# Anonymous Referee #1

Below are the comments from the referee in black and replies from the authors in blue.

## General comments

It has been well known that stratospheric water vapor measurements may be heavily contaminated if the balloon payload passes through low and mid tropospheric clouds; however, the details of this mechanism have not yet been investigated. The manuscript by Jorge et al. investigates the parts of the balloon train that may generate this contamination and the physical processes that take place in the collection and release of the excess water.

The manuscript identifies that supercooled liquid water droplets may impinge on the insides of the inlet tubes of the instrument driven by a significant radial velocity due to the pendulum motion of the payload and the off-vertical orientation of the payload. Depending on the pendulum amplitude and amount of water drops, the upper parts of the inlet tubes may receive large ice coatings than farther down the tube.

Contamination by the balloon wake is more likely to become significant near the burst altitude and may not be as significant in the lower stratosphere.

The paper uses a fluid dynamical model to study the freezing and sublimation processes as well as the mixing processes inside the tube and compare these with a series of in situ observations that triggered this study.

The manuscript is overall well written and strongly suggests processes inside the inlet tubes to be dominant. I can recommend publication of this manuscript after a few mostly technical corrections.

We are grateful to the referee for carefully reading the paper and providing valuable suggestions.

## Detailed comments:

Page 13, line 33: How important is the assumption that the inlet tube is at the same temperature? The recommendation at the end may point towards a heated inlet tube. However, is heating of a few degrees sufficient, or will heating of many 10s of degrees be required to be effective? How might a colder inlet tube (possibly through infrared cooling at night) make the problem worse? A little bit of discussion about this assumption may be useful for the reader.

The temperature of the intake tube and ice layer in the ice sublimation CFD simulations is very important. This temperature is a crucial part of determining how much water vapour is transferred to the incoming dry air. Hence, it determines the level of contamination observed in the intake tube. The extend of the ice layer inside the intake tube also plays a crucial role on determining the overall contamination.

Philipona et al. (2013) determined that the combination of incoming and outgoing long- and short-wave radiation produces radiative heating of very thin thermocouples in the upper troposphere and lower stratosphere (UTLS). The effects are very similar during the day and night. Following this account, we could expect the intake tubes to be warmer in the region of interest - UTLS. We should also consider that the tube has thermal inertia and is travelling from a region of colder into warmer air, at least in the lower stratosphere. Nevertheless, the expected effect of thermal radiation is less than 1 °C for the thermocouples, we assume it would be the same for the intake tubes. This temperature difference does not cause a significant effect in the results of our contamination simulation. Especially, if we also account for the uncertainties of inlet velocity, ice layer length and internal mixing in the tube.

A few lines of discussion were added to this point (page 14, lines 24 to 27 and lines 30 to 32).

We would like to make clear that our recommendation is not to have an heated intake tube. We recommend to perform a short heating cycle of the intake tube after the region of mixed-phase clouds at air temperatures below -38 °C (the homogeneous freezing threshold). This heating cycle should not last longer than a few seconds to minutes. It is more appropriate to heat the intake tube by 10 s of degrees warmer than air, if we envision the heating cycle to be as fast as possible. We further clarified our text in Subsection 6.2 containing the recommendations. (page 24, lines 21 and 22)

A few more words about ANSYS/FLUENT might be useful for readers, who are not familiar with CFD. ANSYS seems to be the manufacturer of the FLUENT software.

We agree with the referee and a few more words regarding Fluent were added (page 11, line 29 to 32 and page 12, line 1 and 2).

The appendix expands the paper significantly, but supports the main arguments. I can't tell if the manuscript may be too long and I would not suggest to remove it. It could be shortened if needed.

Due to conflicting suggestions from the two referees, and after discussion with the editor, we decided to convert Appendices A and B into Supplement material.

## Technical comments:

Abstract, Line 1: delete "(sub)tropical". UTLS water vapor measurements are important in all geographic regions, not just the (sub-) tropics.

We agree with the referee. The word (sub)tropical has been moved to line 4 to characterize the measurements used in this manuscript.

Introduction, line 31 on page 2: better "instrument's Styrofoam box".

Done (page 2, line 31), (page 51, label Figure 16).

Section 2.1, line 11: "automated" instead of "automatized".

Done (page 4, line 11).

Line 12: The instrument seems to control the reflectivity, which may not directly correlate to thickness.

