National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Climate Monitoring in the Mediterranean Coast Network 2018

Cabrillo National Monument

Natural Resource Report NPS/MEDN/NRR—2020/2057



ON THE COVER
Intertidal zone during high tide at Cabrillo National Monument
NPS/Stacey Ostermann-Kelm

Climate Monitoring in the Mediterranean Coast Network 2018

Cabrillo National Monument

Natural Resource Report NPS/MEDN/NRR—2020/2057

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Abstract

The Mediterranean Coast Inventory and Monitoring Network has been monitoring climate at three national park units in southern California since 2011 to support park management. This report details the climate of Cabrillo National Monument during 2018, as represented by temperature, precipitation, drought, oceanic conditions, and streamflow. Gridded GIS maps are used to present broad-brush conditions across the region for each month. This regional presentation is compared to detailed data from weather stations in the Global Historical Climatology Network, automated meteorological stations, and data from USGS stream gages. Prior to analysis, a set of data quality control checks were performed by the author in accordance with guidelines from Kittel (2008), Kittel et al. (2009), and the Rocky Mountain Climate Working Group (2010).

This analysis presents some broad generalizations about climate conditions, although significant variability and exceptions to these patterns certainly existed and are described in the Results section of the report. The regional drought that began in 2012 and slackened in 2017 worsened again from the start to the end of 2018. The El Nino-Southern Oscillation, which is a cyclic ocean-atmosphere climate system centered over the tropical Pacific Ocean that affects sea surface temperatures, began in full La Nina phase (producing drier conditions in southern California) and transitioned during the course of the year to El Nino (producing wetter conditions). Calendar year 2018 had above average temperatures and generally below average precipitation. Streamflows were below the 1982–2010 average for most of the water year and nearly ceased during August. Growing season length was above average for calendar year 2018.

Readers can download the data used in this report and make custom climate graphs and tables of their own by visiting www.ClimateAnalyzer.org.

Acknowledgments

Funding for this report was provided by the National Park Service Inventory and Monitoring Division's Mediterranean Coast Network.

Glossary

GHCN: Global Historical Climatology Network

PRISM: Parameter-elevation Regression on Independent Slopes Model. See http://www.prism.oregonstate.edu/

US Drought Monitor: A broad brush assessment of drought conditions. See https://droughtmonitor.unl.edu/

Tmax / Tmin: mean daily maximum / minimum temperatures

NOAA: National Oceanic and Atmospheric Administration

30-year average or "normal": Official 30-year averages for each weather station are issued every 10 years by NOAA. Currently, the reference period is 1981–2010. Prior to 2011, the official reference period was 1971–2000.

Introduction

This report details the climate of Cabrillo National Monument during 2018 as represented by air temperature, precipitation, drought, oceanic conditions, and streamflow. Climate is an important ecological driver that affects other long-term monitoring programs conducted at the monument (i.e., vegetation, terrestrial herpetofauna, and rocky intertidal communities). In this report, climatic events are presented both from a local perspective, with data from individual weather stations, and from a regional perspective, with maps that depict broad-scale conditions across southern California during each month of the year. The climatic conditions of 2018 are also compared to a historical context, based on a 30-year average or "normal" period calculated over the years 1981–2010, and to historical data from weather stations that go back to 1939.

Typically, when a weather report states that a particular month was "warmer than average" or "cooler than normal," the comparison is to a set of averages calculated over an agreed upon time period. These averages, which are known as "climatological normals," are updated every 10 years by the National Oceanic and Atmospheric Administration (NOAA). From 1991 to 2000, meteorological measurements were compared to 1961–1990 averages; from 2001 to 2010 the reference period was 1971–2000; and starting in calendar year 2011, most weather data have been compared to 1981–2010 averages. NOAA further defines climatological normals as follows:

"In the strictest sense, a "normal" of a particular variable (e.g., temperature) is defined as the 30-year average. For example, the minimum temperature normal in January for a station in Chicago, Illinois, would be computed by taking the average of the 30 January values of monthly-averaged minimum temperatures from 1981 to 2010. Each of the 30 monthly values was in turn derived from averaging the daily observations of minimum temperature for the station. In practice, however, much more goes into NCDC's Normals product than simple 30-year averages. Procedures are put in place to deal with missing and suspect data values. In addition, Normals include quantities other than averages such as degree days, probabilities, standard deviations, etc. Normals are a large suite of data products that provide users with many tools to understand typical climate conditions for thousands of locations across the United States." (Source: https://www.ncdc.noaa.gov/data-access/land-based-station-data/land-based-datasets/climate-normals/1981-2010-normals-data; see also, https://www.ncdc.noaa.gov/monitoring-references/dyk/us-normals.)

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

The ClimateAnalyzer: www.ClimateAnalyzer.org. This website allows you to create custom graphs and tables from both "official," unedited data and from the corrected datasets used in this report. You can also download all the data from the weather stations in the area as spreadsheets.

Western Regional Climate Center (http://www.wrcc.dri.edu/)

Drought Monitor (https://droughtmonitor.unl.edu/)

NOAA (National Oceanic and Atmospheric Administration) National Weather Service https://www.ncdc.noaa.gov/climate-information)

USGS (U.S. Geological Survey) National Water Information System
(http://waterdata.usgs.gov/nwis)

Methods

Selection of Datasets

In order to place Cabrillo National Monument within a regional context, gridded-map-based estimates of precipitation and temperature were used to provide a broad overview of climatic conditions in the area. These estimates were generated with a statistical modeling technique that interpolates precipitation and temperature values between actual climate 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 robust products in a wide variety of studies (Daly et al. 2008). In this report, PRISM data from calendar year 2018 are compared to 1981–2010 PRISM averages for each month by calculating the percent of normal precipitation (2018 precipitation divided by 1981–2010 precipitation, multiplied by 100) or the temperature departure (2018 temperature minus 1981–2010 average temperature) for each grid cell on the map of southern California.

Records from individual precipitation and temperature observing stations were included as a way to highlight intra-regional variability. The process of selecting specific stations included in this report is described in the Rocky Mountain Climate Protocol (Rocky Mountain Climate Working Group 2010). Generally, the selection criteria were:

1. Stations provide good spatial coverage within and near the parks / monuments of interest. In the case of Cabrillo National Monument, National Weather Service (NWS) stations were chosen from nearby locations. Data from these stations are available through the Global Historical Climatology Network (GHCN). GHCN stations have several advantages, including their relatively long period of record (Appendix 1), and the availability of established 30-year averages that can be used to quantify the difference between the current year and “normal” conditions.
2. Stations provide a sufficient length of record to provide historical context for current observations. For this report, GHCN stations were not considered if they had not been in operation during the 1981–2010 period, at a minimum.
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.

