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Global expansion of destructive tropical cyclones

Hamish Ramsay, James Kossin, Matthew Mason

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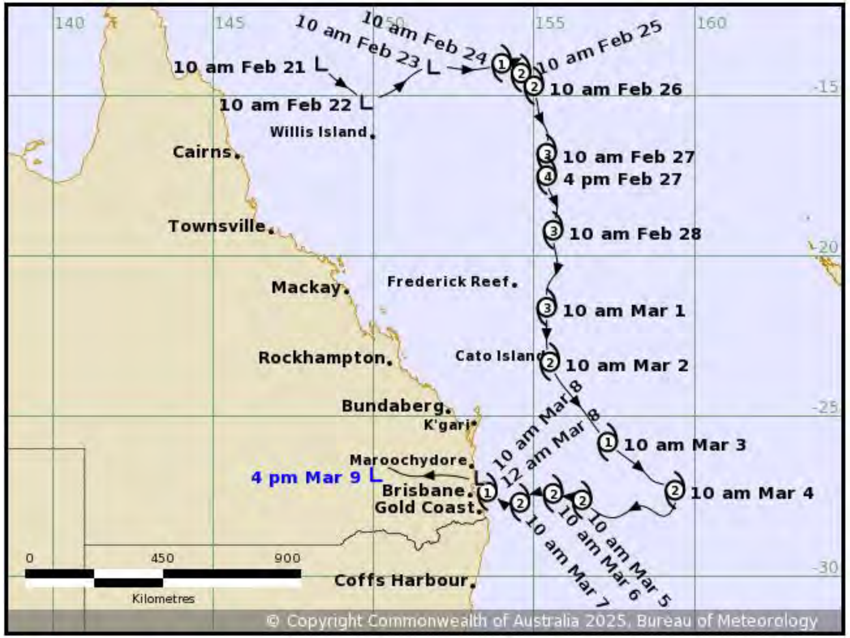
Australia's National Science Agency

Motivation

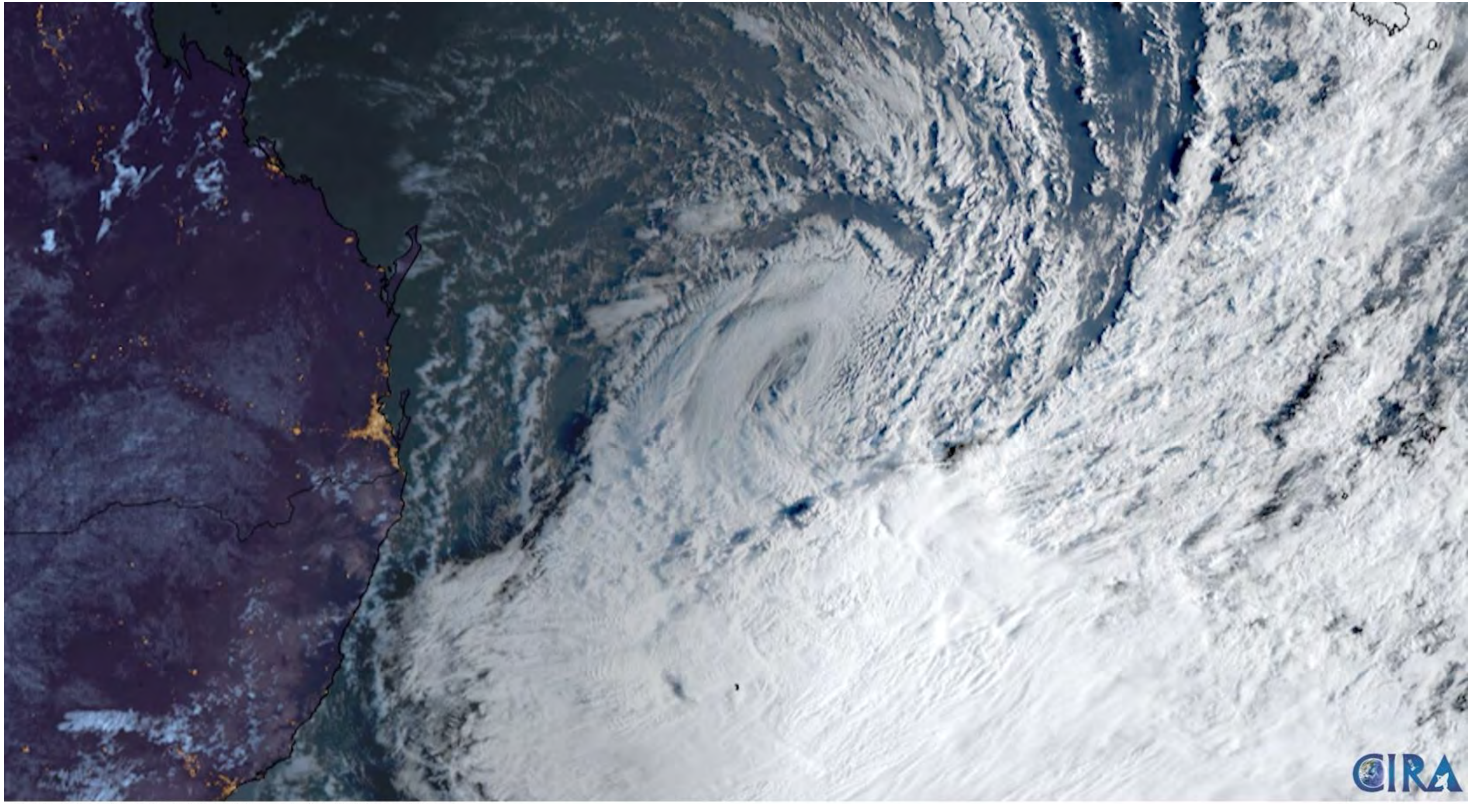
- Past studies have shown pronounced poleward trends in the latitudes of TC peak intensity
- Risk posed by TCs moving into “non-cyclone” zones is a major concern for many sectors
- Greater uncertainty compared to other projected TC changes (e.g., increased rainfall, intensity)
- Buildings in “non-cyclone” zones are typically not designed to withstand TC winds, putting them at considerable risk of failure

