Bradley C. Thomas
Sr. Environmental Scientist

ConocoPhillips Company
700 G Street, ATO-1970
Anchorage, AK 99510
phone 907.263.4741

ConocoPhillips

April 12, 2010

Mr. Doug Hardesty
USEPA Region 10
1435 N. Orchard Street
Boise, Idaho 83706

Subject: ConocoPhillips' Part 71 Chukchi Sea OCS Air Permit Application.

Dear Mr. Hardesty:

On February 12, 2010 ConocoPhillips filed a Part 71 permit application for its planned 2012 Chukchi Sea exploration project. Our cover letter pointed out that the application does not list stationary source standards as applicable requirements for the marine engines, heaters, boilers and other process units located on the jack-up rig. We pointed out that Congress excluded nonroad engine and nonroad vehicle emissions from the definition of a stationary source, and cited ConocoPhillips' October 20, 2009 comments on the August 2009 Shell Chukchi PSD permit for further support on these points.

Your e-mail of March 25, 2010 anticipates that EPA will issue an incompleteness determination on our Part 71 application if it omits stationary source standards as applicable requirements. You explained that EPA does not agree with the position summarized above, and that EPA likely would impose stationary source requirements in the final Shell Chukchi PSD permit. You urged ConocoPhillips to supplement its application by listing NSPS and other stationary source standards as applicable requirements for equipment such as nonroad engines that would not be subject to those standards if the project was located on shore.

With this letter I am submitting an update to our Part 71 application that adds the following stationary source performance standards for the following process units on the jack up rig:

- 40 CFR 60, Subpart IIII to the jack-up rig internal combustion engines as they apply to given model year units;
- 40 CFR 60, Subpart CCCC to the jack-up rig solid waste incinerator

The stationary source standards are included in Attachment A. ConocoPhillips continues to believe that the engine standards do not apply to our project for the reasons set forth in our October 20, 2009 and in our February 17, 2010 comments on the Shell Chukchi PSD permit. We also don't believe the standards apply to the incinerator as detailed in the attached correspondence to the International Association of Drilling Contractors (Attachment B). We reserve the right to challenge the incorporation of these standards as applicable requirements in comments on a draft Title V permit, and possibly on appeal. We recognize, however, that an incompleteness determination would suspend processing of our Title V application, and ConocoPhillips cannot afford to indefinitely suspend the development of our Chukchi Project while we pursue informal and potentially lengthy discussions with EPA managers over the propriety of Region 10's applicability determination.

You also requested that we submit modeling that demonstrates compliance with the new nitrogen dioxide (NO_2) one-hour standard. That modeling is included in Attachment C. We will submit the modeling files to Region 10 separately – they are very large files. We will do this immediately after submitting this correspondence.

Finally, Region 10 staff prefers CALPUFF as the modeling method for future OCS permitting and requested that we run that model for this project. While we don't think the model, or its prognostic meteorology, are yet ready to be employed in permitting, we are committed to assisting EPA in working out the technical issues to the extent possible. In this light, a CALPUFF model run for our project is included in Attachment D. Those modeling files will be transmitted separately as they, too, are very large.

We appreciate your courtesy in flagging for our attention the likelihood that EPA would declare our application incomplete over two of these issues. Your note gave us helpful guidance that hopefully will reduce the risk of project permitting delays.

As always, if you have any questions please do not hesitate to call me. We remain committed to working with Region 10 to resolve any issues needed to move forward with review of the application.

Sincerely,

Bradley C. Thomas
Senior Environmental Scientist

Certification statement & attachments

CERTIFICATION OF TRUTH, ACCURACY, AND COMPLETENESS

Certification Statements [40 CFR 71.5(c)(8)(ii)(B), 40 CFR 71.5(c)(8)(iii)(B), 40 CFR 71.5(c)(9)(i), and 40 CFR 71.5(c)(9)(iii)

Statements

1. "Based on information and belief formed after reasonable inquiry, I certify that the statements and information in and attached to this document are true, accurate, and complete." This statement addresses the language found in 40 CFR 71.5(c)(9)(i).

2. CP will comply in a timely manner with any applicable requirement that becomes effective during the term of this permit. This Statement addresses the language found in both 40 CFR 71.5(c)(8)(ii)(B) and 40 CFR 71.5(c)(8)(iii)(B).

3. CPAI will certify compliance with the applicable requirements contained in the permit annually on the schedule imposed by EPA through its permit terms and conditions (usually by March 31 each year). This Statement addresses the language found in 40 CFR 71.5(c)(9)(iii).

Signed this 12th day of April, 2010.

Geoff Haddad
Responsible Company Official

Signature

VP, Exploration & Land
Title

ConocoPhillips.
Company

Attachment A

Stationary Source Standards

United States Environmental Protection Agency

OMB No. 2060-0336, Approval Expires 09/30/2010

Federal Operating Permit Program (40 CFR Part 71)

INITIAL COMPLIANCE PLAN AND COMPLIANCE CERTIFICATION (I-COMP)

SECTION A - COMPLIANCE STATUS AND COMPLIANCE PLAN

Complete this section for each unique combination of applicable requirements and emissions units at the facility. List all compliance methods (monitoring, recordkeeping and reporting) you used to determine compliance with the applicable requirement described above. Indicate your compliance status at this time for this requirement and compliance methods and check "YES" or "NO" to the follow-up question.

Emission Unit ID(s):

DR-ME-01, DR-ME-02, DR-ME-03, DR-ME-04, DR-CE-01, DR-CE-02, DR-LW-01

Applicable Requirement (Describe and Cite): **(Emission Standards for engines fabricated or modified pre 2007)**

Non-emergency stationary CI ICE fabricated or modified post April 1st 2006 and pre 2007 model year with a displacement of less than 10 liters per cylinder shall comply with the emission standards in Table 1 of Subpart IIII.

Non-emergency stationary CI ICE fabricated or modified post April 1st 2006 and pre 2007 model year with a displacement of greater than or equal to 10 liters per cylinder and less than 30 liters per cylinder must comply with the emission standards in 40 CFR 94.8(a)(1).

40 CFR Part 60 Subpart IIII §60.4204(a)

Compliance Methods for the Above (Description and Citation):

If determined applicable, for stationary CI ICE fabricated or modified post April 1st 2006 and pre 2007 model year which must comply with the emission standards specified in §60.4204(a) or §60.4205(a), compliance shall be demonstrated according to one of the following five methods.
(1) Purchasing an engine certified according to 40 CFR part 89 or 40 CFR part 94, as applicable, for the same model year and maximum engine power. The engine must be installed and configured according to the manufacturer's specifications.
(2) Keeping records of performance test results for each pollutant for a test conducted on a similar engine. The test must have been conducted using the same methods specified in 40 CFR Part 60 Subpart IIII and these methods must have been followed correctly.
(3) Keeping records of engine manufacturer data indicating compliance with the standards.
(4) Keeping records of control device vendor data indicating compliance with the standards.
(5) Conducting an initial performance test to demonstrate compliance with the emission standards according to the requirements specified in §60.4212, as applicable.

Comply with all applicable 40 CFR Part 60 General Provisions as shown in Table 8 to Subpart IIII.

Compliance Status:

In Compliance: Will you continue to comply up to permit issuance? ____Yes ____No X NA
Not In Compliance: Will you be in compliance at permit issuance? X Yes ____No ____NA
Future-Effective Requirement: Do you expect to meet this on a timely basis? X Yes ____No ____NA

Emission Unit ID(s):

DR-ME-01, DR-ME-02, DR-ME-03, DR-ME-04, DR-CE-01, DR-CE-02, DR-LW-01

Applicable Requirement (Describe and Cite): **(Emission Standards for engines fabricated or modified in the 2007 model year or later)**

Non-emergency stationary CI ICE fabricated or modified in the 2007 model year or later with a displacement of less than 30 liters per cylinder shall comply with the emissions standards for new CI engines in §60.4201.

40 CFR Part 60 Subpart IIII §60.4204(b)

Compliance Methods for the Above (Description and Citation):

If determined applicable , for stationary CI ICE fabricated or modified on or after model year 2007 which must comply with the emission standards specified in §60.4204(b) or §60.4205(b), compliance shall be demonstrated by purchasing an engine certified to the emission standards in §60.4204(b), or §60.4205(b), as applicable, for the same model year and maximum engine power. The engine shall be installed and configured according to the manufacturer's specifications.

Comply with all applicable 40 CFR Part 60 General Provisions as shown in Table 8 to Subpart IIII.

Compliance Status:

In Compliance: Will you continue to comply up to permit issuance? ____Yes ____No **X NA**

Not In Compliance: Will you be in compliance at permit issuance? **X Yes** ____No ____NA

Future-Effective Requirement: Do you expect to meet this on a timely basis? **X Yes** ____No ____NA

Emission Unit ID(s):

DR-EE-01

Applicable Requirement (Describe and Cite): **(Emission Standards)**

Emergency stationary CI ICE fabricated or modified post April 1st 2006 and pre 2007 model year with a displacement of less than 10 liters per cylinder, that are not fire pump engines shall comply with the emission standards in Table 1 of Subpart IIII.

Emergency stationary CI ICE fabricated or modified post April 1st 2006 and pre 2007 model year with a displacement of greater than or equal to 10 liters per cylinder and less than 30 liters per cylinder that are not fire pump engines shall comply with the emission standards in 40 CFR 94.8(a)(1).

40 CFR Part 60 Subpart IIII §60.4205(a)

Compliance Methods for the Above (Description and Citation):

If determined applicable , for stationary CI ICE fabricated or modified post April 1st 2006 and pre 2007 model year which must comply with the emission standards specified in §60.4204(a) or §60.4205(a), compliance shall be demonstrated according to one of the following five methods.
(1) Purchasing an engine certified according to 40 CFR part 89 or 40 CFR part 94, as applicable, for the same model year and maximum engine power. The engine must be installed and configured according to the manufacturer's specifications.
(2) Keeping records of performance test results for each pollutant for a test conducted on a similar engine. The test must have been conducted using the same methods specified in 40 CFR Part 60 Subpart IIII and these methods must have been followed correctly.
(3) Keeping records of engine manufacturer data indicating compliance with the standards.
(4) Keeping records of control device vendor data indicating compliance with the standards.
(5) Conducting an initial performance test to demonstrate compliance with the emission standards according to the requirements specified in §60.4212, as applicable.

Emergency stationary ICE shall be operated for the purpose of maintenance checks and readiness testing, provided that the tests are recommended by Federal, State, or local government, the manufacturer, the vendor, or the insurance company associated with the engine. Maintenance checks and readiness testing of such units shall be limited to 100 hours per year. There is no time limit on the use of emergency stationary ICE in emergency situations. Anyone may petition the Administrator for approval of additional hours to be used for maintenance checks and readiness testing, but a petition is not required if the owner or operator maintains records indicating that Federal, State, or local standards require maintenance and testing of emergency ICE beyond 100 hours per year. For owners and operators of emergency engines meeting standards under §60.4205 but not §60.4204, any operation other than emergency operation, and maintenance and testing as permitted in this section is prohibited.

Comply with all applicable 40 CFR Part 60 General Provisions as shown in Table 8 to Subpart IIII.

Compliance Status:

In Compliance: Will you continue to comply up to permit issuance? ____Yes ____No **X NA**

Not In Compliance: Will you be in compliance at permit issuance? **X Yes** ____No ____NA

Future-Effective Requirement: Do you expect to meet this on a timely basis? **X Yes** ____No ____NA

Emission Unit ID(s):

DR-EE-01

Applicable Requirement (Describe and Cite): **(Emission Standards)**

Emergency stationary CI ICE fabricated or modified on or after 2007 model year, with a displacement of less than 30 liters per cylinder, that are not fire pump engines shall comply with the emissions standards for new nonroad CI engines in §60.4202, for all pollutants, for the same model year and maximum engine power.

40 CFR Part 60 Subpart IIII §60.4205(b)

Compliance Methods for the Above (Description and Citation):

If determined applicable , for stationary CI ICE fabricated or modified on or after model year 2007 which must comply with the emission standards specified in §60.4204(b) or §60.4205(b), compliance shall be demonstrated by purchasing an engine certified to the emission standards in §60.4204(b), or §60.4205(b), as applicable, for the same model year and maximum engine power. The engine shall be installed and configured according to the manufacturer's specifications.

Emergency stationary ICE shall be operated for the purpose of maintenance checks and readiness testing, provided that the tests are recommended by Federal, State, or local government, the manufacturer, the vendor, or the insurance company associated with the engine. Maintenance checks and readiness testing of such units shall be limited to 100 hours per year. There is no time limit on the use of emergency stationary ICE in emergency situations. Anyone may petition the Administrator for approval of additional hours to be used for maintenance checks and readiness testing, but a petition is not required if the owner or operator maintains records indicating that Federal, State, or local standards require maintenance and testing of emergency ICE beyond 100 hours per year. For owners and operators of emergency engines meeting standards under §60.4205 but not §60.4204, any operation other than emergency operation, and maintenance and testing as permitted in this section is prohibited.

Comply with all applicable 40 CFR Part 60 General Provisions as shown in Table 8 to Subpart IIII.

Compliance Status:

In Compliance: Will you continue to comply up to permit issuance? ____Yes ____No X NA

Not In Compliance: Will you be in compliance at permit issuance? X Yes ____No ____NA

Future-Effective Requirement: Do you expect to meet this on a timely basis? X Yes ____No ____NA

Emission Unit ID(s):

DR-ME-01, DR-ME-02, DR-ME-03, DR-ME-04, DR-CE-01, DR-CE-02, DR-LW-01, DR-EE-01

Applicable Requirement (Describe and Cite): **(Fuel Requirements)**

Beginning October 1, 2007, owners and operators of stationary CI ICE subject to this subpart that use diesel fuel must use diesel fuel that meets the requirements of 40 CFR 80.510(a).

Beginning October 1, 2010, owners and operators of stationary CI ICE subject to this subpart with a displacement of less than 30 liters per cylinder that use diesel fuel must use diesel fuel that meets the requirements of 40 CFR 80.510(b) for nonroad diesel fuel.

40 CFR Part 60 Subpart IIII §60.4207(a) & (b)

Compliance Methods for the Above (Description and Citation):

If determined applicable, collect fuel samples and keep records.

Comply with all applicable 40 CFR Part 60 General Provisions as shown in Table 8 to Subpart IIII.

Compliance Status:

In Compliance: Will you continue to comply up to permit issuance? ____Yes ____No **X_NA**

Not In Compliance: Will you be in compliance at permit issuance? **X_Yes** ____No ____NA

Future-Effective Requirement: Do you expect to meet this on a timely basis? **X_Yes** ____No ____NA

Emission Unit ID(s):

DR-ME-01, DR-ME-02, DR-ME-03, DR-ME-04, DR-CE-01, DR-CE-02, DR-LW-01, DR-EE-01

Applicable Requirement (Describe and Cite): **(Other Requirements)**

Stationary CI ICE (excluding fire pump engines) that do not meet the applicable requirements for 2007 model year engines shall not be installed.

Stationary CI ICE with a maximum engine power of less than 19 kW (excluding fire pump engines) that do not meet the applicable requirements for 2008 model year engines shall not be installed.

After December 31, 2014, non-emergency stationary CI ICE with a maximum engine power of greater than or equal to 19 kW and less than 56 kW that do not meet the applicable requirements for 2013 model year non-emergency engines shall not be installed.

After December 31, 2013, non-emergency stationary CI ICE with a maximum engine power of greater than or equal to 56 kW and less than 130 kW that do not meet the applicable requirements for 2012 model year non-emergency engines shall not be installed.

After December 31, 2012, non-emergency stationary CI ICE with a maximum engine power of greater than or equal to 130 kW, including those above 560 kW, that do not meet the applicable requirements for 2011 model year non-emergency engines shall not be installed.

After December 31, 2016, non-emergency stationary CI ICE with a maximum engine power of greater than or equal to 560 kW that do not meet the applicable requirements for 2015 model year non-emergency engines shall not be installed.

Stationary CI ICE with a displacement of less than 30 liters per cylinder that do not meet the applicable requirements specified above shall not be imported.

The above requirements shall not apply to stationary CI ICE that have been modified, reconstructed, and do not apply to engines that were removed from one existing location and reinstalled at a new location.

40 CFR Part 60 Subpart IIII §60.4208

Compliance Methods for the Above (Description and Citation):

If determined applicable, maintain documentation of engine emissions certifications on site.

Comply with all applicable 40 CFR Part 60 General Provisions as shown in Table 8 to Subpart IIII.

Compliance Status:

In Compliance: Will you continue to comply up to permit issuance? ____Yes ____No **X__NA**

Not In Compliance: Will you be in compliance at permit issuance? **X__Yes** ____No ____NA

Future-Effective Requirement: Do you expect to meet this on a timely basis? **X__Yes** ____No ____NA

Emission Unit ID(s):

DR-EE-01

Applicable Requirement (Describe and Cite): **(Monitoring Requirements)**

A re-settable hour meter shall be installed prior to startup of the engine.

40 CFR Part 60 Subpart IIII §60.4209(a)

Compliance Methods for the Above (Description and Citation):

If determined applicable, install and maintain a non-resettable hour meter.

Comply with all applicable 40 CFR Part 60 General Provisions as shown in Table 8 to Subpart IIII.

Compliance Status:

In Compliance: Will you continue to comply up to permit issuance? ____Yes ____No **X_NA**

Not In Compliance: Will you be in compliance at permit issuance? **X_Yes** ____No ____NA

Future-Effective Requirement: Do you expect to meet this on a timely basis? **X_Yes** ____No ____NA

Emission Unit ID(s):

DR-ME-01, DR-ME-02, DR-ME-03, DR-ME-04, DR-CE-01, DR-CE-02, DR-LW-01, DR-EE-01

Applicable Requirement (Describe and Cite): **(Compliance Requirements)**

Operate and maintain the stationary CI ICE and control device according to the manufacturer's written instructions or procedures developed by the owner or operator that are approved by the engine manufacturer. In addition, only those settings that are permitted by the manufacturer shall be changed. Also, the requirements of 40 CFR parts 89, 94 and/or 1068, shall be met as applicable.

For stationary CI ICE fabricated or modified <u>post April 1st 2006 and pre 2007 model year</u> which must comply with the emission standards specified in §60.4204(a) or §60.4205(a), compliance shall be demonstrated according to one of the following five methods.
(1) Purchasing an engine certified according to 40 CFR part 89 or 40 CFR part 94, as applicable, for the same model year and maximum engine power. The engine must be installed and configured according to the manufacturer's specifications.
(2) Keeping records of performance test results for each pollutant for a test conducted on a similar engine. The test must have been conducted using the same methods specified in 40 CFR Part 60 Subpart IIII and these methods must have been followed correctly.
(3) Keeping records of engine manufacturer data indicating compliance with the standards.
(4) Keeping records of control device vendor data indicating compliance with the standards.
(5) Conducting an initial performance test to demonstrate compliance with the emission standards according to the requirements specified in §60.4212, as applicable.

For stationary CI ICE fabricated or modified <u>on or after model year 2007</u> which must comply with the emission standards specified in §60.4204(b) or §60.4205(b), compliance shall be demonstrated by purchasing an engine certified to the emission standards in §60.4204(b), or §60.4205(b), as applicable, for the same model year and maximum engine power. The engine shall be installed and configured according to the manufacturer's specifications.

Emergency stationary ICE shall be operated for the purpose of maintenance checks and readiness testing, provided that the tests are recommended by Federal, State, or local government, the manufacturer, the vendor, or the insurance company associated with the engine. Maintenance checks and readiness testing of such units shall be limited to 100 hours per year. There is no time limit on the use of emergency stationary ICE in emergency situations. Anyone may petition the Administrator for approval of additional hours to be used for maintenance checks and readiness testing, but a petition is not required if the owner or operator maintains records indicating that Federal, State, or local standards require maintenance and testing of emergency ICE beyond 100 hours per year. For owners and operators of emergency engines meeting standards under §60.4205 but not §60.4204, any operation other than emergency operation, and maintenance and testing as permitted in this section is prohibited.

40 CFR Part 60 Subpart IIII §60.4211

Compliance Methods for the Above (Description and Citation):

If determined applicable, records will be kept on site to verify operating procedures as well as certification and/or test data.

Comply with all applicable 40 CFR Part 60 General Provisions as shown in Table 8 to Subpart IIII.

