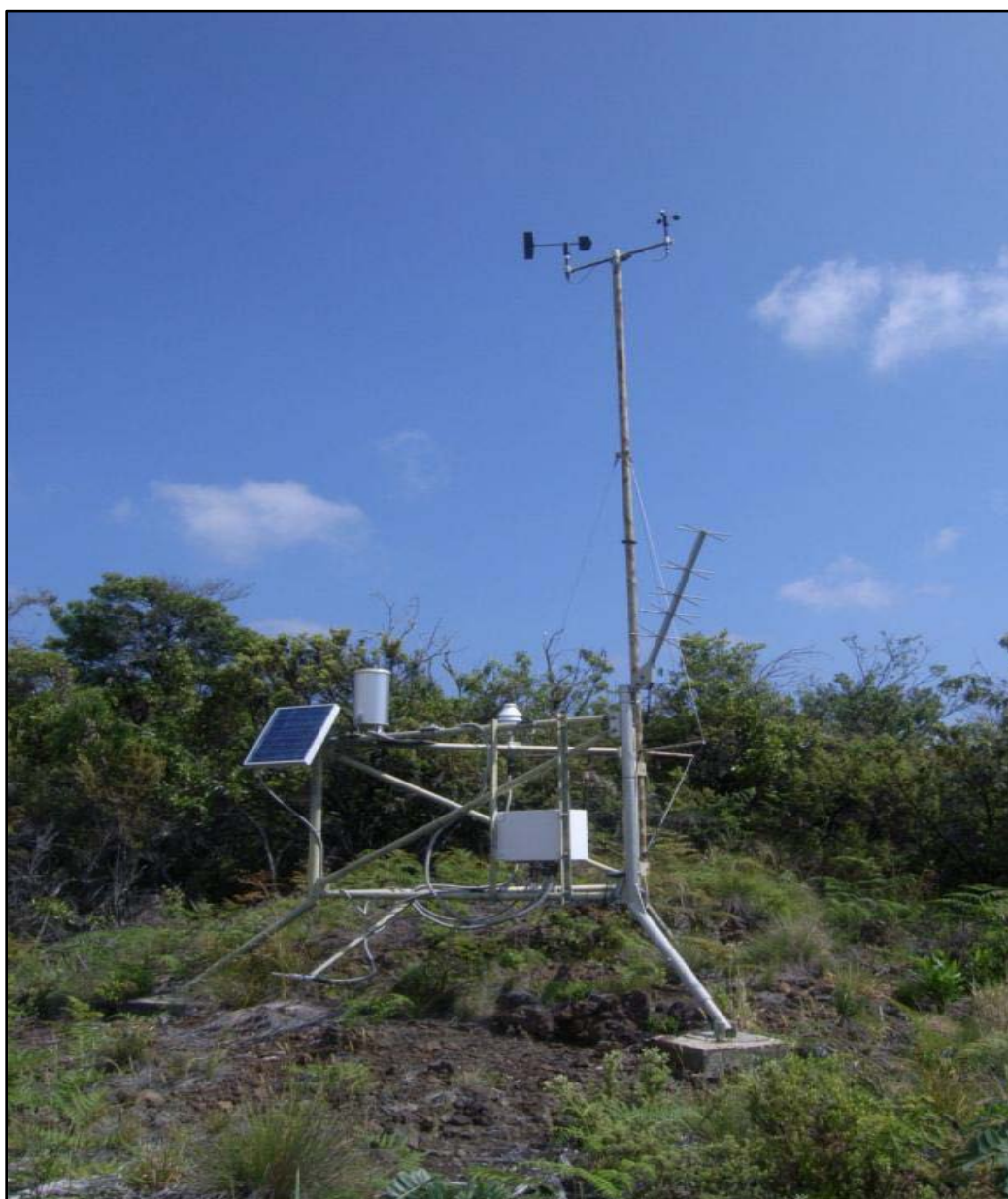




Annual Weather/Climate Data Summary 2009

Pacific Island Network

Natural Resource Data Series NPS/PACN/NRDS—2011/141



ON THE COVER

Keaumo RAWs, on the slope of Mauna Loa, Hawaii.
Photograph by: Karin Schlappa, CESU cooperator

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February 2011

U.S. Department of the Interior
National Park Service
Natural Resource Program Center
Fort Collins, Colorado

The National Park Service, Natural Resource Program Center publishes a range of reports that address natural resource topics of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Data Series is intended for the timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

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Please cite this publication as:

Schlappa, K. B., T. L. C. Casey 2011. Annual weather/climate data summary 2009: Pacific Island Network. Natural Resource Data Series NPS/PACN/NRDS—2011/141. National Park Service, Fort Collins, Colorado.

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Acknowledgments

Many thanks to all park staff who help maintain weather stations and report data – your work is important and appreciated. Part of this report was made possible under a task agreement between the National Park Service, Pacific Island Network and the University of Hawai‘i, Pacific Cooperative Studies Unit (TA no. J2132080313). Data for this report were made available by the Western Regional Climate Center; in addition, data published by the National Climatic Data Center (NCDC) and the Drought Monitor is presented.

ACRONYMS

AAFB	Anderson Air Force Base
ALKA	Ala Kahakai National Historical Trail
AMME	American Memorial Park
CESU	Cooperative Ecosystems Studies Unit
CNMI	Commonwealth of the Northern Mariana Islands
COOP	Cooperative Observer Program
CPC	Climate Prediction Center
CRN	Climate Reference Network
CWOP	Citizen Weather Observer Program
DRI	Desert Research Institute
ENSO	El Niño/La Niña Southern Oscillation
ESCAP/WMO	Economic and Social Commission for Asia and the Pacific/World Meteorological Organization
GOES	Geostationary Operational Environmental Satellite
GPMN	Gaseous Pollutant Monitoring Network
HALEnet	Haleakala Climate Network
HAVO	Hawaii Volcanoes National Park
IQR	Interquartile Range
KAHO	Kaloko-Honokohau National Historical Park
KALA	Kalaupapa National Historical Park
MS	Microsoft
MTSAT	Multifunctional Transport Satellite
NAS	Naval Air Station
NCA	National Coastal Assessment
NCDC	National Climatic Data Center
NEPA	National Environmental Policy Act
NOAA	National Oceanographic and Atmospheric Administration
NPHQ	National Park Headquarters
NPS	National Park Service
NPSA	National Park of American Samoa
NRCS	Natural Resources Conservation Service
NRPM	Natural Resources Publications Management
NWS	National Weather Service
PACN	Pacific Island Network
PDO	Pacific Decadal Oscillation
PEAC	Pacific ENSO Application Climate Center
PUHE	Puukohola Heiau National Historical Site
PUHO	Puu Honua O Honaunau National Historical Park
RAWS	Remote Automated Weather Stations
USGS	United States Geological Survey
VALR	World War II Valor in the Pacific National Monument
WRCC	Western Regional Climate Center
WSMO	Weather Service Meteorological Office
WSO	Weather Service Office

Introduction

Weather/climate monitoring is one of several long-term monitoring efforts of the Pacific Island Network (PACN). The information gained will provide insight into an important physical characteristic of Pacific island ecosystems, aid in interpreting results of other research and monitoring efforts, and inform natural resource management decision-making. Annual reports will summarize data for the previous year and aim to provide as much information from as many weather stations as possible, regardless of the length of the station record. Furthermore, five-year trend reports are planned. These will only focus on data from stations with a long period of record and highest observation frequencies, so more in-depth data verification and analysis can be documented. PACN national parks are located in the Hawaiian Islands, on Guam, Saipan, and in American Samoa (Figure 1) and include the following park units (Table 1).

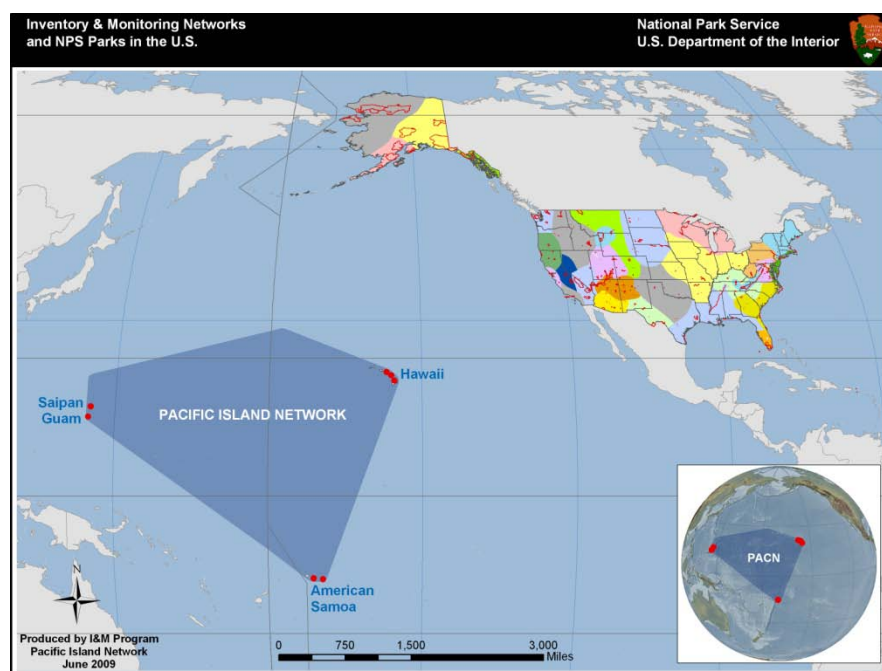


Figure 1. Map showing the extent of the Pacific Island Network; red dots indicate national park units.

The climate in the PACN region is mild, with relatively warm mean temperatures and minimal daily and seasonal temperature fluctuations. The dominant factor shaping the climate is the tropical marine setting. The vast Pacific Ocean dampens the temperature fluctuations and leads to constantly high relative humidity. Parks in the PACN are located between 15°S and 21°N; in this region the northern and southern hemispheres experience persistent northeast and southeast trade winds. Several of the islands in the PACN include high elevations (Table 1) and the interaction of the trade winds and the relief; creates wet windward and dry leeward climate zones with extreme rainfall gradients in some areas. On islands with the highest elevations, Hawai'i and Maui, the national parks even include subalpine climate zones as defined by Koeppen (Giambelluca and Sanderson 1993).

Table 1. National parks in the Pacific Island Network.

National Park	Island	Total size in acres (marine portion)	Terrestrial Elevation Range (ft)
War in the Pacific National Historical Park (WAPA)	Guam	1,980 (990)	0 to 1,043
American Memorial Park (AMME)	Saipan	143 (0)	0 to 9
National Park of American Samoa (NPSA)	Tutuila, Ofu-Olosega, Tau	14,616 (5,261)	0 to 3,169
World War II Valor in the Pacific National Monument (VALR)	Oahu	17 (5)	0 to 75
Kalaupapa National Historical Park (KALA)	Moloka'i	11,251 (2061)	0 to 4,222
Haleakalā National Park (HALE)	Maui	29,032 (0)	0 to 10,022
Ala Kahakai National Historic Trail (ALKA)	Hawai'i	TBD	0 to 400
Pu'ukoholā Heiau National Historic Site (PUHE)	Hawai'i	86 (7)	0 to 170
Kaloko-Honokōhau National Historical Park (KAHO)	Hawai'i	1,188 (536)	0 to 79
Pu'uhonua o Hōnaunau National Historical Park (PUHO)	Hawai'i	571 (0)	0 to 899
Hawai'i Volcanoes National Park (HAVO)	Hawai'i	333,817 (0)	0 to 13,678

Moderately wet and dry seasons exist throughout the PACN region, yet these seasons are not synchronous. For example, in American Samoa the wet season lasts from October to May, in the Marianas from July to November, in most of Hawai'i from October to April, while in some portions of leeward Hawai'i Island (i.e., North Kona) it lasts from April to September.

Tropical cyclones which by definition include tropical depressions, tropical storms, and hurricanes are not uncommon in the region, bringing extreme rainfall, winds, and storm swells to the islands. Hurricane season in Hawai'i lasts from June to November and in American Samoa from November through April. In the western Pacific hurricanes are called typhoons. In this region, which includes Guam and Saipan, these storms are more frequent and often more intense than in the rest of the Pacific. While the majority of typhoons occur between June and November they may occur year-round.

While US mainland climate variability is strongly influenced by the Pacific Decadal Oscillation (PDO), the PDO has much less of an effect on the Pacific island region. Climate variability for this region is, however, strongly affected by the El Niño/Southern Oscillation (ENSO). During an El Niño event atmospheric pressure at sea level tends to rise in the western Pacific and drop in the eastern Pacific, causing a reduction of the prevailing trade winds. As a result some areas of the Pacific experience droughts while others suffer from extreme rainfall events.

The strength of ENSO events is judged by the observed sea surface temperatures or sea level pressure anomalies. Although the intensity and duration of rainfall events, droughts and spatial patterns vary with the strength of individual ENSO events, the following effects have been documented in the PACN region: In Hawai‘i, El Niño related drought starts at the end of an El Niño year and lasts throughout the spring of the following year while La Niña has just the opposite effect on rainfall variations in Hawai‘i (Chu 1995, Chu and Chen 2005). On Saipan and Guam very dry conditions prevail in the year following an El Niño (Ropelewski and Halpert 1987, Lander and Guard 2003, Lander 2004). In American Samoa rainfall increases during all seasons of an El Niño year; in the following year rainfall is also increased, but to a lesser extent in all seasons except during summer when it is slightly decreased (Pacific ENSO Applications Climate Center (PEAC), website). Tropical cyclone activity in the Pacific Ocean is also affected by ENSO (Chu 2004). For example, tropical cyclones occurred near Hawai‘i during El Niño years with fewer storms during La Niña years (Chu and Wang 1997).

Methods

Detailed methods of data collection for weather observations in the PACN are described in the PACN Weather/Climate Monitoring Protocol (Schlappa et al. 2010). In short, the PACN's weather monitoring efforts primarily rely on weather observations obtained from two national weather monitoring networks, the National Weather Service Cooperative Observer Program (COOP), and the Remote Automated Weather Station program (RAWS). Observations for COOP weather stations are taken by either volunteers or contractors to provide observational meteorological data required to define the climate of the United States and to help measure long-term climate changes. Most COOP stations in the PACN are read manually; they measure 24-hour precipitation totals and most stations also measure daily maximum and minimum temperatures. The RAWS provide weather data that assists land management agencies with a variety of projects such as monitoring air quality, rating fire danger, and providing information for research applications. Hourly averages of meteorological variables are downloaded via the Geostationary Operational Environmental Satellite (GOES). Measured variables vary from station to station, but typically include temperature, precipitation, wind, humidity, solar radiation, barometric pressure, fuel temperature, and fuel moisture.

Weather data for RAWS and NWS COOP stations were acquired from Western Regional Climate Center (WRCC) and incorporated into a MS Access database that stores data for all stations included in PACN weather/climate monitoring. The acquired weather data consist of daily values, i.e., hourly RAWS data had already been summarized by WRCC before they were passed on to NPCLime. NPCLime was a project that established electronic access between NPS servers and weather databases. NPCLime was disbanded in early 2010 and the majority of the data was downloaded directly from the COOP or RAWS sites managed by WRCC. The WRCC also performs a preliminary data validation process. Data were imported into R (version 2.10.0) (Gentleman, R and R. Ihaka, 1997) for data analysis and graphing. Further data validation was conducted based on exploratory data analysis. Boxplots were used extensively to place data from 2009 in context with the long-term variability for each station. Boxplots in R are constructed based on the original definition of a boxplot by Tukey (1977). However, since in some publications different definitions are used, the features of a generic boxplot produced in R are illustrated below (Figure 2).

To understand boxplots the term quartile first needs to be defined. Quartiles can be thought of as dividing lines that separate a dataset into four equal parts: 25% of the data points are below the 1st quartile, 25% are between the 1st and 2nd quartile (2nd quartile=median), 25% of the data lie between the 2nd and 3rd quartile, and another 25% lie above the 3rd quartile. Boxplots generally display at least five important pieces of information about a set of data: (1) the median (2nd quartile) of the data is represented by the line in the center of the rectangular box; (2) the lower end of the rectangle represents the 1st quartile; (3) the upper end of the rectangle is the 3rd quartile; (4) the lower whisker extends to the minimum value; and (5) the upper whisker extends to the maximum value. In addition, most boxplots show outliers of the dataset. The rectangle defines the distance between the 1st and 3rd quartile, also called the interquartile range (IQR); the minimum (maximum) value of the dataset is defined as the minimum (maximum) within a distance of 1.5 IQR from the 1st (3rd) quartile; data points beyond those limits are considered outliers. Boxplots in this report are based on long-term datasets for temperature, precipitation, and relative humidity

with data points for 2009 overlaid on the graphics to place the current year's data into the context of long-term variability.

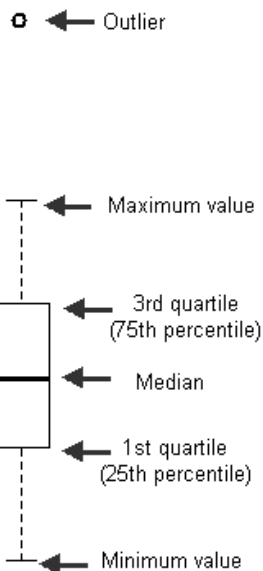


Figure 2. Anatomy of a boxplot. Note that the box defines the interquartile range (IQR) and that the minimum (maximum) value is defined as the minimum (maximum) within a distance of 1.5 IQR from the 1st (3rd) quartile; data points beyond those limits are considered outliers.

Wind graphics were generated using the online data analysis tools for individual RAWS set up by WRCC and the Desert Research Institute (DRI).

The period of record varies for individual stations as stated in the figures and tables. A threshold of 85% valid daily records was used for calculating monthly means or totals. Thus, if more than 15% of daily data were missing for any given month, the data were considered insufficient for the calculation of a monthly mean or total. For that reason, the long-term data for any given month or parameter may be shorter than the period of record for the station. For months with insufficient data, we did not substitute data from nearby stations since often there are no nearby stations available. Furthermore, for precipitation even nearby stations often do not provide representative data, given the steep precipitation gradients on many of the islands.

Tabular data provide comparisons of the 2009 values with climate normals for the 1971-2000 time period published by the NCDC (National Climatic Data Center) (National Oceanic and Atmospheric Administration, (NOAA, 2002), if they are available. A climate normal is defined as the arithmetic average of a climatological element (e.g., temperature or precipitation) for a 30 year time period (Guttman 1989). NCDC computes climate normals for a subset of the COOP stations throughout the country. Thus, in this report, 2009 data for stations for which climate normals are not available (all RAWS and some of the COOP stations) are instead compared to the long-term mean for the station record. In the ideal case, the data record for the 30-year period should not include missing values or inconsistencies such as changes in station location, instrumentation, time of observation, etc. that would lead to inhomogeneous data. However, since logistical factors often result in some missing values or changes to instrumentation, records for some stations are

adjusted using statistical methods to homogenize the data prior to the calculation of the averages. In addition the NCDC makes corrections to the datasets to adjust for the time of observation. The most current time period for which climate normals have been published by the NCDC is from 1971 to 2000.

The goals and objectives of external weather and climate monitoring programs have dictated the numbers and locations of most weather stations in the PACN. In general, a rigid sampling design was not used to locate stations. The NWS-COOP stations, which are manually downloaded, were located mainly based on ease of access as well as suitability as a weather station site. The locations of RAWS stations were generally determined by wildfire threat. Thus, RAWS which are downloaded by satellite are often located in the backcountry. Several parks (AMME, WAPA, and NPSA) do not have any weather stations located within park boundaries; therefore data from nearby COOP stations are analyzed for this report. Maps showing station locations are presented in Appendix B. Nine more stations, made by Campbell Scientific, Inc., will be added in 2011, two in HAVO, two in KALA, two in NPSA, one at PUHO, to replace the WeatherHawk, one at AMME, one at PUHE and WAPA's RAWS station will be put on line. These stations will be automated and will mostly use the GOES satellite. Stations on Guam and Saipan may use the Japanese MTSAT weather satellite, depending on availability.

Station names in this report appear exactly as they do in the NCDC and WRCC databases. For this reason, the spelling may be unusual (as in Puuhonuaohonaunau), Hawaiian names don't include okinas or kahakos, and acronyms that are part of the name are not explained.

Results

General El Niño conditions and tropical cyclone activity for the year are described first. Then data for stations in the western North Pacific (AMME, WAPA) and the South Pacific (NPSA) are presented, followed by results for stations in national parks in the Hawaiian Islands. Finally, an overview of drought conditions in Hawai‘i is presented.

El Niño/La Niña Conditions and Tropical Cyclone Activity

El Niño/La Niña conditions are here summarized based on information obtained from the Pacific ENSO Update (2008, 2009, 2010) and the ENSO diagnostic discussions of the Climate Prediction Center (CPC 2009). After ENSO neutral conditions persisted for most of the second half of 2008, La Niña conditions redeveloped unusually late in the year in December. The weak La Niña conditions remained throughout the first quarter of 2009; in April a transition to ENSO neutral conditions occurred. In June a transition to El Niño conditions took place and a weak El Niño remained throughout July, August, and September. During the last quarter of the year these conditions strengthened and 2009 ended with strong El Niño conditions.

If not referenced otherwise, information about tropical cyclones tracks, storm intensities, and effects was obtained from the Joint Typhoon Warning Center and the Central Pacific Hurricane Center websites. As in the previous two years, 2009 had below normal tropical cyclone activity (29 compared to a normal of 31) in the western North Pacific (Cooper and Falvey 2009) (Figure 3). At the beginning of the year tropical cyclone activity in the western North Pacific was still displaced westward and northward as is typical for La Niña conditions (PEAC 2009). As conditions transitioned to El Niño displacement shifted far eastward as is typical during El Niño years (Chu 2004). The first tropical cyclones in the region formed unusually late in the year in early May. Several tropical cyclones formed east of Guam and super typhoon Choi-wan had severe impacts in the far north of the Commonwealth of the Northern Mariana Islands (CNMI). On October 3rd typhoon Melor brought storm force winds and heavy rain to Saipan as it passed by the island. Tropical cyclone Lupit passed south of Guam on October 15th, bringing moderate rain and strong wind gusts to some parts of the island. No other tropical cyclones had significant effects on either Saipan or Guam in 2009.

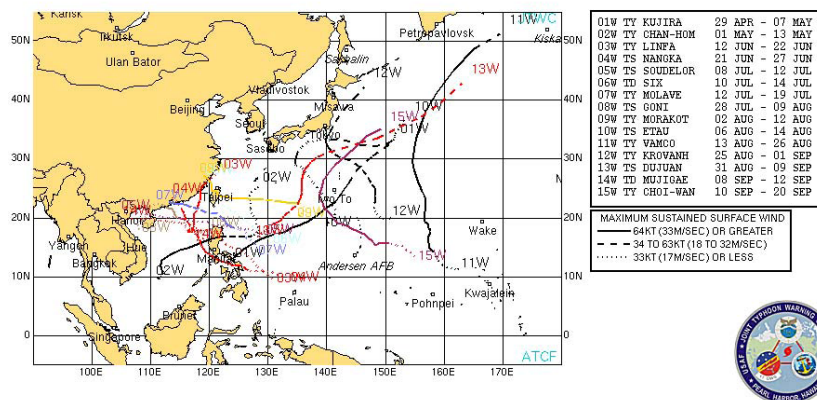


Figure 3. Western North Pacific Tropical Cyclones 01W-15W.

In American Samoa cyclone season lasts from October to May. While the overall number of tropical cyclones (Figure 4) was near normal for the South Pacific (Cooper and Falvey 2009), the 2008/2009 cyclone season was uneventful for the islands. This was likely a result of the La Niña conditions during which monsoon and tropical cyclone activity in the South Pacific east of the dateline are much reduced (Chu 2004b, PEAC 2009). The start of the 2009/2010 season (i.e., the end of 2009) was also uneventful for American Samoa.

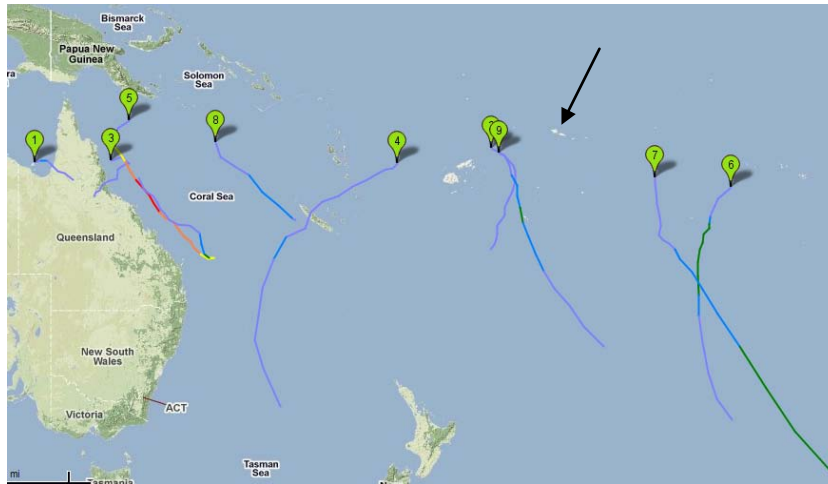


Figure 4. South Pacific Tropical Cyclones 2008-2009. Arrow points to American Samoa (NPSA).

The central North Pacific saw increased tropical cyclone activity in 2009, counting seven tropical cyclones that formed within or moved into the basin compared to a normal of four to five (ESCAP/WMO 2010). Most passed far from the Hawaiian Islands and did not cause any damage or significant winds or rainfall for the islands due to the distance at which they passed and the fact that they had decreased to tropical depressions as they approached Hawaii. Notable exceptions were Hurricane Felicia and Hurricane Neki. After weakening to a tropical depression, Felicia passed between Maui and Hawaii Island on August 11th, causing heavy rain from Oahu to the northern part of Hawaii Island. Neki formed southeast of Hawaii and swung west around the main Hawaiian Islands, then headed north. On October 23rd it passed Papahānaumokuākea Marine National Monument near the French Frigate Shoals reducing the size of Round Island and causing Disappearing Island to vanish as reported in a press release by the marine monument. Both islands provided endangered sea turtle and monk seal nesting habitat.

The Eastern Pacific had 20 tropical depressions, hurricanes and tropical cyclones in 2009 (Figure 5). Table 2 and figures 6-8 present precipitation and temperature data for COOP stations near WAPA on Guam, AMME on Saipan, and NPSA on Tutuila. No wind data were available for these stations, though it may be possible to obtain these in future years. Table 3 shows first quarter precipitation data for several Guam weather stations.

Note that the Agat station on Guam is a rain gauge only (Fig. 6). Total rainfall in 2009 was normal at this location; other stations on Guam had reported totals of between 88% and 119% of normal with most of them reporting a relatively dry first half of the year (first quarter, Table 3) and increased rainfall in the second half of the year (PEAC 2009, 2010). However this pattern is not evident for the Agat station, the four months (Jan, May, Sep, and Dec) with above normal

precipitation were evenly distributed throughout the year. June was the driest month of the year with only 40% of normal precipitation; all other months were between 64% and 99% of normal. The passing of typhoon Melor in the middle of October did not bring unusual rainfall to this location.

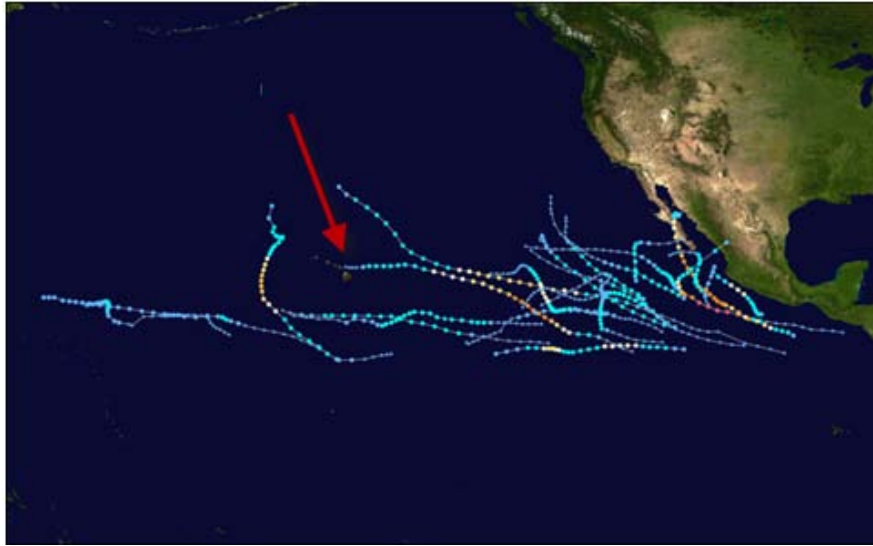


Figure 5. 2009 North Central and Eastern Pacific Hurricane Season Summary. Hawaii is located by the red arrow.

Guam NAS (Naval Air Station) COOP weather station (Fig. 7) is included for comparable data with Agat as well as the temperature data.

On Saipan, Capitol Hill (Fig. 8) had an annual rainfall slightly above the long-term mean (107%), but high variability between months, with the first half of the year drier than the second half, though November's precipitation was only at 50% of the long-term mean. The PEAC reports that the Saipan International Airport station had an annual total of 114% of normal, with the second half of the year wetter than the first. Capitol Hill data shows temperatures were above the long-term mean for the first half of the year, but went below the long-term mean as El Niño conditions developed and strengthened in the second half of the year.

In American Samoa, Pago Pago (Fig. 9) had an annual rainfall total 17% above normal with most of the high rainfall months in the second half of the year. Temperatures were above normal for as long as La Niña conditions or ENSO neutral conditions were present. As El Niño conditions developed and then strengthened throughout the second half of the year, maximum temperatures dipped below normal. Interestingly, minimum temperatures still remained above normal though much less so than earlier in the year.

