Maryland
Department of
the Environment

Wes Moore, Governor
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Serena McIlwain, Secretary
Suzanne E. Dorsey, Deputy Secretary

July 11th, 2023

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JUL 19 2023

Air & Radiation Division

Adam Ortiz
Regional Administrator, US EPA Region 3
Environmental Protection Agency
Four Penn Center
1600 JFK Blvd.
Philadelphia, PA 19103-2029

Dear Mr. Ortiz:

I am writing regarding the use of an alternative model to evaluate how air emissions associated with US Wind's planned Maryland Offshore Wind Project are dispersed over water. The Department has received a request by US Wind to use an alternative to the model stated in federal guidance – the Offshore Coastal and Dispersion model (Guideline on Air Quality Models, 40 CFR 51 Appendix W). Specifically, the company is seeking to use AERMOD in conjunction with AERCOARE prepared meteorological data (AERCOARE/AERMOD) as an alternative model for assessing compliance with air quality standards during the construction and operation and maintenance phases of the planned project.

The Offshore Coastal and Dispersion model contains limitations in model formulation, has technical disadvantages, and presents implementation related issues for the proposed wind project. Collectively, these issues justify the use of an alternative model. In this regard, the Department has reviewed the company's request and supports the use of the stated alternative model, and hereby seeks concurrence from the Environmental Protection Agency.

The attached document provides the detailed basis for the Department's position on the use of an alternative model. It addresses each of the five review elements contained in Appendix W to the aforementioned guideline. If there are any specific questions related to the technical aspects of this air modeling issue, please contact Ms. LiAn Zhuang of MDE-ARA at (410) 537-3122.

Sincerely,

Serena McIlwain
Secretary

cc: Cristina Fernandez, U.S. EPA Region 3 via e-mail, fernandez.cristina@epa.gov
Christopher R. Hoagland, MDE-ARA

Enclosures

Justification for the use of an alternative model to evaluate how air emissions associated with US Wind's planned Maryland offshore wind project are dispersed over water

Project Background

The Permittee is developing an offshore wind energy project of up to approximately 2 gigawatts (GW) under a federal lease. The offshore lease area is approximately 18.5 km (11.5 miles, 10 nautical miles [NM]) off the coast of Maryland. When completed, it is expected that the lease area will include up to 121 wind turbine generators (WTG), four (4) offshore substations (OSS), and one (1) meteorological tower (Met Tower). The wind farm would be interconnected to the onshore electric grid by up to four (4) new export cables into new onshore substations in Delaware.

The generation of offshore wind energy itself does not emit air contaminants. However, there will be air emissions associated with vessel engines and other equipment involved in the construction and operation and maintenance (O&M) of the wind farm. The Permittee is subject to Prevention of Significant Deterioration (PSD) permitting and is required to submit an OCS Air Permit application that includes a dispersion modeling demonstration that air emissions from the project will not cause or contribute to an exceedance of the National Ambient Air Quality Standards (NAAQS) or PSD increments.

This alternative model request addresses the proposed methodology to quantify the ambient air impacts resulting from the air emissions during construction, and operation and maintenance (O&M) activities as required by the MDE-ARA air regulations in the Code of Maryland Air Regulations (COMAR) 26.11.06.14.

Outer Continental Shelf (OCS) source emissions are defined pursuant to 40 CFR Part 55 "as emissions from OCS sources, which include certain vessels while attached to the seabed or to the project, and certain vessels traveling to and from the project when within 25 nautical miles (46.3 kilometers [km]) of the project's center (the 25-NM [46.3 km] centroid or the OCS centroid)." The construction of the wind farm would involve emission sources attached to and erected upon on the OCS. Therefore, an air permit is required by the OCS permitting rules (40 CFR Part 55). The Permittee intends to submit an application for Nonattainment New Source Review (NNSR) and PSD major source air approvals from the MDE-ARA for the construction and O&M phases of the project. The offshore wind farm is subject to both federal and state air quality regulations. Worcester County, Maryland is the nearest onshore area (NOA) for the project, and therefore Maryland air regulations and requirements are applicable.

Justification for the Use of an Alternative Model

The Permittee is seeking an approval to use the alternative model by following the process delineated in Section 3.2.2(a) and 2(b) in the "Appendix W to Part 51 - Guideline on Air Quality Models."

Sections 3.2.2(a) and (b) from Appendix W to Part 51 are cited below:

*"**a**. Determination of acceptability of an alternative model is an EPA Regional Office responsibility in consultation with the EPA's Model Clearinghouse as discussed in paragraphs 3.0(b) and 3.2.1(b). Where the Regional Administrator finds that an alternative model is more appropriate than a preferred model, that model may be used subject to the approval of the EPA Regional Office based on the requirements of this subsection. This finding will normally result from a determination that:*

(1) A preferred air quality model is not appropriate for the particular application; or

(2) a more appropriate model or technique is available and applicable.

***b**. An alternative model shall be evaluated from both a theoretical and a performance perspective before it is selected for use. There are three separate conditions under which such a model may be approved for use:*

1. If a demonstration can be made that the model produces concentration estimates equivalent to the estimates obtained using a preferred model;

2. If a statistical performance evaluation has been conducted using measured air quality data and the results of that evaluation indicate the alternative model performs better for the given application than a comparable model in appendix A; or

3. If there is no preferred model."

Although, EPA's Guideline on Air Quality Models lists the OCD model as the preferred model for over-water dispersion, the Permittee has stated that such "contains limitations in model formulation, technical disadvantages, and implementation related issues for the proposed Project that justify the use of an alternative model."

In the request letter, the Permittee has stated that the alternative model approval "*falls under Condition 3 because OCD, the preferred model, is less appropriate due to practical and theoretical model formulation issues needed for the proposed Project application. However, Condition 1 also applies because according to overwater field studies, the performance of AERCOARE-AERMOD has been found to be comparable to OCD making it a suitable alternative model for regulatory applications*."

"*AERCOARE-AERMOD includes model formulations that reflect more advanced atmospheric dispersion science compared to the OCD model. However, OCD currently has some capabilities that AERCOARE-AERMOD modeling approach does not include:*

1. OCD can simulate platform downwash – In place of OCD's simulation, US Wind will utilize the PRIME downwash algorithm in AERMOD to account for downwash from the offshore substation platforms as a solid structure.

2. OCD can simulate shoreline fumigation – Shoreline fumigation may not be a concern *for this Project given the distance from the Lease area to the coastline.*

To justify the application of an alternative model under Condition 3 in Appendix W, Section 3.2.2(e) the alternative model must meet the following conditions:

1. The model has received a scientific peer review;
2. The model can be demonstrated to be applicable to the problem on a theoretical basis;
3. The data bases which are necessary to perform the analysis are available and adequate;
4. Appropriate performance evaluations of the model have shown that the model is not biased toward underestimates; and
5. A protocol on methods and procedures to be followed has been established."

In their request letter, US Wind provided the following justification for each of the five elements contained in Appendix W, Section 3.2.2(e):

1. **The model has received a scientific peer review.**

"The EPA Region 10 approval from April 2011 indicates that the COARE model formulation implemented into AERCOARE has been published in multiple peer-reviewed journals. In its approval, EPA Region 10 confirmed the scientific legitimacy and applicability of the COARE algorithm to various over-water conditions through a sufficient body of peer-reviewed literature. The EPA Region 10 approval also documented that the algorithms in COARE are configured to handle a wide range of temperature gradient conditions including the extremes that could be found in the Arctic or the tropics.

EPA has also supported a peer-reviewed study that evaluates AERCOARE-AERMOD performance when using inputs from a prognostic meteorological model. The study examines the use of meteorological inputs from WRF-MMIF, performed similarly to AERCOARE-AERMOD modeling using measured data from buoys, in most scenarios. The poorest performing cases in this study were attributed to bias and error in the prognostic dataset due to low-resolution ocean-surface temperature data."

2. **The model can be demonstrated to be applicable to the problem on a theoretical basis.**

In the request letter, the Permittee provided a rationale showing that the model has been demonstrated to be applicable to the problem on a theoretical basis.

The Permittee referenced an EPA Region 10's approval (April 2011) along with the eight (8) additional approvals contain similar documentation which justifies that the COARE algorithm is applicable on a theoretical basis.

The documentation included in approvals is contained at:

"Version 3.0 of the COARE algorithm with journal references and a User's Manual can be accessed at:

ftp://ftp.etl.noaa.gov/users/cfairall/wcrp_wgsf/computer_programs/cor3_0/

and

http://www.coaps.fsu.edu/COARE/flux_algor/
These references provided copies of the code, descriptions of the scientific basis for the code, and detailed descriptions on how to use the COARE program. However, Shell acknowledges that COARE was not specifically designed to provide an input file for AERMOD, and there are certain steps that must be taken to produce the input files for AERMOD.

As stated in the request letter, the current AERCOARE User Manual also states:

"AERCOARE uses Version 3.0 of the COARE algorithm that has been updated several times since the initial international TOGA-COARE field program in the western Pacific Ocean from November 1992 to February 1993.

The basic algorithm uses air-sea temperature difference, overwater humidity, and wind speed measurements to estimate the sensible heat, latent heat, and momentum fluxes. The original algorithm was based on measurements in the tropics with winds generally less than 10 m/s but has since been modified and extensively evaluated against measurements in high latitudes with winds up to 20 m/s. Based on these studies, AERCOARE is expected to be appropriate for marine conditions found at all latitudes including the Arctic."

The review of Fairall et al., 2003 shows that Version 3 of the COARE algorithm was developed in part based on data obtained during the Fronts and Atlantic Storms Experiment (FASTEX) dataset; the FASTEX dataset was obtained in part off the coast of New Brunswick, Canada.

Also, the Permittee referenced and stated that the limitations of the algorithms that OCD uses have been documented by the EPA in the AERCOARE User's Manual V1.0:

"The current EPA guideline model for offshore sources is the OCD model. OCD has not been updated for many years and several of the dispersion model components and procedures are not consistent with AERMOD. The AERMOD modeling system is the U.S. EPA-recommended approach for assessing the near-source (< 50 km) impacts of new or modified sources as part of the New Source Review (NSR) and Prevention of Significant Deterioration (PSD) programs. The modeling system includes an AERMET meteorological processor that processes overland meteorological data for input to AERMOD.

Important routines in OCD that are independent of the onshore/offshore setting are inconsistent with current regulatory practices as embodied within AERMOD, namely:

- *OCD does not contain routines for processing either missing data or hours of calm meteorology. Such processing must be performed with a custom post-processing program.*
- *OCD does not contain the latest regulatory PRIME downwash algorithm (Schulman, L. L. et al., 2000). Many offshore sources are located on ships where downwash effects are important.*
- *The PVMRM and OLM methods are not included in OCD. These techniques are crucial for assessing the new 1-hour NO_2 ambient standard.*
- *The new 24-hour $PM_{2.5}$, 1-hour NO_2, and 1-hour SO_2 ambient standards are based on the 98th, 98th, and 99th percentile concentrations, respectively. These probabilistic standards and the EPA methods recommended for estimating design concentrations must be obtained by post-processing the hourly OCD output files. Such calculations are included in AERMOD.*
- *OCD does not contain a volume source routine and the area source routine only considers circular areas without allowance for any initial vertical dispersion.*
- *Although OCD contains routines to simulate the boundary layer over the ocean, the surface energy flux algorithms are outdated and have been replaced within the scientific community by the COARE air-sea flux algorithms."*

In addition, in their request letter, the Permittee provided more specific evidence of other alternative model approvals. In particular, the Permittee referenced the EPA's Region 1 and 2 approvals (year 2022) for the use of AERCOARE/AERMOD for the Atlantic Shores and Coastal Virginia Offshore Wind Projects. Both EPA regions deemed the use of the alternative model to be appropriate on a theoretical basis for use in the marine environment off the coast of New Jersey and Virginia. Based on these approvals, the use of AERMOD-AERCOARE is also justifiable on a theoretical basis for the assessment of air emissions originating in the planned wind project.

3. **The data bases which are necessary to perform the analysis are available and adequate.**

In the request letter, the Permittee provided a rationale showing that the database to perform the evaluation of AERCOARE as an alternative model is available and accurate.

The Permittee shared information about various datasets. First, the Permittee referenced datasets involving trace gas studies. In addition, the Permittee also referenced approvals by EPA Regions 10 and 1 using available datasets.

As stated in the request letter "*there are four comprehensive historical overwater dispersion datasets available in the record that involve study of air pollutant dispersion in the marine atmospheric boundary layer. The following four tracer gas studies from the 1980s have been used in performance evaluations of OCD, CALPUFF, and*

AERCOARE/AERMOD:

1. Cameron, Louisiana: July 1981 and February 1982 (Dabberdt, Brodzinsky, Cantrell, & Ruff, 1982)

2. Carpinteria, California: September 1985 (Johnson & Spangler, 19869)

3. Pismo Beach, California: December 1981 and June 1982 (Schacher, et al., 1982)

4. Ventura, California: September 1980 and January 1981 (Schacher, et al., 1982)

The EPA Region 10 alternative model approval of AERCOARE/AERMOD utilized tracer gas experiments from the four studies listed above. In all the previous approvals, EPA determined that these datasets were adequate for verification of the AERCOARE/AERMOD system."

These traced studies were also referenced by Vineyard Wind in their alternative model approval request to EPA Region 1, supporting the belief that these studies were sufficiently representative of the marine environment off the coast of Massachusetts. Region 1 concluded that the meteorological datasets used to develop AERCOARE, and the four tracer studies used in the evaluation were sufficiently available and adequate for determining the effectiveness of the modeling approach."

The Permittee is also taking a similar approach and provides statistics for key meteorological parameters for the Ocean City Inlet Buoy station and Delaware Bay 26 NM Buoy station (#44009) located in the Project area. The Delaware Bay 26 NM buoy is located 14 kilometers northeast of the Project centroid and is the nearest offshore meteorological station. The Ocean City Inlet buoy is located 29 km west of the Project centroid.

This data is summarized and presented in Table 1 of the Permittee's request letter. Table 1 summarizes key meteorological data and compares them to data from the tracer studies. *The data demonstrates that the range of atmospheric conditions that typically occur in the Ocean City, Maryland offshore region fit the range of conditions used to develop and verify the COARE 3.0 algorithm.*

The Delaware Bay and Ocean City Inlet buoy air-sea temperature gradient data and wind data from the period 2017-2021 were obtained for comparison to the range of conditions used to develop the COARE 3.0 algorithm and the conditions during the four tracer experiments. Data statistics are provided on the distribution of wind speed and air-sea temperature differences from the four tracer studies, consisting of a total of 101 hourly observations. The maximum hourly average wind speed measured at the Delaware Bay buoy was 23.1 m/s and the 99.9th percentile of wind speed was 18.4 m/s. The maximum hourly average wind speed measured at the Ocean City Inlet buoy was 19.0 m/s. The COARE algorithm was developed and verified with conditions up to 20 m/s.

