SUEWS Manual: Version 2014b

8 October 2014

L. Järvi[1], CSB Grimmond[2], S. Onomura[3], F. Lindberg[3]
[1]University of Helsinki, [2]University of Reading, [3]University of Gothenburg

Web page: http://www.met.reading.ac.uk/micromet/
Email address: c.s.grimmond@reading.ac.uk

Table of Contents

Please do not redistribute the contents of the zip file (data or model). If someone else would like these please have them contact us.

1 Introduction

Surface **U**rban **E**nergy and **W**ater Balance **S**cheme (SUEWS) (Järvi et al. 2011) is able to simulate the urban radiation, energy and water balances using only commonly measured meteorological variables and information about the surface cover. SUEWS utilizes an evaporation-interception approach (Grimmond et al. 1991) similar to that used in forests to model evaporation from urban surfaces.

The model uses seven surface types: paved, buildings, evergreen trees/shrubs, deciduous trees/shrubs, irrigated grass, non-irrigated grass and water. The surface state for each surface type at each time step is calculated from the running water balance of the canopy where the evaporation is calculated from the Penman-Monteith equation. The soil moisture below each surface (excluding the water) is taken into account.

Horizontal movements above and below ground level are allowed. SUEWS runs with 60-min time step[1] and for water balance calculations it adopts a 5-min (300 s) time step. Timestamps refer to the end of the averaging period. The model provides the radiation, energy balance components, surface and soil wetness and drainage of each surface, and surface and soil runoff (See Table 5.1 for hourly output).

The submodels include:

1. NARP (*Net All-wave Radiation Parameterization*) radiation scheme (Offerle et al. 2003, Loridan et al. 2010)
2. Storage heat flux: calculated with OHM (*objective hysteresis model*) (Grimmond et al. 1991, Grimmond & Oke 1999a, 2002)
3. LUMPS (*Local-scale Urban Meteorological Parameterization Scheme,* Grimmond & Oke 2002) does the initial turbulent sensible and latent heat fluxes calculation for stability (Appendix D gives the differences between SUEWS and LUMPS). Note both models outputs are provided in all runs
4. two simple anthropogenic heat flux models(Järvi et al. 2011)
5. a simple urban water use model (Grimmond and Oke 1991)
6. a convective boundary layer (CBL) slab model (Cleugh and Grimmond 2001): calculates the CBL height, temperature, humidity during daytime (Onomura et al. 2014) – not available in this release
7. snowmelt model (Järvi et al. 2014)

The model distributed with this manual can be run in two standard ways:

1) for an individual area
2) for multiple areas that are contiguous.

There is no requirement for the areas to be of any particular shape but here we refer to these as 'grids'.

Model applicability: **Local scale** – so forcing data should be above the height of the roughness elements (trees, buildings)

1.1 New in SUEWS Version 2014b (released 8.10.2014)

These affect the run configuration if previously run with older versions of the model:

a. New input of three additional columns in the Meteorological input file (diffusive and direct solar radiation, and wind direction)
b. Change of input variables in InitialConditions.nml file. Note we now refer to CT as ET (ie. Evergreen trees rather than coniferous trees)
c. In GridConnectionsYYYY.txt, the sitenames should now be without the underscore (e.g "Sm" and not "Sm_")

Other issues:

d. Number of grid areas that can be modelled (for one grid, one year 120; for one grid two years 80)
e. Comment about Time interval of input data
f. Bug fix: Column headers corrected in 5 min file
g. Bug fix: Surface state 60 min file - corrected to give the last 5 min of the hour (rather than cumulating through the hour)
h. Bug fix: units in the Horizontal soil water transfer
i. ErrorHints: More have been added to the problems.txt file.
j. Manual: new section on running the model appropriately
k. Manual: notation table updated
l. Possibility to add snow accumulation and melt: new paper
   Järvi L, Grimmond CSB, Taka M, Nordbo A, Setälä H, and Strachan IB 2014: Development of the Surface Urban Energy and Water balance Scheme (SUEWS) for cold climate cities, *Geosci. Model Dev*. 7, 1691-1711, doi:10.5194/gmd-7-1691-2014.

Previous version changes: see Appendix B. Please let us know if you find problems or have suggestions for the manual.

[1] The model can be run at other time steps. Note 5 min output is available. Other options may need testing

2 Notation (in alphabetical order)

italics	variables names in the tables
bold	input/output filenames
λ_F	frontal area index
ΔQ_S	storage heat flux
BLUEWS	Boundary Layer version of SUEWS
B	coefficient in drainage equation
BLDG	Building surface
CBL	Convective boundary layer
D_0	coefficient in drainage equation
DT	deciduous trees and shrubs
ET	Evergreen trees and shrubs
IG	irrigated grass
UG	unirrigated grass
HL	high-latitude
Id	day of year
$L\downarrow$	incoming longwave radiation
LAI	Leaf area index. - **depends on the local phenology** of the area of interest.
LUMPS	Local scale Urban Meteorological Parameterization Scheme
NARP	Net All-wave Radiation Parameterization (Offerle et al. 2003, Loridan et al. 2010)
OHM	Objective Hysteresis Model (Grimmond et al. 1991, Grimmond & Oke 1999a, 2002)
PAV	paved surface
Q^*	net all-wave radiation
Q_E	latent heat flux
Q_F	anthropogenic heat flux
Q_H	sensible heat flux
Q	specific humidity
SS	two letter code for the measurement site
Ss	model area (Grid) identification code
theta	potential temperature
tt	time step of data
W	water surface
WB	water balance
YYYY	Year
z_i	Convective boundary layer height
z_{0m}	roughness length for momentum

3 Running the model

The following outlines how to setup SUEWS for a simple first time use. In Appendix C some alternative methods are discussed. First it is necessary to select the appropriate compiled version of the model to download. Note as the definition of long double precision varies between computers (e.g. Mac vs Windows) slightly different results may occur in the output files.

Compiled Versions of SUEWS

Operating System	Version	Compiled with	Comments
Apple	10.8.5	gfortran	See section 3.1.1
Linux			Please contact us
Windows		SilverFrost	See section 3.1.3
Windows 7	64 bit	gfortran	See section 3.1.2

3.1 Step 1: Preparing Directories

Example files are provided with the compiled version of the SUEWS (available for download from the website). The zip file has the required input data files and example output files (Section 5). Additionally this manual is available for download (**SUEWS_Manual.pdf)**

	Site	Year	Use
Sm_2011	Helsinki	2011	General SUEWS or LUMPS runs, new snow module
Sc91	Sacramento	1991	BLUEWS - CBL runs (*not this release*)

The files provided should be after installation be in three directories (Table 3.1). The files contained within the zipped file and where they should be located are listed in Table 3.2.

Table 3.1: Files that should be included in each directory for a simple first run. Assuming the site name *SSss_* and year *YYYY*, and one area only.

Site Directory	Input	Output
RunControl.nml	***SSss_YYYY*_data.txt(*)**	Needs to be created - will be empty to begin with
SUEWS_V2014a.exe	***SSss_YYYY*.gis(*)**	
see table below (dll)	***SSss_YYYY*SAHP.nml(*)**	
Input (directory)	**OHM_Coefficients.txt**	
Output (directory)	**SelectOHM*SSss_YYYY*.txt(*)**	
	WaterDist*SSss_YYYY*.txt(*)	
	SiteSpecificParam*SSss_YYYY*.nml(*)	
	HourlyProfile*SSss_YYYY*.txt(*)	
	ModelledYears.txt	
	SUEWS_FunctionalTypes.txt	
	GridConnections*YYYY*.txt (*)	
	InitialConditions*SSss_YYYY*.nml[2]	
	(CBLInput.nml)	
	(CBLinputfiles (directory))	

(*) – One file for each year and grid
Underscore – specified (or not)

Depending on the version selected the following dynamic link library (dll) files are required to run the executable (library files need to be in a path that can be found by the programme.

Windows 7 gFortran	Windows SilverFrost	Apple
cyggcc_s-seh-1.dll cyggfortran-3.dll cygquadmath-0.dll cygwin1.dll	salflibc.dll OR you need to install SilverFrost If you have installed SilverFrost – it will find the **salflibc.dll** file. You do not need to worry where you locate it or copy it each time to the directories you are using.	Contact us to get the files

[2] There is a second file **InitialConditions*SSss_YYYY_end*.nml** or **InitialConditions*SSss_YYYY+1*.nml** in the input directory. At the end of the run the state is written out so that it could be used to start running for example the next year.

Table 3.2: Files included in the.zip files. The last four files are not yet in use. In this release the example data are for a site: **"Sm", year is 2011.**

Filename	Purpose	Place to put it
SUEWS_V2014b.exe	Actual program	Directory where run programme
RunControl.nml	Model run options	Same directory as programme
GridConnections2011.txt	Required input file listing connections between spatial grids	Input directory
HourlyProfileSm_2011.txt	Hourly profiles for QF, irrigation and snow removal	Input directory
InitialConditionsSm_2011.nml	Initial conditions for the model runs	Input directory
Sm_2011.gis	Surface cover information file	Input directory
Sm_2011.txt	Meteorological input file	Input directory
Sm_2011SAHP.nml	File with information for Q_F calculation	Input directory
ModelledYears.txt	Required input file listing modelled years	Input directory
OHM_Coefficients.txt	OHM coefficients	Input directory
SelectOhmSm_2011.txt	OHM coefficients selected	Input directory
SiteSpecificParamSm_2011.nml	Site specific model parameters	Input directory
SUEWS_FunctionalTypes.txt	Model parameter options	Input directory
WaterDisSm_2011.txt	Information for horizontal surface water flows	Input directory
Sm_Filechoices.txt	File including the run options of the example run	Example run
Sm_alldays.txt	Daily output file will all years included	Example run
Sm_2011_5min.txt	Optional output file containing model outputs with 5-min resolution	Example run
Sm_2011_60.txt	60-min output file	Example run
Sm_2011_DailyFile.txt	Daily output file	Example run
Sm_2011_MonthlyFile.txt	Output file containing monthly, seasonal and yearly output data	Example run
Sm_2011_NARPOut.txt	Optional output file containing radiation balance components for the different sub surfaces.	Example run
Sm_2011_SnowOut.txt		
Sm_DailyState.txt	Output file containing daily state variables for each year	Example run
CBLinput.nml	CBL model run options and input parameter	Input directory
CBL_initial_data.txt (*)	Initial data for CBL model	Input/CBLinputfiles
Sonde_SS_YYYY_MMDD_HHMM.txt (*)	Optional file of radiosondes data for CBL model	Input/CBLinputfiles
SS_YYYY_CBL_*id*.txt	CBL model output file	Example run

(*) filename is set in CBLinput.nml (see 4.13).

3.1.1 Apple installation

This will require some dll files. Please contact us. The manual does not at this stage provide the simple instructions that are relevant for iOS. If you intend to use this and need initial help (e.g. with creating directories etc.) let us know and we will update the manual with these details. The models specific information otherwise applies.

3.1.2 Windows 7 (64-bit) gfortran with setup file installation

A Setup file is provided that will put the manual in a third sub-directory. When you initiate the setup you can select what directory the programme is installed into. The setup process also add shortcuts to the manual etc. to the start-menu.

3.1.3 SilverFrost or manual installation

Create a Main site directory and locate SUEWS_V2014a.exe in that directory

1) Create two subdirectories: a) Input and b) Output

After you have **unzipped** the SUEWS file you should save the files in the same locations as indicated in Table 3.1.

3.2 Step 2: Edit Files

It is recommended that you use the sample files as a template for creating your own files. You will need to edit the files with a text editor. Alternatively you can use the XLSX spreadsheet and R programme (Appendix C). Note that in all files an "!" is a comment – so after that the material will not be read

Runcontrol.nml

It is best to start from the ***RunControl.nml*** file, where the site name *SS_* is assigned. Here also the file paths for the other required model input files (Section 3.1) as well the output file path are given. This means before running the model (even the sample) you must either

1) open the ***RunControl.nml*** file and edit input and output file paths and the site name (with a text editor) so that they are correct for your setup

2) Or create these directories
From the given site identification the model identifies the input files and generates the output files (Table 3.2).

ModelledYears.txt
In this file the number of years, which years that they are and the daylight saving (DLS) dates for each year (Table 3.4). Note, Day of Year is used for all calculations. Leap years are taken into account and will be determined separately for each year. *If DLS does not* occur: give a start and end day immediately after it. Important: Make certain the dummy dates are correct for the hemisphere

Northern hemisphere use: 180 181
Southern hemisphere use: 365 1

GridConnectionsYYYY.txt
The site name (*SS*), with a possibility to add areal code (ss) are given in the ***GridConnectionsYYYY.txt*** file (Table 4.2). If you do not have any areal code, please set here *SS* (as in our example). There should be one of these files for each year.

For example if you specify FileOutputPath = "C:\FolderName\SUEWSOutputs\" and use site identification code (e.g. Sm_2011, where Sm is *SS*) the model creates an output file (*Remember to add the last backslash in windows computer and slash in Linux/Mac*):

C:\FolderName\SUEWSOutput\Sm_2011_60.txt.

If the file paths are not correct the program will return an error (Run-time Error, File path not found, see section 5.1 for error messages) when run or the **problems.txt** file. Note that when running multiple grids all files should be in the same input directory.

To run the model you can use Command Prompt or just double click the executable file. Please, see Troubleshooting (Section 6) if you have problems running the model.

3.3 Input and output files

The input files required for SUEWS are listed in Table 3.3 (see other tables in this section and section 4). For the user defined filenames (i.e. *SSss_YYYY) SSss* represents a site name (usually a relevant two letter code is applied), and *YYYY* the year (four digit year is used) or grid identification. Time step *tt* is set to 60-min in the current version of the model. The last column indicates whether the input file is needed one per run (1/run), for each grid (1/grid), for each year (1/year) or once per day (1/day)

Table 3.3: Input and Output files (input filenames are hyperlinked to the appropriate section where more detail is provided) B - BLUEWS

File Name	Description	When Needed [Used]
Input (see section 4)		
RunControl.nml	Namelist file paths and run options.	1/run
ModelledYears.txt	Listing of modelled years	1/run
GridConnections*YYYY*.txt	Definition of modelled grids	1/year
InitialConditions*SSss_YYYY*.nml	Initial conditions for run (NB: also output file -written at the end of a run)	1/grid
SUEWS_FunctionalTypes.txt	Model parameters	1/run
OHM_Coefficients.txt	Parameter options for OHM	1/run
WaterDistSSss_YYYY.txt	water flows between surface stores	1/grid/year
SiteSpecificParamSSss_YYYY.txt	parameters to calculate external water use	1/grid/year
SelectOHM*SSss_YYYY*.txt	Parameters used to calculate OHM	1/grid/year
SSss_YYYY _data.txt	Meteorological forcing data	1/grid/year
SSss_YYYY.gis	GIS data	1/grid/year
*SSss_YYYY*SAHP.nml	Parameter options for Q_F	1/grid/year
HourlyProfile*SSss_YYYY*.txt	Diurnal profile for external water used and for Q_F	1/grid/year
CBLinput.nml	Namelist file paths, run options and input parameters for CBL model	1/run [B]
CBL_initial_data.txt	Initial data for CBL model	1/day [B]
Output (see section 5)		
SSss_YYYY_tt.txt	Model output with timestep *tt*	
*SSss_YYYY*_NARPOut.txt	NARP file (Created if *NARPOutputChoice* = 1)	
*SSss_YYYY*_MonthlyFile.txt	Monthly water balance (WB) file	
*SSss_YYYY*_DailyFile.txt	Daily WB file	

*SSss*_DailyState.txt	Status of the daily storages and other status values	
SSss_alldays.txt	Daily output for multiple years	
*SSss_YYYY*_5min.txt	5-min WB file Created if *write5min*=1	
*SS*_FileChoices.txt	Run choice options	
InitialState*SSss_YYYY*.nml	At the end of the run a file is written that is the initial conditions (it is also written at the end of each year). This goes into the input directory, YYYY**Z** is typically the year +1 otherwise it will be the same yearend	
*SSss_YYYY*_SnowOut.txt	Output file for snow parameters	
CBL_*id*.txt	CBL model output files	[B]

3.4 Settings for your site

This section is being expanded based on our interactions with users. So we expect to develop it with time and is only an initial set of comments to accompany to the current release. We would be very pleased to get any feedback on material that you thing would be useful in this section or in the manual in general.

