Upper Missouri River Basin
January 2016 Calendar Year Runoff Forecast
January 12, 2016

U.S. Army Corps of Engineers, Northwestern Division
Missouri River Basin Water Management
Omaha, NE

Calendar Year Runoff Forecast

Explanation and Purpose of Forecast

The long-range runoff forecast is presented as the Calendar Year Runoff Forecast. This forecast is developed shortly after the beginning of each calendar year and is updated at the beginning of each month to show the actual runoff for historic months of that year and the updated forecast for the remaining months of the year. This forecast presents monthly inflows in million acre-feet (MAF) from five incremental drainage areas, as defined by the individual System projects, plus the incremental drainage area between Gavins Point Dam and Sioux City. Due to their close proximity, the Big Bend and Fort Randall drainage areas are combined. Summations are provided for the total Missouri River reach above Gavins Point Dam and for the total Missouri River reach above Sioux City. The Calendar Year Runoff Forecast is used in the Monthly Study simulation model to plan future system regulation in order to meet the authorized project purposes throughout the calendar year.

December 2015 Calendar Year Runoff

December 2015 Missouri River runoff was 1.2 MAF (155% of normal) above Sioux City. The (preliminary, with no holdouts) calendar year 2015 runoff summation above Sioux City, IA was 25.8 MAF (102% of average), while it was 23.3 MAF (101% of average) above Gavins Point. These preliminary runoff volumes will be finalized within the first few months of 2016.

2016 Calendar Year Forecast Synopsis

The January 1 forecast for the 2016 Missouri River runoff above Sioux City, IA is **23.8 MAF (94% of normal)**. Runoff above Gavins Point Dam is forecast to be **21.6 MAF (94% of normal)**. Due to the amount of variability in precipitation and other hydrologic factors that can occur over the next 12 months, the range of expected inflow is quite large and ranges from the 32.9 MAF upper basic forecast to the 15.7 MAF lower basic forecast. The upper and lower basic forecasts are used in long-term regulation planning models to "bracket" the range of expected runoff given much wetter or drier conditions, respectively. Given that 12 months are being forecasted for this January 1 forecast (0 months observed/12 months forecast), the range of wetter than normal (upper basic) and lower than normal (lower basic) is attributed to all 6 reaches for all 12 months. The result is a large range or "bracket" for each reach, and thus, for

the total runoff forecast. As the year progresses, the range will lessen as the number of observed months increases and number of forecast months decreases.

Current Conditions

Drought Analysis

The latest National Drought Mitigation Center's drought monitor for December 29, 2015 (**Figure 1**), when compared to the drought monitor for November 24, 2015 (**Figure 2**), shows relatively little change in drought conditions in the upper Basin above Sioux City, IA. There has been some contraction in Abnormally Dry (D0) conditions in southern Montana, southwest South Dakota and northwest Nebraska; however, Abnormally Dry (D0) to Severe Drought (D2) conditions are still present in western Montana in the upper Basin. In the lower Basin, heavy December rainfall and snowfall has nearly erased any signs of drought and dryness in Kansas, making the lower Basin drought free. The U.S. Seasonal Drought Outlook in **Figure 3** indicates that drought will persist in western Montana and south central North Dakota; and, drought will likely develop in central and eastern Montana through the end of March 2016.

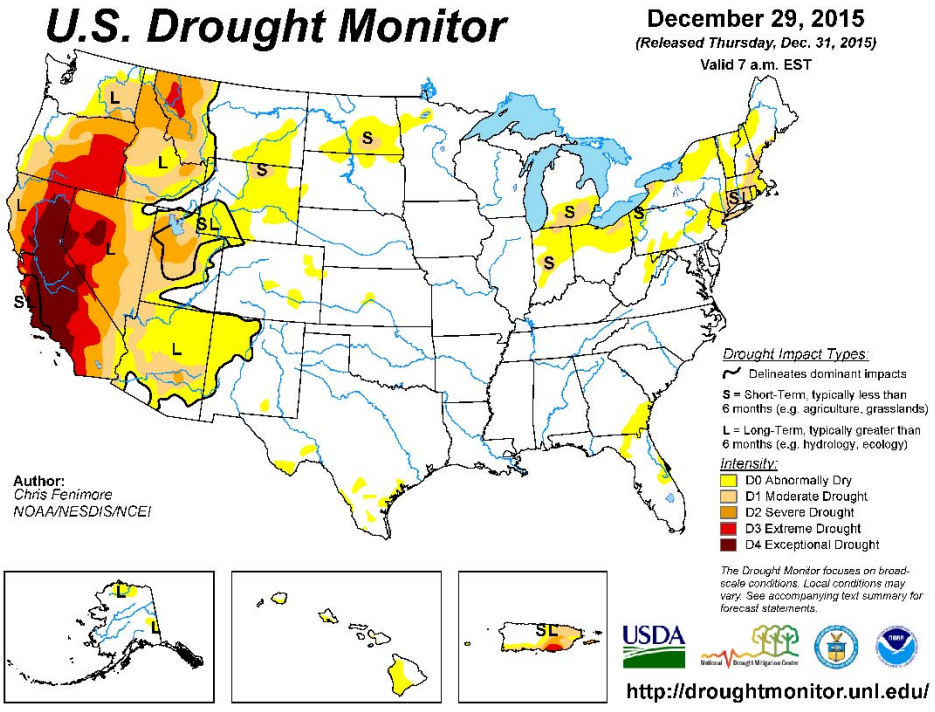


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for December 29, 2015.

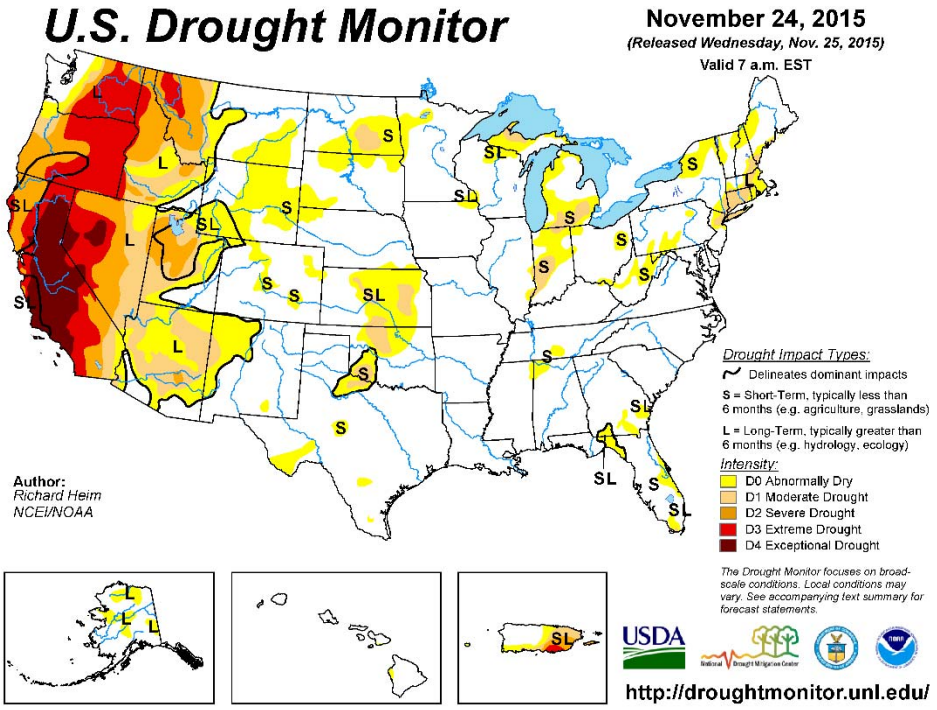


Figure 2. National Drought Mitigation Center U.S. Drought Monitor for November 24, 2015.

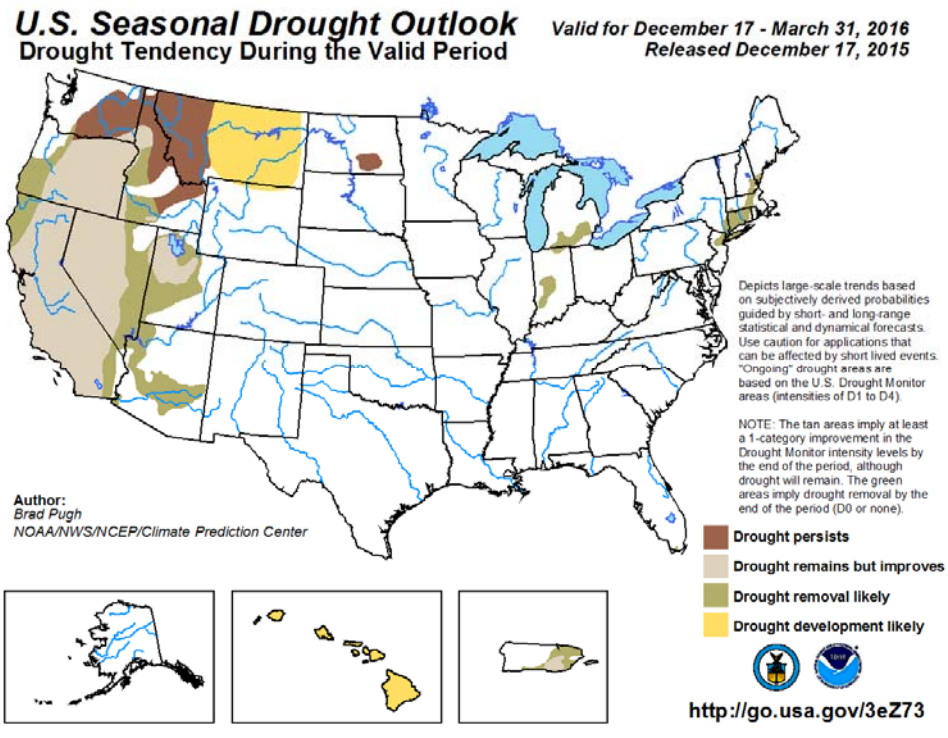


Figure 3. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

December precipitation accumulations are shown in **Figure 4** as both inches of precipitation (left) and percent of normal monthly precipitation (right). Heavy precipitation occurred in two storms during December 12-14 and December 25-28. Heavy precipitation totals ranging from 3 to 6 inches occurred in eastern Nebraska and western Iowa; while precipitation totals in eastern Kansas and Missouri averaged about 6 inches. The Osage and Gasconade Basins in Missouri received 6 to 12 inches of precipitation in December causing major flooding in the lower Basin. December precipitation accumulations were more than 2 times normal in western Montana, central North Dakota, South Dakota, Nebraska, Iowa, Kansas and Missouri.

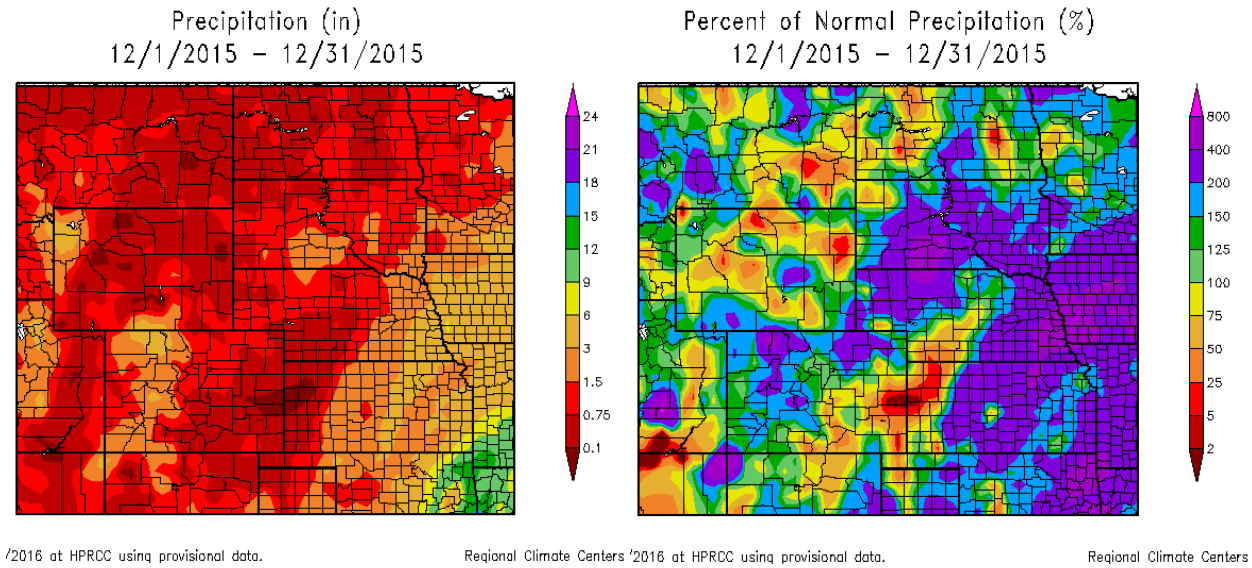


Figure 4. December 2015 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

October-November-December precipitation accumulations are shown in **Figure 5**. The three-month accumulations reflect a dry pattern across central and northern Wyoming, southern and eastern Montana, North Dakota and northern South Dakota. Wetter-than-normal precipitation accumulations occurred in all other areas, highlighted by more than 150% of normal precipitation in central and northern Montana, southwest South Dakota, Nebraska, Iowa, Kansas and Missouri.

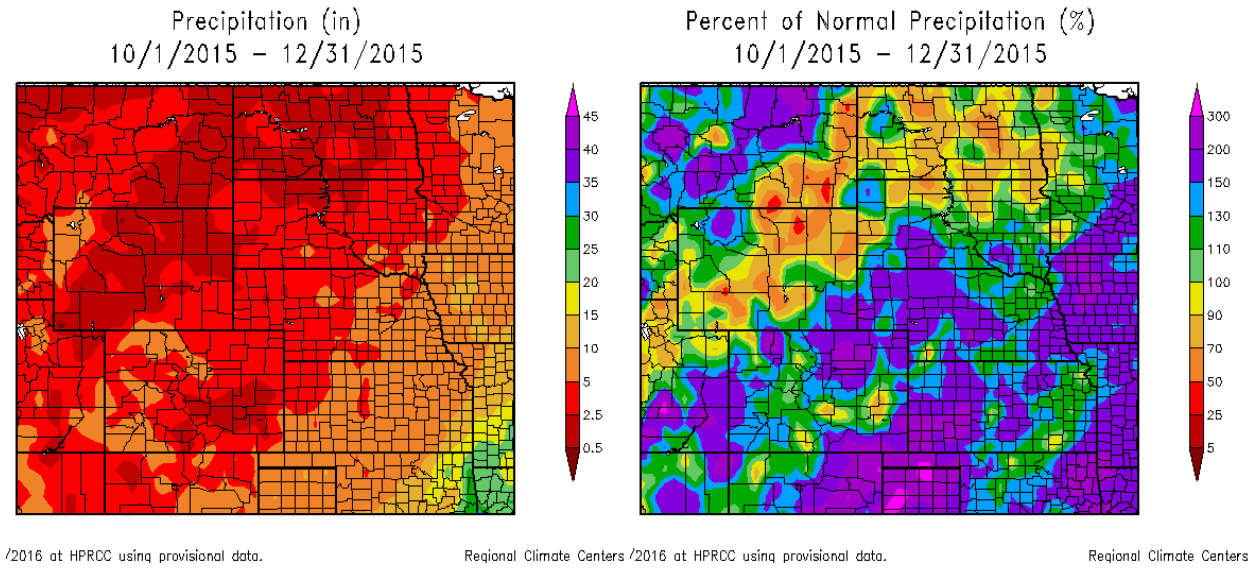


Figure 5. October-November-December 2015 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Temperature

December temperature departures from normal in degrees Fahrenheit (deg F) are shown in **Figure 6**. December temperatures in the Basin ranged from near normal in the Rocky Mountains to over 9 deg F above normal in the Midwest. The warmest temperatures (greater than 9 deg F above normal) occurred over Minnesota, Iowa and Missouri. In December, cold temperatures typically form river ice on the Missouri River and its tributaries above Sioux City; however, much warmer-than-normal temperatures in December inhibited the development of river ice. As a result, December runoff was higher than average due in part to the lack of river ice formation. Three-month (November-December-January) temperature departures are shown in **Figure 7**. The map indicates a very similar pattern of temperature departures over the Missouri Basin.

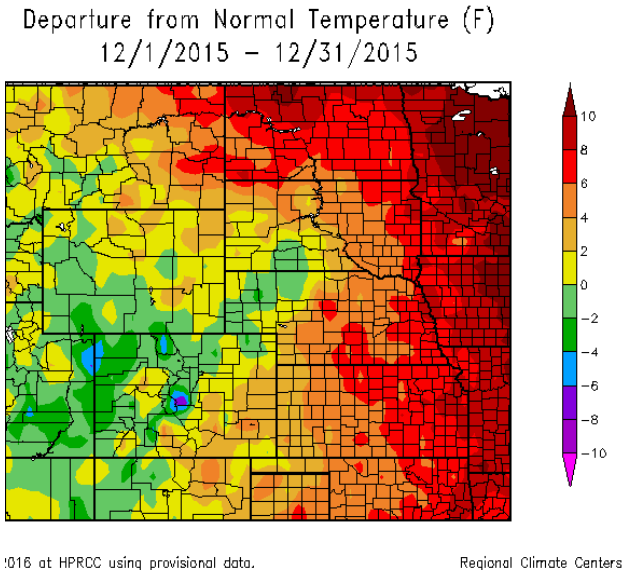


Figure 6. December 2015 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

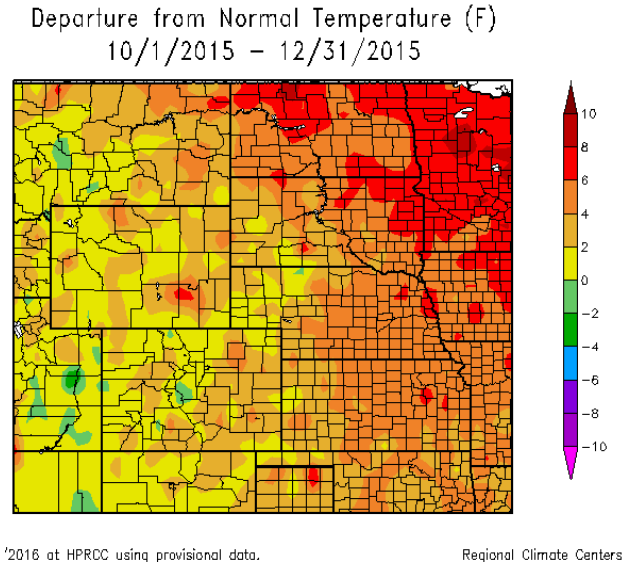


Figure 7. October-November-December 2015 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Soil Moisture

Soil moisture is factored into the forecast as an indicator of wet or dry hydrologic basin conditions. Typically when soil moisture conditions are wet or greater than normal, rainfall and snowmelt runoff is greater than when soil moisture is dry or less than normal. Not only is soil moisture a physical parameter that influences runoff, it can be used as an indicator of future runoff.

Figure 8 shows the NOAA NLDAS ensemble mean soil moisture percentiles on December 30, 2015 for the top 1-meter of the modeled soil column. The NLDAS soil moisture depiction is an average value for the soil moisture column. **Figure 8** indicates above normal soil moisture conditions are present throughout much of the upper Basin, though there are dry areas including north central Wyoming, eastern Montana, and eastern North Dakota. Very wet soil moisture conditions (greater than 95th percentile moisture) are indicated in north central Montana, eastern Nebraska, western Iowa, and the lower Missouri Basin in Missouri.

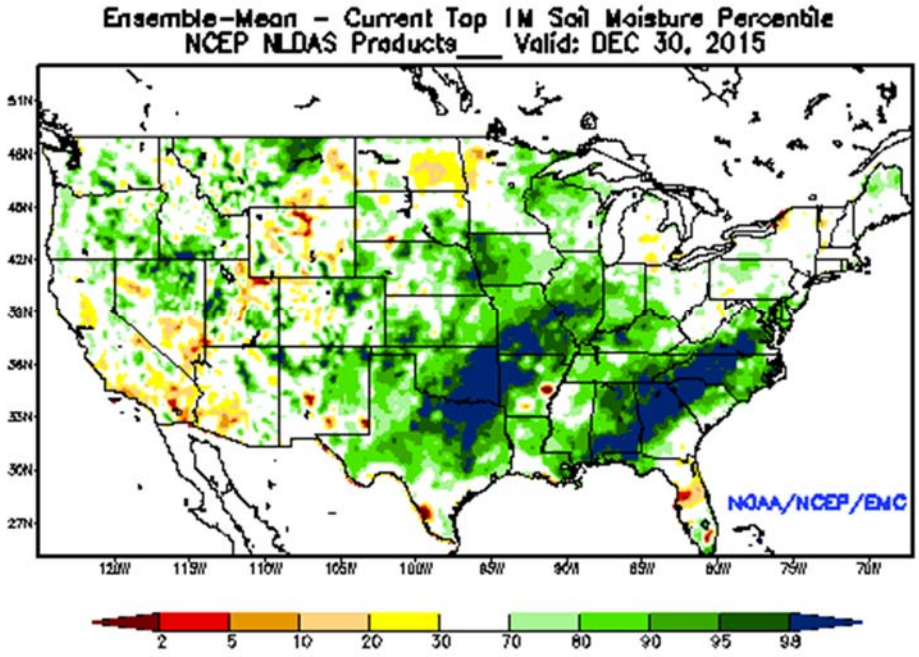


Figure 8. Top 1-Meter Soil Moisture Percentile on December 30, 2015. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

Frost Conditions

Figure 9 shows depth of frost penetration at National Weather Service (NWS) Warning Forecast Office (WFO) locations in the Missouri Basin as of January 4, 2016. While some frost depth measurements are missing, measurements indicate soils have frozen at 12- to 18-inch depths in Montana, 19 inches deep in northwest North Dakota, 16- to 18-inch depths in southern North Dakota and northern and western South Dakota, but only 1 inch deep in Sioux Falls, SD. Shallower frost depths of 6 to 12 inches are also present in central Nebraska, while frost depths ranging from 0 to 2 inches are present in Missouri. Soil frost acts as a semi-impervious layer to snowmelt or precipitation infiltration into the soil.

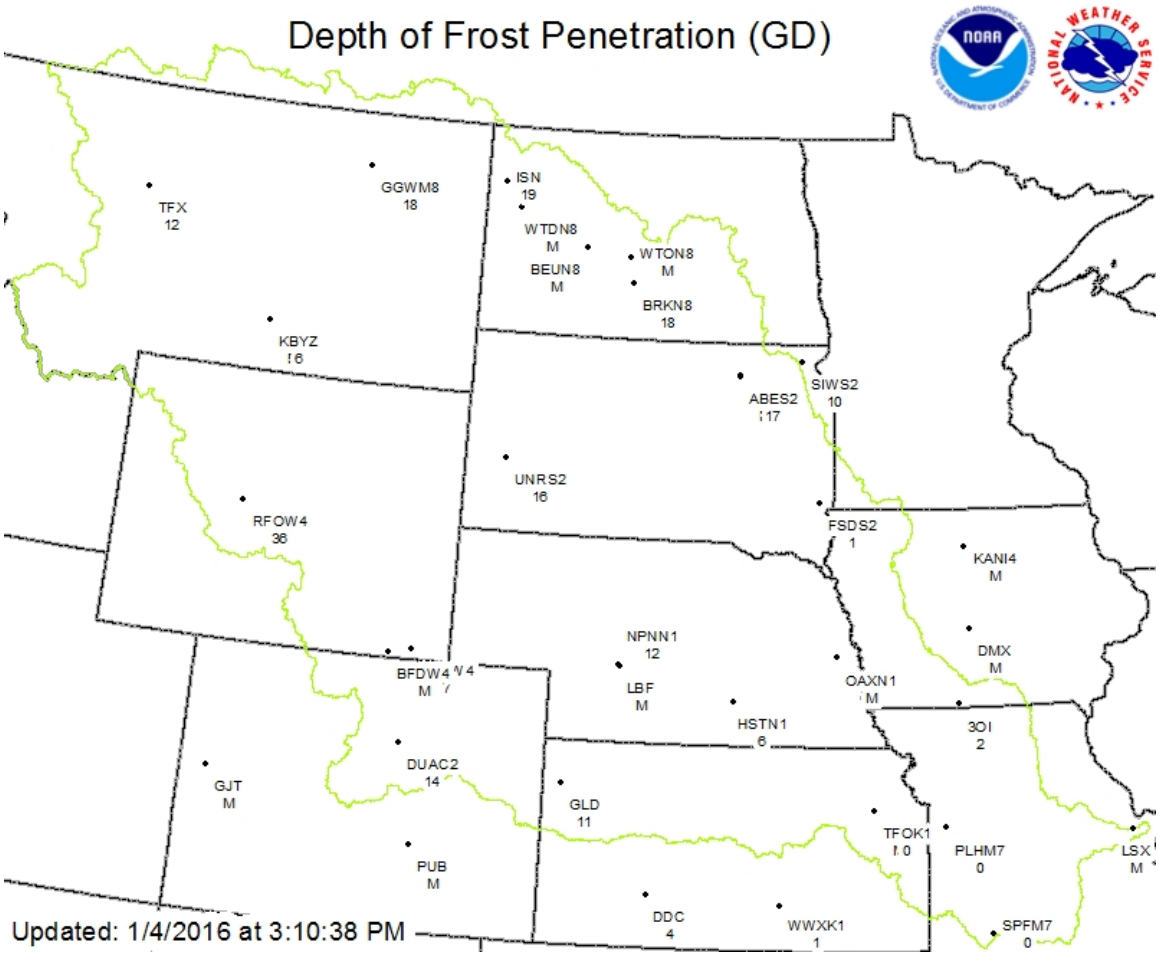
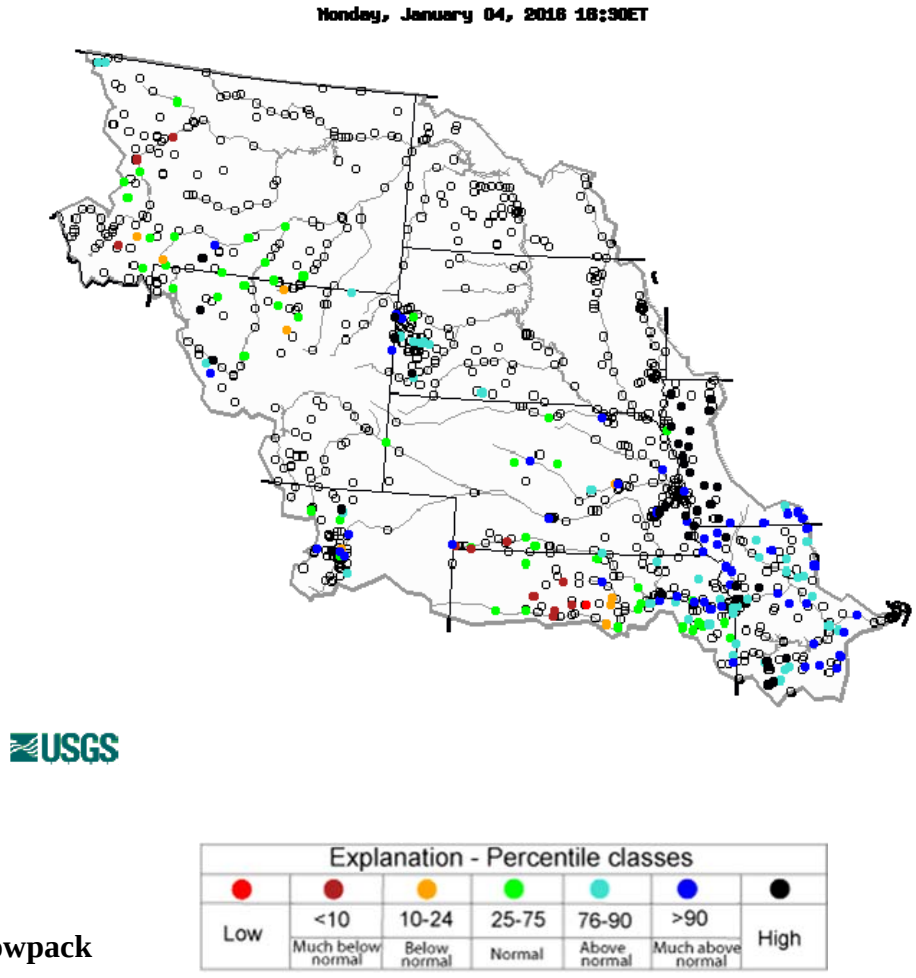


Figure 9. Measured frost depth (inches) at NWS WFO offices as of January 4, 2016. Source: NWS MBRFC.
http://www.crh.noaa.gov/mbrfc

Streamflow Conditions

Missouri Basin streamflow conditions are shown in **Figure 10**. These conditions are based on the ranking of the January 4, 2016 daily streamflow versus the historical record of streamflow for that date. As shown in Figure 10, where streams are currently not influenced by ice formation, streamflow conditions continue to be "Much above normal" (greater than the 90th percentile) in Nebraska, Iowa, Kansas and Missouri. Some locations on the lower Missouri River and its tributaries are considered "High" as a result of record high December precipitation. As a result of this precipitation the Osage River, Gasconade River and lower Missouri River in Missouri experienced "Major" flooding at the end of December. In the upper Basin, a majority of stations have no classification because the current stream gages are either ice-affected or the historical record is ice-affected. The few stations in the upper Basin that are reporting indicate streamflow conditions, particularly in Montana and Wyoming, are "Normal" (25th-75th percentile) to "Below normal" (10th-24th percentile).



Plains Snowpack

Figure 10. USGS Streamflow Conditions as a Percentile of Normal in the Missouri River Basin as of January 4, 2016. Source: USGS. http://waterwatch.usgs.gov/index.php

Plains snowpack is an important parameter that influences the volume of runoff occurring in the basin during the months of March and April. A common misperception is that the March-April runoff is a result of plains snowmelt only. Historically, about 25% of annual runoff occurs in March and April, during the time when plains snow is melting, due to both melting snowpack and rainfall runoff. Runoff occurs in March and April whether or not there is any plains snow to melt. Determining exact rainfall amounts and locations are nearly impossible to predict more than a week in advance. Thus, the March-April runoff forecast is formulated based on existing plains snowpack and existing basin conditions and hydrologic forecasts, which for this year primarily includes long-term precipitation outlooks.

Based on the National Operational Hydrologic Remote Sensing Center (NOHRSC) assessment (**Figure 11**) as of January 1, 2016 there were trace to 1-inch amounts of snow water equivalent (SWE) over most of the upper Missouri Basin above Sioux City, IA. Greater amounts ranging from 1 to 2 inches of SWE are present in western and south central Montana, southern and eastern South Dakota, Wyoming, and northern Nebraska.

To supplement the NOHRSC snow assessment and verify modeled snow depths and SWE, MRBWMD began the 2016 cooperative plains snow survey on January 4, 2016. Volunteers made in-situ depth and SWE measurements in locations across Montana, South Dakota and North Dakota and reported the measurements to MRBWMD. These measurements were provided to NOHRSC and MBRFC, and are posted to MRBWMD's website at: http://www.nwd-mr.usace.army.mil/rcc/snowsurvey/snowsurvey.html.

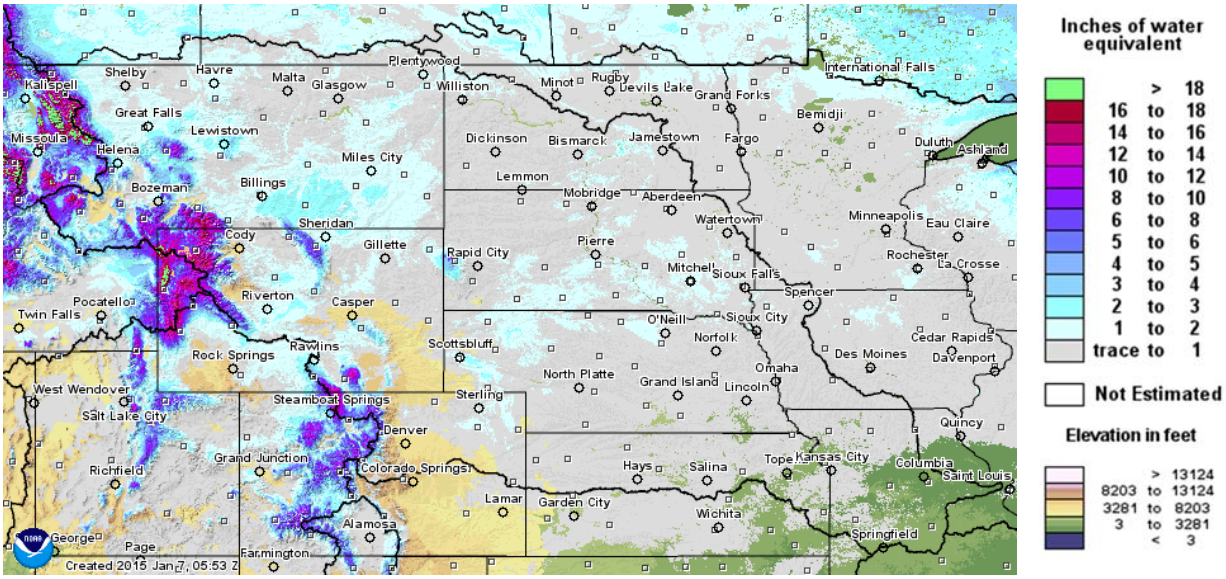
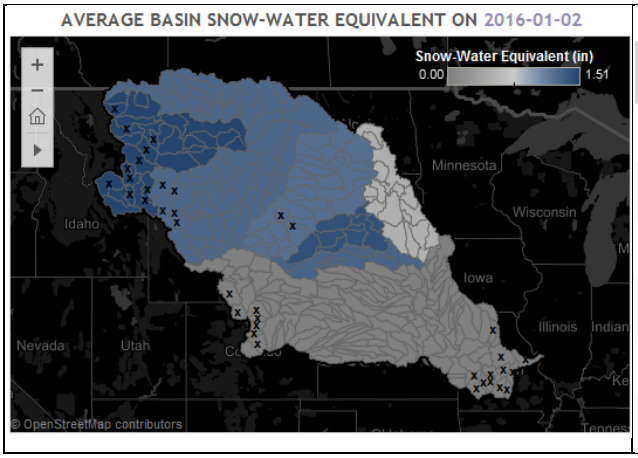


Figure 11. January 1, 2016 NOHRSC modeled plains snow water equivalent. Source: NOAA National Operational Hydrologic Remote Sensing Center. http://www.nohrsc.nws.gov/interactive/html/map.html

MRBWMD and the USACE Cold Regions Research and Engineering Laboratory (CRREL) has developed an application to estimate plains snowpack in the upper Missouri Basin using SSM/I satellite-based estimates of SWE. This application can estimate HUC-8 and reservoir reach

basin-average SWE on a weekly basis. **Figure 13** includes a map of the Missouri Basin with SWE estimated in each of the Mainstem Reservoir reaches for the week ending on January 2, 2016. **Figure 13** indicates that the greatest average reach SWE was present in the Fort Peck and Fort Randall reaches. The least reach SWE was present in the Gavins Point to Sioux City reach. The table in **Figure 13** lists a calculated estimate of average basin SWE for the week ending on January 2, versus the historical median SWE (1987-2015). The table indicates that average basin SWE was greater than median in all reaches except the Gavins Point to Sioux City reach.



DETAILED DATA FOR 2016-01-02

Region	Avg Basin SWE (in)	Historical Median SWE (in)	% of Median SWE
Above Fort Peck	1.51	0.96	156%
Fort Peck to Garrison	1.27	1.26	101%
Fort Randall to Gavins Point	1.30	0.37	350%
Garrison to Oahe	1.22	0.84	145%
Gavins Point to Sioux City	0.49	0.94	52%
Oahe to Fort Randall	1.42	0.65	219%

Figure 12. Experimental SSM/I Satellite-Based Plains Snowpack Estimate for the Mainstem Reservoir System.

Using the MRBWMD snowpack classification method, plains snowpack for the January 1, 2016 runoff forecast was classified according to the terminology listed in **Table 3**. A "Light" snowpack indicates snow cover that is above the median SWE, and a "Moderate" snowpack is greater than "Light". "Average" basin conditions indicate snowpack is less than "Light" with no measureable snow accumulations. March-April runoff in "Average" conditions is expected to be below or near long term average runoff. Runoff resulting from "Light" and "Moderate" snowpack accumulations is expected to be above long term average March-April runoff.

Table 1. Plains snowpack classification for the January 1, 2016 runoff forecast.

Reservoir Reach	Plains Snowpack Classification
Above Fort Peck	Light - Moderate
Fort Peck to Garrison	Average - Light
Garrison to Oahe	Light
Oahe to Fort Randall	Light
Fort Randall to Gavins Point	Light
Gavins Point to Sioux City	Average

Mountain Snow Pack

Mountain snowpack is the primary factor used to predict May-July runoff volumes in the Fort Peck and Fort Peck to Garrison mainstem reaches. During the 3-month May-July runoff period, about 50% of the annual runoff enters the mainstem system as a result of mountain snowmelt and rainfall runoff. Greater-than-average mountain snow accumulations are usually associated with greater-than-average May-July runoff volumes, especially when mountain soil moisture conditions have been wetter than normal as in the past three years. For example, we would expect to see greater-than-average runoff from an average mountain snowpack this year due to wetter-than-normal soil moisture conditions.

Figure 14 includes time series plots of the average mountain SWE beginning on October 1, 2015 based on the NRCS SNOTEL gages for the headwater basin above Fort Peck and the incremental basin from Fort Peck to Garrison. The current average SWE values (shaded blue area) are plotted against the 1981-2010 basin average SWE (bold red line), a recent low SWE year in 2001 (green line), and two historic high SWE years occurring in 1997 (purple) and 2011 (dark blue).

As of **December 31, 2015**, the Corps of Engineers computed an average mountain SWE in the **Fort Peck reservoir reach of 7.0 inches, which is 100% of average** based on the 1981-2010 average SWE for the Fort Peck reach. In the **reservoir reach between Fort Peck Dam and Garrison Dam**, the Corps computed an average mountain SWE of **4.8 inches, which is 76% of average** based on the 1981-2010 average SWE for the Garrison reach. Normally by January 1, 44% of the peak snow accumulation has occurred in the mountains.

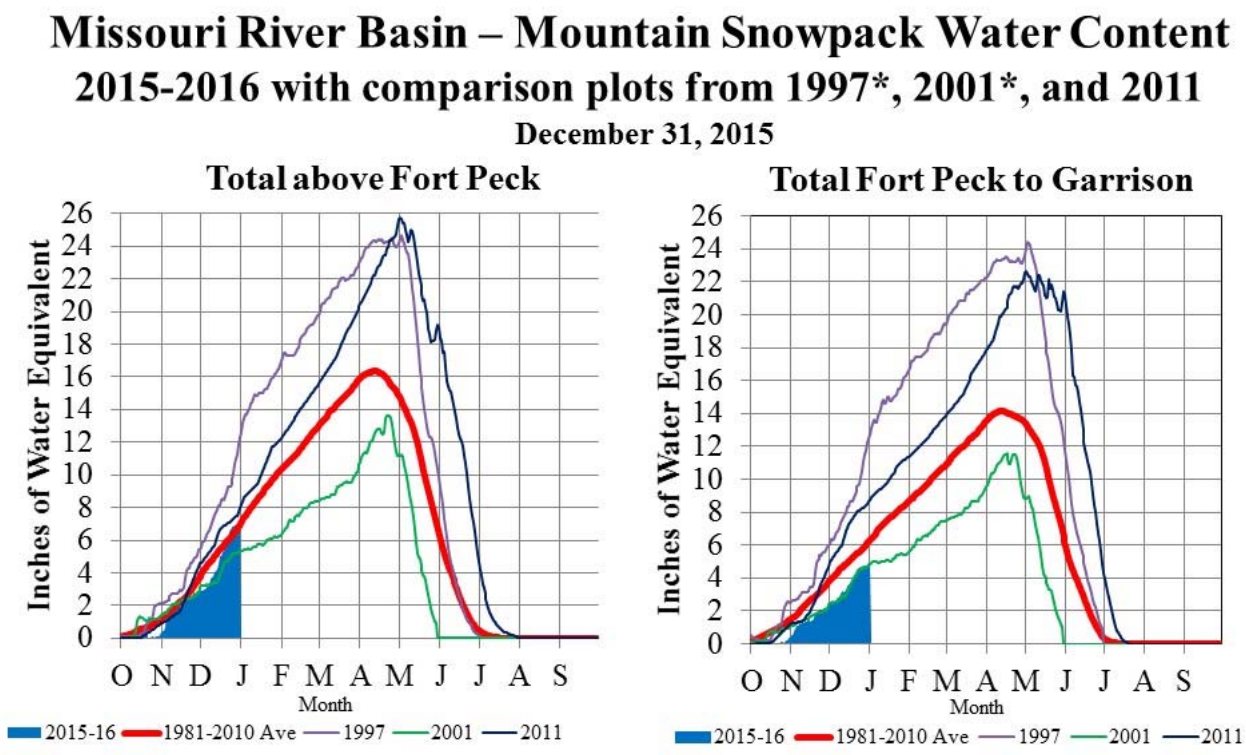


Figure 13. Mountain snowpack water content on December 31, 2015 compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management.

Climate Outlook

ENSO (El Niño Southern Oscillation)

According to the CPC's latest monthly update[1] on January 4, 2016, "***El Niño is expected to remain strong through the Northern Hemisphere winter 2015-2016, with a transition to ENSO-neutral anticipated during the late spring or early summer 2016***". CPC studies are predicting a strong El Niño event at its peak. El Niño winters have a tendency to be warmer and drier than normal in the upper Missouri Basin, and the influence of El Niño has been factored into the CPC's climate outlooks.

MRBWMD participates in the monthly North Central U.S. Climate/Drought Outlook Webinar coordinated through NOAA, the regional climate centers, and the American Association of State Climatologists (AASC). These webinars provide updates on near-term climate outlooks and

[1] http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/lanina/enso_evolution-status-fcsts-web.pdf

impacts including the El Niño climate pattern and its implications on late summer, fall and early winter temperature and precipitation patterns in the Missouri River Basin. The possible impacts of El Niño have been factored into the CPC climate outlooks described below.

Temperature and Precipitation Outlooks

The NOAA Climate Prediction Center climate outlook for January 2015 (**Figure 15**) indicates an increased probability for above normal temperatures in Montana, North Dakota and northern South Dakota, and equal chances for below normal, normal and above normal temperatures over the remainder of the Missouri Basin. Probabilities for above normal temperatures in Montana, North Dakota and South Dakota range from 33.3% to over 40%, complimented by a 33.3% chance that temperatures will be in the normal range, and a 26.7% to 33.3% chance temperatures will be below normal. Stated simply, there is only a slight increase in the chance for above normal temperatures. With regard to precipitation, there are similar increased chances that precipitation will be below normal in Montana, Wyoming, North Dakota and northwest South Dakota, but equal chances precipitation will be below normal, normal and above normal in January throughout the remainder of the Missouri Basin.

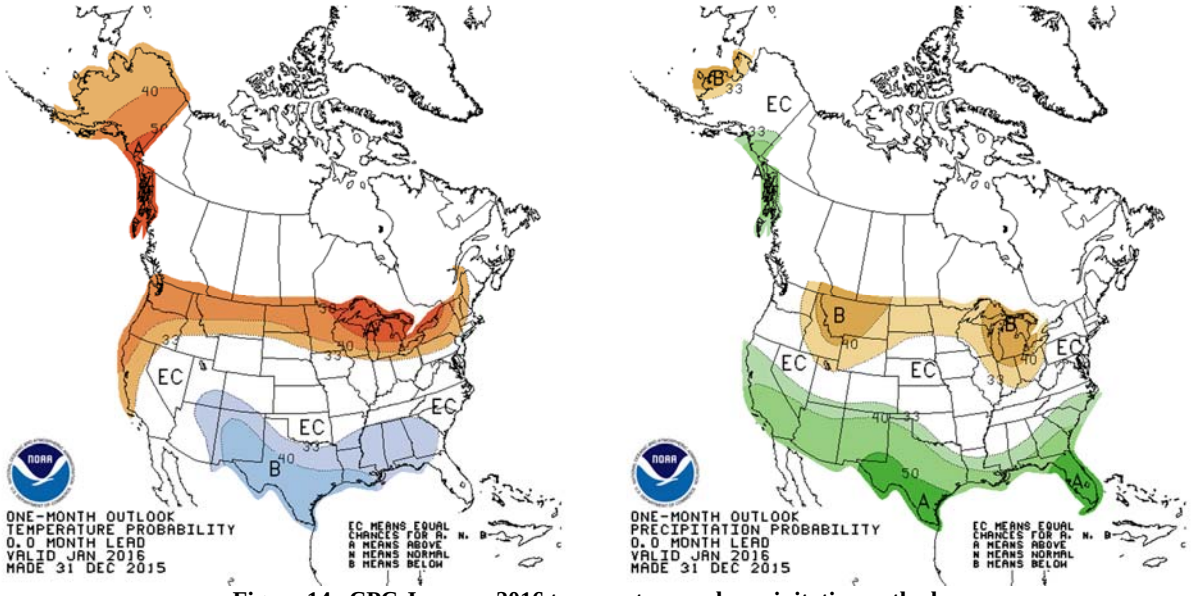


Figure 14. CPC January 2016 temperature and precipitation outlooks.

The winter (January-February-March) temperature outlook (**Figure 16**) indicates a slightly higher probability (33.3% to 40%) that temperatures will be above normal in all of the upper Basin and a majority of the lower Basin. The January-February-March precipitation outlook indicates a greater than 50% chance that precipitation in western Montana will be below normal, and a 33% to 50% chance that precipitation will be below normal in central and eastern Montana, northern Wyoming and North Dakota. Probabilities transition to above normal precipitation in Nebraska and Kansas. Both temperature and precipitation outlooks reflect the influences of El Niño conditions.

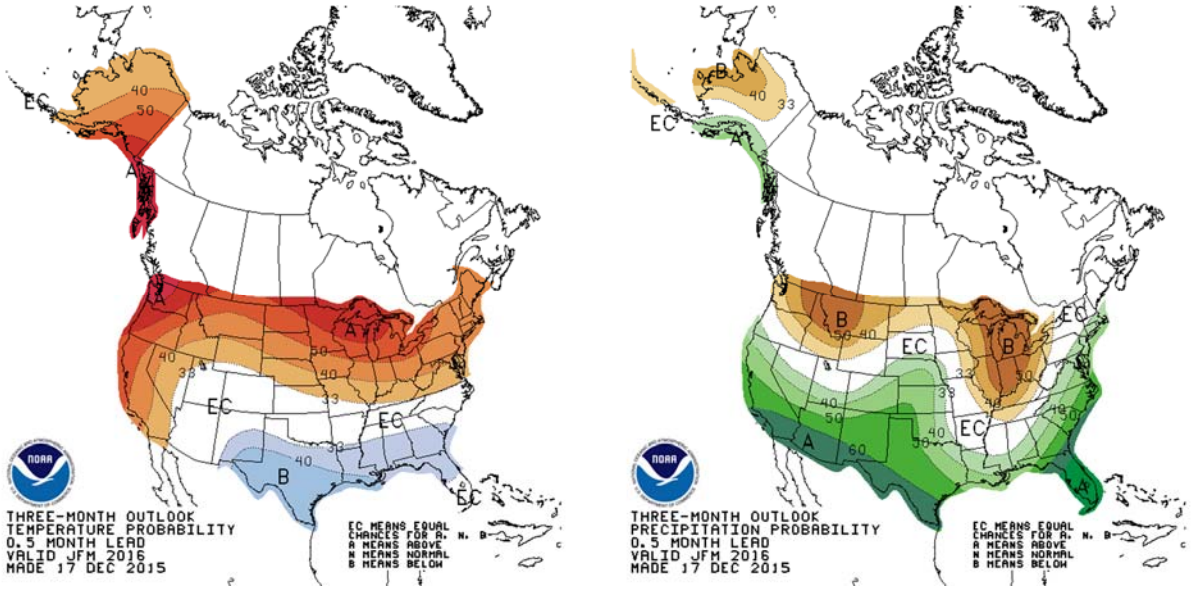


Figure 15. CPC January-February-March 2016 temperature and precipitation outlooks.

The April-May-June 2016 CPC temperature outlook (**Figure 17**) indicates there are increased chances for above normal temperatures across much of the Missouri Basin. In terms of precipitation, there are increased chances for above normal precipitation in the central Rockies transitioning to equal chances in the Northern Rockies. The Plains are expected to have equal chances for above normal, normal, and below normal precipitation; however, there is a slight tilt toward below normal precipitation in the lower Missouri Basin.

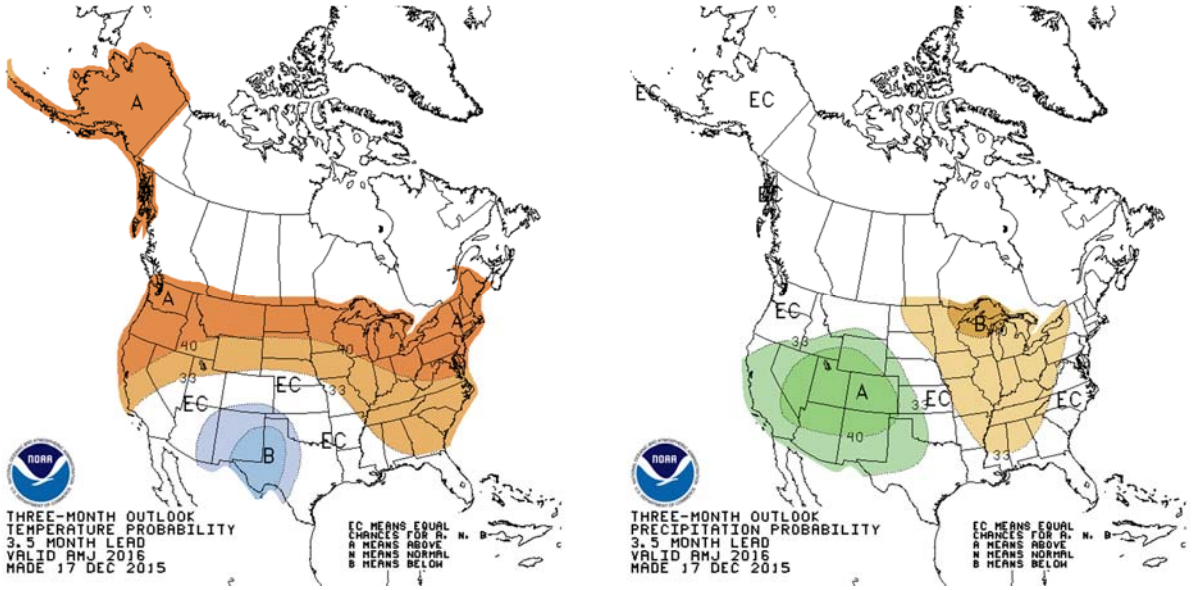


Figure 16. CPC April-May-June 2016 temperature and precipitation outlooks.

During the July-August-September period (**Figure 18**) the CPC outlooks indicate increased chances for above normal temperatures across the entire Missouri Basin, and equal chances for above normal, normal and below normal precipitation. The October-November-December period (**Figure 19**) outlook indicates increased chances for above normal temperatures in the southern half of the Missouri Basin and equal chances for above normal, normal and below normal temperatures in the northern half of the Missouri Basin. With regard to precipitation, the October-November-December outlook indicates there is an increased chance for above normal precipitation in the Northern Rockies and equal chances for much of the remaining Missouri Basin.

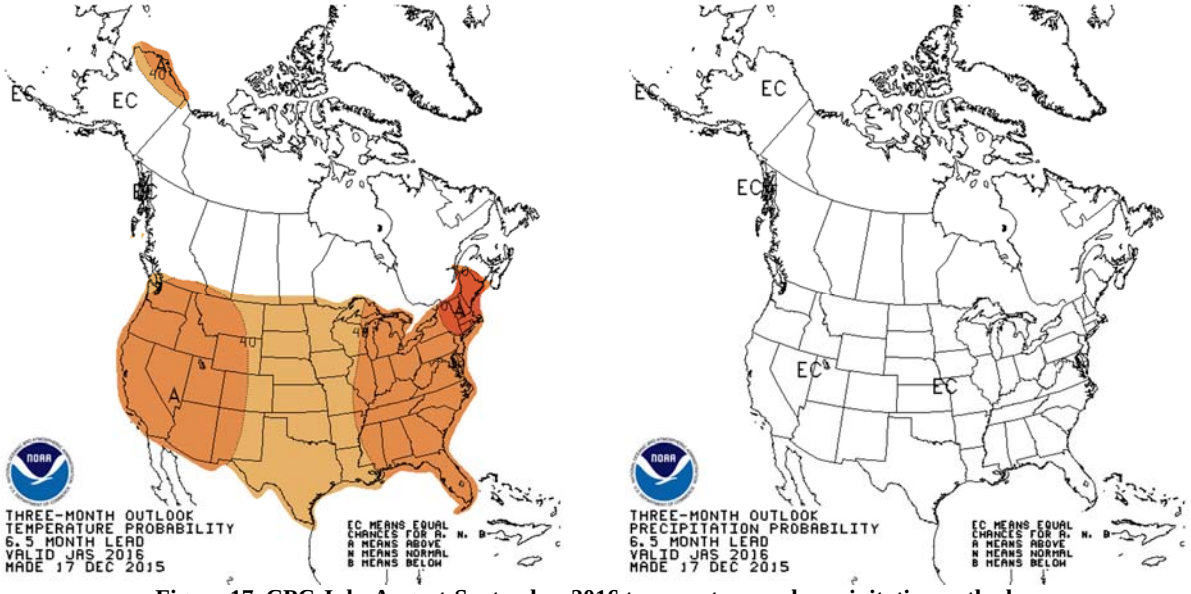


Figure 17. CPC July-August-September 2016 temperature and precipitation outlooks.

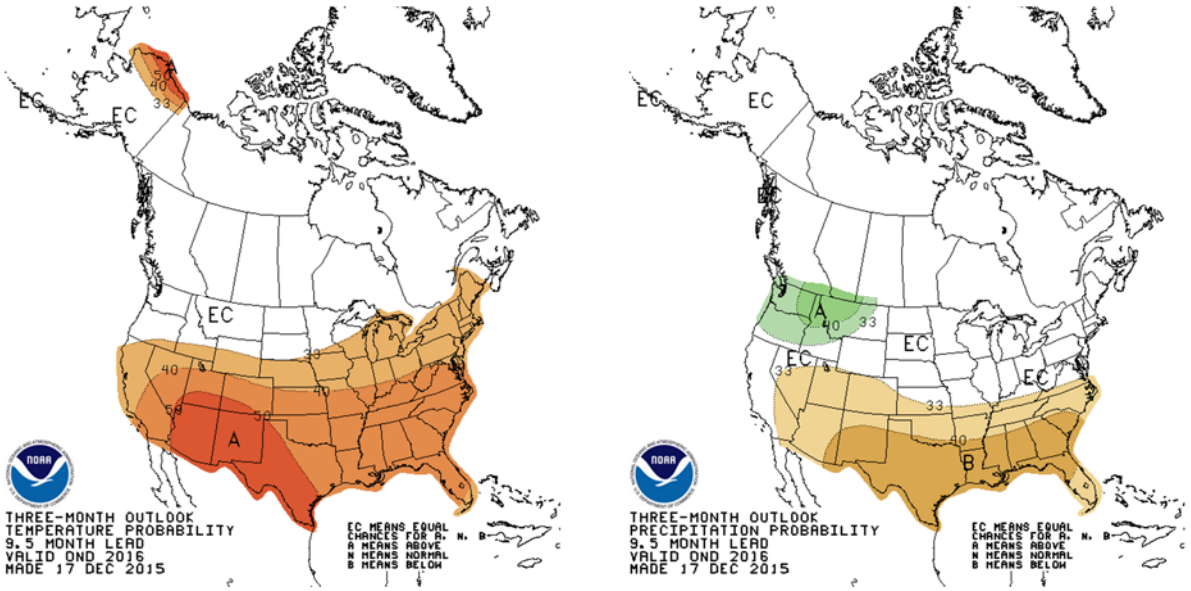


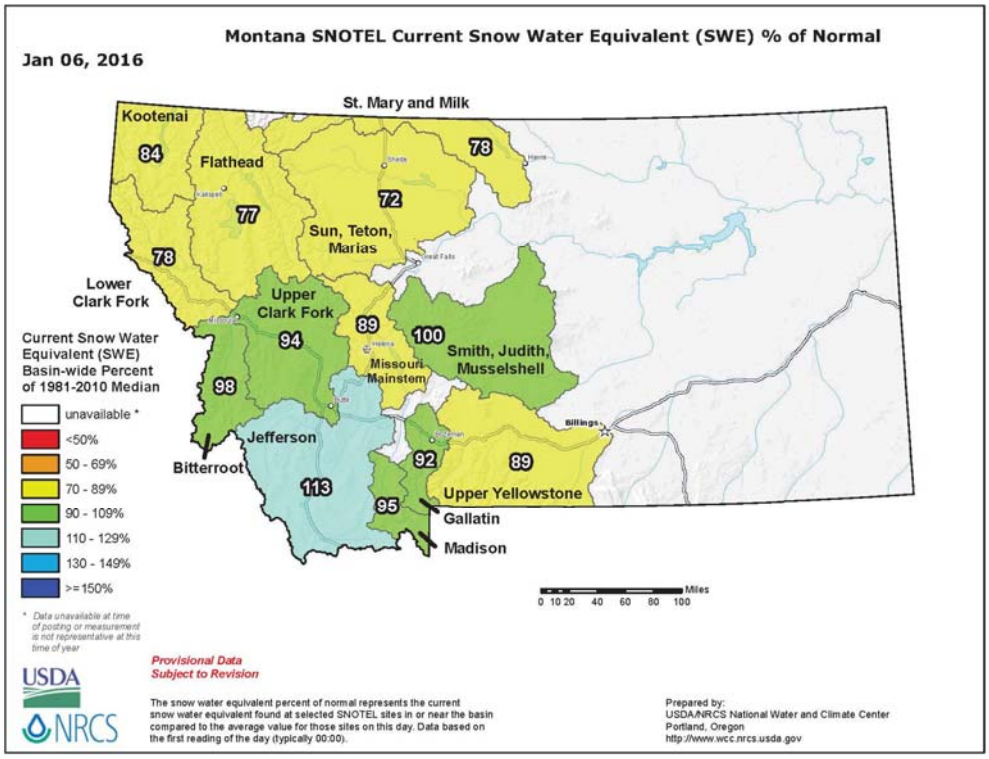
Figure 18. CPC October-November-December 2016 temperature and precipitation outlooks.

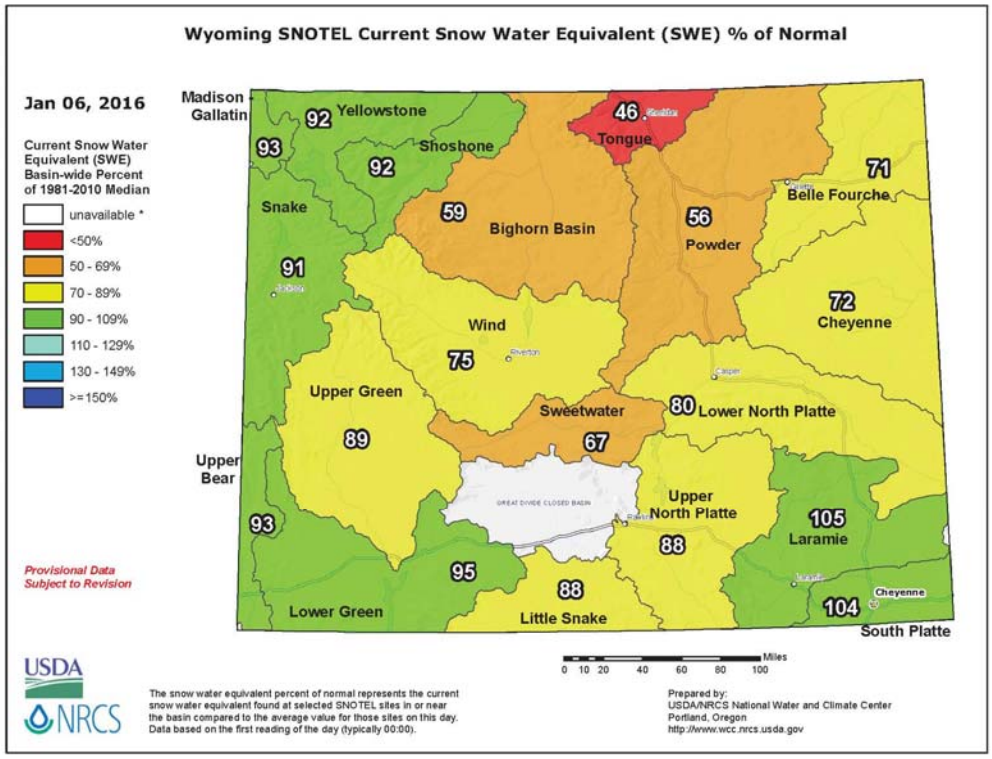
January 2016 Calendar Year Runoff Forecast

In summary, the 2016 calendar year runoff forecast is **23.8 MAF**, **94% of average**. The warmer than normal temperatures that are forecast over the next three months and average plains snowpack will lead to slightly above average runoff during the first three months of 2016. The outlook for warmer temperatures and below normal precipitation in late-winter could limit mountain snowpack accumulations and late-winter plains snowpack formation, and thus cause less than average runoff from April through July.

Due to the amount of variability in precipitation that can occur over the next 12 months, the range of expected inflow is quite large and ranges from the 32.9 MAF upper basic forecast to the 15.7 MAF lower basic forecast.

Additional Figures





USDA NRCS National Water & Climate Center

*** - DATA CURRENT AS OF: January 06, 2016 05:13:39 PM**

- Based on January 01, 2016 forecast values

PRELIMINARY MISSOURI RIVER BASIN FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
Lake Sherburne Inflow	APR-JUL	90	93	110	99	82	70	97
	APR-SEP	105	94	125	113	97	85	112
St. Mary R at Int'l Boundary (2)	APR-JUL	385	89	505	435	340	270	435
	APR-SEP	450	89	570	500	400	330	505
Lima Reservoir Inflow (2)	APR-JUL	77	94	113	92	62	41	82
	APR-SEP	84	94	125	101	67	43	89
Clark Canyon Reservoir Inflow (2)	APR-JUL	94	93	192	134	54	-4.4	101
	APR-SEP	116	97	225	160	72	7.7	120
Jefferson R nr Three Forks (2)	APR-JUL	730	99	1190	915	545	270	740
	APR-SEP	800	100	1310	1010	595	290	800
Hebgen Reservoir Inflow (2)	APR-JUL	340	92	425	375	305	255	370
	APR-SEP	430	91	535	470	390	325	470
Ennis Reservoir Inflow (2)	APR-JUL	560	90	715	620	495	400	625
	APR-SEP	690	89	875	765	615	505	775
Missouri R at Toston (2)	APR-JUL	1690	94	2450	2000	1380	920	1790
	APR-SEP	1940	94	2820	2290	1580	1050	2070
Smith R bl Eagle Ck (2)	APR-JUL	107	101	162	129	85	52	106
	APR-SEP	121	104	185	147	95	58	116
Gibson Reservoir Inflow (2)	APR-JUL	315	80	435	365	270	197	395
	APR-SEP	350	80	480	405	300	225	440
Marias R nr Shelby (2)	APR-JUL	280	81	475	360	197	79	345
	APR-SEP	285	79	490	370	200	80	360
Milk R at Western Crossing	MAR-JUL	26	93	51	36	16.2	1.48	28
	MAR-SEP	27	82	54	38	16.8	1.48	33
	APR-JUL	21	84	43	30	12.6	1.00	25
	APR-SEP	22	85	46	32	12.5	1.00	26

PRELIMINARY YELLOWSTONE RIVER BASIN FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
West Rosebud Ck nr Roscoe (2)	APR-JUL	58	98	68	62	54	48	59
	APR-SEP	74	100	87	79	69	61	74
Wind R ab Bull Lake Ck (2)	APR-JUL	400	88	565	465	330	230	455
	APR-SEP	420	86	605	495	345	235	490
Bull Lake Ck nr Lenore	APR-JUL	117	84	152	131	103	82	139
	APR-SEP	142	84	185	159	125	99	169
Boysen Reservoir Inflow (2)	APR-JUL	400	66	750	540	260	50	610
	APR-SEP	415	62	790	565	265	44	665
Greybull R nr Meeteetse	APR-JUL	118	90	173	140	95	62	131
	APR-SEP	159	90	225	185	132	93	177
Shell Ck nr Shell	APR-JUL	35	64	51	42	28	18.6	55
	APR-SEP	44	67	61	51	36	26	66
Bighorn R at Kane (2)	APR-JUL	515	61	1010	715	320	25	840
	APR-SEP	515	57	1050	730	300	20	905
NF Shoshone R at Wapiti	APR-JUL	450	98	550	490	410	350	460
	APR-SEP	505	98	605	545	460	400	515
SF Shoshone R nr Valley	APR-JUL	210	98	260	230	190	161	215
	APR-SEP	240	98	295	260	220	185	245
Buffalo Bill Reservoir Inflow (2)	APR-JUL	665	99	825	730	600	505	675

	APR-SEP	730	98	900	800	660	560	745
Bighorn R nr St. Xavier (2)	APR-JUL	1040	75	1620	1280	810	470	1380
	APR-SEP	1050	72	1700	1310	790	405	1460
Little Bighorn R nr Hardin	APR-JUL	54	55	108	76	32	1.00	98
	APR-SEP	61	55	121	85	37	1.00	111
Tongue R nr Dayton (2)	APR-JUL	55	64	89	69	41	21	86
	APR-SEP	63	64	100	78	48	26	98
Tongue River Reservoir Inflow (2)	APR-JUL	112	58	220	156	69	5.4	193
	APR-SEP	125	58	245	171	79	12.3	215
NF Powder R nr Hazelton	APR-JUL	5.5	60	9.0	6.9	4.1	2.0	9.1
	APR-SEP	6.0	61	9.6	7.4	4.5	2.4	9.9
Powder R at Moorhead	APR-JUL	76	43	192	123	29	1.00	177
	APR-SEP	92	47	210	141	43	1.00	196
Powder R nr Locate	APR-JUL	83	42	225	140	27	1.00	199
	APR-SEP	98	45	250	160	37	1.00	220

Max (10%), 30%, 50%, 70% and Min (90%) chance that actual volume will exceed forecast.
Averages are for the 1981-2010 period.
All volumes are in thousands of acre-feet.

footnotes:
1) Max and Min are 5% and 95% chance that actual volume will exceed forecast
2) streamflow is adjusted for upstream storage
3) median value used in place of average

Upper Missouri River Basin
February 2016 Calendar Year Runoff Forecast
February 5, 2016

U.S. Army Corps of Engineers, Northwestern Division
Missouri River Basin Water Management
Omaha, NE

Calendar Year Runoff Forecast

Explanation and Purpose of Forecast

The long-range runoff forecast is presented as the Calendar Year Runoff Forecast. This forecast is developed shortly after the beginning of each calendar year and is updated at the beginning of each month to show the actual runoff for historic months of that year and the updated forecast for the remaining months of the year. This forecast presents monthly inflows in million acre-feet (MAF) from five incremental drainage areas, as defined by the individual System projects, plus the incremental drainage area between Gavins Point Dam and Sioux City. Due to their close proximity, the Big Bend and Fort Randall drainage areas are combined. Summations are provided for the total Missouri River reach above Gavins Point Dam and for the total Missouri River reach above Sioux City. The Calendar Year Runoff Forecast is used in the Monthly Study simulation model to plan future system regulation in order to meet the authorized project purposes throughout the calendar year.

January 2016 Calendar Year Runoff

January 2016 Missouri River runoff was 0.9 MAF (114% of average) above Sioux City, IA (Upper Basin). January 2016 runoff above Gavins Point Dam was 0.7 MAF (100% of average). Runoff early in the month was limited due to cold temperatures in the Upper Basin causing the initial Missouri River freeze-up. From mid-January to the end of the month, warmer-than-normal temperatures caused some plains snowmelt and river ice melt causing increased runoff during the last week of January.

2016 Calendar Year Forecast Synopsis

The February 1 forecast for the 2016 Missouri River runoff above Sioux City, IA is **23.3 MAF (92% of average)**. Runoff above Gavins Point Dam is forecast to be **20.9 MAF (90% of average)**. Due to the amount of variability in precipitation and other hydrologic factors that can occur over the next 11 months, the range of expected inflow is quite large and ranges from the 32.0 MAF upper basic forecast to the 15.5 MAF lower basic forecast. The upper and lower basic forecasts are used in long-term regulation planning models to "bracket" the range of expected runoff given much wetter or drier conditions, respectively. Given that 11 months are being forecasted for this February 1 forecast (1 months observed/11 months forecast), the range of

wetter than normal (upper basic) and lower than normal (lower basic) is attributed to all 6 reaches for 11 months. The result is a large range or "bracket" for each reach, and thus, for the total runoff forecast. As the year progresses, the range will lessen as the number of observed months increases and number of forecast months decreases.

Current Conditions

Drought Analysis

The latest National Drought Mitigation Center's drought monitor for January 26, 2016 (**Figure 1**), when compared to the drought monitor for December 29, 2015 (**Figure 2**), shows increased development of Abnormally Dry (D0) and Moderate Drought (D1) conditions in north central Wyoming, southeast Montana, and southeast North Dakota. In contrast, there has been a slight contraction of all drought conditions in western Montana. The U.S. Seasonal Drought Outlook in **Figure 3** indicates that drought will persist in western and southeastern Montana, north central Wyoming and south central North Dakota. New drought conditions will likely develop in central Montana through the end of April 2016.

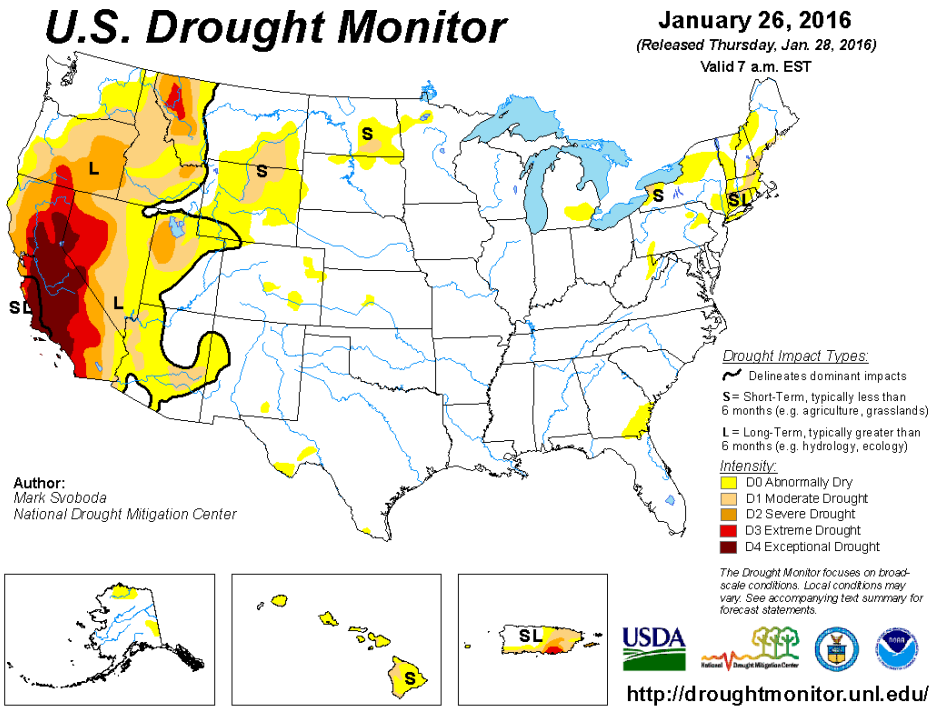


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for January 26, 2016.

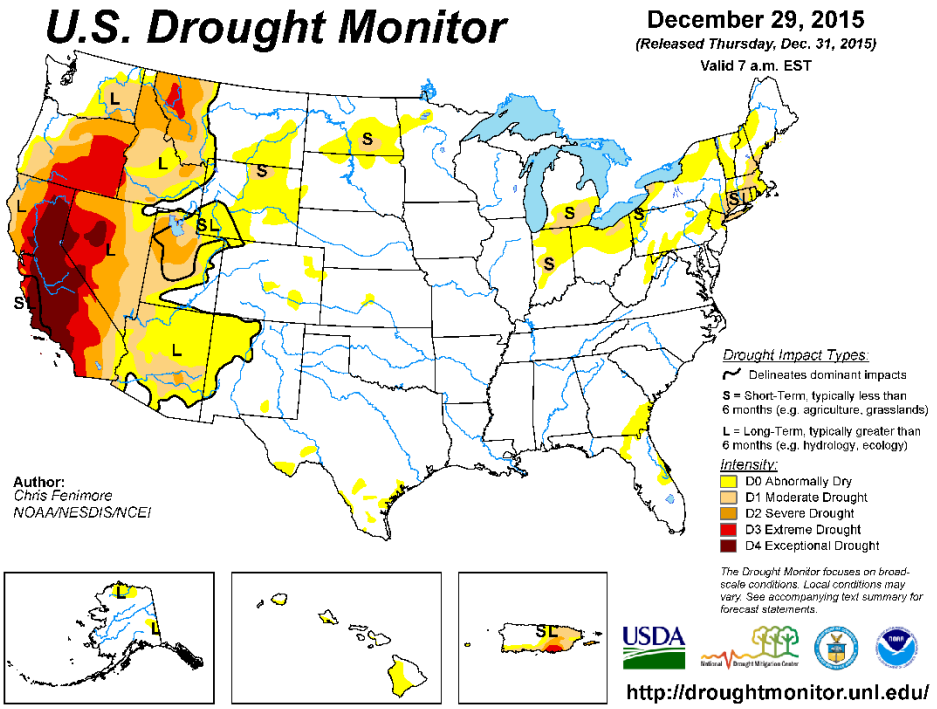


Figure 2. National Drought Mitigation Center U.S. Drought Monitor for December 29, 2015.

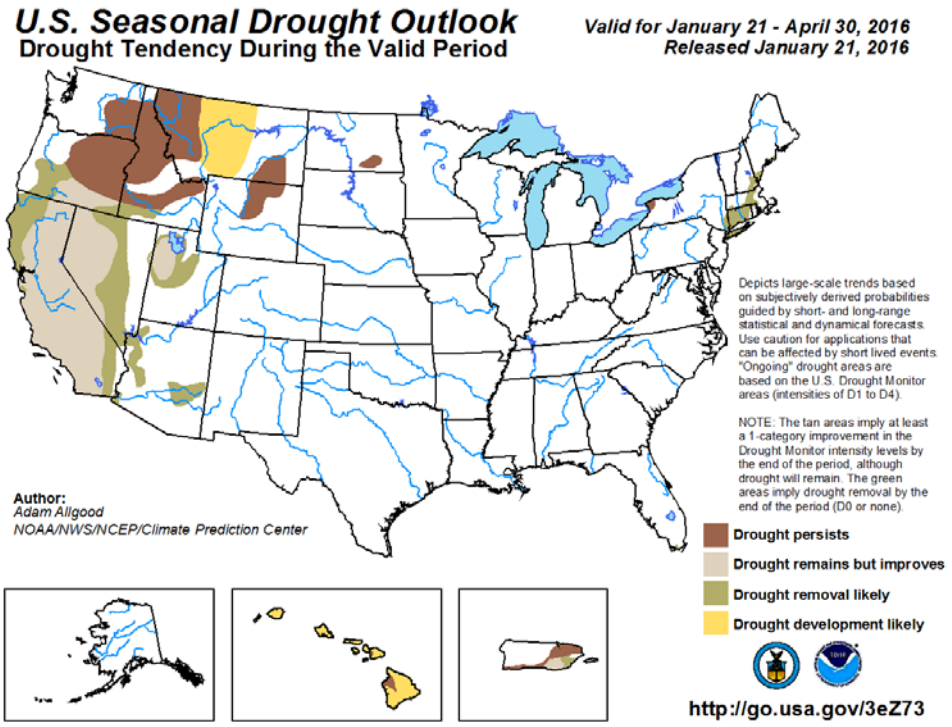


Figure 3. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

January precipitation accumulations are shown in **Figure 4** as both inches of precipitation (left) and percent of normal monthly precipitation (right). Precipitation amounts in the left image of Figure 4 generally ranged from 0.25 to 1.5 inches. The greatest amounts of January precipitation occurred in eastern Nebraska, southwest Iowa, eastern Kansas and Missouri. As a percent of normal in the right image of Figure 4, precipitation was generally below normal in the Upper Basin with some above normal areas including areas of northern Montana, a small area in southeast Montana, central Wyoming, eastern Nebraska and north central Kansas.

