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The Behavior and Characteristics of Squall Lines within Coastal Environments

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This work is part of an ongoing investigation examining the behavior and characteristics of squall lines within coastal environments. Squall lines are observed in a number of coastal regions globally, such as the Mediterranean region, the eastern United States, coastal South America, and southeastern Asia. These storms typically initiate and mature over inland regions and subsequently move toward the coastal waters. The relative depth and thermal perturbation associated a storm's cold pool versus that of the marine atmospheric boundary layer (MABL) within a given environment, in part, predict the resulting squall line evolution, convective lifting mechanism, and storm characteristics (e.g., precipitation, severe weather) as the storm propagates offshore. This work uses idealized numerical simulations to diagnose the storm scale processes governing the evolution of squall lines as they collide with coastal MABLs (i.e. sea breezes).

Numerical simulations are performed in 2-dimensions with the non-hydrostatic Cloud Model 1 (CM1; Bryan and Fritsch 2002) at 200 m horizontal grid spacing. The 20 km vertical grid is stretched, with 50 m spacing from the surface to 3 km increasing to 250 m spacing at 10 km and above, resulting in 110 vertical levels. The left half of the 600 km wide domain is defined as a land surface with the associated frictional properties, while the right half is assigned as water. No radiation or surface fluxes are included. The Weisman and Klemp (1982) thermal profile is used as initial conditions, with the relative humidity above the 1 km LCL reduced by 10% to prevent convective initiation by the MABL. The ambient wind profile increases linearly from zero to 10 m s-1 from the surface to 2.5 km, based on Weisman and Klemp (1982). Convection is initialized at t=0 over land by a +2 K perturbation warm bubble. The squall line develops to maturity prior to encountering the idealized coastline.

Sensitivity experiments are conducted to quantify the influence of the depth and thermal perturbation associated with the offshore MABL on squall line evolution. MABL temperature perturbations of -2 K, -5 K, and -8 K and depths of 250 m, 500 m, 1000 m are used, based on observations. The MABL is initialized simultaneously with the convection as a rectangular region of negative temperature perturbation over the water surface within the right half of the domain.

Preliminary results suggest that the evolution of the convective forcing mechanism upon encountering the MABL may be more sensitive to the MABL thermal perturbation than MABL depth. Initially cold pool forced storms that encounter a MABL with a -8 K thermal perturbation become forced by a wave and accelerate across the domain, for all MABL depths. Storms that encounter a MABL with a smaller thermal perturbation (i.e. -5 K, -2 K) remain cold pool forced. Conversely, squall line precipitation appears to be sensitive to the depth of the MABL. Total accumulated precipitation at the conclusion of the simulations decreases with increasing MABL depth; however, the accumulated precipitation increases and is the largest at the time of collision between the cold pool and 1000 m deep MABL. This increase is not observed in the other experiments. The relationship between precipitation intensity and the components of the pressure perturbations of the storm-MABL system is being explored. Understanding the unique impact of the MABL thermal perturbation versus depth on squall line forcing, propagation speed, and the associated hazards, including precipitation intensity, may advance predictions of the coastal storms.