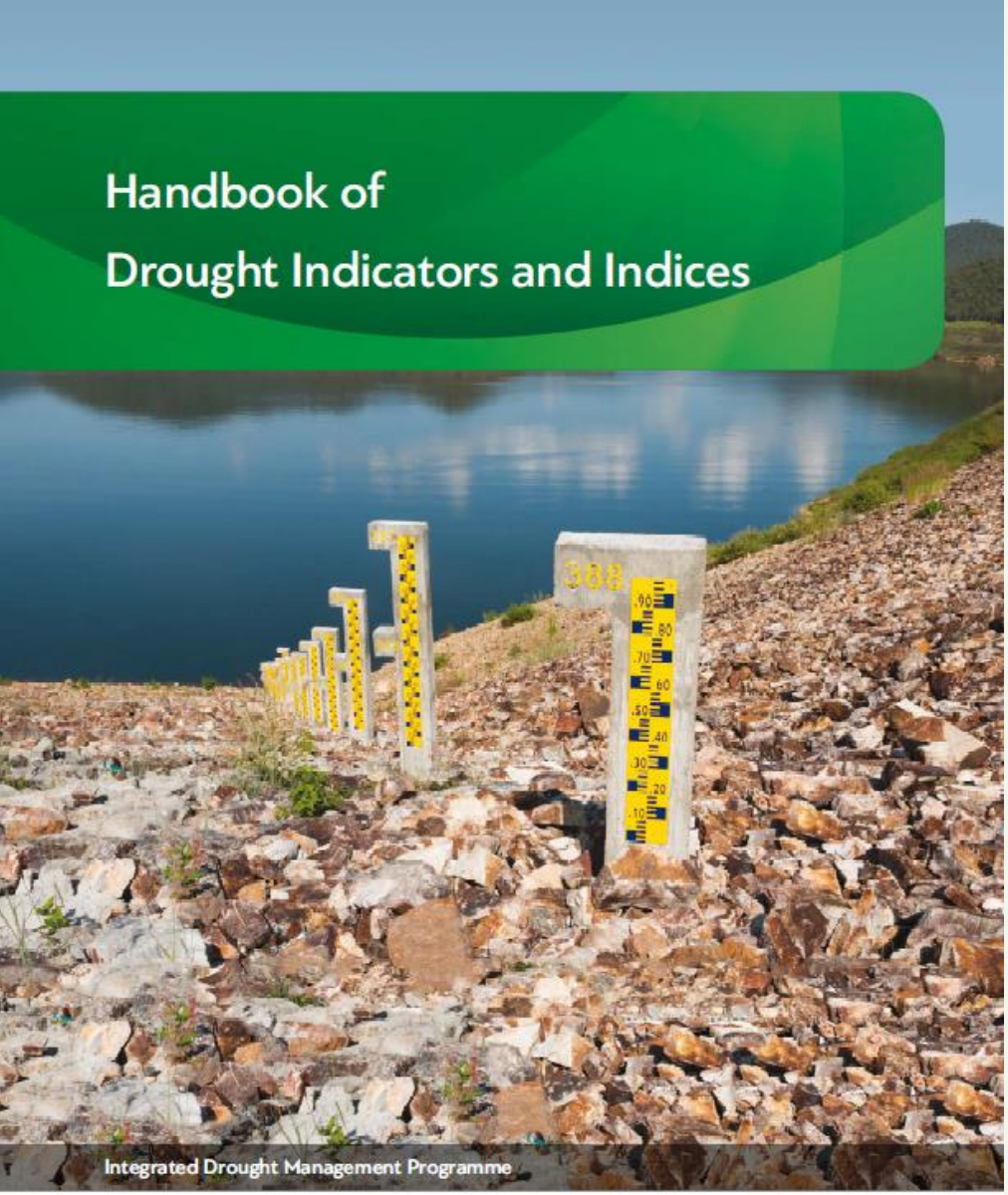






USDA NDMC

http://watermonitor.unl.edu/



- **Freely available on-line**
- http://www.droughtmanagement.info/handbook-drought-indicators-and-indices/