The model allows you to change a large number of characteristics about your site. You should not assume that the values that are currently in the files are appropriate.

The model is designed to use (60 min) hourly input data. Note we are soon to change this to 5 min base run so will be able to use higher resolution data if available.

1	Albedo	**Is the bulk albedo correct?** This is critical because a small error has an impact on all the fluxes (energy and hydrology) *How to check?* If you have measurement of outgoing shortwave radiation – compare those with the modelled values
2	Land cover	These are critical! Make certain that the different surface cover fractions are appropriate for your site *How to check?* Web sites like Bing Maps and Google Maps allow you to see aerial images of your sites or areas of interest. These allow you to determine the land surface cover types and their relative proportions. There are additionally a number of remote sensing resources that can be used.
3	Anthropogenic Heat flux	If you have no information about the site population density needed as an input for LUMPS and SUEWS to calculate Q_F, we recommend that you use LUCY to get a first estimate of these values. Allen L, F Lindberg, CSB Grimmond (2011) Global to city scale model for anthropogenic heat flux, *International Journal of Climatology,* 31, 1990-2005. Lindberg F, Grimmond CSB, Nithiandamdan Y, Kotthaus S, Allen L (2013) Impact of city changes and weather on anthropogenic heat flux in Europe 1995–2015, *Urban Climate*, http://dx.doi.org/10.1016/j.uclim.2013.03.002 http://www.met.reading.ac.uk/micromet/lucy-greaterqf/

4 Input files

4.1 RunControl.nml

The file **RunControl.nml** contains the model run options and two default variable values (Table 4.1). This file should be located in the same directory as the executable file. The type of this folder should be

&RunControl
Parameters and variables from Table 4.1 in any order
/

In Linux and Mac, please add an empty line after the end Slash. This file is not case sensitive.

Table 4.1: Variables and parameters in **RunControl.nml**. (these can be in any order)
VI: Variable that the parameter influences [F- anthropogenic heat flux, A – all fluxes, R radiation, S – Heat storage, W –multiple water balance fluxes, L- LUMPS, M – multiple heat fluxes, N – no fluxes].
ET = evergreen trees and shrubs, DT = deciduous trees and shrubs, IG = Irrigated grass, UG = unirrigated grass, W = water

<table>
<tr><th>Name</th><th>VI</th><th>Description</th></tr>
<tr><td colspan="3">Model run options</td></tr>
<tr><td>AnthropHeatChoice</td><td>F</td><td>Determines if Q_F and how is calculated
<table>
<tr><td>Value</td><td>Comments</td></tr>
<tr><td>0</td><td>• Uses values provided in the forcing file (SSss_YYYY_data.txt).
• If value missing, the defaultQf will be used
• If user does not want to calculate Q_F or supply values, then the values in the meteorological input file should be zero.</td></tr>
<tr><td>1</td><td>• Calculated according to Loridan et al. (2010)
• Coefficients are set in SAHP input file (SSss_YYYYsahp.nml)
• If values are provided in the Meteorological input file (SSss_YYYY_data.txt) the modelled values will be used.</td></tr>
<tr><td>2</td><td>• Recommended!
• Calculated according to Järvi et al. (2011)
• Coefficients are set in SSss_YYYYSAHP.nml; Diurnal pattern in HourlyProfileSSss_YYYY.txt
• If values are provided in the Meteorological input file (SSss_YYYY_data.txt) the modelled values will be used.</td></tr>
</table></td></tr>
<tr><td>CBLuse</td><td></td><td>Determines if a CBL slab model is used to calculate temperature and humidity.
<table>
<tr><td>Value</td><td>Comments</td></tr>
<tr><td>0</td><td>• CBL model is NOT used.
• SUEWS and LUMPS use temperature and humidity provided in Meteorological input file.</td></tr>
<tr><td>1</td><td>• CBL model is used.
• SUEWS and LUMPS use the modelled temperature and humidity.</td></tr>
</table></td></tr>
<tr><td>GISInputType</td><td>A</td><td>Identifies number of lines of GIS data file type
<table>
<tr><td>Value</td><td>Comments</td></tr>
<tr><td>0, 1, 2</td><td>Not used</td></tr>
<tr><td>3</td><td>Stays constant with time so the gis has only one line of data</td></tr>
<tr><td>4</td><td>Varies at each time step so the gis file has a data line for each time step</td></tr>
</table></td></tr>
<tr><td>NetRadiationChoice</td><td>R</td><td>Determines if radiation is observed or modelled (NARP) (Offerle et al. 2003, Loridan et al. 2010) and if a separate output file is to be written
L↓ downwelling longwave radiation
Q* net all wave radiation
<table>
<tr><td>Value</td><td>Comments</td></tr>
<tr><td>0</td><td>Observed values of Q* used</td></tr>
<tr><td>1</td><td>• Modelled, but L↓ observations supplied in forcing data
• Albedo zenith angle not accounted for
• No SSss_YYYY_NARPOut.txt file</td></tr>
<tr><td>2</td><td>• Modelled with L↓ modelled using cloud cover fraction supplied in forcing data file (see Loridan et al. 2010)</td></tr>
</table></td></tr>
</table>

Value	Comments
	• Albedo zenith angle not accounted for • No ***SSss_YYYY*_NARPOut.txt** file
3	• Modelled with $L\downarrow$ modelled using air temperature and relative humidity data (see Loridan et al. 2010) • Albedo zenith angle not accounted for • No ***SSss_YYYY*_NARPOut.txt** file
10	• Modelled but $L\downarrow$ observations supplied in forcing data • Albedo zenith angle not accounted for • ***SSss_YYYY*_NARPOut.txt** file
20	• Modelled with $L\downarrow$ modelled using cloud cover fraction supplied in forcing data file • Albedo zenith angle not accounted for • ***SSss_YYYY*_NARPOut.txt** file
30	• Modelled with $L\downarrow$ modelled using air temperature and relative humidity data (see Loridan et al. 2010) • Albedo zenith angle not accounted for • ***SSss_YYYY*_NARPOut.txt** file
The following are not recommended in this release	
100	• Modelled but $L\downarrow$ observations supplied in forcing data • Albedo zenith angle modelled • ***SSss_YYYY*_NARPOut.txt** file
200	• Modelled with $L\downarrow$ modelled using cloud cover fraction supplied in forcing data file • Albedo zenith angle accounted for • ***SSss_YYYY*_NARPOut.txt** file
300	• Modelled with $L\downarrow$ modelled using air temperature and relative humidity data (see Loridan et al. 2010) • Albedo zenith angle accounted for • ***SSss_YYYY*_NARPOut.txt** file

QSChoice | S | Selects which method is used to determine storage heat flux ΔQ_S

Value	Comments
0	Not used
1	Modelled using the objective hysteresis model (OHM)) (Grimmond et al. 1991, Grimmond & Oke 1999a, 2002) The model is based on surface types
2	*Observed* ΔQ_S values are used from the meteorological input file see also *defaultQs*

RoughLen_heat | M | Method to calculate roughness length for heat to be used

Value	Comments
0	Not used
1	as $0.1z_{0m}$
2	according to Kawai et al. (2009) **(recommended)**
3	according to Voogt and Grimmond (2000)
4	according to Kanda et al. (2007)

smd_choice | W | Soil moisture deficit

Value	Comments
0	Modelled – need values for *soilstoreCap*, *VolSoilMoistCap* and *SatHydraulicConduct* in **SUEWS_FunctionalTypes.txt**
1	Measured Volumetric data supplied in meteorological data file – need values for *SoilDepthMeas*, *SoilRocks* and *smCap* in **SUEWS_FunctionalTypes.txt.**
2	Measured Gravimetric data supplied in forcing data file Need to supply values for *SoilDensity*, *SoilDepthMeas*, *SoilRocks* and *smCap* in **SUEWS_FunctionalTypes.txt**

SnowFractionChoice	M	Defines the method to calculate snow plan area fraction (set to 2). Used only if *SnowUse*=1.
SnowUse	M	1 = snow calculatations are done, 0 = no snow calculations are done
StabilityMethod	M	Defines which atmospheric stability functions are used

Value	Comments

<table>
<tr><td></td><td></td><td colspan="2"><table>
<tr><td>0-1</td><td>Not used</td></tr>
<tr><td>2</td><td>Recommended!
Momentum: Unstable: Dyer (1974), modified by Högstrom (1988)
Stable: Van Ulden & Holtslag (1985)
Heat: Dyer (1974), modified by Högstrom (1988)</td></tr>
<tr><td>3</td><td>Momentum: Campbell & Norman eqn 7.27 p 97
Heat: Unstable: Campbell & Norman
Stable: Dyer (1974) modifed by Högstrom (1988)</td></tr>
<tr><td>4</td><td>Momentum Businger et al. (1971) modifed by Högstrom (1988)
Heat: Businger et al. (1971) modifed by Högstrom (1988)</td></tr>
</table></td></tr>
<tr><td>write5min</td><td>W</td><td colspan="2">Write 5-min output file<table>
<tr><td>Value</td><td>Comments</td></tr>
<tr><td>0</td><td>No</td></tr>
<tr><td>1</td><td>Write 5 min outputfile SSss_YYYY_5min.txt</td></tr>
</table></td></tr>
<tr><td>WU_choice</td><td>W</td><td colspan="2">External water use<table>
<tr><td>Value</td><td>Comments</td></tr>
<tr><td>0</td><td>Modelled using options set in WaterUseProfileSSss_YYYY.nml</td></tr>
<tr><td>1</td><td>Observations are used</td></tr>
</table></td></tr>
<tr><td>z0_method</td><td>A</td><td colspan="2">Determines how aerodynamic roughness length (z_{0m}) and zero displacement height (z_d) are obtained<table>
<tr><td>Value</td><td>Comments</td></tr>
<tr><td>1</td><td>Values in SSss_YYYY.gis file are used
If GISInputType =3 – z_{0m} and z_d are fixed and will not change with time</td></tr>
<tr><td>2</td><td>Calculated from mean building and tree heights with “Rule of Thumb” (Grimmond and Oke 1999)
Heights must be given in GIS file</td></tr>
<tr><td>3</td><td>Calculated using heights, plan area fraction and frontal areal index based on the MacDonald et al. (1998) method
Heights and Frontal area Index must be given in GIS file</td></tr>
</table></td></tr>
<tr><td colspan="4">Default variable values</td></tr>
<tr><td>defaultQf</td><td>M</td><td>W m^{-2}</td><td>Default Q_F (used if AnthropHeatChoice = 0 and input data -999)</td></tr>
<tr><td>defaultQs</td><td>M</td><td>W m^{-2}</td><td>Default ΔQ_S (used if QSChoice = 2 and input data -999)</td></tr>
<tr><td colspan="4">File related</td></tr>
<tr><td>FileCode</td><td>A</td><td>-</td><td>Total site identification code (e.g. SSss)</td></tr>
<tr><td>FileInputPath</td><td>A</td><td>-</td><td>File path with the required input files.</td></tr>
<tr><td>FileOutputPath</td><td>A</td><td>-</td><td>File path where the output files are created.</td></tr>
<tr><td>SkipHeaderGIS</td><td>A</td><td>-</td><td>Number of header lines to skip in GIS input file</td></tr>
<tr><td>SkipHeaderMet</td><td>A</td><td>-</td><td>Number of header lines to skip in meteorological input file</td></tr>
<tr><td colspan="4">Time related</td></tr>
<tr><td>INTERVAL</td><td>A</td><td>sec</td><td>Main time step (Recommended: 3600)</td></tr>
<tr><td>SOLWEIGuse</td><td>N</td><td>-</td><td>Not available in current version and needs to be set to 0.
1 = Grid of mean radiant temperature (Tmrt) are calculated and saved based on high resolution digital surface models.
0 = No Tmrt is calculated.</td></tr>
<tr><td>TIMEZONE</td><td>R</td><td>h</td><td>Time zone relative to UTC (OBS! east is positive)</td></tr>
<tr><td>Tstep</td><td>A</td><td>s</td><td>Time step for sub-interval calculations, important for runoff calculation (Recommended: 300)</td></tr>
<tr><td colspan="4">Height</td></tr>
<tr><td>z</td><td>M</td><td>m</td><td>Height of the meteorological forcing data – the most important height is that of the wind speed measurement</td></tr>
</table>

4.2 ModelledYears.txt

SUEWS can be used to model longer time periods during what the forcing data, surface cover information and different input parameters may vary. The purpose of file **ModelledYears.txt** is to list the years, which are modelled and the respective daylight saving times (needed for anthropogenic heat flux and irrigation). In this file (Table 4.2) the line order is important.

Table 4.2: ModelledYears.TXT. – in this file the **line order is important**.

Line	Description	Example	Comment
1	Number of years that are to be run	1	Just one year will be modelled (see section 4.1 for how to model **multiple years**)
2	Year / Start DLS / End DLS	2011 / 86 / 303	Year is 2011. In **northern hemisphere** example, the day light saving start on day of year 86 and finishes on 303

In the example below "!" indicates comments in the file. Comments are not read by the programme so they can be used by the user to provide notes for their interpretation of the contents.

Example of **ModelledYears.txt** when multiple years (in this case 2008 and 2009) are run

```
2                         !Number of modelled years/time periods
2008    170    240        !Year  -start of daylight savings   -end of daylight savings
2009    172    242
```

Note! For both years all other input files with *YYYY* are needed. The respective output files will be created. Day of Year is used in all calculations. Leap years are taken into account and will be determined for each year.

Example of **ModelledYears.txt** when daylight saving does not occur in Northern hemisphere:

```
1                         !Number of modelled years/time periods
2008    180    181        !Year  -start of daylight savings   -end of daylight savings
```

Example of **ModelledYears.txt** when daylight saving occurs in Southern Hemisphere

```
1                         !Number of modelled years/time periods
2004    275    93         !Year  -start of Daylight savings   -end of daylight savings
```

Example of **ModelledYears.txt** when daylight saving does not occur in Southern Hemisphere

```
1                         !Number of modelled years/time periods
2008    365    1          !Year  -start of daylight Savings   -end of daylight savings
```

4.3 GridConnectionsYYYY.txt

SUEWS is a spatial model which can be run for several areas that are linked to each other as defined in **GridConnections*YYYY*.txt**. The connections are related to the direction that water will flow between the grids (Table 4.3).

Table 4.3: GridConnections*YYYY*.txt. In this file the **line order is important**

Line	Description	Example	Comment
1	Number of model grids	1	Just one area will be modelled (see below how to model **multiple areas**)
2	Site / Fraction / To	'SS' / 0 / 'none'	Site 'SS_' has 0 connection to 'none' The last line should always be 0 to 'none' Note quote marks must be included

In the following example the model is to be run with two areas (in year 2008) Ln*3004_2008* and Ln*2926_2008* and 20% of water leaving grid Ln*3004_2008* as a runoff (either in pipes or above ground) will flow to grid Ln*2926_2008*. Similarly, as there are only two grids, the grid Ln*2926_2008* is not linked to any other grid.

Example of **GridConnections*YYYY*.txt**

```
2                 !Number of grid connections listed below
'Ln3004'   0.2    'Ln2926'
'Ln2926'   0      'none'
!From   fraction   To
```

4.4 *InitialConditionsSSss_YYYY.nml*

This is needed for the first time period for each area. After that the new **InitialConditions*SSss_YYYY*.nml** files will be written for the following years. It is **recommended** that you look at this output which will be located in the input directory to check the status of various surfaces at the end or the run. This may help you get more realistic starting values if you are uncertain what they should be. Note this file will be created for each year for multiyear runs for each grid you run.

