



Mediterranean Coast Network Climate of 2012 Annual Report

Cabrillo National Monument

Natural Resource Data Series NPS/MEDN/NRDS—2013/564



ON THE COVER

Rock on the beach at Cabrillo National Monument
Photo by Ashea Mills

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Executive Summary

This report details the climate (temperature, precipitation, drought, streamflow, and wind conditions) of Cabrillo National Monument during 2012. 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.

After two years of drought free status, 2012 saw the return to drier conditions, particularly during the second half of the year. Despite this, the 2012 water year, which runs from October 2011 – September 2012 was not as dry as the period 2005 - 2009, likely because the region was still benefitting from the wetter than average conditions during 2010 – 2011. Average annual temperatures for 2012 were very near average. In contrast, total annual precipitation at San Diego Lindbergh Field during 2012 (6.6 inches) was only 66% of the long-term average (calculated during 1939 – 2012) of 10 inches. During 2012, March – July were generally cooler than the 1981 – 2010 averages, while August – December were in most cases warmer than average. In general, there was above average precipitation during April, October, and December and below average precipitation during April, October and December. Growing season length was 104% - 122% the 1981 – 2010 averages for weather stations in the region. During the 2011 – 2012 water year, the San Diego River experienced its lowest peak flow rate since 2002. Readers can download the data used in this report and make custom climate graphs and tables of their own by visiting www.ClimateAnalyzer.org and can access the original raw data using the links provided in Appendix 1.

Acknowledgments

Funding for this report was provided by National Park Service Mediterranean Coast Network Inventory and Monitoring Program. We appreciate data collected in collaboration with Dr. Dan Cayan (University of California, San Diego). This report was improved by comments from K. Lombardo (Cabrillo National Monument).

Glossary

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

Climate: Complete and entire ensemble of statistical descriptors of temporal and spatial properties comprising the behavior of the atmosphere. These descriptors include means, variances, frequency distributions, autocorrelations, spatial correlations and other patterns of association, temporal lags, and element-to-element relationships. The descriptors have a physical basis in flows and reservoirs of energy and mass. Climate and weather phenomena shade gradually into each other and are ultimately inseparable (Davey et al. 2006).

Climate normal, 30-year average or “normals” – A long-term average value of a meteorological parameter (i.e. temperature) measured at a specific station. For example, "temperatures are normal for this time of year" means that temperatures are at or near the average climatological value for a given time period. Climate normals are usually taken from data averaged over a 30-year period (e.g., 1971-2000). 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.

Cooperative Observer (COOP) stations – a station where measurements are typically recorded by human observers on paper data sheets that are submitted to NWS for aggregation and error checking. COOP stations can also be automated to collect data at regularly scheduled times.

GHCN: Global Historical Climatology Network.

Met: automated meteorological weather station

NOAA: National Oceanic and Atmospheric Administration

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

Tmax / Tmin: mean daily Maximum / Minimum Temperatures

US Drought Monitor: A broad brush assessment of drought conditions. See <http://drought.unl.edu/dm/monitor.html>

Water Year: The Water Year (or Hydrologic Year) is most often defined as the period from October 1 to September 30 of the following year. It is called by the calendar year in which it ends. Thus, Water Year 2011 is the 12-month period beginning October 1, 2011 and ending September 30, 2011. The period is chosen so as to encompass a full cycle of precipitation accumulation.

Weather: Instantaneous state of the atmosphere at any given time, mainly with respect to its effects on biological activities. As distinguished from climate, weather consists of the short-term (minutes to days) variations in the atmosphere.

Introduction

Climate is a dominant driver of physical and ecologic processes in the Mediterranean Coast Network (MEDN) parks (Davey et al. 2006). Trends in precipitation, wind, and temperature influence how an ecosystem and its organisms function. Through direct and indirect means, climate affects the behavior and reproduction of terrestrial and aquatic animal species (Crozier et al. 2008). Given the importance of climate, it has been identified as a primary vital sign by all 32 Inventory and Monitoring (I&M) networks within the National Park Service (NPS) (Gray 2008). The MEDN monitors climate in order to understand variations in other park resources being monitored, compare current and historic data to understand long-term trends, and to provide data for modeling impacts to park facilities and resources in the future. The climate data developed by the MEDN climate monitoring program plays an important role in understanding and interpreting the other physical and ecological Vital Signs monitored within network parks.

This report details the climate (temperature, precipitation, drought, streamflow, wind) of Cabrillo National Monument (CABR) during 2012. 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 2012 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>)

Approach and Methods

Selection of Datasets

In order to place the climate of CABR within a regional context, grid-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 2012 are compared to 1981 – 2010 PRISM averages for each month by calculating the percent of normal precipitation (2012 precipitation divided by 1981 – 2010 precipitation) or the temperature departure (2012 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 park 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 CABR, and in the nearby San Diego Naval Air station. These stations have not been in operation long enough to have climatological normal or long-term 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 CABR 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 drought conditions across the region. Drought status was also assessed with the Reconnaissance Drought Index (RDI), which can be thought of as the ratio of precipitation (P) to potential evapotranspiration (PET) divided by the average of this ratio for the time period selected minus one, or $((P/PET)/(avg-P/avg-PET)-1)$ (Tsakiris and Vangelis 2005). Evapotranspiration, in turn, is calculated using the Penman-Montieth equation, with methods described by the Food and Agriculture Organization (FAO) (Allen et al 1988). Negative values of the index indicate drier than average conditions, while positive values are wetter than average.

Even though the watercourses in the region are human-controlled and not directly tied to rainfall, USGS stream gage data (<http://waterdata.usgs.gov/nwis>) were used to contrast streamflow during the 2012 water year, which ran from October 2012 to September 2012, with average conditions during the period of record for the gage of interest (in this case 1982 – 2012). Water years (October – September) were also used instead of calendar years (January – December) for the calculation of drought indices because they more closely match the natural cycle of precipitation in region, namely dry summers followed by a resumption of precipitation in the fall that lasts until the end of the following spring.

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.

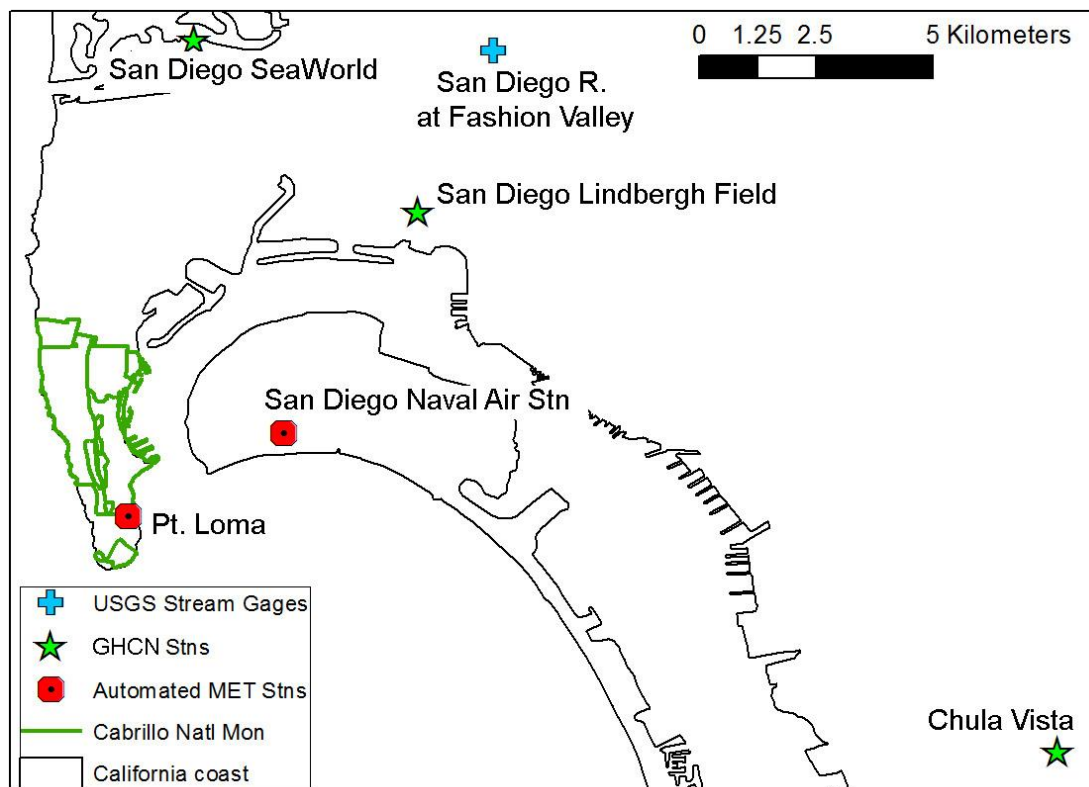


Figure 1. Map showing key climate stations and stream gauges in and near Cabrillo National Monument.

