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 → heat stress → high *overnight* temperatures have greatest effect on health

50 % of worlds population lives in cities → Urban Heat Island effect → cities *hotter at night* than rural areas

UHI mitigation → Green roofs, white roofs, increased irrigation → cooler cities → cooler citizens

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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

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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

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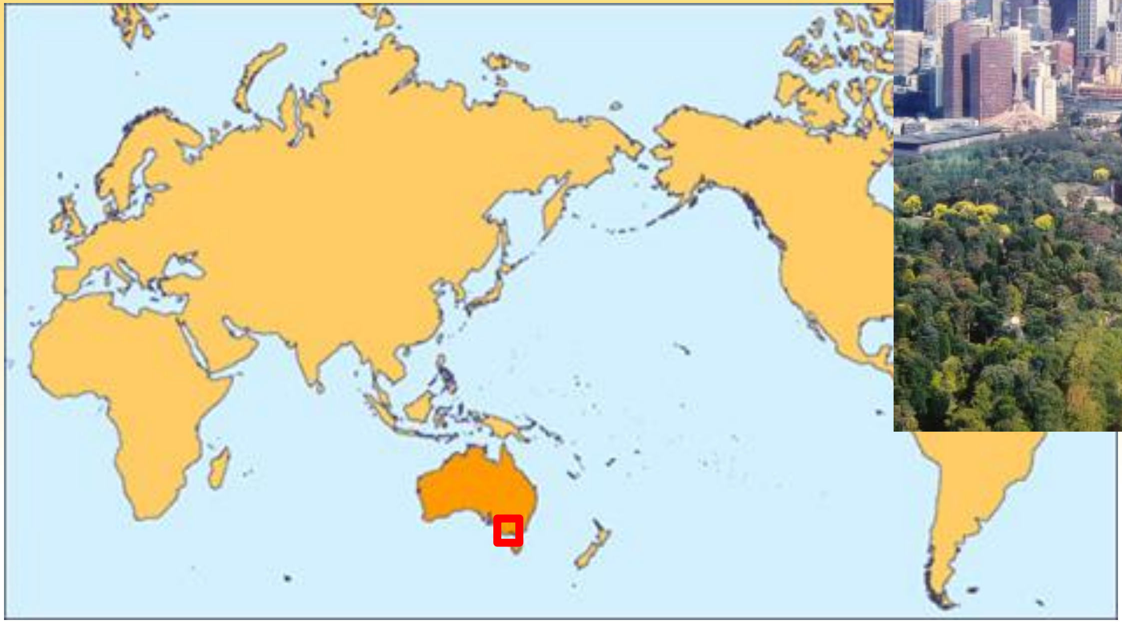
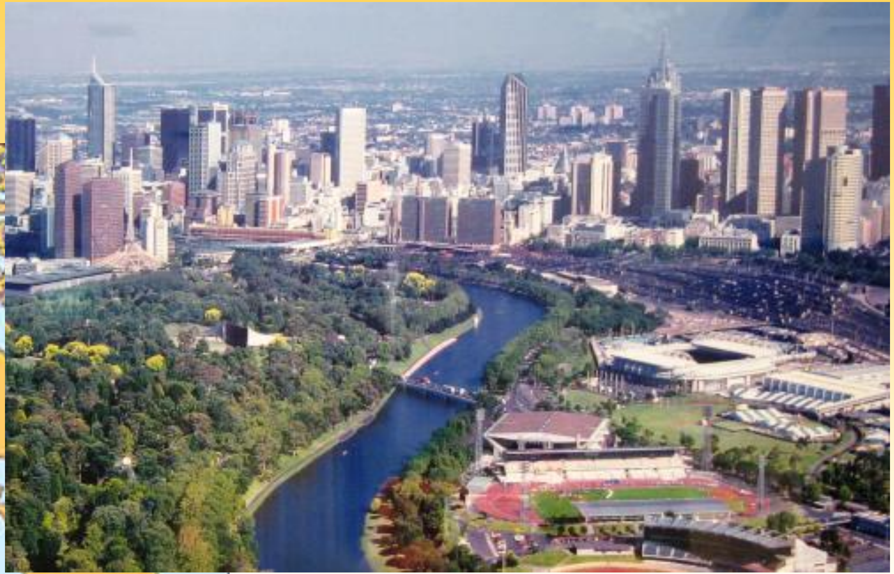
Region of study

