

## **Review of “Vertical Profiles of Liquid Water Content in fog layers during the SOFOG3D experiment” by Costablos et al. submitted to Atmospheric Physics and Chemistry**

This paper studies vertical profiles of liquid water content (LWC) observed in fog layers during a field campaign carried out in southwestern France. The twelve fog events sampled during the campaign concern “thin” fogs occurring in stable conditions, characterized by decreasing LWC and increasing temperature as a function of altitude and vertically developed (or “thick”) adiabatic fog, characterized by increasing LWC and decreasing temperature as a function of altitude.

The work is original in that it relies on a comprehensive set of in-situ measurements of fog microphysics, complemented by remote sensing using a cloud radar and microwave radiometer.

The paper includes several interesting investigations that make it worthwhile to consider this paper for publication in Atmospheric Physics and Chemistry: Vertical profiles of LWC (measured by a cloud droplet probe, CDP) and temperature are analysed at different stages of the fog life cycle. The conditions that lead to thin-to-thick transition are investigated for four fog events using remote sensing measurements, surface measurements and in-situ vertical profiles. This is important to evaluate how the representation of transition can be improved in model simulations. Further, this analysis is compared to a conceptual model of fog adiabaticity proposed and exploited earlier in the literature (Toledo et al. 2021 and Dione et al. 2023) and provides a detailed assessment of the performance of this conceptual model.

The paper is clearly written and well organized. However, two topics require thorough attention and revisions, while others are more minor.

### **Major comment 1: derivation and uncertainty of fog adiabaticity.**

Fog adiabaticity is studied extensively in the paper, both from in-situ LWC measurements and using the conceptual model proposed by Toledo et (2021). The paper presents several methods to derive fog adiabaticity.

1. Equivalent adiabaticity from Closure (Eq. 5), where input variables are derived from remote sensing measurements and horizontal visibility
2. Equivalent adiabaticity from Closure (Eq. 5), where input variables are derived from in-situ CDP measurements
3. Adiabaticity from fitting LWC profiles from the ground to just below the diluted layer.

**Section 3.2 and 3.3** are dedicated to comparing the first two definitions,

The balloon ascent (that carries the CDP sonde) takes 15-40 minutes to cover the vertical extent of the fog layer, depending on its depth. In the equivalent adiabaticity formulation (Eq. 5), there is an inherent hypothesis that the LWC<sub>0</sub> measured at the surface is consistent with the integral of LWC (the liquid water path, LWP) and the fog layer depth (provided by CTH). We know that CTH, LWP and LWC<sub>0</sub> can vary significantly in 20-30 minutes.

Q1.1 Hence what is the uncertainty in deriving equivalent adiabaticity (definition 2) from CDP measurements given the temporal variations of LWC during the ascent or descent of the balloon?

Q1.2 What temporal smoothing or averaging is used for CTH, LWP and visibility to derive equivalent adiabaticity (definition 1).

Q1.3 What is the impact of these uncertainties on the comparisons of the two alpha-closures made in figure 4?

Q1.4 Line 310-311: the alpha-closure derived for IOP11 (22:09 to 22:23) is 0.53, while the same alpha-closure derived by Dione et al; (2023) ranges -0.9 to -1.1. Can you explain this discrepancy?

Q1.5 Line 310-311: the alpha-closure derived for IOP14 (06:11 to 06:47) is 0.45, while the same alpha-closure derived by Dione et al; (2023) is 0.6. Can you explain this discrepancy?

Q1.6 What is the impact LWC0 measurement variability (from CDP and Visibility) on the results presented in Figure 5?

**Section 3.4** compares adiabaticity (definition 3) with equivalent adiabaticity (definition 2).

Alpha (definition 3) does not consider the fog layer at the top that is diluted by entrainment of dry air, hence it is expected to be larger than the equivalent alpha (definition 2) that accounts for the entire for LWP and depth.

Q1.7 What is the impact of the variability in the entrainment layer (depth, shape of LWC profile in the layer) on the comparison shown in Fig. 7 ?

### **Major comment 2: thin-to-thick fog transition**

In Section 2.3, the thin-to-thick fog transition is presented as a time when the transition occurs. And thresholds are defined for five variables to identify the transition time linked to different processes that affect the transition: Net LW radiation, temperature gradient between 50 and 25m, TKE, CTH and LWP. A multi-parameter evaluation of the transition is interesting. However, the transition from thin to thick fog should rather be defined as a time interval with a beginning and an end (as proposed by Dione et al. 2023 using three parameters), rather than as an instant in time. Dione et al. (2023) shows that the duration of the transition phase is variable from one fog event to another.

Here, you propose the transition phase duration to be time interval between the first and the last thresholds of the five variables (L213). Later you mention “scattering” between thresholds (L216) and “period of uncertainty” (L324).

**Q2.1** I suggest that you revise the definitions of thin-to-thick transition to include both thresholds for multiple variables, and time of onset of transition, and time of ending of the

transition when the fog has reached an adiabatic state. This would allow you to evaluate if multiple thresholds are reached in a short amount of time favours a rapid transition from thin to thick, and reversely if a slow transition can be caused by inconsistencies in the different processes involved in the transition.

**Q2.2** Could you propose a more thorough definition of thick-to-thin transition duration and explanation of the duration, based on the values reached by the five variables compared to the threshold that you identified.

L470 (Section 4.2.1) Explain how the time interval between first and last threshold can be compared with the transition phase duration of Dione et al. (2023) for IOP14

L512 (Section 4.2.2) You write “Surprisingly, reverse LWC trends were observed for profiles # 6 and # 7 with  $\alpha < 0$  even though the thin-to-thick transition had already occurred one hour earlier.”

In fact, this is not surprising for a slow transition. The fact that thresholds are reached does not mean that transition is over and that fog has become adiabatic.

Discuss how the LWC profiles temporal evolution that you show in can explain the slow transition.

L637, 638 “uncertainty periods” is used again for transition phase duration. Please revise.

### **Minor comments.**

Section 2.1. Check consistency in the tense used throughout this section (past, present, future).

L106 Change “spread” to “distributed”

L119: CBH cannot be derived unambiguously with a cloud radar alone as the signal in the lower part of the cloud can come from cloud droplets or from drizzle below the cloud. CBH is usually derived from a ceilometer.

L129 “However, we analyse here all the data collected during the SOFOG3D experiment, and we then use independant retrieval.” Not clear, please rephrase.

“independant” → “independent”

L137 “aspirates” → “sucks in”

Table 2. What objective criteria do you do define “radiative” vs “radiative-advective” fog types?

L203 “These discrepancies may be explained by the contrasting environment between the two measurement areas (Thornton et al., 2023).” Explain what contrasts you are referring to ?

L307 “These results highlight that while the adiabatic model correctly represents thermodynamical and microphysical properties of well-mixed fogs, it does not represent the properties of optically thin fogs at all.” Does anyone expect the adiabatic model to correctly represent optically thin fog ?

“highlight” → “highlight”

L378 “significant values” → “large values”

L393 “This attests that differences observed from our dataset result from the actual properties of the fog sampled during SOFOG3D and not from the measurements used (in situ or remote sensing) to compute the fog adiabaticity from closure.” Not clear, please rephrase or explain.

L634 Replace “if” by “while”.

L703 “period of uncertainty” please rephrase according to Major comment 2 discussions.

L703 “more suited ...” than what ?

L711 “ larger negative values ...” than what ?