Table 2. Comparison of precipitation and temperature data from 2009 with long-term records for stations on Guam, Saipan, and Tutuila, Samoa. Comparisons are made with 1971-2000 normals for Agat and Pago Pago WSO AP COOP stations. For Capitol Hill, data are compared to the long-term means (period of record indicated, not including the last year) since normals are not available. Guam NAS has long term data from 1950.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
	Agat (1979-2008)				COOP	Park: near WAPA, Guam				Elev. 10 ft. (3 m)			
Precipitation (in)													
1971-2000 normal	4.30	3.23	3.13	3.77	4.58	6.35	11.48	15.06	11.87	11.58	9.07	6.49	91.18
2009 total	8.06	3.21	2.39	3.10	5.91	2.54	7.98	13.38	13.43	8.50	5.85	16.06	90.41
% Normal	187%	99%	76%	82%	129%	40%	70%	89%	113%	73%	64%	247%	99%
	Capitol Hill (1995-2008)				COOP	Park: near AMME, Saipan				Elev. 827 ft. (252 m)			
Precipitation (in)													
Long-term mean	3.90	4.27	3.10	4.02	3.67	5.13	9.73	12.59	11.39	10.55	8.22	6.05	82.61
2009 total	2.84	3.28	3.95	0.97	3.18	6.61	12.27	18.39	10.72	13.46	4.10	8.95	88.72
% Long-term	73%	77%	127%	24%	87%	129%	126%	146%	94%	128%	50%	148%	107%
Min. temp. (°F)													
Long-term mean	73.4	72.9	73.4	74.0	75.3	75.6	75.2	75.1	75.2	75.0	75.2	74.5	74.6
2009 mean	73.8	73.9	73.7	74.7	75.5	75.8	75.0	75.2	70.2	75.1	75.1	73.8	74.3
Difference	0.4	1.0	0.3	0.6	0.1	0.1	-0.2	0.1	-5.0	0.0	-0.1	-0.7	-0.3
Max. temp. (°F)													
Long-term mean	81.2	80.7	81.9	83.5	84.6	85.0	84.2	83.9	84.1	84.1	83.5	82.6	83.3
2009 mean	82.7	82.1	82.3	84.4	85.4	85.1	84.8	84.0	75.4	82.3	82.2	81.4	82.7
Difference	1.5	1.4	0.4	0.9	0.8	0.1	0.6	0.1	-8.7	-1.8	-1.3	-1.2	-0.6
	Pago Pago WSO AP (1957-2008)				COOP	Park: near NPSA, Samoa				Elev. 12 ft. (3.7 m)			
Precipitation (in)													
1971-2000 normal	14.02	12.14	11.15	11.16	10.43	5.94	5.76	6.43	7.36	10.03	11.16	13.38	118.96
2009 total	11.34	7.62	9.99	9.28	19.17	3.65	9.96	10.41	6.28	7.53	16.65	27.40	139.28
% Normal	81%	63%	90%	83%	184%	61%	173%	162%	85%	75%	149%	205%	117%
Min. temp. (°F)													
1971-2000 normal	76.1	76.3	76.6	76.3	76.2	76.1	75.5	75.5	75.8	76.2	76.5	76.4	76.1
2009	80.4	80.0	80.0	81.2	77.8	77.8	77.3	76.1	76.6	77.1	77.7	77.1	78.2
Difference	4.3	3.7	3.4	4.9	1.6	1.7	1.8	0.6	0.8	0.9	1.2	0.7	2.1
Max. temp. (°F)													
1971-2000 normal	86.8	87.2	87.3	86.9	85.6	84.5	83.8	84.0	84.8	85.2	85.8	86.9	85.7
2009 mean	89.5	90.8	90.3	89.6	86.1	84.4	83.9	83.3	84.0	85.2	84.9	85.6	86.5
Difference	2.7	3.6	3.0	2.7	0.5	-0.1	0.1	-0.7	-0.8	0.0	-0.9	-1.3	0.8

Table 2. Comparison of precipitation and temperature data from 2009 with long-term records for stations on Guam, Saipan, and Tutuila, Samoa. Comparisons are made with 1971-2000 normals for Agat and Pago Pago WSO AP COOP stations. For Capitol Hill, data are compared to the long-term means (period of record indicated, not including the last year) since normals are not available. Guam NAS has long term data from 1950. (continued).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
	Guam NAS(1950-2008)				COOP	Park: near NPSA, Samoa				Elev.254 ft (77m)			
Precipitation (in)													
1950-2008 normal	4.42	3.67	2.55	3.34	5.04	6.48	10.51	14.33	13.51	12.16	8.57	5.64	90.22
2009 total	4.53	1.90	3.06	3.03	3.57	4.58	10.72	26.14	15.54	11.13	5.08	7.85	97.13
% Normal	102%	52%	120%	91%	71%	71%	102%	182%	115%	92%	59%	139%	108%
Min. temp. (°F)													
1950-2008 normal	75.0	74.6	75.0	76.2	76.8	77.1	76.5	76.1	76.1	76.4	76.5	76.1	76.1
2009	76.6	76.7	75.1	77.3	78.2	78.0	77.6	76.6	77.3	77.0	77.9	76.2	77.1
Difference	1.6	2.1	0.1	1.1	1.4	0.9	1.1	0.5	1.2	0.6	1.4	0.1	1.0
Max. temp. (°F)													
1950-2008 normal	85.1	85.3	86.1	87.1	87.4	87.7	87.2	86.8	86.7	87.2	86.7	85.9	86.6
2009 mean	86.0	87.0	86.6	88.0	88.3	88.6	87.7	87.3	86.9	86.8	87.9	86.4	87.3
Difference	0.9	1.7	0.5	0.9	0.9	0.9	0.5	0.5	0.2	-0.4	1.2	0.5	0.7

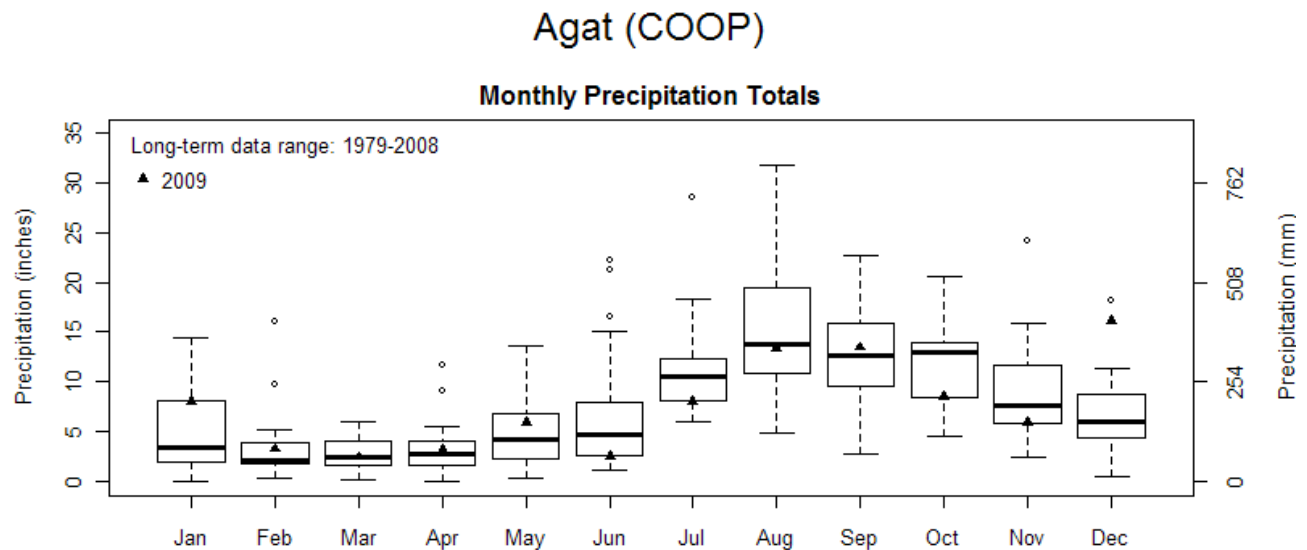


Figure 6. Boxplot of precipitation data for Agat, (COOP) Guam.

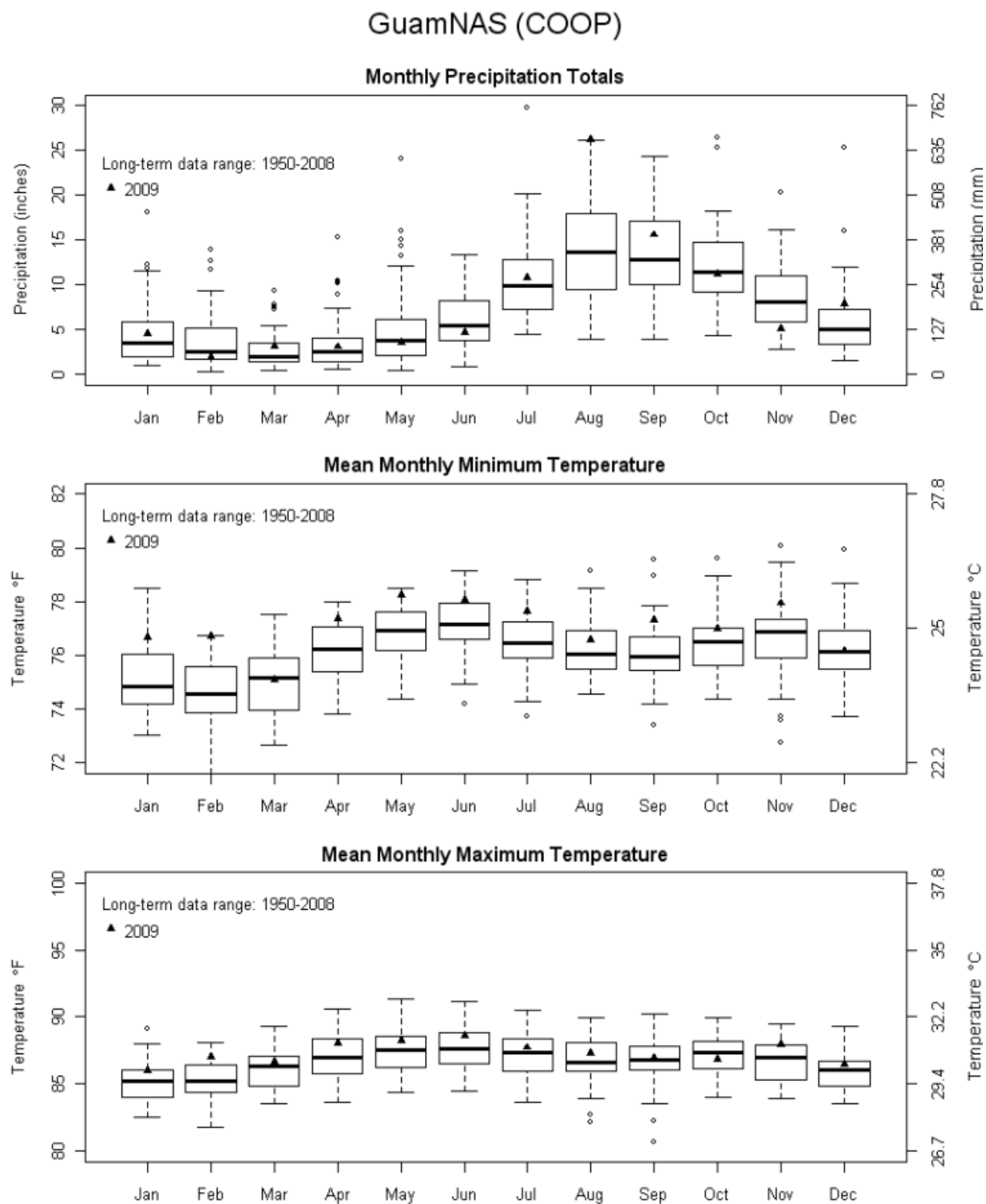


Figure 7. Boxplots of precipitation and temperature data for Guam NAS (COOP).

Table 3. Precipitation data from the first quarter PEAC for several stations on Guam and Saipan for 2009.

Guam		Jan	Feb	Mar	1st Qtr	Predicted
Guam Int Airport	rainfall (inches)	4.53	1.9	3.06	9.49	10.05
	% normal	92%	51%	103%	85%	90%
Anderson AFB	rainfall (inches)	5.55	1.01	3.42	9.98	13.6
	% normal	97%	19%	84%	66%	90%
Univ of Guam	rainfall (inches)	5.94	1.28	2.79	10.01	10.05
	% normal	120%	34%	94%	90%	90%
Dededo	rainfall (inches)	5.44	2.68	3.84	11.96	13.46
	% of AAFB	95%	51%	94%	80%	90%
Ugam Watershed	rainfall (inches)	7.2	1.82	3.47	12.49	18.13
	% of WSMO	82%	39%	53%	62%	90%
Sinajana	rainfall (inches)	5.73	1.68	3.82	11.23	10.05
	% of WFO	116%	45%	128%	101%	90%
CNMI (Saipan)						
Saipan Int Airport	rainfall (inches)	2.83	2.6	2.85	8.28	6.97
	% normal	85%	104%	137%	105%	90%
Capitol Hill	rainfall (inches)	2.84	3.19	3.95	9.98	9.07
	% normal	67%	100%	107%	99%	90%
Tinian Airport	rainfall (inches)	2.01	1.3	2.69	6	7.11
	% normal	60%	52%	129%	76%	90%
Rota Airport	rainfall (inches)	2.85	3.24	8.68	14.77	12.31
	% normal	54%	69%	235%	108%	90%

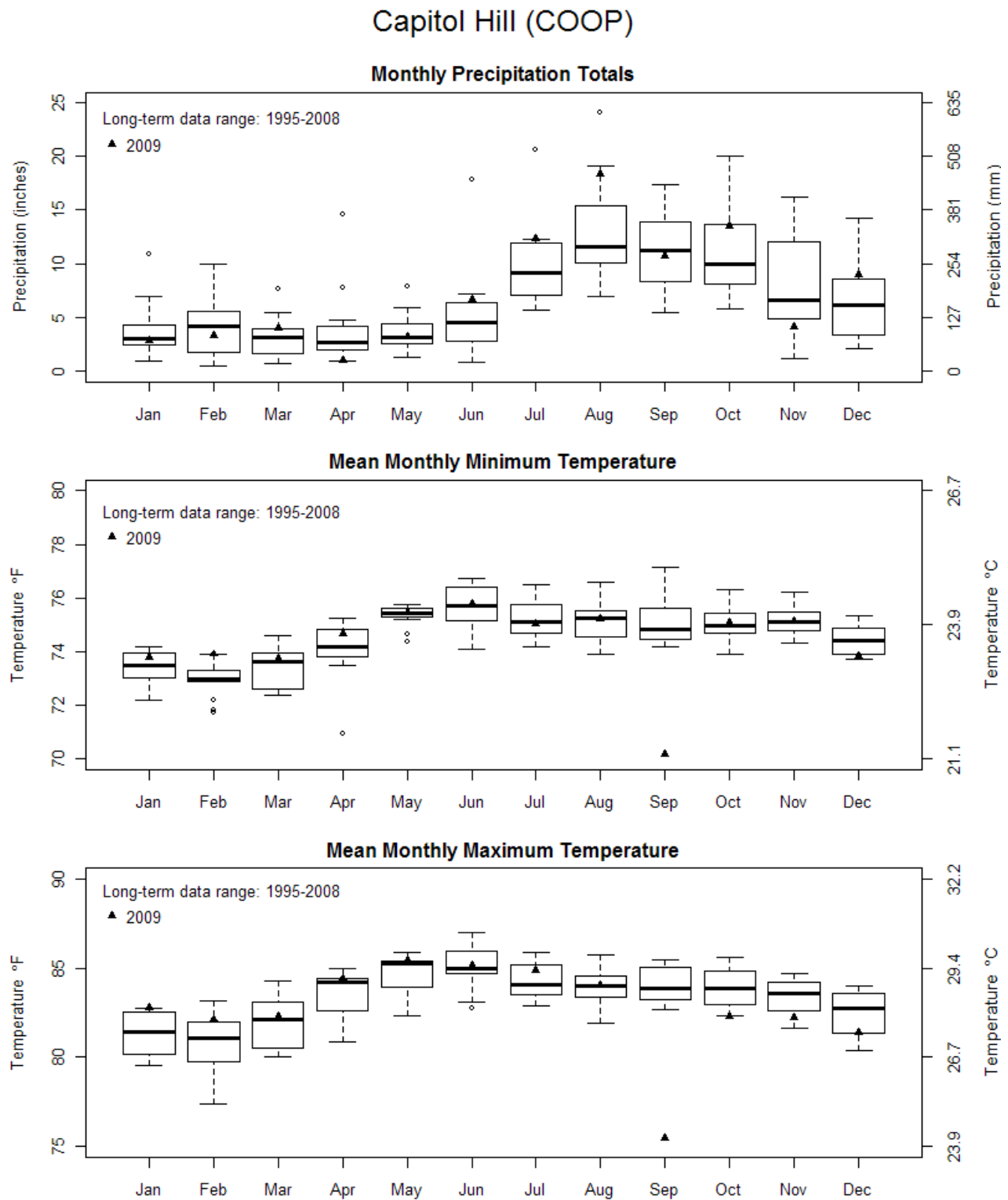


Figure 8. Boxplots of precipitation and temperature data for Capitol Hill (COOP) near AMME, Saipan.

Pago Pago (COOP)

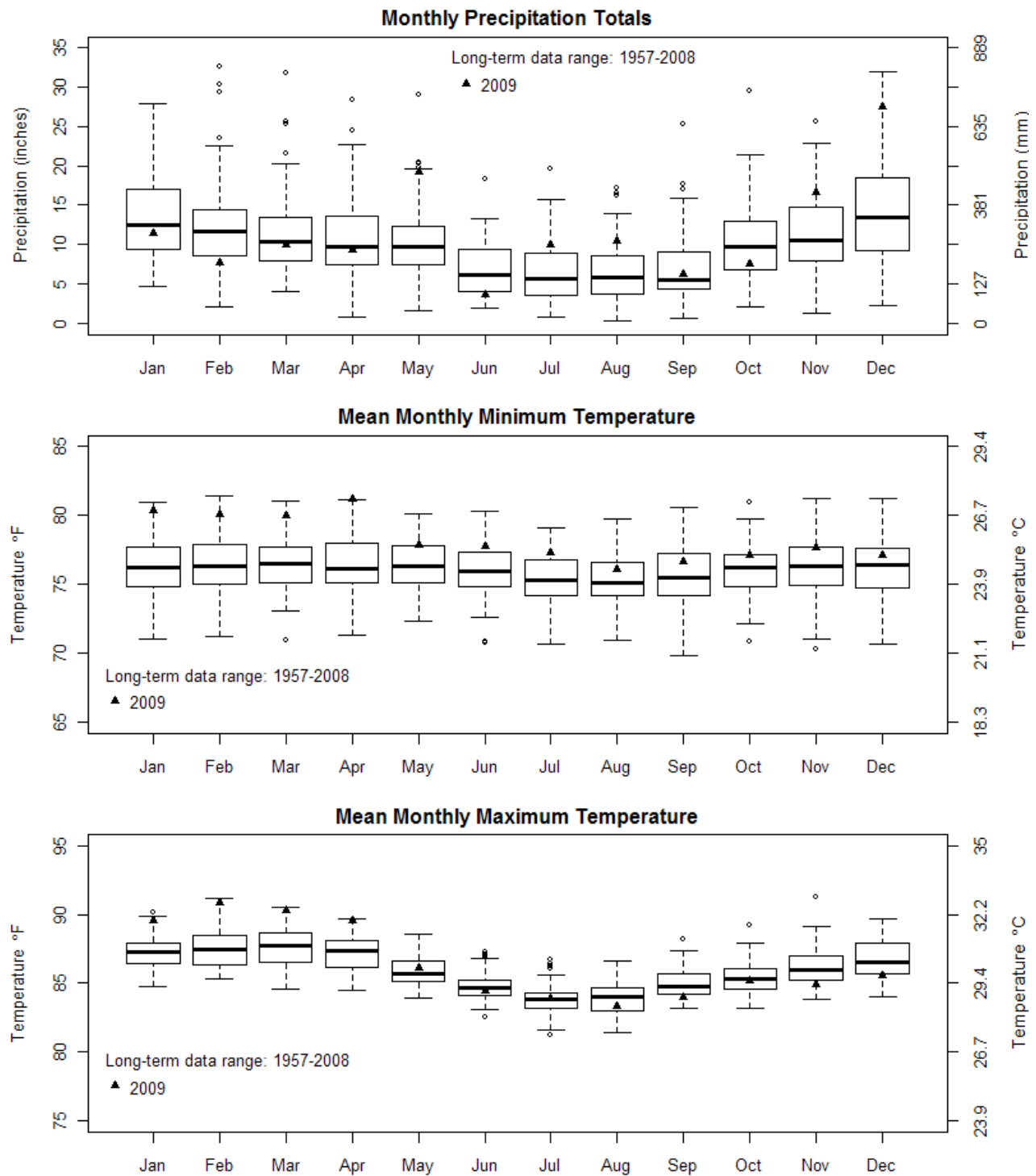


Figure 9. Boxplots of precipitation and temperature data for Pago Pago WSO AP (COOP), Samoa.

Weather events in the Hawaiian Islands

January began with a quick series of cold fronts that passed across the islands bringing very wet weather. On January 16 an active pattern of significant rainfall in 24 hours produced 9.74 inches of rain in Kaupo Gap in Haleakala National Park on Maui. The passage of these fronts produced substantial rainfall which helped eliminate some areas of drought on Kauai and Oahu.

Unfortunately this did not help alleviate the areas of serious drought on the leeward sections of the Big Island and Maui County. A shear line in early February produced the most rainfall in the month, 7-10 inches on the interior of Maui and the Big Island. This produced minor flooding and quarter inch hail. Mid February saw intense three day thunderstorms in the areas of South Kohala and in Kapolei on Oahu. The Kapolei thunderstorm produced a tornado that caused property damage and some injuries. From mid February to early March very little rain fell across the State. Interruptions of the trade winds produced two important rain events from March 7-9 and 12-19. This second storm broke daily records at Hilo airport where 18 inches of rain fell in two days. In July, the climate transitioned from ENSO-neutral conditions to El Niño meaning drought conditions were likely to continue in areas most affected. The next significant weather event was the arrival of Hurricane Felicia, downgraded to a tropical storm by the time it passed through Hawaii heading west from August 7-12. This alleviated drought conditions and water shortages on Maui, and caused mudslides and flooding on Oahu. Hurricane Neki, which started south of Hawaii on Oct 18, migrated northwest, eventually downgraded to a tropical storm when it hit Papahānaumokuākea Marine National Monument near French Frigate Shoals. It completely inundated two small islets; Round Island, which lost some land area, and Disappearing Island, which disappeared.

Hawai'i Volcanoes National Park (HAVO)

There are eight active weather stations in HAVO at this time. Four are COOP stations, three are RAWS and one is a GPMN (Gaseous Pollutant Monitoring Network). Table 4 and Figures 10-21 present precipitation, temperature, relative humidity, and wind data for the two COOP stations and three RAWS. The two COOP stations are Hawaii Vol NP HQ 54 and, Mauna Loa Slope Obs, the three RAWS stations are: Keaumo, Pali2, and the new converted from COOP to RAWS station, Kealakomo. In 2011 PACN will be setting up two new Campbell Scientific weather stations in the Kahuku unit utilizing the automatic RAWS system.

The COOP station, Kahuku Mill Camp, has low observation frequencies (<85%) throughout its entire record. Data flags indicate that subsequent days report accumulated precipitation. To provide at least some information about rainfall in this area of HAVO data are presented in Figure 11. However, since the accuracy of these data is questionable (evaporation is likely whenever data are not collected for several days), these data were not included in Table 4. In the future, with more personnel working in the Kahuku section, data will be more forthcoming. This is actually a monthly rain gauge, but Resource Management personnel try to collect data weekly, so evaporation problems are less. (Al Aviles, NPS Resource Management, pers. comm.)

Figure 20 displays wind data for the Pali 2 RAWS, clearly reflecting the predominant north east trade winds. Monthly data (Appendix A) show that this is the predominant wind direction throughout the year, with January, April, May and December the months with highest variability in wind directions. Data from the Keaumo RAWS (Figure 21, Appendix A) show the influence of the mountain resulting in more variable wind directions on the slopes of Mauna Loa, though northerly winds were most common throughout the year.

Table 4. Comparisons of precipitation and temperature data from 2009 with long term records for stations at Hawaii Volcanoes National Park (HAVO).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Hawaii Vol NP HQ 54 (1945-2009)					COOP		Park: HAVO			Elev. 3,971 ft. (1,210 m)			
Precipitation (in)													
1971-2000 normal	10.78	9.13	14.1	10.38	6.29	5.23	7.21	6.31	6.01	6.83	14.06	11.01	107.34
2009	5.58	5.51	19.60	8.70	3.85	6.18	7.11	1.66	3.94	6.24	9.03	2.56	79.96
% Normal	52%	60%	139%	84%	61%	118%	99%	26%	66%	91%	64%	23%	74%
Min. temp. (°F)													
1971-2000 normal	49.6	49.6	50.5	51.7	52.7	54.2	55.2	55.5	55.2	55	53.7	51.2	52.8
2009 means	47.6	36.8	48.9	47.9	49.6	52.6	54.0	57.1	54.7	49.5	48.8	49.2	49.7
Difference	-2.0	-12.8	-1.6	-3.8	-3.1	-1.6	-1.2	1.6	-0.5	-5.5	-4.9	-2.0	-3.1
Max. temp. (°F)													
1971-2000 normal	67.5	67.5	67.1	67.3	69	70.4	71.5	73	72.9	72	69.6	67.6	67.6
2009	64.6	48.8	60.4	61.5	67.7	69.6	69.8	73.5	72.5	63.5	62.9	69.7	65.4
Difference	-2.9	-18.7	-6.7	-5.8	-1.2	-0.8	-1.7	.5	-0.7	-8.5	-6.7	2.1	-2
Kealakomo 38.8 (1995-2007) COOP, (2008-2009) RAWS Park: HAVO Elev. 290 ft. (88.4 m)													
Precipitation (in)													
Long-term mean	9.46	6.27	9.06	3.59	2.91	2.08	1.76	2.00	2.38	4.47	7.94	7.20	59.10
2009	NA	NA	NA	1.38	10.33	4.01	6.37	0.99	0.02	0.10	0.00	0.01	NA
Difference	NA	NA	NA	-2.21	74.20	1.93	4.61	-1.01	-2.36	-4.37	-7.94	-7.19	
Mauna Loa Slope Obs (1955-2009)					COOP		Park: near HAVO			Elev. 11,150 ft. (3,398.5 m)			
Precipitation (in)													
1971-2000 normal	2.97	1.68	2.29	1.23	0.74	0.53	1.32	1.33	1.25	1.16	2.38	1.89	18.77
2009 means	0.27	1.06	3.04	1.54	0.08	0.06	1.44	1.24	0.00	1.09	0.88	0.30	11.00
% Normal	9%	63%	133%	125%	11%	11%	109%	93%	0%	94%	37%	16%	59%
Min. temp. (°F)													
1971-2000 normal	33.9	33.7	34.1	35.1	37.4	40.3	39.6	39.7	39.1	38.6	37.3	35.2	37.0
2009 means	19.3	20.9	21.5	24.9	24.2	28.6	27.1	26.4	28.3	26.8	21.5	24.2	24.5
Max. temp. (°F)													
1971-2000 normal	50.0	50.2	51.0	52.2	54.2	57.5	56.5	56.6	55.4	54.8	52.6	51.1	53.5
2009 means	30.8	32.9	33.3	37.4	37.2	44.0	40.5	39.1	42.1	40.2	33.7	37.5	37.4

Table 4. Comparisons of precipitation and temperature data from 2009 with long term records for stations at Hawaii Volcanoes National Park (HAVO) (continued).

	Keaumo (2000-2009)				RAWS		Park: HAVO			Elev. 5,520 ft. (1,692 m)				
Precipitation (in)														
Long-term mean	6.40	5.70	5.60	2.40	1.80	0.90	1.90	2.50	3.20	3.20	9.00	6.30	49.10	
2009 means	1.20	0.40	13.80	2.10	3.90	1.00	3.20	0.40	0.90	3.20	4.60	2.20	37.00	
Difference	-5.10	-5.30	8.10	-0.30	2.10	0.10	1.30	-2.10	-2.30	0.00	-4.40	-4.10	-12.10	
Min. temp. (°F)														
Long-term mean	42.7	42.5	43.7	44.8	45.4	47.4	49.3	48.2	48.2	47.7	46.2	44.1	45.8	
2009 means	40.2	41.9	45.5	45.3	44.9	48.3	49.7	48.5	47.3	48.3	47.9	42.1	45.8	
Difference	-2.5	-0.6	1.8	0.5	-0.5	0.1	0.4	0.3	-0.9	0.6	-1.7	-2.0	0.0	
Max. temp. (°F)														
Long-term mean	68.7	68.4	67.9	68.8	71.4	73.6	76.0	76.0	73.2	72.9	72.2	69.9	71.6	
2009	66.9	67.1	62.5	65.8	70.2	72.9	73.9	77.7	74.0	74.4	72.3	70.5	71.6	
Difference	-1.8	-1.3	-5.4	-3.0	-1.2	-0.7	-2.1	1.7	0.8	1.5	0.1	0.6	0.0	
Ave. temp. (°F)														
Long-term mean	54.3	54.2	54.7	55.7	57.8	60.0	62.1	61.3	59.6	59.0	57.7	55.5	57.7	
2009	52.3	52.8	52.7	54.4	57.3	60.1	61.2	62.5	60.4	60.1	58.5	54.8	57.3	
Difference	-2.0	-1.4	-2.0	-1.3	-0.5	0.1	-0.9	1.2	0.8	1.1	0.8	-0.7	-0.4	
	Pali 2 (2000-2009)				RAWS		Park: HAVO			Elev. 2,780 ft. (856 m)				
Precipitation (in)														
Long-term mean	8.7	8.4	9.5	1.9	1.5	0.4	0.9	1.8	1.8	5.2	9.1	7.0	56.2	
2009	5.4	0.5	12.3	1.1	5.9	0.4	4.1	1.7	0.4	4.4	5.3	2.8	44.1	
Difference	-3.3	-7.9	2.8	-0.8	4.4	0.0	3.2	-0.1	-1.4	-0.8	-3.8	-4.2	-12.1	
Min. temp. (°F)														
Long-term mean	56.8	56.2	57.3	58.0	59.1	60.4	62.1	62.8	62.4	61.6	60.5	58.1	59.6	
2009 means	55.3	55.6	56.3	57.4	59.0	60.9	62.3	63.5	62.4	62.9	60.8	57.5	59.5	
Difference	-1.5	-0.6	-1.0	-0.6	-0.1	0.5	0.2	0.7	0.0	-1.3	0.3	-0.6	-0.1	
Max. temp. (°F)														
Long-term mean	71.5	71.3	71.3	72.9	75.0	77.0	79.3	79.6	78.1	76.7	74.9	72.0	75.0	
2009	70.1	69.7	68.5	69.9	72.2	77.2	78.3	79.5	78.7	77.0	75.6	73.5	74.2	
Difference	-1.4	-1.6	-2.8	-3.0	-2.9	0.2	-1.0	-0.1	0.6	0.3	0.7	1.5	-0.8	
Ave. temp. (°F)														
Long-term mean	62.9	62.5	63.3	64.0	65.8	67.4	69.4	69.7	68.7	67.6	66.4	63.8	66.0	
2009	61.3	61.1	61.2	62.5	64.9	67.8	69.0	70.0	69.2	68.6	66.5	64.2	65.5	
Difference	-1.6	-1.4	-2.1	-1.5	-0.9	-0.4	-0.4	0.3	0.5	1.0	0.1	0.4	-0.5	

Hawaii Vol NP HQ 54 (COOP)

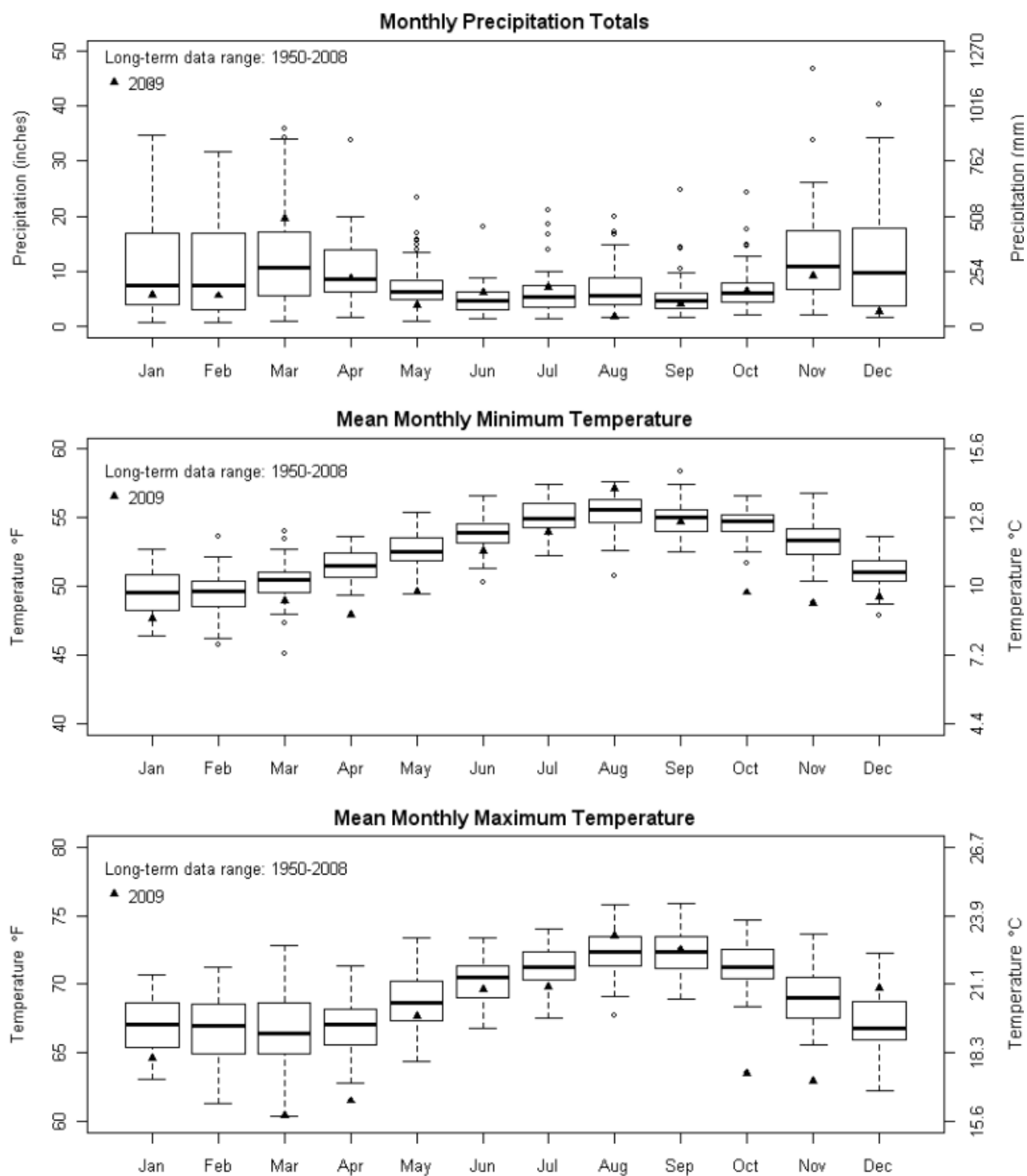


Figure 10. Boxplots of precipitation and temperature data for Hawaii Vol NP HQ 54 (COOP), Hawaii.

