Numerical studies of aerosol activation behaviour in warm clouds compared to in-situ measurements at the high-alpine site Jungfraujoch

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Since 2000, 13 CLACE (Cloud and Aerosol Characterization Experiment) measurement campaigns have been performed at the High Altitude Research Station Jungfraujoch (JFJ, Switzerland, 3580 m asl). Of these, 5 focussed on the activation of aerosol to form warm clouds (i.e. liquid-phase). Additionally, comprehensive measurements of aerosol composition and physical properties have been performed at the Jungfraujoch since 1995. The Jungfraujoch is suitable for this purpose since it is in the free troposphere most of the time, and is also influenced by the continental air over Europe. Combined with the fact that the Jungfraujoch is within clouds for 40% of the time, this makes it an ideal site to study aerosol-cloud interactions.

In earlier studies, the cloud droplet activation of aerosol particles has been investigated by performing field measurements of activation (Henning et al., 2002). A recent study (Hammer et al., 2013) investigated the link between the measured cloud droplet number concentration and the cloud condensation nuclei (CCN) number concentrations that were derived from laboratory measurements. These measurements allowed a determination of the prevailing effective peak supersaturation ($SS_{eff.peak,\ retrieved}$) in ambient clouds, which was responsible for the activation of aerosol particles to cloud droplets.

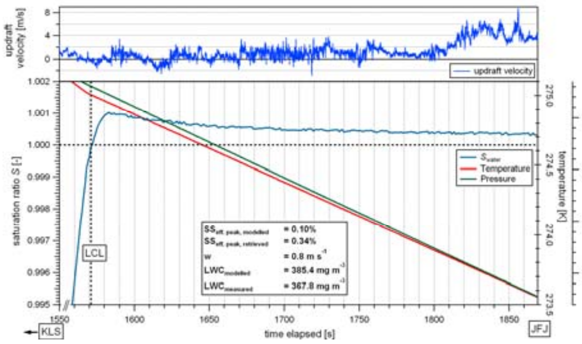

Figure 1. In the upper panel the measured updraft velocity is shown with a time resolution of 20 Hz. The lower panel shows an air parcel back trajectory for air masses starting at KLS and reaching the JFJ. The evolving saturation ratio (blue), temperature (red) and pressure (green) are shown (lower panel). LCL is the lifting condensation level.

The measured aerosol and cloud parameters such as activation diameter, cloud droplet number concentration and effective peak saturation were compared with values predicted by a cloud parcel model. The model, ZOMM (Zurich optical and microphysical model; Luo et al., 2003; Hoyle et al., 2005) simulates the microphysics of aerosols and cloud particles in air parcels including a fully kinetic calculation of water transfer between the gas and liquid phases. The model was initialised with conditions valid for the Kleine Scheidegg (KLS, 2061 m asl) which is located 4 km to the north of the JFJ, at lower altitude.

Figure 1 shows an example of a model simulation, following such an air parcel trajectory. All input parameters (dry aerosol size distribution, temperature, pressure, initial water vapour mixing ratio) were measured at the JFJ. The updraft velocity measured at the JFJ with an ultrasonic anemometer (Metek USA-1) is time-shifted so that it is time-synchronized with the predicted trajectory. It is expected that the air masses approaching the JFJ are experiencing turbulence, which can influence the temperature and thus the saturation ratio. The highest value on the trajectory of the saturation ratio is the maximum peak supersaturation ($SS_{eff.peak,modelled}$) which can be compared with the $SS_{eff.peak,retrieved}$. However, a difference between the predicted (0.10%) and retrieved (0.34%) value is evident. We will present possible explanations for this difference, including the effect of implementing a hygroscopicity parameter. In addition, sensitivity studies were carried out to assess the influence of turbulence on the $SS_{eff.peak,modelled}$.

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