CASE STUDY FACT SHEET

ELECTRICITY SECTOR CLIMATE INFORMATION PROJECT

The threat of severe convective winds to transmission lines

Introduction

This Electricity Sector Climate Information (ESCI) case study, undertaken in collaboration with AusNet Services, presents new scientific understanding of the risk from severe convective winds (SCWs), including downbursts, to electricity transmission infrastructure.

The ESCI case studies are designed to demonstrate the choice and application of appropriate climate information for long-term decision-making for the sector and the use of the ESCI Climate Risk Assessment Framework. This case study is also presented as a Summary Case Study Fact Sheet, along with other ESCI Case Study Fact Sheets, on the ESCI portal.

This case study and other case studies from the project can be found at: www.climatechangeinaustralia.gov.au/en/projects/esci/esci-case-studies

Overview

This case study demonstrates how to apply the ESCI Climate Risk Framework (Figure 1) to improve the understanding of exposure of the electricity transmission network to extreme wind.

Figure 1 ESCI Climate Risk Assessment Framework, based on International Standard ISO 31000 'Risk Management' and Australian Standard AS 5334 'Climate change adaptation for settlements and infrastructure'.

The Electricity Sector Climate Information (ESCI) project was funded by the Department of Industry, Science, Energy and Resources (DISER) and was a collaboration between the Bureau of Meteorology (BOM), the Commonwealth Scientific & Industrial Research Organisation (CSIRO) and the Australian Energy Market Operator (AEMO). The ESCI website is at: www.climatechangeinaustralia.gov.au/esci

Australian Government Department of Industry, Science, Energy and Resources

Australian Government Bureau of Meteorology

CSIRO

AEMO

AusNet services

Understand context

The primary goal of this risk assessment is to understand and improve the management of the potential impact of severe convective wind (SCW) events on transmission lines. Severe wind events, often associated with severe thunderstorms, can cause transmission towers to fail, potentially impacting any nearby roads or dwellings. Also, as a consequence, any resulting power supply disruption decreases the reliability of electricity supply to customers.

A recent example of one of these types of events (January 2020) occurred in south-western Victoria (VIC), where downbursts associated with a severe thunderstorm resulted in major damage to transmission lines, and six 500 kV AusNet transmission towers were destroyed (Figure 2). While major power outages were avoided in the January 2020 event[1] and the towers have now been rebuilt, AusNet wanted to participate in the case study to help all network businesses and industry improve their understanding of downbursts and whether that hazard is likely to be influenced by climate change.

Figure 2 Damage to the Mortlake to Moorabool to Heywood interconnector from the 31 January 2020 event. (Source: AusNet)

Stakeholders

Transmission network operators and asset managers are interested in improved information on SCWs that will inform long-term maintenance and upgrade decisions and, given adequate resolution in the modelling, potential investments in transmission line routes.

The Australian Energy Regulator (AER), representing electricity consumers, also shares an interest in understanding this climate hazard because transmission networks are predominantly regulated assets where any large investment or upgrade decisions need to be approved via the Regulatory Investment Test.[2] Other interested stakeholders include AEMO and those who consider the risk of major outages in their network management.

Furthermore, information regarding SCW exposure can help inform the sector-wide discussion on engineering standards through the International Council on Large Electric Systems (CIGRE) where AusNet, along with other transmission network service providers (TNSPs), are reviewing a possible updated consideration of transmission line failure in extreme wind events.

Scope

While the study focused on the MLTS MOPS 500kV line which runs Moorabool terminal station -> Mortlake power station -> Heywood terminal station -> South Australia 500kV line, all transmission networks in the National Electricity Market (NEM) can suffer damage from SCWs, so this work considers current and future exposure over the whole NEM. The aim was to provide the best available information on current regional distribution of SCWs, and to explore emerging science on future exposure.

1 A Macdonald-Smith and S Evans (31 January 2020). 'SA cut off from national grid as Victoria asked to power down' (Financial Review). https://www.afr.com/companies/energy/sa-cut-off-from-national-grid-as-victorians-asked-to-power-down-20200131-p53wel

2 Australian Energy Regulator (2010). Regulatory investment test for transmission (RIT-T) and application guidelines 2010). https://www.aer.gov.au/networks-pipelines/guidelines-schemes-models-reviews/regulatory-investment-test-for-transmission-rit-t-and-application-guidelines-2010

Identifying climate risk

Severe convective wind characteristics

The Australian Bureau of Meteorology (BOM) defines severe wind-producing thunderstorms based on three-second average wind gust speeds exceeding 25 ms^{-1} (90 km hr^{-1}). However, downbursts have been known to produce gusts of up to 63 ms^{-1} in the United States (Fujita and Wakimoto 1981), and up to 43 ms^{-1} in Australia (Richter et al. 2014; Brown and Dowdy 2019).

