



Annual Weather/Climate Data Summary 2008

Pacific Island Network

Natural Resource Report NPS/PACN/NRDS—2011/129



ON THE COVER

Snow on Mauna Loa, Hawaii, February 2008.

Photograph by: Karin Schlappa, CESU cooperator

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January 2011

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

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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.

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Please cite this publication as:

Schlappa, K. B. 2011. Annual weather/climate data summary 2008, Pacific Island Network. Natural Resource Data Series NPS/PACN/NRDS—2011/129. 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. 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, either directly or via NPCLime. In addition, data published by the National Climatic Data Center (NCDC) are presented. The final version was edited and material added by Tonnie L. C. Casey.

List of Acronyms

ALKA	Ala Kahakai National Historical Trail
AMME	American Memorial Park
CE	Categorical Exclusion
CIRMOUNT	Consortium for Integrated Climate Research in Western Mountains
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
EMAP	Environmental Monitoring and Assessment Program
ENSO	El Nino Southern Oscillation
FAMWEB	National Fire and Aviation Management Web Application
GCM	Global Climate Model or General Circulation Model
GOES	Geostationary Operational Environmental Satellite
GCOS	Global Climate Observing System
GPMN	Gaseous Pollutant Monitoring Network
QPRA	Government Performance and Results Act
HaleNet	Haleakala Climate Network
HAVO	Hawaii Volcanoes National Park
KAHO	Kaloko-Honokohau National Historical Park
KALA	Kalaupapa National Historical Park
NCA	National Coastal Assessment
NCDC	National Climate Data Center
NEPA	National Environmental Policy Act
NFDRS	National Fire Data Rating System
NHPA	National Historic Preservation Act
NIFC	National Interagency Fire Center
NOAA	National Oceanographic and Atmospheric Administration
NPSA	National Park of American Samoa
NRCS	Natural Resource Conservation Service
NWS	National Weather Service
OCS	Oregon Climate Service
PACN	Pacific Island Network
PDO	Pacific Decadal Oscillation
PDS	Protocol Development Summary
PEAC	Pacific ENSO Application Center
PUHE	Puukohola Heiau National Historical Park
PUHO	Puuhonua O Honaunau National Historical Park
RAWS	Remote Automated Weather Stations
ROMAN	Real-Time Observation Monitor and Analysis Network

SPI	Standardized Precipitation Index
USGS	U. S. Geological Survey
VALR	World War II Valor in the Pacific National Monument
WAPA	War in the Pacific National Historical Park
WFMI	Wildland Fire Management Information
WIMS	Weather Information Management System
WRCC	Western Regional Climate Center

Introduction

Weather/climate monitoring is one of twenty 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. However, note that this first report presenting data for 2008, is being published on a delayed schedule because pilot implementation of this monitoring effort only started in the spring of 2009 and the monitoring protocol (Schlappa et al. 2010) is still in revision. Annual reports aim to provide as much information as possible from as many national park weather stations as possible, regardless of the length of the station record. Five-year trend reports are planned, focusing only on data from stations with a long period of record and high observation frequencies, with more in-depth data verification and analysis. National parks in the PACN are located on the Hawaiian Islands, Guam, Saipan, and American Samoa (Figure 1) and include the following park units (Table 1).

Table 1. National parks in the Pacific Island Network

National Park	Island	Total Size in acres (marine portion)	Elevation Range ft
War in the Pacific National Historical Park (WAPA)	Guam	1,980 (990)	-164 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)	-164 to 3,169
World War II Valor in the Pacific National Monument (VALR)	Oahu	17 (5)	-39 to 75
Kalaupapa National Historical Park (KALA)	Moloka'i	11,251 (2061)	-200 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)	-49 to 170
Kaloko-Honokōhau National Historical Park (KAHO)	Hawai'i	1,188 (536)	-151 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

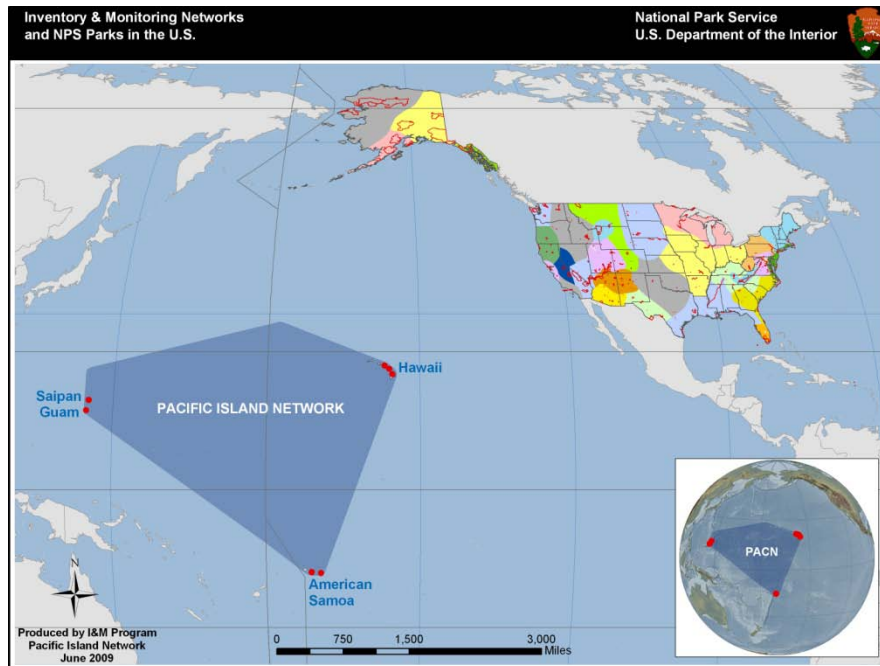


Figure 1. Map showing the extent of the Pacific Island Network; red dots indicate national park units.

Weather is the short term measurement of atmospheric phenomenon, the way the atmosphere is behaving at a short interval of time, from minutes to months. These include measurements of sunshine, rainfall, temperature, humidity, cloud cover, winds, hail, sleet, snow, freezing rain, flooding, blizzards, ice storms, thunderstorms, steady rains, excessive heat, and heat waves, to name a few. All of the weather stations in PACN measure weather: they take daily, hourly or other programmed measurements that are sent to a GOES (Geostationary Operational Environmental Satellite) and data are downloaded at NCDC (National Climate Data Center) and sent to WRCC (Western Regional Climate Center) where they are compiled, checked for quality assurance and control. They are further downloaded by the Inventory and Monitoring Program of the National Park Service, (I&M) for analysis. Data such as those mentioned above, can be analyzed for short term trends in weather patterns (Gutro, R. 2005).

Climate is the long term pattern of weather, usually measured over a minimum of 30 years. Data are **averages** of patterns of weather for a region. For instance, if climatologists have data from a region including precipitation, lake levels, and satellite data, they can tell if a summer has been drier than normal. If these data indicate a trend of dryness over a span of years, this is a change in climate (Gutro, R. 2005).

Data for some long term measurements are contrasted to short term weather measurements in several tables (Tables 2, 3,-----) to give the reader an idea of what trends might be occurring at this time. Generally though, data downloaded from WRCC sites are measurements of weather, not climate

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 the 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).

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 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 September they may occur year-round.

While U.S. 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 the 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 ([PEAC, website](#))¹. 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 and fewer storms during La Niña years (Chu and Wang 1997).

¹ <http://www.soest.hawaii.edu/MET/Enso/index.shtml>

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](http://www.nws.noaa.gov/om/coop/)²), and the Remote Automated Weather Station program ([RAWS](http://www.fs.fed.us/raws/)³). These stations can be accessed on the internet and interested readers can download pertinent information. 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.

The stations used in the data collection and analyses were as follows:

AMME (American Memorial Park, Saipan): Capitol Hill COOP

WAPA (War in the Pacific National Historical Park, Guam): Agat COOP

NPSA (National Park of American Samoa): Pago Pago COOP

HAVO (Hawaii Volcanoes National Park, Hawaii): Hawaii Vol NP HQ 54 COOP, Mauna Loa Slope Obs 39 COOP, Mauka Reservoir 3.11 COOP, Kahuku Mill Camp 6.3 COOP, Kealakomo 38.8 COOP, Keaumo RAWS, Pali2 RAWS

KAHO (Kaloko-Honokōhau National Historical Park, Hawaii): Kaloko-Honokohau RAWS, Honokahau Harbor 68.14 COOP

PUHO (Puuhonua O Honaunau National Historical Park, Hawaii): Puuhonuaohonaunau 27.4 COOP

PUHE (Puukohola Heiau National Historical Park, Hawaii): Puukohola Heiau 98.1 COOP

KALA (Kalaupapa National Historical Park, Molokai): Kalaupapa 583 COOP, Makapulapai RAWS

HALE (Haleakala National Park, Maui): HaleakalaRS338 COOP, Oheo258.6 COOP, KaupoGap RAWS

² <http://www.nws.noaa.gov/om/coop/>

³ <http://www.fs.fed.us/raws/>

Weather data for RAWS and NWS COOP stations were acquired in 2009 from NPCLime, which was available only on the NPS intranet and incorporated into a Microsoft (MS) Access database that stores data for all stations included in PACN weather/climate monitoring. Since this report, NPCLime has been disbanded; future data acquisition will be accomplished via WRCC directly. The acquired weather data consist of daily values, i.e., hourly RAWS data had already been summarized by the Western Regional Climate Center (WRCC) before they were passed on to NPCLime. The WRCC also performs a preliminary data validation process. Quality Assurance and Control (QA/QC) procedures for COOP and RAWS data are performed by NCDC (National Climate Data Center). Data-quality codes are provided along with the 24-hr observations to WRCC 2-4 months after receipt at NCDC. Codes indicate various features of the data, such as missing records or the use of estimation procedures (Garman, 2006)

Data were imported into [R](http://www.r-project.org/)⁴ (version 2.10.0) for data analysis and graphing. Boxplots were used extensively to place data from 2008 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 2008 overlaid on the graphics to place the current year's data into the context of long-term variability.

⁴ <http://www.r-project.org/>

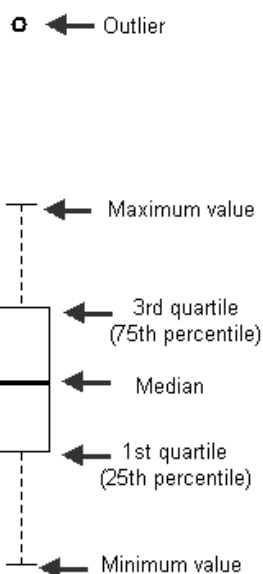


Figure 2. Anatomy of a boxplot. Note that the box defines the interquartile range (IQR) and that the minimum (maximum) value is defined as the minimum (maximum) within a distance of 1.5 IQR from the 1st (3rd) quartile; data points beyond those limits are considered outliers.

Wind graphics were generated using the online data analysis tools for individual RAWS set up by WRCC and the [Desert Research Institute](http://www.raws.dri.edu/wraws/hiF.html)⁵ (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 2008 values with climate normals for the 1971-2000 time period published by the National Climatic Data Center (NOAA 2002), if they are available. The NCDC computes climate normals for a subset of the COOP stations throughout the country. Thus, in this report, 2008 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. 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). 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

⁵ <http://www.raws.dri.edu/wraws/hiF.html>

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 based on ease of access. 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.

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 (PEAC 2008, 2009) and the ENSO diagnostic discussions of the Climate Prediction Center (CPC 2009). The year 2007 ended with moderate-strength La Niña conditions which strengthened during the first couple of months of 2008. Starting in March, La Niña conditions began to weaken and in June a transition to ENSO neutral conditions took place; these conditions remained throughout the rest of the year. However, as pointed out by PEAC (2008), atmospheric conditions throughout the second half of the year still exhibited behavior more typical of La Niña: tradewinds were enhanced and tropical cyclone activity was displaced westward and northward.

As in the previous year, 2008 had below normal tropical cyclone activity (27 compared to a normal of 31) in the western North Pacific (Cooper and Falvey 2008). Due to reduced activity and the geographical shift, tropical cyclones had little impact on rainfall in the PACN islands of Guam and Saipan. Only one tropical cyclone, typhoon Dolphin, which occurred in December and resulted in a tropical storm warning for Guam, added a moderate amount to that month’s rainfall total on Guam (PEAC 2009). In the central North Pacific tropical cyclone activity was also below normal, only one tropical cyclone (Kika) developed in August of 2008, but it stayed over open water and did not noticeably affect weather conditions in the Hawaiian Islands.

Parks in the Western North Pacific and the South Pacific

Table 2 and Figures 3-5 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.

The Agat station on Guam, which is a rain gauge only, had low observation frequencies (<85%) for most months in 2008. 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), these data were not included in the numerical comparison table. PEAC (2009) reports that annual rainfall at the Guam airport and at Anderson Airforce Base on Guam was below normal (81% and 66%); both stations are located north of WAPA park units.

On Saipan, Capitol Hill had an annual rainfall total close to the long-term mean (98%, Table 2), but high variability between months, with some months significantly above and others significantly below long-term mean values. Rainfall tapered off significantly over the last four months. Temperature anomalies (differences compared to the long-term mean) were small with the summer months generally slightly cooler and other months slightly warmer than long-term means.

In American Samoa, Pago Pago had an annual rainfall total 9% above normal with high variability between months. Temperatures were consistently above normal with the exception of a very small negative anomaly for mean maximum temperature in July; mean minimum temperatures were between 0.9 and 3.2 degrees above normal all year (Table 2).

Table 2. Comparison of precipitation and temperature data from 2008 with long-term records for stations on Guam, Saipan, and Tutuila. 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.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
	Agat (1979-2008)				COOP	Park: near WAPA				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
2008 total	1.52	NA	4.30	NA	NA	7.39	NA	NA	NA	NA	NA	NA	NA
% Normal	35%	NA	137%	NA	NA	116%	NA	NA	NA	NA	NA	NA	NA
	Capitol Hill (1995-2008)				COOP	Park: near AMME				Elev. 827 ft. (252 m)			
Precipitation (in)													
Long-term mean	3.93	4.24	2.75	4.18	3.75	4.95	9.96	12.47	11.07	10.57	8.49	6.40	82.76
2008 total	3.55	4.65	7.65	1.89	2.71	7.13	7.04	14.04	15.56	10.24	4.94	1.94	81.34
% Long-term	90%	110%	278%	45%	72%	144%	71%	113%	141%	97%	58%	30%	98%
Min. temp. (°F)													
Long-term mean	73.3	72.8	73.3	73.9	75.3	75.7	75.2	75.1	75.2	75.0	75.1	74.4	74.5
2008 mean	74.2	73.5	74.6	75.2	75.5	75.1	75.3	75.3	74.9	74.7	75.5	75.0	74.9
Difference	0.8	0.7	1.3	1.3	0.2	-0.5	0.1	0.2	-0.3	-0.4	0.3	0.6	0.4
Max. temp. (°F)													
Long-term mean	81.1	80.6	81.9	83.3	84.5	85.0	84.3	84.1	84.1	84.1	83.4	82.5	83.2
2008 mean	82.7	81.6	82.5	84.9	85.7	85.2	83.5	81.9	83.7	84.4	84.2	83.4	83.6
Difference	1.5	0.9	0.6	1.5	1.2	0.2	-0.7	-2.1	-0.5	0.3	0.8	0.9	0.4
	Pago Pago WSO AP (1957-2008)				COOP	Park: near NPSA				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
2008 total	22.15	4.90	10.08	12.89	19.83	12.00	4.46	3.59	6.13	3.23	11.87	18.47	129.60
% Normal	158%	40%	90%	116%	190%	202%	77%	56%	83%	32%	106%	138%	109%
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
2008 mean	79.1	79.3	78.4	78.4	77.6	77.0	77.5	78.4	77.7	78.9	78.3	79.6	78.4
Difference	3.0	3.0	1.8	2.1	1.4	0.9	2.0	2.9	1.9	2.7	1.8	3.2	2.3
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
2008 mean	87.6	89.1	88.5	88.1	87.5	85.1	83.7	85.2	84.9	86.7	88.1	89.4	87.0
Difference	0.8	1.9	1.2	1.2	1.9	0.6	-0.1	1.2	0.1	1.5	2.3	2.5	1.3

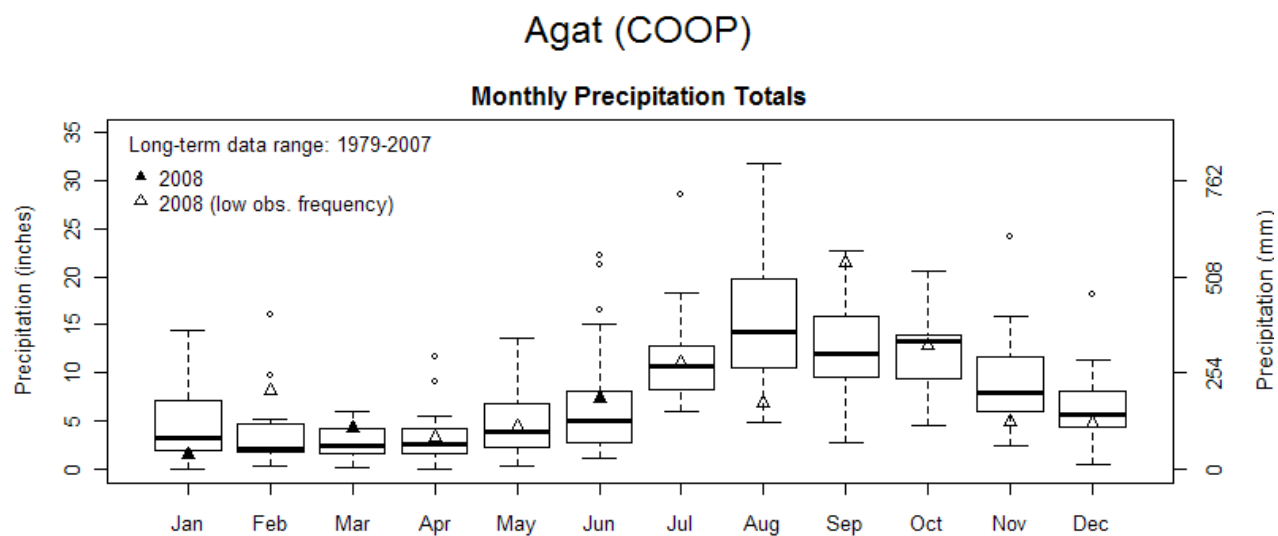


Figure 3. Boxplot of precipitation data for Agat (COOP). To facilitate a better scale the boxplot does not show one outlier at 45 inches for August.

Capitol Hill (COOP)

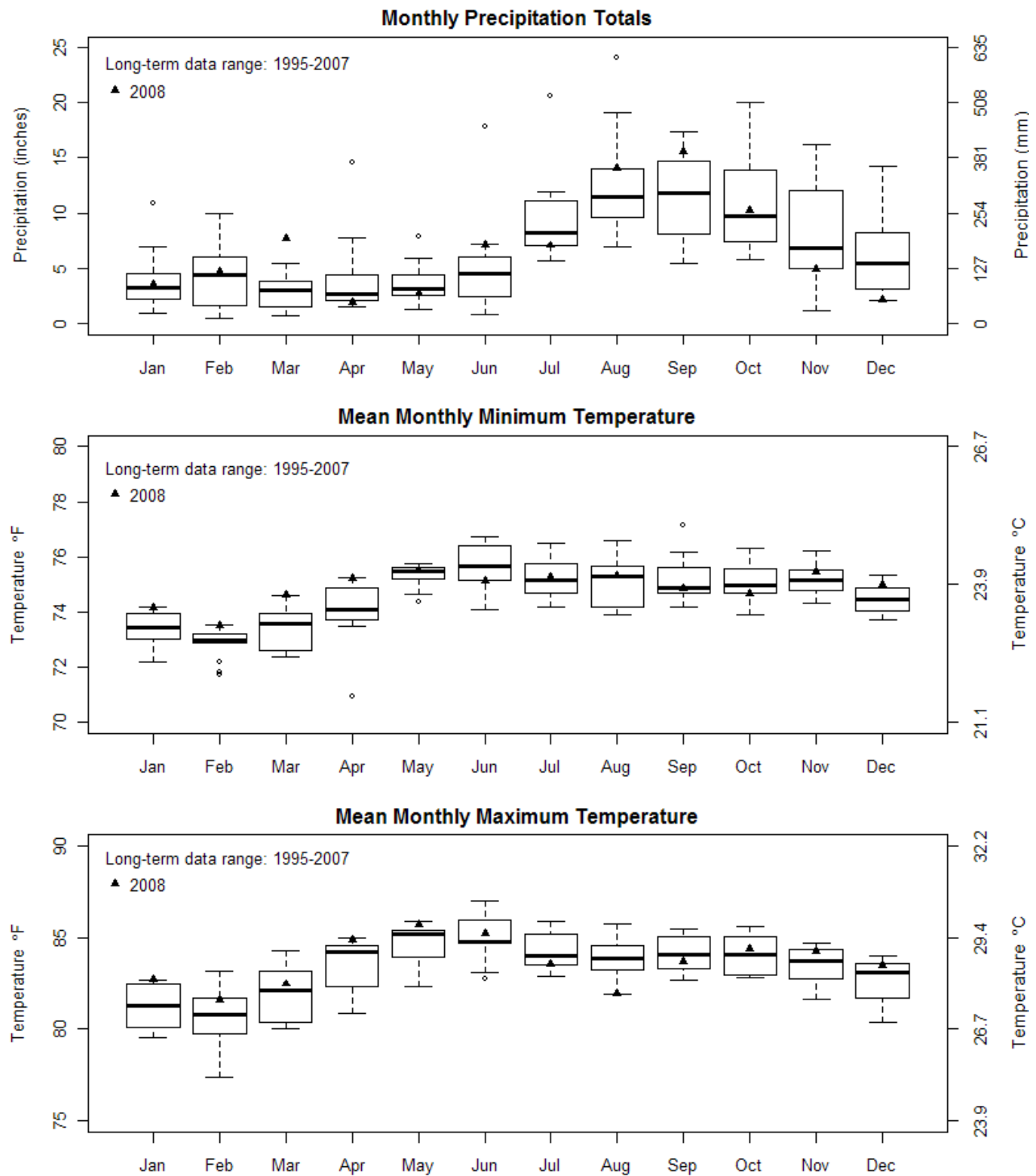


Figure 4. Boxplots of precipitation and temperature data for Capitol Hill (COOP)

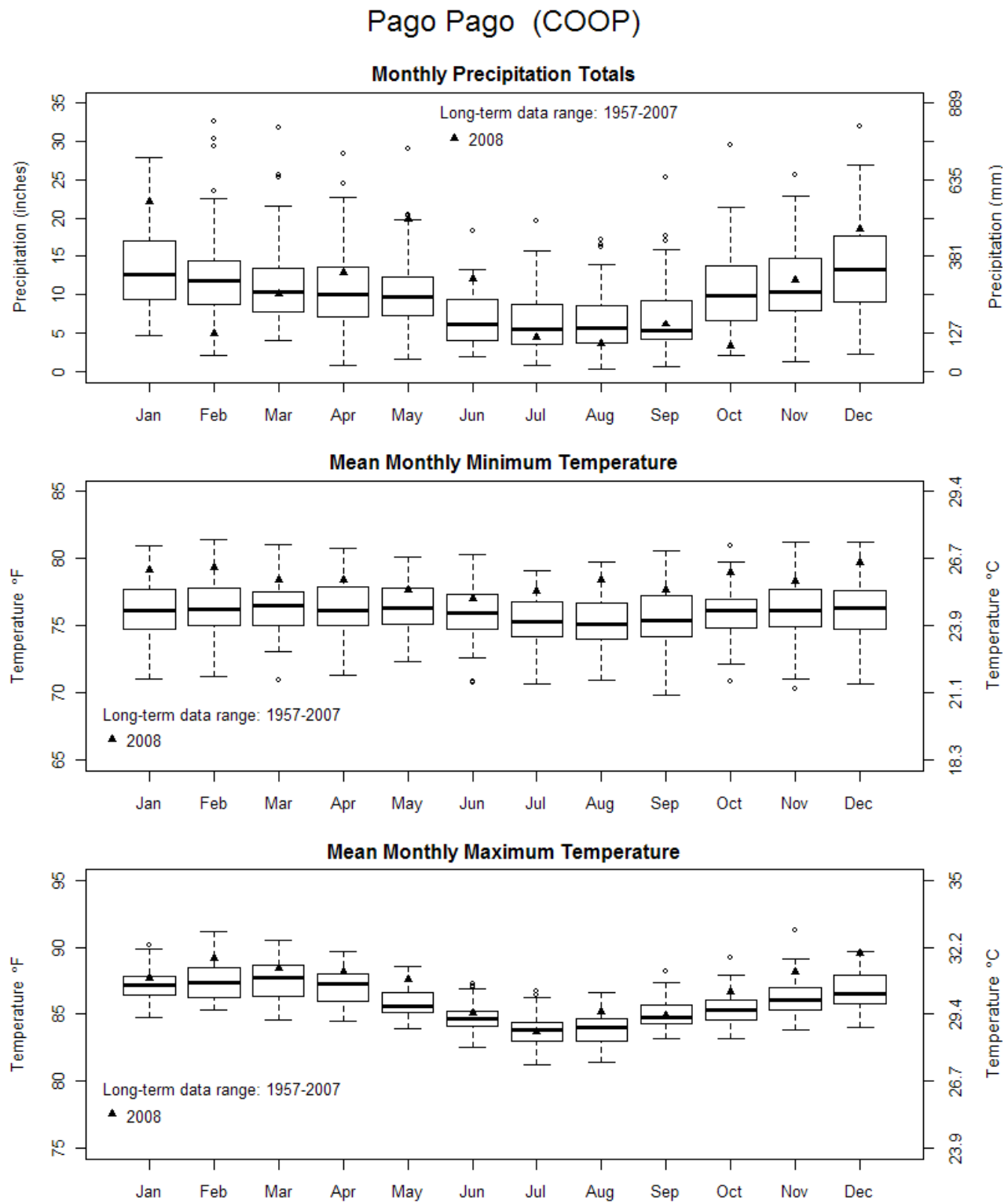


Figure 5. Boxplots of precipitation and temperature data for Pago Pago WSO AP (COOP)

Parks in the Hawaiian Islands

A storm in late January/early February brought extremely heavy rains to many parts of the Hawaiian Islands and a lot of snow to Mauna Kea and Mauna Loa on Hawai‘i Island, as well as to Haleakalā on Maui. Data from stations on the southern and eastern parts of Hawai‘i and Maui especially show the extent of the deluges, but Moloka‘i and even South Kona also received unusually high rainfall. July 22nd and 23rd had heavy rains on Hawai‘i, Maui, and Moloka‘i and December had prolonged heavy rainfall in much of the state. For most stations data from the rest of the year show many months with rainfall substantially below normal or long-term means, indicative of the extended drought conditions that the islands have been experiencing. While a few stations show positive temperature anomalies for some spring or early summer months, most months in 2008 had negative anomalies for most of the year.

