Community Air Monitoring in Oceano, California

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SLO COUNTY apcd

Air Pollution Control District
San Luis Obispo County

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Executive Summary

In response to Assembly Bill 617 (C. Garcia, Chapter 136, Statutes of 2017), CARB established the Community Air Protection Program (CAP Program). The CAP Program's focus is to reduce exposure in communities most impacted by air pollution, while prioritizing disadvantaged communities and sensitive receptors. In March of 2018, a resident of Oceano nominated the community to the CAP Program and identified health concerns from excess particulate matter. To address the community concern, the District allocated the CAP Program funds to purchase, install, and manage particulate matter (PM) sensors and monitors in Oceano.

The District sought community partners to host the various monitors and sensors. The Oceano Community Services District (CSD) agreed to host three different types of particulate monitors at their corporate yard on 1681 Front Street (Hwy 1) in Oceano. These included a BAM 1020 which are the same units used monitoring stations, a BX-895 Real Time Particulate Monitor, and the inexpensive AirVisual Pro particulate sensor. In addition, two members of the Oceano community agreed to host AirVisual Pros at their residences on 22nd Street and in eastern Oceano. The approximate locations of these locations are shown in Figure 3. The Oceano CSD BAM 1020 and Real Time Particulate Monitor were removed in mid-October, but all three AirVisual Pro sensors remain in the field as of January 2020.

After the Oceano CSD BAM 1020 and Real Time Particulate Monitor were removed, the District began analyzing the 6 months of data. The report analysis focuses on the following topics:

- A comparison between the PM_{10} measurements from the collocated AirVisual Pro and the BAM 1020.
- A comparison between the PM_{10} measurements from the collocated BX-895 Real Time Particulate Monitor and the BAM 1020
- A discussion of how PM_{10} in Oceano—as measured by the Oceano CSD BAM 1020 monitor—compares to other PM_{10} measured on the Nipomo Mesa.

Several key conclusions from these analyses are fully explained throughout the report and in the Conclusions and Recommendations section. In summary, the two AirVisual Pro sensors tested alongside the BAM 1020 at the Oceano CSD had very different responses to ambient PM_{10}. This indicates that the response of the AirVisual Pro to PM_{10} is not consistent from one sensor to the next. Nonetheless, some individual sensors can be reasonably accurate, and have the potential to be used as low-cost alternatives to regulatory monitors in certain settings.

The BX-895 Real Time Particulate Monitor that was also collocated at the Oceano CSD was less accurate than both of the AirVisual Pro sensors. As this monitor is more expensive, less accurate, and measures fewer parameters than the AirVisual Pro, the BX-895 will not be used in future projects.

Compared to other South County sites, the BAM 1020 at the Oceano CSD measured the highest background levels of PM_{10}. The elevated background levels are likely due to the influence of traffic, as evidenced by 1) the diurnal pattern having a spike around the time of the morning commute, and 2) a weekday/weekend effect, with significantly lower levels on Sundays compared with the rest of the week. Of all the regulatory monitors in southern San Luis Obispo County, the Oceano CSD monitor was closest to the roadway, so these findings are not surprising.

While background levels were highest at Oceano CSD, it was the less influenced by the windblown dust from the ODSVRA. By comparison, the CSD site only exceeded the state PM_{10} standard on 4 days, while over the same time period the standard was exceeded 32 times at CDF, 23 times at Mesa2, and 7 times at Nipomo Regional Park. Thus, despite having higher background levels than nearby monitoring sites, overall this site measures better air quality than the other sites in the region with the exception of Oso Flaco.

Project History and Funding

In response to Assembly Bill 617 (C. Garcia, Chapter 136, Statutes of 2017), CARB established the Community Air Protection Program (CAP Program). The CAP Program's focus is to reduce exposure in communities most impacted by air pollution while prioritizing disadvantaged communities and sensitive receptors. The CAP Program includes a variety of strategies to address air quality issues and is unique in the fact that community members from across the state could nominate their own community to CARB for consideration into the CAP Program. In March of 2018, a resident of Oceano nominated the community to the CAP Program and identified health concerns from excess particulate matter.

CARB received hundreds of community and air district submittals in 2018 and is still receiving submittals. AB 617 required that the CARB Governing Board select nominated communities with high cumulative exposure burden while prioritizing disadvantaged communities and sensitive receptors. Due to funding limitations, only ten communities were selected by CARB. The Air Districts with selected communities were then tasked to deploy air monitors and/or prepare emission reduction programs.

While Oceano was not among the ten selected communities for the extensive program, there was limited funding for monitoring only. Based on the available funding, the District was awarded $46,142 to implement a monitoring only CAP Program. To address the community concern, the District allocated the CAP Program funds to purchase, install, and manage particulate matter sensors and monitors in Oceano.

The District also understood that the CAP Program aimed to improve community capacity to participate in the process, so to involve the community in this project, staff attended a community meeting hosted by Cal Poly at the Oceano Community Service District Board Chambers on February 19th, 2019. Staff gave a brief overview of the project and asked for volunteers to host air monitors. Several community members volunteered, and two community members were selected to receive AirVisual Pro low-cost sensors.

Additionally, staff worked with the Oceano Community Service District to install a temporary BAM 1020 Particulate Monitor in their yard at 1681 Front Street (Hwy 1), Oceano and collocated it with one of the AirVisual sensors. To involve the community further and ensure community members would be updated on Oceano's current air quality conditions, staff created a webpage on the District website which displayed a map of the three monitors and corresponding AQI information.

Study Design and Field Operations

This project monitored particulate matter—PM_{10} and $PM_{2.5}$—since these are the pollutants of concern identified by community input. With the compressed timeline required by the grant and its limited funding, a long-term deployment of multiple regulatory-grade particulate matter instruments was not possible. With these constraints in mind, the District sought to leverage the temporary use of a high cost reference monitor by comparing its results with low-cost sensors that could be used indefinitely throughout the community.

Equipment

Low-cost sensors. The AirVisual Pro (IQAir, $269; Figure 1)[1] was selected as the low-cost sensor for this project. It simultaneously measures the pollutants of interest, $PM_{2.5}$ and PM_{10}, as well as PM_1, temperature and relative humidity, and it reports data at approximately 5-minute intervals. It was selected for two reasons, the first being ease-of-use: It has a relatively simple user interface and can be configured to continuously stream data to the manufacturer's website[1] via Wi-Fi. The manufacture publishes a smart phone app and an API for convenient retrieval and display of the data. Thus, the sensor only needs a connection to power and access to a Wi-Fi network to collect and transmit data; an external datalogger and/or a (wired) internet connection are not required.

Figure 1: AirVisual Pro, by IQAir.

[1] https://www.airvisual.com/air-quality-monitor

The second reason it was selected was accuracy. Prior to this project, the District already had some experience with the AirVisual Pro and another low-cost sensor, the PA-II (PurpleAir, $229).[2] Like the AirVisual Pro, the PA-II measures PM_1, $PM_{2.5}$, PM_{10}, temperature, and humidity, and it automatically streams its data to the web via Wi-Fi; data can then be retrieved from the manufacturer's website via an API. In evaluations by South Coast AQMD's AQ-SPEC program, both the AirVisual Pro and the PA-II were found to correlate well with regulatory-grade monitors (especially for $PM_{2.5}$);[3] however, when collocated at the District's CDF monitoring station, it was found that PA-II sensor did not respond well to wind-blown dust events. This insensitivity to particulate matter in high wind conditions was later confirmed by AQ-SPEC in other locations. In contrast, the AirVisual Pro collocated at CDF tracked the regulatory monitor well even in high wind conditions.

For these reasons, the AirVisual Pro was selected as the low-cost sensor for this project. A disadvantage of this sensor is that it is not designed for outdoor use; therefore, rainproof enclosures were constructed to house the sensors used in the field.

Regulatory monitor. The District had a spare BAM 1020 Particulate Monitor (Met One Instruments, Grants Pass, Oregon) available and temporarily collocated it with one of the AirVisual sensors. It was configured to collect PM_{10} data. The BAM 1020 is a regulatory-grade instrument, and the District uses this model for PM_{10} and $PM_{2.5}$ monitoring at all of our permanent monitoring stations, including the CDF, Mesa2, and Nipomo Regional Park stations on the Nipomo Mesa. The BAM 1020 used in this project was operated according to the same procedures and quality control measures as the permanent BAM 1020 monitors run by the District. The BAM 1020 was deployed in a weatherproof, temperature-controlled enclosure, and integrated with a datalogger, cellular modem, and wind sensor (Figure 2).

Figure 2: The BAM 1020 PM_{10} monitor in its enclosure.