In addition to the GHCN stations, this report includes data from automated meteorological (MET) stations located at Pt. Loma, within Cabrillo National Monument. These stations have not been in operation long enough to have climatological normals / averages, and they sometimes suffer from equipment malfunctions that produce physically impossible values or missing data. Despite these flaws, however, these stations have the advantage of being located within Cabrillo National Monument itself, unlike more established stations in the region, and carefully screened data from these MET stations can accurately characterize current year temperature and precipitation.

As a way of presenting the integrated effects of temperature and precipitation, maps from the US Drought Monitor (https://droughtmonitor.unl.edu/) were used to depict broad-brush conditions across the region. Even though the watercourses in the region are human-controlled and therefore not directly tied to rainfall, USGS stream gage data (http://waterdata.usgs.gov/nwis) were used to contrast streamflow during the 2018 water year, which ran from October 2017 to September 2018, with average conditions during the period of record for the gage of interest (in this case 1982–2010).

The locations of weather stations cited in this report are shown in Figure 1. Metadata for these stations can be accessed from the internet links provided in Appendix 1.

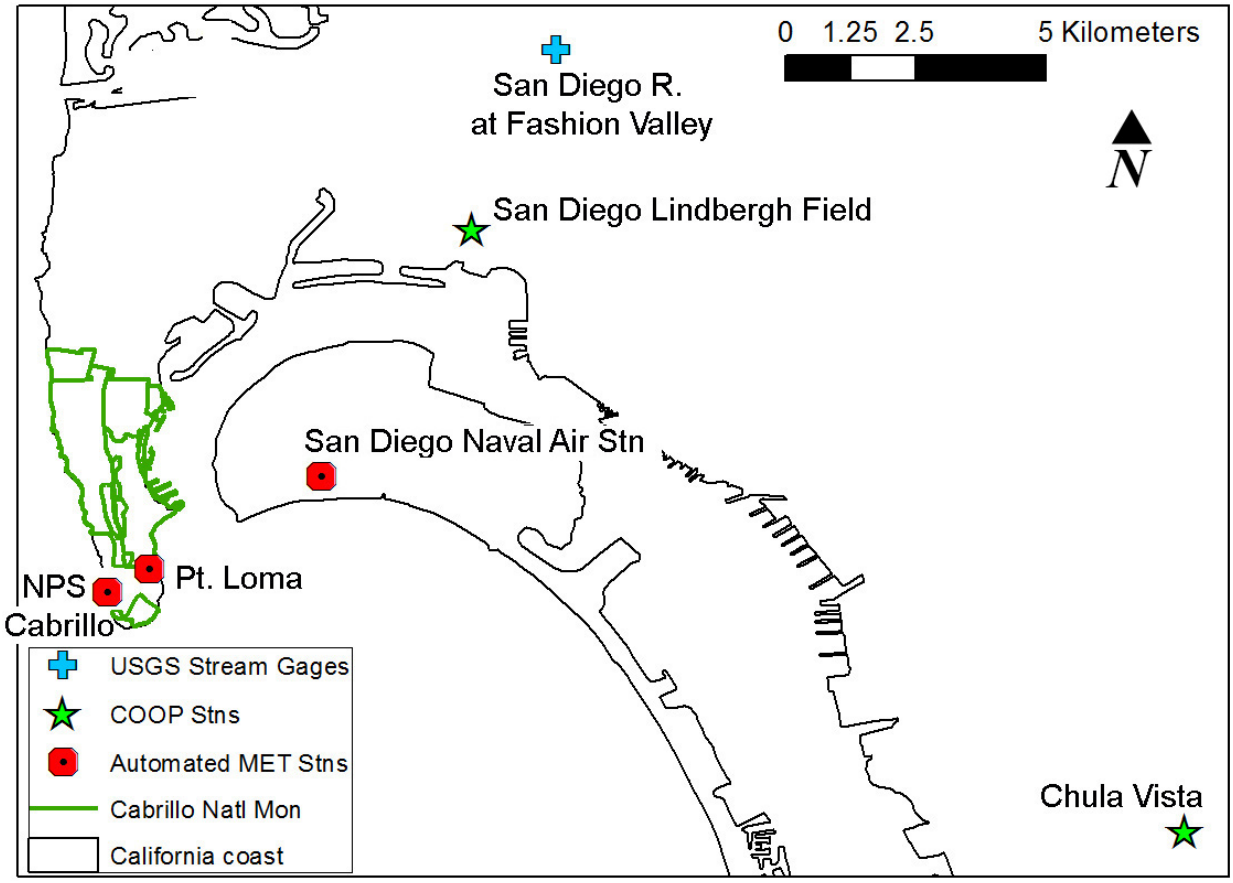


Figure 1. Map showing key climate stations and stream gages in and near Cabrillo National Monument. Cooperative Observer (COOP) stations are operated by the National Weather Service and are accessed through the Global Historical Climatology Network.

Quality Control of Global Historical Climatology Network Data

All of the GHCN stations used in this report are operated by the National Weather Service (NWS). These stations are sometimes referred to as “Cooperative Observer” (COOP) stations because in most cases their measurements are manually recorded by human observers and submitted to NWS for aggregation and error checking.

Data from these weather stations undergo quality control and error-checking by NWS, and as part of this process many of the observations in the data files are assigned “flags” (letter or number codes) that indicate potential problems or other factors that should be taken into consideration when interpreting the data. Consequently, the author of this report has created software tools that assist in the interpretation of the data flags and diagnostic plotting of the data. Following guidelines from Kittel (2008), Kittel et al. (2009), and the Rocky Mountain Climate Working Group (2010), the Qa/Qc employed by these software tools involved graphing and visual inspection of each time series, evaluation of the data quality flags that accompany each observation, 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). Point observations provided by the GHCN stations were also compared to corresponding estimates from the PRISM datasets. If more than 3 days of precipitation data were missing for a particular month, a monthly total was not calculated, and the entire month was instead considered missing. Similarly, if more than 5 days of mean daily maximum temperature (Tmax) or mean daily minimum temperature (Tmin) values were missing, monthly average temperatures were not calculated. The data handling was conservative; no data points were changed unless it was very clear that an erroneous value, for example a precipitation measurement with a missing decimal point that could be verified on the original station records, was found. Readers can download the data used in this report and make custom climate graphs and tables of their own by visiting www.ClimateAnalyzer.org

Quality Control of MET Station Data

Because MET data are collected hourly, daily Tmax, Tmin, and precipitation values must be derived from the automated data stream. Furthermore, precipitation is recorded as a running total that must be translated into daily measurements. If any particular day in a record was missing more than six hours of measurements, the entire day was considered missing. In addition, if the temperature during any day varied by less than 2 °F, data for the entire day were considered invalid due to instrumental error and replaced with missing values. Once daily statistics had been calculated, diagnostic plots were used to screen for physically impossible measurements (e.g., 500 °F), which were ascribed to instrumental error and considered missing. The missing data criteria just described for GHCN stations were used to calculate monthly statistics.

