Characterizing the relationship between tropical precipitation regime transitions and the environment using machine learning

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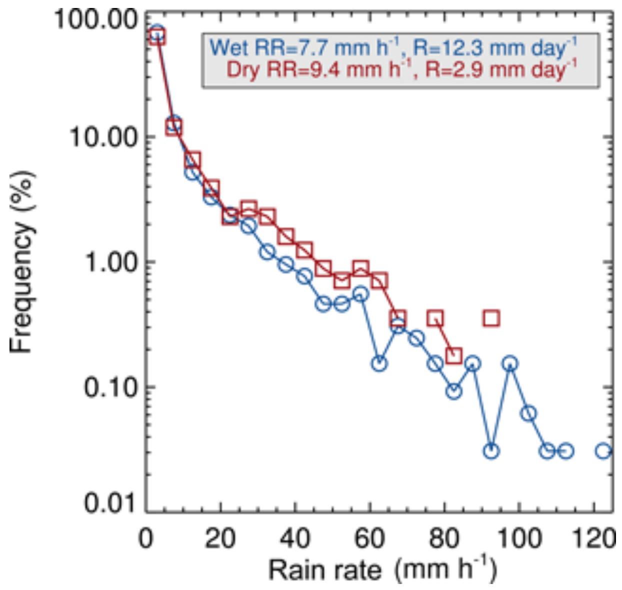
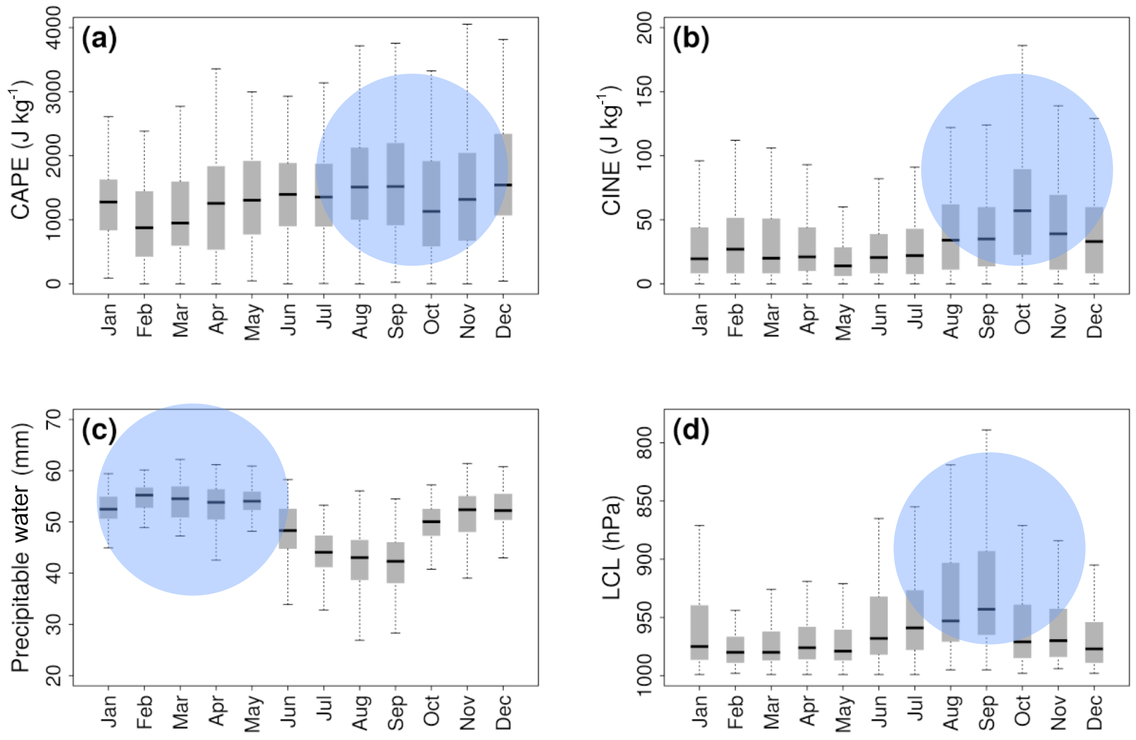
Background

What processes control precipitation regimes?