Hawai‘i Volcanoes National Park

Table 3 and Figures 6-14 present precipitation, temperature, and relative humidity data for three COOP stations and two RAWs at or near HAVO. The Kahuku Mill Camp and Kealakomo COOP stations only collect precipitation data. The Kahuku Mill Camp station had 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 3. 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 3. The influence of the short but intense February storm and the prolonged December rains is reflected in the data for all HAVO stations. July also brought unusually heavy rain to the eastern side of Hawai‘i Island.

Figure 15 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 February, March, April and December the months with highest variability in wind directions. Data from the Keaumo RAWs (Figure 16, 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 3. Comparison of precipitation and temperature data from 2008 with long-term records for stations at Hawai'i Volcanoes National Park. Comparisons are made with 1971-2000 normals or if normals were unavailable 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
Hawaii Vol NP HQ 54 (1945-2008)					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
2008	5.39	31.82	4.54	4.92	5.44	1.83	6.30	2.95	1.99	3.75	3.90	16.83	89.66
% Normal	50%	349%	32%	47%	86%	35%	87%	47%	33%	55%	28%	153%	84%
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
2008 means	48.1	49.3	50.8	51.8	55.0	53.7	54.7	54.4	53.6	53.9	53.4	52.4	52.6
Difference	-1.50	-0.29	0.33	0.12	2.27	-0.53	-0.54	-1.11	-1.63	-1.10	-0.27	1.19	-0.21
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
2008	66.0	67.4	68.6	69.8	72.6	71.0	73.6	73.2	72.1	71.4	70.6	66.8	70.2
Difference	-1.50	-0.12	1.50	2.49	3.63	0.60	2.12	0.16	-0.83	-0.61	0.97	-0.81	2.65
Kealakomo 38.8 (1995-2008)					COOP		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
2008	1.10	19.85	4.28	3.57	1.90	0.35	2.45	0.50	0.51	3.12	4.92	19.94	62.49
Difference	12%	317%	47%	100%	65%	17%	139%	25%	21%	70%	62%	277%	106%
Mauna Loa Slope Obs (1955-2008)					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
2008	0.39	2.54	0.43	NA	0.00	0.23	0.83	1.43	0.02	0.33	0.24	3.89	NA
% Normal	13%	151%	19%	NA	0%	43%	63%	108%	2%	28%	10%	206%	NA
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
2008 means	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
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
2008	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Keaumo (2000-2008)					RAWS		Park: HAVO			Elev. 5,520 ft. (1,692 m)			
Precipitation (in)													
Long-term mean	6.99	4.83	6.21	2.20	2.01	0.78	1.66	2.68	3.51	3.55	10.04	5.97	50.43
2008	1.50	12.90	1.05	3.63	0.80	1.46	3.28	1.43	0.91	0.50	0.93	9.46	37.85
Difference	21%	267%	17%	165%	40%	188%	197%	53%	26%	14%	9%	158%	75%
Min. temp. (°F)													
Long-term mean	42.9	42.6	43.9	44.9	45.6	47.6	49.7	48.4	48.5	48.0	46.3	44.1	46.0
2008 means	40.5	42.0	41.9	44.6	44.3	46.3	47.0	47.3	46.4	45.6	45.1	44.0	44.6
Difference	-2.4	-0.5	-2.0	-0.2	-1.2	-1.3	-2.7	-1.1	-2.1	-2.3	-1.2	-0.1	-1.4

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Max. temp. (°F)													
Long-term mean	68.8	68.6	67.7	68.7	71.5	73.7	76.4	76.3	73.5	72.9	72.2	70.3	71.7
2008	67.8	66.7	69.5	69.1	70.1	73.3	73.7	74.7	71.7	73.2	72.1	67.4	70.8
Difference	-0.9	-2.0	1.8	0.3	-1.4	-0.4	-2.6	-1.6	-1.8	0.3	-0.1	-2.9	-1.0
Ave. temp. (°F)													
Long-term mean	54.5	54.3	54.7	55.6	57.9	60.0	62.6	61.5	59.8	59.1	57.8	55.6	57.8
2008	52.6	53.1	55.1	56.3	56.8	59.6	59.4	60.2	58.0	58.4	57.4	54.6	56.8
Difference	-2.0	-1.2	0.5	0.7	-1.2	-0.4	-3.2	-1.3	-1.8	-0.7	-0.4	-1.0	-1.0
Pali 2 (2000-2008) RAWS Park: HAVO Elev. 2,780 ft. (856 m)													
Precipitation (in)													
Long-term mean	9.7	4.4	9.5	1.3	1.6	0.4	0.7	2.1	2.1	5.9	9.5	5.5	52.7
2008	0.0	40.3	NA	5.8	0.4	0.5	2.4	0.1	0.6	1.1	5.7	17.4	NA
Difference	0%	918%	NA	448%	25%	128%	353%	3%	29%	18%	60%	317%	NA
Min. temp. (°F)													
Long-term mean	56.9	56.3	57.3	58.1	59.3	60.6	62.4	63.0	62.7	61.8	60.7	58.2	59.8
2008 means	56.1	55.4	NA	57.5	57.6	59.4	60.8	61.7	60.6	60.4	59.2	57.6	NA
Difference	-0.8	-0.9	NA	-0.6	-1.8	-1.2	-1.5	-1.3	-2.1	-1.5	-1.5	-0.6	NA
Max. temp. (°F)													
Long-term mean	71.6	71.6	71.4	72.9	75.5	77.4	80.0	79.7	78.5	76.7	74.9	72.4	75.2
2008	70.9	68.7	NA	72.6	72.4	74.7	76.0	78.8	75.7	76.3	74.5	69.6	NA
Difference	-0.7	-3.0	NA	-0.3	-3.1	-2.7	-4.1	-0.9	-2.8	-0.4	-0.4	-2.8	NA
Ave. temp. (°F)													
Long-term mean	63.0	62.6	63.3	64.1	66.2	67.7	69.8	69.9	69.1	67.8	66.6	64.0	66.2
2008	62.0	61.2	NA	63.7	63.7	65.8	67.1	68.6	66.8	66.5	65.3	62.4	NA
Difference	-1.1	-1.4	NA	-0.4	-2.5	-1.9	-2.8	-1.2	-2.3	-1.3	-1.3	-1.6	NA

Hawaii Vol NP HQ 54 (COOP)

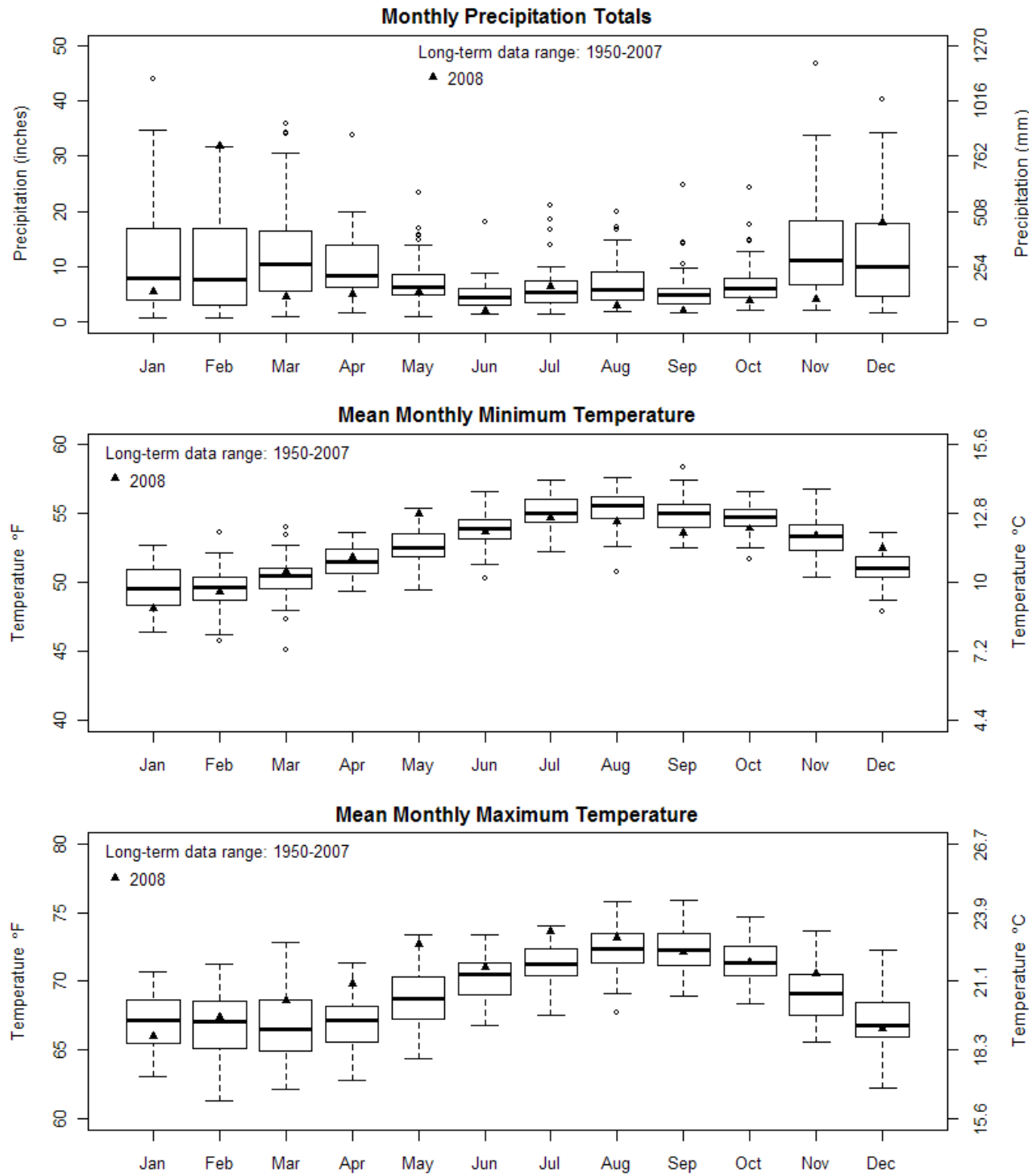


Figure 6. Boxplots of precipitation and temperature data for Hawaii Vol NP HQ 54 (COOP). To facilitate a better scale the precipitation graph omits two outliers: 54 inches (Feb.) and 70 inches (March).

Kahuku Mill Camp 6.3 (COOP)

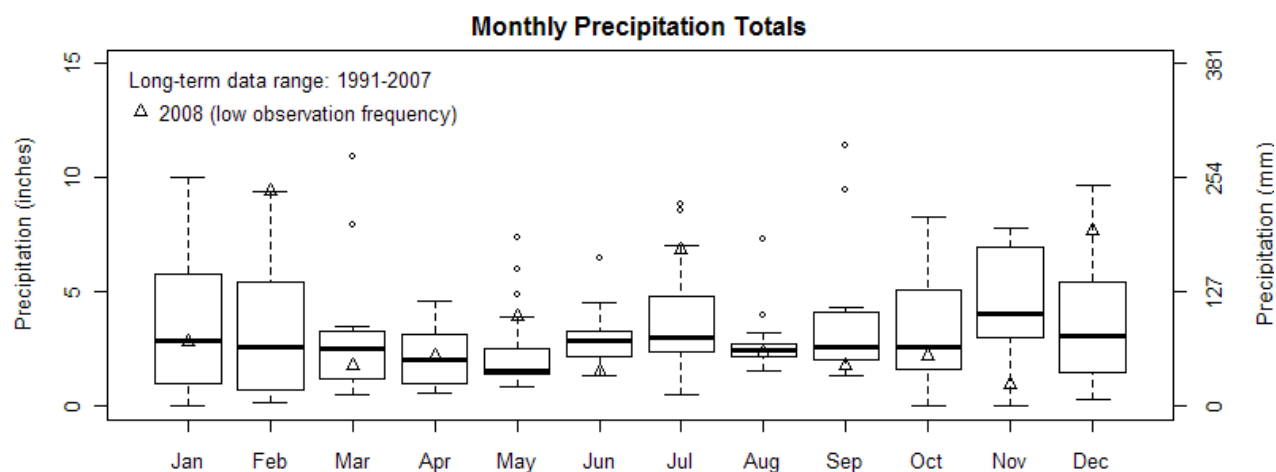


Figure 7. Boxplot of precipitation data for Kahuku Mill Camp 6.3 (COOP). To facilitate a better scale three outliers are omitted, 18 inches (March), 18 and 19 inches (November). Note that all data, long-term and 2008 data, are based on low observation frequencies.

Kealakomo 38.8 (COOP)

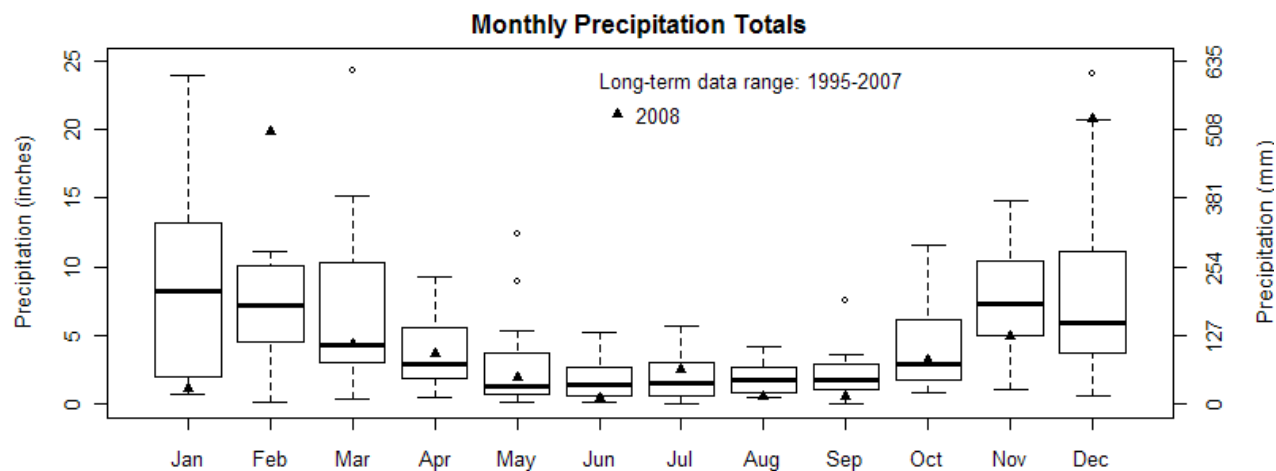


Figure 8. Boxplot of precipitation data for Kealakomo 38.8 (COOP). To facilitate a better scale the plot does not show one outlier at 32 inches for March.

Mauka Reservoir 3.11 (COOP)

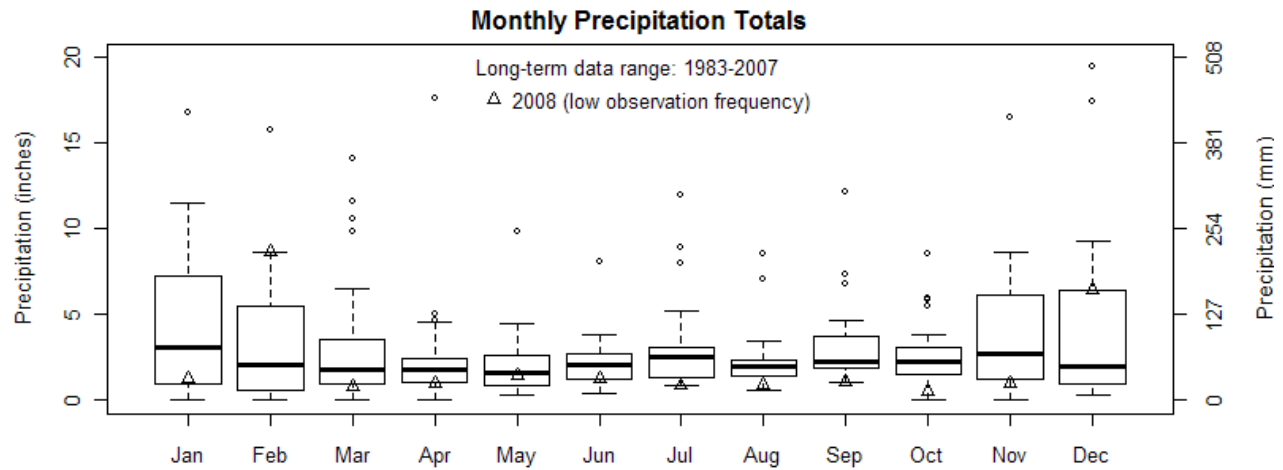


Figure 9. Boxplot of precipitation data for Mauka Reservoir 3.11 (COOP). Note that all data, long-term and 2008 data, are based on low observation frequencies.

Mauna Loa Slope Obs 39 (COOP)

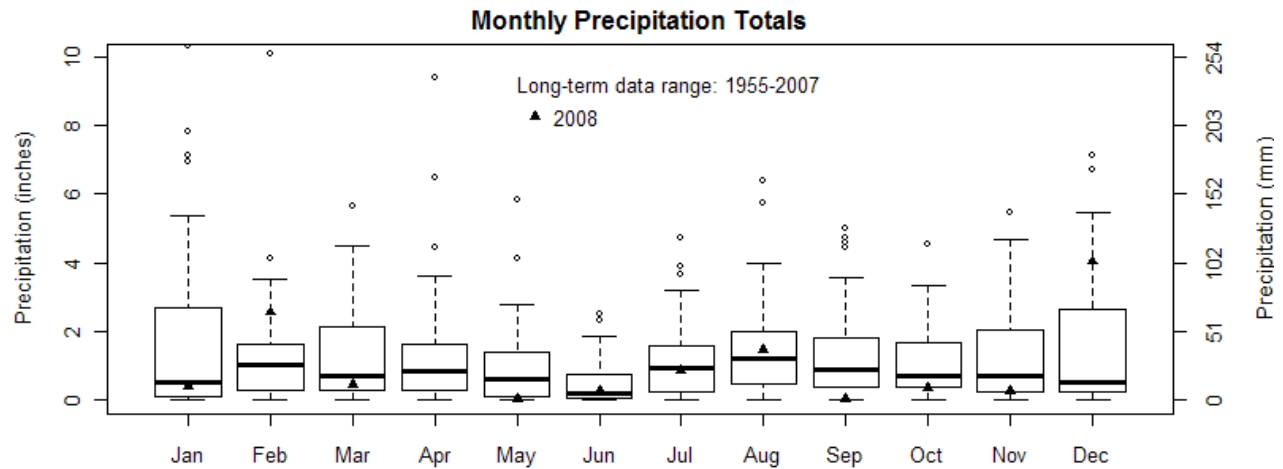


Figure 10. Boxplot of precipitation data for Mauna Loa Slope Obs 39 (COOP). Note that one outlier just over 10 inches is cut off by the frame of the graph and 2 outliers are not shown: 12 (Jan), 17 (Dec). Missing symbols for any month in 2008 indicate missing data.

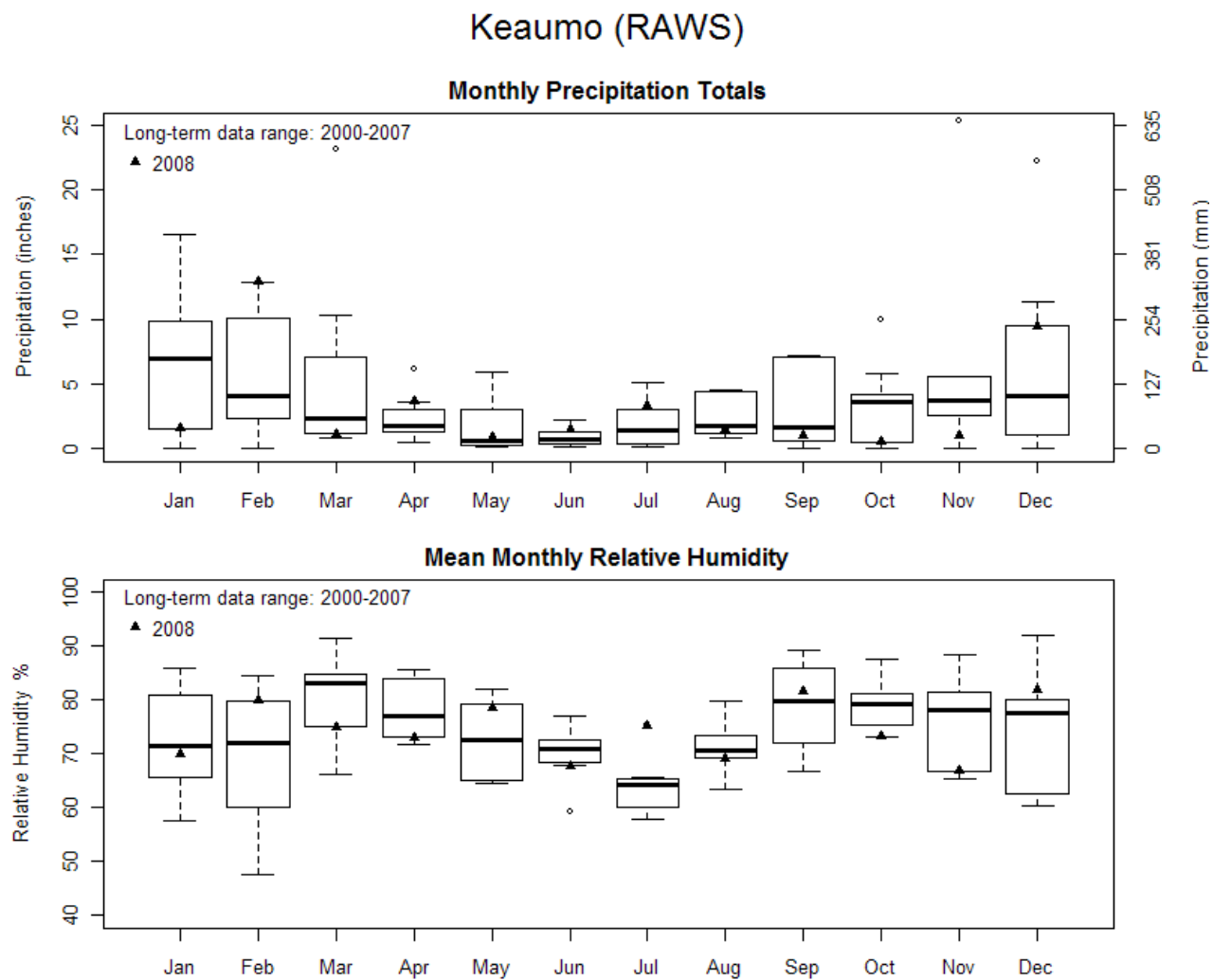


Figure 11. Boxplots of precipitation and relative humidity data for Keaumo (RAWS). To facilitate a better scale the plot does not show one outlier at 36 inches for November.

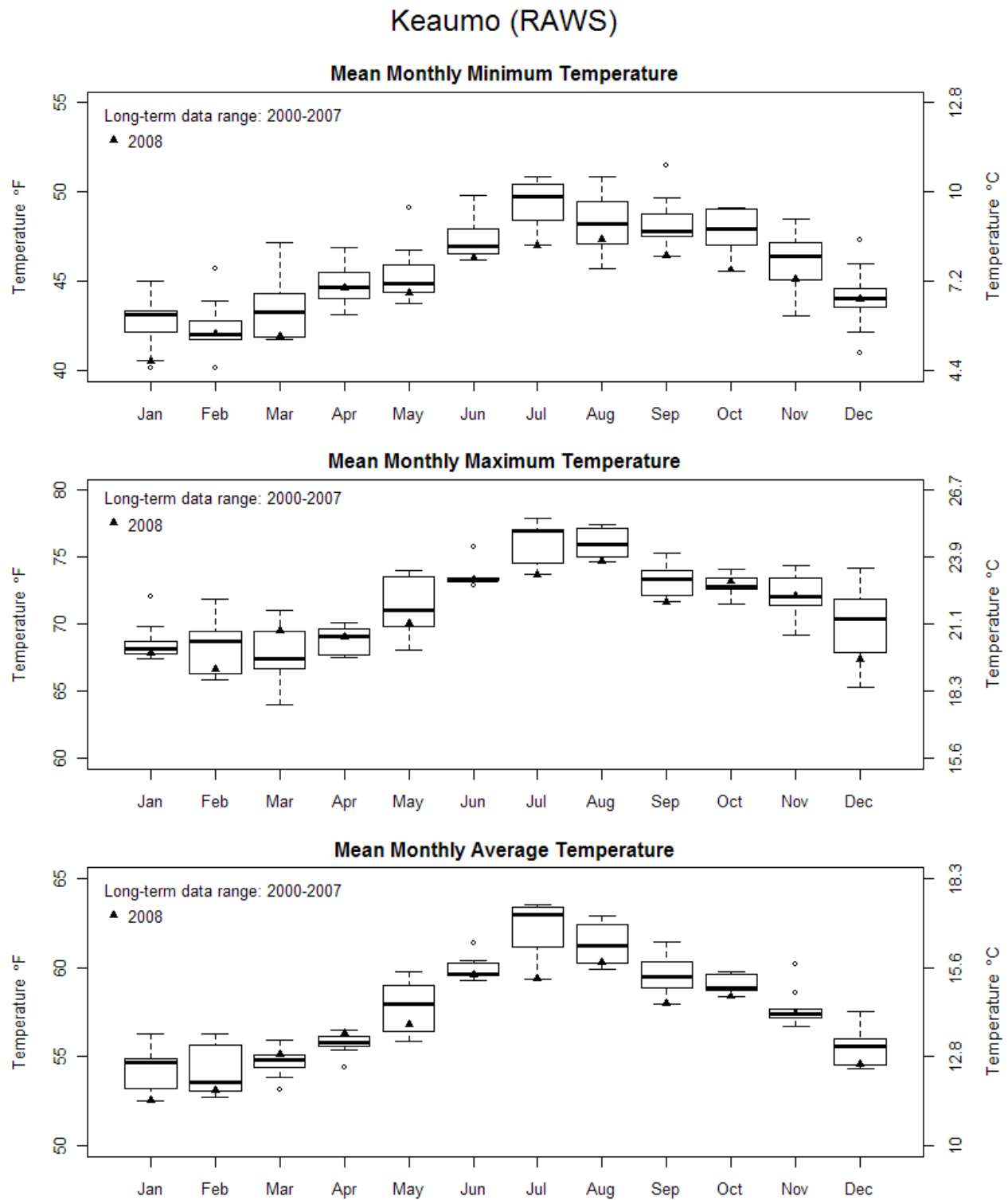


Figure 12. Boxplots of temperature data for Keaumo (RAWS).