Streamflow

We monitor streamflow at one site near Cabrillo National Monument using a USGS stream gage located at San Diego River near Fashion Valley.

Results

The patterns described in this section are often stated as broad generalizations. In most cases there was significant variability across the region and exceptions to the patterns described here were common. In order to appreciate this variability, it is important to examine the PRISM maps (Figures 5–7) and compare them to the weather station data presented in Figures 3–4 and Tables 1–2.

Broader Picture—the Ongoing Drought Became More Severe

The region entered into drought conditions in April 2012 and became progressively drier throughout 2013 and 2014. By the end of 2014, Cabrillo National Monument (NM) was classified as "D4 - Exceptional Drought" by the US Drought Monitor, which is the most severe classification on this scale, and it retained this classification until the end of 2016. In January 2017, the drought began to slacken, eventually moving to the D0 (Abnormally Dry) rating by the beginning of 2018. During the course of 2018, the drought worsened, returning to D2 (Severe Drought) status by the end of the year (Figure 2).

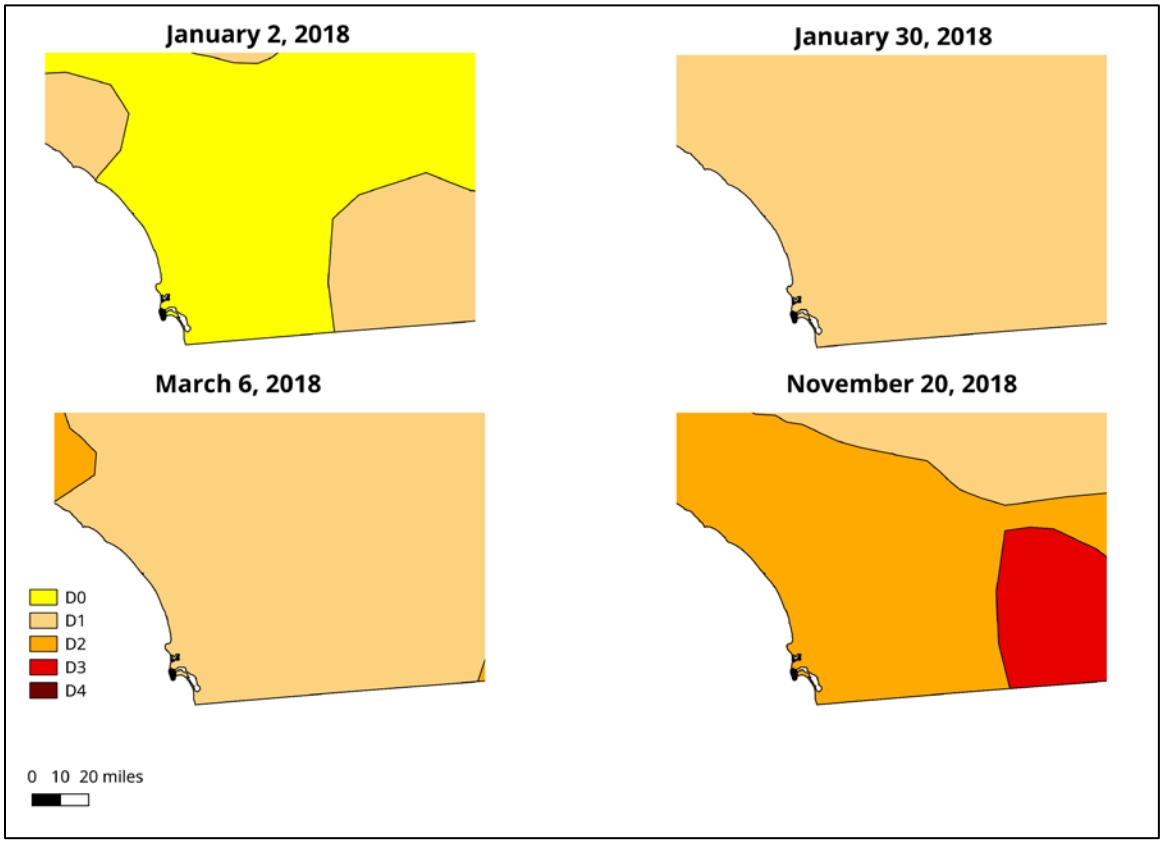


Figure 2. U.S. Drought Monitor maps for Cabrillo National Monument during 2018. Drought codes are D0: Abnormally Dry, D1: Moderate Drought, D2: Severe Drought, D3: Extreme Drought, D4: Exceptional Drought. White areas are the Pacific Ocean. Cabrillo NM is located on the coast, on the lower-left corner of each map (black dots). For more information visit: https://droughtmonitor.unl.edu/.

El Nino–La Nina Status

The El Nino–Southern Oscillation (ENSO) is an oscillation of the ocean–atmosphere climate system centered over the tropical Pacific Ocean that follows a rough cycle of approximately 2–7 years. When ENSO is in its "El Nino phase," sea surface temperatures in the central and eastern tropical Pacific are warmer than average, and this generally produces warmer, drier conditions in the northern continental United States and cooler, wetter conditions in the southern United States, particularly the southwest. In contrast, the opposite conditions prevail when ENSO is in its "La Nina phase." More information on ENSO can be found on the NOAA web site located here: http://www.pmel.noaa.gov/tao/elnino/el-nino-story.html

Calendar year 2018 began in full La Nina phase and transitioned during the course of the year to El Nino. Normally, La Nina conditions produce drier conditions in southern California while El Nino produces wetter conditions. Despite the late-year shift to El Nino, total annual precipitation during 2018 was 72% to 74% of the 30-year average (see below), which allowed the drought to worsen. For long-term El Nino patterns, consult NOAA here: http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml

Weather Station Temperature and Precipitation Data

Generally speaking, there are two components to drought: high temperatures, which increase evapotranspiration, and low precipitation, or the lack thereof. Figures 3 and 4 and Tables 1 and 2 support the following results. Calendar year 2018 had above average temperatures and generally below average precipitation. The 2018 average daytime high at San Diego Lindbergh field (72.6 °F) was 2.9 °F above the 1981–2010. Average daytime lows were similarly about 2.6 °F above average. Total annual precipitation was 74% of average in San Diego and 72% of average in Chula Vista. November (Chula Vista) and December (Chula Vista and San Diego) had above average precipitation (150–200% of average), while the remaining months of the year were near or below average. In San Diego, every month of the year except May had above average temperatures, with August being more than 6 °F above average. Precipitation during the summer months (May–December) is so slight that calculations of percent of average are misleading. An increase of only a few hundredths of an inch can mean the difference between an above vs. below average month.

