How should future building structure and emergency response cope with bushfire attacks?

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Overview

- Introduction
  - Background
  - Past bushfire study
- Objective of the current study
- Result and analysis
- Conclusion and recommendations

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Introduction

- Characteristics of bushfires
  - Huge amount of thermal energy is released
  - Can produce pyro-convective plume and winds up to 70 m/s (250 km/h) (Parkyn and Bannister, 2010)

Google Image

Wind – the primary suspect of wildfire destruction

- 80-85% house losses occur within 100 m from bushland-urban interface (McAneny et al., 2007)
- Black Saturday bushfire survey (BCRC, 2009)
  - More than 2000 houses were destroyed

Attack Mechanism	Percentage
Ember and other	58.6
Fire (flame contact and radiation), wind unknown	33
Fire and wind	8.4
Total	100

Google Image

Evidence of fire generated or fire enhanced wind destruction

Extreme localised winds were powerful enough to uproot large trees from the ground (Lambert, 2010).

Aftermath of fire generated tornado (McRae et al. 2012).

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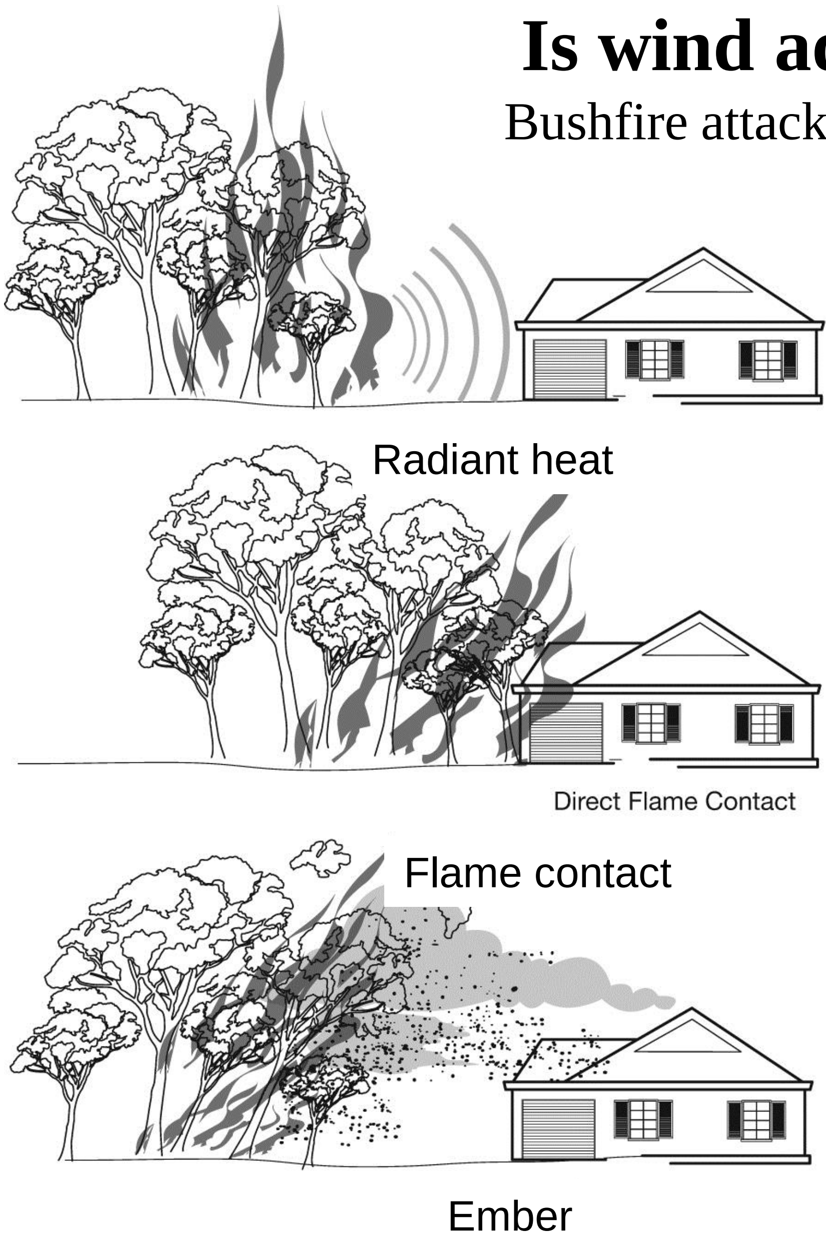
Is wind addressed in bushfire standard?

Bushfire attack mechanism and design for bushfire protection



Bushfire protection standard AS3959 addresses radiant heat, flame contact and ember attacks in bushfire prone areas by specifying

- Structure fire resistance levels
- Clearance distance
- Maximum gaps in building structure
- …

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It bushfire addressed in wind engineering standards?

