Temperature response to future land-use changes in the Sydney area

Daniel Argüeso, Lluís Fita and Jason P. Evans
Climate Change Research Centre, UNSW

INTRODUCTION

Projected urban population increase will result in significant enlargment of cities, which could also expand the Urban Heat Island (UHI) and locally intensify the effects of global warming.

The Weather Research and Forecasting model 3.3 (WRF) at 2-km resolution has been used to simulate present (1990-2009) and future (2040-2059) climate. The projected changes in the urban area of Sydney were incorporated in the future-climate run to determine their potential impact on near-surface temperature.

EXPERIMENTAL SETUP

- Two 20-year period simulations (1990-2009 vs. 2040-2059).
- 2-km domain (Fig 1) centered in Sydney nested in a 10-km domain, in turn nested in a 50-km domain (one-way).
- CSIRO MK3.5 as boundary conditions.
- Standard land-use (LU) replaced by a more accurate dataset over Sydney (OEH) and projected LU changes incorporated the future run (Fig 1).
- Differences are newly urbanised areas.

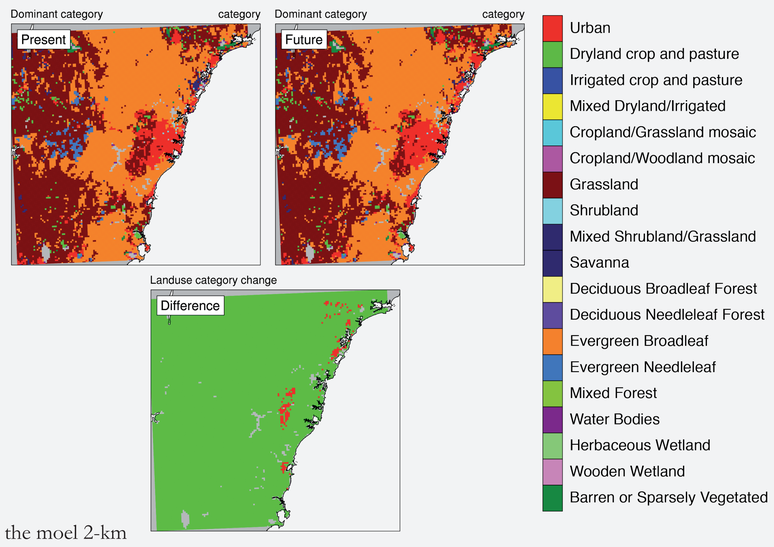

Figure 1. Top: Present and future land-use datasets over the moel 2-km domain. Bottom: Grid cells where land-use is projected to change (red).

MAXIMUM AND MINIMUM TEMPERATURE SEASONAL CHANGES

MAXIMUM temperature changes (Fig. 2)

No detected signal of land-use changes effect on maximum temperature.
Projected increase overall between 1.5ºC along the coast and >3.0ºC in the western mountains.
Changes are generally larger around the Lake Burragorang for all seasons.
Largest changes during summer, more moderate during spring and winter.

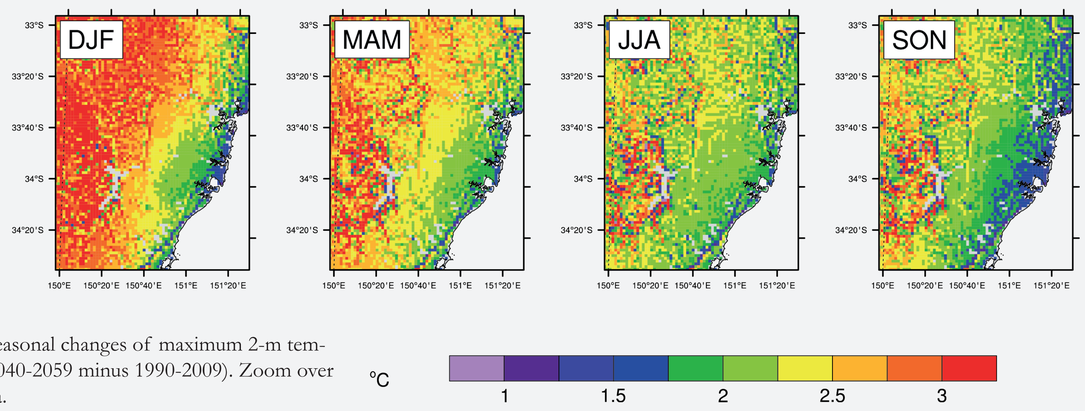

Figure 2. Seasonal changes of maximum 2-m temperature (2040-2059 minus 1990-2009). Zoom over Sydney area.

MINIMUM temperature changes (Fig. 3)

Clear signal of land-use effect changes on minimum temperature: expansion of UHI.
Newly urbanised areas projected to warm twice as much as the surrounding areas.
Newly urbanised areas exposed to changes between 2.5ºC (summer) and 4.0ºC (spring)
LU change footprint is evident in all seasons.