Compliance Status:

In Compliance: Will you continue to comply up to permit issuance? ____Yes ____No X NA
Not In Compliance: Will you be in compliance at permit issuance? X Yes ____No ____NA
Future-Effective Requirement: Do you expect to meet this on a timely basis? X Yes ____No ____NA

Emission Unit ID(s):

DR-ME-01, DR-ME-02, DR-ME-03, DR-ME-04, DR-CE-01, DR-CE-02, DR-LW-01, DR-EE-01

Applicable Requirement (Describe and Cite): **(Notifications, Reports, and Records)**

Non-emergency stationary CI ICE that are greater than 2,237 kW, or have a displacement of greater than or equal to 10 liters per cylinder, or are fabricated or modified post April 1st 2006 and pre 2007 model year engines that are greater than 130 kW and not certified, shall meet the requirements of paragraphs (1) and (2) below.

(1) Submit an initial notification as required in §60.7(a)(1). The notification shall include the information in paragraphs (i) through (v) below.

(i) Name and address of the owner or operator;
(ii) The address of the affected source;
(iii) Engine information including make, model, engine family, serial number, model year, maximum engine power, and engine displacement;
(iv) Emission control equipment; and
(v) Fuel used.

(2) Keep records of the information in paragraphs (i) through (iv) below.

(i) All notifications submitted to comply with 40 CFR Part 60 Subpart IIII and all documentation supporting any notification.
(ii) Maintenance conducted on the engine.
(iii) If the stationary CI internal combustion is a certified engine, documentation from the manufacturer that the engine is certified to meet the emission standards.
(iv) If the stationary CI internal combustion is not a certified engine, documentation that the engine meets the emission standards.

Emergency stationary ICE, do not trigger any requirement to submit an initial notification. Starting with the model years in Table 5 of 40 CFR Part 60 Subpart IIII, if an emergency engine does not meet the standards applicable to non-emergency engines in the applicable model year, records shall be kept of the operation of the engine in emergency and non-emergency service that are recorded through the non-resettable hour meter. The engine operation time and the reason the engine was in operation during that time, shall be recorded.

40 CFR Part 60 Subpart IIII §60.4214

Compliance Methods for the Above (Description and Citation):

If determined applicable, maintain records and submit notifications as specified.

Comply with all applicable 40 CFR Part 60 General Provisions as shown in Table 8 to Subpart IIII.

Compliance Status:

In Compliance: Will you continue to comply up to permit issuance? ____Yes ____No X NA

Not In Compliance: Will you be in compliance at permit issuance? X Yes ____No ____NA

Future-Effective Requirement: Do you expect to meet this on a timely basis? **X Yes** ____No ____NA

Emission Unit ID(s): **DR-NC-01**

Applicable Requirement (Describe and Cite):

Commercial and industrial solid waste incineration (CISWI) units for which construction is commenced after November 30, 1999 or for which modification or reconstruction commenced on or after June 1, 2001 shall comply with 40 CFR Part 60 Subpart CCCC if it meets the following requirements:

(a) Your incineration unit is a new incineration unit as defined in §60.2015.
(b) Your incineration unit is a CISWI unit as defined in §60.2265.
(c) Your incineration unit is not exempt under §60.2020.

Compliance Methods for the Above (Description and Citation):

If determined applicable, exemption: Municipal waste combustion units.

Burn greater than 30 percent municipal solid waste or refuse-derived fuel, as defined in subpart Ea, subpart Eb, subpart AAAA, and subpart BBBB of this part, and that have the capacity to burn less than 35 tons (32 megagrams) per day of municipal solid waste or refuse-derived fuel, if you meet the two requirements in paragraphs (c)(2)(i) and (ii) of this section.
(i) Notify the Administrator that the unit meets these criteria.
(ii) Keep records on a calendar quarter basis of the weight of municipal solid waste burned, and the weight of all other fuels and wastes burned in the unit.

40 CFR Part 60 Subpart CCCC §60.2020(C) (2)

Submit notifications and keep records as specified.

Compliance Status:

In Compliance: Will you continue to comply up to permit issuance? ____Yes ____No **X__NA**

Not In Compliance: Will you be in compliance at permit issuance? **X__Yes** ____No ____NA

Future-Effective Requirement: Do you expect to meet this on a timely basis? **X__Yes** ____No ____NA

B. SCHEDULE OF COMPLIANCE- NA

Complete this section if you answered "NO" to any of the questions in section A. Also complete this section if required to submit a schedule of compliance by an applicable requirement. Please attach copies of any judicial consent decrees or administrative orders for this requirement.

Unit(s)____________________ Requirement____

Reason for Noncompliance. Briefly explain reason for noncompliance at time of permit issuance or that future-effective requirement will not be met on a timely basis:

Narrative Description of how Source Compliance Will be Achieved. Briefly explain your plan for achieving compliance:

Schedule of Compliance. Provide a schedule of remedial measures, including an enforceable sequence of actions with milestones, leading to compliance, including a date for final compliance.

Remedial Measure or Action	Date to be Achieved

C. SCHEDULE FOR SUBMISSION OF PROGRESS REPORTS- NA

Only complete this section if you are required to submit one or more schedules of compliance in section B or if an applicable requirement requires submittal of a progress report. If a schedule of compliance is required, your progress report should start within 6 months of application submittal and subsequently, no less than every six months. One progress report may include information on multiple schedules of compliance.

Contents of Progress Report (describe): First Report____/____/___ Frequency of Submittal_______________
Contents of Progress Report (describe): First Report____/____/___ Frequency of Submittal_______________

D. SCHEDULE FOR SUBMISSION OF COMPLIANCE CERTIFICATIONS

This section must be completed once by every source. Indicate when you would prefer to submit compliance certifications during the term of your permit (at least once per year).

Frequency of submittal **Semiannual** Beginning **1/31/2013**

E. COMPLIANCE WITH ENHANCED MONITORING & COMPLIANCE CERTIFICATION REQUIREMENTS

This section must be completed once by every source. To certify compliance with these, you must be able to certify compliance for every applicable requirement related to monitoring and compliance certification at every unit.

Enhanced Monitoring Requirements: **NA** ____ In Compliance ____ Not In Compliance

Compliance Certification Requirements: **NA** ____ In Compliance ____ Not In Compliance

Attachment B

April 21, 2004 Letter from EPA to IADC

APR 21 2004

OFFICE OF
ENFORCEMENT AND
COMPLIANCE ASSURANCE

Alan Spackman
Director, Offshore Technical and Regulatory Affairs
International Association of Drilling Contractors
P.O. Box 4287
Houston, Texas 77210

Dear Mr. Spackman:

This letter is in response to your letter dated January 2, 2004, and your February 27, 2004 e-mail in which you requested clarification regarding the applicability of the Federal Plan Requirements for Commercial and Industrial Solid Waste Incineration Units (CISWI) that Commenced Construction On or Before November 30, 1999 (40 CFR 62, Subpart III) to incinerators located on drill ships.

In your e-mail, you elaborated upon your request to indicate that you are specifically concerned about the applicability of the rules on the operation of shipboard incinerators on mobile offshore drilling units operating beyond the jurisdiction of an individual State.

Outside the territorial waters of the States, the CISWI Rules are presently not applicable. The Clean Air Act requires an affirmative action to amend the Outer Continental Shelf (OCS) regulations before a standard promulgated for an on shore source becomes applicable to OCS sources, such as drill ships. See 42 U.S.C. §7627(a)(4)(C). Such affirmative action can be done at the time of promulgation or at a later date. As stated in 40 CFR Part 55 concerning the OCS regulations, "[i]f the Administrator determines that additional requirements are necessary to protect Federal and state air quality standards or to comply with Part C of Title I, such requirements will be incorporated into this section." See 40 CFR §55.13.

Because the OCS regulations have not yet been amended to require compliance with the CISWI Rules, the Federal Plan requirements are not currently applicable to OCS sources.

If you have any comments regarding this letter, please contact Rob Lischinsky of my staff at (202) 564-2628 or by e-mail at lischinsky.robert@epa.gov.

Very truly yours,

Michael S. Alushin, Director
Compliance Assessment and Media Programs Division
Office of Compliance

cc: Juei Yang, EPA Region VI
Fred Porter, Office of Air Quality Planning and Standards (OAQPS)

Attachment C

NO_2 1-Hour Standard Modeling

AECOM

Environment

Submitted to:
ConocoPhillips
Anchorage, Alaska

Submitted by:
AECOM
Fort Collins, CO
60136620.A2120
April 2010

Modeling Report – 1-Hour NO_2 Ambient Air Quality Impact Analysis for Proposed Exploratory Drilling (Devil's Paw Prospect) in the Chukchi Sea

AECOM Environment

Submitted to:
ConocoPhillips
Anchorage, Alaska

Submitted by:
AECOM
Fort Collins, CO
60136620.A2120
April 2010

Modeling Report – 1-Hour NO_2 Ambient Air Quality Impact Analysis for Proposed Exploratory Drilling (Devil's Paw Prospect) in the Chukchi Sea

Final

TA Damiana

Reviewed By: Tom Damiana

Contents

List of Tables

List of Figures

1.0 Introduction

On February 12, 2010, ConocoPhillips (CP) submitted an ambient air quality impact analysis for an exploratory drilling activity to be conducted within the Devil's Paw Prospect on the Chukchi Sea (CP Chukchi AQIA) (Ambient Air Quality Impact Analysis for Proposed Exploratory Drilling (Devil's Paw Prospect) in the Chukchi Sea – ConocoPhillips 2010). That analysis was submitted prior to the April 12, 2010 effective date of the 1-hour NO_2 National Ambient Air Quality Standard (NAAQS), and did not include an analysis of 1-hour NO_2 ambient air quality. Therefore, CP is submitting this air quality impact analysis for the exploratory drilling activity described in the CP Chukchi AQIA for the purpose of demonstrating that cumulative ambient air quality impacts associated with the exploratory activity will be below the 1-hour NO_2 NAAQS.

2.0 Technical Approach

The following sections outline the technical approach and results of the ambient Air Quality Impact Analysis (AQIA) conducted to document compliance with the 1-hour NO_2 NAAQS. With the exceptions noted below, modeling was conducted with the procedures described in the CP Chukchi AQIA, and involved the following steps:

- Conduct dispersion modeling to predict cumulative ambient air quality impacts from project emissions and emissions from explicitly modeled non-project sources according to the procedures described in the CP Chukchi AQIA with the exceptions described below.
- Combine model predicted impacts with an appropriate background concentration to demonstrate that cumulative ambient air quality impacts from proposed source emissions under the worst-case operating scenario do not exceed applicable NAAQS.

2.1 General Technical Approach

The following basic modeling assumptions and setup parameters were used to conduct the dispersion modeling.

Model Setup and Application	
Dispersion Model	The USEPA Offshore and Coastal Dispersion (OCD) model (OCD Version 5 Level 00006). The applicability and propriety of this model is explained in Chapter 3 of the CP Chukchi AQIA.
Pollutants and Averaging Periods	The following criteria pollutants and averaging periods were modeled: • NO_2 – 1-hour averaging period Modeling for all other criteria pollutant and averaging periods is presented in the CP Chukchi AQIA.
General Model Options	Model options were set to regulatory defaults outlined in Section 8 of USEPA's Guideline on Air Quality Models (GAQM) (USEPA 2005) as they apply to the current modeling effort. Model options: • included stack-tip downwash; • excluded calculation of gradual plume rise; and • included buoyancy induced dispersion in initial plume calculations.
GEP Stack Height Analysis	All stacks were evaluated to determine if heights are Good Engineering Practice (GEP) as defined in 40 CFR 51.100 and described in GAQM Section 6.2.2.
Building Downwash Parameters	Building downwash parameters were calculated for all stacks which are less than GEP height.

Model Setup and Application	
Treatment of Chemical Transformations	Using a post-processor, NO_2 impacts were predicted by applying the Ozone Limiting Method (OLM) to the total NO_x concentration predicted on an hourly basis at each modeled receptor. OLM is a GAQM approved method for modeling annual NO_2 concentrations and is equally applicable to modeling 1-hour NO_2 impacts. The technique and applicability are described in *A Review of Techniques Available for Estimating Short-Term NO_2 Concentrations* (Cole and Summerhays 1979). Representative ambient ozone data is required by OLM. Representative hourly ambient ozone data used as input to the OLM post-processer was derived from concentrations measured at the Wainwright Near-Term Ambient Air Quality Monitoring Program from July 2009 through November 2009. These data were collected as part of a USEPA approved PSD monitoring program. A full description of the ozone input data is presented in Section 2.4.

Receptor Network	
Treatment of Terrain	The entire modeling domain is over water; therefore, all receptor elevations were set to 0 meters.
Description of Receptor Grids	As fully detailed in Section 5.4 of the CP Chukchi AQIA, a Cartesian receptor grid centered on the worst-case well location (473,600 East, 7,869,600 North, Zone 3, NAD 83) was generated based on UTM coordinates system with the following density: • 25 m resolution extending from the ambient air quality boundary out to a distance of 1 km; • 100 m receptor spacing beyond 1 km out to a distance of 2 km; • 500 m resolution extending from the 2 km out to 5 km; • 1,000 m resolution extending from 5 km to 20 km; and • 2,000 m resolution extending from 20 km to 50 km. Furthermore, additional receptors, spaced at 100 m intervals, were placed in the vicinity of project sources located greater than 2 km from the rig where receptor spacing would otherwise have been greater than 100 m. Graphics depicting all receptor grids can be found in Section 5.4 of the CP Chukchi AQIA.
Ambient Air Boundary	The ambient air boundary was defined by a 500 meter radius circle centered on the drill rig. **Figure 2-1** shows the ambient air quality boundary and the near-field receptor grid.

Meteorological Data	
Surface Meteorological Database	As fully detailed in Chapter 4 of the CP Chukchi AQIA, modeling was conducted for the July through November drilling season with five years of recent meteorological data (1999, 2002, 2004, 2005, and 2006) from the Wainwright NWS station fulfilling both over water and over land data requirements coupled with concurrent mixing heights from Barrow.
Upper Air Database	As fully detailed in Chapter 4 of the CP Chukchi AQIA, modeling was conducted with concurrent estimates of twice-daily mixing heights from the Barrow upper air station.
Meteorological Data Processing	As fully detailed in Section 4.2 of the CP Chukchi AQIA: • To create the OCD required over water meteorological input files over water wind and temperature data were combined with the air-sea temperature difference, Barrow mixing height, and over water humidity data into a free-format ASCII text file. • To create the OCD required over land meteorological input file, over land data consisting of surface observations from Wainwright, Alaska, and twice daily mixing heights from Barrow, Alaska, were processed with USEPA's PCRAMMET processor to format the data for use in the OCD model.

Background Air Quality	
Explicitly Modeled Offsite Inventory	Development of the offsite inventory considered: 1) existing stationary sources, 2) stationary sources which have received PSD permits but have not yet began to operate, 3) emissions from any proposed stationary source for which a complete PSD application exists but for which a permit has not yet been issued, and 4) mobile sources. As fully described in CP Chukchi AQIA Section 8.2, only emissions associated with the Shell Gulf of Mexico Inc. (Shell) exploration activities were explicitly included in the cumulative impact analysis. For a detailed description of the how the Shell exploration activity was included in the modeling including location and emission rates, reference CP Chukchi AQIA Section 8.2.1.
Local Background	To account for non-modeled sources, an ambient background was added to model predicted concentrations. Ambient background pollutant concentrations measured at the Wainwright Near-Term Ambient Air Quality Monitoring Program (Wainwright Monitoring Program) from November 2008 through October 2009, were used in the air quality impact analysis. These data have been collected as part of a USEPA approved PSD monitoring program. Based on an analysis of that data, the background 1-hour NO_2 pollutant concentration not dominated by local stationary and mobile sources explicitly included in the cumulative impact analysis is 11 ppb (21 $\mu g/m^3$).

2.2 Modeled Project Emissions Inventory

A full description of the model emissions inventory is presented in CP Chukchi AQIA Chapter 2. With the following exceptions, specific source simulation details that were used in this analysis are described in CP Chukchi AQIA Sections 5.1 and 5.2:

- For the CP Chukchi AQIA, during OSV supply transfer operations, emissions from the OSRV which lays boom during fuel transfer, were modeled as point sources at a fixed location adjacent to the OSV and drill rig. In reality, this activity is highly mobile; therefore, for this analysis, the OSRV was modeled in four locations encircling the drill rig to simulate the OSRV laying boom around the drill rig and OSV. See **Figure 2-1** for source layout details.
- Modeled NO_x emissions for the engines on the OSV, OSRV, Ware Vessel, and Workboats were reduced to reflect the use of Tier II engines. The NO_x emissions reductions were approximately 45 to 50% on an hourly basis for the engines with changes.
- During a given hour, the probability is low that emergency generators on the drill rig or vessels will operate. Therefore, emissions from emergency generators were excluded from the modeling.
- During a given hour, only two drill rig engines will operate simultaneously. Therefore, only the emissions from two drill rig engines were included in the modeling.

2.3 Modeling Scenario

The modeled short-term scenario presented in the CP Chukchi AQIA was highly conservative in that it simulated many activities occurring at the same time that in reality will not occur simultaneously or have a low probability of occurring simultaneously. This approach was refined for the 1-hour NO_2 modeling. For the 1-hour NO_2 modeling, a realistic worst-case 1-hour scenario was developed which excluded activities that will not operate simultaneously, or have a very low probability of occurring simultaneously.

Based on modeling conducted as part of the CP Chukchi AQIA, it has been determined that Fuel Transfer Preparation activities conducted during the hour preceding and the hour following fuel transfer to the drill rig produces the highest short-term impacts because this activity concentrates the largest amount of sources in the smallest location at any one time. During this hour, an OSV is stationary next to the drill rig either preparing to transfer fuel or finishing transferring fuel and an OSRV is either laying or retrieving oil spill response boom which is placed around the entire operation. This scenario was used to predict maximum 1-hour NO_2 impacts. To develop cumulative modeling for this scenario it was determined that only the following activities have a high probability of occurring simultaneously with Fuel Transfer Preparation activities since fuel transfers will only occur 6 times during a drilling season for a total of 12 hours (i.e., 2 hours during each transfer; 1 hour to lay boom and 1 hour to retrieve boom):

- Regular Oil Spill Response Vessel (OSRV) Operations consisting of a single OSRV.
- Mandated MMS Simulated Spill Response Exercises consisting of two OSRVs and four workboats.
- Ice Management consisting of two patrolling ice breakers.

Full descriptions of these activities are presented in CP Chukchi AQIA Section 5.2. CP Chukchi AQIA Section 5.2, Figure 5-1 shows the modeled location of these activities relative to the drill rig.

2.4 Special Modeling Considerations

<u>Ambient Ozone Data Input to NO_2 Modeling</u>

OLM requires representative hourly ozone concentrations. Data collected from July 2009 through November 2009 at the Wainwright Near-Term Ambient Air Quality Monitoring station in Wainwright, Alaska were used. The Wainwright data is the closest, readily available source of ozone data relative to the project location. Given that concurrent ozone and meteorological data are not available, the OLM analysis used climatologically averaged ozone concentration values derived from the Wainwright measurements. To properly account for seasonal variation and any potential diurnal variation, the Wainwright data was used to develop a set of ozone concentrations that vary by the hour of day for each month. For each month this was based on the average measured ozone concentration for every hour of the day. The resulting file was used as input to the OLM post-processor. An analysis of the monthly variation in ozone measured at Wainwright from July through November 2009 is shown in **Figures 2-2** through **2-6.** OLM post-processor was conducted with the average values displayed on these plots.

