Modulations of local rainfall in Northeast Australia associated with the Madden Julian Oscillation

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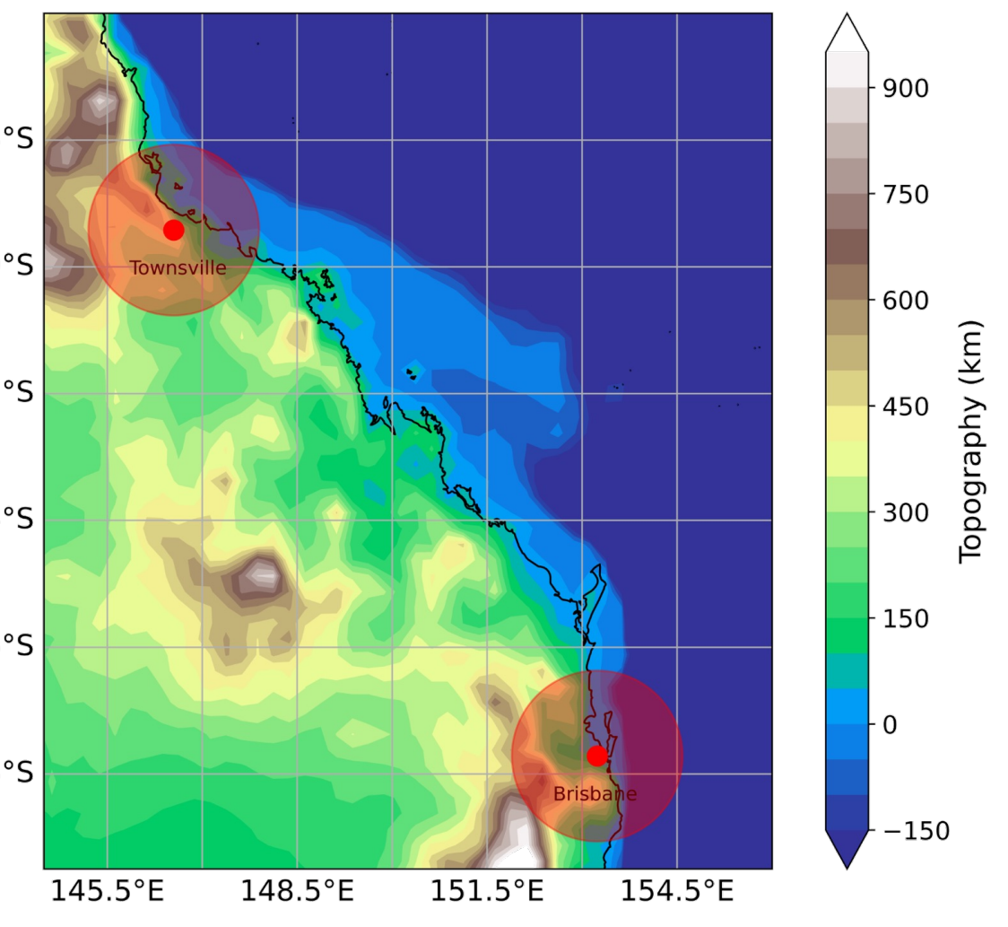
Every catastrophic rainfall event reflects both **large-scale influences** and highly **localized influences**. Understanding these factors and **their interactions** provides important insight into small-scale rainfall variations, therefore directly improving regional rainfall predictions and agricultural management.

