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Future climate projections of severe convective wind events from a convection-permitting regional climate model (BARPA)

Joint annual R&D Workshop and 6th Momentum Partnership Convective Scale Workshop

Session 11 – Regional km-scale climate modelling

Andrew Brown
ARC Centre of Excellence for Climate Extremes, University of Melbourne

With thanks to Andrew Dowdy, Todd Lane, Chun-Hsu Su, Christian Stassen, and Harvey Ye

Introduction

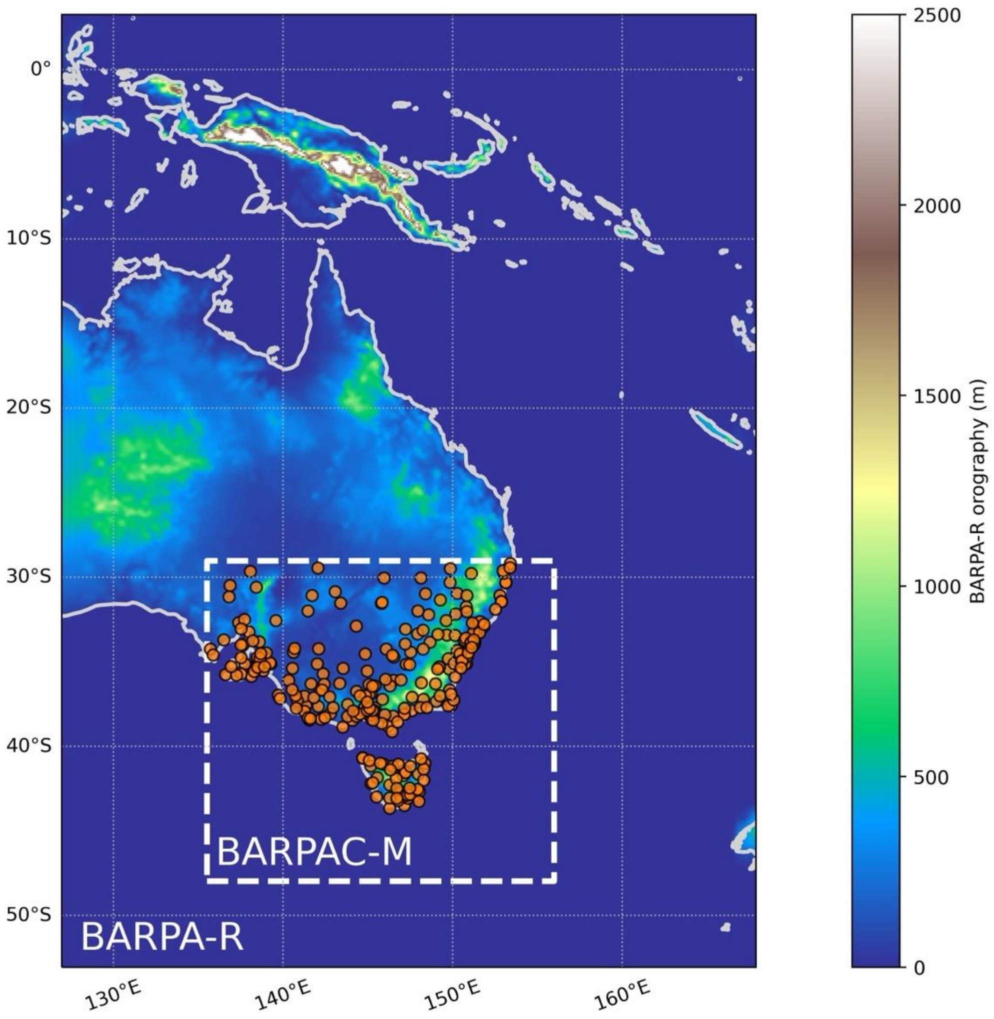
- This work uses km-scale regional climate model data (BARPA-C) to investigate potential future changes in severe surface wind events associated with convection.
    - ‘Severe’ defined by a 10 m wind gust greater than 90 km/hr.
- This includes an investigation how accurately BARPA-C can represent the observed extreme wind distribution, with a focus on severe convective events.
- These severe convective wind events (SCWs) are generally driven by downdrafts associated with convective precipitation.
- SCWs can occur on a range of spatial scales (sub km-scale to 10s of kms) and can cause significant damage, including to power networks.

