Supplementary material for STOTEN article *Impacts of town characteristics on the changing urban climate in Vantaa*

S1 CMIP5 global climate models

Table S1: CMIP5 global climate models used in creating climate change projections for the city of Vantaa. The first and second columns give the model acronym and the country of origin; the EC-EARTH model has been developed by a consortium of several European countries. An asterisk in columns 3–10 indicates that data from the corresponding model was utilized for a variable (Tave: mean surface air temperature; Tmin: daily minimum temperature; Tmax: daily maximum temperature; Prec: precipitation; Solar: incident solar radiation at the surface; Rel. hum: relative humidity at the surface; Speed: surface air wind speed; Dir: wind direction, STD: the monthly standard deviation of the temporal variability of daily mean temperature). For further information about the individual models and key references, see Table 9.A.1 of IPCC (2013).

Model	Country	Tave	Tmin, Tmax	Prec	Solar	Rel. hum	Speed	Dir	STD
ACCESS1-0	Australia	*	*	*	*	*	*		*
ACCESS1-3	Australia	*	*	*	*	*	*		
BCC-CSM1-1	China	*	*	*	*	*	*	*	*
CanESM2	Canada	*	*	*	*	*	*	*	*
CMCC-CM	Italy	*	*	*	*		*	*	*
CMCC-CMS	Italy	*	*	*	*		*	*	*
CNRM-CM5	France	*	*	*	*	*	*	*	*
EC-EARTH	Europe	*	*	*	*		*		*
GFDL-CM3	USA	*	*	*	*	*	*	*	*
GFDL-ESM2M	USA	*	*	*	*	*	*	*	*
GISS-E2-H	USA	*	*	*	*	*	*		
GISS-E2-R	USA	*	*	*	*	*	*		
HadGEM2-CC	UK	*	*	*	*	*	*	*	*
HadGEM2-ES	UK	*	*	*	*	*	*	*	*
INMCM4	Russia	*	*	*	*	*	*	*	*
IPSL-CM5A-LR	France	*		*	*	*	*	*	*
IPSL-CM5A-MR	France	*		*	*	*	*	*	*
MIROC5	Japan	*	*	*	*	*	*	*	*
MIROC-ESM	Japan	*	*	*	*	*	*	*	*
MIROC-ESM-CHEM	Japan	*	*	*	*	*	*		*
MPI-ESM-LR	Germany	*	*	*	*		*	*	*
MPI-ESM-MR	Germany	*	*	*	*		*	*	*
MRI-CGCM3	Japan	*	*	*	*	*	*	*	*
NCAR-CCSM4	USA	*	*	*	*	*			*
NCAR-CESM1-BGC	USA	*	*	*	*	*			
NCAR-CESM1-CAM5	USA	*	*	*	*	*	*		
NorESM1-M	Norway	*	*	*	*	*			*
NorESM1-ME	Norway	*		*	*	*			

S2 Calculation of the downward longwave radiation

Downward longwave radiation at the surface depends mostly on cloudiness, temperature and humidity. Air specific humidity and downward longwave radiation given by HARMONIE-AROME show two separate linear dependencies (see Figure S1), presumably related to cloudy and cloud-free situations; these were utilized in order to create a hourly longwave radiation dataset for the future climate. The method, developed in Saranko (2019), for generating this dataset has the following phases:

1) A linear fit for the whole dataset is generated. 2) This fit is used to divide the whole dataset into two subsets, upper and lower. 3) Linear fits for both subsets are created. 4) A new fit is generated using the parameters of the two subset linear fits, as a mean of the slopes and the intercepts. Steps 2)–4) are repeated until the linear fits for the two subset converge and the two subsets are clearly separate.

