Technical Review of the Vineyard Wind Request to Use the AERCOARE Meteorological Data Preprocessor Program in conjunction with AERMOD in support of its Outer Continental Shelf (OCS) Permit Application for the Park City Wind project

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1. Background and Project Overview

Vineyard Wind is proposing to construct an offshore windfarm on the Outer Continental Shelf (OCS) off the coast of Martha's Vineyard, Massachusetts in Bureau of Ocean Energy Management (BOEM) Lease Area OCS-A 0501 to provide electricity to the New England market via an interconnect in Bridgeport, Connecticut. This project—called Phase 1 of Vineyard Wind South or, alternatively and hereafter, Park City Wind— is an 804 MW offshore wind energy project that will consist of 50 to 62 wind turbine generators (WTGs) each capable of generating 13 to 16 MW of electric power[1], and one to two electrical service platforms (ESPs) that contain step-up transformers and other electrical gear to increase the voltage of power generated by the WTGs. The proposed OCS windfarm requires an OCS air permit under 40 CFR Part 55 and section 328 of the Clean Air Act (CAA). The requirements of EPA's Prevention of Significant Deterioration (PSD) at 40 CFR Part 52.21, including air quality modeling requirements, apply to the Park City Wind project.

The primary pollutants to be emitted by the project are oxides of nitrogen (NO_X), an ozone precursor; carbon monoxide (CO); particulate matter (PM) with diameter 10 microns or less (PM_{10}); and PM with diameter 2.5 microns or less ($PM_{2.5}$), a subset of PM_{10}. Though WTGs and ESPs do not emit pollutants themselves, the project will likely include diesel generators and other emitting equipment located on these devices, and engines on vessels used both during the construction and operations/maintenance phases of the project.

Vineyard Wind has requested to use an alternative model, as provided in §3.2 of the Guideline on Air Quality Models (40 CFR Part 51, Appendix W, hereafter referred to as the *Guideline*), to conduct its PSD air quality modeling analysis. Specifically, Vineyard Wind has requested to use the Coupled Ocean-Atmosphere Response Experiment (COARE) bulk flux algorithm, as implemented in the AERCOARE meteorological data preprocessor program, to prepare meteorological data for use in the American Meteorological Society/Environmental Protection Agency Regulatory Model (AERMOD) dispersion program to assess ambient impacts in a

[1] The exact number of turbines to be constructed as part of the project is unknown at this point but a final revised modeling protocol will assign a likely "worst case" emissions scenario to ensure protection of the NAAQS.

marine environment. Vineyard Wind submitted its request to initiate the alternative model approval process on August 9, 2021 (Attachment 1).

In its August 9, 2021 request, Vineyard Wind indicated its preference to utilize the AERCOARE/AERMOD alternative modeling approach over the EPA's preferred model, the Offshore and Coastal Dispersion (OCD) model. Vineyard Wind's August 9, 2021 request presented ten technical reasons, options, and/or features available in the alternative model to support its request. The presented criteria are listed below:

1. The Plume Rise Model Enhancements (PRIME) downwash algorithm available in AERCOARE/AERMOD can be used to assess impacts in the cavity and wake regions of structures, whereas the OCD model provides downwash for platforms only. The alternative model's downwash algorithm allows for assessing impacts of downwash from solid structures not provided for in OCD along with providing conservative treatment of downwash from the platform by treating it as a solid structure.

2. The alternative modeling approach relies on the use of the current version of AERMOD, which provides the option to use Tier 2 and Tier 3 NOx chemistry models. The Tier 2 ARM2 and the Tier 3 Plume Volume Molar Ratio Method (PVMRM) and Ozone Limiting Method (OLM) screening techniques can be used to estimate the conversion of oxides of nitrogen (NO_X) to nitrogen dioxide (NO_2) within AERMOD.

3. The alternative modeling approach relies on the use of the current version of AERMOD, which provides outputs in the statistical form that is needed to assess compliance with the newer statistically based National Ambient Air Quality Standards (NAAQS), such as 1-hour NO_2 and 24-hour $PM_{2.5}$. The OCD model does not contain this option. (Similarly, the AERMOD portion of the alternative model contains the option to employ the ARM2 Tier 2 screening technique, whereas OCD requires additional post-processing to apply NO_2 screening technique.)

4. AERMOD does not impose limits on the numbers of stationary, area, or line sources that can be included the same model simulation. By default, OCD limits the number of stationary sources to 8,500. OCD also imposes a non-adjustable limit on the number of area sources to five (5) and the number of line sources to one (1).

5. The alternative model allows for the estimation of ambient concentrations resulting from point, area, and volume sources. The OCD model can model point, line, and area sources but cannot model volume sources.

6. Calm wind conditions can be processed by the alternative model. The OCD model does not contain routines for processing either missing data or hours of calm winds—such processing requires custom post-processing.

7. The dispersion algorithm used in the AERMOD portion of AERCOARE/AERMOD is considered state-of-the-science by EPA. OCD is over 30 years old, and the dispersion

algorithms have not been updated to account for current advancements in dispersion theory.

8. AERMOD does not artificially limit the number of receptors that can be considered in an analysis. By default, OCD limits the number of discrete receptors to 3,000, polar receptors to 720, and Cartesian receptors to 1,600.

9. Several of the non-regulatory support programs (MAKEUTM, MAKEGEO) used to generate inputs into the OCD model require changes to the program Fortran code to generate the correct inputs for OCD.

10. Simulated meteorological outputs from the Weather Research and Forecasting (WRF) model can be used with AERCOARE. This capability eliminates the common difficulties associated with overwater buoy data collection and assimilation, such as hourly data recovery that does not meet minimum modeling requirements and the necessity to patch together data from multiple buoys and fill in missing values to meet minimum requirements. The Mesoscale Model Interface (MMIF) program can be used to read WRF data to generate the meteorology necessary for input to AERCOARE.

As discussed in this technical support document, EPA Region 1 has reviewed the applicant's alternative model request and determined that the use of the proposed alternative model is acceptable. As such, EPA Region 1 currently intends to approve the use of AERCOARE in conjunction with AERMOD for the proposed Park City Wind facility.

2. Modeling Approach

Vineyard Wind has not yet submitted its PSD application for the Park City Wind project, which will include an air quality impact analysis (AQIA) report, as required to fulfill requirements under 40 CFR Part 52.21. On January 13, 2021, Vineyard Wind provided EPA with a draft modeling protocol for the Park City Wind project in which OCD was proposed as the modeling platform for near-field impact assessment. The protocol raised the possibility that Vineyard Wind would request the use of the AERCOARE/AERMOD modeling system as an alternative model. EPA provided comments to Vineyard Wind on its draft protocol on May 25, 2021. The draft protocol and EPA comments are available upon request. A summary of the modeling approach is provided in this section.

Vineyard Wind originally proposed to use OCD version 5 to conduct the dispersion modeling analyses necessary to demonstrate compliance with the NAAQS, PSD Increments, and other applicable near-field air modeling analyses. At a later date, Vineyard Wind expressed a desire to instead use the AERCOARE/AERMOD modeling system for the reasons specified above. Upon approval of the alternative modeling approach, near-field modeling (both for NAAQS/PSD increment assessment and Class I screening at 50 km) will be conducted using the AERCOARE/AERMOD system. The AERCOARE/AERMOD modeling approach is summarized in a November 4, 2021 concurrence with the MMIF approach and AERCOARE settings. This information will be included in a final revised modeling protocol. Secondary formation of $PM_{2.5}$ would be determined using the Modeled Emission Rate for Precursors (MERP) methodology based on low-level stack modeling results for nearby representative hypothetical sources.

Vineyard Wind proposes to perform an initial assessment of Class I area impacts at a nominal 50-km distance using the approved near-field model, in accordance with the screening technique outlined in §4.2 of the *Guideline*. As directed in §4.2, if the analysis finds significant impacts at the screening distance, a long-range transport screening analysis will be needed. The long-range transport screening requires an analysis using a modeling system capable of assessing long-range pollutant transport to identify the significance of impacts at the nearest Class I areas. If screening finds impacts may be significant at Class I areas, a full-scale cumulative analysis may be necessary, under the direction specified in §4.2(d).

For the near-field NAAQS and PSD increment modeling analyses, Vineyard Wind will conduct an initial significant impact analysis (SIA) using the approved near-field model to determine if modeled impacts exceeded the significance levels (SILs). For project impacts that exceeded the SILs, a cumulative impact analysis will be conducted to demonstrate compliance with the associated NAAQS and/or PSD Increments.