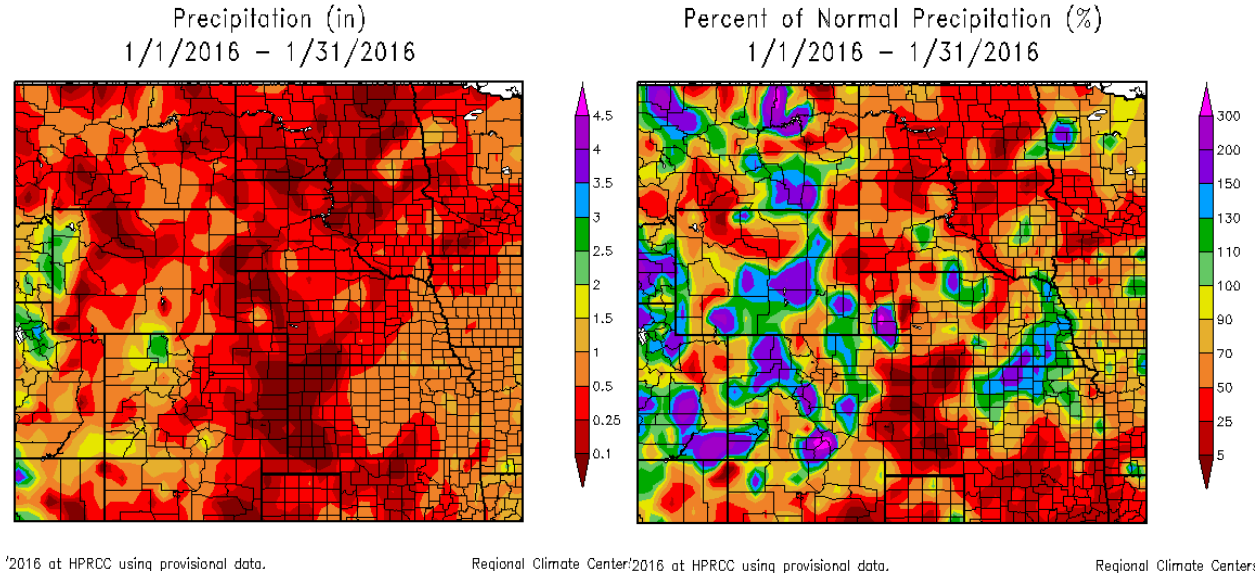


Figure 4. January 2016 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

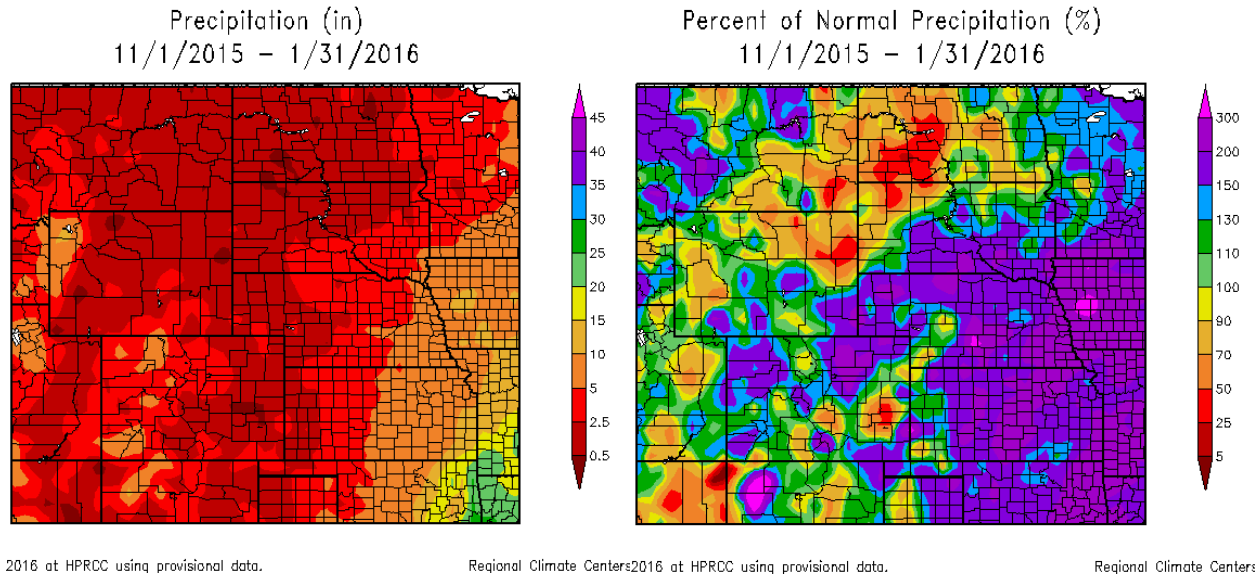


Figure 5. November-December 2015-January 2016 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

November-December 2015-January 2016 precipitation accumulations are shown in **Figure 5**. The three-month accumulations reflect a dry pattern in northeast Wyoming, southeastern and eastern Montana, western and central North Dakota, and northwestern South Dakota. In contrast, a wet or above normal precipitation pattern has been prevalent in western and north central Montana, and most of the Lower Basin, an area that has received greater than 150 percent of normal precipitation since November 1, 2015.

Temperature

January temperature departures from normal are shown in **Figure 6** in degrees Fahrenheit (deg F). January temperature departures in the Upper Basin were generally above normal ranging from 2 to 6 deg F. Temperatures were within 2 deg F of normal in southern South Dakota, the panhandle and eastern Nebraska, Iowa, eastern Kansas and Missouri. Temperatures were well below normal in the central Rocky Mountains of southern Wyoming and Colorado. Three-month (November-December-January) temperature departures are shown in **Figure 6**. The map indicates a very similar above normal pattern of temperatures across much of the Missouri Basin, particularly in the Northern Plains and Lower Basin. Temperatures have been near normal to slightly below normal in the Rocky Mountains.

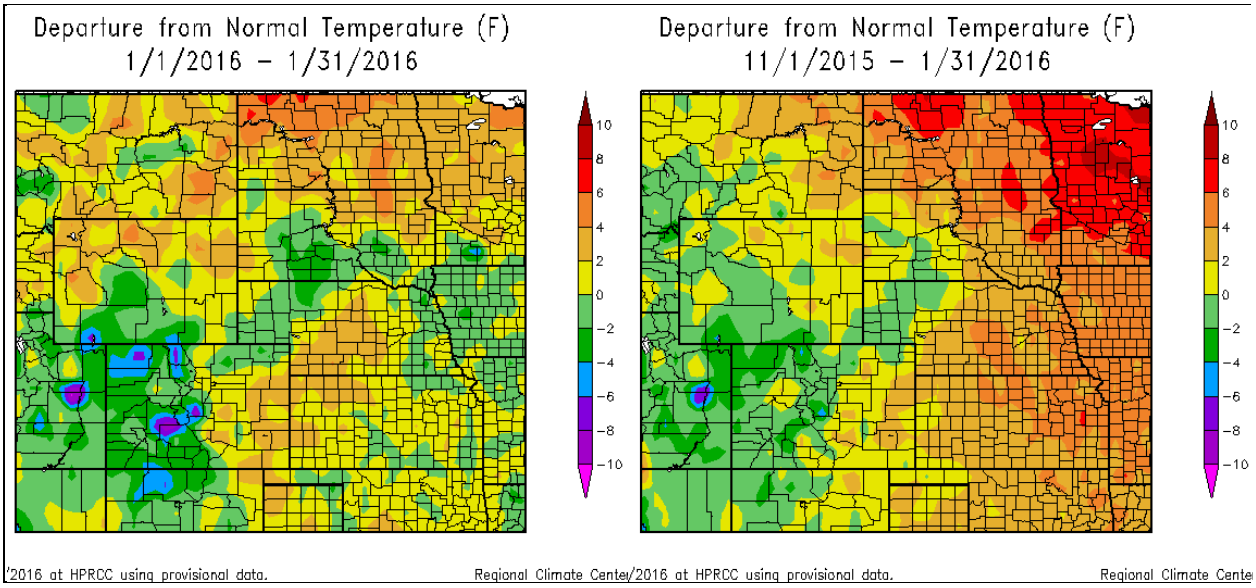


Figure 6. January 2016 and November-December 2015-January 2016 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Soil Moisture

Soil moisture is factored into the forecast as an indicator of wet or dry hydrologic basin conditions. Typically when soil moisture conditions are wet or greater than normal, rainfall and snowmelt runoff is greater than when soil moisture is dry or less than normal. Not only is soil moisture a physical parameter that influences runoff, it can be used as an indicator of future runoff.

Figure 7 shows the NOAA NLDAS ensemble mean soil moisture percentiles on January 29, 2016 for the top 1-meter of the modeled soil column. The NLDAS soil moisture depiction is an average value for the soil moisture column. **Figure 7** indicates above normal soil moisture conditions are present throughout much of the Upper Basin, though there are dry areas including north central Wyoming, eastern Montana, and eastern North Dakota. Wet soil moisture conditions (greater than 90th percentile moisture) are indicated in north central Montana, eastern Nebraska, and western Iowa.

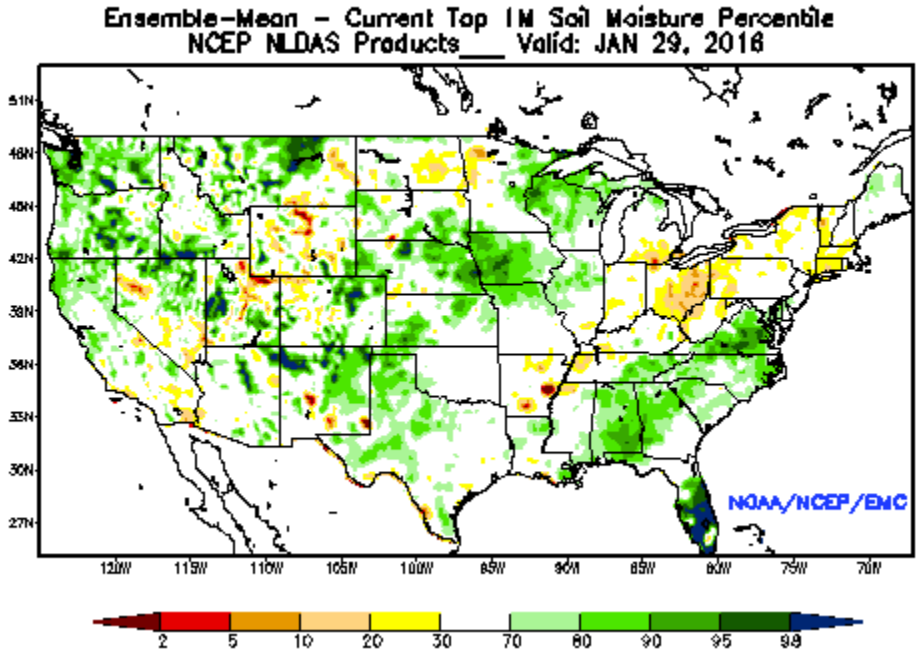


Figure 7. Top 1-Meter Soil Moisture Percentile on January 29, 2016. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

Frost Conditions

Soil frost acts as a semi-impervious layer to snowmelt or precipitation infiltration into the soil. **Figure 8** shows depth of frost penetration at National Weather Service (NWS) Warning Forecast Office (WFO) locations in the Missouri Basin as of February 1, 2016. While some frost depth measurements are missing, measurements indicate soils are frozen at variable depths. Frost depths at Williston and Bismarck are 23 inches and 29 inches, respectively. In South Dakota

reported depths are 16 inches at Rapid City and 24 inches at Aberdeen. In the Lower Basin, most depth measurements report as M (missing) or 0 inches.

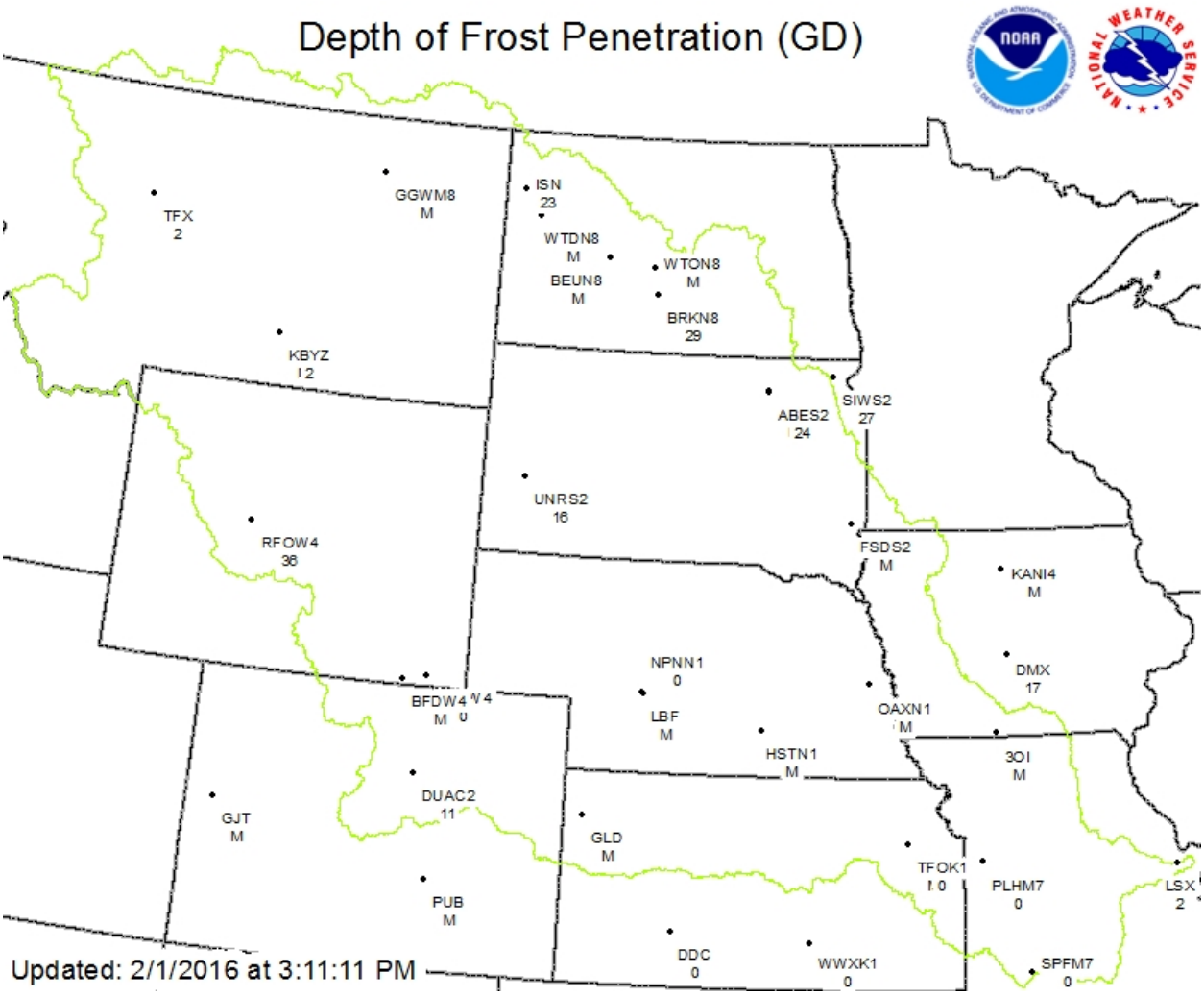


Figure 8. Measured frost depth (inches) at NWS WFO offices as of February 1, 2016. Source: NWS MBRFC.
http://www.crh.noaa.gov/mbrfc

Streamflow Conditions

Missouri Basin streamflow conditions are shown in **Figure 9**. These conditions are based on the ranking of the February 1, 2016 daily streamflow versus the historical record of streamflow for that date. Where streams are currently not influenced by ice formation along the mainstem of the Missouri River below Gavins Point Dam, streamflow conditions continue to be "Above normal" (76^{th} – 90^{th} percentile) or "Much above normal" (greater than the 90^{th} percentile). In the Upper Basin, a majority of stations have no classification because the current stream gages are either ice-affected or the historical record is ice-affected. The few stations in the Upper Basin that are

reporting indicate streamflow conditions, particularly in Montana and Wyoming, are “Normal” (25th-75th percentile) to “Below normal” (10th-24th percentile).

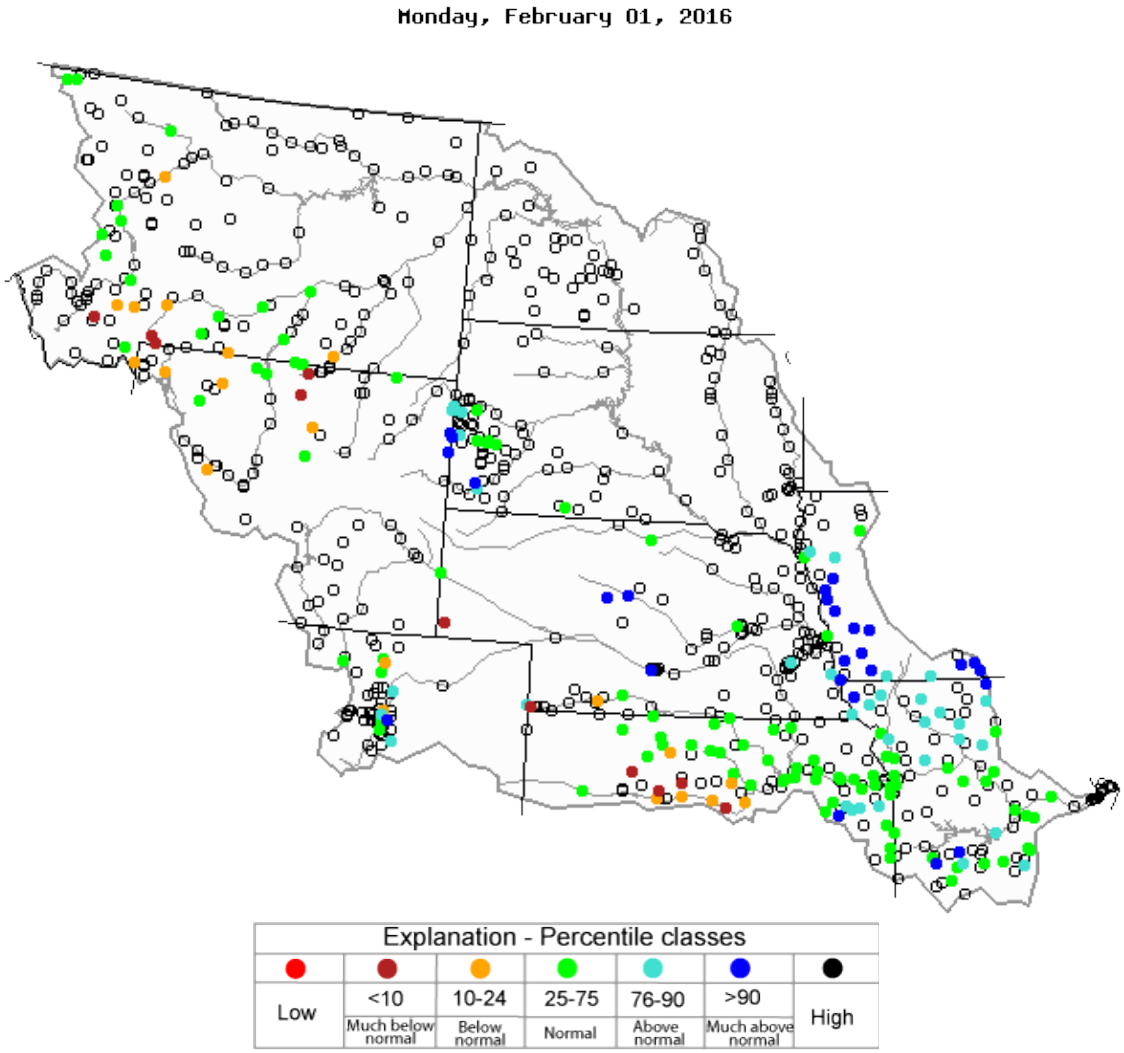


Figure 9. USGS Streamflow Conditions as a Percentile of Normal in the Missouri River Basin as of February 1, 2016. Source: USGS. http://waterwatch.usgs.gov/index.php

Plains Snowpack

Plains snowpack is an important parameter that influences the volume of runoff occurring in the basin during the months of March and April. A common misperception is that the March-April runoff is a result of plains snowmelt only. Historically, about 25% of annual runoff occurs in March and April, during the time when plains snow is melting, due to both melting snowpack and rainfall runoff. Runoff occurs in March and April whether or not there is any plains snow to melt. Determining exact rainfall amounts and locations are nearly impossible to predict more than a week in advance. Thus, the March-April runoff forecast is formulated based on existing plains snowpack and existing basin conditions and hydrologic forecasts, which for this year primarily includes long-term precipitation outlooks.

Based on the National Operational Hydrologic Remote Sensing Center (NOHRSC) assessment (**Figure 10**) as of February 1, 2016 the only consistent snow cover remains in northeastern Montana, portions of central North Dakota, and eastern South Dakota. According to Corps cooperative snow observers, the remaining snow is very shallow, in drifts, or as standing water and ice in ditches. SWE measured by the observers in northeast Montana and the upper James River basin in North Dakota range from 1.0 to 1.5 inches.

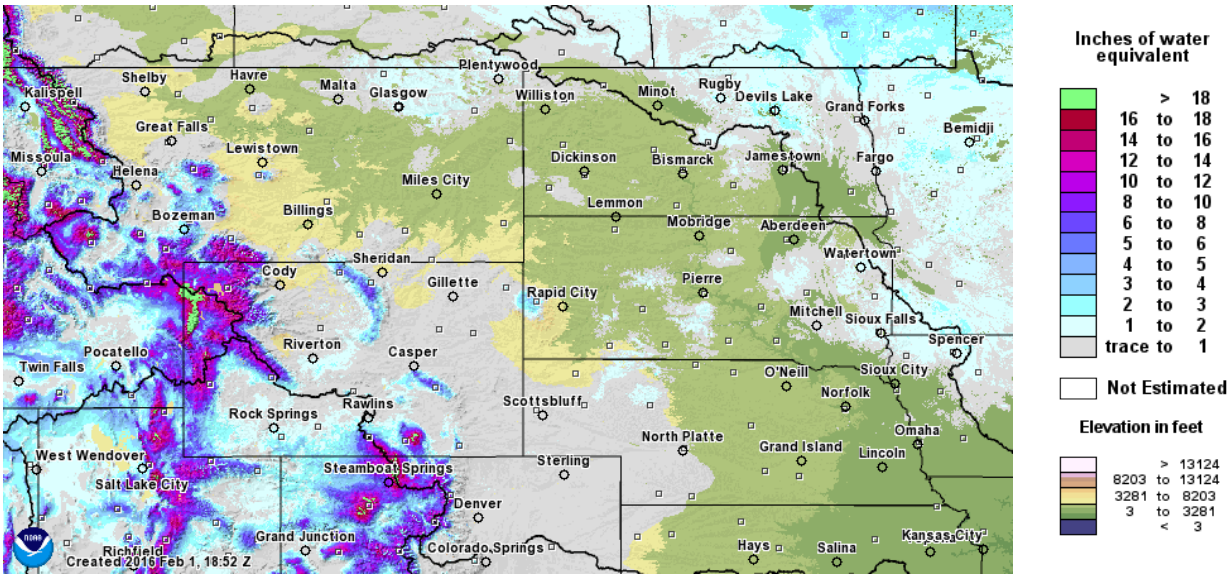


Figure 10. February 1, 2016 NOHRSC modeled plains snow water equivalent. Source: NOAA National Operational Hydrologic Remote Sensing Center. http://www.nohrsc.nws.gov/interactive/html/map.html

Using the MRBWMD snowpack classification method, plains snowpack for the February 1, 2016 runoff forecast was classified according to the terminology listed in **Table 1**. A "Light" snowpack indicates snow cover that is above the median SWE, and a "Moderate" snowpack is greater than "Light". "Average" basin conditions indicate snowpack is less than "Light" with no measureable snow accumulations. March-April runoff in "Average" conditions is expected to be below or near long term average runoff. Runoff resulting from "Light" and "Moderate" snowpack accumulations is expected to be above long term average March-April runoff.

Table 1. Plains snowpack classification for the February 1, 2016 runoff forecast.

Reservoir Reach	Plains Snowpack Classification
Above Fort Peck	Average
Fort Peck to Garrison	Average
Garrison to Oahe	Average
Oahe to Fort Randall	Average
Fort Randall to Gavins Point	Average
Gavins Point to Sioux City	Average-Light

Mountain Snow Pack

Mountain snowpack is the primary factor used to predict May-July runoff volumes in the Fort Peck and Fort Peck to Garrison mainstem reaches. During the 3-month May-July runoff period, about 50% of the annual runoff enters the mainstem system as a result of mountain snowmelt and rainfall runoff. Greater-than-average mountain snow accumulations are usually associated with greater-than-average May-July runoff volumes, especially when mountain soil moisture conditions have been wetter than normal as in the past three years. For example, we would expect to see greater-than-average runoff from an average mountain snowpack this year due to wetter-than-normal soil moisture conditions.

Figure 11 includes time series plots of the average mountain SWE beginning on October 1, 2015 based on the NRCS SNOTEL gages for the basin above Fort Peck and the incremental basin from Fort Peck to Garrison. The current average SWE values (shaded blue area) are plotted against the 1981-2010 basin average SWE (bold red line), 2001 (green line), and two historic high SWE years occurring in 1997 (purple) and 2011 (dark blue).

As of **February 1, 2016**, the Corps of Engineers computed an average mountain SWE in the **Fort Peck reservoir reach of 9.5 inches, which is 92% of average** based on the 1981-2010 average SWE for the Fort Peck reach. In the **reservoir reach between Fort Peck Dam and Garrison Dam**, the Corps computed an average mountain SWE of **6.3 inches, which is 72% of average** based on the 1981-2010 average SWE for the Garrison reach. Normally by February 1, 64% of the peak snow accumulation has occurred in the mountains.

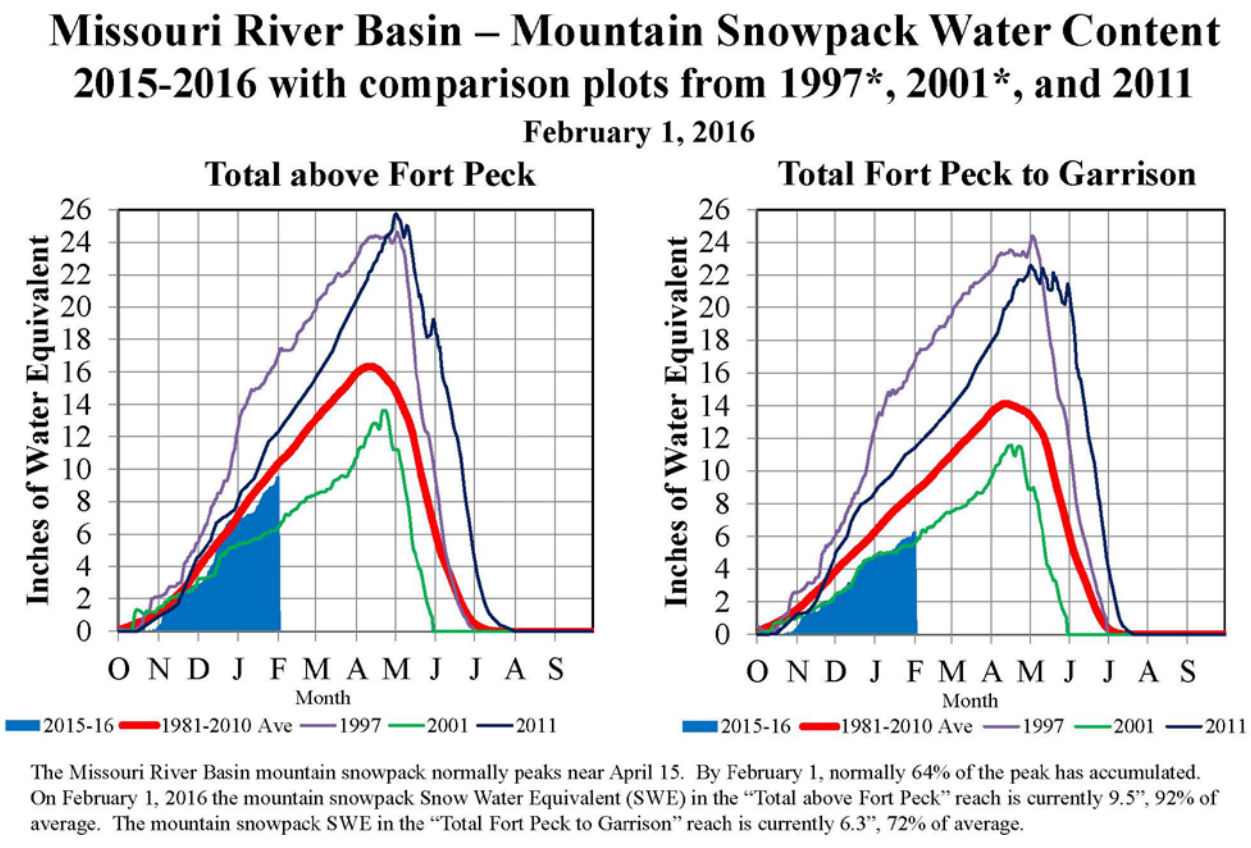


Figure 11. Mountain snowpack water content on February 1, 2016 compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management.

Climate Outlook

ENSO (El Niño Southern Oscillation)

According to the CPC's latest monthly update[1] on February 1, 2016, "***El Niño conditions are present. Positive equatorial sea surface temperature (SST) anomalies continue across most of the Pacific Ocean. A strong El Niño is expected to gradually weaken through spring 2016, and to transition to ENSO-neutral during late spring or early summer 2016***".

MRBWMD participates in the monthly North Central U.S. Climate/Drought Outlook Webinar coordinated through NOAA, the regional climate centers, and the American Association of State Climatologists (AASC). These webinars provide updates on near-term climate outlooks and impacts including the El Niño climate pattern and its implications on winter temperature and precipitation patterns in the Missouri River Basin. The possible impacts of El Niño have been factored into the CPC climate outlooks described below.

[1] http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/lanina/enso_evolution-status-fcsts-web.pdf

Temperature and Precipitation Outlooks

The NOAA Climate Prediction Center climate outlook for February 2016 (**Figure 12**) indicates an increased probability for above normal temperatures in Montana, North Dakota, South Dakota and northern Wyoming, and equal chances for below normal, normal and above normal temperatures over the remainder of the Missouri Basin. Probabilities for above normal temperatures range from a 50% chance temperatures will be above normal in northern Montana and northern North Dakota to a 33.3% to 40% chance in Wyoming and southern South Dakota. With regard to precipitation, there is greater than 40% chance precipitation will be below normal in much of Montana, and 33.3% to 40% chance for below normal precipitation in Wyoming and North Dakota. There are increased chances for above normal precipitation in Colorado, southeastern Wyoming, Nebraska, southern South Dakota, western Iowa, Kansas and northwestern Missouri.

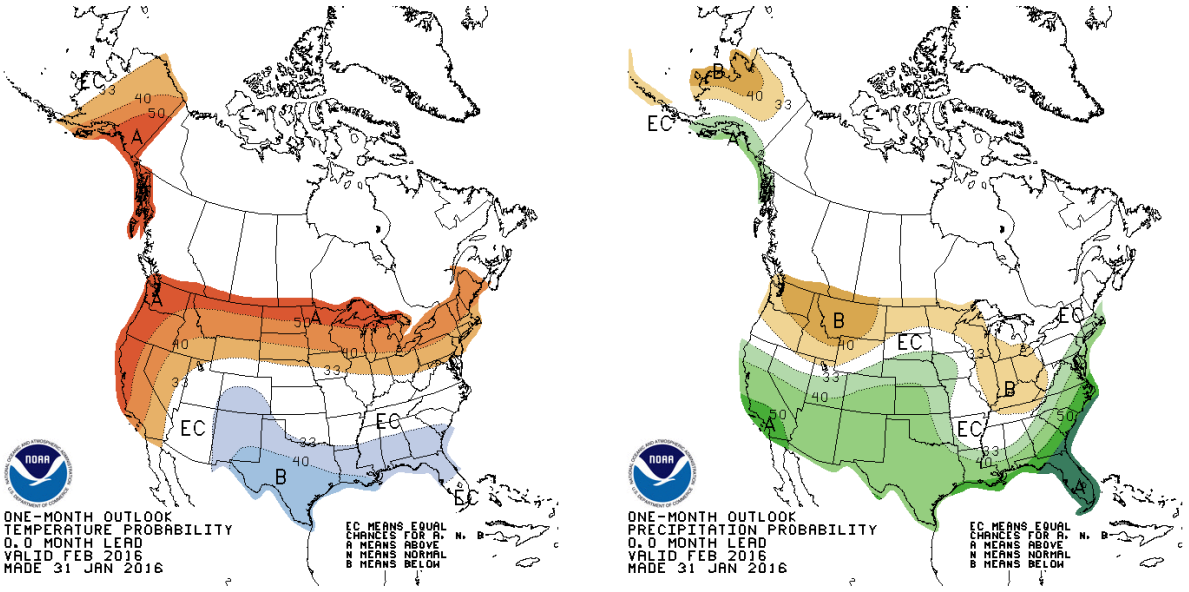


Figure 12. CPC February 2016 temperature and precipitation outlooks.

The February-March-April 2016 temperature outlook (**Figure 13**) indicates expanded areas of increased chances for above normal temperatures through the end of April. The February-March-April precipitation outlook indicates increased chances for below normal precipitation in northwestern Montana, equal chances for above normal, normal and below normal precipitation on the northern plains, and increased chances for above normal precipitation in southeastern Wyoming, Colorado, southern South Dakota, Nebraska and Kansas. The May-June-July 2016 CPC temperature outlook (**Figure 14**) indicates there are increased chances for above normal temperatures across much of the Missouri Basin. In terms of precipitation, there are increased chances for above normal precipitation in the central Rockies transitioning to equal chances in the Northern Rockies and plains.

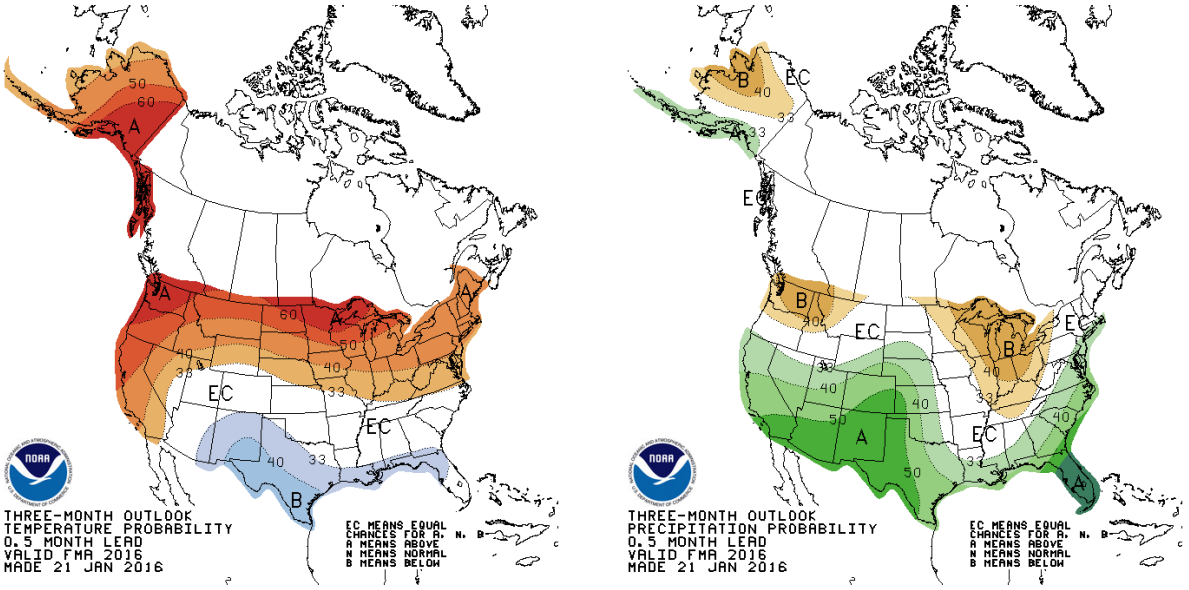


Figure 13. CPC February-March-April 2016 temperature and precipitation outlooks.

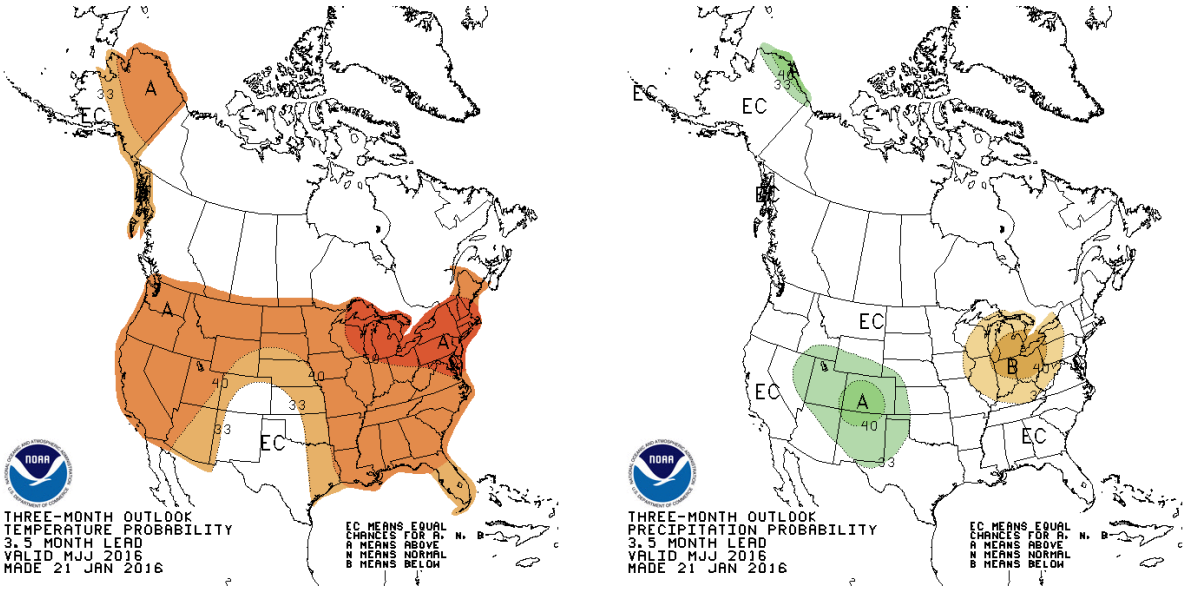


Figure 14. CPC May-June-July 2016 temperature and precipitation outlooks.

During the August-September-October 2016 period (**Figure 15**) CPC outlooks indicate increased chances for above normal temperatures across the entire Missouri Basin, and equal chances for above normal, normal and below normal precipitation. The November-December 2016-January 2017 period (**Figure 16**) outlook indicates increased chances for below normal temperatures in the Northern Rockies and plains. With regard to precipitation, the **Figure 18** outlook indicates there is an increased chance for above normal precipitation in the Northern Rockies and equal chances for much of the remaining Missouri Basin.

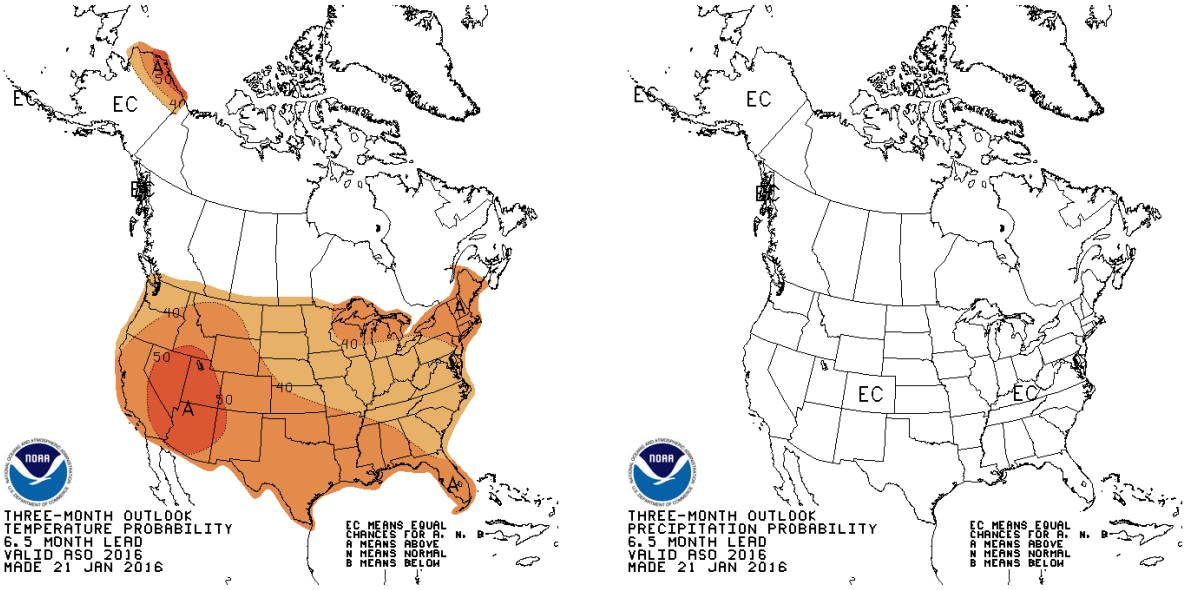


Figure 15. CPC August-September-October 2016 temperature and precipitation outlooks.

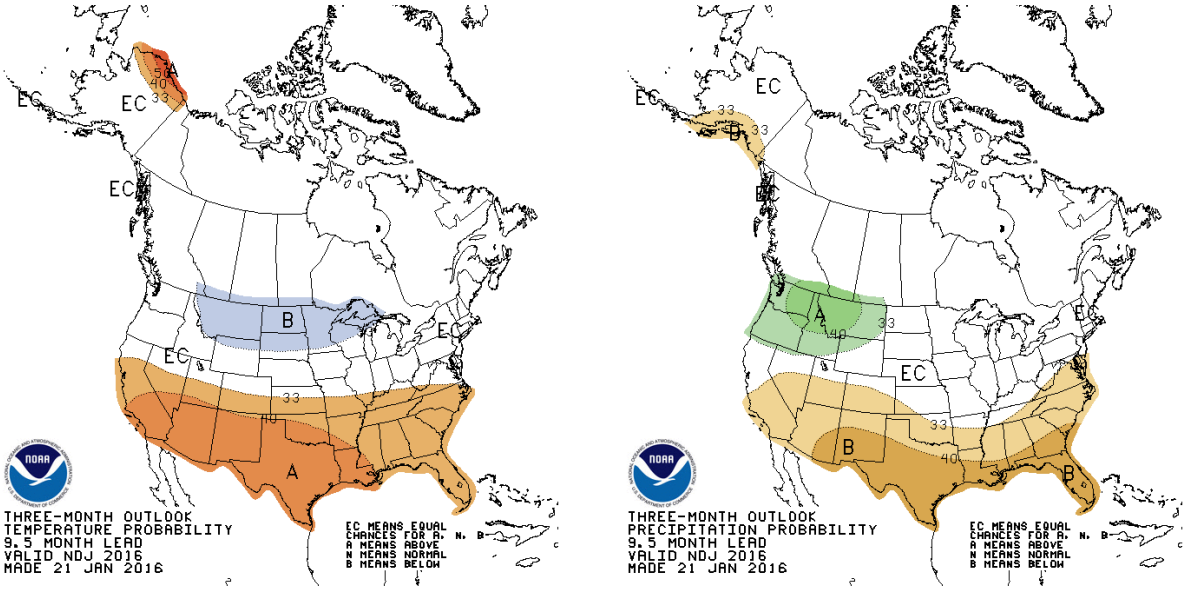
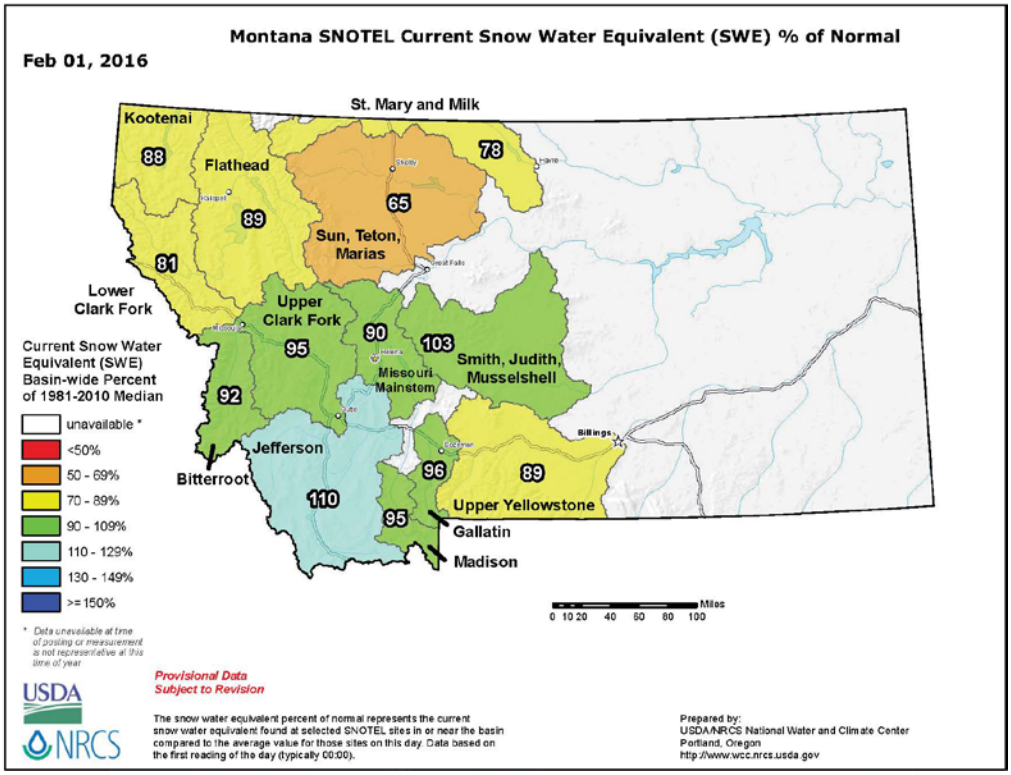


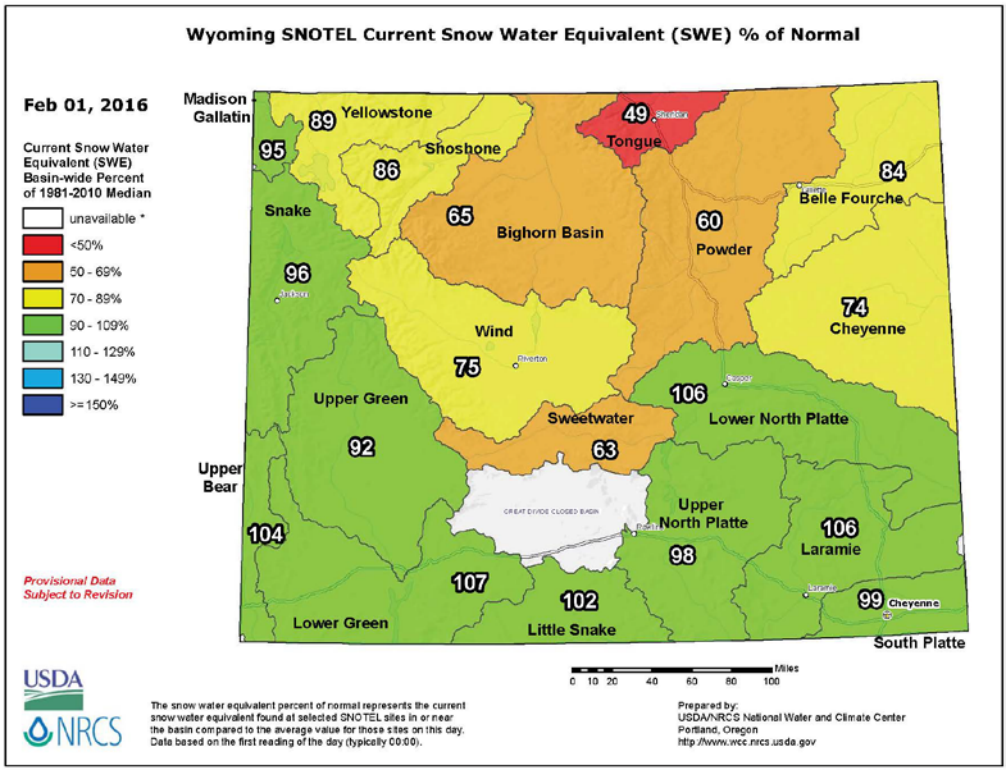
Figure 16. CPC November-December 2016-January 2017 temperature and precipitation outlooks.

February 2016 Calendar Year Runoff Forecast

In summary, the 2016 calendar year runoff forecast is **23.3 MAF**, **92% of average**. Once again, we expect that the warmer-than-normal temperatures that are forecast over the next three months will lead to earlier-than-normal river ice breakup and plains snowmelt. Runoff is forecast to be about average in February and March; however, the lack of a consistent plains snowpack may lead to below average runoff in April. The below average mountain snowpack will likely lead to below average May-June-July runoff in the Fort Peck and Garrison reaches.

Additional Figures





USDA NRCS National Water & Climate Center
 * - DATA CURRENT AS OF: February 03, 2016 06:26:55 PM
   - Based on February 01, 2016 forecast values

PRELIMINARY MISSOURI RIVER BASIN FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
Lake Sherburne Inflow	APR-JUL	84	87	99	90	78	69	97
	APR-SEP	98	88	113	104	92	83	112
St. Mary R at Int'l Boundary (2)	APR-JUL	360	83	460	400	320	260	435
	APR-SEP	415	82	515	455	375	315	505
Lima Reservoir Inflow (2)	APR-JUL	74	90	109	88	59	38	82
	APR-SEP	80	90	119	96	64	41	89
Clark Canyon Reservoir Inflow (2)	APR-JUL	85	84	146	110	61	25	101
	APR-SEP	105	88	175	133	77	36	120
Jefferson R nr Three Forks (2)	APR-JUL	740	100	1120	895	590	365	740
	APR-SEP	805	101	1230	975	635	385	800
Hebgen Reservoir Inflow (2)	APR-JUL	330	89	400	355	300	260	370
	APR-SEP	420	89	500	450	385	335	470
Ennis Reservoir Inflow (2)	APR-JUL	550	88	700	610	490	400	625
	APR-SEP	680	88	855	750	610	505	775
Missouri R at Toston (2)	APR-JUL	1680	94	2320	1940	1420	1030	1790
	APR-SEP	1920	93	2680	2230	1610	1160	2070
Smith R bl Eagle Ck (2)	APR-JUL	107	101	160	128	86	54	106
	APR-SEP	115	99	176	140	90	54	116
Gibson Reservoir Inflow (2)	APR-JUL	275	70	375	315	235	177	395
	APR-SEP	310	70	415	350	265	205	440
Marias R nr Shelby (2)	APR-JUL	205	59	385	275	133	54	345
	APR-SEP	210	58	400	285	134	52	360
Milk R at Western Crossing	MAR-SEP	27	82	54	38	18.9	11.8	33*

PRELIMINARY YELLOWSTONE RIVER BASIN FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
West Rosebud Ck nr Roscoe (2)	APR-JUL	55	93	63	58	52	47	59
	APR-SEP	69	93	80	73	65	58	74
Wind R ab Bull Lake Ck (2)	APR-JUL	370	81	525	430	305	210	455
	APR-SEP	385	79	550	450	315	215	490
Bull Lake Ck nr Lenore	APR-JUL	108	78	141	121	94	74	139
	APR-SEP	130	77	171	146	114	89	169
Boysen Reservoir Inflow (2)	APR-JUL	365	60	725	510	215	2.0	610
	APR-SEP	375	56	755	530	220	2.0	665
Greybull R nr Meeteetse	APR-JUL	98	75	133	112	84	63	131
	APR-SEP	132	75	175	149	115	89	177
Shell Ck nr Shell	APR-JUL	33	60	49	40	27	17.8	55
	APR-SEP	42	64	59	49	35	26	66
Bighorn R at Kane (2)	APR-JUL	420	50	935	630	210	5.0	840
	APR-SEP	405	45	960	630	180	5.0	905
NF Shoshone R at Wapiti	APR-JUL	420	91	505	455	385	335	460
	APR-SEP	470	91	560	505	435	380	515
SF Shoshone R nr Valley	APR-JUL	195	91	235	210	178	153	215
	APR-SEP	220	90	270	240	205	175	245
Buffalo Bill Reservoir Inflow (2)	APR-JUL	610	90	755	670	555	470	675
	APR-SEP	665	89	815	725	605	515	745
Bighorn R nr St. Xavier (2)	APR-JUL	890	64	1510	1140	640	275	1380
	APR-SEP	870	60	1550	1150	595	193	1460
Little Bighorn R nr Hardin	APR-JUL	41	42	89	60	22	-6.9	98
	APR-SEP	47	42	100	68	26	-5.6	111

Tongue R nr Dayton (2)	APR-JUL	46	53	77	59	33	14.8	86
	APR-SEP	54	55	87	67	40	20	98
Tongue River Reservoir Inflow (2)	APR-JUL	94	49	200	137	51	5.0	193
	APR-SEP	106	49	220	151	61	5.0	215
NF Powder R nr Hazelton	APR-JUL	4.9	54	7.4	5.9	3.9	2.4	9.1
	APR-SEP	5.4	55	8.0	6.5	4.3	2.8	9.9
Powder R at Moorhead	APR-JUL	63	36	163	104	22	1.00	177
	APR-SEP	70	36	173	112	28	1.00	196
Powder R nr Locate	APR-JUL	78	39	235	142	15.3	1.00	199
	APR-SEP	85	39	250	152	18.7	1.00	220

Max (10%), 30%, 50%, 70% and Min (90%) chance that actual volume will exceed forecast.
Averages are for the 1981-2010 period.
All volumes are in thousands of acre-feet.

footnotes:
1) Max and Min are 5% and 95% chance that actual volume will exceed forecast
2) streamflow is adjusted for upstream storage
3) median value used in place of average

Upper Missouri River Basin
March 2016 Calendar Year Runoff Forecast
March 4, 2016

U.S. Army Corps of Engineers, Northwestern Division
Missouri River Basin Water Management
Omaha, NE

Calendar Year Runoff Forecast

Explanation and Purpose of Forecast

The long-range runoff forecast is presented as the Calendar Year Runoff Forecast. This forecast is developed shortly after the beginning of each calendar year and is updated at the beginning of each month to show the actual runoff for historic months of that year and the updated forecast for the remaining months of the year. This forecast presents monthly inflows in million acre-feet (MAF) from five incremental drainage areas, as defined by the individual System projects, plus the incremental drainage area between Gavins Point Dam and Sioux City. Due to their close proximity, the Big Bend and Fort Randall drainage areas are combined. Summations are provided for the total Missouri River reach above Gavins Point Dam and for the total Missouri River reach above Sioux City. The Calendar Year Runoff Forecast is used in the Monthly Study simulation model to plan future system regulation in order to meet the authorized project purposes throughout the calendar year.

February 2016 Calendar Year Runoff

February 2016 Missouri River runoff was 1.9 MAF (170% of average) above Sioux City, IA (Upper Basin). February 2016 runoff above Gavins Point Dam was 1.6 MAF (159% of average). Warmer-than-normal temperatures resulted in the melting of nearly the entire plains snowpack, which resulted in above average runoff in February. Much of the runoff that occurred in February 2016 would be expected to occur in March and April in a year with more typical temperatures.

2016 Calendar Year Forecast Synopsis

The February 1 forecast for the 2016 Missouri River Basin runoff above Sioux City, IA (Upper Basin) is **21.6 MAF (85% of average)**. Runoff above Gavins Point Dam is forecast to be **19.3 MAF (83% of average)**. Due to the amount of variability in precipitation and other hydrologic factors that can occur over the next 10 months, the range of expected inflow is quite large and ranges from the 29.0 MAF upper basic forecast to the 15.1 MAF lower basic forecast. The upper and lower basic forecasts are used in long-term regulation planning models to "bracket" the range of expected runoff given much wetter or drier conditions, respectively. Given that 10 months are being forecasted for this March 1 forecast (2 months observed/10 months forecast),

the range of wetter than normal (upper basic) and lower than normal (lower basic) is attributed to all 6 reaches for 10 months. The result is a large range or "bracket" for each reach, and thus, for the total runoff forecast. As the year progresses, the range will lessen as the number of observed months increases and number of forecast months decreases.

Current Conditions

Drought Analysis

The latest National Drought Mitigation Center's drought monitor for March 1, 2016 (**Figure 1**), when compared to the drought monitor for January 26, 2016 (**Figure 2**), shows a slight increase in areal extent of Abnormally Dry (D0) and Moderate Drought (D1) conditions in the upper Basin, primarily in western North Dakota. There has been a slight decrease of drought severity in western Montana. The U.S. Seasonal Drought Outlook in **Figure 3** indicates that drought will persist in western Montana and south-central North Dakota. Drought conditions are likely to ease in south-central Montana and north-central Wyoming through the end of May 2016.

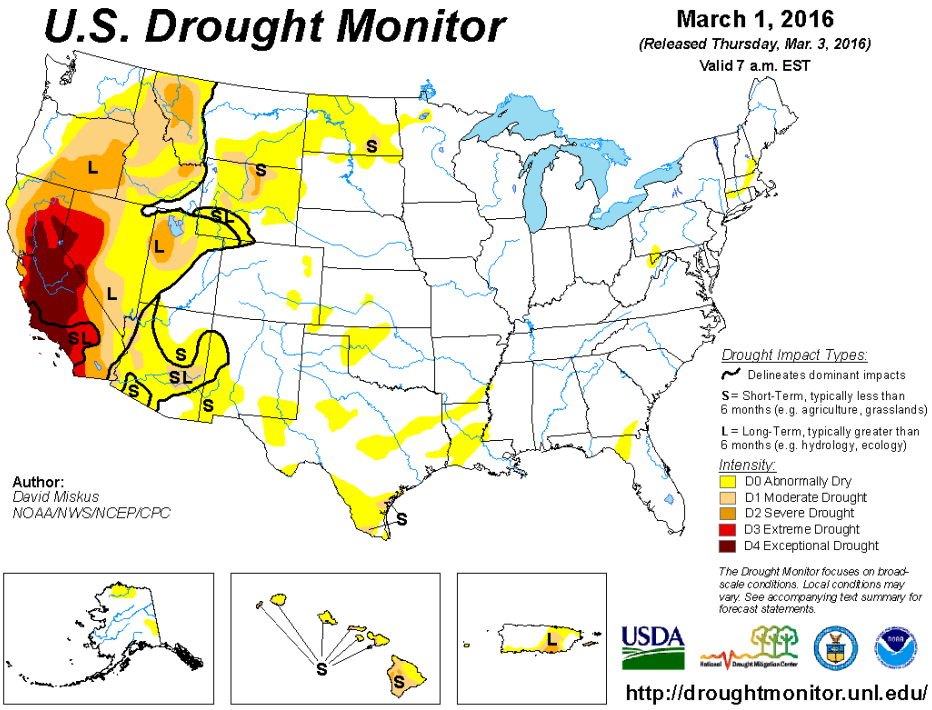


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for February 23, 2016.

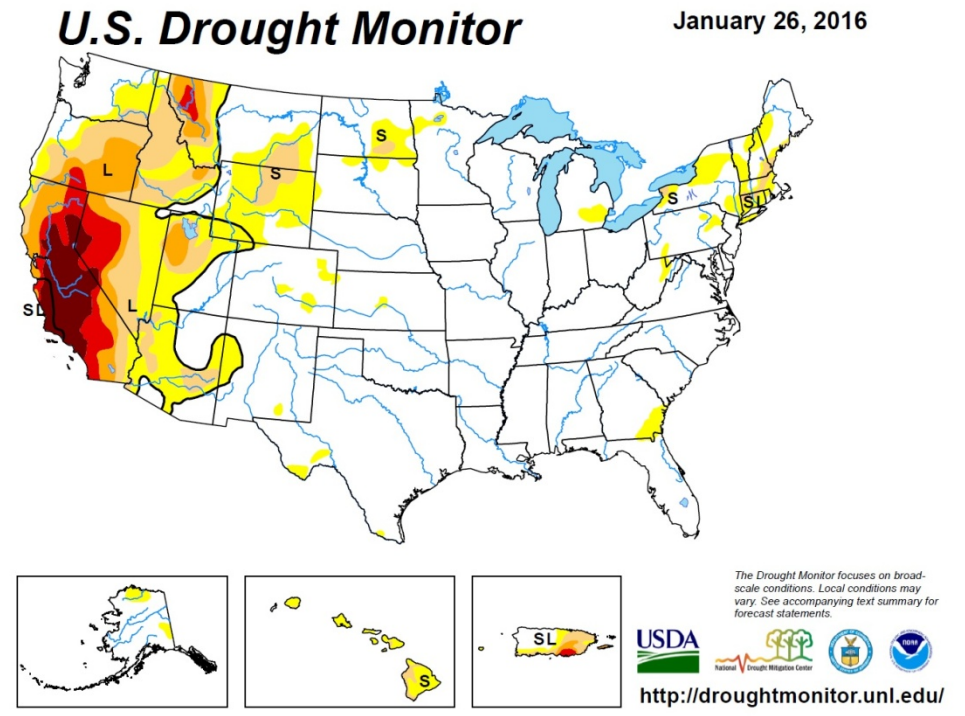


Figure 2. National Drought Mitigation Center U.S. Drought Monitor for January 26, 2016.

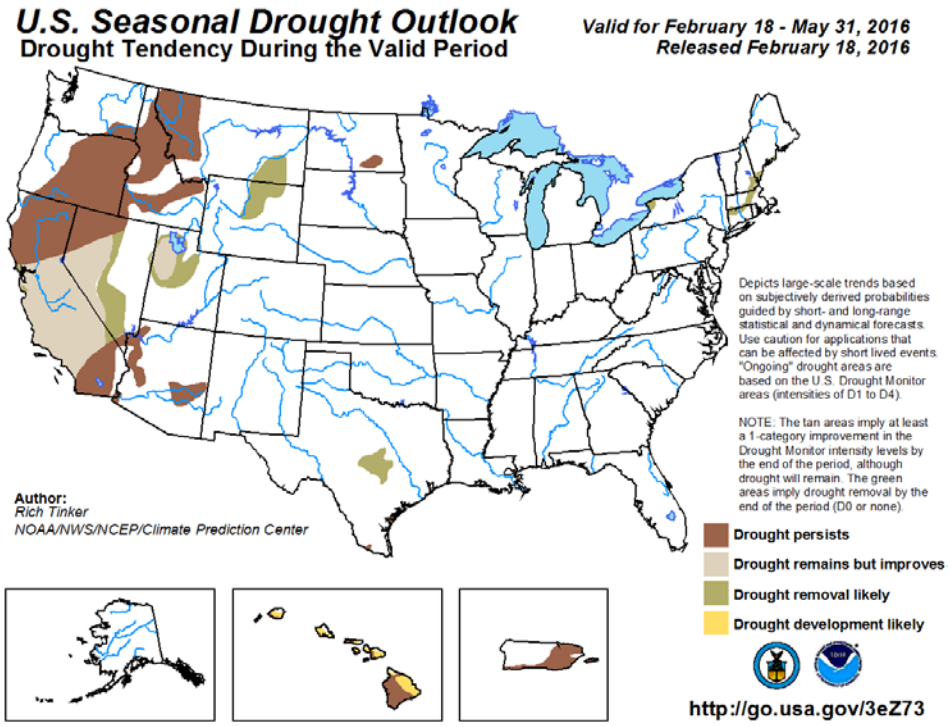


Figure 3. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

February precipitation accumulations are shown in **Figure 4** as both inches of precipitation (left) and percent of normal monthly precipitation (right). Precipitation amounts in the left image of Figure 4 generally ranged from 0.1 to 1.5 inches. The greatest amounts of February precipitation occurred in northwest Kansas extending northeastward into northeast Nebraska and northwest Iowa. As a percent of normal in the right image of Figure 4, precipitation was generally below normal in central and western Montana and much of Wyoming, as well as much of eastern Kansas and Missouri. Above normal areas occurred in eastern Montana, portions of South Dakota and a broad band from eastern Colorado extending northeast towards northwestern Iowa.

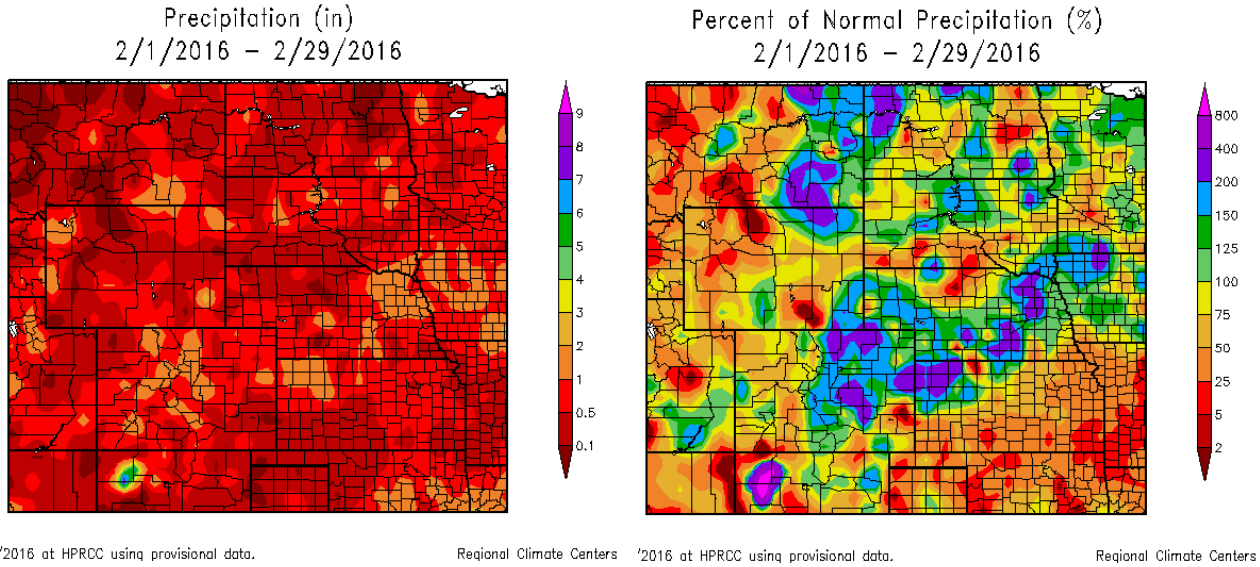


Figure 4. February 2016 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

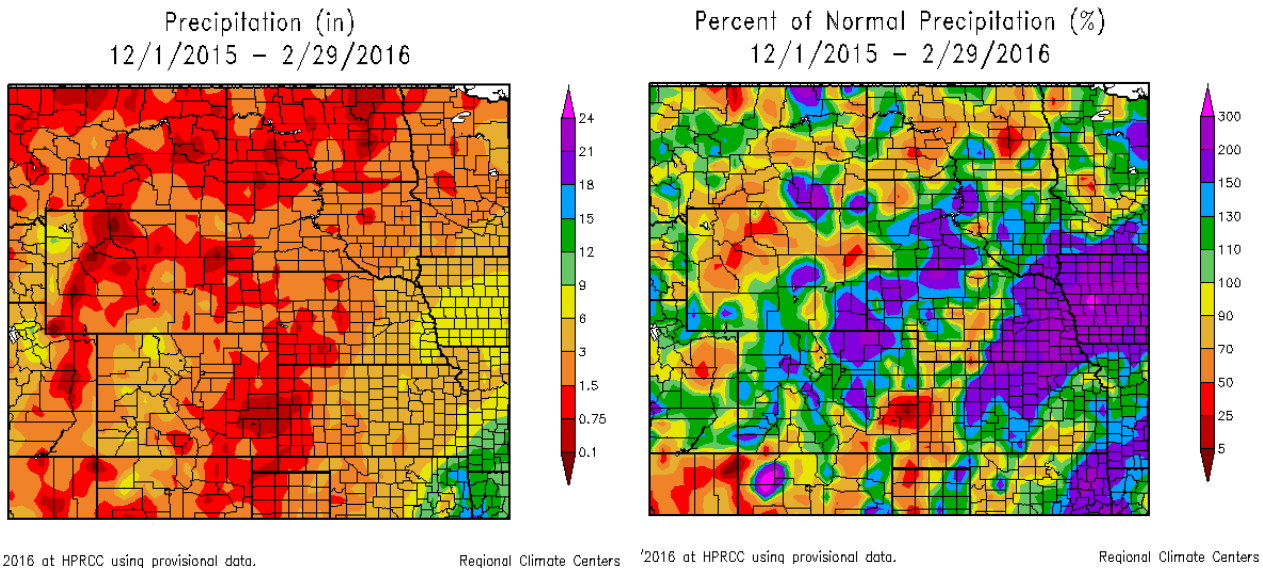


Figure 5. December 2015-February 2016 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

December 2015-January-February 2016 precipitation accumulations are shown in **Figure 5**. The three-month accumulations reflect a generally dry pattern extending from northwest Wyoming through northeastern North Dakota, as well as portions of central Montana. In contrast, a wet or above normal precipitation pattern has been prevalent in portions of western and eastern Montana, from northeast Colorado extending into central South Dakota, and in most of the lower Basin. These areas received greater than 150 percent of normal precipitation since December 1, 2015.

Temperature

February temperature departures from normal are shown in **Figure 6** in degrees Fahrenheit (deg F). February temperature departures in the Upper Basin were generally above normal ranging from 6 to 12 deg F. Temperatures were within 2 deg F of normal in small areas scattered across eastern Nebraska and western Iowa. Three-month (December-January-February) temperature departures are shown in **Figure 6**. The map indicates a very similar above normal pattern of temperatures across much of the Missouri Basin, particularly in the Northern Plains and lower Basin. Temperatures have been near normal to slightly below normal in the Rocky Mountains and through portions of western Nebraska and southwestern South Dakota.

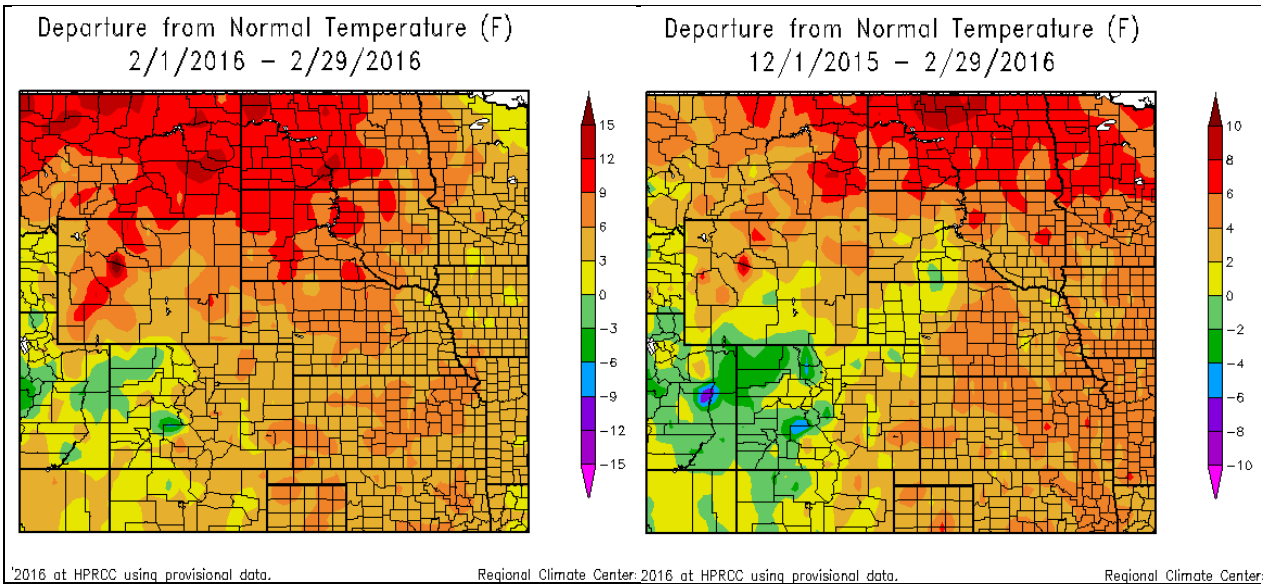


Figure 6. February 2016 and December 2015-February 2016 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Soil Moisture

Soil moisture is factored into the forecast as an indicator of wet or dry hydrologic basin conditions. Typically when soil moisture conditions are wet or greater than normal, rainfall and snowmelt runoff is greater than when soil moisture is dry or less than normal. Not only is soil moisture a physical parameter that influences runoff, it can be used as an indicator of future runoff.

Figure 7 shows the NOAA NLDAS ensemble mean soil moisture percentiles on February 26, 2016 for the top 1 meter of the modeled soil column. The NLDAS soil moisture depiction is an average value for the soil moisture column. **Figure 7** indicates above normal soil moisture conditions are present throughout much of the Upper Basin, though there are dry areas including north-central Wyoming, eastern Montana, and eastern North Dakota, as well as portions of eastern Kansas and western Missouri. Wet soil moisture conditions (greater than 90th percentile moisture) are indicated in north central Montana, eastern Nebraska, and western Iowa.

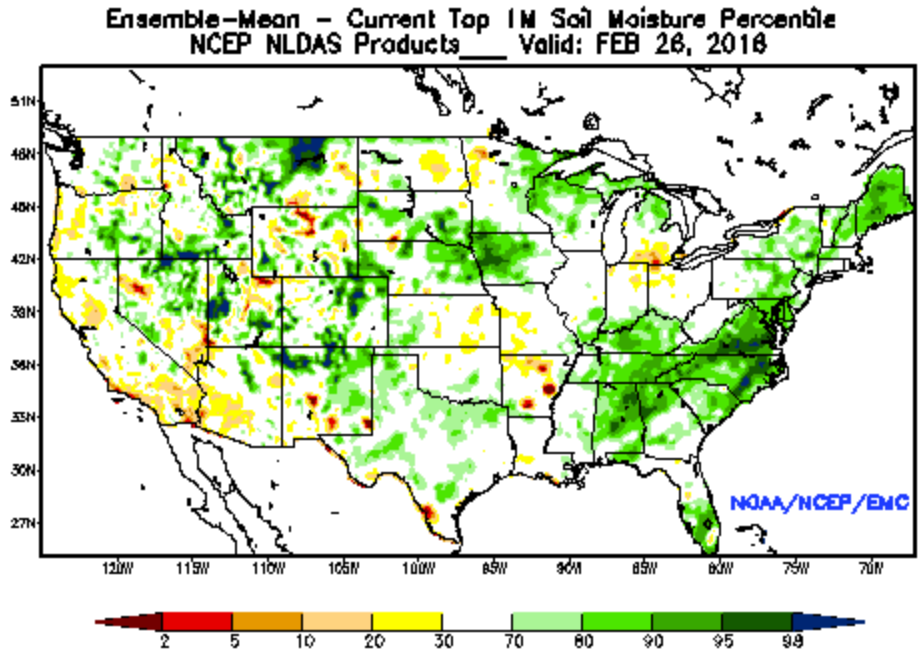


Figure 7. Top 1-Meter Soil Moisture Percentile on February 26, 2016. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

Frost Conditions

Soil frost acts as a semi-impervious layer to snowmelt or precipitation infiltration into the soil. **Figure 8** shows depth of frost penetration at National Weather Service (NWS) Warning Forecast Office (WFO) locations in the Missouri Basin as of February 29, 2016. While some frost depth measurements are missing, measurements indicate soils are frozen at variable depths. Frost depths at Aberdeen and Bismarck are 24 inches and 25 inches, respectively. In much of the remainder of the Basin, most depth measurements report as M (missing) or 0 inches.

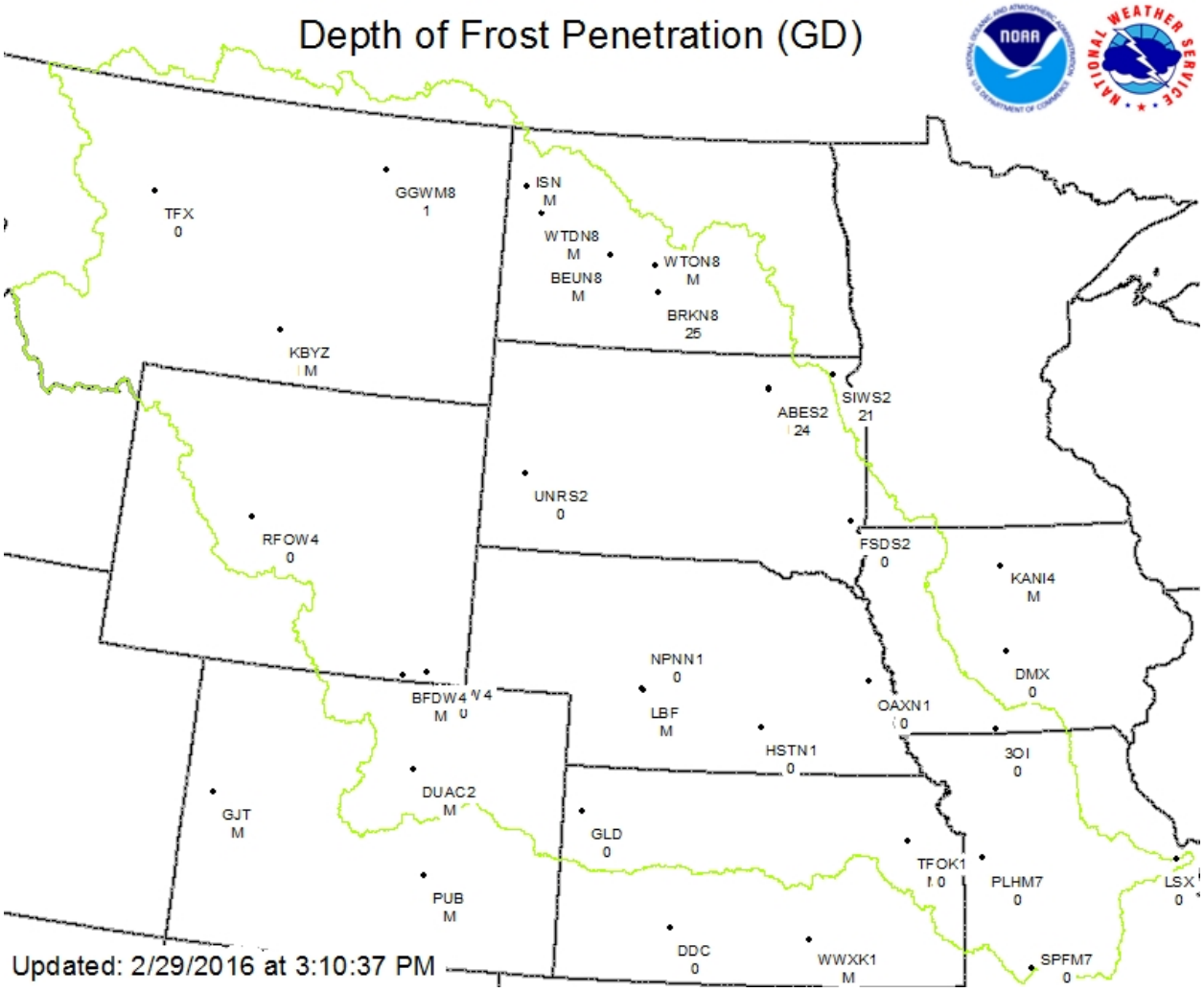


Figure 8. Measured frost depth (inches) at NWS WFO offices as of February 29, 2016. Source: NWS MBRFC. http://www.crh.noaa.gov/mbrfc

Streamflow Conditions

Missouri Basin streamflow conditions are shown in **Figure 9**. These conditions are based on the ranking of the March 2, 2016 daily streamflow versus the historical record of streamflow for that date. Where streams are currently not influenced by ice formation along the mainstem of the Missouri River below Gavins Point Dam, streamflow conditions continue to be "Normal" (25th-75th percentile), "Above normal" (76th – 90th percentile) or "Much above normal" (greater than the 90th percentile). In the Upper Basin, a majority of stations have no classification because the current stream gages are either ice-affected or the historical record is ice-affected. The few stations in the Upper Basin that are reporting indicate streamflow conditions, particularly in Montana and Wyoming, are mostly "Normal" (25th-75th percentile) to "Below normal" (10th-24th percentile), although some locations report "Above Normal" (76th – 90th percentile).

