Pyrmont Over Station Development

Appendix D
Addendum to Pedestrian Wind Assessment

August 2024

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Glossary

Term	Definition
BoM	Bureau of Meteorology
CBD	Central business district
CFD	Computational Fluid Dynamics
Concept and Stage 1 CSSI Application	Application SSI-10038 including all major civil construction works between Westmead and The Bays, including station excavation and tunnelling, associated with the Sydney Metro West line
Concept SSDA	A concept development application as defined in Section 4.22 of the EP&A Act, as a development application that sets out concept proposals for the development of a site, and for which detailed proposals for the site or for separate parts of the site are to be the subject of a subsequent development application or applications.
CSSI	Critical state significant infrastructure
DCP	City of Sydney Development Control Plan 2012
DPE	Department of Planning and Environment
DPHI	Department of Planning, Housing and Infrastructure
EP&A Act	Environmental Planning and Assessment Act 1979
GFA	Gross floor area
NZS	New Zealand Standard
Pedestrian Wind Assessment	Pyrmont Over Station Development Pedestrian Wind Assessment (Appendix O), submitted with the original Concept SSDA
SSDA	State Significant Development Application
SSI	State Significant Infrastructure
Stage 2 CSSI Approval	SSI-19238057, approved 24 August 2022, including major civil construction works between The Bays and Sydney CBD including station excavation and tunnelling, associated with the Sydney Metro West railway line
Stage 3 CSSI Approval	SSI-22765520, approved 25 January 2023, including rail infrastructure, stations, precincts and operation of the Sydney Metro West line
Sydney Metro West	Construction and operation of a metro rail line and associated stations between Westmead and the Sydney CBD
TfNSW	Transport for New South Wales
The site	The Pyrmont Over Station Development site

Executive Summary

This addendum to the Pedestrian Wind Assessment supports a Concept State Significant Development Application (Concept SSDA) submitted to Department of Planning, Housing and infrastructure (DPHI) pursuant to Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act). The Concept SSDA is made under section 4.22 of the EP&A Act.

Sydney Metro is seeking concept approval for an over station development above the Pyrmont Station located at 37-69 Pyrmont Bridge Road, Pyrmont. The proposed development would comprise a mixed use building with a predominantly commercial podium and residential tower above.

The Concept SSDA seeks consent for a mixed use building envelope, a maximum gross floor area (GFA), pedestrian and vehicular access, circulation arrangements and associated car parking. In addition, it also seeks consent for strategies and design parameters for the future detailed design of the development.

The Concept SSDA was lodged with the DPHI in March 2024 and was placed on public exhibition between 12 March 2024 and 8 April 2024. In total, 32 submissions were received from the community, local community groups and organisations. A submission was also received from the City of Sydney Council. No submissions were received from Government agencies or authorities.

DPHI issued a letter to Sydney Metro on 10 April 2024 requesting a response to the issues raised during the public exhibition of the application. The Submissions Report provides a response to the issues raised.

This addendum to the Pedestrian Wind Assessment addresses the City of Sydney Council submission for additional wind modelling to provide assessment of the wind conditions and amenity of the podium external terrace areas and rooftop communal open space.

Wind impacts on pedestrian areas throughout and surrounding the development were assessed using Computational Fluid Dynamics (CFD) simulations combined with statistical analysis of nearby meteorological observations. Assessment was made against the City of Sydney Development Control Plan (DCP) 2012 controls for wind comfort and safety.

The results demonstrate that several terrace areas are considered both uncomfortable and unsafe when assessed against the City of Sydney DCP criteria. Mitigation measures will be required to address these areas, the efficacy of which should be demonstrated at Detailed SSDA stage. Recommended mitigation measures are:

- Level 5 eastern podium terrace: balustrades and dense shrubbery to be installed (required only if the area is to be used for outdoor dining or similar)
- Level 5 northern/western terrace: Suitably high balustrades and canopy/awning
- Level 6 podium roof: Canopies at the base of the tower (required only if the podium roof is a public or private terrace)
- Level 30 roof terrace: Suitably high balustrades.

1 Introduction

1.1 Purpose and Scope

This addendum to the Pedestrian Wind Assessment supports a Concept State Significant Development Application (Concept SSDA) submitted to the Department of Planning, Housing and Infrastructure (DPHI) pursuant to Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act). The Concept SSDA is made under section 4.22 of the EP&A Act.

Sydney Metro is seeking concept approval for an over station development above the Pyrmont Station located at 37-69 Pyrmont Bridge Road, Pyrmont. The proposed development would comprise a mixed use building comprising a predominantly commercial podium and residential tower above.

The Concept SSDA seeks consent for a mixed use building envelope, a maximum gross floor area (GFA), pedestrian and vehicular access, circulation arrangements and associated car parking. In addition, it also seeks consent for strategies and design parameters for the future detailed design of the development.

Previously, wind impacts were assessed as part of the Pedestrian Wind Assessment (EIS Appendix O), prepared to support the Concept SSDA. The findings of the assessment were summarised as follows:

> *"This study has found that nine of the tested locations are likely to exceed the specified criteria and therefore further mitigation measures will be required. However, it was found that five of these locations already exceeded the walking criterion for the baseline investigations and therefore there are only four new exceedances. It is important to note that the proposed development also reduces the expected wind speed at several locations which means that five locations that were exceeding the proposed criterion no longer pose a comfort wind risk. In addition, there are no expected safety wind speed exceedances."*

The Concept SSDA was lodged with the DPHI in March 2024 and was placed on public exhibition between between 12 March 2024 and 8 April 2024. In total, 32 submissions were received from the community, local community groups and organisations. A submission was also received from the City of Sydney Council. No submissions were received from Government agencies or authorities.

This report should be read in conjunction with the Pyrmont Over Station Development Pedestrian Wind Assessment (EIS Appendix O) submitted with the Concept SSDA EIS. This addendum report assesses the safety and amenity impacts of the local wind environment on outdoor terrace areas.

2 Scope of Assessment

The scope of this study is:

- Conduct additional wind modelling to provide assessment of the wind conditions and amenity of the podium external terrace areas and rooftop communal open space.
- Prepare simplified 3D computational geometry, with level of geometric detail suitable for CFD and consistent with AWES-QAM-1-2019.
- Simulate steady atmospheric boundary layer wind conditions in CFD from 16 wind directions.
- Provide assessment against the City of Sydney Development Control Plan 2012 (DCP) criteria (2.1) throughout the podium external terrace areas and rooftop communal open space.
- Provide recommendations for mitigation strategies where any exceedances occur.

