First steps toward a comparison of modelled thermal comfort during a heatwave in Melbourne, Australia

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Outline of talk

Motivation for research
  – Heatwaves
  – Urban heat island mitigation

Model validation
  – Soundings
  – Gridded observational data
  – Weather station data

No urban areas experiment
Motivation

Heatwaves $\Rightarrow$ heat stress $\Rightarrow$ high \textit{overnight} temperatures have greatest effect on health

50\% of world's population lives in cities $\Rightarrow$ Urban Heat Island effect $\Rightarrow$ cities \textit{hotter at night} than rural areas

UHI mitigation $\Rightarrow$ Green roofs, white roofs, increased irrigation $\Rightarrow$ cooler cities $\Rightarrow$ cooler citizens
Research aims

Model best configuration of UHI mitigation infrastructure in Melbourne during a heatwave to improve human thermal comfort

– Will use WRF to model the heatwave
– First step: model validation
First case study

Jan 28-30 2009 heatwave over Melbourne

374 excess deaths, 714 hospital admissions for heat stress

3 days above 43°C, record at the time

1 night above 30°C
Region of study

Melbourne, population of 4 million
Second largest city in Australia
One of the best combinations of physics schemes for southeastern Australia on seasonal (Evans et al. 2011) and sub-daily timescales (Evans and Westra 2012)
Data and domains

Put ERA Interim (Dee et al. 2011) 0.7° x 0.7° data into WRF ➔ dynamically downscale it to Melbourne area using nested domains

Resolutions: ERA Interim 77km ➔ domain 1 (10km) ➔ domain 2 (2km)

Simulations run for three days with the first day discarded as model spin up.
Single layer urban canopy model (Kusaka et al. 2001)

– Add in low, medium and high density urban categories to MODIS land surface

Land Use Category | Land Use Description
---|---
1 | Evergreen Needleleaf Forest
2 | Evergreen Broadleaf Forest
3 | Deciduous Needleleaf Forest
4 | Deciduous Broadleaf Forest
5 | Mixed Forests
6 | Closed Shrublands
7 | Open Shrublands
8 | Woody Savannas
9 | Savannas
10 | Grasslands
11 | Permanent Wetlands
12 | Croplands
13 | Urban and Built-up
14 | Cropland/Natural Vegetation Mosaic
15 | Snow and Ice
16 | Barren or Sparsely Vegetated
17 | Water
18 | Wooded Tundra
19 | Mixed Tundra
20 | Barren Tundra
31 | Low density urban
32 | Medium density urban
33 | High density urban

(Chen et al. 2011)
Modelling the 3 day heatwave

– Showing from 11pm Jan 27 2009 - 10am Jan 31 2009 AEDT
Compare WRF soundings to observations

– Observations are in black, WRF is in pink. Daytime temperature profile very good
– WRF is too moist at the surface and in the boundary layer during the day
Compare WRF to gridded observations

– WRF (2kmx2km) compared to Australian temperature gridded observational data set (5kmx5km)
– WRF minimum temperature is too high, WRF maximum temperature is too low
WRF does not capture diurnal variability during heatwave, potentially due to soil being too moist.

This results in a larger RMSE.

A longer spin up time does not decrease the soil moisture.
Experiment: no urban surfaces

- Urban land surface category removed with nearest neighbour method
- Mostly croplands (olive green) and evergreen broadleaf forest (dark green)
- See how much urban effects or geography impact heatwave in Melbourne
No urban surface experiment

– Minimum temperatures would be 1-3°C colder during the hottest night of the heatwave

Difference in 2m temperature at 3am
Jan 29 2009
Conclusions

– WRF can accurately simulate from the boundary layer to the top of the atmosphere during a heatwave

– WRF maximum temperatures are *too low* compared to observations

– WRF minimum temperatures are *too high* compared to observations

– WRF cannot replicate the diurnal temperature variability, though this will be improved with better soil moisture data

– When the urban areas are removed can see that minimum temperatures in Melbourne would be 1-3°C colder
Future work

– We will model the effectiveness of green infrastructure (green roofs, white roofs) in Melbourne during the heatwave

– We will find the best configuration of infrastructure to improve human thermal comfort on a city wide scale

– We plan to dynamically downscale CMIP5 GCM model data and repeat these experiments using future scenarios to test the resilience of the infrastructure to weather systems from the FUTURE
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References:
3 month spin up, CORDEX/NARCLiM domains

50km

2km

10km

Melbourne AP and Model Sounding