Melbourne, population of 4 million

Second largest city in Australia





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WRF physics schemes

Noah land surface scheme

Rapid Radiative Transfer Model longwave radiation scheme

Yonsei University boundary layer scheme

WRFV3.6.0

Dudhia shortwave radiation scheme

WRF Single Moment 5-class microphysics scheme

Kain-Fritsch cumulus physics scheme

Monin-Obukhov surface similarity scheme

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)

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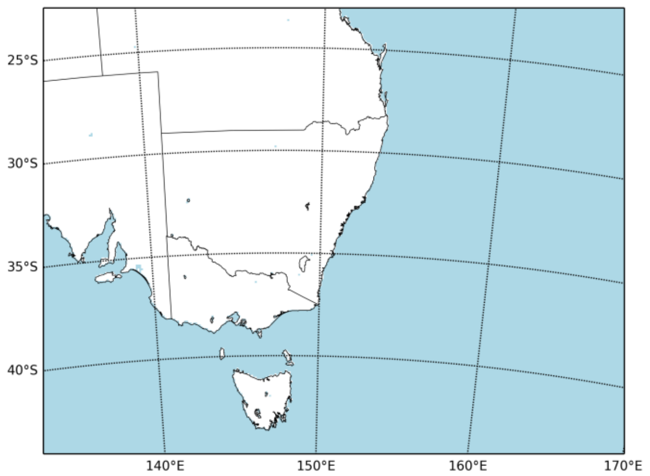
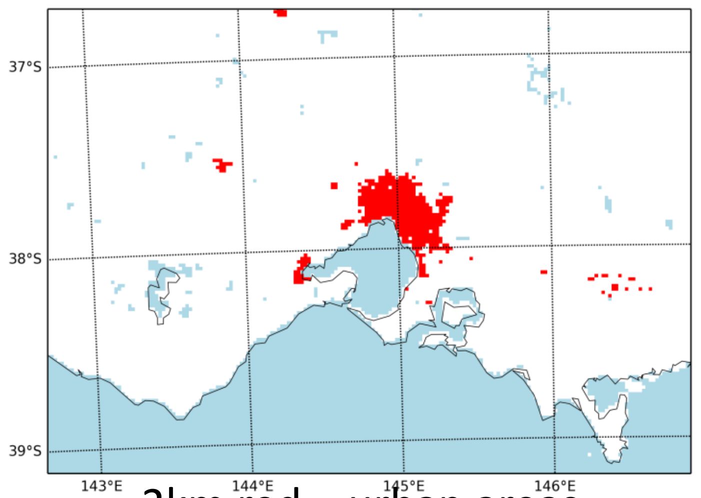
Data and domains

Put ERA Interim (Dee et al. 2011) 0.7˚x0.7˚ data into WRF ➔ dynamically downscale it to Melbourne area using nested domains

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



10km



2km red = urban areas

Simulations run for three days with the first day discarded as model spin up.

