NEIL ABERCROMBIE
GOVERNOR OF HAWAII

LORETTA J. FUDDY, A.C.S.W., M.P.H.
DIRECTOR OF HEALTH

CERTIFIED MAIL -
RETURN RECEIPT REQUESTED
(#7008 1140 0002 7256 4939)

STATE OF HAWAII
DEPARTMENT OF HEALTH
P.O. Box 3378
HONOLULU, HAWAII 96801-3378

In reply, please refer to:
File:

13-1034M&A CAB

December 11, 2013

Ms. Meredith Kurpius
Manager
Air Quality Analysis Office
U.S. EPA, Region IX
75 Hawthorne Street
San Francisco, California 94105

Dear Ms. Kurpius:

SUBJECT: Documentation for Natural Event Excluded Data for the 2011-2012 Exceedances of the Annual $PM_{2.5}$ National Ambient Air Quality Standards (NAAQS)

In the calendar years 2011 and 2012, there were exceedances of the Annual $PM_{2.5}$ NAAQS at the Kona air monitoring station on the Island of Hawaii.

Attached is the final report demonstrating that the exceedances were caused by naturally occurring volcanic emissions. Pursuant to 40 CFR 50.14, *Treatment of air quality monitoring data influenced by exceptional events*, the state is requesting EPA concurrence with the exclusion of the $PM_{2.5}$ exceedances due to the emissions from the Kilauea volcano.

Due to time constraints, the public notice for this document will be concurrent with the submittal to EPA. This report will be placed on the Department of Health, Clean Air Branch (DOH-CAB), website as well as be available at the DOH-CAB offices in Honolulu, Hilo, and Kona for public review for a period of thirty (30) days beginning December 16, 2013 and ending January 14, 2014.

Any significant comments received during the public comment period along with DOH-CAB's corresponding responses will be forwarded to EPA. Affidavits of the public notice through the three local newspapers will also be submitted to EPA once they are available.

If there are any questions concerning the attached, please contact Ms. Lisa Young of my staff at (808) 586-4200.

Sincerely,

NOLAN S. HIRAI, P.E.
Manager, Clean Air Branch

GW:rkb

Attachment

c: Gwen Yoshimura, Air Division, Air Quality Analysis Office (AIR-7), U.S. EPA, Region IX
Carol Bohnenkamp, Air Division, Air Quality Analysis Office (AIR-7), U.S. EPA, Region IX
Rynda Kay, Air Division, Rules Office (AIR-4), U.S. EPA, Region IX

State of Hawaii
Department of Health
Clean Air Branch

Documentation for Natural Events Excluded Data Kona Air Monitoring Station, AQS ID 15-001-1012 2011-2012 $PM_{2.5}$ Exceedances

Final Report
December 2013

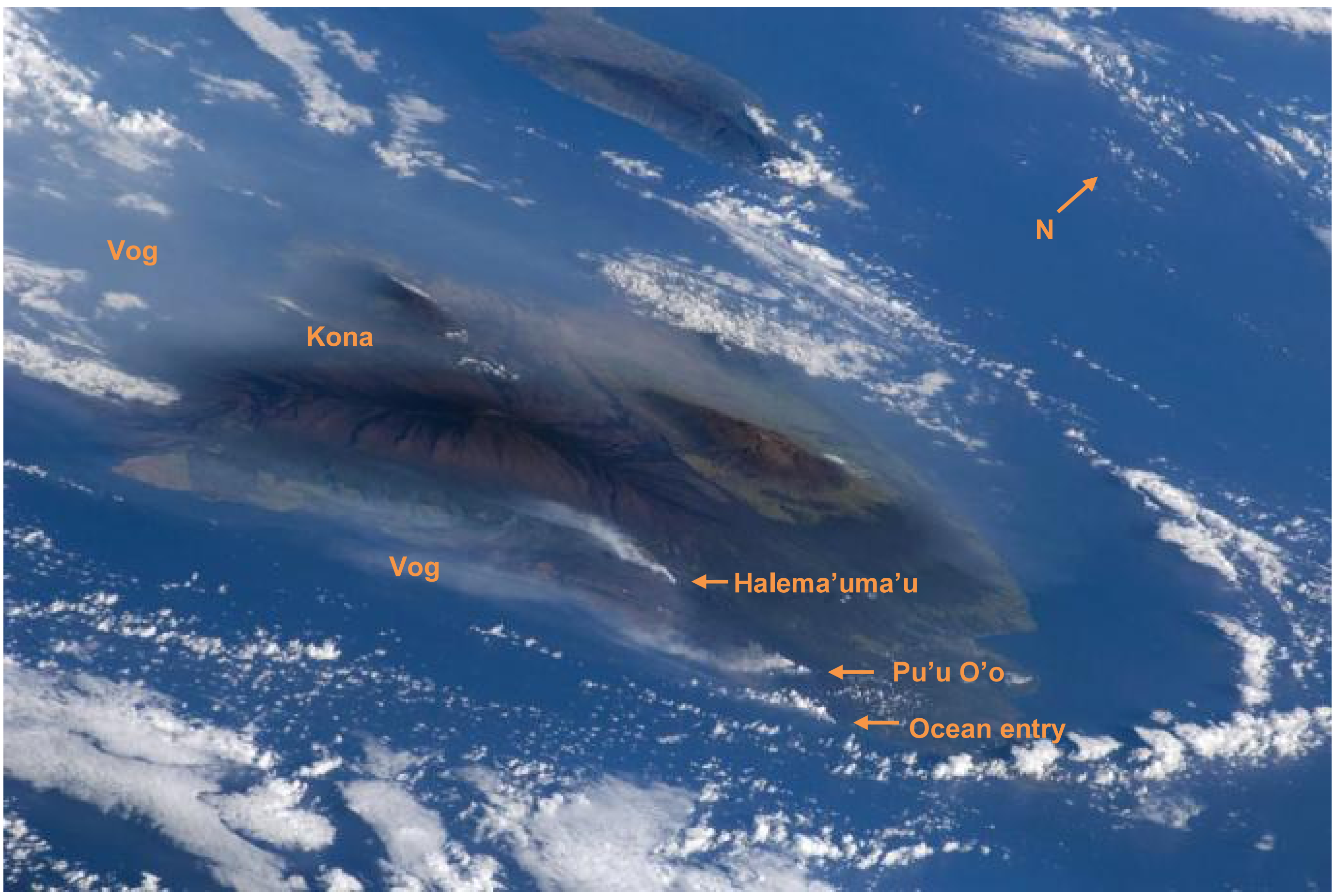

Image by crew of Space Shuttle Atlantis, May 13, 2009

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Introduction

During 2011 and 2012, the Kona air monitoring station recorded annual average particulate matter less than or equal to 2.5 micrometers in diameter ($PM_{2.5}$) concentrations of 12.1 μg/m^3 and 16.2 μg/m^3, respectively. These values exceed the annual $PM_{2.5}$ National Ambient Air Quality Standards (NAAQS) of 12 μg/m^3.

This report is solely to demonstrate that these exceedances at the Kona station, and Kona station alone, were caused by naturally occurring volcanic emissions, were not reasonably controllable or preventable, were associated with measured concentrations in excess of normal historical fluctuations, and would not have occurred "but-for" the volcanic emissions and, therefore, are Exceptional Events as defined by the U.S. Environmental Protection Agency's (EPA) Exceptional Events Rule (EER).

Table I-1 below is a summary of the flagged $PM_{2.5}$ data for 2011 and 2012. A table with a complete listing all the dates that were flagged is included in Appendix B.

Kona (AQS ID 150011012): 2011 and 2012 24-hr $PM_{2.5}$ Flagged Data			
Year	Quarter	Date Range	Number of Flagged Days
2011	1	February13 – March 9	2
2012	1	January 1 to March 31	62
2012	2	April 1 to June 30	87
2012	3	July 1 to September 30	23
2012	4	October 1 to December 28	28

Table I-1. Summary of Flagged Days in 2011 and 2012

There were no exceedances of the 24-hour $PM_{2.5}$ NAAQS of 35 μg/m^3 at the Kona station in 2011 and 2012.

Section 1 of this report provides a summary of the exceptional events rules and requirements and details how those rules are met within the report.

Section 2 of this report introduces the conceptual model of the volcanic event that occurred during 2011-2012, providing a background narrative of the natural event and an explanation that it affected air quality. Section 2 also provides evidence that the exceedances were due to a natural event.

Section 3 of this report establishes a clear causal relationship between the natural events and the exceedances of the annual $PM_{2.5}$ standard at the monitoring station. This section also discusses how sulfur dioxide (SO_2) gas from the volcano turns into sulfate particles as it travels to the Kona coast.

Section 4 of this report provides information on existing anthropogenic sources in the Kona area and the emissions control measures required of these sources. It demonstrates that despite the regulation of these man-made sources, the exceedances were not reasonably controllable or preventable.

Section 5 of this report provides information which help illustrate that the exceptional event produced $PM_{2.5}$ concentrations in excess of normal historical fluctuations.

Section 6 of this report summarizes the demonstration, showing a clear causal relationship between the natural event and the exceedances, and concludes that these exceedances would not have occurred “but-for” the continuing natural event.

Appendix A of this report includes additional figures and tables with supporting information.

Appendix B of this report includes a table with a complete listing all the dates that were flagged.

Appendix C of this report will have the affidavits of publication in three local newspapers (when available) notifying the public of the availability for inspection of this document. The three newspapers are the Honolulu Star-Advertiser (State-wide distribution), the Hawaii Tribune-Herald (East Hawaii newspaper distribution) and the West Hawaii Today (West Hawaii newspaper distribution).

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Cover graphic illustrates the volcanic emission plumes (vog) from the Halema'uma'u and Pu'u O'o vents and the lava ocean entry point being blown to the southern end of Hawaii Island then travelling up to the Kona coast during predominant trade wind regime.

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List of Acronyms and Definitions

QS	Air Quality System
ASAS	Air Surveillance and Analysis Section (State of Hawaii, Department of Health)
BACT	Best Available Control Technology
CEMS	Continuous Emissions Monitoring System
CFR	Code of Federal Regulations
COMS	Continuous Opacity Monitoring System
DOH-CAB	Department of Health Clean Air Branch (State of Hawaii)
EPA	United States Environmental Protection Agency
HAR	Hawaii Administrative Rules
HAVO	Hawaii Volcano Observatory
HAVO OB	Hawaii Volcano Observatory Kilauea Observatory
HAVO VC	Hawaii Volcano Observatory Kilauea Visitor's Center
Hp	Horsepower
Kona winds	This refers to periods of light, variable to southerly winds that typically occur when a subtropical ridge rests over the state.
kW	Kilowatt
MMBtu/hr	One million British Thermal Units per hour
MW	Megawatt
NAAQS	National Ambient Air Quality Standards
NEI	National Emissions Inventory
NO_2	Nitrogen Dioxide
NESHAPS	National Emissions Standards for Hazardous Air Polllutants
NPS	National Park Service
NSPS	New Source Performance Standards
Particulate Matter	A mixture in the air of very small particles and liquid droplets. This includes "fine particles" 2.5 micrometers or less in diameter and "coarse particles" greater than 2.5 micrometers but less than 10 micrometers in diameter.
$PM_{2.5}$	Particulate matter less than or equal to 2.5 micrometers in diameter
ppb	parts per billion
PSD	Prevention of Significant Deterioration
SCR	Selective Catalytic Reduction
SO_2	Sulfur dioxide gas
TPH	Tons per hour
TPY	Tons per year
Trade winds	Refers to the predominant winds in the state of Hawaii which is from the east/northeasterly direction.
USGS	United States Geological Survey
$\mu g/m^3$	micrograms per cubic meter
Vog	This is a local term that refers to "volcanic smog" or a hazy air pollution condition attributed to the active volcano.

Section 1. Exceptional Event Rule (EER) Requirements

Technical and procedural requirements are contained within the EER and must be met in order for EPA to concur with the flagged air monitoring data. This section of the report details the Hawaii Department of Health, Clean Air Branch's (DOH-CAB) effort to address those requirements as required by 40 CFR 50.14 (*Treatment of Air Quality Monitoring Data Influenced by Exceptional Events*).

1.1 Procedural Requirements

Public notification that event was occurring (40 CFR 50.14 (c)(1(i))
Immediate public notification of NAAQS exceedances is provided on the DOH-CAB website at http://health.hawaii.gov/cab/notification-of-exceedance-of-a-national-ambient-air-quality-standard. Notification of the 2012 exceedances of the annual $PM_{2.5}$ NAAQS was posted once the data was validated.

Place informational flag on data in AQS (40 CFR 50.14 (c)(2(ii))
The Department of Health Laboratory Division, Air Surveillance and Analysis Section (ASAS), submits the data into the EPA's Air Quality System (AQS), the official repository of ambient air quality data. A preliminary flag is submitted for data collected that may be influenced by exceptional events.

Notify EPA of intent to flag through submission of initial event description by July 1 of calendar year following event (40 CFR 50.14 (c)(2(iii))
This report is our initial event description. All data has been flagged in AQS.

Document that the public comment process was followed for event documentation (40 CFR 50.14 (c)(3(iv))
Due to time constraints, the public notice for this document will be concurrent with the submittal to EPA. This report will be placed on the DOH-CAB website as well as be available at the DOH-CAB offices in Honolulu, Hilo and Kona for public review for a period of thirty (30) days beginning December 16, 2013 and ending January 14, 2014.

Submit demonstration supporting exceptional event flag (40 CFR 50.14 (a)(1-2))
The deadline for the submittal of this demonstration package is December 12, 2013. DOH-CAB will submit this document to EPA Region IX by the deadline. Any significant comments received during the public comment period along with DOH-CAB's corresponding responses will be forwarded to EPA. Affidavits of the public notice through the three local newspapers will be submitted to EPA once they are available.

1.2 Documentation Requirements

Pursuant to 40 Code of Federal Regulations (CFR) Part 50.14(c)(3)(iii) of the Exceptional Event Rule (EER), the following six elements must be addressed when requesting the EPA exclude event-related concentrations from regulatory requirements:

1) The event affected air quality;
2) The event was not reasonably controllable or preventable;
3) The event was caused by human activity that is unlikely to recur at a particular location, or was a natural event;
4) There exists a clear causal relationship between the specific event and the monitored concentration;
5) The event is associated with a measured concentration in excess of normal historical fluctuations including background; and
6) There would have been no exceedances or violation but for the event.

Section 2 of this report introduces the conceptual model of the volcanic event that occurred during 2011-2012, providing a background narrative of the natural event and an explanation that it “affected air quality”. Section 2 also provides evidence that the exceedances were due to a natural event.

Section 4 of this report provides information on existing anthropogenic sources in the Kona area and the emissions control measures required of these sources. It demonstrates that despite the regulation of these man-made sources, the exceedances were “not reasonably controllable or preventable”.

Section 3 of this report establishes a “clear causal relationship” between the natural events and the exceedances of the annual $PM_{2.5}$ standard at the monitoring station. This section also discusses how sulfur dioxide (SO_2) gas from the volcano turns into sulfate particles as it travels to the Kona coast. The evidence in this section also confirms that the event in question both affected air quality and were the result of a “natural event”.

Section 5 of this report provides information which help illustrate that the exceptional event produced $PM_{2.5}$ concentrations in excess of normal historical fluctuations.

Section 6 of this report summarizes the demonstration, showing a clear causal relationship between the natural event and the exceedances, and concludes that these exceedances would not have occurred “but-for” the continuing natural event.

Section 2. Conceptual Model

The Kona air station is located on the upper campus of Konawaena High School, at 81-1043 Konawaena School Road, in Kailua-Kona, on the Island of Hawaii. The photos below in Figure 2-1 show the station and the surrounding view from the station. The station is at 517.2 meters (~1,697 feet) elevation on the lower slopes of Mauna Loa and approximately 2.6 miles inland from the west coast of the island. For more detailed information on the air station, please see pages 42-43 of the State of Hawaii's 2013 Air Monitoring Network plan available at our CAB website http://health.hawaii.gov/cab/files/2013/05/Air_Monitoring_Network_Plan_2013.pdf.

The closest emission source, Captain Cook Coffee Company, is approximately 1.7 miles away from the Kona station. The permitted equipment at this facility consists of two (2) 20 hp Coffee Bean Peelers, and has the maximum potential emissions of 2.2 TPY of $PM_{2.5}$, and 0.0 TPY of NO_2 and SO_2.

Northwest

North

Northeast

West

Station

East

Southwest

South

Southeast

Figure 2-1. Kona Air Station Photos

Figure 2-2 below is a satellite image taken from Google Earth of the Kona air station and the surrounding area. The image shows that the surrounding area is a mix of residential lots, agricultural lots, small business, forests, and grasslands.

Figure 2-2. Google Earth Photo of Kona Air Station

2.2 Topography and Climate of Hawaii

There are six major populated islands in the state of Hawaii with Kauai being geologically the oldest and Hawaii the youngest. It is the only state that is surrounded by ocean. The islands are actually the summit regions of a long range of undersea volcanic mountains with the largest peaks being Mauna Loa, and Mauna Kea on the island of Hawaii both rising over 13,000 feet above sea level.

Situated in the tropics, there are generally two recognized “seasons”: summer, which extends from May to September and winter from October to April. Hawaii has a temperate climate with a relatively small annual temperature variation with the coldest and warmest months usually occurring in February and August, respectively. Rainfall is influenced by the mountainous nature of the islands with the highest amounts being recorded on the lower flanks of the large peaks of Haleakala, Mauna Loa and Mauna Kea normally during the winter months. There is a large difference in average rainfall amounts between the east side of the island of Hawaii (Hilo) and the west side (Kona). The average rainfall amount from 2000 to 2011 for the Hilo side of the island was 114 inches, while the Kona side averaged 9 inches for the same period (ref. State of Hawaii 2012 Data Book).

The northeasterly trade winds are the predominant wind regime for the islands. These winds are produced by an area of high pressure called the Pacific High which is at its northern most position in summer. Therefore, during May to September, the trades predominate about 80 to 95 percent of the time and diminish when they move south with the sun during the winter months. Additionally, subtropical cyclones, often called Kona lows or Kona storms, occur more often in the winter months. The term Kona is used to describe these storms due to the replacement of the normal northeast trade winds with southerly winds.

The average wind speeds are highest during the trade wind months of May to September and decrease from October to April. When the trade winds are stronger, they prevail over most of the lowlands. However, in some areas such as the Kona coast and the Kihei area on Maui local sea and land breezes may actually be strengthened by the trade winds.

Figure 2-3 below show that the prevailing trade winds from the northeast usually travel over the island of Hawaii and then wraps around the south point of the island up to the Kona coast. A diurnal pattern of land-sea breezes occurs along the Kona coast. During Kona or southerly winds, the wind travels from the south of the island towards the eastern coast of the island.

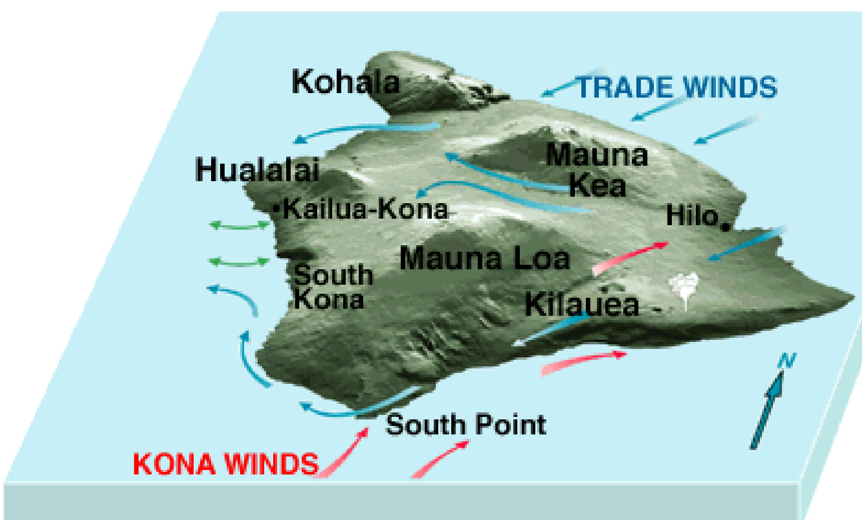

Figure 2-3. Hawaii Island Wind Patterns (courtesy USGS).

Figures 2-4 and 2-5 show how different weather/wind conditions can affect plume behavior. During typical trade wind days, the plume can be seen blowing in the southwesterly direction. During calm winds or Kona wind days, the vent emissions can be seen fumigating the summit and surrounding area.

Figure 2-4. View of Halema'uma'u crater and emission plume looking southeast from the Jagger Museum on trade wind day (taken by DOH staff)

Figure 2-5. View of Halema'uma'u crater and emission plume looking south from the Visitor Center on Kona wind day (taken by DOH staff)

The Kilauea volcano is situated on the southeastern part of the island of Hawaii. Halema'uma'u crater is located at the summit of Kilauea at an elevation of 4,091 feet (1,247 meters) and Pu'u O'o crater is located in the east rift zone at an elevation of

2,290 feet (698 meters). Halema'uma'u is located approximately 10 miles inland while Pu'u O'o is located approximately 6 miles inland.

Figure 2-6 is a topographical map of the Big Island showing the locations of the two vents, the ambient air stations operated by DOH, and the location of large emission sources that include five power plants. Figure 2-7 is a topographical map of the main Hawaiian Islands with information on Meso West and NPS locations. Figure 2-8 is a map of the Hawaiian Islands showing the population bases.

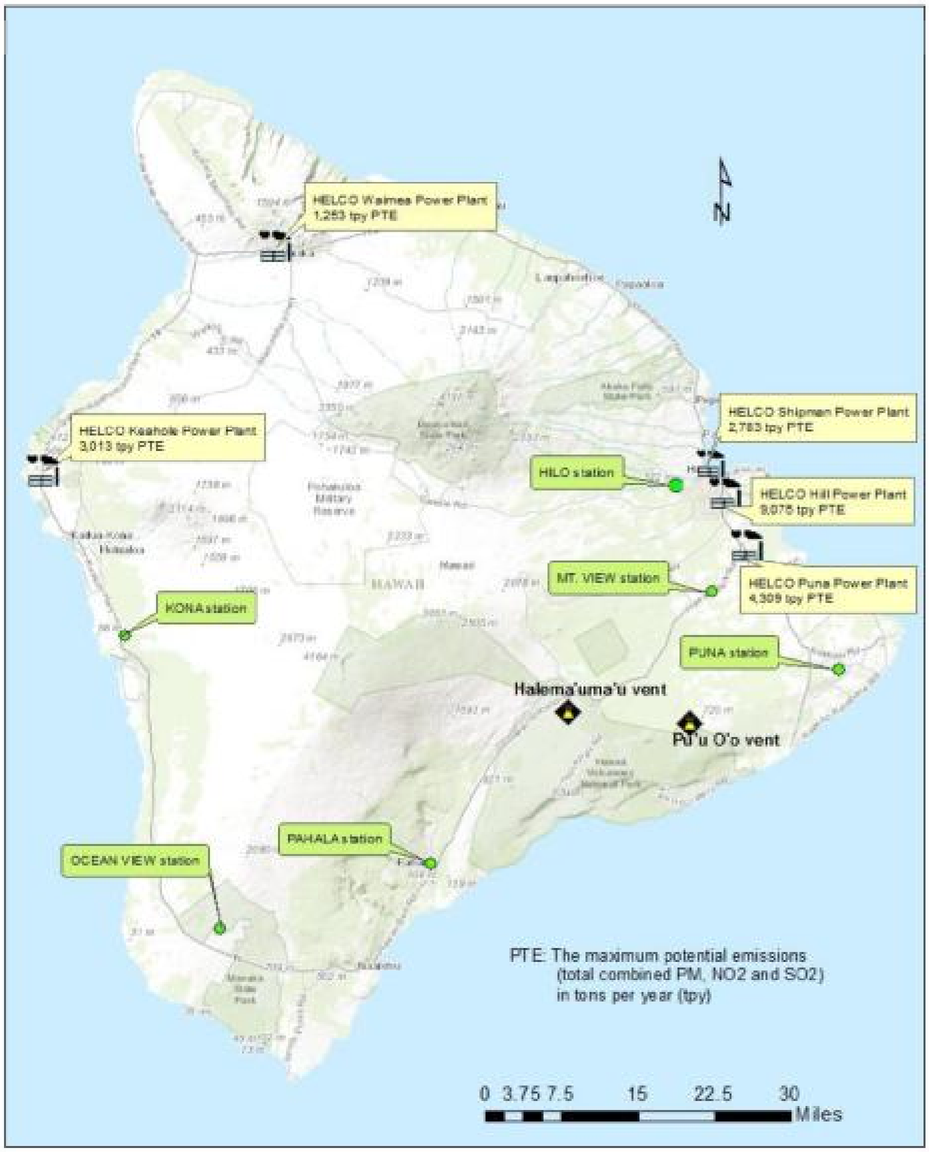

Figure 2-6. Hawaii Island Topographical Map.

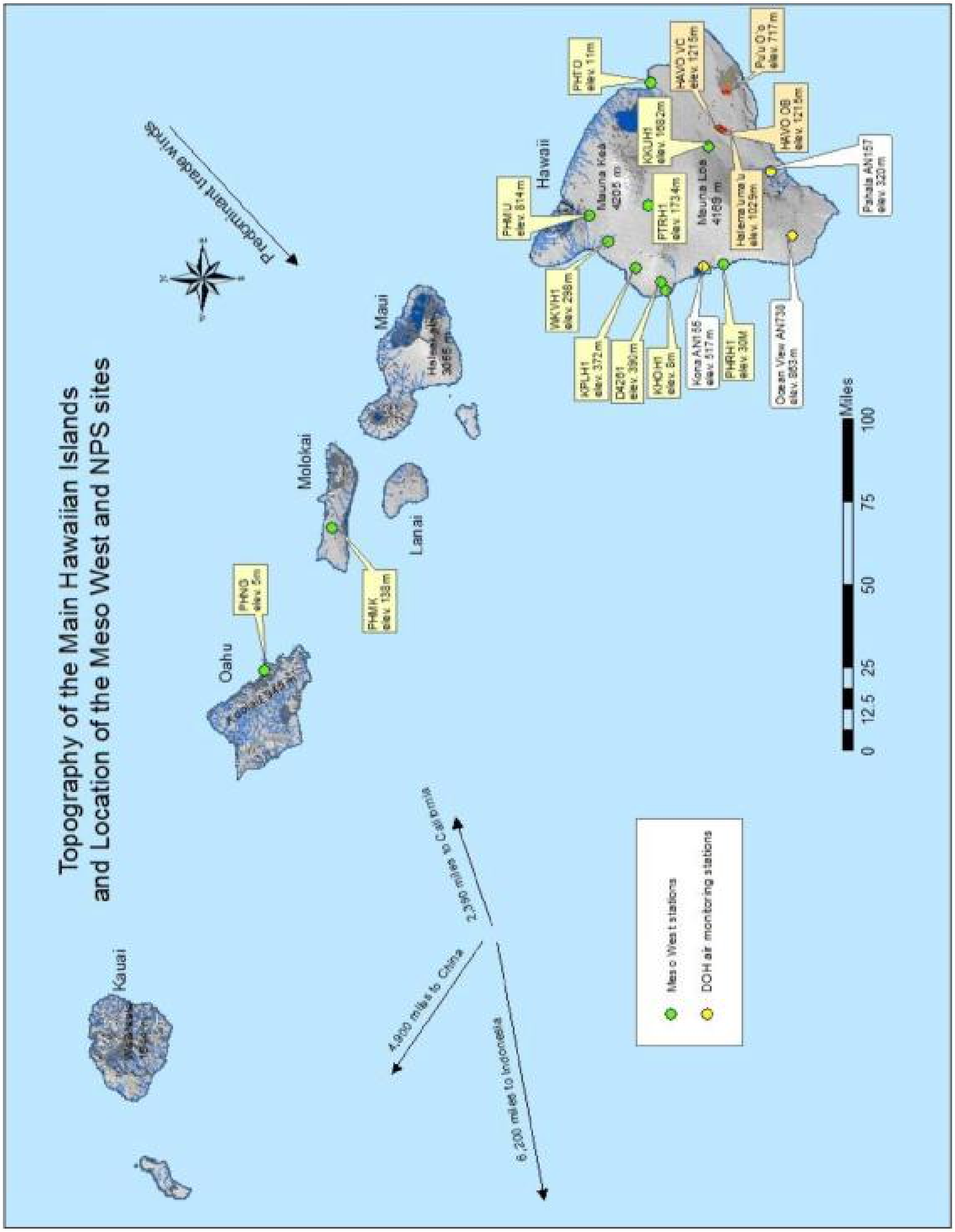

Figure 2-7. Hawaiian Islands Topographical Map.

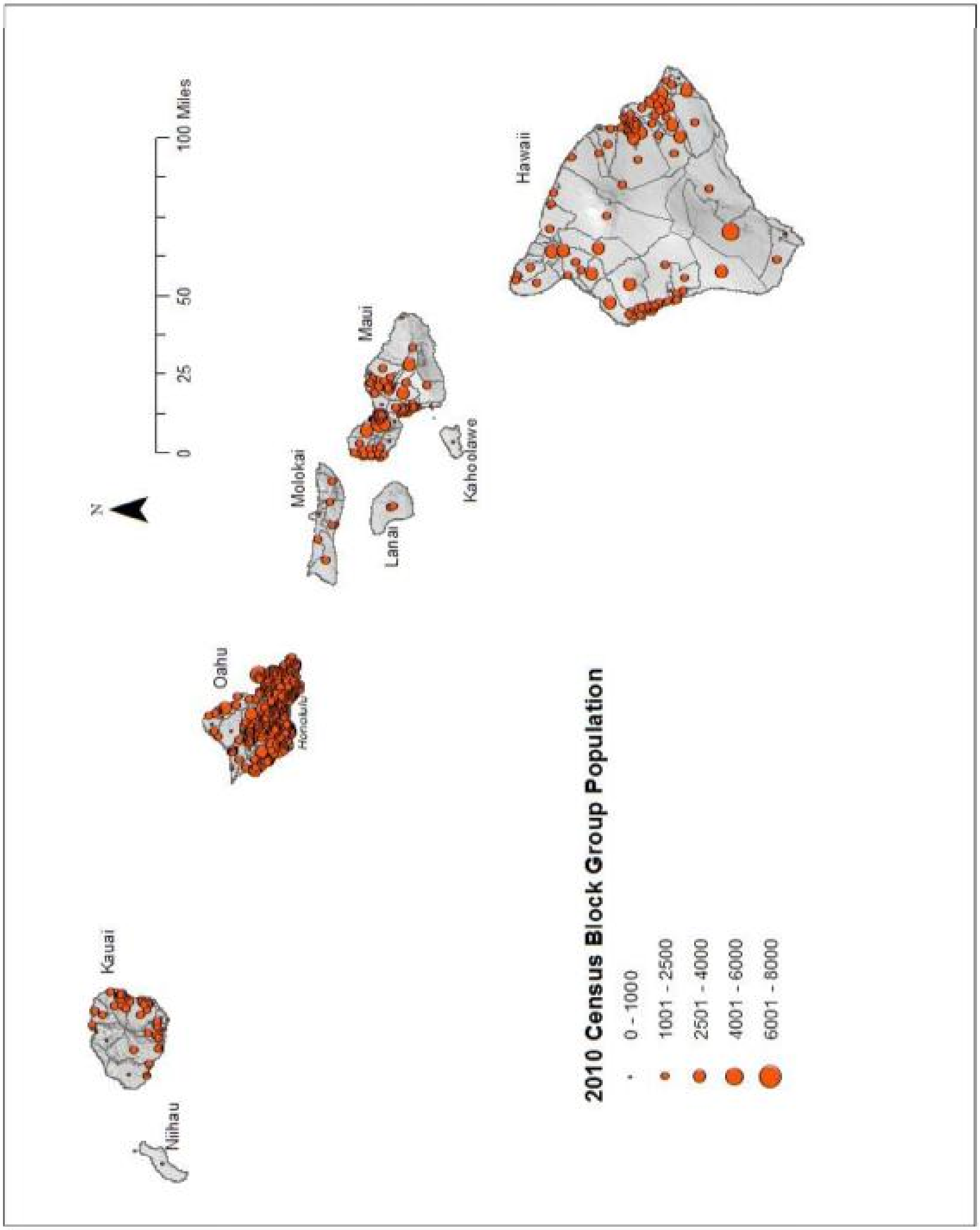

Figure 2-8. Hawaiian Islands Population Map.

2.3 Transformation of SO_2 to Sulfates ($PM_{2.5}$)

The SO_2 released from the Kilauea volcano creates vog when SO_2 reacts chemically with sunlight and constituents in the air to form sulfate aerosols. Effects from vog are evident from annual $PM_{2.5}$ concentration exceedances measured at the Kona air monitoring station as well as the effects on visibility around the Big Island and on other islands hundreds of miles away from the Kilauea volcano.

As the SO_2 gas travels around the southern end of the island, it interacts with other atmospheric constituents to form particulates that affect communities farther away from the vents, such as Kona. When the winds shift to a southerly direction, the volcanic emissions, mainly as SO_2 gas, are carried to towns northeast of the volcano, such as Mountain View and Hilo. Figure 2-9 is a satellite image that depicts this phenomenon.

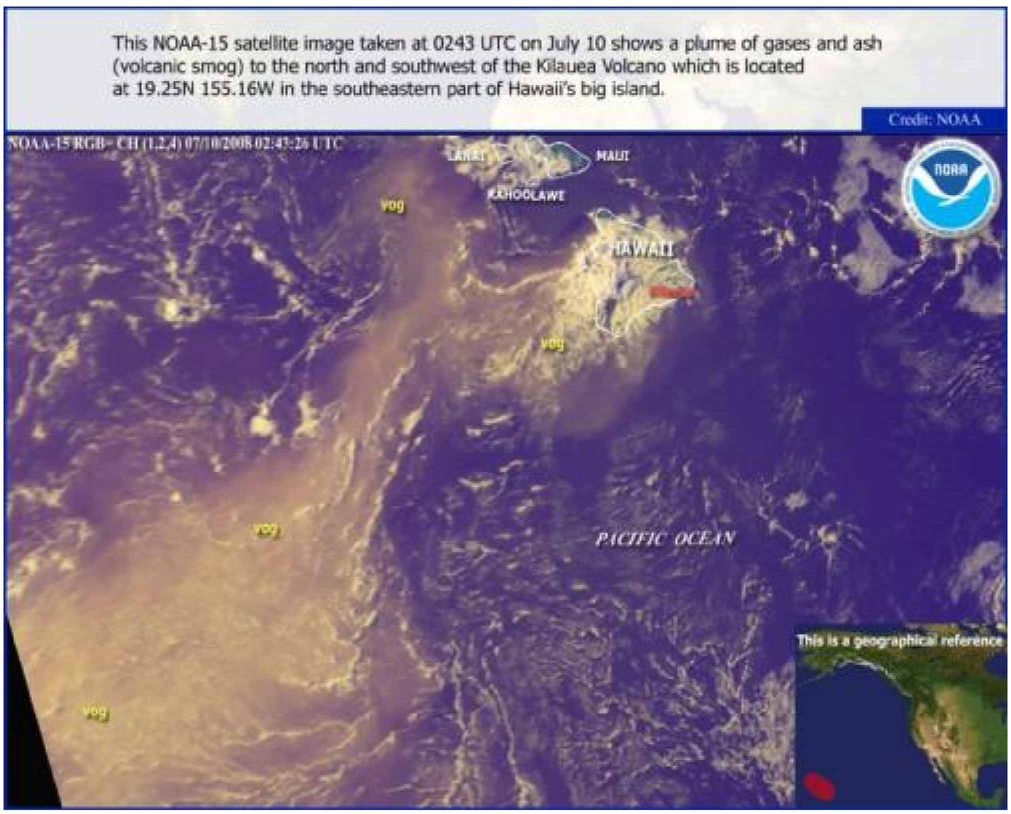

Figure 2-9. Satellite Image of Vog (courtesy NOAA).

The transformation of SO_2 from the Kilauea volcano into aerosol particles, of which $PM_{2.5}$ is a subset, is discussed in Ref. 7. The reference notes that SO_2 is depleted from the air by deposition (dry or wet) in the boundary layer or through chemical reaction to sulphuric acid (H_2SO_4). It notes that for the time period from 2007-2012, Kilauea SO_2 persists in the environment in the range of 16 to 57 hours, and states: "lifetimes are highest in summer when cloud cover is smallest, and shorter for higher cloud fractions in spring and autumn". It further states: "On average, we find a mean SO_2 lifetime of 1.56 days, which is consistent with previous studies."

2.4 SO_2 Emissions

The Kilauea volcano on the island of Hawaii has been erupting almost continuously since1983 typically emitting approximately 2,000 tons of SO_2 per day. The SO_2 is currently being emitted from two vents located at the Halemaʻumaʻu and Puʻu Oʻo craters. Prior to December 2007, approximately 200 tons of SO_2 came from the Halemaʻumaʻu vent and 1,800 tons came from the Puʻu Oʻo vent. In late December 2007, the SO_2 emission rate began to increase; and on March 13, 2008, a new gas vent at Halemaʻumaʻu increased the amount of SO_2 from this location ten-fold, from 200 to 2,000 tons per day.

Figure 2-10 below represents the emissions in tons per year from the Kilauea volcano at the Halema'uma'u and Pu'u O'o (East Rift Zone) vents. This data was provided by the United States Geological Survey (USGS), who provides periodic updates of final emissions estimates; the most recent report (Ref. 4) includes data through 2010.

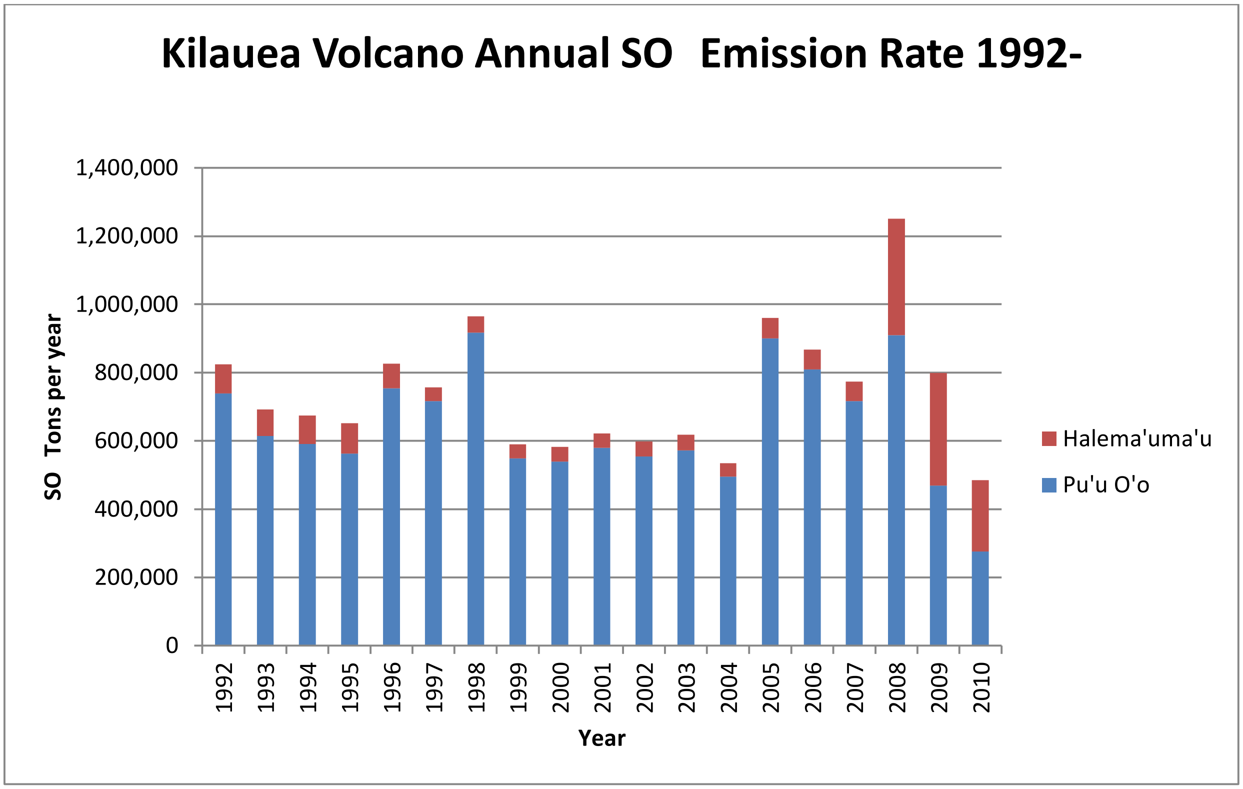

Figure 2-10. Kilauea Volcano Annual SO_2 Emission Rates 1992-2010

Figures 2-11 and 2-12 below show the average daily output of SO_2 during 2011 and 2012 as gathered from the Hawaii Volcanoes Observatory Daily Updates. Preliminary emissions estimates are provided in the updates for both Pu'u O'o and Halema'uma'u. The daily averages for each month were derived by totaling the daily output from each vent for each month, and dividing the total by the number of days in the month.