@abchobart @DrewC593

Jason South via SMH: 13th Feb in Western Victoria

BARPA-C

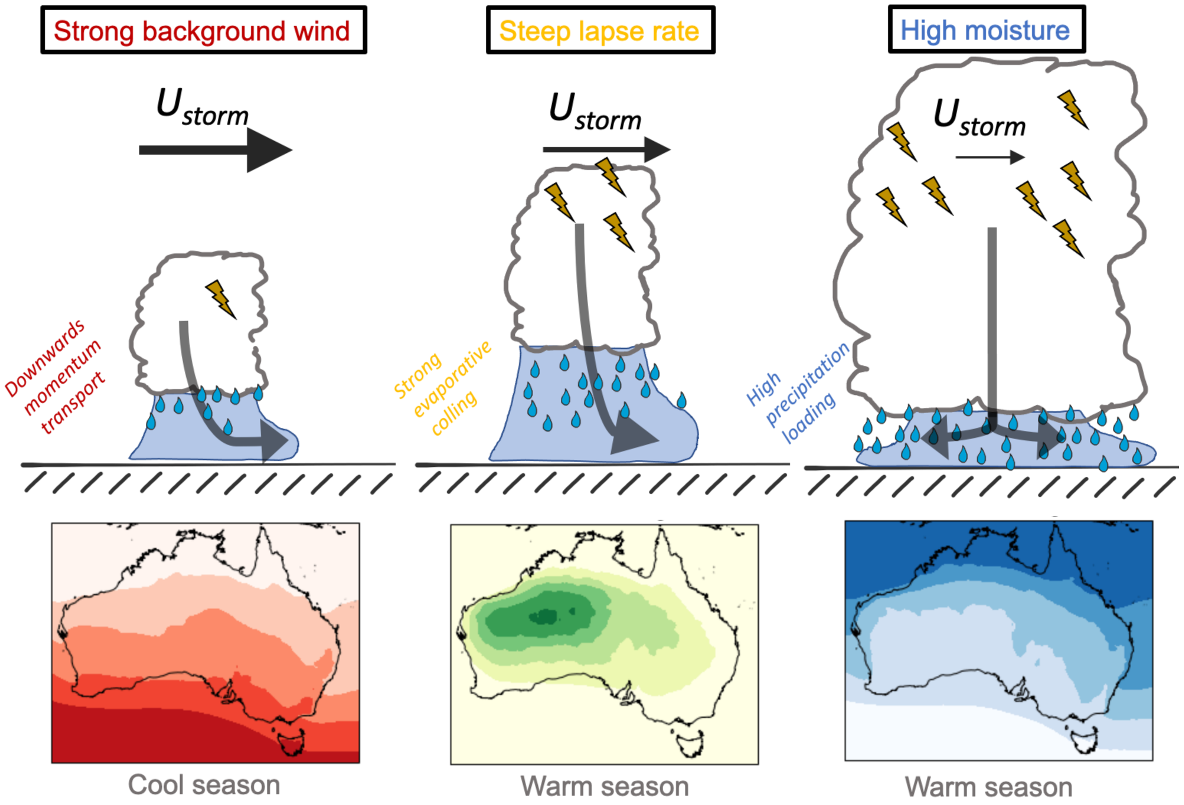
- We use BARPA data from a trial run (Su et. al 2021)* that was developed as part of the Electricity Sector Climate Information (ESCI) project.**
- This includes two nested model configurations:
  - BARPA-R with 12 km grid spacing, parameterised deep convection.
  - BARPAC-M with 2.2 km grid spacing, no convective parameterisation.
- Model evaluation and future projections are based on parameterised surface wind gust data during summer periods, with three large-scale forcings available:
  - ERA-Interim (1990-2015).
  - ACCESS1-0 CMIP5 historical (1985-2005).
  - ACCESS1-0 CMIP5 RCP8.5 (2039-2059).
- We evaluate the BARPAC-M and BARPA-R daily maximum wind gust distributions against gust observations from AWS (3-second average wind speed).



** Different to more recent versions of BARPA. See BRR 057*
*** https://www.climatechangeinaustralia.gov.au/en/projects/esci/*

Types of SCW events

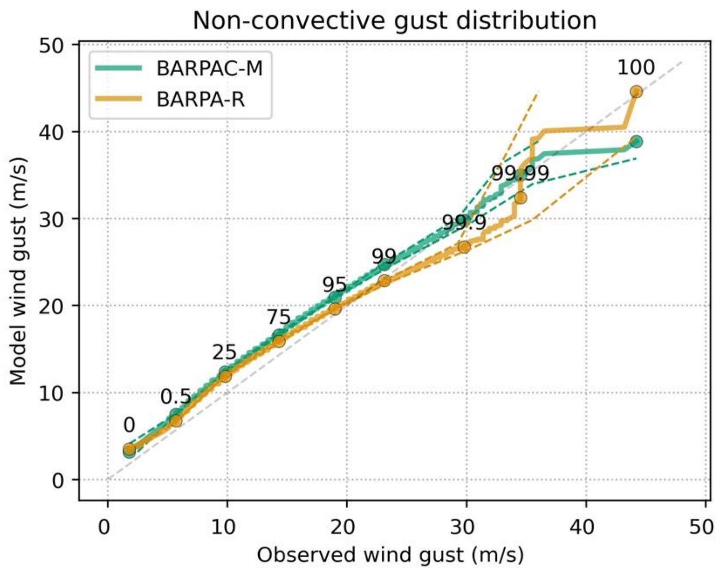
- SCWs can also occur due to several different convective processes in a range of atmospheric environments
- In previous work, we defined three types of SCWs based on historical observations in Australia
- These SCW event types are based on statistical clustering of large-scale atmospheric variables:
    1. Low-level temperature lapse rates
    2. Near-surface moisture
    3. Deep-layer vertical wind shear
    4. Deep-layer mean wind speed
- Some of the BARPA-C evaluation and projections will be done with respect to these event types, based on clustering of the large-scale environment applied to BARPA-R



Spatial data from ERA5, broadly intended to represent where each type of event occurs.
See Brown et al. (2023) in Monthly Weather Review and Weather and Forecasting for further details on clustering methods.

