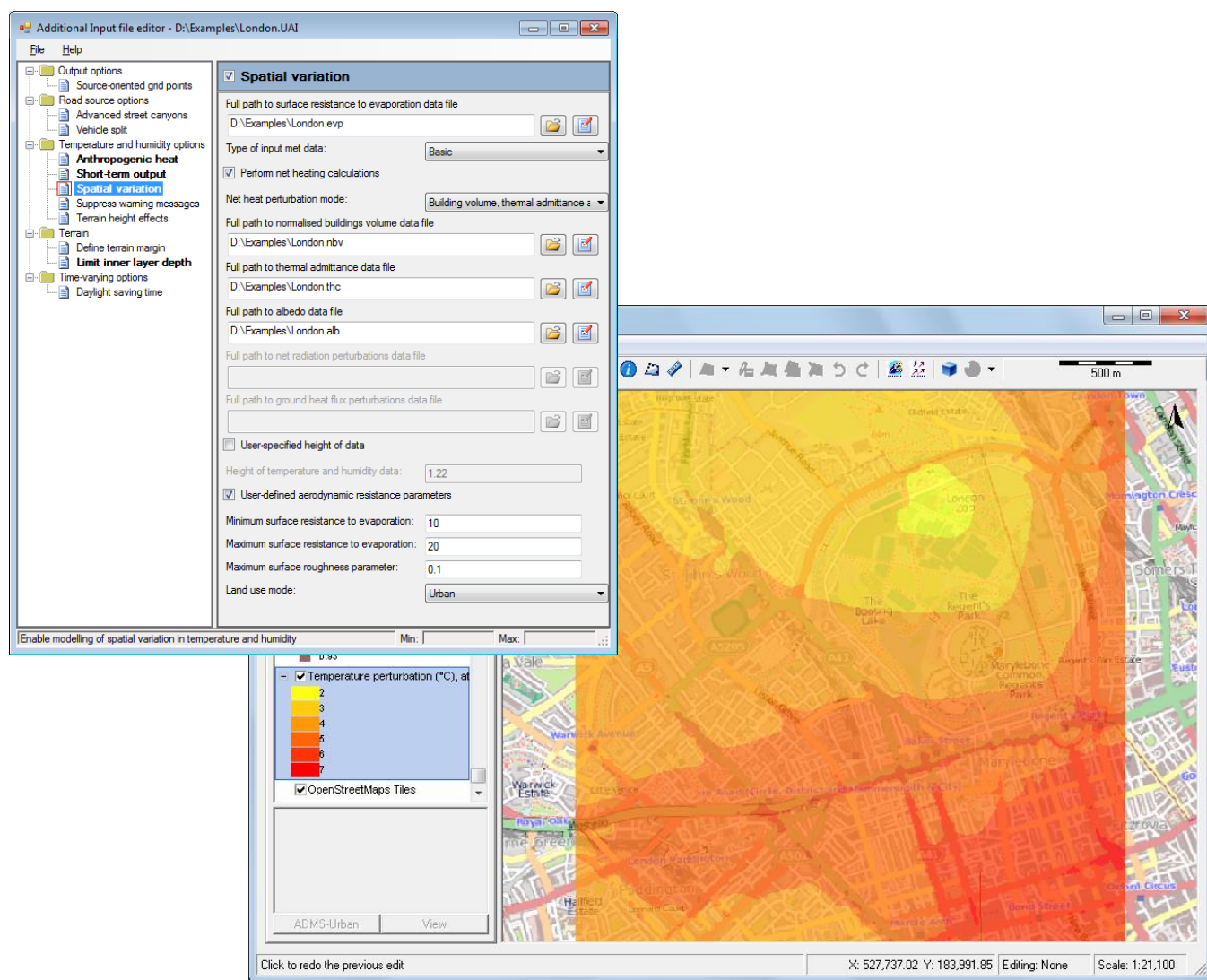# ADMS-Urban

Temperature and Humidity

A supplement to the ADMS-Urban User Guide

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User Guide CERC

ADMS-Urban

Temperature and Humidity

User Guide
(A Supplement to the ADMS-Urban User Guide)

Version 4.1

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Contents

SECTION 1 Introduction

The ADMS-Urban Temperature and Humidity model predicts spatial variations in temperature and humidity due to spatial variations in land use and anthropogenic heat emissions (heat from human activities). The temperature and humidity variations are modelled as perturbations to input upwind values.

The model takes input files that represent the spatial variation of a number of spatially varying parameters derived from land use and buildings data, shown in green in **Figure 1.1**, inputs representing spatial variation in anthropogenic heat sources, shown in red, input representing terrain, shown in brown and input upwind meteorological data, shown in blue.
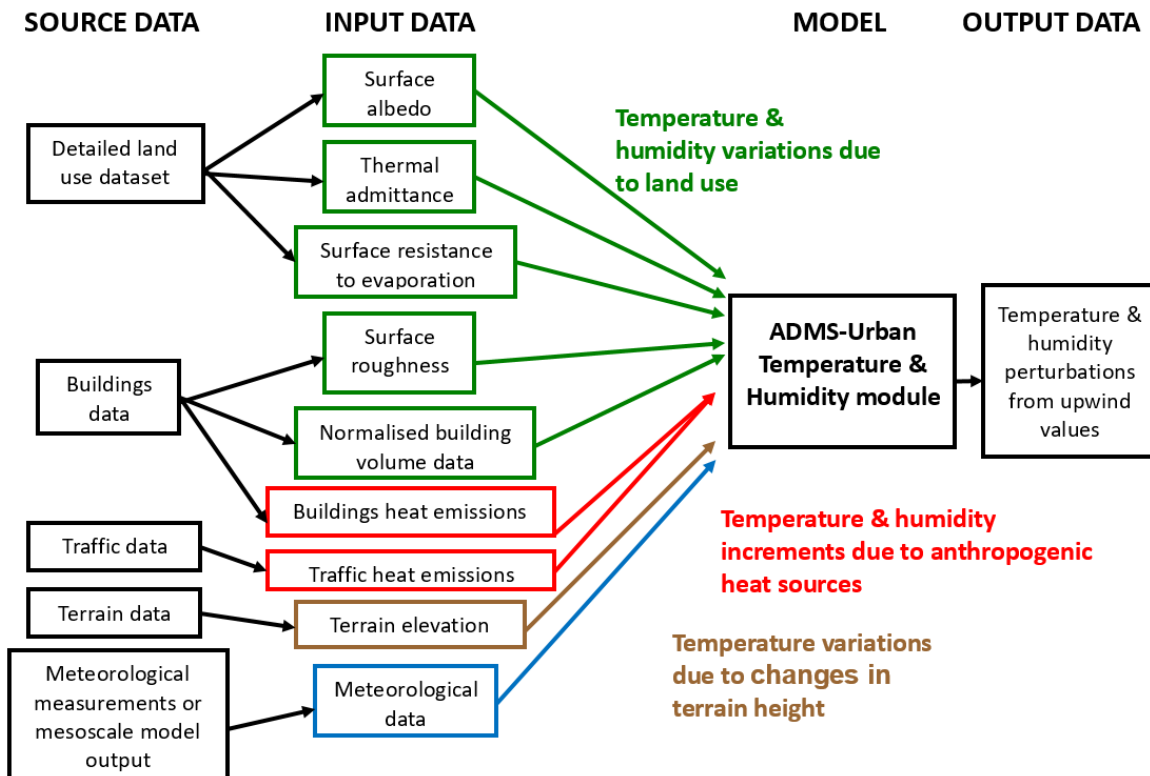
Figure 1.1 – ADMS-Urban Temperature and Humidity flow diagram.

The land use and buildings derived data represent:

- Surface resistance to evaporation (s m^{-1})

  This parameter is a measure of the surface wetness.

- Surface roughness length for momentum transfer (m)

  This parameter represents the height of any obstacles present in the model domain. In its most basic form, in urban areas it is often taken to be one thirtieth of a representative building height.

- Albedo (-)

  The albedo is a measure of the reflectivity of the surface.

- Normalised buildings volume (m)

  The normalised building volume is a measure of the density of the buildings within the domain.

- Thermal admittance (J m^{-2} s$^{-1/2}$ K^{-1})

  The thermal admittance is a measure of the ability of the surface to accept or release heat.

The model calculates spatially varying changes in heat flux that arise from the spatial variations of the input land use parameters, and from this calculates a temperature and a humidity field. The model does this by solving linearised forms of the heat transfer equations with appropriate boundary conditions. Full details of the model calculations are given in Section 10. Alternatively, spatially varying heat flux perturbations may be entered as model inputs directly. In addition, the dispersion of anthropogenic emissions of heat is modelled and converted into temperature increments which are included in the output temperature perturbations.

Temperature and humidity output can be calculated by the model at specified receptor locations and over a grid of output values covering the model domain, at a range of vertical heights above the ground. These output options are available for both hour-by-hour calculations and long-term averages. Further details of these options are described in Section 7.

1.1   What is in the User Guide?

Table 1.1 provides an overview of the contents of this User Guide.

Section number	Section title	Description
2	Getting started	Outlines the changes necessary to set up ADMS-Urban to perform temperature and humidity modelling
3	Model configuration	Provides an overview of model inputs, including outline instructions for a model run
4	Meteorological data	Gives details of the meteorological input data requirements
5	Land use parameters	Gives details of options for spatially varying land use parameter data, including example values
6	Anthropogenic Heat Emissions	Gives details of anthropogenic heat emissions requirements: gridded (used to represent buildings) and road sources
7	Output	Describes the model output
8	Worked examples	Includes three step-by-step worked examples that demonstrate model capabilities
9	Technical summary	Provides a brief summary of the scientific methodology
10	References	Gives references to data and scientific sources

Table 1.1 – Overview of User Guide contents

1.2   Other documentation

In addition to this User Guide, the user is referred to the full ADMS-Urban User Guide for many model features, including model installation. The ADMS-Urban User Guide is located in the *Documents* subdirectory of the model installation directory; alternatively it can be accessed directly from the ADMS-Urban interface from the **Help** menu.

In addition, the ADMS Mapper User Guide may be helpful and can also be found in the *Documents* subdirectory of the ADMS-Urban installation directory, or accessed from the ADMS Mapper Help menu.

SECTION 2 Getting started

Please refer to the ADMS-Urban User Guide, Section 2.2, for details of how to install the primary model. Two further steps are required in order to install the ADMS-Urban Temperature and Humidity model. These steps are summarised below, with references given to ADMS-Urban Temperature and Humidity User Guide sections where further information is provided.

- The options associated with the ADMS-Urban Temperature and Humidity model are accessible from the ADMS-Urban additional input (*.uai*) file. Thus having performed the primary ADMS-Urban installation, it is necessary to update the Additional Input file editor (UAI editor) to display these model options. **This can be done by following the instructions given in Section 2.1.**

   The UAI editor used for temperature and humidity runs differs from the primary UAI editor associated with ADMS-Urban. A copy of the primary UAI editor should be taken before upgrading to the ADMS-Urban Temperature and Humidity UAI editor.

- A *.ptt* file containing the definitions of two pollutants used for modelling anthropogenic heat is supplied with the Temperature and Humidity model. This file should be imported to the ADMS-Urban interface for each new *.upl* file before the creation of anthropogenic heat sources, **as described in Section 2.2.**

2.1 Updating the Additional Input file editor to use the ADMS-Urban Temperature and Humidity model

In order to use the ADMS-Urban Temperature and Humidity model, special *.uai* file options are required. These are available by updating the Additional Input file editor (UAI editor) to use the ADMS-Urban Temperature and Humidity version, which can be done by following the steps below:

Step 1 Back-up the standard UAI Editor files. To do this, create copies of the files *UAIEditor.ini*, *UAIEditor.mnu* and *UAIEditor.syn* which can be found in the ADMS-Urban installation directory. The files could, for example, be copied into a folder under the ADMS-Urban installation directory named *Standard UAI Editor* (as shown in Figure 2.1).

Step 2 Copy the Temperature and Humidity UAI Editor files, *UAIEditor.ini*, *UAIEditor.mnu* and *UAIEditor.syn,* from the *ADMS-Urban_Temperature_Humidity_UAI_Editor* folder provided into the ADMS-Urban installation directory, overwriting the standard UAI Editor files.

Step 3 Copy this User Guide into the *Documents* subdirectory of the ADMS-Urban installation directory.

The ADMS-Urban Temperature and Humidity model is now ready to run.
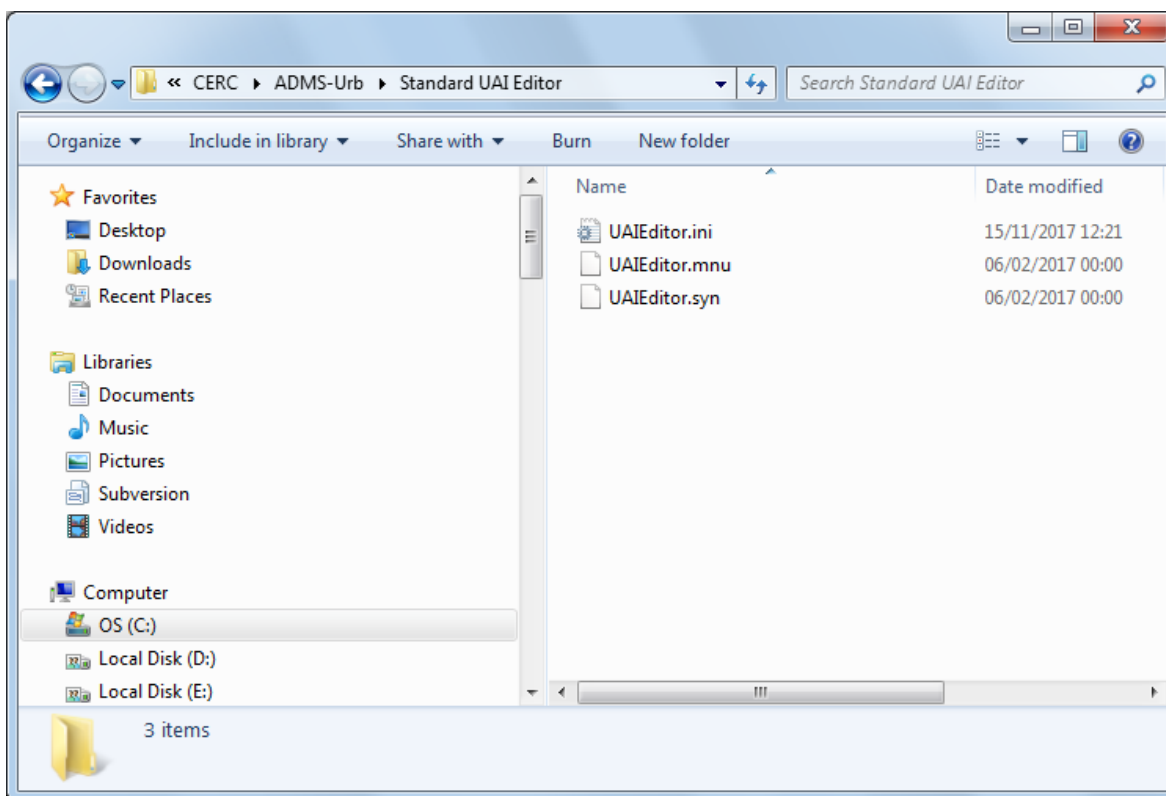
Figure 2.1 – The backed up Additional Input file editor (UAI editor) files.

2.2 Importing the anthropogenic heat pollutants

A *.ptt* file is supplied with the ADMS-Urban Temperature and Humidity model files (*ADMS-Urban_Temperature_Humidity_agh_pollutant_definition*) which contains the definition of the pollutants CO_2 and 'Temperature' which are required for modelling anthropogenic heat emissions. When a new *.upl* file is created, the pollutants should be imported into the interface following these steps:

Step 1   Select **File > Import** from the main interface menu to open the **Import wizard**.

Step 2   Select the **Pollutants** option and browse to the *anthropogenic_heat_pollutants.ptt* file using the **Browse** button, then click the **Next >** button.

Step 3   Choose the option to **Merge palettes, overwriting existing pollutants**, then click the **Next >** button.

Step 4   Verify that two new pollutants will be imported and click the **Import** button.

Step 5   Click **OK** on the screen reporting successful import.

This procedure makes the 'Temperature' and CO_2 pollutants available for use in source emissions and standard model concentration output files.

SECTION 3 Model configuration

The ADMS-Urban Temperature and Humidity model allows for a range of input data, meaning certain parameters can be either specified directly or calculated by the model. Section 3.1 describes these model input options and the input files or parameters which are required for each option.

The ADMS-Urban Temperature and Humidity model is contained within the ADMS-Urban atmospheric dispersion modelling system. In order to run the ADMS-Urban Temperature and Humidity model, it is necessary to set up and run a basic ADMS-Urban dispersion calculation. An example of how to do this is given in Section 3.2.

The majority of the options relating to the ADMS-Urban Temperature and Humidity model are accessible via the ADMS-Urban additional input (*.uai*) file. For further details about this file and how to edit it, please refer to Section 3.1.5 of the ADMS-Urban User Guide. There is a dedicated editor for creating Temperature and Humidity *.uai* files that must be installed before modelling temperature and humidity using ADMS-Urban; Section 2.1 describes this installation process. The *.uai* file options that relate to the ADMS-Urban Temperature and Humidity modelling are described in Section 3.3 of this User Guide.

3.1 Model options

There are a number of model options related to the ADMS-Urban Temperature and Humidity model that the user must specify via the ADMS-Urban additional input file (*.uai* file). Details of how to create and edit these files in the Additional Input file Editor and details of the format of this file are given in Section 3.3.

Section 3.1.1 gives details of the meteorological data input options available, and Section 3.1.2 describes the options for specifying the land use parameter input files. Section 3.1.3 gives details of how the decrease in temperature with height can be accounted for by the model and Section 3.1.4 describes the anthropogenic heat emissions options. An option for suppressing repeated warning messages is discussed in Section 3.1.5.

3.1.1 Meteorology input modes

The ADMS-Urban Temperature and Humidity model calculates perturbations to upwind meteorological conditions. Meteorological inputs should therefore be representative of the conditions before the airflow has entered the modelling domain. This may require input meteorological data to be obtained from several sites around the edge of the modelling domain. Refer to Section 4 for more information about how to set up a *.met* file for temperature and humidity modelling.

There are two options for the type of parameters to specify in the upwind meteorological data: **Basic** and **Hourly heat flux**.

When the model is run with **Basic** meteorological data, the user is required only to

specify *basic* meteorological parameters such as time of day and year, wind speed, wind direction, cloud cover, temperature and humidity. In addition, the user can enter an estimate for the hourly variation of the ratio of ground heat flux to net radiation values; if these data are omitted, a model estimate will be used. When using **Basic** meteorological data, it can be input on screen or via a *.met* file; the ratio of ground heat flux to net radiation can only be specified in a *.met* file.

When the model is run including **Hourly heat flux** data, the input meteorological data file must contain hourly heat flux data (surface sensible heat flux, latent heat flux, ground heat flux and net radiation). **Hourly heat flux** data can only be included when meteorological data is input via a *.met* file.

Full details of the meteorological data required by the model are given in Section 4.

3.1.2 Land use parameter input modes

ADMS-Urban can be used to model the temperature and humidity perturbations due to either:

∗ Spatial variations of the surface resistance to evaporation parameter together with the surface roughness, or

∗ Spatial variations of the surface resistance to evaporation parameter together with the surface roughness, and additionally, parameters that affect the net radiation and ground heat flux values.

Both of the above options require spatially varying surface resistance to evaporation (*.evp*) and roughness (*.ruf*) parameter files to be input to the model. Within the second of these options i.e. when the perturbations to the net radiation and ground heat flux are being modelled, there are two options for input:

∗ The user can specify the spatial variation of parameters that allow the model to calculate the local heat flux perturbation values i.e. normalised building volume, surface albedo and thermal admittance, entered to the model in three separate files (*.nbv*, *.alb* and *.thc* respectively); or

∗ The user can directly specify the spatial variation of the net radiation (*.ird*) and ground heat flux (*.hfx*) values, entered to the model in two separate files.

The surface roughness file is specified via the **Complex terrain** screen, as shown in **Figure 3.1**. The **Grid resolution** for internal model calculations must also be set in the **Complex terrain** screen. When modelling large areas the internal grid resolution should be set as high as possible in order to fully resolve land use changes. Note, however, that higher resolutions will lead to longer model run times. For more information on the internal grid resolution, please refer to Section 4.9.2 of the ADMS-Urban User Guide. All other input files are specified via a *.uai* file, as described in Section 3.3.

Full details of the land use data required by the model (including file format specifications) are given in Section 5.

3.1.3 Decreasing temperature with altitude

Temperature decreases with increasing altitude, as discussed in Section 10.5. The model is able to calculate this variation, if terrain altitudes of the meteorological input data site(s) and the output points are included in the model configuration. This is an optional model input.

A terrain elevation (*.ter*) file must be included when modelling height-related temperature changes, in order to define the altitude of the output points. For more information on terrain files, including their format and related restrictions, refer to Section 4.9 of the ADMS-Urban User Guide. The terrain file is linked to the model in a similar way to the surface roughness file, via the **Complex terrain** screen, as shown in **Figure 3.1**.
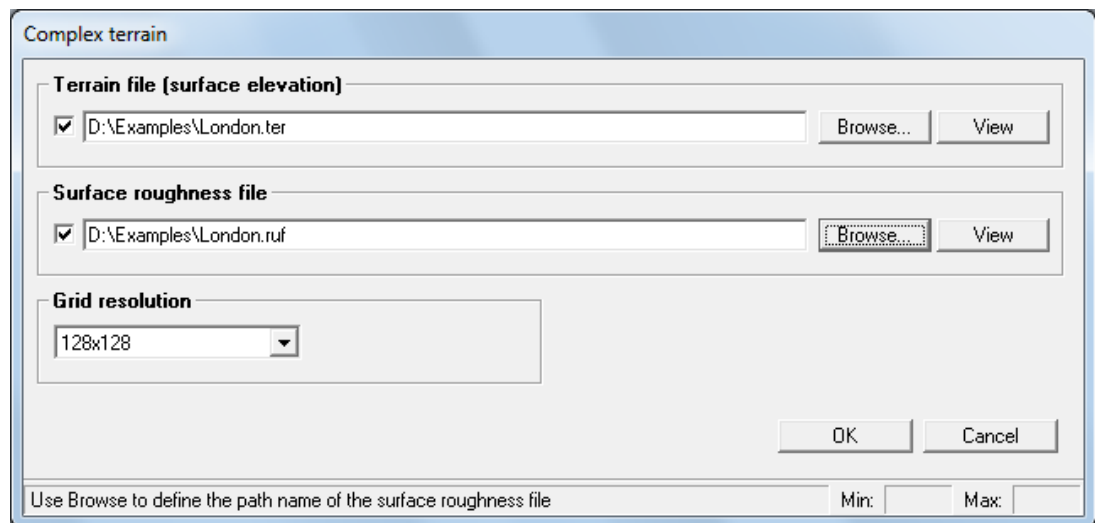
Figure 3.1 – **Complex terrain** options screen showing **Terrain file (surface elevation)** and **Surface roughness file**.

In order to define the terrain height of the upwind meteorological site(s), either the location of the upwind sites can be included (if they are within the limits of the terrain file domain), or elevations can be entered directly. Section 3.3.3 provides details regarding how to define the terrain height for the input meteorological data.

3.1.4 Anthropogenic heat emissions options

The generation of heat by human activities, described as anthropogenic heat emissions, can contribute to urban heat island effects. The ADMS-Urban Temperature and Humidity model can optionally model anthropogenic heat emissions from volume sources and/or from road sources. More information about anthropogenic heat emissions can be found in Section 6.

The geometry and emissions data for anthropogenic heat volume sources are specified in an *.agh* file. The format of the *.agh* file is described in Section 6.1.1 and suggested values for heat emissions from buildings are given in Section 6.1.2.

The geometry for road sources is specified in the ADMS-Urban interface, as used for standard pollutant dispersion calculations. The heat emissions can either be

specified directly in the interface as the anthropogenic heat pollutant 'Temperature' with units of J/km, or indirectly by defining the emissions of CO_2 in the interface and the required conversion factors in the *.uai* file. If both CO_2 and 'Temperature' emissions are specified for the same road, the 'Temperature' emissions will be used. Suggested conversion factor values for fuel energy content and heat release factor are given in Section 6.2.1.

Users are advised to include diurnal and monthly time-varying emission factors for all anthropogenic heat emissions, via a .fac file or .hfc file. Refer to Section 4.1 of the ADMS-Urban User Guide for details of the use of time-varying emission factors.

3.1.5 Suppressing warning messages

When modelling anthropogenic heat emissions, users may wish to suppress repeated messages relating to flowfield resolution and vehicle-induced turbulence. Without the suppression option, the first warning would be issued for each source and modelled hour if the anthropogenic heat sources are large relative to the flowfield resolution. The second warning is issued at the beginning of the run for each road source which does not have NO_x, PM_{10} or VOC emissions.

It is recommended that users select the option to suppress anthropogenic heat warnings in the *.uai* file in order to remove these repeated warnings and reduce the length of the model log files. Details of this *.uai* file option are given in Section 3.3.7.

3.2 Running the ADMS-Urban Temperature and Humidity model

In order to run the ADMS-Urban Temperature and Humidity model, it is necessary to set up a basic ADMS-Urban dispersion calculation with some additional files. The following steps outline the way in which a base model run should be configured.

Step 1   On the **Setup** screen (Figure 3.2 in the ADMS-Urban User Guide):

∗   Within the **Model options** section of the screen, ensure **Complex terrain** is selected and click **Enter parameters**.... The screen displayed in **Figure 3.2** is shown.

Browse to locate a **Surface roughness file** (Section 5.1 describes how to set this up), and select a **Grid resolution** (refer to Section 4.9.2 of the ADMS-Urban User Guide for further details). Click **OK**.
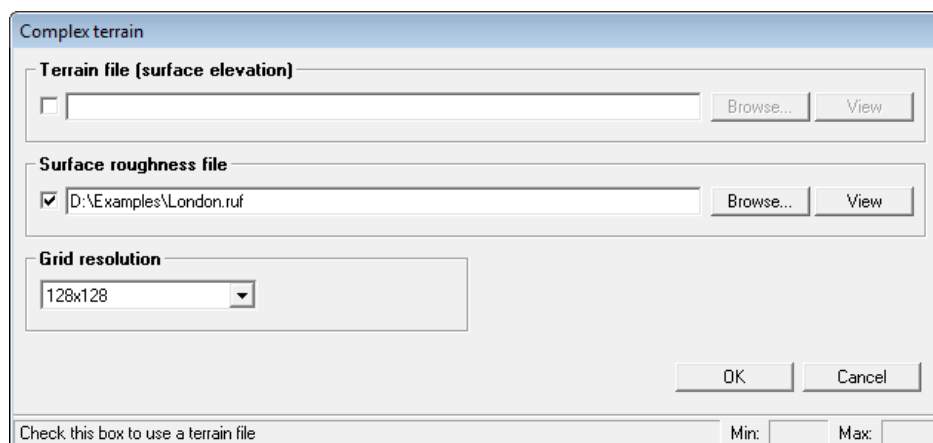
Figure 3.2 – **Complex terrain** options screen showing **Surface roughness file**.

∗ At the bottom of the **Setup** screen browse to locate an **Additional input file** (*.uai*) file.

Please refer to Section 3.3 for information on how to configure the .uai file to allow for the temperature and humidity model options.