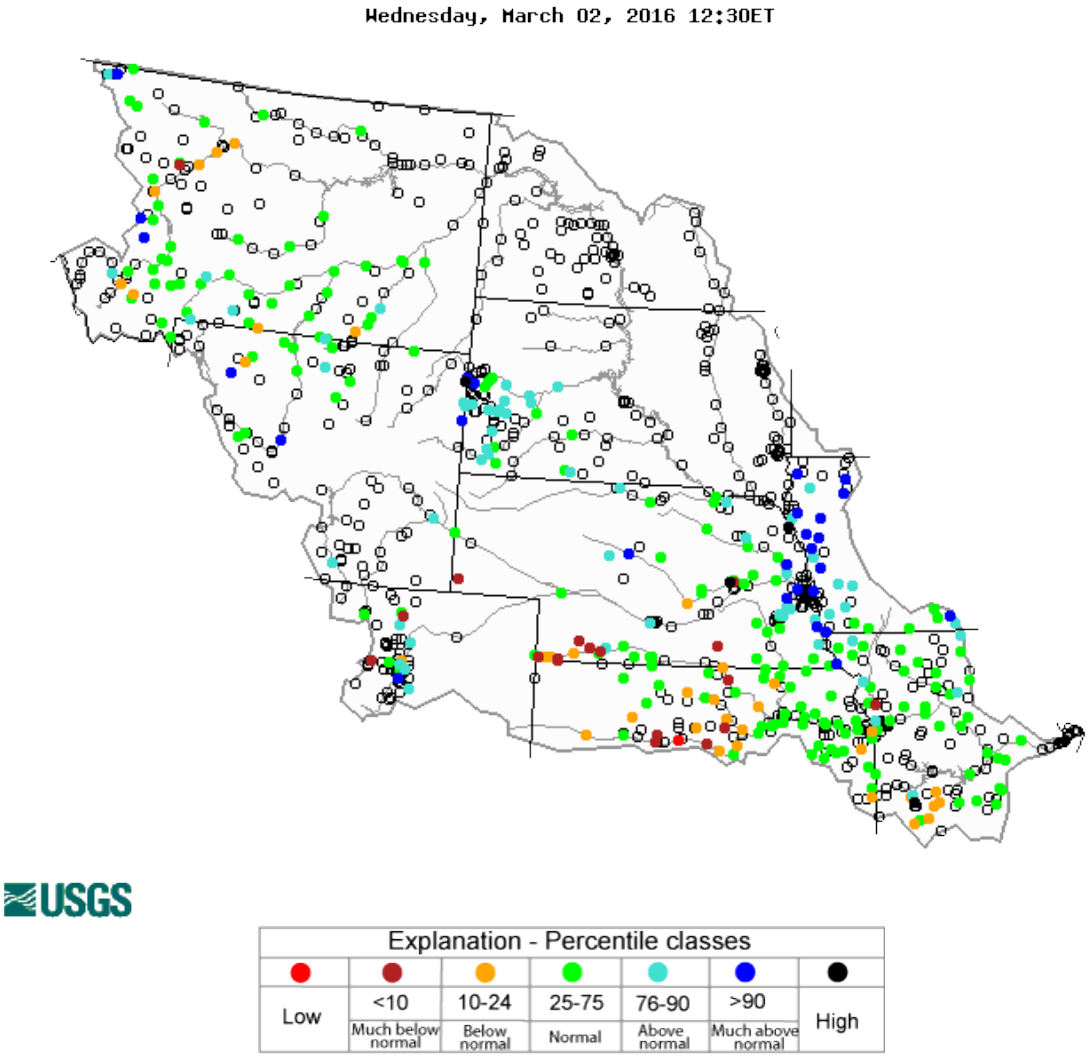


Figure 9. USGS Streamflow Conditions as a Percentile of Normal in the Missouri River Basin as of March 2, 2016. Source: USGS. http://waterwatch.usgs.gov/index.php

Plains Snowpack

Plains snowpack is an important parameter that influences the volume of runoff occurring in the basin during the months of March and April. A common misperception is that the March-April runoff is a result of plains snowmelt only. Historically, about 25% of annual runoff occurs in March and April, during the time when plains snow is melting, due to both melting snowpack and rainfall runoff. Runoff occurs in March and April whether or not there is any plains snow to melt. Determining exact rainfall amounts and locations are nearly impossible to predict more than a week in advance. Thus, the March-April runoff forecast is formulated based on existing plains snowpack and existing basin conditions and hydrologic forecasts, which for this year primarily includes long-term precipitation outlooks.

Based on the National Operational Hydrologic Remote Sensing Center (NOHRSC) assessment (**Figure 10**) as of March 1, 2016 the only plains snow cover remains in a band from north-central

and northeastern Montana through much of South Dakota extending into northern Iowa. According to Corps cooperative snow observers prior to the end-of-month snow storm, the remaining snow was either in drifts or in ditches. SWE measured prior to end of month by the observers in the upper James River basin in North Dakota was 0.6 inches; all other observers were reporting 0.0 inches SWE.

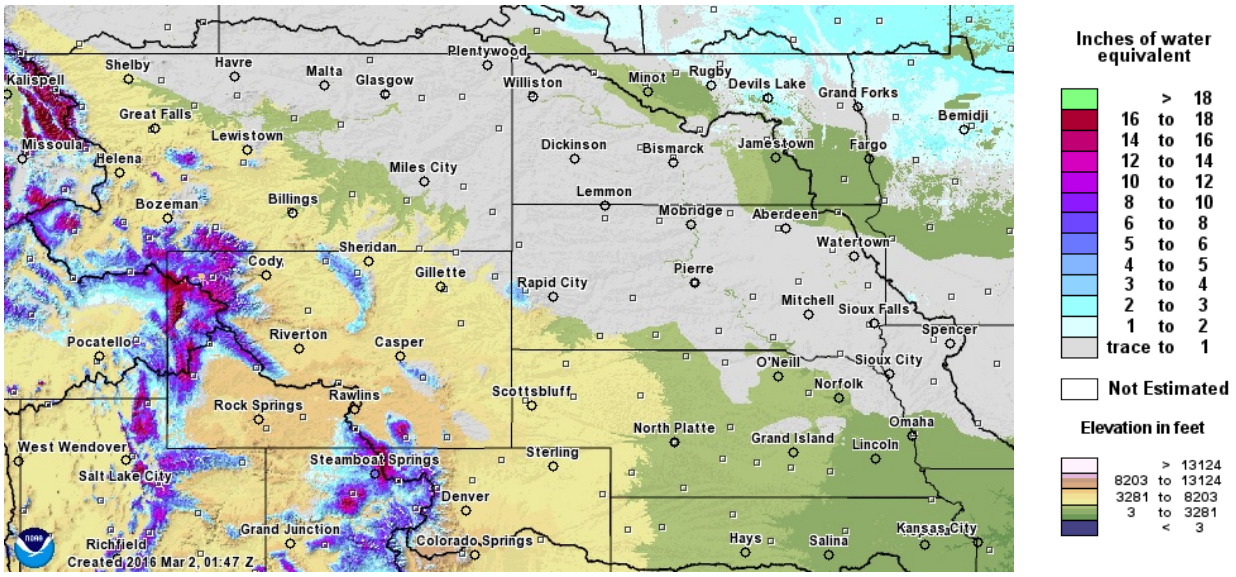


Figure 10. March 1, 2016 NOHRSC modeled plains snow water equivalent. Source: NOAA National Operational Hydrologic Remote Sensing Center. http://www.nohrsc.nws.gov/interactive/html/map.html

Using the MRBWMD snowpack classification method, plains snowpack for the March 1, 2016 runoff forecast was classified according to the terminology listed in **Table 1**. A "Light" snowpack indicates snow cover that is above the median SWE, and a "Moderate" snowpack is greater than "Light". "Average" basin conditions indicate snowpack is less than "Light" with no measureable snow accumulations. March-April runoff in "Average" conditions is expected to be below or near long term average runoff. Runoff resulting from "Light" and "Moderate" snowpack accumulations is expected to be above long term average March-April runoff.

Table 1. Plains snowpack classification for the March 1, 2016 runoff forecast.

Reservoir Reach	Plains Snowpack Classification
Above Fort Peck	None-Average
Fort Peck to Garrison	None-Average
Garrison to Oahe	None-Average
Oahe to Fort Randall	None-Average
Fort Randall to Gavins Point	None-Average
Gavins Point to Sioux City	None-Average

Mountain Snow Pack

Mountain snowpack is the primary factor used to predict May-July runoff volumes in the Fort Peck and Fort Peck to Garrison mainstem reaches. During the 3-month May-July runoff period, about 50% of the annual runoff enters the mainstem system as a result of mountain snowmelt and rainfall runoff. Greater-than-average mountain snow accumulations are usually associated with greater-than-average May-July runoff volumes, especially when mountain soil moisture conditions have been wetter than normal as in the past three years. For example, we would expect to see below-average runoff from a below-average mountain snowpack this year due to soil moisture conditions ranging from drier than normal to wetter than normal.

Figure 11 includes time series plots of the average mountain SWE beginning on October 1, 2015 based on the NRCS SNOTEL gages for the basin above Fort Peck and the incremental basin from Fort Peck to Garrison. The current average SWE values (shaded blue area) are plotted against the 1981-2010 basin average SWE (bold red line), 2001 (green line), and two historic high SWE years occurring in 1997 (purple) and 2011 (dark blue).

As of **February 29, 2016**, the Corps of Engineers computed an average mountain SWE in the **Fort Peck reservoir reach of 11.5 inches, which is 89% of average** based on the 1981-2010 average SWE for the Fort Peck reach. In the **reservoir reach between Fort Peck Dam and Garrison Dam**, the Corps computed an average mountain SWE of **8.2 inches, which is 75% of average** based on the 1981-2010 average SWE for the Garrison reach. Normally by March 1, about 80% of the peak snow accumulation has occurred in the mountains.

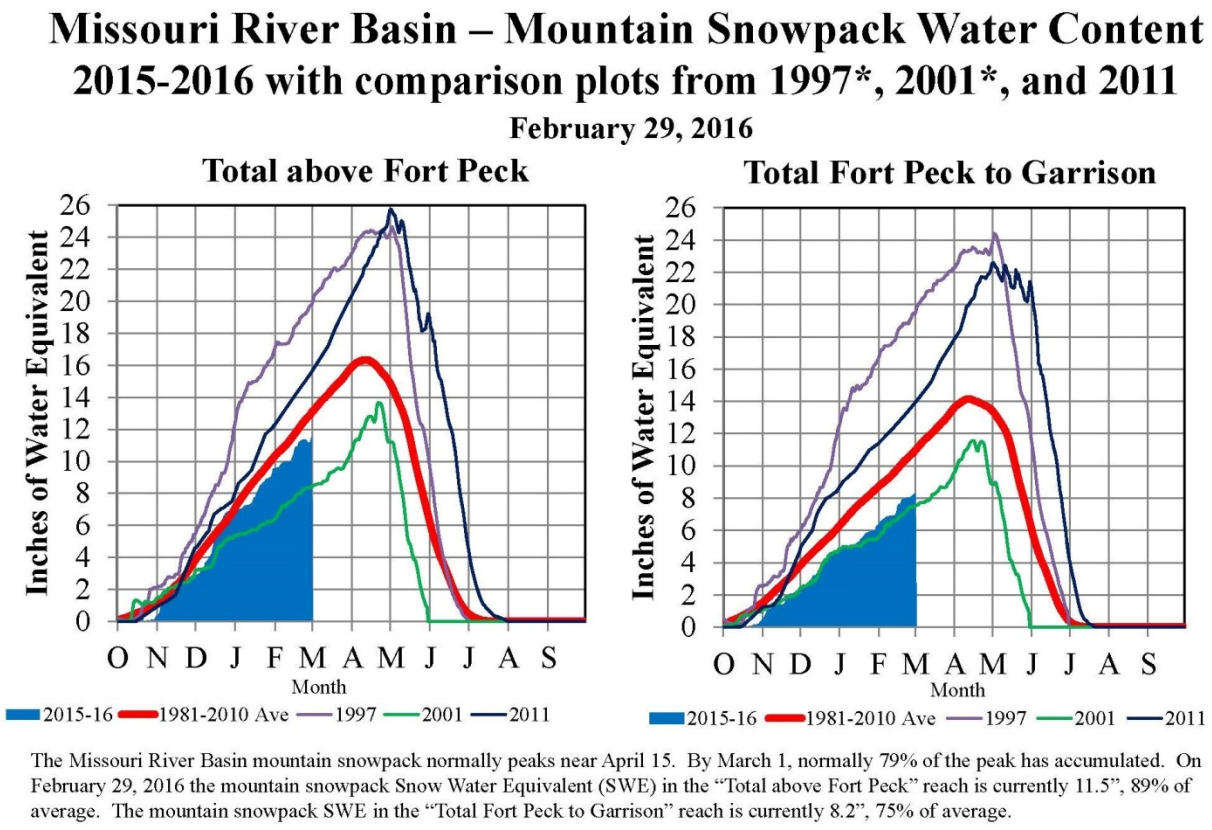


Figure 11. Mountain snowpack water content on February 29, 2016 compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management.

Climate Outlook

ENSO (El Niño Southern Oscillation)

According to the CPC's latest monthly update[1] on February 29, 2016, "***El Niño conditions are present. Positive equatorial sea surface temperature (SST) anomalies continue across most of the Pacific Ocean. A transition to ENSO-neutral is likely during late Northern Hemisphere spring or early summer 2016, with a possible transition to La Niña conditions during the fall.***"

MRBWMD participates in the monthly North Central U.S. Climate/Drought Outlook Webinar coordinated through NOAA, the regional climate centers, and the American Association of State Climatologists (AASC). These webinars provide updates on near-term climate outlooks and impacts including the El Niño climate pattern and its implications on winter temperature and precipitation patterns in the Missouri River Basin. The possible impacts of El Niño have been factored into the CPC climate outlooks described below.

[1] http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/lanina/enso_evolution-status-fcsts-web.pdf

Temperature and Precipitation Outlooks

The NOAA Climate Prediction Center climate outlook for March 2016 (**Figure 12**) indicates an increased probability for above normal temperatures over the entire Missouri Basin with the exception of western Kansas, which has an equal chance of above- or below-normal temperatures. Probabilities for above normal temperatures range from a greater than 60% chance temperatures will be above normal in northern North Dakota to a 33.3% to 40% chance across the Lower Basin. With regard to precipitation, there is a greater than 40% chance precipitation will be below normal in north-central Montana, and a 33.3% to 40% chance for below-normal precipitation in most of the rest of Montana. There are increased chances for above-normal precipitation in Colorado, southeastern Wyoming, Nebraska, southern South Dakota, and Kansas.

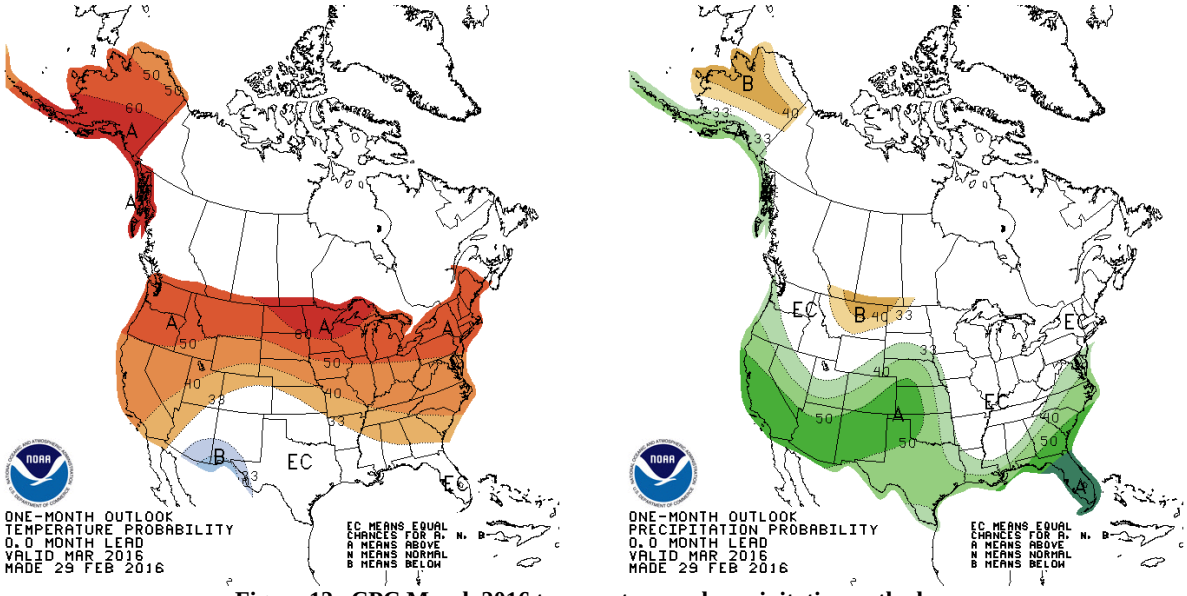


Figure 12. CPC March 2016 temperature and precipitation outlooks.

The March-April-May 2016 temperature outlook (**Figure 13**) indicates a slight reduction in the area of increased chances for above normal temperatures through the end of May. The March-April-May precipitation outlook also indicates a reduction in the area of increased chances for below-normal precipitation for nearly all of Montana as well as a reduction in the area of increased chances for above normal precipitation, although more of Colorado and Wyoming will see an increased chance for above-normal precipitation. The June-July-August 2016 CPC temperature outlook (**Figure 14**) indicates there are increased chances for above-normal temperatures across the entire Missouri Basin. In terms of precipitation, there are equal chances for above- and below-normal precipitation throughout the entire Missouri Basin.

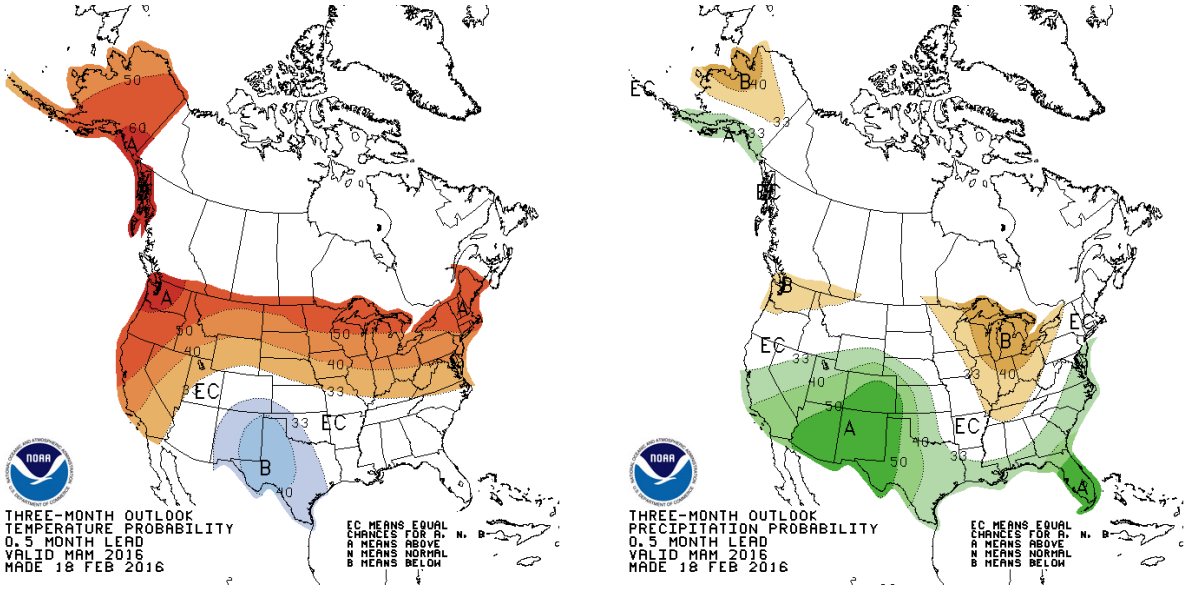


Figure 13. CPC March-April-May 2016 temperature and precipitation outlooks.

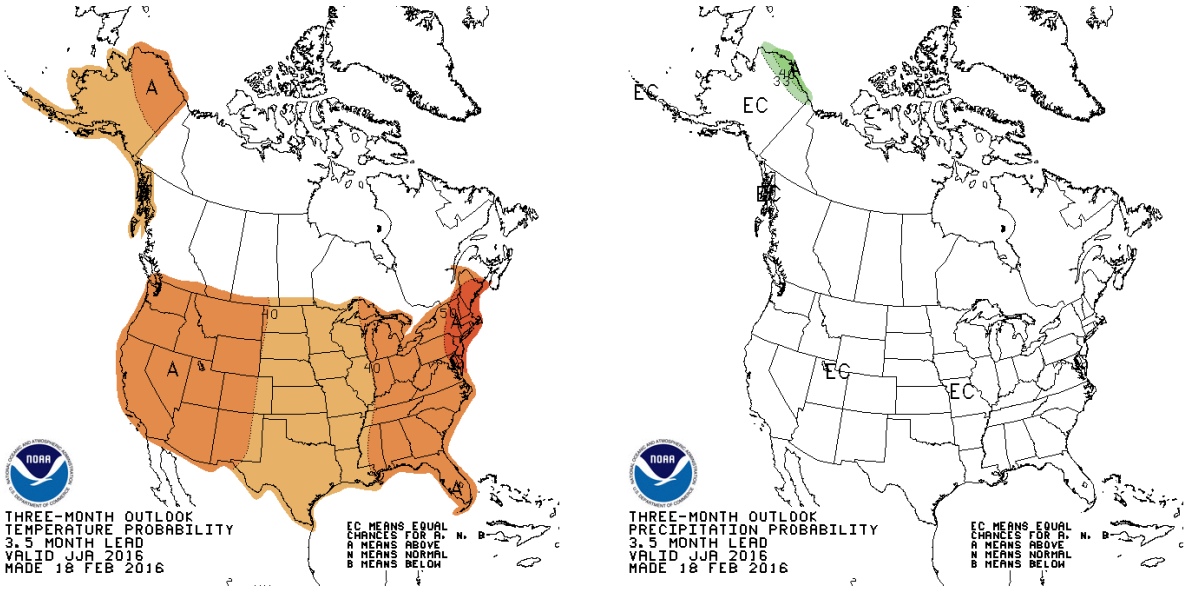


Figure 14. CPC June-July-August 2016 temperature and precipitation outlooks.

During the September-October-November 2016 period (**Figure 15**) CPC outlooks indicate increased chances for above-normal temperatures across the entire Missouri Basin, and equal chances for above-normal, normal and below-normal precipitation, except for Colorado and western Kansas, where there is an increased chance for below-normal precipitation. The December 2016-January-February 2017 period (**Figure 16**) outlook indicates increased chances for below-normal temperatures in the Northern Rockies and plains. With regard to precipitation, the **Figure 18** outlook indicates there is an increased chance for above-normal precipitation in the Northern Rockies and equal chances for much of the remaining Missouri Basin, with the

exception of Colorado and Kansas, which indicates an increased chance for below-normal precipitation.

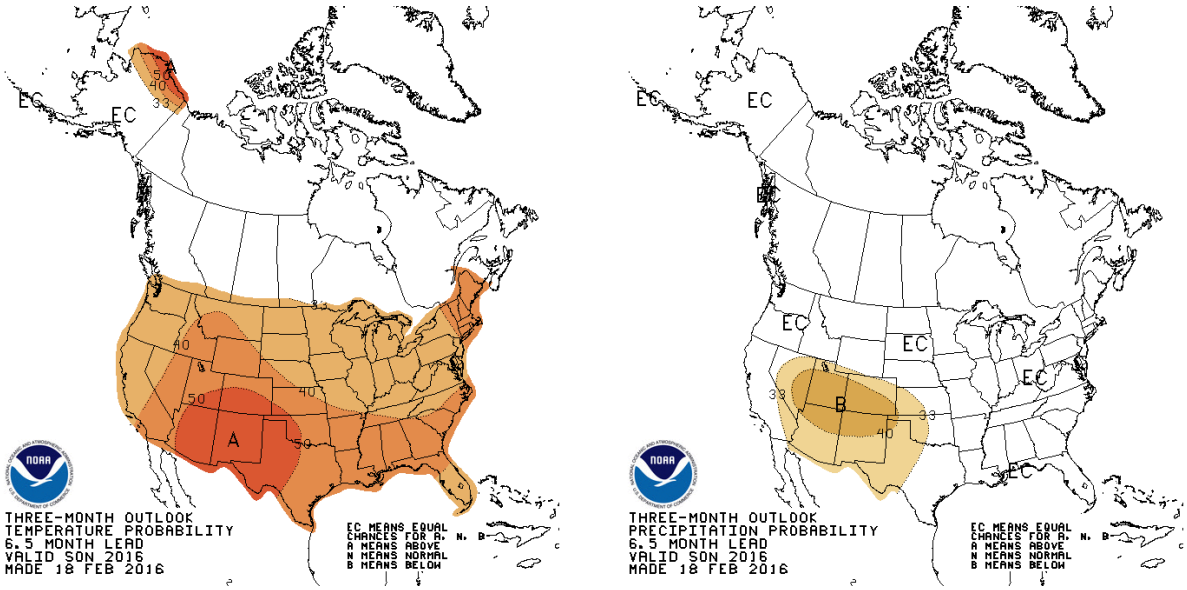


Figure 15. CPC September-October-November 2016 temperature and precipitation outlooks.

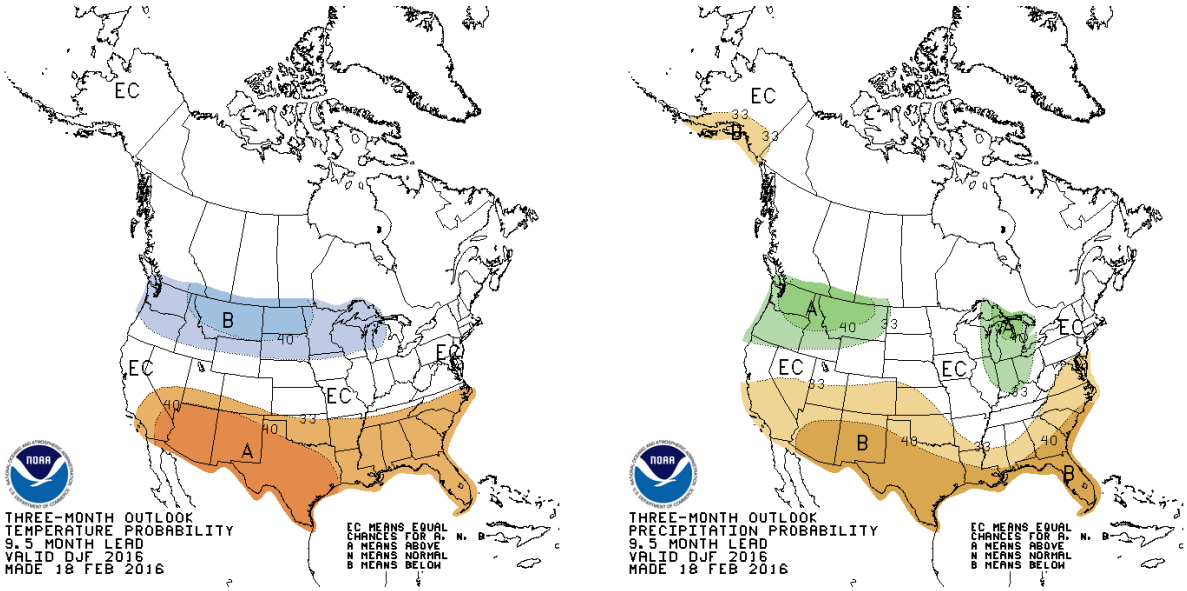


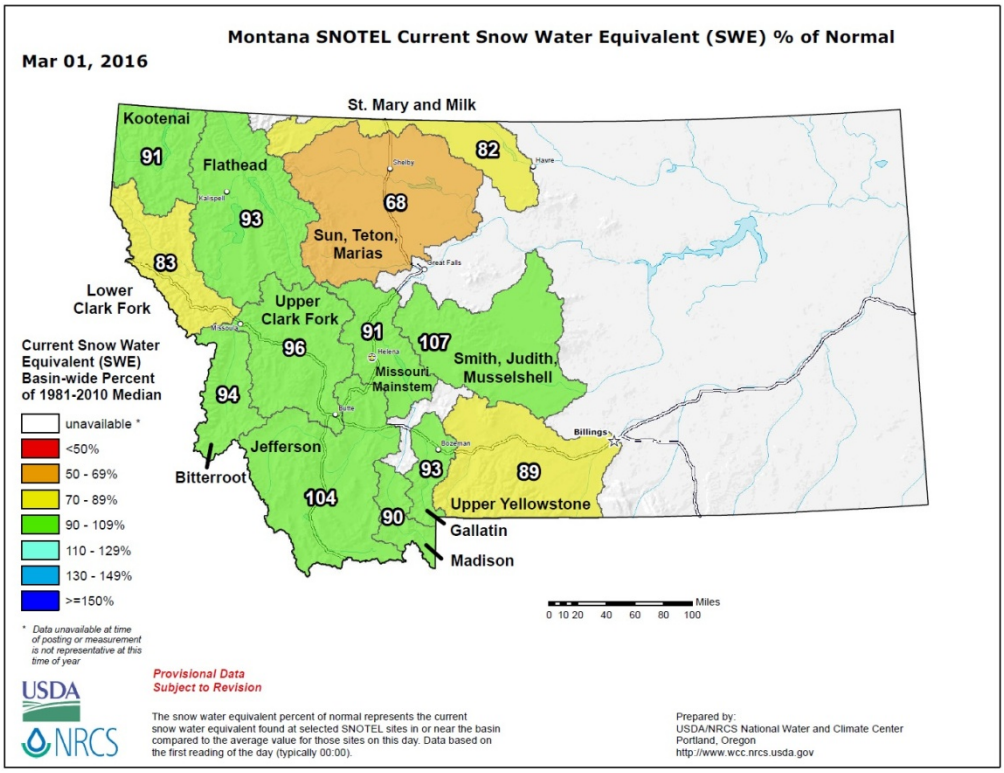
Figure 16. CPC December 2016-January-February 2017 temperature and precipitation outlooks.

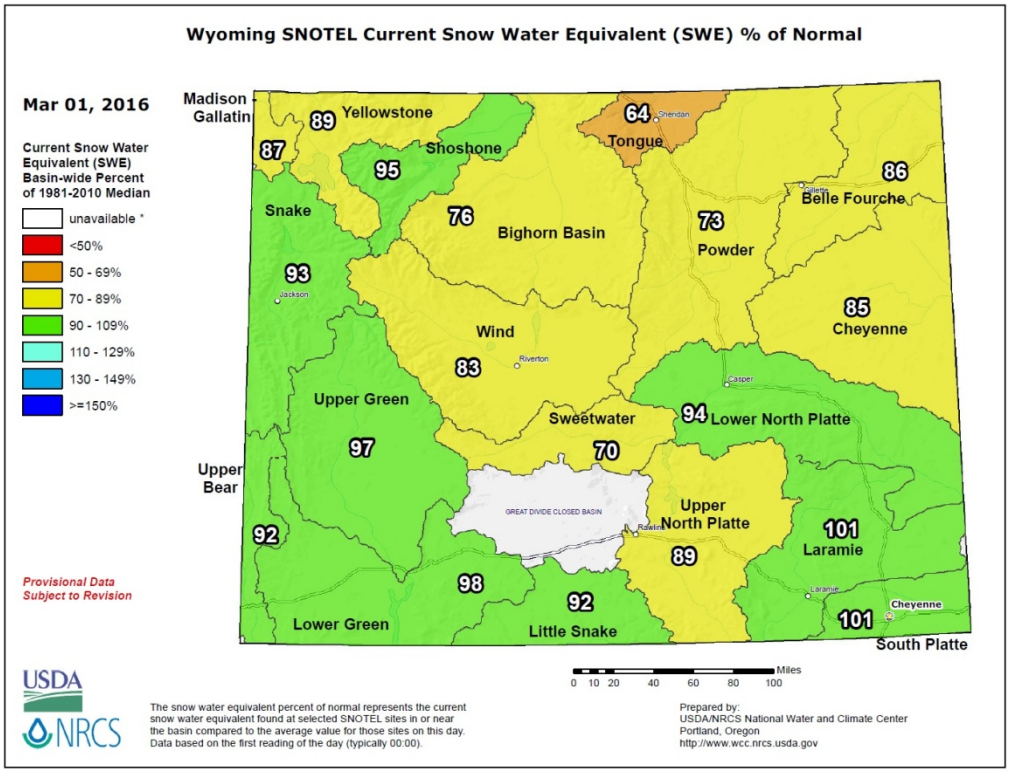
March 2016 Calendar Year Runoff Forecast

In summary, the 2016 calendar year runoff forecast is **21.6 MAF**, **85% of average**. Once again, we expect that the warmer-than-normal temperatures that are forecast over the next three months will lead to melt reduced runoff from rainfall. Runoff is forecast to be below average in March and April, due to early plains snowmelt and a lack of remaining plains snowpack. The below-

average mountain snowpack will likely lead to below-average May-June-July runoff in the Fort Peck and Garrison reaches.

Additional Figures





USDA NRCS National Water & Climate Center
 * - DATA CURRENT AS OF: March 03, 2016 04:40:13 PM
   - Based on March 01, 2016 forecast values

PRELIMINARY MISSOURI RIVER BASIN FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
Lake Sherburne Inflow	APR-JUL	86	89	101	92	80	71	97
	APR-SEP	100	89	117	107	93	83	112
St. Mary R at Int'l Boundary (2)	APR-JUL	380	87	480	420	340	280	435
	APR-SEP	435	86	540	475	395	330	505
Lima Reservoir Inflow (2)	APR-JUL	68	83	102	82	54	34	82
	APR-SEP	74	83	115	90	58	33	89
Clark Canyon Reservoir Inflow (2)	APR-JUL	82	81	167	116	48	21	101
	APR-SEP	100	83	193	138	62	7.2	120
Jefferson R nr Three Forks (2)	APR-JUL	720	97	1150	890	550	295	740
	APR-SEP	780	98	1250	970	590	310	800
Hebgen Reservoir Inflow (2)	APR-JUL	305	82	370	330	275	235	370
	APR-SEP	385	82	465	420	355	310	470
Ennis Reservoir Inflow (2)	APR-JUL	525	84	665	580	470	385	625
	APR-SEP	660	85	825	725	595	495	775
Missouri R at Toston (2)	APR-JUL	1610	90	2300	1890	1330	915	1790
	APR-SEP	1860	90	2670	2190	1530	1050	2070
Smith R bl Eagle Ck (2)	APR-JUL	107	101	163	130	85	51	106
	APR-SEP	117	101	183	144	90	51	116
Gibson Reservoir Inflow (2)	APR-JUL	275	70	380	315	235	171	395
	APR-SEP	310	70	420	355	265	199	440
Marias R nr Shelby (2)	APR-JUL	205	59	385	280	133	27	345
	APR-SEP	210	58	400	285	131	16.3	360
Milk R at Western Crossing	MAR-SEP	25	76	53	38	15.4	6.8	33*

PRELIMINARY YELLOWSTONE RIVER BASIN FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
West Rosebud Ck nr Roscoe (2)	APR-JUL	48	81	57	52	44	39	59
	APR-SEP	62	84	74	67	57	50	74
Wind R ab Bull Lake Ck (2)	APR-JUL	380	84	490	425	335	270	455
	APR-SEP	400	82	530	450	350	270	490
Bull Lake Ck nr Lenore	APR-JUL	116	83	147	128	104	85	139
	APR-SEP	141	83	179	157	125	103	169
Boysen Reservoir Inflow (2)	APR-JUL	400	66	785	555	245	14.9	610
	APR-SEP	425	64	855	600	250	15.0	665
Greybull R nr Meeteetse	APR-JUL	116	89	153	131	101	79	131
	APR-SEP	155	88	205	174	136	107	177
Shell Ck nr Shell	APR-JUL	40	73	55	46	34	25	55
	APR-SEP	50	76	67	57	43	33	66
Bighorn R at Kane (2)	APR-JUL	535	64	1060	750	325	17.1	840
	APR-SEP	545	60	1110	775	315	15.0	905
NF Shoshone R at Wapiti	APR-JUL	425	92	525	465	385	325	460
	APR-SEP	475	92	585	520	430	365	515
SF Shoshone R nr Valley	APR-JUL	205	95	250	225	186	159	215
	APR-SEP	235	96	285	255	215	183	245
Buffalo Bill Reservoir Inflow (2)	APR-JUL	645	96	800	705	580	485	675
	APR-SEP	705	95	885	780	635	530	745
Bighorn R nr St. Xavier (2)	APR-JUL	1040	75	1680	1300	785	410	1380
	APR-SEP	1060	73	1770	1340	770	345	1460
Little Bighorn R nr Hardin	APR-JUL	50	51	97	69	31	3.0	98

	APR-SEP	58	52	110	79	37	5.8	111
Tongue R nr Dayton (2)	APR-JUL	48	56	79	61	35	16.9	86
	APR-SEP	57	58	91	71	43	23	98
Tongue River Reservoir Inflow (2)	APR-JUL	110	57	220	154	66	0.40	193
	APR-SEP	125	58	240	172	78	9.3	215
NF Powder R nr Hazelton	APR-JUL	6.5	71	9.7	7.8	5.2	3.3	9.1
	APR-SEP	7.1	72	10.4	8.5	5.7	3.8	9.9
Powder R at Moorhead	APR-JUL	82	46	196	128	35	1.00	177
	APR-SEP	98	50	215	146	51	1.00	196
Powder R nr Locate	APR-JUL	90	45	225	145	36	1.00	199
	APR-SEP	105	48	250	164	47	1.00	220

Max (10%), 30%, 50%, 70% and Min (90%) chance that actual volume will exceed forecast.
Averages are for the 1981-2010 period.
All volumes are in thousands of acre-feet.

footnotes:
1) Max and Min are 5% and 95% chance that actual volume will exceed forecast
2) streamflow is adjusted for upstream storage
3) median value used in place of average

* Milk River median is for years 1980-2008 & marked "30%" is 25% exceedance and marked "70%" is 75% exceedance.

Upper Missouri River Basin
April 2016 Calendar Year Runoff Forecast
April 5, 2016

U.S. Army Corps of Engineers, Northwestern Division
Missouri River Basin Water Management
Omaha, NE

Calendar Year Runoff Forecast

Explanation and Purpose of Forecast

The long-range runoff forecast is presented as the Calendar Year Runoff Forecast. This forecast is developed shortly after the beginning of each calendar year and is updated at the beginning of each month to show the actual runoff for historic months of that year and the updated forecast for the remaining months of the year. This forecast presents monthly inflows in million acre-feet (MAF) from five incremental drainage areas, as defined by the individual System projects, plus the incremental drainage area between Gavins Point Dam and Sioux City. Due to their close proximity, the Big Bend and Fort Randall drainage areas are combined. Summations are provided for the total Missouri River reach above Gavins Point Dam and for the total Missouri River reach above Sioux City. The Calendar Year Runoff Forecast is used in the Monthly Study simulation model to plan future system regulation in order to meet the authorized project purposes throughout the calendar year.

March 2016 Runoff

March 2016 Missouri River runoff was 1.8 MAF (60% of average) above Sioux City, IA (upper Basin). March 2016 runoff above Gavins Point Dam was 1.3 MAF (51% of average). Very little plains snowpack remained at the beginning of March due to earlier-than-normal snowmelt runoff that occurred in January and February. Furthermore, March precipitation was well-below average in the plains.

2016 Calendar Year Forecast Synopsis

The April 1 forecast for 2016 upper Basin runoff is **21.7 MAF (86% of average)**. Runoff for the basin above Gavins Point Dam is forecast to be **19.0 MAF (82% of average)**. Due to the amount of variability in precipitation and other hydrologic factors that can occur over the next 9 months, the range of expected inflow is quite large and ranges from the 28.3 MAF upper basic forecast to the 15.9 MAF lower basic forecast. The upper and lower basic forecasts are used in long-term regulation planning models to "bracket" the range of expected runoff given much wetter or drier conditions, respectively. Given that 9 months are being forecasted for this April 1 forecast (3 months observed/9 months forecast), the range of wetter than normal (upper basic) and drier than normal (lower basic) conditions is attributed to all 6 reaches for 9 months. The

result is a large range or “bracket” for each reach, and thus, for the total runoff forecast. As the year progresses, the range will lessen as the number of observed months increases and number of forecast months decreases.

Current Conditions

Drought Analysis

The latest National Drought Mitigation Center’s drought monitor for March 29, 2016 (**Figure 1**), when compared to the drought monitor for March 1, 2016 (**Figure 2**), shows an increase in areal extent of Abnormally Dry (D0) and Moderate Drought (D1) conditions in the upper Basin. Also there is additional development of Severe Drought (D2) conditions in southern Montana and northern Wyoming. In contrast, there has been a significant decrease of drought severity in western Montana. D1 and D2 conditions have been removed in most areas, with lingering D0 to D1 conditions in northwest Montana. The U.S. Seasonal Drought Outlook in **Figure 3** indicates that drought will persist in western Montana. Drought conditions are likely to ease in south-central Montana, north-central Wyoming and eastern North Dakota through the end of June 2016.

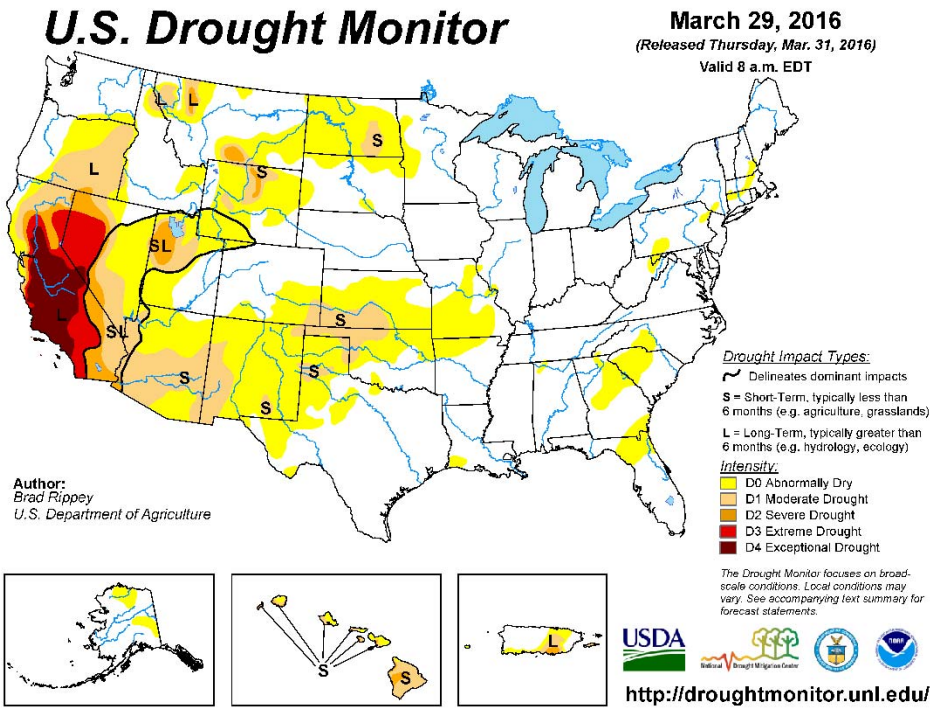


Figure 1 National Drought Mitigation Center U.S. Drought Monitor for March 29, 2016

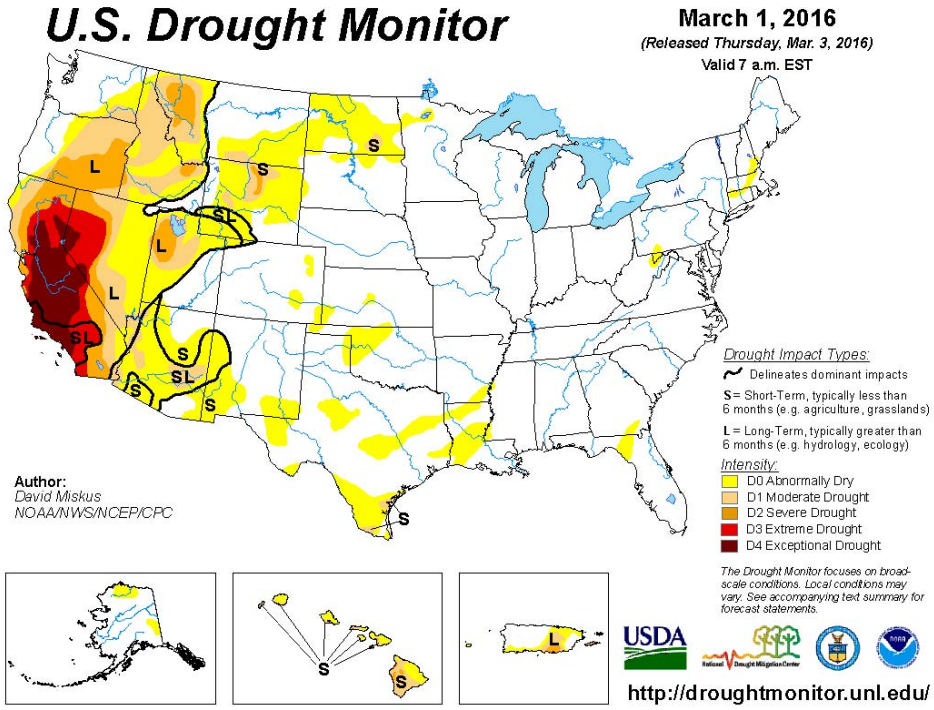


Figure 2. National Drought Mitigation Center U.S. Drought Monitor for March 1, 2016.

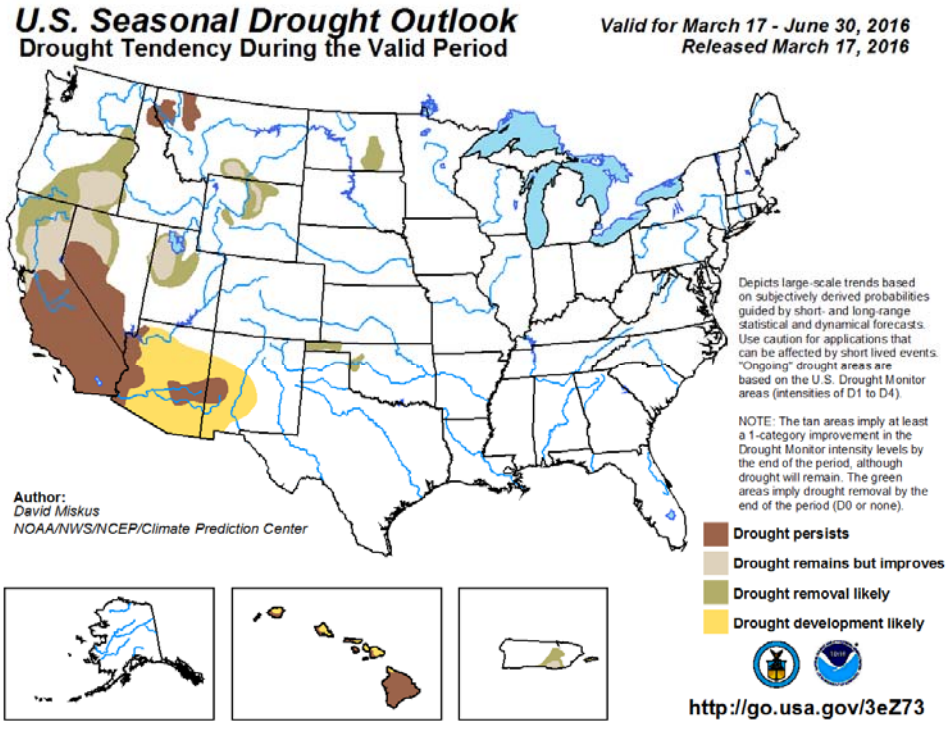


Figure 3. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

March precipitation accumulations are shown in **Figure 4** as both inches of precipitation (left) and percent of normal monthly precipitation (right). March precipitation was below normal from eastern Montana through the central and eastern Dakotas. Precipitation was also well-below normal in most of the lower Basin. Precipitation was more than 150% of normal in Wyoming, western Nebraska, and southwest South Dakota as a result of the winter storm that occurred at the end of March.

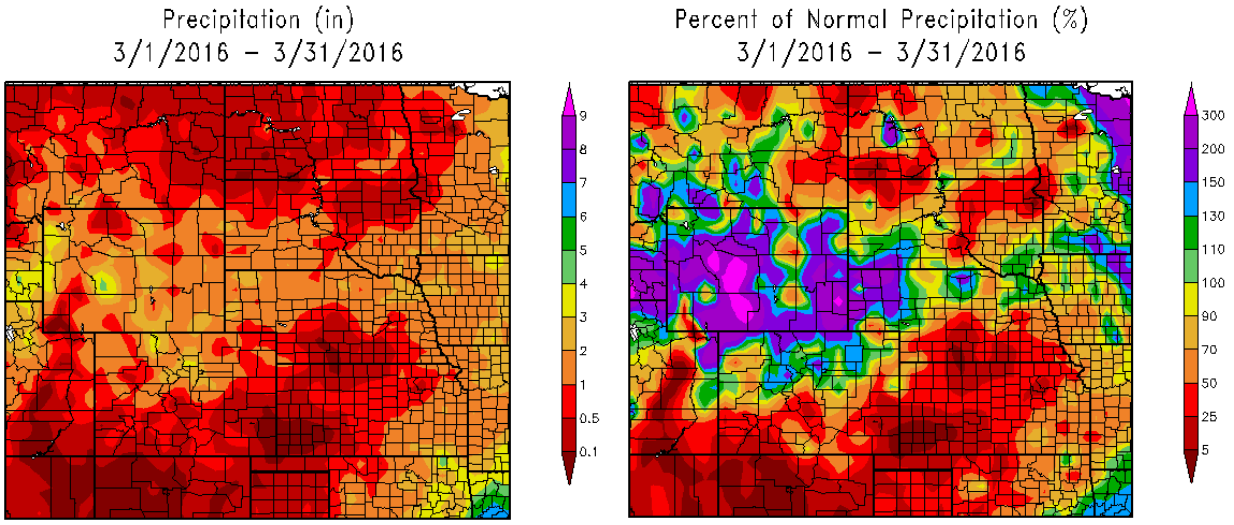


Figure 4. March 2016 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Table 1 contains notable March precipitation and snowfall accumulations in these areas. Riverton, WY and Lander, WY received the greatest March precipitation accumulations due mainly to the end-of-March storm. Precipitation was also above normal at the other locations listed in **Table 1**. Snowfall totals were relatively heavy in Riverton and Lander; however, very little snowfall occurred in Billings, MT and Rapid City, SD.

Table 1. March 2016 snowfall and precipitation totals.

City, State	Snowfall inches	Precipitation inches	Precipitation Departure inches
Riverton, WY	21.5	2.13	1.58
Lander, WY	33.3	4.59	3.43
Worland, WY	m	0.97	0.51
Sheridan, WY	m	1.59	0.61
Billings, MT	1.9	1.55	0.49
Chadron, NE	m	2.44	1.21
Rapid City Arpt, SD	5.8	1.09	0.16

January-February-March 2016 precipitation accumulations are shown in **Figure 5**. The precipitation pattern since January 1 is similar to the March pattern, with the most notable above-

normal accumulations in Wyoming, southern Montana and western Nebraska. The remainder of the upper Basin and much of the lower Basin was drier than normal from January through March.

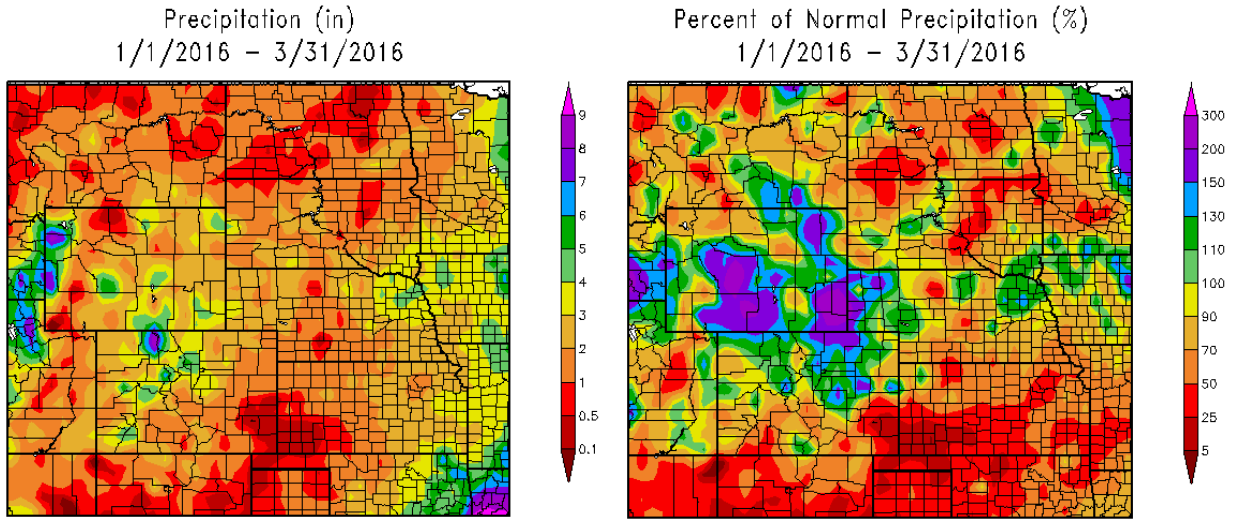


Figure 5. January-February-March 2016 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Temperature

March temperature departures from normal are shown in **Figure 6** in degrees Fahrenheit (deg F). January-February-March 2016 temperature departures are also shown in **Figure 6**. Temperatures during March have ranged from near normal in the northern Rockies to more than 8 degrees F above normal in eastern North Dakota, with a similar pattern since January 1.

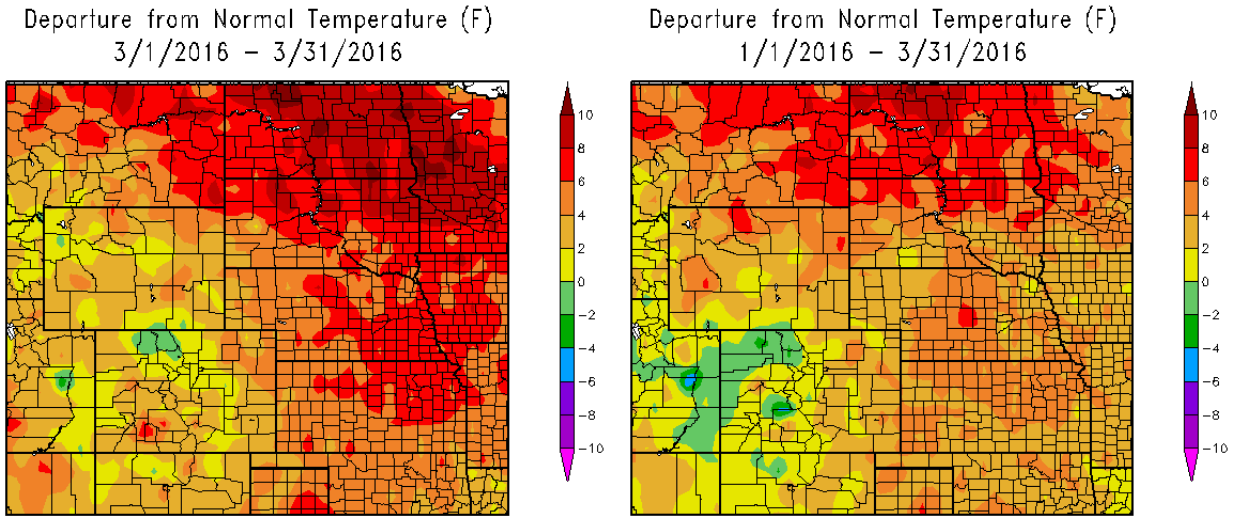


Figure 6. March 2016 and January-February-March 2016 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Soil Moisture

Soil moisture is factored into the forecast as an indicator of wet or dry hydrologic basin conditions. Typically when soil moisture conditions are wet or greater than normal, rainfall and snowmelt runoff is greater than when soil moisture is dry or less than normal. Not only is soil moisture a physical parameter that influences runoff, it can be used as an indicator of future runoff.

Figure 7 shows the NOAA NLDAS ensemble top 1-meter soil moisture anomaly on March 28, 2016. The NLDAS soil moisture depiction is an average value for the soil moisture column. **Figure 7** indicates above-normal soil moisture anomalies in north central and western Montana, western and southeastern South Dakota, western and eastern Nebraska, and western Iowa. Below-normal soil moisture anomalies are present in south central Montana and north central Wyoming, North Dakota, and northern South Dakota.

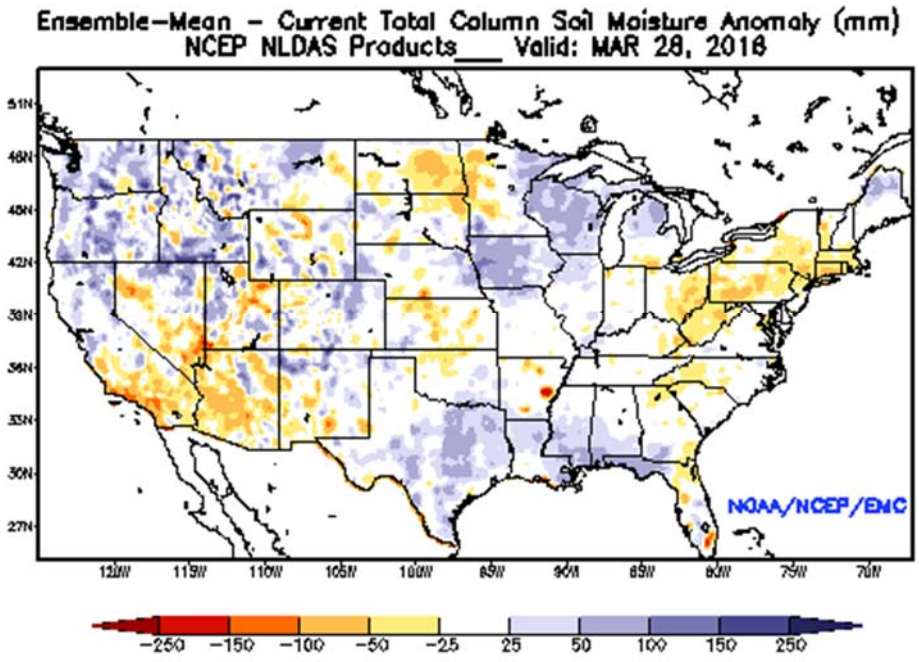


Figure 7. Top 1-Meter Soil Moisture Anomaly on March 28, 2016. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

Frost Conditions

Soil frost acts as a semi-impervious layer to snowmelt or precipitation infiltration into the soil. **Figure 8** shows depth of frost penetration at National Weather Service (NWS) Warning Forecast Office (WFO) locations in the Missouri Basin as of March 31, 2016. At this time, the soil moisture map indicates there is no soil frost in the Basin at the locations where it is measured.

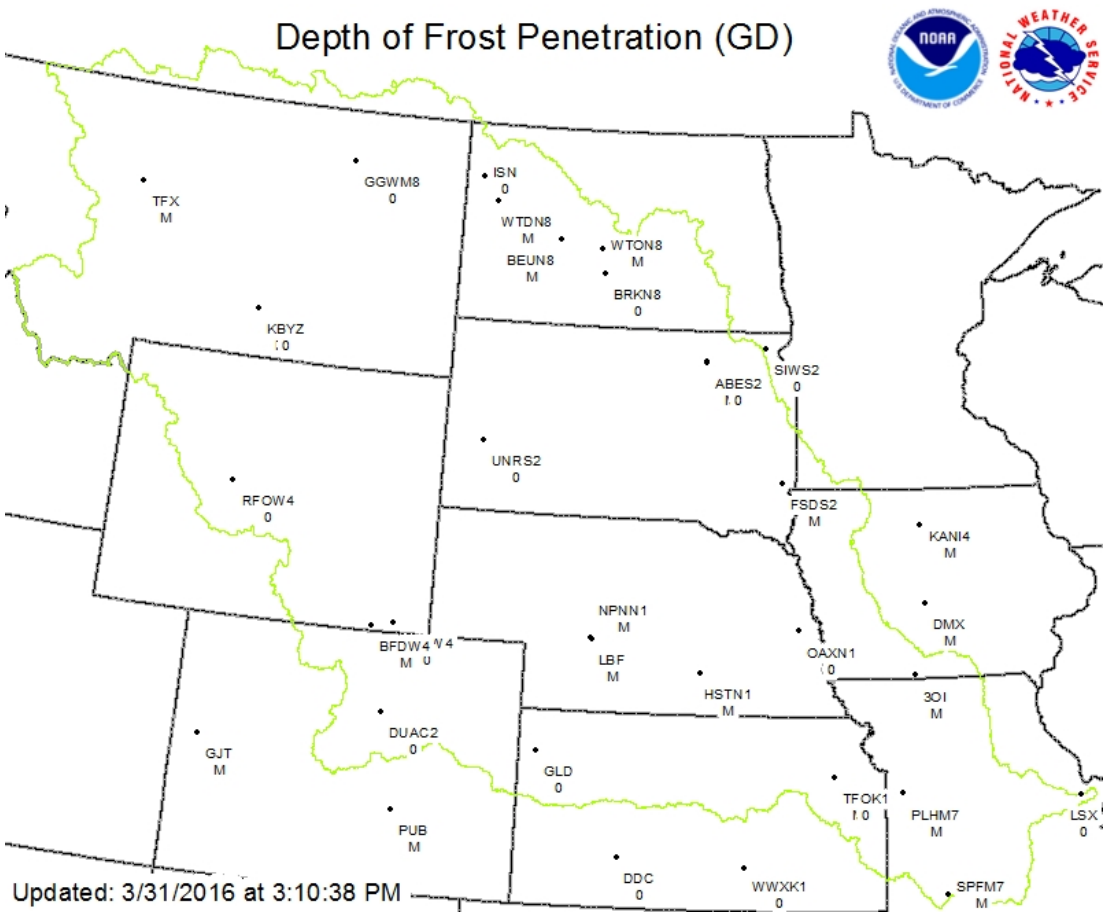


Figure 8. Measured frost depth (inches) at NWS WFO offices as of March 31, 2016. Source: NWS MBRFC. http://www.crh.noaa.gov/mbrfc

Streamflow Conditions

Missouri Basin streamflow conditions are shown in **Figure 9**. These conditions are based on the ranking of the April 2, 2016 daily streamflow versus the historical record of streamflow for that date. All river ice has melted, therefore, streamflow conditions are no longer ice-affected. Streamflow conditions range from "Normal" (25^{th}-75^{th} percentile) to "Below normal" (10^{th}-24^{th} percentile) over a majority of the upper Basin and the lower Basin below Nebraska City. Streamflow conditions are "Normal" to "Above normal" (76^{th} – 90^{th} percentile) in the Black Hills and the Basin from Fort Randall Dam to Nebraska City, NE. A number of stations in these areas are "Above Normal" (76^{th} – 90^{th} percentile).

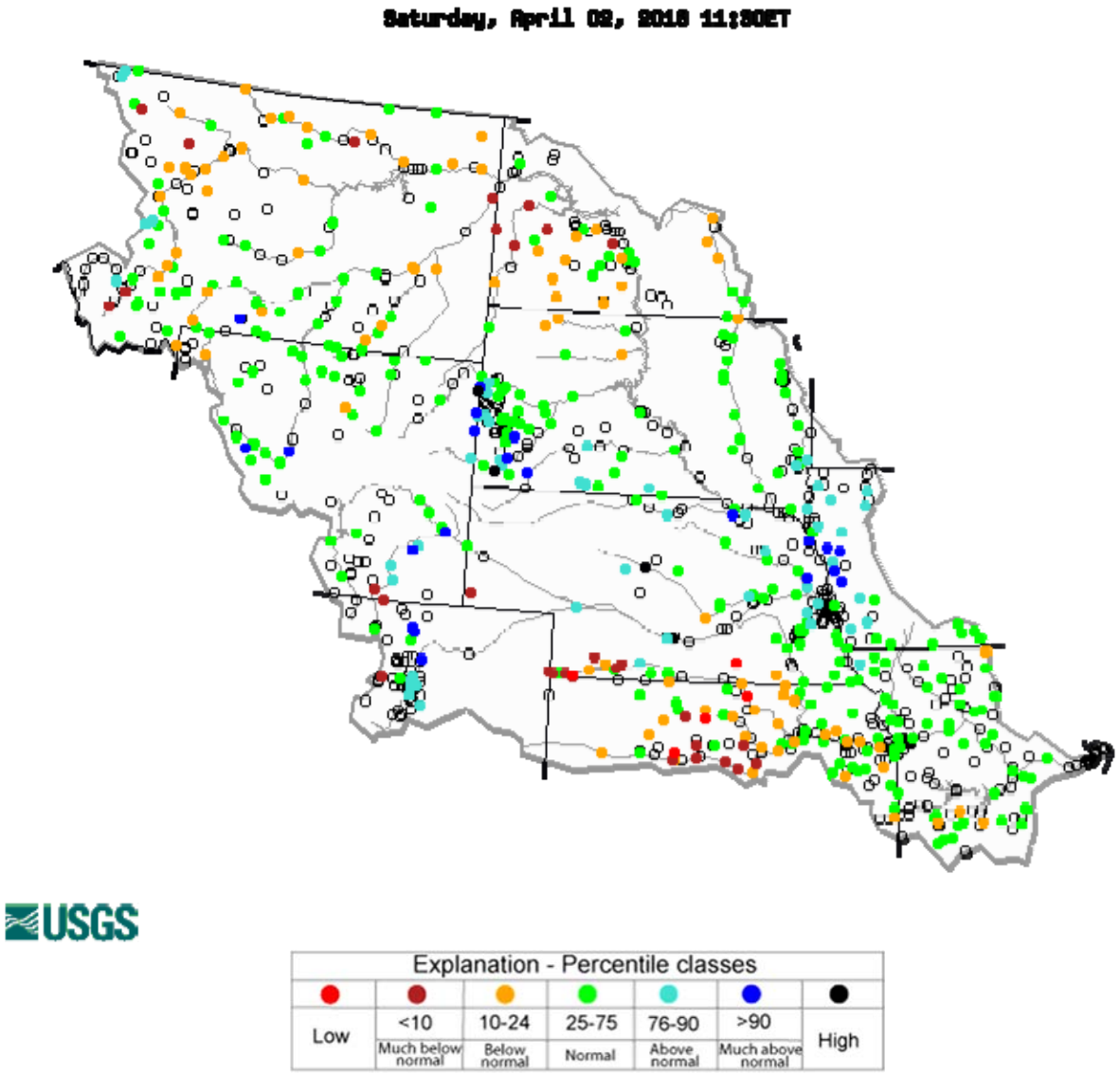


Figure 9. USGS Streamflow Conditions as a Percentile of Normal in the Missouri River Basin as of April 2, 2016. Source: USGS. http://waterwatch.usgs.gov/index.php

Plains Snowpack

Plains snowpack is an important parameter that influences the volume of runoff occurring in the basin during the months of March and April. A common misperception is that the March-April runoff is a result of plains snowmelt only. Historically, about 25% of annual runoff occurs in March and April, during the time when plains snow is melting, due to both melting snowpack and rainfall runoff. Runoff occurs in March and April whether or not there is any plains snow to melt. Determining exact rainfall amounts and locations are nearly impossible to predict more than a week in advance. Thus, the March-April runoff forecast is formulated based on existing plains snowpack and existing basin conditions and hydrologic forecasts, which for this year primarily includes long-term precipitation outlooks.

Based on the National Operational Hydrologic Remote Sensing Center (NOHRSC) assessment (**Figure 10**) as of April 4, 2016, there is currently no plains snowpack. Much of the seasonal plains snowpack had melted by mid-February. Since March 1, additional snowfall has resulted in only short-term accumulations.

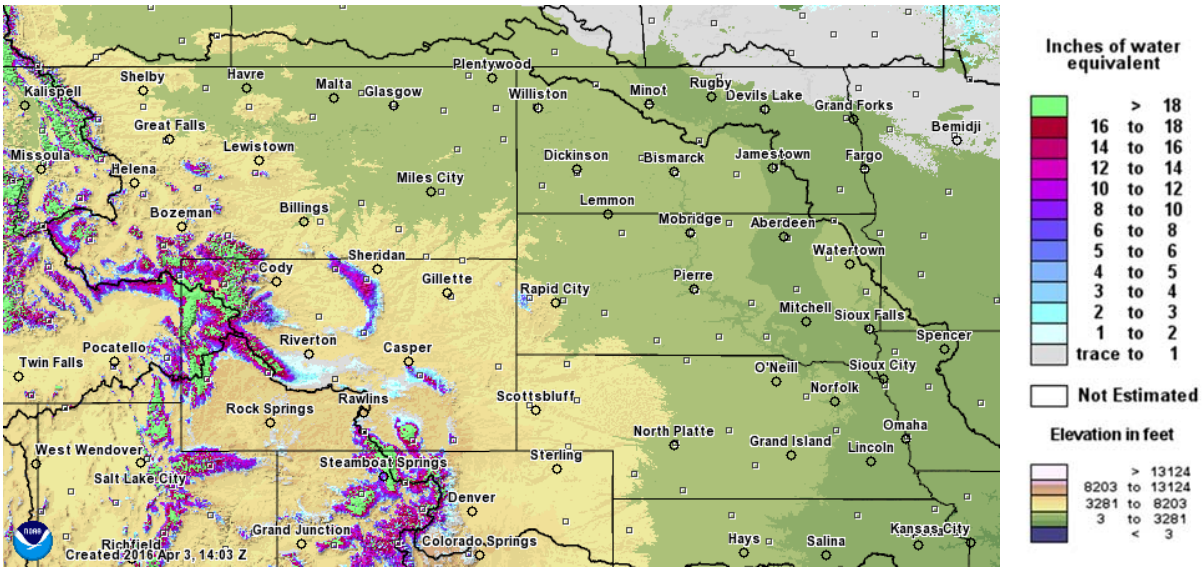


Figure 10. April 4, 2016 NOHRSC modeled plains snow water equivalent. Source: NOAA National Operational Hydrologic Remote Sensing Center. http://www.nohrsc.nws.gov/interactive/html/map.html

Mountain Snowpack

Mountain snowpack is the primary factor used to predict May-July runoff volumes in the Fort Peck and Fort Peck to Garrison mainstem reaches. During the 3-month May-July runoff period, about 50% of the annual runoff enters the mainstem system as a result of mountain snowmelt and rainfall runoff. Greater-than-average mountain snow accumulations are usually associated with greater-than-average May-July runoff volumes, especially when mountain soil moisture conditions have been wetter than normal as in the past three years. For example, we would expect to see below-average runoff from a below-average mountain snowpack this year due to soil moisture conditions ranging from drier than normal to wetter than normal.

Figure 11 includes time series plots of the average mountain SWE beginning on October 1, 2015 based on the NRCS SNOTEL gages for the basin above Fort Peck and the incremental basin from Fort Peck to Garrison. The current average SWE values (shaded blue area) are plotted against the 1981-2010 basin average SWE (bold red line), 2001 (green line), and two historic high SWE years occurring in 1997 (purple) and 2011 (dark blue).

The mountain snow water equivalent (or SWE) has made significant gains over the past month. On February 29 mountain SWE was 11.5 inches (89% of average) in the reach above Fort Peck and 8.2 inches (75% of average) from Fort Peck to Garrison. As of April 1, mountain SWE was 15.0 inches (95% of average) above Fort Peck and 12.2 inches (89% of average) from Fort Peck

to Garrison. The gain in mountain SWE results in an increase in the runoff forecast for Fort Peck and Garrison during the May-June-July period, when runoff from mountain snowmelt occurs. On average, about 97% of the SWE has accumulated by April 1, and mountain snowpack normally peaks around April 15.

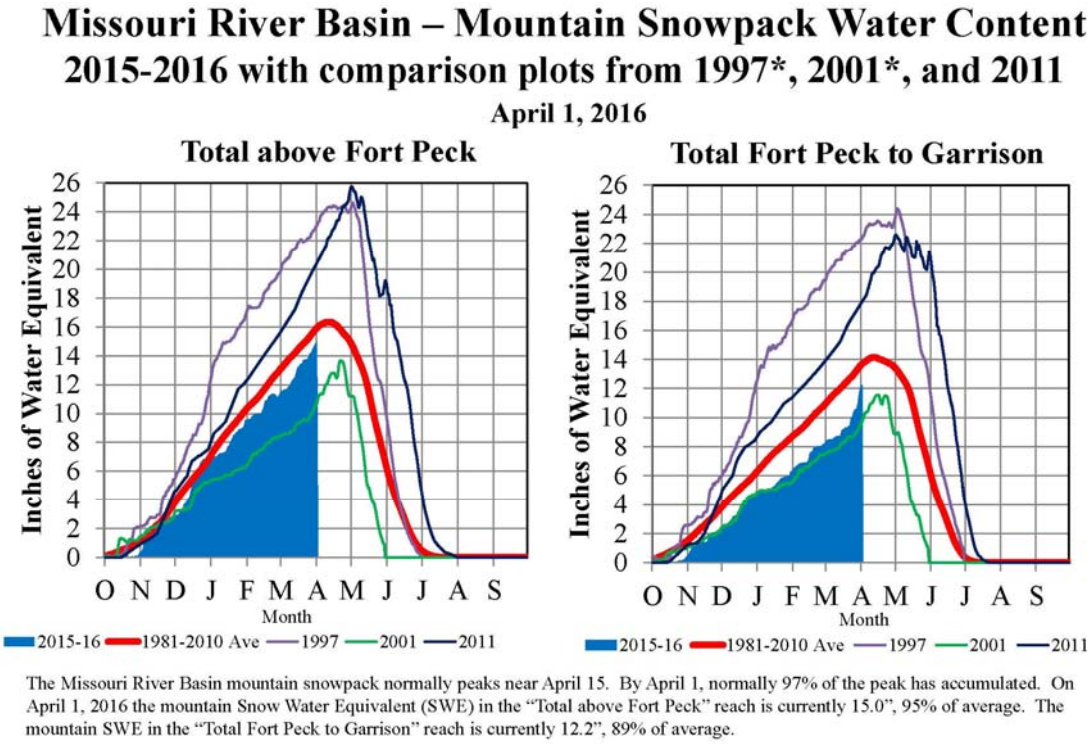


Figure 11. Mountain snowpack water content on April 1, 2016 compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management.

Climate Outlook

ENSO (El Niño Southern Oscillation)

According to the CPC's latest monthly update[1] on April 4, 2016, "***A strong El Niño is present and is weakening. A transition to ENSO-neutral is likely during late Northern Hemisphere spring or early summer 2016, with close to a 50% chance for La Niña conditions to develop by the fall."***

MRBWMD participates in the monthly North Central U.S. Climate/Drought Outlook Webinar coordinated through NOAA, the regional climate centers, and the American Association of State Climatologists (AASC). These webinars provide updates on near-term climate outlooks and impacts including the El Niño climate pattern and its implications on winter temperature and precipitation patterns in the Missouri River Basin. The possible impacts of El Niño have been factored into the CPC climate outlooks described below.

[1] http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/lanina/enso_evolution-status-fcsts-web.pdf

Temperature and Precipitation Outlooks

The NOAA Climate Prediction Center climate outlook for April 2016 (**Figure 12)** indicates that above-normal temperatures will occur over the Basin in April. Probabilities for above-normal temperatures range from 33% chance temperatures will be above normal in the eastern Dakotas to greater than 60% chances in western Montana and western Wyoming. With regard to precipitation, there are increased chances (33% to greater than 40%) that below-normal precipitation will occur in the Northern Plains, equal chances from Montana into Nebraska, and above-normal chances (33% to greater than 40%) in the central Rockies.

