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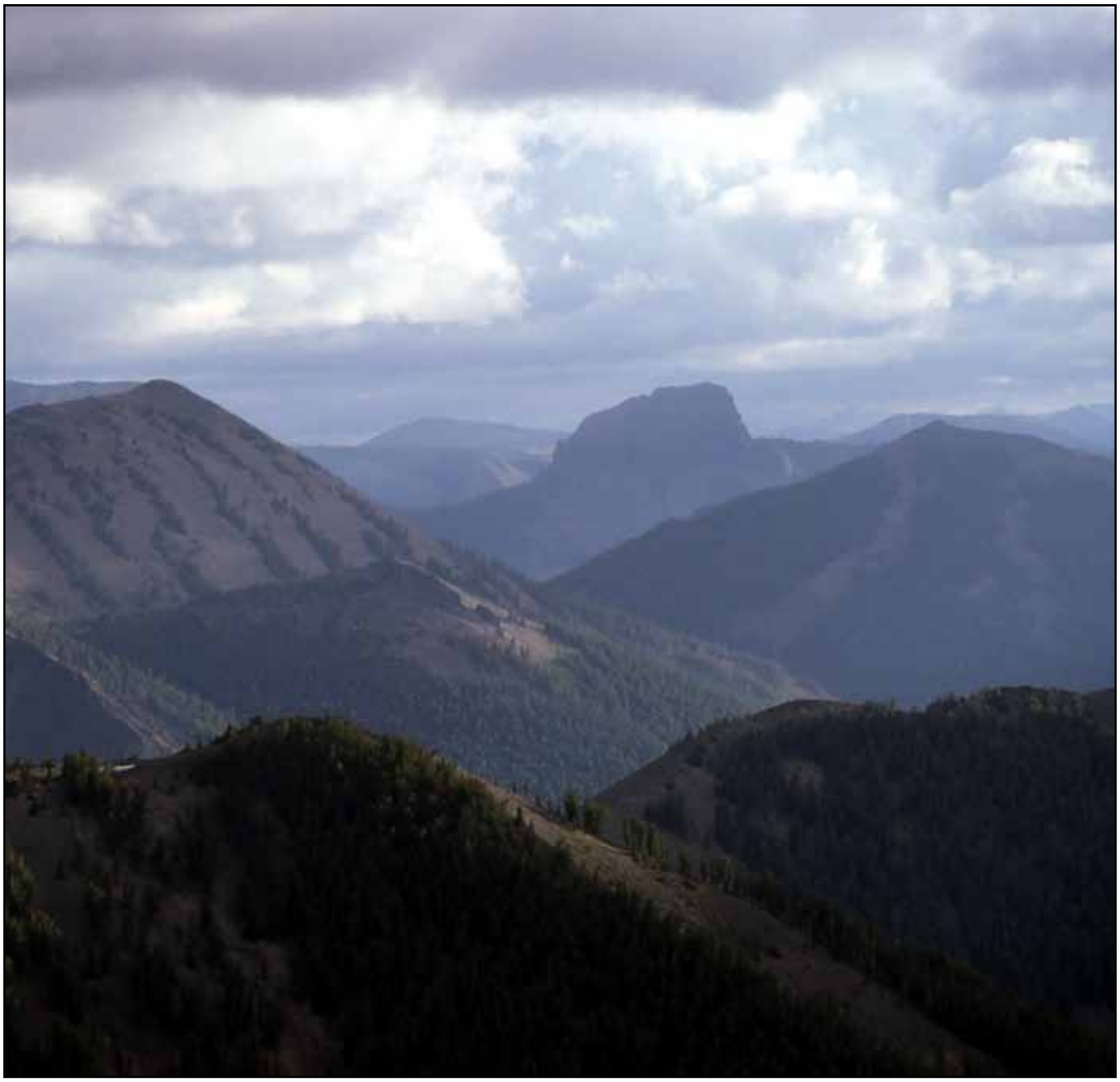
Greater Yellowstone Network

Climate of 2008

Natural Resource Report NPS/GRYN/NRR—2010/173



ON THE COVER

Sylvan Pass area in southeastern Yellowstone National Park, 1977.
NPS photo by J. Schmidt.

Greater Yellowstone Network

Climate of 2008

Natural Resource Report NPS/GRYN/NRR—2010/173

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Summary

This report describes the climate of 2008 for parks in the Greater Yellowstone Network (GRYN; Bighorn Canyon National Recreation Area, Grand Teton National Park, and Yellowstone National Park) and surrounding areas. It focuses on temperature and precipitation, while providing supplemental information on snowpack, streamflow, and the regional drought status. The report includes a series of maps that convey GRYN area climatic conditions, as well as records from individual observing stations used to highlight variability at finer-scales within the GRYN.

Compared to the standard climatological reference period (currently 1971–2000), the GRYN received 87% of average precipitation in 2008. Although the GRYN area was slightly drier than 1971–2000, it was less dry than in 2007 when the area received ~80% of average precipitation. May 2008 was especially notable for bringing major improvements to the area's moisture status. Bighorn Canyon in particular received large amounts of precipitation as a string of storms moved through the area from 22 May to 27 May. July was dry throughout the GRYN area, with parts of Yellowstone and Bighorn Canyon receiving less than 25% of average precipitation. Yellowstone and Grand Teton had lower-than-average precipitation in August and September. Large storms in late December closed the year on a wet note.

Compared to 2007—an especially hot year by most measures—temperatures in 2008 were much closer to average. The GRYN was generally cold in January 2008, but lower-than-average temperatures were especially prominent in Yellowstone and Grand Teton. At Old Faithful in Yellowstone, for example, the maximum temperatures in January were 6.1°F below average, while maximum temperatures at Moran in Grand Teton were 4.5°F below average. Spring and early summer 2008 were cool to near average across the GRYN area. July and August were warm in Yellowstone and Grand Teton, with maximum daily temperatures ranging from 2°F to 4°F warmer than average. Stations in Yellowstone and Grand Teton reported a large number of days exceeding 80°F in 2008. November 2008 was marked by very warm temperatures, with the Mammoth station in Yellowstone recording minimum daily temperatures for the month at 9.3°F above average. Most stations recorded near average temperatures in December 2008, though key locations in Yellowstone were generally ~2°F cooler than long-term means.

The climate of 2008 brought near average snowpack to the GRYN, making it one of the wettest winters the GRYN area has experienced in the last 7–9 years. GRYN area stream conditions were characterized by near-average to slightly higher-than-average discharge. Unlike many years in the past decade, highcountry snowpack persisted into the early summer, leading to near or slightly above average flows later in the summer. Persistent snowpack combined with residual moisture from late May storms helped the area avoid the onset of severe drought conditions later in the summer and fall.

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The Greater Yellowstone Network comprises Bighorn Canyon National Recreation Area, Grand Teton National Park (shown here) including the John D. Rockefeller, Jr. Memorial Parkway, and Yellowstone National Park.

1. Introduction

1.1 Background

This report is the second installment in an annual series detailing the climate of the Greater Yellowstone Network (GRYN). The GRYN comprises three National Park Service units: Bighorn Canyon National Recreation Area, Grand Teton National Park (including the John D. Rockefeller, Jr. Memorial Parkway), and Yellowstone National Park. The GRYN covers a vast area and encompasses a variety of climatic zones (Martner 1986). For example, the Teton Range and the Yellowstone Plateau represent some of the wettest and coolest areas in the Interior West, while the Bighorn Canyon area is one of the driest and warmest. Factors controlling climate vary throughout the GRYN area; western portions of the GRYN are influence by the Pacific Northwest climate, while a mid-continental or Great Plains-type climate prevails in the east (Despain 1987; Whitlock et al. 1995; Mock 1996; Gray et al. 2004).

The purpose of the GRYN annual climate report series is twofold: First, these reports detail recent climatic events from both local (single weather stations) and park-level perspectives. Second, these reports place GRYN climate in a regional setting, and consider recent events in a historical context, based primarily on a standard 30-year climatological reference or "normal" period (currently 1971–2000). The content is generally divided into discussions of temperature and precipitation and further sub-divided into regional- and station-level reviews. Information on recent precipitation and temperature variability is supplemented by sections on snowpack, streamflow, and GRYN area drought status. Figure 1 illustrates the location of stations used in this report and links to all stations and station metadata are available Appendix A, B, and C.

Those interested in additional climate-related information for the GRYN and surrounding areas should seek:

- Western Regional Climate Center (http://www.wrcc.dri.edu/)
- Western Water Assessment (http://wwa.colorado.edu/)
- Drought Monitor (http://drought.unl.edu/dm/monitor.html)
- NOAA (National Oceanic Atmospheric Administration) National Weather Service Climate Prediction Center (http://www.cpc.ncep.noaa.gov/)
- Natural Resources Conservation Service National Water and Climate Center (http://www.wcc.nrcs.usda.gov/)
- USGS (U.S. Geological Survey) Water National Information System (http://waterdata.usgs.gov/nwis)
- Idaho State Climate Services (http://snow.ag.uidaho.edu/index.html)
- Montana Climate Office (http://climate.ntsg.umt.edu/)
- Wyoming State Climate Office (http://www.wrds.uwyo.edu/wrds/wsc/wsc.html)

1.2 Approach and Methodology

Given the relatively sparse network of climate stations and complex topography of the GRYN area, grid-based estimates of precipitation and temperature were used to provide an overview of climatic conditions in the area. These estimates are generated via a statistical modeling technique that interpolates precipitation values between actual climate observing stations while also accounting for the effects of aspect and elevation. Known as the Parameter-elevation Regression on Independent Slopes Model (PRISM; http://www.prism.oregonstate.edu/), this approach has a long history of use in the western United States, and it has been shown to provide highly robust products in a wide variety of studies (Daly et al. 2008). Records from individual precipitation and temperature observing stations are included as a way to highlight intra-regional variability. Snowpack and streamflow measurements are presented as both integrators of multiple aspects of GRYN area climate (e.g., temperature, precipitation, relative humidity) and as key drivers of ecosystem processes. In the final section, drought conditions as reported by the U.S. Drought Monitor (http://drought.unl.edu/dm/monitor.html) provide a general, "broad brush" overview of GRYN area climates throughout the year.

The GRYN parks and surrounding areas are home to dozens of networks and sensor platforms monitoring a wide range of climatic and hydrological variables. The process of selecting networks and specific stations included in this report is described in the document, *Report Preparation and Data Issues: Annual Climate of the Greater Yellowstone Network*, available from the GRYN. Generally the selection criteria were:

1. Networks and stations provide good spatial coverage within the GRYN—networks and stations represent the major climatic and ecological zones within the parks and surrounding areas.

2. Networks and stations provide a sufficient length of record to allow the assessment of trends and provide historical context for current observations.

3. Instrumentation at individual stations is relatively consistent over the life of the record.

4. Instrumentation and siting standards used in selected networks are suitable for providing consistent, continuous, and long-duration records of climate and streamflow.

The agencies responsible for the initial data collection (e.g., National Weather Service) and the parties responsible for archiving these data (e.g., Western Regional Climate Center) performed basic quality control measures. The report authors also performed a series of quality checks involving visual inspection of the time series, comparison with historical observations and observations from surrounding sites, and logical consistency tests (e.g., confirming that minimum daily temperatures were lower than the daily maximum temperatures). In the case of National Weather Service Cooperative Observer (COOP) station data, the authors compared archived observations with the original datasheets provided by observers. Point observations provided by the COOP stations were also compared to corresponding estimates from the PRISM datasets.

Results for temperature, precipitation, and drought are reported on a calendar-year basis. Results for snowpack or snow water equivalent (SWE) and streamflow are reported for the water year (previous October through current September—October 2007 through September 2008 in this report), to capture the full winter contribution to GRYN area moisture status and hydrology. Temperature, precipitation, and snowpack observations for the reporting year are compared against a standard 30-year climatological reference or "normal" period (currently 1971–2000). Because the length of record varies considerably from gauging station to gauging station and not all key gauging station records extend back to 1971, streamflow observations for the reporting year are compared to a baseline encompassing the entire period of record. Lists of individual stations used in this report and links to station data are found in the appendices.