2 https://www2.purpleair.com/

3 http://www.aqmd.gov/aq-spec/home

Real Time Particulate Monitor. The District also collocated a BX-895 Real Time Module (Met One Instruments, Grants Pass, Oregon) with the AirVisual Pro and BAM 1020. This research-grade (non-regulatory) particle counter is claimed to provide minute-resolution PM_{10} data. The District was interested in evaluating the performance of this instrument, as it is much less expensive than the BAM 1020 (though more costly than the AirVisiual Pro), easier to operate, and provides minute-resolution data.

Siting

The District sought community partners to host the various monitors and sensors. The Oceano Community Services District (CSD) agreed to host the BAM 1020, the Real Time Particulate Monitor, and an AirVisual Pro at their yard at 1681 Front Street (Hwy 1), Oceano. Two members of the Oceano community agreed to host AirVisual Pros at their residences on 22nd Street and in eastern Oceano. The approximate locations of these locations are shown in the map below (Figure 3). The location of the Oceano CSD site is shown in relation to the District's permanent monitoring stations in Figure 4. (The other Oceano sites are omitted for clarity.) Photos of the Oceano CSD site are included as Figures 5 and 6.

Unfortunately, with a tight timeline to begin the monitoring, the District was not able to identify a partner willing to host a sensor west of Highway 1 in time for the start of the windy season.

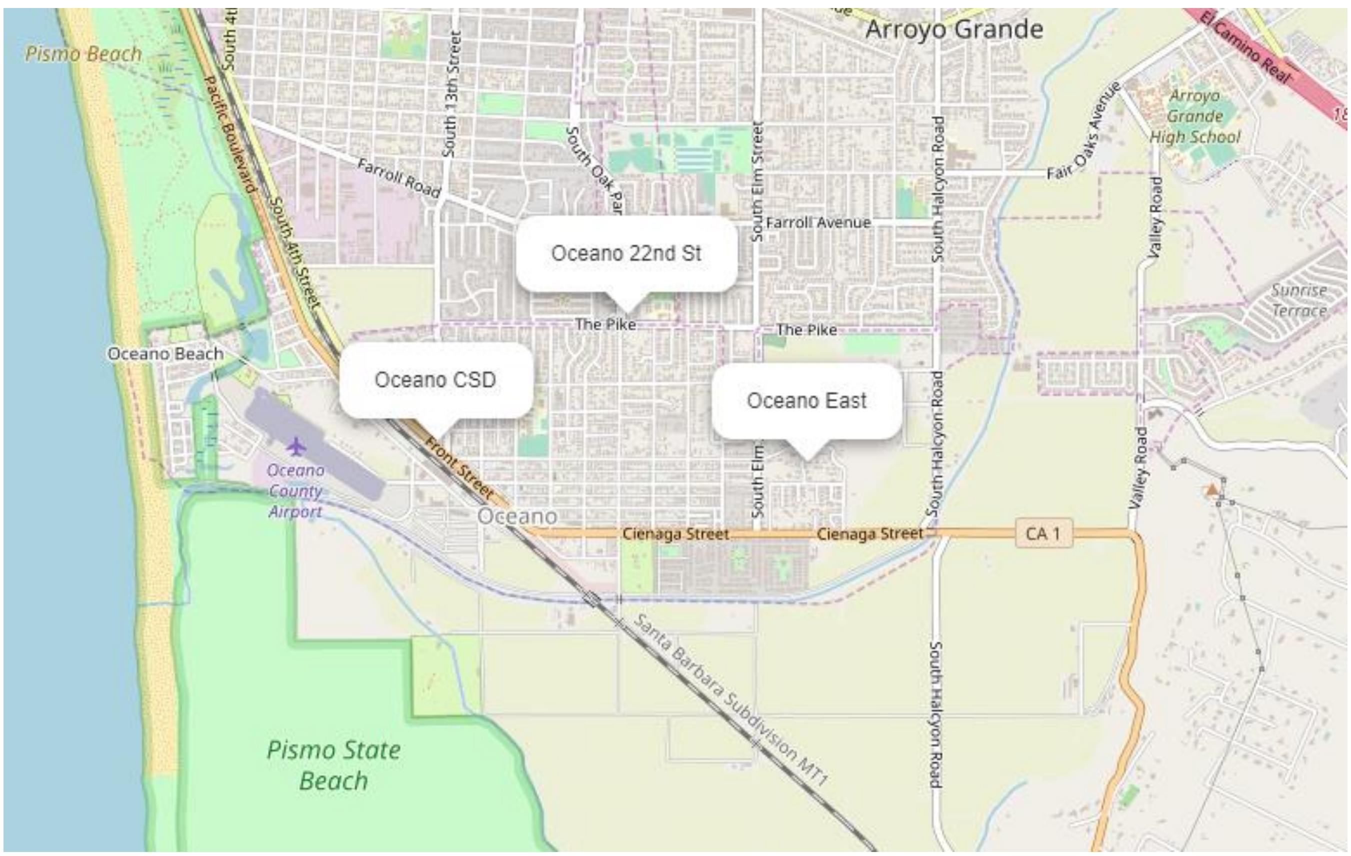

Figure 3: Approximate locations of temporary PM_{10} & $PM_{2.5}$ monitoring locations in Oceano, California.

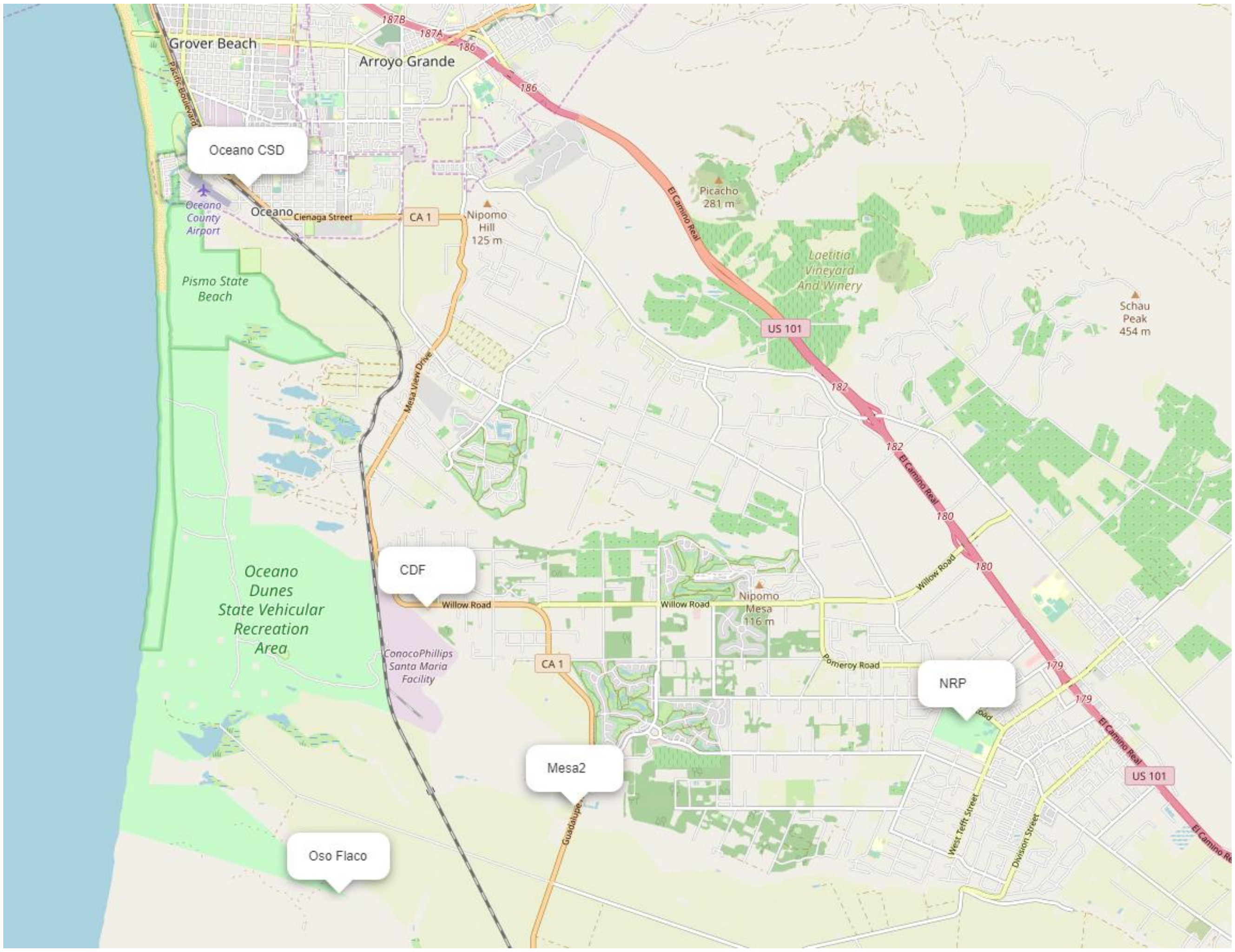

Figure 4: Location of Oceano CSD and nearby permanent PM_{10} & $PM_{2.5}$ monitoring Stations