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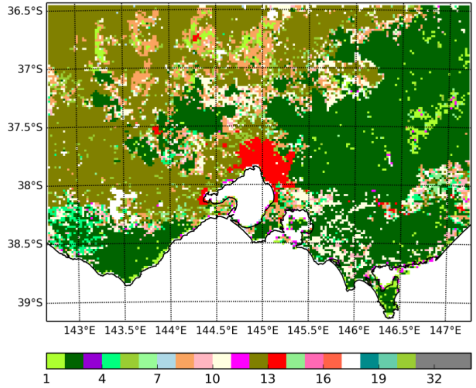
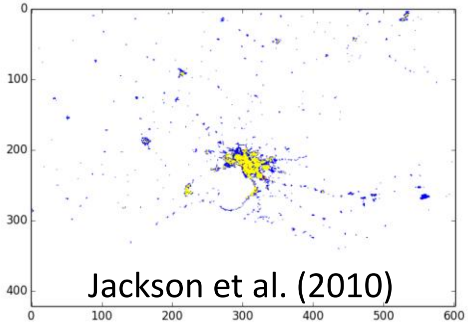
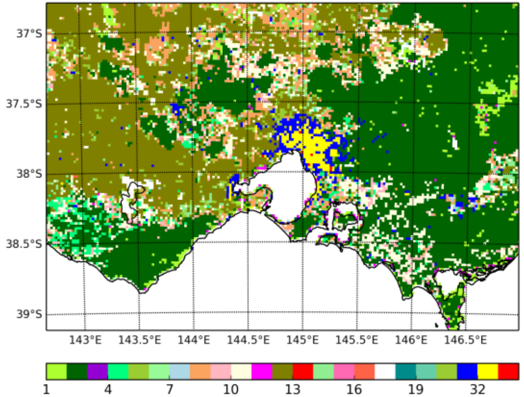
Single layer urban canopy model (Kusaka et al. 2001)

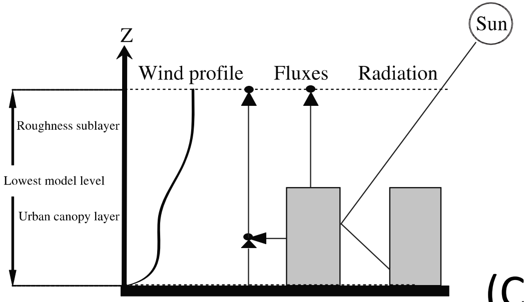
– Add in low, medium and high density urban categories to MODIS land surface





Land Use Category	Land Use Description
1	Evergreen Needleleaf Forest
2	Evergreen Broadleaf Forest
3	Deciduous Needlelaf 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



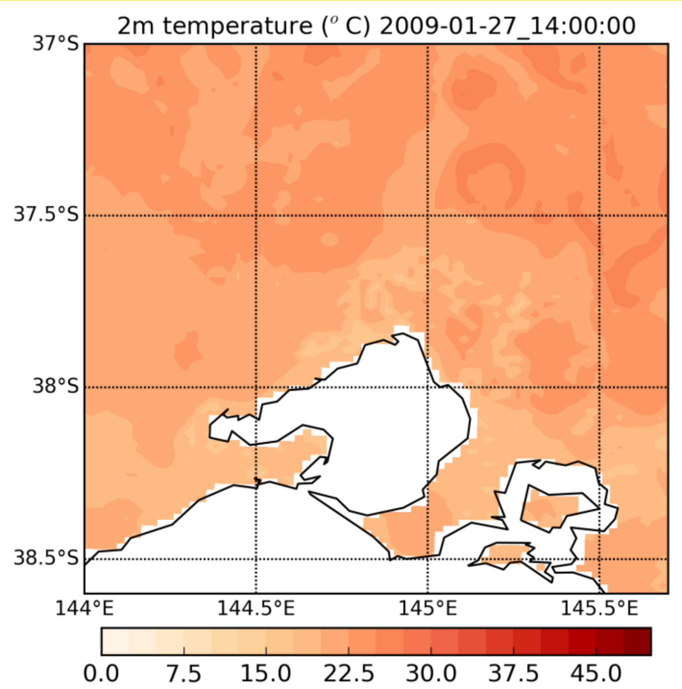


SLUCM

(Chen et al. 2011)

