



Beyond temperature: Advanced thermal comfort metrics for tropical outdoor living

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Darwin Living Lab Symposium

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Australia's National Science Agency



Research Context



Darwin is experiencing a warming climate and there is very high confidence that average temperatures and extreme heat days will increase across all seasons



Increased intensity and duration of heat exposure poses health, sustainability and liveability risks for Darwin



Decision-makers need clear guidance for planning and design of outdoor spaces on the effectiveness of different heat mitigation approaches



Visualise the impacts of wind direction, wind speed and solar radiation on human thermal comfort for the current and future Darwin climate (seasonal, year on year variation)

Measuring effectiveness of climate responsive design

Meteorological input

Dry bulb temperature
°C



Mean radiant temperature
°C



Relative humidity
%



Wind speed
m/sec



Physiological input



Clothing level
Metabolic rate

'Feels like' temperature (°C)

Universal Thermal Comfort Index

UTCI ranges °C	Stress Category
>46	Extreme heat stress
38 to 46	Very strong heat stress
32 to 38	Strong heat stress
26 to 32	Moderate heat stress
9 to 26	No thermal stress
0 to 9	Slight cold stress
-13 to 0	Moderate cold stress
-27 to -13	Strong cold stress
-40 to -27	Very strong cold stress
<-40	Extreme cold stress

Identifies heat (or cold) stress conditions when the body may struggle to maintain core temperature of around 37°C , such as through evaporative cooling

Data inputs

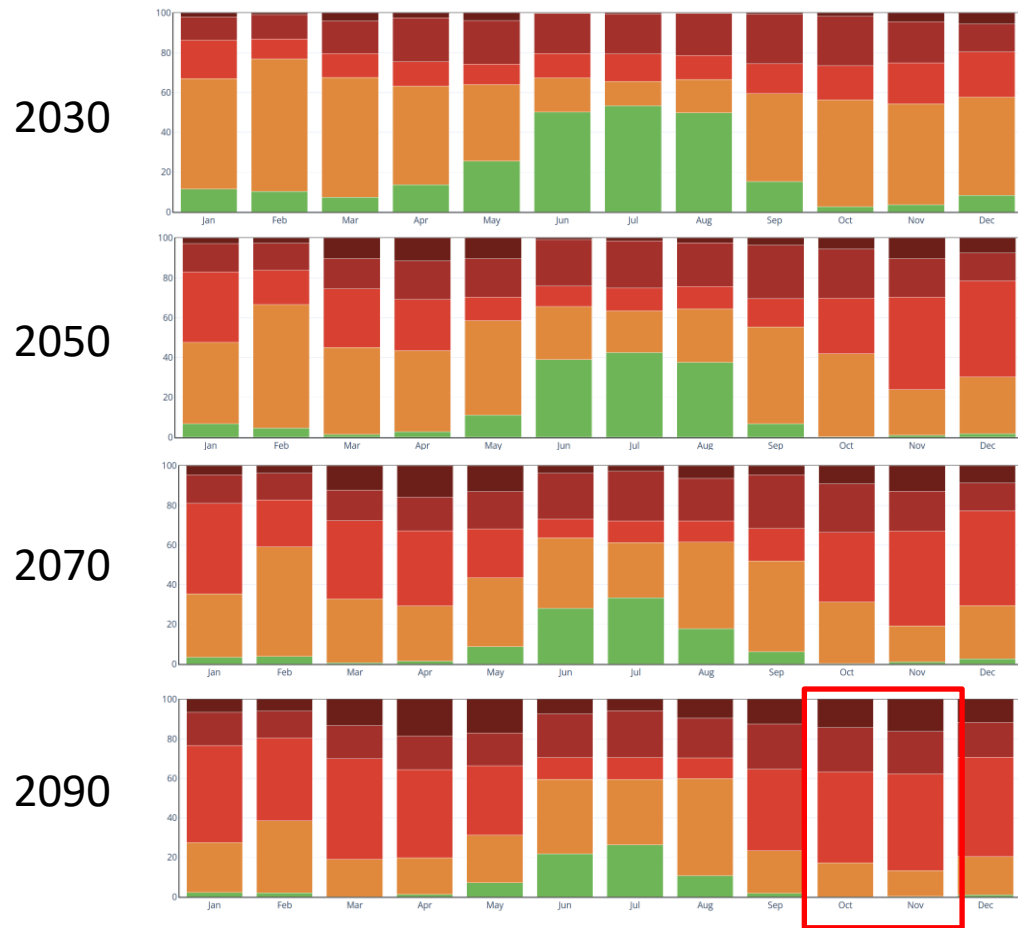
- Typical meteorological year weather files for Darwin from CSIRO Building Energy
- Baseline based on hourly data collected from 1990 to 2020 (DRW)
- 3 future climate scenarios (RCP2.6, RCP4.5, and RCP8.5) and for 4 future years (2030, 2050, 2070, and 2090)