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” or COOP stations because in most cases their measurements are recorded by human observers on paper data sheets that are 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 created software tools that assist in the interpretation of the data flags and diagnostic plotting of the data. This software, the Climate Data Summarizer, can be downloaded from www.YellowstoneEcology.com.

Following guidelines from Kittel (2008), Kittel et al. (2009), and Rocky Mountain Climate Working Group (2010), the Qa/Qc employed by the Climate Data Summarizer 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.

To download the software used for data screening and to learn more about the methods used, visit www.YellowstoneEcology.com. 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.

Analysis of Wind Data

Wind roses were used to present average conditions during both 2011 and 2012 and to contrast them with the period 2001 – 2010. These time periods were chosen because they include the entire length of record available from the met stations in CABR.

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 8 – 10) and compare them to the weather station data presented in Figures 4 – 7 and Tables 1 – 2.

The Broad Picture – The region became drier during the course of 2012

Drought Monitor

After recovering from drought during 2010, the region remained drought free for the entirety of calendar year 2011 (Tercek 2012). Drought free conditions continued throughout the region until below average precipitation in February and March 2012 (data presented below) led to a return of drought in April 2012 (Figure 2). Above average precipitation during April and moderate temperatures kept the region drought free until Fall (Figure 2), when drier and warmer than average conditions during August and September particularly (data presented below) kept the region in “DO – Abnormally Dry” status through the first quarter of 2013 (Figure 2).

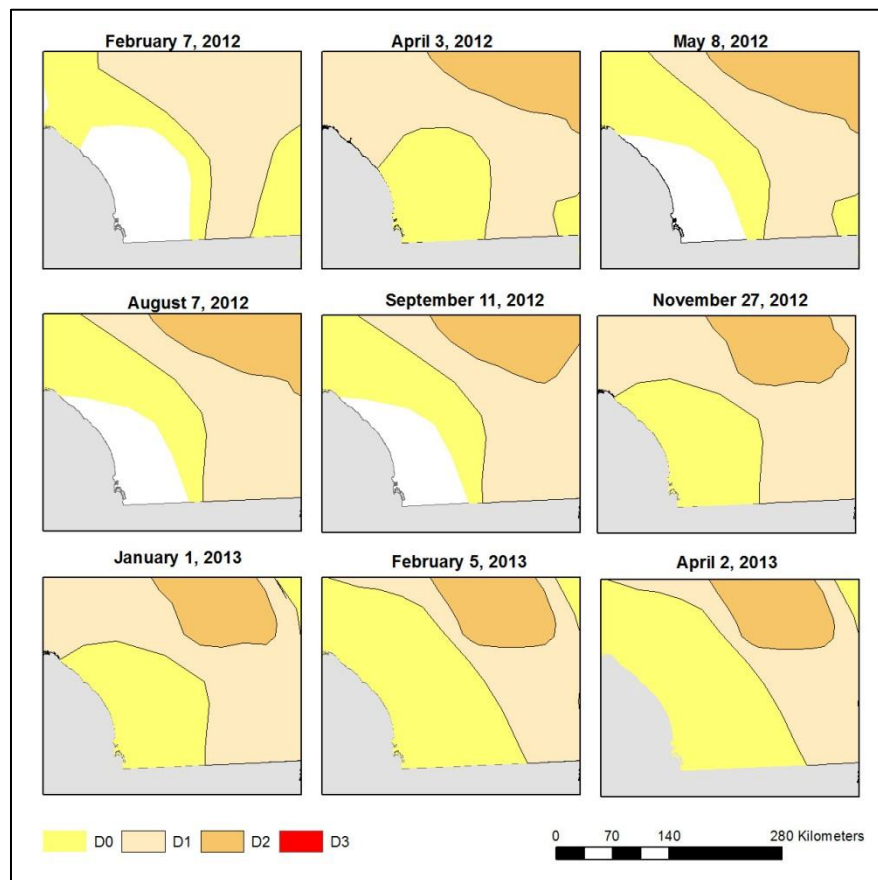
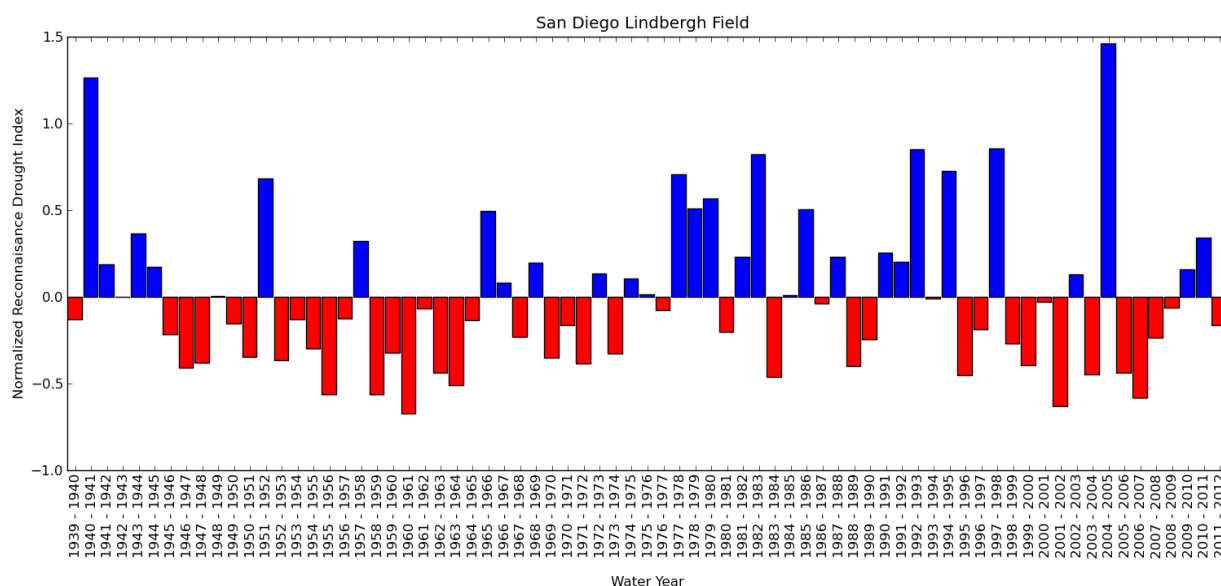


Figure 2. U.S. Drought Monitor maps for Cabrillo National Monument during 2012 - 2013. Drought classifications range from “abnormally dry” (D0) to “exceptional drought” (D4). White areas on the map indicate lack of drought status. Gray areas are the Pacific Ocean. Cabrillo National Monument is located on the lower corner of each map. For more information visit: www.drought.unl.edu/dm/monitor.html

The Reconnaissance Drought Index

When viewed from a longer-term perspective, the 2011 – 2012 water year, which runs from October 2011 – September 2012 (see methods) was not as dry as the period between the water years 2005-2006 to 2008-2009, likely because the region was still benefitting from the wetter than average conditions during 2010 – 2011 (Figure 3). Looking further back in time, only about 30% (5/15) of the water years during 1998 - present have been wetter than average when compared to the long-term drought index at San Diego Lindbergh Field (Figure 3). This relatively dry period was preceded by a wetter than average period (1977 – 1978 to 1997 – 1998) in which only one third (7/21) of the years were drier than the long term average (Figure 3).