2.1 Assessment Criteria

The DCP covers wind effects from the public realm (section 5.1.9 of the DCP). DCP controls are not directly relevant to SSD but provide a useful guideline. The criteria are paraphrased in the below dot points:

- A development subject to a quantitative wind effects report (i.e. the proposed development in this case) must not:
    - cause a wind speed that exceeds the Wind Safety Standard, the Wind Comfort Standard for Walking and the Wind Comfort Standard of Sitting in Parks except where the existing wind speeds exceed the standard
    - worsen, by increasing spatial extent and/or frequency and/or speed, an existing wind speed that exceeds the Wind Safety Standard, the Wind Comfort Standard for Walking and the Wind Comfort Standard for Sitting in Parks.
- For the purposes of complying with the above, the below standards are set out in the DCP:
    - Wind Safety Standard is a wind speed of 24 metres per second
    - Wind Comfort Standard for Walking is a wind speed of 8 metres per second
    - Wind Comfort Standard for Standing is a wind speed of 6 metres per second
    - Wind Comfort Standard for Sitting is a wind speed of 4 metres per second
    - Wind Comfort Standard for Sitting in Parks is a wind speed of 4 metres per second.

Note: The Wind Safety Standard is based on an annual maximum peak 0.5 second gust wind speed in one hour measured between 6 am and 10 pm Eastern Standard Time.

Note: The Wind Comfort Standards are based on an hourly mean wind speed, or gust equivalent mean wind speed, whichever is greater for each wind direction, for no more than 292 hours per annum measured between 6 am and 10 pm Eastern Standard Time (i.e. 5% of those hours).

2.2 Meteorological Data

Historical weather data was used for the analysis and obtained from the Bureau of Meteorology (BoM) weather station at Sydney Kingsford Smith Airport, which is situated 8.5 km southwest of the site. Airport weather stations are generally the most reliable source of wind data as they are typically free from nearby obstructions and have uninterrupted, quality-controlled data for suitable time periods.

From 2001 to 2020, hourly mean and maximum 3-second gust wind speeds were obtained from 10-minute wind observations using methods outlined in Grange (2014). For the assessment of wind comfort, only observations between 6 am and 10 pm were used, as per the DCP criteria. For safety, wind observations from all hours were used.

Scaling to correct for the difference in terrain roughness surrounding the site (i.e., due to buildings, trees, and other obstructions) was made and detailed in Appendix A. Details of the statistical methods used and coefficients describing the wind probability distributions (a Weibull analysis for comfort and an extreme value analysis for safety) can also be found in Appendix A.

The scaled mean wind speed data (between 6 am and 10 pm) is presented in the wind rose plot below, Figure 2-1. Here, the length and colour of the spoke sections represent the frequency and amplitude of recorded wind events, respectively.

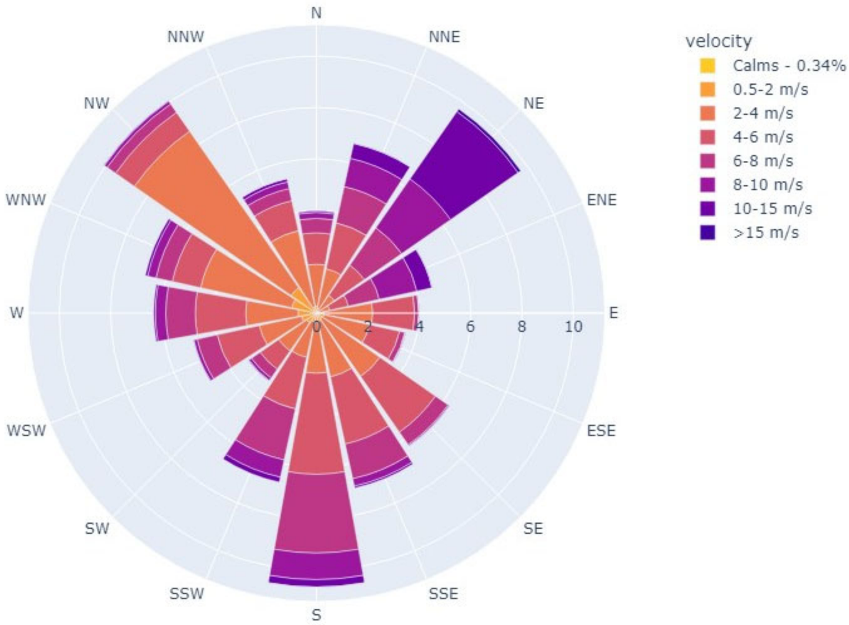

Figure 2-1: Wind rose plot of Sydney Airport mean wind speed data, 2001-2020, 6am-9pm (as used for comfort assessment)

2.3 Computational Model

Surrounding physical features which influence the near field flow, such as significant buildings, structures, or topography, are essential to accurate wind modelling. The development, surrounding buildings and topography within 300 m radius were modelled to sufficient accuracy, following the Australasian Wind Engineering Society Quality Assurance Manual (2019) guidelines. Images of the simplified model are provided below in Figure 2-2 and Figure 2-3. Further detail on the CFD methodology is provided in Appendix B.

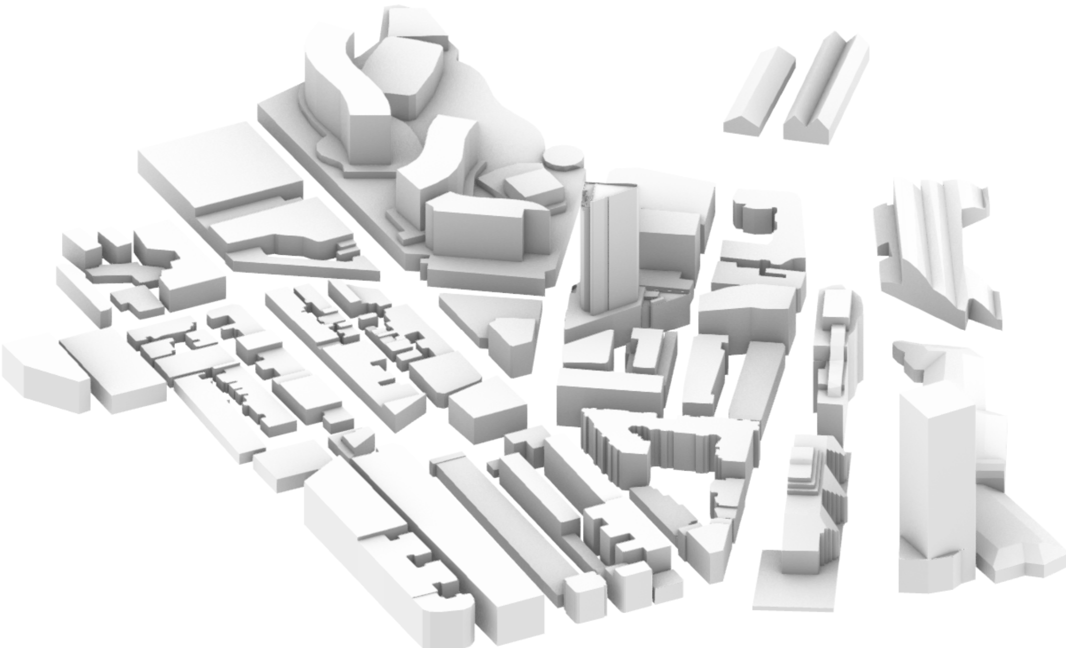

Figure 2-2: Model geometry, showing extents and detail of the surrounding buildings

