Investigating the spatial distribution of a shallow cumulus cloud field

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1. Introduction

Improving the representation of small scale features like shallow cumulus clouds in global climate models requires a better understanding and description of said features. Where in the early days studies on cloud properties like size and spacing depended on satellite data or small sized LES simulations, nowadays we have cloud-resolving regional scale simulations to our disposal. Using this to our advantage, we seek to confirm the linear relation between cloud size and nearest neighbour spacing found by Joseph and Cahalan (1990) (JC90). They based their findings on satellite data, we will use regional scale model data which has the benefit of more clouds and therefore more reliable results.

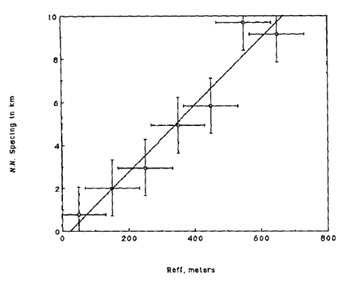

Figure 1: Relation between cloud size (x-axis) and nearest neighbour spacing (y-axis) from JC90.

2. ICON simulation and clustering algorithm

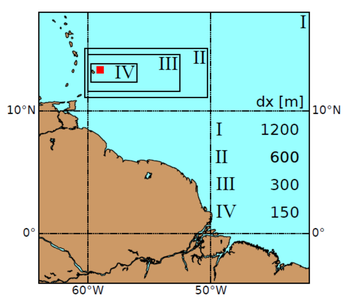

Figure 2: Overview of ICON set-up.

The simulations over the Atlantic are performed with the ICON (Icosahedral Nonhydrostatic) model and carried out by the HD(CP)^2 project. The set-up consists of four nests (Fig. 2), the inner domain is used for analysis. This domain has a resolution of 150 m and is roughly 150x400 km.

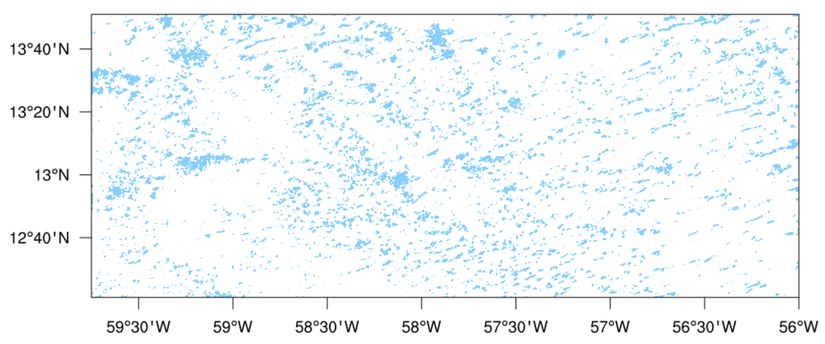

Figure 3: Snapshot of the liquid water field from ICON.

Cloudy cells are selected by using a threshold of 1 x 10^{-8} kg/kg for liquid water (Fig. 3). Subsequently these cells are clustered into clouds and their size is defined as the square root of the horizontal area they cover. Their center of mass is used to compute the distances between them. Every snapshot contains about 4000 clouds. To reduce statistical noise 8 timesteps are averaged for the analysis.

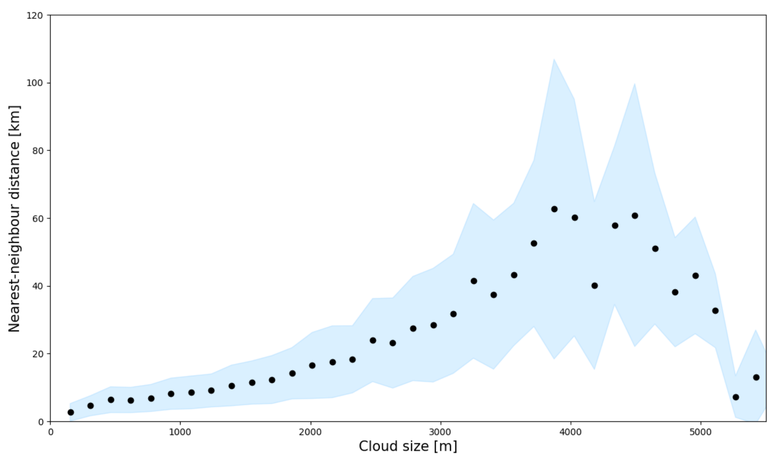

Figure 4: Averaged nearest neighbour distance (black dots) to clouds of the same size, with the standard deviation from the mean in blue.