Tropical Cyclone Alfred (February 2025)



Source: Bureau of Meteorology

Tropical Cyclone Alfred (2025)



2025-03-03 | 20:00 UTC | Himawari-9 | AHI | GeoProxy

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Tropical Cyclone Alfred (2025)

Total cost estimated at $1.7 billion AUD

Largest loss of power in Queensland's history

7-day rainfall > 1 m, record 12.34 m wave measured at Gold Coast

'Rare' Tropical Cyclone Alfred bears down on Australia's east coast

Millions are bracing for impact of first cyclone to hit Queensland and New South Wales since 1974.

Cyclone Alfred heading toward Brisbane and eastern Australia for rare landfall

Alfred is forecast to make landfall near Brisbane, the capital of Queensland and Australia's third largest city.

March 6, 2025

Thousands Told to Evacuate as Australia Braces for Powerful Cyclone

The slow-moving tropical storm, named Alfred, is on track to bring dangerous winds and flooding along the coast of Queensland and New South Wales, including Brisbane.

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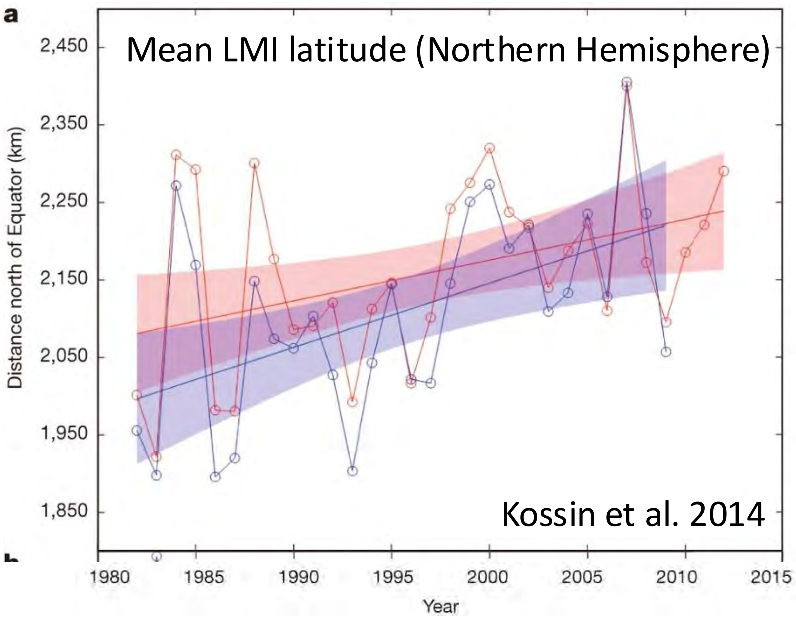
Latitude of TC peak intensity has migrated poleward during the satellite era