Figure 2-1 Location of Near-Field Receptors and Sources

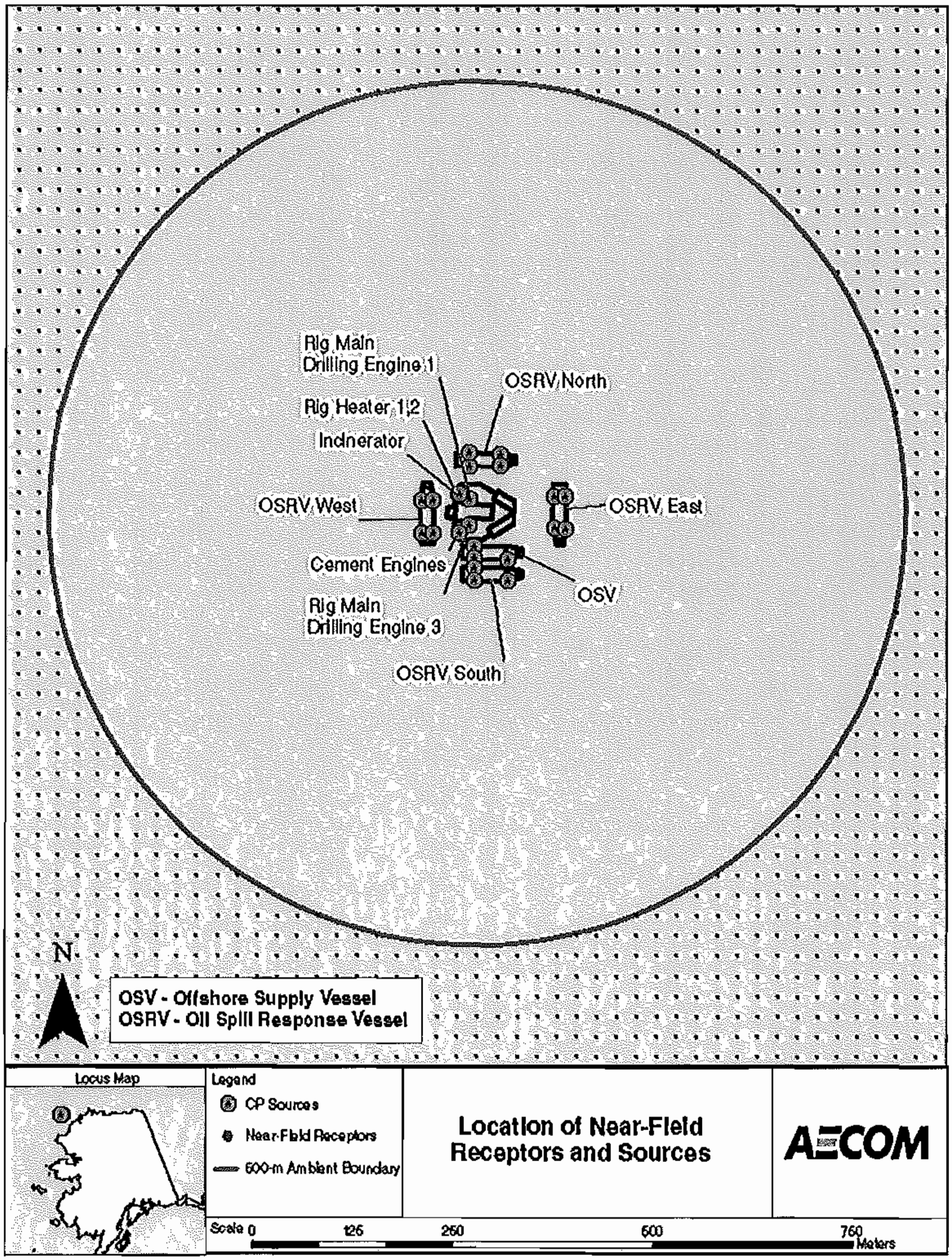


Figure 2-2 Ozone Variation Measured at Wainwright During July 2009

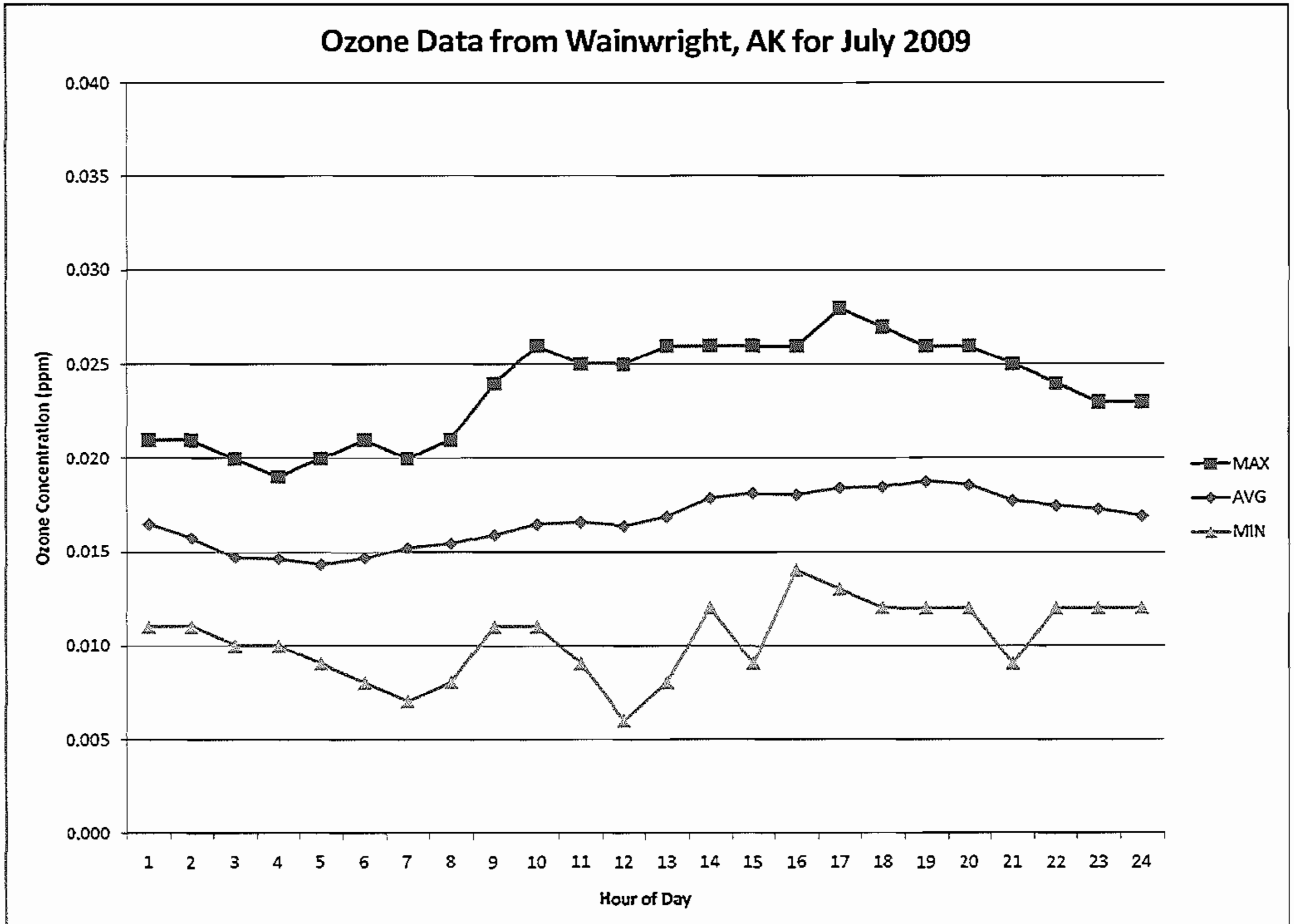


Figure 2-3 Ozone Variation Measured at Wainwright During August 2009

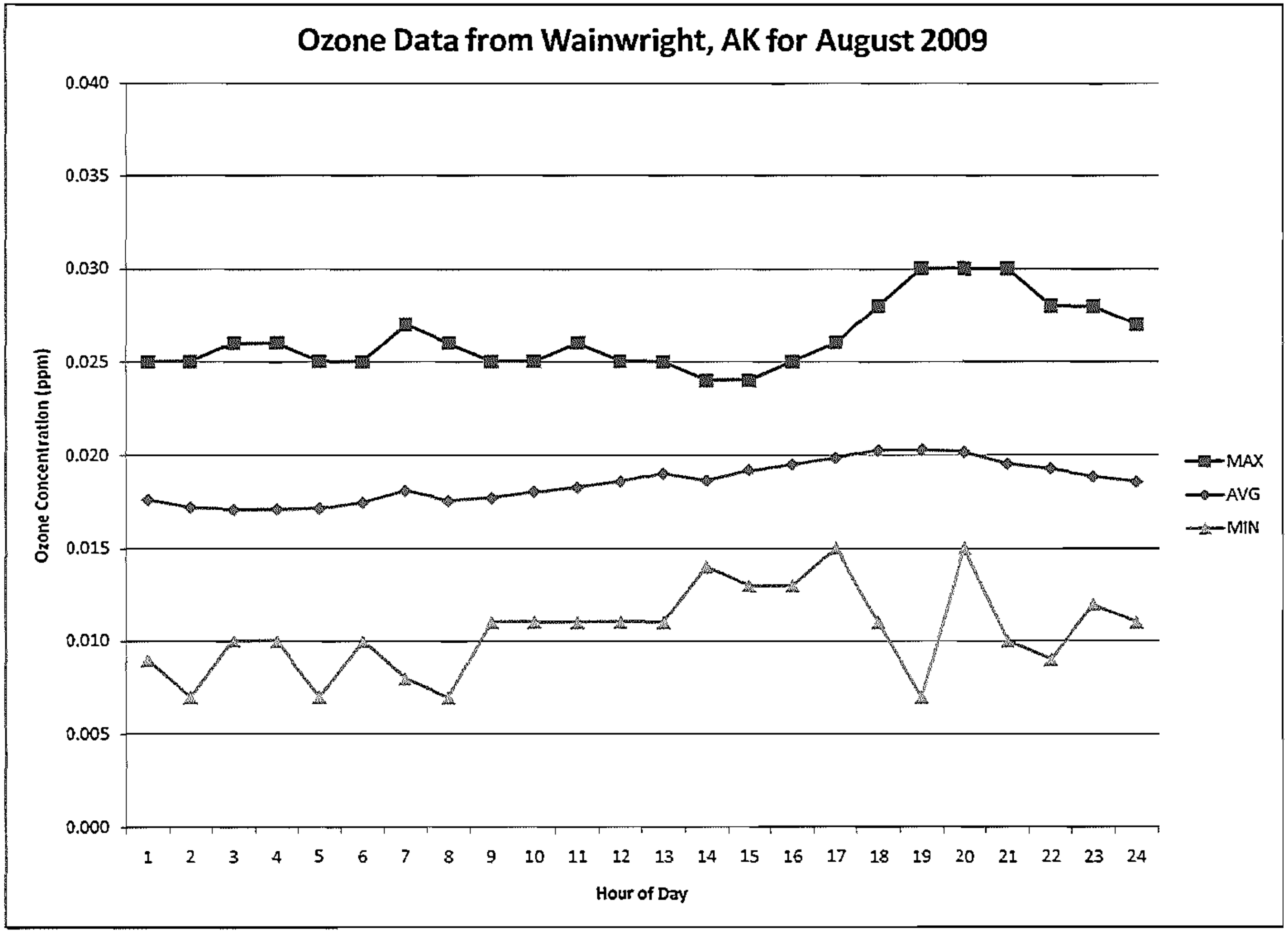


Figure 2-4 Ozone Variation Measured at Wainwright During September 2009

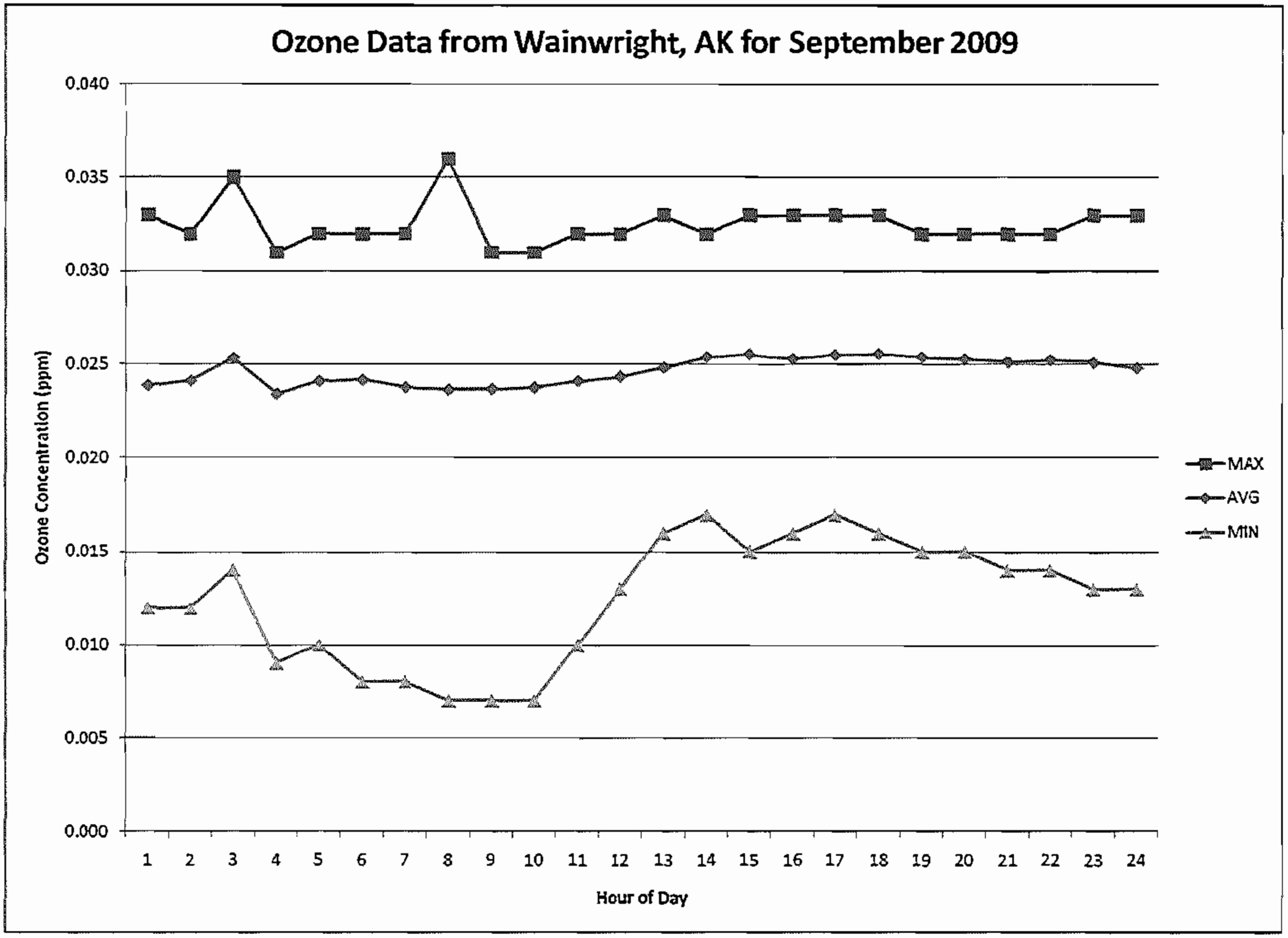


Figure 2-5 Ozone Variation Measured at Wainwright During October 2009

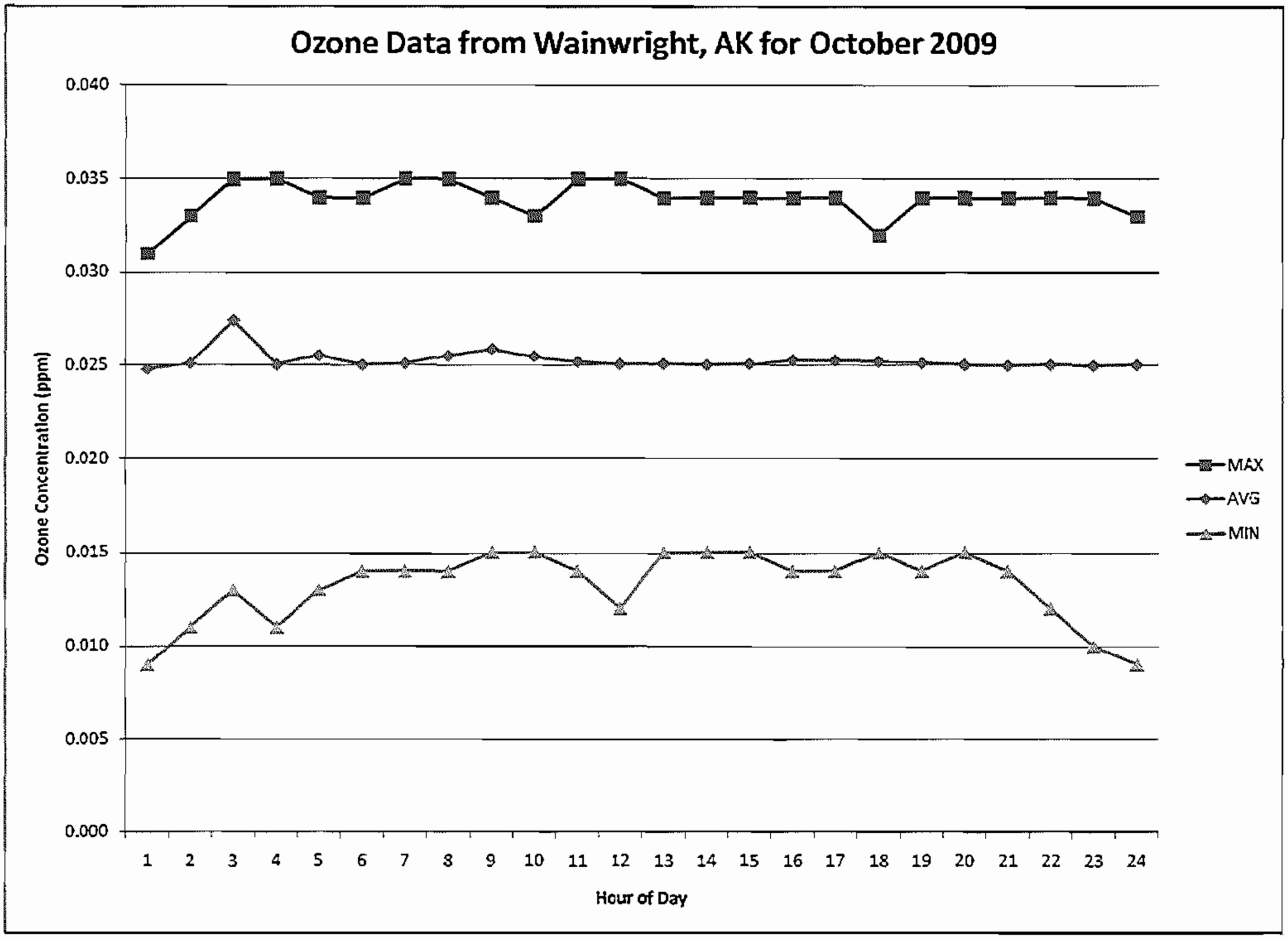
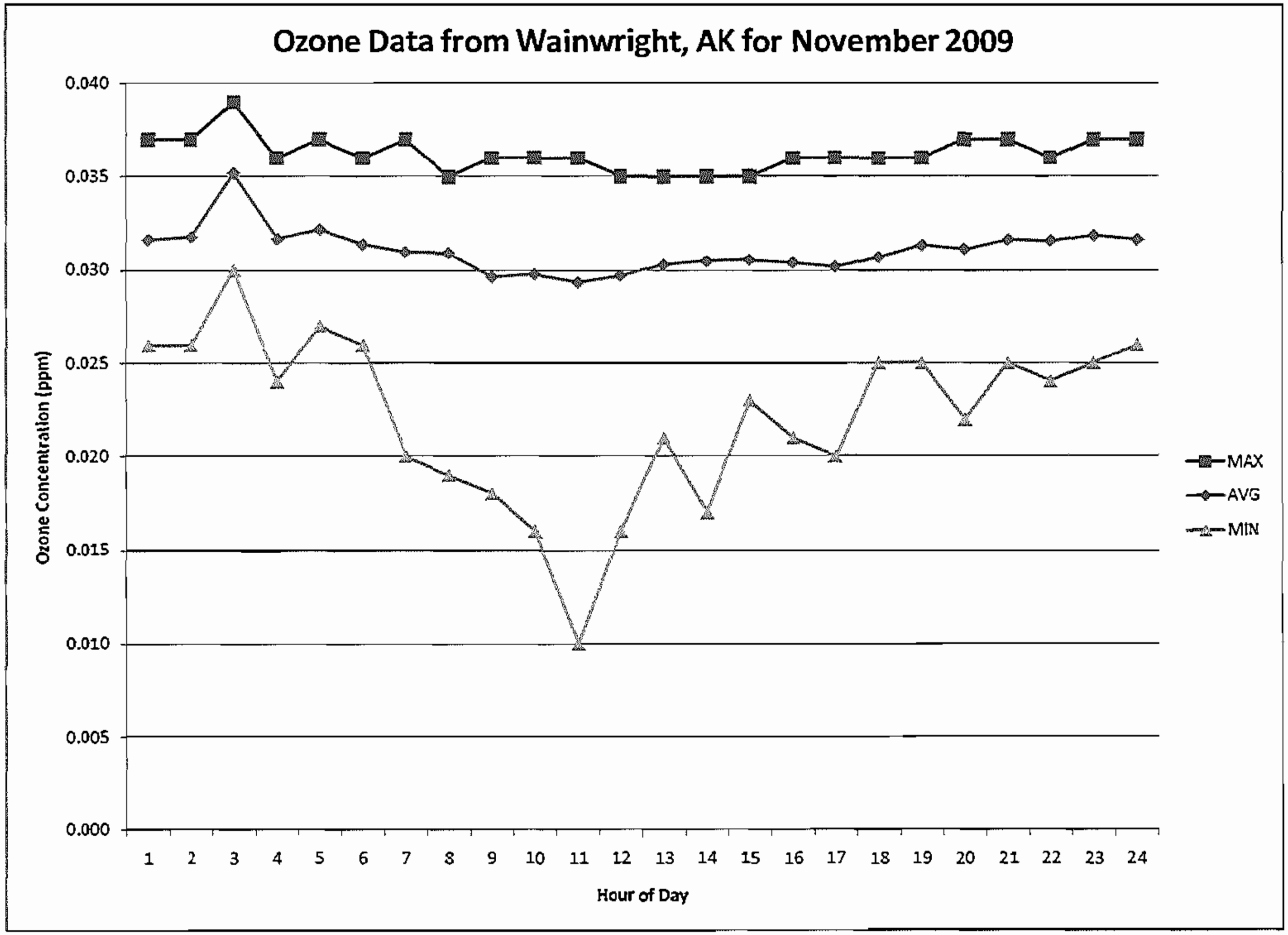


Figure 2-6 Ozone Variation Measured at Wainwright During November 2009



3.0 Cumulative Impact Analysis Results

Results of the cumulative impact analysis are summarized in **Table 3-1** which lists the modeled NO_2 concentration, the ambient background concentration, as well as the total cumulative concentration for comparison to the NAAQS. **Table 3-1** demonstrates that model predicted cumulative air quality impacts are below the 1-hour NO_2 NAAQS.

