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Understanding the Transition to Strong Convection in Realistic and Idealised Cloud-Resolving Simulations of Different Aggregation Scenarios

Anna Deluca[1], Robert S. Plant[2], Christopher E. Holloway[2] and Holger Kantz[1]

(1) Max Planck Institute for the Physics of Complex Systems, Dresden, Germany, (2) Department of Meteorology, University of Reading, United Kingdom

University of Reading

mpipks Nonlinear Time Series Analysis

I. Introduction

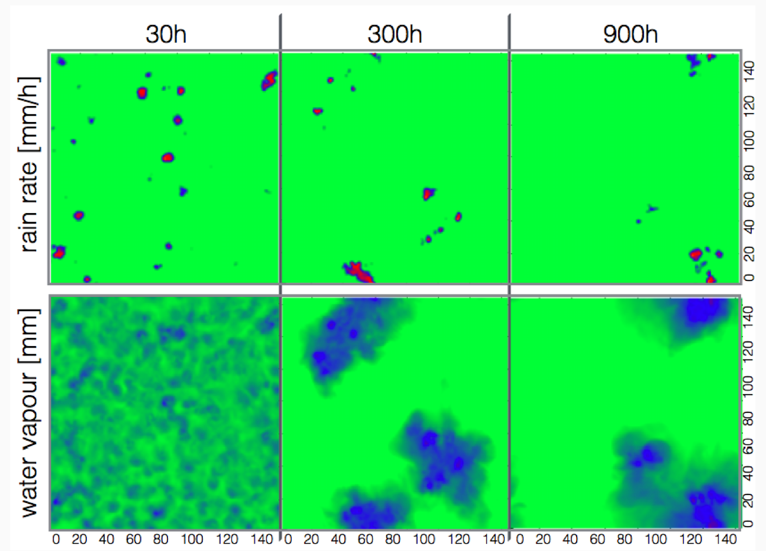
Recent empirical studies across a broad range of observational scales have attempted to characterize aspects of convective phenomena with a view to constraining convective parametrizations.
In this contribution, we aim to characterize aspects of convective phenomena with a view to constraining convective parametrization.We will further characterize precipitation and column moisture content relationship, as well as, study precipitation clusters properties, in order to improve understanding about atmospheric convection self-organization processes.

II. Data - Unified Model Output

We analyse runs from the version 7.5 of the Met Office Unified Model, which is semi-Lagrangian and non-hydrostatic. It has 4km horizontal resolution and 70 vertical levels. The model top is at 40 km and the time step is 30 s. The model physics includes Smagorinsky-type sub-grid mixing in the horizontal and vertical dimensions and a mixed-phase microphysics scheme with three components: ice/snow, cloud liquid water, and rain. Almost all rainfall is generated explicitly.

A. Idealized Case

This case is an idealized control run with the Radiative-Convective Equilibrium setup with fix SST to 300K and no rotation. It has domain size 576X576 km and periodic lateral boundary conditions. It is run for 40 days.

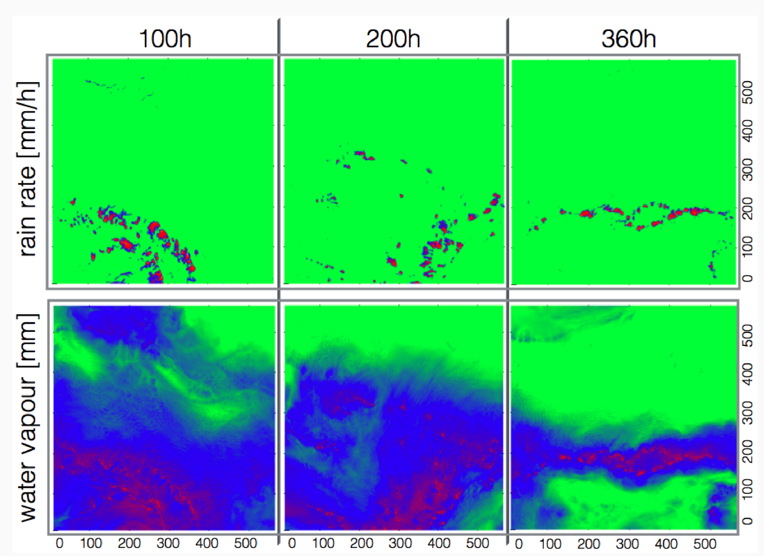


(Run A)