BARPA model evaluation

- We compare the daily maximum wind gust intensity distribution between both BARPA configurations and AWS observations, across all site locations over 11 summers
- Done separately for convective gusts and non-convective gusts
- For non-convective gusts (i.e., long-duration events associated with large-scale winds), both models realistically reproduce the observed distribution



BARPA model evaluation

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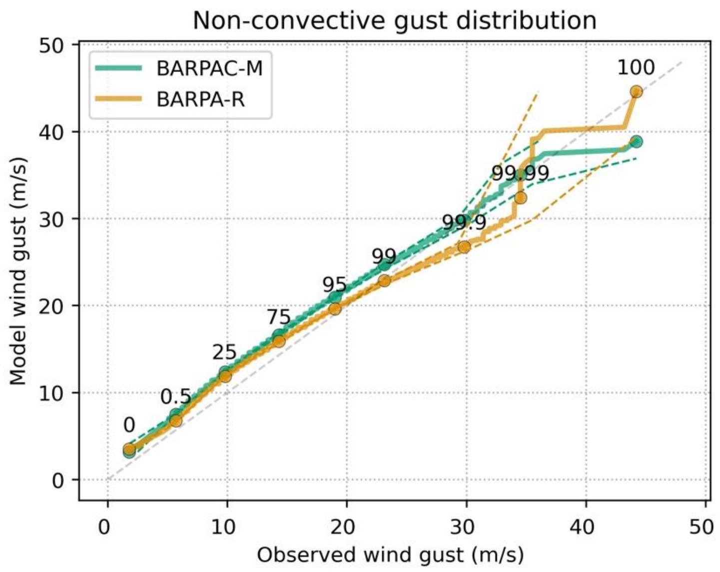
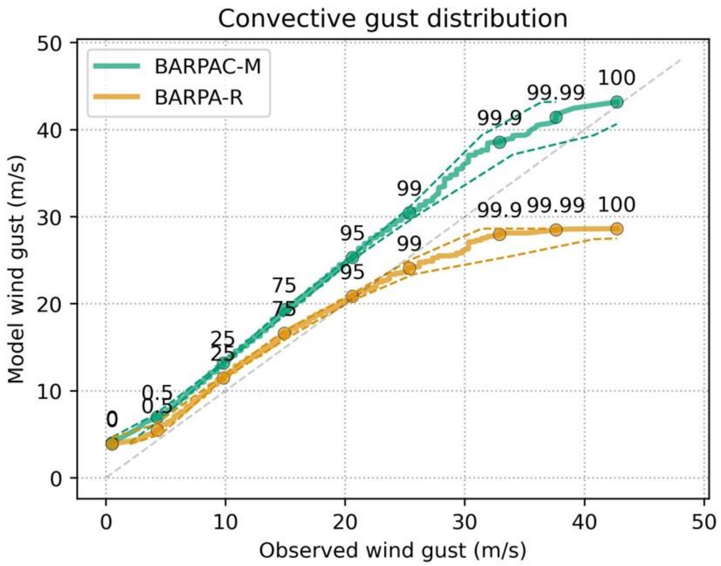
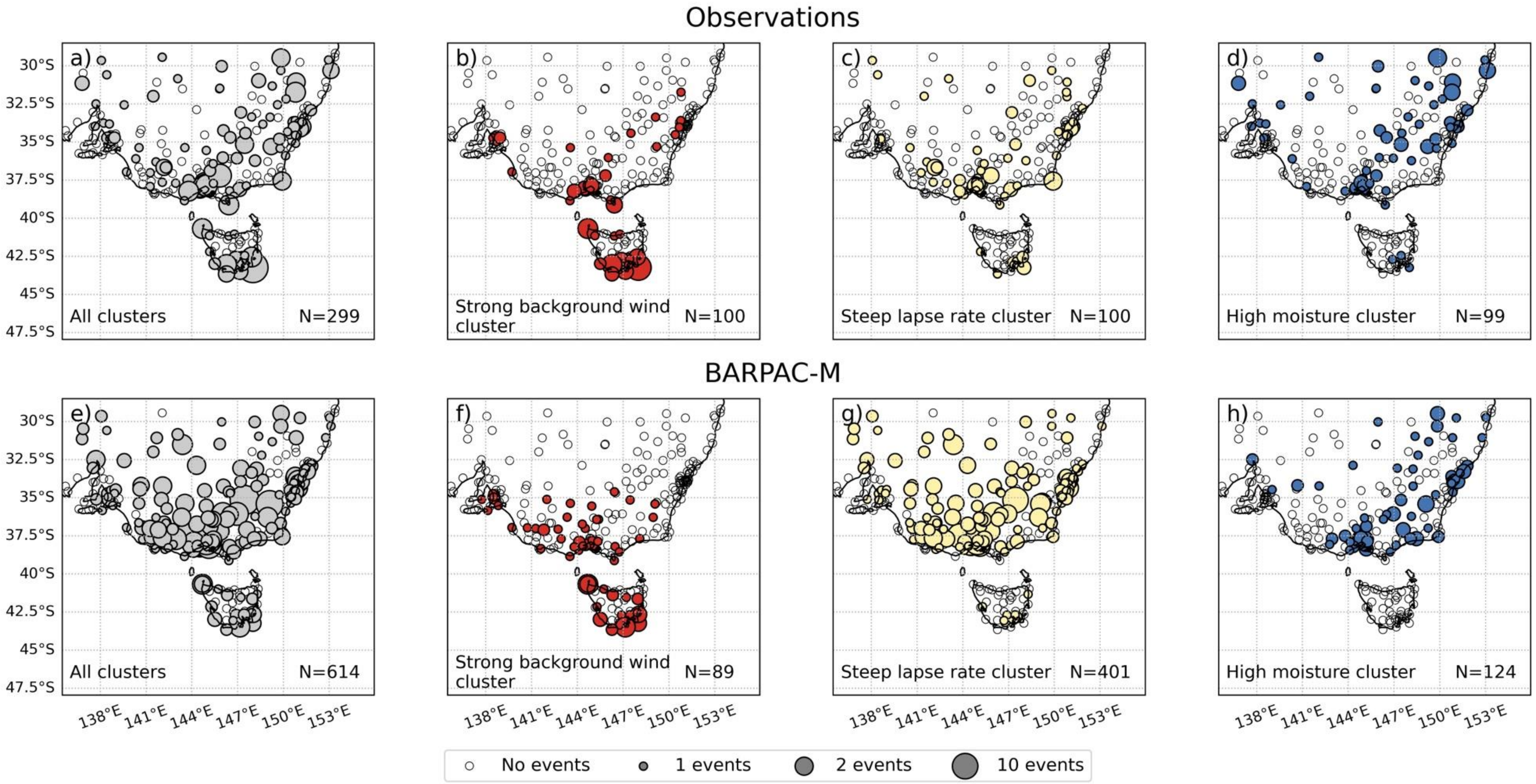
- For non-convective gusts (i.e., long-duration events associated with large-scale winds), both models realistically reproduce the observed distribution
- For convective gusts, BARPA-R cannot reproduce the observed upper tail (above 25 m/s or 99th percentile)
- In contrast, BARPAC-M can produce SCWs above 25 m/s due to partially simulating convective processes, but with a high bias
- **So BARPAC-M adds value by representing the upper tail related to SCWs, although still with significant biases**





