Conference Proceedings of 5th International Conference on Countermeasures to Urban Heat Islands (IC2UHI) 2019
December 2-4, 2019, Hyderabad, India
https://doi.org/10.37285/bsp.ic2uhi.1

Effects of Heat Island Mitigation on Heat-Related Mortality in Montreal during Heat Wave Periods of 2005, 2011 and 2018

Zahra Jandaghian, Research Assistant at Ryerson University
Hashem Akbari[1], Professor at Concordia University (Canada)

ABSTRACT

Heat-related mortality (HRM) is increasing as a result of climate change leading to extreme heat events. Increasing surface reflectivity is applied to mitigate the effects of heat island and high temperature in urban areas. The Weather Research and Forecasting model (WRF) is coupled with a multi-layer of the Urban Canopy Model (ML-UCM) to investigate the effects of heat island mitigation strategy during the 2005, 2011 and 2018 heat wave periods in the Greater Montreal Area (GMA). Three indicators are applied to translate the effects of extreme heat events and the potential of albedo enhancement on HRM rates: air mass type, air temperature and apparent temperature changes for each day of simulations. Using the Spatial Synoptic Classification (SSC) indicates that the moist tropical plus and dry tropical weather have the highest rank in HRM. The non-accidental mortality data during summer period are employed. The heat-induced mortality correlations are defined on daily basis based on consecutive days of the heat wave events, the day in summer season and apparent temperature in ^{o}C. The albedo of roofs, walls and ground increased from 0.2 by 45%, 40% and 25%, respectively. The beneficial contributions of albedo enhancement are a decrease in daily averaged temperature by nearly 1^{o}C and an increase in daily averaged dew point temperature by 0.4^{o}C. Heat island strategy shift days into less oppressive air masses by 50%. The heat-related death will decrease by at least 3 to 5%, meaning that seven to twelve lives could be saved during these heat wave events.

INTRODUCTION

The rate of heat-related mortality is increasing in urban areas because of the impacts of heat island phenomenon. Climate change poses extreme heat events and magnifies the frequency and duration of urban heat island (UHI). Urban heat island intensity causes an increase in morbidity and mortality (Jenkins et al., 2014; Horton et al., 2014 and Hajat et al., 2010). The combination of extreme heat wave events and UHI leads to higher ambient temperatures, causing heat stress for urban dwellers. High temperature is responsible for the heat-related mortality increments in cities around the globe (Basu 2009). In North America, around 700 deaths are categorized as directly linked to high temperatures annually (Center for Disease Control and Prevention 2013). But it is presumed that the total number of heat-related death is even higher because mortality can also be classified under other natural causes, for instant air pollution. The indirect effect of UHI is to increase photochemical reaction rates and thus worsen air quality.

Epidemiological studies show a positive correlation between extreme air temperature and mortality (Diaz et al., 2002 and O'Neill et al., 2009; Jandaghian and Akbari, 2016). Urban areas absorb and trap heat because of high thermal mass and low ventilation, and thus the residence is at great risk (Diaz et al., 2002). Heat-related mortality is increased by 4.5% per degree Celsius and by 0.4% per day in heat wave periods in North America (Anderson and Bell, 2009). In another study, mortality increases by 3.6% per degree Celsius increase in temperature in the United State

[1]Corresponding Author: Hashem.Akbari@Concordia.ca, Heat Island Group, Building, Civil and Environmental Engineering Department, Concordia University Montreal, QC H3G 1M8, Canada.

(Zanobetti et al., 2014) and by 4.6% per degree Celsius rise in apparent temperature (Basu and Samet, 2002). A research indicated that the mortality rates rise as temperatures reach beyond human comfort zone and in the future with the advance of heat wave events the number of heat-death will increase more comparing to cold-death (McMichael et al., 2006).

To mitigate the adverse effects of heat waves and heat island in urban areas, increasing surface albedo can be applied in local and global scales (Akbari et al., 2009; Oleson et al., 2011; Ban-Weiss et al., 2015; Taha 2009). The albedo of roofs or pavements range from 0.1 to 0.2 but can be even higher because of the use of reflective materials (Akbari et al., 2002 and 2016). Jandaghian et al. (2017) showed that by increasing surface albedo, air temperature decreases by 0.2°C, wind speed slightly increases, relative humidity and precipitation respectively decrease by 2.8% and 0.2 mm in Greater Montreal Area (GMA) in 2009. Jandaghian and Akbari (2018a) also showed that increasing surface albedo in Sacramento, Houston and Chicago result in a decrease in air temperature by 2.3°C in urban areas and 0.7°C in suburban areas; a slight increase in wind speed; an increase in relative humidity (3%) and dew point temperature (0.3°C), respectively.