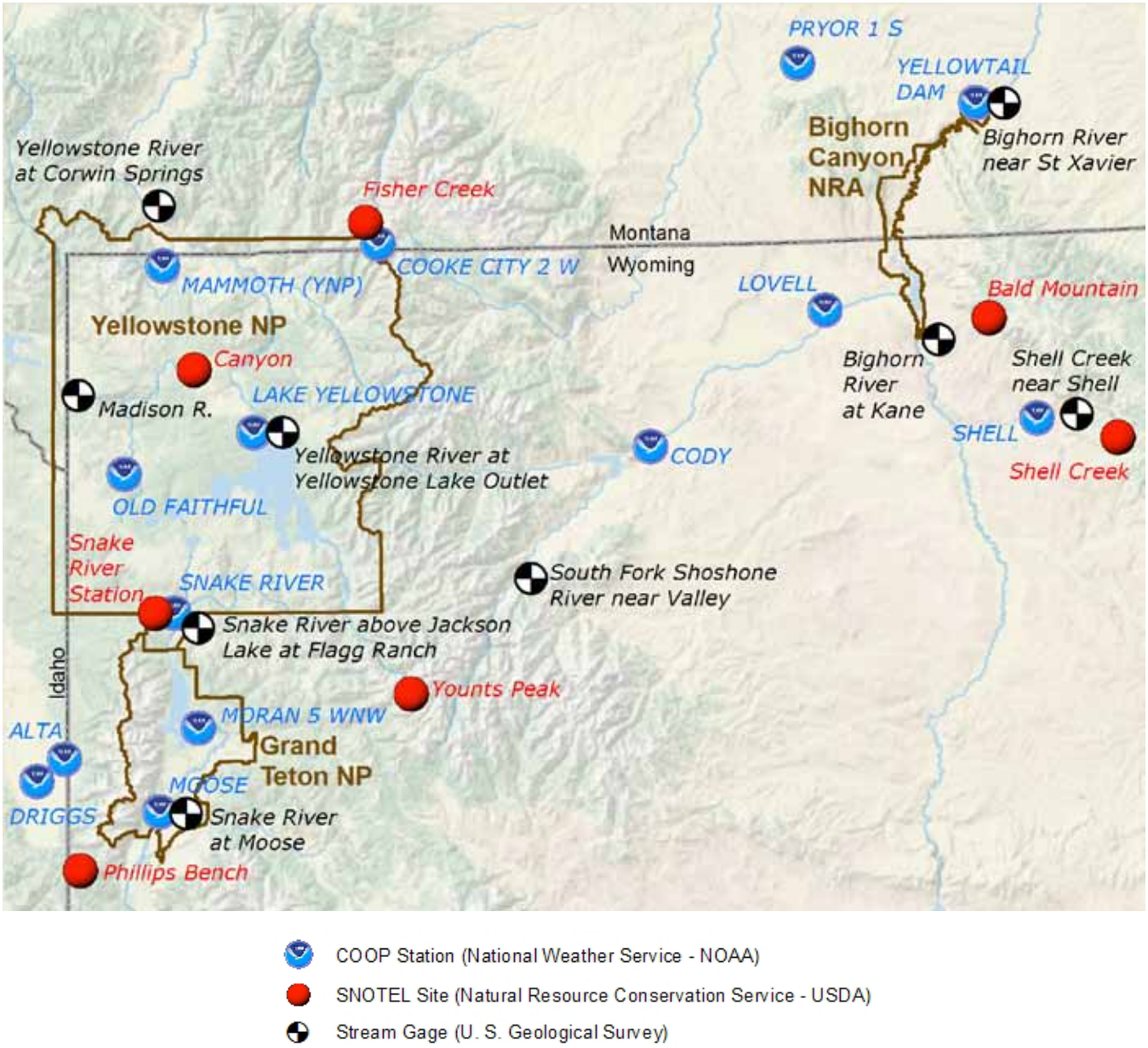

Figure 1. Map showing climate stations used in this report: National Weather Service Cooperative Observer (COOP) stations, Natural Resource Conservation Service SNOTEL sites, and U.S. Geological Survey stream gauges.

PETE SAWTELL

Storms in May 2008 caused precipitation totals to be greater than 200% than the 1971–2000 averages in some areas near Bighorn Canyon National Recreation Area. May precipitation is critical for determining soil moisture during the growing season and forage production, and determining runoff in this area.

2. Annual Summaries for GRYN Area Climate

2.1 Precipitation

Grid-based estimates of precipitation generated via the PRISM approach were used to provide an overview of climatic conditions in the GRYN area. January 2008 was wetter than the 1971–2000 average in most of Yellowstone and Grand Teton, as well as areas surrounding the southern half of Bighorn Canyon (fig. 2). In contrast, much of the watershed above Bighorn Canyon was moderately dry in January. These conditions followed a fall 2007 featured a very wet October and a moderately-dry to severely-dry November (Gray et al. 2009). Generally, precipitation for February 2008 in Yellowstone and Grand Teton was near the 1971–2000 average. March was very wet in Grand Teton, with some areas receiving >175% of average precipitation. These same months were noticeably drier in the Bighorn Canyon region, with less than 25% of average precipitation falling in February. This overall dryness continued through April in Bighorn Canyon and in portions of Grand Teton. The eastern half of Yellowstone also experienced significant dryness during April.

Precipitation in May 2008 brought major changes to moisture status in the GRYN area. To the east of Yellowstone and Grand Teton, May precipitation totals were often greater than 200% of the 1971–2000 average (fig. 2), with much of this precipitation resulting from a string of powerful storms that began passing through the area on 22 May. These storms produced numerous records for 24-hour precipitation at locations surrounding Bighorn Canyon and northern Yellowstone. Yellowstone and Grand Teton were noticeably drier than Bighorn Canyon in May 2008, but were both generally near or above 1971–2000 averages for precipitation. This May 2008 wetness was in stark contrast to conditions in May 2007, when precipitation totals were lower than 25% of average across much of the GRYN. When measured as a percentage of total annual precipitation, May historically represents the wettest or second wettest month of the year in the Bighorn River drainage, Bighorn Canyon, and roughly the northeastern half of Yellowstone. May precipitation is also critical for controlling forage production and soil moisture content over the growing season, as well as for determining runoff in the eastern half of the GRYN area.

June 2008 brought near average conditions to Grand Teton and near average-to-wet conditions in Yellowstone (fig. 2). In the same month, the southern half of Bighorn Canyon and much of the Bighorn Basin experienced significant drying. July was dry throughout

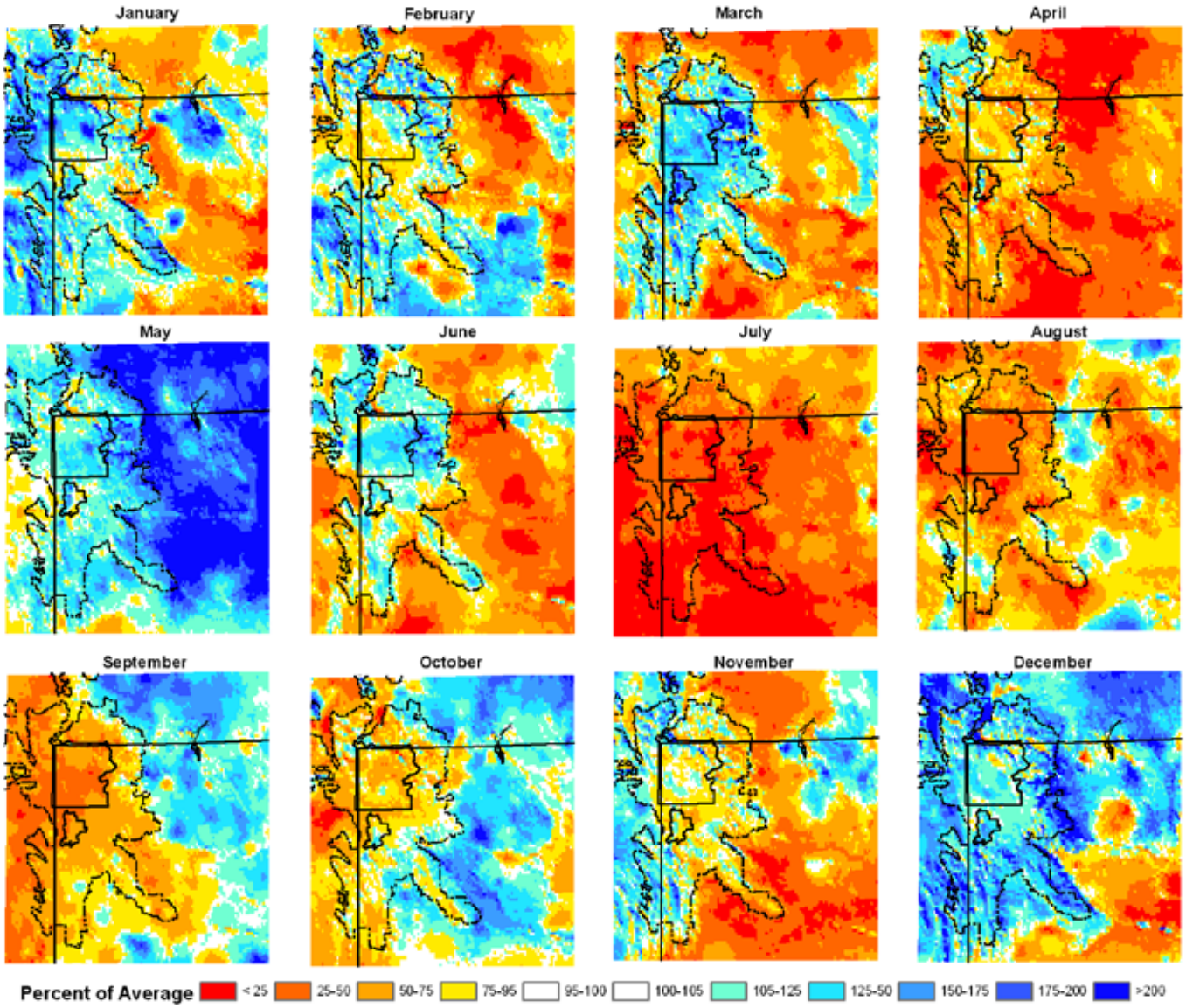

Figure 2. Maps showing percent of average precipitation versus 1971–2000 for each month in calendar year 2008. Maps were created using estimates from the Parameter-elevation Regressions on Independent Slopes Model (PRISM). PRISM interpolates precipitation values between actual observation stations, and corrects these interpolated estimates for changes in topography across the region. For more information, see http://www.prism.oregonstate.edu/.

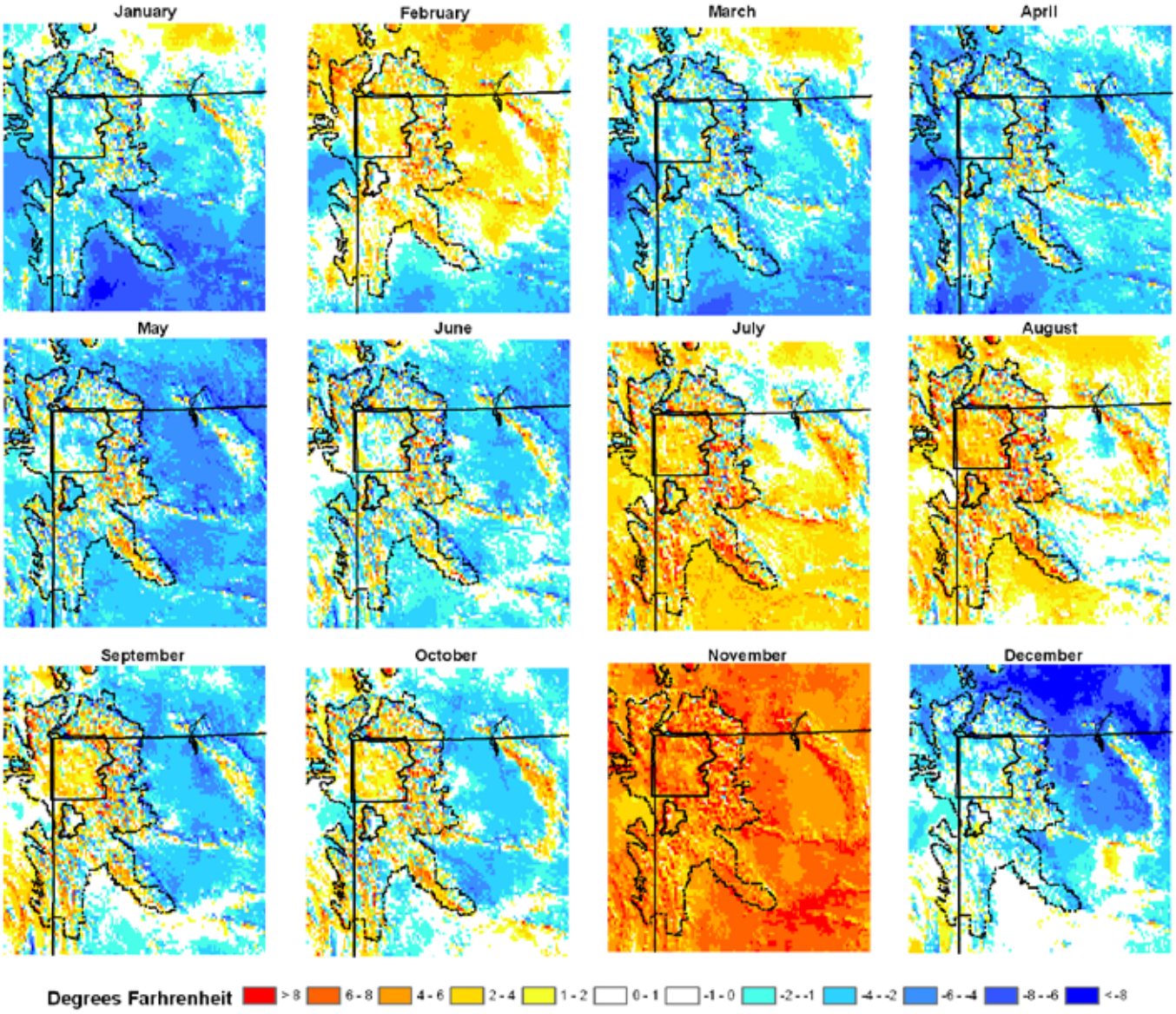

Figure 3. Maps showing departures from average maximum daily temperatures for each month in calendar year 2008 versus 1971–2000. Departure values are reported in degrees Fahrenheit. Maps were created using estimates from the Parameter-elevation Regressions on Independent Slopes Model (PRISM). PRISM interpolates temperature values between actual observation stations, and corrects these estimates for changes in topography across the region. For more information, see http://www.prism.oregonstate.edu/.