1. Introduction

- The role of topography and land-sea breeze has been highlighted in modulating local rainfall under the backdrop of the MJO
- Northeast (NE) Australia's rainfall variability associated with the MJO shows a marked geographical variation (Dao et al., 2023)



Topographic map

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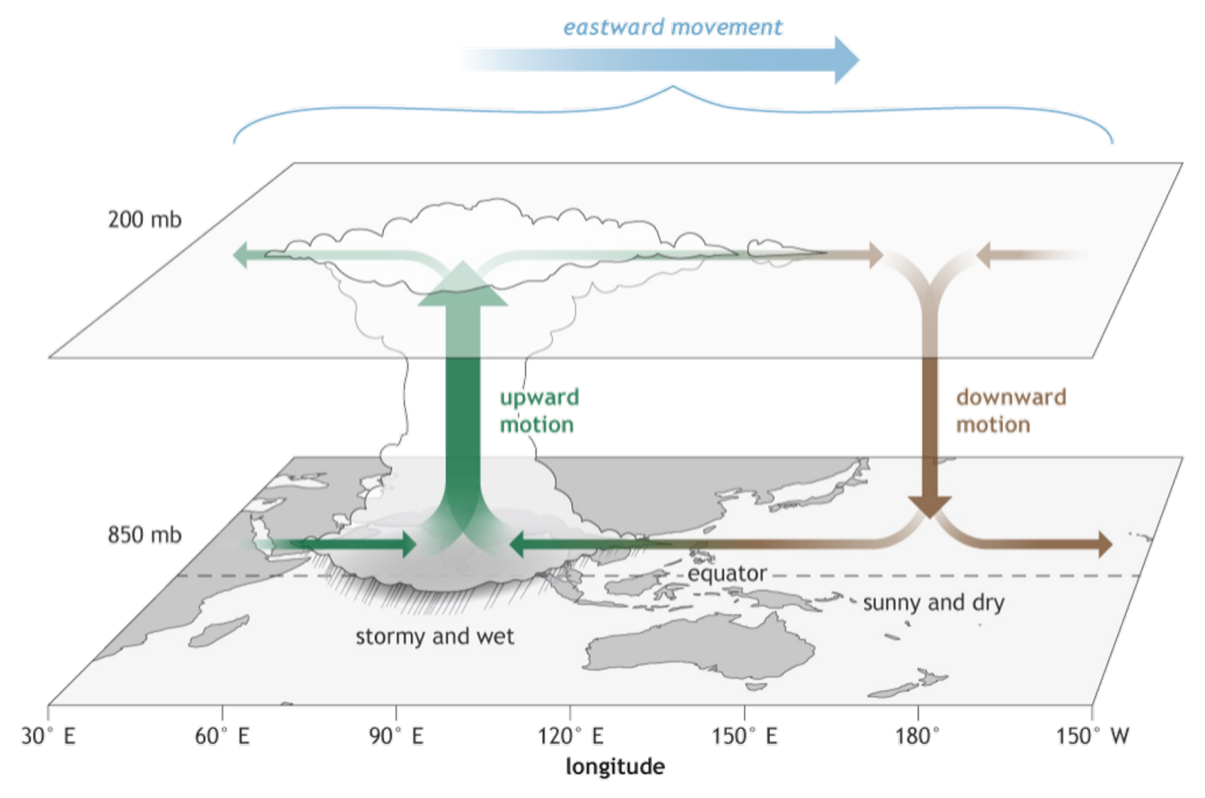


Madden Julian Oscillation (MJO)
(https://www.climate.gov/media/13488)