The Statistics Canada reveals that heat-related death reached to 158-people over a decade. The Canadian Environment Health Atlas (CEHA, 2018) estimates that in Montreal 121 people die each year because of high temperature. In another study, the number of heat-related deaths was estimated to be 209 people during the July 2010 heat wave period in Montreal (Bustinza et al., 2013). More than 90 heat-related death is linked to three consecutive days in 2018 heat wave period in Montreal. In addition, high temperature is known to be responsible for increasing the rate of heart stock, kidney failure and cause many other issues as facing lack of fresh drinkable water that is excluded in this study (Jandaghian and Akbari, 2018b). The intention of this study is to investigate the impacts of extreme heat events and heat island on meteorological parameters and heat-related death over the Greater Montreal Area during three heat wave periods in 2005, 2011 and 2018. We applied the fully coupled online Weather Research and Forecasting model (WRF) with a multi-layer of the Urban Canopy Model (ML-UCM). The second objective is to assess the effects of albedo enhancement on air temperature, wind speed, dew point temperature and changes on air mass type and heat-related death.

METHODOLOGY

Heat-related mortality (HRM) can be magnified in urban areas because of the urban heat island (UHI) effects. UHI intensity and duration cause an increase in mortality. To fight the heat island effects, increasing urban albedo is applied. To investigate the effects of albedo enhancement on heat-related deaths, meteorological simulations are conducted.

Heat-Related Mortality Estimation

Three indicators are applied to translate the effects of extreme heat events and the potential of increasing surface reflectivity on heat-related mortality rates: air mass type, air temperature, and apparent temperature changes for each day during heat wave periods. The air temperature and apparent temperature are calculated based on simulation results. As this research focuses on heat, the summer period of June, July and August (JJA) in the GMA is being analyzed. Vanos et al. (2014) classified weather types into Spatial Synoptic Classification (SSC) (Sheridan, 2002) for 12 cities in Canada. The meteorological data applied to classify weather types into SSC was collected from airport weather stations maintained by the Meteorological Service of Canada. They estimated the heat-related mortality based on daily non-accidental mortality data that were collected across the city's metropolitan area from the Canadian Vital Statistics databases at Statistics Canada over 20 years (1981–2000).

The number of deaths related to each air mass classification is estimated based on the rate above the mean anomalous daily mortality in Montreal per 100,000 people. The Statistics Canada Census estimated the population of Montreal as 4.027,100 people in 2016. The Dry Moderate (DM) weather type, that includes mild and dry air in the summer season, is the most common type in the GMA. The highest rate of mortality during summer periods corresponds to the hotter and more humid air mass type (MT+), while the dry tropical condition (DT) places second (Vanos et al., 2014). Table 1 and Figure 1 represent the specific air mass classification, the summertime frequencies (JJA, %), and heat-related mortality in the GMA (Vanos et al., 2014; Martel B et al., 2010). The Canadian Environment Health Atlas (CEHA) estimates that in Montreal 121 people die each year because of high temperature.

Table 1. Summertime mortality rate for GMA within five weather types (1981–2000): weather type frequency for June, July, and August and relative mortality (the averaged anomalous number of heat-related death above baseline value for mean daily mortality). The standard deviation is presented. [Mortality rate per 100,000 people, calculated based on Statistics Canada 2011 Census as 3,824,221 people in GMA] (Source: Vanos et al., 2014)

Synoptic weather category	Frequency (%)	Deaths	SD	~ Number of deaths based on 2011 Census
DM	32.2	1.96	±0.36	75
DT	1.30	2.27	±0.53	87
MM	24.0	1.95	±0.36	75
MT	22.0	2.13	±0.42	81
MT+	4.40	2.38	±0.59	91
TR	16.1	0	0	0

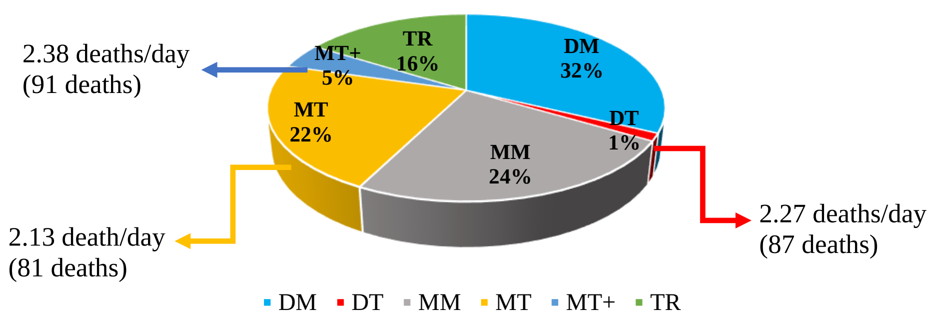


Figure 1. The number of deaths corresponding to each synoptic weather type during summer time (JJA). Dry Moderate (DM): mild and dry air; Dry Tropical (DT): the hottest and driest conditions; Moist Moderate (MM): warmer and more humid conditions; Moist Tropical (MT): warm and very humid; Moist Tropical Plus (MT+): hotter and more humid subset of MT; Transition (TR): days in which one weather type yields to another (Source: Sheridan, 2002)