Modelling the 3 day heatwave

– Showing from 11pm Jan 27 2009 - 10am Jan 31 2009 AEDT



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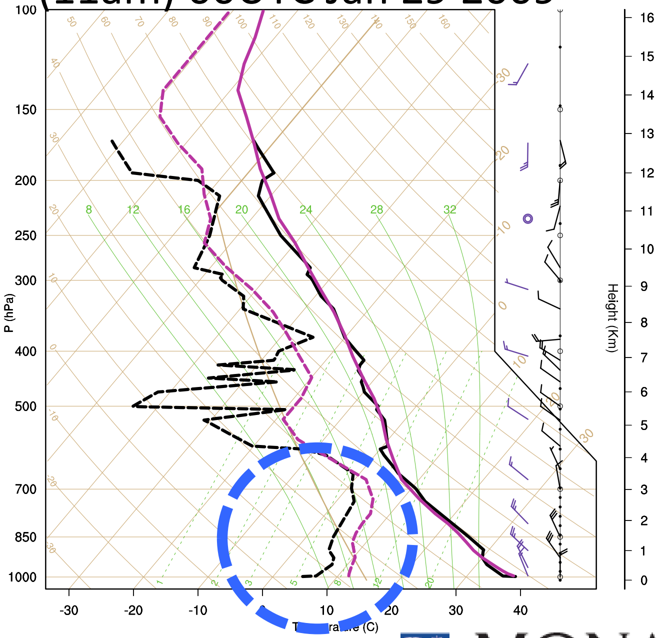
Compare WRF soundings to observations

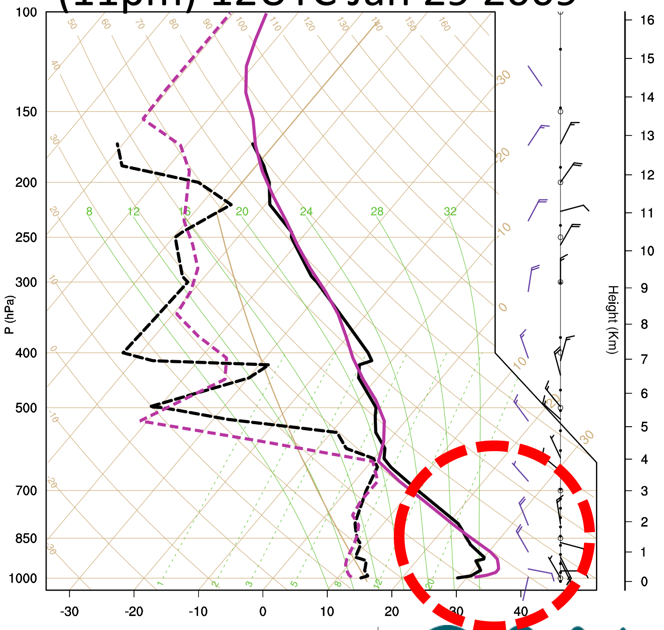
– Observations are in black, WRF is in pink. Daytime temperature profile very good

– WRF is too moist at the surface and in the boundary layer during the day

(11am) 00UTC Jan 29 2009



(11pm) 12UTC Jan 29 2009



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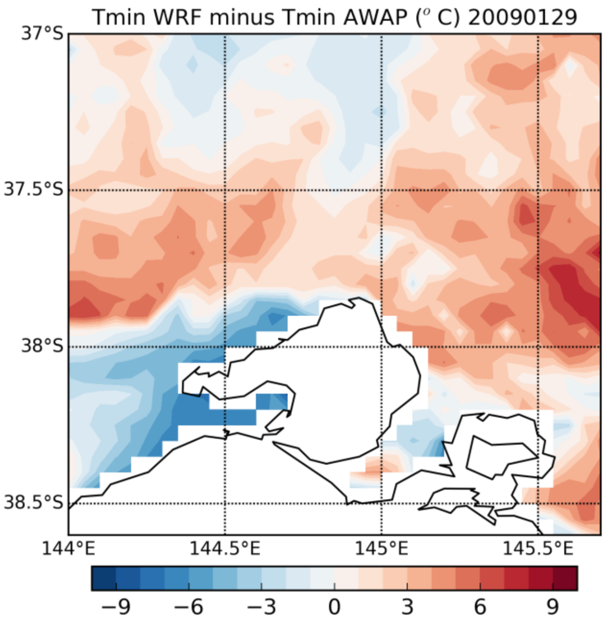
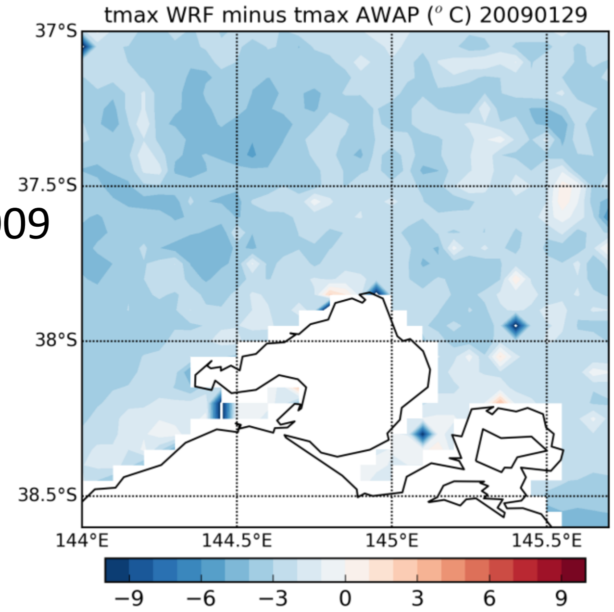
Compare WRF to gridded observations