Step 2 On the **Source** screen (Figure 3.5 in the ADMS-Urban User Guide):

∗ Enter a 'Default Point' source, and ensure it is located in the centre of the model domain. The source location can be visualised by opening up the ADMS Mapper. For more details about the ADMS Mapper, please refer to Section 7.1 of the ADMS-Urban User Guide.

Step 3 On the **Meteorology** screen (Figure 3.22 in the ADMS-Urban User Guide):

∗ In the **Dispersion site** section, ensure **Use advanced options** is selected, and click on **Data**.... On the **Advanced dispersion site data** screen, ensure **Enter value** is selected and an appropriate value of **Minimum Monin-Obukhov length** is entered. Please refer to Section 3.3.2 of the ADMS-Urban User Guide for an explanation of the use of this parameter within the model (a value of at least 30 m is recommended). Click on **OK**.

∗ In the **Met. measurement site** section, ensure that **Use dispersion site value** is selected for **Surface roughness (m)**. Select **Use advanced options**, click on **Data**... and check that **Use dispersion site value** is selected for all three parameters.

∗ In the **Met. data** section, ensure **From file** is selected, then **Browse**... to locate a *.met* file (refer to Section 4 for further details on using *.met* files in temperature and humidity model runs).

∗ Check that the appropriate **Height of recorded wind (m)** has been entered, ensure **Met. data are in sectors of (degrees)** is checked, if appropriate, and ensure that **Met. data are hourly sequential** is checked. Please refer to Section 3.3.3 of the ADMS-Urban User Guide for details of these and other model options that may be appropriate.

Step 4 On the **Grids** screen (Figure 3.31 in the ADMS-Urban User Guide):

∗ An appropriate output grid and/or specified points should be defined in

this screen. They can be visualised along with the source location by opening up the ADMS Mapper. For further details, please refer to Section 7.1.

Step 5   On the **Output** screen (Figure 3.36 in the ADMS-Urban User Guide):

    ∗   Short term (ST) or long term (LT) output should be entered as required using the **New** and **Delete** buttons; please refer to Section 7 for details.

Step 6   Save the file (**File/Save**).

The remaining model options must be set up via the ADMS-Urban additional input file (*.uai*). Details of how to do this are given in Section 3.3 below.

3.3   Additional input file (.uai)

This section supplements the guidance given in Section 3.1.5 of the primary ADMS-Urban User Guide on using the additional input file editor, which describes how to create and edit *.uai* files. The function of the ADMS-Urban Temperature and Humidity Additional Input file editor is identical to that described in the ADMS-Urban User Guide, but only contains options available that are applicable to Temperature and Humidity model runs, as shown in **Figure 3.3**.

There are five sections in the *.uai* file. Two of these relate to temperature and humidity model options:

- **Temperature and humidity options**, which includes **Anthropogenic heat** (Section 3.3.6), **Short-term output** (Section 3.3.2), **Spatial variation** (Section 3.3.1), **Suppress warning messages** (Section 3.3.7) and **Terrain height effects** (Section 3.3.3); and

- **Terrain**, which includes **Define terrain margin** (Section 3.3.4) and **Limit inner layer depth** (Section 3.3.5).

The remaining three sections are identical to those in the standard version of ADMS-Urban, and the user is referred to the relevant sections of the **primary** ADMS-Urban User Guide for further details:

- **Output options** (Section 3.5.2),

- **Road source options** (Section 4.2), and

- **Time-varying options** (Section 4.1.4).
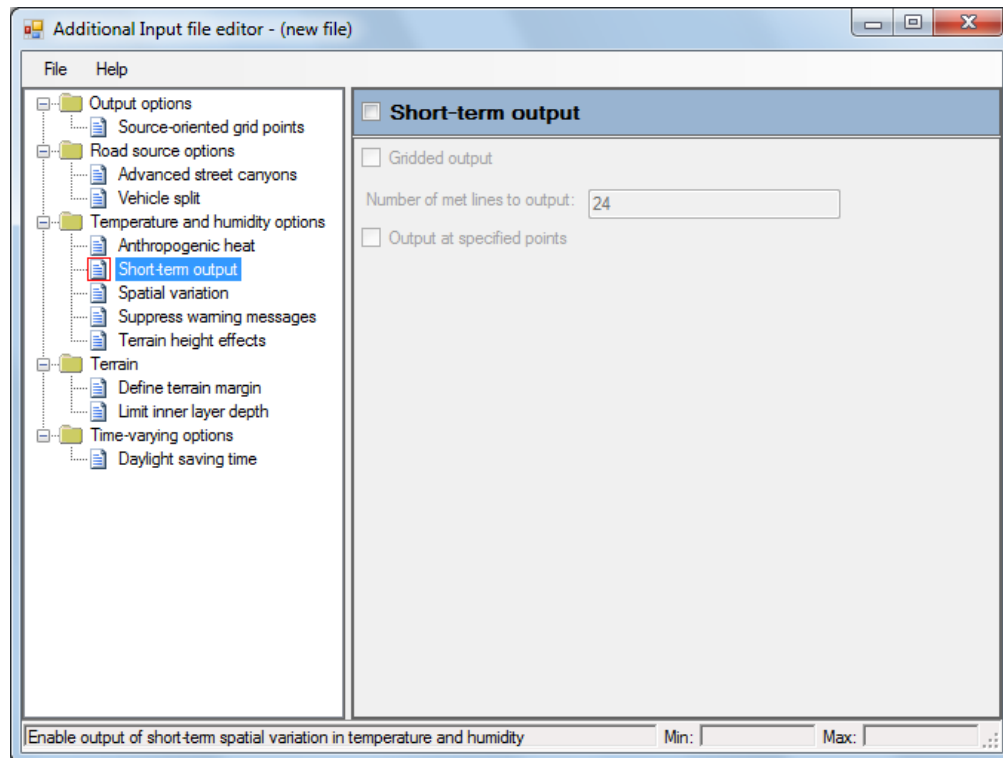
Figure 3.3 – The ADMS-Urban Temperature and Humidity Additional Input file editor.

3.3.1 Spatially varying temperature and humidity options

To specify the spatially varying temperature and humidity options in the Additional Input file editor, enable the **Spatial variation** option, as shown in **Figure 3.4**.

Then the following options may be specified:

- **Type of input met data:**

    Select **Hourly heat flux** if hourly values of surface sensible heat flux, latent heat flux, ground heat flux and net radiation are included in the *.met* file, or select **Basic** if they are not included.

- Enable **Perform net heating calculations** to calculate net heating perturbations, and then select the appropriate **Net heat perturbation mode**.

    Select **Building volume, thermal admittance and albedo** if the model is to calculate net heating perturbations from **normalised building volume**, **thermal admittance** and **albedo** input data, or select **Heat flux data** if the model is to use data from **net radiation perturbations** and **ground heat flux perturbations** directly. Browse to the location of the corresponding files in the relevant locations (**Full path to ... data file**).
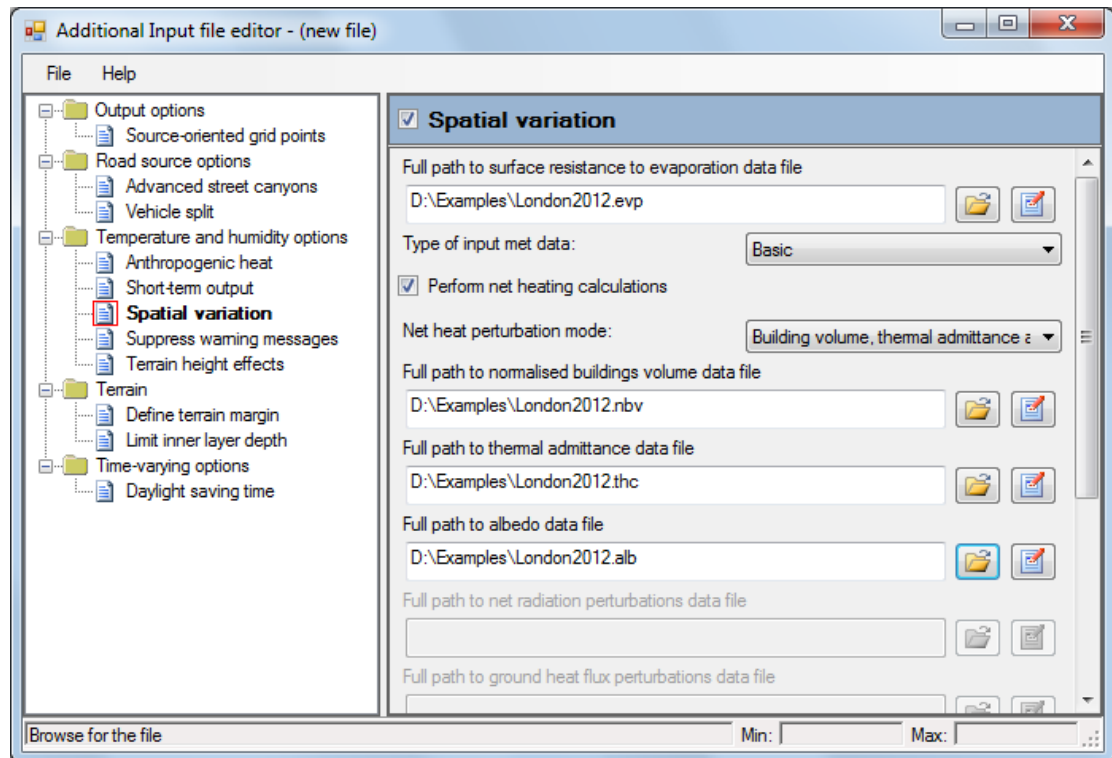
Figure 3.4 – **Spatial variation** of temperature and humidity options screen in the ADMS-Urban Temperature and Humidity Additional Input file editor.

- Enable **User-specified height of data** to specify the height of the temperature and humidity measurements in the *.met* file in **Height of temperature and humidity data**. If unchecked the model will use default values.

- Enable **User-defined aerodynamic resistance parameters** to specify parameters related to the calculation of aerodynamic resistance. If unchecked the model will use default values[1], which are specified below. The following parameters may be specified:

  Minimum surface resistance to evaporation (MinRs), below which the surface roughness is taken to be less than or equal to the specified maximum surface roughness; default = 10 s/m.

  Maximum surface resistance to evaporation (MaxRs), above which no adjustment to the surface roughness value is made; default = 20 s/m.

  Maximum surface roughness parameter (MaxZ0) for areas where the surface resistance to evaporation parameter is less than MinRs. When the surface to resistance to evaporation parameter is between MinRs and MaxRs, the maximum value of the surface roughness parameter applied is an interpolated value between MaxZ0 and the input surface roughness parameter. Default = 0.1 m.

---

[1] It is recommended that the default values of these parameters are used in the first instance

---

Temperatures over expanses of water may be underpredicted by the model. Decreasing MaxZ0 may help to limit the negative temperature perturbations in these situations. Values should be chosen that are consistent with surface roughness over water; refer to Table 5.5 for guidance.

- Select the appropriate **Land use mode**, **Urban** for urban areas or **Rural** for rural areas.

In the *.uai* file the keyword for these options is **SURFACERESISTANCE**.

```
uaifileversion5
SURFACERESISTANCE
Y
PATH ="D:\Examples\London2012.evp"
BASE
Y
NBV_THC_ALB
PATH ="D:\Examples\London2012.nbv"
PATH ="D:\Examples\London2012.thc"
PATH ="D:\Examples\London2012.alb"
Y
2.25
N
Urban
```

Figure 3.5 − An example showing the specification of typical ADMS-Urban Temperature and Humidity model options using the *.uai* file in text format.

3.3.2 Short-term spatially varying temperature and humidity output options

To specify the short-term spatially varying temperature and humidity output options in the UAI Editor, enable the **Short-term output** option, as shown in **Figure 3.6**.
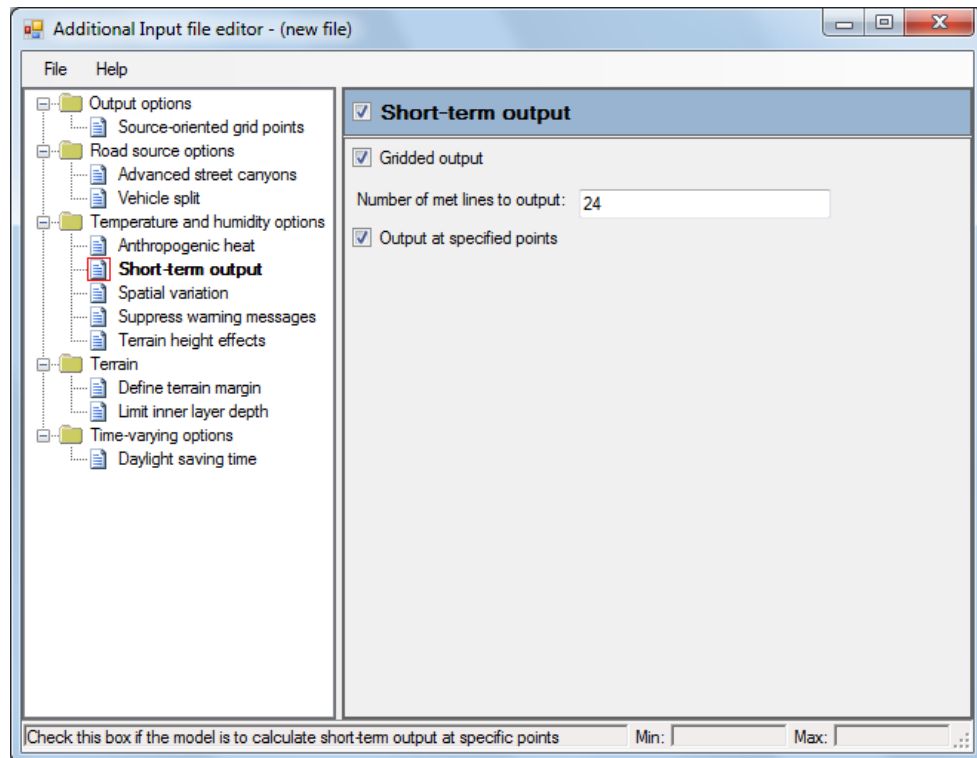
Figure 3.6 – **Short-term output** options for temperature and humidity screen in the ADMS-Urban Temperature and Humidity Additional Input file editor.

Then the following options may be specified:

- Enable **Gridded output** if the model is to calculate short-term gridded temperature and humidity output. The **Number of met lines to output** gridded short-term data for must also be specified if short-term Gridded output is enabled.

- Enable **Output at specified points** to calculate short-term temperature and humidity output at specified receptor points.

In the *.uai* file the keyword for these options is **SURFRESISTOUT_ST**.

```
uaifileversion5
SURFRESISTOUT_ST
Y
Y
24
Y
```

Figure 3.7 − An example showing the specification of the ADMS-Urban Temperature and Humidity model short-term output options using the *.uai* file in text format.

3.3.3 Terrain height effects

As discussed in Section 10.5, temperatures decrease with increasing altitude. In order to allow for the effects of terrain height on the temperature calculations, enable **Include terrain height effects**, as shown in **Figure 3.8**.
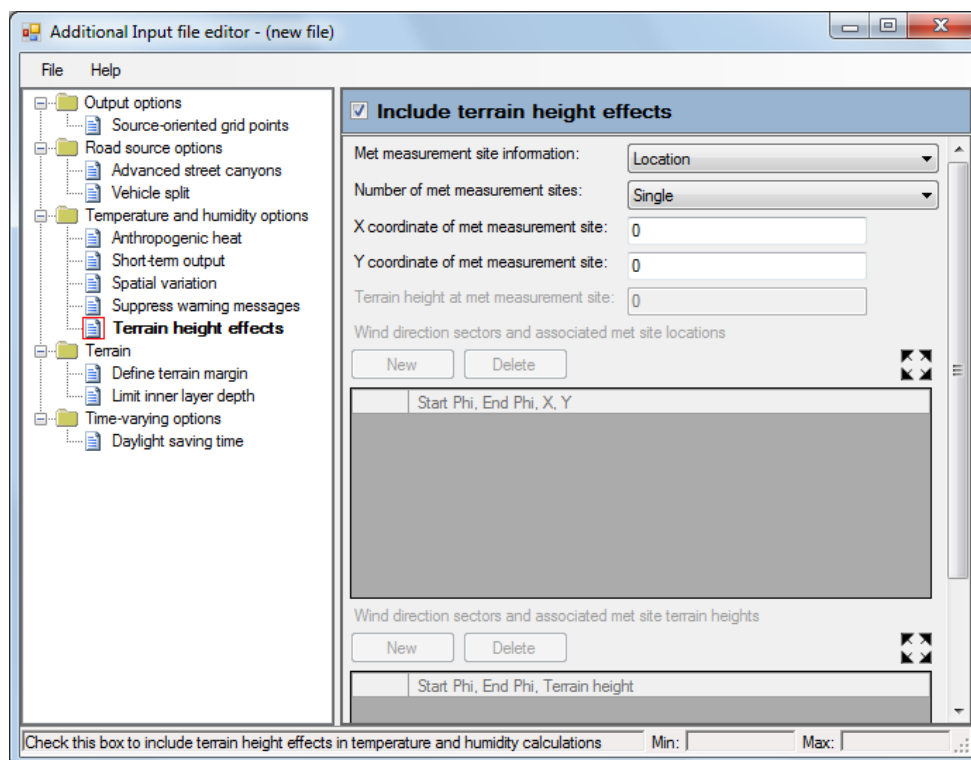
Figure 3.8 – **Terrain height effects** Screen in the ADMS-Urban Temperature and Humidity Additional Input file editor.

The terrain height at the met. measurement site(s) can be specified in two ways:

∗ entered directly into the UAI editor, this requires the selection of **Terrain height** under **Met measurement site information**; or

∗ calculated by the model using the coordinates of the met. site(s), and the data in the terrain file: this requires the selection of **Location** under **Met measurement site information**.

The user must also select the **Number of measurement sites** from the list as either **Single** or **Multiple**. This option is included to allow for input meteorological data to be taken from several met. sites spaced around the modelling area. It is recommended to do this in order to represent the upwind conditions as accurately as possible. If multiple sites are used, the wind sector for each met. site should be calculated. For example, if you have 4 met. sites and they are located in exactly northerly, easterly, southerly and westerly directions from the modelling area, then the wind sectors would be 315° to 45° for the northerly site, 45° to 135° for the easterly site, 135° to 225° for the southerly site and 225° to 315° for the westerly site.

Depending upon the above two selections the user then has one of four sets of information to enter, as shown in Table 3.1. All coordinates and terrain heights must be entered in units of metres. If meteorological data locations are specified by coordinates, the coordinates must be consistent with those used for all the input files and the locations must be within the terrain file data extents.

Case	Location	Terrain height
Single met. site	Enter relevant values under **X coordinate of met measurement site**, and **Y coordinate of met measurement site**	Enter value of **Terrain height at met measurement site**
Multiple met. sites	Fill in the table containing **Start Phi**, **End Phi**, **X** and **Y** for each met. site	Fill in the table containing **Start Phi**, **End Phi**, **Terrain height** for each met. site

Table 3.1 – Available combinations and data required

In the *.uai* file the keyword for these options is **TAHTEREFF**.

```
uaifileversion5
TAHTEREFF
Y
LOCATION
SECTOR
4
315, 45, 0, 5000
45, 135, 5000, 0
135, 225, 0, -5000
225, 315, -5000, 0
```

Figure 3.9 − An example showing the specification of the meteorological data site terrain height by location in a terrain file, using the *.uai* file.

3.3.4 Terrain margin

In the standard ADMS-Urban model, the terrain area must be at least 15% larger than the modelling domain, as explained in Section 4.9.3 of the ADMS-Urban User Guide. When modelling temperature and humidity perturbations due to land use only, this restriction may be too strict and so there is an option to allow for a smaller terrain margin. This option should be used with caution when modelling anthropogenic heat emissions, where the full terrain margin may be required.

To specify the minimum allowed margin between the edge of the terrain and the edge of the modelling area, enable **Define terrain margin**. The minimum margin is then entered in the **Terrain margin to model domain** box in m, as shown in **Figure 3.10**.
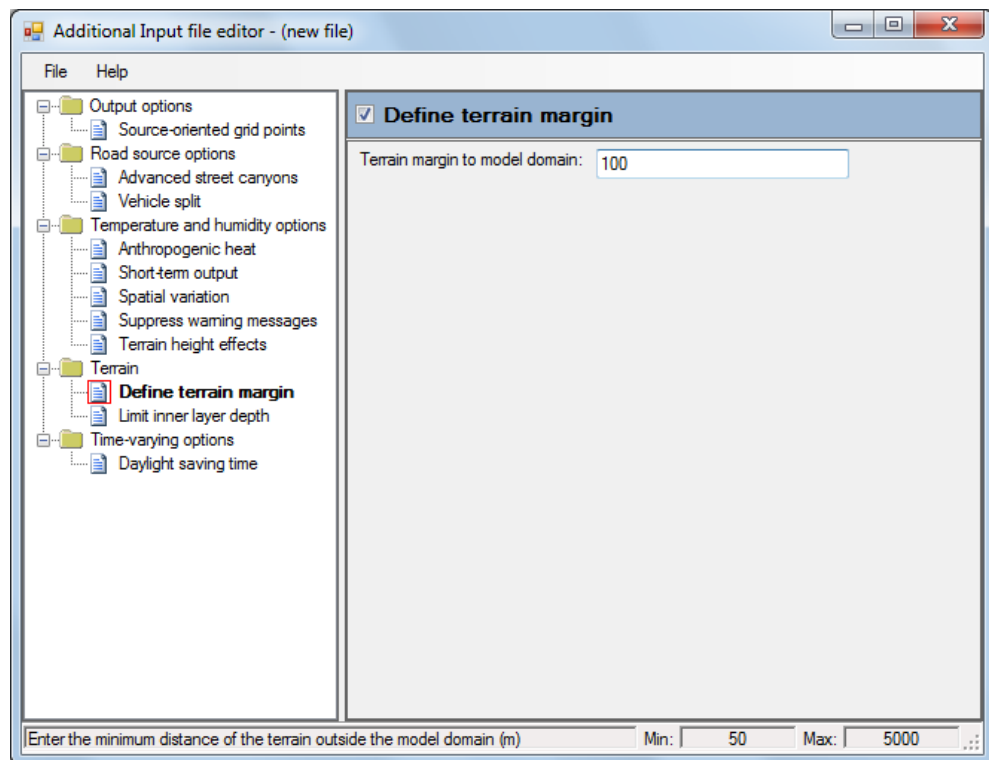
Figure 3.10 – **Define terrain margin** Screen in the ADMS-Urban Temperature and Humidity Additional Input file editor.

In the *.uai* file the keyword for this option is `DEFINETERRAINMARGIN`.

```
uaifileversion5
DEFINETERRAINMARGIN
Y
100
```

Figure 3.11 – An example showing the specification of the ADMS-Urban Temperature and Humidity model minimum terrain margin using the *.uai* file.

3.3.5 Inner layer depth

In the ADMS-Urban model, the boundary layer structure consists of three layers: an inner layer closest to the ground; a middle layer; and an upper layer. The inner layer is defined as the part of the atmosphere where shear stress perturbations are important and stratification is unimportant. The inner layer *depth* is a length scale used in the model formulation. Model testing has demonstrated that predicted temperature perturbations are sensitive to this length scale, particularly at dawn and dusk; restricting this parameter leads to better agreement between model predictions and observed values.

The inner layer depth is restricted to be less than the boundary layer height by the model. The user is also able to apply an upper limit to this value using the **Limit inner layer depth** screen. The limit may be imposed in two ways: as a fraction of the boundary layer height and as an absolute depth limit in metres.

To specify the maximum depth of the inner layer as a fraction of boundary layer height, enable **Set inner layer depth upper limit**. The maximum depth is then entered as

a fraction between 0 and 1 in the **Fraction of boundary layer height** box, as shown in **Figure 3.12**.

To specify an absolute value for the maximum depth of the inner layer, enable **Set inner layer depth upper limit**. The maximum depth is then entered as a height in metres between 0 and 10000 in the **Fixed depth** box, as shown in **Figure 3.12**.
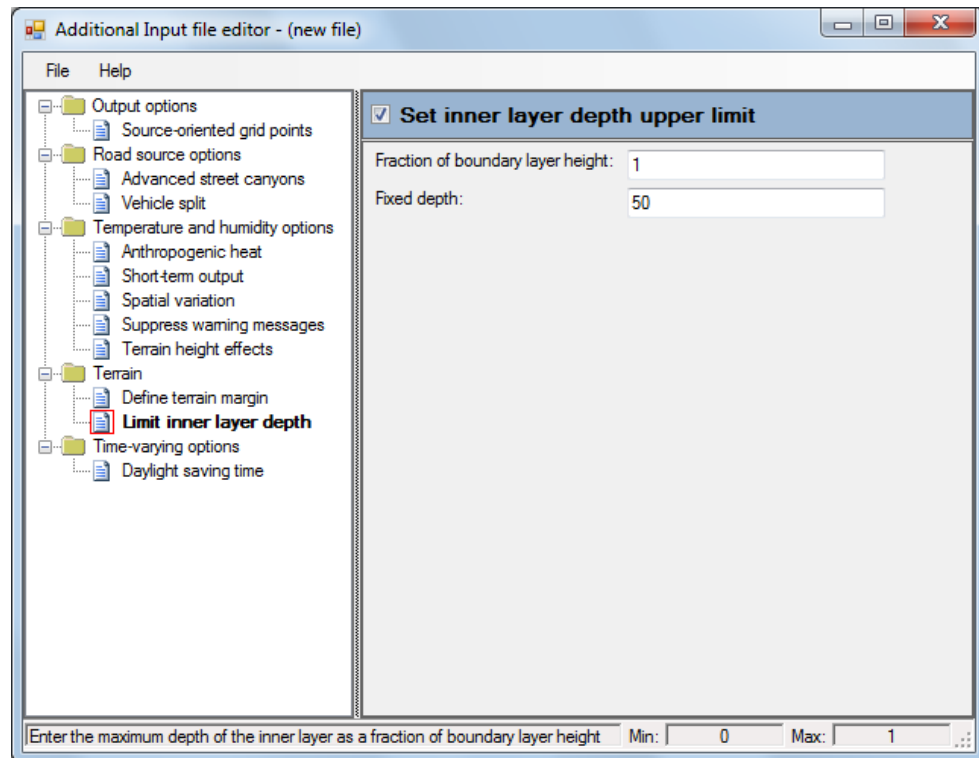
Figure 3.12 – **Limit inner layer depth** Screen in the ADMS-Urban Temperature and Humidity Additional Input file editor.

In the *.uai* file the keyword for this option is **INNERREGIONMAX**.

```
uaifileversion5
INNERREGIONMAX
Y
1
50
```

Figure 3.13 − An example showing the specification of the ADMS-Urban Temperature and Humidity model maximum depth of the inner layer using the *.uai* file.

It is recommended that this option be enabled, and the values 1.0 be used for the maximum fraction of the boundary layer height and 50 m for the absolute maximum depth.

3.3.6 Anthropogenic heat emissions

The ADMS-Urban Temperature and Humidity model can calculate temperature increments due to anthropogenic heat emissions from volume sources and from roads. To use this option, enable the **Model anthropogenic heat emissions option** in the **Anthropogenic heat** section of the Additional Input file editor, shown in **Figure 3.14**.

The following options are available:

- **Model anthropogenic volume source heat emissions** Enable this option to model anthropogenic volume source heat emissions specified in a *.agh* file, as described in Section 6.1.1. Browse to the relevant *.agh* file using the ... button.