The maximum model predicted impact was found to occur in the vicinity of the OSRV practice exercises located 1.6 kilometers (1 miles) east of the drill rig. **Figures 3-2** through **3-4** present isopleths of predicted cumulative 1-hour highest-eight-high (H8H) NO_2 concentrations. **Figures 3-2** and **3-3** depict the drill rig near- and far-fields; and **Figure 3-4** shows concentrations on the entire 100 km square modeling domain.

A digital record containing model input output files, the OLM ozone input file, and the OLM post-processor will be transmitted electronically separate from this document. README file describing the contents of the digital record will be transmitted with it.

Table 3-1 Cumulative Impact Analysis Results

Pollutant	Averaging Period	Impact (µg/m^3) [1]	Background Concentration (µg/m^3)	Total (µg/m^3)	NAAQS (µg/m^3)
NO_2	1-hour	155	21	176	188

[1] Average across all modeled years of the 8th-highest daily 1-hour maximum concentration from the annual distribution of daily 1-hour maximum concentrations.

Figure 3-1 Near-Field Isopleth Plot of Predicted H8H 1-Hour NO_2 Cumulative Impacts

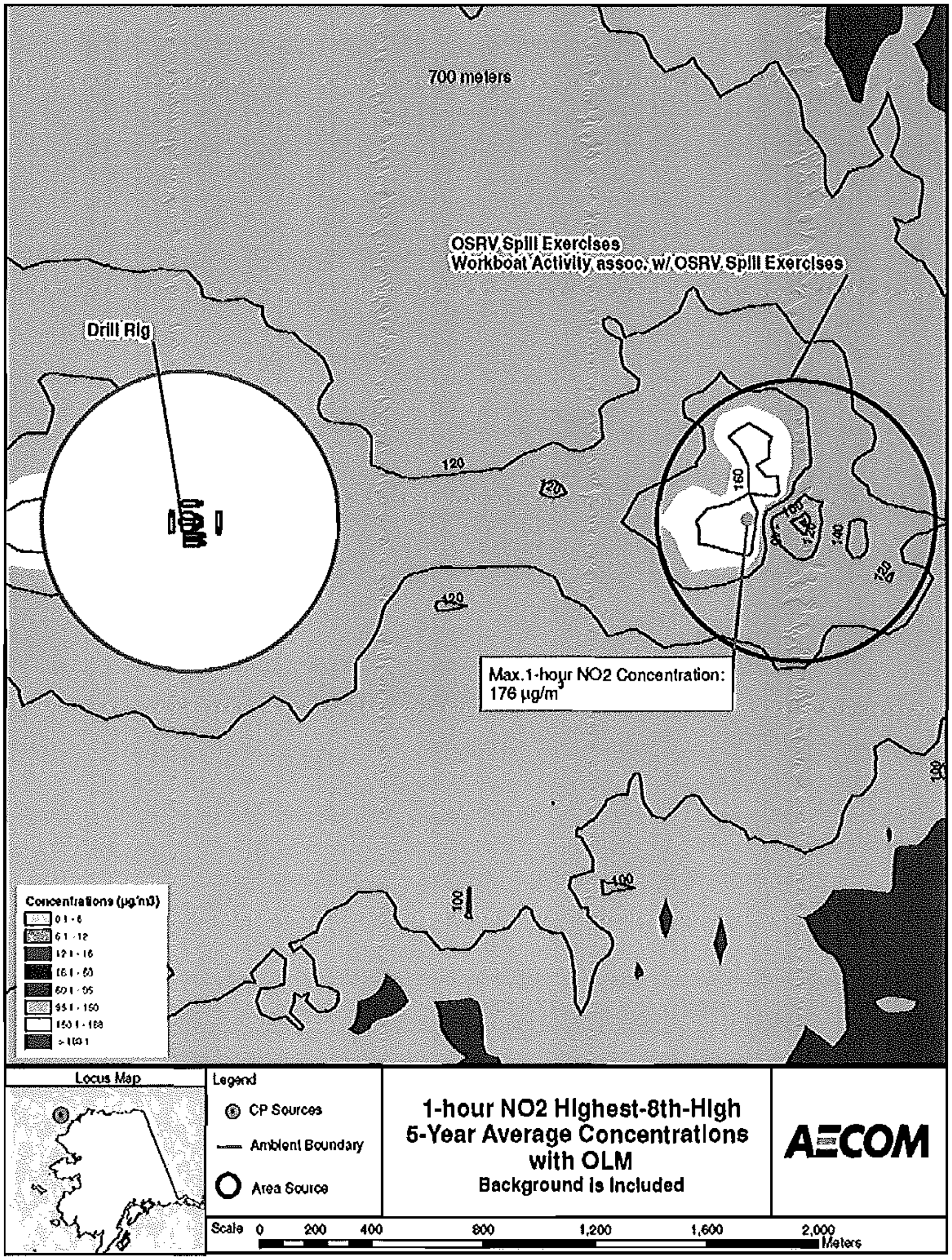


Figure 3-2 Far-Field Isopleth Plot of Predicted H8H 1-Hour NO_2 Cumulative Impacts

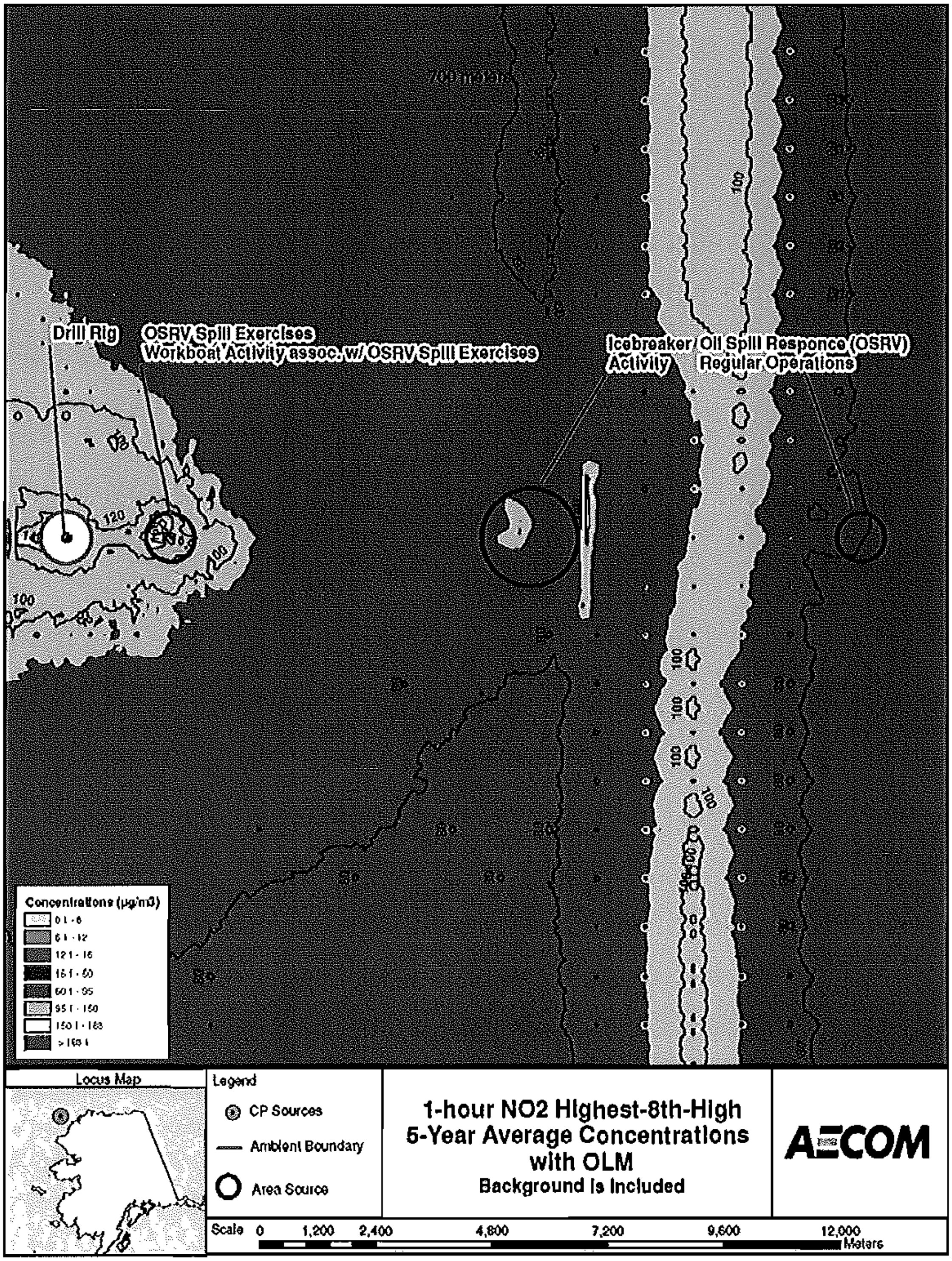
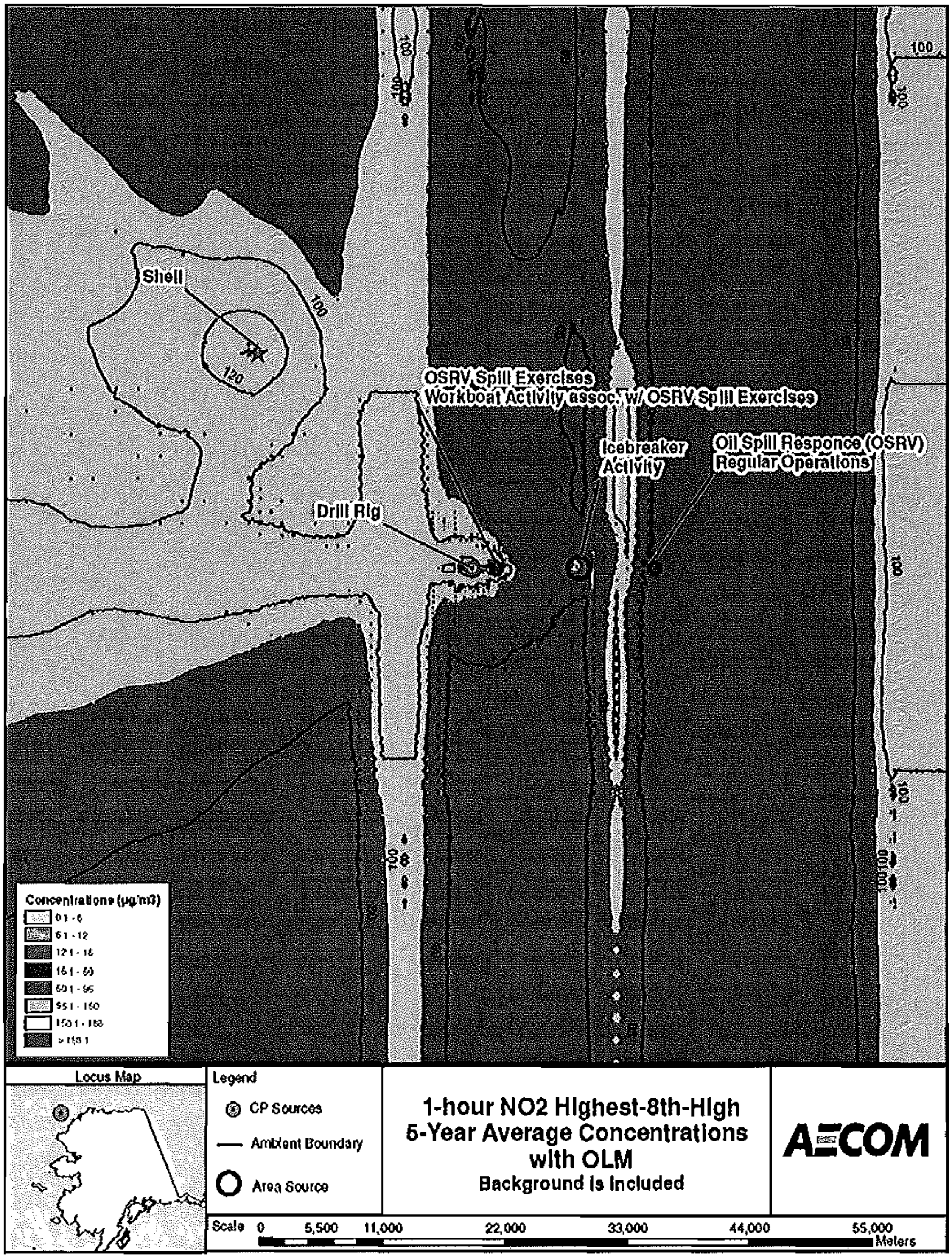


Figure 3-3 Isopleth Plot of Predicted H8H 1-Hour NO_2 Cumulative Impacts on the Entire Modeling Domain



4.0 References

ConocoPhillips 2010. ConocoPhillips Outer Continental Shelf Air Permit Application (Air Quality Modeling Analysis) – Chukchi Sea Devil's Paw Prospect - Volume 2. Submitted to USEPA Region 10 February 12, 2010.

Cole, H. S. and Summerhays, J.E. 1981. A Review of Techniques Available for Estimating Short-Term NO_2 Concentrations. Journal of the Air Pollution Control Association, Vol. 29, no. 8, pg 812-817.

United States Environmental Protection Agency (USEPA). 2005. Guideline on Air Quality Models (GAQM) (Revised). Codified in the Appendix W to 40 CFR Part 51. Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina. November 2005.

Attachment D

CALPUFF Modeling

AECOM Environment

Submitted to:
ConocoPhillips
Anchorage, AK

Submitted by:
AECOM
Fort Collins, CO
60136620 A2110
April 2010

CALPUFF Overwater Modeling Evaluation for a Jack-up Drill Rig in the Chukchi Sea
Final

AECOM Environment

Submitted to:
ConocoPhillips
Anchorage, AK

Submitted by:
AECOM
Fort Collins, CO
60136620 A2110
April 2010

CALPUFF Overwater Modeling Evaluation for a Jack-up Drill Rig in the Chukchi Sea
Final

TA Damiana

Reviewed By: Tom Damiana

Contents

List of Appendices

List of Tables

List of Figures

1.0 Introduction

1.1 Overview

This report discusses an evaluation of air quality impacts predicted by CALPUFF over water in the Chukchi Sea using MM5 meteorological data for a typical jack-up drill rig. This report has been prepared as part of an ongoing effort to facilitate the development of CALPUFF for future use in overwater applications in the Chukchi Sea. It is being submitted as a follow-up to a memo submitted to USEPA Region 10 on March 29, 2010 which presented a comparison of the MM5 meteorology used in this analysis to actual meteorology measured within the modeling domain. This report refers to detailed documentation contained in the permit application: "Permit Application for Proposed Exploratory Drilling (Devil's Paw Prospect) in the Chukchi Sea, Volume II: Modeling Report" (ConocoPhillips 2010), here after referred to as the CP Chukchi AQIA.

The specific location for the analysis is the Devil's Paw Prospect location in the Chukchi Sea off the coast of Alaska, which is shown in **Figure 1-1**.

The CP Chukchi AQIA contains detailed information regarding the project description, source characterization, required analyses, and evaluation methods. Please refer to the Permit Application for project specific details.

1.2 Report Organization

Chapter 2.0 provides details regarding the meteorological data processing and the MMIF program. Chapter 3.0 documents the CALPUFF modeling approach, model options, supporting studies, and source characterization. Chapter 4.0 presents the model results. Chapter 5.0 contains all references.

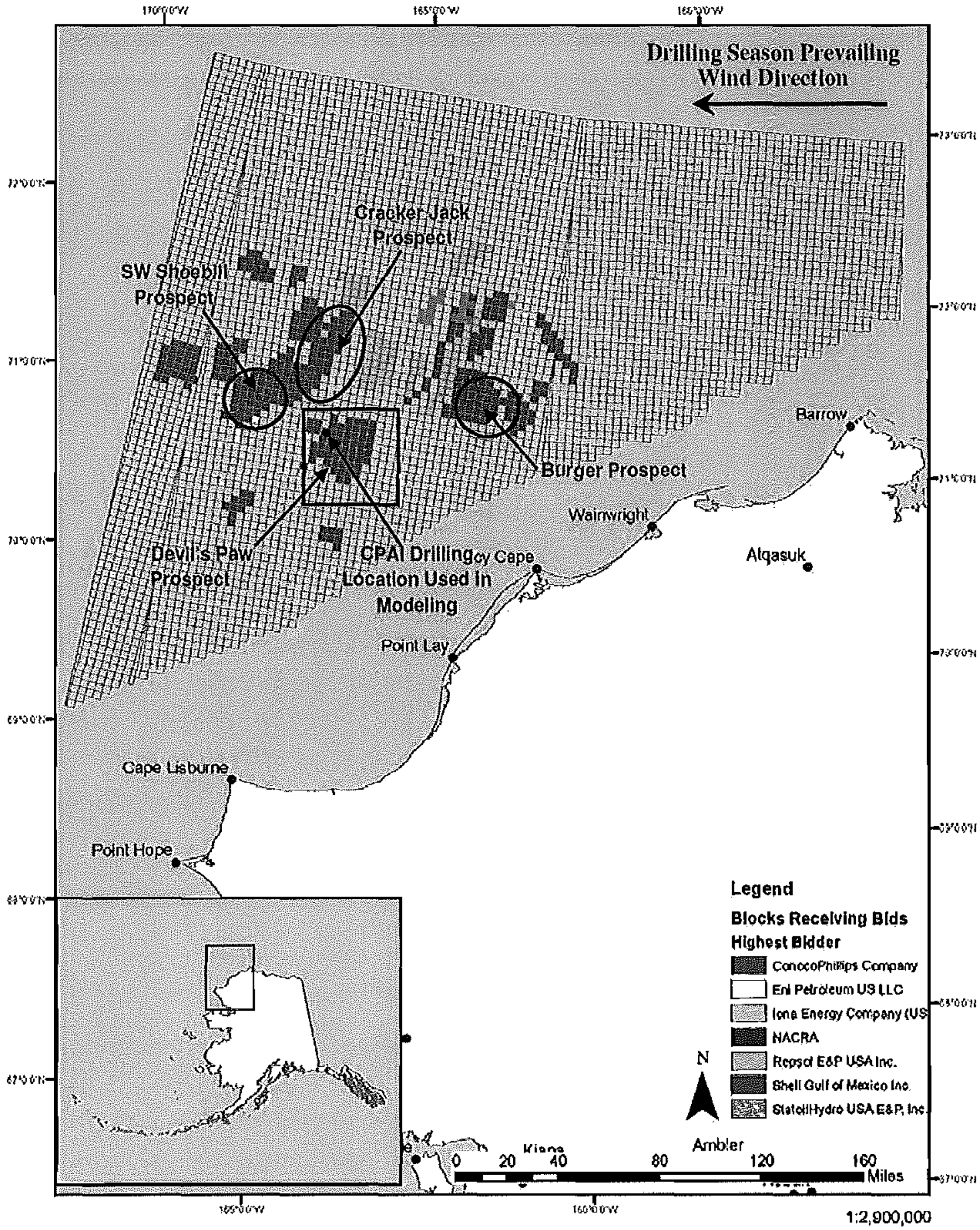


Figure 1-1 Modeled Drill Rig Location

2.0 Meteorological Data Processing

USEPA Region 10 is interested in evaluating the use of the CALPUFF model system for conducting overwater air quality modeling in the Chukchi Sea using the MMIF program instead of CALMET. MMIF is being developed by the USEPA in order to provide a consistent meteorological processing technique for use with CALPUFF modeling. The MMIF program converts prognostic meteorological model output fields (such as output from the Fifth-Generation Mesoscale Meteorological Model, MM5) to the parameters and formats required for direct input into the CALPUFF dispersion model without significant modifications to the original data. Based on the *Draft User's Manual The Mesoscale Model Interface (MMIF) Program, Version 1.0* (referred to hereafter as the MMIF User's Manual): "The processor is intended to be an alternative to CALMET in generating three-dimensional meteorological input fields ... in support of regulatory air quality impact analyses... The program diagnoses certain CALPUFF-required parameters that are not directly available from MM5" (ENVIRON 2009).

