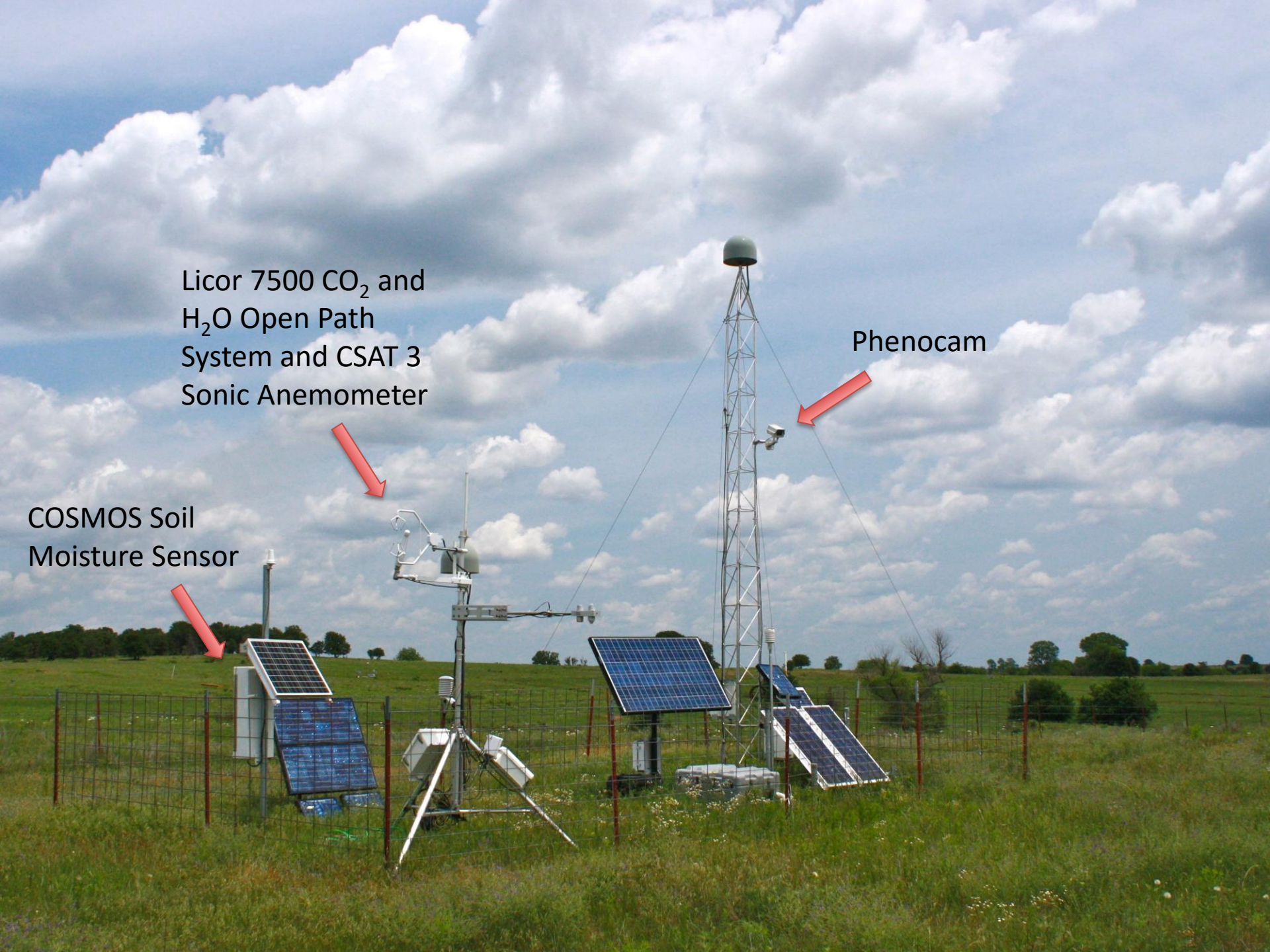
Variability of Observations from the MOISST Flux Tower Associated with Changing Soil Moisture Conditions

Hayden Mahan, Jeffrey Basara, and Rajen Bajgain

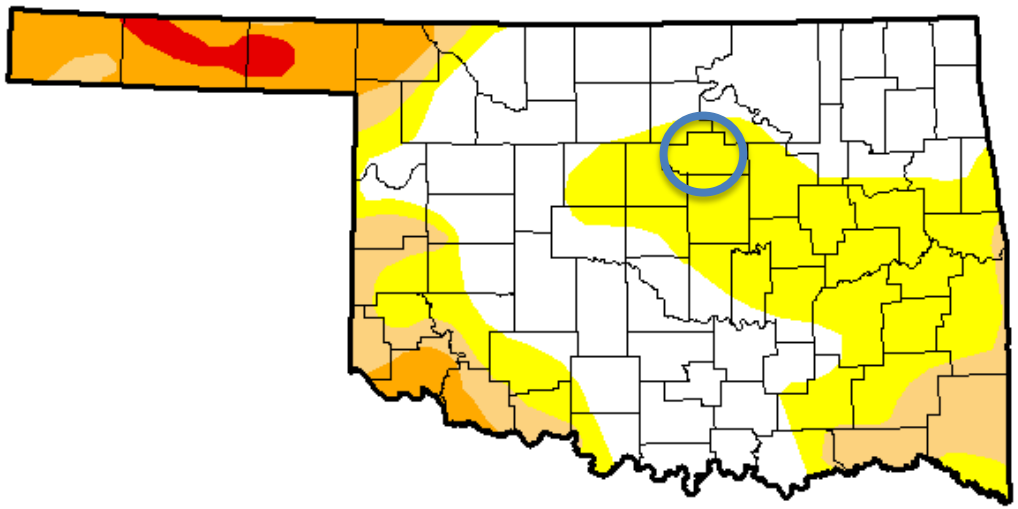

Licor 7500 CO_2 and H_2O Open Path System and CSAT 3 Sonic Anemometer
Phenocam
COSMOS Soil Moisture Sensor

Analysis

- “Flash Drought” period from June – August 2012
- “Flash Recovery” period during May 2015
- Analysis of precipitation, temperature, soil moisture, vegetation index, evaporative fraction, and water use efficiency from MOISST site and Marena Mesonet

U.S. Drought Monitor

Oklahoma



June 12, 2012

(Released Thursday, Jun. 14, 2012)

Valid 7 a.m. EST

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	46.78	53.22	21.54	10.49	1.70	0.00
Last Week *6/5/2012*	34.37	65.63	23.32	11.20	3.26	0.00
3 Months Ago *3/13/2012*	26.53	73.47	48.23	24.10	8.79	3.16
Start of Calendar Year *1/3/2012*	14.83	85.17	78.76	50.55	27.48	3.78
Start of Water Year *9/27/2011*	0.00	100.00	100.00	100.00	78.97	66.42
One Year Ago *6/14/2011*	22.11	77.89	57.87	41.76	33.53	10.32

Intensity:

- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

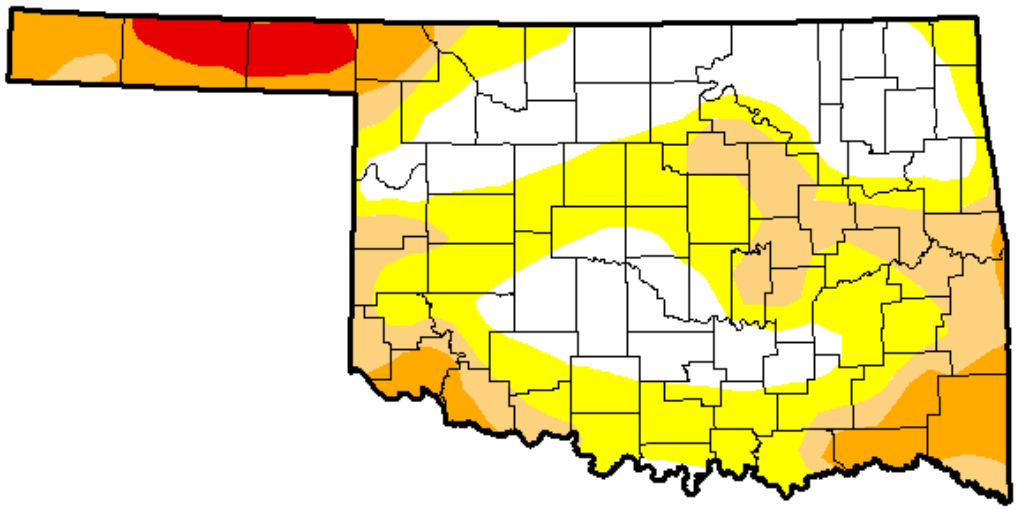
The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

Author:
David Miskus
NOAA/NWS/NCEP/CPC

http://droughtmonitor.unl.edu/

U.S. Drought Monitor

Oklahoma



June 19, 2012

(Released Thursday, Jun. 21, 2012)