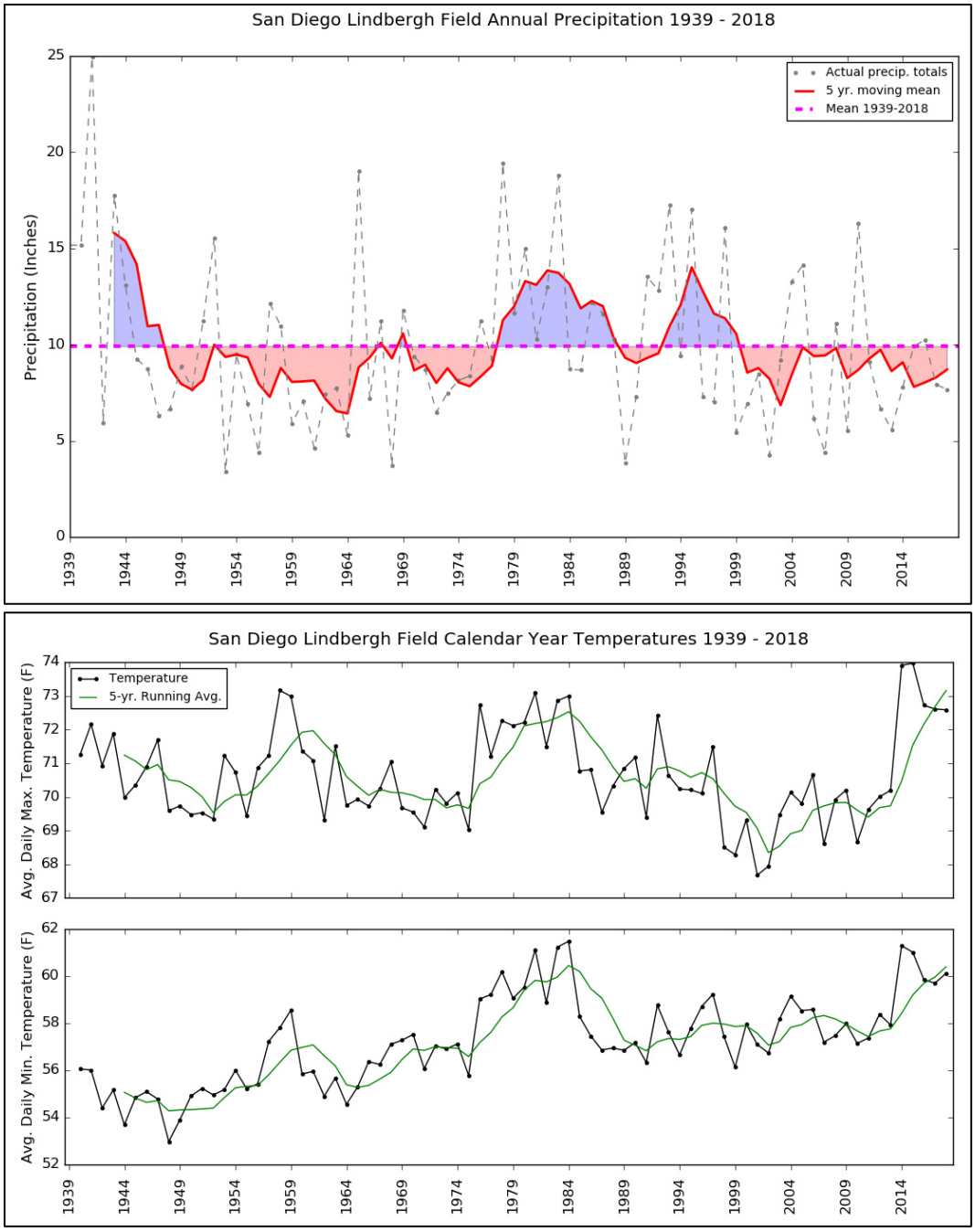


Figure 3. Climate conditions since 1939 at San Diego Lindbergh Field. Top: Total annual precipitation 1939–2018 at San Diego Lindbergh Field (dots). Red-shaded areas = years when the running mean is below the 1939–2018 average (dashed red line). Blue-shaded areas = running mean above the 1939–2018 average. Bottom: Annual averages for daily maximum temperature and daily minimum temperature 1939–2018. Green line = 5 year running average of temperatures. Running averages include the current year and the previous 4 years.