Drought index calculations are relative to the time period selected: 1939 - 2012. Choosing a different set of start / end points may produce different results.

Figure 3. The Reconnaissance Drought Index (RDI) calculated for the San Diego – Lindbergh Field weather station 1939 – 2012. Negative index values indicate water years that were drier than the long-term. Positive values indicate wetter than average water years. Water years run from October – September of the following year. Because of the length of the record, these calculations are based on official National Weather Service data instead of data corrected as described in the methods section of this report.

Long-Term Patterns in Temperature and Precipitation

Generally speaking, there are two components to drought: high temperatures, which increase evapotranspiration and exacerbate drought, and precipitation, which relieves dry conditions. As shown in Figure 4, the average temperatures for 2012 at San Diego Lindbergh Field (70 degrees (F) for average daily maximum (Tmax) and 58 degrees (F) for average daily minimum (Tmin)) were not unusually warm compared to recent years (Figure 4). In contrast, total annual precipitation during 2012 (6.6 inches) was only 66% of the long-term average (calculated during 1939 – 2012) of 10 inches (Figure 4). Notice that the red-shaded area during 1999 - present in Figure 4 (Top) coincides with the dry period 1998 – 1999 described in the previous section on the Reconnaissance Drought Index.

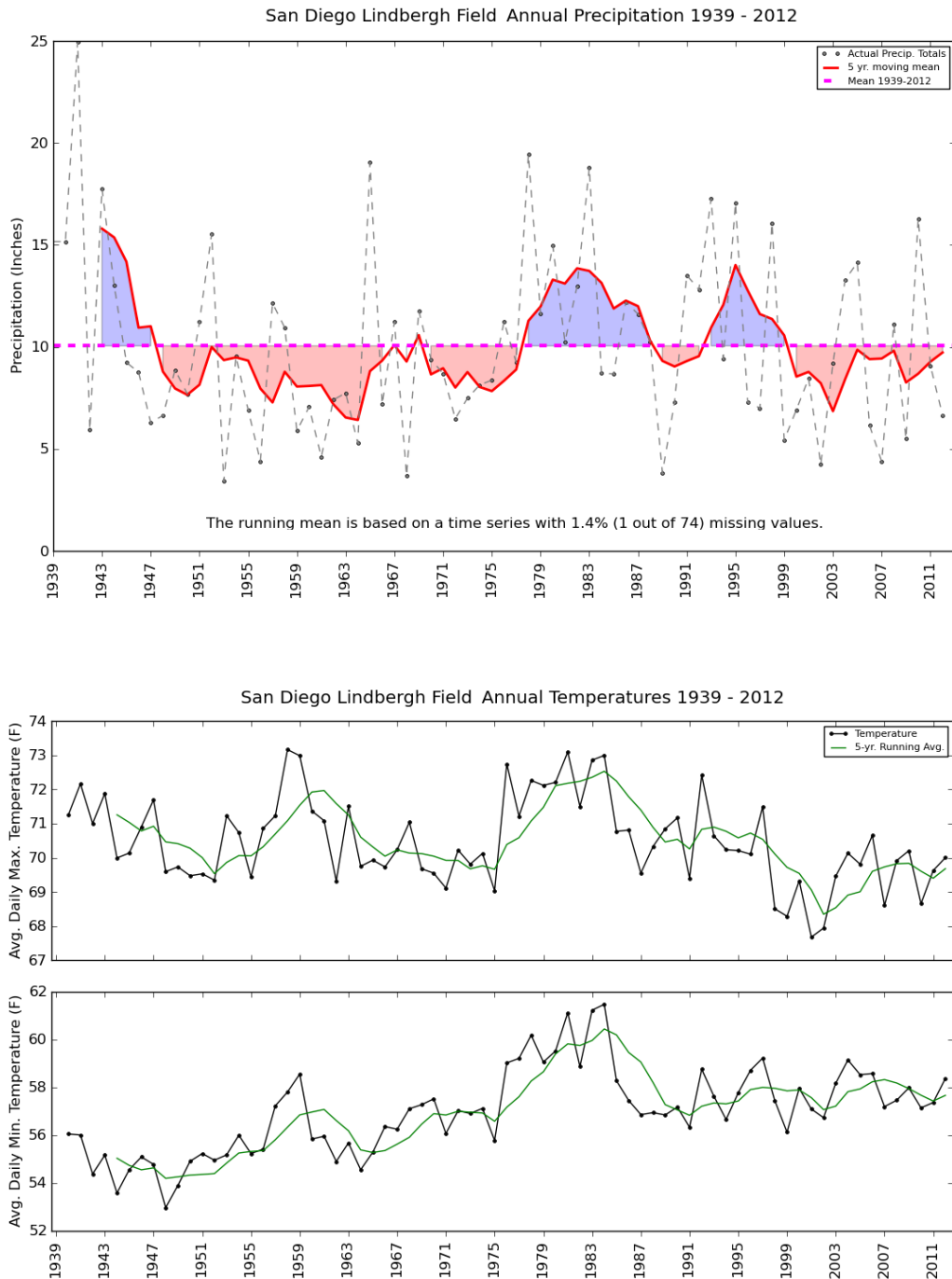


Figure 4. Top: total annual precipitation 1939 – 2012 at San Diego Lindbergh Field (dots). Red-shaded areas = years when the running mean is below the long-term average (dashed red line). Blue-shaded areas = running mean above the long-term average. Bottom: Annual averages for daily maximum temperature and daily minimum temperature 1939 – 2012. Green line = 5 year running average of temperatures. Running averages include the current year and the previous 4 years.

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>

During 2012, ENSO transitioned from La Nina to a neutral state between La Nina and El Nino. Normally, La Nina conditions produce drier conditions in southern California while El Nino produces wetter conditions. Given its transitional state, predicting the effects of ENSO on regional climate in the next 12 months is difficult. For long-term El Nino patterns, consult NOAA here:

http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml

Station Data Compared to 1981 – 2010 Averages

A look at GHCN weather station data from 2012 shows that March – July were generally cooler than the 1981 – 2010 averages, while August – December were in most cases warmer than average (Figures 5, 6). In general, there was above average precipitation during April, October, and December and below average precipitation during January, February, March, and November (Figures 5, 6; Table 1). Note that summer months (May – August) are typically so dry that comparisons to long-term averages are misleading. Even one tenth of an inch of rain can produce a deceptively large change in the calculated percent of average precipitation without having a real practical effect. Average daily maximum temperatures (Tmax) during September were 4.8 degrees above the 1981 – 2010 average at San Diego Lindbergh Field (Table 2), making it the warmest month, relative to the 30-year averages, since October 2008 (Figure 5).