Kahuku Mill Camp 6.3 (COOP)

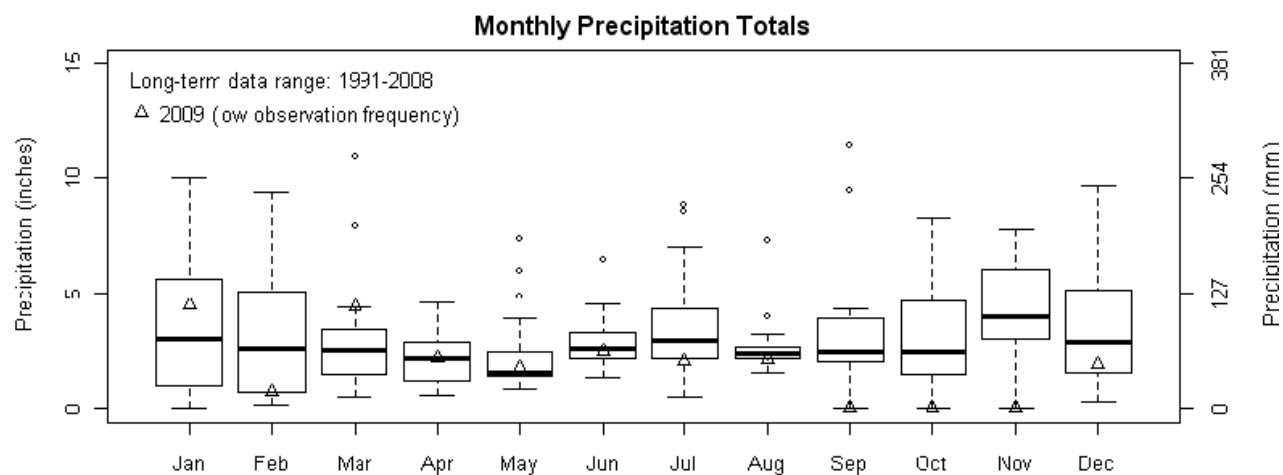


Figure 11. Boxplot of precipitation and temperature data for Kahuku Mill Camp 6.3 (COOP). Note that all long-term and 2009 data are based on low observation frequencies. Data is accumulated and hence problematic since evaporation may occur over time.

Kealakomo 38.8 (COOP)

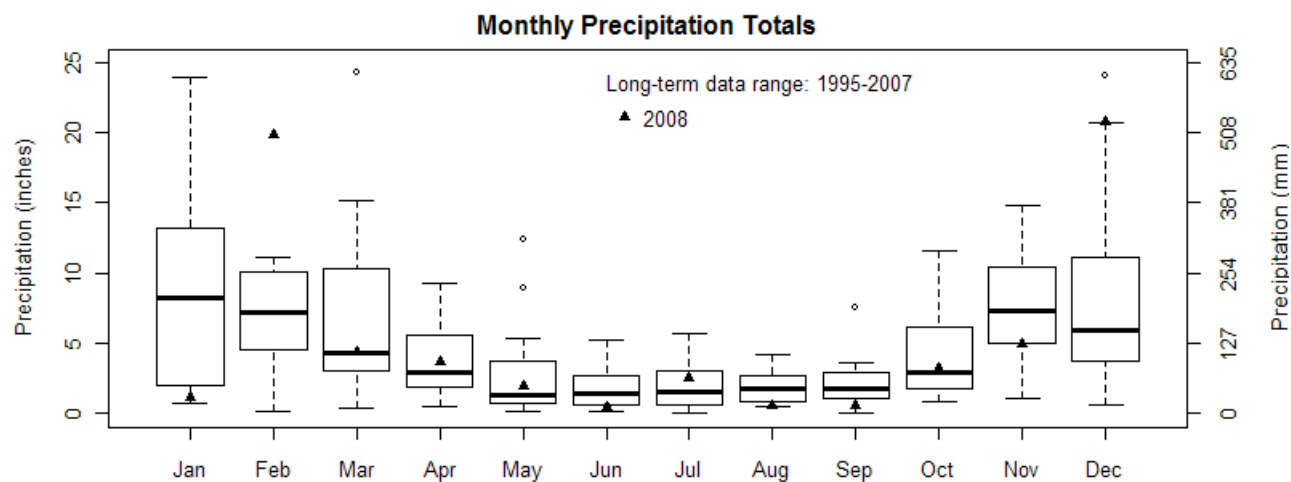


Figure 32. Boxplot of precipitation data for Kealakomo 38.8 (COOP), Hawaii.

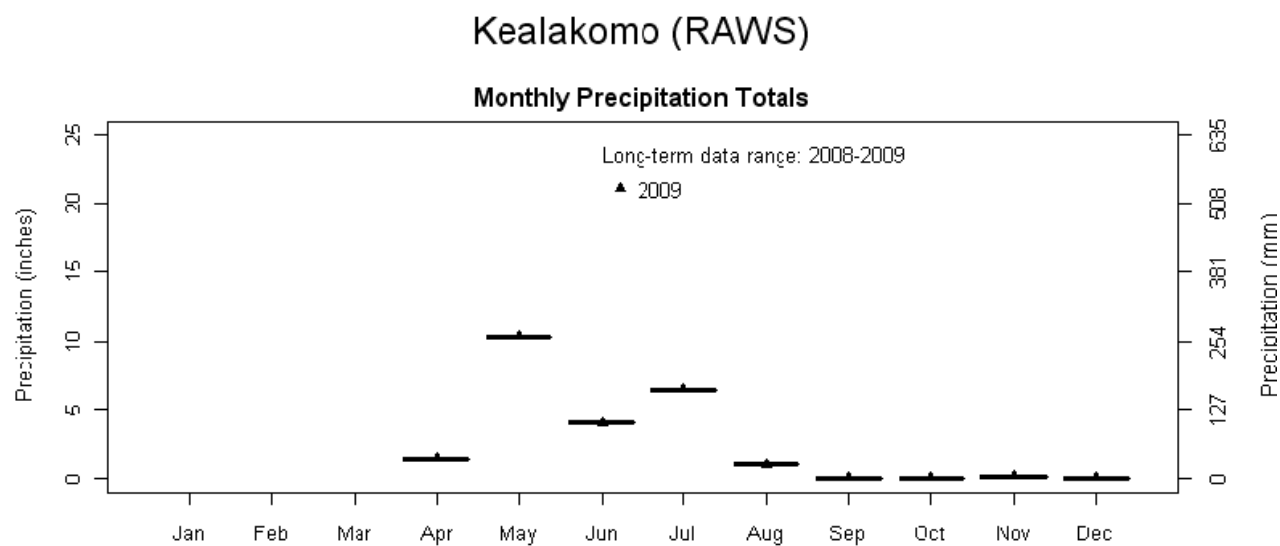


Figure 43. 2009 data for the newly established Kealakomo RAWS, Hawaii station. Compare Kealakomo COOP data in previous figure for long-term data.

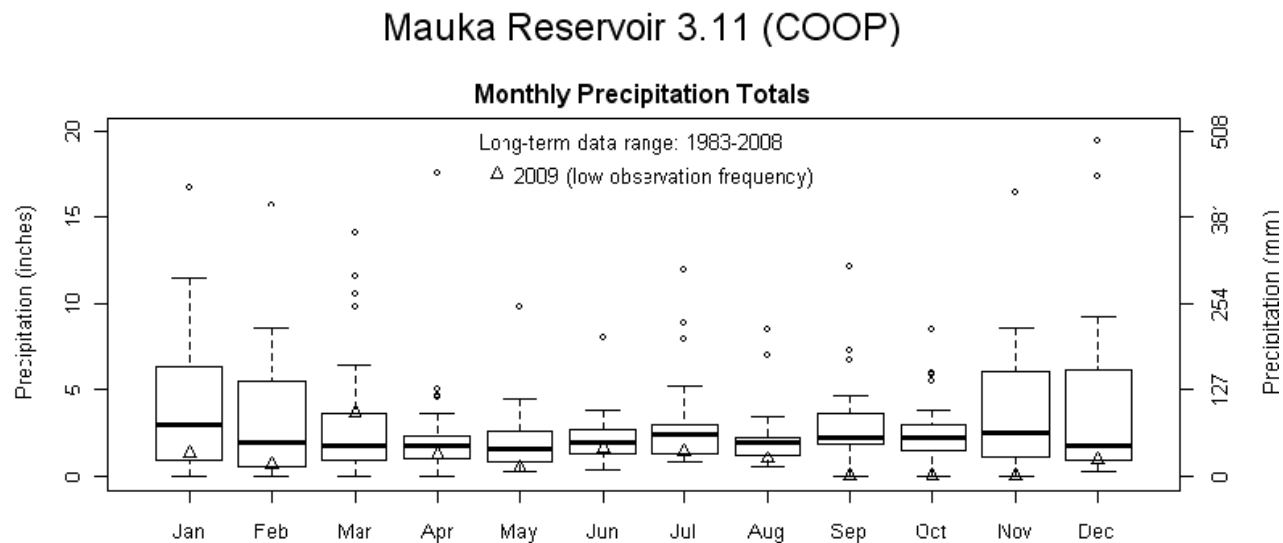


Figure 54. Boxplot of precipitation data for Mauka Reservoir 3.11 (COOP), Hawaii. Note that all data are based on low observation frequencies.

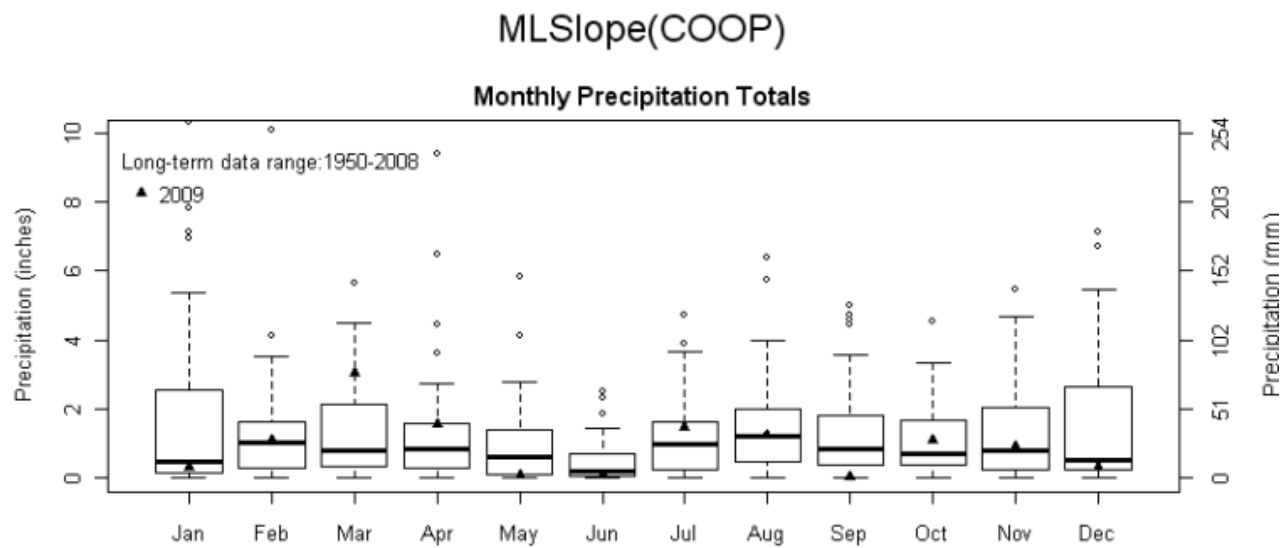


Figure 65. Boxplot of precipitation data for Mauna Loa Slope Obs. 39, (COOP) Hawaii.

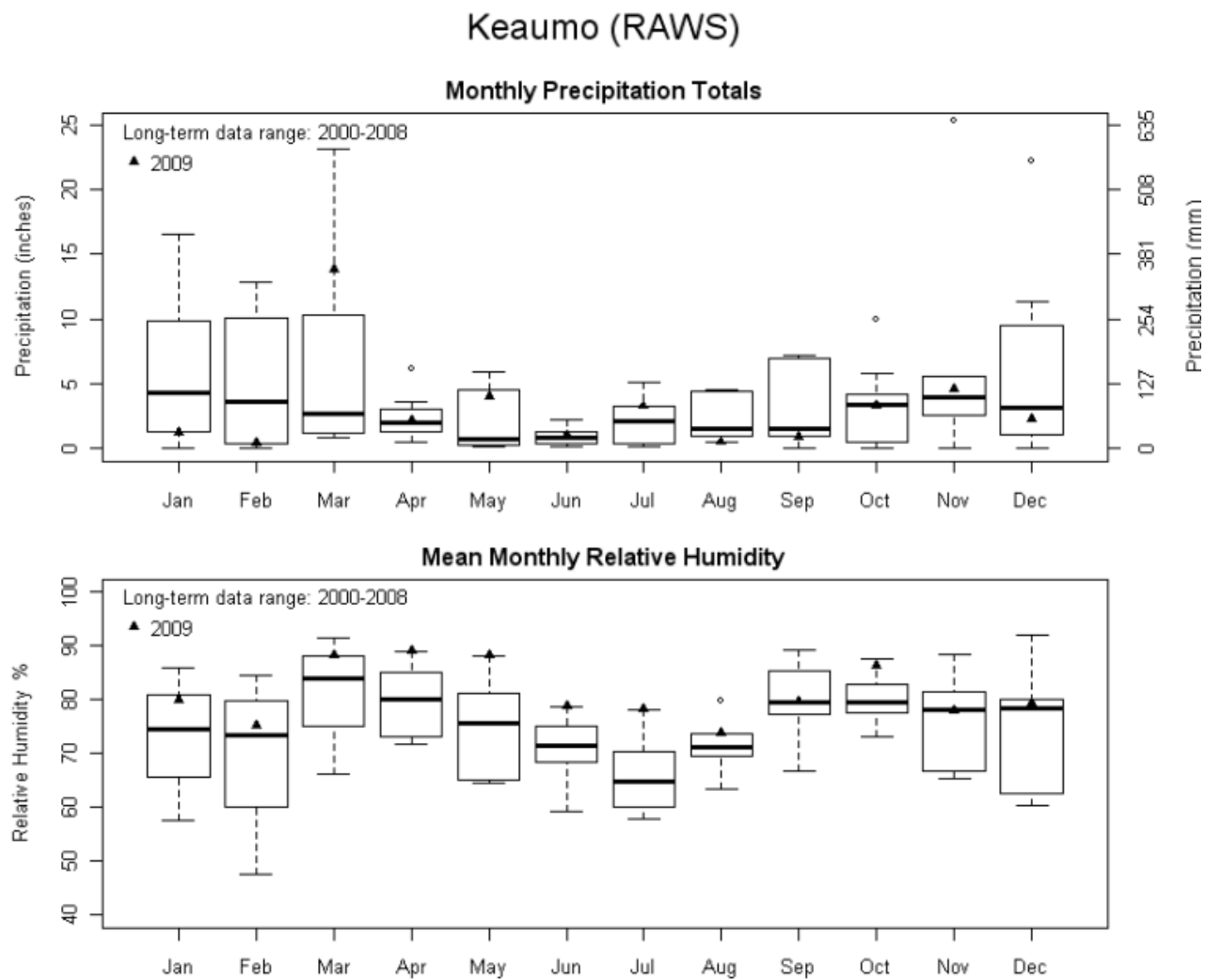


Figure 76. Boxplots of precipitation and relative humidity for Keaumo (RAWS) Hawaii.

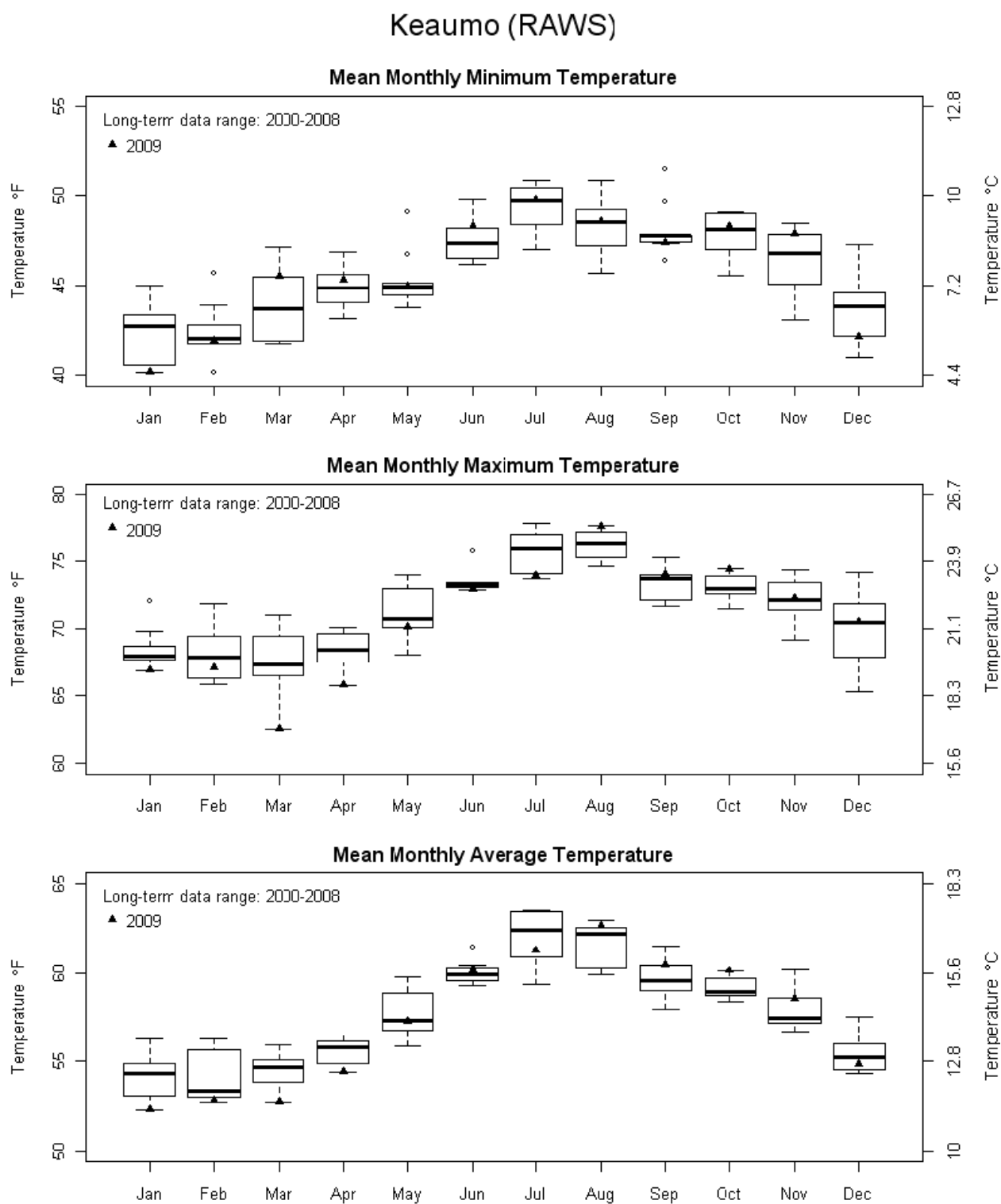


Figure 87. Box plots of temperature data for Keaumo, (RAWS), Hawaii.

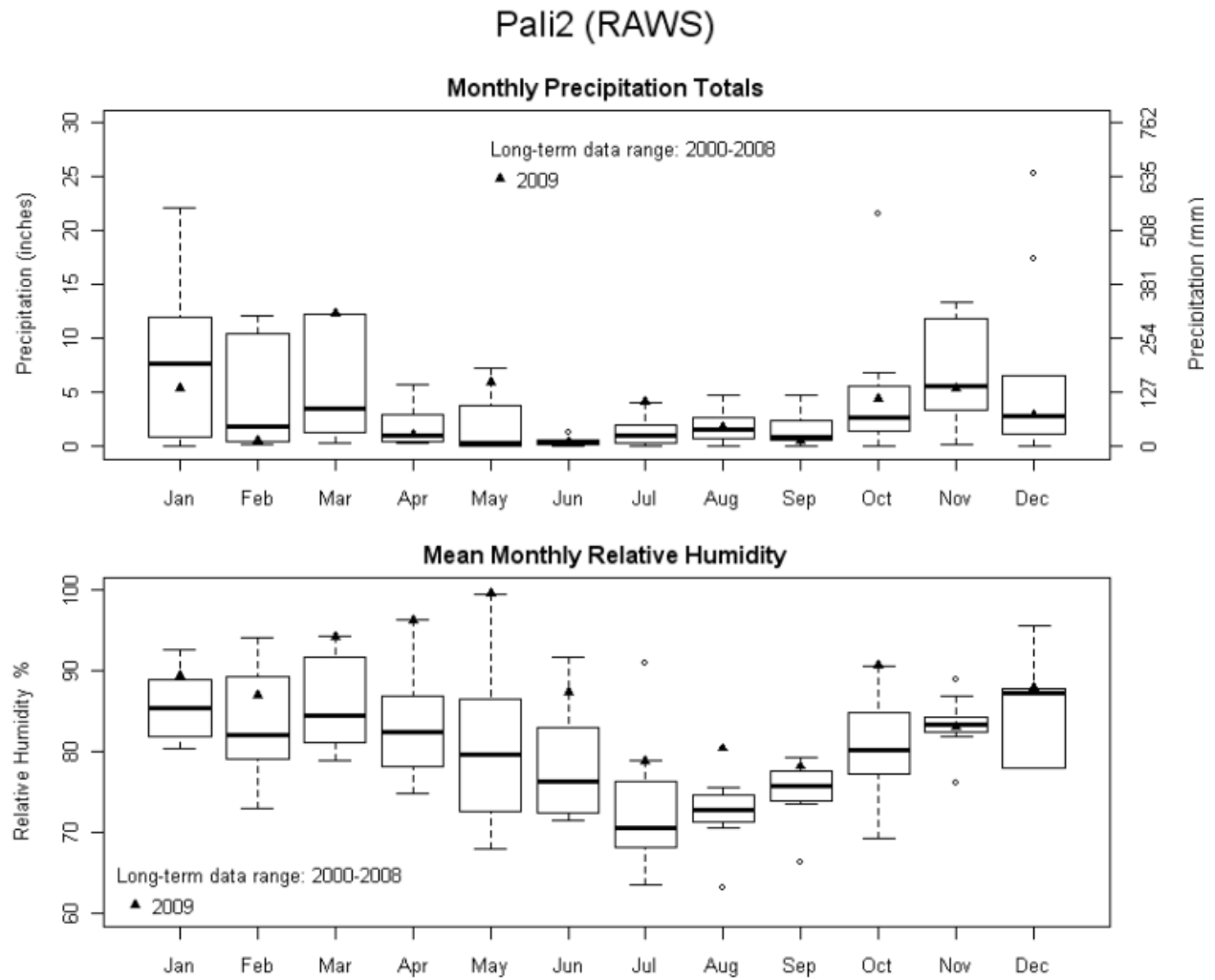


Figure 98. Boxplots of precipitation and relative humidity data for Pali2 (RAWS), Hawaii.

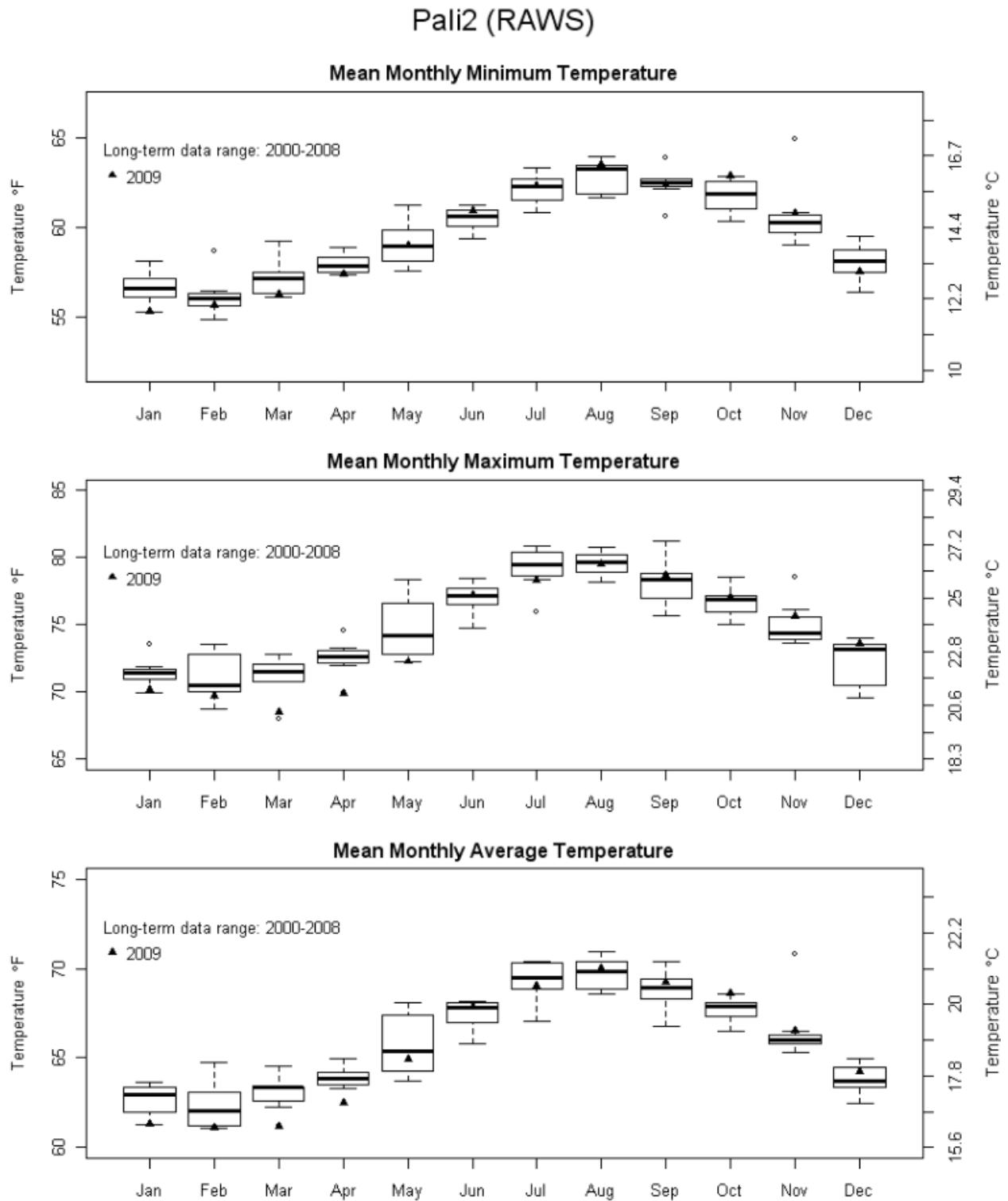


Figure 19. Boxplots of temperature data from Pali 2, (RAWS), Hawaii.

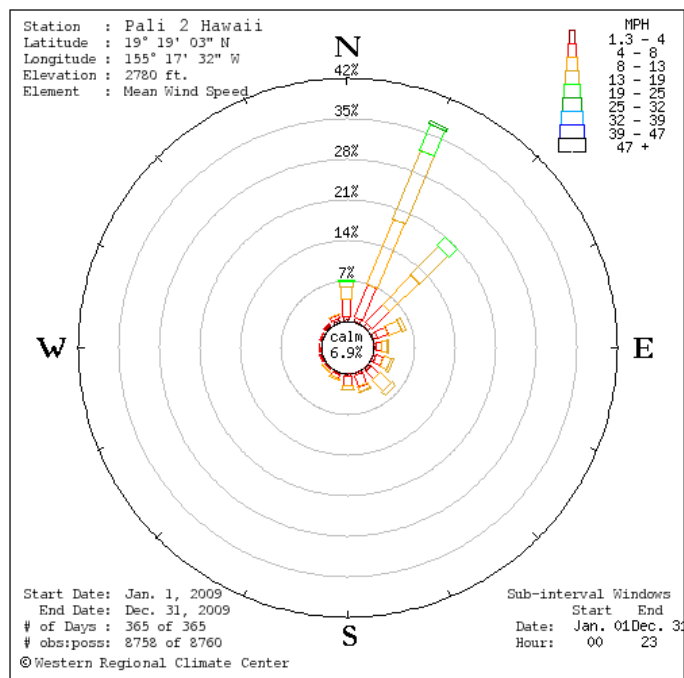


Figure 20. Wind Rose Graph for Pali 2 (RAWS), Hawaii.

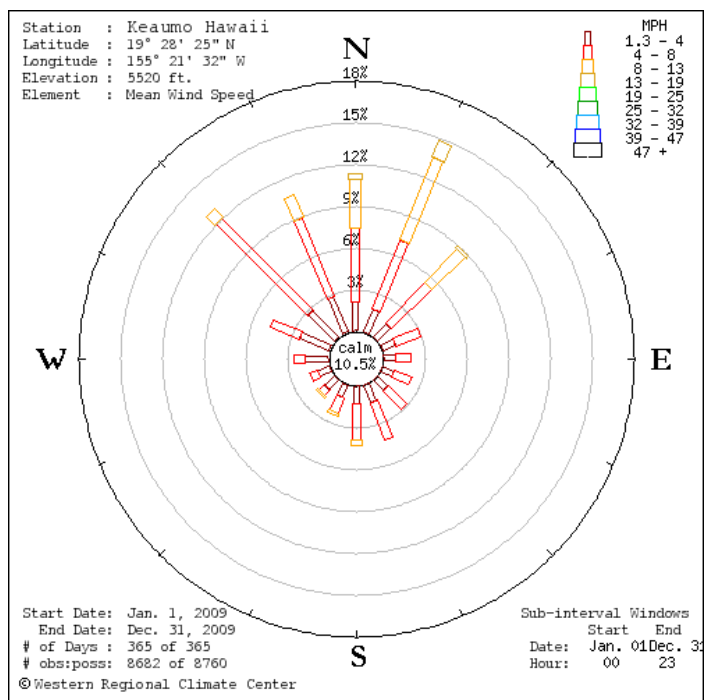


Figure 21. Wind Rose Graph for 2009 data for Keaumo, (RAWS) Hawaii.

