ABflare

A Refined Air Quality Dispersion Model for Evaluating Non-Routine Flaring for Sour Gas Facilities

User Guide, Version 1.02

This page blank

ABflare

A Refined Air Quality Dispersion Model for Evaluating Non-Routine Flaring for Sour Gas Facilities

User Guide, Version 1.02

A Report Prepared for

Alberta Energy Regulator (AER)

Funded in Part by

Petroleum Technology Alliance of Canada (PTAC)
Alberta Upstream Petroleum Research Fund (AUPRF)
Alberta Energy Regulator (AER)

15 April 2014 (revised 18 Feb 2017)

ABflare was developed for
Petroleum Technology Alliance of Canada (PTAC)
Alberta Upstream Petroleum Research Fund (AUPRF)
Alberta Energy Regulator (AER) of Alberta, Canada

by:

Brian W. Zelt, Ph.D., P.Eng.
Zelt Professional Services Inc.

Michael J. Zelensky, M.Sc., P.Eng.
Alberta Energy Regulator

Please Reference this document as:

Alberta Energy Regulator (AER). 2014.
ABflare: A Refined Air Quality Dispersion Model for Evaluating Non-Routine Flaring for Sour Gas Facilities, Version 1.02, 15 April 2014 (revised 18 February 2017)

April 2014 (February 2017)

Distributed by

Alberta Energy Regulator
Centennial Place
Suite 1000, 250 – 5 Street SW
Calgary, Alberta T2P 0R4
Telephone: 403-297-2625
Fax: 403-297-3520
Web site: http://www.aer.ca/regulations-and-directives/directives/directive060

Liability Disclaimer

These models, software and documentation were prepared by the Petroleum Technology Alliance of Canada (PTAC) and AER (Alberta Energy Regulator), to the specifications set by AER. PTAC and AER warrants that the SOFTWARE will perform substantially in accordance with the provided documentation. PTAC and AER, nor any person acting on their behalf, makes any warranty, guarantee, or representation, expressed or implied, that the software and related materials, without limitation, are free of errors, are consistent with any standard of merchantability or will meet user's requirements for a particular application, that any calculations performed by the software are correct or accurate, that the software is compatible with particular computer systems, computer peripherals and other software packages, or that the software will run uninterrupted.

EXCEPT AS PROVIDED ABOVE, THIS DOCUMENTATION AND SOFTWARE IS LICENSED "AS IS" WITHOUT WARRANTY AS TO ITS PERFORMANCE. NO OTHER WARRANTIES APPLY. PTAC and AER DISCLAIMS ALL OTHER WARRANTIES, EITHER EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. THIS LIMITED WARRANTY GIVES YOU SPECIFIC LEGAL RIGHTS. YOU MAY HAVE OTHERS, WHICH VARY FROM PROVINCE TO PROVINCE.

IN NO EVENT SHALL PTAC or AER, OR THEIR SUPPLIERS BE LIABLE FOR ANY DAMAGES WHATSOEVER INCLUDING, WITHOUT LIMITATION, DAMAGES FOR LOSS OF BUSINESS PROFITS, BUSINESS INTERRUPTION, LOSS OF BUSINESS INFORMATION, CONSEQUENTIAL DAMAGES, OR OTHER PECUNIARY LOSS, HOWSOEVER ARISING OUT OF THE USE, ATTEMPTED USE OF OR INABILITY TO USE THIS PRODUCT, EVEN IF AER HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

Minimum System Requirements for *ABflare*

ABflare is a Windows® based software application requiring Microsoft® Excel as a user interface. The minimum system requirements are:

- Windows®10; Windows®8; Windows®7
- Microsoft® Excel. (Office 2016; Office 2013, Office 2010)
- x64 or x86
- 1024x768 monitor resolution
- 2 GHz processor
- 4 GB RAM
- Windows® - compatible mouse

TABLE OF CONTENTS

1. INTRODUCTION

ABflare, a Refined Model for Evaluating Non-Routine Flaring for Sour Gas Facilities

The Petroleum Technology Alliance of Canada (PTAC) and Alberta Energy Regulator (AER) with guidance from the Canadian Association of Petroleum Producers (CAPP) Non-Routine Flaring Task Team have developed *ABflare* for evaluating non-routine and routine flaring for sour gas facilities. This User Guide is for the *ABflare* modelling spreadsheet and associated modules. The User Guide outlines how to install the files, use the model and provides examples on the use of the model.

The *ABflare* model is an extension of the *AERflare* model. The user must have a good understanding of the *AERflare and CALPUFF* model user guides before proceeding with the *ABflare* model. The *ABflare* user guide only discusses *AERflare* inputs as necessary or relevant to the *ABflare* model, otherwise the user is directed to the *AERflare* user guide (AER 2014).

> ***AER****flare* : is an AER spreadsheet tool for the assessment of non-routine flaring using screening to refined methods using the *AERMOD* air quality dispersion model
>
> ***AB****flareUI* : is an AER spreadsheet tool for the assessment of non-routine flaring using refined methods using the *CALPUFF* air quality dispersion model.

The *ABflare* model documentation is comprised of several components that are described in the following table.

Module	Description
ABflareUI.xlsm	a Microsoft®-*Excel* (Office 2010) application software for Windows® containing macros and a user interface to external calculation modules.
ABflare.exe	a stand-alone FORTRAN coded program that creates a time varying flare source input file for CALPUFF based upon user inputs from *ABflareUI.xlsm.*
CALPUFF.exe	a stand-alone FORTRAN coded program that has been modified to accept a new time varying flare source.
METSERIES.exe	a stand-alone FORTRAN coded program that has been modified to output variables required by *ABflareUI.xlsm.*

CALAVE.exe	a stand-alone FORTRAN coded program that is used to post-process CALPUFF binary output files and write a time averaged binary file.
CALMAX.exe	a stand-alone FORTRAN coded program that is used to post-process CALPUFF binary output files combining several files into a single binary file that is the maximum of input files at each time step.
CALRANK.exe	a stand-alone FORTRAN coded program that is used to post-process CALPUFF binary output files calculating statistics at each receptor point such the n^{th} highest concentration or a percentile value.
Examples	Ex1 - A test case that demonstrates some of the features of the *ABflare* model and comparison to monitoring results. Ex2 - A test case that demonstrates features of the *ABflare* model.
User Guide Version 1.02.pdf	this User Guide.
Source Code	source code is provided for each of the stand-alone programs.

All of these documents and programs are available as a single download from the AER website. For the latest updates visit the AER website (see Directive 060):

http://www.aer.ca/rules-and-regulations/directives/

Also required is the *CALPUFF* air dispersion model. The *CALPUFF* source code, documentation and executable files are available at the U.S. EPA Technology Transfer Network website:

/http://www.epa.gov/ttn/scram/dispersion_prefrec.htm#calpuff

User Qualifications

ABflare is freely distributed to assist in D060 temporary flaring permitting, non-routine and routine flaring air dispersion modelling within Alberta. *ABflare* performs both screening level calculations (uses only a few user inputs to create a realistic and conservative estimate of flare emissions and concentrations) and also refined level calculations. Although relatively few inputs are required through the interface, it is a complex tool. *ABflare* requires inputs that may require sound engineering judgement or other technical expertise. It uses site-specific thermodynamics, fluid dynamics, and air dispersion modelling. Flare dispersion

assessment is a multidisciplinary and iterative task with many assumptions and judgments.

The *ABflare* and *AERflare* models were created so that a minimal amount of technical background is required to run the models. However, there remains some technical knowledge required to supply suitable inputs and the ability to understand whether the output is appropriate for the inputs and meets the needs of stakeholders. The user must recognise that the models are technical in nature and the correct interpretation of the result may require technical expertise that proceeds from consequences of the inputs. In any modelling assessment, high quality input data is very important.

The model has been created with a professional commitment to environmental protection and safeguarding the well-being of the public. It is the responsibility of the software user to accept and continue this commitment in their application of the software. The software is supplied as a tool to assist the user to comply with applicable statutes, regulations and bylaws. Neither the software nor application of the software is intended to replace statutes, regulations or bylaws.

Suitable Technical Background

Environmental issues are interdisciplinary in nature. The practice of environmental science requires the integration of diverse disciplines and philosophies; many projects will require a team of appropriate specialists to address complex environmental issues. Persons doing the assessment should undertake only that aspect of environmental work that they are competent to perform by virtue of training and experience. Thus, they should seek out and use appropriate Environmental Specialists to provide expert advice on certain environmental issues.

The basis of the models is technical with expertise required in chemistry, thermodynamics, atmospheric physics, meteorological processes, industrial processes and regulatory affairs. While the full technical background is not a requirement to execute the models, the user of the software is required to have a general engineering and environmental science background; a general knowledge of the emission sources: wells, pipelines, and pipeline networks; and a working knowledge of the most current version of:

- AER *Directive 060* –
- Alberta ESRD Air Quality Model Guideline and Non-Routine Flaring Management: Model Guidance.
- *CALPUFF/CALMET* user guides

There are many technical inputs required by *ABflare* to perform the calculations. Some have been prescribed by as mandatory default entries. Others are input by the user for the specific flaring scenario.

Use of *ABflare* and understanding whether the predictions are appropriate for the user inputs still, however, requires some specific technical understanding.

How this Document is Organized

This User Guide is organized as both an instructional guide and a tutorial. This guide is divided into the following chapters:

Chapter	Description
1 Introduction	Backgrounder for *ABflare*
2 Installation and Setup	How to install the *ABflare* program
3 Program Operation	Description of the program prompts and user entries, and description of the program output calculations and graphics
4 Example 1	Tutorial of a well test flare in complex terrain
5 Example 2	Tutorial of a user defined flare rate
6 Example 3	Tutorial of a vessel/pipeline blowdown

About this Guide

The term *ABflare* is used in reference to the entire modelling suite. The same term is used in reference to Windows executable *ABflare.exe* program. The term *ABflareUI* is used in reference to the *ABflareUI.xls*m spreadsheet user interface.

The following symbols and conventions are used in this guide

Bold	Used for menu, command, and keyboard selections you make and screens you will see.
Italics	Used for emphasis and to identify new terms.
`text`	User typed responses or entries.

variable	A named variable that is used in the spreadsheet to reference a cell location, equation variable or specific technical term.
PAGE	A worksheet page name.
Recalculate	A spreadsheet button that is pressed to start a calculation or process.
	Helpful information about a particular topic.
	Important information to prevent problems and ensure that you are successful in using the software.
link	A hyperlink to a section within the User Guide, an internet web site or email address.

Where to Go for Help

AER welcomes your feedback. For regulatory related questions, comments or concerns about the software tool, please send an email to address below:

Directive060Inbox@aer.ca

Comments on the current version, suggestions for features in future versions, or bug reports in the User Guide or *AERflare* software can be submitted to the email below. Please provide information on the version of Windows you are using, version of Excel, and enough information to duplicate the issue. Thank you.

aertools@zeltpsi.com

What is *ABflare* all about?

The *ABflareUI* spreadsheet tool was created to provide consistency in the calculation of flare-type source parameters for use with standard air quality dispersion models that are based upon chimney-type sources parameters. The basic premise of *ABflare* is to determine the momentum and energy released during a flaring event; this energy is released to the atmosphere giving buoyancy and

momentum plume rise for the flare-type source. *ABflare* then uses the buoyancy and momentum energy and back-calculates chimney-type equivalent source parameters that can be used as inputs in typical air dispersion models. These parameters are the height, diameter, velocity and temperature of the source. The equivalent source parameters are frequently called pseudo-parameters. The parameters are called pseudo-parameters because they are not real-world dimensions, but only calculated inputs that represent the flare-type source so that the correct plume height is used in the standard dispersion model. Standard dispersion models determine the plume rise based upon the calculation of buoyancy and momentum from the entered chimney source parameters (height, diameter, velocity and temperature).

Flaring can be loosely divided into three types: continuous, short-term steady and transient. Continuous flaring is flaring when the emissions occur hour after hour for long periods of time (weeks, months or years). The flared gas for continuous emissions can vary from zero flow rates, to low flow rates and to high flow rates over the course of the flare duration. Short-term steady flaring is similar to continuous flaring but flaring occurs only for prescribed period of time. Transient flaring is similar to short-term steady flaring where the flare is operated for a prescribed period of time, but the flow rate to the flare originates from a high pressure blow down resulting in a scientifically well-defined change in flow rates from very high to low over a specific period of time. In each of the flare types, it is important to examine the range of low flow rates to high flow rates and the pollutants released during these periods. Low flow rates are associated with low plume rise and high flow rates are associated with higher plume rise.

From a regulatory standpoint, flaring is divided into two broad categories: continuous (including short-term steady) flaring for routine operations; and, non-routine flaring (including short-term steady and transient flaring). Non-routine flaring has special regulations because it is associated with specific disposal of large amounts of gas and typically high pollutant emissions. Non-routine flaring is divided into two categories: planned flaring (including well test flaring, maintenance and turn-around operations); and, unplanned flaring (including upsets and emergency flaring). The distinction between routine, non-routine (planned) and non-routine (unplanned) is the frequency of the flaring events and the inherent risk to environmental harm (consequence). Planned non-routine flaring from temporary flares requires a permit from the AER.

ERCBflare version 1.x was originally created to specifically address the concerns related to the applications to AER for non-routine flaring associated with well test flaring. Because non-routine flaring events are often associated high energy and high levels of pollutant emissions, it was necessary to update the calculation tool to incorporate the more complex source conditions demanded by industry users, operations and high impact but low risk predictions. *AERflareincin* version 2.x was created to specifically address these complex questions and therefore *AERflare* is inherently more complex than its predecessors (*ERCBflare* version 1.x and ESRD flare tool). An important change also included in the *AERflareincin* 2.x is the

updated air quality dispersion model used to predict environmental harm (*AERMOD*), and it too is more complex than its relatively simplistic predecessor (*SCREEN3*) used in *ERCBflare* version 1.x. *ABflare* was created for refined air dispersion modelling using the *CALPUFF* model.

The purpose of *ABflare* version 1.x is to provide a relatively easy-to-use user interface tool to assist the user in the complex analysis of routine and non-routine flaring. The goal of *AERflareincin* is to predict a rapid (within minutes), conservative estimate of flaring impacts. It also provides next-step analyses methods to bridge the gap between rapid screening analysis and full-refined air quality dispersion modelling. The modelling associated with *ABflare* is not rapid since many of the steps associated with refined air dispersion modelling with the *CALPUFF-CALMET* system are complex or time-consuming to perform.

2. INSTALLATION AND SETUP

This chapter describes how to install the *ABflare* software. *ABflare* modelling package includes a user interface (a Microsoft®-*Excel* Office 2013 spreadsheet) that assists the user in creating input files to the various included stand-alone programs.

Microsoft Excel must be installed on your computer in order to use the *ABflareUI* tool.

Recommended version for *ABflareUI* are Office 2013 or Office 2016.

Overview of the Installation Process

If you have not already done so, download the installation software from the AERtools website (see below).

The single install ZIP file contains all of the software required for the *ABflare* program to run within the users existing Microsoft Office (including Excel) environment.

STEP 1: The *ABflare* tool is packaged as a downloadable ZIP file which the user can unpack to form a folder tree and access directly. Download the file *ABflare* package from:

http://www.aer.ca/rules-and-regulations/directives/

http://www.zeltpsi.com/aertools/

There are two download files provided

File	Intent	Recommended Download Destination Folder
ABlare_vxxxxxx.zip	Required	c:\myfiles\AERmodels\ABflare\
ABlare_UserGuide_vxxxxxx.pdf	Required	c:\myfiles\AERmodels\ABlare\docs\

The ABflare_vxxxxx.zip file contains the necessary user-interface and example files. It is recommended that the users download and read this user guide for *ABflare*.

The files may be installed to the user's choice of alternate folder locations during the installation. The **iBIN** page within *ABflare* is used to locate the required file locations.

STEP 2: Using the Windows explorer (Windows Key + e) locate the ABflare_vxxxx.zip file that you downloaded in **STEP 1**. Right clip on the file and select 'unzip to here' (if you have the WINZIP utility) or 'unpack' (if you are using the embedded unzip functionality within Windows). The following folders and files will be created (where `[mydir]` is the folder used in **STEP 1**:

`[mydir]ABflareUI_vxxxxx.xlsm`	The *ABflare* user interface spreadsheet tool
`[mydir]bin\`	A convenient location to place the run-time files for *ABflare* operation
`[mydir]bin\ABflare.exe`	The ABflare_vxxxxx.exe accompaniment run-time file
`[mydir]examples\`	ABflare spreadsheet tool example files
`[mydir]metfiles\test_AERflare\(aermod.sfc; aermod.pfl)`	This folder contains an **example** site specific meteorological file. There is a *.SFC and *.PFL file representing an AERMOD ready surface and profile meteorology file, respectively

The program (*.exe) files may be installed to alternate folder locations

Acquiring the CALPUFF v7.x Modelling System Files

The *CALPUFF* model version 7.x is required for normal operation of *ABflare*. The *CALPUFF* modelling system is used in standard form as downloaded (see next steps).

1. Using your internet browser, navigate to the web-site below to download the *CALPUFF* v.7.x source code.

http://www.src.com

Click on the link for Download. You must agree to the (no cost) End-user License Agreement by pressing I Agree. You will be presented with an option to register or you may press Skip Registration to by-pass the registration and proceed to the download page.

2. Download the files listed below and unzip (unpack) each file.

CALPUFF	Version 7.2.1 (150618) -- Non-steady-state transport, dispersion, and deposition model. Updated on June 22, 2015.	Required, performs air dispersion modelling to create predictions of air concentrations
CALMET	Version 6.5.0 (150223) -- 3-D diagnostic meteorological model. Updated on June 22, 2015.	Required, creates meteorology data files used by CALPUFF
TERREL	Version 7.0.0 (141010) -- Combines and grids terrain data. Updated on June 22, 2015.	Required, creates preprocessed terrain files required by CALMET
MAKEGEO	Version 3.2 (110401) -- Merges land use and terrain data to produce the geophysical data file for CALMET. Updated on April 14, 2011.	Required, creates preprocessed files required by CALMET
METSERIES	Version 7.0.0 (140912) -- Extracts meteorological time series (e.g. winds, temperature, water vapor) from 3D.DAT, CALMET.DAT, SURF.DAT, CALMM4.DAT and UP.DAT, and produces frequency tables for windroses. Updated on June 22, 2015.	Required, creates a 1-d meteorological file from CALMET output, required by ABflare to preprocess flaring source information into a flare source time series file for CALPUFF
CALAVE	Version 7.0.0 (140912) – Reads a concentrations dataset (version 2.1 or later output file) and performs either a running average or a block average for 1 user-specified averaging time. Sums and scales concentrations or wet/dry fluxes from two or more source groups from different CALPUFF runs. Updated on June 22, 2015.	Optional, post-processes CALPUFF output and creates block time averaged or running time averaged output files
CALMAX	Version 7.0.0 (140912) – Reads a CALPUFF dataset 2.1 or later (e.g., CONC.DAT) and retains the maximum over all sources and files for each receptor and species-level. Updated on June 22, 2015	Optional, post-processes CALPUFF output by merging multiple files and creating a single output file of the maximum concentration for each hour of the input files.
CALRANK	Version 7.0.0 (140912) – Reads a file of modeled data from a CALPUFF-type data file and ranks all values in magnitude for each species and receptor. Identify the nth-highest values and the percentile values requested by the user. Updated on June 22, 2015.	Optional, post-processes CALPUFF output data

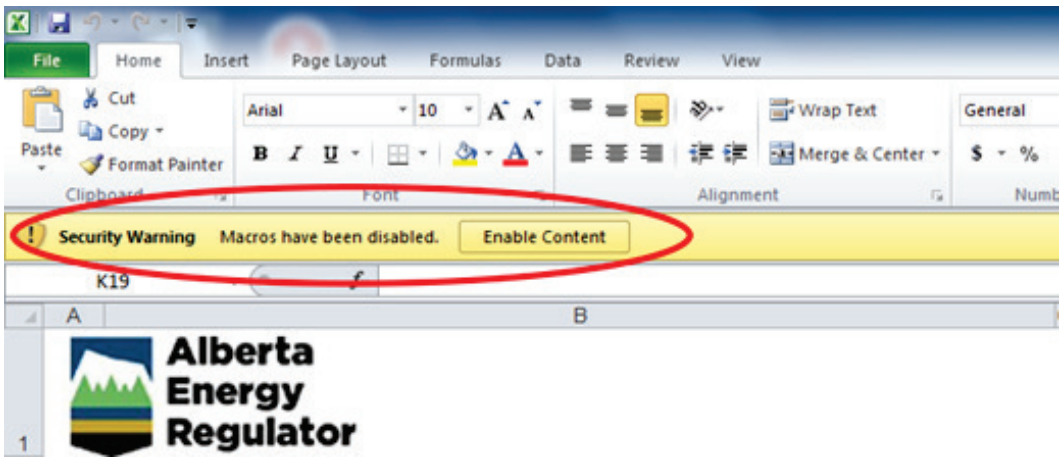
`[mydir]\BIN\`

Initial Setup

Now that you are finished installing the *ABflareUI* spreadsheet tool, you can complete the installation by loading the *ABflareUI* spreadsheet and following the steps below.

1. From the select Windows START->Microsoft Office XXXX->Microsoft Excel XXXX; this will launch Excel. Then using the Excel menu option File->Open or use the Windows Explorer to navigate to the installation folder for *ABflareUI* and `[mydir]` and double-click on the ABflare_vxxxxx.xlsm file. This will load the *ABflareUI* tool into Excel.

2. The *ABflareUI* spreadsheet is an XLSM file that contains typical spreadsheet-like calculations as well as program macros; this is the "M" part of the ".xlsm" filename extension. When the file is opened, your computer and office security settings may display a warning. Select '`Trust this document`', '`Enable Macros for this document`' or '`Enable Content`' depending on your version of Windows if prompted when the file is opened. Failing to do so will prevent *ABflareUI* from operating.



3. Click on the **iSTART** page. Select "Show" for the *Hide iBIN Page* option.

4. Click on the **iBIN** page. For the entry for **ABFLARE**, type the full path and file name of the `ABFLARE.exe` file (previously installed). The Browse... button can be used to navigate your file folder tree using common Windows Explorer methods.

   The files can be placed anywhere on your network. A typical location is:

   `[mydir]\bin\abflare.exe`

5. Repeat the Step 4 process or each of the following run-time executable files required for operation of *ABflare*.

CALPUFF:	default :	`[CALPUFF]\calpuff.exe`
METSERIES:	default :	`[CALPUFF]\metseries.exe`
CALAVE:	default :	`[CALPUFF]\calave.exe`
CALMAX:	default :	`[CALPUFF]\calmax.exe`
CALRANK:	default :	`[CALPUFF]\calrank.exe`

MAKEGEO: OPTIONAL default: `[CALPUFF]\makegeo.exe`
TERREL: OPTIONAL default: `[CALPUFF]\terrel.exe`
CALMET: OPTIONAL default: `[CALPUFF]\calmet.exe`

CALMET, MAKEGEO and CALEMT are listed here as 'OPTIONAL', because you may have already downloaded the CALMET modelling system and you may run it independently of ABflare.

6. If the BROWSE… button was used to select the files or the SAVE button pressed, then *ABflareUI* stores the entry for your computer setup. If you load an uninitialized *ABflareUI* spreadsheet or a spreadsheet initialized to another users folder locations, *ABflareUI* synchronizes the settings to your computer setup. You have the option of saving the file when you have completed the calculations. You can force *ABflareUI* to synchronize by pressing the SYNC button.

7. Click on the **iSTART** page. Select "Hide" for the *Hide iBIN Page* option. Typically, you shouldn't have to revisit the **iBIN** page. However, use the **iSTART** page to show the **iBIN** page to make any changes to your system as required.

Select 'Trust this document' or 'Enable Macros for this document' if prompted when the file is opened. Failing to do so will prevent *ABflareUI* from operating.

ABflareUI spreadsheets must be saved as an XLSM file type to preserve the macro (Visual Basic for Applications) functionality.

This completes the mandatory components initialization of the *ABflareUI*. The user may wish to also initialize several optional components of *ABflareUI*.

MAKEGEO: On the **iBIN** page, for the row entry for *MAKEGEO*, enter the full path for the location of the *MAKEGEO*.exe file or use the BROWSE button to navigate to the installation folder and click on the *MAKEGEO*.exe.

TERREL: On the **iBIN** page, for the row entry for *TERREL*, enter the full path for the location of the *TERREL*.exe file or use the BROWSE button to navigate to the installation folder and click on the TERREL.exe.

CALMET: On the **iBIN** page, for the row entry for *CALMET*, enter the full path for the location of the *CALMET*.exe file or use the BROWSE button to navigate to the installation folder and click on the CALMET.exe.

DEMLIB: On the **iBIN** page, for the row entry for **DEMLIB**, enter the full path for the location of where digital elevation files should be stored when downloaded from the internet. **DEMLIB** represents a library or cache to save time on subsequent analyses to avoid download times. Also, the **DEMLIB** provides a library of files for repeatability of *ABflare* predictions.

LCCLIB: On the **iBIN** page, for the row entry for **LCCLIB**, enter the full path for the location of where land-use classification code (LCC) files should be stored when downloaded from the internet. **LCCLIB** represents a library or cache to save time on subsequent analyses to avoid download times. Also, the **LCCLIB** provides a library of files for repeatability of *ABflare* predictions.

DEMURL: on the **iBIN** page lists the internet URL where DEM files are downloaded from. This entry is not editable.

LCCURL: on the **iBIN** page lists the internet URL where LCC files are downloaded from. This entry is not editable.

It is recommended that you DO NOT continue to use your computer for other concurrent Windows applications because this can cause interference and instability within the calculations.

3. Program Operation

This chapter provides the following information about the general operation of the *ABflare* program:

- what the principal files are and how they work together
- what the buttons/menu items do
- overview of the calculation processes

Introduction

The *ABflare* tool uses the familiar Microsoft Excel as host for the calculations. *ABflareUI*.xlsm contains the user-interface for the calculations, allowing the user to input information and view calculation results. The *ABflare* application consists of

- *ABflareUI*.xlsm spreadsheet and
- Related program stand-alone modules:
  - ABflare.exe
  - METSERIES.exe
  - CALPUFF.exe
  - CALAVE.exe
  - CALMAX.exe
  - CALRANK.exe
  - And optional (to create meteorological files for *CALPUFF* within *ABflare*):
    - MAKEGEO.exe
    - TERREL.exe
    - CALMET.exe

The *ABflareUI* spreadsheet is a stand-alone spreadsheet containing all of the necessary macros and programming to load and process input and output from the modules.

ABflareUI.xlsm is an Excel spreadsheet file (.xlsm) containing macros (programming) that acts as a user interface for input files and output from the processing modules.

All inputs and outputs are stored in folders as directed by the user.

User-Interface

Overview – The ABflareUI GUI in Excel

All user input and output are controlled using an ABflareUI.xlsm file for Microsoft Excel. The GUI (graphical user interface) file (abflareui_v1xxxxx.xlsm) contains several Excel worksheets (**pages**). Each *ABflareUI* module has a separate page. You can change to a page using the mouse by clicking on a tab or using the keyboard using ctrl+pgup or ctrl+pgdn. The pages are shown in Figure 1 and the figure shows the typical work flow linkages between the worksheets. In general, a user will progress through the pages in sequence, step 1, step 2, etc…

Although the spreadsheet workbook is designed to function like a work-desk to manage the processing flow, the spreadsheet can be copied and saved on a project by project basis, thus archiving the specific inputs used for each project.

The spreadsheet contains a synchronizing control so that all work will use the same **iBIN** folders by default. This feature can be turned on and off.

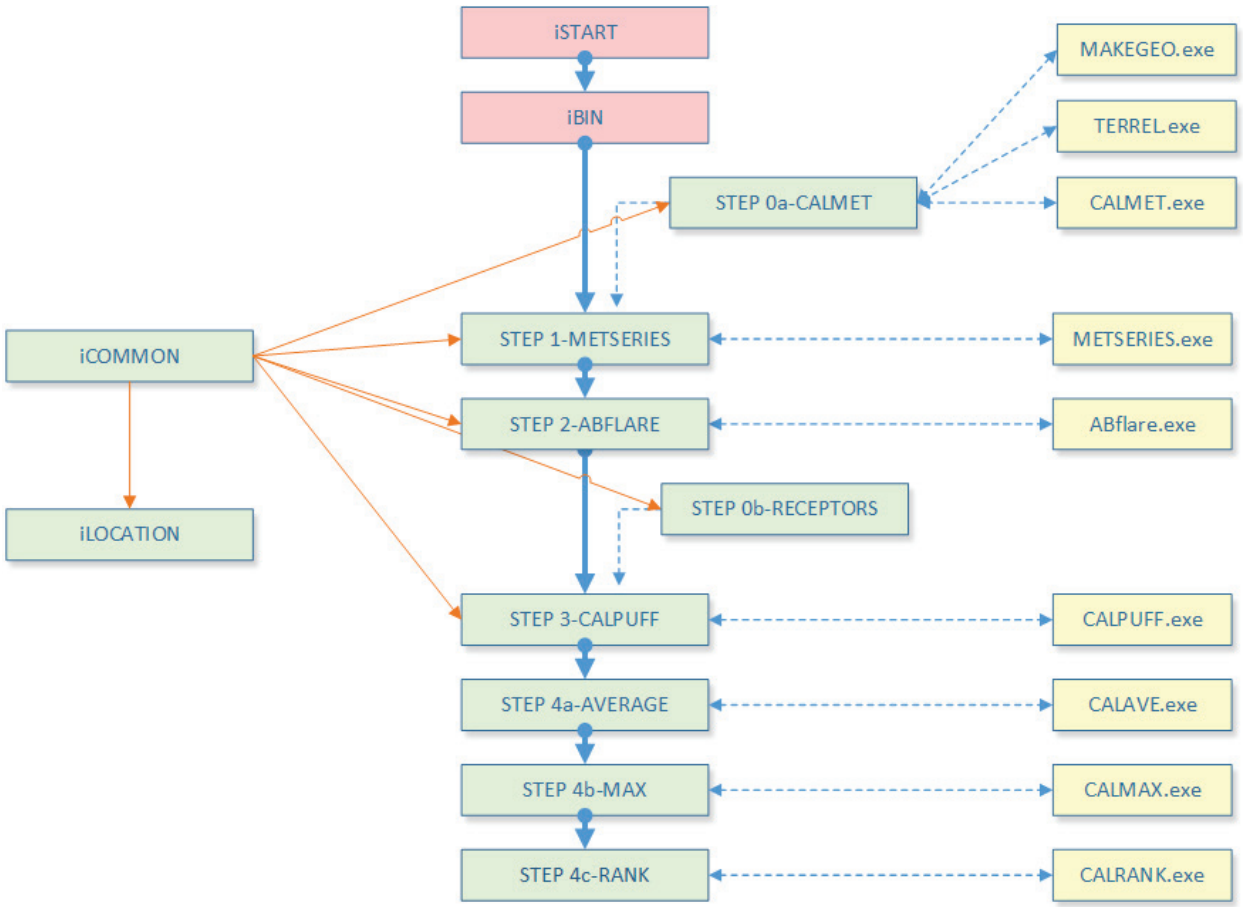


Figure 1: ABflareUI Page Name and Typical Linkage

The ABflareUI Excel Pages

ABflareUI has 12-principal GUI pages in the *ABflareUI* Excel user interface workbook. Pages for input and output are green while information pages are *cyan* (coloured tabs on pages are visible for Office 2002 and newer versions of Excel only).

Tabs for the page types are colour coded **for Office 2002 and newer** versions of Excel (earlier versions do not display the page colours).

Input pages are *green* and information pages are *cyan*.

A complete list of user-interface pages are described in the following table:

Page Name	Purpose	Description
ABOUT	User Information	General information and instructions for use of the spreadsheet. Use this sheet to link to the latest information regarding *ABflare*.
iSTART	User Interface Setup	This page allows the user to configure the AB*flare* control switches and select which pages to display.
iBIN	User Interface File Locations	The *ABflare.xlsm* GUI needs to know where the various post-processing programs have been installed.
iCOMMON	Input Location Setup	This page lists the common settings between the *CALPUFF* modules related to geographic location.
iLOCATION	Input Location MAP	This page shows the location and domain selected in the iCOMMON page. This page is a useful reference to ensure entered location information is reasonable.
Step 0a-CALMET	Input Meteorological Processing	Create site specific meteorology.
Step 0b-RECEPTOR	Input Receptor Processing	Create site specific receptor grid.
Step 1-METSERIEIS	Input Meteorology Setup	Create an input file for the *METSERIES* program to extract meteorological data required by the *ABflare* program.
Step 2-ABflare	Input Source Setup	Create an input file for the *ABflare* program to create a time varying flare source input file for use with *CALPUFF*.
Step 3-CALPUFF	Input Dispersion Modelling	Create an input file for the *CALPUFF* program to create concentration predictions at each receptor point for a specific time period and meteorological data set.
Step 4a-AVERAGE	Input Post-Processing	Create an input file for the *CALAVE* program to create a time averaged concentration data file from *CALPUFF program output*.
Step 4b-MAX	Input Post-Processing	Create an input file for the *CALMAX* program to combine several *CALPUFF* output files into a single file representing the maximum concentration at each receptor location at each time increment in the file.
Step 4c-RANK	Input Post-Processing	Create an input file for the *CALRANK* program to determine n^{th} highest or percentile statistics from *CALPUFF* output files.
sABFLARE	Settings (Technical)	A list of the *ABflare* input file switches, settings and documentation of each that is also provided in the input files.
sCALMET	Settings (Technical)	A list of the *CALMET* input file switches, settings and documentation of each that is also provided in the input files.
sGEO	Settings (Technical)	A list of the *MAKEGEO* input file switches, settings and documentation of each that is also provided in the input files.
sTERREL	Settings (Technical)	A list of the *MAKETERREL* input file switches, settings and documentation of each that is also provided in the input files.
sCALPUFF	Settings (Technical)	A list of the *CALPUFF* input file switches, settings and documentation of each that is also provided in the input files.
sLCC	Settings (Technical)	A list of the Land Classification Characterization of the Bowen ratio, albedo and surface roughness used by *CALMET* for the land-use classification processing by *CALMET* to create the site specific meteorological data file.

The pages flagged having a Purpose of (Technical) may be hidden from view using the **iSTART** hide technical pages option. These pages are not required for routine modelling.

Steps Explained

The *ABflareUI* is organized in a series of pages called *STEPS*. The logical sequence through an air quality assessment is to follow Step 1, then Step 2, etc. Each step is designed to be somewhat independent of the other steps so that the user can make use of the processing of that step having already completed prerequisites for the step using other 3rd party processing or *ABflareUI* processing. Originally, *ABflare.exe* was written as an independent processor to calculate the hour flaring source inputs for *CALPUFF* based upon the meteorology. To make the program universally distributable the GUI was added to assist with inputs and to be compatible with the existing *AERflare* tool.

Steps <1

Steps less than one are pre-processing steps. Knowledgeable *CALPUFF* users may already have the preprocessing steps already completed, and therefore, it is not required to complete these steps. However, modellers new to *CALPUFF* will find the preprocessing steps helpful for *CALPUFF* assessments within Canada since the terrain and land use assessment is automated.

The first pre-processing page is **Step 0a-CALMET**. This page walks the user through a series of sub-steps to create the *CALMET* input files and ultimately run the *CALMET* processing. The page is logically organized from top to bottom. The user is expected to complete each sub-step from top to bottom.

The second pre-processing page is **Step 0b-RECEPTOR**. This page walks the user through a series of sub-steps to create a receptor grid for the air dispersion modelling component of the *CALPUFF* modelling. The page is logically organized from top to bottom. The user is expected to complete each sub-step from top to bottom.

Each of the pre-processing steps contain commands such as Make XYZ or Make Terrel implement a task or command.

Steps ≥ 1

Steps that are numbered greater than one are GUI interfaces for processing for modules (.exe) programs.

- **Step 1-METSERIES** is a required step that creates a time series meteorological file that is a prerequisite for Step 2.
- **Step 2-ABFLARE** creates hourly variable flare source parameters (flrarbemis.dat) that is a prerequisite for step 3.

- **Step 3-CALPUFF** creates the input files for *CALPUFF* that will create the air dispersion modelling output files (*.con).

- Step 4 contains optional post-processing from Step 3, and is divided into three processors **Step 4a-AVERAGE** (to determine various time averages), **Step 4b-MAX** (to combine several *CALPUFF* output predictions into a single time series by taking the maximum of each prediction) and **Step 4c-RANK** (to determine the n'th highest or a probability).

Each of the processing steps is a configuration of an input file for the individual processor. Each processing step is:

1. initiated by loading an existing input file using Browse…,

2. adjusting the fields shown on the processing page and overwriting or creating a new input file Save As…,

3. Executed using the Run or a batch file was created using Save As… for later execution.

The *ABflare* Calculation Process

Calculations are directed by user entry and selections in the *ABflareUI.xlsm* spreadsheet file. The *ABflareUI.xlsm* spreadsheet does not perform any calculations; calculations are performed in the stand-alone modules. The modelling system is described in Figure 3. The green shaded area of Figure 3 represents the *ABflare* modelling system described in this user guide. The *AERflare* screening tool is the logical first step non-routine and routine flare modelling. The *ABflareUI.xlsm* can read the inputs already entered into *AERflare.xlsm* rather than the user having to re-enter the data. It is not necessary to run the *AERflare.xlsm* model before running *ABflare.xlsm* nor are any outputs from *AERflare.xlsm* used or required by *ABflareUI.xlsm*.

As will be described in more detail in the following pages, the *ABflareUI* workbook has been designed to work with an existing modelling assessment (i.e., some of the *CALPUFF* system modules have already been created) or to start a project from scratch. While the *ABflareUI* workbook provides for many detailed settings for the *CALPUFF* modelling system, *ABflare* is designed as a broad-brush approach and specifically geared towards modelling of flares. More specific air quality model configuration tools may be found within the *CALPUFF* modelling system, such as the *CalPro* interface.

The simplified interaction of the *ABflare* calculation process with the common modelling tools is shown in Figure 2. The air quality dispersion assessment of non-routine or routine flaring can start with a screening assessment using *AERflare*. If the terrain is very complex surrounding the flare site or other more refined modelling is required, the *ABflareUI* tool can be used and the basic inputs can be copied from the *AERflare* tool. A second basic input required by *ABflare* is meteorology. The required meteorology can be a low-level 3D.dat file extracted from the AESRD MM5 data or a *CALMET* output file (met.dat). Optionally, a receptor grid (with x,y locations and terrain elevations), and pre-processed land-use data (LU.dat) can be used or created by *ABflare*. The output from the *ABflare* calculations can be further analyzed using Excel spreadsheets or graphics packages such as Golden Software's Surfer (not included in the *ABflare* system). The *ABflare* program will also allow a user to make use of *AERMOD* ready meteorological files. In this latter case, *ABflare* would be configured to read an *AERMET* surface file (AERMET.sfc) and control settings would be selected to create a source file for *AERMOD* rather than CALPUFF. *ABflare* does not run *AERMOD* nor post process *AERMOD* output.

The *ABflare* calculations are two-way, that is the user input directs calculations which are then post-processed and the module output list file is displayed to the user. The user should read the list files provided and check for error or warning messages. The final output from *ABflare* requires the user to post-process the results to view, map and interpret the results using third-party software or Excel basic functionality.

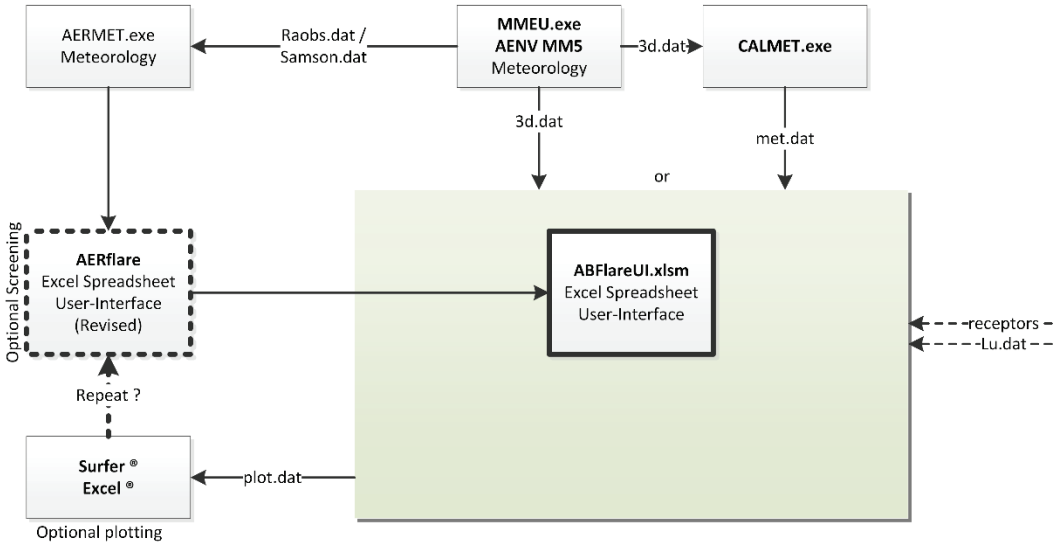


Figure 2: *ABflare* Simplified Calculation Process

The calculation process in more detail is shown in Figure 3 showing the individual modules. The *ABflare* Spreadsheet can be used to read and write the control input files for a wide variety of the *CALPUFF* modelling system modules. Starting from

scratch, *ABflare* can be used to create and run *CALMET* meteorology by first creating land use characterization using *MAKEGEO*.exe and terrain processing using *TERREL*.exe. The *METSERIES*.exe module is required to create a time series meteorology file at flare stack height at the location of the flare. The meteorology input file (met.dat) can be either created internally to the *ABflare* system, or it can be an existing file created by the user external to the *ABflare* modelling system. Using the meteorological time series file (met.tsf) the *ABFLARE*.exe module is used to create a time varying source file (flr.dat) that describes the flare height, diameter, temperature, location and emissions as a function of time. The flare source file is used by *CALPUFF*.exe to define the source conditions and *CALPUFF*.exe creates binary output files that may require post processing to form a variety of time averages or to extract statistics of interest (for example, the 99th percentile value at each receptor location). Three post-processing modules can be used. *CALAVE*.exe is used to create time averaged concentration files similar to *CALPUFF* output files. *CALMAX*.exe is used to merge multiple run output files into a single output file. The maximum concentration for an averaging period from the listed input files is determined and a single *CALPUFF* like binary output file is created. *CALRANK*.exe is used to determine nth highest or percentile concentrations at each receptor location.

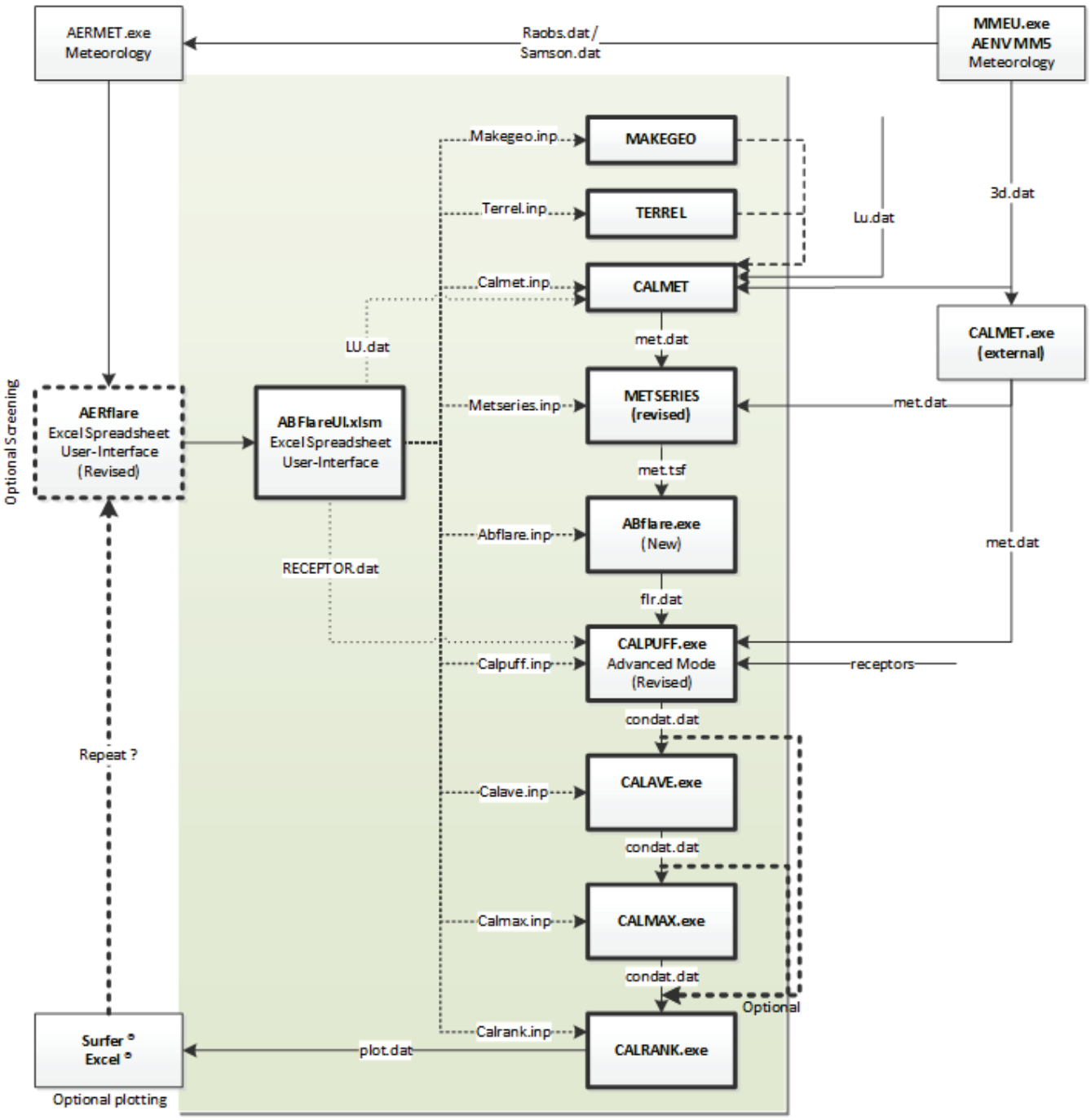


Figure 3: Schematic of ABflare Calculation Process

iSTART

The **iSTART** page fundamental entries are illustrated in the figure below. These options specify cosmetic or convenience modes (i.e., hide or don't hide technical information) but also control switches for how the calculations are to be performed.

Hide Technical Pages

The hide technical pages option is cosmetic for *ABflareUI* operations. Hide technical toggles the visibility of default settings pages for **sABFLARE**, **sCALMET**, **sGEO**, **sTERREL**, **sCALPUFF** and **sLCC**.

Hide iBIN page

The hide **iBIN** page option is cosmetic for *ABflareUI* options. Hide **iBIN** is used to toggle the visibility of the **iBIN** page. Once the *ABflareUI* spreadsheet has been configured, typically operations will not require the **iBIN** page (see Chapter 2: Installation and Setup) and it can be hidden from view.

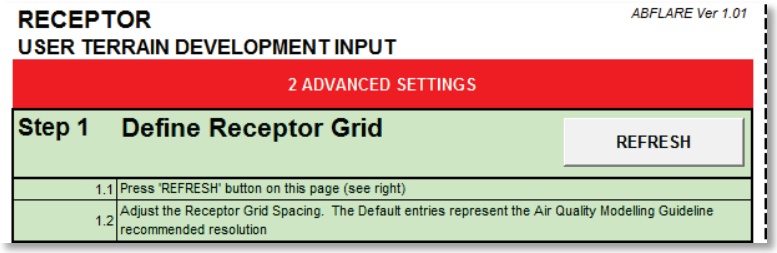
Advanced Switches

The advanced switches are useful for advanced users for debugging and for other automation links. The advanced switch block is shown in the figure below. The Defaults are shown and the user can over-ride the default by entering a value in the Inputs column. Entries different than the default are highlighted for convenience. In the example below, mpause switch is set to `YES`, and mbatonly is set to `YES` whereas their default settings are both `NO`.

Advanced Technical Switches

Description	Variable	Units	Inputs	Default
DEM always download files (1-Yes, 0-No)	mdemget	--	0	0
LCC always download files (1-Yes, 0-No)	mlccget	--	0	0
Minimize run window (1-Yes, 0-No)	mhide	--	1	1
Insert PAUSE at the end of a Batch file (1-Yes, 0-No)	mpause	--	0	0
Creates a batch file to be used at a later time (1-Yes, 0-No)	mbatonly	--	1	0
Uses the 'Do For Each' list when creating files (1-Yes, 0-No)	mdoforeach	--	0	0
Synchronize settings between spreadsheets (1-Yes, 0-No)	msync	--	1	0

When an advanced setting has been selected the output pages are embossed with a warning message to notify the user. For example, the message below was created when two of the non-default advanced settings were used.



MDEMGET

The mdemget setting is used to force *ABflareUI* to download digital terrain data without first looking within the saved library. This switch can be used to ensure that the most up-to-date data is being used in the analysis at the expense of repeated down load time. It is recommended that this setting is set to "0" to not automatically download. For repeatability of the assessment it is recommended that a Library be created. Updates, when available from the download site, can be included by starting a new library periodically.

MLCCGET

Similar to the mdemget option, the mlccget setting is used to force *ABflareUI* to download land classification data without first looking within the saved library. This switch can be used to ensure that the most up-to-date data is being used in the analysis at the expense of repeated down load time. It is recommended that this setting is set to "0" to not automatically download. For repeatability of the assessment it is recommended that a Library be created. Updates, when available from the download site, can be included by starting a new library periodically.

MHIDE

The mhide setting is used to control the display of the run thread window to be minimized or not minimized. When mhide=1, the runtime window containing the execution of the respective model (e.g., *CALMET*.exe) will be minimized to the Windows task bar. When mhide=0, the window remains at its default size. During run time, the user can minimize or maximize the run time window and watch the progress of calculations.

MPAUSE

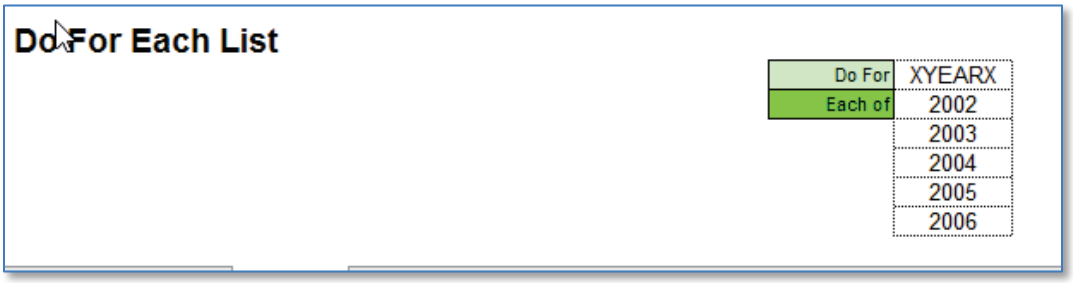
ABflareUI creates a synchronous secondary process using the command prompt. By default *ABflare* minimizes the command prompt to the task bar as a reference during the air dispersion modelling. The command prompt window is closed automatically after execution of a module (e.g., *CALAVE*.exe) and control is returned to *ABflareUI* calculation process. For debugging, a `PAUSE` statement can be added to the `RUN.bat` file to force the user to look at the command prompt window and enter an acknowledgment to proceed. Select mpause=1 to include the `PAUSE` statement. The mrunbat=1 option should also be set to force the `RUN.BAT` file to be re-written.

MBATONLY

The mbatonly switch is used during the operation of **Step 0a-CALMET** and **Step 3-CALPUFF** calculations. When the user presses the Run button on these pages, a batch file will be created rather than actually running *CALMET*.exe or *CALPUFF*.exe. Because both these programs are numerically intensive and may require a significant time period to run, the batch file option can be used to defer the run to later more convenient time (i.e., overnight), run on an alternate machine, or can be edited and run on several different machines.

