



Climate Monitoring in the Mediterranean Coast Network 2017 – Cabrillo National Monument

Natural Resource Report NPS/MEDN/NRR—2018/1836



ON THE COVER

Rocky intertidal zone at CABR

Photo credit: Vijay Narashimhan

Climate Monitoring in the Mediterranean Coast Network 2017 – Cabrillo National Monument

Natural Resource Report NPS/MEDN/NRR—2018/1836

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Executive Summary

This report details the climate (temperature, precipitation, drought, and streamflow) of Cabrillo National Monument during 2017. 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 (GHCN), 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 an established National Park Service protocol. 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 National Park Service Mediterranean Coast Network Inventory and Monitoring Program.

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 <http://drought.unl.edu/dm/monitor.html>

B-91 Forms – Paper data sheets that are used to record climate data at weather stations

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. Prior to 2011, the official reference period was 1971 – 2000.

Introduction

This report details the climate (temperature, precipitation, drought, streamflow) of Cabrillo National Monument during 2017. 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 2017 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 – 2000, meteorological measurements were compared to 1961 – 1990 averages; from 2001 – 2010 the reference period was 1971 – 2000; and starting in calendar year 2011, most weather data has 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:

<http://www.ncdc.noaa.gov/oa/climate/normals/usnormals.html#WHATARENORMALS>)

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

The ClimateAnalyzer: www.ClimateAnalyzer.org. This web site 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 (<http://drought.unl.edu/dm/monitor.html>)

NOAA (National Oceanic Atmospheric Administration) National Weather Service
(<http://www.cpc.ncep.noaa.gov/>)

USGS (U.S. Geological Survey) Water National 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 2017 are compared to 1981 – 2010 PRISM averages for each month by calculating the percent of normal precipitation (2017 precipitation divided by 1981 – 2010 precipitation, multiplied by 100) or the temperature departure (2017 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 period 1981 – 2010 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 (<http://drought.unl.edu/dm/monitor.html>) 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 2017 water year, which ran from October 2016 to September 2017, 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.

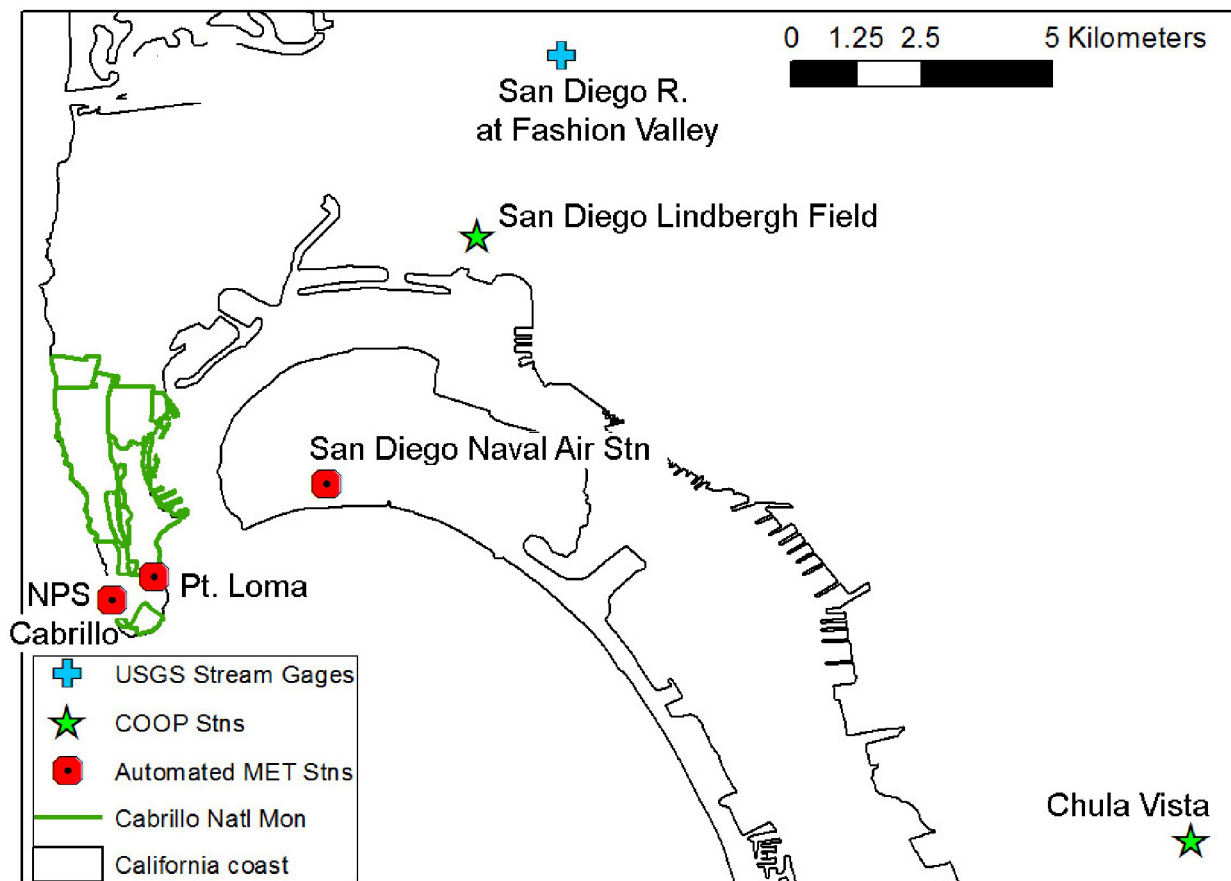


Figure 1. Map showing key climate stations and stream gauges in and near Cabrillo National Monument. Cooperative Observer (COOP) stations are accessed through the Global Historical Climatology Network (see text).