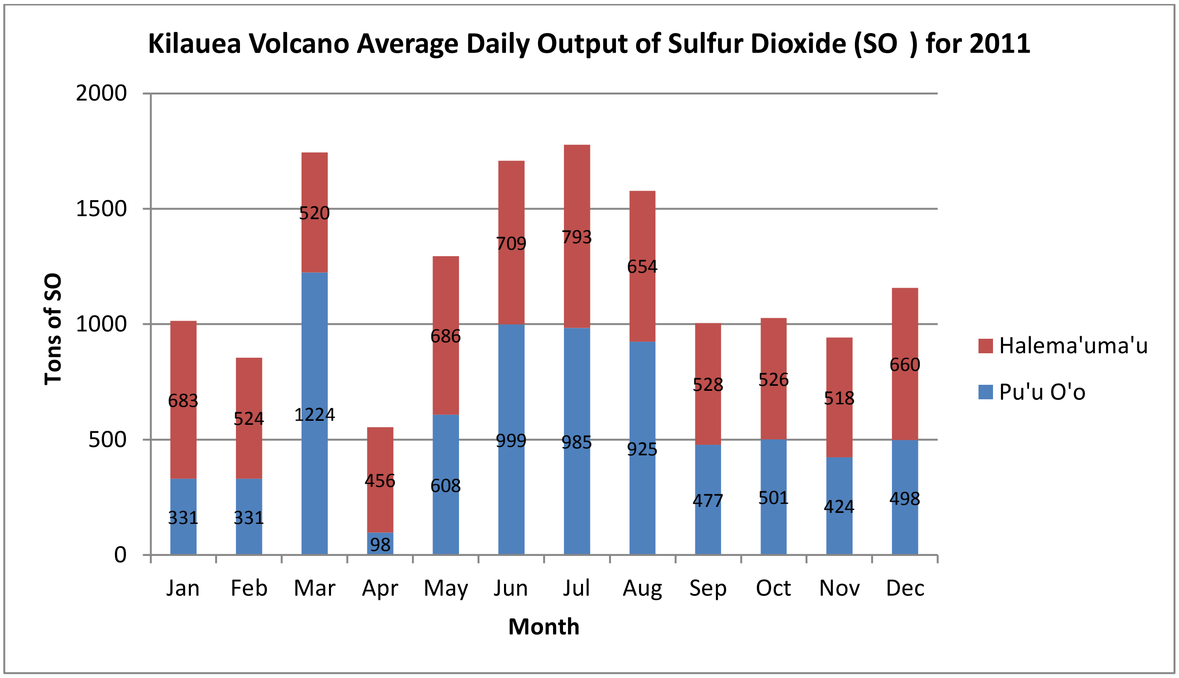

Figure 2-11. Kilauea Volcano Average Daily Output of Sulfur Dioxide (SO_2) for 2011

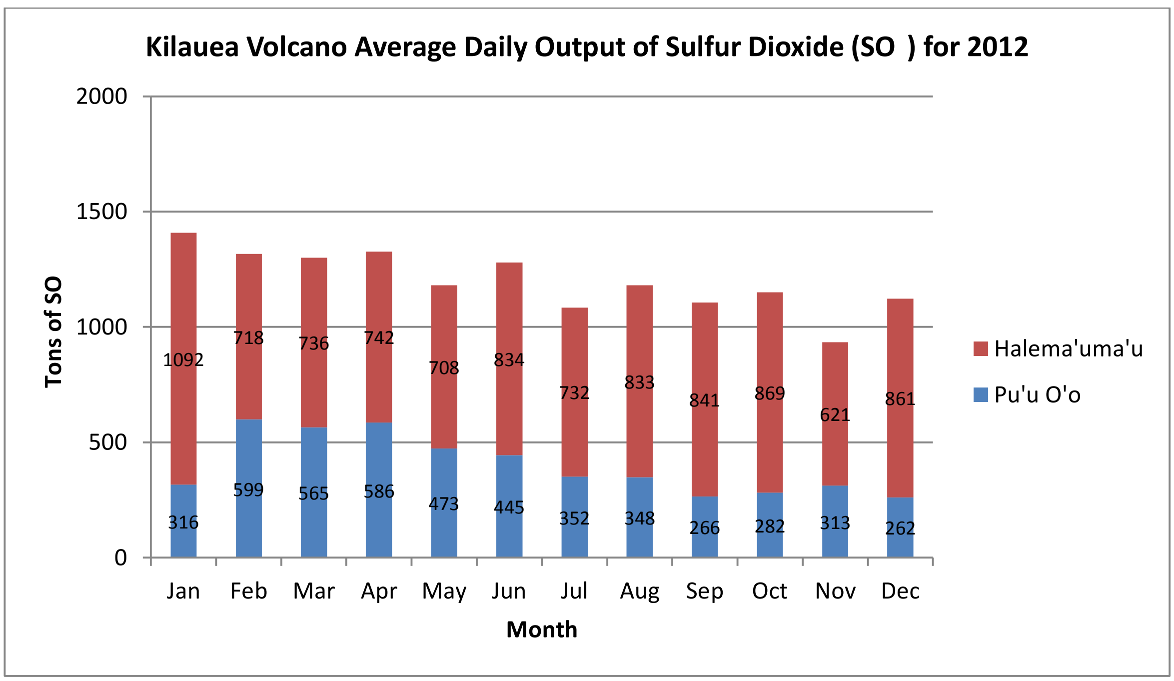

Figure 2-12. Kilauea Volcano Average Daily Output of Sulfur Dioxide (SO_2) for 2012

Emissions from the Halema'uma'u vent were found to have a greater impact on air quality in Kona than those from the Pu'u O'o vent. Because the Halema'uma'u vent is located at a higher elevation and more inland, volcanic emissions would tend to drift more over the island than out to the ocean. Conversely, trade winds would tend to push volcanic emissions from the Pu'u O'o vent more over the ocean because this vent is located at a lower elevation and closer to the coast.

The higher annual $PM_{2.5}$ concentration recorded at the Kona air monitoring station in 2012 is likely the result of a much greater release of SO_2 from the Halema'uma'u vent in 2012 than in 2011. In 2012, SO_2 released from the Halema'uma'u vent was 71,584 tons per year greater than what it released in 2011. The quantity of SO_2 released from the Halema'uma'u vent in 2012 was also 146,518 tons per year greater than that released from the Pu'u O'o vent in 2012. This correlates to the premise that the Halema'uma'u vent has a greater impact on the Kona air monitoring station than the Pu'u O'o vent.

Emissions from the volcano are considerably higher than those from anthropogenic sources in Kona. The SO_2 emissions from the volcano were as high as 447,566 tons per year and 438,958 tons per year for 2011 and 2012, respectively. A comparison of volcano emissions to those from significant anthropogenic sources in Kona found that $PM_{2.5}$ and $PM_{2.5}$ precursors of NO_2 and SO_2 are only 1% of the total emissions (anthropogenic $PM_{2.5}$, NO_2, and SO_2 + volcanic SO_2). This shows that Kilauea volcano is the primary source contributing to annual $PM_{2.5}$ concentration exceedances.

Concentration versus time plot comparisons of annual $PM_{2.5}$ and SO_2 from Kona and Ocean View air monitoring stations show plots that match well between the two stations over the 2011 to 2012 time frame. It should be noted that these stations are 28 miles apart. Similar plots for the two monitoring stations indicate a large regional source is affecting the air quality at the monitoring sites. The Kilauea volcano is a large regional source that is not reasonably controllable or preventable and is the most likely source of emissions responsible for this correlation.

Air pollution control measures provided by regulations that apply to anthropogenic sources in the Kona area, including the HAR, PSD/BACT, NSPS, and NESHAP, are adequate and should be considered reasonable for minimizing $PM_{2.5}$ and $PM_{2.5}$ precursors from permitted sources. Please refer to Section 4.12 for the applicable regulations. As stated in Section 4.13, Title V sources, which include all large facilities in the Kona area, are inspected each year to ensure equipment is operated within the terms of the permits.

Air monitoring data for 2011 and 2012 shows a decrease in annual SO_2 concentration from the Pahala to the Ocean View stations and a further decrease from the Ocean View to Kona stations while there is an increase in annual $PM_{2.5}$ concentration from Kona to the Ocean View stations and an additional increase from the Ocean View to Pahala stations. This supports the concept that SO_2 is converting to sulfates in the wake of the volcano's plume as it drifts along a transport path from Pahala-to-Ocean View-to-Kona. Figure 2.9 shows vog created from gases released by the Kilauea volcano. The presentation by Rudy Husar also illustrates the conversion of SO_2 to sulfates in the island's wake on Page 12: http://datafedwiki.wustl.edu/images/6/6d/130919_Hawaii_EE_DSS.ppt. The transport path for SO_2 released by the volcano is consistent with what would be expected based on wind patterns for the island. As indicated in Section 2.2, prevailing trade winds from the northeast usually travel over the island, wrap around South Point, and then travel up the Kona coast. In Section 3, additional information is provided on the diurnal wind pattern that traps pollutants in the Kona area.

It should be noted that emissions from sources located on the Hilo side of the Big Island would rarely follow the identical transport path as emissions from either the Halema'uma'u or Pu'u O'o craters. At minimum, a northeast trade wind would be required for emissions from sources located in Hilo to follow the same transport path as that for the Halema'uma'u and Pu'u O'o vents. Although the Hawaiian Islands are dominated by northeast trade winds, the winds in the Hilo area are heavily influenced by Mauna Kea and Mauna Loa, producing a dominant southerly wind flow.

This phenomenon can be seen by examining wind roses of two (2) sites. Section 3, Figure 3-10 (left) illustrates a dominant northeast trade wind flow from a meteorological site at Molokai Airport. This site is not influenced by high mountain ranges. In contrast, Section 3 Figure 3-12 (left) illustrates the dominant southerly wind flow at the Hilo International Airport due to the diurnal heating and cooling effects of Mauna Kea and Mauna Loa.

The Waimea area of the Big Island, approximately 55 miles north of the Halema'uma'u and Pu'u O'o craters was also examined to address the effects of source emissions from this location. The winds in this area are also heavily influenced by Mauna Kea and most likely prevents emissions from the Waimea area to follow the same transport path as emissions from Halema'uma'u and Pu'u O'o vents.

2.6 Hawaii Island Attainment Status

The Big Island of Hawaii attainment/non-attainment status is currently unclassifiable for $PM_{2.5}$, NO_2 and SO_2 due to the Kilauea volcano.

Section 3. Causal Relationship

The primary purpose of this effort is to analyze $PM_{2.5}$ monitoring data sets from the Kona monitor on the island of Hawaii with respect to the significant volcanic emissions from the Kilauea volcano. This work is intended to provide supporting documentation for the exclusion of datasets under the Exceptional Events Rule (EER). To accomplish this:

- Volcanic SO_2 emission information from the United States Geological Survey (USGS) and SO_2 and $PM_{2.5}$ pollutant and wind monitoring data from the United States National Parks Service (NPS) were examined (Ref. 9);
- SO_2, $PM_{2.5}$, and wind monitoring data sets from the United States Environmental Protection Agency (EPA; Ref. 10) and University of Utah MesoWest (MesoWest) were analyzed (Ref. 11);
- Additional relevant wind monitoring data was examined with respect to potential pollutant transport paths; and
- The proposed exceptional event days for Kona were examined relative to relevant monitoring data.

The vent from Halema'uma'u, located at a higher elevation and further inland, appears to have a greater impact on the more populated areas of the island than the Pu'u O'o vent, which is situated at a lower elevation and closer to the coast. The prevailing trades would tend to push the plume from Pu'u O'o out more over the ocean while the plume from Halema'uma'u would be blown more directly to the town of Pahala and Ocean View, and subsequently up the Kona coast. During days with southerly winds, the Kona area clears up as the plume from Halema'uma'u would be blown more directly to Hilo and Mountain View.

During Kona or southerly winds, the vog from Kilauea travels up to the other islands in the chain. The DOH-CAB monitors the weather forecasts for these Kona wind days as the vog creates widespread haze (see Figure 3-1) and elevated $PM_{2.5}$ levels can be seen at the stations on Maui, Oahu, and/or Kauai. To date, the vog has not resulted in $PM_{2.5}$ exceedances on these islands. However, on such days, the DOH-CAB often declares a "no-burn" period for agricultural burning on these islands as well as for the east side of Hawaii Island in order to protect human health and prevent additional particulate pollution. Historically, the majority of no-burn days occur during the winter months, when Kona winds are more likely to occur.

The analysis shows that high $PM_{2.5}$ concentrations measured at the Kona air monitoring station are the result of SO_2 released from the volcano's Halema'uma'u and Pu'u O'o vents (Figure 2-7). SO_2 transported from north of Kona would have the SO_2 decreasing from Kona, through Ocean View, and on to Pahala. $PM_{2.5}$ would grow from Kona to Pahala; neither of these is the case. A very large $PM_{2.5}$ north of Kona would not explain the increasing SO_2 concentrations monitored as the postulated pollutant is transported from Kona, to Ocean View and to Pahala.

The elevated Halema'uma'u (summit) emissions after 2007 shown in Figures 2-10, 2-11, and 2-12 are consistent with the USGS observations (Ref. 1, 3, and 4). If there was a potentially large SO_2 emission source other than the volcano upwind of Pahala, it would be a second candidate for causal analysis. However, as shown in Figure 2-6, there is no such source.

The diurnal nature of the winds at Kona, Ocean View, and Pahala provides the coupling between the elevated aerosol concentrations that are observed by satellite observations (e.g. Figure 2-9) and $PM_{2.5}$ and SO_2 concentrations measured at the sites. The good correspondence between time histories of $PM_{2.5}$ and SO_2 concentrations measured at Kona and Ocean View for both 2011 and 2012 is consistent with this transport.

These examinations of pollutant and wind monitoring data indicate that SO_2 emissions from the Kilauea volcano are the cause for the elevated levels of $PM_{2.5}$ at the Kona monitoring site.

Figure 3-1. Honolulu on a Hazy Kona Wind Day (taken by DOH staff)

3.1 Volcanic emissions and pollutant monitoring data from the Kilauea Volcano

3.1.A Overview

The magnitude of SO_2 emissions from the Kilauea volcano on the island of Hawaii is well documented, as is the impact on the Hawaiian Islands. The USGS noted in 2012 that SO_2 plumes from both major Kilauea volcano emission vents, Pu'u 'O'o (rift zone) and Halema'uma'u (summit), significantly impact the Kona area, stating (Ref. 1):

"Unfortunately, both plumes eventually reach the west side of Hawai`i Island in a "doublewhammy" of combined effects, resulting in an especially dense and nearly constant haze of vog along the Kona coast."

The use of the term "nearly constant haze of vog" is consistent with the nearly constant elevated level of $PM_{2.5}$ and SO_2 measured at the Kona monitoring station; monitoring site location and general information available at reference 2. The USGS noted the direct relationship between Kilauea SO_2 emissions and elevated levels of SO_2 and sulfate particles at Kona in their March 7, 1997 "Hawaii Volcano Observatory, Volcano Watch" webpage stating (Ref. 2a):

"This 90% decrease in released SO_2 gas from Kilauea is very good news for Kona residents, for it means that there is simply much less gas to be blown by the prevailing trade winds from degassing sources on Kilauea around South Point, and up along the Kona coast, where it is trapped by the onshore-offshore daily wind regime. On this journey, there is also less gas to react chemically with sunlight, oxygen, dust and water to form the sulfuric acid and other sulfate particles that cause the visible pollution that had become so ubiquitous for Kona residents and visitors."

In 2008, the USGS discussed the connection between elevated SO_2 emissions from the Halema`uma`u vent and $PM_{2.5}$ exceedances around Kona and Pahala (Ref. 2b); this would also include the Ocean View area. Key conditions and observations described by USGS in the article were:

"During prevailing trade winds, the east rift gas plume is generally blown out to sea, where it is dispersed and diluted before being carried back onshore to impact downwind communities. The Halema`uma`u plume remains onshore and is generally blown through the Ka`u desert to directly affect downwind communities."

"Since the new activity at Halema`uma`u began, the EPA standards for SO_2 have been exceeded on numerous occasions in Pahala, and for particulate matter they have been exceeded in both Pahala and Kona. The Pahala air quality monitoring station, which was installed in August 2007, only measured exceedance of SO_2 standards after the opening of the Halema`uma`u vent in March 2008." (See Figure 2-10)

To further examine the link between the volcano and Kona $PM_{2.5}$ measurements, the SO_2 emission time history was examined. The USGS monitors SO_2 emissions from Kilauea vents at the rift zone and summit and reports preliminary values at their "Recent Kilauea Status Reports, Updates, and Information Releases" webpage (Ref.3). While these values are preliminary, the USGS provides periodic updates of final emissions estimates, the most recent of which includes data from 2007 through 2010. This latest report (Ref. 6) includes one reference that estimates Kilauea's 2007-2010 SO_2 average of 751,000 metric tonnes per year (approximately 828,000 tpy), and notes that this is approximately 6% of the global volcanic SO_2 emissions. In addition to providing the total emissions, the report also documents the time history of relative emission from the summit and rift zone from 2000 through the end of 2010, showing the shift in emissions from being dominated by the rift zone through 2007, to a more even division in 2009, with somewhat greater emissions from the summit into 2010 (see Figure 31 of Ref. 6).

The NPS monitors SO_2 and $PM_{2.5}$ levels, along with weather information within the Kilauea National Park from the Hawaii Volcanoes National Park - Visitor Center and Hawaii Volcanoes National Park - Observatory, located near and to the northeast and northwest of the summit vent (See Figure A-1).

3.1.B USGS SO_2 Emissions Estimates & NPS Pollutant and Wind data

Using the preliminary SO_2 emissions information posted on the USGS website (Ref. 5), DOH calculations show a slight decrease in the total SO_2 emissions from the summit and rift zone vents between calendar years 2011 and 2012 (see Figures A-2, A-3), with summit emissions increasing by approximately 33% and rift zone decreasing by 35%. These DOH calculation result in total annual SO_2 emissions for 2011 and 2012 of approximately 448,000 tons per year and 439,000 tons per year, respectively. The increase in SO_2 emissions from the summit of Kilauea is noteworthy since, consistent with the USGS 2008 web posting (Ref. 4) discussed previously, it would indicate an expectation for increased SO_2 and particulate levels for the Pahala, Ocean View, and Kona areas for 2012 relative to 2011.

	2011 Daily Average	**2012 Daily Average**	**2011 to 2012**
USGS webpage based DOH estimate of Kilauea Volcano SO2 Emission Rate	**SO2 (Tonnes / day)**	**SO2 (Tonnes / day)**	**% change**
Summit	550	726	32%
Rift Zone	563	362	-36%
Total	1,112	1,088	-2%

Table 3-1. 2011-2012 USGS preliminary SO_2 emissions data compiled by DOH

The preliminary USGS SO_2 emission estimate was compared to the SO_2 and $PM_{2.5}$ monitoring data from the Kilauea Observatory (HAVO OB), and SO_2 monitoring data from the Kilauea Visitor Center (HAVO VC). For the time-wise comparisons of SO_2 emissions and pollutant monitoring, daily values were normalized to their respective annual averages to account for magnitude differences. Figures A-4 through A-9 present the preliminary SO_2 emission estimates with blue lines and the NPS monitoring data (Ref. 9) with red dots. The normalized emission levels are seen to generally be relatively flat compared to the monitored levels, and there is no significant correlation between any of the paired emission and monitored datasets. While these paired data sets corresponded poorly, this is consistent with the local wind patterns, which tend to transport volcanic emissions away from the two monitoring sites. The pronounced difference between the prevailing winds and pollutant approach direction is indicated in Figures A-10 through A-13. For each figure, the windrose and pollution windroses are presented on the left and right, respectively. The windroses graphically present the total hourly occurrences of winds approaching from the indicated 15 degree quadrants during the monitoring year. The pollution windroses graphically present the total hourly pollutant levels associated with winds approaching from the indicated 15 degree quadrants during the monitoring year. Figures A-10 and A-11 show winds approaching HAVO OB for 2011 and 2012 from the northeast, while SO_2 approaches from the north and southeast. Figures A-12 and A-13 show winds approaching HAVO VC from the northeast, with SO_2 approaching from the southwest. As can be seen with the aid of Figure A-1, the southerly approach directions for indicated by the pollution windroses for HAVO OB and HAVO VC are consistent with approximate line of sight transport from the nearby summit (Halema`uma`u) vent. The northern approach of SO_2 to HAVO OB would be consistent with the partial return of Kilauea summit emissions that are initially transported north of HAVO OB and then return.

Recent satellite based Kilauea SO_2 emission estimates have indicated that emission levels for March through November 2008 that are about 3 times larger than those previously estimated by the USGS using ground based measurements (Ref. 7). The USGS is reviewing these preliminary Kilauea SO_2 emission estimates, as well as values in prior published reports (e.g. Ref. 6), for possible revision. Changes in the USGS ground based measurement methods are also being developed to improve measurement accuracy and address the estimate differences reported in reference 7. The emission levels after revision are currently expected to result in day to day variations that will appear similar to those previously published, but with larger values overall (Ref. 8).

3.1.C Discussion

While the USGS SO_2 emissions estimates for 2011 and 2012 are preliminary, and may be revised upward by USGS, they provide an indication of the magnitude of the total emissions as well as relative emissions associated with the summit and rift zone. Based on the 2008 USGS assessment (Ref. 4), the growth in Kilauea summit SO_2 emissions from 2011 to 2012, from about 221,000 tpy to 293,000 tpy, is consistent with the increase in SO_2 and particulate levels at Kona, Ocean View, and Pahala between 2011 and 2012.

3.2 Pollutant monitoring data from Kona, Ocean View, and Pahala

3.2.A Overview

The locations of DOH pollutant and weather monitors at Kona, Ocean View, and Pahala are shown in Figure 2-7. $PM_{2.5}$ and SO_2 monitoring data from these monitors were downloaded from the EPA AQS Data Mart (Ref. 10). The AQS designations for the Kona, Ocean View, and Pahala monitors are 150011012, 150012020, and 150012016, respectively. The AQS designation for the $PM_{2.5}$ and SO_2 pollutants are 88101 and

42401, respectively; there is an extra "1" at the end of the AQS ID number for datasets downloaded from the AQS Data Mart Data (e.g. the Kona $PM_{2.5}$ ID number is 150011012881011). For each monitoring site and pollutant, pollutant concentrations are nominally reported hourly. The measurement units for $PM_{2.5}$ and SO_2 presented in this assessment are micrograms per meter cubed (μg/m3) and parts per billion (ppb), respectively. Wind direction data associated with these three monitors, as well as for other relevant monitors, was obtained from the University of Utah MesoWest website (Ref. 11). The weather monitors associated with the Kona, Ocean View, and Pahala pollutant monitoring sites are identified by MesoWest as AN155, AN738, and AN157. To confirm apparently erroneous wind direction measurements at the Kona site during the middle of calendar year 2012, data from 3 additional monitoring sites were examined. These sites are identified by MesoWest as D4261, KHOH1, and PHRH1. The locations of these monitoring sites and additional ones discussed in this Section 3.2 are shown in Figure 2-7.

It is important to note that the annual average values presented in throughout Section 3.2 were calculated by averaging all daily values based on all hourly data downloaded from the AQS Data Mart for both $PM_{2.5}$ and SO_2. This calculation method was used to produce a value for normalizing individual datasets, and will not produce the exact results reported in the Introduction (e.g 12.1 $\mu g/m^3$ and 16.2 $\mu g/m^3$ for 2011 and 2012 Kona $PM_{2.5}$, respectively). However, for the purpose of normalizing the downloaded AQS dataset, it is an appropriate methodology and result. The calculations were made using heritage subroutines and limited time and the risk of introducing errors made revisions very unwise considering that the calculation results were used only for this section's visualization and trend establishment purposes.

3.2.B Annual Average for Normalization of $PM_{2.5}$ and SO_2 Pollutant Concentrations

Annual average $PM_{2.5}$ and SO_2 concentration levels from the Kona, Ocean View, and Pahala monitoring sites were calculated for dataset normalization purposes with data from the EPA AQS Data Mart. For all datasets, the nominal hourly measurement values were averaged for each day, and annual averages were calculated by averaging the daily values for a given calendar year. Negative concentration values were included in the averaging process. The annual average for concentrations for $PM_{2.5}$ and SO_2, as well as the percentage increase between 2011 and 2012 (using 2011 as the baseline) are shown in Tables 3-2 and 3-3, respectively. Two important characteristics appear very clear from these values. First, all monitoring sites show pollutant concentration increases between 2011 and 2012. These results, when coupled with the 2008 USGS web posting (Ref. 4), are consistent with the estimated 32% increase in SO_2 emissions from the Kilauea summit; while a range of sources may have had a similar level of change between years, the very large nature of the Kilauea source and it's associated regional impact is unique. Second, the effect of the chemical transformation from SO_2 into $PM_{2.5}$ as the prevailing winds carry the pollutants from Pahala, to Ocean View, and finally up to Kona (as discussed in the 1997 USGS web posting, Ref. 3). For both years, the annual average $PM_{2.5}$ concentrations increase from the smallest values at Pahala, to Ocean View, and finally at the Kona site (Table 3-2). Likewise, the annual average SO_2 concentrations decrease from the largest values at Pahala, to Ocean View, and the Kona site (Table 3-3).

	2011 Annual Ave	2012 Annual Ave	2011 to 2012
Monitor	**PM2.5 (µg/m^3)**	**PM2.5 (µg/m^3)**	**% change**
Kona	12.23	16.18	32%
Ocean View	10.03	12.97	29%
Pahala	6.18	7.59	23%

Table 3-2. 2011-2012 AQS Data Mart Hourly $PM_{2.5}$ Data: Annual Averages

	2011 Annual Ave	2012 Annual Ave	2011 to 2012
Monitor	**SO2 (ppb)**	**SO2 (ppb)**	**% change**
Kona	2.88	5.36	86%
Ocean View	13.38	23.06	72%
Pahala	33.64	52.16	55%

Table 3-3. 2011-2012 AQS Data Mart Hourly SO_2 Data: Annual Averages

Thus, annual average concentration levels for normalization are consistent with both the annual average SO_2 emissions from the Kilauea summit, the expected pollutant transport path, and the expected chemical transformation process.

3.2.C 2011 $PM_{2.5}$ and SO_2 Pollutant Concentrations at Kona & Ocean View

The USGS well outlines the expected transport path for pollutants originating from the Kilauea volcano (Refs. 2, 3, 4), and the annual average pollutant levels are consistent with this description. However, it was recognized that additional confirmation of the linkage between volcanic emissions and monitoring levels could potentially be gleaned from the pollutant time histories measured at the Kona, Ocean View, and Pahala monitoring sites. The linkage between Kona and Ocean View datasets, particularly for the $PM_{2.5}$ pollutant, are very evident from a casual comparison of the plotted time histories (Figure 3-2). The $PM_{2.5}$ concentration peaks and valleys are seen to match quite well throughout 2011.

Note that the time histories presented in this section plot the average of the three daily average values for normalization, centered on the middle (second) day. This smoothing was performed to represent time lag associated with pollutant transport between Ocean View and Kona, as well as provide some smoothing of the large short scale concentration variations that are characteristic of these datasets. The degree of smoothing, plus and minus one day about the center point, is also consistent with the estimated SO_2 average lifetime of 1.56 days discussed in Section 2-3 (Ref. 7).

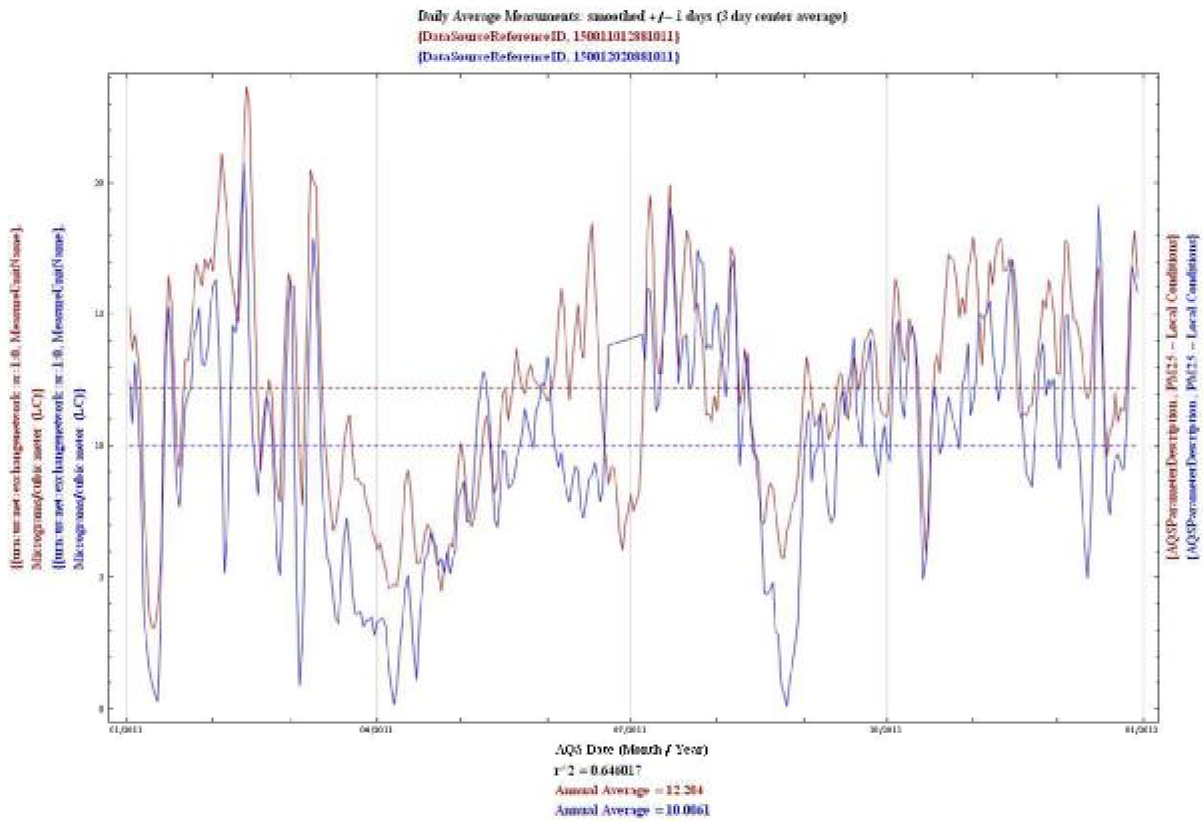

Figure 3-2. 2011 Time History of Kona (red) and Ocean View (blue) $PM_{2.5}$ Concentrations

For comparison, the plot without smoothing is shown in Figure A-14. In both figures, the Pearson correlation (r^2 ; Ref. 12), a quantitative indication of how well the two concentration time histories match, are given below the "AQS Date (Month / Year)" label and are seen to be similar; approximately 0.65 for the smoothed case shown in Figure 3-2 versus approximate 0.56 without smoothing (Fig. A-14); a r^2 value of one is the maximum correlation value. The annual average values are calculated using the daily values used for plotting. Because the smoothing weights the concentration values for the first and last data values at half the value as the remaining 363 for calendar year 2011, the annual average values are seen to be very slightly different between the smoothed and unsmoothed plots (e.g. 12.204 µg/m^3 for 2011 Kona with smoothing versus 12.2259 µg/m^3, the value represented in Table 3-2, without smoothing).

At the bottom of Figure 3-2, the annual average $PM_{2.5}$ concentrations for Kona and Ocean View are shown. The Kona concentration is seen to be approximately 20% larger than for Ocean View. The time histories for Kona and Ocean View show the Kona $PM_{2.5}$ concentrations are generally slightly higher than those at Ocean View. This is consistent with the USGS description of the expected transport path of Kilauea volcano SO_2 and its chemical conversion into sulfate particulates. In an attempt to better visualize the correspondence between the pollutant concentrations at the monitoring sites, their time histories were normalized with respect to their annual averages.

In Figure 3-3, for example, Kona $PM_{2.5}$ concentrations throughout 2011 were divided by the annual average of the daily $PM_{2.5}$ concentrations (after smoothing), and likewise for Ocean View $PM_{2.5}$ concentrations. Through normalization, the relative similarities and differences in the two time histories appear easier to identify. Because the annual averages for the two sites differ by only about 20%, Figure 3-2 and 3-3 appear quite similar.

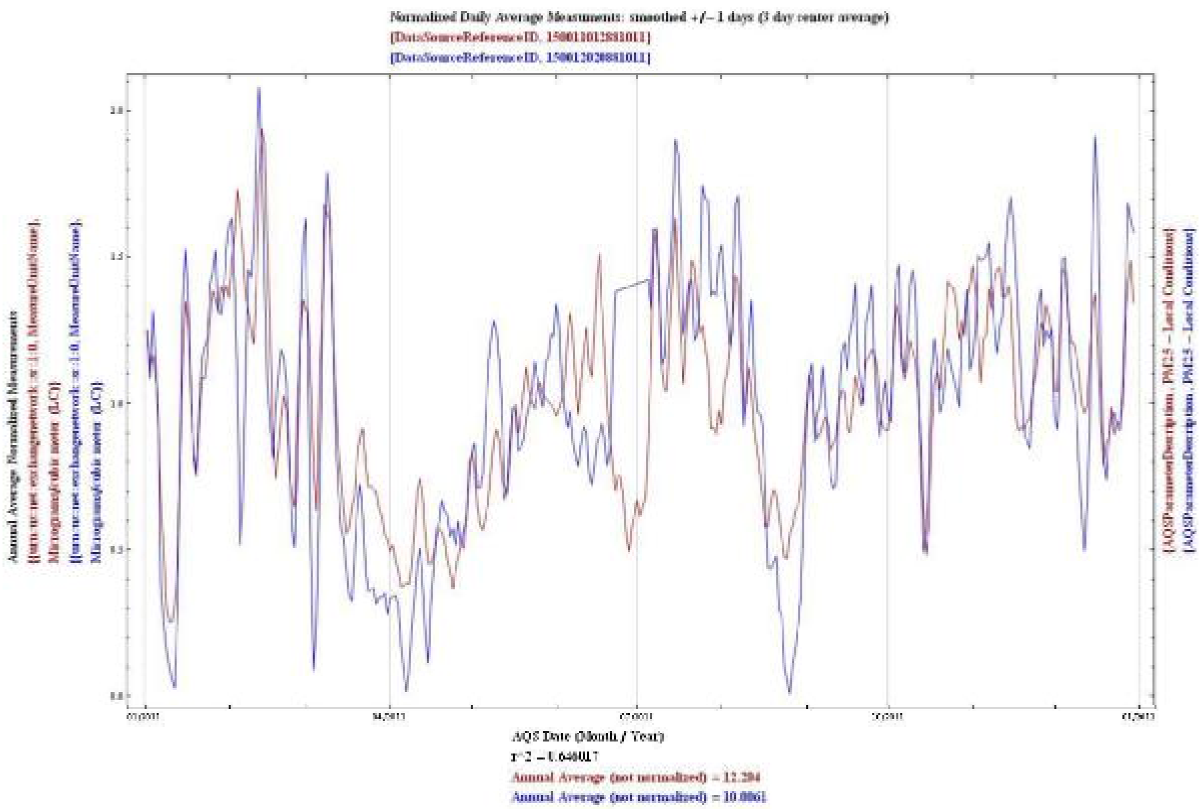

Figure 3-3. 2011 Time History of Kona (red) and Ocean View (blue) normalized $PM_{2.5}$ Concentrations

However, Figure 3-3 does assist in showing that the $PM_{2.5}$ concentration time histories at Kona and Ocean View correspond well. It should be noted that correlation values (r^2) shown in the two figures are identical. This is a feature of the Pearson correlation algorithm, which remains unchanged if one or both datasets are multiplied by a constant.

The good correspondence between the Kona and Ocean View $PM_{2.5}$ time histories though 2011 is continued in 2012. Figure 3-4 shows the smoothed concentrations for 2012; the unsmoothed plot is shown in Figure A-15, and is seen to be similar. As would be expected from the increased SO_2 emissions from the Kilauea summit, the annual average of the $PM_{2.5}$ concentrations at both sites are greater in 2012 than in 2011. The correlation value (r^2) associated with 2012 is only slightly smaller in 2012 than in 2011, approximately 0.57 versus 0.64.

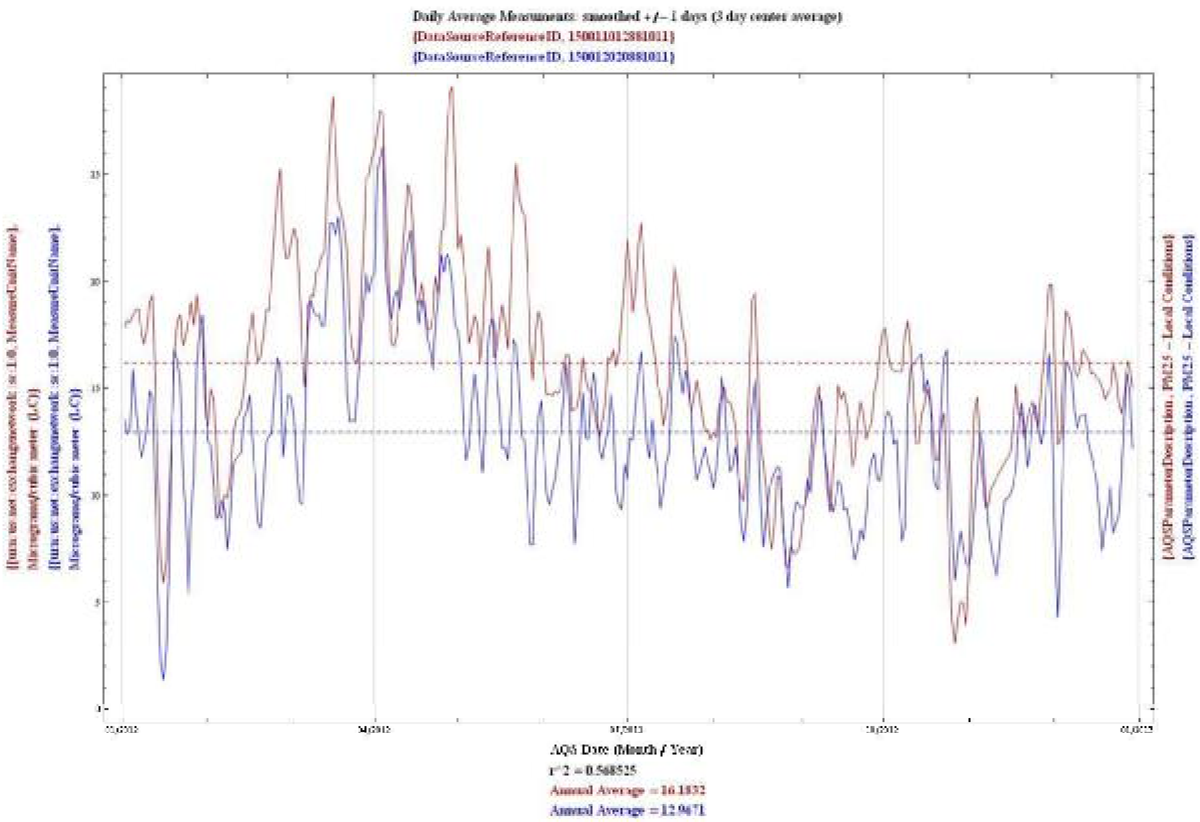

Figure 3-4. 2012 Time History of Kona (red) and Ocean View (blue) $PM_{2.5}$ Concentrations

While the seasonal $PM_{2.5}$ concentration highs and lows are noticeably different between 2011 and 2012, this is to be expected considering the coupling of Kilauea SO_2 emissions variability winds.

The normalized 2012 $PM_{2.5}$ time histories for Kona and Ocean View are shown in Figure 3-5. Perhaps more than with the 2011 datasets, it appears that the good correspondence between pollutant time histories is more evident when the datasets are normalized.