Valid 7 a.m. EST

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	32.88	67.12	33.24	15.20	3.40	0.00
Last Week *6/12/2012*	46.78	53.22	21.54	10.49	1.70	0.00
3 Months Ago *3/20/2012*	63.01	36.99	25.51	11.88	7.42	3.16
Start of Calendar Year *1/3/2012*	14.83	85.17	78.76	50.55	27.48	3.78
Start of Water Year *9/27/2011*	0.00	100.00	100.00	100.00	78.97	66.42
One Year Ago *6/21/2011*	22.11	77.89	63.43	48.14	41.22	32.55

Intensity:

- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

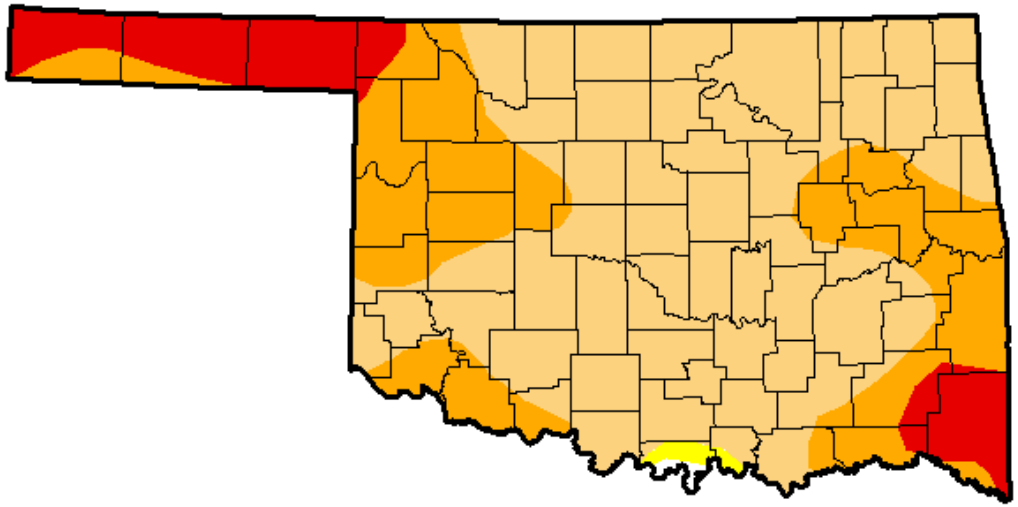
The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

Author:
Richard Heim
NCDC/NOAA

http://droughtmonitor.unl.edu/

U.S. Drought Monitor

Oklahoma



July 10, 2012

(Released Thursday, Jul. 12, 2012)

Valid 7 a.m. EST

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	0.28	99.72	99.15	38.61	10.83	0.00
Last Week *7/3/2012*	0.35	99.65	61.12	18.25	7.58	0.00
3 Months Ago *4/10/2012*	66.53	33.47	18.37	9.72	3.35	0.01
Start of Calendar Year *1/3/2012*	14.83	85.17	78.76	50.55	27.48	3.78
Start of Water Year *9/27/2011*	0.00	100.00	100.00	100.00	78.97	66.42
One Year Ago *7/12/2011*	0.00	100.00	98.46	76.84	58.04	42.94

Intensity:

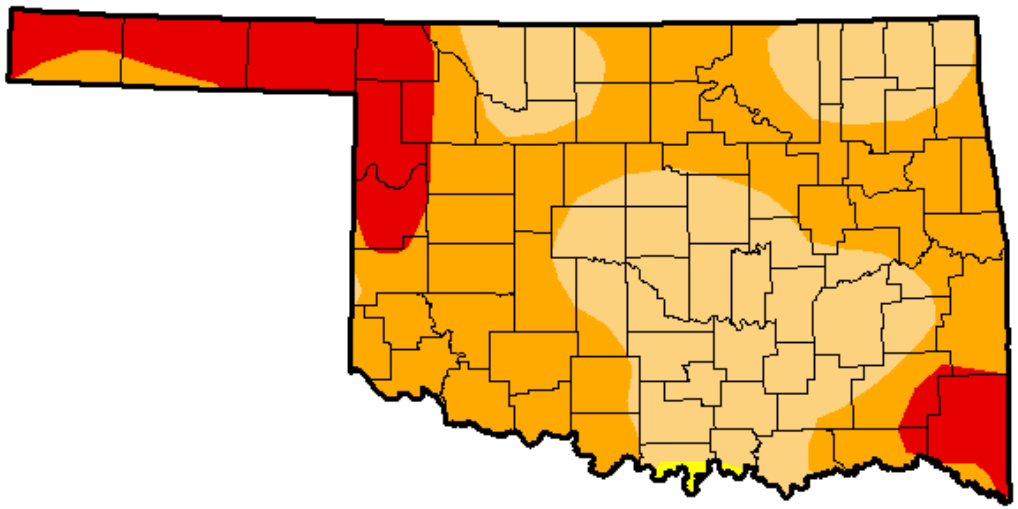
- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

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

Author:
Richard Tinker
CPC/NOAA/NWS/NCEP

http://droughtmonitor.unl.edu/

U.S. Drought Monitor
Oklahoma



July 17, 2012
(Released Thursday, Jul. 19, 2012)
Valid 7 a.m. EST

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	0.00	100.00	99.61	64.31	15.48	0.00
Last Week *7/10/2012*	0.28	99.72	99.15	38.61	10.83	0.00
3 Months Ago *4/17/2012*	74.94	25.06	15.00	9.78	3.36	0.00
Start of Calendar Year *1/3/2012*	14.83	85.17	78.76	50.55	27.48	3.78
Start of Water Year *9/27/2011*	0.00	100.00	100.00	100.00	78.97	66.42
One Year Ago *7/19/2011*	0.00	100.00	99.99	76.84	58.04	42.93

Intensity:

- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

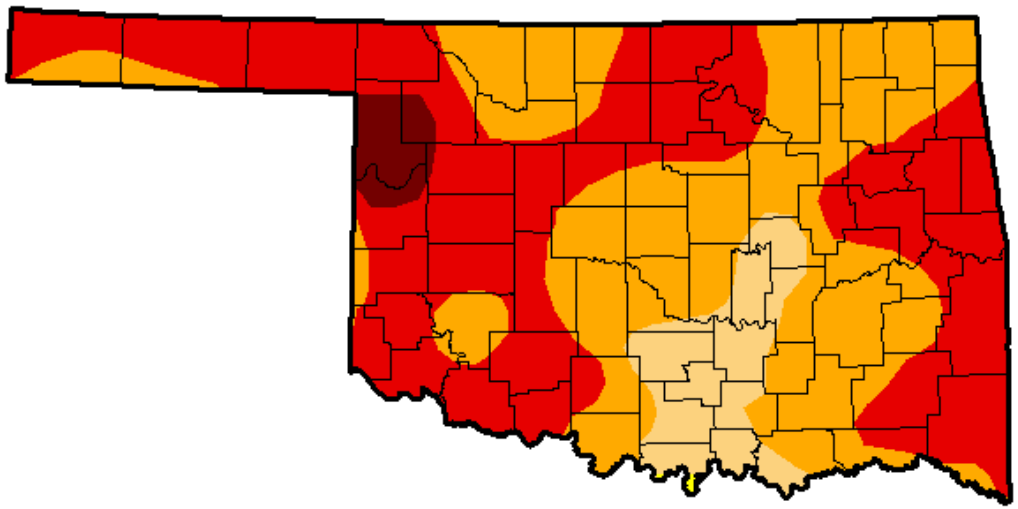
The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

Author:
Richard Heim
NCDC/NOAA

http://droughtmonitor.unl.edu/

U.S. Drought Monitor

Oklahoma



July 24, 2012

(Released Thursday, Jul. 26, 2012)

Valid 7 a.m. EST

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	0.00	100.00	99.90	91.24	50.39	2.71
Last Week *7/17/2012*	0.00	100.00	99.61	64.31	15.48	0.00
3 Months Ago *4/24/2012*	74.94	25.06	15.00	9.78	3.27	0.00
Start of Calendar Year *1/3/2012*	14.83	85.17	78.76	50.55	27.48	3.78
Start of Water Year *9/27/2011*	0.00	100.00	100.00	100.00	78.97	66.42
One Year Ago *7/26/2011*	0.00	100.00	100.00	95.45	67.69	52.20

Intensity:

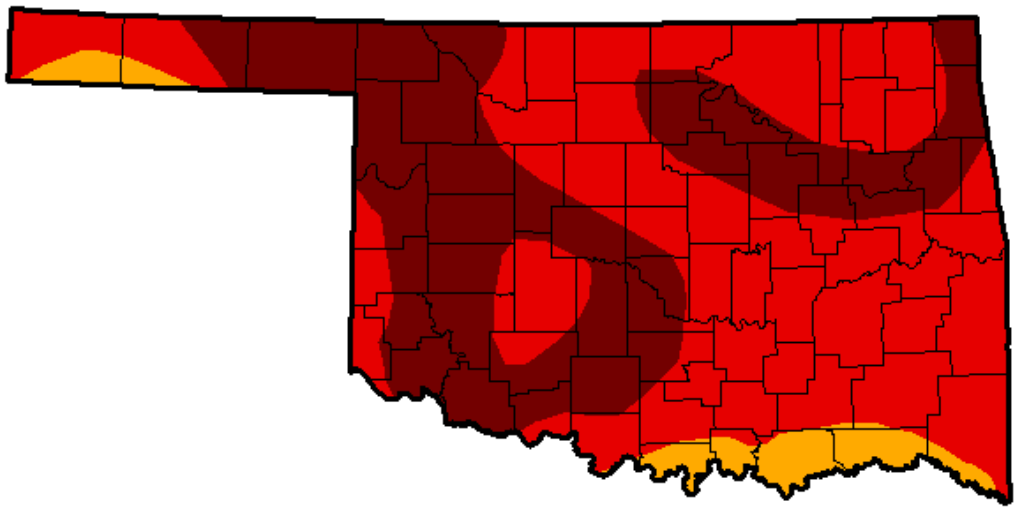
- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

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

Author:
Richard Heim
NCDC/NOAA

http://droughtmonitor.unl.edu/

U.S. Drought Monitor
Oklahoma



August 14, 2012
(Released Thursday, Aug. 16, 2012)
Valid 7 a.m. EST

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	0.00	100.00	100.00	100.00	94.59	38.86
Last Week *8/7/2012*	0.00	100.00	100.00	100.00	96.78	16.03
3 Months Ago *5/15/2012*	76.93	23.07	13.68	9.34	3.54	0.00
Start of Calendar Year *1/3/2012*	14.83	85.17	78.76	50.55	27.48	3.78
Start of Water Year *9/27/2011*	0.00	100.00	100.00	100.00	78.97	66.42
One Year Ago *8/16/2011*	0.00	100.00	100.00	96.35	85.39	66.84

Intensity:

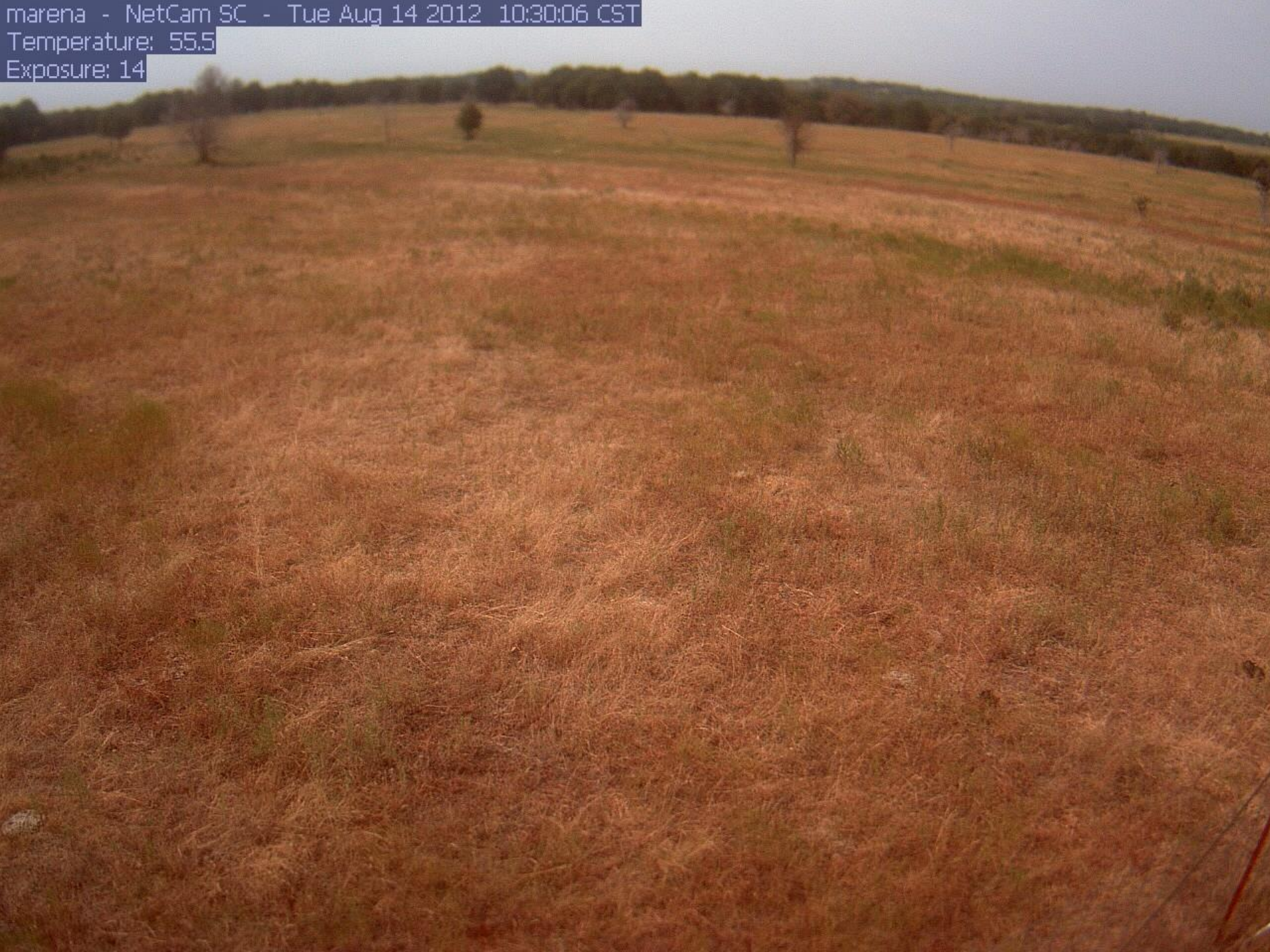
- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

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

Author:
Michael Brewer
NCDC/NOAA

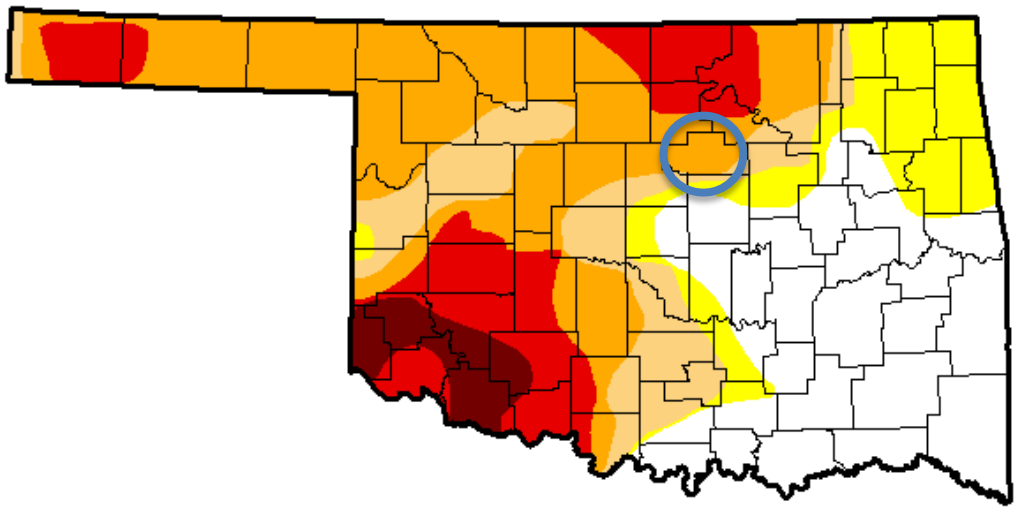
http://droughtmonitor.unl.edu/


NetCam SC Sun Jul 01 13:30:05 2012
Exposure: 19


marena - NetCam SC - Tue Aug 14 2012 10:30:06 CST
Temperature: 55.5
Exposure: 14

U.S. Drought Monitor

Oklahoma



May 5, 2015

(Released Thursday, May. 7, 2015)

Valid 7 a.m. EST

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	29.24	70.76	59.05	46.19	17.95	4.03
Last Week 4/28/2015	30.08	69.92	59.29	47.51	24.34	4.13
3 Months Ago 2/3/2015	5.03	94.97	63.11	45.34	22.58	5.69
Start of Calendar Year 12/30/2014	25.63	74.37	62.03	40.84	21.74	5.70
Start of Water Year 9/30/2014	8.55	91.45	73.31	58.13	20.92	4.64
One Year Ago 5/6/2014	6.67	93.33	80.65	65.94	48.86	29.85

Intensity:

- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

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

Author:

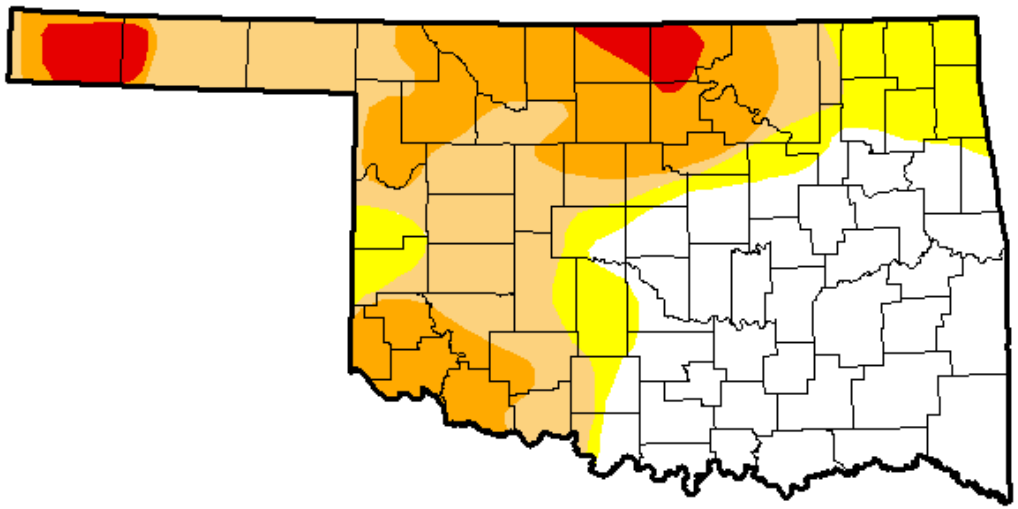
Mark Svoboda

National Drought Mitigation Center

http://droughtmonitor.unl.edu/

U.S. Drought Monitor

Oklahoma



May 12, 2015

(Released Thursday, May. 14, 2015)

Valid 8 a.m. EDT

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	39.66	60.34	47.39	24.52	3.72	0.00
Last Week 5/5/2015	29.24	70.76	59.05	46.19	17.95	4.03
3 Months Ago 2/10/2015	1.48	98.52	65.04	45.54	22.81	5.75
Start of Calendar Year 12/30/2014	25.63	74.37	62.03	40.84	21.74	5.70
Start of Water Year 9/30/2014	8.55	91.45	73.31	58.13	20.92	4.64
One Year Ago 5/13/2014	8.54	91.46	75.09	64.46	50.06	30.43

Intensity:

- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

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

Author:

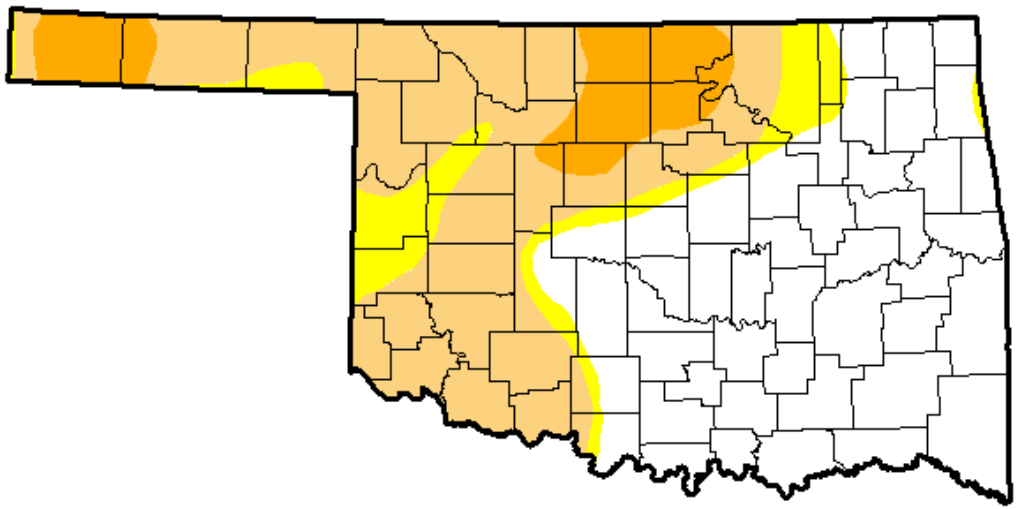
Mark Svoboda

National Drought Mitigation Center

http://droughtmonitor.unl.edu/

U.S. Drought Monitor

Oklahoma



May 19, 2015

(Released Thursday, May. 21, 2015)

Valid 7 a.m. EST

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	49.19	50.81	41.94	8.98	0.00	0.00
Last Week *5/12/2015*	39.66	60.34	47.39	24.52	3.72	0.00
3 Months Ago *2/17/2015*	1.48	98.52	65.04	45.54	22.81	5.75
Start of Calendar Year *12/30/2014*	25.63	74.37	62.03	40.84	21.74	5.70
Start of Water Year *9/30/2014*	8.55	91.45	73.31	58.13	20.92	4.64
One Year Ago *5/20/2014*	5.78	94.22	81.06	73.26	61.24	34.25

Intensity:

- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

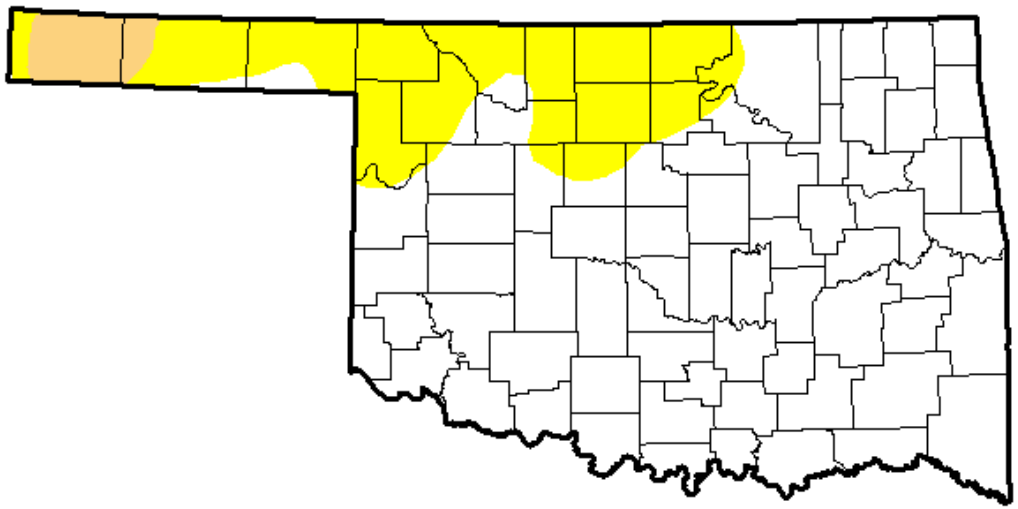
The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

Author:
Brad Rippey
U.S. Department of Agriculture

http://droughtmonitor.unl.edu/

U.S. Drought Monitor

Oklahoma



May 26, 2015

(Released Thursday, May. 28, 2015)

Valid 7 a.m. EST

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	77.31	22.69	2.74	0.00	0.00	0.00
Last Week *5/19/2015*	49.19	50.81	41.94	8.98	0.00	0.00
3 Months Ago *2/24/2015*	1.48	98.52	65.55	48.46	27.80	5.75
Start of Calendar Year *12/30/2014*	25.63	74.37	62.03	40.84	21.74	5.70
Start of Water Year *9/30/2014*	8.55	91.45	73.31	58.13	20.92	4.64
One Year Ago *5/27/2014*	5.78	94.22	79.94	73.26	55.04	26.47

Intensity:

- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

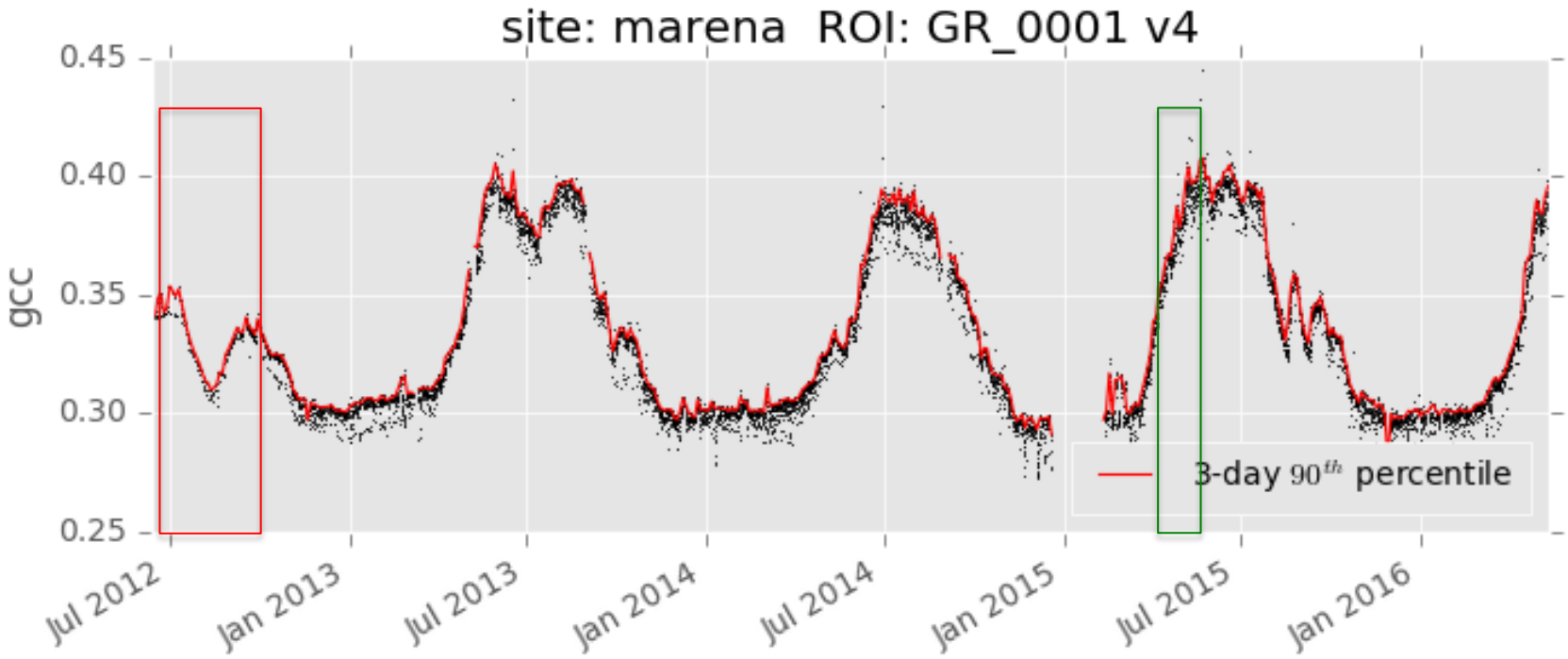
The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