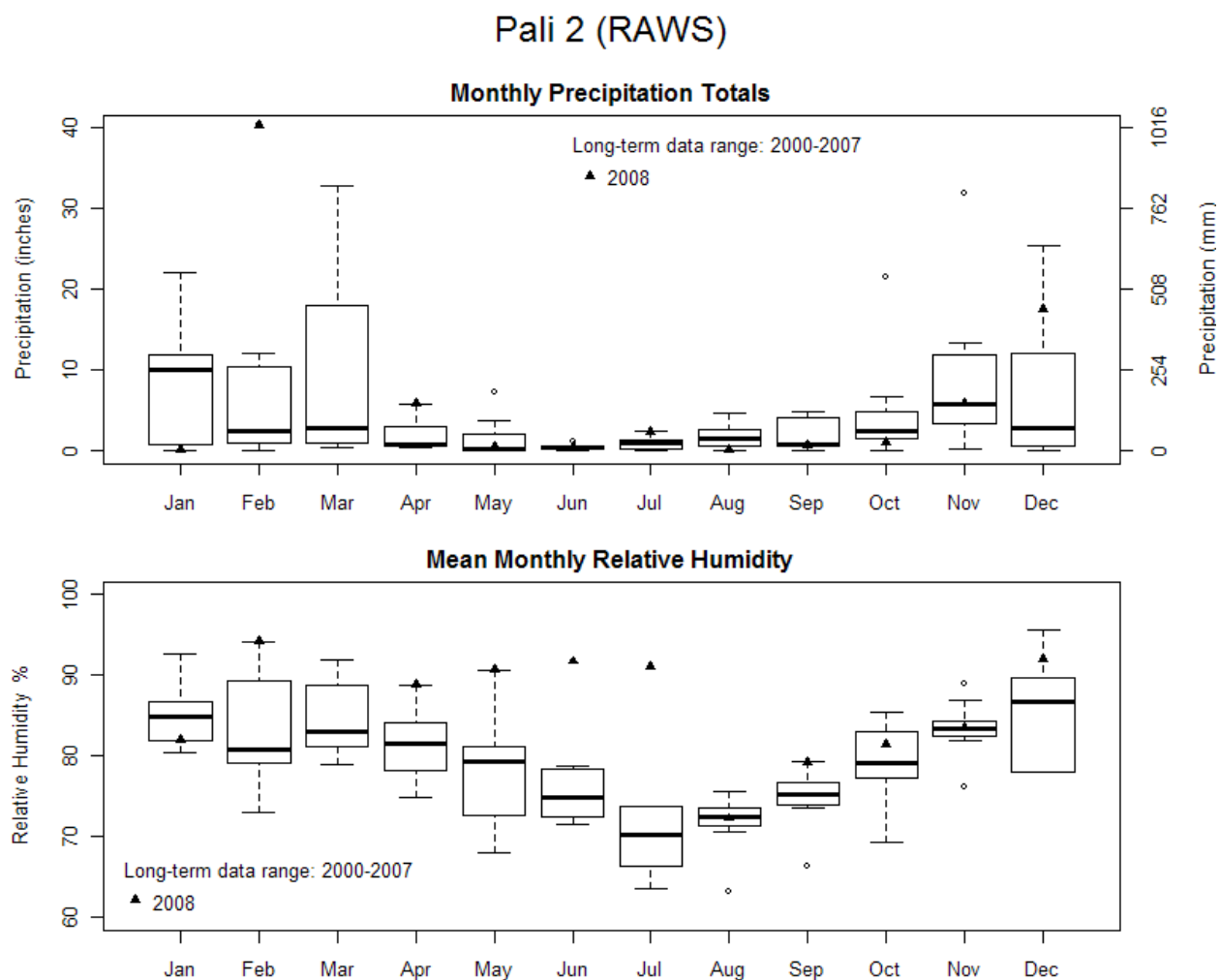


Figure 13. Boxplots of precipitation and relative humidity data for Pali 2 (RAWS). Note that the 2008 datapoint for February covers an outlier with the same value. Missing symbols for any month in 2008 indicate missing data.

Pali 2 (RAWS)

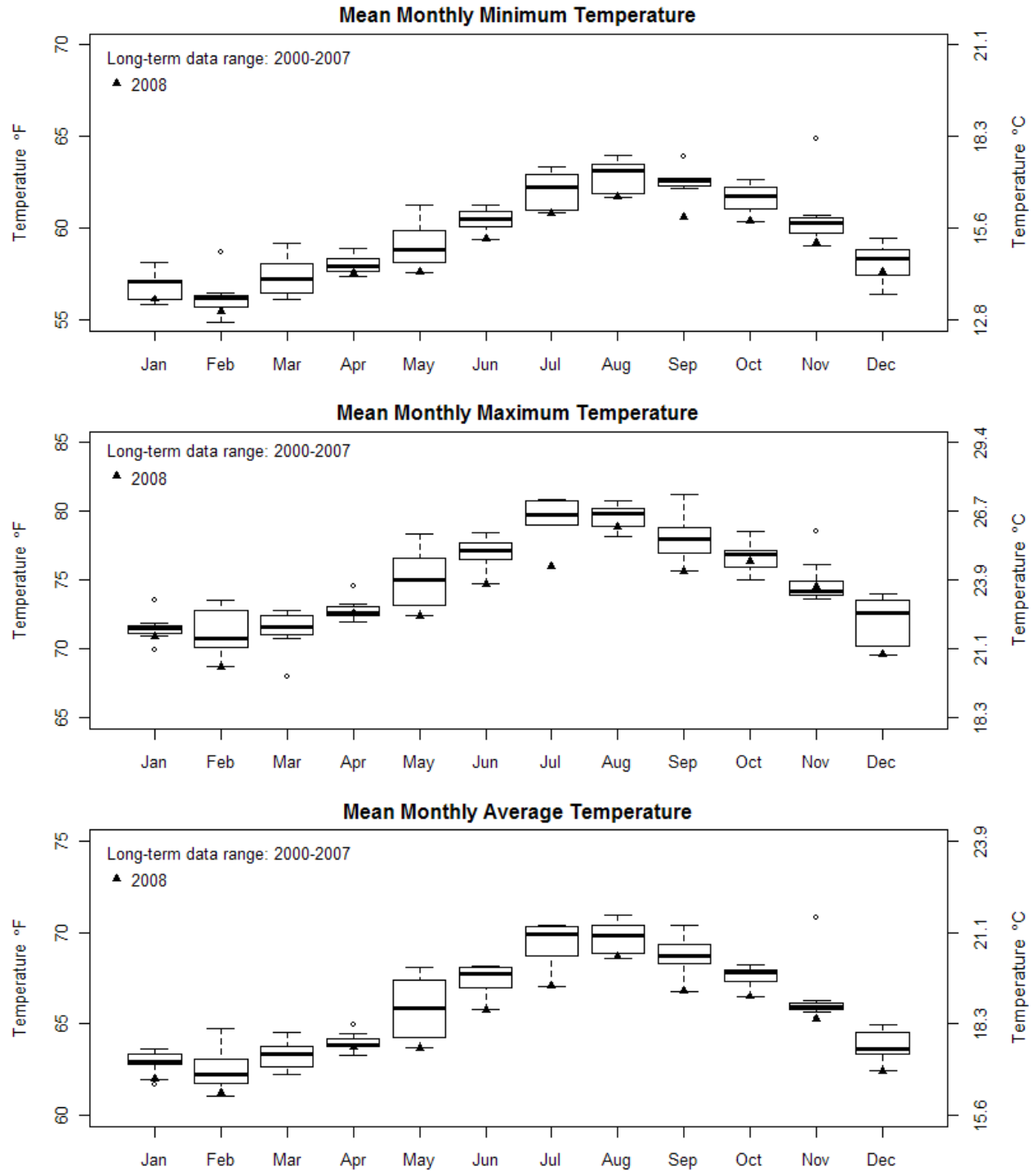


Figure 14. Boxplots of temperature data for Pali 2 (RAWS). Missing symbols for any month in 2008 indicate missing data.

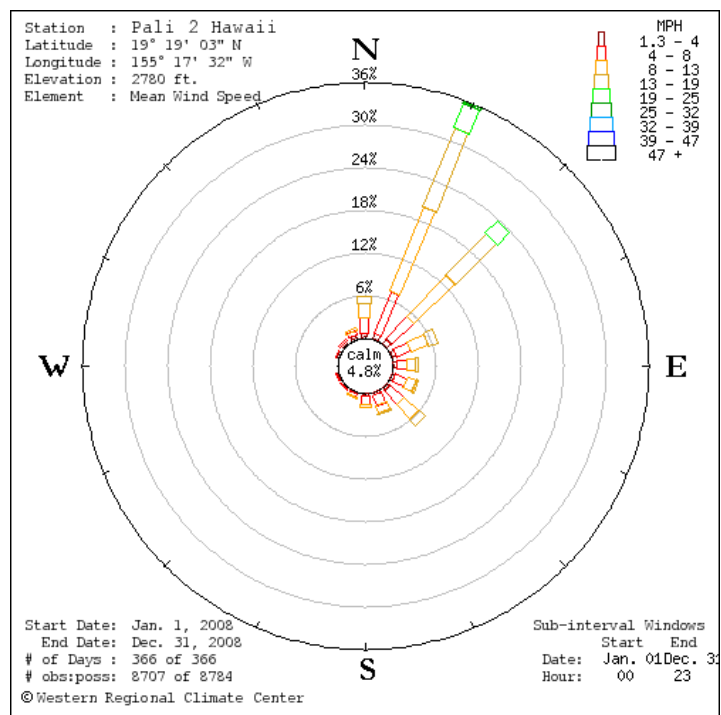


Figure 15. Wind Rose Graph of 2008 data for Pali 2 (RAWS).

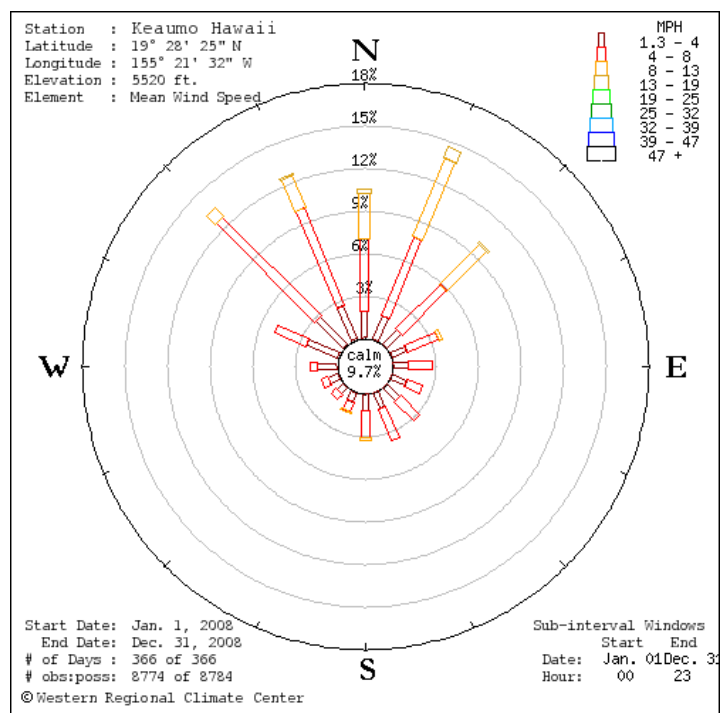


Figure 16. Wind Rose Graph of 2008 data for Keaumo (RAWS).

Kaloko-Honokōhau and Pu‘uhonua o Hōnaunau National Historical Parks and Pu‘ukoholā Heiau National Historic Site,

Table 4 and Figures 17-19 provide precipitation, temperature and relative humidity data for the three west Hawai‘i national parks. The COOP stations at PUHE and KAHO only record precipitation. Puuhonuaohonaunau 27.4 had low observation frequencies (<85%) for several months in 2008. 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 17. 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.

Comparisons of 2008 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. A comparison of the precipitation data from this RAWS with the COOP station in the same park shows that there is a discrepancy between these data. During the 10 months with sufficient data for both stations, the COOP station reported more than twice the rainfall recorded by the RAWS for four months (January, April, September, November) and in July four times the rainfall. Given that the stations are only separated by about 2,700 ft, in an area with a uniform weather pattern, this seems unlikely. Based on the Honokohau-Harbor COOP data, the rainy season which lasts from May to September on this part of the island was unusually wet. Wind graphics (Figure 20, Appendix A) from the KAHO RAWS show highly variable wind directions, and demonstrate that this area is sheltered by the high mountains from the northeast trade winds persistent in these latitudes.

Further north, Pu‘ukoholā Heiau had an unusually wet July, December rainfall near normal, and substantially reduced rainfall for all other months with sufficient data. Both minimum and maximum temperatures were below normal for all but one month, with maximum temperatures showing higher negative anomalies.

Table 4. Comparison of precipitation and temperature data from 2008 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 2 years!) for the RAWS.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Honokohau Harbor 68.14 (1991-2008) 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
2008	0.70	1.08	NA	1.65	1.67	3.70	4.70	1.19	2.29	1.42	0.40	NA	NA
% Normal	33%	138%	NA	75%	217%	336%	461%	106%	153%	97%	56%	NA	NA
Puuhonuaohonaunau 27.4 (1971-2008) 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
2008	0.00	NA	0.40	NA	NA	NA	NA	1.26	NA	0.72	0.73	2.75	NA
% Normal	0%	NA	22%	NA	NA	NA	NA	49%	NA	29%	48%	174%	NA
Puukohola Heiau 98.1 (1977-2008) 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
2008	NA	0.40	0.00	0.37	0.00	NA	0.57	0.04	0.02	0.00	0.25	1.79	NA
Difference	NA	34%	0%	26%	0%	NA	158%	8%	3%	0%	25%	92%	NA
Min. temp. (°F)	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
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
2008 means	NA	64.0	65.4	65.9	67.5	68.3	69.7	70.0	69.2	69.2	67.6	65.6	NA
Difference	NA	-0.1	0.0	-1.0	-0.3	-0.9	-0.6	-0.9	-1.3	-1.2	-0.8	-0.4	NA
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
2008	NA	77.0	78.4	79.7	80.4	80.4	82.0	82.5	81.5	81.2	79.7	78.0	NA
Difference	NA	-1.7	-2.0	-1.8	-1.6	-2.8	-1.8	-2.2	-3.2	-2.5	-1.4	-1.4	NA
Kaloko-Honokohau (2006-2008) RAWS Park: KAHO Elev. 25 ft. (7.6 m)													
Precipitation (in)													
Long-term mean (2 years only)	0.6	2.3	1.7	0.1	1.4	0.8	3.2	0.1	3.0	2.7	1.2	4.5	21.5
2008	0.3	0.8	0.7	0.7	1.2	2.7	1.2	1.2	1.1	1.4	0.2	2.6	13.9
Difference	52%	36%	39%	592%	88%	357%	36%	1170%	36%	52%	14%	57%	65%
Min. temp. (°F)													
Long-term mean	67.6	65.6	68.2	67.8	69.2	71.2	71.9	72.6	72.1	71.4	69.8	68.0	69.6
2008 means	65.1	66.3	68.7	69.4	69.3	71.2	71.4	71.5	70.7	71.2	69.2	67.6	69.3
Difference	-2.5	0.7	0.5	1.5	0.0	0.0	-0.5	-1.1	-1.4	-0.1	-0.6	-0.3	-0.3
Max. temp. (°F)													
Long-term mean	82.7	81.7	82.0	82.7	82.8	84.4	85.2	86.0	84.9	85.7	84.9	82.8	83.8
2008	81.3	80.9	82.1	82.6	81.9	83.0	84.5	85.1	84.5	84.6	83.7	84.8	83.3
Difference	-1.5	-0.8	0.1	-0.2	-0.9	-1.4	-0.7	-0.9	-0.4	-1.1	-1.3	2.0	-0.6
Ave. temp. (°F)													
Long-term mean	75.2	73.8	75.0	75.8	76.3	78.2	78.9	79.7	78.8	78.5	77.2	75.3	76.9
2008	73.3	73.6	75.5	76.1	75.9	77.4	78.4	78.7	77.9	78.0	76.4	76.2	76.4
Difference	-1.9	-0.2	0.5	0.3	-0.4	-0.8	-0.5	-0.9	-0.9	-0.5	-0.7	0.9	-0.4

Puuhonuaohonaunau 27.4 (COOP)

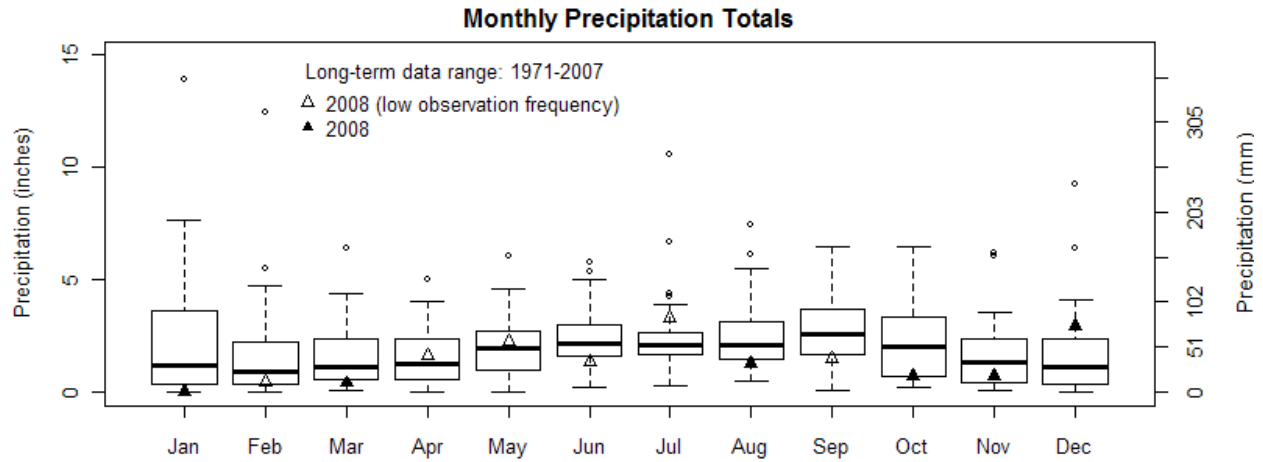


Figure 17. Boxplot of precipitation data for Puuhonuaohonaunau 27.4 (COOP). Note that to facilitate a better scale the boxplot does not show one outlier with 19 inches for April.

Honokohau Harbor 68.14 (COOP)

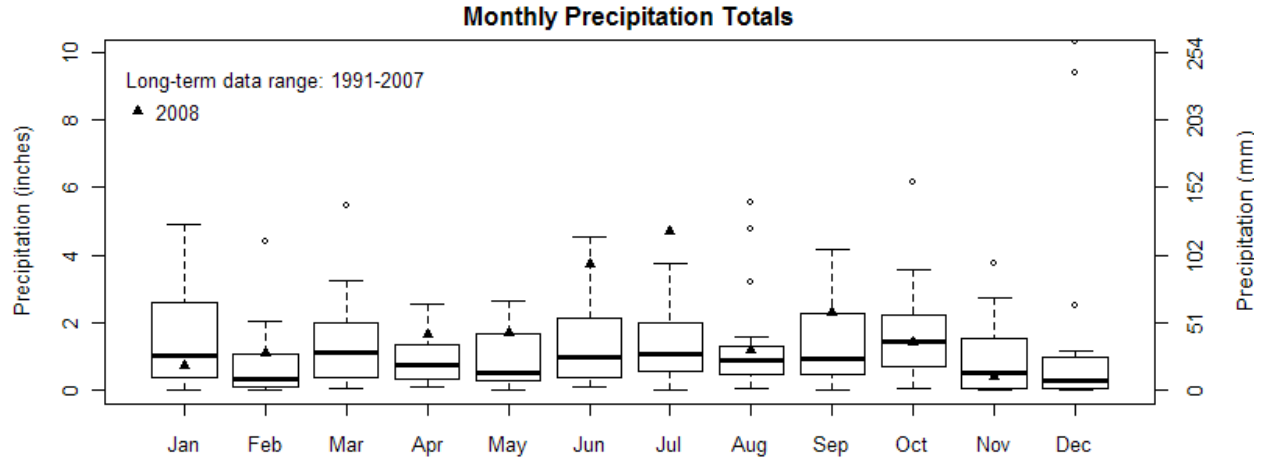


Figure 18. Boxplot of precipitation data for Honokohau Harbor 68.14 (COOP). Missing symbols for any month in 2008 indicate missing data.

Puukohola Heiau 98.1 (COOP)

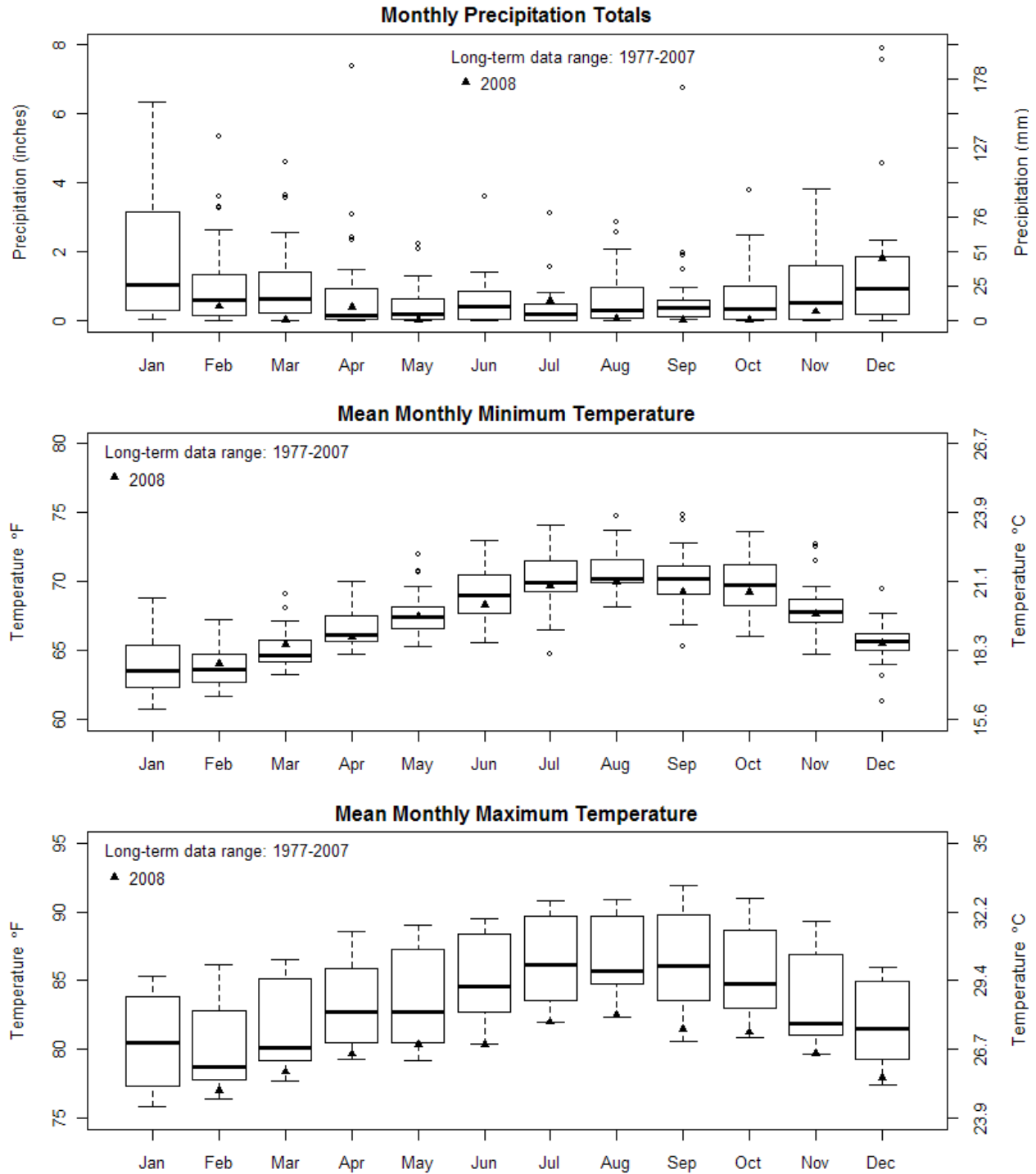


Figure 19. Boxplots of precipitation and temperature data for Puukohola Heiau 98.1 (COOP). To facilitate a better scale the boxplot does not show one outlier of 10 inches for December. Missing symbols for any month in 2008 indicate missing data.

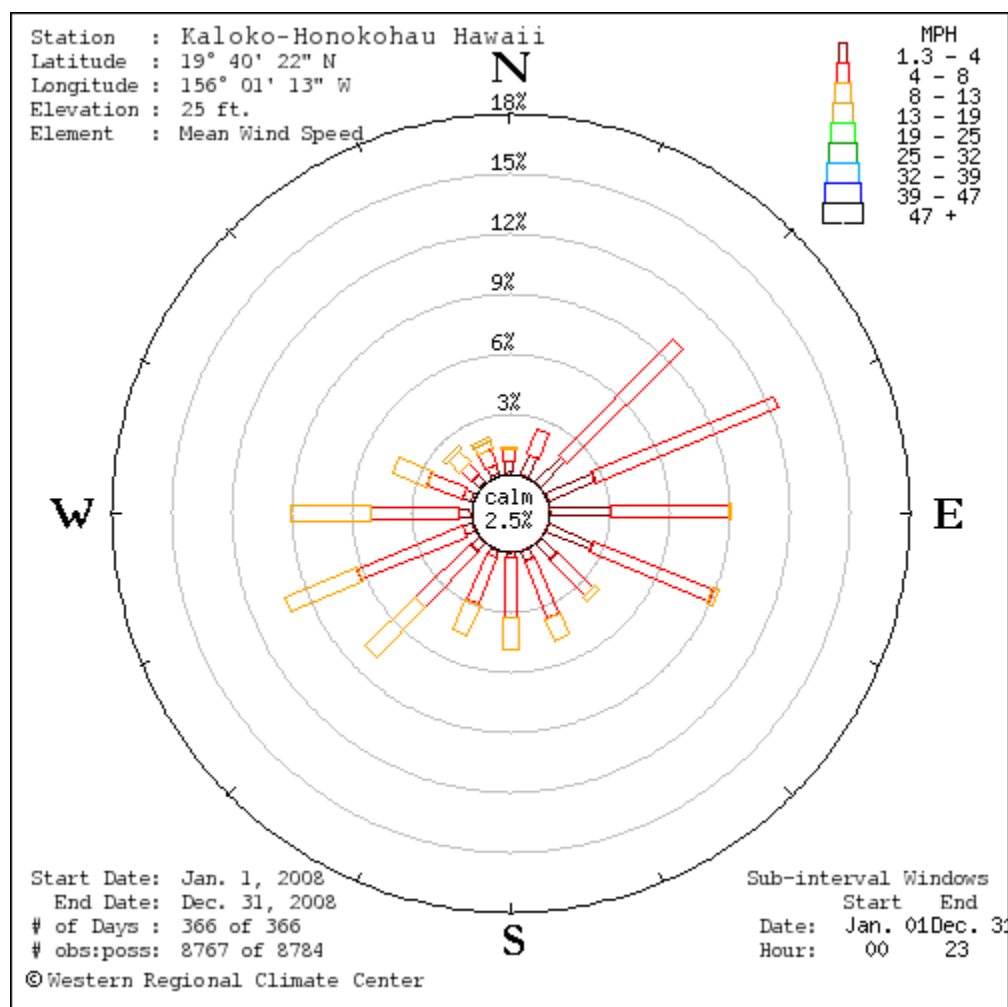


Figure 20. Wind Rose Graph of 2008 data for Kaloko-Honokohau (RAWS).