2.1 Available Meteorological Data

For this evaluation, 45-km resolution MM5 data for the year 2002 were the only readily available prognostic mesoscale data available over the Chukchi Sea. The MM5 modeling protocol and report documenting the MM5 projection, settings, and meteorological options (Geomatrix 2007), are included with the digital archive accompanying this document. Importantly, the MM5 simulations were originally developed for Best-Available Retrofit Technology (BART) analysis conducted for facilities in southern Alaska. As such, the focus of the finer resolution modeling domains (referred to as D1 and D2 in MM5 modeling report) was too far to the south to be used for this project. The coarse gridded D0 MM5 domain, which was used for this evaluation, is shown in **Figure 2-1**. The full D0 domain extends over the state of Alaska and is much larger than required for this project. MMIF has the capability to process a subset of the full MM5 domain, and this functionality was used to select a 630 km square region centered on the project location.

The vertical resolution in an MM5 dataset typically extends into the upper troposphere. Meteorological parameters in the upper troposphere are not necessary for CALPUFF dispersion modeling. Therefore, only the vertical levels below approximately 4,000 m were extracted and input into CALPUFF for this analysis. **Table 2-1** shows all MM5 vertical levels and indicates which levels were extracted by MMIF.

2.2 The MMIF Program

The MMIF program does very little processing of the input meteorological data. MMIF Version 1.0 is initiated with a control file, which contains a variety of user-defined settings. A variety of settings must be defined by the user, including:

- Type of input prognostic model data.
- The processing period.
- Difference between local time and Greenwich Mean Time (GMT).
- Desired MM5 grid nodes to process (the full grid or a subset may be selected).
- Desired vertical MM5 layers to process (the full number of vertical layers or just the lower levels of MM5 may be selected).

Table 2-1 All MM5 Vertical Layers and Layers Input into CALPUFF

MM5 Level	Layer Height Documented in the MM5 Report (m)	Extracted for CALPUFF Modeling (Yes/No)	Layer Height Input to CALPUFF (m)
40 - top	23354.9	No	NA
40	21150.9	No	NA
39	19097.4	No	NA
38	17605	No	NA
37	16065	No	NA
36	14919.9	No	NA
35	13708.1	No	NA
34	12766.3	No	NA
33	11759	No	NA
32	10952.3	No	NA
31	10085.7	No	NA
30	9375.9	No	NA
39	8634.5	No	NA
28	7996.4	No	NA
27	7348.2	No	NA
26	6783.2	No	NA
25	6222.2	No	NA
24	5728.4	No	NA
23	5233.8	No	NA
22	4795.1	No	NA
21	4352.8	No	NA
20	3958.1	Yes	3795.959
19	3558	Yes	3427.017
18	3199.2	Yes	3093.375
17	2833.9	Yes	2750.899
16	2505.1	Yes	2440.214
15	2189	Yes	2139.463
14	1903.9	Yes	1866.511
13	1637.9	Yes	1610.2
12	1398.4	Yes	1378.198
11	1192.2	Yes	1177.538
10	991.1	Yes	980.9698
9	828.6	Yes	821.548
8	661	Yes	656.521
7	537.5	Yes	534.5606

Table 2-1 All MM5 Vertical Layers and Layers Input into CALPUFF

MM5 Level	Layer Height Documented in the MM5 Report (m)	Extracted for CALPUFF Modeling (Yes/No)	Layer Height Input to CALPUFF (m)
6	400	Yes	398.1591
5	303.9	Yes	303.0089
4	193.5	Yes	193.1573
3	131.1	Yes	130.9333
2	61.4	Yes	61.4
1	38.3	Yes	20[1]
0 - ground	0	Yes	0

[1] Due to CALMET's capability to combine surface observations (typically measured at a height of 10m) with MM5 data, CALPUFF requires that the first level be 20m high so that the middle of the level corresponds with the surface observation measurement level. MMIF has algorithms to interpolate the MM5 data to this required height.

Additionally, a user must specify several processing options in the MMIF control file:

- Method for calculating the P-G stability class.
- Option to re-calculate the depth of the Planetary Boundary Layer (PBL).
- Set the maximum and minimum PBL depth.

The details of the MMIF program and the data processing procedures are described in the MMIF User's Manual, which is included in **Appendix A** of this report. In collaboration with USEPA Region 10, small modifications to the MMIF program code were required for this project. These modifications were only made to ensure MMIF interpreted the MM5 data correctly, and did not alter scientific algorithms. Therefore, these modifications are appropriate. These modifications included:

- Acceptance of MM5 data run with the NOAH Land Surface Model rather than the standard land use categories from the US Geological Service (USGS);
- Changed the winter-time surface characteristics (albedo, Bowen ration, soil heat flux, and surface roughness) for the "water bodies" land use category to be appropriate for sea-ice conditions; and
- Changed the Julian date in MMIF switches from winter to summer, such that the date corresponds to the date in MM5 when sea ice is turned "off".

The modified MMIF code, as used for this project, is described in more detail in **Appendix A** of this report.

2.3 Application of MMIF

The MMIF program was used for this project to develop the needed meteorological files to run CALPUFF. The MM5 data described in Section 2.1 was input into MMIF. MMIF was run with the control options shown in **Table 2-2**.

Table 2-2 MMIF Program Options Selected for the Project

MMIF Control Option	Project-specific Input	Description
Output Time Zone	-9	This is the difference between Alaska Standard Time and GMT.
P-G calculation method	2	Method 2 is based on the Golder method (Golder 1972) and was selected because it is the only MMIF option appropriate for over-water applications. Method 1 is based on the Solar Radiation Delta Temperature method, which is not appropriate for over-water applications.
Re-calculate PBL depth	T	Based on USEPA input, the MMIF recalculation of the PBL depth is appropriate for this application. When "true" is selected for this MMIF option and the MM5 grid cell is over water, the PBL depth is recalculated with a critical Richardson number of 0.05. As documented in the MMIF User's Manual, Gryning and Batchvarova have demonstrated that a critical Richardson number of 0.05 yielded better agreement with observations for over-water PBL heights.
Minimum and Maximum PBL Depth	100, 3000	These inputs set a limit on the possible value of the PBL depth. The values of 100m and 3,000m were selected for this analysis. A minimum PBL depth of 100m is appropriate for over water locations in the Arctic Ocean, based on an analysis presented in the CP Chukchi AQIA Appendix J. The PBL depth in the output file never exceeded 1,300m, indicating that the maximum limit of 3,000m was not used by MMIF.
I-range to extract	33, 49	These are the values of the i-nodes in the MM5 dataset that were extracted by MMIF for use in modeling. The spatial extent of the extracted dataset is shown in **Figure 2-1**.
J-range to extract	70, 85	These are the values of the j-nodes in the MM5 dataset that were extracted by MMIF for use in modeling. The spatial extent of the extracted dataset is shown in **Figure 2-1**.
Number of vertical layers	20	This is the number of vertical levels MMIF will extract from the MM5 dataset. For this project 20 levels were extracted by MMIF.
Layer Mapping	1, 2, 3, 4, 5, 6, 7, 8, 9 , 10, 11, 12, 13, 14, 15, 16, 17, 18,19, 20	This indicates which vertical levels to extract from the MM5 dataset. For this analysis, the lowest 20 vertical levels from the MM5 dataset were extracted for CALPUFF modeling. These levels were approved by USEPA Region 10 (AECOM 2010) and represent all available layers below 4,000m, which is more than twice the height of any PBL encountered in this analysis.

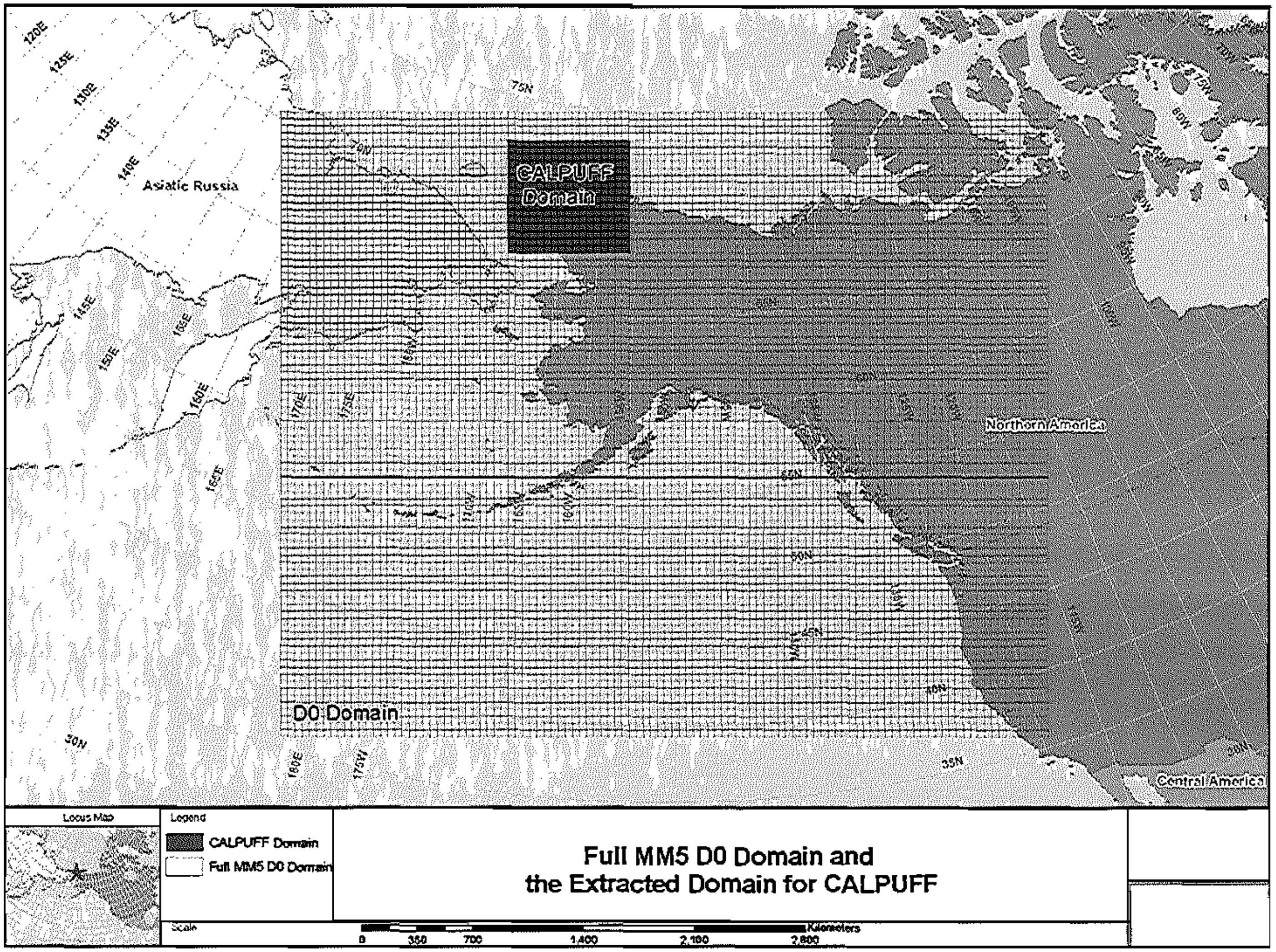


Figure 2-1 Extracted CALPUFF Domain in Relation to the Full MM5 D0 Domain

3.0 CALPUFF Dispersion Modeling

As noted in Chapter 1.0, this report is an evaluation of impacts predicted for a typical Jack-up drill rig detailed in the CP Chukchi AQIA. There is no need to repeat the information already presented in great detail in the CP Chukchi AQIA. Therefore, the reader is referred to the CP Chukchi AQIA for information regarding modeling sources, source characteristics, calculations of modeled emission rates, receptor grids spacing, spatial locations of sources, and building information.

3.1 Detailed Modeling Approach

The CALPUFF modeling system (Scire et al. 2000a, b) was promulgated on April 15, 2003, and is USEPA's guideline model for long-range transport beyond 50 km. This analysis uses the current USEPA-approved version of the CALPUFF modeling system (Version 5.8) to address near-field ambient air quality impacts. As described in detail in Section 3.3, the CALPUFF post-processors, POSTUTIL (Version 1.56, Level 070627), and CALPOST (Version 5.6394, Level 070622), were used for post-processing concentrations.

The CALPUFF modeling system has been evaluated for over water applications (Earth Tech, Inc. 2006), and several features have been added to CALPUFF to improve its performance for over water applications. Those features that are used in this modeling analysis include:

- Changes to the downwash algorithms to account for the large hollow space under drill rig platforms;
- Ability to advect turbulence in the transitional region between land and water; and
- Lower minimum sigma-v for over water areas.

For this evaluation, the CALPUFF modeling domain projection and grid resolution was the same as the as the input MM5 data. Unlike CALMET, MMIF does not modify the grid resolution or change the projection of the MM5 data. Therefore, the project coordinate system is identical to the MM5 dataset, which used a Lambert Conformal Projection (LCP) grid system as follows:

- Datum is the NWS 1984;
- Central reference LCP point (longitude, latitude) = (-151.0° W, 59.0° N);
- Standard latitude parallels at 0° N and 60° N; and
- Grid origin (southwest corner) offset from central reference point = (-990 km, 1102.5 km).

The model domain is a subset of the MM5 domain, as shown in **Figure 2-1**. The spatial extent of the domain is 765 km (east-west) x 720 km (north-south) and is shown relative to the project location in **Figure 3-1**. The design allows for 17 x 16 grid cells and a 45-km grid element size.

CALPUFF model options were set to regulatory defaults in most cases. All non-default model options are listed and explained in **Table 3-1**.

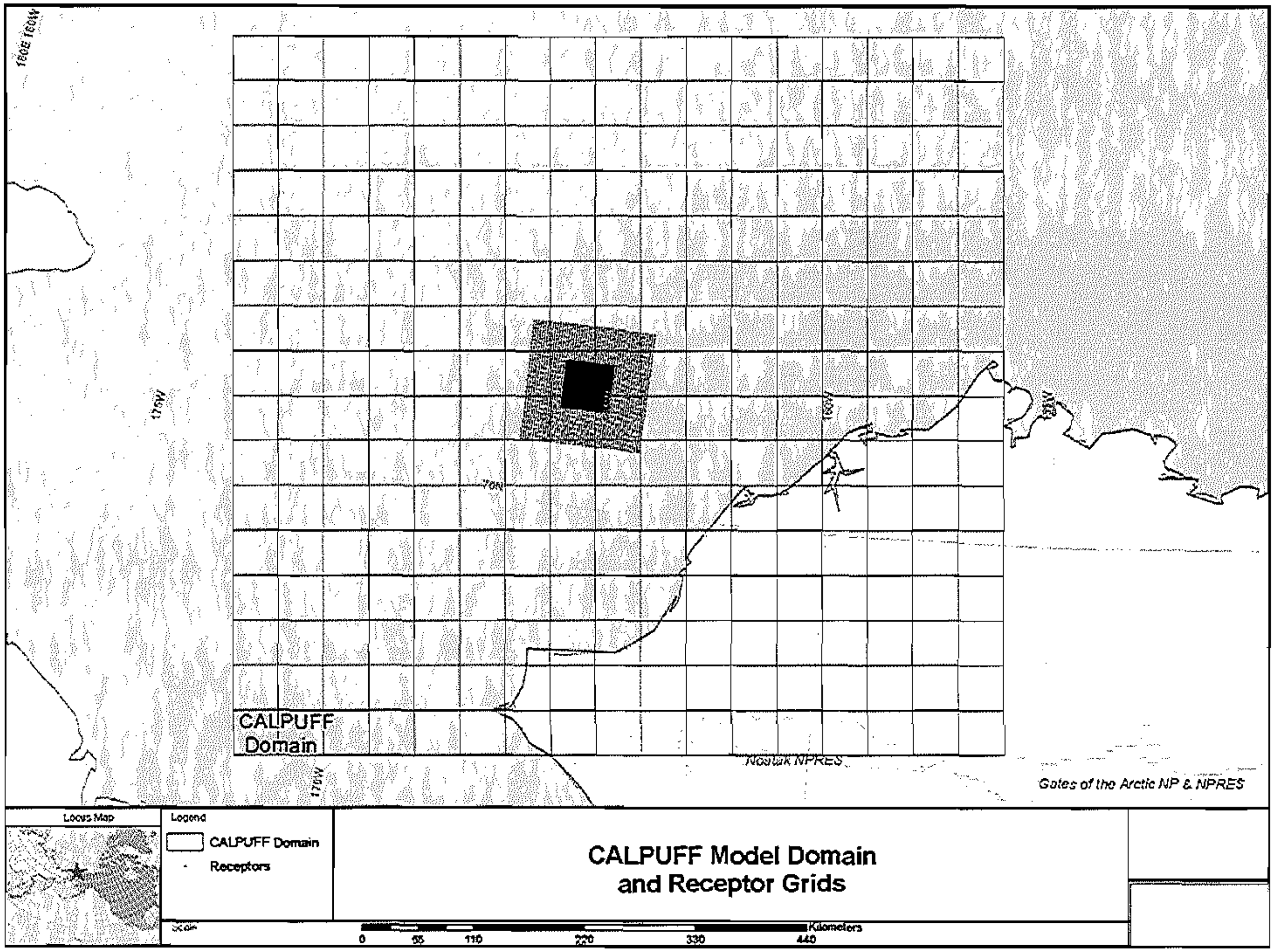


Figure 3-1 CALPUFF Modeling Domain and Receptor Grid

Table 3-1 Non-Default CALPUFF Options

Parameter	Description	Default Value	Chukchi Sea Value	Notes
Group 1				
NSPEC	Number of Chemical Species	5	7	The following species are modeled: SO_2, SO_4, NO_x, NO_3, HNO_3, PM, CO.
NSE	Number of chemical species to be emitted	3	4	The following species are emitted: SO_2, NO_x, PM, CO.
Group 2				
MDISP	Dispersion method	3	2	The use of MDISP=2 combined with MTAUADV=800 was the dispersion option selected for this analysis based on results of CALPUFF tests for overwater applications (Earth Tech, Inc. 2006). These combined technical options produced the best agreement with tracer studies of all the options that were tested. Therefore, these options were the most appropriate for this analysis.
MTAUADV	Method to calculate the timescale for turbulence advection	0	800	Tests of CALPUFF performance for over water applications suggested that the advection of turbulence is a highly important feature for over water applications (Earth Tech Inc. 2006). A timescale of 800 s is based on measurements over Oresund. This option is only used if MDISP=2.
PDF	PDF used for dispersion under convective conditions	0	1	
MBDW	Method used to simulate building downwash	1	Source-specific	ISC downwash algorithm (MBDW=1) for project sources.