SCWs are caused by intense thunderstorm downdrafts which upon reaching the surface can lead to a phenomenon known as a downburst, transferring their momentum (as well as background momentum from higher up in the atmosphere) into the horizontal, at which point a downburst is formed and a 'gust front' is observed at the surface (Figure 3). The strength of a downburst depends on environmental factors such as how temperature, moisture, wind speed and direction vary with height, as well as storm morphology and evolution.

Like other convective phenomena such as lightning and hail, SCWs tend to occur during warmer months of the year, with a peak during the late spring and early/mid-summer, noting that cool-season SCWs are possible with major events having occurred during the early spring in southern Australia (BOM 2016).

Severe convective wind gusts that cause transmission tower failure are well below the resolution of global climate models. Therefore, the ESCI team developed a diagnostic which can relate the large-scale environmental conditions simulated by climate models to SCW occurrence (Brown and Dowdy 2021). The new diagnostic can provide information on current SCW risk from climate model data with greater consistency than existing methods for Australia. The diagnostic is based on a combination of established operational weather forecasting methods and statistical modelling.

It is intended that this diagnostic will be applied to climate model projections to estimate future changes in the frequency of environments conducive to SCWs. For this case study, however, results are based on the diagnostic applied to recent decades.

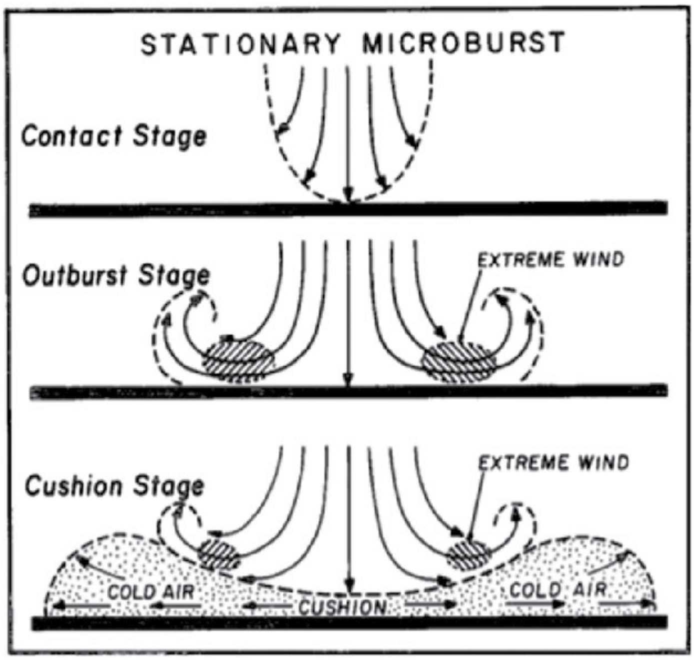

Figure 3 Evolution of a stationary microburst (a small-scale downburst). This includes the contact stage (thunderstorm downdraft reaches the surface), the outburst stage (extreme winds appearing as a gust front at the surface) and the cushion stage (decay of extreme winds with cold air remaining at the surface) (Fujita 1981).

The relationship between severe convective wind environments and tower failure

This case study demonstrates that catastrophic tower failures occur in regions where environments conducive to downbursts occur relatively frequently, these environments have been defined (Brown and Dowdy 2021), and are referred to hereafter as a 'SCW statistical diagnostic'. Figure 4 demonstrates that areas of relatively high environmental frequency (darker blue) are found spatially to correlate (significantly) with 11 historical tower failure events. This 'SCW statistical diagnostic' association with SCWs is a significant advance compared with using the direct wind speed output from available model data to determine SCW hazard (Brown and Dowdy 2021).

In addition, analysis of each individual tower failure event suggests that the statistical diagnostic provides a consistent event-based indication of SCWs. Focusing on the MLTS MOPS 500kV line (Moorabool terminal station -> Mortlake power station -> Heywood terminal station -> South Australia 500kV line), the time-series of the SCW statistical diagnostic is presented for 31 January 2020, which included the loss of the six towers (Figure 2 and Figure 5).

