INSTRUCTIONS FOR LUMPS VERSION 5.6

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1. INTRODUCTION

The Local-scale Urban Meteorological Parameterization Scheme (LUMPS) [1, 2] is a surface flux model that utilizes commonly available meteorological observations and information about the land cover. It can model the variability of fluxes both spatially and temporally.

The current release LUMPS version 5.6 utilizes a number of sub-models to calculate

a) The net all-wave radiation (Q^*) using NARP (Net All-wave Radiation Parameterization) [2, 3]
b) The storage heat flux (ΔQ_S) using the OHM (Objective Hysteresis Model) [4, 5]
c) The turbulent latent (Q_E) and sensible (Q_H) heat fluxes using LUMPS [1].

Please contact us to find out what the **formal reference** for this version of the model should be (as we have a paper submitted that will become the formal reference). Until that time please use:

Grimmond C.S.B. and 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.

The paper we hope will become the formal reference is:

Loridan T., Grimmond C.S.B., Offerle B.D., Young D.T., Smith T. and Järvi L. (2010). LUMPS - NARP an urban land surface scheme: evaluation and development of a new longwave parameterization. *J. Appl. Meteorol. Clim.* (in review).

1.1. VERSION 5.6 IMPROVEMENTS

LUMPS version 5.6 is a spatial version of the model. It is able to calculate surface energy balance for as many grids as defined in Lumps_GridNames.txt. The changes from the previous releases include

a) spatial version – for as many areas (grids – but note the area does not need to be formal grid *per se*) as of interest.
b) possibility to choose if the net all-wave radiation and surface temperature for the different sub-surfaces are calculated and output to a separate file for each grid
c) possibility to calculate objective hysteresis model (OHM) with three dimensional surface. The areal fractions can be provided as an input or can be calculated with the surface cover information. (note this is restoring a previous feature)
d) possibility to choose if the model creates 15-, 30- and 60-minute output files (note this is restoring a previous feature)

1.2. VERSION 5.5 IMPROVEMENTS

Changes in LUMPS Version 5.5 from the previous release:

(a) possibility to calculate net-all wave radiation for 6 different subsurfaces: paved, build, coniferous trees, deciduous trees, irrigated grass and non-irrigated grass. In addition, snow cover is taken into account in the calculation of radiation components separately for each surface.
(b) Model writes the net all-wave radiation, surface temperature, upward long- and short-wave radiation for the different surfaces separately and the bulk values.
(c) Data output is only at the time interval of analysis

1.3. VERSION 5.4 IMPROVEMENTS

Improvements in LUMPS Version 5.4 from previous release:

(a) possibility to have the anthropogenic heat flux as an input variable in the model. It can be calculated with the LUCY model [6], which is available for download from the LUMPS-LUCY web pages under http://geography.kcl.ac.uk/micromet/.

1.4. VERSION 5.3 IMPROVEMENTS

Improvements in LUMPS Version 5.3 from previous releases include:

a) Partitioning to the sensible and latent heat fluxes has been improved so that if an area covered by vegetation is larger than 90% the parameters revert to being closer to complete vegetation cover values. In version 5.3 the alpha and beta coefficients are calculated according to:

$$\begin{cases} \alpha = 0.8 veg\_fr + 0.2, & veg\_fr > 0.9 \\ \alpha = 0.686 veg\_fr + 0.189, & veg\_fr \le 0.9 \text{ and } veg\_type = 1 \\ \alpha = 0.610 veg\_fr + 0.222, & veg\_fr \le 0.9 \text{ and } veg\_type = 2 \end{cases}$$

$$\begin{cases} \beta = 17 veg\_fr + 3, & veg\_fr > 0.9 \\ \beta = 3, & veg\_fr \le 0.9 \end{cases}$$

where *veg_fr* is the fraction of the area vegetated. Calculation of alpha parameter depends on whether *veg_type* (see Table 4) is set to use the vegetation fraction (1) or irrigated vegetation fraction (2).

b) The choice of Vegetation fraction type (as above, *veg_type*) has been turned back-on (after being removed by mistake in Versions 5.1 and 5.2).

1.5. VERSION 5.2 IMPROVEMENTS

Improvements in LUMPS Version 5.2 from the previous releases include:

a) The model has a better treatment of precipitation through inclusion of a simple water balance [7]
b) Parameterization of the downward long wave radiation L↓ in NARP has been improved [3] and currently there are three possible ways to treat L↓.
c) Vegetation phenology has been changed from sinusoidal function to more realistic exponential behavior [3]
d) The model is able to create 15-, 30- and 60-minute output files.