Vineyard Wind plans to evaluate and use prognostic meteorological data provided by EPA from the WRF model and extracted by EPA using MMIF for overwater and on-land locations. A prognostic model evaluation will be provided to demonstrate the WRF data adequately replicate observed conditions in the 2018-2020 time period at the selected sites. The methods used to evaluate the WRF dataset are described in the supplement to the modeling protocol, attached.

3. Alternative Model Proposal Review

a. Regulatory Analysis and Background

Under 40 CFR Part 55.13(d), the PSD preconstruction air permit requirements of 40 CFR Part 52.21 apply to new OCS sources. Part 52.21(k) requires a source impact analysis be conducted as part of the permitting process to confirm the new source will not cause or contribute to the violation of an air quality standard. The source may be exempt from the Part 52.21(k) requirements, if emissions are temporary, as specified under Part 52.21(i)(3). However, if applicable, to qualify for the exemption under Part 52.21(i)(3) a modeling demonstration may be required to show the proposed source will not impact a Class I area.

40 CFR Part 52.21(l) states that all applications of air quality modeling shall be based on the applicable models specified in the *Guideline*. However, Part 52.21(l) also provides that on a case-by-case basis a modification or substitution of an air quality model may be used following written approval from the EPA Regional Administrator. In addition, the use of a modified or substituted model is subject to notice and opportunity for public comment. The alternative model approval process and conditions are outlined in Section 3.2 of the *Guideline*. Section 3.2.2(a)

specifies that the determination of acceptability of an alternative model is a Regional Office responsibility in consultation with EPA's Model Clearinghouse (MCH). An alternative model may be used subject to Regional Office approval if found to satisfy the requirements listed in Section 3.2.2.

Vineyard Wind requested approval of the alternative model AERCOARE/AERMOD under condition 3 of Section 3.2.2(b), i.e., where there is no preferred model for the specific application. The section 3.2.2(b) states the alternative model shall be evaluated from both a theoretical and performance perspective before regulatory use and outlines the three separate conditions where an alternative model may be approved. The request from Vineyard Wind states that "though OCD is listed as the preferred model in Appendix W… the preferred model is less appropriate (i.e., outdated science) for its application to the Project."

The *Guideline* specifies the preferred model for overwater sources is the OCD model. OCD is a straight-line Gaussian model developed to determine the impacts of offshore emissions from point, area, or line sources on the air quality of coastal regions. Some of the key features of OCD potentially applicable to offshore sources are the inclusion of platform building downwash and continuous shoreline fumigation. However, as discussed in Section 1 of this document, OCD does have limitations, as described by Vineyard Wind in its request to use an alternative model for its air quality modeling analyses. The following limitations are of particular importance to the Park City Wind project:

(1) OCD does not provide for the multi-tiered screening approach for NO_2 modeling (specifically the Tier 2 or Tier 3 screening approaches);
(2) OCD does not contain options to generate outputs in the statistical forms consistent with current NAAQS;
(3) OCD does not account for calm wind conditions when calculating predicted pollutant concentrations;
(4) OCD cannot be used to model volume sources, and has a limited ability to model line sources; and
(5) OCD does not account for current advancements in dispersion theory. Namely, OCD determines dispersion parameters through the use of overwater-specific Pasquill-Gifford-Turner stability classes and prescribed curves based on stability class. As recognized in the preamble to the 2005 release of AERMOD[2], the model uses state-of-the-art formulations based on planetary boundary layer principals (Monin-Obukhov Similarity Theory) to determine dispersion parameters rather than the stability-class-based systems used in the replaced models.

In addition, the key features of OCD not provided in AERCOARE/AERMOD are either not applicable to the Park City Wind project, or AERCOARE/AERMOD provides a more appropriate approach. Based on the proposed location of the Park City Wind project being

[2] US EPA (2005): Revision to the Guideline on Air Quality Models: Adoption of a Preferred General Purpose Dispersion Model and Other Revisions; Final Rule. 70 Fed. Reg. 68219

approximately 50 km offshore, and the fact that the controlling concentrations will occur close to the facility at overwater receptors, OCD's feature regarding shoreline fumigation is not needed. Additionally, the shoreline distance from the proposed facility of 50 km occurs at the upper distance limit of a near-field model, such as OCD. Therefore, the applicant has stated that the use of the OCD model to accurately simulate conditions at the shoreline is questionable.

It is also important to note the regulatory model AERMET is not appropriate for the project modeling because it is configured only to provide meteorological inputs to AERMOD over land surfaces. The structure and behavior of the boundary layer of the atmosphere is highly dependent on the amount of heat flux to and from the atmosphere from the earth's surface. The parameterization schemes in AERMET only account for diurnal energy balance over the land surface, which is fundamentally different than the system of energy balance over a body of water.

The system of energy balance over water differs from that over land mainly due to the high heat capacity of water and the related timescales of change. Over land, the atmosphere is easily affected by the diurnal heating cycle due to rapid heating and cooling of the surface in response to solar and terrestrial radiation flux. The surfaces of large bodies of water heat and cool at a much slower rate, responding on a time scale relative to seasonal changes rather than diurnal cycles. AERCOARE computes the atmospheric parameters needed for AERMOD considering heat flux driven by the difference in temperature between the water surface and the atmosphere. This process is relatively independent of time-of-day.

AERMOD alone does not depend on parameterizations specific to over-land conditions. The meteorological inputs to AERMOD provide information to determine the structure of the atmosphere using Monin-Obukhov Similarity Theory. This parameterization scheme is universally applicable to over-land and over-water domains, generally.

Regarding downwash features, while OCD accounts for platform downwash, Vineyard Wind's proposed use of AERCOARE/AERMOD as an alternative model will utilize the PRIME downwash algorithm, which will provide conservative results by treating the proposed platform structure as a solid structure that extends downward to the sea surface. In addition, the PRIME downwash algorithm allows for the more appropriate treatment of downwash from solid structures and ships at sea.

For these reasons, Vineyard Wind has requested the use of an alternative model (AERCOARE/AERMOD) via Condition 3 under Section 3.2.2(b) and provided justification for the alternative model consistent with the requirements listed in Section 3.2.2(e).

Section 3.2.2(e) sets forth the five elements that must be satisfied for alternative model approval under Condition 3 of Section 3.2.2(b):

I. The model or technique has received a scientific peer review.

II. The model or technique can be demonstrated to be applicable to the problem on a theoretical basis.
III. The databases which are necessary to perform the analysis are available and adequate.
IV. Appropriate performance evaluations of the model or technique have shown that the model or technique is not inappropriately biased for regulatory application.
V. A protocol on methods and procedures to be followed has been established.

The EPA has approved use of AERCOARE/AERMOD as an alternative model in the past under §3.2.2(b). The first approval was in 2011, where EPA Region 10 approved the use of the AERCOARE/AERMOD system for a project in the Arctic Ocean off the north coast of Alaska[3]. EPA Region 6 approved the use of AERCOARE/AERMOD for a project off the coast of Texas in the Gulf of Mexico in 2019[4].

The following section of this technical review document provides an examination of Vineyard Wind's justification for the approval of AERCOARE/AERMOD for its overwater source with respect to the requirements of Section 3.2.2(e).

b. Evaluation of Approach under Section 3.2.2(e)

In its alternative model request, Vineyard Wind referenced the April 2011 EPA Region 10 approval and EPA MCH concurrence with the use of AERCOARE/AERMOD for an Arctic marine ice-free environment on the basis that the alternative model satisfied the five criteria contained in Section 3.2.2(e) of the *Guideline*. The April 2011 EPA MCH concurrence memorandum stated the Region 10 approval did not constitute a general approval of AERCOARE/AERMOD for other applications. However, the memorandum did state that the April 2011 Region 10 approval concurrence request did provide "a good basis for consideration of AERCOARE/AERMOD for other applications, subject to Regional Office approval based on an assessment of the appropriateness of the performance evaluations (3.2.2(e), element 4) and the availability of the necessary data bases (3.2.2(e), element 3) on a case-by-case basis." Therefore, the justification for the use of AERCOARE/AERMOD for the Park City Wind modeling analysis addressed each of the five elements in Section 3.2.2(e), with emphasis on elements 3 and 4, as discussed below.