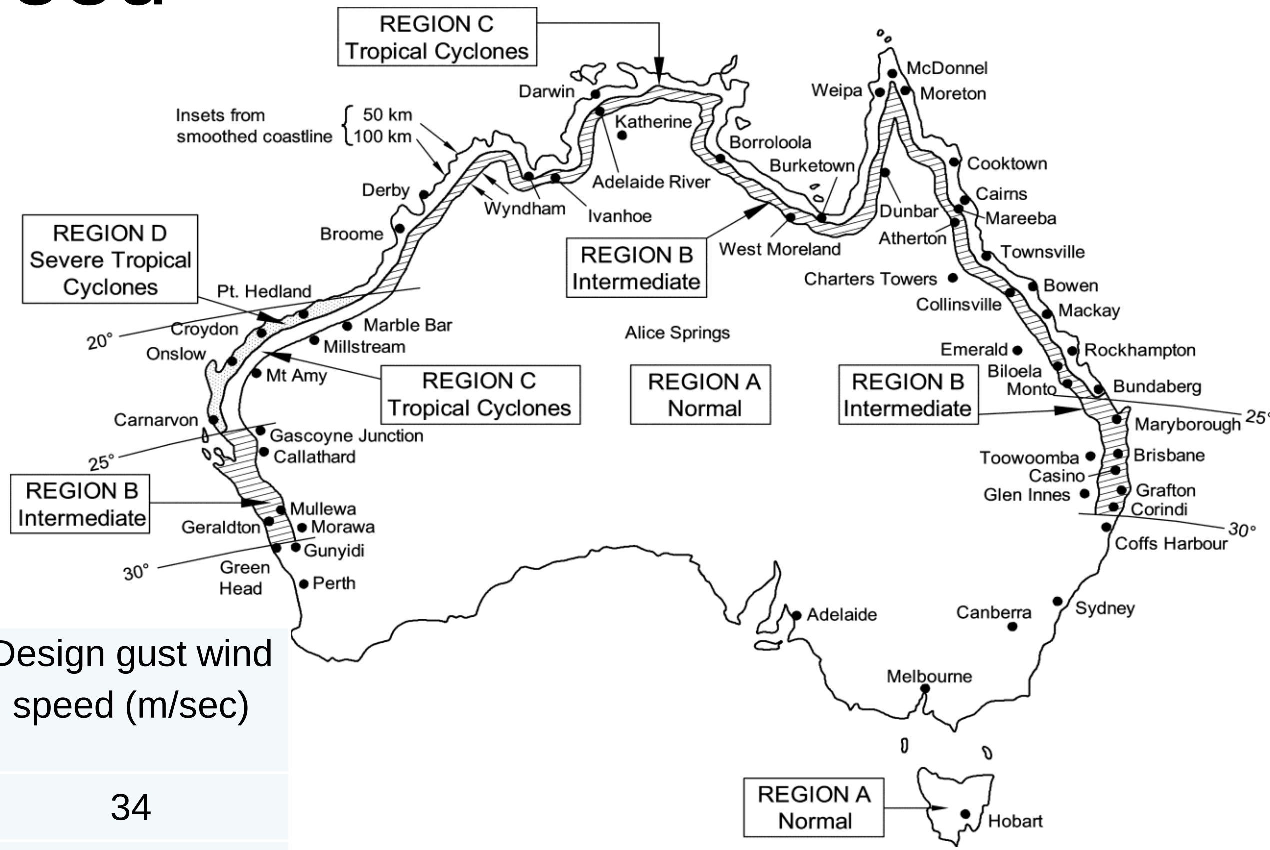
Wind load standard AS/NZS1170.2 and AS4055-2012

- Address structure design issues in relation to wind action due to storms or cyclones
- Define regions and subregions for the determination of wind loading requirements
- Specify design gust wind speed and the corresponding mean wind speed

Division of wind regions and design gust wind speed

(AS4055-2012)

Non cyclonic regions A and B	Cyclonic regions C and D	Design gust wind speed (m/sec)
N1		34
N2		40
N3	C1	50
N4	C2	61
N5	C3	74
N6	C4	86



(ABCB, 2013)

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The BCA performance requirement for structural load for housing

To the degree necessary, the building will :