BARPA model evaluation

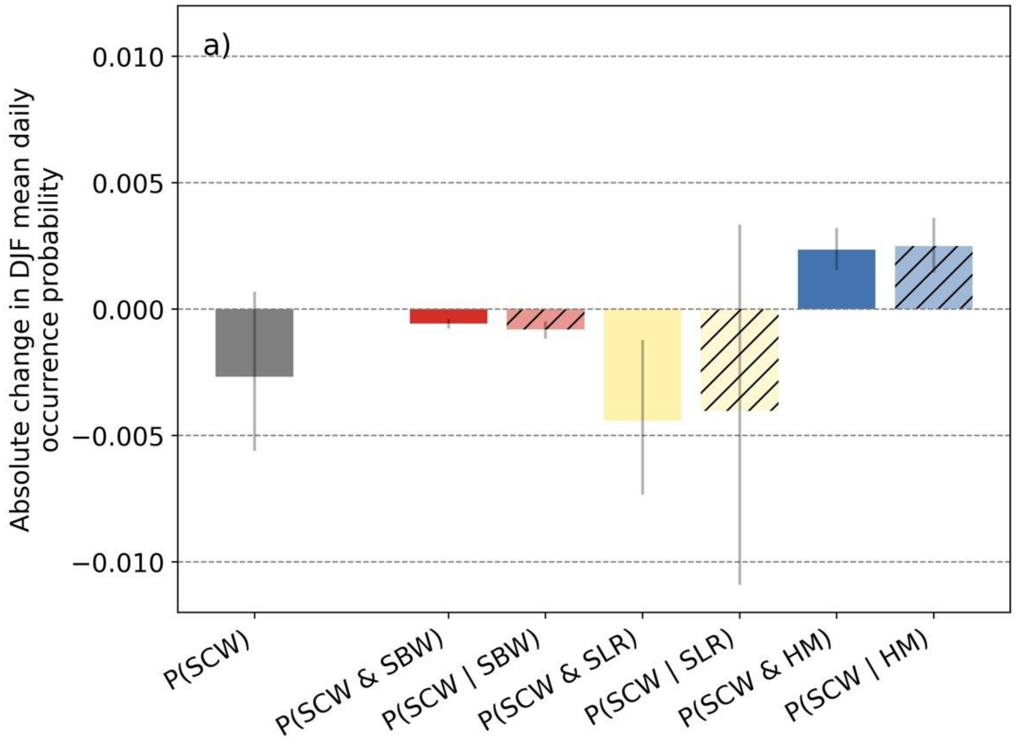
- We can then count the number of SCWs in BARPAC-M (convective gusts exceeding 25 m/s), and compare this with observations at AWS locations
- Done separately for each SCW event type, as defined previously



Future projections

- We also count the number of SCWs across the whole domain, and analyse the change in mean occurrence probability between the historical and future simulations forced by ACCESS1-0
- BARPAC-M indicates a decrease in strong background wind events and steep lapse rate events, and an increase in high moisture events, with an overall **decrease** in event occurrences
- However, this may be influenced by a bias for too many steep lapse rate events

Future change in simulated events (BARPAC-M)



Conclusion

- BARPAC-M provides an improved representation of the observed extreme wind gust distribution due to explicitly representing convective processes (compared with BARPA-R)
- However, BARPAC-M appears to produce too many SCW events, especially in environments with steep low-level temperature lapse rates
- This is potentially consistent with some studies that have found a tendency for convection that is too frequent/intense in some versions of ACCESS/UM (e.g. Bergemann et al. 2022, QJRMS)
- These biases also appear to strongly influence future climate projections of SCWs, given that there are different event types in this region with varying sensitivities to future climate forcing

Brown, A., Dowdy, A., and Lane, T. P.: Convection-permitting climate model representation of severe convective wind gusts and future changes in southeastern Australia, EGUsphere [preprint, accepted for publication in NHESS], https://doi.org/10.5194/egusphere-2024-322, 2024.