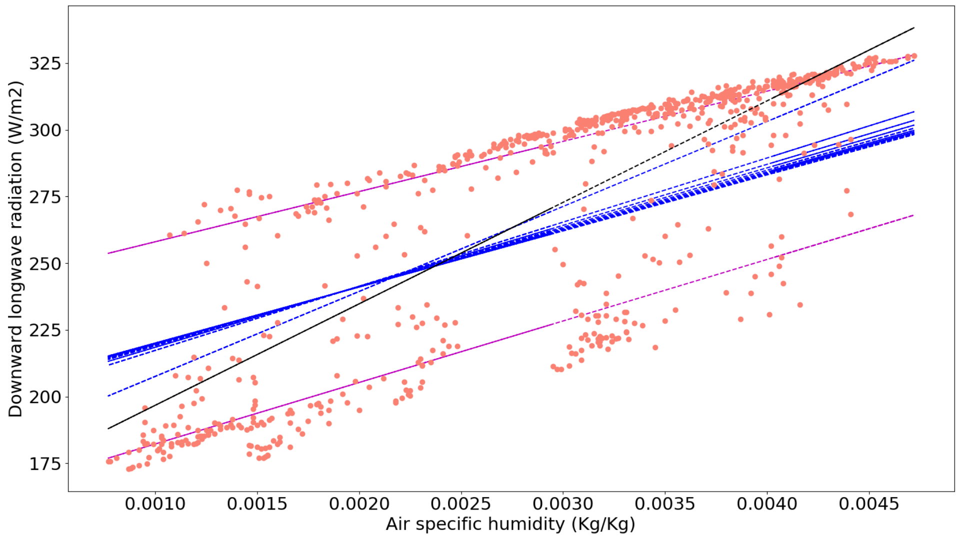

Figure S1: The process of determining downward longwave radiation for 2050s climate. The data set is divided into two subsets (upper and lower) using linear fits and iterative methods. The two subsets correspond to cloudy (upper) and cloud-free (lower) cases.

S3 Verification results

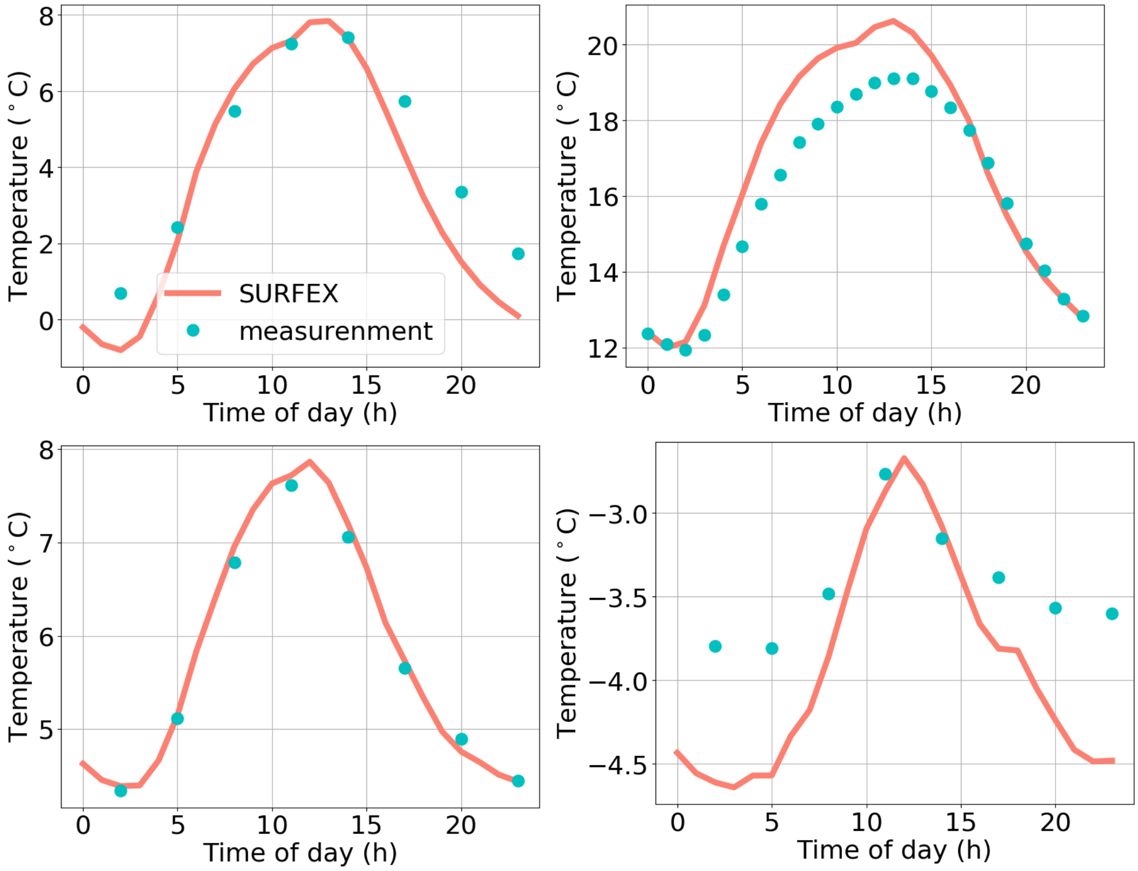

Figure S2: Observed and modelled seasonal mean diurnal temperature cycles at the Helsinki-Vantaa airport for the test-year. Note the different vertical scales in the diagrams. The comparison is shown separately for spring (top left), summer (top right), autumn (bottom left) and winter (bottom right).