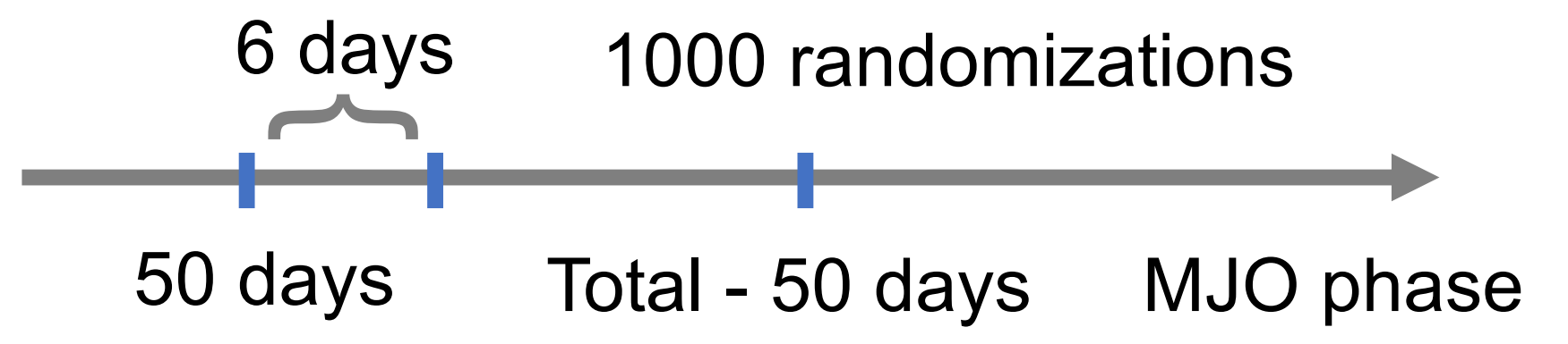
=> How do local features interact with the MJO in regulating rainfall and its diurnal cycle over coastal areas in NE Australia?

2. Data and Methods

- Australia Operational Weather Radar
- Upper-air radiosonde sounding data
- Bureau of Meteorology Atmospheric high-resolution Regional Reanalysis for Australia - Version 2
- UK Met-Office Unified Model (AUS2200) simulations :
  - Spatial grid-spacing of 2.2 km and boundary conditions from the European Center for Medium-Range Weather Forecast ERA5 data
  - Total of **180 simulation days** for three MJO events: 2016 (El Niño), 2013 (Neutral) and 2018 (La Niña)

Daily rainfall probability (%) $$P = \frac{N_{days}(R \geq R_{67})}{N_{total}} * 100\%$$