Amazon



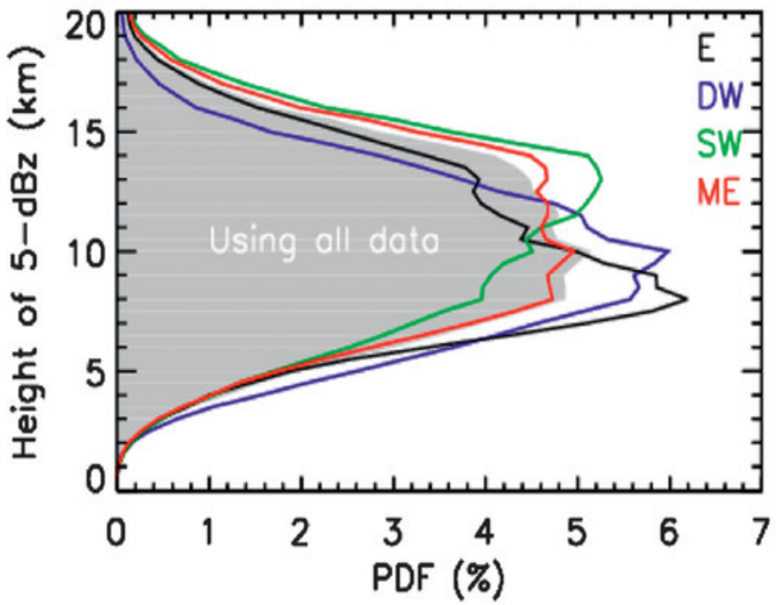


From Machado et al. 2018

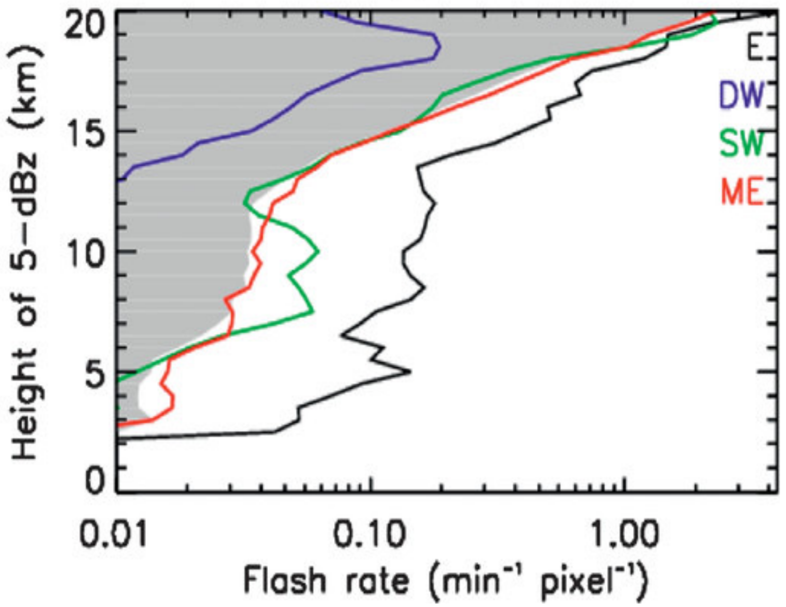
- The dry season generally exhibited higher rainfall rates than the wet season and included more intense rainfall periods.
- However, the cumulative rainfall during the wet season was 4 times greater than that during the total dry season rainfall.
- CAPE and CIN are higher during dry season, PW higher during wet season

