Quantifying the Importance of Cold Pool Mechanisms for Convection Triggering

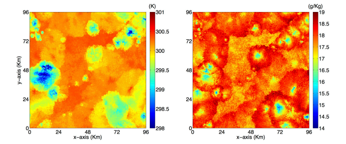
Research Highlight

The organization of the subcloud layer into cold pools, areas of evaporatively cooled downdraft air spreading on the surface, is one of the key processes that help sustainin deep convection. It has long been known cold pools can spawn new convective cells by mechanically lifting air along their gust front. Such lifting could be the result of the interaction of a cold pool with wind shear or sea breeze, or it could be caused by the collision of two or more cold pools. This triggering mechanism is often referred to as “mechanical forcing.” More recently, another mechanism, often referred to as “thermodynamic forcing,” has been suggested, leveraging on the fact that leading edges of cold pools typically present positive moisture anomalies. The enhanced water vapor content of cold pool parcels favors the generation of new convective cells because it can sensibly reduce the convective inhibition encountered by parcels once they start ascending. Although both mechanisms are expected to play a role in different scenarios, a quantification of their importance has not been investigated.

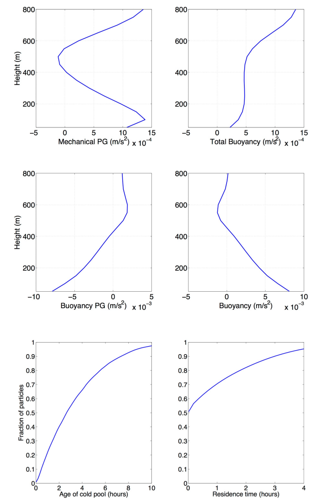
In this paper, a novel method based on a Lagrangian particle model is proposed, distinguishing the two forcings and quantifying their importance in different environments. The distinction is mainly based upon the accelerations experienced by the Lagrangian particles before they reach their level of free convection, with particular focus on buoyancy and mechanical and buoyancy pressure gradient. Further support is also provided by the age of the cold pools when a particle is triggered, with the idea that younger cold pools have stronger gust fronts. Thus, they are likely to spawn convection mechanically and vice versa for old cold pools. Finally, the time spent by particles inside a cold pool is considered, with mechanically lifted particles spending nil or very little time within a cold pool.

The results obtained from a large-eddy simulation over the ocean, with no wind shear, show particles reaching levels of free convection, experiencing positive values of mechanical pressure gradients near the surface. As it turns out, these are due to the lifting by the gust fronts of the cold pools. The particles also experience large values of buoyancy near the surface, although these are largely cancelled by buoyancy pressure gradients, as is often the case in cumulus convection. The total buoyancy, defined as the sum of buoyancy and buoyancy pressure gradients, starts to contribute only in the upper part of the subcloud layer, close to the inhibition layer encountered by the parcels, where it dominates over mechanical pressure gradients. A comparison with a set of idealized parcels lifted from the environment, far from cold pools, also shows that the thermodynamic forcing is crucial to reduce the convective inhibition encountered by the particles.

The picture that emerges from the study suggests that particles reach their level of free convection through a cooperation of the two forcings. First, at the surface, since buoyancy pressure gradients cancel buoyancy almost completely, mechanical lifting is needed for particles to start ascending. Second, the kinetic energy given by the mechanical pressure gradients and the total buoyancy allows particles to reach the base of the inhibition layer. There, the high moisture content of the particles reduces the convective inhibition and allows the particles to reach their level of free convection.



Horizontal sections of (left) potential temperature and (right) water vapor specific humidity at 25 m from the model surface.



The top four panels show the average accelerations of particles reaching LFC. The bottom two panels show cumulative distribution of cold pool ages when particles are lifted (left) and of time spent by particles within cold pools (right).

Reference(s)

Torri G, Z Kuang, and Y Tian. 2015. "Mechanisms for convection triggering by cold pools." Geophysical Research Letters, , . ACCEPTED.

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Working Group(s)

Cloud Life Cycle