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 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 and to the original datasheets (B-91 forms) used by weather station staff. When possible, data missing in the electronic records were recovered from the original datasheets and hand entered by the author of this report. 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) were missing, monthly average temperatures were not calculated. The data handling was conservative, i.e., 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 degrees Fahrenheit, data for the entire day was 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 degrees Fahrenheit), which were ascribed to instrumental error and considered missing; and the missing data criteria just described for GHCN stations were used to calculate monthly statistics.

Results

Temperature, Precipitation, and Drought Status During Calendar Year 2017

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 (See Figures 5 – 7 under PRISM Maps section below) and compare them to the weather station data presented in Figures 3 – 4 and Tables 1 – 2 in the Weather Station Temperature and Precipitation Data section.

Broader Picture – The Ongoing Drought Became More Severe

The region entered into drought conditions in April 2012 (Tercek 2013) and became progressively drier throughout 2013 and 2014. By the end of 2014, Cabrillo 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 (Figure 2). Finally, in January 2017, the drought began to slacken, eventually moving to the D0 rating by the end of the year (Figure 2).

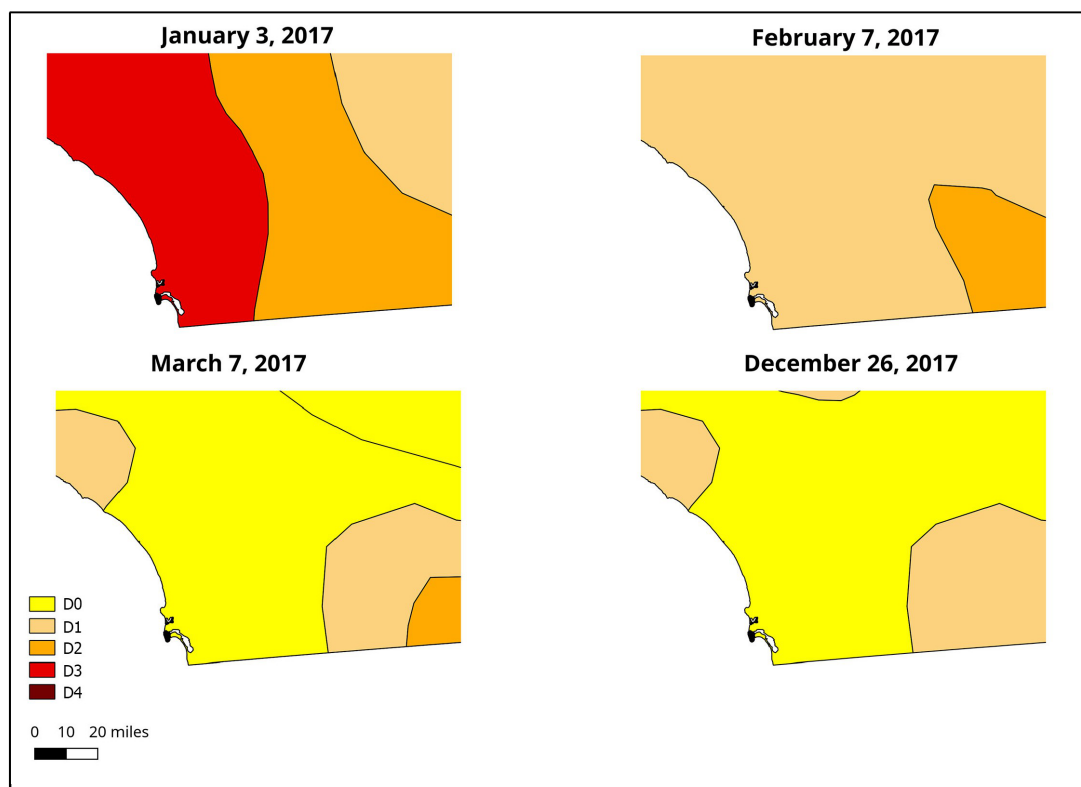


Figure 2. U.S. Drought Monitor maps for Cabrillo National Monument during 2017. Drought codes are D0 – “Abnormally Dry,” D1 – “Moderate Drought,” “D2 – Severe Drought,” “D3 – Extreme Drought,” “D4 – Exceptional Drought.” White areas are the Pacific Ocean. Cabrillo NM is located on the coast, on the lower-left corner of each map. For more information visit: www.drought.unl.edu/dm/monitor.html.

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>

ENSO started 2017 in a transition between El Nino and La Nina, switching fully into La Nina by Autumn. Normally, La Nina conditions produce drier conditions in southern California while El Nino produces wetter conditions. Rain falling early in the year did slightly ameliorate the drought in southern California. 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 precipitation, or the lack thereof. Calendar year 2017 was hot and had generally below average precipitation. As shown in Figure 3, the 2017 average day-time high at San Diego Lindbergh field (72.6 degrees) was 2.9 degrees above the 1981 – 2010 average. Average daytime lows were similarly about 2.2 degrees above average. Total annual precipitation was 77% average in San Diego and 87% average in Chula Vista (Figure 3,4; Tables 1,2). January and February had above average precipitation (152 – 193% average), while the remaining months of the year were below average. Every month of the year had near or above average temperatures, with December being more than 6 degrees above average at San Diego (Figure 3,4; Tables 1,2). Precipitation during the summer months (May – December) is so slight that calculations of percent average are misleading. An increase of only a few hundredths of an inch can mean the difference between an above vs. below average month.