Two categories are considered regarding the air mass classifications for heat-related mortality estimation: dry tropical (DT) and moist tropical / moist tropical plus (MT/MT+). Since the heat-related deaths corresponding to the frequency of DT are significant, the positive weighting factor for the day in sequences (DIS) is only defined for this air mass category. The DIS factor means that for each consecutive day within the DT air mass type, the estimated mortality increases by 1.07. Another weighting factor is for apparent temperature, 0.339, derived from the simulation results and presents the effects of temperature (T2) and dew point temperature (DPR). The other factor is time of season (TOS), derived from Kalkstein et al.'s (2013) HRM correlations for DT and MT/MT+ in the District of Columbia. Accordingly, the daily heat-related mortality calculation for Dry Tropical (DT) that represents the hottest and driest condition is Eq. (1):

$$\mathrm{HRM_D} = -4.32 + 1.07\mathrm{DIS} - 0.066\mathrm{TOS} + 0.339\ \mathrm{AT} \qquad (1)$$

and for Moist Tropical (MT) and Moist Tropical Plus (MT+) that represent very warm and humid condition is Eq. (2):

$$\mathrm{HRM_D} = 2.70 - 0.016\mathrm{TOS} + 0.339\mathrm{AT} \qquad (2)$$

Simulation Setups

The NCAR Weather Research and Forecasting Model (WRFV3.6.1) (Skamarock et al., 2008) is applied within a multi-layer of the Urban Canopy Model (ML-UCM) (Chen et al., 2011) to simulate the meteorological interactions in the urban atmosphere. Montreal is the second largest city in Canada and is centered at the ~45.5ºN and ~73.6ºW. The horizontal domain of the simulations is composed of four two-way nested domains. Figure 2 shows the inner domain with the horizontal resolution of 0.333 km. Three simulations are conducted during the heat wave periods in July of 2005 (10^{th}-12^{th}), 2011 (20^{th}- 23^{rd}) and 2018 (2^{nd}-5^{th}). The NOAH land-surface model employed to provide boundary conditions for the meteorological model. The planetary boundary layer is simulated by the Mellor-Yamada-Janjic scheme. For radiation, microphysics and cumulus models, we respectively applied the Rapid Radiative Transfer Model, Lin scheme and Grell 3D. Two sets of scenarios are defined for each period of the simulation (Jandaghian and Akbari, 2018a, 2018b and 2018c). The base case, where the fraction of urban albedo is assumed to be 0.2 (hereafter referred to as CTRL) and albedo case, where the reflectivity of roofs, walls and grounds are increased by 45%, 40% and 25%, respectively (hereafter referred to as ALBEDO).

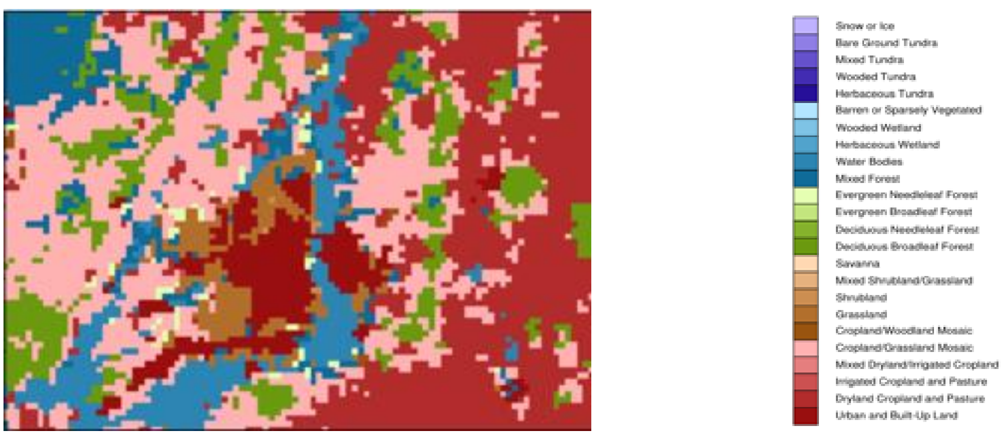


Figure 2. Simulation domain and Land Use Land Cover (LULC) of GMA

RESULTS

Model Performance Evaluation

The Mean Bias Error (MBE), Mean Absolute Error (MAE) and Root Mean Square Error (RMSE) are calculated for 2-m air temperature (T2), 10-m wind speed (WS10), and dew point temperature (DPT) of CTRL results compared with the measurements from four weather stations: McTavish (MT, location:45.50ºN, 73.58ºW), Pierre Elliott Trudeau Intl (PET, location:45.47ºN, 73.75ºW), Montreal/St-Hubert (SH, location: 45.52ºN, 73.42ºW) and Ste-Anne-de-Bellevue (SAB, location: 45.43ºN,~73.93ºW) (Jandaghian and Akbari, 2018a, 2017a, and 2017b). Table 2 presents the MBE, MAE and RSME of aforementioned parameters. Figure 3 shows the comparisons between simulated and measured air temperature for one day of each simulation in 2005, 2011 and 2018.