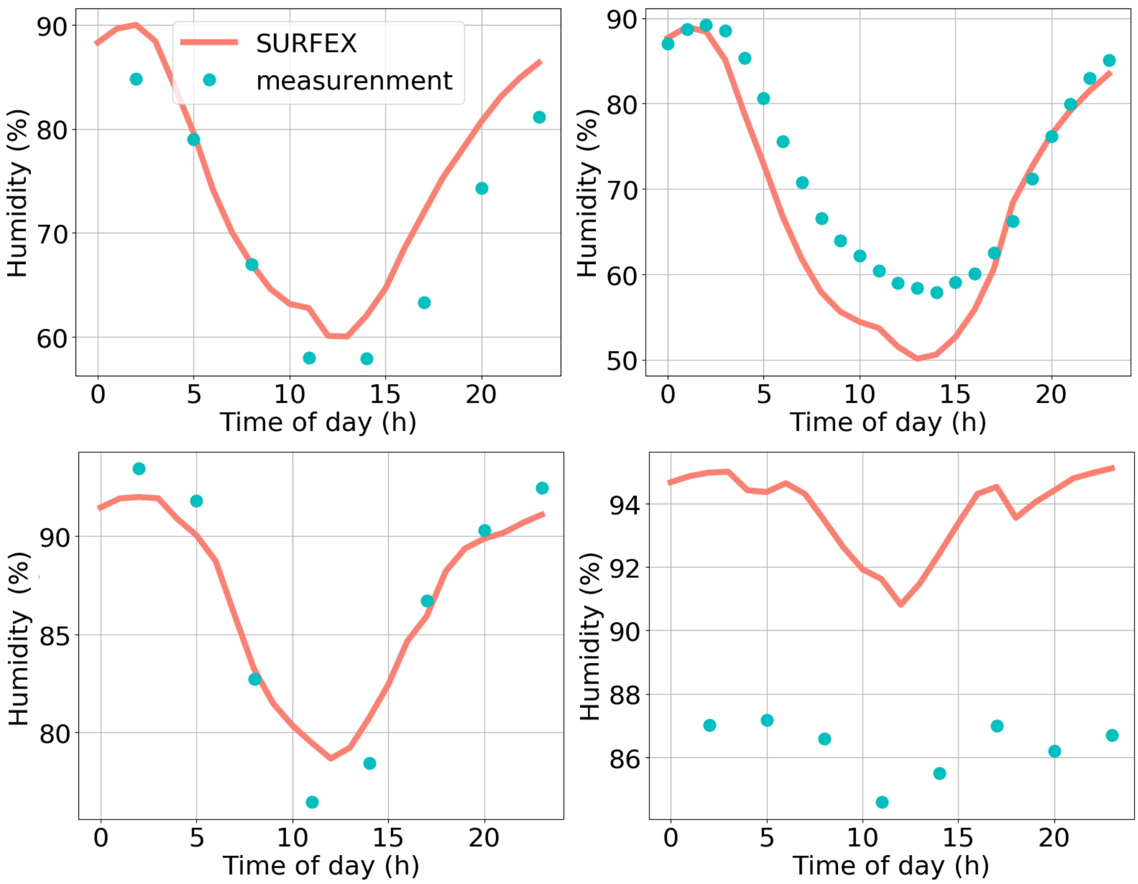

Figure S3: Observed and modelled seasonal mean diurnal cycles of relative humidity at the Helsinki-Vantaa airport for the test-year in spring (top left), summer (top right), autumn (bottom left) and winter (bottom right).