1. Dry Bulb Temperature 🌡️
2. Dew Point Temperature 💧
3. Relative Humidity 💧💧
4. Atmospheric Pressure ⬇️
5. Horizontal Infrared Radiation 📶
6. Direct Normal Radiation (DNI) ☀️
7. Diffuse Horizontal Radiation (DHI) ☁️
8. Wind Direction 🌀
9. Wind Speed 🌀

Thermal comfort in Darwin through the year



Increasing heat stress in a changing climate



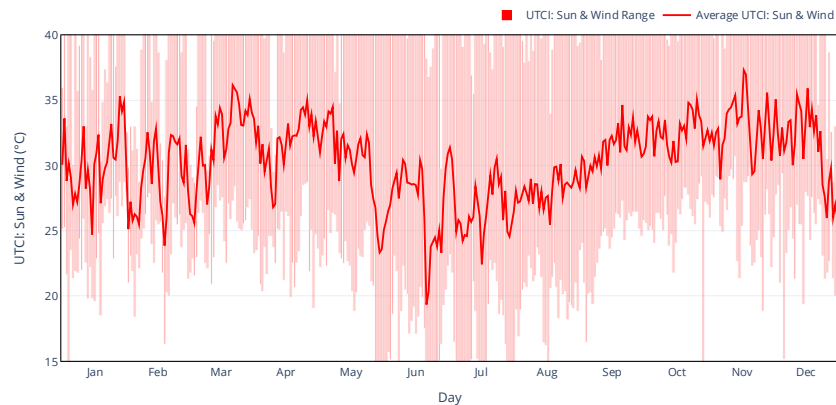
Thermal stress



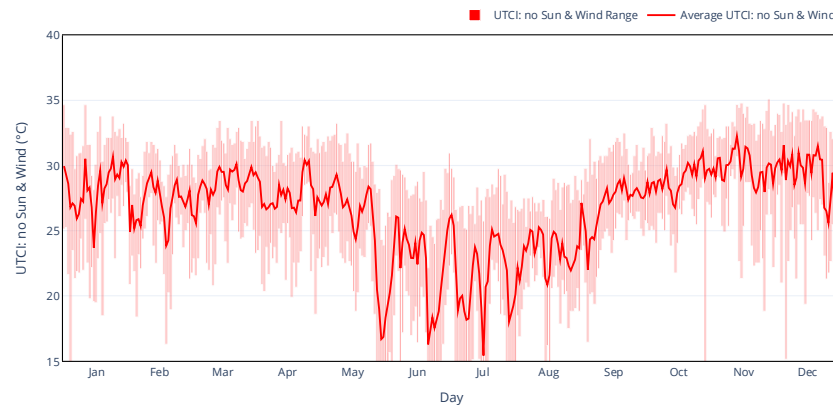
Data source: RCP 8.5 emissions Scenario for NatHERS Climate Zone 1
<https://agdatashop.csiro.au/future-climate-predictive-weather>

How much cooler in the shade?

Full sun



Shaded





Cooling from shade structures with climbing plants

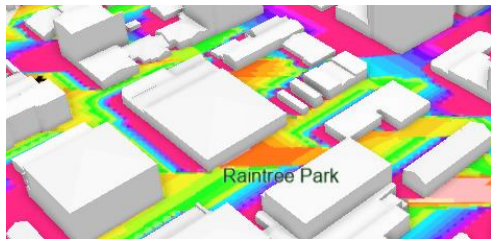




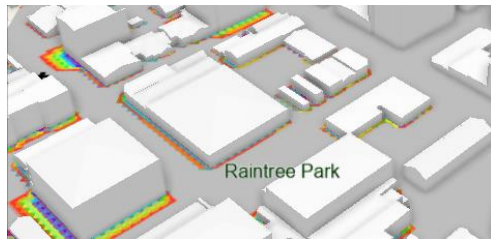
Building shade in the city

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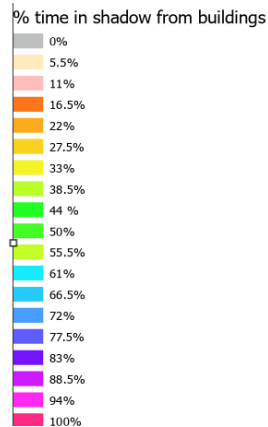
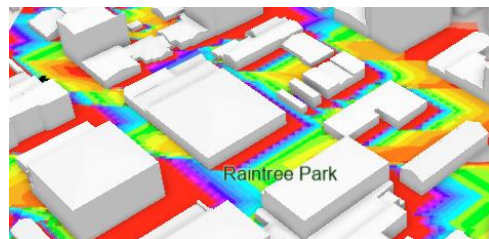
Early morning 7 AM – 10 AM