Therefore, more than 99.9 percent of the Delaware Bay offshore winds are within the COARE evaluation wind speed range and 100 percent of the Ocean City offshore winds are with the COARE evaluation wind speed range. The highest wind speeds that exceed the values in the COARE evaluation range will be associated with highly dispersive conditions such that maximal predicted concentrations will not be a consideration at the wind speeds in excess of the range.

The maximum wind speed in the four tracer studies was 12.7 m/s, during the Pismo Beach study. Average wind speeds during each study ranged from 2.5 to 6.1 m/s. Average wind speed at the Delaware Bay and Ocean City Inlet buoys was 6.3 m/s and 4.1 m/s, respectively. Highest concentrations from the Project are likely to occur during lower wind speeds. The range of wind speed conditions observed during the tracer experiments covers the range of conditions when the maximum project concentrations are expected.

Because the air-sea temperature difference is an important parameter in characterizing the marine boundary layer, a comparison of the air-sea temperature difference at the Delaware Bay and Ocean City buoys was made with the air-sea temperature differences observed in the evaluation tracer studies. Thus, the datasets were examined visually using box and whisker plots. Box and whisker plots are one way of comparing datasets to ascertain the distribution.

The box and whisker plots for wind speed for Delaware Bay, Ocean City Inlet, and the four validation datasets were plotted, and broadly they show that wind speeds at Delaware Bay and Ocean City are moderately higher than those observed during the validation studies. This is one reason the COARE algorithm utilized the Fronts and Atlantic Storm (FASTEX) dataset as it generally contained higher wind speeds than were observed at tropical latitudes. In other words, the COARE algorithm implemented into AERCOARE was specifically evaluated against a higher wind speed dataset to make it more globally applicable. The Box and Whisker Plots for Wind Speed are shown in Figure 2a and 2b.
Similarly, box and whisker plots were used to examine the distribution of the air/sea temperature difference between Delaware Bay, Ocean City, and the four validation studies. The median of the Delaware Bay and Ocean City datasets is similar to the median air/sea temperature difference in the four validation studies and the 25th and 75th percentiles are similar to what was measured during the validation studies. The air/sea temperature difference seen in mid-Atlantic is similar to what was observed during the validation studies. The box and whisker plots for air/sea temperature difference are shown in Figures 3a and 3b. The four tracer studies evaluated do cover a range of wind and temperature gradient conditions and represent the majority of the range of conditions that occur at the Project site, as inferred through the Delaware Bay and Ocean City datasets. Most importantly, the low wind speed conditions that are most likely to result in highest predicted concentrations are well addressed in the tracer studies.

The Permittee concluded that "*the databases available occur under a wide range of* *overwater atmospheric stabilities that might be expected in coastal waters regardless of the latitude, the COARE algorithm implemented in AERCOARE was developed to be applicable for water temperatures from the tropics to the arctic, the COARE algorithm has been validated against local meteorological datasets to specifically account for those conditions. It can be concluded that the necessary datasets to evaluate the AERCOARE are available and are adequate and that the meteorological inputs needed to populate AERCOARE are available and adequate*."

4. **Appropriate performance evaluations of the model have shown that the model is not biased toward underestimates.**

In the request letter, the Permittee provided a rationale showing that appropriate performance evaluations of the model have shown that the model is not biased toward underestimates.

The Permittee shared information about the AERCOARE performance evaluations. The Permittee referenced two model evaluation documents: (1) April 1, 2011, memorandum from EPA Region 10 (April 1, 2011); and (2) EPA/ENVIRON Model Evaluation Study (October 2012). The results of both model performance evaluations indicated the model is not biased toward underestimates.

As documented in the Model Evaluation Study (Oct 2012), "*AERCOARE Version 1.0 (12275) was applied to prepare the overwater meteorological data for the Cameron, Louisiana, and the Pismo Beach, California offshore datasets. AERCOARE simulations were conducted using five different methods for the preparation of the meteorological data, including the estimation of mixing heights, the use of horizontal wind direction (sigma theta data), and limitations on other variables provided to AERMOD to calculate concentrations from the field studies*."

"*For both evaluation studies, AERMOD was run using AERCOARE along with default options for rural flat terrain for both simulations. Quantile-quantile (Q-Q) plots were prepared based on a comparison of independently ranked modeled versus observed concentrations. A Q-Q plot is a useful tool for determining if a model has an underprediction bias especially at the upper end of the observed concentration profile. Figure 4 and Figure 5 provide Q-Q plots for the Cameron, Louisiana, and Pismo Beach, California datasets, respectively. The AERCOARE-AERMOD modeled concentrations are biased toward over-prediction for the highest concentrations, with less than a factor of 2 underprediction bias at the lower concentrations*."

"*Importantly, AERCOARE-AERMOD does not appear to be biased toward underestimates for the higher end of the frequency distribution, regardless of the five different meteorological preparation options examined in this study.*"

In EPA Region 1's review of Park City Wind, examination of whether the use of prognostic meteorological data generated by WRF could result in systematic underprediction of concentrations, lead to the following conclusions:

“Additionally, Region 1 reviewed U.S. EPA (2015) to see if the WRF-MMIF inputs for AERCOARE resulted in underprediction. U.S. EPA (2015) used the four overwater dispersion study datasets listed above to compare AERCOARE/AERMOD predicted concentrations against the measured concentrations from the campaigns.”

“*This study also compared results across a set of combinations of WRF-MMIF inputs and settings. The results of this study show AERCOARE/AERMOD driven by WRF-MMIF inputs resulted in the high-end of the distribution of concentrations exceeding the measured concentrations in the Pismo and Ventura studies. Concentrations agreed well for the Carpinteria study at the high-end of the distribution in most cases. In the Cameron study, and under some of the scenarios in the Carpinteria study, the modeling resulted in underpredictions at the high-end of the distribution in some scenarios. Namely, when mixing heights were diagnosed by MMIF, instead of using the mixing heights directly from WRF, AERCOARE/AERMOD concentrations were underpredicted in some cases. The model runs using WRF-simulated mixing heights performed better, when compared to measured concentrations. Overall, however, the U.S. EPA (2015) study noted concentration bias could be attributed mainly due to error in sea-surface temperatures output from the WRF model.”*

A key element of both the original Region 10 approval study, and the U.S. EPA (2015) study was an evaluation of the sensitivity of the modeling results to a minimum mixing height. The Region 10 approval found AERCOARE/AERMOD results were highly overpredicted when using AERMOD’s default minimum mixing height of 1 meter. “*EPA Region 10’s sensitivity study, summarized in ENVIRON (2012) found a minimum mixing height of 25 meters for overwater applications was more physically realistic and resulted in better model performance. The EPA Region 10 approval allowed for the use of a minimum mixing height of 25 meters for the application of AERCOARE/AERMOD and a minimum limit on the absolute value of Monin-Obukhov Length of 5 meters. These limits are recommended in the EPA’s AERCOARE User’s Guide11.*

Based on the findings from the studies reviewed in the prior EPA approvals and the additional WRF-MMIF- based study, Region 1 concludes it is evident the AERCOARE/AERMOD approach does not result in systematic underprediction of concentrations. Instead, the evidence more likely leads to the conclusion the approach is conservative.”

The Permittee proposes to use 12-km WRF data and MMIF for 2019-2021. The proposed AERCOARE settings will include the recommendations of 25 meters for the minimum mixing height and a minimum Monin-Obukhov length of 5 meters.

5. **A protocol on methods and procedures to be followed has been established.**

The Permittee submitted a modeling protocol on September 16, 2022, to MDE proposing the use of the OCD model.

"*The modeling protocol included a description of modeling methodologies and procedures consistent with the Guideline on Air Quality Models (Appendix W of 40 CFR 51). The modeling protocol has been updated to reflect the use of AERCOARE-AERMOD, which was submitted concurrently to MDE and EPA with this alternative model request.*

US Wind requested prognostic (i.e., WRF data) data from EPA Office of Air Quality Planning and Standards (OAQPS) which was received on February 9, 2023. EPA processed the WRF data using the MMIF (Version 4.0) to convert the WRF prognostic meteorological data (2019-2021) into a format suitable for dispersion modeling applications. The EPA utilized the default settings for AERCOARE processing (i.e., settings specific to AERMET are not applicable) as provided in the User's Manual to the Mesoscale Model Interface Program, Version 4.0 (June 9, 2022)."

The Permittee intends to run AERCOARE using the following settings recommended in EPA's AERCOARE User's Guide, as specified below:

1. The default threshold wind speed will be used to identify calm hours (i.e., WSCALM = 0.5 m/s). Wind speeds below this value will be considered calm;
2. Mixing heights provided by WRF-MMIF will be used, instead of calculated by AERCOARE. The default minimum mixing height of 25 meters will be assigned.
3. Warm layer and cool-skin effects will not be considered.
4. Friction velocity will be determined from wind speed only; wave-height will not be considered.

"*The AERCOARE parameters noted above were previously approved by EPA Regions 2 and 3 and EPA OAQPS in their approvals of the Alternative Model Request for the Dominion Coastal Virginia Offshore Wind- Commercial Wind Farm and Atlantic Shores Projects*."

Summary

MDE ARA performed a detailed technical and procedural review of contents in the Permittee's request for the approval of an alternative model. In their request, the Permittee provided justification that supports the use of AERCOARE-AERMOD as an alternative model, in lieu of OCD, for the evaluation of air emission impact originating from the planned wind project. Based on the justification and recent precedents for approving AERCOARE- AERMOD in the Atlantic OCS, the Permittee proposes the use of AERCOARE-AERMOD as an alternative model for the OCS air permit application. The request provided the necessary details to evidencing that the proposed modeling approach satisfies each of the five elements contained in Appendix W, Section 3.2.2(e) of the Guideline required for alternative model approvals. MDE-ARA believes for the reasons described previously that the use of AERCOARE-AERMOD is justified for this evaluation.

March 10, 2023

Ms. Suna Y. Sariscak
Manager, Air Quality Permits Program
suna.sariscak@maryland.gov
Maryland Department of the Environment
1800 Washington Blvd.
Baltimore, MD 21230

Re: Request for Approval for Use of the Alternative Model AERMOD/AERCOARE and Revised Air Quality Modeling Protocol for Modeling of the Maryland Offshore Wind Project – US Wind, Inc.

Dear Ms. Sariscak:

US Wind, Inc. (US Wind) is developing the Maryland Offshore Wind Project (the Project), an offshore wind energy project of up to approximately 2 gigawatts (GW) of nameplate capacity within the area described in OCS-A 0490 (the Lease), a Lease area of approximately 80,000 acres located approximately 18.5 km (11.5 miles, 10.0 nautical miles [nm]) off the coast of Maryland on the outer continental shelf (OCS). The Project Design Envelope (PDE) includes up to 121 wind turbine generators (WTG), up to four (4) offshore substations (OSS), and one (1) meteorological tower (Met Tower) located in the Lease area. The Project will be interconnected to the onshore electric grid by up to four (4) new 230-275 kV export cables into new onshore substations in Delaware. US Wind is required by the OCS Air Regulations in 40 Code of Federal Regulations (CFR) Part 55.4, to obtain an air permit for the proposed construction and operation and maintenance (O&M) of the Project.

In accordance with the United States Environmental Protection Agency's (EPA) Outer Continental Shelf (OCS) air regulations (40 CFR Part 55) and the Prevention of Significant Deterioration (PSD) permitting regulations (40 CFR Part 52.21), the Project expects to perform an ambient air impact analysis. Based on feedback from the Maryland Department of the Environment provided on December 27, 2022 in comments on the September 16, 2022 Air Quality Modeling Protocol, US Wind is hereby requesting approval to use AERMOD in conjunction with AERCOARE prepared meteorological data (AERCOARE/AERMOD) as an alternative model for assessing compliance with air quality standards for the Project emission sources located over water in lieu of the OCD model, which is the Guideline on Air Quality Models (40 CFR 51 Appendix W) preferred model for over-water dispersion. US Wind is also providing the attached revised Air Quality Modeling Protocol that addresses all of the MDE comments received on December 27, 2022, and proposes the use of AERCOARE/AERMOD.

Please contact me at 410-340-9428 or l.jodziewicz@uswindinc.com if you have any questions regarding this request.

Sincerely,

Laurie Jodziewicz
Senior Director of Environmental Affairs
US Wind, Inc.

Attachment: US Wind – Maryland Offshore Wind Project: Air Quality Modeling Protocol (Revised March 2023)

cc:

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Philadelphia, PA 19103-2029
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Request for Approval for Use of the Alternative Model AERMOD/AERCOARE for Offshore Modeling of Maryland Offshore Wind Project - US Wind, Inc.

Introduction

US Wind, Inc. (US Wind) is developing the Maryland Offshore Wind Project, an offshore wind energy project of up to approximately 2 gigawatts (GW) of nameplate capacity within OCS-A 0490 (the Lease), a federal lease for offshore wind energy development on the OCS. The area within the Lease is approximately 80,000 acres located approximately 18.5 km (11.5 miles, 10 nautical miles [NM]) off the coast of Maryland. The Project Design Envelope (PDE) includes up to 121 wind turbine generators (WTG), up to four (4) offshore substations (OSS), and one (1) meteorological tower (Met Tower) located in the Lease area. The Project would be interconnected to the onshore electric grid by up to four (4) new export cables into new onshore substations in Delaware.

The generation of offshore wind energy itself does not emit air contaminants. However, there will be air emissions associated with vessel engines and other equipment involved in the construction and operation and maintenance (O&M) of the Project. US Wind is subject to Prevention of Significant Deterioration (PSD) permitting and is required to submit an OCS Air Permit application that includes a dispersion modeling demonstration that air emissions from the Project will not cause or contribute to an exceedance of the National Ambient Air Quality Standards (NAAQS) or PSD increments. The NAAQS have been established for six pollutants designated by the EPA as “criteria pollutants”. The criteria pollutants are carbon monoxide (CO), lead (Pb), nitrogen dioxide (NO_2), ozone (O_3), particulate matter (PM), and sulfur dioxide (SO_2). PM is characterized according to size; PM having an effective aerodynamic diameter of 10 microns or less is referred to as PM_{10}, or “respirable particulate.” PM having an effective aerodynamic diameter of 2.5 microns or less is referred to as $PM_{2.5}$, or “fine particulate”; $PM_{2.5}$ is a subset of PM_{10}.

This alternative model request addresses the proposed methodology to quantify the ambient air impacts resulting from the air emissions during Project construction and operation and maintenance (O&M) activities as required by the Maryland Department of the Environment (MDE) air regulations at 26 Code of Maryland Air Regulations (COMAR) 11.06.14. OCS source emissions are defined pursuant to 40 CFR Part 55 as emissions from OCS sources, which include certain vessels while attached to the seabed or to the Project, and certain vessels traveling to and from the Project when within 25 nautical miles (46.3 kilometers [km]) of the Project’s center (the 25-NM [46.3 km] centroid or the OCS centroid). Construction of the Project would involve emission sources attached to and erected upon on the OCS; therefore, an air permit is required by the OCS permitting rules (40 CFR Part 55). US Wind intends to submit an application for a Nonattainment New Source Review (NNSR) and Prevention of Significant Deterioration (PSD) major source air permit from the MDE for the construction and O&M of the Project.