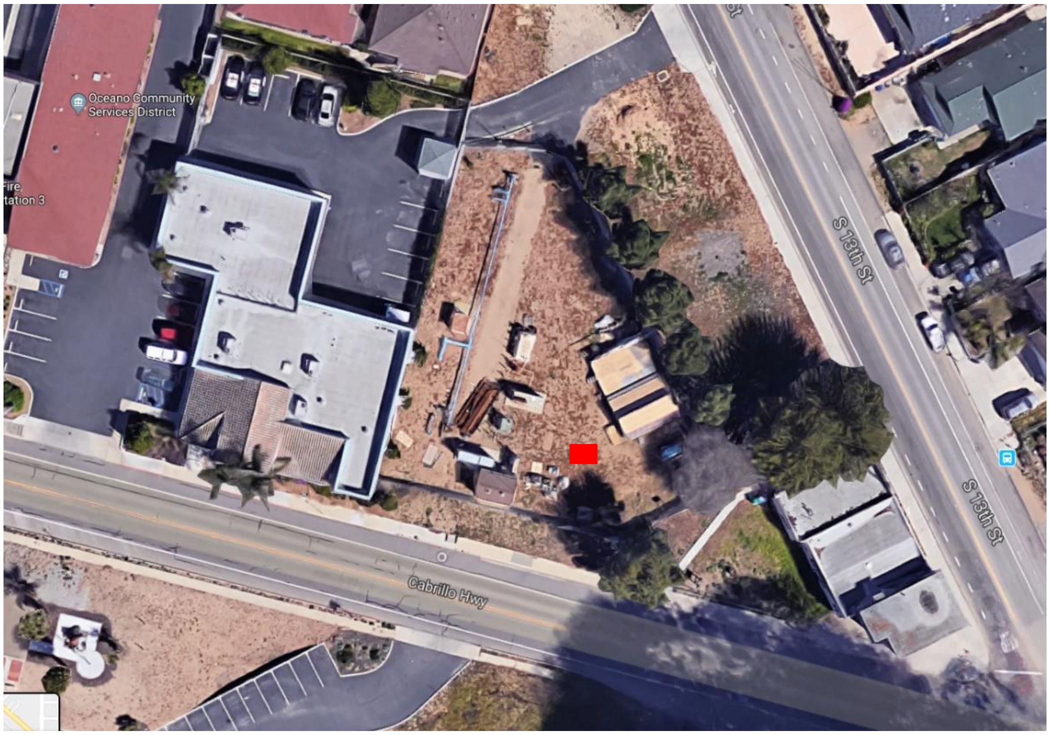

Figure 5: Aerial View of Oceano CSD Monitoring Site. Red box marks location of monitoring equipment.

Figure 6: Oceano CSD Monitoring Site. Left: the view looking south from the enclosure; right: the view looking west from enclosure.

Field Operations and Reporting

The Oceano 22nd Street and Oceano East AirVisual Pro sensors were deployed in late March 2019, and the Oceano CSD equipment was deployed in early April. The Oceano CSD BAM 1020 and Real Time Particulate Monitor were removed in mid-October, but all three AirVisual Pro sensors remain in the field as of January 2020.

Since August 26th, data from these sites has appeared on the District's website in near real-time.[4] PM_{10} and $PM_{2.5}$ are displayed in Air Quality Index (AQI) units on an interactive "data map". See Figure 7 for a screenshot. Initially, the map is zoomed into the Oceano area and displays the AQI for the most recent full hour. Users can zoom out and view the AQI at other monitoring stations on the Nipomo Mesa and also view data for the previous few days. Clicking on a site will display a popup showing the numeric value of the AQI.

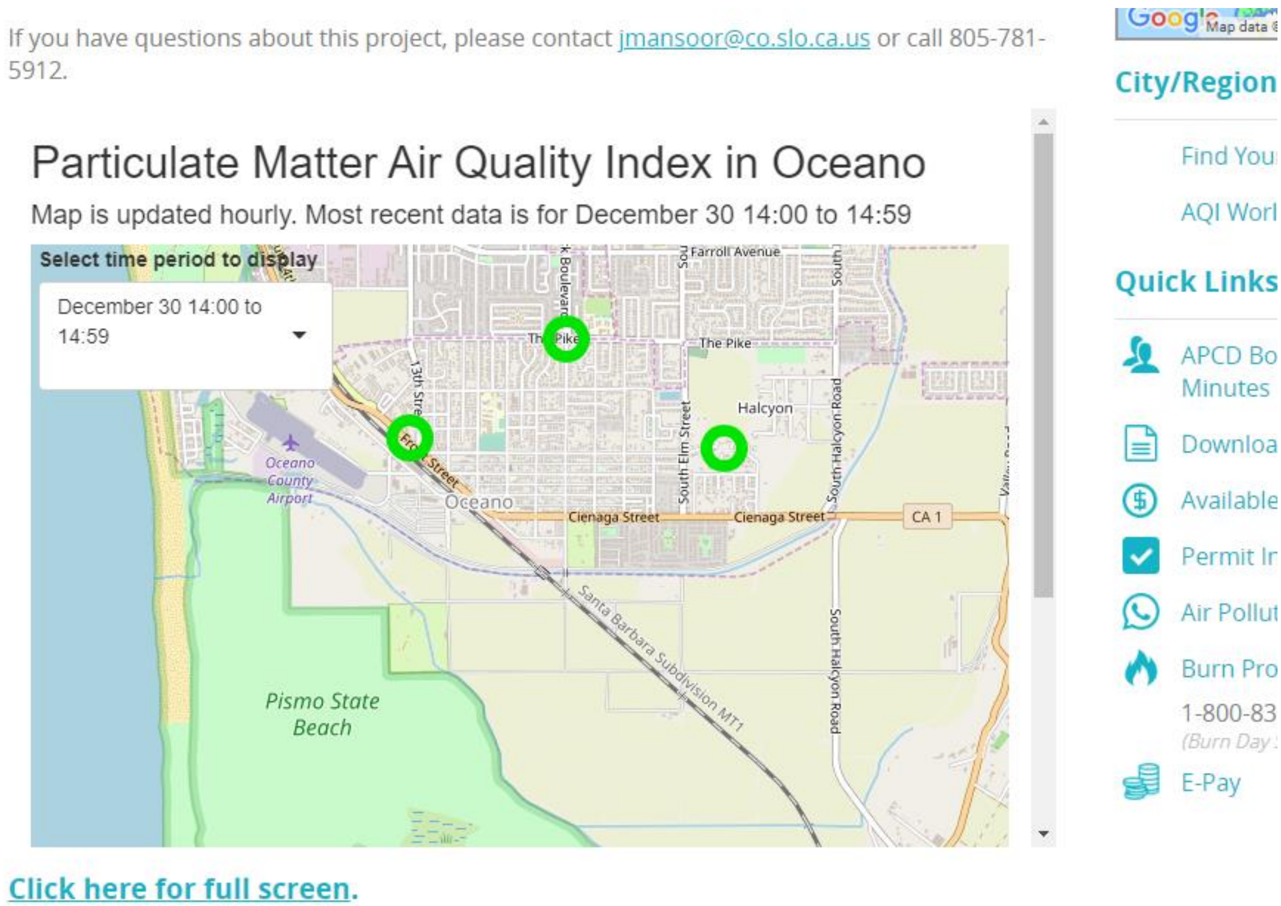

Figure 7: Screenshot of Oceano Data Map on the District website.

4 https://www.slocleanair.org/air-quality/oceano-dunes-efforts/oceano-monitoring.php

Results

The following sections discuss some of the results from the project, including:

- A comparison between the PM_{10} measurements from the collocated AirVisual Pro and the BAM 1020.
- A comparison between the PM_{10} measurements from the collocated Real Time Particulate Monitor and the BAM 1020
- A discussion of how PM_{10} in Oceano—as measured by the Oceano CSD BAM 1020 monitor—compares to other PM_{10} measured on the Nipomo Mesa.

The District has not formally compared the 3 Oceano monitoring sites to each other, but anecdotally, it appears that during windblown dust events there is a gradient of PM_{10} concentrations in Oceano, with higher levels on the western side than on the east.