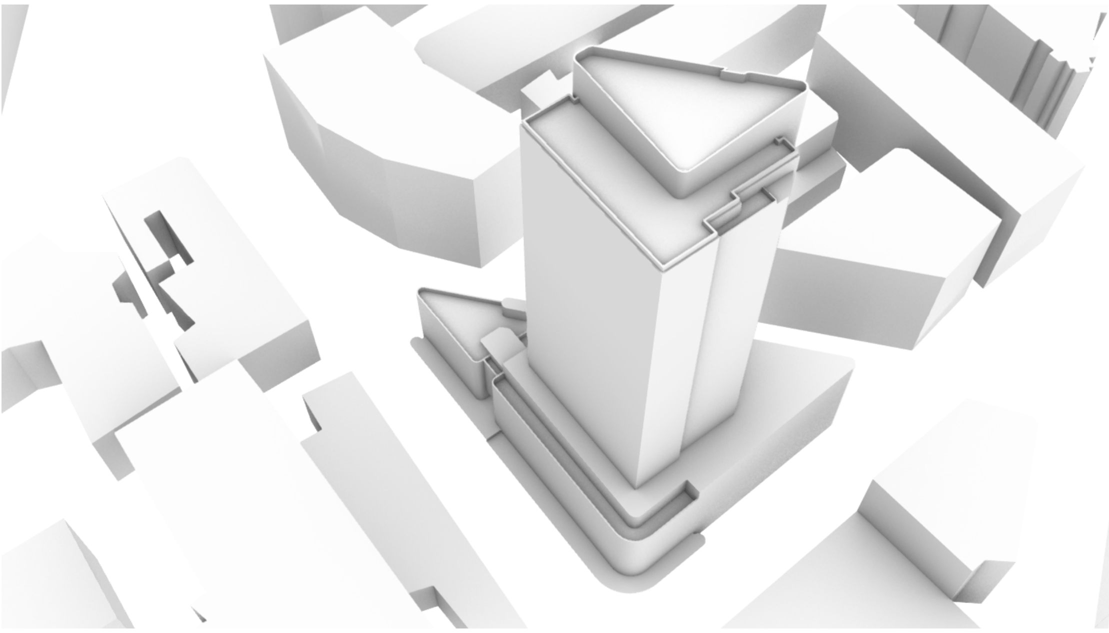

Figure 2-3: Model geometry, showing detail of the proposed development

2.4 Statistical analysis

The methods used to assess CFD results against the DCP criteria are as follows:

- CFD results provided the mean wind speed ($\overline{U}$) and turbulent kinetic energy (k) for 16 wind directions, relative to a reference wind speed of 10 m/s.
- Gust-equivalent mean wind speeds, U_{GEM}, were calculated using:

$$U_{GEM} = \max\left(\overline{\mathrm{U}}, \frac{\overline{U} + 3.0\sqrt{k}}{1.85}\right)$$

  where 3.0 is the peak factor corresponding to a 3-second gust relative to a one-hour mean. The gust factor of 1.85 has been used based on the research published by Lawson (2001).

- Comfort wind speeds were calculated using a Weibull statistical analysis (see Appendix A.2) of hourly mean wind speed observations and the gust-equivalent mean wind speed results, resulting in 3-second gust-equivalent wind speeds with a 5% probability of exceedance from all directions.

$$U_{GEM} = \frac{U_{GEM,CFD}}{\overline{U}_{ref,CFD}} \times \overline{U}_{ref,Weibull}$$

- Safety wind speeds were calculated using an extreme value (Gumbel) statistical analysis (see Appendix A.3) of hourly maximum 3-second gust observations, corrected to 0.5-second gusts according to ESDU 83045, and mean wind speed results, resulting in 0.5-second gust wind speeds with a once-per-annum return period.

$$\widehat{U}_{0.5} = \frac{\overline{U}_{CFD}}{\overline{U}_{ref,CFD}} \times \widehat{U}_{0.5,ref,Gumbell}$$

- Assessments against the criteria were made from results sampled at a height of 1.5 m above floor level.

3 Results

3.1 Comfort

Wind comfort results are displayed in Figure 3-1 and Figure 3-2. These plots can be considered as a weighted average of wind events occurring from all directions (i.e., taking into consideration the relative probability of wind speeds from each direction). Results are presented against the DCP criteria across assessment surfaces 1.5 m above floor levels.

Gust-equivalent mean wind speed ratios (i.e. the speed-up factor compared to the reference (weather station) wind speed) for each wind direction are displayed in Appendix C, to provide an understanding of the wind conditions produced by each wind direction.

The wind comfort results, and mitigation options to be considered prior to Detailed SSDA, are summarised as follows.

Table 3-1 Summary of wind comfort assessment.

Area	CoS DCP Comfort Criteria	Description of Results and Recommended Mitigation Options
Level 5 eastern podium terrace	Walking/ Standing	The majority of the terrace is subjected to wind conditions considered suitably comfortable for walking, with calmer conditions in a small area on the eastern corner of the terrace. It is likely that ‘walking’ conditions are suitable, considering users’ expectations of wind conditions on terraces. However, if the area is intended to be used for outdoor dining, additional wind mitigation will be required, which could be in the form of balustrades and dense shrubbery. Canopies, awnings and umbrellas would be less effective, as the results indicate that accelerated winds are not driven by downwash at this location.
Level 5 northern/western terrace	Walking/ Uncomfortable	As above, a ‘walking’ criteria result may be considered acceptable, depending on the intended use of the area. However, the area near the northwestern corner is shown to experience uncomfortable wind conditions. This is driven by downwash and corner acceleration, from north to easterly and south-westerly to west-south-westerly winds. A canopy/awning and suitably high balustrade would be expected to provide adequate wind mitigation. The heights/extents of which should be determined at Detailed SSDA stage.
Level 6 podium roof	Uncomfortable	The majority of the podium roof is shown to be subjected to uncomfortable wind conditions. This is due to downwash from the northern, western and south-eastern facades. If this area is identified as an open terrace at the Detailed SSDA stage, wind mitigation would have to be provided by a canopy, of suitable extent, at the base of the tower.
Level 29 western balcony	Standing	Wind conditions are suitable for standing, no mitigation is required.
Level 30 roof terrace	Uncomfortable	Wind conditions across the majority of the terrace are considered uncomfortable. Solid balustrades (e.g. 2 m height) are likely to provide adequate wind mitigation and should be considered at Detailed SSDA.