Regimes in Australian monsoon

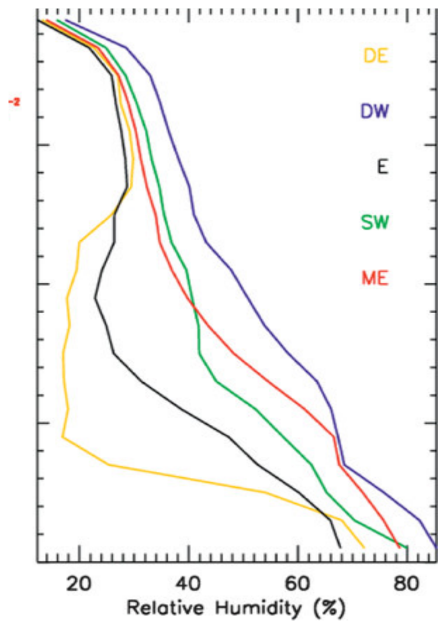
Echo-Top Height



Lightening Frequency



Relative Humidity

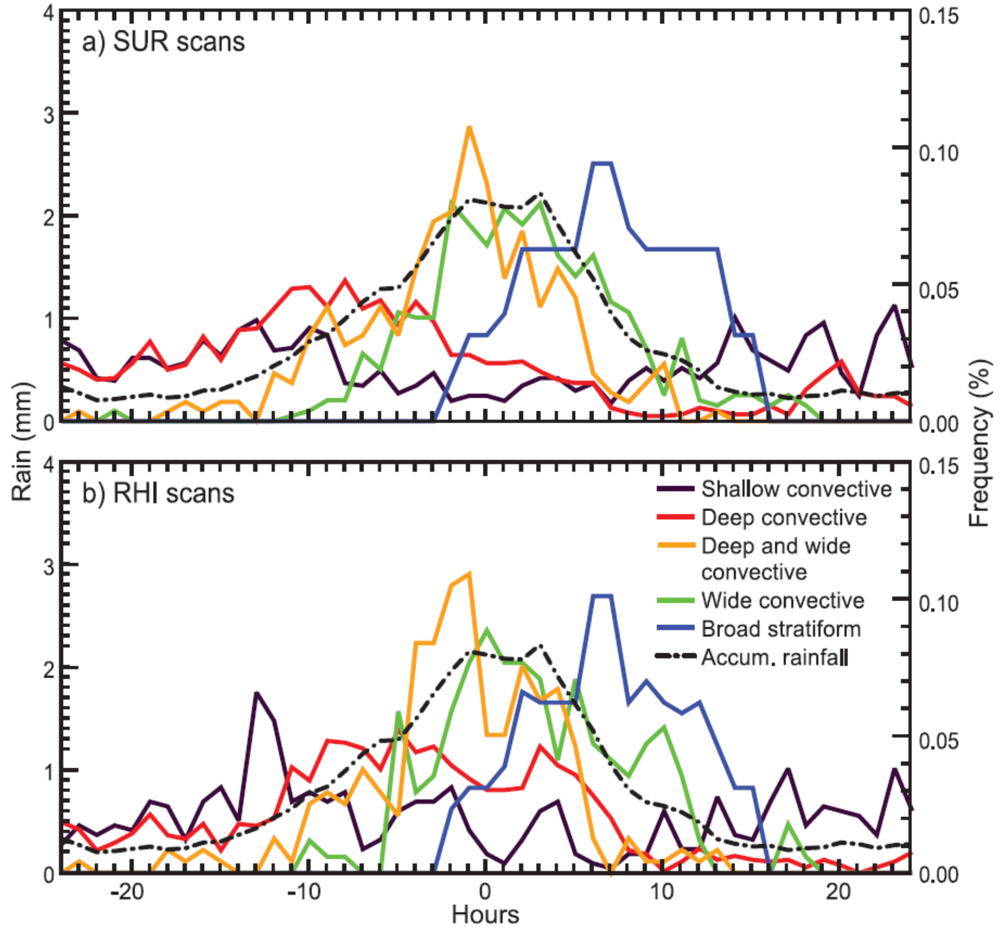


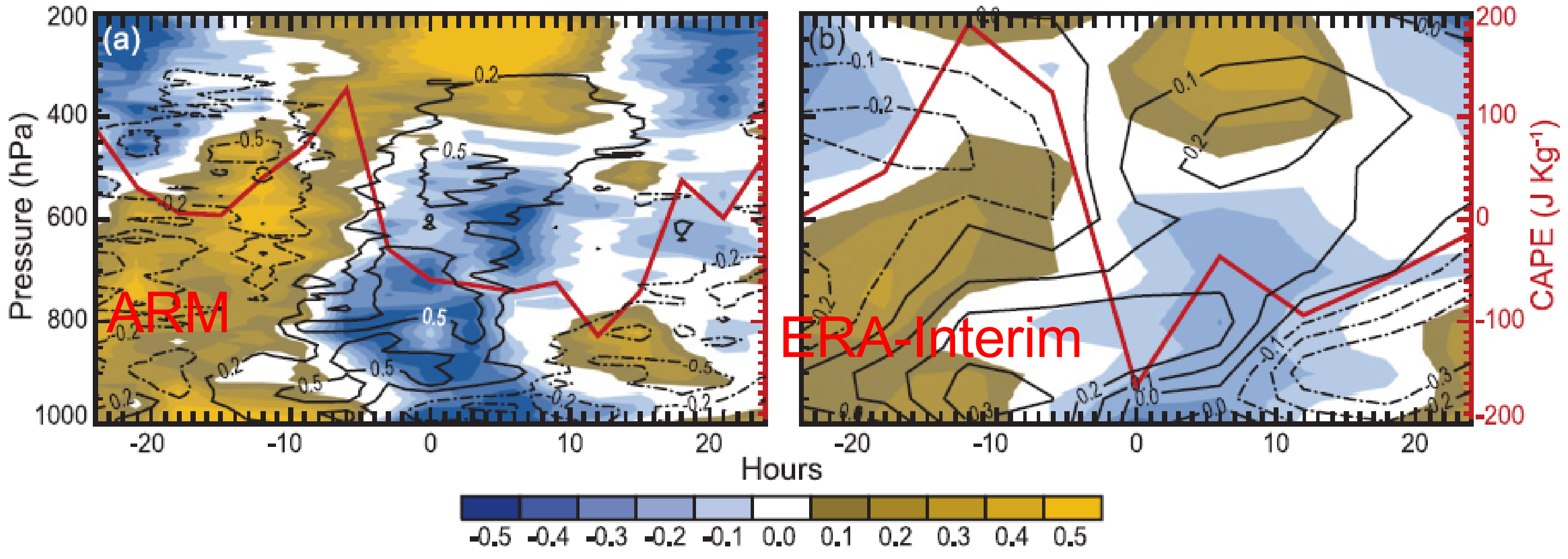
- The echo-top height and lightening frequency of deep westerly (wet regime) are both lower compared to the drier regimes.

Kumar et al. 2013

Regimes in MJO episodes observed during DYNAMO

Five regimes within 3 weeks period



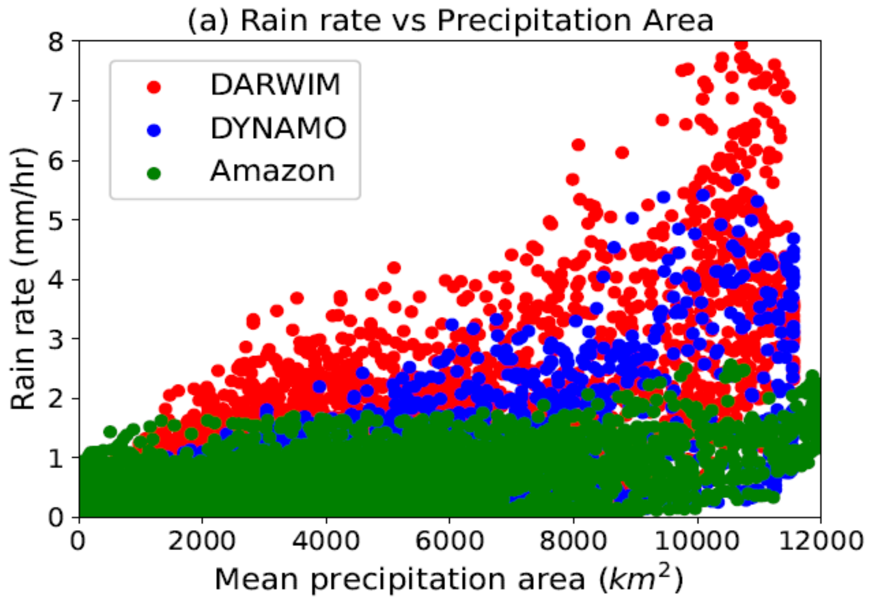


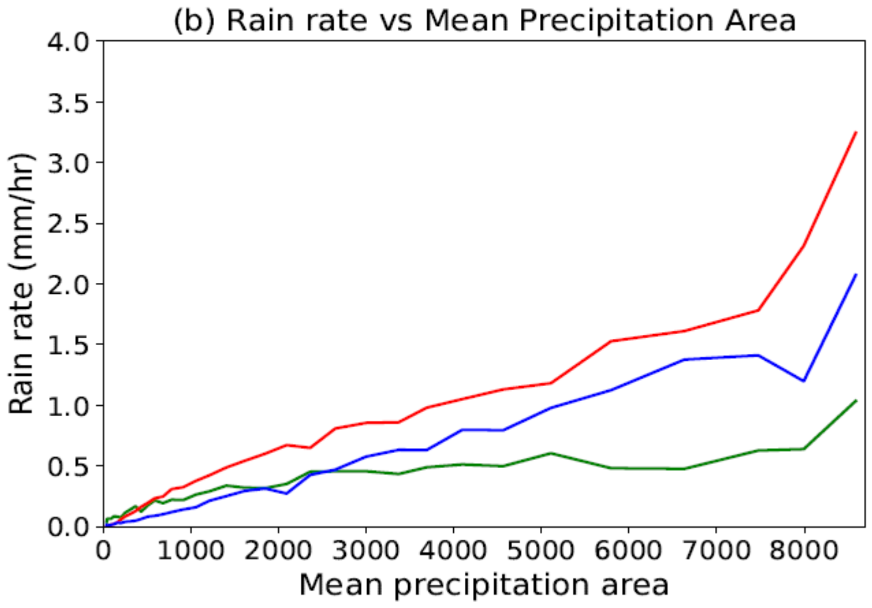
Composite time–height sections of potential temperature (shading, K) and specific humidity (black contours, g/kg); solid contours indicate positive values) anomalies

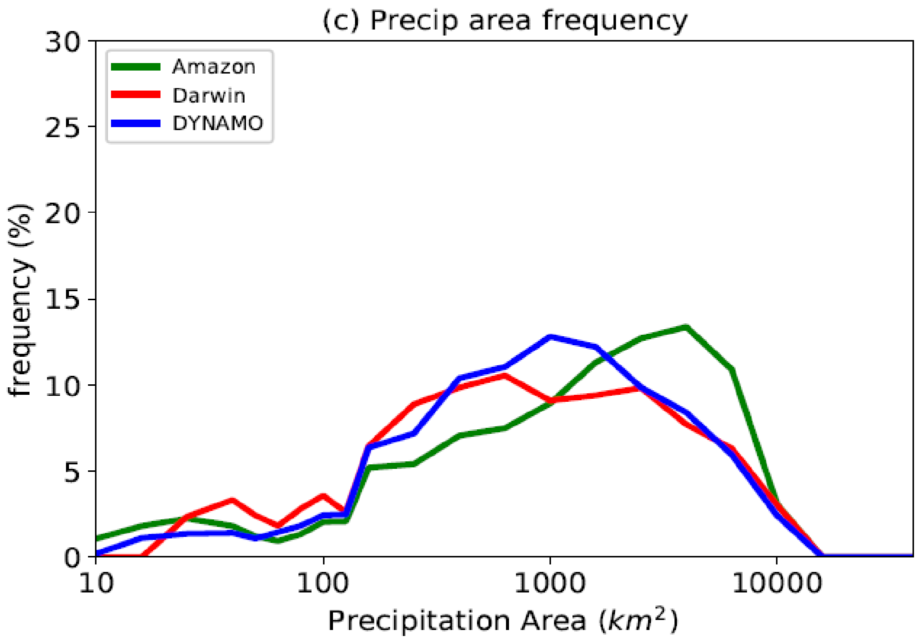
- The evolution of precipitation features is accompanied by transition from warm, high CAPE, relatively dry conditions to moist, low CAPE, cooler conditions.