AirVisual Pro PM_{10} versus BAM 1020 PM_{10}

As previously noted, an AirVisual Pro sensor and a BAM 1020 PM_{10} monitor were collocated at the Oceano CSD. Between April 5 to October 10, 4,317 paired data points of hourly PM_{10} were collected. Early in the project, it was noticed that the AirVisual Pro PM_{10} values were much lower than the collocated BAM 1020, so on May 18th, the AirVisual Pro at the Oceano CSD was removed and replaced with a spare sensor. The correlation improved markedly, as shown in Figure 8, below, which is scatterplot of the hourly PM_{10} values from the AirVisual Pro versus the BAM 1020. The pre-May 18th values are shown in gray; note how they cluster below the dashed 1:1 line, while the values from May 18th and after, shown in blue, cluster around the 1:1 line.

The relationship between the AirVisual Pro sensor and the BAM 1020 was modeled via linear least squares, and the results are summarized in the Table 1. For the original sensor, which operated from April 5 to May 17, the R^2 was 0.589 and the slope was 0.208, indicating the PM_{10} values reported by the AirVisual Pro were about 20% of the actual PM_{10} levels, as reported by the collocated BAM 1020. With the replacement AirVisual Pro installed on May 18, both the correlation and bias improved, with an R^2 value of 0.732 and a slope of 0.936, indicating much better correlation and nearly no bias. On average, the values reported by the replacement AirVisual Pro were about 9% higher than the BAM.

The AirVisual Pro sensor appears to be influenced by relative humidity, reading falsely high when humidity is high. This is depicted in Figure 9, which plots only the data collected with the newer sensor (i.e., May 18 through October 10), with the points colored by relative humidity as reported by the AirVisual sensor itself. Note the cluster of darker blue points above the dashed 1:1 line—these are hours (typically in the early morning) when relative humidity is high and the AirVisual Pro is reporting higher PM_{10} values than the BAM 1020. This pattern suggests that it may be possible to improve the accuracy of the AirVisual Pro PM_{10} values by algorithmically correcting the sensor's raw readings using the relative humidity data (and perhaps other data collected by the sensor), but this has not yet been pursued.

Table 1: Summary of AirVisual Pro vs BAM 1020 relationship.

	Before May 18	May 18 and after
Adjusted - R^2	0.589	0.732
Slope	0.208	0.936
Intercept	3.15	6.97