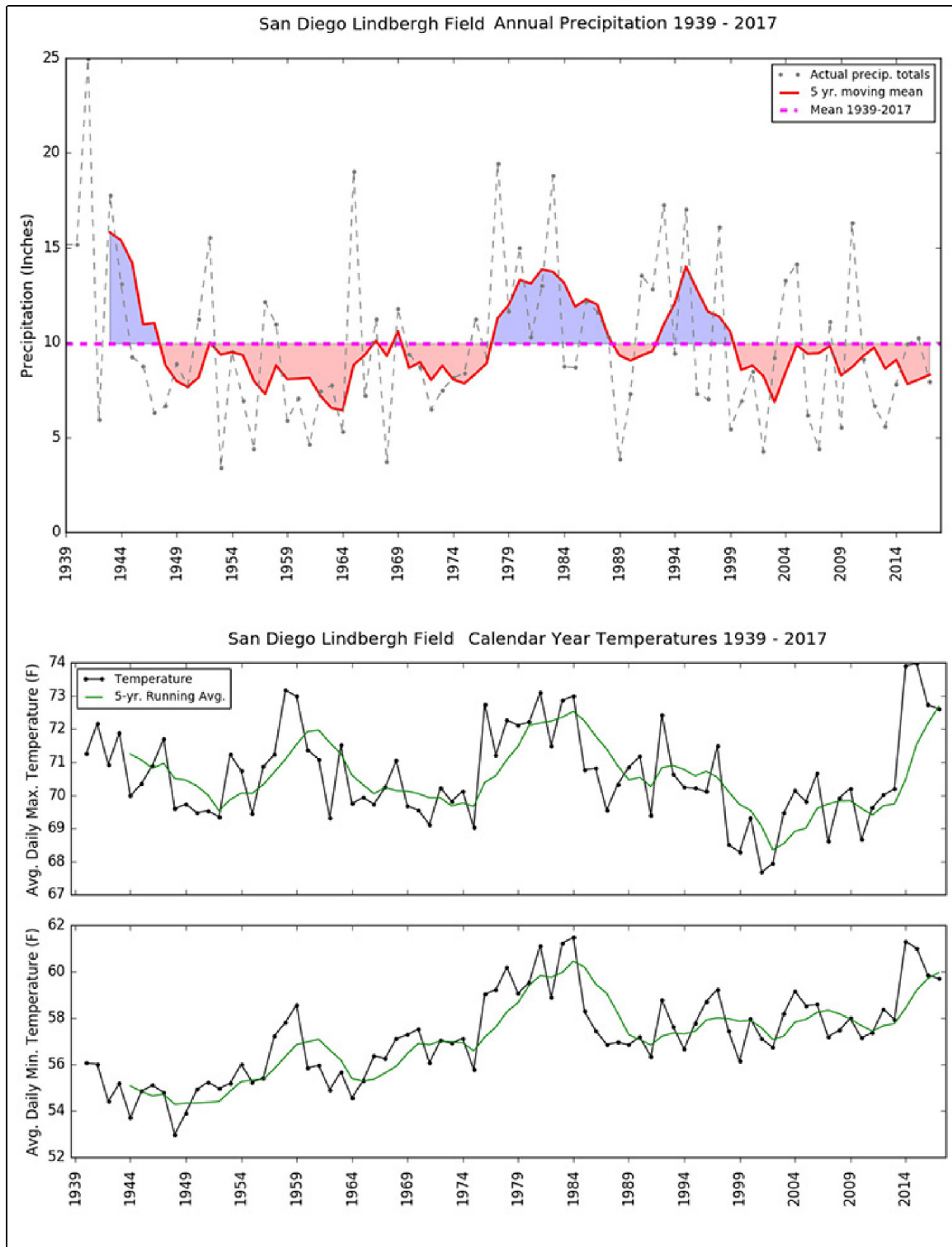


Figure 3. Top: total annual precipitation 1939 – 2017 at San Diego Lindbergh Field (dots). Red-shaded areas = years when the running mean is below the 1939 – 2017 average (dashed red line). Blue-shaded areas = running mean above the 1939 - 2017 average. Bottom: Annual averages for daily maximum temperature and daily minimum temperature 1939 – 2017. Green line = 5 year running average of temperatures. Running averages include the current year and the previous 4 years.