The Project is subject to both federal and state air quality regulations. Worcester County, Maryland is the nearest onshore area (NOA) for the Project, and as it is expected that the NOA will also be the designated corresponding onshore area (COA) per 40 CFR § 55.5. The Project will be subject to the applicable requirements of Title 26 of the COMAR Subtitle 11, which have been incorporated into 40 CFR Part 55 by reference and have been listed in Appendix A of the OCS Air Regulations. While the Project is subject to the federal OCS regulations as administered by MDE through an authorization by the United States Environmental Protection Agency (EPA), most of the Project is located within 25 NM of the NOA's seaward boundary, therefore the COA's applicable air quality rules must be addressed in addition to the federal rules that apply throughout the OCS. Figures 1a and 1b depict the distances from the centroid of the Project area to several nearby onshore locations.

Figure 1a. Distances to Corresponding Onshore Area

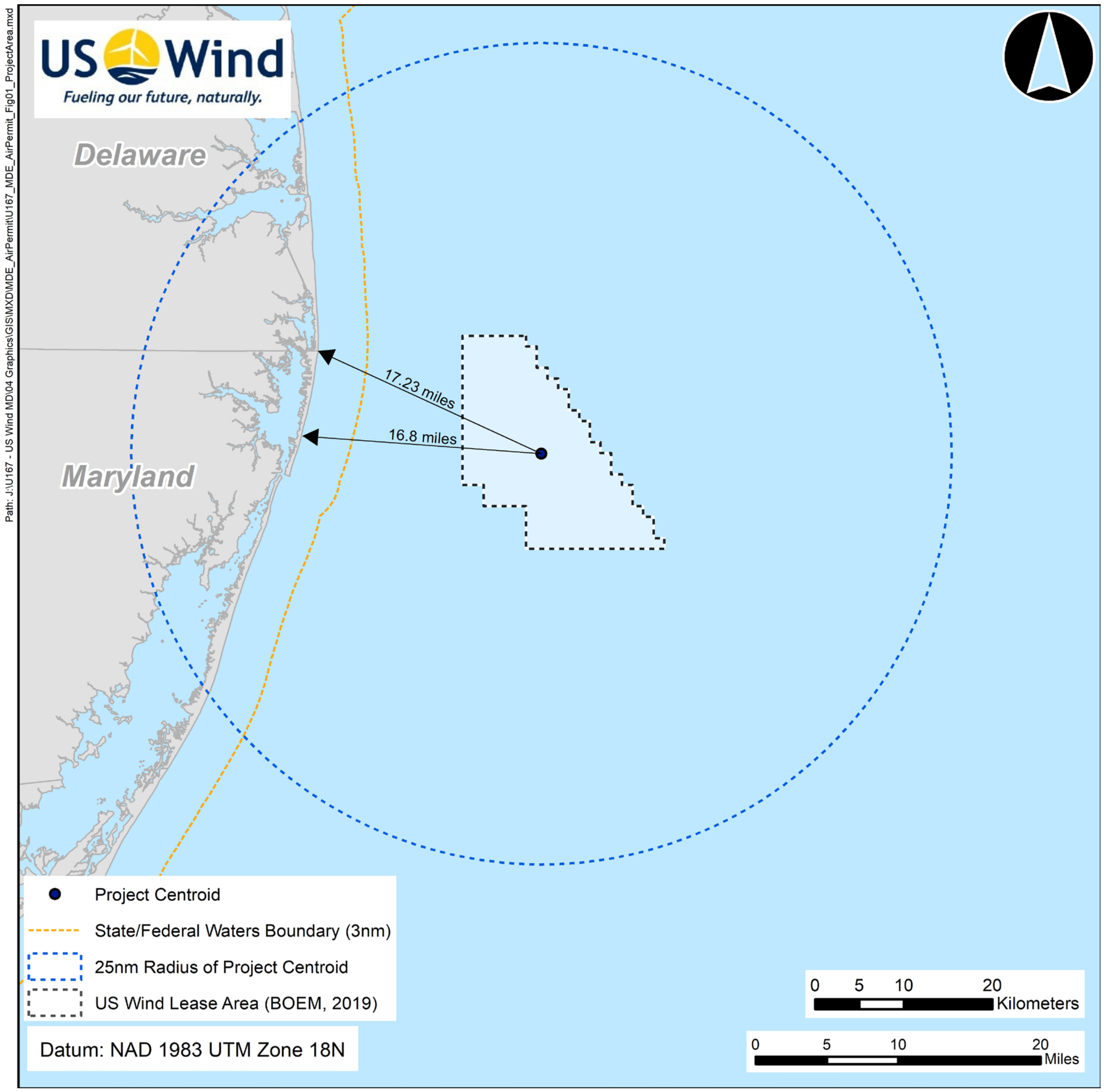
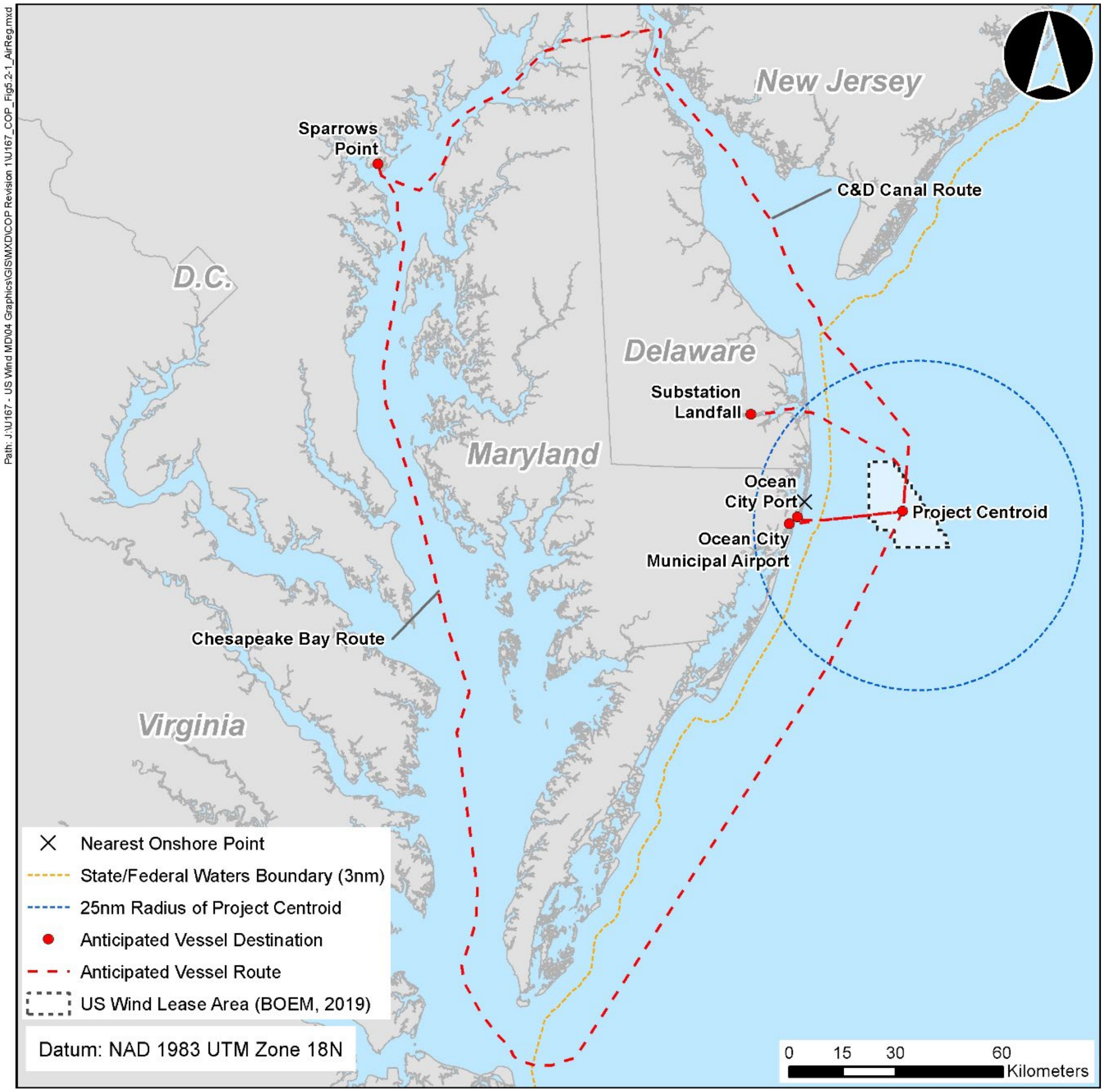


Figure 1b. Project Location of Maryland Offshore Wind Project



US Wind expects that emissions of one or more criteria air pollutants would exceed the pollutant specific PSD/NNSR significant emission rates (SER) and, consequently, an air dispersion modeling analysis will be required for these pollutants. Furthermore, an air quality assessment to determine the potential impact of the project emissions on the National Ambient Air Quality Standards (NAAQS) will be required. The air quality analysis will be required to demonstrate that the Project will be compliant with all applicable PSD increment levels and NAAQS.

EPA's Guideline on Air Quality Models[1] ("Guideline") lists the Offshore and Coastal Dispersion (OCD) model as the preferred model for over-water dispersion. As is discussed in this request, OCD contains limitations in model formulation, technical disadvantages, and implementation related issues for the proposed Project that justify the use of an alternative model. US Wind proposes to use the Coupled Ocean-Atmosphere Response

[1] https://www.epa.gov/sites/default/files/2020-09/documents/appw_17.pdf

Experiment (COARE) bulk flux algorithm as implemented within the AERCOARE program, which is intended for use within AERMOD, for this alternative model approval request. AERCOARE is requested as an alternative to replace the regulatory AERMET preprocessor program that is specifically designed for applications over land. The AERCOARE processor will read and process overwater meteorological data using the COARE methodology designed for marine applications. The output from AERCOARE can then be input to AERMOD for modeling applications in a marine environment.

The COARE bulk flux algorithm consists of equations that utilize air-sea temperature difference, overwater humidity and wind speed to parameterize the boundary layer parameters such as sensible heat, latent heat, and momentum fluxes. Although the COARE algorithm was originally developed based on measurements in the tropics, it has since been improved, expanding its applicability outside of tropical environments. The meteorological preprocessor, AERCOARE, which implements Version 3.0 of the COARE algorithms, is used to generate model-ready meteorological data for use with AERMOD, which is the current EPA preferred model for short-range (within 50 kilometers) dispersion modeling.

EPA's Support Center for Regulatory Atmospheric Modeling (SCRAM) lists AERCOARE[2] as an alternative model and states that the output from AERCOARE can be used by AERMOD in a marine environment.
The SCRAM website indicates that, an AERMOD-COARE approach was approved by EPA Region 10, with concurrence from the EPA Model Clearinghouse, as an alternative model to OCD for application in an Arctic ice-free environment. In that application, the COARE algorithm was applied to overwater measurements and the results assembled in a spreadsheet. AERCOARE replaces the need for post- processing with a spreadsheet, provides support for missing data, adds options for the treatment of overwater mixing heights, and can consider many different input data formats.

On April 1st, 2011, EPA Region 10 granted approval for the use of output from the COARE algorithm coupled with AERMOD to estimate ambient air pollutant concentrations in an ice-free marine environment[3,4]. Since the EPA Region 10 approval in May 2011, there have been eight (8) additional EPA Model Clearinghouse approvals to use AERMOD-AERCOARE. As enumerated below, all but one of the approvals are for offshore wind energy projects:

- November 2019, EPA Region 6, Sea Port Oil Terminal (SPOT), Gulf of Mexico
- January 2022, EPA Region 1, Vineyard Wind, OCS off the coast of Martha's Vineyard, MA
- July 2022, EPA Region 1, Park City Wind, OCS off the coast of Martha's Vineyard, MA
- July 2022, EPA Region 2, Empire Wind, OCS off the coast of Long Island, New York
- July 2022, EPA Region 2, Atlantic Shores, OCS off the coast of New Jersey
- November 2022, EPA Region 3, Dominion Coastal Virginia Offshore Wind-Commercial wind farm project, OCS off the coast of Virginia
- December 2022, EPA Region 1, Beacon Wind, OCS off the coast of Massachusetts
- December 2022, EPA Region 1, Mayflower Wind, OCS off the coast of Massachusetts

As documented in all of the recent approvals (including the most representative of the US Wind Maryland

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[2] https://www.epa.gov/scram/air-quality-dispersion-modeling-related-model-support-programs

[3] COARE Bulk Flux Algorithm to Generate Hourly Meteorological Data for Use with the AERMOD Dispersion Program; Section 3.2.2.e Alternative Refined Model Demonstration, Herman Wong, EPA to Tyler Fox, EPA, April 1, 2011.

[4] Model Clearinghouse Review of AERMOD-COARE as an Alternative Model for Application in an Arctic Marine Ice-Free Environment, George Bridgers, EPA to Herman Wong, EPA, May 6, 2011.

Project, which is the Dominion Coastal Virginia Offshore Wind Project off the coast of Virginia), the AERCOARE-AERMOD model was approved for use in an arctic marine ice-free environment because it satisfied the five criteria contained in Section 3.2.2.e of EPA's Guideline. In each concurrence memorandum, the EPA Model Clearinghouse stated that its concurrence with the approvals did not constitute a generic approval of AERCOARE-AERMOD for other applications. US Wind's alternative model approval request for use of AERCOARE-AERMOD follows the format of previous requests.

Based on the proposed Project location, recent approvals of AERCOARE-AERMOD in the same geographic region, and the following technical advantages, options, and features available in the model, AERCOARE-AERMOD is being proposed as the preferred model in this request.

1. The Plume Rise Model Enhancements (PRIME) downwash algorithm can be used to assess impacts in the cavity and wake regions of structures. While the AERMOD model does not incorporate platform downwash, US Wind has proposed use of PRIME considering the platform as a solid structure which will result in conservative, overprediction of concentrations.

2. The use of EPA Tier 2 and 3 NO_X modeling options are not available in OCD but could be utilized with an AERCOARE-AERMOD approach. Specifically, the Ambient Ratio Method (ARM2), Plume Volume Molar Ratio Method (PVMRM) and Ozone Limiting Method (OLM) could be used by the Project to estimate the conversion of NO_X to NO_2.

3. Output can be generated in the statistical form that is needed to assess compliance with the newer percentile-based NAAQS, such as 1-hour NO_2, SO_2 and 24-hour $PM_{2.5}$.