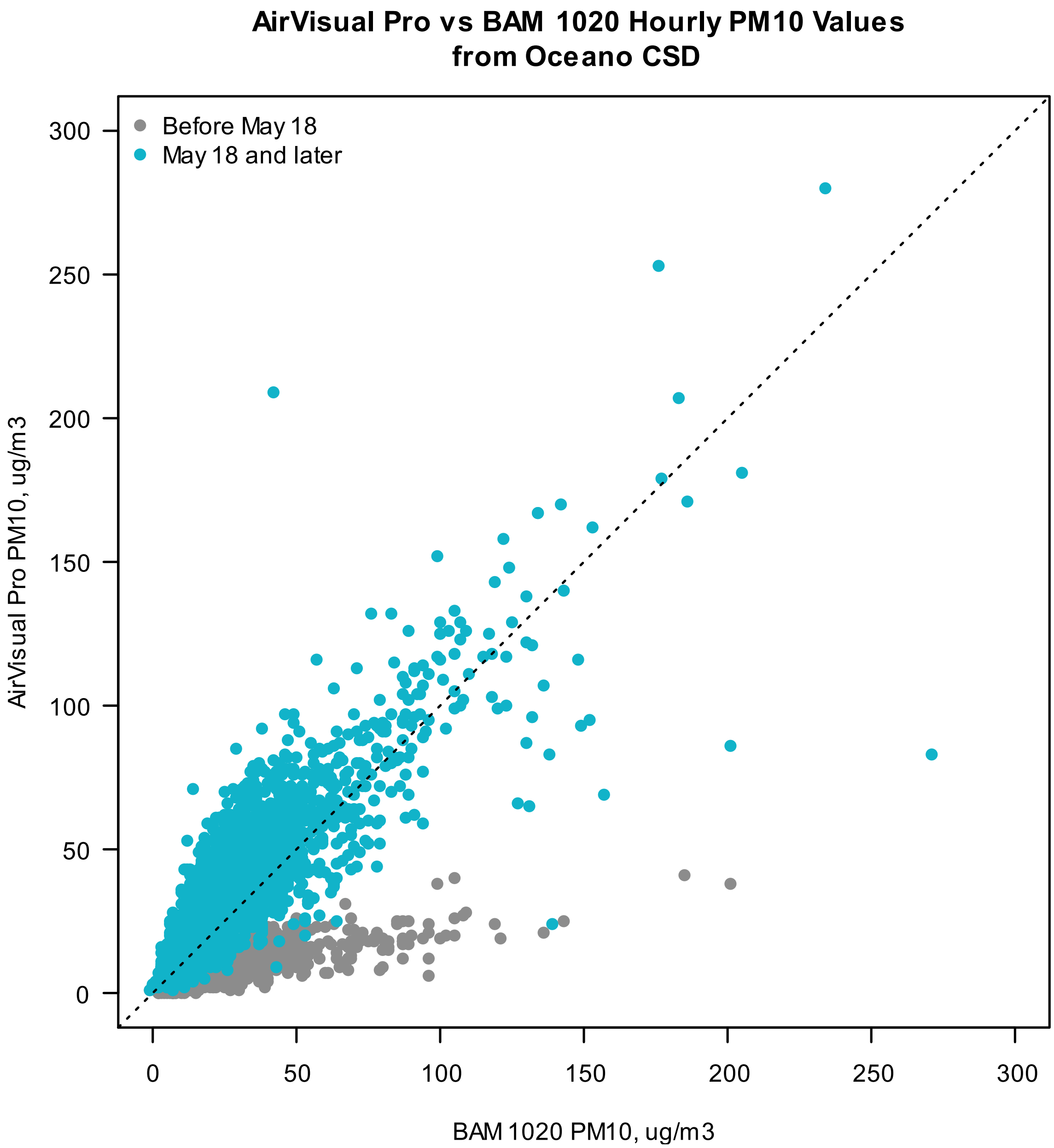

Figure 8: AirVisual Pro versus collocated BAM 1020

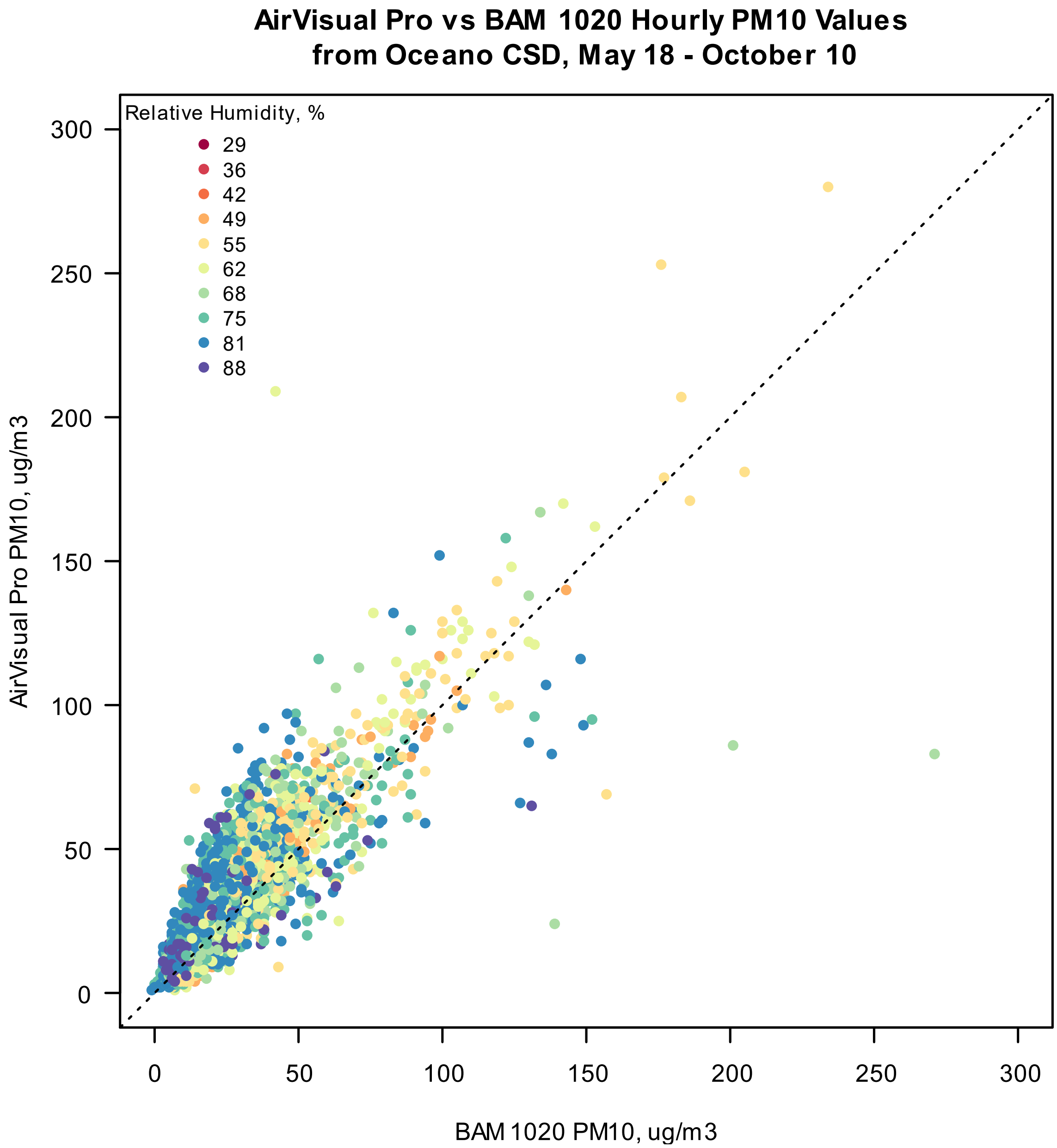

Figure 9: Relative Humidity effect on AirVisual Response.

Real Time Particulate Monitor PM_{10} versus BAM 1020 PM_{10}

A Met One BX-895 Real Time Particulate Monitor was also collocated with the BAM 1020 PM_{10} monitor at the Oceano CSD. Between April 5 to October 10, 4,490 paired data points of hourly PM_{10} were collected. With an R^2 of 0.441, the correlation between the two devices is not as good that between the AirVisual sensor and the BAM 1020 (see Table 1), and as shown in Figure 10, the raw BX-895 output is severely biased, with the BX-895 reporting PM_{10} values that were about 18% of the true PM_{10} values reported by the BAM 1020.

A linear correction equation for the BX-895 was derived via least squares; it is:

$$\text{Corrected BX-895 } PM_{10} = 2.46 * \text{Raw BX-895 } PM_{10} - 4.86$$

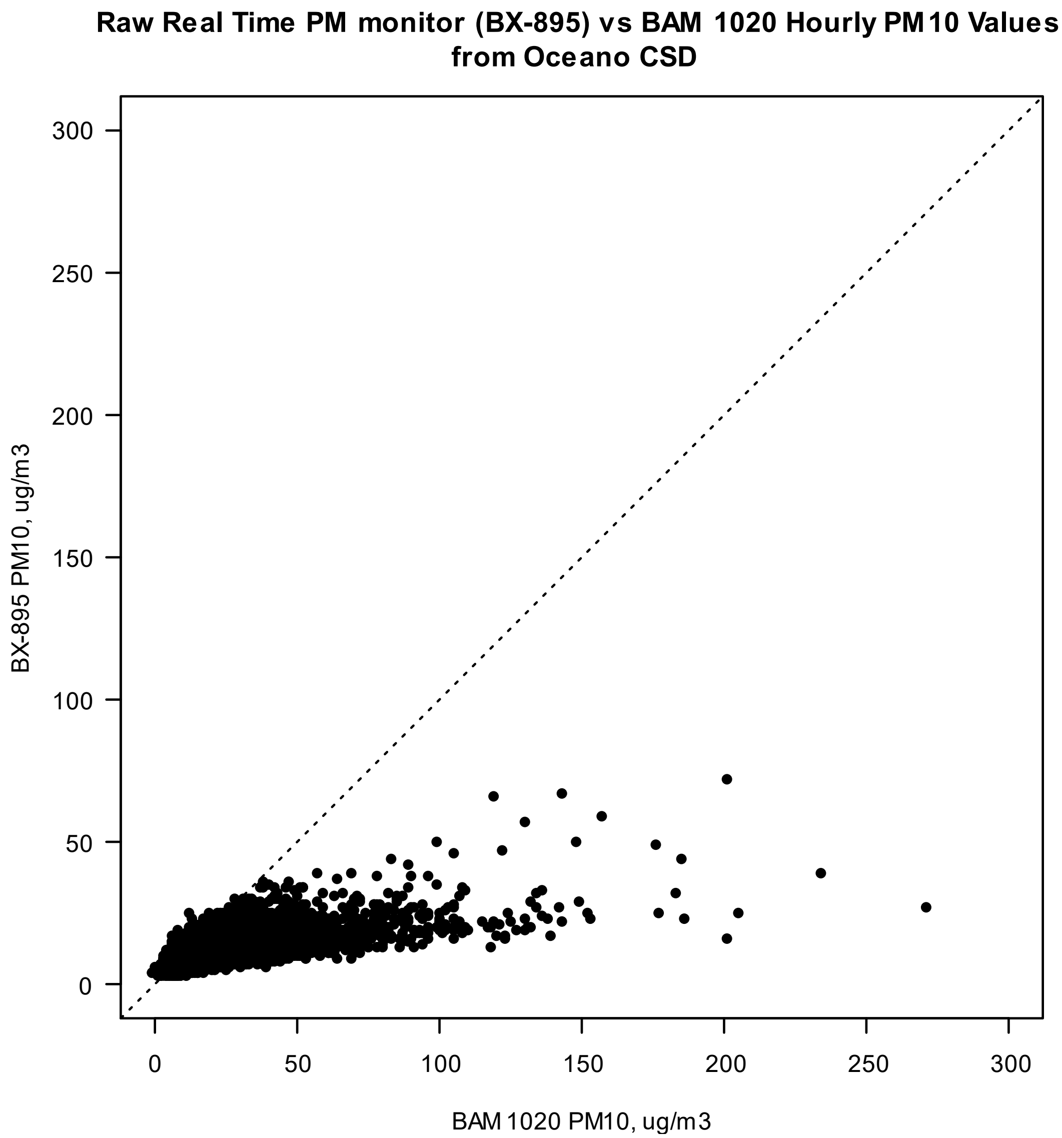

Figure 10: Raw BX-895 PM_{10} vs BAM 1020 PM_{10} from Oceano CSD

Figure 11 plots the corrected BX-895 PM_{10} values against the BAM 1020 concentrations, with points colored by relative humidity (as measured by the collocated AirVisual sensor) as in Figure 9, above. As with the AirVisual sensor, relative humidity strongly influenced the BX-895 measurements, with the monitor biased high in humid conditions, and low in dry conditions. The response of the BX-895 also seemed to change after windblown dust events, become more sensitive for hours or days after a large event, before returning to its baseline sensitivity.