- **Model anthropogenic heat emissions from roads** Enable this option to model anthropogenic heat emissions from sources in the interface, typically roads, using the anthropogenic heat pollutant 'Temperature'.

- **Calculate road heat emissions from CO2 emissions** Enable this option to convert CO_2 emissions from road sources into anthropogenic heat emissions, as described in Section 6.2.1.

- **Energy content of fuel used in road vehicles** Enter the conversion factor from CO_2 emissions to heat emissions from road vehicles, based on the energy content of the fuel. Refer to Section 6.2.1 for example values for this conversion factor.

- **Fuel heat release factor for road vehicles** Enter the proportion of the fuel energy which is released as heat.
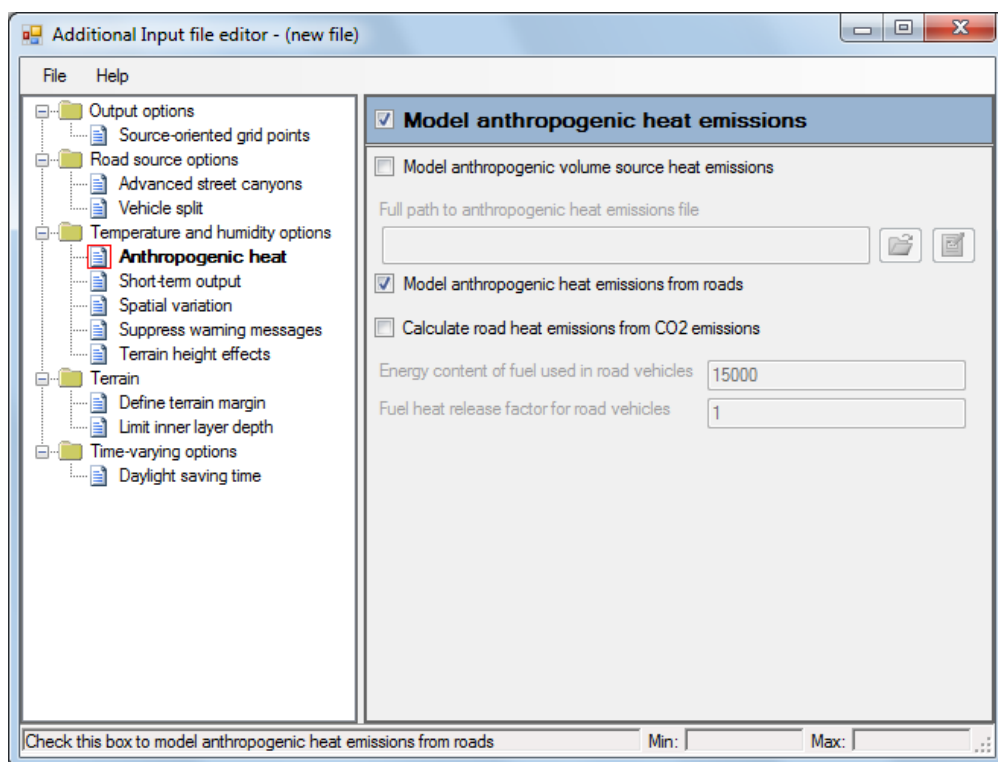
Figure 3.14 – **Anthropogenic heat** Screen in the ADMS-Urban Temperature and Humidity Additional Input file editor.

In the *.uai* file the keyword for this option is **ANTGENHEAT**.

```
ANTGENHEAT
Y
Y
PATH = "D:\Examples\London_AGH_5km.agh"
Y
Y
```

```
15000
1
```

Figure 3.15 − An example showing the anthropogenic heat option in the *.uai* file.

3.3.7 Suppression of warning messages

During ADMS-Urban Temperature and Humidity model runs, certain warning messages can reoccur frequently, which can result in large warning and log files and make it difficult to find other relevant warning and logging messages. These repeating warning messages can be suppressed so that they only occur once, instead of once per source or once per met line. To use this option, enable the **Suppress repeated warning messages** option in the **Suppress warning messages** section of the ADMS-Urban Temperature and Humidity Additional Input file editor, shown in **Figure 3.16**.

Figure 3.16 – **Suppress warning messages** Screen in the ADMS-Urban Temperature and Humidity Additional Input file editor.

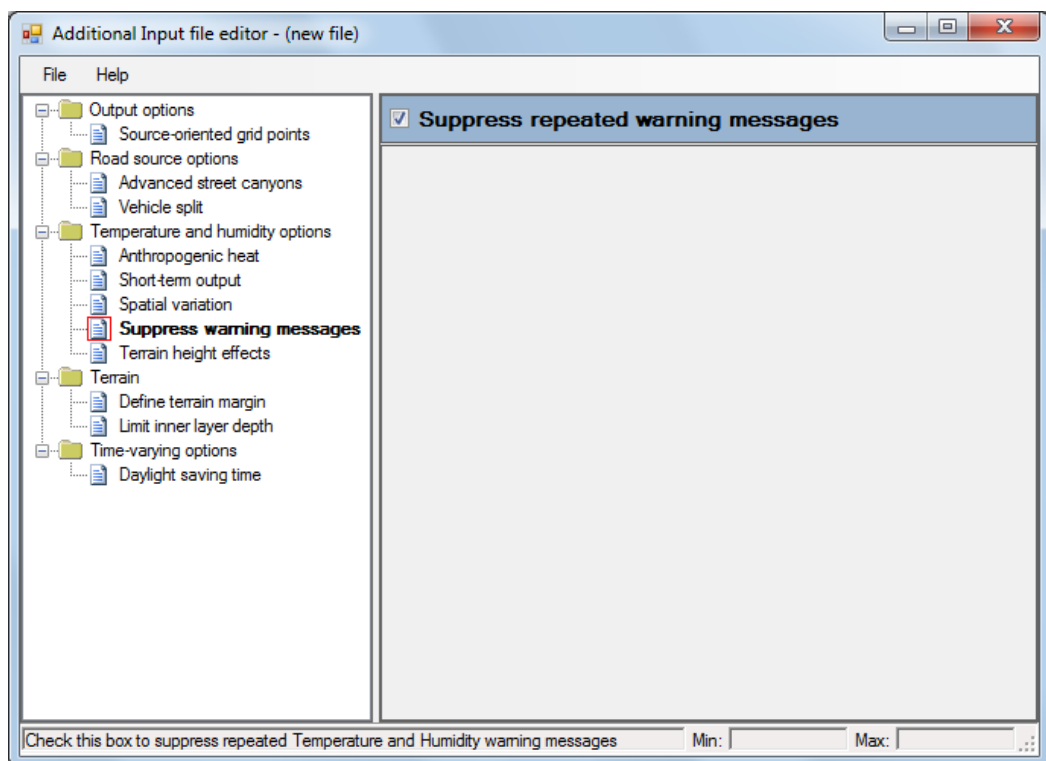In the *.uai* file the keyword for this option is **SUPPRESSUHIWARNINGS**.

```
uaifileversion5
SUPPRESSUHIWARNINGS
Y
```

Figure 3.17 − An example showing the suppression of repeated warnings from the ADMS-Urban Temperature and Humidity model in the *.uai* file.

SECTION 4 Meteorological data

The ADMS-Urban Temperature and Humidity model is configured to run in two meteorology modes, one in which the model calculates the four heat flux terms of the surface energy balance equation, and one where the user enters hourly values of the heat flux terms, for instance as output from a mesoscale meteorological model. Overall differences between the two modes are described in Section 4.1 below, with details of how the model can be run in the two modes given in Sections 4.2 and 4.3. Section 3.3 gives details of how to switch between the two modes using the ADMS-Urban Temperature and Humidity options defined via the *.uai* file.

Model users should refer to the meteorology sections of the ADMS-Urban User Guide for details of how to set up the ADMS-Urban *.met* files. Specifically:

Section 3.3	–	details of the ADMS-Urban **Meteorology** screen
Section 6.1.5	–	details of the meteorological output data (*.mop* file)
Section 10.1	–	technical details regarding the general ADMS-Urban input and output meteorology parameters

As ADMS-Urban models the perturbations to the upwind temperature and humidity, the upwind values must be included in the *.met* file. Either specific humidity (S HUMIDITY) or relative humidity (RHUM) values may be given.

Users may also choose to specify the ratio of the roughness length governing the transfer of heat to the roughness length governing momentum transfer (variable name Z0S/Z0). A model default of 0.2 is currently set.

The model supports an additional ADMS-Urban meteorology parameter that controls the minimum wind speed at 10 m above which calculations will be performed. By default[2], this parameter is 0.75 m/s. This value can be decreased by including the meteorological parameter U10min in the *.met* file.

The U10min parameter should be used when modelling in urban areas where wind speeds are low. A value of 0.5 m/s is recommended.

Note that the U10min parameter is not mentioned in the standard ADMS-Urban User Guide.

---

[2] This default relates to the validity of Gaussian plume models

4.1 Running ADMS-Urban in different meteorological modes

The ADMS-Urban met pre-processor is able to use common meteorological parameters such as the time of day and year, wind speed, temperature, humidity and cloud cover to derive the four heat flux terms in the surface energy balance equation i.e.:

- Surface sensible heat flux $\left(F_{\theta_0}\right)$;

- Latent heat flux (λ_E);

- Net radiation (Q^*); and

- Ground heat storage (G).

The model will calculate these heat flux terms when running in **Basic** mode, as described in Section 4.2.

The ADMS-Urban meteorological pre-processor allows these four heat flux terms to be entered directly into the model, for instance if these data are available as output from a mesoscale model. Details of running the model with input **Hourly heat flux** data are given in Section 4.3.

4.2 Basic mode

In **Basic** mode, the ADMS-Urban model is able to run the temperature and humidity calculations using the basic meteorological input parameters that allow the model to estimate the heat flux terms.

The way in which Q^* is calculated is described in ADMS 5 Technical specification document P05/01R/12. The method for deriving G from Q^* is based on a methodology described in a paper by Camuffo and Bernardi (1982); details are provided in the Technical Summary (Section 10.2). The remaining heat flux terms, F_{θ_0} and λ_E, are calculated according to P05/01R/12.

An example *.met* file for the model running in **Basic** mode is given in **Figure 4.1**.
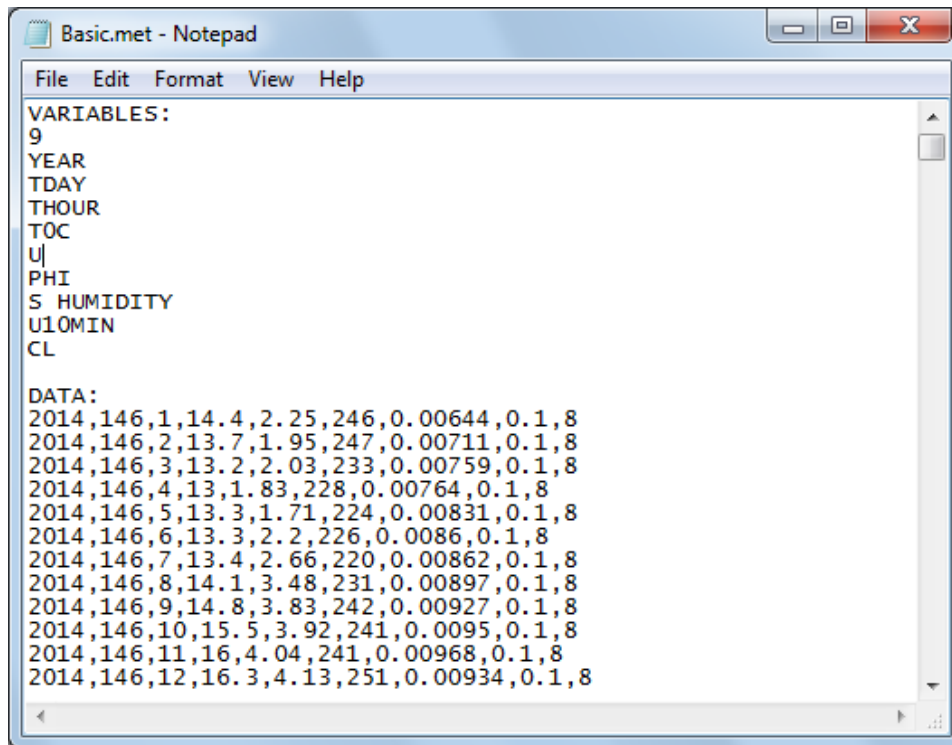
Figure 4.1 – Example **Basic** mode *.met* file.

4.2.1 Temperature and humidity measurement height

By default, when the model is running in **Basic** mode, the height at which the temperature and humidity measurements have been taken is assumed to be 1.22 m. If in reality the measurements available have been taken at a different height, then this height should be specified in the *.uai* file. For details of the format of the *.uai* file, please refer to Section 3.3.

4.3 Hourly heat flux data inputs

When the **Type of input met data** is specified as **Hourly heat flux**, the ADMS-Urban model requires the four energy flux heat balance terms as input i.e. surface sensible and latent heat fluxes, net radiation and ground heat storage. In addition, it is necessary to specify the basic ADMS-Urban met parameters so that the model can calculate, for example, the incoming solar radiation.

An example *.met* file for the model using **Hourly heat flux** data as input is given in **Figure 4.2**.
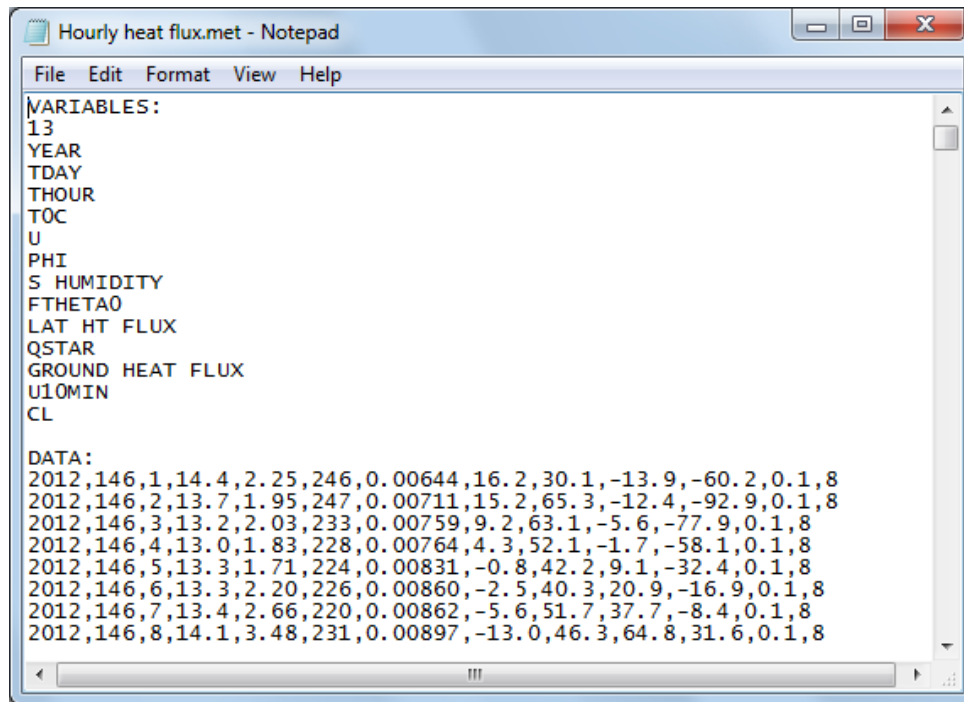
Figure 4.2 – Example **Hourly heat flux** data input *.met* file.

Table 4.1 summarises the ranges allowed for the heat flux data entered in the *.met* file.

Heat flux parameter	Variable name	Minimum (W/m²)	Maximum (W/m²)
Surface sensible heat flux	FTHETA0	-100	1000
Latent heat flux	LAT HT FLUX	-100	1000
Net radiation	QSTAR	-500	1000
Ground heat storage	GROUND HEAT FLUX	-900	1000

Table 4.1 – *.met* file variable names and the associated minimum and maximum heat flux values accepted by ADMS-Urban

4.3.1 Temperature and humidity measurement height

By default, when the model is running using **Hourly heat flux** data inputs, the height at which the temperature and humidity measurements have been taken is assumed to be 2.5 m. If in reality the measurements available have been taken at a different height, then this height should be specified in the *.uai* file. For details of the format of the *.uai* file, please refer to Section 3.3.

SECTION 5 Land use parameters

As outlined in Section 3.1.2, ADMS-Urban can be used to model the temperature and humidity perturbations due to either:

- Spatial variations of the surface resistance to evaporation parameter together with the surface roughness, or

- Spatial variations of the surface resistance to evaporation parameter together with the surface roughness, and additionally, parameters that affect the net radiation and ground heat flux values.

Within the second of these options, i.e. when the perturbations to the net radiation and ground heat flux are being modelled, there are two options for input:

- The user can specify the spatial variation of parameters that allow the model to calculate the local heat flux perturbation values, i.e. normalised building volume, surface albedo and thermal admittance; or

- The user can directly specify the spatial variation of the net radiation and ground heat flux values.

As a consequence, there are seven different parameters that may be used to represent spatial variation of land use. Table 5.1 summarises these parameters in terms of their units, ranges and when the files are required. These model options can be activated by specifying appropriate parameters in the *.uai* file. Please refer to Section 3.3.1 for further details.

Section 5.1 describes the file format in which the land use data should be entered. Section 5.2 gives some suggested values from the literature that may be helpful in setting up the input data files.

Note that when creating the model input files, the rate of spatial variation of parameters should not exceed the spatial accuracy within which the model is able to evaluate a solution. For example, if point data are being used to derive parameters (such as the thermal admittance) it may be necessary to smooth the data prior to use in the model.

5.1   File format

Each set of land use parameters are entered via a text file, with the file extension given in the last column of Table 5.1. These files should be linked to the model run via the *.uai* file, except for the *.ruf* file which is specified in the **Complex terrain** options screen, as described in Section 3.3.

Parameter	Description	Units	When used?	Minimum	Maximum	File extension
Surface resistance to evaporation	A measure of the surface wetness	sm^{-1}	All runs	0^{*}	-	*.evp*
Surface roughness length for momentum transfer	Represents the height of any obstacles present in the model domain	m	All runs	10^{-7}	-	*.ruf*
Albedo	A measure of the reflectivity of the surface	-	For runs that include the net heating perturbations, when the model derives the values	0	1	*.alb*
Normalised buildings volume	A measure of the density of the buildings within the domain	m		0	-	*.nbv*
Thermal admittance	A measure of the ability of the surface to accept or release heat	$Jm^{-2} s^{-1/2} K^{-1}$		0	-	*.thc*
Perturbation to the net radiation	Absolute net radiation perturbations	W/m²	For runs that include the net heating perturbations, when these data are entered directly	-	-	*.ird*
Perturbation to the ground heat flux	Absolute ground heat flux perturbations	W/m²		-	-	*.hfx*

Table 5.1 – Summary of spatially varying parameters that can be entered into the model. [*] If values of 0 are entered to represent wet surfaces, these are increased to 0.1 in order to avoid singular values.

All land use parameter data files should cover approximately the same area

For example, if a run modelling the basic temperature and humidity calculations, together with net radiation and ground heat flux perturbations calculated from land use data was set up, the following files would be required*: example.ruf, example.evp, example.alb, example.nbv* and *example.thc*.

Each parameter text file is in comma delimited format. The data are entered as follows:

```
Row number, x, y, parameter
```

where `parameter` is the albedo, or surface roughness, etc. as required. Up to 770,000 rows of data can be entered into the model. The (x, y) locations should be in the same coordinate system as the remaining model setup. The data do not have to be on a regular grid.

If modelling the perturbations to the net radiation and ground heat flux values, the model requires these data to be specified on coincident grids.

Figure 5.1 shows an example input text file.
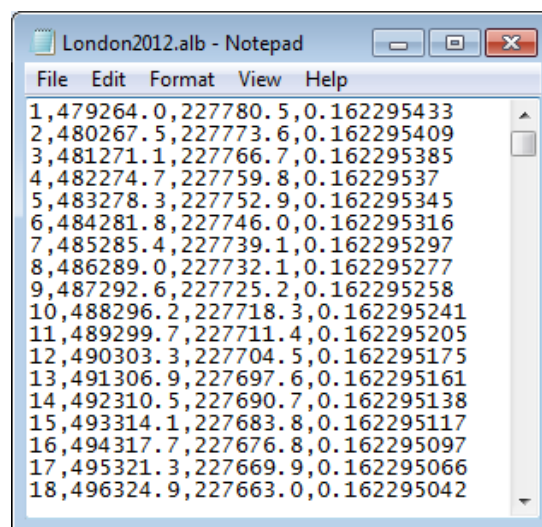
Figure 5.1 – Example input text file format.

5.2 File configuration

Temperature and humidity model predictions are sensitive to the 'upwind conditions'. The 'upwind conditions' are defined by the upwind meteorological data in addition to the land use parameters specified on the upwind edges of the model input files. Consequently, the land use values on the edges of the model input files need to be representative of the upwind met. site(s). Note that these values may not be exactly the same as the land use values within the modelling domain, although ideally parameters should be similar.

If multiple met. sites are being used, the upwind edge should represent the land use for the met. station that is upwind for the appropriate wind directions. This may lead to multiple 'upwind domains' each with their own set of constant parameter values, as indicated in **Figure 5.2**. If the land use is sufficiently similar at all met sites, a single upwind edge

value may be used around the whole edge. Two rows of land use grid points around the perimeter are sufficient for the 'upwind domain'.

In order to avoid any discontinuities in model predictions between the 'upwind domain' and the central model domain where output values are of interest, it is advisable to include a 'buffer zone' (**Figure 5.2**). The size of the buffer zone should be related to the size of the study area and the resolution of the internal model calculations; specifically, it is recommended that at least two internal model grid points lie in the 'buffer zone'.

In summary, when creating the land use parameter files it is advisable to configure them using three separate zones, as summarised in **Table 5.2** and shown in **Figure 5.2**.

Land use file domain	Domain description	Use model output within this region?
Modelling domain	Area where model output is required; contains local land use data.	Yes
Buffer zone	Area between the upwind and the modelling domains; contains local land use data.	No
Upwind domain	Edge of the land use parameter files; represents land use at the upwind met. site(s).	No

Table 5.2 – Summary of suggested land use file domain configuration

Note that land use parameters within the 'upwind domain' must be consistent when comparing multiple scenarios for the same modelling area.
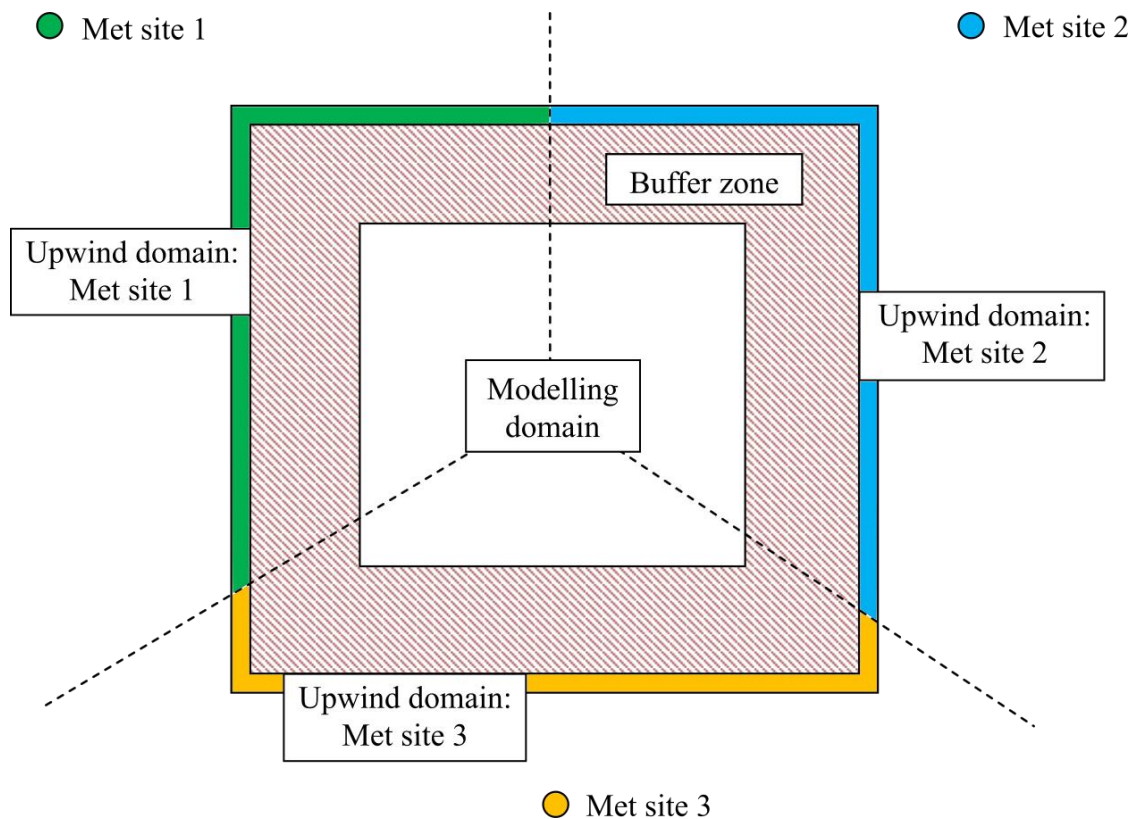
Figure 5.2 – Diagram showing the recommended layout of a land use parameter file.

5.3 Example parameters

The following sections give advice regarding possible values that may be used to represent various land use types. References are given as available.

Some of these parameters will vary seasonally or diurnally, but currently ADMS-Urban Temperature and Humidity does not allow for this behaviour in its modelling.

5.3.1 Surface albedo

Table 5.3 summarises some albedo values taken from literature.

Land use	Minimum or average albedo	Maximum albedo	Reference
Fresh snow	0.950	-	**Stull**
Light-coloured dry soils	0.400	-	**Stull**
Grass	0.200	-	**Stull**
Many agriculture crops	0.200	-	**Stull**
Coniferous forests	0.100	-	**Stull**
Dark wet soils	0.050	-	**Stull**
Urban land	0.180	-	**Stull**
Agriculture	0.170	0.230	**Stull**
Grassland	0.190	0.230	**Stull**
Deciduous forest	0.160	0.170	**Stull**
Coniferous forest	0.120	0.120	**Stull**
Forest swamp	0.140	-	**Stull**
Water or ocean	0.080	-	**Stull**
Marsh or wetland	0.140	-	**Stull**
Roof	0.120	-	**Masson**
Road	0.080	-	**Masson**
Wall	0.500	-	**Masson**

Table 5.3 – Albedo values from literature

5.3.2 Surface resistance to evaporation

Table 5.4 summarises some surface resistance to evaporation parameters from literature. More values are given in **Cox**, but they relate to non-urban areas, and so have been omitted here.

Values of surface resistance to evaporation vary diurnally and seasonally. The current version of the ADMS-Urban Temperature and Humidity model does not automatically allow for this variation. Therefore, it is recommended that model users perform sensitivity testing regarding parameter values, for instance using lower surface resistance to evaporation parameter values for wetter seasons.

Land use	Surface resistance parameter (s/m)	Reference
Open water	0[*]	**Oke**
Short grass	70	**Oke**
Crops	50	**Oke**
Forests	80-150	**Oke**
Urban	~200	**Cox**

Table 5.4 – Surface resistance to evaporation parameters from literature;[*] a minimum value of 10 s/m is recommended with regard to model input due to the sensitivity of model predictions in the limit as the surface resistance to evaporation parameter approaches zero.