2. NOTATION

The following notation is used in this manual.

F	Filepaths
G	Number of grids to be modelled
n	Current version of the model
tt	Time step of data (minutes)
OHM	Objective Hysteresis model
P	Parameter variables
S	Model run options
SS	Two letter code of the measurement site
YY	Year of the measurement period

3. HOW TO RUN LUMPS VERSION 5.6

3.1. COMPILED VERSION

1) The compiled version of the LUMPS version 5.6 (LUMPS_V5_6) is available for download from the LUMPS web page[1].

2) You should save the executable file in the directory where you want to run it. The Lumps_GridNames.txt and LumpsInput.nml should be saved in the same directory as the LUMPS_v5_6.exe file.

3) The required input files (Section 2.3) with identification determined in the Lumps_GridNames.txt should be in file paths defined in LumpsInput.nml. This means before running the model you must open both Lumps_GridNames.txt and LumpsInput.nml file (with a text editor such as notepad, editpad,TextPad etc.) and edit the file paths and names of the input and output files so that they are correct for your setup. File paths which must be specified:

    1. FileChoices (output)
    2. FileGIS (input)
    3. FileMet (input)
    4. FileOHM (input)
    5. FileOut15 (output)
    6. FileOut30 (output)
    7. FileOut60 (output)
    8. FileErrorInf (output)
    9. NARPOut (output)

For example for the FileOut15 you could specify filepath

FileOut15="C:\FolderName\LumpsOutputs\"

and if the identification defined in the Lumps_GridNames.txt would be SSYY_X0001Y0001, a 15-minute output file *SSYY_X0001Y0001_15.txt* would be created in the directory when running the model. If the file paths are not correct the program will return an error when run.

4) <u>To run the model</u> you can use Command Prompt or double click the executable file.

5) The downloads (Table 1) include also the library salflibc.dll which needs to be saved on the computer in order to run the model, and an example dataset with the required input data files and the output files of LUMPS v5.6 (section 4.1).

Please do not redistribute the contents of this zip file (data or model). If someone else would like these please have them contact Sue.Grimmond@kcl.ac.uk.

[1] http://geography.kcl.ac.uk/micromet/

Table 1: Files included in the LUMPS_v5_ ***n***.zip. ***n*** –current version: 6

FileName	**Description**
LUMPSv5_ ***n*** _IO.pdf	Manual
LUMPS_Version_Submitted_14012010.pdf	The latest manuscript by Loridan et al. (2010), which is currently under review in *J. Appl. Meteorol. Climat.*
LUMPS_v5_ ***n***.exe	LUMPS version 5.x executable file
salflibc.dll	The dynamic link library required to run the executable[2]. This needs to be a path that can be found by the programme.
LumpsGridNames.txt	Required input file containing the number of modeled grids and input and output data identification names
LumpsInput.nml	Required input file containing the parameters and model run options for LUMPS
Ln09_X000xY000y.gis	GIS file of the example dataset (grids 1-3)
Ln09_X0001Y0001.ohm	OHM file of the example dataset
Ln09_X0001Y0001 _data.txt	Meteorological input file of the example dataset
Lumps_RunChoices_ Ln09_X000xY000y.txt	File including the run options of the example run
Lumps_ErrorFile_ Ln09_X000xY000y.txt	Output file including possible error messages of the example run
Ln09_X000xY000y _60.txt	60-min output file of the example run
NARPOut_Ln09_X000xY000y.txt	Output file of the example run containing radiation balance components for each sub-surface

3.2. UNCOMPILED VERSION

Please, contact **sue.grimmond@kcl.ac.uk** to obtain the uncompiled version of the LUMPS Version 5. ***n***.

[2] http://dsavas.staff.shef.ac.uk/software/fortran/fortrand.htm#libc

3.3. INPUT AND OUTPUT FILES

The input and output files required for LUMPS 5.6 are listed in Table 2. User defined identification parts defined in Lumps_GridNames.txt (Section 3.1) are shown in **bold.** Here for the user defined filenames *S* represents a site name (usually a relevant two letter code is applied), *tt* the time period of data (two digit numbers in minutes e.g. 60 for hourly data) and *YY* the year (either a two or three digit year is used).

Table 2: Input and Output files for LUMPS 5.6.