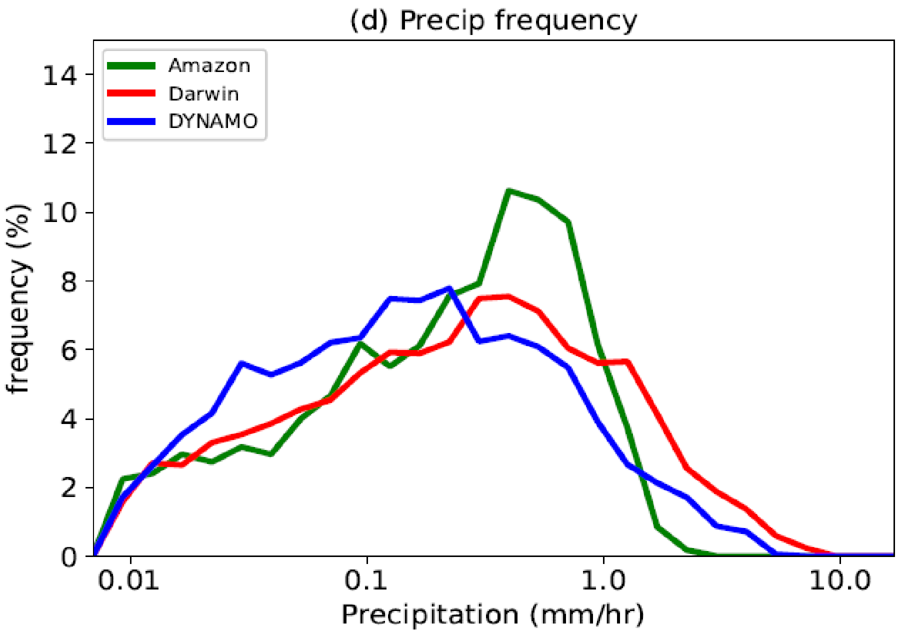
Zuluaga and Houze 2013

Precipitation Area and Intensity statistics



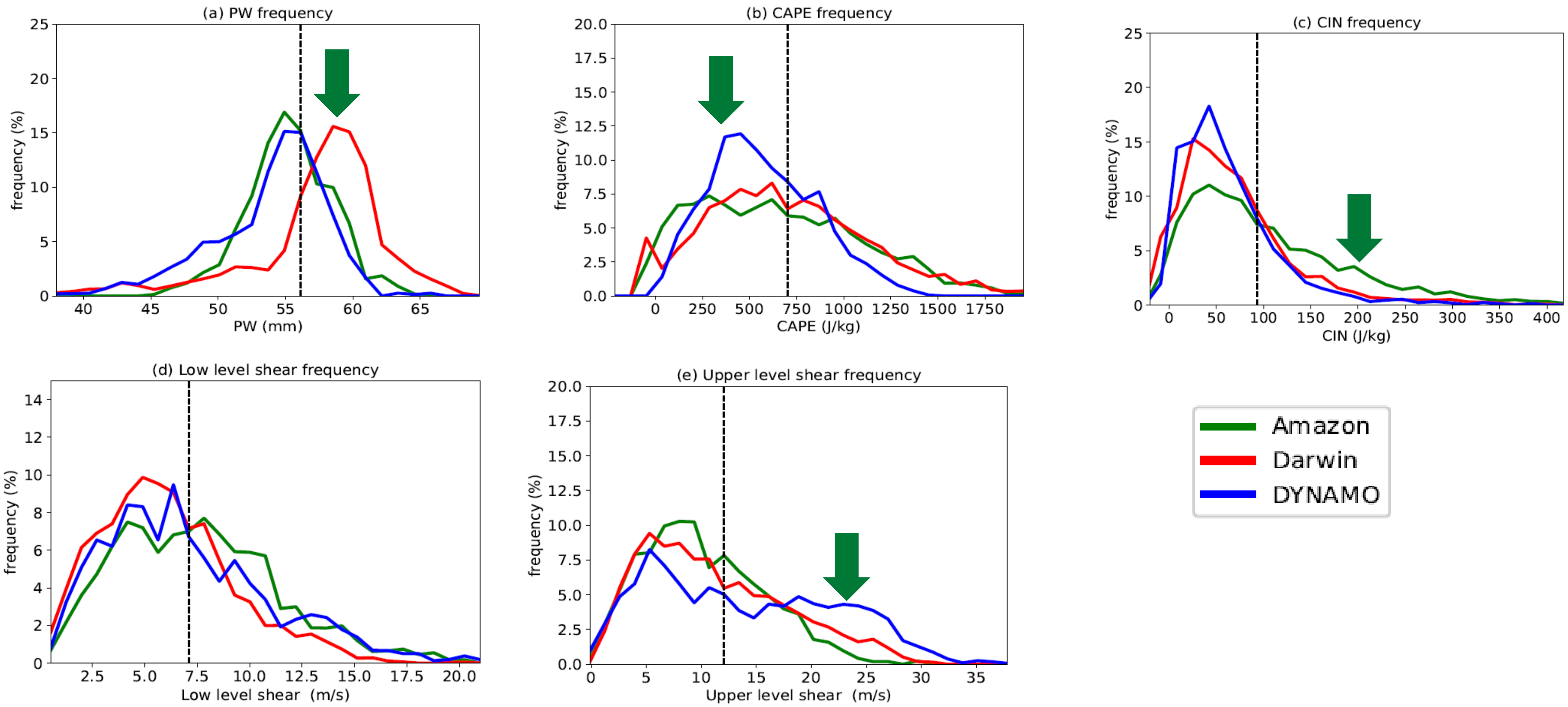






- For the same precipitation area, the precipitation is most intense over monsoonal environment of Darwin Australia and are weakest over Amazon while large-precipitation areas are more frequent over the latter.