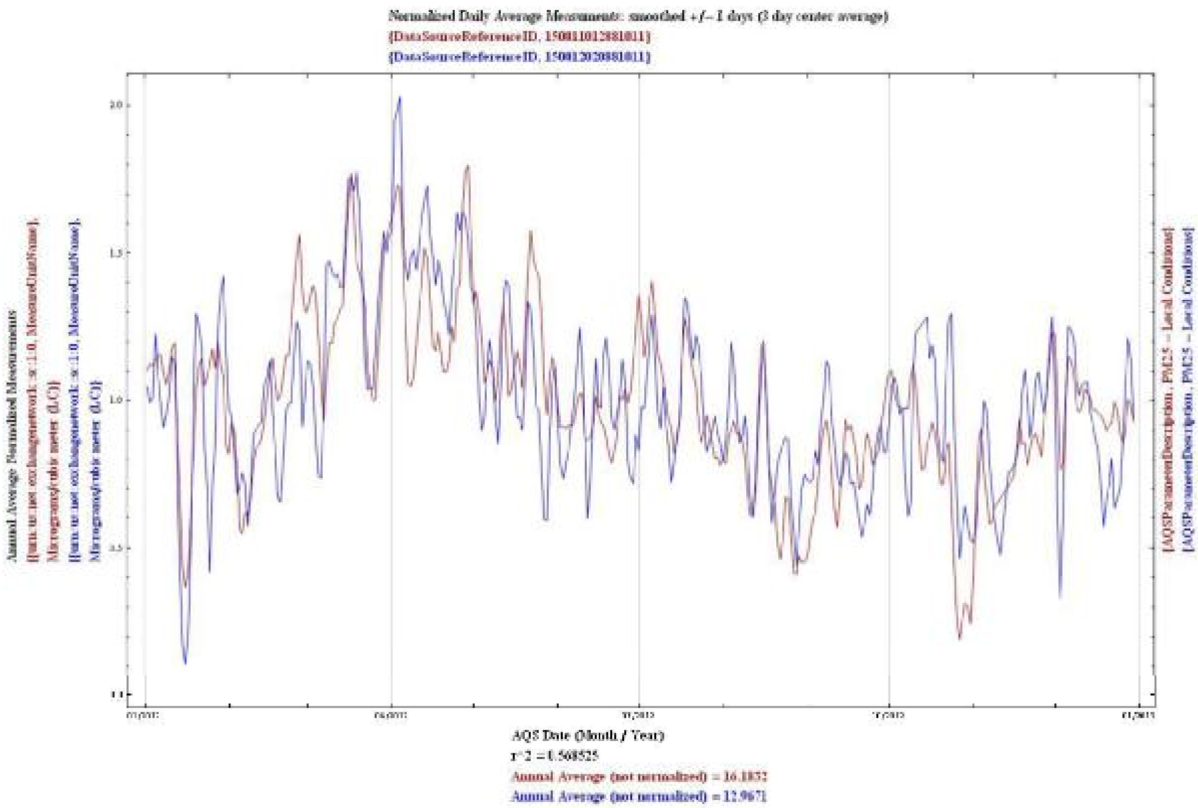

Figure 3-5. 2012 Time History of Kona (red) and Ocean View (blue) Normalized $PM_{2.5}$ Concentrations

The very large SO_2 emissions from the Kilauea volcano would be expected to follow a similar path to Kona as particulates. To examine this assertion, the correspondence between the time histories of SO_2 concentrations at Kona and Ocean View is presented for 2011 and 2012 in Figures 3-6 and 3-7, respectively. These figures include the same temporal smoothing (3 day center average) and normalization that were used in Figures 3-3 and 3-5.

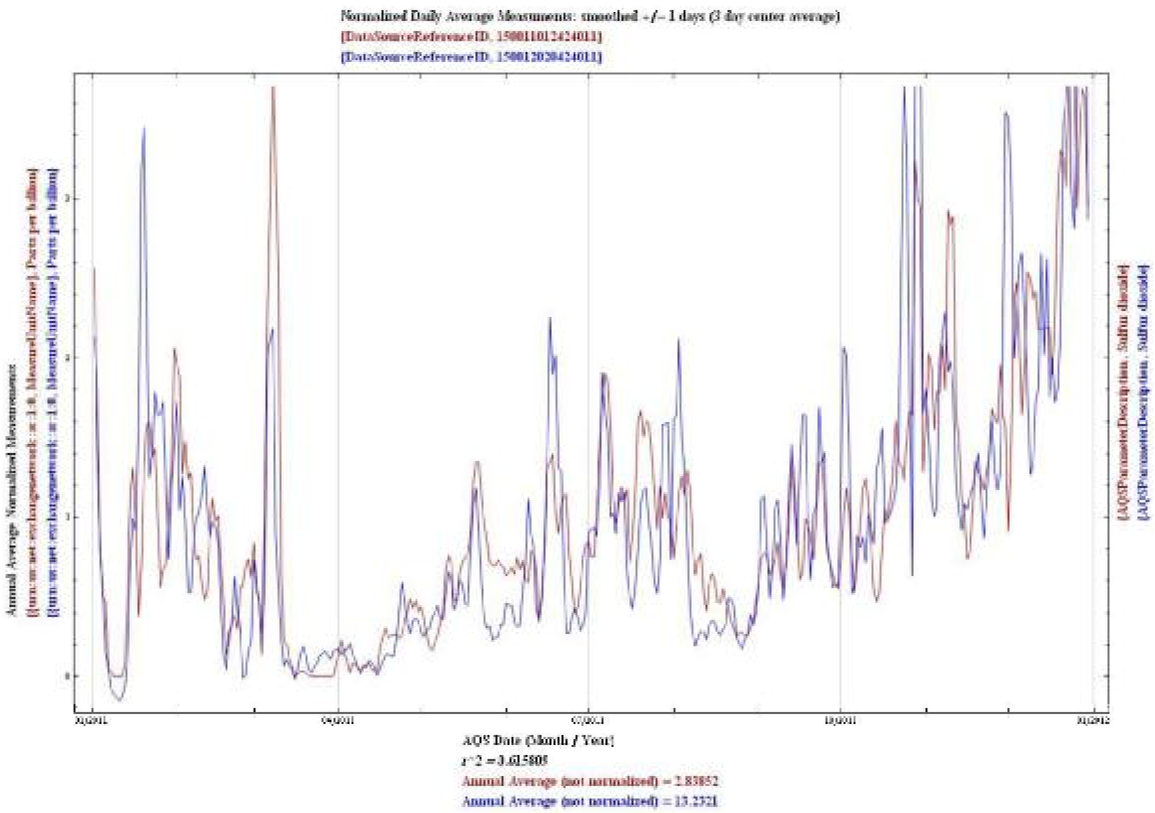

Figure 3-6. 2011 Time History of Kona (red) and Ocean View (blue) Normalized SO_2 Concentrations

For 2011, the time histories of normalized SO_2 concentrations at Kona and Ocean View are seen to correspond similarly well as those seen for $PM_{2.5}$; the correlation value (r^2) is approximately 0.62. The seasonal trends in the SO_2 concentration time histories are seen to correspond well. This relatively high level of correlation between two datasets seems particularly noteworthy considering the absolute concentration difference in the annual averages. Kona has an annual average of approximately 2.8 ppb compared to Ocean View's value of approximately 13.2 ppb. For 2012, with almost twice the annual average SO_2 concentrations at both sites, the correlation value decreases to approximately 0.17. However, the seasonal trends appear to still be well matched in 2012, as are many of the concentration peaks and valleys. There are several large concentration peaks in the Ocean View dataset that appear to be proportionally less prominent by the time they reach Kona. While it is unknown if these differences result from spatial in homogeneities in the volcanic plume, time dependent changes in the chemical conversion rate of SO_2, or some other reason, the SO_2 concentration data appears consistent with the transport of a large pollutant plume from the Kilauea volcano.

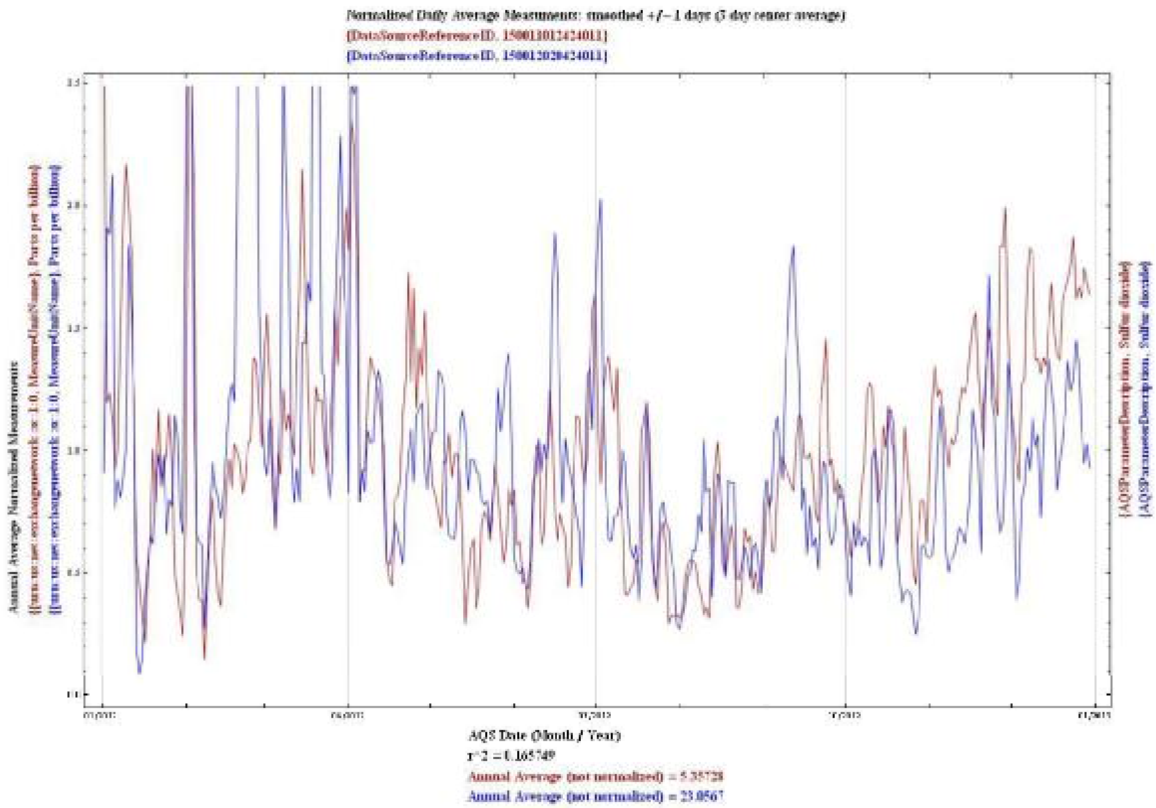

Figure 3-7. 2012 Time History of Kona (red) and Ocean View (blue) Normalized SO_2 Concentrations

The 1997 USGS webpage (Ref. 3) described the Kona pollutants of volcanic origin being "trapped by the onshore-offshore daily wind regime". This description was evaluated. Hourly monitored $PM_{2.5}$ pollutant concentrations for 2011 and 2012 were combined with hourly wind direction data from the collocated AN155 monitor. Hourly wind direction data was also examined. During the review of hourly wind data from the AN155 monitor, it was noted that the windrose for AN155 had an increased frequency of wind approaching from the west (Figure 3-8). Upon further review, it was found that concern about this issue had previously been noted in an October 2012 memo (Ref. 9) which identified that "Kona - Wind direction sensor, all readings were approximately 180 degrees off". An examination of the 2011 AN155 wind direct data showed the consistent diurnal wind pattern indicated in the USGS document. In Figure A-16, the windrose plots for the 12 morning hours are presented in 12 plots.

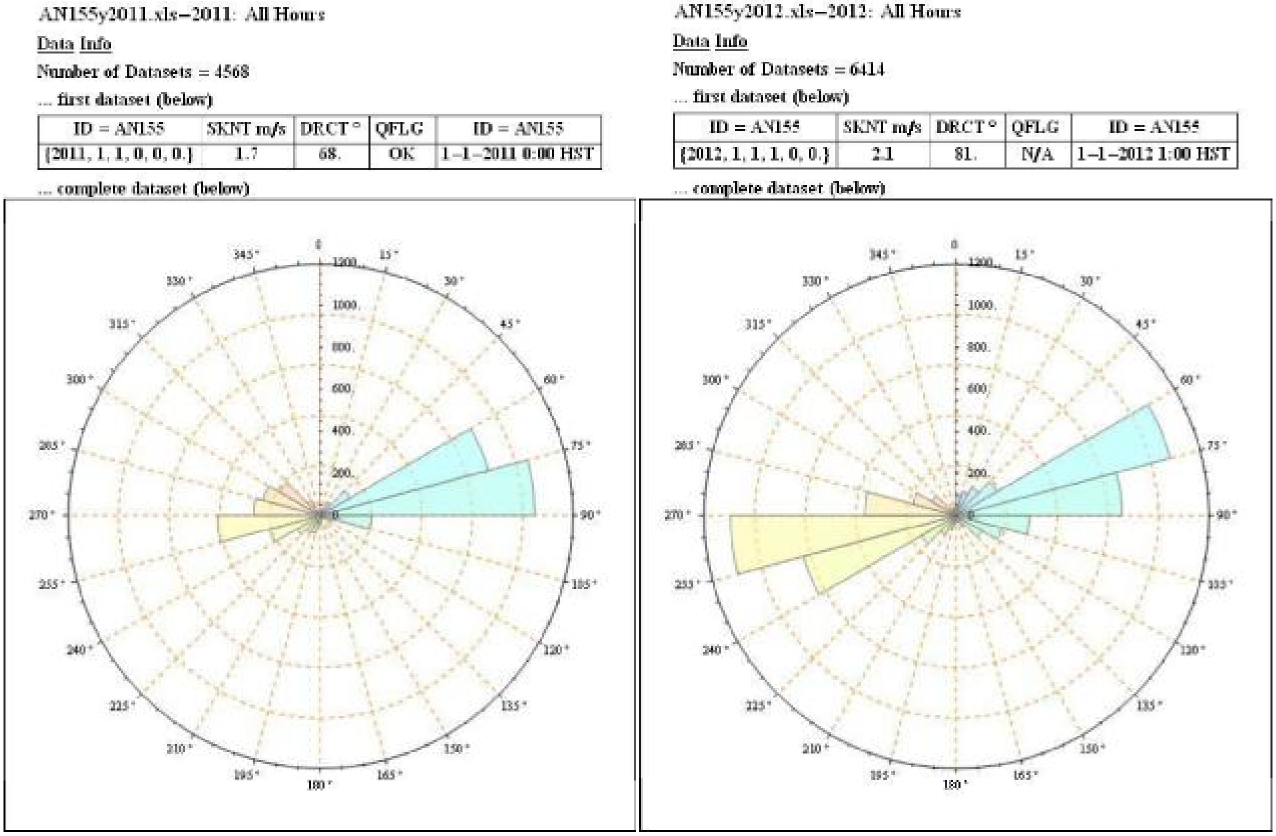

Figure 3-8. Kona Area AN155 Windrose Plots for 2011 (left) and 2012 (right)

The hours begin in the upper left and advance from left to right, beginning at midnight (hour 0) through 2AM (hour 2) in the top row, with each of the subsequent rows continuing the pattern; times are given in Hawaii Standard Time (HST). In Figure A-17, the windrose plots for the 12 evening hours are presented in 12 plots. The morning hours through about 7 AM were dominated by winds approaching from the east (inland).

The 8 AM hour showed winds from both the east and west directions. Beginning in the 9 AM hour and extending through 5 PM, winds approached from the west (offshore). From 6 PM through the 11 PM hour, winds again approached from the east (inland). This diurnal pattern was not reflected in the 2012 dataset. The reason for this difference in the 2011 and 2012 datasets is illustrated in Figures A-18 and A-19 which show the 2012 hourly wind directions as a function of the date. Consistent with the DOH memo, the dominant wind direct associated with each hour is seen to change by about 180 degrees during the middle months of 2012.

With the wind data quality for 2011 confirmed, and the problem with the 2012 dataset understood, hourly wind data and hourly $PM_{2.5}$ concentration for Kona were combined. The hourly pollutant concentrations were binned according to matching hourly wind directions into four 90 degree quadrants. Each quadrant was centered about the four compass points. Figure A-20 shows the individual 2011 hourly $PM_{2.5}$ concentration measurements associated with winds approaching from the north, east, south, and west (from top to bottom in the figure). The average concentrations associated with the primary directions of approach are about 12.0 μg/m^3 from the west (offshore) and 13.5 μg/m^3 from the east (onshore); the values associated with the less frequent approaches from the north and south were 13.5 μg/m^3 and 10.1 μg/m^3, respectively. The relatively small difference between the average 2011 $PM_{2.5}$ concentrations approaching from onshore versus offshore is consistent with the USGS description of pollutants trapped by the local wind pattern.

The 2012 hourly $PM_{2.5}$ and wind datasets were plotted without attempting to correct for the know issue with the wind direction. Figure A-21 shows the result of this combining of the two datasets. While an accurate correction of the wind direction could have been made based on the prevailing diurnal wind pattern, it was felt that the significance of this effort would have been negligible for the purposes of this effort. By visual inspection, the east approaching and west approaching data values for the middle of 2012 do not appear to be significantly different. Without correction, the average $PM_{2.5}$ concentration for winds approaching from the west (offshore) is about 16.4 μg/m^3 versus 15.5 μg/m^3 from the east (onshore); the values associated with the less frequent approaches from the north and south were 13.9 μg/m^3 and 17.0 μg/m^3, respectively. As with 2011, the relatively small difference between the average 2012 $PM_{2.5}$ concentrations approaching from onshore versus offshore is consistent with the USGS description of Kilauea pollutants trapped by the local wind pattern.

3.2.D Seasonal PM2.5 and SO2 Correlations at Kona, Ocean View and Pahala

An examination of the effect of seasonality has on the correlation between $PM_{2.5}$ and SO_2 concentrations at Kona, Ocean View, and Pahala for 2011 and 2012 was made. Each year was divided into four quarters, each three months in length, beginning with January. The results are shown for 2011 and 2012 in figures A-22 and A-23, respectively; note that these correlation calculations were made with the "unsmoothed" AQS datasets. The following observations were noted:

For 2011 and 2012 Kona and Ocean View $PM_{2.5}$, the first quarter of the year had the best correlation (0.615 and 0.483 for 2011 and 2012, respectively). For 2011, the third quarter correlation value (0.613) was almost as large as the first quarter (0.615). For 2012, the second and third quarters were equal (0.384) and a fair amount less than the first quarter (0.483).

For 2011 Ocean View and Pahala $PM_{2.5}$, the first and fourth quarters had the best correlations (0.239 and 0.178 for the first and fourth quarters, respectively). This was also the case for 2012, with first and fourth quarter values of 0.117 and 0.133, respectively. For both 2011 and 2012, the second and fourth quarters had significantly lower correlation values, never exceeding 0.022.

2011 Kona SO_2 correlated best with Kona $PM_{2.5}$ during the second and third quarter with values of 0.469 and 0.499, respectively. 2011 Kona SO_2 correlated best with the second and third quarters of Ocean View PM2.5 with values of 0.357 and 0.351, respectively. 2011 Kona SO_2 correlated best with the first and fourth quarters of Pahala SO_2 with values of 0.351 and 0.281, respectively. 2012 Kona SO_2 correlations had lower values than in 2011. The best correlations were with the second, third, and fourth quarters of Kona $PM_{2.5}$ with values of 0.242, 0.252, and 0.271, respectively.

2011 Pahala SO_2 correlated best with Ocean View SO_2 in the first and second quarters, with values of 0.348 and 0.468, respectively. As previously noted, 2011 Pahala SO_2 also correlated relatively well with the first and fourth quarters of Kona SO_2. For 2012, Pahala SO_2 correlated best with the first, third and fourth quarters of Pahala $PM_{2.5}$, with values of 0.426, 0.219, and 0.207, respectively.

With only two years of data, the observations above seem insufficient to draw conclusions pertaining to seasonal effects. However, evaluation of the data by quarter does help to further illustrate the linkage between the Kona, Ocean View, and Pahala SO_2 and $PM_{2.5}$ datasets.

3.2.E Additional Relevant Wind Data

The wind patterns associated with the island of Hawaii were discussed previously in Section 2-2 and illustrated in Figure 2-3. In this section, additional wind direction monitoring data from the Meso West website will be presented and discussed with respect to candidate pollutant transport pathways and source locations. 2012 data is presented, but 2011 data was also examined and is consistent with the 2012 data. The locations and elevations of the monitors are presented in Figure 2-7.

While diurnal wind patterns dominate Kona monitoring site, trade winds can be seen to be predominant at higher elevations on the island of Hawaii (Fig. 3-9). In addition to the previously discussed HAVO VC and HAVO OB sites near the Kilauea summit vent, the Kamuela monitor (PHMU) situated in the northern part of Hawaii at an elevation of 814 meters. Winds from the north are also predominant for the Keaumo monitor located on the eastern side of Mauna Loa at an elevation of 1682 meters.

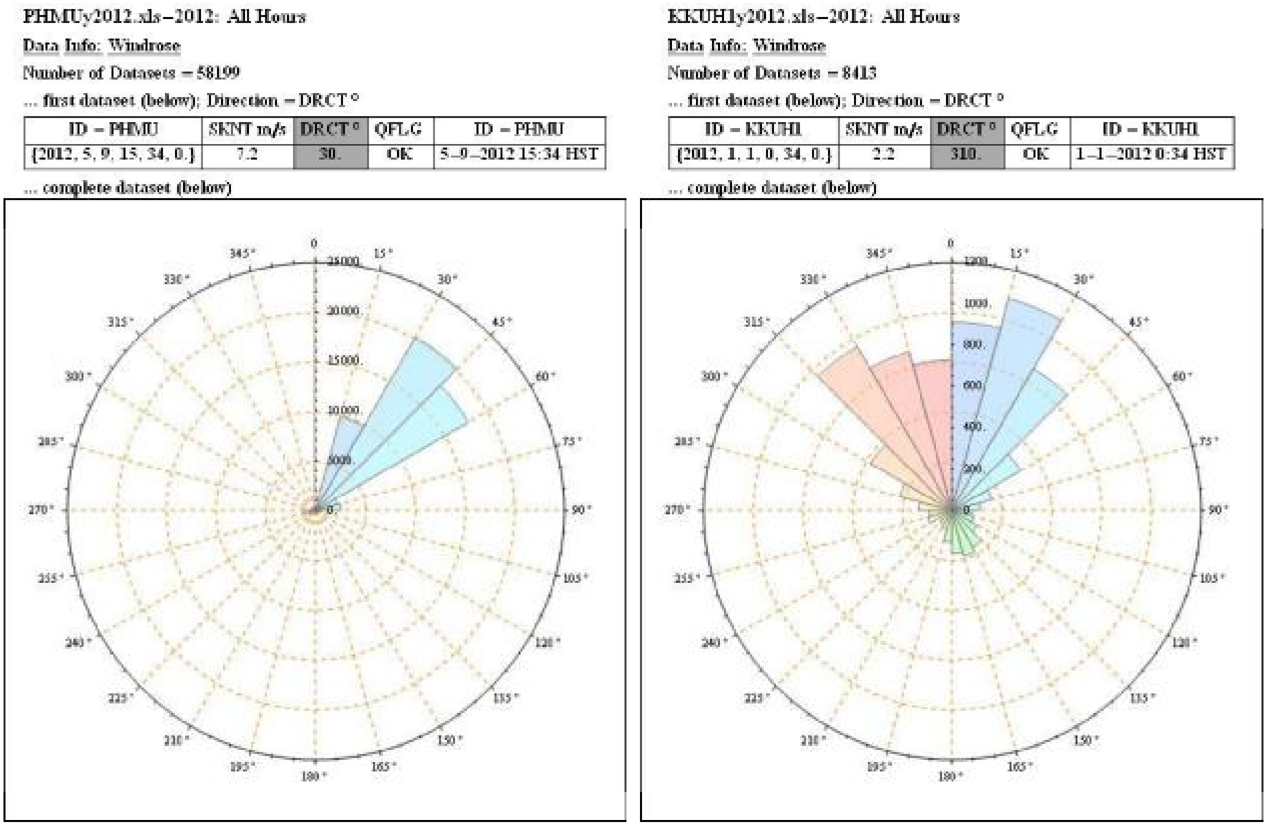

Figure 3-9. 2012 Kamuela (PHMU)(left) & Keaumo (KKUH1)(right) Windrose

The predominance of trade winds can also be seen at lower elevations when the impact of local mountain are small, such as for the Kaunakakai, Molokai Airport (PHMK, 138 meter elevation) and Kaneohe Marine Corps Air Station (PHNG, 5 meter elevation) data sets shown in Figure 3-10. The PHMK and PHNG monitors are located on the islands Molokai and Oahu, respectively.

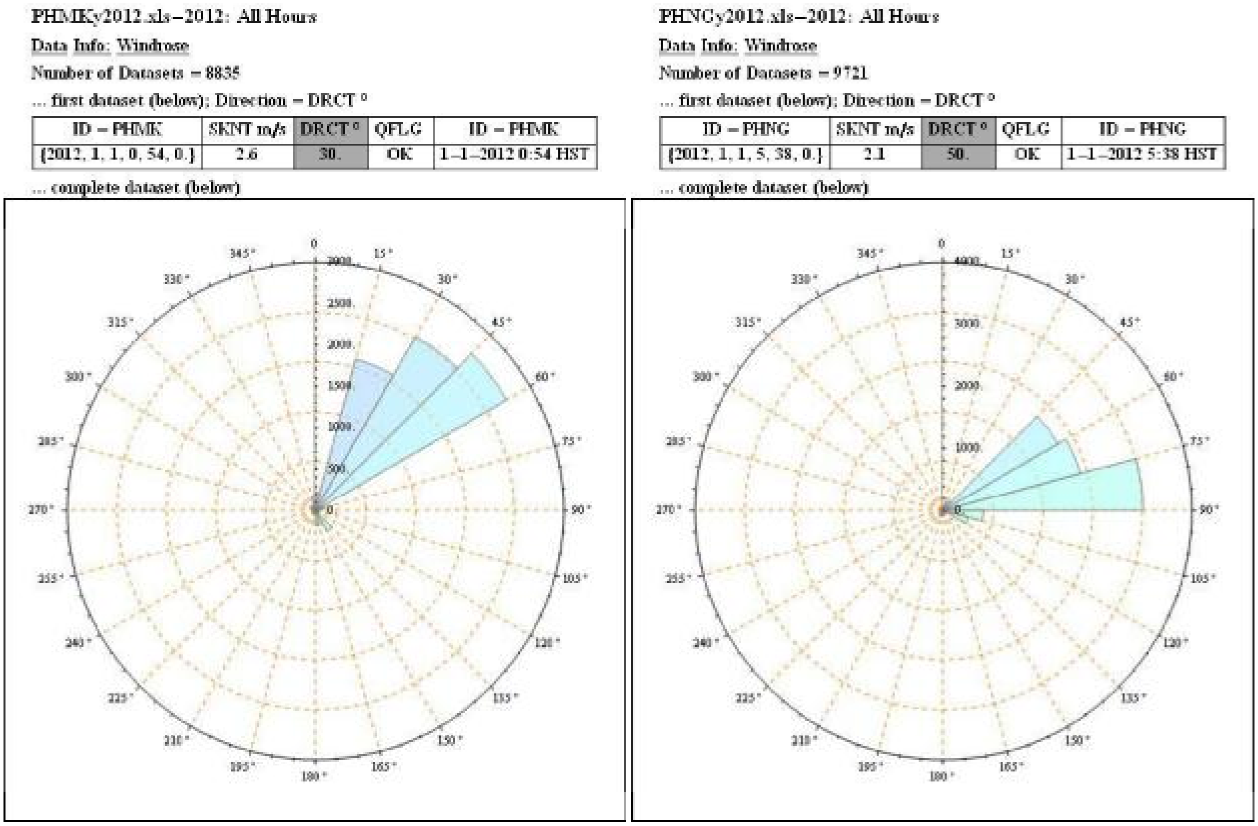

Figure 3-10. 2012 Kaunakakai, Molokai Airport (PHMK)(left) & Kaneohe, Marine Corps Air Station (PHNG)(right) Windrose

In the region north of Kona shown in Figure 2-3, the winds are seen to travel largely from east to west. That figure is consistent with the wind data from the Waikoloa monitor (WKVH1) (Fig. 3-11, left side). Hourly windrose plots are included in Appendix A (Fig. A-24 & A-25) and show the diurnal pattern of the wind for this monitor, with the dominant flow path being from the east. The Kaupulehu Lava Flow (KPLH1) monitor is also north of the Kona monitor, and like the Waikoloa monitor, is near the western coast. The winds associated with KPLH1 come mostly from the west and also the southeast (Fig. 3-12, right side). The diurnal wind pattern can be seen in the hourly windrose plots (Fig. A-26 & A-27).

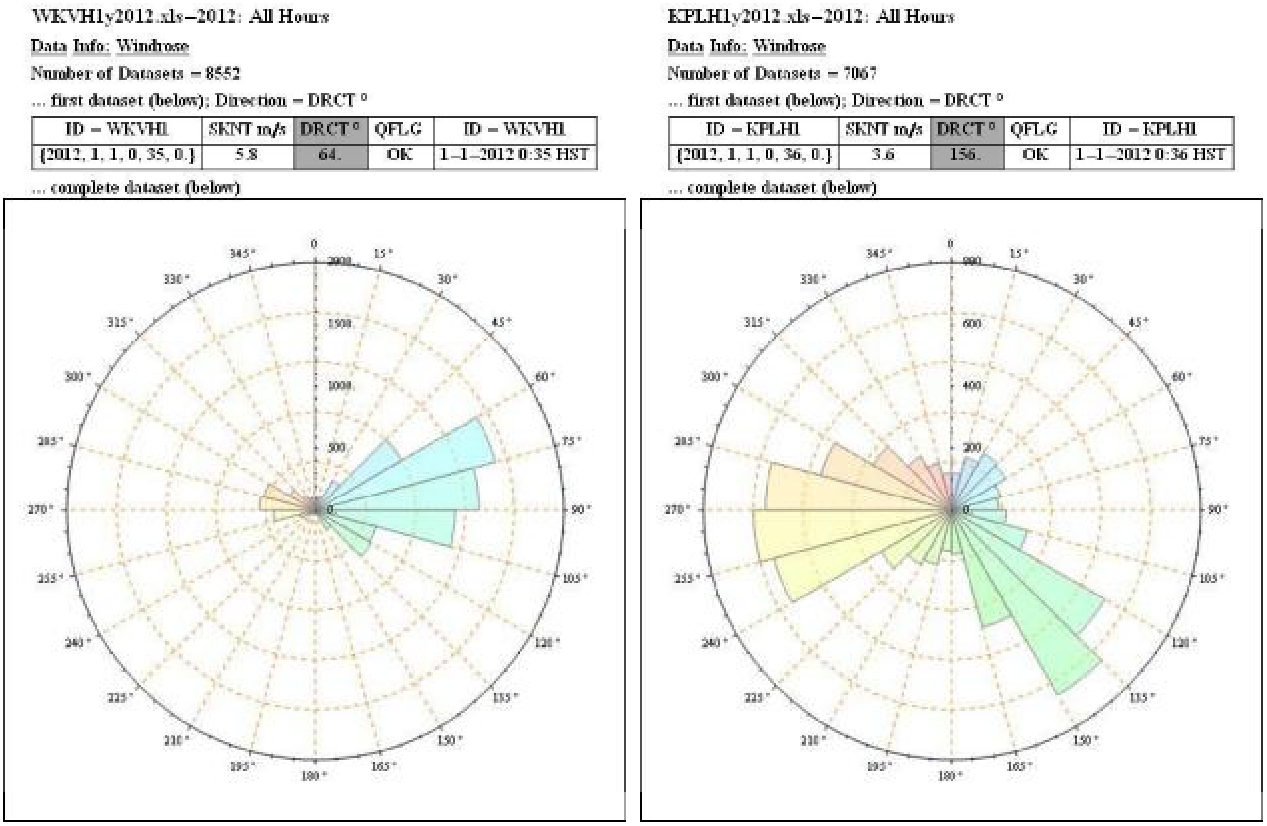

Figure 3-11. 2012 Waikoloa (WKVH1)(left) & Kaupulehu Lava Flow (KPLH1)(right) Windrose

Nearer to the center of the island, wind direction data from the PTA Range 17 monitor (PTRH1) was examined for consistency with Figure 2-3. The windrose plot shows the predominant winds are from the south east, with some from the northwest (Fig 3-12, left). The daytime diurnal winds coming from the western coast would seem to be a likely explanation for the winds from the northwest, with nighttime and morning winds coming from the southeast (Fig. A-28 & A-29).

The Hilo International Airport (PHTO) winds are seen to be dominated by winds from the south west, as indicated by the red arrow approaching Hilo in Figure 2-3. However, while the red "KONA WINDS" designation in Figure 2-3 relates to the less frequent Kona winds, the windrose for PHTO (Fig 3-12, right) is based on year round data. The predominance of winds from the southwest are shown to be associated with a diurnal wind pattern (Fig. A-30 & A-31). Other than the late morning and early afternoon, the winds are predominantly from the southwest.

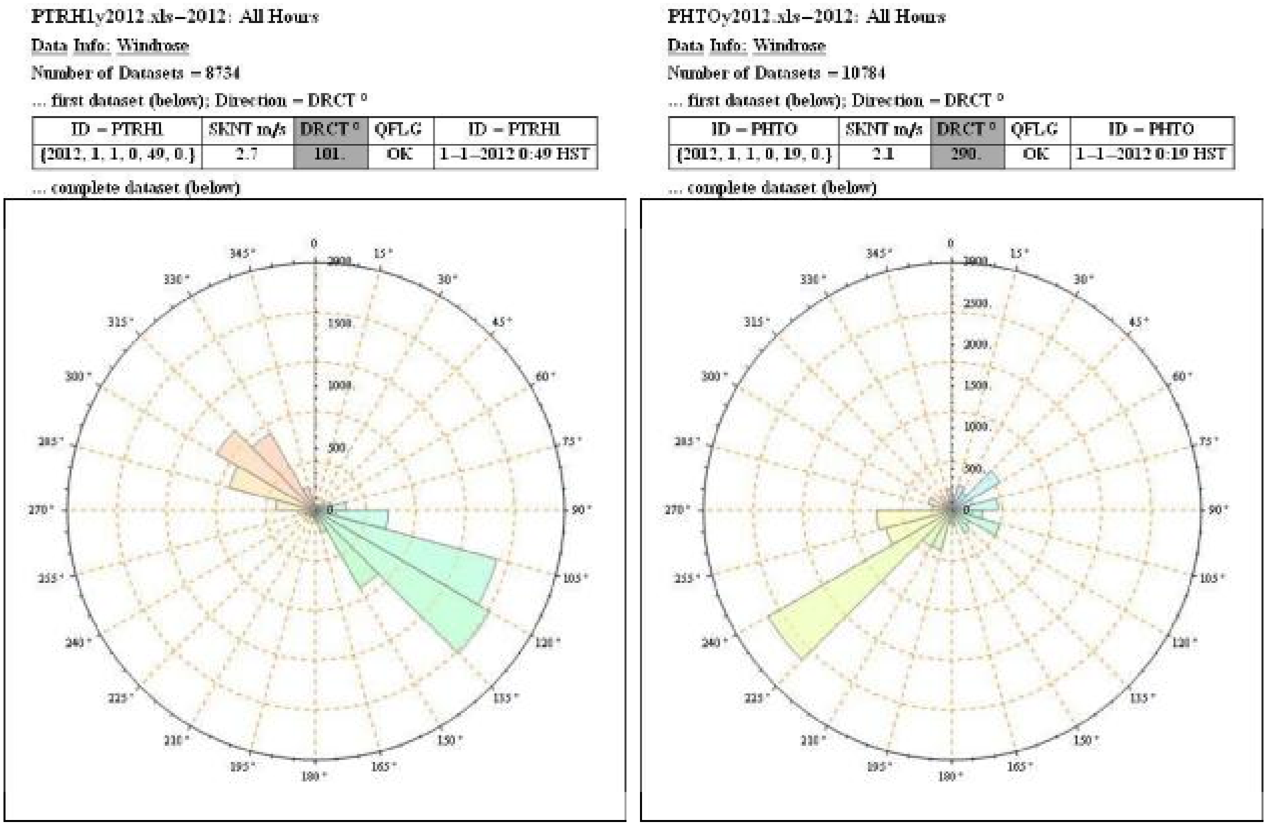

Figure 3-12. 2012 PTA Range 17 (left) & Hilo International Airport (right) Windrose

Annual windroses for Pahala (AN157) and Ocean View (AN738) monitors show relatively even distributions of winds from two directions each. For Pahala (Fig. 3-13, left), winds arrive from the northwest and the east. For Ocean View, winds arrive from the northeast and the southwest. The diurnal nature of the winds can be seen in Fig A-32 and A-33 for Pahala, and Fig A-34 and A-35 for Ocean View. In both cases, morning and evening winds arrive from the direction of the mountain, and daytime winds arrive from the direct of the ocean.

In section 3.2.B, the presence of diurnal winds at the Kona (AN155) monitor was discussed. The wind data presented in this section shows that diurnal wind patterns dominate in many areas, including those near the Ocean View (AN738) and Pahala (AN157) monitors. This diurnal pattern will couple with the bulk transport of pollutants from the Kilauea summit, around the bottom of the island, and up the western coast as described by the USGS (Ref. 3, 4).

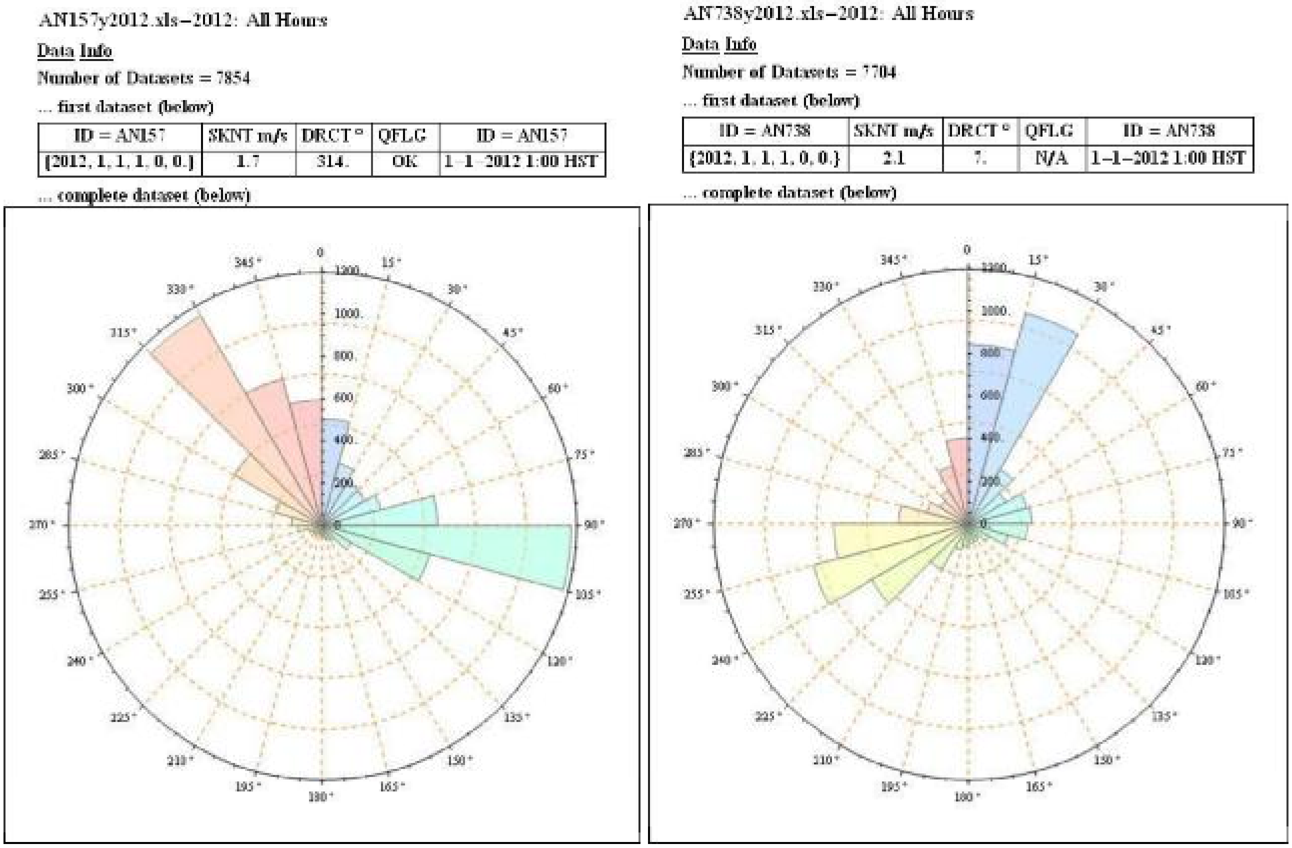

Figure 3-13. 2012 Pahala (AN157)(left) and Ocean View (AN738)(right) Windrose

Considering the wind data discussed in this section the following observations are noted:

As indicated in Figure 3-9 and 3-10, the predominance of trade winds is such that it seems unlikely that the occasional Kona winds would impact the analysis of seasonal average concentrations. Based on the SO_2 chemical transformation description given in reference 7, it seems much more likely that seasonal weather conditions such as cloud cover, humidity, and precipitation would have a much great influence on SO_2 and $PM_{2.5}$ concentration variability.