Table 4.4: InitialConditions*SSss_YYYY*.nml. Variables can be in any order. Note it is important that the vegetation characteristics are set correctly. I.e. is the starting period winter or summer. Are there leaves on the trees or not? All the names that have changes in this released are with different background colour.

Parameters	**Used for**	**Unit**	**Comments**
DaysSinceRain	Wateruse	days	Number of days since rainfall occurred – • important if starting in summer season that this is correct • if starting when external water use is not occurring it will be reset with the first rain so can just be set to 0
Temp_C0	Water use, QF	°C	Daily mean temperature (°C) for the day before the run starts
Id_prev	A	Day	Day of year before the run starts (i.e. previous day) If start of year – use 0
GDD_1_0	LAI	°C	Growing degree days for leaf growth • If leaves are already full, then this should be the same as *GDDFull* in the **FunctionalTypes.txt** • If winter, set to 0 • Needs to be a positive number
GDD_2_0	LAI	°C	Growing degree days for senescence growth • If the leaves are full but in early/mid summer then set to 0 • If late summer or autumn, this should be a negative value • If leaves are off, then use the values of *SDDFull* in **FunctionalTypes.txt** to guide your minimum value • Needs to be a negative number or 0
Above Ground State			
BldgState	W	Mm	Initial wetness state for buildings
ETState	W	Mm	Initial wetness state of evergreen tree
DTState	W	Mm	Initial wetness state of deciduous trees
IGState	W	Mm	Initial wetness state of irrigated grass
UGState	W	Mm	Initial wetness state of unirrigated grass
PavState	W	Mm	Initial wetness state of paved surface
WaterState	W	Mm	Initial state of water
LAIinitialET	W	$m^2\ m^{-2}$	Initial LAI for evergreen trees
LAIinitialDT	W	$m^2\ m^{-2}$	Initial LAI for deciduous trees
LAIinitialIG	W	$m^2\ m^{-2}$	Initial LAI for irrigated grass
LAIinitialUG	W	$m^2\ m^{-2}$	Initial LAI for unirrigated grass
Below Ground State Note! Below water, no soil store is allowed. Horizontal movements are permitted between the soil stores (see section 4.5)			
SoilstoreBldgState	W	Mm	Initial state of the soil water storage under buildings
SoilstoreETState	W	Mm	Initial state of the soil water storage under evergreen trees
SoilstoreDTState	W	Mm	Initial state of the soil water storage under deciduous trees
SoilstoreIGState	W	Mm	Initial state of the soil water storage under irrigated grass
SoilstoreUGState	W	Mm	Initial state of the soil water storage under unirrigated grass
SoilstorePavState	W	Mm	Initial state of the soil water storage under paved surface
Deciduous Vegetation state This should be consistent with *albedo* and DT storage in **SurfaceFunctionalTypes.txt** and time of year			
albDec0	R	-	Deciduous albedo on day 0 of run
decidCap0	A	Mm	Deciduous storage capacity on day 0 of run
porosity0	E	-	Porosity of deciduous vegetation on day 0 of run
Snow (Currently should be set to zero)			
SnowWaterBldgState		Mm	Initial amount of liquid water in the snow on buildings
SnowWaterETState		Mm	Initial amount of liquid water in the snow on evergreen trees

SnowWaterDTState		Mm	Initial amount of liquid water in the snow on deciduous trees
SnowWaterIGState		Mm	Initial amount of liquid water in the snow on irrigated grass
SnowWaterUGState		Mm	Initial amount of liquid water in the snow on unirrigated grass
SnowWaterPavState		Mm	Initial amount of liquid water in the snow on paved surface
SnowWaterWaterState		Mm	Initial amount of liquid water in the snow in water
SnowPackBldg		Mm	Initial snow water equivalent if the snow on buildings
SnowPackET		Mm	Initial snow water equivalent if the snow on evergreen trees
SnowPackDT		Mm	Initial snow water equivalent if the snow on deciduous trees
SnowPackIG		Mm	Initial snow water equivalent if the snow on irrigated grass
SnowPackUG		Mm	Initial snow water equivalent if the snow on unirrigated grass
SnowPackPav		Mm	Initial snow water equivalent if the snow on paved surface
SnowPackWater		Mm	Initial snow water equivalent if the snow on water
SnowFracBldg		-	Initial plan area fraction of snow on buildings
SnowFracET		-	Initial plan area fraction of snow on evergreen trees
SnowFracDT		-	Initial plan area fraction of snow on deciduous trees
SnowFracIG		-	Initial plan area fraction of snow on irrigated grass
SnowFracUG		-	Initial plan area fraction of snow on unirrigated grass
SnowFracPav		-	Initial plan area fraction of snow on paved surface
SnowFracWater		-	Initial plan area fraction of snow on water
SnowDensBldg		kg m^{-3}	Initial snow density on buildings
SnowDensET		kg m^{-3}	Initial snow density on evergreen trees
SnowDensDT		kg m^{-3}	Initial snow density on deciduous trees
SnowDensIG		kg m^{-3}	Initial snow density on irrigated grass
SnowDensUG		kg m^{-3}	Initial snow density on unirrigated grass
SnowDensPav		kg m^{-3}	Initial snow density on paved surface
SnowDensWater		kg m^{-3}	Initial snow density on water

4.5 *SUEWS_FunctionalTypes.txt*

This file must be in the order that is provided in. The parameters that may not need to be changed for each site are specified in **SUEWS_FunctionalTypes.txt** (Table 4.5).

Table 4.5:Parameters used in SUEWS for the surface characteristics: Recommended values for the parameters are given and in the spreadsheet (section 3.4). VI: Variable that the parameter influences [F- anthropogenic heat flux, A – all fluxes, R radiation, S – Heat storage, W –multiple water balance fluxes, L- LUMPS, M – multiple heat fluxes]. ET = evergreen trees and shrubs, DT = deciduous trees and shrubs, IG = Irrigated grass, UG = unirrigated grass, W =water
Values with a -9 indicate that a value is not needed.
Values given are examples of recommended values
Values given are example values

<table>
<tr><th>Line</th><th>Name</th><th>VI</th><th>Units</th><th>Description</th></tr>
<tr><td></td><td>Header</td><td></td><td></td><td>Column header</td></tr>
<tr><td>1</td><td>Albedo</td><td>R</td><td>-</td><td>Effective surface albedo (Full leaf-on, middle of the day value). View factors should be taken into account
<table>
<tr><td>PAV</td><td>BLDG</td><td>ET</td><td>DT</td><td>IG</td><td>UG</td><td>W</td><td>Snow</td><td>Comment</td></tr>
<tr><td>0.09</td><td>0.15</td><td>0.1</td><td>0.16</td><td>0.19</td><td>0.19</td><td>0.08</td><td>0.5</td><td>Järvi et al. (2014) - HL</td></tr>
<tr><td>0.12</td><td>0.15</td><td>0.1</td><td>0.18</td><td>0.21</td><td>0.21</td><td>0.1</td><td>-</td><td>Oke (1987)</td></tr>
</table></td></tr>
<tr><td>2</td><td>Emissivity</td><td></td><td></td><td>Effective surface emissivity. View factors should be taken into account
<table>
<tr><td>PAV</td><td>BLDG</td><td>ET</td><td>DT</td><td>IG</td><td>UG</td><td>W</td><td>Snow</td><td>Comment</td></tr>
<tr><td>0.95</td><td>0.91</td><td>0.98</td><td>0.98</td><td>0.93</td><td>0.93</td><td>0.95</td><td>0.99</td><td>Oke (1987)</td></tr>
</table></td></tr>
<tr><td>3</td><td>BaseT</td><td>W</td><td>°C</td><td>Base temperature for initiating Growing Degree days for leaf on
<table>
<tr><td>PAV</td><td>BLDG</td><td>ET</td><td>DT</td><td>IG</td><td>UG</td><td>W</td><td>Snow</td><td>Comment</td></tr>
<tr><td>-9</td><td>-9</td><td>5</td><td>5</td><td>5</td><td>5</td><td>-9</td><td>-9</td><td>Järvi et al. (2011)</td></tr>
</table></td></tr>
<tr><td>4</td><td>BaseTe</td><td>W</td><td>°C</td><td>Base temperature for initiating Senescence Degree days for leaf off
<table>
<tr><td>PAV</td><td>BLDG</td><td>ET</td><td>DT</td><td>IG</td><td>UG</td><td>W</td><td>Snow</td><td>Comment</td></tr>
<tr><td>-9</td><td>-9</td><td>10</td><td>10</td><td>10</td><td>10</td><td>-9</td><td>-9</td><td>Järvi et al. (2011</td></tr>
</table></td></tr>
</table>

<table>
<tr><td>5</td><td>Minimum Storage Capacity</td><td></td><td>mm</td><td>Minimum storage capacity – this is for upper surface
<table>
<tr><td>PAV[3]</td><td>BLDG[4]</td><td>ET[5]</td><td>DTError! Bookmark not defined.</td><td>IGError! Bookmark not defined.</td><td>UGError! Bookmark not defined.</td><td>W</td><td>Snow</td><td>Comment</td></tr>
<tr><td>0.48</td><td>0.25</td><td>1.3</td><td>0.3</td><td>1.9</td><td>1.9</td><td>0.5</td><td>-9</td><td>See footnotes for recommended values</td></tr>
</table></td></tr>
<tr><td>6</td><td>Maximum Storage Capacity</td><td></td><td>mm</td><td>Maximum Storage Capacity for upper surfaces
<table>
<tr><td>PAV</td><td>BLDG</td><td>ET</td><td>DT[6]</td><td>IG</td><td>UG</td><td>W</td><td>Snow</td><td>Comment</td></tr>
<tr><td>0.48</td><td>0.25</td><td>1.3</td><td>0.8</td><td>1.9</td><td>1.9</td><td>0.5</td><td>-9</td><td>See footnotes for recommended values</td></tr>
</table></td></tr>
<tr><td>7</td><td>Drainage Equations</td><td></td><td></td><td>Drainage equations
<table>
<tr><td>PAV</td><td>BLDG</td><td>ET</td><td>DT</td><td>IG</td><td>UG</td><td>W</td><td>Snow</td><td>Comment</td></tr>
<tr><td>3</td><td>3</td><td>2</td><td>2</td><td>3</td><td>2</td><td>-9</td><td>-9</td><td>Grimmond and Oke (1991)</td></tr>
</table></td></tr>
<tr><td>8</td><td>Drainage Coefficient 1</td><td>W</td><td>mm</td><td>Coefficient D_0 in drainage equation
<table>
<tr><td>PAV</td><td>BLDG</td><td>ET</td><td>DT</td><td>IG</td><td>UG</td><td>W</td><td>Snow</td><td>Comment</td></tr>
<tr><td>10</td><td>10</td><td>0.013</td><td>0.013</td><td>10</td><td>0.013</td><td>-9</td><td>-9</td><td>Grimmond and Oke (1991)</td></tr>
</table></td></tr>
<tr><td>9</td><td>Drainage Coefficient 2</td><td>W</td><td>-</td><td>Coefficient b in drainage equation
<table>
<tr><td>PAV</td><td>BLDG</td><td>ET</td><td>DT</td><td>IG</td><td>UG</td><td>W</td><td>Snow</td><td>Comment</td></tr>
<tr><td>3</td><td>3</td><td>1.71</td><td>1.71</td><td>3</td><td>1.71</td><td>-9</td><td>-9</td><td>Grimmond and Oke (1991)</td></tr>
</table></td></tr>
<tr><td>10</td><td>GDDFull</td><td></td><td>°C</td><td>Growing degree days needed for full capacity of the leaf area index
<table>
<tr><td>PAV</td><td>BLDG</td><td>ET</td><td>DT</td><td>IG</td><td>UG</td><td>W</td><td>Snow</td><td>Comment</td></tr>
<tr><td>-9</td><td>-9</td><td>300</td><td>300</td><td>300</td><td>300</td><td>-9</td><td>-9</td><td>Järvi et al. (2011)</td></tr>
</table></td></tr>
<tr><td>11</td><td>SDDFull</td><td></td><td>°C</td><td>Senescence degree days needed for leaf fall to begin
This should be checked carefully for your study area. Check impact in the dailystate.txt file of the LAI relative to known behaviour in your study area.
<table>
<tr><td>PAV</td><td>BLDG</td><td>ET</td><td>DT</td><td>IG</td><td>UG</td><td>W</td><td>Snow</td><td>Comment</td></tr>
<tr><td>-9</td><td>-9</td><td>-450</td><td>-450</td><td>-450</td><td>-450</td><td>-9</td><td>-9</td><td>Järvi et al. (2011)</td></tr>
</table></td></tr>
<tr><td>12</td><td>LAI Min</td><td></td><td></td><td>Leaf Area Index Minimum
<table>
<tr><td>PAV</td><td>BLDG</td><td>ET[7]</td><td>DT[7]</td><td>IG[8]</td><td>UG[8]</td><td>W</td><td>Snow</td><td>Comment</td></tr>
<tr><td>-9</td><td>-9</td><td>4</td><td>1</td><td>1.6</td><td>1.6</td><td>-9</td><td>-9</td><td>See footnotes for recommended values</td></tr>
</table></td></tr>
<tr><td>13</td><td>LAI Max</td><td></td><td></td><td>Leaf Area Index Maximum
<table>
<tr><td>PAV</td><td>BLDG</td><td>ET</td><td>DT</td><td>IG</td><td>UG</td><td>W</td><td>Snow</td><td>Comment</td></tr>
<tr><td>-9</td><td>-9</td><td>5.1</td><td>5.5</td><td>5.9</td><td>5.9</td><td>-9</td><td>-9</td><td>Breuer et al. (2003)</td></tr>
</table></td></tr>
<tr><td>14</td><td>Maximum conductance for each vegetation type</td><td></td><td>mm s^{-1}</td><td>Maximum Conductance
<table>
<tr><td>PAV</td><td>BLDG</td><td>ET</td><td>DT</td><td>IG</td><td>UG</td><td>W</td><td>Snow</td><td>Comment</td></tr>
<tr><td>-9</td><td>-9</td><td>7.4</td><td>11.7</td><td>40</td><td>33.1</td><td>-9</td><td>-9</td><td>Järvi et al. (2011)</td></tr>
</table></td></tr>
<tr><td>15</td><td>soilstoreCap
Soil water storage below the surface</td><td></td><td>mm</td><td>Soil Storage Capacity (Below each surface)
<table>
<tr><td>PAV</td><td>BLDG</td><td>ET</td><td>DT</td><td>IG</td><td>UG</td><td>W</td><td>Snow</td><td>Comment</td></tr>
<tr><td>150</td><td>150</td><td>150</td><td>150</td><td>150</td><td>150</td><td>-9</td><td>-9</td><td>Järvi et al. (2011)</td></tr>
<tr><td>100</td><td>50</td><td>150</td><td>150</td><td>150</td><td>150</td><td>-9</td><td>-9</td><td>Järvi et al. (2014)</td></tr>
</table></td></tr>
<tr><td>16</td><td>VolSoilMoistCap
Maximum volumetric soil moisture capacity</td><td></td><td>$m^3 m^{-3}$</td><td>Maximum volumetric soil moisture capacity
<table>
<tr><td>PAV</td><td>BLDG</td><td>ET</td><td>DT</td><td>IG</td><td>UG</td><td>W</td><td>Snow</td><td>Comment</td></tr>
<tr><td>0.43</td><td>0.43</td><td>0.43</td><td>0.43</td><td>0.43</td><td>0.43</td><td>-9</td><td>-9</td><td>Järvi et al. (2011)</td></tr>
</table></td></tr>
<tr><td>17</td><td>SatHydraulicConduct</td><td></td><td>mm s^{-1}</td><td>Hydraulic conductivity for saturated soil
<table>
<tr><td>PAV</td><td>BLDG</td><td>ET</td><td>DT</td><td>IG</td><td>UG</td><td>W</td><td>Snow</td><td>Comment</td></tr>
<tr><td>5e-04</td><td>5e-04</td><td>5e-04</td><td>5e-04</td><td>5e-04</td><td>5e-04</td><td>-9</td><td>-9</td><td>Belthier et al. (2006)</td></tr>
</table></td></tr>
<tr><td>18</td><td>Comment line</td><td></td><td></td><td></td></tr>
<tr><td>19</td><td>Conductance</td><td></td><td></td><td>Vegetation surface conductance parameters</td></tr>
</table>

[3] Davies and Hollis (1981)
[4] Falk and Niemczynowicz (1978)
[5] Breuer et al. (2003)
[6] Grimmond and Oke (1991)
[7] Järvi et al. (2011)
[8] references within Grimmond (1988)

Parameters (continued)

G1	G2	G3	G4	G5	G6	Comment
mm s-1	W m-2	kg g-1	g kg-1	°C	mm-1	
16.48	566.1	0.216	3.36	11.07	0.018	Järvi et al. (2011)

20 Conductance related Parameters

Parameters used with the conductance parameters

TH[7]	*TL*[7]	*S1*[9]	*S2*[9]	*KMax*[7]	*Comment*
° C	° C	-	mm	W m-2	
40	0	0.45	15	1200	Järvi et al. (2011)

Should **only be changed** if different surface conductance coefficients (G_1 - G_6) are used.