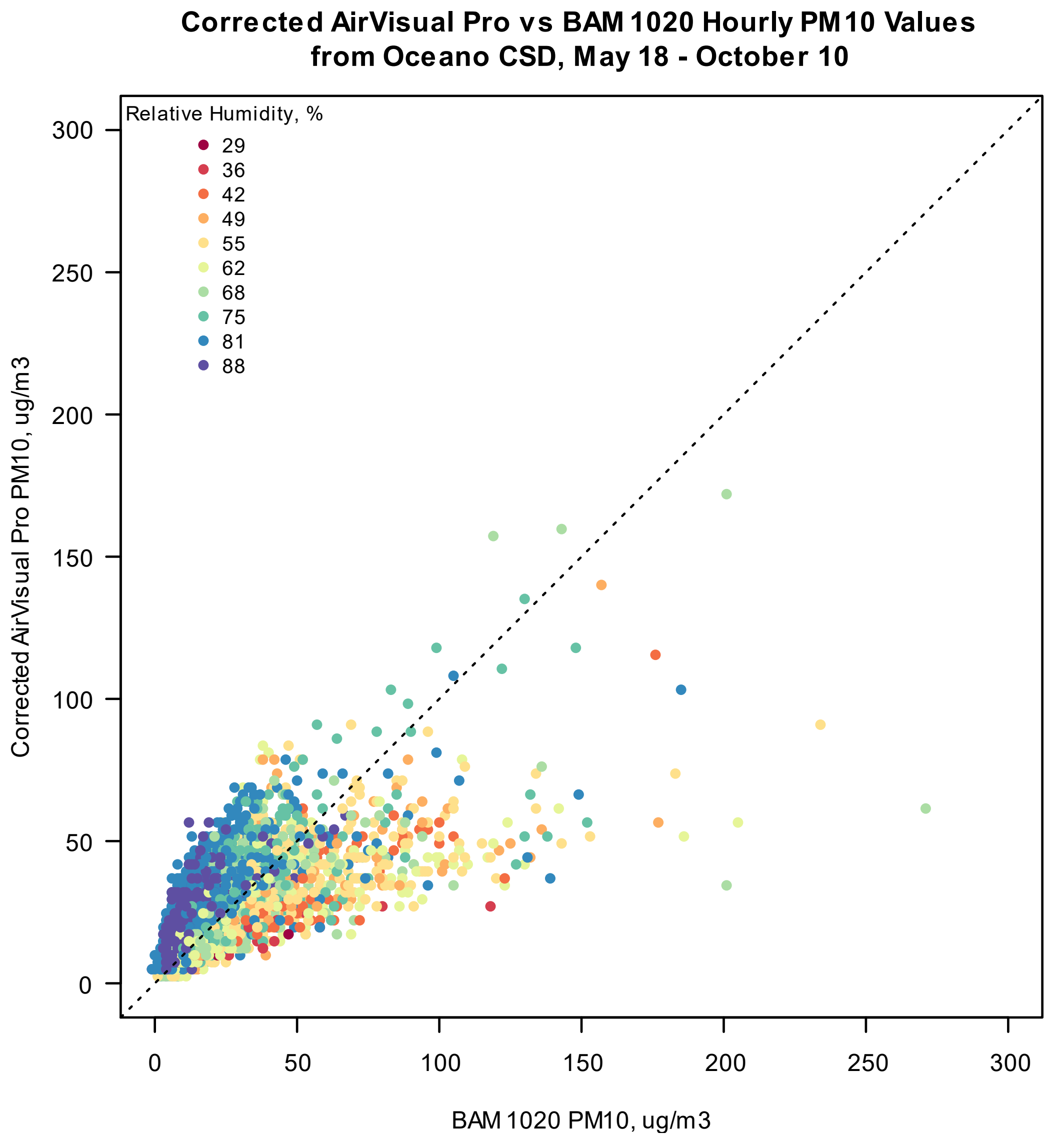

Figure 11: Relative humidity effect on corrected BX-895 response.

PM_{10} in Oceano Compared to Nearby Sites

Summary Statistics. The PM_{10} monitor operated from April 4 through October 10, collecting 4,505 valid hourly PM_{10} measurements, for a data capture rate of 98.7%. During this period, it recorded 4 exceedances of the state PM_{10} standard (50 µg/m^3 over 24 hours), which is fewer than the number of exceedances observed at most nearby monitoring sites over the same period of time, with 32 days exceeding the standard at CDF, 23 days at Mesa2, 7 days at NRP, and 3 at Oso Flaco. For the entire monitoring period, the average Oceano CSD PM_{10} concentration was 24.9 µg/m^3, which is less than the averages for CDF and Mesa2 but greater than that for NRP and Oso Flaco. In contrast, Oceano CSD has the highest median PM_{10} concentration of all sites in the area, but the lowest maximum, indicating somewhat higher background levels. These statistics are summarized in Table 2, while Table 3 summarizes PM_{10} levels for the 4 days when the Oceano CSD monitor exceeded the state standard.

Table 2: Summary Statistics for 24-hour PM_{10} (all units are µg/m^3, Standard Conditions)

Site	Minimum	Median	Average	Maximum	Number of Standard Exceedances
Oceano CSD	6	23	24.9	61	4
CDF	1	19	29.0	115	32
Mesa2	4	18	26.6	104	23
NRP	0	19	22.7	71	7
Oso Flaco	0	13	15.8	79	3

Table 3: PM_{10} Standard Exceedances at Oceano CSD

Date	24 Hour Average PM_{10} (µg/m^3, Standard Conditions)				
	Oceano CSD	CDF	Mesa2	NRP	Oso Flaco
April 17	61	41	43	17	29
June 8	52	41	40	42	33
July 15	54	84	103	58	23
Aug 21	52	116	97	68	19

Windblown Dust Impacts. As shown in Figure 3, the Oceano CSD monitor is less than a mile from the northern tip of the Oceano Dunes State Vehicular Recreation Area (ODSVRA). Windblown dust from the ODSVRA is well documented to impact the CDF, Mesa2, NRP and Oso Flaco monitoring sites, causing dozens of exceedances of the California PM_{10} standard at those sites each year. The District was thus very interested in determining to what extent Oceano is impacted by the ODSVRA.

As noted in Table 1 above, far fewer days exceeded the PM_{10} standard at the Oceano CSD than at CDF and Mesa2, suggesting that this area is less impacted by dust from the ODSVRA. Nonetheless, impacts are discernable. Figure 12, below, plots hourly PM_{10} values for Oceano CSD along with CDF and Mesa2 for July 15, which is one of the 4 days when the PM_{10} standard was exceeded at the monitor. A strong windblown dust event occurred that day, with hourly PM_{10} peaking at more than 500 µg/m^3 in the mid-afternoon at both CDF and Mesa2. The Oceano CSD monitor shows a spike in PM_{10} at the same time, but it is much lower.

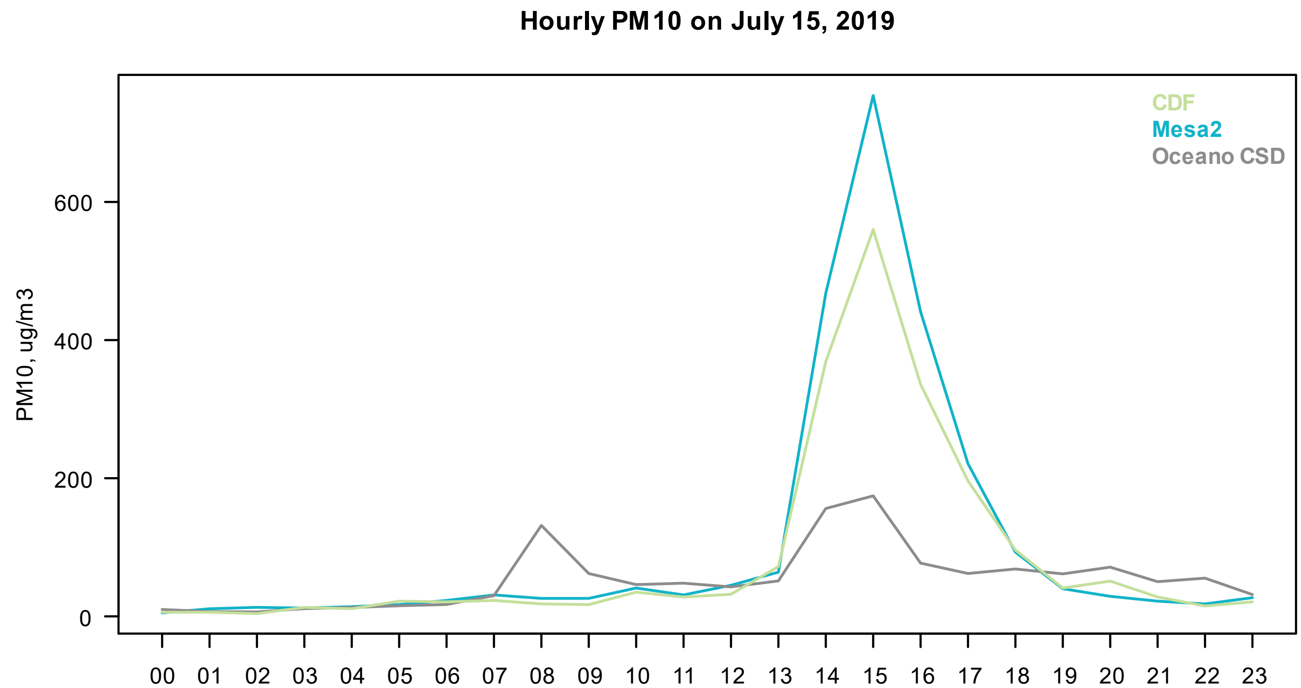

Figure 12: An example of hourly PM_{10} concentrations during windblown dust event.