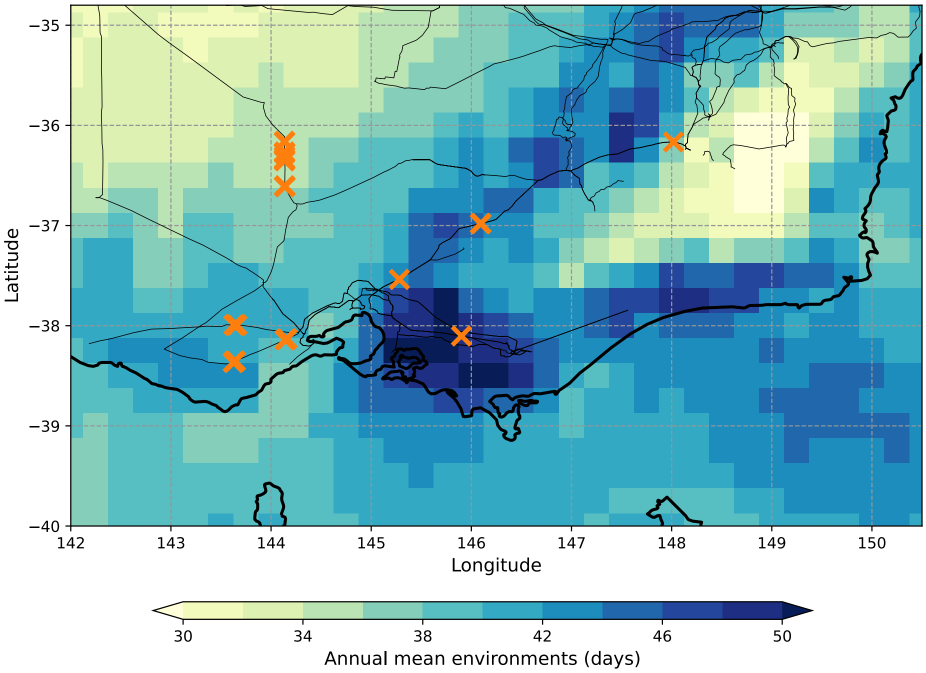

Figure 4 The SCW statistical diagnostic showing annual mean historical environmental frequency of conditions conducive for SCWs greater than 25 ms-1 (averaged over the period 1979–2018) (Source: BOM analysis (Hersbach et al. 2020) with 11 tower failure events, from 1959–2020, indicated (orange 'X'; AusNet Services data))

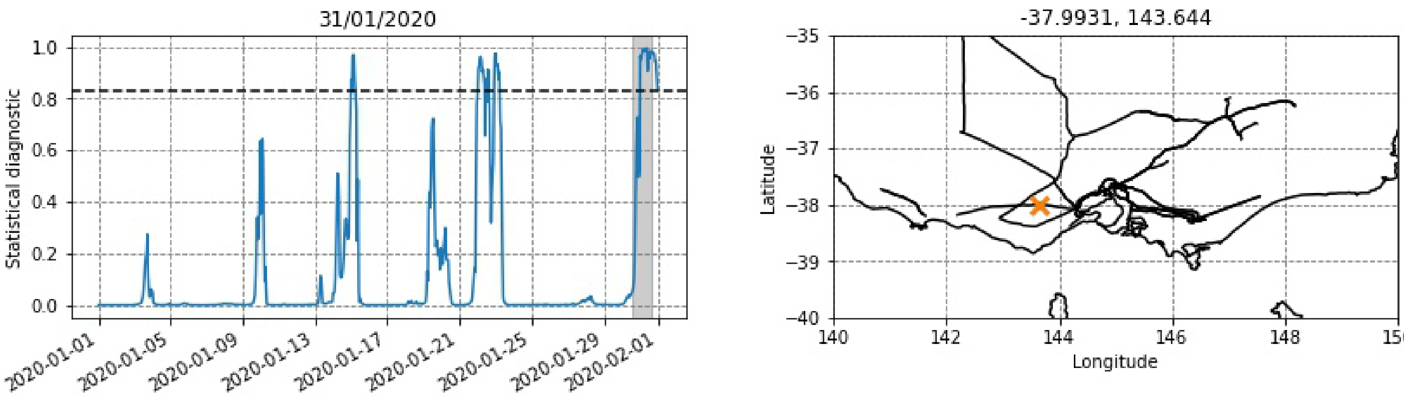

Figure 5 LH plot shows peaks in the SCW statistical diagnostic (above dotted line is considered a risk) in the month including the 31 January event. The shaded area shows the time of the events. The RH plot shows the location of the analysis and the tower failure. (Source: BOM analysis (Hersbach et al. 2020))

All transmission networks in the NEM suffer damage from severe convective winds, so while the focus of the statistical diagnostic for this case study is for the AusNet transmission system in VIC, current and future risk over the whole NEM will need to be considered. The assessment of current wind risk is available for the whole of Australia (Figure 6), with statistical diagnostic maps as indicators of SCW hazard available for all states. These are included in the Appendix and available on the ESCI website.