Author:
Brad Rippey
U.S. Department of Agriculture

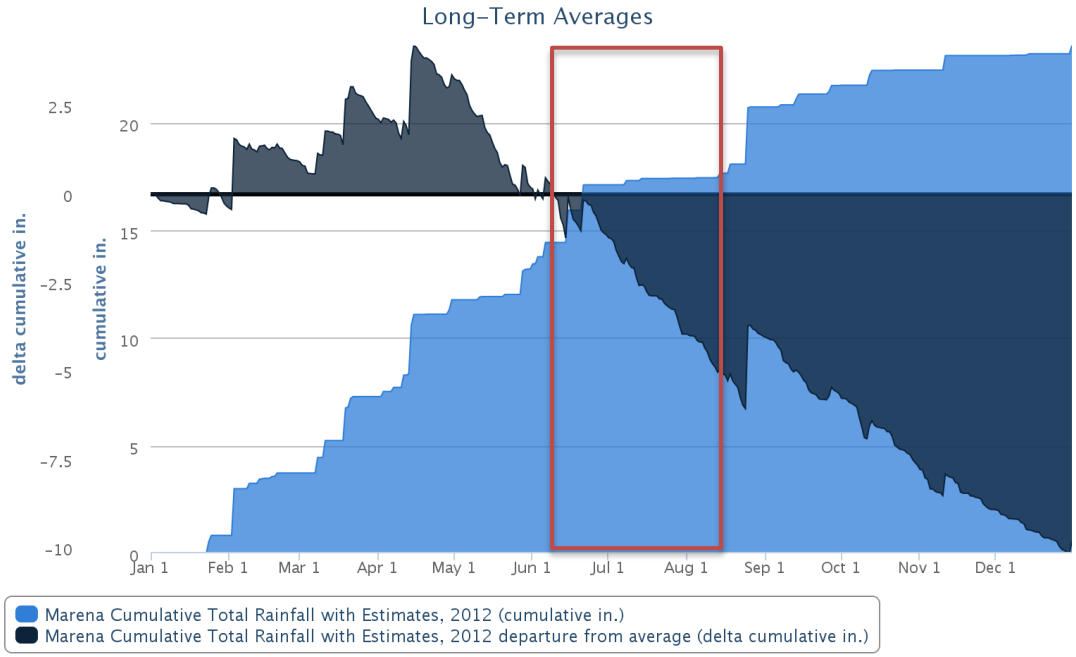
http://droughtmonitor.unl.edu/

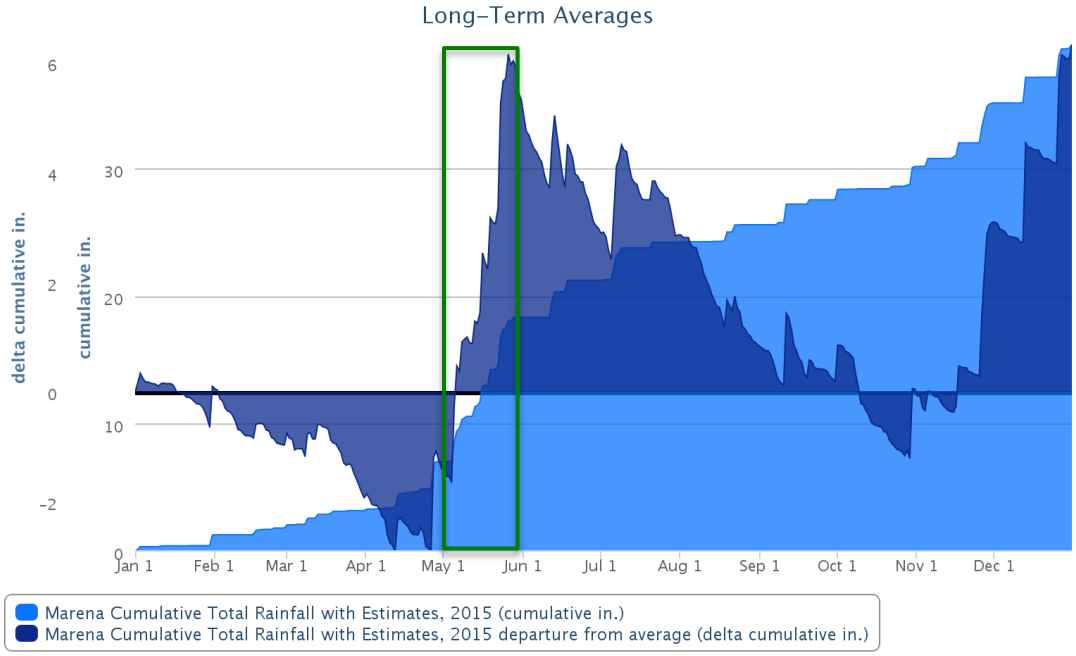

marena - NetCam SC - Tue May 05 2015 08:00:06 CST
Temperature: 39.5
Exposure: 124


marena - NetCam SC - Sun May 24 2015 14:00:07 CST
Temperature: 42.0
Exposure: 103