Kaloko-Honokōhau (KAHO) and Pu‘uhonua o Hōnaunau (PUHO) National Historical Parks and Pu‘ukoholā Heiau (PUHE) National Historic Site

Table 5 and Figures 22-24 provide precipitation, temperature and relative humidity data for the three west Hawai‘i national parks. Figure 25 show wind information for the year at Kaloko-Honokōhau. The COOP stations at PUHE and KAHO only record precipitation.

Puuhonuaohonaunau 27.4 had low observation frequencies (<85%) for five months in 2009. Data flags indicated that subsequent days reported accumulated precipitation data. To provide at least some information about rainfall in this area, data for all months are shown in Figure 22.

However, since the accuracy of these data is questionable (evaporation is likely whenever data are not collected for several days), these data were not included in the numerical comparison table. In 2011, this WeatherHawk station at PUHO will be replaced by a Campbell Scientific automated station using the RAWS network.

Comparisons of 2009 data with long-term records are provided for the Kaloko-Honokōhau RAWS, but it needs to be emphasized that they only provide information for a three-year time period.

The Kaloko-Honokōhau RAWs station only measured precipitation data from January through March. The following months registered zero (0) with no precipitation recorded until Dec 16, 2009 when it was serviced and a small amount of water was added to check the rain gauge function. These first three months data measured 1.9 inches of precipitation.

The COOP station, 2700 yards away, registered precipitation throughout the year, and for those first three months, registered 3.5 inches of precipitation. The cumulative total was 9.7 inches for 2009, compared to an annual normal of 15.31 inches.

There has been quite a discrepancy of total precipitation indices between the two stations for the past two years. With some data lacking on both stations, the difference between last year’s precipitation counts was 4.9 inches, a 26% difference. For the first three months, there was a 46% discrepancy, with 1.9 inches at the RAWS station and 3.5 at the COOP.

Further north, Pu‘ukoholā Heiau National Historic Site had a slightly wet January, and the rest of the year was near normal, but less than normal in all months. Maximum temperatures were below normal all year, with minimum temperatures showing about half less than normal.

Table 5. Comparison of precipitation and temperature data from 2009 with long-term records for stations at three national parks in west Hawai'i. Comparison is made with 1971-2000 normals for the COOP stations and with the long-term mean (only 3 years) for the RAWS.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Honokohau Harbor	68.14 (1991-2009)				COOP		Park: KAHO			Elev. 30 ft. (9.1 m)			
Precipitation (in)													
1971-2000 normal	2.12	0.78	1.44	2.21	0.77	1.10	1.02	1.12	1.50	1.47	0.72	1.06	15.31
2009	2.2	0.3	1.0	0.8	0.1	1.4	0.8	0.9	0.0	0.4	0.4	1.2	9.7
% Normal	104%	38%	69%	36%	13%	127%	78%	80%	0%	27%	56%	113%	63%
Puuhonuaohonaunau	27.4 (1971-2009)				COOP		Park: PUHO			Elev. 15 ft. (4.6 m)			
Precipitation (in)													
1971-2000 normal	2.52	1.64	1.85	1.68	2.30	2.37	2.83	2.55	2.69	2.46	1.53	1.58	26.00
2009	1.9	0.6	1.6	1.2	1.1	3.0	0.7	1.2	2.2	1.1	0.9	0.5	16.2
% Normal	75%	37%	86%	71%	48%	127%	25%	47%	82%	45%	59%	32%	62%
Puukohola Heiau	98.1 (1977-2009)				COOP		Park: PUHE			Elev. 33 ft. (40.5 m)			
Precipitation (in)													
1971-2000 normal	1.75	1.16	0.95	1.43	0.37	0.39	0.36	0.48	0.69	0.66	0.99	1.94	11.17
2009	2.2	0.00	0.64	0.32	0.90	0.32	0.04	0.35	0.00	0.00	0.99	0.48	6.26
Difference	-0.45	1.16	-0.31	-1.11	0.53	-0.07	-0.32	-0.13	-0.69	-0.66	0.00	-1.46	-4.91
Min. temp. (°F)													
1971-2000 normal	64	64.1	65.4	66.9	67.8	69.2	70.3	70.9	70.5	70.4	68.4	66	67.8
2009 means	63.5	64.4	64.2	65.4	67.7	69.9	70.9	71.6	70.7	70.8	68.1	65.1	67.7
Difference	-0.5	0.3	-1.2	-1.5	-0.1	0.7	0.6	0.7	0.2	.40	-0.3	-0.9	0.1
Max. temp (°F)													
1971-2000 normal	78.6	78.7	80.4	81.5	82	83.2	83.8	84.7	84.7	83.7	81.1	79.4	81.8
2009	76.7	77.7	76.8	78.1	79.3	82.9	83.0	84.0	83.3	82.5	80.1	78.3	80.2
Difference	-1.9	-1.0	-3.6	-3.4	-3.7	-0.3	-0.8	-0.7	-1.4	-1.2	-1.0	-1.1	-1.6
Kaloko-Honokohau	(2006-2009)				RAWS		Park: KAHO			Elev. 25 ft. (7.6 m)			
Precipitation (in)													
Long-term mean (3 years only)	0.5	1.8	1.4	0.3	1.3	1.4	2.5	0.5	2.0	2.2	0.8	3.9	18.6
2009	1.3	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9
Difference	0.8	-1.5	-1.1	-0.3	-1.3	-1.4	-2.5	-0.5	-2.0	-2.2	-0.8	-3.9	-16.7
Min. temp. (°F)													
Long-term mean	66.7	65.9	68.4	68.3	69.2	71.2	71.7	72.2	71.4	71.3	69.6	67.8	69.5
2009 means	65.0	65.7	65.6	66.7	51.9	72.6	73.6	74.2	72.7	72.8	70.1	66.2	68.1
Difference	-1.7	-0.2	-2.8	-1.6	-17.3	1.4	1.9	2.0	1.3	1.5	0.5	-1.6	-1.4
Max. temp. (°F)													
Long-term mean	82.2	81.4	82.0	82.7	82.5	84.0	85.0	85.7	84.7	85.3	84.5	83.5	83.6
2009	81.7	81.5	79.8	81.1	81.7	85.2	85.7	87.0	86.8	86.8	83.9	83.1	83.7
Difference	-0.5	0.1	-2.2	-1.5	-0.8	1.2	0.7	1.3	2.1	1.5	-0.6	-0.4	0.1
Ave. temp. (°F)													
Long-term mean	74.5	73.7	75.1	75.9	76.2	77.9	78.7	79.3	78.3	78.3	76.9	75.6	76.7
2009	73.2	73.5	72.7	74.1	71.8	79.2	79.8	80.9	80.1	80.1	76.8	74.9	76.4
Difference	-1.3	-0.2	-2.4	-1.8	-4.4	1.3	1.1	1.6	1.8	1.8	-0.1	-0.7	-0.3

Puuhonuaohonaunau 27.4 (COOP)

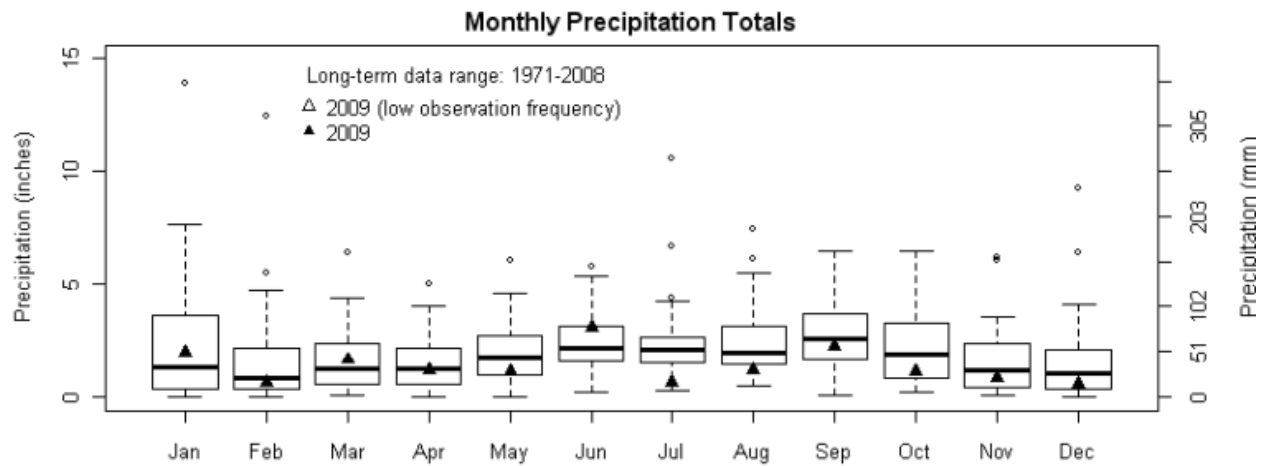


Figure 22. Boxplot of precipitation data for Puuhonuaohonaunau 27.4 (COOP) Hawaii.

Honokohau Harbor 68.14 (COOP)

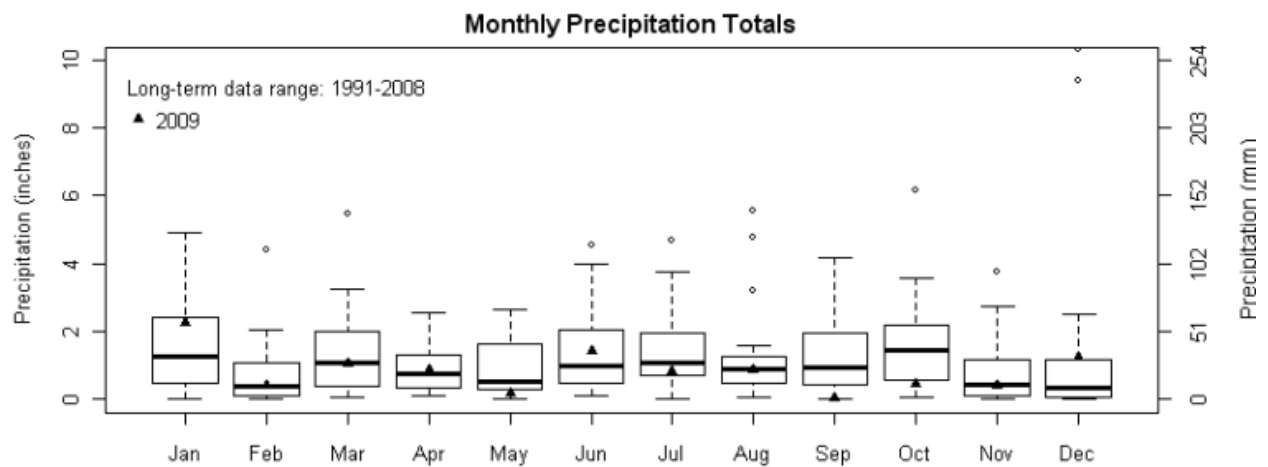


Figure 103. Boxplot of precipitation data for Honokohau Harbor 68.14 (COOP), Hawaii.

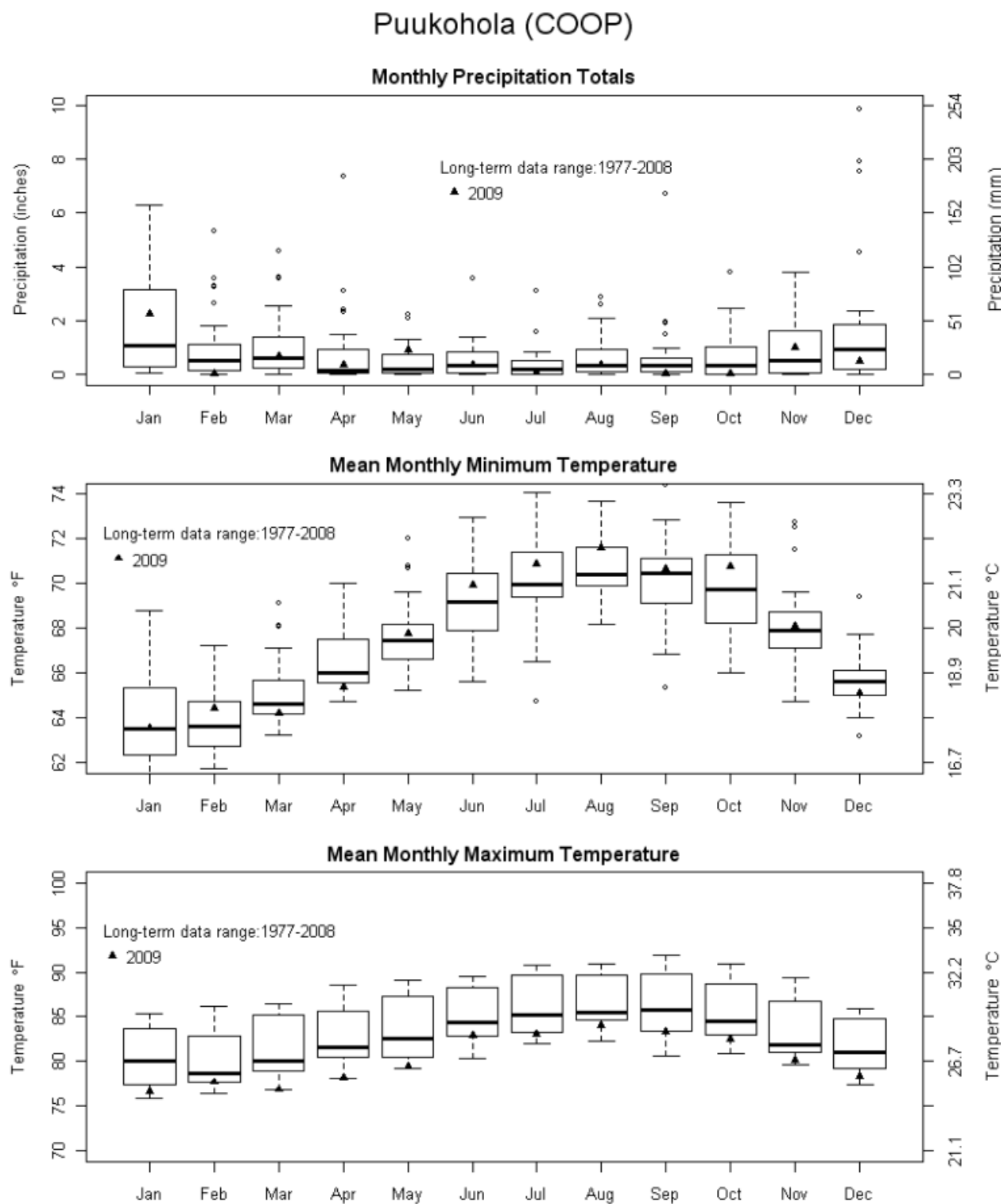


Figure 24. Boxplots of precipitation and temperature data for Puukohola Heiau 98.1 (COOP), Hawaii.

Kaloko-Honokohau Hawaii

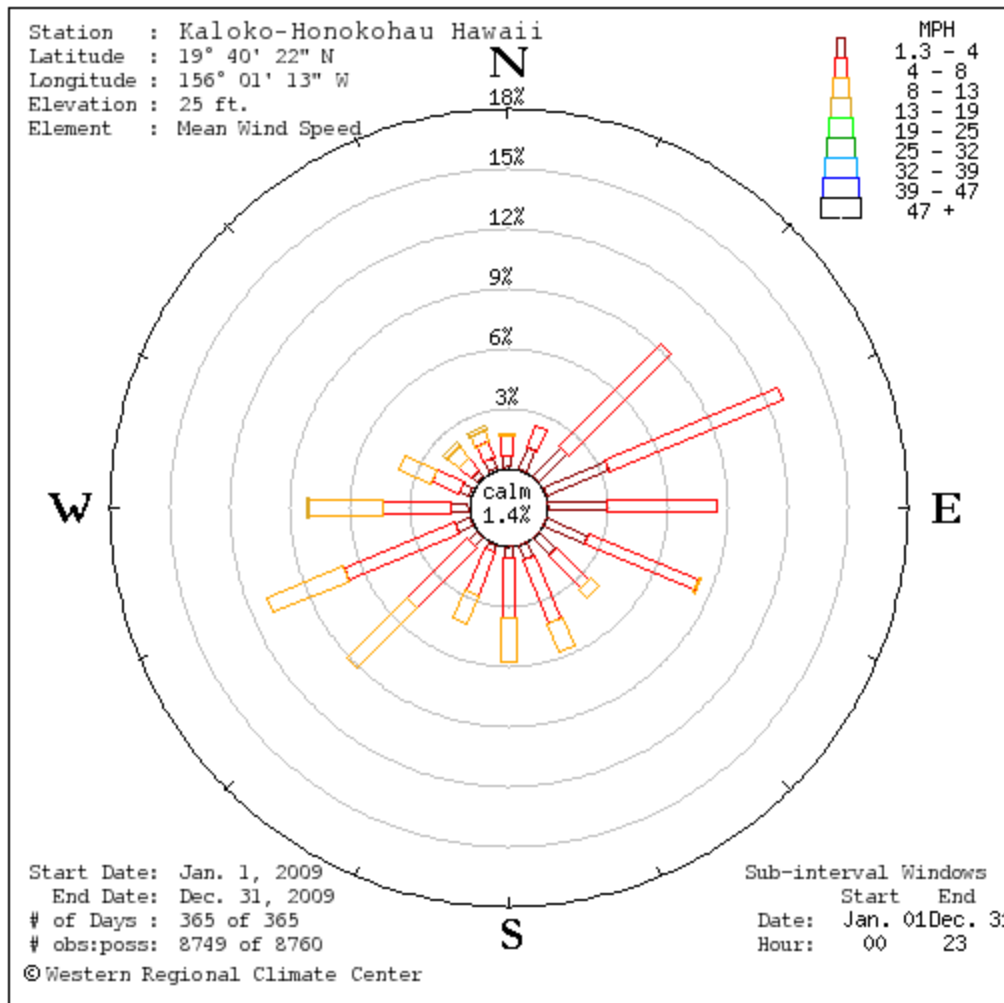


Figure 115. Wind Rose Graph of 2009 data for Kaloko-Honokohau (RAWS), Hawaii.

Kalaupapa National Historical Park

Table 6 and Figures 26-28 present precipitation, temperature, and relative humidity data for a COOP station and a RAWS located on the Kalaupapa peninsula. The Kalaupapa COOP station currently only collects precipitation data, but through the long station record there have been intermittent years during which temperature data were also recorded. These data can be made available, but they are not presented in this report. The Kalaupapa COOP station had low observation frequencies (<85%) for all but one month in 2009. Data flags indicated that subsequent days reported accumulated data. To provide at least some information about rainfall in this area, data for all months are shown in Figure 3. However, since the accuracy of these data is questionable (evaporation is likely whenever data are not collected for several days), they are not included in the numerical comparison table. Wind graphics (Figure 29, Appendix A) illustrate the often intense wind conditions on the peninsula. In January and February winds came out of the north or northeast, but during the rest of the year the predominant wind direction was directly from the east.

Table 6. Comparison of precipitation and temperature data from 2009 with long-term records for stations at Kalaupapa National Historical Park, Molokai, Hawaii. For the COOP station 2009 data for all months had low observation frequencies (<85%) thus only 1971-2000 normals are presented. For the RAWS comparisons are made and with long-term means (period of record indicated, not including the last year).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
	Kalaupapa 563 (1949-2008)					COOP	Park: KALA			Elev. 30 ft. (9.1 m)			
Precipitation (in)													
1971-2000 normal	5.53	4.24	5.10	4.74	2.96	1.47	2.20	2.11	1.54	3.00	4.60	5.89	43.38
2009 (based on cumulative data)	7.3	4.2	3.9	4	2.2	0.3	1.4	2.8	1.4	2.4	5.6	3	38.3
	Makapulapai (1994-2008)					RAWS	Park: KALA			Elev. 75 ft. (22.9 m)			
Precipitation (in)													
Long-term mean	4.30	1.80	7.20	1.60	1.70	0.80	0.90	1.30	1.10	1.80	4.70	3.50	30.80
2009	NA	2.30	3.30	3.80	NA	0.30	1.30	1.20	1.00	1.60	3.20	2.70	NA
% Normal	4%	128%	46%	238%	NA	38%	144%	92%	91%	89%	68%	77%	NA
Min. temp. (°F)													
Long-term mean	67.7	67.8	68.3	69.9	71.7	73.7	74.4	74.7	73.8	73.9	71.3	69.9	71.4
2009 means	NA	66.1	66.0	66.2	NA	72.7	73.3	74.5	73.8	72.6	71.9	66.2	NA
Difference	NA	-1.7	-2.3	-3.7	NA	-1.0	-1.1	-0.2	0.0	-1.3	0.6	-3.7	NA
Max. temp. (°F)													
Long-term mean	79.2	78.2	78.7	79.5	82.2	84.0	84.8	85.6	84.5	84.0	81.2	80.7	81.8
2009	NA	75.6	75.4	76.8	NA	83.7	84.3	85.0	85.5	85.3	81.2	80.7	NA
Difference	NA	-2.6	-3.3	-2.7	NA	-0.3	-0.5	-0.6	0.9	1.3	0.0	0.0	NA
Ave. temp. (°F)													
Long-term mean	73.0	72.7	73.2	74.3	76.6	78.4	79.0	79.6	78.7	78.4	75.8	74.5	76.2
2009	NA	70.4	70.2	71.0	NA	77.7	78.2	79.1	79.2	78.7	76.0	73.1	NA
Difference	NA	-2.3	-3.0	-3.3	NA	-0.7	-0.8	-0.5	0.5	0.3	0.2	-1.4	NA

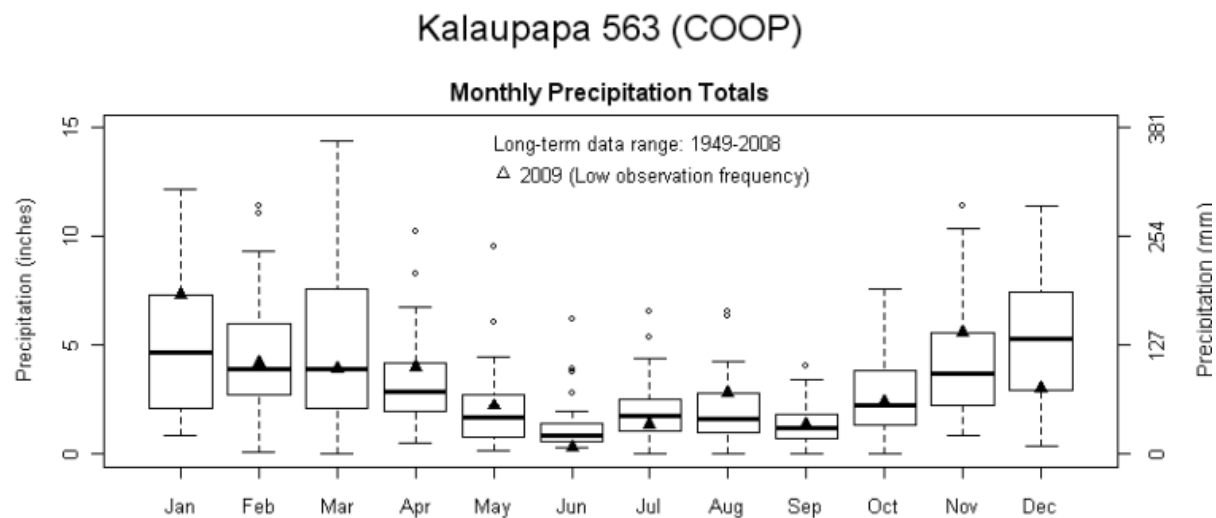


Figure 126. Boxplots of precipitation data for Kalaupapa 563 (COOP), Molokai, Hawaii. All months in 2009 had low observation frequencies

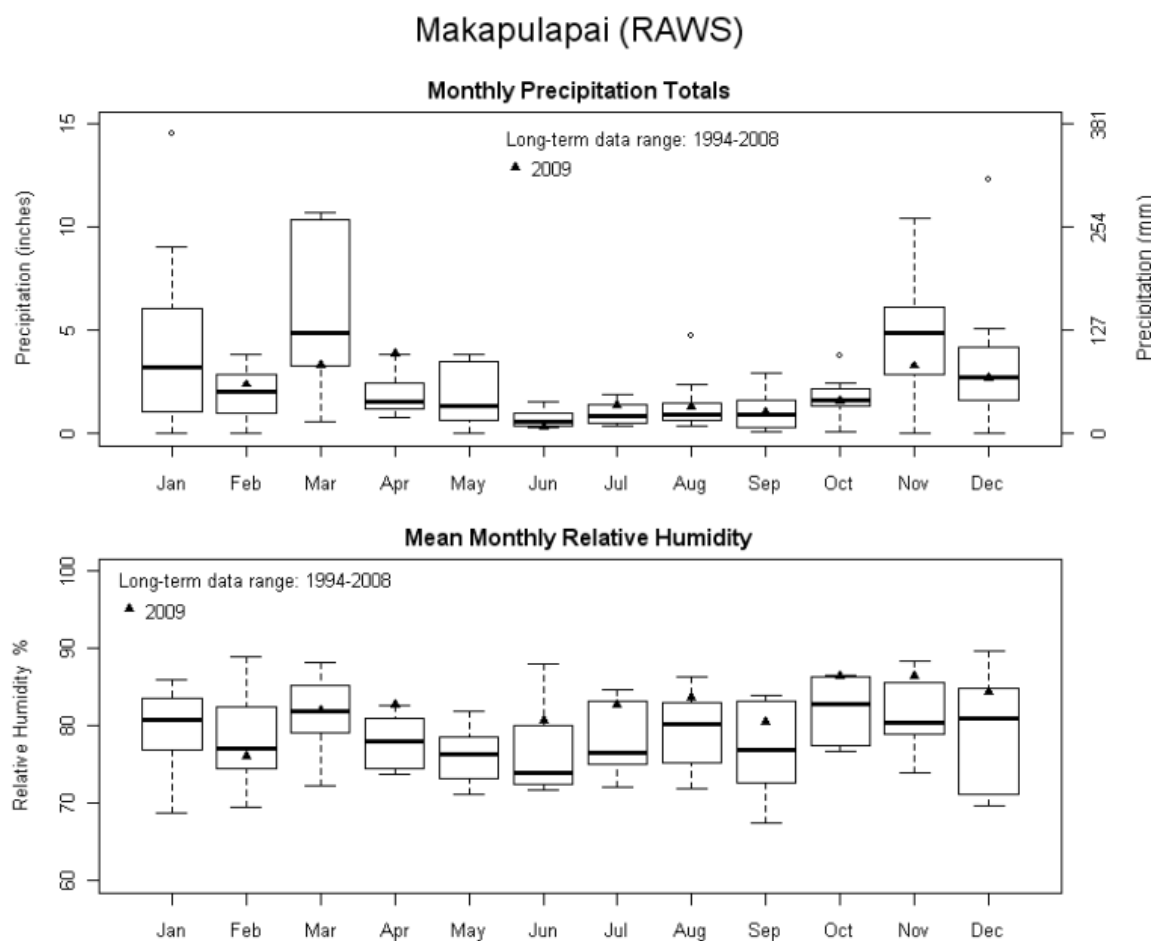


Figure 27. Boxplots of precipitation and relative humidity data for Makapulapai (RAWS), Molokai, Hawaii.

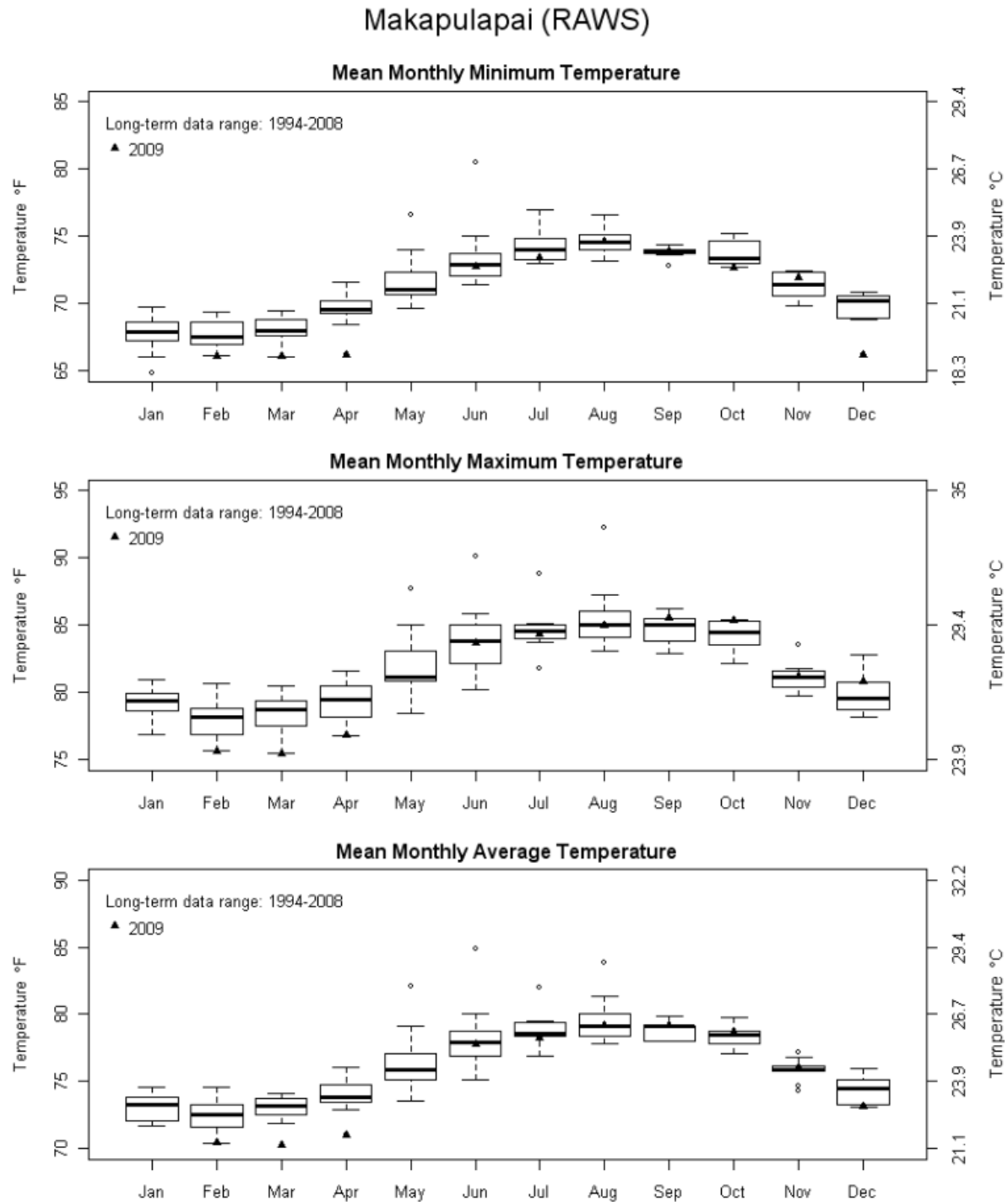


Figure 28. Boxplots of temperature data for Makapulapai (RAWS), Molokai, Hawaii. Missing symbols for any month in 2009 indicate missing data.