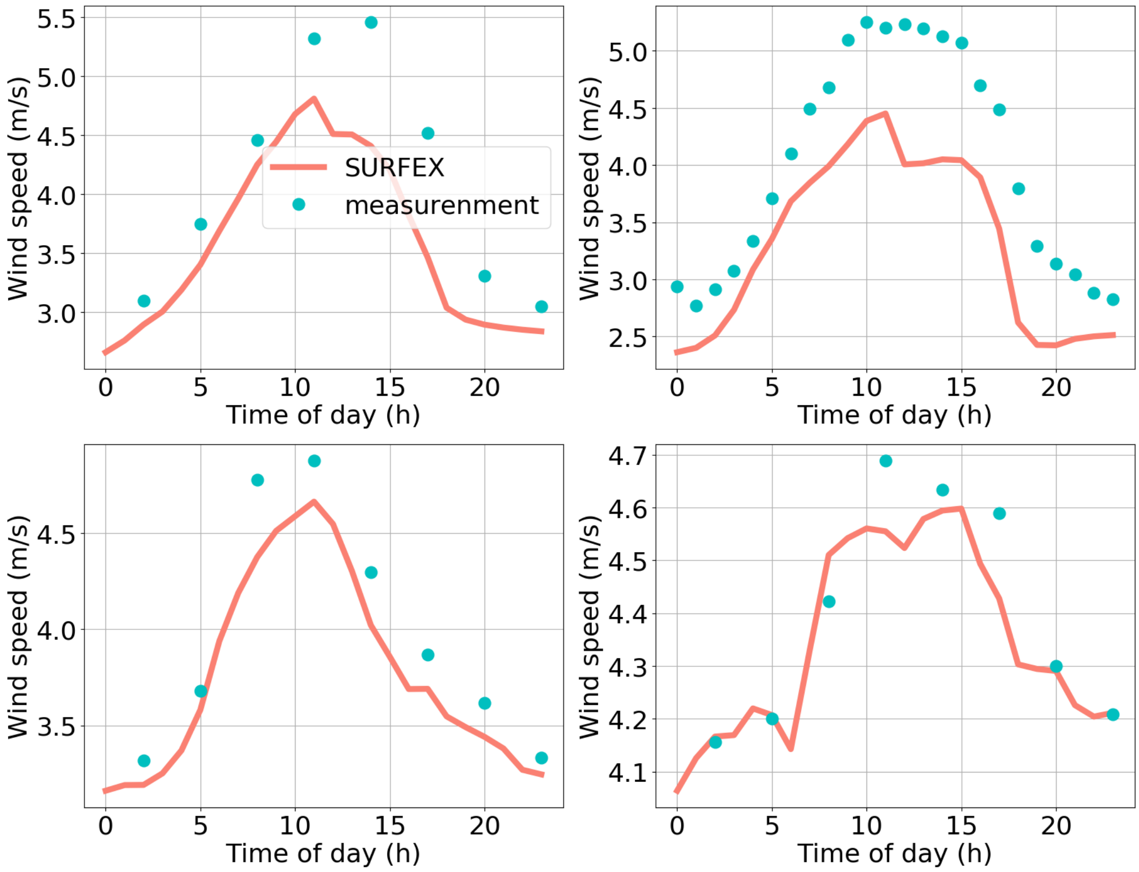

Figure S4: Observed and modelled seasonal mean diurnal cycles of wind speed at Helsinki-Vantaa airport for the test-year in spring (top left), summer (top right), autumn (bottom left) and winter (bottom right).

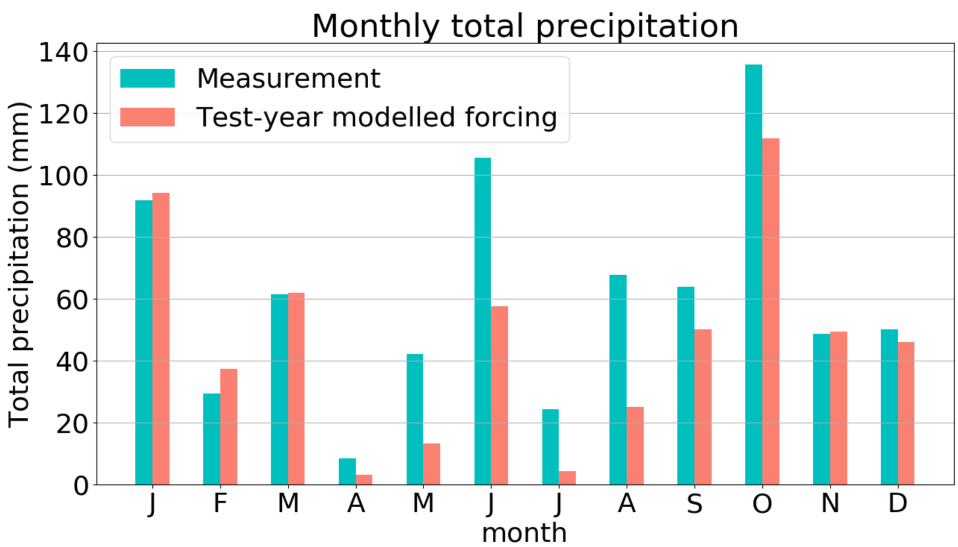

Figure S5: Observed and modelled monthly precipitation totals for the test-year. The observations are from Helsinki-Vantaa airport.