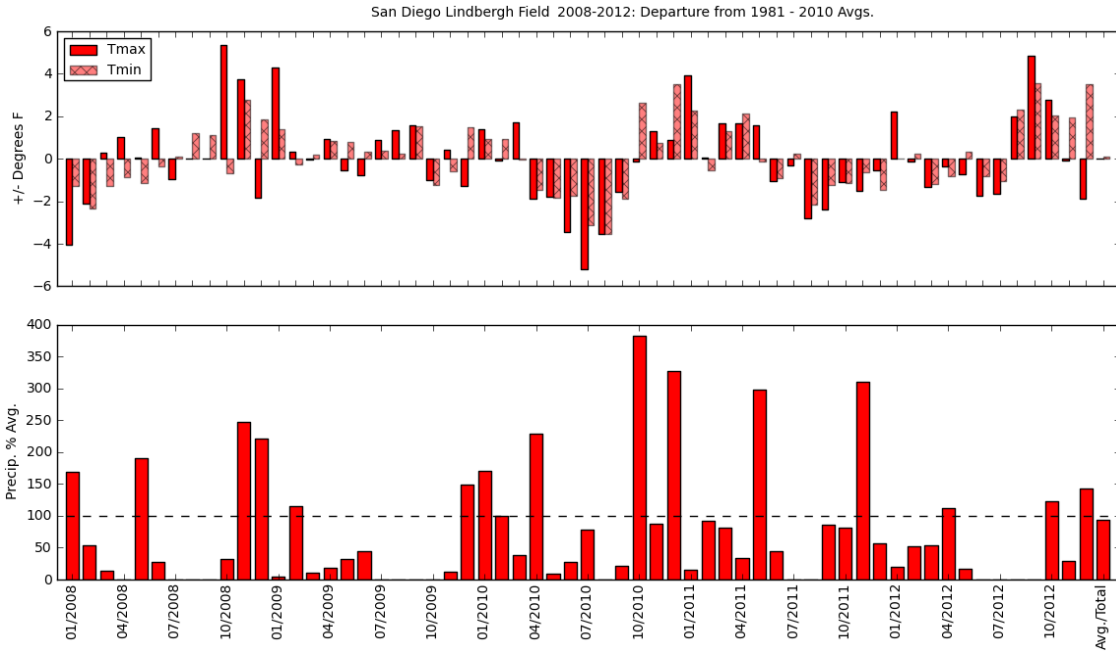


Figure 5. Departure of 2008 - 2012 precipitation, Tmax, and Tmin from 1981 - 2010 averages at San Diego Lindbergh Field. May – August often have less than 0.2 inches average precipitation so 0% average precipitation may be a small absolute difference.

Table 1. Total Monthly Precipitation in inches during 2012 and Percent of 1981 – 2010 averages at key weather stations in and near Cabrillo National Monument.

Station Name	Parameter	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YR
San Diego Lindbergh Field	2012 Precip	0.4	1.19	0.97	0.87	0.02	0	0	0	0	0.7	0.29	2.19	6.64
	% of 1981 - 2010 avg.	20.3	52.3	53.7	112.1	16.4	*	*	*	*	123	28.9	143.1	64.2
Chula Vista	2012 Precip	0.67	1.3	1.69	0.81	0	0	0	0.05	0.02	0.65	0.19	2.7	8.07
	% of 1981 - 2010 avg.	34.7	56.5	99.94	117	0	*	*	*	*	123	20.8	188.6	82.1
San Diego SeaWorld	2012 Precip	(-)	1.39	0.97	1.18	(-)	0	0	0	0	0.54	(-)	3.43	(-)
	% of 1981 - 2010 avg.	(-)	54.9	42.7	144	(-)	*	*	*	*	71.4	(-)	204.1	(-)
Pt. Loma	2012 Precip	0.46	0.51	1.32	(-)	(-)	(-)	(-)	(-)	(-)	0.57	0.29	1.59	(-)
	% of 1981 - 2010 avg.	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
San Diego Naval Air Station	2012 Precip	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
	% of 1981 - 2010 avg.	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)

* Precipitation is so low during summer months that departure calculations can be misleading.

(-) Insufficient data for an accurate calculation

Met stations (last two entries in the table) have not been in operation long enough to have 30-year averages.

San Diego Naval Air Station does not collect precipitation data.

Table 2. Average daily maximum temperatures (Tmax), Average Daily Minimum Temperatures (Tmin) during 2012 and departure from 1981 – 2010 averages expressed as +/- Degrees F.

Station Name	Parameter	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YR
San Diego Lindbergh Field	Tmax (F)	67.34	64.9	64.28	67.14	67.8	69.06	73	78.4	80.7	75.6	68.9	62.84	69.99
	Tmax Departure (+/- F) from 1981 - 2010	2.24	-0.15	-1.32	-0.36	-0.71	-1.74	-2	1.99	4.83	2.79	-0.09	-1.86	0.29
	Tmin (F)	49.02	50.9	52	55.07	59.7	61.18	64	69	68.8	62.6	55.6	51.92	58.35
	Tmin Departure (+/- F) from 1981 - 2010	0.02	0.22	-1.2	-0.83	0.33	-0.82	-1	2.29	3.58	2.02	1.97	3.52	0.85
Chula Vista	Tmax (F)	68.51	66.6	66.38	69.01	71.3	70.53	74	77.3	80.7	76.2	70.4	64.98	71.33
	Tmax Departure (+/- F) from 1981 - 2010	0.01	-1.52	-1.72	-0.39	1.15	-1.47	-2	-0.5	2.66	0.53	-1.37	-2.42	-0.57
	Tmin (F)	45.4	47.6	50.15	52.54	58.1	59.49	63	67.2	65.8	59.1	52.6	49	55.82
	Tmin Departure (+/- F) from 1981 - 2010	-0.4	0.08	-0.15	-0.46	0.56	-1.11	-2	1.59	2.59	1.22	2.37	3.7	0.62
San Diego SeaWorld	Tmax (F)	(-)	61.7	60.3	64.12	(-)	67.71	70	74.8	74.5	71.4	(-)	61.11	(-)
	Tmax Departure (+/- F) from 1981 - 2010	(-)	-2.24	-2.9	-2.78	(-)	-1.09	-2	1.97	2.29	1.98	(-)	-1.79	(-)
	Tmin (F)	(-)	48.2	49.31	53.29	(-)	59.81	63	67.3	66.4	59.9	(-)	50.32	(-)
	Tmin Departure (+/- F) from 1981 - 2010	(-)	-0.67	-1.89	-0.82	(-)	-0.39	-1	2.13	3.89	1.1	(-)	3.52	(-)

Table 2. Average daily maximum temperatures (Tmax), Average Daily Minimum Temperatures (Tmin) during 2012 and departure from 1981 – 2010 averages expressed as +/- Degrees F.

Station Name	Parameter	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YR
Pt. Loma	Tmax (F)	65.02	63	61.65	(-)	(-)	(-)	(-)	(-)	(-)	73.1	66.7	61.59	(-)
San Diego Naval Air Station	Tmax (F)	70.47	68.7	69.05	71.48	75.2	72.21	75	79.5	81.1	76.9	70.5	64.54	72.89

(-) = Insufficient data for an accurate calculation

Met stations (last 2 entries in the table) have not been in operation long enough to have 30-year averages.

A pattern similar to those seen at the GHCN stations was seen at the San Diego Naval Air Station. Even though this station does not have established 30-year averages, a graph showing 2012 temperatures superimposed on past years shows that the first six months of the year had average daily minimum temperatures (Tmin) at the bottom end of the range (Figure 7), and last six months of 2012 were generally warmer than corresponding measurements in past years (Figure 7). In contrast, average daily maximum temperatures (Tmax) at the San Diego Naval Air Station were in the average to above-average range for all of 2012 (Figure 7).

PRISM maps depicting spatial patterns in departure from 1981 – 2010 averages

The precipitation patterns seen in the PRISM maps (Figure 8) are very similar to the patterns seen in the weather station data. Namely, April, October and December had generally above average precipitation, while the other months of 2012 were generally below average (Figure 8). Interestingly, the maps show that most of the region had below average precipitation during October, and only the areas near the weather stations cited in this report were above average (Figure 8). In this context, it is again worth noting that precipitation during May – August is usually less than 0.2 inches per month, and it is therefore easy to misinterpret calculations of “percent normal” for these months. For example, 0.02 inches of rain during June at the Chula Vista weather station would be roughly 25% of the 1981 – 2010 average, but if only an additional 0.06 inches of rain had falls, the month would be approximately 100% normal.

