Evaluation of Prognostic Meteorological Data in AERMOD Overwater Applications

EPA-454/R-23-010
October 2023

Evaluation of Prognostic Meteorological Data in AERMOD Overwater Applications

U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Air Quality Assessment Division
Research Triangle Park, NC

Preface

This document provides an evaluation of the performance of prognostic data in AERMOD via the AERMET pass-through option and the COARE processing option in marine boundary layer environments added to AERMET as part of the 2023 revisions to the *Guideline on Air Quality Models*. The purpose of the document is to provide results to compare results between passing certain meteorological data from WRF through AERMET to AERMOD and using the COARE algorithms in AERMET for the same data. Also, results are presented to show the difference, if any, between using multiple vertical levels of data or a single vertical level of data. Included in this document are descriptions of the inputs, comparison of meteorological output from AERMET using standard AERMET processing and the COARE algorithms, and comparison of AERMOD results between both approaches.

Acknowledgements

This report was developed as part of the 2023 proposal of *The Guideline on Air Quality Models*, Appendix W with input from the meteorological data workgroup comprised of staff from EPA's Office of Air Quality Planning and Standards and Region 10. WRF a processing for the evaluations were processed by General Dynamics Information Technology.

Contents

Figures

Tables

1.0 Introduction

In recent years, applications of AERMOD (U.S. EPA, 2023a) in marine boundary layer environments, i.e., overwater applications, have increased. Calculations of boundary layer parameters for the marine boundary layer present special challenges as the marine boundary layer can be very different from the boundary layer over land. For example, convective conditions can occur in the overnight hours in the marine boundary layer while typically over land, stable conditions occur at night. Also, surface roughness in the marine environment is a function of wave height and wind speed and less static with time than surface roughness over land.

While the Offshore and Coastal Dispersion Model (OCD) (DiCristofaro and Hanna, 1989) is the preferred model for overwater applications, there are applications where the use of AERMOD is applicable. These include applications that utilize features of AERMOD not included in OCD (e.g., NO_2 chemistry). Such use of AERMOD would require consultation with the Regional Office and appropriate reviewing authority to ensure that platform downwash and shoreline fumigation are adequately considered in the modeling demonstration.

For the reasons stated above, a standalone pre-processor to AERMOD, called AERCOARE (U.S. EPA, 2012a) was developed to use the Coupled Ocean Atmosphere Response Experiment (COARE) bulk-flux algorithms (Fairall et al., 2003) to bypass AERMET and calculate the boundary layer parameters for input to AERMOD for the marine boundary layer. AERCOARE can process either measurements from water-based sites such as buoys or prognostic data processed via the Mesoscale Model Interface program (MMMIF) (Ramboll, 2023). AERCOARE was developed in response of a need for overwater meteorology for an AERMOD application in an Arctic Ice Free Environment (U.S. EPA, 2011a) and that the boundary layer calculations in AERMET (U.S. EPA, 2023b) are more suited for land-based data.

To better facilitate the use of the COARE algorithms for AERMOD, EPA included the COARE algorithms into AERMET version 23132 (U.S. EPA, 2023b) as part of the 2023 proposed updates to the *Guideline on Air Quality Models* (U.S. EPA, 2023c), thus eliminating the need for a standalone pre-processor and ensures the algorithms are updated as part of routine AERMET updates. The evaluation of the implementation of COARE into AERMET is presented in U. S. EPA (2023d) and the results of the evaluation indicated that COARE was implemented into AERMET with no issues.

With the implementation of COARE into AERMET, there are now two options for processing prognostic data in AERMET for overwater applications. The first option was incorporated into MMIF 4.0 (Ramboll, 2023) and AERMET 22112. With this option, MMIF outputs an optional data flag with the DATA keyword for the PROG pathway of AERMET (U.S. EPA, 2023b) to let AERMET know if the data is overland, “OL” or overwater , “OW.” When the data are overwater, AERMET will use the MMIF output surface friction velocity (u*), Monin-Obukhov length, convective velocity scale (w*), potential temperature lapse rate, sensible heat flux, hourly surface roughness, and cloud cover, instead of calculating the first five variables, and using monthly surface roughness. This “pass-through” is used instead of AERMET calculating the variables as done for land-based data as the equations used in AERMET are more suitable for land-based applications. With the second option, COARE, AERMET will calculate the variables listed above using the COARE algorithms, as done with the AERCOARE processor using the standard input variables (wind, temperature, etc) in addition to three new variables added to the MMIF output for AERMET: sea surface temperature and measurement depth and longwave downward radiation. See the AERMET User’s Guide (U.S. EPA, 2023b) for details on the COARE processing in AERMET.

This report details the evaluation process to determine the differences between the two options in AERMET for prognostic data in the marine boundary layer environment, the pass through of key variables or COARE calculations. Also, this report will determine the differences between using one level of data as generally done with AERCOARE output from MMIF or multi-level data often generated for most applications of AERMET involving prognostic data. This report will not attempt to determine if prognostic data performs better or worse than observed meteorological data but the results based on observations are shared as a benchmark for comparisons of COARE vs. AERMET pass through and the number of levels.

The comparisons presented in this report do not include the warm layer or cool skin options available for COARE. These options have been included in AERMET but have not been evaluated as the data necessary for these options are not available in the datasets used in this evaluation. Section 2 discusses the methodology of the case studies used for the evaluations. There are four case studies used to evaluate the incorporation of COARE into AERMET: 1) Cameron, LA; 2) Carpinteria, CA, 3) Pismo Beach, CA, and 4) Ventura, CA. This report includes comparisons of meteorological data output from AERMET using the pass-through option, COARE processing, as well as comparisons of the use of single vs. multi-level data. The evaluations also include comparison of AERMOD results using both methods of processing and levels of data. Section 2.0 describes the methodology of the evaluations, Section 3.0 discusses the results of the evaluations, and Section 4.0 is the summary and conclusion of the evaluation.

2.0 Methodology

Following is the methodology of the evaluation of prognostic data with AERMET “pass-through” and COARE processing. Section 2.1 describes the study areas, Section 2.2 describes the AERMET configurations, Section 2.3 describes the meteorological data evaluation and Section 2.4 describes the AERMOD evaluation.

2.1 Study Areas

Four case study areas were considered for evaluation (Figure 1) as noted in Section 1.0. Each study area is detailed below and more information about each can be found in U.S. EPA (2012b).

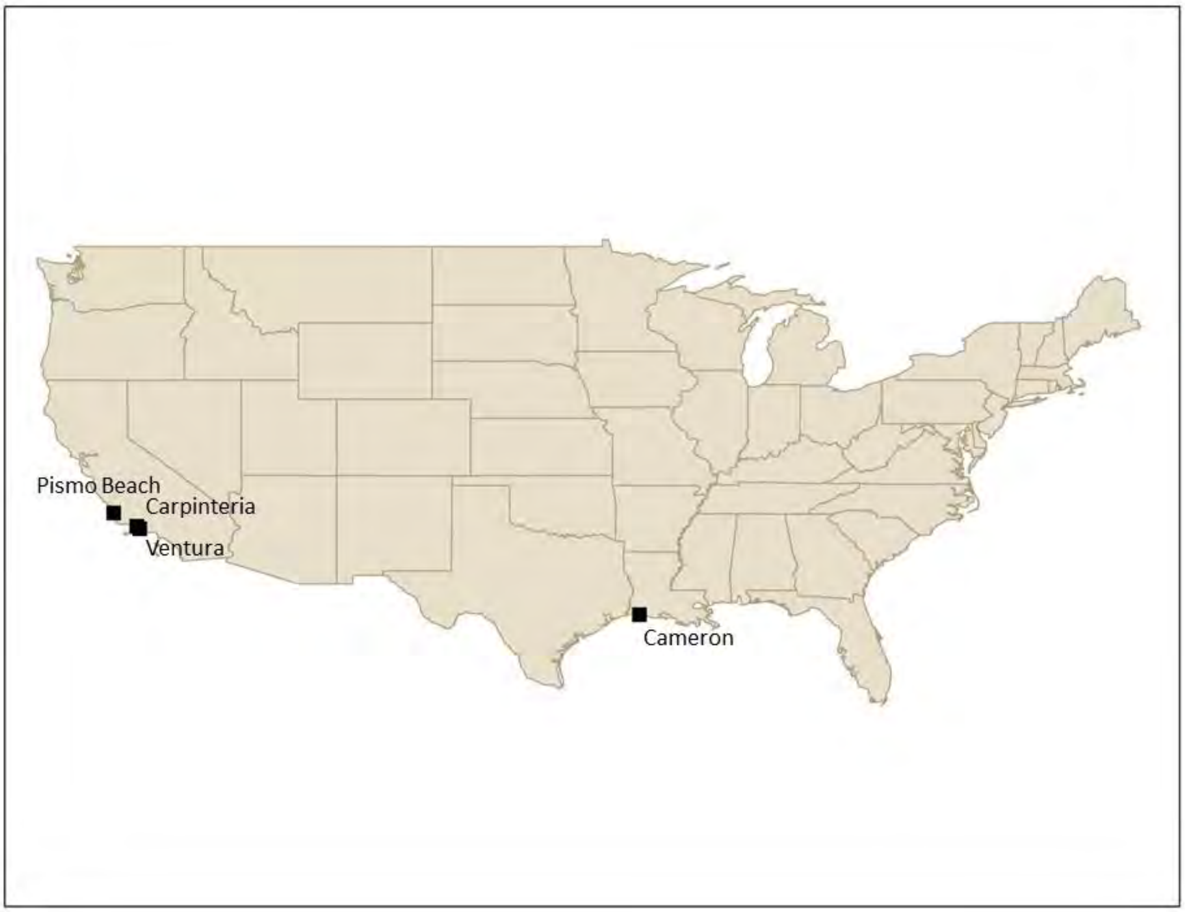


Figure 1. Study areas for COARE to AERMET testing.

2.1.1 Cameron, LA

The Cameron case study consisted of 26 tracer releases from field studies in July 1981 and February 1982. Tracer was released from both a boat and a low-profile platform at a height of 13 m. Receptors were located in flat terrain near the shoreline with transport distances ranging from 4 to 10 km (U.S. EPA, 2012b). **Error! Reference source not found.** shows the general study area. The meteorological data for Cameron is shown in Table 1. Note, for all hours, the station pressure was set to 1000 mb and wind direction was assumed to be 270° because AERMOD would be run in screening mode. The data set contains both very stable and fairly unstable conditions. There are several hours of stable lapse rates accompanied by unstable air-sea temperature differences. For example, on February 15, 1982, hour 1700, the air-sea temperature difference is -0.8 °C, while the virtual potential temperature lapse rate is 0.06 °C/m (extreme stability "G" in OCD). Over 10 m, this virtual potential temperature lapse rate would result in at least an air-sea temperature difference of +0.5 °C. The data was adjusted for the AERCOARE evaluations by adjusting the air-sea temperature difference to be at least as stable as indicated by the virtual potential temperature lapse rate. The sea temperature was adjusted so the air-sea temperature difference matched the measured potential temperature lapse rate (U.S. EPA, 2012b) and those hours are highlighted in Table 1.