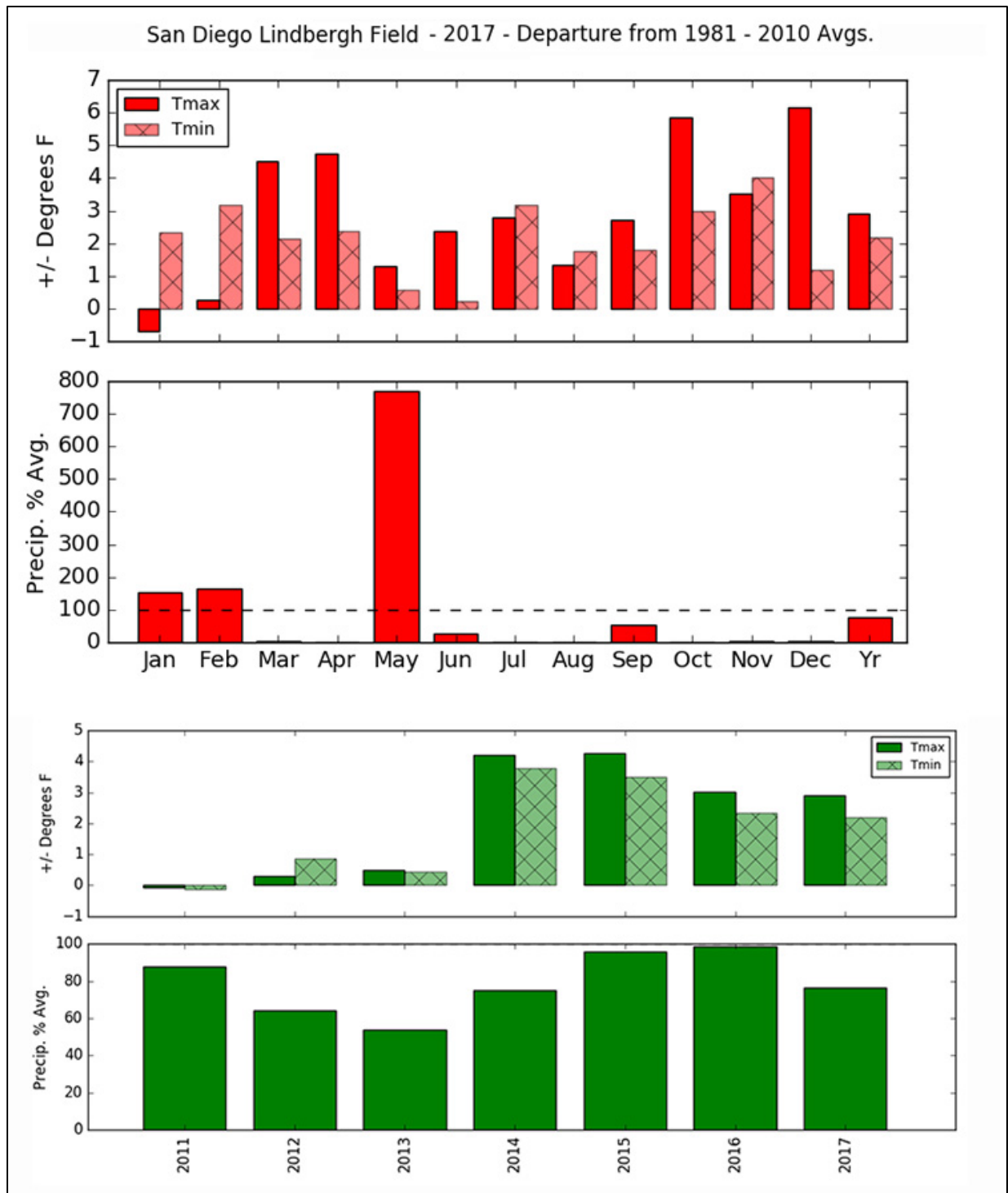


Figure 4. Top: Departure of 2011 - 2017 annual precipitation, Tmax, and Tmin from 1981 - 2010 averages at San Diego Lindbergh Field. Bottom: Monthly departures of precipitation, Tmax, and Tmin from 1981 - 2010 averages during 2017. May - August often have less than 0.2 inches average precipitation so large percent departures, such as shown for August, are a small absolute difference.

Table 1. Total Monthly Precipitation in inches during 2017 and Percent of 1981 – 2010 averages at key weather stations in and near Cabrillo National Monument.

Month	San Diego	San Diego	Chula Vista	Chula Vista
	2017 Precip. (in)	% average	2017 Precip. (in)	% average
January	3.02	152	3.75	193
February	3.71	163	3.61	157
March	0.08	5	0.05	3
April	0.01	2	0.00	0
May	0.92	768*	1.06	1177*
June	0.02	28	0.00	0
July	0.00	0	0.00	0
August	0.00	0	0.07	709*
September	0.08	55	0.02	17
October	0.00	0	0.00	0
November	0.02	2	0.00	0
December	0.07	5	0.03	2
YR	7.93	77	8.6	87

* Precipitation is so low during summer months that departure calculations can be misleading. Summer average precipitation totals are in the range 0.02 – 0.05 inches, making even slight precipitation show a large percent increase.

Table 2a. Average daily maximum temperatures (Tmax) during 2017 and departure from 1981 – 2010 averages expressed as +/- Degrees F. N/A = insufficient data for an accurate calculation. Met stations (last two entries in the table) do not have 30-year averages.