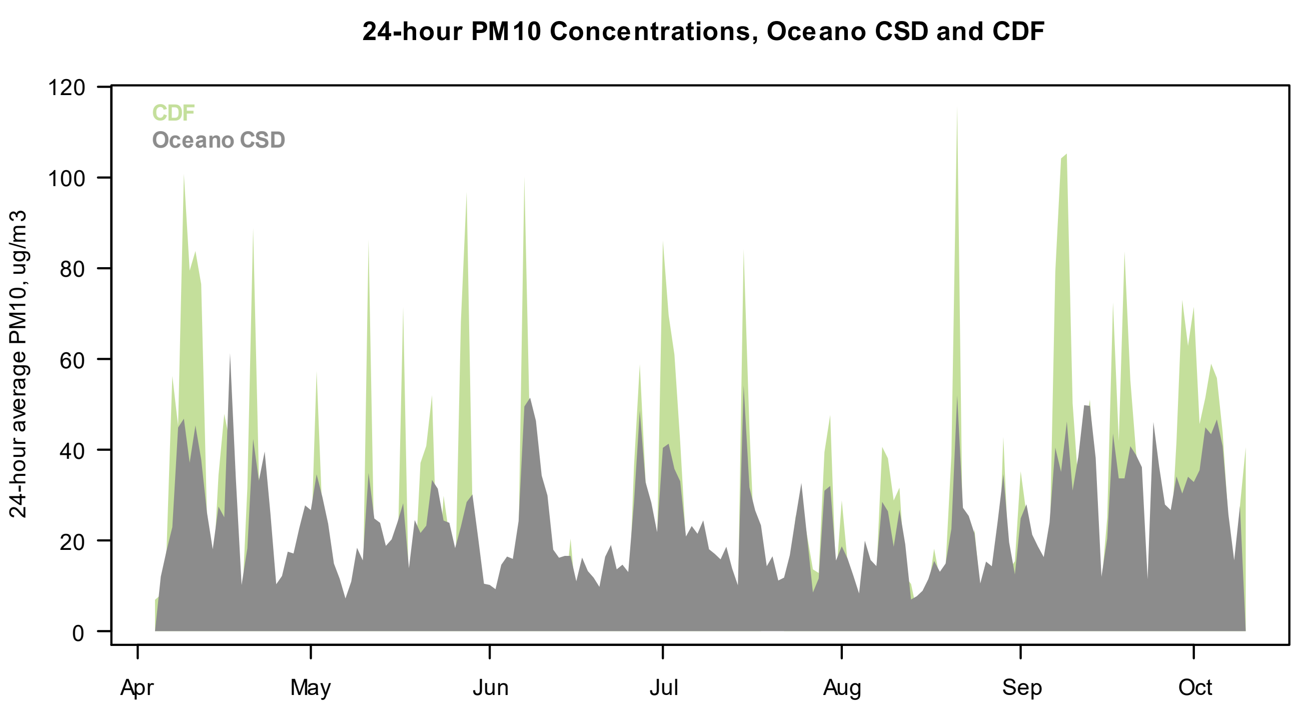

Figure 13: 24-hour PM_{10} Concentrations, April 4 – October 10, 2019

Figure 13, above, plots the 24-hour PM_{10} concentrations for the complete monitoring period for the Oceano CSD and CDF monitors. The "peaks" or "spikes" are windblown dust events, and during these events the CDF concentration is almost always at least twice the Oceano CSD concentration. Figure 14, below, is a scatter plot of these same data, depicting Oceano CSD concentrations (y-axis) as a function of CDF concentrations (x-axis). Exceedances of the PM_{10} standard at Oceano CSD are shown in red, and the dashed line marks the 1:1 line. When CDF daily averages are less than about 20 µg/m^3, the levels at Oceano CSD tend be a little higher than CDF, but when CDF concentrations exceed about 50 µg/m^3, the levels at Oceano CSD are much lower than CDF.

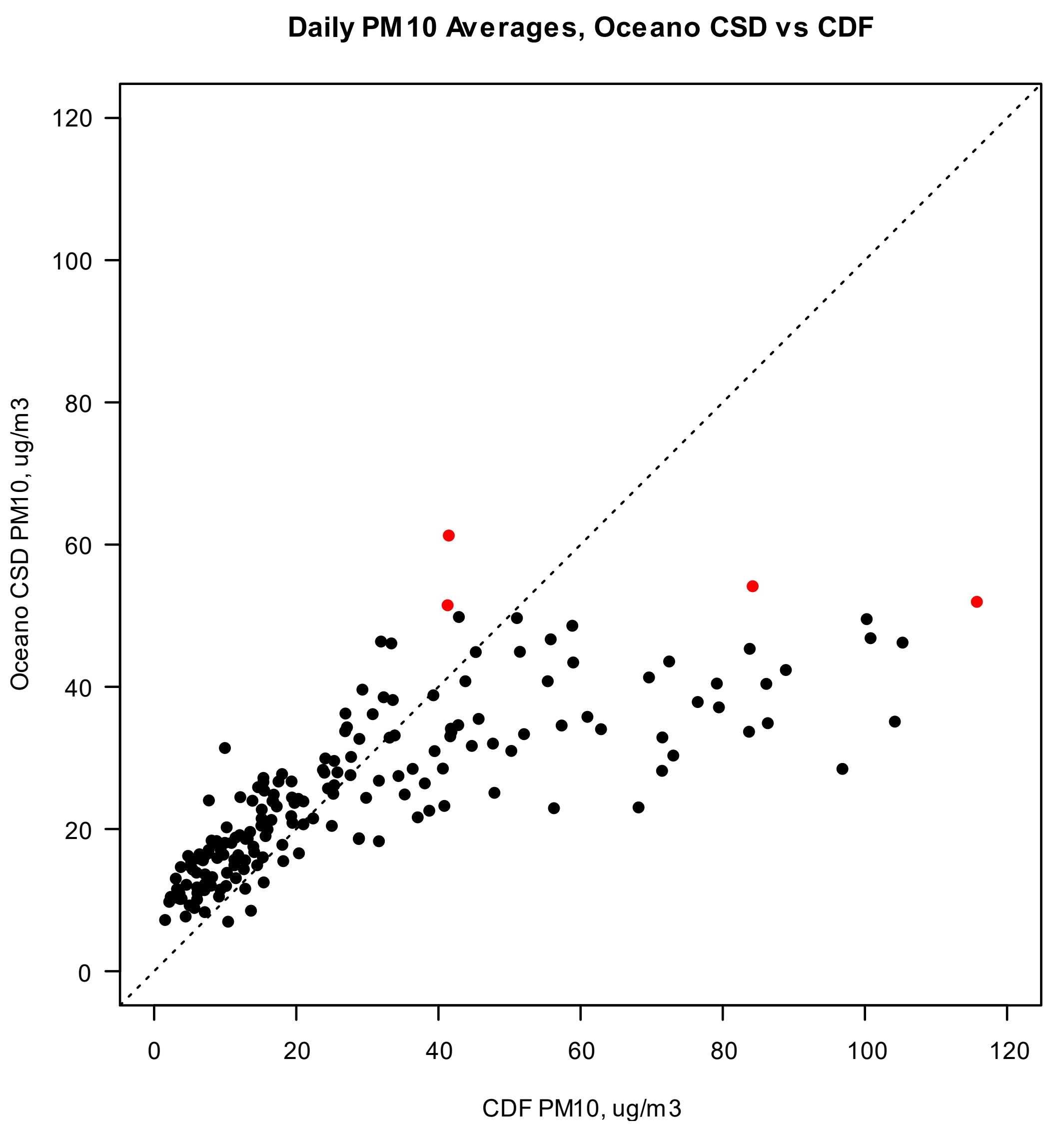

Figure 14: PM_{10} at Oceano CSD vs CDF

Traffic Impacts. Influences other than windblown dust from the ODSVRA are also apparent. For example, as shown in Table 3 and Figure 14 there are two days (April 17th and June 8th) when the PM_{10} standard was exceeded at the Oceano CSD but not at CDF or the other Nipomo Mesa sites, making it unlikely that these exceedances were related to windblown dust. The median daily PM_{10} levels at Oceano CSD are also slightly higher than at the Nipomo Mesa sites (Table 1), indicating higher background levels. As discussed below, the non-windblown dust sources impacting the Oceano CSD are likely traffic on Highway 1 and/or activities at neighboring properties.

A morning spike in PM_{10} at the Oceano CSD is apparent in the plot of the hourly PM_{10} data for July 15, 2019, (Figure 12). This spike occurs during morning commute hours and suggests the influence of traffic. To more formally investigate the influence of traffic, Figure 15, below, plots the mean PM_{10} level by hour of the day for each site. All four sites show mean values peaking in the mid-afternoon—this is due to windblown dust from the ODSVRA. Oceano CSD and CDF also show a smaller morning spike, between 6 and 9 a.m. PST—this is likely due to traffic. Note that relative to the afternoon windblown dust peak, the morning traffic peak is much bigger at the Oceano CSD data than at CDF.

Comparing weekday to weekend values is also informative, as windblown dust events occur without regard to the day of the week, but human activity often exhibits a weekly pattern. As shown in Figure 16, below, Oceano CSD PM_{10} levels are lowest on Sunday; the difference between Sunday and the rest of the week is statistically significant.