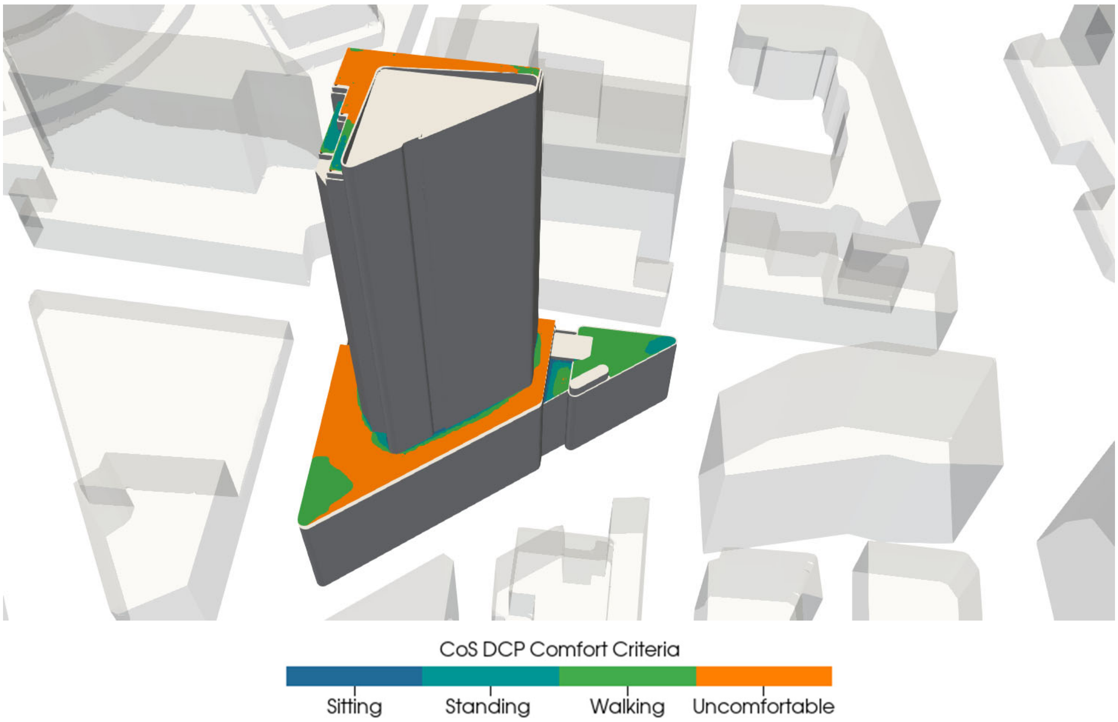

Figure 3-1 DCP Wind Comfort Standard results, viewed from south

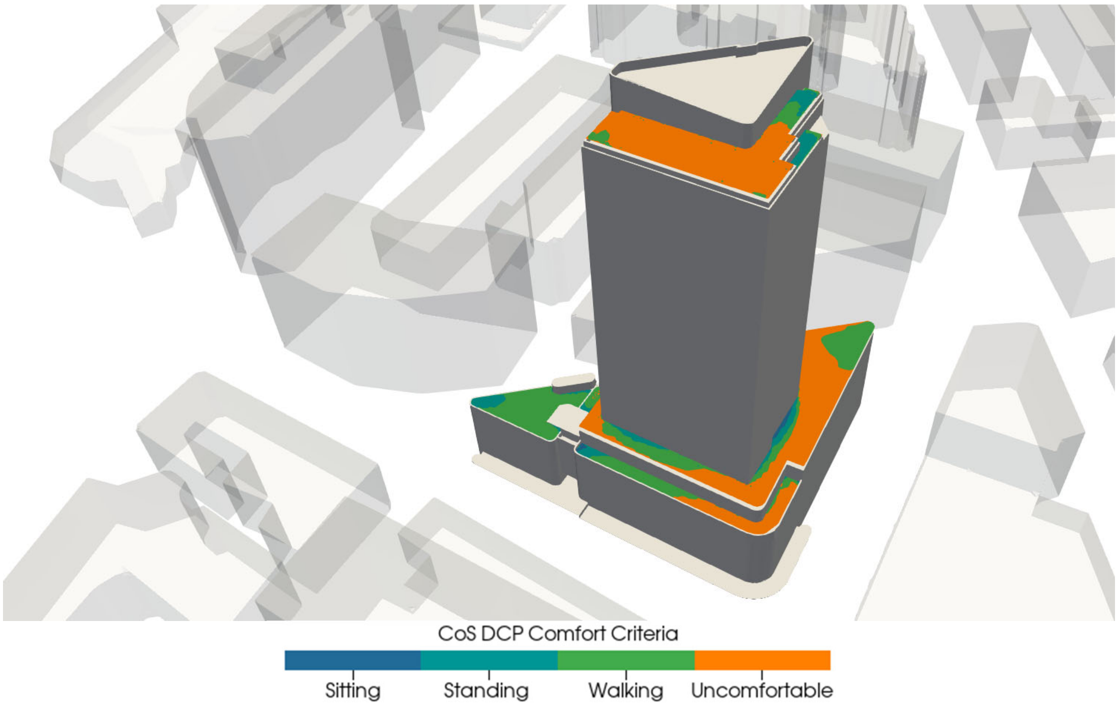

Figure 3-2 DCP Wind Comfort Standard results, viewed from north

3.2 Safety

Wind comfort plots are displayed in Figure 3-3 and Figure 3-4. As with the comfort contours above, the results represent wind events from all directions.

There are several areas of the terraces where the DCP Wind Safety criterion is exceeded. These areas all correspond to locations where a DCP Wind Comfort result of 'uncomfortable' was found. As such, recommended mitigation measures, to be considered at Detailed SSDA stage, are as per the previous section (Table 3-1).