MDOFOREACH

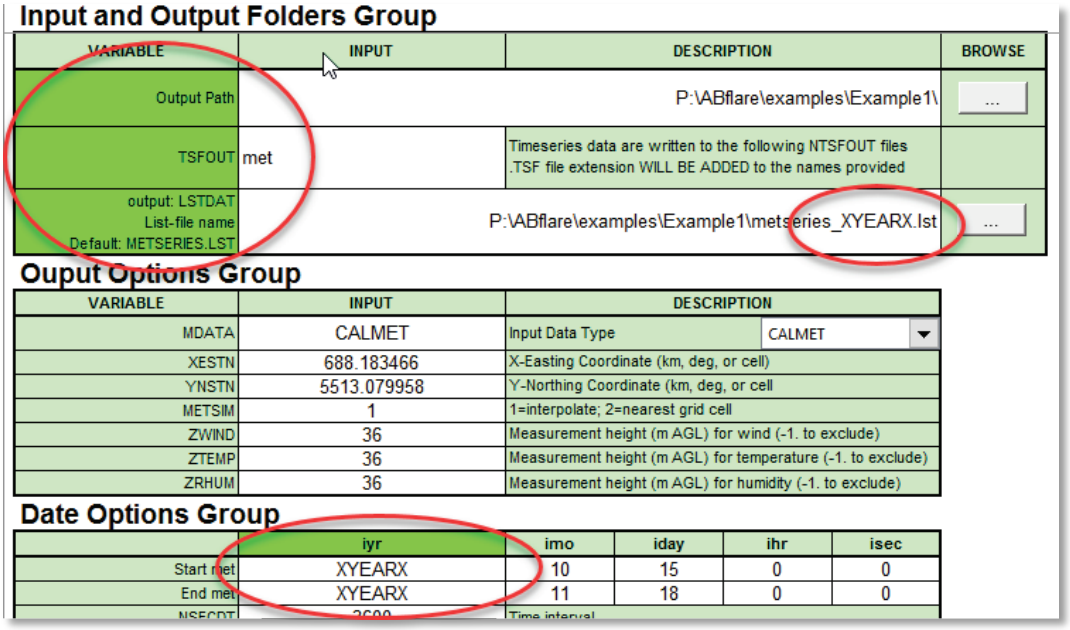
The mdoforeach switch is used as a modifier to enhance the operations of the controls listed in the table that follows this discussion. The mdoforeach modifies the actions of the listed operations by repeating the operation for the listed values of variable defined on the iSTART page.



In the example above, a variable `XYEARX` is defined and a list of 5-values is provided: `2002`, `2003`, `2004`, `2005` and `2006`. When mdoforeach is selected, the user can use the variable `XYEARX` as a replacement for each of the values in the Do-For-Each list. Fields in *ABFLAREui* are specially marked using bright green shading to indicate entries that can use the mdoforeach actions. This functionality

is useful because *CALPUFF* is typically configured to run individual years for a 5-year period. The *ABFLAREui* can be used to configure a single year and the mdoforeach function can be used to repeat the configuration for each of the years in the study.

In the example below, the **STEP 1-METSERIES** page is displayed. This page shows four fields that can be used with mdoforeach: output path, TSFOUT, LSTDAT, and the iyr date year start and year end. In this example, only the LSTDAT and iyr variables make use of the mdoforeach functionality. Instead of specifying the year, eg 2002, the user uses the DOFOR variable defined on the **iSTART** page : `XYEARX`. When the SAVE AS... button is pressed, the save operation is repeated consecutively for each of `2002`, `2003`, `2004`, `2005` and `2006`.



Input and Output Folders Group

VARIABLE	INPUT	DESCRIPTION	BROWSE
Output Path		P:\ABflare\examples\Example1\	...
TSFOUT	met	Timeseries data are written to the following NTSFOUT files .TSF file extension WILL BE ADDED to the names provided	
output: LSTDAT List-file name Default: METSERIES.LST		P:\ABflare\examples\Example1\metseries_XYEARX.lst	...

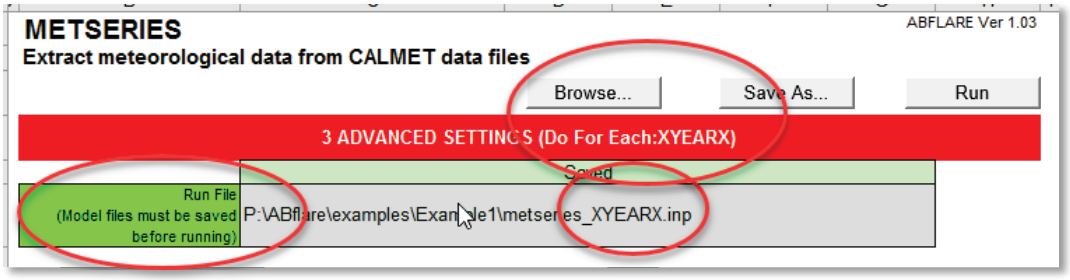
Ouput Options Group

VARIABLE	INPUT	DESCRIPTION
MDATA	CALMET	Input Data Type CALMET
XESTN	688.183466	X-Easting Coordinate (km, deg, or cell)
YNSTN	5513.079958	Y-Northing Coordinate (km, deg, or cell
METSIM	1	1=interpolate; 2=nearest grid cell
ZWIND	36	Measurement height (m AGL) for wind (-1. to exclude)
ZTEMP	36	Measurement height (m AGL) for temperature (-1. to exclude)
ZRHUM	36	Measurement height (m AGL) for humidity (-1. to exclude)

Date Options Group

	iyr	imo	iday	ihr	isec
Start met	XYEARX	10	15	0	0
End met	XYEARX	11	18	0	0
NSECDT	3600	Time interval			

The Run File field is used to define the path and base filename for the output files. The bright green field indicates that mdoforeach will be used. When the mdoforeach with the Save As.. buttons the file is created first with the DoFor variable (in this case `XYEARX`) followed the sequence of files with the DoFor variable substituted for the list of replacements (example, 2002, 2003, 2004, 2005 and 2006). This allows the user to view the output files as well as the skeleton file or to use the skeleton file for batch processing at a later time.



The status bar indicates that the mdoforeach switch is selected and the user defined variable being used. Here XYEARX is displayed as the replacement variable

If the mbatonly switch is selected, then the mdoforeach the switch in conjunction with the Save As.. buttons on the following pages creates a batch file to run the processors with each of the created DoFor input files. The batch files are a handy alternative to the Run buttons, since the batch file can be executed in a separate process leaving the *ABflareUI* available to continue working.

Page	Operation Affected	What it Does
STEP 1-METSERIES	Save As…	Creates NDOFOR input files for *METSERIES*. If mbatonly is selected, a single batch file is created to run each NDOFOR. If mbatonly is not selected, *METSERIES* is run for each NDOFOR while the user waits.
STEP 2-ABFLARE	Save As…	Creates NDOFOR input files for *ABflare.exe.* If mbatonly is selected, a single batch file is created to run each NDOFOR.
	Save As…	Creates NDOFOR input files for *CALPUFF.* If mbatonly is selected, a single batch file is created to run each NDOFOR.
STEP 3-CALPUFF	Create NSEP	Creates NSEP input files for *CALPUFF* each NDOFOR. By Default the NSEP files are named <runfile>_iSEP<extension> where runfile and extension is the user defined entries and the iSEP is the incremented file for each start time from 1 to NSEP. If mbatonly is selected, a single batch file is created to run each NDOFOR and NSEP
STEP 4a-AVERAGE	Save As…	Creates NDOFOR input files for *CALAVE*. If mbatonly is selected, a single batch file is created to run each NDOFOR.

STEP 4b-MAX	Save As…	Creates NDOFOR input files for *CALMAX*. If mbatonly is selected, a single batch file is created to run each NDOFOR.
STEP 4c-RANK	Save As…	Creates NDOFOR input files for *CALRANK*. If mbatonly is selected, a single batch file is created to run each NDOFOR

MSYNC

This switch is used to turn on or off the automatic synchronizing of the settings on the **iBIN** page. Setting msync=0, turns off synchronizing. With msync=0, when the *ABflareUI* spreadsheet opens it does not reset the spreadsheet values to the saved system values. Similarly, with msync=0, when files or folders are specified on the **iBIN** page, they are not saved to the system for later recall.

Non-Default Settings

The non-default setting are useful for advanced users for non-routine assessments and further analysis. The non-default settings block is shown in the figure below. The Defaults are shown and the user can over-ride the default by entering a value in the Inputs column. Entries different than the default are highlighted for convenience. The *ABflareUI* pages are highlighted with a warning flag specifying the number of non-default setting entries that have been used.

Description	Variable	Units	Inputs	Default
Modelling domain for receptor grid	rmaxdist	m	10000	10000
Modelling domain buffer beyond receptor grid	dombuf	m	5000	5000
Meteorological domain grid resolution	dgrid	m	250	250
LCC subsampling	lccsubsample	--	3	3
Receptor Resolution for Maximum Concentration	DXmin	m	20	20

RMAXDIST

RMAXDIST is the size of the *CALPUFF* modelling domain measured from the flare source location. Therefore, RMAXDIST represents a radial distance. The default distance is RMAXDIST=10 km.

DOMBUF

The DOMBUF setting is the domain buffer added to RMAXDIST in which to model the meteorology. The DOMBUF should allow for terrain elevations that may impact the air patterns and hence the air dispersion modelling within the

RMAXDIST modelling domain. The DOMBUF should also allow for the possibility of flow reversals. The default buffer size is DOMBUF=5 km. The default meteorological domain size is therefore,

RMAXDIST + DOMBUF = 15000 m (or 15 km)

DGRID

The *CALPUFF*/*CALMET* modelling domain is divided into grid cells. Within each grid cell, the meteorological parameters will be calculated by *CALMET* and will vary in three dimensions from the adjacent cells. In *CALPUFF*, the meteorological conditions in each grid cell are used to determine the air dispersion for each incremental puff as it advects throughout the domain. The size of the grid cell should reflect the terrain elevation changes. The selection of XORIGKM and YORIGKM (see **iCOMMON**) should take into account the DGRID entry from **iSTART**. If DGRID is large compared to terrain features, terrain influences on the meteorology can be averaged or shifted and thus may strongly impact the air dispersion predictions.

LCCSUBSAMPLE

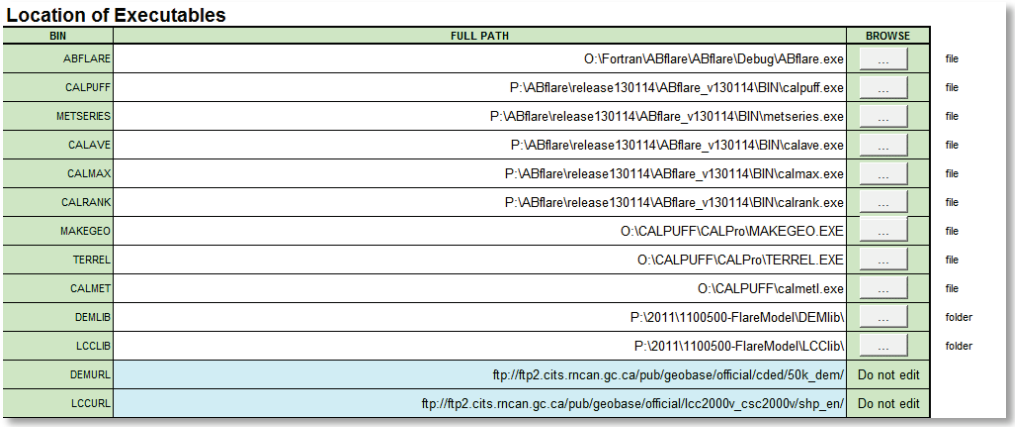
The LCCSUBSAMPLE setting is used to control the number of land-use LCC sub-samples used in the LCC processing of each grid cell. The default setting is LCCSUBSAMPLE=3 which divides each grid cell into 3 regions both vertically and horizontally. Therefore, the LCC shape file polygons are sampled 9-times for each grid cell to characterize the land-use. For a DGRID=250 m the LCCSUBSAMPLE=3 setting will sample land-use every 80 m. Reducing LCCSUBSAMPLE=1 (one sample per grid cell) causes the division of the grid cell coarser and the representation of the land-use for each grid cell will be less representative of the area while reducing the computational effort to characterize the grid cell. Similarly, increasing LCCSUBSAMPLE=5 (25 samples per grid cell) causes the grid cells to be divided into small sub-areas and may better characterize the grid cell land-use at the expense of computational effort.

DXMIN

The DXMIN setting is used to define the minimum receptor distance along the fenceline according to the AQMG. The default setting is DXMIN=20 m.

iBIN PAGE

The **iBIN** page is used to record the folder location and executable names of the binaries for each of the modules listed. The [...] browse buttons can be used to navigate the folder tree(s) to locate each of the files. Once the values have been set, they are copied to the computer system registry so that if the user uses multiple version of the *ABflareUI*.xlsm spreadsheet, all spreadsheets on the user's computer will synchronize to the same binaries when the spreadsheet opens.



Location of Executables

BIN	FULL PATH	BROWSE	
ABFLARE	O:\Fortran\ABflare\ABflare\Debug\ABflare.exe	...	file
CALPUFF	P:\ABflare\release130114\ABflare_v130114\BIN\calpuff.exe	...	file
METSERIES	P:\ABflare\release130114\ABflare_v130114\BIN\metseries.exe	...	file
CALAVE	P:\ABflare\release130114\ABflare_v130114\BIN\calave.exe	...	file
CALMAX	P:\ABflare\release130114\ABflare_v130114\BIN\calmax.exe	...	file
CALRANK	P:\ABflare\release130114\ABflare_v130114\BIN\calrank.exe	...	file
MAKEGEO	O:\CALPUFF\CALPro\MAKEGEO.EXE	...	file
TERREL	O:\CALPUFF\CALPro\TERREL.EXE	...	file
CALMET	O:\CALPUFF\calmetl.exe	...	file
DEMLIB	P:\2011\1100500-FlareModel\DEMlib\	...	folder
LCCLIB	P:\2011\1100500-FlareModel\LCClib\	...	folder
DEMURL	ftp://ftp2.cits.rncan.gc.ca/pub/geobase/official/cded/50k_dem/	Do not edit	
LCCURL	ftp://ftp2.cits.rncan.gc.ca/pub/geobase/official/lcc2000v_csc2000v/shp_en/	Do not edit	

Most of the entries refer to a specific file, while DEMLIB and LCCLIB refer to the base of the folder tree to be used to collect and store DEM and LCC files.

During normal operation of *ABflareUI*, DEM or LCC files will be required to characterize land heights (DEM files) or land-use (LCC files). The data for these are down loaded from free websites for Canadian locations in a specific format(s). *ABflareUI* will download DEM or LCC files if not found within the DEMLIB or LCCLIB folder tree. The user can download all the files for a large region using an FTP client software and storing the 1:50,000 scale maps in the proper tree structure. Thus all the necessary files are available off-line at any time. Or the user, can incrementally build the library as required. Both have advantages and disadvantages. Forcing *ABflareUI* to download each time makes *ABflareUI* use the most recently available data, whereas using the off-library only makes modelling runs consistent between projects. See also the settings for mdemget and mlccget on the **iSTART** page.

iCOMMON Page

The **iCOMMON** page is used to specify the domain location information. This information is common to several modules of the *CALPUFF* modelling system.

The mapping and projection inputs are listed in the table below. These inputs mirror the inputs required for the mapping and projection inputs for *CALMET* and *CALPUFF*. The most convenient and therefore the most common input projection is PMAP=UTM coordinates. If the UTM projection is selected, then FEAST, FNORTH, RLAT0, RLON0, are not required and may be left blank.

For consistency and ease of entry between different modelling input files, a browse button has been added to the right of FEAST and FNORTH. Use the browse button to load the inputs you may have already entered for the creation of a *CALMET* or *CALPUFF* file. The *CALMET* or *CALPUFF* file must exist. The mapping and projection group entries are read from the *CALMET* or *CALPUFF* file and loaded into the *ABflare* input group.

Dropdown list selection boxes are provided for PMAP and DATUM entries to prevent user entry errors. Select the projection and map data datum used from the list of recognized entries.

VARIABLE	INPUT	DESCRIPTION
PMAP	UTM	Map projection, see list to right — UTM
FEAST	0	False Easting and Northing (km) at the projection origin (Used only if PMAP= TTM, LCC, or LAZA)
FNORTH	0	
IUTMZN	11	UTM zone (1 to 60) (Used only if PMAP=UTM)
UTMHEM	N	Hemisphere for UTM projection? (N or S) (Used only if PMAP=UTM)
RLAT0	0N	Latitude and Longitude (decimal degrees) of projection origin (Used only if PMAP= TTM, LCC, PS, EM, or LAZA) e.g.,. RLAT0=60N, RLON0=115W
RLON0	0E	
XLAT1	0N	Matching parallel(s) of latitude (decimal degrees) for projection (Used only if PMAP= LCC or PS)
XLAT2	0N	
DATUM	NAR-B	Datum-region for output coordinates, see list to right — NAR-B
UNITS	KM	m or km
ABTZ	UTC-0700	UTC time zone for output PST = UTC-0800, MST = UTC-0700 ,
NX	120	No. X grid cells
NY	120	No. Y grid cells
DGRIDKM	0.25	Grid spacing
XORIGKM	481	X Coordinate, Reference grid coordinate of SOUTHWEST corner of grid cell (1,1)
YORIGKM	6176	Y Coordinate, Reference grid coordinate of SOUTHWEST corner of grid cell (1,1)

In the upper right of the **iCOMMON** page there is a Load from AERflare button and a Load from *.INP browse button. Load from AERflare is used to load an *AERflare* spreadsheet and extract location information from a screening assessment already completed. Load from *.INP is used to read location information from an existing *CALMET* input file. The *CALMET* input may be from an existing template file or a project already completed in the same area.

Use the Load from *.INP browse button adjacent the FEAST and FNORTH input area to load mapping and projection data from existing *CALMET*.inp or *CALPUFF*.inp files.

PMAP

PMAP is the projection mapping scheme to be used. *CALMET*/*CALPUFF* currently support Universal Transverse Mercator (UTM) grid, Lambert Conformal Projection (LCC) and Tangential Transverse Mercator (TTM). Lambert Conformal Projection should be used when the modeling domain is large, (> 300 km), because a Lambert Conformal grid accounts for the earth's curvature. If the LCC option is specified, the user-specified standard parallels (latitudes) and reference longitude to calculate a "cone constant" and the east-west distance from the reference longitude. The reference longitude is the longitude at which true north and map north are defined to be the same. It also defines where x=0 in the Lambert Conformal grid. The reference latitude defines where y=0 in the Lambert Conformal grid (see Scire et al 2000b).

FEAST, FNORTH

FEAST and FNORTH are the false easting and false northing values (see Scire et al 2000b).

iUTMZN

iUTMZN is the UTM zone number (1 to 60) (see Scire et al 2000b).

UTMHEM

UTMHEM is the hemisphere for UTM projection, entered as either 'N' or 'S' (see Scire et al 2000b).

RLAT0, RLON0

Latitude and Longitude (decimal degrees) of the projection origin. These are not used when PMAP='UTM' (see Scire et al 2000b).

XLAT1, XLAT2

Standard reference latitudes (see Scire et al 2000b). These are not used when PMAP='UTM'.

DATUM

The Datum-Region for the output coordinates is identified by a character string. Many mapping products currently available use the model of the Earth known as the World Geodetic System 1984 (WGS-84). Other local models may be in use, and their selection in *TERREL* will make its output consistent with local mapping products. The list of Datum-Regions with official transformation parameters is provided by the National Imagery and Mapping Agency (NIMA) (see Scire et al 2000b).

UNITS

For the *CALMET*/*CALPUFF* modelling system all locations are referenced in units of kilometres, UNITS='KM'. When the MDSPMOD=2 to create output for *AERMOD*, then the UNITS='M' should be used.

ABTZ

ABTZ defines the base time zone used for the entire simulation. This must match the base time zone of the meteorological data. The time zone is specified in hours relative to UTC (see Scire et al 2000b).

NX, NY

Together with DGRIDKM, the entries for NX and NY define the size of the meteorological modelling domain. These settings must match for both *CALMET* and *CALPUFF* configuration. NX is the number of grid cells in the east-west direction of size DGRIDKM. NY is the number of grid cells in the north-south direction of size DGRIDKM. The cells start at coordinates XORIGKM and YORIGKM at the lower left corner of a grid cell.

DGRIDKM

The size of a grid cell in the *CALMET* and *CALPUFF* configuration. A grid cell has equal dimensions in the east-west and north-south direction, with units of 'KM'.

XORIGKM, YORIGKM

Reference Coordinates of southwest corner of grid cell (1, 1) (see Scire et al 2000b). If the Lambert Conformal projection was selected, then the XORIGKM and YORIGKM and all the (x, y) coordinates must fit the chosen Lambert Conformal grid. Othewise, for PMAP=UTM, the XORIGKM and YORIGKM are the UTM coordinates in KM units. The selection of XORIGKM and YORIGKM should take into account the DGRID entry from **iSTART**. If DGRID is large compared to terrain features, terrain influences on the meteorology can be averaged or shifted and thus may strongly impact the air dispersion predictions.

STEP 0a-CALMET Page

This page can be used to create and run *CALMET* meteorological file to create an output that is a prerequisite for running the *ABflare.exe* source model. The Step 0a-CALMET page is divided into six sub-steps.

The sub-steps walk the user through the development of *CALMET* meteorological file(s) required for *ABflareUI* and *CALPUFF* dispersion modelling.

Step	Title	Purpose
0a-1	Get MMEU Data	**OPTION A:** This step assists the user in specifying the coordinates and the domain size to be entered into the *MMEU* module for meteorological data extraction of the AESRD MM5 meteorological data for 2002-2006. The output from the MMEU is a 3D.dat file(s) for each year of the assessment. **OPTION B:** This step assists the user to extract the MM5 data and create a 3D.dat file(s) using an automated process.
0a-2	Get LCC Data	Land use classification characterization (LCC) data is downloaded from free web sources for Canadian locations and then used to calculate averages for the study domain.
0a-3	Extract DEM data	Digital elevation model (DEM) is downloaded from free web sources and is reformatted for input to the terrain processing module.
0a-4	Make TERREL.dat	The terrain processing module for CALMET is called TERREL. This module is used to create a processed terrain file, TERREL.dat for use in the CALMET program.
0a-5	Create GEO.dat Files for each season	The LCC data is combined with representative albedo, Bowen ratio, heat flux and surface roughness for each LCC. The processing module MAKEGEO is used to combine LCC data and these meteorological variables to create seasonal inputs for CALMET.
0a-6	Make CALMET file	The final step combines 3D.dat, TERREL.dat and seasonal GEO.dat files with processing by CALMET to

create, typically, monthly meteorological files for each year of the assessment.

Step 0a-1 Get MMEU Data

Manual Method

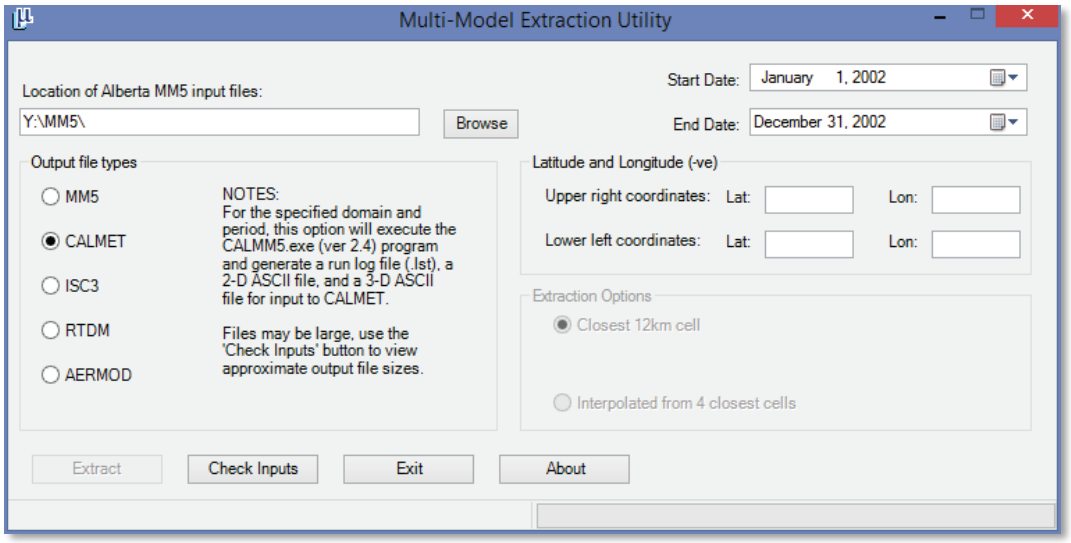
This step assists the user in the extraction of the MM5 data from AESRD using the *MMEU* utility. The MM5 data and the *MMEU* utility may be downloaded from the web from:

http://www.albertamm5data.com/

The following sub-steps guide the user through the meteorological data extraction process:

1. Press REFRESH button on this page (see right). This will copy the mapping and projection information entered on the **iCOMMON** page and convert the information to coordinates that can be used to specify the modelling domain in *MMEU*. (Multi-Model Extraction Utility program).

2. Start the *MMEU* Multi-Model Extraction Utility. You will be asked to agree to an end-user agreement. Press Agree to continue. The main *MMEU* dialog window (version 2.2) will appear similar to the one below.



3. In the *MMEU* dialog window, select the `'CALMET'` output file type.

4. In the *MMEU* dialog window, enter the lower-left (LL) coordinates of your modelling domain, as listed in the table (example is below).

	UTM X	UTM Y	Latitude	Longitude
Lower Left	673183	5498080	49.6104	-114.6027
Upper Right	703183	5528080	49.8706	-114.1723
Centre	688183	5513080	49.7407	-114.3881

5. For computational speed and file size limits, it is better to limit the data extraction to yearly groups. Therefore, this process will have to be repeated for each year of the assessment. Enter start date is January 1, 2002 and end date is January 1, 2003 (allowing for carry over).

6. In the *MMEU* dialog window, press Check Inputs button to ensure inputs are valid.

7. In the *MMEU* dialog window, press Extract button to start extraction process using *MMEU.*

8. A dialog window will appear. Select the folder to where the meteorological data to will be extracted. .Enter the location for the list, 2D.dat and 3D.dat files. .Ensure that the lowest extraction level is 1 and the highest extraction level is 30. .Record your entries for use in Step 3 below. Press OK to proceed with the extraction. The extraction process can take several hours depending upon the computer and network speed. It is therefore best to plan ahead to ensure that this Step 0a-1 is performed well in advance of the analysis.

It is best to plan ahead to ensure that this **Step 0a-1** is performed well in advance of the analysis.

Advanced users also can extract MM5 data into 3D.dat files using the *CALMM5*.exe processor. *CALMM5*.exe is well suited for batch file operations and is available from http://www.src.com/calpuff/calpuff1.html

Automated Method

This step assists the user in the extraction of the MM5 data from AESRD using the *CALMM5* utility. The MM5 data and the *CALMM5* utility may be downloaded from the web from:

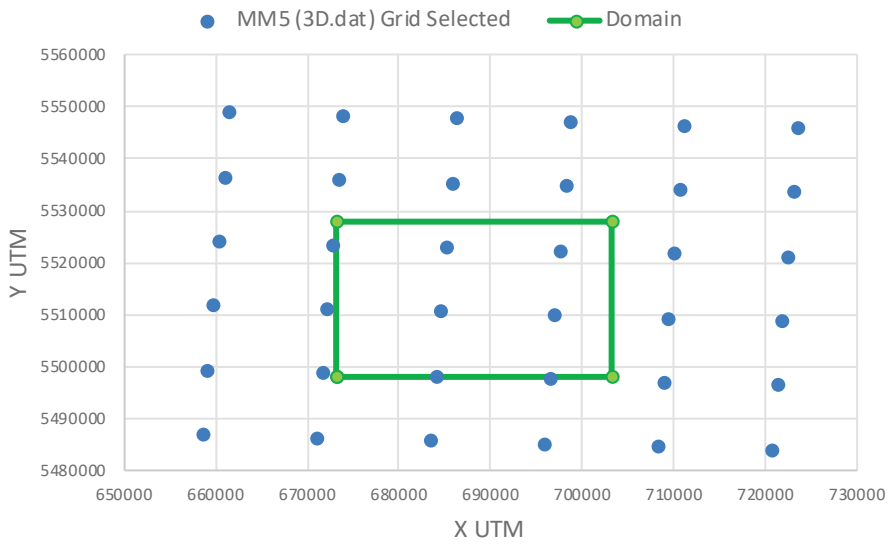
http://www.albertamm5data.com/
http://www.src.com

The following sub-steps guide the user through the meteorological data extraction process:

1. Press REFRESH button on this page (see right). This will copy the mapping and projection information entered on the **iCOMMON** page and convert the information to coordinates that can be used to specify the modelling domain.

	UTM X	UTM Y	Latitude	Longitude
Lower Left	673183	5498080	49.6104	-114.6027
Upper Right	703183	5528080	49.8706	-114.1723
Centre	688183	5513080	49.7407	-114.3881
UTM Zone	11			
Grid Coordinates	i : west/east	j : south/north		
Lower Left	36	10	Refresh Chart	
Upper Right	41	15		

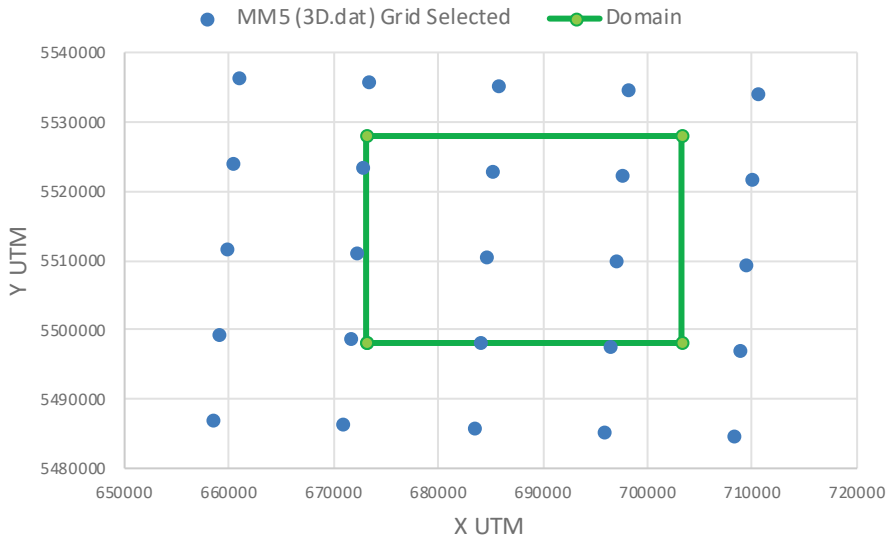
2. The table in 0a-1 is populated, as shown in the example above. The lower left, upper right and centre locations of the domain based upon the information provided on the **iCOMMON** page (i.e., based upon the lower left, nx, ny and grid size). The REFRESH button also estimates the grid coordinates of MM5 data surrounding the domain. The MM5 coordinates are plotted relative to the domain in the figure below the table. *CALMET* works best if the MM5 data exceeds the domain size but file size and numerical processing time increase if the MM5 grid is too large. The example in the figure below, the initial guess by *ABflareUI* shows the MM5 grid could be adjusted lower.



The user can manually adjust the grid by entering MM5 grid coordinates as shown below. Here we lower the top and right coordinates. Pressing Press REFRESH CHART button updates the chart with the table data.

	UTM X	UTM Y	Latitude	Longitude
Lower Left	673183	5498080	49.6104	-114.6027
Upper Right	703183	5528080	49.8706	-114.1723
Centre	688183	5513080	49.7407	-114.3881
UTM Zone	11			
Grid Coordinates	i : west/east	j : south/north		
Lower Left	36	10	Refresh Chart	
Upper Right	40	14		

The revised MM5 grid spacing surrounds the domain.



3. Enter the path for the MM5 raw data and the skeleton filename for the MM5 data. The Alberta MM5 data fileset is composed using the skeleton name: `MM5_XYEARX_XJDAYX_Alberta_12km_MMEU.out`
Where XYEARX and XJDAYX are variables to be replaced with the year and Julian day of interest. Enter the date ranges for each year to be extracted.

MM5 to 3D.dat Data Extraction using CALMM5

Existing File Name Template	MM5_XYEARX_XJDAYX_Alberta_12km_MMEU.out		Reset				
Input Existing MM5 Data Path	Y:\MM5\		...				
Output 3D.dat	Y:\ABflare\AERflare_examples\Example4\met\puf\3dXYEARX.dat		...				
Start of Period			End of Period				Reset Dates
iyr	imo	iday	iyr	imo	iday		
2002	1	1	2003	1	1		Run
2003	1	1	2004	1	1		Run
2004	1	1	2005	1	1		Run
2005	1	1	2006	1	1		Run
2006	1	1	2007	1	1		Run

4. Typical assessments use a complete year of data for year of assessment. Enter month 1 and day 1 to start and enter the start day of the following year to end the extraction period. This will ensure the complete year is extracted.

5. Adjacent to each row of the MM5 extraction date range is a RUN button. When the RUN button is pressed an asynchronous process is launched to run *CALMM5* to create a `3D_XYEARX`.dat file, where `XYEARX` is the start year of the extraction.

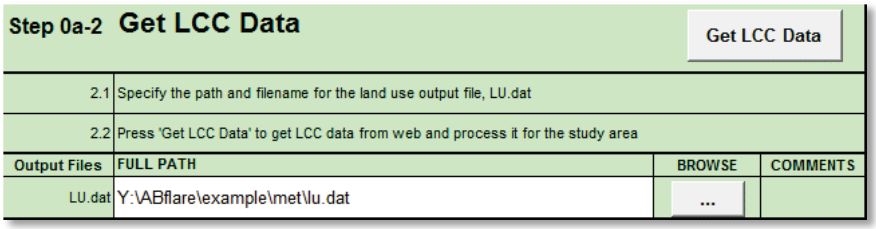
6. The *CALMM5* extraction can take approximately 20min, depending upon the speed the computer and network.

Step 0a-2 Get LCC Data

In this sub-step, land use classification characterization (LCC) data is downloaded from free web sources for Canadian locations and then used to calculate averages for the study domain. The domain is defined on the **iCOMMON** page.

The following sub-steps guide the user through the process of acquiring LCC data and creating the LU.dat file.

1. In the entry below, specify the path and filename for the land use output file, LU.dat. The ... browse button can be used to assist the user in navigating to a folder to specify the file.



2. Press Get LCC Data to get LCC data from web and process it for the study area. During the process, the MAP SHEETS field will be updated with the 1:250,000 scale map sheets used in the analysis.

The processing involves extraction of geographic information systems (GIS) shape files that define polygons of land-use. Each grid cell is divided vertically and horizontally LCCSUBSAMPLE times (see **iSTART**). The Canadian LCC codes are converted to *CALPUFF* codes using the conversion chart on the **sLCC DOC** page.

The output from the Get LCC Data processing is displayed in the table below this processing sub-group. An example of the output is shown below. The table shows the number of sub-sample counts and the fraction of the domain that that is represented by each LCC. In this case, the domain is 97.8% cropland. The user should verify that this interpretation of the land-use for the domain is valid.

CALPUFF Landuse Classification Code Summary

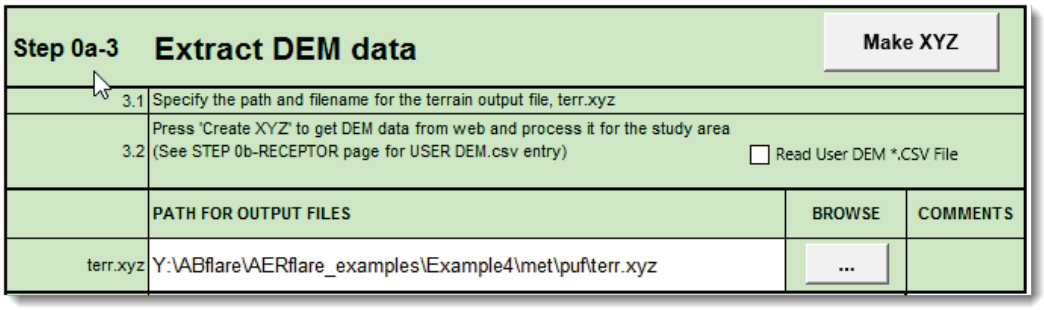
ID	LCC	Description	Count	Percent
0	0	Unknown/Missing/Cloud/Shadow	0	0.0%
1	11	Residential	0	0.0%
2	12	Commerical and Services	0	0.0%
3	13	Industrial	0	0.0%
4	14	Transport/Comm/Utils	0	0.0%
5	15	Industry/Commercial Complexes	0	0.0%
6	16	Mixed Urban or Built-up Land	1476	1.1%
7	17	Other Urban or Built-up Land	0	0.0%
8	21	Croplandand Pasture	126801	97.8%
9	22	Orchards, etc..	0	0.0%
10	23	Confined Feeding Operations	0	0.0%
11	24	Other Agricultural Land	0	0.0%
12	31	Herbaceous Rangeland	0	0.0%
13	32	Shrub and brush Rangeland	0	0.0%
14	33	Mixed Rangeland	0	0.0%
15	41	Deciduaous Forest Land	522	0.4%
16	42	Evergreen Forest Land	0	0.0%
17	43	Mixed Forest Land	0	0.0%
18	51	Streams and Canals	0	0.0%
19	52	Lakes	72	0.1%
20	53	Reservoirs	0	0.0%
21	54	Bays and estuaries	0	0.0%
22	55	Oceans and Seas	0	0.0%
23	61	Forested wetland	153	0.1%
24	62	Nonforested wetland	0	0.0%
25	71	Dry salt flats	0	0.0%
26	72	Beaches	0	0.0%
27	73	Sandy areas other than beaches	9	0.0%
28	74	Bare Exposed Rock	0	0.0%
29	75	Strip Mines, Quarries and Gravel pits	0	0.0%
30	76	Transitional areas	0	0.0%
31	77	Mixed barren land	0	0.0%
32	81	Shrub and brush tundra	0	0.0%
33	82	Herbaceous tundra	567	0.4%
34	83	bare ground	0	0.0%
35	84	Wet tundra	0	0.0%
36	85	Mixed tundra	0	0.0%
37	91	Perennial snow or ice	0	0.0%
38	92	Glaciers	0	0.0%
		Total	**129600**	**100.0%**
		Minimum count in cell	9	
		Maximum count in cell	9	

Step 0a-3 Extract DEM data

The digital elevation model (DEM) data is downloaded from free web sources and is reformatted for input to the terrain processing module.

The following sub-steps guide the user through the process of acquiring DEM data and creating the `TERR.xyz` file.

1. In the entry below, specify the path and filename for the terrain xyz, comma separated output file, `TERR.xyz`. The [...] browse button can be used to assist the user in navigating to a folder to specify the file.



2. Press Create XYZ button to get DEM data from web and process it for the study area. During the process, the MAP SHEETS field will be updated with the 1:50,000 scale map sheets used in the analysis.

The output file is a comma separated file. The first row contains the UTM zone in the third column, as shown in the example below. The first two columns are X,Y in UTM coordinates units of metres, followed by the terrain elevation in metres.

```
1,1,11
484299.4,6176011.9,581.0
484299.5,6176035.1,581.0
484299.5,6176058.3,581.0
484299.6,6176081.5,581.0
484299.7,6176104.7,581.0
```

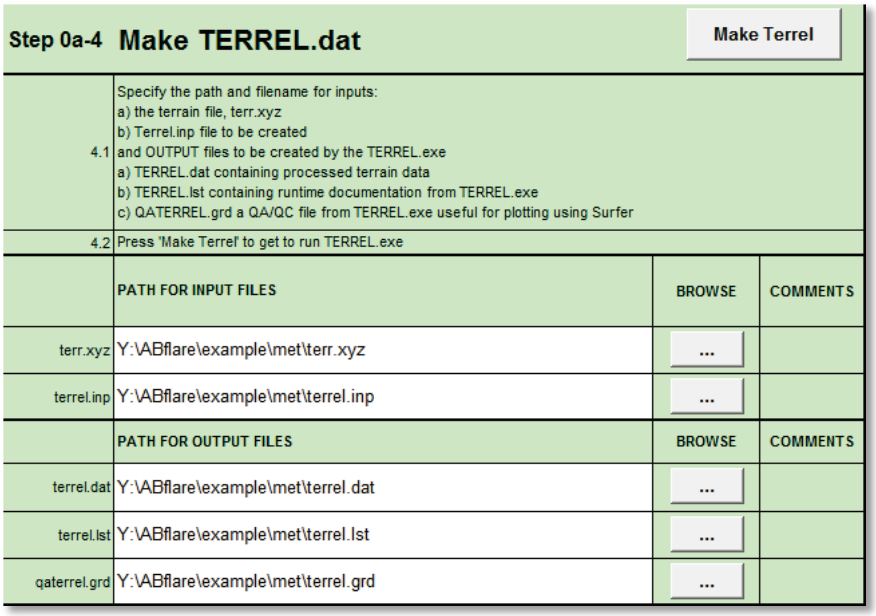
3. The Extract DEM data step also allows the user to specify a comma formatted file (.csv) as input rather than CDEM file download. This allows the user to make use of preprocessed elevation data. The file format is x,y,z with no header row. Check the 'Read User DEM *.csv' option then press Create XYZ.

Step 0a-4 Make TERREL.dat

The terrain processing module for *CALMET* is called *TERREL*. This module is used to create a processed terrain file, `TERREL.dat`, for use in the *CALMET* program.

The following sub-steps guide the user through the process of creating the `TERREL.dat` file.

1. There are two sets of entries, one of INPUT files and the other for OUTPUT files. The `TERR.xyz` is a comma separated file listing the utm zone and raw DEM data for the modelling domain. This file could be created in the Step 0a-3 or a file created by the user. The second file is the name of a control settings file that will be created by *ABflareUI* and is used as the input file for *TERREL*. The [...] browse buttons can be used to assist the user in navigating to a folder to specify the files.



Step 0a-4 **Make TERREL.dat**			Make Terrel
4.1	Specify the path and filename for inputs: a) the terrain file, terr.xyz b) Terrel.inp file to be created and OUTPUT files to be created by the TERREL.exe a) TERREL.dat containing processed terrain data b) TERREL.lst containing runtime documentation from TERREL.exe c) QATERREL.grd a QA/QC file from TERREL.exe useful for plotting using Surfer		
4.2	Press 'Make Terrel' to get to run TERREL.exe		
	PATH FOR INPUT FILES	BROWSE	COMMENTS
terr.xyz	Y:\ABflare\example\met\terr.xyz	...	
terrel.inp	Y:\ABflare\example\met\terrel.inp	...	
	PATH FOR OUTPUT FILES	BROWSE	COMMENTS
terrel.dat	Y:\ABflare\example\met\terrel.dat	...	
terrel.lst	Y:\ABflare\example\met\terrel.lst	...	
qaterrel.grd	Y:\ABflare\example\met\terrel.grd	...	

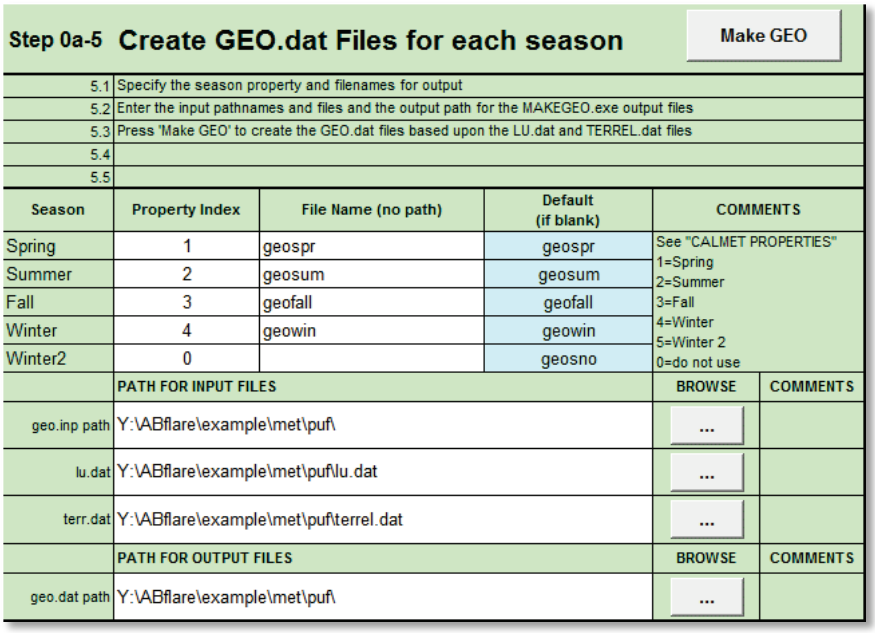
There are two sets of entries, one of INPUT files and the other for OUTPUT files. The `TERR.xyz` is a comma separated file listing the UTM zone and raw DEM data for the modelling domain. This file could be created in the Step 0a-3 or a file created by the user. The second file is the name of a control settings file that will be created by *ABflareUI* and is used as the input file for *TERREL*.exe. The [...] browse buttons can be used to assist the user in navigating to a folder to specify the files.

The `TERREL.dat` file will be created by the *TERREL*.exe processing. It will contain processed terrain elevations for each grid cell based upon the `TERR.xyz` input file. The `TERREL.lst` file will contain a listing of the inputs as interpreted by *TERREL*.exe and will list any warnings or errors. The output file `QATERR.grd` is a Surfer format grid file. It is useful for verification that the terrain elevations have been entered correctly and represent that intended region.

2. Press Make Terrel button to process the terrain using *TERREL*.exe. When the processing is completed the `TERREL.lst` file will be displayed. The user should scroll to the bottom and confirm that the program was run successfully and that there are no errors or warnings.

Step 0a-5 Create GEO.dat Files for each season

The terrain and LCC data is combined with representative albedo, Bowen ratio, heat flux and surface roughness for each LCC. The processing module *MAKEGEO* is used to combine LCC data and these meteorological variables to create seasonal inputs for *CALMET*.



Step 0a-5 Create GEO.dat Files for each season — Make GEO

5.1	Specify the season property and filenames for output
5.2	Enter the input pathnames and files and the output path for the MAKEGEO.exe output files
5.3	Press 'Make GEO' to create the GEO.dat files based upon the LU.dat and TERREL.dat files
5.4	
5.5	

Season	Property Index	File Name (no path)	Default (if blank)	COMMENTS
Spring	1	geospr	geospr	See "CALMET PROPERTIES"
Summer	2	geosum	geosum	1=Spring
Fall	3	geofall	geofall	2=Summer
Winter	4	geowin	geowin	3=Fall
Winter2	0		geosno	4=Winter 5=Winter 2 0=do not use

	PATH FOR INPUT FILES	BROWSE	COMMENTS
geo.inp path	Y:\ABflare\example\met\puf\	...	
lu.dat	Y:\ABflare\example\met\puf\lu.dat	...	
terr.dat	Y:\ABflare\example\met\puf\terrel.dat	...	
	PATH FOR OUTPUT FILES	**BROWSE**	**COMMENTS**
geo.dat path	Y:\ABflare\example\met\puf\	...	

The following sub-steps guide the user through the creation of the GEO.dat files for each season.

1. The default configuration for a flaring assessment divides the year into four seasons: spring, summer, fall and winter. The winter season assumes snow cover. In the Property Index column, specify the season index corresponding to the desired season. The parameters for each Property Index season are defined on the **sLCC** page.

Property Index	Season	Description
0	Do not use	Use this setting to exclude this season from the assessment.

1	Spring	No snow cover, vegetation in transition.
2	Summer	No snow cover, vegetation in full leaf growth.
3	Fall	No snow cover, vegetation in transition to dormant state.
4	Winter	Snow cover, vegetation may be in partial snow cover.
5	Winter 2	No snow cover, vegetation dormant.

2. Specify the complete path for the input files already created in the steps above for, `LU.dat` and `TERREL.dat`. Also, specify the folder where the *MAKEGEO*.exe input control files will be created for each of the seasons. The LU.dat file could be created using other third party software as long as the domain match the settings on **iCOMMON**.

3. Specify the output folder for where the *MAKEGEO*.exe output `GEO.dat` files will be created. These files will be required in the next step of the meteorological file creation process.

4. Press the Make GEO button to create each of the four or five `GEO.dat` files specified in sub-step 1. When the processing is completed the `GEO.lst` file will be displayed for the last season. The user should scroll to the bottom and confirm that the program was run successfully and that there are no errors or warnings. The user should also read the `.lst` files for the other seasons to confirm there are no errors or warnings in those files.

Interesting but not explicitly accounted for in the modelling. The Calgary extreme daily snowfall for June, July and August is 24.9 cm, 0.3 cm, 0.6 cm (Canada Climate Normals). The month with the highest extreme daily snow fall is June. The Edmonton extreme daily snowfall for June, July and August is 0 cm, 0 cm, 2 cm (Canada Climate Normals).

Step 0a-6 Make CALMET file

The final step combines `3D.dat`, `TERREL.dat` and seasonal `GEO.dat` files with processing by *CALMET* to create, typically, monthly meteorological files for each year of the assessment.

The following sub-steps guide the user through the creation of the `CALMET.dat` files for each season.

1. Because only prognostic data are being used in the creation of the *CALMET* data files, the only *CALMET* setting required is for TERRAD. Refer to the *CALMET* documentation for a complete description of the TERRAD setting. This setting adjust the weighting terrain influences on the meteorological outputs such as slope flows and terrain influenced wind directions. Typical range for TERRAD is 10 km to 15 km, with 12 km being a good estimate. The TERRAD selection can be confirmed by reviewing the detailed meteorological output from *CALMET*.exe on an hourly basis to determine whether the wind directions are appropriate with respect to seasonal or time of day compared to expected wind field patterns through complex terrain.

TERRAD	12	

The interpretation of *CALMET* output may require specific technical background in meteorology. Meteorology is one the principal inputs in air dispersion modelling.

2. The second set of inputs required for *CALMET*.exe is the specification of the boundary layer face heights. The Alberta Air Quality Model Guideline (ESRD 2013) specifies a default 12 layer boundary to be used for *CALPUFF* modelling as listed below. Higher resolution in the heights near the stack and plume heights can be used in alternative modeling scenarios to better characterize the effects of shear and dispersion in that region.

zFACE Meteorlogical Layers Definition

NZFACE	12	The number of layers of meteorology	
ZFACE	Elevation (m)	Default (m)	Depth (m)
0	0	0	0
1	20	20	20
2	40	40	20
3	80	80	40
4	120	120	40
5	280	280	160
6	520	520	240
7	880	880	360
8	1320	1320	440
9	1820	1820	500
10	2380	2380	560
11	3000	3000	620
12	4000	4000	1000
13			
14			
15			

3. The third step is to specify dates and corresponding `GEO.dat` files. For typical modelling domains, the meteorological files can be quite large and depending upon the computer platform (Windows operation system, Linux,

and/or hard drive configuration) large files (greater than about two gigabytes) may not be supported or may be difficult to manage (for example, backups). It is recommended that yearly meteorology be divided into monthly divisions. For a typical assessment of five years, this will create 60-monthly meteorological input files, each about 2 gigabytes in size. *ABflareUI* requires the inputs below for each year of the assessment. The start and end date and time for each month is specified and the `GEO.dat` file to be used for each month period is specified. The `GEO.dat` files were created in **0a-5 Create GEO.dat** step (see above).