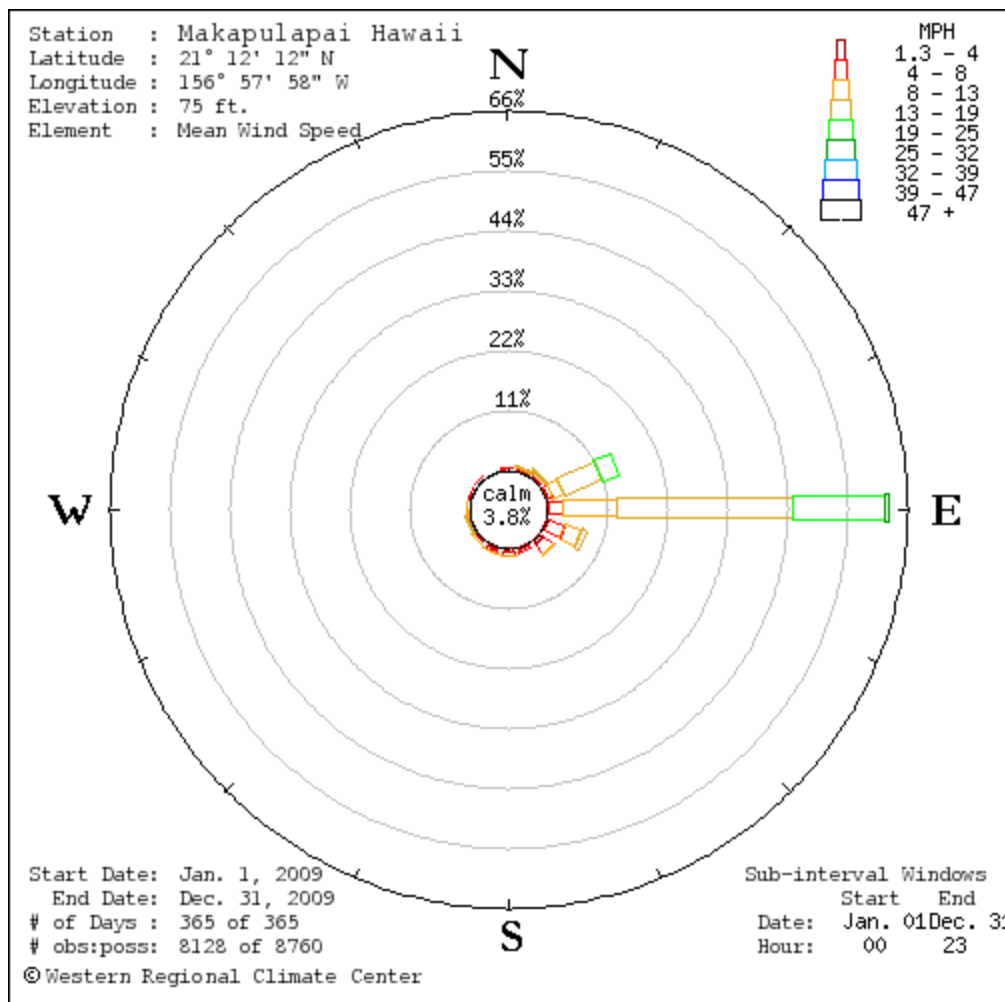


Figure 29. Wind Rose Graph of 2009 data for Makapulapai (RAWS), Molokai, Hawaii.

Haleakalā National Park (HALE)

Table 7 and Figures 30-33 present precipitation, temperature, and relative humidity data for two COOP stations and one RAWS at HALE. As indicated by the low rainfall recorded at the Haleakala RS COOP station the January rainstorm did not affect the Haleakalā summit area, however both the Kaupo Gap and the Oheo areas received deluges. Summer rains varied with above normal precipitation received in June and August at Kaupo Gap, whereas both the summit and Oheo had above normal precipitation in July and November. As on the other islands, temperature anomalies were negative for most of the year except for the spring.

Figure 34 and Appendix A illustrate the wind data for the Kaupo Gap RAWS, showing that while the trade winds have a heavy influence in this area, wind direction is variable and southerly winds are also very common. Northerly winds tend to have the highest wind speeds.

Table 7. Comparison of precipitation and temperature data from 2009 with long-term records for stations at Haleakalā National Park, Maui, Hawaii. Long-term means are based on the period of record indicated for each station, not including the last year.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
	Haleakala RS 338 (1949-2009)					COOP	Park: HALE			Elev. 6,960 ft. (2,121.4 m)			
Precipitation (in)													
1971-2000 normal	9.17	6.2	8.59	5.18	1.76	1.43	2.37	2.08	2.27	2.75	5.43	5.89	53.12
2009	5.1	2.41	3.94	1.68	0.37	0.59	3.28	5.64	0.43	0.71	8.53	1.38	34.06
% Normal	56%	39%	46%	32%	21%	41%	138%	271%	19%	26%	157%	23%	64%
Min. temp. (°F)													
1971-2000 normal	42.0	41.3	42.2	42.6	44.0	46.5	47.7	47.8	46.8	46.4	45.9	43.5	44.7
2009	37.1	33.1	33.2	33.4	44.3	39.6	49.2	49.5	46.2	48.6	46.9	41.1	41.9
Difference	-4.9	-8.2	-9.0	-9.2	.3	-6.9	1.5	1.9	-0.6	2.2	1.0	-2.4	-2.8
Max. temp. (°F)													
1971-2000 normal	60.0	59.1	59.7	60.1	62.3	65.1	65.5	66.1	64.8	64.4	63.2	61.2	62.6
2009	51.8	47.4	45	47.6	60.2	53.7	65.8	66	62.8	64.1	62.3	57.8	57.1
Difference	-8.2	11.7	-14.7	-12.5	-2.1	-11.4	0.3	0.1	-2.0	-0.3	-0.9	-3.4	-5.5
	Oheo (1998-2009 (T))					COOP	Park: HALE			Elev. 120 ft. (36.6 m)			
Precipitation (in)													
1971-2000 normal	7.9	5.9	8.5	6.6	5.3	5.6	7.2	6.8	7.1	8.3	8.3	7.9	85.4
2009	4.6	3.7	9.5	3.7	0.5	5.2	8.6	5.2	4.9	5.6	16.2	3.9	71.8
Difference	-3.3	-2.2	1	-2.9	-4.8	-0.4	1.4	-1.6	-2.2	-2.7	7.9	-4	-13.6
Min. temp. (°F)													
Long-term mean	67.3	67.1	67.7	67.9	69.4	70.6	71.5	72.2	71.9	71.5	70.2	69	69.7
2009	51.6	23.1	59.5	57.2	65.5	61.1	60.2	61.4	62.8	63.7	65.8	51.2	56.9
Difference	15.7	-44	-8.2	-10.7	-3.9	-9.5	-11.3	-10.8	-9.1	-7.8	-4.4	17.8	-12.8
Max. temp. (°F)													
Long-term mean	78.4	77.9	78.5	78.6	80.4	81.1	81.8	82.5	82.5	82.3	80.9	79.4	80.4
2009	62.5	29.5	71.5	65.9	76.8	71.9	68.9	69.9	72	73.2	77.8	65.1	67.1
Difference	15.9	48.4	-7	-12.7	-3.6	-9.2	-12.9	-12.6	10.5	-9.1	-3.1	14.3	-13.3

Table 7. Comparison of precipitation and temperature data from 2009 with long-term records for stations at Haleakalā National Park, Maui, Hawaii. Long-term means are based on the period of record indicated for each station, not including the last year (continued).

Kaupo Gap (1991-2009)					RAWS		Park: HALE			Elev. 4,030 ft. (1,228.3 m)			
Precipitation (in)													
1971-2000 normal	12.18	5.68	12.14	4.22	1.91	1.24	0.98	2.32	3.13	5.08	5.29	4.14	58.31
2009	13.80	7.70	11.10	1.40	1.20	1.40	0.30	6.70	0.70	6.00	NA	NA	NA
% Normal	119%	122%	99%	37%	63%	108%	30%	305%	23%	125%	NA	NA	NA
Min. temp. (°F)													
Long-term mean	53.8	52.4	54.1	54.6	55.5	57.4	59.1	59.4	59.1	58.6	57.8	55.1	56.40
2009means	51.3	49.8	52.3	52.6	53.9	56.8	58.7	57.7	59.0	58.5	NA	NA	NA
Difference	-2.5	-2.6	-1.8	-2.0	-1.6	-0.6	-0.4	-1.7	-0.1	-0.1	NA	NA	NA
Max. temp. (°F)													
Long-term mean	67.6	67.3	68.2	69.8	71.6	73.7	75.9	76.4	75.1	73.9	71.8	68.8	71.7
2009	66.1	65.5	65.4	66.5	69.2	73.4	76.2	76.8	76.6	74.9	NA	NA	NA
Difference	-1.5	-1.8	-2.8	-3.2	-2.3	-0.3	0.3	0.4	1.5	1.0	NA	NA	NA
Ave. temp. (°F)													
Long-term mean	59.7	58.9	60.1	61.2	62.8	64.7	66.7	66.9	65.8	65.0	63.7	60.8	63.0
2009	57.7	56.5	57.6	58.5	61.0	64.3	66.4	66.6	66.7	65.6	NA	NA	NA
Difference	-2.0	-2.4	-2.5	-2.7	-1.8	-0.4	-0.3	-0.3	-0.9	-0.6	NA	NA	NA

Haleakala RS 338 (COOP)

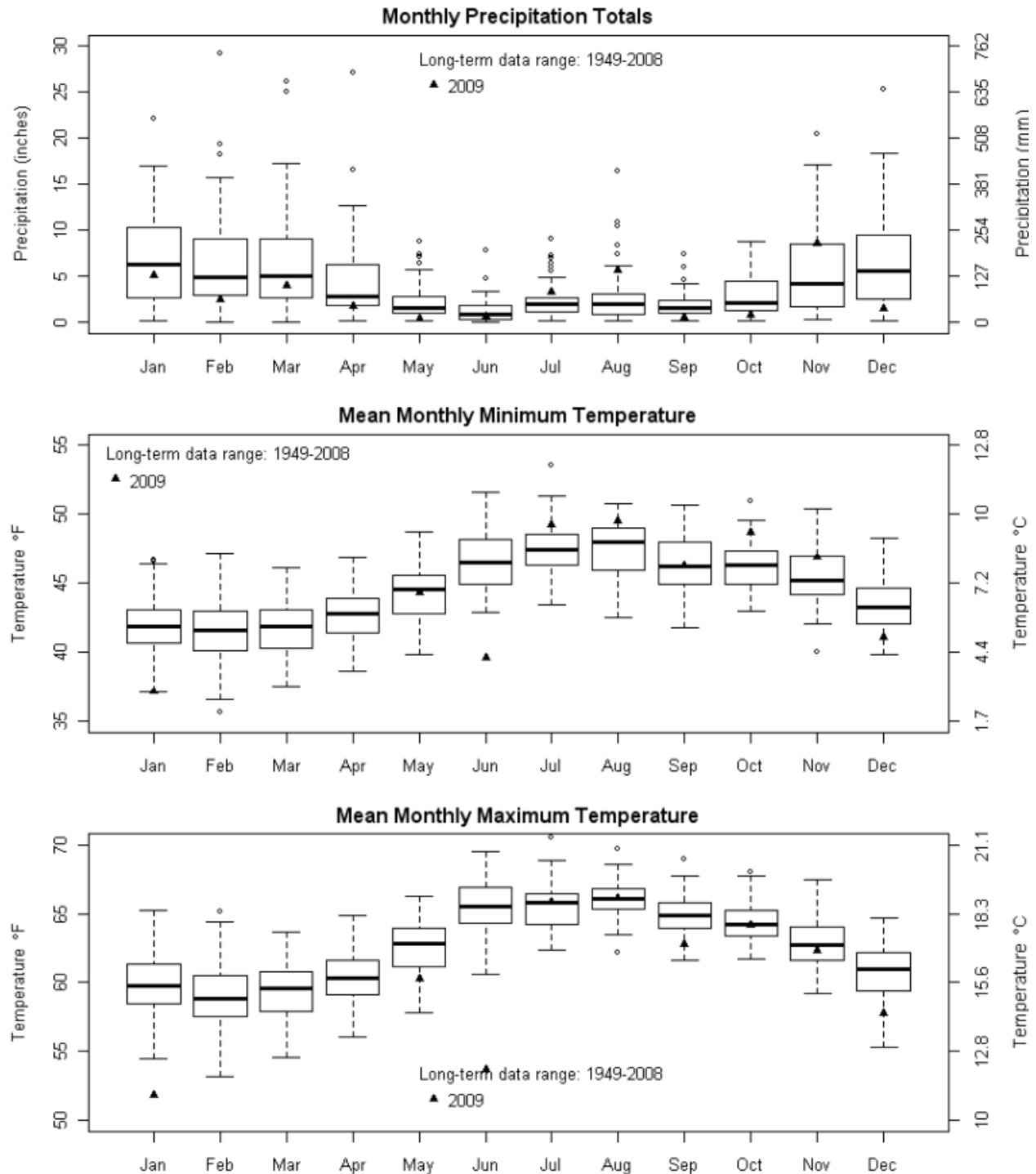


Figure 30. Boxplots of precipitation and temperature data for Haleakala RS (COOP), Maui, Hawaii.

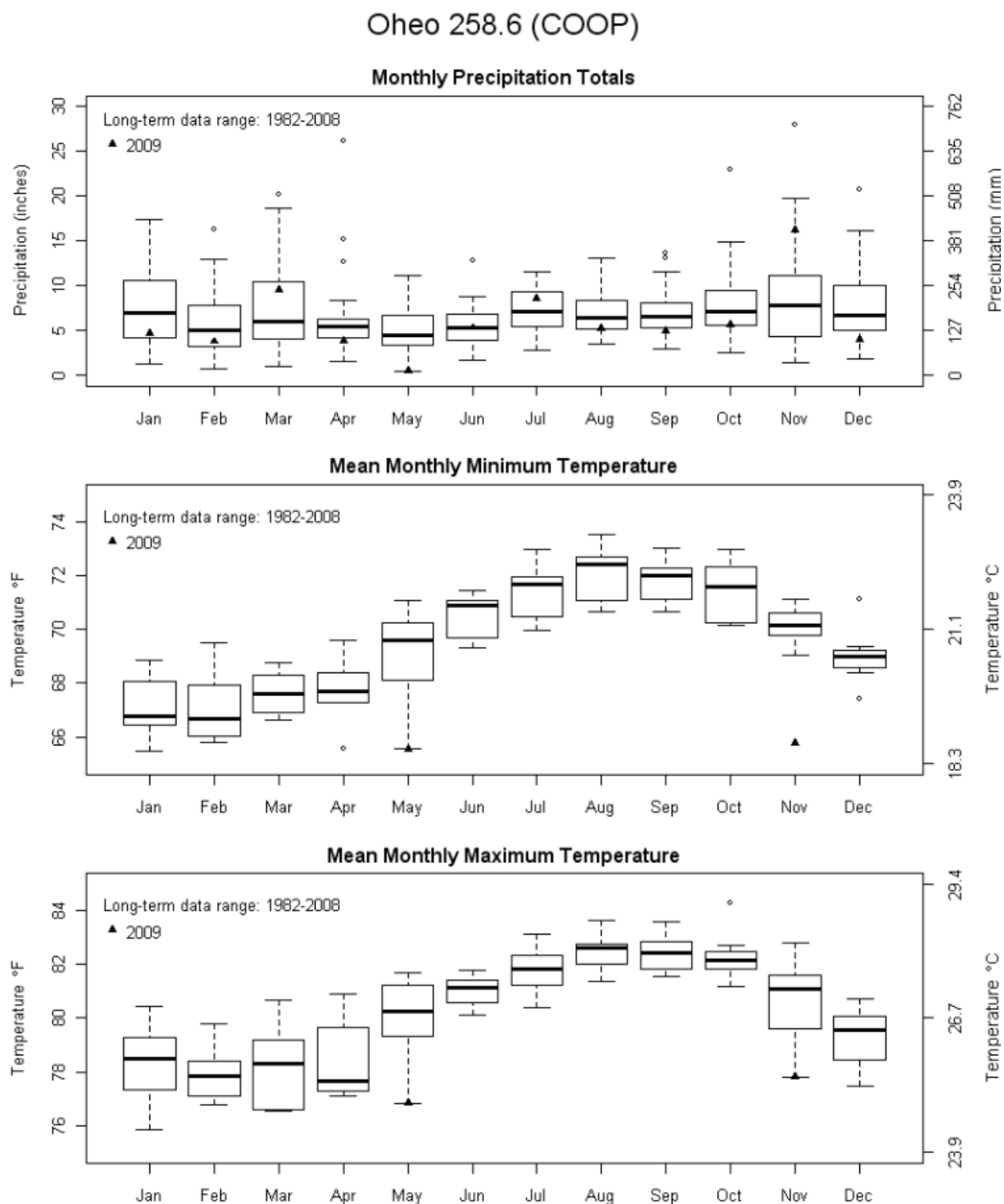


Figure 31. Boxplots of precipitation and temperature data for Oheo 258.6 (COOP), Maui, Hawaii.

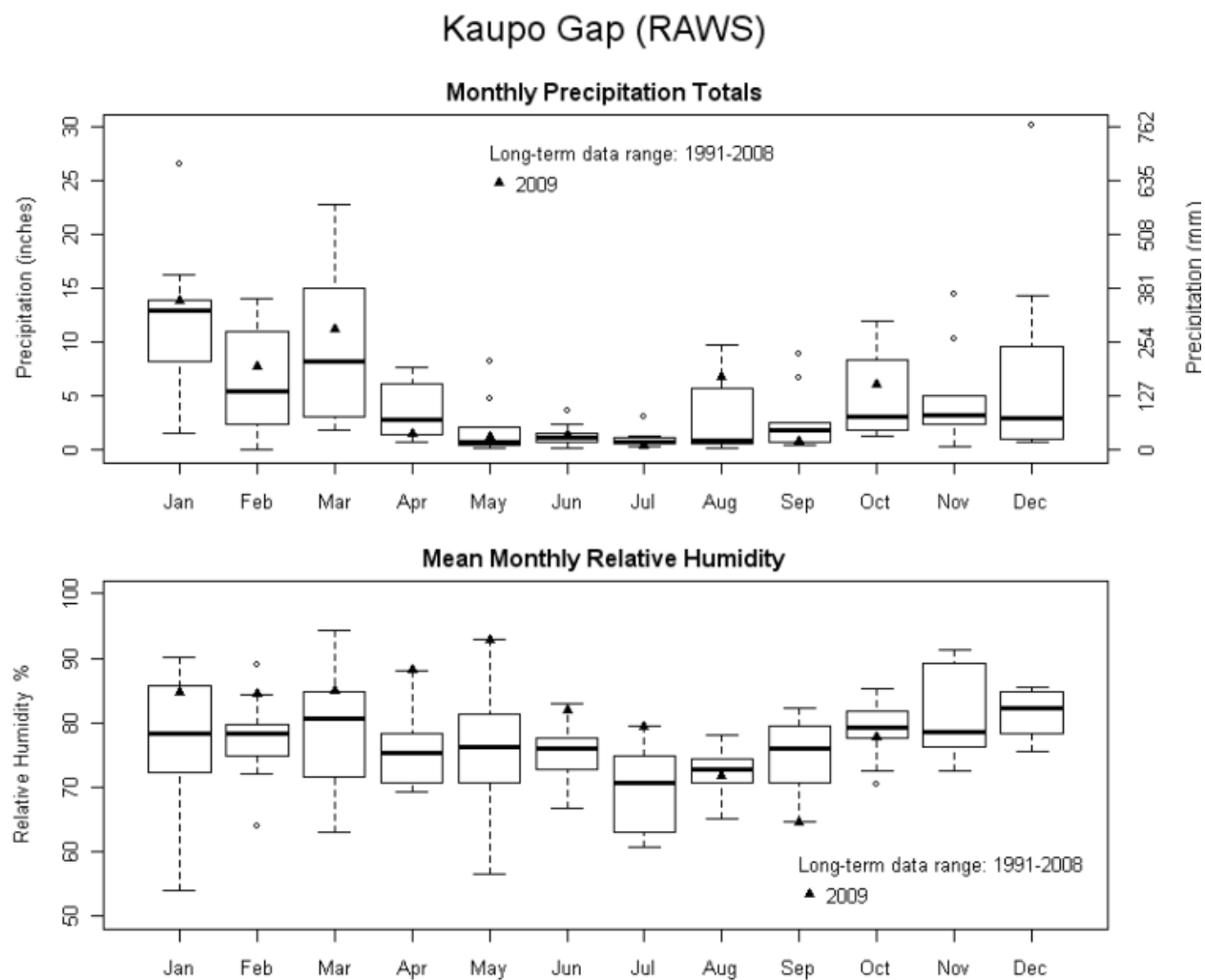


Figure 32. Boxplots of precipitation and relative humidity data for Kaupo Gap (RAWS), Haleakala, Maui.

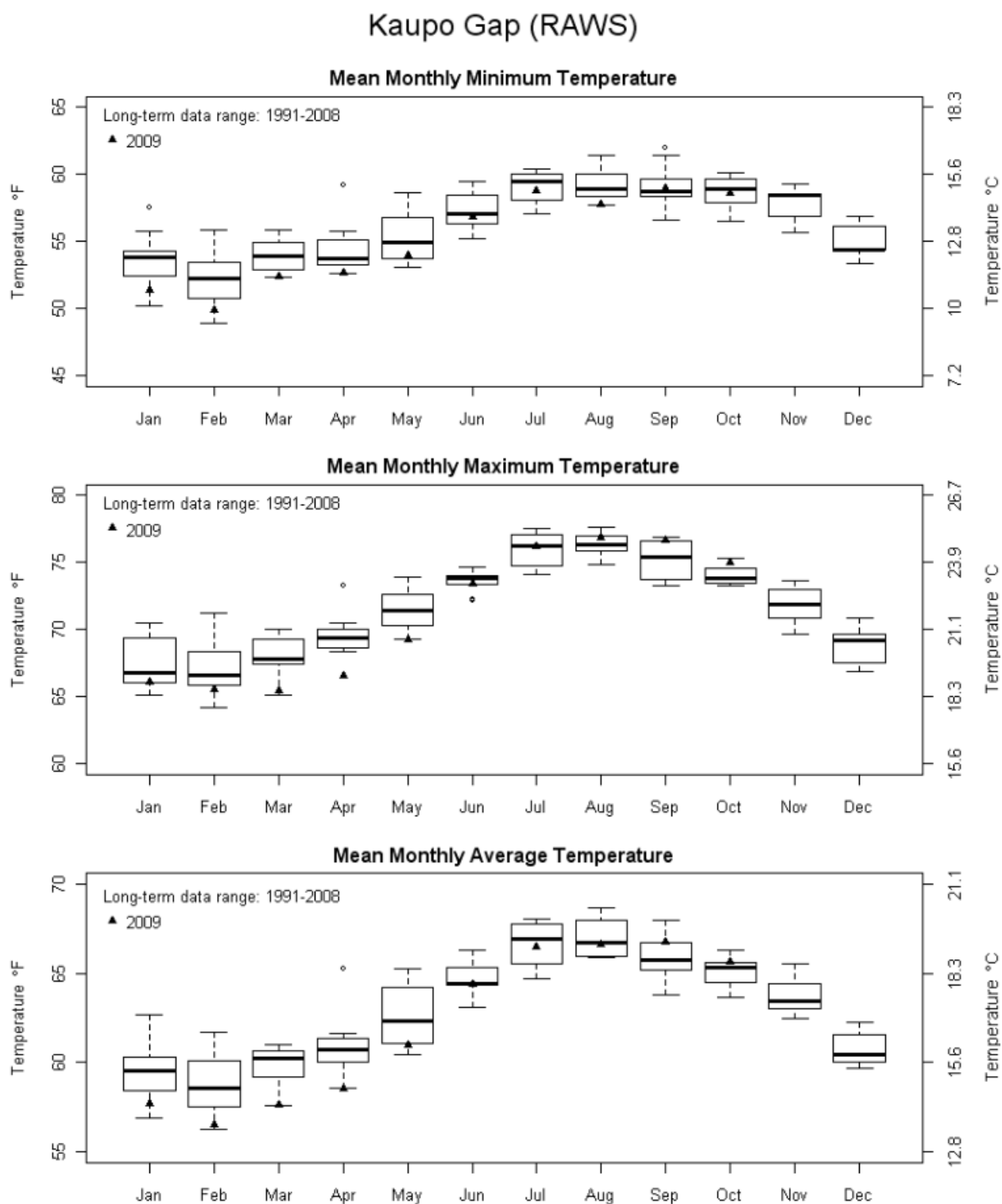


Figure 33. Boxplots of temperature data for Kaupo Gap (RAWS), Haleakala, Maui, Hawaii.

Kaupo Gap Hawaii

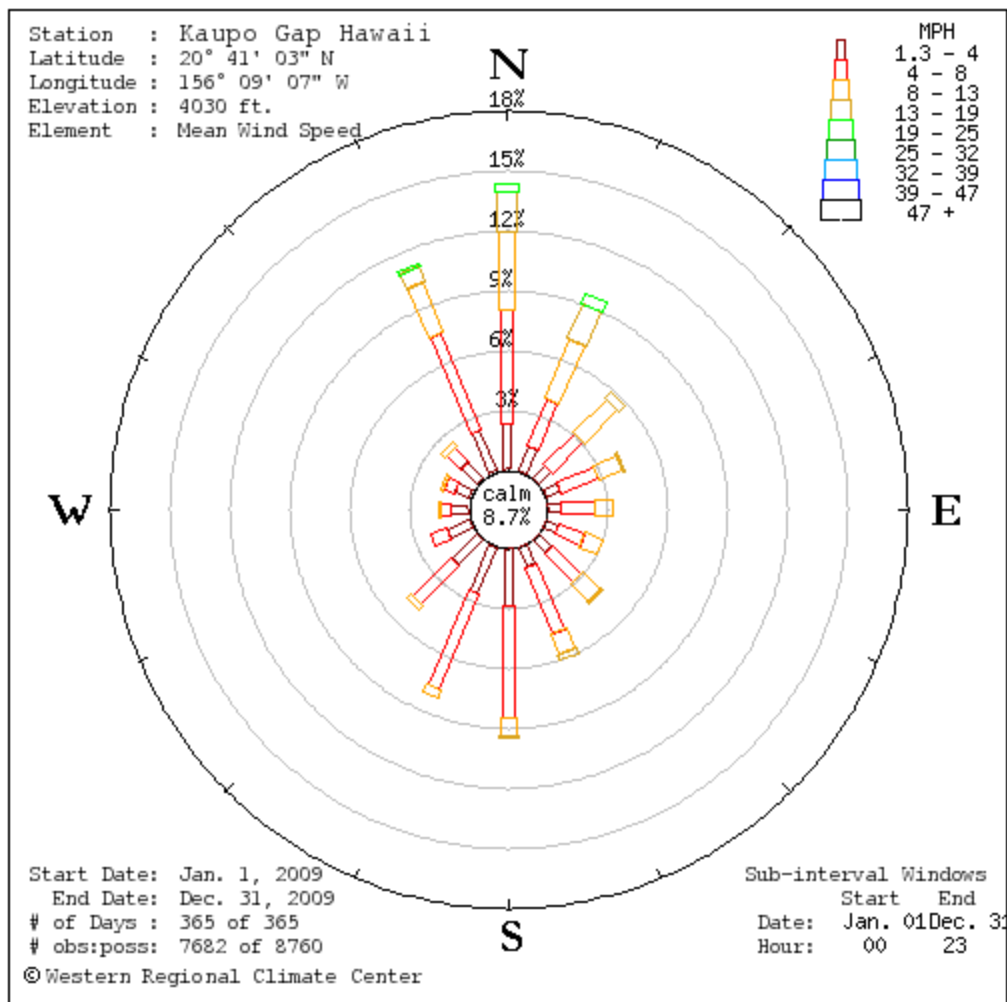


Figure 34. Wind Rose Graph of 2009 data for Kaupo Gap (RAWS), Haleakala, Maui, Hawaii.

Hawai'i Drought Conditions

As part of a comprehensive drought monitoring effort between the USDA, NOAA, and the National Drought Mitigation Center, the Drought Monitor publishes weekly updates of drought conditions in graphics form for all 50 states. The Hawai'i Drought Monitor, also makes these graphics available in addition to state-specific news on drought impacts and available assistance programs. Hawai'i drought conditions are illustrated for bi-monthly time points throughout 2009 (Figures 35-37). Locations of the national parks could not be overlaid since the graphics were created using the Drought Monitor archive tool, but can be referenced using the maps in Appendix B.

The year started with extreme drought conditions in western Molokai and northwestern Hawaii in January, while moderate to extreme conditions continued over Molokai, Maui county and Hawaii Island through March. Conditions lessened by May but increased in severity again by July, and now include Kauai. September saw increased drought conditions on Oahu, and continued extreme drought on the northwest of Hawaii Island, and this increased to include the South Point area by November.

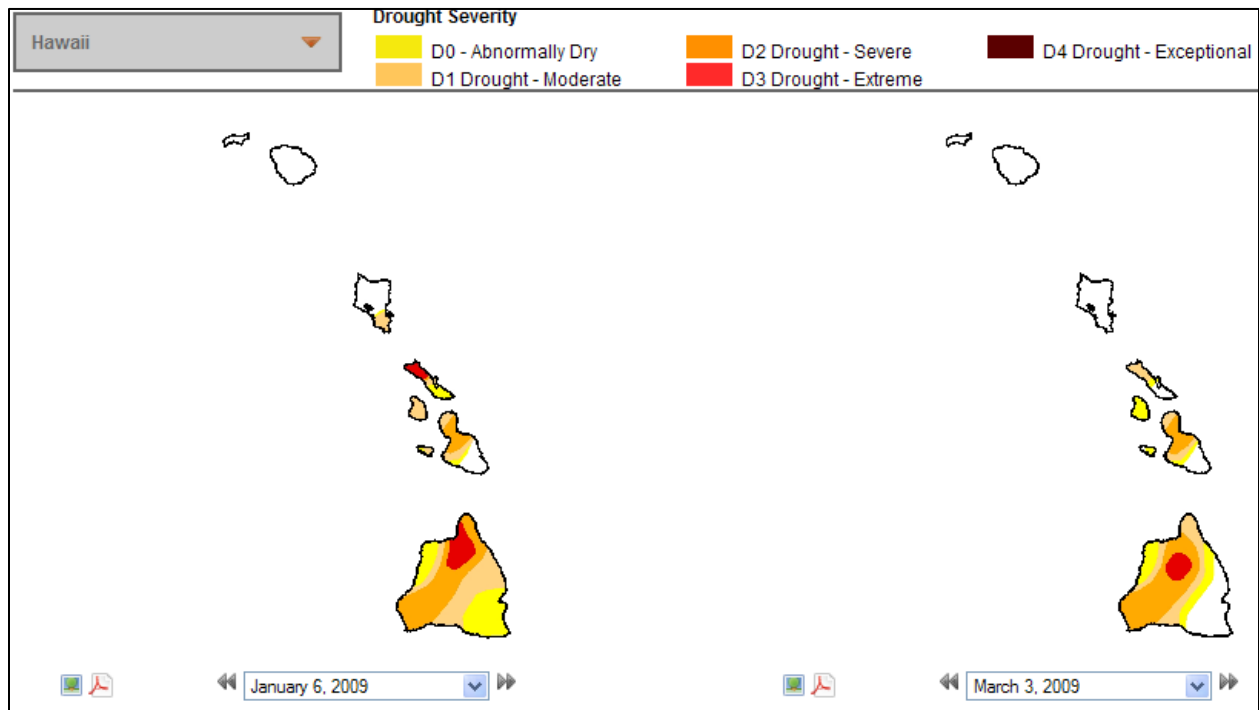


Figure 35. Drought conditions in the State of Hawaii in early January and early March 2009. Figure reproduced from the Hawaii Drought Monitor, 2009.