We also analyze real cases of organized convection that resemble the idealized setup. They are centered on the equator where rotation effects are at a minimum; have an aggregated (highly clustered) state within at least the middle 5 days of the 15-day simulation but still significant mean rainfall during that time; as well as, sufficiently warm sea surface temperatures (SSTs). The lateral boundary conditions come from ECMWF operation analyzes (updated every 6 h), as in Holloway et al. (2013).

B. Indian Ocean Case

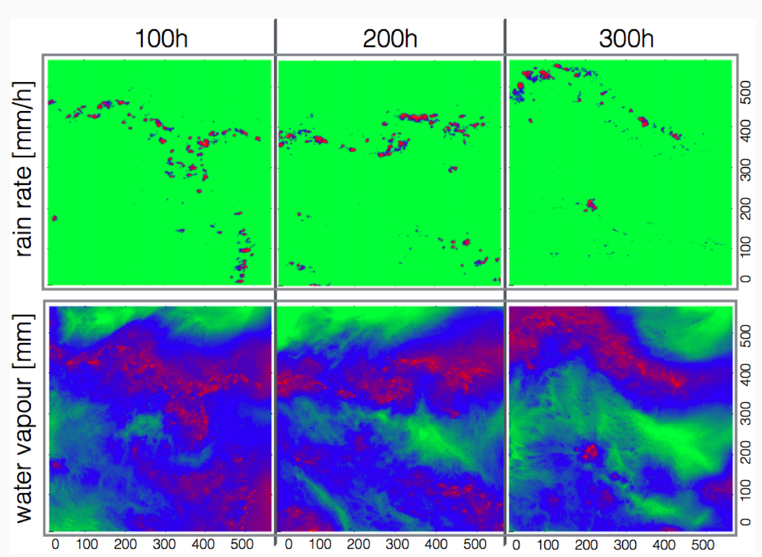
This realistic run starts on the 25-01-2009 and it lasts 15 days. Its domain is 4km griding of 70-80E and 5S-5N. It has some small islands in the north-east section of the domain.



(Run B)

C. West-central Pacific Case

We also data from a realistic simulation a domain in the West Pacific, 10 S - 10 N, 165 E to 185 E, starting on 2009-05-02. It is has no land and it is run for 15 days.



(Run C)

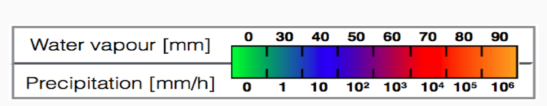
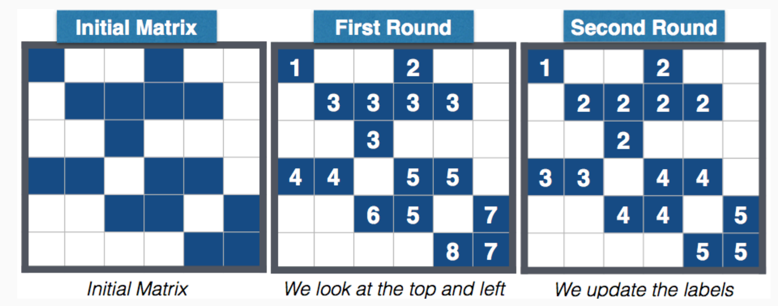


Figure 1: We show precipitation and water vapor fields at the beginning, the middle and the end of the simulation for the three different runs.

III. Methods - 3D Cluster Algorithm



Previous studies have tried to connect convective organization with theories of critical phenomena and statistical physics Peters and Neelin (2006); Peters et al. (2009). We have extended the classic cluster labeling algorithm developed by Hoshen and Kopelman (1976) for 3 dimensions (where time would be the third dimension) and for allowing sites on the corners to be also accounted as neighbors. This algorithm is an application of the well-know to computer scientists Union-Find algorithm.

Figure 2: This figure shows three the initial, intermediate and final step of the cluster identification algorithm used, applied to a matrix of 6x6 which sites can be filled (blue) or empty (white).

