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Investigating tropical squall lines with a cloud resolving model

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Using a cloud resolving model, we attempt to clarify the physical processes responsible for the organization of deep clouds into squall lines in the tropics. To do so, we impose a vertical wind shear, and investigate the response of deep convection to different shear strengths in radiative convective equilibrium. As the magnitude of the shear increases, the convection becomes more and more organized into a line, perpendicular to the shear. It is due to the interaction of the low-level shear with the cold pools associated with convective downdrafts. Beyond a certain shear, called optimal shear, the line tends to orient at an angle to the shear. The existing literature suggests that this angle conserves the projection of the shear on the direction perpendicular to the squall line near the optimal value, a hypothesis that we further investigate here.

In this work, we propose a systematic method, based on image auto-correlation, to determine the angle of the squall line with respect to the shear. We highlight the existence of the sub-critical and super-critical regime, as predicted by earlier studies. In the sub-critical regime, squall lines are indeed perpendicular to the shear. Yet, angles of squall lines in the super-critical regime do not clearly correspond to the conservation of the projected component of the shear near the optimal value. In particular, squall lines often remain more perpendicular to the shear than expected.

We thus investigate the balance between shear and cold pool winds to explain this difference. Using statistical methods on extreme events, we find that this difference is due to an intensification of cold pool potential energy with shear. Cold pool intensification allows the squall line to better resist to the shear, and thus reduces its angle of orientation. This new feature leads us to conclude that two mechanisms maintain a squall line in wind shear : the orientation of clouds and the intensification of cold pools.