The predominance of winds from the south west monitored in the Hilo area reduce the likely hood that pollutants originating in Hilo would impact the pollutant levels monitored by the Kona monitor.

3.2.F Discussion

The pollutant monitoring data from Kona, Ocean View, and Pahala shows decreasing SO_2 concentrations (and increasing $PM_{2.5}$) as prevailing coastal winds travel clockwise from Pahala, to Ocean View, and up to Kona. The monitoring data are consistent with the Kilauea volcano SO_2 transport and chemical conversion process described in references 3, 4, and 7, and discussed in Section 2-3.

SO_2 transported from north of Kona would have the SO_2 decreasing from Kona, through Ocean View, and on to Pahala. $PM_{2.5}$ would grow from Kona to Pahala. Neither of these is the case. A very large $PM_{2.5}$ north of Kona would not explain the increasing SO_2 concentrations monitored as the postulated pollutant is transported from Kona, to Ocean View and to Pahala.

The magnitude of the Kilauea volcano SO_2 emissions is well documented. The elevated Halema'uma'u (summit) emissions after 2007 shown in Figures 2-10, 2-11, and 2-12 are consistent with the USGS observations (Ref. 1, 3, and 4). If there was a potentially large SO_2 emission source other than the volcano upwind of Pahala, it would be a second candidate for causal analysis. However, as shown in Figure 2-6, there is no such source.

The diurnal nature of the winds at Kona, Ocean View, and Pahala provides the coupling between the elevated aerosol concentrations that are observed by satellite observations (e.g. Figure 2-9) and $PM_{2.5}$ and SO_2 concentrations measured at the sites. The good correspondence between time histories of $PM_{2.5}$ and SO_2 concentrations measured at Kona and Ocean View for both 2011 and 2012 is consistent with this transport.

Note that while a direct comparison of the time histories of volcanic SO_2 emissions are monitoring site pollutant measurements was not provided in the document, data sets were compared and the correspondence was not very good. This is not surprising considering the combination of emission characteristics (e.g. buoyancy), weather, wind, and chemistry involved.

These examinations of pollutant and wind monitoring data indicate that SO_2 emissions from the Kilauea volcano are the cause for the elevated levels of $PM_{2.5}$ at the Kona monitoring site.

3.3 Examination of Proposed Kona Exceptional Events Days

3.3.A Overview

The DOH identified days during 2011 and 2012 that are flagged for exclusion from the Kona dataset (see Appendix B). In 2011, there are two flagged days. In 2012, due to the added impact of the increased Kilauea summit SO_2 emissions, there are 200 flagged days. In this section, the flagged days are presented with respect to annual $PM_{2.5}$ time histories (unsmoothed) at Kona and normalized $PM_{2.5}$ and SO_2 concentrations at Kona and Ocean View. The purpose of these comparisons is to illustrate that the appropriateness of the flagging of these days.

3.3.B 2011 Flagged Days

The daily average $PM_{2.5}$ concentrations for 2011 are indicated in red on Figure 3-14.

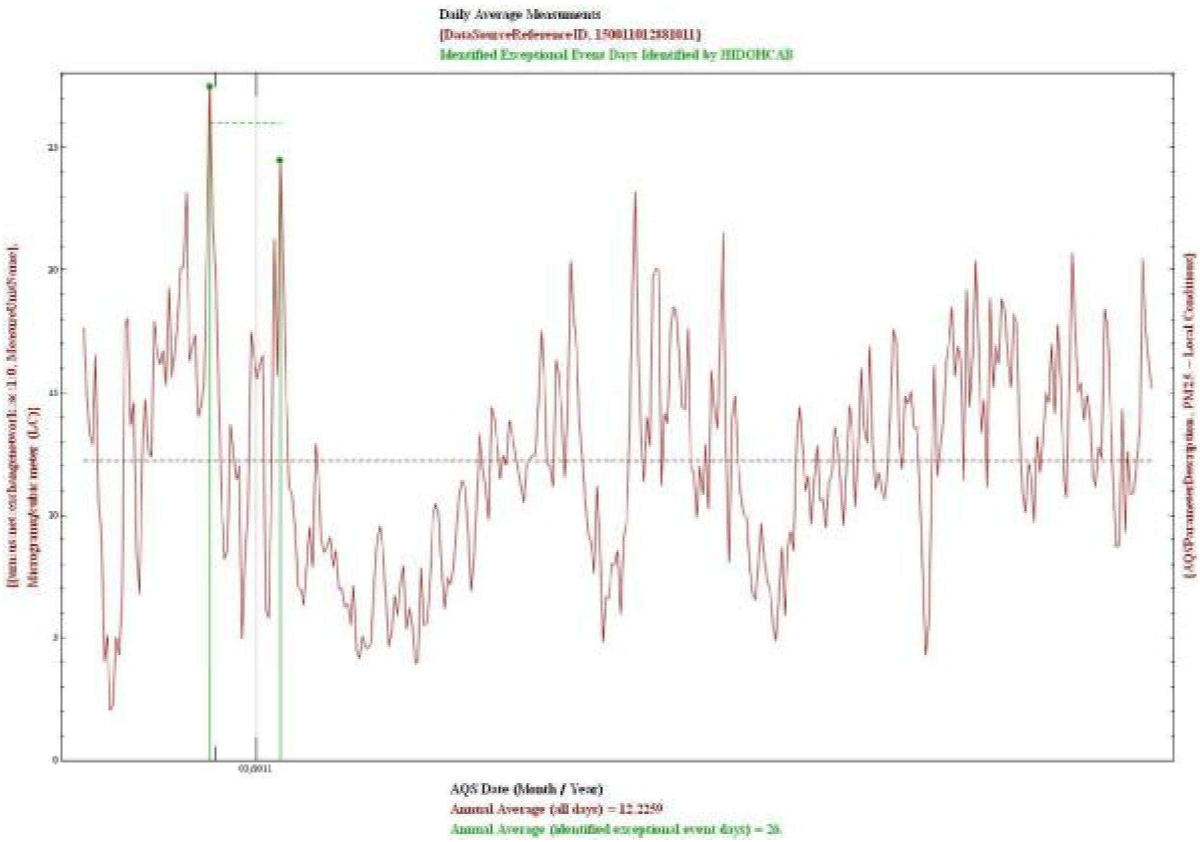

Figure 3-14. 2011 Time History of Kona (red) $PM_{2.5}$ Concentrations with Flagged Days (green)

The flagged days and measurement values are indicated by the green vertical lines and green dots. The average $PM_{2.5}$ concentration used for normalization purposes of the flagged days is 26 $\mu g/m^3$ versus the annual average of all days (before flagging) of approximately 12.2 $\mu g/m^3$. The linkages discussed in Section 3.2.F between volcanic emissions, the pollutant transport path / chemical conversion process, and the monitored concentration levels establish the causal link between elevated $PM_{2.5}$ concentrations and the Kilauea volcano.

As indicated in Figure 3-15, the two flagged days occur during peak periods of $PM_{2.5}$ concentration (smoothed using 3 day center average, then normalized) at the Kona and Ocean View monitors.

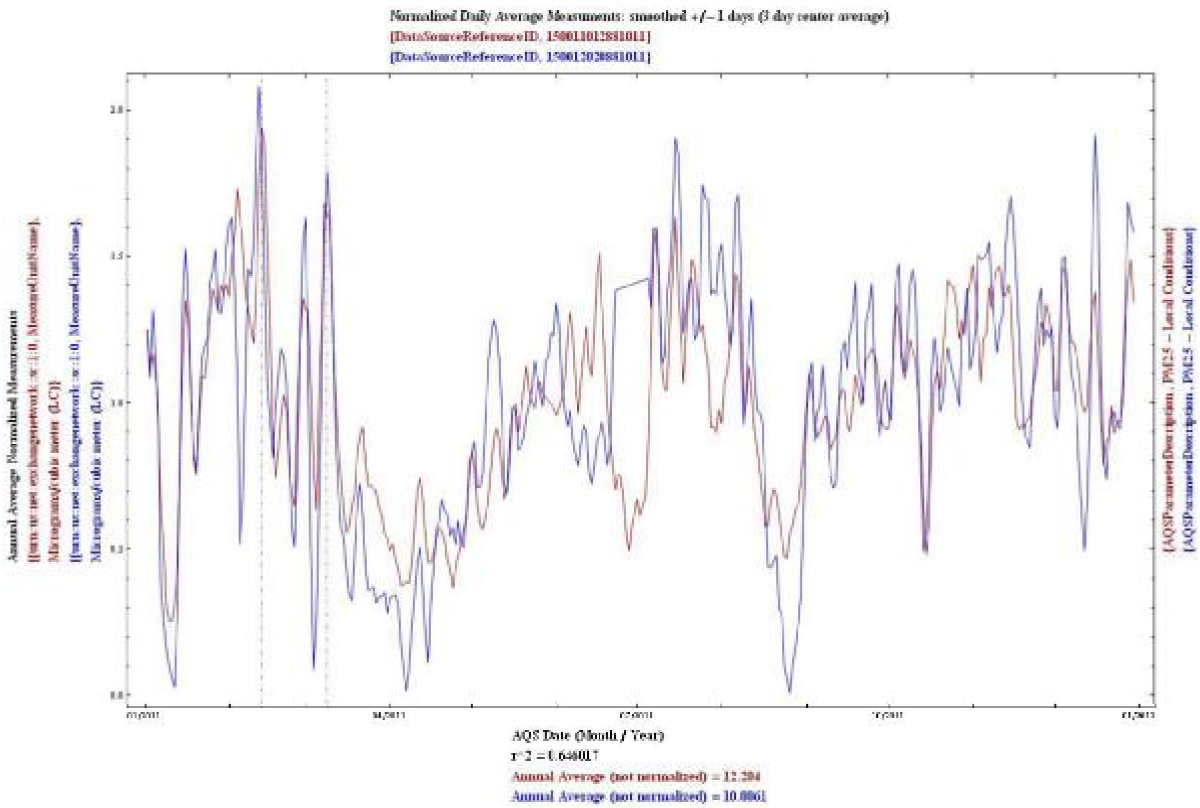

Figure 3-15. Time History of Kona (red) and Ocean View (blue) Normalized $PM_{2.5}$ Concentrations with Flagged Days (vertical broken lines)

Figure 3-16 presents the normalized SO_2 concentration data (smoothed using 3 day center average) for Kona and Ocean View with respect to the two flagged days. While the second flagged day is clearly associated with an SO_2 peak at both monitoring sites, the first flagged day occurs during a period of time that indicates a good correspondence between measurements at the two monitoring sites. While SO_2 concentration for the second day does not occur at relative peak, that is not surprising considering the range of weather and chemistry effects that can influence SO_2 concentrations.

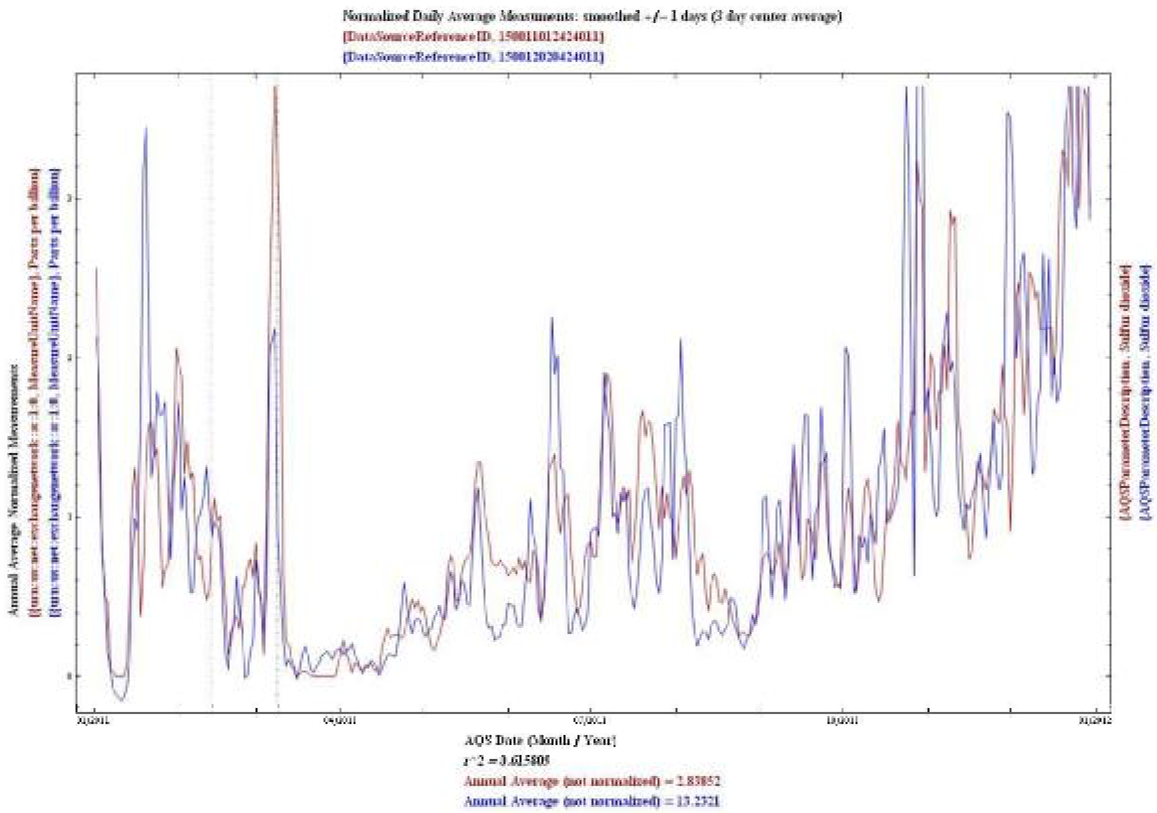

Figure 3-16. 2011 Time History of Kona (red) and Ocean View (blue) Normalized SO_2 Concentrations with Flagged Days (vertical broken lines)

The time history data presented in Figures 3-15 and 3-16 clearly indicates that $PM_{2.5}$ and SO_2 pollutant levels at Kona and Ocean View are strongly linked, and that linkage is due to the large SO_2 emissions from the Kilauea volcano. Though only two days are flagged, the data indicates that pollutant levels are elevated throughout most of the year only because of those volcanic emissions.

3.3.C 2012 Flagged Days

The daily average $PM_{2.5}$ concentrations for 2012 are indicated in red on Figure 3-17. The flagged days and measurement values are indicated by the green vertical lines and green dots. The average $PM_{2.5}$ concentration of the flagged days is 19.4 μg/m^3 versus the annual average of all days (before flagging, used for normalization purposes) of approximately 16.2 μg/m^3. For 2012, 200 days are flagged. The large number of flagged days is a direct result of the significant and persistent impact that Kilauea SO_2 emissions have on the Kona area.

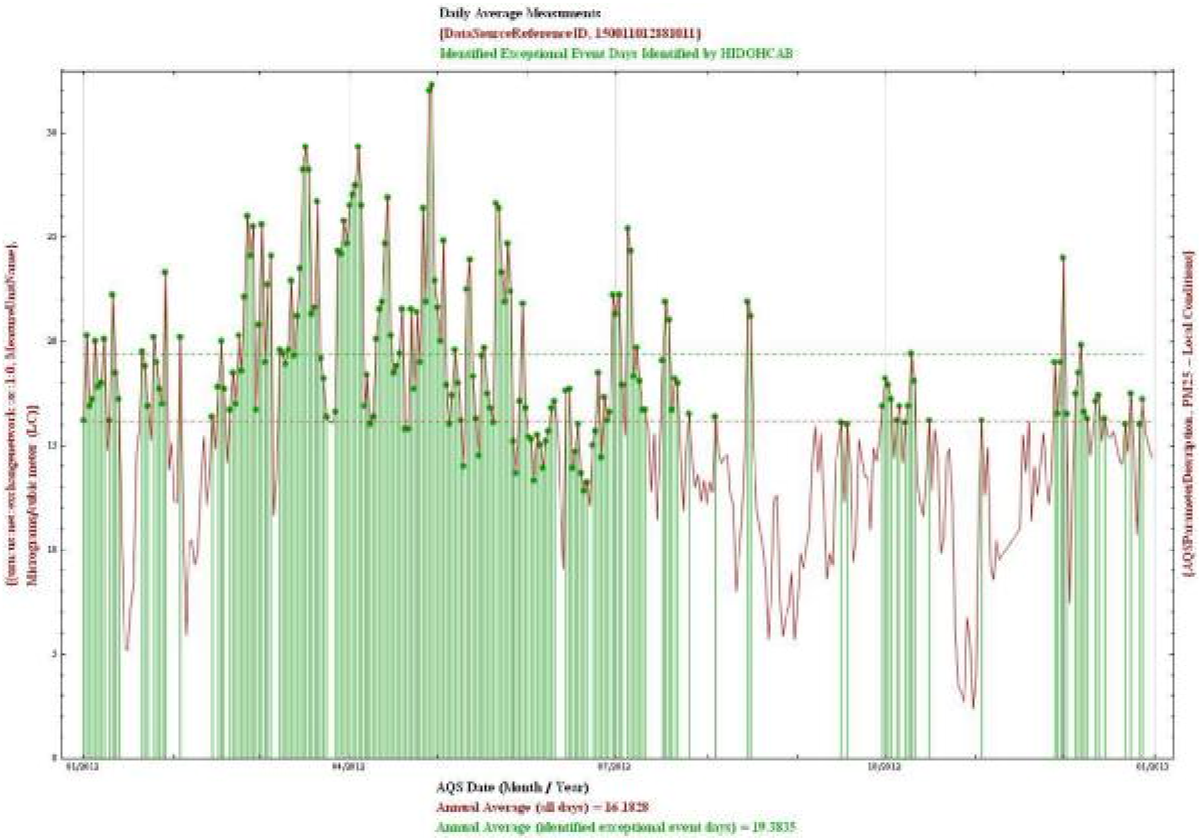

Figure 3-17. 2012 Time History of Kona (red) $PM_{2.5}$ Concentrations with Flagged Days (green)

As indicated in Figure 3-18, the flagged days occur during periods of elevated $PM_{2.5}$ concentration (smoothed using 3 day center average, then normalized) at the Kona and Ocean View monitors.

Figure 3-19 presents the normalized SO_2 concentration data (smoothed using 3 day center average) for Kona and Ocean View with respect to the flagged days. While the correlation between the SO_2 concentration levels at the two sites is not as strong for SO_2 as $PM_{2.5}$, the seasonal trend is evident. As is the case with 2011, the 2012 data indicates that pollutant levels are elevated throughout most of the year only because of volcanic emissions from Kilauea.

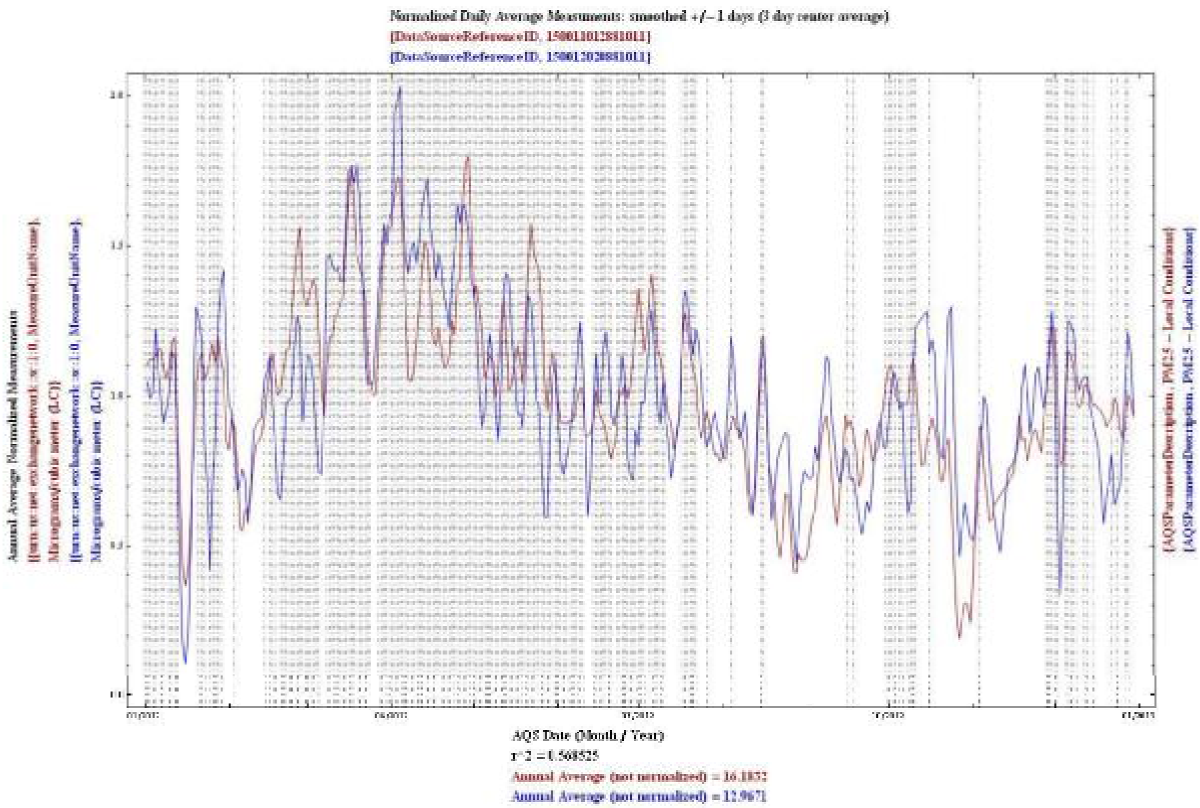

Figure 3-18. 2011 Time History of Kona (red) and Ocean View (blue) Normalized $PM_{2.5}$ Concentrations with Flagged Days (vertical broken lines)

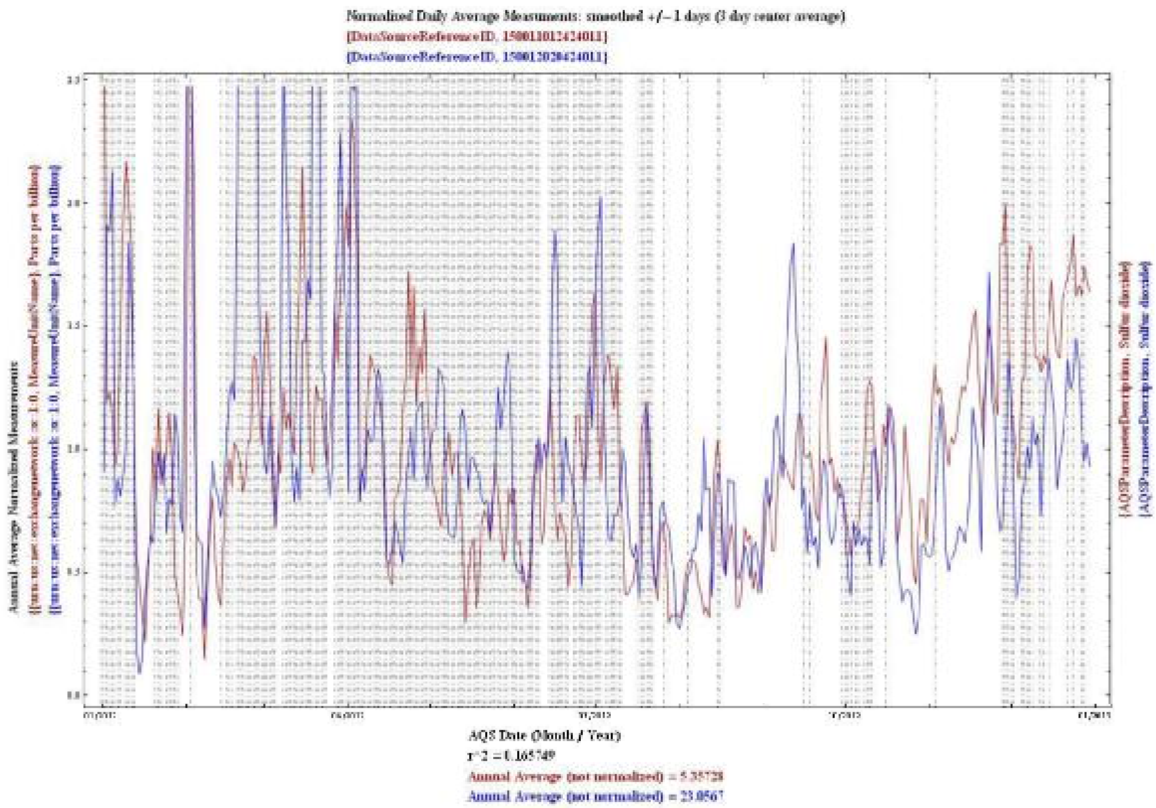

Figure 3-19. 2012 Time History of Kona (red) and Ocean View (blue) Normalized SO_2 Concentrations with Flagged Days (vertical broken lines)

3.3.D Conclusion

The USGS descriptions of the significant impact on the Kona area, as well as the southern region of Hawaii, of the very large SO_2 emissions from the Kilauea volcano are consistent with the observed monitoring data for 2011 and 2012. The time histories of $PM_{2.5}$ concentrations from the Kona and Ocean View monitors indicate a large pollutant plume of common origin impacting both sites. The relative magnitudes of $PM_{2.5}$ and SO_2 measured at the Kona, Ocean View, and Pahala are consistent with the transport path described by the USGS. The hourly $PM_{2.5}$ concentrations at Kona, when coupled with local wind data, present no indication of any local source significantly impacting the measurements. As such, the Kilauea volcano is the only source that could reasonably be considered responsible for the highly elevated levels of $PM_{2.5}$ measured by the Kona monitor. The data and associated analysis fully supports the proposed flagged days from the 2011 and 2012 data sets.

Section 4. Not Reasonably Controllable or Preventable

The ongoing release of SO_2 from Kilauea Volcano is the primary source contributing to annual $PM_{2.5}$ concentration exceedances measured at the Kona air monitoring station in 2011 and 2012. Anthropogenic emissions in the Kona area are significantly lower in comparison to those from the volcano. Control measures for $PM_{2.5}$ and $PM_{2.5}$ precursors of NO_2 and SO_2 from permitted sources in the Kona area are considered reasonable for minimizing emissions.

Emissions were quantified from sources in the Kona area to provide information for this exceptional event demonstration to address the exceedances of the 12 µg/m^3 annual NAAQS for $PM_{2.5}$. Annual $PM_{2.5}$ concentration exceedances being addressed were recorded at the Kona air quality monitoring station for years 2011 and 2012. Table 4-1 below summarizes the air quality exceedances:

KONA AIR MONITORING STATION, AQS ID 15-001-1012		
Year	Annual $PM_{2.5}$ NAAQS (µg/m^3)	Annual Concentration Measured (µg/m^3)
2011	12	12.1
2012	12	16.2

Table 4-1. NAAQS Concentrations

4.1 Pollutant Emissions

Emissions were quantified among significant sources in the Kona area for comparison to SO_2 emissions from Kilauea Volcano. The ton per year (TPY) maximum potential emissions of $PM_{2.5}$ and $PM_{2.5}$ precursors of NO_2 and SO_2 were quantified from stationary and temporary permitted sources. Actual $PM_{2.5}$, NO_2, and SO_2 emissions from Kona International Airport were added to the total anthropogenic emissions. The anthropogenic sources emit $PM_{2.5}$, NO_2, and SO_2 from fuel burning equipment. Anthropogenic emissions also include fugitive dust from vehicle travel on unpaved roads and plant processing (crushing and screening of aggregate, grinding of green waste, and asphalt production).

4.2 Stationary Sources

There are a number of permitted stationary sources operating in the Kona. Locations of these sources are identified on the map from Figure A-1 in Appendix A. The Keahole Power Plant is the largest stationary source that includes three (3) combustion turbine generators. The remaining facilities are smaller sources of emissions. Stationary sources operating in the Kona area are listed in the table 4-2:

STATIONARY SOURCES					
No.	Facility	Type	Equipment	Distance From Kona Station (miles)	Distance From Ocean View Station (miles)
1	BRE/Waikoloa, LLC	Resort	Two 5.07 MMBtu/hr Boilers	27.90	55.43
2	Waste Management of Hawaii, Inc.	Aggregate Processing	340 TPH Crushing Plant and 275 TPH Screening Plant	26.11	53.37
3	Captain Cook Coffee Company, Ltd.	Wholesale Coffee	Two 20 hp Coffee Bean Peelers	1.69	30.11
4[a]	Hawaiian Electric Light Company	Electric Generation	Two 20 MW Combustion Turbine generators, Three 2.5 MW Diesel Engine Generators, and One 500 kW Black Start Diesel Engine Generator	17.06	45.32
5[a]	Hawaiian Electric Light company	Electric Generation	One 18 MW Combustion Turbine Generator	17.33	45.66
6	Hawaiian Electric Light Company	Electric Generation	One 1.5 MW Diesel Engine Generator	4.76	32.79
7	Grace Pacific, LLC	Asphalt Plant	325 TPH Asphalt Plant	13.82	41.99
8	Jas W. Glover, Ltd.	Concrete Batching	150 yd^3/hr Concrete Batch Plant	13.55	41.92
9	West Hawaii Concrete	Concrete Batching	150 yd^3/hr Concrete Batch Plant	14.80	42.93
10	Cremation Services of West Hawaii	Funeral Service	150 lb/hr Pathological Waste Incinerator	14.65	43.13
11	A Hui Hou Funeral and Tribute Service	Funeral Service	150 lb/hr Human Crematory Unit	38.42	10.22

a: Nos. 4 and 5 designate equipment servicing one facility at the same location. There are two permits for equipment at this one facility. These permits are currently being consolidated into one permit.

Table 4-2. Stationary Sources

4.3 Temporary Sources

A majority of temporary permit sources in the Kona area emitting $PM_{2.5}$ and $PM_{2.5}$ precursors are crushing and screening plants that move from one site to another. Other temporary sources include portable asphalt plants, water well drilling rig, and green waste processing facility. The temporary sources may operate outside Kona or on other islands. Temporary sources on outer islands may also relocate to Kona. Each temporary source must submit a Change of Location Request that requires the Department's approval prior to relocating equipment. Table 4-3 summarizes information for these sources:

TEMPORARY SOURCES		
Facility	Type	Equipment
Various Arrow of Oregon/Hawaiian, LLC (random representative company)	Aggregate Processing	Various Equipment Arrow of Oregon/Hawaiian, LLC has a 300 TPH Impact Plant, 400 TPH Impact Plant, and 500 TPH Screening Plant
Black Maui Rose, LLC	Asphalt Plant	300 TPH Portable Asphalt Plant
Road and Highway Builders, LLC	Asphalt Plant	400 TPH Portable Asphalt Plant
Keauhou Kona Construction Cor.	Asphalt Plant	120 TP Portable Asphalt Plant
Water Resources International, Inc.	Water Well Drilling	Two 300 hp Diesel Engines, One 400 hp Diesel Engine, and Two 665 hp Diesel Engines
Menehune Green, LLC dba Hawaiian Earth Products	Green Waste Processing	69 TPH Horizontal Grinder with 765 hp Diesel Engine

Table 4-3. Temporary Sources

4.4 Kona International Airport

The Kona International Airport is another source of primary and secondary $PM_{2.5}$ emissions in the Kona area. Currently, there are no permitted sources at the airport. Mobile sources, such as aircraft, and portable ground support equipment for servicing and starting aircraft are exempt from air permit requirements. Table 4-4 below lists information for the airport.

KONA INTERNATIONAL AIRPORT		
Source	Distance From Kona Station (miles)	Distance From Ocean View Station (miles)
Kona International Airport Various	18.2	46.7

Table 4-4. Kona International Airport

4.5 Kilauea Volcano

Kilauea Volcano is an extremely large source of SO_2 emissions that affect the Kona area. As indicated by U.S. Geological Survey (USGS), the SO_2 emitted from the volcano interacts chemically with atmospheric moisture, oxygen, dust, and sunlight to produce vog. Table 4-5 below lists information for Kilauea volcano.

KILAUEA VOLCANO		
Source	Distance From Kona Station (miles)	Distance From Ocean View Station (miles)
Halema’uma’u Vent	42.2	38.0
Pu’u O’o Vent	53.5	47.9

Table 4-5. Kilauea Volcano

4.6 Stationary Source Emissions

Maximum potential $PM_{2.5}$, NO_2, and SO_2 emissions from permitted stationary sources, assuming controls and permit limits, are shown in Table 4-6.

STATIONARY SOURCE EMISSIONS					
No.	Facility	Equipment	Total Combined Emissions (TPY)		
			$PM_{2.5}$	NO_2	SO_2
1	BRE/Waikoloa, LLC	Two 5.07 MMBtu/hr Boilers	0.01	3.2	0.4
2	Waste Management of Hawaii, Inc.	340 TPH Crushing Plant and 275 TPH Screening Plant	1.2	6.6	1.9
3	Captain Cook Coffee Company, Ltd.	Two 20 hp Coffee Bean Peelers	2.2	0	0
4	Hawaiian Electric Light Company	Two 20 MW Combustion Turbine Generators, Three 2.5 MW Diesel Engine Generators[b], and One 500 kW Black Start Diesel Engine Generator	221.8[a]	983.5	1,067.6
5	Hawaiian Electric Light company	One 18 MW Combustion Turbine Generators	87.6[a]	170.8	481.8
6	Hawaiian Electric Light Company	One 1.5 MW Diesel Engine Generator	1.8	99.1	0.1
7	Grace Pacific, LLC	325 TPH Asphalt Plant	1.4	21.8	4.6
8	Jas W. Glover, Ltd.	150 yd^3/hr Concrete Batch Plant	29.4	10.4	3.2
9	West Hawaii Concrete	150 yd^3/hr Concrete Batch Plant	13.3	0	0
10	Cremation Services of West Hawaii	Two 150 lb/hr Pathological Waste Incinerators	0.8[c]	2.8	1.2
11	A Hui Hou Funeral and Tribute Service	One 150 lb/hr Human Crematory Unit	0.1	1.2	0.7
		Total →	359.6	1,299.4	1,561.5

a: $PM_{2.5}$ emissions based on data for PM_{10}.
b: Two of three 2.5 MW diesel engine generators can operate 8,760 hr/yr. The third 2.5 MW diesel engine generator is limited to 70,000 gal/yr fuel consumption.
c: $PM_{2.5}$ emissions based on data for PM.

Table 4-6. Stationary Source Emissions

4.7 Temporary Source Emissions

Maximum <u>potential</u> $PM_{2.5}$, NO_2, and SO_2 emissions, assuming controls and permit limits, are listed in Table 4-7 for temporary permitted sources that would typically operate in the Kona area.

TEMPORARY SOURCE EMISSIONS					
Source	Typical Number of Plants	Equipment	Total Emissions (TPY)		
			$PM_{2.5}$	NO_2	SO_2
Various	20	Various Equipment Arrow of Oregon/Hawaiian, LLC has a 300 TPH Impact Plant, 400 TPH Impact Plant, and 500 TPH Screening Plant	46.0[a]	456.0[a]	82.0[a]
Asphalt Production Plants	3	300 TPH Portable Asphalt Plant 400 TPH Portable Asphalt Plant 120 TPH Portable Asphalt Plant	27.9	104.0	50.1
Well Drilling Rig with Diesel Engines	1	Two 300 hp Diesel Engines, One 400 hp Diesel Engine, and Two 665 hp Diesel Engines	2.1[b]	39.2	0.1
Green Waste Grinder and Diesel Engine	1	69 TPH Horizontal Grinder with 765 hp Diesel Engine	1.1	44.7	0.1
		Total→	77.1	643.9	132.3

a. Based on emissions from Arrow of Oregon/Hawaiian LLC (CSP No. 0738-01-CT) as a random representative source. Emissions from this facility were multiplied by 20 to approximate total combined emissions from all twenty (20) of the crushing and screening plants.

b. $PM_{2.5}$ emissions are based on emission estimates for PM_{10}.

Table 4-7. Temporary Source Emissions

4.8 Kona International Airport Emissions

Table 4-8 shows estimated actual emissions of $PM_{2.5}$, NO_2, and SO_2 from the Kona International Airport. Emissions were based on information from the National Emissions Inventory (NEI) for year 2011. The NEI data is not yet available for 2012.

KONA INTERNATIONA AIRPORT EMISSIONS				
Source	Equipment	Emissions (TPY)[a]		
		$PM_{2.5}$	NO_2	SO_2
Kona International Airport	Various	11.6	226.7	27.2

a: Based on NEI data for 2011.

Table 4-8. Kona International Airport Emissions

4.9 Anthropogenic Emissions

Anthropogenic emissions of $PM_{2.5}$, NO_2, and SO_2 from significant sources in the Kona area are shown in Table 4-9.

ANTHROPOGENIC EMISSIONS			
Source	Emissions (TPY)		
	$PM_{2.5}$	NO_2	SO_2
Stationary Permitted Sources	359.6	1,299.4	1,561.5
Temporary Permitted Sources	77.1	643.9	132.3
Kona International Airport	11.6	226.7	27.2
Total→	448.3	2,170.0	1,721.0

Table 4-9. Anthropogenic Emissions

4.10 Kilauea Volcano Emissions

As indicated by USGS, Kilauea volcano emits about 2,000 tons of SO_2 gas each day during periods of sustained eruption. Emissions of SO_2 from Kilauea Volcano were quantified for 2011 and 2012, based on information provided by the USGS - HAVO. Table 4-10 provides emissions from the volcano.

KILAUEA VOLCANO EMISSIONS				
Source	Short Tons per Year		Metric Tons per Year	
	2011	2012	2011	2012
Halema'uma'u Vent	221,154	292,738	200,630	265,570
Pu'u O'o Vent	226,412	146,220	205,400	132,650
Total→	447,566	438,958	406,030	398,220

Table 4-10. Kilauea Volcano Emissions

4.11 Anthropogenic and Volcanic Emissions

Figures 4-1 and 4-2 provide a comparison between $PM_{2.5}$, NO_2, and SO_2 emissions from anthropogenic sources and SO_2 emissions from the volcano in 2011 and 2012.

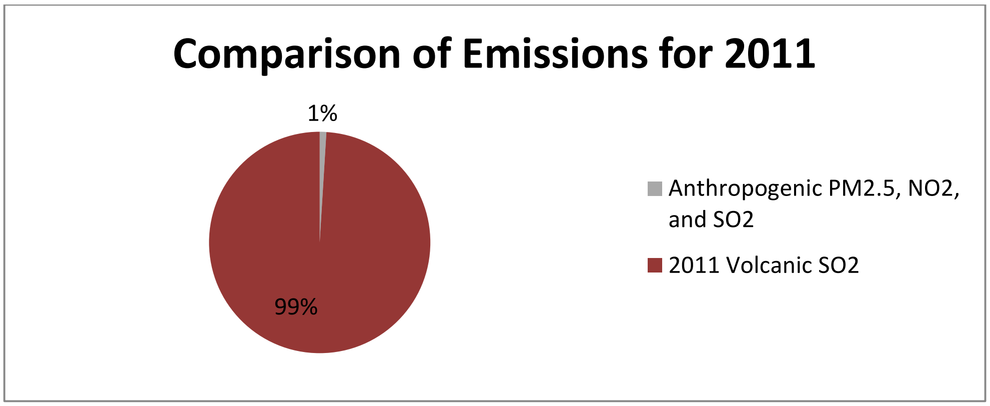

Figure 4-1. Comparison of Emissions for 2011

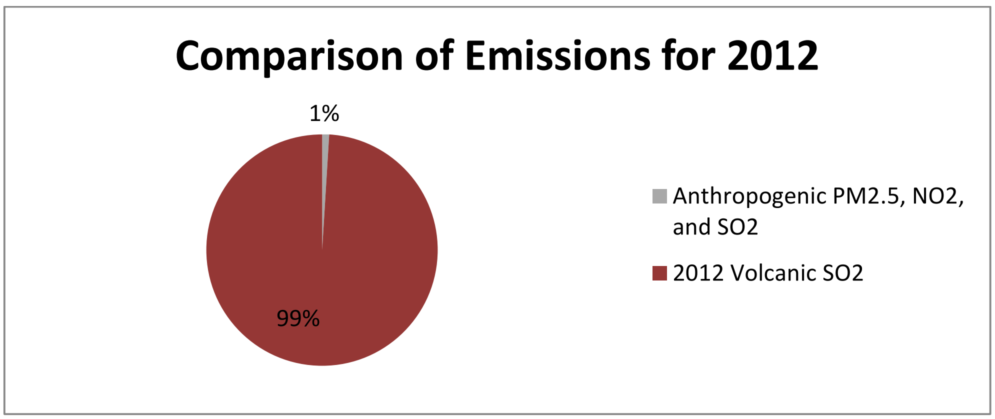

Figure 4-2. Comparison of Emissions for 2012

4.12 Regulatory Measures and Air Pollution Controls

The Department of Health is responsible for implementing measures specified in the applicable regulations to control pollutants from stationary and temporary sources. Requirements from the following regulations are incorporated into permits of facilities in the Kona area according to the applicable source category:

1) Hawaii Administrative Rules (HAR);
2) PSD/BACT, §52.21;
3) 40 CFR Part 60, Subpart OOO, NSPS, Standards of Performance for Nonmetallic Mineral Processing Plants;
4) 40 CFR Part 60, Subpart I, NSPS, Standards of Performance for Hot Mix Asphalt Facilities;
5) 40 CFR Part 60, Subpart GG, NSPS, Standards of Performance for Stationary Gas Turbines; and
6) 40 CFR Part 63, Subpart ZZZZ, NESHAP for Stationary Reciprocating Internal Combustion Engines.