Middle of the day 11 AM – 2 PM



Late afternoon/evening 4 PM – 7 PM



Shadow from buildings analysis (March 2025)

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Constructed shade



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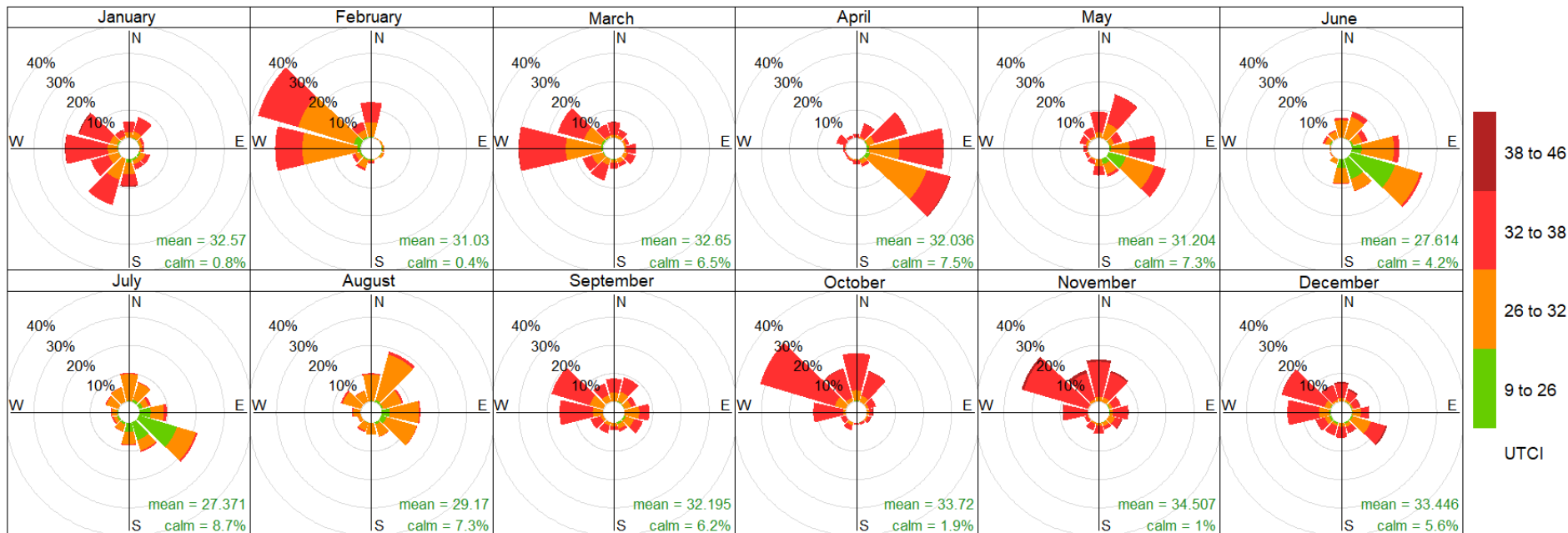


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Cooling breezes

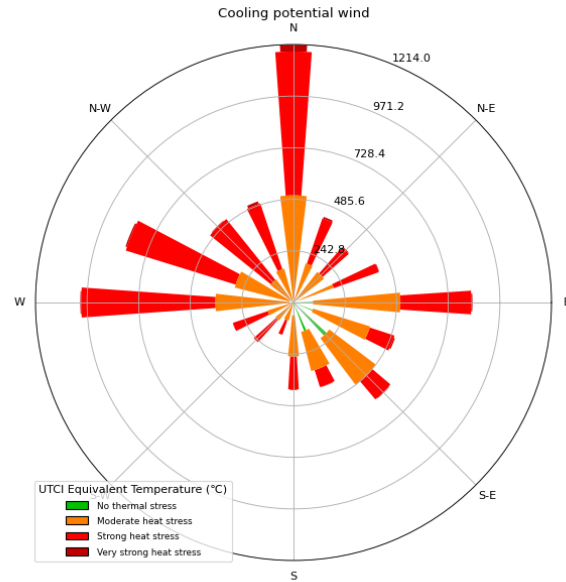


UTCI by wind direction – monthly



Frequency of counts by wind direction (%)

Wind cooling potential



Next steps

Field Data Collection

- Expand on-ground measurements to evaluate the effectiveness of heat mitigation strategies across a range of urban contexts in Darwin at different times of the year

Spatial Analysis

- Develop high-resolution maps of thermal comfort across Darwin

Guides & Resources

- Partner with local stakeholders to identify and map existing and potential **cool refuges**
- Develop online resource





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Photo credit: Darwin Harbour, NT Tourism – Elise Derwin

<https://research.csiro.au/darwinlivinglab/>

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