Date Options Group

NSECDT	3600	Time interval				
Date	iyr	imo	iday	ihr	isec	GEODAT
Met 1-Start	2002	1	1	0	0	geosum
End	2002	1	31	23	3600	
Met 2-Start	2002	2	1	0	0	geowin
End	2002	2	28	23	3600	
Met 3-Start	2002	3	1	0	0	geospr
End	2002	3	31	23	3600	
Met 4-Start	2002	4	1	0	0	geospr
End	2002	4	30	23	3600	
Met 5-Start	2002	5	1	0	0	geospr
End	2002	5	31	23	3600	
Met 6-Start	2002	6	1	0	0	geosum
End	2002	6	30	23	3600	
Met 7-Start	2002	7	1	0	0	geosum
End	2002	7	31	23	3600	
Met 8-Start	2002	8	1	0	0	geosum
End	2002	8	31	23	3600	
Met 9-Start	2002	9	1	0	0	geofall
End	2002	9	30	23	3600	
Met 10-Start	2002	10	1	0	0	geofall
End	2002	10	31	23	3600	
Met 11-Start	2002	11	1	0	0	geofall
End	2002	11	30	23	3600	
Met 12-Start	2002	12	1	0	0	geowin
End	2002	12	31	23	3600	

The default division of the year is listed below:

Month Range	GEO.dat File	Description
Mar-May	GEOspring.dat	No snow, transition to full vegetation.
Jun-Aug	GEOsummer.dat	No snow, full vegetation.
Sep-Nov	GEOfall.dat	No snow, transition to dormant vegetation.
Dec-Feb	GEOwinter.dat	Snow cover, dormant vegetation.

The inputs for the **Date Options Group**, shown previously, are displayed for the 2002 year. The process must be completed for each year of the meteorological assessment 2002, 2003, 2004, 2005 and 2006 according to the Alberta Air Quality Model Guideline (ESRD 2013).

The NSECDT variable is used to control the time step used in the meteorological processing. By default, the time step is 3600 sec. This time step corresponds to the same time step in the meteorological `3D.dat` file being processed. The same time step must be used in the *CALPUFF* modelling configuration. Non-default flaring assessments can process the meteorology using an NSECDT setting that is different than the `3D.dat`

file time step, for instance NSECDT=600 sec. Processing in this way will allow *CALMET* to create time steps of 600 sec (10 minutes) based upon 1 h time steps of meteorology. Although the meteorology inherently changes only on 1 h increments, the *CALPUFF* modelling based upon the NSECDT=600 sec will produce 10 min time averages directly, producing short-term peak concentrations and accounting for along-wind diffusion. This may be suitable for air toxics assessments or NSECDT=180 to 600 sec may be appropriate for odour assessments. The *CALPUFF* results would require post-processing using *CALAVE* to create 1 h averages from the NSECDT=600 sec output created by *CALPUFF*.

4. Complete the input and output files and path name input group table. The table lists user inputs for: the path for creation of `CALMET.inp` file by *ABflareUI;* the full path of the `3D.dat` corresponding to the meteorological period being assessed (see also **Step 0a-1 Get MMEU Data**); and, the path where the `GEO.dat` files can be found.

Input Files	FULL PATH	BROWSE	COMMENTS
CALMET.inp path	Y:\ABflare\example\met\puf\	...	
3D.dat	Y:\ABflare\example\met\puf\mm5_02\3d2002.dat	...	
GEODAT.dat path	Y:\ABflare\example\met\puf\	...	
Output Files	**FULL PATH**	**BROWSE**	**COMMENTS**
CALMET.dat path	Y:\ABflare\example\met\puf\	...	

Also required, is the output path for the where the `CALMET.dat` output files for each month will be created. The `CALMET.dat` output files will be created using the following template filename:

`m[YYYY]_[mm].dat`

where `YYYY` is the four digit year, and `mm` is the two digit month number.

YYYY is now controlled using the mdorforeach setting.
The `_[MM]` is a programmed default

5

5. Press the Make CALMET button to create each of the twelve `CALMET.dat` files specified. When the processing is completed the user should review the

`CALMET.lst` files to confirm that the program was run successfully and that there are no errors or warnings. If the mbatonly setting is used, then the button will create the necessary input files and it will create a batch file `run_calmet.bat` that can be executed at a later time.

The process must be completed for each year of the meteorological assessment 2002, 2003, 2004, 2005 and 2006 according to the Alberta Air Quality Model Guideline.

6. Repeat the **0a-6 Make CALMET** file steps for each of the 2002, 2003, 2004, 2005 and 2006 years for the meteorological assessment.

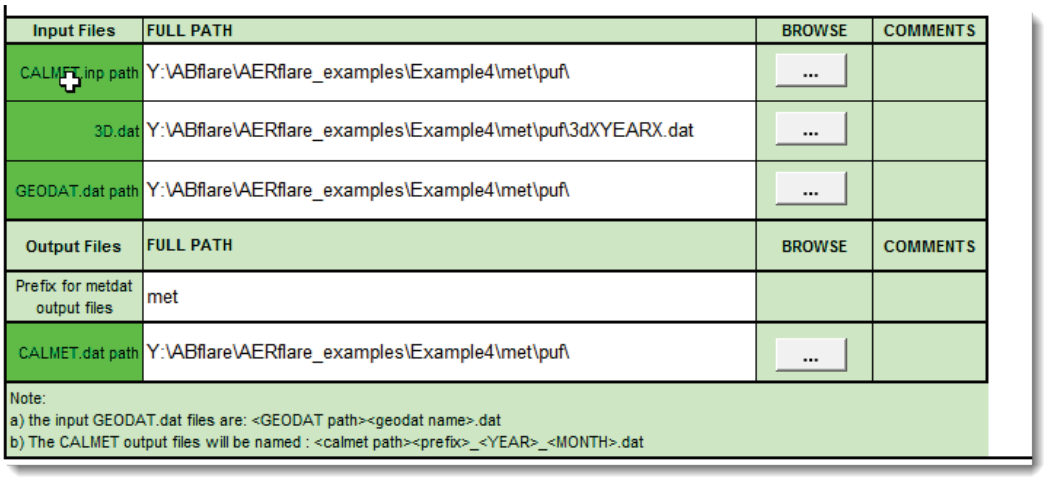
The creation of the CALMET.dat files is numerical intensive and may take extended periods of time. The mbatonly option can be used to create Windows *CMD.exe* batch files so that the *CALMET* creation process can be executed at a later time or divided between several computers.

Alternatively, instead of repeating the steps for each year, the mdoforeach setting can be used. Using the variable XYEARX to represent each year in the sequence 2002, 2003, 2004, 2005 and 2006, the date options group can be written as:

Date Options Group

NSECDT	3600	Time interval				
Date	iyr	imo	iday	ihr	isec	GEODAT
Met 1-Start	XYEARX	1	1	0	0	geowin
End	XYEARX	1	31	23	3600	
Met 2-Start	XYEARX	2	1	0	0	geowin
End	XYEARX	2	28	23	3600	
Met 3-Start	XYEARX	3	1	0	0	geospr
End	XYEARX	3	31	23	3600	
Met 4-Start	XYEARX	4	1	0	0	geospr

And the file name group written as,



Input Files	FULL PATH	BROWSE	COMMENTS
CALMET.inp path	Y:\ABflare\AERflare_examples\Example4\met\puf\	...	
3D.dat	Y:\ABflare\AERflare_examples\Example4\met\puf\3dXYEARX.dat	...	
GEODAT.dat path	Y:\ABflare\AERflare_examples\Example4\met\puf\	...	
Output Files	**FULL PATH**	**BROWSE**	**COMMENTS**
Prefix for metdat output files	met		
CALMET.dat path	Y:\ABflare\AERflare_examples\Example4\met\puf\	...	

Note:
a) the input GEODAT.dat files are: <GEODAT path><geodat name>.dat
b) The CALMET output files will be named : <calmet path><prefix>_<YEAR>_<MONTH>.dat

Here, only the 3D.dat files require individualization with years. If the mbatonly setting is used, then a batch file is created for each year of the mdoforeach list.

STEP 0b-RECEPTOR Page

This page can be used to create a receptor grid that forms part of the *CALPUFF* model input file and is a prerequisite for a modelling assessment.

Field Group	Description
Step 0b-1	Define the receptor grid, location, grid resolution and limits of each nested grid
Step 0b-2	Create the receptors based upon the grid and the options such as user input DEM, sources list, fill interior
Graphics	The receptor grid is represented in a graphic as wells as the fenceline showing the locations of the sources.

Step 0b-1 Define Receptor Grid

Press the REFRESH button to read the flare location coordinates from the **STEP 2-ABFLARE** page. The refresh button also displays the longitude and latitude of the UTM coordinates for reference. The user may alternatively enter the X UTM, Y UTM coordinates manually (without regard to the longitude or latitude values

below the entry) to create a receptor grid centred on the location entered. The grid will be centred on the utm coordinates in the table.

	Centre of Domain
X UTM	496000
Y UTM	6191000
UTM Zone	11
	Conversion to Geographic Coordinates
Longitude	-117.3025
Latitude	55.7294

In the Receptor Grid Spacing table, adjust the receptor grid spacing as desired. The default settings listed in the table define the default receptor grid as specified in the Alberta Air Quality Model Guideline. The user may wish to use a different grid spacing for screening purposes or more refined grid near the location of the point of maximum impingement.

Receptor Grid Spacing

ID	Resolution (m)	Default (m)	Distance	Default	Receptors
1	20	20	100	100	40
2	50	50	500	500	416
3	100	100	500	500	0
4	250	250	2000	2000	264
5	500	500	5000	5000	360
6	1000	1000	10000	10000	320
7	5000	5000	10000	10000	0
				Total	1400

The table has seven layers or Cartesian coordinates grid spacing. By setting a distance equal to an adjacent layer, that layer of receptor is excluded (because it will have zero width relative to the next layer). In the example below, a fenceline is defined at 100 m with 20 m receptor spacing. Beyond the fenceline, to a distance of 2000 m, a receptor spacing of 250 m is used.

Receptor Grid Spacing

ID	Resolution (m)	Default (m)	Distance	Default	Receptors
1	20	20	100	100	40
2	50	50	100	500	0
3	100	100	100	500	0
4	250	250	2000	2000	288
5	500	500	2000	5000	0
6	1000	1000	2000	10000	0
7	5000	5000	2000	10000	0
				Total	328

Entries that differ from the default settings are highlighted in orange colour.

A user defined receptor grid can be inserted into the processing in the next step. The user defined receptor by-passes the **Receptor Grid Spacing** table selections.

Step 0b-2 Create Receptors for CALPUFF

The second step specifies the source of the digital terrain to be used to determine the receptor heights. By default, *ABflareUI* reads DEM data from the DEMlib or downloads the data according to the BIN page. The data is expected to be in Canadian DEM format.

The receptor grid to be processed is specified in the **Step 0b-1** described above. Alternatively, the user may input a comma separated XY data file containing a user defined receptor grid in the same coordinates used in the assessment. This user receptor grid is input into *ABflareUI*, then the DEM processing is applied to each location.

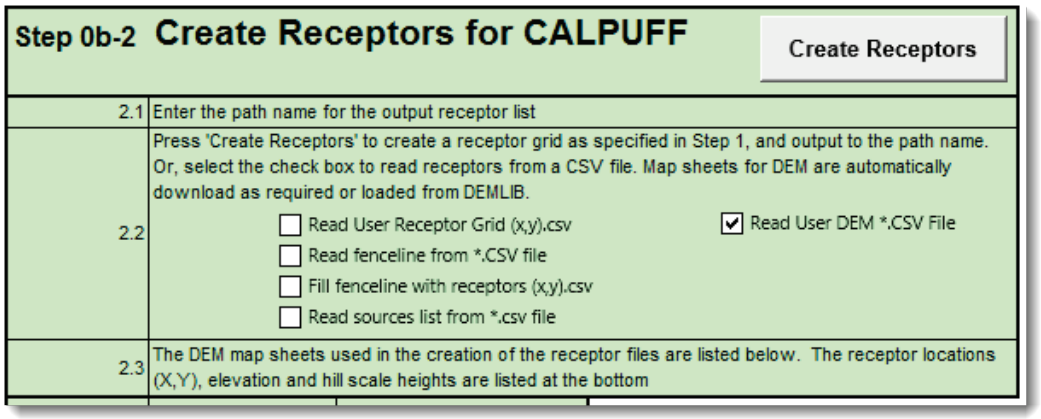
The user may specify flag pole heights for each receptor location as specified by the Flag Pole Receptor Height entry. The flag pole height is applied to each receptor location.

The full path for the output complex file `terrain.ctr` must be specified. This file will be created by *ABflareUI* when the Create Receptors button is pressed. The `terrain.ctr` file will be used as an insert file specifying the receptor locations for the *CALPUFF*.exe input files.

During the processing of the terrain, the Map Sheets field is updated to show the DEM mapsheets used to create the receptor file.

A graphic is displayed at the bottom of the page showing the receptor grid created by *ABflareUI* for references purposes. Below the graphic, is a list of the receptor points and elevations determined from the DEM file. Elevations are determined by triangulation of elevations.

There are several alternative options available as shown in the figure below.



1. the 'Read User DEM *.csv' option allows the user to specify a comma formatted file (.csv) as input rather than CDEM file download. This allows

the user to make use of preprocessed elevation data. The file format is x,y,z with no header row.

2. The 'Read User Receptor Grid (x,y).csv' option allows the user to specify a comma formatted file (.csv) as input containing a list of the discrete receptors to be processed. This option allows the user to specify non-standard grid patterns. The file format is x,y with no header row.

3. The 'Read fenceline from *.csv' option allows the user to specify a comma formatted file (.csv) as input containing the vertices of the fenceline. *ABflareUI* will sub-sample the fenceline with receptor points spaced at DXMIN (see **iSTART**). Note that the centre location of the receptor grid should typically be located within the fenceline.

4. The 'Fill fenceline with receptors' option causes the Create Receptors routine to file the fenceline line area with receptor points using the spacing in the Fill Resolution entry field. The file fenceline with receptors processing will not add a receptor if it is within 5m of a source.

5. The 'Read sources list from *.csv file' option allows the user to specify a list of source(s) locations. Specifying a sources list causes the receptor grid to add a grid of receptors at resolution ID=2, from the *Receptor Grid Spacing* table. This resolution and distance (50m within 500m) matches the minimum receptor spacing requirements according to typical industry practice and is applied to each source.

Receptor processing automatically removes duplicate receptor locations that may have been created by the overlapping grids

STEP 1-METSERIES Page

The **METSERIES** page is composed of five input groups as listed in the table below. The *METSERIES* module is a powerful data extraction tool but entries included in the *ABflareUI* are restricted for the purposes of extracting meteorological time series data. For the other features of *METSERIES,* the user is directed to the *CALPRO* (http://www.src.com/calpuff/calpuff1.htm) GUI.

Field Group	Description
INPUT and OUTPUT FOLDERS	User selects: the folder to contain the output files; root name of the file for output; location of the list file for output.
Output Options	These settings direct *METSERIES* to extract meteorological data at the specified location and height.
Date Options	These settings direct *METSERIES* to extract meteorological data for the specified date range.
Met Files for Extraction	A list of meteorological data files to be processed.

Input and Output Folders Group

The output path (TSFOUT) is the drive, folder and filename path where the output file(s) will be written. The user can make use of the [...] browse button to assist in the navigating folder trees and selecting final location. The output file will have a `.tsf` extension.

The output list file (LSTDAT) is the full path and file name of the list file output which will include an echo of the data read by *METSERIES* and any error or warning messages. The user can make use of the [...] browse button to assist in navigating the folder trees and selecting a file name.

Input and Output Folders Group

VARIABLE	INPUT	BROWSE
Output: TSFOUT.tsf (the extension is auto added)	Y:\ABflare\AERflare_examples\Example4\met\puf\ms_2002.tsf	...
output: LSTDAT List-file name Default: METSERIES.LST	Y:\ABflare\AERflare_examples\Example4\met\puf\ms_2002.lst	...

In the example below, the mdoforeach setting is used and the TSFOUT and LSTDAT have been configured to use the dofor variable `XYEARX`.

Input and Output Folders Group

VARIABLE	INPUT	BROWSE
Output: TSFOUT.tsf (the extension is auto added)	Y:\ABflare\AERflare_examples\Example4\met\puf\ms_XYEARX.tsf	...
output: LSTDAT List-file name Default: METSERIES.LST	Y:\ABflare\AERflare_examples\Example4\met\puf\ms_XYEARX.lst	...

Output Options Group

A dropdown list selection box is provided for the MDATA entry to assist in preventing user entry errors. Alternatively, the user can type a selection into the input box. MetSeries allows several different meteorological inputs, but the typical

settings for MDATA will be `CALMET` (for *CALPUFF* files) and `AERMsurf` or `AERMpfl` (for *AERMOD* files).

Ouput Options Group

VARIABLE	INPUT	DESCRIPTION	
MDATA	CALMET	Input Data Type CALMET	
XESTN	688.183	X-Easting Coordinate (km, deg, or cell)	Not the same as entry on Step2-ABflare
YNSTN	5513.08	Y-Northing Coordinate (km, deg, or cell	Not the same as entry on Step2-ABflare
METSIM	1	1=interpolate; 2=nearest grid cell	
ZWIND	36.59999847	Measurement height (m AGL) for wind (-1. to exclude)	Not the same as entry on Step2-ABflare
ZTEMP	36.59999847	Measurement height (m AGL) for temperature (-1. to exclude)	Not the same as entry on Step2-ABflare
ZRHUM	36.59999847	Measurement height (m AGL) for humidity (-1. to exclude)	Not the same as entry on Step2-ABflare

The example above shows cells that are highlighted. These highlights are described in the comment to the right of the table. The highlights indicate a warning that the entries are different than the same entries on the **STEP 2-ABflare** input page. Typically, the METSERIES should be configured so that the meteorology is output for the stack location and height corresponding to the source on the **STEP 2-ABflare** page.

Date Options Group

The start and end periods of the meteorological data to process are entered in the Data Options Group. The start and end times must be inclusive of the data in the meteorological data being processed.

Date Options Group

	iyr	imo	iday	ihr	isec
Start met	2002	1	1	0	0
End met	2002	12	31	24	0
NSECDT	3600	Time interval			

When a typical 5-year air quality modelling assignment is performed, the mdoforeach setting can be used so that the *Date Options Group* resembles the example below.

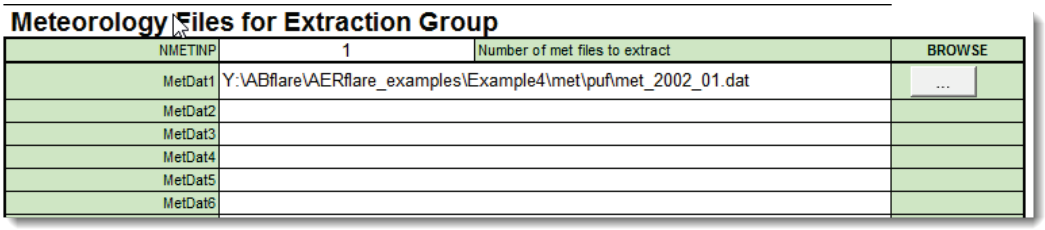
Date Options Group

	iyr	imo	iday	ihr	isec
Start met	XYEARX	1	1	0	0
End met	XYEARX	12	31	24	0
NSECDT	3600	Time interval			

Meteorology Files for Extraction Group

For the meteorology files group the number of meteorological files to process is set using NMETINP entry. The full path and file name of the list of meteorological

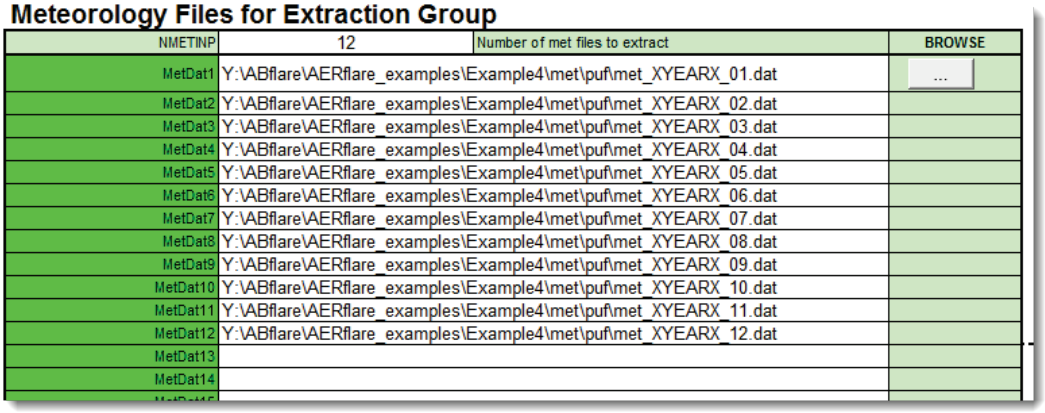
data files to process can be entered in to the list. The first file can be selected using the BROWSE button, and then using the cut and paste functionality of Excel, the user can readily fill in the remaining meteorological file names.



Meteorology Files for Extraction Group

NMETINP	1	Number of met files to extract	BROWSE
MetDat1	Y:\ABflare\AERflare_examples\Example4\met\puf\met_2002_01.dat		...
MetDat2			
MetDat3			
MetDat4			
MetDat5			
MetDat6			

When a typical 5-year air quality modelling assignment is performed, the mdoforeach setting can be used so that the files group resembles the example below.



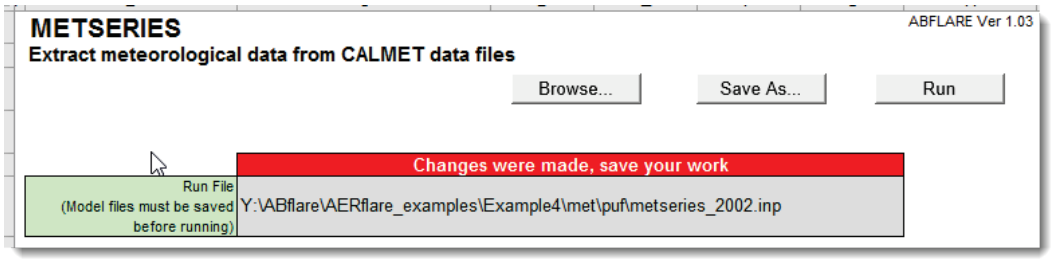
Meteorology Files for Extraction Group

NMETINP	12	Number of met files to extract	BROWSE
MetDat1	Y:\ABflare\AERflare_examples\Example4\met\puf\met_XYEARX_01.dat		...
MetDat2	Y:\ABflare\AERflare_examples\Example4\met\puf\met_XYEARX_02.dat		
MetDat3	Y:\ABflare\AERflare_examples\Example4\met\puf\met_XYEARX_03.dat		
MetDat4	Y:\ABflare\AERflare_examples\Example4\met\puf\met_XYEARX_04.dat		
MetDat5	Y:\ABflare\AERflare_examples\Example4\met\puf\met_XYEARX_05.dat		
MetDat6	Y:\ABflare\AERflare_examples\Example4\met\puf\met_XYEARX_06.dat		
MetDat7	Y:\ABflare\AERflare_examples\Example4\met\puf\met_XYEARX_07.dat		
MetDat8	Y:\ABflare\AERflare_examples\Example4\met\puf\met_XYEARX_08.dat		
MetDat9	Y:\ABflare\AERflare_examples\Example4\met\puf\met_XYEARX_09.dat		
MetDat10	Y:\ABflare\AERflare_examples\Example4\met\puf\met_XYEARX_10.dat		
MetDat11	Y:\ABflare\AERflare_examples\Example4\met\puf\met_XYEARX_11.dat		
MetDat12	Y:\ABflare\AERflare_examples\Example4\met\puf\met_XYEARX_12.dat		
MetDat13			
MetDat14			

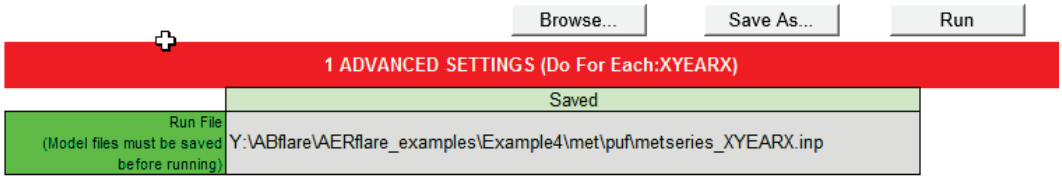
Save and Run

After completing the entry of the each of the input groups, the top of the page will display a flag indicating that changes where made to the page and the information must be saved. This is a reminder that a) you should save the *ABflareUI* spreadsheet to save your work and b) that must save the configuration of the *METSERIES.exe* input file. To save the input the configuration as a METSERIES.exe input file, press the Save As… button. You will be prompted for a location and file name. The input file will be created and the file name will be displayed as the Run File.

Pressing the Run button will execute the *METSERIES.exe* program for the input file in the Run File field. *METSERIES.exe* and *ABflareUI* waits for the output.



When the mdoforeach setting is used, the Run File should be saved with a name that includes the doforeach variable such as shown below. In this case, the Save As... creates the `metseries_XYEARX.inp` file as well as each of the files in the mdoforlist, for example `metseries_2002.inp`, `metseries_2003.inp`, etc.



When mdoforeach is used with mbatonly setting, the Save As... creates the inputs files as well as a batch file that can be used at a later time to run *METSERIES.exe* asynchronously. Because *METSERIES.exe* executes relatively quickly, a single batch file is created to run each of the mdoforlist input files.

```
@echo off
@rem created by ABFLARE Ver 1.03 [SS1.03.160913;M1.03.160913]
O:\CALPUFF\code\METSERIES_v7.0.0_L140912\METSERIES_v7.0.0_L140912\metseries_v7.0.0.exe Y:\ABflare\AERflare_examples\Example4\met\puf\metseries_2002.inp
@rem created by ABFLARE Ver 1.03 [SS1.03.160913;M1.03.160913]
O:\CALPUFF\code\METSERIES_v7.0.0_L140912\METSERIES_v7.0.0_L140912\metseries_v7.0.0.exe Y:\ABflare\AERflare_examples\Example4\met\puf\metseries_2003.inp
@rem created by ABFLARE Ver 1.03 [SS1.03.160913;M1.03.160913]
O:\CALPUFF\code\METSERIES_v7.0.0_L140912\METSERIES_v7.0.0_L140912\metseries_v7.0.0.exe Y:\ABflare\AERflare_examples\Example4\met\puf\metseries_2004.inp
@rem created by ABFLARE Ver 1.03 [SS1.03.160913;M1.03.160913]
O:\CALPUFF\code\METSERIES_v7.0.0_L140912\METSERIES_v7.0.0_L140912\metseries_v7.0.0.exe Y:\ABflare\AERflare_examples\Example4\met\puf\metseries_2005.inp
@rem created by ABFLARE Ver 1.03 [SS1.03.160913;M1.03.160913]
O:\CALPUFF\code\METSERIES_v7.0.0_L140912\METSERIES_v7.0.0_L140912\metseries_v7.0.0.exe Y:\ABflare\AERflare_examples\Example4\met\puf\metseries_2006.inp
```

STEP 2-ABFLARE Page

The STEP 2-ABFLARE page is divided into nine input groups.

Field Group	Description
Input and Output Folders	These define the input and output paths and filenames
Control	These are the control settings to instruct *ABflare.exe* to perform different calculations.
Chemistry	*ABflare* should be run with only a single species at a time for all blowdown cases. *ABflare* was designed to emit either SO_2 or H_2S, as the oxidized or un-combusted raw gas stream emission. For static or non-blowdown situations, other species may added.
Date Options	These settings direct *ABflare.exe* to extract meteorological data for the specified date range.
Source Description	These entries define the source to be modelled
Lift and Flare Assist	These entries describe the various variables relating to flaring assist including fuel gas, lift gas, steam assist, air assist and high pressure fuel assist
Gas Composition	These entries describe the gas composition of the three principal gas streams, raw gas, fuel gas and lift gas. The air composition and steam gas compositions are pre-defined
Meteorology	Typically, the meteorology is described by METSERIES input file, however, static meteorological settings for wind speed, direction, temperature and Pasquill-Gifford stability may be entered.
User Defined Blowdown	ABflare.exe can be configured to calculate a blow down source emissions and characterization. However, in complex situations a user may wish to enter a time series sequence of flowrates, temperatures, source gas composition and fuel gas.

ABflare is designed to accommodate a range of source descriptions as described in the table below. In general, there are only three source type configurations:

1. QMAX and QMIN are used to create pseudo-source parameters;
2. a user defined sequence of QMAX is provided by the user to create pseudo-source parameters; or
3. QMAX and static pseudo-source parameters are provided by the user.

For the first source type, a user can input the QMAX and QTOTAL if these are known or *ABflare* can calculate the QMAX and QTOTAL. QMAX is known if the flare is a steady flare such as for an environmental impact assessment. The QMAX is not known, if the flare is a blowdown and then the user inputs initial conditions such as pressure and volume of the system to blowdown. lternatively, an advanced

user can perform the blowdown calculations and then enter QMAX and QTOTAL that equate to a blowdown.

MINPUT	MBLOWDOWN or STEADY	NPUFFS
1: User inputs source exit conditions; *ABflare* calculates source parameters that vary with meteorology.	1: User provides QMAX and QTOTAL (which represent the exponential blowdown curve).	1: QMAX is used to represent a static hourly emission rate; *ABflare* calculates source parameters that vary with meteorology.
		>1: QMAX and QTOTAL are used by *ABflare* to calculate a blowdown sequence; *ABflare* calculates source parameters that vary with meteorology.
	2: *ABflare* calculates QMAX and QTOTAL based upon user-entry of vessel initial conditions.	*ABflare* calculates a blowdown sequence; *ABflare* calculates source parameters that vary with meteorology.
2: User inputs a repeatable sequence of rates; *ABflare* calculates source parameters that vary with meteorology. See NSEQ.	--	NPUFFS=NSEQ
3: User inputs pre-determined pseudo-stack parameters; *ABflare* uses the user-inputs which **DO NOT** vary with meteorology. See PSHS, PSTS, PSDS, PSUS and QEMIT.	--	NPUFFS=1

It is recommended that a minimum of three equal mass steps be used to represent a blowdown curve. Figure 4 shows an exponential blowdown curve for a vessel of 23.3×10^3 m^3 with an initial flow rate of 1110×10^3 m^3/d. The equal mass sequence will better represent the original curve than the equal duration sequence. The dispersion modelling pseudo-parameters for plume rise closely match the original curve ensuring a realistic representation of the sequence.

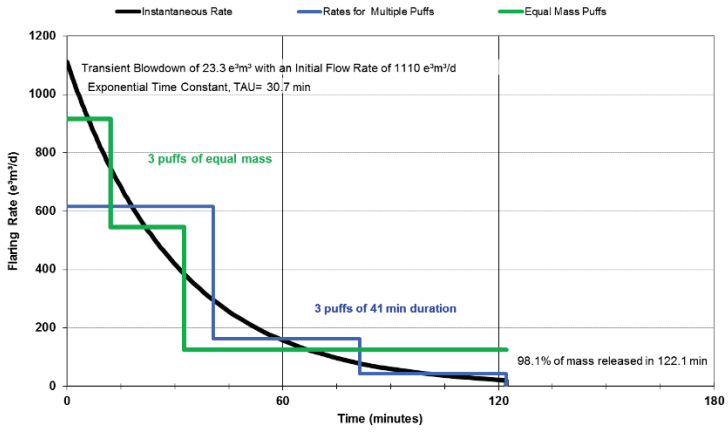
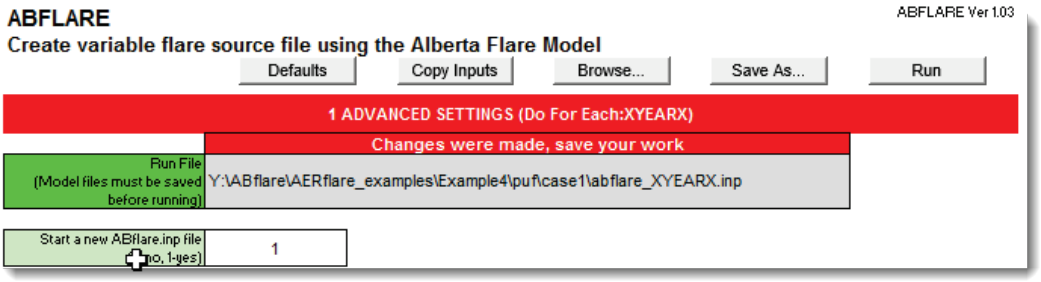


Figure 4: Exponential Blowdown Represented by a Sequence of Puffs

Defaults, Copy Inputs, Browse

Three options are available start creating an input file for *ABflare.exe*. These are controlled by the three buttons at the top of the **STEP 2-ABFLARE** page.

Defaults	This button copies default entries into each of the input fields on the page. Use this button to start new project files.
Copy Inputs	This button copies the relevant inputs from an existing *AERflare* spreadsheet into the corresponding fields of the *ABflareUI.* Use this button as a easy way to start new project files from an existing *AERflare* assessment
Browse	This button prompts the user the to select an existing ABflare.exe input file and loads the settings on the page. Use this button to reload an existing project to make edits.



Input and Output Folders Group

The input and output folders group specifies where files are read from and are to be written to.

SNAME is the source name to be used for the flare. The *ABflare* output file will create an arbitrary time varying input file for use with *CALPUFF*. The source name should not conflict with other sources that may be used in the *CALPUFF* file.

STITLE1 is a one line description that *ABflare* will write to the arbitrary time varying input file for use with *CALPUFF*. STITLE1 only used for the user's future reference to describe the source file.

OUTPATH is the full drive and folder path for where the *ABflare* output will be written to. The output will be a single file if *ABflare* is directed to create a single arbitrary time varying source characterization (MINPUT=1, MBLOWDOWN=1) or may be a set of 24-files representing a blowdown starting at one hour increments (MINPUT=1, MBLOWDOWN=2).

METDAT is the full drive and folder path for the meteorological time series file created by *METSERIES*. *ABflare* uses the meteorological time series to create the source parameters that vary with meteorology. The METDAT file should represent the meteorology at the flare stack tip height. When MDSPMOD=2, METDAT be the *AERMOD* surface (.sfc) file.

METDAT2 is used when MDSPMOD=2. When MDSPMOD=2, METDAT2 be the *AERMOD* profile (.pfl) file

RECINC is the path for the receptor file. This field is used when MDSPMOD=2. *ABflare.exe* will create *AERMOD* ready input files.

LSTDAT is the full drive and folder path for the output listing from *ABflare*. *ABflare* will echo the input source file and will write other run-time information to this file.

LOGDAT is the full drive and folder path for the debug log file. *ABflare* will write debug information to this file. If this output is not required, then this setting should be left blank.

LCFILES is used to force the output file names to be lower case or upper case. This setting is commonly used to prevent errors in LINUX environments where path names are case sensitive.

Input and Output Folders Group

VARIABLE	INPUT	DESCRIPTION	BROWSE
SNAME	FLR1	Source Name (12 chars) A short one word identifier for the source, example: FLARE1	
STITLE1	Example 4-Site C		
OUTNAME basename for ABflare hourly emissions files	flemarb_XYEARX		output will add _XX.dat hour and path
OUTPATH path for ABflare output files	.\		...
input: TSF Metseries output file from METDAT or AERMOD.SFC Default: METDAT.TSF	Y:\ABflare\AERflare_examples\Example4\met\pufMS_XYEARX.tsf		...
input: METDAT2 AERMET Metseries PFL file Default: METDAT.PFL			...
input: RECINC AERMOD receptor include file Default: RECINC.ter			...
output: LSTDAT List-file name Default: ABFLARE.LST	abflare_XYEARX.lst		...
output: LOGDAT debug listing log-file name Default: ABFLARE.LOG	abflare_XYEARX.log		...
LCFILES	T	All file names will be converted to either lower or upper case T = lower case F = UPPER CASE DEFAULT: F	

Fields that are responsive to the mdoforeach settings are highlighted. Typically, only the OUTNAME, METDAT, LSTDAT and LOGDAT variables would be modified with the mdofor variable.

Control Group

The control group settings are used to direct the program flow in *ABflare*. Some controls settings make input entries optional or required entries in the various *ABflare* input groups.

MDSPMOD setting is used to create flare source parameter files for different dispersion models. MDSPMOD=1, creates a *CALPUFF* read output file. MDSPMOD=2, creates input files for *AERMOD*.

MINPUT is used to specify the type of flare source to be input into *ABflare*. The types of sources that can be input into *ABflare* are: (MINPUT=1) QMAX is entered or calculated from a blowdown and pseudo source parameters are calculated; (MINPUT=2) a time series sequence for a blowdown is entered and ABflare calculates the pseudo source parameters.; (MINPUT=3) a static source and the user provides the pseudo-source parameters. MINPUT is described in more detail in the **SOURCE GROUP** description.

MBLOWDOWN is used to specify whether *ABflare* is to calculate the blowdown from user entry of QMAX and QTOTAL or if *ABflare* is to calculate the blowdown from user entry of the vessel or pipeline description. MBLOWDOWN is described in more detail in the **SOURCE GROUP** description.

MDIST directs *ABflare* to divide the blowdown into segments of equal duration or of equal mass. The recommended setting is to calculate segments of equal mass. The blowdown emission curve is well represented by an exponential decrease in emissions with time. The mass emissions are therefore exponentially distributed in time. The *ABflare* calculated source parameters to represent the plume rise are therefore naturally changing as a function of mass emissions. Equal duration steps may be more convenient when trying to match results from other dispersion models or for simplifying the calculation of time averages. If the equal duration steps are used for an exponential blowdown, the source parameters calculated by *ABflare* are based upon the step volume, and therefore at small release times, more mass is released at lower effective plume heights (see also later, Figure 4).

MSTRIP directs *ABflare* to calculate emissions for SO_2 assuming 100% conversion efficiency (the recommended and conservative setting for regulatory modelling in Alberta) or to calculation emissions assuming conversion efficiency varies with meteorology. If MSTRIP=1, then *ABflare* will calculate the emissions of H_2S and source parameters for gases stripped off of the flared gas resulting from cross-wind effects at the combustion zone. The effective source when MSTRIP=1 is set at half of the calculated effective flame height with very little buoyancy rise. These settings are an approximation allowing for momentum of the stripped gases and some radiant heating of the flared gas. If MSTRIP=2, then *ABflare* will calculate the emissions of SO_2 using the calculated efficiency for the meteorology. The efficiency can drop below 98% for high wind speeds, but is not allowed to drop below 25% as a limit of the calculations.

MMET is used to direct *ABflare* to read meteorological data from a file or to use a static user input meteorological conditions for use in calculating emissions and efficiency. MMET is useful for creating input files for comparison to other dispersion models. *ABflare* can process either *CALPUF* (*METSERIES* style) meteorological data or *AERMOD* (*AERMET* style) meteorological data surface files.

MFUELGAS is used to specify whether fuel gas will be used to assist flare combustion and dispersion.

MFGR is used to specify how fuel will be added to the raw gas. MFGR=1 specifies that the fuel gas ratio is proportional to time varying flaring rate. MFGR=2 specifies that the fuel gas ratio is proportional to the initial QMAX rate of the blowdown.

MFASSIST is used to specify if steam, air or high pressure fuel assist is added to the flare combustion zone to aid in mixing and vertical momentum.

MTGAS is used to specify the temperature of the raw and fuel gas streams. MTGAS can be assigned to use a constant value defined by TGINIT, ambient temperature or can be calculated in response to blowdown thermodynamics.

MSCREENING is used so that output matches the variable flare source parameters calculated by *AERflare*. *AERflare* uses a screening approach to reduce computational effort by discretizing the wind speed, temperature and Pasquill-Gifford combinations.

MDEBUG is used so that extra debug information is output to the log file during run-time.

NSEP is the number of hours separating blowdown sequences for a given source file. Each blowdown sequence starts every hour on the hour. Typically, NSEP=24, resulting in *ABflare* creating 24-arbitrary varying flare input files. Each input file is an independent run of *CALPUFF*. When NSEP=24, the blowdown duration must be less than 24 hours and also allow time for the plume to leave the modelling domain. NSEP specifies the frequency of when the starting hour can be used again. NSEP must be a multiple of 24. A blowdown duration greater than 24 should use NSEP=48. A blowdown duration greater than 48 should use NSEP=72. If NSEP=48, *ABflare* will create 48 input files for *CALPUFF*, and if NSEP=72, *ABflare* will create 72 input files for *CALPUFF*. For steady flares with duration of one-hour or sub-hour duration flares, the maximum concentration can be determined using NSEP=1. However, if the along wind dilution effects are to be included in the dispersion modelling, then NPUFFS=1 and NSEP=24 should be used.

NSOURCES is used when MDSPMOD=2. NSOURCES=9 is used to match output from *AERflare*. NSOURCES specifies the number of co-located sources

using the AREMOD plume. The results from the NSOURCES output, is used to approximate the blowdown using AERMOD.

Control Group

VARIABLE	INPUT	DESCRIPTION
MDSPMOD	1	MDSPMOD = 1: create files for CALPUFF 2 : create files for AERMOD DEFAULT = 1
MINPUT	1	MINPUT =1: source conditions are input and steady emissions or blowdown is calculated (see MBLOWDOWN) 2 : blowdown curve sequence is input (see NSEQ) 3 : static source is input (see SOURCE DESCRIPTION GROUP). Use setting 3 for a steady flare source with parameters that that don't vary with meteorology DEFAULT = 1
MBLOWDOWN	1	MBLOWDOWN=1 : user input QMAX and QTOTAL 2 : blowdown exponential model parameters are calculated from pipeline/vessel initial conditions (set NPUFFS=1 for steady, NSTEPS>1 for blowdown) DEFAULT = 2
MDIST	2	MDIST=1 : blowdown sequence is created based upon puffs of equal duration 2 : blowdown sequence is created based upon puffs of equal mass DEFAULT = 2
MSTRIP	0	MSTRIP=0 : source is described by input (100% conversion to SO2) =1 : source is a stripped flow source (H2S) =2 : source is actual SO2 (accounting for efficiency) DEFAULT= 0
MMET	1	MMET=1: meteorology is read from METDAT (CALPUFF) =2: meteorology is read from METDAT (.SFC) and METDAT2 (.PFL) (AERMOD) =3: force met to be WINDSP, WINDDR, TAMB
MFUELGAS	1	Is fuel gas added? MFUELGAS=0 : no fuel gas is added 1 : fuel gas is added Default = NONE
MFGR	2	MFGR = 1 : fuel gas is proportional to qmax(t) rate =2 : fuel gas is constant amount based upon initial qmax (See QMAX below) DEFAULT = 2
MLIFTGAS	0	Is lift gas used ? MLIFTGAS = 0 : no lift gas = 1 : lift gas is used DEFAULT = 0
MFASSIST	0	Is flare assist used ? MFASSIST = 0 : no flare assist 1 : yes (see below, Steam, Air or HP Fuel assist parameters) DEFAULT = 0
MFASSISTSTEAM	0	Is steam assist used? MFASSISTSTEAM=0 : no steam assist = 1 : yes DEAULT = 0
MFASSISTAIR	0	Is air assist used? MFASSISTAIR=0 : no air assist = 1 : yes DEAULT = 0
MFASSISTHPFUEL	0	Is HP fuel assist used? MFASSISTHPFUEL=0 : no HP fuel assist = 1 : yes DEAULT = 0
MTGAS	1	This setting is used to assign the temperature of the gas. MTGAS=0 : use TGINIT = 1 : use TAMB = 2 : use calculated Tei at orifice (MBLOWDOWN=2) DEAULT = 0
MSCREENING	0	This setting is used when MDSPMOD=2 (aermod) is selected so that the flremarb.dat output files match the output from AERflare screening methods. MSCREENING = 0 : does not discretize the meteorology = 1: SCREENING mode, output matches AERFLARE met discretization DEFAULT =1
MDEBUG	0	Print debug and verbose information MDEBUG = 0 : no debug = 1 : print debug/verbose DEFAULT = 0
NSEP	1	Number of hours separating blowdown sequences. Must be a multiple of 24. Each blowdown sequence starts every hour on the hour. NSEP specifies the frequency of when the starting hour can be used again. A blowdown duration greater than 24 should use NSEP=48. A blowdown duration greater than 48 should use NSEP=72. DEFAULT=24
NSOURCES		Number of co-located AERMOD sources to represent range of meteorological sensitive source conditions DEFAULT=9

Chemistry Group

The chemistry group is used to specify the chemical species emitted by the flare. *ABflare* allows only a single species to be emitted at a time, being either SO_2 or H_2S. SO_2 and H_2S cannot be emitted at the same time since the source parameters for these are different because of the how these species are created in the flare combustion zone.

For MSTRIP=0 or MSTRIP=2, CHEMLST= `SO2`. For MSTRIP=1, CHEMLST= `H2S`.

Chemistry Group

VARIABLE	INPUT	DESCRIPTION		
NSPEC	1	Number of species to be modelled NSPEC=1		
	CHEMLST	Mole Weight kg/kmol	Emission Rate g/s	
FLARE: SPEC 1	SO2	64.065	1	This is the Flare source, the emissions are either STATIC or are overwritten by ABflare
STATIC: SPEC 2	H2S	34.082	2	List of chemical species to be modelled Example: SO2, H2S Default =SO2
STATIC: SPEC 3	NOX	46	5234.567	
STATIC: SPEC 4	CO	28.01	0.0123	
STATIC: SPEC 5				List of molecular weights of chemical species to be modelled. Example:SO2=64.065,H2S=34.082 Default =64.065
STATIC: SPEC 6				
STATIC: SPEC 7				
STATIC: SPEC 8				List of static emission rate for all species
STATIC: SPEC 9				
STATIC: SPEC 10				

Date Options Group

The date options group is used to specify the start and end of the source calculations. It must start at *ihr*=0 and *isec*=0. The TIMEINC should match the interval of the meteorology used in the *CALMET* modelling.

Date Options Group

VARIABLE	igr	imo	iday	ihr	isec
START	XYEARX	1	1	0	0
END	XYEARX	12	31	24	0
TIMEINC	3600	Time step, s Default=3600			

In the example above the mdoforeach setting was enabled and the mdofor variable XYEARX has been used instead of the year.

Source Description Group

The source description group is divided into four logical sub-groups. Sub-group 1 are mandatory entries. Sub-group 2 and Sub-group 3 are required only for specific

source characterization. Sub-group 4 has entries that are optional depending upon the specific source characterization.

Sub-group 1, specifies the real location, height above grade and inside diameter at flare stack top.

Sub-group 2 is used only if MINPUT=1 and MBLOWDOWN=2 and is used to describe the initial conditions of the vessel or pipeline for the blowdown calculations. The initial pressure (kPa) and temperature (°C) describe the vessel or pipeline before the blowdown. If the vessel pressure is variable, then the maximum pressure should be entered. If the vessel temperature is variable, then the minimum temperature should be used. To specify the vessel temperature as ambient temperature, enter -9999 and *ABflare* will use the ambient temperature from the METDAT file at the start of the blowdown sequence as the vessel or pipeline initial temperature. *ABflare* uses the ambient temperature from METDAT and not the ambient temperature from MMET=3, if specified. If the vessel or pipeline initial temperature needs to match TAMB when MMET=3, then set the minimum initial vessel temperature to TAMB.

The vessel or pipeline inside diameter and length are relatively straight forward. If the blowdown includes more than just a single vessel, then the equivalent enclosed volume can be calculated and a representative diameter and length can be entered. For a pipeline, the segment length between emergency shut-down values (ESD) should be used.

The minimum orifice diameter will control the rate of gas through and out of the system because of choked flow. The discharge coefficient is not readily determined, since it may be impacted by back pressure through piping to the flare. A limiting case for flow through an orifice (Figure 5, Mannan 2005) provides a default value of 0.6 which allows for pipe friction from the orifice to the flare.

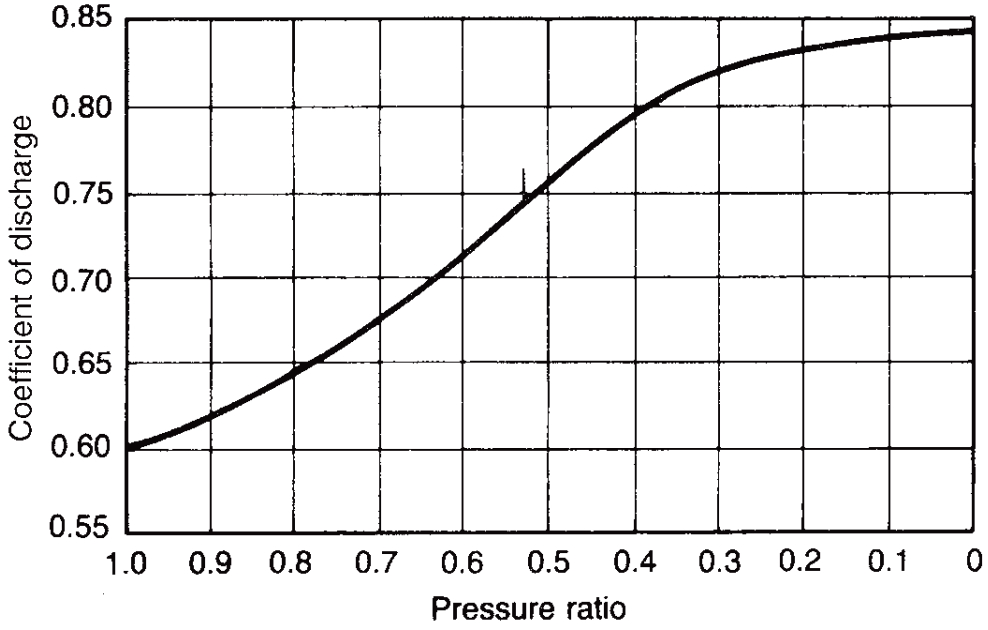


Figure 5: Coefficient of Discharge for Gas Flow Through an Orifice (Mannan 2005)

Sub-group 3 is used only if MINPUT=3. This option allows the user to specify the parameters to be output using *ABflare*. The parameters, since specified by the user, do not change with meteorology. The user should enter the flare pseudo-height, diameter, temperature and velocity as well as the mass emission rate.

Sub-group 4 contains optional and required entries. RH2S is a required entry that is used to specify the H_2S content of the raw gas. RH2S may be different than the gas composition to allow for regulatory limits or the maximum expected value. The gas composition is re-normalized to account for the change in RH2S. If MINPUT=1 and MBLOWDOWN=1, the user may enter QMAX, QTOTAL, DURATION and FREL directly and by-passing the vessel blowdown calculations. This option can be used to specify a flaring rate that is constant in time at QMAX but the flaring parameters will change with meteorology. In this case the user should enter DURATION=3600, FREL=1 and NPUFFS=1. In this case QTOTAL is not used. This option is also useful for debugging purposes or if a vessel blowdown is not a good model for the scenario modelled.

PUFFDUR and NPUFFS can be selected to change how the blowdown curve is divided for modelling. For MDIST=2 (constant mass puffs) the PUFFDUR is ignored and the NPUFFS determines the number of discrete intervals used to divide the exponential blowdown curve. For MDIST=1 (constant duration puffs) either PUFFDUR or NPUFFS can be selected.