We thank the reviewer for this good point. Indeed, our AMTD manuscript does not mention the reflection of the light by the frost-covered mirror, but immediately talks about the thickness of the frost layer, which is one of the quantities affecting the amount of reflected light, but not the only one. Following the reviewer's suggestion we clarify this in the revised text. We do not use "reflectivity", rather "reflectance", which is defined as the ratio of reflected radiant flux (optical power) to the incident flux at a reflecting object, whereas reflectivity refers only to flat, unstructured surfaces. Reflectance is more general, also referring to rough surfaces, where light is scattered, such as the frost on the mirror (Richmond, 1982). (page 4 line 17).

Page 5, line 3: CFH instead of CHF

Done (page 5 line 16).

Page 5, line 10: Why do the authors use 1 hPa instead of more obvious constant altitude or constant time interval?

The use of averaged data in 1 hPa stems from the analysis of the COBALD data. By dividing the atmosphere in 1 hPa bins, we ensure equal mass layers of backscattering material. The same reasoning applies to the water vapour and the energy balance.

Page 11, line 17; space missing before 'cutcell'

Done (page 12 line 9).

Page 11: Remove the acronym SST, since it is not used except here.

SST $k-\omega$ is the name of the model used for the computational fluid dynamics simulations. The description of the SST acronym is only provided because the target readers of the Journal AMT might not be familiar with the computational fluid dynamics terms. We prefer to keep the acronym and the full name for clarity.

Page 16, line 18, extra comma after "until"

Done (page 17 line 19).

Page 17, line 17; what means "extra ice saturation"? Maybe just delete this phrase.

Any reference to "extra ice saturation" has been removed from the text and from Tables 4 and 5. The results are now presented only as "extra $\chi_{\mathrm{H_2O}}$".

Page 18, line 12; remove the hyphen after readily.

Done (page 19 line 12).

Page 19, line 10; add “the” before “CFH” (and a few other places).

Done for all “CFH”, “RS41” and “COBALD” references in the text.

Page 19, line 10; add “than” before “1.45 mg”

We have rephrased the paragraph. (page 20, lines 13 to 15).

Page 19, line 29; maybe clearer: “which the balloon radius changed with pressure”

Done (page 20, lines 28 and 29).

Figures 2 and other similar Figures: The colors are hard to distinguish, in particular pink, light purple and dark purple. Since there is no ambiguity about the ice or liquid on the mirror, maybe one of the traces could be removed.

Indeed, there is ambiguity about the ice or liquid on the mirror up to the first clearing and freezing cycle of the CFH. After it, it is clear that the deposit on the mirror is ice. Before, the deposit can be liquid, mixed-phase or ice. The three colors of the saturation over water lines are sufficiently similar, yet color blind friendly and can be distinguished after magnification.

Figure 2 b: The very high average mixing ratio near the top of the profile seems to go well above 10 ppmv, i.e. contaminated data may be part of this average.

We agree with the referee. Above 20 hPa, the season average mixing ratio excluding the contaminated profiles of the 16/17 StratoClim campaigns goes well above 10 ppmv. Contaminated data is part of this average. This point has been discussed in Brunamonti et al. (2018) and in Section 5.4.1 of this manuscript when we address the contamination from the balloon envelope. However, this point is not clear when Figure 1 and Figure 2 are discussed. This has been changed in Figures 1 and 2b. The contaminated values in the season average mixing ratio profile above the 20-hPa level are now highlight in the figures. There is now also reference to this contamination in the main body of the manuscript in page 3, lines 24 and 25.

Figure 4: The font in the Figure is too small.

The font size in Figures 4 has been increased.

Figure 6 c: The arrow for the inlet flow does not seem to be vertical as I would have expected. I assume the difference is due to the rotational speed. Can this be indicated in the Figure?

Done (page 41). See below the new figure and legend.

Figure 10e: The bottom half of the flow tube seems to have been shifted a little.

This has been corrected, but it might be an error created by the pdf viewer.

Figure 13: What determines the lower and upper limit of the vertical integration interval?

The lower integration limit is the top of the cloud at 13.5 km altitude and the upper integration limit is the cirrus cloud at 17 km altitude at the tropopause. The explanation has been added to the paper (page 20, line 15 and 16)

Figure 14, legend: The second (a) should be (c)

Done.

Figure 3 and Figure A2: The estimated region for the supercooled mixed phase clouds seems to use different selection criteria.