Environmental conditions



- The precipitable water content over Darwin is larger than both of those over DYNAMO and Amazon domain.
- CAPE over the DYNAMO domain is relatively smaller. The upper-level shear is strongest (Fig .1d).
- The low-level shear is relatively weak over Darwin in comparison to that over the other two areas

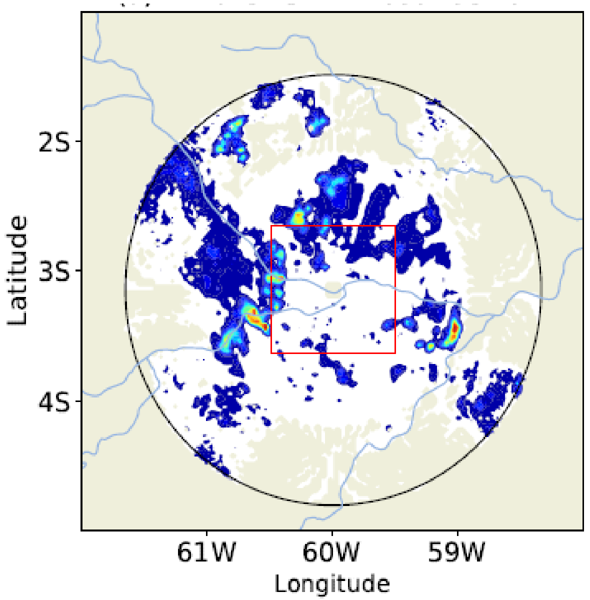
Objectives

This work aims to use a machine learning model and analysis of marginal distributions to

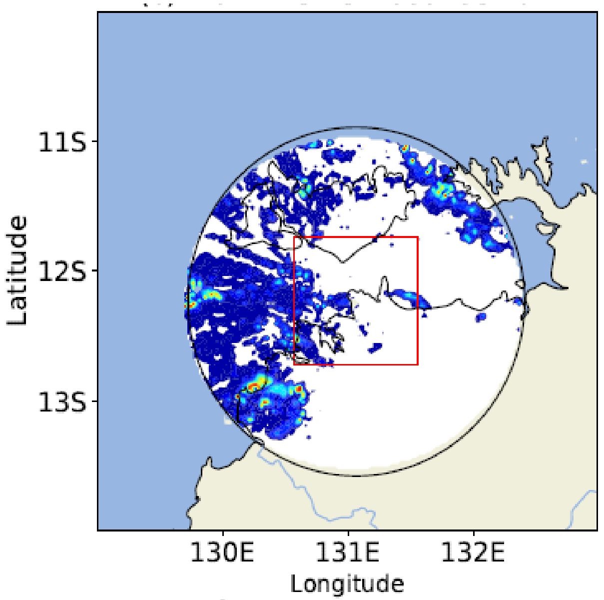
- characterize the **comparative role environmental variables** in precipitation regime transitions in the tropics and
- investigate the origin of **regional differences** in the frequencies of precipitation regimes.

Domains and Data

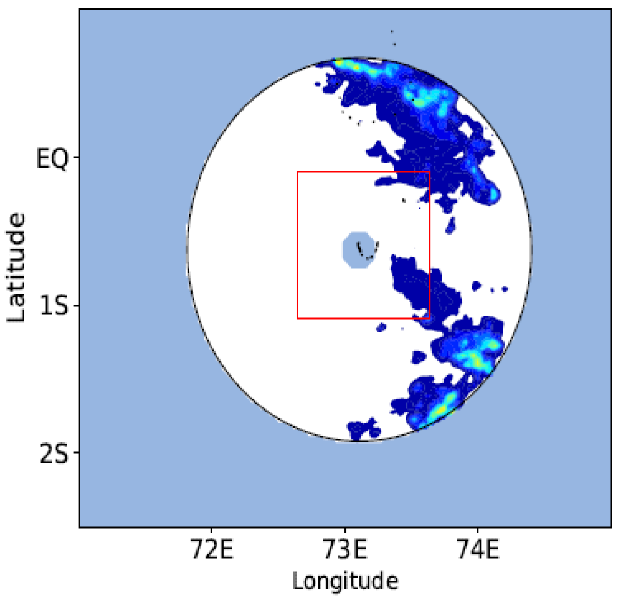
Amazon (SIPAM radar)



Darwin (C-POL radar)



DYNAMO (S-POL radar)