5.3.3 Surface roughness length for momentum transfer

Table 5.5 summarises some surface roughness lengths from literature. As with the surface resistance to evaporation parameters, these values may vary seasonally, particularly in agricultural areas, although they are unlikely to vary diurnally.

Land use	Surface roughness lengths (m)	Reference
Large urban areas	1.5	**ADMS-Urban User Guide**
Cities, woodlands	1	**ADMS-Urban User Guide**
Parkland, open suburbia	0.5	**ADMS-Urban User Guide**
Agricultural areas (max)	0.3	**ADMS-Urban User Guide**
Agricultural areas (min)	0.2	**ADMS-Urban User Guide**
Root crops	0.1	**ADMS-Urban User Guide**
Open grassland	0.02	**ADMS-Urban User Guide**
Short grass	0.005	**ADMS-Urban User Guide**
Sea	0.0001	**ADMS-Urban User Guide**

Table 5.5 – Surface roughness lengths from literature

5.3.4 Normalised building volumes

The 'normalised building volume' (NBV) concept allows the building density to be defined on average over a grid cell. The normalised building volume is calculated as follows:

$$NBV = \frac{V_{buildings}}{A_{cell}}$$

Where $V_{buildings}$ is the volume of the buildings within a grid cell and A_{cell} is the surface area of the grid cell. Care should be taken, therefore, when calculating this parameter, as the plot area over which the averaging is calculated affects results.

For guidance, an example range of NBV values found in Greater London is shown in **Figure 5.3**; note that the vertical scale on this plot showing the the area covered

by each NBV value is presented using a log scale i.e. the majority of London has NBV values less than 2.
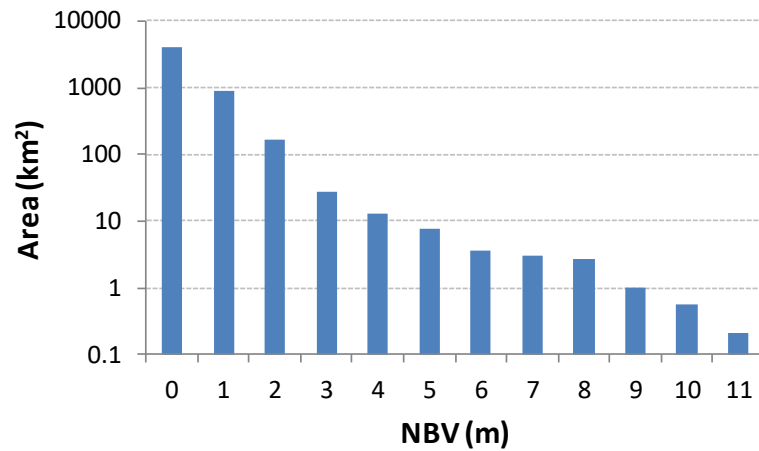
Figure 5.3 – Area within Greater London by ranges of normalised building volume.

5.3.5 Thermal admittance

Table 5.6 summarises some thermal admittance values taken from literature. In addition, the table contains some values in italics, which have been derived from typical density, specific heat capacity and thermal conductivity values.

Land use	Thermal admittance values ($Jm^{-2} s^{-1/2} K^{-1}$)	Reference
Sandy soil, dry	620	**Oke**
Sandy soil, saturated	2550	**Oke**
Clay soil, dry	600	**Oke**
Clay soil, saturated	2210	**Oke**
Peat soil, dry	190	**Oke**
Peat soil, saturated	1420	**Oke**
Snow, fresh	130	**Oke**
Snow, old	195	**Oke**
Ice	2080	**Oke**
Water	1545	**Oke**
Asphalt	1205	**Oke**
Concrete aerated	150	**Oke**
Concrete dense	1785	**Oke**
Stone	2220	**Oke**
Brick	1065	**Oke**
Clay tiles	1220	**Oke**
Buildings	*1505*	*-*
Paths	*1096*	*-*

Table 5.6 – Thermal admittance values from literature

SECTION 6 Anthropogenic Heat Emissions

This section gives details of the input data required for modelling anthropogenic heat emissions in the ADMS-Urban Temperature and Humidity model. The modelling of gridded heat emissions is described in Section 6.1, with details of the input file format and example values of heat emission rates from domestic and commercial buildings.

The modelling of heat emissions from explicit road sources is described in Section 6.2, with example values of conversion factors from carbon dioxide to heat emissions.

Note that time-varying emission factors should be included in modelling of anthropogenic heat emissions, in order to capture diurnal and monthly variations of heat emissions.

6.1 Volume source heat emissions

Anthropogenic heat emissions in an urban area may be represented as volume sources on a range of scales, from individual buildings if modelling a small local area, to aggregated emissions over a few km if modelling a large urban area.

Volume sources may be used to represent aggregated road emissions at a low spatial resolution; if high resolution modelling of anthropogenic heat emissions from roads is required then they should be modelled as explicit road sources as described in Section 6.2.

Anthropogenic heat emissions from volume sources are defined using an *.agh* file in the ADMS-Urban Temperature and Humidity model. The format of this file is defined in Section 6.1.1.

6.1.1 File format for gridded anthropogenic heat emissions data

The *.agh* file is a comma-separated file which consists of a header line followed by one line of data for each anthropogenic heat volume source. The header line is:

```
NAME,X,Y,DX,DY,Z,E
```

While the corresponding data consists of:

- The source name, which can be used to identify the source in a *.fac* or *.hfc* time-varying emissions file;

- The x and y coordinates of the lower-left corner of the volume source, given in metres in a coordinate system consistent with all other inputs to the model;

- The x and y horizontal extents of the volume source, given in metres;

- The vertical extent of the volume source, given in metres; and

- The heat emission rate of the volume source, given in W/m^2.

Note that the volume sources in the .agh *file are assumed to be cuboid, whereas volume sources defined in the ADMS-Urban interface may have any convex polygon footprint with up to 50 vertices. If complex source geometries are required, heat sources can alternatively be defined in the interface with 'Temperature' emissions (units W/m^3 for volume sources or W/m^2 for area sources) with the option to modelling anthropogenic heat emissions from road sources selected.*

Note also that the .agh volume sources may overlap and/or overlay completely. For example, separate overlaying grids of volume sources may be defined to represent aggregated heat emissions from residential buildings, industrial buildings and roads, each with associated time-varying profiles.

An example *.agh* file is provided with the model installation files and is shown in Figure 6.1.
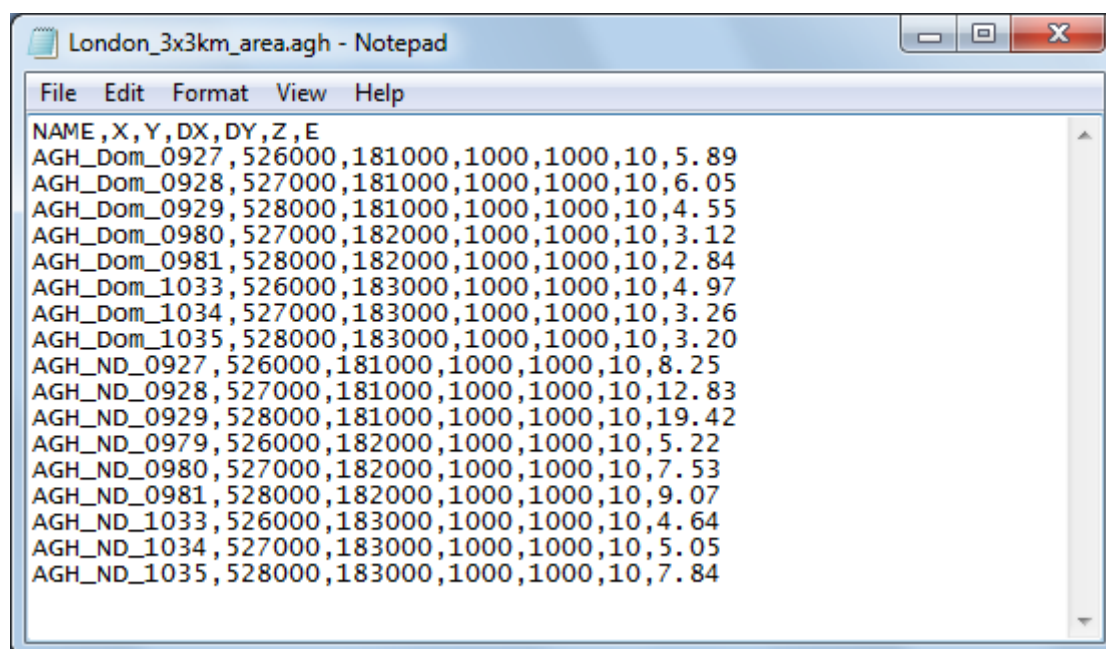

Figure 6.1 – Example *.agh* file format.

6.1.2 Heat emission rates from buildings

Buildings may have a wide range of anthropogenic heat emissions, depending on their use and construction, which also vary diurnally and seasonally. Some example values for buildings heat emission rates, based on UK building stock and energy use data, are given in Table 6.1. These values are taken from **Smith et al.** which also presents many other heat emission rates for other land use types.

These values should be used with caution in non-UK modelling locations where the building construction materials and heating/cooling energy use rates are likely to be different.

Land use in which building located	Typical heat emission rate (W/m²)	Reference
Residential	31	**Smith et al.**
Hospitals	60	**Smith et al.**
Retail	80	**Smith et al.**
Town centre	70	**Smith et al.**
Offices	50	**Smith et al.**

Table 6.1 – Typical energy consumption for buildings within different land use types

6.2 Road heat emissions

On a local scale the emissions of heat from road vehicle exhausts may have significant effects on temperatures. The emissions of heat from road sources can be modelled explicitly in the ADMS-Urban Temperature and Humidity model. General information about defining geometry and emissions for road sources can be found in the ADMS-Urban User Guide.

Street canyon effects on the dispersion of heat from road sources may be included using either the simple canyon height in the ADMS-Urban interface or the Advanced Street Canyon option in the *.uai* file.

Note that neither of these dispersion modelling options take into account any radiative effects of street canyons on temperatures within the canyons.

Heat emissions for road sources can either be specified directly as the anthropogenic heat pollutant 'Temperature' (defined using the *.ptt* file as described in Section 2.2), using effective units of W/km, or indirectly as the emission rate of CO_2 from vehicles. If the latter option is chosen, conversion factors must be specified in the *.uai* file, as described in Section 3.3.6. Section 6.2.1 gives some example values for the conversion factors.

6.2.1 Conversion from carbon dioxide to heat emissions

The heat emitted by a vehicle is expected to be proportional to the fuel consumed, with a conservative estimate that all the energy of the fuel is ultimately converted to heat. The emissions of CO_2 gas from the vehicle can be used as a proxy for fuel consumption, with the emission rate of CO_2 per gram of fuel burned assumed to be constant for a given fuel type. This is a reasonable assumption when the conversion of other carbon-containing exhaust emissions into CO_2 in the atmosphere is taken into account, sometimes described as 'ultimate CO_2' or uCO_2.

Thus we define the rate of heat release from a road using fuel i as $Q_{FV,i}$ in units of W/km, given by

$$Q_{FV,i} = \lambda F_i EF_{CO_2}$$

where: λ is a heat release factor without units; F_i is the conversion factor from CO_2 to heat emissions in units of J/g[CO_2]; and EF_{CO_2} is the emission rate of CO_2 in

g/km/s. Example values for the conversion factor based on UK data are given in Table 6.2. Values for other countries may differ due to differing fuel compositions. A default conversion factor value of 15000 J/g[CO_2] is suggested.

Fuel	Road emission conversion factor J/g[CO_2]	
	Minimum	Maximum
Diesel	14700	14800
Petrol	14970	15770

Table 6.2 – Factors for conversion of road emissions of CO_2 to heat emissions, calculated from literature values of CO_2 emissions per gram of fuel consumed (**BEIS**) and heat content of fuels (**Smith**, **DUKES**).

The heat release factor allows users to specify the proportion of the fuel energy which is released as heat. A default heat release factor of 1 is suggested.

SECTION 7 Output

This section details the outputs generated by ADMS-Urban when running the temperature and humidity model. The temperature and humidity model predictions generated by the model can be output at particular receptor locations, as well as on an output grid, the latter type of output being useful for generating contour plots. Further, the results are classified into short-term (ST), which means they are results on an hour-by-hour basis, or long-term (LT), which means that they are averages over all met conditions modelled.

The model predicts local perturbations of temperature and humidity due to land use variations and anthropogenic heat emissions, which are combined with the upwind values of temperature and humidity to generate total temperature and humidity at each location. If complex terrain is modelled, the total temperature is also modified to take into account the elevation of the receptor, as described in Section 10.5.

Section 7.1 gives details of the way in which the receptor locations and grids are specified, and Section 7.2 explains how ST and LT output can be obtained.

If 'Temperature' is specified on the Output screen of the ADMS-Urban interface and anthropogenic heat sources are modelled then the standard ADMS-Urban concentration output files will contain heat density values due to anthropogenic heat sources, in default units of $\mu J/m^3$. These values can be converted to find the temperature increment due to anthropogenic emissions by correcting from $\mu J/m^3$ to $\mu J/m^3$ and following the expression given in Section 10.6.

The ADMS-Urban meteorological pre-processor output relating to the upwind conditions modelled is written to the *.mop* file. Section 6.1.5 of the ADMS-Urban User Guide gives general details of this file, and additional outputs related to the temperature and humidity calculations are described in Section 7.3.

7.1 Gridded and receptor temperature and humidity output

A grid of temperature and humidity output may be defined in the **Grids** screen of the ADMS-Urban interface. Please refer to Section 3.5.1 of the ADMS-Urban User Guide for further details.

When modelling road traffic anthropogenic heat, the source-oriented grids option can be useful to get higher resolution contour values close to the roads. It may also be beneficial to use the .uai *file option to include a* .igp *file for more control of source-oriented grid point locations, as described in Section 3.5.2 of the ADMS-Urban User Guide.*

If not modelling anthropogenic heat sources, this option is not relevant to temperature and humidity modelling, so it should be disabled.

Locations of particular receptors within the model domain are specified on the **Grids** screen

of the interface, in the **Specified points** section. Up to 50 specified point locations can be entered into the interface; if more are required, then additional data can be entered via an *.asp* file. For further details, please refer to Section 3.5.3 of the ADMS-Urban User Guide.

Note that model predictions at heights below the roughness length are not valid.

7.2 Short- and long-term temperature and humidity output

Long-term output can be obtained by including a 'LT' pollutant on the **Pollutant output** section of the **Output** screen. Similarly, short-term output can be obtained by including a 'ST' pollutant along with a short-term .uai file option, which must also be selected to get short-term output, see Section 3.3.2 for further details.

Table 7.1 summarises the files that are created for output at receptors or on a grid when running the model in ST and LT mode. All output files are in comma-delimited format.

Output required	Receptor	Grids
Short term	*.qst*	*.E01, *.E02, *.E03,...*
Long term	*.qlt*	*.elt*

Table 7.1 – Output file options

Table 7.2 gives details of the ST receptor output file format, Table 7.3 gives details of the LT receptor output file format, and Table 7.4 gives details of the gridded output file format (ST and LT).

Column Heading	Description of data
Year	Year
Day	Julian day
Hour	Hour of day (0-23)
Receptor name	Receptor name, as specified in the model interface or *.asp* file
X(m)	x-location of output point
Y(m)	y-location of output point
Z(m)	z-location of output point
Temp (°C)	Temperature in degrees Celsius
Temp Perturbation (°C)	Temperature perturbation in degrees Celsius
Specific Humidity (kg/kg)	Specific humidity, in kg of water per kg of air
Specific Humidity Perturbation (kg/kg)	Specific humidity perturbation in kg of water per kg of air

Table 7.2 – Format description of the ST receptor output files (*.qst*)

Short-term output options are specified in the **SURFRESISTOUT_ST** section of the *.uai* file. It is possible for the user to specify if receptor point and/or gridded output are required. If gridded output is required, then the number of met lines for which output is required can be

specified. Please refer to Section 3.3.2 for full details.

Whenever long-term output is selected in the **Output** screen of the ADMS-Urban interface, model predictions of temperature and humidity averaged over all met lines are output at both receptor and gridded locations.

Column Heading	Description of data
Receptor name	Receptor name, as specified in the model interface or *.asp* file
X(m)	x-location of output point
Y(m)	y-location of output point
Z(m)	z-location of output point
Temp (°C)	Temperature in degrees Celsius
Temp Perturbation (°C)	Temperature perturbation in degrees Celsius
Specific Humidity (kg/kg)	Specific humidity in kg of water per kg of air
Specific Humidity Perturbation (kg/kg)	Specific humidity perturbation in kg of water per kg of air

Table 7.3 – Format description of the LT receptor output files (*.qlt*)

Column Heading	Description of data
X(m)	x-location of gridded output point
Y(m)	y-location of gridded output point
Z(m)	z-location of gridded output point
Temp (°C)	Temperature in degrees Celsius
Temp Perturbation (°C)	Temperature perturbation in degrees Celsius
Specific Humidity (kg/kg)	Specific humidity in kg of water per kg of air
Specific Humidity Perturbation (kg/kg)	Specific humidity perturbation in kg of water per kg of air

Table 7.4 – Format description of the ST and LT gridded output files (*.E**, *.elt*)

7.2.1 Short-term output with invalid met lines

Currently, when short-term output is required, and there are some invalid hours of meteorological data in the *.met* file, these hours will be omitted from the *.qst* file (for receptor output), and the *.E*** file will not be created for that met. line. It is important therefore to be aware of any invalid met. lines that may be included in the meteorological data prior to inspection of temperature and humidity model output.

7.3 Meteorological data output

When modelling temperature and humidity perturbations using ADMS-Urban, a number of additional outputs are written to the .mop file. Five new parameters are added to the `INPUT_DATA:` section and three new parameters are added to the `PROCESSED_DATA:` section; these additional parameters are summarised in Table 7.5 and Table 7.6 respectively.

Parameter name in *.mop* file	Parameter description
QSTAR	Value of net radiation (W/m²) as entered in the *.met* file when running the model with hourly heat flux data. Set equal to -999 when running with basic met data.
GROUNDHEATFLUX	Value of ground heat flux (W/m²) as entered in the *.met* file when running the model with hourly heat flux data. Set equal to -999 when running with basic met data.
GROUNDHEATFLUX/QSTAR	Value of ratio of ground heat flux to net radiation. Used for all calculations with basic met data, but only used with input hourly heat flux data for invalid met lines.
Z0S/Z0	Ratio of the roughness length governing the transfer of heat to the roughness length governing momentum transfer. A model default of 0.2 is usually used, but users can enter this parameter in the *.met* file.
RSU	The upwind value of surface resistance to evaporation parameter. Only calculated with basic met data, where it is used in the calculation of the modified Priestley-Taylor parameter for the apportionment between surface sensible and latent heat flux.

**Table 7.5** – Additional meteorological parameters in the `INPUT_DATA:` section of the *.mop* file

Parameter name in *.mop* file	Parameter description
QSTAR	Value of net radiation (W/m²) as entered in the *.met* file when inputting hourly heat flux parameters, and calculated by the model when running with basic met data.
RSU	The upwind value of surface resistance to evaporation parameter. With basic met input, equal to the value in the INPUT_DATA: section, with hourly heat fluxes input, derived from the Penman-Monteith equation, but not actually used in the calculations.
ALPHA	Modified Priestley-Taylor parameter. With basic met, this is the value derived from the upwind value of the surface resistance to evaporation parameter, with hourly heat fluxes entered, it is a basic estimate used only in the calculations of boundary layer growth.

Table 7.6 – Additional meteorological parameters in the `PROCESSED_DATA:` section of the *.mop* file
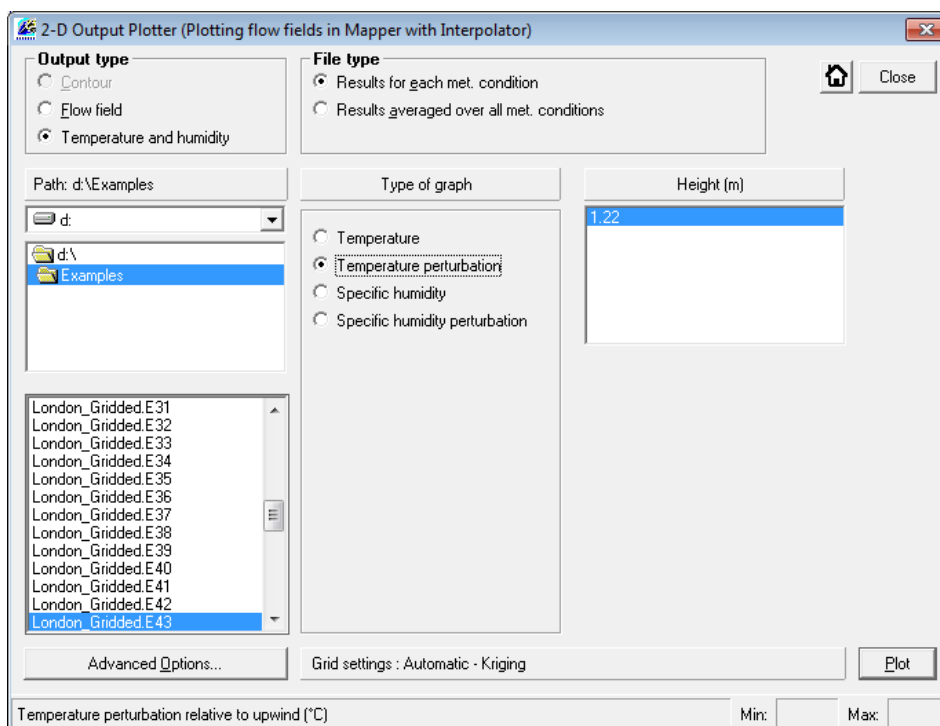
7.4 Contour plots in the ADMS Mapper

For results over an output grid it is useful to view the results as a contour plot. The ADMS Mapper can be used to create and view a contour plot of the results. The following steps describe how to create a contour plot of the temperature perturbation.

Step 1   Launch the ADMS Mapper from the ADMS-Urban interface by selecting **Utilities, ADMS Mapper**. All the input contained in ADMS-Urban interface will be automatically loaded into the ADMS Mapper.

Step 2   A background map can be added to the view using the **Add background map** option or using the **Add layer** option to select a web map service (WMS). For more details of adding background maps from a WMS refer to Section 5.3 of the ADMS Mapper user guide.
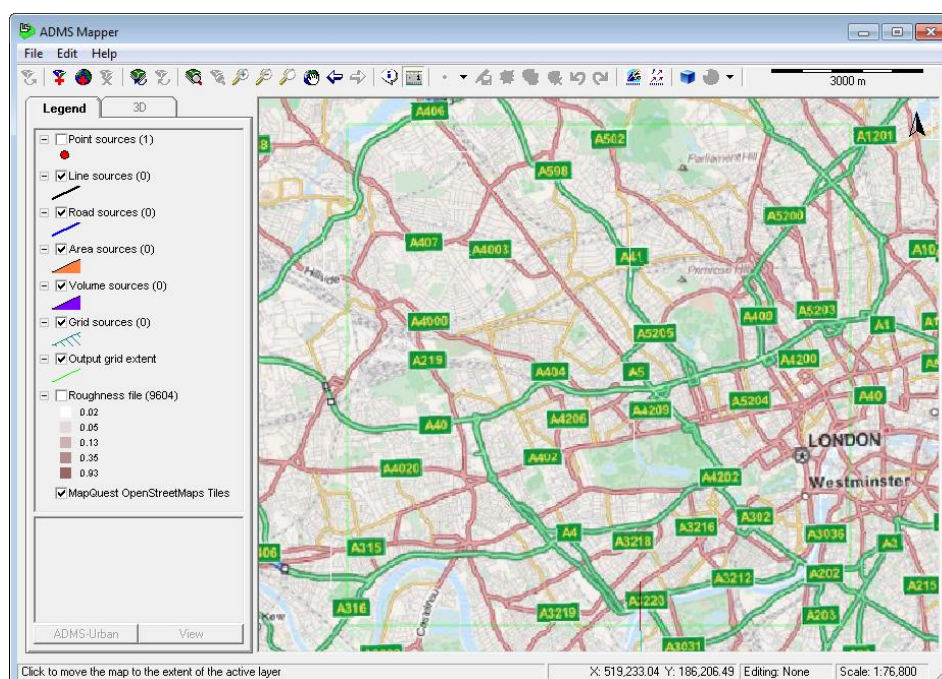

Figure 7.1 – The ADMS Mapper showing the WMS background map (© OpenStreetMap contributors).

Step 3   The contour plot of results can now be created. Launch the **Flow field** plotter from the ADMS Mapper interface, via the button . The flow field plotter is shown in **Figure 7.2**.

Step 4   For a short term average, there is a separate output file for each modelled hour over the gridded receptor area. The files take the same filename as the input *.upl* file with the extension *.E01* for hour 1, *.E02* for hour 2 etc. Select the results file you want to plot, the **Type of graph**, for example **Temperature perturbation**, and the **Height (m)**. Then press **Plot**. Enter an appropriate name for the grid file to be created when prompted.

Figure 7.2 – The flow field plotter showing data selected for plotting.