I. The model or technique has received a scientific peer review.

As detailed in the April 2011 Region 10 approval, the science behind the COARE algorithm, which has been incorporated into AERCOARE, has been published in scientific peer review journals. In its approval, Region 10 confirmed a sufficient body of peer-reviewed literature was available to confirm the scientific legitimacy and applicability of the COARE algorithm to

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[3] The Model Clearinghouse Information Storage and Retrieval System (MCHISRS) Record for the April 2011 Region 10 approval of AERCOARE/AERMOD is available at: https://cfpub.epa.gov/oarweb/MCHISRS/index.cfm?fuseaction=main.resultdetails&recnum=11-X-01
[4] The Model Clearinghouse Information Storage and Retrieval System (MCHISRS) Record for the November 2019 Region 6 approval of AERCOARE/AERMOD is available at: https://cfpub.epa.gov/oarweb/MCHISRS/index.cfm?fuseaction=main.resultdetails&recnum=19-VI-01

various over-water conditions. The Region 10 approval also documented communications with experts confirming the current version of the COARE algorithm is configured to handle a wide range of temperature gradient conditions, up to the extremes that could be found in the tropics or the Arctic.

Though noted in these earlier approvals, it is important to identify a key foundational peer-reviewed article that demonstrated the effectiveness of the COARE 3.0 algorithm when compared to datasets from multiple air-sea flux and bulk meteorological data collection campaigns; Fairall et al. (2003):

Fairall, C.W.; Bradley, E.F.; Hare, J.E.; Grachev, A.A.; Edson, J.B. (2003): Bulk Parameterization of Air-Sea Fluxes: Updates and Verification for the COARE Algorithm. Journal of Climate, Vol. 16, pp. 571-591. https://doi.org/10.1175/1520-0442(2003)016%3C0571:BPOASF%3E2.0.CO;2.

Vineyard Wind noted one of the verification datasets used in Fairall et al. was from the FASTEX marine boundary layer dataset, collected in winter of 1996-1997 across the North Atlantic Ocean, in part off the coast of New Brunswick, Canada, approximately 300 miles from the project. Additional information and references pertaining to the development of the COARE model and its can be found at: http://www.coaps.fsu.edu/COARE/.

The concepts and configuration of the AERCOARE model, and its linkage with AERMOD, were described in the 2016 peer-reviewed article by Region 10 and partner scientists, Wong et al. (2016):

Wong, H.; Elleman, R.; Wolvovsky, E.; Richmond, K.; Paumier, J. (2016): AERCOARE: An overwater meteorological preprocessor for AERMOD, Journal of the Air & Waste Management Association, 66:11, 1121-1140, DOI: 10.1080/10962247.2016.1202156

Wong et al. heavily relied on the findings reported in the EPA-supported study of AERCOARE/AERMOD performance summarized in the 2012 report:

ENVIRON 2012. Evaluation of the Combined AERCOARE/AERMOD Modeling Approach for Offshore Sources. Prepared for U.S. Environmental Protection Agency Region 10, Seattle, WA. EPA Contract EP-D-08-102, Work Assignment 5-17, EPA 910-R-12-007, October 2012.

Furthermore, the EPA supported a study to evaluate AERCOARE/AERMOD performance when specifically using inputs from a prognostic meteorological model, as is proposed for Vineyard Wind's application. The peer-reviewed EPA report demonstrated the approach, using 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 (U.S. EPA (2015)):

U.S. EPA (2015): Combined WRF/MMIF/AERCOARE/AERMOD Overwater Modeling Approach for Offshore Emission Sources, Vol. 2. EPA 910-R-15-001b, October 2015.

II. *The model or technique can be demonstrated to be applicable to the problem on a theoretical basis.*

As Vineyard Wind observes in their request, the EPA has previously found the AERCOARE/AERMOD approach to be applicable, on a theoretical basis, for the simulation of pollutant dispersion in the marine atmospheric boundary layer. In the April 2011 Region 10 alternative model approval, EPA deemed AERCOARE/AERMOD to be appropriate for use in the Arctic marine ice-free environment. In the 2019 Region 6 approval of AERCOARE/AERMOD, EPA determined the model was also appropriate on a theoretical basis for use in the subtropical marine environment off the coast of Louisiana.

Vineyard Wind also notes EPA's current user manual for AERCOARE reflects on the range of findings on the accuracy and applicability of the model for prescribing meteorological parameters over a variety of marine conditions:

> 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.

As stated above, AERCOARE computes the meteorological input parameters needed for AERMOD by accounting for heat flux to and from the atmosphere due to the difference in temperature between the water surface and the air. Wong et al. noted energy flux is determined in the COARE 3.0 algorithm using empirical relationships based on wind speed, temperature gradient, and relative humidity in the marine atmospheric surface layer. Monin-Obukhov Similarity Theory is used in an iterative process to determine friction velocity, Monin-Obukhov scaling length, and sensible heat flux. AERCOARE uses air-water temperature difference and mixing ratio gradients to determine sensible and latent heat flux, whereas AERMET determines fluxes based mostly on use of the Bowen ratio and assumptions regarding the diurnal cycle of solar and terrestrial radiation flux.

Also, as stated above, AERMOD alone does not depend on parameterizations specific to over-land conditions. The meteorological inputs to AERMOD provided by AERCOARE provide the information necessary to parameterize the structure of the marine atmospheric boundary layer using Monin-Obukhov Similarity Theory. This parameterization scheme is universally applicable to over-land and over-water domains. Therefore, it is imperative the COARE algorithm itself produces accurate atmospheric flux and stability parameters for AERMOD.

The COARE 3.0 algorithm uses standard meteorological variables such as wind speed, air temperature, relative humidity, and water temperature to determine bulk transfer coefficients used in Monin-Obukhov Similarity Theory to describe the structure of the atmospheric surface layer. Fairall et al. demonstrates the COARE 3.0 algorithm performs well predicting momentum and scalar transfer coefficients reportedly within 5% for wind speeds up to 10 m/s and within 10% for wind speeds from 10 to 20 m/s. These coefficients determine the shape of the wind profile as well as the turbulent flux parameterization used in AERMOD. These statistics were determined comparing the algorithm to thousands of hourly-averaged measurements taken on multiple campaigns throughout the world, including the NOAA FASTEX experiment conducted in winter of 1996-1997 across the north Atlantic Ocean.

Given the information provided in the literature and documentation supporting prior EPA approval, EPA Region 1 finds the AERCOARE-AERMOD modeling approach is applicable to the project on a theoretical basis.

III. The databases which are necessary to perform the analysis are available and adequate.

This element of §3.2.2 of the *Guideline* refers to the databases collected to develop and verify the proposed modeling methodology. The marine meteorological databases used to develop the COARE algorithm are available publicly in the scientific literature, as listed in Fairall et al.

Datasets from dispersion experiment campaigns have been used to verify the accuracy of the AERCOARE/AERMOD modeling approach. There are a limited number of historical overwater dispersion datasets available in the record that involve study of air pollutant dispersion in the marine atmospheric boundary layer. Historically, four robust studies from the 1980s have been used in the performance evaluations of OCD, CALPUFF, and AERCOARE-AERMOD:

- Cameron, Louisiana: July 1981 and February 1982 (Dabberdt, Brodzinsky, Cantrell, & Ruff, 1982[5])
- Carpinteria, California: September 1985 (Johnson & Spangler, 1986[6])
- Pismo Beach, California: December 1981 and June 1982 (Schacher, et al., 1982[7])
- Ventura, California: September 1980 and January 1981 (Schacher, et al., 1982)

[5] 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.

[6] 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.

[7] 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, Naval Postgraduate School.

Vineyard Wind points out that the Region 10 alternative model approval of AERCOARE/AERMOD utilized tracer gas experiments from the Cameron, Louisiana, and California studies. In both the Region 10 EPA approval and Region 6 EPA 2019 approval, these datasets were determined to be adequate for verification of the AERCOARE/AERMOD system. These same datasets have been used for the analysis of AERCOARE/AERMOD when used with WRF-MMIF data in U.S. EPA (2015) and the Bureau of Ocean Energy Management's review of AERMOD as a replacement model for OCD[8].

Vineyard Wind provided additional information to Region 1 in a November 24, 2021 letter (Attachment 2) to demonstrate the referenced tracer studies were sufficiently representative of the marine environment off the coast of Massachusetts. Key statistics provided for the Buzzards Bay buoy demonstrate that the range of atmospheric conditions that typically occur in the region fit the range of conditions used to develop and verify the COARE 3.0 algorithm.

Buzzards Bay air-sea temperature gradient data and wind data from the April 1997 to December 2008 timeframe were obtained to compare to the range of conditions used to develop the COARE 3.0 algorithm and the conditions during the four tracer experiments. The buoy is located 61 kilometers from the project and is the nearest offshore meteorological station. The maximum hourly average wind speed measured at the buoy was 30.2 m/s and the 99th percentile of wind speed was about 17 m/s. The COARE algorithm was developed and verified with conditions up to 20 m/s.