Statistical significance test



3. Observed radar results

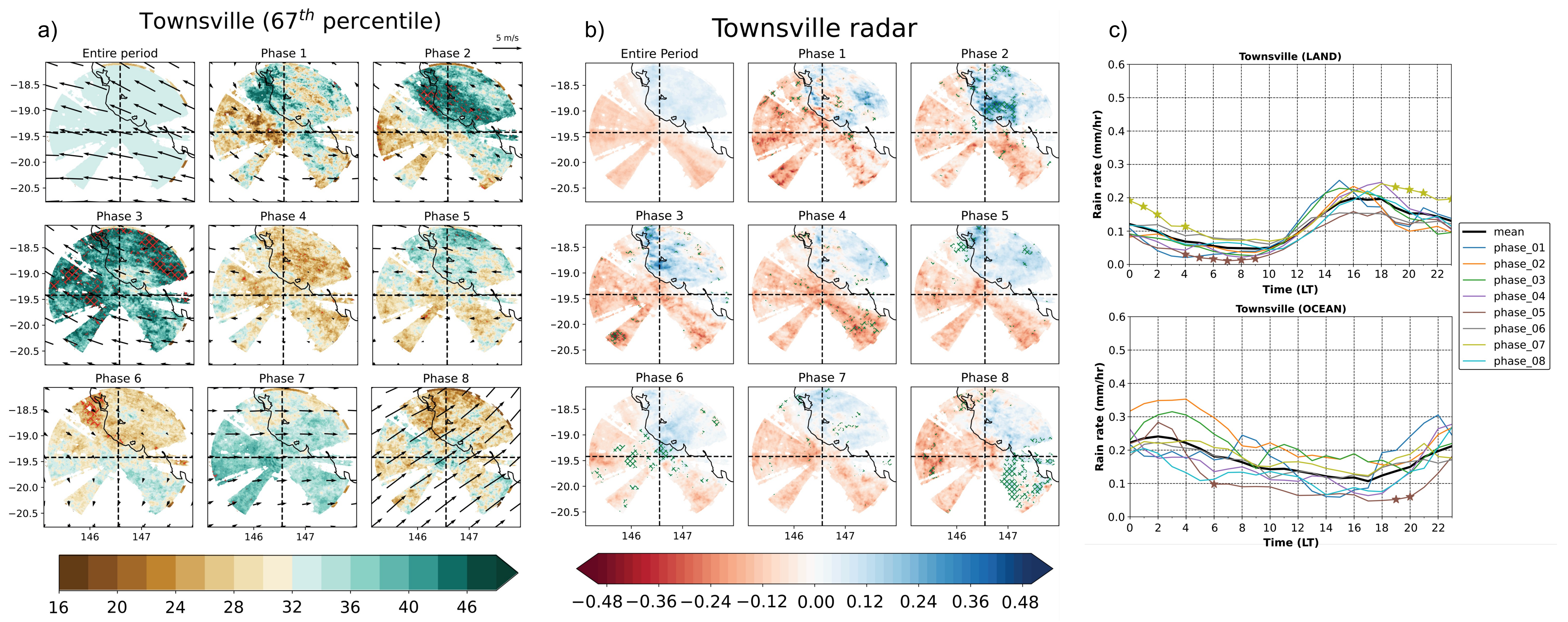


Figure 1: Composite of (a) daily rainfall probability and 850-hPa wind anomalies, (b) hourly rainfall difference between morning and afternoon and (c) diurnal cycle of rainfall during austral summer (DJF) from 2011 to 2022 for different MJO phases.

- Hatches (stars) indicate significant rainfall results at the 90% level

4. Scale interaction mechanisms

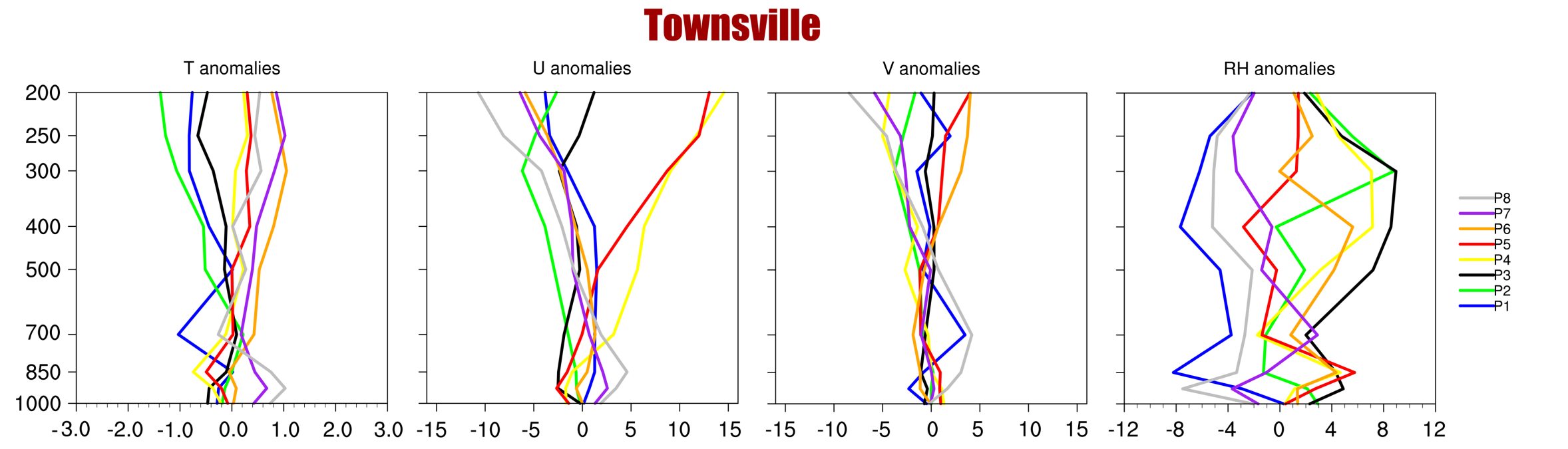


Figure 2: The vertical profile of environmental variables anomalies during austral summer (DJF) from 2011 to 2022 for different MJO phases