Step 5   Once the contour plot has been created in the ADMS Mapper, it can be made transparent to make the background map visible underneath. To do this double-click on the **Legend** entry for the contour plot, this opens the layer properties window shown in **Figure 7.3**. Under the **Layer** tab, adjust the **Transparency** to the required value, a value of 60 allows the background map to be seen clearly.
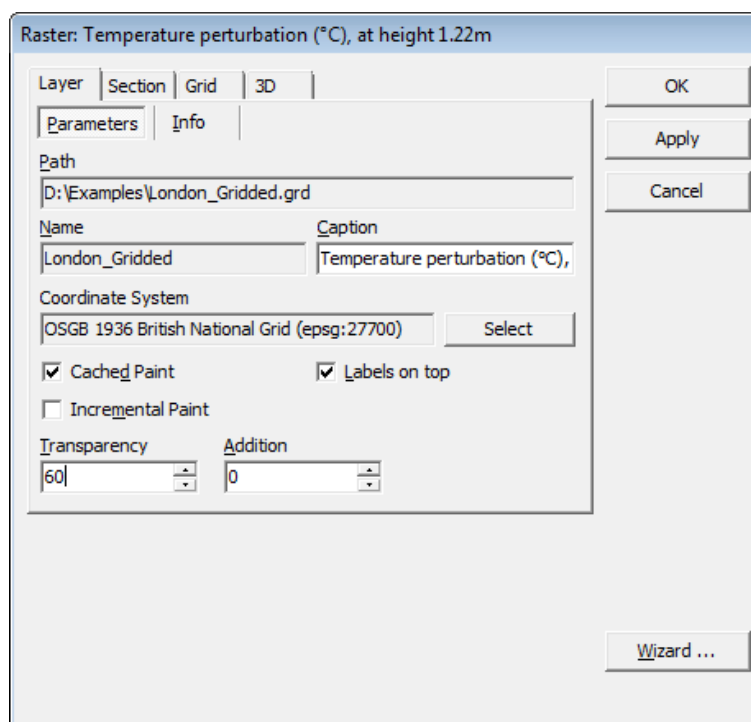
Figure 7.3 –The layer properties window.
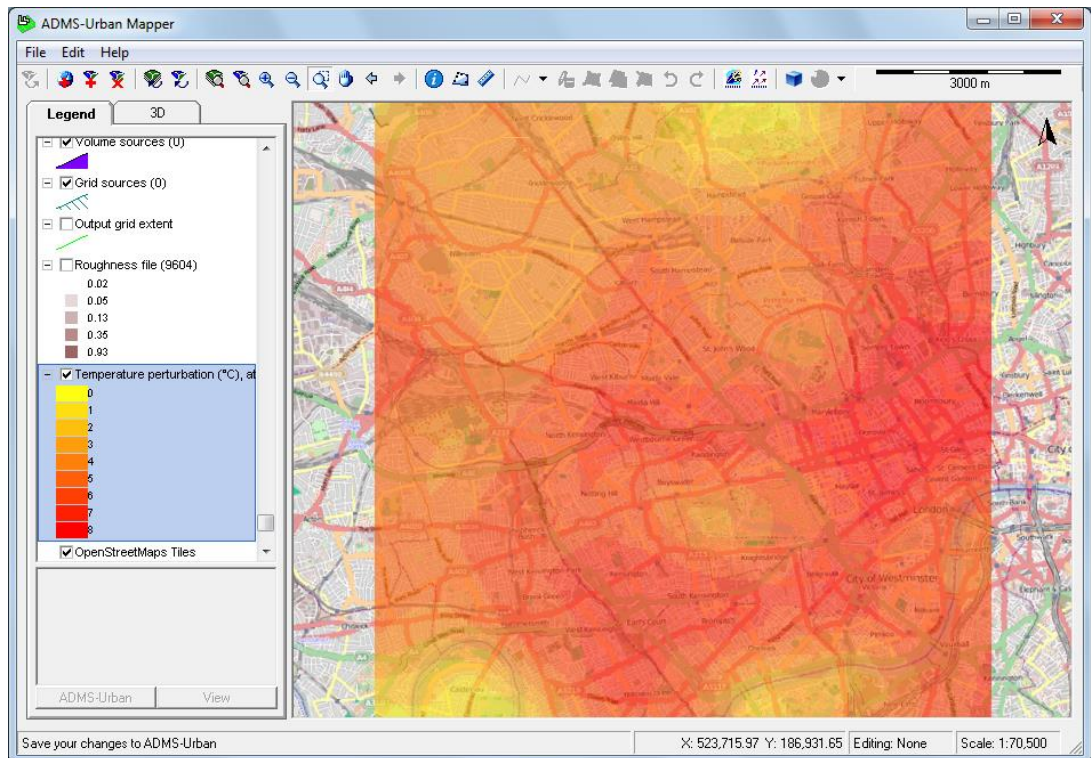
Figure 7.4 –Temperature perturbation plot in the ADMS Mapper (© OpenStreetMap contributors).

SECTION 8 Troubleshooting

When configured correctly, the ADMS-Urban temperature and humidity model is a robust tool that can be used to calculate local climate variations resulting from urbanisation. However, as would be expected, model outputs are sensitive to input parameters, and the model may predict unexpected values if the model has been configured incorrectly. This section provides guidance on how to investigate possible model issues. The majority of these issues relate to how model inputs can be revised to avoid the model predicting unphysically large temperature perturbations (Section 8.1). Other issues discussed include: ways of ensuring that the spatial variation of model output is sufficiently well resolved (Section 8.2); long model run times (Section 8.3) and methods for investigating inaccurate predictions of the diurnal variation of temperature perturbations (Section 8.4).

8.1   Model predicts extreme temperature perturbations

When evaluating model output values, it is highly recommended that the range of values is assessed. Model inputs should be reviewed if temperature perturbations are unexpectedly high (greater than around $10°C^3$). If temperature perturbations are high throughout the model domain, there may be issues with the minimum wind speed value used as input (Section 8.1.1), the atmospheric stability (Section 8.1.2) or the specified output height (Section 8.1.3). If temperature perturbations are high over water expanses, there may be issues with the input values of the surface resistance to evaporation values (Section 8.1.4) or user-defined aerodynamic resistance parameters should be introduced (Section 8.1.5). If temperature perturbations are large at dawn and dusk, it may be necessary to restrict the inner layer depth (Section 8.1.6). Finally, if there are unexpected values of temperature in highly built up areas, the surface roughness parameters should be reviewed (Section 8.1.7)

8.1.1   Minimum input wind speed

The ADMS-Urban Temperature and Humidity model includes some restrictions that relate to the ADMS-Urban *air quality* model. One of these restrictions relates to the minimum value of input wind speed: for air dispersion modelling, the Gaussian plume formulation becomes less valid when wind speeds are very low so, by default, a minimum value of 0.75 m/s is applied to the 10 m wind speed values entered via the *.met* file.

This restriction is not necessary when running the ADMS-Urban Temperature and Humidity model. Indeed, it is important that the model accounts for low wind speeds to some extent because high temperature episodes often occur during stagnation conditions. Users are able to decrease the minimum 10 m wind speed modelled by including the meteorological parameter U10min in the *.met* file (Section 4). A value of 0.5 m/s is recommended for U10min, although results of sensitivity testing using values as low as 0.25 m/s may be of interest.

---

[3] Excluding the effects of terrain elevation

However, it is important not to reduce the value of U10min much below 0.25 m/s because temperature perturbations may become too large when the friction velocity, *u*,* becomes very small.

8.1.2 Meteorological stability

In urban areas, meteorological conditions do not become very stable even at night due to the high levels of atmospheric mixing resulting from the presence of buildings and the urban heat island. The Monin-Obukhov length parameter relates to atmospheric stability and a minimum value should be set to ensure that the meteorological conditions never become too stable (Step 3 in Section 3.2).

8.1.3 Output height

There are two aspects to consider when specifying the height of modelled temperature and humidity output:

- Firstly, consider the height at which temperature and humidity measurements are taken. When recorded alongside other meteorological parameters such as wind speed and wind direction, it is common for temperature measurements to be at 'screen height' which is approximately 1.22 m. Less standardised temperature measurements may be at any height, but usually monitoring equipment is located at least one metre or so above the ground.

- Secondly, the model formulation does not allow for accurate calculations of model output at heights less than the local surface roughness length. The surface roughness length varies spatially, whereas the model output height is fixed. Consequently, the user is required to enter model output heights that are greater than the *maximum* surface roughness value entered in the *.ruf* file (refer to Section 8.1.7 for related information).

If measurement heights are lower than the maximum surface roughness, users should consider both reducing the maximum surface roughness value (Section 8.1.7) and elevating the model output height; comparisons of modelled and measured temperatures at differing heights are still informative.

8.1.4 Surface resistance to evaporation parameter input values

The underlying ADMS-Urban model equations relating to the variations in surface moisture flux are singular in the limit as the surface resistance to evaporation parameter approaches zero, the value for water (Table 5.4); this is because in this limit other physical processes that are not directly accounted for in the model become important. Although the equations have been formulated to allow for this singularity (refer to the model theory described in Section 10.1), temperature and humidity perturbations may still be over-predicted when low values of the surface resistance parameter are entered. Therefore, a minimum value of 10 s/m is recommended, although sensitivity testing for particular model configurations may result in lower values being used.

8.1.5 User-defined aerodynamic resistance parameters

The aerodynamic resistance value is used to calculate the limit value applied within the surface moisture calculations to allow for the 'water' limiting case described in Section 8.1.4. The equation for the aerodynamic resistance given in Section 10.1 is a function of the surface roughness parameter. In order for the limiting case to be well defined, it is necessary to ensure that 'water' is approximately 'flat' i.e. is has a very low surface roughness value.

In terms of the model inputs, the surface resistance to evaporation values and surface roughness values are often derived from different sets of source data. Consequently, it may be difficult for the user to ensure that surface roughness parameters are always low over water. A model option is therefore available that enables the user to specify a maximum surface roughness for areas with low surface resistance to evaporation (refer to Section 3.3.1). It is recommended that this option is used; default values should be sufficient for the majority of model configurations, although users may find sensitivity testing relating to the maximum surface roughness value of use.

8.1.6 Inner layer depth

The inner layer depth is a length scale that is used in the model formulation. Model testing has demonstrated that predicted temperature perturbations are sensitive to this length scale, particularly at dawn and dusk; restricting this parameter leads to better agreement between model predictions and observed values (Section 3.3.5).

8.1.7 Surface roughness input value ranges

There are a number of ways to approximate the spatial variation of surface roughness lengths within an urban area. A common approach is to process 3D buildings data and apply a standard expression (Lettau, 1969, MacDonald, 1998) that relates the surface roughness to building density properties such as frontal and plan areas. The results of such calculations are sensitive to the cell size over which the calculations are performed, with a wide range of surface roughness values being calculated when small cell sizes are used (500 m or less).

It is important to consider that it is not only the buildings that contribute to the representative surface roughness length within an area: trees and street furniture also generate turbulence. Thus, even if buildings are absent from a particular area, the surface roughness length should not necessarily be set to the very small value which may be the result of direct processing of buildings data; a minimum value of, for instance, 0.1 m should be applied.

In city centres, it is common to have a high density of tall buildings. Some expressions for surface roughness result in high values (>10 m) in these areas, particularly if cell sizes are less than 500 m. Although high surface roughness parameters are sometimes reported in the literature, the ADMS-Urban Temperature and Humidity model does not allow for the extreme values; this is in part due to the restriction that model formulation is not valid at heights below the local roughness length (Section 8.1.3).

Users are referred to Section 5.3.3 for typical surface roughness parameter values that are consistent with the ADMS-Urban formulation, although slightly higher values of surface roughness are acceptable; for instance a maximum value of 2.5 m surface roughness value could be used with an output height of 3 m.

8.2 Spatial variations of temperature are insufficiently resolved

The model calculations are performed at a spatial resolution that relates to the calculation grid setting, which is entered via the **Setup** screen (refer to Section 3.2). The grid scale for calculations is approximately equal to the domain extent divided by the calculation grid setting; for example, using a **Grid resolution** of **128×128** with a domain size of 10 km by 10 km results in a calculation grid cell size of approximately 78 m by 78 m.

In order for spatial features within the model domain to be resolved, the calculation grid resolution must be consistent with the resolution of the input data. Thus for the domain extent and calculation grid resolution mentioned above, it would be appropriate for the model input data to be at a resolution of greater than 50 m or so. If the input data are much finer than this then the calculation grid will not resolve the high-resolution features. In this case, it is recommended that the input data are smoothed to the appropriate resolution prior to input in the model.

If the domain extent is very large, the calculation grid resolution may be increased to **512×512** by manually editing the *.upl* file:

```
&ADMS_PARAMETERS_HIL
HilGridSize       = 5
```

However, if this is done, run times will increase by at least a factor of four relative to the equivalent **256 x 256** run. It is advisable to perform sensitivity testing using low calculation grid resolutions and reserve the fine calculation grid resolution for final model results.

8.3 Long run times

Model run times will increase significantly if anthropogenic heat sources are modelled at high resolution over a large domain. It is advisable to:

- First configure and run the model to account for land use variations;
- Then include anthropogenic heat sources at low resolution (e.g. both buildings and roads included in 1 km or 3 km volume sources), which is likely to require conversion of emissions units from CO_2 to W/m^2; and
- If required, refine the resolution of the anthropogenic heat sources.

Figure 8.1 presents a schematic of how to represent the anthropogenic heat sources from roads and buildings within a selected area.

Model run times also increase with the calculation grid resolution, as discussed in Section 8.2.
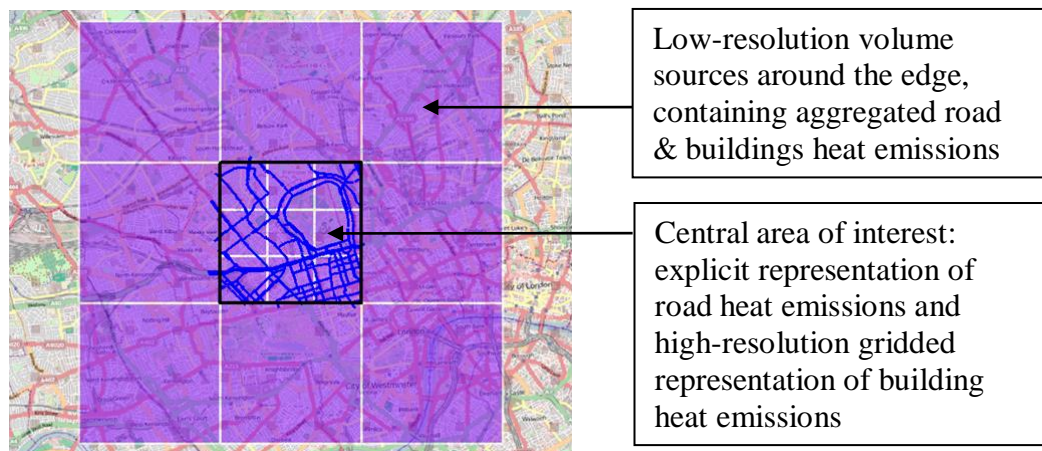
Figure 8.1 – Schematic indicating varying resolution of traffic and building anthropogenic heat sources (© OpenStreetMap contributors)

8.4 Inaccurate diurnal variation of temperature perturbations

There are a number of different approaches to comparing model predictions to measurements. One useful method is to compare average diurnal profiles of temperature perturbations; this is best done seasonally.

Firstly, check that the input meteorological data are in local solar time rather than clock time, if these are not the same; ensure that the measurement data use the same convention.

For city-scale applications of the model, average temperature perturbations relative to upwind temperatures indicate the magnitude of the urban heat island. Typical profiles have a minimum during the day and a maximum in the late afternoon and evening. If the comparisons between modelled and observed profiles are poor, it may be helpful to consider the following:

- Ensure that terrain height effects are accounted for (Section 3.3.3).

- If the diurnal profile of the model does not reduce sufficiently during the day compared to the measurements, consider allowing for the 3D nature of the buildings data in the thermal admittance calculations (see for methodology Aktas *et al.*, 2017).

- If the modelled temperature perturbations are too low overall compared to the measurements consider:

    * Including anthropogenic heat sources in the modelling, if this has not be done already, and

    * Increasing the surface resistance to evaporation parameter in the urban

areas.

- Conversely, if the modelled temperature perturbations are too high overall compared to the measurements consider decreasing the surface resistance to evaporation parameter in the urban area.

- If the diurnal variations of modelled temperature perturbations are out of phase with the measurements, inspect the heat flux terms in the surface energy balance equation, which are output to the *.mop* file: net radiation (QSTAR), surface sensible heat flux (FTHETA0), latent heat flux (LAMBDAE) and the ground heat flux, which may be calculated as the product of QSTAR and GROUNDHEATFLUX/QSTAR. In addition, consider if the measurement data are valid.

- When modelling anthropogenic heat sources, the impact of daylight saving should accounted for (refer to Section 4.1.4 of the ADMS-Urban User Guide for further details).

SECTION 9 Worked examples

In order to help the user to learn how to use the ADMS-Urban Temperature and Humidity model, three worked examples have been set up to cover the main functions of the model. The first two illustrate how to set up scenarios with output at specified receptor points and over a gridded area, how to calculate results under different meteorological conditions, and how to look at the calculated output. The third example demonstrates how anthropogenic heat sources can be modelled.

The *<install_path>\Examples* directory contains premade input files that will be used throughout the three worked examples. This directory also contains the final files from the worked examples for comparison.

You can launch ADMS-Urban in several different ways:

- double-click on the icon for the shortcut created when ADMS-Urban was installed;

- use the Windows **Start** menu and select **Programs, ADMS-Urban**;

- go to the main ADMS-Urban directory *<install_path>* and double-click on the file *adms-urb.exe*;

It is strongly recommended to create a separate directory for setting up and running these examples in order to keep them apart from the examples provided in the *<install_path>\Examples* directory supplied with the model.

New users of the ADMS-Urban Temperature and Humidity model are advised to carry out these worked examples before attempting to set up new runs.

9.1   Example 1: Modelling at specified receptor points

The object of this example is to demonstrate how to set up and run a simple case with specified receptor points and to look at the output available from the ADMS-Urban Temperature & Humidity model.

In particular, this example looks at hourly temperature and humidity model predictions at two different locations in an urban area. One of the receptors is in a park (Hyde Park) and one is a roadside location with a number of buildings (Marylebone Road).
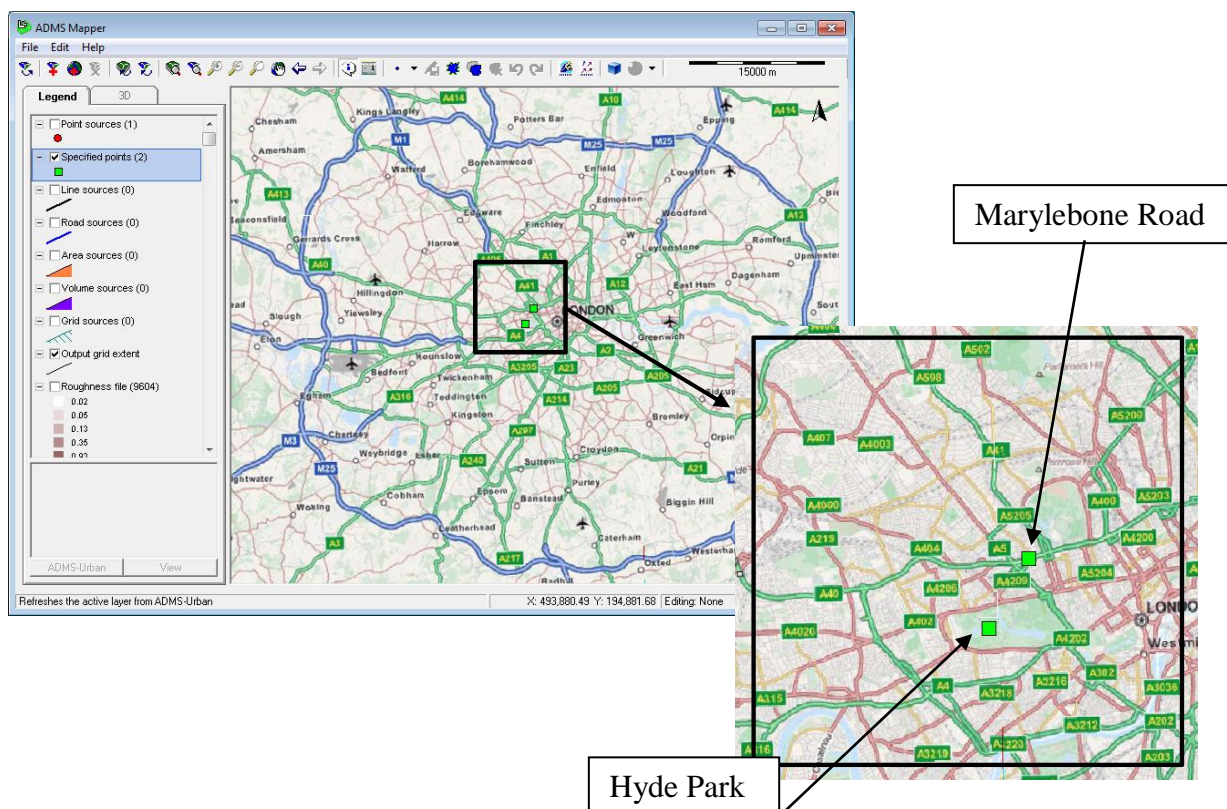
Figure 9.1 – ADMS Mapper showing the modelling domain (London), highlighting the output receptor points (© OpenStreetMap contributors).

9.1.1 Setting up the run

To model the receptor locations, follow the instructions below.

Step 1 Open the ADMS-Urban interface.

Step 2 On the **Setup** screen (Figure 3.2 in the ADMS-Urban User Guide):

Enter **Name of site** and **Name of project** details as appropriate. These are optional, but sensible titles should be entered as they help to differentiate between model runs. The titles will be written out to the log file of the model run. Set the **Coordinate system** to OSGB 1936 British National Grid (epsg: 27700).

Within the **Model options** section of the screen, ensure **Complex terrain** is selected and click **Enter parameters**.... The screen displayed in **Figure 9.3** is shown.

In the **Terrain File (surface elevation)** area of the **Complex terrain** screen, use the **Browse** button to locate the terrain file *London.ter*. Enable the **Surface roughness file** option. Browse to locate the **Surface roughness file** (Section 5.1 describes how to set this up). The roughness file to be used in this calculation is *London.ruf*. Select a **Grid resolution** of **128 x 128** (refer to Section 4.8.2 of the ADMS-Urban User Guide for further details). Click **OK**.
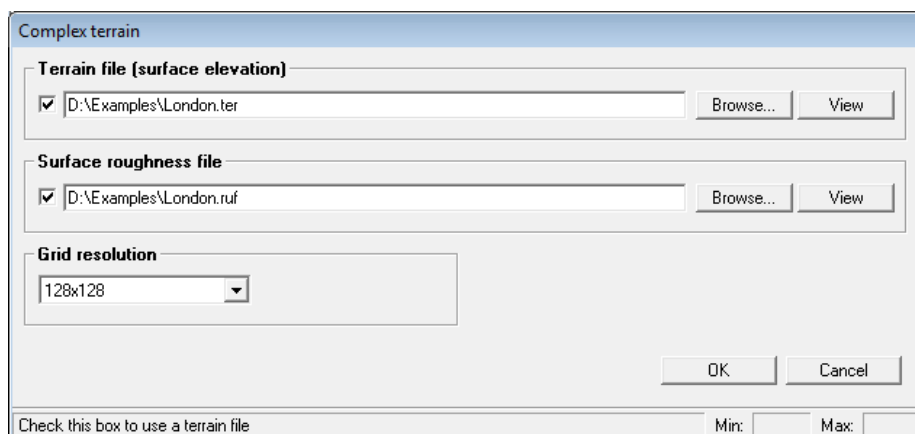
Figure 9.2 – **Complex terrain** options screen.

Step 3 On the **Source** screen (Figure 3.5 in the ADMS-Urban User Guide):

A 'dummy' source is required in order to run the model, which should be located around the centre of the modelling domain. In the **Source** screen select 'Industrial sources' from the list and click on **New** to enter a new source. Edit the source characteristics using the parameters shown in **Table 9.1**.

Name	Default point
Height (m)	0
Diameter (m)	1
Exit velocity (m/s)	0
Temperature (°C)	15
Stack location (m)	530000, 180000
NO$_x$ Emission rate (g/s)	1

Table 9.1 – Dummy source input parameters

Step 4 On the **Meteorology** screen (Figure 3.18 in the ADMS-Urban User Guide):

In the **Site data** area, enter the **Latitude** as 51.5 degrees, and the **Surface roughness** as 0.5 m. In the **Dispersion site** section, ensure **Use advanced options** is selected, and click on **Data...**. On the **Advanced dispersion site data** screen, ensure **Enter value** is selected in the **Surface albedo** and **Minimum Monin-Obukhov length** sections, and enter the values 0.14 and 30 m respectively. Please refer to Section 3.3.2 of the ADMS-Urban User Guide for an explanation of the use of these parameters within the model. Click **OK**.

In the **Met. measurement site** section, select to **Use dispersion site value** of **Surface roughness (m)**, ensure **Use advanced options** is selected, and click on **Data...**. Select **Use dispersion site value** for all three parameters.

In the **Met. data** section, select **From file**, then **Browse...** to locate the example *.met* file, *London2012_4days.met* (refer to Section 4 for further

details on using *.met* files in temperature and humidity model runs).

Enter the **Height of recorded wind (m)** as 10 m, tick the **Met. data are in sectors of (degrees)** box (10 degrees) and tick the **Met. data are hourly sequential** box. Please refer to Section 3.3.3 of the ADMS-Urban User Guide for details of these and other model options that may be appropriate.

Step 5   On the **Grids** screen (Figure 3.27 in the ADMS-Urban User Guide):

In this example temperature and humidity output are required at two receptor locations. Choose to output results at **Specified points**, and add two receptors by clicking **New** twice. Put one receptor in a green area such as Hyde Park (526500, 180200), and one in a built up area such as Marylebone Road (527434, 181828). The receptors should be at a height of 3 m.

Note: The height of output points must be above the roughness length in order to give valid output values.
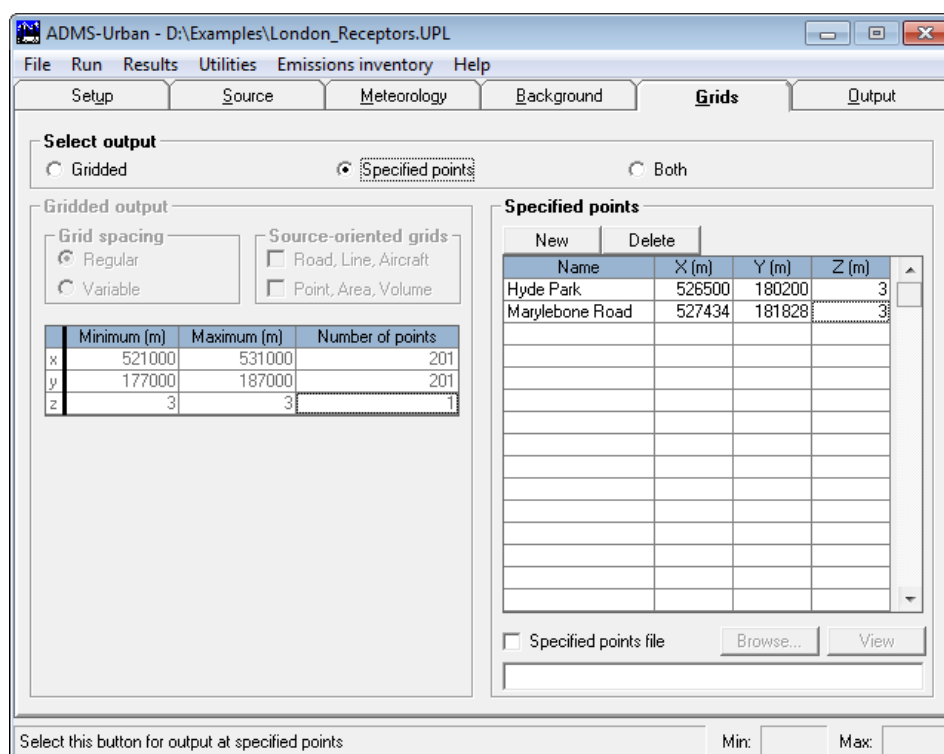
Figure 9.3 – The **Grids** screen showing chosen specified point locations

Step 6   On the **Output** screen (Figure 3.32 in the ADMS-Urban User Guide):

Only short term (ST) output is required for this model run, to ensure that results are generated for every hour of meteorological data input into the model.

Add a **New** line to the **Pollutant output** table. Specify a short-term (**ST**) run, calculating 1-hour averages of NO_x with the units for output as $\mu g/m^3$.

Step 7   From the ADMS-Urban interface, select **File, Save as**... and save the file

with a suitable name, such as *London_receptors.upl*.

Step 8 On the Setup tab, tick the box beside the **Additional input file** option, and press the **Edit** button to start the **ADMS Temperature and Humidity additional input file editor**.