- Observations show that the latitude of lifetime maximum intensity (LMI) has migrated poleward in recent decades, especially in the northwest Pacific region

- These trends have been attributed to a combination of external forcing and internal variability (e.g., low-frequency ENSO)



	NHEM	SHEM	NATL	WPAC	EPAC	NIO	SIO	SPAC	Global
Best track	+53±43	+62±48	+7±98	+37±55	+10±32	−25±78	+67±55	+51±68	+115±70
ADT-HURSAT	+83±50	+35±44	−12±126	+105±71	+34±30	+10±106	+30±52	+54±79	+118±70

LMI latitude trends (km / decade)

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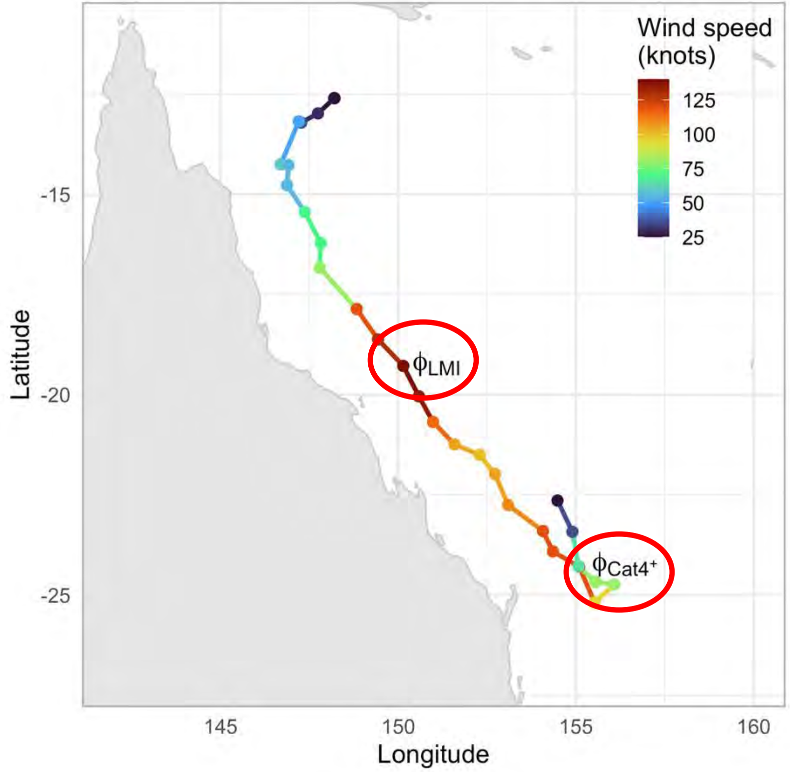
Alternative metric for assessing poleward trends

- Damaging winds (and other hazards) of tropical cyclones can extend well poleward of the location of LMI (e.g., TC Hamish, 2009)
- Here, we investigate trends in a new metric that is arguably more relevant for assessing risks associated with TC poleward migration: *the maximum latitude of TC winds exceeding a given intensity threshold*
- We focus specifically on the maximum latitude of Category 4+ intensity (ϕ_{Cat4+})

Example: TC Hamish (2009)



Data and methods

- ADT-HURSAT temporally consistent tropical cyclone intensity data from 1978-2017 (n = 632 Cat 4+ TCs globally)
- TC potential intensity (PI) calculated from monthly ERA5 reanalysis data
- Focus on the maximum latitude of Category 4 or greater intensity (ϕ_{Cat4+}) rather than LMI latitude
- Trends calculated using both ordinary least squares (OLS) regression and quantile regression (QR)
- Australian wind loading zones obtained from the AZ/NZ1170.2 Standard.