Vineyard Wind provided statistics on the distribution of wind speed and air-sea temperature differences from the four tracer studies, consisting of a total of 100 hourly observations. The maximum wind speed was 12.7 m/s, during the Pismo Beach study. Average wind speeds during each study ranged from 2.3 to 5.0 m/s. Average wind speed at Buzzards Bay buoy was 7.7 m/s, with a 25th percentile wind speed of 5.0 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.

The minimum air-sea temperature differences from the tracer studies were -5, -2, -1, and -1 degrees Kelvin from the Cameron, Ventura, Pismo Beach, and Carpinteria studies, respectively. The 25th percentile air-sea temperature difference at the Buzzards Bay buoy was -2.6 degrees Kelvin, indicating a majority of the conditions with a negative gradient fall within the most extreme range of conditions tested in the AERMOD simulations of the tracer experiments. The 4th percentile of the Buzzards Bay buoy air-sea temperature difference was about -9.0 degrees Kelvin. Therefore, the most extreme statically unstable conditions that may occur at the site are just outside the range of conditions evaluated in the tracer experiments.

[8] Ramboll Environ, 2017. Model Justification Demonstration to Support Outer Continental Shelf Dispersion Modeling in the Arctic. Prepared by Ramboll Environ, Inc., Lynnwood, WA for U.S. Department of the Interior, Bureau of Ocean Energy Management, Alaska OCS Region, Anchorage, AK. February 3, 2017.

Maximum air-sea temperature differences from the tracer studies were 5, 3, 4, and 2 degrees Kelvin from the Cameron, Carpinteria, Pismo Beach, and Ventura studies, respectively. The 75th percentile air-sea temperature difference at the Buzzards Bay buoy was 1.6 degrees Kelvin, indicating a majority of the conditions with a positive gradient fall well within the range of conditions tested in the AERMOD simulations of the tracer experiments. The 99th percentile of temperature differences is about 7 degrees Kelvin. Therefore, the most extreme statically stable conditions that may occur at the site are just a bit outside the range of conditions evaluated in the tracer experiments.

Evaluation of the AERCOARE/AERMOD modeling approach could be improved if additional overwater tracer experiments were conducted under the more extreme temperature gradient conditions found in the marine mid-latitudes. However, we have not found a record of additional tracer experiments conducted in these conditions. The four tracer studies evaluated do cover a range of wind and temperature gradient conditions that cover the majority of the range of conditions that occur at the project site, as inferred through the Buzzards Bay dataset. Most importantly, the low windspeed conditions that result in highest impacts are well addressed in the tracer studies.

The more extreme temperature gradients evaluated in the Cameron study cover the behavior of plumes under the more strongly stable and unstable conditions that could occur in the marine atmospheric surface layer. The ENVIRON (2012) study showed AERCOARE/AERMOD performed well in predicting maximum concentrations from the Cameron tracer study, which occurred during the more statically stable conditions. The Robust High Concentrations (RHC) from the model nearly matched the RHC from the observations in this study.

Based on these findings, 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.

IV. Appropriate performance evaluations of the model or technique have shown that the model or technique is not inappropriately biased for regulatory application.

In their request, Vineyard Wind noted EPA's prior Region 10 approval of AERMOD/AERCOARE relied on the results of demonstrations showing no bias toward underestimates, using the campaign datasets listed above. EPA Region 6's approval of AERMOD/AERCOARE also relied on the results found in the original Region 10 approval.

In the Region 10 evaluation, AERCOARE/AERMOD predictions from five cases using various combinations of meteorological data assembly were obtained for each of three tracer study datasets (the Ventura dataset was not included in the original Region 10 evaluation, due to the receptors being well inland and considered not completely representative of the marine environment). The five combinations tested involved different approaches to mixing height calculation, use or no use of wind direction variance, and other settings. Statistical procedures were applied to evaluate whether the AERCOARE/AERMOD alternative modeling approach was biased towards underpredictions.

Vineyard Wind's analysis focused on Q-Q plots for the Cameron and Pismo Beach studies, comparing the combinations of AERCOARE/AERMOD simulations to measurements from each study. The plots demonstrate the model tends to overestimate concentrations at the upper-end of the distribution for both studies. The highest concentrations in the Cameron case from all modeled combinations match well to the observations. The highest concentrations in the Pismo Beach case are well above the observations, exceeding more than the factor-of-two threshold. The Region 10 approval also included a Q-Q plot of the results from the Carpinteria study, which showed AERCOARE/AERMOD results at the high end of the distribution exceeding the measured concentrations. It is also noted, the five combinations of AERCOARE configurations tested result in predicted concentrations that are all generally of the same magnitude.

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. 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 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[9].

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

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

approach does not result in systematic underprediction of concentrations. Instead, the evidence more likely leads to the conclusion the approach is conservative.

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

Vineyard Wind submitted a modeling protocol to EPA on in January 2021. The modeling protocol outlined the modeling techniques employed in the air modeling analyses conducted in support of the Park City Wind project. This modeling protocol supplemented the applicant's demonstration of AERCOARE/AERMOD as an alternative model contained in their August 9, 2021 request. The original protocol did not include the methods and procedures for developing the input meteorology using WRF-MMIF nor did it include the methods and procedures for the use of AERCOARE. A supplemental attachment was sent on November 4th, 2021 outlining the following:

i. A description of the EPA's 2018-2020 WRF dataset to be used to provide input meteorology.

Vineyard Wind intends to use EPA's national 2018-2020 12-km Weather Research & Forecasting prognostic model dataset to provide meteorological inputs to the AERCOARE/AERMOD system. The EPA's 2018-2020 WRF run was conducted using WRF version 4. A nested grid system was used, with an innermost grid at 9 km resolution, which will be used for the meteorological inputs for this project.

ii. Details regarding the prognostic model evaluation approach. The evaluation must be included with the AQIA as part of the permit application.

Vineyard Wind will provide a prognostic model evaluation as part of the AQIA, as required under §8.4.5.2. of the *Guideline*. Vineyard Wind will compare WRF model performance at a number of NOAA surface weather stations, including marine stations monitoring ocean sea-surface temperature. In this evaluation, Vineyard Wind will include a qualitative comparison of modeled and measured wind roses and plots of seasonal wind speed, wind direction, temperature, and relative humidity. Vineyard Wind will also include quantitative evaluations of WRF model bias and error of wind speed, wind direction, temperature, and relative humidity at each of these locations.

iii. The settings to be used in MMIF.

Vineyard Wind has asked EPA Region 1 to run MMIF to provide the meteorological input files for AERCOARE from the EPA's 2018-2020 national WRF dataset, which is stored on EPA's national ATMOS Beowulf cluster computer system. EPA's guidance for use of MMIF for AERMOD applications[10] will be referred to in setting up and running MMIF. Vineyard Wind

[10] U.S. EPA (2018): Guidance on the Use of the Mesoscale Model Interface Program (MMIF) for AERMOD Applications. EPA-454/B-18-005, U.S. EPA Office of Air Quality Planning and Standards. Available at: https://gaftp.epa.gov/Air/aqmg/SCRAM/models/related/mmif/MMIF_Guidance.pdf

has specified use of coordinates: 70.648° W, 40.904° N (the centroid of the project) as the data extraction point for the prognostic dataset. MMIF will be ran by EPA using the following settings:

- Use of WRF output settings for mixing height ("AER_MIXHT = WRF", as opposed to a MMIF-diagnosis of mixing height).
- Use of surface characteristics provided by WRF (as opposed to use of AERSURFACE)
- Use of a minimum mixing height of 25 meters, as used in the EPA Region 10 approval, discussed above.
- Use of a minimum absolute value of Monin-Obukhov Length of 5 meters, as used in the EPA Region 10 approval, discussed above.
- Minimum wind speed of 0 m/s ("AER_MIN_SPEED = 0")

iv. The setup and settings to be used in AERCOARE.