Source Description Group

VARIABLE	INPUT	DESCRIPTION
XCOORD	496	Easting location of the flare, see DATUM coordinates
YCOORD	6187	Northing location of the flare, see DATUM coordinates
ZCOORD	649	Terrain elevation at source, m
HS	30.5	Actual height of the flare, m
DS	0.305	Actual inside diameter of flare at top, m
RH2S	0.301	Mole fraction of H2S in raw gas
TGINIT	262.1109925	Initial fuel gas and raw gas temperature, K, or negative to set to ambient
Expected Maximum Initial Pressure		kPa (gauge) If MBLOWDOWN=2, enter the maximum initial pressure of the vessel or pipeline
Expected Minimum Initial Gas Temperature		K If MINPUT=1, enter the minimum initial temperature of the vessel or pipeline
Expected Minimum Final Pressure		kPa (gauge) If MBLOWDOWN=2, enter the minimum final pressure of the vessel or pipeline when flaring is stopped and the gas release is shut-in
Pipeline/Vessel Inside Diameter		m If MBLOWDOWN=2, enter the vessel or pipeline inside diameter
Pipeline/Vessel Length		m If MBLOWDOWN=2, enter the vessel or pipeline length
Minimum Orifice Diameter		mm If MBLOWDOWN=2, enter the minimum orifice diameter where the gas escapes from the vessel or pipeline
Discharge Coefficient		-- If MBLOWDOWN=2, enter the orifice discharge coefficient DEFAULT=0.6
psHS		Pseudo-Height of flare source, m Used if MINPUT=3
psDS		Pseudo-diameter of flare source, m Used if MINPUT=3
psTS		Pseudo-temperature of flare source, K Used if MINPUT=3
psUS		Pseudo-velocity of flare source, m/s Used if MINPUT=3
QMAX	695.6400596	Peak flow rate of flared gas, e³m³/d Used if MINPUT=1
QTOTAL	151.2945757	Total volume of gas contained within pipeline or vessel to be flared, e³m³/d Used if MINPUT=1
DURATION	3600	Duration of blowdown, s Used if MINPUT=1
FREL	0.978645133	Fraction of gas remaining in pipeline or vessel at the end of DURATION. Default= 0.99 Used if MBLOWDOWN=2
PUFFDUR		Using MDIST=1, the user can specify either the puff duration (s) or the number of puffs, NPUFFS below.
NPUFFS	3	npuffs = 0 : Program calculates number of puffs, when PUFFDUR is specified and MDIST=1 npuffs = 1 : Force blowdown to a single puff of duration PUFFDUR, if MINPUT=1 and MBLOWDOWN=1 then NPUFF=1 for a hourly varying flare or if MINPUT=3, then use input source rather than calculated blowdown. Use this setting for a steady flare source with parameters that that vary with meteorology npuffs > 1 : Number of puffs in blowdown Default = 3

Flare Assist Group

The flare assist group includes entries for fuel gas, steam assist and air assist flares.

If MFUELGAS=1, then FGR should be set to the fuel gas ratio for the flaring event. FGR is (e³m³/d fuel gas)/(e³m³/d raw gas). The fuel gas ratio could be a constant flow prorated to QMAX or a flow proportional to exponential blowdown curve. This option is set using MFGR=1 (constant) or MFGR=2 (proportional).

If MFASSIST=1 to 3, then the flare is steam and/or air assisted. Steam assist parameters are entered in the STM_ sub-group entries, and the air assist parameters are entered in the AIR_ sub-group entries. Steam assist requires the number and diameter of the injection ports. If the steam quality (pressure and/or temperature)

is known, then these values can be entered. If these values are not known, then saturated steam is assumed. Steam may be specified in either mass or volume units (STM_IMASSVOL=1 for mass flow or STM_IMASSVOL=2 for volume flow). The flow amount is entered as STM_FLOW.

Air assist requires the number and diameter of the air assist injection ports . Air flow is entered as volumetric using AIR_FLOW.

Both steam and air assist assume vertical momentum and complete mixing within the combustion zone. Caution should be used when setting flare assist, since too much steam or air can extinguish the flare.

Lift and Flare Assist Group

VARIABLE	INPUT	DESCRIPTION
FGR	0	Fuel gas ratio. Ratio of flow rate of fuel $10^3m^3/d$ to the flow rate of raw flared gas $10^3m^3/d$
QLIFTGAS		Lift gas flow rate $10^3m^3/d$
STM_NPORTS	300	Number of steam injection ports
STM_DIA	0.009	Diameter of an individual steam injection port,m
STM_PRESS		Steam injection pressure, kPa, if known else leave blank
STM_TEMP	320	Steam injection temperature, K, if known else leave blank
STM_IMASSVOL	1	=1 if steam flow is to be entered as mass flow, kg/s =2 if steam flow is entered as volume flow, $10^3m^3/d$
STM_FLOW	5	Steam flow, in kg/s or e^3m^3/d as specified by STM_IMASSVOL
AIR_NPORTS	300	Number of air injection ports
AIR_DIA	0.009	Diameter of an individual air injection port, m
AIR_FLOW	2	Air flow, $10^3m^3/d$

CAUTION should be used when setting steam and flare assist since the addition of too much steam and/or air will create an over-assisted flare and extinguish the flame.

Gas Composition Group

The gas composition group provides entries for the raw gas and fuel gas streams. The flare assist streams of steam and air have known gas composition and don't require entry. The user should provide a documented raw gas stream composition that may or may not have the same H_2S concentration as the flare modelled amount. The reason for this is to allow for regulatory H_2S limit or fluctuating range of H_2S. The *ABflare* model will re-normalize the raw gas composition using RH2S in place of the H_2S content specified in the Raw Gas composition.

The fuel gas composition is similarly entered. Typically, fuel gas will be 100% propane if the flaring is performed at remote locations. Otherwise, fuel gas may be supplied by pipeline spec natural gas which contains typically >90% methane. Representative pipeline quality natural gas composition is listed in Hubbard (2009) and TransCanada (2012) are listed in Table 1.

Table 1: Representative Pipeline Quality Natural Gas (Hubbard 2009)

Major & Minor Components (Mole%)	Minimum	Maximum	Alberta Maximums
Methane	75	--	Not specified
Ethane	--	10	Not specified
Propane	--	5	Not specified
Butanes	--	2	Not specified
Pentanes plus	--	0.5	Not specified
Nitrogen & other inerts	--	3-4	Not specified
Carbon dioxide	--	3-4	2% by Volume
Trace Components			
Hydrogen Sulphide	--	0.25-1.0 gr/100scf	23 mg/m³
Mercaptan Sulphur	--	0.25-1.0 gr/100scf	
Total Sulphur	--	5-20 gr/100scf	115 mg/m³
Water Vapour	--	7.0 lb/mmscf	65 mg/m³
Oxygen	--	0.2-1.0 ppmv	0.4% by volume

The gas composition must sum to exactly 1. If the entries do not sum to 1, a warning is displayed as shown below. This feature assists in preventing typographical errors.

Gas Composition

Gas Compositions (mole fraction)	Fuel Gas	Lift Gas	Raw Gas	WARNINGS	COMMENTS
H_2O					Dry gas composition may have to be adjusted to pre-flare-tip conditions of temperature and pressure
H_2					
He					
N_2		1			
CO_2					
H_2S					Model will adjust reference analysis to maximum requested H_2S, see RH2S
CH_4			1		
C_2H_6					
C_3H_8	1				Set C_3H_8 to 1 for propane fuel gas
$i\text{-}C_4H_{10}$					
$n\text{-}C_4H_{10}$					
$i\text{-}C_5H_{12}$					
$n\text{-}C_5H_{12}$					
$n\text{-}C_6H_{14}$					
C_7+					
CO					
NH_3					
Ar					
Total	1	1	1		

Meteorology Group

The meteorology group entries must be provided if MMET=3. The meteorology group allows a specific meteorology to be used for the purposes calculating the flare emission parameters.

Meteorology Group

VARIABLE	INPUT	DESCRIPTION
WINDSP	3.5	Wind speed, m/s
WINDDR	90	Wind direction, degrees wind blowing from set to -1, to use real wind
TAMB	278.15	Ambient temperature, K
PGCLASS	4	Pasquill-Gifford atmospheric stability, (1=A,2=B,3=C,4=D,5=E,6=F)
ZREF	10	Windspeed anemometer height

User Defined Blowdown Group

The user defined blowdown group allows entry of a repeatable time series of flow rate defining the blowdown, using MINPUT=2. This option can be used if the *ABflare* single vessel or pipeline exponential blowdown is not appropriate and the user can provide the time series independently. The user defined blowdown is processed by *ABflare* in the same way as the default single vessel or pipeline blowdown curve, that is, each time increment of the flaring curve is processed by *ABflare* to determine the flare source parameters and the effects of the meteorology on the parameters.

The user defined blowdown allows entry for rate (e^3m^3/d) of raw gas flared, duration of time (seconds) at that rate, the H_2S mole fraction at that increment and the fuel gas ratio for that increment.

The user defined blowdown can be used to define an arbitrary time varying flare rate by continuing the number of points in the sequence indefinitely. The last entry of the time sequence should have a duration long enough to extend beyond the end time period, to prevent repeating of the sequence. *ABflare* creates NSEP number of files to start the sequence at each start hour of the day. If the user defined curve is arbitrary then the user should run all NSEP cases, however, if the user defined curve matches the start hour of the modelling, then the only the first *ABflare* output file can be used.

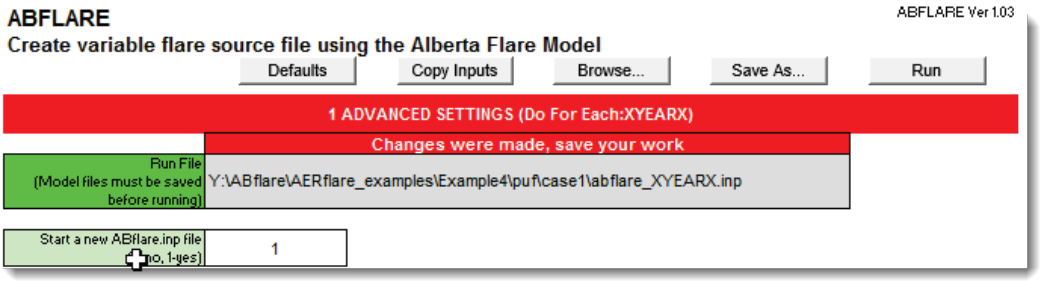
User Defined Blowdown Group

NSEQ	3	Number of points in the user defined blowdown curve. Used when MINPUT=2		
SEQ #	Rate ($10^3m^3/d$)	Duration (s)	H_2S Mole Fraction	FGR
1	574.728486	7419.563618	0.301	0
2	342.8203142	12438.68694	0.301	0
3	81.34544142	52421.30955	0.301	0
4				
5				
6				
7				

Save As and Run

After completing the entry of the each of the input groups, the top of the page will display a flag indicating that changes where made to the page and the information must be saved. This is a reminder that a) you should save the *ABflareUI* spreadsheet to save your work and b) that must save the configuration of the *ABflare.exe* input file. To save the input the configuration as an *ABflare.exe* input file, press the Save As... button. You will be prompted for a location and file name. The input file will be created and the file name will be displayed as the Run File.

Pressing the Run button will execute the *ABflare.exe* program for the input file in the Run File field. In this case *ABflare.exe* executes and *ABflareUI* waits for the output.



If the mdoforeach setting is used, Run File should be saved using the mdofor variable (in the case shown above `XYEARX`). Pressing Save As... will create the skeleton Run File with the mdofor variables in place, and will create an input file for each of the mdoforlist. If the mbatonly setting is used, then a batch file is created with each mdoforlist settings. The batch file name is `run_abflare.bat`.

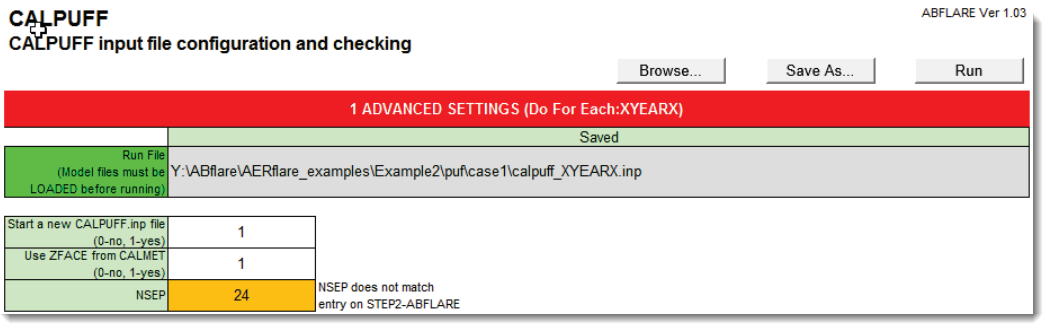
The Start a new ABflare.inp setting is used to control how the information is written to the file. If the setting is `Yes`, then a new input file will be created based upon the text fields listed on the sABFLARE page. If the setting is `No`, then the existing file if it exists, will be modified by replacing the variable values in the file with the variables from the **STEP 2-ABFLARE** page. This setting is useful if comments or alternative entries are routinely stored in the input file.

Step 3-CALPUFF Page

The *CALPUFF* module is used to check *CALPUFF* model input files for settings compatible with recommended settings. The module reads an existing *CALPUFF* input file and parameters are changed in the two groups below: file locations; and

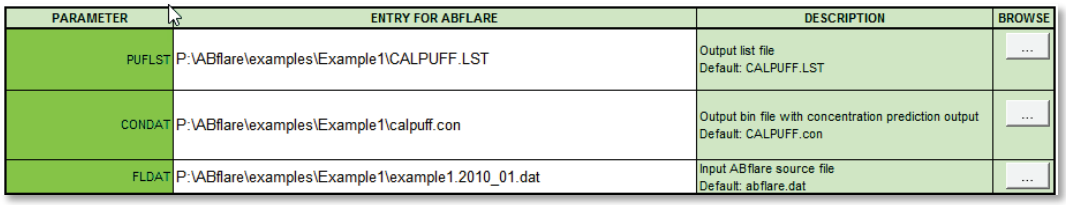
parameter settings. The existing *CALPUFF* input file should contain proper reference to meteorology, mapping and projection, and receptor locations.

At the top of the **Step 3-CALPUFF** page, the Browse… button can be used to open an existing *CALPUFF.exe* input file. Alternatively, a user can start a new file by selecting Start A New CAPUFF.inp File and filling in the input filed on the page. When Start A New CAPUFF.inp File is selected, the default settings from the **sCALPUFF** page are used to complete the inputs not found on the **Step 3-CALPUFF** page. When Start A New CAPUFF.inp File is not selected, the values of the variables in the Run File are replaced with corresponding filed from **Step 3-CALPUFF** page.



Input and Output Folders Group

The *CALPUFF* module can be used to change three file path and file names: PUFLST, CONDAT and FLRDAT. The PUFLST is the output list for the *CALPUFF* model run. CONDAT is the concentration output file for the *CALPUFF* model run. FLRDAT is the *ABflare.exe* output and the *CALPUFF* flare arbitrary emissions source input file. These three settings should be changed for each modelling run. *CALPUFF* warnings and errors are listed in the PUFLST file.



Date Options Group

Typically, a flaring assessment will be for a 5-year meteorological period. In this case, each meteorological year is typically run as a separate *CALPUFF* run, then the results from each year are analyzed and the worse year is compared to

endpoints. In the **Date Options Group**, enter the start and end date and time for this assessment. Shorter-term assessments are performed in a similar fashion, but the start and end dates might be for a portion of a year.

The entry for NSECDT for the *CALPUFF* input file must match the NSECDT setting used in the creation of the `CALMET.dat` files used in the assessment.

Date Options Group

	YEAR	MONTH	DAY	HOUR	SEC
Start met	2010	10	28	0	0
End met	2010	11	8	0	0
NSECDT	3600	time step (seconds) must match the METDAT file setup			

The entry for NSECDT for the *CALPUFF* input file must match the NSECDT setting used in the creation of the `CALMET.dat` files used in the assessment. See **Step 0a-CALMET**.

When the mdoforeach setting is used, the **Date Options Group** would be configured using the mdofor variable as shown in the example below. When the Save As... button is pressed, the mdofor variable (here XYEAX) is replaced with each of the mdoforlist entries.

Date Options Group

	YEAR	MONTH	DAY	HOUR	SEC
Start met	XYEARX	1	1	0	0
End met	XYEARX	12	31	24	0
NSECDT	3600	time step (seconds) must match the METDAT file setup			

Meteorological Data Group

In the **Meteorological Data Group** entry area, the list of `CALMET.dat` files that match the **Date Options Group** entries are input. For a flaring assessment covering an annual period, typically twelve `CALMET.dat` files are specified. In the example below, a short-term assessment only uses month #7 of year 2002, so only a single file is entered.

Meteorological Data Group

NMETDAT	1		
METDAT	Y:\ABflare\AERflare_examples\Example1\met\puf\met_2002_07.dat	1	...
METDAT		2	...
METDAT		3	...
METDAT		4	...

When the mdoforeach setting is used, the meteorological data group would typically be configured as shown in the figure below. For a typical air quality assesment a complete yar of meteorology is used. For convenience, meteorology for a year is divided into 12-monthly files so that file size is managable.

Meteorological Data Group

NMETDAT	12		
METDAT	Y:\ABflare\AERflare_examples\Example1\met\puf\met_XYEARX_01.dat	1	...
METDAT	Y:\ABflare\AERflare_examples\Example1\met\puf\met_XYEARX_02.dat	2	...
METDAT	Y:\ABflare\AERflare_examples\Example1\met\puf\met_XYEARX_03.dat	3	...
METDAT	Y:\ABflare\AERflare_examples\Example1\met\puf\met_XYEARX_04.dat	4	...
METDAT	Y:\ABflare\AERflare_examples\Example1\met\puf\met_XYEARX_05.dat	5	...
METDAT	Y:\ABflare\AERflare_examples\Example1\met\puf\met_XYEARX_06.dat	6	...
METDAT	Y:\ABflare\AERflare_examples\Example1\met\puf\met_XYEARX_07.dat	7	...
METDAT	Y:\ABflare\AERflare_examples\Example1\met\puf\met_XYEARX_08.dat	8	...
METDAT	Y:\ABflare\AERflare_examples\Example1\met\puf\met_XYEARX_09.dat	9	...
METDAT	Y:\ABflare\AERflare_examples\Example1\met\puf\met_XYEARX_10.dat	10	...
METDAT	Y:\ABflare\AERflare_examples\Example1\met\puf\met_XYEARX_11.dat	11	...
METDAT	Y:\ABflare\AERflare_examples\Example1\met\puf\met_XYEARX_12.dat	12	...

Discrete Receptor Group

The **Discrete Receptor Group** entry area is used to specify the complex terrain receptor insert file that was created using **Step 0b-Receptor**. Use the [...] browse button to navigate using Windows explorer or enter the `RECFIL.ctr` file by typing the complete path in the field. If the browse button is used, the `RECFIL.ctr` is scanned for the number of receptor found in the file and is listed in the NREC field for reference.

Discrete Receptor Input Group

RECFIL.ctr	Y:\ABflare\PeaceRiver\puf\userter.ctr	CALPUFF ready discrete receptor insert file. See the MakeReceptors pre-processor page. Blank if the file was input and is being revised.	...
NREC	2920	Numer of receptor points found in file	

Switch Checker Group

CALPUFF model switches and settings relevant to flare modelling are listed in this input group and shown in the table below. The table provides: the *ABflare* default setting and the user setting. If a user setting has been selected that is different than the recommended *ABflare* setting, it is flagged as a warning (orange background). The *CALPUFF* default settings are listed on the **sCALPUFF** page.

SWITCH CHECKER GROUP

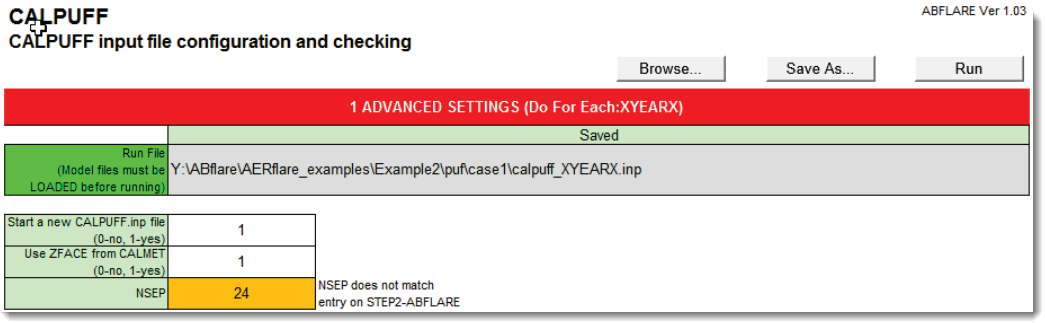
PARAMETER	ABFlare DEFAULT	USER ENTRY	DESCRIPTION
NSPEC	1	1	Number of Chemical Species modelled is run specific
NSE	1	1	Number of chemical species emitted is run specific
AVET	60	60	Averaging time assumed for Pasquill Gifford plume spreads
PGTIME	60	60	Reference averaging time for Pasquill Gifford plume spreads
MGAUSS	1	1	Gaussian distribution used in near field
MCTADJ	3	3	Partial plume path terrain adjustment
MCTSG	0	0	Complex terrain not modelled
MSLUG	0	0	Near-field puffs; not modelled as slugs
MTRANS	1	1	Transitional plume rise not modelled
MTIP	1	1	Stack tip downwash used (except for upset flaring where stack tip down wash is accounted for in the source term using the AER spreadsheet)
MRISE	1	1	1=Brigg's rise; 2=Numerical Rise
MBDW	2	2	Method to simulate building downwash 1=isc, 2=prime\nPrime is the preferred method
MSHEAR	1	1	Vertical wind shear not modelled
MSPLIT	0	0	Puffs are not split
MCHEM	0	0	Transformation rates: 0=turned off 3=computed internally using RIVAD/ARM3 scheme
MAQCHEM	0	0	Aqueous pahse transformation flage (used only if MCHECM=6 or 7)
MLWC	1	1	Liquid Water Content flag (Used only if MAQCHEM=1)
MWET	0	0	Wet removal modelled
MDRY	0	0	Dry removal modelled
MTILT	0	0	Gravitational settling (plume title) modelled
MDISP	2	2	dispersion coefficients from internally calculated sigma v, sigma w using micrometeorological variables (u*, w*, L)
MTURBVW	3	3	Use both ?v and ?z not adjusted for roughness
MDISP2	3	3	Backup method for dispersion, PG dispersion coefficients for rural areas (using ISCST3 approximation) areas when measured turbulence data missing
MTAULY	0	0	Method used for Lagrangian timescale for Sigma-y\n(used only if MDISP=1,2 or MDISP2=1,2)\n0 = Draxler default 617.284 (s)
MTAUADV	0	0	Method used for Advective-Decay timescale for Turbulence\n(used only if MDISP=2 or MDISP2=2)\n0 = No turbulence advection
MCTURB	1	1	Method used to compute turbulence sigma-v &\nsigma-w using micrometeorological variables\n(Used only if MDISP = 2 or MDISP2 = 2)\n1 = Standard CALPUFF subroutines
MROUGH	0	0	PG Sigma_y and sigma_z adjusted for roughness
MPARTL	1	1	No partial plume penetration of elevated inversion
MPARTLBA	0	0	Partial plume penetration of elevated inversion modelled for buoyant area sources
MTINV	0	0	Strength of temperature inversion computed from default gradients
MPDF	1	1	PDF used for dispersion under convective conditions
MSGTIBL	0	0	Sub-grid TIBL module not used for shoreline
MBCON	0	0	Boundary concentration conditions not modelled
MSOURCE	0	0	Individual source contributions saved
MFOG	0	0	Do not configure for FOG model output
MREG	0	0	Do not test options specified to see if they conform to USEPA regulatory values
CSPEC	SO2	SO2	Species modelled SO2, H2S \n(0-No, 1-Yes, 2-Computed)
SO2	1,1,0,0	1,1,0,0	Modelled, emitted, deposited, group number
NPT1	0	0	Number of point sources with constant stack parameters or variable emission rate scale factors
NSPT1	0	0	Number of source-species combinations with variable emissions scaling factors
NPT2	0	0	Number of point sources with variable emission parameters provided in external file
NAR1	0	0	Number of polygon area sources
NSAR1	0	0	Number of source-species combinations with variable emissions scaling factors
NAR2	0	0	Number of point sources with variable emission parameters provided in external file
NLN2	0	0	Number of buoyant line sources with variable location and emission parameters
NLINES	0	0	Number of buoyant line sources with variable location and emission parameters
NSLN1	0	0	Number of source-species combinations with variable emissions scaling factors
NVL1	0	0	Number of volume sources
NSVL1	0	0	Number of source-species combinations with variable emissions scaling factors
NVL2	0	0	Number of point sources with variable emission parameters provided in external file
NFL2	1	1	Number of flare sources defined in FLEMARB.DAT
MTIP_FL	0	0	For Flare Sources: Stack tip downwash is NOT used (because stack tip down wash is accounted for in the source term using the AER spreadsheet)
MRISE_FL	1	1	For flare source(s): 1=Brigg's rise; 2=Numerical Rise (Default: 1)
NFLDAT	1	1	Number of flare source files

Save As and Run

After completing the entry of the each of the input groups, the top of the page will display a flag indicating that changes where made to the page and the information must be saved. This is a reminder that a) you should save the *ABflareUI* spreadsheet to save your work and b) that must save the configuration of the *CALPUFF.exe* input file. To save the input the configuration as an *CALPUFF.exe* input file, press the Save As… button. You will be prompted for a location and file name. The input file will be created and the file name will be displayed as the Run File.

Pressing the Run button will execute the *CALPUFF.exe* program for the input file in the Run File field. In this case *CALPUFF.exe* executes and *ABflareUI* waits

for the output. It is recommended that you DO NOT use the Run because the run times for *CALPUFF.exe* are long. Instead of using this button, the mbatonly setting should be used and the batch file `run_calpuff.bat` be executed at a convenient time.



If the mdoforeach setting is used, Run File should be saved using the mdofor variable (in the case shown above `XYEARX`). Pressing Save As... will create the skeleton Run File with the mdofor variables in place, and will create an input file for each of the mdoforlist. If the mbatonly setting is used, then a batch file is created with each mdoforlist settings.

The Start a new CALPUFF.inp setting is used to control how the information is written to the file. If the setting is `Yes`, then a new input file will be created based upon the text fields listed on the sCALPUFF page. If the setting is `No`, then the existing file if it exists, will be modified by replacing the variable values in the file with the variables from the **STEP 3-CALPUFF** page. This setting is useful if comments or alternative entries are routinely stored in the input file.

The Use ZFace from CALMET setting ensures that the *CALPUFF* input file has the same ZFace settings as listed on the *CALMET* page of the *ABflareUI*.

The NSEP setting tells the *ABflareUI* processing to create *CALPUFF.exe* input files using NSEP flremarb.inp files assumed to exist.

Step 4a-CALAVE Page

Browse

To configure a CALAVE input file the user can load an existing CALAVE.inp file by pressing the Browse... button or the user can make changes to the fields as necessary.

CALAVE Settings

The *CALAVE* module is used to post-process the CONDAT file output from *CALPUFF*. *CALAVE* creates block averages or running averages from a binary CONDAT file and outputs a binary averaged concentration file. *CALAVE* was created principally for the determination of 24 hour running averages but can be used for other time averages, such as 3 h or 8 h averages. Running averages (MODE=1) and block averages (MODE =2) can be created as described below. The averaging period is set by either AVGPD_HH (hours) or AVGPD_MM (minutes). The total averaging period is:

AVGPD_HH***3600 +** AVGPD_MM***60 = seconds.**

CALAVE processes one or more *CALPUFF* binary output files (dataset v2.1 (*CALPUFF* output file created by *CALPUFF* prior to v6.41) or v2.2 (current output format with *CALPUFF* v6.42 and v6.42FL) and computes running or block averages of concentrations, dry fluxes or wet fluxes. An output file is created for each input file.

A binary output file with a format similar to that of a binary CALPUFF output file is generated for each *CALPUFF* binary file that is being processed. When block-averages are selected, the output file will be a 'standard' *CALPUFF* file that can be processed by any of the postprocessors in the *CALPUFF* system. Running averages use the same format, but because begin and end-times for each average span a time longer than the interval between the reported values, most of the postprocessors will not accept the running averages.

The output from *CALAVE* has the same file name but is appended with OUT_EXT in the same path location. Filenames can be forced to upper or lower case using the LCFILES switch.

Mode 1: Running Averages

In Mode 1, *CALAVE* reads a *CALPUFF* output file (CONC, WET, DRY) and creates a running average of its contents. These averages are reported from a specified start-time (START_HHMM) and are written for each data period thereafter.

For example, if 24-hour averages starting at 10 AM (start time, START_HHMM = 1000) are requested and the original *CALPUFF* output file contains half-hour values beginning at 0930 on March 13, the following averages will be computed:

1) First 24-hour average: 1000 (March 13) to 1000 (March 14)

2) Second 24-hour average: 1030 (March 13) to 1030 (March 14)

3) Third 24-hour average: 1100 (March 13) to 1100 (March 14)

4) The last 24-hour period will end at the end of the last 30-minute period in the file

A file containing 1 h average values for a single year, will have 8760 values at each receptor. After running *CALAVE* for a 24 h running average, the output will have 8760 values at each receptor representing a 24 h average.

Mode 2: Block Averages

In Mode 2, *CALAVE* reads a *CALPUFF* output file (CONC, WET, DRY) and creates a blocked average of its contents. These averages are reported from a specified start-time (START_HHMM) and are written end-to-end thereafter.

For example, if calendar-day 24-hour averages are requested (start time, START_HHMM = 0000) and the original *CALPUFF* output file contains half-hour values beginning at 0930 on March 13, the following averages will be computed:

1) First 24-hour average: 0000 (March 14) to 0000 (March 15)

2) Second 24-hour average: 0000 (March 15) to 0000 (March 16)

3) Third 24-hour average: 0000 (March 16) to 0000 (March 17)

4) The last 24-hour period will end at the end of the last full day in the file

A file containing 1 h average values for a single year, will have 8760 values at each receptor. After running *CALAVE* for a 24 h block average, the output will have 365 values at each receptor representing a 24 h average.

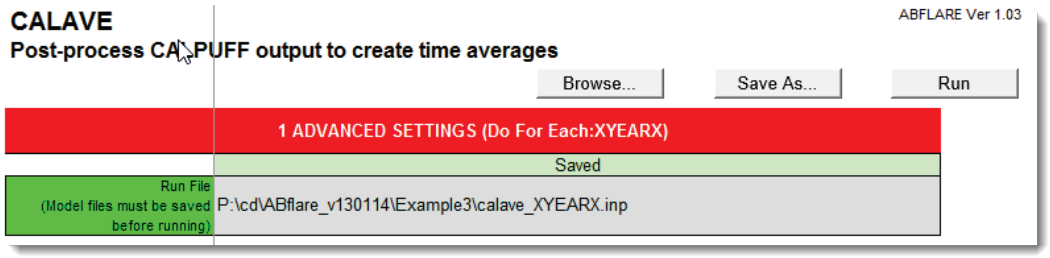
VARIABLE	INPUT	DESCRIPTION	BROWSE
AVGPD_HH	24	Averaging Period (hours)	
AVGPD_MM	0	Averaging Period (minutes)	
MODE	1	1 = Running averages 2 = Block averages	
START_HHMM	0	Starting time (HHMM)	
OUT_EXT	.24r	The output associated with the file(s) listed below for 'source1.dat' would be named 'source1.dat.ave' Output data file extension DEFAULT: .ave	
output: LSTFILE List-file name Default: CALAVE.LST	P:\2011\1100500-FlareModel\ex3\calave_XYEARX.lst		...
LCFILES	T	All file names will be converted to either lower or upper case T = lower case F = UPPER CASE DEFAULT: F	
INPFILE 1	P:\cd\ABflare_v130114\Example3\Output\ABFLARE_XYEARX_01.CON		...
INPFILE 2	P:\cd\ABflare_v130114\Example3\Output\ABFLARE_XYEARX_02.CON		
INPFILE 3	P:\cd\ABflare_v130114\Example3\Output\ABFLARE_XYEARX_03.CON		
INPFILE 4	P:\cd\ABflare_v130114\Example3\Output\ABFLARE_XYEARX_04.CON		
INPFILE 5	P:\cd\ABflare_v130114\Example3\Output\ABFLARE_XYEARX_05.CON		
INPFILE 6	P:\cd\ABflare_v130114\Example3\Output\ABFLARE_XYEARX_06.CON		
INPFILE 7	P:\cd\ABflare_v130114\Example3\Output\ABFLARE_XYEARX_07.CON		

In the example above, the mdoforeach setting was selected on the **iSTART** page. The fields for LSTFILE and INPFILE are highlighted to indicate they accept the

mdofor variable. In the example above, several INPFILE entries will be processed at the same time for each XYEARX and a single LSTFILE is created for each XYEARX. In this example, the raw *CALPUFF* output file ABFLARE_XYEARX_01.con will be averaged using a 24h running average and the output will be ABFLARE_XYEARX_01.con.24r

Save As and Run

Once the fields are completed, the *CALAVE* input file is created by selecting the Save As... button. The user is prompted for a file name and a location. The resulting file is displayed in the Run File field. The Run File field is used to define the path and base filename for the output files. The bright green field indicates that mdoforeach will be used. When the mdoforeach with the Save As.. buttons the file is created first with the DoFor variable (in this case XYEARX) followed the sequence of files with the DoFor variable substituted for the list of replacements (example, 2002, 2003, 2004, 2005 and 2006). This allows the user to view the output files as well as the skeleton file or to use the skeleton file for batch processing at a later time.



Step 4b-CALMAX Page

The *CALMAX* module is used to post-process CONDAT files output from *CALPUFF*. *CALMAX* determines the maximum concentration for each of the same time period in the files and outputs a single file with the maximum concentrations. *CALMAX* will read output from *CALAVE* running averages.

CALMAX reads a set of *CALPUFF*-type binary output files (CONC, WET, or DRY) and selects the maximum value at each receptor for each time period, for each species. Many such files can be included without limit and *CALMAX* will cycle through all. Since the main output file from *CALMAX* is also a *CALPUFF*-type binary file, *CALMAX* can be applied sequentially, using a mix of 'regular' *CALPUFF* files, *CALAVE* output files, and *CALMAX* files. The receptors and species must be the same in all files, and the period of data in each file must include

the processing period requested. Because *CALAVE* generates *CALPUFF*-like binary output files, the output from *CALAVE* can be processed by *CALMAX* (and vice versa).

A *CALMAX* application creates two output data files:

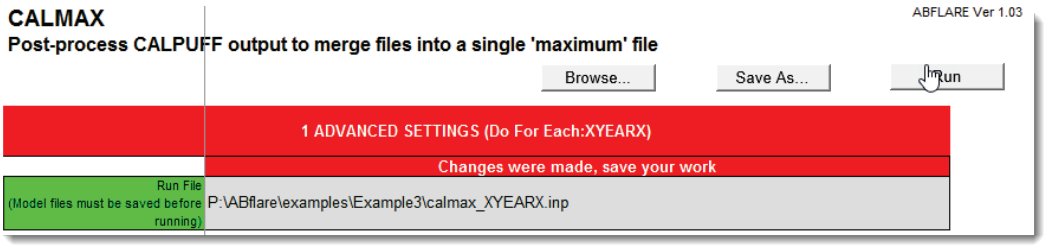
1. An ASCII file of Calendar Day maximum values (`DAILYMAX.OUT`) for each species (one value per species per calendar day).
2. A binary *CALPUFF*-format file of all maximum values (one maximum value at each receptor for each 'timestep' (z timestep being either an actual *CALPUFF* timestep or an averaging time set in *CALAVE*).

A file containing 1 h average values for a single year, will have 8760 values at each receptor. After running *CALAVE* for a 24 h running average, the output will have 8760 values at each receptor representing a 24 h average. Running *CALMAX* on a set these files, will produce a single file with 8760 values representing 24-h running averages.

CALMAX cannot be run on set of block-averaged files, if the start times were incremented on each file.

Browse

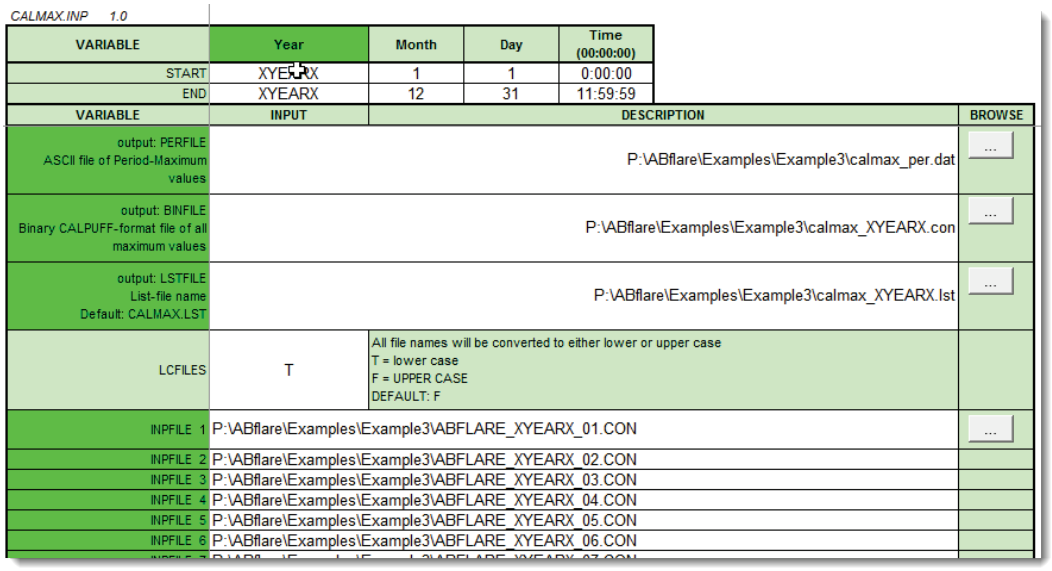
To configure a CALMAX input file the user can load an existing CALMAX.inp file by pressing the Browse... button or the user can make changes to the fields as necessary.



CALMAX Entries

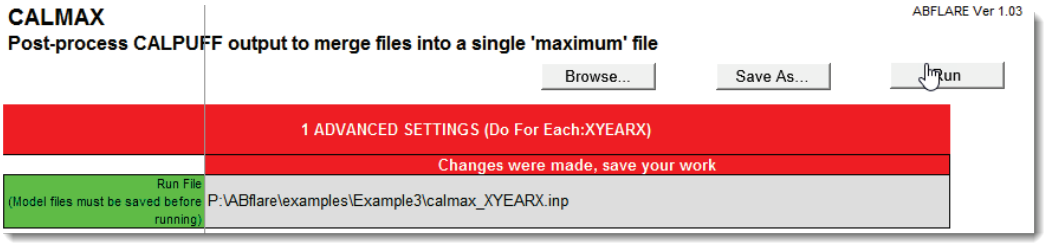
An example of the *CALMAX* input page is shown below. The mdoforeach setting was used and is indicated by the highlighted variables. Each of the highlighted variables accepts the mdofor variable; here mdofor=`XYEARX`. In this example, a typical assessment for a year period has months 1 through 12, and days 1 through 31. This assessment shows 24 INPFILE entries `abflare_XYEARX_01.con` through `abflare_XYEARX_24.con` will be merged into a single PERFILE, BINFILE and LSTFILE: `calmax_XYEARX.dat`, `calmax_XYEARX.con` and

calmax_XYEARX.lst. The abflare_XYEARX_XHHX.con files represent hourly time averages output from *CALPUFF* that were modelled using the blowdown configuration of ABflare.exe (MINPUT=1, MBLOWDOWN=2, NPUFFS=3, NSEP=24). Each blowdown sequence starts on the hour in each file. Using *CALMAX*, abflare_XYEARX_XHHX.con output files are merged into a single hourly time series by selecting the maximum concentration for a given calendar hour across the files. The calmax_XYEARX.con output file represents the worst-case concentrations for a blowdown that may have started on any hour of the day throughout the year.



Save As and Run

Once the fields are completed, the CALMAX input file is created by selecting the Save As… button. The user is prompted for a file name and a location. The resulting file is displayed in the Run File field. The Run File field is used to define the path and base filename for the output files. The bright green field indicates that mdoforeach will be used. When the mdoforeach with the Save As.. buttons the file is created first with the DoFor variable (in this case XYEARX) followed the sequence of files with the DoFor variable substituted for the list of replacements (example, 2002, 2003, 2004, 2005 and 2006). This allows the user to view the output files as well as the skeleton file or to use the skeleton file for batch processing at a later time.



Step 4c-CALRANK Page

The *CALRANK* module is used to post-process CONDAT files output from *CALPUFF*. *CALRANK* determines the n^{th} highest or percentile concentration at each receptor location for the input file and outputs a plot file for each of the selected n^{th} highest or percentiles. *CALMAX* will read output from *CALAVE* running averages.

CALRANK reads a *CALPUFF*-type concentration/flux output file (dataset v2.1 or v2.2), ranks the timeseries for each species at each receptor for the entire application period, and identifies the nth-highest values and the percentile values requested in the `CALRANK.inp` input file. More than one rank or percentile can be requested in a single run, and because of the overhead of ranking all of the values at each receptor, a single application with all desired ranks is normally prepared.

Individual plot-files are created for each requested rank/percentile, and include the location of each receptor, the value of the requested rank/percentile at that receptor, and the date and time at which that value occurred. If more than one species is in the file, this information is provided for each species. Additionally, the largest among all receptors is tabulated for each requested rank/percentile and species in the `CALRANK.lst` file.

CALRANK can be used to process running average statistics for 24 h averages using the ICDAY flag setting. If ICDAY =0, each time period result in the file is processed as is; this is suitable for processing 1 h time averages. If ICDAY=1, each time period result in the file is first grouped into calendar day and the maximum value is included in the ranking; this is suitable for ranking 24 h running averages (8760 values from 1 h time averages) to produce statistics for a calendar year (365 days).

The output from the CALRANK program is a `.dat` file for each of the n'th highest or percentiles in the list. The output file name will have the following format:

```
<listfile.lst>_PLOT_PCTL-<percentile F6.3>.dat
```

Or

```
<listfile.lst>_PLOT_RANK-<rank I4.4>.dat
```

VARIABLE	INPUT	DESCRIPTION	BROWSE
input: DATFILE File of modeled data (include path if desired)		P:\ABflare\examples\Example1\CALPUFF_XYEARX.CON	...
output: LSTFILE List-file name Default: CALRANK.LST		P:\ABflare\examples\Example1\calrank_XYEARX.lst	...
LCFILES	T	All file names will be converted to either lower or upper case T - lower case F - UPPER CASE DEFAULT: F	
ICDAY	0	Peak values that are ranked may be restricted to no more than 1 per calendar day (e.g., the calendar-day maximum). The day in which a value is placed is determined by its start-time. Report as Calendar-Day maximums? 0 - No : all values at each receptor are ranked (more than 1 rank may be in same day) 1 - Yes : peak value in calendar day at each receptor is ranked	
MASS_UNIT	3	Reported mass units: 1: g/m**3 or g/m**2/hr grams 2: mg/m**3 or mg/m**2/hr milligrams (1.0e-03 g) 3: ug/m**3 or ug/m**2/hr micrograms (1.0e-06 g) 4: ng/m**3 or ng/m**2/hr nanograms (1.0e-09 g) 5: pg/m**3 or pg/m**2/hr picograms (1.0e-12 g) Default: 1	

VARIABLE	INPUT		VARIABLE	INPUT %	COMMENT	
NTH_HIGHEST 1	1		PERCENTILE 1	50		
NTH_HIGHEST 2	2		PERCENTILE 2	60		
NTH_HIGHEST 3	9		PERCENTILE 3	70		
NTH_HIGHEST 4			PERCENTILE 4	80		
NTH_HIGHEST 5			PERCENTILE 5	90		
NTH_HIGHEST 6			PERCENTILE 6	95		
NTH_HIGHEST 7			PERCENTILE 7	96		
NTH_HIGHEST 8			PERCENTILE 8	97		
NTH_HIGHEST 9			PERCENTILE 9	98		
NTH_HIGHEST 10			PERCENTILE 10	98.5		
NTH_HIGHEST 11			PERCENTILE 11	99		
NTH_HIGHEST 12			PERCENTILE 12	99.5		
NTH_HIGHEST 13			PERCENTILE 13	99.8		
NTH_HIGHEST 14			PERCENTILE 14	99.9		
NTH_HIGHEST 15			PERCENTILE 15			
NTH_HIGHEST 16			PERCENTILE 16			
NTH_HIGHEST 17			PERCENTILE 17			
NTH_HIGHEST 18			PERCENTILE 18			
NTH_HIGHEST 19			PERCENTILE 19			
NTH_HIGHEST 20			PERCENTILE 20			
NTH_HIGHEST 21			PERCENTILE 21			
NTH_HIGHEST 22			PERCENTILE 22			
NTH_HIGHEST 23			PERCENTILE 23			
NTH_HIGHEST 24			PERCENTILE 24			
NTH_HIGHEST 25			PERCENTILE 25			

The data file output provides the rank or percentile concentration at each receptor. The data file is ASCII formatted and suitable for postprocessing using surfer or excel. An example of the header for a percentile output (rank is similar) is shown below:

```
             ---------------------------------------------
             Requested Values for Percentile (%) =  99.900
             Corresponding Nth-Highest N         =       9
             All Values in Each Day are Included
             Number of times in period           =    8760
             ---------------------------------------------


Model data for each receptor are ranked over all times based on magnitude and
the requested Nth-Highest and/or Percentile values are reported for each receptor


     Location         Species - Level  Starting UTC-0700
    X         Y       SO2           1    Date     Time
  (KM)      (KM)      ug/m3           (YYYY_JJJ)(HH:MM:SS)

 481.134  6112.245     9.6021692E+02   2006_209  11:00:00
 481.134  6112.265     8.5096545E+02   2006_141  18:00:00
 481.134  6112.285     6.7367041E+02   2006_209  12:00:00
 481.134  6112.305     6.2017560E+02   2006_134  13:00:00
 481.134  6112.325     5.0326978E+02   2006_176  17:00:00
```

4. EXAMPLE 1: Tutorial for Hour-by-Hour Steady Flare

In this chapter, we will walk through an example of using *ABflare* to model a steady flare in complex terrain. This example mirrors the Example 1in *AERflare*.

The flare location from *AERflare* is shown below:

UTM Zone		11
Surface Coordinates of Device	X Coord (m Easting) or Longitude	481234
	Y Coord (m Northing) or Latitude	6112345
Device Base Elevation	m	669.6114319

The flare in this example is modelled as a steady flare. That is, the source and emissions are assessed at the maximum, average and 1/8th maximum flow rates, each as a continuous but independent source. These rates cover the range of emissions as well as the likely range in plume heights associated with the energy released from the gas.

Requested Maximum Raw Gas H_2S Concentration for **Subject** Zone or Source	% (for Permits round up to 0.5% increment)	30.10000%
Stack Tip Exit Height	m	30.5
Stack Tip Exit Diameter	mm	305

	Flaring Type?	◉ Continuous or Steady ○ Transient	
Continuous or Steady	UNITS	ENTRY	WARNINGS
Maximum Raw Gas Flow Rate for Subject Zone Source of Sour Gas	$10^3m^3/d$ (15°C and 101.325 kPa)	250	
MUST enter any 2 of the fields: i) **VOLUME** of Raw Gas to be Burned for Subject Zone or Source	i) **Volume** 10^3m^3 (15°C and 101.325 kPa)	400	--
ii) **AVERAGE FLOW RATE** of Raw Gas	ii) **Average Flow Rate** $10^3m^3/d$ (15°C and 101.325 kPa)	125	--
iii) **DURATION** of Burning	iii) **Duration** hours		76.8

Initialize Domain Common Variables

Similar to the *CALPUFF* suite of utility routines, the *ABflare* system has a set of common variables and coordinates. Rather than entering these variables on individual pages, they are entered on the **iCOMMON** page. However, in order to make each page an independent step, the modeller must remember to press the Refresh button to copy the coordinates to the page the modeller is currently working on.

If the modeller has already used the *AERflare* tool to model the flare, then the coordinates of the assessment can be extracted from the *AERflare* spreadsheet by pressing Load from AERflare button. If the modeller has already configured a CALPUFF modelling domain external to *ABflare* the common coordinates can be extracted from an existing CALPUFF.inp or CALMET.inp file by pressing the Load from *.inp. Alternatively, the modeller can enter the values manually.

For this example, the coordinates that represent the modelling domain are shown below.

VARIABLE	INPUT	DESCRIPTION	
PMAP	UTM	Map projection, see list to right	UTM
FEAST	0	False Easting and Northing (km) at the projection origin (Used only if PMAP= TTM, LCC, or LAZA)	
FNORTH	0		
IUTMZN	11	UTM zone (1 to 60) (Used only if PMAP=UTM)	
UTMHEM	N	Hemisphere for UTM projection? (N or S) (Used only if PMAP=UTM)	
RLAT0	55.0218N	Latitude and Longitude (decimal degrees) of projection origin (Used only if PMAP= TTM, LCC, PS, EM, or LAZA) e.g.,. RLAT0=60N, RLON0=115W numeric value must end with W,E,N or S	
RLON0	-117.5281E		
XLAT1	0N	Matching parallel(s) of latitude (decimal degrees) for projection (Used only if PMAP= LCC or PS)	
XLAT2	0N		
DATUM	NAR-B	Datum-region for output coordinates, see list to right	NAR-B
UNITS	KM	m or km (Used in ABflare.exe input and ARBflareEmis.dat output)	
ABTZ	UTC-0700	UTC time zone for output PST = UTC-0800, MST = UTC-0700 ,	
NX	3	No. X grid cells	
NY	3	No. Y grid cells	
DGRIDKM	10	Grid spacing	
XORIGKM	466.234	X Coordinate, Reference grid coordinate of SOUTHWEST corner of grid cell (1,1)	
YORIGKM	6097.345	Y Coordinate, Reference grid coordinate of SOUTHWEST corner of grid cell (1,1)	
Domain	(press 'Refresh Coords' to update the domain coordinates)		
XDOM0	466234	UTM X Coordinate, Reference grid coordinate of SOUTHWEST corner of grid cell (1,1)	
YDOM0	6097345	UTM Y Coordinate, Reference grid coordinate of SOUTHWEST corner of grid cell (1,1)	
XDOM1	496234	UTM X Coordinate, Reference grid coordinate of NORTHEAST corner of grid cell (nx,ny)	
YDOM1	6127345	UTM Y Coordinate, Reference grid coordinate of NORTHEAST corner of grid cell (nx,ny)	
RLAT0	55.0218N	X Coordinate, Latitude grid coordinate of SOUTHWEST corner of grid cell (1,1)	
RLON0	-117.5281E	Y Coordinate, Longitude grid coordinate of SOUTHWEST corner of grid cell (1,1)	
RLAT1	55.2925N	X Coordinate, Latitude grid coordinate of NORTHEAST corner of grid cell (nx,ny)	
RLON1	-117.0593E	Y Coordinate, Longitude coordinate of NORTHEAST corner of grid cell (nx,ny)	
East-West	30	km Domain Size	
North-South	30	km Domain Size	

Coordinates

Similar to CALPUFF, not all of the settings are necessary for every situation but they may be necessary for some situations. For a typical assessment, the map projection should be set to PMAP=`UTM`, with the IUTMZN (UTM zone) matching the location, in this case IUTMZN=`11` and UTMHEM=`N` (northern hemisphere). Typical assessments will also require setting the DATUM=`NARB` (Canadian datum), UNITS=`KM` and ABTZ=`UTC-0700` (the time zone without daylight savings time of the location).

The next five entries define the size and resolution of the meteorological domain. The meteorological domain should be larger than the air dispersion modelling domain of interest so that edge effects such as flow recirculation can be accounted for, or wind patterns that are affected by terrain. Refer to the CALMET user guide for further assistance on selecting the domain size. The coordinates of the lower left corner of the domain are entered in UTM kilometer coordinates, XORIGKM

and YORIGKM. In this example, a very coarse meteorological grid has been selected to reduce run-times, DGRIDKM=10 (km). A typical assessment will use a fine resolution such as DGRIDKM=0.25 (km) to resolve the terrain features as necessary. The NX and NY variables control the number of grid cells in each direction and therefore define the extent of the domain. For a typical assessment, the air dispersion modelling domain is a 10km radius around the flare, therefore the domain is 20km×20km. The meteorological domain adds 5km around the outside, therefore the meteorological domain is typically 30km×30km. When the grid size is large as in this example, it is recommended to position the flare at the centre of a grid cell to avoid unpredictable results. For instance, if in this example, DGRIDKM=7.5(km) and NX=4 and NY=4, then the source located at the centre of the domain would be influenced by four meteorological cells (one from each quadrant).