Step 9 Enable the **Short-term output** option in the additional input file editor. Select the option **Output at specified points.**
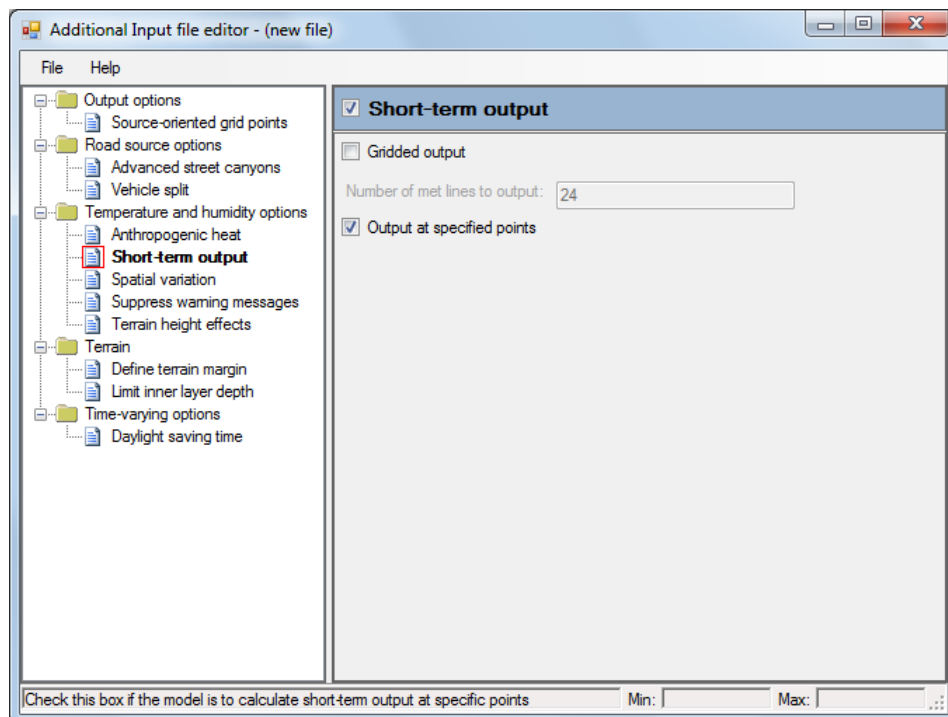
Figure 9.4 – The **ADMS Temperature and Humidity additional input file editor** screen showing **Short-term output** options

Step 10 Select the **Spatial variation** option. In this section of the additional input file editor, all the files containing spatially varying land use or heat flux data are specified. All the files named below can be found in your *<Examples>* directory. Enable the **Spatial variation** option, and then enter the following:

- Specify the **Full Path to surface resistance to evaporation data file** as *London2012.evp*
- Set the type of input met data to **Basic**
- Enable **Perform net heating calculations**, using the **Building volume, thermal admittance and albedo** mode
- Specify the **Full Path to normalised buildings volume data file** as *London2012.nbv*
- Specify the **Full Path to thermal admittance data file** as *London2012.thc*
- Specify the **Full Path to albedo data file** as *London2012.alb*
- Set the **Land use mode** to **Urban**
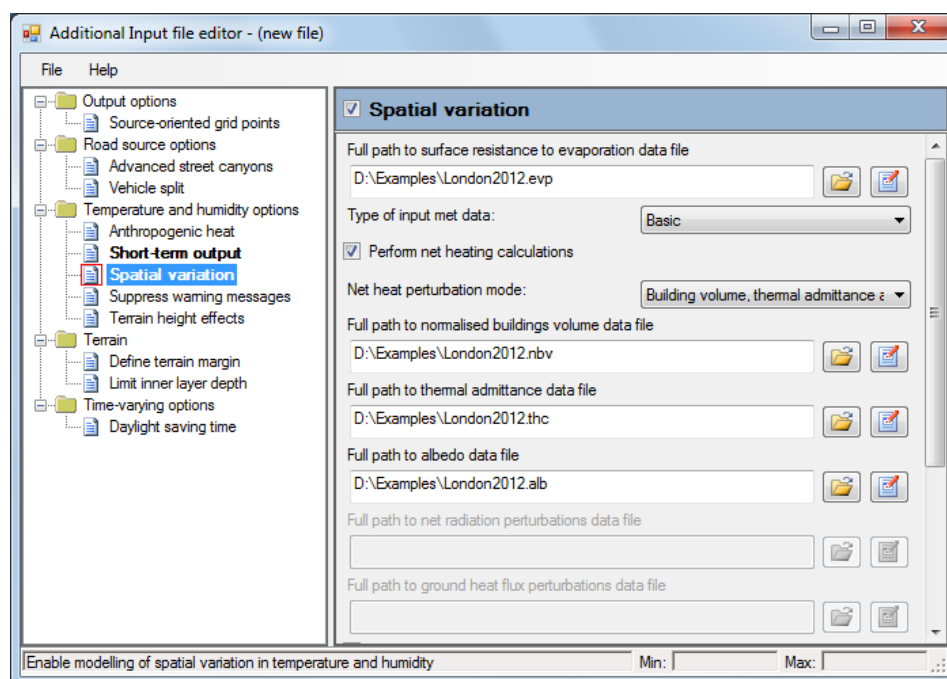
Figure 9.5 – The **ADMS Temperature and Humidity additional input file editor** screen showing chosen **Spatial variation** options

Step 11 On the **Terrain height effects** screen enable the **Include terrain height effects** option in the additional input file editor. The terrain heights for the meteorological stations can be specified either by referencing locations in the terrain file, or by specifying terrain heights directly. As some of the met. stations lie outside the area covered by the terrain file, terrain heights must be specified directly.

Set the Met measurement site information to **Terrain height** and the Number of met measurement sites to **Multiple (by wind sector)**, as multiple met. sites were used to represent upwind conditions for all wind directions.

Set the wind direction sectors and associated met site terrain heights given in **Figure 9.6**.

Start Phi	End Phi	Terrain height (m)
312	35	128
35	134	3
134	199	170
199	259	38
259	312	204

Table 9.2 – Met station wind direction sectors and terrain heights
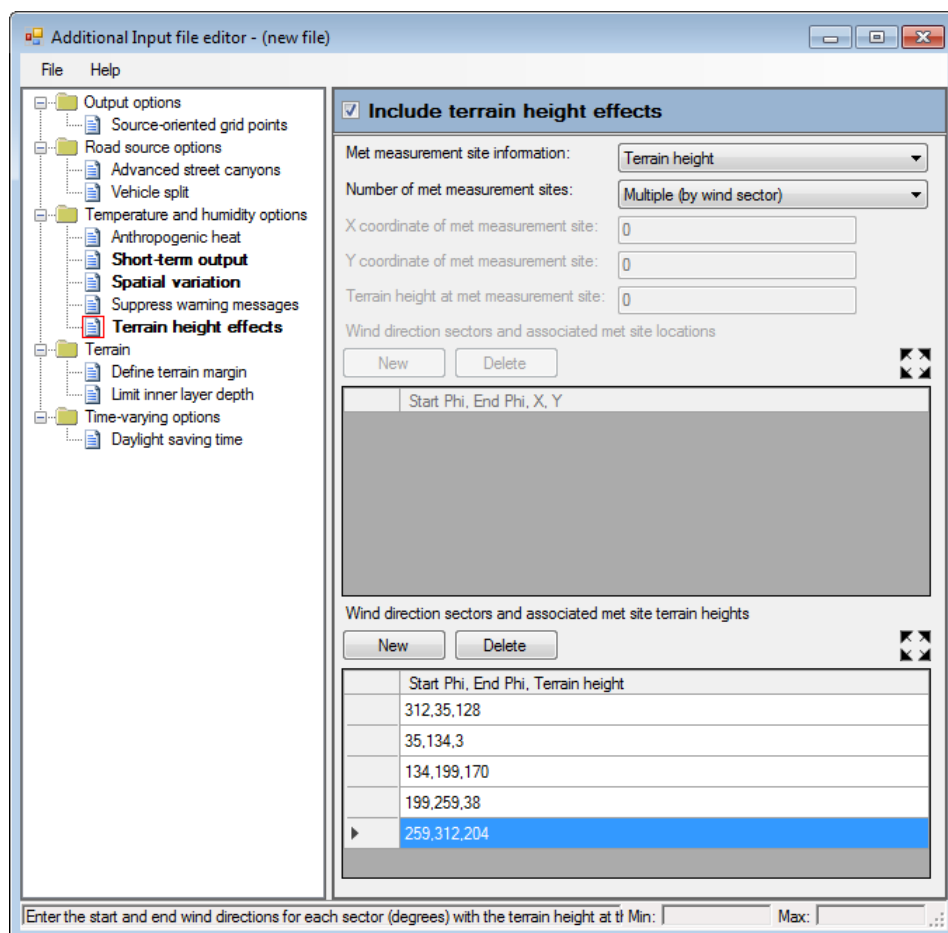
Figure 9.6 – The **Terrain height effects** options

Step 12 On the **Limit inner layer depth** screen, enable the **Set inner layer depth upper limit** option in the additional input file editor. Set the **Fraction of boundary layer height** to 1, and the **Fixed depth** to 50 m. These settings will avoid extreme values in the results.
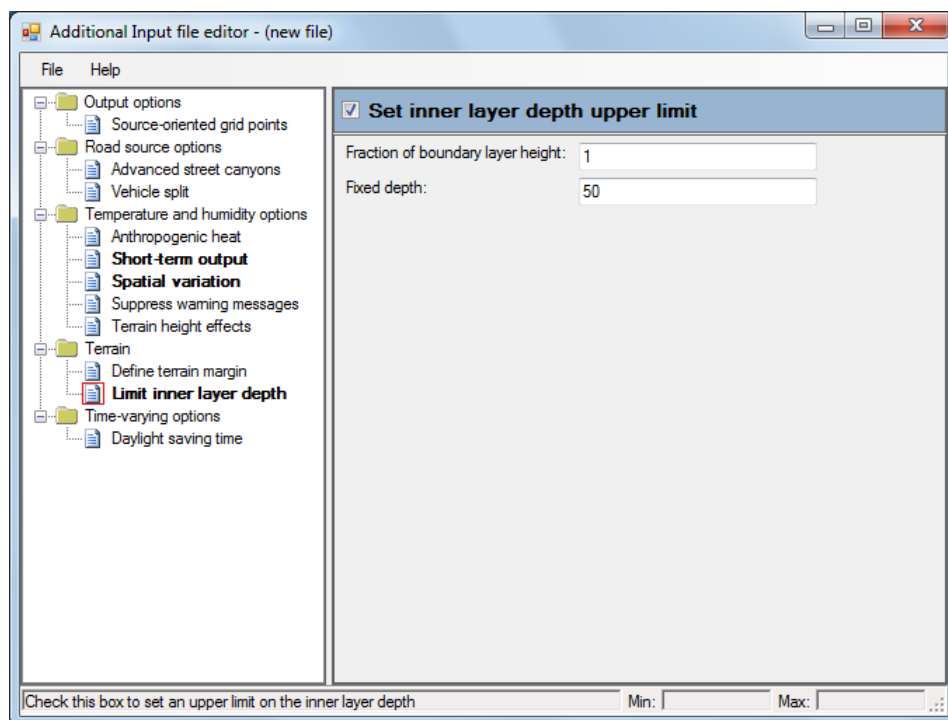
Figure 9.7 – The **Limit inner layer depth** screen showing chosen options

Step 13 All the data required for the additional input file has now been entered, select **File, Save as**... and save the file with a suitable name, such as *London_Receptors.uai*. Close the additional input file editor, and in the **Setup** screen of ADMS-Urban browse to enter the name of the additional input file you have created.

Step 14 From the ADMS-Urban interface, select **File, Save.**

Step 15 It is a good idea to check the locations of your sources, output grid and terrain data before starting a run. From the ADMS-Urban interface, go to **Utilities, ADMS Mapper** to view the locations of all your input data, as shown in **Figure 9.8**.
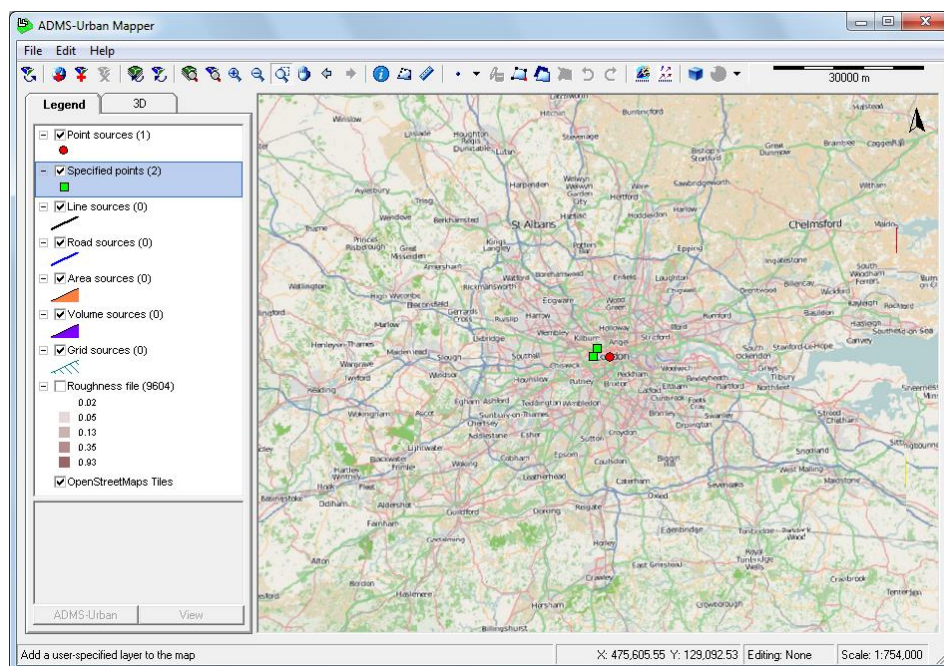
Figure 9.8 – The ADMS Mapper showing input data (© OpenStreetMap contributors)

A background map may be added to the Mapper, using the **Add background map** *option.*

Step 16 Select **ADMS-Urban** from the **Run** menu to run the model.

The run will only take a few minutes for this example. A Run window similar to Figure 9.9 will appear. The file name is shown in the title bar of the window. The first messages to appear on the screen are related to the licence details for the model, followed by messages related to the meteorological data.
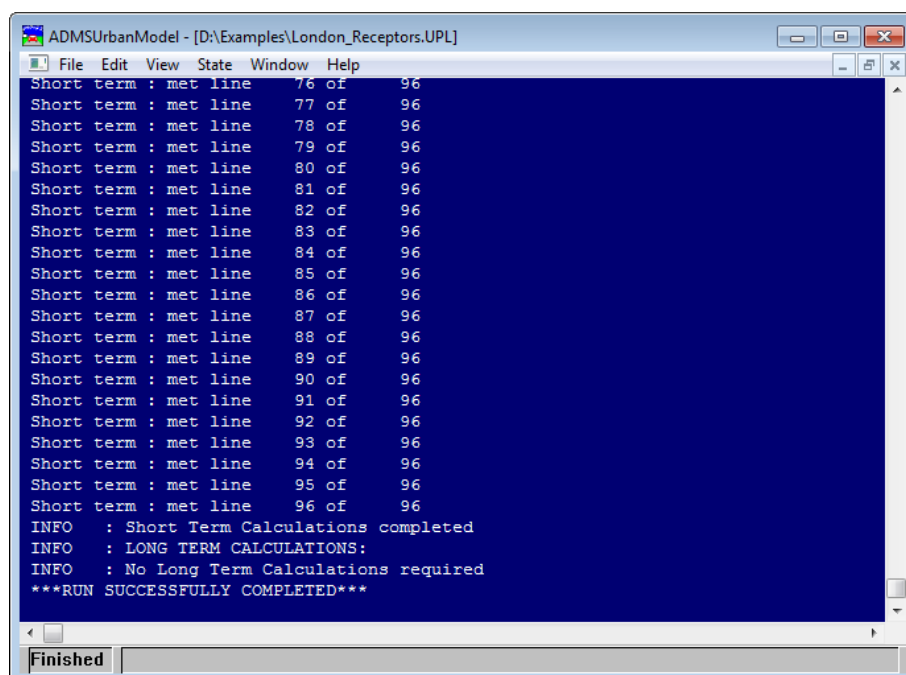
Figure 9.9 – The run window

Step 17 At the end of the run the dialogue box shown in **Figure 9.10** will appear. This means that the run has finished.
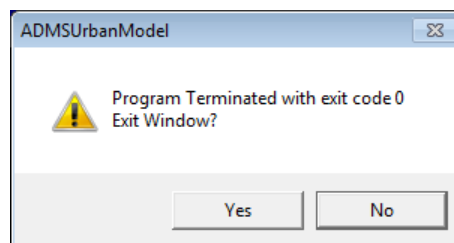
Figure 9.10 – The end-of-run dialog box

9.1.2 Viewing output results

For short-term averages at specified points it is usual to view the results numerically and produce time series plots of the results.

A number of numerical output files are created for each run. These numerical files can be viewed by clicking on the **Results, Numerical**... menu command. This automatically opens an editor on your machine such as Notepad, WordPad or Microsoft Excel and gives an **Open** dialogue box listing the output files that are available for this run.

Users may find the files easiest to read when opened in Excel.

The temperature and humidity results are contained in a file with the extension *.qst*. An example of a numerical output file is shown in **Figure 9.11** below. The file contains the absolute temperature, humidity and their perturbations from upwind values at the receptor points for each meteorological data line.

**Figure 9.11** − Example *.qst* file viewed numerically.

The results in the *.qst* file can be sorted and plotted to produce time series plots of

the output parameters of interest. **Figure 9.12** shows the temperature perturbation from the ambient temperature for the two receptor points modelled in Section 9.1.1.
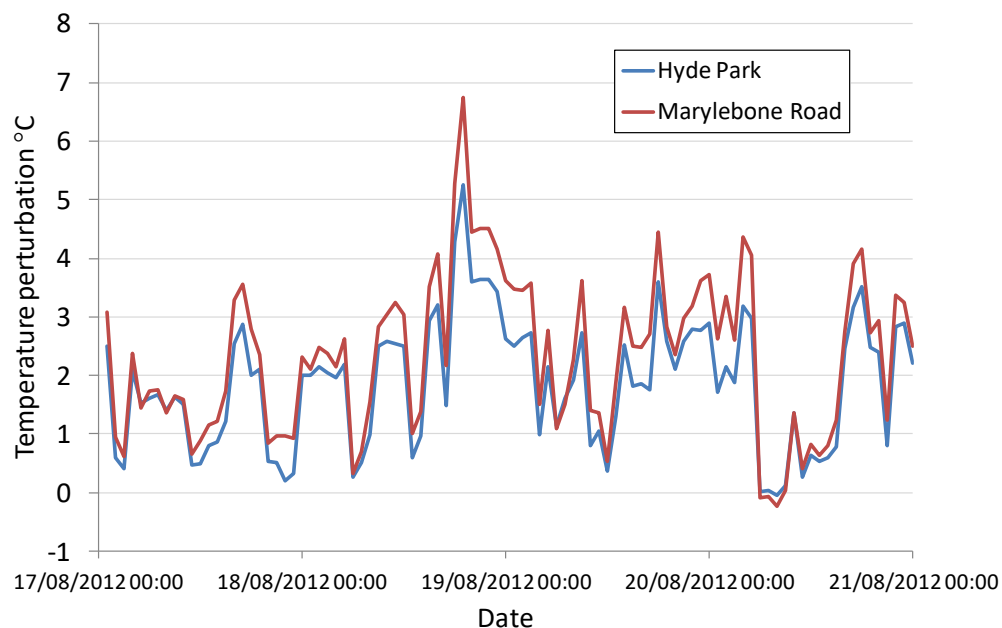
Figure 9.12 – Temperature perturbation calculated at the two modelled receptor points.

Figure 9.12 shows that in the more built up area, Marylebone Road, the temperatures are higher than over the green area at Hyde Park.
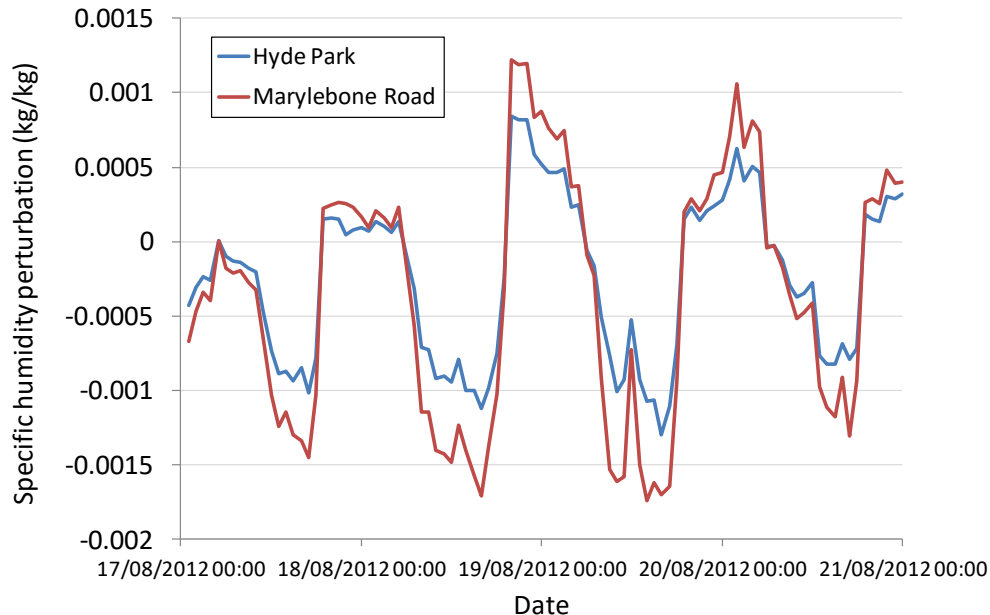

Figure 9.13 – Humidity perturbation calculated at the two modelled receptor points.

Figure 9.13 shows the humidity perturbation calculated at the two receptor points.

9.2 Example 2: Modelling a contour region

The previous example looked at temperature and humidity perturbations at discrete receptor points. Now, we will calculate the perturbations over a continuous region of a city, as shown in **Figure 9.14**.
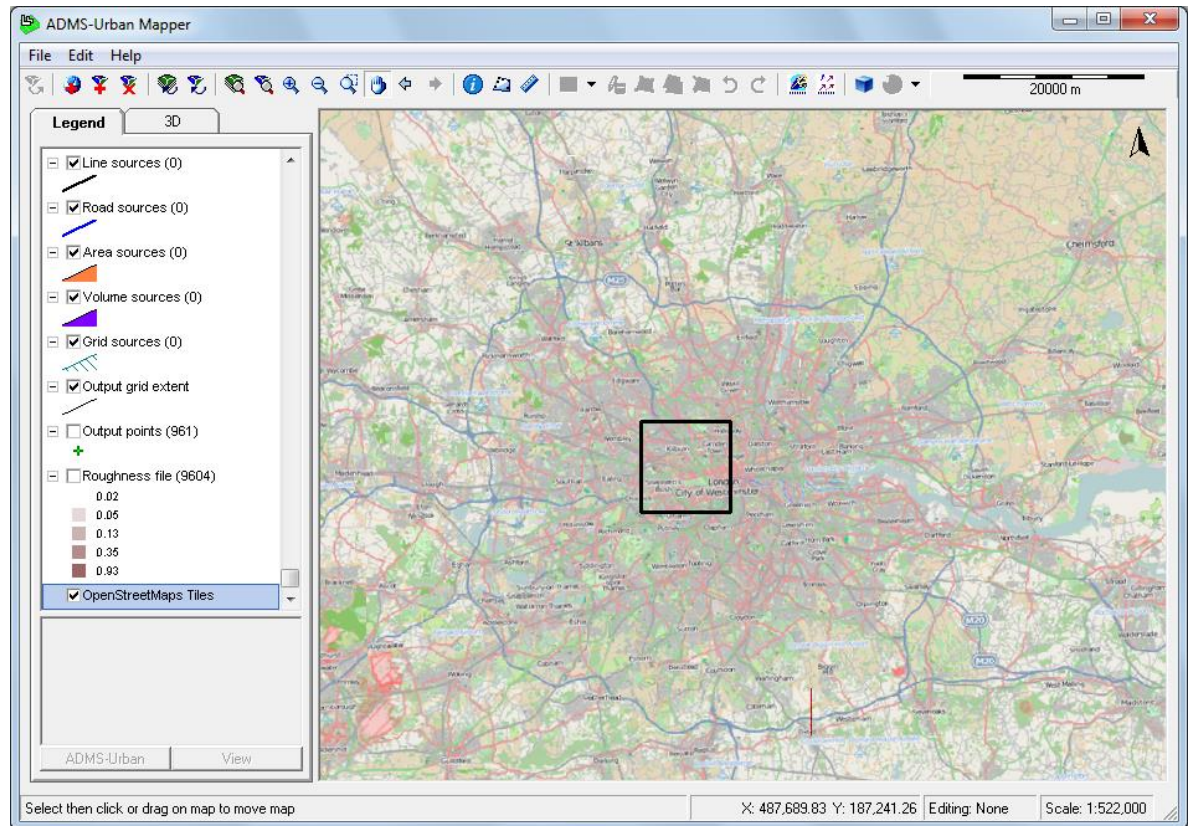
Figure 9.14– ADMS-Urban Mapper showing the model output domain, highlighted by the black box(© OpenStreetMap contributors)

### 9.2.1 Setting up the run

The file set up in Example 1 will be used as the starting point, and the output grid options changed to calculate the results over a regular Cartesian grid.

To set up the example, proceed as follows.

Step 1 Open ADMS-Urban and click on **File, Open**... and browse to the previously saved example, *London_Receptors.upl*. Save this file with a new name by selecting **File, Save As**... and choose an appropriate name, such as *London_Contour.upl*.

Step 2 Firstly, a change in required in the *.uai* file. Open the *London_Receptors.uai* file in the editor by selecting **Edit** in the **Additional input file** section of the **Setup** tab of ADMS-Urban. Save the *.uai* with a new name by selecting **File, Save As**... and choose an appropriate name, such as *London_Contour.uai*.

Step 3 In the **Additional Input file editor**, go to the **Short-term output** section and check the box **Gridded Output**, enter the number of met lines to output as 48, and uncheck the box **Output at specified points**. Select **File, Save** to save the additional input file and close the editor.
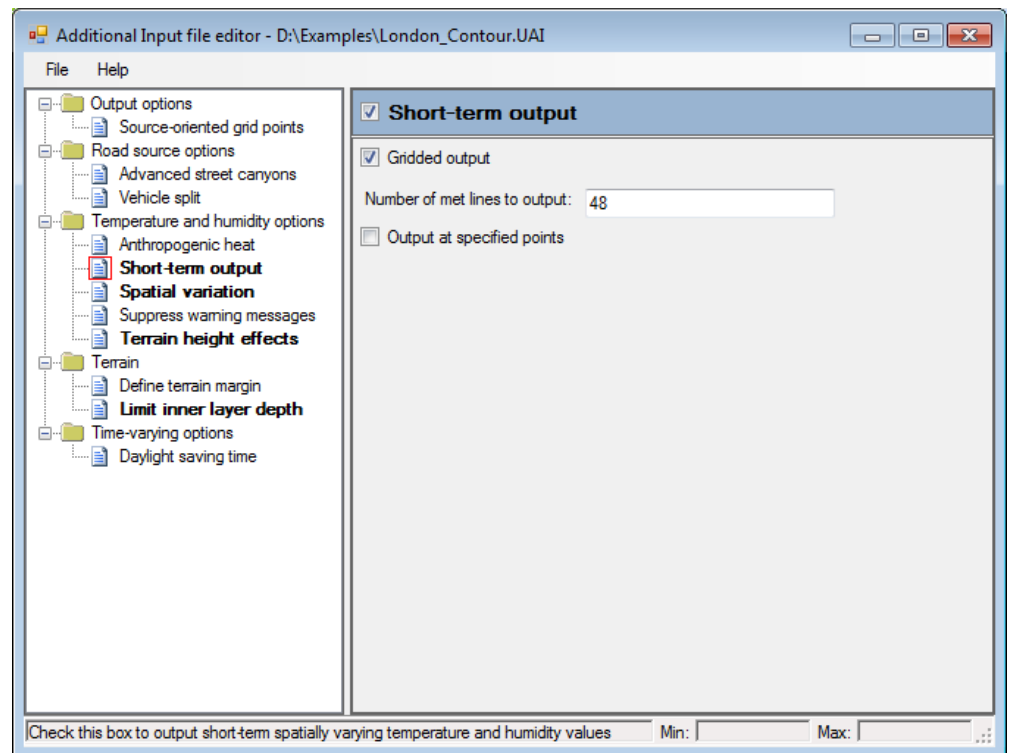

Figure 9.15 – Additional input file settings for the gridded output run.