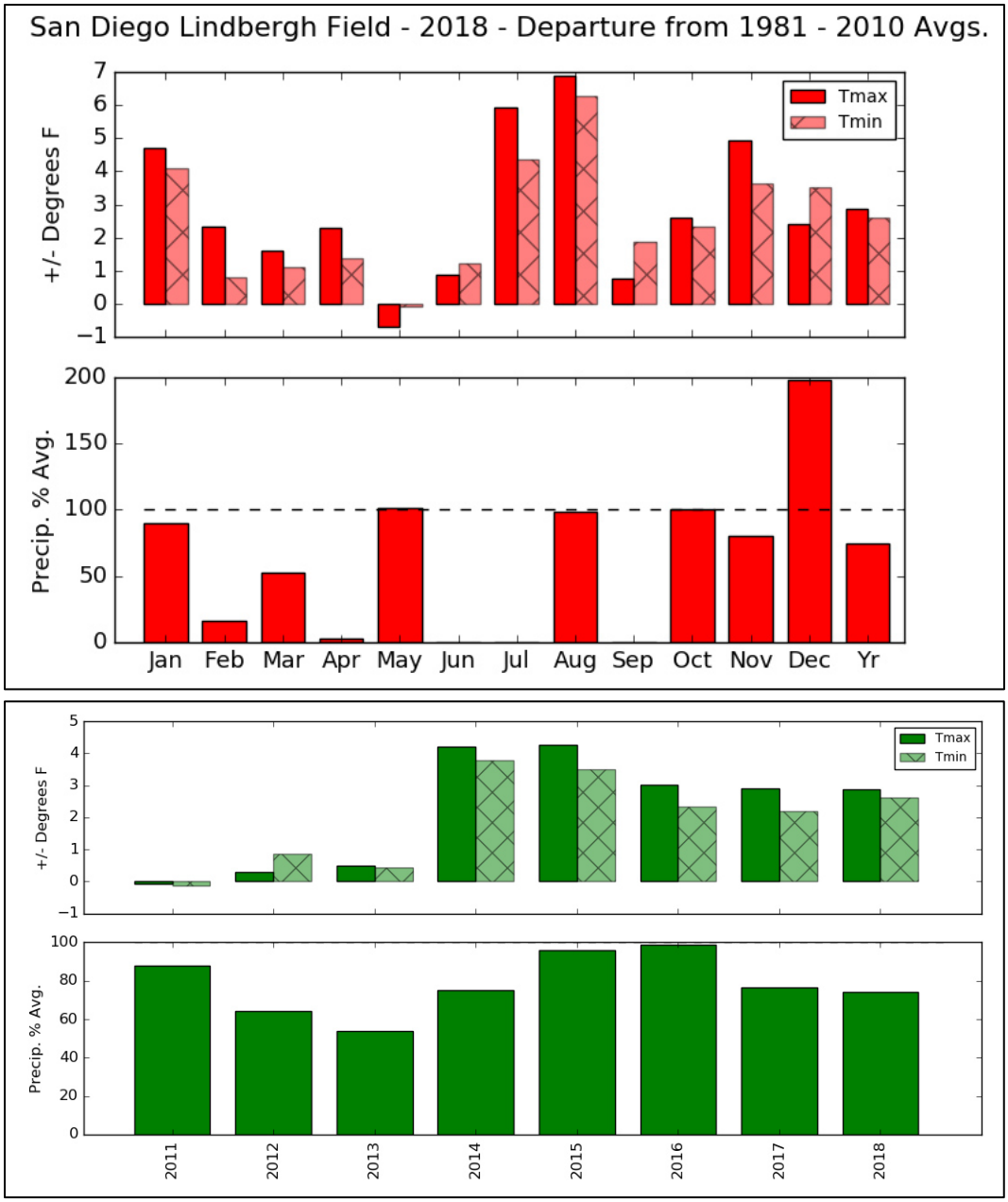


Figure 4. Departure from average climate conditions at San Diego Lindbergh Field. Top: Monthly departures of precipitation, Tmax, and Tmin from 1981–2010 averages during 2018. May–August often have less than 0.2 inches average precipitation so large percent departures, such as shown for August, are a small absolute difference. Bottom: Departure of 2011–2018 annual precipitation, Tmax, and Tmin from 1981–2010 averages at San Diego Lindbergh Field.

Table 1. Total monthly precipitation in inches during 2018 and percent of 1981–2010 averages at key weather stations in and near Cabrillo National Monument. Precipitation is so low during summer months that departure calculations can be misleading. Summer average precipitation totals are in the range of 0.02–0.05 inches, making even slight precipitation show a large percent increase.

Time Period	San Diego Lindbergh Field 2018 Precip. (in)	San Diego Lindbergh Field (% of average)	Chula Vista 2018 Precip. (in)	Chula Vista (% of average)
January	1.78	90	1.20	62
February	0.36	16	0.5	22
March	0.95	53	1.06	63
April	0.024	33	0.05	7
May	0.122	102	0.2	219
June	0	0	0	0
July	0	0	0	0
August	0.02	98	0	0
September	0	0	0	0
October	0.57	100	0.1	19
November	0.81	80	1.34	148
December	3.02	197	2.6	182
Year	**7.66**	**74**	**7.06**	**72**

Table 2. Average daily maximum temperatures (Tmax) and average daily minimum temperatures (Tmin) during 2018 in the San Diego, CA, region and departure from 1981–2010 averages.

Metric	Time Period	San Diego Lindbergh Field—2018 (°F)	San Diego Lindbergh Field—Departure (+/-°F)	Chula Vista—2018 (°F)	Chula Vista—Departure (+/-°F)	Pt. Loma—2018 (°F) [1]	NPS Cabrillo—2018 (°F) [1]
Tmax	January	69.8	4.7	70.1	1.6	N/A	N/A
	February	67.35	2.3	66.3	-1.8	N/A	N/A
	March	67.2	1.6	66.1	-2.0	N/A	N/A
	April	69.8	2.3	67.8	-1.6	N/A	N/A
	May	67.8	-0.7	67.1	-3.0	N/A	N/A
	June	71.7	0.9	70.3	-1.7	N/A	N/A
	July	80.5	6	78.0	2.1	N/A	N/A
	August	83.3	6.9	79.9	2.1	N/A	N/A
	September	76.7	0.8	75.2	-2.8	N/A	N/A
	October	75.4	2.6	74.4	-1.3	N/A	N/A
	November	73.9	4.9	72.3	0.5	N/A	N/A
	December	67.1	2.4	65.9	-1.5	N/A	N/A
	Year	**72.6**	**2.9**	**71.1**	**-0.8**	**N/A**	**N/A**
Tmin	January	53.1	4.08	49.8	4.1	N/A	N/A
	February	51.5	0.8	48.2	0.7	N/A	N/A
	March	54.3	1.13	51.3	1.0	N/A	N/A
	April	57.3	1.37	54.6	1.6	N/A	N/A
	May	59.3	-0.08	57.5	0.0	N/A	N/A
	June	63.2	1.23	61.5	0.9	N/A	N/A
	July	69.8	4.35	67.6	3.1	N/A	N/A
	August	73.0	6.27	69.9	4.3	N/A	N/A
	September	67.1	1.89	64.7	1.5	N/A	N/A
	October	62.9	2.34	59.4	1.5	N/A	N/A
	November	57.2	3.63	52.8	2.7	N/A	N/A
	December	51.97	3.54	48.0	2.7	N/A	N/A
	Year	**60.1**	**2.6**	**57.2**	**2.0**	**N/A**	**N/A**

[1] N/A = Insufficient data for an accurate calculation; MET stations (Pt. Loma and NPS Cabrillo) do not have 30-year averages.

PRISM Maps Depicting Spatial Patterns in Departure from 1981–2010 Averages

The regional precipitation and temperature patterns seen in the PRISM maps (Figures 5–7) are similar to the patterns seen in the weather station data, with small variations. November and December had above average precipitation while the remaining non-summer months were below average (Figure 5). May air temperature was near to below average in most parts of the region, while the remaining months were generally above average (Figure 6).