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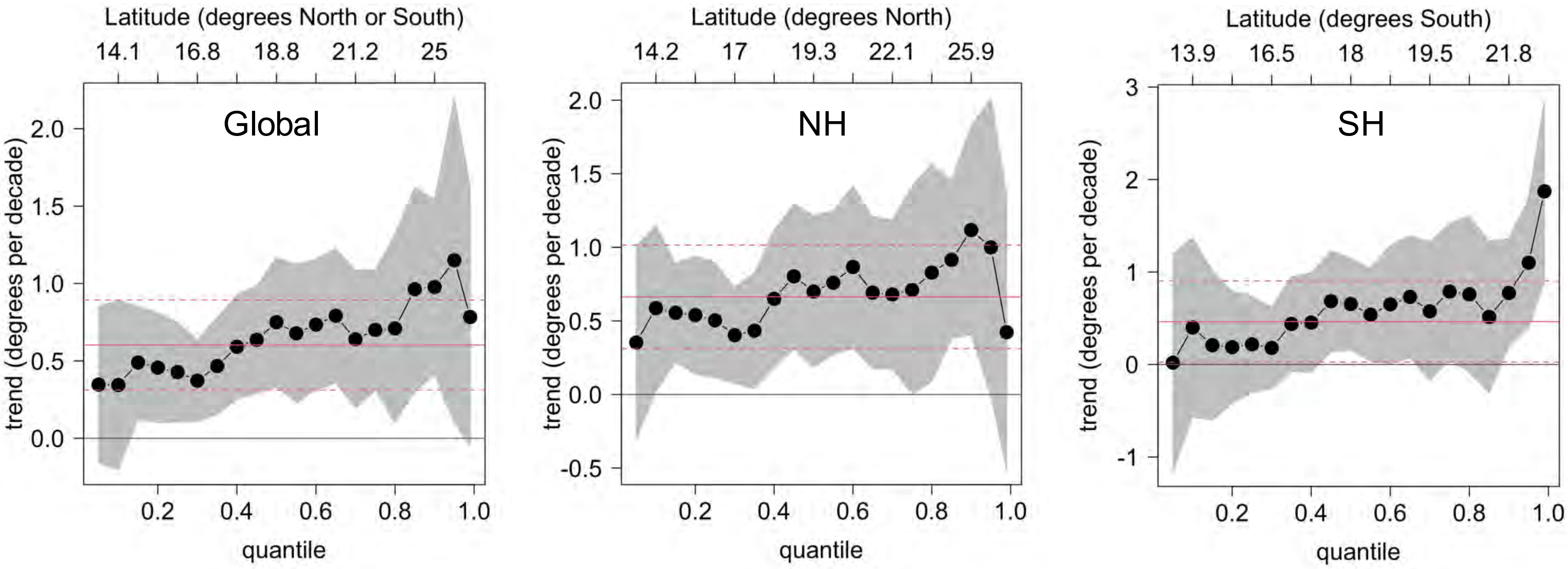
Trends in maximum latitude of Cat 4+ TC intensity



