Conceptual model explains how thunderstorm clouds bunch together

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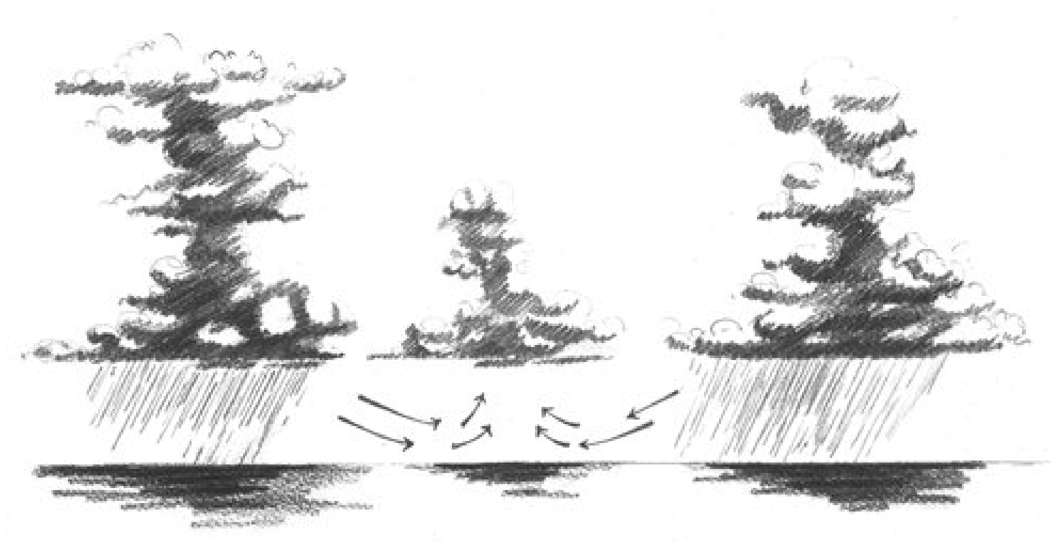

In an area with more clouds, the colder, denser air under them, caused by the rainfall, extends downwards and outwards from the cloud. A gust front is formed, and collides with fronts from other clouds. The air is subsequently forced upwards, and a new cloud is formed by the rising air. Credit: Søren Granat

Understanding the weather and climate change is one of the most important challenges in science today. A new theoretical study from Associate Professor Jan Härter at the Niels Bohr Institute, University of Copenhagen, presents a new mechanism for the self-aggregation of storm clouds, a phenomenon by which storm clouds bunch together in dense clusters. The researcher used methods from complexity science and applied them to formerly established research in meteorology on the behavior of thunderstorm clouds. The study is now published in *Geophysical Research Letters*.

The life and death of a storm cloud

When the sun warms up the surface of the ocean, warm, humid air rises from the ocean surface, forming tall, columnar thunderstorm clouds that reach heights of approximately 12 km and measure typically only a few kilometers across. As these clouds produce rain, some of it evaporates and cools the local area under the cloud.

The initial circulation of air forming the cloud is shut down and the cloud dissipates. If it were this simple, this should be the end of the thunderstorm cloud. However, the dense air below the cloud needs to equilibrate with less dense air surrounding it: "Cold air is denser, and it spreads away from the cloud. Gust fronts are formed, which can collide with gust fronts from other clouds. As a consequence, the air rises up, and new clouds are produced. This means that areas where sufficiently many clouds are, are more likely to set off additional clouds," Jan Härter explains (Illustration 1).

"Areas with fewer clouds exhibit further reduction of clouds. As energy needs to enter the system, and since energy comes from the sunlight, there is a limit to how big the cloud lumps can grow—so we put a constraint into our model. The result is that cloud clusters form, with cloud-free regions in between. This is also seen in observations for the tropical ocean."

Combining theory with real world phenomena

Building models is purely theoretical, but still manages to explain phenomena. "It is a theoretical argument, a suggestion for a mechanism that can now be tested. Clustering of thunderstorm clouds has been observed in the real world, but still lacks a scientific explanation. If we contrast two extreme cases, where one cloud is created, it ends up shutting itself down. Then statistical mechanics says no convective self aggregation will take place. Comparing this to another model where two clouds create another one, aggregation can take place. That's basically what the theoretical model can do. This type of self organization is hugely interesting and can occur in a range of systems from biology to magnetism."

Tropical meteorology is, due to the strong interaction of clouds with solar irradiation there, relevant for climate change. More clustering in a future climate might affect how much the ocean warms, relative to the rate seen today. Prediction of clustering of storm clouds could affect the weather in Denmark as well, and fairly recent events in Denmark with surprise flash floods, flooded sewers and basements, and damage to infrastructure have prompted questions on the origin of such sudden floods. Deeper understanding of how clouds interact could shed new light on the occurrence of such floods.

More information: Jan O. Haerter. Convective Self-Aggregation As a Cold Pool-Driven Critical Phenomenon, *Geophysical Research Letters* (2019). DOI: 10.1029/2018GL081817

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