Month	San Diego	San Diego	Chula Vista	Chula Vista	Pt. Loma	NPS Cabrillo
	2017 Tmax (F)	Departure (+/-	2017 Tmax (F)	Departure (+/-	2017 Tmax (F)	2017 Tmax (F)
January	64.4	-0.7	64.0	-4.5	N/A	N/A
February	65.3	0.3	64.8	-3.3	N/A	N/A
March	70.1	4.5	69.3	1.2	N/A	N/A
April	72.3	4.8	70.5	1.1	N/A	N/A
May	69.8	1.3	68.3	-1.8	N/A	N/A
June	73.2	2.4	71.0	-1	N/A	N/A
July	77.4	2.8	75.6	-0.3	N/A	N/A
August	77.7	1.3	75.6	-2.2	N/A	N/A
September	78.6	2.7	77.6	-0.4	N/A	N/A
October	78.6	5.8	78.7	3	N/A	N/A
November	72.5	3.5	72.0	0.2	N/A	N/A
December	70.8	6.2	71.0	3.65	N/A	N/A
YR	72.6	2.9	71.6	-0.3	N/A	N/A

Table 2b. Average daily minimum temperatures (Tmin) during 2017 and departure from 1981 – 2010 averages expressed as +/- Degrees F. N/A = insufficient data for an accurate calculation. Met stations (last two entries in the table) do not have 30-year averages.

	San Diego	San Diego	Chula Vista	Chula Vista	Pt. Loma	NPS
Month	2017 Tmin	Tmin	2017 Tmin	Tmin	2017 Tmin	2017 Tmin
January	51.3	2.6	48.0	2.2	N/A	N/A
February	53.9	2.7	51.0	3.5	N/A	N/A
March	55.4	3.4	51.8	1.5	N/A	N/A
April	58.3	3.1	54.6	1.6	N/A	N/A
May	60.0	1.8	57.8	0.3	N/A	N/A
June	62.2	2.2	61.1	0.5	N/A	N/A
July	68.6	0.6	67.3	2.8	N/A	N/A
August	68.5	1.2	66.7	1.1	N/A	N/A
September	67.0	0.8	65.1	1.9	N/A	N/A
October	63.6	3.1	60.4	2.6	N/A	N/A
November	57.6	3.4	54.2	4	N/A	N/A
December	49.6	3.1	46.3	1	N/A	N/A
YR	59.7	2.2	57.1	1.9	N/A	N/A

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. January and while the remaining non-summer months were below average. January and February were near to below average in most parts of the region, while the remaining months were above average. December was particularly warm, with temperatures more than 6 degrees above average.