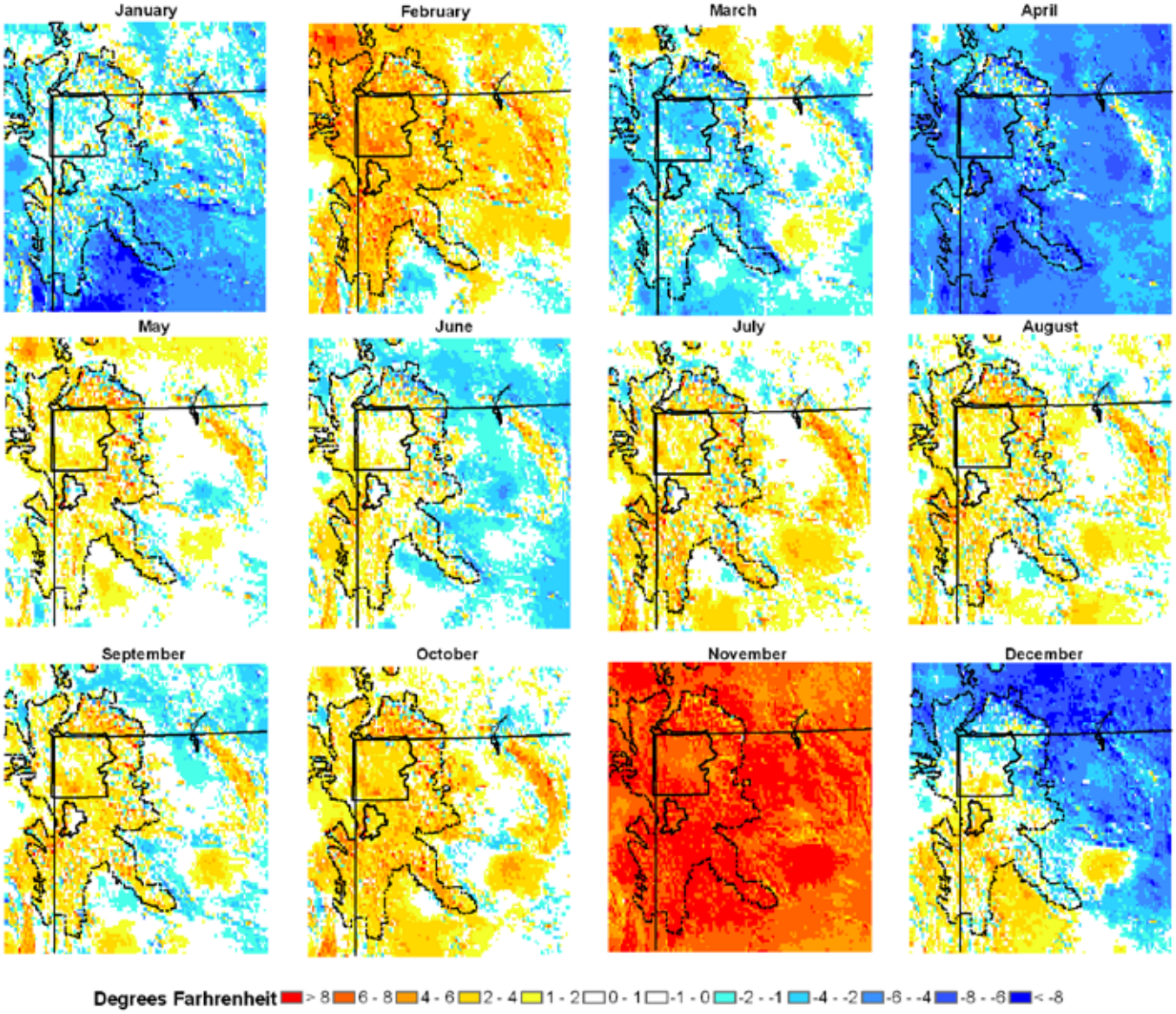

Figure 4. Maps showing departures from average minimum daily temperatures for each month in calendar year 2008 versus 1971–2000. Departure values are reported in degrees Fahrenheit. Maps were created using estimates from the Parameter-elevation Regressions on Independent Slopes Model (PRISM). PRISM interpolates temperature values between actual observation stations, and corrects these estimates for changes in topography across the region. For more information, see http://www.prism.oregonstate.edu/.

the GRYN, with parts of Yellowstone and the Bighorn Canyon area receiving less than 25% of the 1971–2000 average for precipitation. This pattern of relative dryness continued throughout the area in August, and lower-than-average precipitation was observed in Yellowstone and Grand Teton through September. While this string of dry months from June through September undoubtedly brought significant short-term impacts to the GRYN, residual moisture from the late May 2008 storms combined with average-to-relatively cool spring temperatures and a long-lasting snowpack kept conditions from deteriorating into severe drought later in the growing season.

Scattered storms occurred in October and November, but this precipitation had little effect on the GRYN area's moisture status (fig. 2). December brought several significant snow storms to the GRYN area, particularly in the second half of the month. The largest of these storms began moving through the area on 22 December, and heavy snowfall continued in some parts of Yellowstone and Grand Teton through 26 December. Total accumulated precipitation for December 2008 was generally above the 1971–2000 average, and this moisture helped ease the impacts of summer dryness.

2.2 Temperature

As in the case of precipitation in the GRYN area, PRISM-based estimates were used to develop this overview of GRYN area temperatures. When averaged across the entire calendar year 2008, maximum daily temperatures were near or slightly below 1971–2000 averages in the GRYN (fig. 3). However, significant intra-GRYN area and month-to-month variations were also observed. Throughout most of the GRYN maximum daily temperatures in January, March, April, May, and June were 2–3°F below average. February and July through October had slightly warmer than average (~1–3°F) maximum daily temperatures in parts of Yellowstone, but the magnitude and sign of departures from the 1971–2000 average varied elsewhere. November had very warm maximum daily temperatures, with departures from the 1971–2000 average estimated at >6°F in some areas. Yellowstone and Grand Teton had near average maximum daily temperatures in December 2008, but cooler air dominated the Bighorn Basin and Bighorn Canyon throughout much of this month.

On the whole, minimum temperature patterns (fig. 4) were similar to those for maximum temperatures. Nighttime departures for the months of February, May, and October do appear slightly warmer than the corresponding departures for daytime temperatures. However, the overall magnitude of these differences was usually only 1–2°F, making it difficult to determine their climatological significance. The opposite scenario (i.e., cooler than 1971–2000 averages) was also true for minimum temperatures in April, and for July through September. As in the case of maximum temperatures, November 2008 was notable for its warm nights. Most areas within the GRYN showed minimum temperatures for November that were 6–7°F above average, and positive departures of greater than 8°F were common.

Compared to 2007—an especially hot year by most measures—2008 was relatively cool. Spring and summer 2007 were particularly warm, and these temperatures contributed to the development of severe drought conditions in GRYN last year. In contrast, spring and early summer 2008 were cool to near average, and this likely helped keep dryness in July and August from turning into what could have become a much more serious drought situation.

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When taken as an average across all key precipitation reporting sites within the Greater Yellowstone Network, 2008 was slightly drier than the 1971–2000 average (87%). Weather stations in Yellowstone National Park generally recorded greater than average precipitation totals in the beginning of 2008.

3. Annual Summaries for GRYN Area Climate Stations

3.1 Precipitation

While PRISM-based estimates provide an overview of month-to-month precipitation variability across the entire GRYN area, records from select National Weather Service COOP stations show key aspects of local variability within and around the three park units (appendix 1). As in the GRYN area maps (fig. 2), individual stations in or near Yellowstone and Grand Teton generally reported greater than average precipitation totals in January 2008 (table 1). This wetness was especially apparent at the Mammoth and Old Faithful stations in Yellowstone (Wyoming), both of which reported ~150% of the 1971–2000 average precipitation for the month. Similarly, the Moose and Moran, Wyoming, stations in Grand Teton reported 137% and 130% of average precipitation, respectively. The Lovell and Powell, Wyoming, stations located near the southern end of Bighorn Canyon reported >215% of average precipitation for January. Large amounts of precipitation were recorded in far northeast Yellowstone in January, as reflected in the 166% of average recorded in Cooke City, Montana. On the other hand, no station in the immediate vicinity of Bighorn Canyon reported more than 17% of average precipitation for February, and two stations—Powell, Wyoming, and Pryor, Montana—reported no precipitation for the entire month. This contrast between wetness in Yellowstone and Grand Teton and dryness in Bighorn Canyon continued into March. Two locations within Grand Teton (Moose and Moran, Wyoming) reported 161% and 179% of 1971–2000 average precipitation for the month of March 2008, whereas the station at the outlet from Bighorn Lake (Yellowtail Dam, Montana) reported only 23% of average. With the exception of Cooke City, Montana, near the northeast entrance to Yellowstone, all GRYN area stations reported relatively dry conditions in April 2008.

The remarkable turnaround in moisture conditions that was brought on by a series of strong storms in late May 2008 is particularly noticeable in the individual station records from Bighorn Canyon and surrounding areas (table 1). Three of the four reporting

Table 1. Total monthly precipitation in inches and percentage of average monthly precipitation versus 1971–2000 averages for select Greater Yellowstone Network area stations during 2008