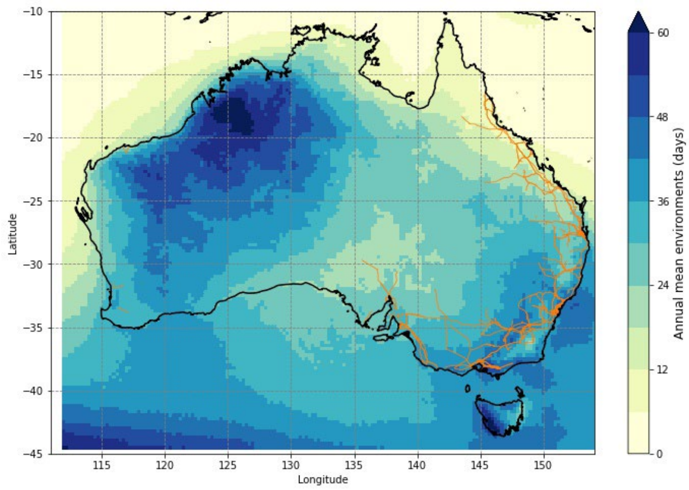

Figure 6 SCW statistical diagnostic for Australia (1979–2018) with transmission lines overlaid in orange. (Source: BOM analysis)

Limitations including fine-scale aspects of severe convective winds

It is important to note that the highly localised nature of SCWs means that a downburst may occur where the SCW indicates high risk, but without impacting a transmission tower. Also, conditions may be conducive for SCW, but a thunderstorm may not develop. Both limitations result in a high false alarm rate. False alarms appear to occur between two and seven days per month based on analysis of failure events at point locations (shown, for example, by unshaded peaks in Figure 5).

Although the SCW statistical diagnostic indicator approach described and applied as part of this case study is useful for long-term analysis of SCW environments, its application for the energy sector has limitations. For example, the gust direction is relevant for wind loadings on structures, but is currently not included in this method. In addition, topographic interactions with downbursts, as well as the height above ground level of the maximum gust caused by thunderstorms is not considered here. Furthermore, this analysis is restricted to identification of environments associated with SCW occurrence, broadly defined by a threshold of 25 ms^{-1} at a height of 10 m, and is not able to provide indications of downburst intensity.

Analyse future climate risk

In some cases, the direction and/or magnitude of future changes can be estimated through extrapolation of current trends. Analysis of 40 years (1979–2018) of data across the NEM suggests no significant trend during summer for the frequency of days indicated by the statistical diagnostic, with potential regions of decreased risk indicated for some inland locations. Trends differ for other seasons, but as the majority of SCWs in Australia occur in summer and impact on the NEM is likely to be higher, the analysis focuses on this season. Although this study uses the best available observational information on SCWs, considerable uncertainties remain, and important factors are not included in the diagnostic method (such as mechanisms that initiate thunderstorm formation, which may also change in a changing climate).

Evaluate future climate risk

The statistical diagnostic will be used to analyse potential future changes in frequency of SCW events, but this work is not yet complete.

Risk treatment—brief discussion of adaptation options

Improved characterisation of SCW exposure can be helpful for long-term planning of maintenance and line routes and may contribute to changes in engineering standards to improve the reliability of the system (see sidebar on current engineering standards).

Risk mitigation/management options for TNSPs may (where assessed as necessary and appropriate) include one or more of targeted monitoring, maintenance, de-rating, emergency preparations and primary equipment solutions. Primary equipment solutions may include one or more of the following:

- add strain structures
- reinforce towers
- add intermediate structures to divide wind-span
- tower replacement

System/societal adaptation options may include, for example, new lines on alternative routes, local generation for demand centres and stand-alone power systems.

The solution will, in each case, depend on cost–benefit analysis informed by relevant factors, including physical assessments of asset condition, remaining service potential and failure rates, risk of bushfire ignition and health and safety, and tolerance of residual risk. Economic factors also contribute to the cost–benefit analysis, including the risk of collateral damage, and market impact valued using standard metrics such as the Value of Unserved Energy (VUE).