IDMP
Integrated Drought Management Programme

Meteorological Based	Page	Ease of Use	Inputs Required	Additional Information
Aridity Anomaly Index (AAI)		Green	P,T, PET, ET	Operationally available for India
Deciles		Green	P	Ease of calculation and examples from Australia useful
Keetch-Byram Drought Index (KBDI)		Green	P,T	KBDI calculations are based upon the climate of the area of interest
Percent of Normal Precipitation		Green	P	Simple calculations
Standardized Precipitation Index (SPI)		Green	P	The WMO highlighted the SPI as a starting point for meteorological drought monitoring
Weighted Anomaly Standardized Precipitation (WASP)		Green	P,T	Uses gridded data in monitoring drought in tropical regions
Aridity Index (AI)		Yellow	P, T	Can also be used in climate classifications
China Z Index (CZI)		Yellow	P	Intended to improve upon what the SPI provides
Crop Moisture index (CMI)		Yellow	P,T	Weekly values are needed
Drought Area Index (DAI)		Yellow	P	Gives an indication of how the monsoon season perform
Drought Reconnaissance Index (DRI)		Yellow	P, T	Monthly temperature and precipitation needed
Effective Drought Index (EDI)		Yellow	P	Program is available through direct contact with originator
Hydro-Thermal Coefficient (HTC)		Yellow	T,P	Ease in calculations and several examples in Russia
NOAA Drought Index (NDI)		Yellow	P	Best used in agricultural applications
Palmer Drought Severity Index (PDSI)		Yellow	P,T, AWC	Not green due to complexity of calculations and the need for serially complete data
Palmer Z Index		Yellow	P,T, AWC	One of the many outputs of the Palmer Drought Severity Index calculations
Rainfall Anomaly Index (RAI)		Yellow	P	Serially complete data required
Self-Calibrated Palmer Drought Severity Index (sc-PDSI)		Yellow	P,T, AWC	Not green due to complexity of calculations and serially complete data needed
Standardized Anomaly Index (SAI)		Yellow	P	Point data used to describe regional conditions
Standardized Precipitation Evapotranspiration Index (SPEI)		Yellow	P, T	Serially complete data required, output similar to the SPI but with a temperature component
Agricultural Reference Index for Drought (ARID)		Red	P,T, Mod	Regionally produced in the southeastern United States and not tested widely outside of the region
Crop Specific Drought Index (CSDI)		Red	P,T,Td,W,Rad,AWC,Mod,crop data	Quality data of many variables needed, making its use a challenge
Reclamation Drought Index (RDI)		Red	P,T,S,R, SF	Similar to the SWSI, but contains a temperature component
Soil Moisture Based		Ease of Use	Inputs Needed	Additional Information
Soil Moisture Anomaly (SMA)		Yellow	P,T, AWC	Intended to improve upon the water balance of the PDSI
Evapotranspiration Deficit Index (ETDI)		Red	Mod	Complex calculations with multiple inputs needed
Soil Moisture Deficit Index (SMDI)		Red	Mod	Weekly calculations at different soil depths, complicated to calculate
Soil Water Storage (SWS)		Red	AWC,RD,ST,SWD	Due to variation in both soil and crop types, interpolation over large areas is challenging
Hydrological Based		Ease of Use	Inputs Needed	Additional Information

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Critical Observations:

1) Typically, ***No single*** indicator/index is used solely in determining appropriate actions

2) Instead, ***different*** thresholds from ***different*** combinations of inputs is typically (not always) the best way to approach monitoring and triggers using a variety of indices and indicators

Final Thoughts:

- ***CDI:"Convergence of Evidence"*** approach allows for:
  - Ensemble-like approach
  - Don't Cry Wolf….or "all clear", too soon!
- Decision makers want ***ONE*** map, not multiple maps
  - Annual User Forums and stakeholder engagements tell us this repeatedly…
  - However, scientists like ***MANY*** maps! ☺
- Multiple CDI ***(regional/seasonal/sectoral-thematic)*** can be tested or made operational depending on the need and ability to validate them
- ***PCA/Data Mining*** to explore CDI and various input parameter relationships/weighting/auto-correlation

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Questions?

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Photo Credit: Daniel Griffin