Deep, in-cloud Kelvin-Helmholtz billows observed simultaneously by the MU radar, a fisheye camera and two lidars.

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On 11 June 2015, during the ShUREX 2015 campaign (Kantha et al., 2017, this issue), a train of deep Kelvin-Helmholtz (KH) billows were observed by the MU radar in mid-level cloud at the altitude of ~6.5 km. Four to five KH billows showing formation and decay stages were observed for about 20 min at the altitude of a strong speed shear (> ~30 m $s^{-1}km^{-1}$) a few hundred meters above the cloud base. The billows had a spacing of about 3.5-4.0 km and an aspect ratio of ~ 0.3. Without apparent relationship, a Mid-level Cloud-base Turbulent (MCT) layer had developed at the cloud base about 10 min earlier and persisted for hours. The KH billows produced vertical velocity disturbances of up to ~+/-3.5 ms^{-1} on both sides of the critical level. A fisheye camera detected the signature of the KH wave at the cloud base and showed that the KH billows were mainly frozenly advected by the wind. The camera pictures also indicated a very small transverse extent (~6-7 km) suggesting that the KH billows were generated by a very localized source. The main characteristics of the KH wave (horizontal wavelength, phase front direction, phase speed …) obtained from the analysis of the pictures were fully consistent with those found from radar data based on standard models. Micro-pulse lidar (MPL) and Raman-Mie lidar data also permitted us to confirm some of the characteristics of the event. Finally, the turbulence kinetic energy dissipation rate estimated was of the order of 10-50 mW/kg, corresponding to moderate to severe turbulence according to ICAO classification.

References

Kantha et al, this issue, 2017