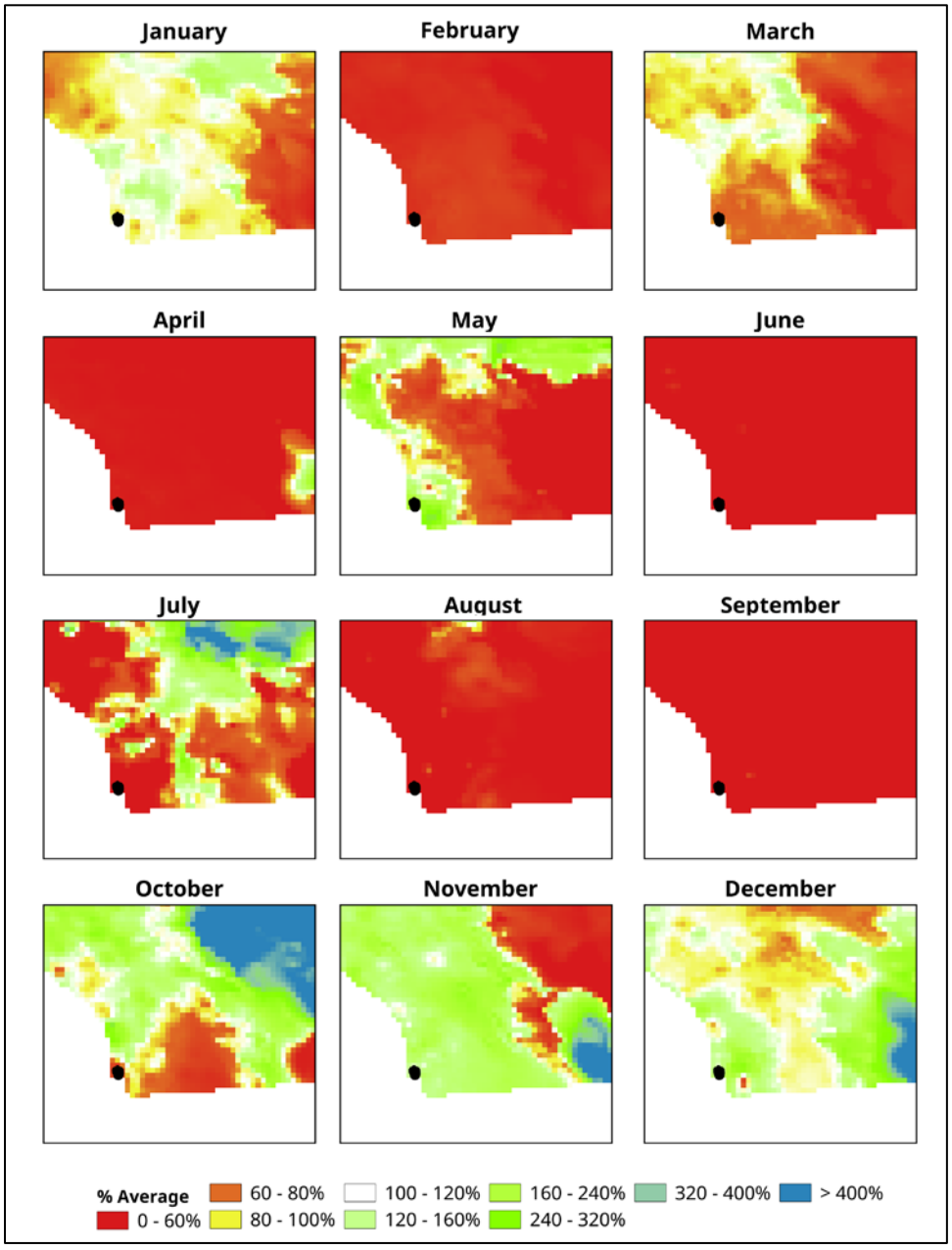


Figure 5. Maps showing percent of average precipitation relative to 1981–2010 for each month during 2018 in the San Diego, CA, region. Estimates are from the Parameter-elevation Regressions on Independent Slopes Model (PRISM). White areas = Pacific Ocean. Cabrillo National Monument is located in the bottom left corner of each map. For more information, see http://www.prism.oregonstate.edu/.