IV. Results - Rain rate and water vapor distributions

The rain rate distributions are broad. For rain rate higher than 0.1 mm/h can be approximated with a power law with an exponential tail. Moreover, the distributions for different runs are quite similar. The column water vapor distributions are bimodal. When we conditioned to water vapors when precipitation is non-zero, we observe a maximum before the so-called 'critical value' in Peters and Neelin (2006). We do not obtain long tails on the CWV distribution as seen by these authors for satellite data.

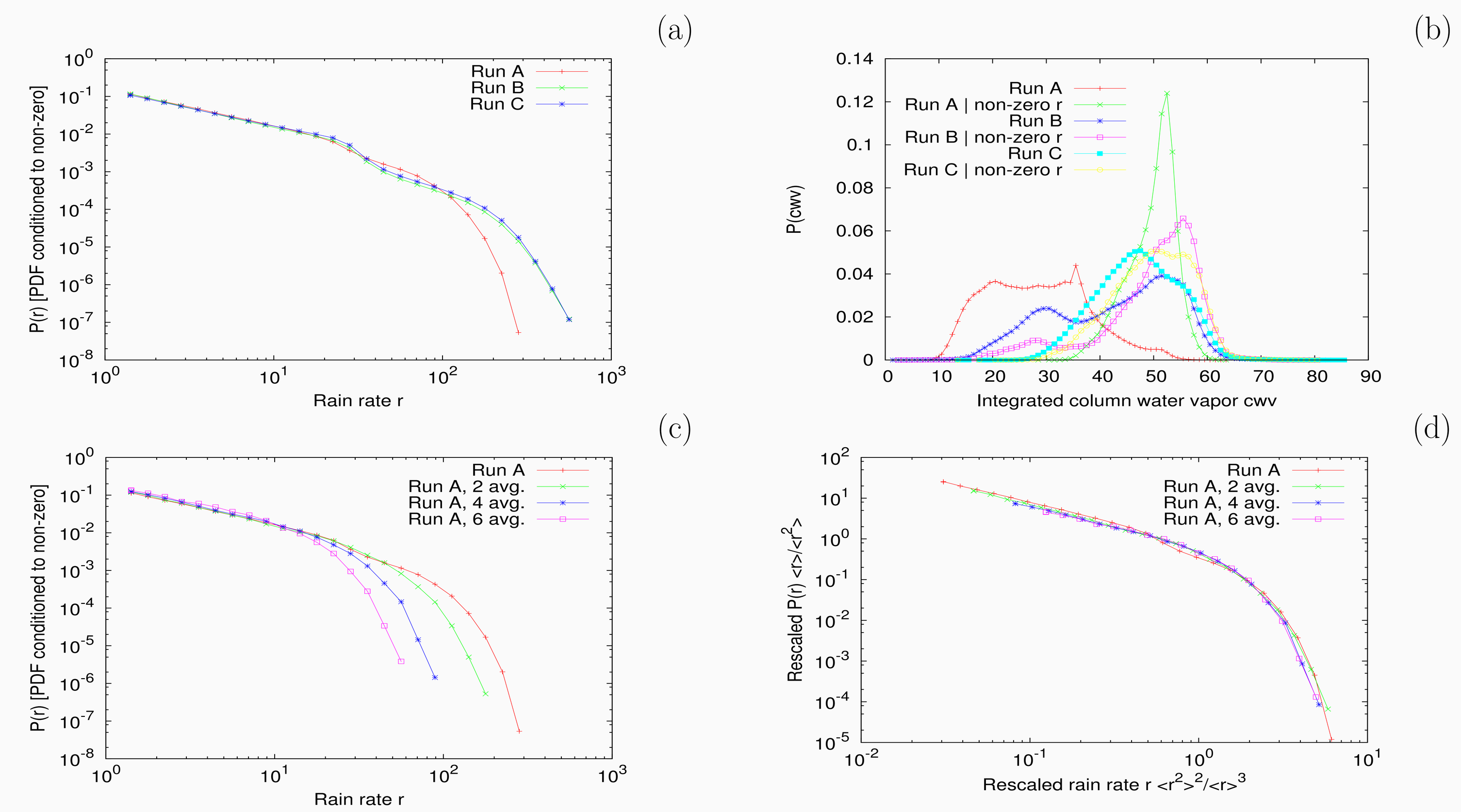


Figure 3: Distributions of the rain rate (a) and the integrated column water vapour (b) for the different runs. In (c) is shown the distribution of the rain rate for run A for different coarse grained (averaging to one single value, values corresponding to 2x2 grid points, 4x4 grid points and 6x6 grid points). Figure (d) shows the same as (c) but rescaled.

