Advancing synergistic remote sensing applications in the cloudy atmosphere

In the last ~10 years, ground-based remote sensing observatories for have been established in many places over Europe and the U.S.A. So-called supersites, have at minimum a cloud radar, a microwave radiometer, a backscatter lidar and wind profiler/Doppler lidar to retrieve thermodynamic and dynamic structure of the clear & cloudy atmospheric column. However, some measurements are attenuated by clouds, others have a very low vertical resolution, and again others are only very indirectly related to the desired meteorological variable. Thus, a clear picture of the atmospheric column can only be obtained by combining complementary measurements of different sensors, including satellites. Synergy can be realized in different ways, i.e. by taking the available variables from each instrument and combining them in a logical decision process for the derivation of further variables (i.e. Cloudnet algorithm for cloud type classification) or by running a variational retrieval so the that derived quantitative measures (i.e. cloud water content, temperature etc..) match the measurements via a forward model. While these types of synergistic approaches seem obvious and such techniques possess high potential for improving climate models, they have hardly been exploited so far.

By giving specific examples obtained within HD(CP)2, but also in the scope of other European research initiatives such as ITARS or ACTRIS, we will show the added value and highlight the potential of an efficient synergy of different ground-based remote sensors, together with satellite observations and corresponding a priori constraints. Progress encompasses variational retrieval studies for improving cloud water content, effective radii through cloud radar and microwave radiometer as well as for obtaining total water content below, within and above the cloud from water vapor lidar and microwave radiometer synergy. In addition to the common Cloudnet algorithm, an advanced method for drizzle onset detection is derived as well as a statistical characterization of boundary layer clouds regarding their coupling to the surface and geometrical extent. Satellite measurement above ground-based stations also provide a more complete picture of the atmospheric column, i.e. by increasing the number of degrees of freedom for signal for temperature and humidity profiles and thus also increasing the potential to predict atmospheric instability.