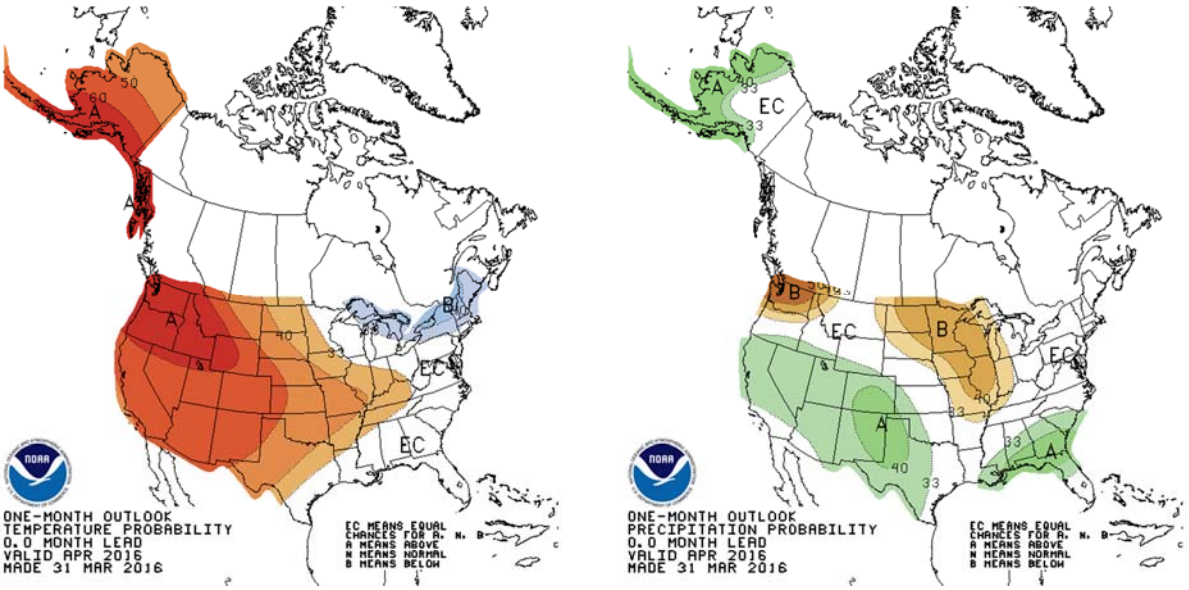


Figure 12. CPC April 2016 temperature and precipitation outlooks.

The April-May-June 2016 temperature outlook (**Figure 13**) indicates there are increased chances (33% to greater than 50%) for above-normal temperatures over the upper Basin, and equal chances in the lower Basin. With regard to precipitation, the April-May-June outlook indicates there are equal chances over most of the upper Basin, and increased chances (33% to greater than 40%) for above-normal precipitation in much of Wyoming and the central Rockies. The July-August-September 2016 CPC temperature outlook (**Figure 14**) indicates there are increased chances (33% to greater than 40%) for above-normal temperatures across the entire Missouri Basin. In terms of precipitation, there are equal chances for above- and below-normal precipitation throughout the entire Basin during July-August-September.

During the October-November-December 2016 period (**Figure 15**) CPC outlooks indicate increased chances (33% to greater than 40%) for above-normal temperatures in Wyoming, southern South Dakota, Nebraska, Iowa and the remaining lower Basin. There are equal chances for above-normal, normal and below-normal temperatures in Montana, North Dakota, and the northern half of South Dakota. With regard to precipitation, the October-November-December outlook indicates there are increased chances (33% to greater than 40%) for above-normal precipitation in western and central Montana, and equal chances elsewhere in the Basin. The

increased chances for above-normal precipitation in Montana during October-November-December are a reflection of the possible impact that a La Niña ENSO pattern could have on the upper Basin climate.

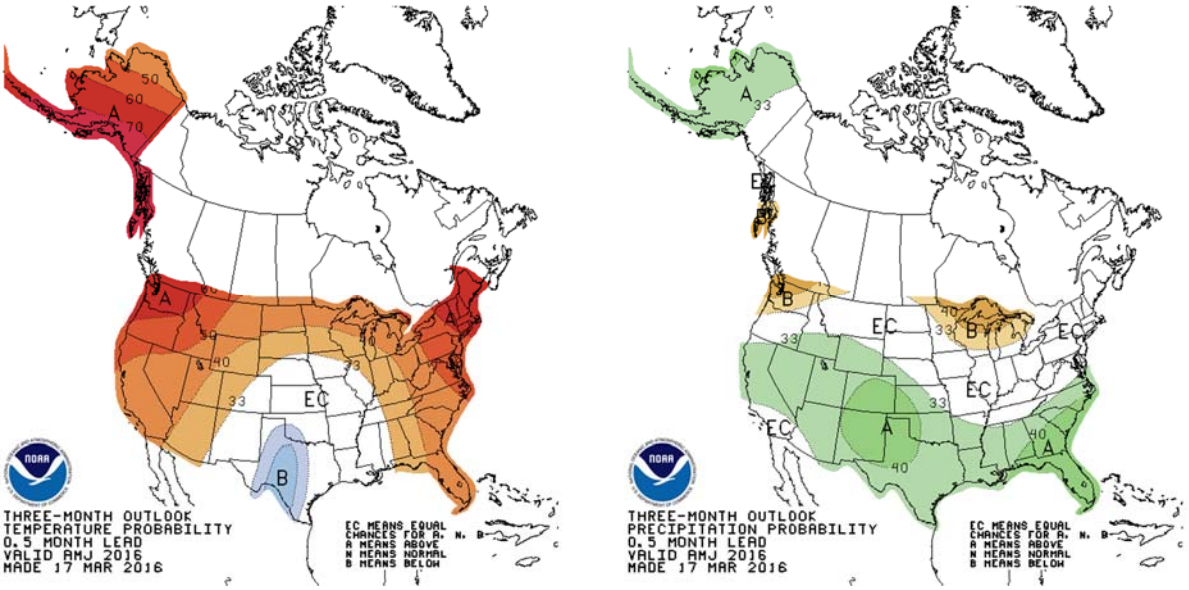


Figure 13. CPC April-May-June 2016 temperature and precipitation outlooks.

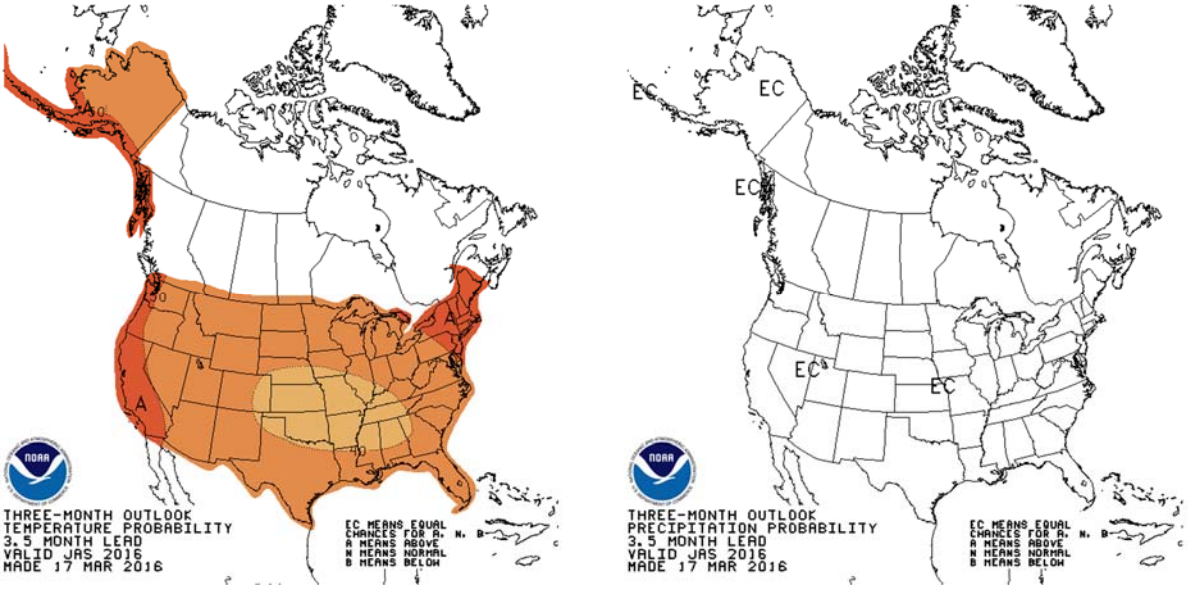


Figure 14. CPC July-August-September 2016 temperature and precipitation outlooks.

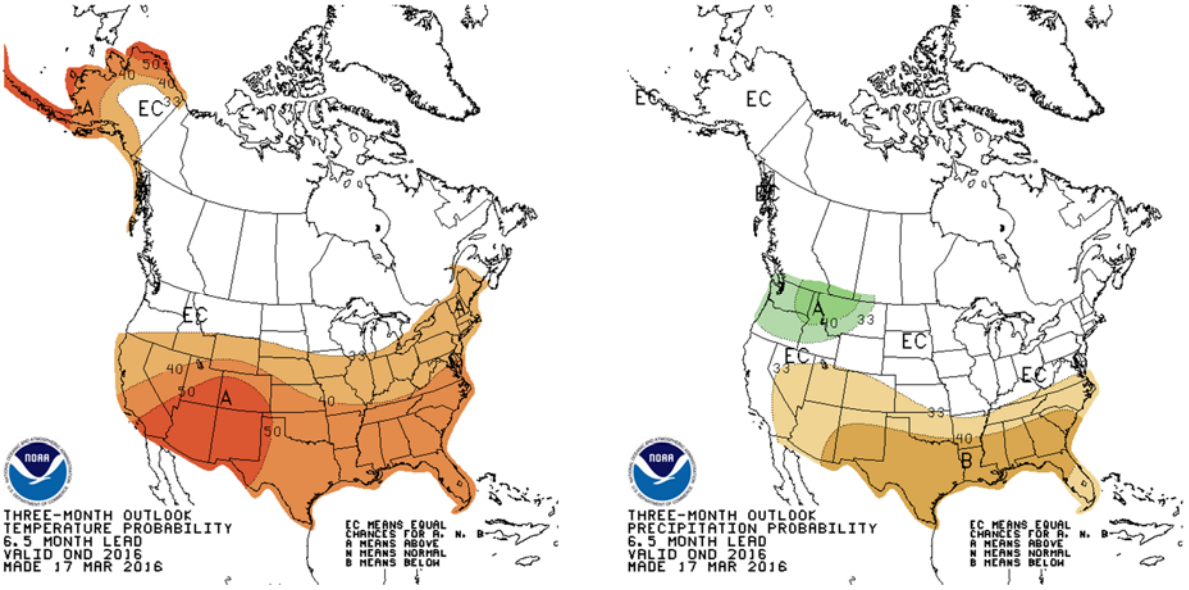
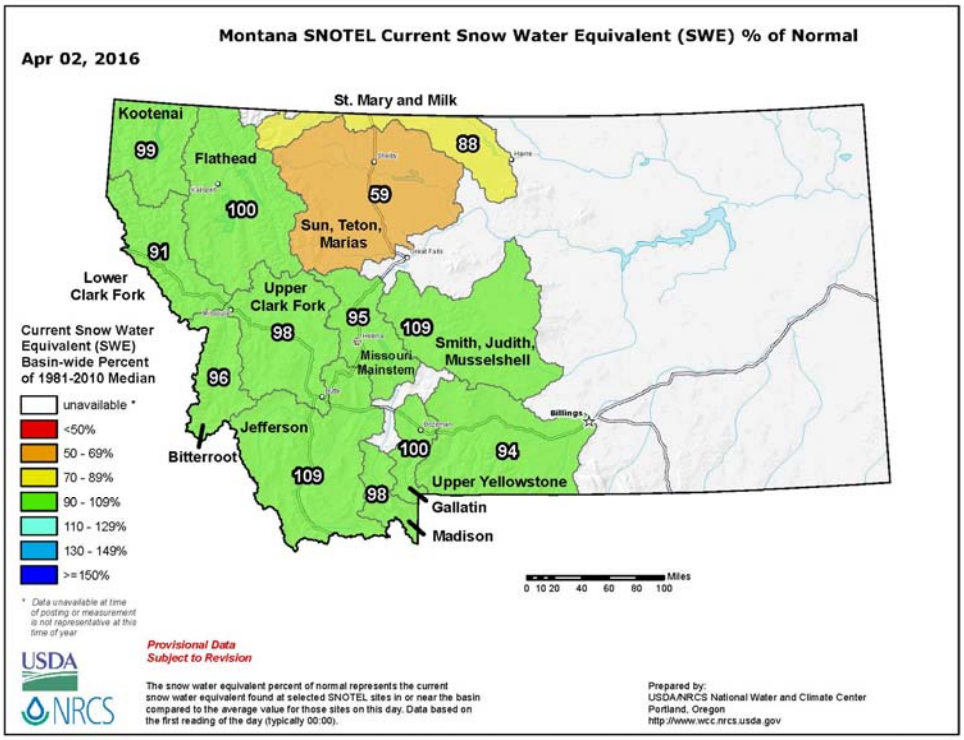


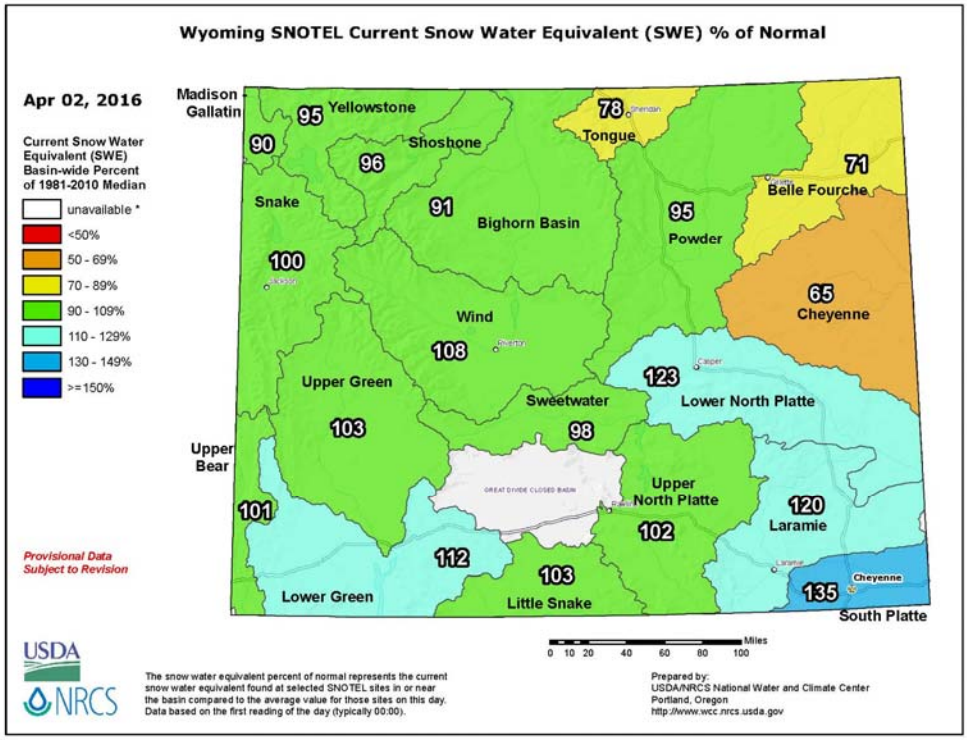
Figure 15. CPC October-November-December 2016 temperature and precipitation outlooks.

April 2016 Calendar Year Runoff Forecast

In summary, the 2016 calendar year runoff forecast is **21.7 MAF**, **86% of average**. Runoff for the basin above Gavins Point Dam, excluding the contributing area between Gavins Point Dam and Sioux City, IA, is forecast to be **19.0 MAF (82% of average)**. Although runoff is forecast to be well-below normal in the plains during the next two months, gains in mountain snowpack has increased the May-June-July runoff forecast. We will continue to monitor Basin conditions and make forecast adjustments as conditions change.

Additional Figures





USDA NRCS National Water & Climate Center
 * - DATA CURRENT AS OF: April 04, 2016 05:49:53 PM
   - Based on April 01, 2016 forecast values

PRELIMINARY MISSOURI RIVER BASIN FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
Lake Sherburne Inflow	APR-JUL	92	95	106	98	86	78	97
	APR-SEP	106	95	122	113	99	90	112
St. Mary R at Int'l Boundary (2)	APR-JUL	410	94	505	450	370	315	435
	APR-SEP	470	93	570	510	430	370	505
Lima Reservoir Inflow (2)	APR-JUL	75	91	92	82	68	58	82
	APR-SEP	81	91	101	89	73	61	89
Clark Canyon Reservoir Inflow (2)	APR-JUL	96	95	163	123	69	29	101
	APR-SEP	117	98	188	146	88	46	120
Jefferson R nr Three Forks (2)	APR-JUL	815	110	1160	955	675	475	740
	APR-SEP	875	109	1250	1030	720	490	800
Hebgen Reservoir Inflow (2)	APR-JUL	330	89	380	350	310	280	370
	APR-SEP	420	89	480	445	395	360	470
Ennis Reservoir Inflow (2)	APR-JUL	595	95	710	640	545	475	625
	APR-SEP	735	95	870	790	680	600	775
Missouri R at Toston (2)	APR-JUL	1820	102	2380	2050	1590	1250	1790
	APR-SEP	2090	101	2780	2370	1810	1400	2070
Smith R bl Eagle Ck (2)	APR-JUL	107	101	159	128	86	55	106
	APR-SEP	117	101	180	143	91	54	116
Gibson Reservoir Inflow (2)	APR-JUL	240	61	320	275	205	158	395
	APR-SEP	270	61	360	305	230	178	440
Marias R nr Shelby (2)	APR-JUL	176	51	340	240	110	12.3	345
	APR-SEP	182	51	360	255	109	10.4	360

PRELIMINARY YELLOWSTONE RIVER BASIN FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
West Rosebud Ck nr Roscoe (2)	APR-JUL	56	95	63	59	53	49	59
	APR-SEP	71	96	82	75	67	60	74
Wind R ab Bull Lake Ck (2)	APR-JUL	470	103	565	510	430	375	455
	APR-SEP	500	102	615	545	455	385	490
Bull Lake Ck nr Lenore	APR-JUL	151	109	187	166	136	115	139
	APR-SEP	183	108	230	200	164	137	169
Boysen Reservoir Inflow (2)	APR-JUL	675	111	1010	810	540	340	610
	APR-SEP	730	110	1100	880	580	360	665
Greybull R nr Meeteetse	APR-JUL	140	107	184	158	122	96	131
	APR-SEP	190	107	245	210	168	136	177
Shell Ck nr Shell	APR-JUL	40	73	54	46	34	25	55
	APR-SEP	51	77	68	58	45	35	66
Bighorn R at Kane (2)	APR-JUL	870	104	1390	1080	660	350	840
	APR-SEP	940	104	1510	1170	710	370	905
NF Shoshone R at Wapiti	APR-JUL	450	98	525	480	420	375	460
	APR-SEP	505	98	590	540	470	415	515
SF Shoshone R nr Valley	APR-JUL	225	105	260	240	210	188	215
	APR-SEP	260	106	305	280	240	215	245
Buffalo Bill Reservoir Inflow (2)	APR-JUL	700	104	835	755	645	565	675
	APR-SEP	770	103	930	835	705	610	745
Bighorn R nr St. Xavier (2)	APR-JUL	1420	103	2030	1670	1170	810	1380
	APR-SEP	1500	103	2200	1780	1220	800	1460
Little Bighorn R nr Hardin	APR-JUL	52	53	94	69	35	10.3	98
	APR-SEP	61	55	107	80	42	15.0	111

Tongue R nr Dayton (2)	APR-JUL	53	62	80	64	42	26	86
	APR-SEP	63	64	93	75	51	33	98
Tongue River Reservoir Inflow (2)	APR-JUL	124	64	225	164	84	25	193
	APR-SEP	140	65	245	182	98	35	215
NF Powder R nr Hazelton	APR-JUL	7.4	81	9.8	8.4	6.4	5.0	9.1
	APR-SEP	8.0	81	10.6	9.1	6.9	5.4	9.9
Powder R at Moorhead	APR-JUL	137	77	250	184	90	22	177
	APR-SEP	151	77	270	199	103	32	196
Powder R nr Locate	APR-JUL	156	78	295	210	100	17.6	199
	APR-SEP	170	77	320	230	110	22	220

Max (10%), 30%, 50%, 70% and Min (90%) chance that actual volume will exceed forecast.
Averages are for the 1981-2010 period.
All volumes are in thousands of acre-feet.

footnotes:
1) Max and Min are 5% and 95% chance that actual volume will exceed forecast
2) streamflow is adjusted for upstream storage
3) median value used in place of average

Upper Missouri River Basin
May 2016 Calendar Year Runoff Forecast
May 6, 2016

U.S. Army Corps of Engineers, Northwestern Division
Missouri River Basin Water Management
Omaha, NE

Calendar Year Runoff Forecast

Explanation and Purpose of Forecast

The long-range runoff forecast is presented as the Calendar Year Runoff Forecast. This forecast is developed shortly after the beginning of each calendar year and is updated at the beginning of each month to show the actual runoff for historic months of that year and the updated forecast for the remaining months of the year. This forecast presents monthly inflows in million acre-feet (MAF) from five incremental drainage areas, as defined by the individual System projects, plus the incremental drainage area between Gavins Point Dam and Sioux City. Due to their close proximity, the Big Bend and Fort Randall drainage areas are combined. Summations are provided for the total Missouri River reach above Gavins Point Dam and for the total Missouri River reach above Sioux City. The Calendar Year Runoff Forecast is used in the Monthly Study simulation model to plan future system regulation in order to meet the authorized project purposes throughout the calendar year.

April 2016 Runoff

April 2016 Missouri River runoff was 2.6 MAF (90% of average) above Sioux City, IA (upper Basin). March 2016 runoff above Gavins Point Dam was 2.2 MAF (86% of average). April runoff was 90% of average above Sioux City, IA, with inflows above Oahe Dam at 69% of average and inflows from Oahe Dam to Sioux City at 153% of average. Runoff was well below average during the first half of April due to lack of rainfall and a lack of plains snowpack coupled with an earlier than normal snowmelt in January and February. Significant rainfall events resulted in runoff being average to much above average throughout the basin during the last half of April.

2016 Calendar Year Forecast Synopsis

The May 1 forecast for 2016 upper Basin runoff is **22.5 MAF (89% of average)**. Runoff for the basin above Gavins Point Dam is forecast to be **19.7 MAF (85% of average)**. Due to the amount of variability in precipitation and other hydrologic factors that can occur over the next 8 months, the range of expected inflow is quite large and ranges from the 28.2 MAF upper basic forecast to the 17.4 MAF lower basic forecast. The upper and lower basic forecasts are used in long-term regulation planning models to "bracket" the range of expected runoff given much

wetter or drier conditions, respectively. Given that 8 months are being forecasted for this May 1 forecast (4 months observed/8 months forecast), the range of wetter than normal (upper basic) and drier than normal (lower basic) conditions is attributed to all 6 reaches for 8 months. The result is a large range or "bracket" for each reach, and thus, for the total runoff forecast. As the year progresses, the range will lessen as the number of observed months increases and number of forecast months decreases.

Current Conditions

Drought Analysis

The latest National Drought Mitigation Center's drought monitor for April 26, 2016 (**Figure 1**), when compared to the drought monitor for March 29, 2016 (**Figure 2**), shows a decrease in areal extent of Abnormally Dry (D0) and Moderate Drought (D1) conditions in the upper Basin with an increase of D0 and D1 conditions in portions of Missouri. The U.S. Seasonal Drought Outlook in **Figure 3** indicates that drought is expected to ease in Montana, Wyoming, North Dakota, South Dakota, Kansas and Missouri through the end of July 2016.

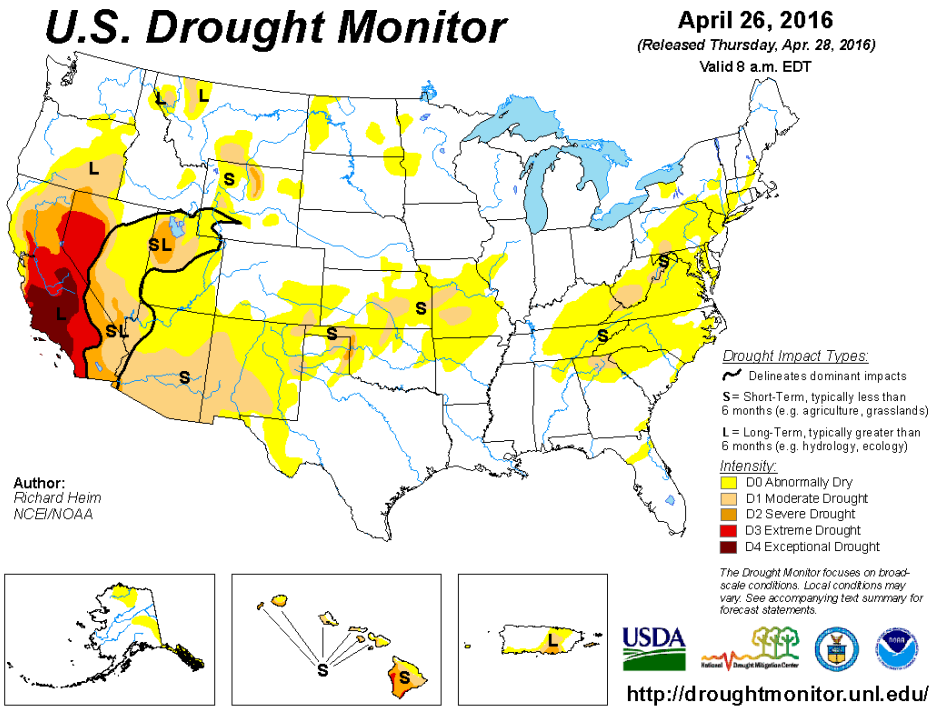


Figure 1 National Drought Mitigation Center U.S. Drought Monitor for April 26, 2016

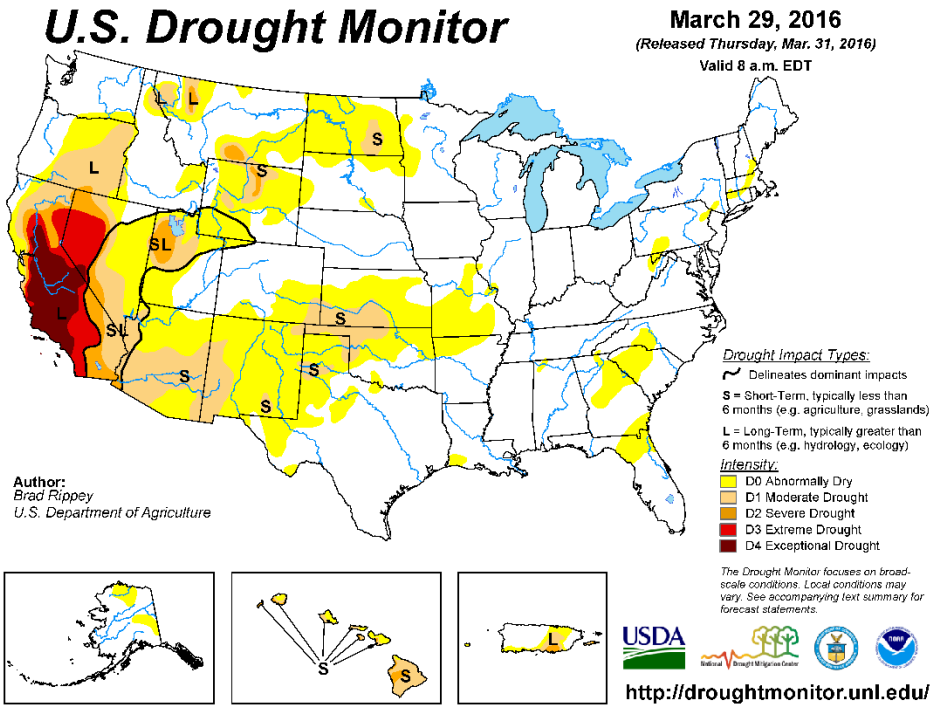


Figure 2. National Drought Mitigation Center U.S. Drought Monitor for March 29, 2016.

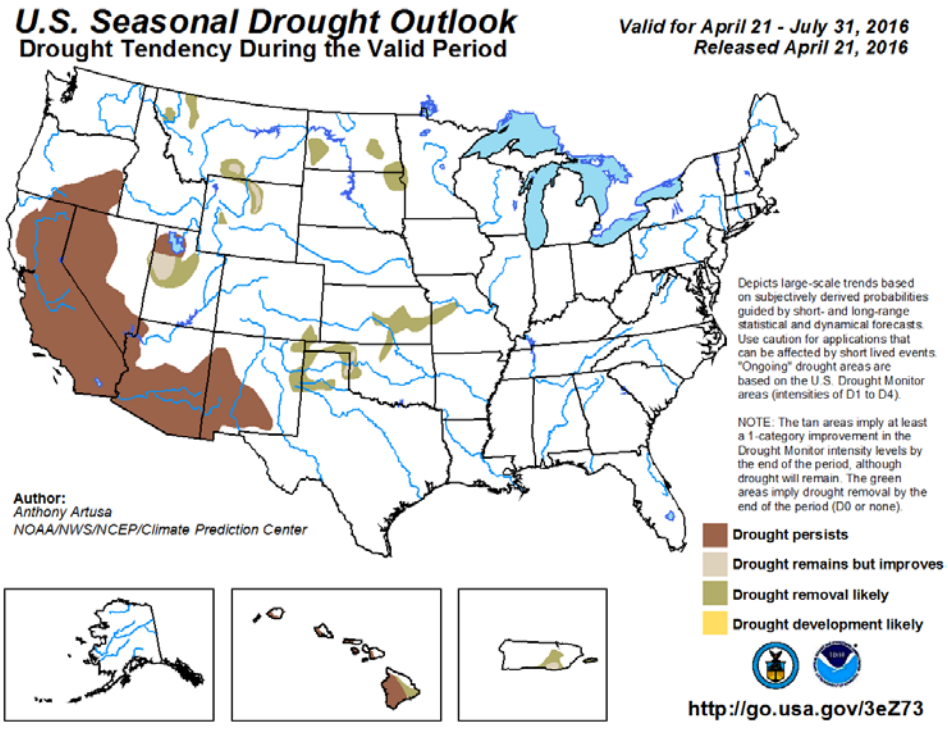


Figure 3. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

April precipitation accumulations are shown in **Figure 4** as both inches of precipitation (left) and percent of normal monthly precipitation (right). April precipitation was more than 150% of normal stretching northward from central Kansas through North Dakota, extending into eastern Colorado, most of Wyoming and eastern Montana, as well as western Iowa and northwestern Missouri, as a result of a series of storms beginning in mid-April. Precipitation was below normal in southwestern Montana, northwestern Wyoming, the Black Hills region of South Dakota extending into northeastern Wyoming, and most of Missouri.

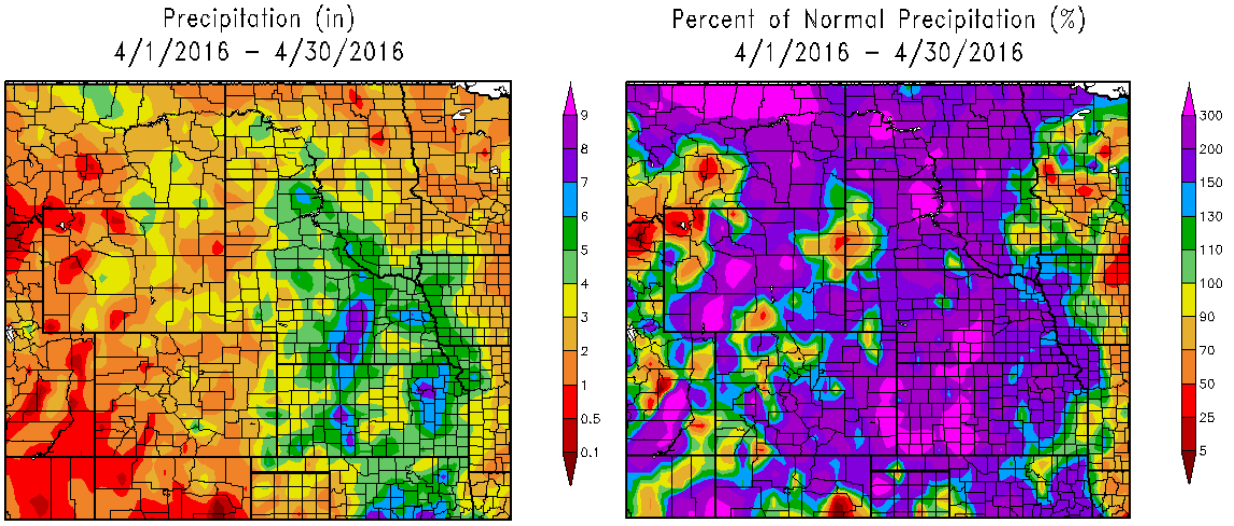


Figure 4. April 2016 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Table 1 contains notable April precipitation and snowfall accumulations in these areas. Riverton, WY, Miles City, MT and Hill City, KS were locations that set month-of-April precipitation records. A large portion central Kansas, Nebraska and south-central South Dakota saw monthly precipitation values greater than 5 inches, as can be seen in **Table 1**. Precipitation was also above normal at the other locations listed in **Table 1** with the exception of Billings, MT. Snowfall totals were relatively heavy in portions of Colorado and Wyoming; however, little snowfall occurred in Montana.

Table 1. April 2016 snowfall and precipitation totals.

City, State	Snowfall inches	Precipitation inches	Precipitation Departure inches
Denver, CO	15.6	2.56	0.85
Riverton, WY	12.7	3.31*	2.01
Lander, WY	4.3	4.61	2.74
Worland, WY	m	1.34	0.48
Sheridan, WY	m	3.36	1.76
Casper, WY	14.5	3.63	2.34
Cheyenne, WY	19.4	3.06	1.28
Great Falls, MT	7.2	2.83	1.41

Havre, MT	T	3.55	2.71
Miles City, MT	m	4.36*	2.99
Billings, MT	1.8	1.28	-0.38
Glasgow, MT	3.2	2.61	1.76
Hill City, KS	m	6.72*	4.60
Goodland, KS	2.3	3.99	2.40
Topeka, KS	tr	6.92	3.39
Manhattan, KS	m	7.92	5.12
Kansas City, KS	0	7.15	3.45
St. Joseph, MO	m	6.43	2.64
Chadron, NE	m	3.66	1.68
Scottsbluff, NE	3.2	4.13	2.30
McCook, NE	m	6.10	3.79
Grand Island, NE	0	5.05	2.52
Kearney, NE	m	5.18	2.95
Hastings, NE	0	5.69	3.13
North Platte, NE	2.5	5.36	3.09
Valentine, NE	1.5	4.62	2.40
Omaha, NE	tr	5.40	2.44
Lincoln, NE	0	4.37	1.66
Norfolk, NE	tr	5.21	2.56
Sioux City, IA	0	5.81	2.86
Sioux Falls, SD	tr	4.62	1.61
Huron, SD	tr	4.14	1.83
Rapid City Arpt, SD	4.2	1.85	0.05
Faith, SD	m	4.02	2.39
Winner, SD	m	5.37	2.88
Aberdeen, SD	tr	3.66	1.81
Watertown, SD	tr	2.26	0.24
Pierre, SD	tr	3.92	2.11
Mobridge, SD	tr	4.62	3.05
Bismarck, ND	0.2	4.15	2.89
Williston, ND	0.0	1.95	0.95

* Indicates Record for the Month

February-March-April 2016 precipitation accumulations are shown in **Figure 5**. The precipitation pattern since January 1 is similar to the April pattern, with the most notable above-normal accumulations in Wyoming, eastern Montana, western North Dakota, central South Dakota, eastern Colorado, the western two-thirds of Nebraska and western Kansas. The remainder of the Basin was drier than normal from February through April.

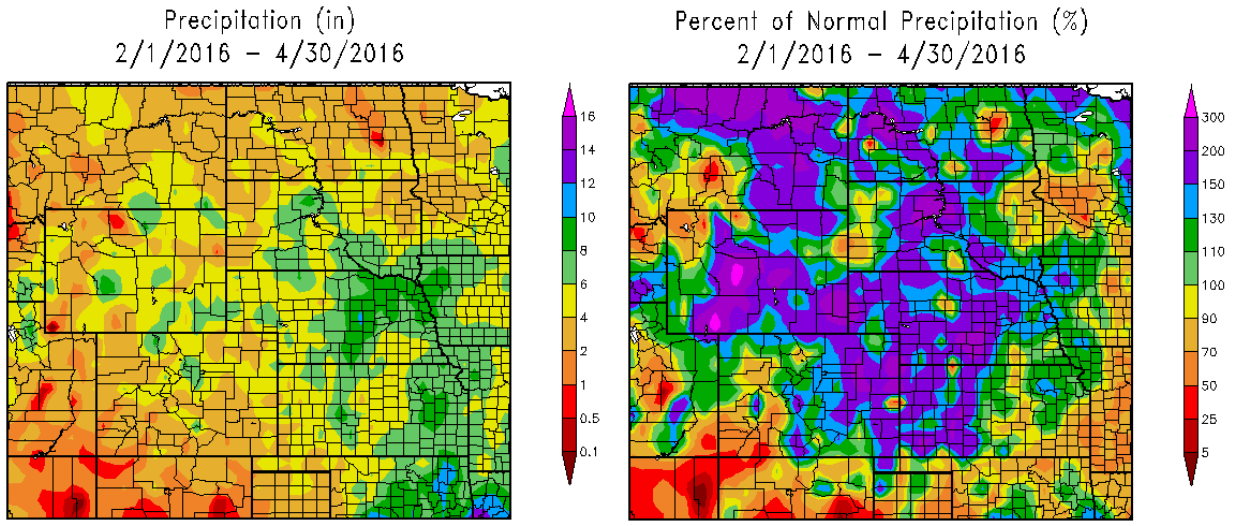


Figure 5. February-March-April 2016 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Temperature

April temperature departures from normal are shown in **Figure 6** in degrees Fahrenheit (deg F). February-March-April 2016 temperature departures are also shown in **Figure 6**. Temperatures during March have ranged from near normal to slightly above normal through most of North Dakota into central South Dakota southwestward into portions of eastern Colorado to more than 5 deg F above normal in western Montana. Temperatures over the past three months have been 2-6 deg F above normal throughout nearly the entire basin, with only portions of eastern Colorado being near normal.

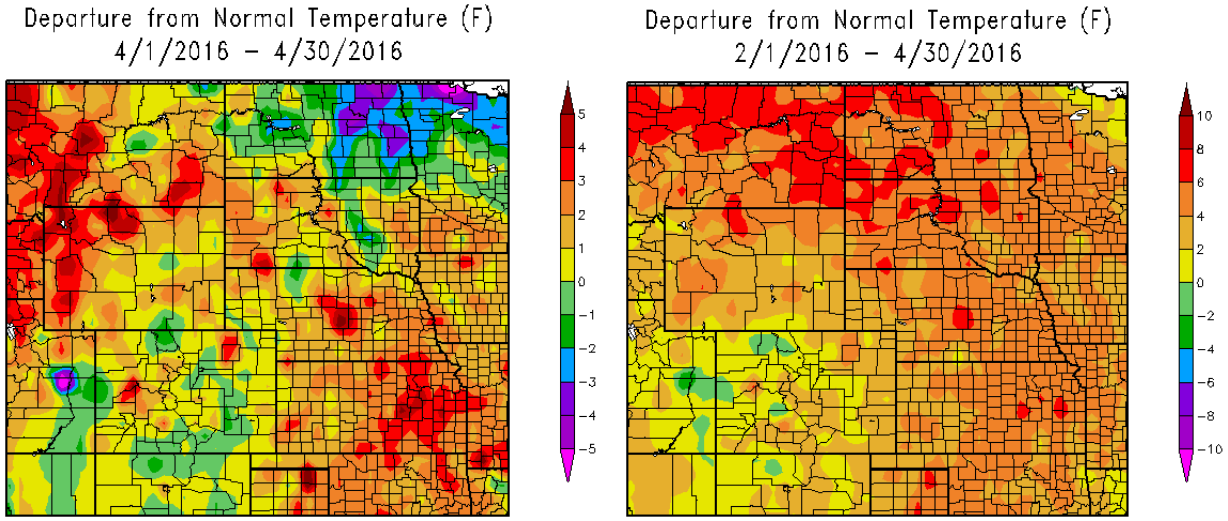


Figure 6. April 2016 and February-March-April 2016 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Soil Moisture

Soil moisture is factored into the forecast as an indicator of wet or dry hydrologic basin conditions. Typically when soil moisture conditions are wet or greater than normal, rainfall and snowmelt runoff is greater than when soil moisture is dry or less than normal. Not only is soil moisture a physical parameter that influences runoff, it can be used as an indicator of future runoff.

Figure 7 shows the NOAA NLDAS ensemble top 1-meter soil moisture anomaly on April 27, 2016. The NLDAS soil moisture depiction is an average value for the soil moisture column. **Figure 7** indicates above-normal soil moisture anomalies in eastern Montana, western North Dakota, much of Wyoming and South Dakota, nearly all of Nebraska, western Iowa, northwestern Missouri and most of Kansas. Below-normal soil moisture anomalies are present in small areas of south central Montana and north central Wyoming, eastern North Dakota, west central South Dakota and northeast Wyoming and eastern Kansas and Missouri.

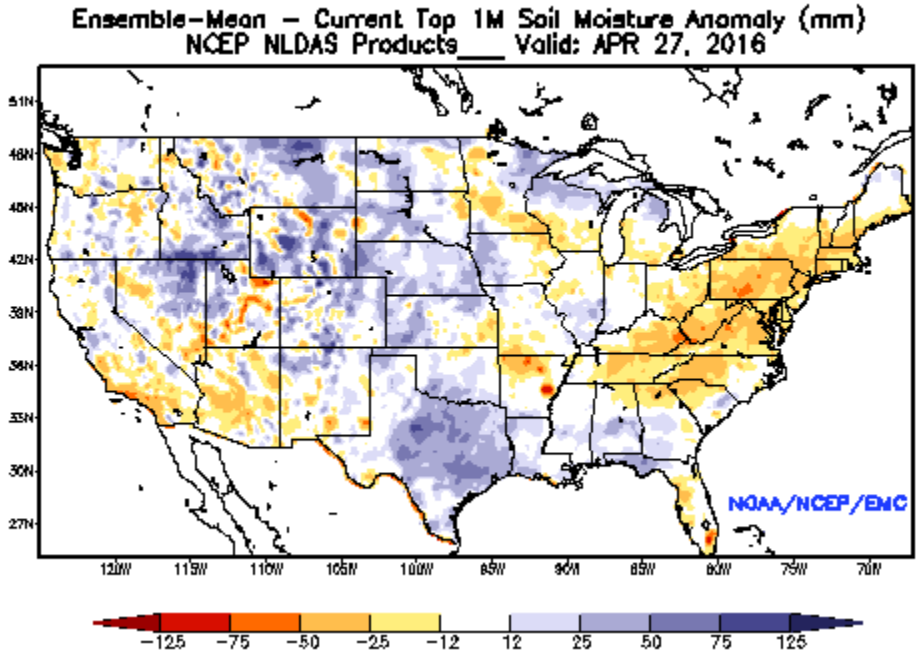


Figure 7. Top 1-Meter Soil Moisture Anomaly on April 27, 2016. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

Streamflow Conditions

Missouri Basin streamflow conditions are shown in **Figure 8**. These conditions are based on the ranking of the May 2, 2016 daily streamflow versus the historical record of streamflow for that date. Streamflow conditions are generally "Normal" (25^{th}-75^{th} percentile) above Garrison Dam and range from "Normal" (25^{th}-75^{th} percentile) to "Above Normal" (76^{th} – 90^{th} percentile) across

the rest of the Basin. Streamflow conditions are "Much Above Normal" (>90th percentile) to "High" (Daily High) across south-central South Dakota, much of eastern Nebraska and western Iowa and northwestern Missouri.

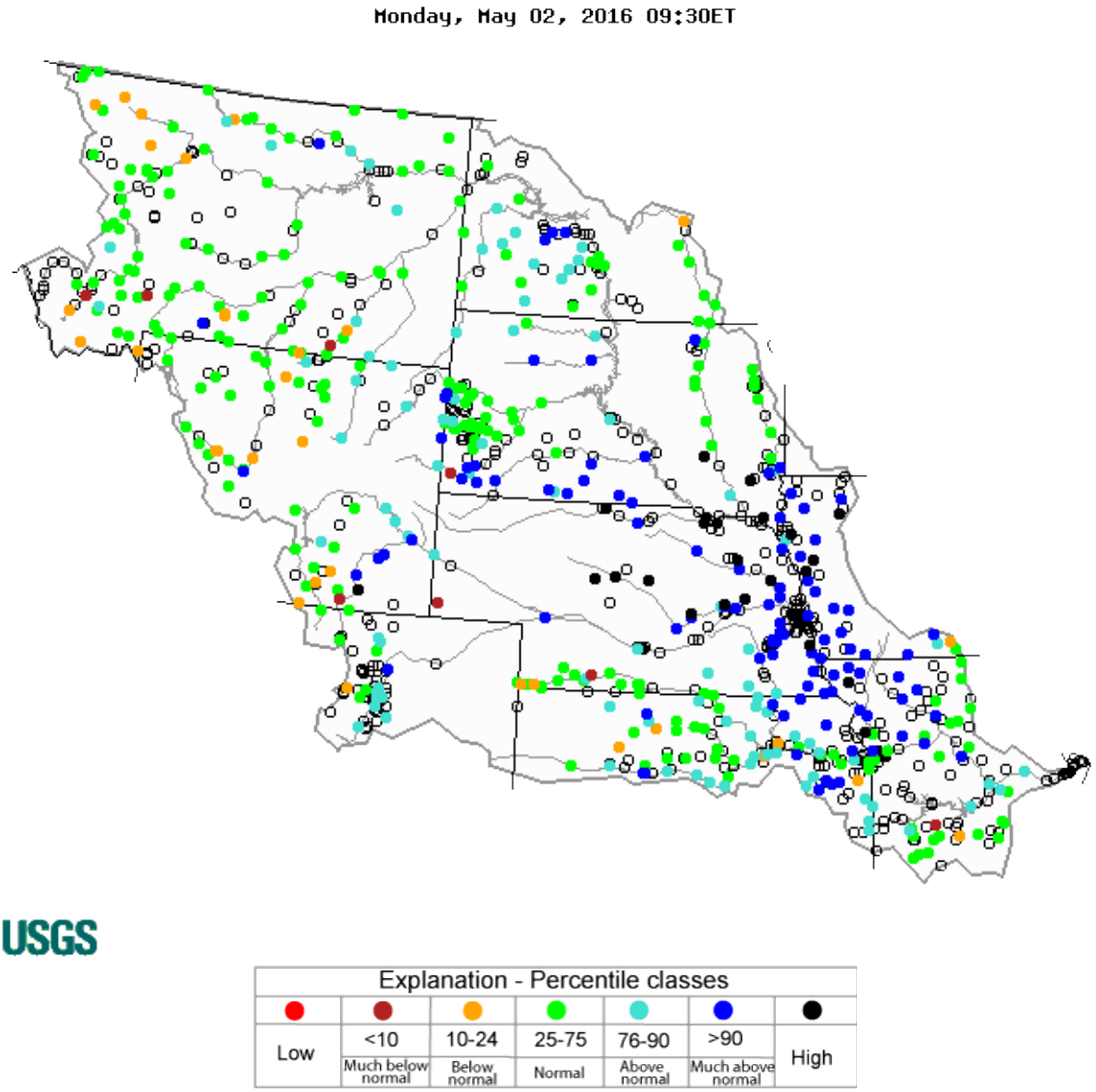


Figure 8. USGS Streamflow Conditions as a Percentile of Normal in the Missouri River Basin as of May 2, 2016. Source: USGS. http://waterwatch.usgs.gov/index.php

Plains Snowpack

Based on the National Operational Hydrologic Remote Sensing Center (NOHRSC) assessment (**Figure 9**) as of May 2, 2016, there is little plains snowpack. Much of the seasonal plains snowpack had melted by mid-February. Since March 1, additional snowfall has resulted in only short-term accumulations and has little impact on total runoff.

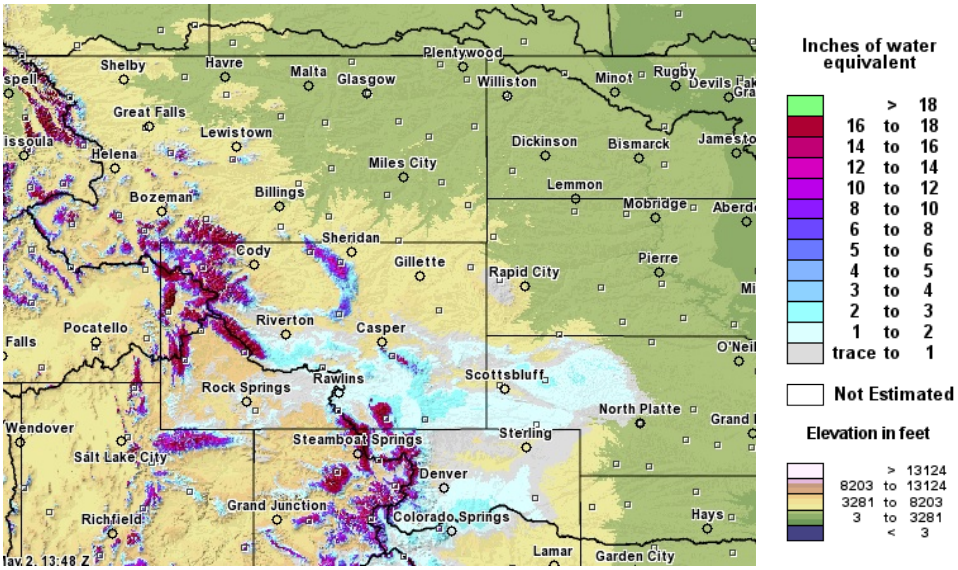


Figure 9. May 2, 2016 NOHRSC modeled plains snow water equivalent. Source: NOAA National Operational Hydrologic Remote Sensing Center. http://www.nohrsc.nws.gov/interactive/html/map.html

Mountain Snowpack

Mountain snowpack is the primary factor used to predict May-July runoff volumes in the Fort Peck and Fort Peck to Garrison mainstem reaches. During the 3-month May-July runoff period, about 50% of the annual runoff enters the mainstem system as a result of mountain snowmelt and rainfall runoff. Greater-than-average mountain snow accumulations are usually associated with greater-than-average May-July runoff volumes, especially when mountain soil moisture conditions have been wetter than normal as in the past three years. For example, we would expect to see below-average runoff from a below-average mountain snowpack this year due to soil moisture conditions ranging from drier than normal to wetter than normal.

Figure 10 includes time series plots of the average mountain SWE beginning on October 1, 2015 based on the NRCS SNOTEL gages for the basin above Fort Peck and the incremental basin from Fort Peck to Garrison. The current average SWE values (shaded blue area) are plotted against the 1981-2010 basin average SWE (bold red line), 2001 (green line), and two historic high SWE years occurring in 1997 (purple) and 2011 (dark blue).

The mountain snow water equivalent (or SWE) has decreased over the past month, although the decreases have not been consistent spatially. On April 1 mountain SWE was 15.0 inches (95% of average) in the reach above Fort Peck and 12.2 inches (89% of average) from Fort Peck to Garrison. As of May 1, mountain SWE was 11.0 inches (75% of average) above Fort Peck and 11.6 inches (87% of average) from Fort Peck to Garrison. The Fort Peck reach peaked at 15.0 inches of SWE on April 1, while Fort Peck to Garrison peaked at 12.2 inches of SWE, or 93% and 86% of average annual peak SWE, respectively. Both reaches lost about 15% of their peak SWE during the first half of April due to warmer than normal temperatures and low precipitation, but Fort Peck lost another 15% of SWE during the second half of April, while the

Garrison reach gained nearly 11% during the same time due to differences in the distribution of precipitation. On average, about 92% of the peak SWE accumulation remains by May 1, as mountain snowpack normally peaks around April 15.

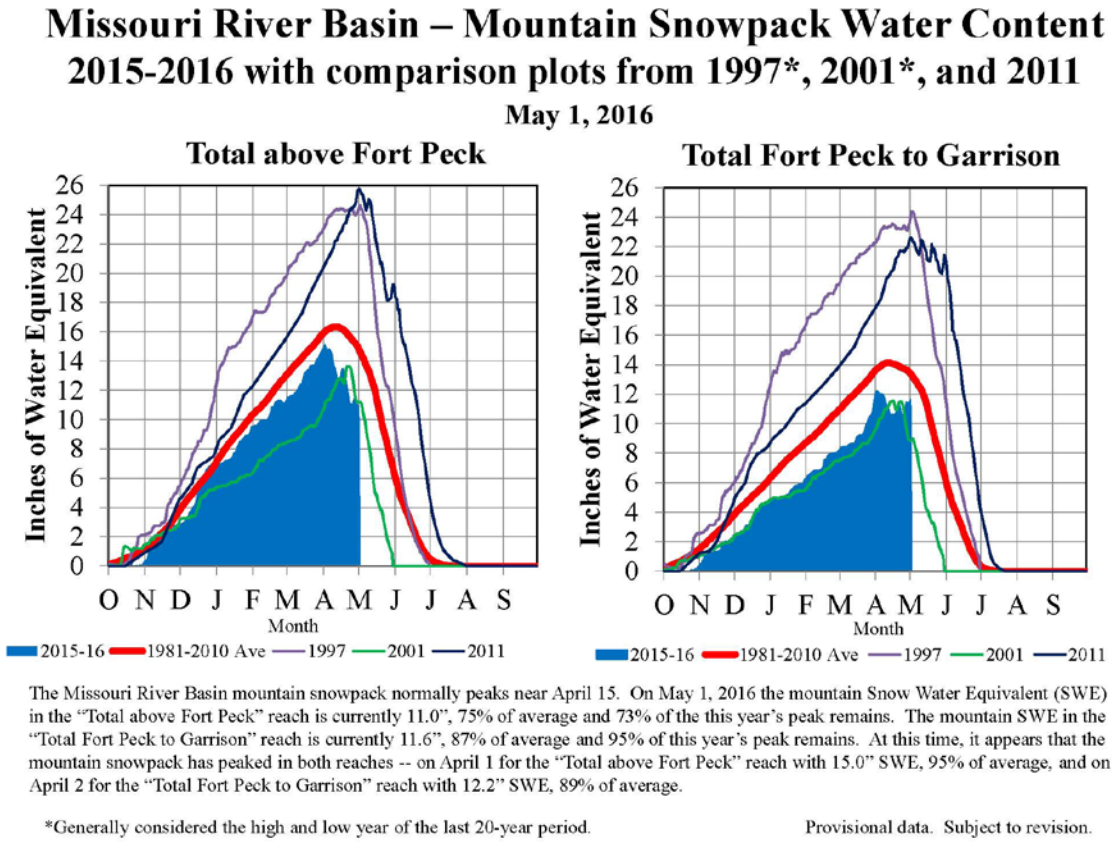


Figure 10. Mountain snowpack water content on May 1, 2016 compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management.

Climate Outlook

ENSO (El Niño Southern Oscillation)

According to the CPC's latest monthly update[1] on May 2, 2016, ***"El Niño is present and is weakening. A transition to ENSO-neutral is likely during late Northern Hemisphere spring or early summer 2016, with an increasing chance for La Niña during the second half of the year."***

MRBWMD participates in the monthly North Central U.S. Climate/Drought Outlook Webinar coordinated through NOAA, the regional climate centers, and the American Association of State Climatologists (AASC). These webinars provide updates on near-term climate outlooks and impacts including the El Niño climate pattern and its implications on winter temperature and

[1] http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/lanina/enso_evolution-status-fcsts-web.pdf

precipitation patterns in the Missouri River Basin. The possible impacts of El Niño have been factored into the CPC climate outlooks described below.

Temperature and Precipitation Outlooks

The NOAA Climate Prediction Center climate outlook for April 2016 (**Figure 11)** indicates that above-normal temperatures will occur over much of the upper Basin in May. Probabilities for above-normal temperatures range from 33% chance temperatures will be above normal across central South Dakota and southern Montana to greater than 50% chances in northern Montana and northern North Dakota. Below-normal temperatures are indicated across southern Wyoming, western Nebraska and Kansas and all of Colorado. With regard to precipitation, there are increased chances (33% to greater than 40%) that below-normal precipitation will occur in North Dakota and eastern South Dakota, equal chances from Montana southeastward into southern Missouri, and above-normal chances (33% to greater than 40%) in Wyoming, Colorado and western Nebraska and Kansas.

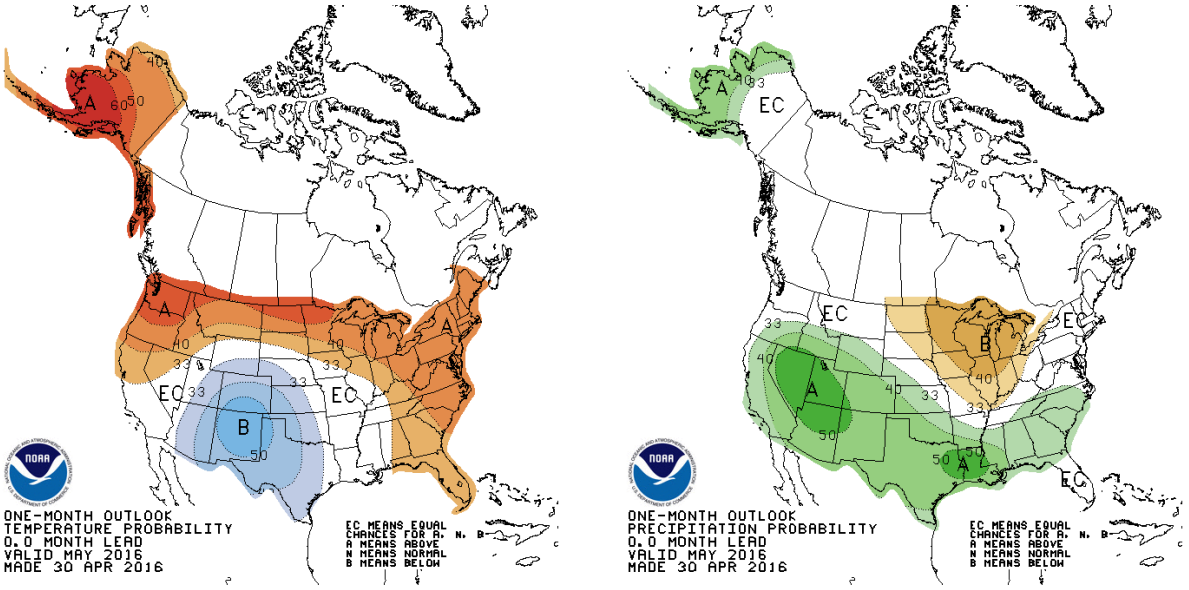


Figure 11. CPC May 2016 temperature and precipitation outlooks.

The May-June-July 2016 temperature outlook (**Figure 12**) indicates there are equal chances of above- or below-normal temperatures in southwestern Wyoming, far western Missouri and nearly all of Nebraska, Kansas and Colorado, with increased chances (33% to greater than 50%) for above-normal temperatures for the rest of the Basin. With regard to precipitation, the May-June-July outlook indicates there are equal chances over most of the upper Basin and most of Iowa, Nebraska and Missouri, and increased chances (33% to greater than 40%) for above-normal precipitation in much of Wyoming, Colorado and Kansas and western Nebraska. The August-September-October 2016 CPC temperature outlook (**Figure 13**) indicates there are increased chances (33% to greater than 40%) for above-normal temperatures across the entire Missouri Basin. In terms of precipitation, there are increased chances for below-normal precipitation across Colorado, Kansas, southern Wyoming, Nebraska, southern Iowa and

northern Missouri, with equal chances for above- and below-normal precipitation in the rest of the Basin.

During the November-December 2016 – January 2017 period (**Figure 14**) CPC outlooks indicate increased chances (33% to greater than 40%) for above-normal temperatures in southern Wyoming, Colorado, Kansas, and southwestern Nebraska. There are increased chances for below-normal temperatures in Montana, North Dakota and extreme northern South Dakota, with equal chances for above-normal, normal and below-normal temperatures in the rest of the Basin. With regard to precipitation, the November-December-January outlook indicates there are increased chances (33% to greater than 40%) for above-normal precipitation in nearly all of Montana, and equal chances elsewhere in the Basin. The increased chances for below-normal temperatures and above-normal precipitation in Montana during November-December-January are a reflection of the possible impact that a La Niña ENSO pattern could have on the upper Basin climate.

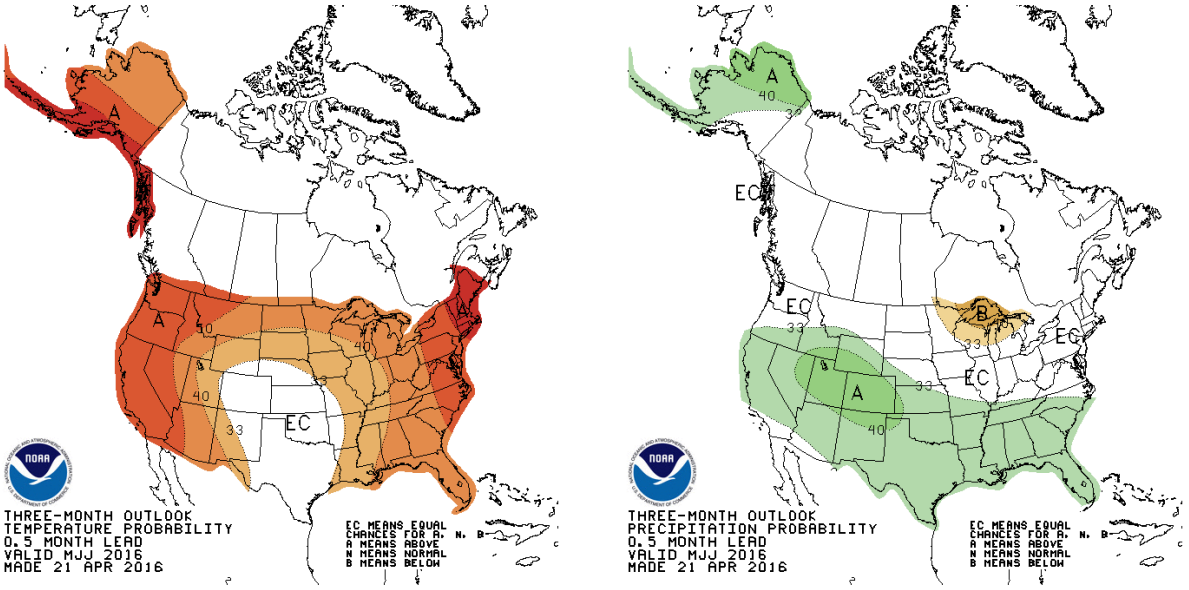


Figure 12. CPC May-June-July 2016 temperature and precipitation outlooks.

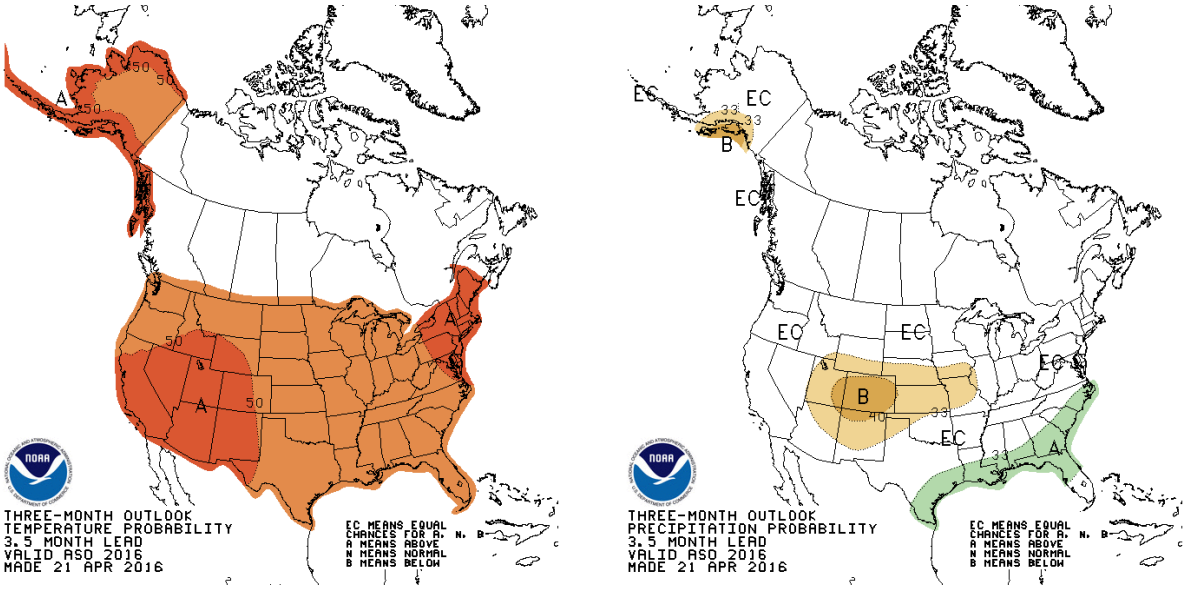


Figure 13. CPC August-September-October 2016 temperature and precipitation outlooks.

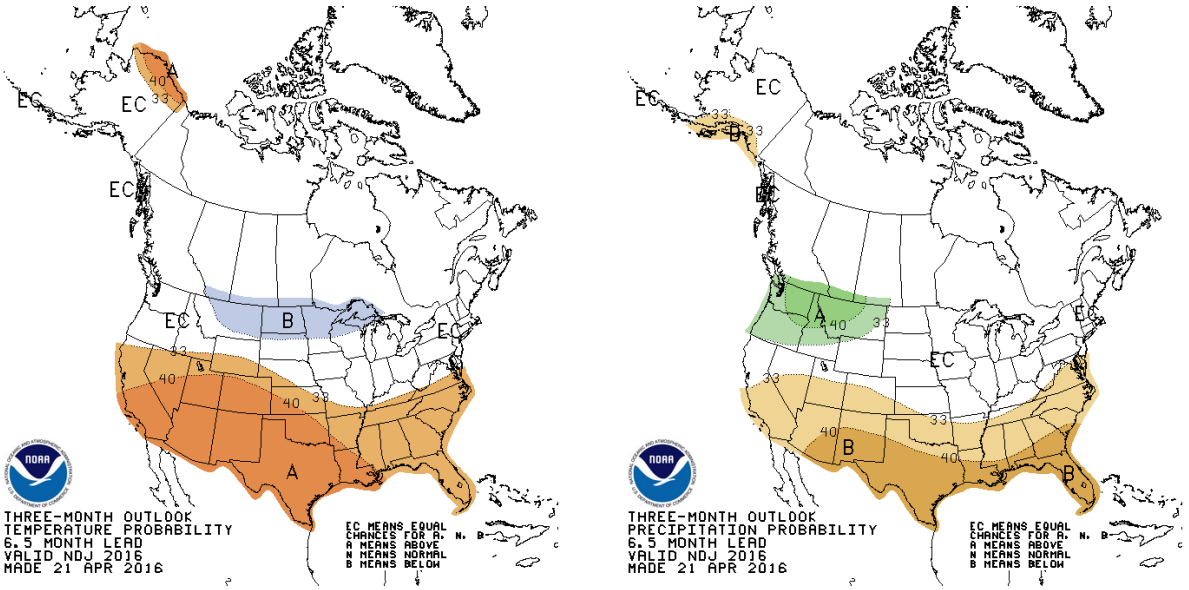


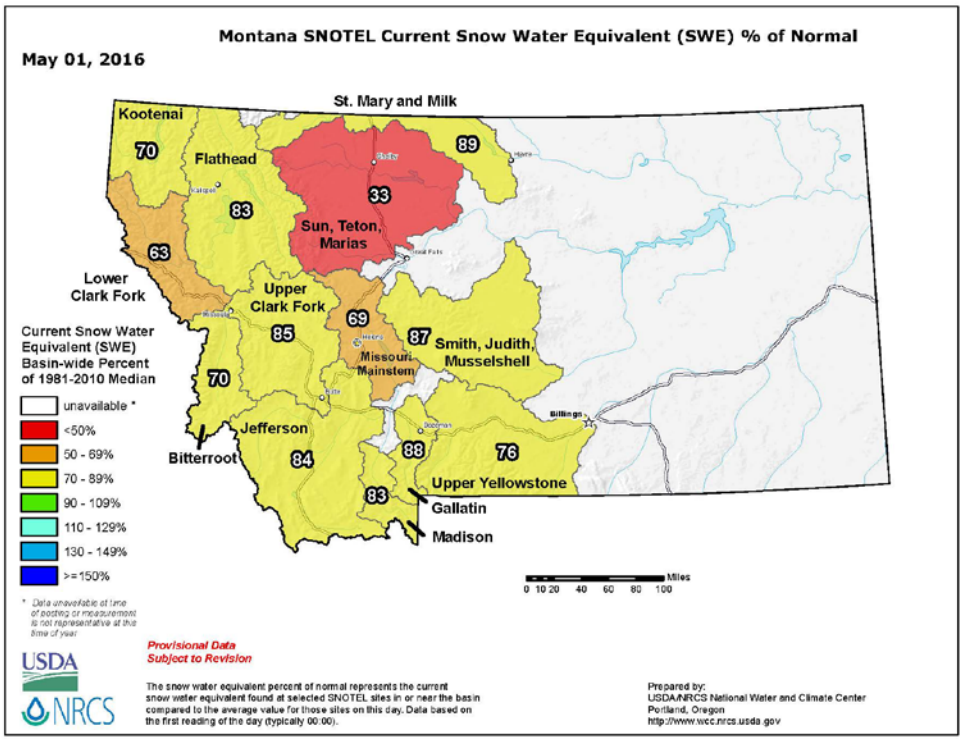
Figure 14. CPC November-December 2016-January 2017 temperature and precipitation outlooks.

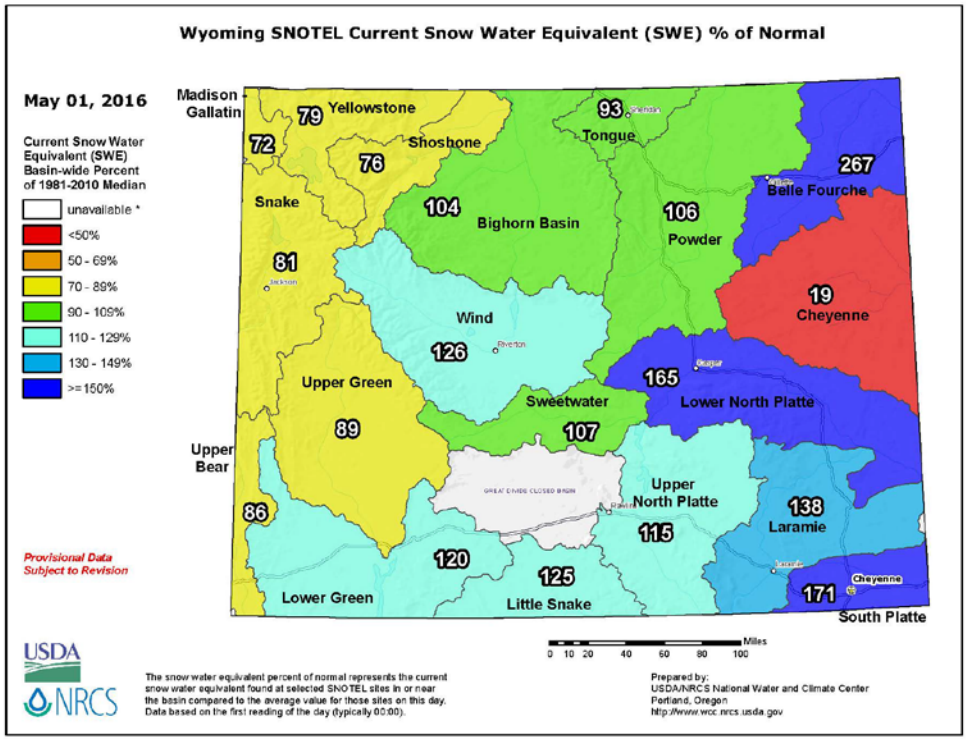
April 2016 Calendar Year Runoff Forecast

In summary, the 2016 calendar year runoff forecast is **22.5 MAF**, **89% of average**. Runoff for the basin above Gavins Point Dam, excluding the contributing area between Gavins Point Dam and Sioux City, IA, is forecast to be **19.7 MAF (85% of average)**. Recent gains in the Fort Peck to Garrison mountain snowpack and wet weather over the plains has increased the May-June-

July runoff forecast compared to the April 1 forecast. We will continue to monitor Basin conditions and make forecast adjustments as conditions change.

Additional Figures





USDA NRCS National Water & Climate Center
 * - DATA CURRENT AS OF: May 04, 2016 06:50:46 PM
   - Based on May 01, 2016 forecast values

PRELIMINARY MISSOURI RIVER BASIN FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
Lake Sherburne Inflow	MAY-JUL	69	80	83	75	63	55	86
	MAY-SEP	83	82	99	90	76	67	101
St. Mary R at Int'l Boundary (2)	MAY-JUL	315	79	400	350	280	230	400
	MAY-SEP	375	80	470	415	335	280	470
Lima Reservoir Inflow (2)	MAY-JUL	34	60	53	42	26	15.1	57
	MAY-SEP	37	58	59	46	28	14.7	64
Clark Canyon Reservoir Inflow (2)	MAY-JUL	35	55	94	59	11.3	-24	64
	MAY-SEP	47	57	110	73	21	-16.4	83
Jefferson R nr Three Forks (2)	MAY-JUL	480	83	770	595	360	188	575
	MAY-SEP	520	82	850	655	385	190	635
Hebgen Reservoir Inflow (2)	MAY-JUL	225	74	275	245	205	173	305
	MAY-SEP	305	75	365	330	280	245	405
Ennis Reservoir Inflow (2)	MAY-JUL	410	77	520	455	365	300	530
	MAY-SEP	540	79	670	595	485	410	680
Missouri R at Toston (2)	MAY-JUL	1240	84	1700	1420	1050	775	1480
	MAY-SEP	1460	83	2030	1690	1230	885	1760
Smith R bl Eagle Ck (2)	MAY-JUL	74	83	120	93	55	28	89
	MAY-SEP	85	86	141	108	62	29	99
Gibson Reservoir Inflow (2)	MAY-JUL	177	50	240	205	151	113	355
	MAY-SEP	210	53	280	235	179	137	395
Marias R nr Shelby (2)	MAY-JUL	110	39	255	168	52	15.0	285
	MAY-SEP	116	39	275	181	51	20	300

PRELIMINARY YELLOWSTONE RIVER BASIN FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
West Rosebud Ck nr Roscoe (2)	MAY-JUL	51	89	58	54	48	44	57
	MAY-SEP	65	90	76	69	61	54	72
Wind R ab Bull Lake Ck (2)	MAY-JUL	445	103	540	485	405	350	430
	MAY-SEP	475	102	585	520	430	365	465
Bull Lake Ck nr Lenore (2)	MAY-JUL	156	116	185	168	144	127	135
	MAY-SEP	190	114	225	205	175	153	166
Boysen Reservoir Inflow (2)	MAY-JUL	715	128	960	815	615	470	560
	MAY-SEP	775	126	1060	890	660	490	615
Greybull R nr Meeteetse	MAY-JUL	150	121	172	159	141	128	124
	MAY-SEP	205	121	250	225	186	158	170
Shell Ck nr Shell	MAY-JUL	41	79	55	47	35	27	52
	MAY-SEP	52	83	67	58	46	37	63
Bighorn R at Kane (2)	MAY-JUL	935	121	1250	1060	805	620	770
	MAY-SEP	1000	120	1350	1140	860	650	830
NF Shoshone R at Wapiti	MAY-JUL	390	91	470	425	360	310	430
	MAY-SEP	440	91	530	475	405	350	485
SF Shoshone R nr Valley	MAY-JUL	205	103	235	220	192	173	200
	MAY-SEP	240	102	275	255	225	205	235
Buffalo Bill Reservoir Inflow (2)	MAY-JUL	590	94	715	640	540	465	630
	MAY-SEP	660	94	800	715	605	520	700
Bighorn R nr St. Xavier (2)	MAY-JUL	1390	110	1790	1550	1240	1000	1260
	MAY-SEP	1480	110	1920	1660	1300	1040	1340
Little Bighorn R nr Hardin	MAY-JUL	61	72	91	73	49	31	85
	MAY-SEP	72	74	104	85	59	40	97

Tongue R nr Dayton (2)	MAY-JUL	70	88	97	81	59	43	80
	MAY-SEP	82	89	111	93	70	53	92
Tongue River Reservoir Inflow (2)	MAY-JUL	150	86	240	186	114	60	175
	MAY-SEP	171	86	265	210	132	75	198
NF Powder R nr Hazelton	MAY-JUL	7.7	93	10.4	8.8	6.6	5.0	8.3
	MAY-SEP	8.4	93	11.3	9.6	7.2	5.5	9.0
Powder R at Moorhead	MAY-JUL	139	92	225	174	104	53	151
	MAY-SEP	157	92	245	193	121	67	170
Powder R nr Locate	MAY-JUL	153	93	260	197	109	44	164
	MAY-SEP	172	93	290	220	124	53	185

PRELIMINARY RAPID VALLEY UNIT FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
Deerfield Reservoir Inflow (2)	MAY-JUL	3.0	77	6.5	4.4	1.53	0.50	3.9
Pactola Reservoir Inflow (2)	MAY-JUL	11.3	65	30	18.9	3.7	1.00	17.5

PRELIMINARY PLATTE RIVER BASIN FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
North Platte R nr Northgate	MAY-JUL	235	126	315	270	200	154	187
	MAY-SEP	265	126	360	305	225	171	210
Encampment R nr Encampment	MAY-JUL	138	117	171	151	125	105	118
	MAY-SEP	148	117	183	162	134	113	127
Rock Ck nr Arlington	MAY-JUL	54	113	65	59	49	43	48
	MAY-SEP	57	114	69	62	52	45	50
Seminoe Reservoir Inflow (2)	MAY-JUL	745	121	1040	865	625	450	615
	MAY-SEP	815	122	1140	945	685	490	670
Sweetwater R nr Alcova	MAY-JUL	51	111	74	60	42	28	46
	MAY-SEP	56	112	81	66	46	31	50
La Prele Ck ab La Prele Reservoir	MAY-JUL	22	148	31	26	18.4	13.0	14.9
	MAY-SEP	23	155	32	27	19.4	14.1	14.8
North Platte R bl Glendo Res (2)	MAY-JUL	860	128	1100	960	760	615	670
	MAY-SEP	895	128	1150	995	795	645	700
North Platte R bl Guernsey Res (2)	MAY-JUL	860	128	1160	980	740	565	670
	MAY-SEP	905	129	1210	1030	780	600	700
Laramie R nr Woods	MAY-JUL	140	130	174	154	126	106	108
	MAY-SEP	153	129	191	168	138	115	119
Little Laramie R nr Filmore	MAY-JUL	57	119	71	63	51	43	48
	MAY-SEP	61	117	77	67	55	45	52

Max (10%), 30%, 50%, 70% and Min (90%) chance that actual volume will exceed forecast.
Averages are for the 1981-2010 period.
All volumes are in thousands of acre-feet.

footnotes:
1) Max and Min are 5% and 95% chance that actual volume will exceed forecast
2) streamflow is adjusted for upstream storage
3) median value used in place of average

Upper Missouri River Basin
June 2016 Calendar Year Runoff Forecast
June 8, 2016

U.S. Army Corps of Engineers, Northwestern Division
Missouri River Basin Water Management
Omaha, NE

Calendar Year Runoff Forecast

Explanation and Purpose of Forecast

The long-range runoff forecast is presented as the Calendar Year Runoff Forecast. This forecast is developed shortly after the beginning of each calendar year and is updated at the beginning of each month to show the actual runoff for historic months of that year and the updated forecast for the remaining months of the year. This forecast presents monthly inflows in million acre-feet (MAF) from five incremental drainage areas, as defined by the individual System projects, plus the incremental drainage area between Gavins Point Dam and Sioux City. Due to their close proximity, the Big Bend and Fort Randall drainage areas are combined. Summations are provided for the total Missouri River reach above Gavins Point Dam and for the total Missouri River reach above Sioux City. The Calendar Year Runoff Forecast is used in the Monthly Study simulation model to plan future system regulation in order to meet the authorized project purposes throughout the calendar year.