Phase	1	2	3	4	5	6	7	8	Mean
CAPE	530.1	593.6	**372.4**	338.5	443.5	414.3	499.9	539.6	466.5
CIN	-24.4	-34.4	**-18.5**	-24.8	-24.3	-35.3	-41.9	-48.9	-31.6

Table 1: CAPE and CIN values (J/kg) for different MJO phases

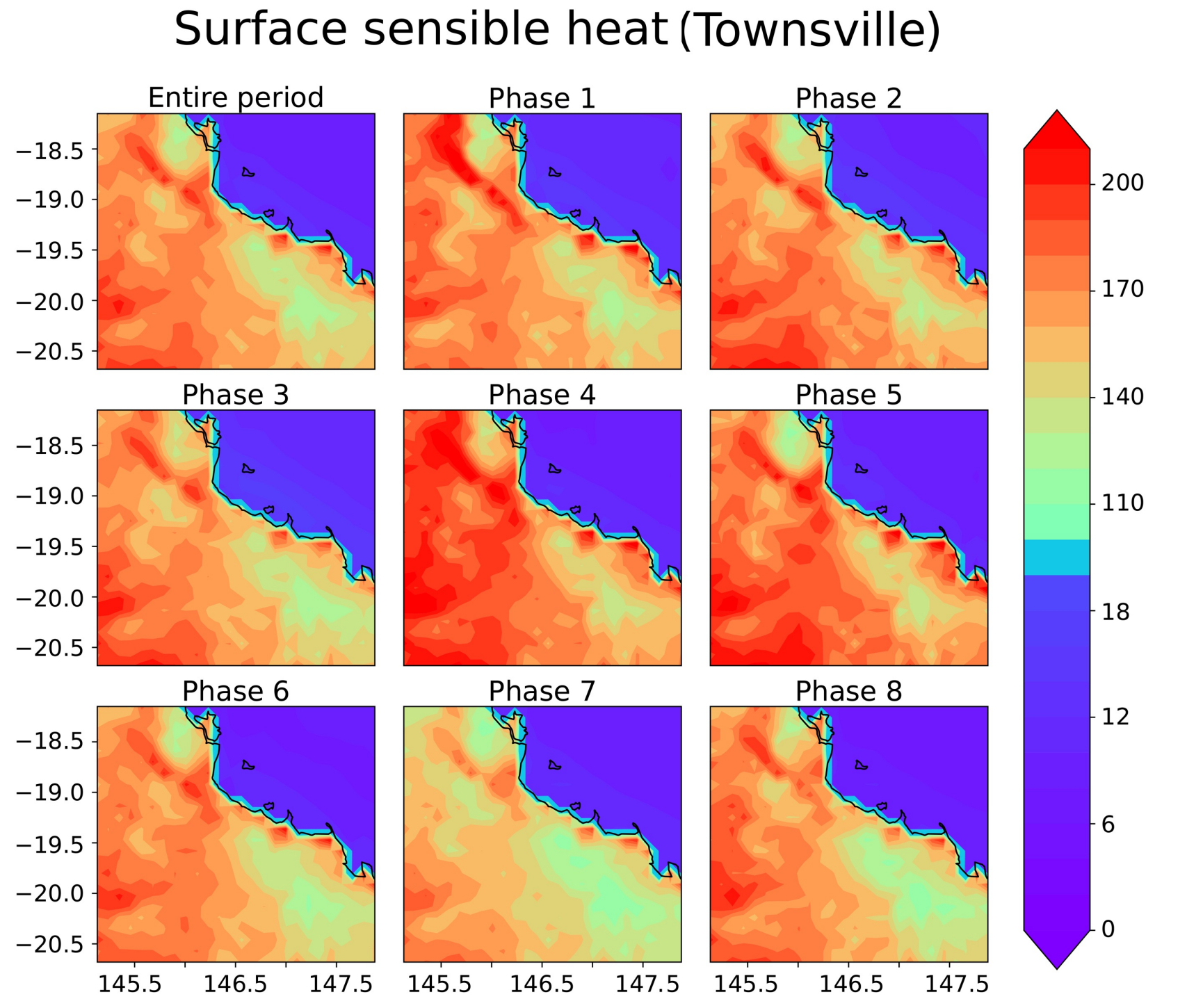


Figure 3: Composite of surface sensible heat fluxes (W/m^{-2}) during austral summer from 2011 to 2022 for different MJO phases