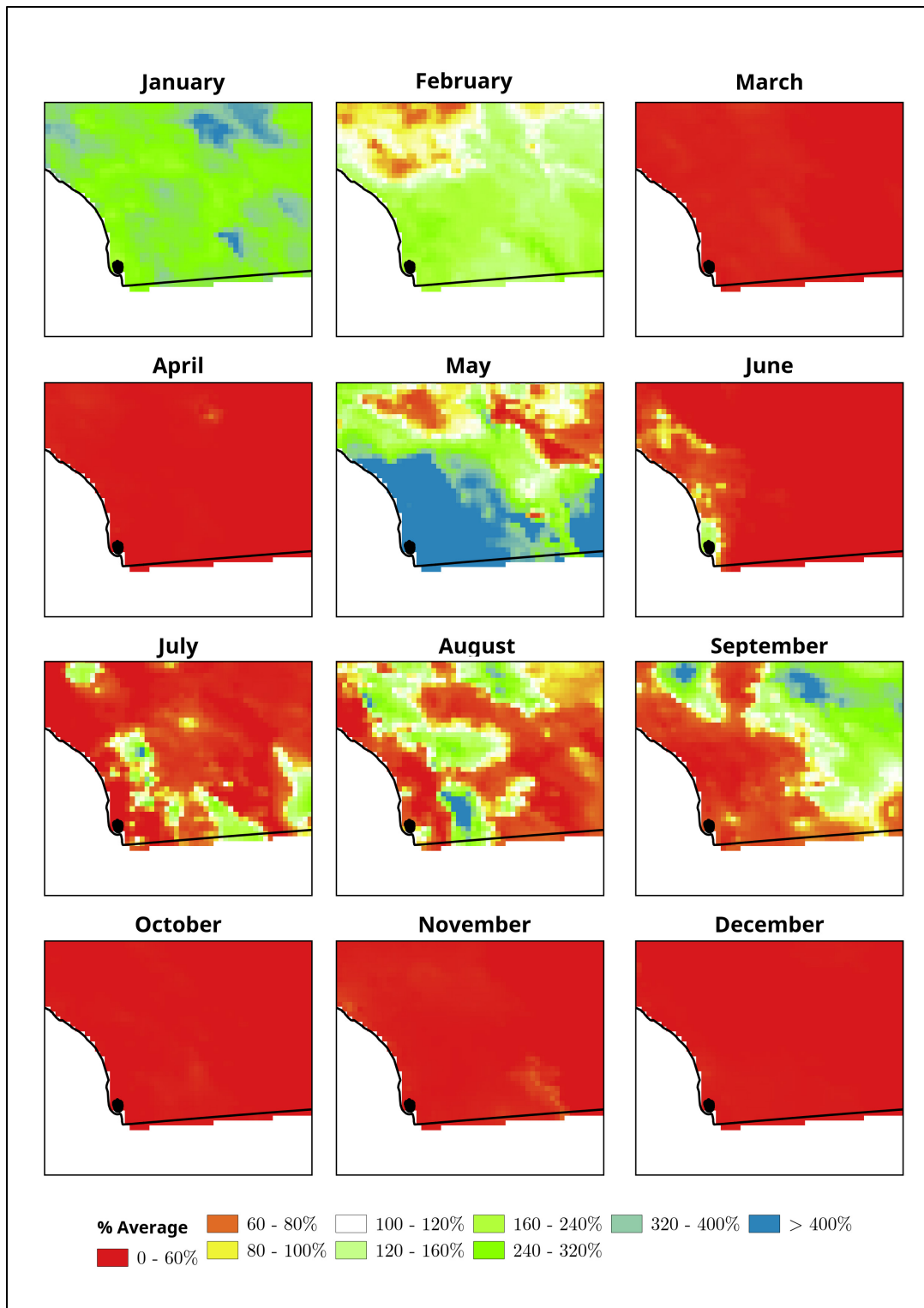


Figure 5. Maps showing percent of average precipitation relative to 1981–2010 for each month during 2017. Estimates are from the Parameter-elevation Regressions on Independent Slopes Model (PRISM). White areas = Pacific Ocean. Cabrillo is located in the bottom left corner of each map. For more information, see <http://www.prism.oregonstate.edu/>.

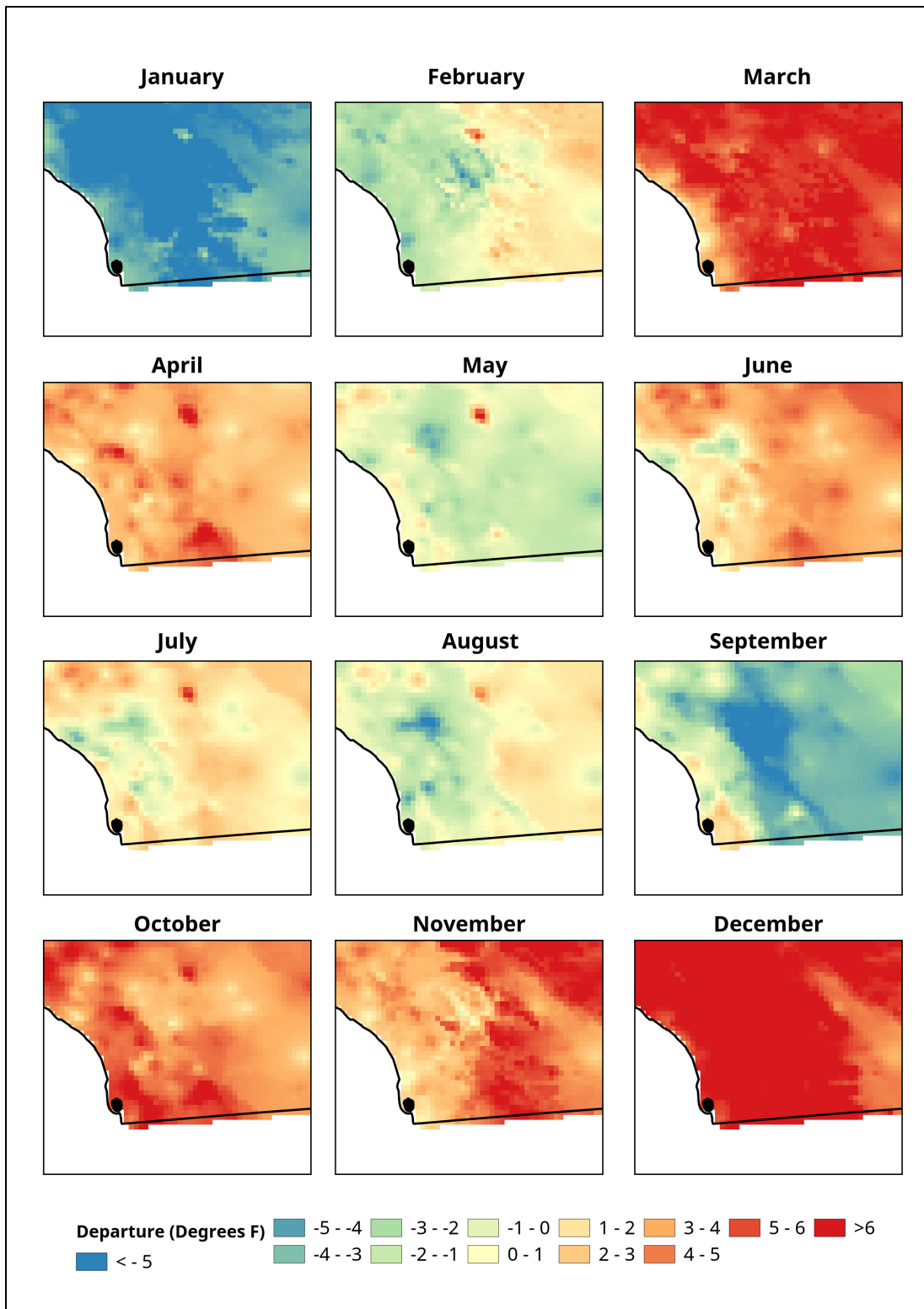


Figure 6. Maps showing departures from 1981 – 2010 average daily maximum temperatures (Tmax) in degrees Fahrenheit during 2017. Estimates are from the Parameter-elevation Regressions on Independent Slopes Model (PRISM). White areas = Pacific Ocean. Cabrillo NM is on the coast, bottom left. For more information, see <http://www.prism.oregonstate.edu/>.