Table 3-1 Non-Default CALPUFF Options

MREG	Check for regulatory default options	1	0	MREG=1 performs checks to ensure that the regulatory default methods are used. Some regulatory defaults are not appropriate for over water applications, as discussed in the options above. Therefore, MREG was set not to perform any regulatory checks.
Group 3				
CSPEC	Modeled chemical species	No Default	SO_2, SO_4,NO_x, HNO_3, NO_3, PM, and CO	SO_2, SO_4, NO_x, PM, and CO are directly emitted by sources, other modeled species are formed in the atmosphere. Near-field concentrations of SO_2, NO_x, PM, and CO were predicted with CALPUFF.
Group 4				
PMAP	Map projection	UTM	LCC	Project used Lambert Conformal Conic projection for consistency with the MM5 input data.
RLAT0	Latitude of projection origin	No Default	59.0N	Consistent with the MM5 projection datum.
RLON0	Longitude of projection origin	No Default	151.0W	Consistent with the MM5 projection datum.
XLAT1	Matching parallel(s) of latitude for projection	No Default	0N	Consistent with the MM5 projection datum.
XLAT2	Matching parallel(s) of latitude for projection	No Default	60N	Consistent with the MM5 projection datum.
DATUM	Datum-region for output coordinates	WGS-84	NWS-84	Consistent with MM5 projection datum.
NX	No. X grid cells	No Default	17	Grid extends 765 km in the east-west direction.
NY	No. Y grid cells	No Default	16	Grid extends 720 km in the north-south direction.
NZ	No. vertical layers	No Default	20	Retains the most lower level layers from MM5 simulation, while collapsing the upper layers at levels consistent with the USEPA guidance.

Table 3-1 Non-Default CALPUFF Options

DGRIDKM	Grid spacing (km)	No Default	45	Grid spacing is consistent with the MM5 simulation.
ZFACE	Cell face heights	No Default	0., 20., 61.4, 130. 9333, 193.1573, 303.0089, 398.1591, 534.5606, 656.5210, 821.5480, 980.9698, 1177.538, 1378.198, 1610.2, 1866.511, 2139.463, 2440.214, 2750.899, 3093.375, 3427.017, 3795.959	Values are from the MM5 simulation, with layer collapsing of the upper-level layers. Maximum height is less than 4,000m, based on USEPA guidance.
XORIGKM	Reference Coordinates of SOUTHWEST corner of grid cell (1, 1), km	No Default	-990	Based on the grid extent.
YORIGKM	Reference Coordinates of SOUTHWEST corner of grid cell (1, 1), km	No Default	1102.5	Based on the grid extent.
IBCOMP	X index of LL corner; computational grid	No Default	1	Based on the grid extent.
JBCOMP	Y index of LL corner; computational grid	No Default	1	Based on the grid extent.
IECOMP	X index of UR corner; computational grid	No Default	17	Based on the grid extent.
JECOMP	Y index of UR corner; computational grid	No Default	16	Based on the grid extent.
LSAMP	Logical flag indicating if gridded receptors are used	T	F	Use receptor locations consistent with OCD permit application. No gridded receptors are used for CALPUFF modeling.

Table 3-1 Non-Default CALPUFF Options

Group 5				
IDRY	Create dry flux file	1	0	File is not required since dry deposition calculations were not performed.
IWET	Create wet flux file	1	0	File is not required since wet deposition calculations were not performed.
IVIS	Create RH file for visibility processing	1	0	File is not required since visibility calculations were not performed.
IPRTU	Print output units (1 – g/m**3; g/m**2/s)	1	3	Output in units of micrograms.
Group 7				
Dry Gas Deposition	Chemical parameters of gaseous deposition species	User Defined	SO_2=0.1509, 1000, 8, 0, 0.04 NO_2=0.1656, 1, 8, 5, 3.5 HNO_3=0.1628, 1, 18, 0, 8 E-8	Default values provided in CALPUFF user's guide.
Group 8				
Dry Particulate Deposition	Size parameters of particulate deposition species	User Defined	SO_4: 0.48, 2 NO_3: 0.48, 2 PM: 0.48, 2	CALPUFF user's guide referenced values for SO_4 and NO_3. Used the same size parameters for PM to represent settling of fine particles.
Group 10				
Wet Deposition	Wet deposition parameters	User Defined	Table 2-10 CALPUFF user's guide	PM and CO were not modeled with removal by precipitation scavenging (i.e., wet deposition).
Group 11				
MOZ	Ozone data source	1	0	Default is to provide concurrent hourly ozone data measured at stations throughout the modeling domain. No such data exists in the model domain.

Table 3-1 Non-Default CALPUFF Options

BCKO3	Monthly ozone value (ppb)	80	37., 41., 35., 40., 41., 23., 21., 24., 31., 32., 34., 34.	Representative monthly varying ozone data were derived from hourly ozone measurements collected at Wainwright, AK from Nov. 2008-Nov. 2009. The 90th percentile of hourly ozone values were calculated for each month.
Group 13				
FMFAC	FMFAC is a source-specific vertical momentum flux factor (0. or 1.0) used to represent the effect of rain-caps or other physical configurations that reduce momentum rise associated with the actual exit velocity.	1.0	Source-specific	FMFAC=0 for horizontal stacks and =1.0 for vertical stacks.
ZPLTFM	ZPLTFM is the platform height (m) for sources influenced by an isolated structure that has a significant open area between the surface and the bulk of the structure, such as an offshore oil platform. ZPLTFM is used only with MBDW=1 (ISC downwash method) for sources with building downwash.	0.0	Source-specific	ZPLTFM=12.5 (meters) was used for the sources located on the drill rig platform.

3.2 Emissions Source Characterization

In general, the emissions sources were modeled identically to how the sources are characterized and described in Appendix G of the CP Chukchi AQIA. However, the CALPUFF model has different input data requirements than OCD, in some cases. Relevant differences are described below:

- For CALPUFF modeling, coordinates of the point sources were converted from the Universal Transverse Mercator (UTM), used in OCD modeling, to Lambert Conformal Conic (LCC) projection utilizing ArcMap GIS software. The LCC was identical to the projection used in the MM5 dataset.

- The EPA Building Profile Input Program (BPIP) was run for each point source, including the Project and Shell source, to generate building downwash input to CALPUFF. Lakes Environmental software was used to digitize the rig and ship structures and run BPIP program.

- A platform height (ZPLATFM) of 12.5 meters was used for the sources located on the drill rig platform. CALPUFF uses the platform height is in the downwash algorithm for sources influenced by an isolated structure that has a significant open area between the surface and the bulk of the structure.

- Unlike the OCD model, in CALPUFF, a stack height is the release above the base elevation (zero for the ocean) and not above the rig platform. Therefore, stack height of the sources located on the platform was calculated to be equal to the actual stack height plus the platform height of 12.5 meters.OCD model allows a user to specify stack angle to define vertical or horizontal releases. In CALPUFF, horizontal releases are modeled by suppressing a vertical momentum flux with the FMFAC switch. The vertical momentum can be either 1, for a full momentum, or 0, for no momentum used.

4.0 CALPUFF Modeling Results

Results of the modeling analysis conducted for the jack-up drill rig impact analysis are summarized in **Table 4-1** which lists all modeled concentrations.

A digital record containing model input output files will be transmitted electronically separate from this document. A README file describing the contents of the digital record will be transmitted with it.

Table 4-1 Model Predicted Ambient Air Quality Impacts

Pollutant	Averaging Period	Maximum Model Predicted Concentration ($\mu g/m^3$)
CO	1-hour	577
	8-hour	357
NO_2 [1]	Annual	2
PM_{10}	24-hour	20
$PM_{2.5}$	24-hour	20
	Annual	0.3
SO_2	3-hour	5
	24-hour	2
	Annual	0.02

[1] Includes 75% ARM NO_x to NO_2 conversion.

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Appendix A

Documentation of The Mesoscale Model Interface (MMIF) Program

Order of Appendix:

1.0 Draft User's Manual The Mesoscale Model Interface (MMIF) Program, Version 1.0

Draft User's Manual

THE MESOSCALE MODEL INTERFACE PROGRAM (MMIF) Version 1.0

EPA Contract No. EP-D-07-102
Work Assignment 2-06

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11 June 2009

1. INTRODUCTION

The Mesoscale Model Interface Program (MMIF) converts prognostic meteorological model output fields to the parameters and formats required for direct input into the CALPUFF dispersion model. The processor is intended to be an alternative to CALMET in generating three-dimensional meteorological input fields for long-range transport assessments in support of regulatory air quality impact analyses. Processing data directly from the prognostic meteorological models into a CALPUFF-ready form will bring a much higher level of consistency to the review process and will allow the use of specific or specialized meteorological simulations without additional modification or additional performance evaluation.

MMIF specifically processes geophysical and meteorological output fields developed by the Fifth Generation Mesoscale Model (MM5, version 3) and the Weather Research and Forecasting (WRF) model (Advanced Research WRF [ARW] core, versions 2 and 3). The program diagnoses certain CALPUFF-required parameters that are not directly available from MM5 or WRF. It also offers the option to directly pass through planetary boundary layer (PBL) heights from the meteorological models, or to independently diagnose them from other variables. The program does not generate any cloud information, nor does it perform interpolation to different map projections or grid resolutions (all gridded fields remain on the same projection and resolution as the meteorological model). However, it can produce CALPUFF inputs for any sub-domain of the meteorological modeling grids. All program code is well organized and documented, and able to compile and run on both Windows and Unix/Linux platforms.

This user's manual documents MMIF v1.0 and includes descriptions of the algorithms, the program code, user input, and runtime instructions. The remainder of this section provides background information. The initial development of MMIF was sponsored by the U.S. Environmental Protection Agency (EPA), Office of Air Quality Planning and Standards (OAQPS), under Contract EP-D-7-102, Work Assignment 2-06.

1.1 BACKGROUND

The idea for a direct CALPUFF meteorological pre-processor in the style of EPA's Models-3 Meteorology-Chemistry Interface Processor (MCIP) was first discussed as a potential option for the CALPUFF system at EPA's 8th Conference on Air Quality Modeling in September 2005 (Anderson, 2008). CALMET has long supported the use of raw output data from MM5 and other prognostic meteorological models to define background or first-guess fields, and this capability has proven to be particularly useful in data-sparse areas. A direct interface processor, on the other hand, offers the advantage of minimizing the manipulation of prognostic meteorological data before input to CALPUFF. Prognostic meteorological model output quality has advanced in recent years and many users find it preferable to use the data without further manipulation for downstream air quality modeling applications.

The EPA/OAQPS, along with several EPA regional offices and Federal Land Management (FLM) agencies, have sponsored the development of MMIF for regulatory applications as an alternative to CALMET. Such a tool brings a much higher level of consistency to the review process, and it is recognized that many other organizations and projects could benefit from the use of a single-purpose direct converter, since many modelers often rely on CALMET to simply pass MM5 meteorological fields through to CALPUFF in the "NOOBS" mode.

The EPA recently developed a prototype meteorological re-reformatting tool (Anderson, 2008) designed to process MM5 data directly to CALPUFF input formats. The prototype was based on a combination of ENVIRON's MM5CAMx converter and EPA's MCIP. ENVIRON was tasked by EPA/OAQPS to thoroughly review, update, and test the prototype to ensure it is bug-free and of sufficient quality for regulatory review and public distribution. The code update included an entire re-write in Fortran 90 employing dynamic memory allocation to maximize code portability, efficiency and ease of use. The update also expanded the capabilities of the processor to optionally process output fields from WRF/ARW versions 2 and 3. The code is organized within a highly modular structure, and in-code documentation was added to facilitate external review and future upgrades. The product of this work is MMIF version 1.0.

Limited preliminary testing of MMIF was conducted by ENVIRON using pre-existing MM5 and WRF datasets that were available in-house. Additional and more comprehensive testing will be conducted by EPA and various federal land management agencies as part of the regulatory review process.

2. FORMULATION

MMIF was developed from ENVIRON's MM5CAMx and EPA's MCIP meteorological interface software. Key features include:

- Applicability on either Linux/Unix or Windows platforms;
- A simple text-based user interface "control" file;
- Two options to determine Pasquill-Gifford (PG) stability class;
- Options to re-diagnose or pass through PBL depth;
- An option to generate output on a sub-set of the meteorological modeling grid;
- An optional mass-weighted vertical aggregation of multiple MM5/WRF layers.

The following variables are generated by MMIF and written to a CALMET.DAT file format:

<u>Time-invariant fields</u>

- 2-D surface roughness length, m (Z0);
- 2-D landuse code, dimensionless (ILANDU);
- 2-D topographic elevation, m (ELEV);
- 2-D leaf area index, dimensionless (XLAI).

<u>Time-variant fields</u>

- 3-D U-component (west-east) scalar wind, m/s (U-LEV);
- 3-D V-component (south-north) scalar wind, m/s (V-LEV);
- 3-D W-component (vertical) scalar wind, m/s (WFACE);
- 3-D temperature, K (T-LEV);
- 2-D PG stability, dimensionless (IPGT);
- 2-D surface friction velocity scale, m/s (USTAR);
- 2-D PBL depth, m (ZI);
- 2-D Monin-Obukhov length, m (EL);
- 2-D convective velocity scale, m/s (WSTAR);
- 2-D rainfall rate, mm/hr (RMM);
- 2-D surface temperature, K (TEMPK);
- 2-D density, kg/m^3 (RHO);
- 2-D surface solar flux, W/m^2 (QSW);
- 2-D relative humidity, % (IRH);
- 2-D precipitation code, dimensionless (IPCODE).

MMIF writes CALPUFF-ready input files equivalent to the CALMET "NOOBS" option (number of surface, upper air, and over-water sites are all zero) and to the CALGRID option (3-D gridded fields of wind components and temperature).

2.1 GRID STRUCTURE

MMIF generates gridded meteorological fields for CALPUFF on the same Lambert Conic Conformal (LCC) horizontal map projection and grid resolution as defined by the meteorological models; that is, no interpolation to a different projection or resolution is possible (horizontal winds are the only minor exception, as described below). MMIF does allow the user to define a sub-domain of the meteorological model grid on which to generate CALPUFF input fields. The interface program also allows the user to aggregate multiple vertical meteorological model layers to a subset of CALPUFF layers. It is not necessary to define a CALPUFF vertical layer structure that extends to the top of the meteorological model domain.

The horizontal grid structure of CALMET/CALPUFF is defined such that all variables are carried at grid cell center (Figure 2-1). Both MM5 and WRF carry the horizontal wind components (U and V) in a staggered arrangement relative to the state variables, referred to as "Arakawa B" and "Arakawa C" staggering, respectively. Therefore, the U and V wind components from the meteorological model are averaged to cell center within MMIF. For MM5 data, the four corner wind points are averaged with uniform weighting to cell center. For WRF data, the two U-face and two V-face winds are separately averaged with uniform weighting from their locations to cell center.

MMIF allows a CALPUFF sub-domain to be extracted from the full MM5 or WRF grid. Figure 2-2 illustrates an example of the grid indexing convention used in both MM5 and WRF. The meteorological models index their grids according to the grid cell corners (MM5) or interfaces (WRF), which are noted by the external tick marks labeled 1 through 11 around the edge of the domain. These are the locations at which the wind components are carried by MM5 and WRF. The actual grid cells are indexed by the red values 1 through 10 (note that there is always 1 less grid cell than the number of interfaces/corners). When selecting a CALPUFF sub-domain in MMIF, the CALPUFF grid is defined by a range of grid cells (red values); in the example shown in Figure 2-2, the CALPUFF grid ranges from grid cell 4 through 7 in the x-direction, and from grid cell 3 through 7 in the y-direction. The southwest corner point coordinate used to geo-locate the CALPUFF grid is taken from the respective MM5/WRF corner point, which is at (4,3) in Figure 2-2.

In the vertical, all CALPUFF variables are carried at layer center (between the vertical levels defined by the ZFACE variable) except for vertical velocity, which is carried at the layer interfaces (i.e. at the ZFACE levels). The vertical arrangement in MM5 and WRF is similar to CALMET/CALPUFF (Figure 2-3). The horizontal wind and temperature variables are averaged to a subset of layers defined by the user; this averaging is performed on a mass-weighted basis (using the MM5 and WRF pressure coordinates). Vertical velocity, however, is directly set to the value of the MM5/WRF vertical velocity at corresponding levels with no weighting.

The meteorological models' vertical grid structure is based on a normalized pressure system, generally referred to as "sigma". While the sigma layer structure is constant, the corresponding layer heights vary in space according to underlying topographic elevation and surface pressure. Sigma layers expand and contract in height across valleys and ridges, respectively. Conversely, the layer structure in CALPUFF is defined to be a single static vertical height profile above terrain (referred to as "ZFACE"). In the case of MM5, the ZFACE heights are defined from a conversion of the sigma coordinate assuming a 1000 mb surface pressure, and using standard temperature/pressure lapse rates provided in the MM5 output file. In the case of WRF, the sigma

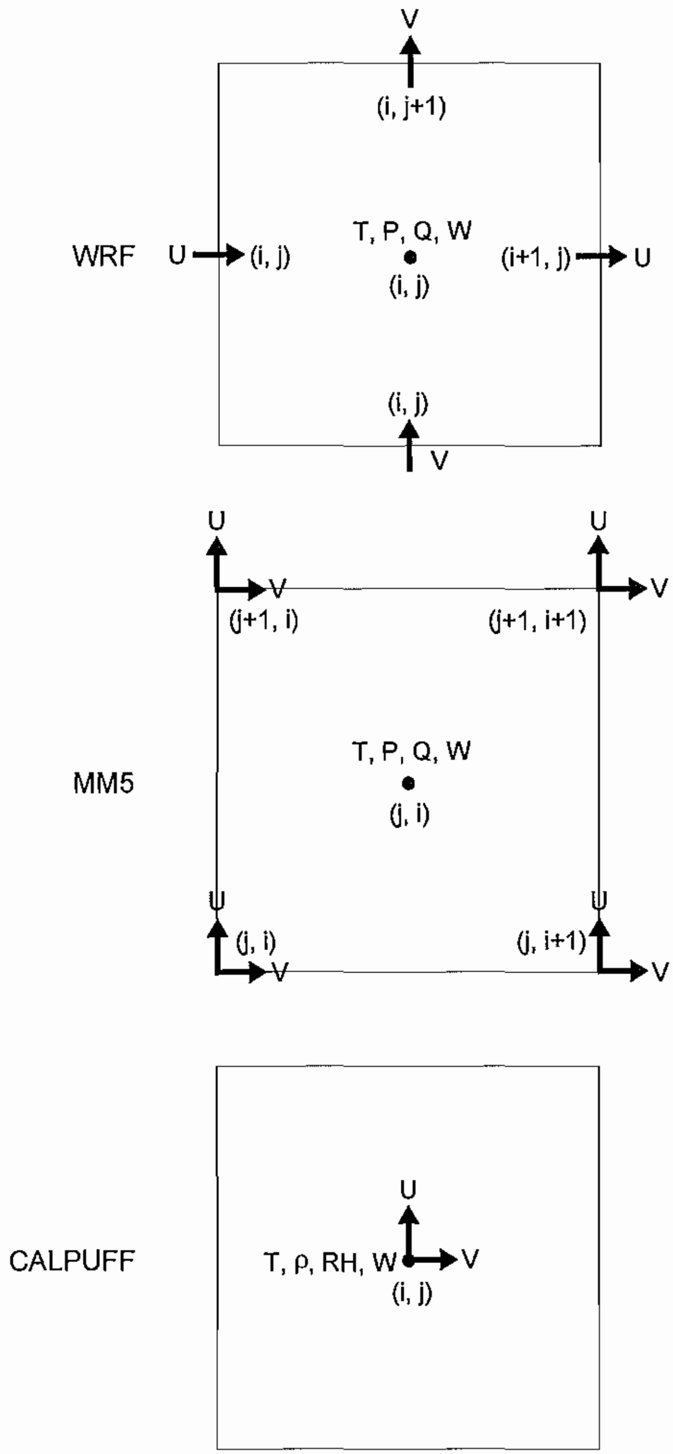

Figure 2-1. Horizontal grid cell arrangements for wind (U, V, W) and state (T, P, Q, ρ, RH) variables among the three models addressed by MMIF.