V. Results - Precipitation-Moisture Relationship

We analyze the functional relationship between column water vapor and the average precipitation. In this case, the idealized run curve picks up much earlier than the realistic runs. For the idealized run and for the spatially coarse grained corresponding output, the curves are compatible an asymptotic approach to a maximum cwv value. For the realistic runs, it is unclear if it saturates or not around a precipitation average value.

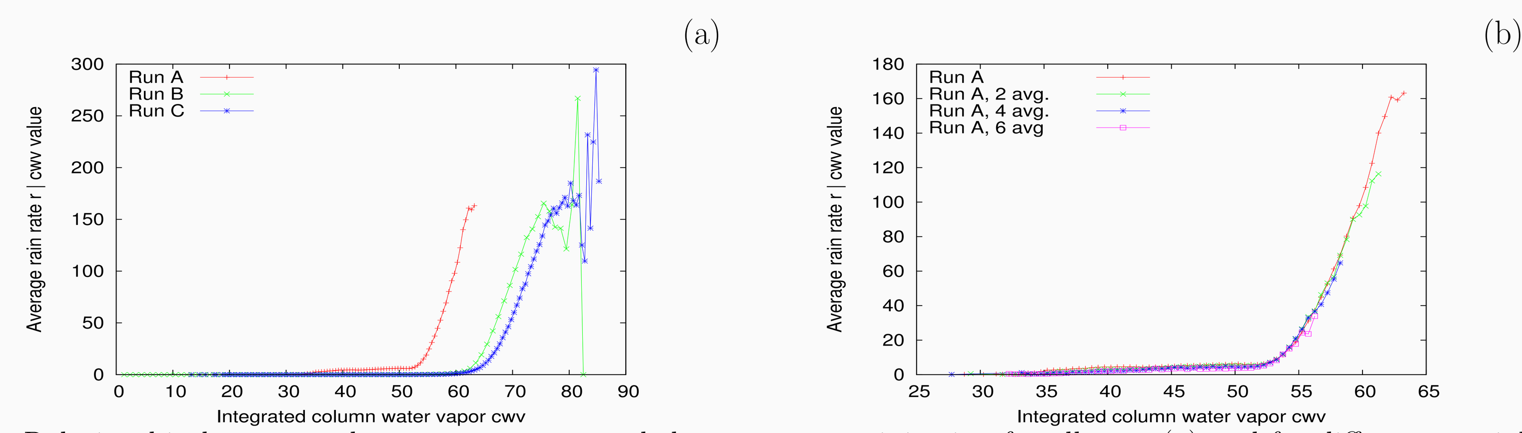
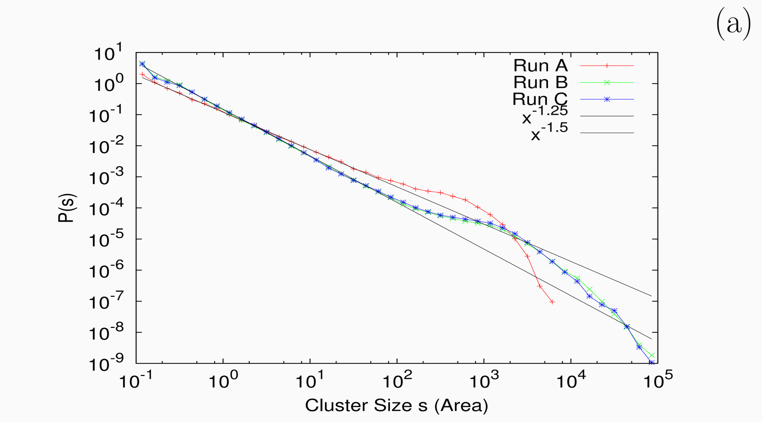


Figure 4: Relationship between column water vapor and the average precipitation for all runs (a) and for different spatial averages for run A.