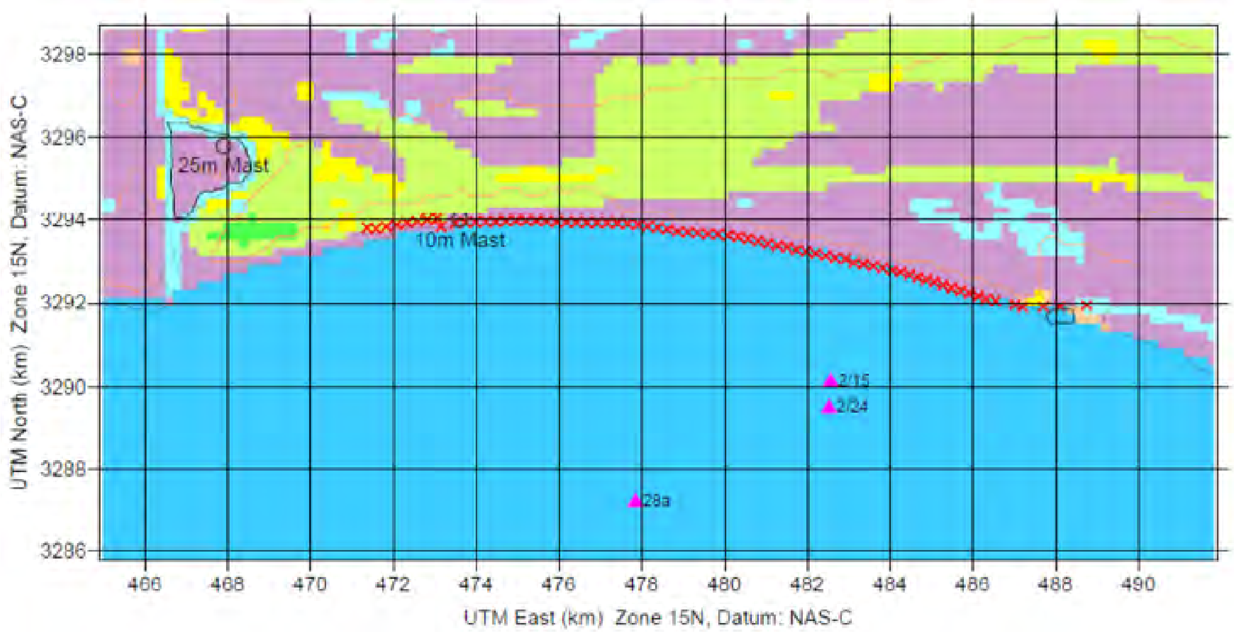


Figure 2. Cameron, LA study area

Table 1. Cameron measured meteorological data.

Date	Hour (LST)	Wind ht (m)	Wind speed (m/s)	Temperature/RH height (m)	RH (%)	Air temperature (°C)	Sea temperature (°C)	σ_θ (°)	Mixing height (m)
7/20/81	14	10	4.6	10	63	29.25	31.95	6.4	800
7/20/81	15	10	4.8	10	64	29.45	32.05	4.9	800
7/23/81	17	10	4.3	18	73	30.45	31.85	4.7	225
7/23/81	18	10	5.1	18	74	30.55	31.75	4.7	225
7/27/81	20	10	2.1	18	82	27.05	31.45	999	400
7/27/81	22	10	4.5	18	82	26.85	31.35	999	450
7/29/81	16	10	4.6	18	69	29.85	32.05	9.6	420
7/29/81	17	10	5	18	68	29.85	31.85	6.4	430
7/29/81	19	10	5	18	68	29.95	31.65	9.6	450
2/15/82	16	10	5.7	10	89	14.25	13.75	999	200
2/15/82	17	10	5.6	10	88	13.95	13.45	999	200
2/15/82	20	10	5.9	10	87	14.25	13.75	999	200
2/17/82	14	10	3.3	10	93	15.65	13.55	2.5	200
2/17/82	15	18	3.7	18	93	14.95	14.05	7.6	200
2/17/82	16	18	4.3	18	93	14.85	14.25	3.9	200
2/17/82	17	18	3.5	18	93	14.55	14.19	3.8	200
2/17/82	18	18	3.5	18	93	14.25	13.89	2.1	200
2/22/82	14	18	5.2	18	75	17.45	16.15	2.7	100
2/22/82	16	18	4.7	18	76	17.45	16.55	2.4	100
2/22/82	17	18	4.5	18	76	17.75	16.95	2.8	100
2/23/82	14	18	4.8	18	84	18.35	14.65	0.6	50
2/23/82	17	18	6.2	18	88	18.05	15.75	3.2	80
2/24/82	15	18	3.7	18	49	19.95	14.95	2.7	50
2/24/82	16	18	3.7	18	50	19.75	15.15	3.2	50
2/24/82	17	18	3.5	18	50	19.75	15.05	3.3	50
2/24/82	19	18	4.1	18	52	17.55	14.85	2.6	50

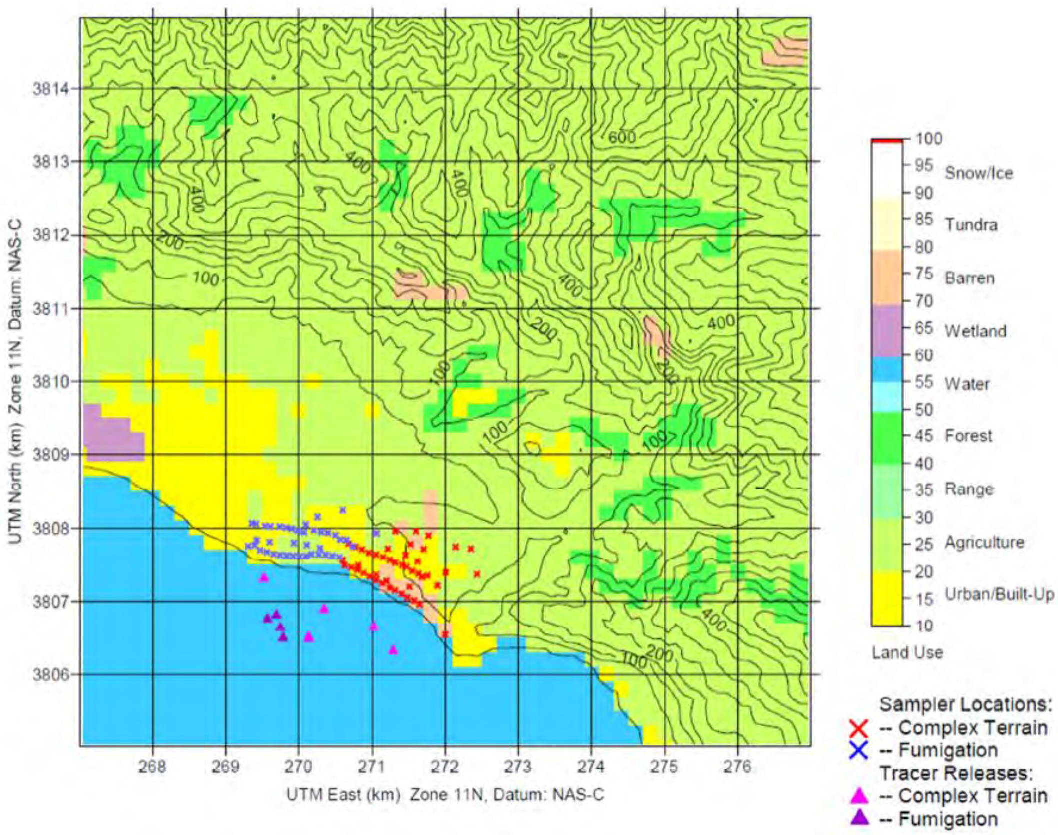
Table 2 shows the Cameron source and receptor data for AERMOD. Release heights for releases was 13.0 m. AERMOD was run in screening mode with westerly winds with the source location at (0,0). Receptor coordinates are (X,0) where X is the downwind distance of the peak observed concentration.

Table 2. Cameron source and receptor data.

Release number	Date	Hour (LST)	Building ht (m)	Building width (m)	Receptor distance (m)
1	7/20/81	14	0.0	0.0	7180
2	7/20/81	15	0.0	0.0	7400
3	7/23/81	17	0.0	0.0	8930
4	7/23/81	18	0.0	0.0	8710
5	7/27/81	20	0.0	0.0	7020
6	7/27/81	22	0.0	0.0	7859
7	7/29/81	16	0.0	0.0	7820
8	7/29/81	17	0.0	0.0	9780
9	7/29/81	19	0.0	0.0	9950
10	2/15/82	16	7.0	20.0	4834
11	2/15/82	17	7.0	20.0	5762
12	2/15/82	20	7.0	20.0	4526
13	2/17/82	14	0.0	0.0	7000
14	2/17/82	15	0.0	0.0	6985
15	2/17/82	16	0.0	0.0	7400
16	2/17/82	17	0.0	0.0	7260
17	2/17/82	18	0.0	0.0	6950
18	2/22/82	14	0.0	0.0	7095
19	2/22/82	16	0.0	0.0	7070
20	2/22/82	17	0.0	0.0	6955
21	2/23/82	14	0.0	0.0	7769
22	2/23/82	17	0.0	0.0	7245
23	2/24/82	15	7.0	20.0	5669
24	2/24/82	16	7.0	20.0	5669
25	2/24/82	17	7.0	20.0	6023
26	2/24/82	19	7.0	20.0	4786

2.1.2 Carpinteria, CA

The Carpinteria tracer study was conducted in September and October 1985. Studies were conducted to examine offshore impacts caused by both interaction with complex terrain and shoreline fumigation. The current analysis only evaluated the complex terrain data set as the AERCOARE-AERMOD approach currently cannot simulate shoreline fumigation.



shows the land use and terrain for the Carpinteria field study. The shoreline receptors are located on a 20 m to 30 m high bluff within 0.8 km to 1.5 km of the offshore tethersonde release. Two tracers were released with heights varying from 18 m to 61 m. The tethersonde was well above the anchor boat and downwash was not considered in the simulations.

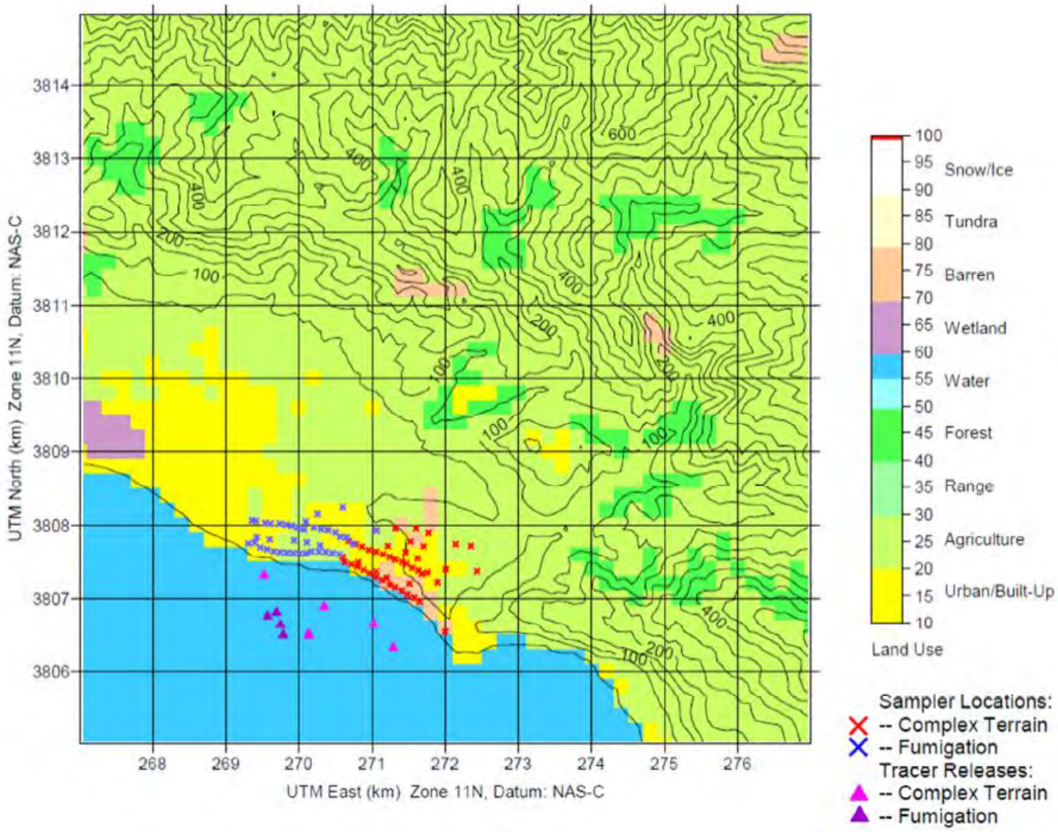


Figure 3. Carpinteria, CA study area.

Table 3 displays the meteorological data used in the current simulations and previous evaluations of OCD and CALPUFF. The winds were very light for most of the releases, especially considering the wind measurement heights were from 30 m to 49 m. Note that the air temperature and relative humidity measuring height was 9 m for all hours, station pressure was 1,000 mb for all hours, and the mixing height was 500 m for all hours. The combined influences of low wind speeds and the air-sea temperature differences in Table 3 result in cases with unstable to very stable stratifications. Unlike the Cameron data set, the virtual potential temperature lapse rates do not contradict the gradient inferred from the air temperature difference measurements. One suspect aspect of the data is the constant mixed layer height of 500 m for the entire data set. In cases where plumes are not trapped under a strong inversion, CALPUFF and OCD are less sensitive to the mixing height than AERMOD. Thus, uncertainty in the boundary layer height in this experiment may not have been important to the original investigators.

