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Effects of Shear on Cloud Field Organization

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Introduction

Shear causes two effects which are currently not well represented in deep cumulus parametrization schemes. First, it causes the vertical transport of horizontal momentum, which can "play a large role in the momentum balance of the atmosphere" [1]. Second, through interaction of the low-level shear and cold pools, low-level shear can organize the convection into larger structures such as squall lines [2]. The upscale transport of energy will be the focus of this study.

The method for studying convective organization is to run high-resolution Cloud-Resolving Models (CRMs) under different shear profiles to generate organized convective structures [3, 4]. The spatial scales of organization are then analysed for 2 different shear profiles using a simple measure of organization.

Model Setup

The CRM used was the latest version of the idealized UK Met Office Unified Model (vn10.6). It was run over a biperiodic domain of 256x256 km^2, with 1 km horizontal resolution, variable vertical resolution with 70 levels, and a 30 s timestep. The effects of radiation were modelled with a 2 K day^{-1} prescribed cooling, which is broadly typical for tropical cooling rates through long-wave radiation. There was no Coriolis force and no geostrophic forcing.

2 experiments were run: **no wind** and **strong shear**. In the **strong shear** experiment, the mean wind profile was relaxed back to a profile shown in **Figure 1**, as in previous studies [4].

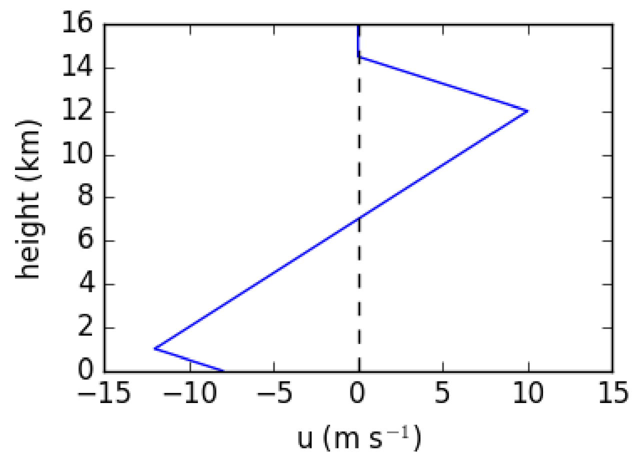

Figure 1: The mean wind profile for the **strong shear** experiment. The u-wind was relaxed back to this profile with a timescale of 25,600 s. The v-wind was relaxed back to a profile of zero mean wind.

Results – no wind

As shown in **Figure 2**, convective cells are created across the domain, being clearly visible in the upward wind, *w*, and cloud liquid water, *qcl*. An example of cell splitting is shown in **Figure 3**.

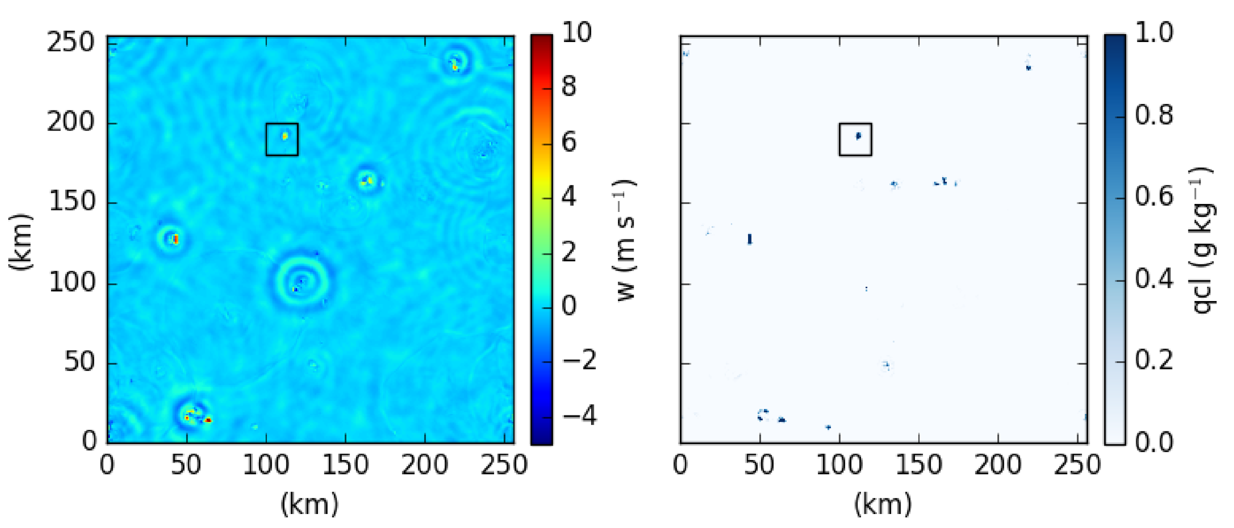

Figure 2: *w* and *qcl* at 2422 m for the **no wind** experiment. Box shows initial location of cell shown in **Figure 3**. Both fields are at 10 days into the simulation.