For further information

High-resolution maps of the diagnostic used in this case study are available from the ESCI portal. ESCI can provide the maps on the base grid of 0.05 degrees throughout Australia, as shown in Figures 4 and 6.

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Engineering standards

Transmission lines are built to the engineering standards of the time, which means that the oldest transmission lines may have lower tolerances. Maintenance and upgrades consider several factors, including exposure, history of failure and physical condition of the tower, but generally towers are not systematically upgraded to today's engineering standards.

The relevant engineering standard is AS/NZS 1170.2:2011, which requires transmission lines in Victoria to resist 0.2 s wind gusts of 43 m/s . AS/NZS 1170 divides Australia into eight wind zones of which three delineate a coastal standard for a narrow region north around the coast from central Western Australia to southern Queensland. The rest of Australia is divided into two broad regions and a narrower one over the Great Dividing Range. While some consideration is given to terrain and topographical conditions using recommended multipliers, the standard generally assumes regional wind speed to be uniform.

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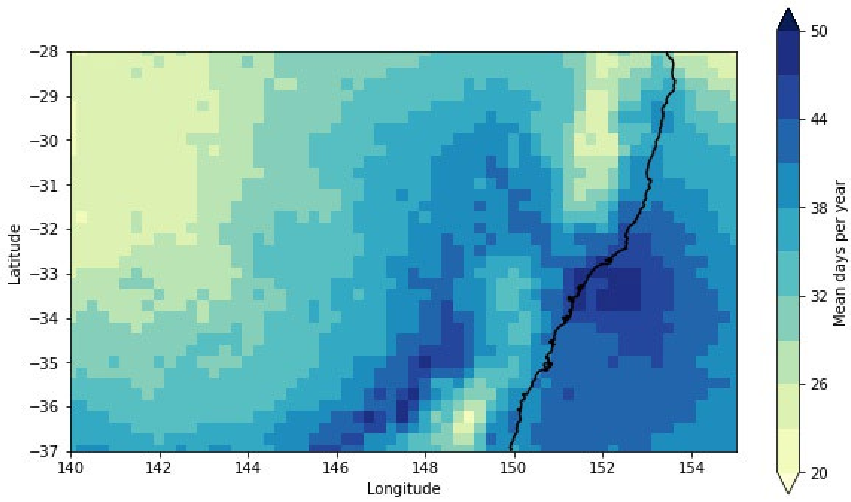
Appendix: Annual mean SCW environment days using the statistical diagnostic for all States comprising the NEM

NSW



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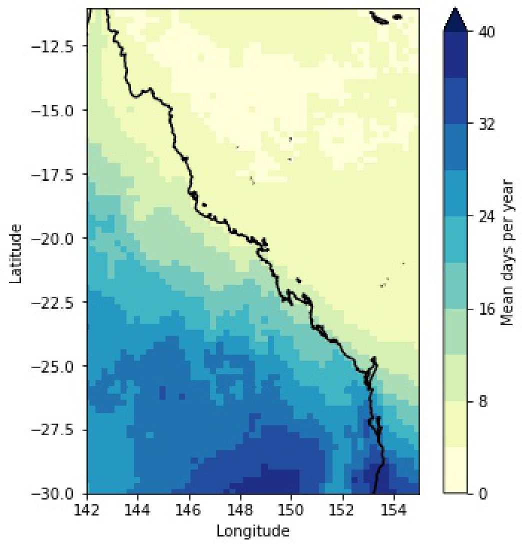

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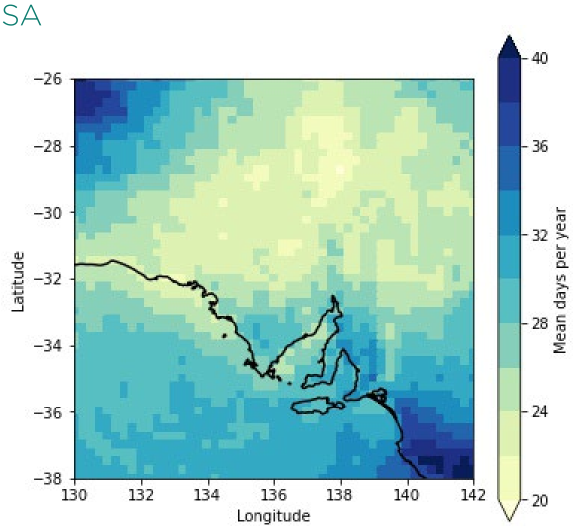

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