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Boundary-layer clouds are ubiquitous across a wide range of conditions, yet most of our understanding of boundary-layer cloudiness is based on idealized, subtropical, largely barotropic marine environments. Here we are concerned with process-level understanding and prediction of boundary-layer clouds associated with midlatitude synoptic cyclones. The regions of a synoptic system are characterized by meteorological properties and boundary-layer structure. We use the Naval Research Laboratory's (NRL) Coupled Ocean–Atmosphere Mesoscale Prediction System (COAMPS) to explore low-cloud properties and mesoscale organization of clouds across a synoptic system. Here we present a weeklong COAMPS simulation of an extratropical cyclone impacting the Azores archipelago during the ACE-ENA field campaign (2017/18). We run the simulations at somewhat coarse grid spacings, so the results have operational utility for real-time mesoscale numerical weather prediction (NWP).

We evaluate the simulation output against observations taken at the Department of Energy Eastern North Atlantic site located on Graciosa Island. These include measurements of cloud boundaries and precipitation from lidars and a Ka-band radar, liquid water path retrievals from microwave radiometer, and regular soundings and surface meteorological measurements. To foster meaningful comparison between the fixed-in-space observations and the COAMPS results, we cast both model and observations in an analysis framework relative to the synoptic system. We accomplish this using the automated method of Naud et al. (2016), which identifies the low center, and cold and warm fronts, to composite the COAMPS results into a cold-front-centered coordinate system. This technique highlights the differences between pre-frontal, frontal, and post-cold frontal environments, and allows for straightforward comparisons between the different regions.

COAMPS credibly captures properties of the synoptic system, including 500-hPa heights, 850-hPa potential temperature, and mean sea level pressure. Similar to other studies, it underestimates the liquid water path and boundary layer heights as compared to ACE-ENA observations. COAMPS produces too little drizzle and too much heavy precipitation. Cold-sector boundary layer clouds are associated with strong positive surface sensible and latent heat fluxes, subsidence, strong inversions, and a deep, well-mixed boundary layer. Cloud features reminiscent of shallow cumulus are also found in the warm sector in areas of upward motion, weak surface sensible and latent heat fluxes, a stable boundary layer, and weak inversion strength. This analysis framework is highly useful for parameterization evaluation and development.
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