Kalaupapa National Historical Park

Table 5 and Figures 21-23 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 months in 2008. 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. In addition to the earlier mentioned February storm and prolonged December rains, Moloka‘i experienced a couple of intense rain events in November, raising that month’s rain total. Highest negative temperature anomalies were seen in the summer. Wind graphics (Figure 24, 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 5. Comparison of precipitation and temperature data from 2008 with long-term records for stations at Kalaupapa National Historical Park. For the COOP station 2008 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
2008	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Makapulapai (1994-2008)					RAWS		Park: KALA			Elev. 75 ft. (22.9 m)		
Precipitation (in)													
Long-term mean	4.59	1.81	7.17	1.68	1.75	0.86	0.94	1.38	1.14	1.79	4.74	3.30	31.14
2008	1.39	NA	NA	1.20	NA	0.32	0.58	0.91	0.86	NA	4.52	5.07	NA
% Normal	30%	NA	NA	72%	NA	37%	62%	66%	76%	NA	95%	154%	NA
Min. temp. (°F)													
Long-term mean	67.7	67.8	68.2	70.1	71.7	74.0	74.6	74.8	75.6	73.9	71.5	70.1	71.7
2008 means	67.5	67.2	68.7	68.4	NA	71.5	73.1	73.1	72.8	NA	69.8	68.9	NA
Difference	-0.2	-0.6	0.5	-1.6	NA	-2.5	-1.5	-1.7	-2.9	NA	-1.7	-1.2	NA
Max. temp. (°F)													
Long-term mean	79.4	78.2	78.6	79.5	82.2	84.1	84.8	85.8	87.6	84.0	81.3	80.0	82.1
2008	77.1	78.8	80.3	79.9	NA	82.8	84.6	84.2	84.4	NA	80.4	78.4	NA
Difference	-2.2	0.6	1.7	0.4	NA	-1.3	-0.2	-1.5	-3.2	NA	-0.8	-1.5	NA
Ave. temp. (°F)													
Long-term mean	73.2	72.7	73.1	74.3	76.6	78.6	79.1	79.8	81.3	78.4	76.0	74.7	76.5
2008	71.9	72.8	74.1	73.8	NA	76.9	78.5	78.2	78.0	NA	74.7	73.3	NA
Difference	-1.2	0.1	1.0	-0.5	NA	-1.6	-0.7	-1.6	-3.3	NA	-1.3	-1.4	NA

Kalaupapa 563 (COOP)

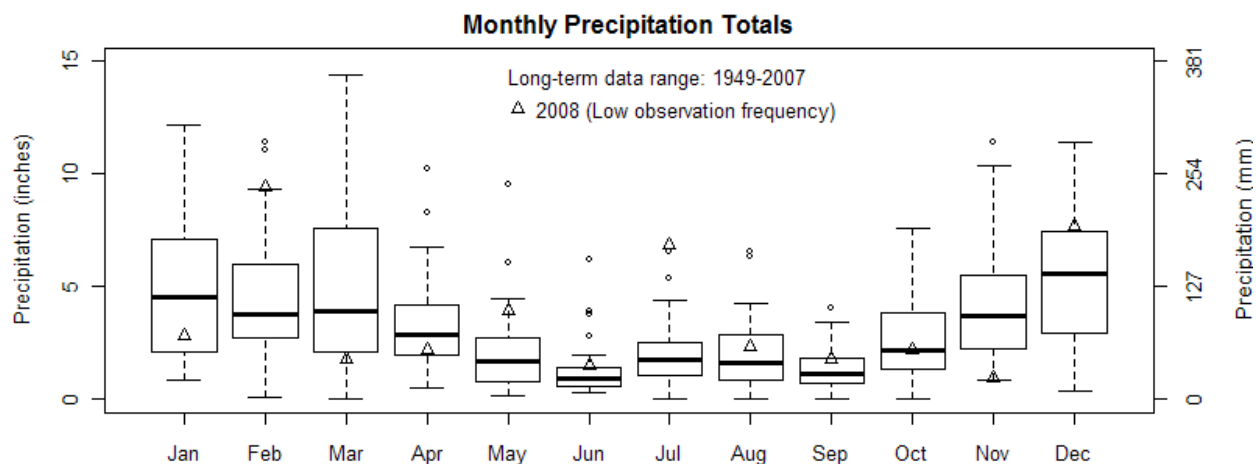


Figure 21. Boxplots of precipitation data for Kalaupapa 563 (COOP). To facilitate a better scale the boxplot does not show the following three outliers: 21 inches for March and 16 and 20 inches for November. All months in 2008 had low observation frequencies; also note that throughout the long-term record of the station for any individual month approximately 50% of the years had low observation frequencies thus the variability shown in this graph reflects only half the station record.

Makapulapai (RAWS)

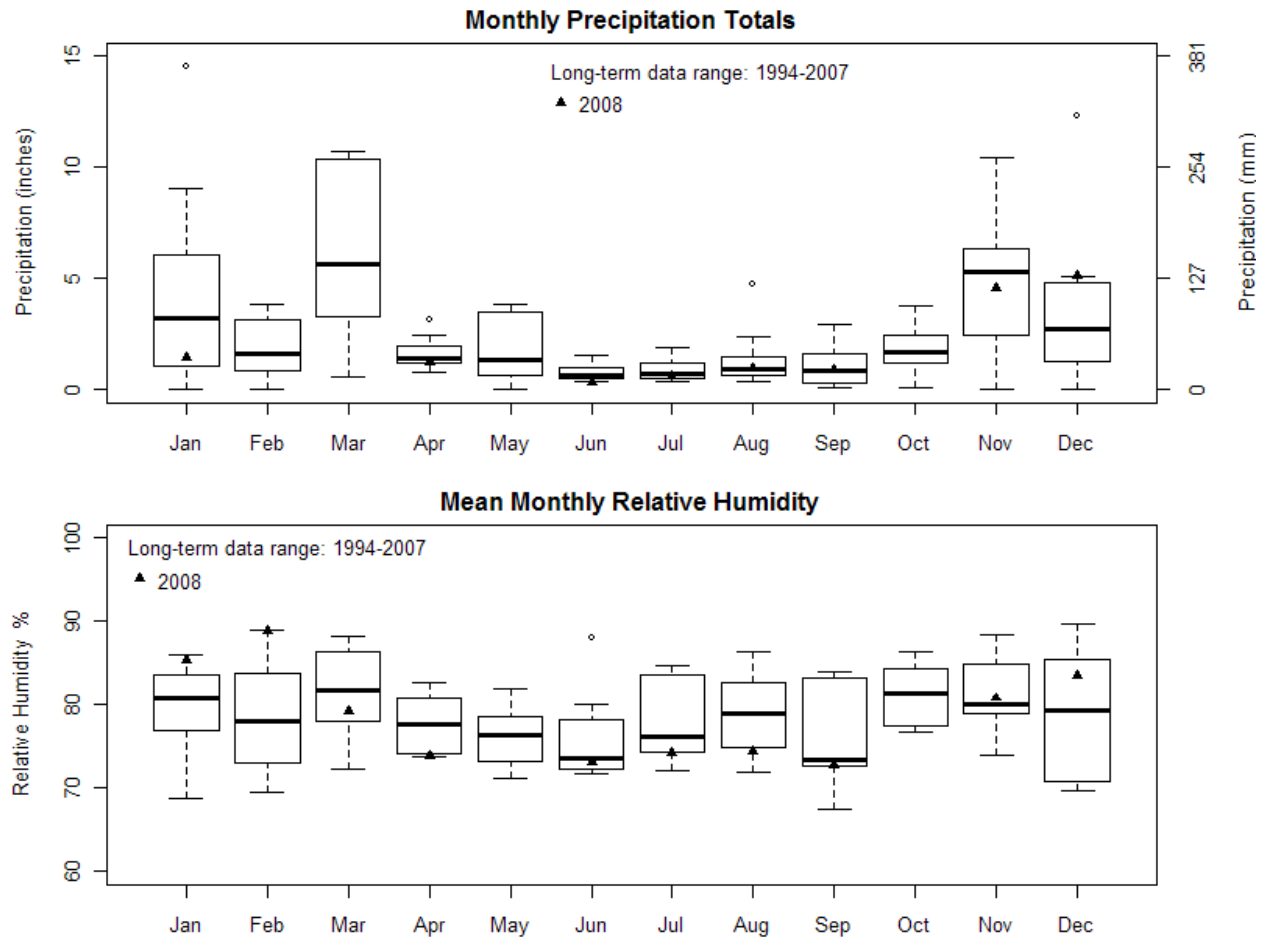


Figure 22. Boxplots of precipitation and relative humidity data for Makapulapai (RAWS). One outlier of 23 inches for March is not shown. Missing values for any month in 2008 indicate missing data.

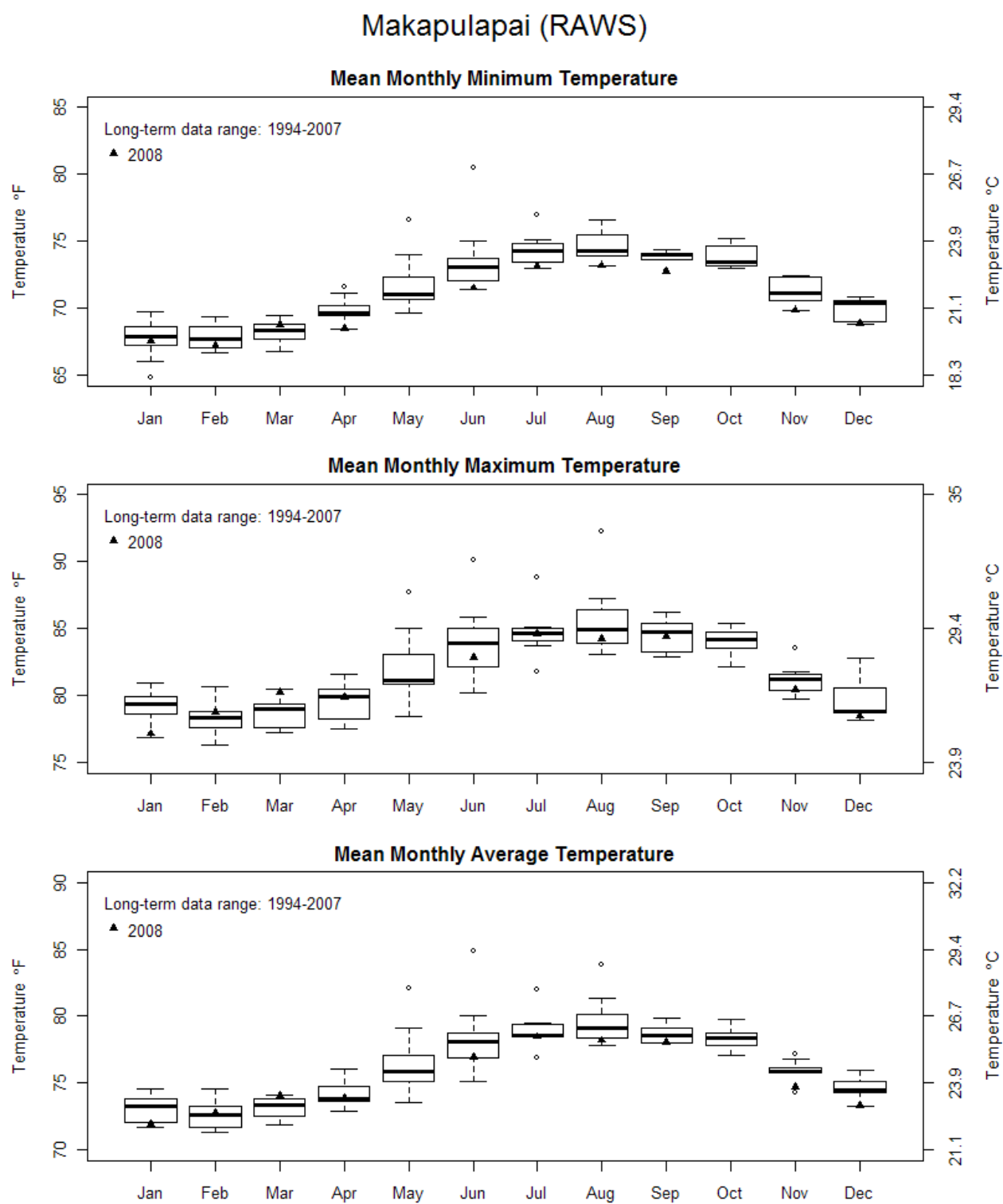


Figure 23. Boxplots of temperature data for Makapulapai (RAWS). Missing symbols for any month in 2008 indicate missing data.

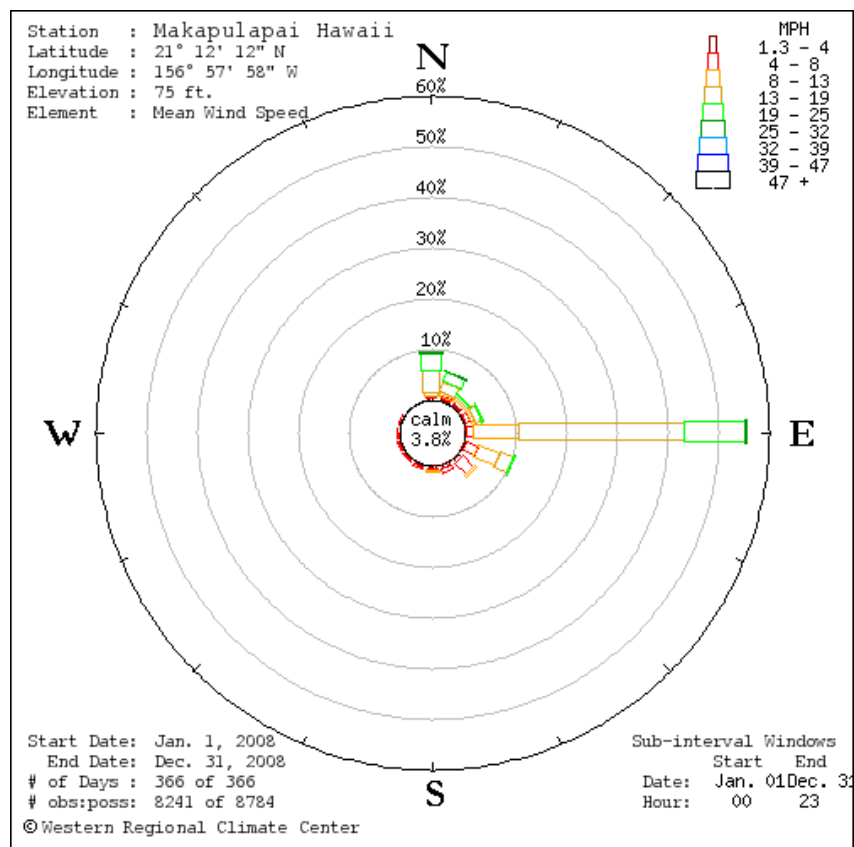


Figure 24. Wind Rose Graph of 2008 data for Makapulapai (RAWS).

Haleakalā National Park

Table 6 and Figures 25-28 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 February 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 July at Kaupo Gap, whereas both the summit and Oheo had above normal precipitation in August. Prolonged December rains are recorded at all three stations, but the Kaupo Gap area received exceptionally high rainfall. As on the other islands, temperature anomalies were negative for most of the year except for the spring.

Figure 29 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 6. Comparison of precipitation and temperature data from 2008 with long-term records for stations at Haleakalā National Park. 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 (1949-2008)					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
2008	8.31	2.86	0.08	0.81	0.98	0.27	2.29	4.26	0.74	0.78	4.21	10.21	35.80
% Normal	91%	46%	1%	16%	56%	19%	97%	205%	33%	28%	78%	173%	67%
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
2008	40.7	NA	NA	44.3	NA	NA	47.4	47.0	45.3	NA	46.8	45.6	NA
Difference	-1.34	NA	NA	1.71	NA	NA	-0.27	-0.83	-1.54	NA	0.86	2.11	NA
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
2008	55.8	NA	NA	61.7	NA	NA	64.0	64.7	63.1	NA	63.6	60.8	NA
Difference	-4.17	NA	NA	1.55	NA	NA	-1.47	-1.38	-1.65	NA	0.42	-0.38	NA
	Oheo (1998-2008 (T))					COOP	Park: HALE			Elev. 120 ft. (36.6 m)			
Precipitation (in)													
1971-2000 normal	7.79	5.67	8.49	7.01	5.05	5.43	6.96	6.83	6.41	7.84	8.75	7.11	83.34
2008	11.07	12.97	3.55	2.53	2.76	5.39	5.47	9.13	3.61	5.96	2.48	13.79	78.71
% Normal	142%	229%	42%	36%	55%	99%	79%	134%	56%	76%	28%	194%	94%
Min. temp. (°F)													
Long-term mean	67.5	67.3	67.7	67.9	69.6	70.8	71.6	72.3	72.0	71.7	70.2	69.1	69.8
2008	65.4	65.8	NA	67.4	67.6	69.3	70.8	71.0	71.0	70.2	70.0	69.0	NA
Difference	-2.0	-1.5	NA	-0.6	-2.0	-1.5	-0.8	-1.4	-1.0	-1.5	-0.3	-0.1	NA
Max. temp. (°F)													
Long-term mean	78.5	78.0	78.5	78.3	80.3	81.1	81.8	82.6	82.6	82.3	80.9	79.4	80.4
2008	77.3	77.1	NA	80.9	81.7	80.7	82.3	81.8	81.9	82.2	81.1	79.7	NA
Difference	-1.2	-0.9	NA	2.5	1.4	-0.4	0.6	-0.8	-0.8	-0.1	0.3	0.3	NA

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
	Kaupo Gap (1991-2008)				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
2008	6.28	14.08	1.77	0.66	2.09	2.00	1.24	1.47	1.72	2.34	2.41	30.13	66.19
% Normal	52%	248%	15%	16%	109%	161%	127%	63%	55%	46%	46%	728%	114%
Min. temp. (°F)													
Long-term mean	54.0	52.4	54.2	54.6	55.7	57.6	59.3	59.5	59.4	58.8	58.0	55.2	56.6
2008 means	52.0	51.9	52.5	54.1	53.4	55.2	57.2	58.3	56.6	56.5	55.9	54.4	54.8
Difference	-1.9	-0.5	-1.7	-0.5	-2.4	-2.4	-2.1	-1.2	-2.8	-2.4	-2.1	-0.8	-1.7
Max. temp. (°F)													
Long-term mean	67.8	67.4	68.0	69.7	71.8	73.8	76.1	76.4	75.3	74.0	71.9	68.7	71.7
2008	66.5	66.6	70.1	70.5	70.2	72.2	74.3	75.9	73.5	73.4	71.2	69.2	71.1
Difference	-1.3	-0.8	2.0	0.8	-1.5	-1.6	-1.8	-0.5	-1.8	-0.6	-0.7	0.5	-0.6
Ave. temp. (°F)													
Long-term mean	59.9	58.9	60.1	61.1	63.0	64.9	67.0	67.1	66.1	65.2	63.9	60.8	63.2
2008	58.1	58.4	60.0	61.3	60.8	63.1	64.7	65.9	63.8	63.6	62.5	60.5	61.9
Difference	-1.8	-0.5	0.0	0.2	-2.2	-1.8	-2.3	-1.1	-2.3	-1.6	-1.4	-0.4	-1.3

Haleakala RS 338 (COOP)

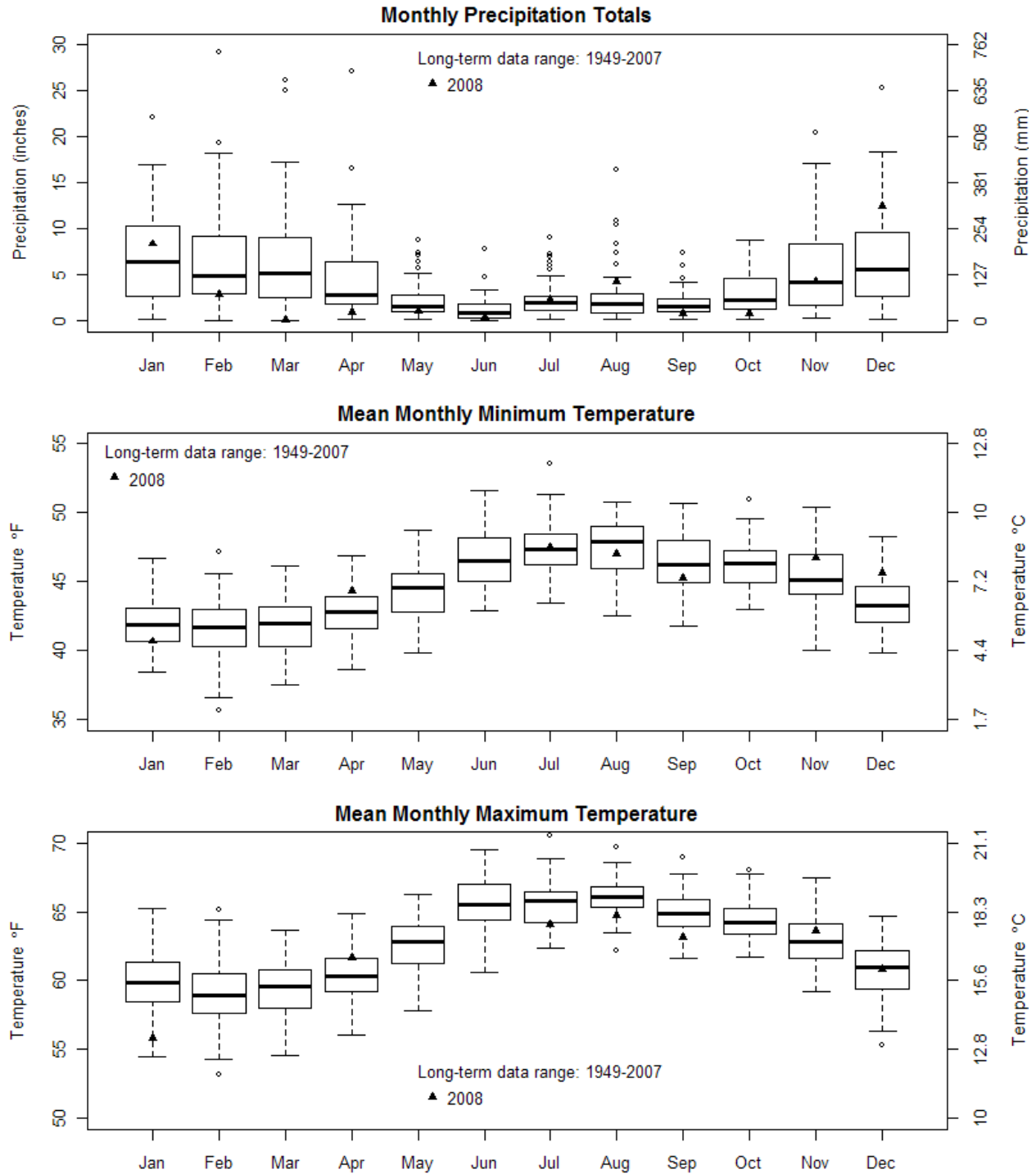


Figure 25. Boxplots of precipitation and temperature data for Haleakala RS (COOP). Missing symbols for any month in 2008 indicate missing data.

Oheo 258.6 (COOP)

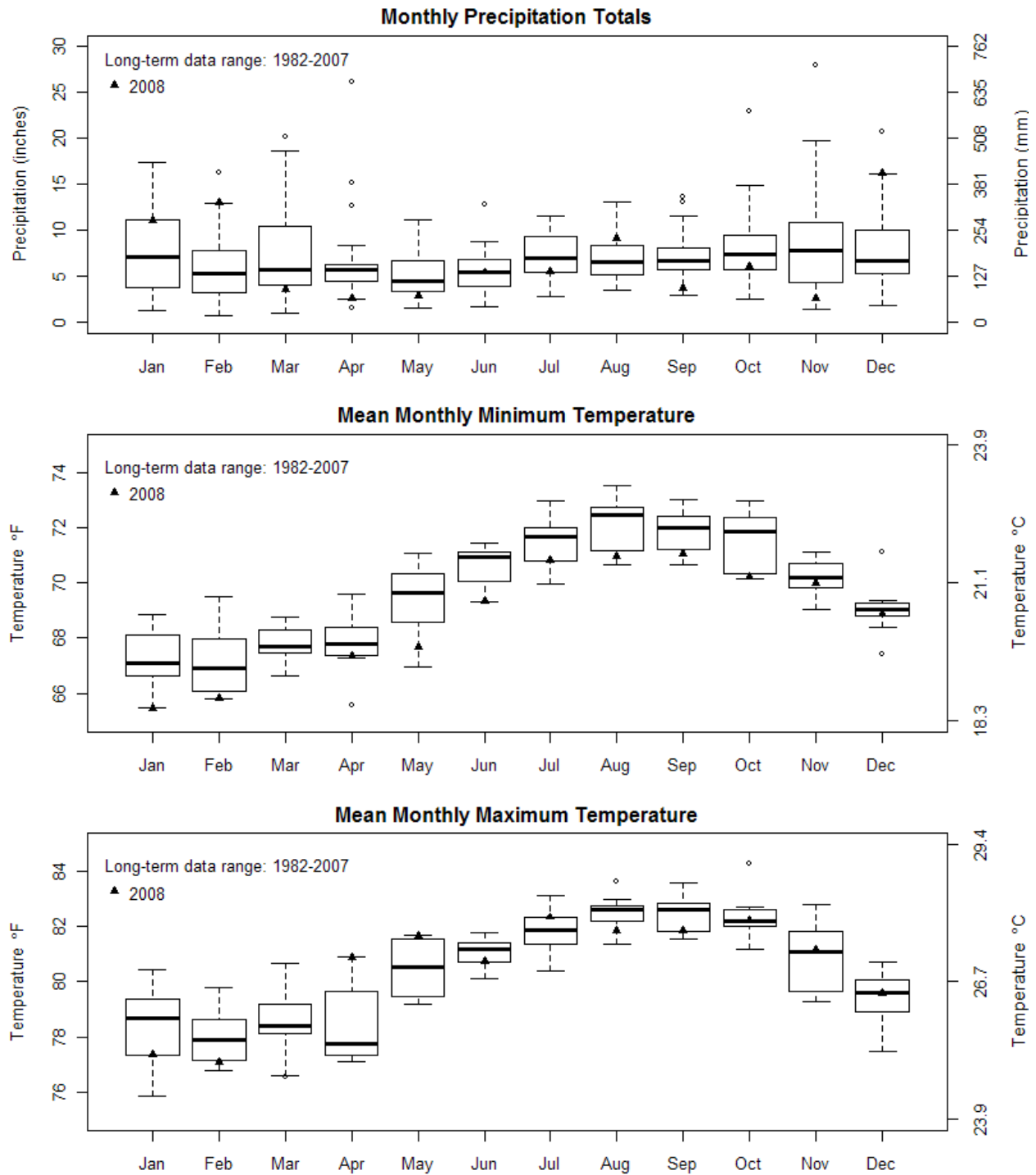


Figure 26. Boxplots of precipitation and temperature data for Oheo 258.6 (COOP).