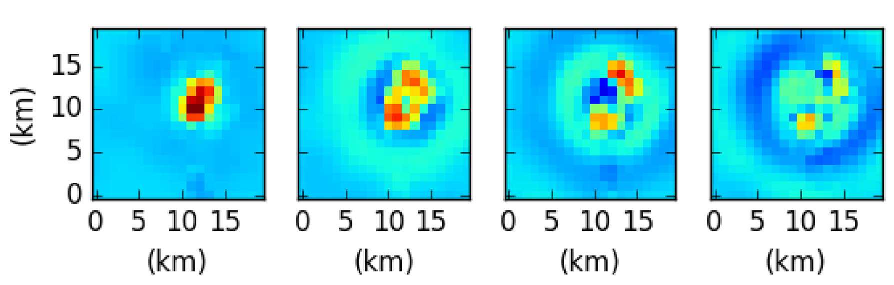

Figure 3: Close up box in **Figure 2** - cell undergoing cell splitting, showing 4 snapshots of *w*,10 minutes apart.

Results - strong shear

Under strong shear, the convection organizes itself into long, linear features resembling squall lines (**Figure 4**). These squall lines persist for several hours, decreasing the temperature and water vapour in their trailing cold pools (**Figure 5**). Both of these effects act to inhibit future convection.

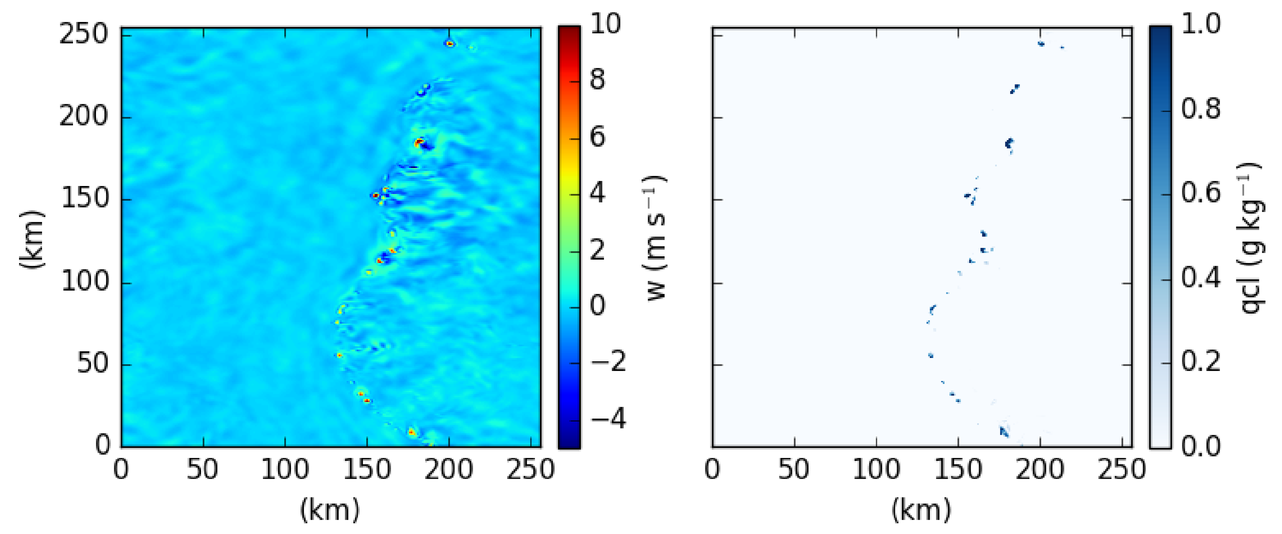

Figure 4: *w* and *qcl* at 2422 m for **strong shear**, after 19 days. Clearly defined long-lived squall lines develop in this simulation, traversing from east to west with the mean wind profile.

