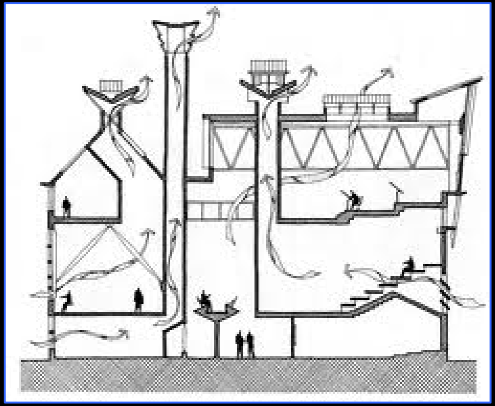
Comfort Performance of Residential Wind Towers in Sydney

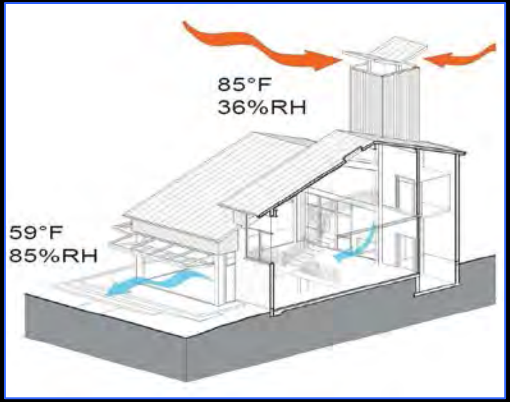
Dr Mahsan Sadeghi – University of Sydney ➔ Renson
Dr Graeme Wood – CPP ➔ Arup
Prof Richard de Dear – University of Sydney

WIND TOWER COOLING SYSTEM IN VERNACULAR ARCHITECTURE

The wind tower (a.k.a. *baudgir* or wind catcher in Persian) has been used as a passive cooling system throughout Persia and neighbouring countries since 1300 BC (Roaf, 1988)

WIND TOWER IN CONTEMPORARY ARCHITECTURE





Queen’s building at De Montfort University, UK
Source: http://walkingarchitecture.co.uk

Jubilee Campus at Nottingham University, UK
Source: http://newsofthesouth.com

Carnegie Centre for Ecology in Stanford University, USA
http://www.carboun.com/tag/wind-tower

RESEARCH CONTRIBUTION

- Most previous researchers have used the wind tunnel method to study wind tower ventilation impact on a single room, ignoring effects of…
  - Whole building
  - urban context
- Previous research has used indoor air change rate or air speed as dependent variable, ignoring impacts on occupant thermal comfort
- To date no wind tower research has been done in Australian residential context

RESEARCH QUESTIONS

- Can wind towers provide thermal comfort benefits in the humid sub-tropical Australian metropolitan residential context?
- How does the pressure difference generated by the wind tower ventilation translate into air movement within the occupied zone of a medium density apartment?
- How do the comfort benefits of a wind tower compare with conventional through-window cross ventilation?

RESEARCH METHODS

Wind Tunnel Experiments
- 1- Pressure distribution measurement over the building
- 2- calculating the pressure coefficient differences between the openings (in/out)
- 3- Calculating the indoor air movement

Case Study Sydney
- 1- applying Sydney 2013 TMY file into the wind tunnel analyses
- 1- Calculating the velocity coefficient based on outdoor wind speed and direction
- 2- Calculation indoor air speed hourly in 6 hot/warm months