File Name	**Description**	**Input/ Output**	**Further Information**
Lumps_GridNames.txt	The number of grids to be analyzed and the identification of input and output files.	Input	Contents of the file are described in Table 3.
LumpsInput.NML	Namelist containing model parameters, file paths and run options.	Input	Contents of the file are described in Table 5.
SSYY_X000xY000y.ohm	Contains a list of parameter options used to run the OHM.	Input	File path defined in LumpsInput.nml [FileOHM] and filename without the extension in Slumps_FileNames.txt
SSYY_X000xY000y_data.txt	Meteorological input data to run the model.	Input	List of variables – Table 6
SSYY_X000xY000y.gis	GIS input data	Input	Contents of the file are described in Table 6. Format – Table4. [GISInputType]
SSYY_X000xY000y _tt.txt	Model output with timestep *tt*	Output	Output variables – Table 8
LUMPS_ErrorFile_**SSYY_X000xY000y.txt**	Model output with timestep *tt*	Output	Output variables, including possible error messages
NARPOut_**SSYY_X000xY000y.txt**	NARP output file	OutPut	Created if NARPOutputChoice = 1

4. INPUT FILES

4.1. LUMPS_GRIDNAMES.TXT

The Lumps_GridNames.txt contains information on how many grids (*G*) the model is run, is there separate OHM and meteorological input files for the different grids, and what the identifications for the different input and output files of grids (x,y) are.

The structure of the file should be

G !NroGrids: Number of modelled grids
0 !DifferentOhm: Different OHM file used for for the different runs ([0] no, [1] yes)
0 !DifferentMet: Does Meteorological data vary with Grid (0 no, 1 yes)
SSYY_X0001Y0001
…
SSYY_X000xY000y

Table 3: Examples of Lumps_GridNames.txt

Description	Lines in Lumps_GridNames.txt	Required input files	Required output files
One grid	1 0 0 SSYY_X0001Y0001	SSYY_X0001Y0001.gis SSYY_X0001Y0001.ohm SSYY_X0001Y0001_data.txt	SSYY_X0001Y0001 _tt.txt LUMPS_ErrorFile_SSYY_X0001Y0001.txt NARPOut_SSYY_X0001Y0001.txt
Two grids with same OHM file	2 1 1 SSYY_X0001Y0001 SSYY_X0001Y0002	SSYY_X0001Y0001.gis SSYY_X0001Y0002.gis SSYY_X0001Y0001.ohm SSYY_X0001Y0001_data.txt SSYY_X0001Y0002.ohm SSYY_X0001Y0002_data.txt	SSYY_X0001Y0001 _tt.txt SSYY_X0001Y0002 _tt.txt LUMPS_ErrorFile_SSYY_X0001Y0001.txt LUMPS_ErrorFile_SSYY_X0001Y0002.txt NARPOut_SSYY_X0001Y0001.txt NARPOut_SSYY_X0001Y0002.txt
Three grids with separate OHM files	3 0 0 SSYY_X0001Y0001 SSYY_X0001Y0002 SSYY_X0001Y0003	SSYY_X0001Y0001.gis SSYY_X0001Y0002.gis SSYY_X0001Y0003.gis SSYY_X0001Y0001.ohm[1] SSYY_X0001Y0001_data.txt[1]	SSYY_X0001Y0001 _tt.txt SSYY_X0001Y0002 _tt.txt SSYY_X0001Y0003 _tt.txt LUMPS_ErrorFile_SSYY_X0001Y0001.txt LUMPS_ErrorFile_SSYY_X0001Y0002.txt LUMPS_ErrorFile_SSYY_X0001Y0003.txt NARPOut_SSYY_X0001Y0001.txt NARPOut_SSYY_X0001Y0002.txt NARPOut_SSYY_X0001Y0003.txt

[1] If same ohm and meteorological input files are used for all grids, they should be named according to the first file identification

4.2. LUMPSINPUT.NML

Table 4 contains a list of the parameters (*P*), filenames (*F*) and model run options (*S*) for LUMPS contained in the compulsory file LumpsInput.NML.

Table 4: Namelist and description of the variables in LumpsInput.NML in alphabetical order. They can be in any order in the file.