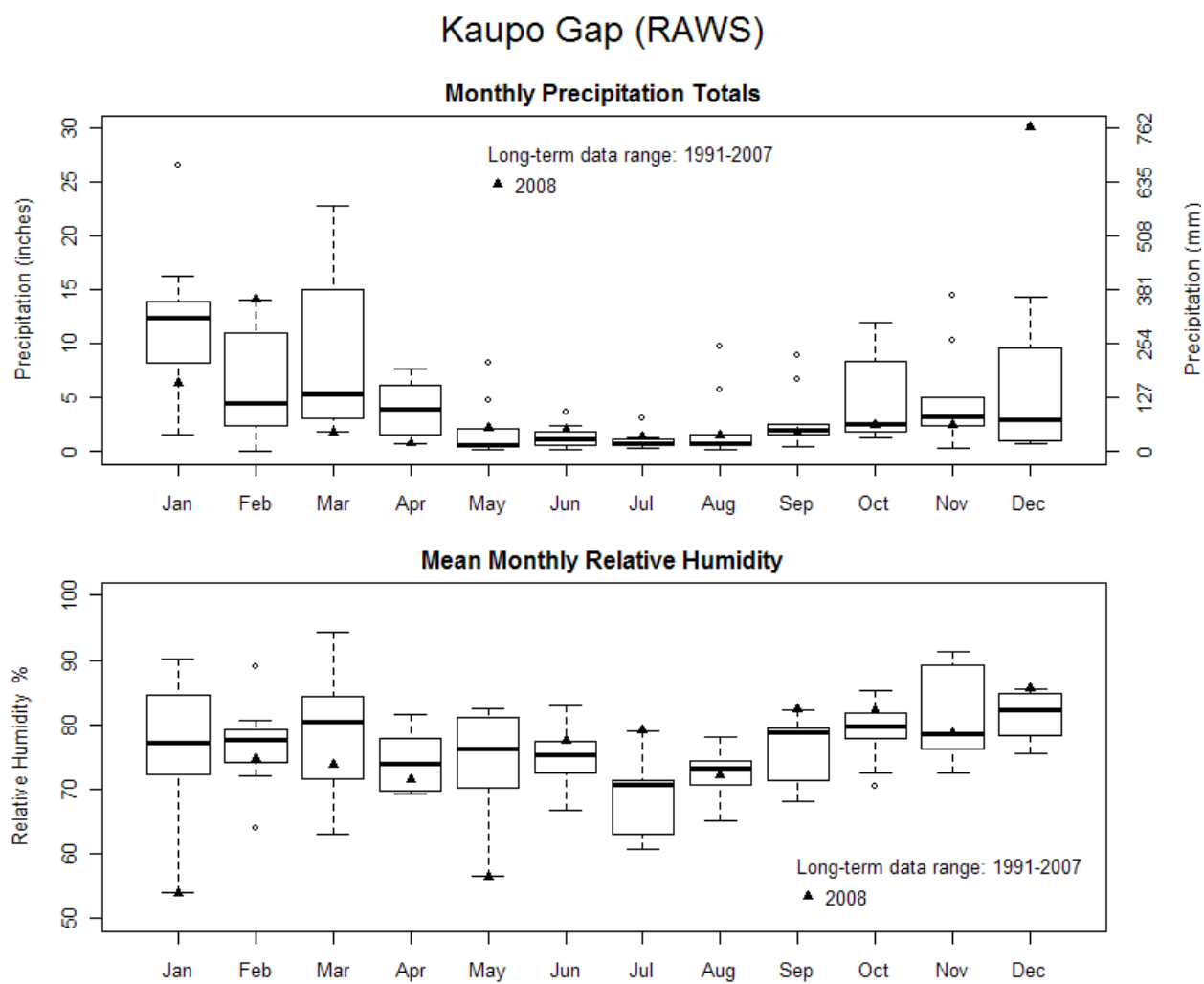


Figure 27. Boxplots of precipitation and relative humidity data for Kaupo Gap (RAWS).

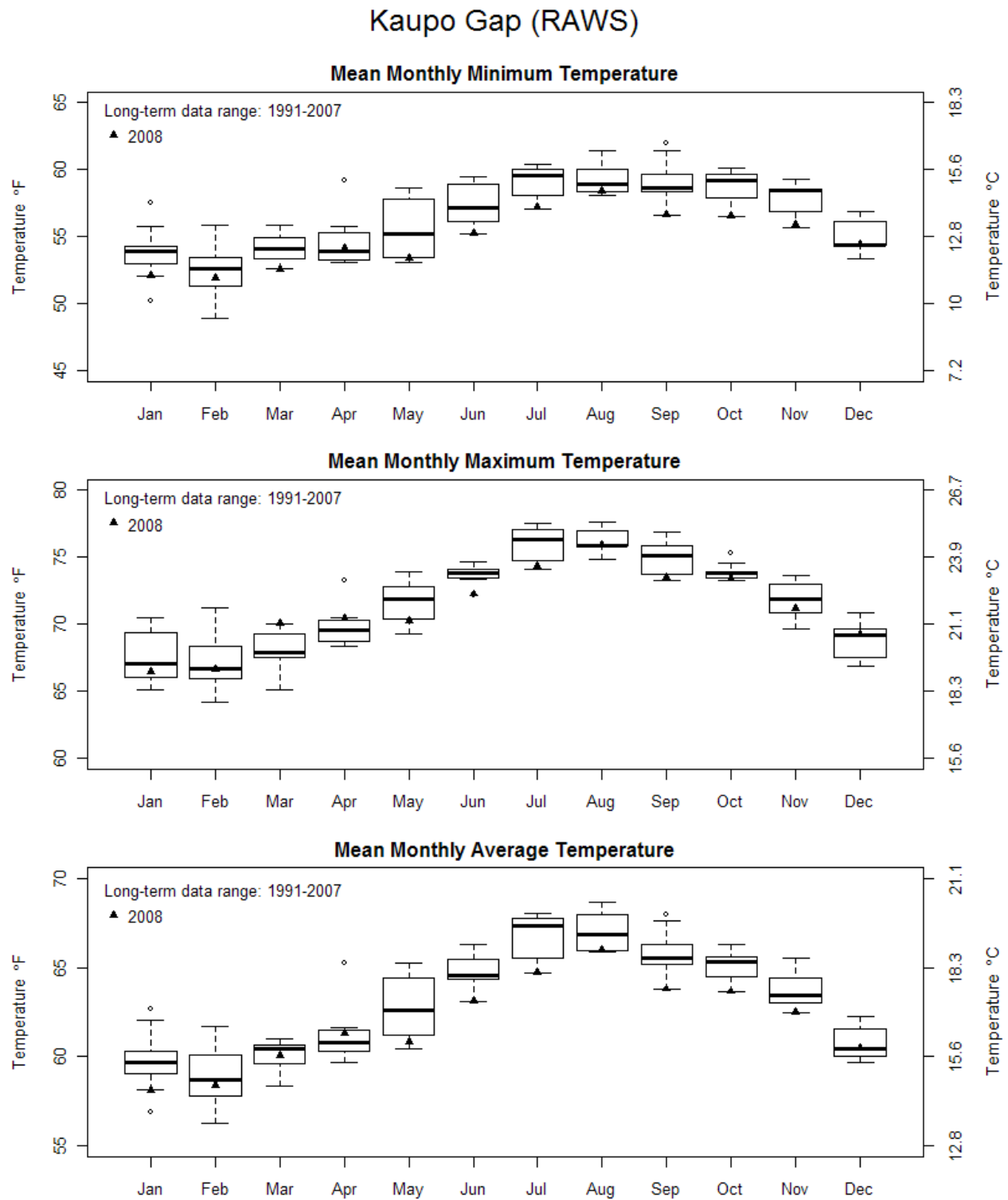


Figure 28. Boxplots of temperature data for Kaupo Gap (RAWS).

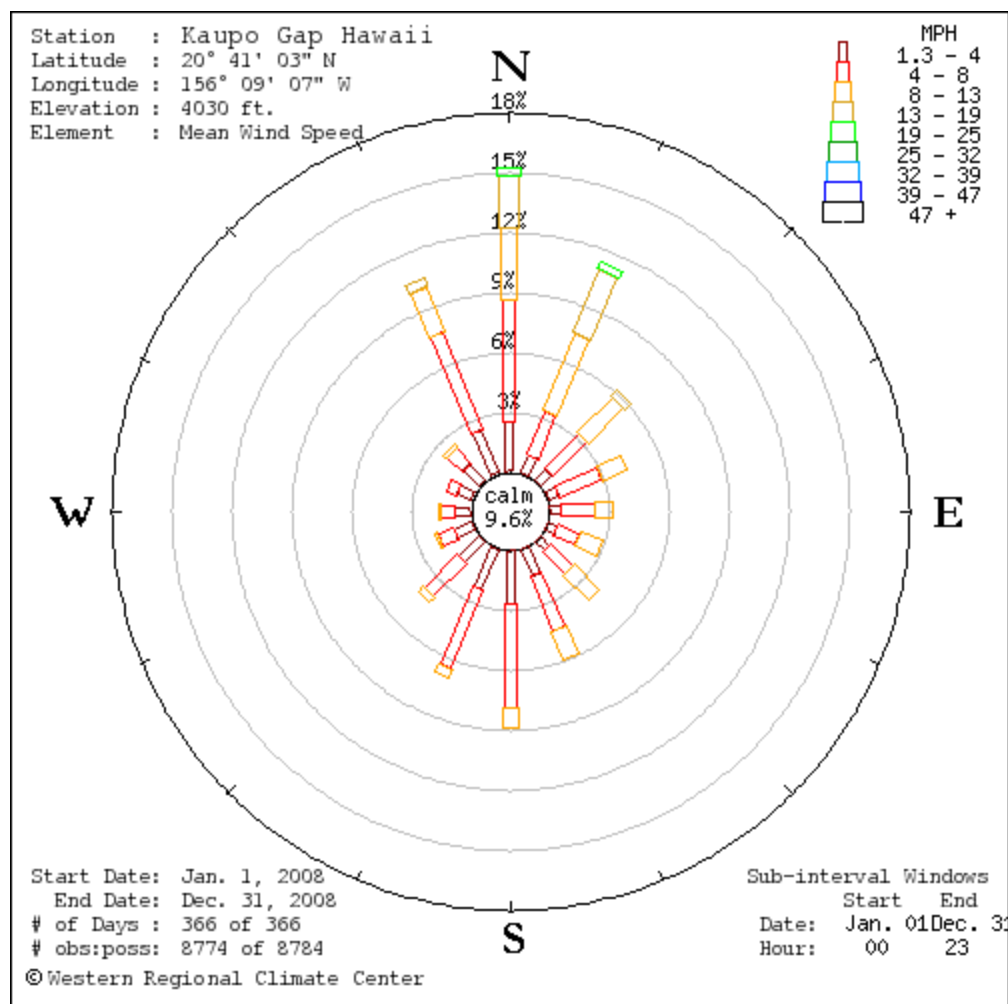


Figure 29. Wind Rose Graph of 2008 data for Kaupo Gap (RAWS).

Hawai'i Drought Conditions

As part of a comprehensive drought monitoring effort between the USDA, NOAA, and the [National Drought Mitigation Center](http://www.drought.unl.edu/)⁶, the [Drought Monitor](http://drought.unl.edu/dm/index.html)⁷ publishes weekly updates of drought conditions in graphics form for all 50 states. The [Hawai'i Drought Monitor](http://hawaii.gov/dlnr/drought/impacts.htm#hawaiidroughtmonitor)⁸, 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 2008 (Figures 30-32). 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 without any drought conditions, but abnormally dry conditions developed in early March throughout much of the state, and drought conditions worsened through the year. December's prolonged rain brought some relief for Niihau, Kauai and Oahu, but all other islands (and national park units on those islands) were still affected by various levels of drought.

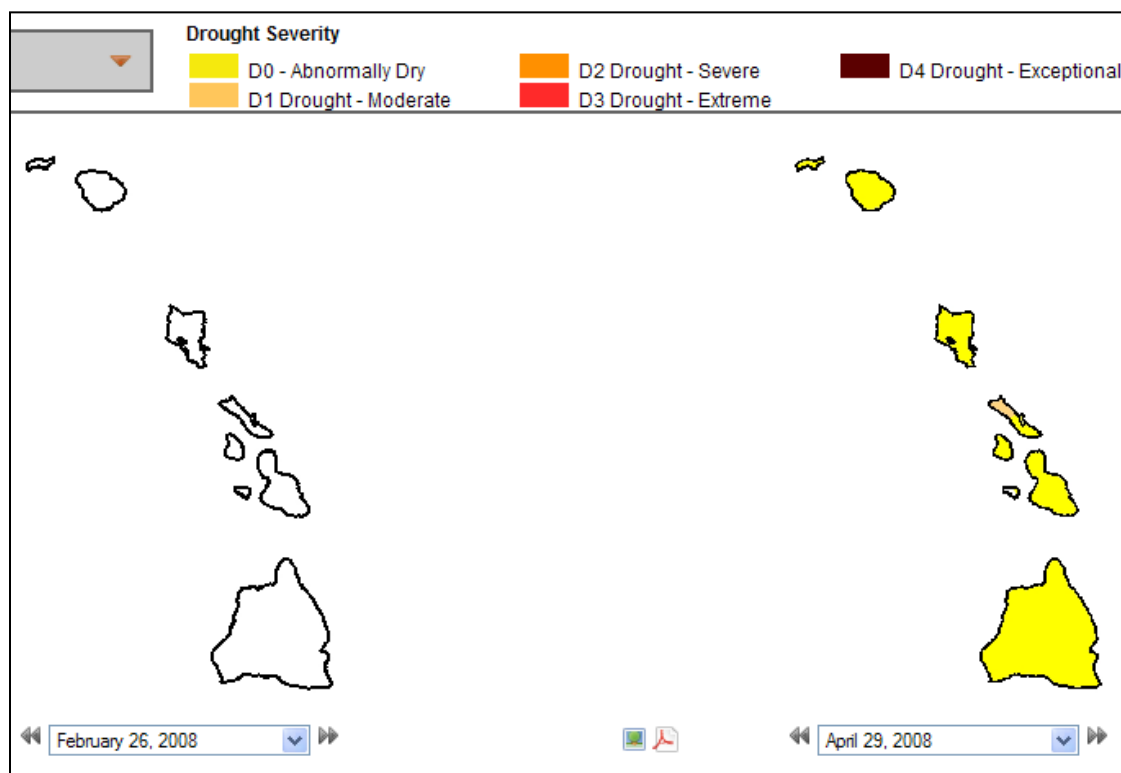


Figure 30. Drought conditions in the State of Hawai'i in late February and late April 2008. Figure reproduced from the Drought Monitor.

⁶ <http://www.drought.unl.edu/>

⁷ <http://drought.unl.edu/dm/index.html>

⁸ <http://hawaii.gov/dlnr/drought/impacts.htm#hawaiidroughtmonitor>

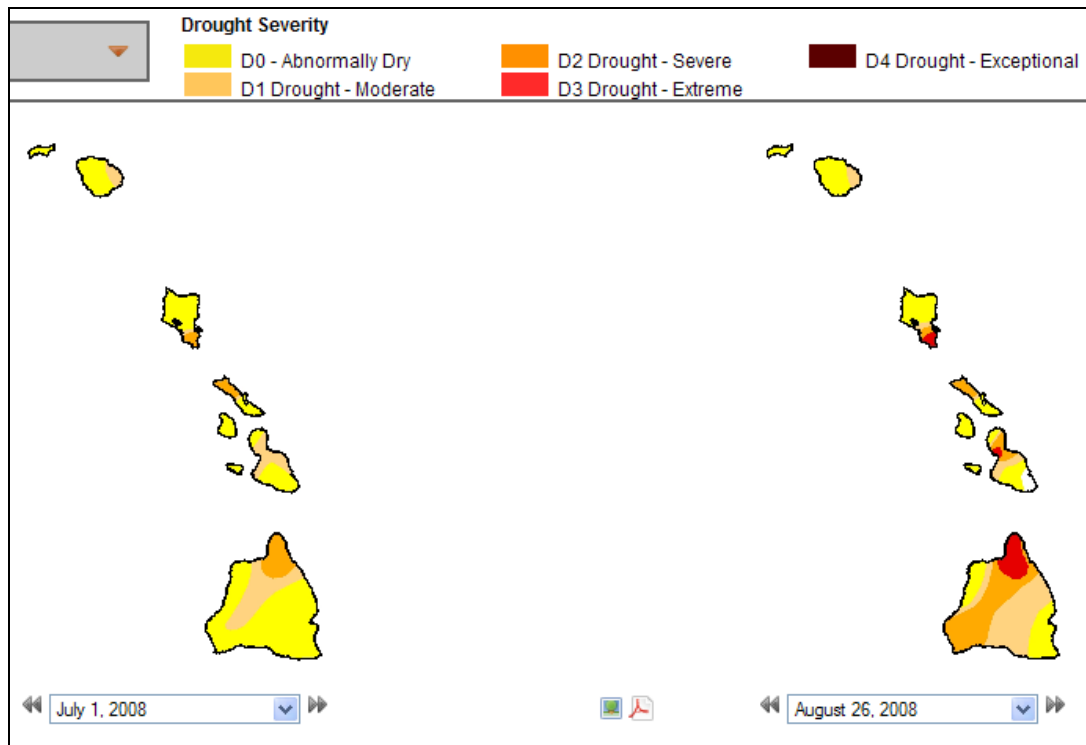


Figure 31. Drought conditions in the State of Hawai'i in early July and late August 2008. Figure reproduced from the Drought Monitor.

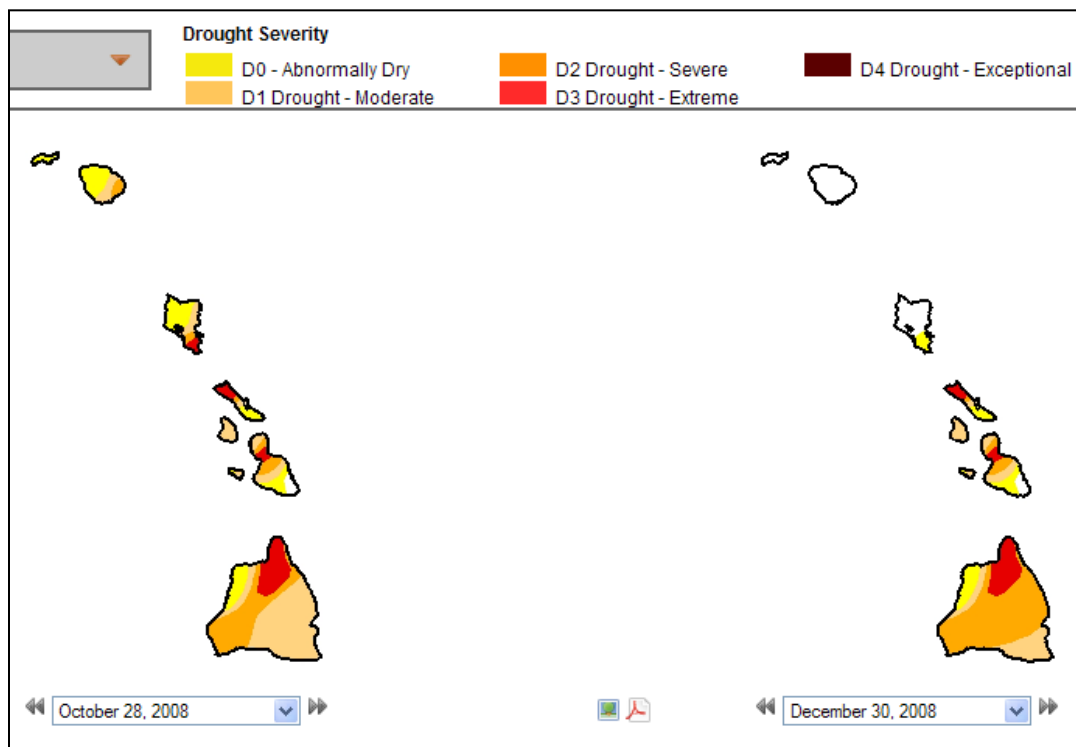


Figure 32. Drought conditions in the State of Hawai'i in late October and late December 2008. Figure reproduced from the Drought Monitor.

Discussion and Recommendations

The boxplots place the 2008 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 influence of the La Niña conditions that were present for the first half of the year. However, not all months at all locations show 'typical' La Niña patterns and conversely some La Niña patterns persisted into the ENSO neutral second half of the year.

Hawai'i La Niña years and especially the winter months tend to be wetter than normal (Ropelewski and Halpert 1989, Chu and Chen 2005). In 2008 many stations in the Hawai'i national parks had annual rainfall totals near or above normal. However, these totals were reached as a result of several short but intense rainfall events during one or two months and prolonged rainfall in December of 2008, while most of the remaining months had rainfall totals below normal showing that overall drought conditions still exist. Winter temperatures in Hawai'i tend to be lower than normal during La Niña winters (Kiladis and van Loon 1988) and that was the case in 2008. In fact, temperature anomalies in Hawai'i were negative for most months despite the shift to ENSO neutral conditions.

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 and variable precipitation in the remaining year at the COOP station near AMME with an overall total for the year near normal. PEAC (2009) reports below normal values (66-86%) for several stations on Guam in 2008.

The first quarter of 2008 was dry for American Samoa, which is typical for La Niña winters (Ropelewski and Halpert 1989, PEAC 2009), while rainfall during the rest of the year was highly variable, with the year's total slightly above normal. Unlike most of the global tropics the area around American Samoa tends to have positive surface temperature anomalies during La Niña years (Halpert and Ropelewski 1992); this was the case for 2008. Because there is a steep ridge bordering NPSA, precipitation throughout the park is likely different than the reported data for Pago Pago.

Data analysis for this report revealed some problems with respect to data coverage, observation frequencies, and possible problems with data collection. Thus the following recommendations are made:

- The PACN weather database should be expanded to include a station on the island of Guam that provides long-term records for precipitation and temperature such as the Guam airport COOP station.

- A number of the COOP stations in the PACN have very low observation frequencies due to the fact that they are manual stations often located in remote areas. The parks should consider upgrading these to automated stations. The initial cost would be offset by the reduced need for station visits and reliable, long-term datasets would make the investment worthwhile.
- Some of the differences in monthly precipitation totals recorded between the KAHO RAWs and the KAHO COOP station are substantial and should be investigated. It is not surprising that the long-term means differ given the vastly different length of station records, but considering the proximity of the stations (see map in Appendix A) the differences between the stations for the 2008 records are disconcerting.

