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The Impact of Coastal Topography on Mesoscale Convective System Dynamics

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Mesoscale Convective Systems (MCSs) can cause hazardous flash flooding, high winds, frequent lightning, hail, and tornadoes. As these organized deep convective storms move across Earth's surface, they are impacted by the underlying topography and the associated lower-tropospheric heterogeneities, such as the offshore stable marine atmospheric boundary layer (MABL) and mountainous terrain. The complex storm-land surface-ocean interconnectivity translates to particularly challenging forecasts and promotes the need to evaluate storm response as they move over a large parameter space of surface features in different environmental conditions. Idealized numerical simulations allow us to explore this parameter space and identify the fundamental physical processes controlling MCS response as storms translate over Earth's heterogeneous surface.

This presentation will highlight recent results from an ongoing and evolving series of numerical sensitivity experiments designed to quantify the impact of the MABL, mountains, and the combined impact of both on MCSs. Simulations are performed in 2D and 3D, with 200-m horizontal resolution and 50-m vertical resolution in the lowest 3 km stretched to 250-m at the top of the domain. MABL characteristics range between a -2 K to -8 K potential temperature deficit and a 250-m to 1.5-km depth. Plateau and island shaped terrain features are included with differing heights, 600-m to 3-km, and slopes. Altering the thermodynamic-kinematic vertical profile used to initialize the model provides an opportunity to evaluate the robustness of the results.

Recent simulations reveal that the relationship between the buoyancy of the MCS cold pool and MABL determines storm response as a storm moves over the stable boundary layer following collision between the two features. Furthermore, the presence of a surface stable layer is not always a detriment to storm survival, and at times can contribute to enhanced storm intensity. As storms move over topographic relief, they respond to the resultant changes in ambient instability and vertical wind shear. Their cold pools also respond to the ascending and descending sloping surfaces, impacting storm-scale physical processes and storm characteristics. Identifying these storm-land surface-ocean relationships will help advance our understanding of MCSs moving over heterogeneous surfaces, and ultimately have the potential to contribute to improved storm prediction.