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Present Day and Future Cooling Enabled by Integrated Water Management

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INTRODUCTION

As critical input to development of future Australian urban water policy we were engaged by the Australian Government to use TARGET[1] (The Air temperature Response to Green infrastructure Evaluation Tool) to assess urban heat amelioration associated with various levels of IWM (amounts of water and green infrastructure in the urban landscape) for nine Australian cities (Adelaide, Brisbane, Canberra, Darwin, Melbourne, Perth, Sydney, Albury-Wodonga and Townsville) for two future time frames (2030 and 2050) and for multiple emissions scenarios (SSP 1.2-6, 3.7-0 and 5.8-5). In further work (not discussed here), the results from the urban climate modelling were then to be used to develop estimates of the potential health-economic benefits of using IWM to deliver cooler climates under current and future climates.

APPROACH

To run TARGET, a relatively simple and efficient urban climate model, two sources of information are required: 1) meteorological time series of air temperature, humidity, wind speed, air pressure, and incoming short- and longwave radiation, and 2) gridded land cover fractions that include percentages of roof, road, water, concrete, vegetation (i.e., trees), dry grass, and irrigated grass. Since not all the targeted cities have the required input data readily available, these datasets were sourced from generic and state-of-the-art data sources and re-structured to fit the requirements of this project.

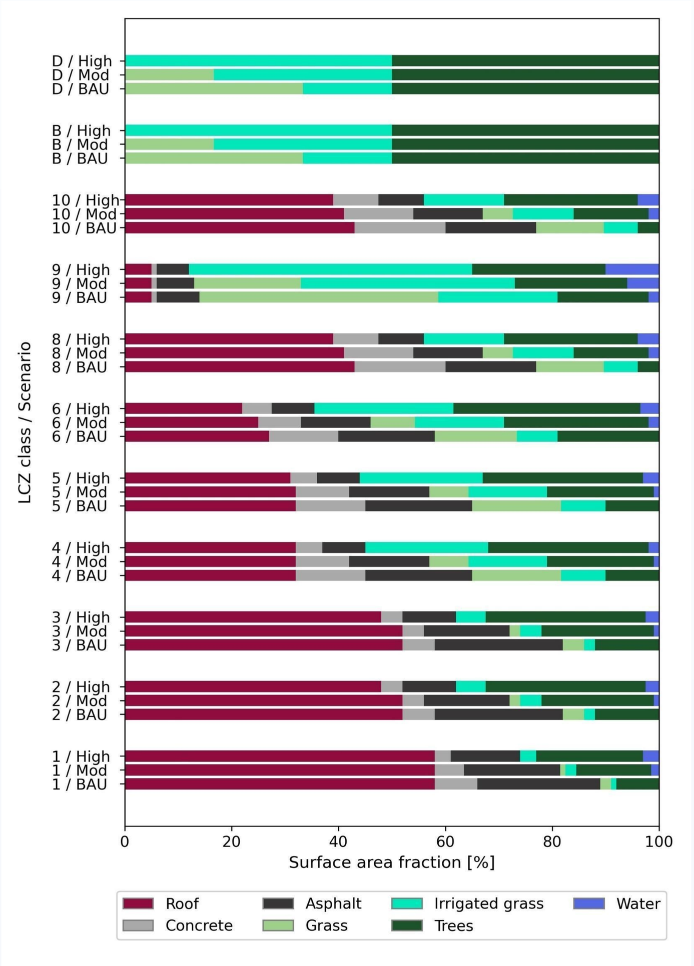

Figure 1: Surface cover fractions of each LCZ for BAU, moderate, and high IWM interventions.

A unique approach was developed to morph the future climate data (taken from the most recent CMIP6 archive[2] developed for the IPCC 6th Assessment) onto historical data (derived from the ERA5 Reanalysis product) for the 2010-2020 period. We used locally appropriate Local Climate Zones[3,4] (LCZs) for Australian cities and developed scenarios for implementation of moderate and high levels of IWM across each of the LCZs that are consistent with published guidelines from local and state government and municipal water authorities (Figure 1). We also developed a methodology allowing urban climate data modelled at the LCZ level to be aggregated to the statistical area (SA4) and city-wide levels so that it could be used with the privacy requirements of the available health data.