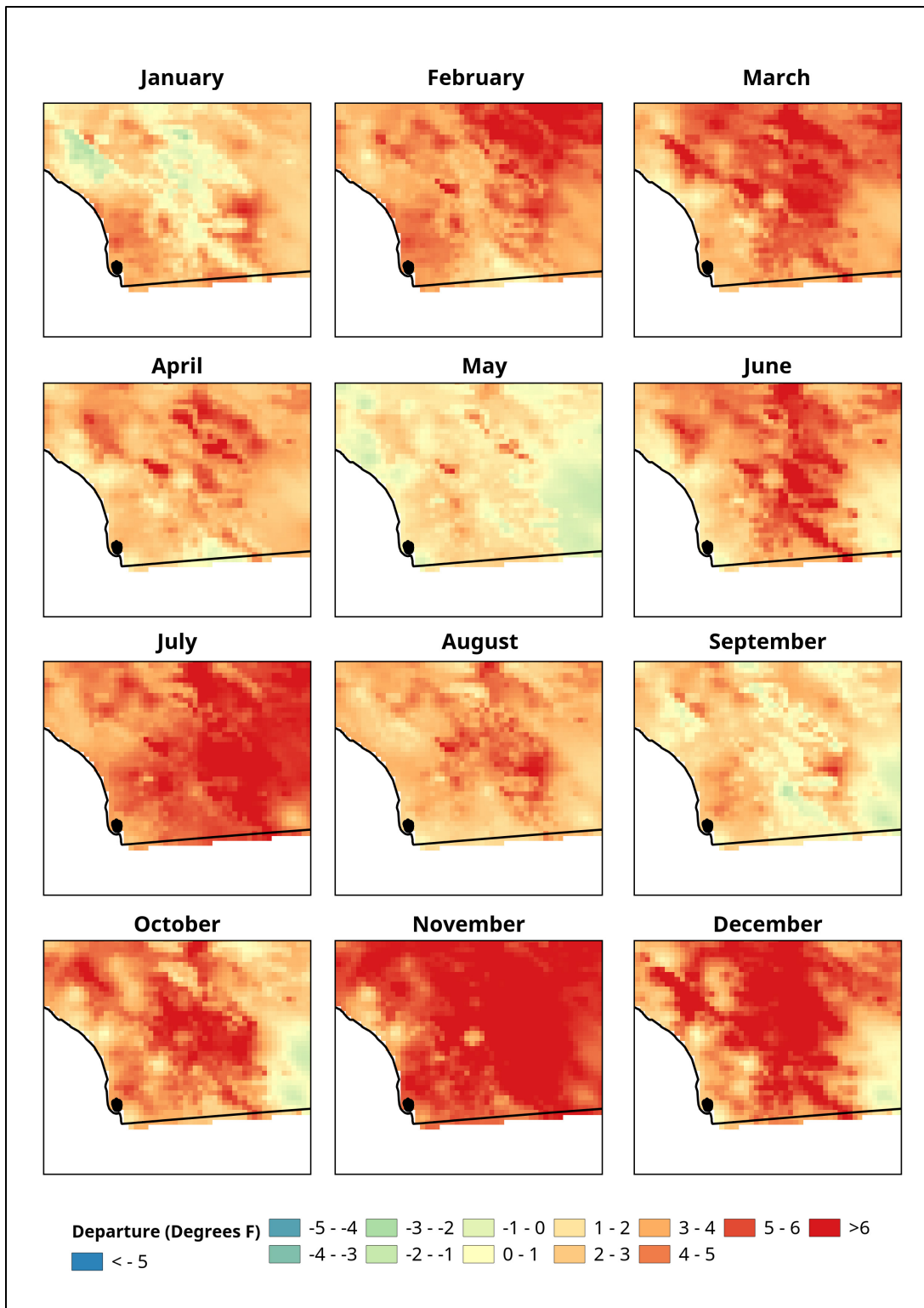


Figure 7. Maps showing departures from 1981 – 2010 average daily minimum temperatures (Tmin) in degrees Fahrenheit during 2017. Estimates are from the Parameter-elevation Regressions on Independent Slopes Model (PRISM). White areas = Pacific Ocean. Cabrillo NM is on the coast, bottom left. For more information, 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 were near normal during the earlier, wetter part of the year and below average during the drier, latter half of the year (Figure 8).

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 degrees Fahrenheit. 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. Similarly, AGDD50 is calculated with a base temperature of 50 (F).

When viewed from the perspective of growing season length, calendar-year 2017 was above average (Table 3). At San Diego Lindbergh Field, AGDD 40 was 113% the 1981 – 2010 average and AGDD 50 was 122%. At Chula Vista, AGDD40 was 116% and AGDD50 was 129% the average.

Table 3. Accumulated Growing Degree Days (AGDD) and days above or below critical temperature thresholds during 2017. N/A = insufficient data for an accurate calculation. Met stations (last 2 entries in the table) do not have 30-year averages.