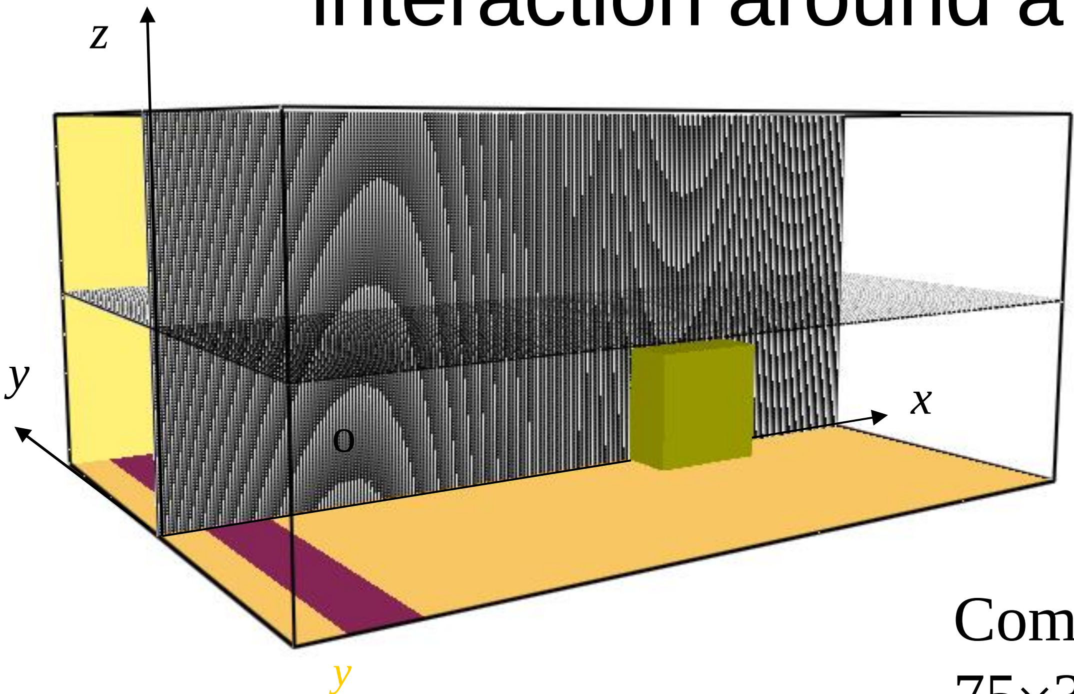
- Remain stable and not collapse;
- Prevent progressive collapse;
- Minimise local damage; and
- Avoid damage to other buildings.

Would the compliance to the above performance requirements be sufficient to protect buildings against bushfire attacks?

Objective of the current study

- To demonstrate the fire enhancement of wind
- To analyses the result against the wind statistics and design criteria

Numerical simulation of wind-fire-building interaction around a simple cube



Kwok *et al*. (2012)
He *et al*. (2013)

Computational domain:
75×36×24 m rectangular space
Grid size: 0.15 ~ 0.25 m
A 3 m deep fire front at *x*=2 m
Fire intensity: 5 ~12 MW/m