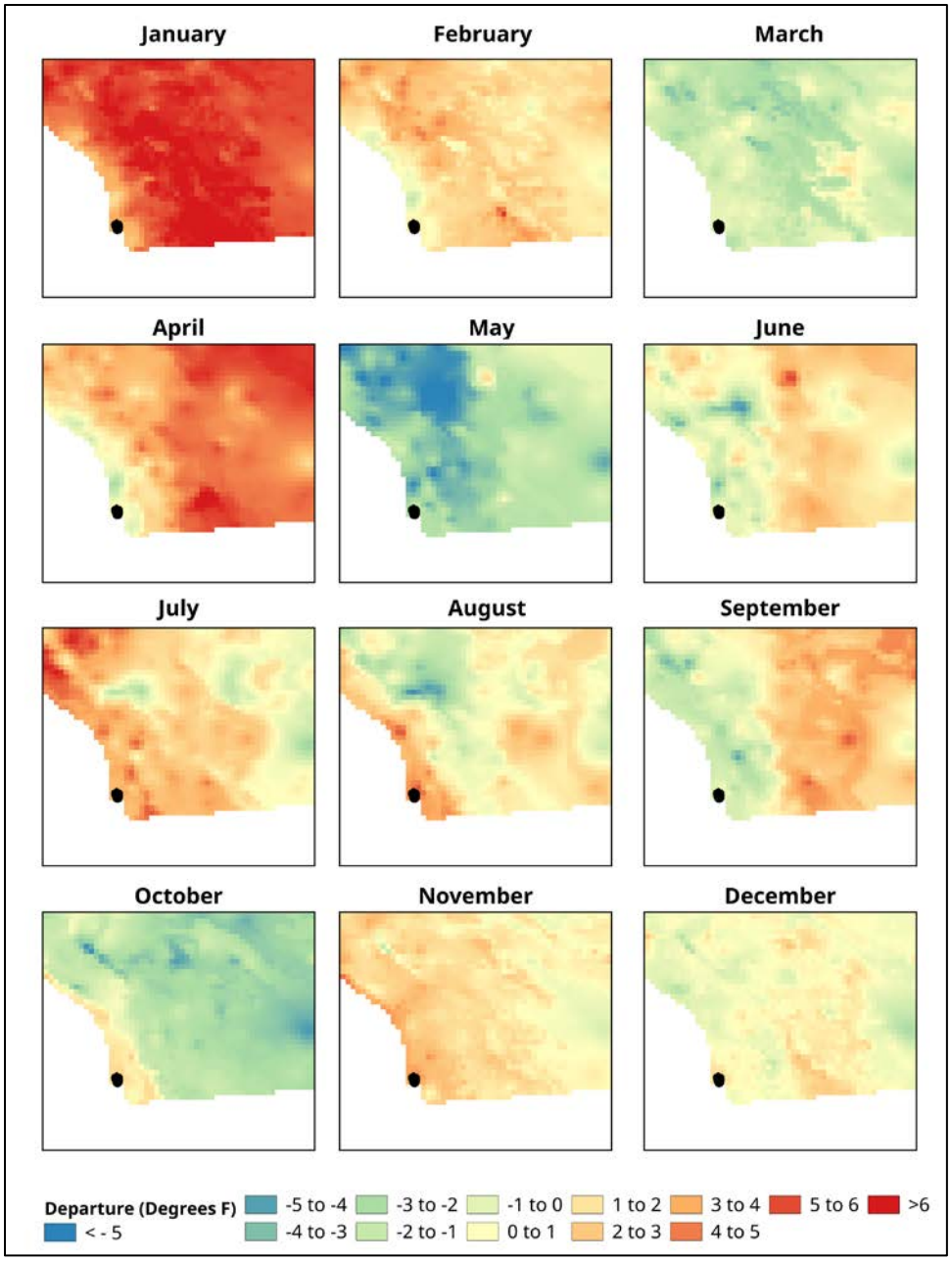


Figure 6. Maps showing departures from 1981–2010 average daily maximum temperatures (Tmax) in degrees Fahrenheit during 2018 in the San Diego, CA, region. Estimates are from the Parameter-elevation Regressions on Independent Slopes Model (PRISM). White areas = Pacific Ocean. Cabrillo National Monument is on the coast, bottom left. For more information, see http://www.prism.oregonstate.edu/.

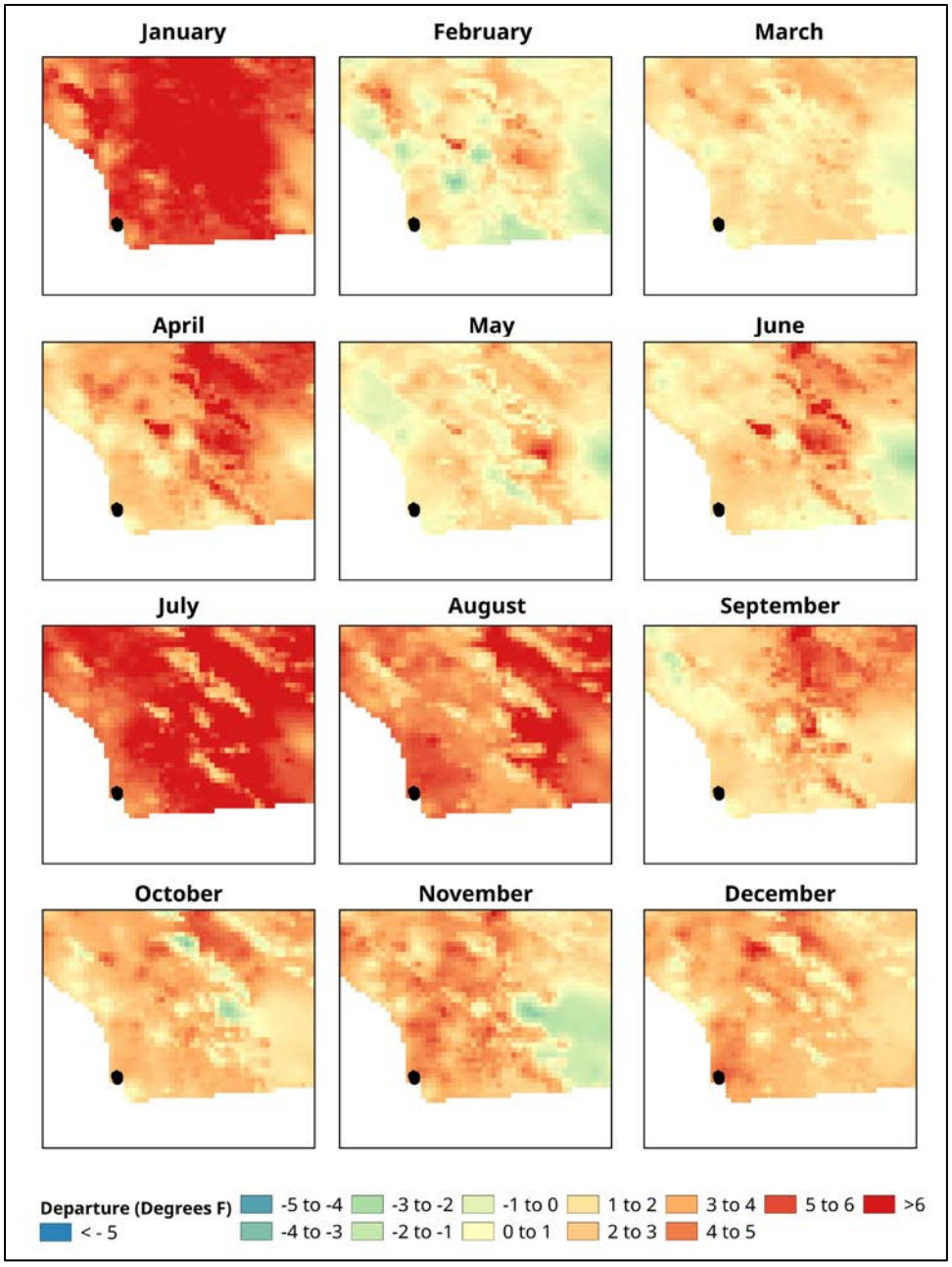


Figure 7. Maps showing departures from 1981–2010 average daily minimum temperatures (Tmin) in degrees Fahrenheit during 2018 in the San Diego, CA, region. Estimates are from the Parameter-elevation Regressions on Independent Slopes Model (PRISM). White areas = Pacific Ocean. Cabrillo National Monument is on the coast, bottom left. For more information, see http://www.prism.oregonstate.edu/.

Streamflow

Since the rivers near Cabrillo National Monument are all heavily influenced by human activity, including artificial dams, streamflow is as much a result of management priorities as annual climatic events. Nevertheless, it is worth noting that streamflows in the San Diego River at Fashion Valley were below the 1982–2010 average for most of the water year and nearly ceased during August (0.07 CFS on August 16, 2018; Figure 8).