Station Name	Time Period	AGDD40	AGDD50	# days >= 90 F	# days <= 32F
San Diego Lindbergh Field	2017 Value	9544	5894	6	0
	1981 - 2010 Avg.	8478	4832	2.5	0
Chula Vista	2017 Value	8875	5225	4	0
	1981 - 2010 Avg.	7679	4059	1.9	0.9
Pt. Loma	2017 Value	N/A	N/A	N/A	N/A
NPS Cabrillo	2017 Value	N/A	N/A	N/A	N/A

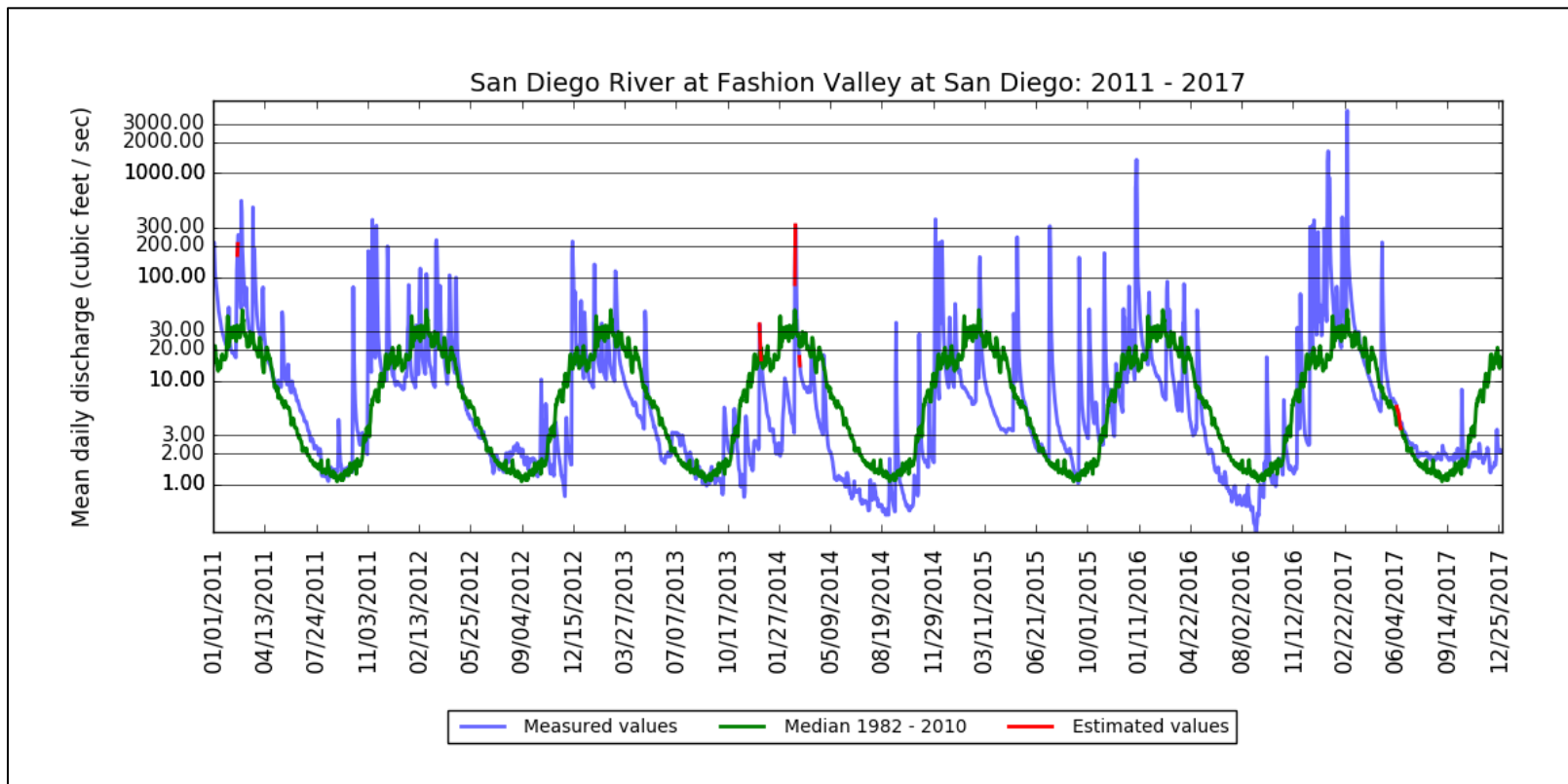


Figure 8. Stream discharge on the San Diego River near Cabrillo National Monument during 2011 – 2017.

Conclusions

- ENSO started 2017 in a transition between El Nino and La Nina, switching fully into La Nina by Autumn. Normally, La Nina conditions produce drier conditions in southern California while El Nino produces wetter conditions. Rain falling early in the year did slightly ameliorate the drought in southern California.
- The region entered into drought conditions in April 2012 (Tercek 2013) and became progressively drier throughout 2013 and 2014. By the end of 2014, Cabrillo 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 (Figure 2). Finally, in January 2017, the drought began to slacken, eventually moving to the D0 rating by the end of the year (Figure 2).
- Calendar year 2017 was hot and had generally below average precipitation. As shown in Figure 3, the 2017 average day-time high at San Diego Lindbergh field (72.6 degrees) was 2.9 degrees above the 1981 – 2010 average. Average daytime lows were similarly about 2.2 degrees above average. Total annual precipitation was 77% average in San Diego and 87% average in Chula Vista (Figure 3 and 4; Tables 1 and 2)
- January and February had above average precipitation (152 – 193% average), while the remaining months of the year were below average. Every month of the year had near or above average temperatures, with December being more than 6 degrees above average at San Diego (Figure 3 and 4; Tables 1 and 2). Precipitation during the summer months (May – December) is so slight that calculations of percent average are misleading. An increase of only a few hundredths of an inch can mean the difference between an above vs. below average month.

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Appendix A

Table A1. Climate stations used in this report. Detailed histories, period of record, and 30-year averages can be accessed from the links provided. GHCN = Global Historical Climatology Network.

Name	Stn type	Stn 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

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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