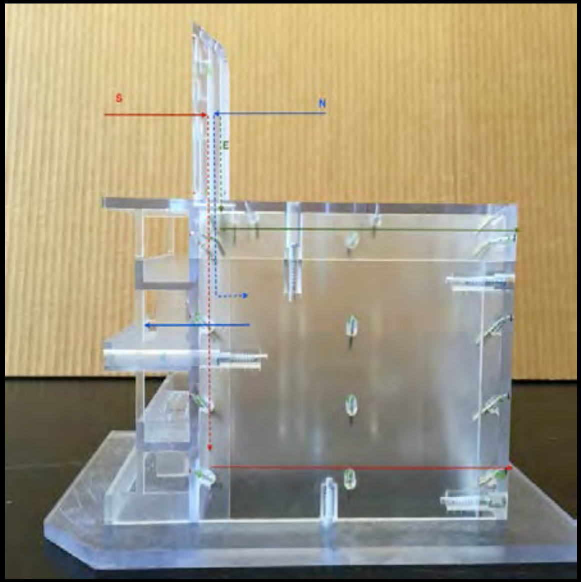
Indoor Thermal Comfort Analyses
- 1- SET* simulation hourly for six hot/warm months of the 2013 year
- 2- calculating ΔSET* as the impact of the increased Vi in compare with the cross ventilation
- 3- Calculation of indoor thermal comfort improvement in degree hours

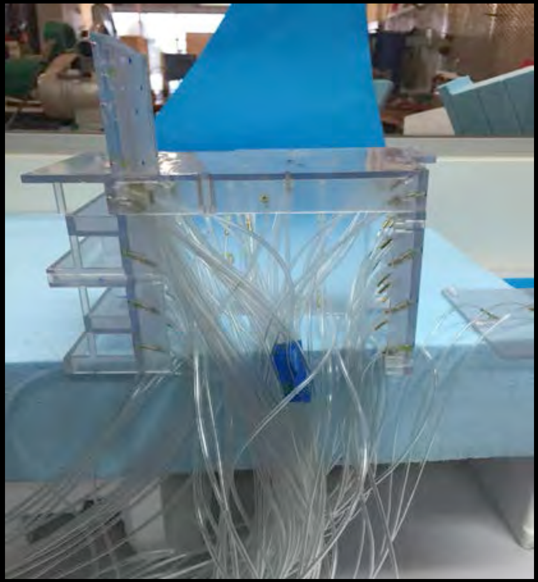
Apartment Building Design

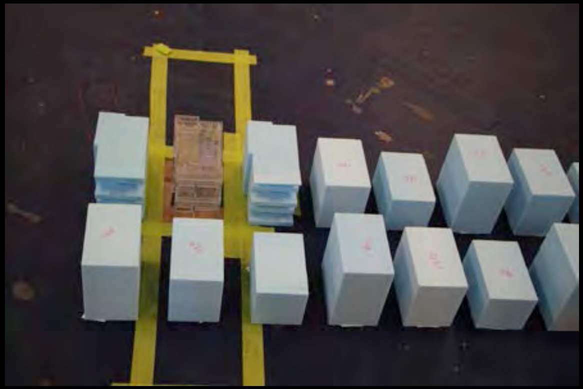
Climate Change Adaptation Research Facility (NCCARF, 2013)

The apartment building design adopted in this study is typical of the medium–density apartment development being widely forecast to increase in popularity in many Australian cities by 2030 (NCCARF, 2013).