S4 Projected trends

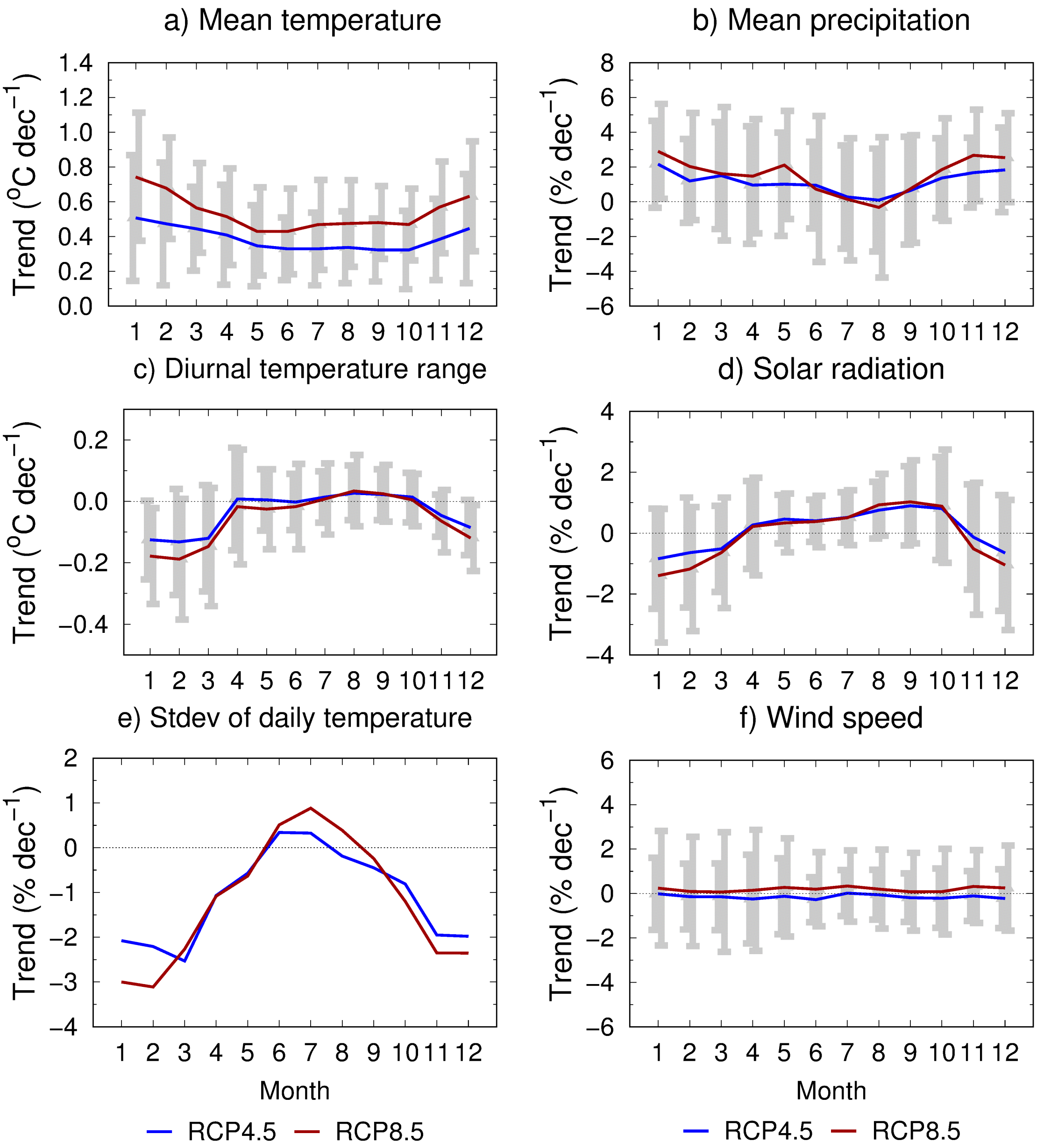

Figure S6: Projected trends in (a) monthly mean air temperature, (b) monthly precipitation total, (c) diurnal temperature range, (d) solar radiation, (e) monthly standard deviation of the temporal variability of daily mean temperature and (f) wind speed between the baseline period (1981–2010 for a–d and f, 1971–2000 for e) and 2040–2069 at Vantaa under the Representative Concentration Pathways RCP4.5 and RCP8.5. The multi-model mean projections for each calendar month (1 = January, 12 = December) are depicted by solid curves (blue for RCP4.5 and red for RCP8.5). The grey bars indicate the 90 % uncertainty intervals for the change (left for RCP4.5 and right for RCP8.5).