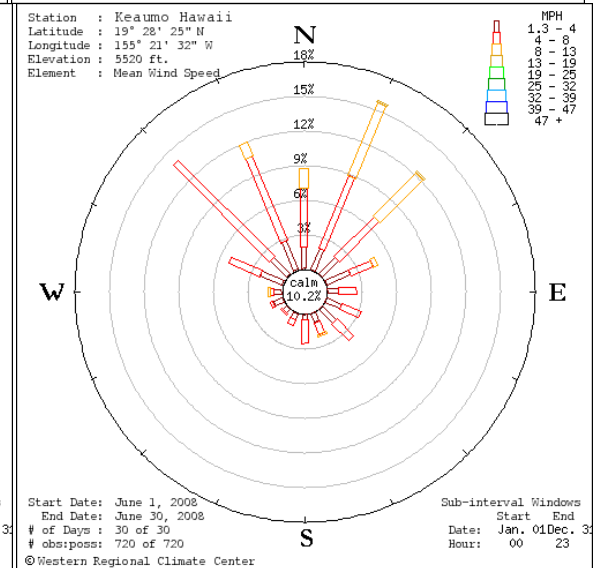
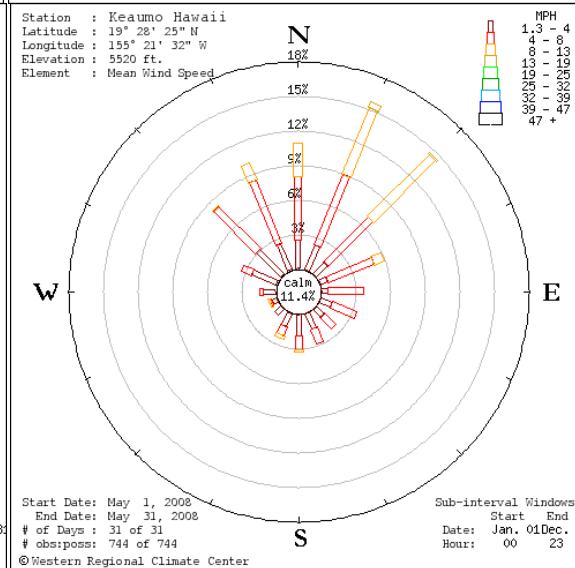
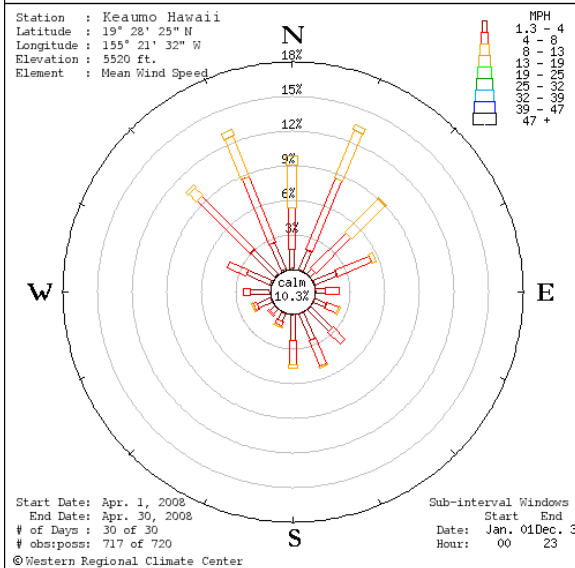
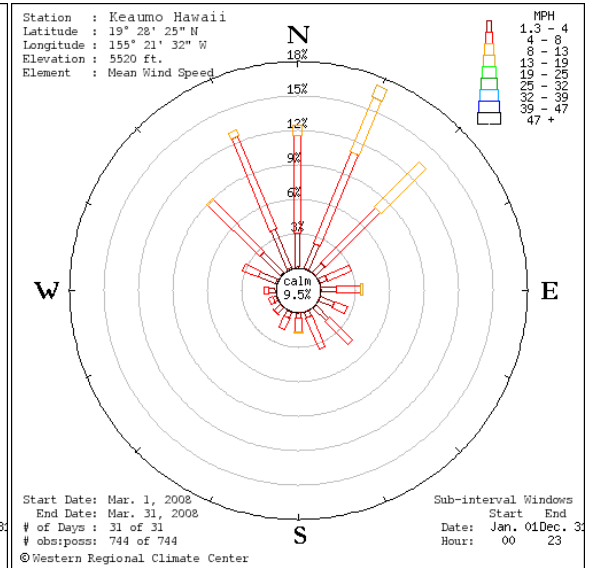
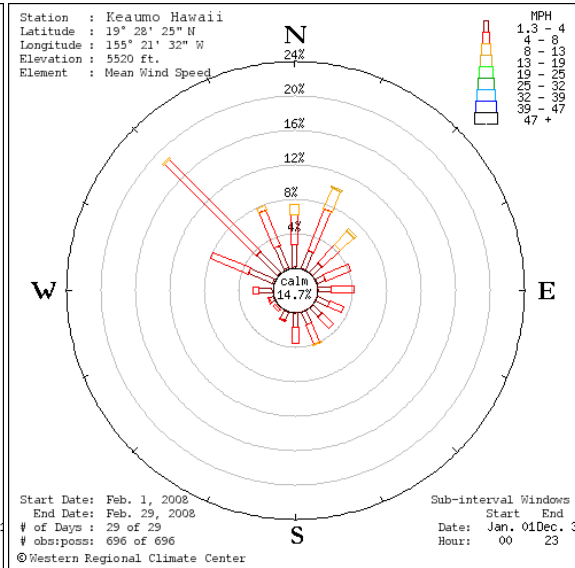
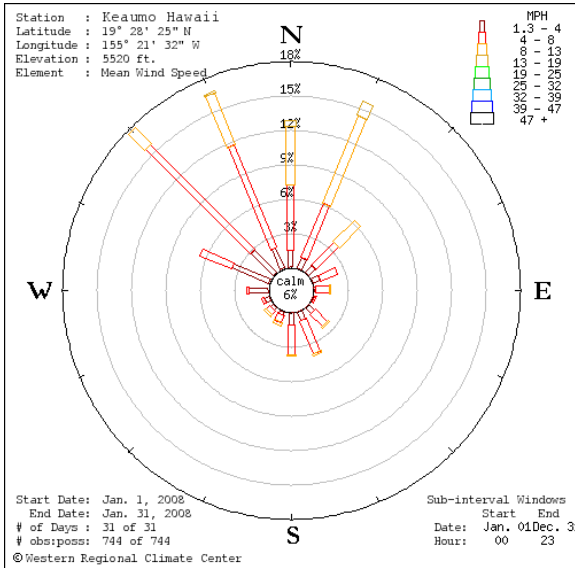
Literature Cited

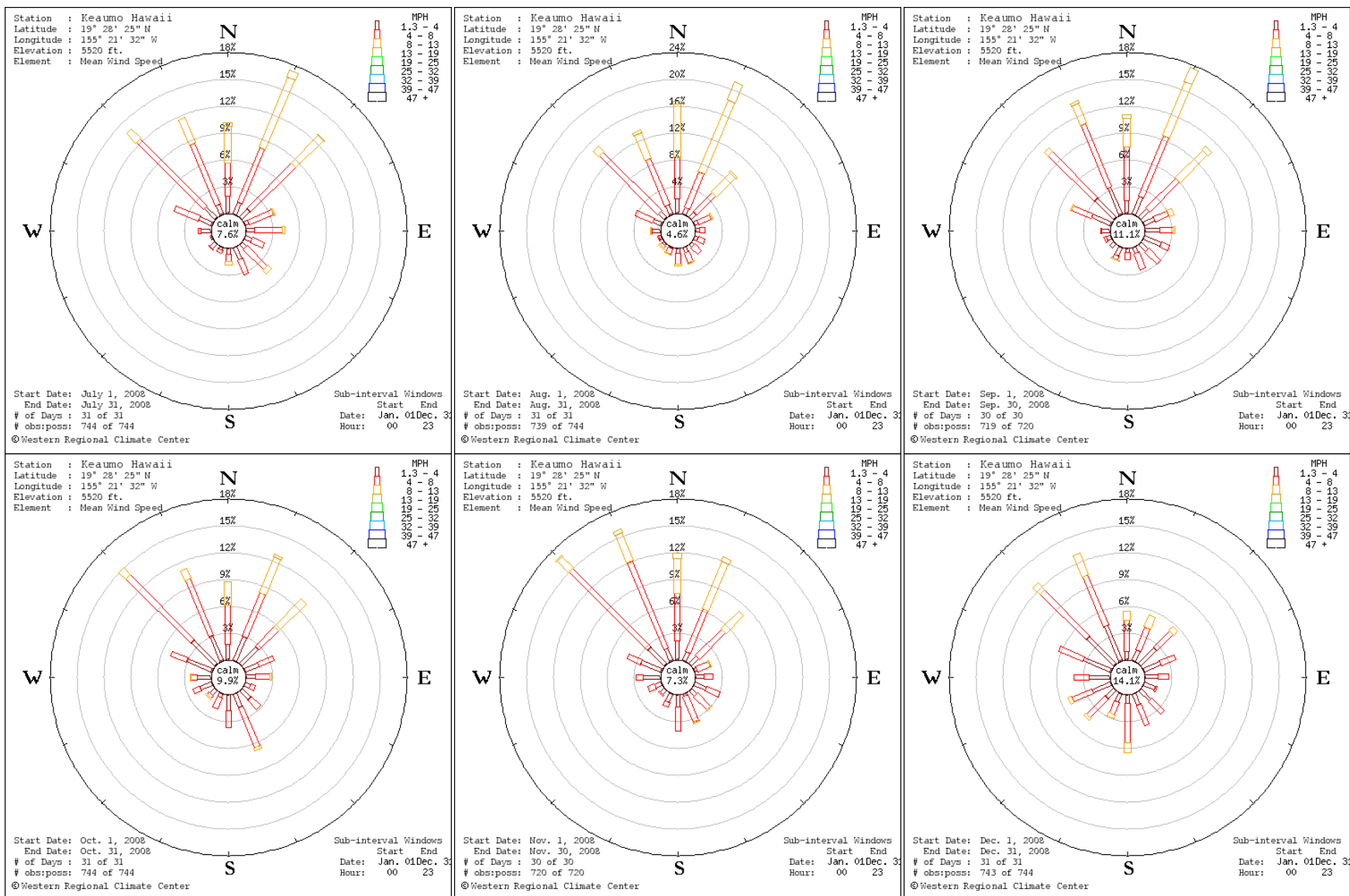
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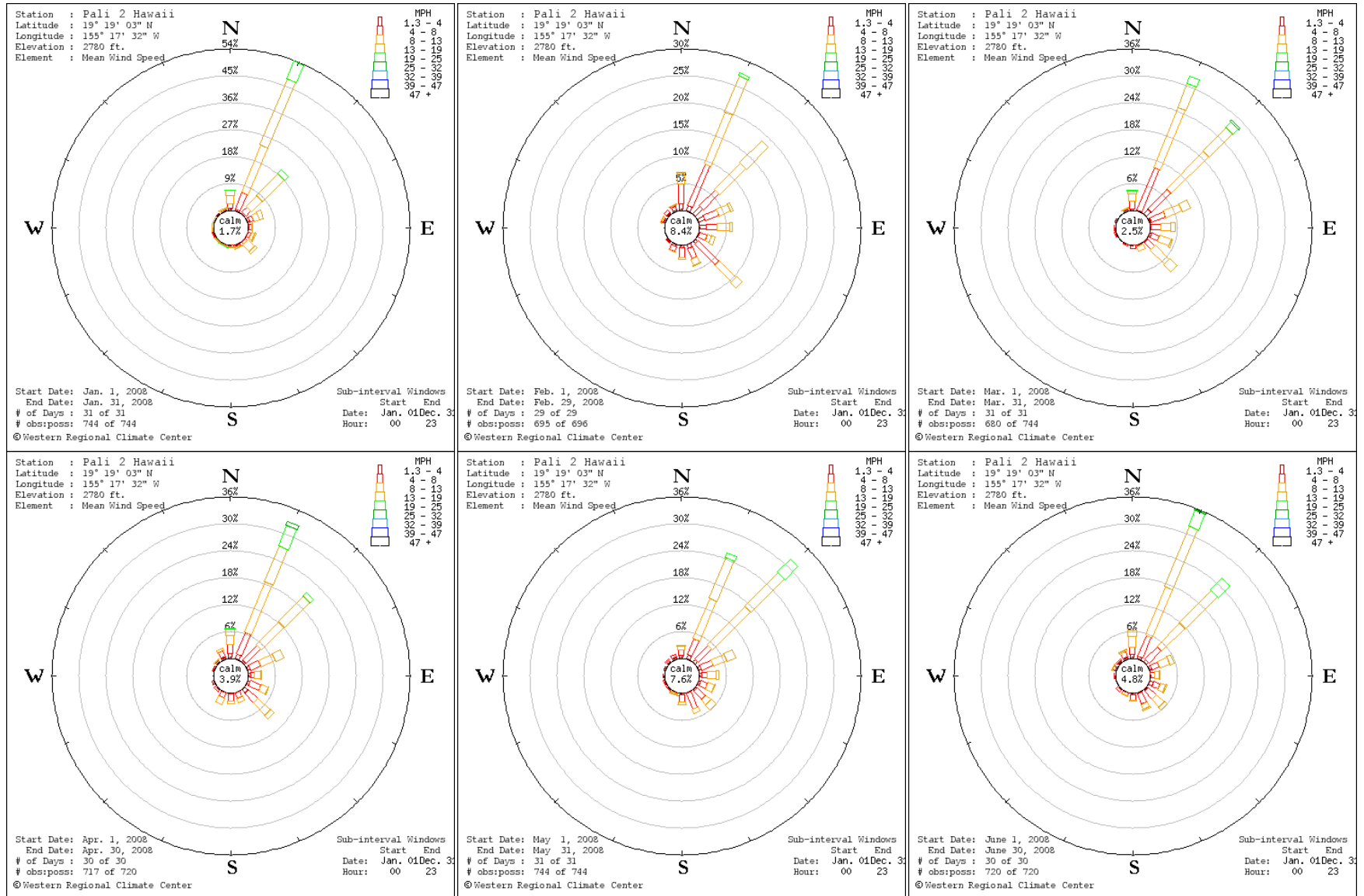
Appendix A. Monthly Wind Data

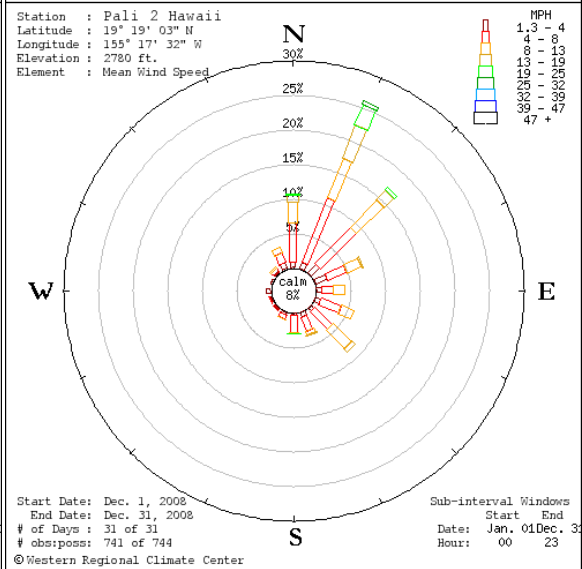
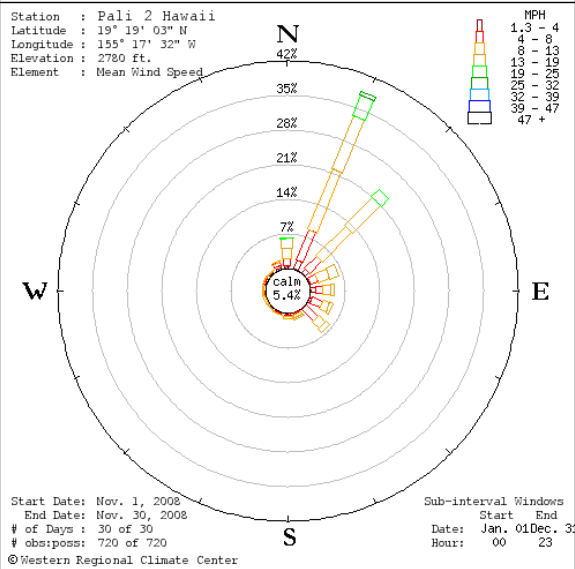
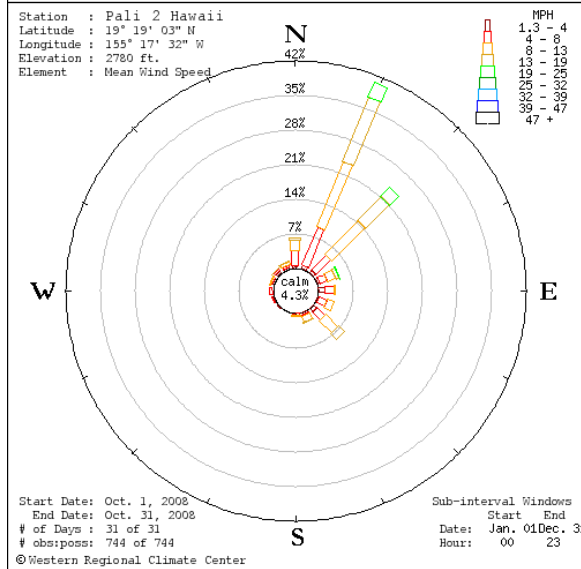
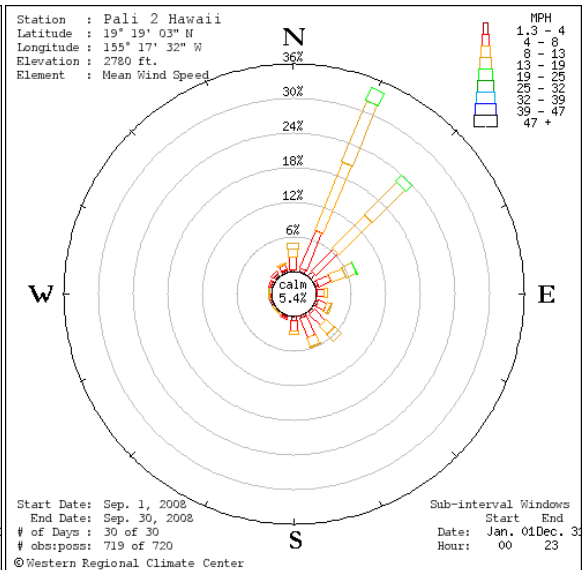
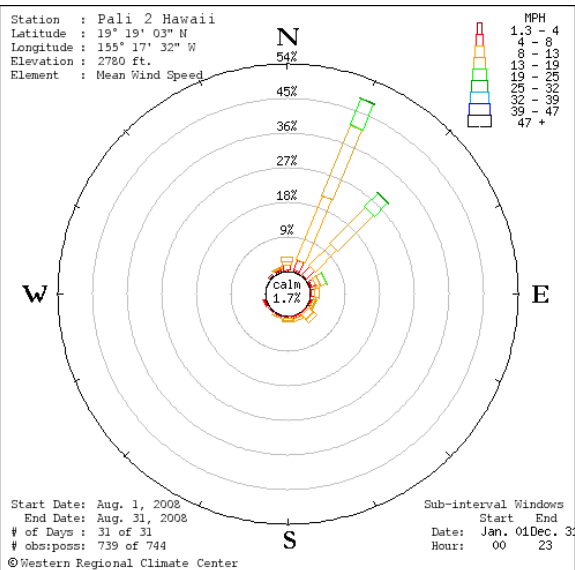
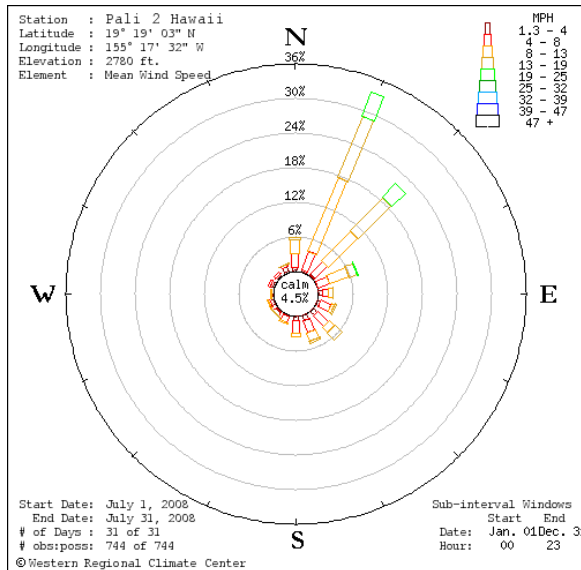
Hawai'i Volcanoes National Park, Keaumo (RAWS)



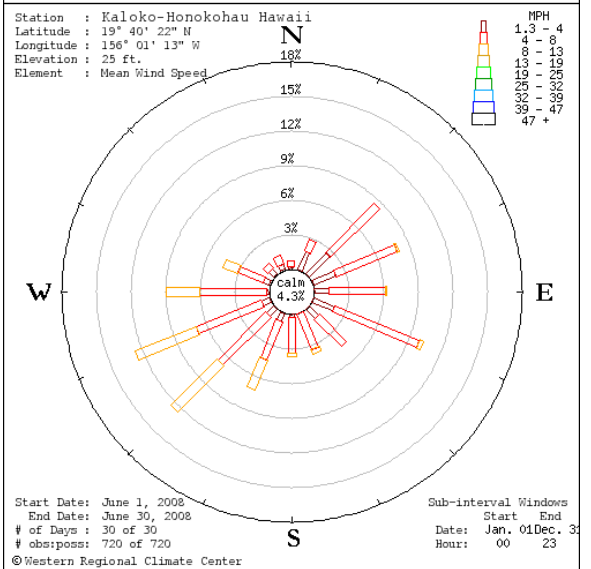
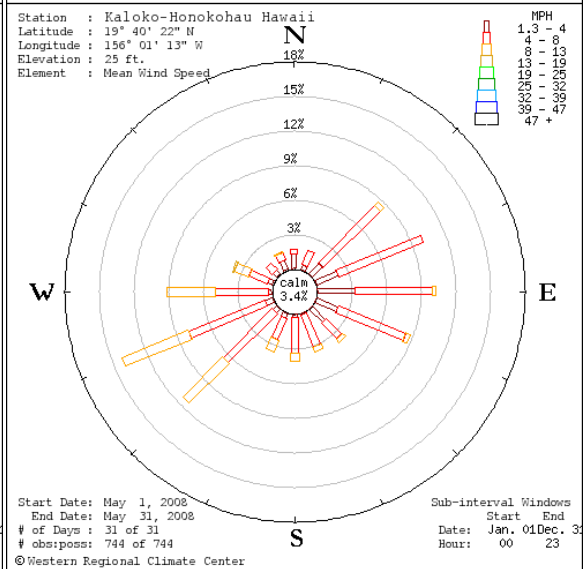
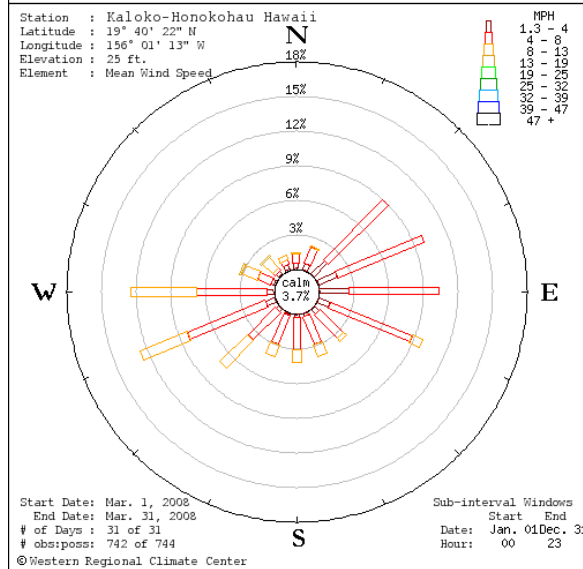
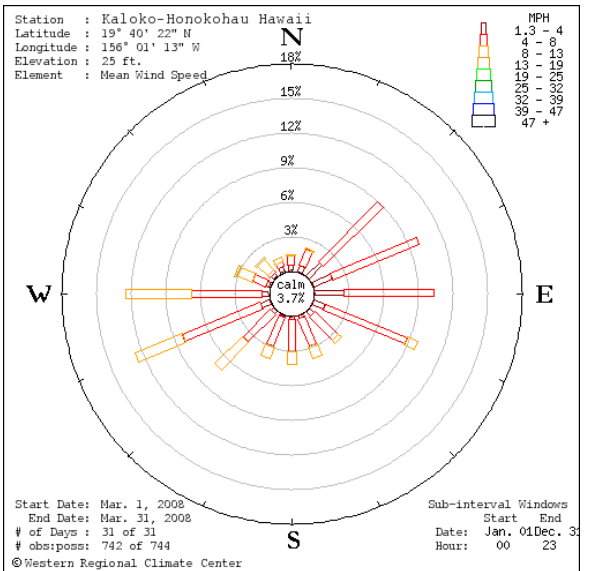
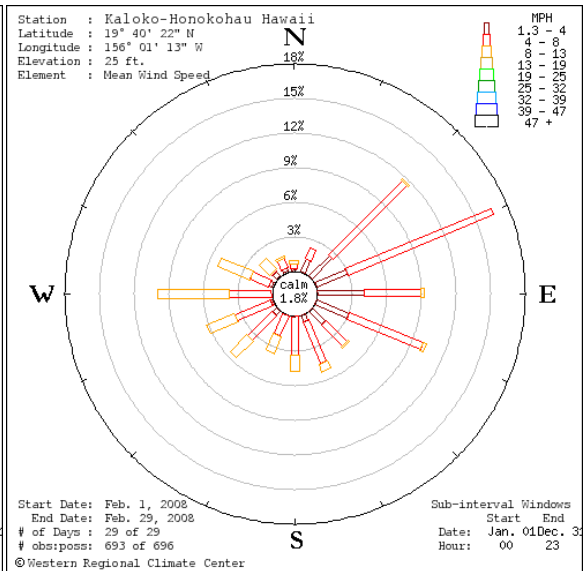
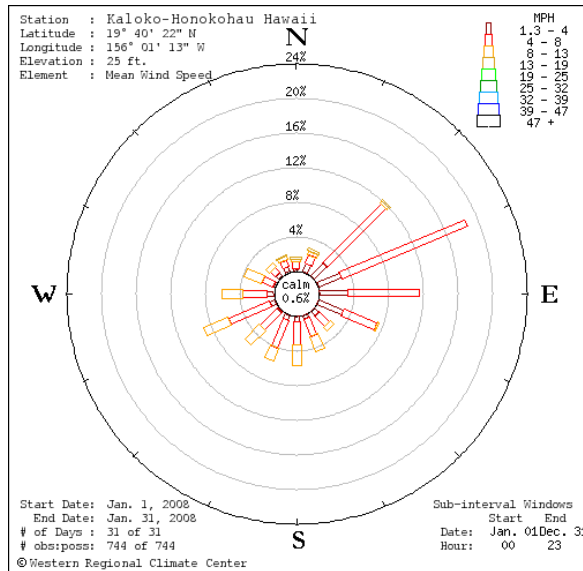