KMax	Annual maximum hourly downward radiation
TH, TL	Maximum, Minimum temperature limit.

21 Comment line

22 Soil Characteristics For observed data

SoilDensity	*SoilDepthMeas*	*SoilRocks*	*smCap*
kg m-3	mm	%	kg kg-1 **or** m3 m-3
Density of soil -used if gravimetric	Soil depth of measured soil moisture	Fraction of soil without rocks	Maximum water content in the soil
1.16	150	0.85	0.425
-999 if soil moisture modelled or not used			

23 Comment line

24 LUMPS – surface wetness

Surface wetness control

DRAINRT	*RAINCOVER*	*RAINMAXRES*	Comment
mm h-1	mm	mm	
Drainage rate of the "water bucket"	Limit when the surface is totally covered with water	Maximum water bucket reservoir	
0.25	1	10	Offerle (2002), Loridan et al. (2011)

25 Comment line

26 Snow control

RadMeltFact	*TempMeltFact*	*AlbMin*	*AlbMax*	*tau_a*	*tau_f*	PrecipiLimAlb	Comment
Hourly radiation melt factor of snow	Hourly temperature melt factor of snow	Albedo minimum	Fresh snow albedo	Time constant for snow albedo aging in cold snow	Time constant for snow albedo aging in melting snow	Limit for hourly precipitation when snow albedo is reset to AlbMax	
0.0016	0.12	0.18	0.85	0.018	0.11	2	Järvi et al. (2014)

27 Snow related

snowDensMin	*snowDensMax*	*tau_r*	C^R_{min}	C^R_{max}	*PlimSnow*	*Comment*
kg m-3	kg m-3				mm	
Fresh snow density	Maximum density	Time constant for snow density	Minimum water holding capacity of snow	Maximum water holding capacity of snow	Precipitation limit for snow	
100	400	0.043	0.05	0.2	2.2	Järvi et al. (2014)

28 SnowD

Limit of snow water equivalent when surface fraction starts to be non-snow (maximum SWE)

PAV	BLDG	CT	DT	IG	UG	Comment
190	190	190	190	190	190	Järvi et al. (2014)

29 Comment line

30 *NARP related* | R | - | *TRANS_SITE* Atmospheric transmissivity (0-1) of the site (used in NARP)

31 *Comment line*

32 *Leaf area Index*

LAItype	*LAIpower(1)*	*LAIpower(2)*	*LAIpower(3)*	*LAIpower(4)*	Comment
-	-	-	-	-	
Method to calculate LAI	Power of LAI for leaf growth	Constant in the leaf growth equation	Power of LAI for leaf off	Constant in the leaf off equation	
0	0.03	0.0005	0.03	0.0005	Järvi et al. (2011)
1	0.04	0.001	-1.5	0.0015	Järvi et al. (2014)

33 *Empty line in Mac and Linux*

[9] Grimmond and Oke (1991)

4.6 *Meteorological input file (SSss_YYYY_data.txt)*

SUEWS is designed to run using commonly measured meteorological variables. Required inputs must be continuous – i.e. gap fill any missing data. Table 4.6 gives the required and optional additional input variables. Variables marked with **#** in the comment column are not required and can be replaced with **-999.0** if the user's dataset does not include the variable. Cloud fraction is used in one option of the downwelling longwave radiation calculation (see *RadiationChoice* in **RunControl.nml**). **Incoming shortwave radiation is always required** (and measured daytime values must be > 0 W m^{-2}). Make certain these are not TAB delimited files. Depending on your text editor you have created your meteorological input data, you may need to leave an extra lines at the end of the data (UTF-8 Mac)

Table 4.6: Meteorological input data to run SUEWS (***SSss_YYYY*_data.txt**). Model – refers to the name within the model code.

Col	Variable	Model	Units	Comments
1	Day of year	*id*	-	
2	Time	*it*	-	
3	Decimal time	*dectime*	-	
4	Net all-wave radiation	*qn*	W m^{-2}	#, needed with *NetRadiationChoice*=1
5	Obs. sensible heat flux	*qh*	W m^{-2}	#
6	Obs. latent heat flux	*qe*	W m^{-2}	#
7	Obs. storage heat flux	*qs*	W m^{-2}	#
8	Anthropogenic heat flux	*qf*	W m^{-2}	#
9	Mean wind speed	*U*	m s^{-1}	If *U* = 0 the model uses the default value defined in **RunControl.nml**. To avoid this set in *U* = 0.001
10	Mean relative humidity	*RH*	%	
11	Mean air temperature	*Tair*	°C	
12	Mean air pressure	*Pres_kPa*	kPa	
13	Rain	*pr*	mm t^{-1}	Reported for the time interval *t*
14	Incoming solar radiation	*Kdown*	W m^{-2}	
15	Snow cover fraction (0-1)	*snow*	-	#, Set to zero if not needed.
16	Downward longwave radiation	*ldown*	W m^{-2}	#
17	Cloud faction	*fcld*	Tenths	#
18	External water use	*wuh*	m^3 t^{-1}	#
19	Soil moisture	*xsmd*	m^3 m^{-3} or kg kg^{-1}	#
20	Leaf Area Index	*lai_hr*	-	#
21	Diffusive radiation	*kdiff*	W m^{-2}	#, needed with CBLuse ==1
22	Direct radiation	*kdir*	W m^{-2}	#, needed with CBLuse ==1
23	Wind direction	*wdit*	°	#, needed with CBLuse ==1

4.7 *WaterDist*SSss_YYYY*.txt*

WaterDist*SSss_YYYY*.txt file is used to allow water to move between canopy storages within a grid/area. This way impervious connectivity can be taken into account.

1) The sum of a row must equal 1
2) Water cannot drain to itself - so in that column there should be a zero (0)
3) The **columns** are where the water is going to. The **row** is where it is coming from

Example: if we consider water from Building surface it can drain to a variety of surfaces:

PAV	BLD	CT	DT	IG	UG	W	Runoff	Soil	To	
0									1	**PAV**
0.01	0	0.01	0.01	0.01	0.01	0	0.95	0	2	**BLD**

Table 4.7: WaterDistSSss_YYYY.txt file. Pav- paved, BLD= Building, ET = evergreen trees and shrubs, DT = deciduous trees and shrubs, IG = Irrigated grass, UG = unirrigated grass, W = water

PAV	BLDS	ET	DT	IG	UG	W	Runoff	Soil		To
0									1	Paved
	0								2	Buildings
		0							3	Evergreen/Conif
			0						4	Decid
				0					5	IrrigGrass
					0				6	UnirrigGrass
						0			7	Water

4.8 Site specific parameters including water use model (SiteSpecificParamSSss_YYYY.nml)

SUEWS includes a simple model for external water use if data are not available. The model calculates daily water use from the mean daily air temperature, days since rain and fraction of irrigated area using automatic/manual irrigation (Table 4.8). Water use is divided into hours according to ready or user defined hourly profiles (Table 4.9).

Table 4.8: Input included in **SiteSpecificParam*SSss_YYYY*.nml**. The order in this file does not matter.

Name in Model	Units	Description		
Ie_start	doy	Starting day of the irrigation period		
Ie_end	doy	Ending day of the irrigation period		
InternalWaterUse	mm tt^{-1}	Internal water use on the study area (set to 0 if water use is modelled)		
Faut	-	Fraction of irrigated area using automatic sprinklers		
Ie_a(1)	mm	Coefficient for **automatic** irrigation model	-84.54	*Järvi et al. (2011)*
Ie_a(2)	mm °C^{-1}	Coefficient for automatic irrigation model	9.96	*Järvi et al. (2011)*
Ie_a(3)	mm d^{-1}	Coefficient for automatic irrigation model	3.67	*Järvi et al. (2011)*
Ie_m(1)	mm	Coefficient for **manual** irrigation model	-25.36	*Järvi et al. (2011)*
Ie_m(2)	mm °C^{-1}	Coefficient for manual irrigation model	3.00	*Järvi et al. (2011)*
Ie_m(3)	mm d^{-1}	Coefficient for manual irrigation model	1.10	*Järvi et al. (2011)*
DayWat(7)		Irrigation allowed on Sundays [1], if not [0]		
DayWat(1)		Irrigation allowed on Mondays [1], if not [0]		
DayWat(2)		Irrigation allowed on Tuesdays [1], if not [0]		
DayWat(3)		Irrigation allowed on Wednesdays [1], if not [0]		
DayWat(4)		Irrigation allowed on Thursdays[1], if not [0]		
DayWat(5)		Irrigation allowed on Fridays [1], if not [0]		
DayWat(6)		Irrigation allowed on Saturdays [1], if not [0]		
DayWatPer(7)		Fraction of properties using irrigation on Sundays [0-1]		
DayWatPer(1)		Fraction of properties using irrigation on Mondays [0-1]		
DayWatPer(2)		Fraction of properties using irrigation on Tuesdays [0-1]		
DayWatPer(3)		Fraction of properties using irrigation on Wednesdays [0-1]		
DayWatPer(4)		Fraction of properties using irrigation on Thursdays [0-1]		
DayWatPer(5)		Fraction of properties using irrigation on Fridays [0-1]		
DayWatPer(6)		Fraction of properties using irrigation on Saturdays [0-1]		
FlowChange	mm	Difference of input and output flows of the water surface type		
RunoffTowater	fraction	Fraction of above ground runoff flowing to water surface in the case of flooding		
SurfaceArea	ha	Area of the study site		
WaterUseAreaGrass	ha	Area for observed water use to grass (Set to -999 if water use is modelled)		
WaterUseAreaTrees	ha	Area for observed water use to Trees (Set to -999 if water use is modelled)		
Lat	°	Latitude (Coordinate system WG84)		
Long	°	Longitude (Coordinate system WG84)		
PipeCapacity	mm	Storage Capacity of pipes to transfer water (runoff)		
SnowLimBuild	mm	Limit of snow water equivalent when snow is removed from building surface		
SnowLimPaved	mm	Limit of snow water equivalent when snow is removed paved surfaces		

4.9 HourlyProfileSSss_YYYY.TXT

The hourly profiles for water use, anthropogenic heat flux and snow removal are specified in this file.

1. Water use
2. Weekday anthropogenic heat flux
3. Weekend anthropogenic heat flux
4. Snow removal profile

The file format is specified in Table 4.9. In Table 4.10 example values are given. For the water use the values are based on observations in Vancouver and Los Angeles, and for anthropogenic heat flux observations in Vancouver

Table 4.9: File format for hourly profile Filename: HourlyProfile*SSss*_YYYY.TXT

Line	Data Included	Comments
1	Site code and year	
2	Water use profile hours 0 to 23	24 values / These should sum to 1
3	**Weekday** anthropogenic heat flux hours 0 to 23	24 values / Daily value is the mean. The hourly values adjust the coefficients relative to that. Thus values are smaller and larger than 1. A value of 1 would produce the daily mean for that hour
4	**Weekend** anthropogenic heat flux hours 0 to 23	24 values
5	Snow removal for hours 0 to 23	Set those hours to one when snow removal from paved and roof surface is allowed IF the snow removal limit set in the SiteSpecificParam*SSss_YYYY*.nml are exceeded.

Table 4.10: Example profile values for external water use and anthropogenic heat flux.

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	
Water Use Profile values																								
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.13	0.13	0.13	0.13	0.01	0.01	0.01	0.01	Vs 1987
0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.12	0.12	0.12	0.12	0.03	0.03	0.03	0.03	Manual LA
0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	Automatic LA
Anthropogenic Heat Flux Profile values																								
0.30	0.23	0.15	0.13	0.15	0.45	1.20	1.70	1.55	1.40	1.30	1.30	1.35	1.37	1.45	1.60	1.75	1.70	1.20	1.10	0.95	0.65	0.38	0.33	AHDIUPRF
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	AHDIUPRF
0.57	0.45	0.43	0.40	0.40	0.45	0.71	1.20	1.44	1.29	1.28	1.31	1.30	1.32	1.35	1.44	1.51	1.41	1.14	0.99	0.86	0.85	0.80	0.70	AHDIUPRF1
0.65	0.49	0.46	0.47	0.47	0.53	0.70	1.13	1.37	1.37	1.30	1.37	1.33	1.30	1.27	1.36	1.44	1.30	1.10	0.98	0.84	0.90	0.87	0.74	AHDIUPRF2
Snow removal																								
0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	Helsinki

4.10 GIS input file (SSss_YYYY.gis)

This input file includes the plan area surface cover fractions for the different surface types, the roughness length for momentum and zero displacement height and frontal area fraction λ_F. Table 4.11 summarizes the GIS file format.

Table 4.11: *SSss_YYYY*.gis. Used when *GISInputFormat* = 3 or 4 (see Table 4.1). Note that the sum of columns from 3 to 10 has to equal 1. # indicates optional: Set to -999 if not used. CT = coniferous trees and shrubs, DT = deciduous trees and shrubs, IG = Irrigated grass, UG = unirrigated grass, W =water

Col	Name in model	Description/Comment	
1	*id*	Day of year. Set to 3 if *GISInputFormat*=3	
2	*it*	Time in hours. Set to 3 if *GISInputFormat*=3	
3	*build*	Areal cover fraction – buildings	
4	*paved*	Areal cover fraction – paved	
5	*unman*	Areal cover fraction – unmanaged e.g. bare soil	
6	*ET_sh*	Areal cover fraction – ET	
7	*DT_sh*	Areal cover fraction – DT	
8	*UG*	Areal cover fraction – UG	
9	*IG*	Areal cover fraction – IG	
10	*wtr*	Areal cover fraction – water	
11	*bldgH*	Mean building height (units: m)	#
12	*treeH*	Mean tree height (units: m)	#
13	*FAIblgs*	Frontal area fraction for buildings	#
14	*FAItree*	Frontal area fraction for trees	#

15	*z0m*	Roughness length for momentum (units: m)	#
16	*Zdm*	Zero displacement height (units: m)	#
17	*Alt*	Mean topographic height (units: m)	
18	*IrrTreesFrac*	Fraction of irrigated trees (not fully implemented in this release)	#

*4.11 OHM file (***SelectOHMSS_YYYY***.txt)*

OHM – the Objective Hysteresis Model - is used for the storage heat flux calculations.