Table 4-11summarizes regulations that apply to sources in the Kona area that provide control requirements to minimize $PM_{2.5}$ and $PM_{2.5}$ precursors of NO_2 and SO_2.

No.	Source	Regulation(s)	Regulatory Measures for PM2.5, NO_2, and SO_2
1	BRE/Waikoloa, LLC[a,b] Two 5.07 MMBtu/hr Boilers	HAR	Provides stack opacity standards.
2	Waste Management of Hawaii, Inc.[a] Crushing and & Screening Plant	HAR	Provides standards for stack opacity and visible emissions of fugitive dust from and beyond property.
3	Captain Cook Coffee Company, Ltd. Two Coffee Bean Peelers	HAR	Provides stack opacity standards.
4	Hawaiian Electric Light Company[a] Two 20 MW Combustion Turbine Generators, Three 2.5 MW Diesel Engine Generators, and One 500 kW Black Start Diesel Engine Generator	HAR Subpart ZZZZ Subpart GG PSD	Provides stack opacity standards. Specifies ultra-low sulfur fuel for diesel engine generators. Requires particulate control measures for engine crankcase. Specifies NO_2 controls. Provides combustion turbine BACT emission limits for PM, NO_2, and SO_2 among other pollutants. Provides diesel engine generator BACT emission limit for NO_2. Continuous emission monitoring systems (CEMS) for combustion turbine NO_2 limit as well as other pollutant emission limits. Continuous opacity monitor system (COMS) for combustion turbine opacity. Monthly visible emission evaluations performed for diesel engine generator stack opacity. Performance testing conducted at least every two years to determine compliance with combustion turbine BACT limits.
5	Hawaiian Electric Light Company[a] One 18 MW Combustion Turbine Generator	HAR Subpart GG PSD	Provides stack opacity standards. Specifies NO_2 controls. Provides combustion turbine BACT emission limits for PM, NO_2, and SO_2 among other pollutants. CEMS for combustion turbine NO_2 limit as well as other pollutant emission limits. COMS for combustion turbine opacity. Performance testing at least every two years for BACT emission limits.
6	Hawaiian Electric Light Company[a] One 1.5 MW Diesel Engine Generator	HAR Subpart ZZZZ	Provides opacity standards. Specifies ultra-low sulfur fuel for the diesel engine generator. Requires particulate control measures for engine crankcase.

No.	Source	Regulation(s)	Regulatory Measures for PM2.5, NO_2, and SO_2
7	Grace Pacific, LLC[a] 325 TPH Asphalt Plant	HAR Subpart ZZZZ Subpart I	Provides standards for stack opacity and visible emissions of fugitive dust from and beyond the property. Specifies ultra-low sulfur fuel for diesel engine generator. Requires particulate control measures for engine crankcase. Provides opacity and particulate emissions standards for drum mixer dryer. Monthly visible emissions evaluations for stack opacity. Performance testing of drum mixer dryer at least every two years for particulate matter emission limit and opacity.
8	Jas W. Glover[a] 150 yd^3/hr Concrete Batch Plant	HAR	Provides standard for visible emissions of fugitive dust from and beyond the property.
9	West Hawaii Concrete[a] 150 yd^3/hr Concrete Batch Plant	HAR	Provides standard for fugitive dust from and beyond the property.
10	Cremation Services of West Hawaii[a] - 150 yd^3/hr Pathological Waste Incinerator	HAR	Provides stack opacity standards.
11	A Hui Hou Funeral and Tribute Service[a] - 150 yd^3/hr Crematory	HAR	Provides stack opacity standards.
----	Arrow of Oregon/Hawaiian, LLC[c,d,e] (random representative company) Crushing and Screening Equipment	HAR Subpart OOO	Provides standards for stack opacity and visible emissions of fugitive dust from and beyond property. Provides fugitive dust opacity standards. Monthly visible emissions evaluations for fugitive emissions and stack opacity. Performance testing at least every two years for fugitive dust opacity limits.
-----	Black Maui Rose, LLC[c] Road and Highway Builders, LLC[c] Keauhou Kona Construction Corporation[c] Portable Asphalt Plants	HAR Subpart I	Provides standards for stack opacity and visible emissions of fugitive dust from and beyond the property. Provides particulate emission limit and opacity standards for drum mixer dryer. Monthly visible emissions evaluations for stack opacity. Performance testing at least every two years for drum mixer dryers for opacity and particulate matter emission limits.
-----	Water Resources International, Inc.[c] Temporary Water Well Drilling Rig with Portable Diesel Engine Gen.	HAR	Provides stack opacity standards.
-----	Menehune Green, LLC dba Hawaiian Earth Products[c] Portable Green Waste Grinder	HAR	Provides standards for stack opacity and visible emissions of fugitive dust from and beyond the property.

a. Stationary source.
b. Subpart JJJJJJ, NESHAP for Area Sources: Industrial Commercial, and Institutional Boilers will apply in 2014 that will require biennial boiler tune ups.
c. Temporary source.
d. Temporary sources consist of 19 covered sources and 1 noncovered source.
e. Covered sources are subject to both HAR and Subpart OOO. Noncovered source is only subject to requirements from HAR.

Table 4-11. Regulatory Measures for Anthropogenic Sources

Table 4-12 summarizes control measures utilized by sources in the Kona area to minimize $PM_{2.5}$ and $PM_{2.5}$ precursors of NO_2 and SO_2.

No.	Source	Air Pollution Control Measures
1	BRE/Waikoloa, LLC[a] Two 5.07 MMBtu/hr Boilers	Proper maintenance and operation for stack opacity.
2	Waste Management of Hawaii, Inc.[a] Crushing and & Screening Plant	Wet suppression methods for fugitive dust. Proper maintenance and operation for stack opacity.
3	Captain Cook Coffee Company, Ltd.[a] Two Coffee Bean Peelers	Cyclone dust collector for peelers to control particulate and for opacity. Proper maintenance and operation for stack opacity.
4	Hawaiian Electric Light Company[a] Two 20 MW Combustion Turbine Generators, Three 2.5 MW Diesel Engine Generators, and One 500 kW Black Start Diesel Engine Generator	Selective catalytic reduction (SCR) and water injection for combustion turbine to control NO_2. Burning ultra-low sulfur fuel to minimize SO_2 from diesel engine generators. Crankcase filtration systems for diesel engine generators to control particulate. Proper equipment maintenance and operation for stack opacity.
5	Hawaiian Electric Light Company[a] One 18 MW Combustion Turbine Generator	Water injection system for combustion turbine to control NO_2. Proper maintenance and operation for stack opacity.
6	Hawaiian Electric Light Company[a] One 1.5 MW Diesel Engine Generator	Ultra-low sulfur fuel fired by unit to minimize SO_2. Crankcase filtration system for engine to minimize particulate emissions
7	Grace Pacific, LLC[a] 325 TPH Asphalt Plant	Wet suppression methods for fugitive dust. Baghouse for drum mixer dryers to control particulate for opacity and particulate matter emission limits. Proper maintenance and operation for stack opacity.
8	Jas W. Glover[a] 150 yd^3/hr Concrete Batch Plant	Wet suppression measures for fugitive dust. Baghouses for transit mix truck and cement silo loading.
9	West Hawaii Concrete[a] 150 yd^3/hr Concrete Batch Plant	Wet suppression measures for fugitive dust. Baghouses for transit mix truck and cement silo loading.
10	Cremation Services of West Hawaii[a] 150 yd^3/hr Pathological Waste Incinerator	Wet suppression measures for fugitive dust. Baghouses for transit mix truck and cement silo loading.
11	A Hui Hou Funeral and Tribute Service[a] 150 yd^3/hr Crematory	Secondary chamber to reduce particulate. Proper maintenance and secondary chamber for stack opacity. Visual alarm if opacity exceeds 10%.
----	Arrow of Oregon/Hawaiian, LLC[b] (random representative company) Crushing and Screening Equipment	Wet suppression measures for fugitive dust. Proper maintenance and operation for stack opacity.
-----	Black Maui Rose, LLC[b] Road and Highway Builders, LLC[b] Keauhou Kona Construction Corporation[b] Portable Asphalt Plants	Wet suppression methods for fugitive dust. Baghouses to control particulate from drum mixer dryers for opacity and particulate matter emissions limit. Proper maintenance and operation for stack opacity.
-----	Water Resources International, Inc.[b] Temporary Water Well Drilling Rig with Portable Diesel Engine Generators	Proper maintenance and operation for stack opacity.
-----	Menehune Green, LLC dba Hawaiian Earth Products[b] Portable Green Waste Grinder	Wet suppression methods for fugitive dust. Proper maintenance and operation for stack opacity.

a. Stationary source.
b. Temporary source.

Table 4-12. Air Pollution Control Measures for Anthropogenic Sources

4.13 Inspections

Title V sources, which include all large facilities in the Kona area, are inspected each year to ensure equipment is operated within the terms of the permits.

Section 5. Historical Norm

Prior to the opening of the new vent at Halema'uma'u, there was no $PM_{2.5}$ monitoring being conducted at the Kona station, nor at any of the other air monitoring stations on the Big Island. The earliest $PM_{2.5}$ monitoring began at the Kona station in March 2008, Pahala in April 2008, and Hilo in May 2008, necessitated by the increase of volcanic emissions and concern for public health and safety. Since no $PM_{2.5}$ data is available prior to 2008, there is no possible way to show that "the exceptional event is associated with a measured $PM_{2.5}$ concentration in excess of normal historical fluctuations."

However, historical SO_2 monitoring data is available for the Kona and Hilo stations beginning in 2000. Sampling for SO_2 at the Pahala station began on August 10, 2007. Figure 5-1 below shows the annual average of measured SO_2 at the three stations. The chart shows an increase in measured SO_2 at the three stations beginning 2008, coinciding with the March 18, 2008 Halema'uma'u event. As explained in previous sections of this report, the increased SO_2 emissions correlate with the increase in measured $PM_{2.5}$ concentrations.

Taking into consideration the correlation between SO_2 emissions and measured $PM_{2.5}$ concentrations, the information presented in this chart show that "the exceptional event is associated with a measured concentration in excess of normal historical fluctuations."

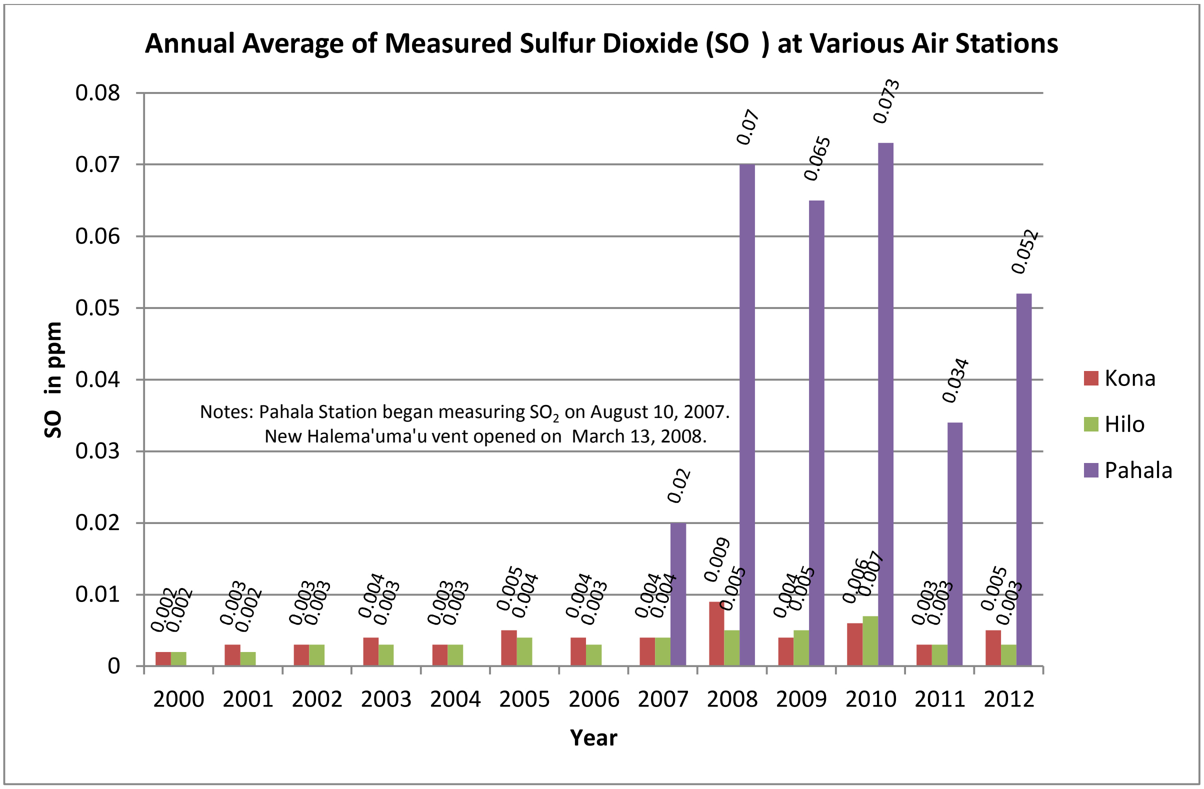

Figure 5-1. Annual Average of Measured SO_2 at Various Air Stations

Section 6. "But-for" Analysis/Conclusions

In accordance with 40 CFR 50.14(c)(3)(iv)(D), exceptional event packages must demonstrate that "there would have been no exceedance or violation but for the event." Based on the data evaluated, this exception event package has demonstrated that annual monitored $PM_{2.5}$ concentrations in 2011 and 2012 were not reasonably controllable or preventable and there is a clear causal relationship between transported SO_2 from the Kilauea volcano and measured $PM_{2.5}$ exceedances from the Kona air monitoring station. Concentrations of SO_2 in excess of historical fluctuations were also measured after the Halema'uma'u vent opened in 2008. Considering the transport path and magnitude of SO_2 emissions associated with the volcano plume, there would have been no exceedances of the annual $PM_{2.5}$ standard but for the naturally occurring and ongoing eruption of Kilauea volcano.

The ongoing release of SO_2 from Kilauea Volcano is the primary source affecting air quality and contributing to annual $PM_{2.5}$ concentration exceedances measured at the Kona air quality monitoring station in 2011 and 2012. According to the USGS, SO_2 released from the volcano creates vog when SO_2 reacts chemically with sunlight, oxygen, dust particles, and moisture in the air to form sulfate aerosols (fine particles and droplets). As discussed in section 2 of this report, the USGS indicates that trade winds blow the vog from its main source on the volcano to the southwest, where wind patterns send it up the Kona coast. Also, the vog becomes trapped along the Kona coast by daytime (onshore) and nighttime (offshore) breezes. Emissions of $PM_{2.5}$ and $PM_{2.5}$ precursors of NO_2 and SO_2 from anthropogenic sources in the Kona area are only 1% of the total emissions (anthropogenic $PM_{2.5}$, NO_2, and SO_2 + volcanic SO_2). Please refer to Figures 4-1 and 4-2 of Section 4 for a comparison of the emissions. The air pollution control measures for permitted sources are adequate and should be considered reasonable for minimizing primary and secondary $PM_{2.5}$.

Table 4-1 from Section 4, shows a higher annual $PM_{2.5}$ concentration measured at the Kona air monitoring station in 2012 than in 2011. The higher 2012 concentration is likely attributed to larger SO_2 emissions from the volcano's Halema'uma'u vent that were 71,584 tons per year higher in 2012 than in 2011. In 2012, the SO_2 emissions from the Halema'uma'u vent were also 146,518 tons per year higher than those from the Pu'uO'o vent. Please refer to Table 4-10 from Section 4 for volcano emissions. As stated in a previous evaluation, the Halema'uma'u vent, being situated at a higher elevation and further inland, appears to have a greater impact on the more populated areas of the island than the Pu'u O'o vent, which is situated at a lower elevation and closer to the coast. This would indicate a clear causal connection between the quantity of emissions released from the Halema'uma'u vent and annual $PM_{2.5}$ exceedances measured in 2012 from the Kona air monitoring station.

Total emissions from permitted sources in the Kona area were based on each facility's <u>maximum potential to emit</u> which over estimates the emissions from anthropogenic sources in contributing to annual $PM_{2.5}$ exceedances.

Air monitoring data for 2011 and 2012 in Tables 3-2 and 3-3 of Section 3 show a decrease in annual SO_2 concentration from Pahala to Ocean View stations and a further decrease from Ocean View to Kona stations while there is an increase in annual $PM_{2.5}$ concentration from Kona to Ocean View stations and an additional increase from Ocean View to Pahala stations. This is consistent with what would be expected as SO_2 is converted to sulfates in the wake of the volcano's plume as it drifts from Pahala-to-Ocean View-to-Kona. This demonstrates a clear causal link between SO_2 released by the volcano, the time necessary to form sulfates in the presence of sunlight and atmospheric constituents, the volcanic plume transport path, and monitored concentrations. Figure 2.7 in Section 2 shows vog created from gases released by the Kilauea volcano.

Similar concentration versus time plots of air quality data from the Kona and Ocean View air monitoring stations indicate a large regional source is affecting air quality at the monitoring sites. The Kilauea volcano is a large regional source that is not reasonably controllable or preventable and overwhelms the quantity of emissions from anthropogenic sources. The volcano is the likely source responsible for the correlation in the concentration versus time plots. Emissions from permitted facilities and the airport are significantly lower than those from the volcano. These anthropogenic sources are also scattered in location on the island. Therefore, anthropogenic sources cannot be the cause of correlation at the Kona and Ocean View air monitoring sites. The $PM_{2.5}$ and SO_2 plot comparisons for the two monitoring stations are shown in Figures 3-2, 3-3, 3-4, 3-5, 3-6, and 3-7 of Section 3.

Air monitoring data in Figure 5-1 of Section 5 shows that increased SO_2 concentrations at the Kona, Hilo, and Pahala are associated with the opening of the Halema'uma'u vent. This demonstrates an event that is associated with a measured concentration in excess of normal fluctuations.

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11. University of Utah, MesoWest, Weather Observations; http://mesowest.utah.edu/

12. Wikipedia, "Pearson product-moment correlation coefficient"; http://en.wikipedia.org/wiki/Pearson_product-moment_correlation_coefficient

13. Hawaii, Department of Health, Clean Air Branch, "Clean Air Branch (CAB) 2012 Performance Audit Data - Hilo, Kona, Mountain View, Pahala, Puna E., and Waikoloa Monitoring Stations", October 18, 2012, 12-850M&A CAB.

Appendix A

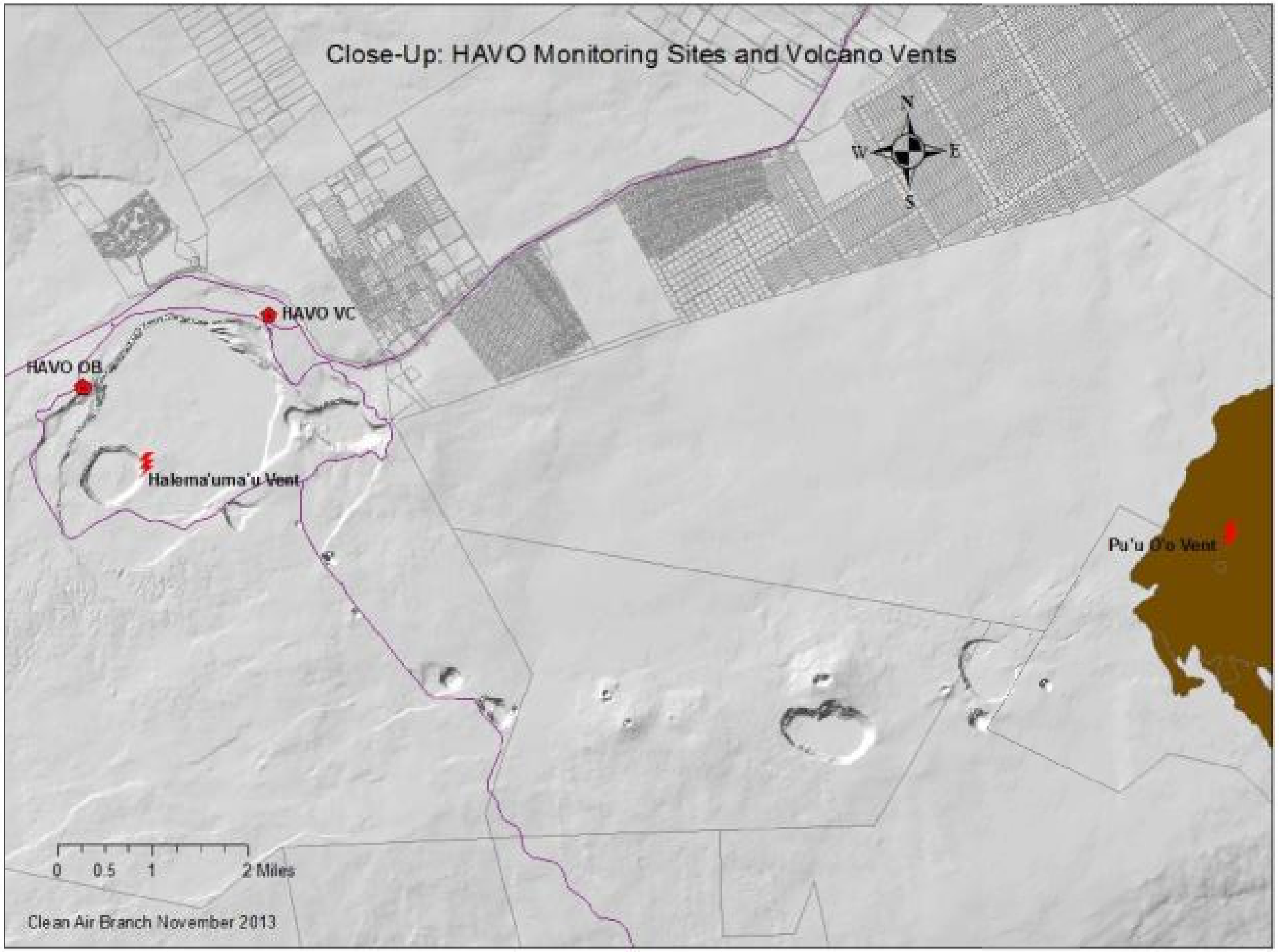


Figure A-1. Hawaii Volcanoes (HAVO) Monitoring Sites and Kilauea Volcano Vents

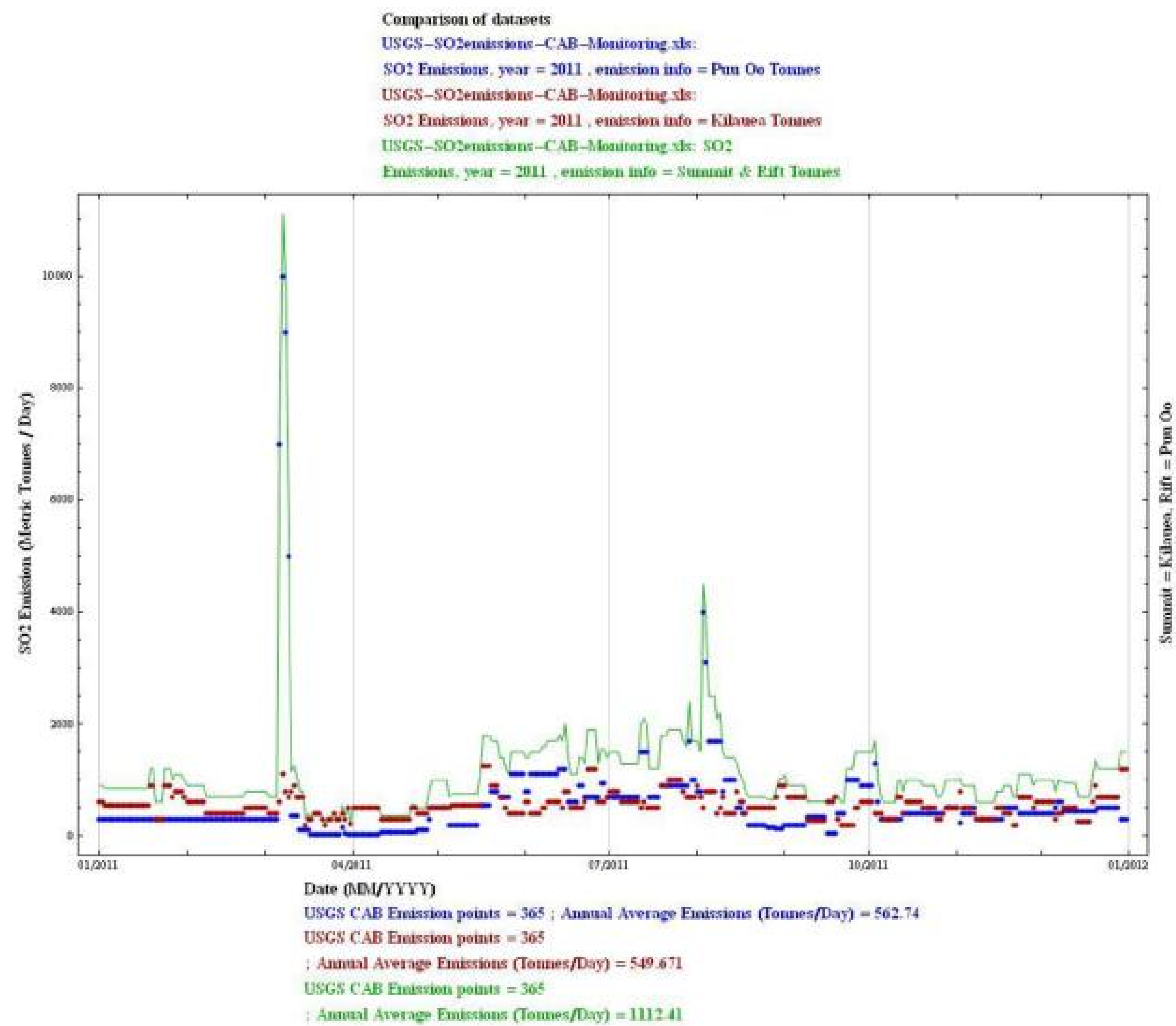


Figure A-2. 2011 Preliminary USGS Sulfur Dioxide Emission Estimates from Kilauea Volcano

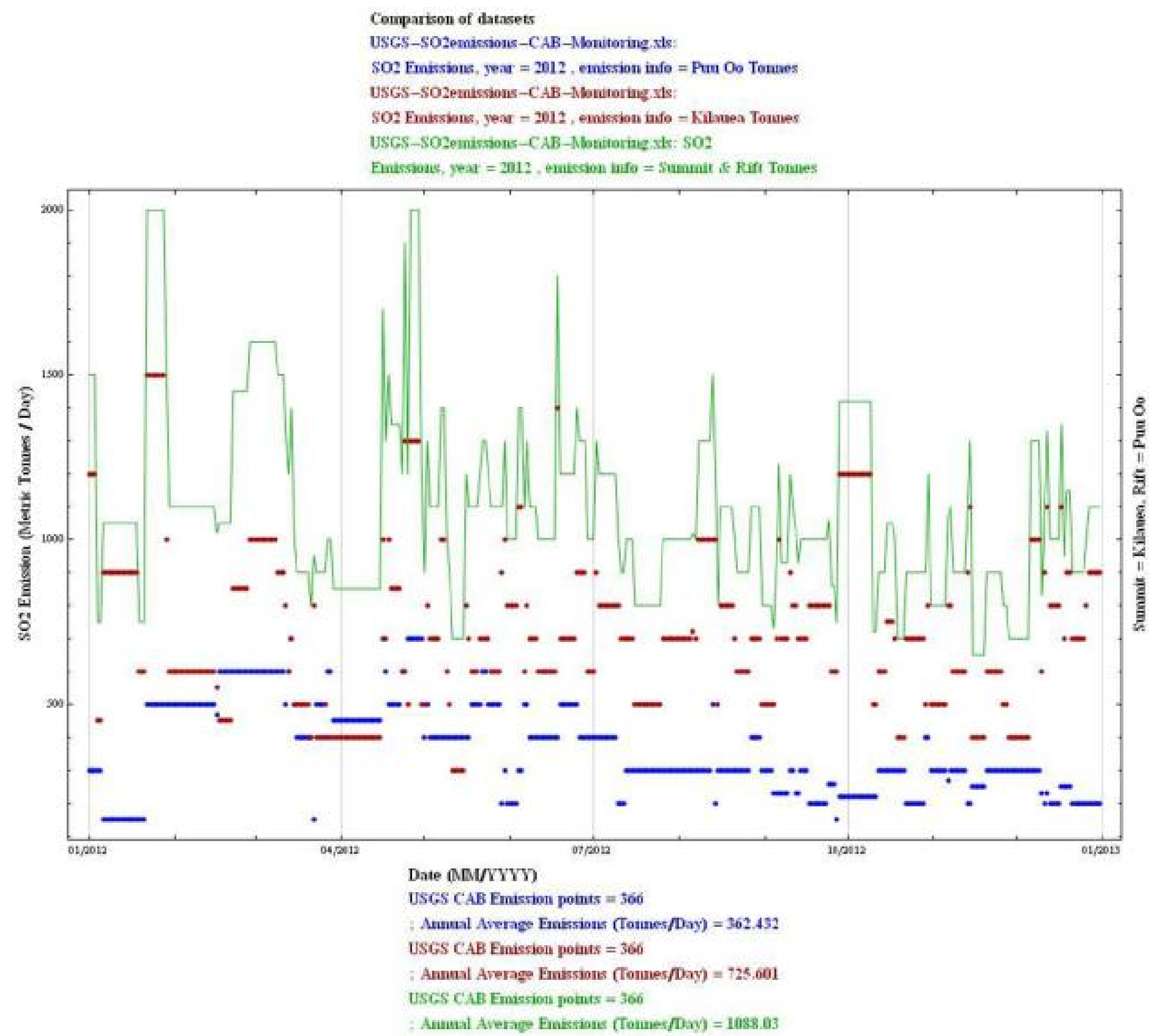


Figure A-3: 2012 Preliminary USGS Sulfur Dioxide Emission Estimates from Kilauea Volcano

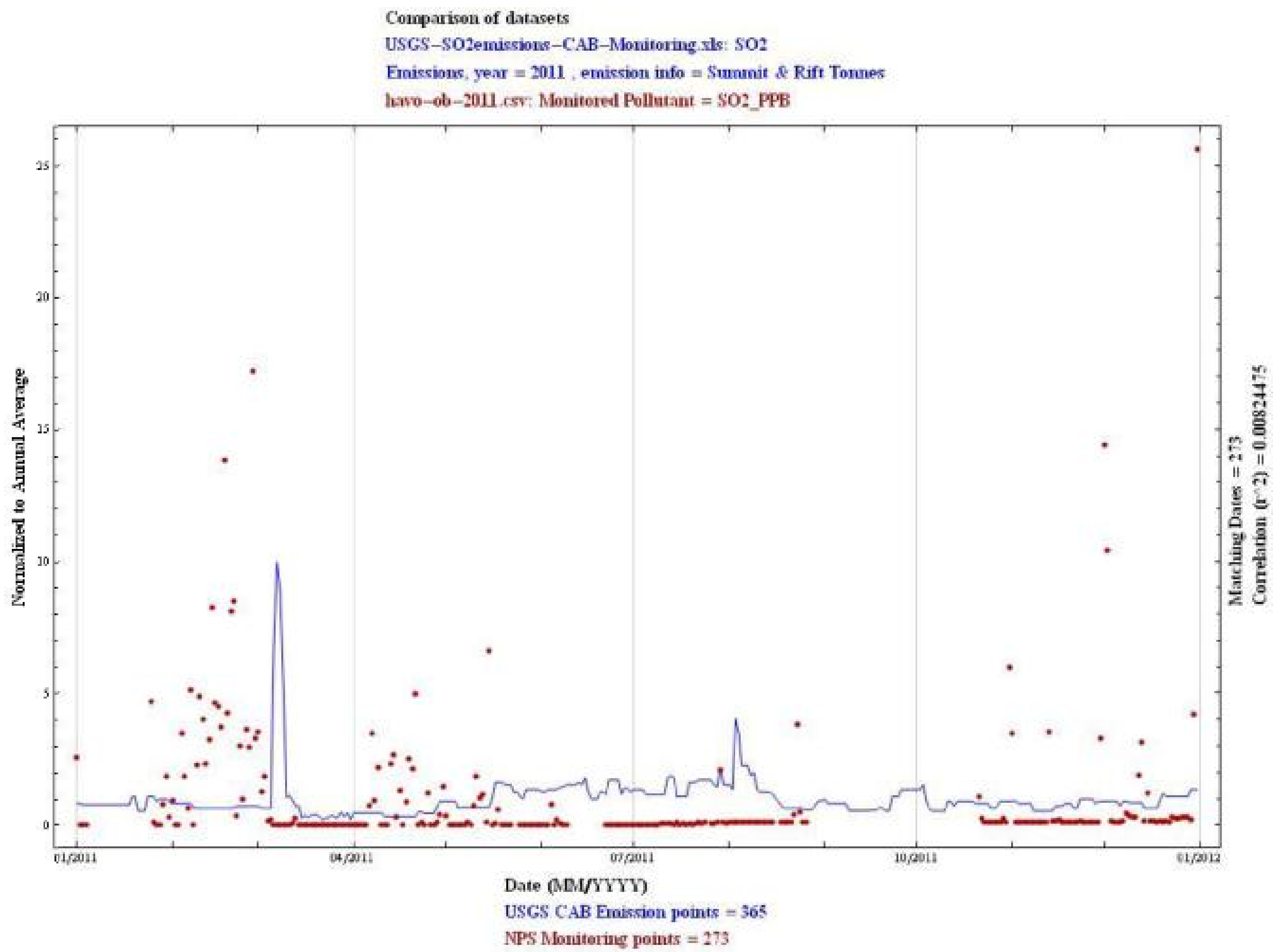


Figure A-4. 2011 Comparison of normalized Preliminary USGS Sulfur Dioxide Emission Estimates from Kilauea Volcano (blue) with normalized NPS monitored Sulfur Dioxide at the HAVO Observatory (red)

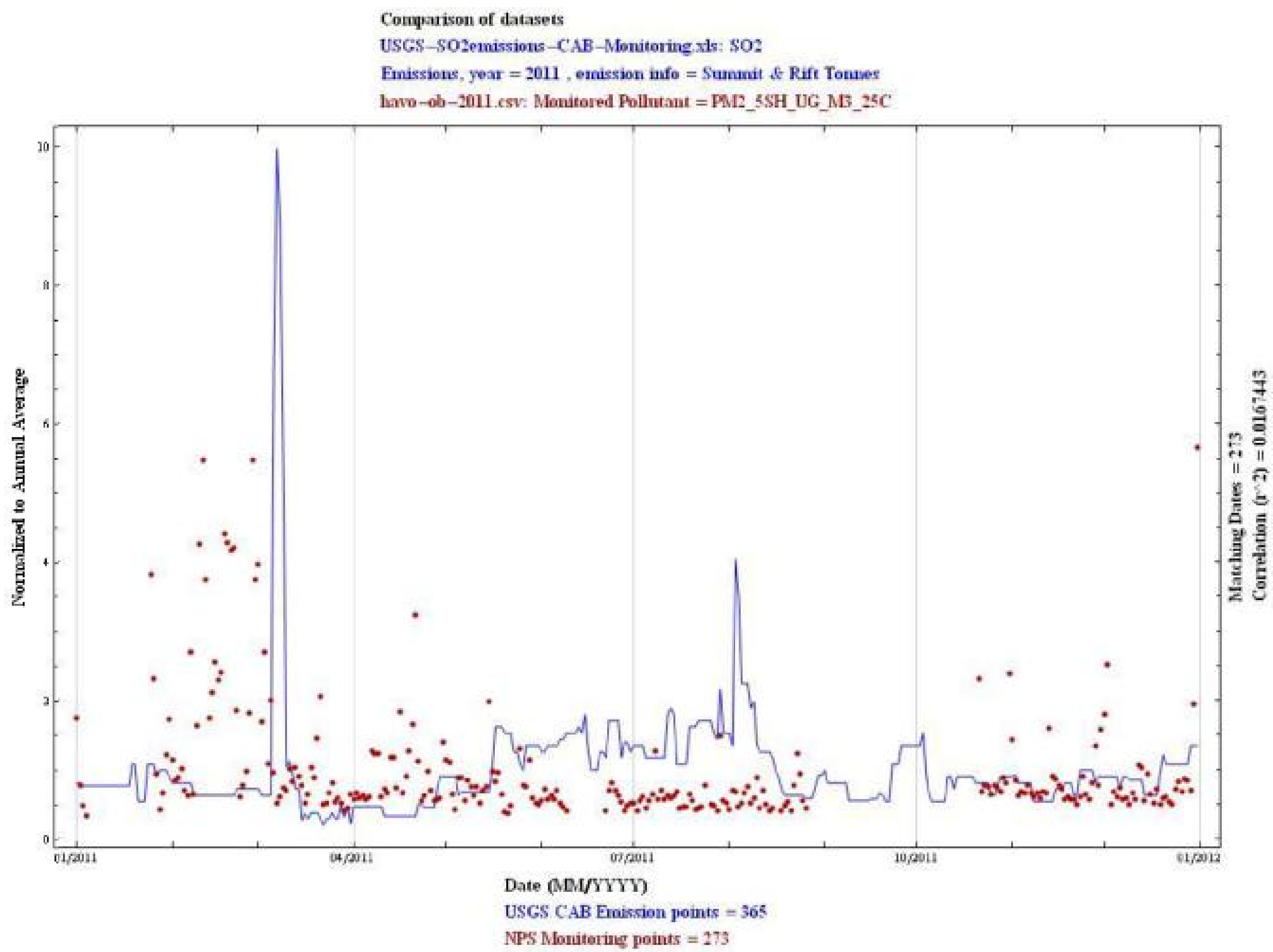


Figure A-5: 2011 Comparison of normalized Preliminary USGS Sulfur Dioxide Emission Estimates from Kilauea Volcano (blue) with normalized NPS monitored PM2.5 at the HAVO Observatory (red)

