Version 03, 1 July 2024

Manuscript Title: *In situ observations of supercooled liquid water clouds over Dome C, Antarctica by balloon-borne sondes* **by Ricaud et al.**

Referee #2

→ Specific changes have been made in response to the reviewer's comments and are described below. The reviewer's comments are recalled in blue.

The paper describes observations of supercooled liquid water clouds over Dome C, Antarctica with multiple instruments: balloon-borne Vaisala PTU and Anasphere SLW sondes, LIDAR, and HAMSTRAD microwave radiometer during field campaigns carried out in the period of 2021-2022. Generally supercooled liquid water clouds were observed near temperature inversion zone where atmospheric motion is capped. Both consistency and discrepancy among the different measurements were observed.

→ First of all, thank you for your positive feedback on the manuscript.

There are a few questions I would like the authors to address:

1. I totally get it that it is difficult to perform in-situ measurements over Antarctic and it is important that someone are doing it. On the other hand, as a scientific paper, can you emphasize the novelty and impact of this paper, i.e., what is the new findings of this paper that readers cannot get somewhere else?

→ The three main outcomes from our analysis are:

a) The in-situ observations of SLW clouds with SLWC sondes at Concordia station in Antarctica are the first observations so far in Antarctica with an SLWC sonde. The location in height of the SLW clouds observed by the SLWC sonde is consistent with the profiles of humidity and temperature (and the deduced inflection points).

b) On average, the heights of the SLW clouds as observed by in-situ sondes and remonte-sensing LIDAR are consistent.

c) The Liquid Water Path (LWP, the vertically-integrated supercooled liquid water content (SLWC)) deduced by the sondes generally equals or is greater than LWP remotely sensed by a ground-based microwave radiometer in spite of its low values (< 10 g m-2). Unfortunately, on some occasions far from nominal operation (surface liquid fog, low vertical ascent of the balloon), the sonde vertically-integrated SLWCs were overestimated by a factor of 5-10 compared to the HAMSTRAD LWPs.

We have highlighted these 3 points in the abstract and in the conclusions of the revised manuscript.

2. Under nominal conditions, the LWP values obtained by integrating SLWC sonde profiles are consistent with the HAMSTRAD measurements. Under non-ideal conditions, they are way off. The authors suggest the HAMSTRAD values are more trustworthy. Is this always the case? If

yes, why don't we just perform HAMSTRAD observations all the time? What is the added value of doing SLWC sonde profiling?

→ The referee did not get the main point of the article, probably because we were not clear enough in the explanation. The radiometer HAMSTRAD is able to retrieve Liquid Water Path (LWP) that is to say the vertically-integrated liquid water content (liquid water content is usually referred to as Supercooled Liquid Water Content = SLWC) at a 1-min time resolution. However, HAMSTRAD is not able to detect the height of the Supercooled Liquid Water (SLW) cloud. Conversely, the LIDAR is able to retrieve the vertical distribution of SLW cloud but not the SLWC values within the cloud. The sonde we have used combine the two main advantages of the radiometer and of the LIDAR, that is to say the detection of the vertical distribution of SLW clouds and SLWC within the cloud.

We have synthetized the pros and cons of the three instruments in Table 3. (see replies to the comments of the Reviewer#1).

3. Figure 1 is not informative at all, which could be replaced by a cartoon drawing showing how things work.

→ We partly agree with this point. Figure 1 is, in our opinion, very informative since it clearly shows the great difficulty of handling 2 different sondes (Vaisala PTU and SLWC sondes) simultaneously in order to minimize the oscillations inferred by the launch itself and by the handling of the sondes. We have underlined this point more clearly in the revised version of the manuscript by detailing the methodology employed to launch the 2 sondes simultaneously and modified the incriminated Figure.

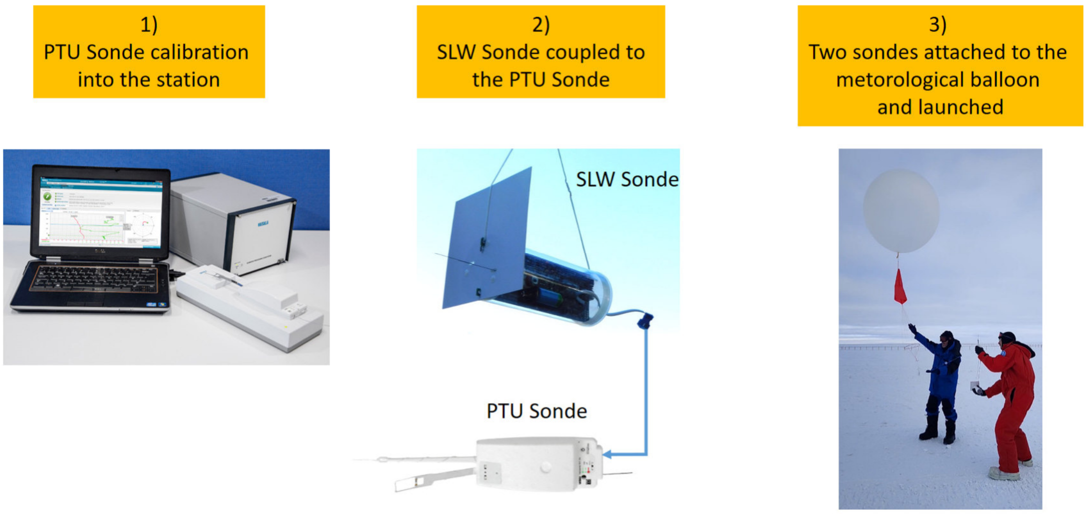

Figure 1. The methodology employed to launch both the SLWC and the PTU sondes with meteorological balloons is synthetized as follow. 1) The Vaisala PTU sondes are calibrated into the quiet building of the Concordia station at room temperature using the standard Digicora ground-check system. 2) The SLWC sonde is connected to the PTU sonde at room temperature and then is transported outdoors to the meteorological shelter. The two sondes are attached to the meteorological balloon after inflation of the balloon. 3) Then, after leaving the shelter, a person holds the SLWC sonde in his/her hands while another holds both the meteorological balloon and the PTU sonde. When the meteorological and technical

conditions are optimised, the balloon is launched. The picture represents a launch of a Vaisala PTU sonde (left hand of the man in blue) and an Anasphere SLWC sonde (right hand of the man in red) attached to the Totex TA100 meteorological balloon, together with the red parachute and the unwinder for the first flight on 22 December 2021.

4. What is the functionality of unwound string or unwinder? It is not clear.

→ For optimal operation, the PTU sondes should be a few tens of meters away from the balloon. The use of an unwinder copes with inconvenience of having a long string to manage before launching and reduce the pulling forces at the start of ascent until the balloon has reached its nominal ascent rate. Nevertheless, unwinding after launch produces a pendular rotation of the sonde until the unwinding terminates. But only the SLWC sonde is affected by the rotation. Concretely, we have noticed that an unwinder stabilizes the SLWC sondes more rapidly than no unwinder. On average, it takes about one minute for the SLWC sonde to stabilize, thus with an ascending velocity of 5 m s^{-1}, the first 300 m height cannot be scientifically exploitable. We have enlarged the vertical threshold to 400 m height in our study in order to minimize as much as possible the impact of the launch to the SLWC sonde stabilization.

We have clarified this point in the revised version.