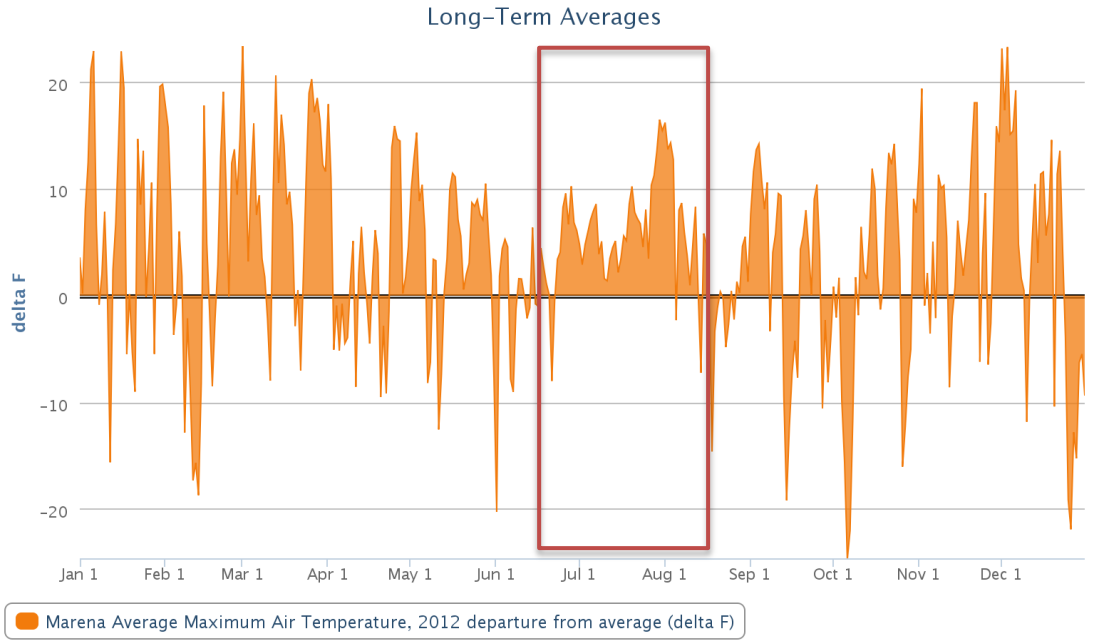


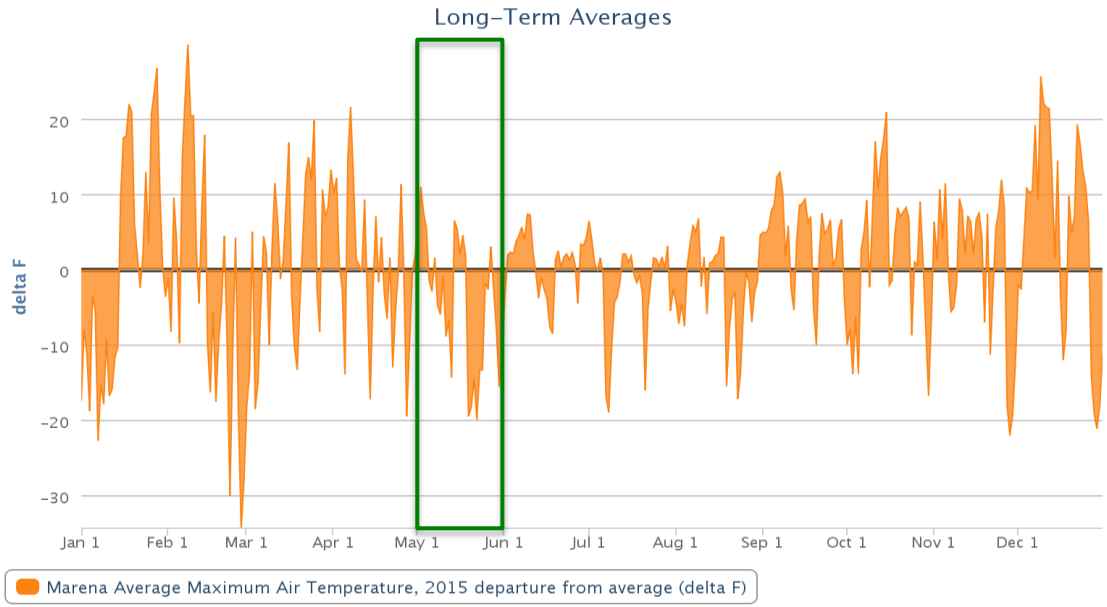
- Flash drought period begins with a very low GCC compared to the same time in other years and falls to ~.30 by the peak of the drought.
- The flash recovery period is harder to pinpoint a substantial change in the GCC given the green up due to the start of the growing season.
- However, during the flash recovery the slope of the GCC curve is very steep suggesting a very quick vegetation growth.


Long-Term Averages
delta cumulative in.
cumulative in.
2.5
0
-2.5
-5
-7.5
-10
20
15
10
5
0
Jan 1
Feb 1
Mar 1
Apr 1
May 1
Jun 1
Jul 1
Aug 1
Sep 1
Oct 1
Nov 1
Dec 1
Marena Cumulative Total Rainfall with Estimates, 2012 (cumulative in.)
Marena Cumulative Total Rainfall with Estimates, 2012 departure from average (delta cumulative in.)

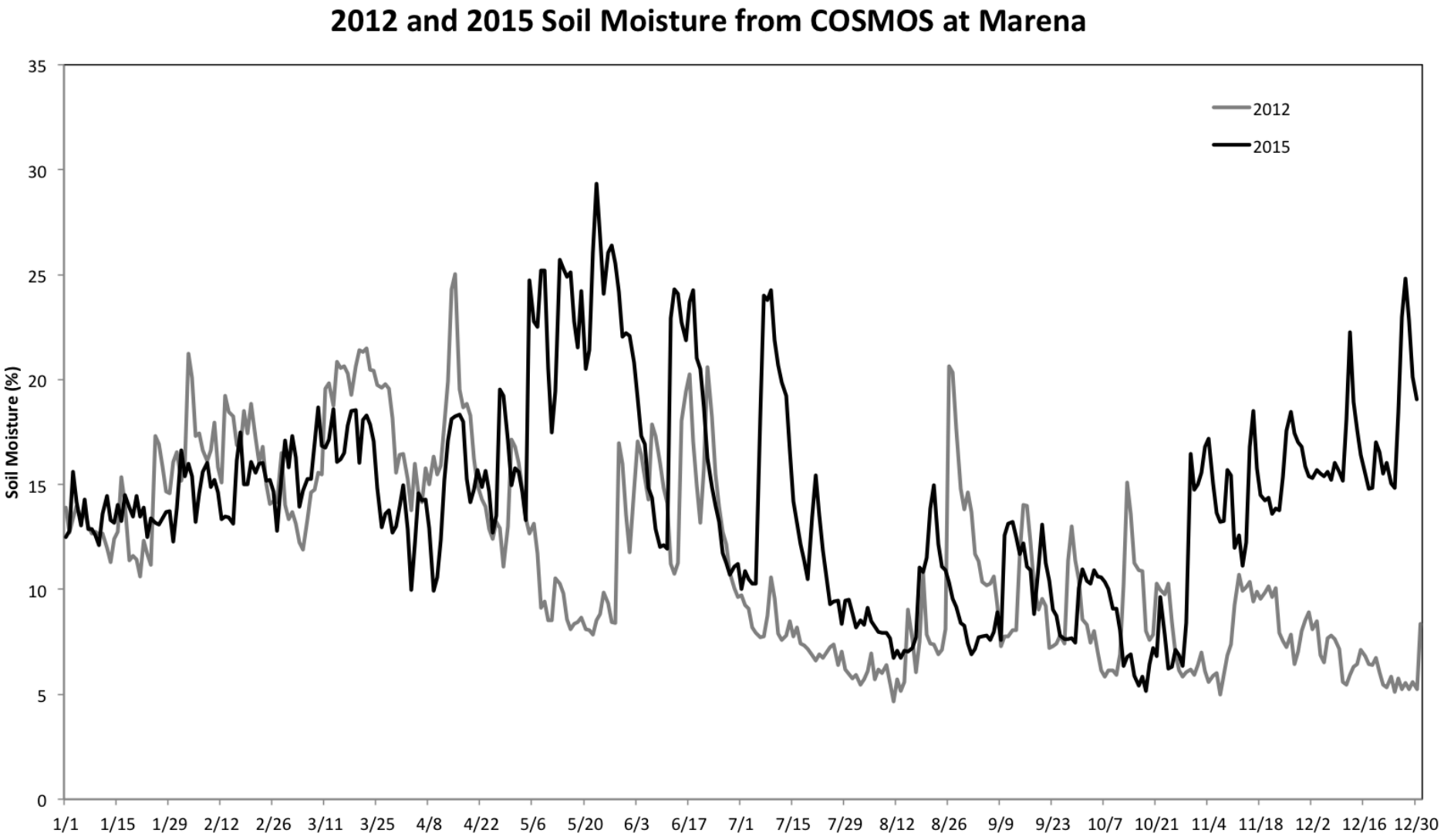

Long-Term Averages
delta cumulative in.
cumulative in.
6
4
2
0
-2
30
20
10
0
Jan 1
Feb 1
Mar 1
Apr 1
May 1
Jun 1
Jul 1
Aug 1
Sep 1
Oct 1
Nov 1
Dec 1
Marena Cumulative Total Rainfall with Estimates, 2015 (cumulative in.)
Marena Cumulative Total Rainfall with Estimates, 2015 departure from average (delta cumulative in.)