Table 4 lists the source release parameters used for the AERCOARE simulations of the Carpinteria data set. Unlike the other databases, actual wind directions, source locations and receptor sites were used in the analysis to consider the effects of terrain elevation on the model predictions. Receptor elevations and scale heights for AERMOD were calculated with AERMAP

(Version 11103) (EPA, 2011b) using 1/3 arc-second terrain data from the National Elevation Data (NED) set. The peak predicted concentration was compared to the peak measured concentration for each release.

Table 3. Carpinteria measured meteorological data.

Date	Hour (LST)	Wind ht (m)	Wind speed (m/s)	Wind direction (°)	RH (%)	Air temperature (°C)	Sea temperature (°C)	σ_θ (°)
9/19/85	9	30	1.3	259.7	78.8	16.3	17.4	26.8
9/19/85	10	30	1.3	235.4	79	16.8	17.6	28.4
9/19/85	11	30	2.6	214.1	80.1	17	17.7	24.4
9/19/85	12	30	3.1	252.9	80.1	17.1	17.8	32.9
9/22/85	9	30	1	220.8	70.6	17.4	16.9	32.1
9/22/85	10	30	1.2	251.1	81	17	16.7	17.4
9/22/85	11	30	2.4	253.8	92.1	16.4	15.4	8
9/22/85	11	30	2.4	230	92.1	16.4	15.4	8
9/22/85	12	30	2.8	248.4	91.1	16.3	15.2	17.4

9/22/85	12	30	2.8	237.7	91.1	16.3	15.2	17.4
9/25/85	10	24	1	163.8	60.3	21.2	18.4	41.7
9/25/85	11	46	1.6	163.8	69.9	21	18.7	9.9
9/25/85	12	46	1	165.6	90.3	20.9	18.8	26.1
9/25/85	13	46	1	175	90.4	21.4	18.7	18.4
9/26/85	12	49	3.8	262	83.5	18.7	19.4	10.9
9/26/85	13	49	4	262.2	81	18.8	19.8	11.8
9/28/85	10	24	5.4	155.8	85.1	18.1	18.7	8.9
9/28/85	10	24	5.4	155.8	85.1	18.1	18.7	8.9
9/28/85	11	24	3.2	174.7	84.1	18	18.8	10.9
9/28/85	11	24	3.2	177	84.1	18	18.8	10.9
9/28/85	13	24	1.5	234.5	82.5	18.3	18.9	10.9
9/28/85	13	24	1.5	229.5	82.5	18.3	18.9	10.9
9/28/85	14	24	2.1	215	81.7	18.5	18.8	11.8
9/28/85	14	24	2.1	215	81.7	18.5	18.8	11.8
9/29/85	11	30	3.4	243.7	86	18.2	18.5	18.4
9/29/85	12	30	3.1	238.9	87.8	18.1	18.5	5
9/29/85	12	30	3.1	232.7	87.8	18.1	18.5	5
10/1/85	9	61	2	215.5	92.1	16.5	17.4	19.2
10/3/85	10	61	1	164.6	89	26.3	24.2	12.8
10/3/85	11	61	1.8	215.5	95.9	24.8	21.4	32.9
10/4/85	12	76	1.7	216.9	70.3	21.6	18.3	14.7
10/4/85	9	76	2.6	231.2	71.9	21.7	18.4	11.8
10/4/85	10	76	1.7	186.4	76.4	21.3	18	13.7
10/5/85	11	91	1.3	171.3	66.8	20.9	20.2	28.4
10/5/85	11	91	1.5	208.2	64.8	21.3	20.6	19.2
10/5/85	12	91	1	195.2	62.7	21.5	20.8	28.4

Table 4. Carpinteria source parameters data.

Release number	Date	Hour (LST)	Release type	Release ht (m)	UTM East (m)	UTM North (m)
1	9/19/85	9	SF6	30.5	270,343	3,806,910
2	9/19/85	10	SF6	30.5	270,343	3,806,910
3	9/19/85	11	SF6	30.5	270,343	3,806,910
4	9/19/85	12	SF6	30.5	270,343	3,806,910
5	9/22/85	9	SF6	18.3	270,133	3,806,520
6	9/22/85	10	SF6	18.3	270,133	3,806,520
7	9/22/85	11	SF6	18.3	270,133	3,806,520
8	9/22/85	11	Freon	36.6	270,133	3,806,520
9	9/22/85	12	SF6	18.3	270,133	3,806,520

10	9/22/85	12	Freon	36.6	270,133	3,806,520
11	9/25/85	10	SF6	24.4	271,024	3,806,660
12	9/25/85	11	SF6	24.4	271,024	3,806,660
13	9/25/85	12	SF6	24.4	271,024	3,806,660
14	9/25/85	13	SF6	24.4	271,024	3,806,660
15	9/26/85	12	Freon	24.4	269,524	3,807,330
16	9/26/85	13	Freon	24.4	269,524	3,807,330
17	9/28/85	10	SF6	24.4	271,289	3,806,340
18	9/28/85	10	Freon	42.7	271,289	3,806,340
19	9/28/85	11	SF6	24.4	271,289	3,806,340
20	9/28/85	11	Freon	42.7	271,289	3,806,340
21	9/28/85	13	SF6	24.4	270,133	3,806,520
22	9/28/85	13	Freon	39.6	270,133	3,806,520
23	9/28/85	14	SF6	24.4	270,133	3,806,520
24	9/28/85	14	Freon	39.6	270,133	3,806,520
25	9/29/85	11	SF6	30.5	270,133	3,806,520
26	9/29/85	12	SF6	30.5	270,133	3,806,520
27	9/29/85	12	Freon	61	270,133	3,806,520

2.1.3 Pismo Beach, CA

The Pismo Beach experiment was conducted during December 1981 and June 1982. A depiction of land use, release point locations and receptor sites are shown in Figure 4 based on U.S. EPA (2012b). Tracer was released from a boat mast height of 13.1 m to 13.6 m above the water. Peak concentrations occurred near the shoreline at sampling distances from 6 km to 8 km away. The Pismo Beach evaluation database consists of 31 samples.

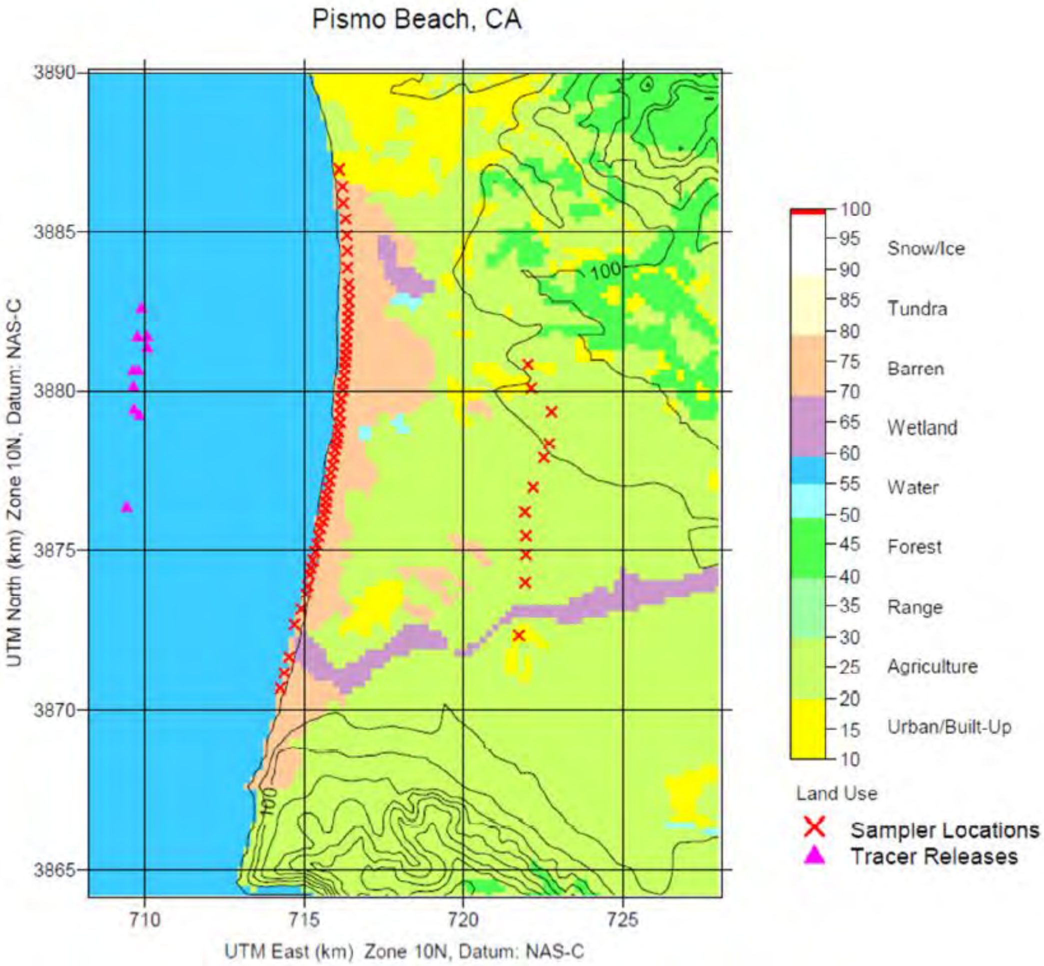


Figure 4. Pismo Beach, CA study area.

Table 5 lists the overwater meteorological data used in the current study. Note for all hours the station pressure was 1000 mb, wind measurement height was 20.5 m, air temperature/relative humidity measurement height was 7.0 m, and wind direction was assumed to be 270° because AERMOD was run in screening mode. Examination of the meteorological data in Table 5 reveals several inconsistencies between the air-sea temperature difference and the virtual potential temperature lapse rate. As with Cameron, the virtual potential temperature lapse rate sometimes indicates a stable boundary layer (positive) when the air-sea temperature difference is unstable (negative). Either there was a low mixed layer not reflected by the mixing height measurements in Table 5, or one of the measurements is not representative of the boundary layer profile. The air-sea temperature difference was adjusted to be at least as stable as indicated by the virtual potential temperature lapse rate to address this inconsistency in our evaluation. In these instances, the sea temperature was adjusted so the air-sea temperature difference matched the measured potential temperature lapse rate. The revised estimates are highlighted in gray in Table 5.

Table 5. Pismo Beach measured meteorological data.

Date	Hour (LST)	Wind speed (m/s)	RH (%)	Air temperature (°C)	Sea temperature (°C)	σ_θ (°)	Mixing height (m)
12/8/81	15	2.2	67	14.55	13.25	9.4	100
12/8/81	16	1.6	75	14.35	13.15	12.9	100
12/11/81	14	4.5	74	12.45	12.45	5.6	600
12/11/81	15	5.4	73	12.95	12.95	4.6	600
12/11/81	17	8.6	84	12.85	12.75	2.1	700
12/11/81	19	7.9	81	12.95	12.75	45	900
12/13/81	14	5.4	95	12.35	13.15	0.9	50
12/13/81	15	6.1	97	12.15	12.95	2.4	50
12/13/81	17	7.9	92	13.05	12.7	1.9	50
12/14/81	13	7.7	79	14.05	12.75	1.2	50
12/14/81	15	10.9	90	13.25	12.85	1.2	50
12/14/81	17	9.9	88	13.55	12.65	1.8	50
12/15/81	13	5.6	88	12.95	12.65	14.4	50
12/15/81	14	6.1	83	14.55	13.45	45	50
12/15/81	19	1.6	70	16.25	12.85	45	50
6/21/82	15	4.3	84	14.35	12.85	1.4	800
6/21/82	16	3.8	86	14.15	12.75	2.1	800
6/21/82	17	2.7	87	14.15	12.65	6.8	800
6/21/82	18	3	89	13.75	12.55	19.7	800
6/22/82	15	3.7	80	15.45	13.75	6.1	700
6/22/82	16	5.2	78	15.65	13.55	3.3	700
6/22/82	19	3.2	84	14.05	12.75	10.6	700
6/24/82	13	3.9	82	14.95	14.05	27.8	600
6/24/82	15	5.3	84	14.95	14.35	7.5	600
6/25/82	12	5.6	76	15.75	13.55	1.4	100
6/25/82	13	6.5	80	15.35	12.75	1.6	100
6/25/82	15	9.8	82	15.15	12.55	5.5	100
6/25/82	16	9.1	82	15.15	12.25	0.9	100
6/25/82	17	9.5	81	15.25	12.05	1.2	100
6/27/82	16	12.7	93	13.85	10.45	1.1	100
6/27/82	18	10.2	94	14.55	10.85	7.7	100

Table 6 shows the source-to-receptor relationships and the release characteristics assumed for the AERCOARE simulations. All simulations were performed with a unit emission rate and without plume rise. Building downwash from the release boat was considered using the dimensions with a constant building height of 7.0 m and building width of 20.0 m. As in the original OCD and CALPUFF evaluations, only peak concentration predictions and observations for each hour are compared in the current evaluation. To ensure that plume centerlines travelled over the receptor with the highest observed concentration, a constant westerly wind was assumed, and predictions were obtained at a single receptor located the correct distance east of the release point.