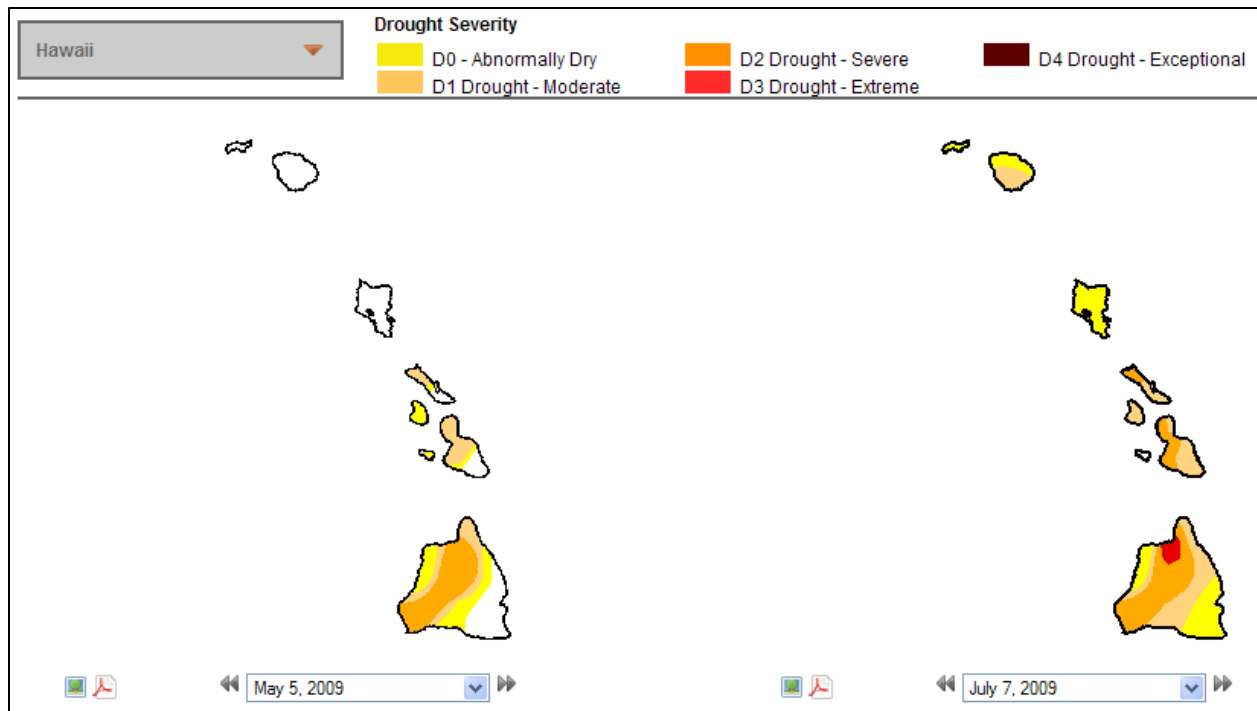


Figure 36. Drought conditions in the State of Hawaii in early May and early July 2009. Figure reproduced from the Hawaii Drought Monitor (2009).

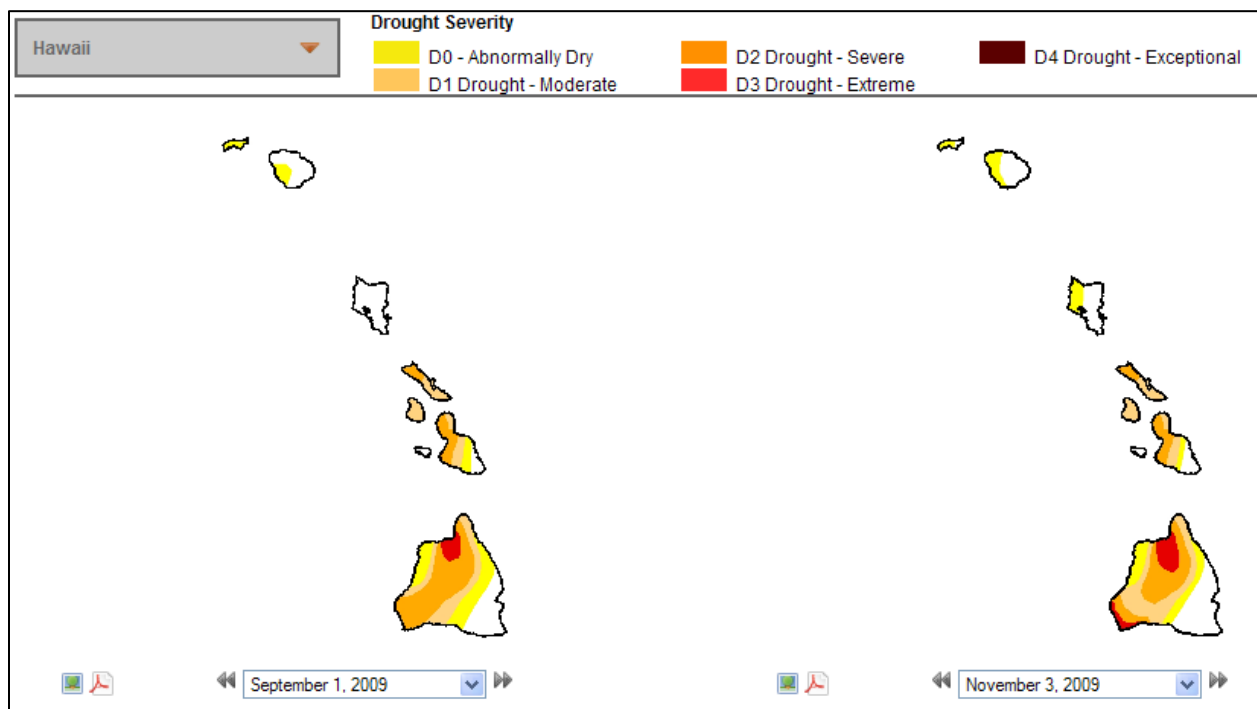


Figure 37. Drought conditions in the State of Hawaii in early September and early November 2009. Figure reproduced from Hawaii Drought Monitor (2009).

Discussion

The boxplots place the 2009 data in a useful context within the long-term station record and provide information about the range of variability as well as extremes for any given station. However, the data presented graphically and in tabular form need to be interpreted carefully given that many of the comparisons are made with long-term means (as opposed to 1971-2000 normals) and considering that the record length varies significantly between stations.

Rainfall and temperature data for the islands in the PACN show the transition from ENSO neutral conditions to the influence of the El Niño for the first half of the year. On July 9th, the ENSO Alert status system went from an El Niño “Watch” to El Niño “Advisory”. This status change came from several measurements of atmospheric and oceanographic phenomenon, 1) the warming of the surface and at depth Pacific Ocean waters, 2) a fall in sea level across most of Micronesia, (Figure 38) and 3) a lessening of the easterly flow of air mass with intermittent flow of westerly surface air masses and tropical cyclones shifted to the west.

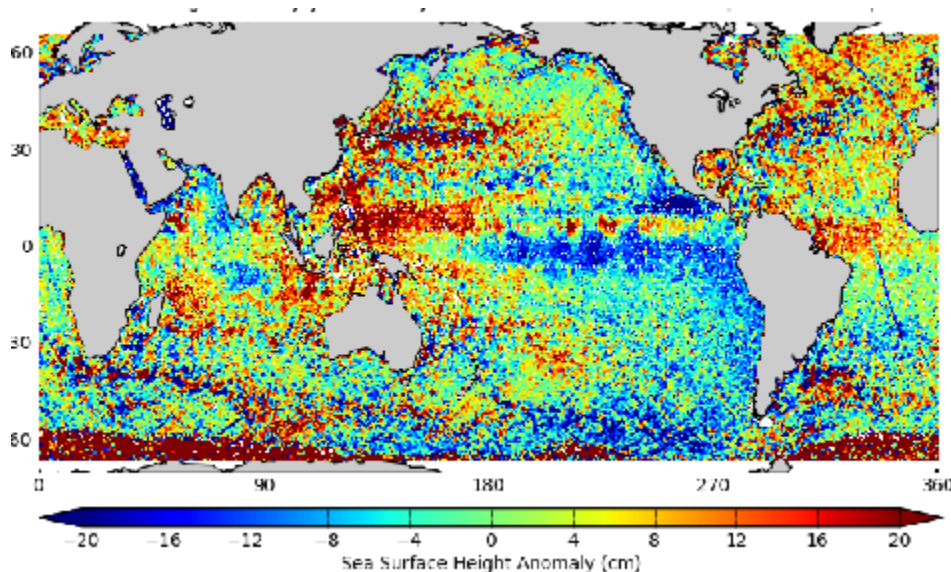


Figure 38. Sea Surface Height Anomaly (NASA, 2010)

Hawai‘i El Niño years and especially the winter months tend to be drier than normal (Ropelewski and Halpert 1989, Chu and Chen 2005). In 2009 many stations in the Hawai‘i national parks had annual rainfall totals far less than normal. Winter temperatures in Hawai‘i tend to be lower than normal during El Niño winters (Kiladis and van Loon 1988) and that was the case in 2009. El Niño and La Niña conditions are illustrated in Figure 39, where sea surface temperatures fluctuate across the Pacific. In fact, temperature anomalies in Hawai‘i were negative for most months despite the shift to ENSO neutral conditions.

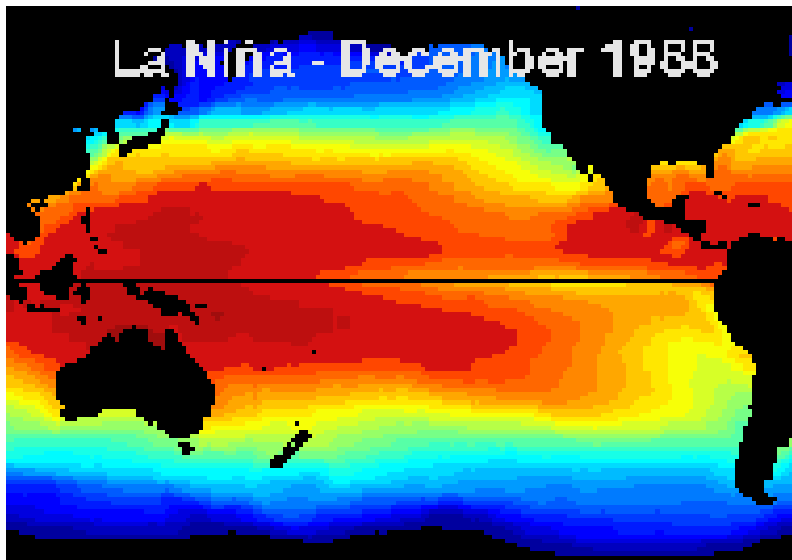
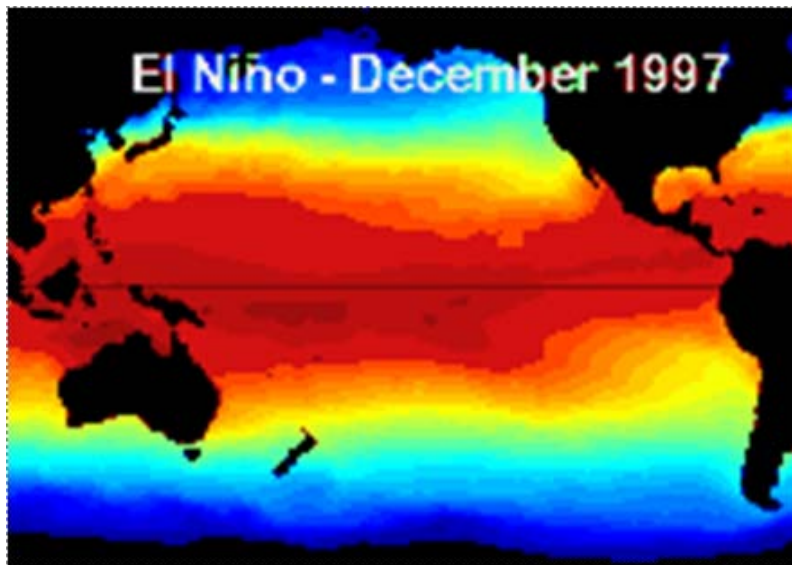


Figure 39. Sea Surface Temperatures in the Equatorial Pacific during El Niño and La Niña, (NOAA, 2011).

For Guam and Saipan and other islands in the west Pacific precipitation patterns during La Niña are less likely to follow a clear pattern compared to other areas of the Pacific, though in the majority of La Niña events winter and spring are wetter than normal (Ropelewski and Halpert 1989). Our data show a wet beginning of the year (187% in Guam, 127% in Saipan, and 184% in NPSA.) and variable precipitation in the remaining year at the COOP station near AMME with an overall total for the year near normal. PEAC (2010) reports below normal values (66-86%) for several stations on Guam in 2009.

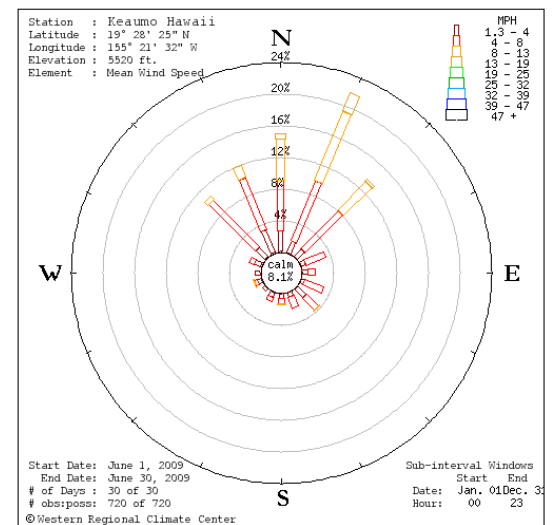
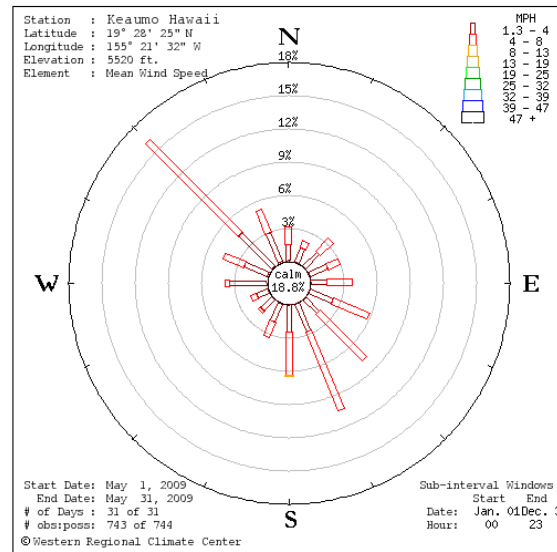
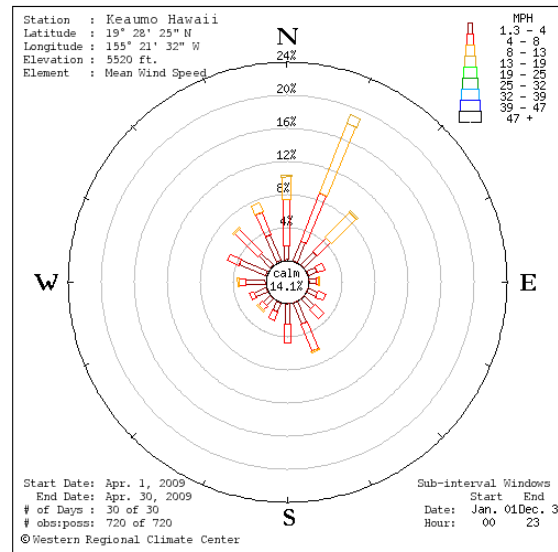
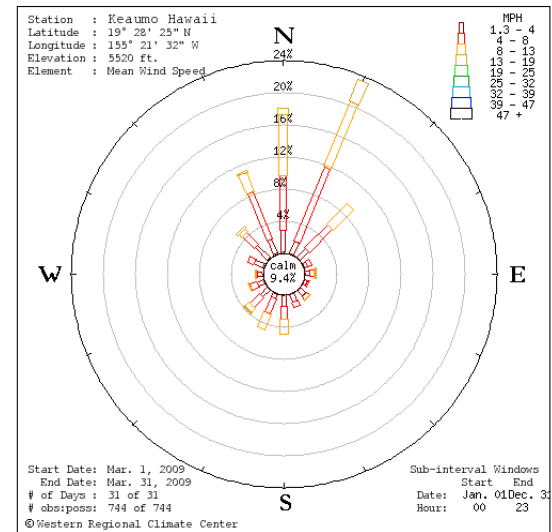
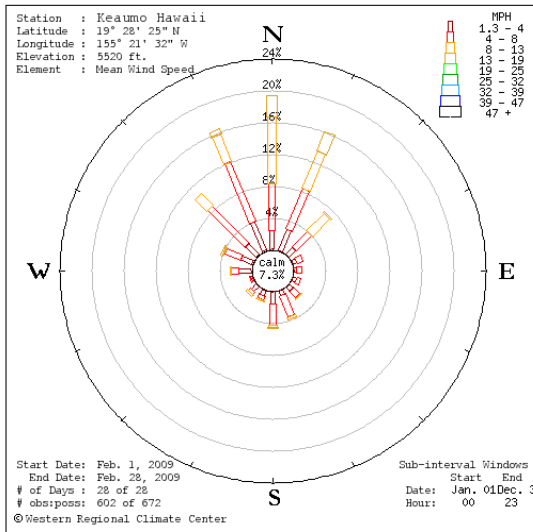
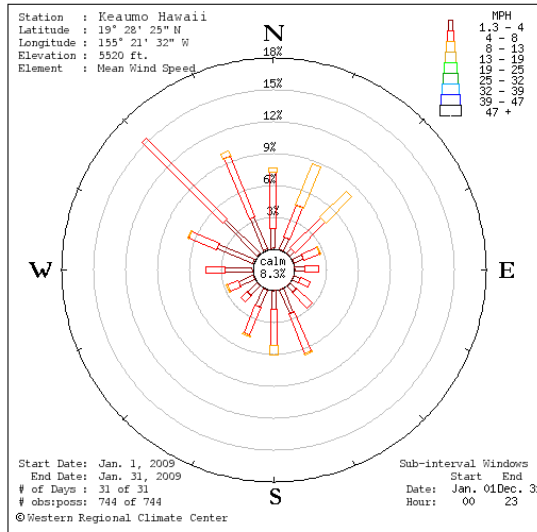
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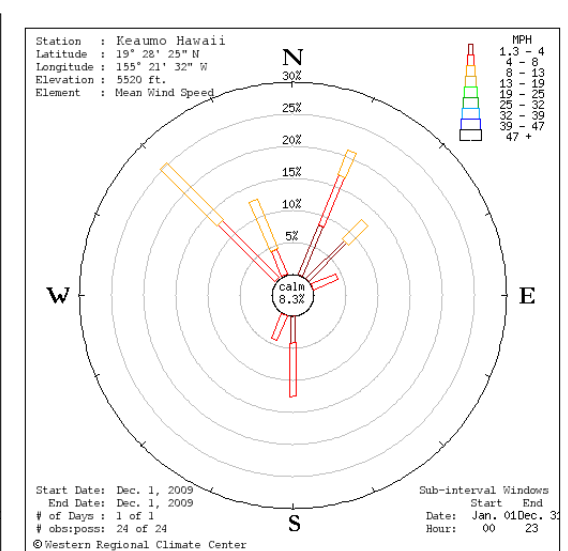
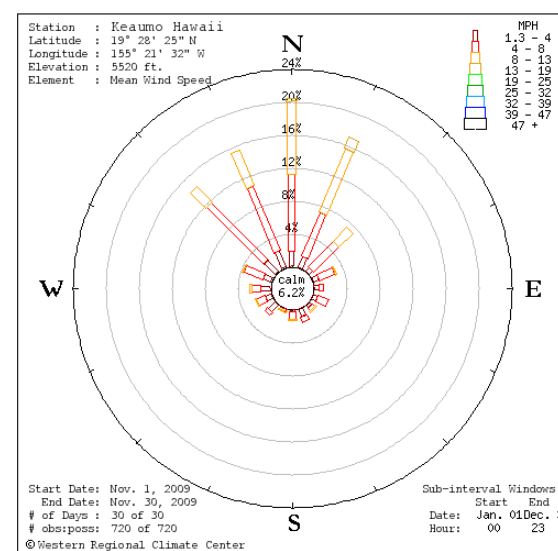
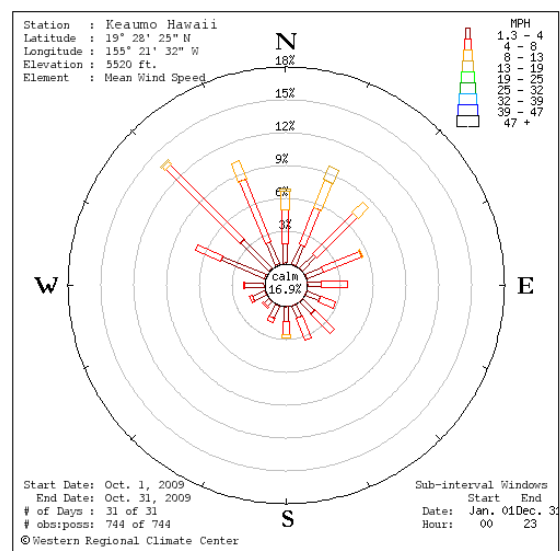
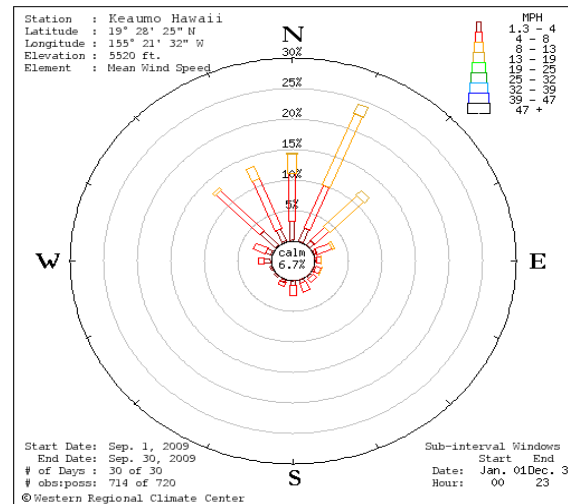
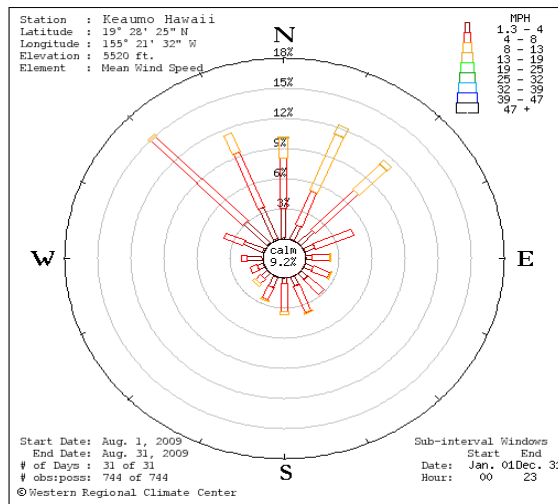
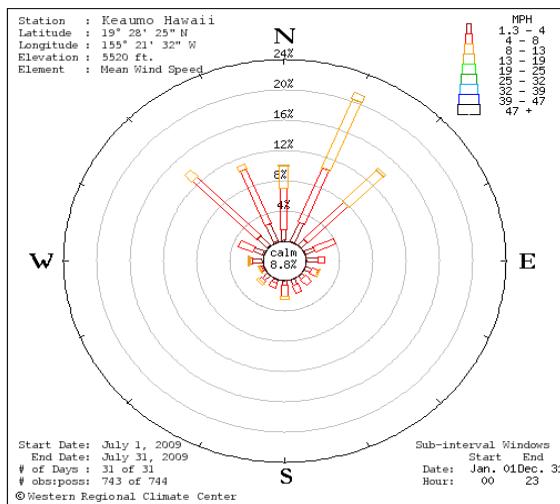
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Appendix A. Monthly Wind Data

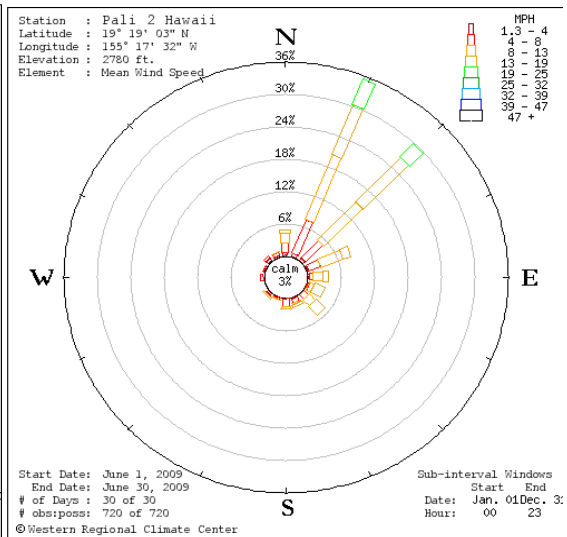
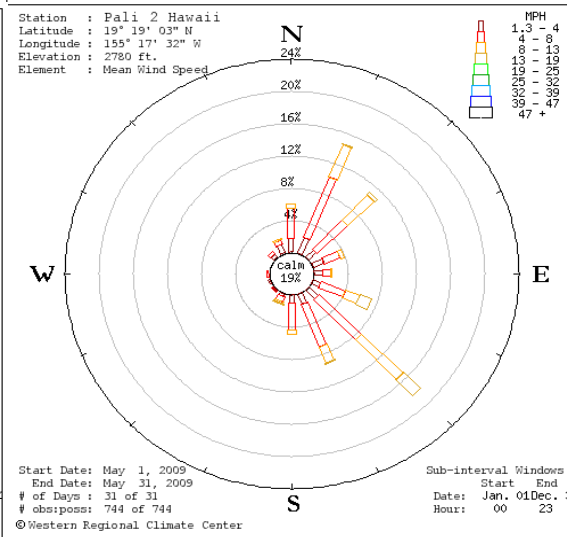
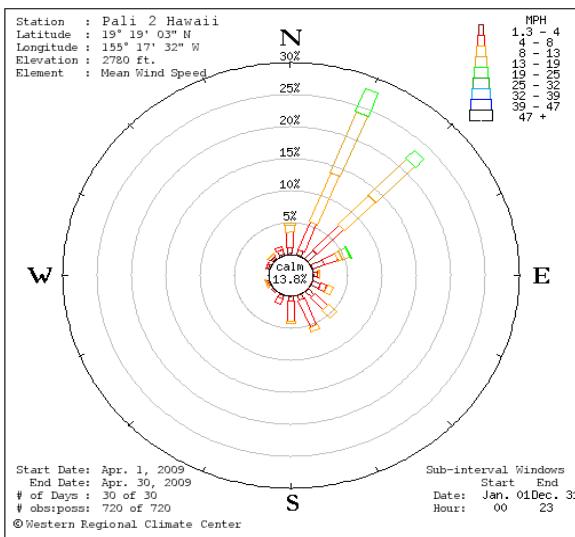
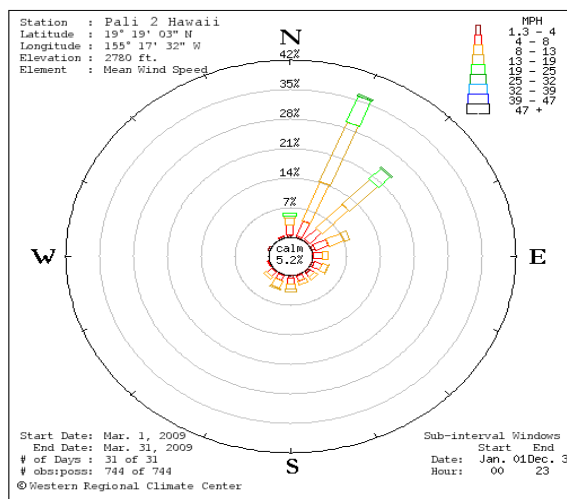
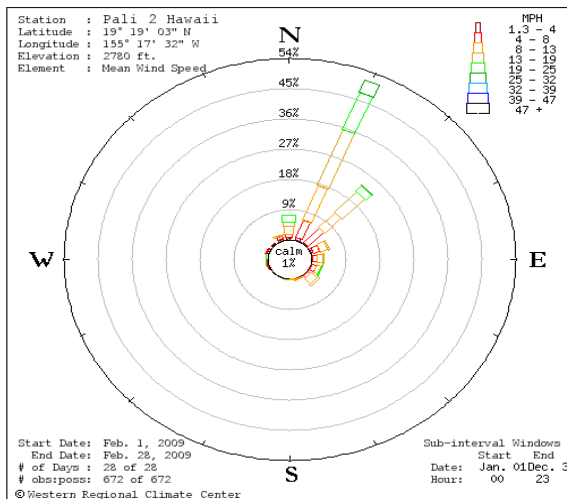
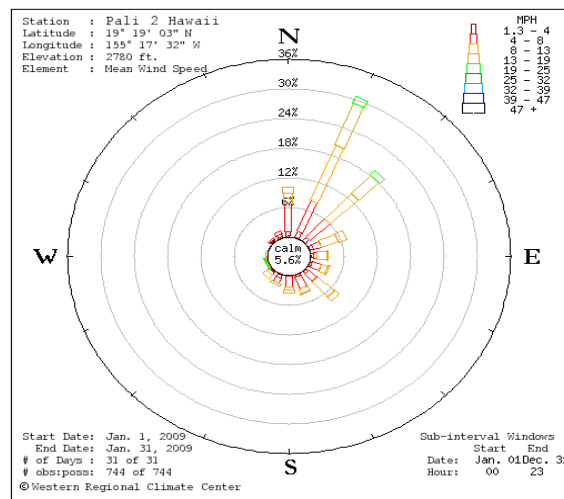
Hawai'i Volcanoes National Park, Keaumo (RAWS)