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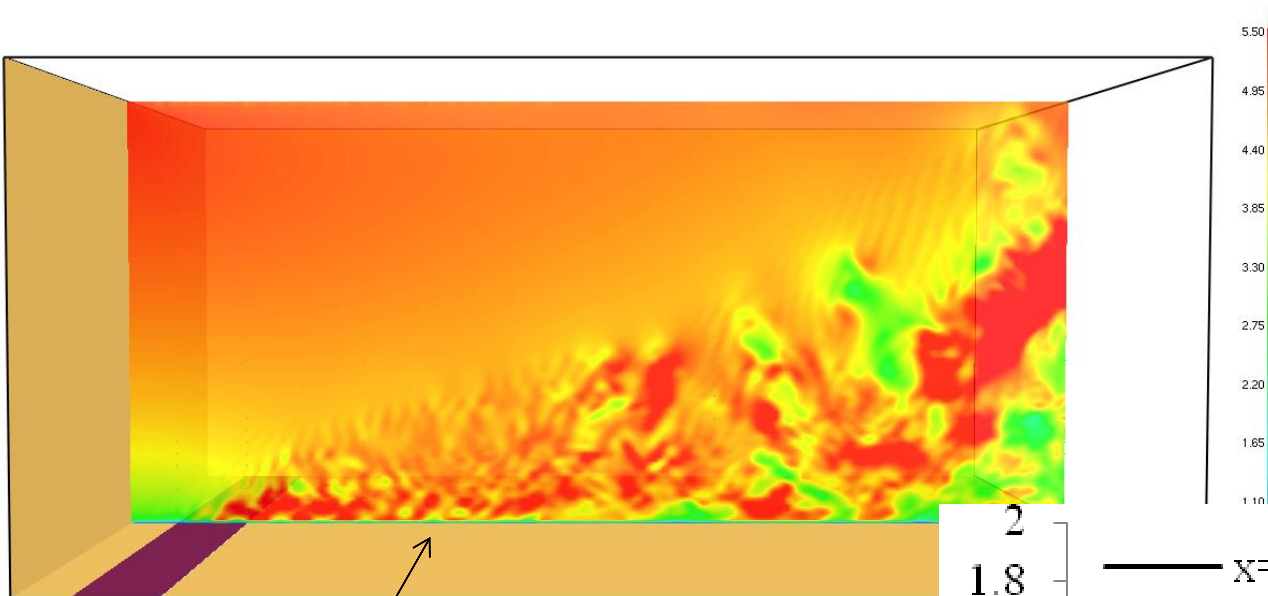
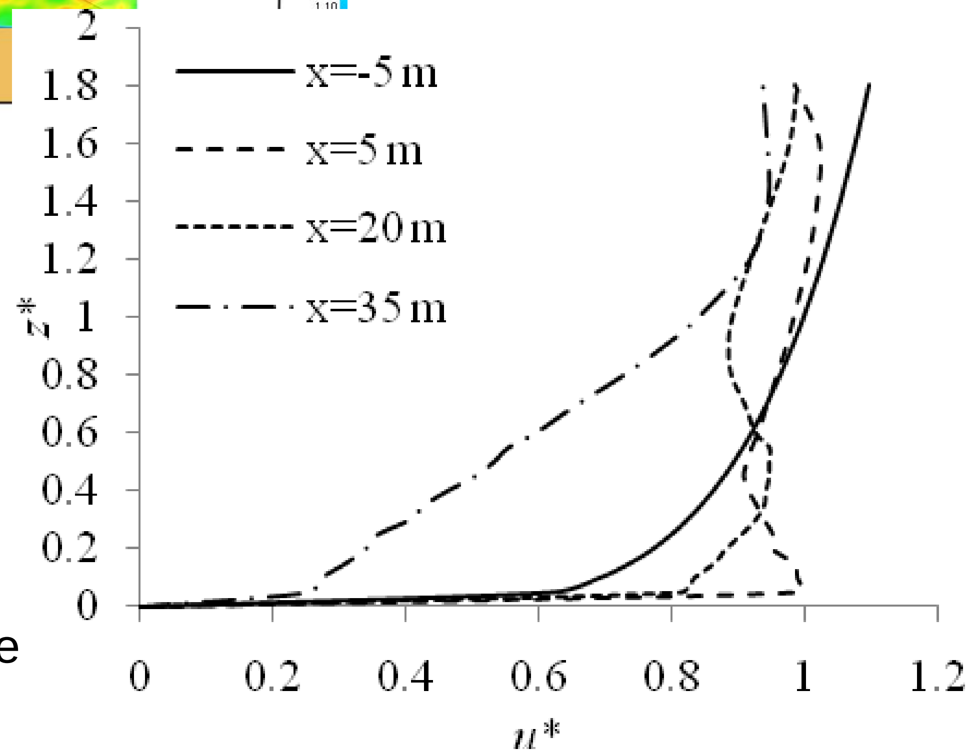
Result: Buoyancy enhanced flow without building