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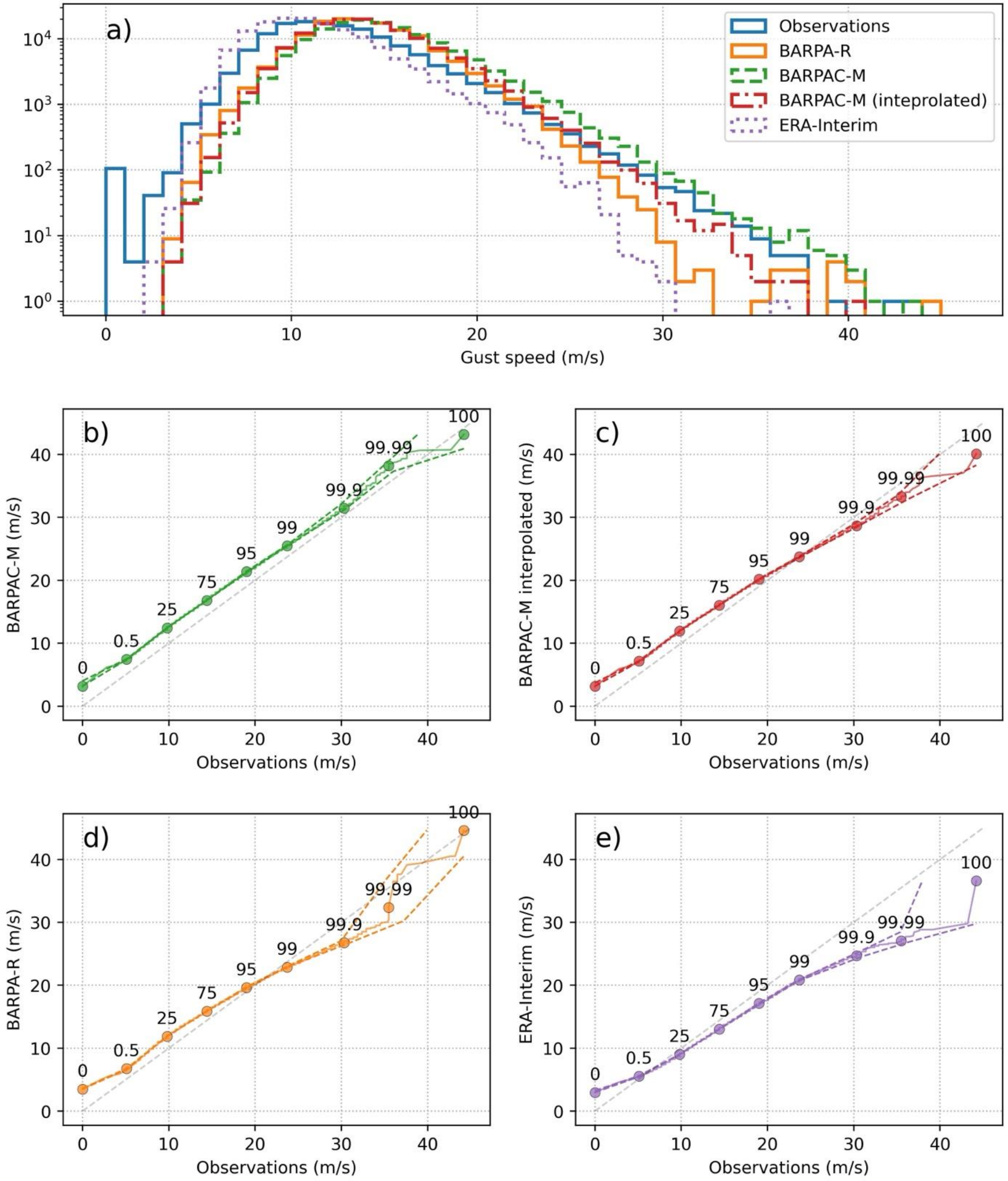
Supplementary slides

Wind gust distributions



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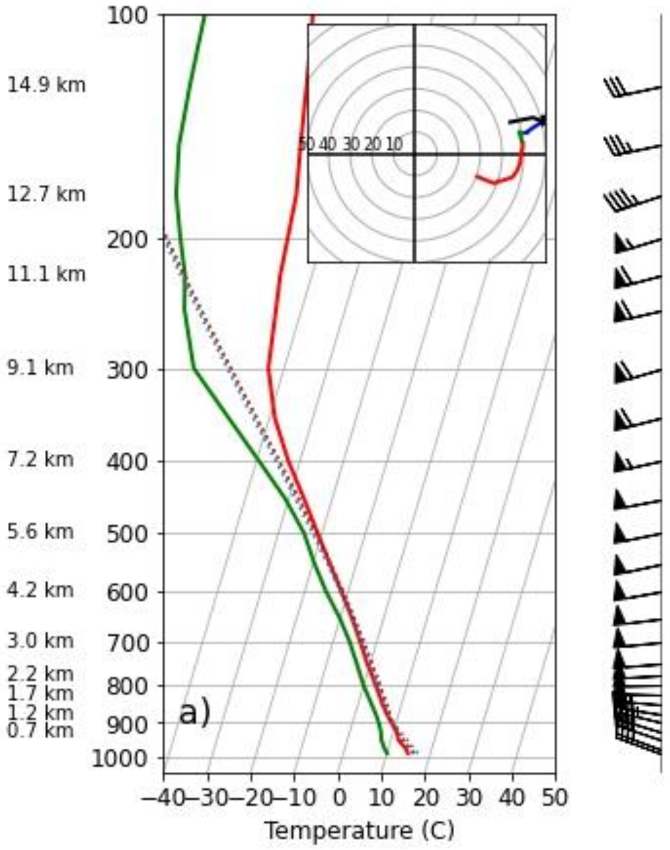
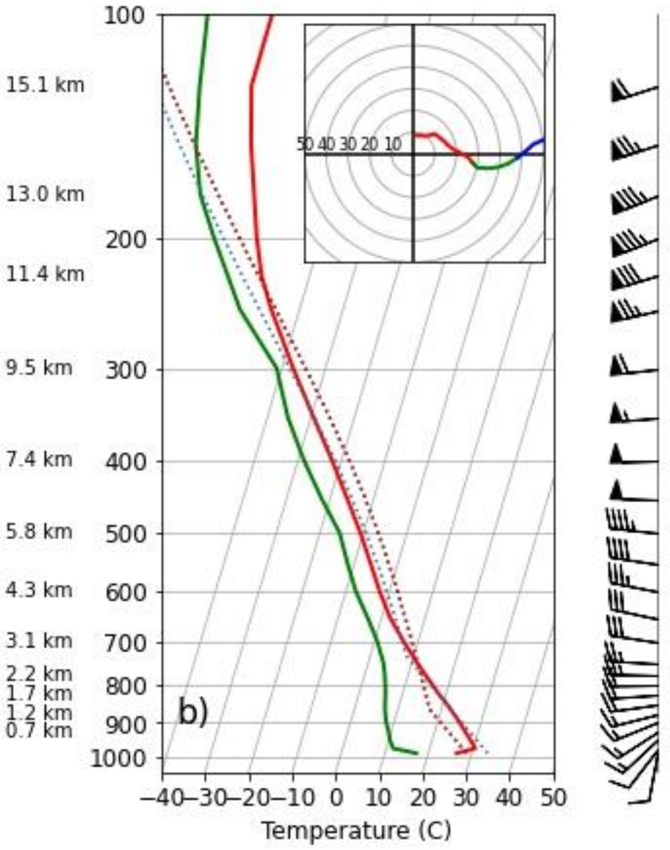
Inverted-V and steep lapse rates