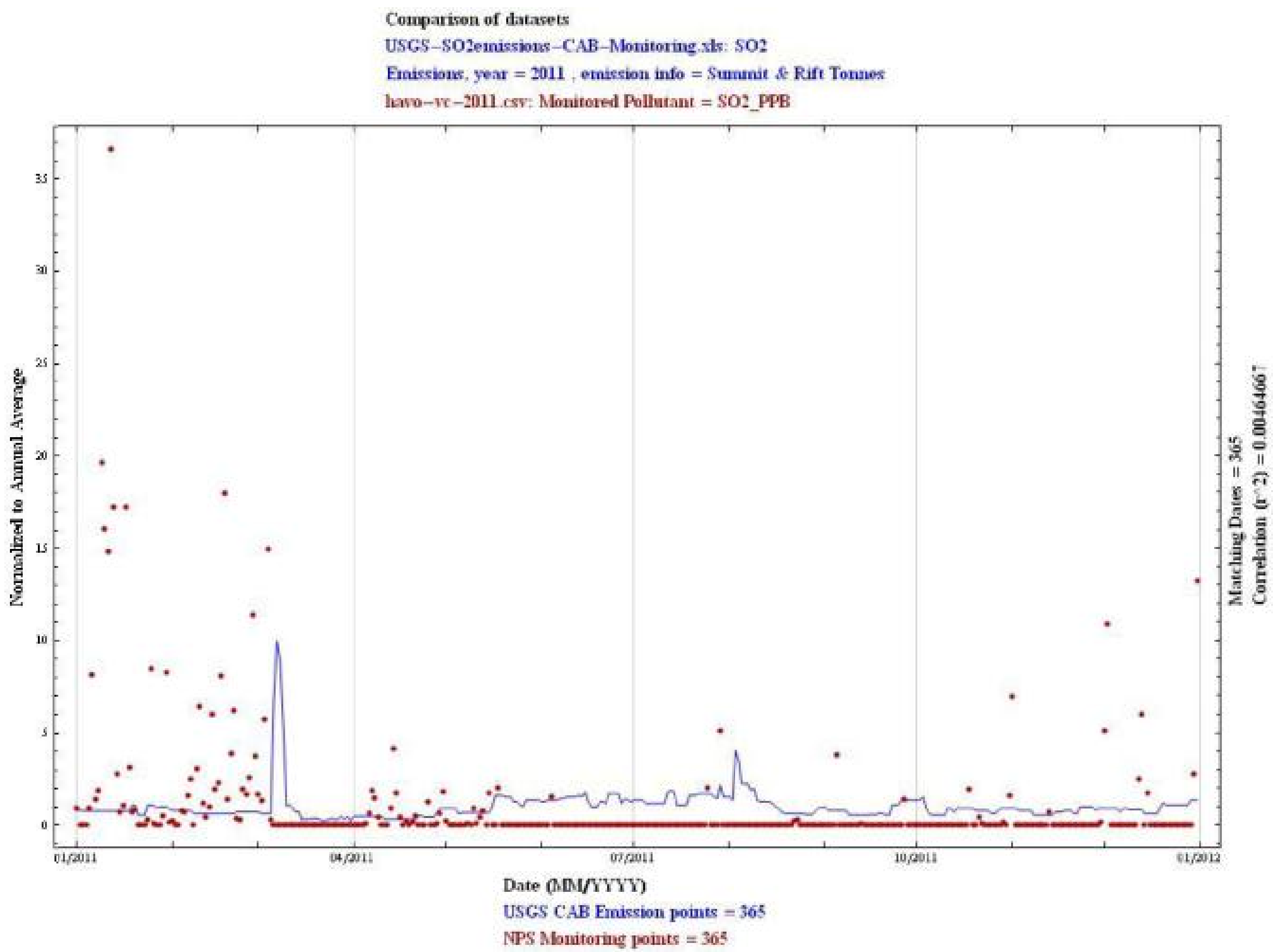


Figure A-6. 2011 Comparison of normalized Preliminary USGS Sulfur Dioxide Emission Estimates from Kilauea Volcano (blue) with normalized NPS monitored Sulfur Dioxide at the HAVO Visitor Center (red)

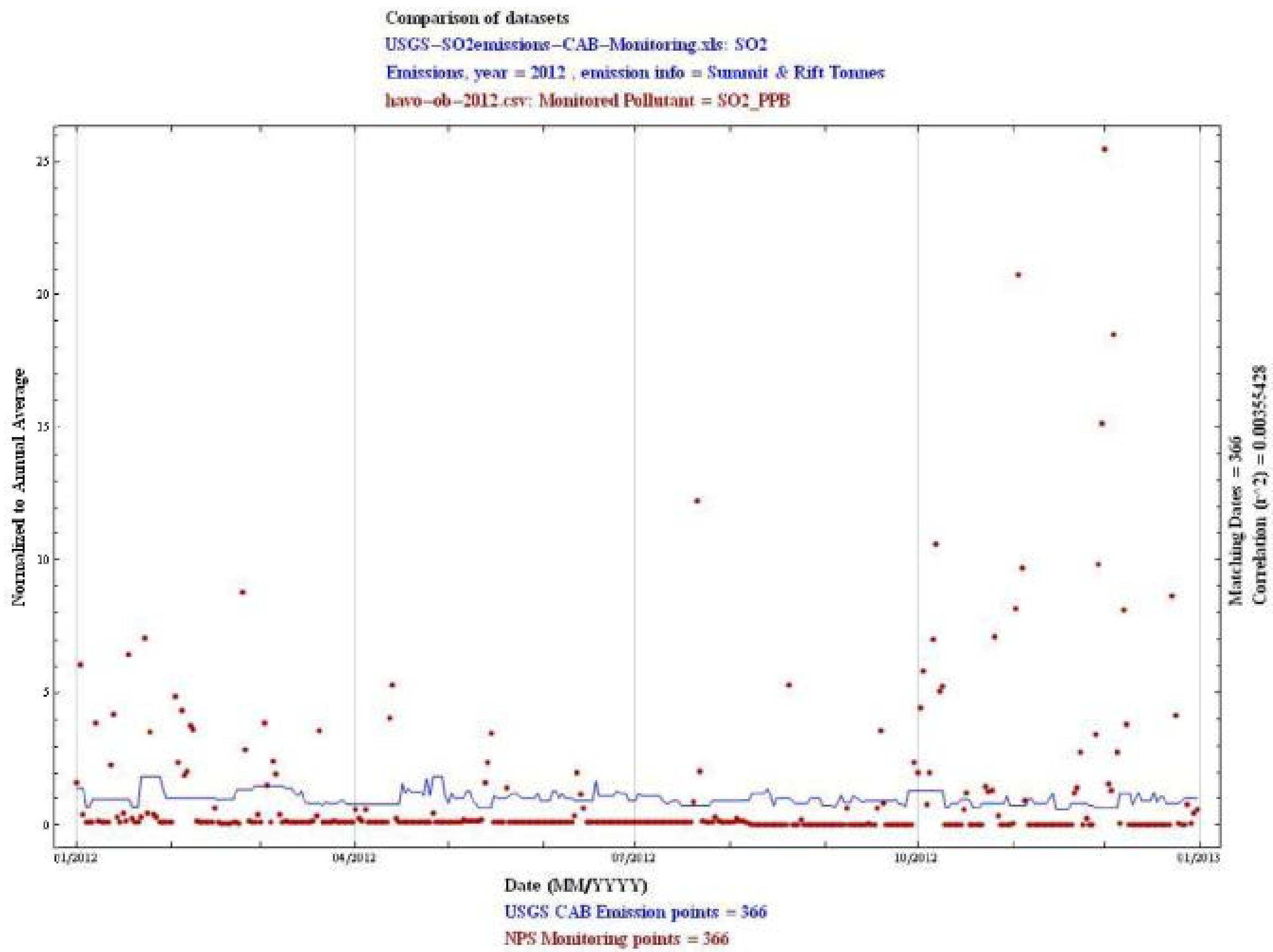


Figure A-7. 2012 Comparison of normalized Preliminary USGS Sulfur Dioxide Emission Estimates from Kilauea Volcano (blue) with normalized NPS monitored Sulfur Dioxide at the HAVO Observatory (red)

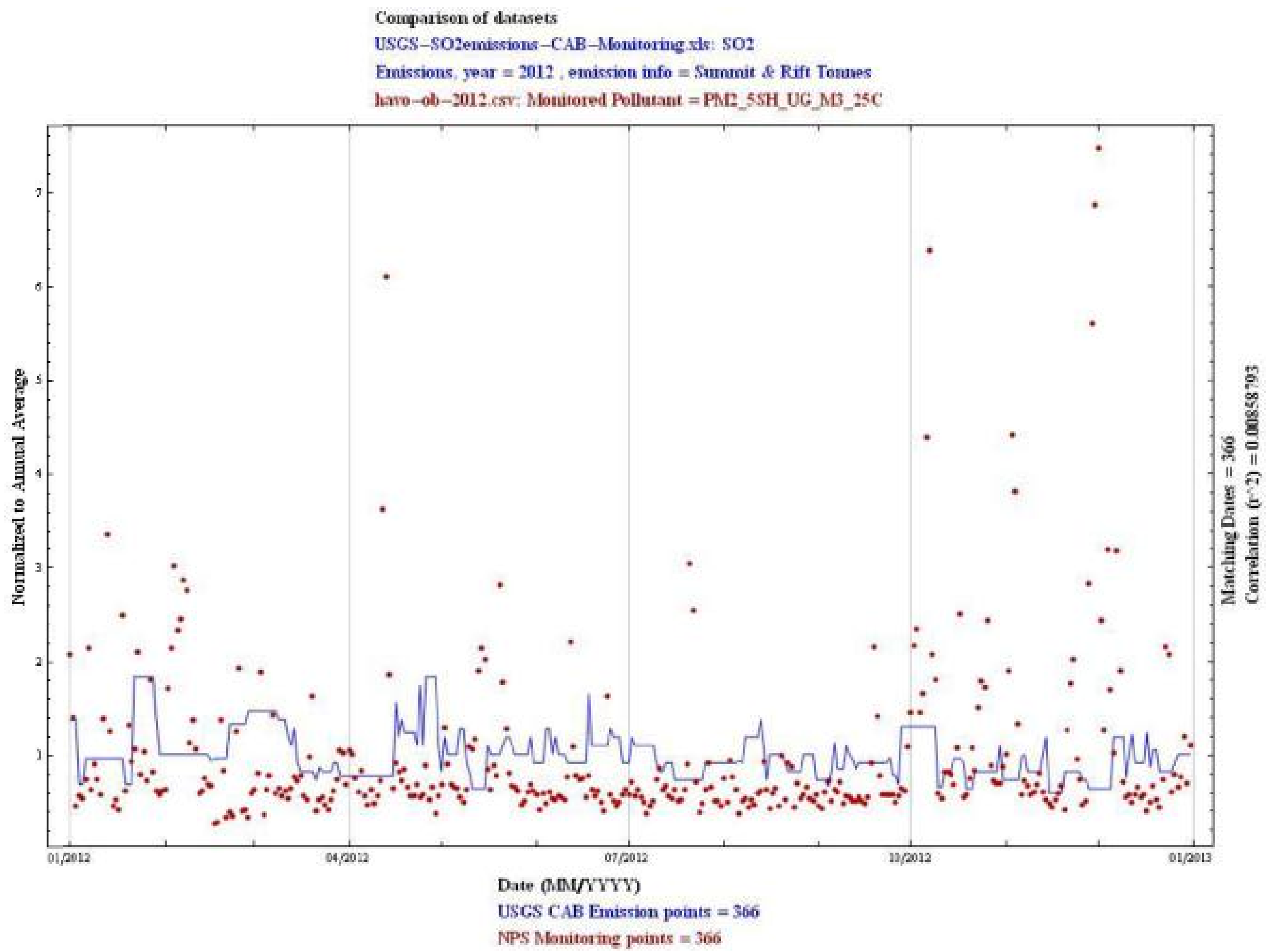


Figure A-8. 2012 Comparison of normalized Preliminary USGS Sulfur Dioxide Emission Estimates from Kilauea Volcano (blue) with normalized NPS monitored PM2.5 at the HAVO Observatory (red)

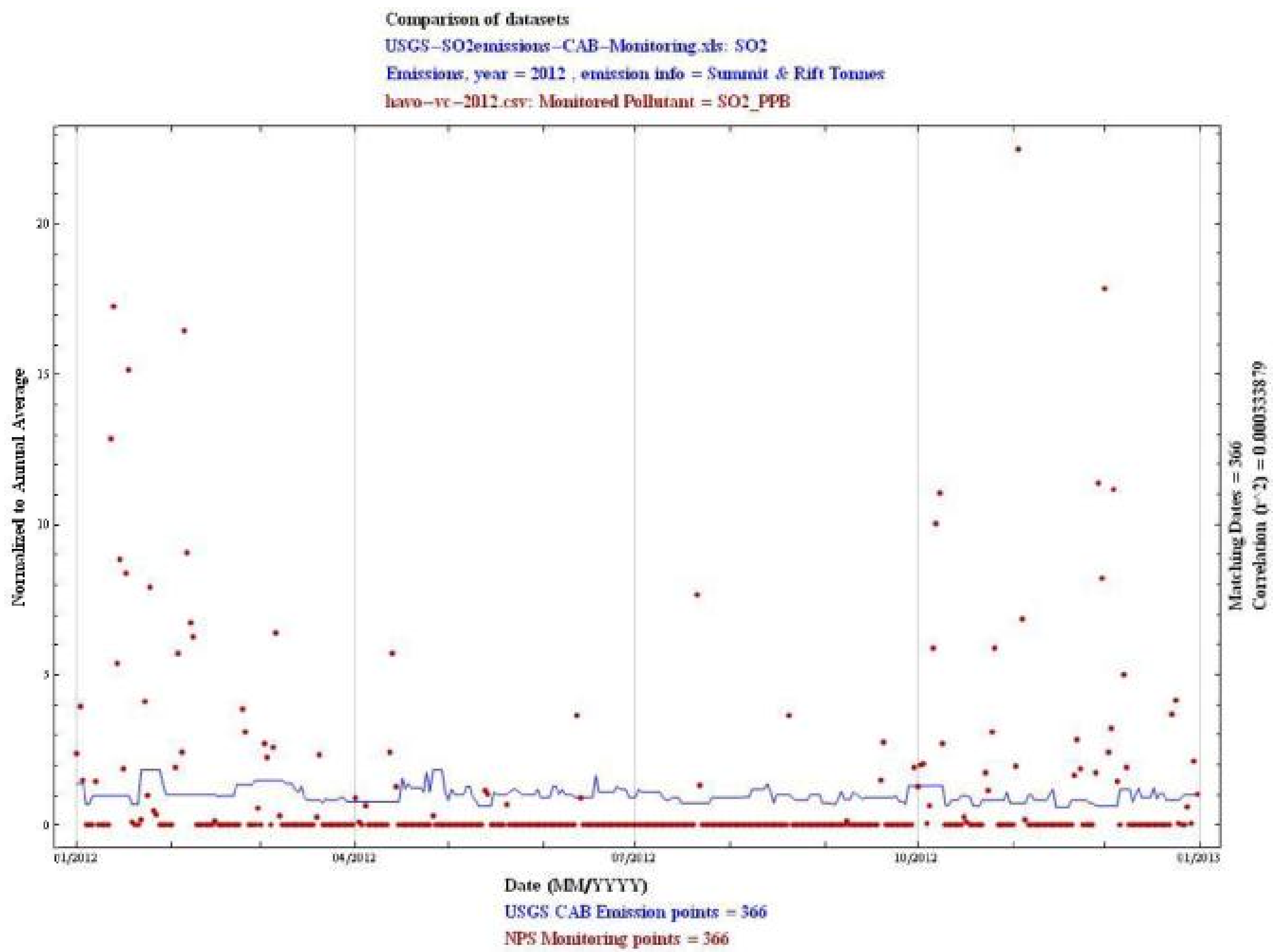
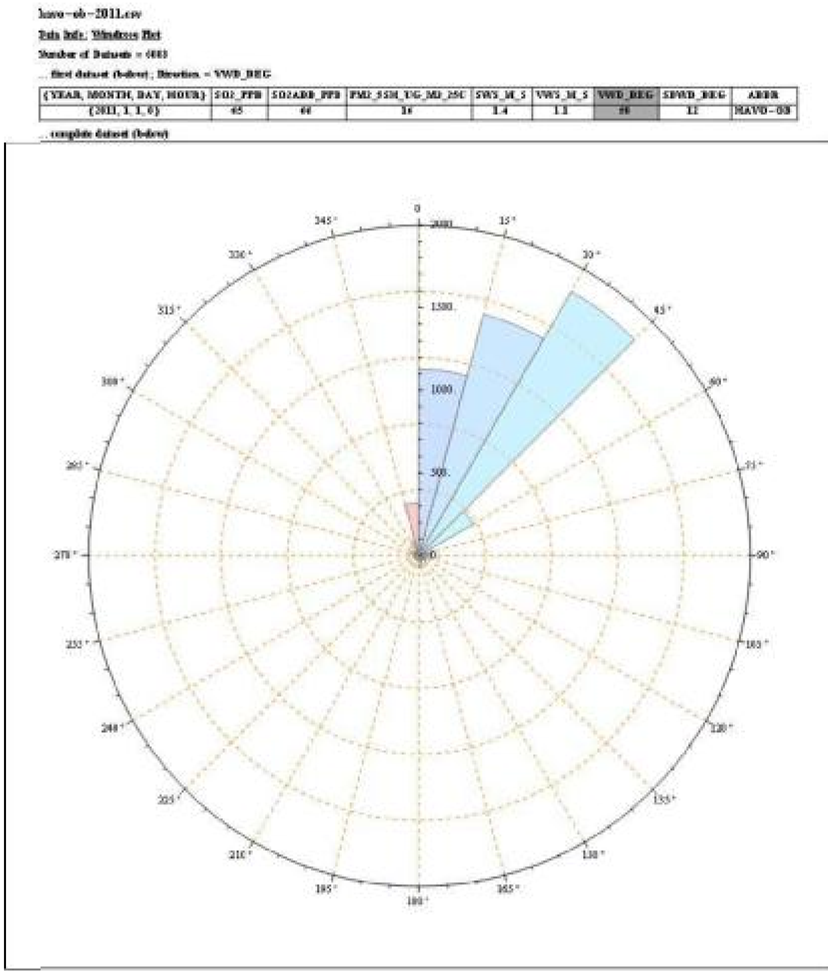


Figure A-9. 2012 Comparison of normalized Preliminary USGS Sulfur Dioxide Emission Estimates from Kilauea Volcano (blue) with normalized NPS monitored Sulfur Dioxide at the HAVO Visitor Center (red)



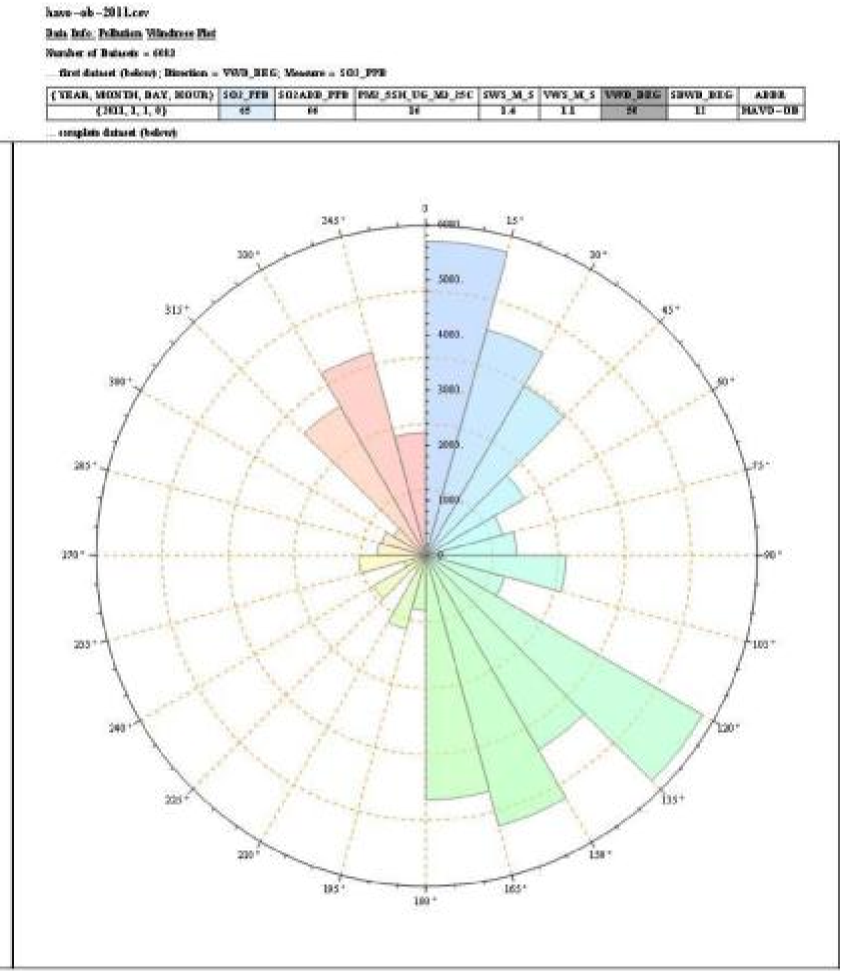


Figure A-10. 2011 HAVO Observatory Windrose (left) and SO2 Pollution windrose (right)

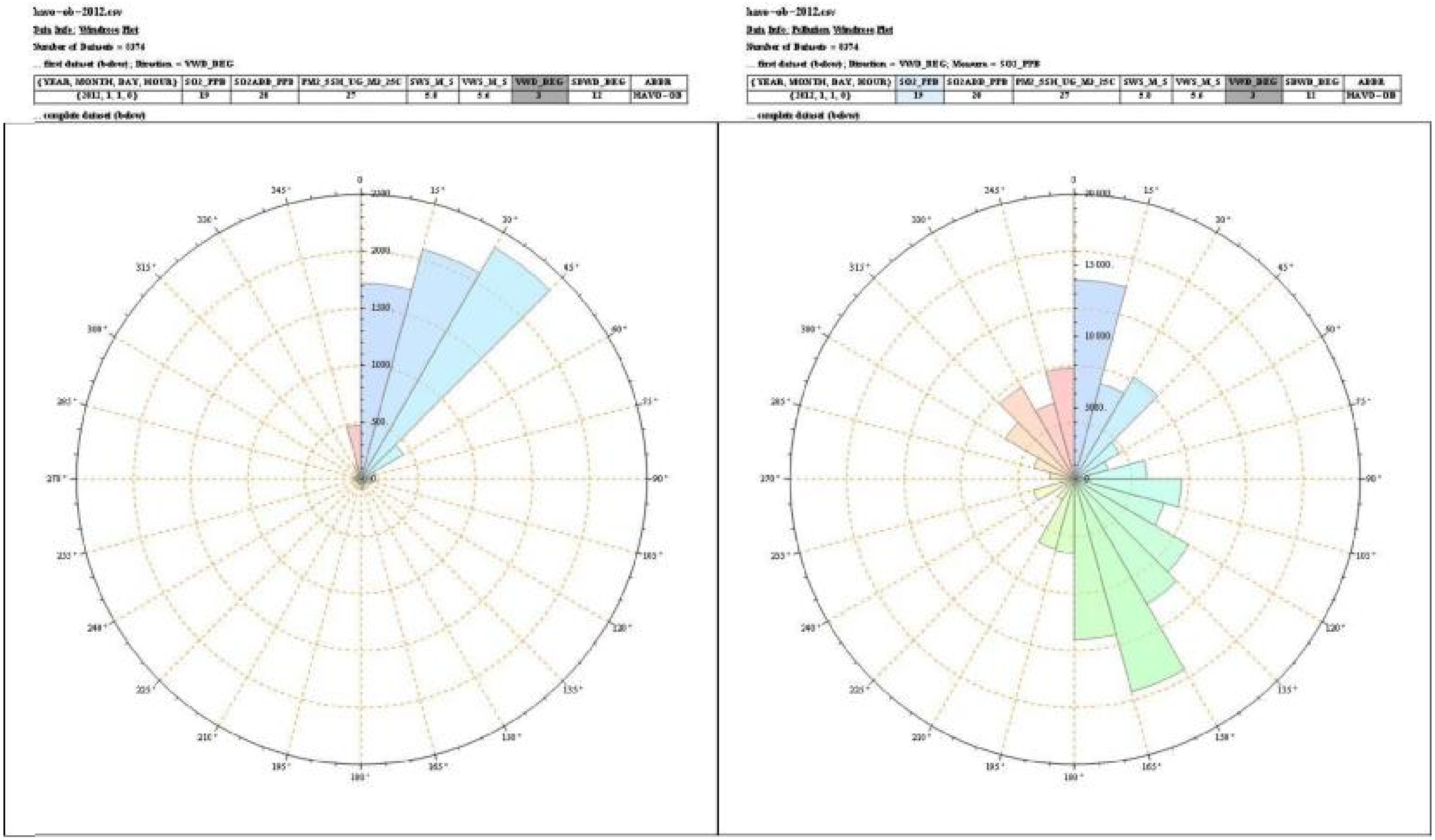


Figure A-11. 2012 HAVO Observatory Windrose (left) and SO2 Pollution windrose (right)

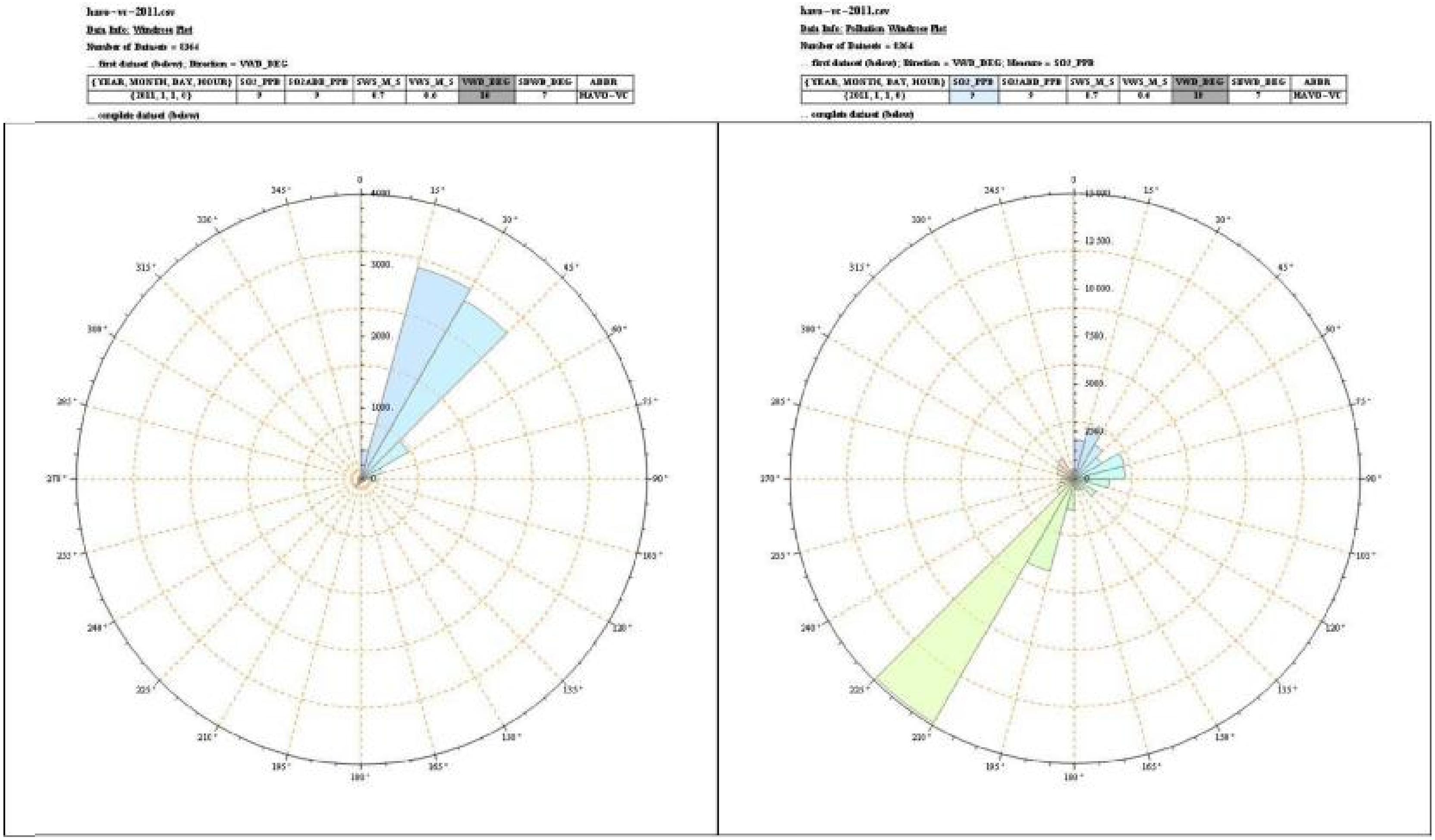


Figure A-12. 2011 HAVO Visitor Center Windrose (left) and SO2 Pollution windrose (right)

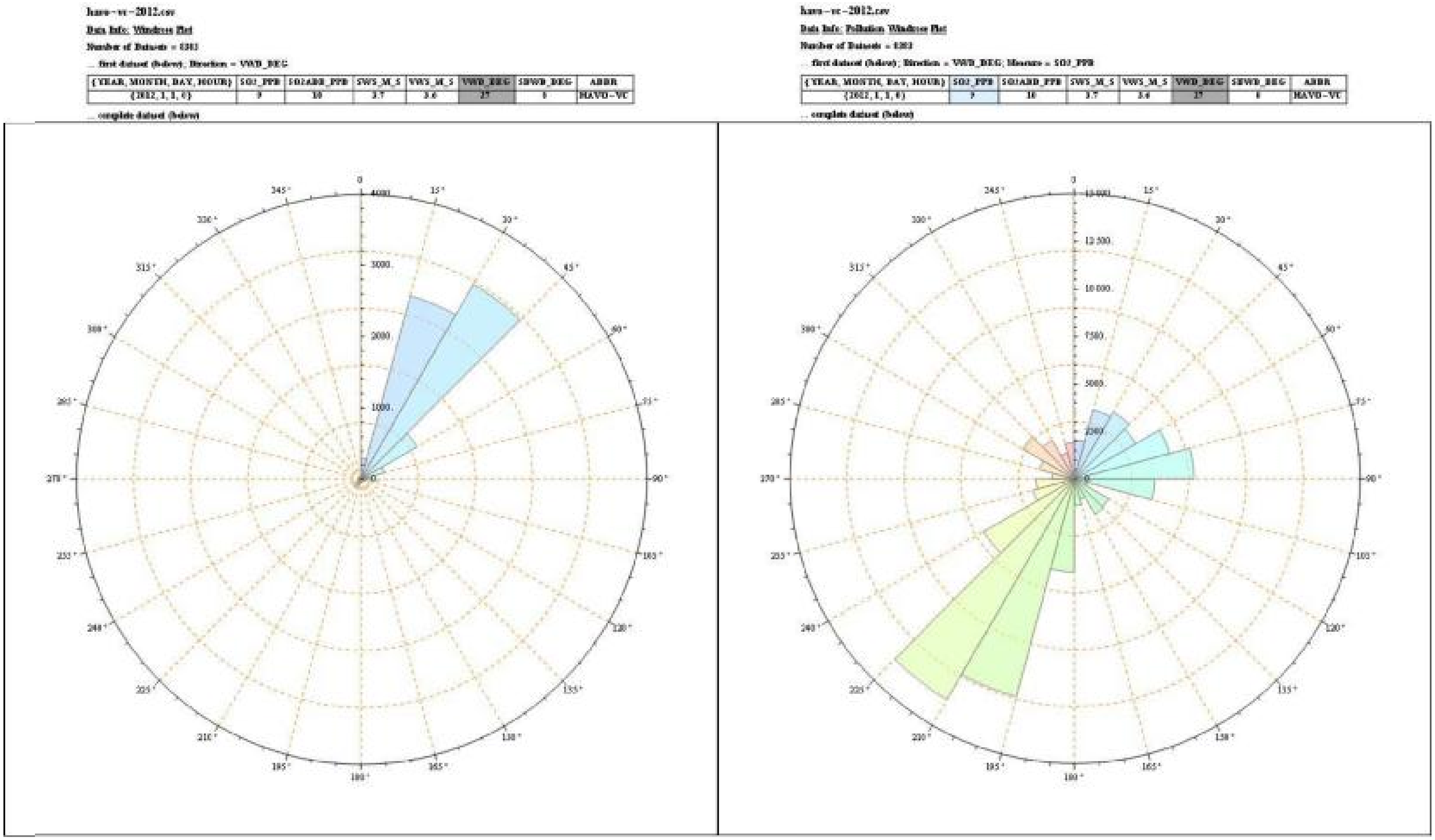


Figure A-13. 2012 HAVO Visitor Center Windrose (left) and SO2 Pollution windrose (right)

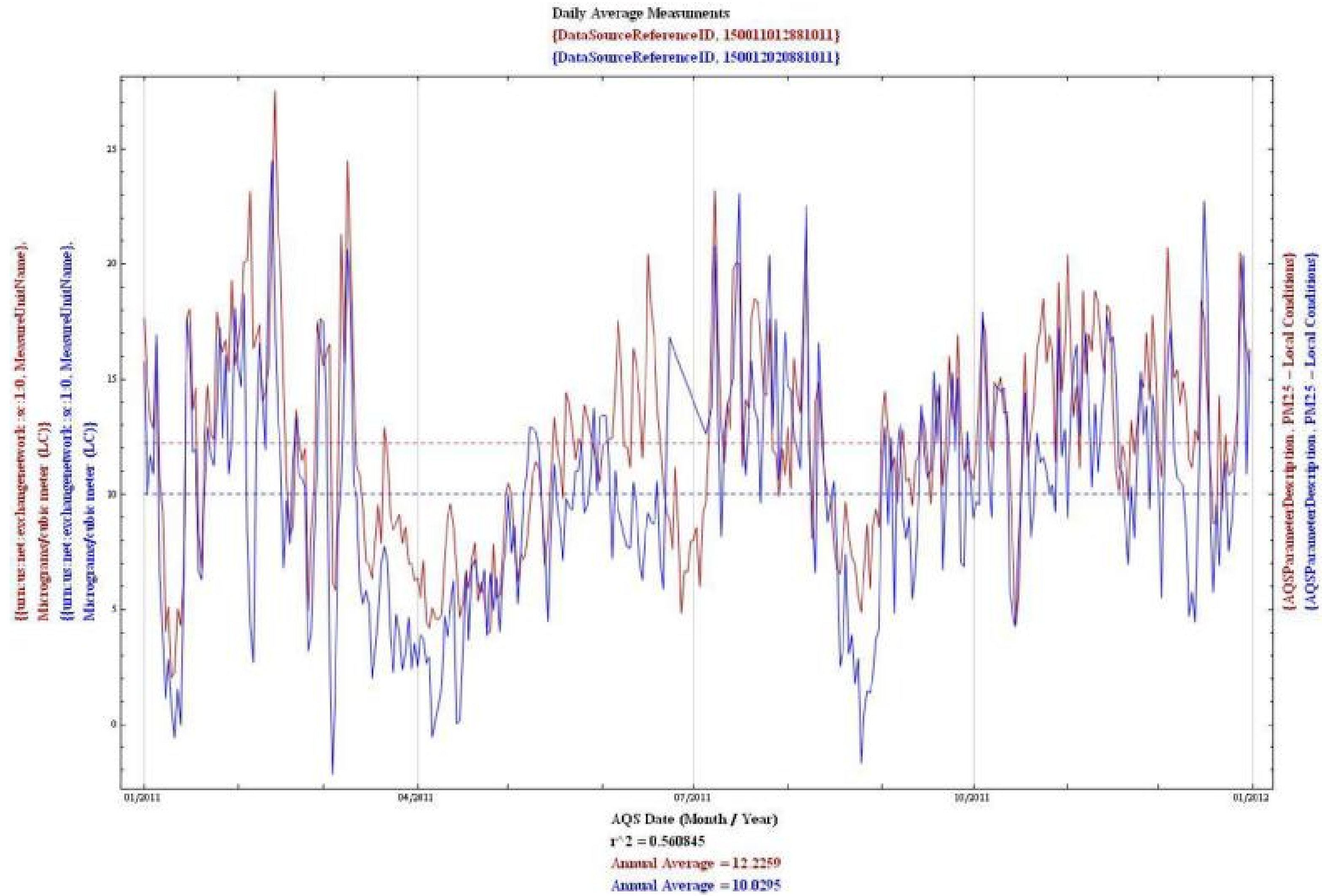


Figure A-14. 2011 Time History of Kona (red) and Ocean View (blue) $PM_{2.5}$ Concentrations (unsmoothed data)

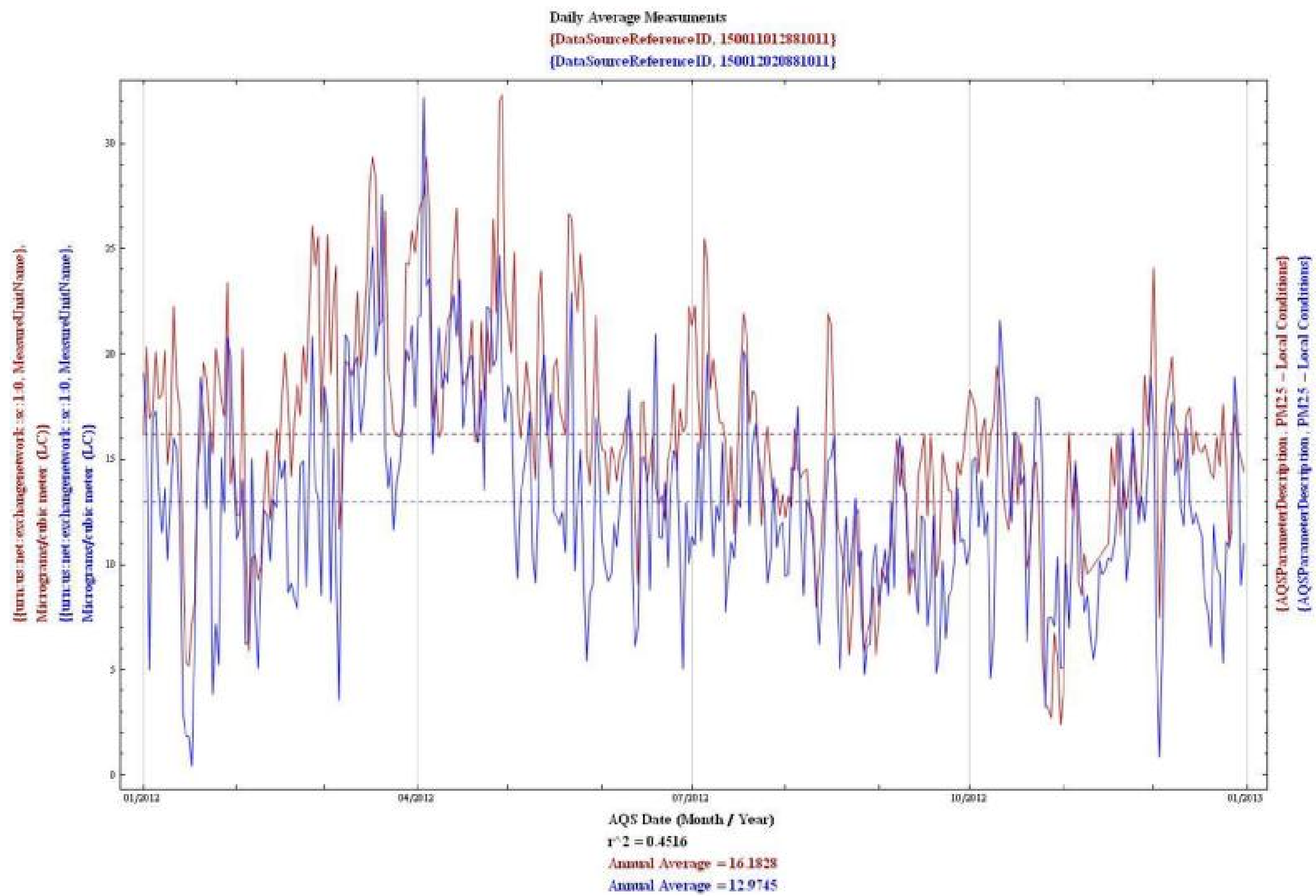


Figure A-15. 2012 Time History of Kona (red) and Ocean View (blue) $PM_{2.5}$ Concentrations (unsmoothed data)