WIND TUNNEL SET UP WITH SCALE MODEL

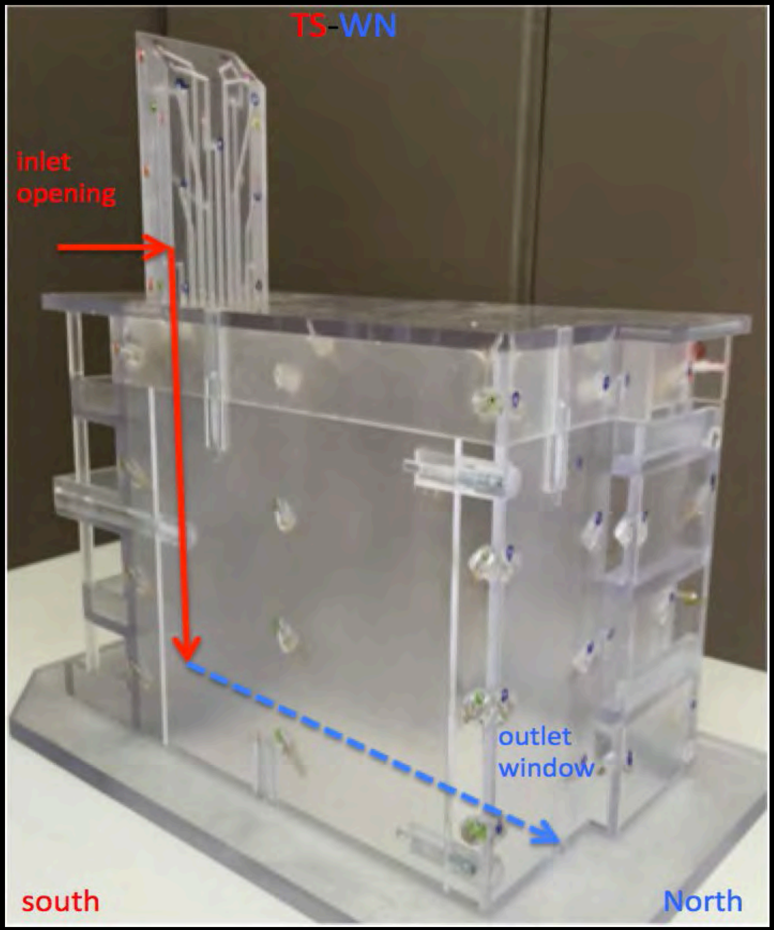


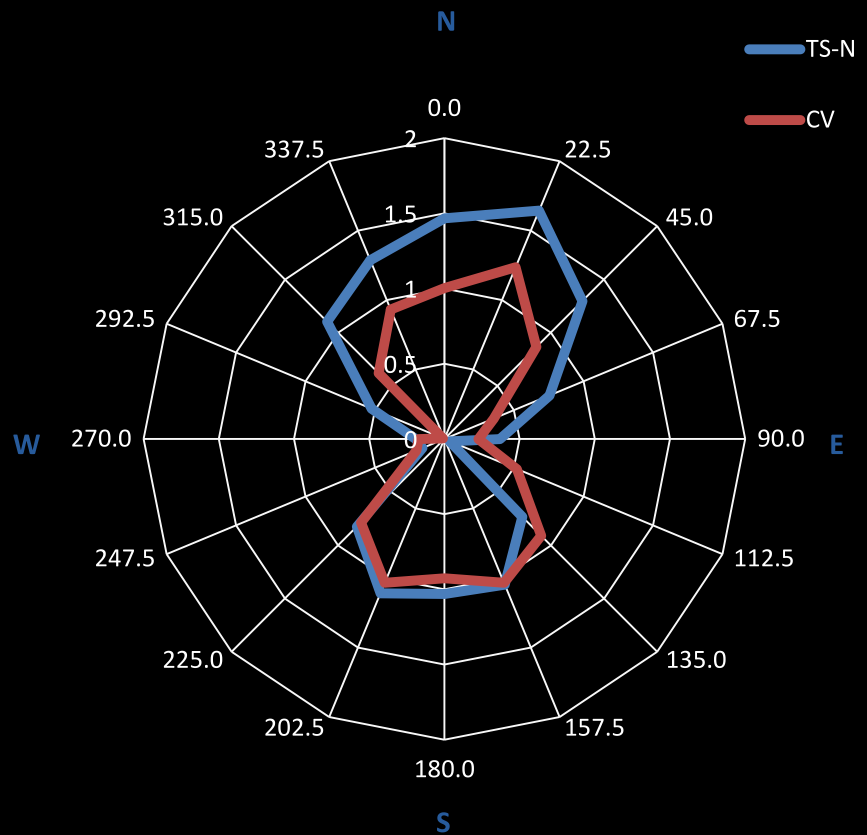




Sealed model at 1:100 scale with 299 pressure taps spread over 5 facades

Mean pressure coefficient difference, ΔCP (n.d.) across the openings





Average pressure coefficient difference between tower openings in south the building windows in north facade (TS-N) compared with the window cross ventilation(CV)