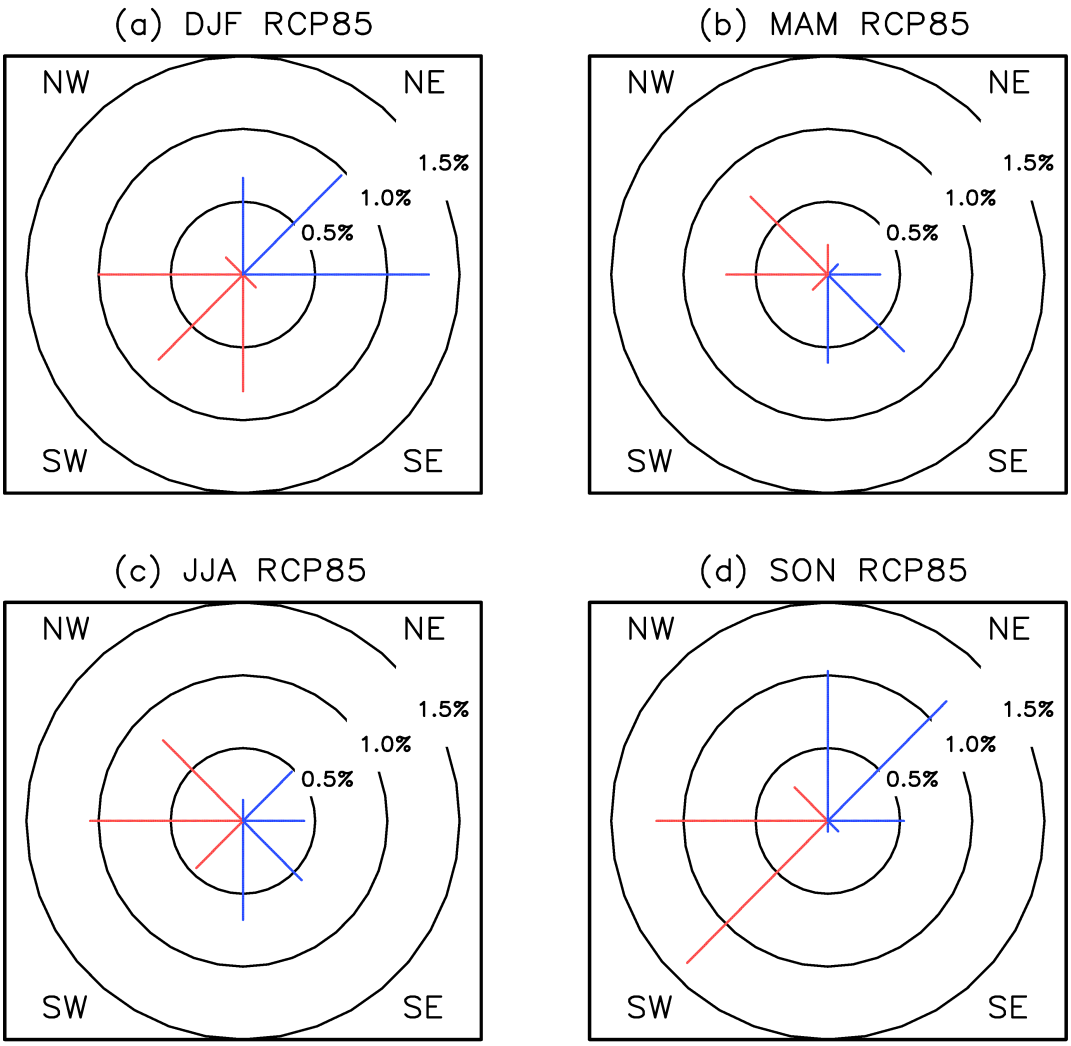

Figure S7: Projected multi-model mean changes in the frequency distributions of simulated wind directions in winter (DJF), spring (MAM), summer (JJA) and autumn between the periods 1971–2000 and 2040–2069 at Vantaa under the RCP8.5 scenario. The changes are provided in percentage points, with red bars depicting an increase and blue bars a decrease in the frequency. The circles indicate the scale of changes for each cardinal and intercardinal direction with an interval of 0.5 percentage points.