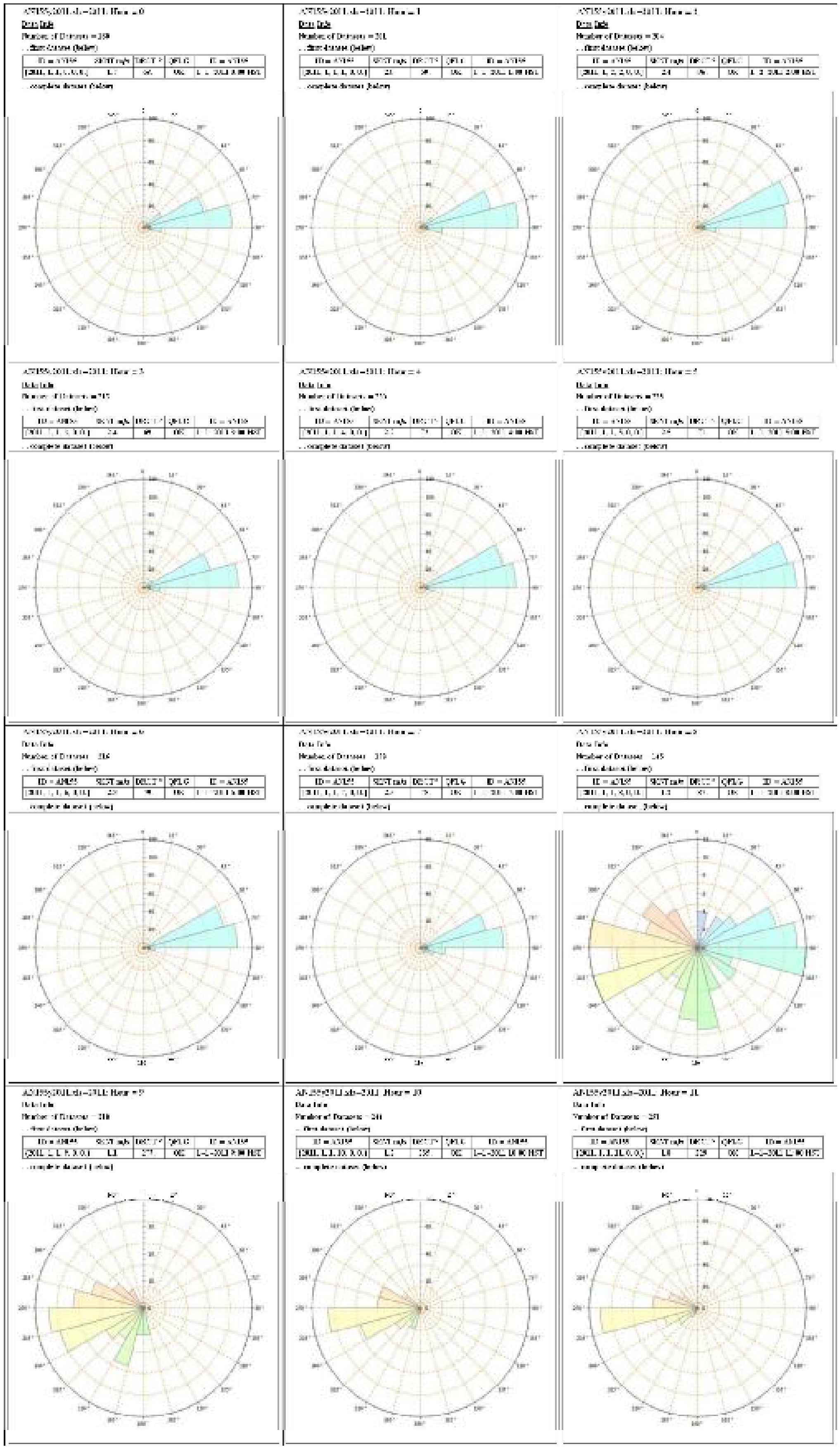


Figure A-16. 2011 Kona (AN155) Windrose - Morning Hours

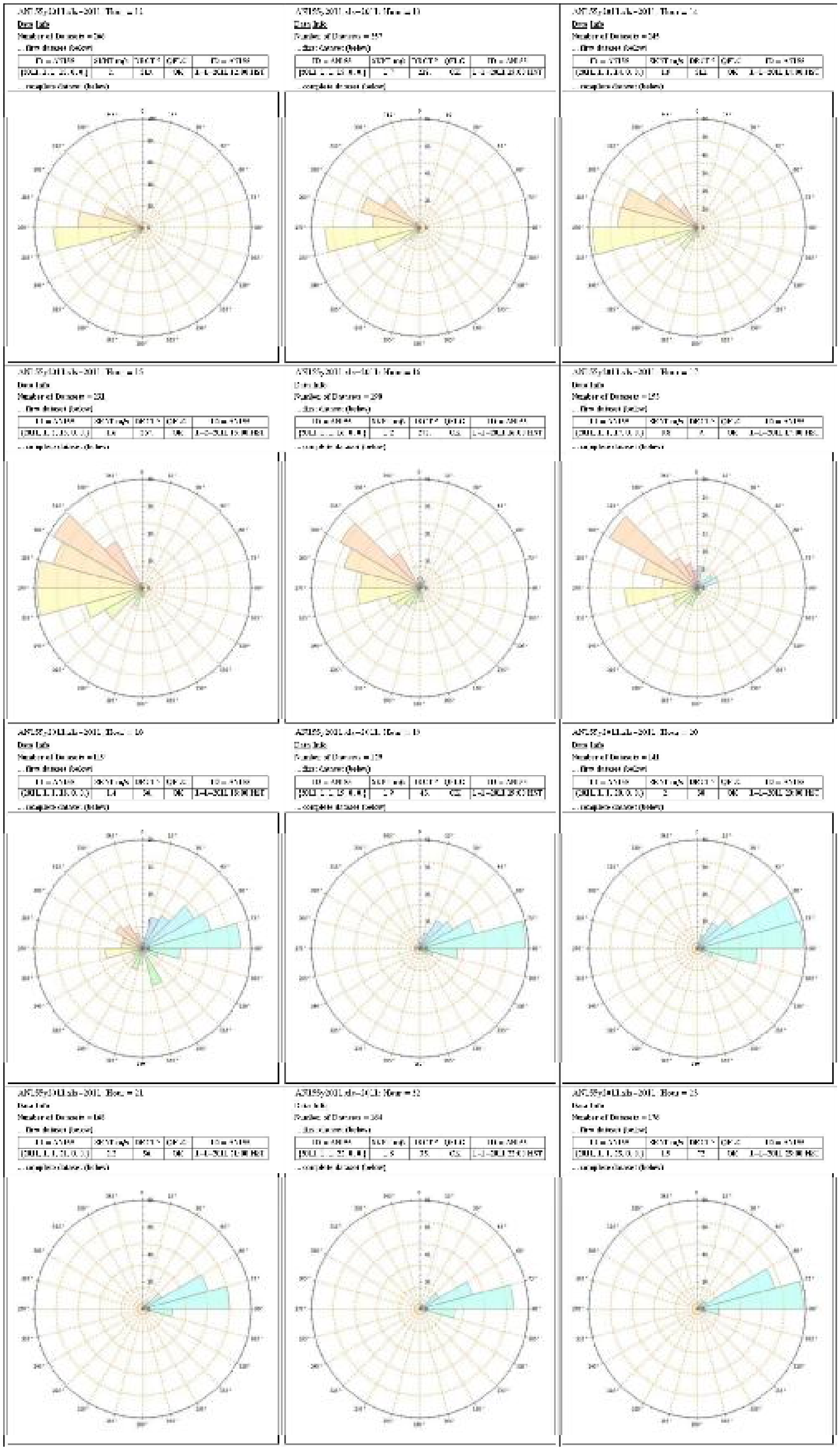


Figure A-17. 2011 Kona (AN155) Windrose - Evening Hours

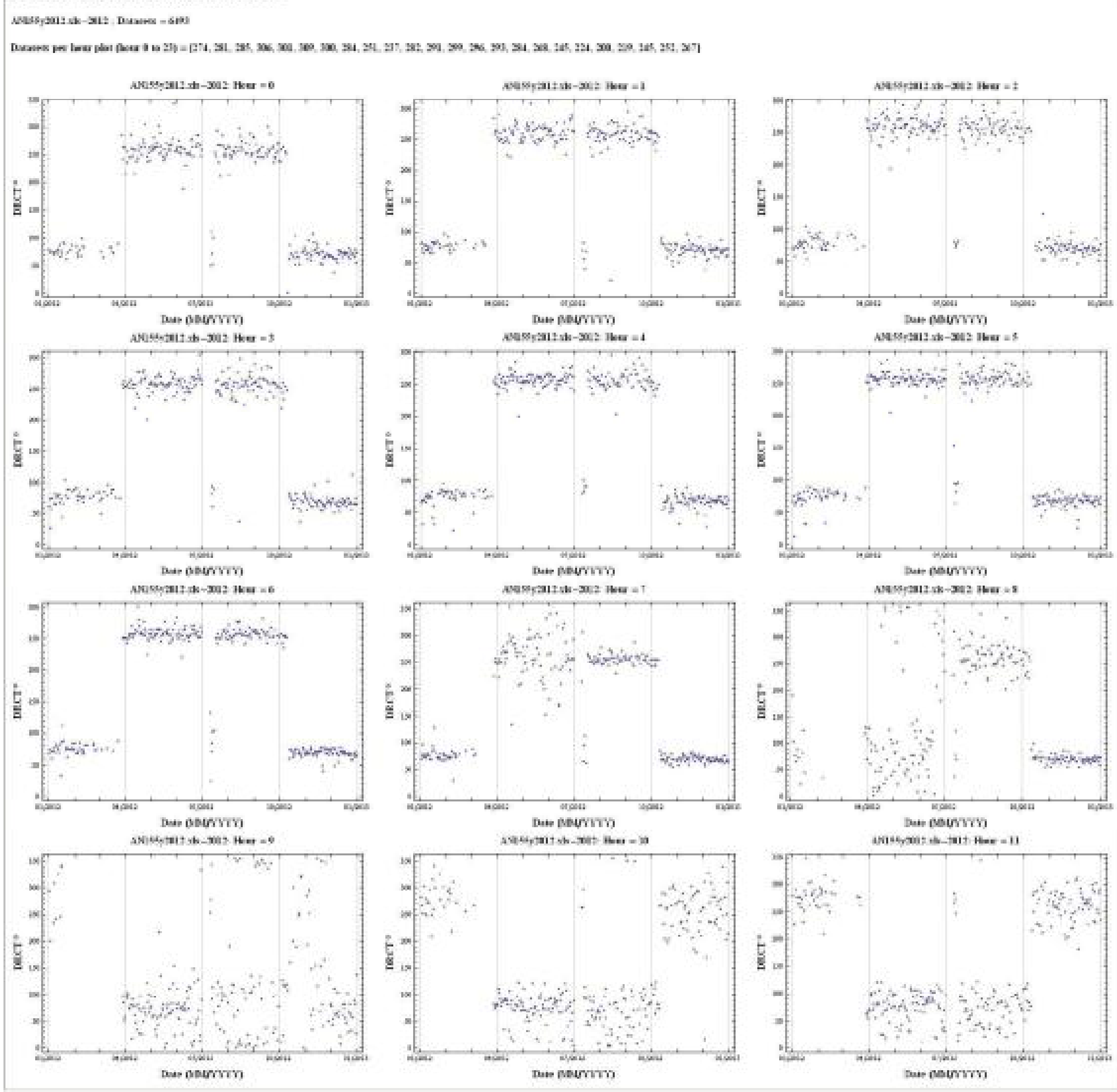


Figure A-18. 2012 Kona (AN155) Wind Direction Time History - Morning Hours

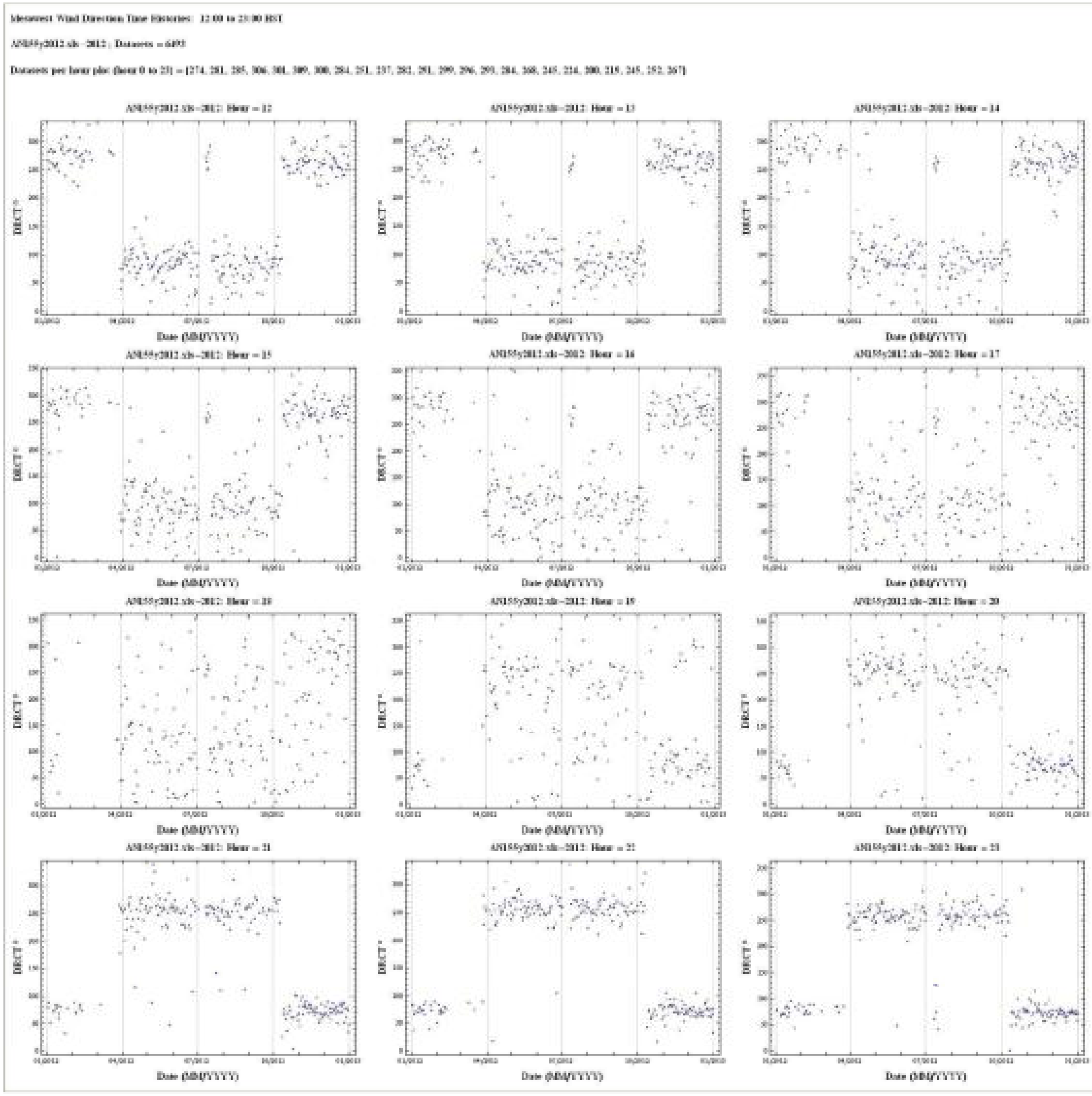


Figure A-19. 2012 Kona (AN155) Wind Direction Time History - Evening Hours

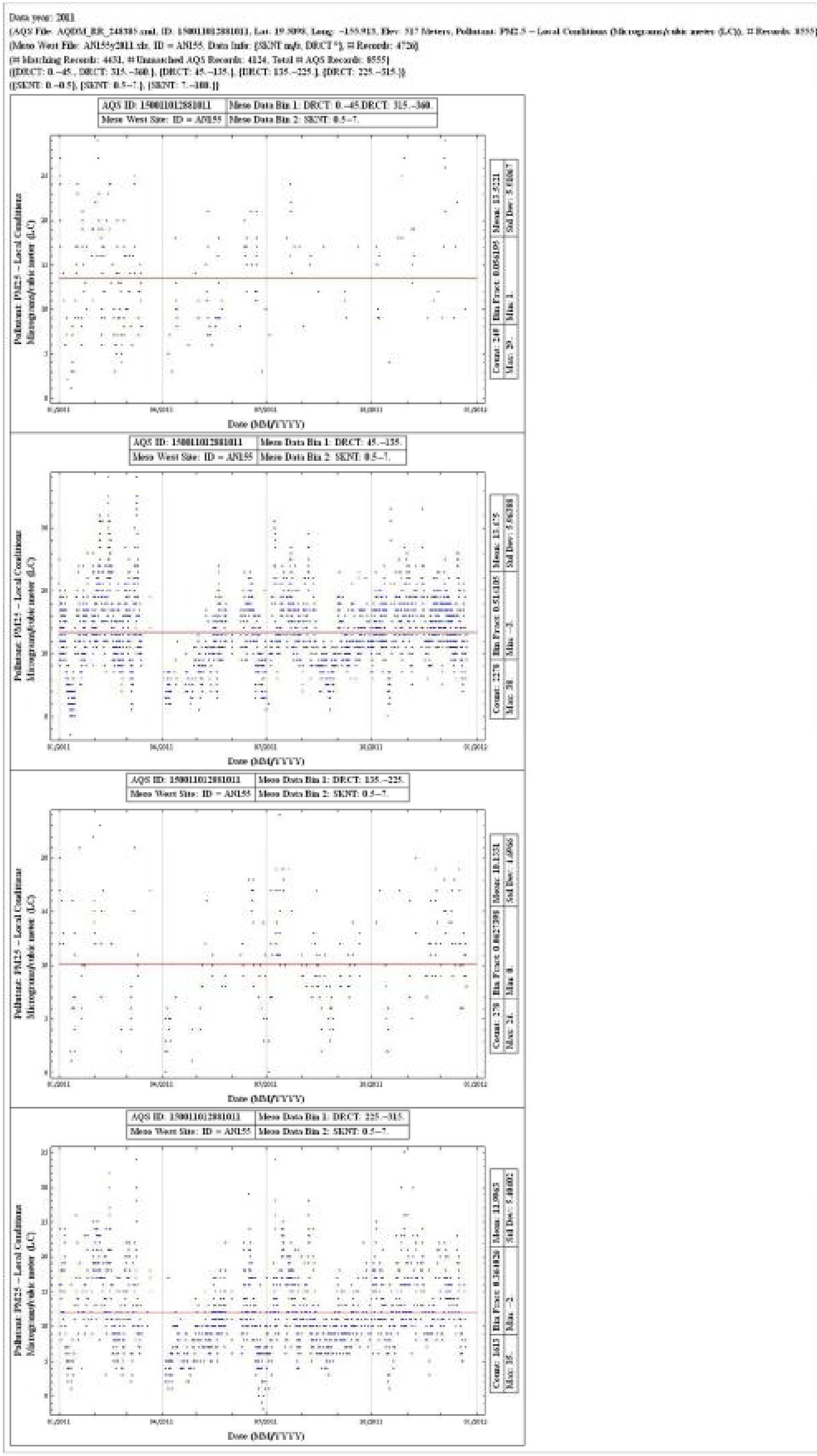


Figure A-20. 2011 Kona (AN155) PM2.5 Pollution Time History by Wind Quadrant

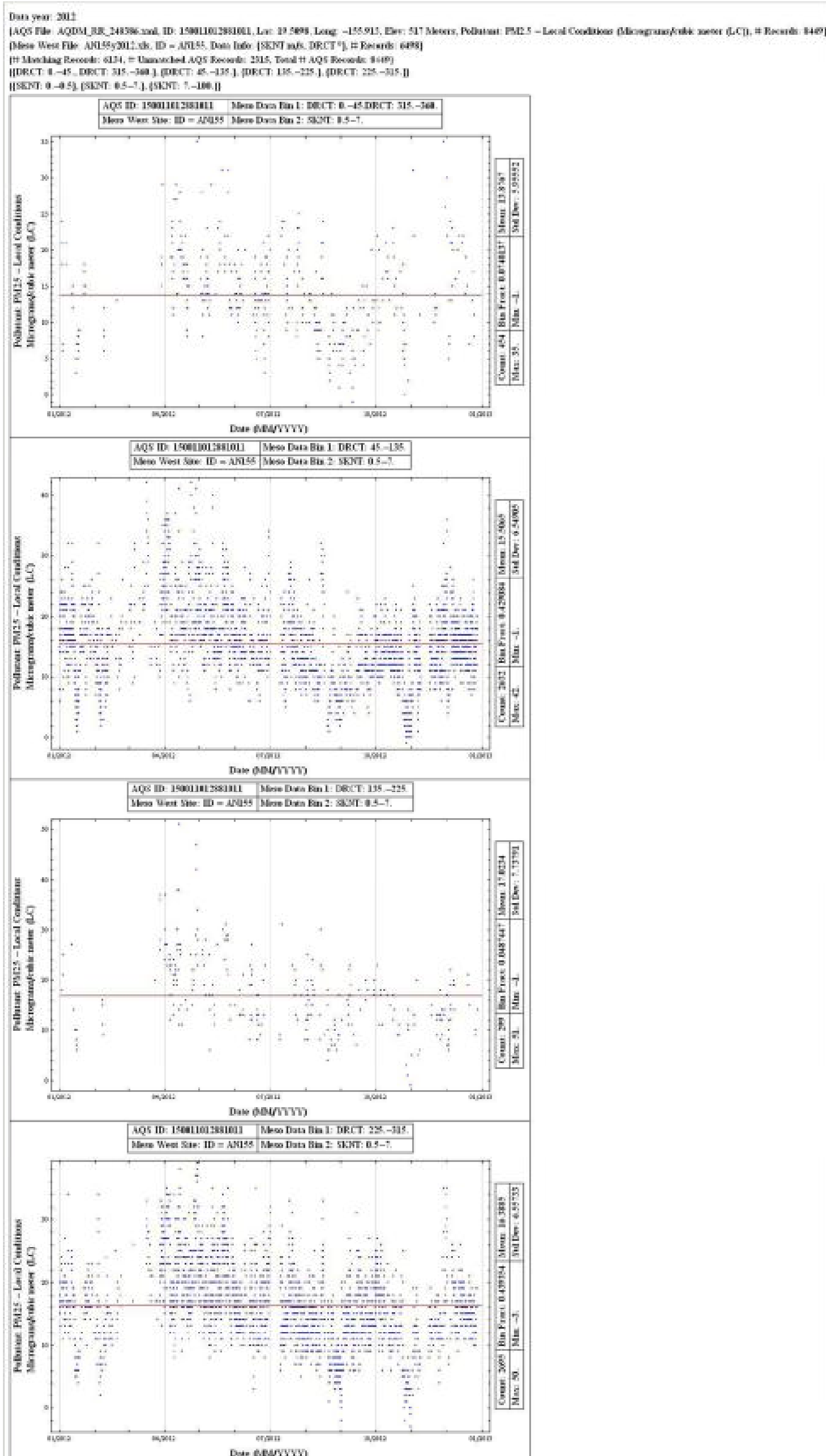


Figure A-21. 2012 Kona (AN155) PM2.5 Pollution Time History by Wind Quadrant

Annual & Quart r^2: 2011	Kona PM2.5			Ocean View PM2.5			Pahala PM2.5			Kona SO2			Ocean View SO2			Pahala SO2		
AQS Ref ID	150011012881011			150012020881011			150012016881011			150011012424011			150012020424011			150012016424011		
Average Type	Annual AveQtr	Quarterly r^2	#pts	Annual AveQtr	Quarterly r^2	#pts	Annual AveQtr	Quarterly r^2	#pts	Annual AveQtr	Quarterly r^2	#pts	Annual AveQtr	Quarterly r^2	#pts	Annual AveQtr	Quarterly r^3	#pts
		1.	90		0.615	90		0.08	90		0.329	90		0.103	90		0.133	90
Kona PM2.5	1.	1.	87	0.561	0.375	80	0.12	0.005	85	0.285	0.469	87	0.115	0.276	87	0.136	0.255	86
150011012881011	1.	1.	92	0.506	0.613	88	0.057	0.014	92	0.343	0.499	91	0.114	0.045	92	0.158	0.238	92
		1.	92		0.42	92		0.129	92		0.073	88		0.033	92		0.006	92
		0.615	90		1.	90		0.239	90		0.244	90		0.133	90		0.181	90
Ocean View PM2.5	0.561	0.375	80	1.	1.	84	0.15	0.019	79	0.197	0.347	83	0.391	0.052	84	0.114	0.105	83
150012030881011	0.506	0.613	88	1.	1.	88	0.114	0.022	88	0.24	0.351	87	0.37	0.08	88	0.114	0.167	88
		0.42	92		1.	92		0.178	92		0.017	88		0.016	92		0.003	92
		0.08	90		0.239	90		1.	90		0.006	90		0.026	90		0.031	90
Pahala PM2.5	0.12	0.005	85	0.15	0.019	79	1.	1.	86	0.109	0.001	85	0.123	0.014	86	0.26	0.133	85
150012016881011	0.057	0.014	92	0.114	0.022	88	1.	1.	92	0.024	0.	91	0.033	0.	92	0.184	0.239	92
		0.129	92		0.178	92		1.	92		0.089	88		0.091	92		0.331	92
		0.329	90		0.244	90		0.006	90		1.	90		0.265	90		0.353	90
Kona SO2	0.285	0.469	87	0.197	0.347	83	0.109	0.001	85	1.	1.	90	0.39	0.279	90	0.417	0.214	89
150011012424011	0.343	0.499	91	0.24	0.351	87	0.024	0.	91	1.	1.	91	0.246	0.142	91	0.255	0.172	91
		0.073	88		0.017	88		0.089	88		1.	88		0.299	88		0.281	88
		0.103	90		0.133	90		0.026	90		0.265	90		1.	90		0.348	90
Ocean View SO2	0.115	0.276	87	0.091	0.052	84	0.123	0.014	86	0.39	0.279	90	1.	1.	91	0.391	0.468	90
150012020424011	0.114	0.045	92	0.07	0.08	88	0.033	0.	92	0.246	0.142	91	1.	1.	92	0.302	0.166	92
		0.033	92		0.016	92		0.091	92		0.299	88		1.	92		0.226	92
		0.133	90		0.181	90		0.031	90		0.353	90		0.348	90		1.	90
Pahala SO2	0.136	0.255	86	0.114	0.105	83	0.26	0.133	85	0.417	0.214	89	0.391	0.468	90	1.	1.	90
150012016424011	0.158	0.238	92	0.114	0.167	88	0.184	0.239	92	0.255	0.172	91	0.302	0.166	92	1.	1.	92
		0.006	92		0.003	92		0.331	92		0.281	88		0.226	92		1.	92

Figure A-22. 2011 Kona (AN155), Ocean View (AN738), and Pahala (AN157) Annual and Seasonal (Quarterly) Correlations for SO2 and PM2.5

Annual & Quart r^2: 2012	Kona PM2.5			Ocean View PM2.5			Pahala PM2.5			Kona SO2			Ocean View SO2			Pahala SO2		
AQS Ref ID	150011012881011			150012020881011			150012016881011			150011012424011			150012020424011			150012016424011		
Average Type	Annual AveQtr	Quarterly r^2	#pts	Annual AveQtr	Quarterly r^2	#pts	Annual AveQtr	Quarterly r^2	#pts	Annual AveQtr	Quarterly r^2	#pts	Annual AveQtr	Quarterly r^2	#pts	Annual AveQtr	Quarterly r^3	#pts
		1.	91		0.483	91		0.006	91		0.136	87		0.109	91		0.071	91
Kona PM2.5	1.	1.	90	0.452	0.384	90	0.011	0.006	90	0.15	0.242	90	0.08	0.018	90	0.022	0.	90
150011012881011	1.	1.	91	0.379	0.384	91	0.017	0.	91	0.225	0.252	88	0.055	0.012	91	0.019	0.002	91
		1.	86		0.264	82		0.055	83		0.271	85		0.081	85		0.003	86
		0.483	91		1.	91		0.117	91		0.127	87		0.184	91		0.125	91
Ocean View PM2.5	0.452	0.384	90	1.	1.	91	0.057	0.019	91	0.085	0.202	91	0.101	0.064	91	0.039	0.	91
150012030881011	0.379	0.384	91	1.	1.	92	0.068	0.005	92	0.098	0.015	89	0.078	0.001	92	0.035	0.003	92
		0.264	82		1.	88		0.133	85		0.046	87		0.061	88		0.012	88
		0.006	91		0.117	91		1.	91		0.007	87		0.003	91		0.426	91
Pahala PM2.5	0.011	0.006	90	0.057	0.019	91	1.	1.	91	0.001	0.	91	0.003	0.	91	0.054	0.001	91
150012016881011	0.017	0.	91	0.068	0.005	92	1.	1.	92	0.005	0.006	89	0.018	0.003	92	0.213	0.219	92
		0.055	83		0.133	85		1.	89		0.009	88		0.065	88		0.207	89
		0.136	87		0.127	87		0.007	87		1.	87		0.052	87		0.011	87
Kona SO2	0.15	0.242	90	0.085	0.202	91	0.001	0.	91	1.	1.	91	0.089	0.159	91	0.024	0.004	91
150011012424011	0.225	0.252	88	0.098	0.015	89	0.005	0.006	89	1.	1.	89	0.106	0.07	89	0.02	0.026	89
		0.271	85		0.046	87		0.009	88		1.	91		0.145	90		0.041	91
		0.109	91		0.184	91		0.003	91		0.052	87		1.	91		0.002	91
Ocean View SO2	0.08	0.018	90	0.101	0.064	91	0.003	0.	91	0.089	0.159	91	1.	1.	91	0.022	0.011	91
150012020424011	0.055	0.012	91	0.078	0.001	92	0.018	0.003	92	0.106	0.07	89	1.	1.	92	0.044	0.093	92
		0.081	85		0.061	88		0.065	88		0.145	90		1.	91		0.069	91
		0.071	91		0.125	91		0.426	91		0.011	87		0.002	91		1.	91
Pahala SO2	0.022	0.	90	0.039	0.	91	0.054	0.001	91	0.024	0.004	91	0.022	0.011	91	1.	1.	91
150012016424011	0.019	0.002	91	0.035	0.003	92	0.213	0.219	92	0.02	0.026	89	0.044	0.093	92	1.	1.	92
		0.003	86		0.012	88		0.207	89		0.041	91		0.069	91		1.	92

Figure A-23. 2012 Kona (AN155), Ocean View (AN738), and Pahala (AN157) Annual and Seasonal (Quarterly) Correlations for SO2 and PM2.5