4. AERMOD-AERCOARE has the capability of handling a wider array of source configurations and does not limit the number of modeled sources compared to OCD, including multiple line sources, and more than 5 areas sources within the same model run.

5. The AERMOD-AERCOARE model can model volume sources, whereas OCD cannot.

6. Calm wind conditions can be processed by the AERMOD-AERCOARE model, whereas OCD cannot.

7. The dispersion algorithms used in the AERMOD portion of AERCOARE-AERMOD are considered state-of-art by EPA. OCD dispersion algorithms have not been updated to account for current advancements in boundary layer physics.

8. AERCOARE-AERMOD does not have a limit on the number of receptors that can be considered in an analysis, whereas OCD does limit the total number of receptors.

9. AERCOARE has the capability to utilize prognostic data from the Weather Research and Forecasting (WRF) model and output from the Mesoscale Model Interface (MMIF) program.

10. AERMOD incorporates options for the inclusion of varying ambient background concentrations by season and hour of day during the model run. In contrast, OCD does not have an option to incorporate ambient background concentrations within the model. Ambient background concentrations could be applied to the OCD predicted concentrations in a postprocessing step. A custom postprocessor for OCD would need to be developed.

11. Unlike OCD, AERMOD does not include algorithms to evaluate shoreline fumigation conditions. However, shoreline fumigation is not expected to be an important impact consideration for the Project emission sources. Shoreline fumigation can occur when plumes traveling in relatively stable air near the shoreline encounter the thermal internal boundary layer (TIBL) and fumigate downward, potentially resulting in elevated pollutant concentrations at the ground. The TIBL is the boundary layer that can form between the more stable over-water air mass and the less stable over-land air mass and typically forms during sea breeze conditions. EPA modeling guidance indicates that shoreline fumigation can be an important phenomenon on and near the shoreline of bodies of water for sources with tall stacks located on or just inland of a shoreline. However, the Project emissions (primarily vessels) are emitted from stacks with low release heights that will generally be located far offshore (the Project site is located 18.5 km offshore). Exhaust plumes are expected to be substantially dispersed before encountering the TIBL and potential fumigation conditions. Therefore, shoreline fumigation is not expected to be an important impact condition for Project emissions and is not proposed to be specifically evaluated for the air quality analysis.

Alternative Model Justification

Section 3.2.2 of EPA's Guideline provides an approach for approval of an alternative model to determine whether it is more appropriate for a given application. Section 3.2.2 states that the request for an alternative approach must meet one of the following three (3) conditions:

1. If a demonstration can be made that the model produces concentration estimates equivalent to the estimates obtained using a preferred model;
2. If a statistical performance evaluation has been conducted using measured air quality data and the results of that evaluation indicate the alternative model performs better for the given application than a comparable model; or
3. If the preferred model is less appropriate for the specific application, or there is no preferred model.

US Wind's alternative model approval request falls under Condition 3 because OCD, the preferred model, is less appropriate due to practical and theoretical model formulation issues needed for the proposed Project application. However, Condition 1 also applies because according to overwater field studies[5], the performance of AERCOARE-AERMOD has been found to be comparable to OCD making it a suitable alternative model for regulatory applications.

AERCOARE-AERMOD includes model formulations that reflect more advanced atmospheric dispersion science compared to the OCD model. However, OCD currently has some capabilities that AERCOARE-AERMOD modeling approach does not including:

1. OCD can simulate platform downwash – In place of OCD's simulation, US Wind will utilize the PRIME downwash algorithm in AERMOD to account for downwash from the offshore substation platforms as a solid structure.

2. OCD can simulate shoreline fumigation - Shoreline fumigation is not a concern for this Project given the distance from the Lease area to the coastline, and therefore the simulation is not necessary.

To justify the application of an alternative model under Condition 3 in Appendix W, Section 3.2.2.e, the

[5] AERCOARE: An Overwater Meteorological Preprocessor for AERMOD, Wong, Herman, et. al, Journal of the Air & Waste Management Association, 2016, Vol 66, No 11, 1121-1140.

alternative model must meet the following conditions:

1. The model has received a scientific peer review;
2. The model can be demonstrated to be applicable to the problem on a theoretical basis;
3. The data bases which are necessary to perform the analysis are available and adequate;
4. Appropriate performance evaluations of the model have shown that the model is not biased toward underestimates; and
5. A protocol on methods and procedures to be followed has been established.

US Wind provides the following justification for each of the five elements contained in Section 3.2.2.e.

1. The model has received a scientific peer review.

The EPA Region 10 approval from April 2011 indicates that the COARE model formulation implemented into AERCOARE has been published in multiple peer-reviewed journals[6]. In its approval, EPA Region 10 confirmed the scientific legitimacy and applicability of the COARE algorithm to various over-water conditions through a sufficient body of peer-reviewed literature. The EPA Region 10 approval also documented that the algorithms in COARE are configured to handle a wide range of temperature gradient conditions including the extremes that could be found in the Arctic or the tropics.

EPA has also supported a peer-reviewed study that evaluates AERCOARE-AERMOD performance when using inputs from a prognostic meteorological model. The study examines the use of meteorological inputs from WRF-MMIF, performed similarly to AERCOARE-AERMOD modeling using measured data from buoys, in most scenarios. The poorest performing cases in this study were attributed to bias and error in the prognostic dataset due to low-resolution ocean-surface temperature data[7].

2. The model can be demonstrated to be applicable to the problem on a theoretical basis.

The EPA Region 10, April 2011 approval along with the eight (8) additional approvals contain similar documentation which justifies that the COARE algorithm is applicable on a theoretical basis.

The documentation included in approvals is contained below:

"Version 3.0 of the COARE algorithm with journal references and a User's Manual can be accessed at: ftp://ftp.etl.noaa.gov/users/cfairall/wcrp_wgsf/computer_programs/cor3_0/ and http://www.coaps.fsu.edu/COARE/flux_algor/

These references provided copies of the code, descriptions of the scientific basis for the code, and detailed descriptions on how to use the COARE program. However, Shell acknowledges that COARE was not specifically designed to provide an input file for AERMOD, and there are certain steps that must be taken to produce the input files for AERMOD.

Communication with Ken Richmond of ENVIRON and marine boundary layer experts Dr. Andrey Grachev and Dr. Chris Fairall from the National Oceanic and Atmospheric Administration (NOAA) provided the following insight:

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[6] http://www.coaps.fsu.edu/COARE/

[7] Combined WRF/MMIF/AERCOARE/AERMOD Overwater Modeling Approach for Offshore Emission Sources, Vol. 2. EPA 910-R-15-001b, October 2015.

From Dr. Chris Fairall:

The original COARE version (2.5) (and the 2003 version (3.0)) was set up so that it could handle water and air temperatures from the tropics to the Arctic. Parameters such as the kinematic viscosity of air have T dependencies. I have listed below a few references to Arctic applications I dug up.

Minimum meteorological variables needed to run the COARE algorithm are the wind speed, the sea surface temperature, the air temperature, and some form of humidity measurement (e.g., relative humidity, absolute humidity, dew point, and wet bulb temperature). Barometric pressure, precipitation, and a typical mixed layer height are also input variables that can be provided or assigned by COARE default parameters. If options are selected for warm-layer heating and/or cool- skin effects, then solar radiation and downward longwave radiation are needed. Shell is not planning to invoke these options but has tested and provided a framework for the provision of these variables using measured solar radiation, cloud cover and ceiling height. COARE also contains several options for the surface roughness length based on wave period and wave height. Shell plans to use the default option that does not need these variables."

The current AERCOARE User Manual also states:

"AERCOARE uses Version 3.0 of the COARE algorithm that has been updated several times since the initial international TOGA-COARE field program in the western Pacific Ocean from November 1992 to February 1993. The basic algorithm uses air-sea temperature difference, overwater humidity, and wind speed measurements to estimate the sensible heat, latent heat, and momentum fluxes. The original algorithm was based on measurements in the tropics with winds generally less than 10 m/s but has since been modified and extensively evaluated against measurements in high latitudes with winds up to 20 m/s. Based on these studies, AERCOARE is expected to be appropriate for marine conditions found at all latitudes including the Arctic."

Review of Fairall et al 2003 shows that Version 3 of the COARE algorithm was developed in part based on data obtained during the Fronts and Atlantic Storms Experiment (FASTEX) dataset; the FASTEX dataset was obtained in part off the coast of New Brunswick, Canada.

The limitations of the algorithms that OCD uses have been documented by the EPA in the AERCOARE User's Manual V1.0:

"The current EPA guideline model for offshore sources is the OCD model. OCD has not been updated for many years and several of the dispersion model components and procedures are not consistent with AERMOD. The AERMOD modeling system is the U.S. EPA-recommended approach for assessing the near-source (< 50 km) impacts of new or modified sources as part of the New Source Review (NSR) and Prevention of Significant Deterioration (PSD) programs. The modeling system includes an AERMET meteorological processor that processes overland meteorological data for input to AERMOD.

Important routines in OCD that are independent of the onshore/offshore setting are inconsistent with current regulatory practices as embodied within AERMOD, namely:

- *OCD does not contain routines for processing either missing data or hours of calm meteorology. Such processing must be performed with a custom post-processing program.*
- *OCD does not contain the latest regulatory PRIME downwash algorithm (Schulman, L. L. et al,*

2000). Many offshore sources are located on ships where downwash effects are important.

- *The PVMRM and OLM methods are not included in OCD. These techniques are crucial for assessing the new 1-hour NO_2 ambient standard.*
- *The new 24-hour $PM_{2.5}$, 1-hour NO_2, and 1-hour SO_2 ambient standards are based on the 98th, 98th, and 99th percentile concentrations, respectively. These probabilistic standards and the EPA methods recommended for estimating design concentrations must be obtained by post-processing the hourly OCD output files. Such calculations are included in AERMOD.*
- *OCD does not contain a volume source routine and the area source routine only considers circular areas without allowance for any initial vertical dispersion.*
- *Although OCD contains routines to simulate the boundary layer over the ocean, the surface energy flux algorithms are outdated and have been replaced within the scientific community by the COARE air-sea flux algorithms."*

In the 2022 AERCOARE/AERMOD approvals for the Atlantic Shores and Coastal Virginia Offshore Wind Projects, EPA Regions 1 and 2 deemed it was appropriate on a theoretical basis for use in the marine environment off the coast of New Jersey and Virginia.

Based on this justification, AERMOD-AERCOARE is applicable to the US Wind application on a theoretical basis.

3. The data bases which are necessary to perform the analysis are available and adequate.

The database to perform that evaluation of AERCOARE as an alternative model are available and accurate:

"The four model evaluation data sets used in the current study were provided by EPA R10 from the archives supporting development of the MMS (BOEM) version of CALPUFF and OCD Version 4 (DiCristofaro and Hanna, 1989). These studies occur under a wide range of overwater atmospheric stabilities that might be expected in coastal waters regardless of the latitude. The tracer measurements in Pismo Beach and Cameron occur in level terrain near the shoreline downwind of offshore tracer releases. These two studies provide tests of overwater dispersion without the complications due to air modification over the land or complex terrain. The Ventura study is similar; however, the receptors are located 500 meters (m) to one kilometer (km) inland from the shoreline, so some air modification may have affected dispersion in this study. The Carpinteria complex terrain tracer study involved shoreline measurements observed on a bluff near plume level. The Carpinteria data set had much lighter winds and the transport distances were less than the other three studies."

The EPA Region 10 approval in May 2011 indicated the following with respect to the limited tracer study data in its application to an arctic marine environment:

"R10 is aware that there are not tracer gas experiments for every geographic region, climatic region, or synoptic region for use in a performance evaluation. That includes the Arctic region. Nonetheless, R*10 determined the three tracer gas experiments are acceptable because of the similarity of the tracer gas experiment and marine Arctic sea-surface temperatures and as discussed below."*

The following is a passage from Shell's 11 March 2011 response to the R10 Technical Staff AERMOD-COARE Information and Data Request dated 07 March 2011 (Shell 2011b).

"The selection of experiments to use in the model evaluation was extensively discussed with EPA throughout the fall of 2010. Originally, Shell has selected only the Pismo Beach, CA and Cameron, LA experiments for the evaluation using based on the shoreline, near sea-level location of the receptors. At the specific request of EPA,

the Carpinteria, CA experiment was added. Shell suggested at the time that the Carpinteria experiment was not appropriate since the setting involved receptors on a bluff located on the coastline, a setting not seen in the Arctic. The Carpentaria experiment was also more a test of the complex terrain algorithms, not over water dispersion. However, Shell included the Carpinteria experiments at EPA's request. No mention or request was made by EPA at that time to include either the Ventura, CA experiments or the Oresund experiments. The reason for not including the Ventura, CA experiments was that receptors in that case were well inland and no longer reflected the marine environment. The COARE-AERMOD approach is not equipped to simulate changes in the meteorology along the path of the plume. The Oresund experiments were never used in any previous OCD evaluation. They were only used in earlier CALPUFF evaluations. Shell felt that the differences in the use of CALPUFF, principally a long-range transport model, and AERMOD, used for within 50 kilometers, made this comparison less relevant. In addition, the other experiments had already been prepared for OCD and that made it straightforward to adapt them to evaluation with the COARE-AERMOD approach. With the Oresund experiments, the input data were in CALPUFF format and transforming these data to a format for the COARE-AERMOD approach would involve a number of assumptions and judgments that could ultimately impact the results. Shell's concern was that the results of the evaluation could depend on these assumptions and judgments rather than the true model performance."

Further, EPA Region 1 requested that additional data be provided for the August 9, 2021, alternative model request for Park City Wind. The additional data requested was to support that the argument that the development of the COARE algorithms occurred using data sets with similar observations patterns (i.e., wind speed and air/sea temperature difference) representative of the project area off the New England coast. Based on the additional data provided by Park City Wind, which is included Attachment 2 of EPA Region 1's technical Review of the Vineyard Wind alternative model approval request, EPA Region 1 concluded the following in their technical review:

"Region 1 concludes the meteorological datasets used to develop AERCOARE and the four tracer studies used in the evaluation are sufficiently available and adequate for determining the effectiveness of the modeling approach."

There are four comprehensive historical overwater dispersion datasets available in the record that involve study of air pollutant dispersion in the marine atmospheric boundary layer. The following four tracer gas studies from the 1980s have been used in performance evaluations of OCD, CALPUFF, and AERCOARE/AERMOD:

1. Cameron, Louisiana: July 1981 and February 1982 (Dabberdt, Brodzinsky, Cantrell, & Ruff, 1982[8])
2. Carpinteria, California: September 1985 (Johnson & Spangler, 1986[9])
3. Pismo Beach, California: December 1981 and June 1982 (Schacher, et al., 1982[10])
4. Ventura, California: September 1980 and January 1981 (Schacher, et al., 1982)

The EPA Region 10 alternative model approval of AERCOARE/AERMOD utilized tracer gas experiments from the four studies listed above. In all of the previous approvals, EPA determined that these datasets were adequate for verification of the AERCOARE/AERMOD system.