Phase 3 has relatively low CAPE, but low CIN, deep positive moisture anomalies, and the strongest onshore zonal wind anomalies. Mesoscale modelling is used to examine how these factors lead to the observed enhanced rainfall

5. Modelling results

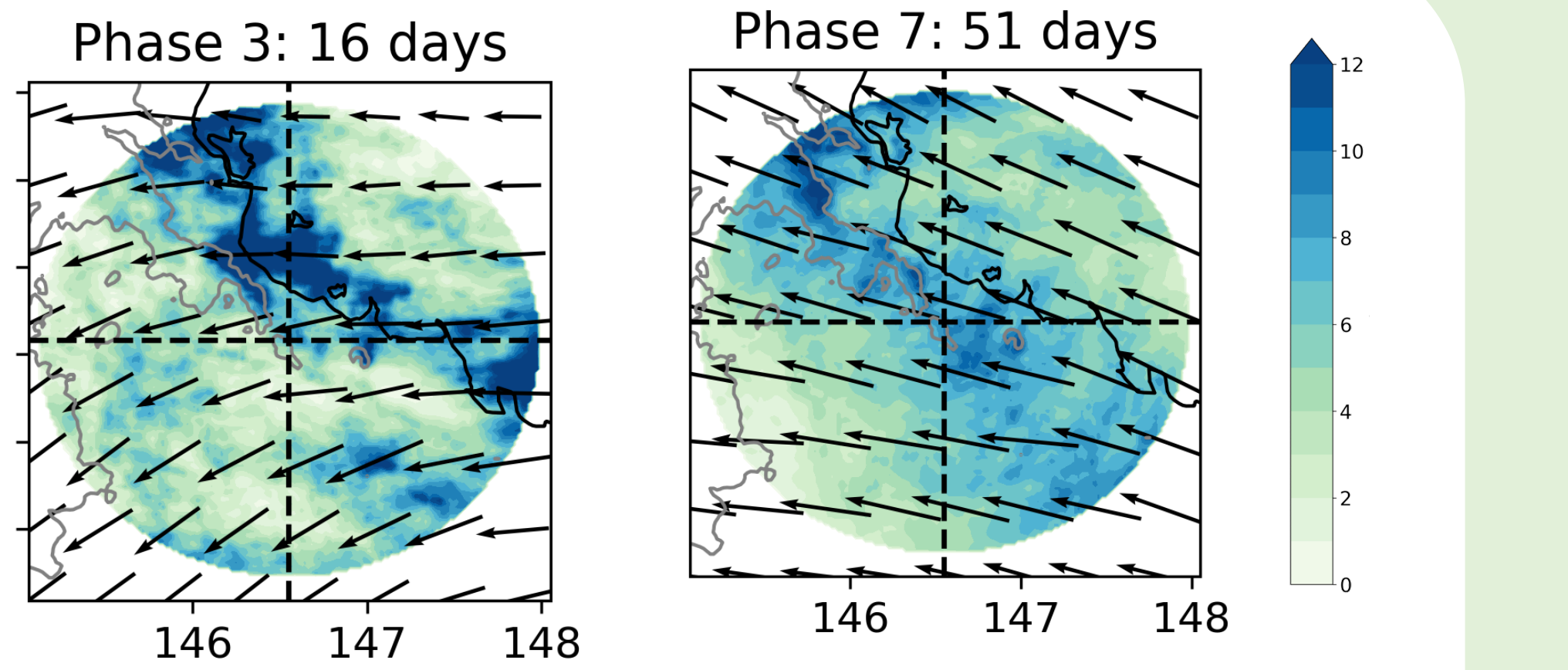


Figure 4: Composite of daily rainfall (mm/day) and 850-hPa wind (m/s) for two MJO phases from AUS2200 simulations