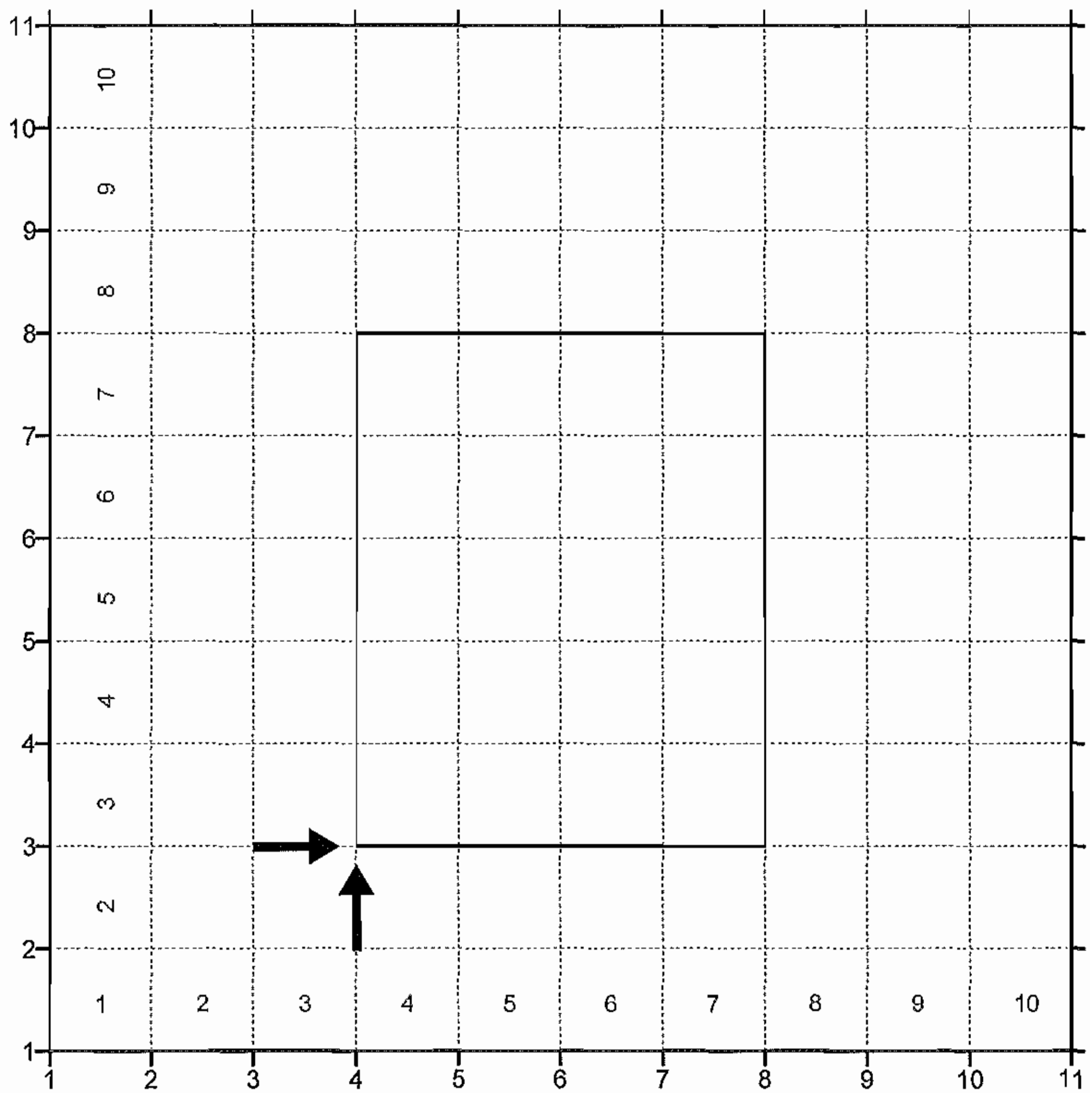

Figure 2-2. An example illustration of a full MM5/WRF grid (outer grid with 11x11 grid points and 10x10 grid cells) and a CALPUFF sub-domain (inner grid with 4x5 grid cells). The CALPUFF sub-domain is defined as ranging from grid cells 4 through 7 in the x-direction, and grid cells 3 through 7 in the y-direction. The arrows point to the southwest corner point of the CALPUFF grid, which defines its reference coordinate location.

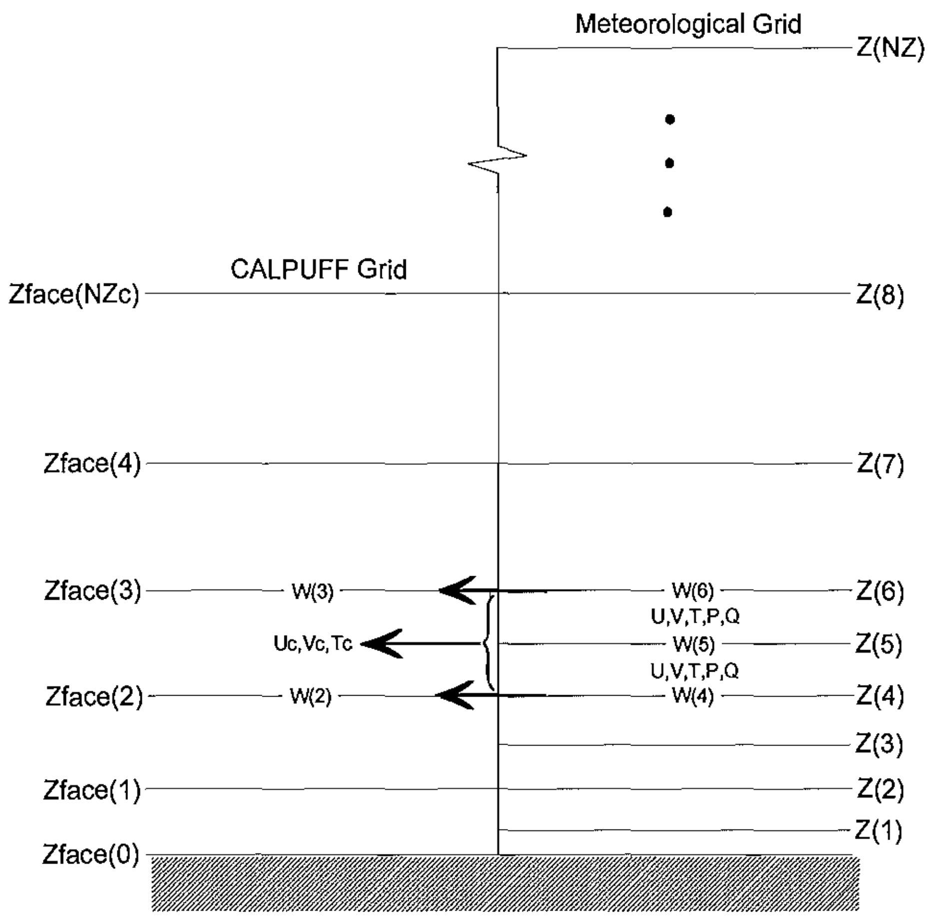

Figure 2-3. Vertical layer structure arrangements for the meteorological model (right) and CALPUFF (left). Vertical velocities (W) are at located at layer interfaces and are assigned in CALPUFF from the meteorological model; CALPUFF horizontal winds (Uc,Vc) and temperature (Tc) are averaged from the meteorological layers (U,V,T) in a mass-weighted manner using pressure (P).

coordinate is converted to a spatially-variant height coordinate for all grid columns across the input domain, which is then averaged over the domain to define a single ZFACE height profile.

CALPUFF assumes that the first layer depth is 20 m, resulting in a 10 m layer midpoint that is consistent with the height at which most meteorological measurement probes are located. The meteorological model grid structure will usually not match this constraint. Therefore, MMIF generates a 20 m first layer, using 10 m winds output by the meteorological model (if available, or by diagnosing them) as well as 10 m temperature using surface similarity theory. This will usually lead to inconsistencies in the definition of the depth of layer 2 between CALPUFF and the meteorological models. Four different cases have been identified in which layer 2 winds and temperature and level 1 vertical velocity must be re-diagnosed using interpolation:

1. ZFACE(1) < 19 m, ZFACE(2) < 39 m
   Layer indices 3 through NZc are shifted down, thereby removing one layer;
   ZFACE(1) is reset to 20 m;
   Layer 2 winds and temperature are interpolated from original layers 2 and 3;
   Level 1 vertical velocity is interpolated from original levels 1 and 2.
2. ZFACE(1) < 19 m, ZFACE(2) ≥ 39 m
   Layer indices 2 through NZc remain the same;
   ZFACE(1) is reset to 20 m;
   Layer 2 winds and temperature are interpolated from layers 2 and 3;
   Level 1 vertical velocity is interpolated from levels 1 and 2.
3. 19 m ≤ ZFACE(1) < 39 m
   Layer indices 2 through NZc remain the same;
   ZFACE(1) is reset to 20 m;
   Layer 2 winds and temperature are interpolated from layers 1 and 2;
   Level 1 vertical velocity is interpolated between level 1 and the ground.
4. ZFACE(1) ≥ 39 m
   Layer indices 1 through NZc are shifted up, thereby adding one layer;
   ZFACE(1) is reset to 20 m;
   Layer 2 winds and temperature are interpolated from original layers 1 and 2;
   Level 1 vertical velocity is interpolated between original level 1 and the ground.

Figure 2-4 depicts these cases schematically.

2.2 SURFACE CHARACTERISTICS

MMIF generates static two-dimensional surface fields of roughness, landuse code, topographic elevation and leaf area index (LAI). All but LAI and WRF surface roughness are directly read from meteorological model output files and passed through to CALPUFF. MMIF assumes that MM5 and WRF were run using the standard 24-category U.S. Geological Survey (USGS) landuse/landcover dataset. If any other dataset is diagnosed from the meteorological output files, MMIF will stop with an error. The over-water landuse codes are set to "16", consistent with this USGS categorization.

The LAI and WRF surface roughness is diagnosed from the 24-cateogory landuse code according to the methodology developed by U.S. Forest Service (USFS) for use in the BlueSky/RAINS modeling system (MM52GEO program). This methodology assigns seasonally

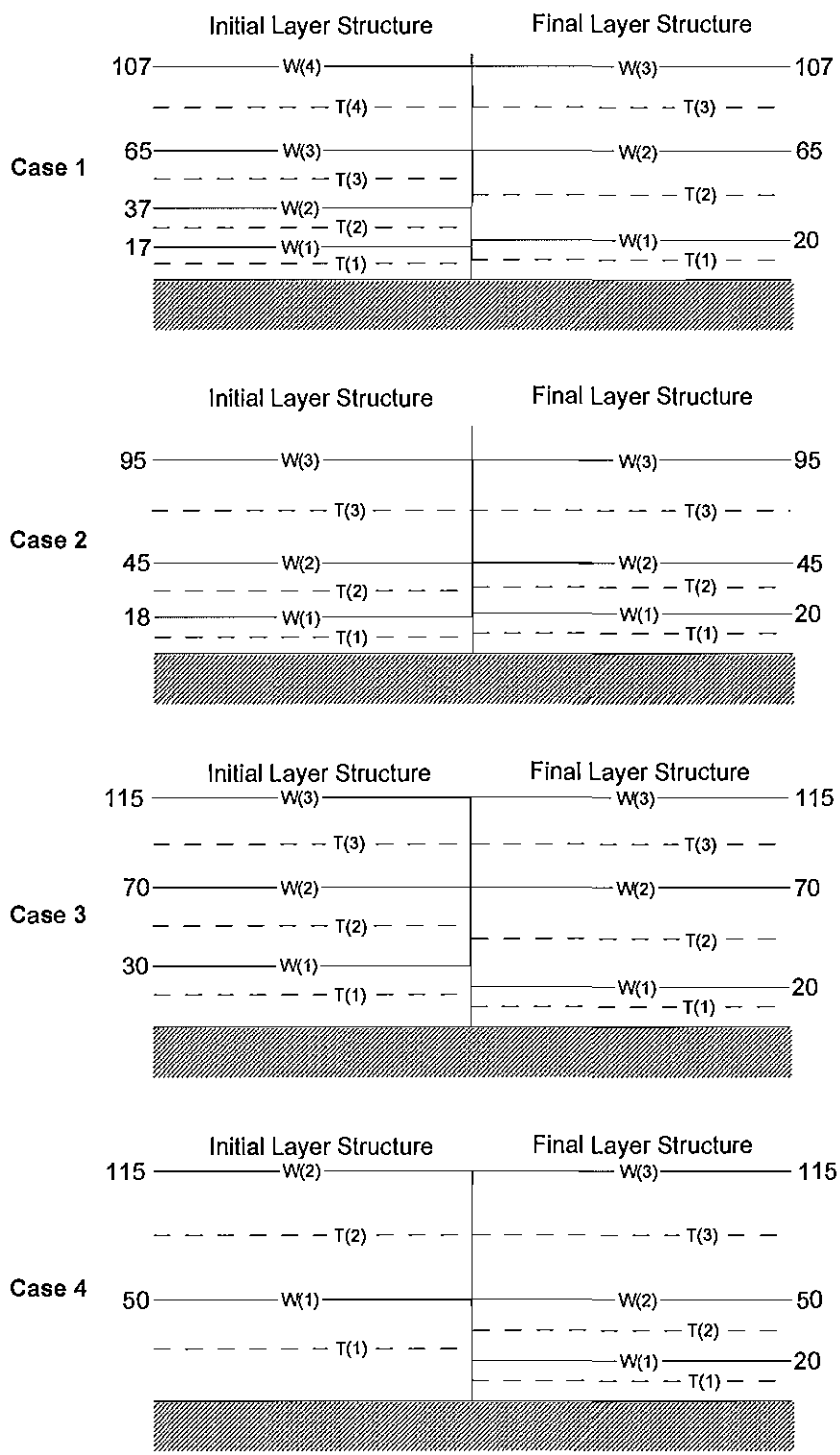

Figure 2-4. Schematic examples of the approach to introduce a 20-m deep first layer for CALPUFF from the MM5 layer structure. The four cases are described in the text: **[1]** ZFACE(1) < 19 m, ZFACE(2) < 39 m; **[2]** ZFACE(1) < 19 m, ZFACE(2) ≥ 39 m; **[3]** 19 m ≤ ZFACE(1) < 39 m; and **[4]** ZFACE(1) ≥ 39 m. Locations of vertical velocity (W) and temperature (T) are shown in each case.

dependent (winter/summer) albedo, Bowen ratio, soil heat flux, anthropogenic heat flux, LAI and surface roughness to each of the 24 landuse categories (Table 2-1). The summer season is defined to run from Julian date 105 to Julian date 287 (April 15 to October 14, respectively, for non-leap years).

Table 2-1. Surface characteristics assigned to USGS 24-category landuse/landcover in the USFS BlueSky/RAINS MM52GEO program.

	Albedo (%)		Bown Ratio		Soil Heat Flux (W/m^2)		LAI		Surface Roughness (cm)	
Landuse	**Summer**	**Winter**	**Summer**	**Winter**	**Summer**	**Winter**	**Summer**	**Winter**	**Summer**	**Winter**
Urban	18	18	1.5	1.5	0.25	0.25	1.5	1	50	50
Dryland crop/pasture	17	23	1.0	1.0	0.15	0.15	0	0	15	5
Irrigated crop/pasture	18	23	1.0	1.0	0.15	0.15	1	0	15	5
Mixed crop/pasture	18	23	1.0	1.0	0.15	0.15	0.5	0	15	5
Crop/grass mosaic	18	23	1.0	1.0	0.15	0.15	0	0	14	5
Crop/woodland mosaic	16	20	1.0	1.0	0.15	0.15	3	0.5	20	20
Grassland	19	23	1.0	1.0	0.15	0.15	0	0	12	10
Shrubland	22	25	1.0	1.0	0.15	0.15	2	0.5	10	10
Mix shrub/grass	20	24	1.0	1.0	0.15	0.15	1	0.25	11	10
Savanna	20	20	1.0	1.0	0.15	0.15	2	0.5	15	15
Deciduous broadleaf	16	17	1.0	1.0	0.15	0.15	6	0	50	50
Deciduous needle	14	15	1.0	1.0	0.15	0.15	5	0	50	50
Evergreen broadleaf	12	12	1.0	1.0	0.15	0.15	5	5	50	50
Evergreen needle	12	12	1.0	1.0	0.15	0.15	8	7	50	50
Mixed forest	13	14	0.5	0.5	0.25	0.25	4	2	50	50
Water bodies	8	8	0	0	1.00	1.00	0	0	1	1
Herbaceous wetland	14	14	0.5	0.5	0.25	0.25	2	1	20	20
Wooden wetland	14	14	0.5	0.5	0.25	0.25	5	3	40	40
Barren sparsely vegetated	25	25	1.0	1.0	0.15	0.15	0	0	10	10
Herbaceous tundra	15	60	0.5	0.5	0.15	0.15	1	0	10	10
Wooded tundra	15	50	0.5	0.5	0.15	0.15	1	0	30	30
Mixed tundra	15	55	0.5	0.5	0.15	0.15	1	0	15	15
Barren tundra	25	70	0.5	0.5	0.15	0.15	0	0	10	5
Snow/ice	55	70	0.5	0.5	0.15	0.15	0	0	5	5

2.3 PBL PARAMETERS

MMIF reads certain PBL and surface similarity parameters from the meteorological model output files, including PBL depth, friction velocity (U*), ground temperature, and 10-meter wind components (if available). Using these data as well as surface roughness (z0) and layer 1 gridded winds, temperature, pressure, and humidity, MMIF calculates two-dimensional surface fields of air density, relative humidity (RH), 10-meter temperature, Monin-Obukhov length (L) and convective velocity scale (W*). MMIF will also diagnose 10-meter wind components if not available from the meteorological model files. Finally, the program will optionally re-diagnose PBL depths according to a user input flag.

The calculation of surface similarity variables L and W* are determined from the Richardson-number based methodology of Louis (1979). These values together with U* and z0 are then applied in a standard surface-layer scaling algorithm to derive 10-meter wind and temperature from input layer 1 winds and temperature in each grid cell.

The optional re-diagnosis of PBL depth is determined from the bulk Richardson approach of Vogelezang and Holtslag (1996) using the Louis (1979) surface parameters determined above. The re-diagnosis also incorporates the methodology of Gryning and Batchvarova (2003), which varies critical Richardson number for over-water PBL heights. Experiments have shown that a critical Richardson of 0.05 for over-water PBL heights yielded better agreement when using the Vogelezang and Holtslag bulk Richardson method.

2.4 DIAGNOSIS OF STABILITY CLASS

The Phase II guidance (EPA, 1998) from the Interagency Workgroup on Air Quality Modeling (IWAQM) recommends the use of PG stability class in CALPUFF long range transport analyses. The EPA Model Clearinghouse reaffirmed this approach in early 2006 (EPA, 2006). Hence, the FLMs typically will not accept turbulence-based dispersion modeling for long range transport analyses at Class I receptor locations. Furthermore, a number of algorithms inside CALPUFF (such as puff splitting and chemistry) are dependent upon PG stability class even if turbulence-based dispersion is selected. It is therefore necessary that MMIF constructs gridded PG fields from available MM5 data fields.

CALMET calculates PG stability class based on the Turner (1970) method. CALMET supports two different methods for calculating PG class:

1. Observation-based (ceiling height and cloud cover from standard surface data);
2. "NOOBS" method (ceiling height and cloud cover derived from MM5 hydrometeors)

Note that the "NOOBS" method introduced by Robe (Earth Tech, 2001) constructs PG from MM5-estimated ceiling heights and diagnostic cloud cover.

Two options are available in MMIF for calculating PG stability class; they both differ from the CALMET approach in that they do not rely on the diagnosis of cloud cover and ceiling height:

1. SRDT method
   - PG is based upon the wind speed, solar radiation, and the "Delta-T" (SRDT) method published in Supplement C to the Guideline on Air Quality Models (EPA, 1993).
   - Daytime stability is derived from the Turner method using 10-meter wind speed and solar radiation to estimate an insolation class. Nighttime stability is derived from the sign of the temperature difference between 10 meter and surface temperature.
   - The code was implemented directly from the Meteorological Processor for Regulatory Models (MPRM).

2. Golder (1972) method
   - PG is based upon relationships among Monin-Obukhov lengths and surface ronghness.
   - The code was implemented from the AERMOD LTOPG subroutine.

Table 2-2 displays PG stability in option 1 according to wind speed, insolation class, and temperature difference. Insolation is taken from the gridded downward solar radiation output by the meteorological models. The advantage of this approach is that the modeled solar radiation includes attenuation from modeled cloud cover, eliminating the need to indirectly derive cloud cover from gridded hydrometeor data. The nighttime stability (Delta-T method) is activated when insolation equals zero.

Table 2-2. PG stability class according to surface wind speed (S, m/s), daytime solar radiation (R, W/m^2), and nighttime vertical temperature gradient (DeltaT) in the SRDT algorithm. Stability ranges from very un-stable (1) to very stable (6).

		Windspeed Category					
		$0 \geq S > 2$	$2 \geq S > 2.5$	$2.5 \geq S > 3$	$3 \geq S > 5$	$5 \geq S > 6$	$S \geq 6$
Day	$R \geq 925$	1	1	1	2	3	3
	$675 \geq R > 925$	1	2	2	2	3	4
	$175 \geq R > 675$	2	3	3	3	4	4
	$0 \geq R > 175$	4	4	4	4	4	4
Night	DeltaT < 0	5	4	4	4	4	4
	DeltaT ≥ 0	6	5	4	4	4	4

3. CODE STRUCTURE AND COMPILATION

MMIF is written in Fortran90 (F90) and consists of a main driving program and several subroutines and F90 modules that are all separated into individual files. The program is highly modular to allow for easy addition or substitution of alternate routines in the future. All code is well documented to include such information about the tasks performed and a history of modifications. All of the program's global data structures are dynamically allocated during program startup according to the dimensions of the meteorological models' grid definition. This alleviates the need to customize and re-compile the program for a particular application.