Vineyard Wind intends to run AERCOARE using default settings recommended in EPA's AERCOARE User's Guide[11], except as specified below:

- Minimum wind speed used by AERMOD is 0.283 m/s. Wind speeds below this value will be considered calms; WSCALM = 0.283 m/s
- Mixing heights provided by WRF-MMIF will be used, instead of calculated by AERCOARE. The minimum mixing height of 25 meters, assigned under the MMIF processing step, will be maintained.
- Warm layer and cool-skin effects will not be considered.
- Friction velocity will be determined from wind speed only; wave-height will not be considered.

v. Conclusions and Conditions for Use

EPA Region 1 has reviewed the alternative model request submittal provided by Vineyard Wind and has determined that the proposed AERCOARE-AERMOD modeling approach is acceptable as an alternative model for the air quality modeling analysis submitted in support of its OCS air permit application. Additionally, we find the modeling approach is appropriate for use with meteorological inputs provided by a prognostic meteorological model. Based on our review, we find that the proposed approach addresses the five elements contained in Section 3.2.2(e) of the *Guideline*. As such, pursuant to Sections 3.0(b) and 3.2.2(a), Region 1 currently intends to approve the use of AERCOARE/AERMOD as an acceptable alternative model for the Park City Wind project.

As with the April 2011 Region 10 alternative model approval of AERMOD-COARE, approval to use this alternative model is made on a case-by-case basis. Should an air permit applicant or state desire to use AERCOARE/AERMOD in an overwater modeling analysis for a different facility

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

and/or location, a request for alternative approval must be made to the appropriate EPA Regional Office containing the appropriate technical justifications/demonstrations consistent with the *Guideline*.

Attachment 1 - Vineyard Wind’s Alternative Model Request dated August 9, 2021

August 9th, 2021

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Mr. Leiran Biton
United States Environmental Protection Agency
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via email at: biton.leiran@epa.gov

Subject: Request for Approval for Use of COARE Bulk Flux Algorithm to Generate Hourly Meteorological Data for use with AERMOD

Dear Mr. Biton:

Vineyard Wind is proposing to construct, own, and operate the Park City Wind (PCW) offshore wind project (the Project, also referred to as Phase 1 of Vineyard Wind South) off the coast of Martha's Vineyard in Bureau of Ocean Energy Management (BOEM) Lease Area OCS-A 0501. PCW will be comprised of 50 to 62 wind turbine generators (WTGs) capable of generating 13 to 16 MW of power. PCW would be in federal waters within the Outer Continental Shelf (OCS), approximately 17.6 miles from Noman's Land Island[1] and 19.9 miles off the coast of Martha's Vineyard, MA. Figure 1 shows the location of PCW.

PCW is subject to Prevention of Significant Deterioration (PSD) preconstruction permitting and the associated source impact analysis requirements of 40 Code of Federal Regulations (CFR) 52.21(k). The primary pollutants to be emitted would be Oxides of Nitrogen, Carbon Monoxide, particulate matter 10 microns or smaller (PM10); and particulate matter 2.5 microns or smaller (PM2.5, a subset of PM10).

While the generation of renewable offshore wind energy does not emit air contaminants, there will be air emissions from vessels and other equipment involved in the construction and O&M of the Project. Any air emission source that is "attached to the seabed and erected thereon" within the OCS and is used to develop the Project is an OCS source regulated by EPA's OCS Air Regulations. OCS sources from the Project will likely include diesel generators located on the WTGs and ESP(s) as well as any engines on jack-up

[1] Noman's Land Island while the nearest on-shore area to the Project, has public access restrictions due to the possible presence of unexploded ordinance, Home - Nomans Land Island - U.S. Fish and Wildlife Service (fws.gov).

vessels (while their legs are attached to the seafloor), anchored vessels, and vessels that are tethered to an OCS source.

The Offshore and Coastal Dispersion (OCD) model is currently listed as the preferred model for over-water dispersion in the United States Environmental Protection Agency's (USEPA) Guideline on Air Quality Models (see Section 4.2.2.3 of Appendix W). PCW is seeking approval for the proposed Project to use the Coupled Ocean-Atmosphere Response Experiment (COARE) bulk flux algorithm as implemented within the AERCOARE program.

The COARE bulk flux algorithm is a series of equations which use the air-sea temperature difference, overwater humidity, and wind speed measurements to estimate the sensible heat, latent heat, and momentum fluxes. The COARE algorithm was developed based on measurements in the tropics, but has been extensively refined, evaluated, and globalized to improve its applicability in environments outside of the tropics (Fairall et al, 2003). The version 3 of the COARE algorithm has been implemented within the meteorological data processor program AERCOARE, to prepare meteorological data for use in the American Meteorological Society/Environmental Protection Agency Regulatory Model (AERMOD). AERCOARE, in conjunction with AERMOD is an alternative model for assessing compliance with air quality standards when emission sources and dispersion occur over water.

AERCOARE-AERMOD is preferred by PCW over OCD because of the following technical advantages, options, and features available in the model:

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 OCD model does incorporate platform downwash, PCW has proposed use of PRIME considering the platform as a solid structure which will result in conservative, overprediction of concentrations.

2. The Plume Volume Molar Ratio Method (PVMRM) and Ozone Limiting Method (OLM) may be used by the Project to estimate the conversion of oxides of nitrogen (NOx) to nitrogen dioxide (NO_2). If PVMRM or OLM are not used, the Ambient Ratio Method (ARM2) screening technique will be used within the model.

3. Output can be generated in the statistical form that is needed to assess compliance with the newer statistically based National Ambient Air Quality Standards (NAAQS), such as 1-hour NO_2, and PM2.5.

4. The AERMOD-AERCOARE model can model multiple line sources, and more than 5 areas sources within the same model run and does not limit the number of sources that can be modeled simultaneously.

5. The AERMOD-AERCOARE model can model volume sources.

6. Calm wind conditions can be processed by the AERMOD-AERCOARE model.

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

8. AERCOARE-AERMOD does not artificially limit the number of receptors that can be considered in an analysis.

9. Several of the programs (MAKEUTM, MAKEGEO) used to generate inputs into the OCD model require changes to the program Fortran code to generate the correct inputs for OCD.

10. AERCOARE will directly accept Weather Research and Forecasting (WRF) data model predicted hourly meteorological output from the Mesoscale Model Interface (MMIF) program.

Pursuant to Section 3.0 and 3.2.2.a of 40 CFR 51, Appendix W (Guideline on Air Quality Models[2]), approval of an alternative refined model is the responsibility of the Regional Administrator (USEPA Region 1). There are three separate conditions outlined in Section 3.2.2.b of Appendix W under which an alternate model may be approved by the Regional Administrator for regulatory use, as listed below:

3.2.2.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

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

3. If there is no preferred model.

Park City Wind will be seeking approval to use AERCOARE-AERMOD using Condition 3. Although OCD is listed as a preferred model in Appendix W, this request is made because the preferred model is less appropriate (i.e., outdated science) for its application to the Project. In addition, model performance of the AERCOARE-AERMOD modeling approach has been found to be comparable to OCD using the tracer studies from overwater field studies[3]. In this study, the authors conclude that AERCOARE-AERMOD could be applied as an alternative to OCD for many regulatory applications.

It should be noted that while the AERCOARE-AERMOD modeling approach contain algorithms for simulating the atmosphere that are technically superior to the OCD model, the OCD model currently has capabilities that AERCOARE-AERMOD modeling approach does not. Namely, OCD has algorithms to estimate the effects of both platform downwash and shoreline fumigation.

The PCW WTGs resemble platforms, so consideration of platform downwash effects is relevant. However, PCW will treat any platforms as solid structures without airflow under the platform. This procedure will result in an overestimate of downwash effects and lead to conservative, overprediction of concentrations.

Similarly, consideration of shoreline fumigation may be relevant, given the proximity of PCW to shore. However, PCW will demonstrate as part of the permit record that concentrations are below the Class II significant impact levels at the nearest publicly accessible state boundaries to the Project.[4]

Under Condition 3, there are five elements that must be addressed (see Section 3.2.2.e):

1. The model has received scientific peer review;
2. The model can be demonstrated to be applicable to the problem on a theoretical basis;
3. The databases that are necessary to perform the analysis are available and adequate;

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[3] 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.

[4] As shown in Figure 1, PCW is 19.9 miles from Martha's Vineyard Island, this represents the nearest publicly accessible location to PCW.

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.

On April 1st, 2011, the USEPA 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.[5,6] The COARE algorithm output was assembled with other meteorological variables in a spreadsheet to form the AERMOD overwater meteorological input files. After USEPA's 2011 approval of the use of the COARE algorithm in spreadsheet form the COARE air-sea flux procedure was coded into the AERCOARE program.

On October 1st, 2019, the proposed Sea Port Oil Terminal (SPOT) requested the use of AERCOARE-AERMOD for a proposed offshore oil export facility. The SPOT request documented several limitations of OCD, as well as the key dispersion features of OCD that are not available within AERCOARE-AERMOD (i.e., platform downwash and shoreline fumigation). The SPOT request documented that the applicant would model the platform sources as solid structures and that the project's operation was sufficiently offshore that shoreline fumigation would not be a concern.