As the user enters information into the **iCOMMON** fields, the fields in the **DOMAIN** summary at the bottom of the page are updated. Alternatively, the user can press the Refresh Coords button to update the domain. The **DOMAIN** table lists the lower left and upper right coordinates of the domain in UTM and geographic coordinates.

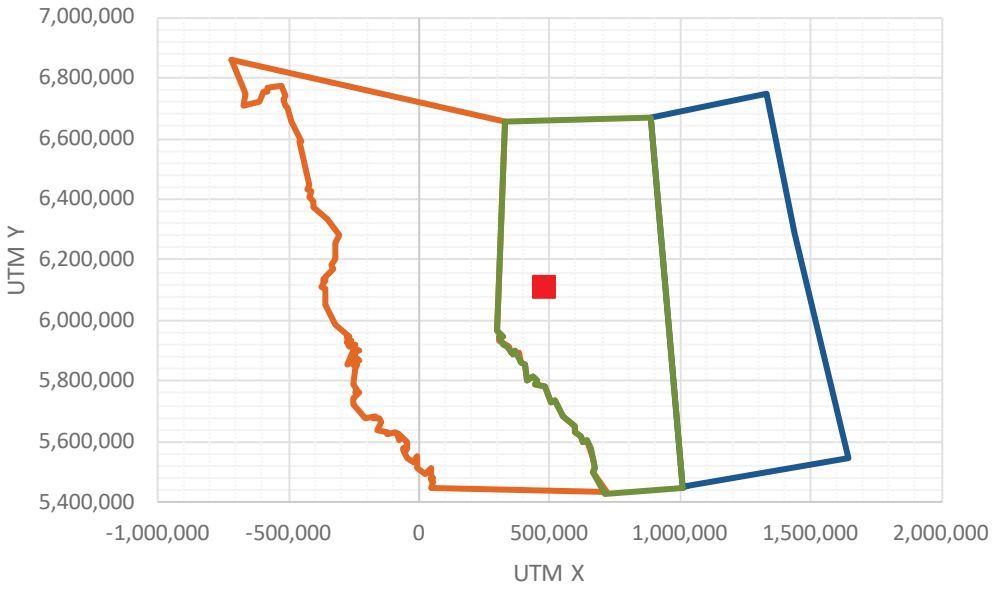
iLOCATION

The iLOCATION is a handy reference map that displays the domain in relation to a map of Canada western provinces most involved in flaring. The page should refresh the coordinates from the iCOMMON page when the modeller selects the iLOCATION page. Alternatively, the modeller can press the Refresh button to update the coordinates.

The coordinates of the flare location (centre of domain) are provided in the table in UTM, 10TM and geographical coordinates. Also provided, for reference is the Canadian NTS map sheet for the flare location.

	UTM Flare Location	10TM Flare Location
X UTM	481234.0	-146129.8
Y UTM	6112345.0	6112261.5
UTM Zone	11	10TM
	Conversion to Geographic Coordinates	
Longitude	-117.2945	
Latitude	55.1574	
	Map File	
Map File	083n03	

For this example, the UTM coordinate map shows the flare location to be in the northwestern corner of the Alberta. (note, the coordinates for this example were selected randomly and matching coordinates with an existing facility is a coincidental).



Creating Meteorological Files

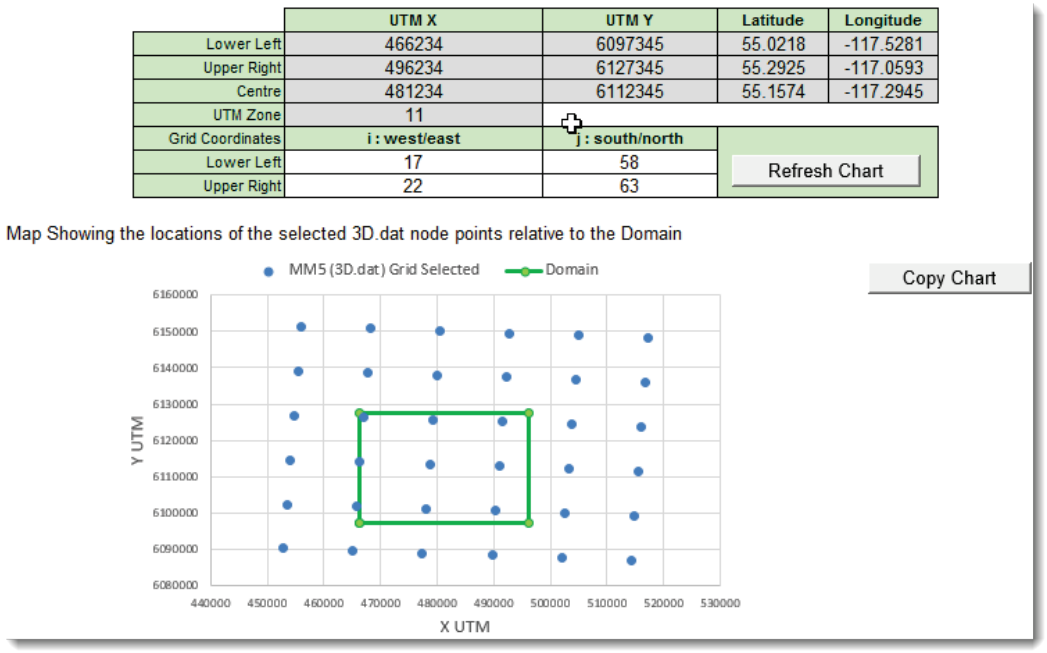
An important step in the modelling process is the creation of a set of meteorological files. The meteorological files contain the wind flow field vectors and wind speeds into which the pollutants are released. The meteorological flow filed also contain important thermodynamics properties that will impact plume rise and turbulence. The modeller is referred to the CALMET user guide for detailed information about creating meteorological input files for CALPUFF. The **Step 0a-CALMET** page is designed to create meteorological input using the Alberta MM5 (or other Canadian MM5) datasets.

The creation of meteorological files requires several sub-steps, that must be performed in order:

1. MM5 data extraction
2. Define land-use characteristics
3. Extract digital terrain
4. Process digital terrain
5. Create geographical input files for CALMET
6. Run CALMET

MM5 Data Extraction

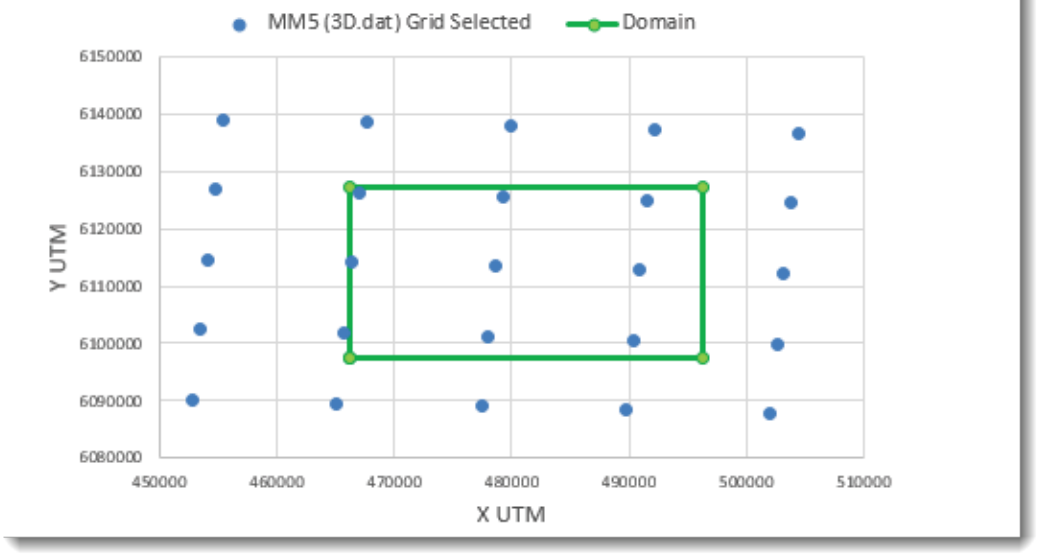
The first sub-step requires the extraction of MM5 raw data into a 3D.dat file. The 3D.dat file represents meteorological data for several nodes of the MM5 modelling domain. It is necessary to determine which nodes to extract. The modeller can press the Refresh button at the top of the **Step 0a-CALMET** page to refresh the coordinates from the **iCOMMON** page. The table shows coordinates of the meteorological domain and the estimated MM5 nodes to be extracted. The MM5 data should be larger than meteorological domain. However, the default estimate (as shown below) may not be suitable and can be manually adjusted. In this case, the MM5 % is unnecessarily too far north and to far east.



Adjusting the upper right coordinate yields a more satisfying result. This is no harm in using the larger MM5 grid, however, the 3D.dat file will be larger than necessary. Press the Copy Chart button to copy the chart to the clipboard, and the figure can be pasted into a report to document the meteorological domain.

Lower Left	17	58	Refresh
Upper Right	21	62	

ing the locations of the selected 3D.dat node points relative to the Domain



The data entry fields relevant to the MM5 extraction are shown below. The first two fields refer to the existing MM5 data library. The Name Template will not be required to change for Alberta data (since this format match the Alberta MM5 data) but a modeller outside of Alberta may require changing the template to match the local data set. The template uses two variables `XYEARX` and `XJDAYX` which will be replaced with the current year and Julian data during the extraction.

MM5 to 3D.dat Data Extraction using CALMM5

Existing File Name Template	MM5_XYEARX_XJDAYX_Alberta_12km_MMEU.out	Reset					
Input Existing MM5 Data Path	Y:\MM5\	...					
Output 3D.dat	Y:\ABflare\AERflare_examples\Example1\met\puf\3dXYEARX.dat	...					
Start of Period			End of Period			Reset Dates	
iyr	imo	iday	iyr	imo	iday		
2002	1	1	2003	1	1	Run	
2003	1	1	2004	1	1	Run	
2004	1	1	2005	1	1	Run	
2005	1	1	2006	1	1	Run	
2006	1	1	2007	1	1	Run	

The MDOFOREACH setting must be selected

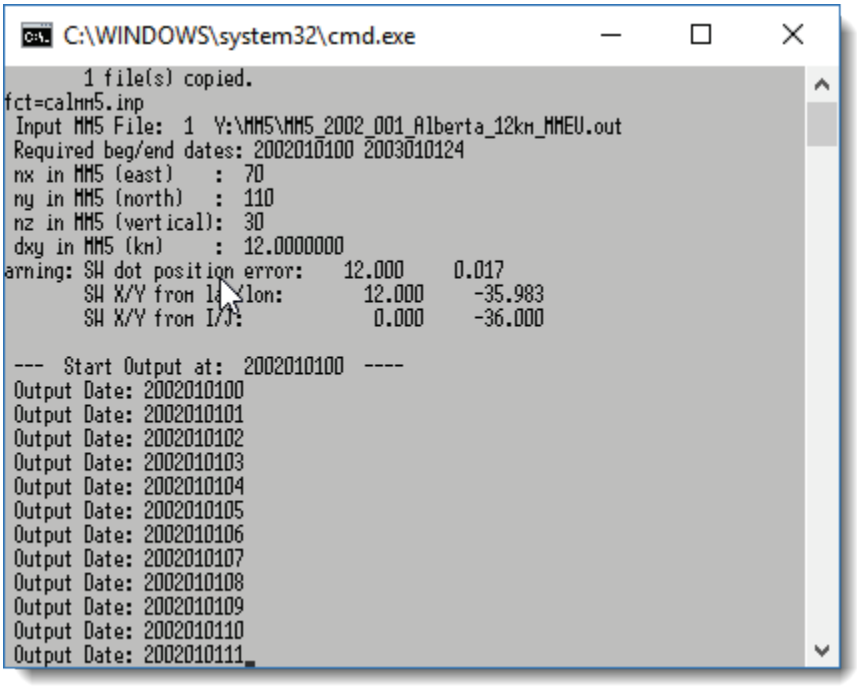
The Output 3d.dat field uses MDOFOREACH variable to define the output 3D.dat file names. A 3D.dat file will be created for each year of the assessment and the XYEARX variable in the Output 3d.dat field is replaced with the year 2002, 2003, 2004, 2005, 2006 respectively.

The table shows the start date and time for each year and the ending to be the start of the next year. This overlap will ensure that a complete year of meteorology is extracted and ready for processing by *CALMET*.

Once the table is completed, the Run buttons can be pressed to launch independent threads (batch processes) to extract the MM5 data. These threads are executed asynchronously, so that the modeller may continue working on the spreadsheet tasks while the extract ion is proceeding. The extraction may take some time depending upon the processor speed and network speed.

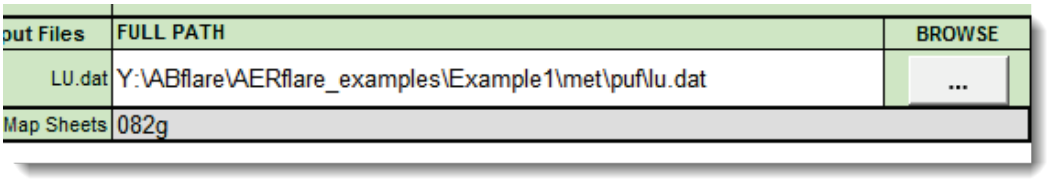
The modeller can continue working on Land-use Characteristics, Digital Terrain Data, Terrain Input file and Geographical Input Files while the MM5 data is being extracted.

The processing windows will show the progress of the data extraction as shown below.



Land Use Characteristics

The land-use characteristics are an important component of the meteorological file creation which is used to define the surface roughness, albedo and Bowen ratio. The modeller needs only select the output path then press the Get LCC Data button to start the extraction. The status bar will display the progress.



The map file(s) used by the extraction are listed once the button is pressed. The location of the LCC files is provided by the LCCLIB entry on the **iBIN** page. The lccsubsample variable can be adjusted on the **iSTART** page to adjust the sub-sampling for each grid cell. For large grid cells, a larger setting for lccsubsample is recommended. A value of lccsubsample=3, means that a grid cell will be divided into nine sub-cells and LCC at the point location of the sub-cell is used in the average. A higher value for lccsubsample will result in a more representative average at the expense of higher computational effort.

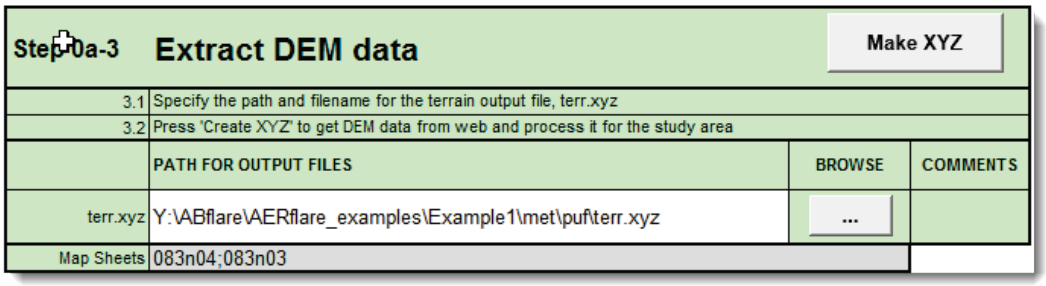
The result of the LCC analysis is presented below. In this example, the *CALPUFF* was configured with nx=3 and ny=3 which has 9 meteorological grid cells. With a lccsubsample=3, each cell is sub-divided into 9-sub-cells. Therefore, a total of 9×9=81 LCC samples is used. The results of the LCC show that the predominant land-use classification is deciduous forest and cropland/pasture.

CALPUFF Landuse Classification Code Summary

ID	LCC	Description	Count	Percent
0	0	Unknown/Missing/Cloud/Shadow	0	0.0%
1	11	Residential	0	0.0%
2	12	Commercial and Services	0	0.0%
3	13	Industrial	0	0.0%
4	14	Transport/Comm/Utils	0	0.0%
5	15	Industry/Commercial Complexes	0	0.0%
6	16	Mixed Urban or Built-up Land	0	0.0%
7	17	Other Urban or Built-up Land	0	0.0%
8	21	Cropland and Pasture	26	32.1%
9	22	Orchards, etc..	0	0.0%
10	23	Confined Feeding Operations	0	0.0%
11	24	Other Agricultural Land	0	0.0%
12	31	Herbaceous Rangeland	0	0.0%
13	32	Shrub and brush Rangeland	5	6.2%
14	33	Mixed Rangeland	0	0.0%
15	41	Deciduous Forest Land	26	32.1%
16	42	Evergreen Forest Land	5	6.2%
17	43	Mixed Forest Land	0	0.0%
18	51	Streams and Canals	0	0.0%
19	52	Lakes	2	2.5%
20	53	Reservoirs	0	0.0%
21	54	Bays and estuaries	0	0.0%
22	55	Oceans and Seas	0	0.0%
23	61	Forested wetland	10	12.3%
24	62	Non-forested wetland	0	0.0%
25	71	Dry salt flats	0	0.0%
26	72	Beaches	0	0.0%
27	73	Sandy areas other than beaches	0	0.0%
28	74	Bare Exposed Rock	0	0.0%
29	75	Strip Mines, Quarries and Gravel pits	0	0.0%
30	76	Transitional areas	0	0.0%
31	77	Mixed barren land	0	0.0%
32	81	Shrub and brush tundra	0	0.0%
33	82	Herbaceous tundra	7	8.6%
34	83	bare ground	0	0.0%
35	84	Wet tundra	0	0.0%
36	85	Mixed tundra	0	0.0%
37	91	Perennial snow or ice	0	0.0%
38	92	Glaciers	0	0.0%
		Total	**81**	**100.0%**
		Minimum count in cell	9	
		Maximum count in cell	9	

Digital Terrain Data

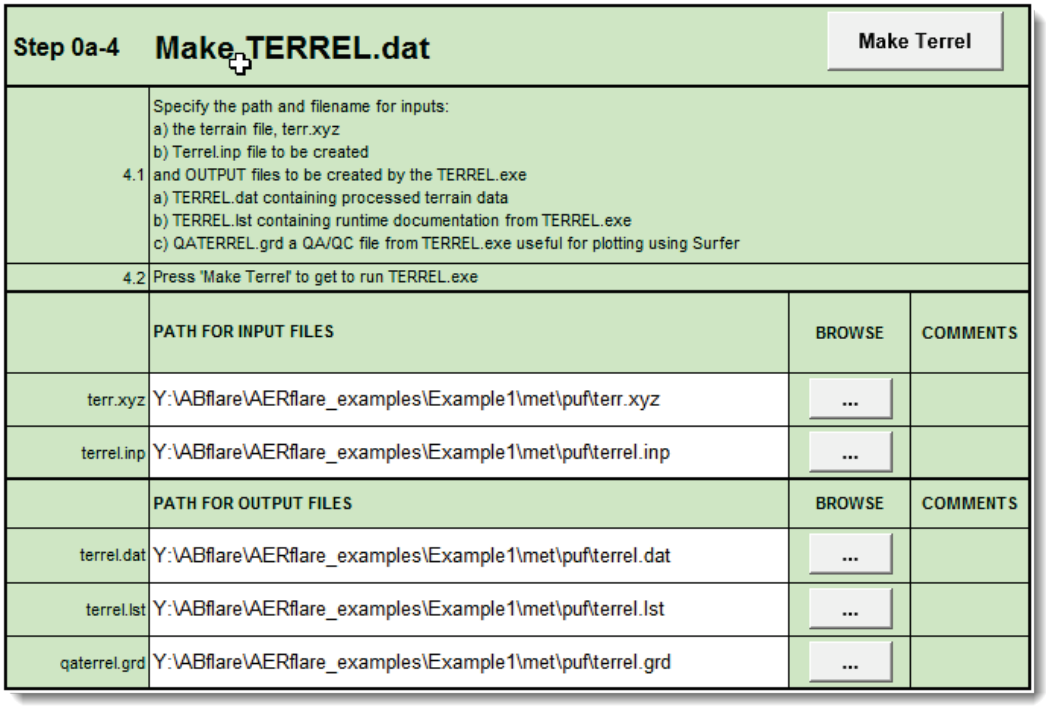
CALMET preprocessing has a terrain processor *TERREL.exe*. DEM data is extracted from the Canadian DEM format to a generic XYZ format for input into *TERREL.exe*. Enter the path for the output file as shown below then press the Make XYZ to start the extraction process. The map sheets used in the extraction are displayed below the output path. The status bar will display the progress during extraction.



Step 0a-3	Extract DEM data		Make XYZ
3.1	Specify the path and filename for the terrain output file, terr.xyz		
3.2	Press 'Create XYZ' to get DEM data from web and process it for the study area		
	PATH FOR OUTPUT FILES	BROWSE	COMMENTS
terr.xyz	Y:\ABflare\AERflare_examples\Example1\met\puf\terr.xyz	...	
Map Sheets	083n04;083n03		

Terrain Input File

Once the `TERR.xyz` file has been extracted, the *TERREL.exe* processing can be configured. Enter the path of the `TERR.xyz` file extracted above, and specify the path for the input file for *TERREL.exe*. There are three output files from *TERREL.exe*: TERREL.dat the primary output required for the next step (MakeGEO.exe), TERREL.lst will provide valuable information such as missing data or error messages, TERREL.grd the terrain file in *SURFER* ready format (in km coordinates).



Step 0a-4	Make TERREL.dat		Make Terrel
4.1	Specify the path and filename for inputs: a) the terrain file, terr.xyz b) Terrel.inp file to be created and OUTPUT files to be created by the TERREL.exe a) TERREL.dat containing processed terrain data b) TERREL.lst containing runtime documentation from TERREL.exe c) QATERREL.grd a QA/QC file from TERREL.exe useful for plotting using Surfer		
4.2	Press 'Make Terrel' to get to run TERREL.exe		
	PATH FOR INPUT FILES	BROWSE	COMMENTS
terr.xyz	Y:\ABflare\AERflare_examples\Example1\met\puf\terr.xyz	...	
terrel.inp	Y:\ABflare\AERflare_examples\Example1\met\puf\terrel.inp	...	
	PATH FOR OUTPUT FILES	BROWSE	COMMENTS
terrel.dat	Y:\ABflare\AERflare_examples\Example1\met\puf\terrel.dat	...	
terrel.lst	Y:\ABflare\AERflare_examples\Example1\met\puf\terrel.lst	...	
qaterrel.grd	Y:\ABflare\AERflare_examples\Example1\met\puf\terrel.grd	...	

Press the Make Terrel button to start the terrain processing. A command-line window will open (minimized) to run the program in the background. The status bar will display the progress.

Geographical Input File(s)

The next step for CALMET preprocessing is the creation of Geographical inputs. The preferred method in Canadian climates uses a 4-season configuration (winter, spring, summer and fall) where winter is characterized by significant snow cover, spring is characterized by sparse leafy vegetation and emerging vegetation, summer is characterized by full foliage, and fall is characterized by sparse vegetation, cut crops and lack of snow.

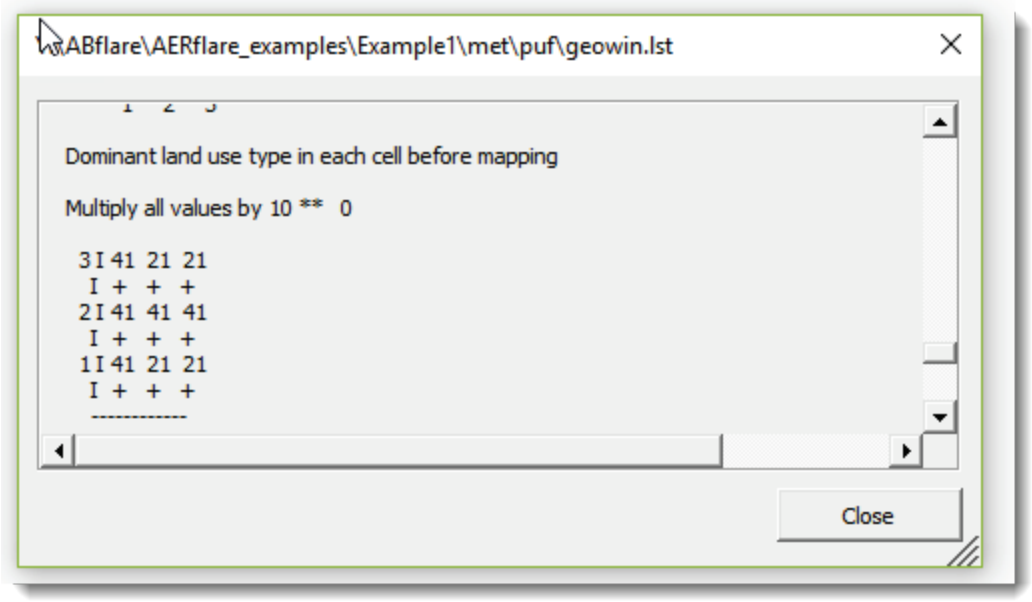
In the group **Step 0a-5** input section, complete the table of geographical inputs as shown below. The Property Index entry corresponds to the recommended properties listing on page **sLCC** of the spreadsheet. Typically, the properties will not be required to be changed. The months assigned to each season are configured in the next step.

Season	Property Index	File Name (no path)	Default (if blank)	COMMENTS
Spring	1	geospr	geospr	See "CALMET PROPERTIES"
Summer	2	geosum	geosum	1=Spring 2=Summer
Fall	3	geofall	geofall	3=Fall
Winter	4	geowin	geowin	4=Winter 5=Winter 2
Winter2	0		geosno	0=do not use

For now, all that is required is create the files. Complete the table of entries as shown below. The GEO.inp entry is for the path for the input files and GEO.dat entry is the path for the output files. These paths can be the same. The LU.dat entry is the file created by above for the land-use. The TERR.dat entry is the file created above for the terrain processing.

	PATH FOR INPUT FILES	BROWSE	COMMENTS
geo.inp path	Y:\ABflare\AERflare_examples\Example1\met\puf\	...	
lu.dat	Y:\ABflare\AERflare_examples\Example1\met\puf\lu.dat	...	
terr.dat	Y:\ABflare\AERflare_examples\Example1\met\puf\terrel.dat	...	
	PATH FOR OUTPUT FILES	BROWSE	COMMENTS
geo.dat path	Y:\ABflare\AERflare_examples\Example1\met\puf\	...	

Press the Make Geo but to start the geographical file processing. After each of the season files is create the output list file is displayed for viewing. The user should scroll through the output .lst files and check the processing. You are looking to ensure there is data created for each cell and to scan for error messages. Below is an example of the .lst file showing land-use analyzed for each 3×3 grid cell.



Running CALMET

It is highly recommended to create CALMET input files and run-time batch files. This is suggested because CALMET will take significant numerical processing resources which is better suited to parallel-processing or night-time processing.

When CALMET is configured in the NOOBS mode (no surface or upper air observations) using only the MM5 data, there are only two remaining parameters to specify: TERRAD and ZFACE. TERRAD is a scaling parameter used to in the processing of slope flows. A value of TERRAD=12 (range 10-15) is common. A value of TERRAD=12 has been found to represent most conditions and creates intuitive flow patterns in most grid cells. Tweaking TERRAD to alternative values requires extraction of the CALMET output to vector plots where the user can scan flow vectors for every hour of the hour. The ZFACE settings are used to specify the boundary layer levels. This is an important entry which must be configured in careful consideration of the levels available in the MM5 data, terrain and terrain roughness/land-use. In Aberta, Alberta Environment and Parks recommends the settings below, and these settings should not be changed for air quality modelling assessment within this context.

TERRAD	12	

zFACE Meteorlogical Layers Definition

NZFACE	12	The number of layers of meteorology	
ZFACE	Elevation (m)	Default (m)	Depth (m)
0	0	0	0
1	20	20	20
2	40	40	20
3	80	80	40
4	120	120	40
5	280	280	160
6	520	520	240
7	880	880	360
8	1320	1320	440
9	1820	1820	500
10	2380	2380	560
11	3000	3000	620
12	4000	4000	1000
13			
14			
15			

A typical air quality assessment requires 5-years of meteorological data processing using CALMET. The methodology shown in the example below is a template based method to reduce the repetitive and error prone sequence of creating 60 individual month files (5 years × 12 months). Monthly files are to reduce overall file sizes (as opposed to using a single file for each year) and to reduce computation time accessing data within a file. The recommended template shown below. The table shows month, day, hour and second start and end settings for a template year. Note that, end day for leap year months is adjusted programmatically during the file creation. The table entries use the variable name `XYEARX` to replace the individual years of an assessment. In Alberta, this would typically be 2002-2006 to match the MM5 data. The variable XYEARX is replaced by the list of entries specified on the **iSTART** page for the mdoforeach=1 setting and dofor=`XYEARX`, 2002, 2003, 2004 ,2005, 2006.

Creates a batch file to be used at a later time (1-Yes, 0-No)	mbatonly	--	1	0
Uses the 'Do For Each' list when creating files (1-Yes, 0-No)	mdoforeach	--	1	0
Synchronize settings between spreadsheets (1-Yes, 0-No)	msync	--	1	0

Non-Default Settings

Description	Variable	Units	Inputs	Default
Modelling domain for receptor grid	rmaxdist	m	10000	10000
Modelling domain buffer beyond receptor grid	dombuf	m	5000	5000
Meteorological domain grid resolution	dgrid	m	250	250
LCC subsampling	lccsubsample	--	3	3
Receptor Resolution for Maximum Concentration	DXmin	m	20	20

These settings are intended for calculations performed outside of Alberta, Canada

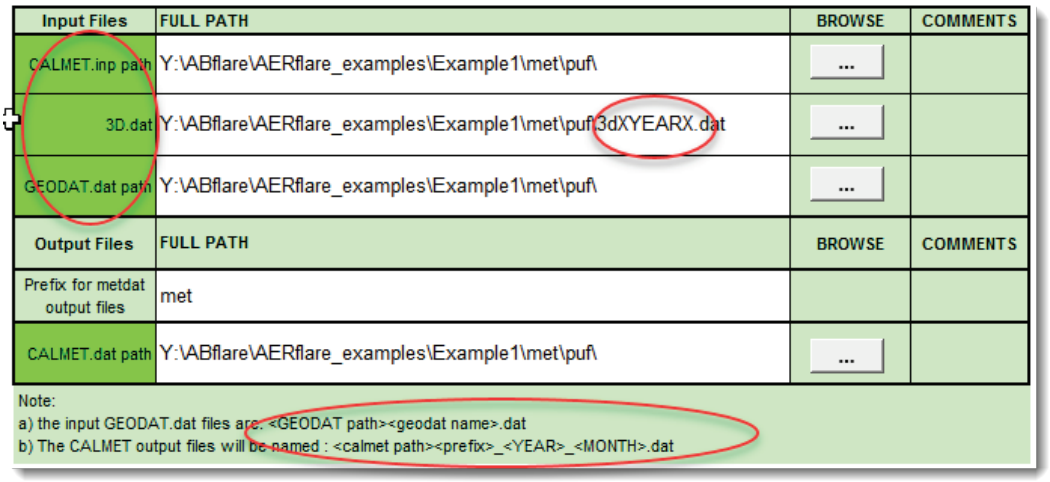
Do For Each List

Do For	XYEARX
Each of	2002
	2003
	2004
	2005
	2006

Date Options Group

NSECDT	3600	Time interval				
Date	iyr	imo	iday	ihr	isec	GEODAT
Met 1-Start	XYEARX	1	1	0	0	geowin
End	XYEARX	1	31	23	3600	
Met 2-Start	XYEARX	2	1	0	0	geowin
End	XYEARX	2	28	23	3600	
Met 3-Start	XYEARX	3	1	0	0	geospr
End	XYEARX	3	31	23	3600	
Met 4-Start	XYEARX	4	1	0	0	geospr
End	XYEARX	4	30	23	3600	
Met 5-Start	XYEARX	5	1	0	0	geospr
End	XYEARX	5	31	23	3600	
Met 6-Start	XYEARX	6	1	0	0	geosum
End	XYEARX	6	30	23	3600	
Met 7-Start	XYEARX	7	1	0	0	geosum
End	XYEARX	7	31	23	3600	
Met 8-Start	XYEARX	8	1	0	0	geosum
End	XYEARX	8	31	23	3600	
Met 9-Start	XYEARX	9	1	0	0	geofall
End	XYEARX	9	30	23	3600	
Met 10-Start	XYEARX	10	1	0	0	geofall
End	XYEARX	10	31	23	3600	
Met 11-Start	XYEARX	11	1	0	0	geofall
End	XYEARX	11	30	23	3600	
Met 12-Start	XYEARX	12	1	0	0	geowin
End	XYEARX	12	31	24	3600	

The *CALMET* processing requires three further inputs (see below): the CALMET.inp path (this is the path for the output of *ABflare* processing that creates the CALMET.inp files which, in turn, are the input for *CALMET*), the 3D.dat file created early from the extraction of the MM5 data, and the path to the GEODAT.dat files created above. The GEODAT.dat file used for a particular month is entered by the user on the right-hand side of the table, shown above. The GEODAT.dat file name (do not enter the extension) should match the filenames used in the geographical **Step 0a-5** above.



Input Files	FULL PATH	BROWSE	COMMENTS
CALMET.inp path	Y:\ABflare\AERflare_examples\Example1\met\puf\	...	
3D.dat	Y:\ABflare\AERflare_examples\Example1\met\puf\3dXYEARX.dat	...	
GEODAT.dat path	Y:\ABflare\AERflare_examples\Example1\met\puf\	...	
Output Files	**FULL PATH**	**BROWSE**	**COMMENTS**
Prefix for metdat output files	met		
CALMET.dat path	Y:\ABflare\AERflare_examples\Example1\met\puf\	...	

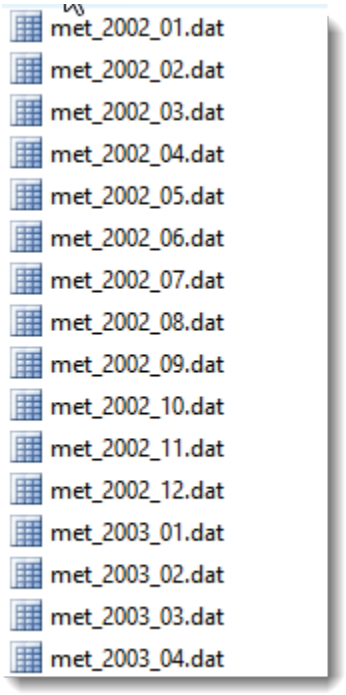
Note:
a) the input GEODAT.dat files are: <GEODAT path><geodat name>.dat
b) The CALMET output files will be named : <calmet path><prefix>_<YEAR>_<MONTH>.dat

The highlighted (bright green) entries correspond to the mdoforeach setting. In this case, only the 3D.dat entry uses the dofor setting. During the processing, the path will be adjusted from 3DXYEARX to 3D2002, 3D2003, 3D2004, 3D2005, and 3D2006 respectively. The expected template for the inputs for geographical files is shown below the table above. The path for the output CALMET.inp files is also listed below the table above, where <YEAR> and <MONTH> will be automatically replaced with the numerical value for the year and month of processing.

Make sure the mbatonly=1 setting is used on the **iSTART** page. Then press the Make CALMET button to start the processing of CALMET.inp file creation. The status bar will show the progress as the files are created. Upon completion, the output path will contain CALMET.inp files and a batch file for each year of processing. These batch files can run as provided or further modified for advanced parallel processing. The contents of the batch file are shown below.

```
@echo off
@rem created by ABFLARE Ver 1.03 [SS1.03.160913;M1.03.160913]
P:\ERCBtools\ABflare\bin\calmet_v6.5.0.exe met_2006_01.inp
@rem created by ABFLARE Ver 1.03 [SS1.03.160913;M1.03.160913]
P:\ERCBtools\ABflare\bin\calmet_v6.5.0.exe met_2006_02.inp
@rem created by ABFLARE Ver 1.03 [SS1.03.160913;M1.03.160913]
P:\ERCBtools\ABflare\bin\calmet_v6.5.0.exe met_2006_03.inp
@rem created by ABFLARE Ver 1.03 [SS1.03.160913;M1.03.160913]
P:\ERCBtools\ABflare\bin\calmet_v6.5.0.exe met_2006_04.inp
@rem created by ABFLARE Ver 1.03 [SS1.03.160913;M1.03.160913]
P:\ERCBtools\ABflare\bin\calmet_v6.5.0.exe met_2006_05.inp
@rem created by ABFLARE Ver 1.03 [SS1.03.160913;M1.03.160913]
P:\ERCBtools\ABflare\bin\calmet_v6.5.0.exe met_2006_06.inp
@rem created by ABFLARE Ver 1.03 [SS1.03.160913;M1.03.160913]
P:\ERCBtools\ABflare\bin\calmet_v6.5.0.exe met_2006_07.inp
@rem created by ABFLARE Ver 1.03 [SS1.03.160913;M1.03.160913]
P:\ERCBtools\ABflare\bin\calmet_v6.5.0.exe met_2006_08.inp
@rem created by ABFLARE Ver 1.03 [SS1.03.160913;M1.03.160913]
P:\ERCBtools\ABflare\bin\calmet_v6.5.0.exe met_2006_09.inp
@rem created by ABFLARE Ver 1.03 [SS1.03.160913;M1.03.160913]
P:\ERCBtools\ABflare\bin\calmet_v6.5.0.exe met_2006_10.inp
@rem created by ABFLARE Ver 1.03 [SS1.03.160913;M1.03.160913]
P:\ERCBtools\ABflare\bin\calmet_v6.5.0.exe met_2006_11.inp
@rem created by ABFLARE Ver 1.03 [SS1.03.160913;M1.03.160913]
P:\ERCBtools\ABflare\bin\calmet_v6.5.0.exe met_2006_12.inp
```

After the batchfiles have been run, the output path will contain the CALMET output files for each month as shown below.



Receptor Grid File

The receptor grid must reside within the meteorological boundaries and it must be representative of the source(s) being modelled and the expected location of the maximum concentration predictions. Multiple modelling runs may be required so that the density of the receptor grid matches regulator expectations near the location of maximum concentration.

The **Step 0b-RECEPTOR** page can be used to create a CALPUFF ready receptor grid. Press the REFRESH button to copy the source location from the **STEP 2-ABFLARE** page. Alternatively, the user can enter the coordinates of the source. The source location represents the centre of the receptor grid. This is adequate for most single source modelling assessments. Otherwise the user can generate the XY coordinates for a user-defined grid and insert the receptor coordinates into the processing as shown later.

	Source Location
X UTM	481234
Y UTM	6112345
UTM Zone	11
	Conversion to Geographic Coordinates
Longitude	-117.2945
Latitude	55.1574

The receptor grid used in ABflare is a 7-level nested Cartesian discrete list of coordinates. The nested levels are represented in the table as shown below. Typically, only five levels are required but 7-levels are provided (2 levels have no receptors by default). Each level is configured to have a receptor spacing density (resolution in metres) and the distance outward to where this receptor density applies. By default, the first level represents a default fenceline of 100m (square) radius with points along the fenceline of 20m. The next level in the table below has a receptor density of 50m and will extended from the previous level (100m) to the default distance of 500m (square) radius from the source. Each level is built upon the previous level. In this example, the receptor grid contains a total of1400 receptors, between 100m and 10km.

Receptor Grid Spacing

ID	Resolution (m)	Default (m)	Distance	Default	Receptors
1	20	20	100	100	40
2	50	50	500	500	416
3	100	100	500	500	0
4	250	250	2000	2000	264
5	500	500	5000	5000	360
6	1000	1000	10000	10000	320
7	5000	5000	10000	10000	0
				Total	1400

Note: receptor spacing for ID=3 and ID=7 are non-default and allow for special considerations

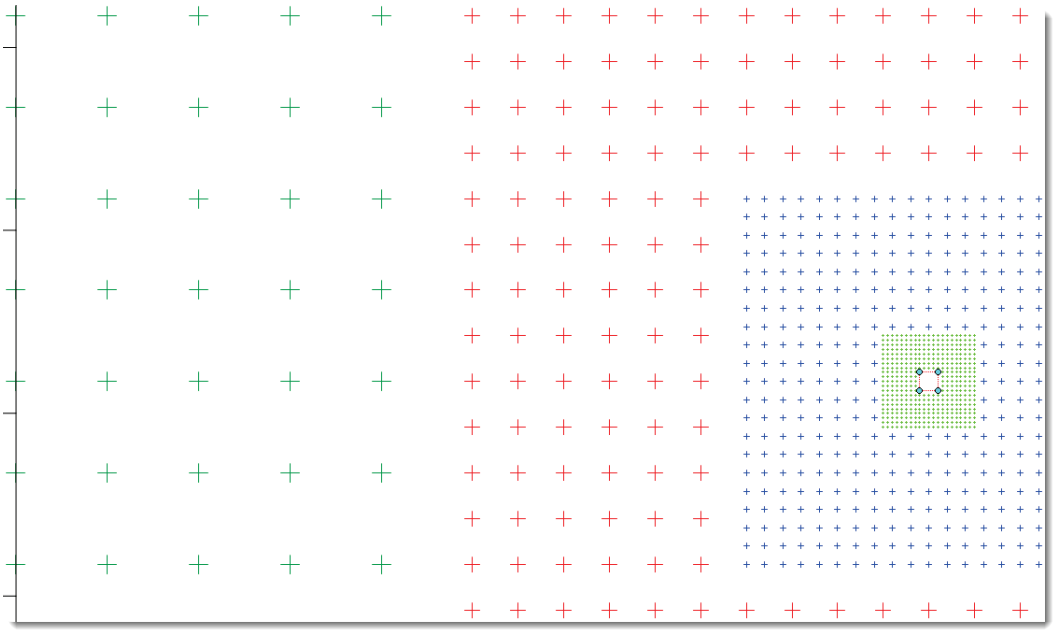
There are several user selectable options available for advanced receptor grid creation. However, in this case (just for fun) we will adjust the default grid to use a slightly higher resolution for level 4 as shown below. Here, we use a resolution of 200m for the interval of 500m to 2000m instead of the default 250m resolution.

Receptor Grid Spacing

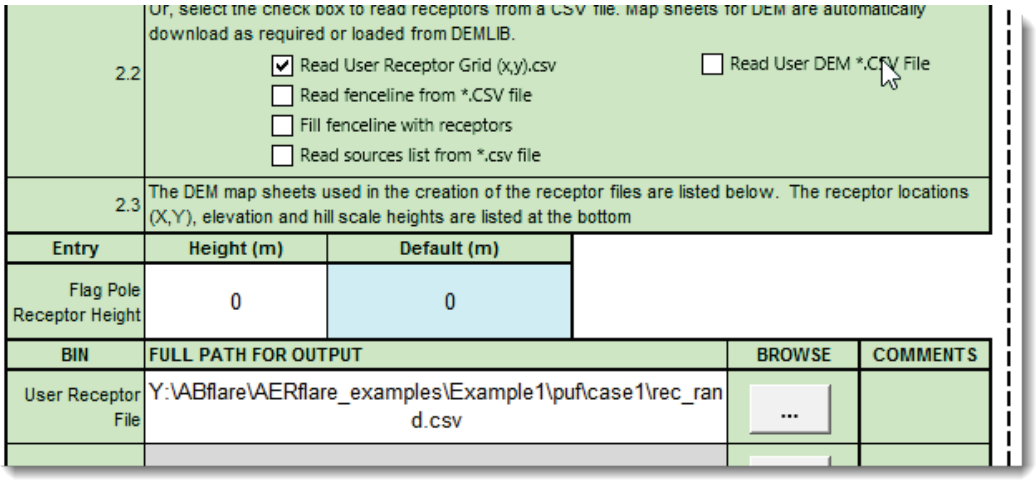
ID	Resolution (m)	Default (m)	Distance	Default	Receptors
1	20	20	100	100	40
2	50	50	500	500	416
3	100	100	500	500	0
4	200	250	2000	2000	416
5	500	500	5000	5000	360
6	1000	1000	10000	10000	320
7	5000	5000	10000	10000	0
				Total	1552

Note: receptor spacing for ID=3 and ID=7 are non-default and allow for special considerations

This receptor spacing is illustrated in the figure below.



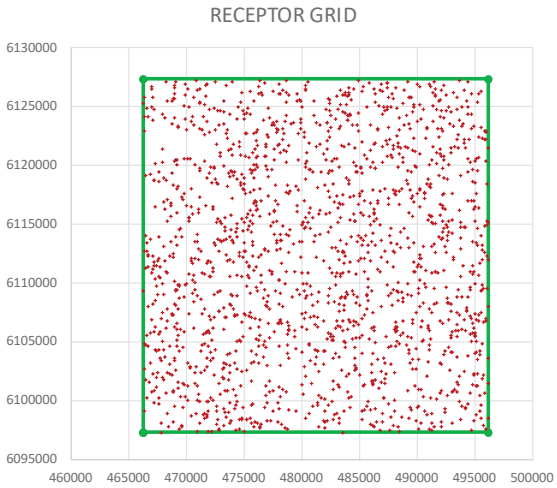
If a user wanted to create a receptor manually it can be inserted using the 'Read 'User Receptor Grid' option, as shown below. For this option, all receptor locations are assumed to be contained within the User Receptor file. That is, no fenceline is added to the user receptor grid.

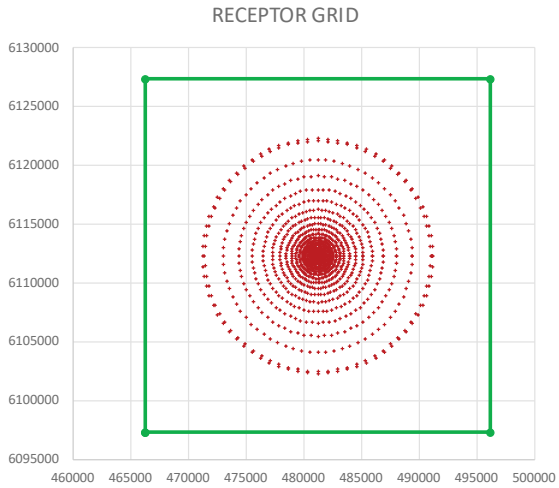


For this example, the file format for a user receptor grid is comma separated x,y values in the UTM coordinate zone for the project. In this example, the x,y receptors were selected to be at random within the domain. Also shown below is an example with radial receptor locations.

X,Y receptor file using a comma separated format.

```
483338,6106824
491483,6109587
492934,6121599
473953,6119508
486234,6097779
487582,6116740
492987,6105602
478823,6104066
491325,6098106
483189,6124791
494609,6107186
496187,6112021
489250,6119597
494396,6125007
```





Similarly, a user defined fenceline can be used by creating an x,y list of vertices of the fenceline in comma separated file. A sources list is incorporated the same way using an x,y comma separated file. In the example shown below additional sources have been added at the corners of the fenceline. The effect of the sources file, is to add level 2 receptor points around each source. When the sources file is used, the receptor locations are normalized to a common grid using a resolution of 10m.

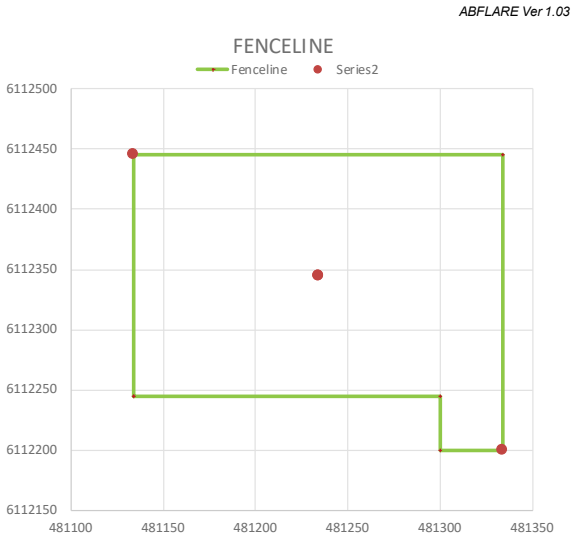
Fenceline File.csv

```
481134,6112245
481134,6112445
481334,6112445
481334,6112200
481300,6112200
481300,6112245
481134,6112245
```

Sources File.csv

```
481134,6112445
481334,6112200
481234.0,6112345.0
```

The figure below shows the fenceline and sources from above.



Meteorological File at Stack Height

ABflare source parameter calculations require the wind speed time series at stack height. The *CALPUFF* utility program *METSERIES*.exe can be used to extract the wind speed at any X,Y and elevation within the *CALMET* model domain. On page **STEP 1-METSERIES** the *METSERIES*.exe inputs is configured.

The **STEP 1-METSERIES** page uses a *LoadFile, SaveFile, RunFile* work flow designed around the necessary inputs to run *METSERIES* for *ABflare*. The basic overall-steps for this page are:

1. Browse for and load an existing METSERIES input file (click BROWSE). Or just modify the values on the page and jump to step 2.

2. Save the page inputs to a METSERIES input file using Save As... . If the mbatonly=1 variable is used, then the button also creates batch file that can executed at a later time.

3. The RUN button will run the displayed METSERIES input file (run file) immediately.

It is recommended to use the mdoforeach=1 variable for processing the *METSERIES* data. You will know if the mdoforeach variable is set, because fields on the **STEP 1-METSERIES** page Run File, Output, or MetDat will be highlighted bright green.

There are four option groups to be completed on the **STEP 1-METSERIES** page:, Input/Output Folders, Output Options, Date Options and Meteorological Files.

You will notice that often when an entry asks for a file name a complete path is used as opposed to just the file name. You could enter just the file name and the operation will write to the current folder where the batch file or command was executed from. You could also enter relative paths such "`.\listfiles\metseries.lst`"; which would output the list file for METSERIES into a folder below the current folder.

We require METSERIES.exe time series data for each of the years for the assessment, which will be 2002, 2003, 2004, 2005, and 2006. In the Input/Output Folders Group enter the filenames to be used for the METSERIES output and the associated list file. For the year 2002, we would enter the following.

Input and Output Folders Group

VARIABLE	INPUT	BROWSE
Output: TSFOUT.tsf (the extension is auto added)	Y:\ABflare\AERflare_examples\Example1\met\puf\ms_2002.tsf	...
Output: LSTDAT List-file name Default: METSERIES.LST	Y:\ABflare\AERflare_examples\Example1\met\puf\ms_2002.lst	...

However, to simplify the overall process, we will enter XYEARX in place of the year of interest. So, enter the following for the output files.

Input and Output Folders Group

VARIABLE	INPUT	BROWSE
Output: TSFOUT.tsf (the extension is auto added)	Y:\ABflare\AERflare_examples\Example1\met\puf\ms_XYEARX.tsf	...
Output: LSTDAT List-file name Default: METSERIES.LST	Y:\ABflare\AERflare_examples\Example1\met\puf\ms_XYEARX.lst	...

Don't forget to scan and read the output lists files after the program runs. They may contain important warnings or error messages.

The Output Options Group specifies the X,Y location and the height at which you want the output. The X,Y location of interest is the source location (as you have entered on the **STEP 2-ABflare** page). The height of interest is the stack height. The entry table will warn you if you entered a setting that is different than the **STEP 2-ABflare** page. Below shows the entries for the tutorial, with a typo. The entry for ZWIND was incorrectly entered as 30.3 instead of 30.5, where 30.5 is the entry on the **STEP 2-ABflare** page. So, correct the entry, before continuing.