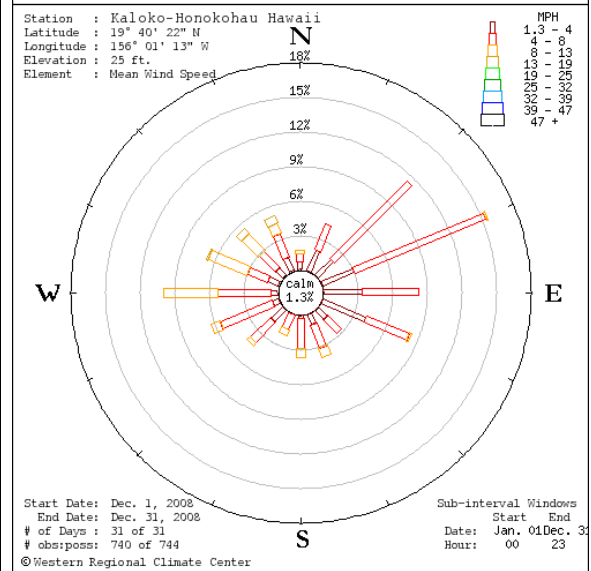
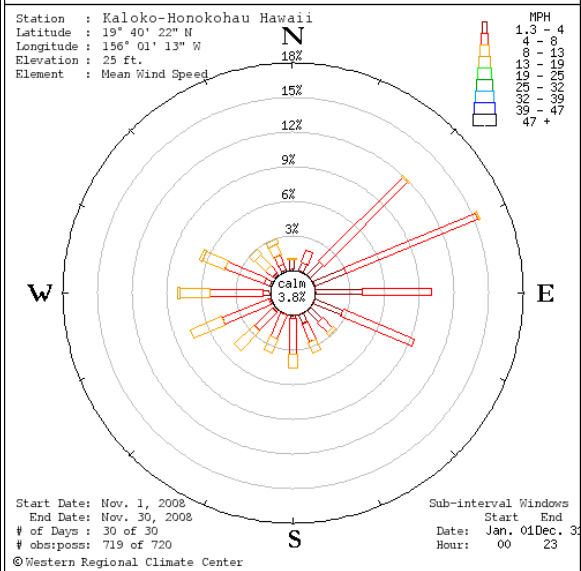
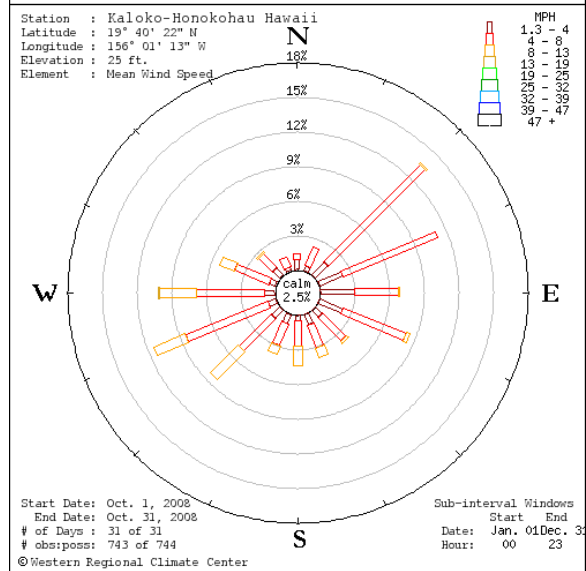
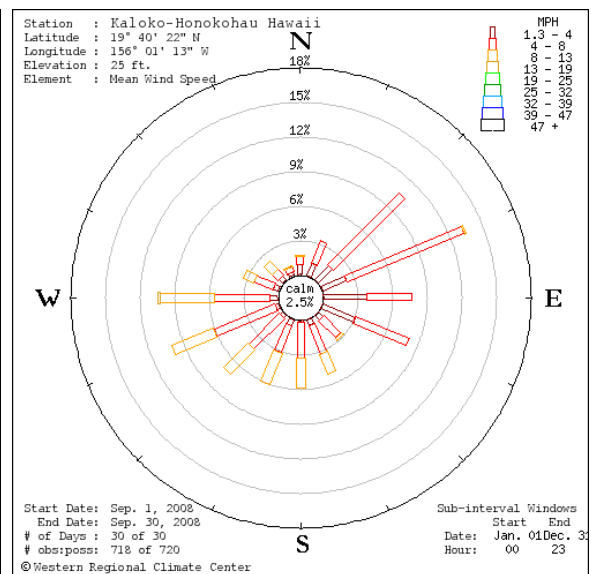
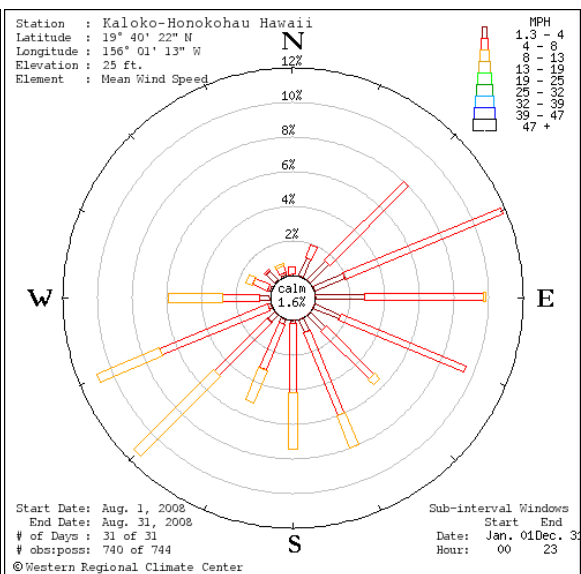
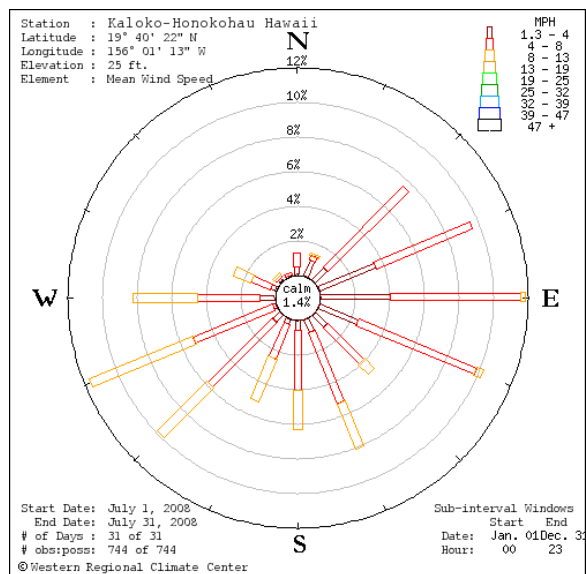
Hawai'i Volcanoes National Park, Pali 2 (RAWS)



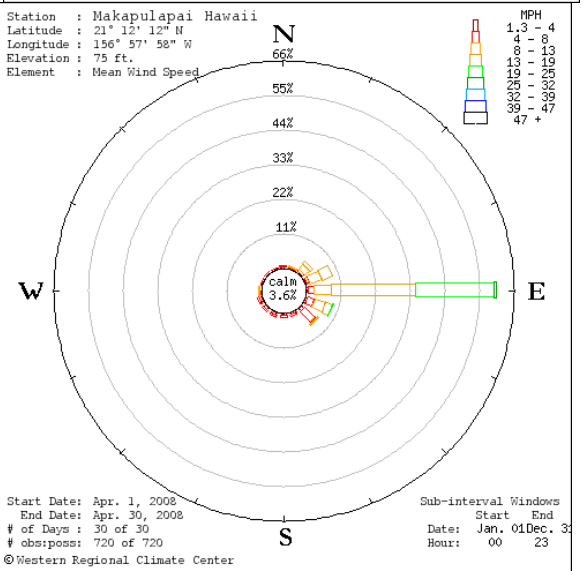
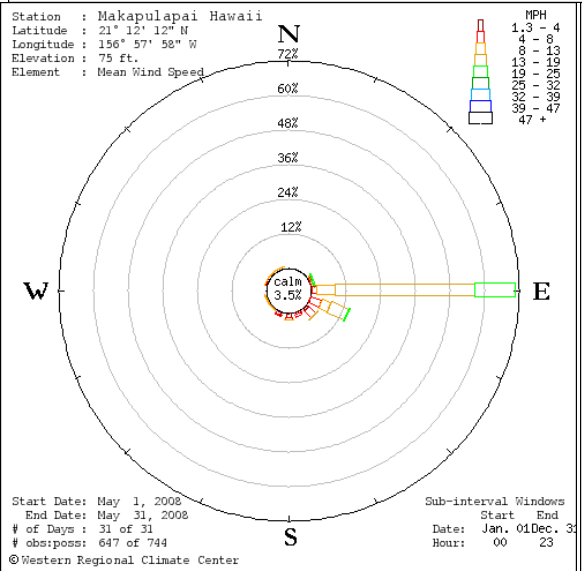
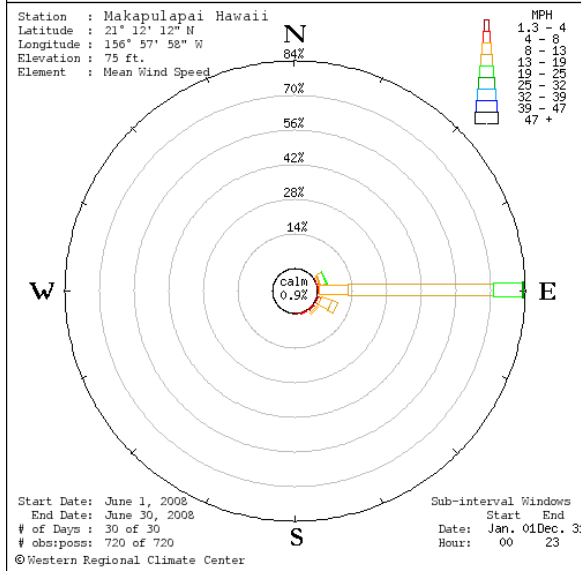
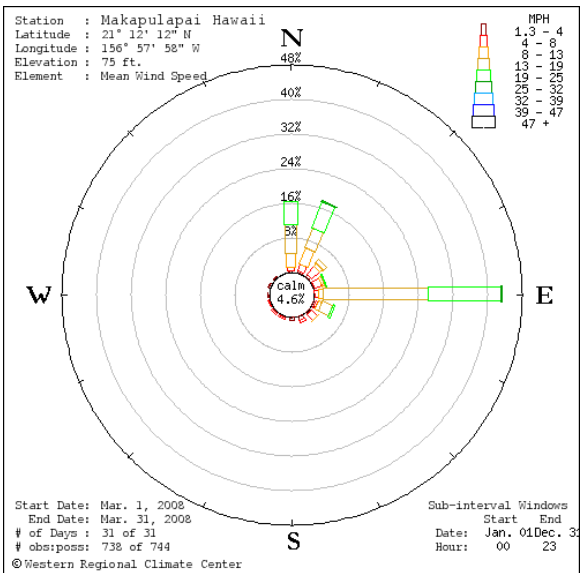
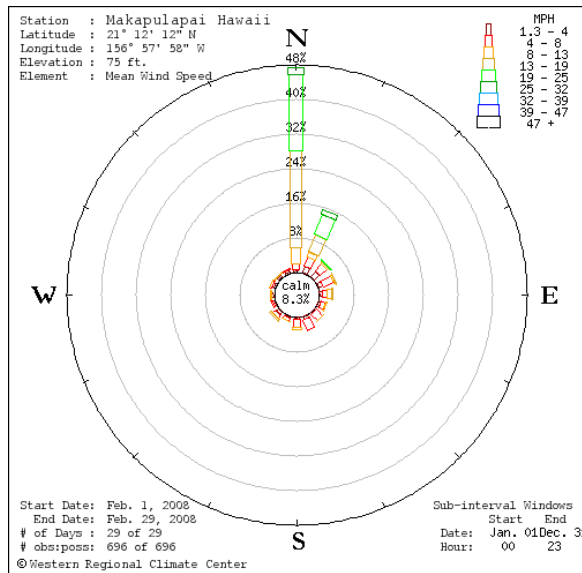
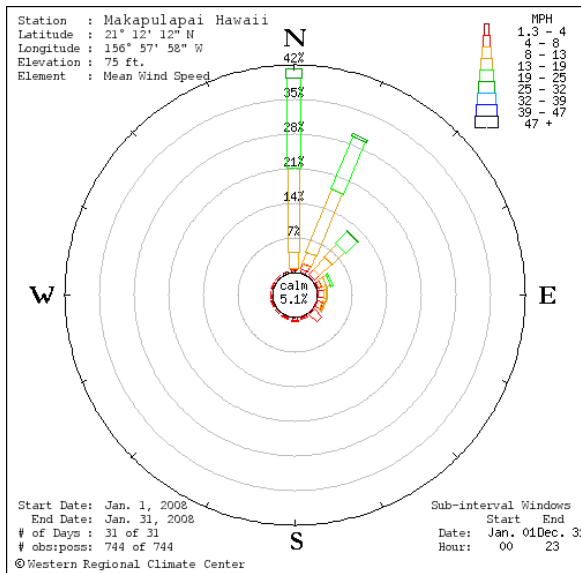


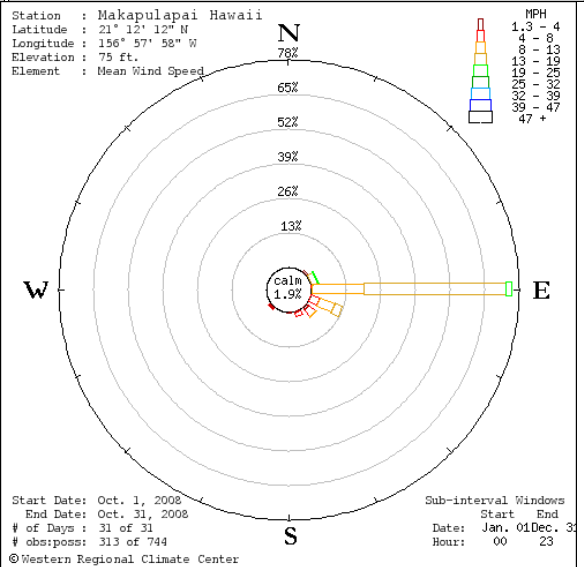
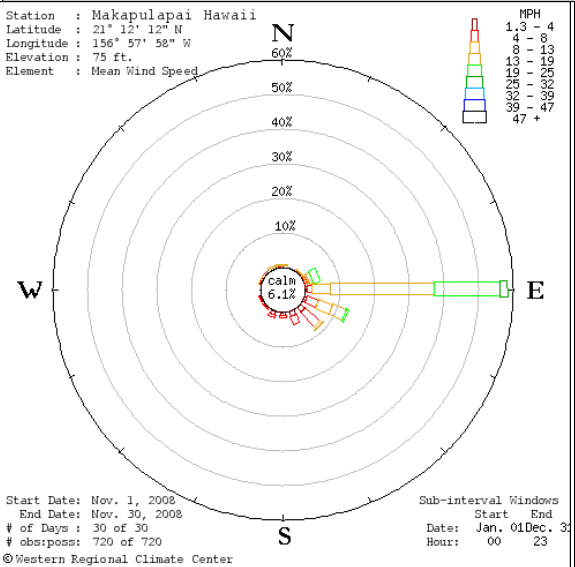
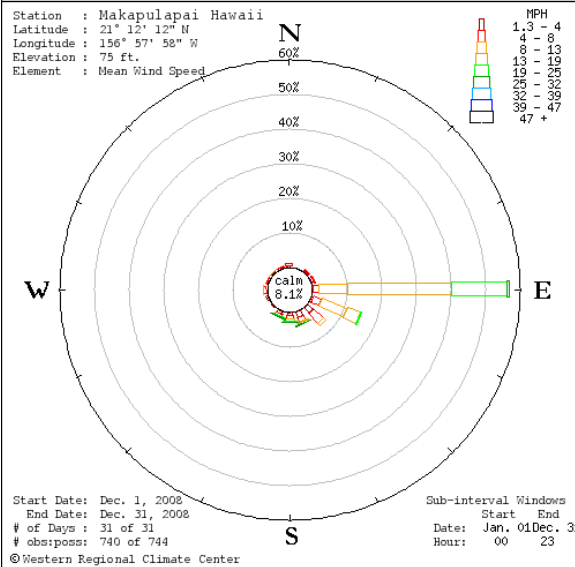
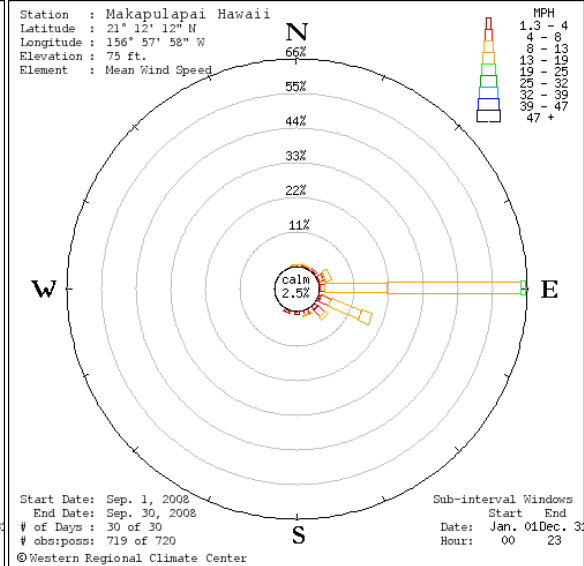
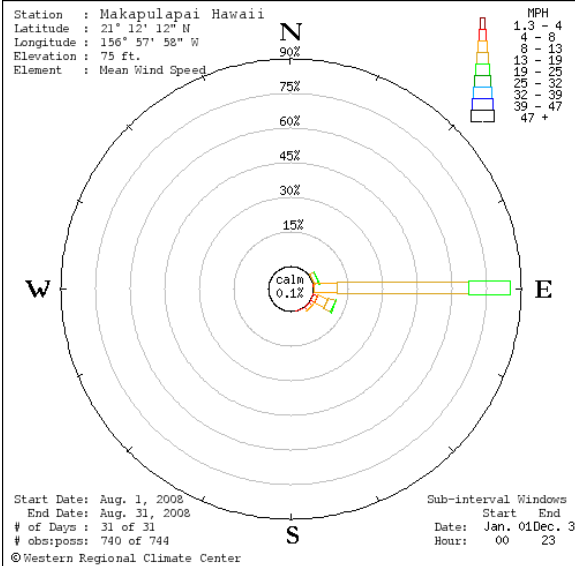
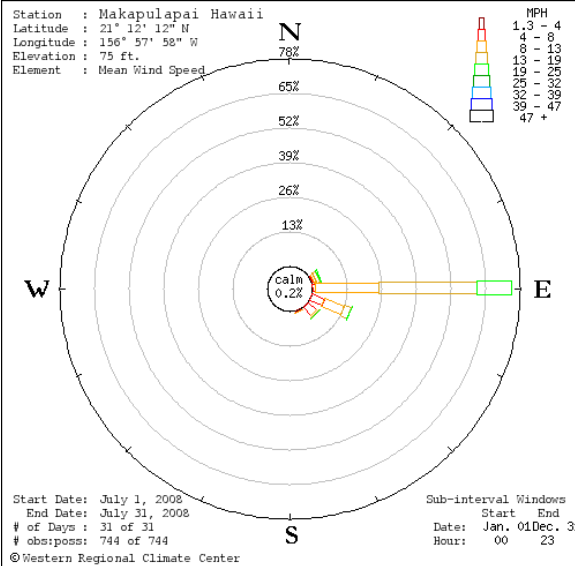
Kaloko-Honokōhau National Historical Park, Kaloko-Honokohau (RAWS)



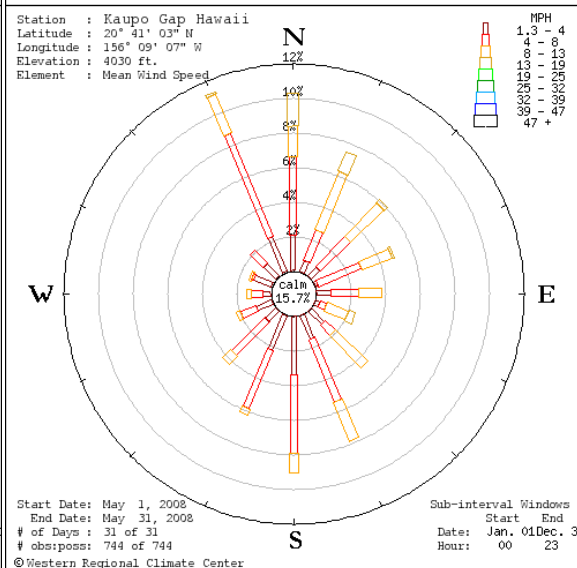
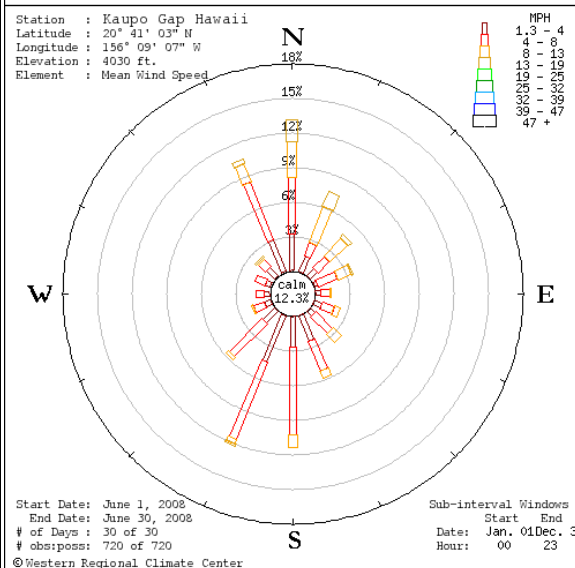
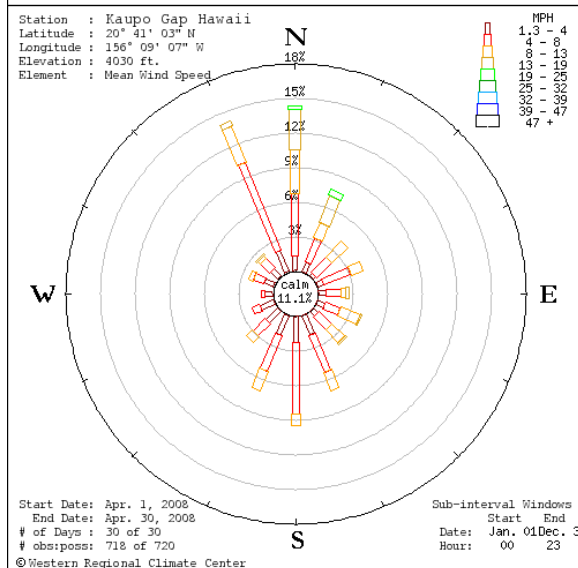
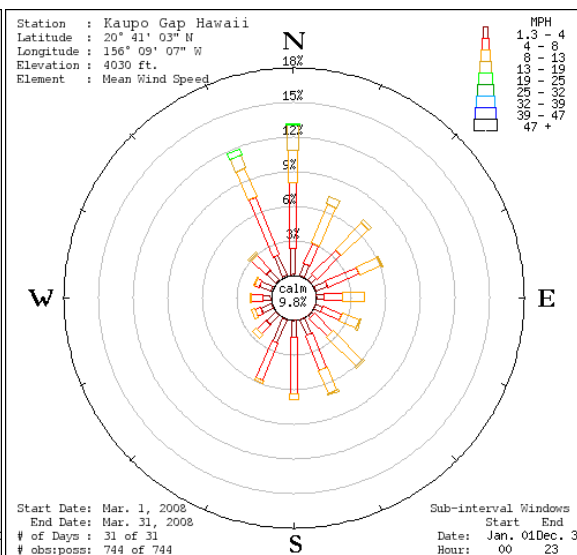
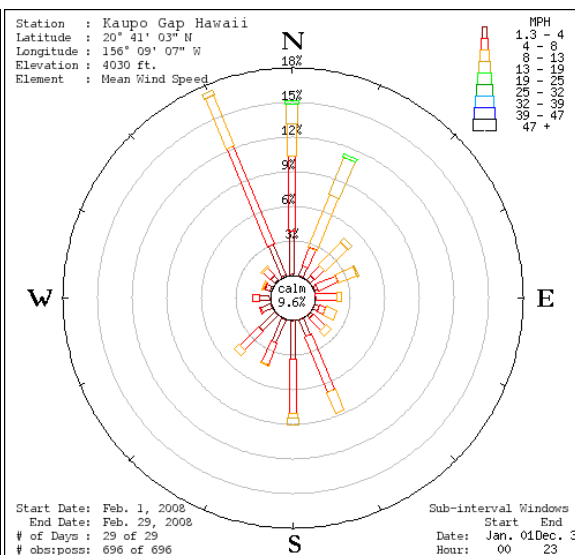
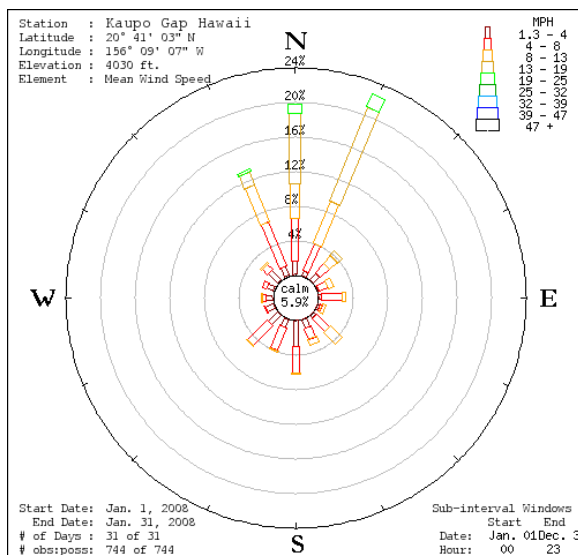