OHM coefficients

a) New coefficients can be easily added to the file **OHM_Coefficients.txt**
b) The choice of coefficients can be dynamic within a run. The coefficients can be changed depending on the surface wetness of individual materials. This switching is based on the calculated the surface wetness state in the model. The coefficients also can change with season (summer, winter). This is based on a 5-day running average of mean air temperature. If greater than 5 °C then the summer coefficients are used. Note these options are turned off by setting the coefficients to be the same irrespective of wet/dry and summer/winter.

Process to select OHM coefficients

1. **If using coefficients already provided** – then open the file **OHM_Coefficients.txt**. Identify which coefficients are to be used for each surface type and surface condition (season, wet/dry). Each should have a unique code.
2. Enter the code associated with each equation in the appropriate location in the **SelectOHM*SS_YYYY*.txt** file The **SelectOHM*SS_YYYY*.txt** file requires four lines of data which are the codes for the selected set of coefficient by surface type (Table 4.7). Note a code needs to be given in every part of the table but it does not get necessarily get used if that code is not applicable; for example, if there is no water within the area.

3. **If adding new coefficients** - for example you want to average some equations in a different way or have new observations - these need to be added into the **OHM_Coefficients.txt** file with a new and **unique code**. After this has been done the new codes can be used within in the **SelectOHM*SS_YYYY*.txt** file

Table 4.12: Format of **SelectOHM*SS_YYYY*.txt. Content is codes from**'OHM_Coefficients.txt' – see Table 4.13, Note ! indicate comments in the file. These must be in the file before the text

Paved	Buildings	Evergreen	Deciduous	Grass	Bare Soil	Water	Canyon	Snow		
									summer	Wet
									summer	Dry
									winter	wet
									Winter	dry

Bare soil – coefficients are used for the unmanaged surface cover fraction.
Canyons – are currently not used

In the model run, canyons are excluded, and vegetation is divided into trees/shrubs & shrubs/water, and paved surfaces into concrete and asphalt

Table 4.13: Values from the literature for the OHM Coefficients (if you have recommendations for others to be included please let us know) In the model run, canyons are excluded, and vegetation is divided into trees/shrubs & shrubs/water, and paved surfaces into concrete and asphalt. For all surfaces the coefficients are calculated as the mean value of the assigned materials).

Surface type		**Author**	**a_1**	**a_2**	**a_3**
Canyon	E-W canyon	Yoshida *et al.* (1990, 1991)	0.71	0.04	-39.7
	N-S canyon	Nunez (1974)	0.32	0.01	-27.7
Vegetation	Mixed forest	McCaughey (1985)	0.11	0.11	-12.3
	Short grass	Doll *et al.* (1985)	0.32	0.54	-27.4
	Bare soil	Novak (1982)	0.38	0.56	-27.3
	Bare soil (wet)	Fuchs & Hadas (1972)	0.33	0.07	-34.9
	Bare soil (dry)	Fuchs & Hadas (1972)	0.65	0.43	-36.5
	Bare soil	Asaeda & Ca (1993)	0.36	0.27	-42.4
	Water Shallow – Turbid	Souch *et al.* (1998)	0.50	0.21	-39.1
	Unirrigated grass (Crops)	Grimmond et al. (1993)	0.21	0.11	-16.1
	Short irrigated grass	Grimmond et al. (1993)	0.35	-0.01	-26.3
Roof	Tar and gravel, Vancouver	Yap (1973)	0.17	0.10	-17.0
	Uppsala	Taesler (1980)	0.44	0.57	-28.9

	Membrane and concrete, Kyoto	Yoshida et al. (1990,1991)	0.82	0.34	-55.7
	Average gravel/tar/conc. flat industrial, Vancouver	Meyn (2000)	0.25	0.92	-22.0
	Dry --gravel/tar/conc. flat industrial, Vancouver	Meyn (2000)	0.25	0.70	-22.0
	Wet -- gravel/tar/conc. flat industrial, Vancouver	Meyn (2000)	0.25	0.70	-22.0
	Bitumen spread over flat industrial membrane, Vancouver	Meyn (2000)	0.06	0.28	-3.0
	Asphalt shingle on plywood residential roof , Vancouver	Meyn (2000)	0.14	0.33	-6.0
	Star – high albedo asphalt shingle residential roof	Meyn (2000)	0.09	0.18	-1.0
	Star - Ceramic Tile	Meyn (2000)	0.07	0.26	-6.0
	Star - Slate Tile	Meyn (2000)	0.08	0.32	0.0
	Helsinki – Suburban	Järvi et al. (2014)	0.19	0.54	-15.1
	Montreal – Suburban	Järvi et al. (2014)	0.12	0.24	-4.5
	Montreal – Urban	Järvi et al. (2014)	0.26	0.85	-21.4
Impervious	Concrete	Doll *et al.* (1985)	0.81	0.10	-79.9
	Concrete	Asaeda & Ca (1993)	0.85	0.32	-28.5
	Asphalt	Narita *et al.* (1984)	0.36	0.23	-19.3
	Asphalt	Asaeda & Ca (1993)	0.64	0.32	-43.6
	Asphalt	Anandakumar (1999)	0.82	0.68	-20.1
	Asphalt (winter)	Anandakumar (1999)	0.72	0.54	-40.2
	Asphalt (summer)	Anandakumar (1999)	0.83	-0.83	-24.6

Since V2012a – this information is included in the file '**OHM_Coefficients.txt**' rather than coded into the programme

A1	A2	A3	code	comment
Value	value	value	used to select the coefficients for a site – needs to be unique for each row	! description of the surface material,state of surface, wind conditions, reference location in reference

4.12 SAHP input file (SSss_YYYYSAHP.nml)

1) If anthropogenic heat flux is calculated the coefficients from SSss_YYYYsahp.nml are used with the profile from the **HourlyProfile*SSss_YYYY*.txt**. The coefficients needed depend on the *AnthropHeatChoice* selected in **RunControl.nml.**
2) If anthropogenic heat flux is not calculated (*AnthropHeatChoice* = 0) the user can provide it in the meteorological forcing file ***SSss_YYYY*_data.txt**.

Table 4.14: Description of choices in ***SSss_YYYSAHP*.nml** file. The file can be in any order. MD = midlatitude city, HD = highlatitude city

Name	Units	Explanation/Details/ Description	
QF_A(1)	$W\ m^{-2}\ (Cap\ ha^{-1})^{-1}$	*AnthropHeatChoice* = 2	Base value for weekday Q_F
		0.3081	Järvi et al. (2011) - MD
		0.100	Järvi et al. (2014) - HD
QF_B(1)	$W\ m^{-2}\ K^{-1}\ (Cap\ ha^{-1})^{-1}$	*AnthropHeatChoice* = 2	Parameter related to **cooling** degree days on weekdays
		0.0099	Järvi et al. (2011) - MD
		0.0099	Järvi et al. (2014) - HD
QF_C(1)	$W\ m^{-2}\ K^{-1}\ (Cap\ ha^{-1})^{-1}$	*AnthropHeatChoice* = 2	Parameter related to **heating** degree days on weekdays
		0.0102	Järvi et al. (2011) - MD
		0.0102	Järvi et al. (2014) - HD
QF_A(2)	$W\ m^{-2}\ (Cap\ ha^{-1})^{-1}$	*AnthropHeatChoice* = 2	Base value for weekend Q_F
		0.3081	Järvi et al. (2011) - MD
		0.100	Järvi et al. (2014) - HD
QF_B(2)	$W\ m^{-2}\ K^{-1}\ (Cap\ ha^{-1})^{-1}$	*AnthropHeatChoice* = 2	Parameter related to **cooling** degree days on weekends
		0.0099	Järvi et al. (2011) - MD
		0.0099	Järvi et al. (2014) - HD
QF_C(2)	$W\ m^{-2}\ K^{-1}\ (Cap\ ha^{-1})^{-1}$	*AnthropHeatChoice* = 2	Parameter related to **heating** degree days on weekends
		0.0102	Järvi et al. (2011) - MD
		0.0102	Järvi et al. (2014) - HD
NumCapita	Inhabitants ha^{-1}	Number of people per hectare	
		30.7	
BaseTHDD	°C	Base temperature for heating degree days for Q_F	Comment

		18.2 | Sailor and Vasireddy (2006)
AH_MIN	W m-2	*Source of recommended values Loridan et al. (2011)* *AnthropHeatChoice* = 1 | Minimum Q_F 15 | *Loridan et al. (2011)*
AH_SLOPE	W m^{-2} K^{-1}	*AnthropHeatChoice* = 1 | Slope between Q_F and air temperature 2.7 | *Loridan et al. (2011)*
T_CRITIC	°C	*AnthropHeatChoice* = 1 | Critical temperature 7 | *Loridan et al. (2011)*

4.13 CBL input file (CBLInput.nml)

Note – this is not included in this release

If CBL slab model is used (CBLuse=1), this file needs to be prepared. This includes the run options, parameters and input file names.

Table 4.15: Description of choices in **CBL_input_file.nml** file. The file can be in any order.

Name	Units	Explanation/Details/ Description
EntrainmentType	-	Determines an entrainment scheme (see Cleugh and Grimmond 2000) for discusson Value | Comments 1 | Tennekes and Driedonks (1981) **Recommended** 2 | McNaughton and Springs (1986) 3 | Rayner and Watson (1991) 4 | Tennekes (1973)
QH_choice	-	Determines Q_H used for CBL model. Value | Comments 1 | Q_H values modelled by SUEWS 2 | Q_H values modelled by LUMPS 3 | *Observed* Q_H values are used from the meteorological input file
wsb	m s^{-1}	Subsidence velocity in eq. 1 and 2 of *Onomura et al. (2013).* Subsidence velocity -0.01 **Recommended.**
CBLday(id)	-	CBL model is used for the days you choose. Set CBLday(id) = 1 e.g. if CBL model is set to run during 175 – 177 (Day of year), CBLday(175) = 1, CBLday(176) = 1, CBLday(177) = 1
CO2_included	-	In the current version, it should be set to zero.
tstep_s	s	Time step for sub-interval calculations of eq. 1 and 2 in *Onomura et al. (2013)* It needs to be smaller time than interval (min) in RunControl.nml (**Recommended:** 900)
InitialData_use	-	Determines initial values (z_{i0}, gamt_Km, gamq_gkgm, Theta+_K, q+_gkg, Theta_K and q_gkg) (see Table 4.15). Value | Comments 0 | All initial values are calculated. This is NOT available yet in this version. 1 | Take z_{i0}, gamt_Km and gamq_gkgm from input data file. Theta+_K, q+_gkg, Theta_K and q_gkg are calculated using *Temp_C*, *avrh* and *Pres_kPa* in meteorological input file. 2 | Take all initial values from input data file (see 4.14)
InitialData_FileName	-	If InitialData_use=1, write the file name including the path from site directory e.g. InitialData_FileName='CBLinputfiles\CBL_initial_data.txt'
sondeflag	-	0 does not read radiosonde vertical profile data, 1 if does. The data file is prepared in example zip folder (see Table 3.3) but **recommend to set 0** thus not to use this option for the other sites.
FileSonde(id)	-	If sondeflag=1, write the file name including the path from site directory e.g. FileSonde(id)= 'CBLinputfiles\XXX.txt', XXX is an arbitrary name.

4.14 CBL_initial_data.txt

If CBL slab model is used (CBLuse=1), this file needs to be prepared. This file gives initial data every morning when CBL model starts running. The file name should match the *InitialData_FileName* in table 4.15.

Table 4.16 Definitions and example file of initial values prepared for Sacramento

zi_0	initial convective boundary layer height (m)
gamt_Km	vertical gradient of potential temperature (K m^{-1})
gamq_gkgm	vertical gradient of specific humidity (g kg^{-1} m^{-1})
Theta+_K	potential temperature at the top of CBL (K)
q+_gkg	specific humidity at the top of CBL (g kg^{-1})
Theta_K	potential temperature in CBL (K)
q_gkg	specific humidiy in CBL (g kg^{-1})

gamt_Km and gamq_gkgm written to two significant figures are required for the model performance in appropriate ranges Onomura et al. (2014).

id	z_{i0}	gamt_Km	gamq_gkgm	Theta+_K	q+_gkg	theta_K	q_gkg
234	188	0.032	0.00082	290.4	9.6	288.7	8.3
235	197	0.089	0.089	290.2	8.4	288.3	8.7
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

5 Output files

5.1 *Error Messages*

If there are problems with running the programme an error message will be written to **problems.txt**. In most cases the programme will stop after that.

We have a large number of error messages included to try and capture common errors to help the user determine what the probable problem is**. If you encounter an error that does not provide an error message to *Problem.txt* please can you capture the details so we can hopefully provide better error messages**.

See Troubleshooting section for help solving problems.
If the file paths are not correct the program will return an error when run (see How to run the model).

5.2 *Model output files*

SUEWS produces the main output file (***SSss_YYYY_tt*.txt**). Both files have time resolution defined by the *INTERVAL*. These contain a header with a selection of model run information. An example is presented below.

line	Information Included
1	model version and any additional modules that may have been run.
2	indicates if multiple areas were used and how the net radiation was calculated.
3	method used to calculate the storage heat flux (OHM always used in SUEWSv1)
4	*veg_type* used in LUMPS and which *ldown_option* choice was used.

Example
% Version= SUEWS_v2014b
% common[1]Common choices for all site Q*=[2]Modelled -NARP
% QS=[1]OHM [2] Dyer (1974) modified by Ho
% veg_type: 1 ldown_option: 1

The columns in the output file are explained in Table 5.1.

Table 5.1: SUEWS output file format: ***SSss_YYYY _tt*.txt** where tt is the model interval in minutes (60 in the current version of the model)

Col	Header	Name	Units
1	*Id*	Day of Year	-
2	*It*	Time	-
3	*dectime*	Decimal Time	-
4	*kdown*	Incoming shortwave radiation	W m^{-2}
5	*kup*	Reflected shortwave radiation	W m^{-2}
6	*ldown*	Downwelling longwave radiation	W m^{-2}
7	*lup*	Upwelling longwave radiation	W m^{-2}
8	*Tsurf*	Surface temperature	°C
9	*qn*	Net all-wave radiation	W m^{-2}

10	*h_mod*	Sensible heat flux-LUMPS	W m^{-2}
11	*e_mod*	Latent heat flux-LUMPS	W m^{-2}
12	*qs*	Storage heat flux	W m^{-2}
13	*QF*	Anthropogenic heat flux	W m^{-2}
14	*QH*	Sensible heat flux-SUEWS	W m^{-2}
15	*QE*	Latent heat flux-SUEWS	W m^{-2}
16	*P/i*	Rain per interval	mm
17	*Ie/i*	External water use in the study area	mm
18	*E/i*	Evaporation per interval	mm
19	*DR/i*	Drainage per interval	mm
20	*Ch/i*	Change of surface and soil stores per interval	mm
21	*ST/i*	Land surface state per interval	mm
22	*ROsoil/i*	Soil runoff per interval	mm
23	*RO/i*	Runoff per interval	mm
24	*ROpipe*	Runoff in pipes per interval	mm
25	*ROpav*	Above ground runoff on paved surface per interval	mm
26	*ROveg*	Above ground runoff on vegetation surface per interval	mm
27	*ROwater*	Runoff occurring through water body per interval	mm
28	*Ra*	Aerodynamic resistance	s m^{-1}
29	*Rs*	Surface resistance	s m^{-1}
30	*ustar*	Friction velocity	m s^{-1}
31	*L_mod*	Modelled Obukhov length	m
32	*SoilSt_pav*	Soil moisture deficit of paved surface	mm
33	*SoilSt_blgs*	Soil moisture deficit of building surface	mm
34	*SoilSt_ET*	Soil moisture deficit of evergreen surface	mm
35	*SoilSt_DT*	Soil moisture deficit of deciduous surface	mm
36	*SoilSt_IG*	Soil moisture deficit of irrigated grass	mm
37	*SoilSt_UG*	Soil moisture deficit of unirrigated grass	mm
38	*St_pav*	State of paved surface	mm
39	*St_bldg*	State of building surface	mm
40	*St_ET*	State of evergreen surface	mm
41	*St_DT*	State of deciduous surface	mm
42	*St_IG*	State of irrigated grass	mm
43	*St_UG*	State of unirrigated grass	mm
44	*St_water*	State of the water body	mm
45	*Fcld*	Cloud cover fraction	-
46	*SoilState*	Soil moisture state	mm
47	*smd*	Soil moisture deficit	mm
48	*LAI*	Leaf area index	-
49	*Fw*	Additional water flow to the water body	mm
50	*addWater*	Water input from other grids	mm
51	*Iegrass/i*	External water use in the grass surface	mm
52	*Ietrees/i*	External water use in the tree surfaces	mm
53	*Qn_SF*	Net all-wave radiation from snow free area	W m^{-2}
54	*Qn_S*	Net all-wave radiation from snow surface	W m^{-2}
55	*Qm*	Snow related heat exchange	W m^{-2}
56	*delta_QSI*	Internal energy change	W m^{-2}
57	*Qrain*	Raind on snow heat	W m^{-2}
58	*SWE*	Snow water equivalent	mm
59	*MwStore*	Meltwater store	mm
60	*snowRem_pav*	Snow removal from paved surfaces	mm
61	*snowRem_bldg*	Snow removal from roofs	mm
62	*ChSnow/i*	Change of snowpack per interval	mm