RESULTS

The climate modelling for this project produced a vast amount of data, so summary data only are provided here. These are average daily values for 10-year time periods centred on 2015 (historical data), 2030, and 2050. Cooling for all cities associated with implementation of IWM is calculated as moderate [MOD] or high [HIGH] minus business as usual [BAU] temperatures. Figure 2 provides the example of current-climate Melbourne summer minimum and maximum temperatures aggregated to the SA4 level, along with the relevant LCZ map. During the night (time of minimum

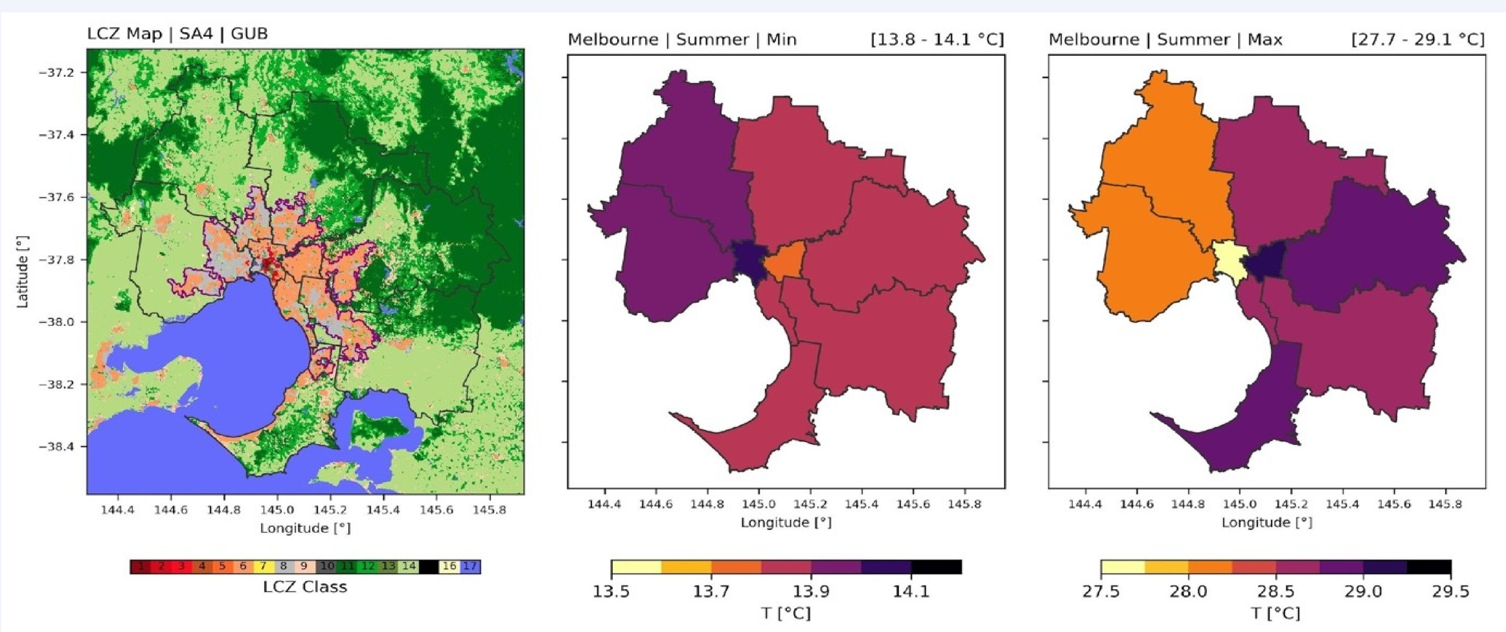

Figure 2: Present day LCZ map for Melbourne (left panel), with SA4 (grey) boundaries. The middle and right panels indicate the (BAU) mean summer daily minimum (Min) and maximum (Max) temperatures respectively, for Melbourne. Values in square brackets indicate the air temperature range across the available SA4 sections

temperature – middle panel), the SA4 that encompasses the CBD tends to be warmer than the lower building density and heavily treed suburbs to the east, mainly as a result of increased heat storage and reduced radiative loss from the built environment. During the day (right panel), shading and heat storage during the day leads to cooler temperatures in highly built-up areas. Broadly, IWM tends to be more beneficial in low to medium density areas during the day.