Velocity planar distribution

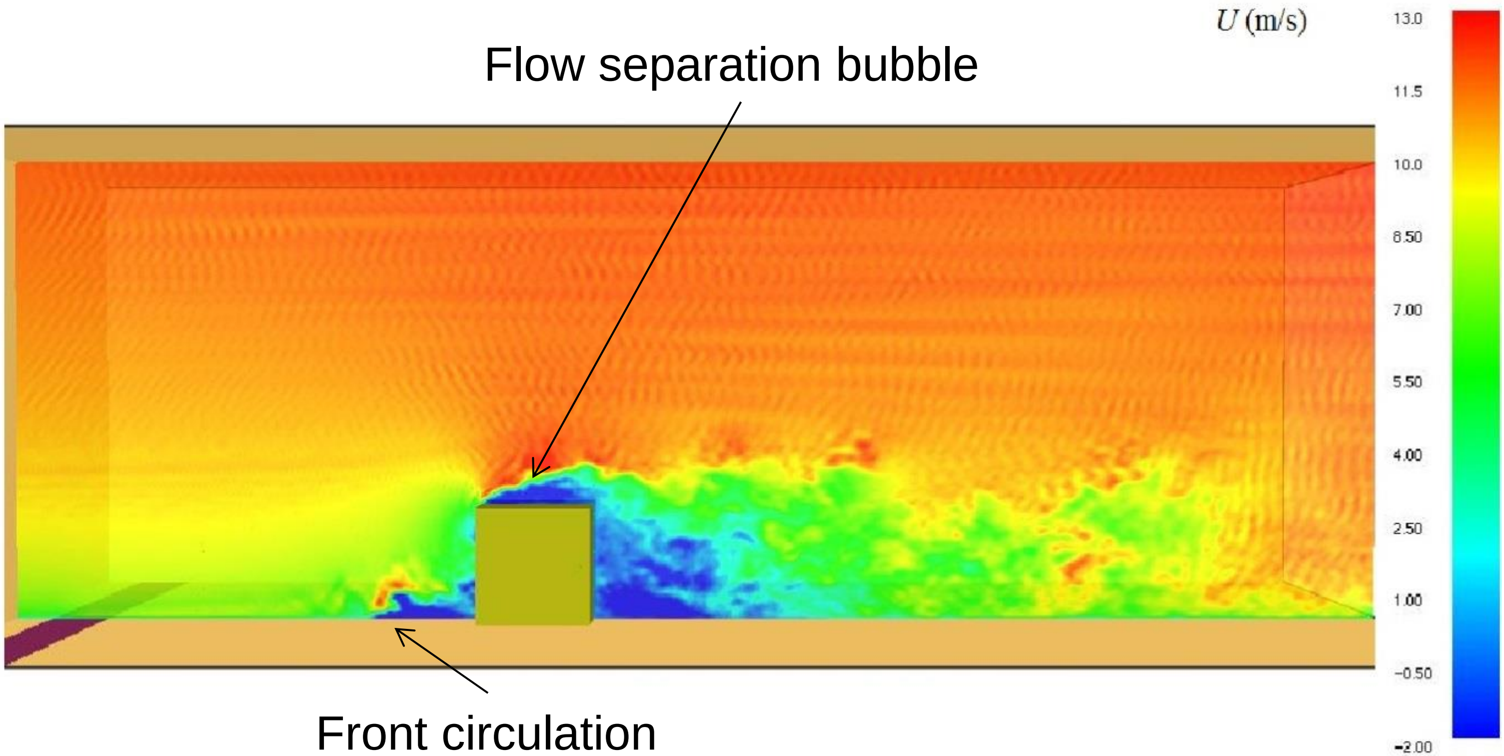
Boundary jet and Coanda effect

*z** =*z/H*
H=6 m



Velocity profile

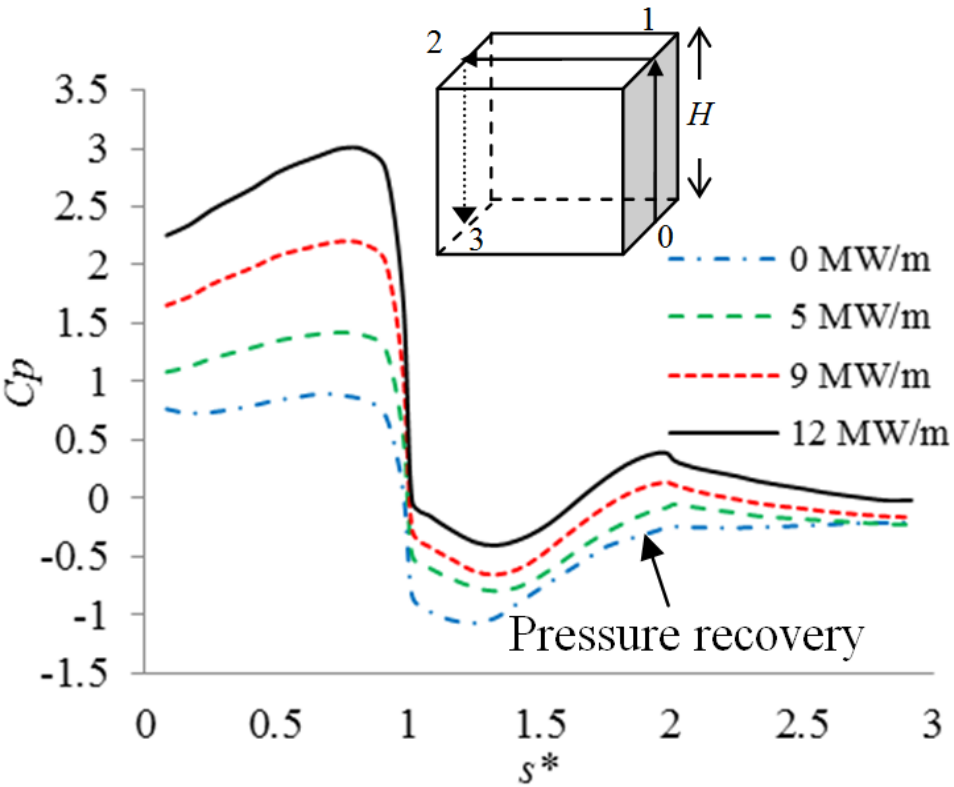
Result: Impact of buoyancy enhanced flow on a building