5.3 Daily and monthly output files

In addition to the output files with time resolution defined by *INTERVAL* the model generates output files containing daily (***SSss_YYYY*_DailyFile.txt**) and monthly (***SSss_YYYY*_MonthlyFile.txt**) values. Table 5.2 give the content by column for both of these files. When running multiple years, ***SSss_YYYY*_DailyFile.txt** from each year will be combined to ***SSss_YYYY*_DailyFile.txt.**

Table 5.2: Output included in ***SSYY*_DailyFile.txt** and ***SSYY*_MonthlyFile.txt** files ordered by column (Col)

Col	Header	Name	Units
1	*day*	Day of Year	-
2	*counter*	Counter	-
3	*qn*	Net all-wave radiation	W m^{-2}
4	*qs*	Storage heat flux	W m^{-2}
5	*qf*	Anthropogenic heat flux	W m^{-2}
6	*qe_S*	Latent heat flux-SUEWS	W m^{-2}
7	*pp*	Precipitation	mm
8	*ext_Ie*	External water use on grass	mm
9	*int_Ie*	Internal water	mm
10	*tot_Ie*	Total (ext+int) water use	mm
11	*E_S*	Evaporation per day/month	mm
12	*Change*	Storage change	mm
13	*R_Soil*	Soil runoff	mm
14	*R*	Surface runoff	mm
15	*Fw*	Additional water flow to the water body	mm
16	*addWater*	Water input from other grids	mm
17	*QH_S*	Turbulent sensible heat flux	W m^{-2}
18	*Qm*	Snow related heat exchange	W m^{-2}
19	*delta4_QSI*	Internal energy change	W m^{-2}
20	*Qrain*	Raind on snow heat	W m^{-2}
21	*SWE*	Weighted snow water equivalent	mm
22	*MwStore*	Meltwater store	mm
23	*snowRem_pav*	Snow removal from paved surfaces	mm
24	*snowRem_bldg*	Snow removal from roofs	mm
25	*ChSnow/i*	Change of snowpack per interval	mm

5.4 5-min output file

If user chooses to have the 5 minute output which is specified by write5min=1 (in the file SuewsInput*SSYY*.nml), SUEWS will create an output file ***SSss_YYYY*_5min.txt** including water balance results with 5-min resolution (Table 5.3). Note this will likely make the model runs much slower as there is going to be large amount of additional input.

Table 5.3: Structure of the 5 min output files: ***SSss_YYYY*_5min.txt**.

Col	Header	Name	Units
1	*id*	Day of Year	-
2	*5min*	Time	-
3	*dectime*	Decimal time	-
4	*pp*	Rain	mm
5	*Ie*	External water use	mm
6	*E*	Evaporation	mm
7	*St_pav*	State of paved surface	mm
8	*St_blg*	Moisture state of building surface	mm
9	*St_ET*	Moisture state of evergreen surface	mm
10	*St_DT*	Moisture state of deciduous surface	mm
11	*St_IG*	Moisture state of irrigated grass	mm
12	*St_UG*	Moisture state of unirrigated grass	mm
13	*St_wtr*	State of the water surface type	mm
14	*SoilSt_pav*	Soil moisture state of paved surface	mm
15	*SoilSt _bldg*	Soil moisture state of building surface	mm
16	*SoilSt _ET*	Soil moisture state of evergreen surface	mm
17	*SoilSt _DT*	Soil moisture state of deciduous surface	mm
18	*SoilSt _IG*	Soil moisture state of irrigated grass	mm
19	*SoilSt_UG*	Soil moisture state of unirrigated grass	mm
20	*D_pav*	Drainage - paved surface	mm
21	*D_bldg*	Drainage – buildings	mm
22	*D_ET*	Drainage – evergreen trees	mm
23	*D_DT*	Drainage – deciduous trees	mm
24	*D_IG*	Drainage – irrigated grass	mm

25	*D_UG*	Drainage – unirrigated grass	mm
26	*r_pav*	Runoff - paved surface	mm
27	*r_bldg*	Runoff - buildings	mm
28	*r_ET*	Runoff - evergreen trees	mm
29	*r_DT*	Runoff - deciduous trees	mm
30	*r_IG*	Runoff - irrigated grass	mm
31	*r_UG*	Runoff - unirrigated grass	mm
32	*Soilr_pav*	Soil runoff - paved surface	mm
33	*Soilr_bldg*	Soil runoff - buildings	mm
34	*Soilr_ET*	Soil runoff - evergreen trees	mm
35	*Soilr_DT*	Soil runoff - deciduous trees	mm
36	*Soilr_IG*	Soil runoff - irrigated grass	mm
37	*Soilr_UG*	Soil runoff - unirrigated grass	mm
38	*Snowr_pav*	Snow runoff - paved surface	mm
39	*Snowr_bldg*	Snow runoff - buildings	mm
40	*Snowr_ET*	Snow runoff - evergreen trees	mm
41	*Snowr_DT*	Snow runoff - deciduous trees	mm
42	*Snowr_IG*	Snow runoff - irrigated grass	mm
43	*Snowr_UG*	Snow runoff - unirrigated grass	mm
44	*SWE_pav*	Snow water equivalent paved surface	mm
45	*SWE_bldg*	Snow water equivalent buildings	mm
46	*SWE_ET*	Snow water equivalent evergreen trees	mm
47	*SWE_DT*	Snow water equivalent deciduous trees	mm
48	*SWE_IG*	Snow water equivalent irrigated grass	mm
49	*SWE_UG*	Snow water equivalent unirrigated grass	mm
50	*SWE_wtr*	Snow water equivalent water	mm
51	*snowCh_pav*	Change in snow state paved surface	mm
52	*snowCh_bldg*	Change in snow state buildings	mm
53	*snowCh_ET*	Change in snow state evergreen trees	mm
54	*snowCh_DT*	Change in snow state deciduous trees	mm
55	*snowCh_IG*	Change in snow state irrigated grass	mm
56	*snowCh_UG*	Change in snow state unirrigated grass	mm
57	*snowCh_wtr*	Change in snow state water	mm
58	*mwh_pav*	Meltwater paved surface	mm
59	*mwh_bldg*	Meltwater buildings	mm
60	*mwh_ET*	Meltwater coniferous trees	mm
61	*mwh_DT*	Meltwater deciduous trees	mm
62	*mwh_IG*	Meltwater irrigated grass	mm
63	*mwh_UG*	Meltwater unirrigated grass	mm
64	*mwh_wtr*	Meltwater water	mm

5.5 NARP output file

If *NARPOutput* = 1, SUEWS generates a NARP output file which includes radiation balance components and surface temperatures for each sub surface. Table 5.4 lists the variables included in this file.

Table 5.4: NARP output file format: ***SSss_YYYY* _NARPOut.txt**

Col	Header	Name	Units
1	*id*	Day of Year	-
2	*dectime*	Decimal Time	-
3	*kup_pav*	Reflected shortwave radiation from paved areas	W m^{-2}
4	*kup_blgs*	Reflected shortwave radiation from roofs	W m^{-2}
5	*kup_ET*	Reflected shortwave radiation from evergreen trees	W m^{-2}
6	*kup_DT*	Reflected shortwave radiation from deciduous trees	W m^{-2}
7	*kup_IG*	Reflected shortwave radiation from irrigated grass	W m^{-2}
8	*kup_UG*	Reflected shortwave radiation from unirrigated grass	W m^{-2}
9	*kup_wtr*	Reflected shortwave radiation from water	W m^{-2}
10	*lup_pav*	Upwelling longwave radiation from paved areas	W m^{-2}
11	*lup_blgs*	Upwelling longwave radiation from roofs	W m^{-2}
12	*lup_ET*	Upwelling longwave radiation from evergreen trees	W m^{-2}
13	*lup_DT*	Upwelling longwave radiation from deciduous trees	W m^{-2}

14	*lup_IG*	Upwelling longwave radiation from irrigated grass	W m^{-2}
15	*lup_UG*	Upwelling longwave radiation from unirrigated grass	W m^{-2}
16	*lup_wtr*	Upwelling longwave radiation from water	W m^{-2}
17	*Ts_pav*	Surface temperature - paved areas	°C
18	*Ts_blgs*	Surface temperature - roofs	°C
19	*Ts_ET*	Surface temperature - evergreen trees	°C
20	*Ts_DT*	Surface temperature – deciduous trees	°C
21	*Ts_IG*	Surface temperature - irrigated grass	°C
22	*Ts_UG*	Surface temperature - unirrigated grass	°C
23	*Ts_wtr*	Surface temperature – water body	°C
24	*qn_pav*	Net all-wave radiation - paved areas	W m^{-2}
25	*qn_blgs*	Net all-wave radiation - roofs	W m^{-2}
26	*qn_ET*	Net all-wave radiation - evergreen trees	W m^{-2}
27	*qn_DT*	Net all-wave radiation – deciduous trees	W m^{-2}
28	*qn_IG*	Net all-wave radiation - irrigated grass	W m^{-2}
29	*qn_UG*	Net all-wave radiation - unirrigated grass	W m^{-2}
30	*qn_wtr*	Net all-wave radiation – water body	W m^{-2}

5.6 *SSss_YYYY_SnowOut.txt*

The program prints out a separate output file for snow (*snowUse* = 1 in **runcontrol.nml**)

Table 5.5: File format of ***SSss*_YYYY_SnowOut.txt**

Col	Header	Name	Units
1	*Doy*	Day of year	
2	*It*	Time	
3	*Dectime*	Decimal time	
4	*SWE_pav*	Snow water equivalent – paved	mm
5	*SWE_bldg*	Snow water equivalent – buildings	mm
6	*SWE_ET*	Snow water equivalent – evergreen	mm
7	*SWE_DT*	Snow water equivalent – deciduous	mm
8	*SWE_IG*	Snow water equivalent – irrigated grass	mm
9	*SWE_UG*	Snow water equivalent – unirrigated grass	mm
10	*SWE_wtr*	Snow water equivalent – water surface	mm
11	*snowRem_pav*	Snow removal from paved surfaces	mm
12	*snowRem_bldg*	Snow removal from roofs	mm
13	*Mw*	Overall meltwater	mm h^{-1}
14	*Mw_pav*	Meltwater – paved	mm h^{-1}
15	*Mw_bldg*	Meltwater – buildings	mm h^{-1}
16	*Mw_ET*	Meltwater – evergreen	mm h^{-1}
17	*Mw_DT*	Meltwater – deciduous	mm h^{-1}
18	*Mw_IG*	Meltwater – irrigated grass	mm h^{-1}
19	*Mw_UG*	Meltwater – unirrigated grass	mm h^{-1}
20	*Mw_wtr*	Meltwater – water surface	mm h^{-1}
21	*Qm*	Overall heat consumed in melting/freezing processes	W m^{-2}
22	*Qm_pav*	Snowmelt related heat – paved	W m^{-2}
23	*Qm_bldg*	Snowmelt related heat – buildings	W m^{-2}
24	*Qm_ET*	Snowmelt related heat – evergreen	W m^{-2}
25	*Qm_DT*	Snowmelt related heat – deciduous	W m^{-2}
26	*Qm_IG*	Snowmelt related heat – irrigated grass	W m^{-2}
27	*Qm_UG*	Snowmelt related heat – unirrigated grass	W m^{-2}
28	*Qm_wtr*	Snowmelt related heat – water surface	W m^{-2}
29	*Qa_pav*	Advective heat – paved	W m^{-2}
30	*Qa_bldg*	Advective heat – buildings	W m^{-2}
31	*Qa_ET*	Advective heat – evergreen	W m^{-2}
32	*Qa_DT*	Advective heat – deciduous	W m^{-2}
33	*Qa_IG*	Advective heat – irrigated grass	W m^{-2}
34	*Qa_UG*	Advective heat – unirrigated grass	W m^{-2}
35	*Qa _wtr*	Advective heat – water surface	W m^{-2}
36	*QmFr_pav*	Heat related to freezing of surface store – paved	W m^{-2}
37	*QmFr_bldg*	Heat related to freezing of surface store – buildings	W m^{-2}

38	*QmFr_ET*	Heat related to freezing of surface store – evergreen	W m^{-2}
39	*QmFr_DT*	Heat related to freezing of surface store – deciduous	W m^{-2}
40	*QmFr_IG*	Heat related to freezing of surface store – irrigated grass	W m^{-2}
41	*QmFr_UG*	Heat related to freezing of surface store – unirrigated grass	W m^{-2}
42	*QmFr_wtr*	Heat related to freezing of surface store – water	W m^{-2}
43	*fr_pav*	Fraction of snow – paved	-
44	*fr_bldg*	Fraction of snow – buildings	-
45	*fr_ET*	Fraction of snow – evergreen	-
46	*fr_DT*	Fraction of snow – deciduous	-
47	*fr_IG*	Fraction of snow – irrigated grass	-
48	*fr_UG*	Fraction of snow – unirrigated grass	-
49	*alb_snow*	Albedo of the snowpack	-
50	*RainSn_pav*	Rain on snow – paved	mm
51	*RainSn_bldg*	Rain on snow – buildings	mm
52	*RainSn_ET*	Rain on snow – evergreen	mm
53	*RainSn_DT*	Rain on snow – deciduous	mm
54	*RainSn_IG*	Rain on snow – irrigated grass	mm
55	*RainSn_UG*	Rain on snow – unirrigated grass	mm
56	*RainSn_wtr*	Rain on snow – water surface	mm
57	*qn_pavSnow*	Net all-wave radiation – paved	W m^{-2}
58	*qn_blgSnow*	Net all-wave radiation – buildings	W m^{-2}
59	*qn_ETSnow*	Net all-wave radiation – evergreen	W m^{-2}
60	*qn_DTSnow*	Net all-wave radiation – deciduous	W m^{-2}
61	*qn_IGSnow*	Net all-wave radiation – irrigated grass	W m^{-2}
62	*qn_UGSnow*	Net all-wave radiation – unirrigated grass	W m^{-2}
63	*qn_wtrSnow*	Net all-wave radiation – water body	W m^{-2}
64	*kup_pav*	Reflected shortwave radiation – paved	W m^{-2}
65	*kup_blg*	Reflected shortwave radiation – buildings	W m^{-2}
66	*kup_ETSnow*	Reflected shortwave radiation – evergreen	W m^{-2}
67	*kup_DTSnow*	Reflected shortwave radiation – deciduous	W m^{-2}
68	*kup_IGSnow*	Reflected shortwave radiation – irrigated grass	W m^{-2}
69	*kup_UGSnow*	Reflected shortwave radiation – unirrigated grass	W m^{-2}
70	*kup_wtrSnow*	Reflected shortwave radiation – water body	W m^{-2}
71	*frMelt_pav*	Amount of freezing melt water – paved	mm
72	*frMelt_bldg*	Amount of freezing melt water – buildings	mm
73	*frMelt_ET*	Amount of freezing melt water – evergreen	mm
74	*frMelt_DT*	Amount of freezing melt water – deciduous	mm
75	*frMelt_IG*	Amount of freezing melt water – irrigated grass	mm
76	*frMelt_UG*	Amount of freezing melt water – unirrigated grass	mm
77	*frMelt_wtr*	Amount of freezing melt water – water	mm
78	*MwStore_pav*	Melt water store – paved	mm
79	*MwStore_bldg*	Melt water store – buildings	mm
80	*MwStore_ET*	Melt water store – evergreen	mm
81	*MwStore_DT*	Melt water store – deciduous	mm
82	*MwStore_IG*	Melt water store – irrigated grass	mm
83	*MwStore_UG*	Melt water store – unirrigated grass	mm
84	*MwStore_wtr*	Melt water store – water	mm
85	*densSnow_pav*	Snow density – paved	kg m^{-3}
86	*densSnow_bldg*	Snow density – buildings	kg m^{-3}
87	*densSnow_ET*	Snow density – evergreen	kg m^{-3}
88	*densSnow_DT*	Snow density – deciduous	kg m^{-3}
89	*densSnow_IG*	Snow density – irrigated grass	kg m^{-3}
90	*densSnow_UG*	Snow density – unrrigated grass	kg m^{-3}
91	*densSnow_wtr*	Snow density – water	kg m^{-3}
92	*Sd_pav*	Snow depth – paved	mm
93	*Sd_bldg*	Snow depth – buildings	mm
94	*Sd_ET*	Snow depth – evergreen	mm
95	*Sd_DT*	Snow depth – deciduous	mm
96	*Sd_IG*	Snow depth – irrigated grass	mm
97	*Sd_UG*	Snow depth – unirrigated grass	mm
98	*Sd_water*	Snow depth – water body	mm