Name	Units	Type	Description
ALB(1)	-	*P*	Effective surface albedo of paved surfaces– sky view factor should be taken into account
ALB(2)	-	*P*	Effective surface albedo of buildings – sky view factor should be taken into account
ALB(3)	-	*P*	Effective surface albedo of coniferous tree surfaces– sky view factor should be taken into account
ALB(4)	-	*P*	Effective surface albedo of deciduous tree surfaces – sky view factor should be taken into account
ALB(5)	-	*P*	Effective surface albedo of irrigated grass – sky view factor should be taken into account
ALB(6)	-	*P*	Effective surface albedo of non-irrigated grass – sky view factor should be taken into account
ALB_SNOW	-	*P*	Effective surface albedo for snow
CommonChoiceAllSites	-	*S*	Determines if multiple sites are considered – impacts OHM sub-model
D3_CalcYes	-	*S*	Determines if 3dimensional surface fractions are calculated (yes [1], no [0])
defaultFcld	-	*P*	Default cloud cover fraction (used if meteorological data is missing)
defaultPres	Pa	*P*	Default pressure (used if meteorological data is missing)
defaultRH	%	*P*	Default relative humidity (used if meteorological data is missing)
defaultT	°C	*P*	Default air temperature (used if meteorological data is missing)
DifferentOutPuts	-	*S*	Defines are output files only with the time interval of the input files [0] or with all 15-, 30- and 60-min outputs
DRAINRT	mm h^{-1}	*P*	Drainage rate of the “water bucket”
EMIS(1)	-	*P*	Effective surface emissivity of paved surfaces– sky view factor should be taken into account
EMIS(2)	-	*P*	Effective surface emissivity of buildings – sky view factor should be taken into account
EMIS(3)	-	*P*	Effective surface emissivity of coniferous tree surfaces– sky view factor should be taken into account
EMIS(4)	-	*P*	Effective surface emissivity of deciduous tree surfaces – sky view factor should be taken into account
EMIS(5)	-	*P*	Effective surface emissivity of irrigated grass – sky view factor should be taken into account
EMIS(6)	-	*P*	Effective surface emissivity of non-irrigated grass – sky view factor should be taken into account
EMIS_SNOW	-	*P*	Effective surface emissivity for snow
FileChoices	-	*F*	Filepath and starting of the filename to which run options and errors are written
FileGIS	-	*F*	Data path for the GIS input file

FileMet	-	*F*	Data path for the meteorological input data file
FileOHM	-	*F*	Data path for the OHM data file
FileOut15	-	*F*	Directory of the 15 minute output data file
FileOut30	-	*F*	Directory of the 30 minute output data file
FileOut60	-	*F*	Directory of the 60 minute output data file
FileErrorInf	-	*F*	Directory and start of the error messages (Appendix A)containing output file where the error messages are written
NARPOut	-	*F*	Directory of the NARP output file.
GISInputType	-	*S*	Declares GIS data file type (*See below*)
GrassFractionIrrigated	-	*P*	Fraction of irrigated grass (0 to 1)
INTERVAL	-	*S*	Time interval of input data (can be set to 15, 30 or 60 min)
lat	°	*P*	Latitude
lng	°	*P*	Longitude (NB. west of 0° should be set as NEGATIVE)
NARPOutPut	-	*S*	Determines if NARP output for different subsurfaces is printed out (No [0], yes[1])
NetRadiationChoice	-	*S*	Determines net-radiation scheme (*See below*)
ldown_option	-	*S*	Determines which method is utilised for downwelling longwave radiation (only relevant for NetRadiationChoice=2) (*See below*)
OhmFileType	-	*S*	Determines OHM method. This should be set to 2.
PavedFractionIrrigated	-	*P*	Fraction of irrigated paved areas (0-1)
QSChoice	-	*S*	Identifies which Q_S method is used – set to 1 to use OHM (*See below*)
RainCover	mm	*P*	Defines the limit when the surface is totally covered with water
RainMaxRes	mm	*P*	Capacity of the surface to hold water
SDEC1	-	*P*	Starting date of the leaf-on season
SDEC2	-	*P*	Ending date of the leaf-on season
SDEC3	-	*P*	Starting date of the leaf-off season
SDEC4	-	*P*	Ending date of the leaf-off season
SkipHeaderGIS	-	*S*	Number of header lines to skip in GIS input file
SkipHeadersMet	-	*S*	Number of header lines to skip in meteorology input file
TIMEZONE	-	*V*	Time zone relative to UTC (east is positive)
TRANS_SITE	-	*P*	Atmospheric transmissivity (0-1) of the site (used in NARP)
TreeFractionIrrigated	-	*P*	Fraction of land in which trees are irrigated.
Veg_type	-	*S*	Type of vegetation fraction to use for the turbulent heat flux calculations
year	-	*V*	Year of study (important to determine if a leap year)

<u>*GISInputType*</u>

For GIS data there are two possible temporal resolutions. The land cover data can
GISInputType = 3 stay constant through time
GISInputType = 4 vary each timestep