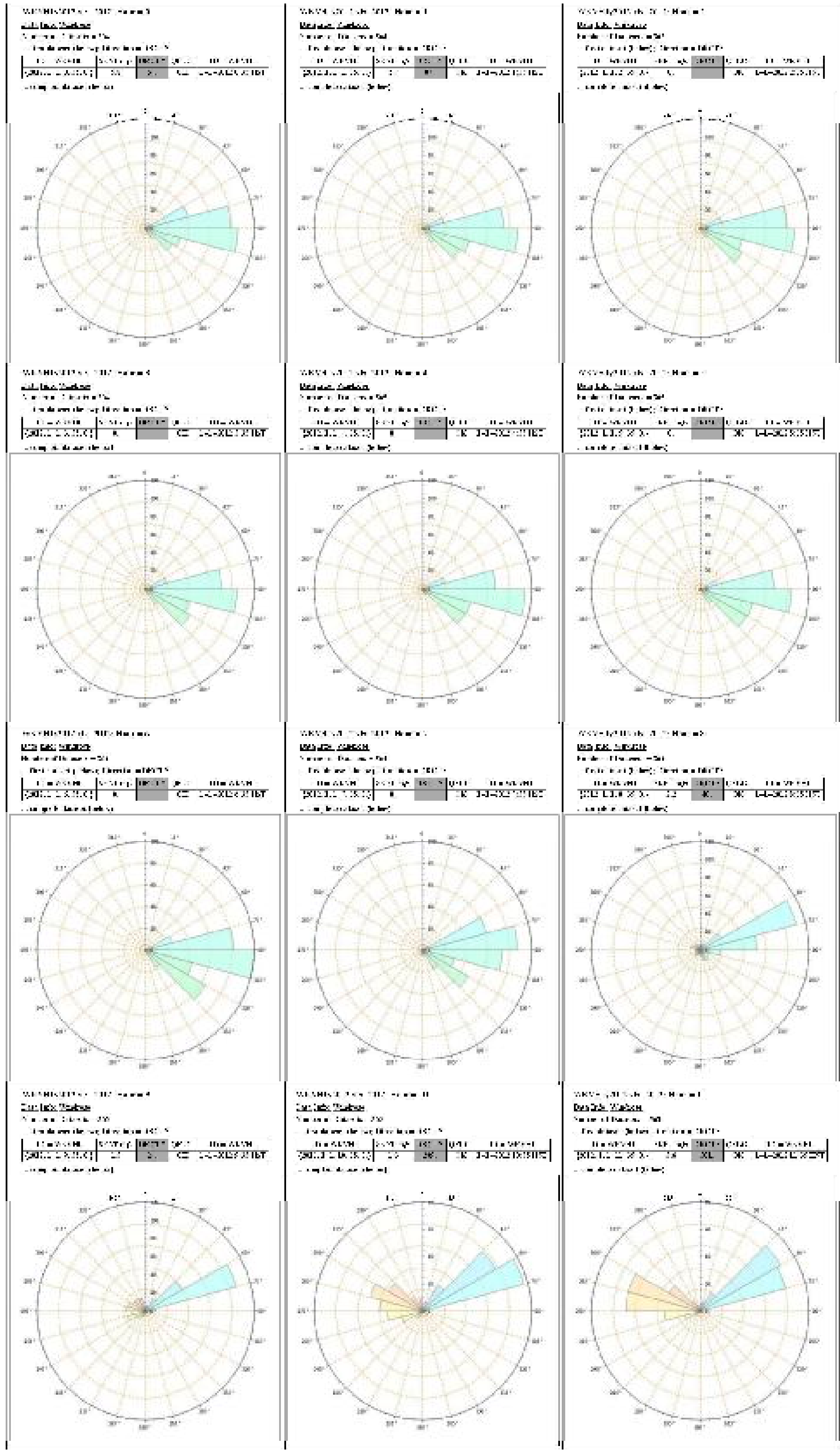


Figure A-24. 2012 Wailoloa (WKVH1) Windrose - Morning Hours

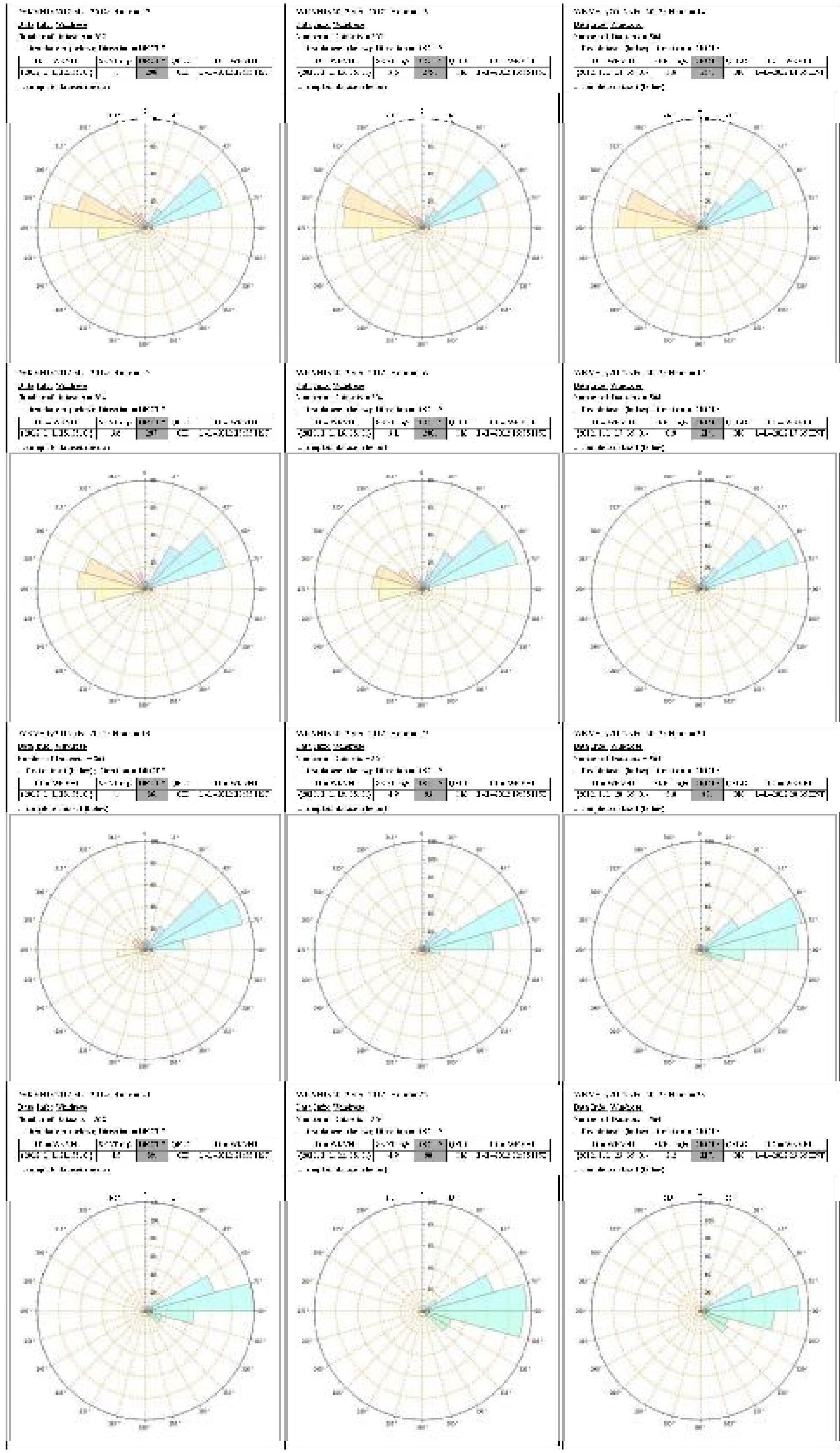


Figure A-25. 2012 Wailoloa (WKVH1) Windrose - Evening Hours

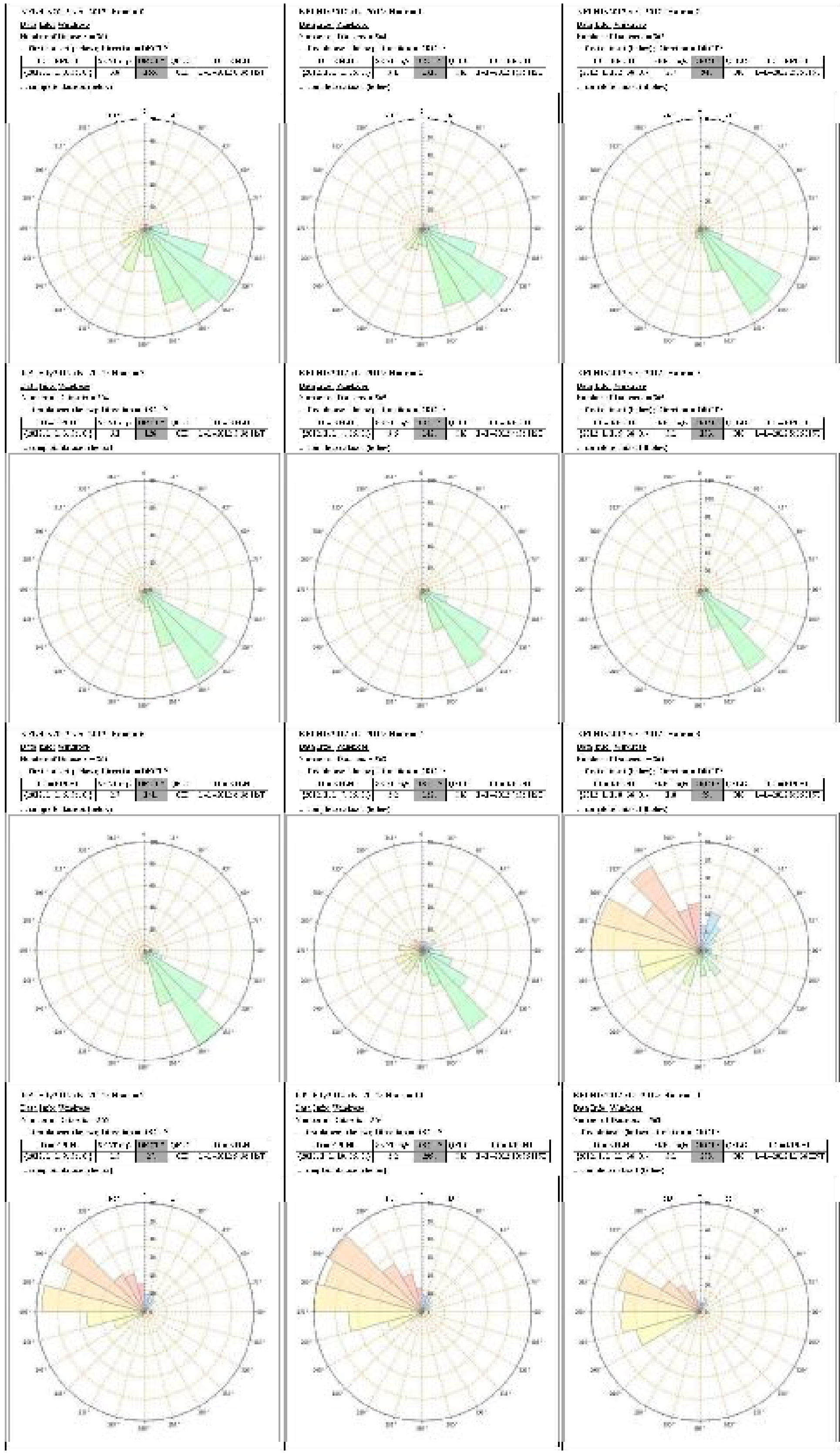


Figure A-26. 2012 Kaupulehu Lava Flow (KPLH1) - Morning Hours

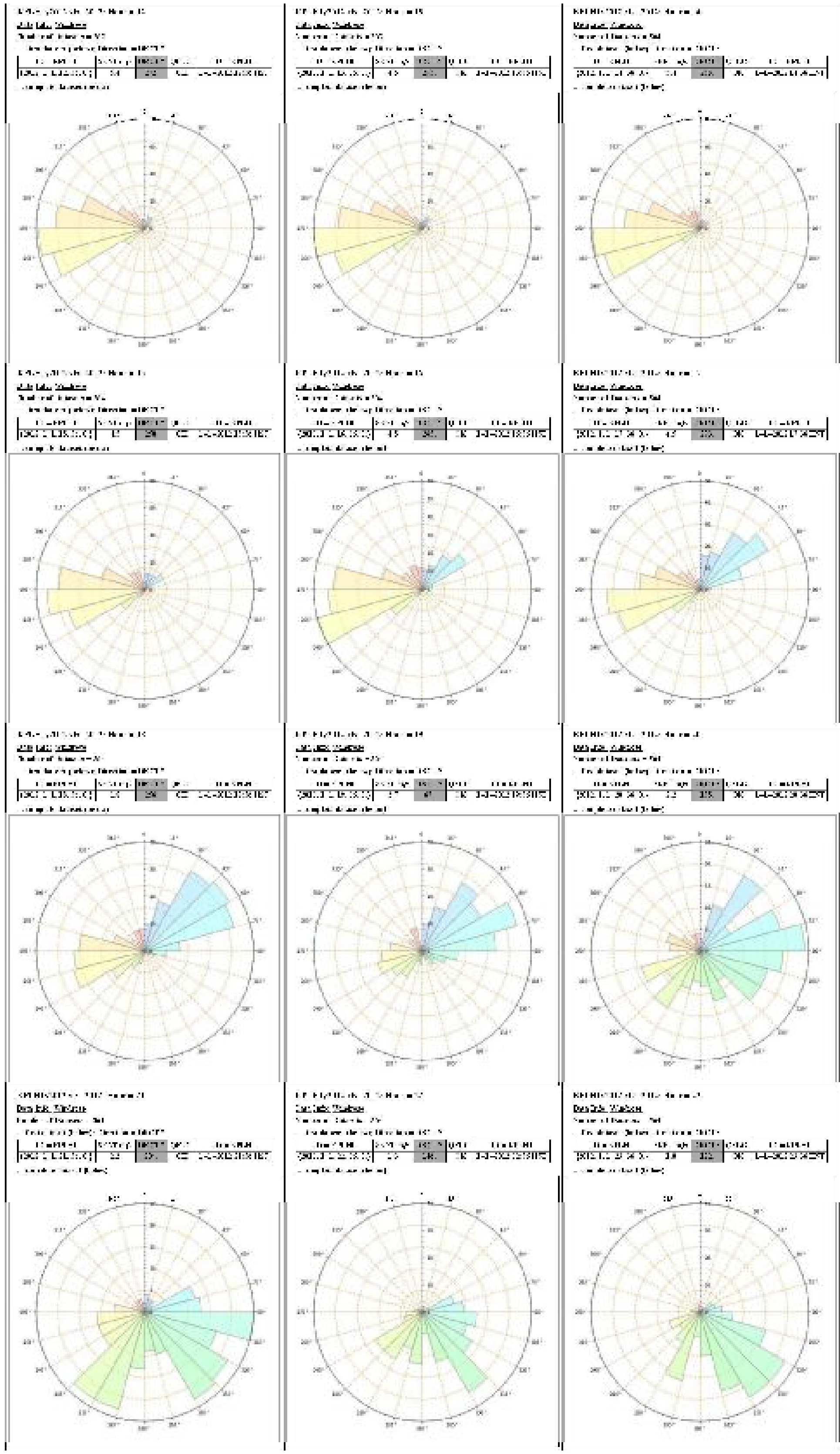


Figure A-27. 2012 Kaupulehu Lava Flow (KPLH1) - Evening Hours

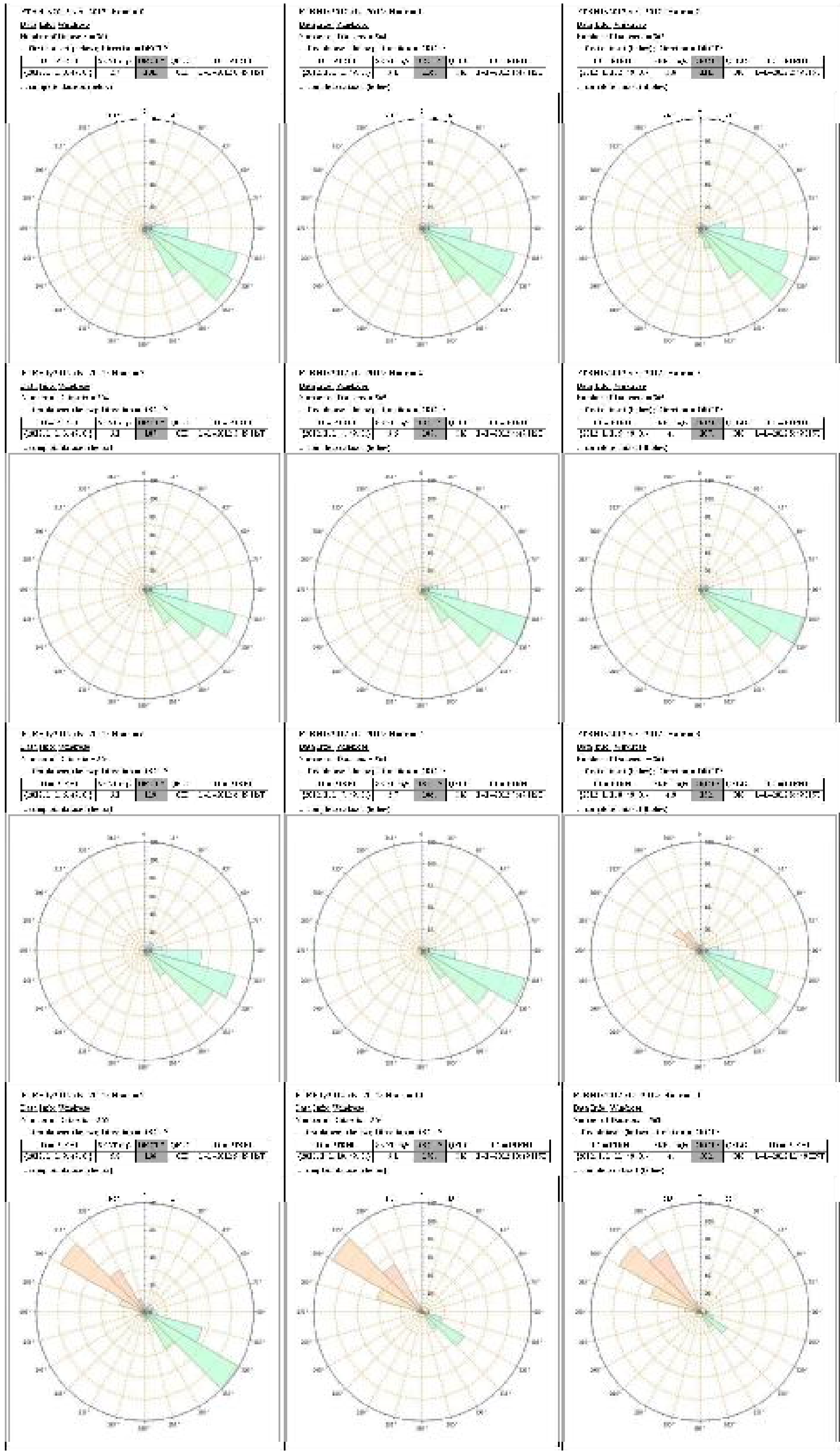


Figure A-28. PTA Range 17 (PTRH1) Windrose - Morning Hours

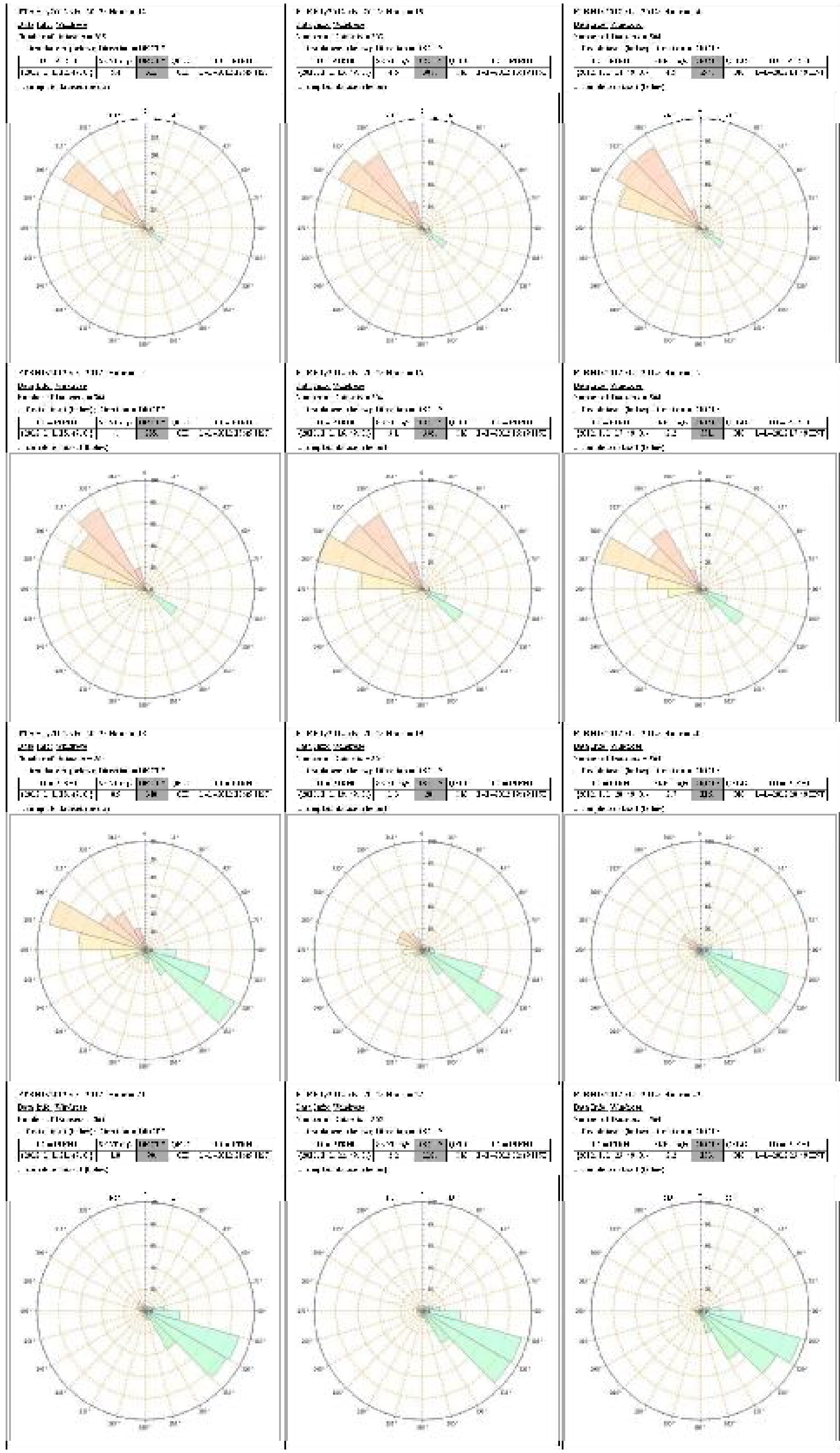


Figure A-29. PTA Range 17 (PTRH1) Windrose - Evening Hours

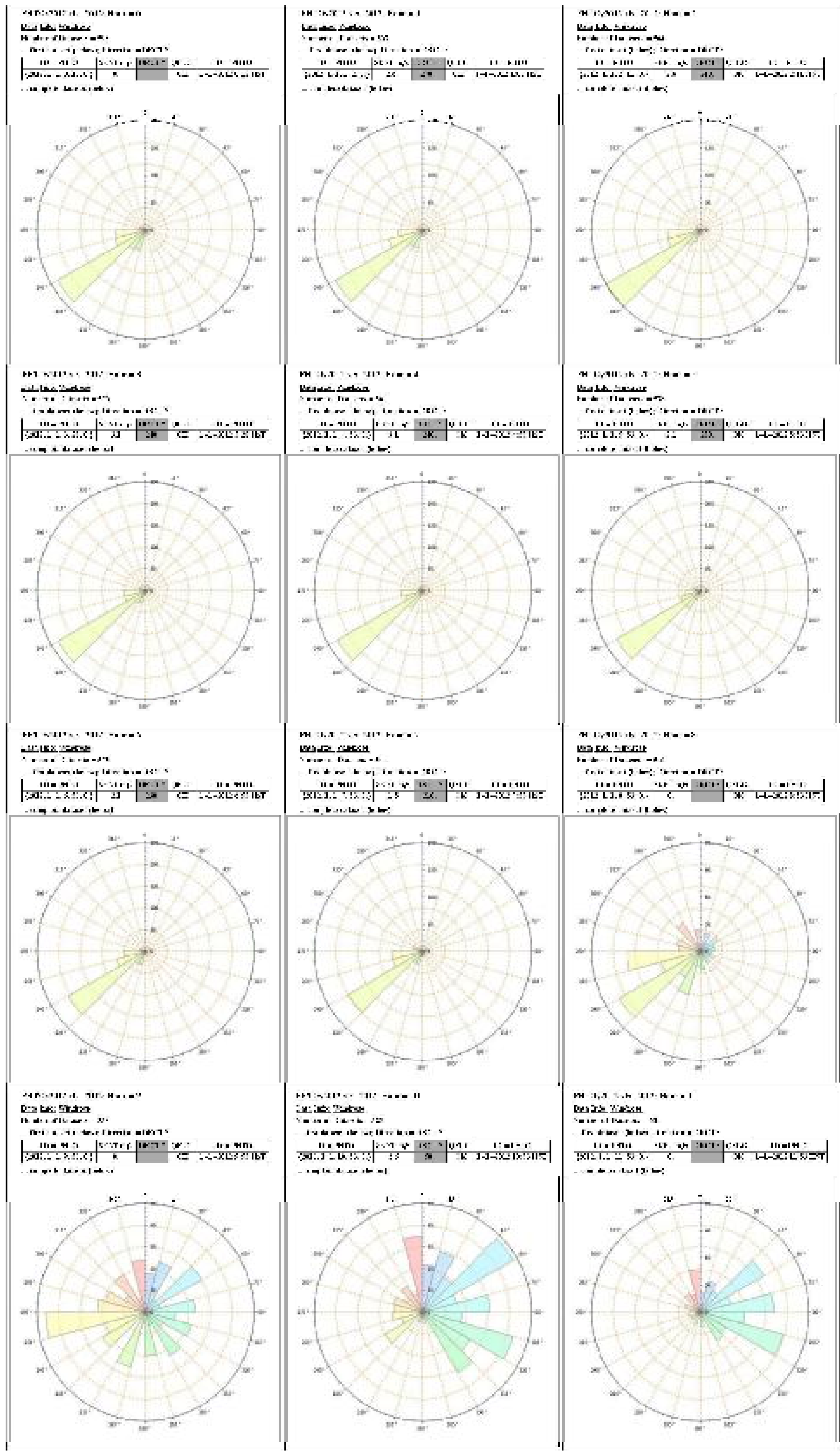


Figure A-30. Hilo International Airport (PHTO) Windrose - Morning Hours

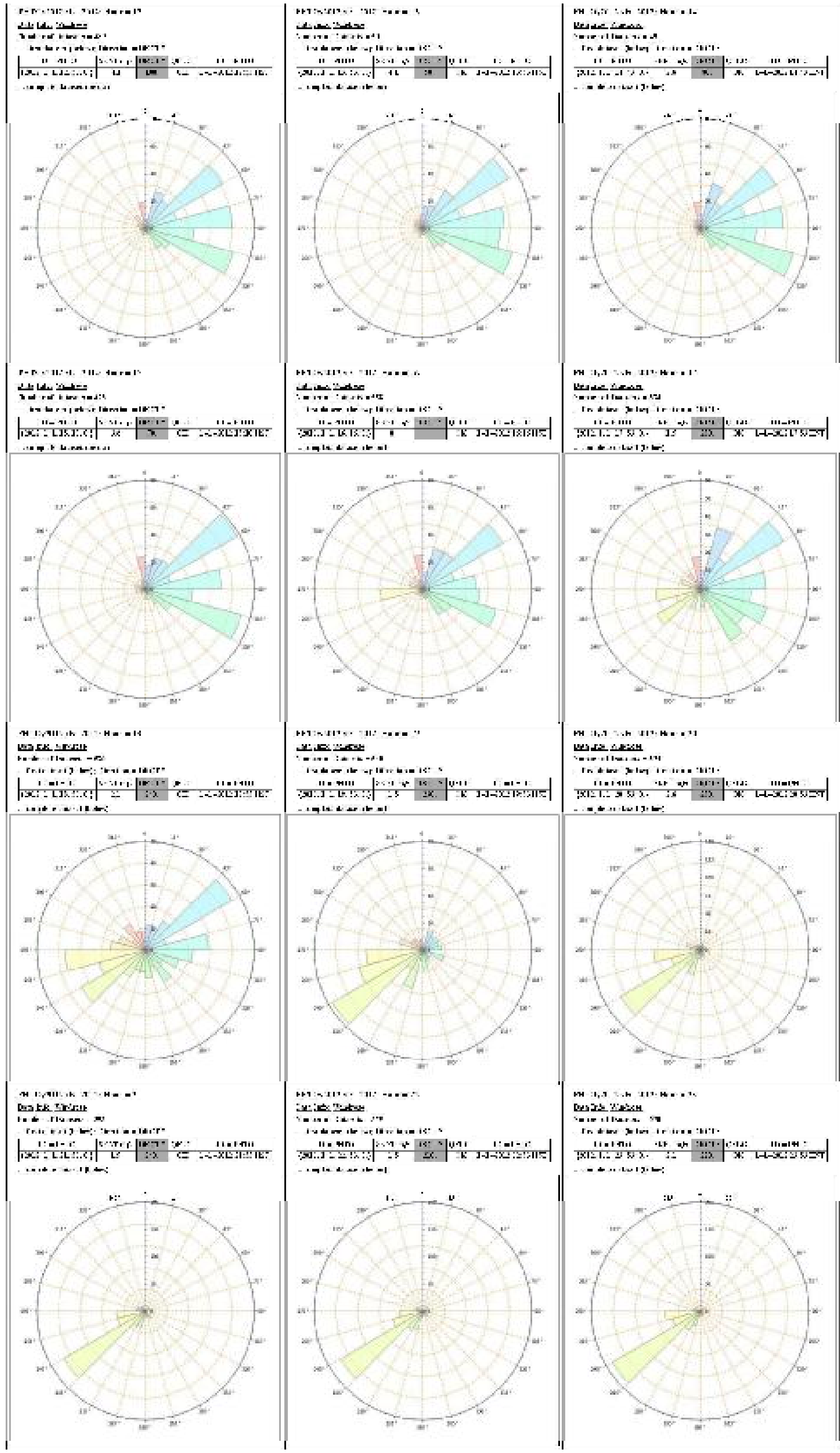


Figure A-31. Hilo International Airport (PHTO) Windrose - Evening Hours

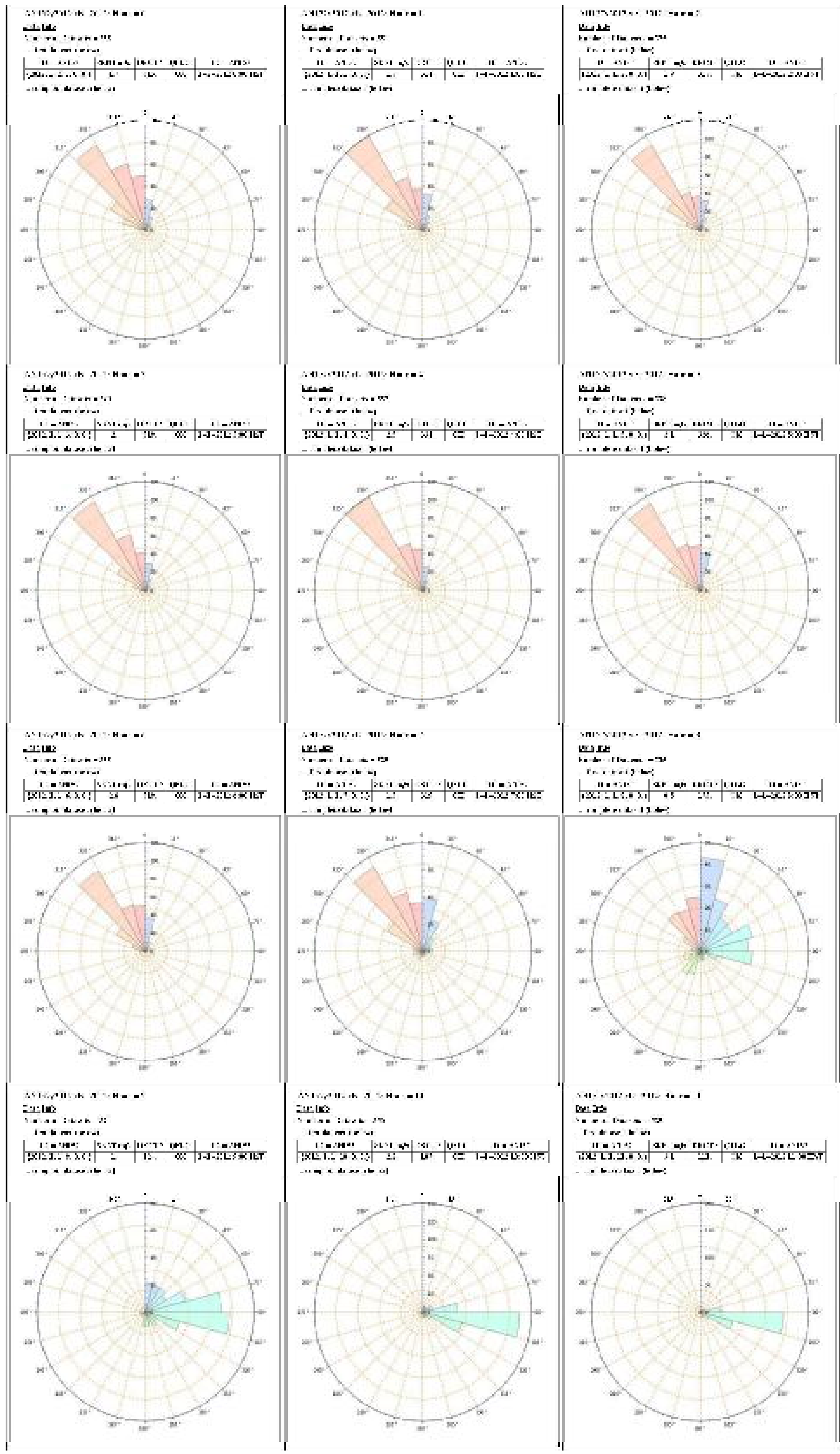


Figure A-32.: Pahala (AN157) Windrose - Morning Hours

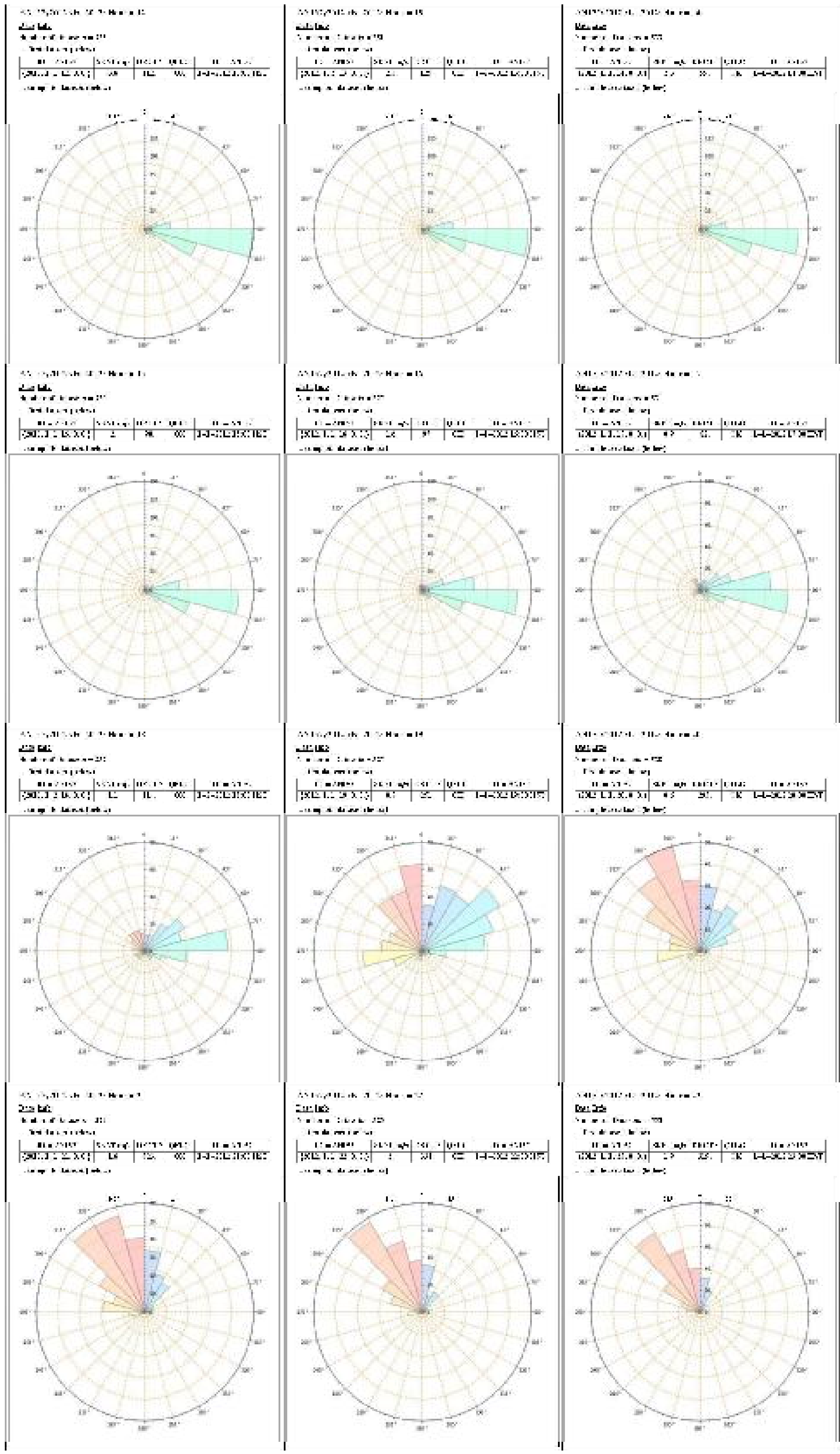


Figure A-33. Pahala (AN157) Windrose - Evening Hours

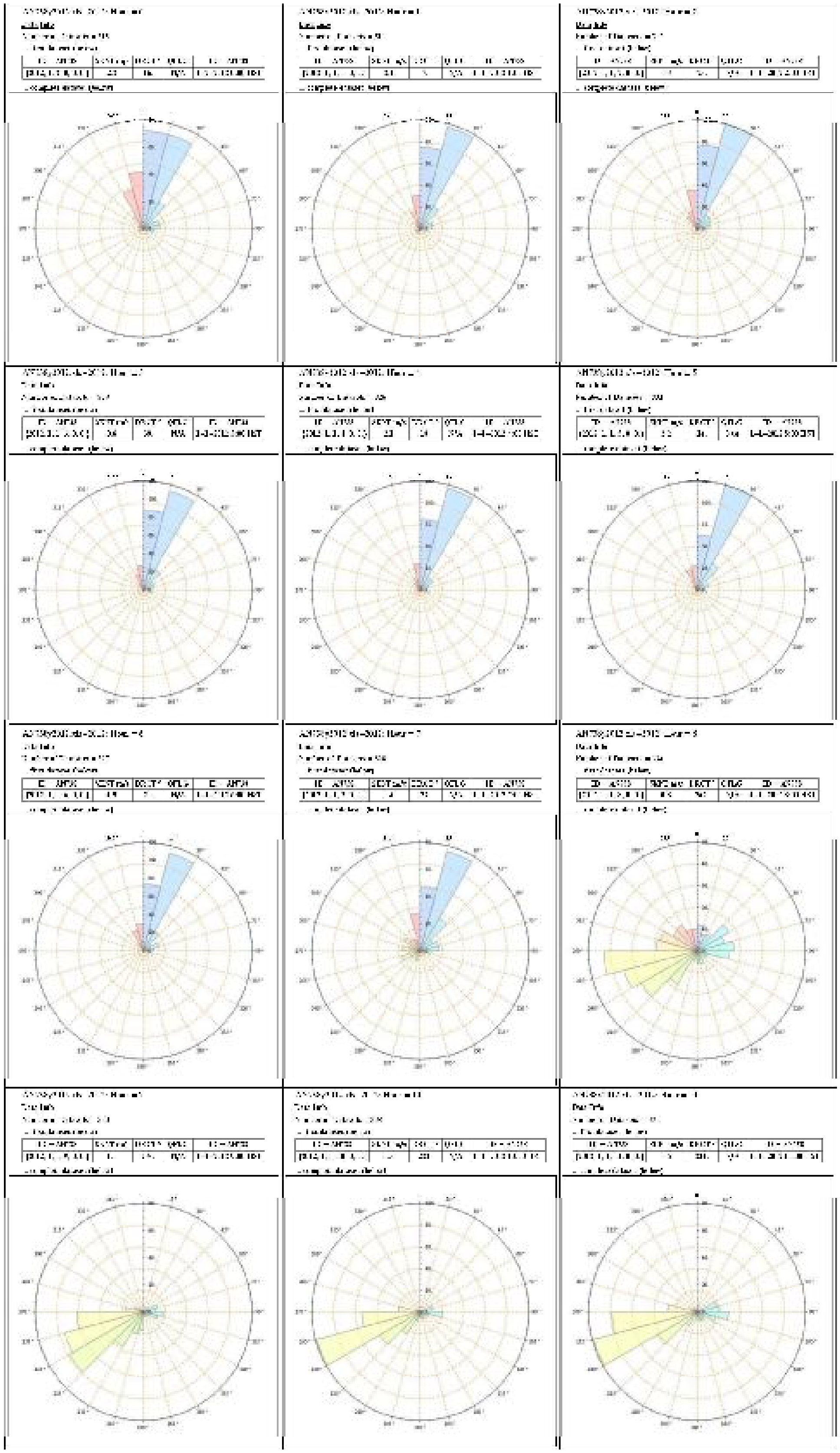


Figure A-34. Ocean View (AN738) Windrose - Morning Hours

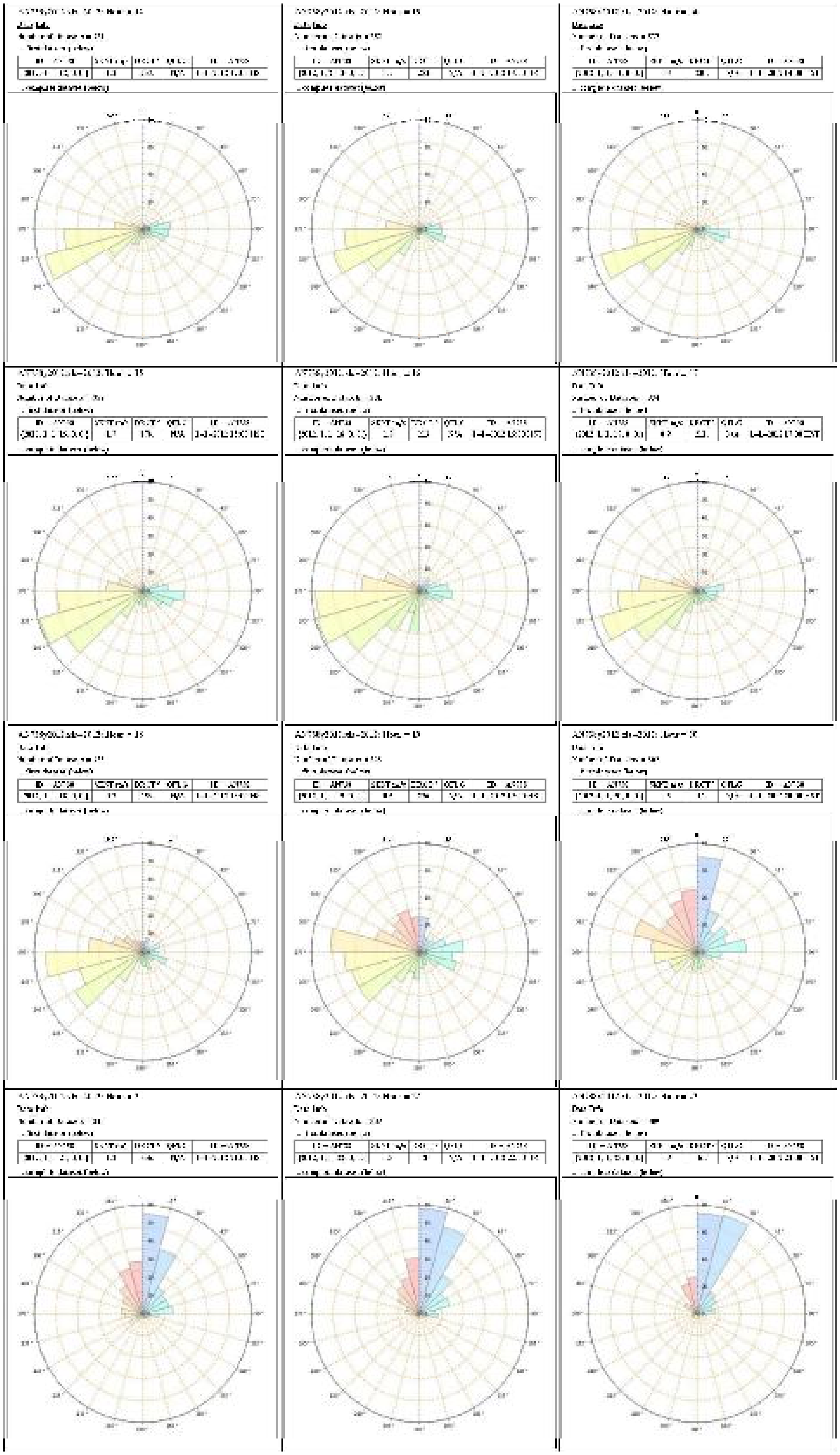


Figure A-35. Ocean View (AN738) Windrose - Evening Hours

Appendix B

Kona (AQS ID 150011012): 2011 and 2012 24-hr $PM_{2.5}$ Flagged Data									
2011		2012							
Q1	μg/m^3	Q1	μg/m^3	Q1 (cont'd)	μg/m^3	Q2	μg/m^3	Q2 (cont'd)	μg/m^3
2/13/11	27.5	1/1/2012	16.2	3/20/2012	21.6	4/1/2012	26.5	5/23/2012	23.3
3/9/11	24.5	1/2/2012	20.3	3/21/2012	26.7	4/2/2012	27.0	5/24/2012	21.9
		1/3/2012	16.9	3/22/2012	19.2	4/3/2012	27.5	5/25/2012	24.7
		1/4/2012	17.2	3/23/2012	18.2	4/4/2012	29.3	5/26/2012	22.4
		1/5/2012	20.0	3/24/2012	16.4	4/5/2012	26.5	5/27/2012	15.2
		1/6/2012	17.8	3/27/2012	16.6	4/6/2012	16.9	5/28/2012	13.7
		1/7/2012	18.0	3/28/2012	24.3	4/7/2012	18.4	5/29/2012	17.1
		1/8/2012	20.1	3/29/2012	24.2	4/8/2012	16.0	5/30/2012	21.8
		1/10/2012	16.2	3/30/2012	25.8	4/9/2012	16.4	5/31/2012	16.8
		1/11/2012	22.2	3/31/2012	24.7	4/10/2012	20.1	6/1/2012	15.4
		1/12/2012	18.5			4/11/2012	21.5	6/2/2012	15.3
		1/13/2012	17.2			4/12/2012	21.9	6/3/2012	13.3
		1/21/2012	19.5			4/13/2012	24.7	6/4/2012	15.5
		1/22/2012	18.8			4/14/2012	26.9	6/5/2012	15.0
		1/23/2012	16.9			4/15/2012	20.3	6/6/2012	13.9
		1/25/2012	20.2			4/16/2012	18.5	6/7/2012	15.2
		1/26/2012	19.0			4/17/2012	18.8	6/8/2012	15.7
		1/27/2012	17.7			4/18/2012	19.4	6/9/2012	16.8
		1/28/2012	17.0			4/19/2012	21.5	6/10/2012	17.1
		1/29/2012	23.3			4/20/2012	15.8	6/14/2012	17.6
		2/3/2012	20.2			4/21/2012	15.8	6/15/2012	17.7
		2/14/2012	16.4			4/22/2012	21.5	6/16/2012	13.9
		2/16/2012	17.8			4/23/2012	17.7	6/17/2012	14.7
		2/17/2012	20.0			4/24/2012	21.4	6/18/2012	16.0
		2/18/2012	17.7			4/25/2012	19.0	6/19/2012	13.7
		2/20/2012	16.7			4/26/2012	26.4	6/20/2012	12.8
		2/21/2012	18.5			4/27/2012	21.9	6/21/2012	13.2
		2/22/2012	17.0			4/28/2012	32.0	6/23/2012	15.0
		2/23/2012	20.3			4/29/2012	32.3	6/24/2012	15.7
		2/24/2012	18.6			4/30/2012	22.9	6/25/2012	18.5
		2/25/2012	22.1			5/1/2012	21.6	6/26/2012	14.4
		2/26/2012	26.0			5/2/2012	20.0	6/27/2012	17.3
		2/27/2012	24.1			5/3/2012	24.8	6/28/2012	16.2
		2/28/2012	25.5			5/4/2012	17.9	6/29/2012	16.6
		2/29/2012	16.7			5/5/2012	16.0	6/30/2012	22.2
		3/1/2012	20.8			5/6/2012	17.4		
		3/2/2012	25.6			5/7/2012	19.6		
		3/3/2012	19.0			5/8/2012	18.0		
		3/4/2012	22.7			5/9/2012	16.2		
		3/5/2012	24.1			5/10/2012	14.0		
		3/8/2012	19.6			5/11/2012	22.5		
		3/9/2012	19.4			5/12/2012	23.9		
		3/10/2012	18.9			5/13/2012	18.3		
		3/11/2012	19.6			5/14/2012	16.3		
		3/12/2012	22.9			5/15/2012	14.5		
		3/13/2012	19.3			5/16/2012	19.3		
		3/14/2012	21.2			5/17/2012	19.7		
		3/15/2012	23.5			5/18/2012	17.5		
		3/16/2012	28.2			5/19/2012	16.8		
		3/17/2012	29.3			5/20/2012	16.1		
		3/18/2012	28.2			5/21/2012	26.6		
		3/19/2012	21.3			5/22/2012	26.4		

Appendix B

Kona (AQS ID 150011012): 2011 and 2012 24-hr $PM_{2.5}$ Flagged Data									
		2012 Continued							
		Q3	µg/m^3	Q4	µg/m^3				
		7/1/2012	21.3	10/1/2012	18.2				
		7/2/2012	22.2	10/2/2012	17.9				
		7/3/2012	17.9	10/3/2012	17.2				
		7/5/2012	25.4	10/5/2012	16.2				
		7/6/2012	24.3	10/6/2012	16.9				
		7/7/2012	18.3	10/8/2012	16.1				
		7/8/2012	19.7	10/9/2012	16.9				
		7/9/2012	18.1	10/10/2012	19.4				
		7/10/2012	16.7	10/11/2012	18.1				
		7/11/2012	16.7	10/16/2012	16.2				
		7/17/2012	19.1	11/3/2012	16.2				
		7/18/2012	21.9	11/28/2012	19.0				
		7/19/2012	21.0	11/29/2012	16.5				
		7/20/2012	16.7	11/30/2012	19.0				
		7/21/2012	18.2	12/1/2012	24.0				
		7/22/2012	18.0	12/2/2012	16.5				
		7/26/2012	16.5	12/5/2012	17.5				
		8/4/2012	16.4	12/6/2012	18.5				
		8/15/2012	21.9	12/7/2012	19.8				
		8/16/2012	21.2	12/8/2012	16.6				
		9/16/2012	16.1	12/9/2012	16.3				
		9/18/2012	16.0	12/12/2012	17.1				
		9/30/2012	16.9	12/13/2012	17.4				
				12/15/2012	16.3				
				12/22/2012	16.0				
				12/24/2012	17.5				
				12/27/2012	16.0				
				12/28/2012	17.2				