What causes mammatus?

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Mammatus clouds are an intriguing enigma of atmospheric fluid dynamics and cloud physics. Most commonly observed on the underside of cumulonimbus anvils, mammatus also occur on the underside of cirrus, cirrocumulus, altocumulus, altostratus, and stratocumulus, as well as in contrails from jet aircraft and pyrocumulus ash clouds from volcanic eruptions. Despite their aesthetic appearance, mammatus have been the subject of few quantitative research studies. Observations of mammatus have been obtained largely through serendipitous opportunities with a single observing system (e.g., aircraft penetrations, visual observations, lidar, radar) or tangential observations from field programs with other objectives. Theories describing mammatus remain untested as adequate measurements for validation do not exist because of the small distance scales and short time scales of mammatus. Modeling studies of mammatus are virtually nonexistent. As a result, relatively little is known about the environment, formation mechanisms, properties, microphysics, and dynamics of mammatus.

This talk presents a review of mammatus clouds that addresses these mysteries. Previous observations of mammatus and proposed formation mechanisms are discussed. Idealized cloud-modeling studies of mammatus clouds are presented, believed to be the first ever to model mammatus explicitly. Finally, because much still remains to be learned, research opportunities are described for using mammatus as a window into the microphysical, turbulent, and dynamical processes occurring on the underside of clouds.