<u>*NetRadiationChoice*</u> [2,3]
NetRadiationChoice = 1 net all-wave radiation Q^* can be observed
NetRadiationChoice = 2 modelled using the net all-wave parameterization (NARP)

ldown_option

There are three possible ways to take the downwelling longwave radiation into account [3].

ldown_option = 1 observations

ldown_option = 2 calculated from cloud cover fraction

ldown_option = 3 calculated from air temperature and relative humidity

QSChoice

QSChoice = 1 storage heat flux is modeled using the objective hysteresis model (OHM). The model is based on surface types [4, 5]

Veg_type

This determines how the vegetation fraction is used to model the turbulent heat fluxes

Veg_type =1 total fraction of vegetation: vegetation (sum of trees, grass, water) fractions

Veg_type=2 fraction of vegetation that is irrigated (active evapotranspiring rather than dry vegetation)

4.3. METEOROLOGICAL INPUT DATA

LUMPS 5.6 is designed to run using commonly measured meteorological variables [1]. These can be the same for the different grids or can vary with each grid. Table 5 summarizes the default 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. Columns 18 and 19 relate to the calculation of the downwelling longwave radiation and in the current version there are three possibilities [3]:

1) The observed downward longwave radiation in column 15 (*ldown_option* = 1)
2) The downward longwave radiation is calculated from the cloud cover in column 16 (*ldown_option* = 2)
3) The downward longwave radiation is calculated from relative humidity and air temperature data (*ldown_option* = 3)

Table 5: Default meteorological data input to run LUMPS_V5_6.

Column	**Variable**	**Model**	**Units**	**Comments**
1	Day of year	Id	-	
2	Time	It	hr	
3	Decimal time	Dectime	-	
4	Net all-wave radiation	qn1	W m^{-2}	Needed with NetRadiationChoice=1 #
5	Mean wind speed	avu1	m s^{-1}	
6	Mean relative humidity	Avrh	%	
7	Mean air temperature	Temp_C	°C	
8	Mean wind direction	dir30	°	
9	Station air pressure	Pres_kPa	kPa	
10	Precipitation	Ph	mm t^{-1}	Reported for the data time interval (e.g. for hourly data mm $hour^{-1}$)
11	Mean incoming solar radiation	Avkdn	W m^{-2}	#
12	Snow cover fraction on paved area	Snow_pav	-	#, between 0-1
13	Snow cover fraction on buildings	Snow_blg	-	#
14	Snow cover fraction on coniferous trees	Snow_con		#
15	Snow cover fraction on deciduous trees	Snow_dec		#
16	Snow cover fraction on grass	Snow_grass		#
17	Obs. downward longwave radiation	ldown_obs	W m^{-2}	#
18	Obs. cloud faction	fcld_obs	Tenths	#
19	Anthropogenic heat flux	qf	W m^{-2}	#

4.4. GIS INPUT DATA

The LUMPS 5.6 requires plan area land cover fractions for impervious and vegetated surfaces in the local area (i.e. for each grid cell or area). Table 6 summarizes the GIS file format.

The last four columns are related to the three dimensional calculation of the surface cover in OHM. If only one dimensional surface cover is examined, the columns 11-14 should be set to zero. If three dimensional surface cover is used (canyons included in the ohm file) there are currently two possibilities to have the needed information

1. The areal fraction of buildings including the walls can be given in column 11 and the areal fraction of non flat roof can be given in column 12. In this case columns 13 and 14 can be set to zero. D3_CalcYes should be set to 0.

2. Parameter cany3D is calculated from the whole frontal area fraction in the study area (column 13) when it gets value build+fron, and parameter roof3D is calculated from the average slope of the roofs (column 14) with equation build/cos(angle). In this case D3_CalcYes should be set to 1 and columns 11 and 12 can be set to zero.

Table 6: Dedicated GIS file format for use when *GISInputFormat* = 3 or 4. Note that the sum of columns from 4 to 10 has to equal 1.

Column	Name	Model	Description/Comment
1	Day of year	id	Set to 3 if using constant values
2	Time	it	Set to 3 if using constant values
3	quality	iqual	Not used (set to 1)
4	Building fraction	build	Areal cover fraction – buildings
5	Paved fraction	ximper	Areal cover fraction – paved
6	Unmanaged fraction	unman	Areal cover fraction – unmanaged e.g. bare soil
7	Coniferous tree cover fraction	con_sh	Areal cover fraction – coniferous trees
8	Deciduous tree cover fraction	dec_sh	Areal cover fraction – deciduous trees
9	Grass fraction	gras	Areal cover fraction – grass
10	Water fraction	watr	Areal cover fraction – water
11	3D building fraction	cany3D	Three dimensional areal cover fraction of buildings
12	3D roof fraction	roof3D	Three dimensional areal cover fraction of roofs
13	Building frontal area fraction	fron	This should include all buildings in the study area
14	Roof angle	angle	Angle of the roof from horizontal

4.5. OHM FILE

The OHM file contains information on how the different surface types are taken into account in the calculation of heat storage. That is what values should be used for the parameters in the OHM equation [3, 4]. The possible choices (Table 7) are followed by examples of OHM files.