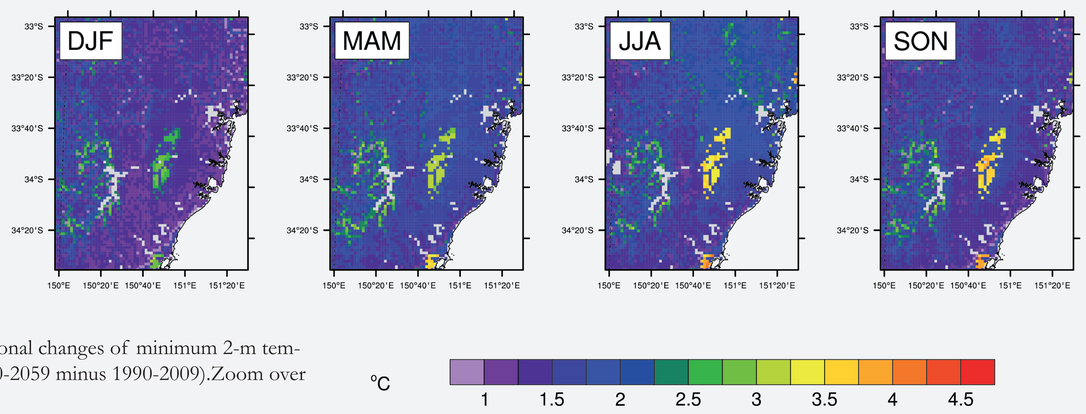

Figure 3. Seasonal changes of minimum 2-m temperature (2040-2059 minus 1990-2009).Zoom over Sydney area.

TEMPERATURE DAILY CYCLE

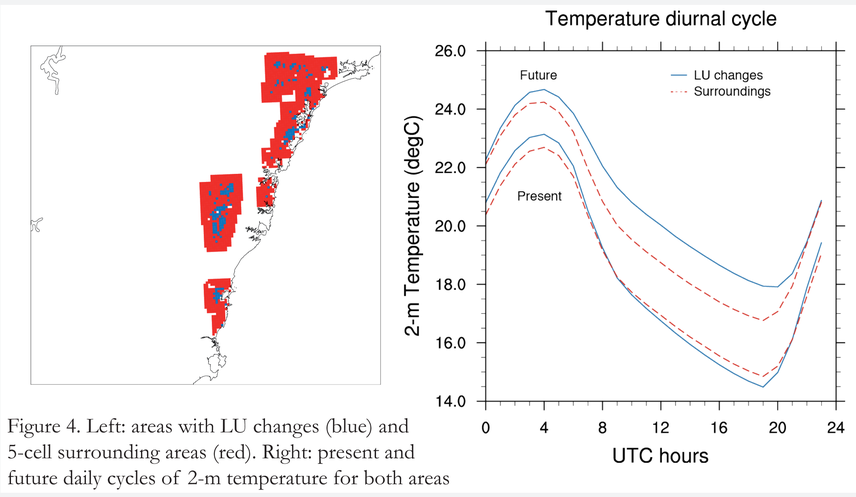

Figure 4. Left: areas with LU changes (blue) and 5-cell surrounding areas (red). Right: present and future daily cycles of 2-m temperature for both areas

Areas with no LU changes (red), minor alteration of daily cycle. Nearly uniform warming throughout the day.
Areas with LU changes (blue), much warmer nights.
Double the increase with respect to surrounding areas.

TROPICAL NIGHTS

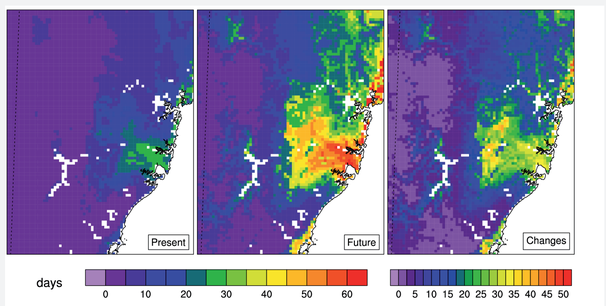

Figure 5. Present, future and changes in the number of tropical nights (Tmin>20ºC) per year.

Number of warm nights (Tmin>20ºC) is projected to markedly increase in Sydney (up to three times the current values).
Areas with LU changes especially affected (~ 35 more nights/year)

SURFACE EVAPORATION

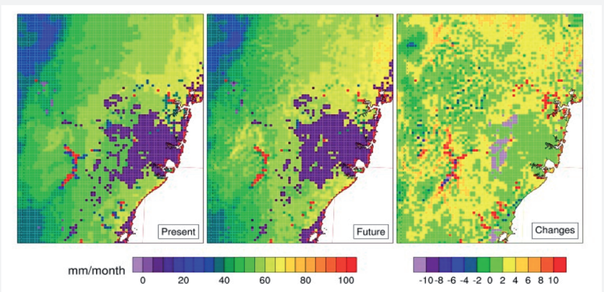

Figure 6. Present, future and changes in surface evaporation.

Surface evaporation (Fig. 6) and heat capacity of urban land-use play a critical role.
Contrast between newly urbanised areas and surroundings (decrease vs. increase of evap.).
New partition of heat (↑sensible,↓ latent). Heat released at night.

CONCLUSIONS

- Near-surface maximum temperature is little affected by LU changes.
- LU changes (new urban areas) strongly affect minimum temperature. Indeed, minimum temperature increases over these areas could double the increase due to global warming alone.
- The effect of LU is noticeable throughout the year, but especially marked during winter and spring.
- Tropical nights are projected to substantially increase in Sydney, but newly urbanised areas will experience the largest increases.
- Surface evaporation decrease, together with higher land heat capacity, could explain these LU change effects.

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CONTACT: Daniel Argüeso email: **d.argueso@unsw.edu.au**

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