– WRF (2kmx2km) compared to Australian temperature gridded observational data set (5kmx5km)

– WRF minimum temperature is *too high*, WRF maximum temperature is *too low*



Jan 29 2009



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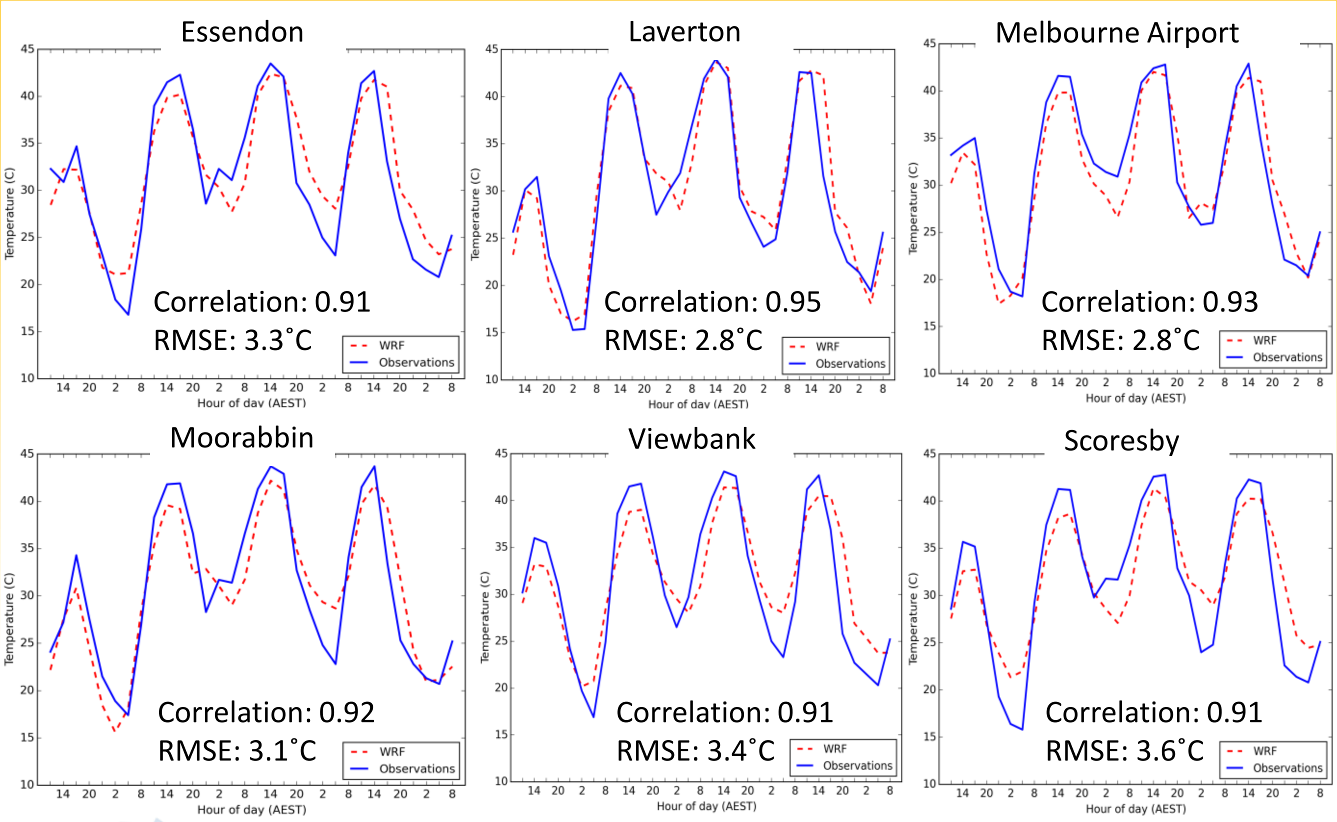
3 hourly 2m temperature 11am Jan 27 - 9am Jan 31 2009