Table 6. Pismo Beach release heights and receptor distances.

Release number	Date	Hour (LST)	Release ht (m)	Receptor distance (m)
1	12/8/81	15	13.1	6730
2	12/8/81	16	13.1	6506
3	12/11/81	14	13.1	6422
4	12/11/81	15	13.1	6509
5	12/11/81	17	13.1	6619
6	12/11/81	19	13.1	7316
7	12/13/81	14	13.1	6516
8	12/13/81	15	13.1	6372
9	12/13/81	17	13.1	6870
10	12/14/81	13	13.1	6378
11	12/14/81	15	13.1	6378
12	12/14/81	17	13.1	6526
13	12/15/81	13	13.1	6944
14	12/15/81	14	13.1	6697
15	12/15/81	19	13.1	8312
16	6/21/82	15	13.6	6532
17	6/21/82	16	13.6	6589
18	6/21/82	17	13.6	6748
19	6/21/82	18	13.6	6532
20	6/22/82	15	13.6	6125
21	6/22/82	16	13.6	6214
22	6/22/82	19	13.6	6054
23	6/24/82	13	13.6	6244
24	6/24/82	15	13.6	6244
25	6/25/82	12	13.6	6406
26	6/25/82	13	13.6	6377
27	6/25/82	15	13.6	6406
28	6/25/82	16	13.6	6435
29	6/25/82	17	13.6	6455
30	6/27/82	16	13.6	6630
31	6/27/82	18	13.6	6579

2.1.4 Ventura, CA

The Ventura experiment was conducted during September 1980 and January 1981. Land use, release point locations and receptor sites are shown in Figure 5 based on the files from the CALPUFF evaluation archives. The tracer was released from a boat mast height of 8.1 m above the water. Peak concentrations occurred along the closet arc of receptors in Figure 5 at sampling distances from 7 km to 11 km away. The Ventura evaluation database consists of 17 samples.

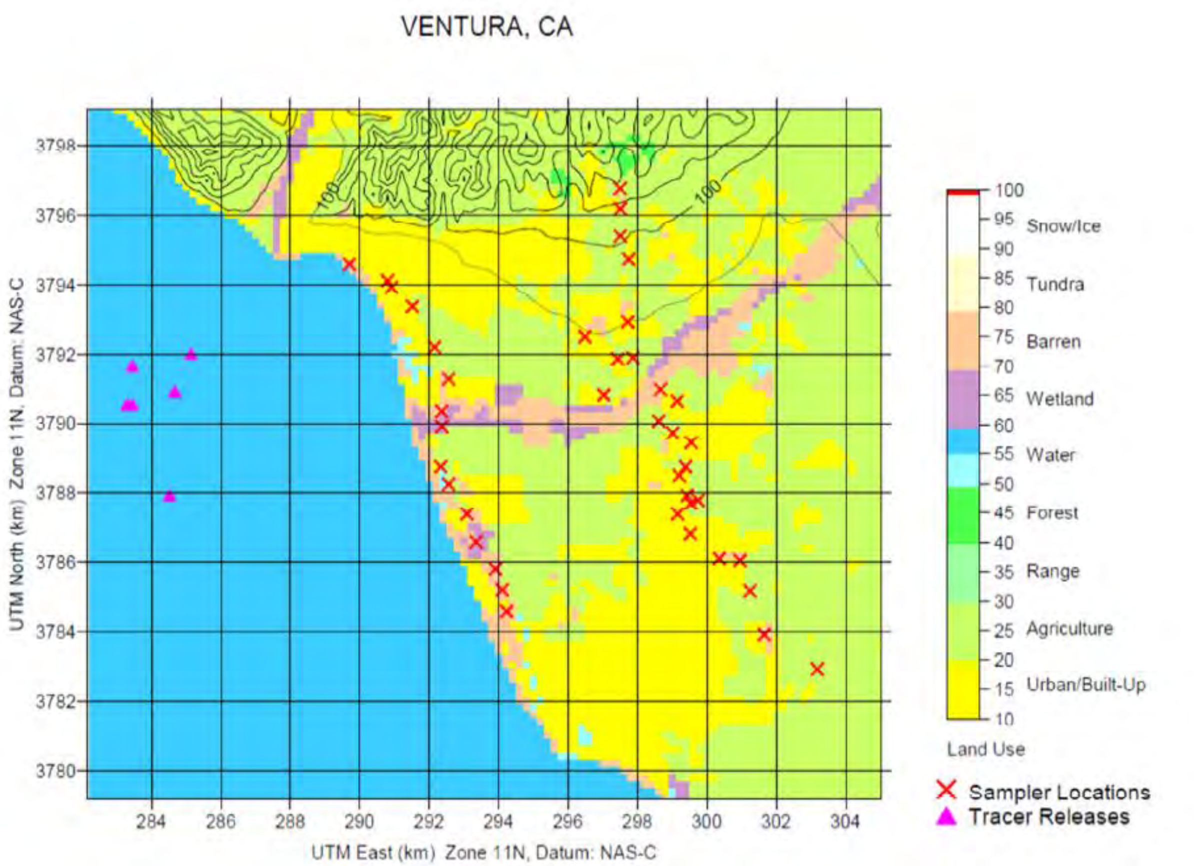


Figure 5. Ventura, CA study area.

The Ventura meteorological data used in the current analysis are shown in Table 7. Note for all hours the station pressure was 1000 mb, wind measurement height was 20.5 m, air temperature/relative humidity measurement height was 7.0 m, and wind direction was 270° because AERMOD was run in screening mode. The OCD and CALPUFF model evaluation data set stabilities ranged from moderately unstable to slightly stable. As with the Pismo Beach data, there are several hours of stable lapse rates accompanied by unstable air-sea temperature differences. For example, on September 29, 1980, hour 1400, the air-sea temperature difference is -0.8 °C, while the virtual potential temperature lapse rate is 0.03 °C/m. These contradictory data were resolved using the same methodology as in the Pismo Beach and Cameron datasets and the revised estimates are highlighted in gray in Table 7.

Table 7. Ventura measured meteorological data.

Date	Hour (LST)	Wind speed (m/s)	RH (%)	Air temperature (°C)	Sea temperature (°C)	σ_θ (°)	Mixing height (m)
9/24/80	16	4.1	72	15.15	17.25	8	400
9/24/80	18	6.2	78	14.85	16.85	6.5	400
9/24/80	19	6.9	77	14.85	16.95	6	400
9/27/80	14	6.3	80	14.85	16.75	4.7	400
9/27/80	19	6.1	80	15.85	16.85	3.6	400
9/28/80	18	3.1	80	16.85	16.85	4.4	250
9/29/80	14	3.3	76	15.55	15.44	5	100
9/29/80	16	5.1	76	16.15	16.04	3.9	100
9/29/80	18	5.2	76	16.05	15.94	5.2	50
1/6/81	16	4	60	17.15	15.55	21.5	50
1/6/81	17	5.1	58	17.45	15.75	13.1	50
1/6/81	18	4.9	60	17.25	15.45	9.4	50
1/9/81	15	4.7	87	14.45	15.35	3.4	100
1/9/81	16	4.6	85	14.85	15.35	4.8	100
1/9/81	18	4.9	87	15.05	15.35	3.1	100
1/13/81	15	5.8	65	16.95	15.55	11.6	50
1/13/81	17	4.2	84	15.85	15.45	8.5	50

Table 8 shows the source and receptor characteristics used in the Ventura tracer simulations. The boat releases assumed a release height of 8.1 m, building height of 7 m and a width (and length) of 20 m. Downwind receptor distances were varied to match the downwind distances of the measurement site with the highest observed concentration for each period.

Table 8. Ventura receptor distances.

Release number	Date	Hour (LST)	Receptor distance (m)
1	9/24/80	16	9291
2	9/24/80	18	9211
3	9/24/80	19	10799
4	9/27/80	14	9123
5	9/27/80	19	9123
6	9/28/80	18	9145
7	9/29/80	14	8085
8	9/29/80	16	7854
9	9/29/80	18	7854
10	1/6/81	16	7463
11	1/6/81	17	7416
12	1/6/81	18	7463
13	1/9/81	15	7956
14	1/9/81	16	7749
15	1/9/81	18	7704
16	1/13/81	15	7705
17	1/13/81	17	6914

2.2 AERMET configurations

2.2.1 WRF simulations

WRF version 4.4.2 was applied over multiple near-shore locations in Louisiana and California. The time periods modeled for each location are indicated in Table 9 below. These simulations were conducted using nested domains of 12-km, 4-km, and 1.33-km and utilizing a 35-layer vertical resolution. These WRF domains encompass the entire dispersion modeling domain and are shown for each location in Figure 6 through Figure 9. The ERA-Interim 6-hourly reanalysis dataset was used for initialization. All WRF simulations utilized the physics options outlined below:

- Microphysics: Thompson

- Planetary Boundary Layer: UW
- Cumulus: Kain-Fritsch
- Radiation: RRTMG
- Land Surface Model: NOAH
- Surface Layer: Eta

An effort was made to select model options and domains like work conducted during the development of AERCOARE (U.S. EPA, 2015). That report outlines extensive model performance evaluation and is the basis for the options selected here.

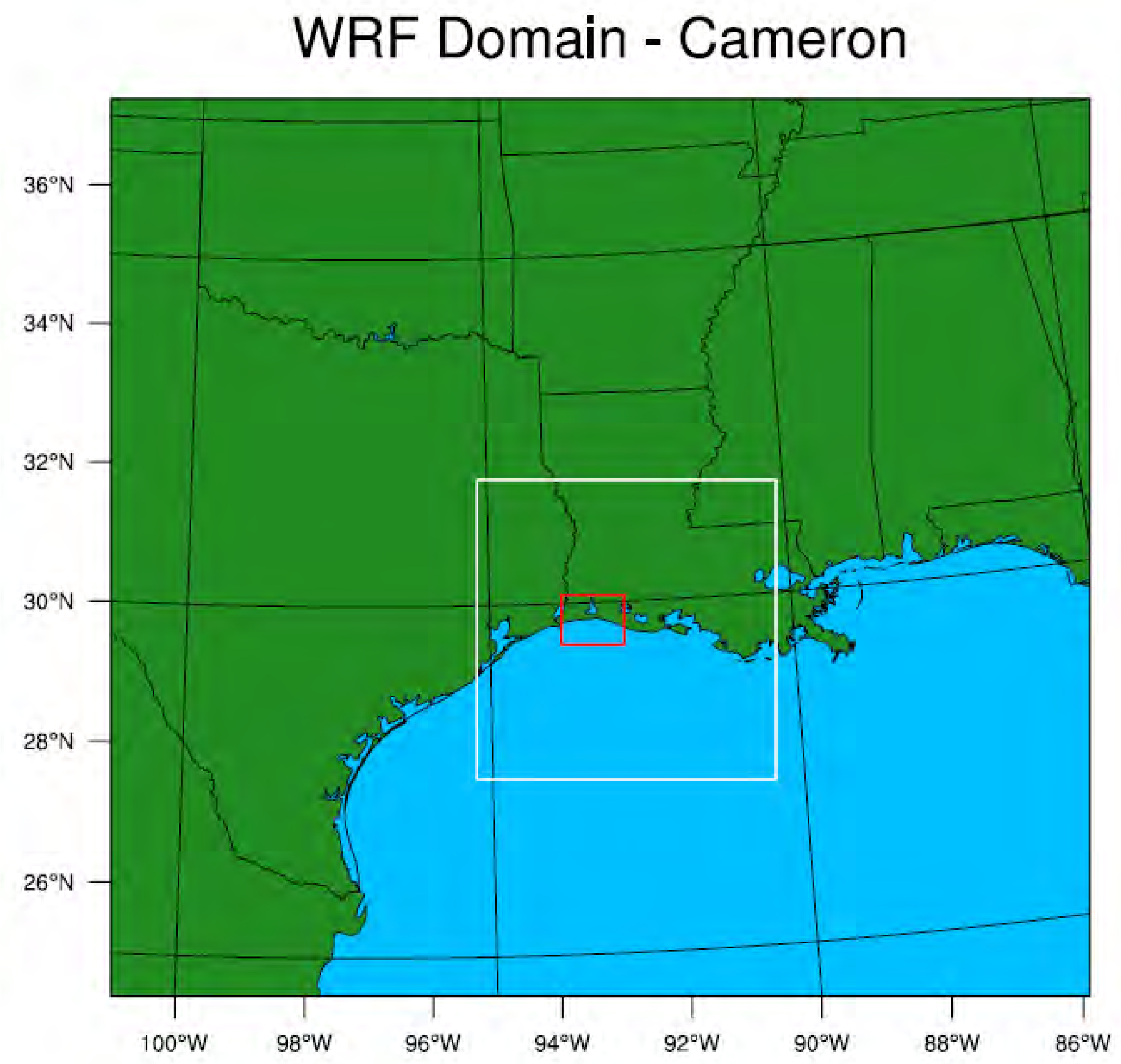


Figure 6. Cameron, LA WRF domains. The large outer box is the 12-km domain, the white box is the 4-km domain, and the red box is the 1.33 km domain.