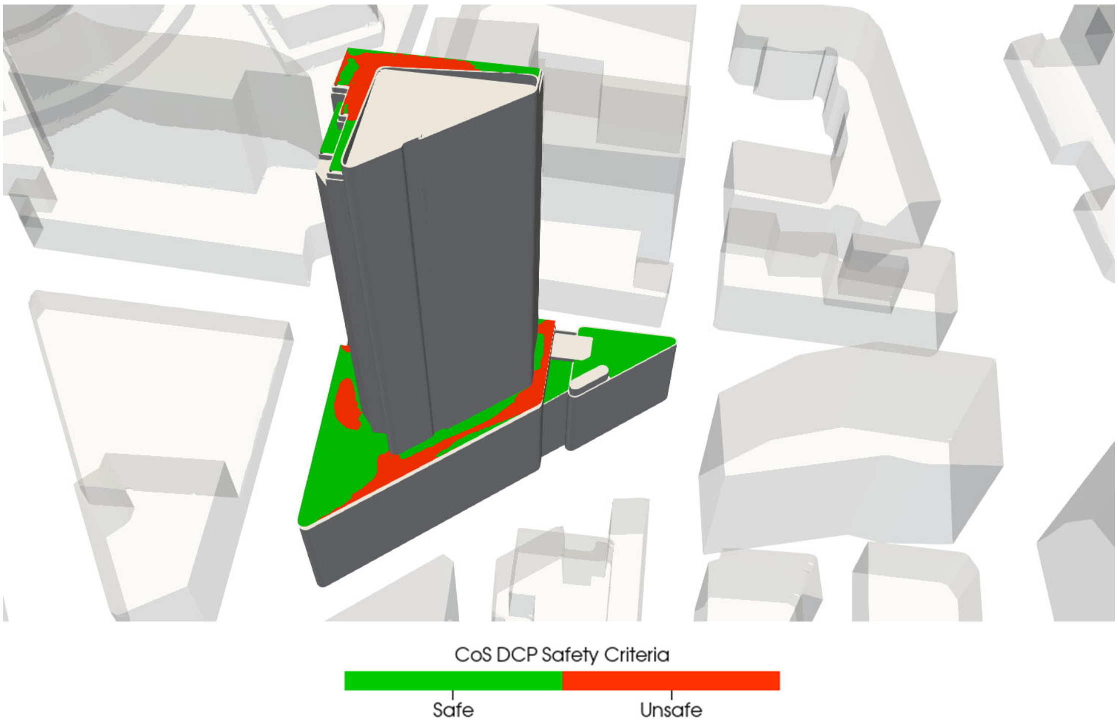

Figure 3-3 DCP Wind Safety Standard results, viewed from south

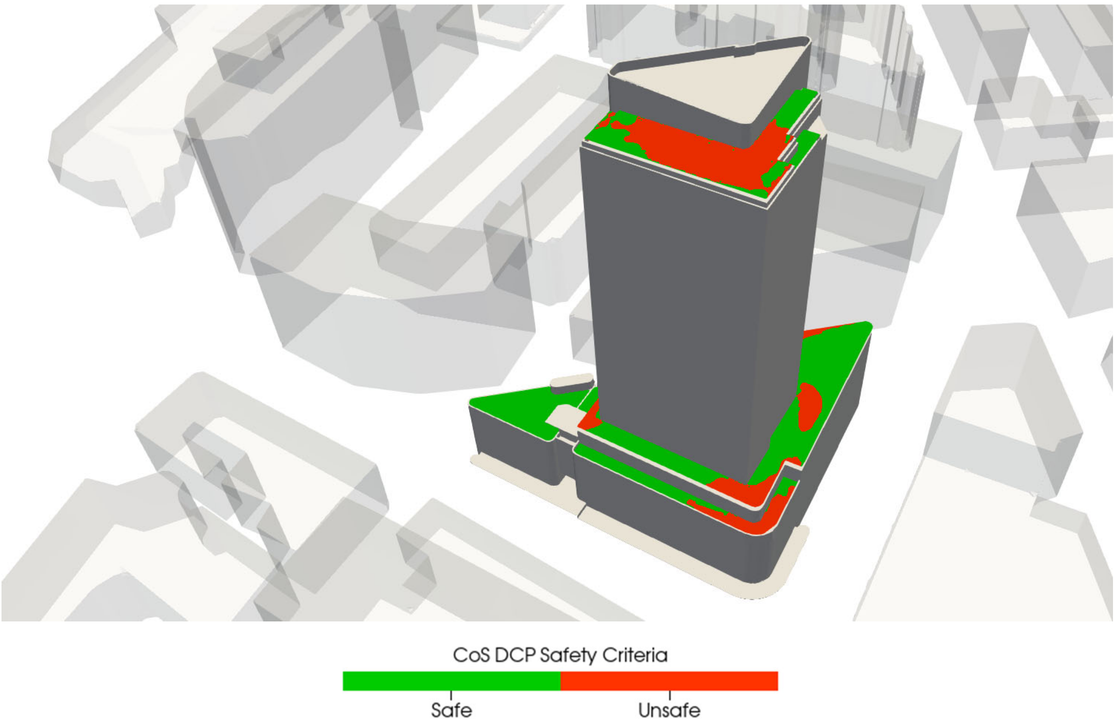

Figure 3-4 DCP Wind Safety Standard results, viewed from north

4 Conclusion

This addendum to the Pedestrian Wind Assessment has been prepared to support the Concept SSDA and to respond to the City of Sydney Council submission.

The assessment addresses the request for additional wind modelling to provide assessment of the wind conditions and amenity of the podium external terrace areas and rooftop communal open space.

Wind impacts on pedestrian areas throughout and surrounding the development were assessed using Computational Fluid Dynamics (CFD) simulations combined with statistical analysis of nearby meteorological observations. Assessment was made against the DCP controls for wind comfort and safety.

The results demonstrate that several terrace areas are considered both uncomfortable and unsafe when assessed against the DCP criteria. Mitigation measures will be required to address these areas of concern, the efficacy of which should be demonstrated at Detailed SSDA stage. Recommended mitigation measures are:

- Level 5 eastern podium terrace: balustrades and dense shrubbery to be installed (required only if the area is to be used for outdoor dining or similar)
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- Level 6 podium roof: Canopies at the base of the tower (required only if the podium roof is a public or private terrace)
- Level 30 roof terrace: Suitably high balustrades.

References

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AS/NZS 1170.2:1989, "Minimum design loads on structures" (known as the SAA Loading Code), Part 2: Wind Loads.

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Grange, S, (2014), "Technical note: Averaging wind speeds and directions", 10.13140/RG.2.1.3349.2006.

Holmes, J, (2021), "The Wind Climate of The Melbourne Metropolitan Area - wind speed and directional probabilities at four stations", 10.13140/RG.2.2.16175.66725.

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Appendix A Statistical Analysis of Meteorological Data

A.1 Scaling Methods

Modelling of local wind effects requires accurate representation of the surrounding terrain and built environment. The influence of terrain and built environment over the development length is incorporated into AS/NZS 1170.2:2021 as different terrain categories. Based on the terrain category, a suitable model of the atmospheric boundary layer (change in velocity and turbulence intensity with height) is given, which accounts for nearby structures and terrain (roughness). This model uses a logarithmic law to describe the mean wind speed profile in terms of roughness length.

Wind data from Sydney Airport was corrected to open terrain (category 2) using methods outlined in Holmes, 2021. To scale to the terrain roughness surrounding the site (e.g. category 3), scaling was applied using mean wind speed terrain/height multipliers from AS/NZS 1170.2:1989; i.e., multiplying by 0.44/0.6 = 0.733.

A.2 Weibull Analysis

To accurately account for the relative contributions of wind events from different directions, comfort exceedance probabilities were defined using a Weibull distribution. The probability of the wind speed at a certain location, U_i, exceeding a speed, V, for any given direction, θ, is given by:

$$p(U_i > V, \theta) = A(\theta\,)e^{\left[-\left(\frac{V}{C(\theta)}\right)^{k(\theta)}\right]}$$

Here $k(\theta)$ and $C(\theta)$ are Weibull coefficients for the azimuth sector, θ, and $A(\theta)$ is the marginal probability of the wind direction being within the azimuth sector. Therefore, the sum of all the marginal probabilities will be equal to one and the following will hold true:

$$\sum_{all\ sectors} A(\theta) = 1$$

Consequently, the exceedance probability is given by:

$$p(U_i > V) = \sum_{all\ sectors} A(\theta)e^{\left[-\left(\frac{V}{C(\theta)}\right)^{k(\theta)}\right]}$$

The coefficients describing Sydney Airport hourly mean wind speed data, for hours between 6am and 10pm, are shown below in Table B-1.