Step 4 In the **Additional input file** section of the **Setup** tab of ADMS-Urban select **Browse**... to locate the newly created additional input file.

Step 5 Next, select the **Grids** tab in ADMS-Urban.

Step 6 Under **Select Output**, select **Gridded** output points with **Regular** grid spacing. The grid will cover a 10 km by 10 km grid, with a grid spacing of 50 m in each direction. Enter the minimum and maximum grid coordinates, as shown in **Figure 9.16**, with 201 points in both the x and y directions. The height of the receptor grid should be set to 3 m.

The height of output points must be above the roughness length in order to give valid output values.
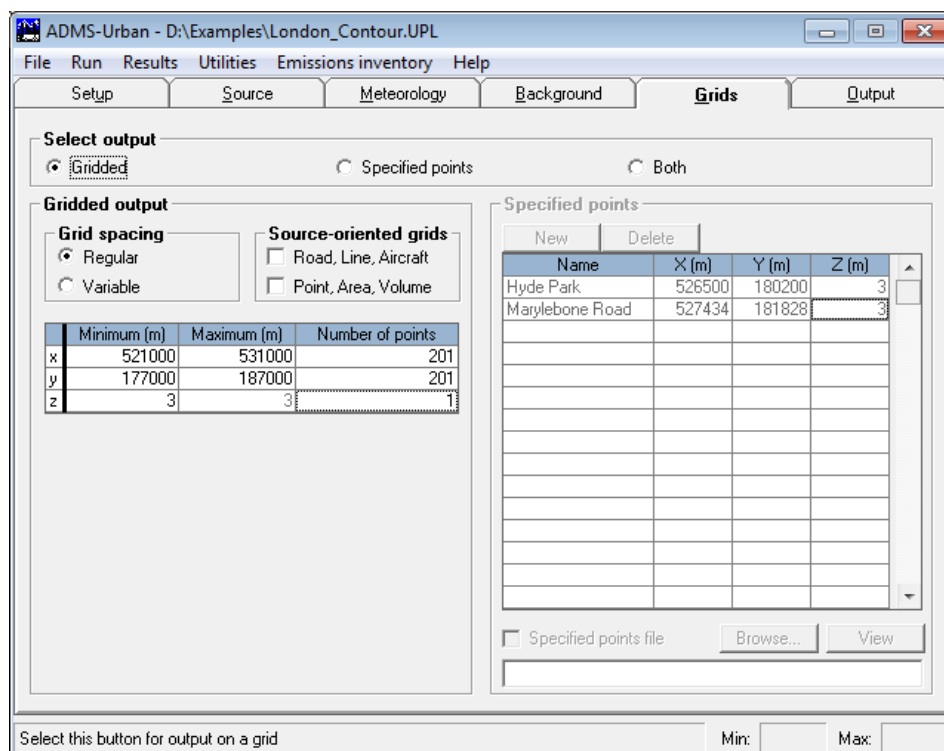
Figure 9.16 – The **Grids** screen showing the required input.

> **Step 7** All the required changes have now been made, select **File, Save**. Then run the model by selecting **Run, ADMS-Urban**.

9.2.2 Viewing output results

Follow the steps given in Section 7.4 to create a contour plot of the temperature perturbation over the area modelled in Section 9.2.1. In this example we will plot the temperature perturbation for 6pm on the 18th August 2012. The results for this hour of met data are contained in the file *London_Contour.E42*, as this particular hour is the 42nd in the met file used in the example. Enter an appropriate name for the grid file to be created when prompted, such as *London_Contour.grd*.

Figure 9.17 shows that the model predicts an increase in temperature throughout the model domain, with the temperature perturbations within parks lower than those seen in built-up areas.
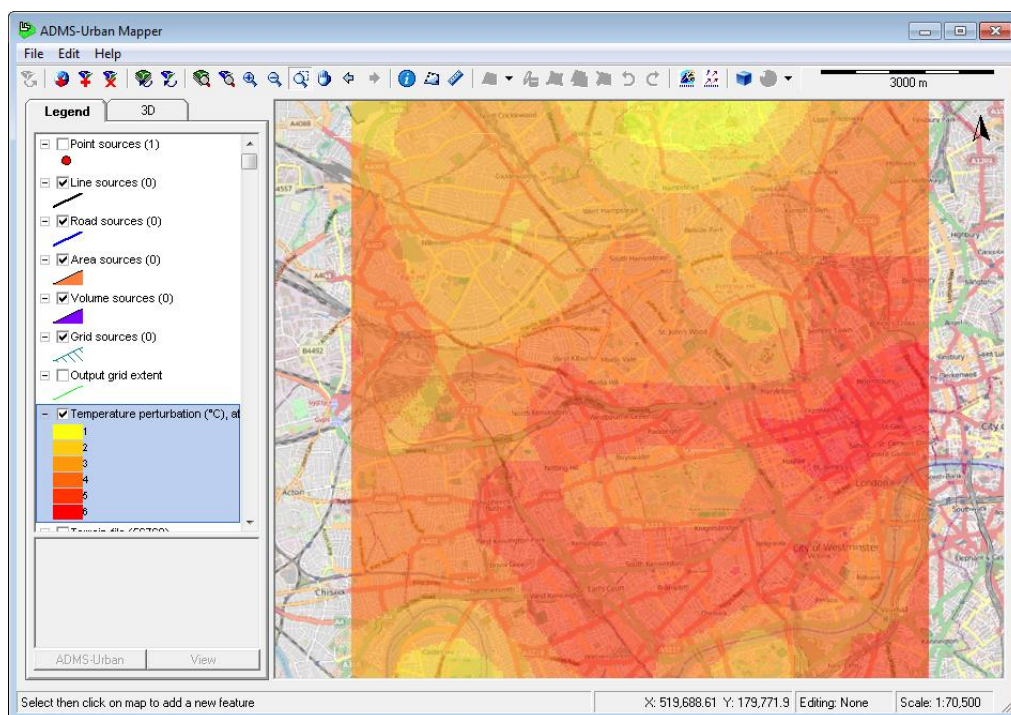
Figure 9.17 – Temperature perturbation contour plot in the ADMS Mapper (© OpenStreetMap contributors).

9.3   Example 3: Modelling anthropogenic heat emissions

9.3.1   Setting up the run

The file set up in Example 2 will be used as the starting point, and options will be changed to calculate the temperature changes when including anthropogenic heat emissions.

To set up the example, proceed as follows.

Step 1   Open the ADMS-Urban interface, click on **File, Open**... and browse to the first saved example, *London_Contour.upl*. Save this file with a new name by selecting **File, Save As**... and choose an appropriate name, such as *London_anthropogenic.upl*.

Step 2   Modelling anthropogenic heat sources requires extra pollutants to be added to the **Palette of Pollutants**. Anthropogenic heat emissions from road sources are expressed either directly, using the pollutant name "Temperature", or as CO_2, as described in Section 6.2.

We will add both of these pollutants to the **Palette of Pollutants**. Select **File, Import** to open the **Import wizard.** Select the **Pollutants** checkbox and browse to the supplied file *anthropogenic_heat_pollutants.ptt*.
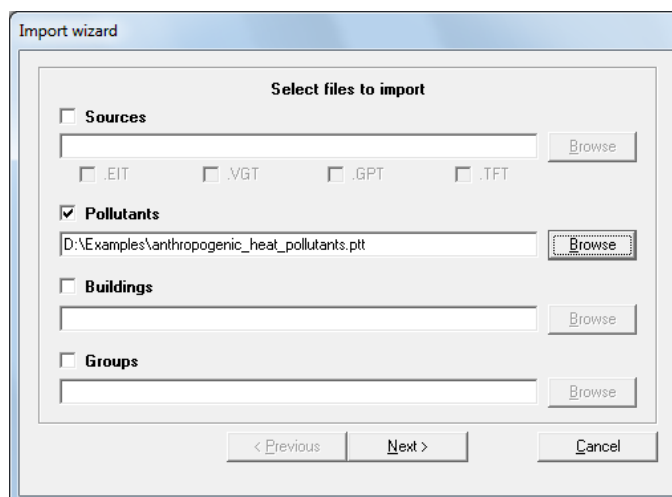
Figure 9.18 – The Import Wizard.

Step 3   Press the **Next >** button, then select the option **Merge palettes, overwriting existing pollutants** in the **Pollutant settings** screen. Finally, select **Import** on the **Confirm import** screen, you will receive a message to inform you that 2 new pollutants have been imported.
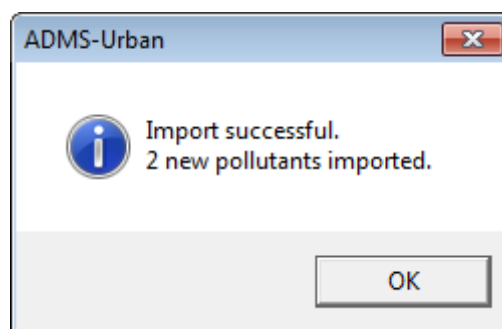

Figure 9.19 – Successful import message.

Step 4   In the **Setup** tab of the ADMS-Urban interface, select **Data...** under the **Palette** section. Inspection of the **Pollutants Palette** should show the two new pollutants CO_2 and Temperature. Click **OK** to close the **Pollutants Palette.**

Step 5   In the **Additional input file** section, press the **Edit** button, to open up the previously used file *London_Contour.uai*. You will need to make several edits to this file in order to include anthropogenic heat sources. Select **File, Save as**..., and save the file under a new name, such as *London_anthropogenic.uai*.

Step 6   Go to the **Anthropogenic heat** screen, found in the **Temperature and humidity options** folder. Select to **Model anthropogenic heat emissions**, and tick the **Model anthropogenic volume source heat emissions** box. Browse to the supplied file *London_3x3km_area.agh* available from the *Examples* directory. This file contains the volume source heat emissions over a 3x3 km area within central London. Select to **Model anthropogenic heat from roads.** Select **Calculate road heat emissions from CO2 emissions** and set the **Energy content of fuel in road vehicles** to 15,000 J/g[CO_2] and the **Fuel heat release factor for road vehicles** to 1. Refer to Section 6.2.1 for an
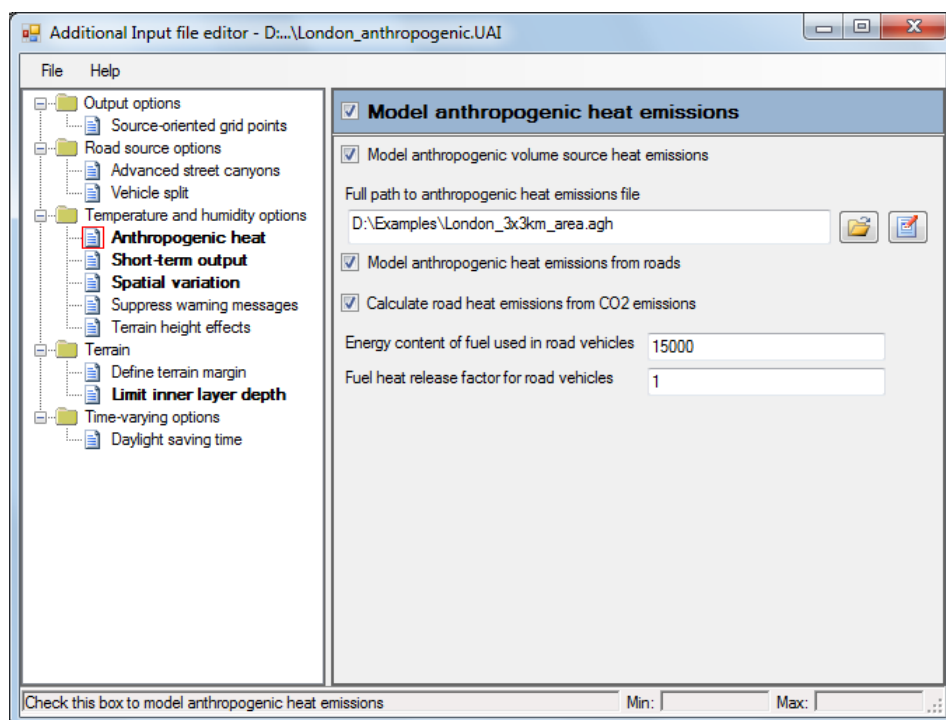
explanation of these values.

Figure 9.20 – The **Anthropogenic heat** settings.

Step 7 Within the **Short-term output** section, select **Gridded output** for 24 hours.
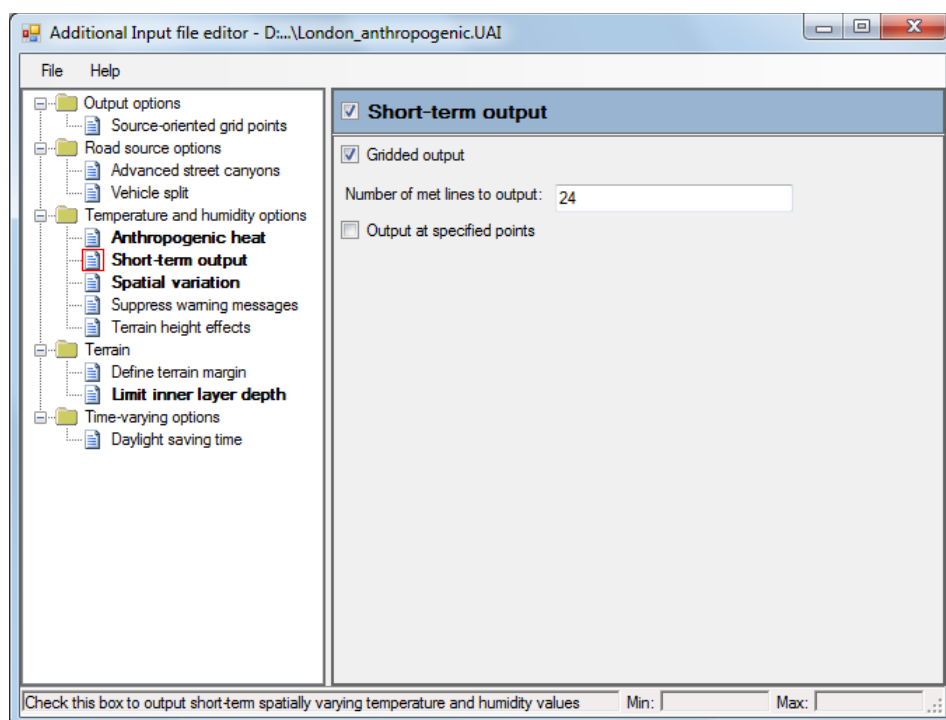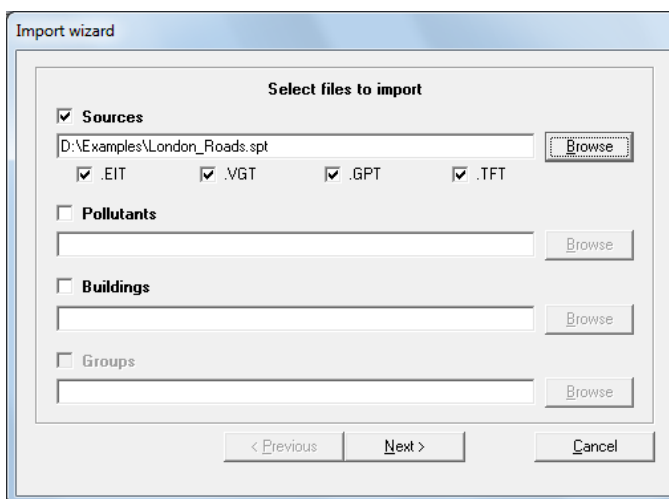

Figure 9.21 – The **Anthropogenic heat** settings.

Step 8 Save the additional input file, and close the **Additional Input file editor**.

Step 9 Under the **Additional input file** section of the **Setup** tab of the ADMS-Urban interface, browse to select your newly created file, *London_anthropogenic.uai*.

Step 10 A set of road sources for central London has been supplied in your examples directory. Use the **Import Wizard** to add these road sources to the interface. Select **File, Import**, and under the **Sources** section browse to the file *London_Roads.spt*.

Figure 9.22 – The **Anthropogenic heat** settings.

Step 11 Pressing the **Next >** button twice brings up the **Select sources** screen, press the **Add All >>** button to move all the road sources into the **Included** section, then press the **Next >** button, followed by **Import**.
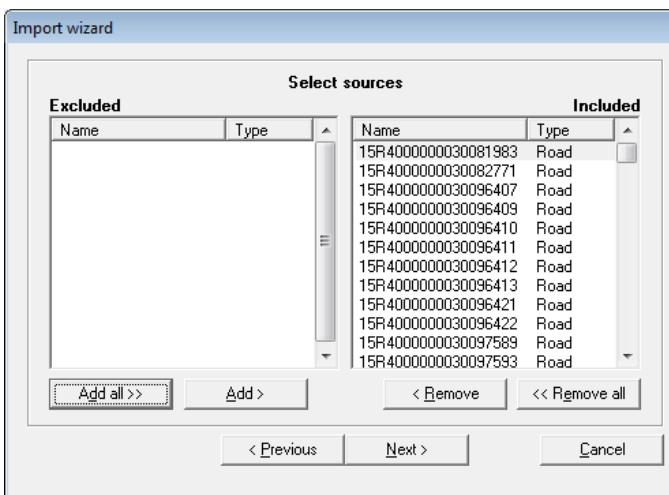
Figure 9.23 – The **Import Wizard**.

192 roads will be added to the **Source** screen of ADMS-Urban. Inspection of the road source emissions shows that each road source has an emission rate of CO_2 defined.

Step 12 It is important to vary the emissions from road sources and volume sources throughout the day. This can be done using a time varying emissions file, an example of which has been supplied. Select the **Time varying emissions** checkbox at the bottom of the **Source** screen. Then press the **Data Source**... button to open the **Time varying emission factors** screen.
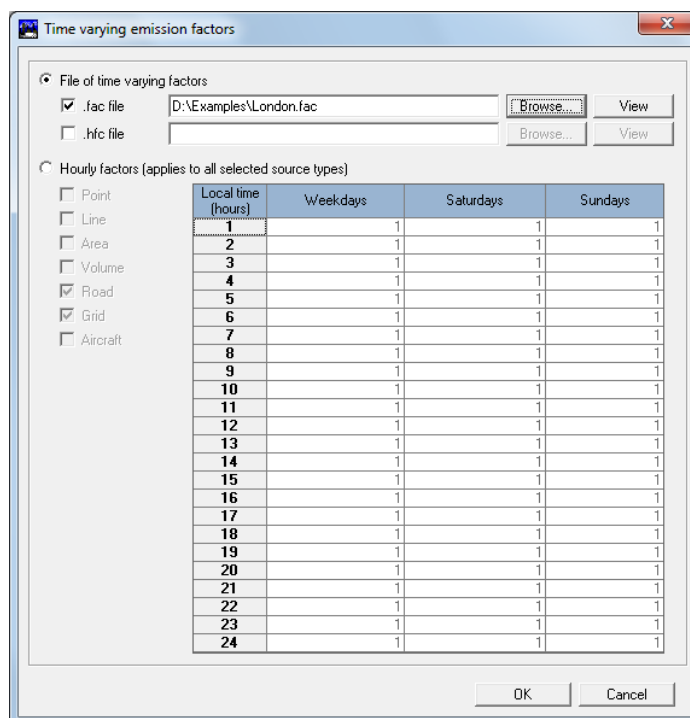
Figure 9.24 – The **Time varying emission factors screen**.

Step 13 Select to input a **File of time varying factors** and check the **.fac file** option. Locate the supplied file *London.fac* by pressing the **Browse**... button under the **.fac file** section. Press **OK** at the bottom of the screen to return to the ADMS-Urban interface.

Step 14 Run times increase when modelling anthropogenic heat, so for this example choose to model a one day subset of the met. data. The supplied met. data file contains data for the 17th to 20 August 2012, select a day within these dates for your model run.

Figure 9.25 – Choosing a subset of met. data to model.

Step 15 Finally in the **Grids** screen specify a new output grid which covers the area 526000 to 529000 in the X direction and 181000 to 184000 in the Y direction, with 21 points in each direction and a grid height of 3 m. Tick the check box under **Source-oriented grids** for **Road, Line, Aircraft** to include extra receptor points along the road sources.

Figure 9.26 – The **Grids** screen.

Step 16 Save your input file and run the model. This example will take a few minutes to run.

9.3.2 Viewing output results

Follow the steps given in Section 7.4 to create a contour plot of the temperature over the area modelled in Section 9.3.1. In this example we will plot the spatial variation of temperatures for 5pm on the 17th August 2012. The results for this hour of met data are contained in the file *London_Anthropogenic.E17*, as this particular hour is the 17th in the met file used in the example. Enter an appropriate name for the grid file to be created when prompted, such as *London_Anthropogenic.grd*.
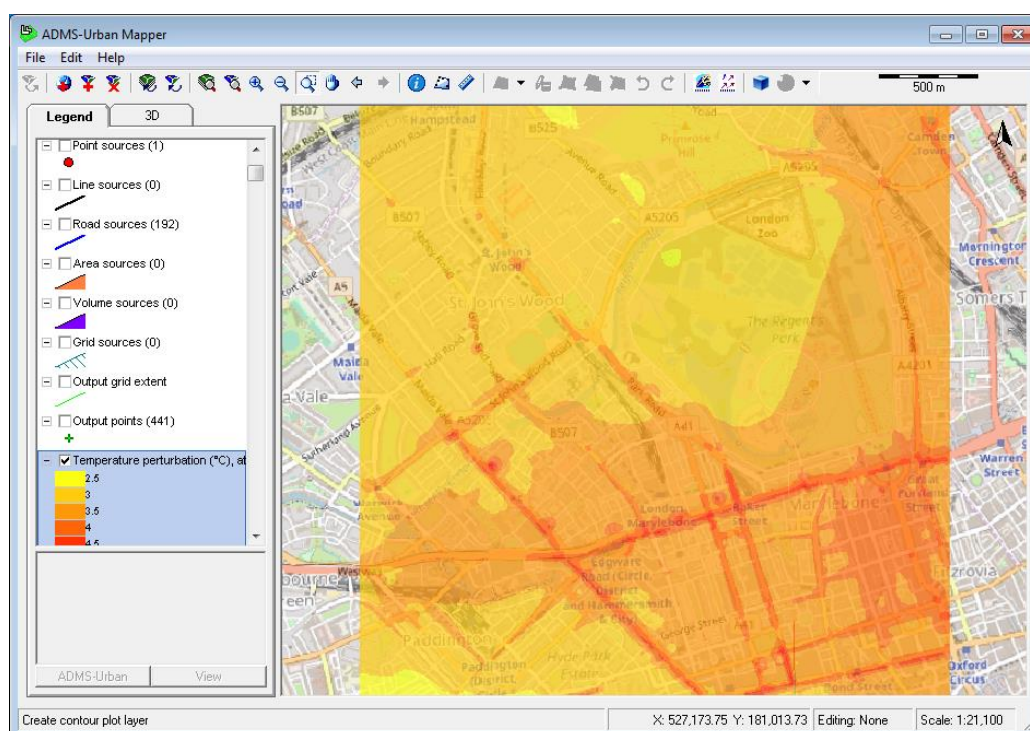
Figure 9.27 – Contours of temperature displayed in the ADMS Mapper (© OpenStreetMap contributors).

The resulting contour plot shows higher temperatures within the more built up areas and also along the busy road sources. The lowest temperatures are shown over the area of parkland to the north of the modelled area, as expected.

SECTION 10 Technical summary

10.1 Model theory

The ADMS-Urban Temperature and Humidity model takes into account the effect of spatial variation of surface properties on the local temperature and humidity fields. The surface properties that are modelled are:

- Albedo (-);

- Normalised buildings volume (m);

- Surface resistance to evaporation (sm^{-1});

- Roughness length (m); and

- Thermal admittance (Jm^{-2} s$^{-1/2}$ K^{-1}).

The method used to model perturbations of these parameters is based on that presented in Carruthers and Weng (1992). Potential temperature, θ, and humidity, q, perturbations over surfaces of variable surface resistance to evaporation are calculated using uncoupled variables a, b which are related to the perturbations to the potential temperature and specific humidity by

$$\theta = \frac{a + b}{\rho c_p (S + 1)}$$

$$q = \frac{Sa - b}{\rho \lambda (S + 1)}$$

where $S = \left(\frac{\lambda}{c_p}\right)\frac{dq_s}{dT}$ evaluated at $T = T_0$, $q_s(T)$ the saturated specific humidity at temperature T, c_p the specific heat of air, ρ the density of air and λ the latent heat of vaporization of water. T_0 is the temperature at screen height (1.22 m).

We define the Fourier transform of a variable, a, to be

$$\tilde{a}(k_1 k_2, z) = \int\limits_{-\infty}^{\infty}\int\limits_{-\infty}^{\infty} a\,(x, y, z)e^{-ik_1 x - ik_2 y}\,dx dy$$

Then **Carruthers and Weng** gives

$$\tilde{a} = \frac{2a_*}{\kappa}\left[\tilde{\phi}_{a_0} - \frac{\tilde{\tau}_{R_0}}{2u_*^2}\right]\frac{K_0(\beta)}{\beta_0\,K_1(\beta_0)} + \frac{a_*\tilde{m}}{\kappa}\left[\frac{2}{u(l)} + 1\right]\left[\frac{K_0(\beta/\sqrt{2}) - K_0(\beta)}{K_0(\beta_0/\sqrt{2})}\right]$$

$$\tilde{b} = \frac{1}{\kappa}\left[CB_0\tilde{R} + Sa_*\tilde{\phi}_{a_0} - \frac{b_*\tilde{\tau}_{R_0}}{2u_*^2}\right]\left[\frac{K_0(\beta)}{CK_0(\beta_0) + (\beta_0/2)K_1(\beta_0)}\right]$$
$$+ \frac{b_*\tilde{m}}{\kappa}\left[\frac{2}{u(l)} + 1\right]\left\{\frac{K_0(\beta/\surd 2) - K_0(\beta)}{K_0(\beta_0/\surd 2)}\right.$$
$$\left. - \left[\frac{K_0(\beta_0/\surd 2) - K_0(\beta_0)}{K_0(\beta_0/\surd 2)}\right]\right\}\left[\frac{C}{CK_0(\beta_0) + (\beta_0/2)K_1(\beta_0)}\right]$$

where R is the perturbation due to surface resistance to evaporation, ϕ_{a_0} is the surface value of the normalized net heating flux perturbation, τ_{R_0} is the shear stress perturbation due to roughness changes evaluated at $z = z_0$, m is roughness parameter $m = \ln(z_0/z_{0u})$ and

$$C = \frac{(S + 1)}{\kappa u_* r_{su}}$$

$$B_0 = \rho\lambda(q_s - q)$$

$$\beta = 2\sqrt{2i\,\text{sgn}(k_1)\zeta}$$

$$\beta_0 = 2\sqrt{2i\,\text{sgn}(k_1)\zeta_0}$$

$$u(l) = \ln\left(\frac{l}{z_{0u}}\right)$$

$$\zeta = \frac{z + z_{0u}}{l}, \qquad \zeta_0 = \frac{z_{0bc}}{l}$$

$$a_* = \frac{Q^* - G}{u_*}$$

$$b_* = \frac{SF_{\theta_0} - \lambda_E}{u_*}$$

with u_* the friction velocity, r_{su} the upstream surface resistance to evaporation, z_{0u} the upstream surface roughness, z_{0bc} a 'boundary condition' roughness, l the inner region depth, Q^* the net radiation, G the ground heat storage, F_{θ_0} the sensible heat flux, λ_E the latent heat flux, κ is von Karman's constant and K_0 and K_1 the Bessel functions.