Table 7: Description of choices in SSYY_X000xYX000y.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 as	[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 Ln09_X0001Y0021.ohm file contained within the Ln09 example on the "downloads" page has the following structure

```
%     #Ln09.ohm
      1   Canyons included: [1] Y [2] N
      2   Canyons: [2] mean of all
      1   Vegetation as one [1] Y [2] Separate grass/trees&shrubs/water
      2   Vegetation: [2] Mixed forest
      3   Vegetation: [3] Short grass
      8   Vegetation: [8] Water
      0   Ends vegetation reading
      1   Roof [1] Mean of all
      1   Impervious as one [1] Y [2] Concrete & asphalt separate
      1   Impervious   [1] Mean of all
```

In the model run, roofs and paved surfaces are treated as one type of material with assigned coefficients determined as the mean value of the coefficients for each surface type presented in LUMPS (Appendix A).

Another example excludes canyons and treats vegetation as a mean. For roof, mean coefficient is used, whereas impervious surfaces are separated to concrete and asphalt.

```
%     #SSYY.ohm
      2   Canyons included: [1] Y [2] N
      1   Vegetation as one [1] Y [2] Separate grass/trees & shrubs/water
      1   Vegetation: [1] mean of all
      1   Roof: Mean of all
      2   Impervious as one [1] Y [2] Concrete & asphalt separate
      2   Impervious: concrete according to Doll et al. (1985)
      6   Impervious: asphalt according to Anandakumar (1998)
      0   Ends impervious surface reading
```

5. OUTPUT FILES

LUMPS 5.6 will produce an output file (*SSYYX000xY000y_15.txt, SSYYX000xY000y_30.txt* or *SSYYX000xY000y_60.txt,* or all them if chosen so), an output file (*LUMPS_ErrorFile_SSYYX000xY000y.txt*) including possible error messages (Appendix B) with the time resolution defined by *INTERVAL* and is chosen an output file containing the radiation balance components for different sub-surfaces (*NARPOut_ SSYYX000xY000y.txt*).

The model data output files contain a header with a selection of model run information. An example is presented below.

Line 1 highlights the model version and any additional modules that may have been run.
Line 2 identifies if multiple sites were considered (this option should remain as 1 in LUMPS V5.5) and how the net radiation was calculated.

Line 3 identifies which method was utilised to calculate the storage heat flux (OHM always used in LUMPS V5.5).