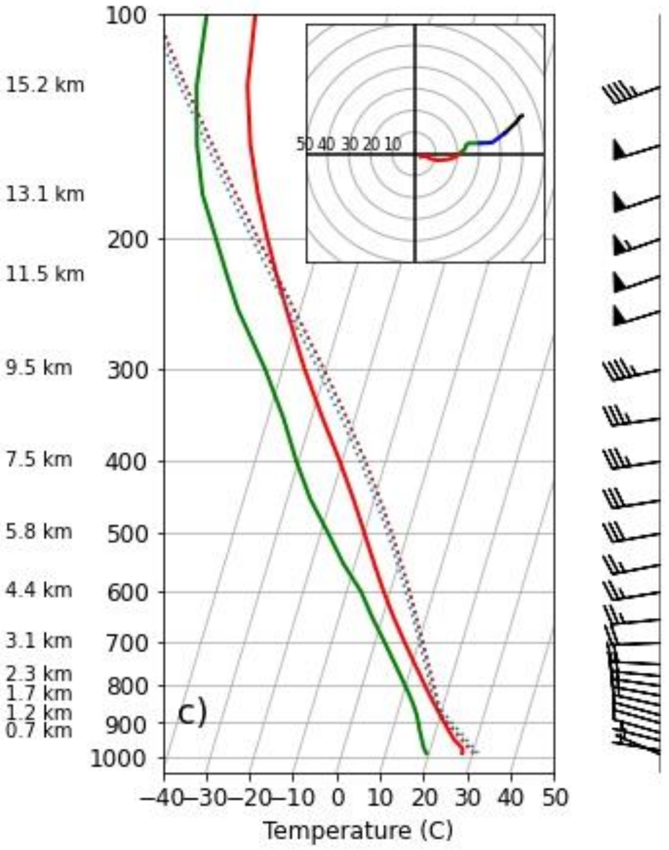
Cluster 1:
Strong winds near surface



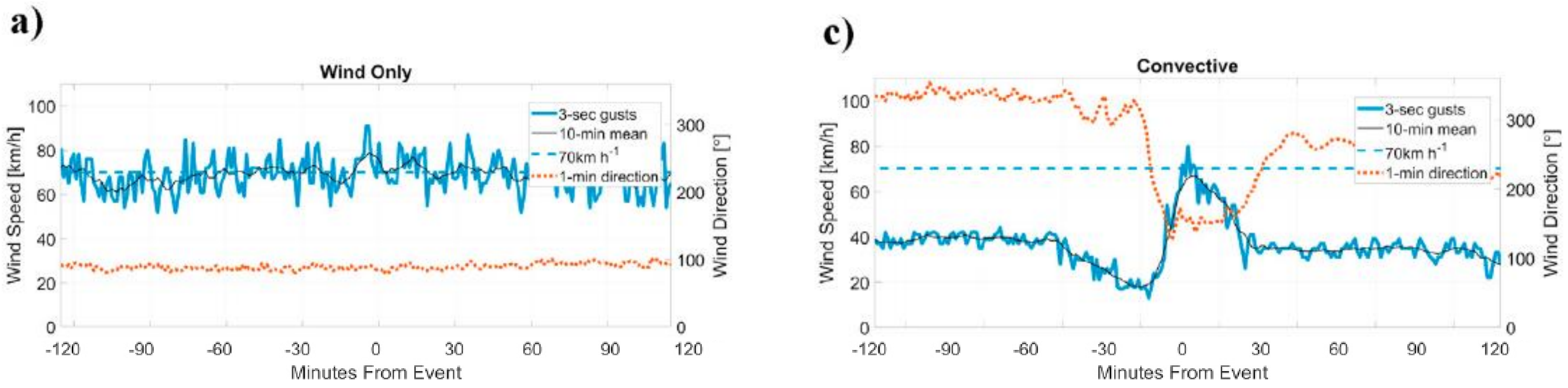
Cluster 2:
Inverted-V sounding favourable for downbursts



