Quantifying Convective Aggregation using the Tropical Moist Margin Length

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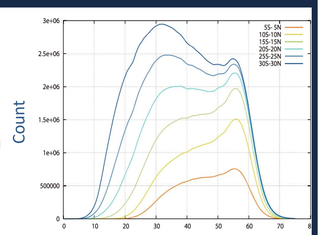
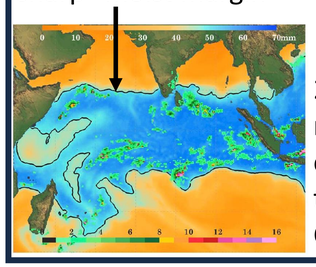
Motivation

1) Tropical atmosphere tends to be either moist or very dry
→ Bimodal distribution of CWV, separated by a sharp "moist margin"

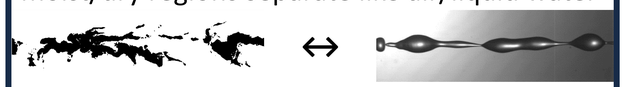




2) The evolution of this moist margin's length can help us understand the organization of CWV and convection

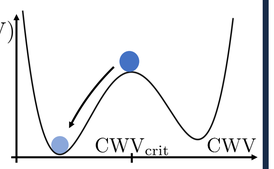
A Phase Separation Analogy

1) We make the analogy that in the trop. atm., moist/dry regions separate like air/liquid water

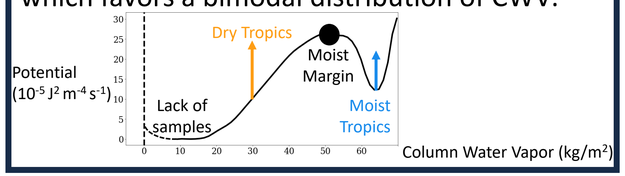


2) We also assume that the evolution of CWV is entirely determined by a potential function V:

$$\frac{\partial \mathrm{CWV}}{\partial t} = -\frac{dV(\mathrm{CWV})}{d\mathrm{CWV}}$$

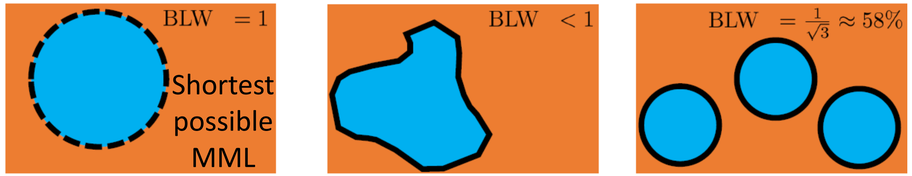


3) Calculating V from reanalysis data of the Atlantic ITCZ, we find that it often has 2 wells, which favors a bimodal distribution of CWV:

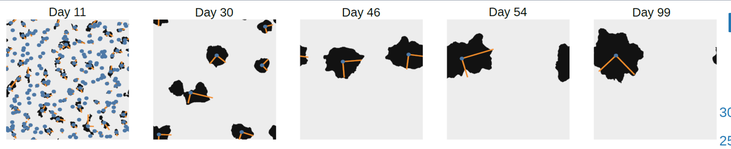


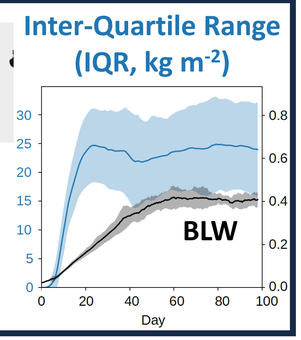
We introduce a new index (BLW) to measure the degree of aggregation of a given CWV field

From the phase separation analogy, we show that a shorter moist margin length (MML) corresponds to a more bimodal/aggregated state, leading us to formulate a simple convective organization index: $\mathrm{BLW} \stackrel{\mathrm{def}}{=} \left(\frac{\text{Minimal Contour}}{\mathrm{MML}}\right)$



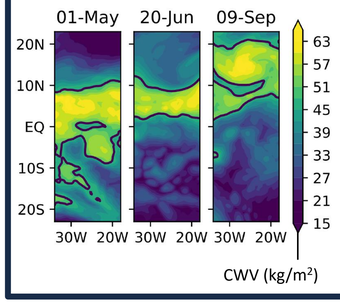
Application 1: Radiative-Convective Equilibrium



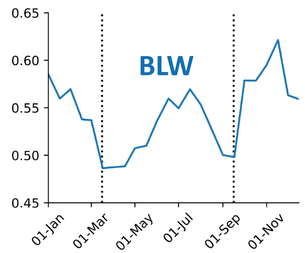


We test BLW in a suite of storm-resolving simulations of radiative-convective equilibrium with the COSMO model (movies at this link). Without tuning, BLW can track both the coalescence and coarsening phases of self-aggregation across climates, unlike e.g., the IQR of CWV.

Application 2: Inter-Tropical Convergence Zone



Applied to ERA5 reanalysis, BLW quantifies the seasonal cycle of the Atlantic ITCZ organization from hourly snapshots of the CWV field. The most disaggregated states occur during boreal spring/fall.



Key Points

1) The length of the margin separating moist and dry regions in the tropics can measure convective aggregation in simulations and obs.
2) We build a framework relating the moisture field's spatial organization to its time-evolution via a phase separation analogy.
3) We infer an index quantifying convective aggregation in radiative-convective equilibrium simulations and the tropical Atlantic ITCZ.

Conclusion

Why BLW to quantify convective organization?

- Easy to interpret as the moist margin can be superimposed on the CWV field.
- Rooted in theory.
- Transparent to calculate with only 2 choices:

1) CWV percentile defining the moist margin,
2) Reference underlying shape of CWV field.

Implications

- (Dis)aggregation ≈ Competition between aggregating tendencies (double-well V) and disaggregating tendencies (single-well V).
- BLW can help study the effect of aggregation on precipitation, climate sensitivity, etc.

Key references

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