May 2016 Runoff

May 2016 Missouri River Basin above Sioux City, IA (upper Basin) runoff was 4.5 MAF (136% of average). May runoff was 114% of average in the Fort Peck reach, 128% of average in the Garrison reach, 75% of average in the Oahe reach, 170% of average in the Fort Randall reach, 214% of average in the Gavins Point reach, and 244% of average in the Sioux City reach. Significant rainfall events resulted in runoff being above average in the Fort Randall, Gavins Point, and Sioux City reaches. Earlier-than-normal snowmelt in the Rocky Mountains and areas of above-average rainfall resulted in above-average runoff in the Fort Peck and Garrison reaches.

2016 Calendar Year Forecast Synopsis

The June 1 forecast for 2016 upper Basin runoff is **25.3 MAF (100% of average)**. Runoff for the basin above Gavins Point Dam is forecast to be **21.8 MAF (94% of average)**. Due to the amount of variability in precipitation and other hydrologic factors that can occur over the next 7 months, the range of expected inflow is quite large and ranges from the 30.4 MAF upper basic forecast to the 20.8 MAF lower basic forecast. The upper and lower basic forecasts are used in long-term regulation planning models to "bracket" the range of expected runoff given much wetter or drier conditions, respectively. Given that 7 months are being forecasted for this June 1

forecast (5 months observed/7 months forecast), the range of wetter than normal (upper basic) and drier than normal (lower basic) conditions is attributed to all 6 reaches for 7 months. The result is a large range or "bracket" for each reach, and thus, for the total runoff forecast. As the year progresses, the range will lessen as the number of observed months increases and number of forecast months decreases.

Current Conditions

Drought Analysis

The latest National Drought Mitigation Center's drought monitor for May 31, 2016 (**Figure 1**), when compared to the drought monitor for April 26, 2016 (**Figure 2**), shows very limited change to drought conditions in the upper Basin. There has been some improvement to conditions in north central Wyoming and northwest Montana. The U.S. Seasonal Drought Outlook in **Figure 3** indicates that drought is expected to ease in Montana and Wyoming; however, drought is expected to develop in northeast North Dakota.

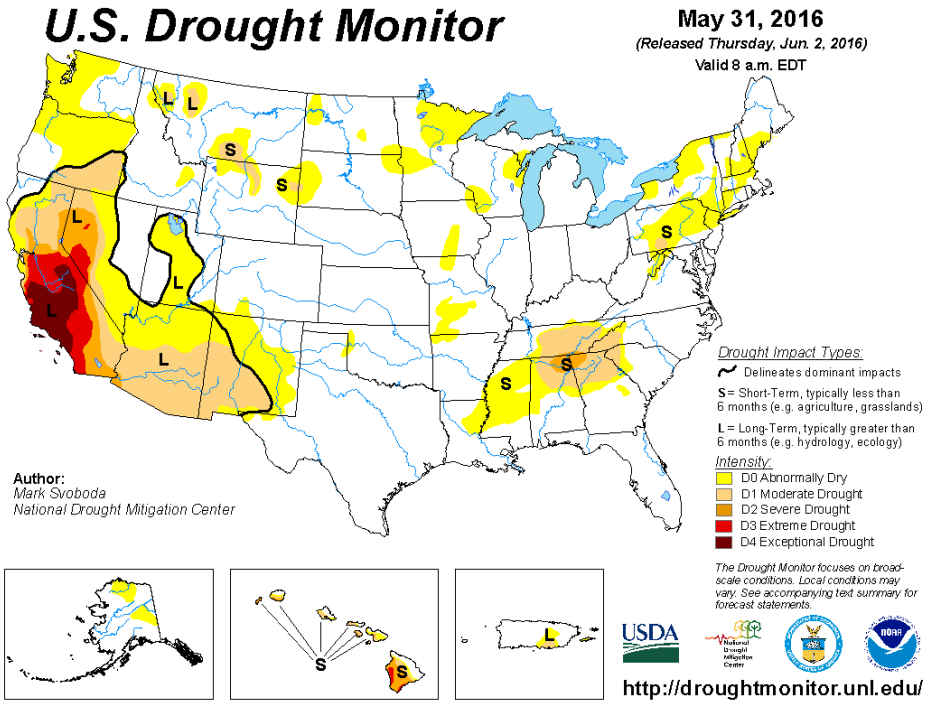


Figure 1 National Drought Mitigation Center U.S. Drought Monitor for May 31, 2016

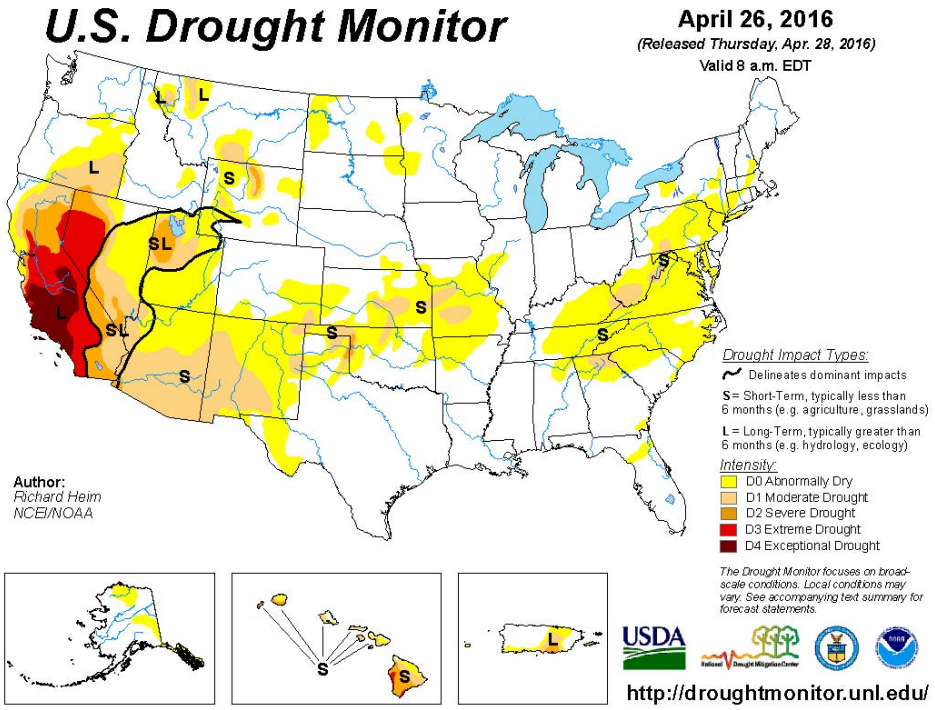


Figure 2. National Drought Mitigation Center U.S. Drought Monitor for April 26, 2016.

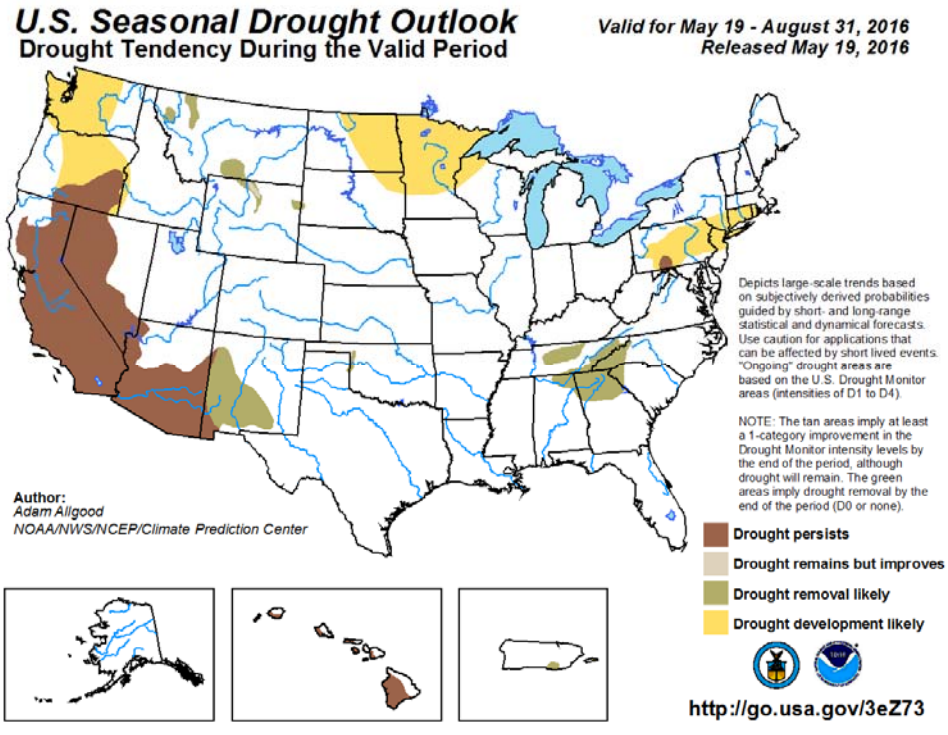


Figure 3. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

May precipitation accumulations are shown in **Figure 4** as both inches of precipitation (left) and percent of normal monthly precipitation (right). May precipitation was above average to more than 150% of average over a large portion of central and northern Montana, portions of central and southern Wyoming, the Gavins Point reach, and parts of the lower Basin extending from southeast South Dakota through Nebraska and Kansas into western Missouri. In contrast, May precipitation was less than 50% of average in southeast Montana, northeast Wyoming, western and central South Dakota, and southwest North Dakota.

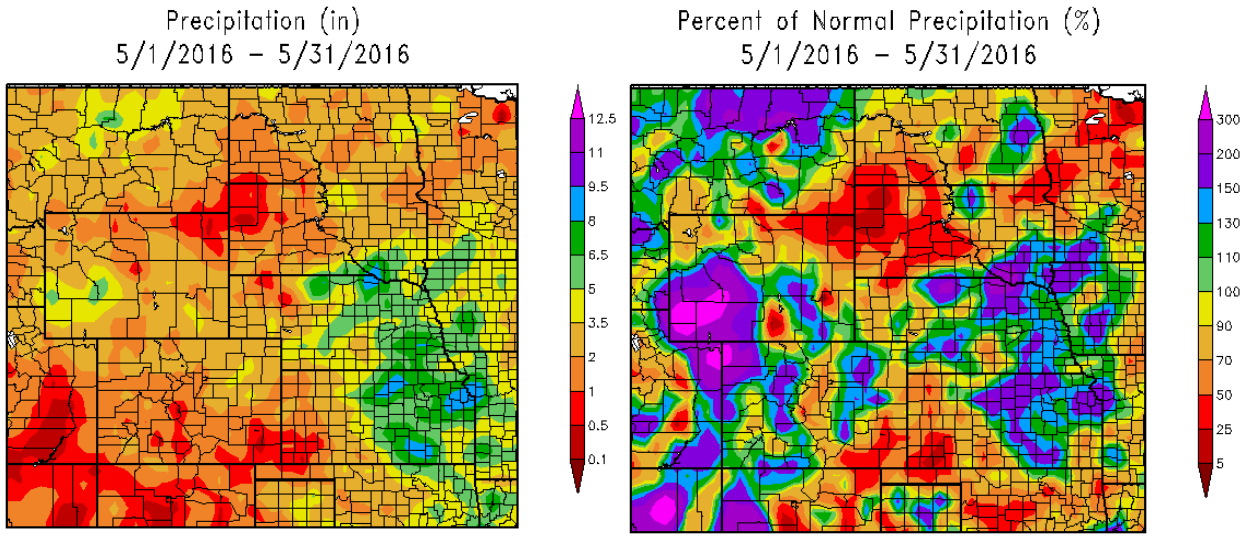


Figure 4. May 2016 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Table 1 contains notable May precipitation and departures in many locations in the Missouri Basin. Precipitation departures were variable in Montana and Wyoming ranging from large above-average departures in Havre, MT and Lander, WY to large below-average departures in Sheridan, WY and Gillette, WY. Below-average precipitation that occurred in the Oahe Basin is highlighted by below-average departures across much of central and western South Dakota. In contrast to this area of below-average precipitation, above-average precipitation departures were observed in much of the lower Basin. Notable departures in the lower Basin include: 2.43 inches above average in Grand Island, NE; 3.91 inches above average in Topeka, KS; and, 4.27 inches above average at the Kansas City International Airport.

Table 1. May 2016 precipitation and precipitation departures.

City, State	Precipitation inches	Precipitation Departure inches
Bozeman, MT	2.56	0.06
Lewistown, MT	3.98	1.13
Livingston, MT	2.41	-0.25
Great Falls, MT	2.04	-0.38
Havre, MT	3.48	1.74

City, State	Precipitation inches	Precipitation Departure inches
Miles City, MT	2.43	0.25
Billings, MT	2.04	-0.14
Glasgow, MT	4.46	2.54
Wolf Point, MT	1.97	0.19
Lander, WY	5.03	2.83
Lake Yellowstone, WY	2.81	0.54
Sheridan, WY	1.06	-1.29
Gillette, WY	0.67	-1.78
Jamestown, ND	2.79	0.13
Bismarck, ND	1.96	-0.44
Williston, ND	1.81	-0.11
Huron, SD	2.73	-0.38
Rapid City Arpt, SD	0.84	-2.38
Aberdeen, SD	2.13	-0.98
Watertown, SD	2.10	-0.54
Pierre, SD	1.20	-1.95
Mobridge, SD	3.75	0.93
Sioux Falls, SD	3.11	-0.29
Sioux City, IA	5.02	1.28
Valentine, NE	7.09	3.96
North Platte, NE	3.90	0.62
Grand Island, NE	6.84	2.43
Norfolk, NE	6.68	2.75
Lincoln, NE	5.42	1.13
Omaha, NE	4.84	0.08
Manhattan, KS	5.88	1.40
Topeka, KS	8.82	3.91
Lawrence, KS	7.38	2.19
Kansas City Intl Arpt, KS	9.50	4.27
St. Joseph, MO	5.92	0.50

March-April-May 2016 precipitation accumulations and percent of normal (average) precipitation are shown in **Figure 5**. The precipitation pattern since March 1 shows above-average precipitation (right image) in north central and portions of central Montana, a majority of Wyoming, southern South Dakota, Nebraska, western Iowa, northeast Colorado and Kansas. A below-average precipitation pattern has been prevalent in southeast Montana, southwest North Dakota, northeast Wyoming and western South Dakota. Furthermore, the lower Basin in central and eastern Missouri has received below-average precipitation since March 1.

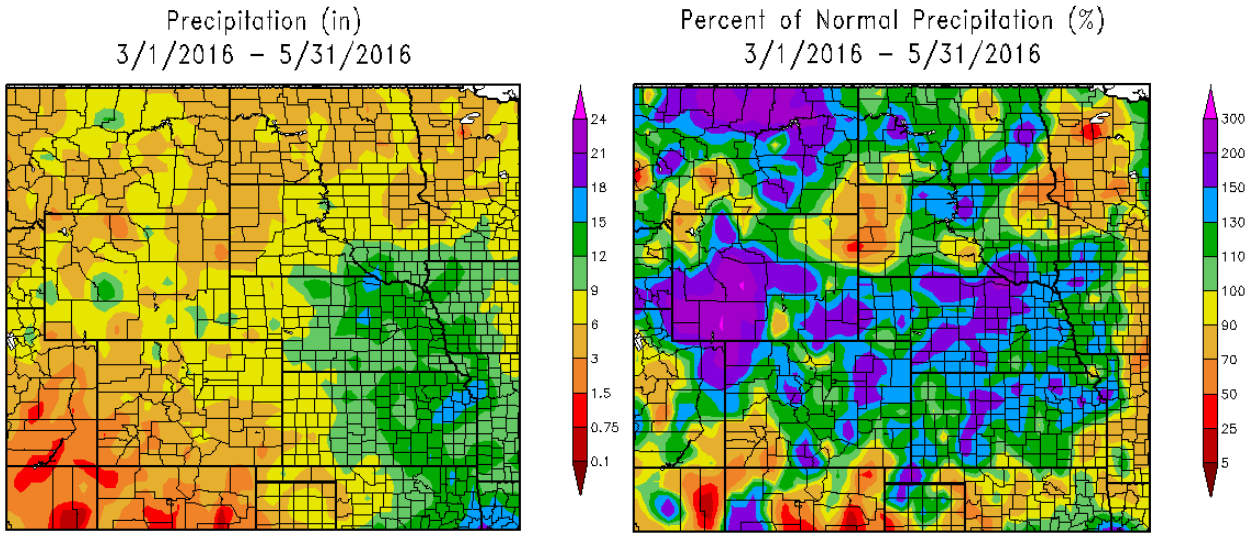


Figure 5. March-April-May 2016 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Temperature

May temperature departures from normal are shown in the left image of **Figure 6** in degrees Fahrenheit (deg F). March-April-May 2016 temperature departures are also shown in the right image of **Figure 6**. Temperatures during May (left image) have been below normal across most of the Rocky Mountains in Montana and Wyoming, in the Central Plains of Nebraska, northeast Colorado, Kansas, Iowa and Missouri. The cooler temperatures are a reflection of moist May conditions and the frequent track of weather systems that have delivered the moisture. In contrast, temperatures were above normal in eastern Montana, North Dakota and much of South Dakota. During the March-April-May period, an overall warmer-than-normal temperature pattern has prevailed throughout the entire Missouri Basin. Warmer temperatures in March and April led to earlier-than-normal peak mountain snow accumulations and earlier-than-normal snowmelt in the Northern Rockies. Temperatures in the Central Rockies have been near to below normal, resulting in normal peak mountain snow accumulations and snowmelt in the Platte River basin.

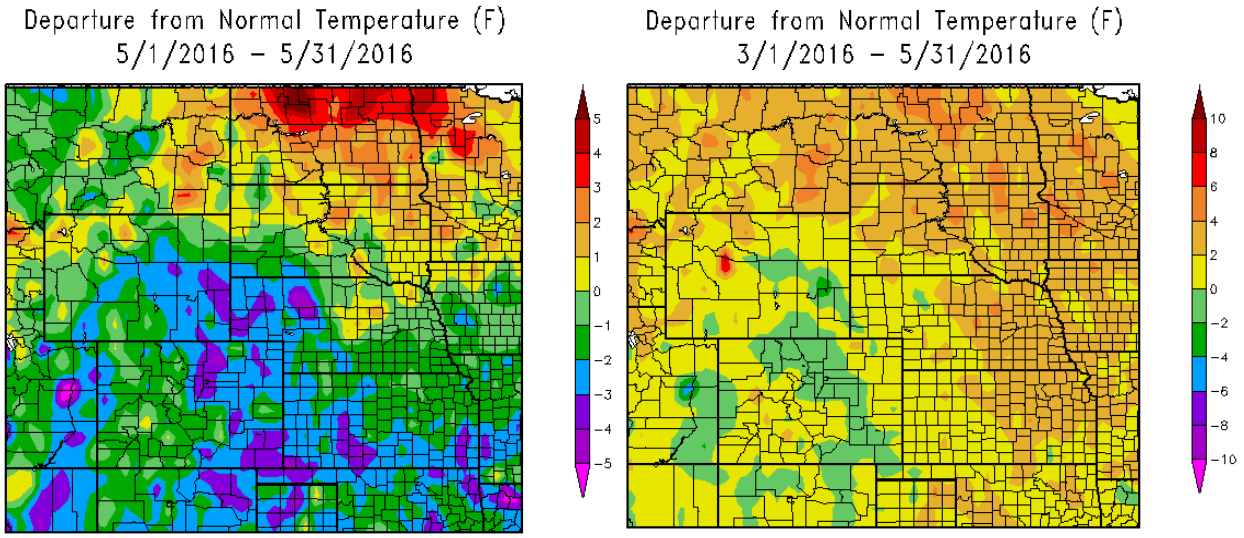


Figure 6. May 2016 and March-April-May 2016 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Soil Moisture

Soil moisture is factored into the forecast as an indicator of wet or dry hydrologic basin conditions. Typically when soil moisture conditions are wet or greater than normal, rainfall and snowmelt runoff is greater than when soil moisture is dry or less than normal. Not only is soil moisture a physical parameter that influences runoff, it can be used as an indicator of future runoff.

Figure 7 shows the NOAA NLDAS ensemble top 1-meter soil moisture anomaly on June 2, 2016. The NLDAS soil moisture depiction is an average value for the soil moisture column. **Figure 7** indicates above-normal soil moisture anomalies in northern and central Montana, western North Dakota, much of Wyoming, eastern South Dakota, Nebraska, western Iowa, eastern Colorado, Kansas, and northwest Missouri. Below-normal soil moisture anomalies are present in the several mountain ranges of Montana and northern Wyoming, portions of North Dakota, and western South Dakota.

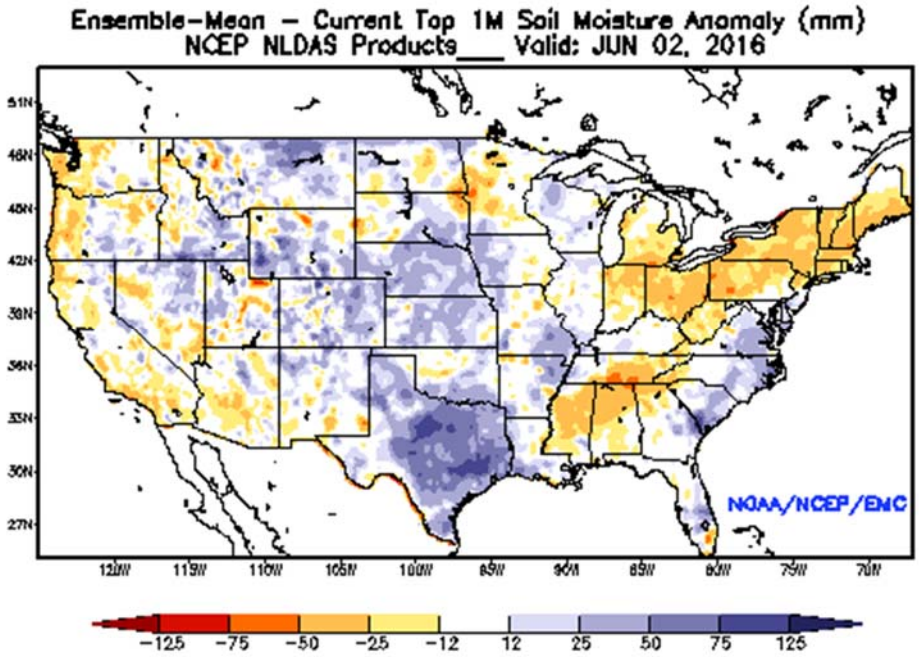


Figure 7. Top 1-Meter Soil Moisture Anomaly on June 2, 2016. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

Streamflow Conditions

Missouri Basin streamflow conditions are shown in **Figure 8**. These conditions are based on the ranking of the June 1, 2016 daily streamflow versus the historical record of streamflow for that date. Streamflow conditions are generally "Normal" (25th-75th percentile) in Montana and Wyoming, though there are a number of tributaries that have fallen into the "Below Normal" (10th to 24th percentile) class as a result of early low elevation mountain snowmelt and below-average precipitation. Streamflow has also been "Normal" to "Below Normal" in North Dakota, and from western to northeast South Dakota. Streamflow in the North Platte Basin in southeast Wyoming is "Above Normal" (76th – 90th percentile) to "Much Above Normal" (>90th percentile). The Missouri River and its tributaries from Sioux City to Kansas City range from "Above Normal" to "Much Above Normal" due to above-average precipitation in May.

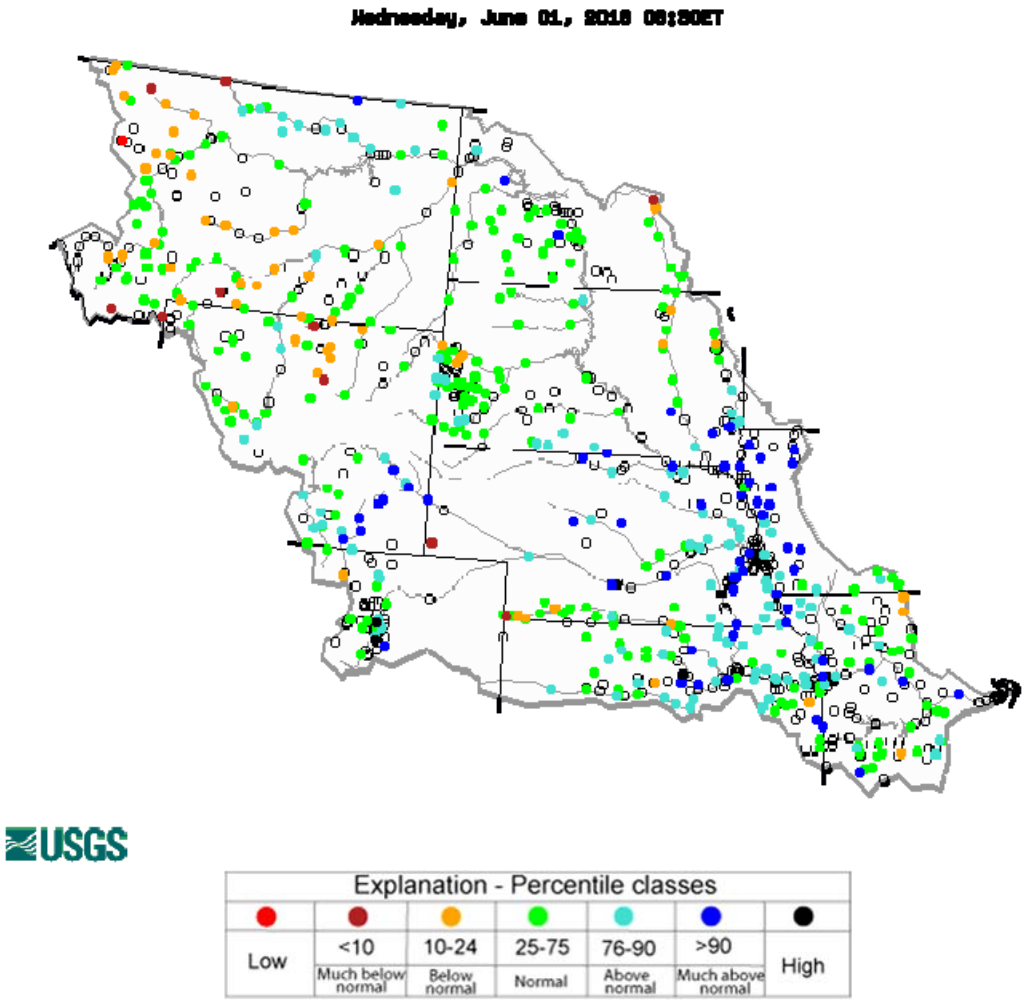


Figure 8. USGS Streamflow Conditions as a Percentile of Normal in the Missouri River Basin as of June 1, 2016. Source: USGS. http://waterwatch.usgs.gov/index.php

Mountain Snowpack

Mountain snowpack is the primary factor used to predict June-July runoff volumes in the Fort Peck and Fort Peck to Garrison mainstem reaches. During the 3-month May-June-July runoff period, about 50% of the annual runoff enters the mainstem system as a result of mountain snowmelt and rainfall runoff. Greater-than-average mountain snow accumulations are usually associated with greater-than-average June-July runoff volumes, especially when mountain soil moisture conditions have been wetter than normal as in the past three years. For example, we would expect to see below-average runoff from a below-average mountain snowpack this year due to soil moisture conditions ranging from drier than normal to wetter than normal.

Figure 10 includes time series plots of the average mountain snow water equivalent (SWE) beginning on October 1, 2015 based on the NRCS SNOTEL gages for the basin above Fort Peck and the incremental basin from Fort Peck to Garrison. The current average SWE values (shaded blue area) are plotted against the 1981-2010 basin average SWE (bold red line), 2001 (green

line), and two historic high SWE years occurring in 1997 (purple) and 2011 (dark blue). On average, mountain SWE normally peaks around April 15, and about 39% of the peak SWE accumulation remains by June 1.

The Fort Peck reach peaked at 15.0 inches of SWE on April 1, while Fort Peck to Garrison peaked at 12.2 inches of SWE on April 2, or 95% and 89% of average annual peak SWE, respectively. The mountain SWE has decreased rapidly over the past month as low to mid-level mountain snowpack melted due to warmer-than-normal temperatures in the Northern Rockies. On May 1, mountain SWE was 11.0 inches (75% of average) in the reach above Fort Peck and 11.6 inches (87% of average) from Fort Peck to Garrison. As of May 31, mountain SWE was 4.6 inches (74% of average) above Fort Peck and 4.5 inches (72% of average) from Fort Peck to Garrison. High elevation snowpack was occurring during the first week of June and is expected to be substantially complete by mid-June.

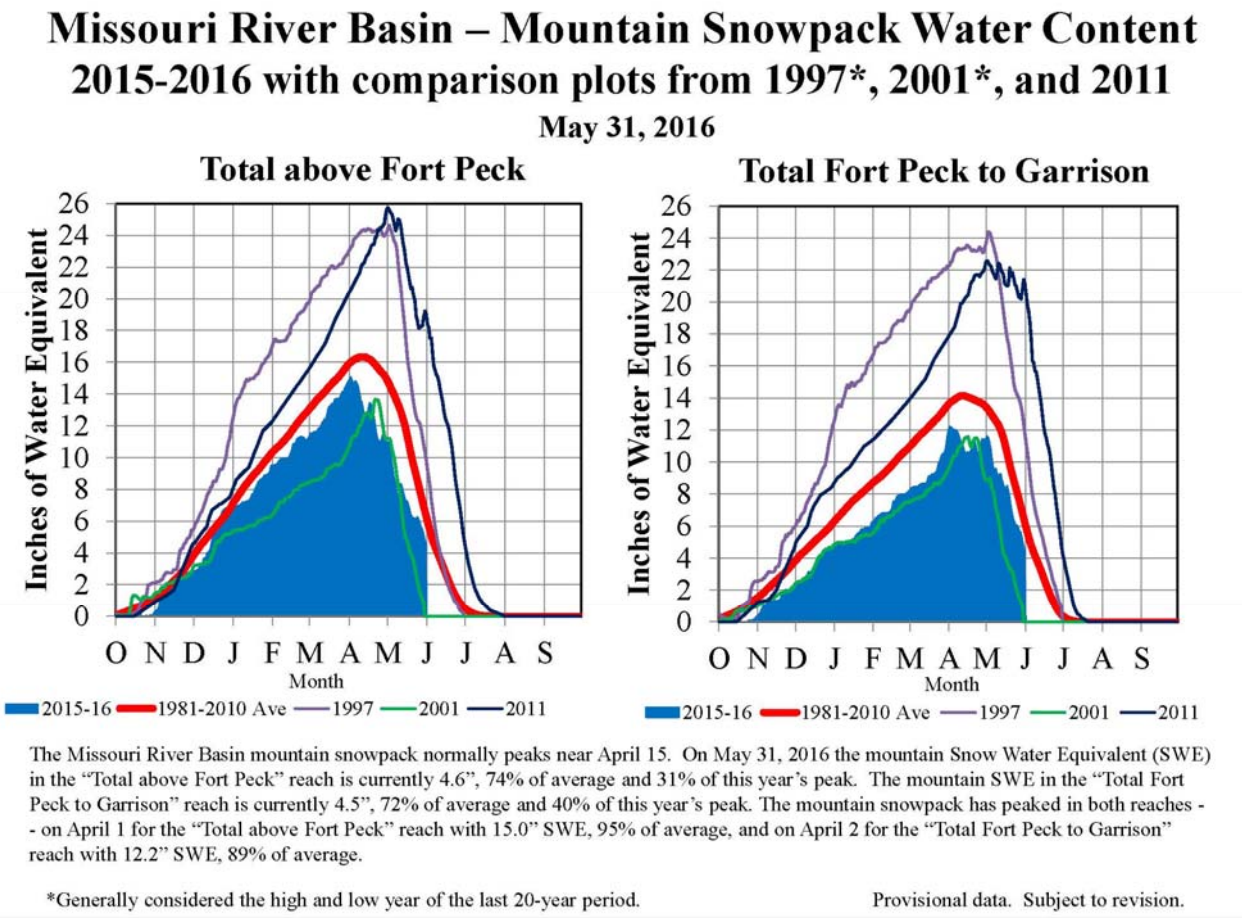


Figure ~~9~~10. Mountain snowpack water content on May 31, 2016 compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management.

Climate Outlook

ENSO (El Niño Southern Oscillation)

According to the CPC's latest monthly updated[1] on May 30, 2016, "***El Niño is weakening. La Niña is favored to develop during the Northern Hemisphere summer 2016, with about a 75% chance of La Niña during the fall and winter 2016-2017.***"

MRBWMD participates in the monthly North Central U.S. Climate/Drought Outlook Webinar coordinated through NOAA, the regional climate centers, and the American Association of State Climatologists (AASC). These webinars provide updates on near-term climate outlooks and impacts including the La Niña climate pattern and its implications on winter temperature and precipitation patterns in the Missouri River Basin. During La Niña winters, the probability for a colder-than-normal and slightly wetter-than-normal weather pattern in the Northern Rockies and Northern Plains is higher. The possible impacts of La Niña have been factored into the CPC climate outlooks described below.

Temperature and Precipitation Outlooks

The NOAA Climate Prediction Center climate outlook for June 2016 (**Figure 11)** indicates there are increased probabilities for above-normal temperatures in Montana and Wyoming, equal chances in the center of the Missouri Basin, and slightly increased chances for below-normal temperatures in the lower Basin. With regard to precipitation, there are equal chances for above-normal, normal and below-normal precipitation in the Missouri Basin; however, the mid-term outlooks through mid-June indicate the Missouri Basin will be drier-than-normal.

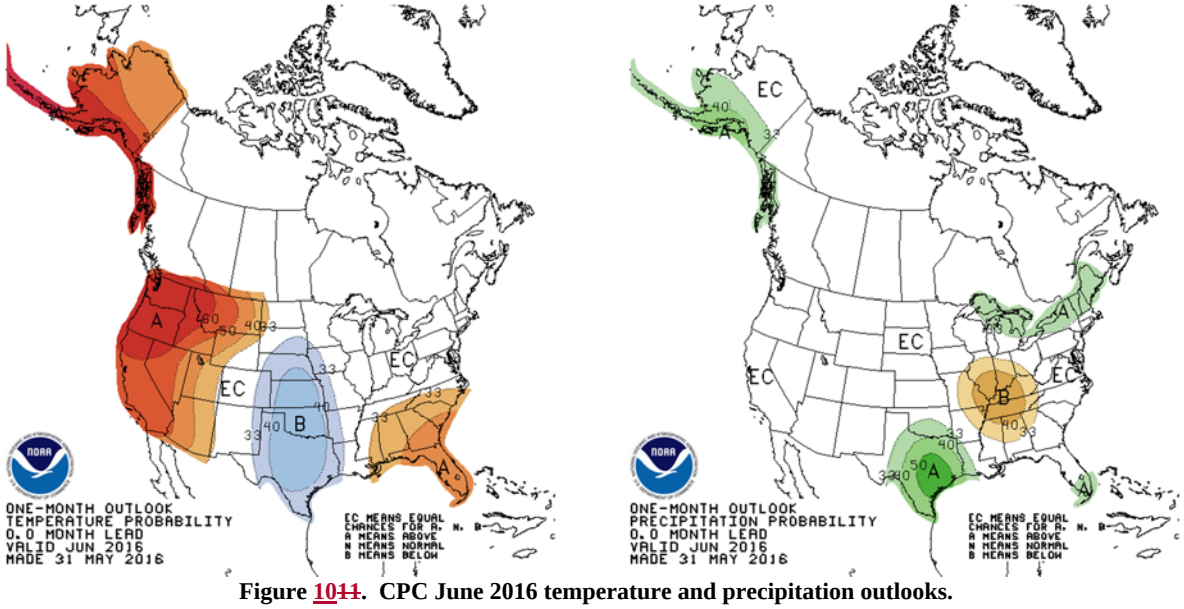


Figure 10~~11~~. CPC June 2016 temperature and precipitation outlooks.

[1] http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/lanina/enso_evolution-status-fcsts-web.pdf

The June-July-August 2016 temperature outlook (**Figure 12**) indicates there are equal chances of above- or below-normal temperatures in the center of the Missouri Basin, surrounded by increased chances for above-normal temperatures in the remainder of the Missouri Basin. The equal chances area is a reflection of moist soil conditions, which can reduce daytime temperatures, and the possibility of a continued storm track through the center of the Missouri Basin. With regard to precipitation, the June-July-August outlook indicates there are equal chances over Montana and North Dakota, but slightly increased chances for above-normal precipitation from southern Montana through Wyoming, South Dakota, Nebraska, Colorado, western Iowa, Kansas and western Missouri.

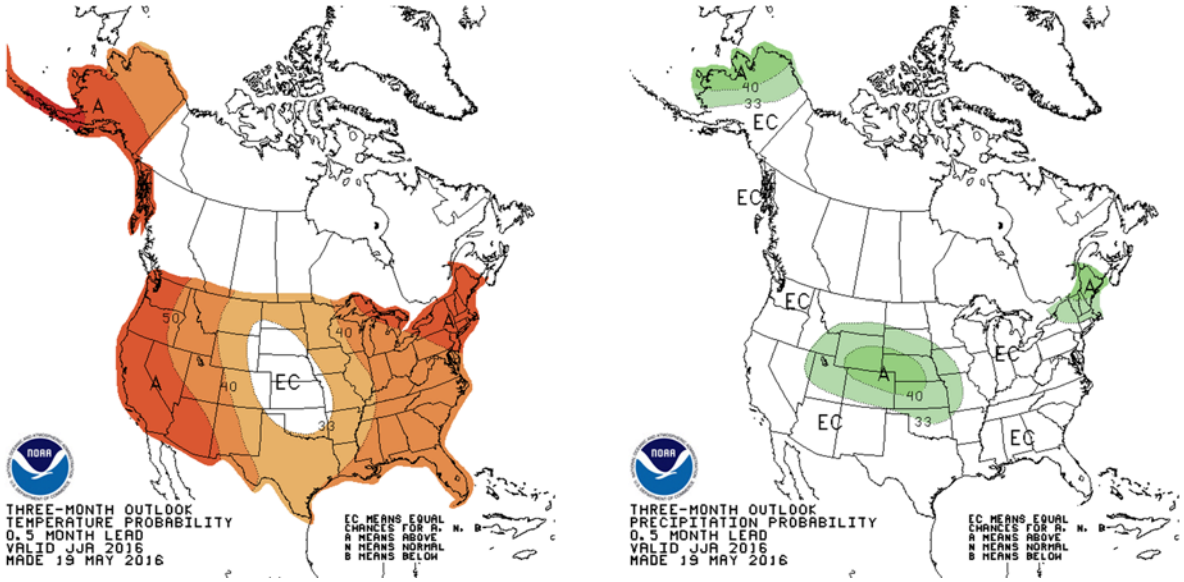


Figure 11~~12~~. CPC June-July-August 2016 temperature and precipitation outlooks.

The September-October-November 2016 CPC temperature outlook (**Figure 13**) indicates there are increased chances (40% to greater than 50%) for above-normal temperatures across the entire Missouri Basin. In terms of precipitation, there are equal chances for above-normal, normal and below-normal precipitation across Missouri Basin.

During the December 2016 – January-February 2017 period (**Figure 14**) CPC outlooks indicate increased chances (33% to greater than 40%) for below-normal temperatures in the Northern Rockies and Northern Plains based on the 75% chance that La Niña will develop in the fall and winter. Also, the CPC outlook indicates increased chances (33% to greater than 40%) that precipitation will be above normal in Montana. There are equal chances for precipitation in most other areas of the Missouri Basin through February 2017.

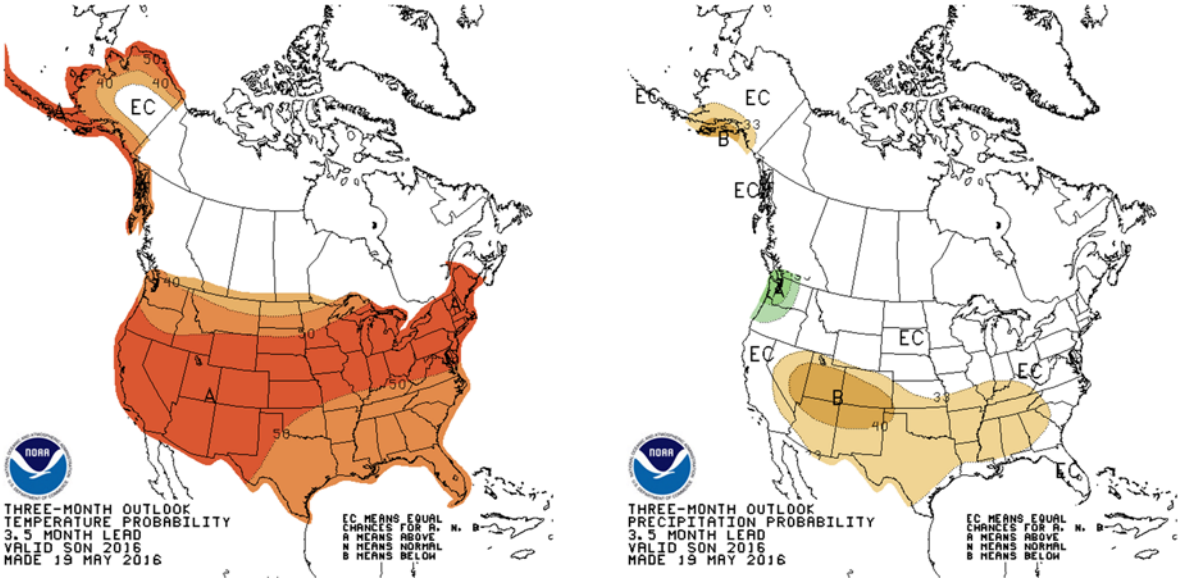


Figure 12~~13~~. CPC September-October-November 2016 temperature and precipitation outlooks.

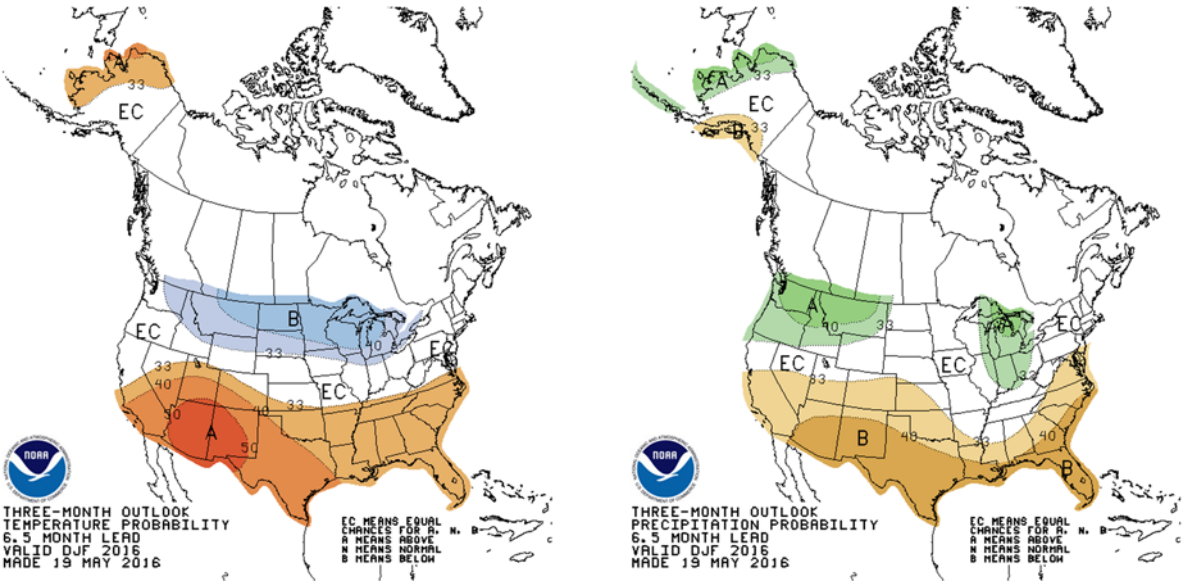
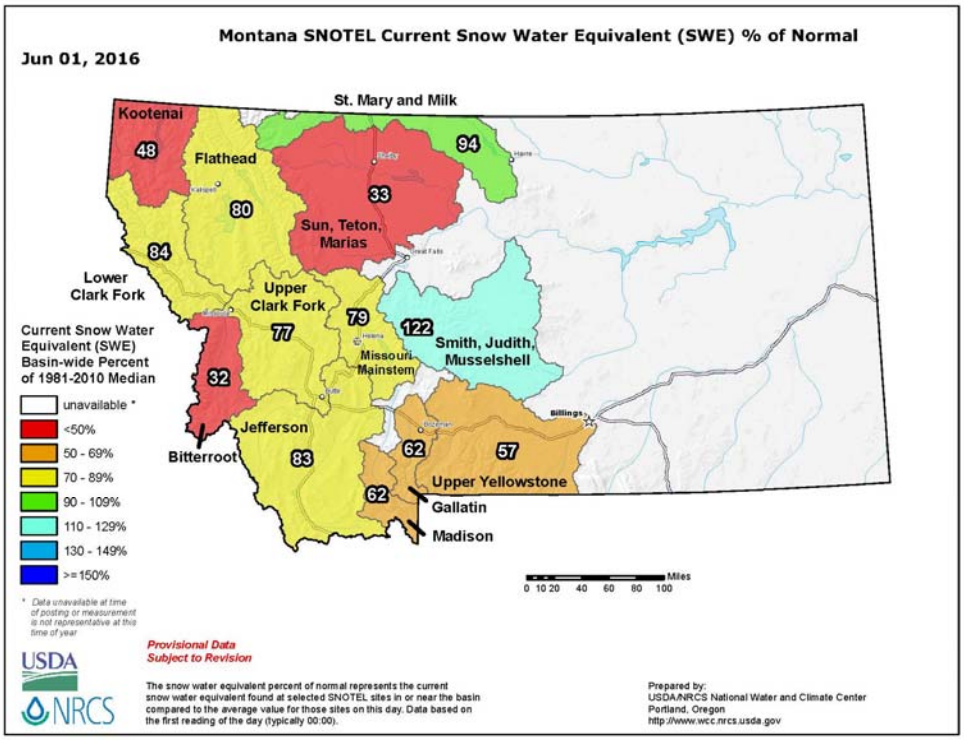


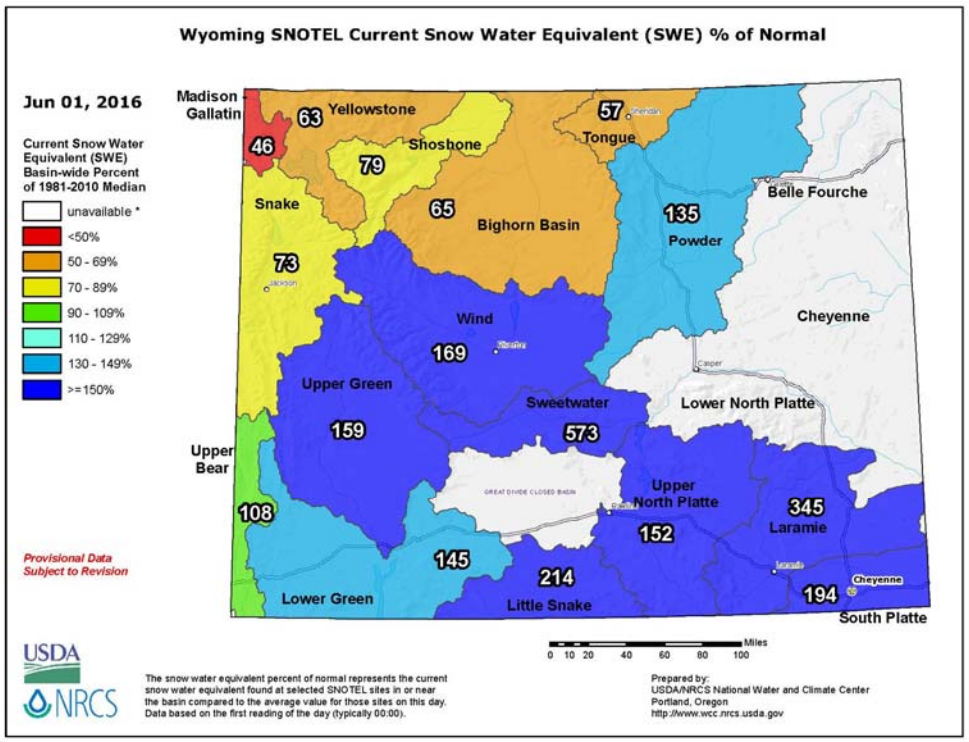
Figure 13~~14~~. CPC December 2016-January-February 2017 temperature and precipitation outlooks.

June 2016 Calendar Year Runoff Forecast

In summary, the 2016 calendar year runoff forecast is **25.3 MAF**, **100% of average**. Runoff for the basin above Gavins Point Dam, excluding the contributing area between Gavins Point Dam and Sioux City, IA, is forecast to be **21.8 MAF (94% of average)**. May runoff was 136% of average. The above-normal runoff was due to mountain snowmelt and above-average observed precipitation in the upper Basin. We will continue to monitor Missouri Basin conditions and make forecast adjustments as conditions change.

Additional Figures





USDA NRCS National Water & Climate Center
 * - DATA CURRENT AS OF: June 06, 2016 01:28:36 PM
   - Based on June 01, 2016 forecast values

PRELIMINARY MISSOURI RIVER BASIN FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
Lake Sherburne Inflow	JUN-JUL	47	84	60	52	42	34	56
	JUN-SEP	61	86	76	67	55	46	71
St. Mary R at Int'l Boundary (2)	JUN-JUL	220	80	290	245	191	149	275
	JUN-SEP	280	81	355	310	250	200	345
Lima Reservoir Inflow (2)	JUN-JUL	20	65	34	26	14.5	6.3	31
	JUN-SEP	25	64	43	32	17.9	7.4	39
Clark Canyon Reservoir Inflow (2)	JUN-JUL	21	60	65	39	3.1	-23	35
	JUN-SEP	34	62	84	54	13.6	-16.4	55
Jefferson R nr Three Forks (2)	JUN-JUL	290	82	480	365	210	96	355
	JUN-SEP	345	83	575	440	250	109	415
Hebgen Reservoir Inflow (2)	JUN-JUL	126	71	169	143	109	83	178
	JUN-SEP	210	75	260	230	189	158	280
Ennis Reservoir Inflow (2)	JUN-JUL	260	79	325	285	235	193	330
	JUN-SEP	395	81	480	430	360	310	485
Missouri R at Toston (2)	JUN-JUL	725	77	1090	875	575	360	940
	JUN-SEP	970	80	1480	1180	765	465	1220
Smith R bl Eagle Ck (2)	JUN-JUL	55	102	89	69	41	21	54
	JUN-SEP	67	103	112	85	48	21	65
Gibson Reservoir Inflow (2)	JUN-JUL	115	55	169	137	93	61	210
	JUN-SEP	150	60	210	173	127	92	250
Marias R nr Shelby (2)	JUN-JUL	65	45	175	109	21	-15.0	143
	JUN-SEP	76	48	200	127	25	-15.0	158

PRELIMINARY YELLOWSTONE RIVER BASIN FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
West Rosebud Ck nr Roscoe (2)	JUN-JUL	40	85	48	43	37	32	47
	JUN-SEP	53	84	64	57	49	42	63
Wind R ab Bull Lake Ck (2)	JUN-JUL	360	109	455	400	320	265	330
	JUN-SEP	395	108	505	440	350	285	365
Bull Lake Ck nr Lenore (2)	JUN-JUL	137	127	161	147	128	114	108
	JUN-SEP	172	124	205	185	159	140	139
Boysen Reservoir Inflow (2)	JUN-JUL	635	149	820	710	560	450	425
	JUN-SEP	705	145	935	800	610	475	485
Greybull R nr Meeteetse	JUN-JUL	113	118	138	123	103	88	96
	JUN-SEP	164	115	197	177	151	131	142
Shell Ck nr Shell	JUN-JUL	21	60	31	25	17.1	11.5	35
	JUN-SEP	30	65	41	35	25	18.6	46
Bighorn R at Kane (2)	JUN-JUL	765	134	1010	860	670	525	570
	JUN-SEP	860	137	1160	980	740	560	630
NF Shoshone R at Wapiti	JUN-JUL	275	90	330	295	250	215	305
	JUN-SEP	325	90	395	355	295	250	360
SF Shoshone R nr Valley	JUN-JUL	155	99	181	165	145	129	157
	JUN-SEP	187	99	220	200	173	153	189
Buffalo Bill Reservoir Inflow (2)	JUN-JUL	440	95	545	480	400	335	465
	JUN-SEP	510	95	640	565	460	380	535
Bighorn R nr St. Xavier (2)	JUN-JUL	1090	118	1400	1220	970	785	920
	JUN-SEP	1220	121	1620	1380	1050	815	1010
Little Bighorn R nr Hardin	JUN-JUL	32	60	61	44	20	3.3	53
	JUN-SEP	42	64	76	56	28	8.0	66

Tongue R nr Dayton (2)	JUN-JUL	30	61	46	36	24	14.0	49
	JUN-SEP	41	66	60	49	33	22	62
Tongue River Reservoir Inflow (2)	JUN-JUL	63	57	107	81	45	18.0	110
	JUN-SEP	81	60	137	104	59	25	134
NF Powder R nr Hazelton	JUN-JUL	2.7	60	4.9	3.6	1.84	0.56	4.5
	JUN-SEP	3.4	65	5.8	4.3	2.4	0.97	5.2
Powder R at Moorhead	JUN-JUL	67	73	121	89	45	12.2	92
	JUN-SEP	87	79	153	114	60	21	110
Powder R nr Locate	JUN-JUL	74	73	146	103	45	2.3	101
	JUN-SEP	95	78	186	132	58	4.3	122

Max (10%), 30%, 50%, 70% and Min (90%) chance that actual volume will exceed forecast.
Averages are for the 1981-2010 period.
All volumes are in thousands of acre-feet.

footnotes:
1) Max and Min are 5% and 95% chance that actual volume will exceed forecast
2) streamflow is adjusted for upstream storage
3) median value used in place of average

Upper Missouri River Basin
July 2016 Calendar Year Runoff Forecast
July 7, 2016

U.S. Army Corps of Engineers, Northwestern Division
Missouri River Basin Water Management
Omaha, NE

Calendar Year Runoff Forecast

Explanation and Purpose of Forecast

The long-range runoff forecast is presented as the Calendar Year Runoff Forecast. This forecast is developed shortly after the beginning of each calendar year and is updated at the beginning of each month to show the actual runoff for historic months of that year and the updated forecast for the remaining months of the year. This forecast presents monthly inflows in million acre-feet (MAF) from five incremental drainage areas, as defined by the individual System projects, plus the incremental drainage area between Gavins Point Dam and Sioux City. Due to their close proximity, the Big Bend and Fort Randall drainage areas are combined. Summations are provided for the total Missouri River reach above Gavins Point Dam and for the total Missouri River reach above Sioux City. The Calendar Year Runoff Forecast is used in the Monthly Study simulation model to plan future system regulation in order to meet the authorized project purposes throughout the calendar year.

June 2016 Runoff

June 2016 Missouri River Basin above Sioux City, IA (upper Basin) runoff was 4.1 MAF (74% of average). June runoff was 57% of average in the Fort Peck reach, 82% of average in the Garrison reach, 45% of average in the Oahe reach, 18% of average in the Fort Randall reach, 91% of average in the Gavins Point reach, and 156% of average in the Sioux City reach. Early mountain snowmelt in the northern Rocky Mountains coupled with significantly below-normal precipitation and above-normal temperatures led to the below-normal runoff in the Fort Peck and Garrison reaches, while significantly below normal rainfall led to the well below-normal runoff in the Oahe and Fort Randall reaches. Runoff in the Gavins Point and Sioux City reaches was largely due to wet antecedent soil moisture conditions, as rainfall was below normal in much of these two reaches as well.

2016 Calendar Year Forecast Synopsis

The July 1 forecast for 2016 upper Basin runoff is **23.0 MAF (91% of average)**. Runoff for the basin above Gavins Point Dam is forecast to be **19.5 MAF (85% of average)**. Due to the amount of variability in precipitation and other hydrologic factors that can occur over the next 6 months, the range of expected inflow is quite large and ranges from the 25.3 MAF upper basic

forecast to the 20.9 MAF lower basic forecast. The upper and lower basic forecasts are used in long-term regulation planning models to "bracket" the range of expected runoff given much wetter or drier conditions, respectively. Given that 6 months are being forecasted for this July 1 forecast (6 months observed/6 months forecast), the range of wetter than normal (upper basic) and drier than normal (lower basic) conditions is attributed to all 6 reaches for 6 months. The result is a range or "bracket" for each reach, and thus, for the total runoff forecast. As the year progresses, the range will further lessen as the number of observed months increases and number of forecast months decreases.

Current Conditions

Drought Analysis

The latest National Drought Mitigation Center's drought monitor for June 28, 2016 (**Figure 1**), when compared to the drought monitor for May 31, 2016 (**Figure 2**), shows an increase in severity and areal extent of drought conditions in the upper Basin. There has been some worsening and increase in areal extent of drought conditions in western North Dakota and northeastern Wyoming, and southern Iowa, southeastern Nebraska, eastern Kansas and northern Missouri. The U.S. Seasonal Drought Outlook in **Figure 3** indicates that drought is expected to persist in portions of Montana, Wyoming and North Dakota with some drought development expected to develop in western Montana.

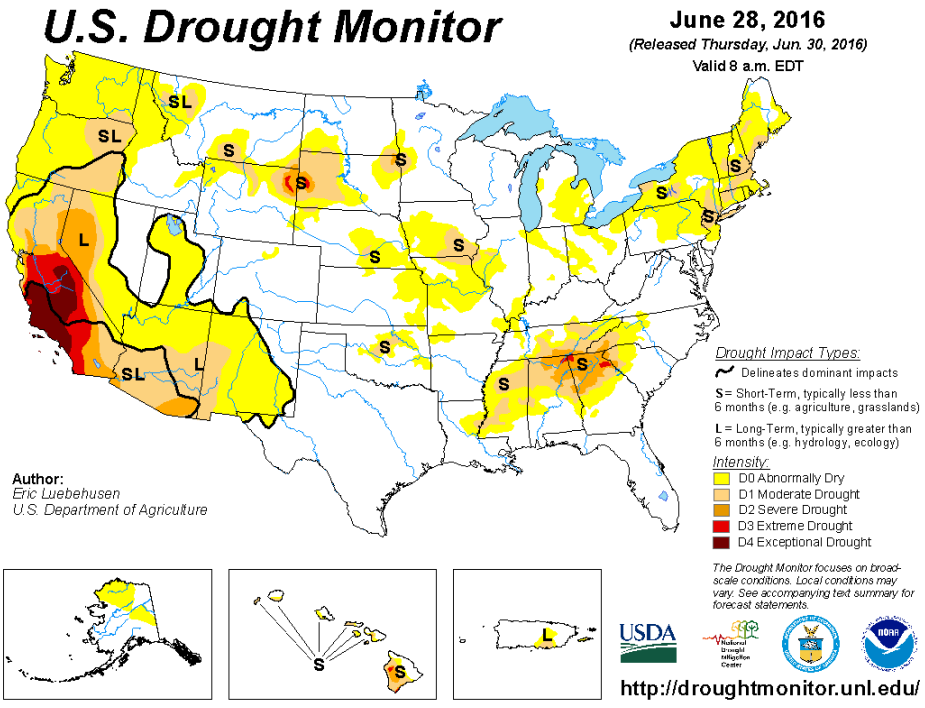


Figure 1 National Drought Mitigation Center U.S. Drought Monitor for June 28, 2016

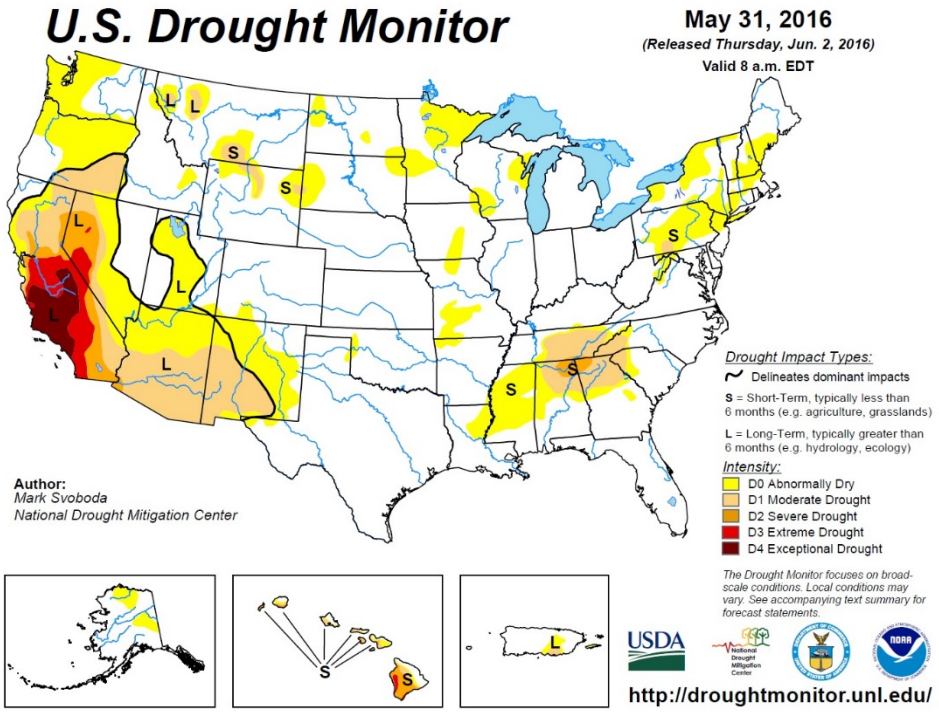


Figure 2. National Drought Mitigation Center U.S. Drought Monitor for May 31, 2016.

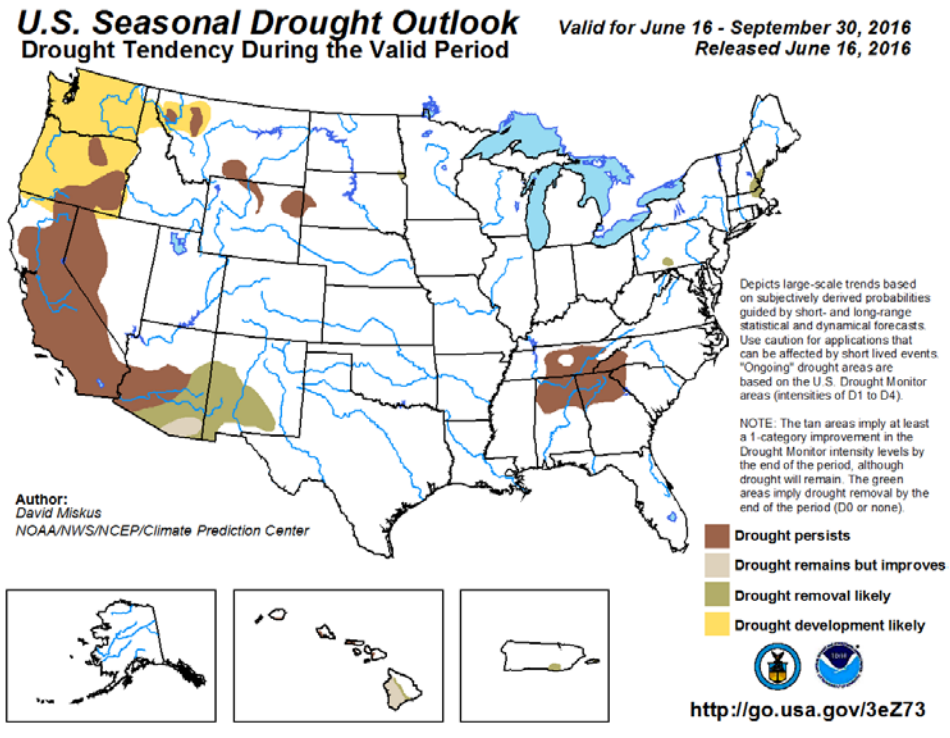


Figure 3. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

June precipitation accumulations are shown in **Figure 4** as both inches of precipitation (left) and percent of normal monthly precipitation (right). June precipitation was much below average in most of the Basin. The only areas of above-normal precipitation were in northeastern Montana and a few isolated pockets extending from southern North Dakota into north-central Nebraska and into northeastern Colorado. Large areas of Montana, Wyoming, western North Dakota, South Dakota, eastern Nebraska and Kansas, and western Iowa and Missouri received less than 50% of average precipitation in June.

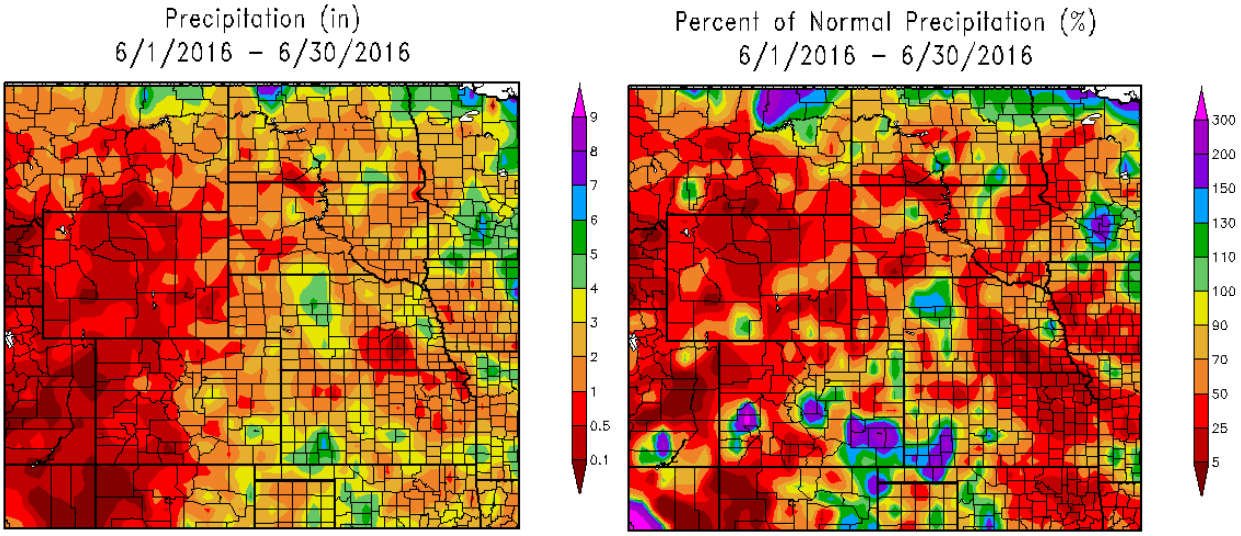


Figure 4. July 2016 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Table 1 contains notable June precipitation and departures in many locations in the Missouri Basin. Precipitation departures were variable across the basin ranging from large above-average departures in Glasgow, MT and Billings, MT to large below-average departures in Grand Island, NE and Billings, MT. Notable departures in the upper Basin include: 2.32 inches below normal in Lewistown, MT, 2.29 inches below normal in Aberdeen, SD, 1.89 inches below normal in Billings, MT, and 1.21 inches above normal in Bismarck, ND. Notable departures in the lower Basin include: 4.37 inches below normal in Lawrence, KS, 4.25 inches below normal in Grand Island, NE and Kansas City, MO, 3.77 inches below normal in Lincoln, NE, and 3.24 inches below normal in Omaha, NE.

Table 1. June 2016 precipitation and precipitation departures.

City, State	Precipitation inches	Precipitation Departure inches	Percent of Normal
Bozeman, MT	1.17	-1.23	49%
Lewistown, MT	0.76	-2.32	25%
Livingston, MT	0.73	-1.66	31%
Great Falls, MT	0.96	-1.57	38%
Havre, MT	1.93	-0.26	88%

City, State	Precipitation inches	Precipitation Departure inches	Percent of Normal
Miles City, MT	0.69	-1.82	27%
Billings, MT	0.23	-1.89	11%
Glasgow, MT	3.51	1.18	151%
Wolf Point, MT	3.20	0.49	118%
Lander, WY	0.57	-0.70	45%
Lake Yellowstone, WY	0.95	-1.05	48%
Sheridan, WY	0.39	-1.73	18%
Gillette, WY	0.44	-1.77	20%
Jamestown, ND	2.45	-0.74	77%
Bismarck, ND	4.38	1.21	138%
Williston, ND	1.84	-0.68	73%
Huron, SD	1.91	-2.02	49%
Rapid City Arpt, SD	1.22	-1.31	48%
Aberdeen, SD	1.41	-2.29	38%
Watertown, SD	1.53	-2.05	43%
Pierre, SD	1.83	-1.74	51%
Mobridge, SD	2.41	-0.75	76%
Sioux Falls, SD	1.72	-2.20	44%
Sioux City, IA	1.38	-2.51	35%
Valentine, NE	4.16	0.60	117%
North Platte, NE	3.26	-0.16	95%
Grand Island, NE	0.05	-4.25	1%
Norfolk, NE	3.21	-1.05	75%
Kearney, NE	0.46	-3.47	12%
Lincoln, NE	0.58	-3.77	13%
Omaha, NE	0.94	-3.24	22%
Manhattan, KS	1.25	-3.84	25%
Topeka, KS	2.39	-3.01	44%
Lawrence, KS	1.09	-4.37	20%
Kansas City Intl Arpt, KS	0.98	-4.25	19%
St. Joseph, MO	0.71	-3.47	17%
Columbia, MO	1.46	-3.01	33%
Jefferson City, MO	1.53	-3.03	34%

April-May-June 2016 precipitation accumulations and percent of normal (average) precipitation are shown in **Figure 5**. The precipitation pattern since April 1 shows above-average precipitation (right image) in much of Nebraska, Kansas, and Colorado, southern Wyoming, northeastern Montana and portions of North and South Dakota into northwestern Iowa. A below-average precipitation pattern has been prevalent in southern Montana, southwest North Dakota, northeast Wyoming and western South Dakota. Additionally, the lower Basin in southern Iowa and Missouri has received below-average precipitation since April 1. The areas with the driest conditions over the past three months closely correspond with areas noted as being in drought conditions above.

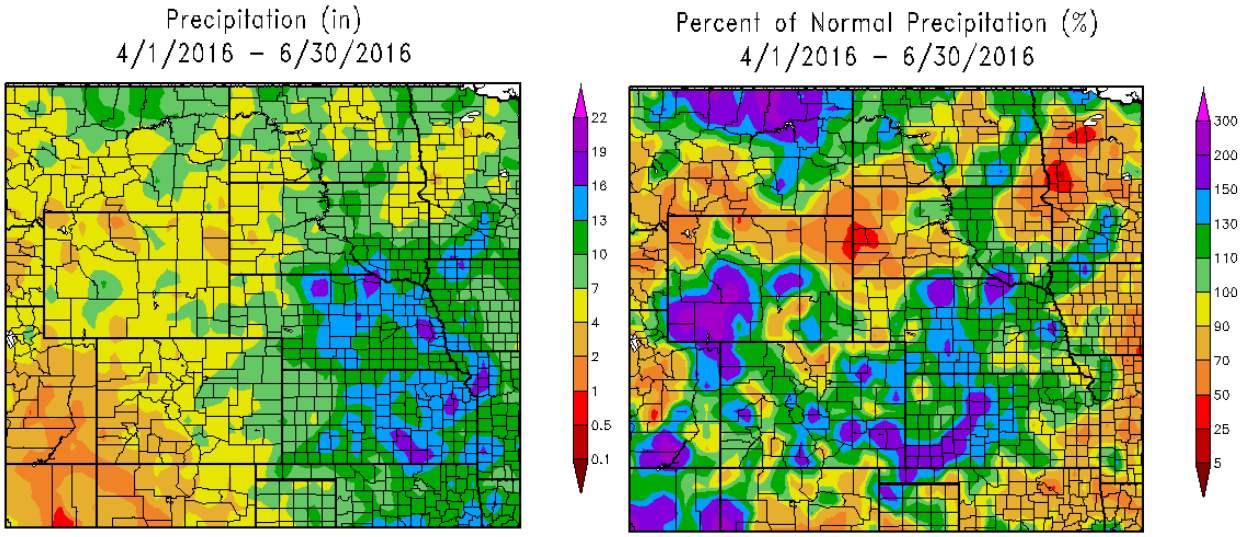


Figure 5. April-May-June 2016 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Temperature

June temperature departures from normal are shown in the left image of **Figure 6** in degrees Fahrenheit (deg F). April-May-June 2016 temperature departures are also shown in the right image of **Figure 6**. Temperatures during June (left image) have been above normal the entire Basin, with the exception of a few isolated pockets along the Canada-Montana border. The wsarmer temperatures are a reflection of dry June conditions. During the April-May-June period, an overall warmer-than-normal temperature pattern has prevailed throughout the entire Missouri Basin with the exception of isolated areas across northern Montana, North and South Dakota, Wyoming, Nebraska, Colorado and Kansas. Warmer temperatures in March through May led to earlier-than-normal peak mountain snow accumulations and earlier-than-normal snowmelt in the Northern Rockies. Temperatures in the Central Rockies have been closer to normal, resulting in normal to slightly above normal peak mountain snow accumulations and snowmelt in the Platte River basin.

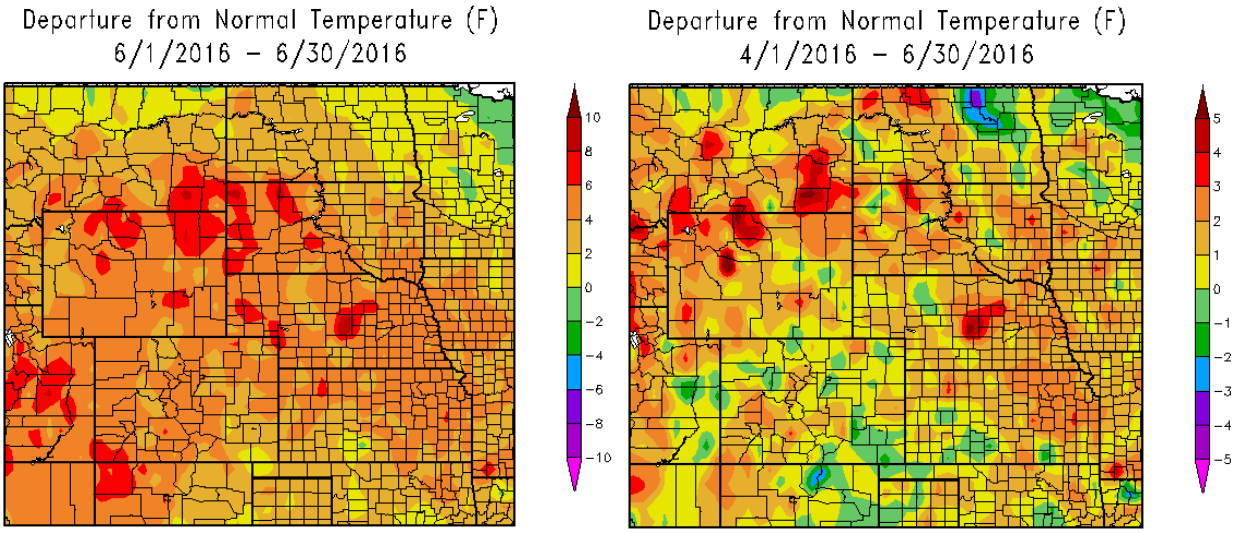


Figure 6. June 2016 and April-May-June 2016 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Soil Moisture

Soil moisture is factored into the forecast as an indicator of wet or dry hydrologic basin conditions. Typically when soil moisture conditions are wet or greater than normal, rainfall and snowmelt runoff is greater than when soil moisture is dry or less than normal. Not only is soil moisture a physical parameter that influences runoff, it can be used as an indicator of future runoff.

Figure 7 shows the NOAA NLDAS ensemble top 1-meter soil moisture anomaly on June 26, 2016. The NLDAS soil moisture depiction is an average value for the soil moisture column. **Figure 7** indicates above-normal soil moisture anomalies in northeastern Montana, most of southern Wyoming, western Nebraska and Kansas, and eastern Colorado. Below-normal soil moisture anomalies are present across southern Montana and northern Wyoming, most of North and South Dakota, eastern Kansas, and most of Iowa and Missouri.