The PRISM temperature maps (Figures 9,10) emphasize one feature that is also present in the station data: August – December 2012 were warmer than the 1981 – 2010 averages, with September and October being more than 6 degrees (F) above average in some parts of the region. It is also interesting to note that December average daily minimum temperatures (Tmin) were above average throughout most of the region (Figure 10) while December average daily maximum temperatures (Tmax) were generally below average (Figure 9).

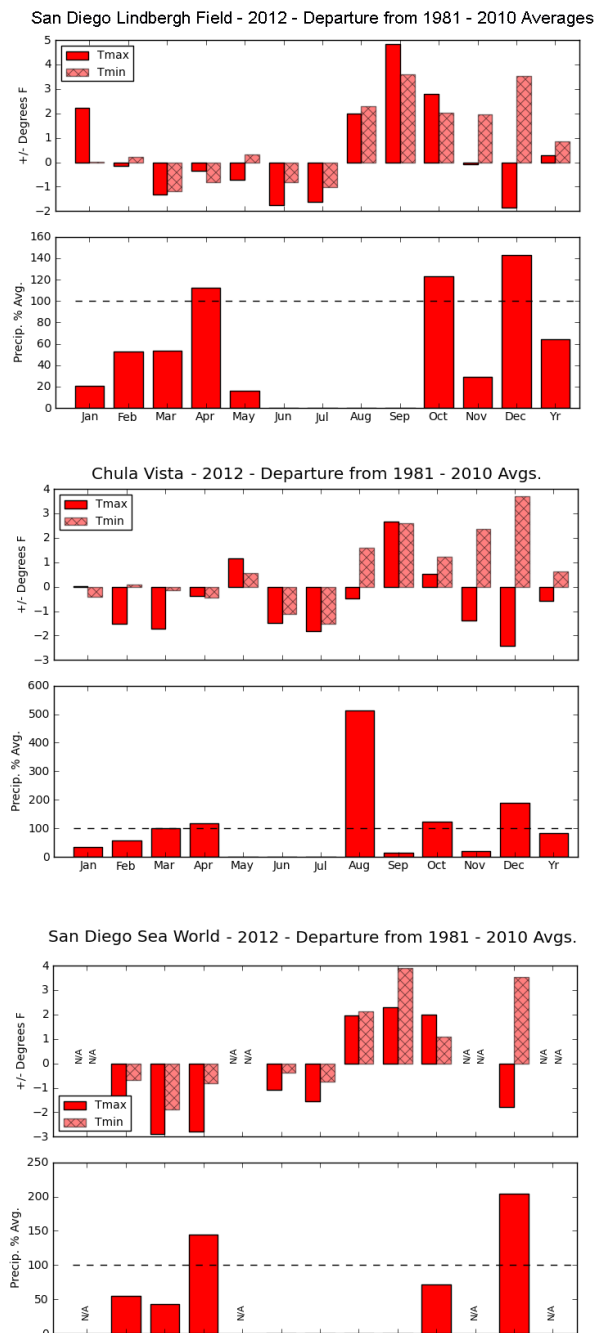


Figure 6. Departure of 2012 Temperature and Precipitation from 1981 – 2010 averages at key weather stations near Cabrillo National Monument. Tmax = average daily maximum temperature. Tmin = average daily minimum temperature.

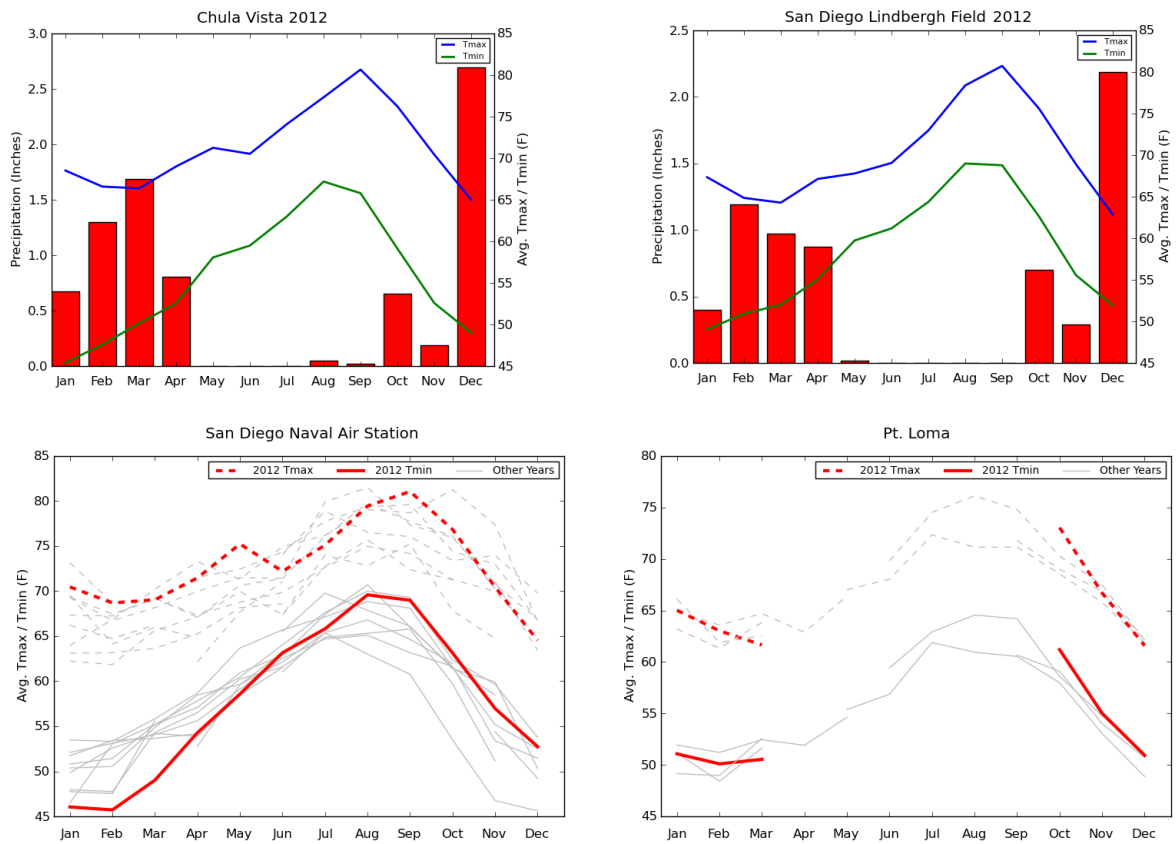


Figure 7. Top: monthly average temperature and precipitation during 2012 at Chula Vista and San Diego Lindbergh Field. Bottom: Monthly average temperature during 2012 (red lines) at the two Met Stations in and near Cabrillo NM, with temperatures from past years superimposed (gray lines). Tmax = Average daily maximum temperature. Tmin = average daily minimum temperature.