– 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

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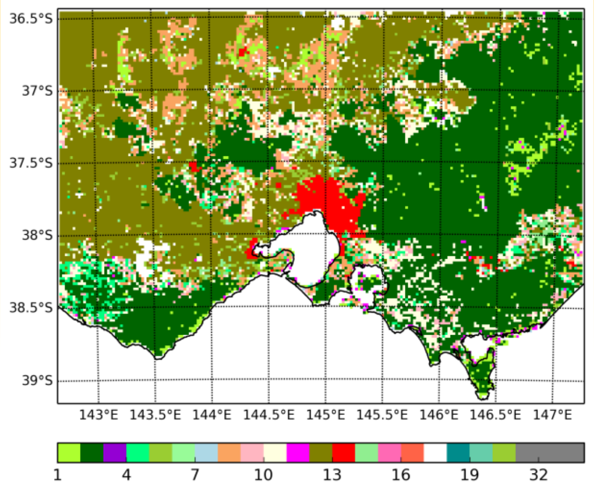
Experiment: no urban surfaces

- 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



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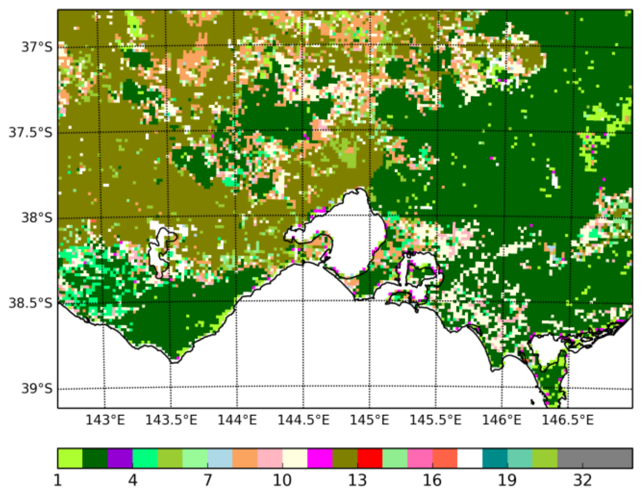

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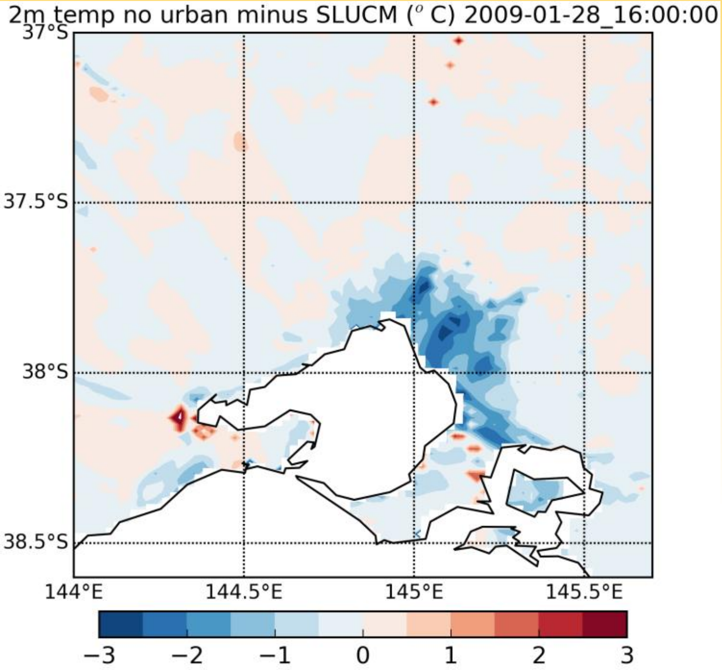
No urban surface experiment