Mesonet

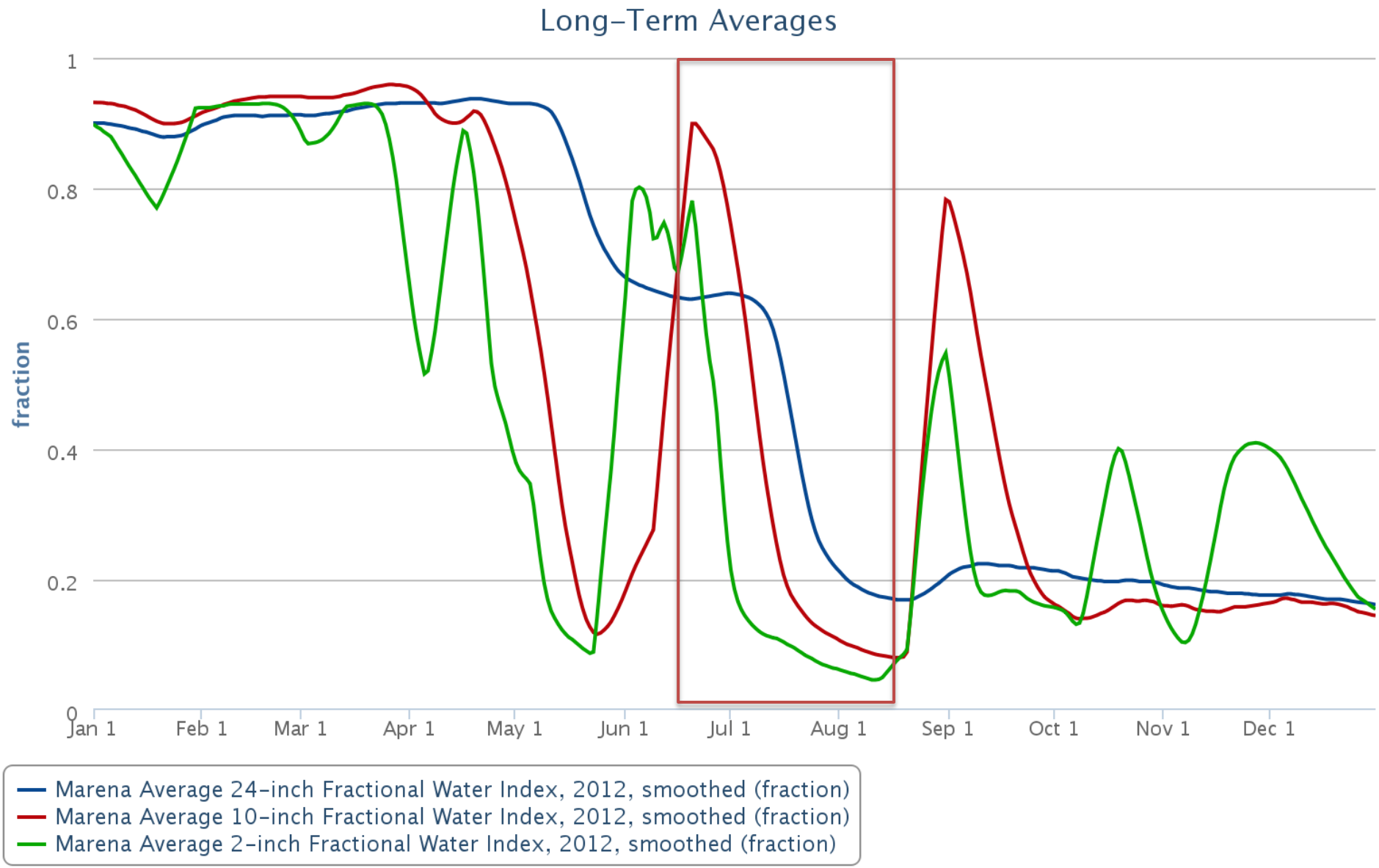

Long-Term Averages
delta F
20
10
0
-10
-20
Jan 1
Feb 1
Mar 1
Apr 1
May 1
Jun 1
Jul 1
Aug 1
Sep 1
Oct 1
Nov 1
Dec 1
Marena Average Maximum Air Temperature, 2012 departure from average (delta F)

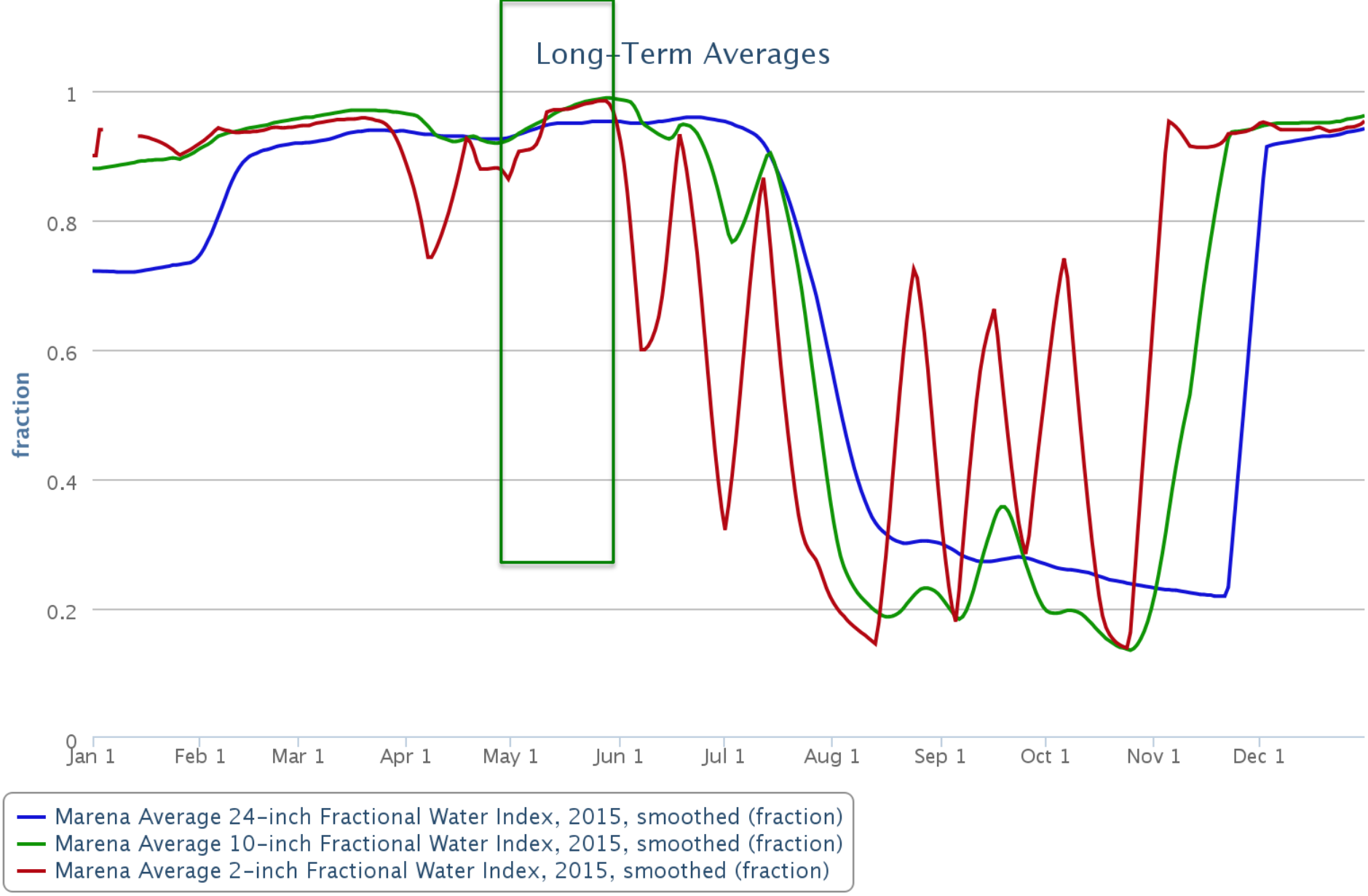

Long-Term Averages
delta F
20
10
0
-10
-20
-30
Jan 1
Feb 1
Mar 1
Apr 1
May 1
Jun 1
Jul 1
Aug 1
Sep 1
Oct 1
Nov 1
Dec 1
Marena Average Maximum Air Temperature, 2015 departure from average (delta F)

