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MU radar and lidar observations of clear-air turbulence and mammatus underneath cirrus

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Mammatus are smooth hanging protuberances on the undersurface of a cloud (Glossary of Meteorology). Their mechanisms for formation and their role in the atmosphere are still not well-known. We obtained Rayleigh/Mie/Raman (RMR) lidar measurements of cirrus mammatus in the night of 07-08 June 2006 at Shigaraki Observatory (34.85°N, 136.10°E, Japan). Coincident observations from the VHF (46.5 MHz) MU radar in range imaging (FII) mode revealed the presence of downward developing turbulent layers and oscillatory vertical wind perturbations (+/-0.7 m/s) near the cirrus cloud base and in the mammatus environment. Moreover, simultaneous radiosonde data showed the presence of a dry and weakly stable layer underneath the cirrus. Our analysis suggests that turbulence and mammatus were generated by convective overturns due to evaporative cooling in the subcloud region. The cooling was likely the consequence of sublimation of ice crystals below the cloud base due to either precipitation or, more likely, spontaneous mixing of the saturated air and the dry air through the cloud-base detrainment instability (CDI) mechanism at the cloud base. Clear air downdrafts measured by the MU radar were associated with the descending mammatus lobes and clear air updrafts were observed between the lobes. Consequently, in addition to a possible negative buoyancy of the cloudy air, the cloudy air might have been pushed down by the downdrafts of the “upside-down” convective instability and pushed up by the updrafts to form mammatus lobes.