OLS: 0.6 deg/decade
QR (0.95): 1.15 deg/ decade

OLS: 0.66 deg/decade
QR (0.95): 1.0 deg/decade

OLS: 0.46 deg/decade
QR (0.95): 1.1 deg/decade

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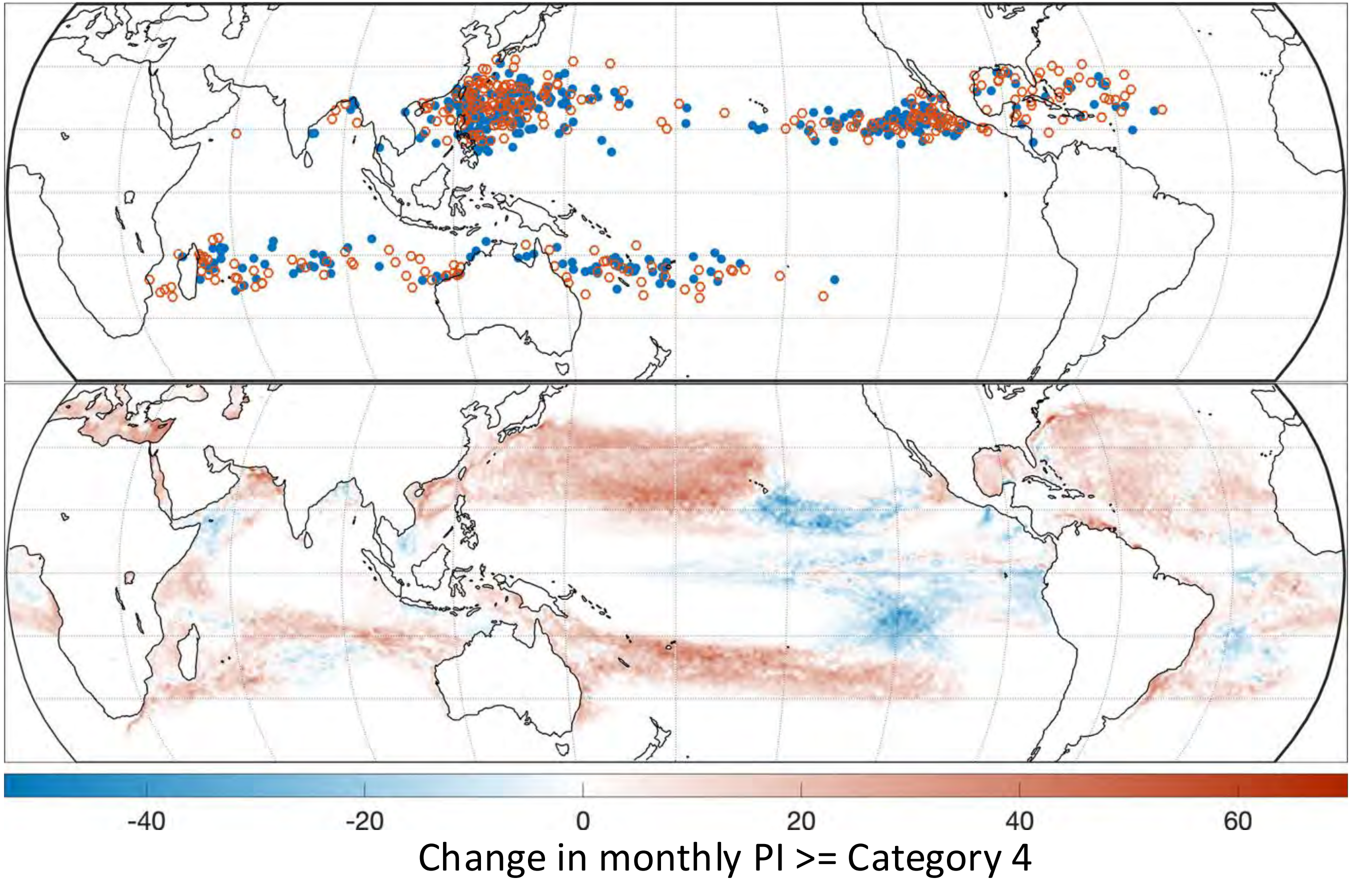
TC potential intensity is increasing in the subtropics



ϕ_{Cat4+} locations

Early (blue)
vs.
Late (red)

ΔPI >=Cat 4

1999-2018
minus
1979-1998

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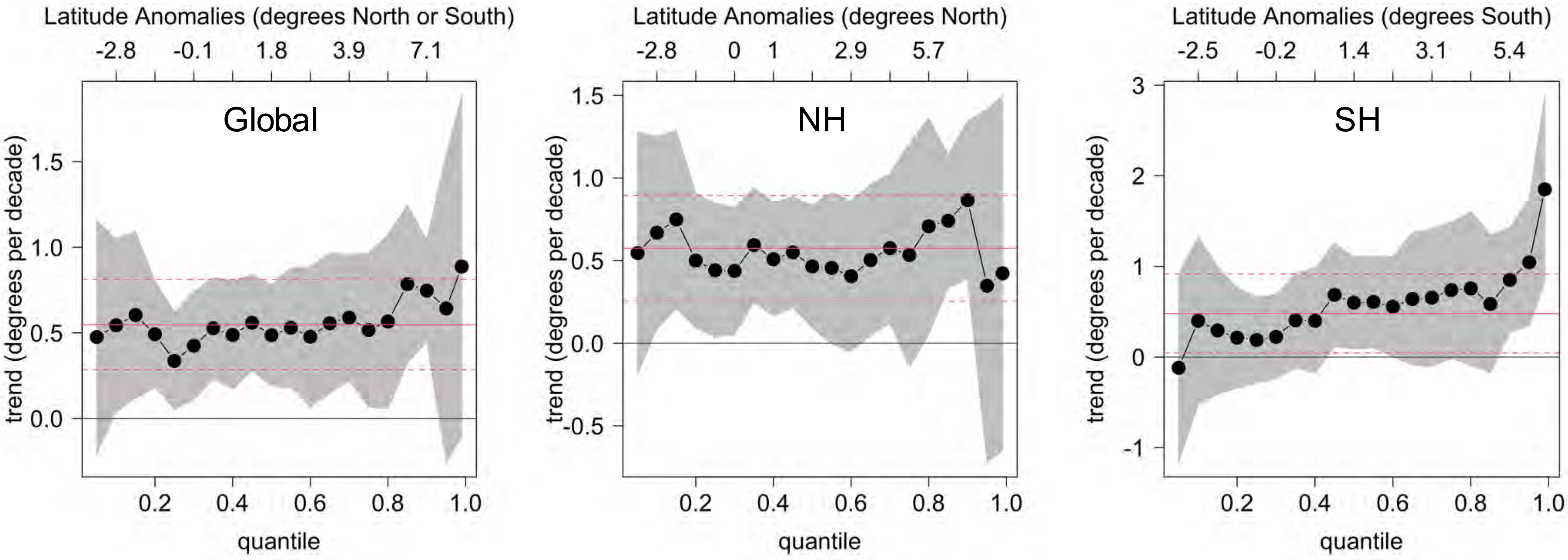
Accounting for inter-basin differences in ϕ_{Cat4+}