S5 Forcing changes

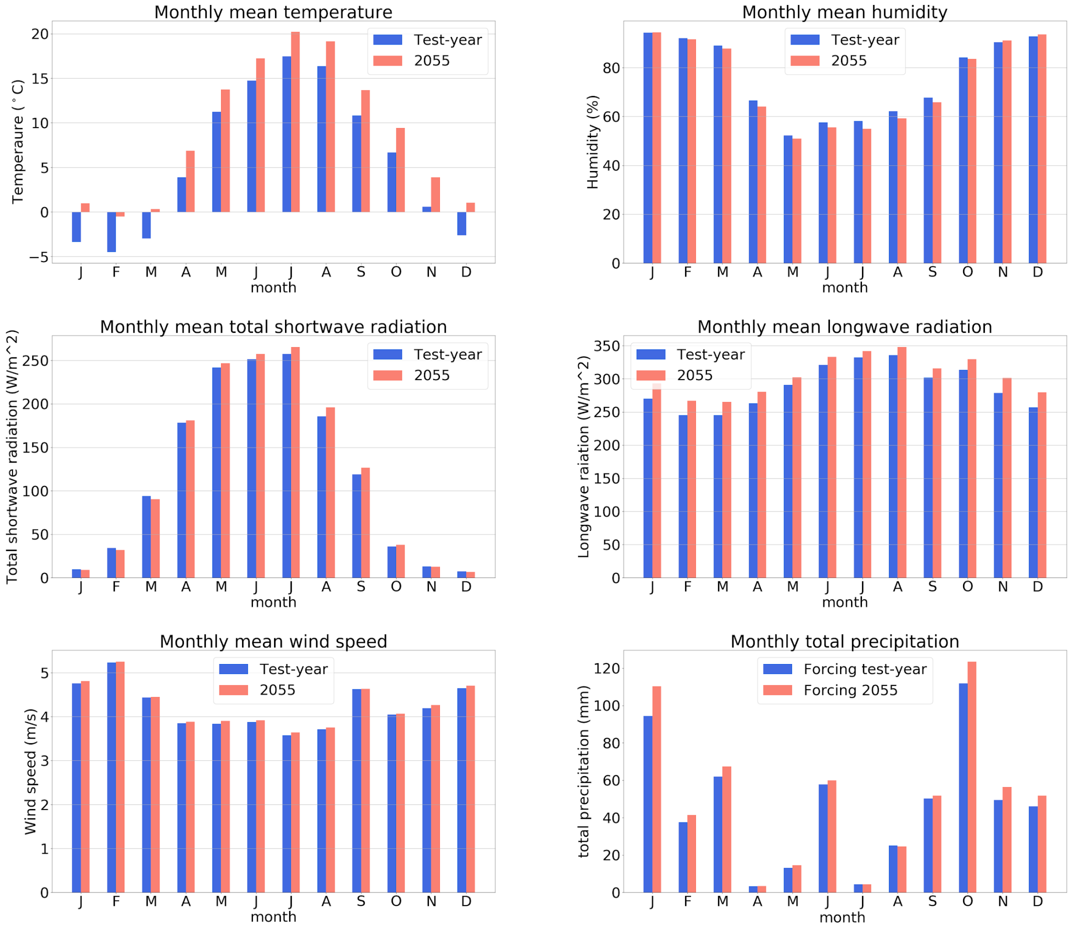

Figure S8: Monthly averaged meteorological forcing extracted from the simulated data for the Helsinki-Vantaa airport. Blue: as given by HARMONIE for the test-year. Red: as modified to represent the mid-2050s climate according to the Representative Concentration Pathway RCP8.5. Panels from the top left to the bottom right show air temperature, relative humidity, insolation, downwelling terrestrial radiation, wind speed and precipitation amount, respectively. Temperature, humidity and wind speed represent conditions at 12 m above the ground.

S6 Changes in seasonal average meteorological conditions

Table S2: Seasonal average daily minimums and maximums and mean temperature values for both the recent past and mid-century climate at Tikkurila without interventions (top section), and the differences between those values and the ones in Sipoonkorpi National Park (middle section) and Tikkurila with interventions (bottom section). In all sections, the seasons are in the following order: winter (December, January March), spring, summer and autumn.