Ouput Options Group

VARIABLE	INPUT	DESCRIPTION	
MDATA	CALMET	Input Data Type CALMET	
XESTN	481.234	X-Easting Coordinate (km, deg, or cell)	Same as entry on Step2-ABflare
YNSTN	6112.345	Y-Northing Coordinate (km, deg, or cell	Same as entry on Step2-ABflare
METSIM	1	1=interpolate; 2=nearest grid cell	
ZWIND	30.3	Measurement height (m AGL) for wind (-1. to exclude)	Not the same as entry on Step2-ABflare
ZTEMP	30.5	Measurement height (m AGL) for temperature (-1. to exclude)	Same as entry on Step2-ABflare
ZRHUM	30.5	Measurement height (m AGL) for humidity (-1. to exclude)	Same as entry on Step2-ABflare

METSERIES can extract meteorology from a number of different data sets (such as *AERMOD* meteorological files). The MDATA setting should match the meteorology used for the assessment so that the source parameters are consistent with the meteorology used for dispersion modelling. Here, the *CALMET* data type is used since we are using *CALMET* meteorological data in the air dispersion modelling assessment.

The Date Options Group would be completed as follows for a typical year. METSERIES uses hours 0-23, however in the table enter 24 to ensure that the extraction includes the final hour for the year. The time interval (NSECDT) should match the interval used for the air dispersion modelling. Typically this will be 1 hour or 3600 sec.

Date Options Group

	iyr	imo	iday	ihr	isec
Start met	2002	1	1	0	0
End met	2002	12	31	24	0
NSECDT	3600	Time interval			

Because we are using the mdoforeach setting, change the Date Options entry to use the XYEARX variable for the year setting (highlighted bright green).

Date Options Group

	iyr	imo	iday	ihr	isec
Start met	XYEARX	1	1	0	0
End met	XYEARX	12	31	24	0
NSECDT	3600	Time interval			

Complete the Meteorology Files Group by specifying where the CALMET files are for the year for this configuration; here this would 2002. The Browse button is available for the first file, and the user can copy and paste the entry to the remaining rows and edit accordingly.

Meteorology Files for Extraction Group

NMETINP	12	Number of met files to extract	BROWSE
MetDat1	Y:\ABflare\AERflare_examples\Example1\met\puf\met_2002_01.dat		...
MetDat2	Y:\ABflare\AERflare_examples\Example1\met\puf\met_2002_02.dat		
MetDat3	Y:\ABflare\AERflare_examples\Example1\met\puf\met_2002_03.dat		
MetDat4	Y:\ABflare\AERflare_examples\Example1\met\puf\met_2002_04.dat		
MetDat5	Y:\ABflare\AERflare_examples\Example1\met\puf\met_2002_05.dat		
MetDat6	Y:\ABflare\AERflare_examples\Example1\met\puf\met_2002_06.dat		
MetDat7	Y:\ABflare\AERflare_examples\Example1\met\puf\met_2002_07.dat		
MetDat8	Y:\ABflare\AERflare_examples\Example1\met\puf\met_2002_08.dat		
MetDat9	Y:\ABflare\AERflare_examples\Example1\met\puf\met_2002_09.dat		
MetDat10	Y:\ABflare\AERflare_examples\Example1\met\puf\met_2002_10.dat		
MetDat11	Y:\ABflare\AERflare_examples\Example1\met\puf\met_2002_11.dat		
MetDat12	Y:\ABflare\AERflare_examples\Example1\met\puf\met_2002_12.dat		
MetDat13			(Ctrl)

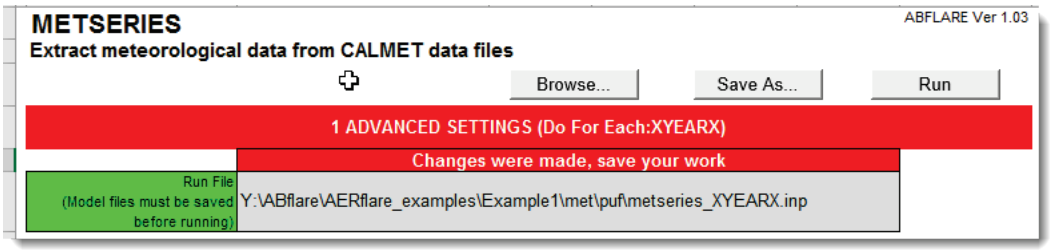
Again, however, it will be easier to use the mdoforeach variable in place of the actual year as shown below.

Meteorology Files for Extraction Group

NMETINP	12	Number of met files to extract	BROWSE
MetDat1	Y:\ABflare\AERflare_examples\Example1\met\puf\met_XYEARX_01.dat		...
MetDat2	Y:\ABflare\AERflare_examples\Example1\met\puf\met_XYEARX_02.dat		
MetDat3	Y:\ABflare\AERflare_examples\Example1\met\puf\met_XYEARX_03.dat		
MetDat4	Y:\ABflare\AERflare_examples\Example1\met\puf\met_XYEARX_04.dat		
MetDat5	Y:\ABflare\AERflare_examples\Example1\met\puf\met_XYEARX_05.dat		
MetDat6	Y:\ABflare\AERflare_examples\Example1\met\puf\met_XYEARX_06.dat		
MetDat7	Y:\ABflare\AERflare_examples\Example1\met\puf\met_XYEARX_07.dat		
MetDat8	Y:\ABflare\AERflare_examples\Example1\met\puf\met_XYEARX_08.dat		
MetDat9	Y:\ABflare\AERflare_examples\Example1\met\puf\met_XYEARX_09.dat		
MetDat10	Y:\ABflare\AERflare_examples\Example1\met\puf\met_XYEARX_10.dat		
MetDat11	Y:\ABflare\AERflare_examples\Example1\met\puf\met_XYEARX_11.dat		
MetDat12	Y:\ABflare\AERflare_examples\Example1\met\puf\met_XYEARX_12.dat		
MetDat13			

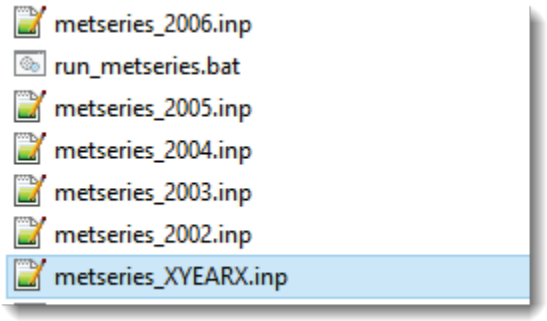
At this point you will undoubtedly be frustrated by trying to use search and replace but receiving an Excel error message. Excel won't allow search and replace functionality on a protected sheet, sorry. An easy work-around is to copy the cells to a new Excel workbook. Because the new workbook is not protected, you can use search and replace. Then copy the edited entries back to the *ABflare* workbook.

Because you have made changes to the worksheet, you will now notice at the top of the worksheet that two warning messages are displayed as shown below. The top message indicates that mdoforeach variable is set and that the variable name is XYEARX. The second line indicates that changes were made to the page but the page hasn't been saved. If you pressed RUN now, the run command would use the input file displayed in the Run File field but would use whatever values were currently saved to the file, not the values displayed on the screen.



Press the Save As… button to save the entries and you will be prompted for a filename. You can used the same file name or enter a new name.

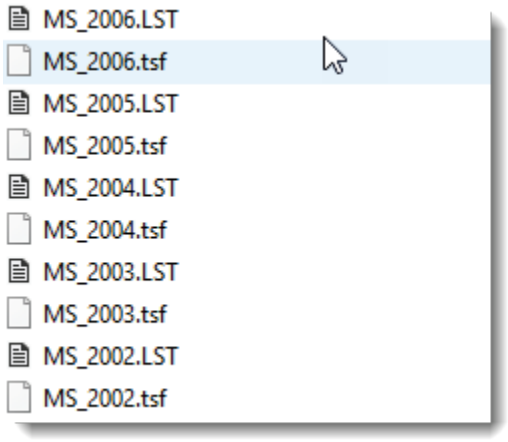
When the mdoforeach variable is used, you should include the dofor variable in the filename such as shown above. When the mdoforeach variable is used the Save As… button will first save the settings to a template file that includes the dofor variable as shown on the worksheet, then it will use the doforlist to save the worksheet settings for each of the values in the list. In this case, the Save As… operation creates the following input files and a batch file.



The batch file contains the path to the METSERIES.exe and input files as shown below. Because the METSERSIES.exe is only moderately numerically intensive (takes only a medium amount of time) all of the commands are included in a single batch file as shown below. Using windows explorer (Windows Key + e) navigate to where you saved the input files then click on the run_metseries.bat file to run the *METSERIES*.exe program.

```
@echo off
@rem created by ABFLARE Ver 1.03 [SS1.03.160913;M1.03.160913]
O:\CALPUFF\code\METSERIES_v7.0.0_L140912\METSERIES_v7.0.0_L140912\metseries_v7.0.0.exe
Y:\ABflare\AERflare_examples\Example1\met\puf\metseries_2002.inp
@rem created by ABFLARE Ver 1.03 [SS1.03.160913;M1.03.160913]
O:\CALPUFF\code\METSERIES_v7.0.0_L140912\METSERIES_v7.0.0_L140912\metseries_v7.0.0.exe
Y:\ABflare\AERflare_examples\Example1\met\puf\metseries_2003.inp
@rem created by ABFLARE Ver 1.03 [SS1.03.160913;M1.03.160913]
O:\CALPUFF\code\METSERIES_v7.0.0_L140912\METSERIES_v7.0.0_L140912\metseries_v7.0.0.exe
Y:\ABflare\AERflare_examples\Example1\met\puf\metseries_2004.inp
@rem created by ABFLARE Ver 1.03 [SS1.03.160913;M1.03.160913]
O:\CALPUFF\code\METSERIES_v7.0.0_L140912\METSERIES_v7.0.0_L140912\metseries_v7.0.0.exe
Y:\ABflare\AERflare_examples\Example1\met\puf\metseries_2005.inp
@rem created by ABFLARE Ver 1.03 [SS1.03.160913;M1.03.160913]
O:\CALPUFF\code\METSERIES_v7.0.0_L140912\METSERIES_v7.0.0_L140912\metseries_v7.0.0.exe
Y:\ABflare\AERflare_examples\Example1\met\puf\metseries_2006.inp
```

When the batch file is completed, the output folder (as per the worksheet entries) will contain the output files as listed below:



The list file will contain a satisfactory execution message.

```
CALMET.inp file created by ABFLARE Ver 1.03
 Starting time YYYY MM DD HH SSSS:  2006 11 1 0 0


 12  Y:\ABFLARE\AERFLARE_EXAMPLES\EXAMPLE1\MET\PUF\MET_2006_12.DAT
 CALMET.DAT      2.1            No-Obs file structure with embedded control file
 Internal Coordinate Transformations  ---  COORDLIB   Version: 1.10.0   Level: 14
 CALMET.INP      2.1
 CALMET.inp file created by ABFLARE Ver 1.03
 Starting time YYYY MM DD HH SSSS:  2006 12 1 0 0

CALMET.DAT data extraction completed

 Finished Time-Series Files
```

Source Input File(s)

The **STEP 2-ABFLARE** page uses a *LoadFile, SaveFile, RunFile* work flow designed around the necessary inputs to run *ABflare.exe*. The basic overall-steps for this page are:

1. Browse for and load an existing *ABflare.exe* input file (click BROWSE). Or just modify the values on the page and jump to step 2.

2. Save the page inputs to a *ABflare.exe* input file using Save As… . If the mbatonly=1 variable is used, then the button also creates batch file that can executed at a later time.

3. The RUN button will run the displayed *ABflare.exe* input file (run file) immediately.

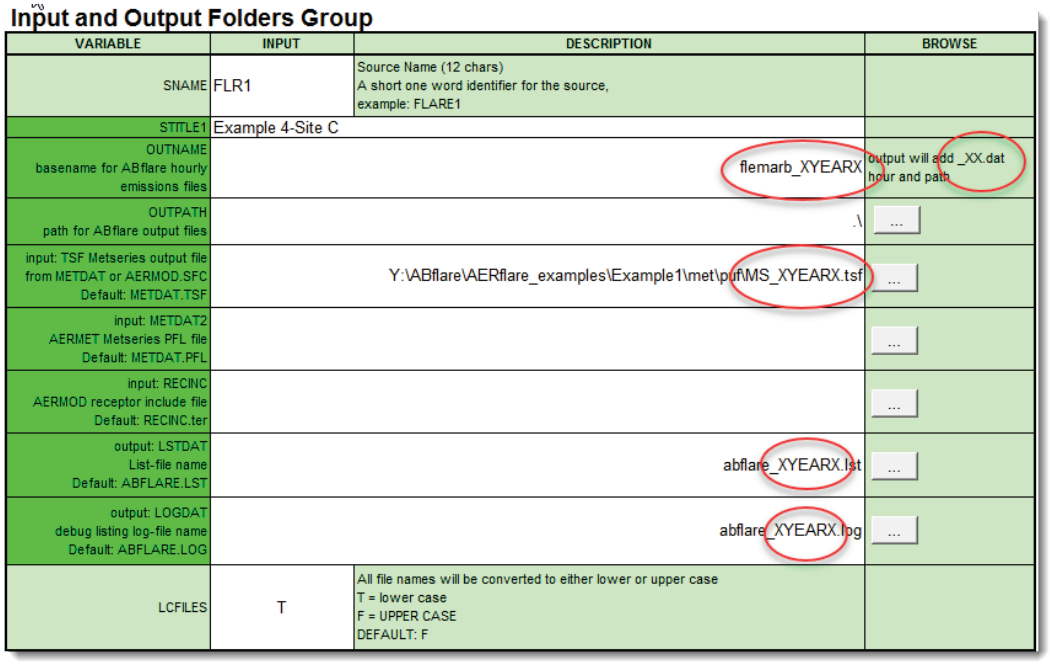
Two additional buttons are available for convenience. The DEFAULTS button sets all the inputs on the worksheet to default values. This is a convenient way to reset the page. The Copy Inputs button is used to copy the settings used in an *AERflare* worksheet assessment. This button will copy domain settings to the common page as well the source configuration such as blow down settings.

The inputs on The **STEP 2-ABFLARE** page are within the following groups: Input and Output Folders, Control, Date Options, Source Description, Lift and Flare Assist, Gas Composition, Meteorology and User Defined Blowdown.

For this example, the flare source is a steady flare that we want to model using hour-by-hour meteorology using *ABflare* and *CALPUFF*. For this example, the Meteorology and User Defined Blowdown group entries are not required and will be grayed out.

The Input and Output Folders group will be configured similar to the way METSERIES was configured, that is, using the mdoforeach setting and dofor variable. There are four primary entries in this group as highlighted with circles in the following figure. The OUTNAME setting specifies the file name to be used for ABflare.exe output source parameters. The OUTNAME file will be the input to the CALPUFF dispersion model. Because we are performing a multiyear assessment the mdoforeach setting is convenient and the OUTNAME should contain the dofor variable (XYEARX). The ABflare.exe calculations require the meteorology at the stack location and stack height. The Input TSF entry is used to specify the *METSERIES* output file created in the previous step. The dofor variable is used in the file to select the appropriate file for the current year of assessment. The LSTDAT is used to specify the list file for output messages and LOGDAT entry is used to specify the log file (related to debugging and technical information).

For *ABflare* source configurations that require a blowdown, the air dispersion modelling uses a a blowdown sequence that restarts every hour. Therefore, instead of a single ABflare.exe input file, 24-input files are created. In this case the OUTNAME entered by the user will be appended with "_XX" where "XX" indicates the hour 01 to 24 of the blowdown. For this example, onaly a single source file be created per year of assessment.



Input and Output Folders Group

VARIABLE	INPUT	DESCRIPTION	BROWSE
SNAME	FLR1	Source Name (12 chars) A short one word identifier for the source, example: FLARE1	
STITLE1	Example 4-Site C		
OUTNAME basename for ABflare hourly emissions files	flemarb_XYEARX	output will add _XX.dat hour and path	
OUTPATH path for ABflare output files	.\	...	
input: TSF Metseries output file from METDAT or AERMOD.SFC Default: METDAT.TSF	Y:\ABflare\AERflare_examples\Example1\met\pufMS_XYEARX.tsf	...	
input: METDAT2 AERMET Metseries PFL file Default: METDAT.PFL		...	
input: RECINC AERMOD receptor include file Default: RECINC.ter		...	
output: LSTDAT List-file name Default: ABFLARE.LST	abflare_XYEARX.lst	...	
output: LOGDAT debug listing log-file name Default: ABFLARE.LOG	abflare_XYEARX.log	...	
LCFILES	T	All file names will be converted to either lower or upper case T = lower case F = UPPER CASE DEFAULT: F	

The Control Group settings specify the flow of the source parameter calculations. For this assessment, the primary settings are:

VARIABLE	INPUT	DESCRIPTION
MDSPMOD	1	The output from the ABflare.exe will be a source file for use with CALPUFF.
MINPUT	1	This setting is used to specify how the source flowrate is modelled by the user. There are three modelling options, flowrates are calculated as per MBLOWDOWN; flowrates are input as a user defined sequence of time steps; or flowrate is static (not changing hour-by-hour) and the user must enter the source parameters. The last setting is typically used for debugging. The first setting will be used for the majority of the dispersion modelling.
MBLOWDOWN	1	This setting is used to specify how the source flowrate is calculated. The option is to either specify the max flowrate and volume to be flared or to specify the vessel volume, pressure and temperature and allow *ABflare.exe* to calculate the release rate. For a steady flare, we use the first option, and only QMAX is required and the volume flared is not required.
MDIST	2	For blowdowns, the sequence is calculated based upon subdivisions of equal mass. The MDIST setting is not used for the steady flare scenario.
MSTRIP	0	Stripped gas are not modelled or accounted for. The default air quality assessment assumes that 100% of the pollutants leave the flare tip.
MMET	1	The input file will be created for the CALPUFF modelling system and will be using the CALMET meteorology. Although it is possible to use AERMOD meteorology to create the

		source files for CALPUFF it is not recommended. The AERMOD setting is intended for advanced source file creation for use with AERMOD.
MFUELGAS	1	Fuel gas will be added to the flared gas
MFGR	2	The fuel gas ratio is set to be proportion to the QMAX gas rate specified below. For controlled blowdowns or user-specified time varying flowrates the fuel gas ratio can be set to vary with the current time step flow rate using MFGR=1.
MLIFTGAS	0	Lift gas is not used in the example
MFASSIST	0	Flare assist is not used in the example
MFASSISTSTEAM	0	Flare assist using steam is not used in the example
MFASSISTAIR	0	Flare assist using air is not used in the example
MFASSISTHPFUEL	0	Flare assist using HP fuel is not used in the example
MTGAS	1	Set the temperature of the gas to TAMB
MSCREENING	0	This setting is used to force the source configuration to mimic the AERflare screening assessment. This setting should normally be off.
MDEBUG	0	Turn debug off
NSEP	1	For a steady source, the separation between sequences is 1 time step.

The Date Options Group is configured the same way that was performed for the *METSERIES* entry. Here the dofor variable is used in replacement of an actual year of assessment

Date Options Group

VARIABLE	iyr	imo	iday	ihr	isec
START	XYEARX	1	1	0	0
END	XYEARX	12	31	24	0
TIMEINC	3600	Time step, s Default=3600			

The Source Description Group for a stead flare source (as specified by the MINPUT and MBLOWDOWN settings) will show most of the entries are conveniently grayed out, meaning that they are not required. The XCOORD, YCOORD and ZCOORD are the utm X,Y location and elevation of the flare source. The stack height is the physical stack height of the flare. The diameter is the physical inside diameter at the top of the flare stack. The RH2S setting is the licensed or desired modelling gas composition of hydrogen sulphide (H_2S). The RH2S setting can be the same as the measured gas composition (see later), higher or lower. Typically, the measure gas composition will be a calendar measurement that is lower than the licenced or maximum allowable H_2S for the facility or flare. The RH2S setting will be used to re-normalize the entered gas composition (see later). The TGINIT setting specifies the temperature of the raw gas and fuel gas. A typical assessment will use MTGAS setting so that the temperature of the raw and fuel gas is the hourly ambient temperature.

Source Description Group

VARIABLE	INPUT	DESCRIPTION
SUB-GROUP 1		
XCOORD	481.234	KM Easting location of the flare, see DATUM coordinates
YCOORD	6112.345	KM Northing location of the flare, see DATUM coordinates
ZCOORD	655.8701328	Terrain elevation at source, m
HS	30.5	Actual height of the flare, m
DS	0.305	Actual inside diameter of flare at top, m
RH2S	0.301	Mole fraction of H2S in raw gas
TGINIT	278.15	Initial fuel gas and raw gas temperature, K, or negative to set to ambient see MTGAS
SUB-GROUP 2		
Expected Maximum Initial		kPa (gauge)

The Sub-Group 3 settings specify the flowrates to be flared. For a steady flare, the QMAX is the flowrate of the raw gas to be flared. The QTOTAL is volume to be flared and is not used for a steady flare. The duration of the flaring period for a steady continuous flare is 3600 sec. For a flare that is steady but only lasts for 15 min, the duration is entered as 900 sec. The FREL setting is only required for blowdown calculations. The NPUFFS setting for a steady flare is set to 1. If NPUFFS is set greater than 1, then the source is modelled as a blowdown of N puffs, using the QMAX, QTOTAL and duration.

psUS		Used if MINPUT=3
SUB-GROUP 3		
QMAX	90	Peak flow rate of flared gas, e³m³/d Used if MINPUT=1
QTOTAL	3.75	Total volume of gas contained within pipeline or vessel to be flared, e³m³ Used if MINPUT=1 and MBLOWDOWN=1
DURATION	3600	Duration of blowdown, s Used if MINPUT=1 and MBLOWDOWN=1
FREL	0	Fraction of gas remaining in pipeline or vessel at the end of DURATION. Default= 0.99 Used if MBLOWDOWN=2
PUFFDUR		Using MDIST=1, the user can specify either the puff duration (s) or the number of puffs, NPUFFS below.
NPUFFS	1	npuffs = 0 : Program calculates number of puffs, when PUFFDUR is specified and MDIST=1 npuffs = 1 : Force blowdown to a single puff of duration PUFFDUR, if MINPUT=1 and MBLOWDOWN=1 then NPUFF=1 for a hourly varying flare or if MINPUT=3, then use input source rather than calculated blowdown. Use this setting for a steady flare source with parameters that that vary with meteorology npuffs > 1 : Number of puffs in blowdown Default = 3

For a steady flare, NPUFFS=1
For a blowdown, NPUFFS≥3

The MFGR was set, so the FGR entry must be completed as shown below. For this example, the FGR=0.95, meaning that for a raw gas flowrate of QMAX, the fuel gas is flowrate is an additional QMAX×FGR.

The Gas Composition Group is used to specify the gas compositions of the input streams. *ABflare* is configured for four input gas stream compositions, raw gas, fuel gas, lift gas and air (air is not configurable). For this example, fuel gas and raw gas compositions (as defined in the *AERflare* example) are listed below. Note that the H_2S composition of the raw gas is adjusted to the RH2S value entered above during processing.

Gas Composition Group

Gas Compositions (mole fraction)	Fuel Gas	Lift Gas	Raw Gas	WARNINGS	COMMENTS
H_2O	0	0	0		Dry gas composition may have to be adjusted to pre-flare-tip conditions of temperature and pressure
H_2	0	0	0.0002		
He	0	0	0.0001		
N_2	0	1	0.0197		
CO_2	0	0	0.07		
H_2S	0	0	0.275		Model will adjust reference analysis to maximum requested H_2S, see RH2S
CH_4	0	0	0.6328		
C_2H_6	0	0	0.0014		
C_3H_8	1	0	0.0002		Set C_3H_8 to 1 for propane fuel gas
i-C_4H_{10}	0	0	0.0001		
n-C_4H_{10}	0	0	0.0001		
i-C_5H_{12}	0	0	0.0001		
n-C_5H_{12}	0	0	0.0001		
n-C_6H_{14}	0	0	0.0001		
C_7+	0	0	0.0001		
CO	0	0	0		
NH_3	0	0	0		
Ar	0	0	0		
O2	0	0	0		
Total	1	1	1		

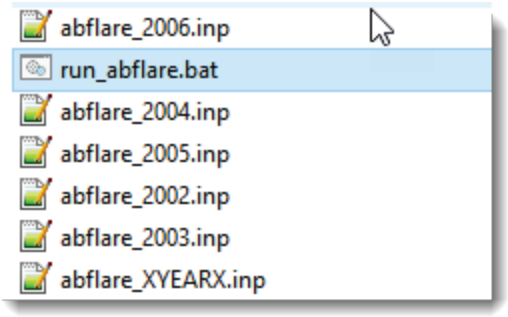
Scrolling to the top of the worksheet, you see that two warning messages are displayed. One, indicating that that advanced setting for mdoforeach is selected and two, that changes were made to the entries on the page that have not been saved. When the Save As... button is pressed, the user is prompted for a filename and path to save the input settings. Because the mdoforeach variable is used, the user should include the dofor variable in the filename as shown below.

1 ADVANCED SETTINGS (Do For Each:XYEARX)

Changes were made, save your work

Run File (Model files must be saved before running)	Y:\ABflare\AERflare_examples\Example4\puf\case1\abflare_XYEARX.inp
Start a new ABflare.inp file (0-no, 1-yes)	1

When the file is saved, using the mdoforeach, an input file is created for each of the entries in the doforeach list, plus the template file with the dofor variable included in the file, plus a batch file if the mbatonly setting was selected.

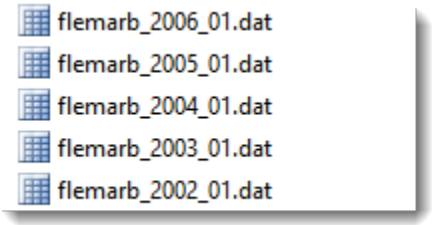


The user can select Start a new file before saving the file. When this setting is used the format and default settings from the **sABFLARE** page are used to create the input file.

The batch file contains all of the ABflare.exe commands and input files. In the example below, the MPAUSE option was used to insert a pause at the end of the commands which can be useful during debugging. Because the *ABFLARE*.exe is only moderately numerically intensive (takes only a medium amount of time) all of the commands are included in a single batch file as shown below. Using windows explorer (Windows Key + e) navigate to where you saved the input files then click on the `run_abflare.bat` file to run the *ABFLARE*.exe program.

```
@echo off
@rem created by ABFLARE Ver 1.03 [SS1.03.160913;M1.03.160913]
O:\Fortran\ABflare\ABflare\Debug\ABflare.exe
Y:\ABflare\AERflare_examples\Example1\puf\case1\abflare_2002.inp
@rem created by ABFLARE Ver 1.03 [SS1.03.160913;M1.03.160913]
O:\Fortran\ABflare\ABflare\Debug\ABflare.exe
Y:\ABflare\AERflare_examples\Example1\puf\case1\abflare_2003.inp
@rem created by ABFLARE Ver 1.03 [SS1.03.160913;M1.03.160913]
O:\Fortran\ABflare\ABflare\Debug\ABflare.exe
Y:\ABflare\AERflare_examples\Example1\puf\case1\abflare_2004.inp
@rem created by ABFLARE Ver 1.03 [SS1.03.160913;M1.03.160913]
O:\Fortran\ABflare\ABflare\Debug\ABflare.exe
Y:\ABflare\AERflare_examples\Example1\puf\case1\abflare_2005.inp
@rem created by ABFLARE Ver 1.03 [SS1.03.160913;M1.03.160913]
O:\Fortran\ABflare\ABflare\Debug\ABflare.exe
Y:\ABflare\AERflare_examples\Example1\puf\case1\abflare_2006.inp
@PAUSE
```

When *ABFLARE.exe* is completed, the arbitrary emissions files will be created in the location you specified.



CALPUFF Model Configuration for Flaring

For most flaring assessments the CALPUFF model configuration is relatively straightforward since there will be only a single source (the flare) and no chemistry (SO_2 assessments assume 100% conversion of H_2S to SO_2 with no allowance for poor conversion efficiency).

The **STEP 3-CALPUFF** page uses a *LoadFile, SaveFile, RunFile* work flow designed around the necessary inputs to run *CALPUFF.exe* for an *ABflare* assessment. The basic overall-steps for this page are:

1. Browse for and load an existing *ABflare.exe* input file (click BROWSE). Or just modify the values on the page and jump to step 2. If you are performing advanced *CALPUFF* dispersion modelling with multiple sources (beyond the scope of this tutorial) the *LoadFile* option allows you import *CALPUFF* settings for your specific situation and *ABflare* will tweak the inputs necessary for the flare source.

2. Save the page inputs to a *CALPUFF.exe* input file using Save As... . If the mbatonly=1 variable is used, then the button also creates batch file that can executed at a later time.

3. The RUN button will run the displayed *CALPUFF.exe* input file (run file) immediately.

It is recommended that you do not use the RUN button because the run-times for CALPUFF are long and the run-files are implemented sequentially.

The inputs on The **STEP 3-CALPUFF** page are within the following groups: Input and Output Folders, Date Options, Meteorological Data, Discrete Receptor, and Switch Checker.

The Input and Output Folders group will be configured similar to the way *METSERIES* and *ABflare* was configured, that is, using the mdoforeach setting and dofor variable. There are three primary entries in this group as highlighted with circles in the following figure. The PUFLST entry is the list file name for the *CALPUFF* output that contains a re-iteration of the *CALPUFF* inputs as well important run-time information. The CONDAT entry is the binary *CALPUFF* output containing the dispersion calculation output. The FLDAT file is the ABflare arbitrary emissions file (this is the same as the OUTNAME entered on the **STEP 2-ABFLARE** page.) Because we are performing a multiyear assessment

the mdoforeach setting is convenient and each of the PUFLST, CONDAT, and FLDAT entries should contain the dofor variable (XYEARX).

Input and Output Folders Group

PARAMETER	ENTRY FOR CALPUFF	DESCRIPTION	BROWSE
PUFLST	Y:\ABflare\AERflare_examples\Example1\puf\case1\CALPUFF_XYEARX.LST	Output list file Default: CALPUFF.LST	...
CONDAT	Y:\ABflare\AERflare_examples\Example1\puf\case1\calpuff_XYEARX.con	Output bin file with concentration prediction output Default: CALPUFF.con	...
FLDAT	Y:\ABflare\AERflare_examples\Example1\puf\case1\flemarb_XYEARX.dat	Input ABflare source file Default: abflare.dat	...

The Date Options Group is configured the same way that was performed for the *METSERIES* and *ABflare* entries. Here the dofor variable is used in replacement of an actual year of assessment.

Date Options Group

VARIABLE	iyr	imo	iday	ihr	isec
START	XYEARX	1	1	0	0
END	XYEARX	12	31	24	0
TIMEINC	3600	Time step, s Default=3600			

The Meteorological Data Group is configured the same way that was performed for the *METSERIES* entries. Here the dofor variable (XYEARX) is used in replacement of an actual year of assessment

Meteorological Data Group

NMETDAT	12		
METDAT	Y:\ABflare\AERflare_examples\Example1\met\puf\met_XYEARX_01.dat	1	...
METDAT	Y:\ABflare\AERflare_examples\Example1\met\puf\met_XYEARX_02.dat	2	...
METDAT	Y:\ABflare\AERflare_examples\Example1\met\puf\met_XYEARX_03.dat	3	...
METDAT	Y:\ABflare\AERflare_examples\Example1\met\puf\met_XYEARX_04.dat	4	...
METDAT	Y:\ABflare\AERflare_examples\Example1\met\puf\met_XYEARX_05.dat	5	...
METDAT	Y:\ABflare\AERflare_examples\Example1\met\puf\met_XYEARX_06.dat	6	...
METDAT	Y:\ABflare\AERflare_examples\Example1\met\puf\met_XYEARX_07.dat	7	...
METDAT	Y:\ABflare\AERflare_examples\Example1\met\puf\met_XYEARX_08.dat	8	...
METDAT	Y:\ABflare\AERflare_examples\Example1\met\puf\met_XYEARX_09.dat	9	...
METDAT	Y:\ABflare\AERflare_examples\Example1\met\puf\met_XYEARX_10.dat	10	...
METDAT	Y:\ABflare\AERflare_examples\Example1\met\puf\met_XYEARX_11.dat	11	...
METDAT	Y:\ABflare\AERflare_examples\Example1\met\puf\met_XYEARX_12.dat	12	...

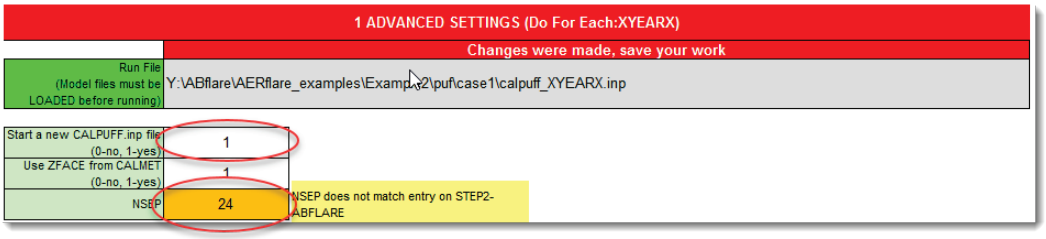
The Discrete Receptors Group is requires only the entry of the path for the discrete receptors file created on the **STEP0-RECEPTOR** page. When the browse button [...] is used to select the file, the file is automatically scanned for the number of receptors which is displayed for convenience below the path entry. For advanced assessments, the path may be left blank and the receptor group that is contained in an existing CALPUFF input file is used.

Advanced Users: If you have configured a *CALPUFF* input exterior to *ABflare*, use the Browse button to load the file. Enter the FLDAT and review the switch settings. Leave the RECFIL entry blank and *ABflare* will not update the existing receptor settings.

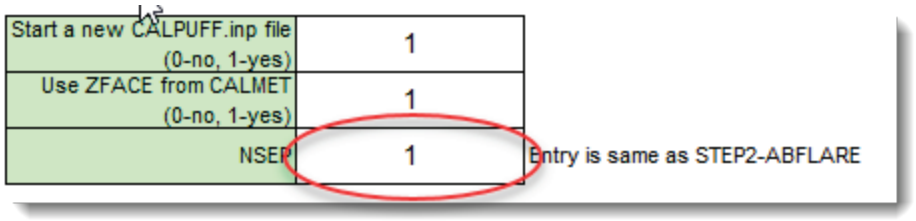
The Switch Checker Group is provided to review the *CALPUFF* switch settings. The *ABflare* default settings listed are those regulatory settings preferred by Alberta AER and AEP. At the bottom of the list are the important settings to run an *ABflare* source within *CALPUFF*. The default settings represent the typical settings for a single flare source assessment. NFL2 is the number of sources in the arbitrary time varying flare emission file and NFLDAT is the number of files to be used, both of which will typically be 1. MTIP_FL allows *CALPUFF* to be configured to turn off flare tip downwash explicitly for the flare sources. The *CALPUFF* setting MTIP is used to control the downwash setting for other stacks and sources. MTIP_FL must be 0 because *ABflare* incorporates the effects of downwash in the effective flare height calculations. MRISE_FL is set to use the Brigg's plume rise calculations which is the preferred option for flaring sources.

NVL2	0	0	Number of point sources with variable emission parameters provided in external file
NFL2	1	1	Number of flare sources defined in FLEMARB.DAT
MTIP_FL	0	0	For Flare Sources: Stack tip downwash is NOT used (because stack tip down wash is accounted for in the source term using the AER spreadsheet)
MRISE_FL	1	1	For flare source(s): 1=Brigg's rise; 2=Numerical Rise (Default: 1)
NFLDAT	1	1	Number of flare source files
END			

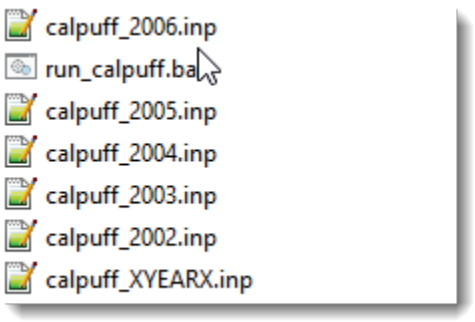
Scrolling to the top of the worksheet, you see that two warning messages are displayed. One, indicating that that advanced setting for mdoforeach is selected and two, that changes were made to the entries on the page that have not been saved. When the Save As… button is pressed, the user is prompted for a filename and path to save the input settings. Because the mdoforeach variable is used, the user should include the dofor variable in the filename as shown below.



An important setting is the NSEP variable. This setting must match the setting used in the **STEP2-ABFLARE** page. For this example, NSEP=1 is the correct entry.



When the file is saved, using the mdoforeach, an input file is created for each of the entries in the doforeach list, plus the template file with the dofor variable included in the file, plus a batch file if the mbatonly setting was selected.

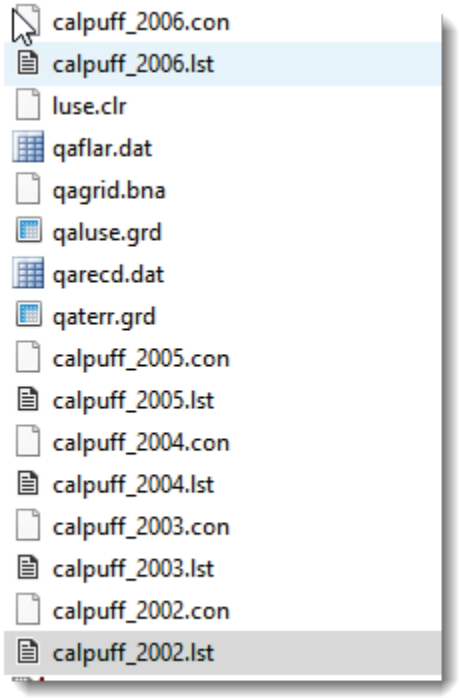


The user can select Start a new file before saving the file. When this setting is used the format and default settings from the **sCALPUFF** page are used to create the input file. Otherwise, the file that was loaded will only be modified with the settings on the worksheet.

The batch file contains all of the *CALPUFF*.exe commands and input files. In the example below, the MPAUSE option was used to insert a pause at the end of the commands which can be useful during debugging. *CALPUFF*.exe is VERY numerically intensive (takes a LONG time). Although all of the commands are included in a single batch file as shown below, for an annual assessment it may be better to execute each year individually on separate computers. Using windows explorer (Windows Key + e) navigate to where you saved the input files then click on the `run_calpuff.bat` file to run the *CALPUFF*.exe program.

```
@echo off
@rem created by ABFLARE Ver 1.03 [SS1.03.160913;M1.03.160913]
P:\ERCBtools\ABflare\bin\calpuff_v7.2.1.exe
Y:\ABflare\AERflare_examples\Example1\puf\case1\calpuff_2002.inp
@rem created by ABFLARE Ver 1.03 [SS1.03.160913;M1.03.160913]
P:\ERCBtools\ABflare\bin\calpuff_v7.2.1.exe
Y:\ABflare\AERflare_examples\Example1\puf\case1\calpuff_2003.inp
@rem created by ABFLARE Ver 1.03 [SS1.03.160913;M1.03.160913]
P:\ERCBtools\ABflare\bin\calpuff_v7.2.1.exe
Y:\ABflare\AERflare_examples\Example1\puf\case1\calpuff_2004.inp
@rem created by ABFLARE Ver 1.03 [SS1.03.160913;M1.03.160913]
P:\ERCBtools\ABflare\bin\calpuff_v7.2.1.exe
Y:\ABflare\AERflare_examples\Example1\puf\case1\calpuff_2005.inp
@rem created by ABFLARE Ver 1.03 [SS1.03.160913;M1.03.160913]
P:\ERCBtools\ABflare\bin\calpuff_v7.2.1.exe
Y:\ABflare\AERflare_examples\Example1\puf\case1\calpuff_2006.inp
@PAUSE
```

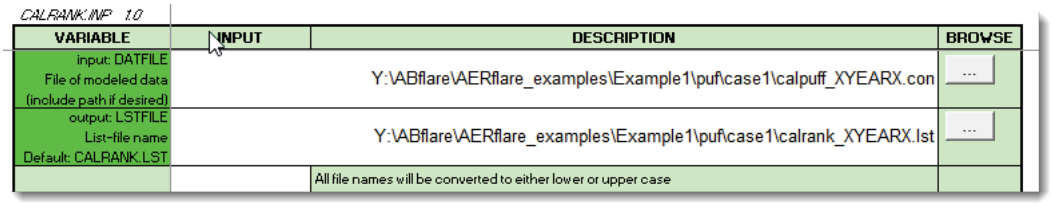
When *CALPUFF.exe* is completed, the CONDAT and PUFLST files will be created in the location you specified.



Post-Processing

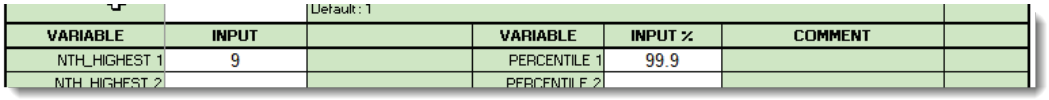
The post-processing for a steady flare is relatively straightforward, only the *CALRANK* processor is required. *CALRANK* is configured **STEP4c-RANK** page.

The Input and Output Folders group will be configured similar to the way *METSERIES, ABflare* and *CALPUFF* was configured, that is, using the mdoforeach setting and dofor variable. There are two primary entries in this group as highlighted with circles in the following figure. The DATFILE entry is the same as the CONDAT for the *CALPUFF* output containing the dispersion calculation output. The LSTFILE file will contain the output from the *CALRANK.exe* program. Because we are performing a multiyear assessment the mdoforeach setting is convenient and each of the DATFILE and LSTFILE entries should contain the dofor variable (XYEARX).



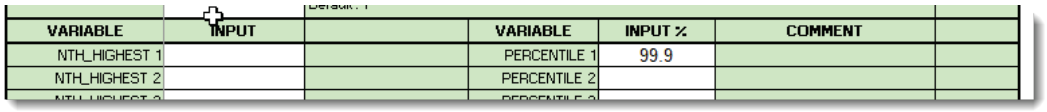
The Switch Settings Group contains the ICDAY variable to control whether the hourly values are used in the ranking or the calendar day maximum hourly value. The later is used for emerging regulatory endpoints. The MASS_UNIT setting can be used to scale the *CALPUFF* output to various common mass concentration units.

The Percentiles Group contains two columns of entries. The user may enter either the n^{th} highest statistic or the percentile statistics. Typically, for a standard year of 8760 h, the regulatory endpoints allow comparison of the 9^{th} highest predicted (modelled) concentration to the ambient air quality guideline for design calculations. Therefore, for a standard year, the following calculations produce the same results for the hourly concentration predictions.



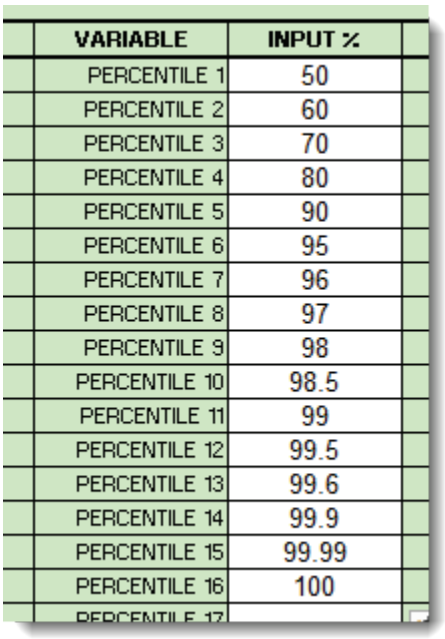
VARIABLE	INPUT		VARIABLE	INPUT %	COMMENT	
NTH_HIGHEST 1	9		PERCENTILE 1	99.9		
NTH_HIGHEST 2			PERCENTILE 2			

To account for non-standard years such as leap years, or years where the meteorological record is not complete (must be >90% complete, Alberta Air Monitoring Directive) the percentile statistic best matches the implied statistic for removal of extreme values. Therefore, the recommended assessment should be the minimum as shown below, using the 99.9^{th} percentile.



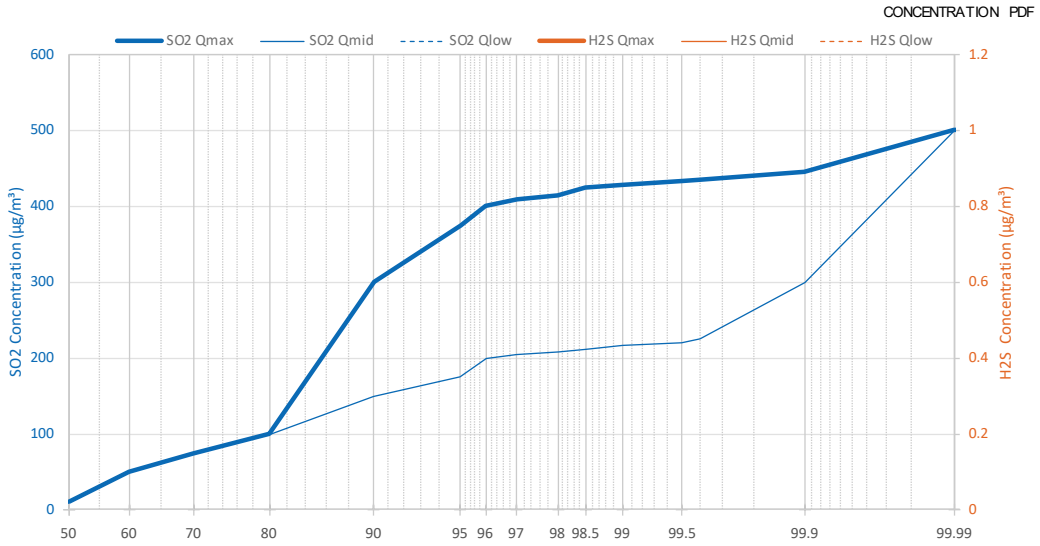
VARIABLE	INPUT		VARIABLE	INPUT %	COMMENT	
NTH_HIGHEST 1			PERCENTILE 1	99.9		
NTH_HIGHEST 2			PERCENTILE 2			

It is common practice to display and review a percentile chart of the predictions. A typical set of percentiles might be represented by the list below.



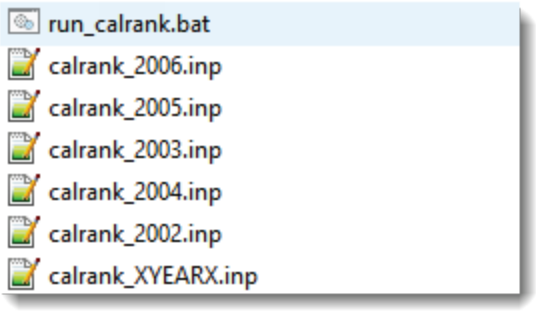
VARIABLE	INPUT %
PERCENTILE 1	50
PERCENTILE 2	60
PERCENTILE 3	70
PERCENTILE 4	80
PERCENTILE 5	90
PERCENTILE 6	95
PERCENTILE 7	96
PERCENTILE 8	97
PERCENTILE 9	98
PERCENTILE 10	98.5
PERCENTILE 11	99
PERCENTILE 12	99.5
PERCENTILE 13	99.6
PERCENTILE 14	99.9
PERCENTILE 15	99.99
PERCENTILE 16	100
PERCENTILE 17	

The percentile chart of results from such as list allows the reviewer to determine the robustness of the predictions being less than ambient concentrations. For instance, in the hypothetical case shown below, the both predictions show concentrations that are less than the ambient guideline value of 450 µg/m³ at 99.9th percentile with the same peak concentration prediction. The bold line slope near 99.9th percentile is shallow, indicating that for a wide range of conditions the flare will exceed regulations. The thin line, however, has a steep slope and the conclusion is more robust than the bold line (variability in ± concentrations or ± percentiles are less likely to change the predictions to an exceedance.) There is greater confidence in results from an assessment based upon the thin line.



Scrolling to the top of the worksheet, you see that two warning messages are displayed. One, indicating that that advanced setting for mdoforeach is selected and two, that changes were made to the entries on the page that have not been saved. When the Save As… button is pressed, the user is prompted for a filename and path to save the input settings. Because the mdoforeach variable is used, the user should include the dofor variable in the filename as shown below.

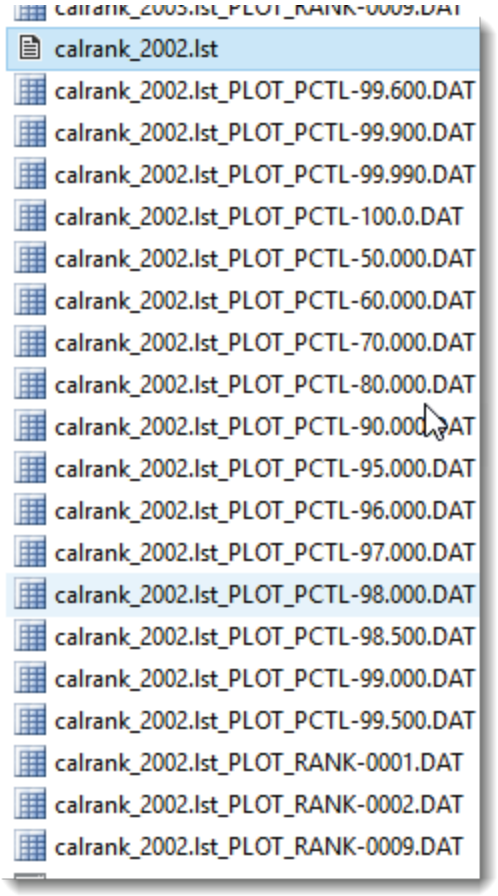
When the file is saved, using the mdoforeach, an input file is created for each of the entries in the doforeach list, plus the template file with the dofor variable included in the file, plus a batch file if the mbatonly setting was selected.



The batch file contains all of the *CALRANK*.exe commands and input files. In the example below, the MPAUSE option was used to insert a pause at the end of the commands which can be useful during debugging. *CALRANK*.exe is not numerically intensive. All of the commands are included in a single batch file as shown below. Using windows explorer (Windows Key + e) navigate to where you saved the input files then click on the `run_calrank.bat` file to run the *CALRANK*.exe program.

```
@echo off
@rem created by ABFLARE Ver 1.03 [SS1.03.160913;M1.03.160913]
O:\CALPUFF\code\CALRANK_v7.0.0_L140912\CALRANK_v7.0.0_L140912\calrank_v7.0.0.exe
Y:\ABflare\AERflare_examples\Example1\puf\case1\calrank_2002.inp
@rem created by ABFLARE Ver 1.03 [SS1.03.160913;M1.03.160913]
O:\CALPUFF\code\CALRANK_v7.0.0_L140912\CALRANK_v7.0.0_L140912\calrank_v7.0.0.exe
Y:\ABflare\AERflare_examples\Example1\puf\case1\calrank_2003.inp
@rem created by ABFLARE Ver 1.03 [SS1.03.160913;M1.03.160913]
O:\CALPUFF\code\CALRANK_v7.0.0_L140912\CALRANK_v7.0.0_L140912\calrank_v7.0.0.exe
Y:\ABflare\AERflare_examples\Example1\puf\case1\calrank_2004.inp
@rem created by ABFLARE Ver 1.03 [SS1.03.160913;M1.03.160913]
O:\CALPUFF\code\CALRANK_v7.0.0_L140912\CALRANK_v7.0.0_L140912\calrank_v7.0.0.exe
Y:\ABflare\AERflare_examples\Example1\puf\case1\calrank_2005.inp
@rem created by ABFLARE Ver 1.03 [SS1.03.160913;M1.03.160913]
O:\CALPUFF\code\CALRANK_v7.0.0_L140912\CALRANK_v7.0.0_L140912\calrank_v7.0.0.exe
Y:\ABflare\AERflare_examples\Example1\puf\case1\calrank_2006.inp
@PAUSE
```

When *CALRANK.exe* is completed, the LSTFILE file will be created in the location you specified. The nth highest and percentile output from CALRANK.exe are output to individual files, respectively for each setting, using the LSTFILE file and postfix of the nth highest or percentile value as shown below.