The program code is arranged in the following file structure:

`MMIF.f90`	Main driving routine
`command_line.F90`	Reads the command line (get the control filename)
`geodat.f90`	Surface characteristics routine (from USFS MM52GEO program)
`lcpgeo.f90`	LCC-to-lat/lon coordinate converter
`ltopg.f90`	PG stability class (from AERMOD LTOPG routine)
`met_fields.f90`	F90 module defining and allocating global variable arrays
`pblmet.f90`	Surface layer similarity and PBL re-diagnostic routine
`pgstb.f90`	SRDT PG stability class (from MPRM)
`read_mm5.f90`	Reading routine for MM5 output data
`read_wrf.f90`	Reading routine for WRF output data
`timesubs.f90`	Group of date/time manipulation routines
`vertmap.f90`	Vertical aggregation routine
`wrf_netcdf.f90`	F90 module containing NetCDF I/O routines
`write_header.f90`	CALMET header writing routine
`write_hour.f90`	CALMET hourly data writing routine

Only one file, `command_line.F90`, requires passing through the FORTRAN pre-processor. This allows a single code to support multiple platforms using conditional compilation and "-D" macros.

3.1 COMPILING MMIF ON WINDOWS

The code includes a batch file named "`compile.bat`", which can be used to compile the program on Windows using Intel FORTRAN (ifort). MMIF has been tested with ifort version 11.073 on Windows XP.

Compiling the source code and running the executable requires access to the NetCDF libraries, regardless of whether MM5 or WRF output data are to be processed. The files "`netcdf.inc`", "`netcdf.lib`" and "`netcdf.dll`" from NetCDF version 3.6.1 are included, and were obtained from the Unidata website[1]. The files "`netcdf.inc`" and "`netcdf.lib`" should be placed in the same directory as the FORTRAN files for compilation, and the file "`netcdf.dll`" must be placed in the same directory as the resulting executable. On many

[1] ftp://ftp.unidata.ucar.edu/pub/netcdf/contrib/win32/netcdf-ifort-3.6.1.zip

Windows systems, it can also be placed in "`C:\WINDOWS\System32\`" to make it globally available.

MMIF is compiled by either double-clicking `compile.bat` in Windows Explorer; or by opening a Command Prompt (DOS box), changing to the appropriate directory, and typing "`compile.bat`" at the prompt.

3.2 COMPILING MMIF ON LINUX/UNIX

The code includes a "`makefile`" to facilitate compilation of the program on Linux/Unix platforms. The makefile will compile MMIF source code into an executable program and currently supports the Portland Group F90 compiler (pgf90), the Intel FORTRAN compiler (ifort), and the Gnu FORTRAN compiler (gfortran).

The user may edit the makefile, un-commenting the `$FC` and `$FFLAGS` variables for the desired compiler, and commenting out the blocks for the other compilers.

Compiling the source code requires access to NetCDF libraries, regardless of whether MM5 or WRF output data are to be processed. The NetCDF libraries should be obtained from http://www.unidata.ucar.edu/software/netcdf/ and installed on the computer on which MMIF is compiled. The user must alter the makefile variable `$NETCDF` for the specific path on their computer (often, but not always, the same as the environment variable `$NETCDFHOME`). This version of MMIF has been tested with NetCDF version 3.6.1.

MMIF is compiled by issuing the command "`make`" at a shell prompt within the main source directory. It will generate an executable program called "`MMIF`" that will reside in the source code directory.

3.3 A NOTE ON BINARY INPUT/OUTPUT FILES

MM5 output and CALPUFF input files are written as Fortran "unformatted" (binary) files. This means that the data are written directly to the output unit as represented in memory, without translation from binary to the ASCII character set. This reduces file volume and improves read/write speed. However, there are two ways to represent machine-level formats for storing binary information in memory: IEEE "big-endian" and "little-endian". The difference between these is essentially the order of the bits in a word, and which order is used depends on the computer platform and its operating system. The native format for many Unix workstations is big-endian, and this includes Sun, SGI, HP, and IBM. Exceptions are DEC and Linux/Windows PCs, which use little-endian by default.

WRF output files are written as NetCDF files, which are platform-independent. This means that the usual method of supplying the "`-convert big_endian`" (ifort) or "`-byteswapio`" (pgf90) compiler flags will not work, as it applies globally and only MM5 files (not WRF files) require this conversion. Fortunately, most modern compilers (pgf90, ifort, gfortran) now support the "`convert=big_endian`" option in the FORTRAN `open()` statement.

In general, MMIF can be run on machines that use either the big- or little-endian binary formats, as long as MM5 and CALPUFF are run on the same type of platform. If any component of the modeling system is run on a different platform using the opposite binary representation, I/O files will not be properly read and will likely lead to a program crash. A typical run-time error message from using the wrong binary format is “input record too long,” so if you get this error message, check for consistency between your binary files and compiler options.

The binary compatibility between Windows (ifort) and Linux (pgf90) has been verified. For example, PRTMET-compiled-on-Linux can read MMIF-compiled-on-Windows binary output, and vice-versa.

4. RUNNING MMIF

When executing, the MMIF program will by default open and read a control file named "MMIF.inp" that must exist in the current directory. If a filename is given on the command line, that file is read as the control file. The control file contains all of the user configuration options, flags, and pathnames to the meteorological output data files and the CALMET.DAT-formatted output file.

Run MMIF by typing its name at the command prompt, and optionally supplying a control file filename. Some examples from the DOS prompt are shown below (the first example reads "MMIF.inp"):

```
C:\Projects\MMIF\code>MMIF
C:\Projects\MMIF\test_mm5>..\code\MMIF test_mm5.inp
```

The user can also double-click the MMIF executable in the Windows Explorer, though the utility of this method is reduced when the Command Prompt automatically closes after the run has finished, before its contents can be viewed by the user.

Note that the file "netcdf.dll" must exist either in the same directory as the executable, or in a system-wide directory.

Useful information is printed to the screen during execution, including information on the horizontal and vertical extents of both the input (MM5/WRF) and output (CALMET.DAT-formatted) grids. Messages are printed as MM5/WRF files are opened and closed, and as time-stamps are written to the output file.

4.1 CONTROL FILE FORMAT

The MMIF control file has the following syntax:

```
MM5 or WRF?         |MM5
Start Extracting    |2006 05 29 01
Stop  Extracting    |2006 05 30 00
Output Time Zone    |-6
P-G Calc Method     |1
Re-calc PBL Depth?  |F
Min, Max PBL Depth  |50.0 3000.0
I-range to Extract  |0 0
J-range to Extract  |0 0
Num Output Layers   |21
Layer Mapping       |1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,19,21,23,25
Useful Info File    |test_mm5.info.txt
Output Filename     |test_mm5.met
Num MM5/WRF Files   |2
/dquad9c/aacog/mm5/2006mm5_4km.run4/2006-05-28/MMOUT_DOMAIN4_01
/dquad9c/aacog/mm5/2006mm5_4km.run4/2006-05-28/MMOUT_DOMAIN4_02
```

The first 20 characters of each record are reserved for a record description, with the exception of the MM5/WRF input file list (the last lines). Input data are supplied starting on column 21 in free format. The following describes each line of the control file.

`MM5 or WRF?`	Flag defining which meteorological model format to read.
`Start Extracting`	Date/hour to start processing (YYYY, MM, DD, HH). Note that CALPUFF labels the first hour of a day as hour 1, i.e. the hour starting at midnight and ending at 1:00 AM. Similarly, the last hour of a day is 0, the hour between 11:00 PM and midnight. Thus HH should be set to "1" if it is desired that 24-hour average concentrations should start at midnight.
`Stop Extracting`	Date/hour to stop processing (YYYY, MM, DD, HH). See note above; HH should be set to "0" for 24-hour averages to end at midnight.
`Output Time Zone`	Time zone shift from UTC (0=UTC, -5=EST, -6=CST, -7=MST, -8=PST) for model output. CALPUFF is run in local time, but MM5 and WRF use UTC. Note that CALPUFF v5.8 and earlier always assumes it is run in the Western hemisphere with a positive time zone shift. MMIF uses the actual time zone shift (negative for the Western hemisphere) to maximize global flexibility.
`P-G Calc Method`	1 = use the SRDT method, 2 = use the LTOPG method.
`Re-calc PBL Depth?`	F = pass through PBL depth from the meteorological model, T = re-diagnose PBL depth using a bulk Richardson method.
`Min, Max PBL Depth`	Similar to CALMET's `ZIMIN` and `ZIMAX` parameters, these limit the extremes of the planetary boundary layer depth, regardless of whether it is passed through or re-diagnosed.
`I-range to Extract`	Sub-domain to process in the I (west-east) direction, I_{MIN} to I_{MAX}. Set either value to ≤ 0 to use corresponding min/max of the input MM5/WRF domain.
`J-range to Extract`	Sub-domain to process in the J (south-north) direction, J_{MIN} to J_{MAX}. Set either value to ≤ 0 to use corresponding min/max of the input MM5/WRF domain.
`Num OUTPUT Layers`	Number of desired CALMET/CALPUFF layers (i.e. the number of elements in the following line).
`Layer Mapping`	Array of layer indices where CALPUFF layer interfaces match MM5 or WRF layer interfaces. Example: 1, 2, 3, 4, 5, 6, 7, 9, 12, 15, 18, 21 means CALPUFF layers 1-7 exactly match MM5 layers 1-7, CALPUFF layer 8 interface matches MM5 layer interface 9 (so MM5 layers 8 and 9 are collapsed to CALPUFF layer 8), CALPUFF layer 9 interface matches MM5 layer interface 12 (so MM5 layers 10, 11, and 12 are collapsed to CALPUFF layer 9), etc. See Section 2.1 for details.

`Useful Info File`	Optional output text file containing some variables that CALPUFF will require in its control file (e.g. RLAT0, DATUM, NX,NY,NZ, ZFACE, etc.). Enter "none" to suppress output.
`Output Filename`	Name of the CALMET.DAT-formatted output path/file.
`Num MM5/WRF Files`	Number of MM5 or WRF files to process (i.e. the number of path/filenames to follow).

This is followed by the same number of lines providing the raw meteorological model output path/file names, without the 20 leading blank spaces. Any time-stamps found in MM5/WRF files that are before the requested "start extracting" time-stamp are skipped. If MMIF encounters an MM5/WRF file with time-stamps that have already been processed, those time-stamps are skipped (except for precipitation processing, see next section). This allows consecutive MM5/WRF files to include some hours of overlap, a common practice.

4.2 A NOTE ON PRECIPITATION PROCESSING

Both MM5 and WRF save a field representing the accumulated precipitation (mm) since the beginning of the simulation. At each grid point, this value only grows with each time step. However, CALPUFF requires the hourly precipitation rate (mm/hr) at each grid point. The MMIF program converts accumulated precipitation to hourly precipitation rate automatically, by subtracting the last hour's field from the current hour's field, point by point. This requires the user to pay special attention to the first hour of each MM5/WRF run that is to be processed.

If the first hour to be processed by MMIF is also the first hour of an MM5 or WRF simulation, then the accumulated precipitation and the hourly precipitation rate are the same, and the program writes these values to the output file. However, it is common practice to allow for some "spin-up" time when running MM5 or WRF and often these first hours of the simulation are written to separate output files and ignored. If, for example, the first MM5/WRF file given in the `MMIF.INP` file starts at the 12th hour of a run, and that hour corresponds to the "`Start Extracting`" time-stamp, then MMIF cannot subtract the precipitation field from the 11th hour. In these cases, MMIF sets the initial precipitation field to zero everywhere.

For "spin-up" cases, it is therefore important to supply MMIF with at least one hour of MM5/WRF data from *before* the "`Start Extracting`" time-stamp, so that MMIF can subtract that hour's precipitation field from the first requested output hour's precipitation field. This is true both for the very first hour to be processed, as well as for the first hour of each subsequent MM5/WRF run to be processed. The former case is reasonably obvious, but the latter case is perhaps not as obvious. Consider the following example:

A user has an annual MM5 simulation for 2005 that was run as a series of 5-day runs with 12 hours of overlapping spin-up each, as is common practice. The first MM5 run starts at 2004-12-31_12 (YYYY-MM-DD_HH), the second run at 2005-01-04_12, and so on. Each hour's model output is written to a separate file. For simplicity's sake, let's assume the filenames have already been converted to LST during post-processing, so we can ignore the UTC-LST time shift. Because the user intends to ignore the first 12 hours of each run to allow for model spin-up, he enters the following filenames into the MMIF.INP file:

```
Input MM5 or WRF    |mm5
Start Extracting    |2005 01 01 01
[...]
C:\mm5\2004-12-31\mmout_d1.2005-01-01_01
C:\mm5\2004-12-31\mmout_d1.2005-01-01_02
C:\mm5\2004-12-31\mmout_d1.2005-01-01_03
[...]
C:\mm5\2004-12-31\mmout_d1.2005-01-04_00
C:\mm5\2005-01-04\mmout_d1.2005-01-04_01
C:\mm5\2005-01-04\mmout_d1.2005-01-04_02
C:\mm5\2005-01-04\mmout_d1.2005-01-04_03
[...]
```

This file list will cause MMIF to set the entire precipitation field to zero for the first output hour (2005-01-01_01), because it does not have access to the previous hour's precipitation field. The solution is to include the file

```
C:\mm5\2004-12-31\mmout_d1.2005-01-01_00
```

as the first MM5 file listed in the control file.

A second, more subtle problem occurs at hour 1:00 on 2005-01-04, when we switch from one MM5 run to the next. MMIF will subtract the precipitation field found in `2004-12-31\mmout_d1.2005-01-04_00` from the precipitation field in `2005-01-04\mmout_d1.2005-01-04_01`. Because MM5 is imperfect, it is unlikely that frontal systems and rain bands will be perfectly aligned from run to run. This may result in negative precipitation rates at some grid points, when MMIF subtracts the one from the other. The solution is to include one hour's data from *before* the end of the spin-up period of *each* run. The correct set of files to include in the MMIF.INP file for this example is:

```
Input MM5 or WRF    |mm5
Start Extracting    |2005 01 01 01
[...]
C:\mm5\2004-12-31\mmout_d1.2005-01-01_00
C:\mm5\2004-12-31\mmout_d1.2005-01-01_01
C:\mm5\2004-12-31\mmout_d1.2005-01-01_02
C:\mm5\2004-12-31\mmout_d1.2005-01-01_03
[...]
C:\mm5\2004-12-31\mmout_d1.2005-01-04_00
C:\mm5\2005-01-04\mmout_d1.2005-01-04_00
C:\mm5\2005-01-04\mmout_d1.2005-01-04_01
C:\mm5\2005-01-04\mmout_d1.2005-01-04_02
C:\mm5\2005-01-04\mmout_d1.2005-01-04_03
[...]
```

Note that `mmout_d1.2005-01-04_00` is included twice, once from each run. Even though MMIF *reads* the MM5 data for time-stamp 2005-01-04_00 twice, it only *writes* the data from the first file to the output. The data from the second file is read (but not written) and its precipitation field is stored, and subsequently subtracted when the next file containing a new time-stamp is read by the program.

If the user instead has MM5/WRF data files that contain more than one time-stamp of data, e.g. 24 hours per file, the same care must be taken to assure that the first output time-stamp of each run is not the first time-stamp from that run which MMIF has encountered. This is true for both MM5 files (which are read "linearly") and WRF files (which may be read "direct access"). Although WRF files are NetCDF files, for which it is possible to read only the desired data subset (i.e. read just one field from the *N*th time-stamp from the "middle" of a file), MMIF parses all the time-stamps in WRF files to assure the correct processing of precipitation.

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2.0 Project-Specific MMIF Code Modifications

Small modifications to the MMIF program code were required for this project. These modifications included:

- Acceptance of MM5 data run with the NOAH Land Surface Model rather than the standard land use categories from the US Geological Service (USGS);
- Changed the winter-time surface characteristics (albedo, Bowen ration, soil heat flux, and surface roughness) for the "water bodies" land use category to be appropriate for sea-ice conditions; and
- Changed the Julian day within MMIF that it is set to switch from winter to summer, such that the day is consistent with the date the MM5 data set turns sea ice physics off.

The MMIF program required that the 24-category land use system from the USGS be used. The MMIF code was modified to remove 24-category land use requirement and added error trapping in case a different land use was used. The original code halted MMIF program if MM5 header information indicated that a non-standard land use categorization was used (i.e. # of land use categories didn't equal 24).

The modified code checks the actual land use category number in every i, j cell in the MM5 data that is processed by MMIF. For a land use category that exceeds the value of 24, MMIF will stop executing and provide an error message. Note that this modification does not actually process additional/different land use categories, but MMIF will stop running when it encounters a land use category that is different from the USGS 24-category system.

Specific modifications included:

- Line numbers 198-203 of the original "read_mm5" subroutine were commented out.
- Added if loop between line numbers 349-350 of the original "read_mm5" subroutine to test for land use categories >24.
- Header of read_mm5 subroutine was modified to reflect changes to code.

The original MMIF code did not have surface characteristics that are consistent with sea-ice. This is problematic when using MM5 data that was initiated with sea ice in the winter because the resulting meteorological data file may have conditions that are not physically possible.

The MMIF code was modified to add winter time sea ice surface characteristics to be consistent with the MM5 data. Variables that were modified in the geodat subroutine are: albd(2,16)=70, sfz0(2,16)= 0.05, bowen(2,16)=0.5, and heatflux(2,16)=0.15. These new values are consistent with Table 2-1 for "snow/ice" in winter in MMIF User's Manual. Only sfz0 is used in data file resulting from MMIF. Additionally, the Julian date that distinguishes between summer and winter was also modified to be consistent with the dates where MM5 was initialized with sea ice coverage. Summer is now defined as the period from jday=151-286. The header of geodat was modified to indicate the changes that have been made.

3.0 Project-Specific MMIF Code Implementation

To describe the implementation of the MMIF program for this project, it is important to understand how the Alaska 2002 MM5 runs were set up and executed.

A 5 day run is initialized in MM5 and this run is split into 6 output files:

- _00 (single 12Z hour)
- _01 (24-hours from 13Z of initial date +24hours)
- _02 (2day of run from 13Z-12Z)
- _03 (3day from 13Z-12Z)
- _04 (4day from 13Z-12Z)
- _05 (5day from 13Z-12Z)

Importantly, the sea ice surface characteristics from MMIF should exactly correspond to the time of sea ice in the MM5 runs. MM5 was processed with 100% sea ice coverage in runs initialized on January 1st, 2002 through May 26th, 2002 and again from runs initialized on October 13th, 2002 through December 31st, 2002. The summer runs (initialized on May 30th through October 9th) have 0% sea ice coverage.

The MMIF code assigns surface characteristics (e.g. surface roughness length) based on land use category and Julian date. Julian date is an integer value calculated from the MM5 run for the day in GMT, not local time. Due to the fact that MM5 files are for the period from 13Z through 12Z the following day, and the fact that MMIF assigns surface characteristics based on a Julian date starting at 0Z GMT, then there will be a disconnect between the MM5 meteorology and the MMIF assigned surface characteristics for those hours where there is still sea ice in the MM5 run, but MMIF switches to "summer" surface characteristics at 0Z GMT.

This is avoided by ending the MMIF processing of the MM5 data file at 0Z GMT, which requires breaking the runs apart. When the Julian Date equals 151 at 0Z GMT, the local Alaska time is May 30th from 1400 to 1500, which is equivalent to an ending time stamp of 05 30 15. Therefore, the MMIF control file for the month of May will end processing on 05 30 15 (using the last MM5 file with sea ice in May,"2002-05-26_05") and the June control file will begin processing on 05 30 15 (using the first MM5 file without sea ice, "2002-05-30_01"). Likewise, October processing will be broken into 2 files to correspond with the MM5 no sea ice and 100% sea ice periods. The beginning October period will be processed until 0Z GMT on Julian Date 287 (local time is Oct 13th, hour 15) using the MM5 no sea ice run "2002-10-09_05". A second October file will be generated with MMIF starting on 0z GMT Julian Date 287 (local time Oct 13th, hour 15) using the MM5 data generated with sea ice "2002-10-13_01".