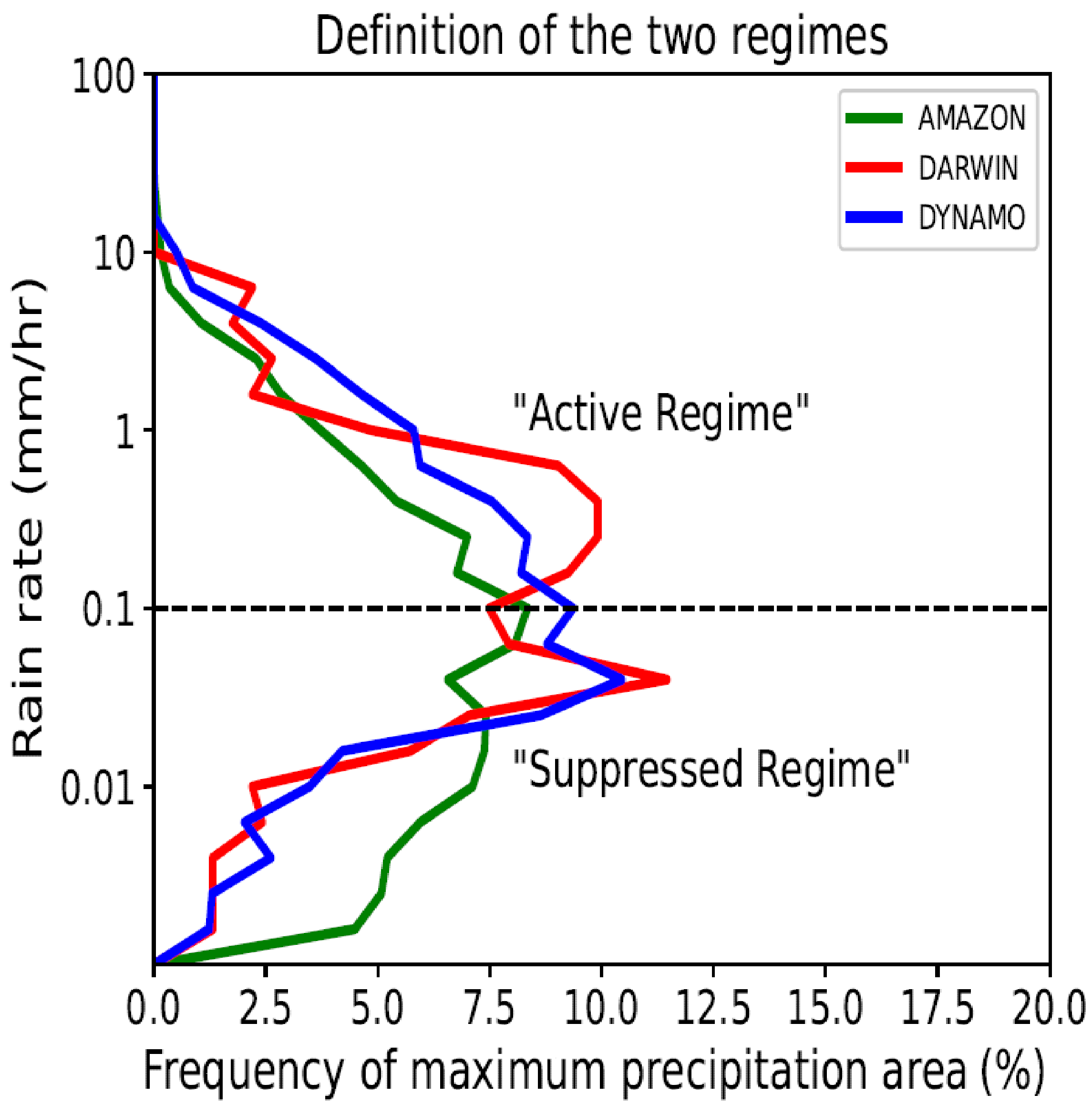


Grid box

- For the three radar domains and periods a $1^{o}\times1^{o}$ box is defined and average hourly precipitation is calculated'
- ERA5 column integrated precipitable water (PW), CAPE, CIN, Lower tropospheric shear ($|v_{500hpa} - v_{850hpa}|$), Upper tropospheric wind shear ($|v_{200hpa} - v_{500hpa}|$) are averaged over the box.

A common definition

- Two regimes are defined based on the areal coverage of precipitation.



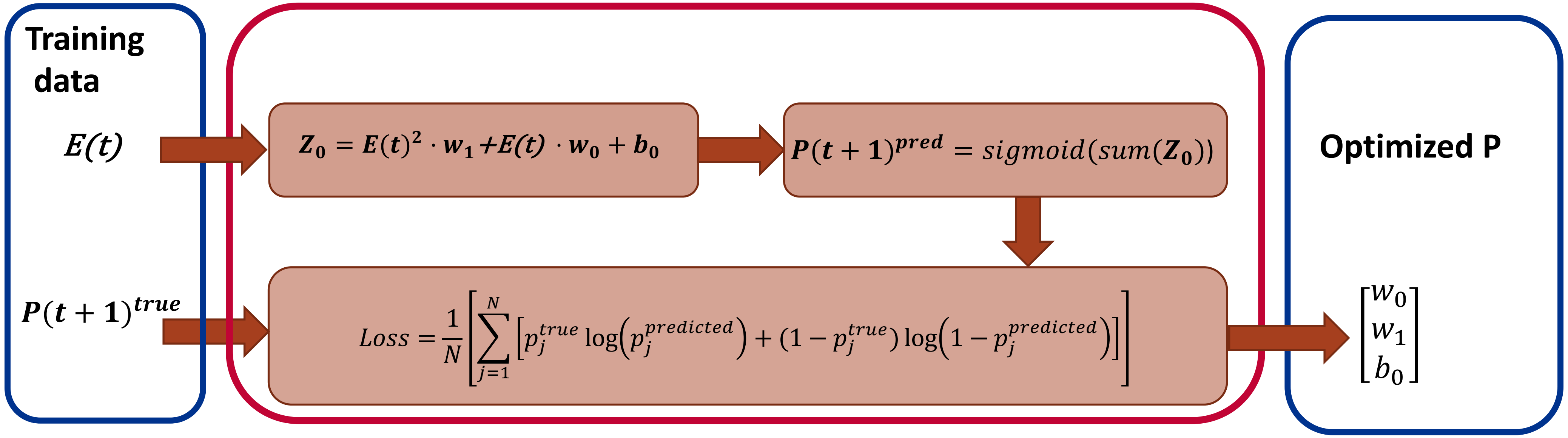
The Machine Learning Model

- The simple machine learning model that predicts the probability of transition from suppressed to an active regime is designed and optimized.

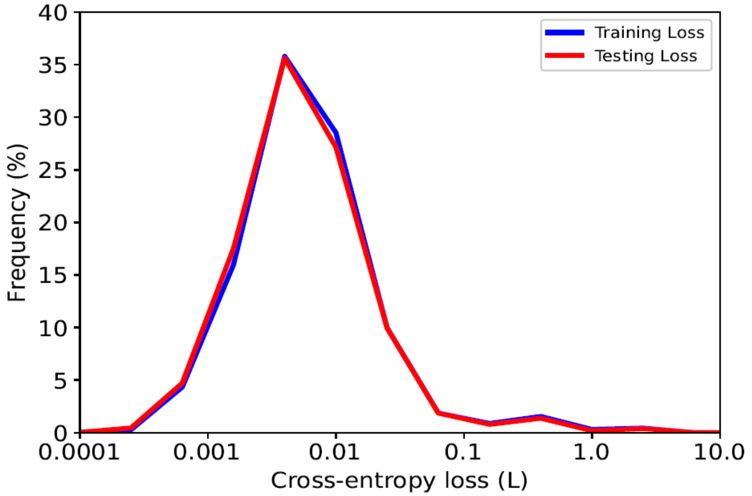
$$E(t) = [R(t), PW(t), CAPE(t), CIN(t), LLSHEAR(t), ULSHEAR(t)]$$

$$P_{t+1hr}(E(t)) = sigmoid\left(sum(\boldsymbol{E(t)^2} \cdot \boldsymbol{w_1} + \boldsymbol{E(t)} \cdot \boldsymbol{w_0} + \boldsymbol{b_0})\right)$$