	Recent past climate			2050s climate (RCP8.5)		
	min (°C)	mean (°C)	max (°C)	min (°C)	mean (°C)	max (°C)
Tikkurila, no intervention						
DJF	-6.1	-2.9	-0.4	-1.7	1.0	3.1
MAM	0.5	5.3	9.8	3.7	8.4	13.0
JJA	13.0	18.2	23.1	15.6	20.9	25.9
SON	4.0	6.7	9.2	7.2	9.7	12.1
Sipoonkorpi National Park - Tikkurila, no intervention						
DJF	-1.1	-0.9	-0.7	-1.0	-0.8	-0.7
MAM	-3.1	-2.3	-1.9	-1.9	-1.8	-2.1
JJA	-1.8	-1.8	-2.5	-1.5	-1.7	-2.3
SON	-1.4	-1.1	-1.0	-1.3	-1.0	-1.0
Tikkurila, with intervention - Tikkurila, no intervention						
DJF	-0.4	-0.4	-0.4	-0.3	-0.3	-0.3
MAM	-0.7	-0.8	-1.0	-0.5	-0.7	-1.1
JJA	-0.6	-0.7	-1.1	-0.5	-0.7	-1.0
SON	-0.5	-0.4	-0.4	-0.4	-0.4	-0.4

Table S3: Seasonal average daily minimums and maximums and mean relative humidity values for both the recent past and mid-century climate at Tikkurila without interventions (top section), and the differences between those values and the ones in Sipoonkorpi National Park (middle section) and Tikkurila with interventions (bottom section).

	Recent past climate			2050s climate (RCP8.5)		
	min (%)	mean (%)	max (%)	min (%)	mean (%)	max (%)
Tikkurila, no intervention						
DJF	82.8	89.8	95.9	86.3	91.9	96.5
MAM	49.8	67.3	86.2	47.9	66.9	86.6
JJA	41.6	62.2	85.1	39.7	60.9	84.7
SON	72.5	83.0	92.1	73.3	84.1	93.5
Sipoonkorpi National Park - Tikkurila, no intervention						
DJF	7.0	5.6	3.0	6.2	4.6	2.5
MAM	10.7	12.0	10.1	7.9	8.9	8.0
JJA	8.7	8.4	8.4	6.7	7.0	7.8
SON	5.5	5.5	4.8	5.3	5.0	4.0
Tikkurila, with intervention - Tikkurila, no intervention						
DJF	4.6	3.5	2.1	3.3	2.7	1.7
MAM	7.3	5.2	3.5	5.5	3.9	2.6
JJA	4.3	3.3	3.0	3.1	2.7	2.7
SON	2.6	2.6	2.5	2.5	2.4	2.1

Table S4: Seasonal average daily minimums and maximums and mean wind speed values for both the recent past and 2050s climate at Tikkurila without interventions (top section), and the differences between those values and the ones in Sipoonkorpi National Park (middle section) and Tikkurila with interventions (bottom section).

	Recent past climate			2050s climate (RCP8.5)		
	min (m/s)	mean (m/s)	max (m/s)	min (m/s)	mean (m/s)	max (m/s)
Tikkurila, no intervention						
DJF	1.0	1.6	2.3	0.9	1.6	2.3
MAM	0.8	1.4	2.1	0.8	1.4	2.1
JJA	0.7	1.3	1.9	0.7	1.4	2.0
SON	0.8	1.4	2.1	0.8	1.5	2.1
Sipoonkorpi National Park - Tikkurila, no intervention						
DJF	1.3	2.5	3.7	1.3	2.5	3.7
MAM	0.7	1.6	2.7	0.7	1.7	2.7
JJA	0.4	1.1	1.9	0.4	1.1	2.0
SON	0.8	1.6	2.4	0.8	1.6	2.4
Tikkurila, with intervention - Tikkurila, no intervention						
DJF	0.6	1.2	1.7	0.6	1.2	1.7
MAM	0.3	0.9	1.5	0.4	0.9	1.5
JJA	0.3	0.9	1.4	0.4	0.9	1.4
SON	0.4	1.0	1.5	0.4	1.0	1.5

References

Saranko, O. (2019). “Modelling winter conditions of streets and pavements in a changing climate.” Master’s thesis. University of Jyväskylä, Department of Physics.