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[8] Dabberdt, W., Brodzinsky, R., Cantrell, B., & Ruff, R. (1982). Atmospheric Dispersion Over Water and in the Shoreline Transition Zone, Final Report Volume II: Data. Menlo Park, CA: Prepared for American Petroleum Institute by SRI International.
[9] Johnson, V., & Spangler, T. (1986). Tracer Study Conducted to Acquire Data for Evaluation of Air Quality Dispersion Models. San Diego, CA: WESTEC Services, Inc. for the American Petroleum Institute
[10] Schacher, G., Spiel, D., Fairall, C., Davidson, K., Leonard, C., & Reheis, C. (1982). California Coastal Offshore Transport and Diffusion Experiments: Meteorological Conditions and Data. Monterey, CA: Report NPS-61-82-007

Additional information was provided by Vineyard Wind to Region 1 to demonstrate the referenced tracer studies were sufficiently representative of the marine environment off the coast of Massachusetts. Likewise, US Wind provides statistics for key observed meteorological parameters for the Ocean City Inlet Buoy station and Delaware Bay 26 NM Buoy station (#44009) located in the Project area. US Wind requested prognostic (i.e., WRF data) data from EPA Office of Air Quality Planning and Standards (OAQPS) which was received on February 9, 2023. EPA processed the WRF data using the MMIF (Version 4.0) to convert the WRF prognostic meteorological data (2019-2021) into a format suitable for dispersion modeling applications. The WRF Data was provided for the following points in Table 1. US Wind is also providing statistics for key WRF meteorological parameters for the nearest WRF nodes to the Ocean City Inlet Buoy station, Delaware Bay 26 NM Buoy station (#44009), Ocean City ASOS, and Project Centroid.

Table 1: Meteorological Extraction Points and WRF Grid Point Locations

Data	Latitude	Longitude	Comment
Overwater extraction point for AERCOARE/AERMOD Modeling	38.3467	-74.7605	Corresponds to the Project Centroid
Delaware Bay 26 NM Buoy - OBS	38.460	-74.692	~14 km northeast of Project Centroid
Ocean City Inlet Buoy - OBS	38.328	-75.091	~29 km west of Project Centroid
Ocean City Airport ASOS - OBS	38.309	-75.123	~32 km west of Project Centroid
Ocean City Airport ASOS – WRF	38.327	-75.140	Nearest WRF node to Ocean City Airport ASOS
Delaware Bay 26 NM Buoy - WRF	38.460	-74.671	Nearest WRF node to Delaware Bay 26 NM Buoy
Ocean City Inlet Buoy - WRF	38.327	-75.140	Nearest WRF node to Ocean City Inlet Buoy
Project Centroid - WRF	38.354	-74.704	Nearest WRF node to Project Centroid

Table 2 summarizes key meteorological data and compares them to data from the tracer studies. The data demonstrates that the range of atmospheric conditions that typically occur in the Ocean City, Maryland offshore region fit the range of conditions used to develop and verify the COARE 3.0 algorithm.

Table 2: Comparison of Meteorological Data Summary Statistics

Location	Observations	Range	10th Percentile	25th Percentile	Median	Average	75th Percentile	90th Percentile
	Wind Speed (m/s)							
Cameron, LA	**26**	**2.1 to 6.2**	**3.5**	**3.7**	**4.6**	**4.5**	**5**	**5.7**
Carpinteria, CA	**27**	**1 to 5.4**	**1**	**1.4**	**2.4**	**2.5**	**3.2**	**3.9**
Pismo Beach, CA	**31**	**1.6 to 12.7**	**2.7**	**3.9**	**5.6**	**6.1**	**8.3**	**9.9**

	Observations	Range	10th Percentile	25th Percentile	Median	Average	75th Percentile	90th Percentile
Ventura, CA	17	3.1 to 6.9	3.7	4.2	4.9	5	5.8	6.2
OBS - Delaware Bay, DE	27,187	0 to 23.1	2.3	3.9	5.9	6.3	8.3	10.8
OBS - Ocean City Inlet, MD	40,897	0 to 19.0	1.5	2.4	3.7	4.1	5.5	7.3
WRF - Delaware Bay, DE	26,299	0.1 - 24.3	2.9	4.4	6.6	6.9	9.1	11.6
WRF - Ocean City, MD	26,299	0.1 - 17.9	2.1	3.0	4.3	4.5	5.8	7.3
WRF – Project Centroid	26,299	0.1 - 24.5	2.8	4.4	6.6	6.9	9.0	11.5
WRF – Ocean City ASOS, MD	26,299	0.1 - 17.9	2.1	3.0	4.3	4.5	5.8	7.3
	Air/Sea Temperature Difference (K)							
Cameron, LA	26	-4.5 to 5	-2.7	-1.6	0.5	0.3	1.9	4.2
Carpinteria, CA	27	-1.1 to 2.8	-0.8	-0.7	-0.4	0.2	1	2.2
Pismo Beach, CA	31	-0.8 to 3.7	0.0	0.4	1.3	1.3	2.2	3.2
Ventura, CA	17	-2.1 to 1.8	-2.0	-1	0	-0.2	0.4	1.6
OBS - Delaware Bay, DE	27,187	-16.1 to 8.2	-4.7	-2.0	-0.4	-1.1	0.7	1.5
OBS - Ocean City Inlet, MD	40,897	-15.3 to 17.1	-4.8	-2.2	-0.2	-0.5	1.4	3.2
WRF - Delaware Bay, DE	26,299	-14.1 - 7.0	-4.4	-1.7	-0.1	-0.7	0.8	1.7
WRF - Ocean City, MD	26,299	-18.1 - 14.0	-6.1	-2.7	0.2	-0.5	2.0	3.8
WRF – Project Centroid	26,299	-14.4 - 6.8	-4.4	-1.6	-0.1	-0.7	0.8	1.7
WRF – Ocean City ASOS, MD	N/A – Land Based Meteorological Station							

The observed Delaware Bay and Ocean City Inlet buoy air-sea temperature gradient data and wind data from the period 2017-2021 were obtained for comparison to the range of conditions used to develop the COARE 3.0 algorithm and the conditions during the four tracer experiments. Data statistics are provided on the distribution of wind speed and air-sea temperature differences from the four tracer studies, consisting of a total of 101 hourly observations. The maximum hourly average wind speed measured at the Delaware Bay buoy was 23.1 m/s and the 99.9th percentile of wind speed was 18.4 m/s. The maximum hourly average wind speed measured at the Ocean City Inlet buoy was 19.0 m/s. The COARE algorithm was developed and verified with conditions up to 20 m/s. Therefore, more than 99.9 percent of the observed Delaware Bay offshore winds are within the COARE evaluation wind speed range and 100 percent of the observed Ocean City offshore winds are within the COARE evaluation wind speed range. The highest wind speeds that exceed the values in the COARE evaluation range will be associated with highly dispersive conditions such that maximal predicted concentrations will not be a consideration at the wind speeds in excess of the range.

The WRF data air-sea temperature gradient data and wind data from the period 2019-2021 were obtained as discussed above for comparison to the range of conditions used to develop the COARE 3.0 algorithm and the conditions during the four tracer experiments. The maximum hourly average wind speed at the Delaware Bay buoy (WRF) was 24.3 m/s and the 99.9th percentile of wind speed was 18.6 m/s. The maximum hourly average wind speed at the Project Centroid (WRF) was 24.5 m/s and the 99.9th percentile of wind speed was 18.4 m/s. The maximum hourly average wind speed at the Ocean City Inlet buoy (WRF) and Ocean City ASOS (WRF) was 17.9 m/s. The COARE algorithm was developed and verified with conditions up to 20 m/s. Therefore, more than 99.9 percent of the WRF modeled Delaware Bay and Project Centroid offshore winds are within the COARE evaluation wind speed range and 100 percent of the WRF modeled Ocean City Inlet offshore winds and Ocean City ASOS surface winds are within the COARE evaluation wind speed range.

The maximum wind speed in the four tracer studies was 12.7 m/s, during the Pismo Beach study. Average wind speeds during each study ranged from 2.5 to 6.1 m/s. Average observed wind speed at the Delaware Bay and Ocean City Inlet buoys was 6.3 m/s and 4.1 m/s, respectively. The average WRF modeled wind speeds ranged from 4.5 m/s to 6.9 m/s. Highest concentrations from the Project are likely to occur during lower wind speeds. The range of wind speed conditions observed during the tracer experiments covers the range of conditions when the maximum project concentrations are expected.

Because the air-sea temperature difference is an important parameter in characterizing the marine boundary layer, a comparison of the observed air-sea temperature difference at the Delaware Bay and Ocean City buoys was made with the air-sea temperature differences observed in the evaluation tracer studies. Additionally, a comparison of the WRF modeled air-sea temperature differences at the Delaware Bay and Ocean City buoys, and Project Centroid was made with the air-sea temperatures observed in the evaluation tracer studies. Thus, the datasets were examined visually using box and whisker plots. Box and whisker plots are one way of comparing datasets to ascertain the distribution.

The box and whisker plots for observed wind speed for Delaware Bay, Ocean City Inlet, and the four validation datasets were plotted, and broadly they show that wind speeds at Delaware Bay and Ocean City are moderately higher than those observed during the validation studies. Additionally, the box and whisker plots for the WRF modeled wind speed for the Delaware Bay and Ocean City Inlet Buoys and Project Centroid broadly show similar results to the observed data. This is one reason the COARE algorithm utilized the Fronts and Atlantic Storm (FASTEX) dataset as it generally contained higher wind speeds than were observed at tropical latitudes. In other words, the COARE algorithm implemented into AERCOARE was specifically evaluated against a higher wind speed dataset to make it more globally applicable. The Box and Whisker Plots for Wind Speed are shown in Figures 2a through 2f.

Similarly, box and whisker plots were used to examine the distribution of the observed air/sea temperature difference between Delaware Bay, Ocean City, and the four validation studies. The median of the Delaware Bay and Ocean City datasets is similar to the median air/sea temperature difference in the four validation studies and the 25th and 75th percentiles are similar to what was measured during the validation studies. Additionally, the box and whisker plots for the WRF modeled air-sea temperature differences for the Delaware Bay and Ocean City Inlet Buoys and Project Centroid broadly show similar results to the observed data. The air/sea temperature difference seen in the mid-Atlantic is similar to what was observed during the validation studies. The box and whisker plots for air/sea temperature difference are shown in Figures 3a through 3e. The four tracer studies evaluated do cover a range of wind and temperature gradient conditions and represent the majority of the range of conditions that occur at the Project site, as inferred through the Delaware Bay and Ocean City datasets. Most importantly, the low wind speed conditions that are most likely to result in highest predicted concentrations are well addressed in the tracer studies.

Based on the information above: that the databases available occur under a wide range of overwater atmospheric stabilities that might be expected in coastal waters regardless of the latitude, the COARE algorithm implemented in AERCOARE was developed to be applicable for water temperatures from the tropics to the arctic, the COARE algorithm has been validated against a local meteorological datasets to specifically account for those conditions. It can be concluded that the necessary datasets to evaluate the AERCOARE are available and are adequate and that the meteorological inputs needed to populate AERCOARE are available and adequate.

Figure 2a: Box and Whisker Plots for OBS - Delaware Bay 26 NM Buoy and 4 Tracer Study Data Sets – Wind Speed (m/s)

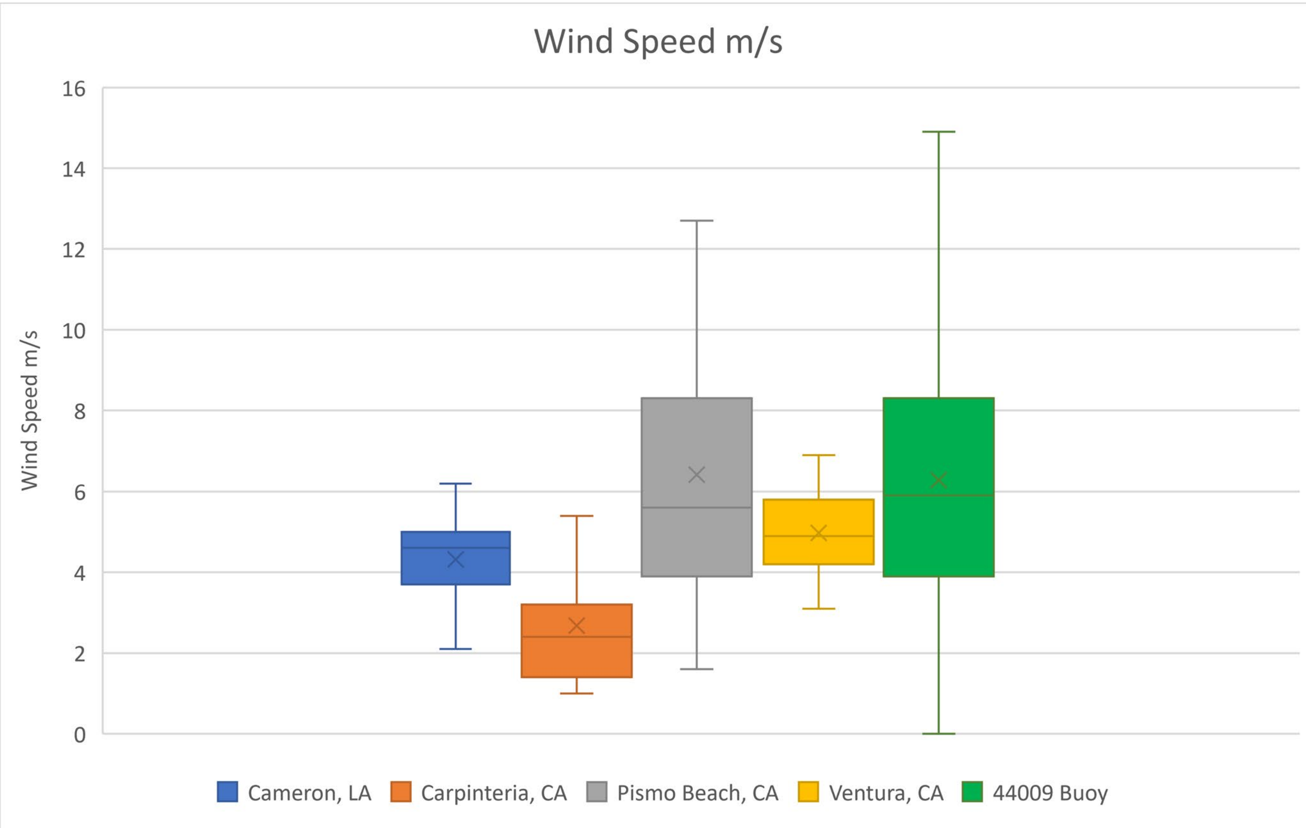


Figure 2b: Box and Whisker Plots for OBS - Ocean City Inlet and 4 Tracer Study Data Sets – Wind Speed (m/s)