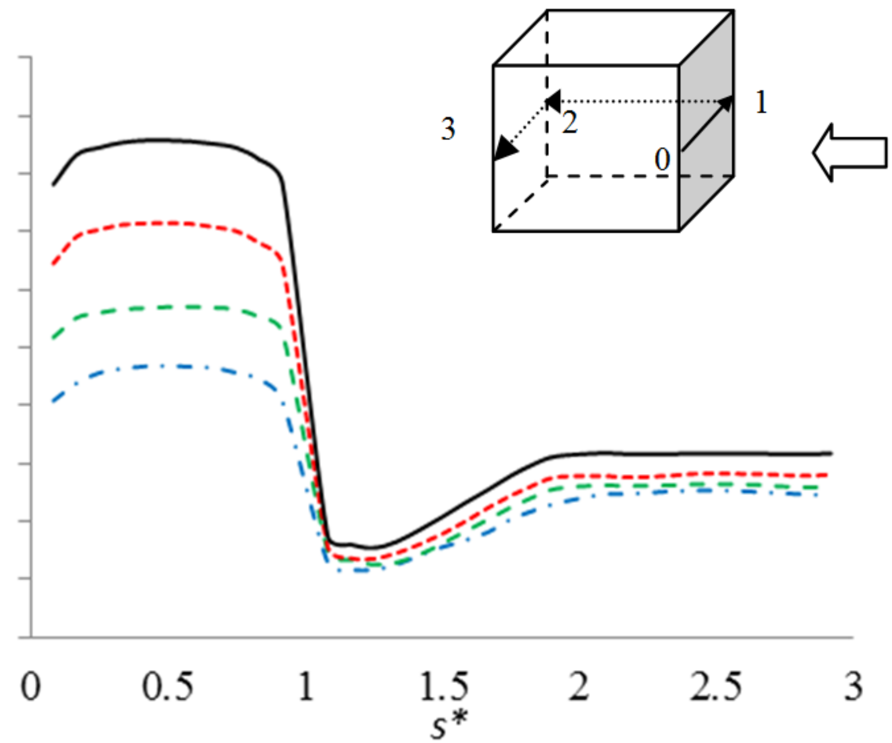
Velocity planar distribution

Result: Impact of buoyancy enhanced flow on a building

Pressure coefficient distributions



(a) Vertical profile distribution, $y^*=3$



(b) Horizontal profile distribution, $z^*=0.5$

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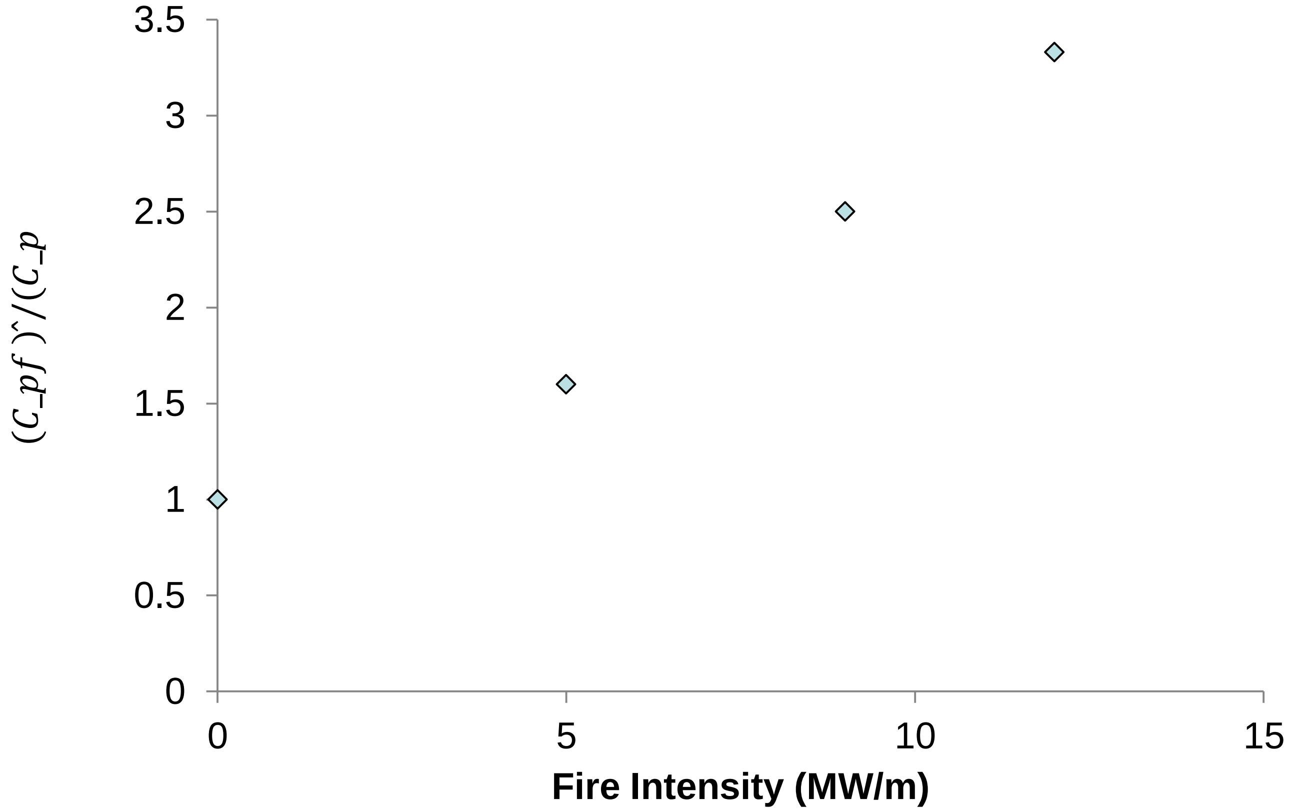