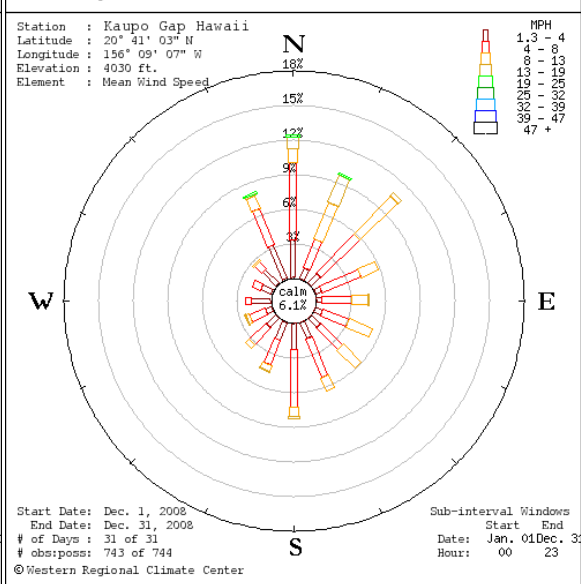
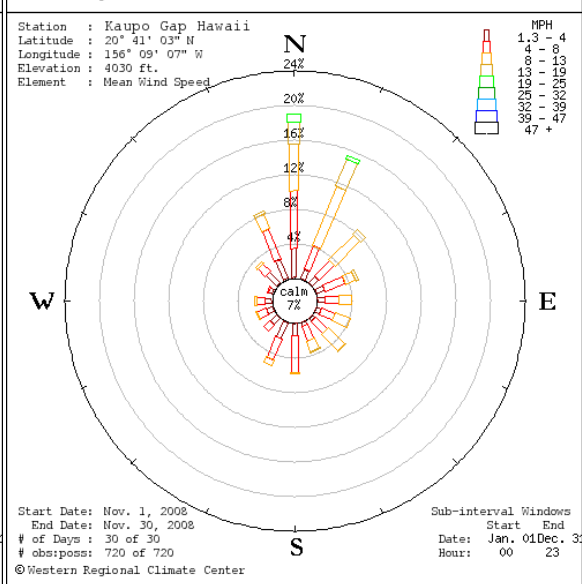
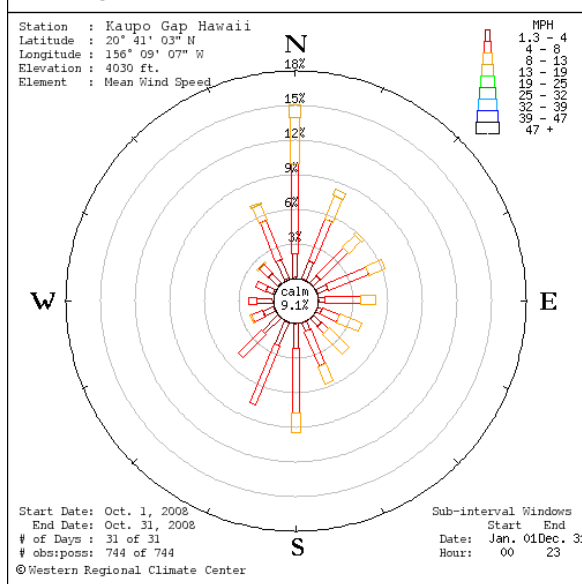
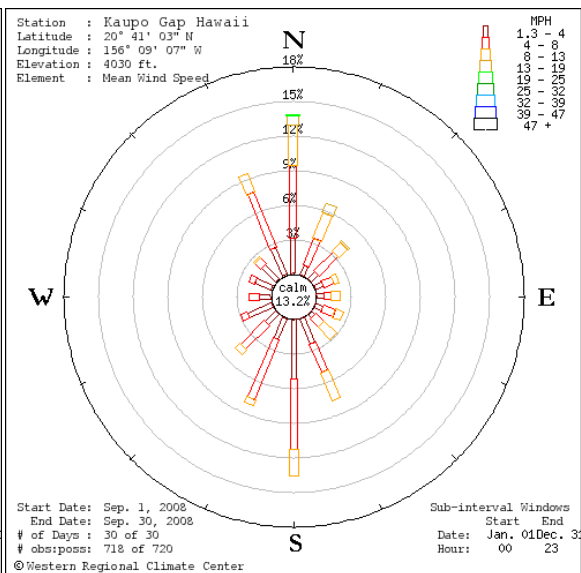
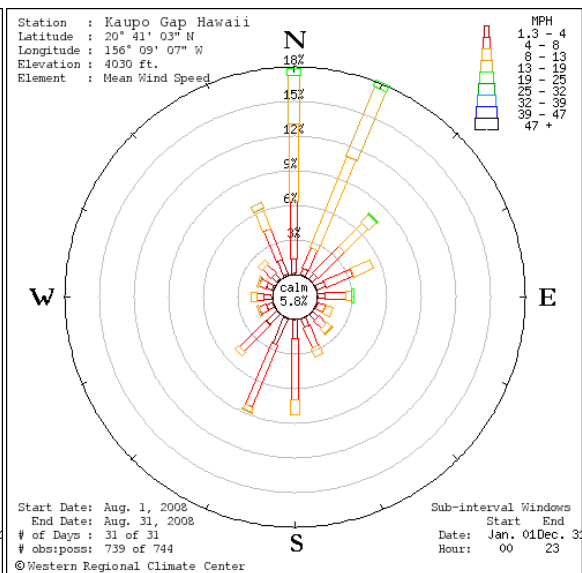
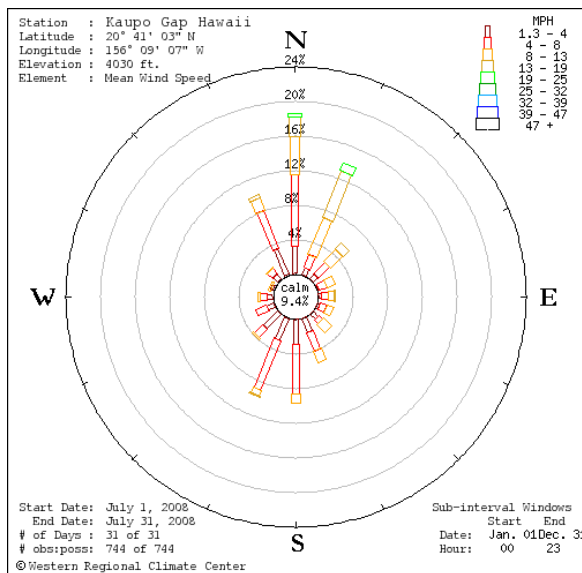
Kalaupapa National Historical Park, Makapulapai (RAWS)





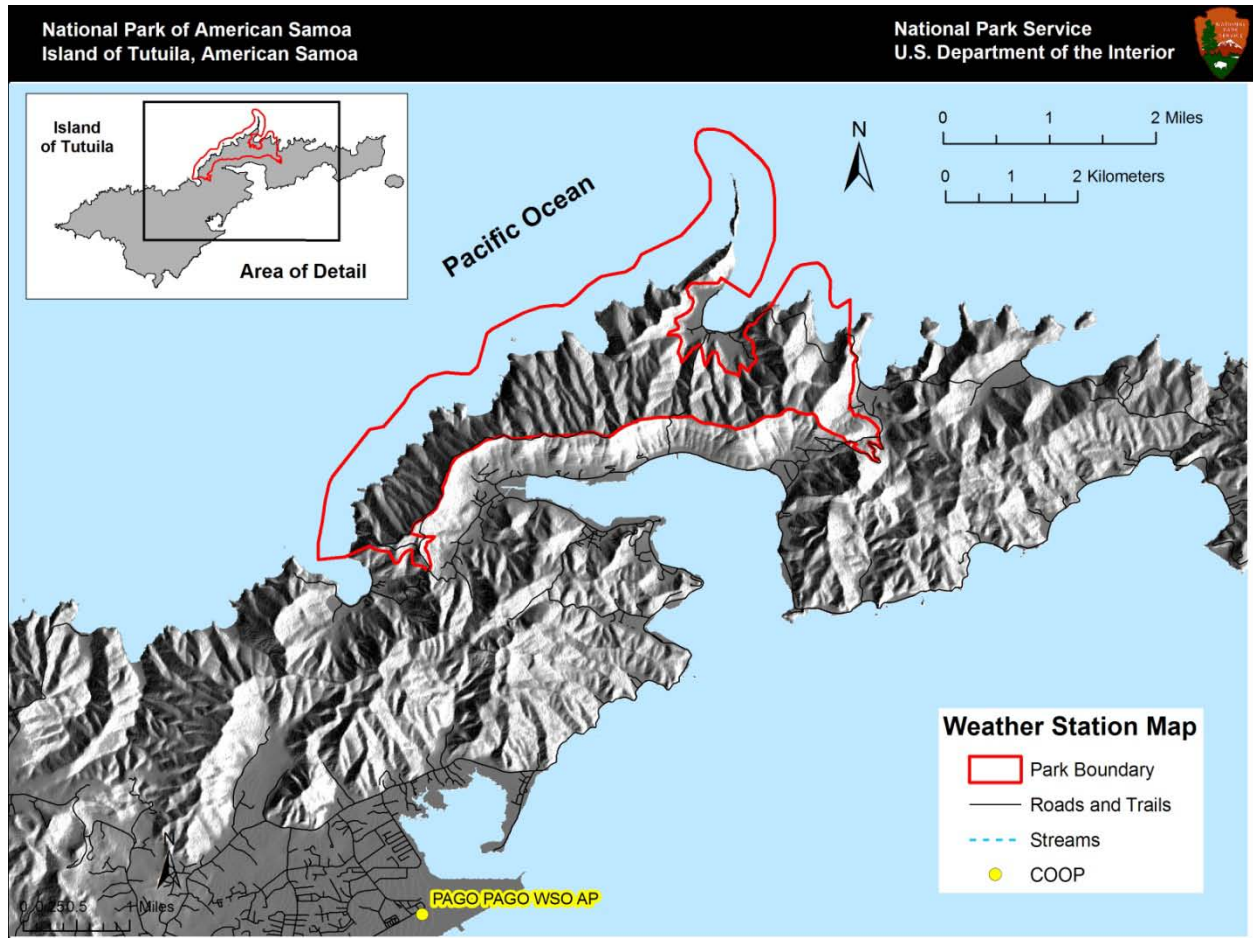
Haleakalā National Park, Kaupo Gap (RAWS)

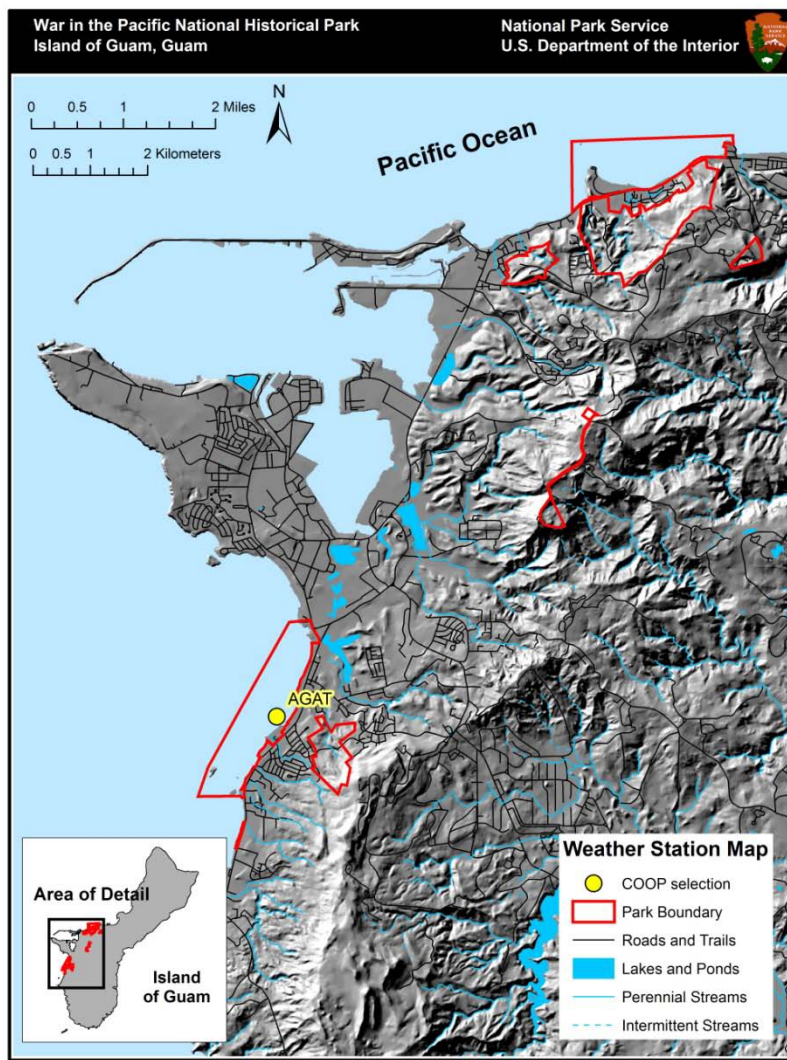
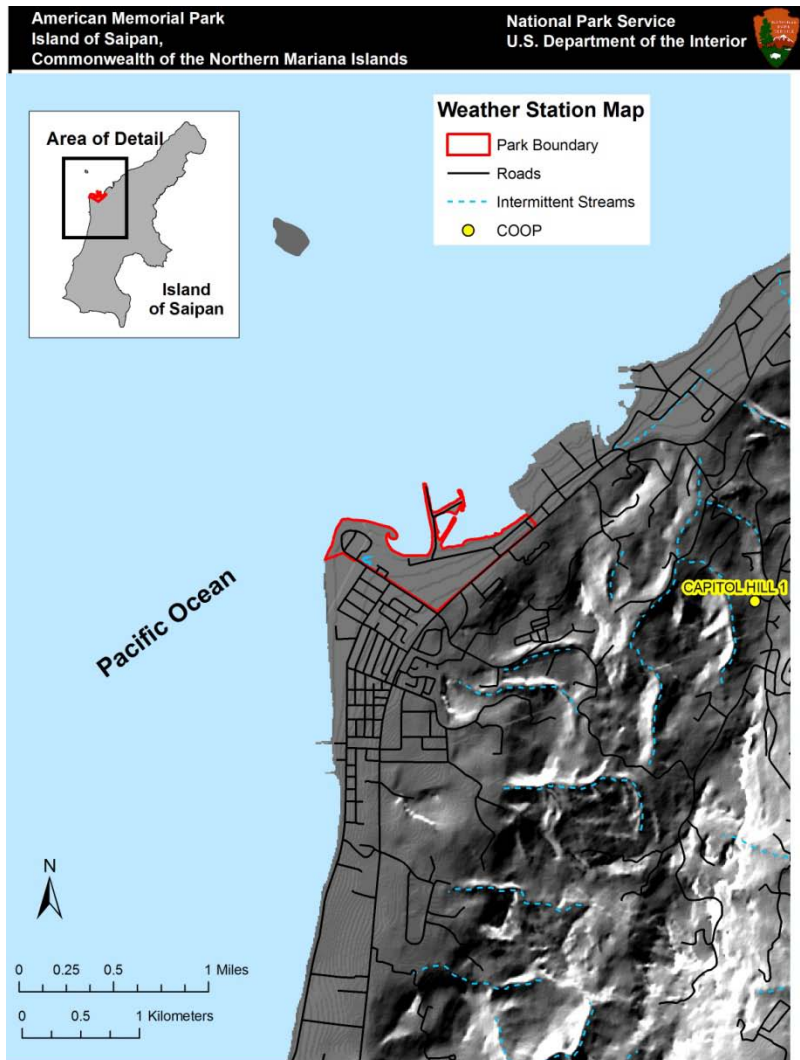




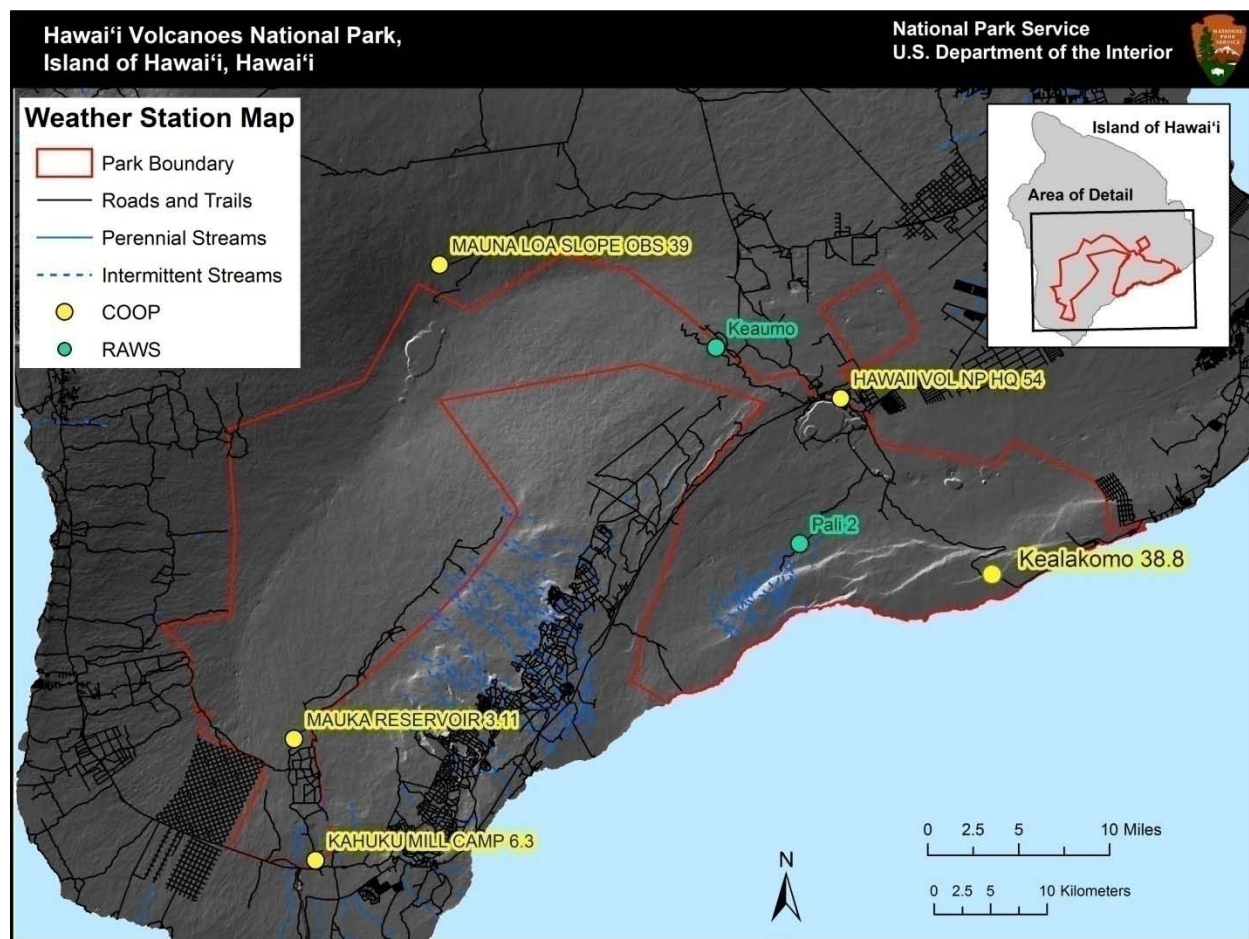
Appendix B. Maps Showing Station Locations

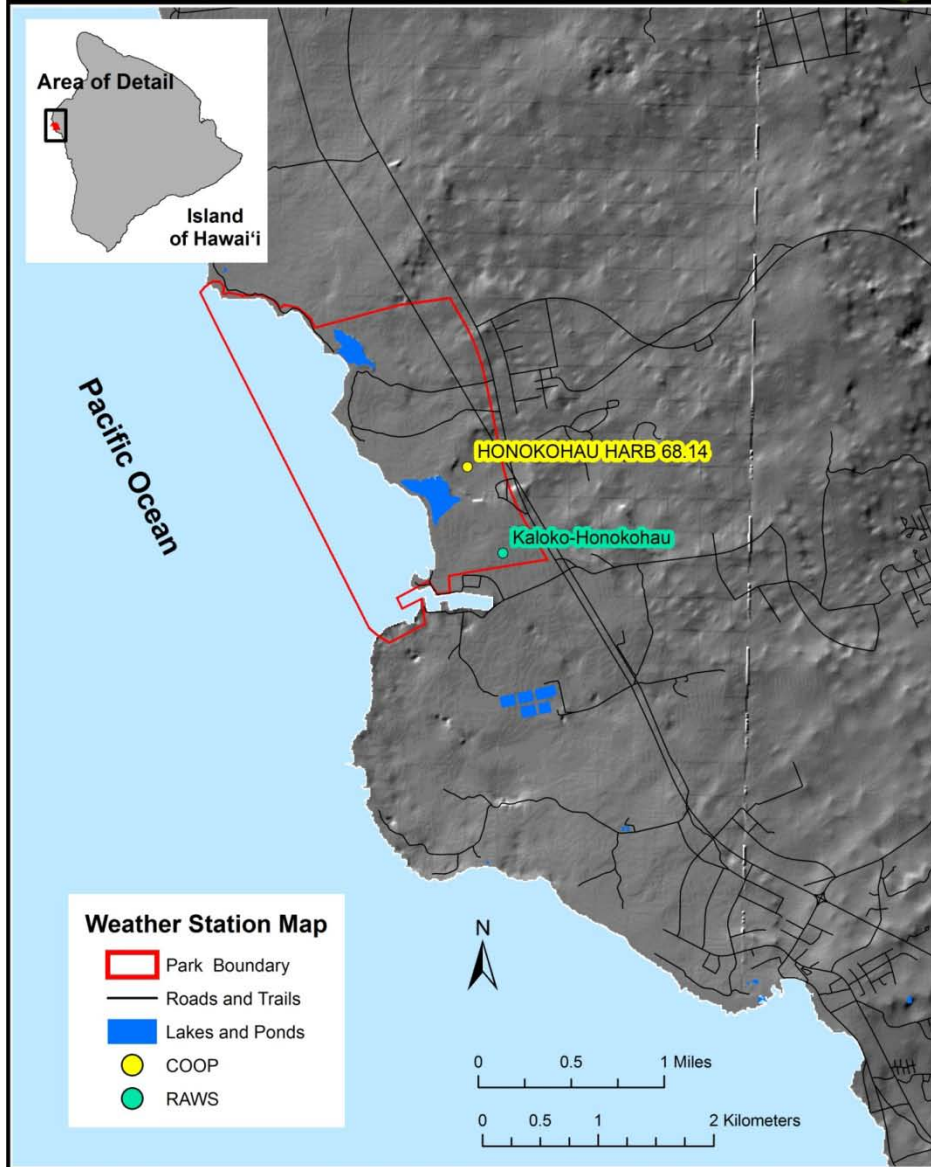
Parks in the West and South Pacific

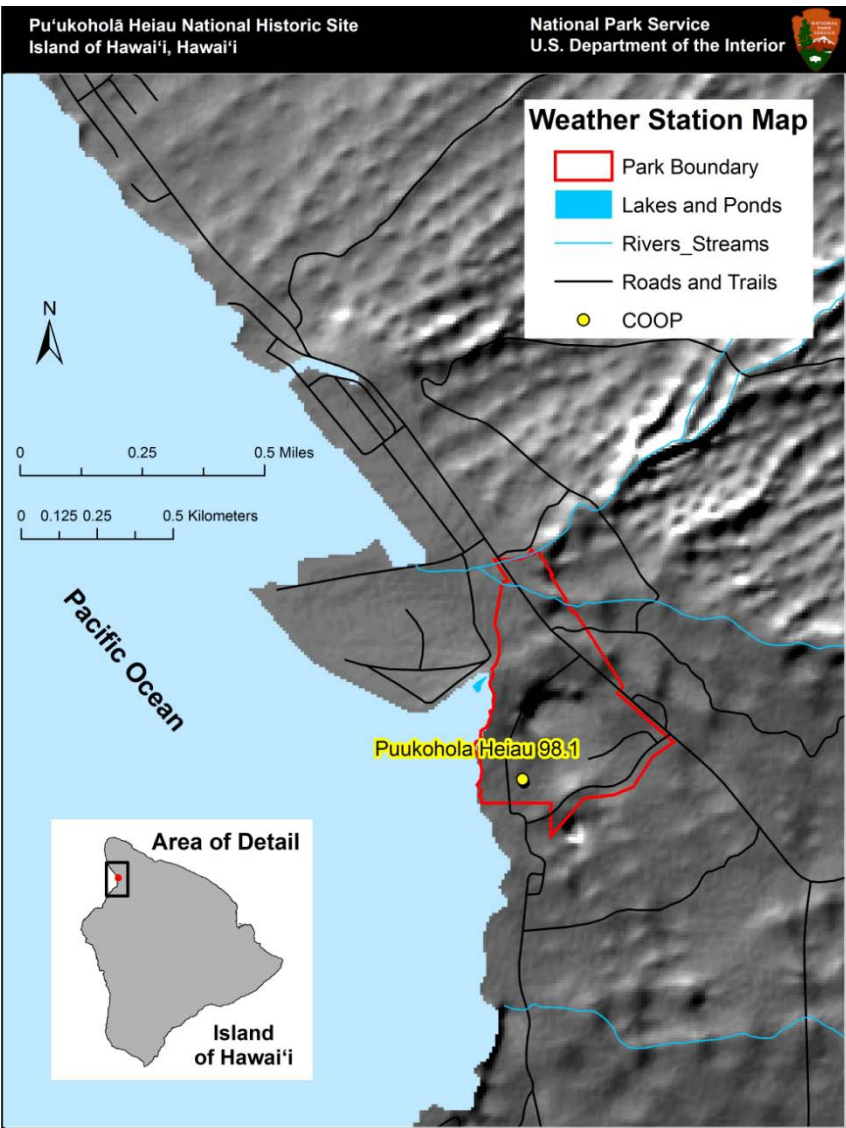
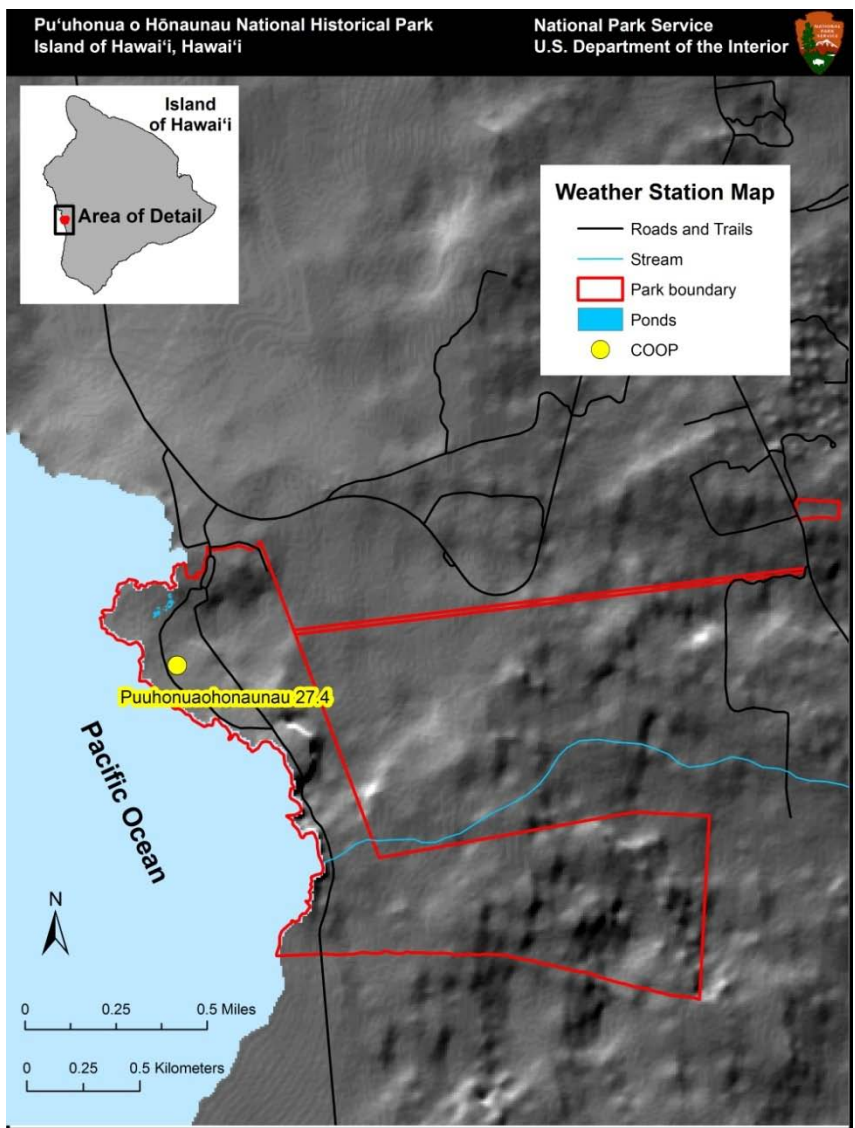




Parks on Hawai'i Island







Parks on Maui and Moloka'i