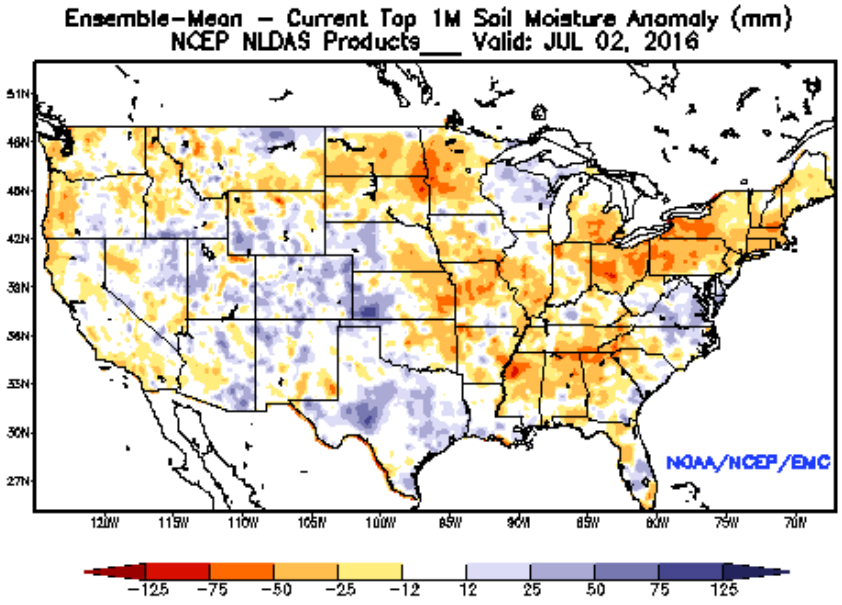


Figure 7. Top 1-Meter Soil Moisture Anomaly on July 2, 2016. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

Streamflow Conditions

Missouri Basin streamflow conditions are shown in **Figure 8**. These conditions are based on the ranking of the July 1, 2016 daily streamflow versus the historical record of streamflow for that date. Streamflow conditions are generally "Normal" (25th-75th percentile) and "Below Normal) (10th to 24th percentile) in Montana and Wyoming, though there are a number of tributaries that have fallen into the "Much Below Normal" (below 10th percentile) class as a result of early low elevation mountain snowmelt and below-average precipitation across areas of western and southern Montana. Streamflow has also been "Normal" to "Below Normal" in North Dakota and South Dakota, with some tributary headwaters locations in both states in the "Much Below Normal" class. Streamflow in the North Platte Basin in southeast Wyoming is "Normal" to "Above Normal" (76th – 90th percentile). The Missouri River and its tributaries from Sioux City to Kansas City range from "Normal" to "Much Above Normal" (above 90th percentile) due to precipitation in late June, with a few locations falling into "Below Normal" scattered throughout the area, depending on the location of late-month rainfall.

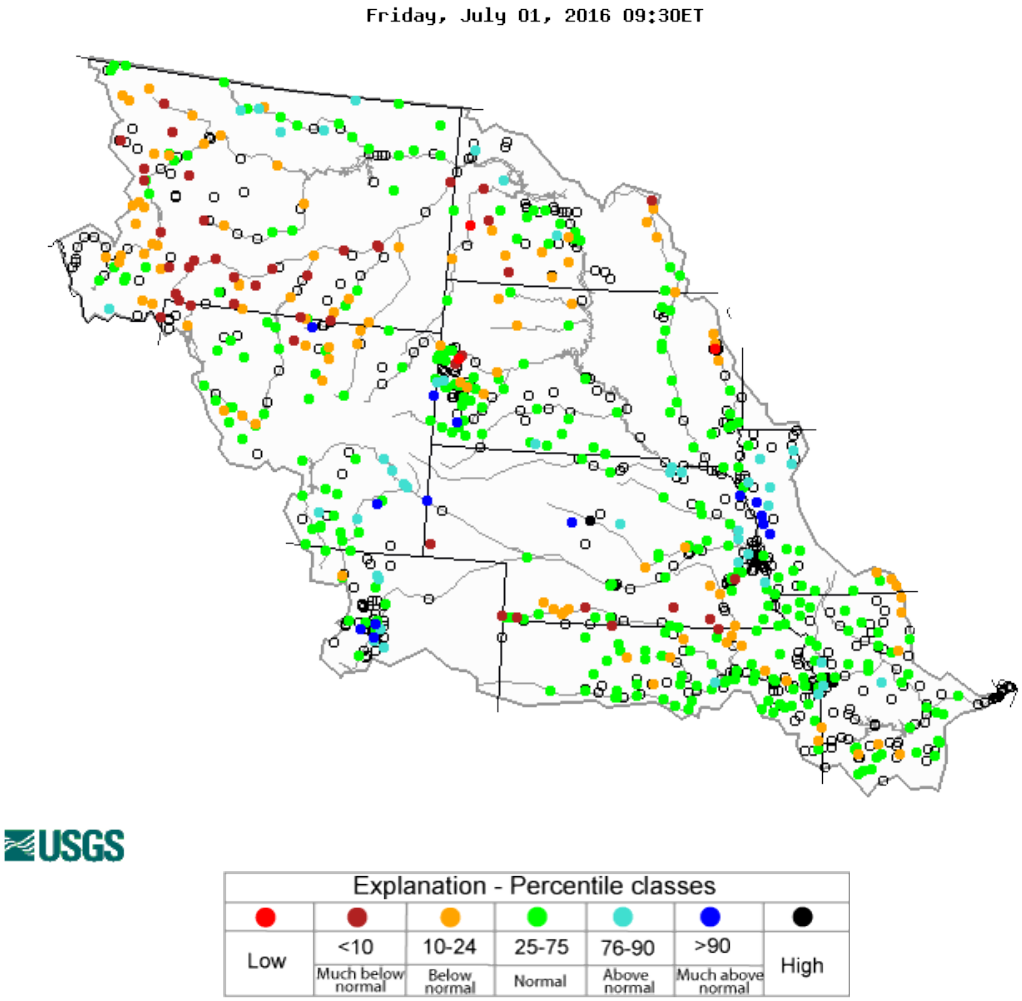


Figure 8. USGS Streamflow Conditions as a Percentile of Normal in the Missouri River Basin as of July 1, 2016. Source: USGS. http://waterwatch.usgs.gov/index.php

Mountain Snowpack

Mountain snowpack is the primary factor used to predict June-July runoff volumes in the Fort Peck and Fort Peck to Garrison mainstem reaches. During the 3-month May-June-July runoff period, about 50% of the annual runoff enters the mainstem system as a result of mountain snowmelt and rainfall runoff. Greater-than-average mountain snow accumulations are usually associated with greater-than-average June-July runoff volumes, especially when mountain soil moisture conditions have been wetter than normal as in the past three years. For example, we would expect to see below-average runoff from a below-average mountain snowpack this year due to soil moisture conditions ranging from drier than normal to wetter than normal.

Figure 9 includes time series plots of the average mountain snow water equivalent (SWE) beginning on October 1, 2015 based on the NRCS SNOTEL gages for the basin above Fort Peck and the incremental basin from Fort Peck to Garrison. The current average SWE values (shaded blue area) are plotted against the 1981-2010 basin average SWE (bold red line), 2001 (green

line), and two historic high SWE years occurring in 1997 (purple) and 2011 (dark blue). On average, mountain SWE normally peaks around April 15, and about 39% of the peak SWE accumulation remains by June 1.

The Fort Peck reach peaked at 15.0 inches of SWE on April 1, while Fort Peck to Garrison peaked at 12.2 inches of SWE on April 2, or 95% and 89% of average annual peak SWE, respectively. The mountain SWE has decreased rapidly over the past month as low to mid-level mountain snowpack melted due to warmer-than-normal temperatures in the Northern Rockies. On May 31, mountain SWE was 4.6 inches (74% of average) above Fort Peck and 4.5 inches (72% of average) from Fort Peck to Garrison. As of July 1, the mountain snowpack in both the Fort Peck and the Fort Peck to Garrison reaches had melted. No further snowmelt is anticipated in July.

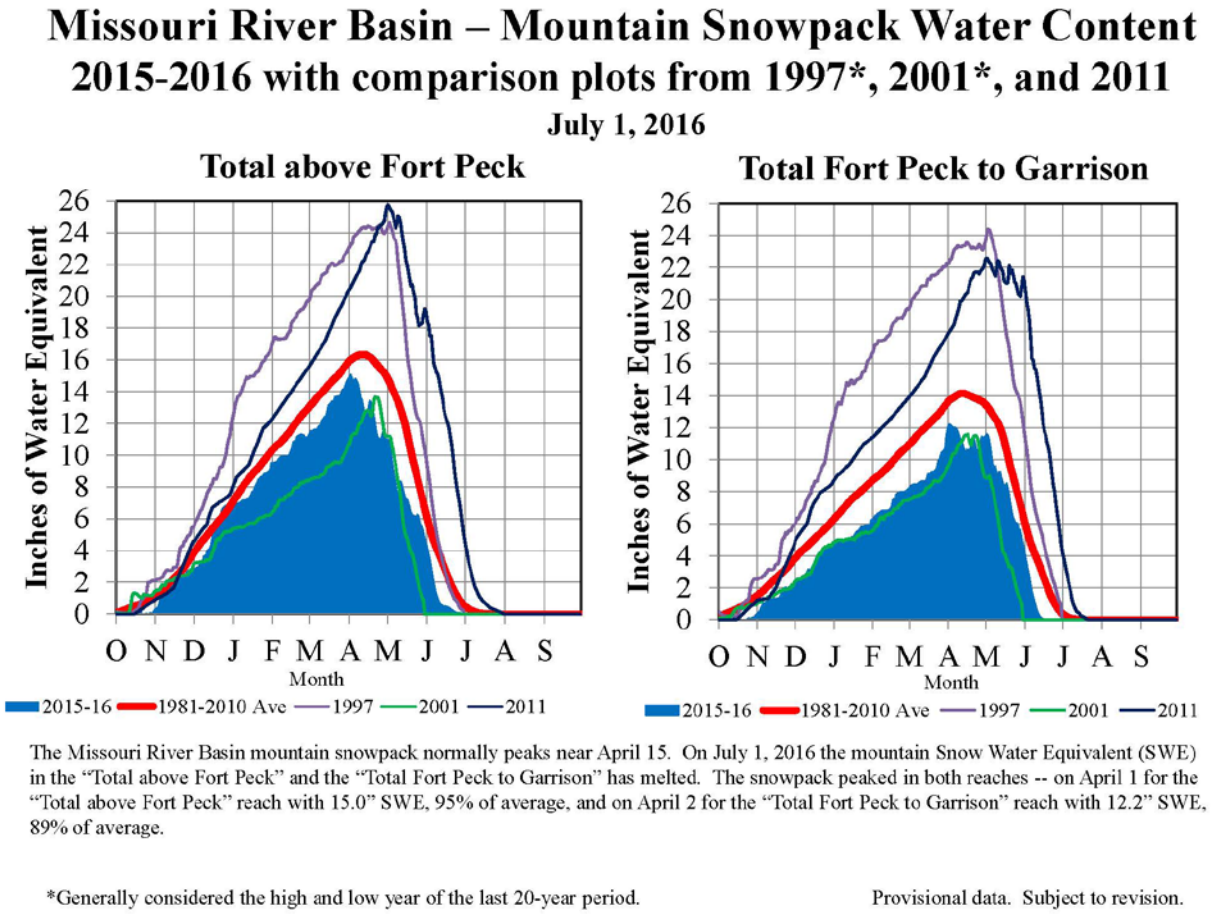


Figure 9. Mountain snowpack water content on July 1, 2016 compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management.

Climate Outlook

ENSO (El Niño Southern Oscillation)

According to the CPC's latest monthly updated[1] on July 5, 2016, "***ENSO-neutral conditions are present. La Niña is favored to develop during the Northern Hemisphere summer 2016, with about a 75% chance of La Niña during the fall and winter 2016-2017."***

MRBWMD participates in the monthly North Central U.S. Climate/Drought Outlook Webinar coordinated through NOAA, the regional climate centers, and the American Association of State Climatologists (AASC). These webinars provide updates on near-term climate outlooks and impacts including the La Niña climate pattern and its implications on winter temperature and precipitation patterns in the Missouri River Basin. During La Niña winters, the probability for a colder-than-normal and slightly wetter-than-normal weather pattern in the Northern Rockies and Northern Plains is higher. The possible impacts of La Niña have been factored into the CPC climate outlooks described below.

Temperature and Precipitation Outlooks

The NOAA Climate Prediction Center climate outlook for July 2016 (**Figure 10)** indicates there are increased probabilities for above-normal temperatures throughout the entire Basin. With regard to precipitation, there are equal chances for above-normal, normal and below-normal precipitation in the Missouri Basin with the exception of western Montana, which has an increased probability for below-normal precipitation. However, the mid-term outlooks through mid-July indicate that Montana and Wyoming will be cooler-than-normal, while northern Montana, North Dakota, eastern South Dakota, western Iowa, eastern Nebraska, eastern Kansas and Missouri will be wetter than normal.

[1] http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/lanina/enso_evolution-status-fcsts-web.pdf

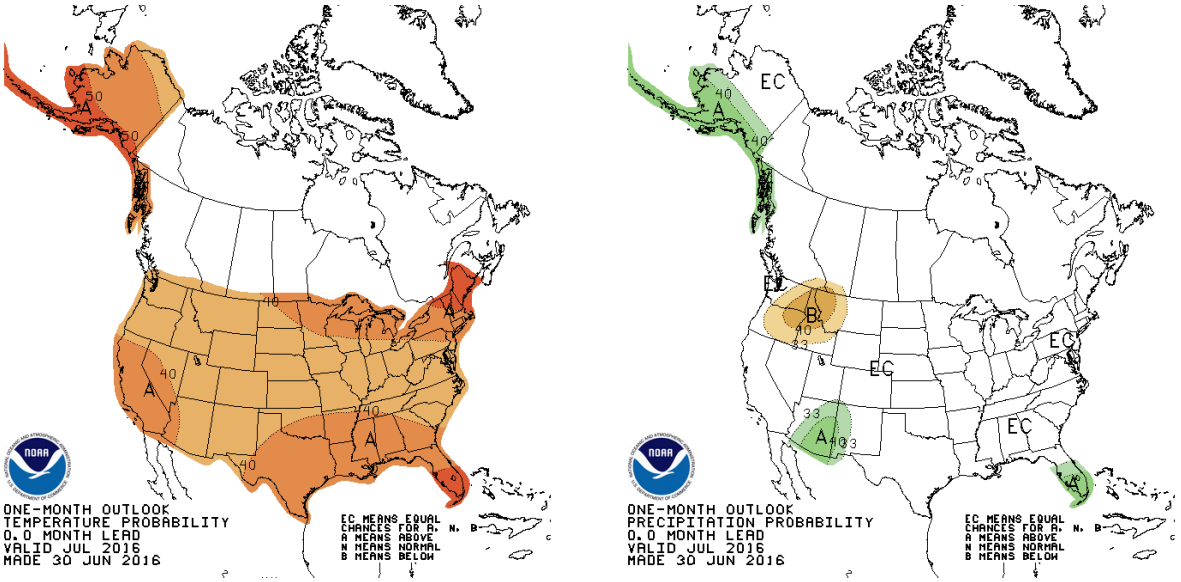


Figure 10. CPC July 2016 temperature and precipitation outlooks.

The July-August-September 2016 temperature outlook (**Figure 11**) indicates there are increased chances for above-normal temperatures throughout the entire Missouri Basin. With regard to precipitation, the July-August-September outlook indicates that is an increased probability of below-normal precipitation in western Montana, an increased probability of above-normal precipitation in nearly all of South Dakota, and equal chances for above-normal, normal or below-normal precipitation over the remainder of the Basin.

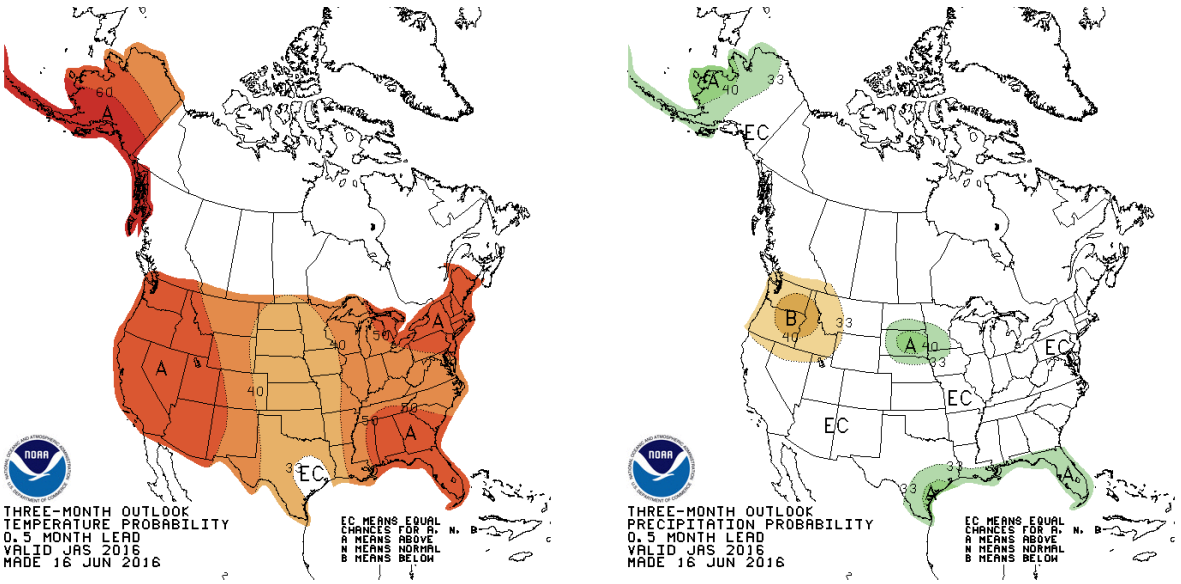


Figure 11. CPC July-August-September 2016 temperature and precipitation outlooks.

The October-November-December 2016 CPC temperature outlook (**Figure 12**) indicates there are equal chances for above-normal, normal or below-normal temperatures across nearly all of Montana and North Dakota and increased chances for above-normal temperatures across the

remainder of the Missouri Basin. In terms of precipitation, there are increased chances for above-normal precipitation across western Montana, increased chances for below-normal precipitation across nearly all of Colorado and equal chances for above-normal, normal and below-normal precipitation across the rest of the Missouri Basin.

During the January-February-March 2017 period (**Figure 13**) CPC outlooks indicate increased chances (33% to greater than 40%) for below-normal temperatures in the Northern Rockies and Northern Plains based on the 75% chance that La Niña will develop in the fall and winter. The CPC outlook indicates increased chances (33% to greater than 40%) that precipitation will be above normal in Montana. There are equal chances for precipitation in most other areas of the Missouri Basin through March 2017, with the exception of Colorado, Nebraska and Kansas, which have an increased probability of below-normal precipitation.

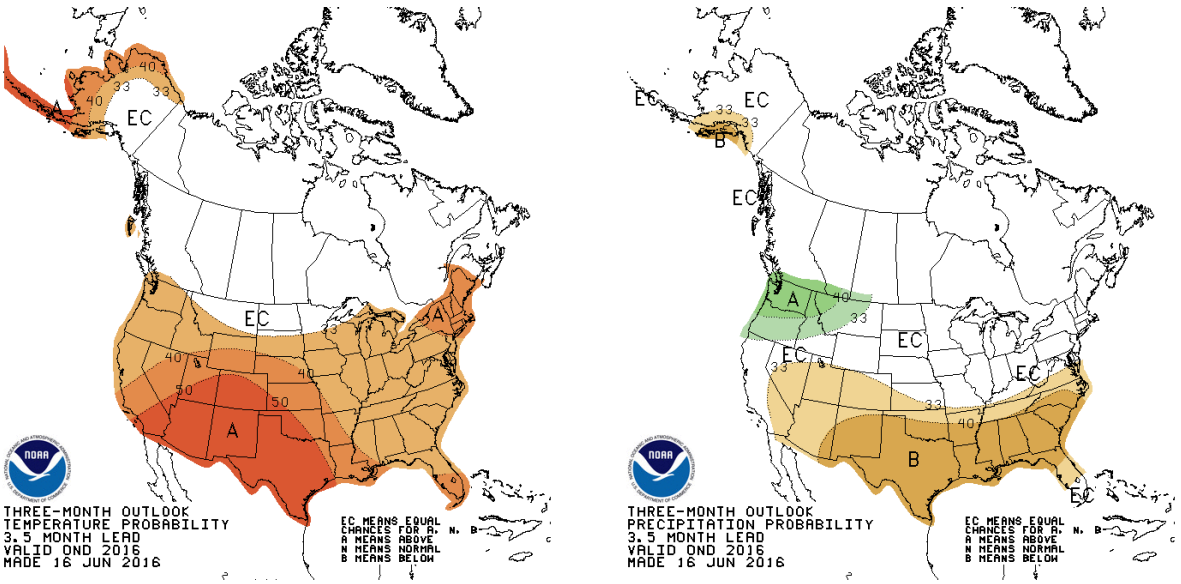


Figure 12. CPC October-November-December 2016 temperature and precipitation outlooks.

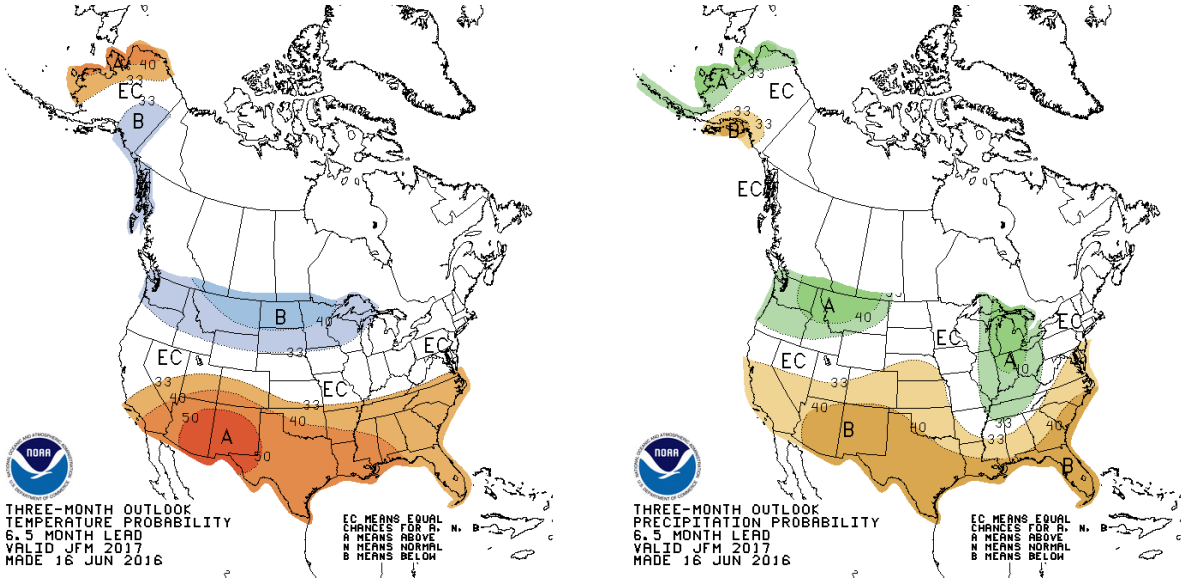
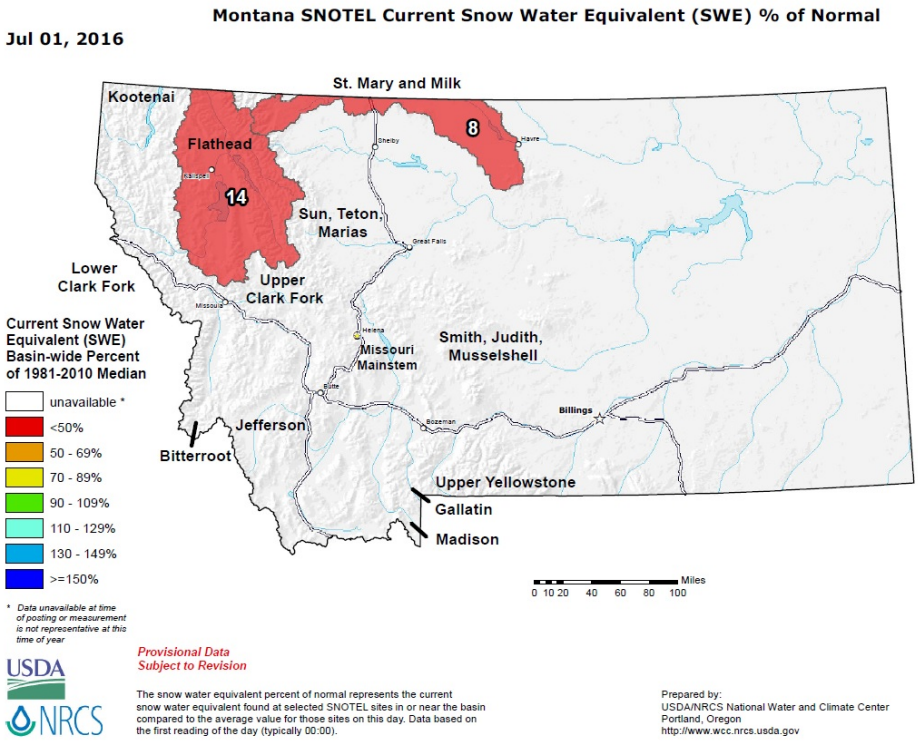


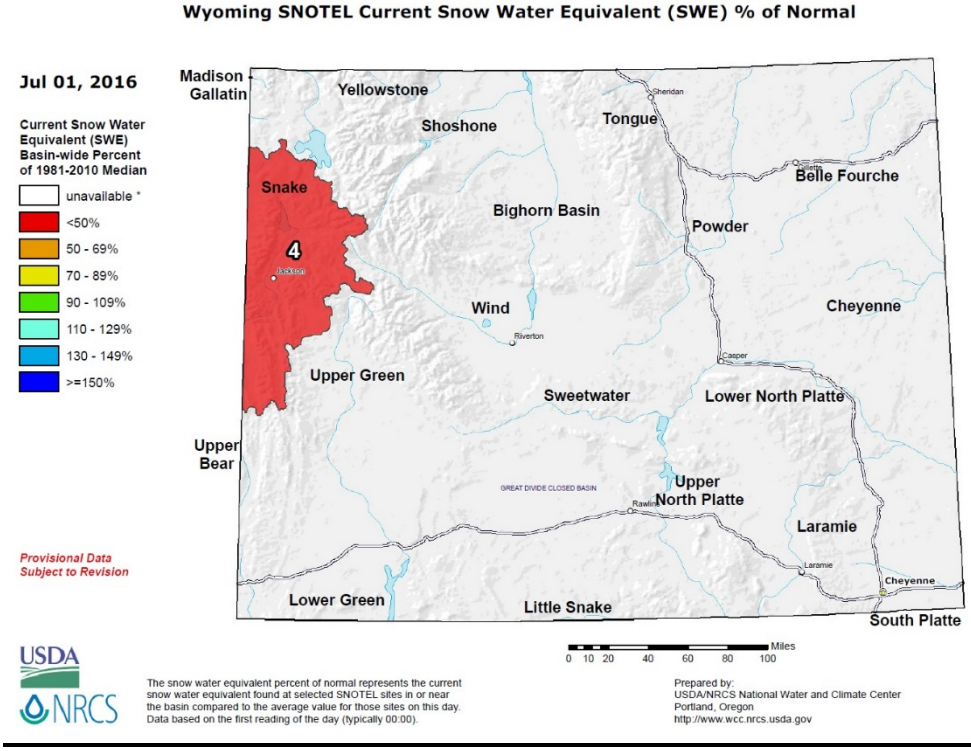
Figure 13. CPC January-February-March 2017 temperature and precipitation outlooks.

June 2016 Calendar Year Runoff Forecast

In summary, the 2016 calendar year runoff forecast is **23.0 MAF**, **91% of average**. Runoff for the basin above Gavins Point Dam, excluding the contributing area between Gavins Point Dam and Sioux City, IA, is forecast to be **19.5 MAF (85% of average)**. June runoff was 74% of average. The below-normal runoff was due to an earlier-than-normal mountain snowmelt and below-average observed precipitation in the upper Basin coupled with above-average temperatures. We will continue to monitor Missouri Basin conditions and make forecast adjustments as conditions change.

Additional Figures





USDA NRCS National Water & Climate Center
 * - DATA CURRENT AS OF: June 06, 2016 01:28:36 PM
   - Based on June 01, 2016 forecast values

PRELIMINARY MISSOURI RIVER BASIN FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
Lake Sherburne Inflow	JUN-JUL	47	84	60	52	42	34	56
	JUN-SEP	61	86	76	67	55	46	71
St. Mary R at Int'l Boundary (2)	JUN-JUL	220	80	290	245	191	149	275
	JUN-SEP	280	81	355	310	250	200	345
Lima Reservoir Inflow (2)	JUN-JUL	20	65	34	26	14.5	6.3	31
	JUN-SEP	25	64	43	32	17.9	7.4	39
Clark Canyon Reservoir Inflow (2)	JUN-JUL	21	60	65	39	3.1	-23	35
	JUN-SEP	34	62	84	54	13.6	-16.4	55
Jefferson R nr Three Forks (2)	JUN-JUL	290	82	480	365	210	96	355
	JUN-SEP	345	83	575	440	250	109	415
Hebgen Reservoir Inflow (2)	JUN-JUL	126	71	169	143	109	83	178
	JUN-SEP	210	75	260	230	189	158	280
Ennis Reservoir Inflow (2)	JUN-JUL	260	79	325	285	235	193	330
	JUN-SEP	395	81	480	430	360	310	485
Missouri R at Toston (2)	JUN-JUL	725	77	1090	875	575	360	940
	JUN-SEP	970	80	1480	1180	765	465	1220
Smith R bl Eagle Ck (2)	JUN-JUL	55	102	89	69	41	21	54
	JUN-SEP	67	103	112	85	48	21	65
Gibson Reservoir Inflow (2)	JUN-JUL	115	55	169	137	93	61	210
	JUN-SEP	150	60	210	173	127	92	250
Marias R nr Shelby (2)	JUN-JUL	65	45	175	109	21	-15.0	143
	JUN-SEP	76	48	200	127	25	-15.0	158

PRELIMINARY YELLOWSTONE RIVER BASIN FORECASTS

Forecast Point	period	50% (KAF)	% of avg	max (KAF)	30% (KAF)	70% (KAF)	min (KAF)	30-yr avg
West Rosebud Ck nr Roscoe (2)	JUN-JUL	40	85	48	43	37	32	47
	JUN-SEP	53	84	64	57	49	42	63
Wind R ab Bull Lake Ck (2)	JUN-JUL	360	109	455	400	320	265	330
	JUN-SEP	395	108	505	440	350	285	365
Bull Lake Ck nr Lenore (2)	JUN-JUL	137	127	161	147	128	114	108
	JUN-SEP	172	124	205	185	159	140	139
Boysen Reservoir Inflow (2)	JUN-JUL	635	149	820	710	560	450	425
	JUN-SEP	705	145	935	800	610	475	485
Greybull R nr Meeteetse	JUN-JUL	113	118	138	123	103	88	96
	JUN-SEP	164	115	197	177	151	131	142
Shell Ck nr Shell	JUN-JUL	21	60	31	25	17.1	11.5	35
	JUN-SEP	30	65	41	35	25	18.6	46
Bighorn R at Kane (2)	JUN-JUL	765	134	1010	860	670	525	570
	JUN-SEP	860	137	1160	980	740	560	630
NF Shoshone R at Wapiti	JUN-JUL	275	90	330	295	250	215	305
	JUN-SEP	325	90	395	355	295	250	360
SF Shoshone R nr Valley	JUN-JUL	155	99	181	165	145	129	157
	JUN-SEP	187	99	220	200	173	153	189
Buffalo Bill Reservoir Inflow (2)	JUN-JUL	440	95	545	480	400	335	465
	JUN-SEP	510	95	640	565	460	380	535
Bighorn R nr St. Xavier (2)	JUN-JUL	1090	118	1400	1220	970	785	920
	JUN-SEP	1220	121	1620	1380	1050	815	1010
Little Bighorn R nr Hardin	JUN-JUL	32	60	61	44	20	3.3	53
	JUN-SEP	42	64	76	56	28	8.0	66

Tongue R nr Dayton (2)	JUN-JUL	30	61	46	36	24	14.0	49
	JUN-SEP	41	66	60	49	33	22	62
Tongue River Reservoir Inflow (2)	JUN-JUL	63	57	107	81	45	18.0	110
	JUN-SEP	81	60	137	104	59	25	134
NF Powder R nr Hazelton	JUN-JUL	2.7	60	4.9	3.6	1.84	0.56	4.5
	JUN-SEP	3.4	65	5.8	4.3	2.4	0.97	5.2
Powder R at Moorhead	JUN-JUL	67	73	121	89	45	12.2	92
	JUN-SEP	87	79	153	114	60	21	110
Powder R nr Locate	JUN-JUL	74	73	146	103	45	2.3	101
	JUN-SEP	95	78	186	132	58	4.3	122

Max (10%), 30%, 50%, 70% and Min (90%) chance that actual volume will exceed forecast.
Averages are for the 1981-2010 period.
All volumes are in thousands of acre-feet.

footnotes:
1) Max and Min are 5% and 95% chance that actual volume will exceed forecast
2) streamflow is adjusted for upstream storage
3) median value used in place of average

Upper Missouri River Basin
August 2016 Calendar Year Runoff Forecast
August 4, 2016

U.S. Army Corps of Engineers, Northwestern Division
Missouri River Basin Water Management
Omaha, NE

Calendar Year Runoff Forecast

Explanation and Purpose of Forecast

The long-range runoff forecast is presented as the Calendar Year Runoff Forecast. This forecast is developed shortly after the beginning of each calendar year and is updated at the beginning of each month to show the actual runoff for historic months of that year and the updated forecast for the remaining months of the year. This forecast presents monthly inflows in million acre-feet (MAF) from five incremental drainage areas, as defined by the individual System projects, plus the incremental drainage area between Gavins Point Dam and Sioux City. Due to their close proximity, the Big Bend and Fort Randall drainage areas are combined. Summations are provided for the total Missouri River reach above Gavins Point Dam and for the total Missouri River reach above Sioux City. The Calendar Year Runoff Forecast is used in the Monthly Study simulation model to plan future system regulation in order to meet the authorized project purposes throughout the calendar year.

July 2016 Runoff

July 2016 Missouri River Basin above Sioux City, IA (upper Basin) runoff was 2.3 MAF (69% of average). July runoff was 58% of average in the Fort Peck reach, 60% of average in the Garrison reach, 125% of average in the Oahe reach, 53% of average in the Fort Randall reach, 85% of average in the Gavins Point reach, and 117% of average in the Sioux City reach. Mountain snowpack had melted by the end of June, a couple weeks earlier than normal. The absence of any remaining mountain snowpack in early July coupled with significantly below-normal precipitation led to below-normal runoff in the Fort Peck and Fort Peck to Garrison reaches. Above normal rainfall in the northern portion of the Oahe reach contributed to above normal runoff for Oahe. Runoff in the Sioux City reaches was largely due to higher-than-average baseflow that carried over from above average May and June runoff and tributary streamflow.

2017 Calendar Year Forecast Synopsis

The August 1 forecast for 2016 upper Basin runoff is **22.7 MAF (89% of average)**. Runoff for the basin above Gavins Point Dam is forecast to be **19.3 MAF (83% of average)**. Due to the amount of variability in precipitation and other hydrologic factors that can occur over the next 5

months, the range of expected inflow ranges from the 23.9 MAF upper basic forecast to the 21.5 MAF lower basic forecast. The upper and lower basic forecasts are used in long-term regulation planning models to "bracket" the range of expected runoff given much wetter or drier conditions, respectively. Given that 5 months are being forecasted for this August 1 forecast (7 months observed/5 months forecast), the range of wetter than normal (upper basic) and drier than normal (lower basic) conditions is attributed to all 6 reaches for 5 months. The result is a range or "bracket" for each reach, and thus, for the total runoff forecast. As the year progresses, the range will continue to lessen as the number of observed months increases and number of forecast months decreases.

Current Conditions

Drought Analysis

The latest National Drought Mitigation Center's drought monitor for July 26, 2016 (**Figure 1**), when compared to the drought monitor for June 28, 2016 (**Figure 2**), shows an increase in severity and areal extent of drought conditions in the upper Basin. There has been some worsening in drought conditions in the basin. This includes an increase in the areal extent of Extreme Drought (D3) conditions from northeast Wyoming to western South Dakota, and expansion of Moderate Drought (D0) conditions in western and southern Montana and northern Wyoming. The U.S. Seasonal Drought Outlook in **Figure 3** indicates that drought conditions are expected to persist in portions of Montana and Wyoming, but drought conditions are expected to improve in the Black Hills region of Wyoming and South Dakota.

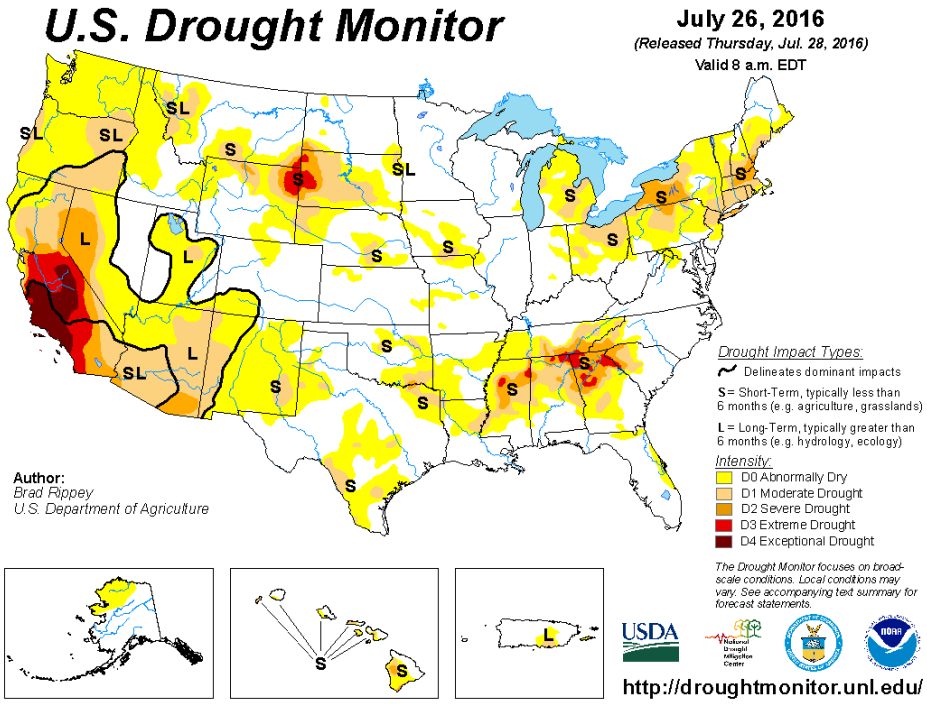


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for July 26, 2016

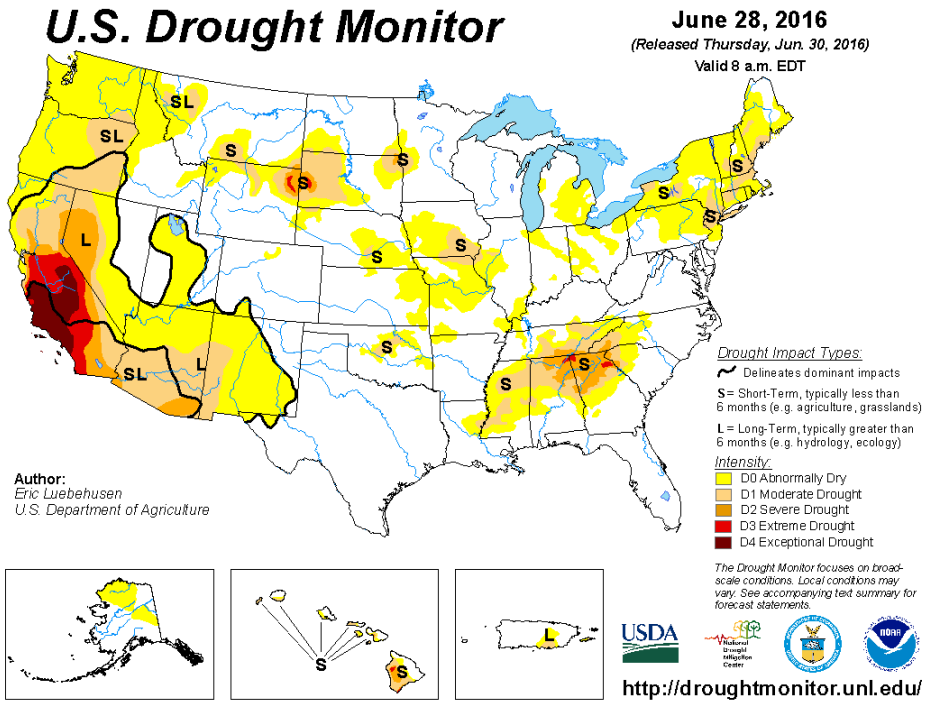


Figure 2. National Drought Mitigation Center U.S. Drought Monitor for June 28, 2016

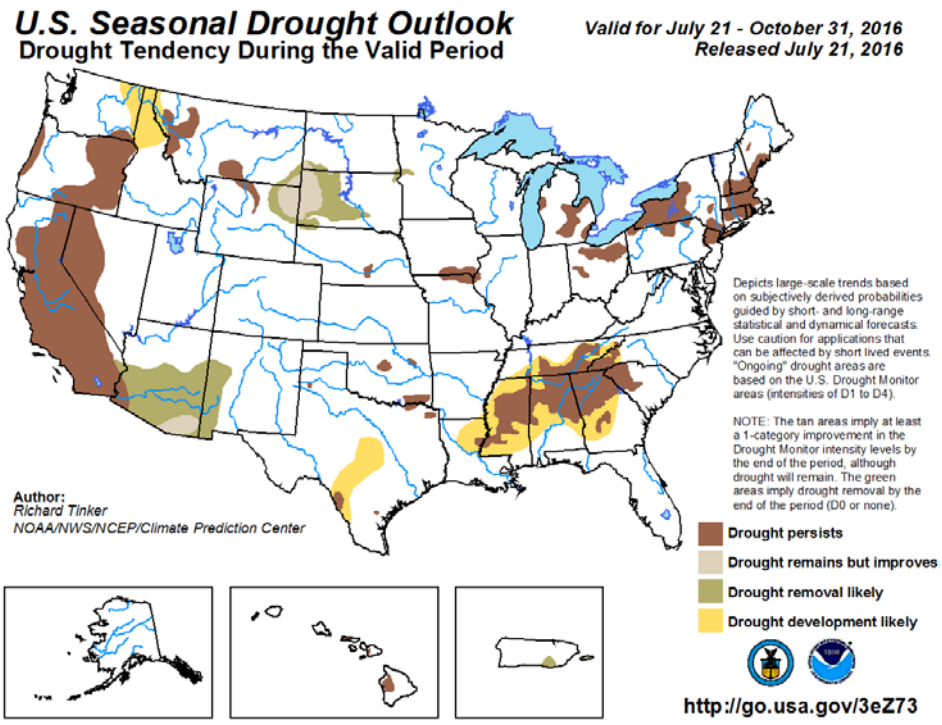


Figure 3. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

July precipitation accumulations are shown in **Figure 4** as both inches of precipitation (left) and percent of normal monthly precipitation (right). July precipitation was above average in large areas of northern Montana and North Dakota, and in smaller areas of South Dakota, and north central Nebraska. In the lower Basin, precipitation was above average in a small area of eastern Nebraska, southwest Iowa, eastern Kansas and central Missouri. Precipitation was well below average across most of Wyoming and several smaller regions of southern Montana, northwest South Dakota, and eastern South Dakota.

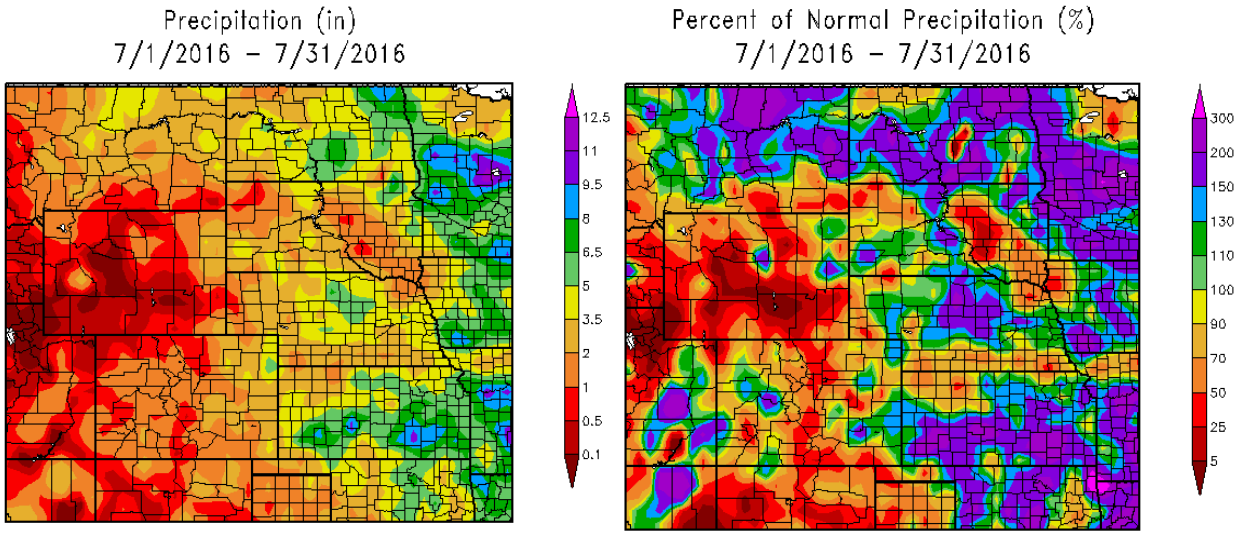


Figure 4. July 2016 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

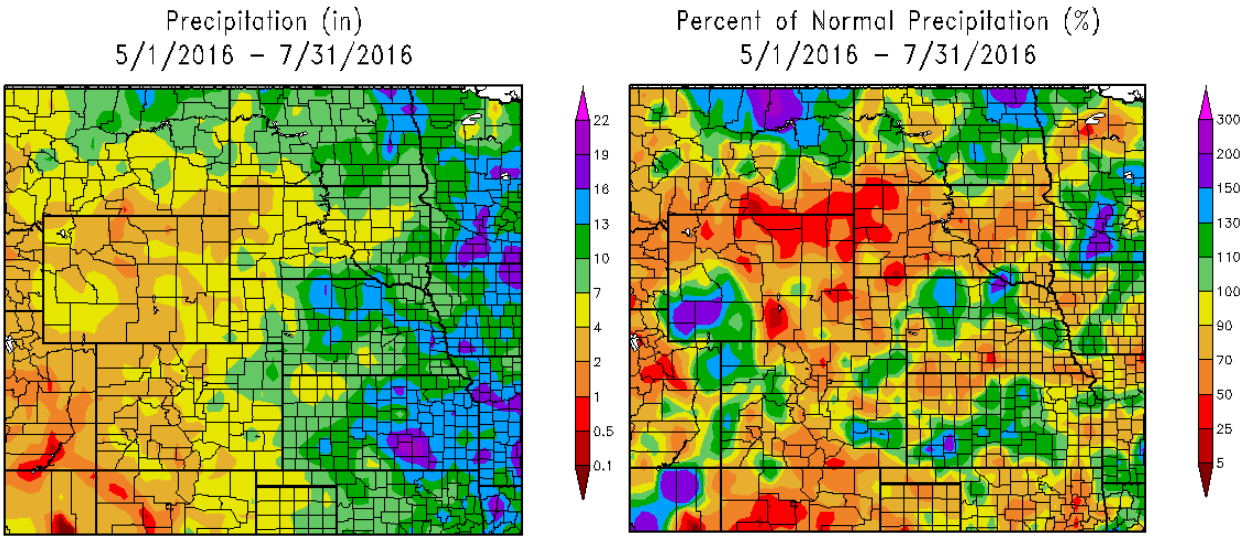


Figure 5. May-June-July 2016 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Table 1 contains notable July 2016 precipitation amounts and precipitation departures in many locations in the Missouri Basin. Low July precipitation totals occurred in Billings, MT (0.45 inches); Lander, WY (trace); and Sheridan, WY (0.22 inches). In contrast high precipitation totals occurred in Glasgow, MT (3.42 inches / 192%); Bismarck, ND (5.1 inches / 176%); and Pierre, SD (4.31 inches / 165%). High precipitation totals also occurred at many locations in the lower Basin including Omaha, NE (6.61 inches / 173%); Kansas City, MO (8.76 inches / 197%); and Columbia, MO (10.91 inches / 250%). Despite the very heavy rainfall, high volumes of runoff did not occur in the Missouri Basin in July.

May-June-July 2016 precipitation accumulations and percent of normal (average) precipitation are shown in **Figure 5**. The precipitation pattern since May 1 has been very dry in southern Montana, much of Wyoming, South Dakota, northwest Iowa, and southeast Nebraska. Areas that have received above average precipitation include north central Montana, eastern North Dakota, and portions of eastern Kansas and central Missouri.

Table 1. July 2016 precipitation and precipitation departures.

City, State	Precipitation inches	Precipitation Departure inches	Percent of Normal
Lewistown, MT	3.41	1.48	177%
Great Falls, MT	1.20	-0.30	80%
Havre, MT	2.43	0.79	148%
Miles City, MT	1.34	-0.30	82%
Billings, MT	0.45	-0.87	34%
Glasgow, MT	3.42	1.64	192%
Wolf Point, MT	2.43	0.45	123%
Lander, WY	Trace	-0.78	
Lake Yellowstone, WY	0.91	-0.56	62%
Sheridan, WY	0.22	-0.96	19%
Jamestown, ND	5.88	2.53	176%
Bismarck, ND	5.10	2.21	176%
Williston, ND	2.39	-0.15	94%
Rapid City Arpt, SD	2.83	0.98	153%
Aberdeen, SD	3.69	0.67	122%
Watertown, SD	2.48	-0.54	82%
Pierre, SD	4.31	1.70	165%
Mobridge, SD	2.33	-0.37	86%
Sioux Falls, SD	2.32	-0.77	75%
Sioux City, IA	2.19	-1.25	64%
North Platte, NE	3.84	0.77	126%
Grand Island, NE	4.10	0.70	121%
Lincoln, NE	4.67	1.27	137%
Omaha, NE	6.61	2.78	173%
Topeka, KS	5.36	1.54	140%
St. Joseph, MO	8.54	3.35	165%
Kansas City Intl Arpt, MO	8.76	4.31	197%
Columbia, MO	10.91	6.54	250%
Jefferson City, MO	7.99	3.71	187%

Temperature

July temperature departures from normal are shown in the left image of **Figure 6** in degrees Fahrenheit (deg F). May-June-July 2016 temperature departures from normal are also shown in the right image of **Figure 6**. July temperature departures (left image) have varied across the upper Basin and lower Basin. Temperatures were generally cooler than normal in areas that received above-normal precipitation, and temperatures were generally warmer than normal in the below-normal precipitation areas. Temperature departures during May-June-July in the right image of **Figure 6** have been generally above normal across the entire Missouri Basin.

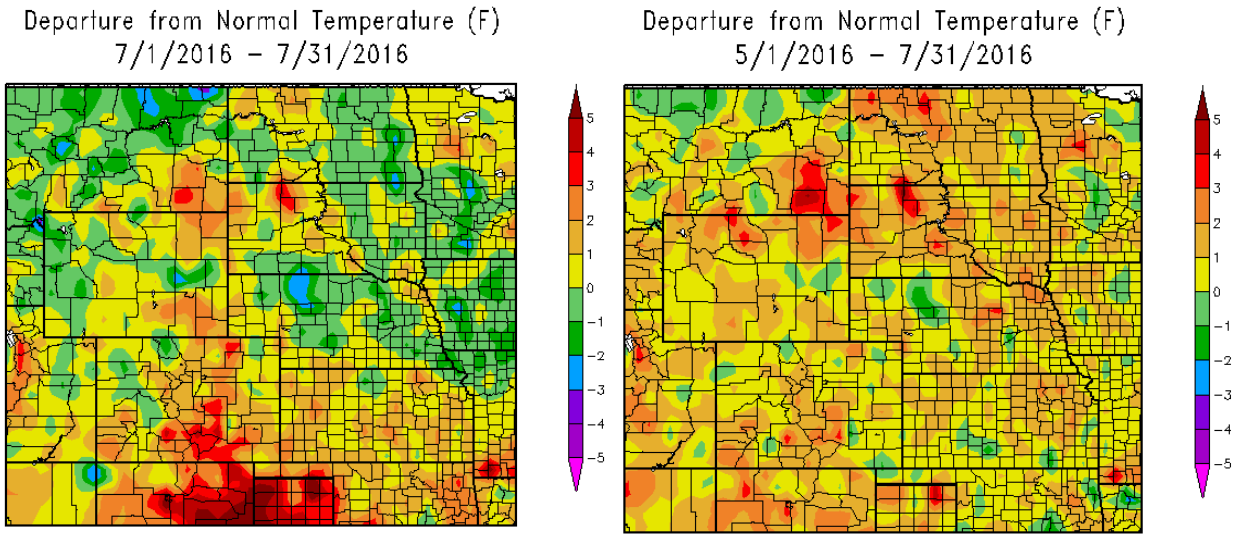


Figure 6. July 2016 and May-June-July 2016 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Soil Moisture

Soil moisture is factored into the forecast as an indicator of wet or dry hydrologic basin conditions. Typically when soil moisture conditions are wet or greater than normal, rainfall and snowmelt runoff is greater than when soil moisture is dry or less than normal. Not only is soil moisture a physical parameter that influences runoff, it can be used as an indicator of future runoff.

Figure 7 shows the NOAA NLDAS ensemble top one-meter soil moisture anomaly on July 29, 2016. The NLDAS soil moisture depiction is an average value for the one-meter soil moisture column. **Figure 7** indicates that soil moisture is predominantly drier than normal (below normal anomalies) over large portions of the Missouri Basin including southern and western Montana, Wyoming, southern North Dakota, South Dakota, southeast Nebraska and northern Missouri. Soil moisture is above normal in north central Montana, western Nebraska, western and central Kansas,and much of central Missouri.

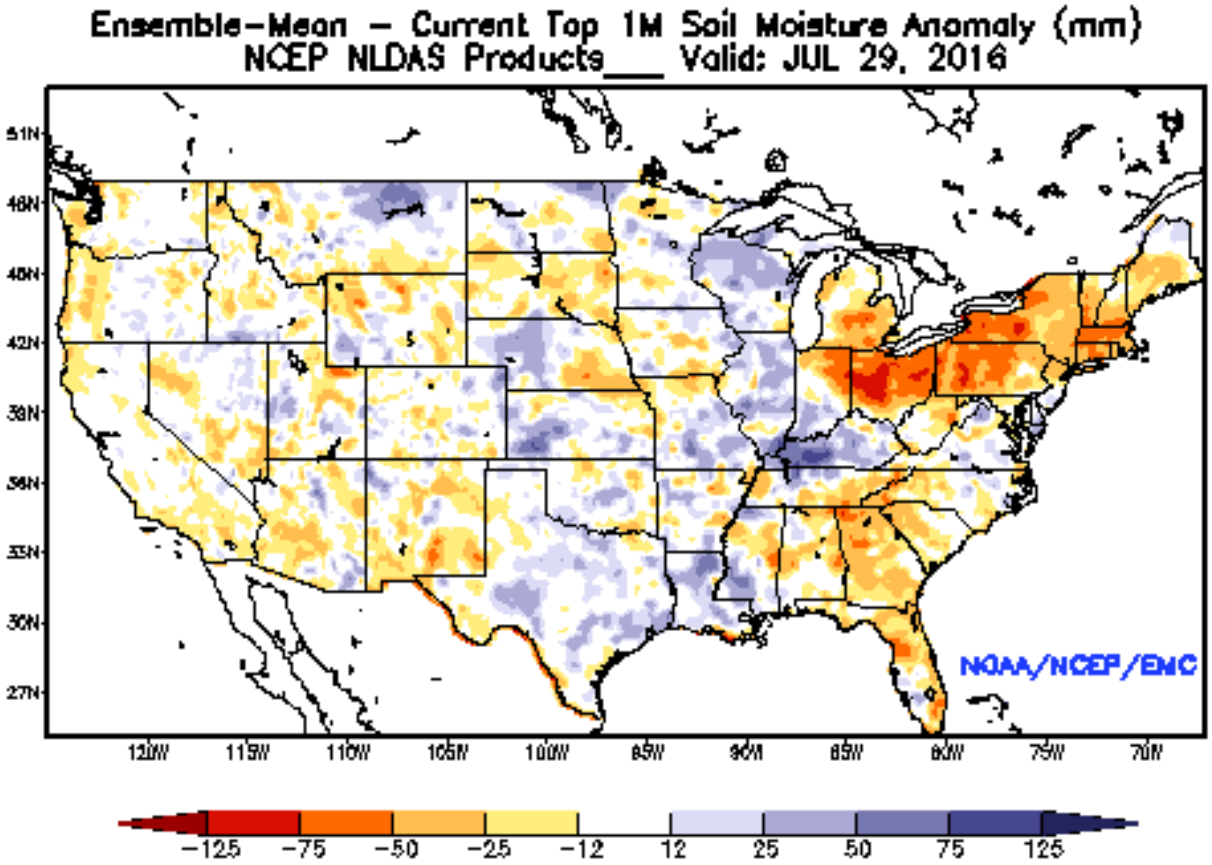


Figure 7. Top 1-Meter Soil Moisture Anomaly on July 29, 2016. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

Streamflow Conditions

Missouri Basin streamflow conditions are shown in **Figure 8**. These conditions are based on the ranking of the August 1, 2016 daily streamflow versus the historical record of streamflow for that date. Streamflow conditions are generally "Normal" (25th-75th percentile) and "Below Normal) (10th to 24th percentile) in Montana and Wyoming, though there are a number of tributaries that have fallen into the "Much Below Normal" (below 10th percentile) class as a result of the absence of remaining snowpack and low precipitation accumulations in July. Streamflow on the lower Platte River Basin and on the Missouri River from Sioux City to Nebraska City was "Above Normal" (76th – 90th percentile) to "Much Above Normal" (above 90th percentile). Also some Missouri tributaries in Missouri were "Much Above Normal" (above 90th percentile).

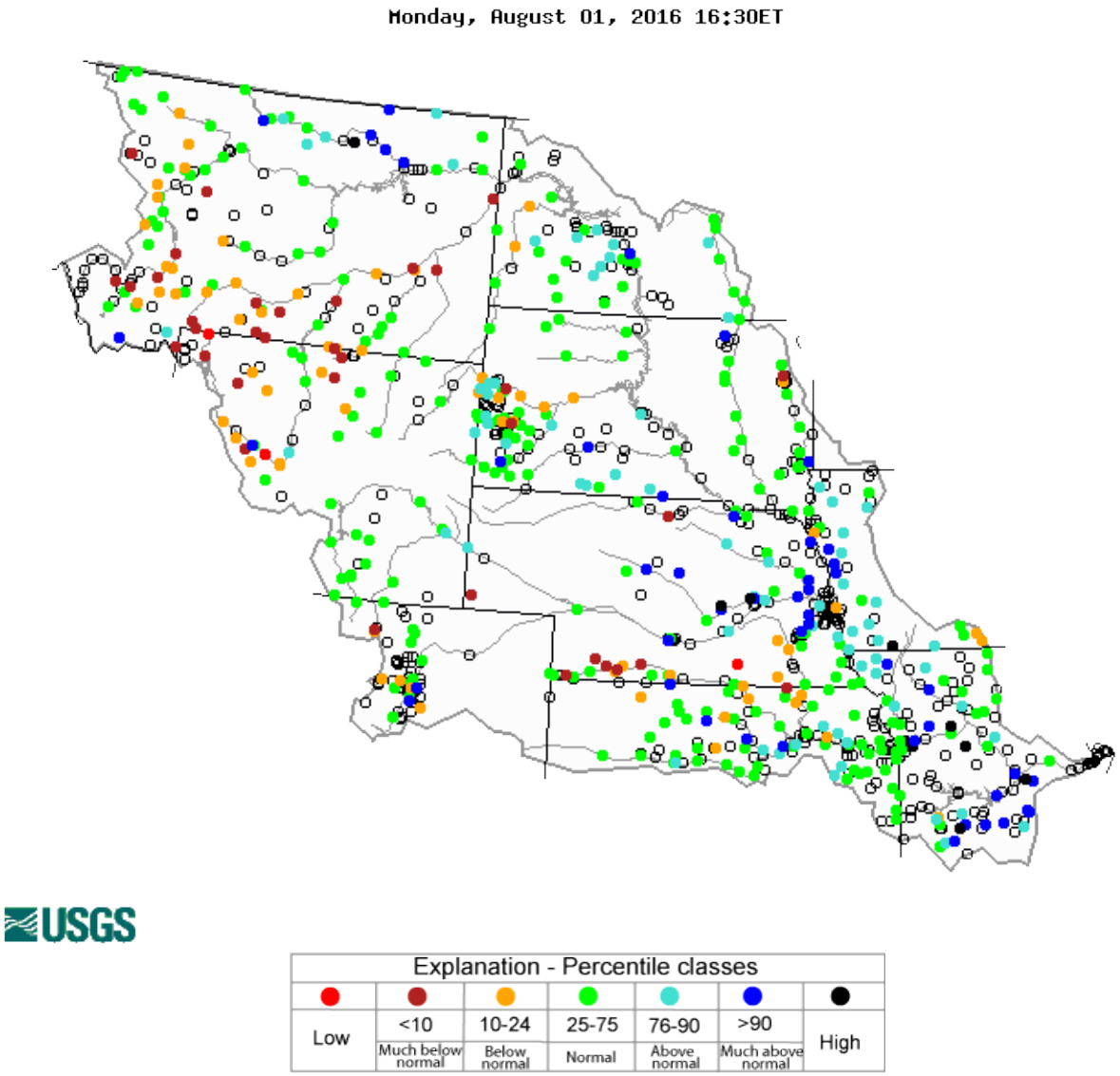


Figure 8. USGS Streamflow Conditions as a Percentile of Normal in the Missouri River Basin as of August 1, 2016. Source: USGS. http://waterwatch.usgs.gov/index.php

Mountain Snowpack

Mountain snowpack is the primary factor used to predict June-July runoff volumes in the Fort Peck and Fort Peck to Garrison mainstem reaches. During the 3-month May-June-July runoff period, about 50% of the annual runoff enters the mainstem system as a result of mountain snowmelt and rainfall runoff. Greater-than-average mountain snow accumulations are usually associated with greater-than-average June-July runoff volumes, especially when mountain soil moisture conditions have been wetter than normal as in the past three years. For example, we would expect to see below-average runoff from a below-average mountain snowpack this year due to soil moisture conditions ranging from drier than normal to wetter than normal.

Figure 9 includes time series plots of the average mountain snow water equivalent (SWE) beginning on October 1, 2015 based on the NRCS SNOTEL gages for the basin above Fort Peck and the incremental basin from Fort Peck to Garrison. The current average SWE values (shaded blue area) are plotted against the 1981-2010 basin average SWE (bold red line), 2001 (green line), and two historic high SWE years occurring in 1997 (purple) and 2011 (dark blue). On average, mountain SWE normally peaks around April 15, and about 39% of the peak SWE accumulation remains by June 1.

The Fort Peck reach peaked at 15.0 inches of SWE on April 1, while Fort Peck to Garrison peaked at 12.2 inches of SWE on April 2, or 95% and 89% of average annual peak SWE, respectively. As of July 1, the mountain snowpack in both the Fort Peck and the Fort Peck to Garrison reaches had melted.

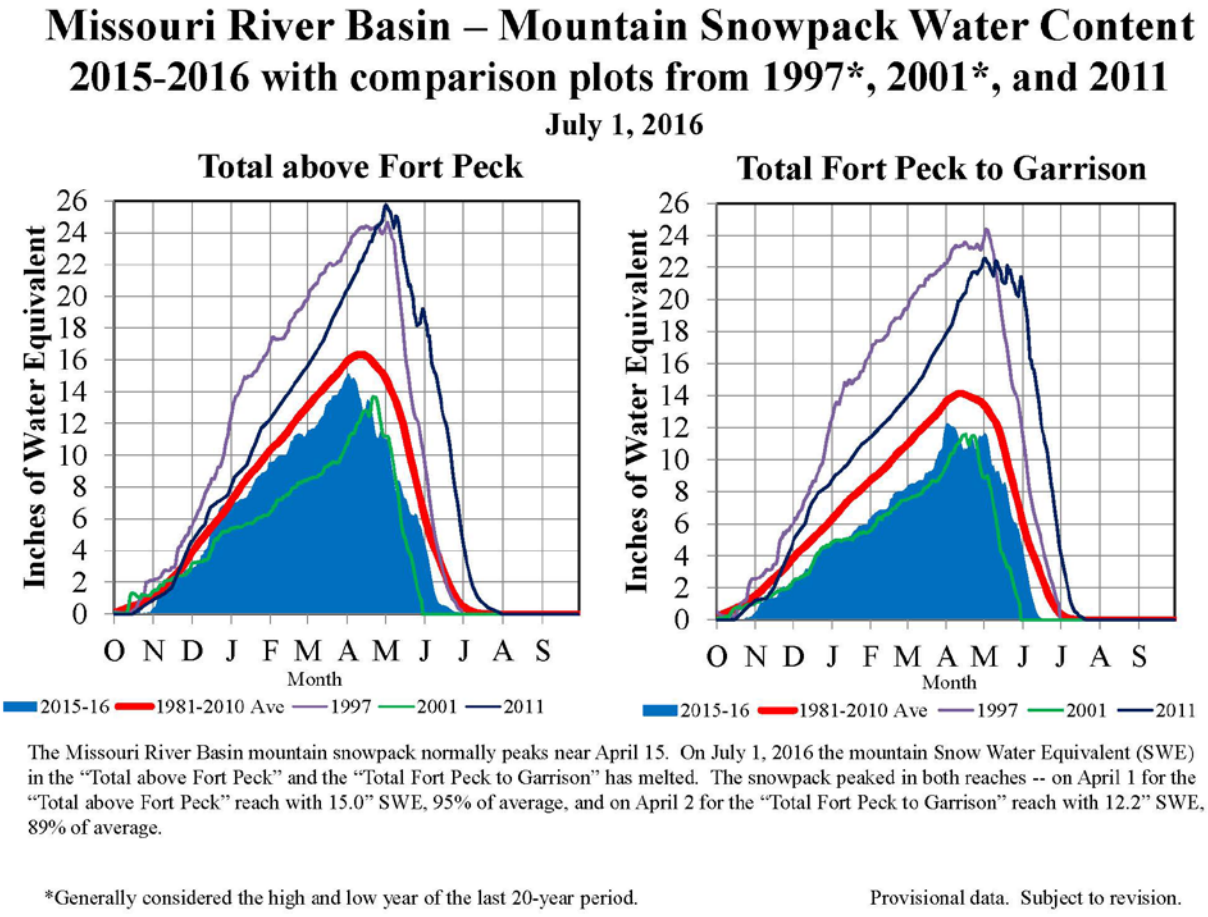


Figure 9. Mountain snowpack water content on July 1, 2016 compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management.

Climate Outlook

ENSO (El Niño Southern Oscillation)

According to the CPC's latest monthly updated[1] on August 1, 2016, "***ENSO-neutral conditions are present. La Niña is favored to develop during August-October 2016, with about a 55-60% chance of La Niña during the fall and winter 2016-2017.***"

MRBWMD participates in the monthly North Central U.S. Climate/Drought Outlook Webinar coordinated through NOAA, the regional climate centers, and the American Association of State Climatologists (AASC). These webinars provide updates on near-term climate outlooks and impacts including the La Niña climate pattern and its implications on winter temperature and precipitation patterns in the Missouri River Basin. During La Niña winters, the probability for a colder-than-normal and slightly wetter-than-normal weather pattern in the Northern Rockies and Northern Plains is higher. The possible impacts of La Niña have been factored into the CPC climate outlooks described below.

Temperature and Precipitation Outlooks

The NOAA Climate Prediction Center climate outlook for August 2016 (**Figure 10)** indicates there are equal chances for above-normal, normal and below-normal temperatures throughout the upper Basin and most of the lower Basin. The August outlook indicates increased chances for above-normal temperatures in eastern Kansas and most of Missouri. With regard to precipitation, there are increased chances for below-normal precipitation in western Montana, increased chances for above-normal precipitation in South Dakota, Nebraska, Iowa and northern Missouri, and equal chances for above-normal, normal and below-normal precipitation in the remainder of the Missouri Basin.

The August-September-October 2016 temperature outlook (**Figure 11**) indicates there are increased chances for above-normal temperatures throughout the entire Missouri Basin. With regard to precipitation, the August-September-October outlook indicates there are increased chances of below-normal precipitation in western Montana, an increased probability of above-normal precipitation in eastern Montana, northeast Wyoming, the Dakotas and northern Nebraska, and equal chances for above-normal, normal or below-normal precipitation over the remainder of the Basin.

[1] http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/lanina/enso_evolution-status-fcsts-web.pdf

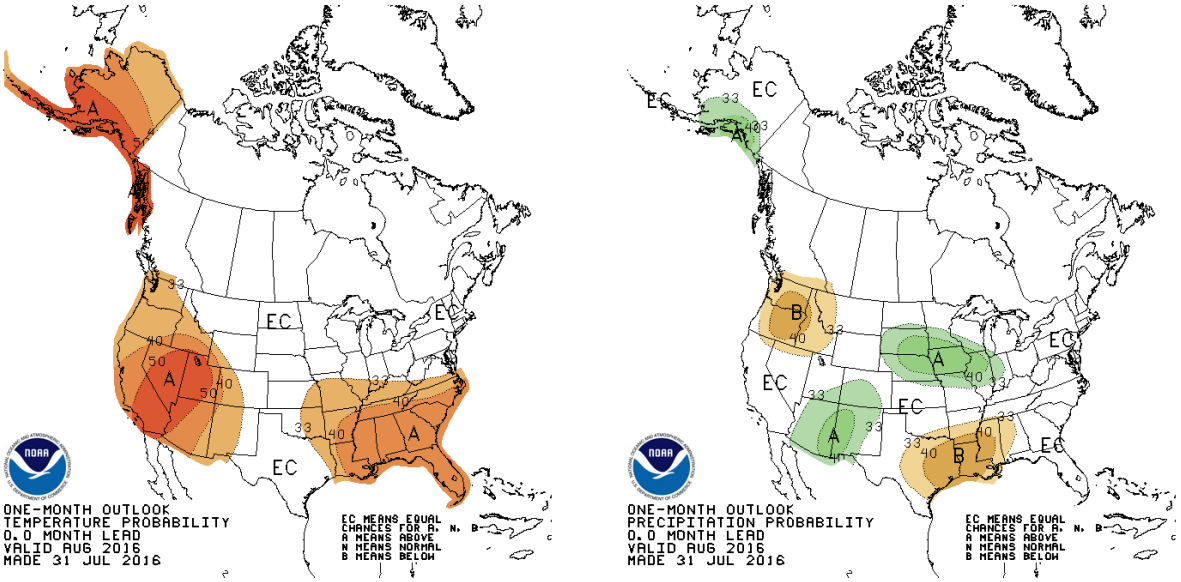


Figure 10. CPC August 2016 temperature and precipitation outlooks.

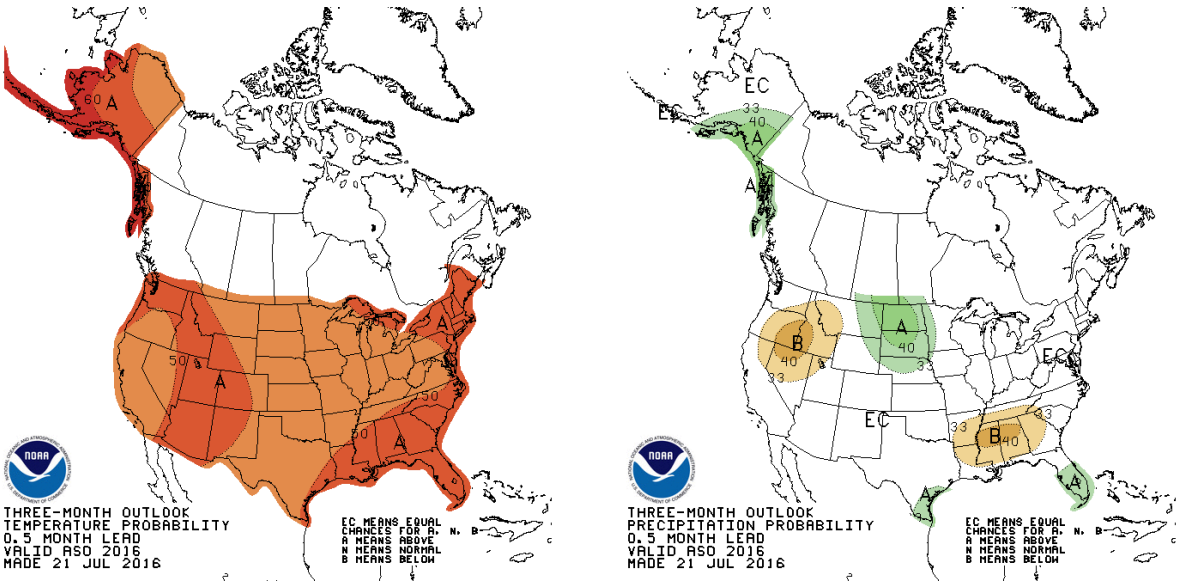


Figure 11. CPC August-September-October 2016 temperature and precipitation outlooks.

The November-December 2016-January 2017 CPC temperature outlook (**Figure 12**) indicates there are equal chances for above-normal, normal or below-normal temperatures across much of the upper Basin. There are increased chances for above-normal temperatures in western Montana, most of Wyoming, western Nebraska, Colorado and Kansas. With regard to precipitation, there are increased chances for above-normal precipitation across Montana, northern Wyoming, western North Dakota and northwest South Dakota because of the possibility of La Niña developing during the 2016 fall season. There are equal chances for precipitation in the remainder of the Missouri Basin from November 2016 to January 2017. During the February-March-April 2017 period (**Figure 13**) CPC outlooks indicate increased chances for

below-normal temperatures in most of the upper Basin as a result of La Niña, and equal chances in the remainder of the Missouri Basin. There are equal chances for precipitation in much of the upper Basin, and increased chances for precipitation in northwest Montana. There are increased chances for below normal precipitation in the southern half of Nebraska, Colorado and Kansas.

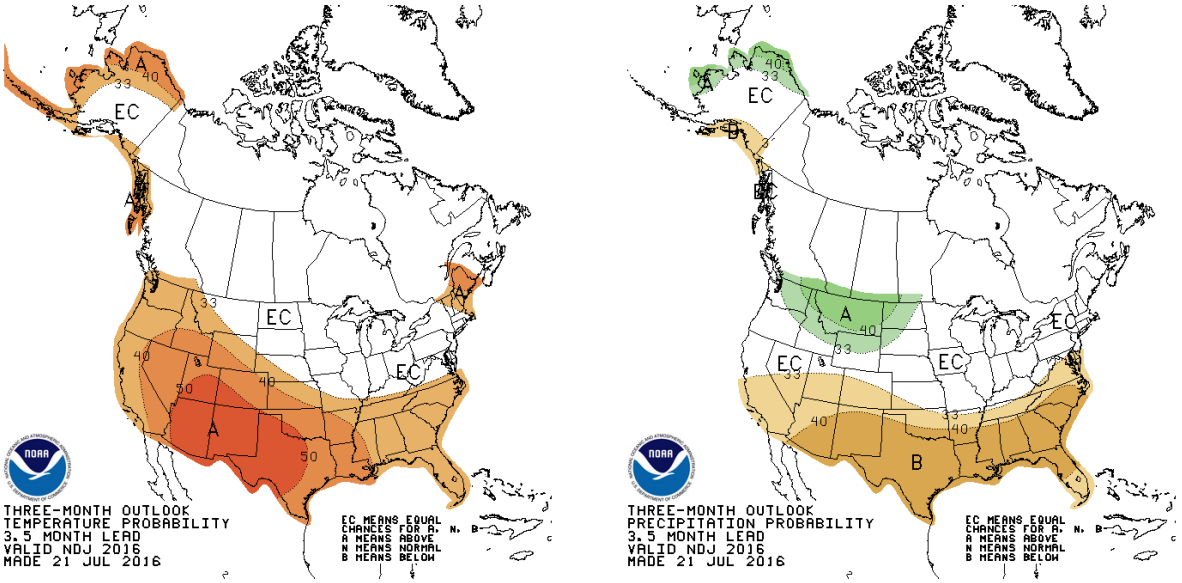


Figure 12. CPC November-December 2016-January 2017 temperature and precipitation outlooks.