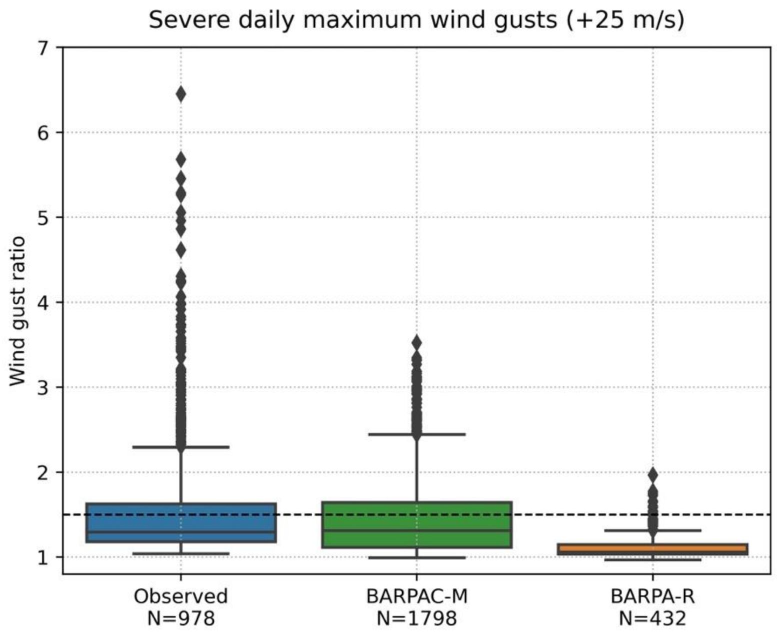
Cluster 3:
High CAPE leading to deep convective storms



Wind gust ratio

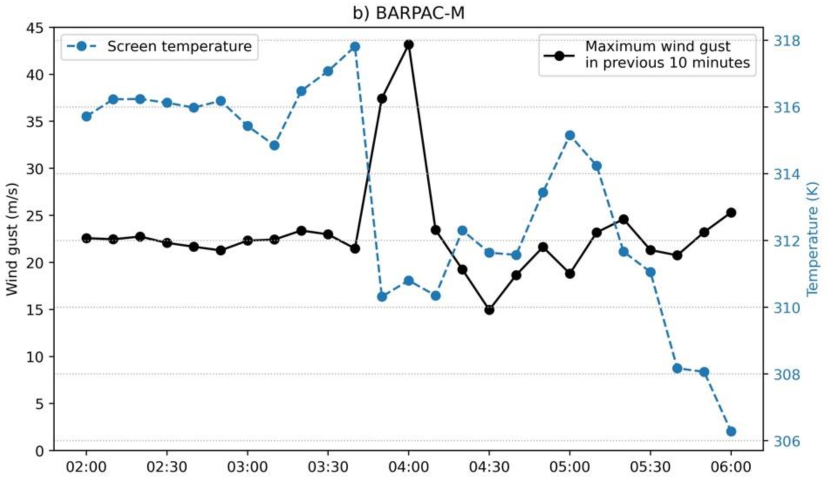


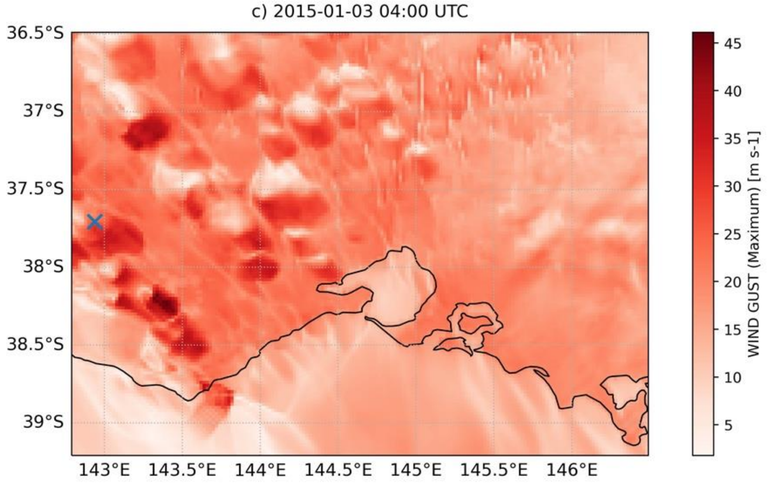
Spassiani and Mason (2021). Journal of Wind Engineering and Industrial Aerodynamics



