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# The Organization and Vertical Structure of Shallow Convection in Marine Cold-Air Outbreaks, based on the Cold-Air Outbreaks in the Marine Boundary Layer Experiment (COMBLE): Observations

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When cold air blows off boreal continents or the Arctic ice over open water, a well-recognized cloud pattern forms with clouds streets and, further downwind, an open cellular structure. Despite the ubiquity of this cold-air outbreak (CAO) cloud regime over high-latitude oceans, we have a rather poor understanding of its properties, including its macroscale organization. In the 2019-'20 cold season, the COMBLE campaign was conducted along the coast of northern Norway, to examine the relations between surface fluxes, boundary-layer structure, aerosol, cloud and precipitation properties, and mesoscale circulations in marine CAOs. One of the hypotheses driving the COMBLE campaign is that cloud and precipitation processes control mesoscale organization and transitions. At the coastal site, located over 1000 km from the Arctic ice, an open-cellular structure prevailed, characterized by rather high surface heat fluxes just offshore, pockets of strong updrafts and convective turbulence (alternating with decaying convective cells), occasionally high reflectivity with heavy surface precipitation rate, high cloud tops (typically >2-3 km MSL), much liquid water in the updrafts, and broken cloud cover. A less common cloud mode appears to form under weaker surface heat fluxes, and is characterized by weak vertical drafts (up- and down-drafts) and turbulence, cloud tops around 2 km MSL, widespread but low reflectivity values, light precipitation rate, nearly overcast cloud cover, rather high amounts of supercooled liquid water, and common presence of cloud top generating cells. These cloud modes will be described using data from an array of instruments, including profiling and scanning radar data,

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