The model, on average, well predicts air temperature, slightly underestimates wind speed and dew point temperature. The reason is because the effects of micro scale parameters cannot be captured in mesoscale models precisely. The heat emission from buildings and transportation sectors is miscalculated in model estimation. Jandaghian et al. (2017) run a sensitivity analysis of physical parameterizations in WRF for urban climate simulations in Greater Montreal Area for 3 consecutive days in 2009. The results indicated the mean absolute error (MAE) of the 2-m air temperature, wind speed, relative humidity, and precipitation are approximately 1.4^{o}C, 1 m/s, 16% and 2mm, respectively. In other studies, the comparison of thermal components of WRF and the Fifth-Generation NCAR/Penn State Mesoscale Model (MM5) indicated that both models have the MBE of T2 as almost -3.8^{o}C to 0.2^{o}C during a year. (Gilliam et al., 2006 and Wang et al., 2012). Thus, the performance of WRF is generally consistent with the measurements and the results are well reliable for further investigations.

Table 2. The Mean Bias Error (MBE), Mean Absolute Error (MAE) and Root Mean Square Error (RMSE) of 2-m air temperature (oC), 10-m wind speed (m/s) and dew point temperature (oC) simulation results in CTRL case vs. measurements obtained from weather stations over the Greater Montreal Are during the 2005, 2011 and 2018 heat wave periods

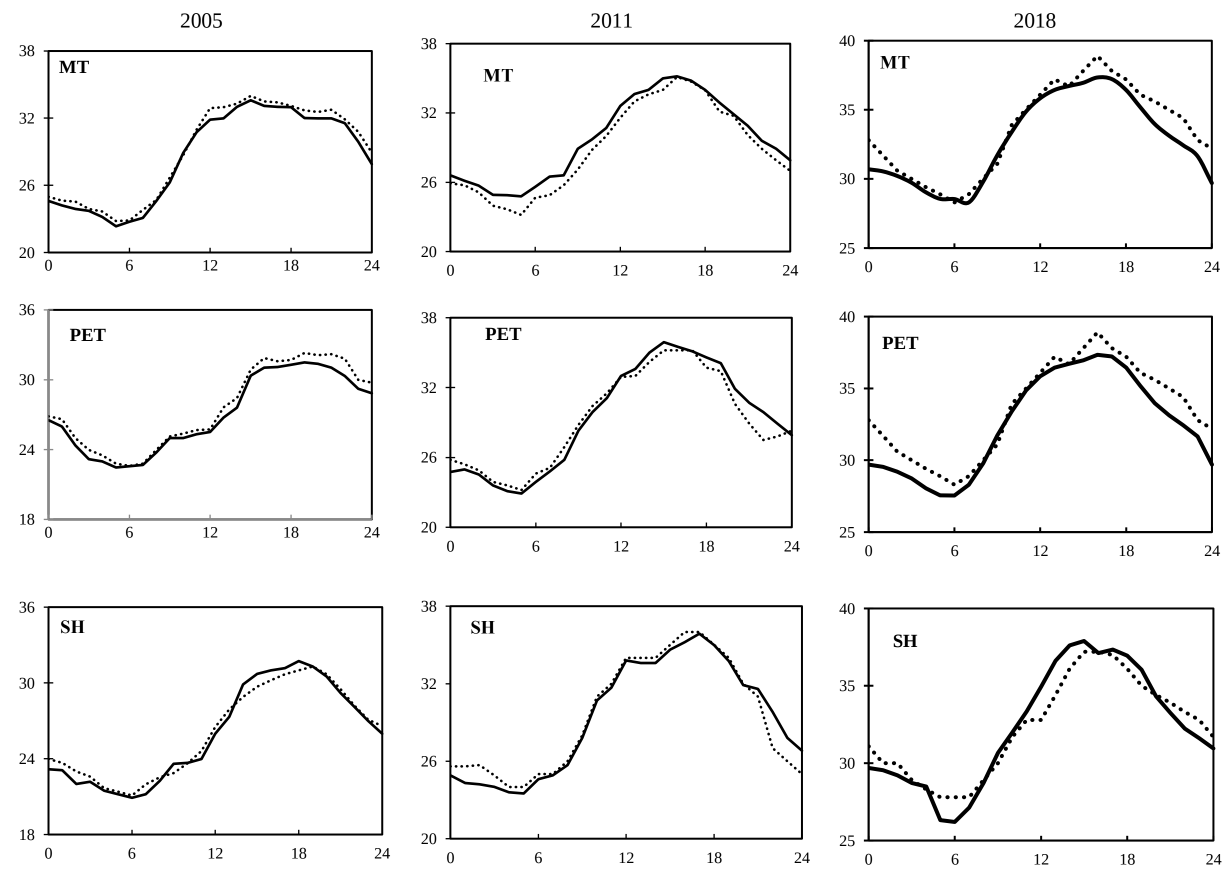
Station	Air temperature (^{o}C) in 2005			Air temperature (^{o}C) in 2011			Air temperature (^{o}C) in 2018		
	MBE	MAE	RMSE	MBE	MAE	RMSE	MBE	MAE	RMSE
MT	0.08	1.50	1.76	0.07	1.51	1.91	0.11	1.01	1.33
PET	-0.62	1.20	1.44	-0.88	1.37	1.83	-0.30	0.80	1.01
SH	0.02	1.19	1.50	-0.94	1.30	1.70	0.22	1.10	1.47
SAB	1.07	1.28	1.65	0.03	1.10	1.47	0.19	1.12	1.30
Average	0.12	1.25	1.53	-0.43	1.32	1.73	0.06	1.01	1.28
Station	Wind speed (m/s) in 2005			Wind speed (m/s) in 2011			Wind speed (m/s) in 2018		
	MBE	MAE	RMSE	MBE	MAE	RMSE	MBE	MAE	RMSE
MT	1.66	1.82	2.30	-0.61	0.85	0.91	1.8	1.90	2.11
PET	-0.63	1.88	2.11	-2.17	2.25	2.40	0.87	1.22	1.87
SH	-0.13	2.38	2.21	-2.83	3.11	2.11	0.34	1.19	1.49
SAB	0.54	1.88	2.11	-0.33	1.25	2.81	1.05	1.70	2.18
Average	0.36	1.99	2.18	-0.93	1.86	2.05	1.01	1.50	1.91
Station	Dew point temperature (^{o}C) in 2005			Dew point temperature (^{o}C) in 2011			Dew point temperature (^{o}C) in 2018		
	MBE	MAE	RMSE	MBE	MAE	RMSE	MBE	MAE	RMSE
MT	0.82	0.83	0.90	0.52	0.58	0.71	0.21	0.54	0.69
PET	0.33	0.55	0.61	0.71	0.74	0.91	0.51	0.30	0.41
SH	-0.19	0.51	0.61	0.47	0.48	0.61	0.22	0.48	0.64
SAB	-0.16	0.38	0.52	0.93	0.93	1.01	0.30	0.61	0.67
Average	0.21	0.56	0.44	0.65	0.68	0.81	0.31	0.48	0.62