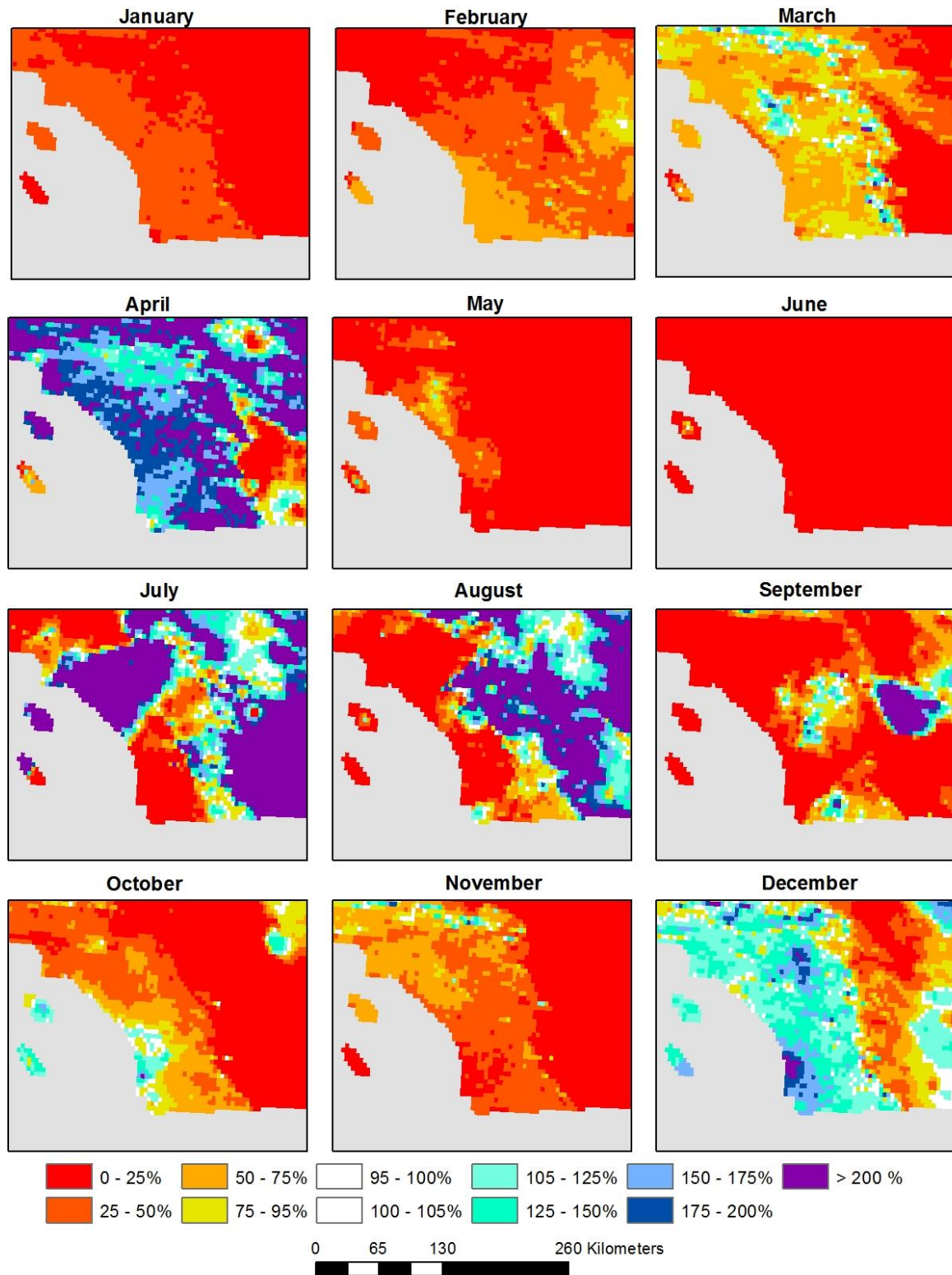


Figure 8. Maps showing percent of average precipitation relative to 1981–2010 for each month during 2012. Estimates are from the Parameter-elevation Regressions on Independent Slopes Model (PRISM). Gray areas = Pacific Ocean. For more information, see <http://www.prism.oregonstate.edu/>.

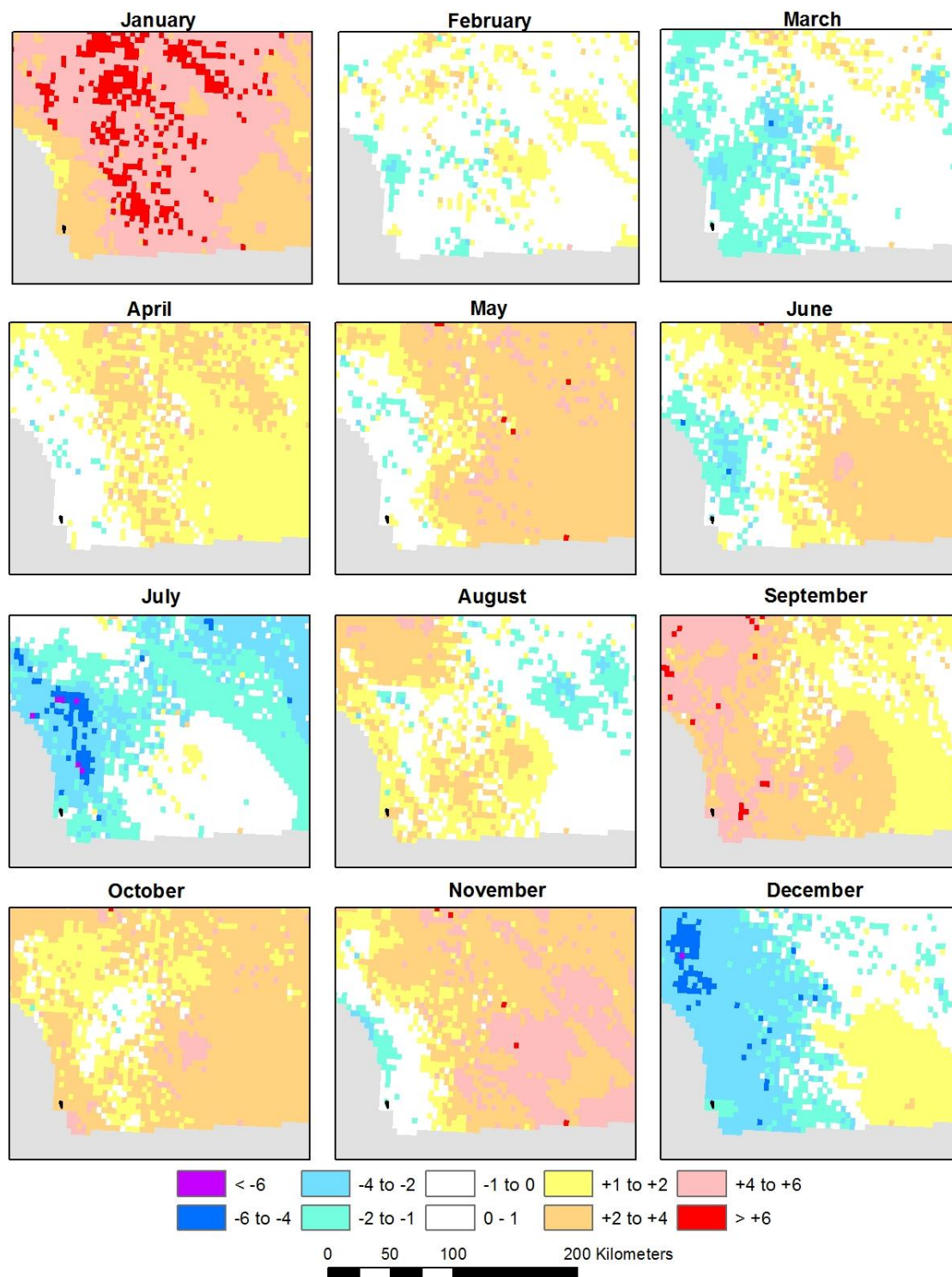


Figure 9. Maps showing departures from 1981 – 2010 average daily maximum temperatures (Tmax) in degrees Fahrenheit during 2012. Estimates are from the Parameter-elevation Regressions on Independent Slopes Model (PRISM). Gray areas = Pacific Ocean. Cabrillo NM is on the coast, bottom left. For more information, see <http://www.prism.oregonstate.edu/>.