DERIVATION OF MEAN INDOOR AIR SPEED

Air changes per hour

- ACH = √ΔCp * Ve * Ao/Volume / √total energy loss coefficient * 3600

Airflow rate per hour (m^3/h)

- Air changes per hour * room volume

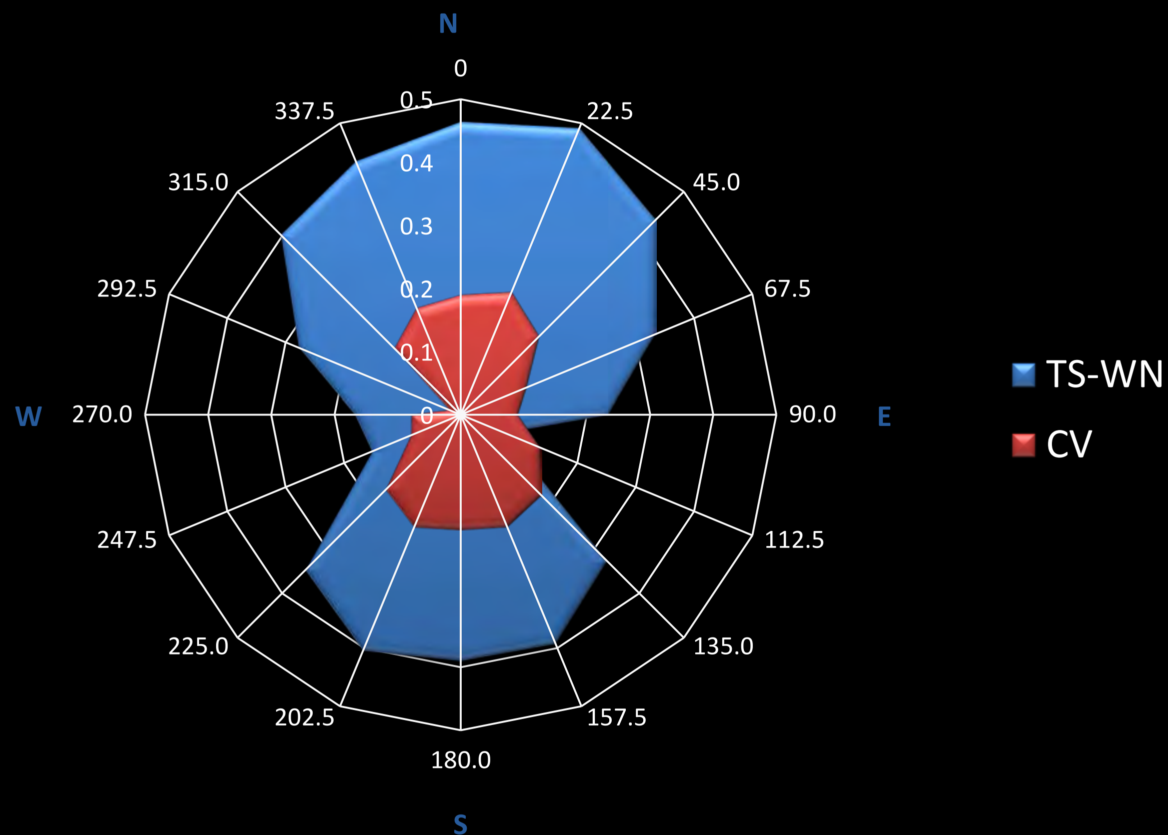
Indoor Air Speed (m/s)

- Vi = airflow/3600/Ar

where,
ΔCp = pressure coefficient differential (n.d.)
Ve = mean exterior velocity at building height (m/s)
Ao = area of openings on windward building façade (m)
Total Energy Loss coefficient= entry loss + exit loss + bend losses + friction loss (n.d.)
Vi = indoor air speed (m/s)
Ar = Room cross-sectional area (m^2)