Line 4 shows which veg_type and ldown_option choices were used.

```
% Version= LUMPS_v 5.6
% 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 LUMPS output file columns are explained in Table 8 and the NARP output file in Table 9.

Table 8: LUMPS v5.6 output file format.

Column	Header Name	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	Ts	Surface temperature	°C
9	qn	Net all-wave radiation	W m^{-2}
10	h_mod	Sensible heat flux	W m^{-2}
11	e_mod	Latent heat flux	W m^{-2}
12	qs	Storage heat flux	W m^{-2}
13	FCLD	Cloud cover fraction	-
14	V	Vegetation phenology	-

Table9: NARP output file format.

Column	Header Name	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_blg	Reflected shortwave radiation from roofs	W m^{-2}
5	kup_con	Reflected shortwave radiation from coniferous area	W m^{-2}
6	kup_dec	Reflected shortwave radiation from deciduous area	W m^{-2}
7	kup_igr	Reflected shortwave radiation from irrigated grass	W m^{-2}
8	kup_ugr	Reflected shortwave radiation from unirrigated grass	W m^{-2}
9	lup_pav	Upwelling longwave radiation from paved areas	W m^{-2}
10	lup_blg	Upwelling longwave radiation from roofs	W m^{-2}
11	lup_con	Upwelling longwave radiation from coniferous area	W m^{-2}
12	lup_dec	Upwelling longwave radiation from deciduous area	W m^{-2}
13	lup_igr	Upwelling longwave radiation from irrigated grass	W m^{-2}
14	lup_ugr	Upwelling longwave radiation from unirrigated grass	W m^{-2}
15	Ts _pav	Surface temperature - paved areas	°C
16	Ts _blg	Surface temperature - roofs	°C
17	Ts _con	Surface temperature - coniferous trees	°C
18	Ts _dec	Surface temperature – deciduous trees	°C
19	Ts _igr	Surface temperature - irrigated grass	°C
20	Ts _ugr	Surface temperature - unirrigated grass	°C
21	qn _pav	Net all-wave radiation - paved areas	W m^{-2}
22	qn _blg	Net all-wave radiation - roofs	W m^{-2}
23	qn _con	Net all-wave radiation - coniferous trees	W m^{-2}
24	qn _dec	Net all-wave radiation – deciduous trees	W m^{-2}
25	qn _igr	Net all-wave radiation - irrigated grass	W m^{-2}
26	qn _ugr	Net all-wave radiation unirrigated grass	W m^{-2}

5.1. EXAMPLE OUTPUT FILES