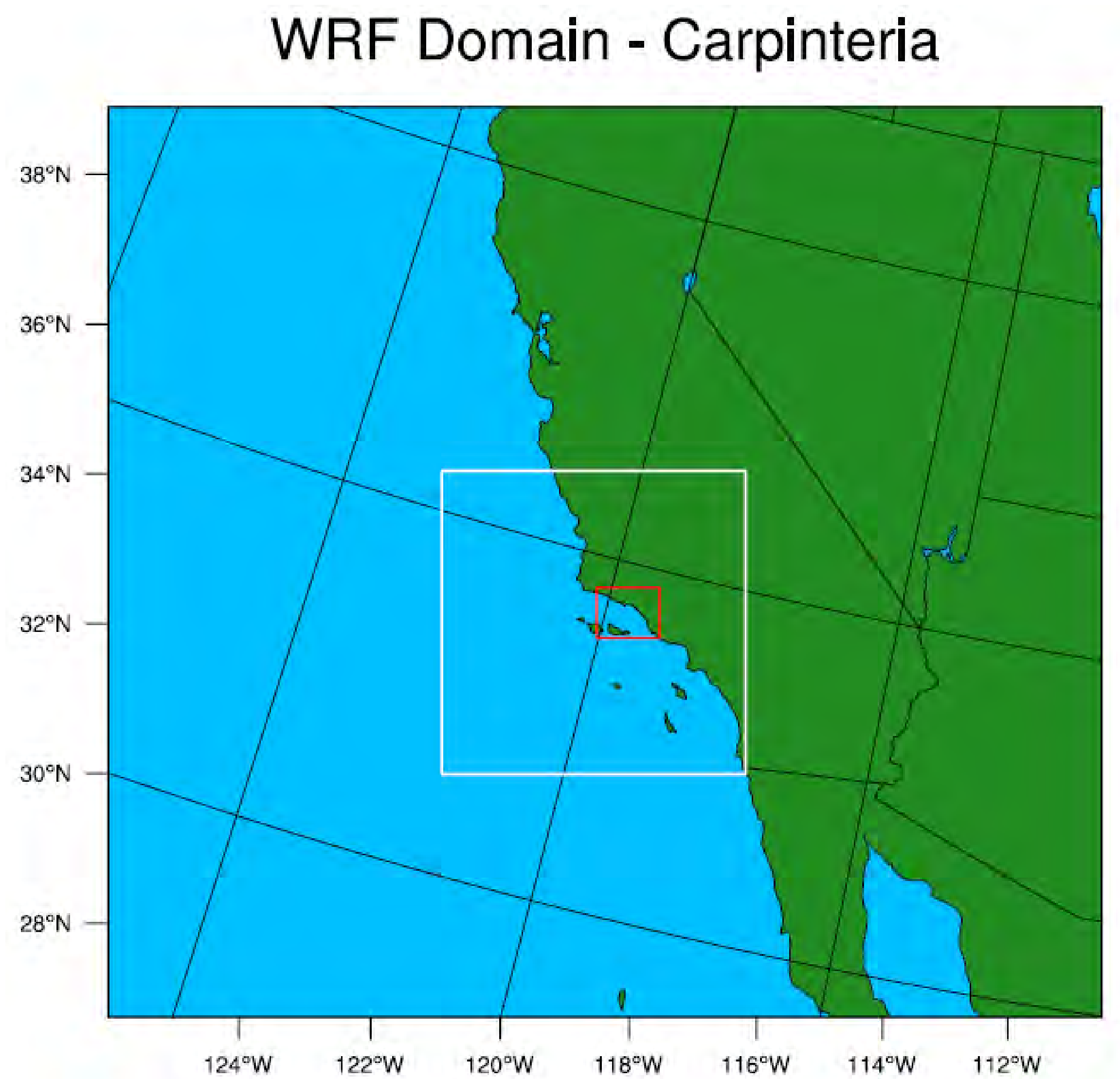


Figure 7. Carpinteria, CA WRF domains. The large outer box is the 12-km domain, the white box is the 4-km domain, and the red box is the 1.33 km domain.

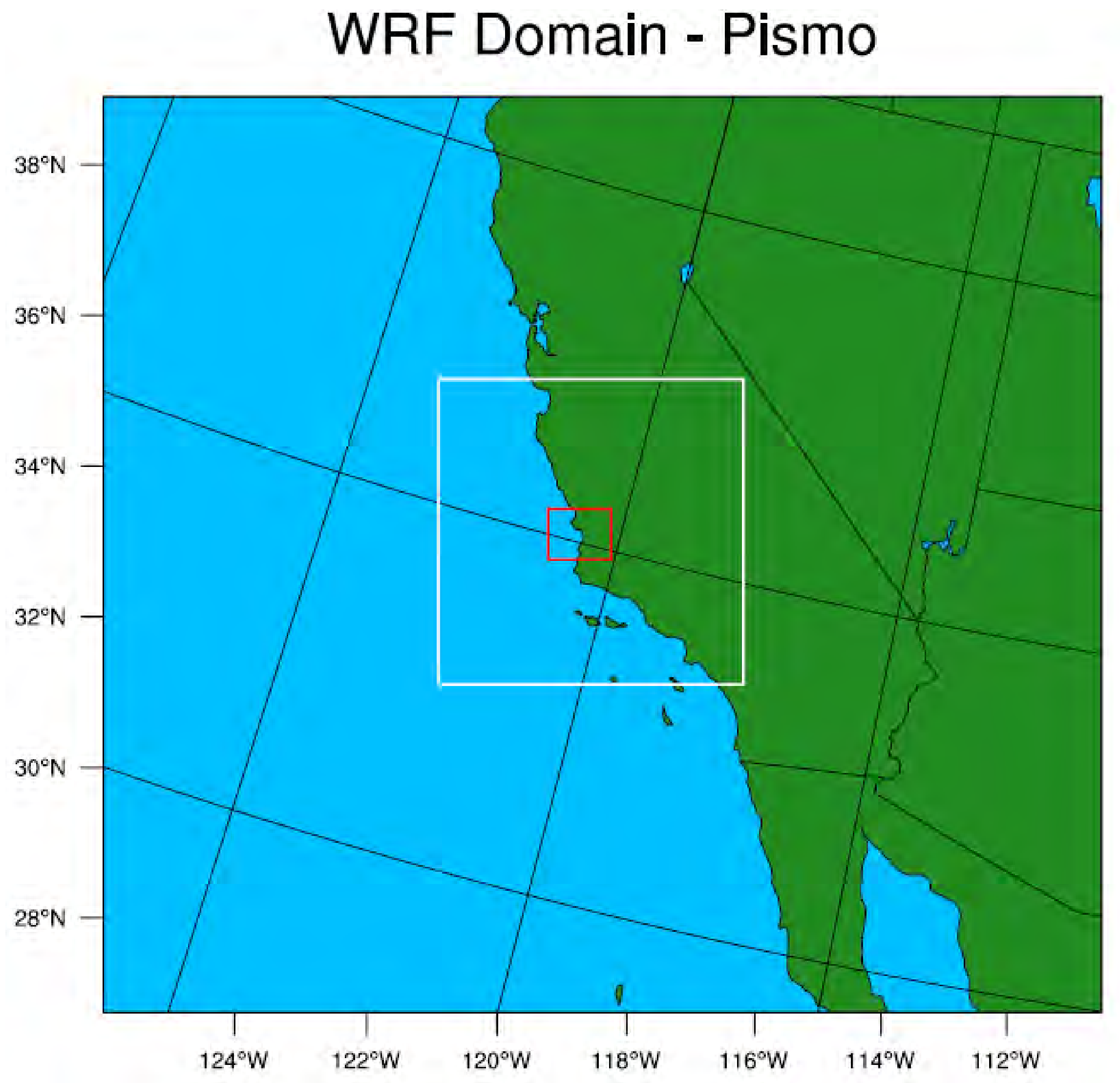


Figure 8. Pismo Beach, CA WRF domains. The large outer box is the 12-km domain, the white box is the 4-km domain, and the red box is the 1.33 km domain.

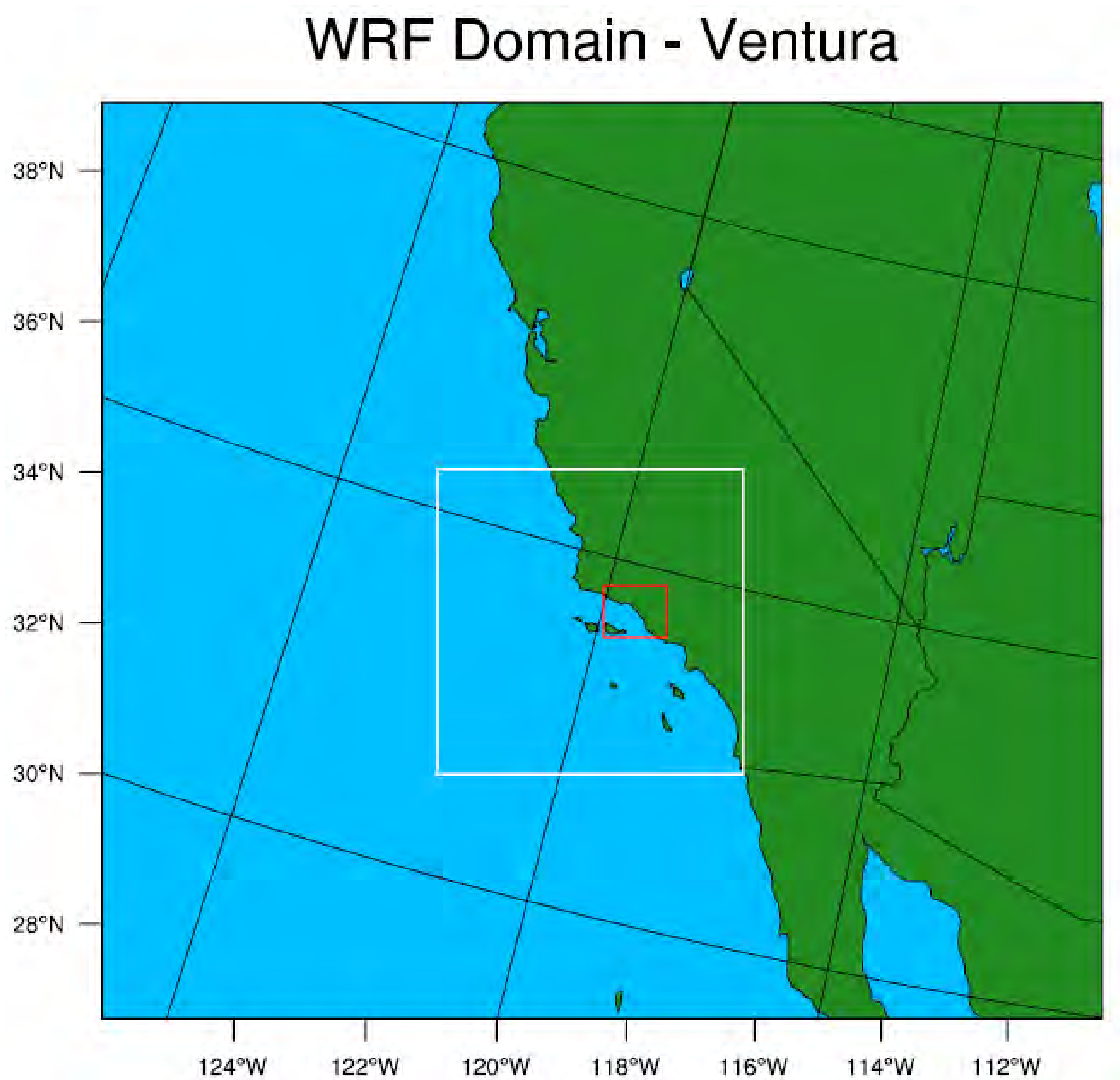


Figure 9. Ventura, CA WRF domains. The large outer box is the 12-km domain, the white box is the 4-km domain, and the red box is the 1.33 km domain.