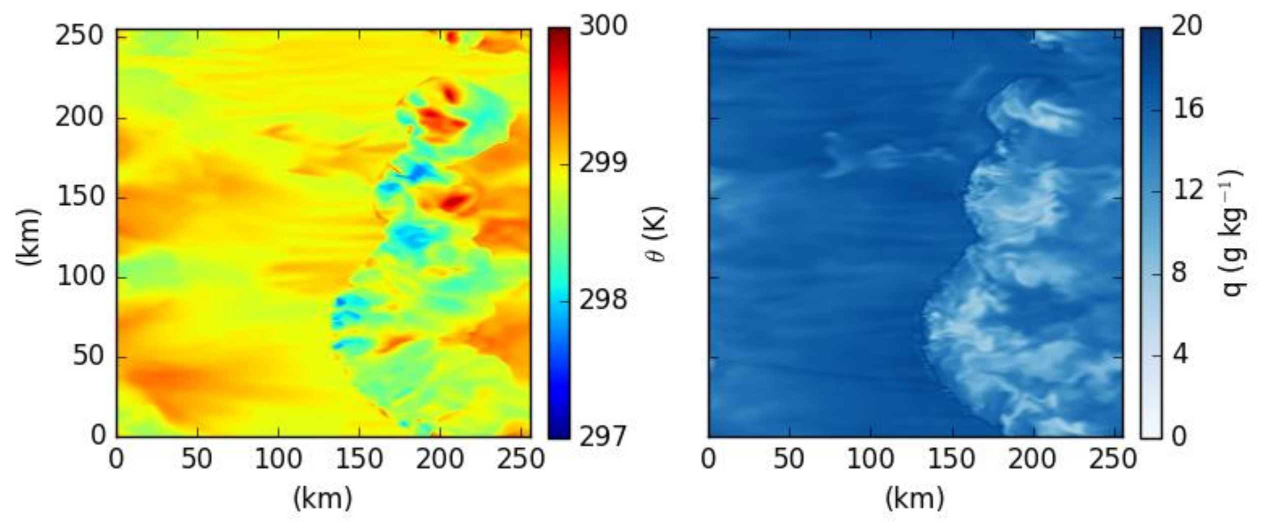

Figure 5: Boundary layer effects of organization. The potential temperature at 5 m and the water vapour at 500 m show strong cooling and drying respectively.

Measure of organization

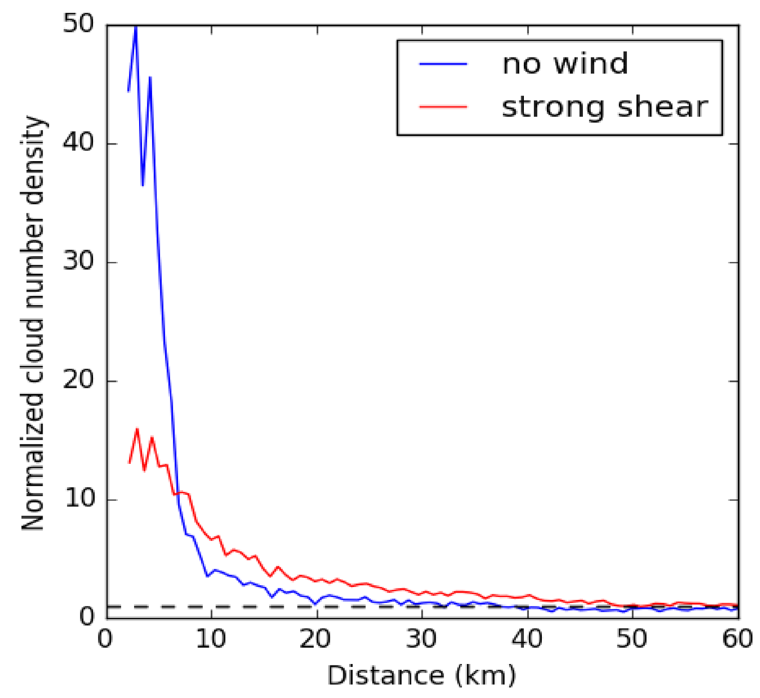

Figure 6: The lines show the area weighted number of clouds found at a given distance from each cloud considered in turn – random cloud cell spacing would have a value of 1 at all distances as indicated by the horizontal dashed line. The **no wind** experiment shows signs of strong clustering of clouds near to existing clouds, at 10 km distances or less. This is due to the cell splitting outlined above, and the fact that cells are often created close to existing cells. The **strong shear** experiment shows larger organization from 10 – 40 km, indicating that in this experiment the scales of organization are larger.

Summary

Realistic convective structures are seen in both experiments. The squall lines seen are similar to those in other high-resolution modelling studies [3, 4]. A simple measure of organization captures the spatial scale of organization of both experiments.

In future work these experiments can be used to calculate PDFs of the mass-flux through the clouds, which in turn can serve as a basis for modifying a stochastic convection parametrization scheme.

References

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Acknowledgements

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