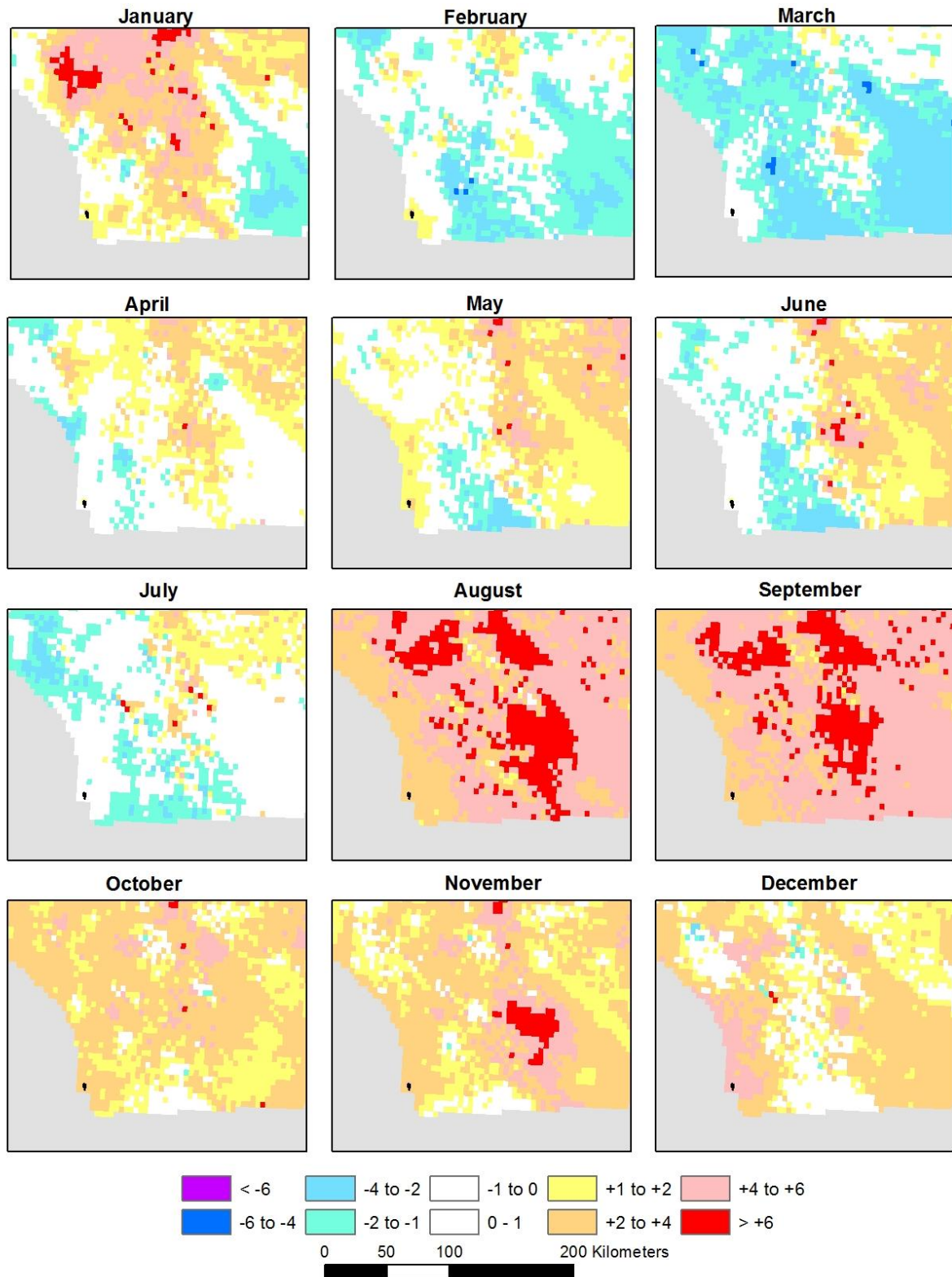


Figure 10. Maps showing departures from 1981 – 2010 average daily minimum temperatures (Tmin) in degrees Fahrenheit during 2012. Estimates are from the Parameter-elevation Regressions on Independent Slopes Model (PRISM). Gray areas = Pacific Ocean. Cabrillo NM is on the coast, bottom left. For more information, 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 during the 2011 – 2012 water year, the San Diego River experienced its lowest peak flow rate (356 cubic feet per second on 11/13/2011) since 2002 (Figure 11).

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 AGDD 40, 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, AGDD 50 is calculated with a base temperature of 50 (F).

When viewed from the perspective of growing season length, calendar-year 2012 was slightly above average. At San Diego Lindbergh Field, AGDD 40 was 104% the 1981 – 2010 average and AGDD 50 was 108%. At Chula Vista, AGDD 40 was 112% and AGDD 50 was 122% the average.

Wind Speed and Direction

The number of missing values in the Pt. Loma record prevented the calculation of annual wind summaries. Data from the San Diego Naval Air Station show that, unlike 2001 – 2010, 2011 and 2012 had no wind events greater than 19 miles per hour (Figure 12). Wind directions during the last two years were generally the same during 2011 and 2012 vs. 2001 – 2010, however the last two years had a greater proportion of winds out of the north, northwest and south, southwest (Figure 12).

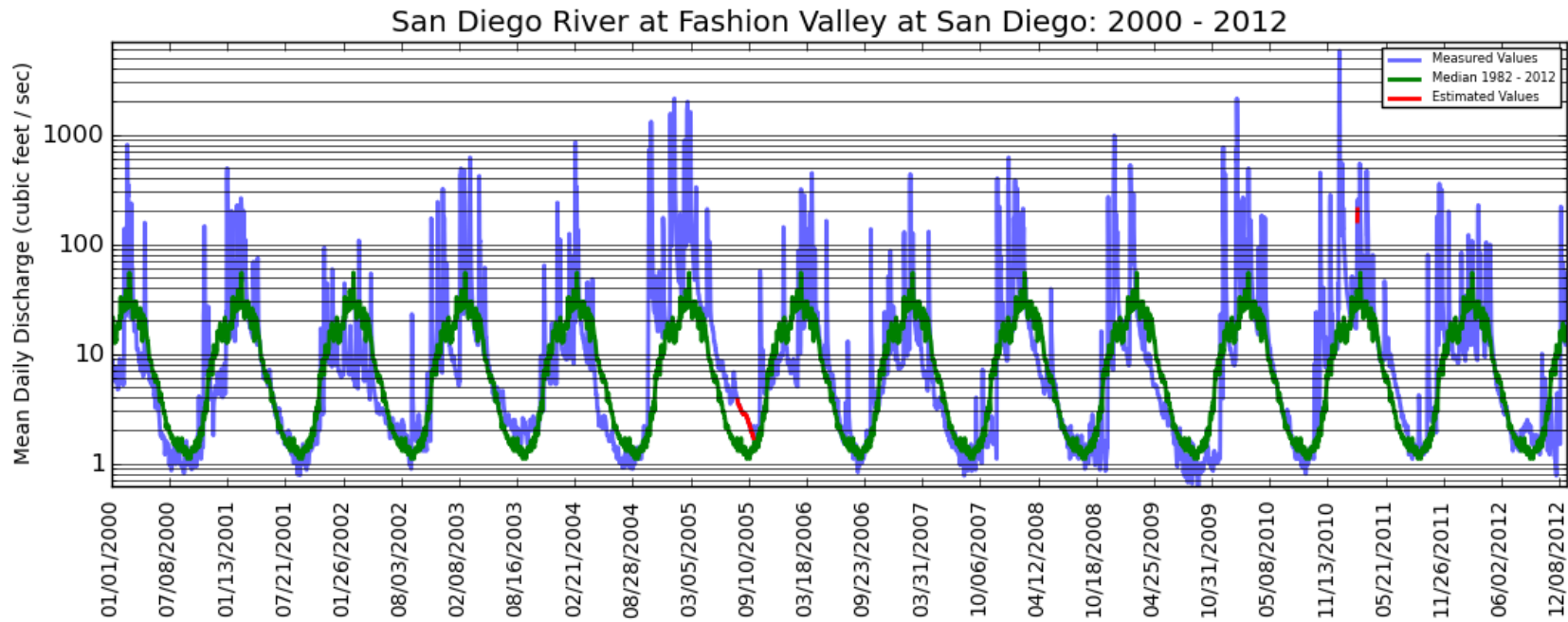


Figure 11. Stream discharge on the San Diego River near Cabrillo National Monument during 2000 – 2012.

