

Review #2

Comment on uncertainty

The authors claim measurement uncertainties of 10% in cloud-droplet number concentration (N_d) and cloud liquid water content (LWC) from the CDP probe in the campaign data that they analyze. This seems overly optimistic compared with other studies. For instance, consider a monodisperse cloud parcel in which all droplets have radius r . LWC can be expressed as

$$\text{LWC} = (4/3) \pi r^3 \rho_l N_d$$

where ρ_l is liquid-water density. Propagating uncertainties leads to:

$$\delta \text{LWC} / \text{LWC} = 3(\delta r / r) + (\delta N_d / N_d)$$

Where δ is 1-sigma uncertainty. Baumgardner et al. (2017) assess uncertainties in a range of light-scattering probes, including the CDP probe used in the present study, and find that $\delta r/r$ is between 0.1 and 0.5 and $\delta N_d/N_d$ is between 0.1 and 0.3. Even the most optimistic values from these ranges have $\delta \text{LWC}/\text{LWC} = 0.4$, which is four times larger than the measurement uncertainties claimed by the authors. I therefore recommend changing the uncertainty claimed in the paper to match the review paper by Baumgardner et al. (2017) or arguing more clearly for why a smaller uncertainty range is justified.

Baumgardner, D. B., et al. (2017). Chapter 9 Cloud Ice Properties: In Situ Measurement Challenges. 1–23. <https://doi.org/10.1175/AMSMONOGRAPHS-D-16-00111.1>

Authors response

We thank the reviewer for this comment. We agree that the wording in the main text should make clearer that the 10% uncertainties assigned to N_d and LWC represent the best-case measurement scenario. The uncertainty of CDP-derived cloud properties depends strongly on the measurement conditions, probe characterization, and aircraft maneuver during the cloud penetration. In the present study, the main analysis is based on the best-case uncertainty scenario, while the sensitivity to larger, more conservative uncertainties is already evaluated in the Supplement.

We also note that the reviewer's illustrative estimate assumes a monodisperse droplet population and applies the uncertainty in a single characteristic radius directly to LWC. In the CDP measurements we are using, LWC is calculated by integrating over the measured polydisperse droplet size distribution. Consequently, sizing errors can include redistribution of particles among neighboring size bins and do not necessarily correspond to a systematic displacement of the complete size distribution by $\delta r/r$.

We have edited section 3.7.3 of the manuscript as follows to address your comment:

“The uncertainties reported in the main text correspond to the best-case measurement scenario, for which relative uncertainties of 10 % in LWC and N_d are adopted. This value represents the lower range of uncertainty expected under favorable sampling conditions, particularly during straight and stable cloud penetrations through non-precipitating clouds, for which the cloud liquid water is predominantly contained within the droplet-size range measured by the CCP-CDP. Although LWC is particularly sensitive to droplet-sizing uncertainties because it is derived from the third moment of the measured droplet size distribution, the uncertainty in integrated LWC cannot be obtained directly by applying a single sizing uncertainty uniformly to all droplets in a polydisperse distribution. Laboratory calibrations of CDP instruments using droplets of known size have demonstrated that sizing accuracy depends on calibration conditions, droplet size, and position within the probe sample area (Lance et al., 2010; Faber et al., 2018). To account for less favorable measurement conditions and larger uncertainties associated with CDP sizing and sampling effects, a conservative case assuming 30 % uncertainty in LWC is also evaluated in section S2.2 of the Supplementary Material. The corresponding uncertainties in the energy terms and derived supersaturations provide an upper-bound assessment of the sensitivity of the method to uncertainties in the cloud microphysical measurements.”