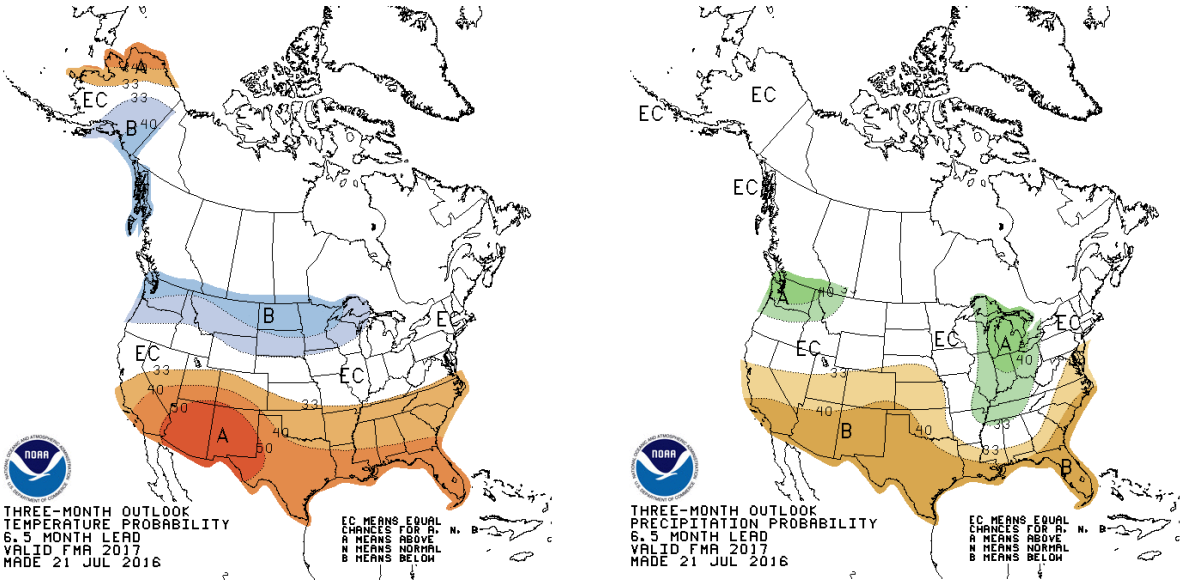


Figure 13. CPC February-March-April 2017 temperature and precipitation outlooks.

August 2016 Calendar Year Runoff Forecast

In summary, the 2016 calendar year runoff forecast is **22.7 MAF, 89% of average**. Runoff for the basin above Gavins Point Dam, excluding the contributing area between Gavins Point Dam and Sioux City, IA, is forecast to be **19.3 MAF (83% of average)**. July runoff was 2.3 MAF (69% of average). Runoff was 58% and 60% of average in the Fort Peck and Garrison reaches, respectively. These reaches generally received well-below normal rainfall in July, and no mountain snowpack remained at the beginning of July. Current soil moisture and drought conditions indicate runoff for the next few months will likely be below average even with normal precipitation conditions. Precipitation outlooks for the plains region of the upper Basin indicate increased probabilities for above normal precipitation through the fall, however, there are increased chances for below normal precipitation in western Montana. Winter precipitation, which normally comes in the form of mountain or plains snow, will have little impact on runoff during the 2016 calendar year. We will continue to monitor Missouri Basin conditions and make forecast adjustments as conditions change.

Upper Missouri River Basin
September 2016 Calendar Year Runoff Forecast
September 2, 2016

U.S. Army Corps of Engineers, Northwestern Division
Missouri River Basin Water Management
Omaha, NE

Calendar Year Runoff Forecast

Explanation and Purpose of Forecast

The long-range runoff forecast is presented as the Calendar Year Runoff Forecast. This forecast is developed shortly after the beginning of each calendar year and is updated at the beginning of each month to show the actual runoff for historic months of that year and the updated forecast for the remaining months of the year. This forecast presents monthly inflows in million acre-feet (MAF) from five incremental drainage areas, as defined by the individual System projects, plus the incremental drainage area between Gavins Point Dam and Sioux City. Due to their close proximity, the Big Bend and Fort Randall drainage areas are combined. Summations are provided for the total Missouri River reach above Gavins Point Dam and for the total Missouri River reach above Sioux City. The Calendar Year Runoff Forecast is used in the Monthly Study simulation model to plan future system regulation in order to meet the authorized project purposes throughout the calendar year.

August 2016 Runoff

August 2016 Missouri River Basin above Sioux City, IA (upper Basin) runoff was 1.0 MAF (76% of average). August runoff was 72% of average in the Fort Peck reach, 40% of average in the Garrison reach, 231% of average in the Oahe reach, 127% of average in the Fort Randall reach, 87% of average in the Gavins Point reach, and 128% of average in the Sioux City reach. Dry antecedent soil moisture conditions coupled with significantly below-normal precipitation led to below-average runoff in the Fort Peck and Fort Peck to Garrison reaches. Above-normal rainfall in the northern portion of the Oahe reach contributed to above-average runoff for Oahe. Runoff in the Sioux City reach was largely due to higher-than-average baseflow that carried over from above-average May through July runoff and tributary streamflow coupled with areas of high precipitation across portions of North Dakota and South Dakota.

2016 Calendar Year Forecast Synopsis

The September 1 forecast for 2016 upper Basin runoff is **22.4 MAF (89% of average)**. Runoff for the basin above Gavins Point Dam is forecast to be **19.0 MAF (82% of average)**. Due to the amount of variability in precipitation and other hydrologic factors that can occur over the next 4 months, the range of expected inflow ranges from the 23.3 MAF upper basic forecast to the 21.7

MAF lower basic forecast. The upper and lower basic forecasts are used in long-term regulation planning models to "bracket" the range of expected runoff given much wetter or drier conditions, respectively. Given that 4 months are being forecasted for this September 1 forecast (8 months observed/4 months forecast), the range of wetter than normal (upper basic) and drier than normal (lower basic) conditions is attributed to all 6 reaches for 4 months. The result is a range or "bracket" for each reach, and thus, for the total runoff forecast. As the year progresses, the range will continue to lessen as the number of observed months increases and number of forecast months decreases.

Current Conditions

Drought Analysis

The latest National Drought Mitigation Center's drought monitor for August 30, 2016 (**Figure 1**), when compared to the drought monitor for July 26, 2016 (**Figure 2**), shows a mix of increase and decrease in severity and areal extent of drought conditions in the upper Basin. There has been some worsening in drought conditions in the basin, including an increase in the areal extent of Abnormally Dry through Severe Drought (D0-D2) conditions from north-central Wyoming to western Montana. A decrease in severity and areal extent in Abnormally Dry through Extreme Drought (D0-D3) conditions have occurred in northeastern Wyoming, southeastern Montana and western South Dakota, with decrease in areal extent of Abnormally Dry (D0) conditions in isolated areas of Nebraska, Iowa, Kansas and Missouri. The U.S. Seasonal Drought Outlook in **Figure 3** indicates that drought conditions are expected to persist in portions of western Montana, but drought conditions are expected to improve in the Black Hills region of Wyoming and South Dakota, as well as south-central Montana and north-central Wyoming.

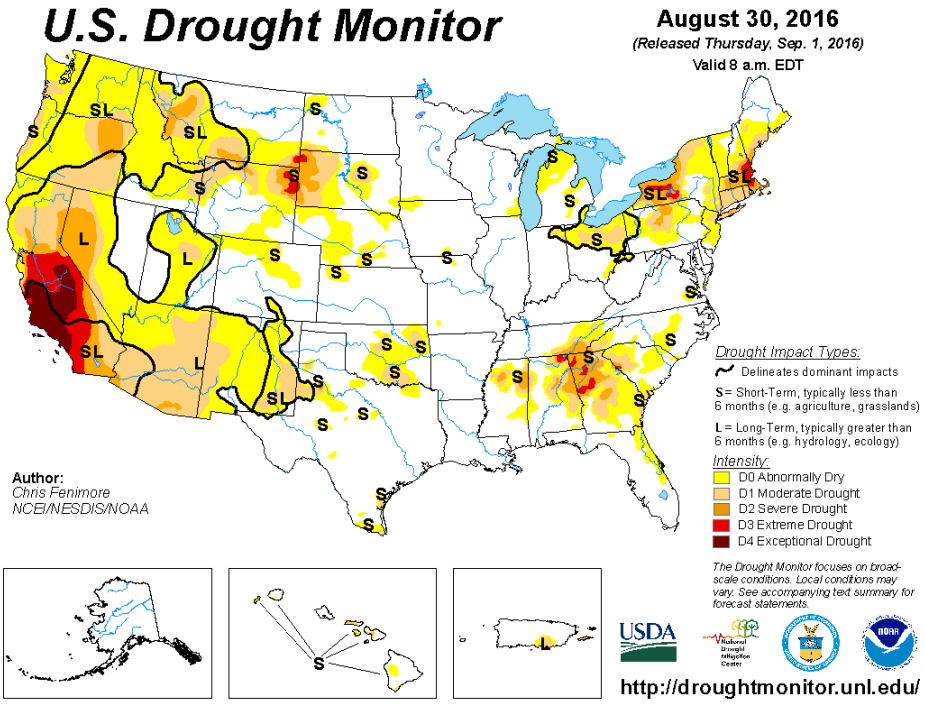


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for August 30, 2016

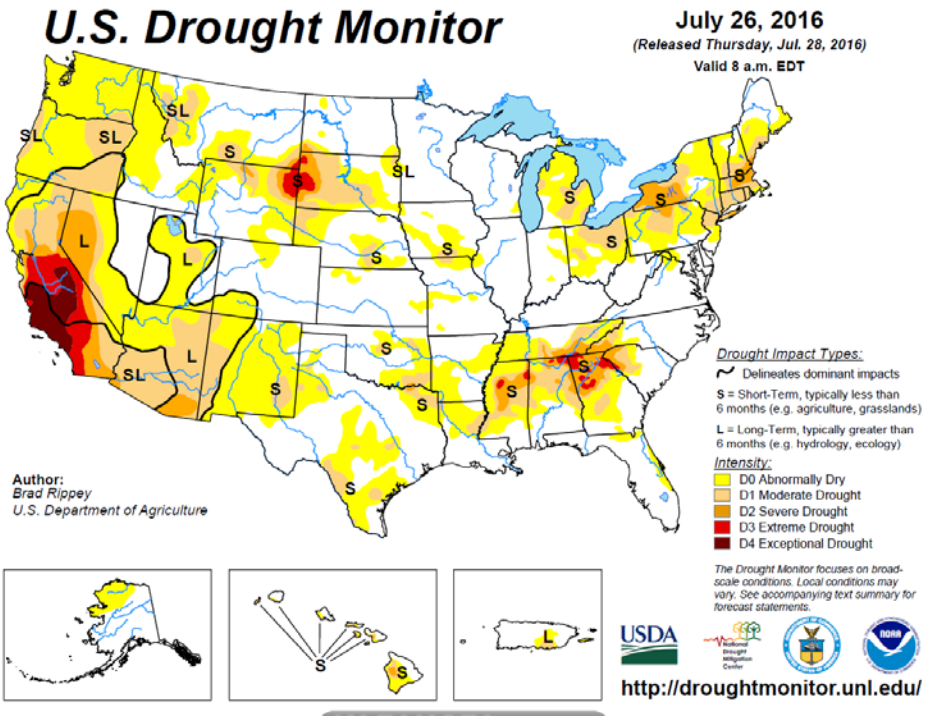


Figure 2. National Drought Mitigation Center U.S. Drought Monitor for July 26, 2016

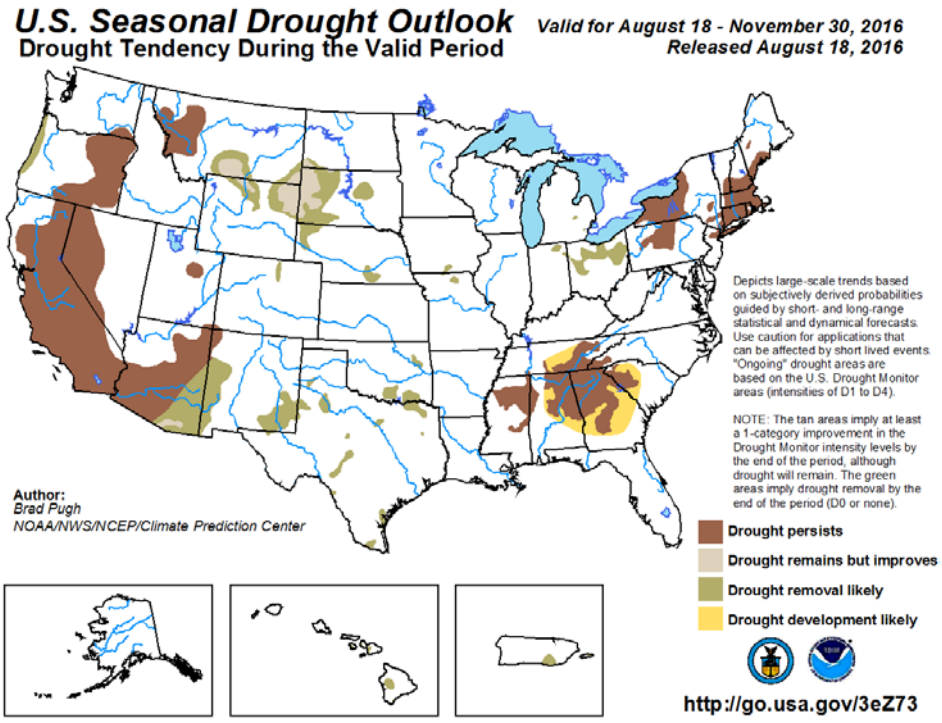


Figure 3. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

August precipitation accumulations are shown in **Figure 4** as both inches of precipitation (left) and percent of normal monthly precipitation (right). August precipitation was above average in a large area from south central Montana into southwestern South Dakota and northwestern Nebraska, portions of eastern North Dakota and South Dakota, southeastern Nebraska, eastern Kansas, and much of Iowa and Missouri. Precipitation was well below average across most of western North Dakota, northwestern and southeastern Wyoming, eastern Colorado and central Nebraska.

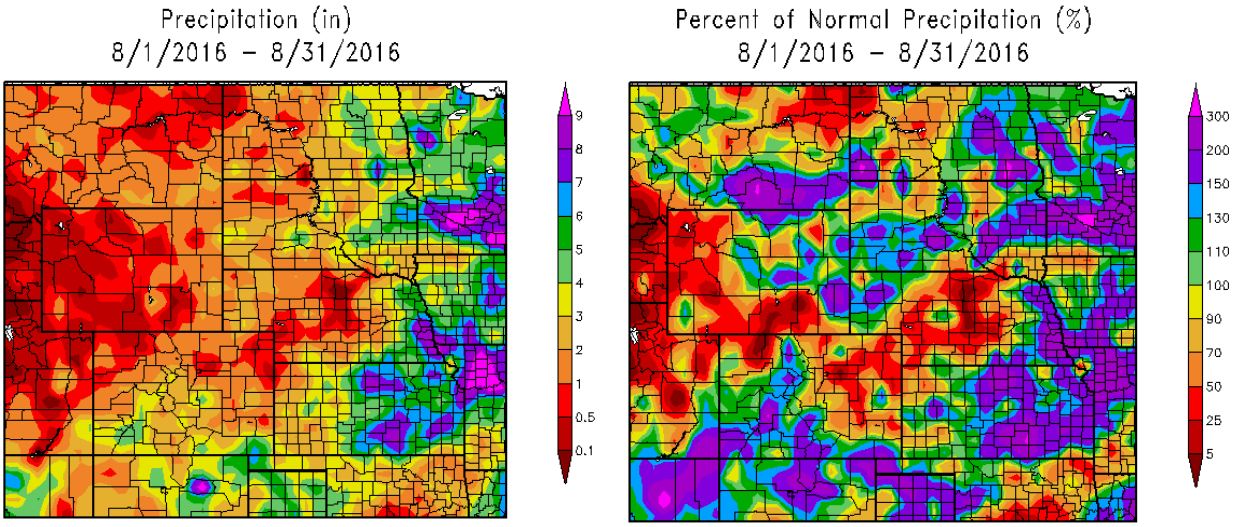


Figure 4. August 2016 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

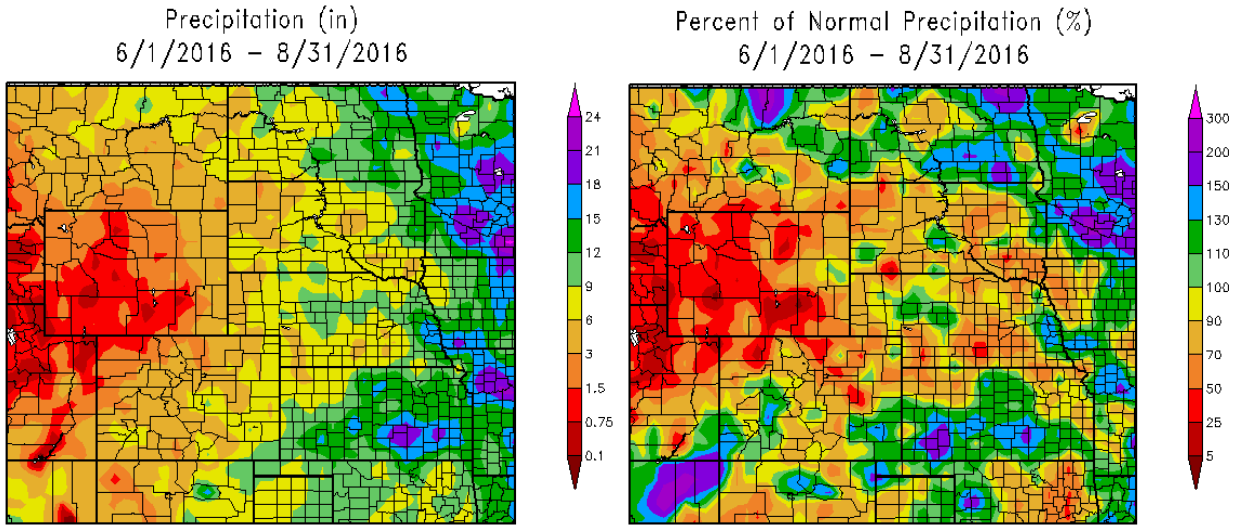


Figure 5. June-July-August 2016 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Table 1 contains notable August 2016 precipitation amounts and precipitation departures in many locations in the Missouri Basin. Low August precipitation totals occurred in many locations including Dillon, MT (0.12 inches); Denver, CO (0.22 inches); Lake Yellowstone, WY (0.31 inches); and Williston, ND (0.45 inches). In contrast high precipitation totals occurred in numerous places including Billings, MT (1.67 inches / 223%); Sheridan, WY (1.44 inches / 200%); Jamestown, ND (4.59 inches / 219%); Watertown, SD (6.98 inches / 251%); and Kansas City, MO (9.16 inches / 235%). Despite the very heavy rainfall, high volumes of runoff did not occur in many areas of the Missouri Basin in August.

June-July-August 2016 precipitation accumulations and percent of normal (average) precipitation are shown in **Figure 5**. The precipitation pattern since June 1 has been very dry in southern Montana, much of Wyoming, Colorado, Nebraska and South Dakota, as well as northwest Iowa. Areas that have received above average precipitation include north central Montana, eastern North Dakota, much of central Kansas, extreme eastern Nebraska, southwestern Iowa and northern Missouri.

Table 1. August 2016 precipitation and precipitation departures.

City, State	Precipitation inches	Precipitation Departure inches	Percent of Normal
Dillon, MT	0.12	-0.93	11%
Great Falls, MT	1.12	-0.45	71%
Billings, MT	1.67	0.92	223%
Glasgow, MT	0.52	-0.72	43%
Wolf Point, MT	0.73	-0.55	57%
Casper, WY	1.30	0.45	153%
Lake Yellowstone, WY	0.31	-1.21	20%
Sheridan, WY	1.44	0.72	200%
Jamestown, ND	4.59	2.49	219%
Williston, ND	0.45	-1.00	31%
Rapid City Arpt, SD	2.28	0.72	146%
Watertown, SD	6.98	4.20	251%
Sioux Falls, SD	2.32	-0.73	76%
Mitchell, SD	3.31	0.93	139%
Sioux City, IA	5.05	1.82	156%
Cheyenne, WY	1.05	-0.90	54%
Denver, CO	0.22	-1.47	13%
North Platte, NE	0.88	-1.41	38%
Kearney, NE	1.16	-1.92	38%
Grand Island, NE	0.57	-2.55	18%
Lincoln, NE	3.83	0.34	110%
Omaha, NE	5.78	1.96	151%
Topeka, KS	5.83	1.59	138%
Manhattan, KS	6.92	2.64	162%
St. Joseph, MO	6.74	2.76	169%
Kansas City Intl Arpt, MO	9.16	5.27	235%
Columbia, MO	5.84	1.48	134%
Jefferson City, MO	6.40	2.14	150%

Temperature

August temperature departures from normal are shown in the left image of **Figure 6** in degrees Fahrenheit (deg F). June-July-August 2016 temperature departures from normal are also shown in the right image of **Figure 6**. August temperature departures (left image) have varied across the upper Basin and lower Basin. Temperatures were generally cooler than normal in areas west of the Missouri River and warmer east of the Missouri River. Temperature departures during June-July-August in the right image of **Figure 6** have been generally above normal across the entire Missouri Basin with the exception of north-central Montana and eastern North Dakota.

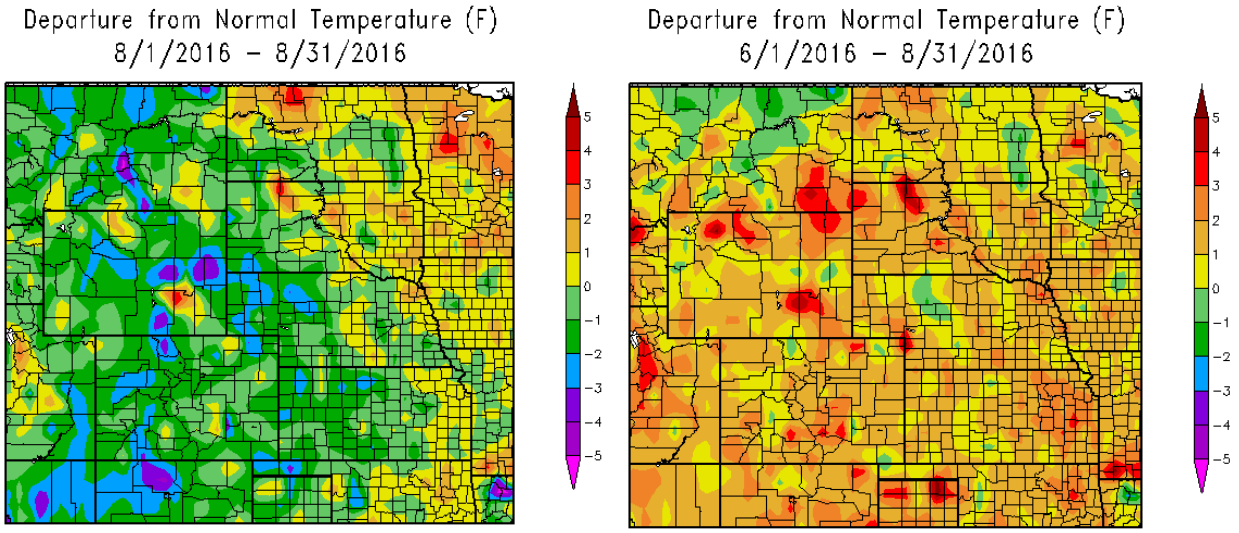


Figure 6. August 2016 and June-July-August 2016 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Soil Moisture

Soil moisture is factored into the forecast as an indicator of wet or dry hydrologic basin conditions. Typically when soil moisture conditions are wet or greater than normal, rainfall and snowmelt runoff is greater than when soil moisture is dry or less than normal. Not only is soil moisture a physical parameter that influences runoff, it can be used as an indicator of future runoff.

Figure 7 shows the NOAA NLDAS ensemble top one-meter soil moisture anomaly on August 27, 2016. The NLDAS soil moisture depiction is an average value for the one-meter soil moisture column. **Figure 7** indicates that soil moisture is predominantly drier than normal (below normal anomalies) over large portions of the Missouri Basin including western Montana, northern and southeastern Wyoming, North Dakota, South Dakota, central Nebraska and northwestern Iowa. Soil moisture is above normal in northeastern Montana, western Nebraska, eastern Nebraska and southwestern Iowa and much of Kansas and Missouri.

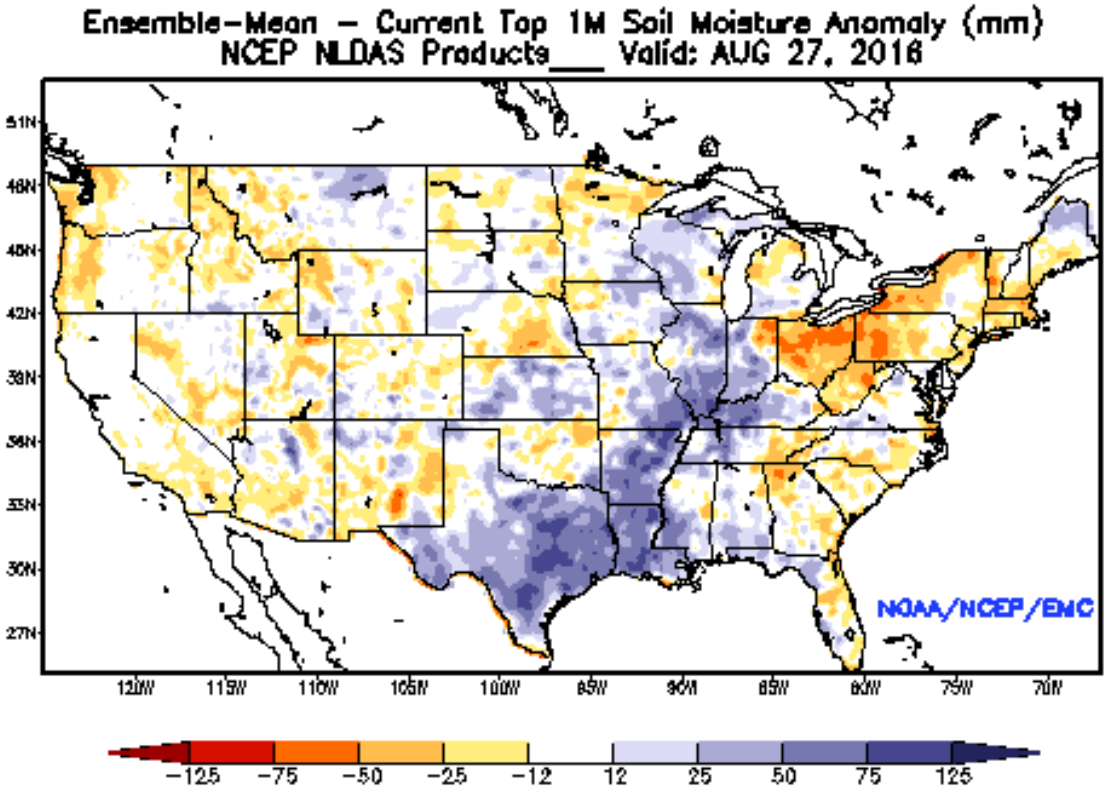


Figure 7. Top 1-Meter Soil Moisture Anomaly on August 27, 2016. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

Streamflow Conditions

Missouri Basin streamflow conditions are shown in **Figure 8**. These conditions are based on the ranking of the September 1, 2016 daily streamflow versus the historical record of streamflow for that date. Streamflow conditions are generally "Normal" (25th-75th percentile) and "Below Normal) (10th to 24th percentile) in Montana and Wyoming, though there are a number of tributaries that have fallen into the "Much Below Normal" (below 10th percentile) class as a result of the antecedent dry conditions and low precipitation accumulations in August. Streamflow between Garrison Dam and Sioux City, IA is generally in the "Normal" (25th – 75th percentile), while most of the lower Basin is in the "Above Normal" (75th – 90th percentile) to "Much Above Normal" (above 90th percentile) due to wetter than normal soil moisture and above average precipitation across much of the lower Basin.

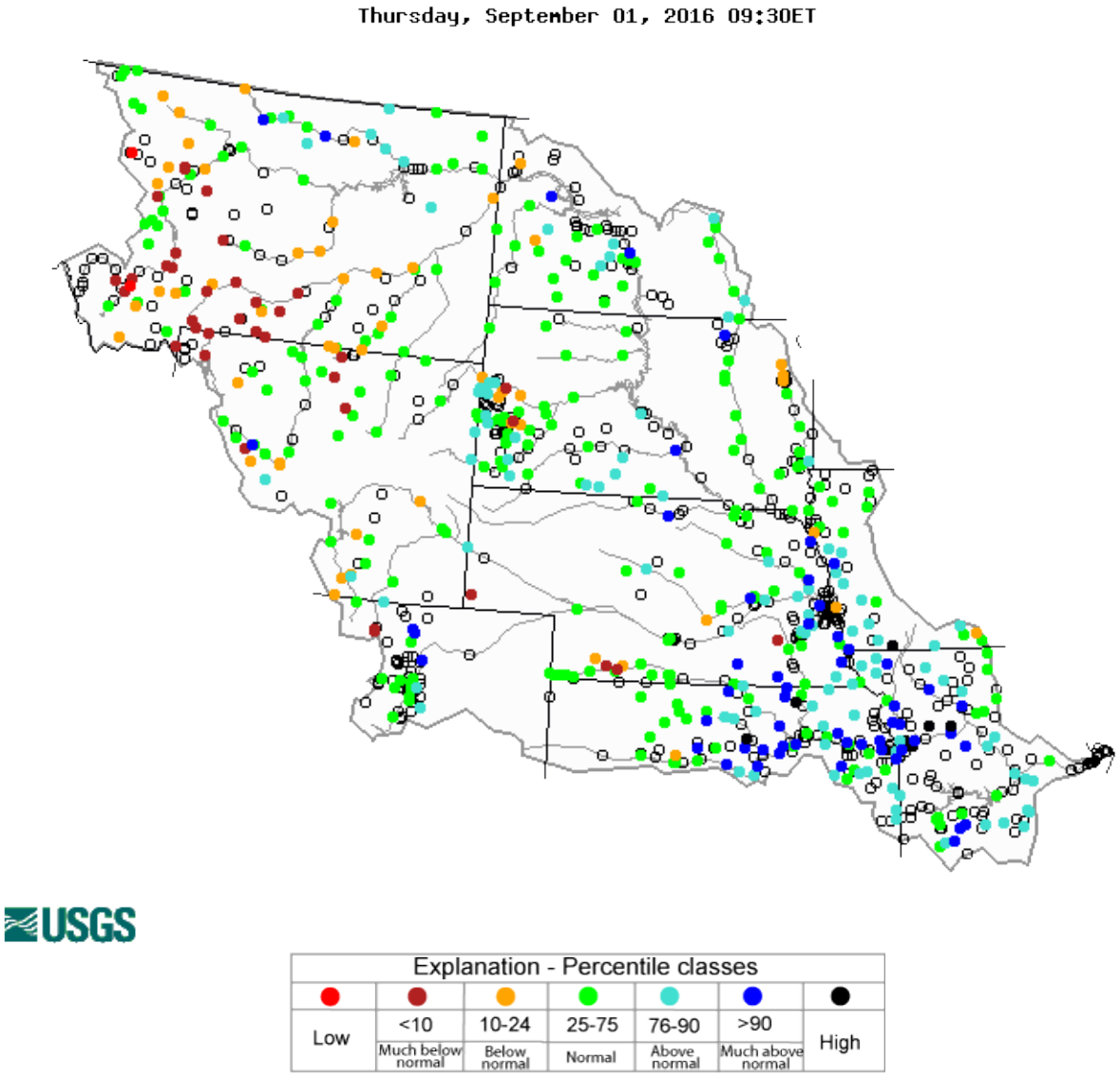


Figure 8. USGS Streamflow Conditions as a Percentile of Normal in the Missouri River Basin as of September 1, 2016. Source: USGS. http://waterwatch.usgs.gov/index.php

Climate Outlook

ENSO (El Niño Southern Oscillation)

According to the CPC's latest monthly updated[1] on August 29, 2016, "***ENSO-neutral conditions are present. La Niña is slightly favored to develop during August-October 2016, with about a 55-60% chance of La Niña during the fall and winter 2016-2017."***

MRBWMD participates in the monthly North Central U.S. Climate/Drought Outlook Webinar coordinated through NOAA, the regional climate centers, and the American Association of State Climatologists (AASC). These webinars provide updates on near-term climate outlooks and impacts including the La Niña climate pattern and its implications on winter temperature and precipitation patterns in the Missouri River Basin. During La Niña winters, the probability for a colder-than-normal and slightly wetter-than-normal weather pattern in the Northern Rockies and Northern Plains is higher. The possible impacts of La Niña have been factored into the CPC climate outlooks described below.

Temperature and Precipitation Outlooks

The NOAA Climate Prediction Center climate outlook for September 2016 (**Figure 9)** indicates there are equal chances for above-normal, normal and below-normal temperatures throughout the entire Basin. With regard to precipitation, there are increased chances for above-normal precipitation in eastern North Dakota and South Dakota, much of eastern Nebraska, and nearly all of Iowa, and equal chances for above-normal, normal and below-normal precipitation in the remainder of the Missouri Basin.

The September-October-November 2016 temperature outlook (**Figure 10**) indicates there are increased chances for above-normal temperatures throughout the entire Missouri Basin. With regard to precipitation, the September-October-November outlook indicates there are increased chances of above-normal precipitation in nearly all of Montana and North Dakota, extreme northern Wyoming, and most of northern South Dakota, and equal chances for above-normal, normal or below-normal precipitation over the remainder of the Basin.

[1] http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/lanina/enso_evolution-status-fcsts-web.pdf

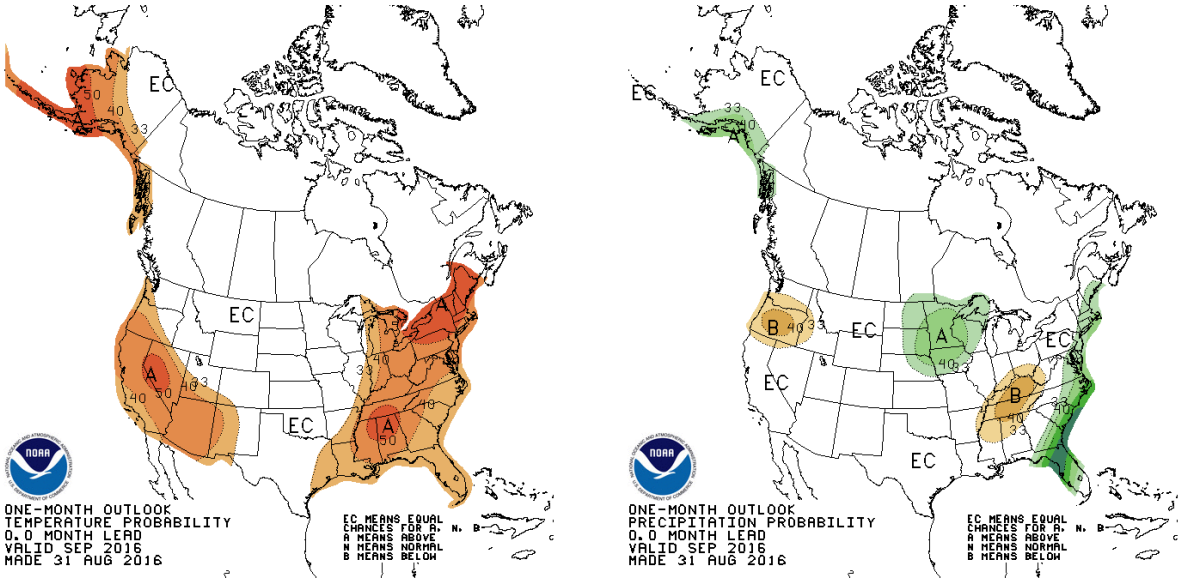


Figure 9. CPC September 2016 temperature and precipitation outlooks.

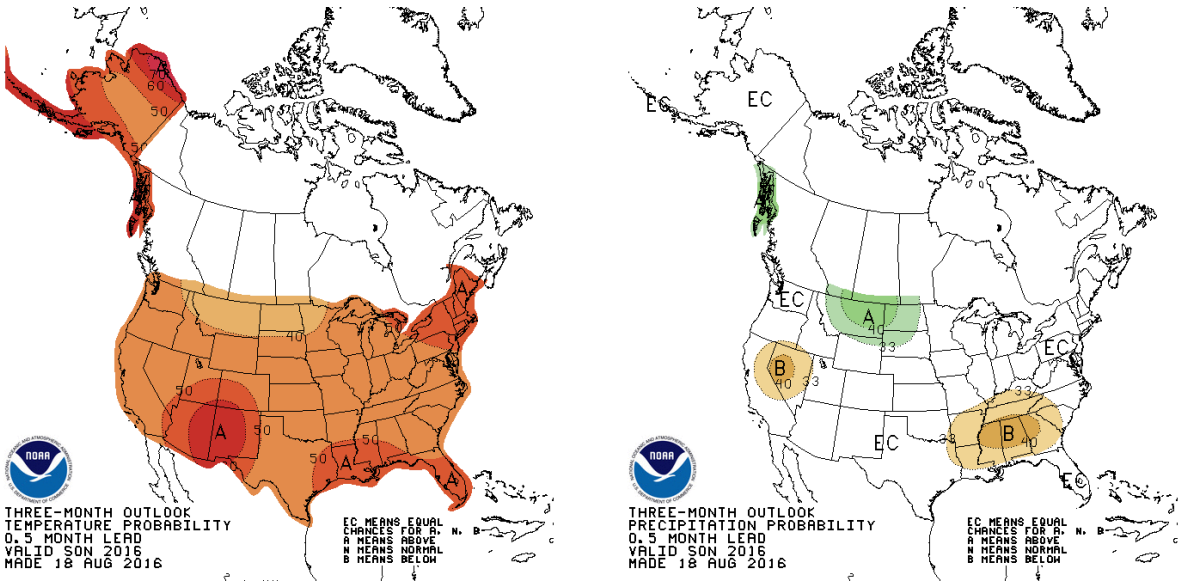


Figure 10. CPC September-October-November 2016 temperature and precipitation outlooks.

The December 2016-January-February 2017 CPC temperature outlook (**Figure 11**) indicates there are increased chances for below-normal temperatures across the northern plains into the northern Rockies, with equal chances for above-normal, normal or below-normal temperatures across nearly the rest of the Basin. With regard to precipitation, there are increased chances for above-normal precipitation across Montana, northern Wyoming, western North Dakota and northwest South Dakota because of the possibility of La Niña developing during the 2016 fall season. There are equal chances for precipitation in the remainder of the Missouri Basin from December 2016 to February 2017. During the March-April-May 2017 period (**Figure 12**) CPC outlooks indicate increased chances for below-normal temperatures in most of the upper Basin as

a result of La Niña, increased chances for above-normal temperatures for Colorado, Kansas and Missouri, and equal chances in the remainder of the Missouri Basin. There are equal chances for above-normal, normal or below-normal precipitation across the entire Basin.

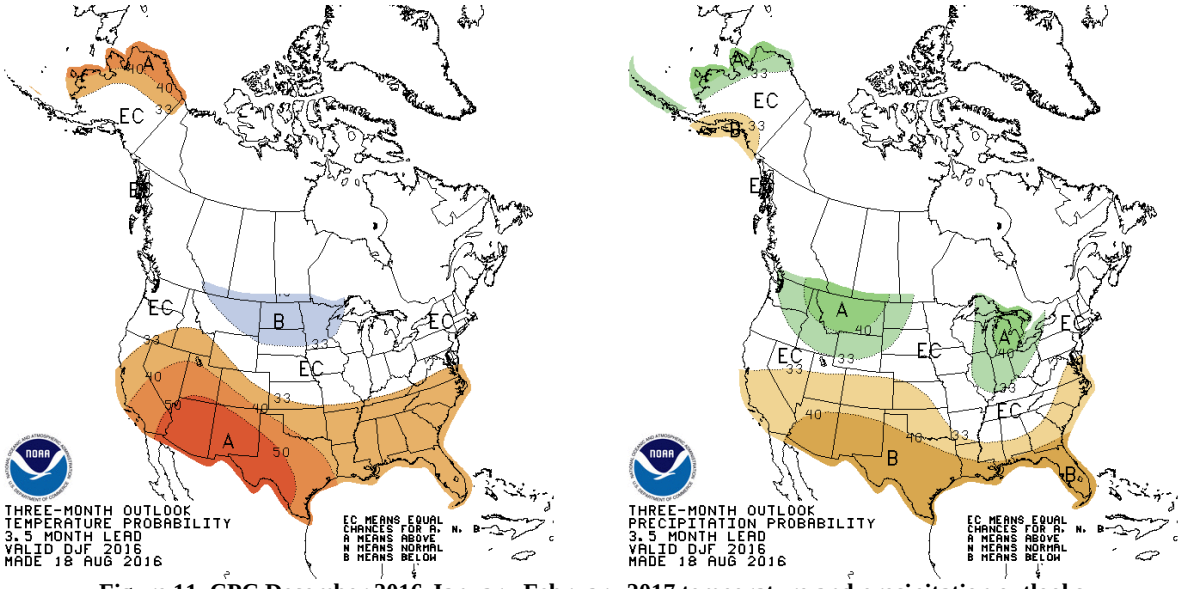


Figure 11. CPC December 2016-January-February 2017 temperature and precipitation outlooks.

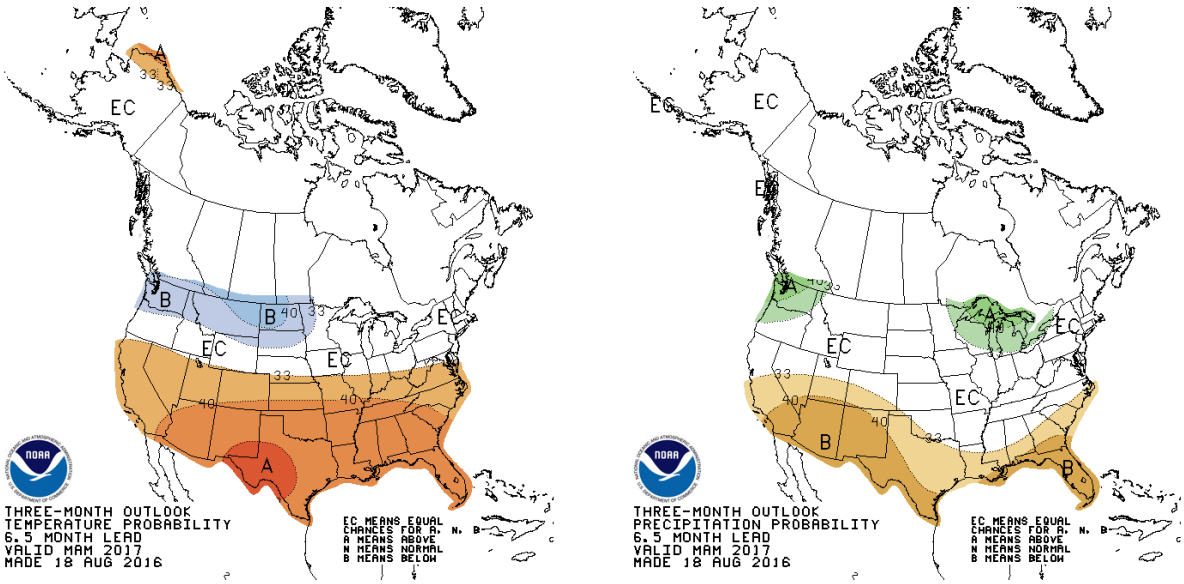


Figure 12. CPC March-April-May 2017 temperature and precipitation outlooks.

September 2016 Calendar Year Runoff Forecast

In summary, the 2016 calendar year runoff forecast is **22.4 MAF, 89% of average**. Runoff for the basin above Gavins Point Dam, excluding the contributing area between Gavins Point Dam and Sioux City, IA, is forecast to be **19.0 MAF (82% of average)**. August runoff was 1.0 MAF (76% of average). Runoff was 72% and 40% of average in the Fort Peck and Garrison reaches, respectively. These reaches generally received well-below normal rainfall in July, and no mountain snowpack has remained since the beginning of July. Current soil moisture and drought conditions indicate runoff in most of the upper Basin for the next few months will likely be below average even with normal precipitation conditions. Precipitation outlooks for the plains region of the upper Basin indicate increased probabilities for above normal precipitation through the fall and into winter. Winter precipitation, which normally comes in the form of mountain or plains snow, will have little impact on runoff during the 2016 calendar year. We will continue to monitor Missouri Basin conditions and make forecast adjustments as conditions change.

Upper Missouri River Basin
October 2016 Calendar Year Runoff Forecast
October 12, 2016

U.S. Army Corps of Engineers, Northwestern Division
Missouri River Basin Water Management
Omaha, NE

Calendar Year Runoff Forecast

Explanation and Purpose of Forecast

The long-range runoff forecast is presented as the Calendar Year Runoff Forecast. This forecast is developed shortly after the beginning of each calendar year and is updated at the beginning of each month to show the actual runoff for historic months of that year and the updated forecast for the remaining months of the year. This forecast presents monthly inflows in million acre-feet (MAF) from five incremental drainage areas, as defined by the individual System projects, plus the incremental drainage area between Gavins Point Dam and Sioux City. Due to their close proximity, the Big Bend and Fort Randall drainage areas are combined. Summations are provided for the total Missouri River reach above Gavins Point Dam and for the total Missouri River reach above Sioux City. The Calendar Year Runoff Forecast is used in the Monthly Study simulation model to plan future system regulation in order to meet the authorized project purposes throughout the calendar year.

September 2016 Runoff

September 2016 Missouri River Basin above Sioux City, IA (upper Basin) runoff was 1.0 MAF (91% of average). September runoff was 62% of average in the Fort Peck reach, 62% of average in the Garrison reach, 87% of average in the Oahe reach, 157% of average in the Fort Randall reach, 114% of average in the Gavins Point reach, and 259% of average in the Sioux City reach. Dry antecedent soil moisture conditions at the beginning of September led to below-average runoff in the Fort Peck, Garrison and Oahe reaches. Above-average runoff in the Sioux City reach was due to higher-than-average precipitation during September.

2016 Calendar Year Forecast Synopsis

The October 1 forecast for 2016 upper Basin runoff is **22.7 MAF (90% of average)**. Runoff for the basin above Gavins Point Dam is forecast to be **19.0 MAF (82% of average)**. Due to the amount of variability in precipitation and other hydrologic factors that can occur over the next 3 months, the range of expected inflow ranges from the 23.3 MAF upper basic forecast to the 22.1 MAF lower basic forecast. The upper and lower basic forecasts are used in long-term regulation planning models to "bracket" the range of expected runoff given much wetter or drier conditions, respectively. Given that 3 months are being forecasted for this October 1 forecast (9 months

observed/3 months forecast), the range of wetter than normal (upper basic) and drier than normal (lower basic) conditions is attributed to all 6 reaches for 3 months. The result is a range or "bracket" for each reach, and thus, for the total runoff forecast.

Current Conditions

Drought Analysis

The latest National Drought Mitigation Center's drought monitor for September 27, 2016 (**Figure 1**), when compared to the drought monitor for August 30, 2016 (**Figure 2**), shows a mix of increased and decreased severity and areal extent of drought conditions in the upper Basin. There has been some worsening of drought conditions in southwestern Montana and northwestern Wyoming, but improvement of drought conditions in northeastern Wyoming and western South Dakota. Moderate (D1) to Severe (D2) drought conditions persist in western Montana, northwestern and northeastern Wyoming and western South Dakota. There is a small area of Extreme (D3) drought in northwestern South Dakota and northeastern Wyoming. The U.S. Seasonal Drought Outlook in **Figure 3** indicates that drought conditions are expected to improve in all areas except for northwestern South Dakota, where drought conditions are expected to persist.

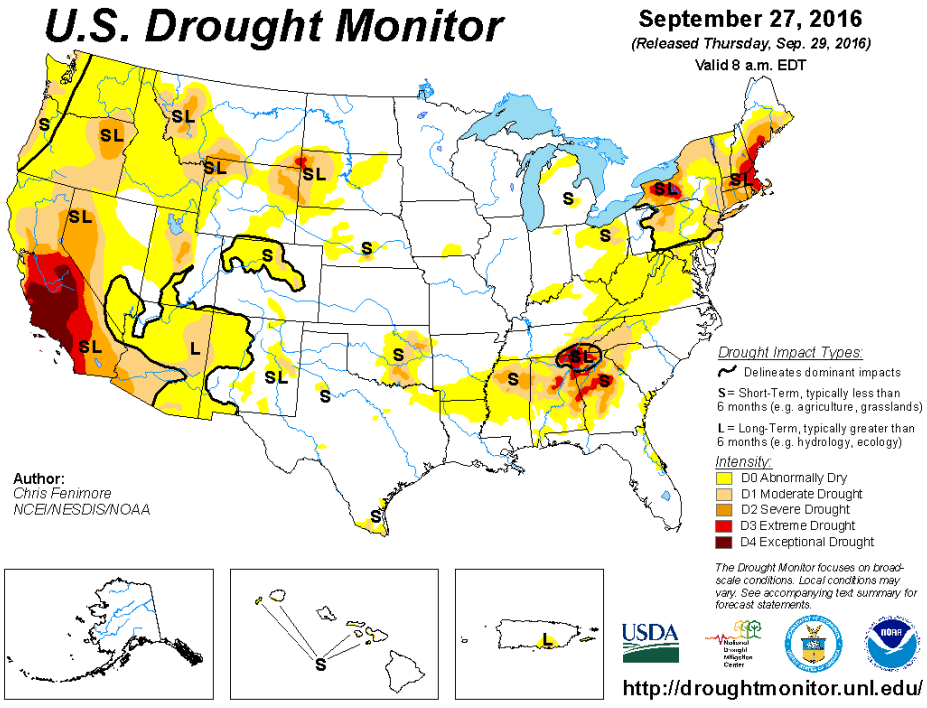


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for September 27, 2016

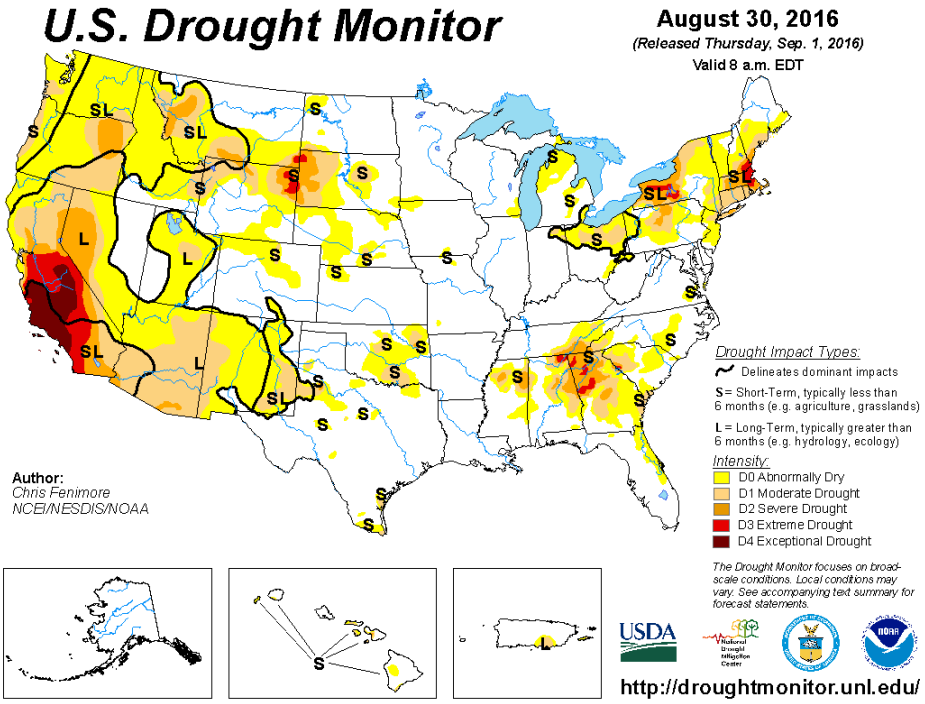


Figure 2. National Drought Mitigation Center U.S. Drought Monitor for August 30, 2016

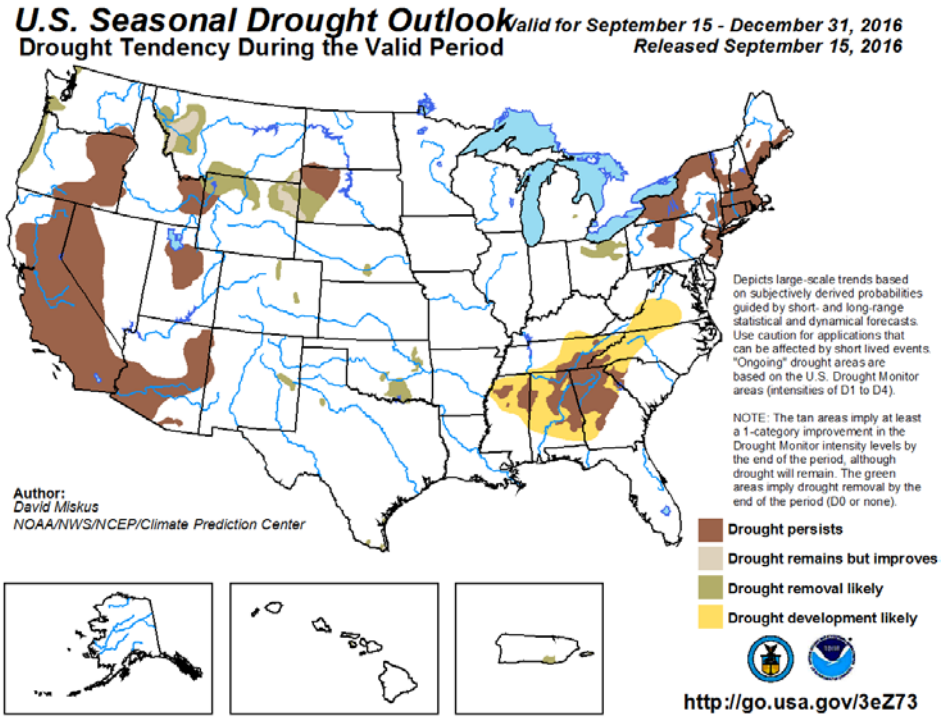


Figure 3. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

September precipitation accumulations are shown in **Figure 4** as both inches of precipitation (left) and percent of normal monthly precipitation (right). September precipitation occurred along two major storm tracks or paths in the Missouri Basin. The first track extended across Wyoming, Montana and North Dakota. Storms on this track produced September precipitation totals in these states ranging from 150 to nearly 400 percent of average. The second track extending across Kansas, eastern Nebraska, southeastern South Dakota and Iowa also produced areas of heavy precipitation. Precipitation was well-below average between these tracks over Colorado, western Nebraska and South Dakota.

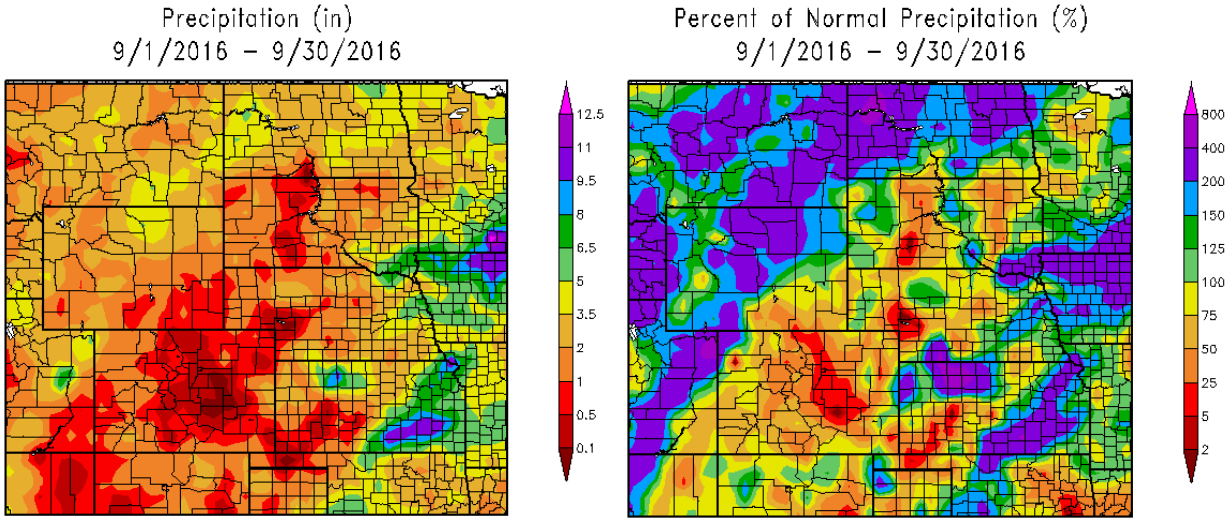


Figure 4. September 2016 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

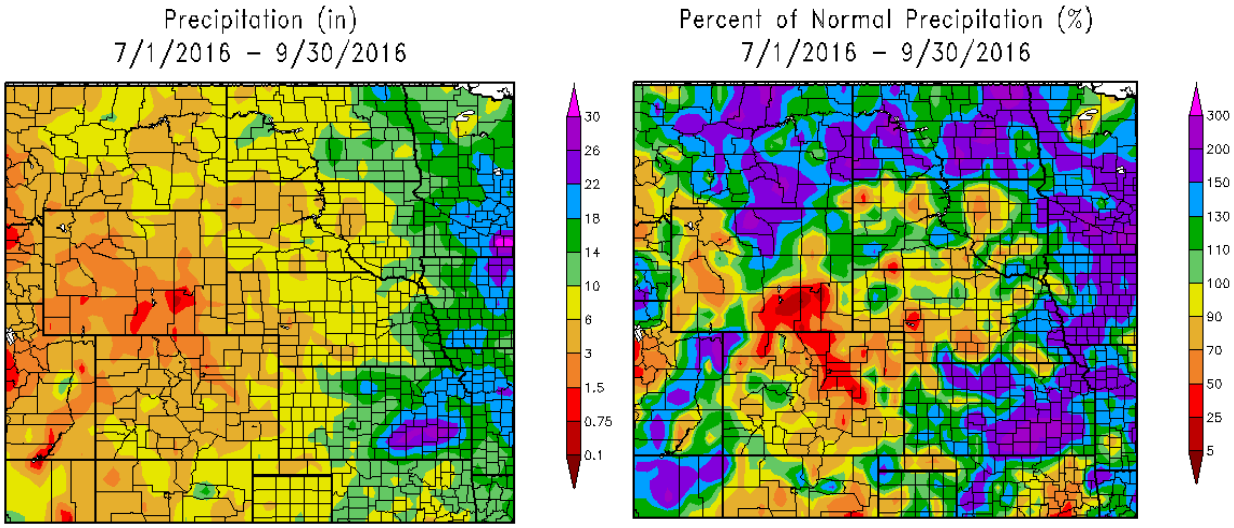


Figure 5. July-August-September 2016 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

July-August-September 2016 precipitation accumulations and percent of normal precipitation are shown in **Figure 5**. The precipitation pattern since July 1 has been very wet (130-200% of normal) over much of Montana, northern Wyoming, North Dakota, eastern Nebraska, Iowa, Kansas and Missouri. Areas that have received below normal precipitation include western and southern Wyoming, portions of South Dakota, Colorado and western Nebraska.

Table 1 contains notable September 2016 precipitation amounts and precipitation departures in many locations in the Missouri Basin. High September precipitation totals as a percent of normal occurred in many upper Basin locations in Montana and Wyoming, and lower Basin locations in Nebraska, Kansas and Missouri. Below average precipitation totals occurred at locations in central South Dakota. A few notable above average precipitation totals occurred at Miles City, MT (259%); Wolf Point, MT (231%); Sheridan, WY (259%); Williston, ND (334%); Sioux Falls, SD (175%); Omaha, NE (165%); St. Joseph, MO (253%); and, Columbia, MO (189%).

Table 1. September 2016 precipitation and precipitation departures.

City, State	Precipitation inches	Precipitation Departure inches	Percent of Normal
Dillon, MT	1.48	0.61	170
Great Falls, MT	2.22	0.80	156
Billings, MT	1.58	0.28	122
Livingston, MT	1.64	0.43	136
Miles City, MT	2.80	1.72	259
Glasgow, MT	1.67	0.73	178
Wolf Point, MT	2.31	1.31	231
Lander, WY	1.68	0.63	160
Lake Yellowstone, WY	2.65	1.35	204
Sheridan, WY	3.71	2.28	259
Cheyenne, WY	0.80	-0.68	54
Denver, CO	0.28	-0.68	29
Jamestown, ND	3.91	1.91	196
Williston, ND	3.54	2.48	334
Rapid City Arpt, SD	1.22	-0.37	77
Watertown, SD	2.06	-0.58	78
Pierre, SD	1.23	-0.64	66
Mitchell, SD	2.15	-0.17	93
Sioux Falls, SD	7.55	3.24	175
Sioux City, IA	2.78	-0.18	94
North Platte, NE	0.94	-0.47	67
Grand Island, NE	2.53	0.30	113
Omaha, NE	4.42	1.74	165
Manhattan, KS	3.62	0.45	114
Topeka, KS	7.78	4.12	213
Lawrence, KS	6.12	1.96	147
St. Joseph, MO	8.66	5.24	253
Kansas City Intl Arpt, MO	4.94	0.32	107
Columbia, MO	7.33	3.46	189
St. Louis, MO	4.95	1.82	158

Temperature

September temperature departures from normal are shown in the left image of **Figure 6** in degrees Fahrenheit (deg F). July-August-September 2016 temperature departures from normal are shown in the right image of **Figure 6**. Across much of the upper Basin and lower Basin, temperature ranged from 1 to 4 deg F above normal. In Montana temperature departures varied from slightly cooler than normal in western Montana to above normal in eastern Montana. Temperature departures during the July-August-September period in the right image of **Figure 6** have been normal to slightly cooler than normal in the upper Basin. In the lower basin temperatures have ranged from normal to about 2 deg F above normal.

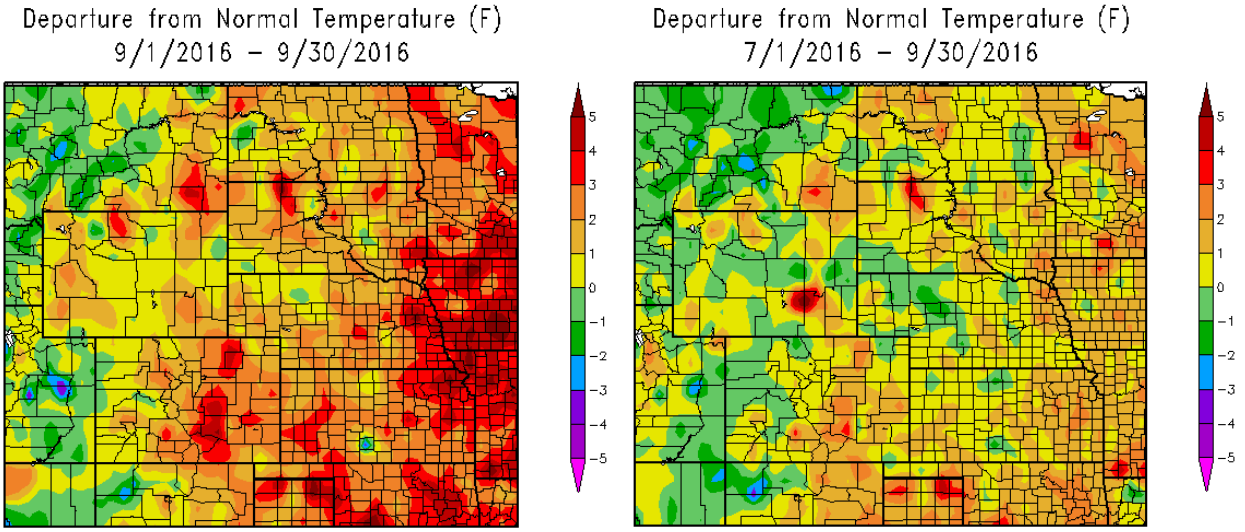


Figure 6. September 2016 and July-August-September 2016 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Soil Moisture

Soil moisture is factored into the forecast as an indicator of wet or dry hydrologic basin conditions. Typically when soil moisture conditions are wet or greater than normal, rainfall and snowmelt runoff is greater than when soil moisture is dry or less than normal. Not only is soil moisture a physical parameter that influences runoff, it can be used as an indicator of future runoff.

Figure 7 shows the NOAA NLDAS ensemble top one-meter soil moisture anomaly on September 27, 2016. The NLDAS soil moisture depiction is an average value for the one-meter soil moisture column. **Figure 7** indicates that soil moisture is predominantly wetter than normal (above normal anomalies) over large portions of Montana, Wyoming, North Dakota, eastern Nebraska, Iowa, Kansas and portions of Missouri. Drier than normal soil moisture conditions (below normal anomalies) are present in western Montana, northwestern and southeastern Wyoming, South Dakota, Colorado and much of Nebraska. As the calendar year approaches

winter, the wet and dry soil moisture conditions will provide some insight into late winter and early spring runoff potential.

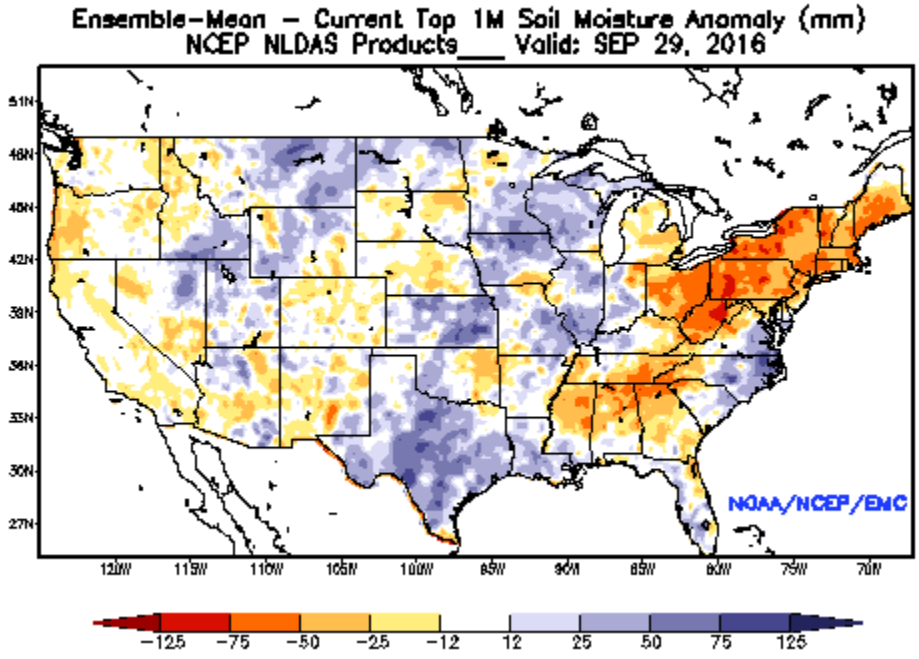


Figure 7. Top 1-Meter Soil Moisture Anomaly on September 29, 2016. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

Streamflow Conditions

Missouri Basin streamflow conditions are shown in **Figure 8**. These conditions are based on the ranking of the October 3, 2016 daily streamflow versus the historical record of streamflow for that date. Streamflow conditions were generally "Normal" (25th-75th percentile) and "Below Normal (10th to 24th percentile) in Montana and Wyoming with the exception of a few streams that were "Above Normal" (75th – 90th percentile). Streamflow between Garrison Dam and Gavins Point Dam was generally "Normal" (25th – 75th percentile), while most of the Missouri River below Gavins Point Dam was "Above Normal" (75th – 90th percentile) to "Much Above Normal" (above 90th percentile) due to wetter than normal soil moisture and above average precipitation in portions of the lower Basin.

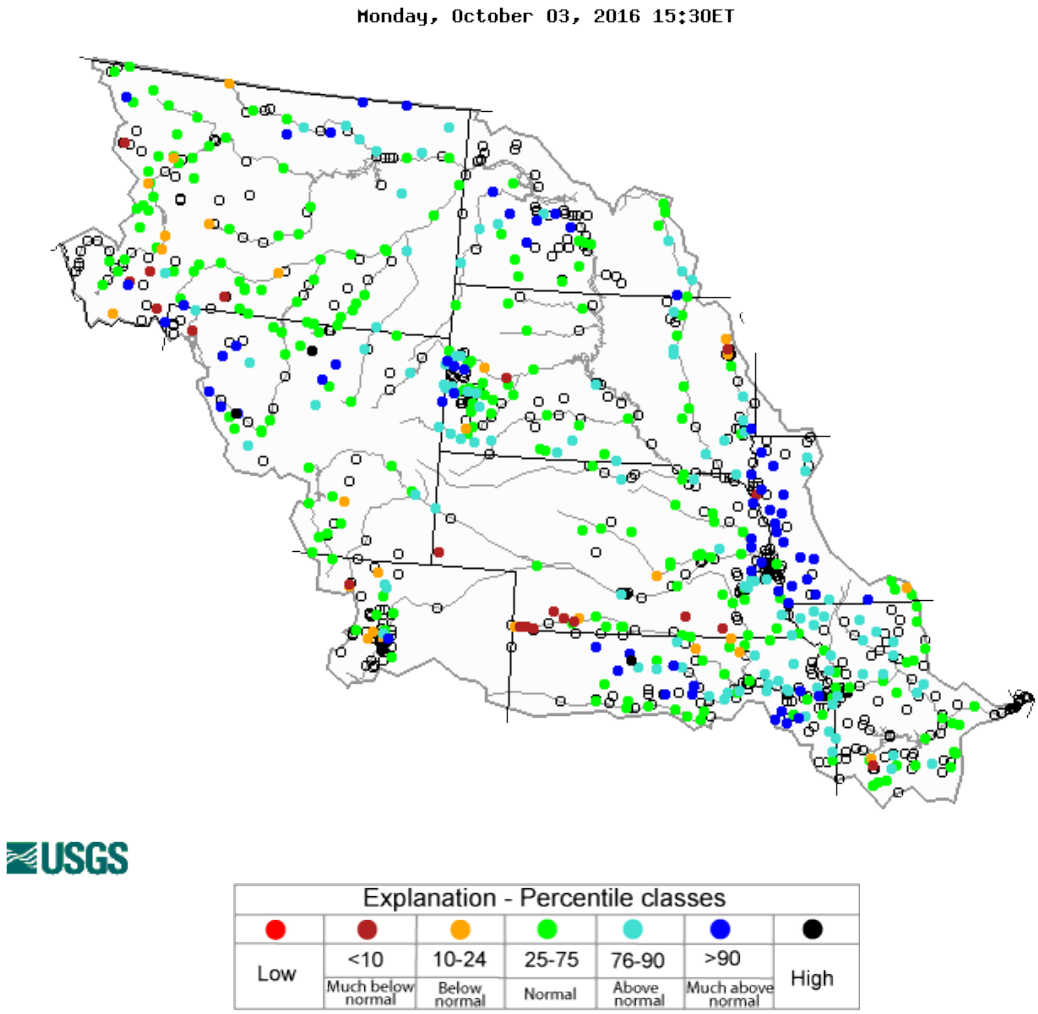


Figure 8. USGS Streamflow Conditions as a Percentile of Normal in the Missouri River Basin as of October 3, 2016. Source: USGS. http://waterwatch.usgs.gov/index.php

Climate Outlook

ENSO (El Niño Southern Oscillation)

MRBWMD participates in the monthly North Central U.S. Climate/Drought Outlook Webinar coordinated through NOAA, the regional climate centers, and the American Association of State Climatologists (AASC). These webinars provide updates on near-term climate outlooks and impacts including the ENSO climate pattern and its implications on winter temperature and precipitation patterns in the Missouri River Basin.

The CPC ENSO climate update, posted October 3, indicated ENSO neutral conditions were present in the equatorial Pacific Ocean. ENSO-neutral conditions are slightly favored (between 55-60%) during the fall and winter 2016-2017, and a La Niña winter is no longer anticipated. ENSO-neutral conditions add some uncertainty to the winter weather outlooks.

Temperature and Precipitation Outlooks

The NOAA Climate Prediction Center climate outlook for October 2016 (**Figure 9)** indicates there is a slight increase in the chances for above-normal temperatures throughout the entire Basin. With regard to precipitation, there are increased chances for above-normal precipitation in the upper Basin and portions of the lower Basin including western Iowa and Nebraska. So far in October, precipitation in Montana, western North Dakota, and western Wyoming has been well-above normal.

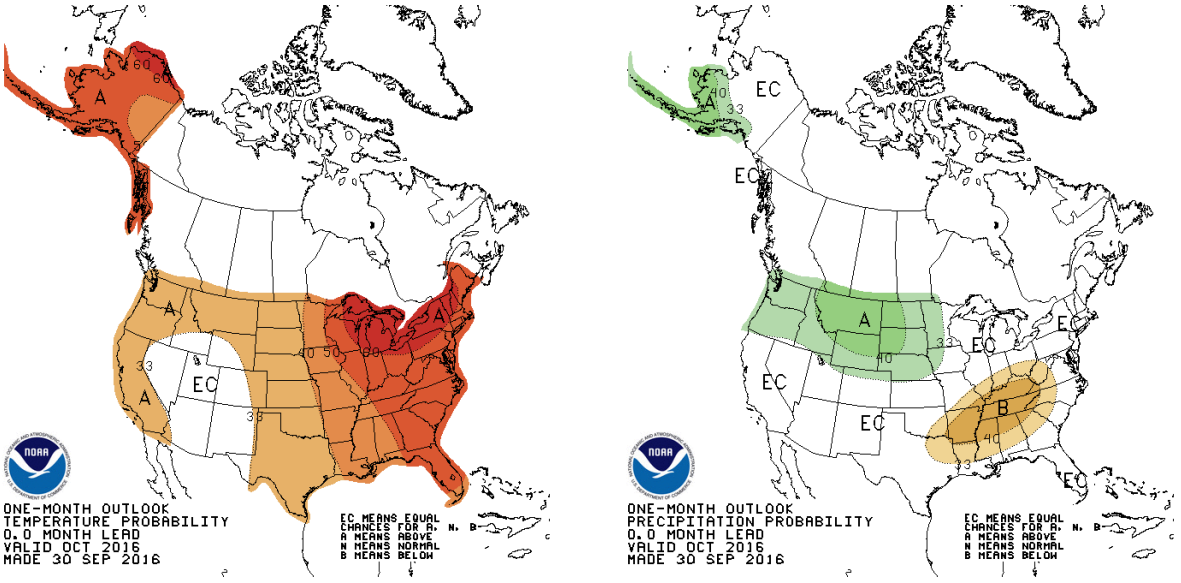


Figure 9. CPC October 2016 temperature and precipitation outlooks.

The October-November-December 2016 temperature outlook (**Figure 10**) indicates there are increased chances for above-normal temperatures throughout the entire Missouri Basin, particularly in the mountains. With regard to precipitation, there are increased chances for above-normal precipitation in Montana. There are equal chances for above-normal, normal or below-normal precipitation over the remainder of the Missouri Basin.

The January-February-March 2017 CPC temperature outlook (**Figure 11**) indicates there are increased chances for below-normal temperatures across the northern plains extending through northeastern Montana, North Dakota, and northern South Dakota. There are equal chances for above-normal, normal or below-normal temperatures across the remainder of the Missouri Basin. With regard to precipitation, there are increased chances for above-normal precipitation across Montana and the northern half of Wyoming. There are equal chances for precipitation in the remainder of the Missouri Basin from January through March 2017.

During the April-May-June 2017 period (**Figure 12**) CPC outlooks indicate equal chances for above-normal, normal and below-normal temperatures in most of the upper Basin, and increased chances for above-normal temperatures in the lower Basin. There are equal chances for above-

normal, normal and below-normal precipitation across the Missouri Basin, with the exception of a slight increase in the chances for above normal precipitation in North Dakota.

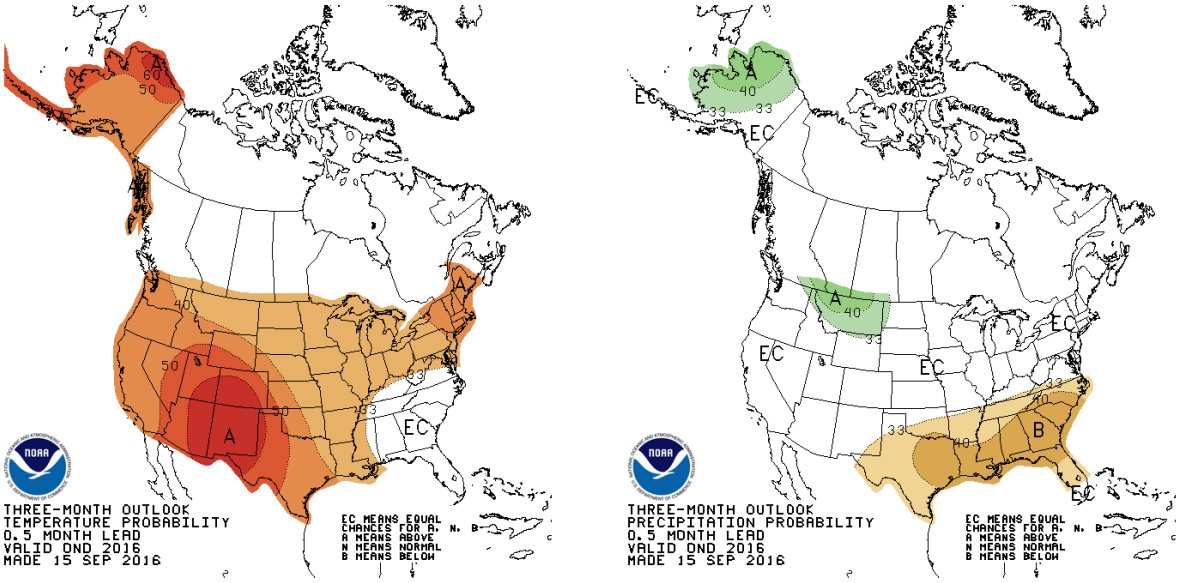


Figure 10. CPC October-November-December 2016 temperature and precipitation outlooks.