Table B-1: Weibull coefficients for all 16 assessment directions

Direction	A	C	k
N	0.040	5.106	1.064
NNE	0.068	6.873	1.099
NE	0.097	9.559	1.147
ENE	0.046	8.250	1.149
E	0.040	4.320	1.091
ESE	0.036	4.288	1.083
SE	0.063	4.699	1.130
SSE	0.070	5.427	1.129
S	0.107	6.332	1.125
SSW	0.067	6.281	1.100
SW	0.032	4.618	1.057
WSW	0.049	4.876	1.043
W	0.063	5.222	1.020
WNW	0.068	4.327	1.016
NW	0.101	3.489	1.025
NNW	0.054	4.833	1.036

A.3 Extreme Value Analysis

For analyses involving high return periods, infrequent wind events of high wind speed are considered. Such wind events have been described using a Type 1 Extreme Value Distribution (or Gumbel Distribution) with Gringorten's modification, which models infrequent events more accurately than the Weibull distribution. The probability of the wind speed at a given location, U_i, exceeding a speed, V, for any given direction, θ, is given by:

$$p(U_i > V, \theta) = 1 - e^{-e^{\left[\frac{V - u(\theta)}{a(\theta)}\right]}}$$

Where $u(\theta)$ and $a(\theta)$ are the calculated coefficients for each azimuth sector. The return period for exceedance velocity, V, for each sector is the inverse of the exceedance probability, i.e.:

$$R_\theta = \frac{1}{p(U_i > V, \theta)}$$

The overall exceedance probability for all wind directions is given by:

$$1 - \frac{1}{R} = \prod_\theta \left(1 - \frac{1}{R_\theta}\right)$$

$$1 - \frac{1}{R} = \prod_\theta e^{-e^{\left[\frac{V - u(\theta)}{a(\theta)}\right]}}$$

Therefore, the return period for winds from all directions is:

$$R = \frac{1}{1 - \prod_{\theta} e^{-e^{\left[\frac{V-u(\theta)}{a(\theta)}\right]}}}$$

The Extreme Value coefficients for annual maximum gusts from Sydney Airport, using data for all hours of the day, corrected from a 3-second to 0.5-second gust, are shown below in Table A-2.

Table A-2 Extreme Value distribution coefficients for all 36 assessment directions

Direction	u	a
N	18.34	2.18
NNE	21.77	2.43
NE	25.42	2.92
ENE	21.04	4.46
E	12.69	2.24
ESE	13.32	3.37
SE	14.28	2.28
SSE	15.44	2.16
S	18.79	1.44
SSW	18.18	2.07
SW	16.01	2.00
WSW	16.14	1.98
W	18.09	1.49
WNW	17.95	1.28
NW	16.86	2.12
NNW	20.34	2.40

Appendix B Detailed CFD Methodology

B.1 Numerical Methods

The analysis uses a Computational Fluid Dynamics (CFD) model which predicts fluid flows by mathematically modelling the Reynolds Averaged Navier-Stokes equations; fundamental equations which describe fluid motion. OpenFOAM software was used; its reliability well validated by academic researchers and independent organisations.

CFD simplifies estimates of turbulence, models average flow conditions well and random flow conditions with less accuracy. The turbulence closure scheme used for the modelling in this report was the realisable k-ε model. This model has been extensively validated for urban flows and has been shown to have superior performance for highly separated flows when compared with the standard k-ε model.

B.2 Computational Domain and Meshing

A cylindrical computational domain was used for the analysis. The domain size was selected to allow at least 10h from the extents of significant geometry to the boundary, where h is the height of the tallest building, following COST recommendations. Mesh refinements were made down to a minimum 0.16 m edge length.

B.3 Approach Flow and Boundary Conditions

Accurate CFD simulations require appropriate modelling of conditions at the model boundaries. Of particular importance are the inlet velocity and turbulence conditions, which were modelled using the AS/NZS 1170.2:1989 boundary layer profiles for mean velocity and turbulent kinetic energy. The ground plane roughness was modelled to ensure the boundary layer profile remained constant (neutrally stable) throughout the approach and far-field.

Additional boundary definitions were:

- the top boundary having a shear stress and vertical gradient in epsilon following the recommendations of Richards and Hoxey (1993),
- outflow boundary with zero gradient in pressure,
- side boundaries based on a mixed inlet/outlet condition,
- bottom (ground) boundary as a no-slip wall with wall roughness function applied, and
- building surfaces as no-slip walls.

Wall functions were used to model the viscous sublayer flows near no-slip walls to accurately model wall friction effects. Changes in wind speed with direction were accounted for in postprocessing calculations using Weibull distribution parameters (Appendix A.2).

Appendix C Gust-equivalent Mean Wind Speed Ratios from Individual Wind Directions

Wind speeds presented in the following images are gust-equivalent mean wind speeds, normalised to a reference mean wind speed of 10 m/s at 10 m height.

No scaling has been applied to account for the relative strength and frequency of winds from the different directions.

Wind conditions surrounding the development are shown on a plane at 10 m height and do not represent ground-level wind conditions surrounding the development.

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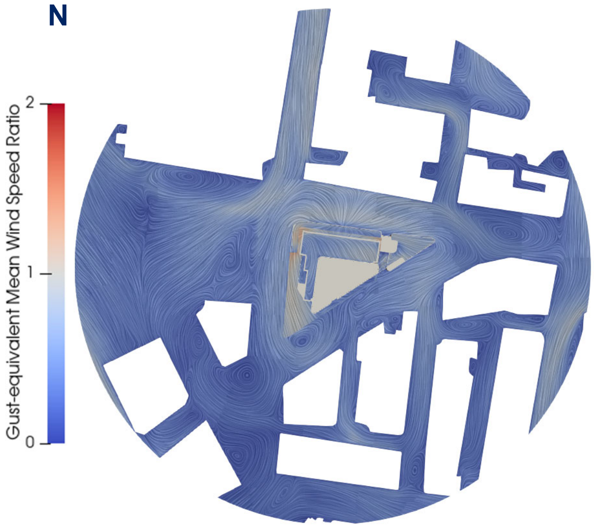

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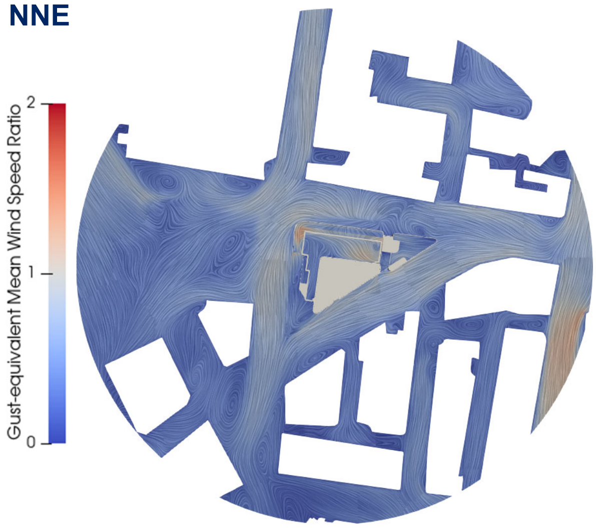