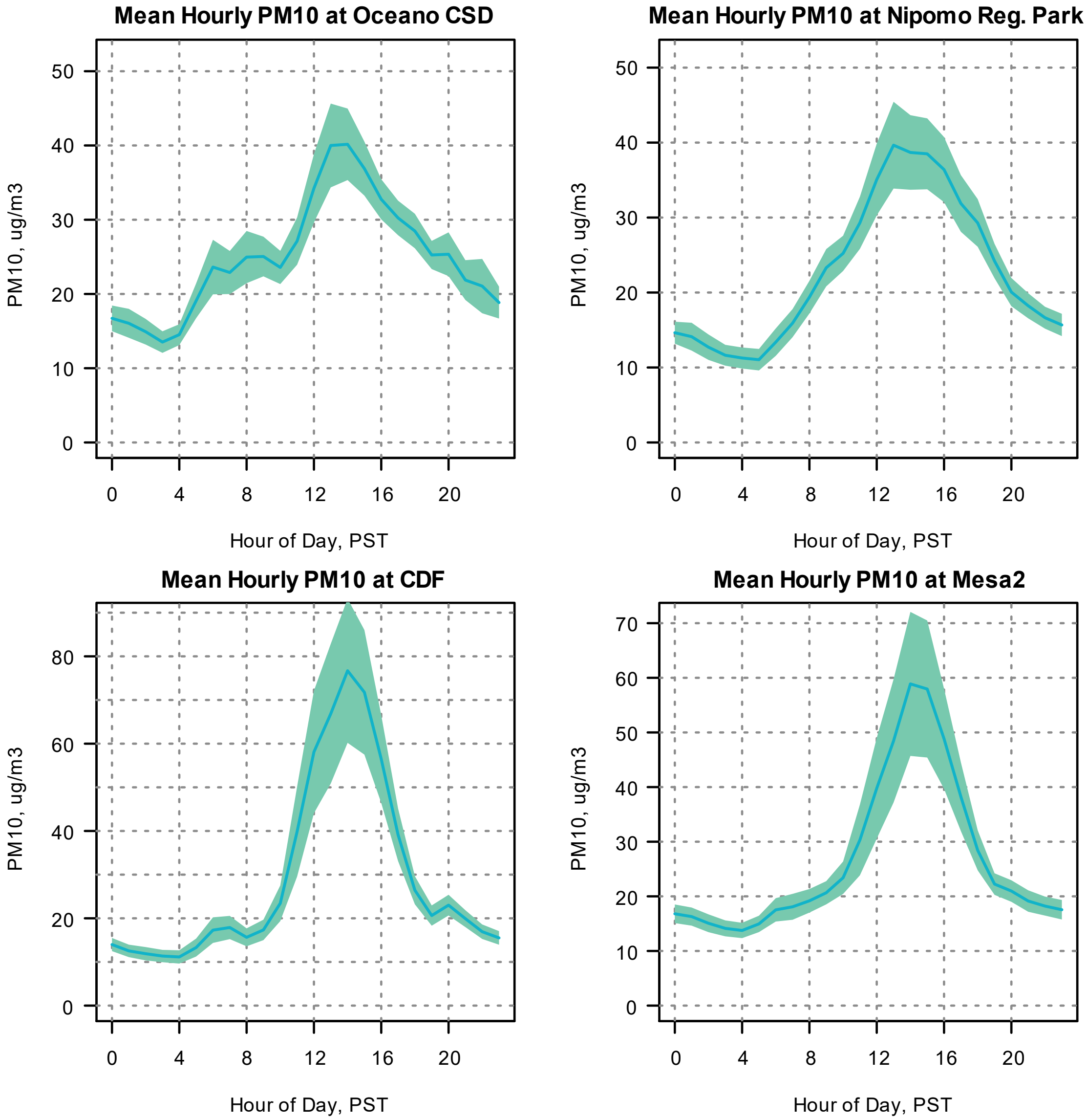

Figure 15: Mean Hourly PM$_{10}$ by Site. 95% Confidence intervals shown in green.

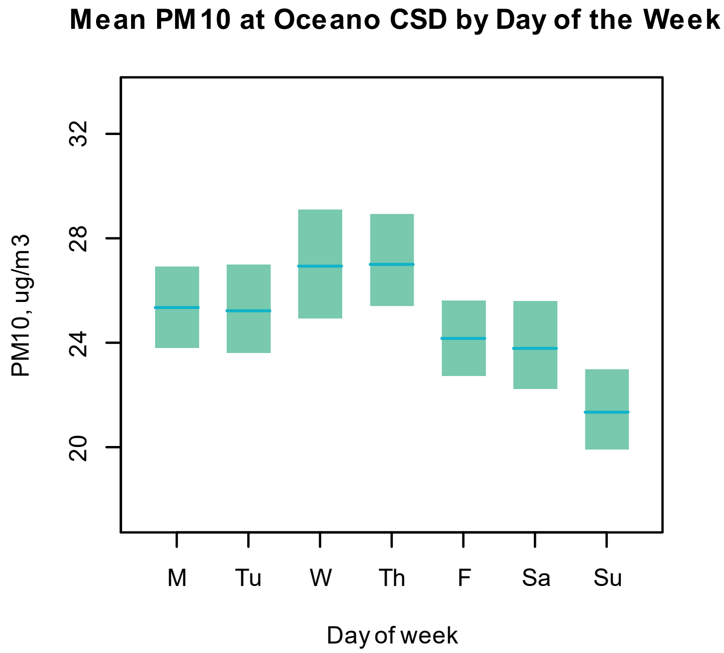

Figure 16: Mean PM_{10} at Oceano CSD by Day of the Week. 95% Confidence intervals shown in green.

Conclusions and Recommendations

In the spring of 2019, the District placed 5 particulate matter measurement devices in three locations in Oceano. The objectives of the project were to evaluate air quality in the area—particularly impacts from the ODSVRA—as well evaluate the performance of two different low-cost sensors: the IQAir's AirVisual Pro and Met One Instruments' BX-895 Real Time Particulate Monitor.

The two AirVisual Pro sensors were collocated with the regulatory monitor at the Oceano CSD yard. The two sensors had very different responses to ambient PM_{10}, with the first unit biased low by a factor of 5 and the second unit essentially unbiased and correlating well (R^2 = 0.732 for hourly data) with the regulatory monitor. This indicates that the response of the AirVisual Pro to PM_{10} is not consistent between sensors. Nonetheless, some individual sensors can be reasonably accurate, and have the potential to be used as low-cost alternatives to regulatory monitors. It is recommended that in future projects each AirVisual sensor should be collocated with a regulatory-grade PM_{10} monitor for period of time to characterize its response. Units with low sensitivity should not be used, and/or individual correction factors should be developed prior to field deployment.

The single BX-895 that was tested was also biased low by about a factor of 5 to 6, and its correlation with the regulatory particulate matter monitor was worse than both of the AirVisual Pros. As the BX-895 is more expensive, less accurate, and measures fewer parameters than the AirVisual Pro (i.e. only PM_{10}), the BX-895 will not be used in future projects.

The regulatory-grade PM_{10} monitor in Oceano collected data at the Oceano CSD yard from April 4 through October 10. Compared to other South County sites, it measured the highest background levels of PM_{10}. The elevated background levels are likely due to the influence of traffic, as evidenced by 1) the diurnal pattern having a spike around the time of the morning commute, and 2) a weekday/weekend effect, with significantly lower levels on Sundays compared with the rest of the week. Of all the regulatory monitors in southern San Luis Obispo County, the Oceano CSD monitor was closest to the roadway, so these findings are not surprising.

While background levels were highest at Oceano CSD, it was the less influenced by the windblown dust from the ODSVRA. Only 4 days exceeded the state PM_{10} standard, while over the same time period the standard was exceeded 32 times at CDF, 23 times at Mesa2, and 7 times at Nipomo Regional Park. Thus, despite having higher background levels than nearby monitoring sites, overall this site measures better air quality than the other sites in the region except Oso Flaco. On the EPA's Air Quality Index scale, air quality at the monitor was in the "Good" range for all days in the monitored period except one (April 17) when it was in the "Moderate" range.

Comparing the AirVisual Pro sites with each other, there appears to be a west-to-east gradient of PM_{10} values during windblown dust events, with higher levels of particulates on the western side of Oceano than the eastern side. This conclusion should be treated with caution, however, given the inter-unit comparison issues noted above. The responses of the individual sensors were not characterized or calibrated prior to deployment, so another possible explanation for the observed gradient could be that units have different sensitivities, and the westernmost happens to be the most sensitive, and the easternmost the least.