On November 19th, 2019, USEPA approved the use of AERCOARE-AERMOD for SPOT.[7] PCW's request to use AERCOARE-AERMOD is modeled after the SPOT request.

As documented in the USEPA Region 10 memorandum and the USEPA Region 6 SPOT approval, 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 Appendix W. In both concurrence memorandums, the USEPA's Model Clearinghouse stated that its concurrences with the approvals did not constitute a generic approval of

[5] 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, USEPA to Tyler Fox, USEPA, April 1, 2011.

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

[7] Model Clearinghouse review of an alternative model application of AERCOARE in conjunction with AERMOD for the proposed Sea Port Oil Terminal (SPOT) Terminal Services LLC's Deepwater Port Project, George Bridgers, USEPA to Ashley Mohr, USEPA November 19th, 2019.

AERCOARE-AERMOD for other applications. However, USEPA's Model Clearinghouse stated:

"As similarly stated in the May 2011, EPA Region 10 concurrence response, this case-specific Model Clearinghouse concurrence does not constitute a generic approval of a coupled AERCOARE-AERMOD approach for other applications elsewhere. However, the scope of the technical assessment submitted with this EPA Region 6 Model Clearinghouse and the previous EPA Region 10 requests provide a good basis for such considerations."

Therefore, PCW provides the following justification for each of the five elements contained in Section 3.2.2.e.

1. The model has received scientific peer review.

As described in the Region 10, April 2011 approval, the science behind the COARE algorithm which has been implemented in AERCOARE has been published in multiple peer-reviewed journals. Information pertaining to scientific peer review can be found at the following site: http://www.coaps.fsu.edu/COARE/.

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

Both the Region 10, April 2011 approval and the 2019 SPOT approvals contain the same documentation that the COARE algorithm is applicable on a theoretical basis. That documentation is repeated verbatim 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:

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 paper 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, approximately 300 miles from PCW.

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 PM2.5, 1-hour NO2, and 1-hour SO2 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 recent versions of 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."

For these reasons PCW believes that AERMOD-AERCOARE is applicable to the problem on a theoretical basis.

3. The databases that are necessary to perform the analysis are available and adequate.

The AERCOARE model evaluation document describes the tracer datasets available for analysis:

"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 Region 10 approval noted the following regarding the limited tracer 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, R10 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.""

PCW is located offshore, in an ice-free environment with level terrain near the shoreline. The terrain and offshore conditions mimic the immediate environment of the Cameron, Louisiana and Pismo Beach, California studies. The sea-surface temperatures seen in the vicinity of PCW would be expected to fall somewhere in between the tropical temperatures experienced in Cameron and the arctic temperatures experienced in Alaska.

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, it can be concluded that the necessary datasets to evaluate the AERCOARE are available and are adequate.

Furthermore, 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.

The April 1, 2011, memorandum from USEPA Region 10, in conjunction with the USEPA/ENVIRON October 2012 Model Evaluation Study, present the detailed results of the model evaluation studies. Each of these studies reach the conclusion that the model is not biased toward underestimates.

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.

AERMOD was run using default dispersion options for rural flat terrain for both simulations. Peak calculated concentrations were compared to peak observed concentrations (from tracer gas in-field concentration measurements), resulting in a total of 101 paired samples for statistical analysis. Quantile-quantile (Q-Q) plots were prepared, among other statistical analyses, to test the ability of the model predictions to represent the frequency distribution of the observations. Q-Q plots are ranked pairings of predicted and observed concentrations. The rank of the predicted concentration is plotted against the same ranking of the observed concentration. The Q-Q plots were evaluated to determine whether the models are biased toward underestimates at the important upper end of the frequency distribution.

The Q-Q plot for the Cameron, Louisiana, dataset is presented as Figure 2 and the Q-Q plot for Pismo Beach, California is shown as Figure 3. As shown, the model concentrations generally are within the factor of 2 bounds of the plot. In addition, no apparent difference in the model performance under the five different AERCOARE meteorological data preparation cases were observed. The AERMOD predictions using AERCOARE-prepared meteorological data tend to be biased toward over-prediction for the highest concentrations, with less than a factor of 2 under-prediction 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.

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

PCW has developed and submitted a modeling protocol document for USEPA Region 1 review and approval using OCD. The modeling protocol outlines the modeling techniques that will be employed by the PCW Project, and it conforms with the modeling procedures outlined in the Guideline on Air Quality Models (Appendix W of 40 CFR 51), associated USEPA modeling policy and guidance, as well as Massachusetts Department of Environmental Protection (MassDEP) Air Quality Modeling Guidelines. This protocol will be updated to reflect the use of AERCOARE-AERMOD if approved by USEPA.

Summary

Based on the information and rationale provided in this document, along with supporting references, data and past precedents, PCW believes that the proposed AERCOARE-AERMOD modeling approach is justified as a more suitable method for estimating dispersion in the OCS off the Atlantic Coast than OCD. The surface fluxes calculated by the COARE algorithm in conjunction with the overwater meteorological data are preferred to the conventional application of AERMET, which is only applicable over land surfaces. AERMOD is preferred over OCD because of the PRIME downwash algorithm, the ability to simulate volume sources, the ability to incorporate NOx to NO2 conversion using PVMRM or OLM, AERMOD's ability to generate the concentrations in the statistical form of the new NAAQS, and the distance of the proposed source location from the shoreline.

If you have any questions or require additional information, please contact me at 978-461-6265 or jsabato@epsilonassociates.com.

Sincerely,

EPSILON ASSOCIATES, Inc.

Joseph Sabato, CCM
Senior Consultant

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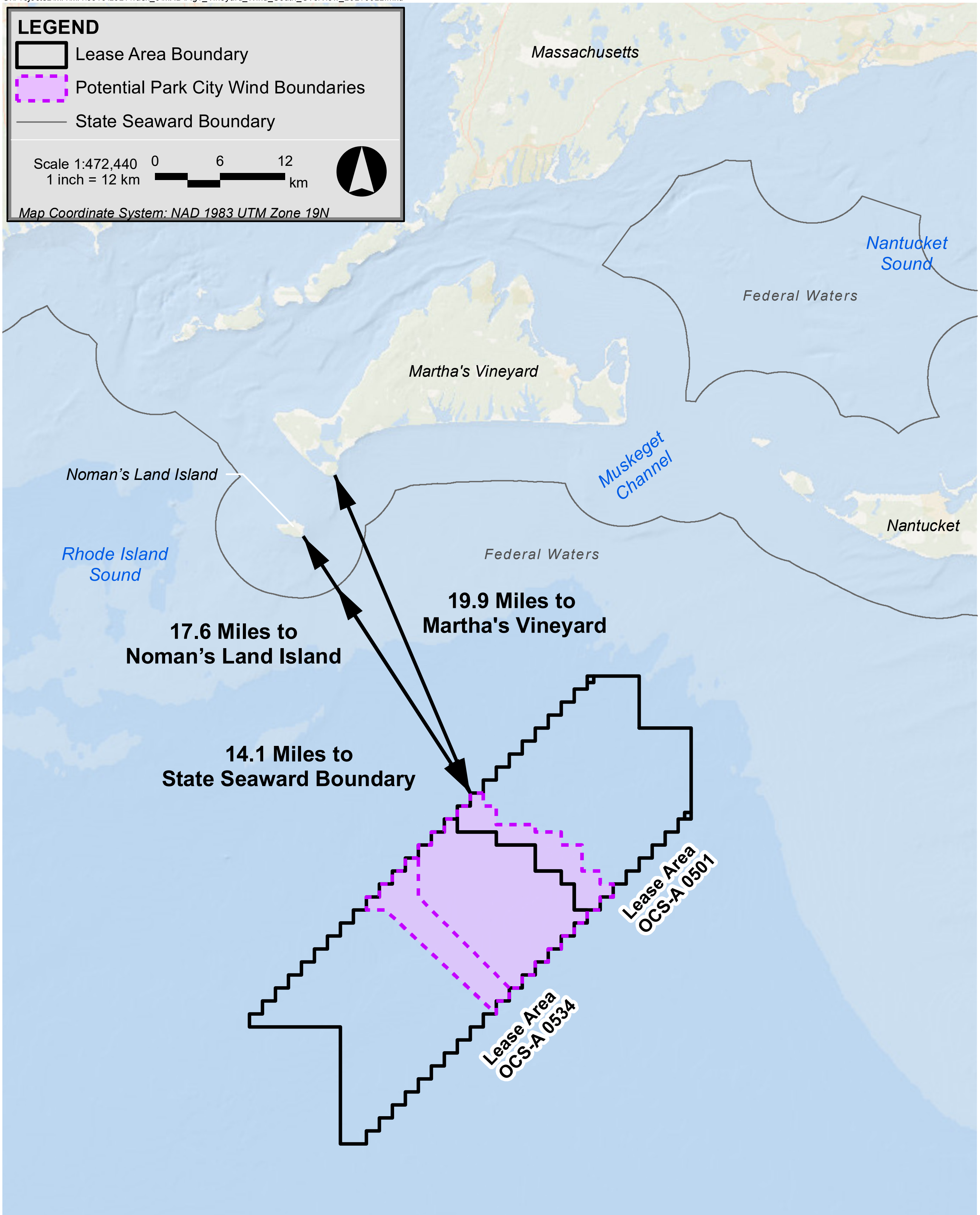