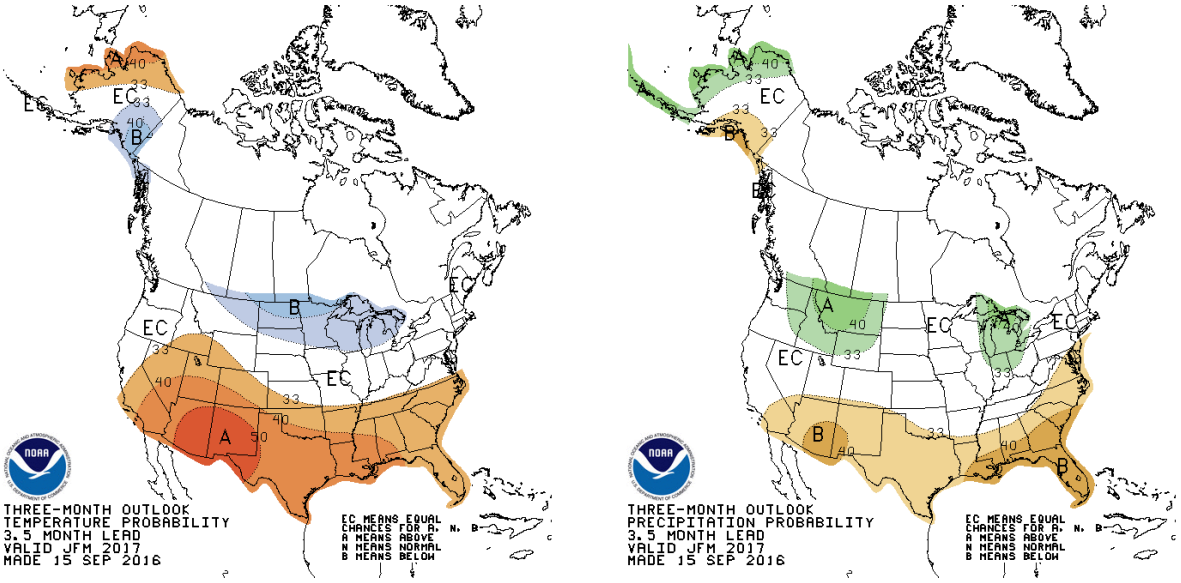


Figure 11. CPC January-February-March 2017 temperature and precipitation outlooks.

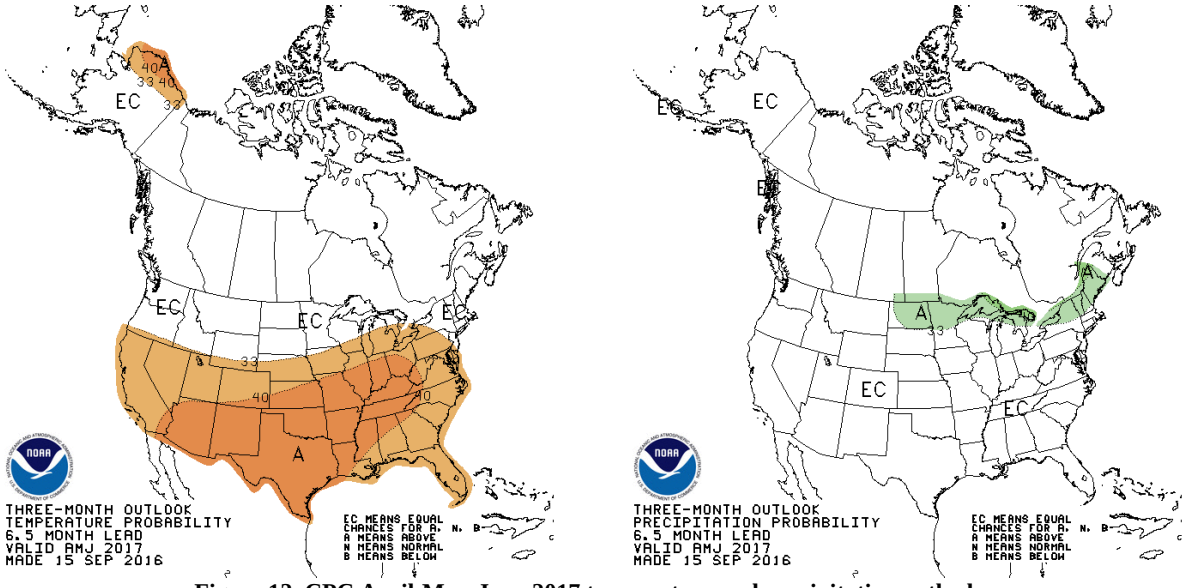


Figure 12. CPC April-May-June 2017 temperature and precipitation outlooks.

October 2016 Calendar Year Runoff Forecast

In summary, the 2016 calendar year runoff forecast is **22.7 MAF, 90% of average**. Runoff for the basin above Gavins Point Dam, excluding the contributing area between Gavins Point Dam and Sioux City, IA, is forecast to be **19.0 MAF (82% of average)**. September runoff was 1.0 MAF (91% of average). Runoff was 62% of average in both the Fort Peck and Garrison reaches, despite the well-above average rainfall during September. Precipitation outlooks for the mountain and plains regions of the upper Basin indicate increased probabilities for above normal precipitation through the end of the calendar year. Winter precipitation, which normally comes in the form of mountain or plains snow, will have little impact on runoff during the 2016 calendar year. We will continue to monitor Missouri Basin conditions and make forecast adjustments as conditions change.

Upper Missouri River Basin
November 2016 Calendar Year Runoff Forecast
November 3, 2016

U.S. Army Corps of Engineers, Northwestern Division
Missouri River Basin Water Management
Omaha, NE

Calendar Year Runoff Forecast

Explanation and Purpose of Forecast

The long-range runoff forecast is presented as the Calendar Year Runoff Forecast. This forecast is developed shortly after the beginning of each calendar year and is updated at the beginning of each month to show the actual runoff for historic months of that year and the updated forecast for the remaining months of the year. This forecast presents monthly inflows in million acre-feet (MAF) from five incremental drainage areas, as defined by the individual System projects, plus the incremental drainage area between Gavins Point Dam and Sioux City. Due to their close proximity, the Big Bend and Fort Randall drainage areas are combined. Summations are provided for the total Missouri River reach above Gavins Point Dam and for the total Missouri River reach above Sioux City. The Calendar Year Runoff Forecast is used in the Monthly Study simulation model to plan future system regulation in order to meet the authorized project purposes throughout the calendar year.

October 2016 Runoff

Heavy rainfall occurred over north central Montana and northwestern Wyoming in early October, resulting in 162% of average runoff into Fort Peck and 173% of average runoff into Garrison. The heavy rainfall in northern Montana caused major flooding on tributaries of the Milk River and minor to moderate flooding on the Milk River. Runoff in the Oahe and Fort Randall reaches was well below average. Upper Basin runoff was 155% of average, or 0.8 MAF greater than forecast on October 1.

2016 Calendar Year Forecast Synopsis

The November 1 forecast for 2016 upper Basin runoff is **24.1 MAF (95% of average)**. This is a total increase of 1.4 MAF in the calendar year forecast since October 1. Runoff for the basin above Gavins Point Dam is forecast to be **20.2 MAF (88% of average)**. Due to the amount of variability in precipitation and other hydrologic factors that can occur over the next 2 months, forecasted runoff ranges from the 23.7 MAF upper basic forecast to the 24.7 MAF lower basic forecast. The upper and lower basic forecasts are used in long-term regulation planning models to "bracket" the range of forecast runoff given much wetter or drier conditions, respectively. Given that 2 months are forecast for this November 1 forecast (10 months observed/2 months

forecast), the range of wetter than normal (upper basic) and drier than normal (lower basic) conditions is attributed to all 6 reaches for 2 months. The result is a range or "bracket" for each reach, and thus, for the total runoff forecast.

Current Conditions

Drought Analysis

The latest National Drought Mitigation Center's drought monitor for October 25, 2016 is shown in **Figure 1.** The drought monitor for September 27, 2016 is shown in **Figure 2.** The U.S. Drought Monitor indicates there are some patches of Moderate Drought (D1) in western Montana, and Moderate (D1) to Severe Drought (D2) in northeastern Wyoming, southeastern Montana, and western South Dakota. The Seasonal Drought Outlook in **Figure 3** indicates drought conditions will be removed where there is Moderate Drought, but remain where there is Severe Drought.

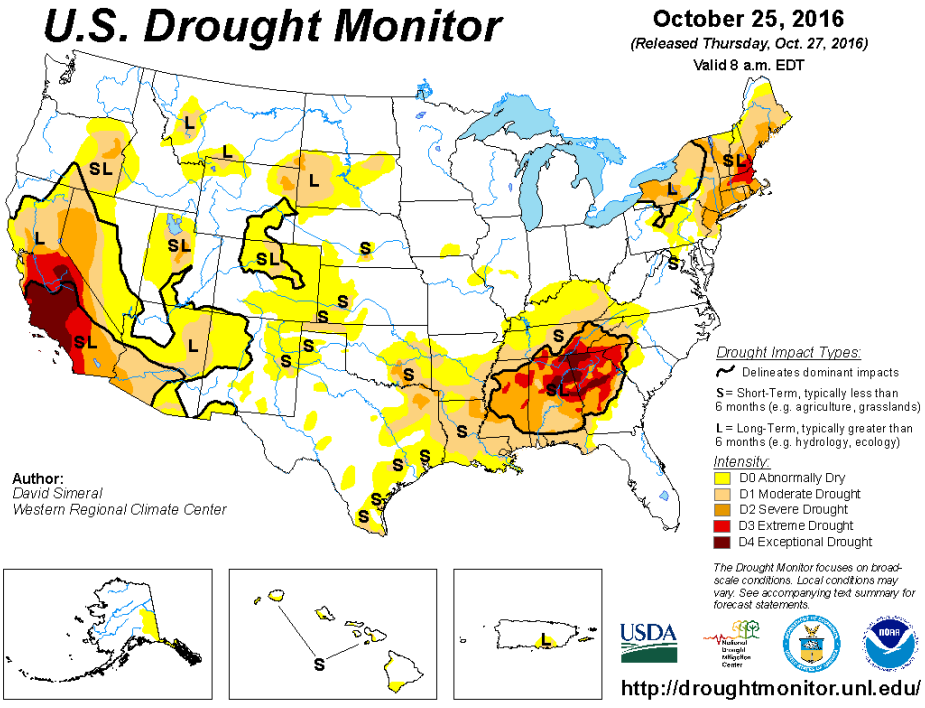


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for October 25, 2016

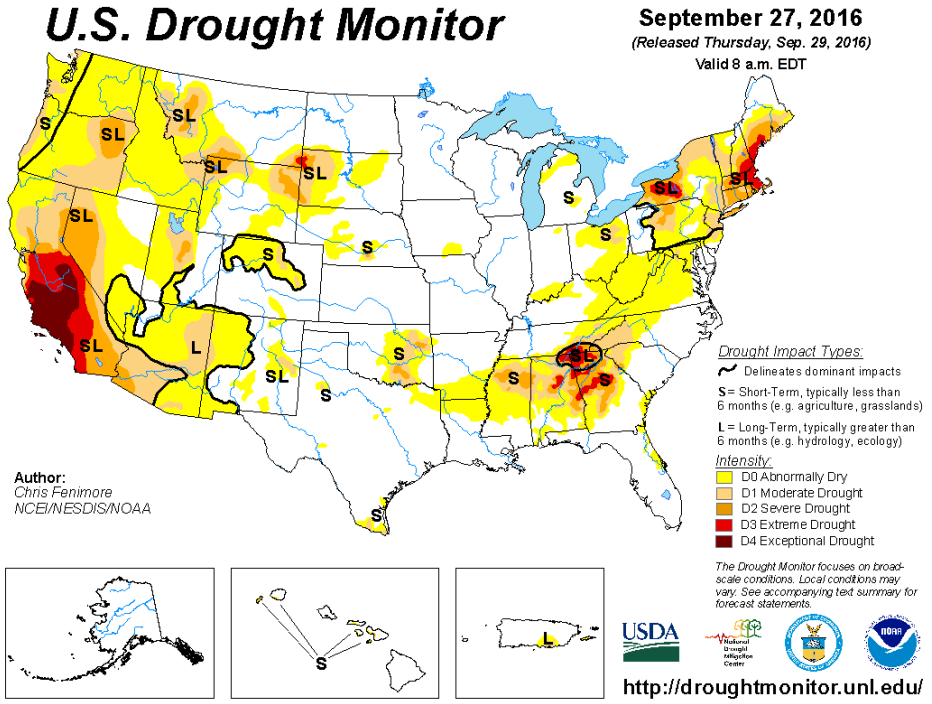


Figure 2. National Drought Mitigation Center U.S. Drought Monitor for September 27, 2016

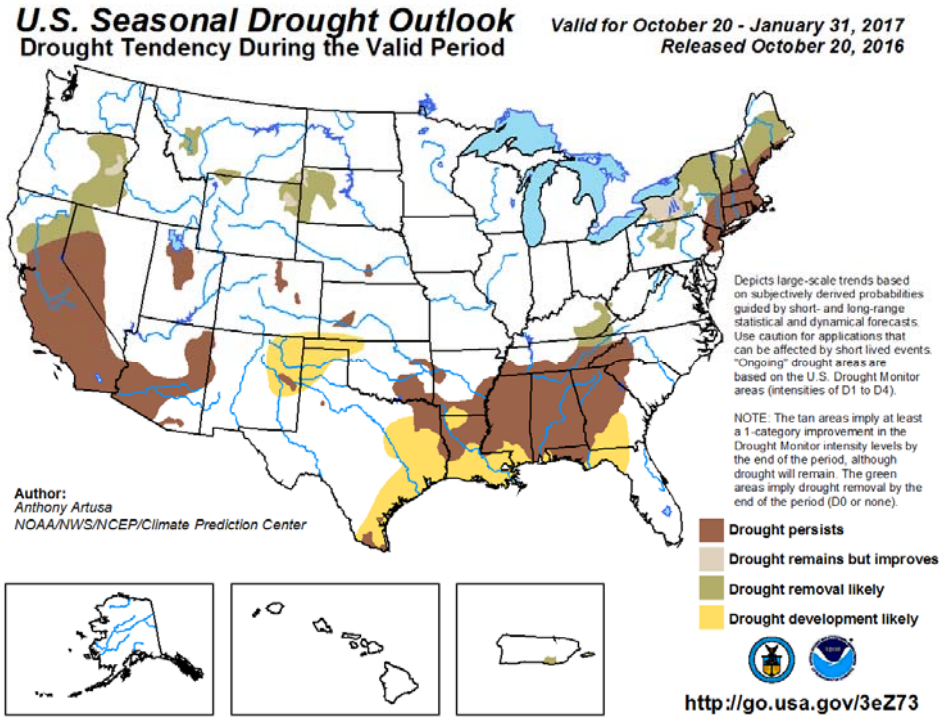


Figure 3. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

October precipitation accumulations are shown in **Figure 4** as both inches of precipitation (left) and percent of normal monthly precipitation (right). Heavy precipitation occurred in north central Montana, southwestern Montana and northwestern Wyoming. Precipitation in these areas generally ranged from 6 to 7 inches, while some locations exceeded 7 inches. Precipitation over a majority of the Missouri Basin, however, was less than 2 inches. Precipitation was greater than 200% of normal in western and central Montana and western Wyoming; it was predominantly below normal in the remainder of the upper Basin. Precipitation was less than 50% of normal in large portions of eastern Wyoming, the Dakotas and central Nebraska.

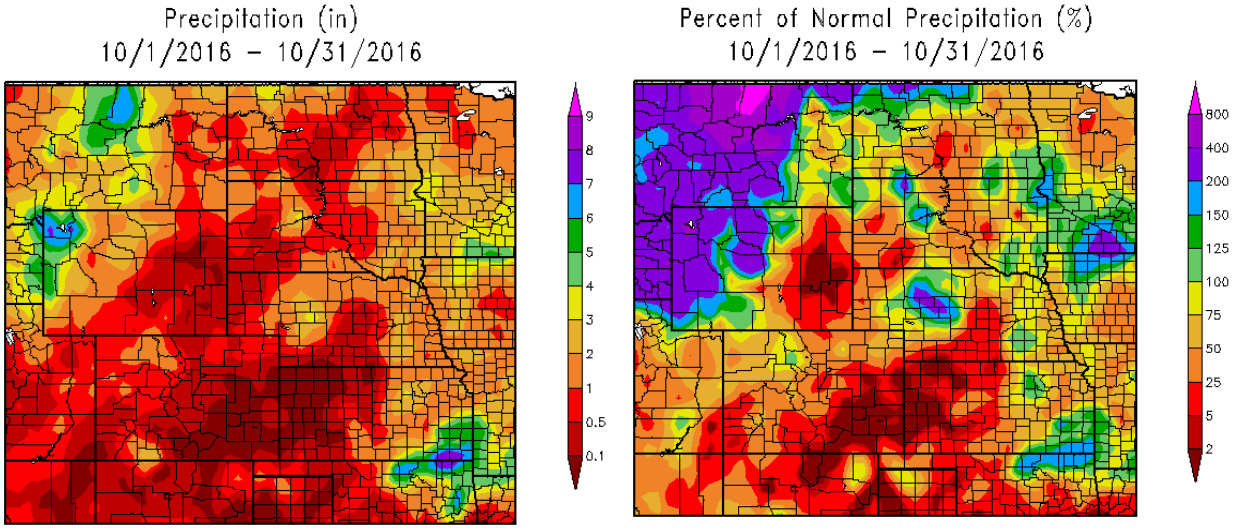


Figure 4. October 2016 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

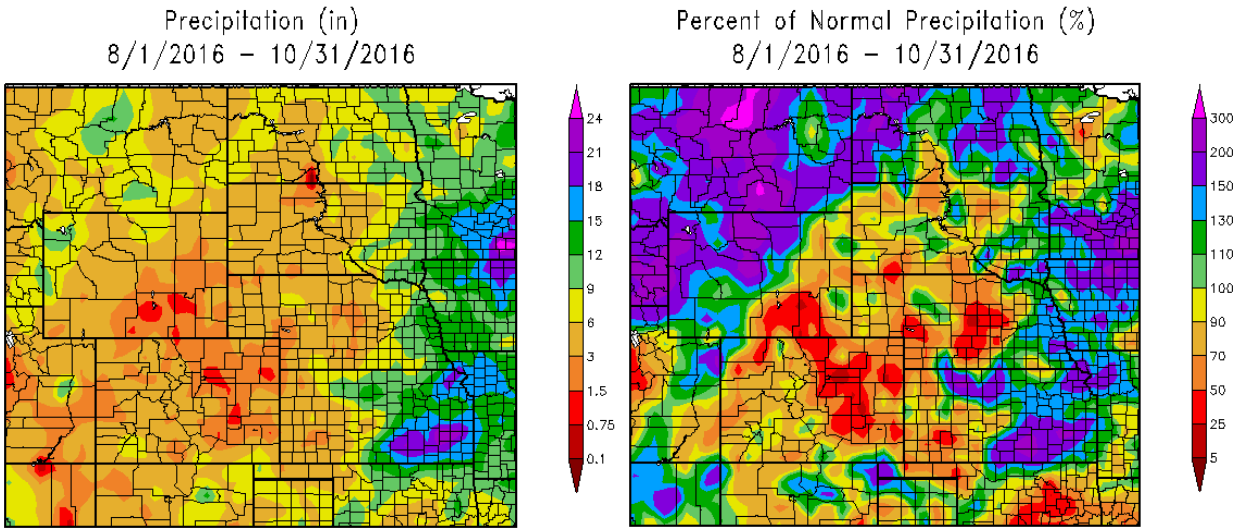


Figure 5. August-September-October 2016 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

August-September-October 2016 precipitation accumulations and percent of normal precipitation are shown in **Figure 5**. The wet precipitation pattern has continued to impact Wyoming and Montana and the dry pattern has continued in Colorado, eastern Wyoming, western Nebraska and South Dakota. Large regions of Montana and Wyoming have received greater than 150% of normal precipitation. The three-month precipitation accumulation also shows wet areas in portions of the lower Basin below Gavins Point Dam.

Table 1 contains notable October 2016 precipitation amounts and precipitation departures in the Missouri Basin. Heavy October precipitation amounts as a percent of normal occurred in Montana and Wyoming, while precipitation was predominantly below normal in the lower Basin. Some notable above-average precipitation totals include Havre, MT (607%); Billings, MT (297%); Glasgow, MT (415%); and, Lake Yellowstone, WY (428%).

Table 1. October 2016 precipitation and precipitation departures.

City, State	Precipitation inches	Precipitation Departure inches	Percent of Average
Dillon, MT	2.22	1.46	292
Bozeman, MT	2.45	1.35	223
Great Falls, MT	1.76	0.90	205
Billings, MT	3.51	2.33	297
Livingston, MT	3.32	2.06	263
Miles City, MT	0.97	0.05	105
Havre, MT	3.52	2.94	607
Lewistown, MT	4.01	2.88	355
Glasgow, MT	3.11	2.36	415
Wolf Point, MT	1.50	0.69	185
Lander, WY	0.98	-0.31	76
Lake Yellowstone, WY	5.78	4.43	428
Sheridan, WY	1.45	0.04	103
Cheyenne, WY	0.27	-0.66	29
Denver, CO	0.26	-0.76	25
Bismarck, ND	0.24	-1.01	19
Jamestown, ND	1.15	-0.4	74
Williston, ND	1.06	0.14	115
Rapid City Arpt, SD	0.46	-0.96	32
Aberdeen, SD	1.81	-0.18	91
Pierre, SD	0.82	-0.83	50
Sioux Falls, SD	3.09	0.92	142
Sioux City, IA	1.60	-0.53	75
North Platte, NE	1.54	-0.01	99
Grand Island, NE	0.12	-1.74	6
Omaha, NE	1.66	-0.49	77
Topeka, KS	1.32	-1.71	44
St. Joseph, MO	1.66	-1.15	59
Kansas City Intl Arpt, MO	2.58	-0.58	82
Columbia, MO	1.58	-1.73	48

Temperature

October temperature departures from normal are shown in the left image of **Figure 6** in degrees Fahrenheit (deg F). August-September-October 2016 temperature departures from normal are shown in the right image of **Figure 6**. October temperatures in the Missouri Basin were generally 2 to 6 deg F above normal. Above-normal departures were greater in the southern Missouri Basin. October departures were normal to slightly below normal in northern Montana. Temperature departures during the August-September-October period in the right image of **Figure 6** are generally normal to about 2 deg F above normal in central portions of the Missouri Basin. Departures were normal to about 2 deg F below normal in central and northern Montana. Departures in the lower Basin were generally 2 to 4 deg F above normal.

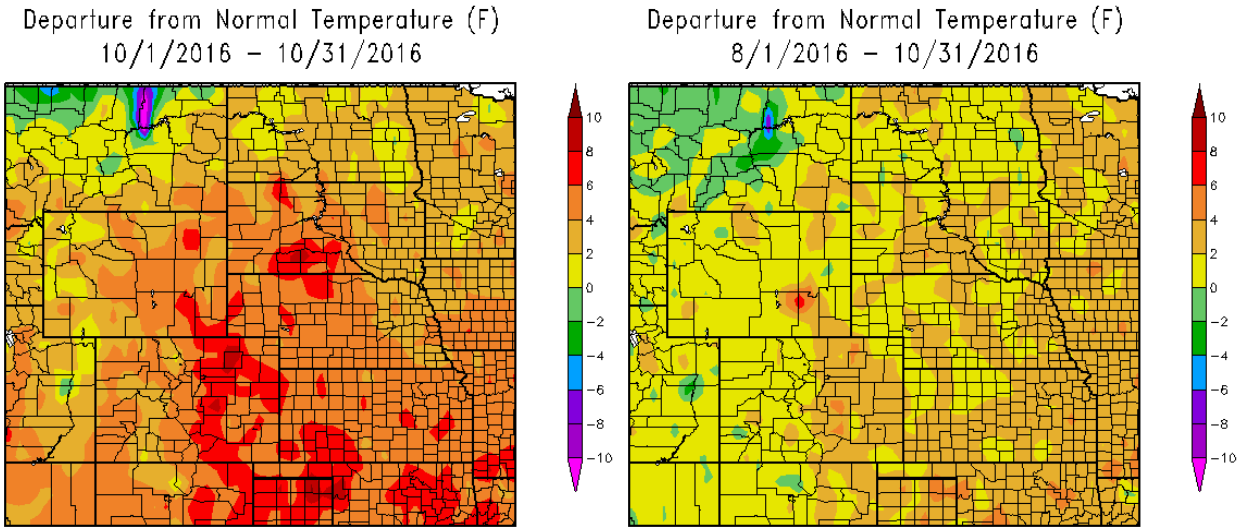


Figure 6. September 2016 and July-August-September 2016 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Soil Moisture

Soil moisture is factored into the forecast as an indicator of wet or dry hydrologic basin conditions. Typically when soil moisture conditions are wet or greater than normal, rainfall and snowmelt runoff is greater than when soil moisture is dry or less than normal. Not only is soil moisture a physical parameter that influences runoff, it can be used as an indicator of future runoff.

Figure 7 shows the NOAA NLDAS ensemble top one-meter soil moisture anomaly on October 28, 2016. The NLDAS soil moisture depiction is an average value for the one-meter soil moisture column. **Figure 7** indicates that soil moisture is predominantly wetter than normal (above normal anomalies) over Montana, western and northern Wyoming, western North Dakota, western Iowa and Kansas. Drier-than-normal soil moisture conditions (below normal anomalies) are present in central North Dakota, South Dakota, eastern Wyoming, Nebraska and

western Missouri. As the calendar year approaches winter, the wet and dry soil moisture conditions will provide some insight into late winter and early spring runoff potential.

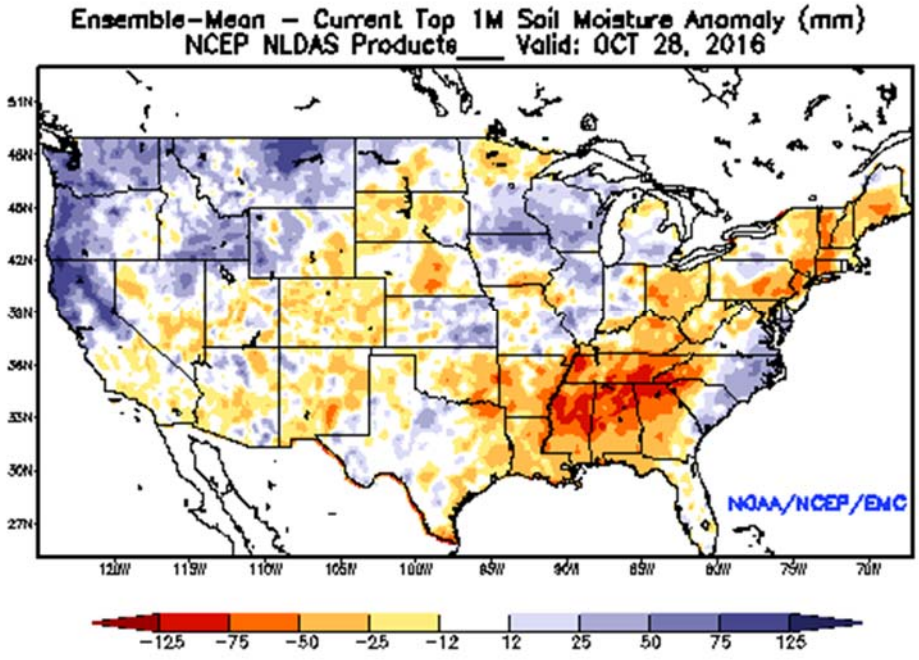


Figure 7. Top 1-Meter Soil Moisture Anomaly on October 28, 2016. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

Streamflow Conditions

Missouri Basin streamflow conditions are shown in **Figure 8**. These conditions are based on the ranking of the November 1, 2016 daily streamflow versus the historical record of streamflow for that date. Streamflow is "High" in north central and southern Montana, and central Wyoming as a result of recent heavy precipitation. Streamflow conditions range from "Normal" (25^{th}-75^{th} percentile) to "Below Normal (10^{th} to 24^{th} percentile) in southeastern Montana, eastern Wyoming and much of South Dakota due to below average precipitation. Streamflow conditions are "Above Normal" (75^{th} – 90^{th} percentile) to "Much Above Normal" (above 90^{th} percentile) in eastern Nebraska and western Iowa.

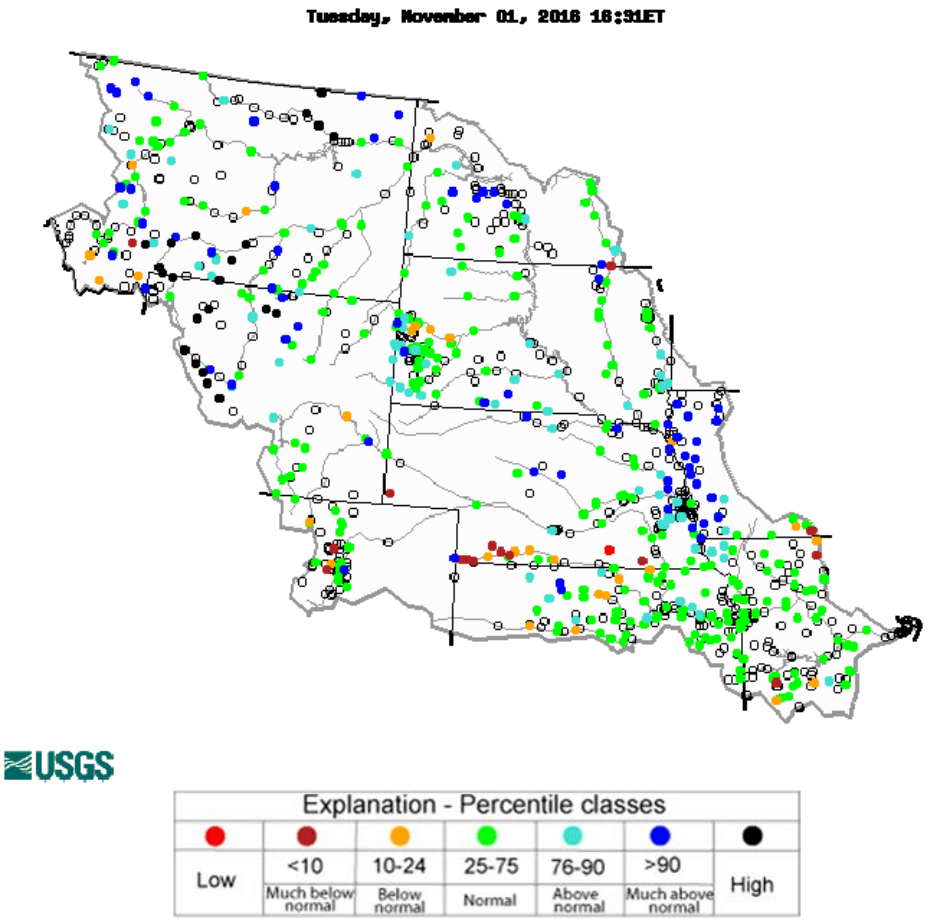


Figure 8. USGS Streamflow Conditions as a Percentile of Normal in the Missouri River Basin as of November 1, 2016. Source: USGS. http://waterwatch.usgs.gov/index.php

Mountain Snow Pack

Mountain snowpack is the primary factor used to predict May-July runoff volumes in the Fort Peck and Fort Peck to Garrison mainstem reaches. It is typically NOT a factor influencing runoff at the end of a calendar year.

Figure 9 includes time series plots of the average mountain SWE beginning on October 1, 2016 based on the NRCS SNOTEL data for the headwater basin above Fort Peck and the incremental basin from Fort Peck to Garrison. The current average SWE values (shaded blue area) are plotted against the 1981-2010 basin average SWE (bold red line), a recent low SWE year in 2001 (green line), and two historic high SWE years occurring in 1997 (purple) and 2011 (dark blue).

As of November 1, 2016, the Corps of Engineers computed an average mountain SWE in the Fort Peck reservoir reach of 0.4 inches, which is 33% of average based on the 1981-2010 average SWE for the Fort Peck reach. In the reservoir reach between Fort Peck Dam and Garrison Dam, the Corps computed an average mountain SWE of 0.9 inches, which is 59% of average based on the 1981-2010 average SWE for the Garrison reach. Typically by November

1, only 9% of the total accumulation occurs. Warmer-than-average temperatures in the upper Basin during late October caused some of the early-season mountain snowpack to melt.

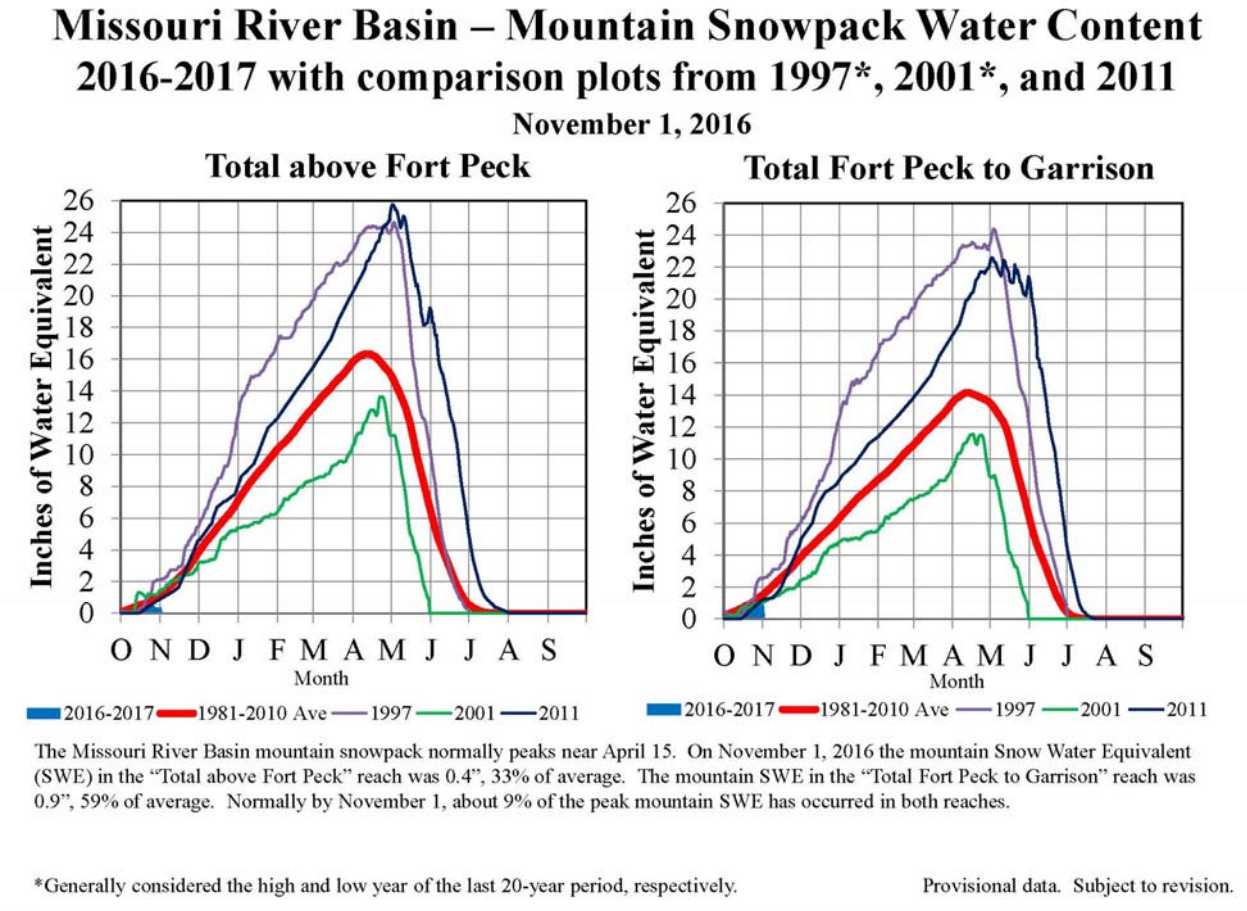


Figure 9. Mountain snowpack water content on November 1, 2016 compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management.

Climate Outlook

ENSO (El Niño Southern Oscillation)

MRBWMD participates in the monthly North Central U.S. Climate/Drought Outlook Webinar coordinated through NOAA, the regional climate centers, and the American Association of State Climatologists (AASC). These webinars provide updates on near-term climate outlooks and impacts including the ENSO climate pattern and its implications on winter temperature and precipitation patterns in the Missouri River Basin.

The latest climate update, posted October 31, indicates ENSO-neutral conditions are present. There is roughly a 70% chance La Niña conditions will develop during the fall with a 55% chance they will persist during the winter. The impact of La Niña on Missouri Basin climate is reflected in the three-month CPC temperature and precipitation outlooks.

Temperature and Precipitation Outlooks

With regard to November weather, the CPC November temperature outlook in **Figure 10** indicates a high probability for above-normal temperatures. The November precipitation outlook indicates there are equal chances for precipitation in most of Montana, however there are increased chances for below-normal precipitation in the remainder of the upper Basin. There are equal chances for above-normal, normal, or below-normal precipitation in much of the lower Basin. The three-month November through January temperature outlook in **Figure 11** indicates mostly equal chances for temperatures in the upper Basin, while the three-month precipitation outlook indicates a slight increase in the chances for above-normal precipitation in Montana, Wyoming and the western Dakotas, with equal chances in the remainder of the upper Basin.

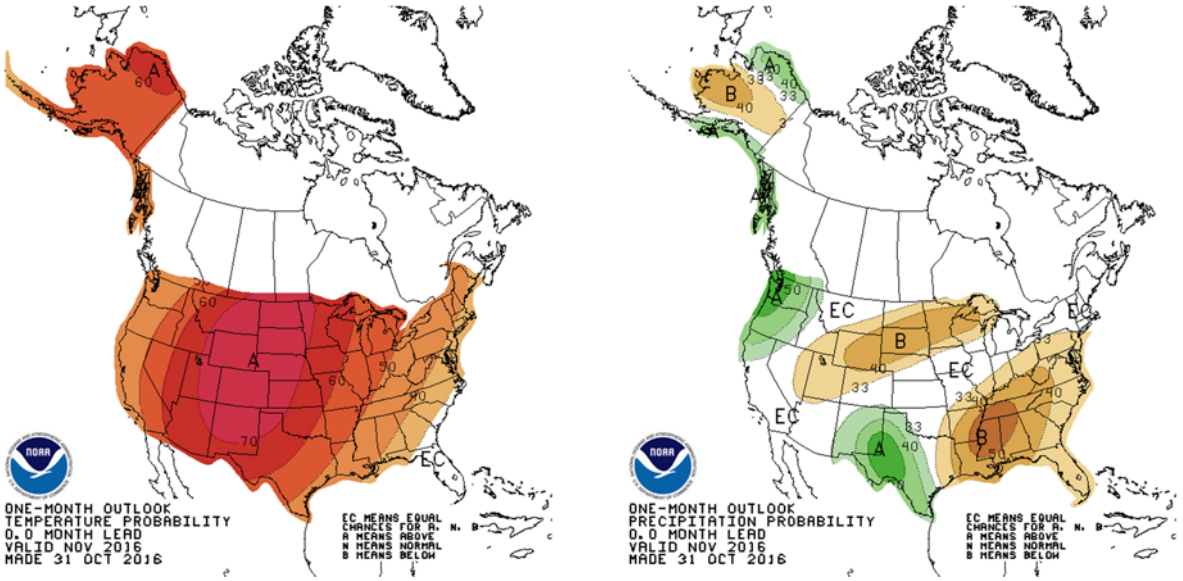


Figure 10. CPC November 2016 temperature and precipitation outlooks.

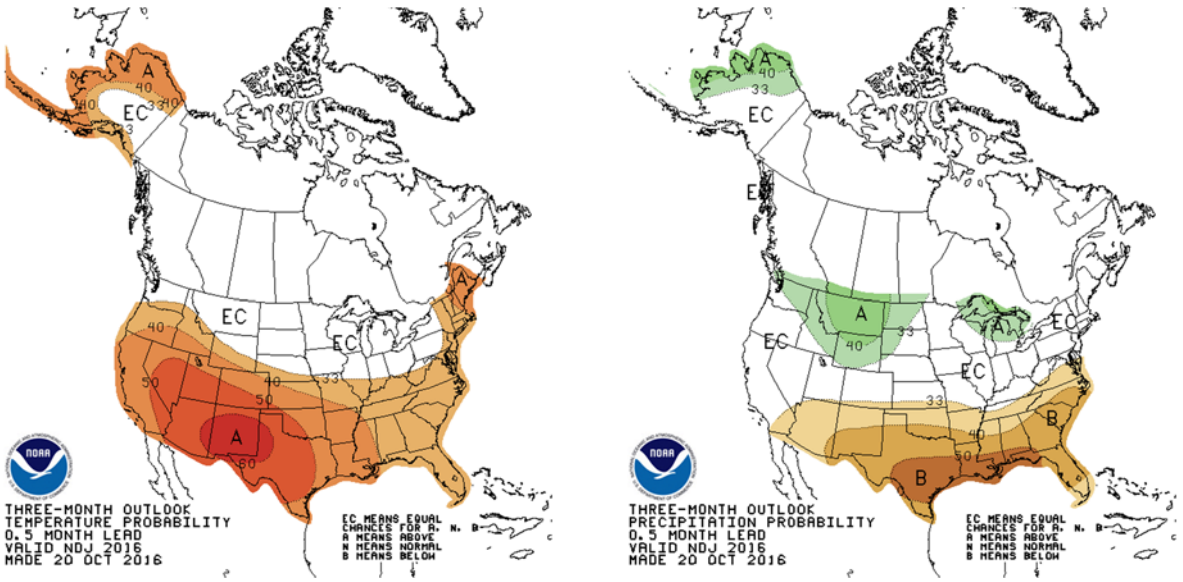


Figure 11. CPC November-December 2016-January 2017 temperature and precipitation outlooks.

The February-March-April 2017 CPC temperature outlook (**Figure 12**) indicates there are increased chances for below-normal temperatures across the northern plains extending across northern Montana and North Dakota. There are equal chances for above-normal, normal or below-normal temperatures across the remainder of the Missouri Basin. With regard to precipitation, there are increased chances for above-normal precipitation across Montana, northern Wyoming and North Dakota. There are equal chances for precipitation in the remainder of the Missouri Basin. Both temperature and precipitation outlooks indicate weak La Niña weather impacts in the Missouri Basin.

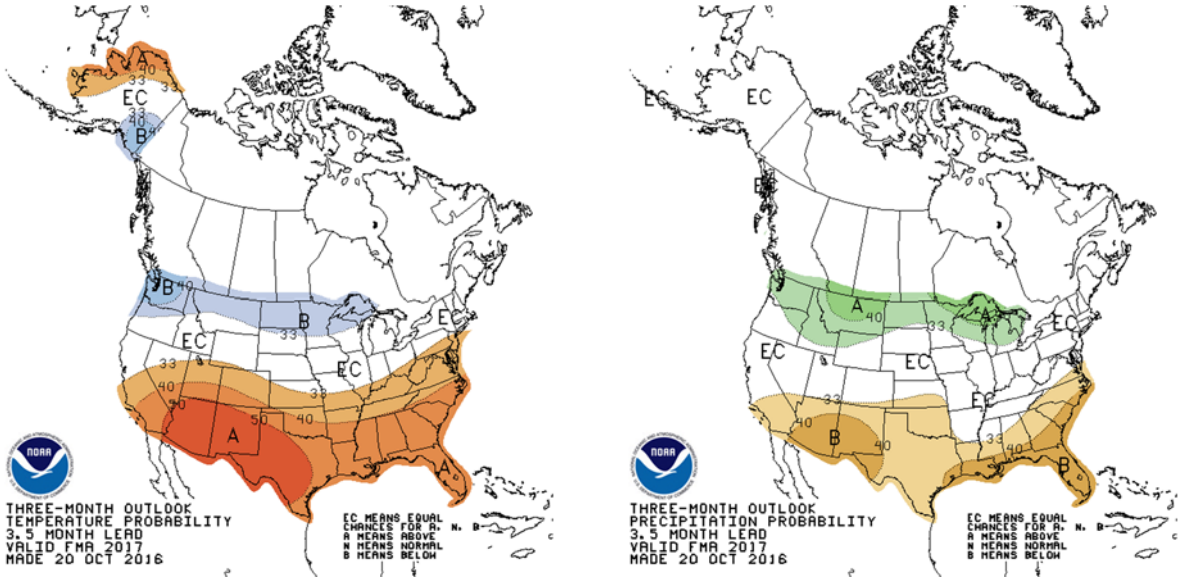


Figure 12. CPC February-March-April 2017 temperature and precipitation outlooks.

November 2016 Calendar Year Runoff Forecast

The 2016 calendar year runoff forecast is **24.1 MAF, 95% of average**. Runoff for the basin above Gavins Point Dam, excluding the contributing area between Gavins Point Dam and Sioux City, IA, is forecast to be **20.2 MAF (88% of average)**. October runoff was 1.9 MAF (155% of average). Increased streamflow in Montana and Wyoming enhanced by recent rainfall could cause Fort Peck and Garrison runoff to be well-above average through the end of the calendar year. Furthermore some precipitation that normally accumulates as mountain snowpack has cause elevated mountain streamflow. We will continue to monitor Missouri Basin conditions and make forecast adjustments as conditions change.

Upper Missouri River Basin
December 2016 Calendar Year Runoff Forecast
December 6, 2016

U.S. Army Corps of Engineers, Northwestern Division
Missouri River Basin Water Management
Omaha, NE

Calendar Year Runoff Forecast

Explanation and Purpose of Forecast

The long-range runoff forecast is presented as the Calendar Year Runoff Forecast. This forecast is developed shortly after the beginning of each calendar year and is updated at the beginning of each month to show the actual runoff for historic months of that year and the updated forecast for the remaining months of the year. This forecast presents monthly inflows in million acre-feet (MAF) from five incremental drainage areas, as defined by the individual System projects, plus the incremental drainage area between Gavins Point Dam and Sioux City. Due to their close proximity, the Big Bend and Fort Randall drainage areas are combined. Summations are provided for the total Missouri River reach above Gavins Point Dam and for the total Missouri River reach above Sioux City. The Calendar Year Runoff Forecast is used in the Monthly Study simulation model to plan future system regulation in order to meet the authorized project purposes throughout the calendar year.

November 2016 Runoff

Record warm temperatures in the upper Missouri Basin melted some mountain snow and early-season plains snow, causing increased streamflow in the mountain streams and Missouri River tributaries in eastern South Dakota. As a result, November runoff in the upper Basin above Sioux City, IA was 1.5 MAF (141% of average). Total November runoff in the System reaches above Gavins Point Dam was 1.3 MAF (132% of average).

2016 Calendar Year Forecast Synopsis

The December calendar year runoff forecast for the upper Basin, is **24.3 MAF** (96% of average). Runoff for the basin above Gavins Point Dam is forecast to be **20.3 MAF** (88% of average). Runoff in January and February of 2017 is currently forecast to be about normal, but it will depend greatly on winter temperatures. Due to the amount of variability in precipitation and other hydrologic factors that can occur over the next month, forecasted runoff for 2016 ranges from the 24.6 MAF upper basic forecast to the 24.1 MAF lower basic forecast. The upper and lower basic forecasts are used in long-term regulation planning models to "bracket" the range of forecast runoff given much wetter or drier conditions, respectively. Given that one month is forecast for this December 1 forecast (11 months observed/one month forecast), the range of

wetter than normal (upper basic) and drier than normal (lower basic) conditions is attributed to all six reaches for one month.

Current Conditions

Drought Analysis

The latest National Drought Mitigation Center's drought monitor for November 29, 2016 is shown in **Figure 1.** The drought monitor for October 25, 2016 is shown in **Figure 2.** The U.S. Drought Monitor indicates there are some areas of Moderate Drought (D1) and Severe Drought (D2) in northeastern Wyoming, southeastern Montana, and western South Dakota. There are also some areas of D1 drought in western Montana, south central North Dakota and northeastern South Dakota. Abnormally Dry (D0) conditions encompass these areas. The Seasonal Drought Outlook in **Figure 3** indicates drought conditions will persist with no improvement in northeastern Wyoming, southeastern Montana, and western South Dakota through the end of February.

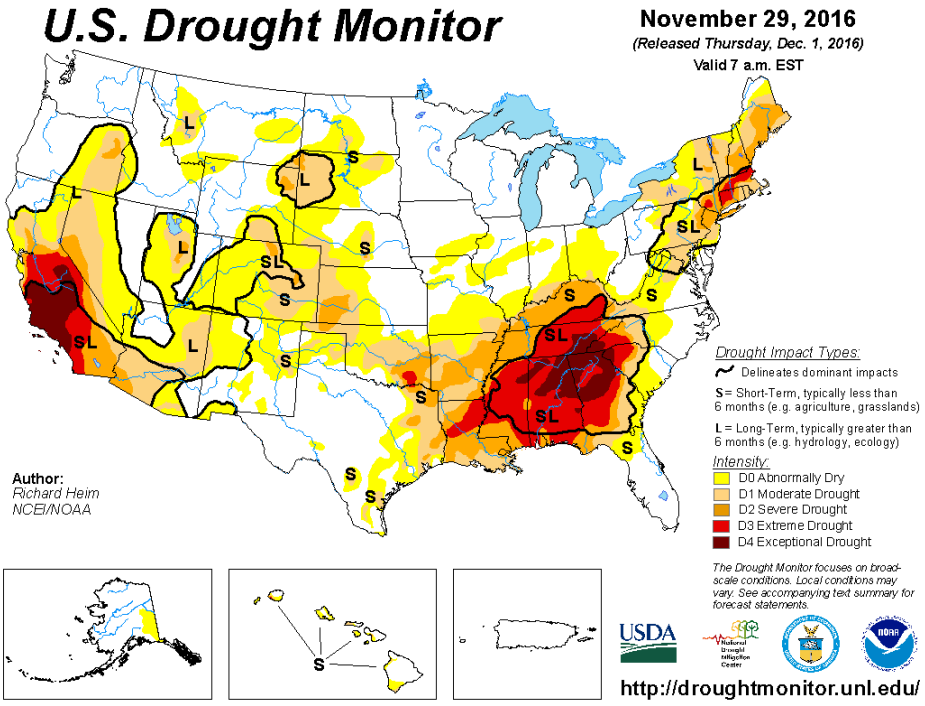


Figure 1. National Drought Mitigation Center U.S. Drought Monitor for November 29, 2016.

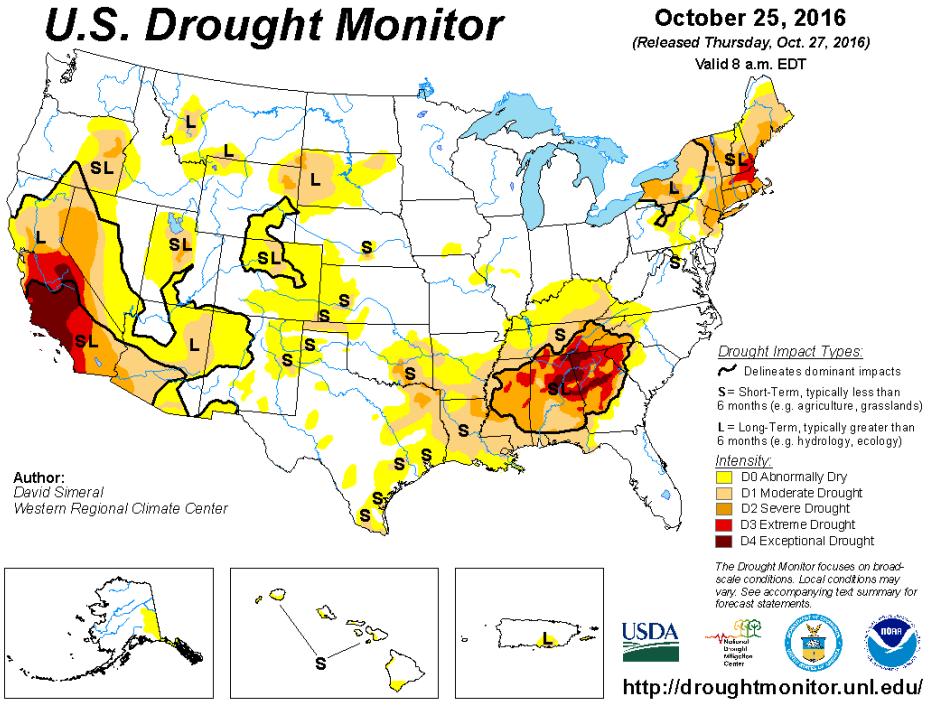


Figure 2. National Drought Mitigation Center U.S. Drought Monitor for October 25, 2016.

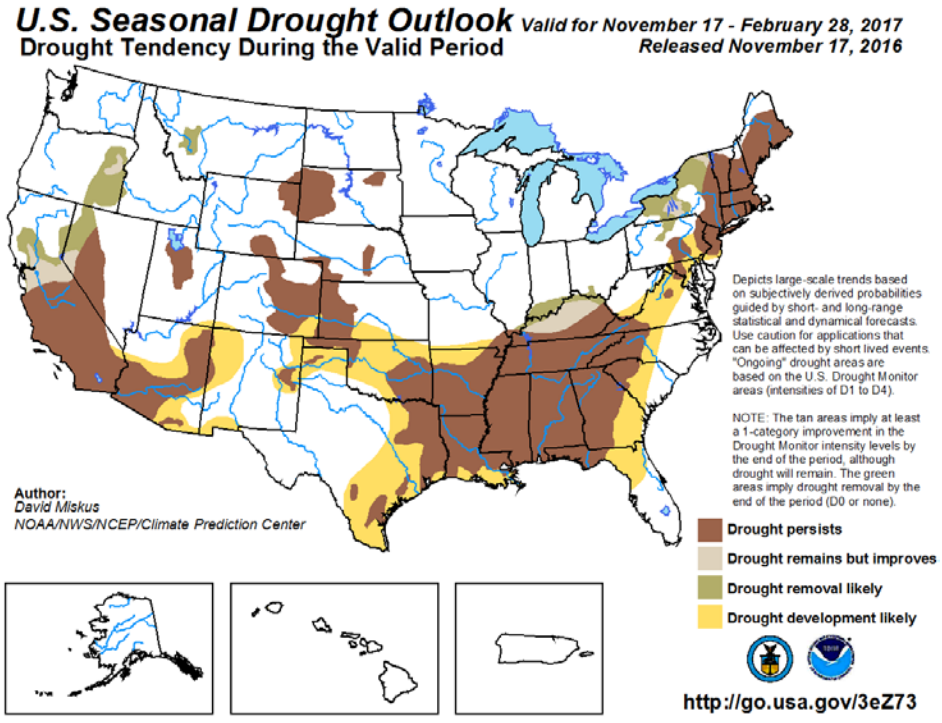


Figure 3. National Drought Mitigation Center U.S. Drought Seasonal Drought Outlook.

Precipitation

November precipitation accumulations are shown in **Figure 4** as both inches of precipitation (left) and percent of normal monthly precipitation (right). Precipitation was above average in central and eastern North Dakota, eastern South Dakota, and central Wyoming. Precipitation was below average in much of Montana, western South Dakota and western Nebraska. November precipitation and snowfall totals are listed in **Table 1**. At the beginning of November moderate snowfall occurred over eastern South Dakota. Near the end of November, a very large and persistent snow storm produced very heavy snow over North Dakota and northern South Dakota. Three-day snowfall totals centered in central North Dakota ranged from 6 to 24 inches. **Table 2** lists three-day snowfall totals in North Dakota ending on the date specified in the table.

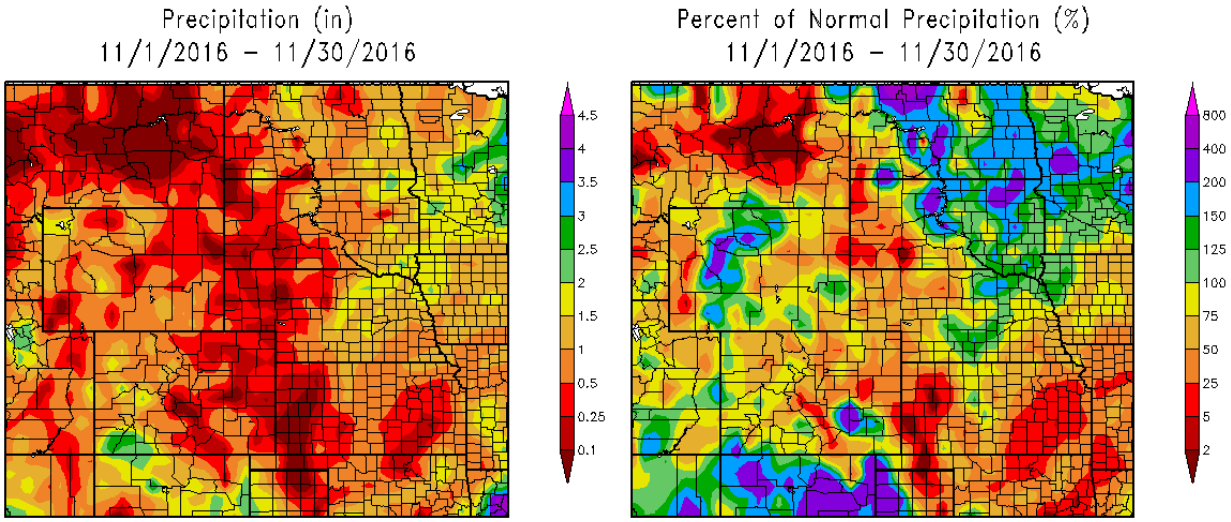


Figure 4. November 2016 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Table 1. November 2016 precipitation, snowfall and November 30 snow depth in the upper Basin.

Location	November Precipitation, inches	November Snowfall, inches	Nov. 30 Snow Depth, inches
Glasgow, MT	0.06	T	--
Bismarck, ND	1.42	19.0	15
Jamestown, ND	1.05	--	--
Williston, ND	0.24	--	--
Rapid City Arpt, SD	0.23	2.8	T
Aberdeen, SD	1.71	5.2	T
Mobridge, SD	1.05	11.4	5
Pierre, SD	1.54	10.1	9
Sioux Falls, SD	1.81	6.0	T

Table 2. Three-day snowfall in North Dakota ending on the specified date and time.

Location	Amount inches	Date	Time
Hannover	26.0	30-Nov	0451 PM
Northeast Bismarck	24.5	30-Nov	0330 PM
Bismarck, North of Capitol	21.0	30-Nov	0900 AM
Hazen	21.0	30-Nov	0600 AM
Mandan	20.0	30-Nov	1230 PM
Underwood	20.0	30-Nov	0649 AM
Washburn	19.0	30-Nov	0552 PM
NWS Bismarck Airport	18.7	30-Nov	0600 AM
Minot Air Force Base	16.0	30-Nov	0901 AM
1 NNW Garrison	15.0	30-Nov	0700 AM
Dickinson	14.5	30-Nov	0816 PM
New Town	13.0	29-Nov	0315 PM
Heart Butte Dam	10.0	30-Nov	0800 AM
Watford City	8.0	29-Nov	0800 AM
Williston	6.0	29-Nov	0345 AM

September-October-November 2016 precipitation accumulations and percent of normal precipitation are shown in **Figure 5**. Since September, precipitation accumulations have been above normal in Wyoming and Montana, while the dry pattern has continued in Colorado, eastern Wyoming, western Nebraska and much of South Dakota. Large regions of Montana and Wyoming received greater than 150% of normal precipitation. Southeastern South Dakota and northwestern Iowa also received greater than 150% of normal precipitation since September 1.

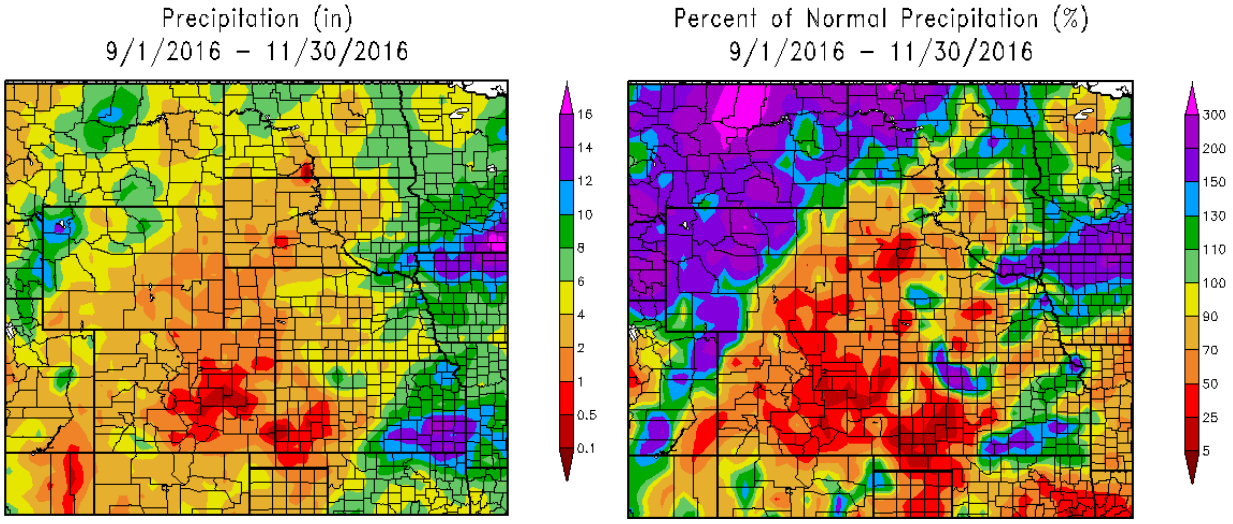


Figure 5. September-October-November 2016 Precipitation (inches) and Percent of Normal Precipitation. Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Temperature

November temperature departures from normal are shown in the left image of **Figure 6** in degrees Fahrenheit (deg F). September-October-November 2016 temperature departures from normal are shown in the right image of **Figure 6**. Temperatures were 6 to 12 deg F above normal in much of the upper Basin, highlighted by a record warm November in Jamestown, ND and the second warmest November on record in Bismarck. In contrast, the last four days of November were much colder than normal due to a very large and persistent winter storm that primarily effected North Dakota and portions of South Dakota. Temperature departures during the September-October-November period in the right image of **Figure 6** range from 2 to 8 deg F above normal in Montana and Wyoming and 4 to 8 deg F above normal in the Dakotas, Nebraska, Iowa, Kansas and Missouri. Warmer-than-normal temperatures have slowed the formation of mountain snowpack in Montana and Wyoming.

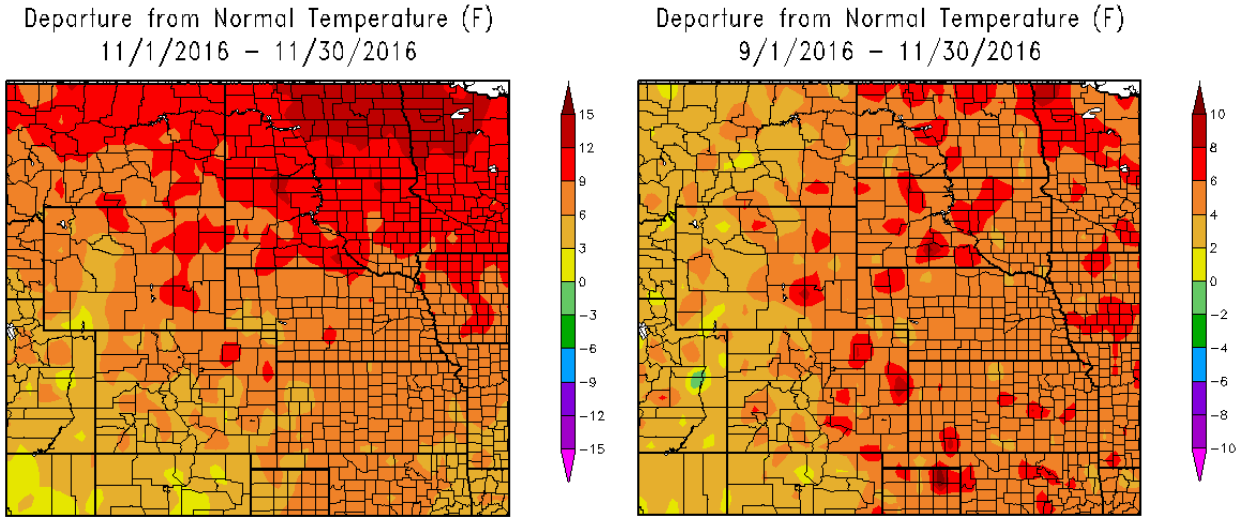


Figure 6. November 2016 and September-October-November 2016 Departure from Normal Temperature (deg F). Source: High Plains Regional Climate Center, http://www.hprcc.unl.edu/.

Soil Moisture

Soil moisture is factored into the forecast as an indicator of wet or dry hydrologic basin conditions. Typically when soil moisture conditions are wet or greater than normal, rainfall and snowmelt runoff is greater than when soil moisture is dry or less than normal. Not only is soil moisture a physical parameter that influences runoff, it can be used as an indicator of future runoff. As the calendar year approaches winter, the wet and dry soil moisture conditions will provide some insight into late winter and early spring runoff potential.

Figure 7 shows the NOAA NLDAS ensemble top one-meter soil moisture anomaly on November 28, 2016. The NLDAS soil moisture depiction is an average value for the one-meter soil moisture column. **Figure 7** indicates that soil moisture is predominantly wetter than normal (above normal anomalies) over Montana, western and northern Wyoming, northwestern North Dakota, northern and western Iowa and southeastern South Dakota. Drier-than-normal soil

moisture conditions (below normal anomalies) are present in central North Dakota, South Dakota, eastern Wyoming, Nebraska and Missouri.

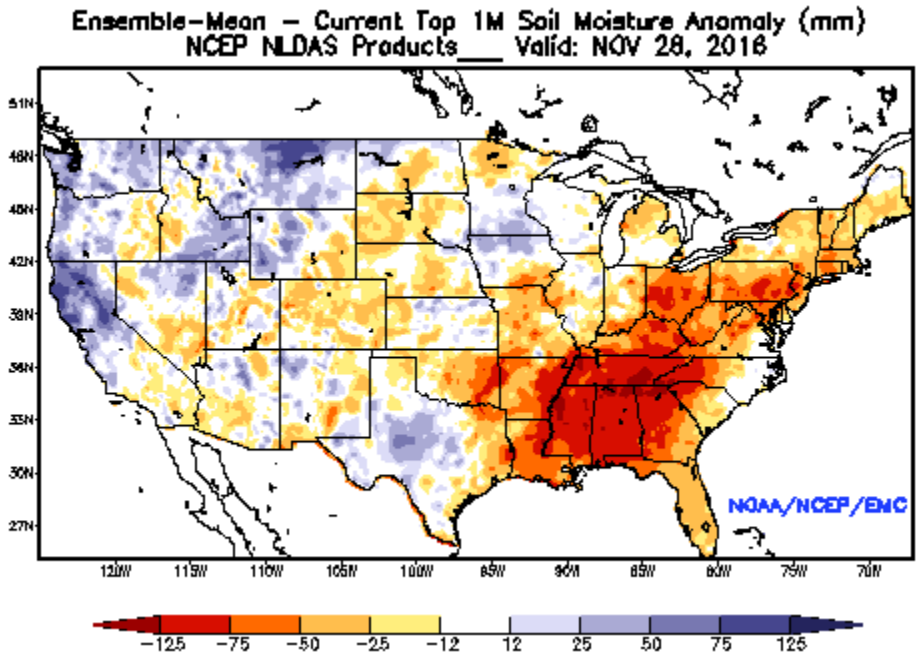


Figure 7. Top 1-Meter Soil Moisture Anomaly on November 28, 2016. Source: NOAA NLDAS Drought Monitor Soil Moisture. http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

Mountain Snowpack

Mountain snowpack is the primary factor used to predict May-July runoff volumes in the Fort Peck and Fort Peck to Garrison mainstem reaches. It is typically NOT a factor influencing runoff at the end of a calendar year.

Figure 8 includes time series plots of the average mountain SWE beginning on October 1, 2016 based on the NRCS SNOTEL data for the headwater basin above Fort Peck and the incremental basin from Fort Peck to Garrison. The current average SWE values (shaded blue area) are plotted against the 1981-2010 basin average SWE (bold red line), a recent low SWE year in 2001 (green line), and two historic high SWE years occurring in 1997 (purple) and 2011 (dark blue).

As of November 30, 2016, the Corps of Engineers computed an average mountain SWE in the Fort Peck reservoir reach of 1.39 inches, which is 37% of average based on the 1981-2010 average SWE for the Fort Peck reach. In the reservoir reach between Fort Peck Dam and Garrison Dam, the Corps computed an average mountain SWE of 2.3 inches, which is 61% of average based on the 1981-2010 average SWE for the Garrison reach. It is very early in the mountain snowpack accumulation period. By December 1, only 26% of the total accumulation normally occurs. Warm temperatures have been a major factor in the slow accumulation of mountain snowpack.

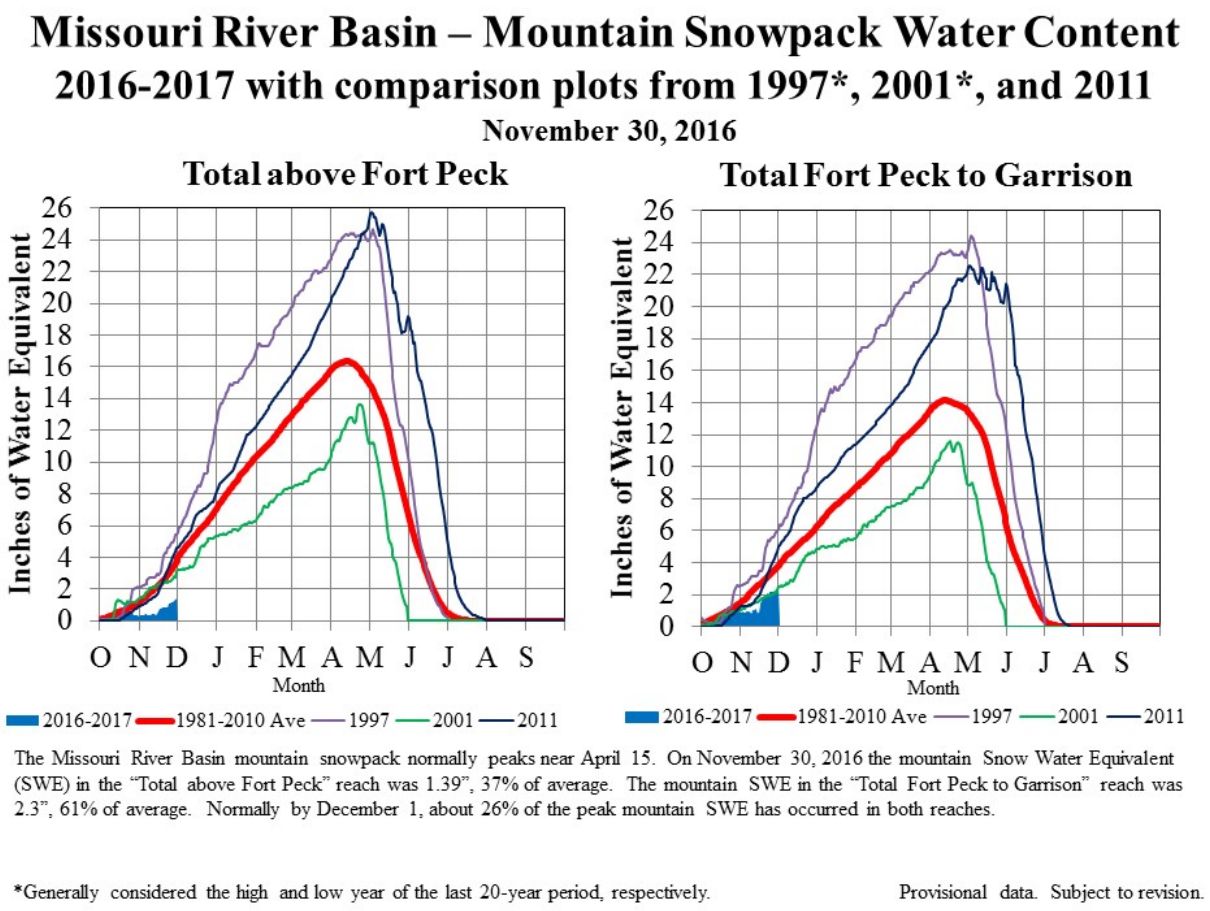


Figure 8. Mountain snowpack water content on November 30, 2016 compared to normal and historic conditions. Corps of Engineers - Missouri River Basin Water Management.

Climate Outlook

MRBWMD participates in the monthly North Central U.S. Climate/Drought Outlook Webinar coordinated through NOAA, the regional climate centers, and the American Association of State Climatologists (AASC). These webinars provide updates on near-term climate outlooks and impacts including the ENSO climate pattern and its implications on winter temperature and precipitation patterns in the Missouri River Basin.

ENSO (El Niño Southern Oscillation)

The latest ENSO update, posted November 28, indicates that a weak La Niña condition is present and will persist through the 2016-2017 winter. The impact of La Niña on Missouri Basin climate is reflected in the one-month and three-month CPC temperature and precipitation outlooks.

Temperature and Precipitation Outlooks

With regard to future weather, the CPC outlooks for the next two weeks indicate a high chance for below-normal temperatures in the Missouri Basin and a moderate chance for above-normal precipitation. The December outlooks in **Figure 9** indicate a moderately high chance for below-normal temperatures in the upper Basin and an increased chance for above-normal precipitation. The December through February temperature outlooks in **Figure 10** indicate increased chances for below-normal temperatures in the north central U.S. and increased chances for above-normal precipitation in the northern Rockies and northern Plains.

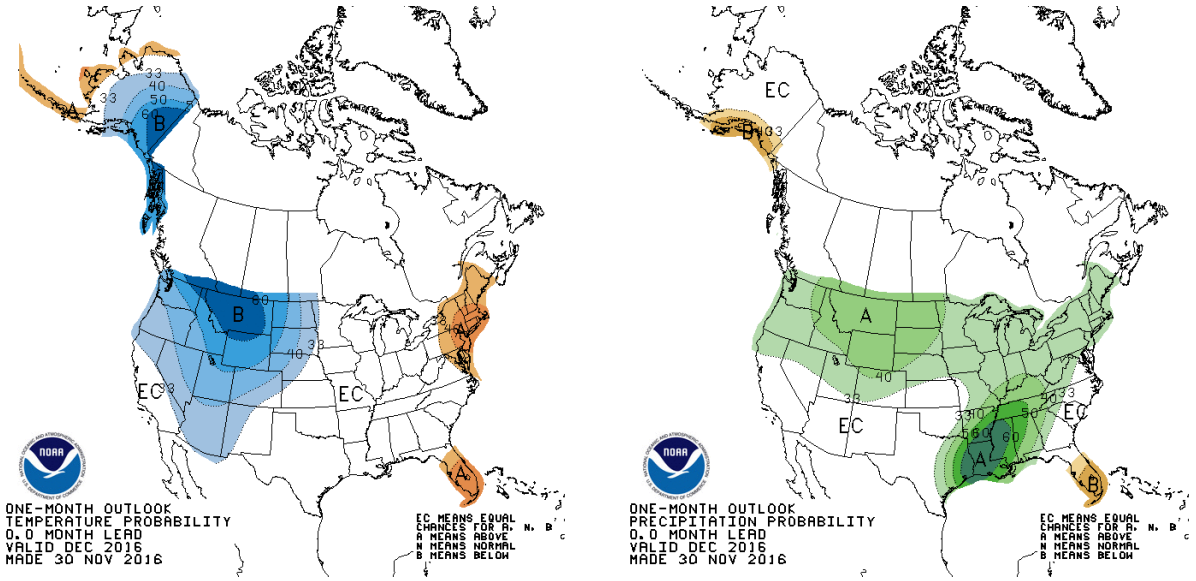


Figure 9. CPC December 2016 temperature and precipitation outlooks.

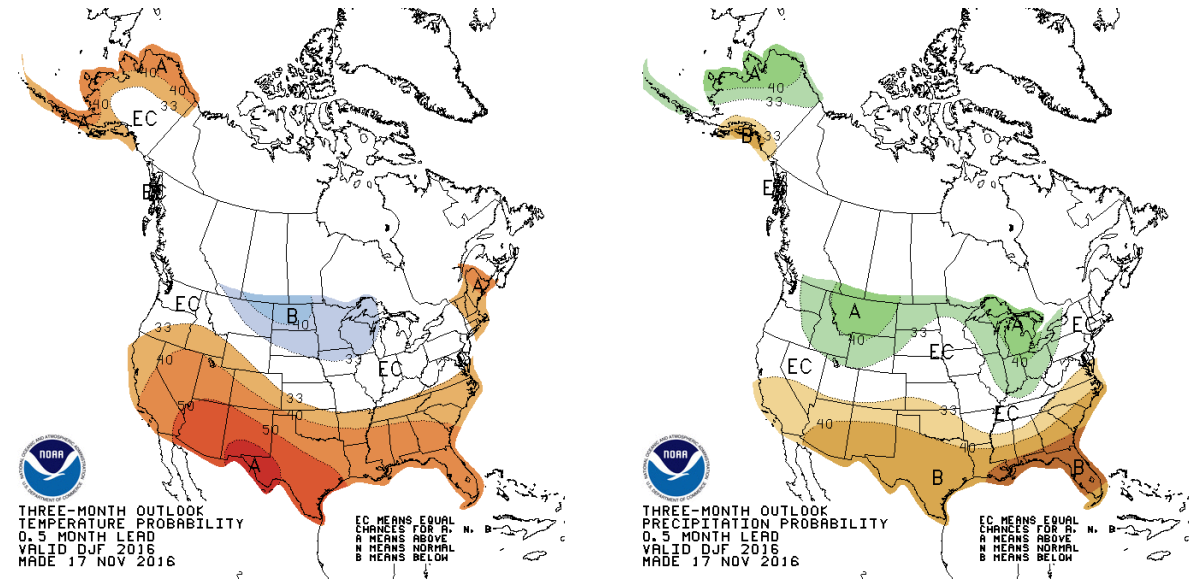


Figure 10. CPC December 2016-January-February 2017 temperature and precipitation outlooks.

December 2016 Calendar Year Runoff Forecast

The December calendar year runoff forecast for the upper Basin, is **24.3 MAF** (96% of average). Runoff for the basin above Gavins Point Dam is forecast to be **20.3 MAF** (88% of average). Runoff in January and February of 2017 is currently forecast to be about normal, but it will depend greatly on winter temperatures.