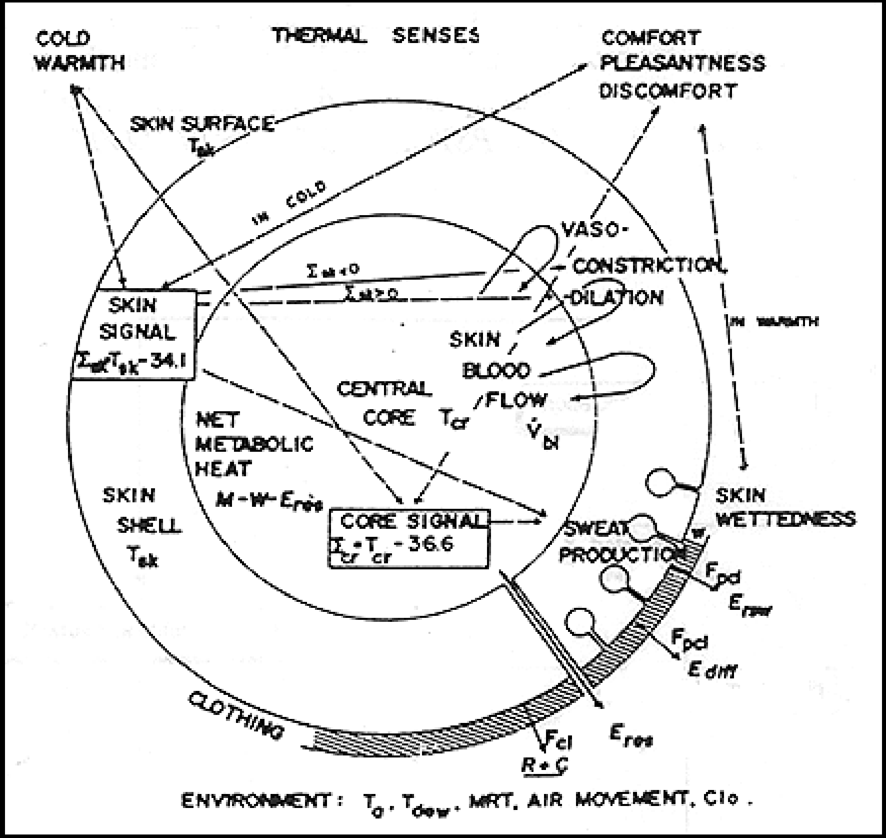
Air speed (m/s) within the occupied zone

- Most conservative design in first floor
- Tower opening 3 m^2
- Tower opening height: 0.75 m over roof in center (shortest height)



Mean indoor air speed in Jan 2013 via wind tower south opening & north window(TS-WN)
Benchmarked against through-window ventilation (CV)

CALCULATING COMFORT BENEFITS OF INCREASED INDOOR AIR MOVEMENT



Gagge, Nishi *et al.*'s 2-node model and Standard Effective Temperature (SET*)

Inputs include…

- Air temperature
- Mean radiant temperature
- Humidity
- Air speed
- Clo
- Met

RESULT AND DISCUSSION

THERMAL COMFORT ANALYSES, SET*

Aim: To evaluate thermal comfort benefits of increased indoor air speed generated by wind tower on thermal comfort (6 warmest months)

- Outdoor air temperature & humidity: TMY 2013
- Operative temperature: EnergyPlus simulations
- Metabolic rate: assumed 1.1 met
- Clothing: assumed 0.5 clo (typical summer residential)
- Indoor air speed: simulated wind tunnel analyses

- Cooling potential of the wind tower $\Delta SET^* = (SET^*_{cv}) - (SET^*_{wt})$

- Hourly indoor SET* for the six hot/warm months, In wind tower ventilation & cross ventilation modes

- $\Sigma\Delta SET^*$ = 1,726 degree hours free cooling compared to the through-window cross ventilation

CONCLUSION

- Wind towers represent an ancient yet still useful passive comfort technology
- They can source ***more*** and ***healthier ventilation air*** beyond the polluted urban canyon
- They represent a **zero carbon**, ***healthy comfort*** alternative to the current default option of mechanical cooling solution for ventilation in medium density residential developments along busy transport corridors