Park City Wind

VINEYARD WIND

Figure 1
Park City Wind Overview

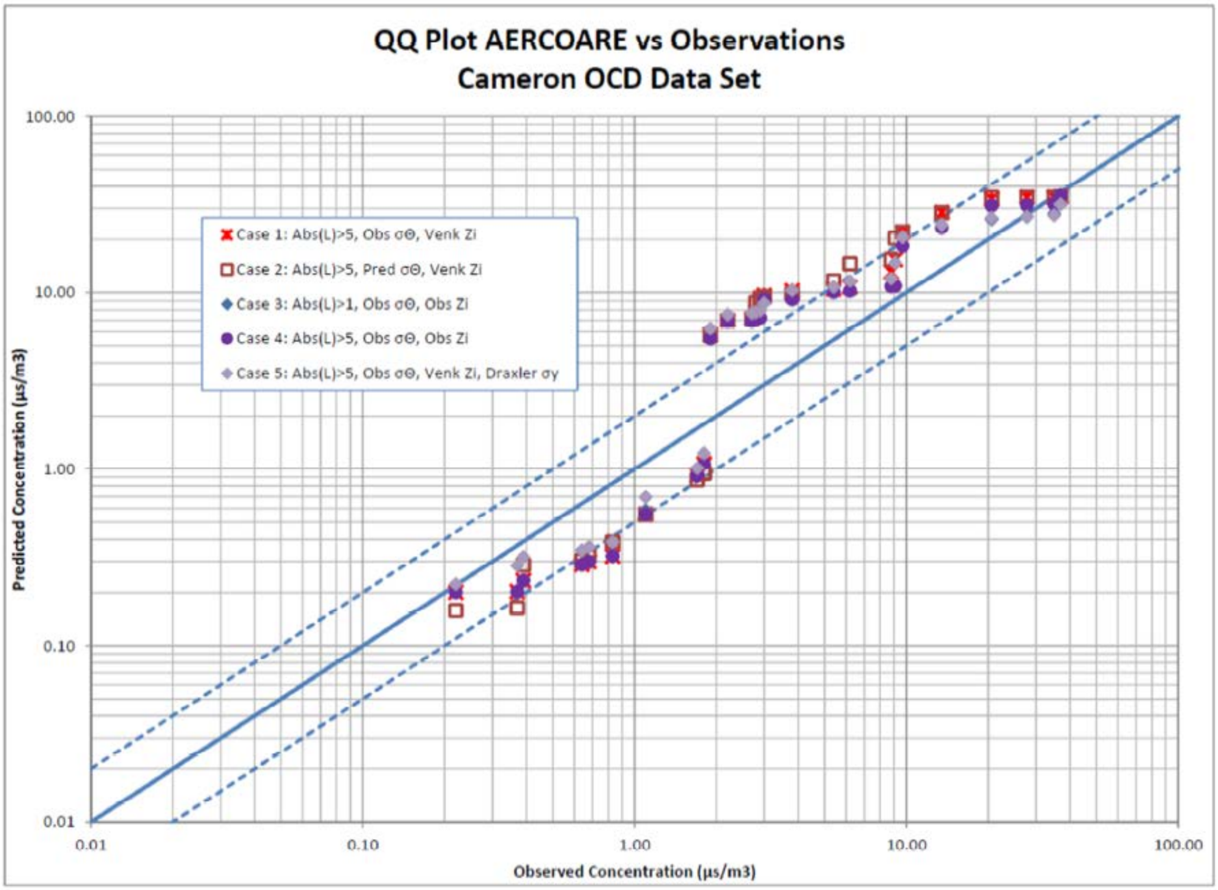

Figure 2: QQ Plot of AERCOARE versus Cameron, Louisiana, Tracer Study Results

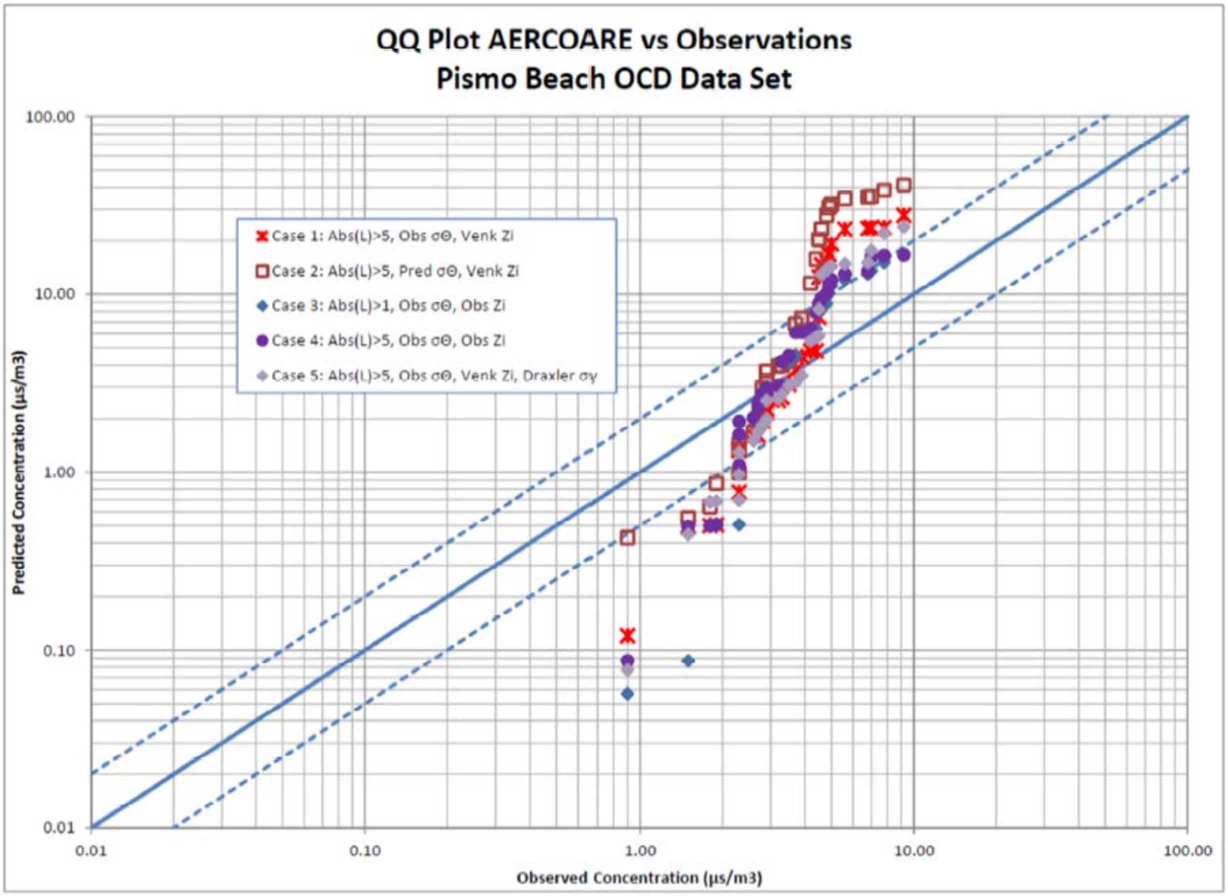

Figure 3: QQ Plot of AERCOARE versus Pismo Beach, California, Tracer Study Results

Attachment 2 – Vineyard Wind's letter sent November 24th, 2021, in response to EPA's request for additional information.