Table 9. Time periods modeled for each location.

Location	Period
Cameron, LA	Period 1: 7/15/1981 – 7/31/1981 Period 2: 2/10/1982 – 2/25/1982
Carpinteria, CA	Period 1: 9/15/1985 – 9/30/1985
Pismo Beach, CA	Period 1: 12/5/1981 – 12/20/1981 Period 2: 6/15/1982 – 6/30/1982
Ventura, CA	Period 1: 9/15/1980 – 9/30/1980 Period 2: 1/1/1981 – 1/15/1981

2.2.1.1 MMIF output

Once WRF simulations were completed, the 1.3 km WRF output was processed in MMIF to generate data formatted for input to AERMET. Locations for extraction were based on the release point locations shown in Figure 2 through

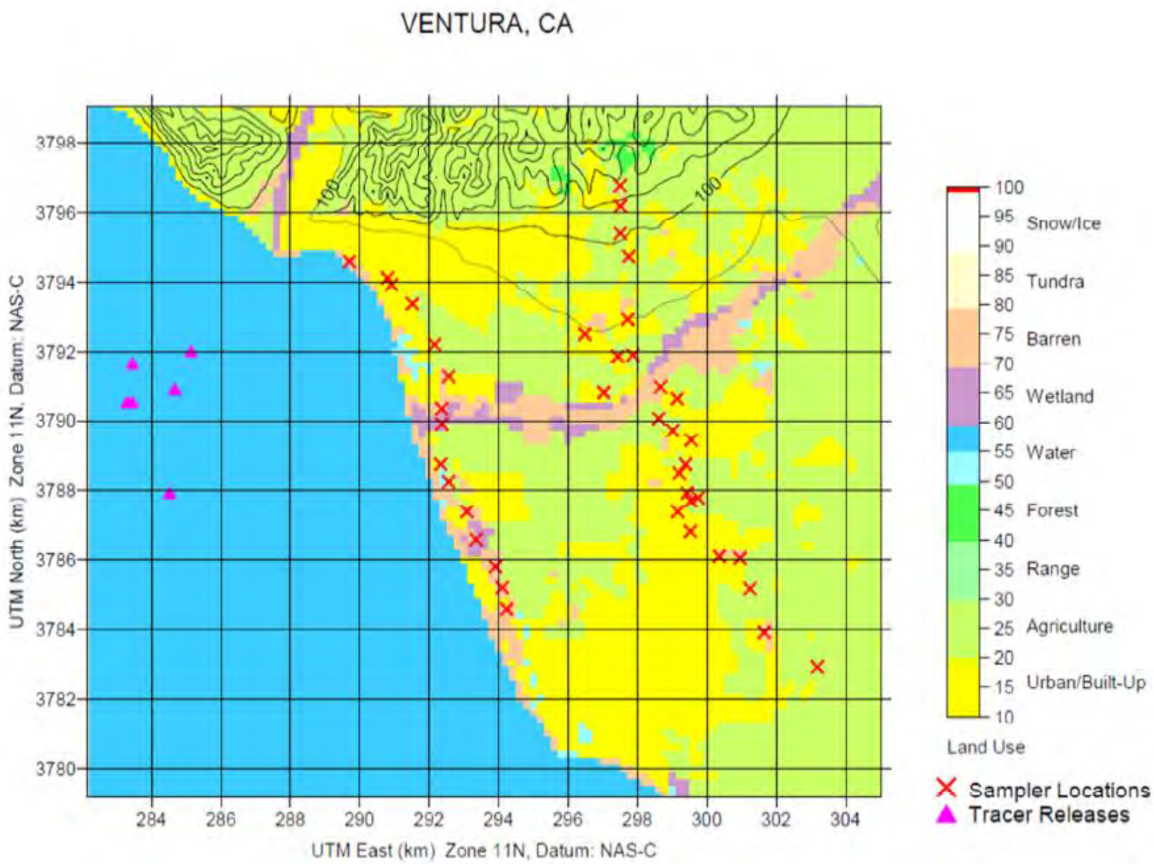


Figure 5.

Files generated for AERMET input would be processed in AERMET using both the pass-through option and the COARE processing option. These files contained all of the variables output by MMIF for overwater grid cells for AERMET processing in MMIF (Ramboll, 2023). Winds, temperature, and relative humidity were output at several levels in meters: 12.5, 37.5, 62.5, 87.5, 112.5, 137.5, 162.5, 187.5, 225, 275, 325, 375, 425, 75, 550, 650, 750, 850, 950, 1250, 1750, 2250, 2750, 3250, 3750, 4250, and 4750. Additionally, 2 m temperature was output.

Files generated for AERCOARE output were processed in AERMET using the COARE option and included winds at 10 m and temperature and relative humidity at 2m. See the MMIF user's guide (Ramboll, 2023) for AERCOARE formatted output. In addition to winds, temperature, and relative humidity, sea surface temperature, pressure, downward solar radiation, downward longwave radiation, precipitation, total sky cover, mixing height, vertical potential temperature gradient above the PBL, and depth of sea surface temperature measurement. See the MMIF user's guide (Ramboll, 2023) for AERCOARE formatted output.

2.2.2 AERMET-COARE configurations

The following scenarios were run for the COARE processing and are shown in Table 10. An 'X' in the cell for a scenario and location indicates that scenario was run for the case location. These scenarios are analogous to the scenarios used in the original AERCOARE work (U.S. EPA, 2012b). In addition to the prognostic data, the observed data were also processed in AERMET and AERMOD for the following scenarios as part of the evaluation of COARE implementation into AERMET. Details about the observed data processing are in U.S. EPA (2023d). Table 11 shows the names of the AERMET/AERMOD simulations associated with both the observed and prognostic data scenarios processed with COARE. Prognostic data run in AERMET with the pass-through option is designated as AERMET_PASS. For all COARE processing, surface roughness values were calculated based on surface friction velocity (option ZO_U* in AERMET).

- Scenario 1[1]:
    - Reset absolute value of Monin-Obukhov length to 5 m if absolute value of Monin-Obukhov length is less than 5 m. Retain original sign (+ or -) of Monin-Obukhov length
    - Use observed mixing height for convective mixing height and calculate mechanical mixing height without smoothing; Reset mechanical mixing height to 25 m if less than 25 m.
- Scenario 1a:
    - Reset absolute value of Monin-Obukhov length to 5 m if absolute value of Monin-Obukhov length is less than 5 m. Retain original sign (+ or -) of Monin-Obukhov length
    - Use observed mixing height for convective mixing height and calculate mechanical mixing height without smoothing; Reset mechanical mixing height to 1 m if less than 1 m.
- Scenario 1b:

[1] The observed meteorological data for Scenario 1 and 1a-1c contains turbulence data for use in AERMOD while the prognostic data does not contain turbulence. The observed meteorological data also has a Scenario 2, where the observed turbulence data is not used AERMOD but the other meteorological parameters are the same as Scenario 1. See U.S. EPA (2023d) for details.

- Reset absolute value of Monin-Obukhov length to 5 m if absolute value of Monin-Obukhov length is less than 5 m. Retain original sign (+ or -) of Monin-Obukhov length
- Use observed mixing height for convective mixing height and calculate mechanical mixing height without smoothing; Reset mechanical mixing height to 5 m if less than 5 m.

- Scenario 1c:
  - Reset absolute value of Monin-Obukhov length to 5 m if absolute value of Monin-Obukhov length is less than 5 m. Retain original sign (+ or -) of Monin-Obukhov length
  - Use observed mixing height for convective mixing height and calculate mechanical mixing height without smoothing; Reset mechanical mixing height to 15 m if less than 15 m.
- Scenario 2:
  - Reset absolute value of Monin-Obukhov length to 1 m if absolute value of Monin-Obukhov length is less than 1 m. Retain original sign (+ or -) of Monin-Obukhov length
  - Use observed mixing height for convective and mechanical mixing heights; Reset mechanical mixing height to 1 m if less than 1 m.
- Scenario 3:
  - Reset absolute value of Monin-Obukhov length to 5 m if absolute value of Monin-Obukhov length is less than 5 m. Retain original sign (+ or -) of Monin-Obukhov length
  - Use observed mixing height for convective and mechanical mixing heights; Reset mechanical mixing height to 1 m if less than 1 m.

Table 10. AERMET-COARE configurations for prognostic data.

Scenario	Cameron	Carpinteria	Pismo Beach	Ventura
1	X	X	X	X
1a		X	X	
1b		X	X	
1c		X	X	
2	X	X	X	X
3	X	X	X	X

For the comparisons using prognostic data, AERMET was run with a wind speed threshold of 0.3 m/s instead of the recommended value of 0 m/s in U.S. EPA (2023e). This was done because the same prognostic data was used in the COARE implementation evaluation in U.S. EPA (2023d) and AERCOARE does not contain the reset of winds below $2^{1/2}$ x σ_{vmin} where σ_{vmin}=0.2 m/s to $2^{1/2}$ x σ_{vmin} that AERMET does.

Table 11. AERMET-COARE configuration names for prognostic data.

Scenario	Observed data	Prognostic data processed with COARE	
		AERMET multi-level	AERMET single level
1	OBS_1	COARE_ML_1	COARE_SL_1
1a	OBS_1A	COARE_ML_1A	COARE_SL_1A
1b	OBS_1B	COARE_ML_1B	COARE_SL_1B
1c	OBS_1C	COARE_ML_1C	COARE_SL_1C
2	OBS_3	COARE_ML_2	COARE_SL_2
3	OBS_4	COARE_ML_3	COARE_SL_3

2.3 Meteorological data evaluation

Meteorological data comparisons between the observed data and prognostic data will encompass mean bias and fractional bias calculations for several key variables, wind speed, reference air temperature, sea surface temperature, air-sea temperature differences, relative humidity, Monin-Obuklov length, mixing height, surface friction velocity, and surface roughness. Fractional bias is calculated as:

$$FB = 2\left[\frac{PR-OB}{OB+PR}\right] \quad (1)$$

Where PR is the prognostic value and OB is the observed value. Negative (positive) values indicate that the prognostic data underpredicts (overpredicts) compared to observations. The mean bias is the essentially the numerator of equation 1.

For mixing height, convective and mechanical mixing heights are compared separately. Also, for each hour and scenario, the maximum of the two heights is used to represent the mixing height for a given hour and scenario. This is done because AERMOD uses the maximum of the two heights for each hour. Carpinteria was the only case study that used actual wind directions, so wind direction difference statistics were calculated. For the wind direction difference statistics, a difference called displacement, which is the difference in the U and V vectors of the modeled and observed winds and was used. This was used in the assessment of the 2011 12km WRF simulations over the U.S. (US EPA, 2014). The displacement can be calculated as:

$$D = abs((U_M - U_O + V_M - V_O) \times (1\ km/1000\ m) \times (3600\ s/hr) \times 1hr) \qquad (2)$$

Where D is the displacement in km, U_M and V_M are the u and v components respectively of the prognostic wind vector and U_O and V_O are the u and v components of the observed wind vector.