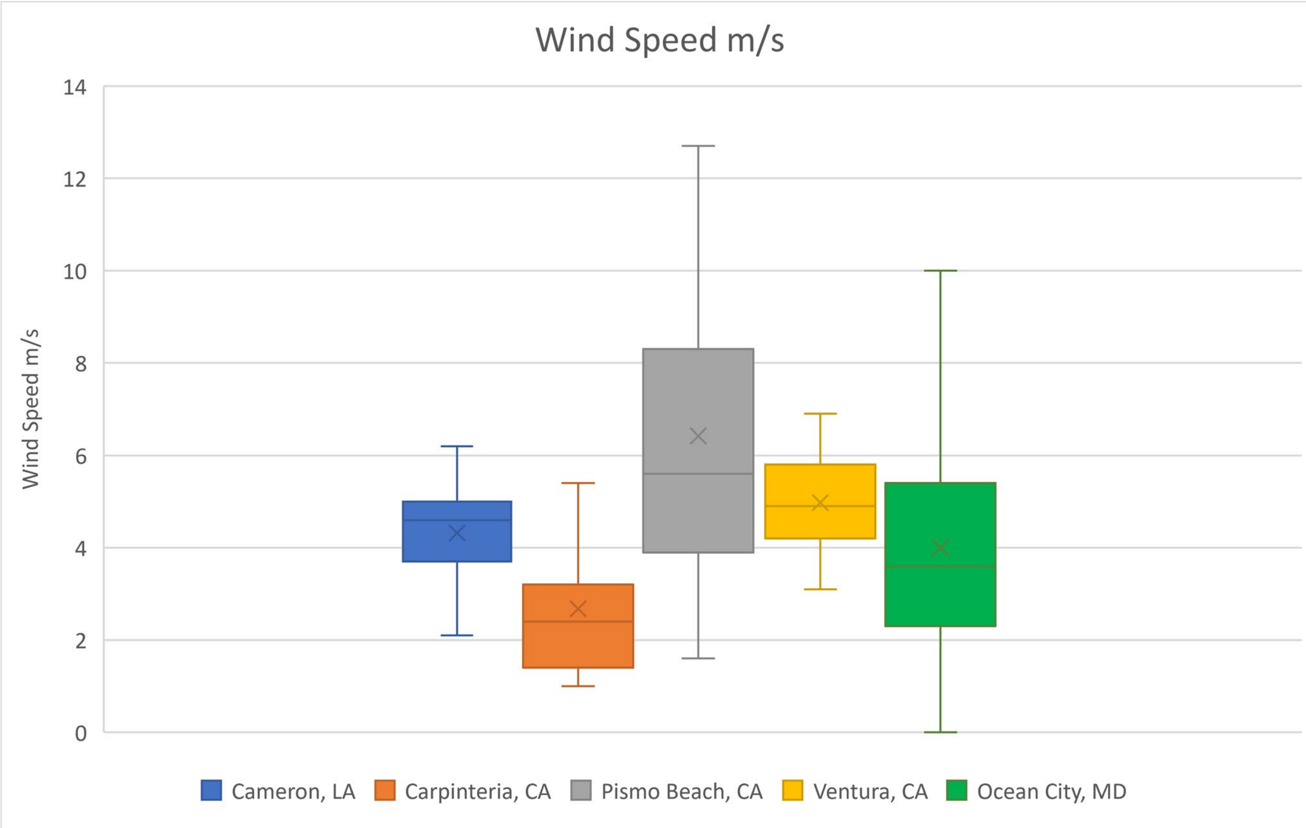


Figure 2c: Box and Whisker Plots for WRF - Delaware Bay 26 NM Buoy and 4 Tracer Study Data Sets – Wind Speed (m/s)

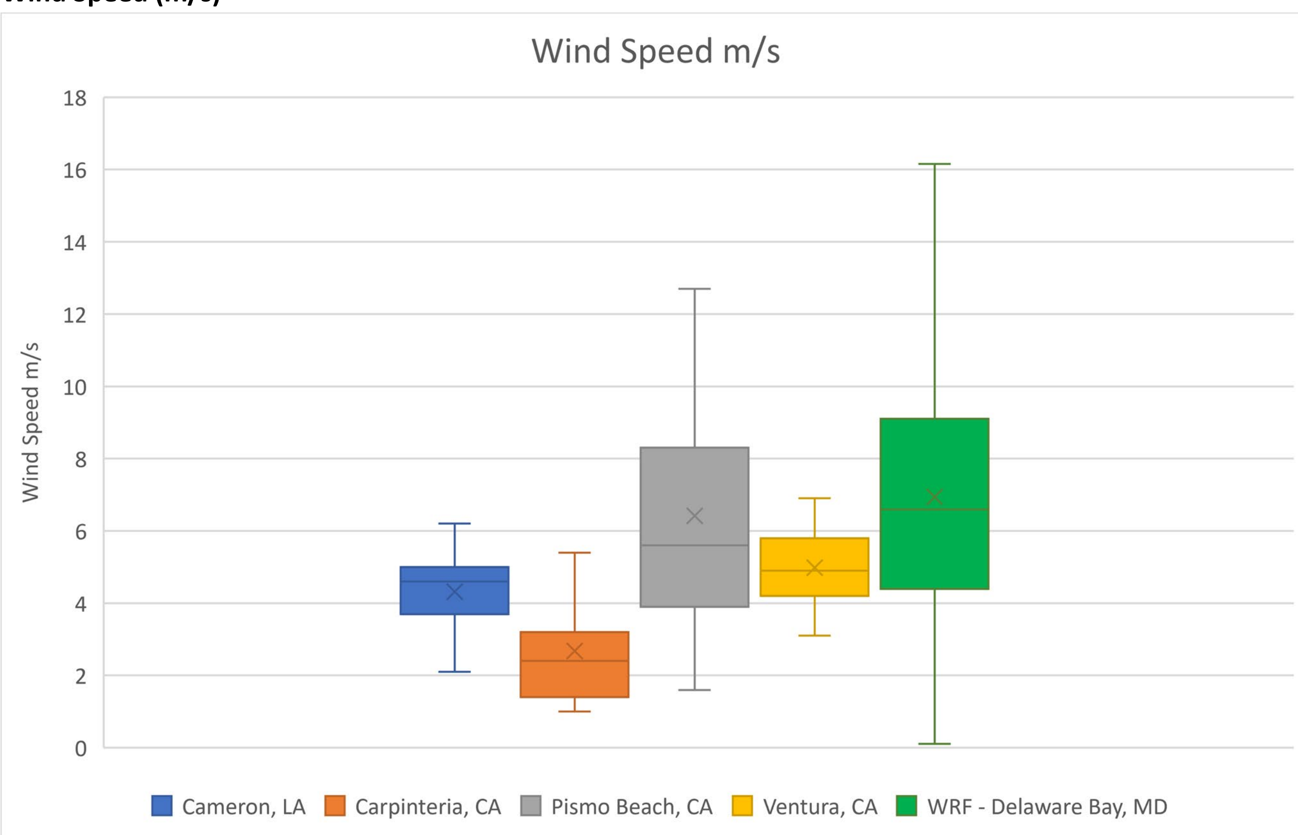


Figure 2d: Box and Whisker Plots for WRF - Ocean City Inlet and 4 Tracer Study Data Sets – Wind Speed (m/s)

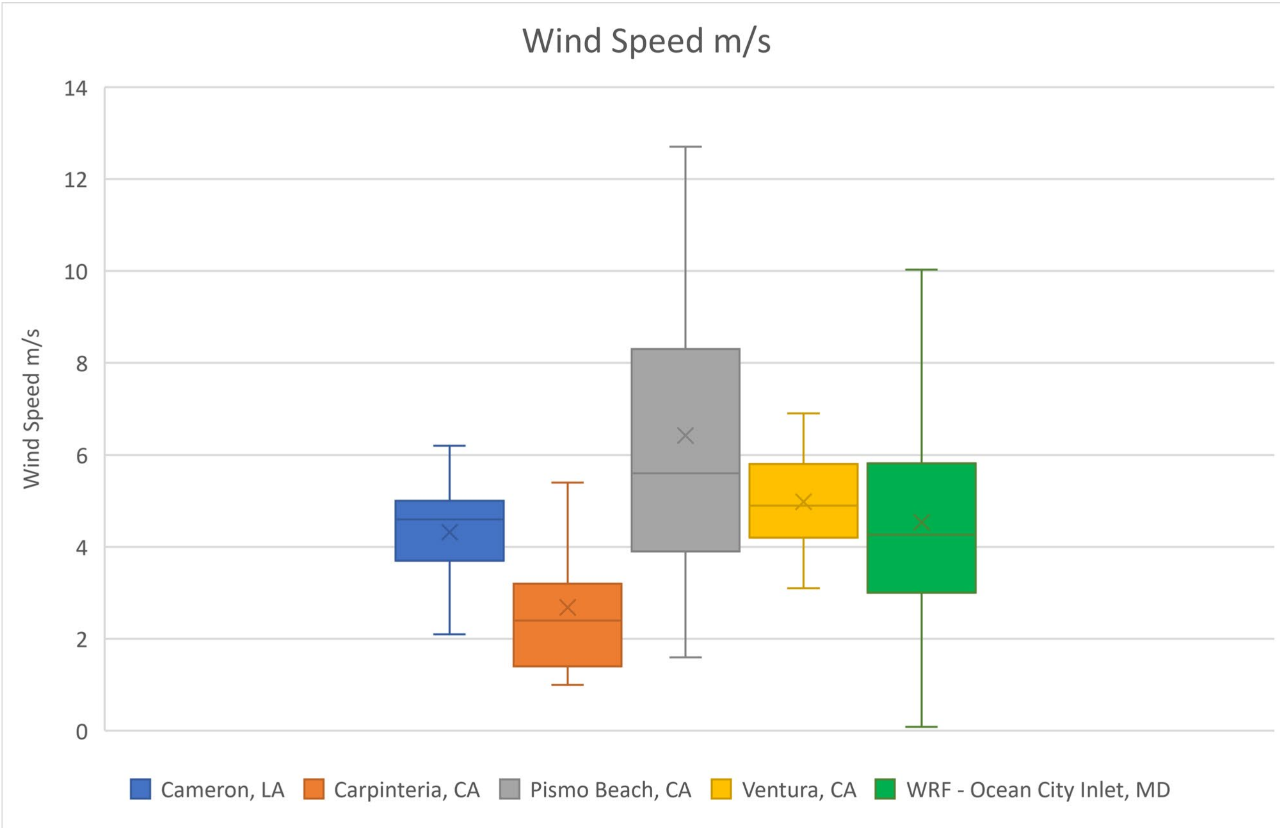


Figure 2e: Box and Whisker Plots for WRF – Project Centroid and 4 Tracer Study Data Sets – Wind Speed (m/s)

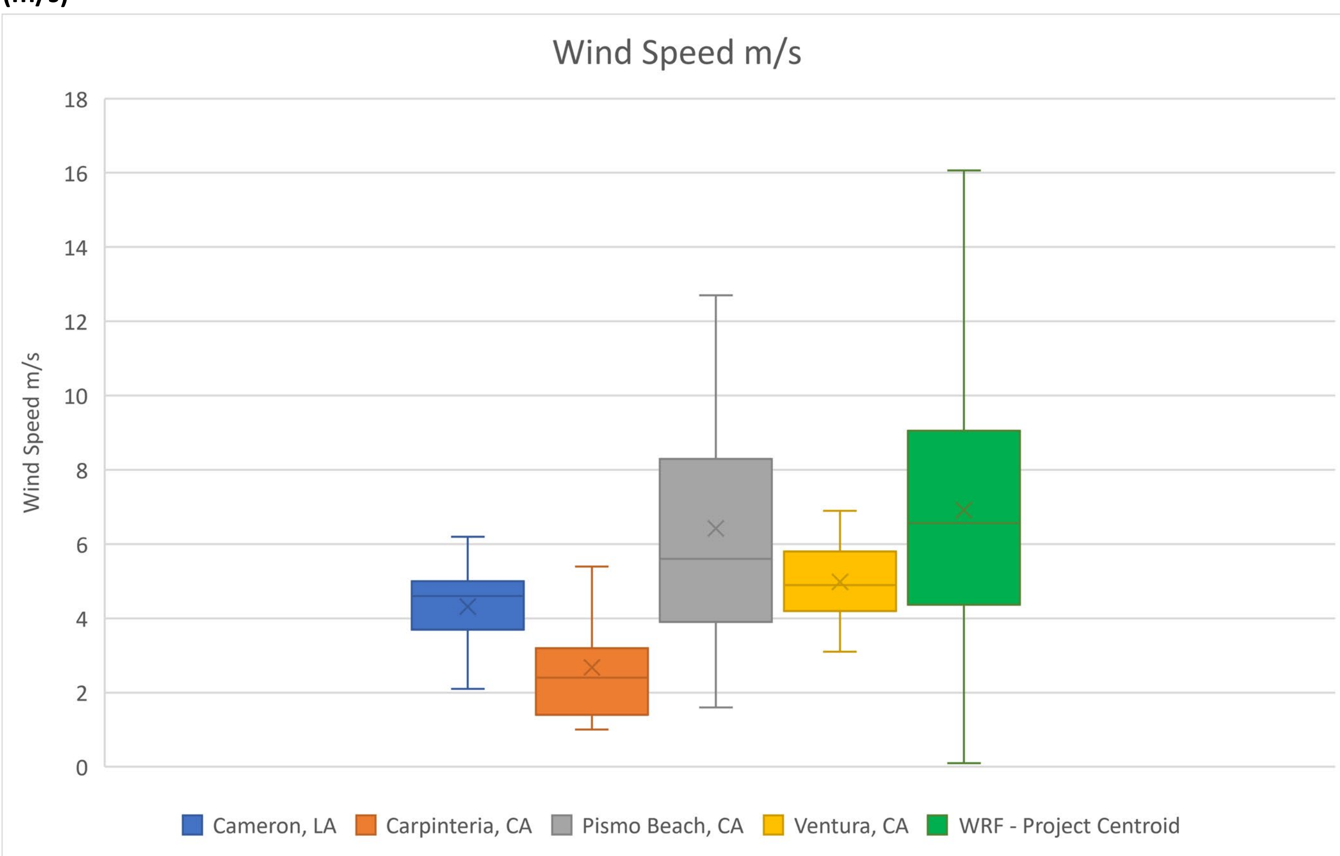


Figure 2f: Box and Whisker Plots for WRF – Ocean City ASOS and 4 Tracer Study Data Sets – Wind Speed (m/s)