Table 3. Accumulated Growing Degree Days (AGDD) and days above or below critical temperature thresholds during 2012.

Station Name	Time Period	AGDD40	AGDD50	# days ≥ 80 F	# days ≥ 90 F	# days ≤ 32F
San Diego Lindbergh Field	2012 Value	8852.1	5192.64	44	2	0
	1981 - 2010 Avg.	8478	4832	(-)	2.5	0
Chula Vista	2012 Value	8636.19	4979.7	41	2	0
	1981 - 2010 Avg.	7679	4059	(-)	1.9	0.9
San Diego SeaWorld	2012 Value	(-)	(-)	(-)	(-)	(-)
	1981 - 2010 Avg.	8014	4366	(-)	0.4	0
Pt. Loma	2012 Value	(-)	(-)	(-)	(-)	(-)
San Diego Naval Air Station	2012 Value	9237.95	5632.45	65	7	11

(-) = Insufficient data for an accurate calculation

Met stations (last 2 entries in the table) have not been in operation long enough to have 30-year averages.

Conclusions

- After two years of drought free status, 2012 saw a return to drier conditions, particularly during the second half of the year (Figure 2). Despite this, the 2012 water year, which runs from October 2011 – September 2012 was not as dry as the period 2005 - 2009, likely because the region was still benefitting from the wetter than average conditions during 2010 – 2011.
- Average annual temperatures for 2012 were very near average. In contrast, total annual precipitation at San Diego Lindbergh Field during 2012 (6.6 inches) was only 66% of the 1939 – 2012 average of 10 inches (Figure 4).
- During 2012 March – July were generally cooler than the 1981 – 2010 averages, while August – December were in most cases warmer than average (Figures 5, 6, 9, 10; Table 2).
- In general, there was above average precipitation during April, October, and December and below average precipitation during the other months of the year (Figures 5, 6, 8; Table 1). Summer (May – August) precipitation in the region is so low that it is not appropriate to make comparisons to 30-year normal.
- Growing season length was 104% - 122% the 1981 – 2010 averages for weather stations in the region.
- During the 2011 – 2012 water year, the San Diego River experienced its lowest peak flow rate (356 cubic feet per second on 11/13/2011) since 2002 (Figure 11).

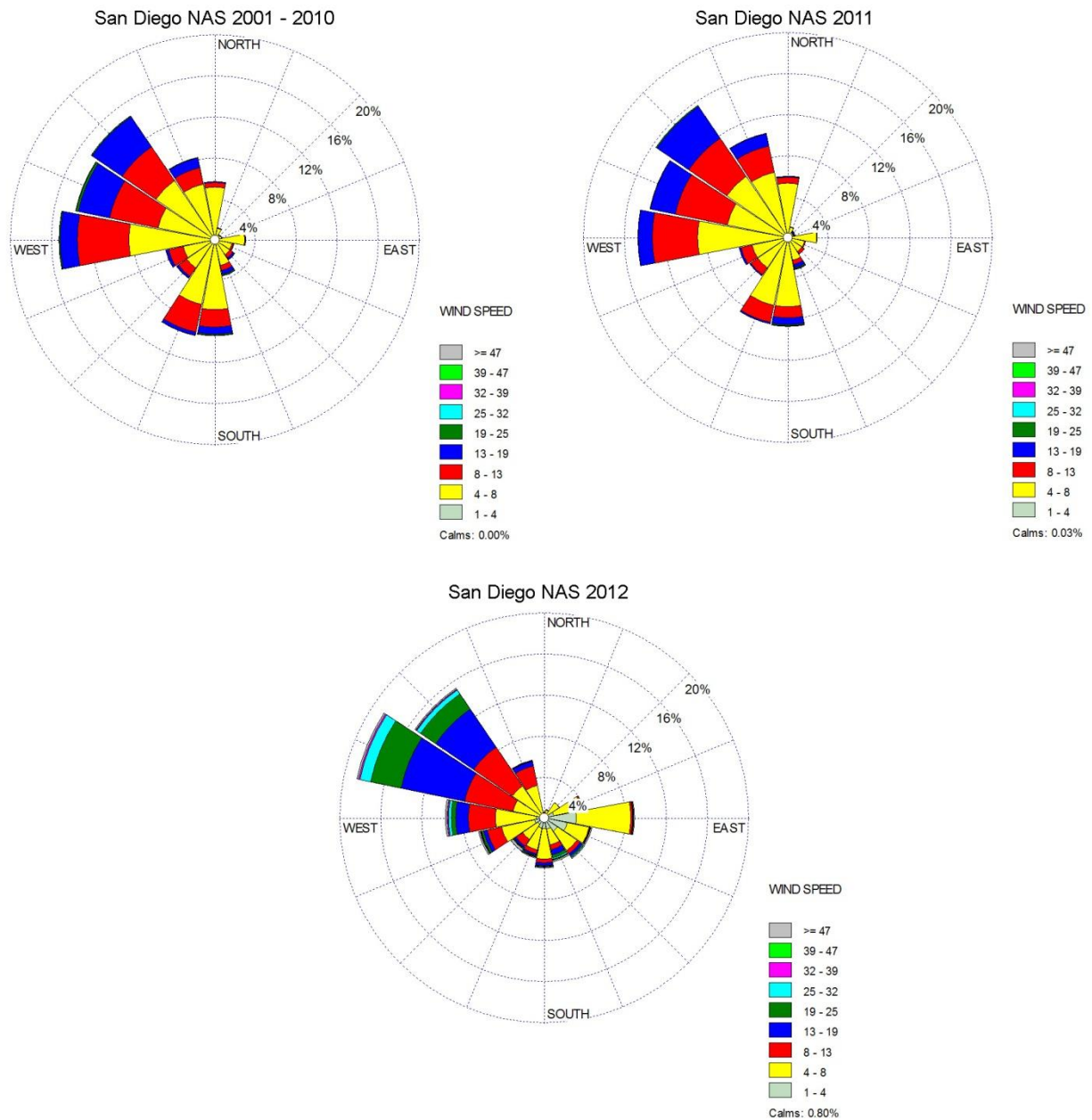


Figure 12. Wind roses for data from the San Diego Naval Air Station, contrasting calendar years 2011 and 2012 to the averages for 2001 – 2010. The orientation of a spoke indicates wind direction (compass heading, degrees from which the wind originated), and the length of a spoke indicates the amount of time (%) that wind from a given direction occurred. Colors within the spokes express the amount of time (%) that wind from each direction had the indicated velocity. Speeds are miles per hour.

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Appendix 1

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

Name	Stn type	Stn ID	Metadata
Pt. Loma	MET	SDL13	http://www.climateanalyzer.org/medn/raws/pt_loma/
San Diego Naval Air Station	MET	KNZY	http://www.climateanalyzer.org/medn/raws/KNZY/
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 Sea World	GHCN	47741	http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?ca7741
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

GHCN = Global Historical Climatology Network