Each output file, (.dat) is a text file with columns of X,Y and Concentration suitable for plotting or contouring using SURFER. An example of the output file is shown below for the 99.9th percentile prediction.

```
1
2
3                ---------------------------------------------
4                Requested Values for Percentile (%) =  99.900
5                Corresponding Nth-Highest N         =      9
6                All Values in Each Day are Included
7                Number of times in period           =   8760
8                ---------------------------------------------
9
10
11  Model data for each receptor are ranked over all times based on magnitude and
12  the requested Nth-Highest and/or Percentile values are reported for each receptor
13
14
15
16       Location          Species - Level  Starting UTC-0700
17     X          Y        SO2           1    Date      Time
18    (KM)       (KM)      ug/m3            (YYYY_JJJ)(HH:MM:SS)
19
20    481.134  6112.245     7.2375732E+02   2002_236  16:00:00
21    481.134  6112.265     6.3978491E+02   2002_188  17:00:00
22    481.134  6112.285     5.7145068E+02   2002_236  17:00:00
23    481.134  6112.305     5.0010449E+02   2002_143  19:00:00
24    481.134  6112.325     4.4757651E+02   2002_166  17:00:00
25    481.134  6112.345     4.6255829E+02   2002_116  18:00:00
26    481.134  6112.365     2.5427936E+02   2002_143  18:00:00
27    481.134  6112.385     2.4956189E+02   2002_143  17:00:00
```

Completing the Assessment

In this example, the flare was modelled at the maximum flow rate. For a flaring assessment, however, the dispersion modelling must be completed for maximum, average and 1/8th maximum flow rates. Therefore, the modeller must repeat the steps starting with the sub-section Source Input File(s).

5. EXAMPLE 2: Well Test Flare in Complex Terrain

This example was selected to demonstrate the ability of *ABflare* to model real-world flares and produce realistic predictions. The focus of the modelling was on matching observed conditions rather than modelling for regulatory approval. For regulatory approval the AESRD (2002-2006) meteorological data set would be used and maximum flow rates would be modelled.

Location

The well test flare is located in south west Alberta at the coordinates below:

Northing (m)	5513080
Easting (m)	688183
Site Elevation (m ASL)	1878

UTM-Z11-NAD83

The domain coordinates are UTM-Z11-NAD83:

Model	X	Y	Corner
CALPUFF	678184	5503080	BL
	698184	5523080	TR
CALMET	673184	5498080	BL
	703184	5528080	TR

UTM-Z11-NAD83

The topography in the region surrounding the well site is shown in Figure 6. The Terrain rises from 1878 m at the well test flare location to 2245 m within 2.2 km. The well test was operated with 12 real-time air quality monitoring stations surrounding the flare location. The locations of the monitoring stations are listed in Table 2.

Table 2: Locations of Well Test Air Quality Monitoring Stations

Label	X	Y	Elev	Distance (m)	Direction To	Wind From
#1:	688628	5514341	2052	1337	19	199
#2:	689424	5514228	2027	1690	47	227
#3:	689837	5513678	2127	1758	70	250
#4:	689888	5512886	2140	1716	96	276
#5:	689216	5512564	2123	1154	117	297
#6:	689018	5512180	2120	1227	137	317
#7:	688899	5511785	2103	1480	151	331
#8:	686141	5509059	2028	4510	207	27
#9:	685848	5510684	1893	3346	224	44
#10:	681292	5509794	1861	7635	245	65
#11:	683804	5512380	2026	4435	261	81
#12:	687461	5513001	1935	727	264	84

UTM-Z11-NAD83

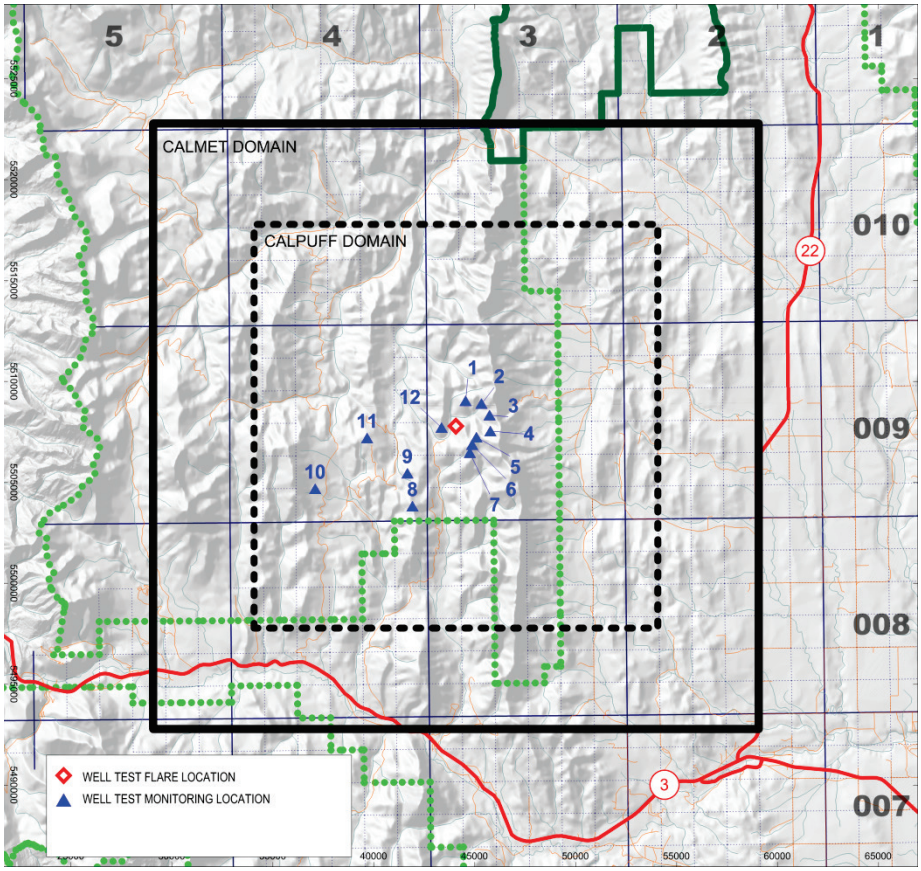


Figure 6: Topography in the Region of the Well Test Flare Showing Terrain Elevations and Locations of Monitoring stations

More detail of the elevations near the well test flare location is shown in Figure 7. Receptor locations for air quality modelling were selected in two patterns: a grid over the entire domain similar to what would be used for regulatory approval air quality modelling; and, localized arc arrays over an 11.25° arc centred at the monitoring station. It is shown in the next section that the observed winds were predominantly from 200° (or blow to 20°, station #1). However, the modelled meteorology predicted winds at some times during the same interval towards 20°, 50° and 73°. Therefore, the modelling receptor grid used arc arrays to capture likely concentrations that would be comparable to the observed record.

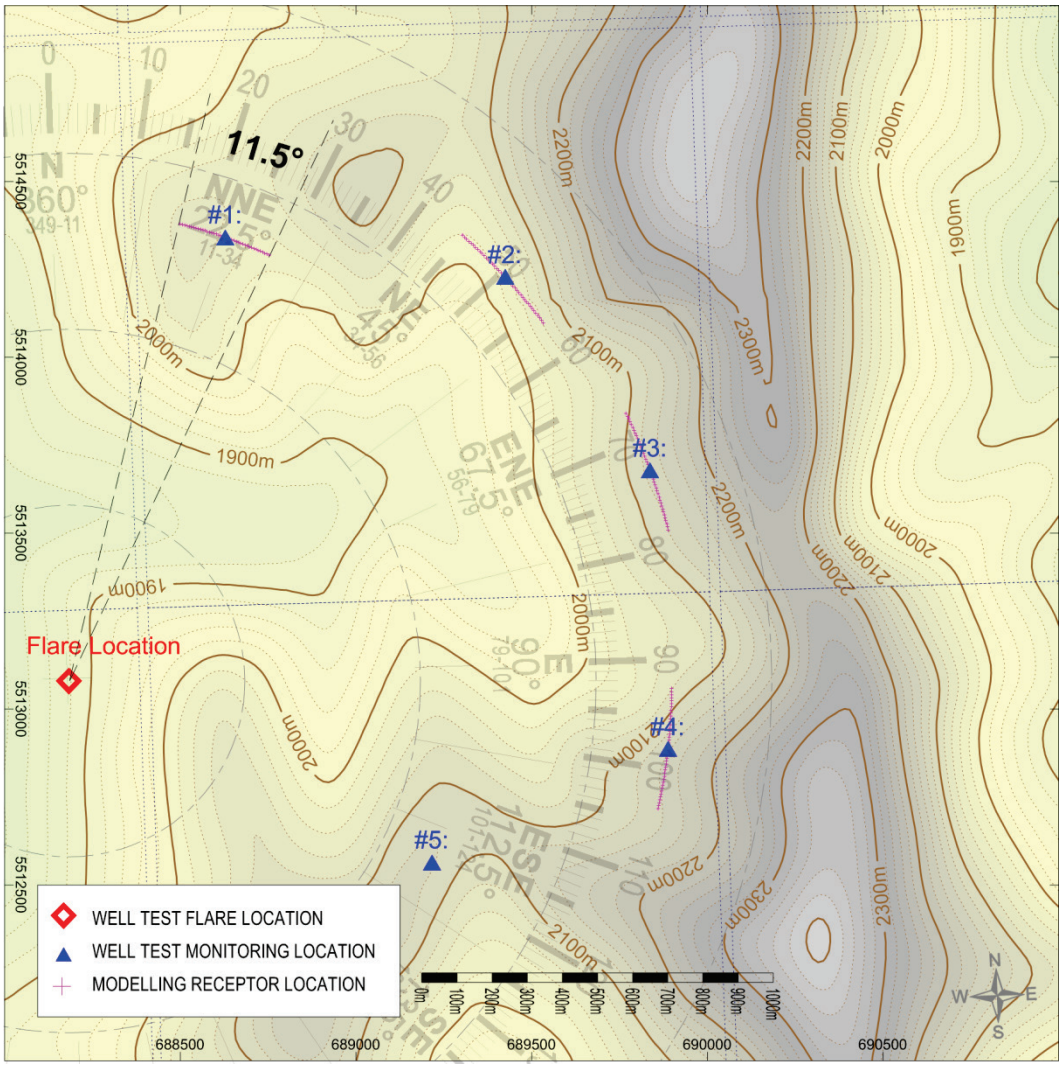


Figure 7: Air Quality Modelling Receptor Locations Near Monitoring Locations with Measurements

Meteorology

The meteorology used in this example was created from historical WRF data for the time of the well test. RWDI Calgary (www.rwdiair.com) provided a CALMET ready `3D.dat` file for the time period (15-Oct-2010 to 18 Nov-2010) of the well test flare at 1 km resolution. This data was input into *CALMET* using land-use (Geobase 2009) and terrain elevations (Geobase 2000).

A comparison of the wind rose observed at the site to the modelled *CALMET* wind rose is shown in Figure 8. The observed windrose (Figure 8-left) shows an almost exclusive wind direction from S-SSW. Whereas, the *CALMET* derived windrose (Figure 8-right) shows influences of Western-Canada typical westerly winds as well as other directions.

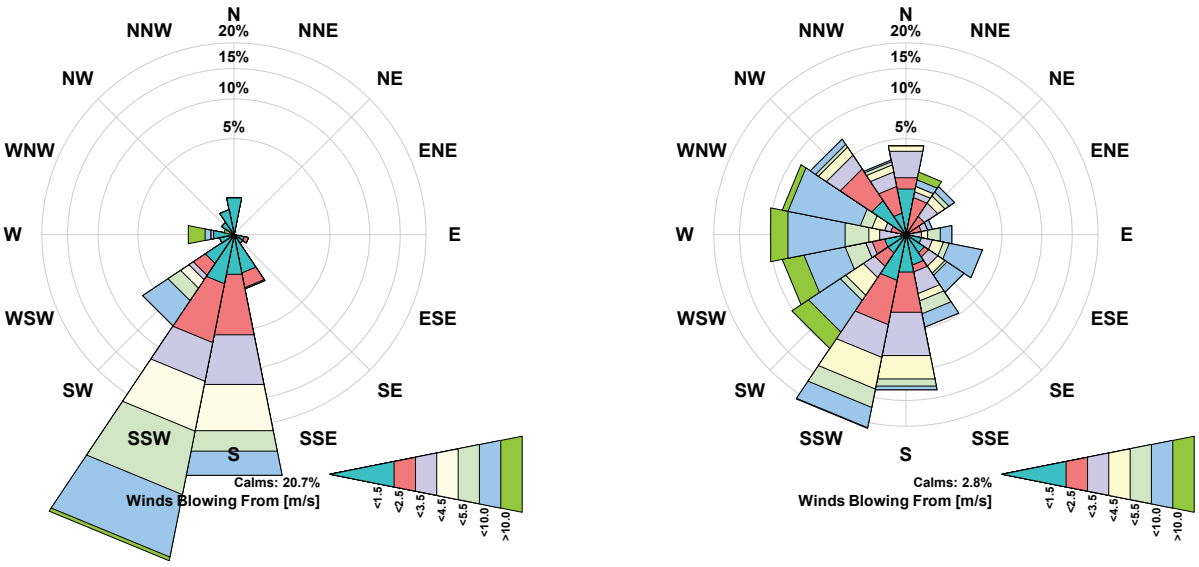


Figure 8: Comparison of Wind Rose observed at the Well Test Site Location (left) and Extracted from CALMET Derived Meteorology (right)

A comparison of the wind direction time series observed at the site (1 h running average of 15 min samples, measured at 32.2 m) to the modelled *CALMET* wind directions (1 h averages, extracted at flare tip height 36.6 m) are shown in Figure 9. The concentration data collected at monitoring stations showed observations between 29-Oct to 1-Nov and nominally over the period 27-Oct to 8-Nov. There is general agreement between the observed and the modelled for parts of the period. The observed wind direction blows steadily toward monitoring station #1 (from 200°) whereas the resolved *CALMET* meteorology predicts winds blowing alternating between station #1, station #2 and station #3 (from 200°, 227° to 250°).

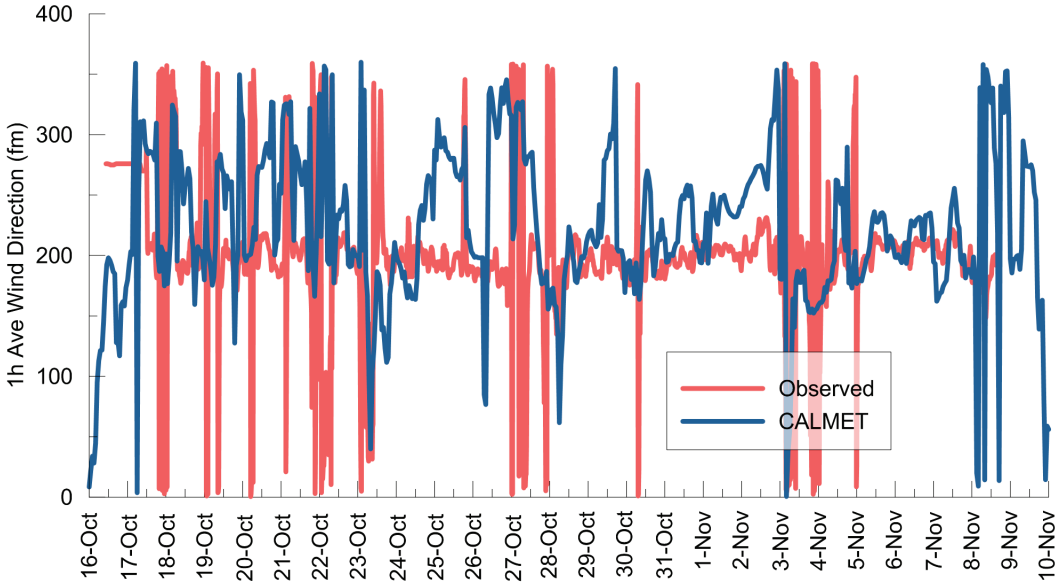


Figure 9: Comparison of Observed to Modelled Meteorology: Wind Direction (27-Oct to 8-Nov)

The predicted wind speeds closely resemble the observed (1 h average) wind speeds (Figure 10). Wind speed can have important impacts on the efficiency of the flare combustion and the predicted concentrations are inversely proportional to wind speed. However, because the dispersion is in complex terrain, the velocity along the flight path between source and receptor is not measured, and therefore the wind speed at the source is just an indication of dispersion differences.

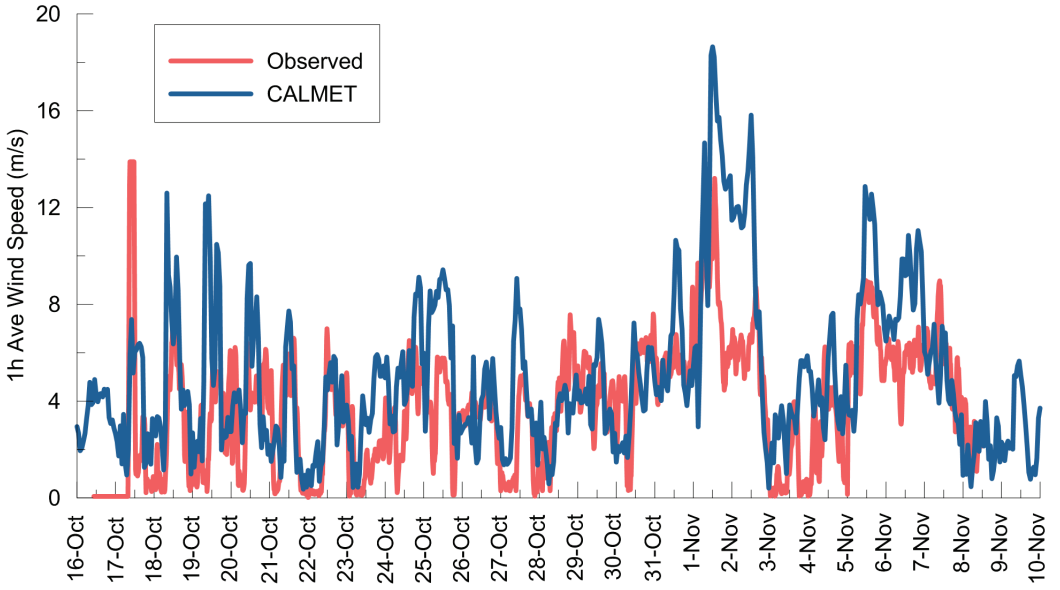


Figure 10: Comparison of Observed to Modelled Meteorology: Wind Speed (27-Oct to 8-Nov)

Predicted verses observed atmospheric turbulence, at the flare location, are shown in Figure 11. The Pastquill-Gifford (PG) stability class is a useful simplification for comparison of turbulence. Again, there are periods of time that show good relative agreement between the observed PG and modelled PG. During this period the differences are predominantly ±1 PG class and never more than 2 PG classes.

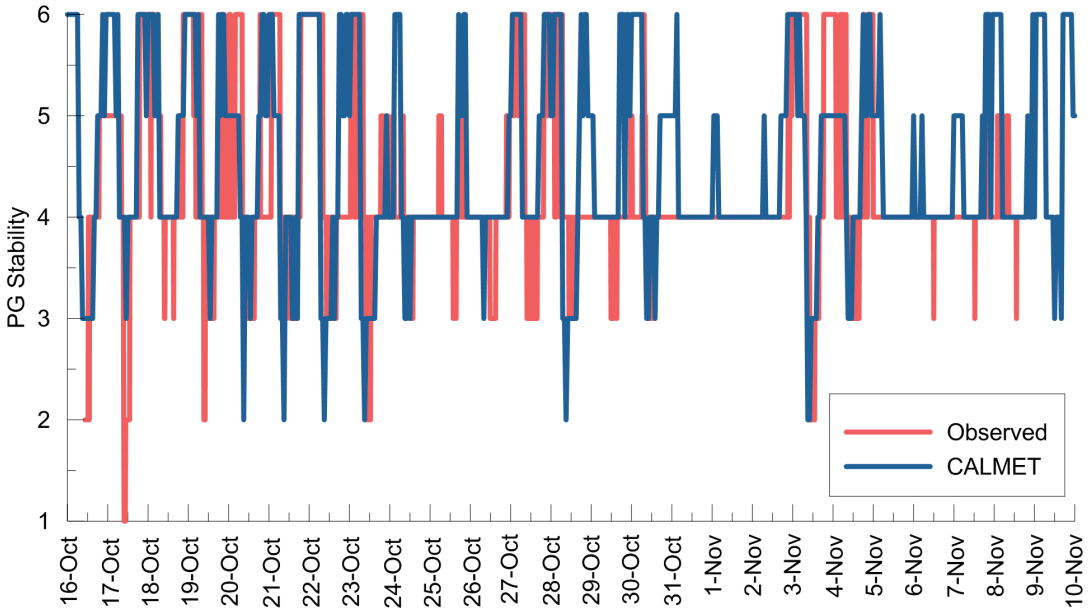


Figure 11: Comparison of Observed to Modelled Meteorology: Turbulence PG Stability Class (27-Oct to 8-Nov)

Source

The well clean up and associated gas rates being flared vary in time as shown in Figure 12. The flare rates were stopped, as marked, based upon real-time air quality dispersion modelling to prevent potential ground level exceedances. The gas rates observed during the well test are listed in the table below. The average gas rate was used in this modelling example to best represent observed conditions. For regulatory modelling for approval of a well test flare, the maximum rate gas should be used.

Flare Stack Tip Exit Height	m	36.6
Flare Stack Tip Exit Diameter	mm	154
Requested Maximum Raw Gas H_2S Concentration for **Subject** Zone	% (for approvals round up to 0.5% increment)	27.500%
Total Volume of Raw Gas to be Flared during Clean-up and Testing of **ALL** Zones	10^3m^3 (15°C and 101.325 kPa)	1.9
Maximum Raw Gas Flow Rate for **Subject** Zone	$10^3m^3/d$ (15°C and 101.325 kPa)	45.000

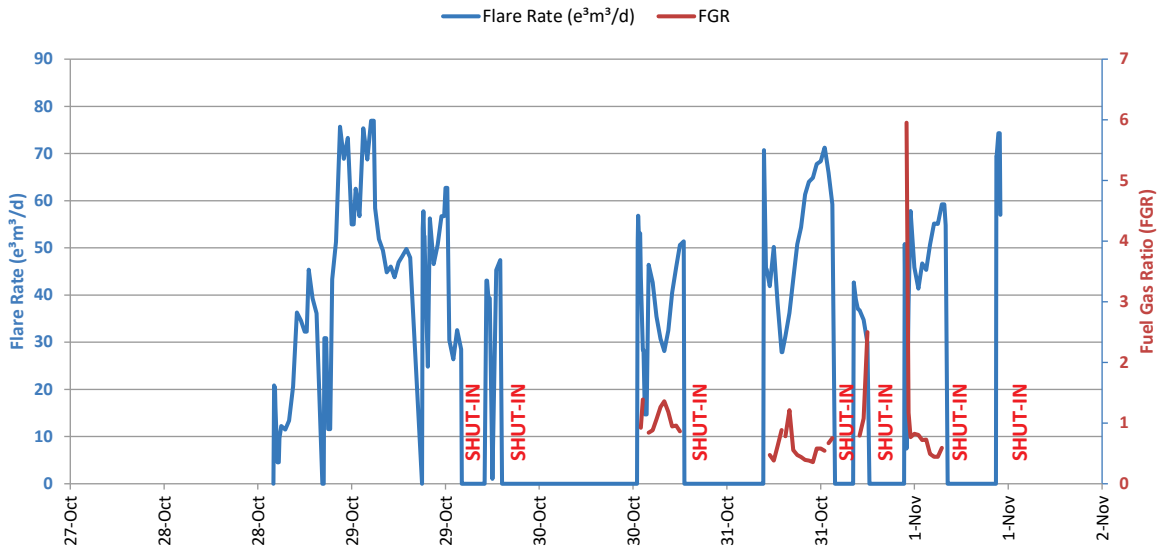


Figure 12: Flare Gas Rate and Fuel Gas Ratio During Well Test Flaring

Fuel gas (propane) was added to the raw gas flared but the rates were sparsely recorded. The average fuel gas ratio (FGR) was 0.95.

The gas analysis used for the well test flare was taken during clean-up operations. It represents the best estimate of the gas being flared.

Gas Compositions (mole fraction)	Fuel Gas	Raw Gas
H_2O		0
H_2		0.0002
He		0.0001
N_2		0.0197
CO_2		0.07
H_2S		0.275
CH_4		0.6328
C_2H_6		0.0014
C_3H_8	1	0.0002
i-C_4H_{10}		0.0001
n-C_4H_{10}		0.0001
i-C_5H_{12}		0.0001
n-C_5H_{12}		0.0001
n-C_6H_{14}		0.0001
C_7^+		0.0001
CO		0
NH_3		0
Total	1	1.0000

ABflare Modelling

This section of the example shows how to enter information in the *ABflare* modelling framework to model the example well test flare.

Step 0b-RECEPTOR

In this case a standard receptor grid is not of interest, but instead, a series of receptors were created centred at the monitoring sites during the well test flare. The receptor locations were determined external to *ABflare*. The receptor locations were saved as a comma separated XY file of the locations.

Selecting the Read User Receptor Grid option (see below) when the Create Receptors button is pressed, the user is prompted for the name of the CSV file. In this case, navigate to the Example 2 folder and selected the file.

Step 2	Create Receptors for AERMOD	Create Receptors
2.1	Enter the path name for the output receptor list	
2.2	Press 'Create Receptors' to create a receptor grid as specified in Step 1, and output to the path name. Or, select the check box to read receptors from a CSV file. Map sheets for DEM are automatically download as required or loaded from DEMLIB. ☑ Read User Receptor Grid	
2.3	The DEM map sheets used in the creation of the receptor files are listed below. The receptor locations (X,Y), elevation and hill scale heights are listed at the bottom	

Entry	Resolution (m)	Default (m)
Flag Pole Receptor Height	0	0

Step 1–METSERIES

The first step in preparation for modelling the well test flare is to extract a time series of meteorological data at the flare location at the flare tip height. The meteorological data is extracted from an existing *CALMET* data set as previously described above.

The mapping and projection input group were configured with the following settings that match the location and data.

VARIABLE	INPUT	DESCRIPTION	
PMAP	UTM	Map projection, see list to right	UTM
FEAST	0	False Easting and Northing (km) at the projection origin (Used only if PMAP= TTM, LCC, or LAZA)	
FNORTH	0		
IUTMZN	11	UTM zone (1 to 60) (Used only if PMAP=UTM)	
UTMHEM	N	Hemisphere for UTM projection? (N or S) (Used only if PMAP=UTM)	
RLAT0	0N	Latitude and Longitude (decimal degrees) of projection origin (Used only if PMAP= TTM, LCC, PS, EM, or LAZA) e.g.,. RLAT0=60N, RLON0=115W	
RLON0	0E		
XLAT1	0N	Matching parallel(s) of latitude (decimal degrees) for projection (Used only if PMAP= LCC or PS)	
XLAT2	0N		
DATUM	NAR-B	Datum-region for output coordinates, see list to right	NAR-B
UNITS	KM	m or km	

The output group settings are selected to match the stack tip height. *CALMET* is a gridded data set, and *METSERIES* is directed (METSIM=1) to interpolate the meteorological time series at the well flare location.

VARIABLE	INPUT	DESCRIPTION	
MDATA	CALMET	Input Data Type	CALMET
XESTN	688.183	X-Easting Coordinate (km, deg, or cell)	
YNSTN	5513.08	Y-Northing Coordinate (km, deg, or cell	
METSIM	1	1=interpolate; 2=nearest grid cell	
ZWIND	36.6	Measurement height (m AGL) for wind (-1. to exclude)	
ZTEMP	36.6	Measurement height (m AGL) for temperature (-1. to exclude)	
ZRHUM	36.6	Measurement height (m AGL) for humidity (-1. to exclude)	

The well test flare monitoring period was Oct 15 through Nov 18, 2010.

	iyr	imo	iday	ihr	isec
Start met	2010	10	15	0	0
End met	2010	11	18	0	0
NSECDT	3600	Time interval			

There is only a single meteorological data file to be processed since the time period is relatively short. The full path of the data file is entered.

NMETINP	1	Number of met files to extract	BROWSE
MetDat1	Y:\2011\11005\met\m1_01.dat		...
MetDat2			

The input and output folders group are selected to match the users' computer configuration. The root name for the output is used by *METSERIES* in the naming of its output files.

VARIABLE	INPUT	DESCRIPTION
Output Path	P:\2011\1100500\ex1\	
TSFOUT	m2010	Timeseries data are written to the following NTSFOUT files .TSF file extension WILL BE ADDED to the names provided
output: LSTDAT List-file name Default: METSERIES.LST	P:\2011\1100500l\ex1\metseries.lst	

The user should then save the *ABflare.xlsm* spread sheet and the user should then save the *METSERIES* page inputs by pressing the SAVE AS… button at the top of the page. The SAVE AS… button creates a *METSERIES* input file and displays the selected file name at the top of the page for reference.

Step 2 – ABflare Variable Source

The default source model for *ABflare* creates an hour-by-hour variable emissions source. The control variables for *ABflare* are listed below. *ABflare* is configured with MINPUT=1 and MBLOWDOWN=1. In this case, the source is not a blowdown, but a steady rate at QMAX. MSTRIP=0, indicating that a conservative modelling approach is used with 100% H_2S being converted to SO_2. Otherwise *ABflare* uses the calculated combustion efficiency for all other calculations.

VARIABLE	INPUT	DESCRIPTION
MDSPMOD	1	MDSPMOD = 1 : create files for CALPUFF 2 : create files for AERMOD DEFAULT = 1
MINPUT	1	MINPUT =1 : source conditions are input and blowdown is calculated (see MBLOWDOWN) 2 : blowdown curve sequence is input (see NSEQ) 3 : static source is input (see SOURCE DESCRIPTION GROUP). Use setting 3 for a steady flare source with parameters that that don't vary with meteorology DEFAULT = 1
MBLOWDOWN	1	MBLOWDOWN=1 : user input QMAX and QTOTAL 2 : blowdown exponential model parameters are calculated from pipeline/vessel initial conditions DEFAULT = 2
MDIST	2	MDIST=1 : blowdown sequence is created based upon puffs of equal volume 2 : blowdown sequence is created based upon puffs of equal mass DEFAULT = 2
MSTRIP	0	MSTRIP=0 : source is described by input (100% conversion to SO2) =1 : source is a stripped flow source (H2S) =2 : source is actual SO2 (accounting for efficiency) DEFAULT= 0
MMET	1	MMET=1: meteorology is read from METPATH (CALPUFF) =2: meteorology is read from METPATH (AERMOD) =3: force met to be WINDSP, WINDDR, TAMB DEFAULT = 1
MFUELGAS	1	Is fuel gas added? MFUELGAS=0 : no fuel gas is added 1 : fuel gas is added Default = NONE
MFGR	2	MFGR =1 : fuel gas is proportional to qmax rate =2 : fuel gas is constant amount based upon initial qmax DEFAULT = 2
MLIFTGAS	0	Is lift gas used ? MLIFTGAS = 0 : no lift gas = 1 : lift gas is used DEFAULT = 0
MFASSIST	0	Is flare assist used ? MFASSIST = 0 : no flare assist 1 : steam assist 2 : air assist 3 : both steam and air assist is used DEFAULT = 0
MDEBUG	0	Print debug and verbose information MDEBUG = 0 : no debug = 1 : print debug/verbose DEFAULT = 0
NSEP	24	Number of hours separating blowdown sequences. Must be a multiple of 24. Each blowdown sequence starts every hour on the hour. NSEP specifies the frequency of when the starting hour can be used again. A blowdown duration greater than 24 should use NSEP=48. A blowdown duration greater than 48 should use NSEP=72. DEFAULT=24
NSOURCES		Number of co-located AERMOD sources to represent range of meteorological sensitive source conditions DEFAULT=9

The mapping and projection group is configured the same as for the *METSERIES* module.

The chemistry group inputs are listed below. These settings reflect the selection of MSTRIP=1, and therefore SO_2 is modelled.

VARIABLE	INPUT	DESCRIPTION		
NSPEC	1	Number of species to be modelled NSPEC=1		
	CHEMLST	Mole Weight kg/kmol	Emission Rate g/s	
FLARE: SPEC 1	SO2	64.065	1	This is the Flare source, the emissions are either STATIC or are overwritten by ABflare

The full time period of the meteorological data set is run.

VARIABLE	iyr	imo	iday	ihr	isec
START	2010	10	15	0	0
END	2010	11	18	0	0
TIMEINC	3600	Time step, s Default=3600			

The source description group inputs are listed below. The flare location is entered as the X,Y origin. The actual stack height and flare tip inside diameter are entered. RH2S list the maximum H_2S content in the raw gas and will be used to re-normalize the raw gas composition, as previously listed.

VARIABLE	INPUT	DESCRIPTION
XCOORD	688.183	Easting location of the flare, see DATUM coordinates
YCOORD	5513.08	Northing location of the flare, see DATUM coordinates
ZCOORD	1878.4	Terrain elevation at source, m
HS	36.6	Actual height of the flare, m
DS	0.154	Actual inside diameter of flare at top, m
RH2S	0.275	Mole fraction of H2S in raw gas

And

QMAX	45	Peak flow rate of flared gas, e³m³/d Used if MINPUT=1
QTOTAL	45	Total volume of gas contained within pipeline or vessel to be flared, e³m³/d Used if MINPUT=1
DURATION	3600	Duration of blowdown, s Used if MINPUT=1
FREL	0.95	Fraction of gas remaining in pipeline or vessel at the end of DURATION. Default= 0.99 Used if MBLOWDOWN=2
PUFFDUR		Using MDIST=1, the user can specify either the puff duration (s) or the number of puffs, NPUFFS below.
NPUFFS	1	npuffs = 0 : Program calculates number of puffs, when PUFFDUR is specified and MDIST=1 npuffs = 1 : Force blowdown to a single puff of duration PUFFDUR, if MINPUT=1 and MBLOWDOWN=1 then NPUFF=1 for a hourly varying flare or if MINPUT=3, then use input source rather than calculated blowdown. Use this setting for a steady flare source with parameters that that vary with meteorology npuffs > 1 : Number of puffs in blowdown Default = 3

After saving the inputs to an `ABflare.inp` file, the RUN button is pressed to execute the *ABflare* program. The run-time list file is presented when the program completes. The list file contains a print-out of the parameters read. Error or warning messages will be displayed at the bottom of the listing should any occur.

A listing of the *ABflare* output file is provided for the first 12 hours in Figure 13. Notice how the effective X,Y location change hour by hour as a result of the wind speed and direction at flare tip pushes the flame over. Also changing hour by hour are the effective height, diameter, temperature and vertical speed. The mass emission rate does not change since the modelling is being performed assuming 100% conversion of H_2S to SO_2. Because of the relatively high flare rate compared to the ambient wind speed, the flare efficiency is relatively high. In Figure 14, the mass emission including flare combustion efficiency is shown and is greater than 99% efficient.

```
FLEMARB.DAT     1.0             Initial configuration
   7
 Time-invariant (8 variables) var1=stack input type  var2-var8=not used
      var1=1:  T(K), U, V, W (m/s)
      var1=2:  Fb, Fmx, Fmy, Fmz  (i.e., buoyancy and momentum fluxes)
 Time-variant (if var1=1)
   X(km),Y(km),Z(mAGL),Elev(mMSL),D(m),T(K),U,V,W,Sigy(m),Sigz(m),Q(g/s)...
 Time-variant (if var1=2)
   X(km),Y(km),Z(mAGL),Elev(mMSL),D(m),Fb,Fmx,Fmy,Fmz,Sigy(m),Sigz(m),Q(g/s)...
UTM
  11N
NAR-B
  KM
UTC-0700
2010 288   0    0  2010 322   0    0
   1   1
'SO2'
      64.065
'FLR1'    1.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
   2010 288  0    0   2010 288  1    0
'FLR1'  688.19737 5513.08602     39.623   1878.400       8.252  1133.7   0.000   0.000   2.054           0.000           0.000   388.07364
   2010 288  1    0   2010 288  2    0
'FLR1'  688.19729 5513.08569     39.843   1878.400       8.251  1133.2   0.000   0.000   2.054           0.000           0.000   388.07364
   2010 288  2    0   2010 288  3    0
'FLR1'  688.19709 5513.08615     39.842   1878.400       8.249  1132.7   0.000   0.000   2.054           0.000           0.000   388.07364
   2010 288  3    0   2010 288  4    0
'FLR1'  688.19711 5513.08631     39.718   1878.400       8.246  1132.2   0.000   0.000   2.055           0.000           0.000   388.07364
   2010 288  4    0   2010 288  5    0
'FLR1'  688.19731 5513.08642     39.437   1878.400       8.243  1131.7   0.000   0.000   2.055           0.000           0.000   388.07364
   2010 288  5    0   2010 288  6    0
'FLR1'  688.19774 5513.08589     39.194   1878.400       8.238  1131.0   0.000   0.000   2.055           0.000           0.000   388.07364
   2010 288  6    0   2010 288  7    0
'FLR1'  688.19794 5513.08500     39.265   1878.400       8.235  1130.1   0.000   0.000   2.055           0.000           0.000   388.07364
   2010 288  7    0   2010 288  8    0
'FLR1'  688.19793 5513.08389     39.450   1878.400       8.234  1129.6   0.000   0.000   2.055           0.000           0.000   388.07364
   2010 288  8    0   2010 288  9    0
'FLR1'  688.19806 5513.08309     39.296   1878.400       8.233  1129.6   0.000   0.000   2.055           0.000           0.000   388.07364
   2010 288  9    0   2010 288 10    0
'FLR1'  688.19810 5513.08283     39.219   1878.400       8.233  1129.6   0.000   0.000   2.055           0.000           0.000   388.07364
   2010 288 10    0   2010 288 11    0
'FLR1'  688.19816 5513.08262     39.121   1878.400       8.233  1129.8   0.000   0.000   2.055           0.000           0.000   388.07364
   2010 288 11    0   2010 288 12    0
'FLR1'  688.19794 5513.08197     39.251   1878.400       8.236  1130.3   0.000   0.000   2.055           0.000           0.000   388.07364
```

Figure 13: Listing of the *ABflare* Time Varying Source Output File

```
FLEMARB.DAT     1.0             Initial configuration
   7
 Time-invariant (8 variables) var1=stack input type  var2-var8=not used
      var1=1:  T(K), U, V, W (m/s)
      var1=2:  Fb, Fmx, Fmy, Fmz  (i.e., buoyancy and momentum fluxes)
 Time-variant (if var1=1)
   X(km),Y(km),Z(mAGL),Elev(mMSL),D(m),T(K),U,V,W,Sigy(m),Sigz(m),Q(g/s)...
 Time-variant (if var1=2)
   X(km),Y(km),Z(mAGL),Elev(mMSL),D(m),Fb,Fmx,Fmy,Fmz,Sigy(m),Sigz(m),Q(g/s)...
UTM
  11N
NAR-B
  KM
UTC-0700
2010 288   0    0  2010 322   0    0
   1   1
'SO2'
      64.065
'FLR1'    1.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
   2010 288  0    0   2010 288  1    0
'FLR1'  688.19737 5513.08602     39.623   1878.400       8.252  1133.7   0.000   0.000   2.054           0.000           0.000   386.00725
   2010 288  1    0   2010 288  2    0
'FLR1'  688.19729 5513.08569     39.843   1878.400       8.251  1133.2   0.000   0.000   2.054           0.000           0.000   386.15200
   2010 288  2    0   2010 288  3    0
'FLR1'  688.19709 5513.08615     39.842   1878.400       8.249  1132.7   0.000   0.000   2.054           0.000           0.000   386.15358
   2010 288  3    0   2010 288  4    0
'FLR1'  688.19711 5513.08631     39.718   1878.400       8.246  1132.2   0.000   0.000   2.055           0.000           0.000   386.08053
   2010 288  4    0   2010 288  5    0
'FLR1'  688.19731 5513.08642     39.437   1878.400       8.243  1131.7   0.000   0.000   2.055           0.000           0.000   385.86708
   2010 288  5    0   2010 288  6    0
'FLR1'  688.19774 5513.08589     39.194   1878.400       8.238  1131.0   0.000   0.000   2.055           0.000           0.000   385.61414
   2010 288  6    0   2010 288  7    0
'FLR1'  688.19794 5513.08500     39.265   1878.400       8.235  1130.1   0.000   0.000   2.055           0.000           0.000   385.70509
   2010 288  7    0   2010 288  8    0
'FLR1'  688.19793 5513.08389     39.450   1878.400       8.234  1129.6   0.000   0.000   2.055           0.000           0.000   385.89158
   2010 288  8    0   2010 288  9    0
'FLR1'  688.19806 5513.08309     39.296   1878.400       8.233  1129.6   0.000   0.000   2.055           0.000           0.000   385.74180
   2010 288  9    0   2010 288 10    0
'FLR1'  688.19810 5513.08283     39.219   1878.400       8.233  1129.6   0.000   0.000   2.055           0.000           0.000   385.65475
   2010 288 10    0   2010 288 11    0
'FLR1'  688.19816 5513.08262     39.121   1878.400       8.233  1129.8   0.000   0.000   2.055           0.000           0.000   385.52720
   2010 288 11    0   2010 288 12    0
'FLR1'  688.19794 5513.08197     39.251   1878.400       8.236  1130.3   0.000   0.000   2.055           0.000           0.000   385.68668
   2010 288 12    0   2010 288 13    0
'FLR1'  688.19754 5513.08113     39.428   1878.400       8.238  1130.7   0.000   0.000   2.055           0.000           0.000   385.86511
```

Figure 14: Listing of the *ABflare* Time Varying Source Output File with Emissions calculated from Combustion Efficiency

Step 3 – CALPUFF

Only *ABflare*-default settings were used for the modelling using Figure 13 emissions. An important setting to remember is, MTIP_FL=0. This setting turns OFF stack tip downwash for flare sources, since stack tip down wash is accounted for in the source parameters.

NFL2	1	1	Number of flare sources defined in FLEMARB.DAT
MTIP_FL	0	0	For Flare Sources: Stack tip downwash is NOT used (because stack tip down wash is accounted for in the source term using the AER spreadsheet)
MRISE_FL	1	1	For flare source(s): 1=Brigg's rise; 2=Numerical Rise (Default: 1)
NFLDAT	1	1	Number of flare source files

Step 4a – CALAVE

In this short-term example, the only time period of interest is the 1 h average, therefore the *CALAVE* module is not required.

Step 4b – CALMAX

In this short-term example, the only time period of interest is the 1 h average, therefore the *CALMAX* module is not required.

Step 4c – CALRANK

The *CALRANK* module is configured to read the *CALPUFF* output file `calpuff.con`. A typical ranking file request is listed below. The n^{th} highest values are useful for direct comparison to regulatory modelling required criteria. The percentile values are useful for plotting the probability distribution of predictions. For a dataset with 8760 hourly predictions, the 99.9^{th} prediction will be the same as the 9^{th} highest.

VARIABLE	INPUT		VARIABLE	INPUT %
NTH_HIGHEST 1	1		PERCENTILE 1	50
NTH_HIGHEST 2	2		PERCENTILE 2	60
NTH_HIGHEST 3	9		PERCENTILE 3	70
NTH_HIGHEST 4			PERCENTILE 4	80
NTH_HIGHEST 5			PERCENTILE 5	90
NTH_HIGHEST 6			PERCENTILE 6	95
NTH_HIGHEST 7			PERCENTILE 7	96
NTH_HIGHEST 8			PERCENTILE 8	97
NTH_HIGHEST 9			PERCENTILE 9	98
NTH_HIGHEST 10			PERCENTILE 10	98.5
NTH_HIGHEST 11			PERCENTILE 11	99
NTH_HIGHEST 12			PERCENTILE 12	99.5
NTH_HIGHEST 13			PERCENTILE 13	99.8
NTH_HIGHEST 14			PERCENTILE 14	99.9

The ICDAY option is not required in this case, since only hourly maximum averages are of interest.

The input file is saved to a `calrank.inp` file and then the *CALRANK* program is executed. A run-time file listing is displayed after the program terminates. The list file displays the type. The list file is shown below in Figure 15. The location and time of the maximum n^{th} highest and percentile values are listed in the list file.

CALRANK also creates plottable file output for each of the n^{th} highest and percentile values. The file names for these outputs are listed in the list file and the files are located in the folder containing the list file.

```
                    CALRANK RESULTS SUMMARY
                 VERSION:1.1            LEVEL:120915


 File Processed: p:\abflare\examples\example1\calpuff.con

 Selected Header Information From File:
--------------------------------------------------------------------------------------------------------------------------------
----
Produced by CALPUFF Version: 6.42_x1.  Level: 121203
Internal Coordinate Transformations  ---  COORDLIB   Version: 1.99   Level: 070921
CALPUFF.INP     2.1             Group 18 added
ABflare test case r1
48-hour simulation using CALMET met data
Arc Receptors 41 on 30x30km met grid
--------------------------------------------------------------------------------------------------------------------------------
----

 Information about data in file

 Averages (DAY,HH,MM,SS) =   0 1 0 0
 Type of Averaging       =  BLOCK
 Number of averages/day  =  24
 Number of days          =  11
 Number of receptors     =  4120
 Number of species       =  1
 First day (YYYYJJJ)     =  2010301     UTC-0700
 Last day (YYYYJJJ)      =  2010311     UTC-0700


 Model data for each receptor are ranked over all times based on magnitude and
 the requested Nth-Highest and/or Percentile values are reported for each receptor
 in the output files:

 p:\abflare\examples\example1\calrank.lst_PLOT_RANK-0001.DAT
 p:\abflare\examples\example1\calrank.lst_PLOT_RANK-0002.DAT
 p:\abflare\examples\example1\calrank.lst_PLOT_RANK-0009.DAT
 p:\abflare\examples\example1\calrank.lst_PLOT_PCTL-50.000.DAT
 p:\abflare\examples\example1\calrank.lst_PLOT_PCTL-60.000.DAT
 p:\abflare\examples\example1\calrank.lst_PLOT_PCTL-70.000.DAT
 p:\abflare\examples\example1\calrank.lst_PLOT_PCTL-80.000.DAT
 p:\abflare\examples\example1\calrank.lst_PLOT_PCTL-90.000.DAT
 p:\abflare\examples\example1\calrank.lst_PLOT_PCTL-95.000.DAT
 p:\abflare\examples\example1\calrank.lst_PLOT_PCTL-96.000.DAT
 p:\abflare\examples\example1\calrank.lst_PLOT_PCTL-97.000.DAT
 p:\abflare\examples\example1\calrank.lst_PLOT_PCTL-98.000.DAT
 p:\abflare\examples\example1\calrank.lst_PLOT_PCTL-98.500.DAT
 p:\abflare\examples\example1\calrank.lst_PLOT_PCTL-99.000.DAT
 p:\abflare\examples\example1\calrank.lst_PLOT_PCTL-99.500.DAT
 p:\abflare\examples\example1\calrank.lst_PLOT_PCTL-99.800.DAT
 p:\abflare\examples\example1\calrank.lst_PLOT_PCTL-99.900.DAT
```

Figure 15: CALRANK program output list file

```
 The largest of these for each rank are tabulated below with the location and time


              -------------------------------------------
              Tabulation for Requested Nth-Highest Values
              Results for the Maximum Receptor
              All Values in Each Day are Included
              -------------------------------------------
                                                                      Location       Starting UTC-0700
                                                                    X         Y       Date      Time
    N Percentile  Species - Level     Modeled      Units           (KM)      (KM)   (YYYY_JJJ)(HH:MM:SS)

    1   99.811    SO2           1   6.9553643E+03  ug/m3          688.450  5513.000  2010_306  18:00:00
    2   99.432    SO2           1   3.8266162E+03  ug/m3          688.450  5513.000  2010_308  18:00:00
    9   96.780    SO2           1   3.0401165E+03  ug/m3          688.375  5513.075  2010_306  12:00:00

-------------------------------------------
Note:  number of times in period =   264



              -------------------------------------------
              Tabulation for Requested Percentile Values
              Results for the Maximum Receptor
              All Values in Each Day are Included
              -------------------------------------------
                                                                      Location       Starting UTC-0700
                                                                    X         Y       Date      Time
    N Percentile  Species - Level     Modeled      Units           (KM)      (KM)   (YYYY_JJJ)(HH:MM:SS)

  133   50.000    SO2           1   1.4546561E+02  ug/m3          688.400  5513.200  2010_308  23:00:00
  107   60.000    SO2           1   3.5565048E+02  ug/m3          688.425  5513.175  2010_310  08:00:00
   80   70.000    SO2           1   7.9965356E+02  ug/m3          688.375  5513.175  2010_309  19:00:00
   54   80.000    SO2           1   1.2728715E+03  ug/m3          688.400  5513.200  2010_310  11:00:00
   27   90.000    SO2           1   2.1104839E+03  ug/m3          688.375  5513.175  2010_305  21:00:00
   14   95.000    SO2           1   2.6285774E+03  ug/m3          688.375  5513.125  2010_306  08:00:00
   12   96.000    SO2           1   2.8103999E+03  ug/m3          688.350  5513.100  2010_306  12:00:00
    9   97.000    SO2           1   3.0401165E+03  ug/m3          688.375  5513.075  2010_306  12:00:00
    6   98.000    SO2           1   3.3129653E+03  ug/m3          688.375  5513.075  2010_306  10:00:00
    5   98.500    SO2           1   3.4995078E+03  ug/m3          688.325  5513.075  2010_306  09:00:00
    4   99.000    SO2           1   3.6119949E+03  ug/m3          688.325  5513.075  2010_306  10:00:00
    2   99.500    SO2           1   3.8266162E+03  ug/m3          688.450  5513.000  2010_308  18:00:00
    2   99.800    SO2           1   3.8266162E+03  ug/m3          688.450  5513.000  2010_308  18:00:00
    1   99.900    SO2           1   6.9553643E+03  ug/m3          688.450  5513.000  2010_306  18:00:00

-------------------------------------------
Note:  number of times in period =   264
```

Figure 15: CALRANK program output list file (continued)

A map of the 99.9th percentile concentrations for the region shown in Figure 7 is presented in Figure 16 for the full meteorological time period modelled at the average flare rate and FGR=0.95. The map shows that there is potential for high concentrations (greater than the regulatory limit of 450 µg/m³) throughout the mapped area which is within 2.5 km of the flare source.

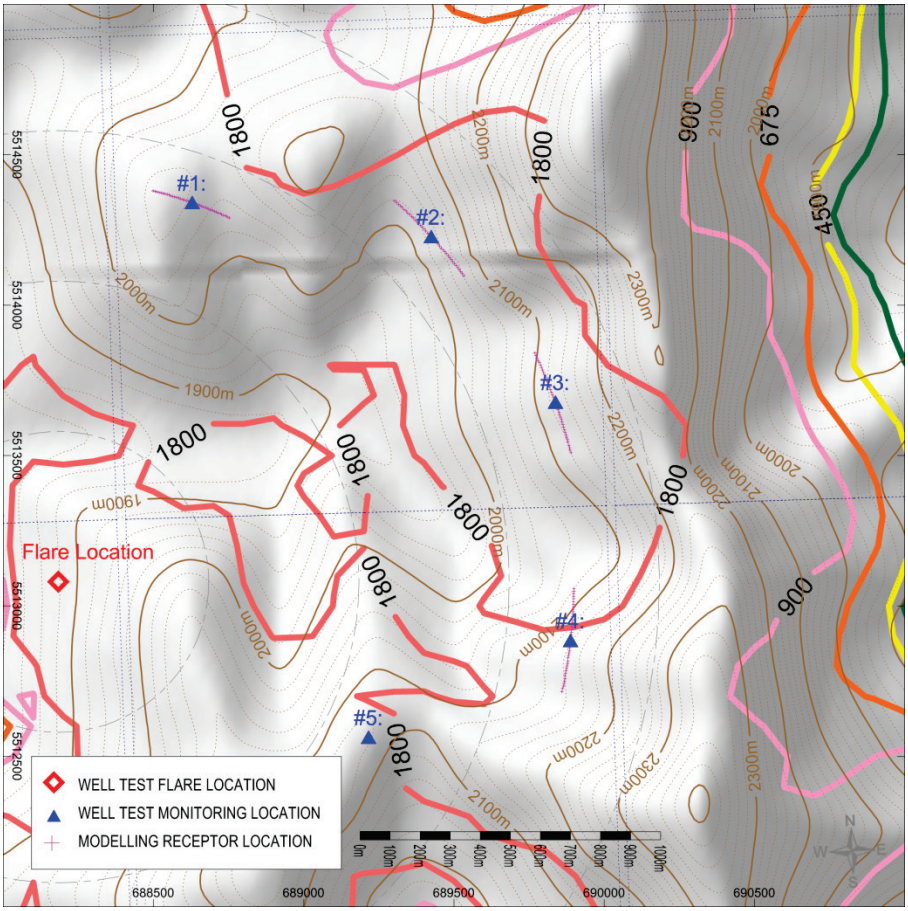


Figure 16: 99.9th Percentile Predicted Concentrations for the Complete Meteorological Time Period at Average Emission and FGR=0.95

Comparison to Monitoring Data

CALPUFF was reconfigured for only the period where active flaring was occurring (28th Oct -2st Nov) and only for receptor array locations as shown in Figure 7 that would resemble the distances and locations for the monitoring data collected.