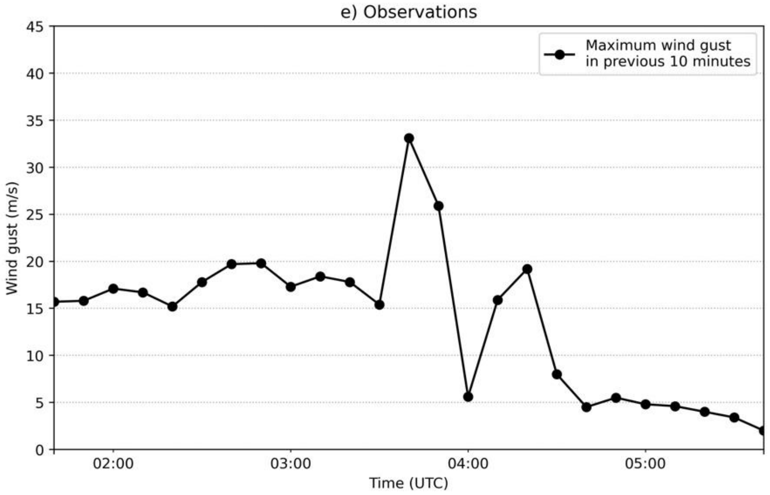
Convective wind event example

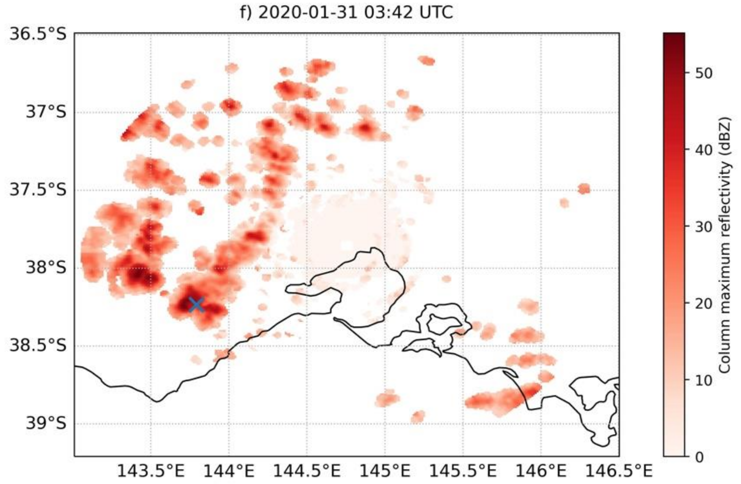
BARPAC-M SCW event





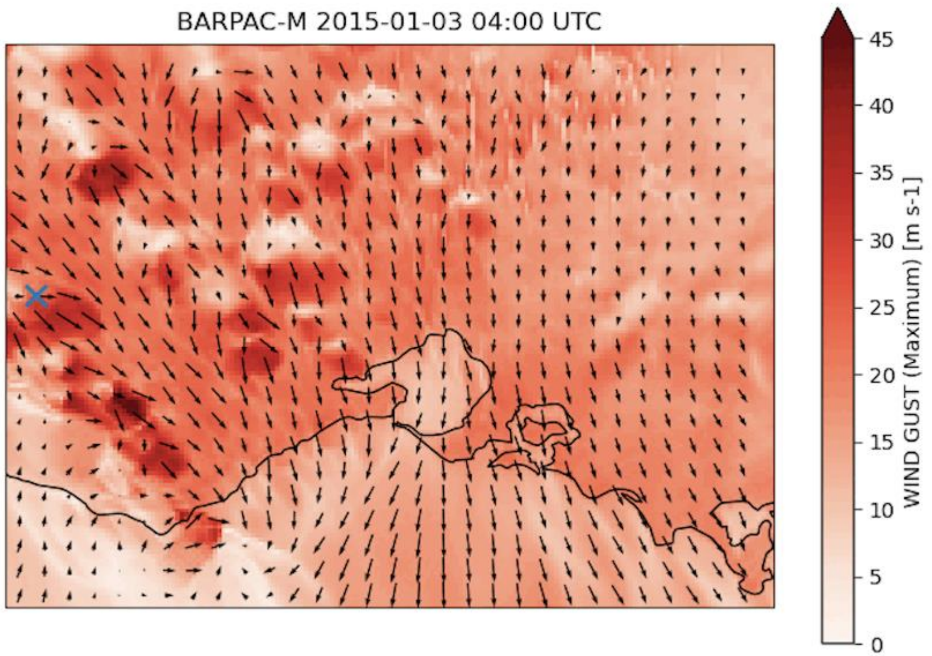
Analogous observed SCW event



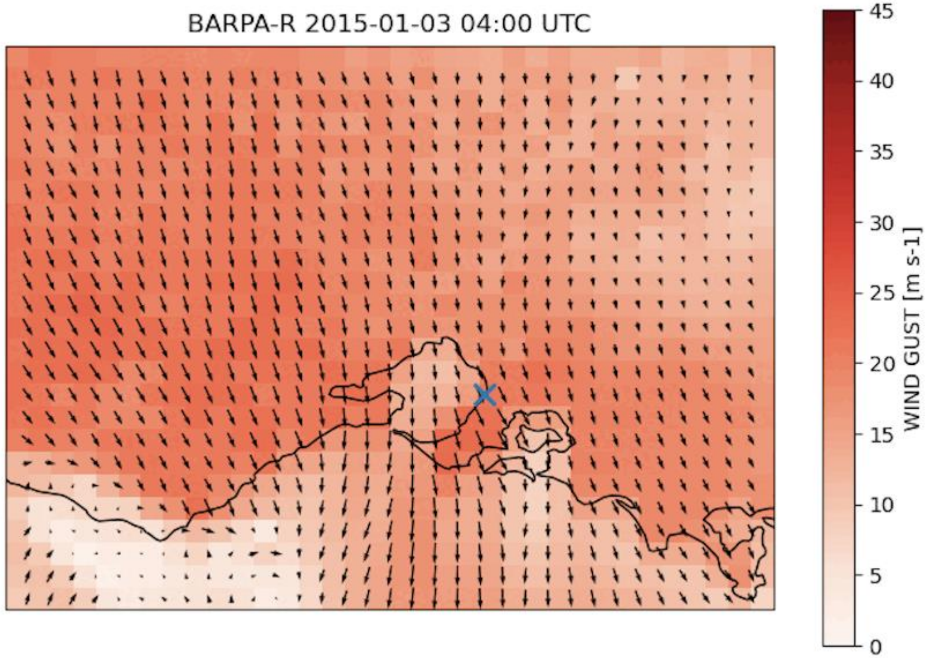


Convective wind event example

BARPAC-M SCW event



At the same time for BARPA-R



Types of SCW events: Convective storm morphology