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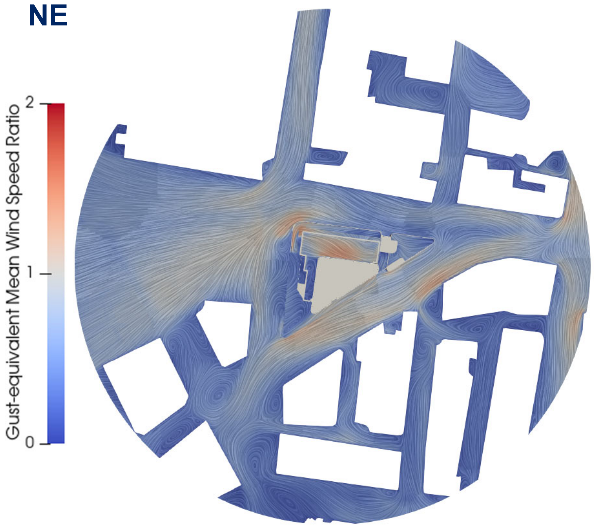

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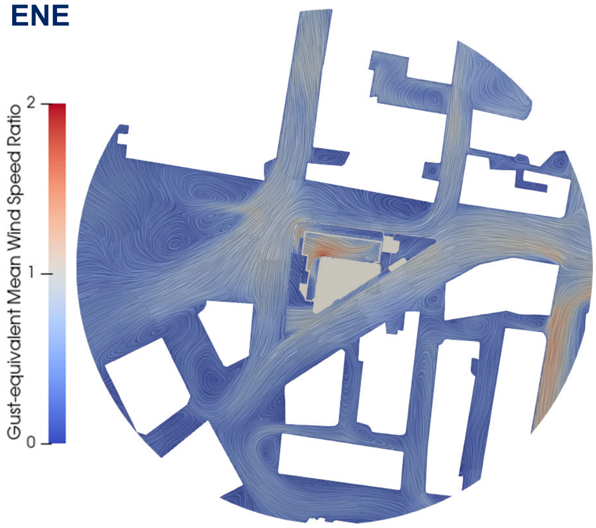

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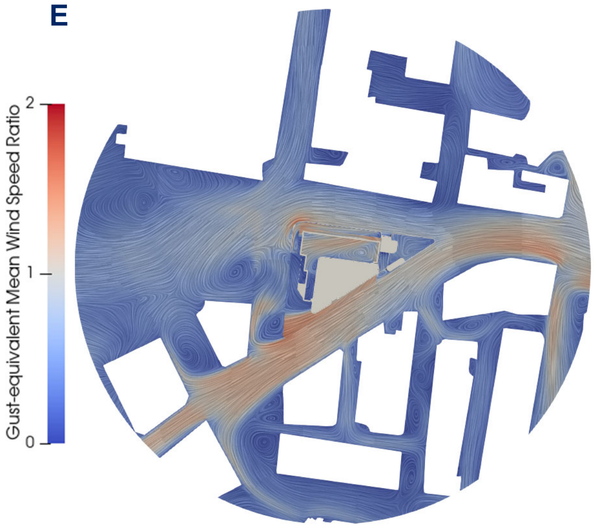

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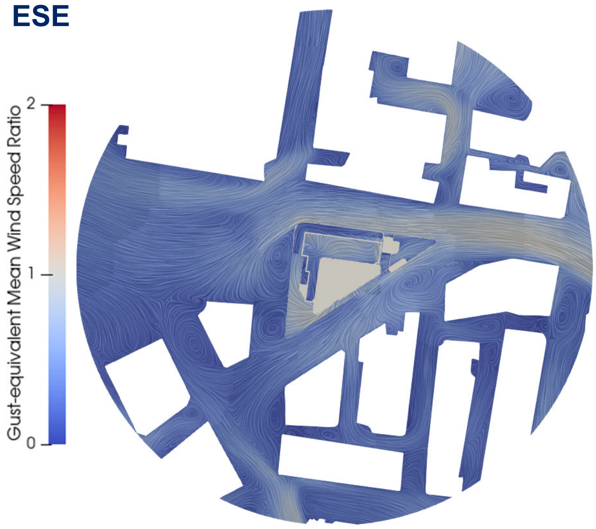

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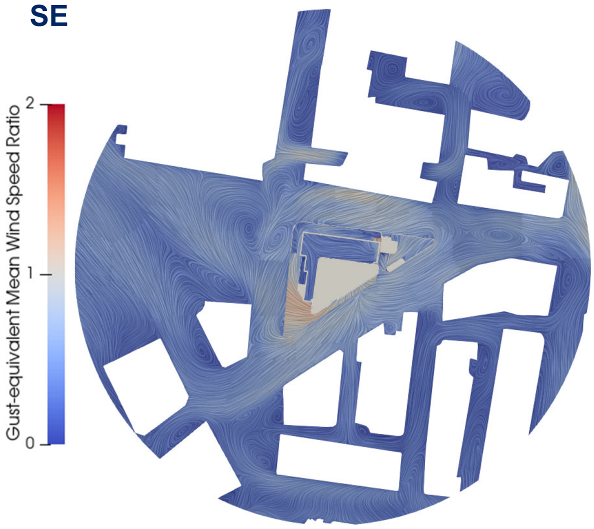

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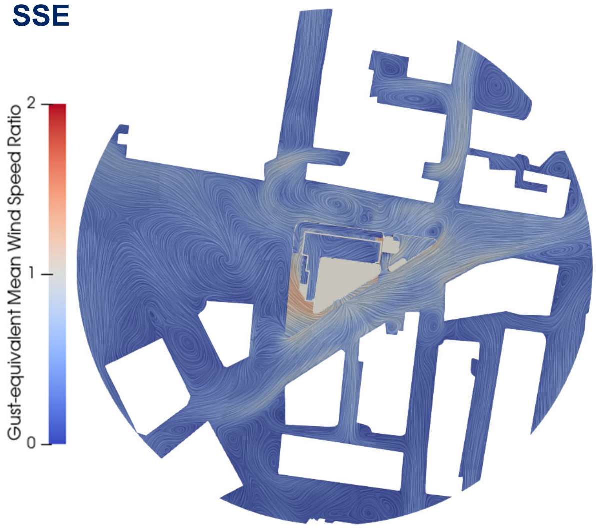