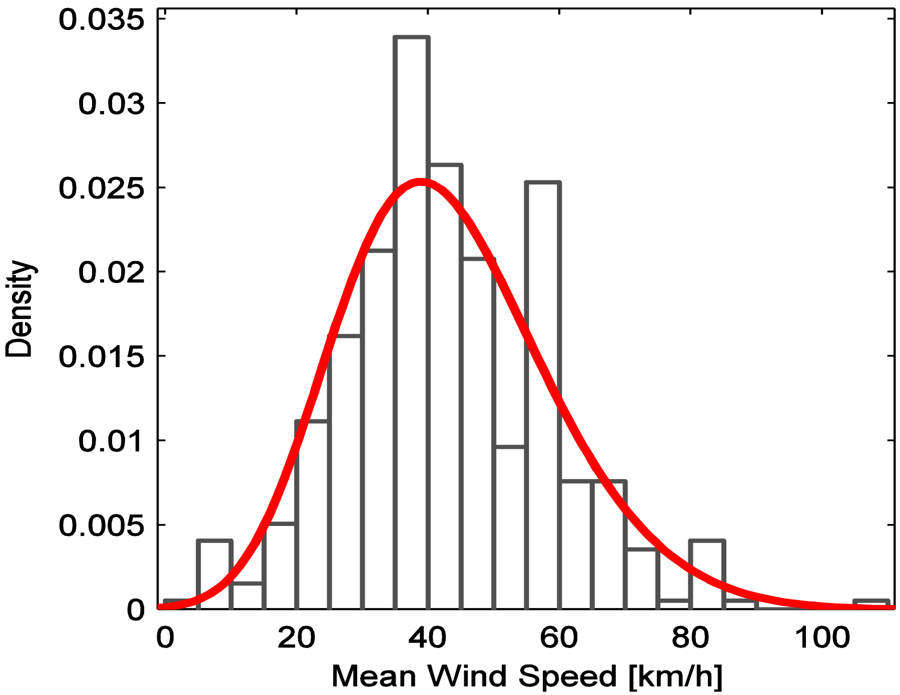
Variation of $\widehat{C_{pf}}/\widehat{C_p}$ with fire intensity

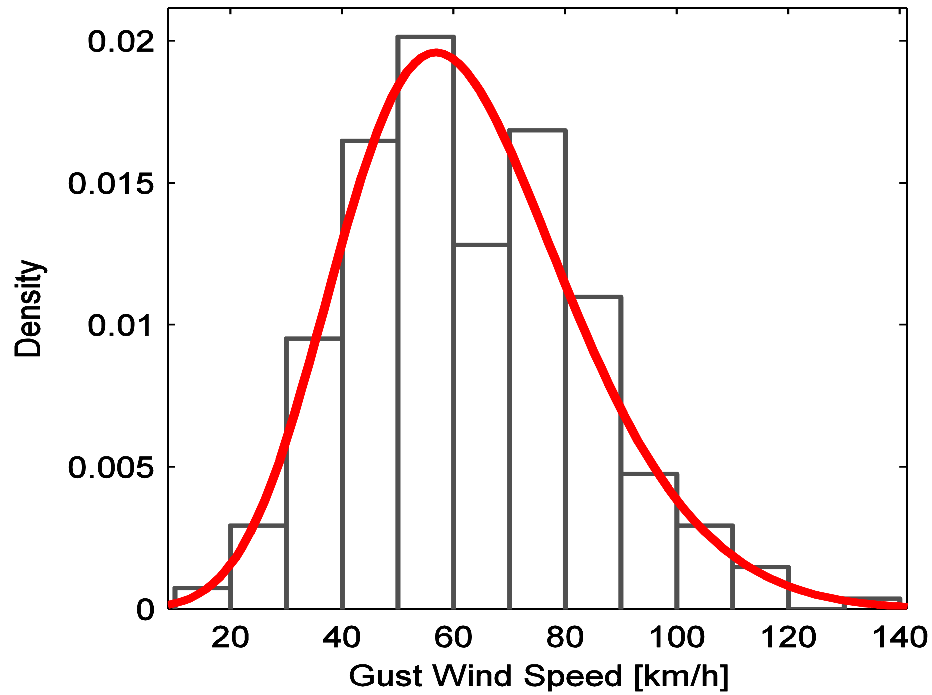
$\widehat{C_p}$ Peak mean pressure coefficient under no-fire condition
$\widehat{C_{pf}}$ Peak mean pressure coefficient under fire condition