2.4 AERMOD evaluation

Except for Carpinteria, all AERMOD runs were run in screening mode, i.e., the receptor was assumed to be on the plume centerline and the AERMOD SCREEN model option used. For those screening mode cases using measured data, the wind direction was set to 270°, or westerly winds. Carpinteria AERMOD runs reflected actual source-receptor distances and orientation. All AERMOD runs were with version 22112. A test statistic called Robust Highest Concentrations (RHC) (U.S. EPA, 1992) was calculated and compared as well for each study area. The RHC is calculated as:

$$RHC = X(N) + [\bar{X} - X(N)] \times \ln\left[\frac{3N-1}{2}\right] \qquad (3)$$

Where X(N) is the Nth largest value, X is the average of N-1 values, and N is the number of values exceeding the threshold value, in this case 10.

3.0 Results

3.1 Meteorological data comparisons

Mean biases and fractional biases of wind speed, temperature, sea surface temperature, air-sea temperature differences, and relative humidity are shown in Table *12*. These variables represent input variables and are independent of the scenarios discussed in Section 2.2.2. Table *13* through Table 19 show the mean and fractional biases for surface friction velocity (u*), convective mixing height, mechanical mixing height, mixing height used in AERMOD (maximum of the convective or mechanical mixing height for an hour), surface roughness length used in AERMOD[2], Monin-Obukhov length, and absolute Monin-Obukhov length respectively. Both actual Monin-Obukhov length and absolute Monin-Obukhov length are presented because there are hours for each study area where the sign of Monin-Obukhov length can be opposite between the observed and prognostic meteorological data, skewing the bias statistics. Results in Table *12* show that the prognostic data and observed data are generally in fairly good agreement, fraction biases less than 2.0. Wind speeds tend to be less than 1 m/s in differences and air and sea temperatures tend to be within 2 degrees. Relative humidity also tends to be in relatively good agreement. For Carpinteria, wind displacement ranged from 0.39 km to 28 km with a mean of 11 km. For the calculated variables in Table *13* through Table 19 there are differences and fractional biases tend to be generally acceptable. Fractional biases for Monin-Obukhov length for Ventura (Table 18) tend to have large fractional biases but that is due to the hours where the signs of Monin-Obukhov length are opposites between observed data and prognostic data. Based on Table 19, the magnitudes of the Monin-Obukhov lengths are comparable between observed and prognostic data.

[2] When AERMOD reads the surface meteorological file, it will reset surface roughness values < 0.0001 m to 0.0001 m. The surface roughness values compared in the table are based on those reset values.

Table 12. Mean and fractional biases (Prognostic – observations) for each study area for wind speed, air temperature, sea surface temperature, air-sea temperature difference, and relative humidity.

Variable	Study area							
	Cameron		Carpinteria		Pismo Beach		Ventura	
	Mean Bias	Fractional Bias	Mean Bias	Fractional Bias	Mean Bias	Fractional Bias	Mean Bias	Fractional Bias
Wind speed	0.79	0.13	1.80	0.44	1.48	0.29	-0.49	-0.11
Air temperature	1.88	0.006	0.15	0.0005	0.16	0.0005	0.1	0.0003
Sea Surface Temperature	2.17	0.008	-0.34	-0.001	1.61	0.005	-0.66	-0.002
Air-sea surface temperature difference	-0.29	-1.63	0.49	-1.67	-1.45	-1.37	0.76	-1.54
Relative humidity	12.46	0.17	0.59	0.009	6.11	0.07	12.47	0.16

Table 13. Mean and fractional biases for each study area for surface friction velocity (u*). An X indicates that a particular scenario is not valid for a particular case study.

Scenario	Cameron		Carpinteria		Pismo Beach		Ventura	
	MB	FB	MB	FB	MB	FB	MB	FB
AERMET-OBS_1	0.04	0.28	0.06	0.68	0.08	0.54	-0.02	-0.15
AERMET-OBS_1A	X	X	0.06	0.68	0.08	0.54	X	X
AERMET-OBS_1B	X	X	0.06	0.68	0.08	0.54	X	X
AERMET-OBS_1C	X	X	0.06	0.68	0.08	0.54	X	X
AERMET-OBS_3	0.04	0.30	0.06	0.72	0.08	0.56	-0.02	-0.15
AERMET-OBS_4	0.04	0.28	0.06	0.68	0.08	0.54	-0.02	-0.15
COARE_1-OBS_1	0.04	0.28	0.06	0.60	0.09	0.57	-0.02	-0.13
COARE_1A-OBS_1A	X	X	0.06	0.60	0.09	0.57	X	X
COARE_1B-OBS_1B	X	X	0.06	0.60	0.09	0.57	X	X
COARE_1C-OBS_1C	X	X	0.06	0.60	0.09	0.57	X	X
COARE_3-OBS_3	0.04	0.30	0.06	0.58	0.09	0.59	-0.02	-0.13
COARE_4-OBS_4	0.04	0.28	0.06	0.60	0.09	0.57	-0.02	-0.13
COARE1_1-OBS_1	0.05	0.30	0.07	0.63	0.09	0.59	-0.01	-0.10
COARE1_1A-OBS_1A	X	X	0.07	0.63	0.09	0.59	X	X
COARE1_1B-OBS_1B	X	X	0.07	0.63	0.09	0.59	X	X
COARE1_1C-OBS_1C	X	X	0.07	0.63	0.09	0.59	X	X
COARE1_3-OBS_3	0.05	0.32	0.06	0.62	0.09	0.61	-0.01	-0.10
COARE1_4-OBS_4	0.05	0.30	0.07	0.63	0.09	0.59	-0.01	-0.10

Table 14. Mean and fractional biases for each study area for convective mixing height. An X indicates that a particular scenario is not valid for a particular case study.

Scenario	Cameron		Carpinteria		Pismo Beach		Ventura	
	MB	FB	MB	FB	MB	FB	MB	FB
AERMET-OBS_1	-228.56	-0.69	-357.31	-1.13	-335.40	-0.92	-73.00	-1.17
AERMET-OBS_1A	X	X	-357.31	-1.13	-335.40	-0.92	X	X
AERMET-OBS_1B	X	X	-357.31	-1.13	-335.40	-0.92	X	X
AERMET-OBS_1C	X	X	-357.31	-1.13	-335.40	-0.92	X	X
AERMET-OBS_3	-228.56	-0.69	-357.31	-1.13	-335.40	-0.92	-73.00	-1.17
AERMET-OBS_4	-228.56	-0.69	-357.31	-1.13	-335.40	-0.92	-73.00	-1.17
COARE_1-OBS_1	-228.56	-0.69	-357.31	-1.13	-335.40	-0.92	-69.67	-1.08
COARE_1A-OBS_1A	X	X	-357.31	-1.13	-335.40	-0.92	X	X
COARE_1B-OBS_1B	X	X	-357.31	-1.13	-335.40	-0.92	X	X
COARE_1C-OBS_1C	X	X	-357.31	-1.13	-335.40	-0.92	X	X
COARE_3-OBS_3	-228.56	-0.69	-357.31	-1.13	-335.40	-0.92	-73.00	-1.17
COARE_4-OBS_4	-228.56	-0.69	-357.31	-1.13	-335.40	-0.92	-73.00	-1.17
COARE1_1-OBS_1	-228.56	-0.69	-357.31	-1.13	-335.40	-0.92	-69.67	-1.08
COARE1_1A-OBS_1A	X	X	-357.31	-1.13	-335.40	-0.92	X	X
COARE1_1B-OBS_1B	X	X	-357.31	-1.13	-335.40	-0.92	X	X
COARE1_1C-OBS_1C	X	X	-357.31	-1.13	-335.40	-0.92	X	X
COARE1_3-OBS_3	-228.56	-0.69	-357.31	-1.13	-335.40	-0.92	-73.00	-1.17
COARE1_4-OBS_4	-228.56	-0.69	-357.31	-1.13	-335.40	-0.92	-73.00	-1.17

Table 15. Mean and fractional biases for each study area for mechanical mixing height. An X indicates that a particular scenario is not valid for a particular case study.

Scenario	Cameron		Carpinteria		Pismo Beach		Ventura	
	MB	FB	MB	FB	MB	FB	MB	FB
AERMET-OBS_1	17.96	0.21	51.96	0.25	21.82	0.19	-105.41	-1.08
AERMET-OBS_1A	X	X	57.78	0.72	23.43	0.28	X	X
AERMET-OBS_1B	X	X	57.19	0.58	23.43	0.28	X	X
AERMET-OBS_1C	X	X	55.30	0.40	22.96	0.24	X	X
AERMET-OBS_3	-112.69	-0.32	-390.33	-1.37	-181.54	-0.39	-139.82	-0.92
AERMET-OBS_4	-112.69	-0.32	-390.33	-1.37	-181.54	-0.39	-139.82	-0.92
COARE_1-OBS_1	63.12	0.41	82.37	0.46	129.57	0.71	-27.06	-0.19
COARE_1A-OBS_1A	X	X	85.37	0.76	131.18	0.76	X	X
COARE_1B-OBS_1B	X	X	84.78	0.66	131.18	0.76	X	X
COARE_1C-OBS_1C	X	X	83.00	0.50	130.71	0.75	X	X
COARE_3-OBS_3	-121.77	-0.60	-411.59	-1.44	-269.61	-0.85	-149.88	-1.10
COARE_4-OBS_4	-121.77	-0.60	-411.59	-1.44	-269.61	-0.85	-149.88	-1.10
COARE1_1-OBS_1	68.73	0.43	86.56	0.48	139.61	0.74	-20.88	-0.14
COARE1_1A-OBS_1A	X	X	90.41	0.80	141.21	0.79	X	X
COARE1_1B-OBS_1B	X	X	89.81	0.71	141.21	0.79	X	X
COARE1_1C-OBS_1C	X	X	88.00	0.55	140.75	0.77	X	X
COARE1_3-OBS_3	-107.92	-0.52	-411.59	-1.44	-269.61	-0.85	-149.88	-1.10
COARE1_4-OBS_4	-107.92	-0.52	-411.59	-1.44	-269.61	-0.85	-149.88	-1.10

Table 16. Mean and fractional biases for each study area for mixing height used in AERMOD. An X indicates that a particular scenario is not valid for a particular case study.

Scenario	Cameron		Carpinteria		Pismo Beach		Ventura	
	MB	FB	MB	FB	MB	FB	MB	FB
AERMET-OBS_1	-57.38	0.0006	-133.93	-0.49	-13.71	0.10	-105.41	-1.08
AERMET-OBS_1A	X	X	-128.11	-0.01	-12.11	0.19	X	X
AERMET-OBS_1B	X	X	-128.70	-0.16	-12.11	0.19	X	X
AERMET-OBS_1C	X	X	-130.59	-0.34	-12.57	0.15	X	X
AERMET-OBS_3	-81.81	-0.21	-370.07	-1.27	-172.36	-0.36	-139.82	-0.92
AERMET-OBS_4	-81.81	-0.21	-370.07	-1.27	-172.36	-0.36	-139.82	-0.92
COARE_1-OBS_1	-14.04	0.19	-101.70	-0.23	87.04	0.59	-27.06	-0.19
COARE_1A-OBS_1A	X	X	-98.70	0.06	88.64	0.65	X	X
COARE_1B-OBS_1B	X	X	-99.30	-0.03	88.64	0.65	X	X
COARE_1C-OBS_1C	X	X	-101.07	-0.20	88.18	0.63	X	X
COARE_3-OBS_3	-121.77	-0.60	-411.59	-1.44	-269.61	-0.85	-149.88	-1.10
COARE_4-OBS_4	-121.77	-0.60	-411.59	-1.44	-269.61	-0.85	-149.88	-1.10
COARE1_1-OBS_1	-8.92	0.21	-97.67	-0.22	94.89	0.62	-20.88	-0.14
COARE1_1A-OBS_1A	X	X	-93.81	0.10	96.50	0.67	X	X
COARE1_1B-OBS_1B	X	X	-94.41	0.02	96.50	0.67	X	X
COARE1_1C-OBS_1C	X	X	-96.22	-0.14	96.04	0.66	X	X
COARE1_3-OBS_3	-107.92	-0.52	-411.59	-1.44	-269.61	-0.85	-149.88	-1.10
COARE1_4-OBS_4	-107.92	-0.52	-411.59	-1.44	-269.61	-0.85	-149.88	-1.10

Table 17. Mean and fractional biases for each study area for surface roughness (z_o). An X indicates that a particular scenario is not valid for a particular case study.