Station Name	Station ID	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Mammoth YNP	489905	1.34 (152)	0.57[a] (89)	1.19 (110)	0.72 (66)	1.96 (98)	— (—)	2.02 (127)	0.93 (65)	— (—)	1.32[a] (139)	1.09 (116)	1.26 (159)	12.40 (85)
Cooke City 2 W, MT	241995	2.07 (90)	2.97 (166)	3.29[c] (165)	1.86 (104)	4.07 (151)	3.12 (109)	0.60 (28)	0.53 (25)	1.29 (66)	1.20 (75)	1.55 (76)	— (—)	22.55 (89)
Lake Yellowstone	485345	— (—)	— (—)	— (—)	— (—)	— (—)	3.33[b] (160)	0.85[c] (51)	0.41 (24)	0.40 (25)	0.75 (57)	1.63[b] (95)	2.25[a] (134)	21.13 (104)
Old Faithful, WY	486845	3.36[a] (145)	1.36[a] (65)	3.40 (159)	— (—)	4.13 (169)	2.84 (133)	0.24 (15)	0.23[a] (17)	0.84[a] (53)	— (—)	2.52 (107)	3.36 (130)	23.36 (96)
Snake River, WY	488315	3.84[a] (98)	— (—)	— (—)	— (—)	1.64[a] (60)	2.28[b] (99)	0.49 (29)	0.63 (38)	— (—)	— (—)	— (—)	— (—)	12.27 (39)
Moose, WY	486428	3.50[b] (137)	2.48 (118)	2.66[a] (161)	0.42 (29)	1.91[c] (95)	1.21 (71)	0.50[a] (35)	— (—)	1.23[b] (93)	1.49[a] (118)	2.97 (134)	3.97 (161)	22.34 (104)
Moran 5 WNW, WY	486440	4.19 (130)	2.51 (106)	4.01 (179)	0.96 (48)	2.18 (94)	2.11 (138)	— (—)	0.40 (31)	— (—)	1.29 (81)	2.10 (73)	— (—)	19.75 (78)
Alta 1 NW, WY	480140	2.56 (109)	1.84[b] (103)	3.72 (188)	0.82 (39)	3.72 (106)	1.40 (66)	1.80 (100)	1.86 (121)	— (—)	— (—)	2.75 (130)	3.55 (171)	24.02 (96)
Driggs, ID	102676	2.10[b] (162)	0.98[b] (94)	1.12[b] (90)	0.32[b] (24)	2.36 (110)	0.60 (46)	0.86 (67)	0.50 (48)	1.21 (105)	1.14 (93)	1.77 (145)	— (—)	12.96 (82)
Cody, WY	481840	0.02 (4)	0.28 (104)	0.45 (88)	0.22 (19)	4.58 (234)	0.32 (20)	0.26 (21)	0.88 (98)	2.17 (192)	0.49[a] (56)	0.09 (19)	— (—)	9.76 (90)
Lovell, WY	485770	0.52 (217)	0.00 (0)	0.18 (55)	0.15 (25)	2.58 (213)	0.09 (9)	0.06[a] (8)	0.00 (0)	— (—)	— (—)	0.35 (146)	0.39 (170)	4.32 (64)
Shell, WY	488124	1.23 (216)	0.08 (17)	0.49 (83)	0.53 (55)	3.45 (216)	1.38 (98)	0.42 (45)	0.00 (0)	1.67 (130)	1.25[b] (145)	0.77[a] (143)	1.13 (226)	12.40 (121)
Pryor 1 S, MT	246747	0.32 (48)	0.00 (0)	0.80 (65)	0.00 (0)	6.56 (206)	1.67[b] (80)	0.46 (32)	— (—)	— (—)	3.30[b] (192)	0.00 (0)	— (—)	13.11 (78)
Yellowtail Dam, MT	249240	0.79[c] (92)	0.05 (7)	0.32[a] (23)	0.57 (27)	4.88 (158)	2.34 (106)	1.09 (75)	0.27 (28)	3.27 (185)	2.01 (106)	0.56 (59)	— (—)	16.15 (88)

Note: Percentages of average monthly precipitation versus 1971–2000 averages are given in parentheses. Station IDs are from National Weather Service Cooperative Observer stations. Monthly statistics are not reported if more than 3 days of data are missing. Individual months are not used for calculating annual statistics if more than 5 days of data are missing.
[a]1 day missing.
[b]2 days of data missing.
[c]3 days of data missing.

stations nearest to Bighorn Canyon (Lovell and Shell, Wyoming, and Pryor, Montana) reported >200% of 1971–2000 average precipitation during this month. Old Faithful in Yellowstone and Cooke City, Montana, were also quite wet in May 2008, with the two stations reporting 169 and 151% of average, respectively. On 22 May, the station at Cody, Wyoming, received 1.98 inches of liquid precipitation, making it the highest one-day total ever recorded in the month of May, and the third highest total for any 24-hour period since 1915. Other GRYN area stations showed similarly high one-day totals for 22 May, notably Moose, Wyoming, at 0.95 inches (the second highest one-day precipitation total for any May on record) and Powell, Wyoming, at 0.90 (the fifth highest one-day total for any May on record). Though not as powerful as the 22 May to 23 May storms, 26 May to 27 May also brought heavy precipitation to much of the GRYN. On 27 May the station at Yellowtail Dam, Montana, received 1.61 inches, an astounding amount for one of the most arid locations within the GRYN area.

Most stations in Yellowstone and Grand Teton recorded near average to wet conditions in June 2008 (table 1). Lake Yellowstone, Wyoming, was the wettest reporting station in June at 160% of the 1971–2000 average. The most notable exception to this pattern in the Yellowstone and Grand Teton portion of the GRYN was Moose, Wyoming, at 71% of average for June. In July 2008, key stations across the GRYN experienced a general drying trend, with 8 of 14 sites reporting less than 50% of the 1971–2000 average. The stations at Old Faithful in Yellowstone and Lovell, Wyoming, were especially dry during July. Most stations in the GRYN area recorded little precipitation in August 2008, and two stations near Bighorn Canyon (Shell and Lovell, Wyoming) reported none.

Table 2. Average maximum daily temperatures in degrees Fahrenheit for select Greater Yellowstone Network area stations during 2008

Station Name	Station ID	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Mammoth YNP	489905	24.81 (-4.4)	35.97 (1.9)	30.77 (-9.6)	42.40 (-6.5)	— (—)	— (—)	81.61 (3.0)	80.65 (2.8)	— (—)	53.23[a] (-0.6)	43.74 (6.4)	26.93 (-2.3)	46.68 (-5.3)
Cooke City 2 W, MT	241995	20.80 (-2.8)	30.10 (-0.3)	33.00 (-3.8)	40.60 (-3.7)	51.60 (-2.1)	63.40 (-0.9)	76.60 (3.6)	74.60 (2.6)	63.10 (1.5)	48.50 (-0.4)	35.90 (4.3)	— (—)	48.93 (2.0)
Lake Yellowstone	485345	— (—)	28.17 (-0.1)	— (—)	— (—)	— (—)	59.77 (-1.3)	74.26 (3.9)	74.68[c] (4.3)	59.40 (-0.9)	47.29 (-0.9)	34.08[d] (1.0)	22.23[a] (-2.6)	49.99 (4.3)
Old Faithful, WY	486845	20.90 (-6.1)	27.10 (-5.4)	31.81 (-7.8)	38.00 (-7.8)	50.81 (-4.2)	61.70 (-3.8)	76.58 (2.1)	75.06 (1.6)	63.69[a] (1.1)	— (—)	40.22 (5.7)	24.39 (-2.2)	46.39 (-2.5)
Snake River, WY	488315	20.68 (-5.0)	27.86 (-3.4)	— (—)	— (—)	52.00 (-3.7)	63.43 (-3.2)	78.65 (3.2)	77.48 (2.5)	— (—)	— (—)	— (—)	— (—)	53.35 (4.1)
Moose, WY	486428	23.00 (-2.4)	31.93 (1.0)	36.16 (-3.4)	43.80 (-5.4)	56.71 (-3.9)	68.57 (-2.2)	82.26 (3.2)	— (—)	69.93[b] (1.3)	55.90[a] (0.7)	42.44 (5.3)	30.29 (4.8)	49.18 (-2.5)
Moran 5 WNW, WY	486440	22.23 (-4.5)	30.59 (-2.2)	35.26 (-5.3)	44.80 (-4.0)	56.16 (-2.3)	67.23 (-2.0)	— (—)	81.03 (3.7)	— (—)	52.86 (-1.8)	39.33 (2.8)	— (—)	47.72 (-3.8)
Alta 1 NW, WY	480140	22.58 (-6.4)	30.17 (-3.6)	32.81 (-7.2)	40.47 (-8.0)	55.52 (-4.1)	66.33 (-3.5)	80.29 (2.1)	78.29 (0.9)	— (—)	— (—)	41.96 (3.9)	28.61 (-0.8)	47.70 (-4.5)
Driggs, ID	102676	23.50 (-5.2)	29.20 (-3.9)	33.30 (-6.9)	44.30 (-6.7)	58.50 (-3.1)	68.10 (-3.1)	80.30 (1.5)	78.80 (0.6)	67.50 (-1.3)	54.40 (-2.2)	43.40 (3.7)	— (—)	52.85 (-0.3)
Cody, WY	481840	33.71 (-1.2)	42.83 (2.3)	45.87 (-2.6)	56.07 (-0.6)	64.94 (-0.6)	77.03 (1.4)	87.55 (4.6)	86.26 (4.9)	71.77 (0.8)	60.37[a] (0.9)	49.81 (5.9)	— (—)	61.47 (3.4)
Lovell, WY	485770	27.87 (-1.2)	38.14 (0.4)	46.55 (-2.4)	54.17 (-4.8)	62.97 (-5.3)	75.03 (-3.7)	87.06 (0.5)	85.47[a] (0.0)	— (—)	— (—)	49.37 (6.0)	30.54 (-1.4)	55.72 (-2.9)
Shell, WY	488124	29.39 (0.6)	37.24 (-1.5)	46.16 (-3.0)	54.27 (-5.4)	63.87 (-5.2)	76.07 (-3.6)	90.55 (3.1)	87.94 (2.3)	71.90 (-2.1)	60.28[b] (-1.3)	46.00[a] (3.3)	32.18 (-0.8)	57.99 (-1.1)
Pryor 1 S, MT	246747	— (—)	— (—)	— (—)	— (—)	— (—)	— (—)	— (—)	— (—)	— (—)	— (—)	— (—)	— (—)	— (—)
Yellowtail Dam, MT	249240	35.70 (-4.5)	43.90 (-2.2)	49.20 (-4.8)	56.90 (-6.5)	65.50 (-7.2)	76.30 (-6.4)	89.50 (-1.5)	90.10 (-0.9)	73.10 (-6.1)	62.20 (-3.9)	54.40 (5.4)	— (—)	63.35 (-1.5)

Note: Monthly average maximum daily temperature departures from 1971–2000 averages are given in parentheses in degrees Fahrenheit. Station IDs are from National Weather Service Cooperative Observer stations. Monthly statistics are not reported if more than 5 days of data are missing. Individual months are not used for calculating annual statistics if more than 5 days of data are missing.
[a]1 day missing.
[b]2 days of data missing.
[c]3 days of data missing.
[d]4 days of data missing.
[e]5 days of data missing.

The general dryness in Yellowstone continued through September 2008 when the Lake Yellowstone station reported only 25% of the 1971–2000 average. Some but not all stations within the GRYN recorded considerable amounts of precipitation September through November. Stations across the entire GRYN recorded significant moisture in December 2008, with many locations reporting >150% of average.

When taken as an average across all key precipitation reporting sites within the GRYN, 2008 was slightly drier than the 1971–2000 average (87%). However, 2008 was wetter than 2007, when the average across all 14 key stations was 79% of the 1971–2000 mean. The year 2008 also had more precipitation than 2006, when the eastern half of the GRYN received less than 70% of average.

3.2 Temperature

Observations from key stations in the GRYN area agree quite closely with the PRISM-derived temperature estimates used in the GRYN area climate overview, and station records also highlight important, fine-scale variations. The GRYN area as a whole was cool in January 2008, but individual station records show that daytime temperatures lower than the 1971–2000 average were especially prominent in Yellowstone and Grand Teton (table 2). At Old Faithful in Yellowstone, for example, maximum temperatures for January were 6.1°F below the 1971–2000 average, while Moran in Grand Teton was 4.5°F below average. Cold temperatures in January 2008 are partly reflected in the large number of days below 0°F recorded at stations throughout the area (table 3). Temperatures below 0°F are observed relatively infrequently in Cooke City, Montana, and Moran, Wyoming, yet both of these stations recorded more than 45 days below this threshold

Table 3. First and last freeze and frost dates, accumulated growing degree days, and days above or below critical temperature thresholds for key stations in the Greater Yellowstone Network during 2008