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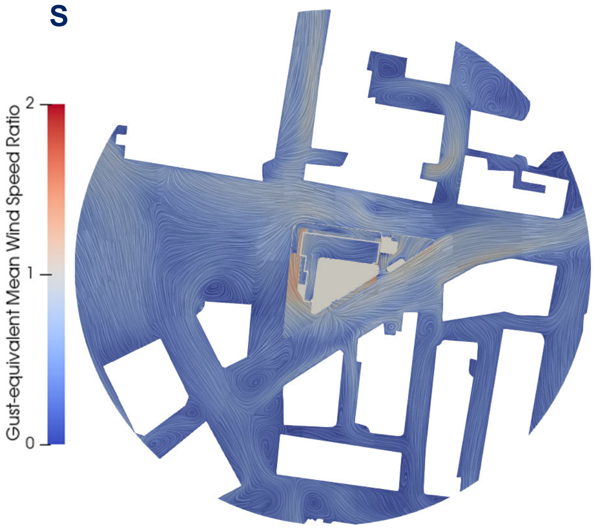

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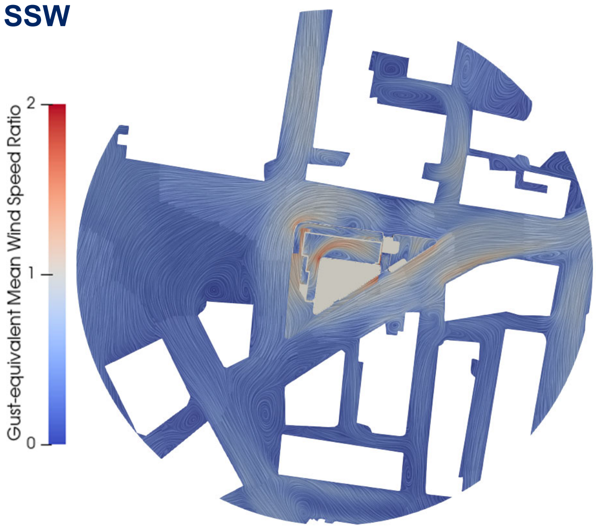

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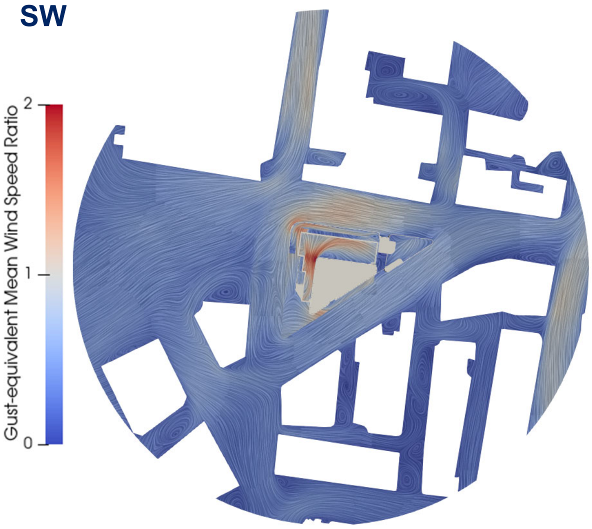

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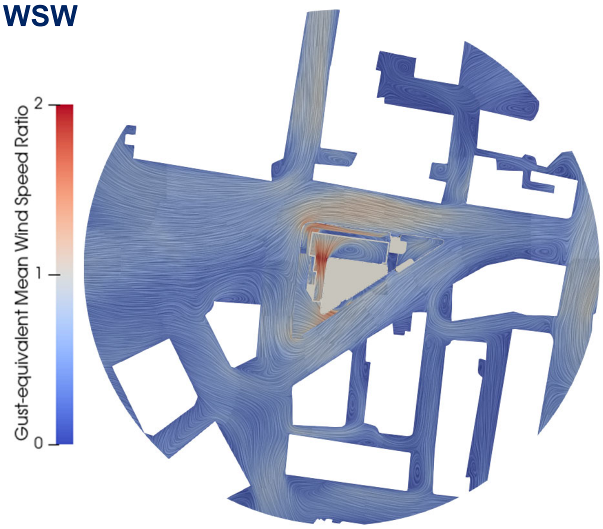

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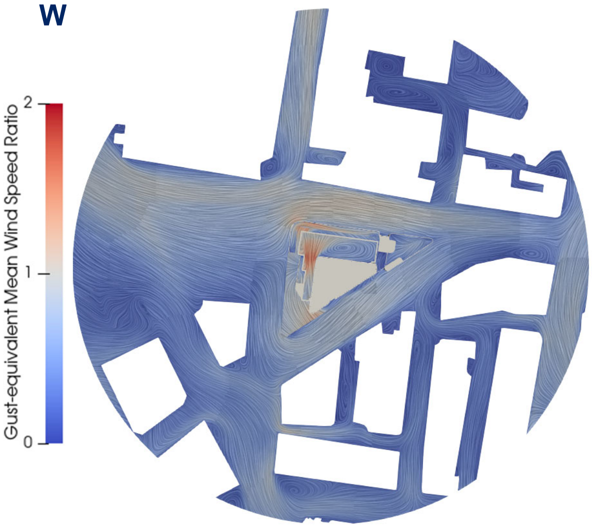

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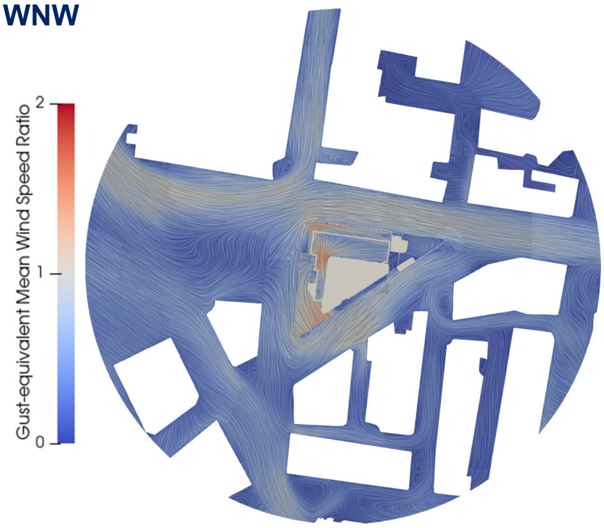

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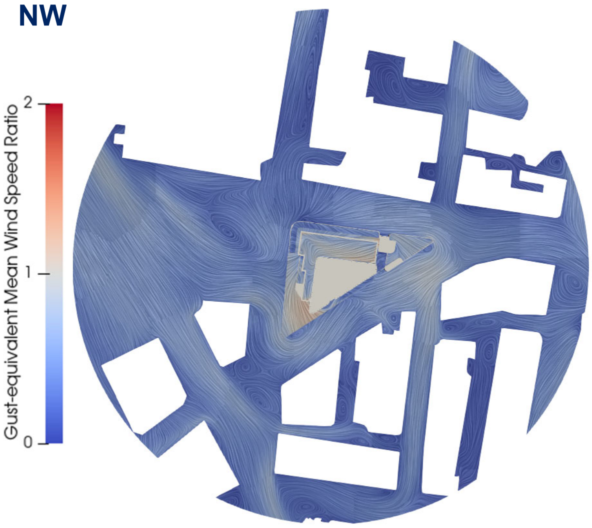

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