(a) The machine learning training algorithm

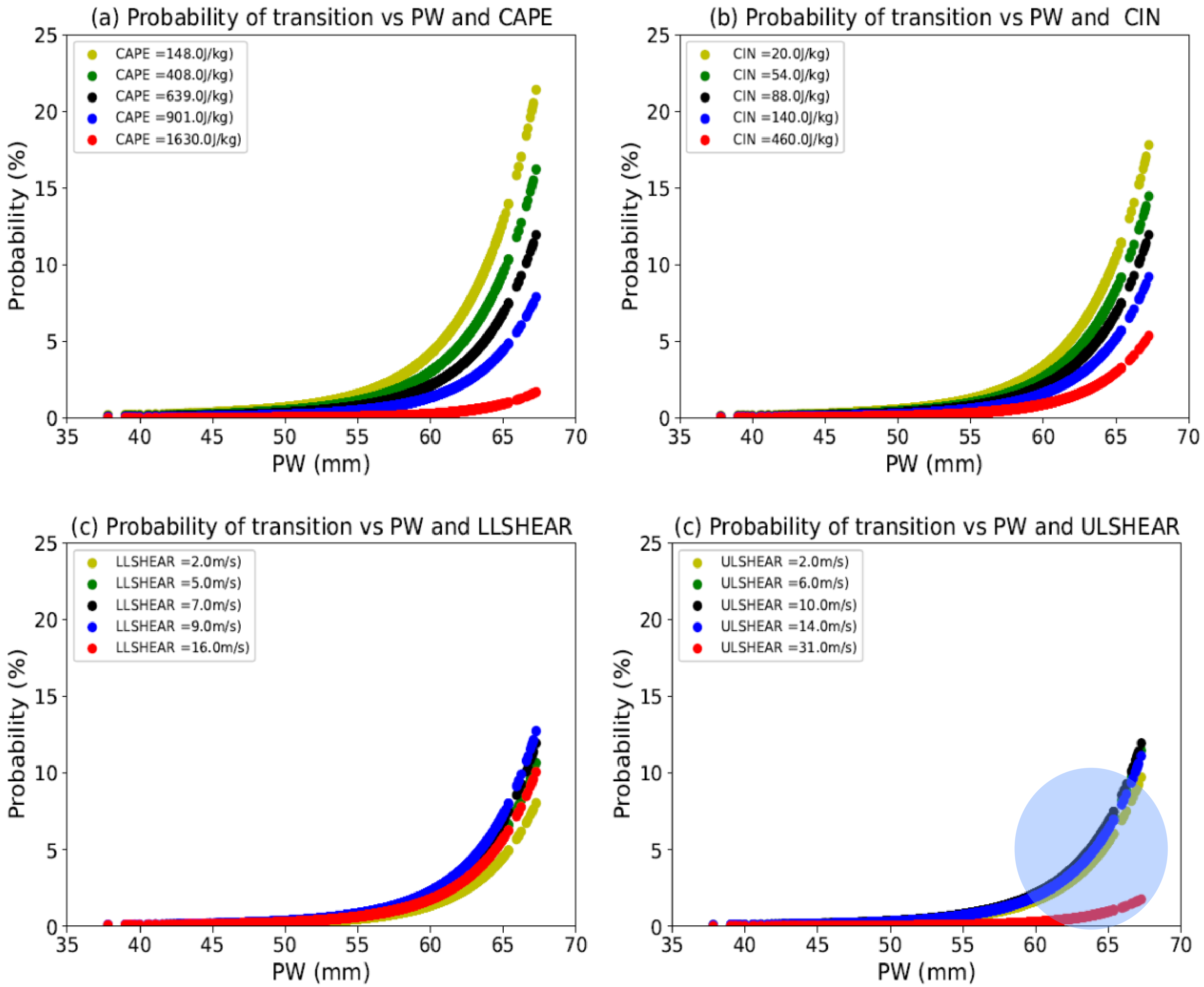


(b) Error in the prediction



Results from the ML model

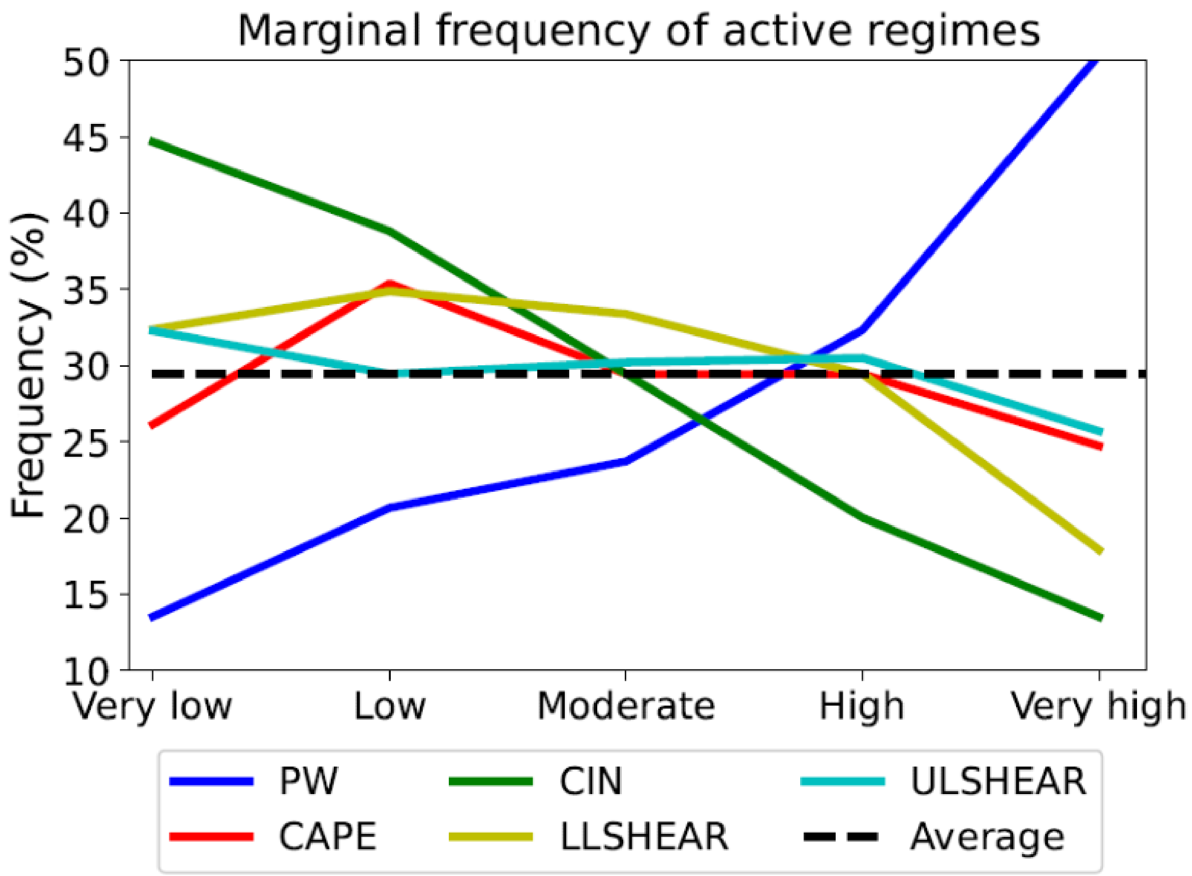
- The probability of transition is relationship is most sensitive to PW
- Both high CAPE and CIN are unfavorable for transition
- Transition is much less sensitive to low-level shear
- Very strong upper-level shear unfavorable for transition