Station Name	Station ID	Last date ≤28°F in spring	Earliest date ≤28°F in fall	Last date ≤32°F in spring	Earliest date ≤32°F in fall	Accumulated growing degree days 40°F	Accumulated growing degree days 50°F	Number of days ≥80°F	Number of days ≥90°F	Number of days ≤0°F	Number of days ≤32°F
Mammoth YNP	489905	5/13 (5/23)	10/9 (9/17)	6/11 (6/14)	9/2 (9/8)	2782 (2731)	1340 (1200)	49 (31)	0 (0)	19 (0)	198 (215)
Cooke City 2 W, MT	241995	7/12 (6/25)	9/4 (8/28)	7/14 (7/13)	8/12 (8/13)	1566 (1606)	467 (473)	16 (0)	0 (0)	47 (0)	282 (272)
Lake Yellowstone	485345	6/13 (6/29)	9/2 (8/25)	7/12 (7/16)	8/22 (8/13)	1661 (1422)	577 (388)	9 (0)	0 (0)	42 (62)	194 (283)
Old Faithful, WY	486845	7/13 (6/28)	8/16 (8/23)	7/19 (7/15)	8/12 (8/9)	1569 (1721)	508 (545)	15 (0)	0 (0)	67 (64)	287 (273)
Snake River, WY	488315	7/12 (7/5)	8/12 (8/15)	7/31 (7/21)	8/12 (8/8)	1622 (1778)	528 (571)	25 (0)	0 (0)	58 (66)	225 (286)
Moose, WY	486428	6/9 (6/12)	9/5 (9/3)	6/14 (7/2)	8/12 (8/22)	2233 (2338)	926 (925)	50 (27)	1 (0)	48 (24)	252 (250)
Moran 5 WNW, WY	486440	6/13 (6/16)	8/27 (9/1)	6/20 (7/10)	8/12 (8/17)	1360 (1971)	471 (675)	21 (0)	0 (0)	45 (0)	211 (247)
Alta 1 NW, WY	480140	6/11 (6/3)	9/11 (9/10)	6/13 (6/30)	8/22 (8/30)	2707 (2656)	1258 (1151)	41 (5)	0 (0)	18 (0)	218 (221)
Driggs, ID	102676	6/12 (6/1)	9/11 (9/9)	6/12 (6/26)	9/5 (8/31)	2690 (2756)	1174 (1194)	39 (39)	0 (0)	21 (0)	218 (222)
Cody, WY	481840	5/3 (5/6)	10/10 (10/1)	5/10 (5/18)	10/9 (9/21)	4351 (4047)	2431 (2107)	87 (68)	22 (0)	18 (0)	173 (173)
Lovell, WY	485770	5/3 (5/1)	10/13 (10/2)	5/4 (5/16)	10/9 (9/19)	3722 (4086)	1956 (2215)	72 (81)	19 (0)	23 (0)	190 (190)
Shell, WY	488124	5/3 (5/10)	10/13 (10/1)	5/5 (5/24)	9/9 (9/18)	3874 (4101)	2124 (2220)	89 (87)	39 (0)	25 (0)	201 (199)
Yellowtail Dam, MT	249240	4/23 (4/19)	9/5 (10/15)	5/3 (5/7)	9/2 (10/2)	4377 (5217)	2351 (2951)	87 (96)	34 (41)	15 (0)	161 (142)

Note: Averages for 1971–2000 are given in parentheses. Historical values for above average freeze or frost dates are based on the entire period of available record, and historical values for all other periods are based on observations during the 1971–2000 period. Station IDs are from National Weather Service Cooperative Observer stations.

in 2008. February showed a pattern of maximum daily temperatures that were generally below the 1971–2000 average and minimum temperatures that were above average (table 4). The Snake River station located on the southern border of Yellowstone provides the most striking example of this with February maximum temperatures 3.4°F below average and minimum temperatures at 4.4° F above average.

Daytime temperatures in spring and early summer 2008 were cooler than the 1971–2000 average across the GRYN area (table 2). Departures from average were generally smaller for minimum temperatures except in April (table 4). The onset of spring, as measured by the last day with temperatures below 28°F, may have been delayed in some portions of the GRYN (table 3). In addition, 9 of the 13 key GRYN area stations (the 14th key climate station, Pryor S 1, Montana, did not record temperature data in 2008 or 2007) with reports showed lower-than-average growing degree accumulations, another measure of growing-season length, in 2008.

July and August were warm in Yellowstone and Grand Teton, with maximum daily temperatures at key stations ranging from 2 to 4°F warmer than the 1971–2000 averages (table 2). Yellowstone and Grand Teton area stations reported a relatively large number of days exceeding 80°F in 2008 (table 3). Three stations in the Bighorn River drainage (Cody, Lovell, and Shell, Wyoming, stations) also reported numerous days above 90°F, which is somewhat rare in the history of those stations. This continues the general pattern of large numbers of hot days recorded in 2007 (table 4). In several cases throughout the GRYN, these warm July and August daytime temperatures did not extend to nighttime temperatures, though average daily minimums were relatively high at Mammoth and Lake Yellowstone, Wyoming (table 5).

Excluding several unusual cool reports from Yellowtail Dam, station-level temperature records for September and October 2008 were near the 1971–2000 averages. Likewise, most dates for first frost (≤32°F) and first freeze (≤28°F) were near average (table 3). November

Table 4. First and last freeze and frost dates, accumulated growing degree days, and days above or below critical temperature thresholds for key stations in the Greater Yellowstone Network during 2007

Station Name	Station ID	Last date ≤28°F in spring	Earliest date ≤28°F in fall	Last date ≤32°F in spring	Earliest date ≤32°F in fall	Accumulated growing degree days 40°F	Accumulated growing degree days 50°F	Number of days ≥80°F	Number of days ≥90°F	Number of days ≤0°F	Number of days ≤32°F
Mammoth YNP	489905	5/7 (5/23)	10/7 (9/17)	5/26 (6/14)	9/10 (9/8)	3331 (2731)	1720 (1200)	69 (31)	20 (0)	15 (0)	182 (215)
Cooke City 2 W, MT	241995	6/26 (6/25)	9/10 (8/28)	6/27 (7/13)	8/25 (8/13)	2080 (1606)	821 (473)	38 (0)	0 (0)	35 (0)	254 (272)
Lake Yellowstone	485345	6/19 (6/29)	9/10 (8/25)	6/26 (7/16)	9/10 (8/13)	1287 (1422)	488 (388)	16 (0)	0 (0)	40 (62)	167 (283)
Old Faithful, WY	486845	6/26 (6/28)	9/10 (8/23)	6/27 (7/15)	8/23 (8/9)	2049 (1721)	807 (545)	34 (0)	0 (0)	56 (64)	257 (273)
Snake River, WY	488315	6/26 (7/5)	8/25 (8/15)	6/27 (7/21)	8/9 (8/8)	2007 (1778)	798 (571)	47 (0)	5 (0)	49 (66)	227 (286)
Moose, WY	486428	6/9 (6/12)	9/10 (9/3)	6/26 (7/2)	9/10 (8/22)	3086 (2338)	1522 (925)	70 (27)	23 (0)	46 (24)	229 (250)
Moran 5 WNW, WY	486440	5/3 (6/16)	9/10 (9/1)	5/31 (7/10)	8/25 (8/17)	2039 (1971)	904 (675)	50 (0)	6 (0)	53 (0)	245 (247)
Alta 1 NW, WY	480140	5/29 (6/3)	9/10 (9/10)	6/8 (6/30)	9/10 (8/30)	3305 (2656)	1672 (1151)	57 (5)	5 (0)	28 (0)	197 (221)
Driggs, ID	102676	5/30 (6/1)	9/10 (9/9)	6/26 (6/26)	9/10 (8/31)	3235 (2756)	1568 (1194)	57 (39)	3 (0)	34 (0)	201 (222)
Cody, WY	481840	4/13 (5/6)	10/21 (10/1)	5/5 (5/18)	10/6 (9/21)	4995 (4047)	2778 (2107)	90 (68)	32 (0)	9 (0)	135 (173)
Lovell, WY	485770	4/14 (5/1)	10/28 (10/2)	5/7 (5/16)	9/10 (9/19)	3744 (4086)	2035 (2215)	76 (81)	31 (0)	18 (0)	171 (190)
Shell, WY	488124	4/14 (5/10)	10/22 (10/1)	5/25 (5/24)	9/10 (9/18)	4891 (4101)	2855 (2220)	106 (87)	56 (0)	30 (0)	172 (199)
Yellowtail Dam, MT	249240	4/14 (4/19)	11/6 (10/15)	4/14 (5/7)	10/27 (10/2)	5530 (5217)	3221 (2951)	101 (96)	56 (41)	9 (0)	123 (142)

Note: Averages for 1971–2000 are given in parentheses. Historical values for above average freeze or frost dates are based on the entire period of available record, and historical values for all other periods are based on observations during the 1971–2000 period. Station IDs are from National Weather Service Cooperative Observer stations.

2008, however, was marked by very warm temperatures across the GRYN area (tables 2 and 4). Across all 13 key GRYN area stations offering reports, maximum daily temperatures were ~4.5°F above the 1971–2000 averages for this November, with minimum daily temperatures 6.5°F above. Mammoth was the warmest station overall, with maximum and minimum daily temperatures for November at 6.4 and 9.3°F above average. In terms of absolute temperatures, average maximum daily temperatures from all key reporting stations were well above freezing for the month, and several locations near Bighorn Canyon showed average minimum temperatures that were only 1–3°F below freezing. Most stations recorded temperatures near 1971–2000 averages in December 2008, though key locations in Yellowstone tended to be ~2°F cooler than the long-term means.

Analysis of the individual station records confirms that for 2008 GRYN area temperatures were generally near or slightly below the 1971–2000 averages. For the year as a whole, the coolest stations in the GRYN area were Moran and Alta, two sites representing Grand Teton. The Snake River and Lake Yellowstone stations in Yellowstone were the warmest stations, with Lake Yellowstone recording minimum temperatures that were 6.9°F above the 1971–2000 average. Individual station records from 2008 were cooler than those for 2007. Of particular note is that while still warm compared to the 1971–2000 records, July 2008 was roughly 5–7°F cooler than July 2007. GRYN stations also recorded fewer days with extreme high temperatures (≥90°F) in 2008 (tables 3 and 4). The heat of summer 2007 was a major contributor to the drought that developed that year.

Table 5. Average minimum daily temperatures in degrees Fahrenheit for select Greater Yellowstone Network area stations during 2008

Station Name	Station ID	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Mammoth YNP	489905	8.35 (-0.3)	15.31 (3.8)	15.42 (-2.3)	19.23 (-6.2)	— (—)	— (—)	48.55 (2.2)	48.55 (3.5)	— (—)	30.83[a] (3.7)	26.17 (9.3)	8.58 (-0.1)	24.55 (-1.9)
Cooke City 2 W, MT	241995	2.20 (0.1)	9.70 (5.5)	8.90 (-1.2)	14.70 (-2.9)	28.00 (1.5)	32.80 (-0.1)	36.50 (-1.1)	35.80 (-0.7)	29.10 (0.2)	21.30 (-0.3)	16.30 (5.8)	— (—)	21.39 (2.2)
Lake Yellowstone	485345	— (—)	5.11[a] (6.6)	— (—)	— (—)	— (—)	34.00 (1.5)	41.90 (4.4)	40.29[c] (3.8)	28.67 (0.1)	23.03 (2.1)	15.27[d] (5.3)	4.23[a] (3.1)	24.06 (6.9)
Old Faithful, WY	486845	-4.06 (-2.6)	2.33[b] (1.3)	3.55 (-5)	10.63 (-6.7)	26.71 (-0.6)	32.83 (-1.5)	38.48 (-0.2)	35.19 (-1.3)	26.52[a] (-1.8)	— (—)	15.72[a] (7.5)	2.40[a] (4)	17.30 (-0.8)
Snake River, WY	488315	-6.16 (-4.3)	4.38 (4.4)	— (—)	— (—)	26.35 (-0.3)	31.80 (-1.4)	36.77 (-0.3)	33.39 (-1.7)	— (—)	— (—)	— (—)	— (—)	21.09 (3.9)
Moose, WY	486428	-2.52 (-3.4)	8.17 (5.4)	8.35 (-4.1)	16.00 (-5.8)	31.42 (0.4)	37.67 (0.3)	40.87 (-1.1)	— (—)	31.86[b] (-1.6)	24.13[a] (-0.4)	20.03 (5.8)	5.77 3.8)	20.16 (-1.8)
Moran 5 WNW, WY	486440	-1.58 (-3.9)	3.90 (-0.4)	5.39 (-7.1)	11.07 (-10.3)	27.71 (-2.8)	35.10 (-2.5)	— (—)	38.23 (-3.1)	— (—)	23.48 (-2.1)	19.77 (4.3)	— (—)	18.12 (-4.6)
Alta 1 NW, WY	480140	6.48 (-4.3)	12.31 (-1.3)	15.35 (-4.3)	20.57 (-6.1)	32.97 (-2.2)	42.03 (-0.7)	48.87 (0.5)	45.97 (-0.5)	— (—)	— (—)	25.13 (6)	10.65 (-0.3)	26.03 (-2.5)
Driggs, ID	102676	6.00 (-2.3)	10.50 (-0.9)	14.20 (-4.9)	21.40 (-5.1)	34.90 (1.1)	42.10 (1.3)	47.90 (1.6)	45.10 (0.3)	36.30 (-0.3)	27.90 (0.1)	24.80 (6.4)	— (—)	28.28 (1.4)
Cody, WY	481840	13.00 (-1.5)	19.86 (1)	24.74 (-1)	29.20 (-3.3)	42.74 (1.8)	51.03 (2)	58.35 (3.6)	57.10 (3.3)	45.37 (0.5)	36.33[a] (0.4)	30.70 (6)	— (—)	37.13 (2.7)
Lovell, WY	485770	4.19 (-0.5)	15.48 (3.6)	21.65 (-0.8)	26.40 (-4.8)	41.03 (-0.5)	47.43 (-2.3)	54.19 (-0.1)	51.90[a] (0.1)	— (—)	— (—)	26.97 (8.4)	5.55 (-2.3)	29.48 (-0.9)
Shell, WY	488124	2.81 (-1)	12.00 (0)	22.16 (0.9)	23.90 (-5.7)	40.10 (2.4)	46.23 (-0.4)	54.87 (2.9)	50.97 (1.3)	41.00 (1.6)	30.48[b] (1.6)	25.90[a] (9.6)	3.89 (-3)	29.53 (0.8)
Pryor 1 S, MT	246747	— (—)	— (—)	— (—)	— (—)	— (—)	— (—)	— (—)	— (—)	— (—)	— (—)	— (—)	— (—)	— (—)
Yellowtail Dam, MT	249240	14.60 (-3.1)	21.80 (-0.1)	26.20 (-1.8)	32.00 (-4.2)	44.30 (-0.2)	48.80 (-3.6)	58.10 (0.9)	53.40 (-2.7)	35.00 (-12.2)	35.50 (-3)	31.40 (3.7)	— (—)	36.46 (-0.8364)

Note: Monthly average minimum daily temperature departures from 1971–2000 averages are given in parentheses in degrees Fahrenheit. Station IDs are from National Weather Service Cooperative Observer stations. Monthly statistics are not reported if more than 5 days of data are missing. Individual months are not used for calculating annual statistics if more than 5 days of data are missing.