VI. Results - Clusters Properties

The distribution of cluster sizes are present differences for the idealized and the realistic runs. The distributions can be approximate by a power law for several orders of magnitude (as seen for real data by Peters et al. (2009); Wood and Field (2011)). The next figure show indicative exponents, which clearly differ in value for both cases.

Figure 5: Cluster size (horizontal area of the cluster) distribution for the different runs. Exponents are indicative and values are not exact.



We also look at how cluster statistical properties change with coarse graining. In this case, we consider 'Energy released', which is the area multiplied by the total amount of rain. A clear data collapse is obtained for the different spatial aggregations.

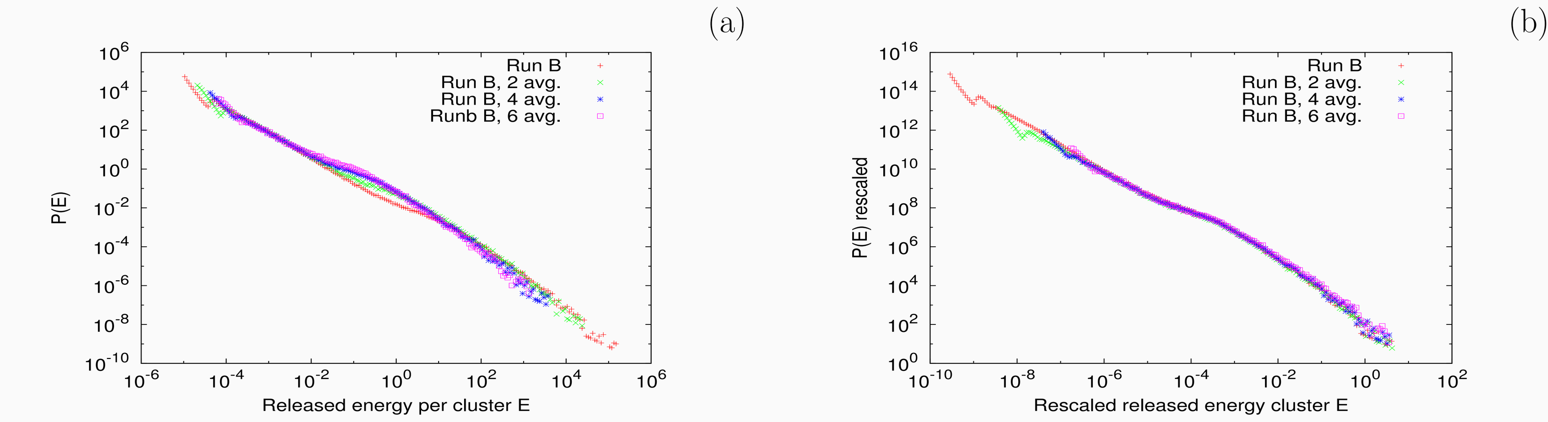


Figure 6: Figure shows different cluster energy distributions for run B (a). (b) is like (a) but rescaled.

Conclusions

- The rain rate distributions can be approximated with a power law with an exponential tail for the three cases studied.
- The column water vapor distribution picks up around the so-called 'critical value' in Peters and Neelin (2006), however we do not observe long tails.
- The functional relationship between column water vapor and the average precipitation has a clear pick up.
- The point of pick up depends on the run. For high water vapor values the shape is unclear.
- In addition, the effect of spatial averaging does not explain the differences, as suggested by Yano et al. (2012). As recently pointed out by Gilmore (2015) and Ahmed and Schumacher (2015), this relationship study is ill-posed due to its big sensitivity to noises.
- The distribution of cluster sizes are present differences for the idealized and the realistic runs. W
- The energy released per cluster distribution has scaling properties.

Outlook

- We are working on expanding the analysis to 1 minute temporal resolution (current analysis uses hourly data).
- Distinguish if the precipitation comes from a convective or an stratiform cloud.
- Analyze correlations of the precipitation and CWV fields in time and space.

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Contact me: adeluca@pks.mpg.de