In Figure 17 the monitoring data for 1h concentrations is compared to the flaring rates. The on-off cycle of the flaring rate was used to prevent ground level exceedences based upon real-time air quality modeling. In Figure 18, the monitoring data at Station #1 is compared to modelled predictions at Arc 1. Because of the differences between the observed wind rose and the modelled meteorology windrose, an exact replication of the flare test results is not expected. Figure 18, shows the wind directions are missing the Arc 1 receptor locations.

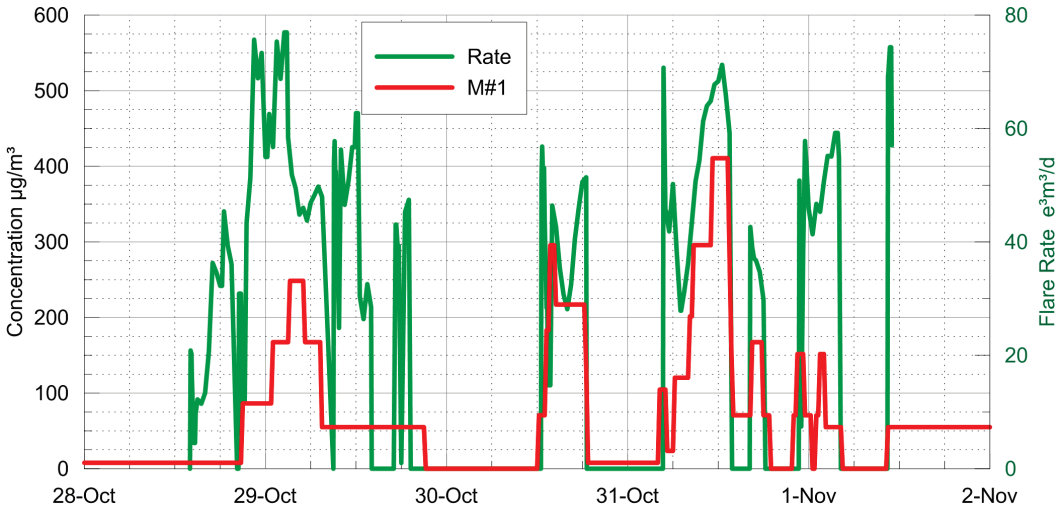


Figure 17: Concentration Monitoring 1h Data at Station #1 Compared to Flaring Rates

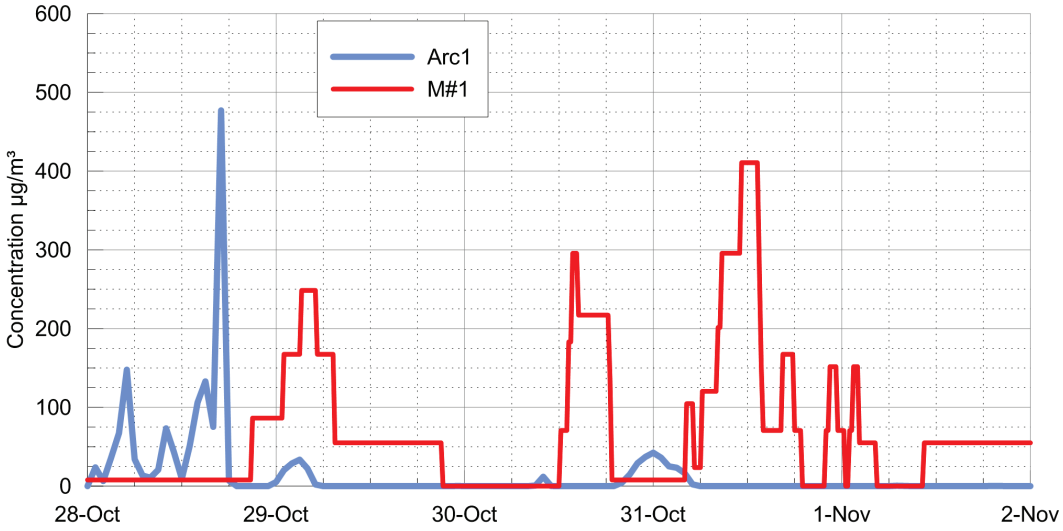


Figure 18: Concentration Monitoring 1h Data at Station #1 Compared to Modelled 1h Predictions at Arc 1

The receptor arcs used in the modelling are at similar distances from the flare source (see Table 2). Therefore, ignoring the influence of terrain elevation, the concentrations should be similar at one monitoring location compared to another. Figure 19 shows a comparison of the maximum of Arc 1, 2, 3 and 4 predictions compared to the maximum of Monitoring Station #1, #2,#3 and #4 data. In this comparison some of the discrepancy of wind direction is removed, however,

influence of terrain, among other things, may contribute to differences. In general, there is good agreement between the modelling and the observations. The probability distribution shown in Figure 20 indicates that based upon these modelling results for a constant flare rate at the average rate and average fuel gas ratio, the modelling over predicts the concentrations by a factor of two.

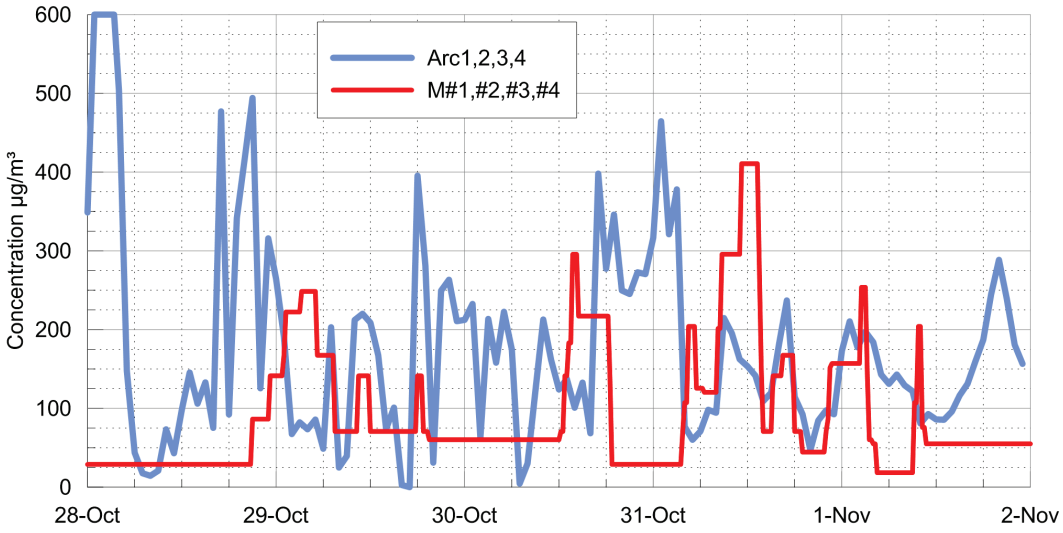


Figure 19: Concentration Monitoring 1h Data at Station #1, #2, #3 and #4 Compared to Modelled 1h Predictions at Arc 1, 2, 3 and 4

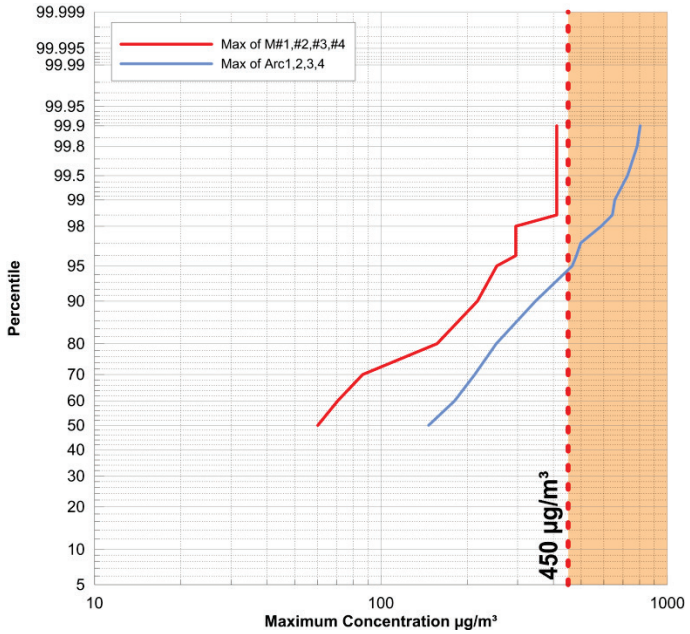


Figure 20: Probability Distribution Comparison of Concentration Monitoring 1h Data at Station #1, #2, #3 and #4 Compared to Modelled 1h Predictions at Arc 1, 2, 3 and 4

6. EXAMPLE 3: User Defined Flare Rate

An extension to the example shown in Example 2, is the application of *ABflare* to the actual flare rate and fuel gas flare assist as shown in Figure 12. The *ABflare* was configured using the following settings in the control group. The change from Example 2 to Example 3, is MINPUT=2, which directs *ABflare* to read a user defined blow down curve and MSTRIP=2, which directs *ABflare* to use actual SO_2 emissions including the effects of combustion efficiency.

The user defined blowdown, in this case, is not a blowdown but the time series of flare rates of variable duration as recorded during the flare event. The rates are listed in Table 3. The H_2S mole fractions are set to -1 and the RH2S variable is used to define the assumed constant gas analysis. The FGR is alternately set between -1 and the actual rate. When the table FGR is -1, the fuel gas ratio uses the default setting in the variable FGR=0.95. In this example, the FGR varies and is assumed to be proportional to an initial flow of 47 $\times 10^3$ m^3/d, therefore, set MFGR=2 and set QMAX=47.

When *ABflare* is run, it creates 24-source files according to the NSEP =24 setting. This setting is used for blowdown curves and presumes a blowdown starts at each hour of the day. In this case, we are using *ABflare* to create the source file and are using only the first output file. The first output file matches the date/time of the flare rates Oct 28 through Nov 2. The remaining 23-*ABflare* output files are discarded.

The results of this modelling are shown in Figure 21 for the maximum of receptor arc 1, 2, 3 and 4 compared to the maximum of monitoring locations #1, #2, #3, and #4. There is relatively good agreement between the modelling and the observations. In Figure 22 a comparison of the probability distributions shows that the distribution of concentrations also agrees well with observations.

The combustion efficiency of this flare is high because of the relatively high rate as shown in Figure 23. In this case the option to use MSTRIP=2 (SO_2 emissions include the conversion efficiency) versus the conservative MSTRIP=0 (SO_2 emissions assume 100% conversion) does not impact the predicted SO_2 concentrations in a significant amount.

VARIABLE	INPUT	DESCRIPTION
MDSPMOD	1	MDSPMOD = 1 : create files for CALPUFF 2 : create files for AERMOD DEFAULT = 1
MINPUT	2	MINPUT =1 : source conditions are input and blowdown is calculated (see MBLOWDOWN) 2 : blowdown curve sequence is input (see NSEQ) 3 : static source is input (see SOURCE DESCRIPTION GROUP). Use setting 3 for a steady flare source with parameters that that don't vary with meteorology DEFAULT = 1
MBLOWDOWN		MBLOWDOWN=1 : user input QMAX and QTOTAL 2 : blowdown exponential model parameters are calculated from pipeline/vessel initial conditions DEFAULT = 2
MDIST		MDIST=1 : blowdown sequence is created based upon puffs of equal volume 2 : blowdown sequence is created based upon puffs of equal mass DEFAULT = 2
MSTRIP	2	MSTRIP=0 : source is described by input (100% conversion to SO2) =1 : source is a stripped flow source (H2S) =2 : source is actual SO2 (accounting for efficiency) DEFAULT= 0
MMET	1	MMET=1: meteorology is read from METPATH (CALPUFF) =2: meteorology is read from METPATH (AERMOD) =3: force met to be WINDSP, WINDDR, TAMB DEFAULT = 1
MFUELGAS	1	Is fuel gas added? MFUELGAS=0 : no fuel gas is added 1 : fuel gas is added Default = NONE
MFGR	2	MFGR =1 : fuel gas is proportional to qmax rate =2 : fuel gas is constant amount based upon initial qmax DEFAULT = 2
MLIFTGAS	0	Is lift gas used ? MLIFTGAS = 0 : no lift gas = 1 : lift gas is used DEFAULT = 0
MFASSIST	0	Is flare assist used ? MFASSIST = 0 : no flare assist 1 : steam assist 2 : air assist 3 : both steam and air assist is used DEFAULT = 0
MDEBUG	0	Print debug and verbose information MDEBUG = 0 : no debug = 1 : print debug/verbose DEFAULT = 0
NSEP	24	Number of hours separating blowdown sequences. Must be a multiple of 24. Each blowdown sequence starts every hour on the hour. NSEP specifies the frequency of when the starting hour can be used again. A blowdown duration greater than 24 should use NSEP=48. A blowdown duration greater than 48 should use NSEP=72. DEFAULT=24
NSOURCES		Number of co-located AERMOD sources to represent range of meteorological sensitive source conditions DEFAULT=9

Table 3: Actual Flare Rates and Fuel Gas

#	Rate (e^3m^3/d)	Duration (s)	FGR	#	Rate (e^3m^3/d)	Duration (s)	FGR	#	Rate (e^3m^3/d)	Duration (s)	FGR	#	Rate (e^3m^3/d)	Duration (s)	FGR	#	Rate (e^3m^3/d)	Duration (s)	FGR	#	Rate (e^3m^3/d)	Duration (s)	FGR
1	0.0	3600	-1.00	51	68.7	1800	-1.00	101	0.0	300	-1.00	151	32.5	1800	1.18	201	71.2	60	0.54	251	0.0	300	-1.00
2	0.0	3600	-1.00	52	77.0	1200	-1.00	102	0.0	900	-1.00	152	40.5	1800	0.95	202	71.2	1740	-1.00	252	0.0	300	-1.00
3	0.0	3600	-1.00	53	77.0	600	-1.00	103	0.0	900	-1.00	153	45.9	1800	0.96	203	65.9	1800	0.67	253	0.0	300	-1.00
4	0.0	3600	-1.00	54	58.4	1800	-1.00	104	0.0	1800	-1.00	154	50.6	60	0.86	204	59.2	1200	0.75	254	0.0	900	-1.00
5	0.0	3600	-1.00	55	51.8	1800	-1.00	105	0.0	1800	-1.00	155	50.6	1740	-1.00	205	0.0	300	-1.00	255	0.0	900	-1.00
6	0.0	3600	-1.00	56	49.5	1800	-1.00	106	0.0	1800	-1.00	156	51.4	300	0.85	206	0.0	300	-1.00	256	0.0	900	-1.00
7	0.0	3600	-1.00	57	44.8	1800	-1.00	107	0.0	1800	-1.00	157	0.0	300	-1.00	207	0.0	900	-1.00	257	0.0	900	-1.00
8	0.0	3600	-1.00	58	46.0	1800	-1.00	108	0.0	1800	-1.00	158	0.0	300	-1.00	208	0.0	900	-1.00	258	0.0	1800	-1.00
9	0.0	3600	-1.00	59	43.8	1800	-1.00	109	0.0	1800	-1.00	159	0.0	900	-1.00	209	0.0	1800	-1.00	259	0.0	1800	-1.00
10	0.0	3600	-1.00	60	46.9	1800	-1.00	110	0.0	1800	-1.00	160	0.0	900	-1.00	210	0.0	1800	-1.00	260	0.0	1800	-1.00
11	0.0	3600	-1.00	61	48.3	1800	-1.00	111	0.0	1800	-1.00	161	0.0	900	-1.00	211	0.0	1800	-1.00	261	0.0	1800	-1.00
12	0.0	4500	-1.00	62	49.8	1800	-1.00	112	0.0	1800	-1.00	162	0.0	1800	-1.00	212	0.0	300	-1.00	262	0.0	1800	-1.00
13	0.0	5400	-1.00	63	47.9	5400	-1.00	113	0.0	1800	-1.00	163	0.0	1800	-1.00	213	0.0	300	-1.00	263	0.0	1800	-1.00
14	0.0	900	-1.00	64	0.0	300	-1.00	114	0.0	1800	-1.00	164	0.0	1800	-1.00	214	0.0	300	-1.00	264	0.0	1800	-1.00
15	0.0	300	-1.00	65	54.1	300	-1.00	115	0.0	1800	-1.00	165	0.0	1800	-1.00	215	42.6	900	-1.00	265	0.0	1800	-1.00
16	20.8	300	-1.00	66	57.8	300	-1.00	116	0.0	1800	-1.00	166	0.0	1800	-1.00	216	39.1	900	0.76	266	0.0	1800	-1.00
17	20.3	120	-1.00	67	52.4	300	-1.00	117	0.0	1800	-1.00	167	0.0	1800	-1.00	217	37.1	900	-1.00	267	0.0	1200	-1.00
18	20.3	180	-1.00	68	52.4	600	-1.00	118	0.0	1800	-1.00	168	0.0	1800	-1.00	218	36.7	1800	0.79	268	0.0	300	-1.00
19	16.3	900	-1.00	69	40.2	900	-1.00	119	0.0	1800	-1.00	169	0.0	1800	-1.00	219	34.7	1800	1.08	269	0.0	300	-1.00
20	4.5	600	-1.00	70	24.8	900	-1.00	120	0.0	1800	-1.00	170	0.0	1800	-1.00	220	29.8	900	2.50	270	69.3	60	1.00
21	4.5	300	-1.00	71	56.3	1800	-1.00	121	0.0	1800	-1.00	171	0.0	1800	-1.00	221	0.0	300	-1.00	271	69.3	840	-1.00
22	9.7	900	-1.00	72	46.5	1800	-1.00	122	0.0	1800	-1.00	172	0.0	1800	-1.00	222	0.0	300	-1.00	272	74.3	300	-1.00
23	12.2	1800	-1.00	73	50.7	1800	-1.00	123	0.0	1800	-1.00	173	0.0	1800	-1.00	223	0.0	300	-1.00	273	74.3	300	-1.00
24	11.5	1800	-1.00	74	56.7	1200	-1.00	124	0.0	1800	-1.00	174	0.0	1800	-1.00	224	0.0	900	-1.00	274	74.3	300	-1.00
25	13.3	1800	-1.00	75	56.7	600	-1.00	125	0.0	1800	-1.00	175	0.0	1800	-1.00	225	0.0	900	-1.00	275	57.0	60	1.21
26	20.6	1800	-1.00	76	62.7	900	-1.00	126	0.0	600	-1.00	176	0.0	1800	-1.00	226	0.0	900	-1.00	276	0.0	540	-1.00
27	36.3	1800	-1.00	77	62.7	900	-1.00	127	0.0	5400	-1.00	177	0.0	1800	-1.00	227	0.0	900	-1.00	277	0.0	46200	-1.00
28	34.6	1800	-1.00	78	30.5	1800	-1.00	128	0.0	1200	-1.00	178	0.0	1800	-1.00	228	0.0	1800	-1.00				
29	32.3	900	-1.00	79	26.4	1800	-1.00	129	0.0	3600	-1.00	179	0.0	1800	-1.00	229	0.0	1800	-1.00				
30	32.3	900	-1.00	80	32.6	1800	-1.00	130	0.0	1200	-1.00	180	0.0	300	-1.00	230	0.0	1800	-1.00				
31	45.4	1800	-1.00	81	28.5	300	-1.00	131	0.0	2280	-1.00	181	0.0	300	-1.00	231	0.0	1800	-1.00				
32	39.3	1800	-1.00	82	0.0	300	-1.00	132	0.0	120	-1.00	182	0.0	300	-1.00	232	0.0	1800	-1.00				
33	36.1	2700	-1.00	83	0.0	300	-1.00	133	0.0	1200	-1.00	183	70.7	900	-1.00	233	0.0	1800	-1.00				
34	0.0	300	-1.00	84	0.0	900	-1.00	134	0.0	2400	-1.00	184	45.5	300	0.53	234	0.0	300	-1.00				
35	0.0	300	-1.00	85	0.0	900	-1.00	135	0.0	1800	-1.00	185	45.5	1500	-1.00	235	0.0	300	-1.00				
36	0.0	300	-1.00	86	0.0	900	-1.00	136	0.0	300	-1.00	186	41.9	1800	0.47	236	0.0	300	-1.00				
37	30.9	900	-1.00	87	0.0	1800	-1.00	137	51.3	300	-1.00	187	50.2	1800	0.38	237	50.8	900	-1.00				
38	30.9	900	-1.00	88	0.0	1800	-1.00	138	56.8	300	-1.00	188	38.2	1800	0.62	238	7.4	900	5.95				
39	11.6	900	-1.00	89	0.0	1800	-1.00	139	53.1	600	0.73	189	27.9	300	0.88	239	38.0	900	1.17				
40	11.6	900	-1.00	90	0.0	1800	-1.00	140	53.1	300	-1.00	190	27.9	1500	-1.00	240	57.8	1740	0.77				
41	43.4	1800	-1.00	91	0.0	900	-1.00	141	43.9	900	0.92	191	31.3	1800	0.78	241	45.9	1860	0.82				
42	51.3	1800	-1.00	92	43.1	300	-1.00	142	28.4	300	1.39	192	36.2	1800	1.21	242	41.3	1800	0.81				
43	75.7	1800	-1.00	93	43.1	600	-1.00	143	28.4	600	-1.00	193	43.4	1800	0.55	243	46.7	1800	0.72				
44	68.9	1800	-1.00	94	39.3	600	-1.00	144	14.7	900	2.78	194	50.7	1800	0.47	244	45.3	1800	0.73				
45	73.3	1800	-1.00	95	39.3	1200	-1.00	145	14.7	900	-1.00	195	54.4	1800	0.44	245	50.7	1800	0.49				
46	55.0	900	-1.00	96	1.0	1800	-1.00	146	46.4	1800	0.84	196	61.3	1800	0.39	246	55.2	1800	0.44				
47	55.0	900	-1.00	97	45.3	1800	-1.00	147	42.7	1800	0.88	197	64.0	1800	0.38	247	55.1	1800	0.45				
48	62.6	1800	-1.00	98	47.4	900	-1.00	148	35.5	1800	1.06	198	64.8	1800	0.36	248	59.2	1200	0.59				
49	56.7	1800	-1.00	99	0.0	300	-1.00	149	30.7	1800	1.26	199	67.8	1800	0.58	249	59.2	600	-1.00				
50	75.3	1800	-1.00	100	0.0	300	-1.00	150	28.1	1800	1.36	200	68.3	1800	0.58	250	54.8	900	0.79				

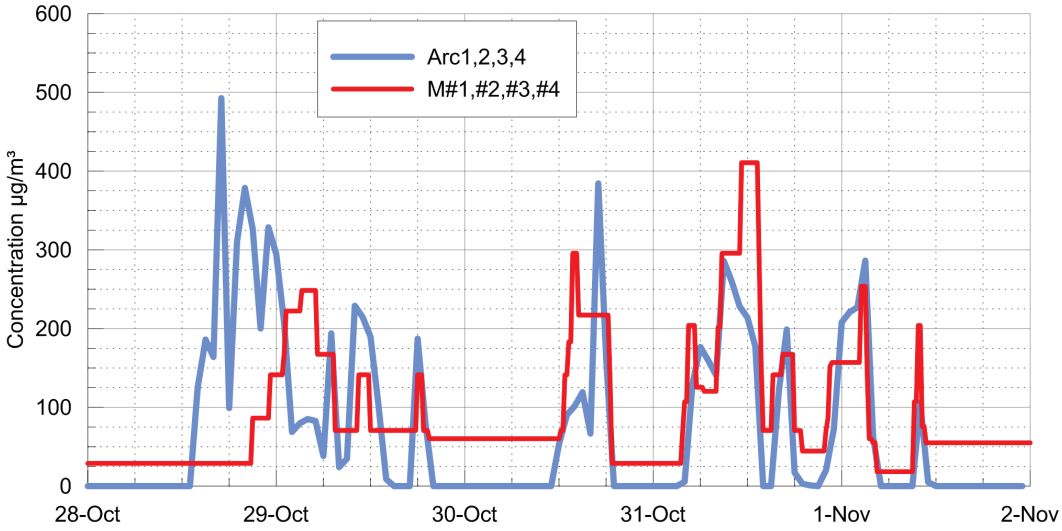


Figure 21: Example 3 Concentration Monitoring 1h Data at Station #1, #2, #3 and #4 Compared to Modelled 1h Predictions at Arc 1, 2, 3 and 4

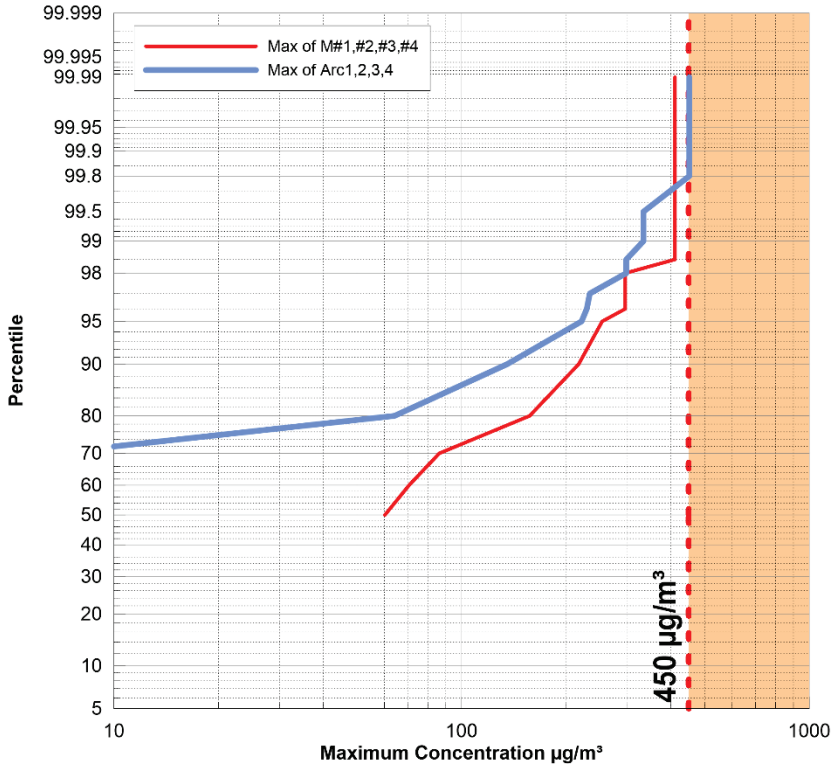


Figure 22: Example 3 Probability Distribution Comparison of Concentration Monitoring 1h Data at Station #1, #2, #3 and #4 Compared to Modelled 1h Predictions at Arc 1, 2, 3 and 4

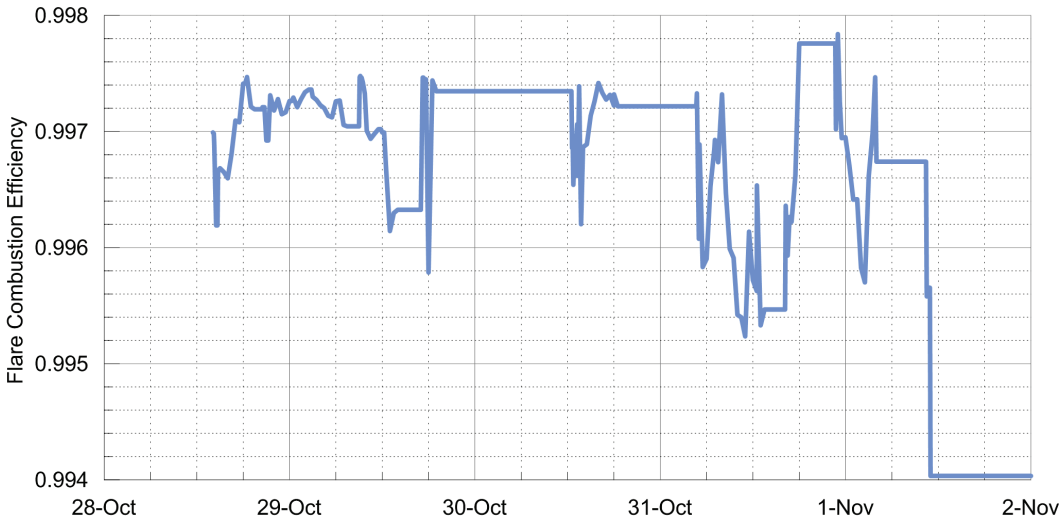


Figure 23: Predicted Combustion Efficiency as a Function of Time

7. EXAMPLE 4: Vessel/Pipeline Blowdown

This example is derived from a composite of emergency flaring cases for the purposes of demonstrating features of *ABflare*.

Source

The source in this example is a 25.1 km pipeline that goes through a blowdown sequence in order to service the pipeline for hydrate blockage. The pipeline carries gas with a maximum licenced H_2S content of 28%. The pipeline inside diameter is 436.4 mm. The pipeline is connected to a flare and the minimum orifice diameter in the system between the pipeline and the flare is 43 mm. The distance between the orifice and the flare exit is unknown, the default discharge coefficient of 0.6 is appropriate. However, in this example a conservative assumption adopted a discharge coefficient of 1.0. The maximum expected initial pressure of the pipeline is 4200 kPa with a zero final pressure. The pipeline is heated to 30 °C. The flare height is 30.5 m and has a flare tip inside diameter of 203 mm.

The gas composition of the raw gas to be flared is listed below. The facility does not have the option to add fuel gas.

Gas Compositions (mole fraction)	Fuel Gas	Lift Gas	Raw Gas
H_2O			
H_2			0
He			0.0001
N_2		1	0.0021
CO_2			0.053
H_2S			0.0619
CH_4			0.8557
C_2H_6			0.0204
C_3H_8	1		0.004
i-C_4H_{10}			0.0009
n-C_4H_{10}			0.0008
i-C_5H_{12}			0.0003
n-C_5H_{12}			0.0002
n-C_6H_{14}			0.0002
C_7+			0.0004
CO			
NH_3			
Ar			
Total	1	1	1

ABflare Modelling

Step 1 – METSERIES

METSERIES was run for the time period of the example.

Step 2 – ABFLARE Variable Source

The *ABflare* module settings for the source have been listed above. The control group settings required for this vessel/pipeline blowdown are listed below. The MINPUT=1 to have *ABflare* calculate source parameters based upon input source characteristics. MBLOWDOWN=2 to have *ABflare* calculate a blowdown curve based upon the vessel/pipeline specifications.

VARIABLE	INPUT	DESCRIPTION
MDSPMOD	1	MDSPMOD = 1 : create files for CALPUFF 2 : create files for AERMOD DEFAULT = 1
MINPUT	1	MINPUT =1 : source conditions are input and blowdown is calculated (see MBLOWDOWN) 2 : blowdown curve sequence is input (see NSEQ) 3 : static source is input (see SOURCE DESCRIPTION GROUP). Use setting 3 for a steady flare source with parameters that that don't vary with meteorology DEFAULT = 1
MBLOWDOWN	2	MBLOWDOWN=1 : user input QMAX and QTOTAL 2 : blowdown exponential model parameters are calculated from pipeline/vessel initial conditions DEFAULT = 2
MDIST	2	MDIST=1 : blowdown sequence is created based upon puffs of equal volume 2 : blowdown sequence is created based upon puffs of equal mass DEFAULT = 2
MSTRIP	0	MSTRIP=0 : source is described by input (100% conversion to SO2) =1 : source is a stripped flow source (H2S) =2 : source is actual SO2 (accounting for efficiency) DEFAULT= 0
MMET	1	MMET=1: meteorology is read from METPATH (CALPUFF) =2: meteorology is read from METPATH (AERMOD) =3: force met to be WINDSP, WINDDR, TAMB DEFAULT = 1
MFUELGAS	0	Is fuel gas added? MFUELGAS=0 : no fuel gas is added 1 : fuel gas is added Default = NONE
MFGR		MFGR =1 : fuel gas is proportional to qmax rate =2 : fuel gas is constant amount based upon initial qmax DEFAULT = 2
MLIFTGAS	0	Is lift gas used ? MLIFTGAS = 0 : no lift gas = 1 : lift gas is used DEFAULT = 0
MFASSIST	0	Is flare assist used ? MFASSIST = 0 : no flare assist 1 : steam assist 2 : air assist 3 : both steam and air assist is used DEFAULT = 0
MDEBUG	0	Print debug and verbose information MDEBUG = 0 : no debug = 1 : print debug/verbose DEFAULT = 0
NSEP	24	Number of hours separating blowdown sequences. Must be a multiple of 24. Each blowdown sequence starts every hour on the hour. NSEP specifies the frequency of when the starting hour can be used again. A blowdown duration greater than 24 should use NSEP=48. A blowdown duration greater than 48 should use NSEP=72. DEFAULT=24
NSOURCES		Number of co-located AERMOD sources to represent range of meteorological sensitive source conditions DEFAULT=9

The source description group settings include both the flare description and the vessel/pipeline description. For simplicity, the minimum number of blowdown divisions was selected (NPUFFS=3).

VARIABLE	INPUT	DESCRIPTION
XCOORD	649.532	Easting location of the flare, see DATUM coordinates
YCOORD	5648.184	Northing location of the flare, see DATUM coordinates
ZCOORD	1946	Terrain elevation at source, m
HS	30.5	Actual height of the flare, m
DS	0.203	Actual inside diameter of flare at top, m
RH2S	0.28	Mole fraction of H2S in raw gas
TGINIT	278.15	Initial fuel gas and raw gas temperature, K, or negative to set to ambient

Expected Maximum Initial Pressure	4200	kPa (gauge) If MBLOWDOWN=2, enter the maximum initial pressure of the vessel or pipeline
Expected Minimum Initial Gas Temperature	303.15	K If MINPUT=1, enter the minimum initial temperature of the vessel or pipeline
Expected Minimum Final Pressure	0	kPa (gauge) If MBLOWDOWN=2, enter the minimum final pressure of the vessel or pipeline when flaring is stopped and the gas release is shut-in
Pipeline/Vessel Inside Diameter	0.4364	m If MBLOWDOWN=2, enter the vessel or pipeline inside diameter
Pipeline/Vessel Length	25100	m If MBLOWDOWN=2, enter the vessel or pipeline length
Minimum Orifice Diameter	43	mm If MBLOWDOWN=2, enter the minimum orifice diameter where the gas escapes from the vessel or pipeline
Discharge Coefficient	1	-- If MBLOWDOWN=2, enter the orifice discharge coefficient DEFAULT=0.6

NPUFFS	3	npuffs = 0 : Program calculates number of puffs, when PUFFDUR is specified and MDIST=1 npuffs = 1 : Force blowdown to a single puff of duration PUFFDUR, if MINPUT=1 and MBLOWDOWN=1 then NPUFF=1 for a hourly varying flare or if MINPUT=3, then use input source rather than calculated blowdown. Use this setting for a steady flare source with parameters that that vary with meteorology npuffs > 1 : Number of puffs in blowdown Default = 3

In this case, the discharge coefficient is adjusted from the default value of 0.6 to 1.0. The flow rate is determined by an orifice well upstream of the discharge location and the minimum orifice is smaller than the discharge location.

When *ABflare* is run for this configuration, it creates 24-output flare source files for *CALPUFF*. Each file contains a blowdown sequence of equal mass puffs starting on the hour for each hour of the day. The first file contains blowdown curves starting on hour 1, the second file contains blowdown curves starting on hour 2, etc. The blowdown sequence is shown in Figure 24.

The source parameters for this blowdown curve are determined as a function of the hour by hour meteorology. The effective height and pseudo-source parameters (diameter and velocity) are shown as a function of blowdown step in Figure 25. The effective height shows a wide variation which results from the effects of stack top wind speed on the bent over flame.

The effective location of the source is also a function of the bent-over flame tip location. The effective locations for this blowdown flare are shown in Figure 26.

The distribution of the locations will be a function of the windrose and flare rate. The figure displays concentric *rings* which are a function of the discrete regimes of the model.

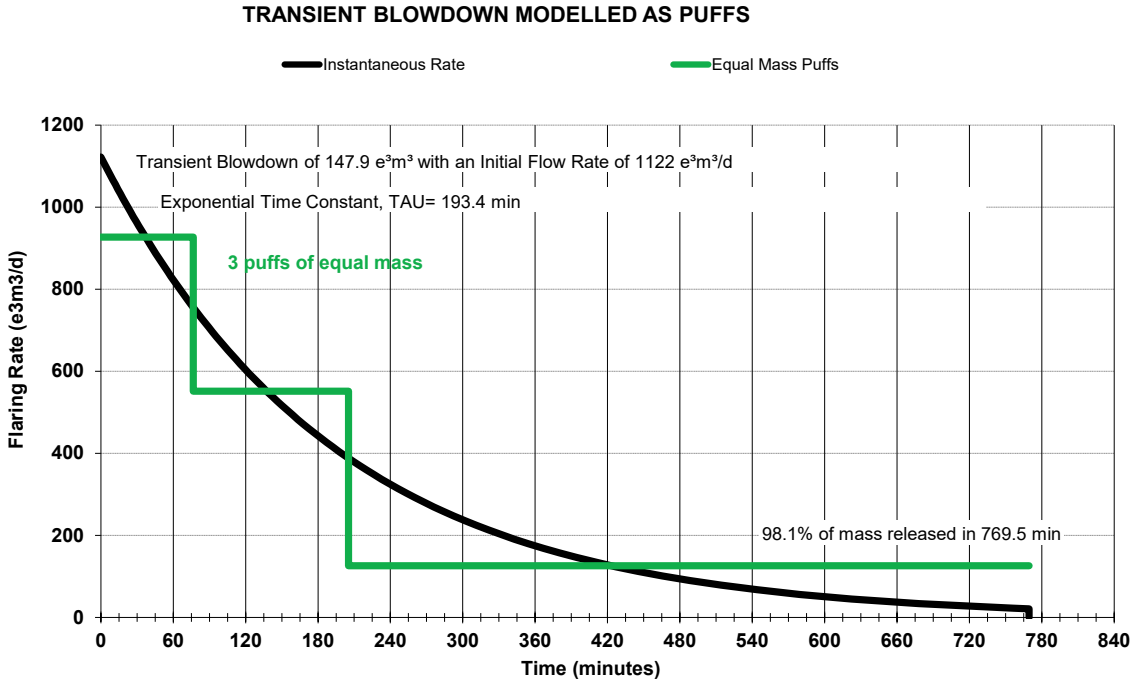


Figure 24: Example 4 Blowdown Curve

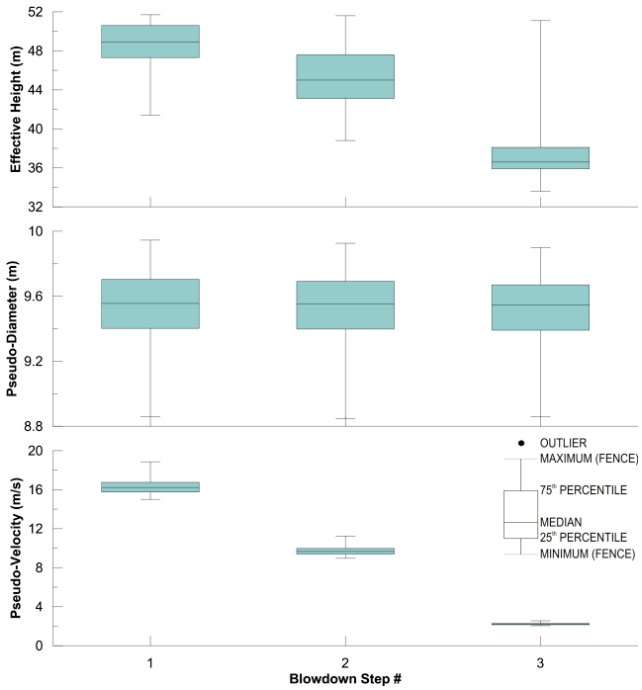


Figure 25: The Pseudo-Parameters for the Blowdown Curve for Complete Year 2002 showing Variation for Each Step of the Blowdown (NPUFFS=3)

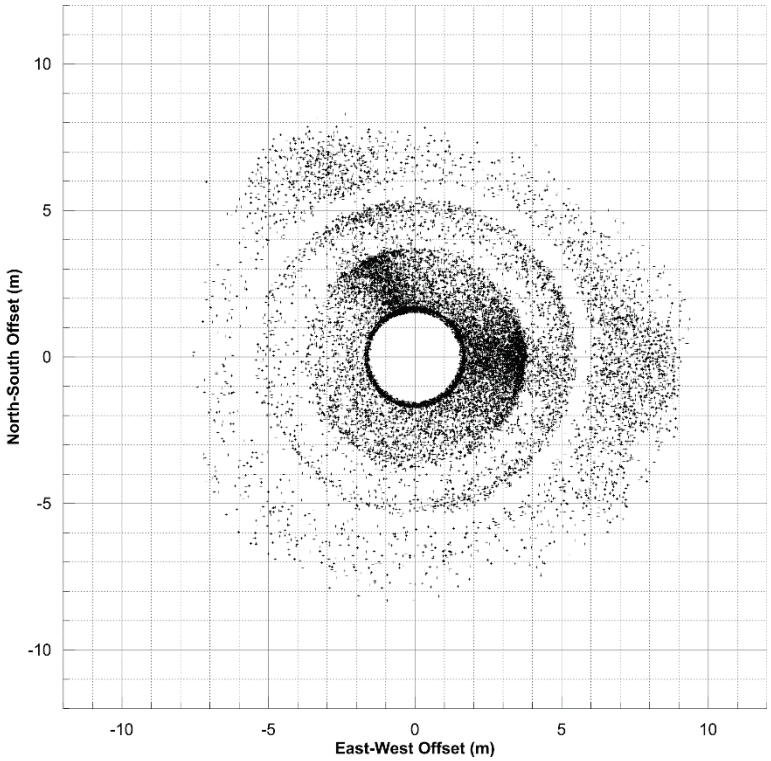


Figure 26: Effective Flare Location for Complete Year 2002

Step 3 – CALPUFF

The blowdown source and *ABflare* creates 24-flare source files. Each file must be independently run using *CALPUFF*. Therefore, *CALPUFF* must be run 24-times in order to determine the possible start hour-blowdown combinations.

Step 4a – CALAVE

In this case, because the flare for the blowdown will extend more than 10-hours, the maximum allowable daily average concentration is an important regulatory restriction for environmental protection. The daily average is calculated using a combination of the *CALAVE, CALMAX* and *CALRANK*.

The first step is to determine the running 24-h average for each of the individual 24- *CALPUFF* output files. *CALAVE* is configured with the inputs shown below. The time average required is 24 hours, therefore AVGPD_HH=24. The two averaging periods AVGPD_HH and AVGPD_MM are additive, so in this case AVGPD_MM=0. The running sum is required, MODE=1. The start hour for all

of the output files is START_HHMM=0. A valid file extension is selected ".24r" to represent "24h running average".

VARIABLE	INPUT	DESCRIPTION
AVGPD_HH	24	Averaging Period (hours)
AVGPD_MM	0	Averaging Period (minutes)
MODE	1	1 = Running averages 2 = Block averages
START_HHMM	0	Starting time (HHMM)
OUT_EXT	.24r	The output associated with the file(s) listed below for 'source1.dat' would be named 'source1.dat.ave' Output data file extension DEFAULT: .ave

After *CALAVE* is run, it will create a time-averaged version of the *CALPUFF* output file. *CALAVE* is run once for each of the *CALPUFF* output files.

Step 4b – CALMAX

The 24-files create by the *CALAVE* processing can be combined using the *CALMAX* module. *CALMAX* will determine the maximum concentration from each of the input files, at each period in the record. Therefore, 24-files are input into *CALMAX* and a single file containing the maximum running averages for each hour of the day is output.

CALMAX creates a binary *CALPUFF*-like output file containing the running averages for each hour at each hour of the day. Also output is a dayfile that contains a listing of the maximum calendar day outputs. This output is only useful for the 24h average running sums.

An example configuration is shown below.

VARIABLE	INPUT	DESCRIPTION
output: PERFILE ASCII file of Period-Maximum values		calmax.24h.dat
output: BINFILE Binary CALPUFF-format file of all maximum values		calmax.24h.con
output: LSTFILE List-file name Default: CALMAX.LST		calmax.24h.lst
LCFILES	T	All file names will be converted to either lower or upper case T = lower case F = UPPER CASE DEFAULT: F
INPFILE 1	P:\2011\1100500\ex3\abflare_00.2002.con.24r	
INPFILE 2	P:\2011\1100500\ex3\abflare_01.2002.con.24r	
INPFILE 3	P:\2011\1100500\ex3\abflare_02.2002.con.24r	
INPFILE 4	P:\2011\1100500\ex3\abflare_03.2002.con.24r	
INPFILE 5	P:\2011\1100500\ex3\abflare_04.2002.con.24r	
INPFILE 6	P:\2011\1100500\ex3\abflare_05.2002.con.24r	
INPFILE 7	P:\2011\1100500\ex3\abflare_06.2002.con.24r	
INPFILE 8	P:\2011\1100500\ex3\abflare_07.2002.con.24r	
INPFILE 9	P:\2011\1100500\ex3\abflare_08.2002.con.24r	
INPFILE 10	P:\2011\1100500\ex3\abflare_09.2002.con.24r	
INPFILE 11	P:\2011\1100500\ex3\abflare_10.2002.con.24r	
INPFILE 12	P:\2011\1100500\ex3\abflare_11.2002.con.24r	
INPFILE 13	P:\2011\1100500\ex3\abflare_12.2002.con.24r	
INPFILE 14	P:\2011\1100500\ex3\abflare_13.2002.con.24r	
INPFILE 15	P:\2011\1100500\ex3\abflare_14.2002.con.24r	
INPFILE 16	P:\2011\1100500\ex3\abflare_15.2002.con.24r	
INPFILE 17	P:\2011\1100500\ex3\abflare_16.2002.con.24r	
INPFILE 18	P:\2011\1100500\ex3\abflare_17.2002.con.24r	
INPFILE 19	P:\2011\1100500\ex3\abflare_18.2002.con.24r	
INPFILE 20	P:\2011\1100500\ex3\abflare_19.2002.con.24r	
INPFILE 21	P:\2011\1100500\ex3\abflare_20.2002.con.24r	
INPFILE 22	P:\2011\1100500\ex3\abflare_21.2002.con.24r	
INPFILE 23	P:\2011\1100500\ex3\abflare_22.2002.con.24r	
INPFILE 24	P:\2011\1100500\ex3\abflare_23.2002.con.24r	

Step 4c – CALRANK

The third step in the post-processing sequence is to determine the data set statistics. For the 24 h averages statistics can be determined from the running averages using *CALRANK* using the ICDAY switch. When ICDAY=1, the peak concentration in each calendar day is selected from the input file and included in the data set for the statistics. For running averages, each hour of the day contains the average of the following 24 hours. Thus for each calendar in the data set, there are 24 data points representing 24 h running averages. *CALMAX* with ICDAY=1 selects the maximum of the 24 data points for each calendar day.

When *CALRANK* is run, it will create a plottable output file for each of the n^{th} highest statistics or percentile values selected. Each file will contain the n^{th} highest (or percentile) statistic at each receptor point. The output listing file for *CALRANK* will list the maximum statistical for all receptor locations.

For 1 h averages, *CALAVE* and *CALMAX* are not required, and *CALRANK* can be run on the *CALPUFF* output files directly. Select different list file names for `CALRANK.lst` to distinguish the output files such as:

`CALRANK-1h.lst` for 1h averages
`CALRANK-24r.lst` for 24h averages

8. References

AEP (Alberta Environment and Parks) 2013. Air Quality Model Guideline. Alberta Environment, October 2013. http://aep.alberta.ca/air/modelling/documents/AirQualityModelGuideline-Oct1-2013.pdf

AEP (Alberta Environment and Parks). 2006b. Multi-Model Extraction Utility (MMEU) & 2002–2006 Alberta Meteorological Data Set. Climate Change, Air and Land Policy Branch, Alberta Environment. http://aep.alberta.ca/air/modelling/meteorological-data-for-dispersion-models.aspx

AEP (Alberta Environment and Parks). 2009. Screening and MM5 Data for Dispersion Models. Regional Screening Data Sets, http://aep.alberta.ca/air/modelling/meteorological-data-for-dispersion-models.aspx

AEP (Alberta Environment and Parks). 2014. Non-Routine Flaring Management: Modelling Guidance. Prepared by B.W. Zelt, Zelt PSI. 17 April 2014. http://aep.alberta.ca/air/modelling/documents/NonRoutineFlaringModelling-May09-2014A.pdf

AER (Alberta Energy Regulator). 2016. ERCBflare: A Screening Model for Non-Routine Flaring Approvals and Routine Flare Air Modelling for Sour Gas Facilities, User Guide, Version 2.00

AER (Alberta Energy Regulator). 2016. Directive 060-Upstream Petroleum Industry Flaring, Incinerating and Venting. http://www.aer.ca/documents/directives/Directive060.pdf

Canadian Association of Petroleum Produces (CAPP). 2011. Framework: Sour Non-Routine Flaring, draft 29 July 2011.

Energy Resources Conservation Board (ERCB). 2010. Dispersion Modelling Exit Parameters for Flares and Incinerators. Developed by Michael Zelensky. March 1, 2010.

ERCBflare. 2010. Directive 060 Spreadsheets - March 22, 2010 http://www.ercb.ca/regulations-and-directives/directives/directive060

Geobase, 2009. Land Cover, Circa 2000-Vector Feature Catalogue, Centre for Topographic Information, Earth Sciences Sector, Natural Resources Canada, Sherbrooke, Quebec http://www.geobase.ca/doc/specs/pdf/GeoBase_LCC2000V_feature_catalogue_en.pdf

Geobase. 2000. Canadian Digital Elevation Data. Government of Canada, Natural Resources Canada, Earth Sciences Sector, Centre for Topographic Information. http://www.geobase.ca/geobase/en/find.do?produit=cded

Hubbard,R.. 2009. The Role of Gas Processing in the Natural-Gas Value Chain. Society of Petroleum Engineers, Journal of Petroleum Technology, August 2009.

Mannan,S. 2005. Lees' Loss Prevention in the Process Industries, 3rd Ed. Elsevier Inc., Burlington, MA

Scire, J.S., D.G. Strimaitis and R.J. Yamartino. 2011. CALPUFF Modelling System Version 6 user Instructions. Concord, MA: Earth Technologies Inc.

Scire,J.S., Robe,F.R., Fernau,M.E., Yamartino,R.J., 2000b. A User's Guide for the CALMET Meteorological Model (Version 5.0). Concord, MA: Earth Technologies Inc.

TransCanada Corporation. 2012. Gas Quality Specification, TransCanada and other pipelines. http://www.transcanada.com/customerexpress/docs/assets/Gas_Quality_Specifications_Fact_Sheet.pdf

United States Environmental Protection Agency (U.S. EPA). 2011. User's Guide for the AMS/EPA Regulatory Model AERMOD. EPA-454/B-03-001 (September 2004). March 2011.