[a]1 day missing.
[b]2 days of data missing.
[c]3 days of data missing.
[d]4 days of data missing.
[e]5 days of data missing.

4. Winter Snowpack in the GRYN Area

The Natural Resources Conservation Service (NRCS) operates automated snow measurement (SNOTEL) stations throughout the GRYN (appendix 2). These stations offer the best available means for tracking the accumulation and ablation (melting or vaporization) of GRYN area snowpack. As measured in terms of SWE—the amount of liquid water held in a given volume of snow—the Bighorn River drainage upstream from Bighorn Canyon had snowpack near the 1971–2000 average in winter 2008 (fig. 5). For key stations in the Bighorn Mountains (e.g., Shell Creek and Bald Mountain, Wyoming), total accumulated SWE was generally similar to the previous winter, but melt-off came two to three weeks later than in 2007. The contrast between winter 2007 and 2008 was more pronounced in the Absaroka Mountains and Shoshone River drainage. As represented by the Younts Peak SNOTEL station data (fig. 5c), winter 2008 featured SWE near the 1971–2000 average and a melt-out date near mid-June, as opposed to 2007 when the station recorded a very low snowpack and melt-out came four weeks early.

Individual SNOTEL sites in Yellowstone and the Yellowstone River drainage recorded higher than average SWE values throughout most of winter 2008 (fig. 6). As shown at the Fisher Creek and Canyon stations, the timing of melt-out was also near the 1971–2000 average and was three to five weeks later than in winter 2006 or 2007. In the Snake River drainage and Grand Teton, late March snows and a cool April pushed SWE up to or above the 1971–2000 average. This pattern continued throughout the spring and early summer (fig. 6). The timing of melt-out in the Snake River drainage was near the 1971–2000 average, and this was also three to four weeks later than in 2007.

Again, 2008 brought only near-average snowpack to the GRYN, but this still made it one of the wettest winters the GRYN area has experienced in the last 7–9 years. Of particular importance for its impact on drought conditions, the highcountry snowpack from winter 2008 persisted well into the early summer. Though, historically speaking, having snow linger in the mountains until June or July is common in the GRYN, the past decade has featured several years with an early melt and subsequent early runoff (fig. 7).

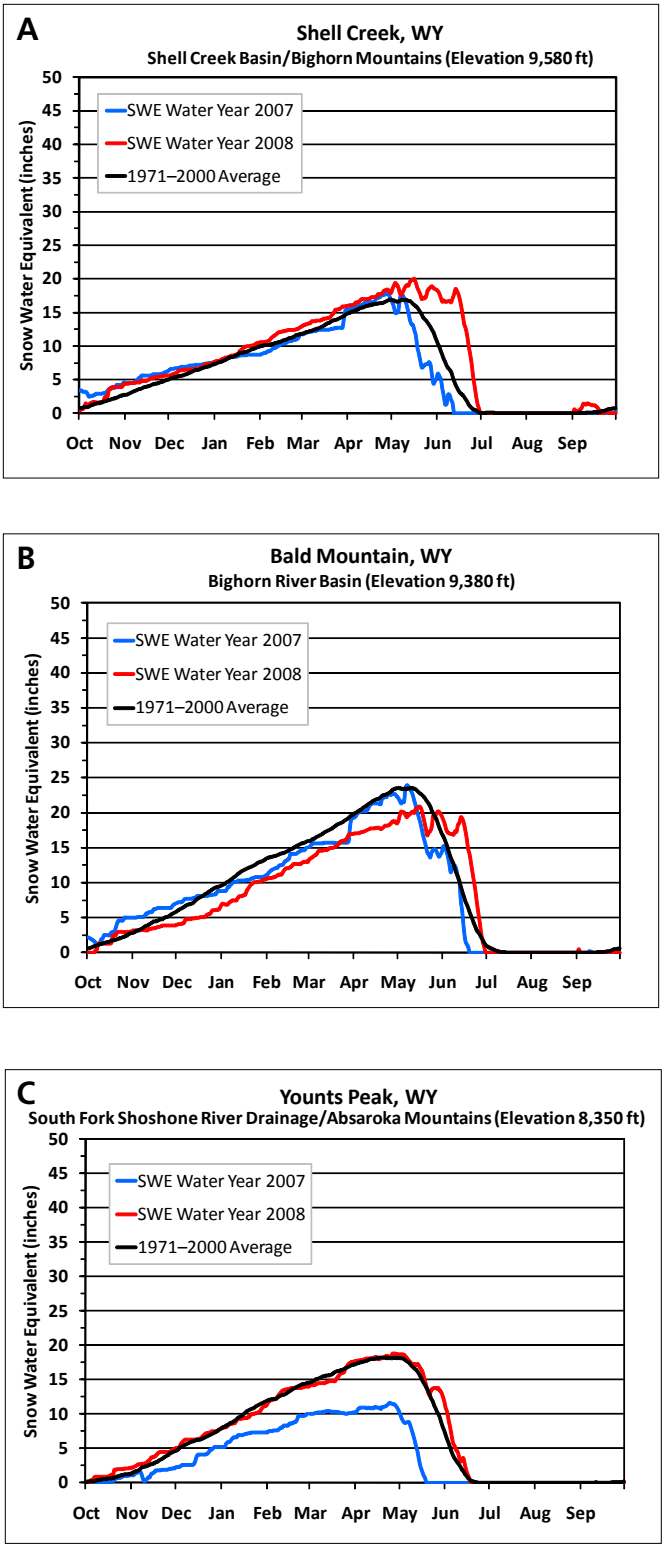

Figure 5. Daily measurements of snow water equivalent (SWE) from representative sites in the Greater Yellowstone Network area from October 2007 to September 2008. Values from 2007 (*blue*) and 2008 (*red*) are compared to averages from the 1971–2000 period (*black*). Data courtesy of the Natural Resource Conservation Service. *A and B*, daily measurements of SWE from two representative sites in the Bighorn River drainage upstream from Bighorn Canyon and Bighorn Lake; *C*, daily measurements of SWE from a site in the Shoshone River drainage upstream from Bighorn Canyon and Bighorn Lake. This provisional data is subject to change.

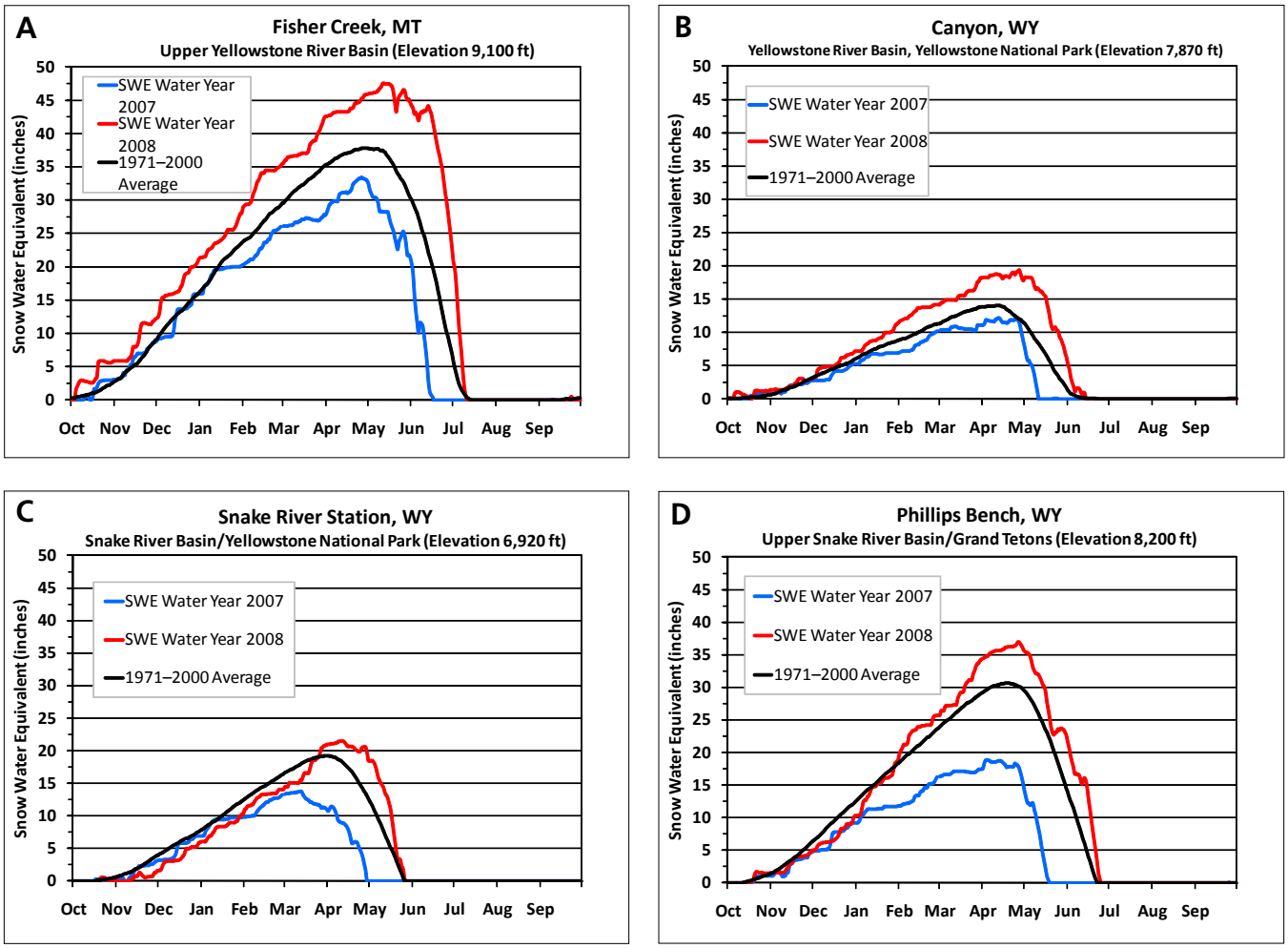

Figure 6. Daily measurements of snow water equivalent (SWE) from representative sites in the Greater Yellowstone Network area from October 2007 to September 2008. Values from 2007 (*blue*) and 2008 (*red*) are compared to averages from the 1971–2000 period (*black*). Data courtesy of the Natural Resource Conservation Service. *A and B*, daily measurements of SWE from two representative sites in portions of the Yellowstone River drainage within the Greater Yellowstone Network; *C and D*, daily measurements of SWE from two representative sites in portions of the Snake River drainage within the Greater Yellowstone Network. This provisional data is subject to change.