OLS: 0.55 deg/decade
QR (0.95): 0.64 deg/ decade

OLS: 0.57 deg/decade
QR (0.95): 0.34 deg/decade

OLS: 0.48 deg/decade
QR (0.95): 1.05 deg/decade

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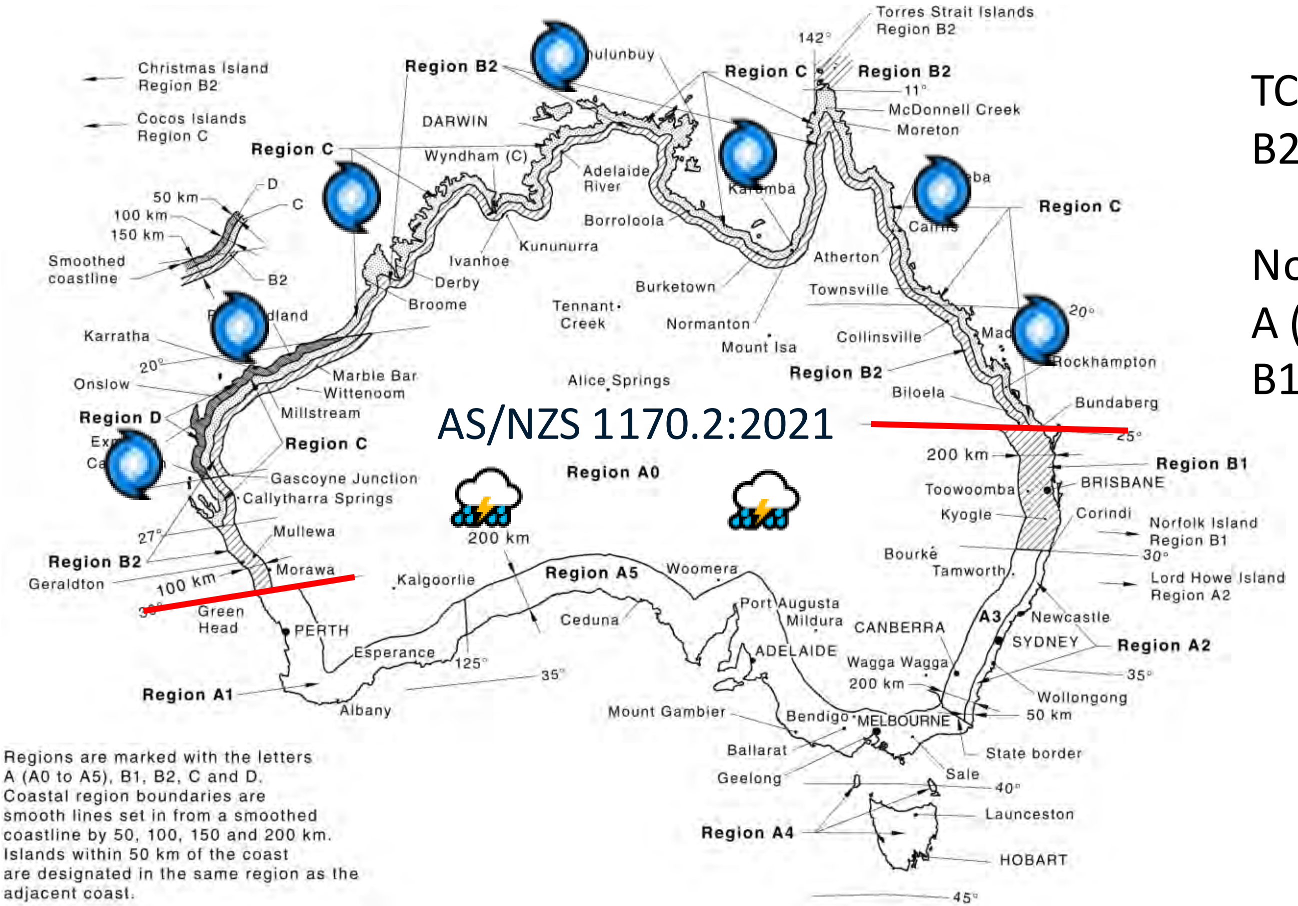
Implications of ϕ_{Cat4+} trends for wind load standards