The 'boundary condition' roughness length, z_{0bc}, is set as follows, depending on the upstream roughness length z_{0u}:

- If z_{0u} is the minimum roughness over the domain, then z_{0bc} is the maximum roughness over the domain;
- If z_{0u} is the maximum roughness over the domain, then z_{0bc} is the minimum roughness over the domain; and
- If z_{0u} is neither the maximum or the minimum roughness, then z_{0bc} is the maximum roughness over the domain.

The inner region depth, l, is given by

$$l\left(\ln\left(\frac{l}{z_{0_{bc}}}\right) - 1\right) + z_{0_{bc}} = \frac{2\kappa^2\left(1 + l^{2/3}\beta\right)}{|k_1|}$$

which is the same expression used for the roughness change calculation. Note that in order to restrict temperature and humidity perturbations, the inner region height may be limited; refer to Section 3.3.5 for details.

The Bessel functions K_0 and K_1 may be expressed in terms of Kelvin functions ker and kei (Abramowitz and Stegan (1968)) and making use of

$$K_0\left(xe^{-i\pi/4}\right) = K_0^*\left(xe^{i\pi/4}\right)$$

where * represent the complex conjugate.

So

$$K_0(\beta) = \ker_0(A) \pm i\kei_0(A)$$

$$K_0(\beta_0) = \ker_0(A_0) \pm i\kei_0(A_0)$$

$$K_1(\beta_0) = \exp\left(\frac{i\pi}{2}\right)(\ker_1(A_0) \pm i\kei_1(A_0))$$

where the upper sign is taken for positive k_1 and the lower sign taken for negative k_1 and $A = 2(2\zeta_1)^{1/2}$; $A_0 = 2(2\zeta_0)^{1/2}$.

The shear stress perturbation due to roughness changes, τ_{R0}, is calculated as:

$$\widetilde{\tau}_{R_0} = 2\kappa u_* A\exp\left(-\frac{z}{l}\right)\widetilde{m}(\sqrt{\zeta})\sqrt{i\mathrm{sgn}(k_1)}K_1\left(\sqrt{i\mathrm{sgn}(k_0)\zeta}\right)$$

and the net heating perturbation, ϕ_{a0}, is defined as

$$\widetilde{\phi}_{a0} = \Delta\widetilde{Q}^* - \Delta\widetilde{G}$$

where the net radiation perturbation, ΔQ^*, and ground heat flux perturbation, ΔG, are either entered directly or calculated using the methods outlined in Sections 10.3 and 10.4. The perturbation due to the surface resistance to evaporation is given by

$$\tilde{R}(k_1, k_2, z) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\frac{\left(\frac{\delta r_s}{r_{su}}\right)}{1 + \left(\frac{\delta r_s}{r_{su}}\right) + \mu}e^{-ik_1x - ik_1y}\,dxdy$$

where $\delta r_s = (r_s - r_{su})$ and μ is a factor to ensure this is well behaved as $r_s \to 0$.

The calculation of μ is based on the value of the aerodynamic resistance r_a,

$$r_a = \frac{\ln((z_0 + z_R)/z_0)\ln((z_{0S} + z_R)/z_{0S})}{\kappa^2 U_R}$$

where z_R is the reference height, z_0 is the roughness length governing momentum transfer, z_{0S} is the roughness length governing the transfer of heat, κ is von Karman's constant and U_R is the wind speed at the reference height. The upwind aerodynamic resistance r_{au} is calculated using z_{0u} in the expression for r_a.

If $\delta r_s > 0$ then $\mu = 0$ otherwise if $r_{au} \geq r_a$ then

$$\frac{1}{\mu} = \frac{r_{su}}{r_{au}}$$

If $\delta r_s < 0$ and $r_{au} < r_a$ we define

$$\chi = \left(1 - \frac{r_{au}}{r_a}\right)\left[\left(S + 1 + \frac{r_{su}}{r_{au}}\right) - \frac{S(Q^* - G)}{\lambda_E}\right]$$

for upstream values of Q^*, G and λ_E and then

$$\frac{1}{\mu} = \begin{cases} \dfrac{r_{su}}{r_a} & \chi \geq \dfrac{r_{su}}{r_{au}} - \dfrac{r_{su}}{r_a} \\ \dfrac{r_{su}}{r_{au}} - \chi & \text{otherwise} \end{cases}$$

10.2 Calculation of upwind ground heat flux

The surface energy balance equation can be expressed as

$$Q^* - G = F_{\theta_0} + \lambda_E$$

where F_{θ_0} is the surface sensible heat flux and λ_E is the latent heat flux. A method based on work by Camuffo and Bernardi (1982) has been used to estimate the ground heat storage, G, from the net radiation Q^* (calculated according to the ADMS 5 Technical specification document P05/01R/12).

According to Camuffo and Bernardi (1982), G may be estimated using the expression:

$$G = a_1 \frac{dQ^*}{dt} + a_2 Q^* + a_3$$

The coefficients a_1, a_2 and a_3 can be derived from modelled or observed values of G and Q^*. In the ADMS-Urban Temperature and Humidity model, 'hybrid' values of these coefficients are used that allow for:

- the high proportion of net radiation that is absorbed into the ground during the day in urban areas, and re-released overnight;

- the asymmetry in G which relates to the urban fabric absorbing a larger proportion of heat in the earlier part of the day; and

- the need for the boundary layer height to relate to stable conditions at night.

Values of a_1, a_2 and a_3 are consistent with those found in the literature (Grimmond & Oke, 1998, Keogh et al., 2012). However, the values chosen do not fully represent the relationship between G and Q^* in an urban area due to the restriction that the boundary layer height must relate to stable conditions at night; in reality, in urban areas, the heat flux from the ground often remains positive through the night. This restriction is required because the model requires the boundary layer height to be representative of meteorological conditions *upwind* of the model domain.

Values a_1, a_2 and a_3 are taken to vary sinusoidally throughout the year:

$$a_1 = \text{a}_{1\_0} + \text{a}_{1\_a} \sin\left[\frac{2\pi}{365}\text{JDay} + \frac{\pi}{2}\right]$$

$$a_2 = \text{a}_{2\_0} + \text{a}_{2\_a} \sin\left[\frac{2\pi}{365}\text{JDay} - \frac{\pi}{2}\right]$$

$$a_3 = \text{a}_{3\_0} + \text{a}_{3\_a} \sin\left[\frac{2\pi}{365}\text{JDay} + \frac{\pi}{2}\right]$$

with mean coefficient parameters a_{1_0}, a_{2_0} and a_{3_0} and amplitude coefficient parameters a_{1_a}, a_{2_a} and a_{3_a}; JDay is the Julian day. The values used in the model are given in Table 10.1.

	a_1 (h) parameters	a_2 parameters	a_3 (W/m²) parameters
Mean coefficient parameters	$\text{a}_{1\_0} = 0.7$	$\text{a}_{2\_0} = 0.3$	$\text{a}_{3\_0} = -7.5$
Amplitude coefficient parameters	$\text{a}_{1\_a} = 0.1$	$\text{a}_{2\_a} = -0.1$	$\text{a}_{3\_0} = 2.5$

Table 10.1 – Mean and amplitude parameters used to define a_1, a_2 and a_3

10.3 Modelling perturbations to net radiation

Perturbations to the net radiation are calculated from changes in the albedo and the normalised buildings volume. From the ADMS 5 Technical specification document the net radiation, Q^*, is given by

$$Q^* = \frac{(1-r)K^+ + 5.31 \times 10^{-13}(T_0^K)^6 - 5.67 \times 10^{-8}(T_0^K)^4 + 60(c_L/8)}{1.12}$$

where K^+ is the incoming solar radiation, T_0^K the temperature in Kelvin, c_L the cloud cover and r the albedo. If we were to look at the perturbation to the net radiation due to the change in albedo this would give us

$$\Delta Q^* = Q_l^* - Q_u^* = (r_u - r_l)\frac{K^+}{1.12}$$

where a subscript u indicates an upwind quantity and a subscript l represents a local quantity. To take into account the normalised buildings volume we change this to become

$$\Delta Q^* = Q_l^* - Q_u^* = \left(\frac{F(r_l, NBV_l)}{F(r_u, NBV_u)}(1 - r_l) - (1 - r_u) \right) \frac{K^+}{1.12}$$

where NBV is the normalised buildings volume and $F(r, NBV)$ is a function which describes how the incoming solar radiation may be effected by the local environment (here described by albedo and normalised buildings volume). The function returns a factor which is equal to 1 if the local environment has no effect, if the local environment decreases the absorption of incoming solar radiation the function is less than 1 and if the local environment increases the absorption of incoming solar radiation the function is more than 1.

Values of the function $F(r, NBV)$ have been derived from data supplied by UCL for a discrete set number of albedos and normalised building volumes. The values calculated are shown in Table 10.2 and an interpolation is used to calculate values for any albedo and normalised buildings volume. For normalised building volumes greater than 40 the factor returns 1.

| Albedo	Normalised building volume					
	0.0	**2.5**	**4.0**	**7.4**	**12.4**	**40.0**
0.00	1.000	1.085	1.058	1.053	0.968	1.000
0.05	1.000	1.085	1.058	1.053	0.968	1.000
0.20	1.000	1.096	1.088	1.094	1.002	1.000
0.35	1.000	1.109	1.120	1.143	1.047	1.000
1.00	1.000	1.109	1.120	1.143	1.047	1.000

Table 10.2 – Values of $F(r, NBV)$ for input values of albedo (r) and normalised building volume (NBV).

10.4 Modelling the perturbations to the ground heat flux

The perturbations to the ground heat flux are calculated from spatially varying values of thermal admittance, along with the spatially varying values of surface resistance to evaporation. In order to calculate the perturbation to ground heat flux we must first look at the energy balance at a single surface.

10.4.1 Energy balance at a single surface

Using the notation as given in the ADMS-Urban Technical Specification document P05/01, the available heat/net radiation is Q^*. **Figure 10.1** below shows a schematic diagram of the incoming radiation heating up the ground relative to above and below the ground.
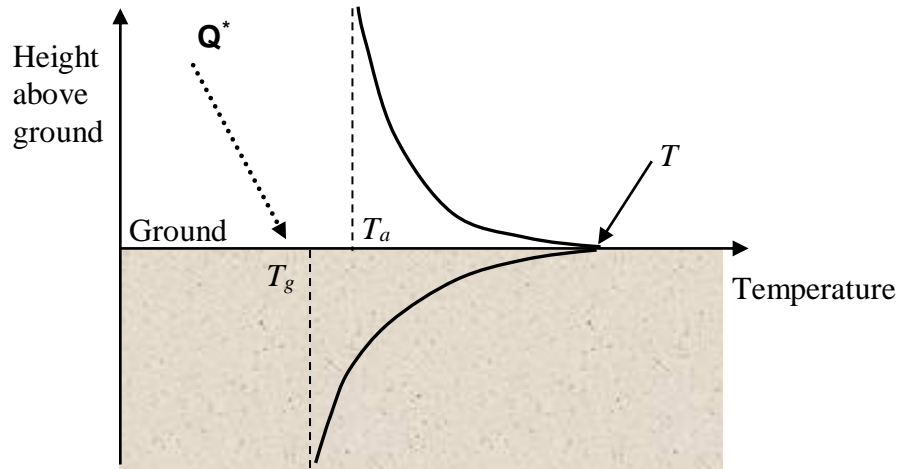
Figure 10.1 − Schematic diagram showing the temperature differences at the surface compared to above and below the ground.

If the temperature at the surface is taken to be T, and the ambient air temperature is T_a, then the heat entering the atmosphere depends on the temperature difference between the surface and ambient air above, $T - T_a$, and the atmospheric turbulence. Assume that the turbulence remains unchanged for different surfaces. The surface sensible heat flux, F_{θ_0}, can be expressed as:

$$F_{\theta_0} = d_{conv}(T - T_a)$$

where d_{conv} is a factor that accounts for the atmospheric turbulence.

If the Bowen ratio, $B = F_{\theta_0}/\lambda E$, is known (where λE is the latent heat flux) and c is the fraction of available heat going into the atmosphere as both sensible and latent heat then

$$cQ_* = d_{conv}\left(1 + {}^1/_B\right)(T - T_a)$$

The heat flux into the ground, G, depends on the difference between the temperature at the surface and the mean temperature below ground, $T - T_g$, as well as the surface thermal admittance $\mu = (\rho C_H k)^{1/2}$, where ρ is the density, C_H the specific heat capacity and k the thermal conductivity. G can then be expressed as:

$$G = d_{ground}\mu\left(T - T_g\right) = (1 - c)Q^*$$

where d_{ground} is related to the typical time scale of temperature changes (i.e. diurnal).

For the purposes of these calculations, it is assumed that T_g is constant. Then if $T - T_a = \Delta T$ and $T - T_g = \gamma\Delta T$ we have the two approximate equations:

$$cQ^* = d_{conv}\left(1 + {}^1/_B\right)\Delta T \tag{1}$$

$$(1 - c)Q^* = d_{ground}\, \mu\, \gamma \Delta T \qquad (2)$$

10.4.2 Modelling local changes in ground properties

It is of interest how the apportionment of the net radiation, Q^*, changes when the ground properties change. **Figure 10.2** below shows how example temperature profiles change when the ground changes from being soil to concrete. In the example shown, the local temperature at the ground decreases when the airflow passes from a soil to a concrete surface because the thermal admittance of the concrete is higher than that of the soil, and therefore the heat can be removed from the surface at a faster rate.

Note that this analysis only takes into account the change in the substance the ground is made out of – no consideration has been made for other surface properties such as roughness, surface resistance to evaporation or albedo.
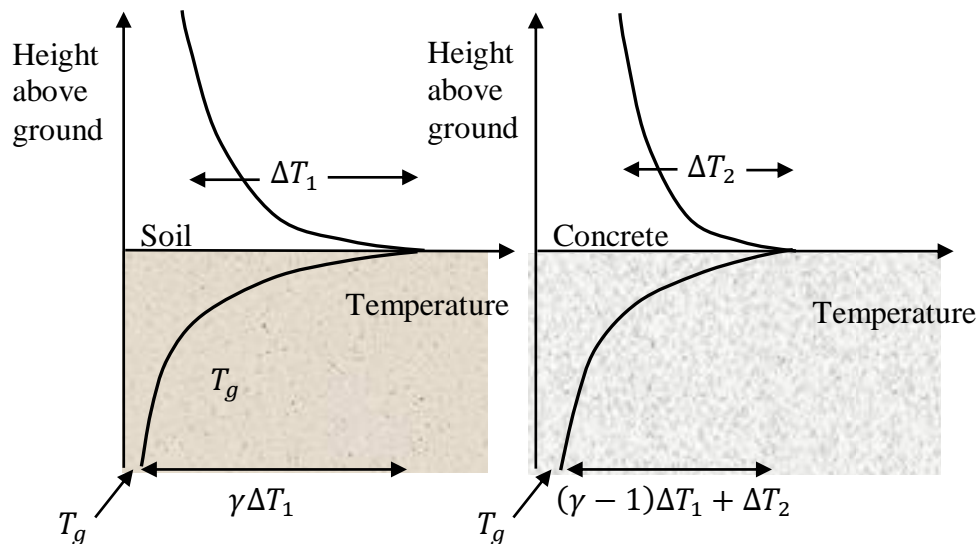
Figure 10.2 − Diagrams showing the temperature differences as the ground composition changes from the upwind soil conditions to the local concrete conditions.

Both upwind and locally, the ground compositions are known i.e. μ is defined. Upwind, all terms of the energy balance equation are known i.e. c, and the Bowen ratio B, are known.

Locally, in order to evaluate the faction of heat going into the atmosphere, it is necessary to make the following assumptions:

    (a) The aerodynamic properties of the two surfaces are the same i.e. d_{conv} is the same for both surfaces. This is reasonable given that the other surface properties such as roughness are assumed constant.

    (b) The ground scaling factor d_{ground}, is also the same for both surfaces. This is reasonable as differences in ground properties are already taken account of with μ.

Applying the notation where suffixes 1 and 2 refer to surfaces 1 and 2, the fraction

of available heat going into the atmosphere over surface 2 (c_2) can be evaluated by:

$$c_2 = c_1 \frac{\Delta T_2}{\Delta T_1} f(B_1, B_2) \qquad (3)$$

where

$$\frac{\Delta T_2}{\Delta T_1} = \left(\gamma c_1 f(B_1, B_2) + (1 - c_1) \frac{\mu_2}{\mu_1} \right) \left[\gamma - \frac{\mu_2}{\mu_1} (1 - c_1)(\gamma - 1) \right]^{-1}$$

and

$$f(B_1, B_2) = \frac{1 + {}^1\!/_{B_2}}{1 + {}^1\!/_{B_1}}$$

Equation (3) can be used to calculate c_2 if a value of the Bowen ratio, B_2, can be estimated. As $\Delta T_2 / \Delta T_1$ and c_2 are found to be quite insensitive to the ratio of temperature difference upstream (γ), it is assumed that $\gamma = 1$.

10.4.3 Estimation of the local value of the Bowen ratio

In addition to the Bowen ratio, the modified Priestley-Taylor parameter, α, is also a measure of how the available heat is apportioned between the surface sensible and latent heat fluxes (**Holtslag**). The relationship between the modified Priestley-Taylor parameter and the Bowen ratio B is:

$$\alpha = \frac{(S+1)(Q^* - G)}{(B+1)(20(S+1) + S(Q^* - G))} \qquad (4)$$

where

$$S = \left(\frac{\lambda}{c_p} \right) \frac{\partial q_s}{\partial T}$$

q_s is the saturated specific humidity at the temperature T, λ is the latent heat of vaporisation of water and c_p is the specific heat capacity of air. Equation (4) varies with $Q^* - G$, but only slowly when $Q^* - G$ is moderately large (greater than approximately 20 W/m^2).

Simple estimates for the modified Priestley-Taylor parameter are used in the ADMS-Urban dispersion model. These are summarised in columns 1 and 2 of Table 10.3 below.

Modified Priestley-Taylor parameter (as used in ADMS-urban)		Bulk surface resistance parameter (as given in Cox)	
Values	Example surfaces	Values	Example surfaces
0.0	Dry bare earth	100-200	Soil, urban
0.45	Dry grassland (**Holtslag**)	60-80	Arable, short/long grass
1.0	Moist grassland, water	0.0	Inland lake

Table 10.3 – Summary of modified Priestley-Taylor and bulk surface resistance

parameters

The bulk surface resistance parameter, r_s, is related to the modified Priestley-Taylor parameter by the following equation:

$$\alpha = \frac{S(Q^*-G)+\rho\lambda(q_s(T_R)-q_R)/r_a}{(S+1+r_s/r_a)(S(Q^*-G)/(S+1)+20)} \tag{5}$$

where ρ is the density of air, $q_s(T_R)$ is the saturated specific humidity at the reference height (z_R) temperature T_R and q_R is the specific humidity at the reference height and r_a is the aerodynamic resistance.

Equation (5) indicates that the modified Priestley-Taylor parameter is inversely proportional to the bulk surface resistance parameter, for large values of r_s. Considering some example values of r_s given in **Cox**, it is possible to broadly relate the values of α to r_s, as indicated in Table 10.3. Taking these estimates, a basic empirical relationship between α and r_s can be taken as:

$$\alpha = \exp(-\gamma r_s) \tag{6}$$

where $\gamma = 0.0114$. **Figure 10.3** shows this relationship. Note that this relationship has *not* been derived from equation (5).
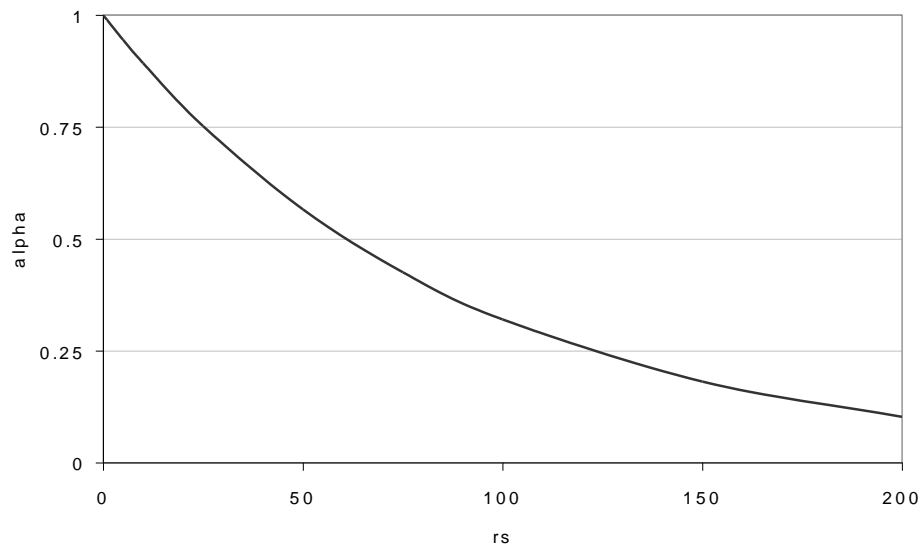
Figure 10.3 − Approximate relationship between the modified Priestley-Taylor parameter, , and the bulk surface resistance parameter, r_s.

Rearranging equation (4) to give an expression for the Bowen ratio, and substituting in the empirical relationship for the modified Priestley-Taylor parameter, α, equation (6) gives:

$$B = \frac{cQ^*(S+1)\exp(\gamma r_s)}{(20(S+1)+cQ^*S)} - 1$$

When c is $O(1)$ and Q^* is greater than approximately 20 W/m^2, this expression for B varies most with the exponential dependence on the local values of surface

resistance to evaporation parameter, r_s. Therefore, as a first approximation, the upwind properties surface 1, S_1 and $c_1 Q^*$ and the local value of surface resistance to evaporation parameter, r_{s2}, are taken to represent the difference in the Bowen ratio at surface 2 compared to surface 1, i.e.

$$B_2 = \frac{c_1 Q^* (S_1 + 1) \exp(\gamma r_{s2})}{(20(S_1 + 1) + c_1 Q^* S_1)} - 1$$

10.4.4 Heat release

During the some of the day, a proportion of the energy that radiates into the earth's atmosphere from the sun is stored in the ground. *Later in the day and at night* some of this heat is released back into the atmosphere, and the rest remains in the ground, which is assumed to act as an infinite sink.

Define the integrals over the upwind (terms with subscript u) positive ground heat fluxes (storage), and the negative ground heat fluxes (release) as follows:

$$\overline{G}_{uStorage} = \int_{G_u > 0} G_u \text{ and } \quad \overline{G}_{uRelease} = \int_{G_u < 0} G_u$$

10.4.4.1 Modelling the local variations of heat released

Locally, the method described in Section 10.4.2 gives a prediction of the local ground heat flux value stored during the daytime. This allows the following integral representing the local heat storage to be defined:

$$\overline{G}_{lStorage} = \int_{G_l > 0} G_l$$

The heat released *later in the day and at night*, G_l, can be approximated by:

$$G_l = G_u + \frac{(\overline{G}_{lStorage} - \overline{G}_{uStorage})}{nNightHrs} \frac{nDayHrs}{nDayHrsValid} \qquad (7)$$

where $nNightHrs$ is the total number of night-time hours in the current night; $nDayHrs$ is the total number of daytime hours in the previous day; and $nDayHrsValid$ is the number of hours in the previous day which had valid input data.

There are cases where the model does not have any information relating to the quantity of heat stored during the previous day, for instance if a model run starts at midnight, no storage information is available from the start of the model run until dawn. In these situations, basic assumptions regarding the relationship between the ground heat flux and net radiation are assumed i.e.:

- in an urban area, $G/Q^* = 0.4$, and
- in a rural area, $G/Q^* = 0.1$,

where the urban or rural **Land use mode** is defined in the *.uai* file (Section 3.3).

These default values of G/Q^* are then used in the daytime expression (3) that relates the upwind and local ground heat flux.

Users are advised that the predicted temperature variations on the first day may be inaccurate before dawn.

10.4.4.2 Implementation

This approach to modelling the release of heat is dependent on the full day prior to the "night" in question having been modelled. It this is the case, then equation (7) can be used to evaluate the local ground heat flux data.

If the previous day has not been modelled, then certain broad assumptions regarding the heat released must be made.

Firstly, it will be assumed that the amount of heat absorbed by the ground during the day is all released i.e.:

$$\frac{\overline{G}_{uRelease}}{\overline{G}_{uStorage}} = 1$$

Further, removing any dependence on the atmospheric conditions, we have the following relationship between the upwind and local variations of the ratio of ground heat flux to net solar radiation values during the day (using the notation from Section 10.4.2):

$$c_2 = c_1 \left(c_1 + (1 - c_1)\frac{k_2}{k_1} \right)^{-1}$$

The default value of c_1 is set by the user using the **Land use mode** option in the *.uai* file (Section 3.3). Thus the local release of heat can be approximated as:

$$G_l = \left(c_1 \frac{k_1}{k_2} + (1 - c_1) \right)^{-1} \times G_u$$

10.5 Decreasing temperature with altitude

Within the boundary layer, temperature decreases as altitude increases; the rate at which is this occurs relates to referred to as the lapse rate. Within the ADMS-Urban Temperature and Humidity model, the spatial variation of potential temperature is modelled as described in sections 10.1 to 10.4. Absolute temperatures are then derived from the potential temperature values using the following expression:

$$T(z_u) - T(z) = \theta(z_u) - \theta(z) - \gamma_d(z_u - z)$$

where $T(z)$ and $\theta(z)$ are the temperature and potential temperature at height z above the ground respectively, $\gamma_d = g/c_p \approx 0.01°C/m$ is the adiabatic lapse rate (g =9.807 m/s^2,

$c_p = 1000$ J/kg°C); z_u and z are the heights of the upwind met site and the receptor of interest respectively.

10.6 Temperature increments due to anthropogenic heat emissions

The dispersion of emissions of heat from anthropogenic heat sources follow the standard ADMS-Urban dispersion calculations, with no additional calculations of buoyancy effects. Some differences may be seen between dispersion calculations in runs with and without the ADMS-Urban Temperature and Humidity module due to differences in the pre-processing of meteorological data, which may change the boundary layer height and Monin-Obukhov length and thus the stability.

The dispersed 'energy density field', with units of J/m^3, is converted to values of temperature increment in °C by assuming that the heat energy is used to heat the atmosphere at constant temperature and density. The resulting temperature increment is given by

$$\Delta T = \frac{C_T}{\rho c_p}$$

where C_T is the energy density field (J/m^3), ρ is the density of air (kg/m^3) and c_p is the specific heat capacity of air (kJ/kgK). The density and specific heat capacity are both taken as standard values for a temperature of 15 C for the purposes of the conversion, with values of 1.225 kg/m^3 and 1012 kJ/kgK respectively.

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