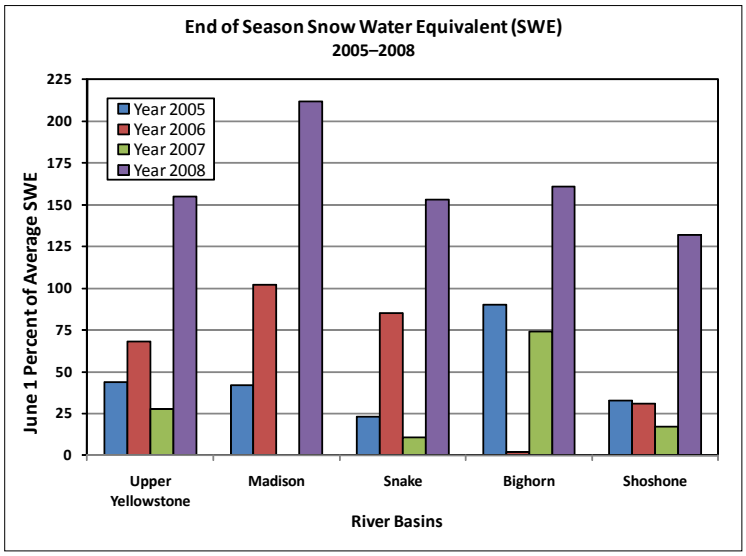

Figure 7. Comparison between late spring (June 1) snowpack in 2008 versus conditions in 2005–2007. Data are shown as percentage of the 1971–2000 average snow water equivalent (SWE) for major river basins in the Greater Yellowstone Network. Values are derived from all available Natural Resources Conservation Service SNOTEL sites in each of the river basins.

NPS

A gauge at the Snake River showed annual flows at 121% of 1984–2007 averages in water year 2008. with slightly higher-than-average flows in the summer and early fall.

5. GRYN Area Streamflow

The U.S. Geological Survey (USGS) monitors streamflow at numerous locations throughout the GRYN. Key aspects of GRYN area hydrology can be represented by a subset of these gauging stations (appendix 3). The Shell Creek near Shell, Wyoming, and South Fork of the Shoshone River, near Valley, Wyoming, gauges represent small, higher-elevation and relatively unregulated watersheds upstream from Bighorn Canyon and Bighorn Lake (figs. 8e and 9a). Total discharge at Shell Creek and the South Fork of the Shoshone was near average (compared to data for the entire period of record, 31 and 51 years, respectively) for water year 2008 (October 2007 through September 2008). Timing of peak runoff was also near period of record averages. In 2007, both of these gauges recorded mid to late summer (i.e., July through August) flows that were noticeably lower than average, but this was not the case in 2008.

The Bighorn River at the Kane, Wyoming, gauge (fig. 8a) shows that total 2008 inflows to Bighorn Canyon and Bighorn Lake were ~70% of average compared to the past 79 years (1929–2008). The majority of the water entering Bighorn Lake is released from two upstream reservoirs—Buffalo Bill Reservoir near Cody, Wyoming, and Boysen Reservoir near Riverton, Wyoming. In response to ongoing drought conditions, releases from both of these reservoirs were kept relatively low from October 2007 through May 2008 (U.S. Bureau of Reclamation 2008). When combined with a cool April that delayed runoff from unregulated streams above Bighorn Lake, these low releases led to spring inflows that were well below the average for the period of record. With snowpack in the Bighorn River drainage near long-term averages, releases above Bighorn Lake increased in summer 2008 and the reservoir reached historical average (compared to 1967–2007) levels by September. Releases from Bighorn Lake (fig. 8b) showed a similar pattern over the course of the year with relatively low flows in winter and spring followed by near to above average releases in summer and fall.

As represented by gauges at the Yellowstone Lake Outlet and at Corwin Springs, Montana, in 2008 the Yellowstone River drainage showed total annual runoff at 115–120% of their period of record averages (79 and 102 years, respectively), with the timing of peak runoff also near period of record averages (fig. 9c and 9d). In comparison to water year 2007, water year 2008 also featured much higher levels of late summer flow. Flow records from the Madison River near West Yellowstone, Montana, depict similar patterns (fig. 8c).

The Snake River at Flagg Ranch, Wyoming, gauge represents unregulated inflows to Grand Teton and Jackson Lake. During water year 2008 this gauge record showed total annual flows at 121% of the period of record (25 year) average, with slightly higher-than-average flows in the summer and early fall. Total releases from Jackson Lake dam were 93% of the 1995–2007 average, with peak flows occurring near the beginning of July (fig. 8e).

On the whole, GRYN area streamflow for water year 2008 were characterized by near average to slightly higher-than-average discharge and runoff timing similar to historical observations. These flow patterns were driven by a near historical average snowpack which persisted into early summer. Unlike many years in the past decade, retaining the highcountry snowpack through the early summer also led to near or slightly-above-average flows later in the summer season.

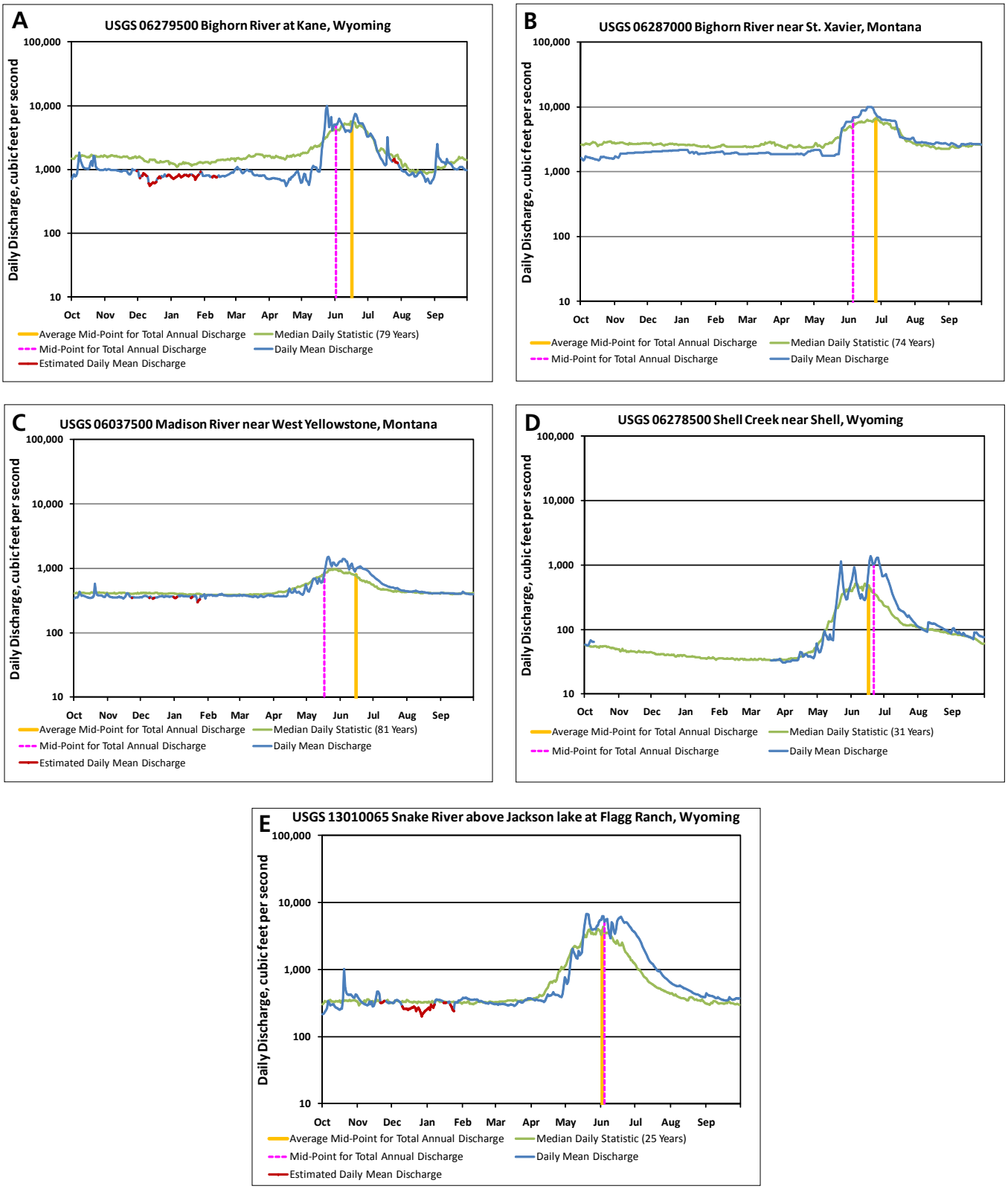

Figure 8. Streamflows from representative gauges within the Greater Yellowstone Network area. Daily flows for the 2008 water year (October 2007 through September 2008) are shown versus median daily flows for the period of record. Data courtesy the U.S. Geological Survey. Stream gauge data from: Bighorn river inflow (*A*) and outflow (*B*) for Bighorn Canyon and Bighorn Lake; *C*, Madison River as it leaves Yellowstone; *D*, representative flows on relatively unregulated streams above Bighorn Canyon and Bighorn Lake; *E*, representative flows from unregulated Snake River inflows to Grand Teton and Jackson Lake.

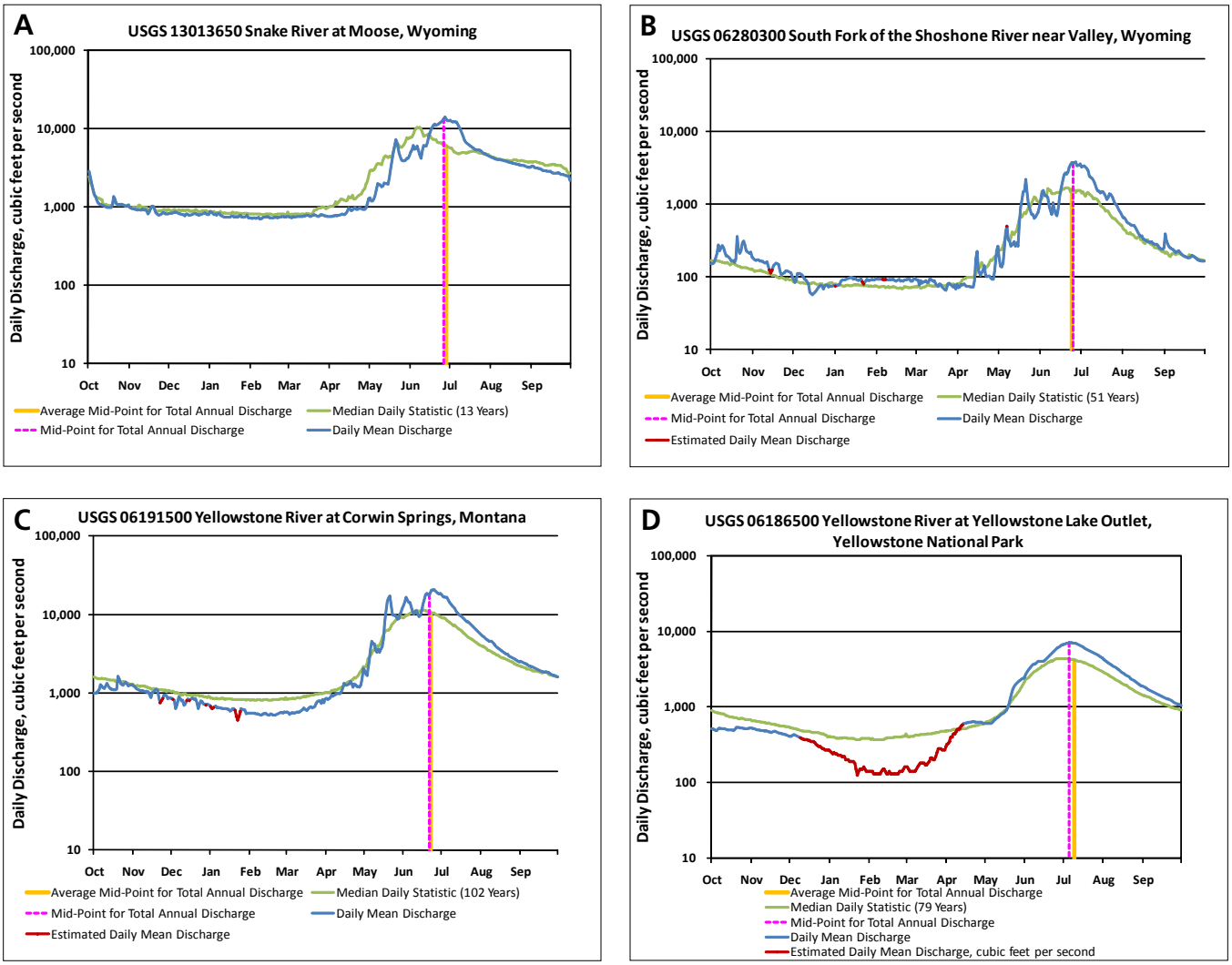

Figure 9. Streamflows from representative gauges within the Greater Yellowstone Network area. Daily flows for the 2008 water year (October 2007 through September 2008) are shown versus median daily flows for the period of record. Data courtesy the U.S. Geological Survey. Stream gauge data from: *A*, representative flows from unregulated Snake River outflow from Jackson Lake dam; *B*, representative flows on relatively unregulated streams above Bighorn Canyon and Bighorn Lake; *C and D*, Yellowstone River in Yellowstone.