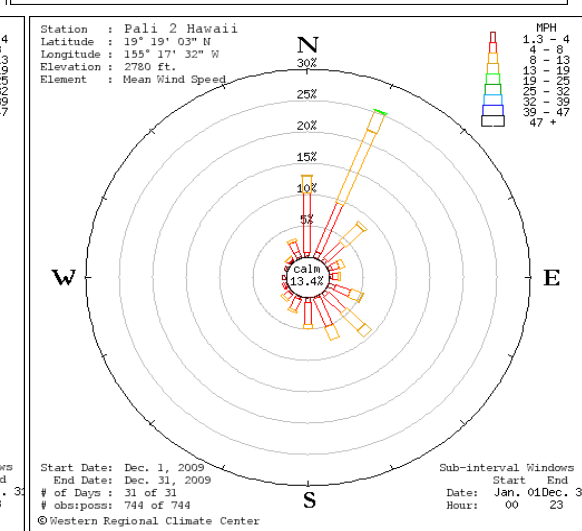
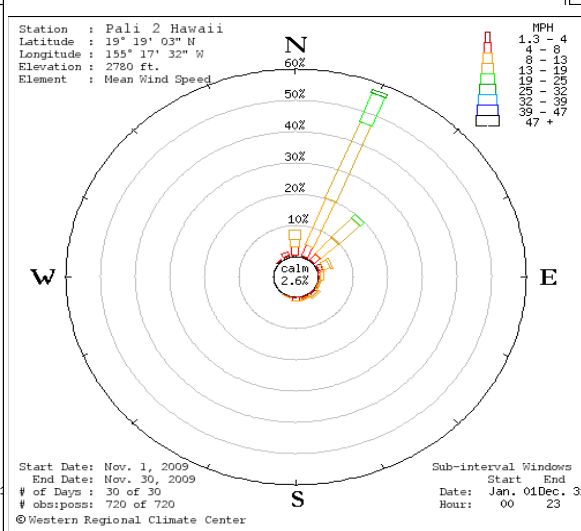
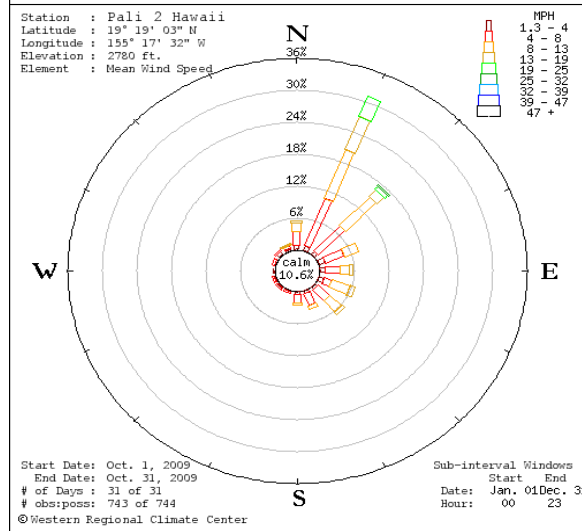
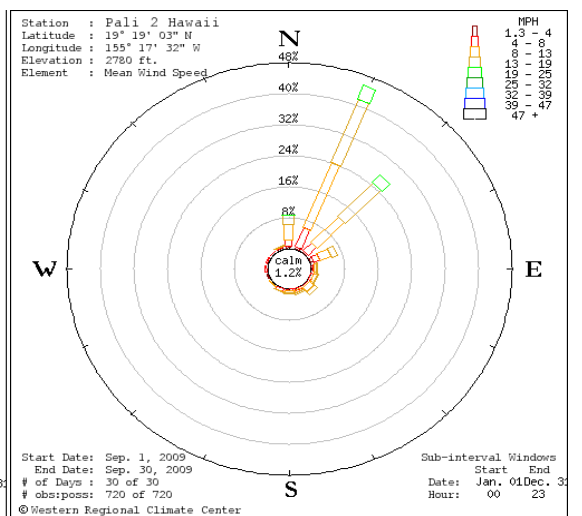
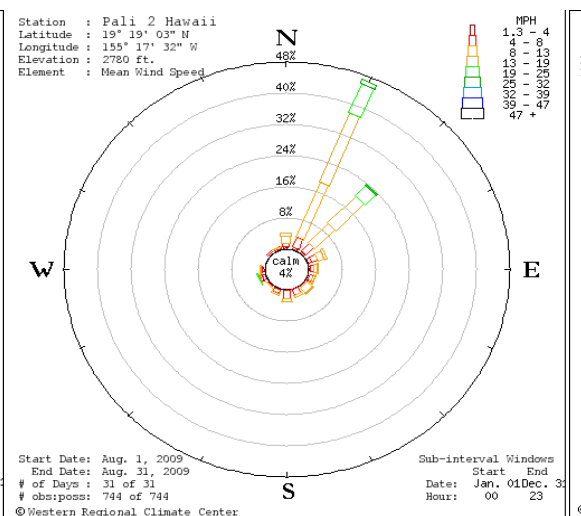
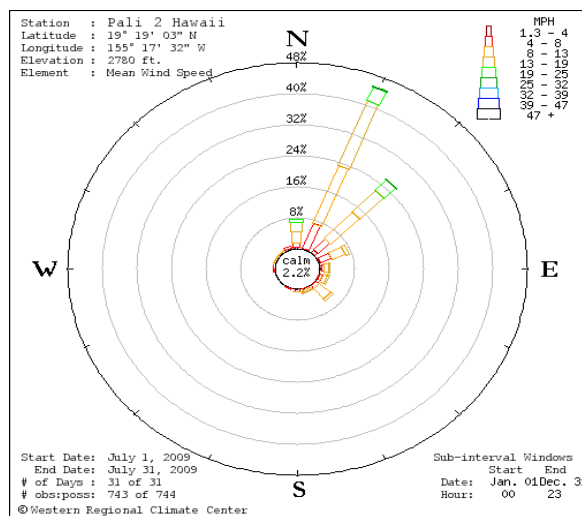
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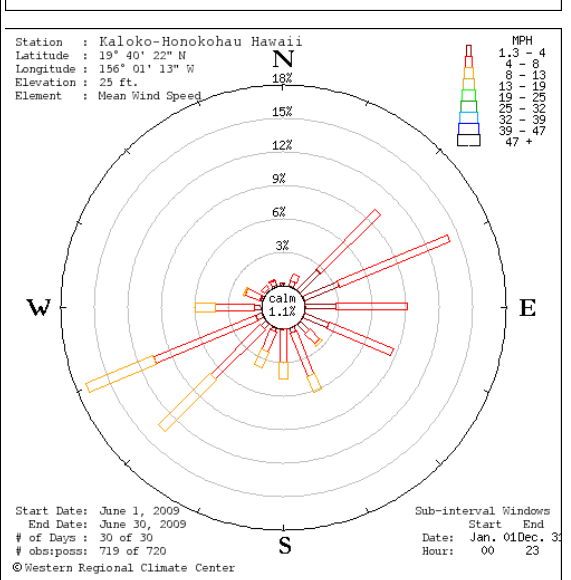
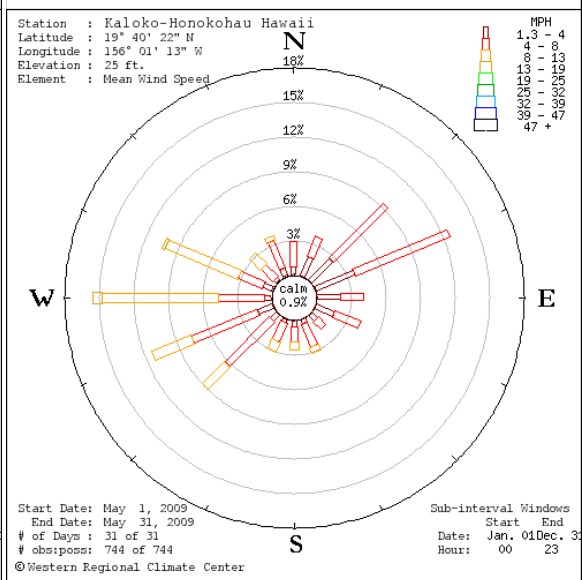
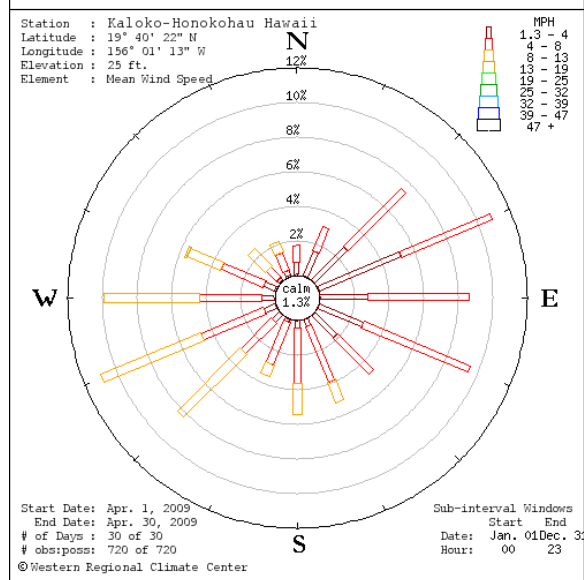
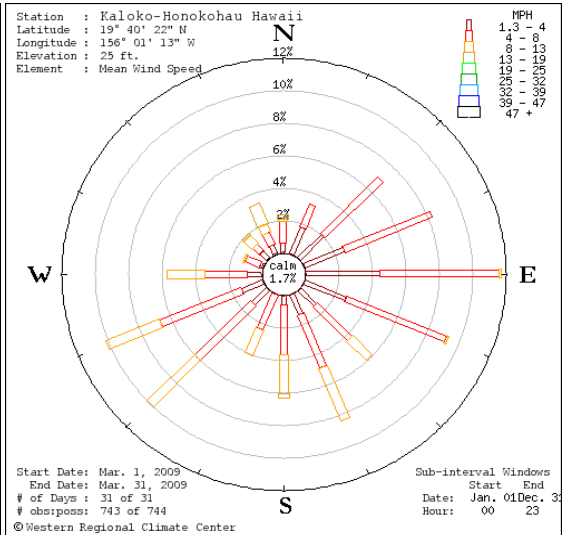
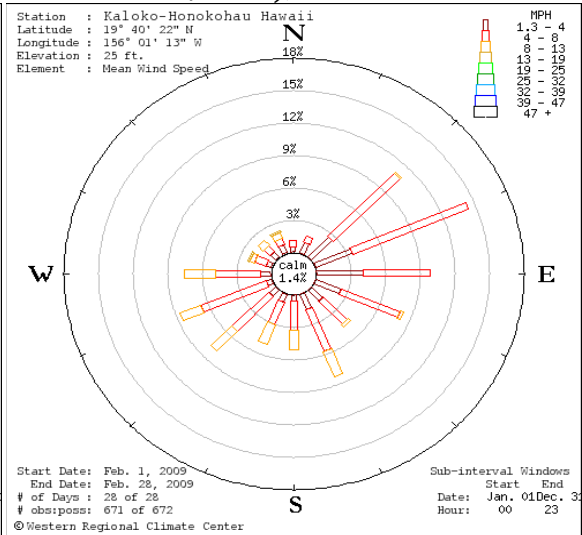
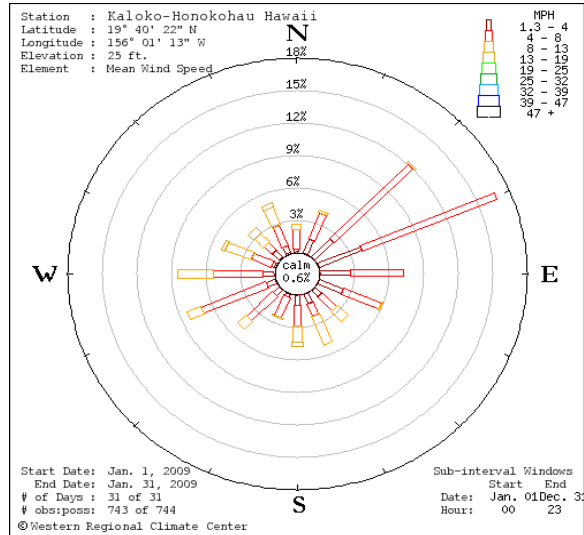
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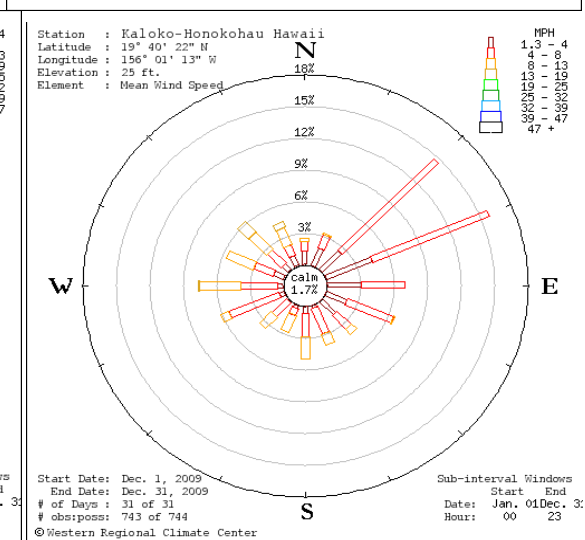
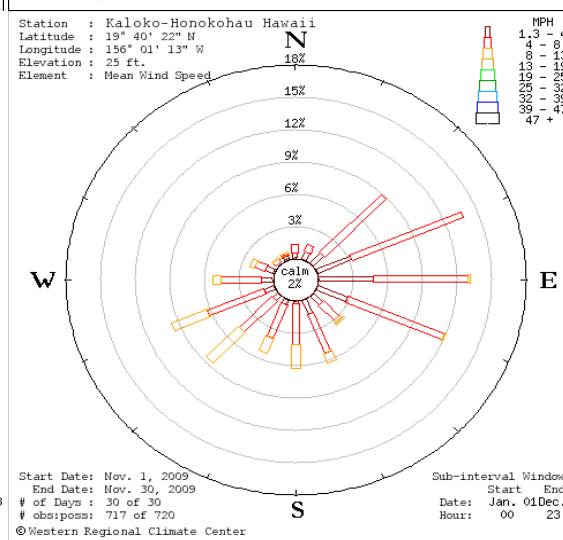
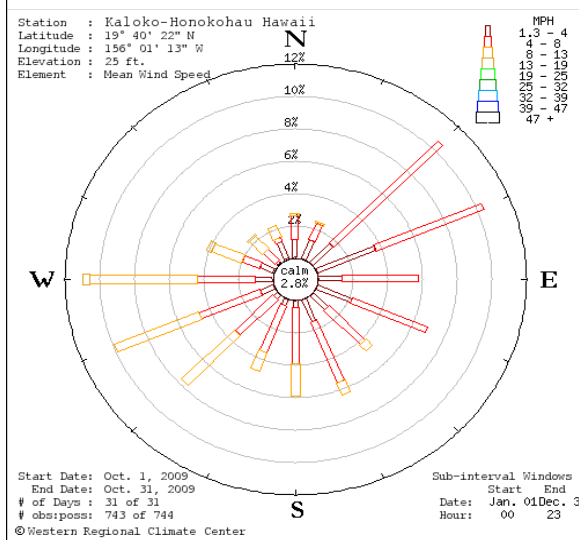
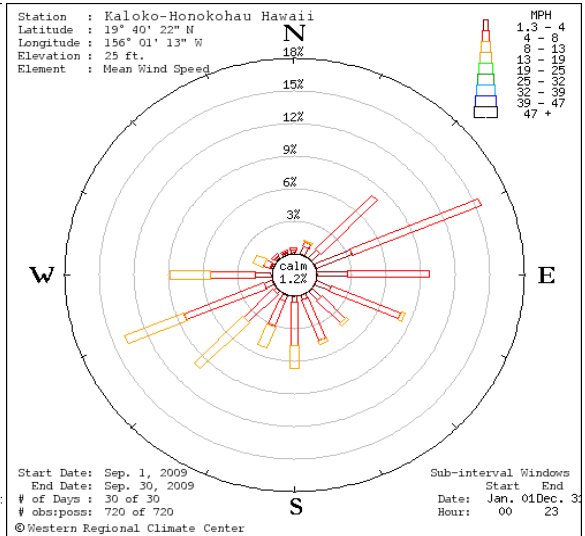
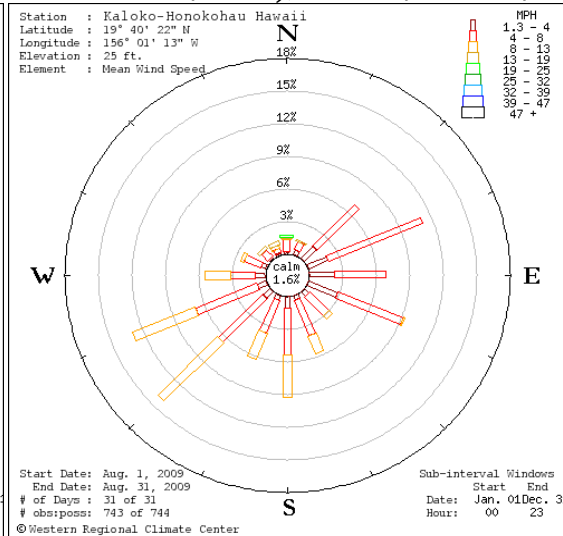
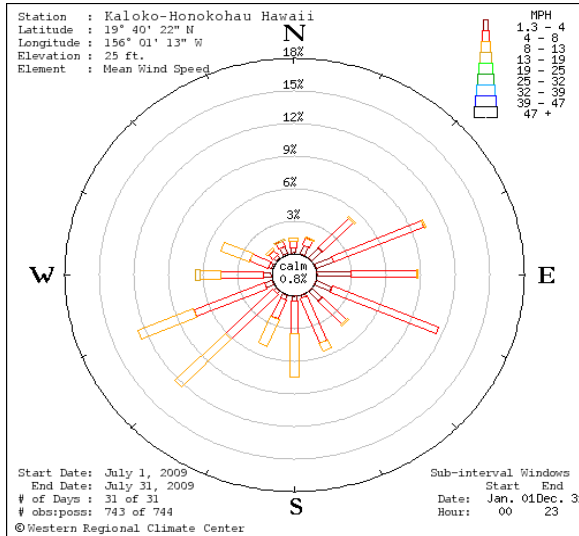
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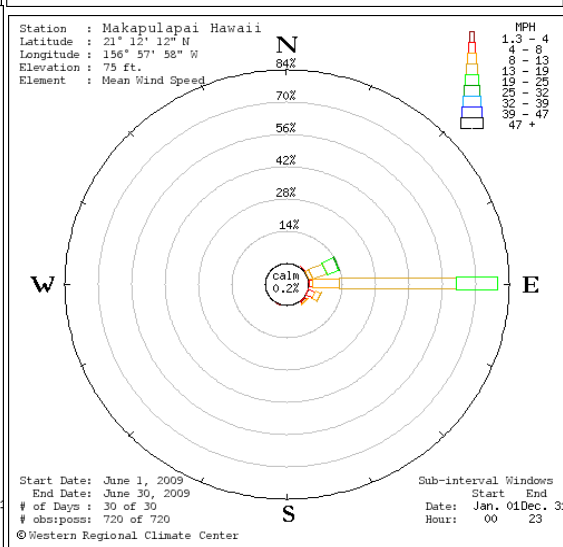
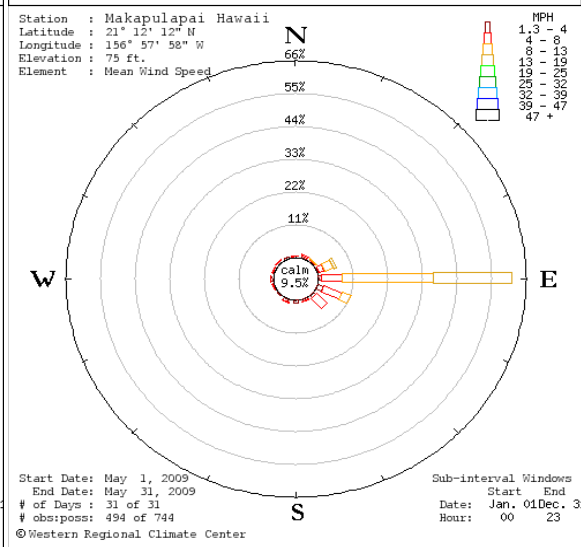
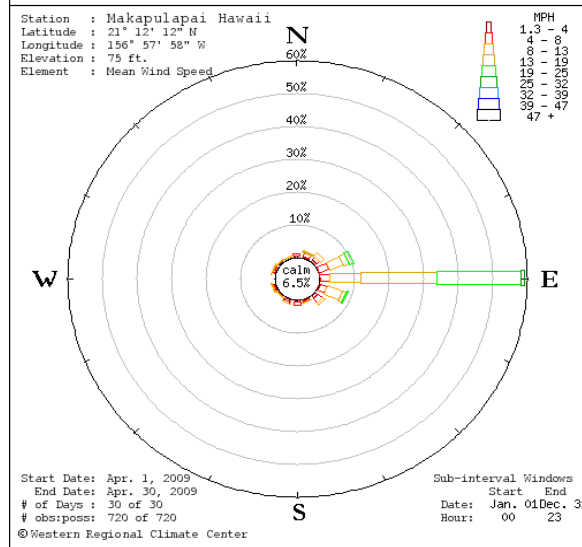
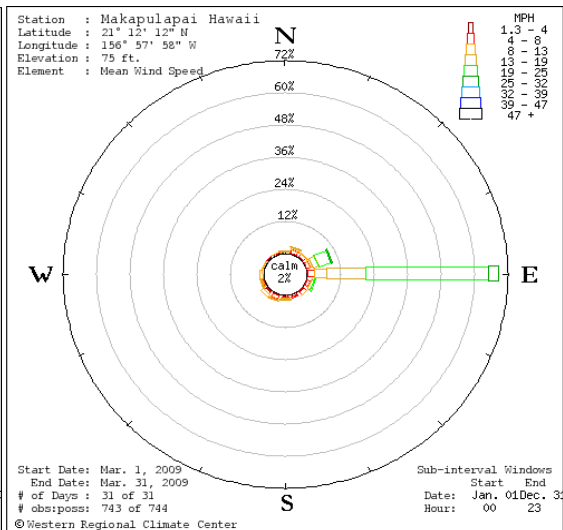
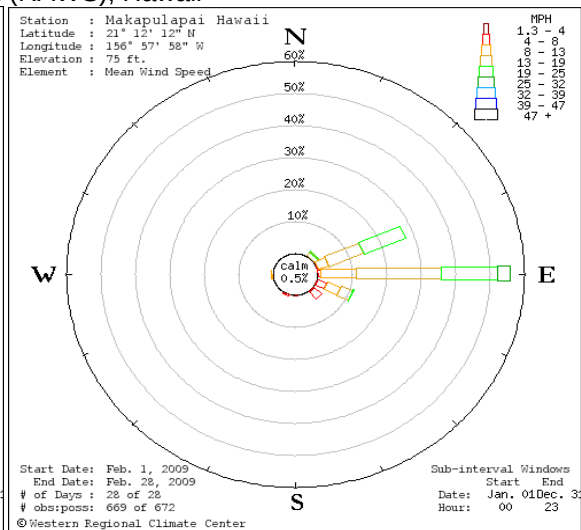
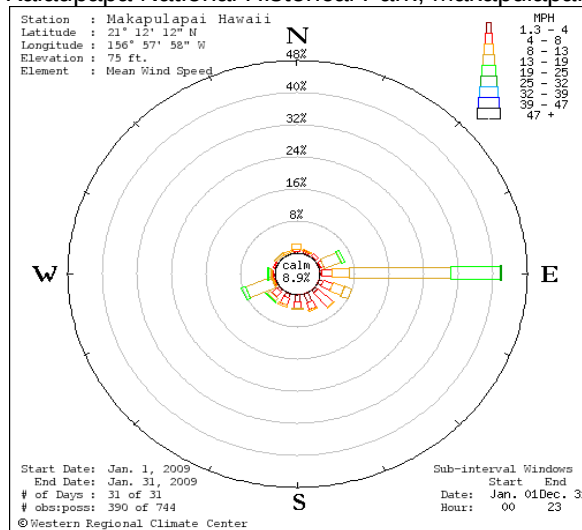
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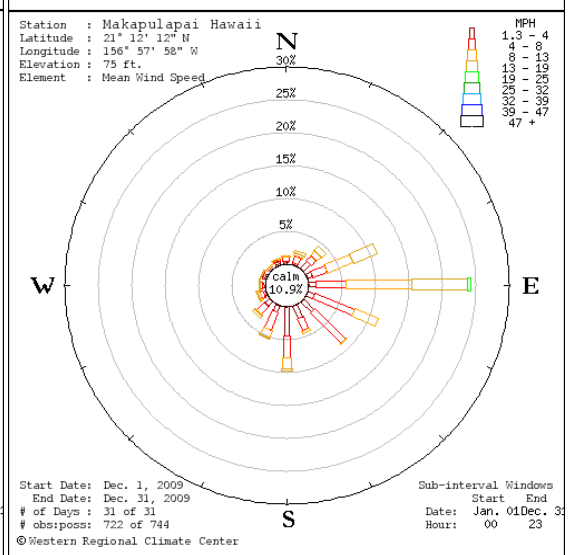
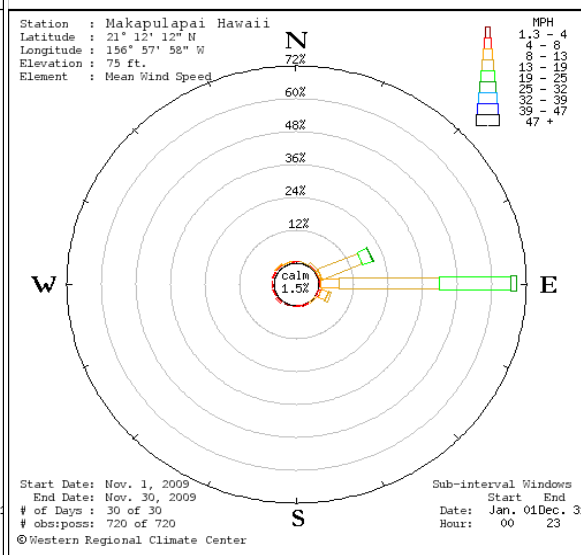
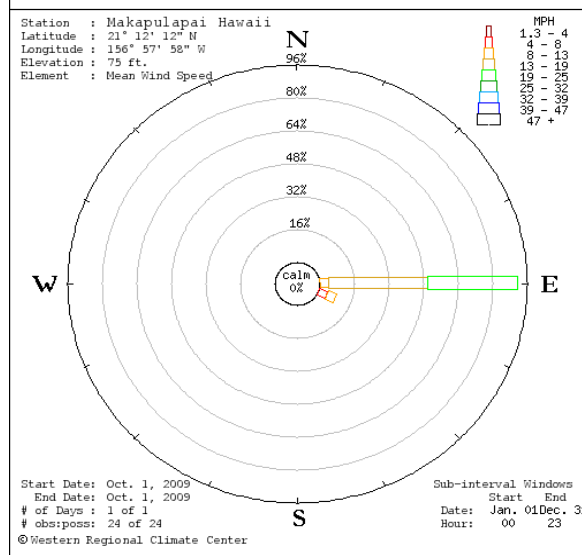
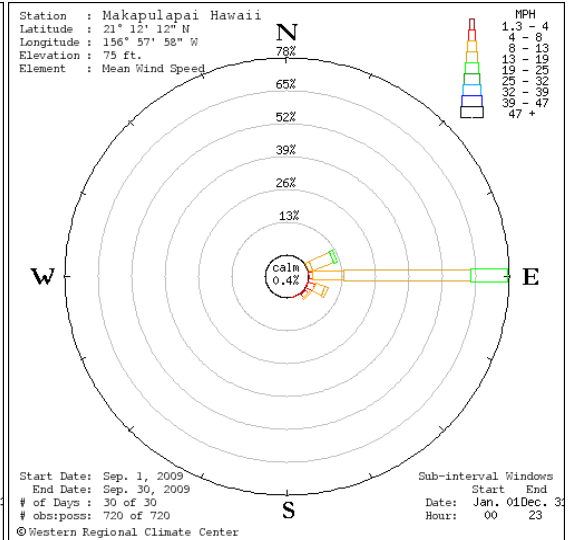
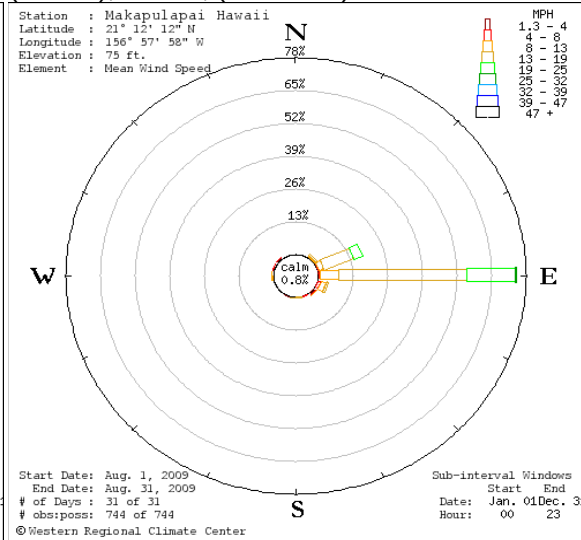
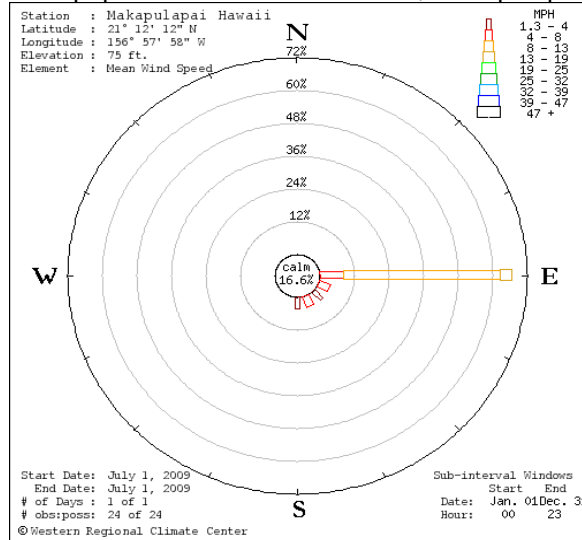
Kaloko-Honokohau National Historical Park, Kaloko-Honokohau (RAWS), Hawaii, (continued).