Mesonet

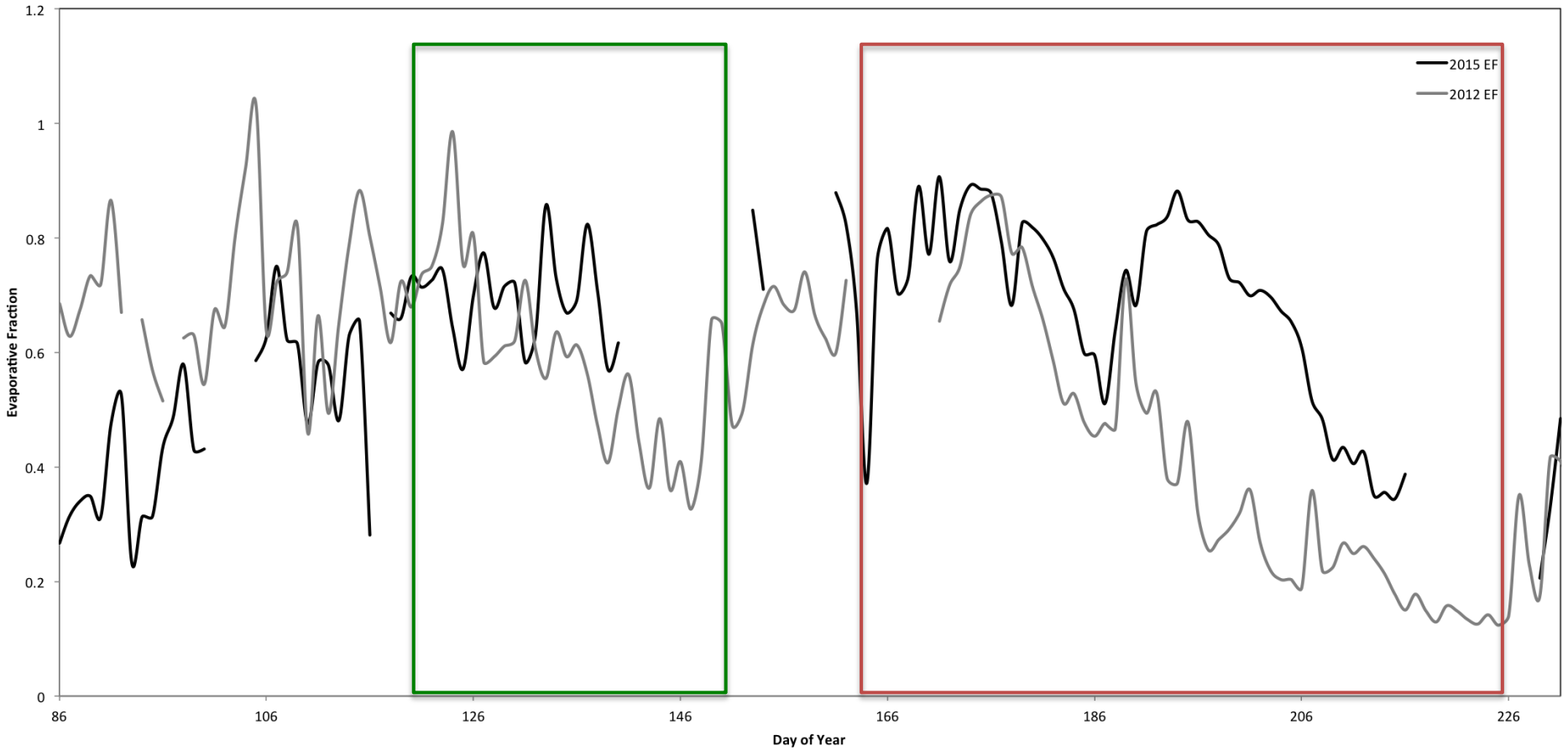


- Footprint radius of 130 – 240 m
- Penetration depth 15-83 cm (Kohli et al. 2015)


Long-Term Averages
fraction
1
0.8
0.6
0.4
0.2
0
Jan 1
Feb 1
Mar 1
Apr 1
May 1
Jun 1
Jul 1
Aug 1
Sep 1
Oct 1
Nov 1
Dec 1
Marena Average 24-inch Fractional Water Index, 2012, smoothed (fraction)
Marena Average 10-inch Fractional Water Index, 2012, smoothed (fraction)
Marena Average 2-inch Fractional Water Index, 2012, smoothed (fraction)

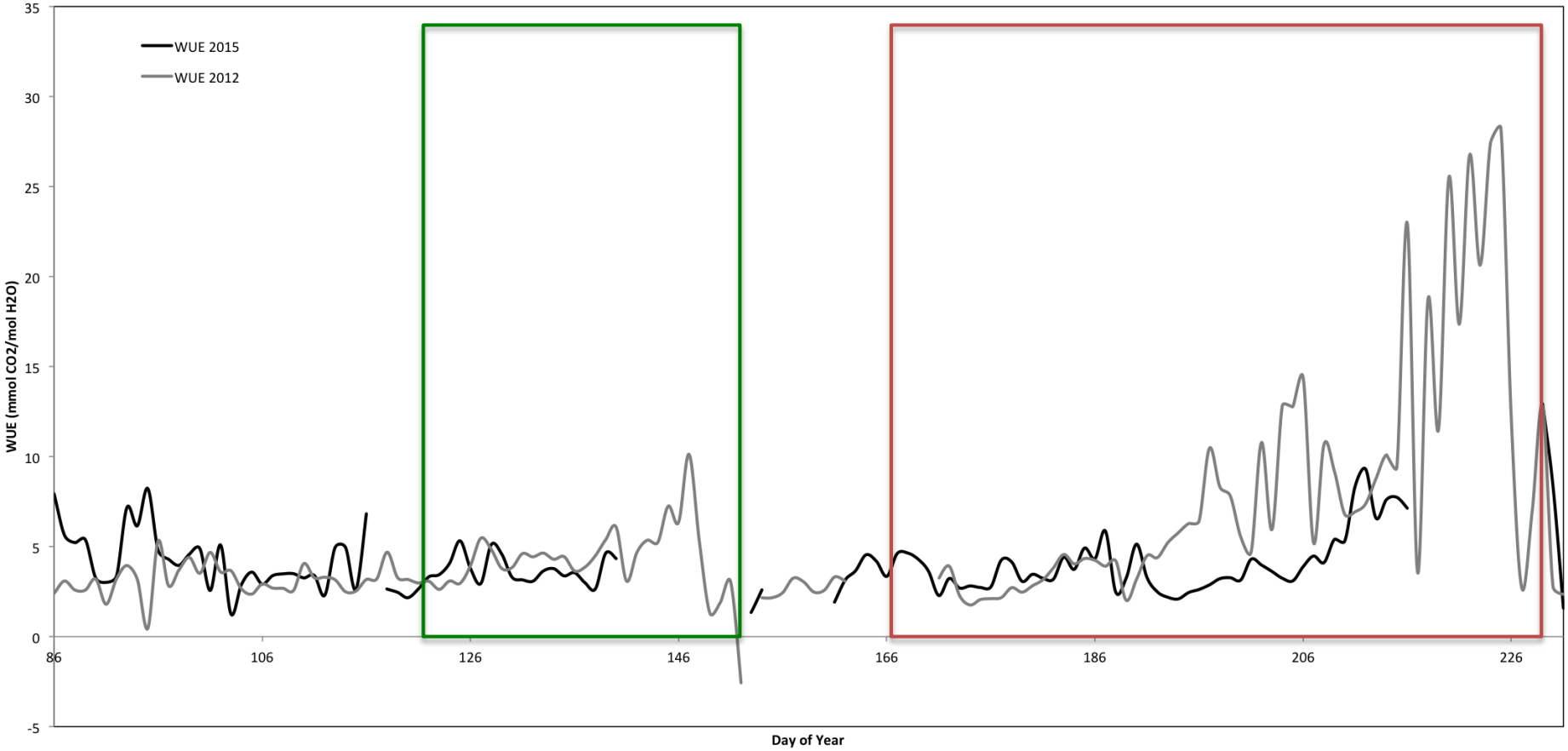

Long-Term Averages
1
0.8
0.6
0.4
0.2
0
fraction
Jan 1
Feb 1
Mar 1
Apr 1
May 1
Jun 1
Jul 1
Aug 1
Sep 1
Oct 1
Nov 1
Dec 1
Marena Average 24-inch Fractional Water Index, 2015, smoothed (fraction)
Marena Average 10-inch Fractional Water Index, 2015, smoothed (fraction)
Marena Average 2-inch Fractional Water Index, 2015, smoothed (fraction)

Evaporative Fraction for 2012 and 2015 at Marena



$$EF = \frac{Q_e}{Q_e + Q_h}$$

Water Use Efficiency for 2012 and 2015 at Marena



Flash Drought Timeline

April/May

- No drought
- Anomalously warm and dry period
- Soils start to dry

June

- Early rainfall increased shallow soil moisture but not deep soil moisture
- EF increases
- WUE decreases
- Rainfall ends
- Temperature anomaly increases
- Moderate drought sets in

July

- Vegetation still appears healthy based on GCC
- No rainfall occurs
- EF falls to about .2
- Temps ~10 degrees above normal
- Soil moisture goes from 20% to 5% and FWI below .2 for all depths
- Moderate drought transitions to severe and then extreme
- GCC starts to decrease
- WUE increases

August

- Ecosystem collapsed
- Exceptional drought
- 6 inches of rain below normal
- 15 degrees above normal
- Soil moisture at 5%
- EF ~.1
- WUE very high

Flash Recovery Timeline

May: Week 1

- Severe drought
- GCC ~.35
- 2.62” rain
- Below normal temps
- Soil Moisture rose from 12% to 25%
- EF increases to .7
- WUE low for the entire period

May: Week 2

- Severe/Moderate drought
- 1.79” rain
- Below normal temps
- Soil moisture stayed around 25%

May: Week 3

- Moderate drought/abnormally dry
- 2.82” rain
- Up to 20 degrees below normal temps
- Soil moisture stayed around 25%
- EF increased to .8

May: Week 4

- Drought is gone
- Vegetation healthy
- 4.09” rain
- Below normal temps
- Soil moisture rose to over 30%

Flash Drought Conclusions

- Flash drought occurred from anomalously low precipitation.
  - This led to a negative feedback loop by reducing vegetation health, which led to lower latent heat flux and increased sensible heat fluxes that induced higher temperature anomalies.
- A recharge in shallow soil moisture helped to increase ET rates and deplete deeper soil moisture before flash drought occurred.
  - This recharge resulted in low WUE values
- EF fell below .5 during flash drought signaling a decrease in latent heating and an increase in sensible heating.
- Flash drought resulted in greater WUE as conditions became more water scarce

Flash Recovery Conclusions

- Flash recovery occurred as a result of anomalously high precipitation.
  - Created anomalously low temperature that reduced evaporative demand.
- Flash recovery was not as substantial as the flash drought period. However, there was still 3 drought class changes (Severe → None) in less than a months time.
- EF rose above .5 during flash recovery.
- Precursor to flash recovery is much more difficult to deduce than flash drought as it is more atmospherically driven.
- Very different warm season ecosystem compared to flash drought year, as a result of moist conditions

Thanks for your attention!

Questions?