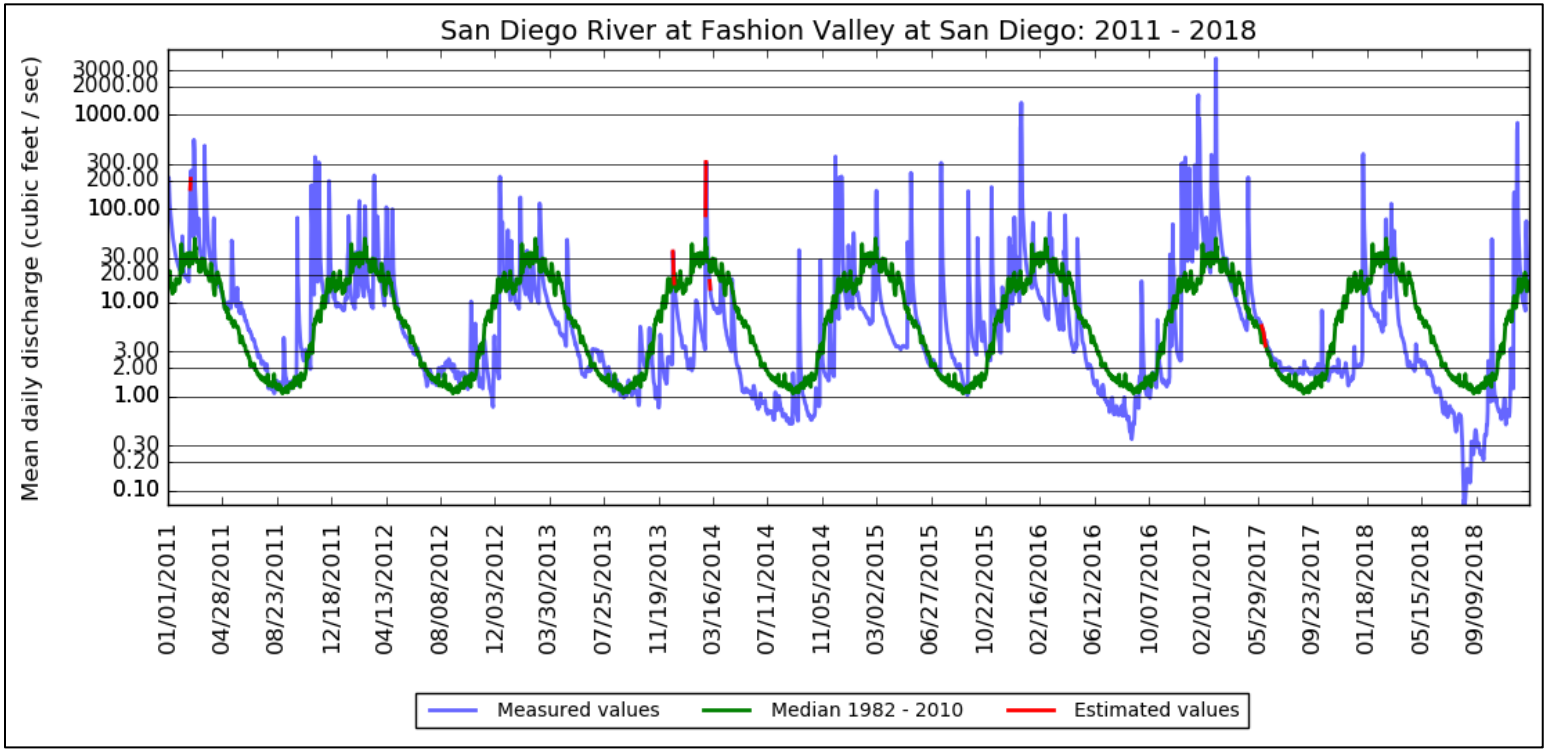


Figure 8. Stream discharge on the San Diego River near Cabrillo National Monument during 2011–2018.

Accumulated Growing Degree Days, an Index of Growing Season Length

Accumulated Growing Degree Days (AGDD) are often used as an index of growing season length. They are calculated as the sum of the differences between the average temperature for each day of the year and a base temperature. This base temperature is often chosen as the threshold below which plants are thought to be metabolically inactive. In the case of AGDD40, the base temperature is 40 °F. Consequently, 40 is subtracted from the mean temperature for each day, and these differences are added up for the entire year, giving a single number (which is not actually a count of days). Similarly, AGDD50 is calculated with a base temperature of 50 (°F).

When viewed from the perspective of growing season length, calendar year 2018 was above average (Table 3). At San Diego Lindbergh Field, AGDD 40 was 113% of the 1981–2010 average and AGDD 50 was 123% of average. At Chula Vista, AGDD40 was 115% of the average and AGDD50 was 127% of the average.

Table 3. Accumulated Growing Degree Days (AGDD) and days above or below critical temperature thresholds during 2018 at weather stations in and around Cabrillo National Monument.

Station Name	Time Period (Metric)	AGDD40	AGDD50	# days >90 °F	# days <32 °F
San Diego Lindbergh Field	2018 (Value)	9617	5967	2	0
	1981–2010 (Average)	8478	4832	2.5	0
Chula Vista	2018 (Value)	8819	5173	1	0
	1981–2010 (Average)	7679	4059	1.9	0.9
Pt. Loma[1]	2018 (Value)	N/A	N/A	N/A	N/A
NPS Cabrillo[1]	2018 (Value)	N/A	N/A	N/A	N/A

[1] N/A = Insufficient data for an accurate calculation; MET stations (Pt Loma and NPS Cabrillo) do not have 30-year averages.

Conclusions

Above average temperatures and generally below average precipitation during 2018 returned the San Diego region to severe drought conditions, after a brief reprieve in 2017. The resulting warming daytime and nighttime temperatures that were documented in 2018 can have important effects on native vegetation and wildlife, both of which are monitored as vital signs of park health at Cabrillo National Monument. This summary of climate conditions in 2018 is intended to support park staff and collaborators with the information they need to understand and manage native plants and animals in the monument and surrounding San Diego region.

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Appendix 1

Table A-1. Climate stations used in this report. Detailed histories, period of record, and 30-year averages can be accessed from the links provided.

Name	Station Type[1]	Station ID	Metadata
Pt. Loma	MET	SDL13	http://mesowest.utah.edu/cgi-bin/droman/meso_base.cgi?stn=SDL13&unit=0&timetype=LOCAL
NPS Cabrillo	MET	HP017	http://mesowest.utah.edu/cgi-bin/droman/meso_base.cgi?stn=HP017&unit=0&timetype=LOCAL
Chula Vista	GHCN	41758	http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?ca1758
San Diego WSO Airport AKA Lindbergh Field	GHCN	47740	http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?ca7740
San Diego Naval Air Station	MET	KNZY	http://www.climateanalyzer.org/raws/KNZY/
San Diego R at Fashion Valley	Stream Gage	11023000	http://waterdata.usgs.gov/nwis/dvstat/?format=sites_selection_links&search_site_no=11023000&agency_cd=USGS&referred_module=sw

[1] Station Type: GHCN = Global Historical Climatology Network; MET = automated meteorological stations.

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