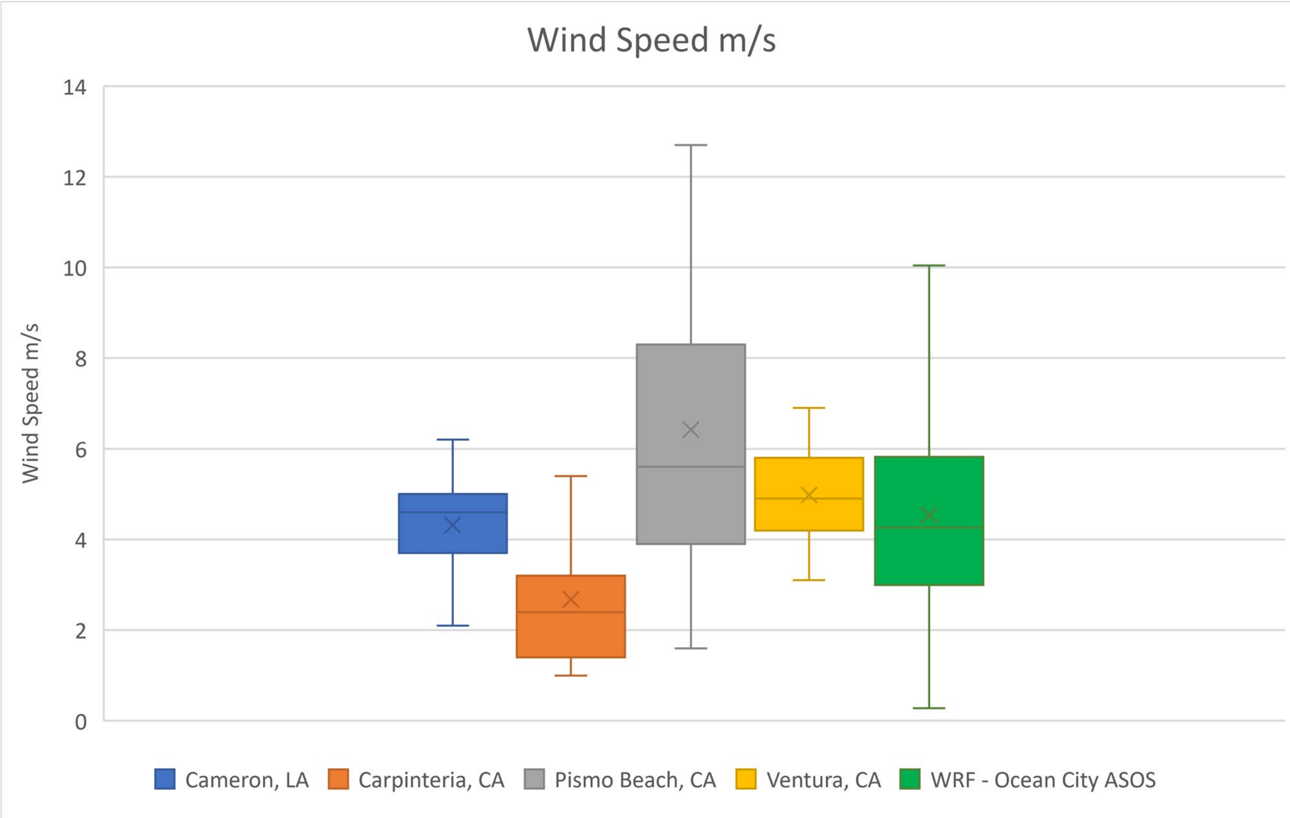


Figure 3a: Box and Whisker Plots for OBS - Delaware Bay 26 NM Buoy and 4 Tracer Study Data Sets – Air-Sea Temperature Difference (K)

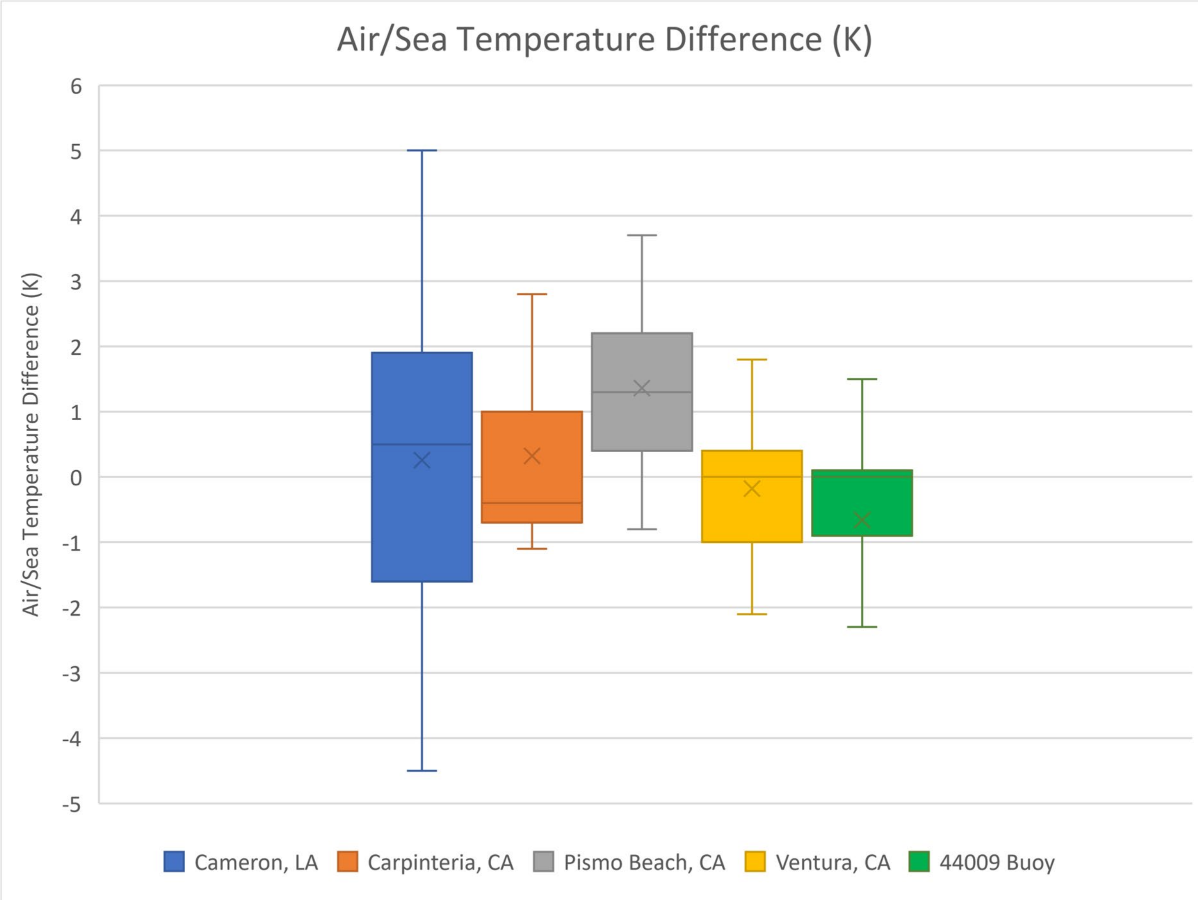


Figure 3b: Box and Whisker Plots for OBS - Ocean City and 4 Tracer Study Data Sets – Air-Sea Temperature Difference (K)

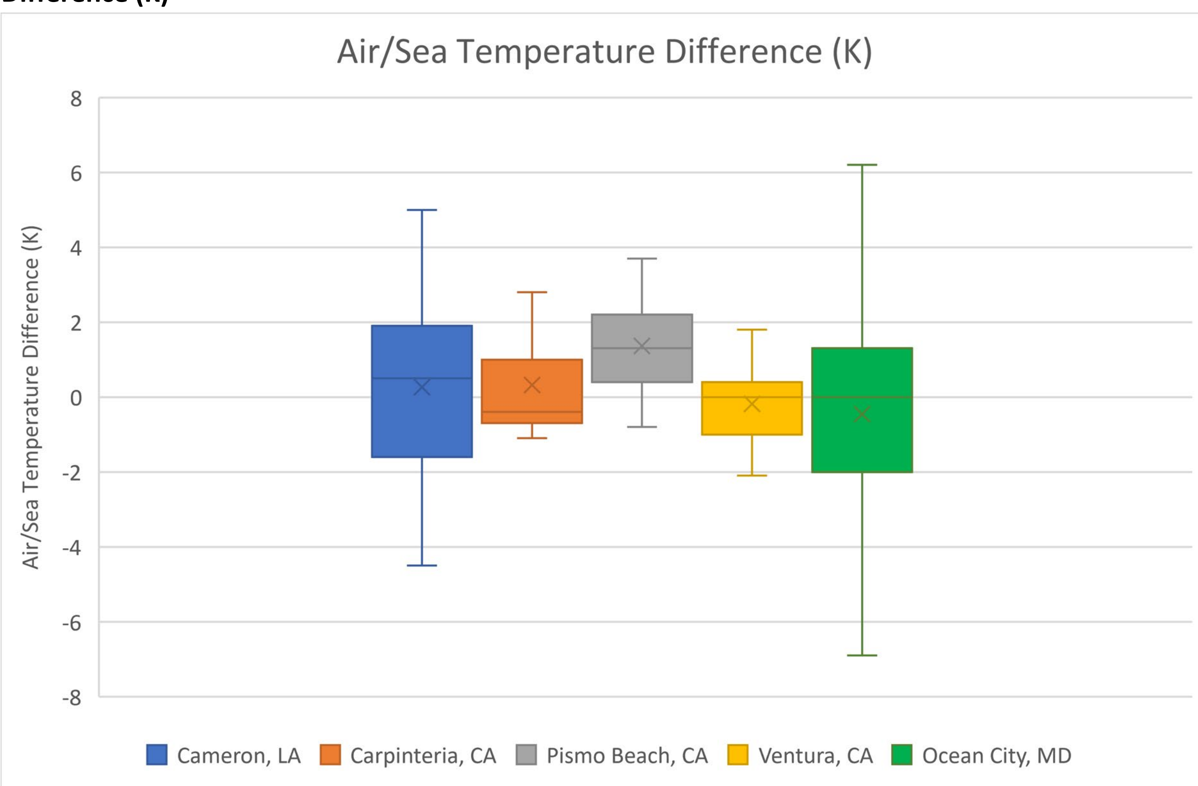


Figure 3c: Box and Whisker Plots for WRF - Delaware Bay 26 NM Buoy and 4 Tracer Study Data Sets – Air-Sea Temperature Difference (K)

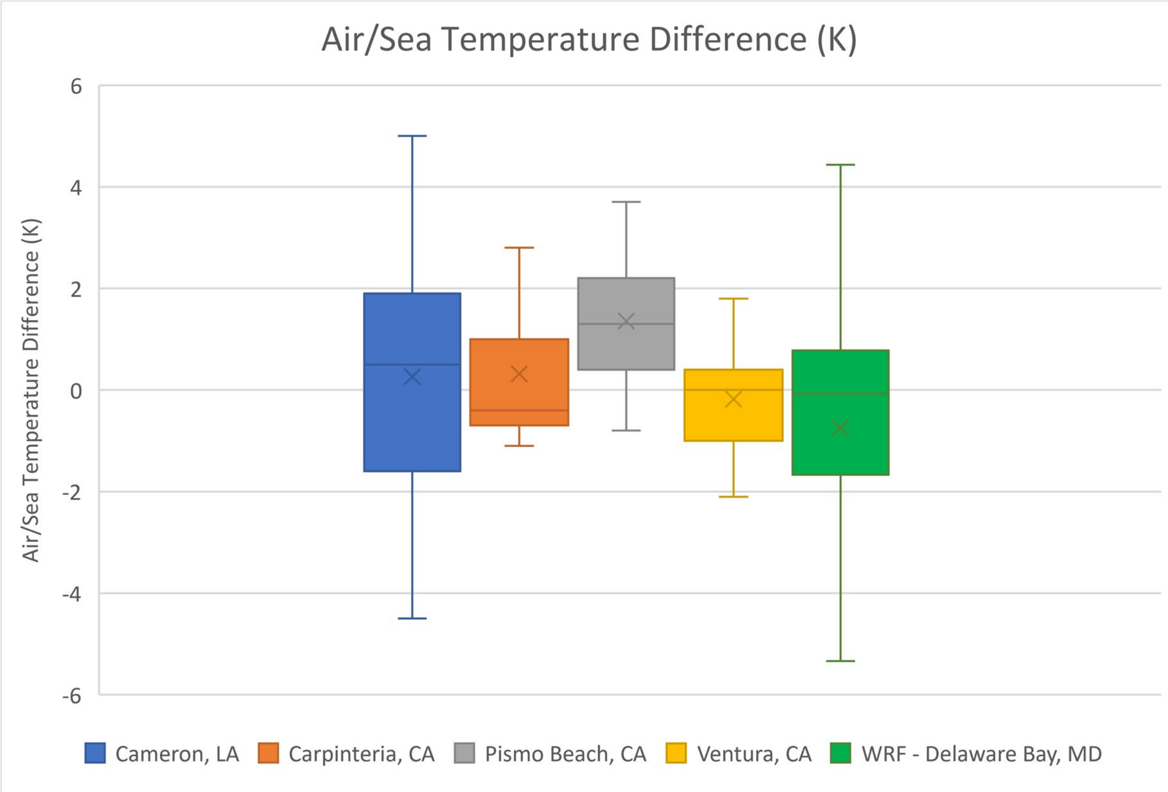


Figure 3d: Box and Whisker Plots for WRF - Ocean City Inlet and 4 Tracer Study Data Sets – Air-Sea Temperature Difference (K)