99	*Tsnow_pav*	Snow surface temperature – paved	°C
100	*Tsnow_bldg*	Snow surface temperature – buildings	°C
101	*Tsnow_ET*	Snow surface temperature – evergreen	°C
102	*Tsnow_DT*	Snow surface temperature – deciduous	°C
103	*Tsnow_IG*	Snow surface temperature – Irrigated grass	°C
104	*Tsnow_UG*	Snow surface temperature – unirrigated grass	°C
105	*Tsnow_wtr*	Snow surface temperature – water body	°C
106	*delta_Qi*	Change of snow internal energy	W m^{-2}

5.7 SSss_DailyState.txt

The program writes for each day the information about the state of surface and soil parameters. When running multiple years, the file will contain all days.

Table 5.6: Daily state file format: ***SSss*_DailyState.txt**

Col	Header	Name	Units
1	*Year*	Year	
2	*id*	Day of year	
3	*HD1h*	Heating degree days	°C
4	*HDD2c*	Cooling degree days	°C
5	*HDD3m*	Average temperature	°C
6	*HDT5d*	5 day running mean air temperature	°C
7	*Prec*	precipitation	mm
8	*DaSR*	Days since rain	Days
9	*GDD1g*	Growing degree days for leaf growth	DD °C
10	*GDD2s*	Growing degree days for senescence	DD °C
11	*GDmn*	Daily minimum temperature	°C
12	*GDmx*	Daily maximum temperature	°C
13	*dauLG*	Day length	h
14	*LAIc*	LAI of CT	m^2 m^{-2}
15	*LAId*	LAI of DT	m^2 m^{-2}
16	*LAIgI*	LAI of IG	m^2 m^{-2}
17	*LAIgU*	LAI of UG	m^2 m^{-2}
18	*DEcap*	Storage capacity of DT	mm
19	*Por*	Porosity of DT	
20	*Albdec*	Albedo of DT	-
21	*WU(1)*	Total water use on grass	mm
22	*WU(2)*	Automatic water use total on grass	mm
23	*WU(3)*	Manual water use total on grass	mm
24	*WU(4)*	Total water use on tree surface	mm
25	*WU(5)*	Automatic water use total on tree surface	mm
26	*WU(6)*	Manual water use total on tree surface	mm
27	*LAIchange*	Change in LAI (normalized)	
28	*LAIlumps*	LAI used in LUMPS for vegetation fraction	
29	*alb_snow*	Snow albedo	-
30	*dens_snow_pav*	Snow density in paved surface	kg m^{-3}
31	*dens_snow_bldg*	Snow density in building surface	kg m^{-3}
32	*dens_snow_ET*	Snow density in evergreen surface	kg m^{-3}
33	*dens_snow_DT*	Snow density in deciduous surface	kg m^{-3}
34	*dens_snow_IG*	Snow density in irrigated grass surface	kg m^{-3}
35	*dens_snow_UG*	Snow density in unirrigated grass surface	kg m^{-3}
36	*dens_snow_wtr*	Snow density in water surface	kg m^{-3}

5.8 *CBL_id.txt*

Meteorological variables modelled by CBL portion of the model are output in to this file created for each day with time step (see 4.13).

Table 5.7: CBL model output file format: ***CBL_id*.txt**

Col	Header	Name	Units
1	*id*	Day of year	
2	*it*	Time	
3	*dectime*	Decimal time	
4	z_i	Convectibe boundary layer height	m
5	*Theta*	Potential temperature in the inertial sublayer	K
6	*Q*	Specific humidity in the inertial sublayer	g kg^{-1}
7	*theta+*	Potential temperature just above the CBL	K
8	*q+*	Specific humidity just above the CBL	g kg^{-1}
9	*Temp_C*	Air temperature	°C
10	*RH*	Relative humidity	%
11	*QH_use*	Sensible heat flux used for calculation	W m^{-2}
12	*QE_use*	Latent heat flux used for calculation	W m^{-2}
13	*Press_hPa*	Pressure used for calculation	hPa
14	*avu1*	Wind speed used for calculation	m s^{-1}
15	*ustar*	Friction velocity used for calculation	m s^{-1}
16	*avdens*	Air density used for calculation	kg m^{-3}
17	*lv_J_kg*	Latent heat of vaporization used for calculation	J kg^{-1}
18	*avcp*	Specific heat capacity used for calculation	J kg^{-1} K^{-1}
19	*gamt*	Vertical gradient of potential temperature	K m^{-1}
20	*gamq*	Vertical gradient of specific humidity	kg kg^{-1} m^{-1}

6 Troubleshooting

1. How to **create a directory** please search the web using this phrase if you do not know how to create a folder or directory
2. How **to unzip a file** - please search the web using this phrase if you do not know how to unzip a file
3. A **Text editor** is a program to edit plain text files. If you search on the web using the phrase 'text editor' you will find numerous programs. These include for example, NotePad, EditPad, Text Pad etc
4. **Command prompt**: From Start select run –type cmd – this will open a window. Change directory to the location of where you stored your files. The following website may be helpful if you do not know what a command prompt is: http://dosprompt.info/
5. SUEWSV2014a.exe - this is the actual program
6. Website: http://LondonClimate.info
   http://www.met.reading.ac.uk/micromet/
7. **Day of year** – January 1st is day 1, February 1st is day 32. If you search on the web using the phrase 'day of year calendar' you will find tables that allow rapid conversions. Note remember that in a Leap year the days will be different after February 28th.
8. Check the **problems.txt** file (see section 5.1 and this section)
9. Look in the output directory for the ***SS*_FileChoices.txt** – this allows you to check all options that were used in the run. You may want to compare it with the original supplied version.
10. Check file options – in **RunControl.nml** (see section 4.1)
    e.g. **GISInputType** - is your data constant or varying for each time period? What have you specified?
11. A pop-up saying "**file path not found**"
    This means the program cannot find the file paths defined in RunControl.nml file. Possible solutions:
    - Check that you have created the folder that you specified in RunControl.nml.
    - Check does the output directory exist?
    - Check that you have a single or double quote's around the FileInputPath, FileOutputPath and FileCode
12. How should I **setup** my filenames if I want to run only **one time period for one area**
    Example: If your forcing data are for 2005 and your site identification code is Ab01

    ModelledYears.txt

    ```
    1       !Number of modelled years/time periods
    2005
    ```

    GridConnections2005.txt

	2 !Number of grid connections listed below 'Ab01_2005' 0 'none' !From fraction To The rest of the input files for this location should be HeaderInputAb01_2005.nml / Ab01_2005.gis SUEWSInputAb01_2005.nml / Ab01_2005.ohm CanopyMoistureInputAb01_2005.nml / Ab01_2005sahp.nml WaterUseProfileAb01_2005.txt / Ab01_2005_data.txt	
13	"*%sat_vap_press.f temp=0.0000 pressure dectime*"	Temperature is zero and in calculation of water vapour pressure parameterization is used. You don't need to worry if the temperature should be 0°C. If it should not be 0°C this suggests that there is a problem with the data.
14	**%T changed to fit limits [TL =0.1]/ [TL =39.9]**	You may want to change the coefficients for surface resistance. If you have data from these temperatures, we would happily determine them.
15	***"salflibc.dll is either not designed to run on Windows or it contains an error. Contact your system administrator or the software vendor for support."***	In this situation, your computer does not support the type of dll file and you are advised to download the Silverfrost compiler from the internet for free (http://www.silverfrost.com/32/ftn95/ftn95_personal_edition.aspx)
16	***Salford run-time library. Insufficient memory available for CHECK mode. Fatal run-time error***	In this situation, your computer does not support the type of dll file and you are advised to download the Silverfrost compiler from the internet for free (http://www.silverfrost.com/32/ftn95/ftn95_personal_edition.aspx)
17	***"Reference to undefined variable, array element or function result"***	Parameter(s) missing from Input files. See also the error messages provided in **Problems.txt**
18	***Program received signal SIGSEGV: Segmentation fault - invalid memory reference.*** ***Backtrace for this error:*** ***#0 0x1017c2f92*** ***#1 0x1017c375e*** ***#2 0x7fff9438a909*** ***#3 0x1011ecf04*** ***#4 0x1011e3dcb*** ***#5 0x1011b2223*** ***#6 0x1011b22cb*** ***Segmentation fault: 11***	This message appears if you try to run more years and grids that your computer is able to with the 5 minute output file. In this case, you set write5min = 0 in the RunControl.nml.
19		

7 Acknowledgements

People who have contributed to the development of SUEWS (plus co-authors of papers):
Current contributors:

Prof C.S.B. Grimmond (University of Reading; previously Indiana University, King's College London, UK); Dr Leena Järvi (University of Helsinki, Finland); Shiho Onomura (Göteborg University, Sweden), Dr Helen Ward (University of Reading), Dr Fredrik Lindberg (Göteborg University, Sweden)

Past Contributors:

Dr Brian Offerle (previously Indiana University, USA; now FluxSense Sweden)
Dr Thomas Loridan (King's College London, now RMS London)

Users who have brought things to our attention to improve this manual and the model:

Dr Andy Coutts (Monash University, Australia), Kerry Nice (Monash University, Australia), Shiho Onomura (Göteborg University, Sweden), Helen Ward (King's College London, UK; University of Reading, UK); Duick Young (King's College London), Ning Zhang (Nanjing University, China)

Funding to support development:

National Science Foundation (USA, BCS-0095284, ATM-0710631), EU Framework 7 BRIDGE (211345); EU emBRACE; UK Met Office; NERC ClearfLO, NERC TRUC

8 References

Anandakumar K. (1999). A study on the partition of net radiation into heat fluxes on a dry asphalt surface. *Atmos. Env.* 33, 3911-3918.

Asaeda T. & Ca V.T. (1993). The subsurface transport of heat and moisture and its effect on the environment: a numerical model. *Boundary-Layer Meteorol.* 65, 159-178.

Businger JA, Wyngaard JC, Izumi Y. & Bradley E.F. (1971). Flux-Profile Relationships in the Atmospheric Surface Layer. *J. Atmos. Sci.*, **28**, 181–189.

Campbell G.S. & Norman J.M (1998).Introduction to Environmental Biophysics. Springer Science, US.

Cleugh HA & Grimmond CSB (2001). Modelling regional scale surface energy exchanges and cbl growth in a heterogeneous, urban-rural landscape. *Bound.-Layer Meteor.* 98, 1-31.

de Bruin H.A.R. & Holtslag A.A.M. (1982). A simple parameterization of surface fluxes of sensible and latent heat during daytime compared with the Penman–Monteith concept. *J. Appl. Meteor.*, 21, 1610–1621.

Doll D., Ching J. K. S. & Kaneshiro J. (1985). Parameterisation of subsurface heating for soil and concrete using net radiation data. *Boundary-Layer Meteorol.* 32, 351-372.

Dyer A.J., (1974). A review of flux-profile relationships. *Boundary-Layer Meteorol*. 7, 363-372.Fuchs M. & Hadas A. (1972). The heat flux density in a non-homogeneous bare loessial soil. *Boundary-Layer Meteorol.* 3, 191-200.

Grimmond C.S.B. & Oke T. R. (1991). An Evaporation-Interception Model for Urban Areas. Water Resour. Res. 27, 1739-1755.

Grimmond CSB & Oke TR (1999a) Heat storage in urban areas: Local-scale observations and evaluation of a simple model. *J. Appl. Meteorol.* 38, 922-940.

Grimmond C.S.B. & Oke T.R. (1999b). Aerodynamic properties of urban areas derived from analysis of surface form. *J. Appl. Meteorol.* 38, 1262-1292.

Grimmond C.S.B. & Oke T.R. (2002). Turbulent Heat Fluxes in Urban Areas: Observations and a Local-Scale Urban Meteorological Parameterization Scheme (LUMPS). *J. Appl. Meteorol.* 41, 792-810.

Grimmond C.S.B., Cleugh H.A. & Oke T.R. (1991). An objective urban heat storage model and its comparison with other schemes. *Atmos. Env.* 25B, 311-174.

Grimmond, C.S.B. & Oke, T.R. (1999) Heat storage in urban areas: Local-scale observations and evaluation of a simple model. *J. Appl. Meteorol.* 38, 922-940.

Högström U. (1988). Non-dimensional wind and temperature profiles in the atmospheric surface layer: A re-evaluation. *Boundary-Layer Meteorol.* 42, 55–78.

Järvi L., Grimmond C.S.B. & Christen A. (2011) The **S**urface **U**rban **E**nergy and **W**ater Balance **S**cheme (SUEWS): Evaluation in Los Angeles and Vancouver *J. Hydrol.* 411, 219-237.

Järvi L., Grimmond C.S.B., Taka M, Nordbo A, Setälä H. &Strachan I.B. (2014) Development of the Surface Urban Energy and Water balance Scheme (SUEWS) for cold climate cities, *Geosci. Model Dev*. 7, 1691-1711, doi:10.5194/gmd-7-1691-2014.

Kanda M., Kanega M., Kawai T., Moriwaki R. & Sugawara H. (2007). Roughness lengths for momentum and heat derived from outdoor urban scale models. *J. Appl. Meteorol. Clim.* 46, 1067-1079.

Kawai T., Ridwan M.K. & Kanda M. (2009). Evaluation of the simple urban energy balance model using selected data from 1-yr flux observations at two cities. *J. Appl. Meteorol. Clim.* 48, 693-715.

Loridan T, CSB Grimmond, BD Offerle, DT Young, T Smith, L Järvi, F Lindberg (2011)**.** Local-Scale Urban Meteorological Parameterization Scheme (LUMPS): longwave radiation parameterization & seasonality related developments. *Journal of Applied Meteorology & Climatology* 50, 185**-**202, doi: 10.1175/2010JAMC2474.1

MacDonald R.W., Griffiths R.F. & Hall D.J. (1998). An improved method for estimation of surface roughness of obstacle arrays. *Atmos. Env.* 32, 1857-1864.