Note: The definitions of statistical measurements are as follows Jandaghian et al. (2018c) [51]: MBE = $\frac{1}{N}\sum_1^N(C_M - C_O)$, MAE $= \frac{1}{N}\sum_1^N|C_M - C_O|$, RMSE $= \left[\frac{1}{N}\sum_1^N(C_M - C_O)^2\right]^{1/2}$, C_M and C_O are modeled and observed concentrations, respectively and N is the total number of model and observation pairs.

Albedo Enhancement Effects

The albedo of roofs, walls and grounds increased from 0.2 in CTRL scenarios to 0.65, 0.60, and 0.45 in ALBEDO scenarios, respectively. Table 3 represents the averaged 2-m air temperature, 10-m wind speed and dew point temperature differences between CTRL and ALBEDO scenarios. The averaged 2-m air temperature decreased by nearly 1^{o}C in urban areas (MT and PET) and by 0.5^{o}C in rural areas (SH and SAB). The simulation results indicate that the T2 reduces less at 12 p.m. compared to 6 p.m. because of the heat that is absorbed by the ground surface during sunlight and then released at sunset and thus added up to the air temperature in the evening. The averaged 10-m wind speed differences between CTRL and ALBEDO scenarios indicate that an increase in surface albedo causes a slight increase in the wind speed. The increase in wind assists the decrease in air temperature in those areas. The averaged dew point temperature differences between these scenarios show a slight decrease in air humidity by nearly 0.3^{o}C.

The results indicate that an increase in surface albedo causes a decrease in apparent temperature and discomfort indices that makes the environment more preferable and suitable for urban dwellers during summer time and therefore reduces the risk of heat-related morbidity and mortality. We applied two indicators; 2-m air temperature and dew point temperature that extracted from ALBEDO simulation results in these estimations. The consequences of albedo increments show that the Discomfort Index (DI) improved by nearly 3-5% and the Apparent Temperature (AT) decreased by nearly 3^{o}C in urban area.