The example dataset includes output files calculated for three different grids in central London. Below an example of the output data is shown. The different grids represent different surface covers with high surface fractions of buildings and paved areas (Ln09_X0001Y0021), vegetation (Ln09_X0001Y0027) and water (Ln09_X0001Y0029). The annual energy balances for whole central London modeled with the LUMPS v5.6 are plotted in Fig. 2.

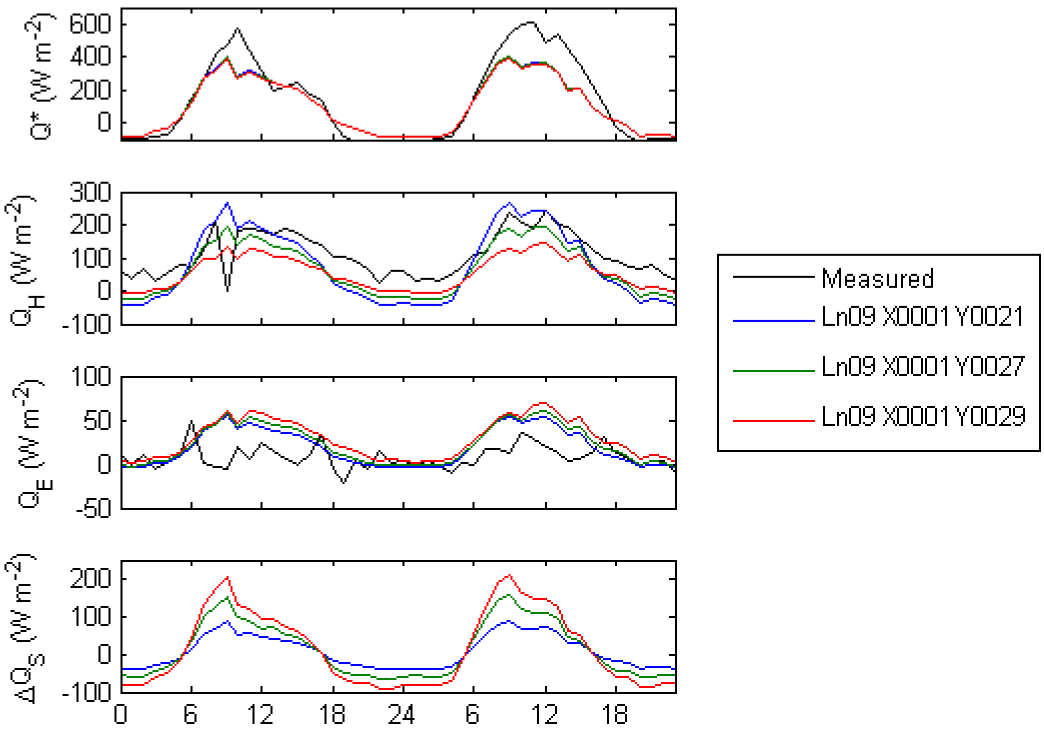

Figure 1: Example of results obtained with the LUMPS v5.6.

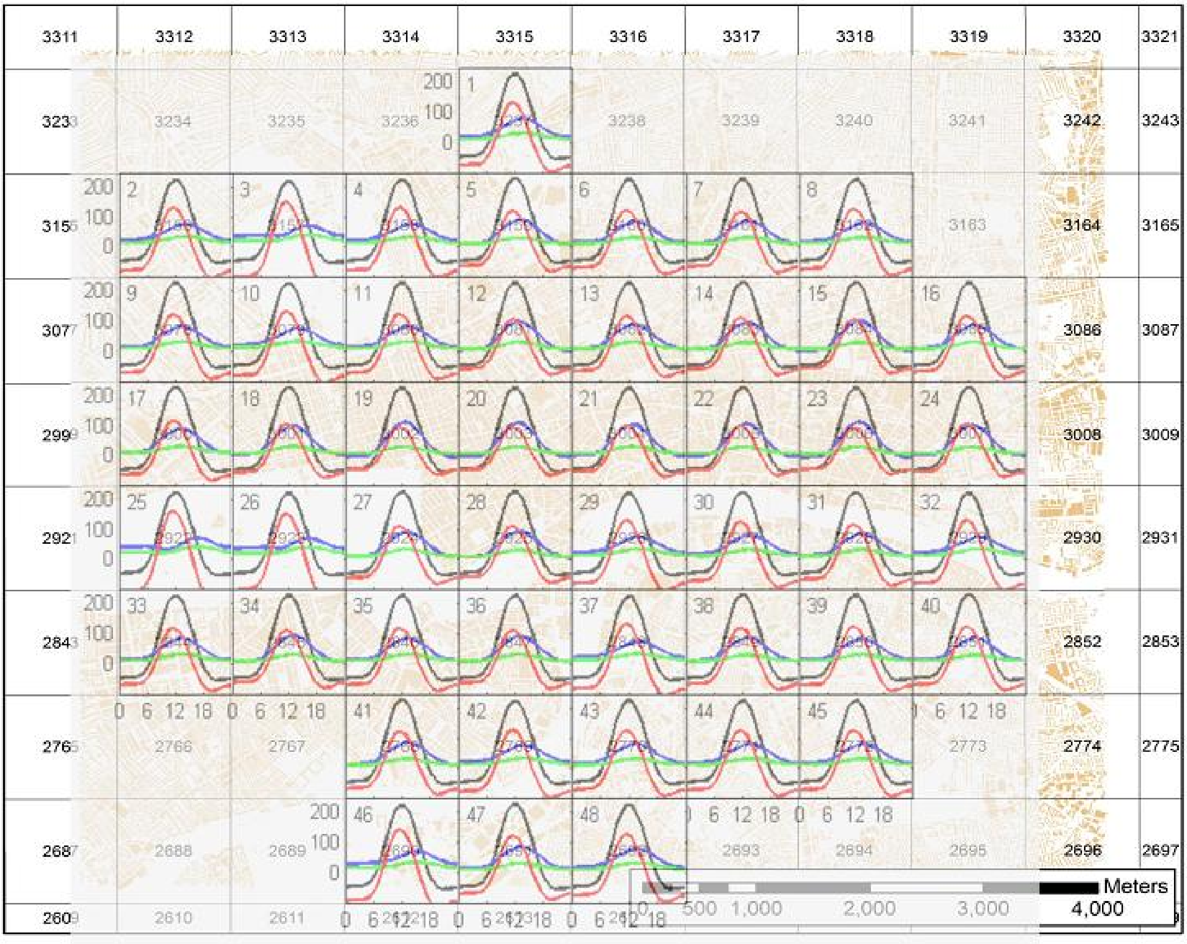

Figure 2. Model runs made for central London. Black line stands for the net all-wave radiation Q^*, red line the storage heat flux ΔQ_S , blue line the sensible heat flux Q_H and green line the latent heat flux Q_E.

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APPENDIX A: DIFFERENT COEFFICIENTS FOR OHM

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
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
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

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APPENDIX B: ERROR MESSAGES

“*dectime 1000 avU U default data used=> 3*”	Your input wind speed data is unrealistic. Default data used. *Dectime* indicates the day and time in the day (as a decimal fraction) when the problem was seen and *avU* is the input wind speed value.
“*dectime xxxx dir30 WD default data used=> 130*”	Your input wind direction data is unrealistic. Default data used. *dir30* is the input wind direction value.
“*dectime xxxx Tem_C T default data used=> Default T*”	Your input air temperature data is unrealistic. Default data used. *Temp_C* is the input meteorological value.
“*dectime xxxx Pres_kPa P default data used=> Default P*”	Your input pressure data is unrealistic. Default data used. *Pres_kPa* is the input meteorological value.
“*dectime xxxx avrh RH default data used=> Default RH*”	Your input relative humidity data in unrealistic. Default data used. *avrh* is the input meteorological value.
If above mentioned error messages arise from missing data (-999), you can consider filling the gaps in more sophisticated way before running the LUMPS.	
“*%sat_vap_press.f temp=0.0000 pressure dectime*”	Temperature is zero and in calculation of water vapour pressure an 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.
“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)