The thermal impacts associated with the various degrees of IWM were marked and

RESULTS (cont'd)

geographically differentiated, depending on the climatic characteristics of the various cities (Table 1). For the current climate high IWM intervention provided reductions in annual mean daily maximum temperature ranging from -0.77 ˚C in Darwin, up to -1.86 ˚C in Perth. Generally, the drier southern cities of Sydney, Canberra, Albury, Melbourne, Adelaide, and Perth, produced the greatest thermal response to implementation of IWM and the more tropical cities with higher rainfalls the least response. For some southern cities cooling was >-3.0 ˚C at the time of maximum summer temperatures (not shown here). Interestingly high levels of IWM produced modest warming of minimum overnight temperatures, especially for the cooler southern cities. The cooling behaviours described above are in line with expectations and are driven by the physical processes operating. MOD and HIGH IWM interventions provide increasing amounts of vegetation, shading and water availability compared with BAU. Evapotranspiration is maximised for abundant vegetation with a good water supply and is an extremely effective cooling mechanism, especially when the ambient air is dry and hot. At the time of minimum temperature (overnight, especially in winter) The warming effect of IWM at times of minimum overnight temperature is also in line with expectations and is driven largely by increased storage of daytime heat in the soil (water dramatically increases soil thermal conductivity) followed by its nocturnal release. The degree of warming at the time of minimum temperature was unexpected and suggests that IWM could potentially provide health benefits at both ends of the temperature spectrum.

Table 1: Present day (BAU) mean annual daily, maximum (max) and minimum (min) temperatures for each capital or regional city, and the associated temperature changes resulting from moderate (MOD) and high (HIGH) IWM interventions.

	Annual (mean daily) temperature								
City	BAU mean	BAU max	BAU min	MOD mean	MOD max	MOD min	HIGH mean	HIGH max	HIGH min
Adelaide	15.81	24.03	9.56	-0.19	-0.97	0.3	-0.31	-1.67	0.55
Albury	14.86	23.37	8.28	-0.22	-1.05	0.24	-0.35	-1.78	0.45
Brisbane	19.86	26.91	14.49	-0.09	-0.56	0.15	-0.12	-0.86	0.28
Canberra	12.64	21.23	6.22	-0.18	-0.96	0.23	-0.29	-1.63	0.42
Darwin	27.33	33.99	22.39	-0.12	-0.51	0.08	-0.18	-0.77	0.14
Melbourne	14.34	20.79	9.29	-0.14	-0.82	0.28	-0.21	-1.43	0.51
Perth	17.41	26.46	10.86	-0.15	-1.05	0.43	-0.25	-1.86	0.8
Sydney	17.01	25.49	10.83	-0.14	-0.89	0.24	-0.22	-1.49	0.45
Townsville	23.54	29.46	18.89	-0.11	-0.41	0.07	-0.17	-0.62	0.12

The cooling benefits of IWM were seen across all future climate scenarios and are a real opportunity to offset projected temperature increases resulting from climate change. Here we show only future climate data for the dry summer climate city of Perth for the mid-range emissions scenario of SSP 3.7-0 (Table 2). The green highlighting shows that not only do MOD and HIGH IWM interventions provide potential cooling of >-3.0 ˚C at the time of maximum summer temperatures but can reduce temperatures to below present levels under BAU.

Table 2: Mean daily (mean), maximum (max) and minimum (min) temperatures for present day (ERA5), 2050 SSP3-7.5 emissions scenario, and for the implementation of moderate (MON) and high (HIGH) IWM. The green highlight shows temperatures that are lower than for the present-day (ERA5).

PERTH	ANN mean	ANN max	ANN min	DJF mean	DJF max	DJF min	JJA mean	JJA max	JJA min
ERA5	17.41	26.46	10.86	24.52	36.03	16.08	10.79	17.42	5.98
2050 SSP 3.7-0	18.5	27.82	11.8	25.74	37.5	17.17	11.67	18.52	6.72
2050 SSP 3.7-0 + MOD	18.36	26.73	12.28	25.16	35.7	17.45	11.93	18.12	7.43
2050 SSP 3.7-0+ HIGH	18.27	25.89	12.68	24.7	34.3	17.67	12.18	17.84	8.01

CONCLUSIONS

TARGET modelling using forcing data from ERA5 and CMIP6 along with LCZs for land surface cover is an efficient and effective approach for modelling air temperatures in Australian cities. Implementation of IWM reduces mean daily maximum temperatures yet increases mean minimum temperatures with a net effect of reducing mean daily temperatures, especially in the warmer months. IWM is shown to have potential to offset warming from climate change, especially for maximum summer temperatures in the drier southern Australian cities.

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