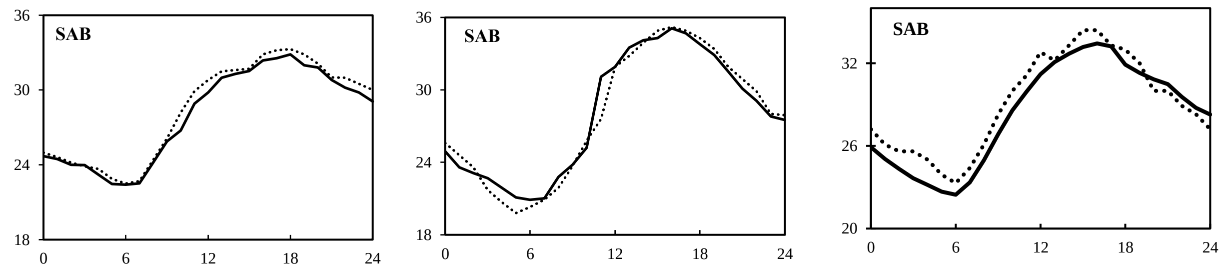


Figure 3. Simulation results averaged diurnal cycle of 2-m air temperature (oC) in CTRL [solid line] vs. measurements [dashed line] from four weather stations: MT (McTavish), PET (Pierre Elliott Trudeau Intl), SH (St-Hubert), SAB (Ste-Anne-de-Bellevue) over Greater Montreal Area during the 2005 [left], 2011 [middle] and 2018 [right] heat wave periods

Table 3. Averaged 3-day differences of 2-m air temperature(oC), 10-m wind speed(km/h) and dew point temperature(oC) between CTRL and ALBEDO scenarios in Greater Montreal Area during 2005, 2011 and 2018 heat wave periods

CTRL-ALBEDO	Heat-wave	MT	PET	SH	SAB
ΔT2 (ºC)	2005	0.7	0. 5	0.2	0.7
	2011	0.8	0.7	0.2	0.6
	2018	0.9	0.8	0.4	0.7
ΔWS_{10} (m/s)	2005	-0.2	-0.05	-0.01	-0.01
	2011	-0.3	-0.09	-0.02	0.01
	2018	-0.4	-0.2	-0.01	-0.04
ΔDPT (ºC)	2005	0.19	0.27	0.18	0.25
	2011	0.28	0.38	0.13	0.29
	2018	0.22	0.29	0.21	0.31

Heat-Related Mortality Changes

The synoptic air mass classifications are defined for each day of the simulation based on meteorological changes such as air temperature, dew point temperature, and wind velocity over the GMA. Table 4 shows the changes in air mass type during the 2005, 2011 and 2018 heat wave periods for CTRL and ALBEDO scenarios. The moist tropical plus air mass type is improved to moist tropical because of the mitigation strategy and surface modification that leads to a decrease in air temperature and dew point temperature. The dry tropical classification has also transformed to dry moderate, which is a more benign condition. These changes cause a decrease in heat-related mortality during these three heat wave events in the Greater Montreal Area.

Table 4. Air mass classifications on each day during 2005, 2011 and 2018 heat wave periods in GMA, the bold entries show changes in air mass type resulted in increasing surface albedo

Scenario	CTRL	ALBEDO
10-Jul-2005	DT	DT
11-Jul-2005	MT+	MT
12-Jul-2005	DT	DT
21-Jul-2011	MT+	MT
22-Jul-2011	MT	MT
23-Jul-2011	DT	DM

03-Jul-2018	MT+	MT
04-Jul-2018	DT	DM
05-Jul-2018	MT+	MT

The results of heat-related mortality estimations are presented in Table 5 in CTRL and ALBEDO scenarios for the three heat wave periods in the GMA. The consequences of albedo enhancement indicate that there would be around 3%, 4% and 5% reduction in heat-related mortality in the 2005, 2011 and 2018 heat events, respectively. Accordingly, as the air mass classification shifted from oppressive condition (e.g., DT) to a benign situation (e.g., DM), a reduction in HRM is more noticeable.

Table 5. Daily heat-related mortality estimation per 100,000 population based on HRM calculations for DT, MT and MT+ during the 2005, 2011 and 2018 heat wave periods. For human lives, the numbers are shown with 1 decimal

Mortality Estimations		
Scenario	**CTRL**	**ALBEDO**
10-Jul-2005	4.9	4.8
11-Jul-2005	13.9	13.6
12-Jul-2005	7.8	7.6
Total HRM	~ 27	~ 26
Average Mortality	8.9	8.7
Averaged Reduction (%)		**2.7%**
21-Jul-2011	13.9	13.8
22-Jul-2011	13.6	13.4
23-Jul-2011	7.3	6.2
Total HRM	~ 35	~ 33
Average Mortality	11.6	11.2
Averaged Reduction (%)		**3.7%**
03-Jul-2018	20.9	17.1
04-Jul-2018	19.9	18.1
05-Jul-2018	18.7	18.5
Total HRM	~ 60	~ 54
Average Mortality	19.8	17.5
Averaged Reduction (%)		**4.7%**