Scenario	Cameron		Carpinteria		Pismo Beach		Ventura	
	MB	FB	MB	FB	MB	FB	MB	FB
AERMET-OBS_1	0.00001	0.08	-0.00006	-0.15	0.00003	0.19	0.00	0.00
AERMET-OBS_1A	X	X	-0.00006	-0.15	0.00003	0.19	X	X
AERMET-OBS_1B	X	X	-0.00006	-0.15	0.00003	0.19	X	X
AERMET-OBS_1C	X	X	-0.00006	-0.15	0.00003	0.19	X	X
AERMET-OBS_3	0.00001	0.08	-0.00006	-0.15	0.00003	0.19	0.00	0.00
AERMET-OBS_4	0.00001	0.08	-0.00006	-0.15	0.00003	0.19	0.00	0.00
COARE_1-OBS_1	0.00	0.00	-0.00006	-0.20	0.00	0.00	0.00	0.00
COARE_1A-OBS_1A	X	X	-0.00006	-0.20	0.00	0.00	X	X
COARE_1B-OBS_1B	X	X	-0.00006	-0.20	0.00	0.00	X	X
COARE_1C-OBS_1C	X	X	-0.00006	-0.20	0.00	0.00	X	X
COARE_3-OBS_3	0.00	0.00	-0.00006	-0.20	0.00	0.00	0.00	0.00
COARE_4-OBS_4	0.00	0.00	-0.00006	-0.20	0.00	0.00	0.00	0.00
COARE1_1-OBS_1	0.00	0.00	-0.00006	-0.20	0.00	0.00	0.00	0.00
COARE1_1A-OBS_1A	X	X	-0.00006	-0.20	0.00	0.00	X	X
COARE1_1B-OBS_1B	X	X	-0.00006	-0.20	0.00	0.00	X	X
COARE1_1C-OBS_1C	X	X	-0.00006	-0.20	0.00	0.00	X	X
COARE1_3-OBS_3	0.00	0.00	-0.00006	-0.20	0.00	0.00	0.00	0.00
COARE1_4-OBS_4	0.00	0.00	-0.00006	-0.20	0.00	0.00	0.00	0.00

Table 18. Mean and fractional biases for each study area for Monin-Obukhov length. An X indicates that a particular scenario is not valid for a particular case study.

Scenario	Cameron		Carpinteria		Pismo Beach		Ventura	
	MB	FB	MB	FB	MB	FB	MB	FB
AERMET-OBS_1	-80.94	2.00	51.59	0.91	-287.24	0.90	112.41	3.78
AERMET-OBS_1A	X	X	51.59	0.91	-287.24	0.90	X	X
AERMET-OBS_1B	X	X	51.59	0.91	-287.24	0.90	X	X
AERMET-OBS_1C	X	X	51.59	0.91	-287.24	0.90	X	X
AERMET-OBS_3	-80.90	2.02	52.19	1.20	-286.88	0.92	112.41	3.78
AERMET-OBS_4	-80.94	2.00	51.59	0.91	-287.24	0.90	112.41	3.78
COARE_1-OBS_1	-158.83	1.83	-49.16	1.01	-55.81	1.78	134.18	1.83
COARE_1A-OBS_1A	X	X	-49.16	1.01	-55.81	1.78	X	X
COARE_1B-OBS_1B	X	X	-49.16	1.01	-55.81	1.78	X	X
COARE_1C-OBS_1C	X	X	-49.16	1.01	-55.81	1.78	X	X
COARE_3-OBS_3	-158.80	1.84	-49.65	0.99	-55.46	1.80	134.18	1.83
COARE_4-OBS_4	-158.83	1.83	-49.16	1.01	-55.81	1.78	134.18	1.83
COARE1_1-OBS_1	-161.72	1.83	-50.86	1.01	-680.56	1.76	140.17	1.63
COARE1_1A-OBS_1A	X	X	-50.86	1.01	-680.56	1.76	X	X
COARE1_1B-OBS_1B	X	X	-50.86	1.01	-680.56	1.76	X	X
COARE1_1C-OBS_1C	X	X	-50.86	1.01	-680.56	1.76	X	X
COARE1_3-OBS_3	-161.68	1.84	-51.20	1.03	-680.21	1.78	140.17	1.63
COARE1_4-OBS_4	-161.72	1.83	-50.86	1.01	-680.56	1.76	140.17	1.63

Table 19. Mean and fractional biases for each study area for absolute Monin-Obukhov length. An X indicates that a particular scenario is not valid for a particular case study.

Scenario	Cameron		Carpinteria		Pismo Beach		Ventura	
	MB	FB	MB	FB	MB	FB	MB	FB
AERMET-OBS_1	105.66	1.16	277.70	0.64	229.38	1.20	38.65	0.19
AERMET-OBS_1A	X	X	277.70	0.64	229.38	1.20	X	X
AERMET-OBS_1B	X	X	277.70	0.64	229.38	1.20	X	X
AERMET-OBS_1C	X	X	277.70	0.64	229.38	1.20	X	X
AERMET-OBS_3	105.93	1.18	278.60	0.93	229.73	1.22	38.65	0.19
AERMET-OBS_4	105.66	1.16	277.70	0.64	229.38	1.20	38.65	0.19
COARE_1-OBS_1	178.52	1.36	415.23	0.82	608.97	1.33	74.38	0.40
COARE_1A-OBS_1A	X	X	415.23	0.82	608.97	1.33	X	X
COARE_1B-OBS_1B	X	X	415.23	0.82	608.97	1.33	X	X
COARE_1C-OBS_1C	X	X	415.23	0.82	608.97	1.33	X	X
COARE_3-OBS_3	178.79	1.37	415.04	0.80	609.33	1.35	74.38	0.40
COARE_4-OBS_4	178.52	1.36	415.23	0.82	608.97	1.33	74.38	0.40
COARE1_1-OBS_1	186.72	1.38	436.44	0.83	632.64	1.34	82.02	0.45
COARE1_1A-OBS_1A	X	X	436.44	0.83	632.64	1.34	X	X
COARE1_1B-OBS_1B	X	X	436.44	0.83	632.64	1.34	X	X
COARE1_1C-OBS_1C	X	X	436.44	0.83	632.64	1.34	X	X
COARE1_3-OBS_3	186.99	1.39	436.39	0.85	632.99	1.36	82.02	0.45
COARE1_4-OBS_4	186.72	1.38	436.44	0.83	632.64	1.34	82.02	0.45

3.2 AERMOD results

Table 20 lists the lists the modeled Robust Highest Concentration (RHC) for each scenario and case study area based on prognostic data as well as the observed meteorology (for comparison) for each of the study areas. Except for Cameron, the prognostic data output tended to overpredict when compared to the observed RHC and did not agree as well with the observed RHC as did the observed meteorological data, which is not unexpected. The treatment of the prognostic data with COARE vs. the AERMET pass through tended to also agree better with the observed RHC. Results between the number of levels used with the COARE treatment tended to be mixed, with Carpinteria presenting more difference between RHC values for the multi-level and single-level RHC values, while the other study areas showed little difference between multi-level and single-level RHC values.

Table 20. AERMOD Robust Highest Concentration for measured meteorological data and prognostic data. Observed RHC value are in parenthesis with the study area name. An X indicates that a particular scenario is not valid for a particular case study.

Scenario	Cameron (40.8)	Carpinteria (142.9)	Pismo Beach (9.0)	Ventura (4.3)
OBS_1 (with turbulence)	49.9	148.5	35.0	5.7
OBS_2 (no turbulence)	51.2	323.1	55.1	19.8
OBS_1A	X	373.2	36.1	X
OBS_1B	X	263.5	36.1	X
OBS_1C	X	221.1	36.2	X
OBS_3	39.9	469.1	18.3	7.8
OBS_4	43.7	307.5	20.5	7.8
AERMET_PASS	16.4	298.4	25.3	32.3
COARE_ML_1	17.9	302.9	16.9	20.0
COARE_ML_1A	X	311.2	16.9	X
COARE_ML_1B	X	311.2	16.9	X
COARE_ML_1C	X	311.2	16.9	X
COARE_ML_2	31.0	326.2	32.8	52.0
COARE_ML_3	31.0	301.9	32.8	52.0
COARE_SL_1	17.1	245.4	15.0	18.2
COARE_SL_1A	X	247.3	15.0	X
COARE_SL_1B	X	247.3	15.0	X
COARE_SL_1C	X	247.3	15.0	X
COARE_SL_2	30.8	417.1	31.7	50.2
COARE_SL_3	30.8	243.7	31.7	50.2

4.0 Summary and Conclusions

COARE algorithms were incorporated into AERMET version 23132 to allow processing of measured or prognostic meteorological data to calculate representative boundary layer parameters for the marine boundary layer environment. Four case studies were used to assess the differences between treating prognostic data with the COARE algorithms in AERMET vs a pass through of variables from MMIF to AERMET. Also, results between single-level and multi-level data using COARE were assessed. The results generally showed that treatment of prognostic data with COARE in AERMET agreed better with observations than the pass-through. Results were mixed between comparisons of the single-level and multi-level data in COARE. For guidance on the use of COARE algorithms with prognostic data see the

AERMET User's Guide (U.S. EPA, 2023b) and MMIF guidance for AERMOD applications (U.S. EPA, 2023e).

5.0 References

DiCristofaro, D.C. and S.R. Hanna, 1989. OCD: The Offshore and Coastal Dispersion Model, Version 4. Volume I: User's Guide, and Volume II: Appendices. Sigma Research Corporation, Westford, MA. (NTIS Nos. PB 93-144384 and PB 93-144392).

Fairall, C.W., E.F. Bradley, J.E. Hare, A.A. Grachev, and J.B. Edson, 2003: "Bulk Parameterization of Air-Sea Fluxes: Updates and Verification for the COARE Algorithm." *J. Climate*, **16**, 571-591.

Ramboll, 2023: The Mesoscale Model Interface Program (MMIF) Version 4.1 User's Manual.

U.S. EPA, 1992: Protocol for Determining the Best Performing Model, EPA-454/R-92-025. U.S. Environmental Protection Agency, Research Triangle Park, NC.

U.S. EPA, 2011a: *Model Clearinghouse Review AERMOD-COARE as an Alternative Model in an Arctic Ice Free Environment*. George Bridgers Memorandum dated May 6, 2011, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina, 27711. https://gaftp.epa.gov/Air/aqmg/SCRAM/mchisrs/R1444_Bridgers_6_May_11_AMEROD-COARE.pdf

U.S. EPA, 2011b: *User's Guide for the AERMOD Terrain Preprocessor (AERMAP)*. EPA-454/B-03-003. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

U.S. EPA, 2012a: *User's Manual AERCOARE Version 1.0*. EPA-910/R-12-008. U.S. EPA, Region 10, Seattle, WA.

U.S. EPA, 2012b: *Evaluation of the Combined AERCOARE/AERMOD Modeling Approach for Offshore Sources*. EPA-910/R-12-007. U.S. EPA, Region 10, Seattle, WA.

U.S. EPA, 2014: Meteorological Model Performance for Annual 2011 WRF v3.4 Simulation.

http://www.epa.gov/ttn/scram/reports/MET_TSD_2011_final_11-26-14.pdf

U.S. EPA, 2015: *Combined WRF/MMIF/AERCOARE/AERMOD Overwater Modeling Approach for Offshore Emission Sources: Volume 3 – Analysis of AERMOD Performance Using Weather Research and Forecasting Model Predicted Meteorology and Measured Meteorology in the Arctic*. EPA-910/R-15-001c. U.S. EPA, Region 10, Seattle, WA.

U.S. EPA, 2023a: *User's Guide for the AMS/EPA Regulatory Model (AERMOD).* EPA-454/B-23-008. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

U.S. EPA, 2023b: *User's Guide for the AERMOD Meteorological Preprocessor (AERMET).* EPA-454/B-23-005. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

U.S. EPA, 2023c: *Guideline on Air Quality Models.* 40 CFR Part 51 Appendix W.

U.S. EPA, 2023d: *Evaluation of the Implementation of the Coupled Ocean Atmosphere Response Experiment (COARE) Algorithms into AERMET for Marine Boundary Layer Environments.* EPA-454/R-23-008. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

U.S. EPA, 2023e: *Guidance on the Use of the Mesoscale Model Interface Program (MMIF) for AERMOD Applications.* EPA-454/B-23-006. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

United States Environmental Protection Agency	Office of Air Quality Planning and Standards Air Quality Assessment Division Research Triangle Park, NC	Publication No. EPA-454/R-23-010 October 2023