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November 24, 2021

Mr. Jerrold McAlpine
United States Environmental Protection Agency
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via email at: McAlpine.Jay@epa.gov

Subject: Supplemental Information for the Request for Approval for Use of COARE Bulk Flux Algorithm to Generate Hourly Meteorological Data for use with AERMOD

Dear Mr. McAlpine:

The Park City Wind (PCW) offshore wind project requested the use of the COARE Bulk Flux Algorithm to generate hourly meteorological data for use in AERMOD on August 9, 2021. PCW received a request from EPA for additional information. EPA requested that PCW provide key arguments that support the distribution of meteorological conditions (specifically wind speed and air/sea temperature difference) used to develop COARE and occurred during the AERCOARE/AERMOD verification studies cover a range of conditions of importance off the New England coast. This letter provides the supplemental information requested.

As described in the alternative model approval request there are four tracer datasets that were used to validate the AERCOARE model, three of them occur in California and one in Louisiana. The four validation datasets contain a total of 100 hours of meteorological data for comparison. These same validation studies are the ones that were used to validate the Off-Shore Coastal (OCD) Dispersion Model which is the EPA preferred overwater model.

Data from the Buzzards Bay (BUZM3) buoy was downloaded from April 27th, 1997, through December 31st, 2008, from the National Data Buoy Center as this was the period where data was available for both wind speed and the air/sea temperature difference. The Buzzards Bay buoy is located 61 kilometers miles from PCW and represents the closest location where both wind speed and air/sea temperature difference data are available.

The data from Buzzards Bay and the four tracer gas studies were examined to determine the distribution of each dataset for wind speed (meters/second, m/s) and air/sea temperature difference (Kelvin, K). Wind speed at the Buzzards Bay buoy ranges from 0 to 30 m/s and from 1 to 12 m/s across the four validation datasets. Air/Sea Temperature Difference ranges from -20.6 to 13.1 K at the Buzzards Bay buoy and from -5 to 5 K across the four validation datasets. The distribution of wind speed and air/sea temperature difference appears in Table 1 below for each of the datasets.

Table 1: Wind Speed and Air/Sea Temperature Difference Summary Statistics

Wind Speed (m/s) Summary Statistics for Selected Locations								
Location	Variable	Observations	Minimum	25th Percentile	Median	Average	75th Percentile	Maximum
Cameron, LA	Wind Speed (m/s)	26	2.1	3.7	4.6	4.5	5.0	6.2
Carpinteria, CA		36	1.0	1.3	2.1	2.3	3.1	5.4
Pismo Beach, CA		31	1.3	3.8	5.6	6.0	8.3	12.7
Ventura, CA`		17	3.1	4.2	4.9	5.0	5.8	6.9
Buzzards Bay		97,765	0.0	5.0	7.3	7.7	9.9	30.2
Air/Sea Temperature (K) Difference Summary Statistics for Selected Locations								
Cameron, LA	Temp. Difference (K)	26	-5	-2	1	0	2	5
Carpinteria, CA		26	-1	-1	0	1	2	3
Pismo Beach, CA		31	-1	0	1	1	2	4
Ventura, CA`		17	-2	-1	0	0	0	2
Buzzards Bay		63,279	-20.6	-2.6	0.0	-0.8	1.6	13.1

The datasets were also 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 Buzzards Bay and the four validation datasets were plotted, broadly they show that wind speeds at Buzzards Bay 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.[1] 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 1.

Similarly, box and whisker plots were used to examine the distribution of the air/sea temperature difference between Buzzards Bay and the four validation studies. The median of the Buzzards Bay dataset 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 and that the air/sea temperature difference seen in New England is similar to what was measured during the validation

[1] See Fairall et al, 2003. "Most of our measurements for U > 12 m/s were acquired in the Fronts and Atlantic Storms Experiment (FASTEX) (North Atlantic) and Moorings (North Pacific) field studies."

studies. The Box and Whisker Plots for Air/Sea Temperature Difference are shown in Figure 2.

Summary

Based on the information and rationale provided both in the initial alternative model approval request and in this document, along with the supporting references, data and past precedents, PCW continues to believe that the proposed AERCOARE-AERMOD modeling approach is justified as a more suitable method for estimating dispersion in the OCS off the Atlantic Coast than OCD. The surface fluxes calculated by the COARE algorithm in conjunction with the overwater meteorological data are preferred to the conventional application of AERMET, which is only applicable over land surfaces. AERMOD is preferred over OCD because of the PRIME downwash algorithm, the ability to simulate volume sources, the ability to incorporate NOx to NO2 conversion using PVMRM or OLM, AERMOD's ability to generate the concentrations in the statistical form of the new NAAQS, and the distance of the proposed source location from the shoreline.

While the wind speeds seen off the coast of New England do appear to be moderately higher than what was measured during the validation studies, the COARE algorithm has been validated against a dataset to specifically account for those conditions.

If you have any questions or require additional information, please contact me at 978-461-6265 or jsabato@epsilonassociates.com.

Sincerely,

EPSILON ASSOCIATES, Inc.

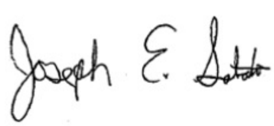

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Figure 1 Box and Whisker Plots of Wind Speed (m/s)

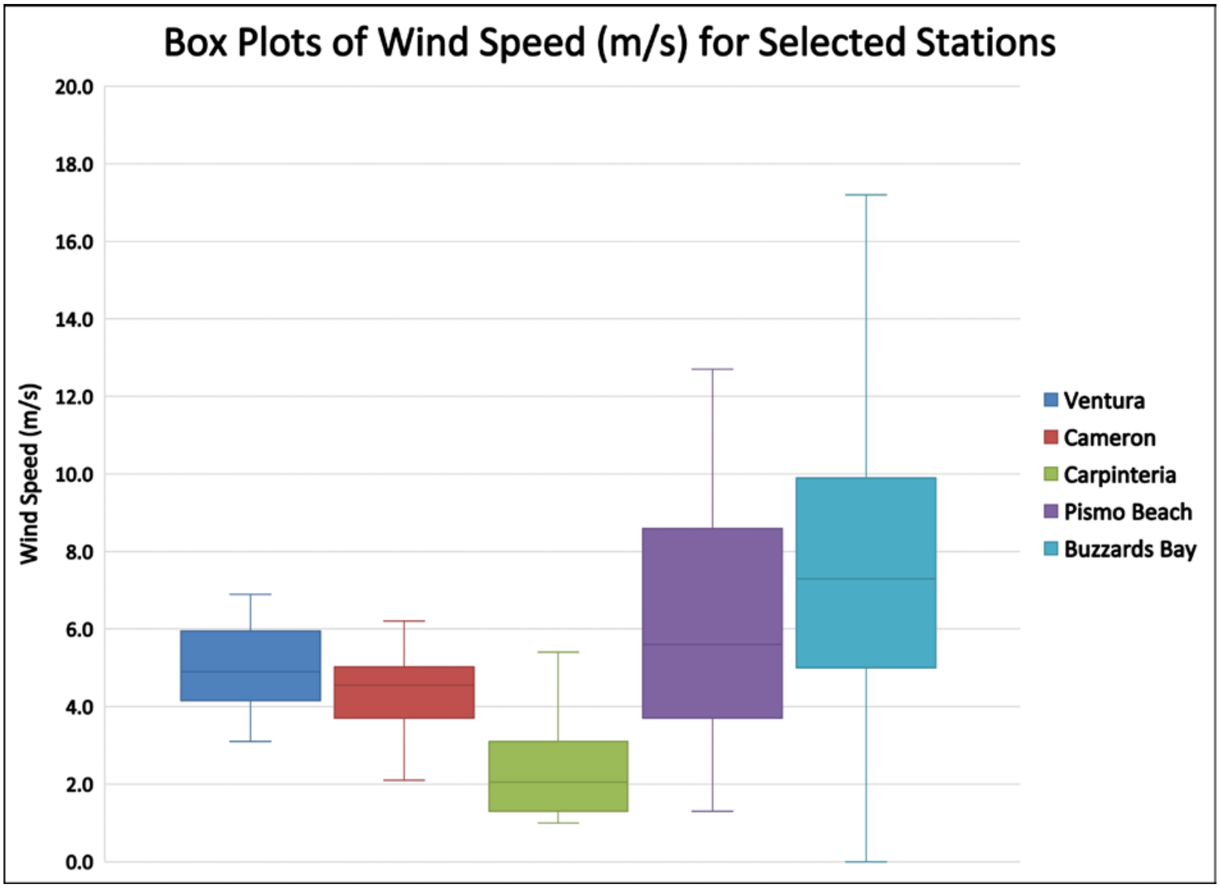

Figure 2 Box and Whisker Plots of Air/Sea Temperature Difference (K)