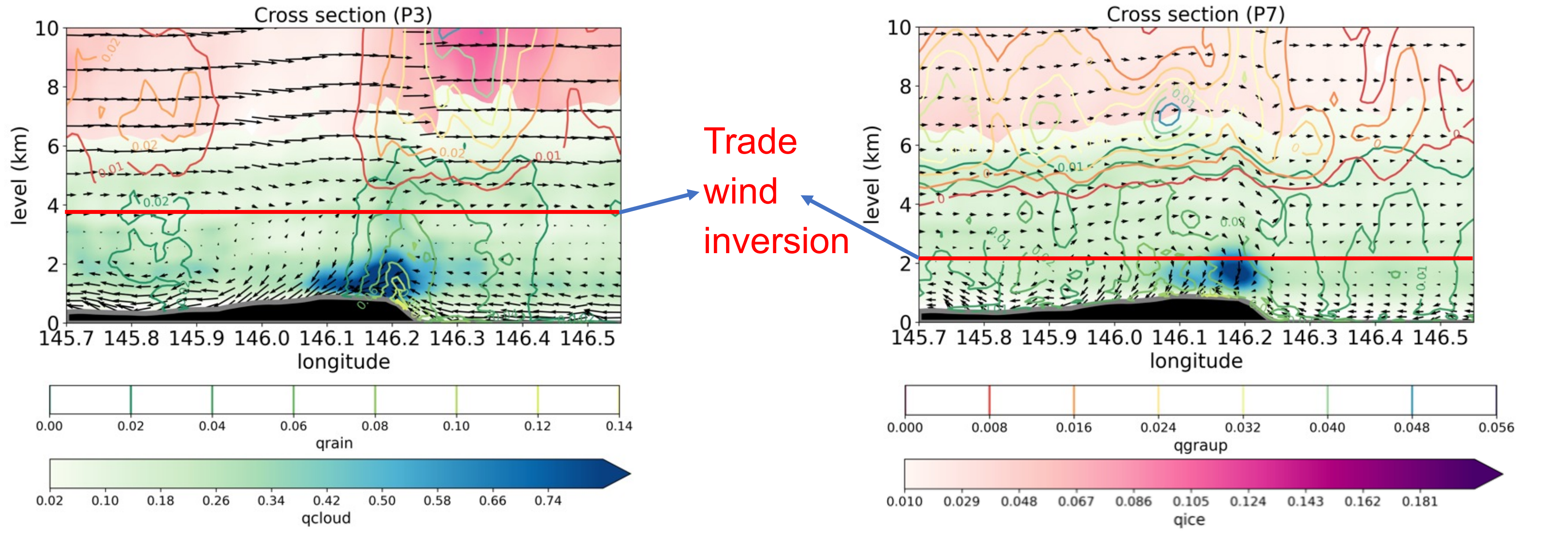


Figure 5: Vertical cross section of cloud, rain, ice, and graupel mass fraction (kg/kg) for two MJO phases from AUS2200 simulations

6. Conclusions

- ✓ Widespread increased rainfall signals during the enhanced convection phases of the MJO are generated by large-scale forcings associated with the MJO convection
- ✓ Locally enhanced rainfall probability during suppressed convection phases of the MJO possibly results from mesoscale convective systems such as sea breezes and the interaction of easterly trade-winds and topography
- ✓ Coastal rainfall during suppressed convection phases is sensitive to the trade-wind inversion height
- ✓ The results pose unresolved questions about the inland-extent of coastal rainfall and topographically-initiated deep convection near the coast. Next steps involve understanding the role of topography, moisture distribution and wind inversion on coastal rainfall

Dao, T. L., Vincent, C. L., & Lane, T. P. (2023). Multiscale Influences on Rainfall in Northeast Australia. *Journal of Climate*, *36*(17), 5989-6006. https://doi.org/10.1175/JCLI-D-22-0835.1

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