NPS

Bighorn Canyon National Recreation Area was considered as abnormally dry by the U.S. Drought Monitor at the start and end of 2008.

6. GRYN Area Drought Status

The Drought Monitor, a collaboration between federal, state, and academic partners, tracks drought conditions across the nation on a weekly basis, and it incorporates data and expert input from a variety of state and federal agencies. The Drought Monitor is designed to provide a "broad brush," regional perspective on drought, and therefore offers an ideal tool for tracking generalized drought conditions throughout the GRYN and surrounding areas.

According to the Drought Monitor, calendar year 2008 began with most of Yellowstone in a state of moderate (D1) drought, while all of Grand Teton was listed as in severe (D2) drought conditions (fig. 10a). Bighorn Canyon was also mapped as abnormally dry (D0) at the start of the year. Accumulated snowfall through January and into March led to general improvements in drought status for Yellowstone and Grand Teton (fig. 10b). The beginning of March also saw the removal of the abnormally dry classification from Bighorn Canyon, largely as a response to increasing snowpack in the watershed above Bighorn Lake. Dryness through the month of April helped return abnormally dry conditions to Bighorn Canyon, but otherwise the overall status of the GRYN area remained unchanged through the first weeks of May (fig. 10c).

As noted in section 2.1 of this report, Drought Monitor conditions changed dramatically as a result of late May storms (fig. 10d). In one week, moisture deficits improved enough to warrant removal of the moderate drought (D1) designations from Grand Teton and the watershed above Bighorn Canyon. Likewise remaining areas of abnormal dryness (D0) were removed from Bighorn Canyon and the remainder of Yellowstone. Relatively warm and dry conditions in July and August 2008 eventually led to the reintroduction of the abnormally dry (D0) classification to the GRYN (fig. 10e). Similar conditions persisted throughout the remainder of 2008 (fig. 10f).

In terms of Drought Monitor status, 2008 was markedly less dry than 2007. The previous year featured extended periods with portions of the GRYN in the extreme drought (D3) category. Severe (D2) designations were also common throughout 2007. The drought conditions that occurred in 2007 were undoubtedly the continuation of a multi-year dry event beginning in the late 1990s or early 2000s—2002 and 2003 were among some of the driest seen in the GRYN area for over a century. It remains to be seen if 2008 signals the start of a return to near average conditions, and the impacts of long-term dryness will linger in the GRYN for years to come.

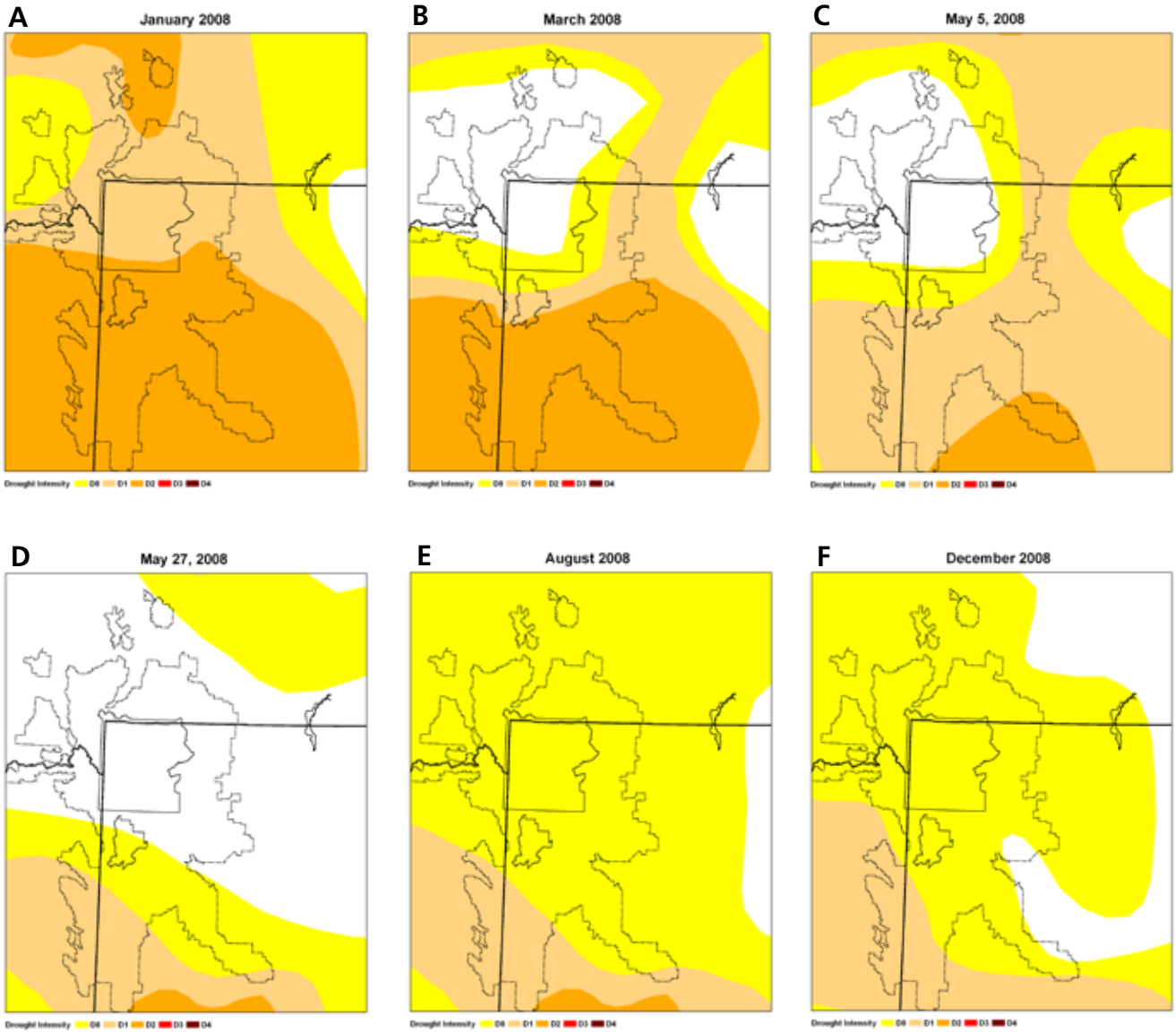

Figure 10. U.S. Drought Monitor maps for the Greater Yellowstone Network area over the course of calendar year 2008. Drought classifications range from "abnormally dry" (D0) to "exceptional drought" (D4).

7. References

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Appendix A: National Weather Service COOP Stations

Table 1. National Weather Service Cooperative Observer (COOP) stations used in this report

Station	NWS ID	Elevation (ft)	Latitude	Longitude	Latitude DD	Longitude DD	State	County
Alta 1 NW, WY (http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?wy0140)	481140	6,410	43 47	-111 02	43.7833	-111.0333	WY	Teton
Cody, WY (http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?wy1840)	481840	5,050	44 31	-109 04	44.5166	-109.0667	WY	Park
Cooke City 2 W, MT (http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?mt1995)	241995	7,460	45 01	-109 58	45.0153	-109.9711	MT	Park
Driggs, ID (http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?id2676)	102676	6,116	43 43	-111 07	43.7297	-111.1236	ID	Teton
Lake Yellowstone (http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?wy5345)	485345	7,870	44 34	-110 24	44.5650	-110.3969	WY	Yellowstone NP
Lovell, WY (http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?wy5770)	485770	3,840	44 50	-108 28	44.8333	-108.4667	WY	Big Horn
Mammoth YNP (http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?wy9905)	489905	6,240	44 58	-110 42	44.9667	-110.7000	WY	Yellowstone NP
Moose, WY (http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?wy6428)	486428	6,470	43 39	-110 43	43.6564	-110.7160	WY	Teton
Moran 5 WNW, WY (http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?wy6440)	486440	6,798	43 51	-110 35	43.8572	-110.5881	WY	Teton
Old Faithful, WY (http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?wy6845)	486845	7,380	44 28	-110 50	44.4667	-110.8333	WY	Yellowstone NP
Pryor, 1 S MT (http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?mt6747)	246747	4,127	45 25	-108 32	45.4267	-108.5333	MT	Big Horn
Shell, WY (http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?wy8124)	488124	4,280	44 33	-107 46	44.5556	-107.7667	WY	Big Horn
Snake River, WY (http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?wy8315)	488315	6,882	44 08	-110 40	44.1333	-110.6658	WY	Yellowstone NP
Yellowtail Dam, MT (http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?mt9240)	249240	3,305	45 19	-107 56	45.3167	-107.9333	MT	Big Horn

Note: Station URL is given in parentheses. DD = decimal degrees.

Appendix B: Natural Resources Conservation Service SNOTEL Stations

Table 1. Natural Resources Conservation Service SNOTEL stations used in this report

Station	NRCSS ID	Elevation (ft)	Latitude	Longitude	Latitude DD	Longitude DD	State	County
Bald Mountain, WY (http://www.wcc.nrcs.usda.gov/snotel/snotel.pl?sitenum=309&state=wy)	07e21s	9,380	4448	10751	44.8000	-107.8500	WY	Big Horn
Canyon, WY (http://www.wcc.nrcs.usda.gov/snotel/snotel.pl?sitenum=384&state=wy)	10e03s	8,090	4443	11032	44.7167	-110.5333	WY	Yellowstone NP
Fisher Creek, MT (http://www.wcc.nrcs.usda.gov/snotel/snotel.pl?sitenum=480&state=mt)	09d06s	9,100	4504	10957	45.0667	-109.9500	MT	Park
Phillips Bench, WY (http://www.wcc.nrcs.usda.gov/snotel/snotel.pl?sitenum=689&state=wy)	10f23s	8,200	4331	11055	43.5167	-110.9167	WY	Teton
Shell Creek, WY (http://www.wcc.nrcs.usda.gov/snotel/snotel.pl?sitenum=751&state=wy)	07e23s	9,580	4430	10726	44.5000	-107.4333	WY	Big Horn
Snake River Station, WY (http://www.wcc.nrcs.usda.gov/snotel/snotel.pl?sitenum=764&state=wy)	10e12s	6,920	4408	11040	44.1333	-110.6667	WY	Park
Younts Peak, WY (http://www.wcc.nrcs.usda.gov/snotel/snotel.pl?sitenum=878&state=wy)	09f18s	8,350	4356	10949	43.9333	-109.8167	WY	Park

Note: Station URL is given in parentheses. DD = decimal degrees.

Appendix C: U.S. Geological Survey Stream Gauging Stations

Table 1. USGS stream gauging stations used in this report

Station	USGS ID	Latitude	Longitude	Latitude DD	Longitude DD	State	County
Madison River near West Yellowstone, MT (http://waterdata.usgs.gov/nwis/uv?06037500)	6037500	44 39	-111 04	44.6569	-111.0675	MT	Gallatin
Yellowstone River at Yellowstone Lake Outlet, YNP (http://waterdata.usgs.gov/nwis/uv?06186500)	6186500	44 34	-110 23	44.5675	-110.3800	WY	Teton
Yellowstone River at Corwin Springs, MT (http://waterdata.usgs.gov/nwis/uv?06191500)	6191500	45 07	-110 48	45.1119	-110.7936	MT	Park
Bighorn River at Kane, WY (http://waterdata.usgs.gov/nwis/uv?06279500)	6279500	44 45	-108 11	45.7556	-108.1685	WY	Big Horn
Bighorn River near St. Xavier, MT (http://waterdata.usgs.gov/nwis/uv?06287000)	6287000	45 19	-107 55	45.3167	-107.9167	MT	Big Horn
Shell Creek near Shell, WY (http://waterdata.usgs.gov/nwis/uv?06278500)	6278500	44 34	-107 43	44.5650	-107.7122	WY	Big Horn
South Fork Shoshone River near Valley, WY (http://waterdata.usgs.gov/nwis/uv?06280300)	6280300	44 13	-109 33	44.2083	-109.5542	WY	Park
Snake River AB Jackson Lake at Flagg Ranch, WY (http://waterdata.usgs.gov/nwis/uv?13010065)	13010065	44 06	-110 40	44.0989	-110.6675	WY	Teton
Snake River at Moose, WY (http://waterdata.usgs.gov/nwis/uv?13013650)	13013650	43 39	-110 43	43.6525	-110.7092	WY	Teton

Note: Station URL is given in parentheses. DD = decimal degrees.

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