Histogram and fitted GEV density functions for the recorded daily maximum wind speed.



(a) mean wind speed



(b) gust wind speed

Based on the data from Risk Frontiers' PerilAUS database (Crompton *et al*., 2010) and BoM

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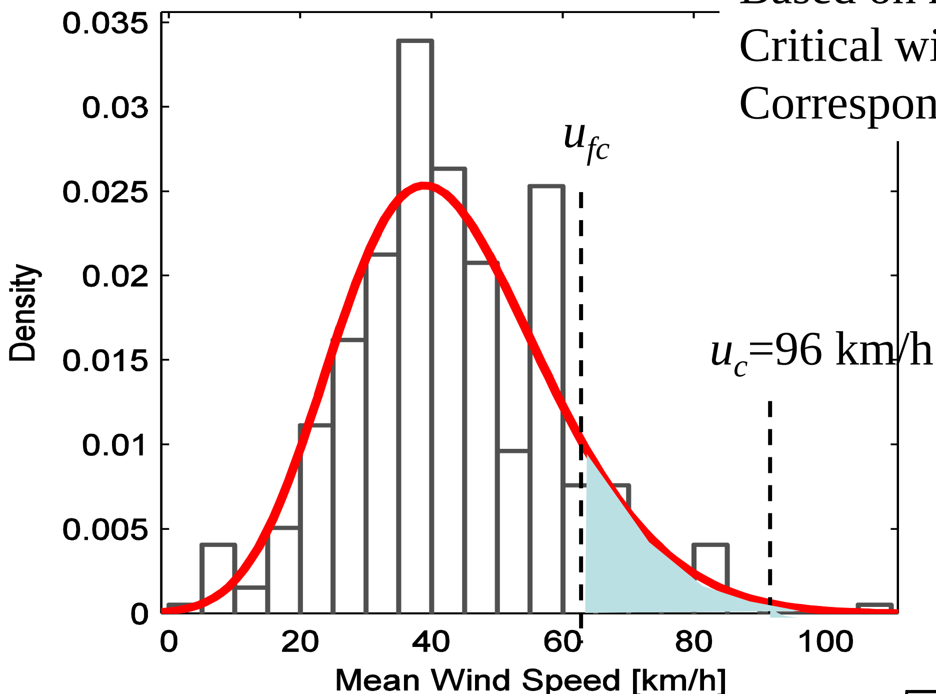
Critical wind speed for wind load design



Based on return period of 500 years
Critical wind gust speed = 162 km/h
Corresponding critical mean wind speed u_c =96 km/h

It can be derived that $$u_{fc} = u_c / \sqrt{\widehat{C_{pf}} / \widehat{C_f}}$$

u_{fc} – critical mean wind speed if a fire is involved.

$$\sqrt{\widehat{C_{pf}} / \widehat{C_f}} > 1 \text{ therefore, } u_{fc} < u_c$$

and Prob{ $u>u_{fc}$} >Prob{$u>u_c$}

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Relationship between simulated strip-source fire intensity and peak windward pressure coefficients and probability of bushfire associated wind load exceeding design strength

Fire intensity (MW/m)	$\widehat{C_{pf}}/\widehat{C_p}$	**Probability to exceed design wind pressures (%)**
0	1	0.15
5	1.6	3
9	2.5	13
12	3.33	26

Conclusions

- The interactions between wind and bushfire can produce strong local effect at the scales that are comparable to building sizes.
- The peak pressure is proportional to the fire intensity.
- it is highly probable that bushfire (grassland fire) enhanced wind may exceed the design wind conditions prescribed in the wind standards
- In addition to stability and thermal insulation, structure integrity under windy condition should also be a concern for building in bushfire prone areas

Recommendations

- Further investigations into the wind-fire interaction mechanisms is needed.
- Field data is needed to verify and validate the wind-fire-structure interaction near ground
- A tool may be developed
  - to provide quick estimates of wind-fire interaction intensities for given weather and fire conditions.
  - to guide building construction in bushfire prone areas;
  - To guide residents and fire rescue personnel in their evacuation and fire fighting activities.

(Lambert, 2010)