Mixed-phase cloud retrieval from radar Doppler spectra

Mixed-phase clouds often have bi-modal radar Doppler spectra, with a distinct spectral mode for each phase. For example, in Fig. 4b, the cloud liquid component is indicated by the spectral mode containing upward (negative) Doppler velocities, while the cloud ice component is indicated by downward velocities. The liquid is only observed in the upper portion of the cloud, while the ice is observed to fall below the liquid with increasing fall speed as the crystals grow.

The liquid and ice modes can be treated independently, each characterized by a unique set of spectral moments. Various cloud liquid and ice retrievals (Matrosov et al. poster) can be used to derive cloud microphysical and optical parameters independently from each mode. Here, as an example, we use empirical relationships between radar reflectivity and cloud liquid and ice water contents (Fig. 5). Related retrievals can be used to derive cloud particle sizes.

Based on the retrieved cloud microphysics, SW and LW radiative transfer calculations are made (using CSU BugsRad) to provide atmospheric heating rates associated with this mixed-phase cloud (Fig. 6).

Mixed-phase cloud heating rates

Figure 6 shows strong LW radiative cooling and moderate SW warming at cloud top and LW warming at cloud base. The net cooling at cloud top is necessary for liquid formation and maintenance at the top of this cloud. The LW warming at cloud base is most pronounced at the liquid base at 5 km.

Cloud induced heating rates

SW and LW radiative transfer calculations are made with the CSU BugsRad model using the retrieved cloud microphysical properties. Retrieved physical crystal sizes are converted to effective sizes that are more appropriate for use in radiative transfer. Example heating rate profiles in the trailing anvil are shown in Fig. 3. The cloud top LW cooling is of the same magnitude as the cloud base LW heating. The SW warming effects at cloud top are small due to low sun angle at this time.

Figure 2

Leading anvil region

Cloud Radar Studies at the CRYSTAL-FACE Eastern Ground Site on July 29, 2002

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