FINAL REPORT PROGRAM LEFE

Program LEFE/ IMAGO	Project Title In-situ Observations of Supercooled Liquid Water Clouds above Dome C with drone (DRONE-DC)	Years 2021 – 2023

PI name, email and lab:
Philippe RICAUD, philippe.ricaud@meteo.fr, CNRM
Participating Laboratories :
LAERO

Contribution to
YOPP

Other funding sources : IPEV, OMP & LAERO

Context The frequency of occurrence of supercooled liquid water (SLW, liquid water occurring below 0°C) clouds (SLWC) over Antarctica decreases sharply from the coast to the pole. SLWCs are not well captured by state-of-the-art numerical weather prediction models, yielding biases in the net energy budget at the surface, up to a few tens of watts per square meter. Such biases limit these models to accurately predict the surface temperature and thereby the large-scale circulations over Antarctica and beyond.

Objectives / scientific questions The main objective of DRONE-DC is to measure in-situ (balloon- and drone-borne observations) the properties of SLWCs over Dome C, namely their vertical and horizontal distributions and the temporal distribution of their occurrence during the summer period in order to quantify and understand their impacts on the net surface radiation. A secondary objective is to fly for the first time a drone with a scientific payload in this harsh environment (3200 m altitude, less than -20°C at ground).

Main results

Two campaigns have been held in Concordia (Antarctica) over the summer seasons 2021-2022 (balloon) and 2022-2023 (balloon and drone). Sondes especially dedicated to the SLW in-situ observations were purchased in the US (Anasphere company). They were installed below a meteorological balloon together with standard Pressure-Temperature-Humidity (PTU) sondes (2021-22) from the Vaisala Company. 8 vertical profiles of SLW were realized. They were compared to Liquid Water Path recorded simultaneously by the HAMSTRAD ground-based microwave radiometer and to Lidar observations. Preliminary results show that, on average, the vertical distributions of SLWC from the sondes were consistent with the vertical distribution of the low depolarisation (liquid water) observed by the Lidar. Nevertheless, the amount of SLW was about 5-10 times greater in the sondes compared to the radiometer measurements. This needs to be further investigated.

During the 2022-2023 summer (December-January), a drone has been sent to Concordia, which was the main objective of DRONE-DC. The drone was acquired to the DeltaQuad company (https://www.deltaquad.com/). It is a Vertical Takeoff and Landing (VTOL) drone (Figure 1) without any modification related to the strong constraints encountered at Concordia: summertime surface temperature of -30°C, altitude of 3233 m, and strong issues related to magnetic field due to the high latitude of the station at 75°S. The concept was to install both the Vaisala and the Anasphere sondes onboard the drone, the SLW sonde connected to the PTU sonde, with a real-time data transfer to the Vaisala meteorological ground-station. Note that DRONE-DC was labelled by LEFE as a "risky project". Two phases were defined to fly with the drone corresponding to 1) technological flights (no sondes onboard) and 2) scientific flights (sondes onboard). Although it was a risky project, we have been able to operate a drone in this harsh environment and provide scientific results. Namely, 13 flights have been performed from 24 December 2022 to 17 January 2023: 9 as technological and 4 as scientific.

Prior to the flights, a mission plan defined their maximum altitude and their horizontal hippodrome shape (a rectangle-like shape of 1000 x 600 m) from the surface to 400-600 m height (about 3600-3800 m altitude). The duration of the flights varied from 20 minutes (400 m) to 30 minutes (600 m). Each flight required an official authorization (NOTAM). Almost all flights showed some difficulties (from light to extreme) for the drone to take off and to land. After interacting with the DeltaQuad company, this was a problem obviously due to the compass and the shape of the geomagnetic field at high latitudes. This has been partly solved by using a manual take-off and landing procedure. Because GPS signals are altered at high latitudes (low elevation angle), the altitude of the drone was biased by 20-30 m compared to the actual altitude. This has been considered in the mission plan. After 2-3 severe landings and in view of the damage encountered, the measurement campaign was stopped on 17

January 2023. During the period from mid-December 2022 to end of January 2023, there were unfortunately no SLWCs for more than 2-hour periods over the Concordia station in the local afternoon when surface temperatures were reaching -25°C. As a consequence, the scientific flights only measured vertical profiles of temperature and humidity with an unprecedented vertical and horizontal resolutions. Note that flights were performed in the local afternoon (temperatures 5-10°C higher than in the local morning) with wind speed less than 5-6 m s^{-1}.

Figure 1. The VTOL drone at Concordia station prior to a flight.

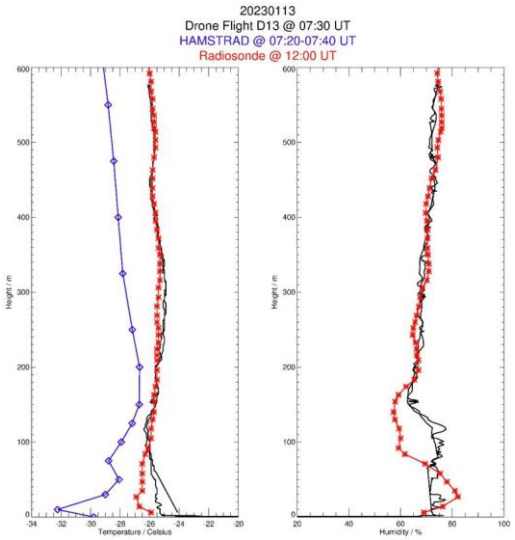

Figure 2. Vertical profiles of temperature (left) and relative humidity (right) as measured by the PTU sonde onboard the drone (black, upward and downward flight), the operational sonde (red) and, for temperature, the HAMSTRAD radiometer (blue).

Four vertical profiles of temperature and relative humidity have been obtained with the drone on 2, 10, 11 and 13 January 2023 up to heights of 400, 400, 500 and 600 m, respectively. The drone-borne measurements performed on 13 January 2023 at 07:30 UT are shown in Figure 2, compared with operational radiosondes at 12:00 UT and the HAMSTRAD radiometer for temperature within 07:20-07:40 UT. The Vaisala PTU sondes (onboard the drone and attached to the operational meteorological balloon) are consistent above 200 m despite the 4.5 h difference. The HAMSTRAD temperature profile shows a systematic cold bias of -2°C above 50 m height. The scientific flights, although challenging, were successful given the harsh environment encountered and will need to be pursued in a forthcoming summer campaign in order to actually observe in situ the SLWCs.

Future of the project:

At the present time, we are in the process of analysing the data. Comparisons with models are still to be performed with ARPEGE and/or AROME. Although the observations of temperature and relative humidity are of very good quality, we really need to solve the issue of the take-off and landing of the drone. Interactions with the DeltaQuad company tend to show that this could be achieved in a few months. In that case, a new proposal could then be sent to IPEV in order to observe SLWCs. Another option could be to interact with colleagues from New Zealand encountered at Casey Station in January 2023 who will perform drone observations at Scott Base in the forthcoming years by means of a drone developed by their Institute with the compass issue solved.

Number of publications, communications and theses

Since the campaign just finished in January 2023, there is no publication yet. We intend to publish 2 articles: one particularly focussed on the drone (flights, constraints, etc.) and the other one on the scientific results obtained in the planetary boundary layer.

Data availability

The observations are still to be analysed and are not yet available for the scientific community. Once analysed, we will provide them to the scientific community along with the HAMSTRAD data that are freely available at http://www.umr-cnrm.fr/spip.php?article961.