3. Nearest neighbour distance

The distance between nearest neighbours is visualized in two different ways. First, only the distance to clouds of a similar size is taken into account. Averaging all these distances for clouds of similar size results in Figure 4. The uncertainty (blue shaded area) is larger for bigger clouds since there are less. Second, the distance to any other cloud is used for computing the minimal distance, averaged per cloud size (Fig. 5). The latter method corresponds to the method of JC90. Both figures show an increase of nearest neighbour distance with size.

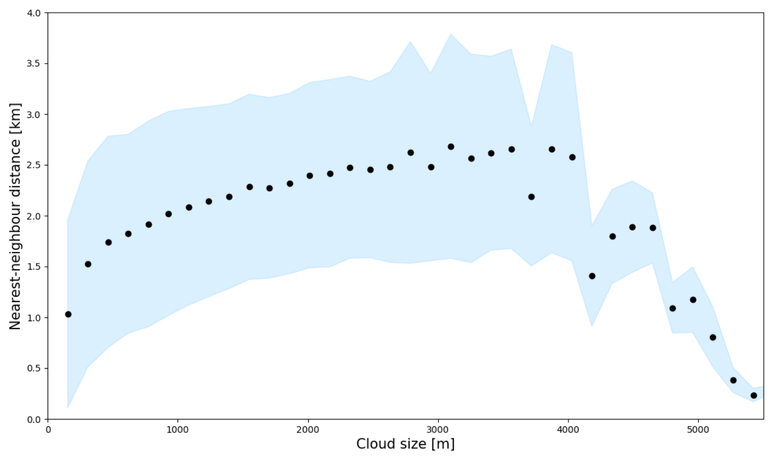

Figure 5: Averaged nearest neighbour distance (black dots) to all clouds (following JC90), with the standard deviation from the mean in blue.

4. Nearest neighbour size

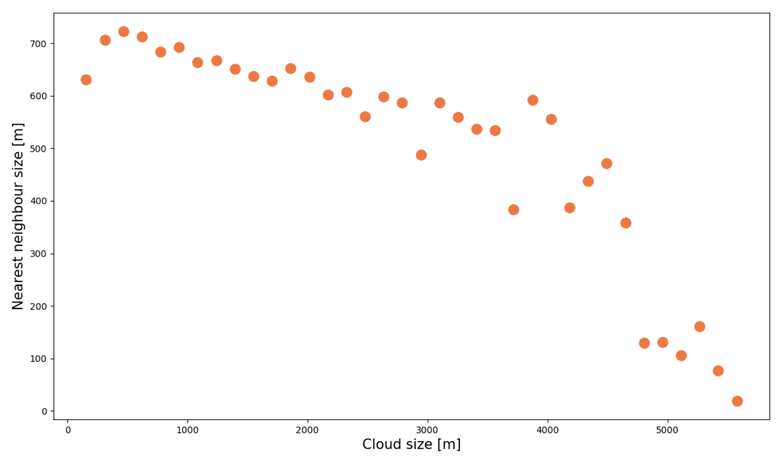

Figure 6: Size of the nearest neighbour, averaged over similar cloud sizes.

To gain more insight into the patterns of clustering also the size of the nearest neighbours is investigated. For clouds of similar size, the size of their neighbours is averaged (Fig. 6). A general decrease of neighbour size with increasing cloud size can be seen, this confirms the findings of section 3. The small dip for small cloud sizes could mean that small clouds cluster first together rather than with larger clouds. This can however also hint at noise in the data for the smallest clouds. The big drop-off for larger cloud sizes is due to the small amount of clouds of this size.

5. Conclusions and Outlook

We have found that nearest neighbour spacing increases with cloud size. As a consequence, the average size of the nearest neighbour slightly decreases with cloud size.
To reduce uncertainty, more than just one nearest neighbour can be taken into account. Next to that we will use artificial regularly spaced cloud fields with a similar cloud size distribution as the original data. The difference between these regular fields and the model output in terms of spacing can give more information on the role of clustering and organization in the cloud field.

References: J.H. Joseph and R.F. Cahalan, 1990: Nearest Neighbor Spacing of Fair Weather Cumulus Clouds. Journal of Applied Meteorology, **29**.

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