Analysis of marginal distributions

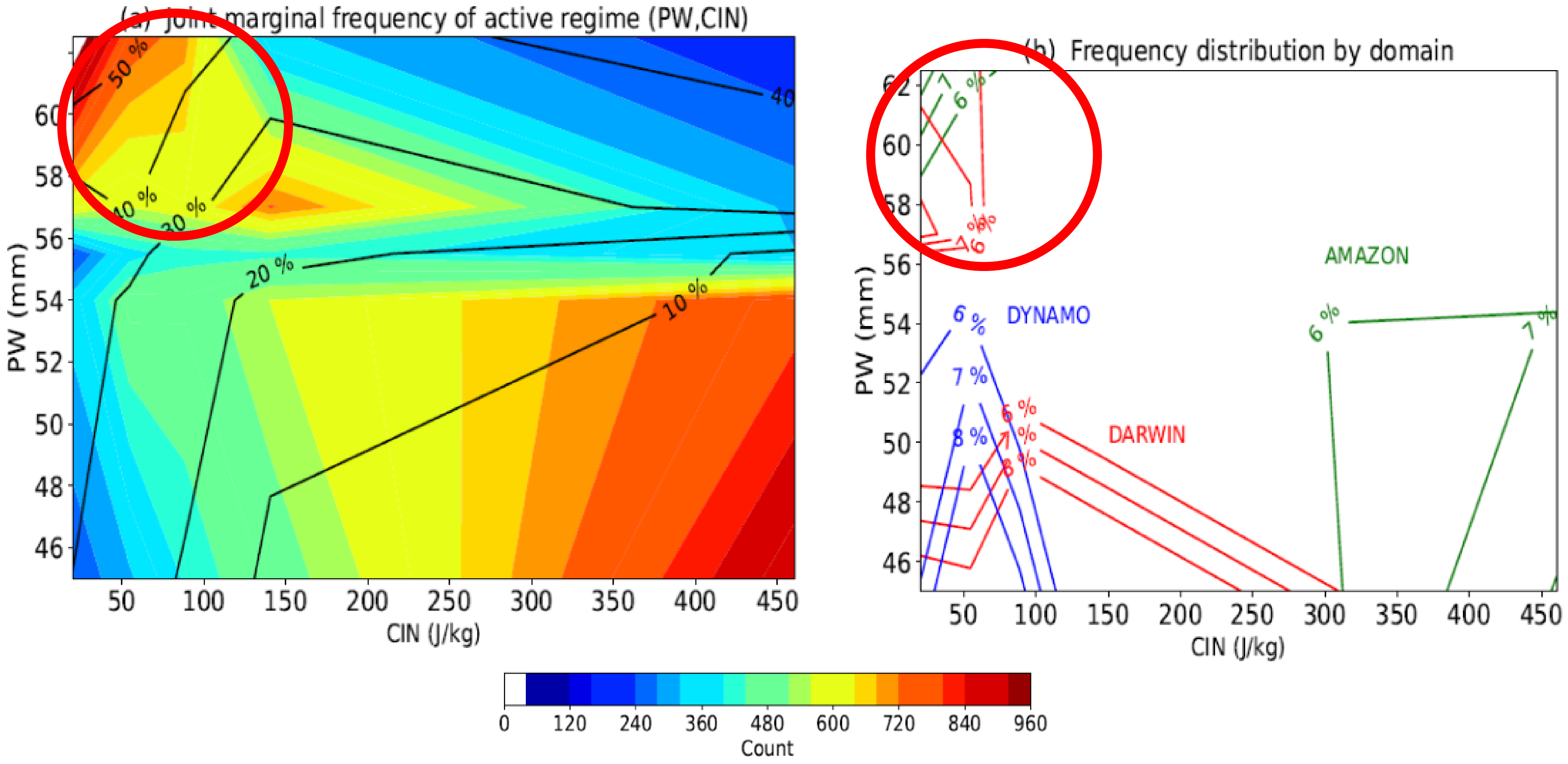
- The distribution of probability of an active regime is calculated in a five-dimensional environment space.

Variable/Bin	Very low	Low	Moderate	High	Very high
PW	37 mm to 53 mm	53 mm to 55 mm	55 mm to 56 mm	56 mm to 58 mm	58 mm to 67 mm
CAPE	1 J/kg to 295 J/kg	295 J/kg to 521 J/kg	521 J/kg to 758 J/kg	758 J/kg to 1045 J/kg	1045 J/kg to 2216 J/kg
CIN	0 J/kg to 40 J/kg	40 J/kg to 69 J/kg	69 J/kg to 108 J/kg	108 J/kg to 173 J/kg	173 J/kg to 748 J/kg
LLSHEAR	0 m/s to 4 m/s	4 m/s to 6 m/s	6 m/s to 8 m/s	8 m/s to 11 m/s	11 m/s to 21 m/s
ULSHEAR	0 m/s to 5 m/s	5 m/s to 8 m/s	8 m/s to 12 m/s	12 m/s to 16 m/s	16 m/s to 46 m/s



- Frequency of active regimes is most sensitive to PW and CIN
- Much weaker but negative relationship to CAPE

Implications for regional differences



- DARWIN : Low CIN, Much of variability related to PW.
- DYNAMO: Low PW, Low CIN, weak variability
- AMAZON: Large variability in both PW and CIN

Summary

- Much of the variability and regional differences in the tropical precipitation regimes is related to that in **precipitable water** and **convective inhibition**.

Thank you