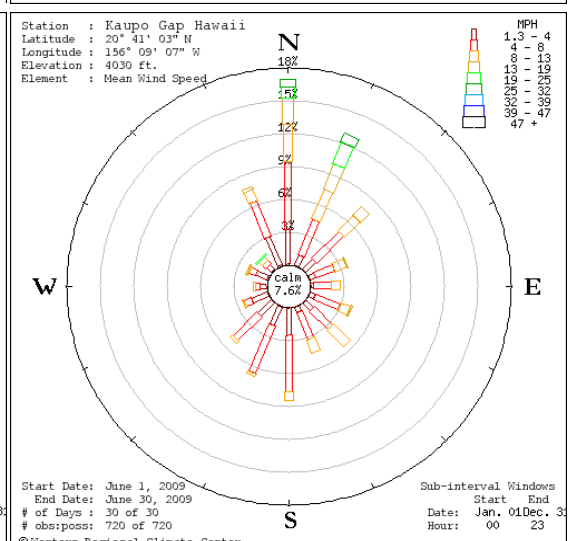
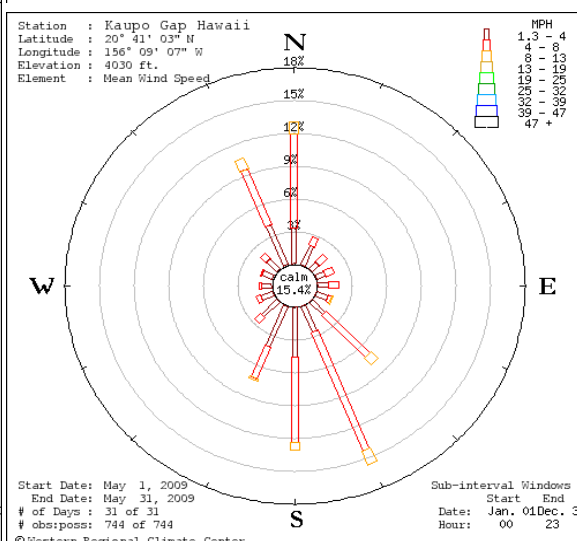
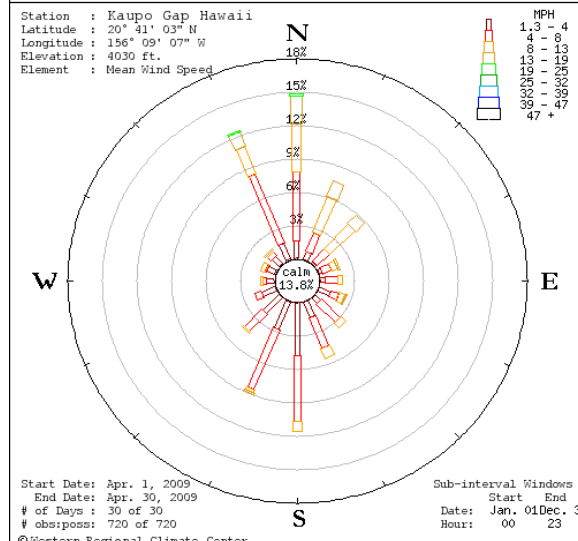
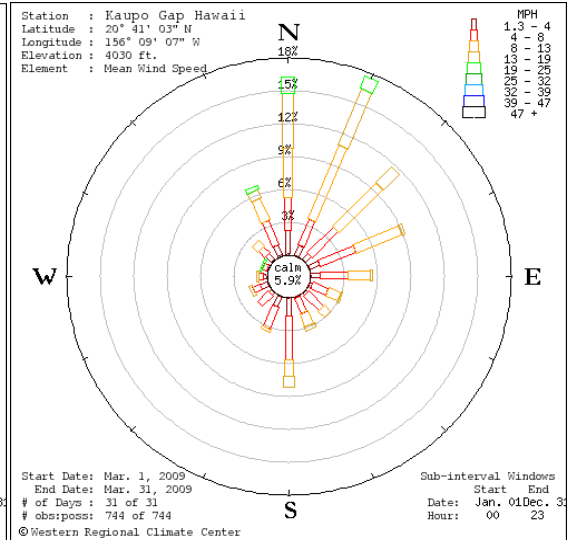
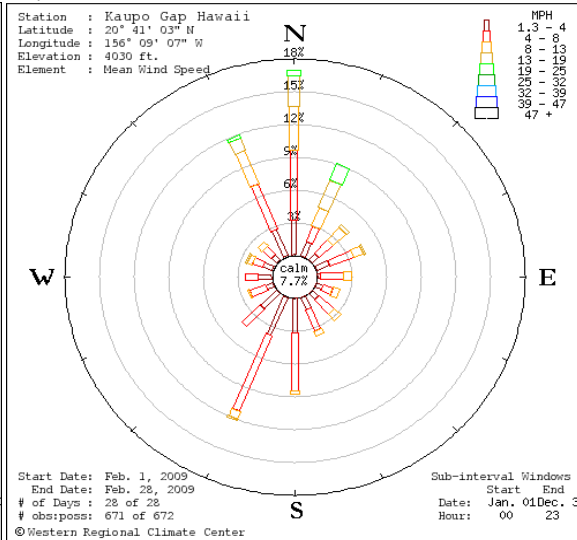
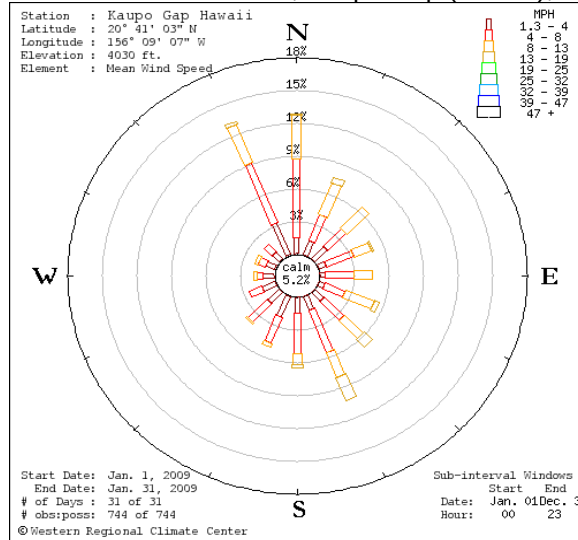
Kalaupapa National Historical Park, Makapulapai (RAWS), Hawaii



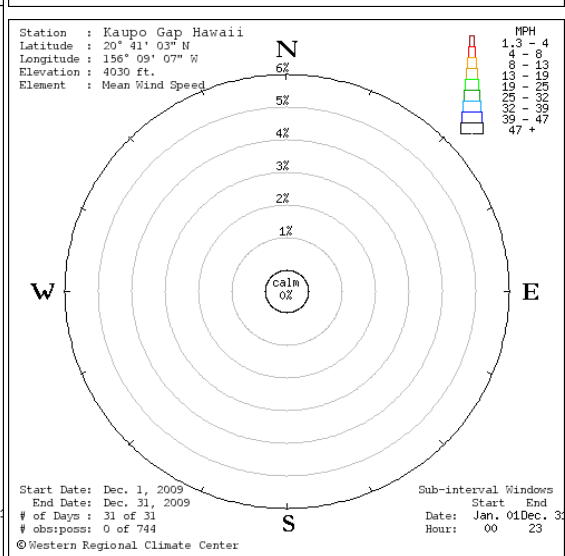
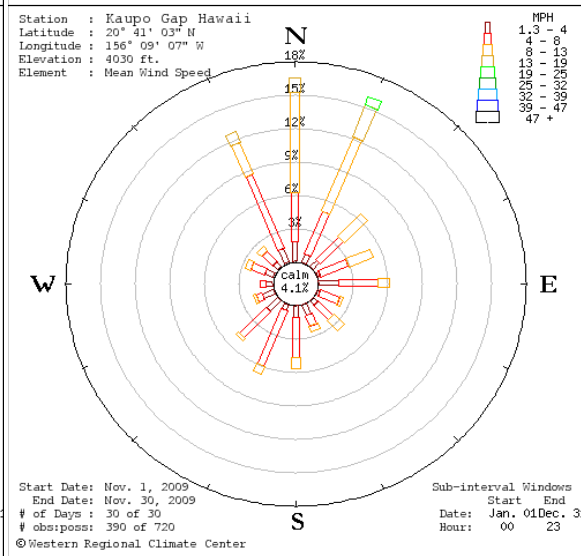
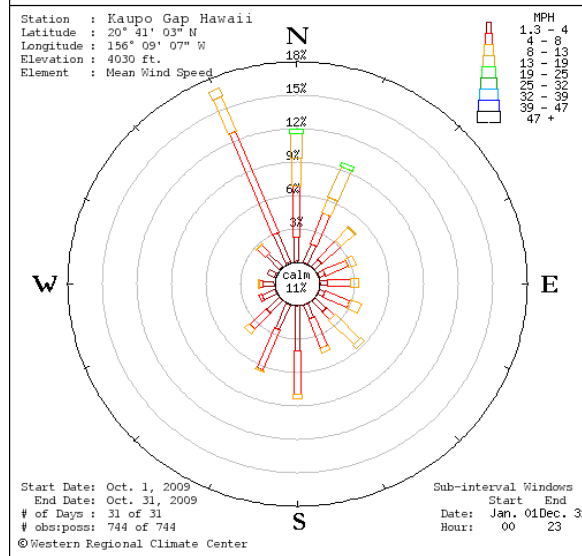
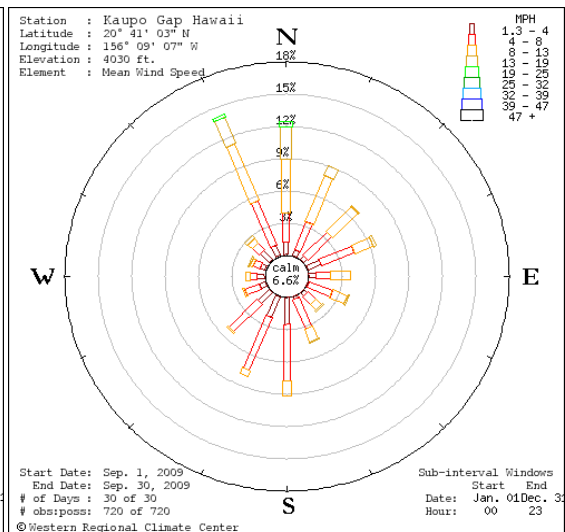
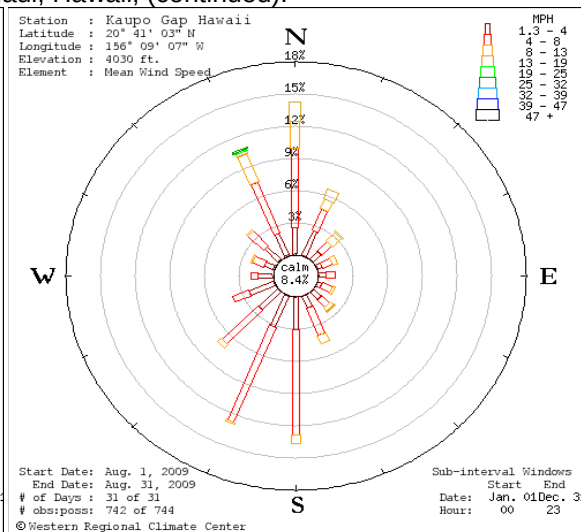
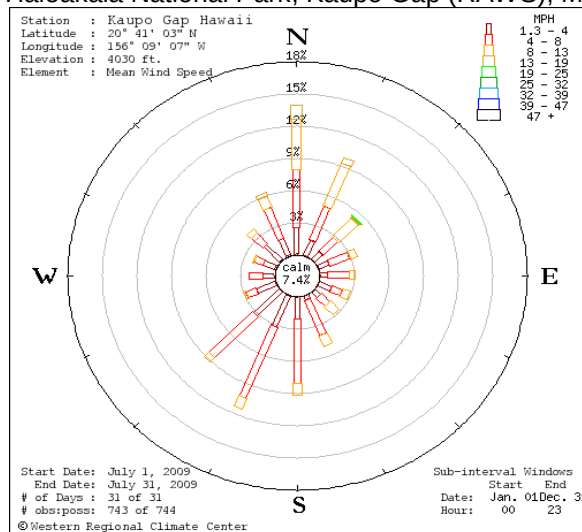
Kalaupapa National Historical Park, Makapulapai (RAWS), Hawaii, (continued).



Haleakala National Park, Kaupo Gap (RAWS), Maui, Hawaii.

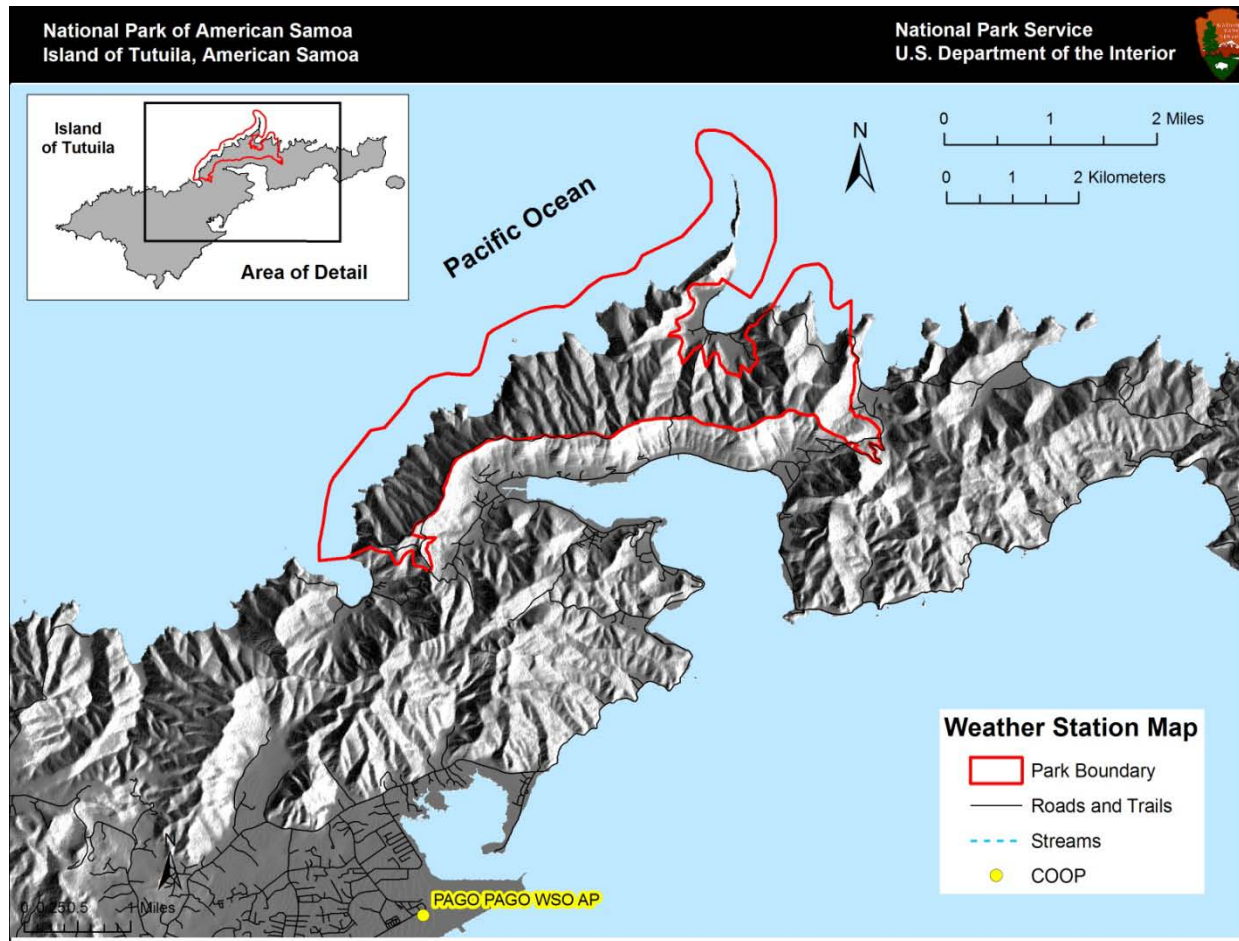


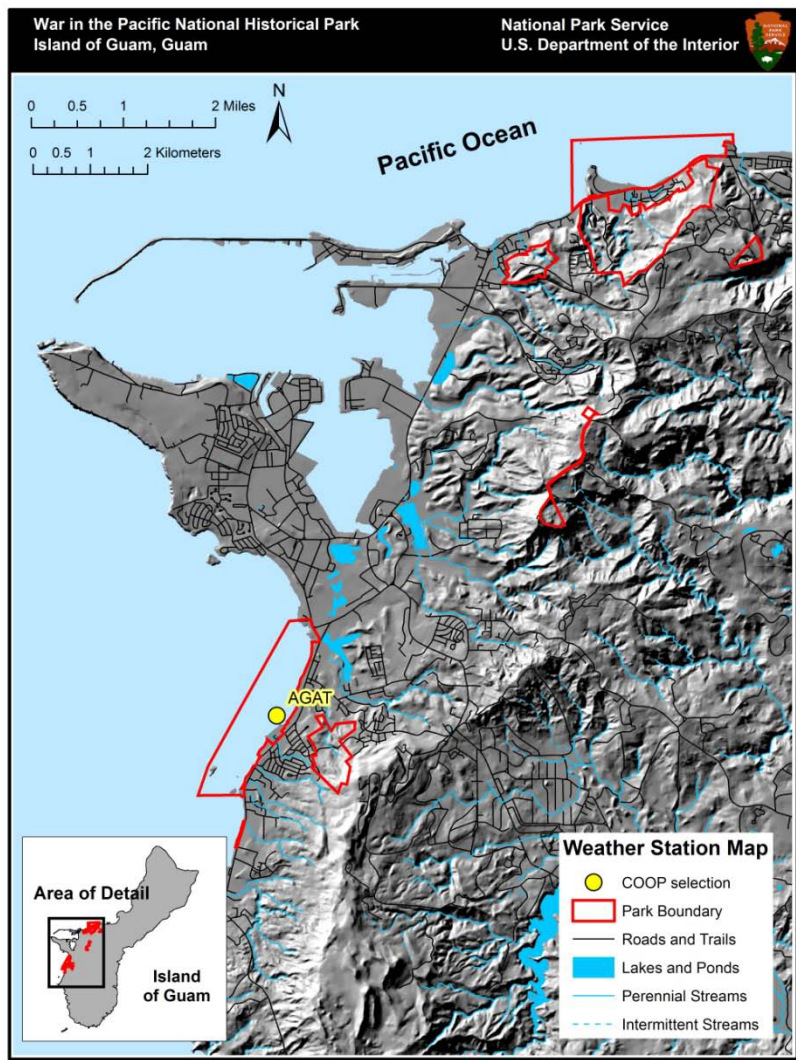
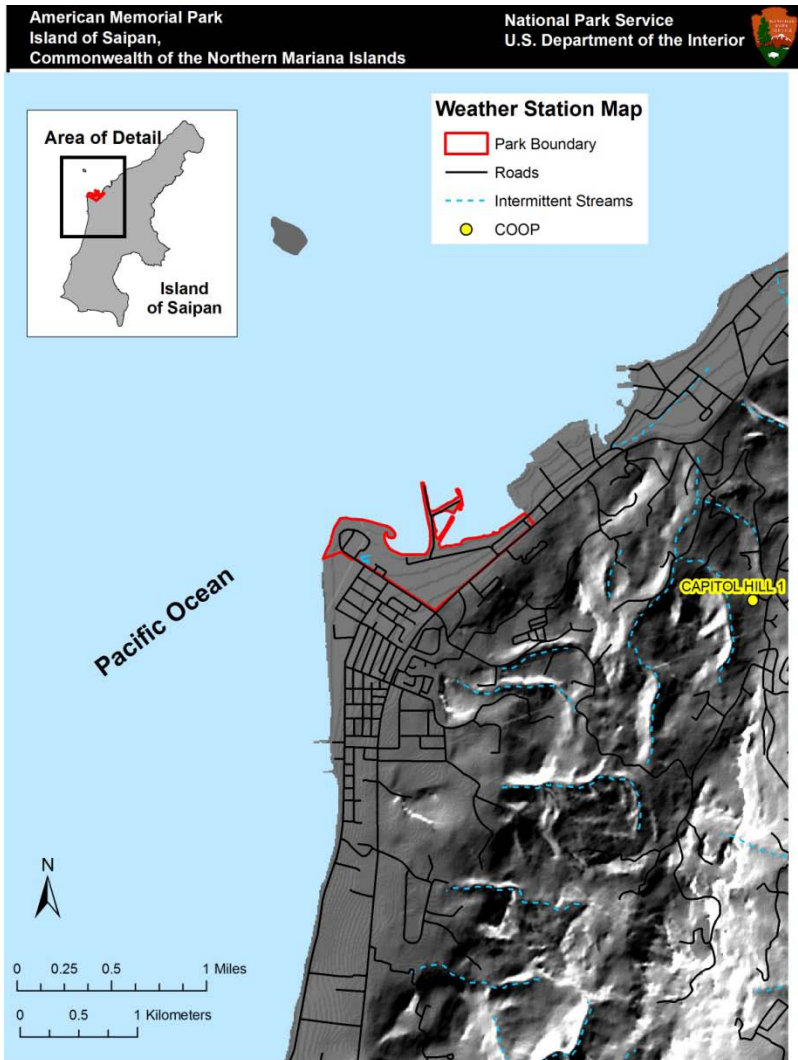
Haleakala National Park, Kaupo Gap (RAWS), Maui, Hawaii, (continued).



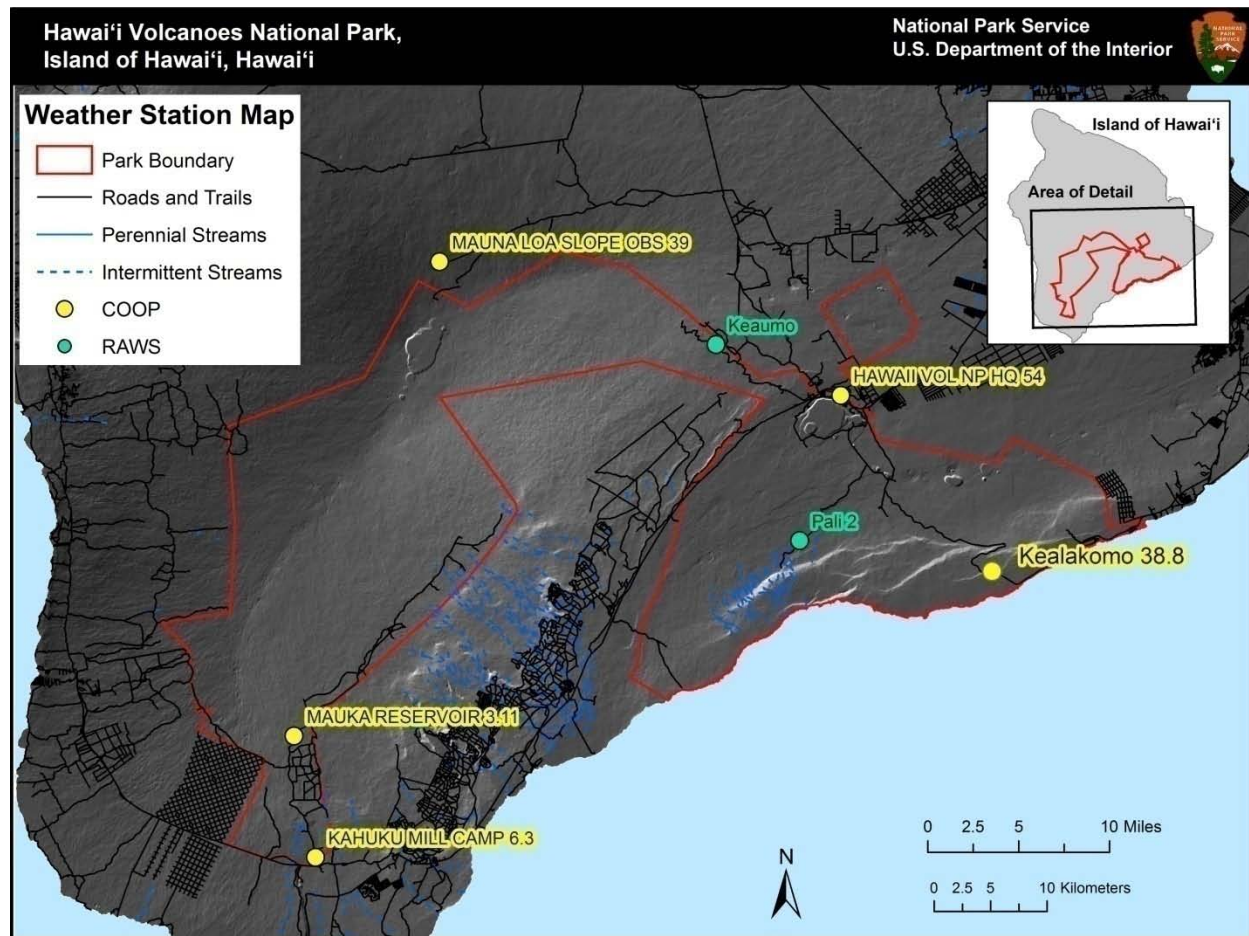
Appendix B. Maps Showing Station Locations

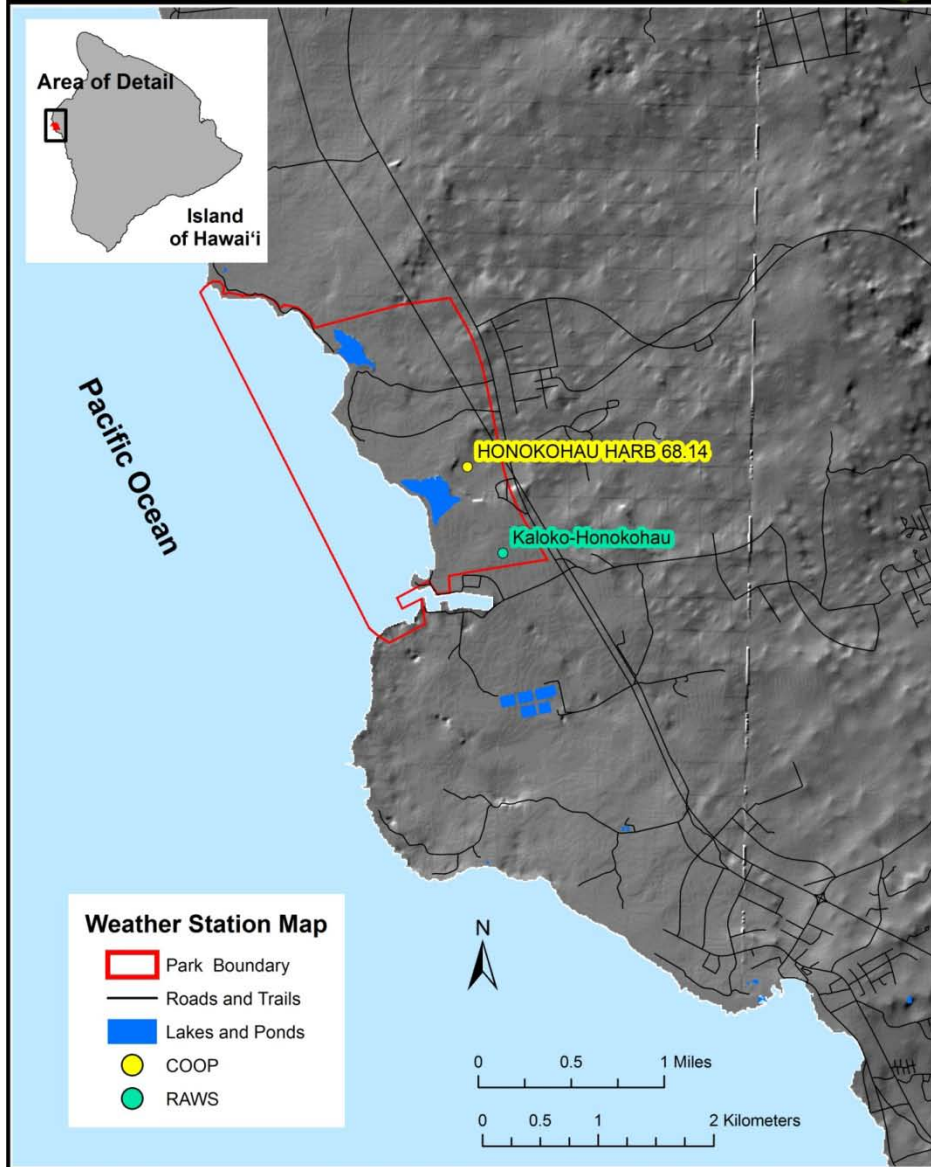
Parks in the West and South Pacific

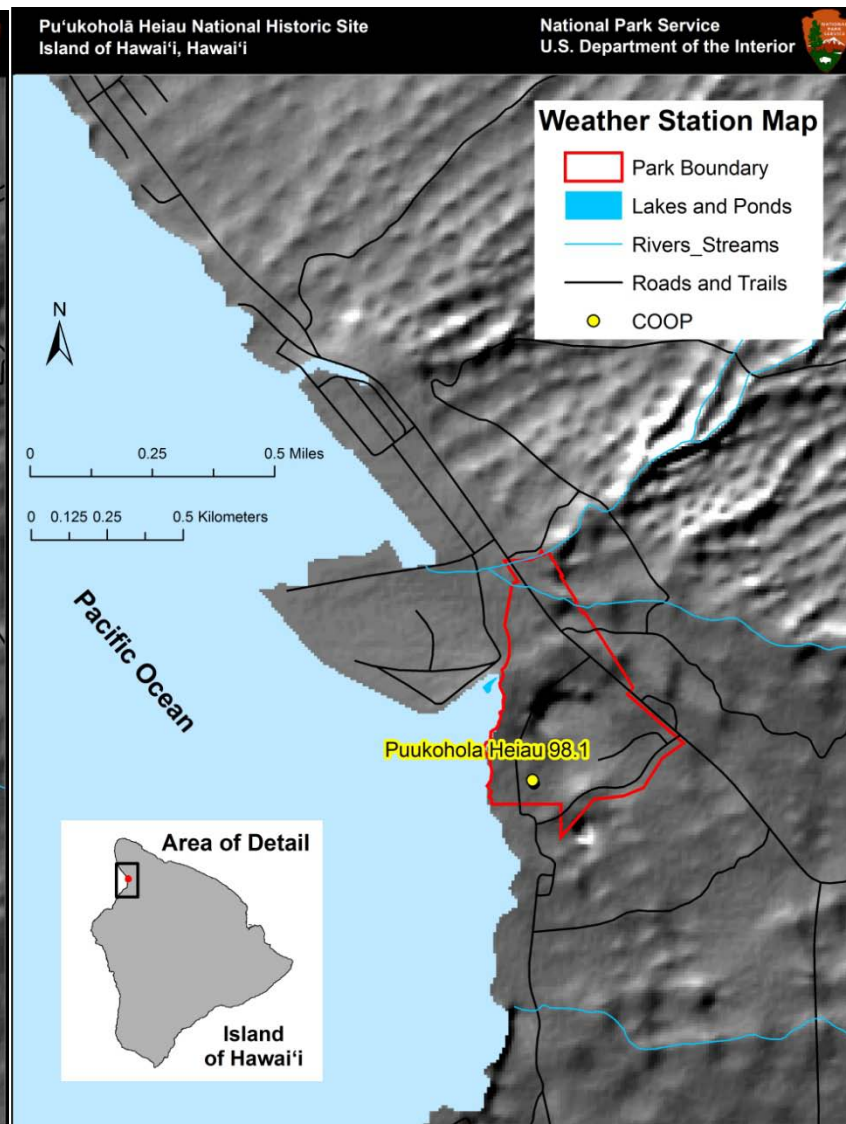
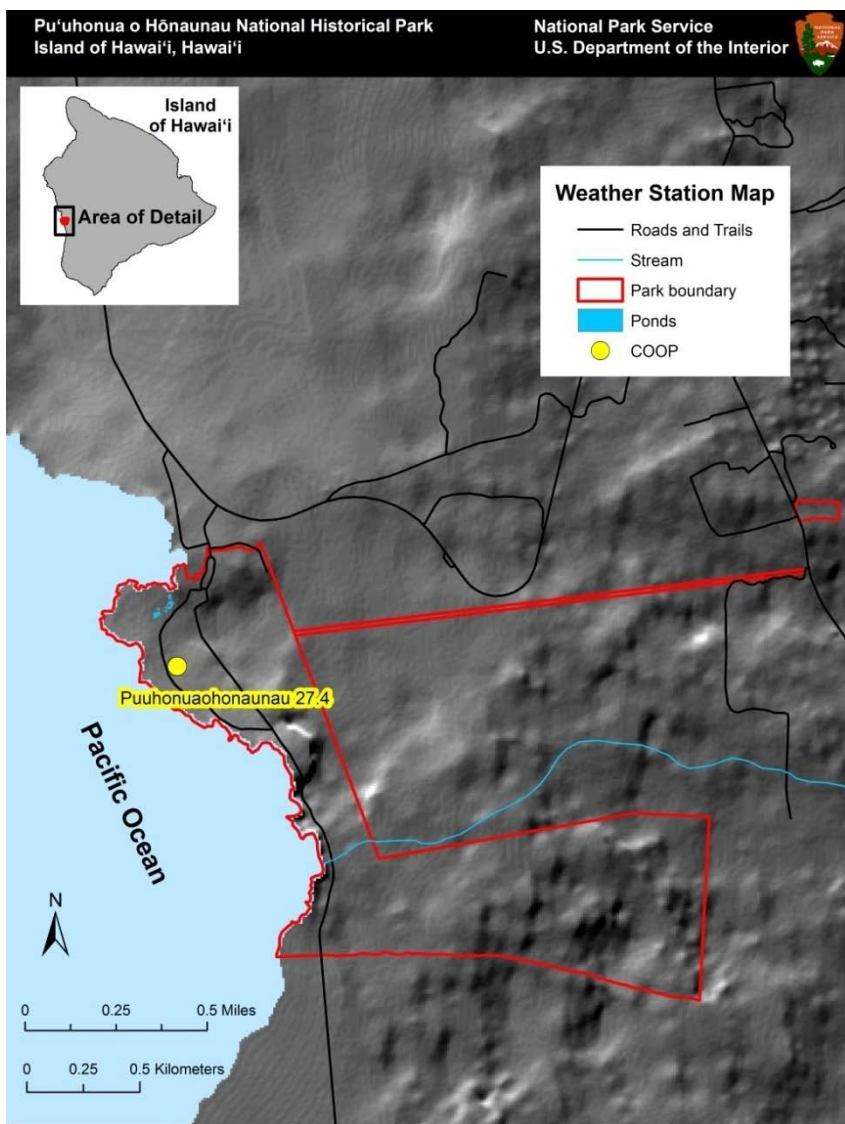




Parks on Hawai'i Island







Parks on Maui and Moloka'i

