Cloud statistics and cloud radiative effect for a low-mountain site

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Clouds and their interaction with radiation still pose the single largest source of uncertainty in future climate projections. In order to better understand and eventually predict the cloud radiative effect (CRE) more detailed observations are urgently needed. Today the most accurate estimates of vertically resolved cloud properties and corresponding surface irradiances can be gained from the synergy of ground-based instruments including at least cloud radar, lidar, microwave radiometer and radiation sensors. Such instrumentation is operated only at a few anchor sites world wide, such as the the three permanent and two mobile facilities of the Atmospheric Radiation Measurement Program (ARM) and those organised in the Cloudnet program, i.e. Cabauw, Chilbolton, SIRTA at Palaiseau and Lindenberg.

In 2007, the ARM Mobile Facility (AMF) was operated for a nine month period in the Murg Valley, Black Forest, Germany, in support of the Convective and Orographically-induced Precipitation Study (COPS). The synergy of AMF and COPS partner instrumentation in combination with the Cloudnet retrieval algorithms was exploited to derive a set of high quality thermodynamic and cloud property profiles with 30 s resolution. This data set is used to analyze the cloud statistics for this low-mountain site and to assess the cloud radiative effect and forcing using the broadband radiative transfer model RRTMG of the Atmospheric and Environmental Research, Inc. The largest uncertainties in the derived shortwave and longwave fluxes are related to horizontal inhomogeneities in the cloud field, which are not represented in the calculated fluxes using the column derived thermodynamical and cloud properties in the 1D radiative transfer calculations.

Furthermore, sensitivity studies are performed which address the uncertainty in the derived radiative fluxes due to uncertainties in the input parameter: i.e. ice water content (IWC), liquid water content (LWC), and corresponding effective radii. First results for single-layer water clouds have shown, for example, that uncertainties in shortwave surface and top-of-atmosphere cloud radiative effect are dominated by the liquid water path (LWP) uncertainty when LWP is low. For LWP values larger than 100 gm^{-2}, the uncertainty in the cloud radiative effect due to variations in the cloud liquid effective radius is of the same order of magnitude as the uncertainty due to LWC variations.

In addition to a simple LWC retrieval, we also applied the Integrated Profiling Technique (IPT; Löhnert el al., 2008) which combines measurements of MWR, cloud radar and radiosondes with a priori information in the framework of the optimal estimation technique (Rodgers, 2000). Furthermore, for thin liquid clouds with low LWP (<60 gm^{-2}), spectral infrared and microwave radiance observations were combined within the MIXCRA retrieval (Turner, 2007) to derive accurate values for LWP and effective radius. The benefit of both retrieval techniques is assessed with respect to the radiative effect of single-layer water clouds.