CONCLUSIONS

The effects of increasing surface albedo are assessed on heat-related mortality in Greater Montreal Area during three heat wave periods in 2005, 2011 and 2018. Numerical simulations were conducted using the online WRF coupled with a ML-UCM. A series of metrics calculation are employed to evaluate the model performance and compared the simulation results with the measurements obtained from four weather stations over the domain. The comparisons of the base case simulations indicated that the model on average well predicts the meteorological variables.

The albedo of roofs, walls and grounds were increased by 45%, 40% and 25%, respectively. The average daily 2-m air temperature reduced by nearly 0.8 to 1^{o}C in urban areas during heat wave events, whereas this reduction in rural area was around 0.2-0.6^{o}C. The albedo enhancement caused a slight increase in wind speed in urban areas that increase the convection heat transfer and thus decrease the skin temperature. A higher wind speed reduces the effects of heat and ambient temperature and produces a more pleasant condition for urban dwellers. It should be noted that increasing surface albedo is a region-specific strategy and needs to be evaluated over any interested area because it depends on urban characteristics and morphology.

Here, three indicators are applied to translate the effects of extreme heat events and the potential of increasing surface reflectivity on heat-related mortality rates: air mass type, air temperature and apparent temperature changes for each day during heat-wave periods. The results of surface modifications indicated that the moist tropical plus and dry tropical air mass types are shifted to moist tropical and dry moderate, respectively. These changes cause a decrease in heat-related mortality during these three heat wave events. Three of the six heat wave days showed air mass changes from more to less oppressive conditions. The beneficial outcome is a reduction in heat-related death by approximately 3-5% during heat wave periods, meaning that seven to twelve lives (out of 3,82 million) could be saved during these periods. It should be noted that by reducing ambient temperature, the pollutants emission from biogenic and anthropogenic sources and thus photochemical reaction rates will reduce. So, the death related to air quality will also reduce. In addition, increasing surface reflectivity shift days into less oppressive air masses by 50%.

The heat-related mortality estimation is based upon some assumptions and limitations. The effects of air pollution, radiation budget changes, human physical characteristics, such as age, gender, economic and educational status, have not been taken into account. This study shows that increasing surface reflectivity contributes to a reduction in ambient temperature in urban area. It illustrates that cooling temperature to even less than a degree can lead to air mass category changes, reduce the adverse effects of elevated temperature, thus improving human comfort and decreasing heat-related mortality to some noticeable extent. Albedo enhancement will not decrease the rate of heat death by a significant number but saving even one human life and improving the level of comfort for inhabitants are, as always, important that requires rapid action.

ACKNOWLEDGMENT

The funding for this research provided by the National Science and Engineering Research Council of Canada under discovery program.

REFERENCES

Akbari H., Menon S., Rosenfeld A. 2009. Global cooling: increasing world-wide urban albedos to offset CO2. Climatic Change, 94 (3-4): 275-286.

Akbari H., Kolokotsa D. 2016. Three decades of urban heat islands and mitigation technologies research. Enbuild. 133: 834-842.

Anderson B.G., Bell M.L. 2009. Weather-related mortality: how heat, cold, and heat waves affect mortality in the United States. Epidemiology. 20(2): 205–213.

Basu R. 2009. High ambient temperature and mortality: a review of the epidemiologic studies from 2001 to 2008. Enviro Health. 8: 40-48.

Basu R., Samet J.M. 2002. Relation between elevated ambient temperature and mortality: a review of the epidemiologic evidence. Epidemio Rev. 24(2):190–202.

Ban-Weiss G.A., Woods J., Levinson R. 2014. Using remote sensing to quantify albedo of roofs in seven California cities, Part 1: Methods. Sol Energy. 115: 777-790.

Chen F., Kusaka H., Bornstein R., Ching J., Grimmond C. S. B., Grossman-Clarke S., Loridan T., Manning K.W., Martilli A., Miao S., Sailor D., Salamanca F.P., Taha H., Tewari M., Wang X., Wyszogrodzkia A.A, Zhang C.

2011. The integrated WRF/urban modelling system: development, evaluation, and applications to urban environmental problems. Int. J. Climatol. 31: 273-288.

Diaz J., Jordan A., García R., Lopez C., Alberdi J., Hernandez E., Otero A. 2002. Heat waves in Madrid 1986-1997: effects on the health of the elderly. Int. Arch. Occup. Environ. Health. 75 (3): 163-170.