TC zones:
B2,C,D

Non-TC zones:
A (A0 to A5),
B1

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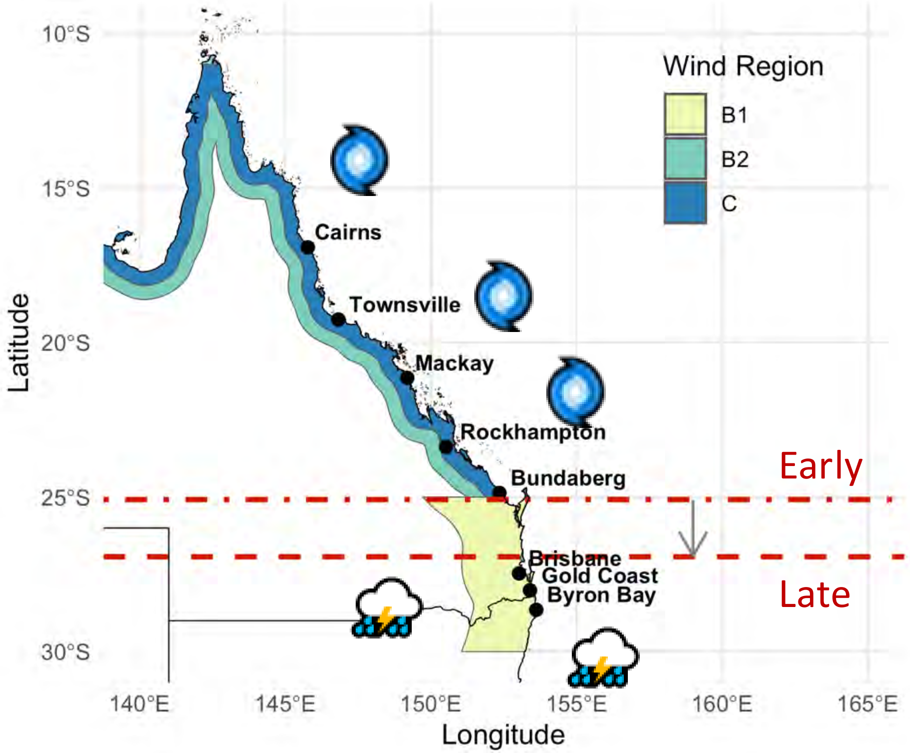
Damaging TCs are migrating into "non-cyclone" zones

- Lower bound design wind speed for TC region C of Australia is 53 m/s (103 kt), closer to Category 3+ intensity in the ADT-HURSAT data (i.e., ≥ 100 kt)
- Southern boundary (0.99 quantile) of Category 3+ winds has shifted southward by ~2 degrees into region B1 ("non-cyclone"), when comparing the first and second halves of the ADT-HURSAT data
- Shift poses considerable risk to structures built according to the current standard, especially for major cities such as Brisbane (2.7 million people)



Conclusions

- There has been a robust and statistically significant poleward migration of the maximum latitudes of Category 4+ (ϕ_{Cat4+}) TC intensity over the 40-year period 1978-2017
- This migration is most pronounced at the edge of the tropics and into the subtropics, supported by changes in potential intensity (PI) exceeding Category 4 over a similar period
- For Australia, the southward migration of the lower bound design wind speed for TCs into “non-cyclone” regions on the east coast poses considerable risk to structures built according to the current standard, with cities such as Brisbane now more vulnerable to intense tropical cyclones than in previous decades

Thank you

CSIRO Environment
Hamish Ramsay
Principal Research Scientist

+61 2 9239 4400
hamish.ramsay@csiro.au

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