McCaughey J. H. (1985). Energy balance storage terms in a mature mized forest at Petawawa Ontario - a case study. *Boundary-Layer Meteorol.* 31, 89-101.

Meyn S. K. (2001). *Heat fluxes through roofs and their relevance to estimates of urban heat storage*. M. Sc. Thesis. Department of Earth and Ocean Sciences, The University of British Columbia, Vancouver.

Narita K., Sekine T. & Tokuoka T. (1984). Thermal properties of urban surface materials – Study on heat balance at asphalt pavement. *Geogr. Rev. Japan* 57, 639-651.

Novak M. D. (1982). *The moisture and thermal regimes of a bare soil in the Lower Fraser Valley during spring*. Ph.D. Thesis, The University of British Columbia, Vancouver

Nunez M. (1974). *The energy balance of an urban canyon*. Ph.D. Thesis, The University of British Columbia, Vancouver

Offerle B., Grimmond C.S.B. & Oke T.R. (2003). Parameterization of Net All-Wave Radiation for Urban Areas. *J. Appl. Meteorol.* 42, 1157-1173.

Onomura S, Grimmond CSB, Lindberg F, Holmer B & Thorsson S (2014). BLUEWS - Manuscript in preparation.

Souch C., Grimmond C. S. B. & Wolfe C. (1998). Evaporation rates for wetlands with different disturbance histories: Indiana Dunes National Lakeshore. *Wetlands* 18, 216-229.

Taesler R. (1980). *Studies of the development and thermal structure of the urban boundary layer in Uppsala, Part I: Experimental program; and Part II: Data, analysis and results*. Report 61, Met. Instit., Uppsala University, Uppsala.

Van Ulden A.P. & Holtslag A.A.M. (1985). Estimation of atmospheric boundary layer parameters for boundary layer applications. *J. Clim. Appl. Meteorol.* 24, 1196-1207.

Voogt J.A & Grimmond C.S.B. (2000). Modeling surface sensible heat flux using surface radiative temperatures in a simple urban terrain.

J. Appl. Meteorol. 39, 1679-1699.
Yap D. H. (1973). *Sensible heat fluxes in and near Vancouver, BC*. Ph.D. Thesis, The University of British Columbia, Vancouver.
Yoshida A., Tominaga K. & Watatani S. (1990). Field measurements on energy balance of an urban canyon in the summer season. *Energy and Buildings* 15, 417-423.
Yoshida A., Tominaga K. & Watatani S. (1991). Field investigation on heat transfer in an urban canyon. *Heat transfer – Japanese Research* 20, 230-244

Appendix A: Coding Guidelines

If you are interested in contributing to the code please contact Sue Grimmond.

1. Code written in Fortran – currently Fortran 95
2. Variables
    a. Names should be defined at least in one place in the code – ideally when defined
    b. Implicit None should be used in all subroutines
    c. Variable name should include units. e.g. Temp_C, Temp_K
3. Code should be written generally
4. Data set for testing should be provided
5. Demonstration that the model performance has improved when new code has been added or that any deterioration is warranted.
6. Additional requirements for modelling need to be indicated in the manual
7. All code should be commented in the program (with initials of who made the changes – name specified somewhere and institution)
8. The references used in the code and in the equations will be collected to a webpage
9. Current developments that are being actively worked on

Topic	**Status**	**Lead**
Snow	Completed	Univ Helsinki
Convective boundary layer development	Active	Göteborg Univ
Mean radiant temperature model	Active	Göteborg Univ

Appendix B: Version History

New in SUEWS Version 2014a.1 (released February 26, 2014)

a) Please see the large number of changes made in the 2014a release in Appendix C
b) This is a minor change to address installing the software.
c) Minor updates to the manual

New in SUEWS Version 2014a (released 21 Feb 2014)

1) Bug fix: External **irrigation** is calculated as combined from automatic and manual irrigation and during precipitation events the manual irrigation is reduced to 60% of the calculated values. In previous version of the model, the irrigation was in all cases taken 60% of the calculated value, but now this has been fixed.
2) In previous versions of the model, **irrigation** was only allowed on the irrigated grass surface type. Now, irrigation is also allowed on evergreen and deciduous trees/shrubs surfaces. These are not however treated as separate surfaces, but the amount of irrigation is evenly distributed to the whole surface type in the modelled area. The amount of water is calculated using same equation as for grass surface (equation 5 in Järvi et al. 2011), and the fraction of irrigated trees/shrubs (relative to the area of tree/shrubs surface) is set in the gis file (See **Table 4.11: *SSss_YYYY*.gis**)
3) In the current version of the model, the user is able to adjust the leaf-on and leaf-off lengths in the FunctionalTypes. nml file. In addition, user can choose whether to use temperature dependent functions or combination of temperature and day length (advised to be used at high-latitudes)
4) In the gis-file, there is a new variable **Alt** that is the area altitude above sea level. If not known exactly use an approximate value.
5) Snow removal profile has been added to the HourlyProfile*SSss_YYYY*.txt. Not yet used!
6) Model time interval has been changed from minutes to seconds. Preferred interval is 3600 seconds (1 hour)
7) Manual correction: input variable Soil moisture said soil moisture deficit in the manual – word removed
8) Multiple compiled versions of SUEWS released. There are now users in Apple, Linux and Windows environments. So we will now release compiled versions for more operating systems (section 3).
9) There are some changes in the output file columns so please, check the respective table of each used output file.
10) Bug fix: with very small amount of vegetation in an area – impacted Phenology for LUMPS

New in SUEWS Version 2013a

1) Radiation selection bug fixed
2) Aerodynamic resistance – when very low - no longer reverts to neutral (which caused a large jump) – but stays low
3) Irrigation day of week fixed
4) New error messages

5 min file – now includes a decimal time column – see Section 5.4 – Table 5.3

New in SUEWS Version 2012b

1) Error message generated if all the data are not available for the surface resistance calculations
2) Error message generated if wind data are below zero plane displacement height.
3) All error messages now written to 'Problem.txt' rather than embedded in an ErrorFile. Note some errors will be written and the program will continue others will stop the program.
4) Default variables removed (see below). Model will stop if any data are problematic. File should be checked to ensure that reasonable data are being used. If an error occurs when there should not be one let us know as it may mean we have made the limits too restrictive.

Contents no longer used	File
defaultFcld=0.1 defaultPres=1013 defaultRH=50 defaultT=10 defaultU=3	RunControl.nml - Just delete lines from file - Values you had were likely different from these example value shown here

New in SUEWS Version 2012a

1) Improved error messages when an error is encountered. Error message will generally be written to the screen and to the file 'problems.txt'
2) **Format of all input files have changed**.
3) New excel spreadsheet and R programme to help prepare required data files. (Not required)
4) Format of coef flux (OHM) input files have changed.
   a. This allows for clearer identification for users of the coefficients that are actually to be used
   b. This requires an additional file with coefficients. These do not need to be adjusted but new coefficients can be added. We would appreciate receiving additional coefficients so they can be included in future releases – Please email Sue. This file replaces the content of Appendix B1
5) Storage heat flux (OHM) coefficients can be changed by
   a. time of year (summer, winter)
   b. surface wetness state
6) New files are written: DailyState.txt
   a. Provides the status of variables that are updated on a daily or basis or a snapshot at the end of each day.
7) Surface Types
   a. Clarification of surface types has been made. See GIS and OHM related files

New in SUEWS Version2011b

1) Storage heat flux (ΔQ_S) and anthropogenic heat flux (Q_F) can be set to be 0 W m^{-2}
2) Calculation of hydraulic conductivity in soil has been improved and *HydraulicConduct* in SUEWSInput.nml is replaced with name *SatHydraulicConduct*
3) Following removed from HeaderInput.nml
    a. *HydraulicConduct*
    b. *GrassFractionIrrigated*
    c. *PavedFractionIrrigated*
    d. *TreeFractionIrrigated*
       The lower three are now determined from the water use behaviour used in SUEWS
4) Following added to HeaderInput.nml
    a. *SatHydraulicConduct*
    b. *defaultQf*
    c. *defaultQs*
5) If ΔQ_S and Q_F are not calculated in the model but are given as an input, the missing data is replaced with the default values.
6) Added to SAHP input file
    a. AHDIUPRF – diurnal profile used if *AnthropHeatChoice* = 1

V2012a this became obsolete OHM file (SSss_YYYY.ohm)

The OHM file contains information on how the different surface types are taken into account in the calculation of net storage heat flux. That is what values should be used for the parameters in the OHM equation[5,6]. The possible choices (Table 4.7 old) are followed by examples of OHM files.

Table 4.7-old: Description of choices in ***SSss_YYYY*.ohm** file

Statement	Choice options	Comment
Are canyons included	[1] Yes [2] No	
Calculation of the coefficients for canyons	[2] Mean [3] Yoshida *et al.* (1990, 1991) – E-W canyon [4] Nunez (1974) – N-S canyon	Line added in the ohm-file only if **YES** was chosen on the previous line
Vegetation is calculated	[1] one [2] separated to grass/trees & shrubs/water	
Calculation of the coefficients for vegetation	[1] Mean [2] Mixed forest – McCaughey (1985) [3] Short grass -- Doll *et al.* (1985) [4] Bare soil -- Novak (1982) [5] Bare soil (wet) -- Fuchs & Hadas (1972) [6] Bare soil (dry) -- Fuchs & Hadas (1972) [7] Bare soil -- Asaeda & Ca (1993) [8] Water Shallow - Turbid -- Souch *et al.*(1998)	If option [1] is **NOT** used, put as many choices in the following rows as you want to take into account and add zero when finished
Calculation of the coefficients for roof	[1] Mean of all [2] Tar and gravel -- Yap (1973) [3] Taseler (1980) [4] Yoshida et al. (1990, 1991) [5] Average gravel/tar/conc. flat industrial -- Meyn (2000) [6] Dry -- gravel/tar/conc. flat industrial -- Meyn (2000) [7] Wet -- gravel/tar/conc. flat industrial -- Meyn (2000) [8] Bitumen spread over flat industrial membrane -- Meyn (2000) [9] Asphalt shingle on plywood residential roof – Meyn (2000) [10] Star - high albedo asphalt shingle residential roof -- Meyn (2000) [11] Star - Ceramic Tile -- Meyn (2000) [12] Star - Slate Tile -- Meyn (2000)	If option [1] is **NOT** used, put as many choices in the following rows as you want to take into account and add zero when finished
Impervious areas are calculated as	[1] one [2] separated to concrete & asphalt	
Calculation of the coefficients for impervious areas	[1] Mean [2] Concrete – Doll *et al.* (1985) [3] Concrete -- Asaeda & Ca (1993) [4] Asphalt – Narita et al. (1984) [5] Asphalt -- Asaeda & Ca (1993) [6] Asphalt – Anandakumar (1999) [7] Asphalt (winter) – Anandakumar (1999) [8] Asphalt (summer) – Anandakumar (1999)	If option [1] is **NOT** used, put as many choices in the following rows as you want to take into account and add zero when finished

The **Ln*3004_2008*.ohm** file contained within the example dataset has the following structure.

```
%        # Ln08.ohm
%        2    Canyons included: [1] Y [2] N
```

%	2	Vegetation as one [1] Y [2] Separate grass/trees&shrubs/water
%	3	Vegetation: [3] Short grass -- Doll *et al.* (1985)
%	4	[4] Bare soil -- Novak (1982)
%	0	
%	1	Roof: [1] Mean of all
%	2	Impervious as one [1] Y [2] Concrete & asphalt separate
%	2	Impervious surface: [2] Concrete – Doll *et al.* (1985)
%	4	[4] Asphalt – Narita et al. (1984)
%	0	

Appendix C: Interfaces for Preparing Data for SUEWS

Excel spreadsheet and R programme

This is not required to run the programme but is available to facilitate usage. The excel spreadsheet contains example inputs from other runs of the model. The R programme is used to read the spreadsheet and create the files for running the SUEWS programme.

E.1 Preparation

Software needed:

1) Software that can read/write XLSX files - e.g. Microsoft Excel (could be made backward compatible)
2) R programme[10] with XLSX package installed.

E.2 XLSX file

In this file there are series of worksheets that correspond to the files that are needed to run SUEWS.

Enter the data for the site as appropriate – see additional information below about the options and the comments in the spreadsheet etc.

SAVE the spreadsheet.

E.3 R programme

1) Make certain you adjust the directory at the top – note that rather than \ this is used /
2) You will then to create a site section, and indicate the rows and columns that are to be used from the spreadsheet to create the file.
3) Note R is case sensitive (i.e. MainDir and maindir and mainDir are each different)

Please email Sue Grimmond if you would like this.

Other User Friendly Versions are being prepared – Please contact Sue Grimmond to find out status

[10] http://www.r-project.org/ (This software is free)

Appendix D: Differences between SUEWS, LUMPS and FRAISE

The largest difference between LUMPS and SUEWS is that the latter simulates the urban water balance in detail while LUMPS takes a simpler approach for the sensible and latent heat fluxes and the water balance ("water bucket"). The calculation of evaporation/latent heat in SUEWS is more biophysically based. Due to its simplicity, LUMPS requires less parameters in order to run. Table 1.1 lists the differences between LUMPS and SUEWS. SUEWS gives turbulent heat fluxes calculated with both models as an output. The model can run LUMPS alone without running SUEWS (Table 4.1 – *SuewsStatus*).

Table 1.1: Similarities and differences between LUMPS and SUEWS.

	LUMPS	SUEWS
Net all-wave radiation (Q^*)	Input or NARP	Input or NARP
Storage heat flux (ΔQ_S)	Input or from OHM	Input or from OHM
Anthropogenic heat flux (Q_F)	Input or calculated	Input or calculated
Latent heat (Q_E)	DeBruin and Holtslag (1982)[11]	Penman-Monteith equation[2]
Sensible heat flux (Q_H)	DeBruin and Holtslag (1982)	Residual from available energy minus Q_E
Water balance	No water balance included	Running water balance of canopy and water bala of soil
Soil moisture	Not considered	Modelled
Surface wetness	Simple water bucket model	Running water balance
Irrigation	Only fraction of surface area that is irrigated	Input or calculated with a simple model
Surface cover	buildings, paved, vegetation	buildings, paved, coniferous and deciduous trees/shrubs, irrigated and unirrigated grass

FRAISE Flux Ratio – Active Index Surface Exchange

FRAISE provides an estimate of mean midday (±3 h around solar noon) energy partitioning from information on the surface characteristics and estimates of the mean midday incoming radiative energy and anthropogenic heat release. Please refer to Loridan and Grimmond (2012)[12] for further details.

- Complexity:
  - Simplest: FRAISE
    - LUMPS
  - More complex: SUEWS
- Software provided:
  - FRAISE: R code
  - LUMPS: Windows exe (written in Fortran)
  - SUEWS: Windows exe (written in Fortran)
- Applicable period:
  - FRAISE:Midday (within 3 h of solar noon)
  - LUMPS:hourly
  - SUEWS: 5min-hourly-annual
- Unique features:
  - FRAISE: calculates active surface – and fluxes
  - LUMPS: radiation and energy balances
  - SUEWS: radiation, energy and water balance (includes LUMPS)

[11] de Bruin H.A.R. & Holtslag A.A.M. (1982). A simple parameterization of surface fluxes of sensible and latent heat during daytime compared with the Penman–Monteith concept. *J. Appl. Meteor.*, 21, 1610–1621.

[12] Loridan T & CSB Grimmond (2012) Characterization of energy flux partitioning in urban environments: links with surface seasonal properties Journal of Applied Meteorology and Climatology 51, 219-241 doi: 10.1175/JAMC-D-11-038.1