Grell G.A, Devenyi D. 2002. A generalized approach to parameterizing convection combining ensemble and data assimilation techniques. Geophysical Research Letters. 29 (14): 31-38.

Gilliam R.C., Hogrefe C., Rao S.T. 2006. New methods for evaluating meteorological models used in air quality applications. Atmos. Environ. 40: 5073–5086.

Horton D.E., Skinner C.B., Singh D., Diffenbaugh N.S. 2014. Occurrence and persistence of future atmospheric stagnation events. Nat Clim Change Lett. 4: 698-703.

Hajat S., O'Connor M., Kosatsky T. 2010. Health effects of hot weather: from awareness of risk factors to effective health protection. Lancet. 375(9717): 856–863.

Environment Canada, (2017). Online: http://climate.weather.gc.ca/historical_data/search_historic_data_e.html

IPCC. 2014. Summary for policymakers. In: Climate Change 2014. Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. 1-32, New York (NY), USA.

Jenkins K., Hall J., Glenis V., Kilsby C., McCarthy C., Goodess D., Smith N., Malleson M. 2014. Probabilistic spatial risk assessment of heat impacts and adaptations for London, Clim. Change 124: 105–117.

Jandaghian, Z., Touchaei, G.A., and Akbari, H. 2017. Sensitivity analysis of physical parameterizations in WRF for urban climate simulations and heat island mitigation in Montreal. Urban Climate. 24: 577-599.

Jandaghian, Z., and Akbari, H. 2018a. The effects of increasing surface reflectivity on heat-related mortality in Greater Montreal Area, Canada. Urban Climate. 25: 135-151.

Jandaghian, Z., and Akbari, H. 2018b. The effects of increasing surface albedo on urban climate and air quality: a detailed study for Sacramento, Houston and Chicago. Climate. 6: 2-27.

Jandaghian, Z., and Akbari, H. 2019. Effects of increasing surface reflectivity on aerosol, radiation and cloud interactions in urban atmosphere. Submitted to a Journal.

Jandaghian, Z., and Akbari, H. Urban Heat Island and Human Health. 4th International Conference on Countering Urban Heat Island (UHI) and Climate Change Through Mitigation and Adaptation, May- 2016.

Kalkstein L., Sailor D., Shickman K., Sherdian S., Vanos J. 2013. Assessing the health impacts of urban heat island reduction strategies in the District of Columbia. Report DDOE ID#2013-10-OPS, Global Cool Cities Alliance.

Martel B., Giroux J.X., Gosselin P., Chebana F., Ouarda T.B.M.J., Charron C. 2010. Indicateurs et seuils météorologiques pour les systèmes de veille-avertissement lors de vagues de chaleur au Québec. Québec: Institut national de santé publique du Québec. ISBN 978-2-550-59896-1.

McMichael A., Woodruff R.E., Hales S. 2006. Climate change and human health: present and future risks. 367(9513):859-69.

O'Neill M.S., Ebi K.L. 2009. Temperature extremes and health: impacts of climate variability and change in the United States. J Occup Environ Med 51: 13–25.

Oleson K.W., Bonan G.B., Feddema J., Jackson T. 2011. An examination of urban heat island characteristics in a global climate model, Int. J. Climatol. 31(12): 02-22

Skamarock W.C., Klemp J.B., Dudhia J, Gill D.O., Barker D.M., Duha M.G., Huang X.Y., Wang W., Powers J.G., 2008. A Description of the Advanced Research WRF Version 3. National Center for Atmospheric Research: Boulder, CO, USA.

Sheridan S.C. 2002. The redevelopment of a weather-type classification scheme for North America. Int J Climatol 22(1):51–68.

Taha H., 2009. In: Mesoscale and Meso-urban Meteorological and Photochemical Modeling of Heat Island Mitigation in California: Results and Regulatory Aspects Conference on Countermeasures to UHI, Berkeley (CA) USA.

Vanos J.K., Hebbern C., Cakmak S. 2014. Risk assessment for cardio- vascular and respiratory mortality due to air pollution and synoptic meteorology in 10 Canadian cities. Environ Pollut 185:322–332.

Wang X.Y., Barnett A.G., Yu W., FitzGerald G., Tippett V., Aitken P., Neville G., McRae D., Verrall K., Tong S. 2012. The impact of heatwaves on mortality and emergency hospital admissions from non-external causes in Brisbane, Australia. Occup. Environ. Med. 69 (3), 163-169.

Zanobetti A., Luttmann-Gibson H., Horton E.S., Cohen A., Coull B.A., Hoffmann B., Schwartz J.D., Mittleman M.A., Li Y., Stone P.H., de Souza C., Lamparello B., Koutrakis P., Gold D.R., 2014. Brachial artery responses to ambient pollution, temperature, and humidity in people with type 2 diabetes: a repeated- measures study. Environ. Health Perspect. 122 (3), 242.