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



Difference in 2m temperature at 3am Jan 29 2009

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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

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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

Acknowledgments

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References:

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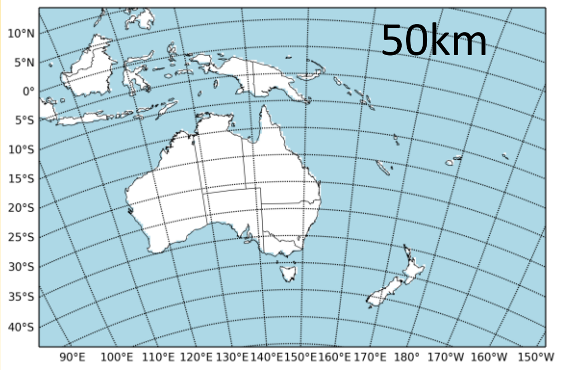
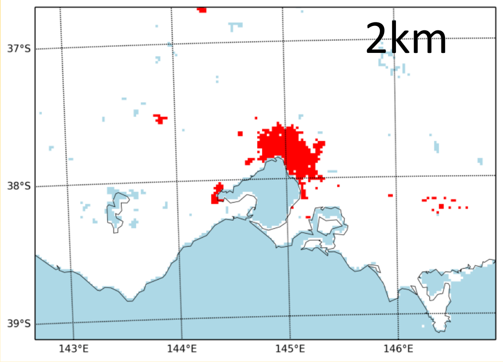
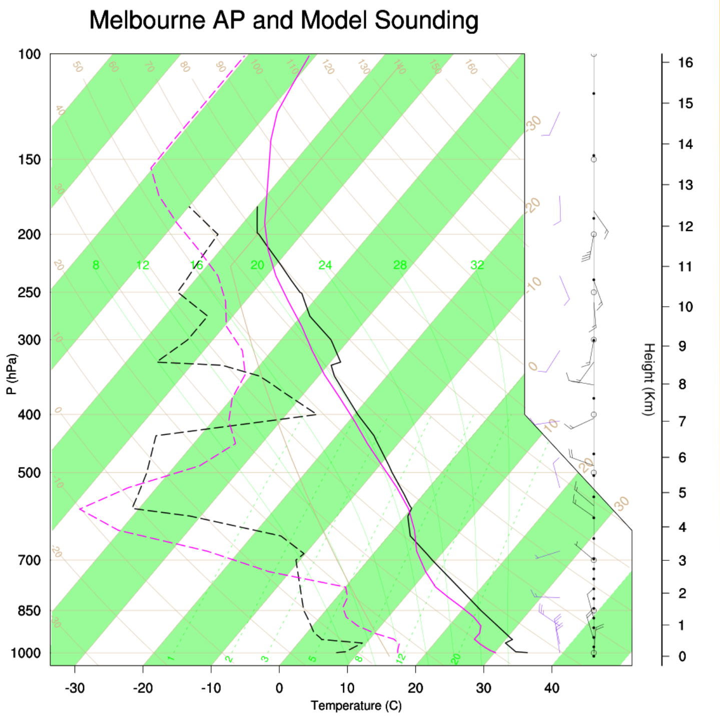
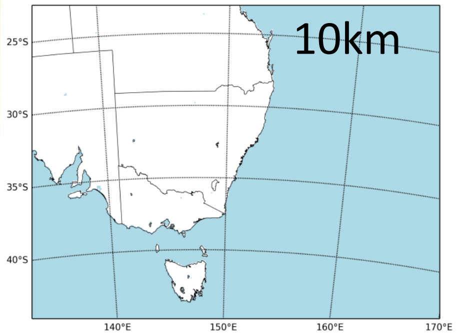
3 month spin up, CORDEX/NARCLiM domains









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