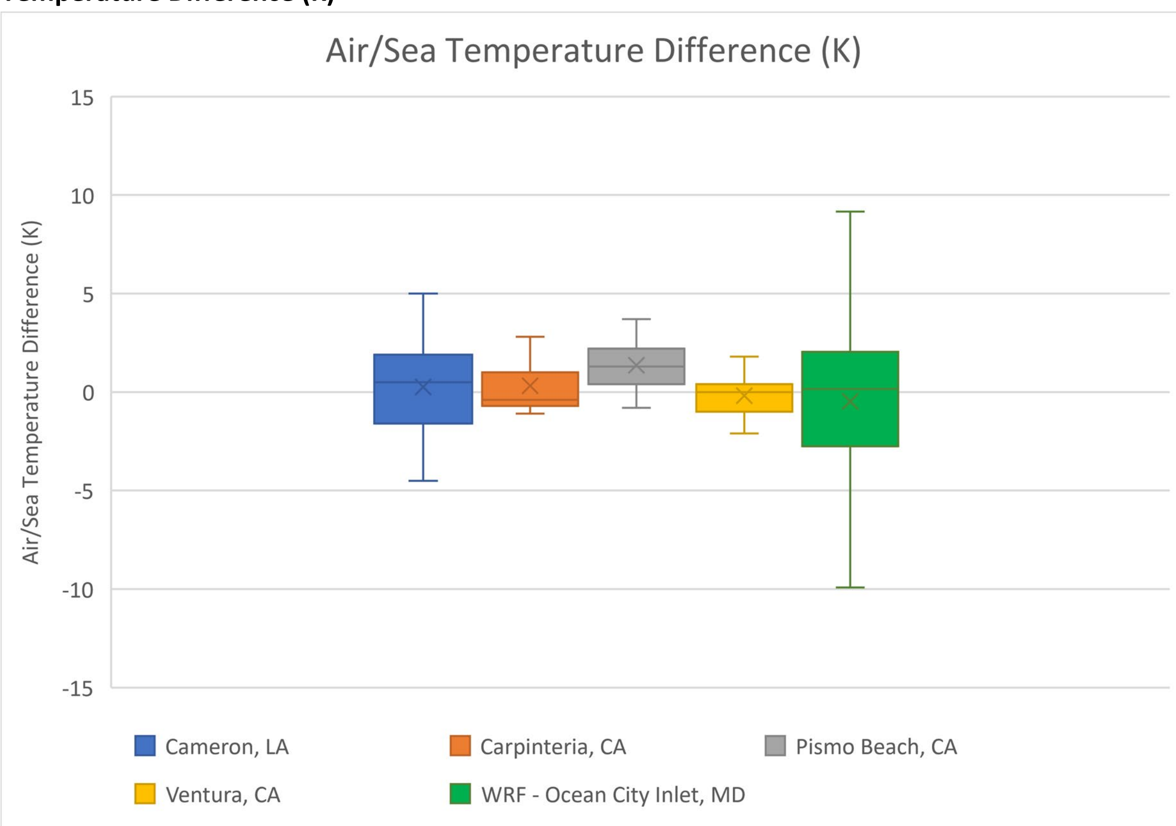
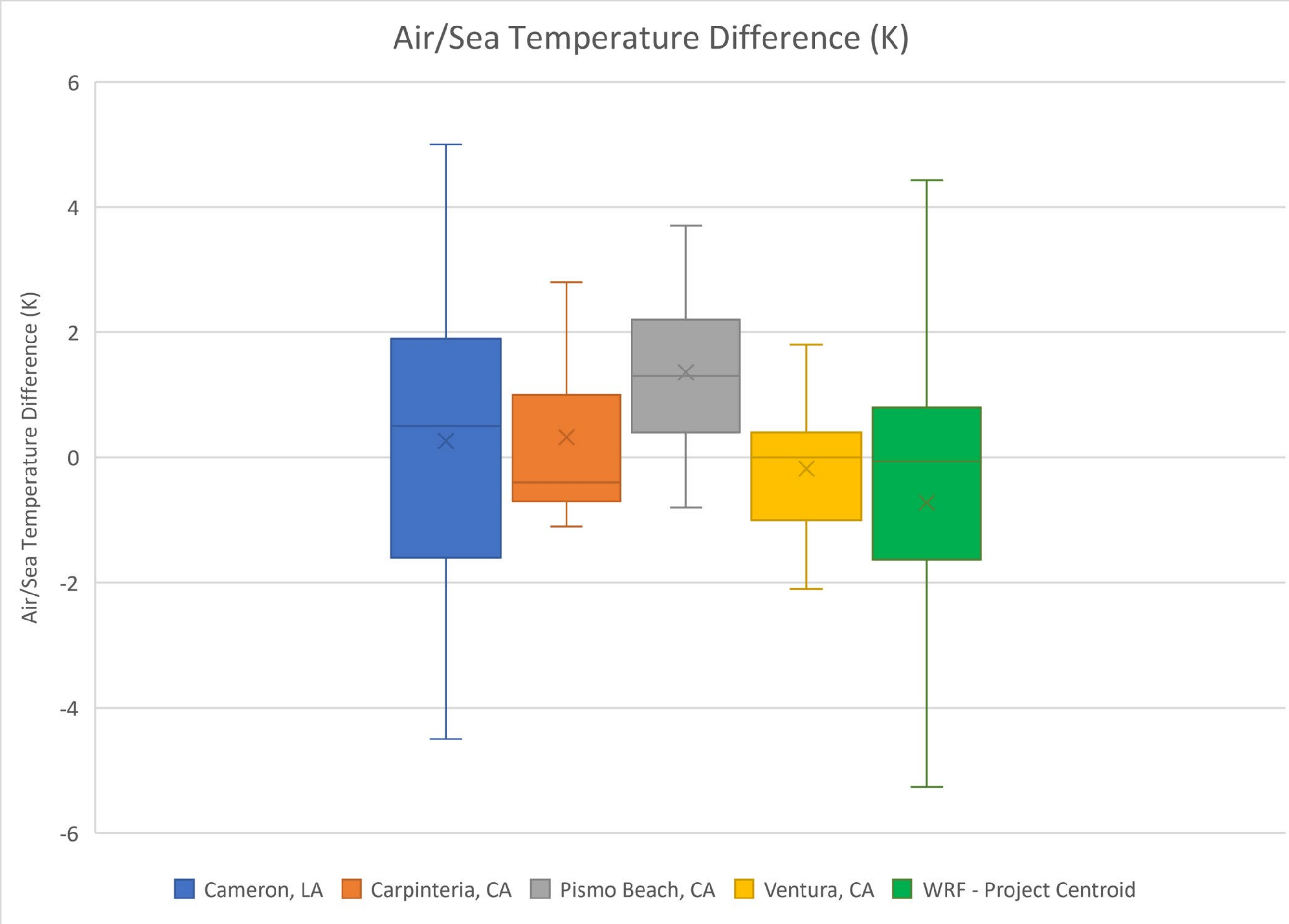


Figure 3e: Box and Whisker Plots for WRF – Project Centroid and 4 Tracer Study Data Sets – Air-Sea Temperature Difference (K)



4. Appropriate performance evaluations of the model have shown that the model is not biased toward underestimates.

Model evaluation results for AERCOARE were presented in detail in two documents: (1) April 1, 2011, memorandum from EPA Region 10 and (2) EPA/ENVIRON October 2012 Model Evaluation Study. The results of both model performance evaluations indicated the model is not biased toward underestimates as discussed below.

As documented in the October 2012 Model Evaluation Study, AERCOARE Version 1.0 (12275) was applied to prepare the overwater meteorological data for the Cameron, Louisiana, and the Pismo Beach, California offshore datasets. AERCOARE simulations were conducted using five different methods for the preparation of the meteorological data, including the estimation of mixing heights, the use of horizontal wind direction (sigma theta data), and limitations on other variables provided to AERMOD to calculate concentrations from the field studies.

For both evaluation studies, AERMOD was run using AERCOARE along with default options for rural flat terrain for both simulations. Quantile-quantile (Q-Q) plots were prepared based on a comparison of independently ranked modeled versus observed concentrations. A Q-Q plot is a useful tool for determining if a model has an underprediction bias especially at the upper end of the observed concentration profile. Figure

4 and Figure 5 provide Q-Q plots for the Cameron, Louisiana, and Pismo Beach, California datasets, respectively. The AERCOARE-AERMOD modeled concentrations are biased toward over-prediction for the highest concentrations, with less than a factor of 2 underprediction bias at the lower concentrations. Importantly, AERCOARE-AERMOD does not appear to be biased toward underestimates for the higher end of the frequency distribution, regardless of the five different meteorological preparation options examined in this study.

In EPA Region 1's review of Park City Wind, examination of whether the use of prognostic meteorological data generated by WRF could result in systematic underprediction of concentrations lead to the following conclusions:

"Additionally, Region 1 reviewed U.S. EPA (2015) to see if the WRF-MMIF inputs for AERCOARE resulted in underprediction. U.S. EPA (2015) used the four overwater dispersion study datasets listed above to compare AERCOARE/AERMOD predicted concentrations against the measured concentrations from the campaigns. This study also compared results across a set of combinations of WRF-MMIF inputs and settings. The results of this study show AERCOARE/AERMOD driven by WRF-MMIF inputs resulted in the high-end of the distribution of concentrations exceeding the measured concentrations in the Pismo and Ventura studies. Concentrations agreed well for the Carpinteria study at the high-end of the distribution in most cases. In the Cameron study, and under some of the scenarios in the Carpinteria study, the modeling resulted in underpredictions at the high-end of the distribution in some scenarios. Namely, when mixing heights were diagnosed by MMIF, instead of using the mixing heights directly from WRF, AERCOARE/AERMOD concentrations were underpredicted in some cases. The model runs using WRF-simulated mixing heights performed better, when compared to measured concentrations. Overall, however, the U.S. EPA (2015) study noted concentration bias could be attributed mainly due to error in sea-surface temperatures output from the WRF model.

A key element to both the original Region 10 approval study and the U.S. EPA (2015) study was an evaluation of the sensitivity of the modeling results to a minimum mixing height. The Region 10 approval found AERCOARE/AERMOD results were highly overpredicted when using AERMOD's default minimum mixing height of 1 meter. EPA Region 10's sensitivity study, summarized in ENVIRON (2012) found a minimum mixing height of 25 meters for overwater applications was more physically realistic and resulted in better model performance. The EPA Region 10 approval allowed for the use of a minimum mixing height of 25 meters for the application of AERCOARE/AERMOD and a minimum limit on the absolute value of Monin-Obukhov Length of 5 meters. These limits are recommended in the EPA's AERCOARE User's Guide[11].

Based on the findings from the studies reviewed in the prior EPA approvals and the additional WRF-MMIF-based study, Region 1 concludes it is evident the AERCOARE/AERMOD approach does not result in systematic underprediction of concentrations. Instead, the evidence more likely leads to the conclusion the approach is conservative."

US Wind proposes to use 12-km WRF data and MMIF for 2019-2021. The proposed AERCOARE settings will include the recommendations of 25 meters for the minimum mixing height and a minimum Monin-Obukhov length of 5 meters.

5. A protocol on methods and procedures to be followed has been established.

US Wind submitted a modeling protocol on September 16, 2022, to MDE proposing the use of the OCD model.

[11] https://gaftp.epa.gov/Air/aqmg/SCRAM/models/related/aercoare/AERCOAREv1_0_Users_Manual.pdf

The modeling protocol included a description of modeling methodologies and procedures consistent with the Guideline on Air Quality Models (Appendix W of 40 CFR 51). The modeling protocol has been updated to reflect the use of AERCOARE-AERMOD, which was submitted concurrently to MDE and EPA with this alternative model request.

US Wind requested prognostic (i.e., WRF data) data from EPA Office of Air Quality Planning and Standards (OAQPS) which was received on February 9, 2023. EPA processed the WRF data using the MMIF (Version 4.0) to convert the WRF prognostic meteorological data (2019-2021) into a format suitable for dispersion modeling applications. The EPA utilized the default settings for AERCOARE processing (i.e., settings specific to AERMET are not applicable) as provided in the User's Manual to the Mesoscale Model Interface Program, Version 4.0 (June 9, 2022).

US Wind intends to run AERCOARE using the following settings recommended in EPA's AERCOARE User's Guide, as specified below:

1. The default threshold wind speed will be used to identify calm hours (i.e., WSCALM = 0.5 m/s). Wind speeds below this value will be considered calms;
2. Mixing heights provided by WRF-MMIF will be used, instead of calculated by AERCOARE. The default minimum mixing height of 25 meters will be assigned.
3. Warm layer and cool-skin effects will not be considered.
4. Friction velocity will be determined from wind speed only; wave-height will not be considered.

The AERCOARE parameters noted above were previously approved by EPA Regions 2 and 3 and EPA OAQPS in their approvals of the Alternative Model Request for the Dominion Coastal Virginia Offshore Wind-Commercial Wind Farm and Atlantic Shores Projects.

Conclusions

The justification contained herein supports the use of AERCOARE-AERMOD as an alternative model, in lieu of OCD, for the US Wind Project. Based on this justification and recent precedents for approving AERCOARE-AERMOD in the Atlantic OCS, US Wind proposes the use of AERCOARE-AERMOD as an alternative model for the OCS air permit application. As shown above, the proposed approach satisfies each of the five elements contained in Section 3.2.2(e) of the Guideline required for alternative model approvals. US Wind requests MDE's and EPA's concurrence on this request for approval.

Figure 4: QQ Plot of AERCOARE versus Cameron, Louisiana, Tracer Study Results

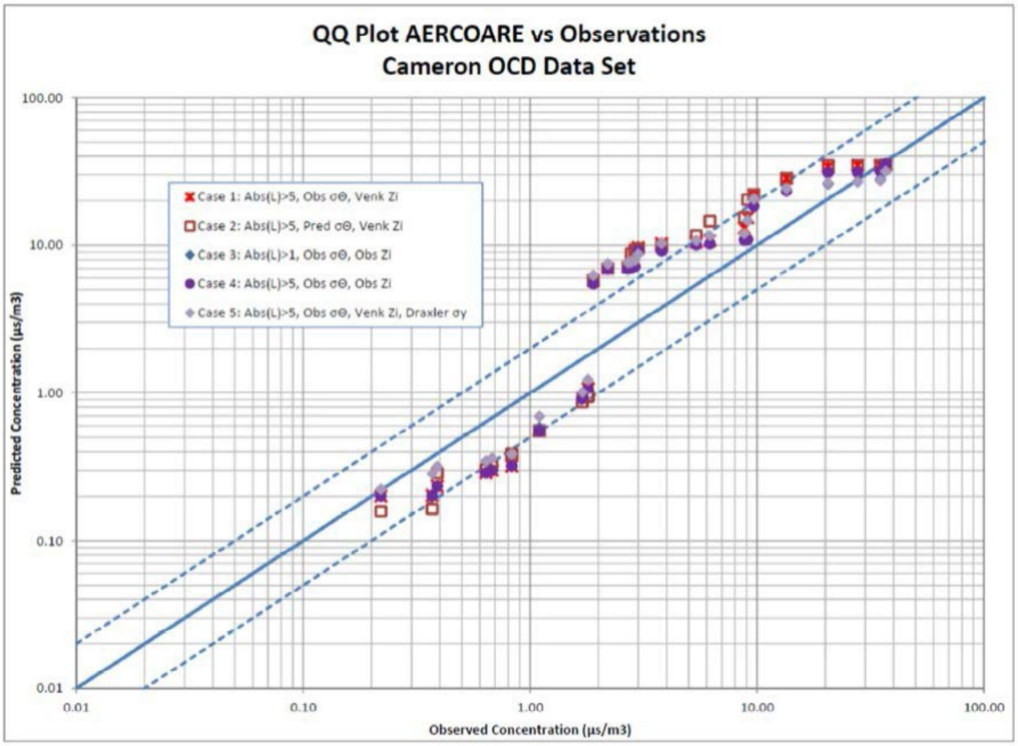


Figure 5: QQ Plot of AERCOARE versus Pismo Beach, California, Tracer Study Results