The selection criteria for the supercooled mixed-phase clouds in Figures 3 and now Figure 2 of the Supplement is the same. The COBALD CI should be higher than 20. CI of 20 is an indication of an ice cloud, while CI around 30 stems from Mie oscillations in the transition regime and thus from the presence of smaller and more monodispersed scatterers, most likely super cooled cloud droplets.

In addition, the water saturation should be compatible with liquid water. Most often liquid droplets exist only when the water saturation is 1, or very close to 1 [0.99 - 1.00]. However, if we consider the process modelled in section 2.4 of the paper, we conclude that if the water droplet size distribution consists of many small droplets and a few big droplets, once the first ice crystals nucleate, the small droplets evaporate fast to feed the solid phase (up to six minutes) but the the big droplets remain in a water sub saturated environment. The process can take up to 17 minutes. However, there is a sub saturation limit to this process too. Through our simulations, we found this limit to be around $S_{liq} \sim 0.85$ for the temperature of the clouds of NT011 and NT029.

So, the selection criteria for the supercooled mixed phase clouds are $S_{liq} > 0.85$ and $CI > 20$. We realize that this might not be very clear in the paper, so we have rephrased the transition between section 2.3 and 2.4 (page 7, lines 9 to 13) and emphasized the selection criteria for the cold mixed-phase clouds (page 8, lines 21 to 25)

Table 1 and Table 3 legend: Move NT007 into first place following the ordering in the table.

Done.

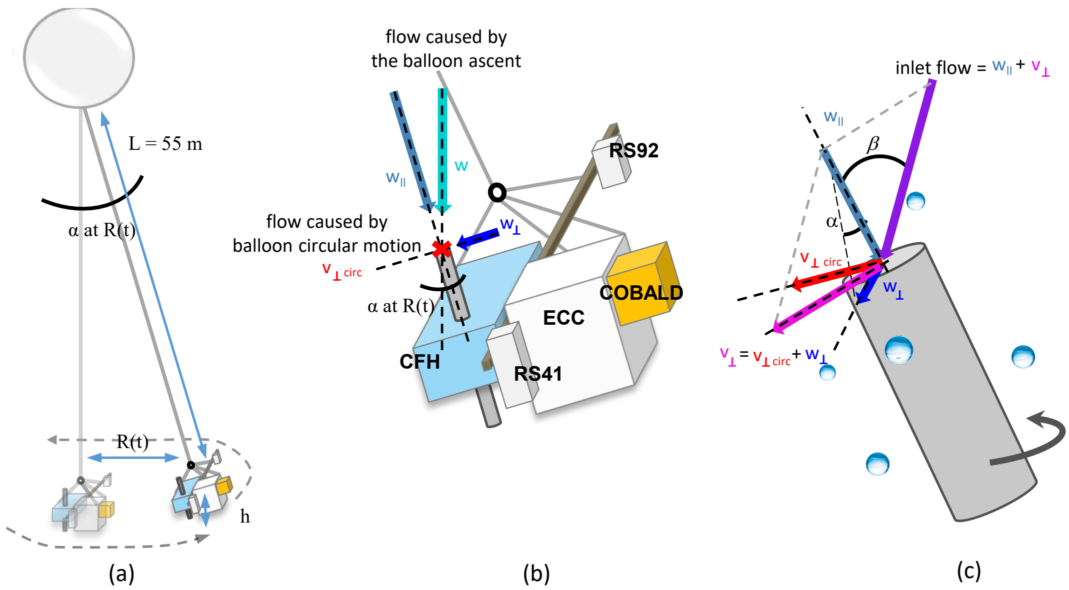


Figure 1: (a) Schematic of balloon and payload (not to scale). Payload is connected to the balloon by a 55 m long light-weight nylon cord. Payload oscillates with tilt angles $\alpha$ up to 25° during ascent. (b) Schematic of payload with the 2 radiosondes (RS41 and RS92), and the 3 instruments (CFH, ECC Ozone and COBALD) and of intake flow geometry due to balloon ascent and payload rotation. The flow caused by the vertical balloon ascent ($w$) has a component parallel to the intake tube ($w_{||}$) and a component perpendicular to the tube walls ($w_{\perp}$). Circular motion of the payload adds an additional component ($v_{\perp\text{circ}}$) in the plane perpendicular to the intake tube. (c) The total velocity perpendicular to the tube becomes $v_{\perp} = v_{\perp\text{circ}} + w_{\perp}$. The total perpendicular velocity $v_{\perp}$ and the parallel component of the ascent velocity to the intake tube $w_{||}$ determine the inlet flow and the impact angle $\beta$.

# References

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